Charm Production in CC DIS at HERA

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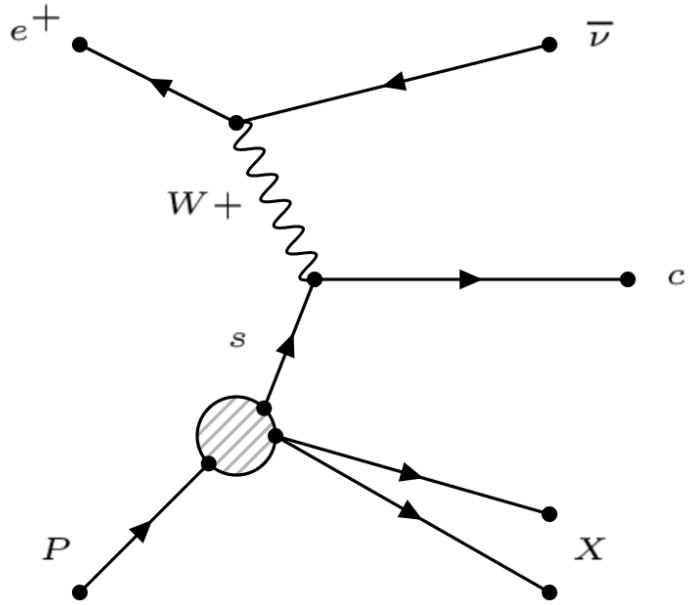
Motivations

- Charm cross section measurement in high-Q^2 charged current (CC) DIS.
  → Constraints on $s(x, Q^2)$



← LO Charm production Feynman diagram

- Allows for $s(x, Q^2)$ measurement.
- The process via d is Cabibbo-suppressed.
- Due to the final state neutrino, a large missing P_T is observed.
- Charmed particle has a long lifetime since it decays weakly.
- Invariant kinematic variables (x, y, Q^2) defined by using Jacquet-Blondel Method.

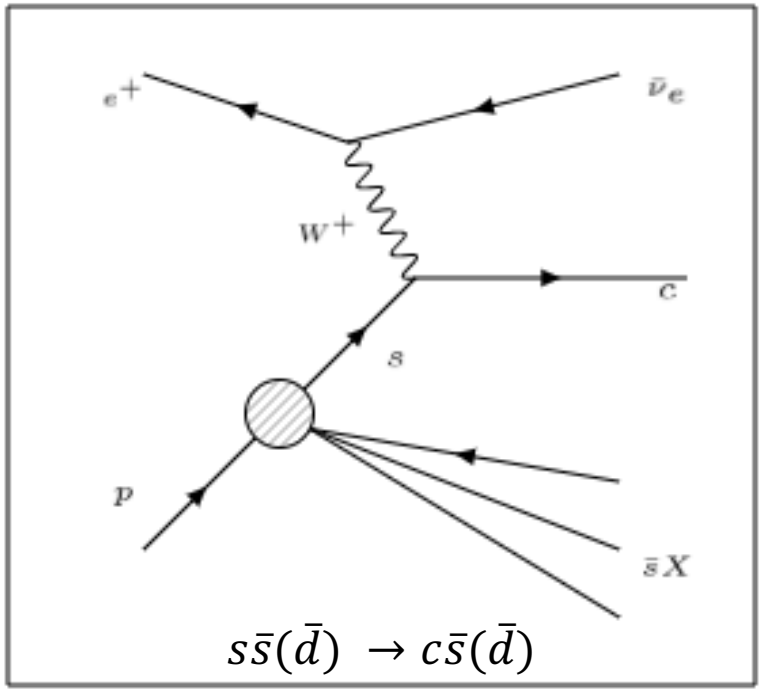
$$y_{JB} = \frac{\sum_h (E - p_z)_h}{2E_{e,beam}} \qquad Q^2_{JB} = \frac{p^2_{T,h}}{1 - y_{JB}} \qquad x_{JB} = \frac{Q^2_{JB}}{s y_{JB}}$$

- Complementary measurement (high-Q^2) to the previous analyses at low-Q^2.

→CCFR/NuTeV : $\frac{\int_0^1 dx[xs+x\bar{s}]}{\int_0^1 dx[x\bar{u}+x\bar{d}]} = 0.477^{+0.063}_{-0.053}$ $(Q^2 = 4\ GeV^2)$ **Z.Phys.C65:189-198,1995

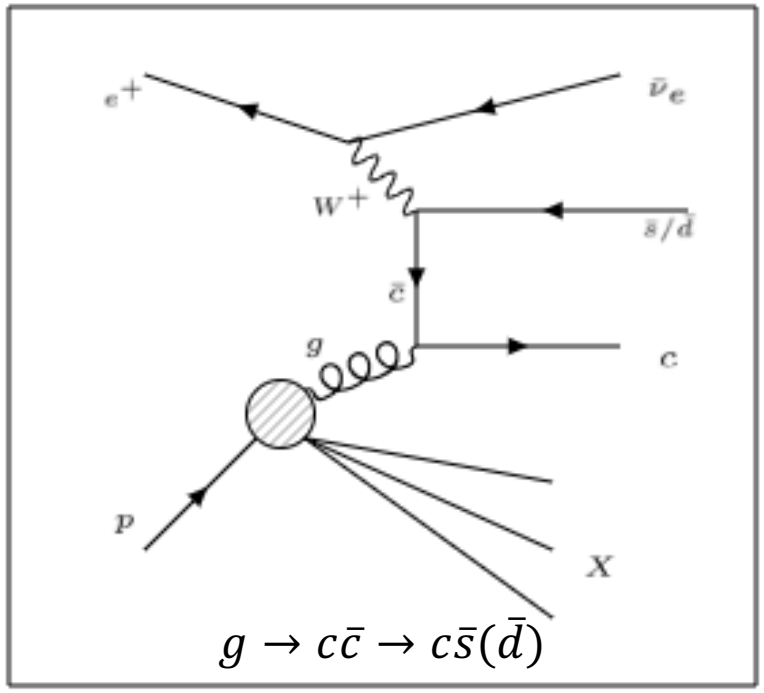
→ATLAS : $\frac{s+\bar{s}}{\bar{u}+\bar{d}} = 1.13 \pm 0.05$ $(Q^2 = 1.9\ GeV^2, x = 0.023)$ **Eur. Phys. J. C 77 (2017) 367

Charmed Sub-processes



$s\bar{s}(\bar{d}) \rightarrow c\bar{s}(\bar{d})$

- LO quark-initiated process (QI)
  - sensitive to strange content.



$g \rightarrow c\bar{c} \rightarrow c\bar{s}(\bar{d})$

- NLO boson-gluon fusion (BGF)
  - sensitive to gluon content.

- All three schemes have the same initial & final state and are EW processes.
  $\rightarrow s(x, Q^2)$ determined with this method will be model-depandant.

DATA & Monte Carlo Samples

Data

- HERA II ($L \cong 360\ pb^{-1}$)
  - $e^{-}p$: $05e, 06e$ w/ $L \cong 185\ pb^{-1}$
  - $e^{+}p$: $0304p, 0607p$ w/ $L \cong 173\ pb^{-1}$

Year	Collision	Integrated Luminosity (pb^{-1})
2003/04	$e^{+}p$	~ 38
2004/05	$e^{-}p$	~ 133
2006	$e^{-}p$	~ 52
2006/07	$e^{+}p$	~ 135

MC

- DIS
  - Inclusive CCDIS MC, DJANGOH 1.6, ARIADNE 4.12, CTEQ-5D.
- Background
  - Inclusive NCDIS MC: DJANGOH 1.6, ARIADNE 4.12, CTEQ-5D
  - Photoproduction MC: HERWIG, resolved & direct
  - Background contribution was found to be negligible.

DIS Selection Summary

General Selection	
Trigger	FLT 60 || 63 || 39 || 40 || 41 || 43 || 44 SLT EXO 4 TLT EXO 2 || EXO 6 DST 34
DQ	EVTAKE, POLTAKE, MVDTAKE, STTTAKE
p_T	p_T > 12 GeV p'_T > 10 GeV
Kinematic	200 < Q2 < 60,000 GeV2 y < 0.9
Tracking Based Selection	
Vertex	|Zvtx| < 30 cm
ϕcal - ϕtrk	dϕ < 90 degrees
Beam Gas Trk	Ntrkvtx > 0.125 * (Ntrk - 20)

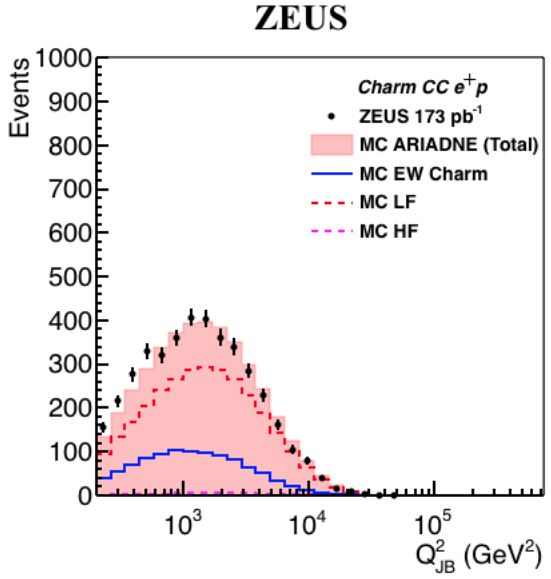
**Based on 0607p CC MC by Ciesielski & Oliver

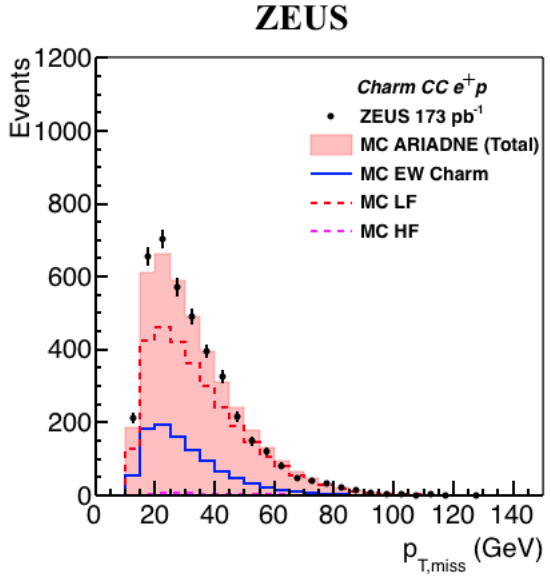
Calorimeter Based Selection	
Timing	Consistent with ep interaction
PhP, Beam Gas	Vap/Vp < 0.25 if (Pt < 20 GeV) Vap/Vp < 0.35 else
Cosmics	Reject if: Ncell < 40 or (BAC/BRMU cosmic muon) or E_RCAL > 2 GeV and f_RHAC > 0.5 or E_BCAL > 2 GeV and f_BHAC > 0.85 or f_BHAC1 > 0.7 or f_BHAC2 > 0.4 or E_FCAL > 2 GeV and f_FHAC < 0.10 or f_FHAC > 0.85 or f_FHAC1 > 0.7 or f_FHAC2 > -.6
Halo Muon	Reject if: MaxEtCell_nr <= 16384 and RCAL asosE > 0.3 GeV (FCAL) or Tsu_halo > 0 (TSUBAME in BCAL) or (BAC/BRMU halo muon)
NC DIS	Reject if: PT < 30 GeV&& E-Pz > 30 GeV && E_e > 4 GeV && E_in < 5 GeV && (Ptrk/Ee > 0.25 for 15 < θe < 164 or Ete > 2 GeV for θe > 164)

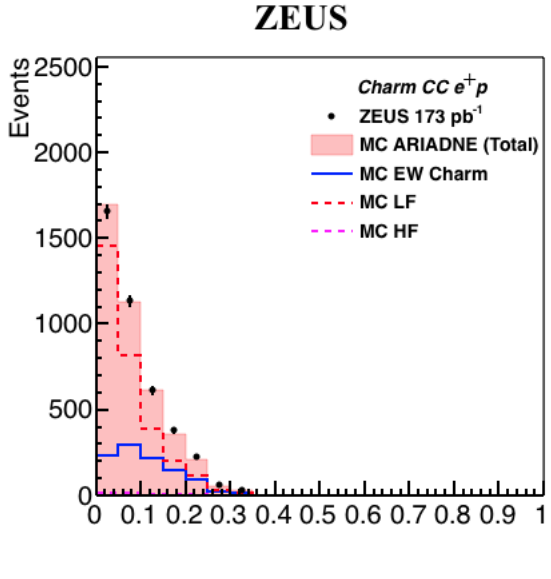
yellow – Varies between run periods
-STTTAKE = 0 for 05e data
-FLT 63 active after run 54115

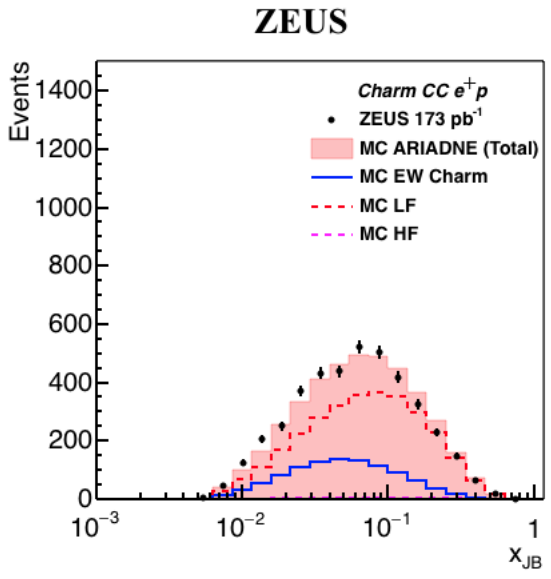
green – Only applied on data
-Timing cut only on data

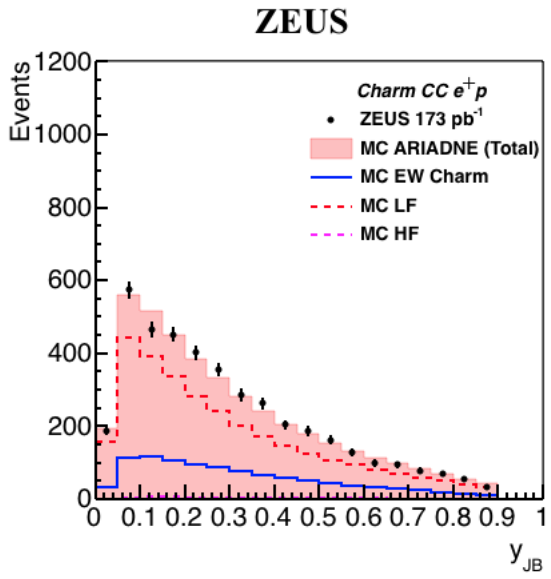
Control Plots – Event (e^+p)

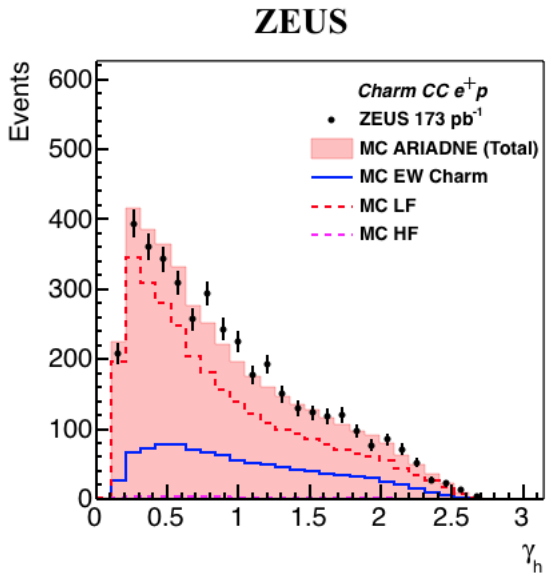








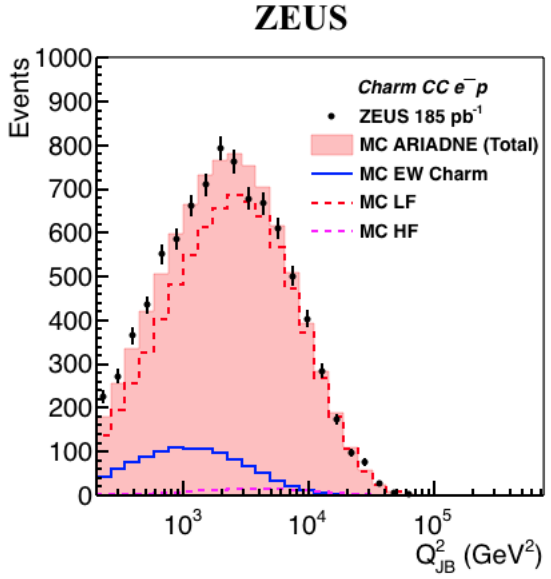


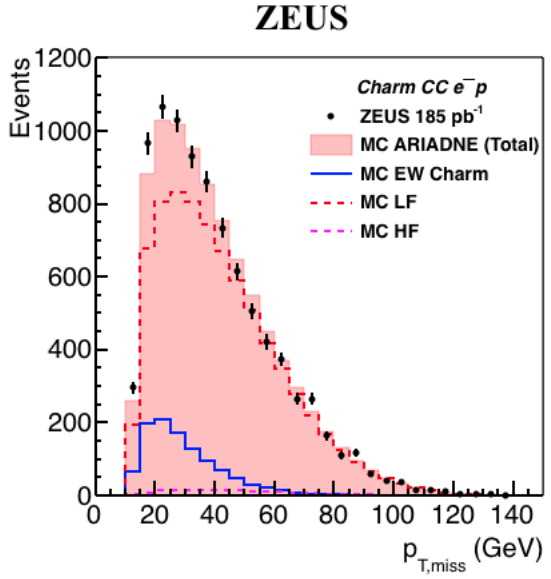


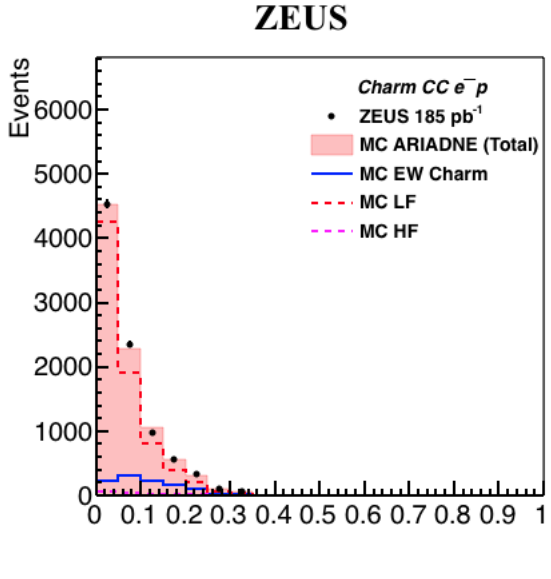
- Good agreement between MC and data.

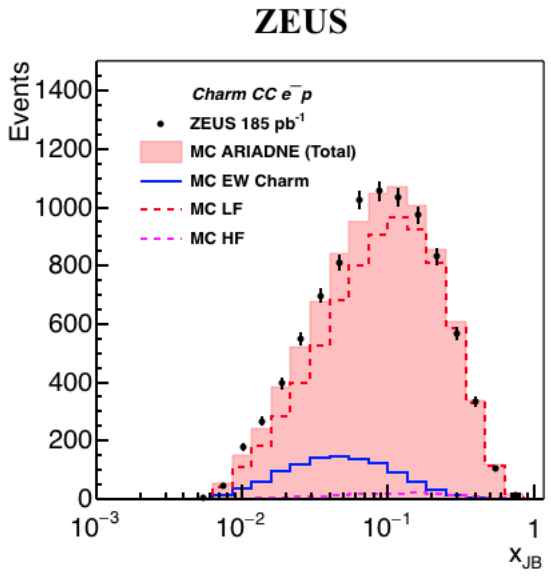
**MC LF (paper) to MC LF (slides)

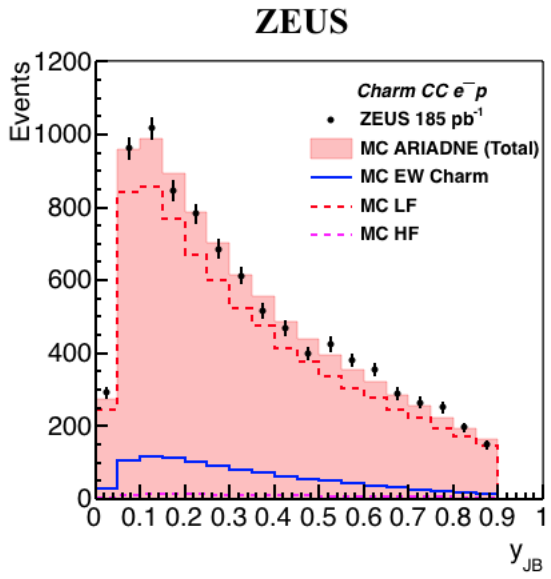
Control Plots – Event ($e^- p$)

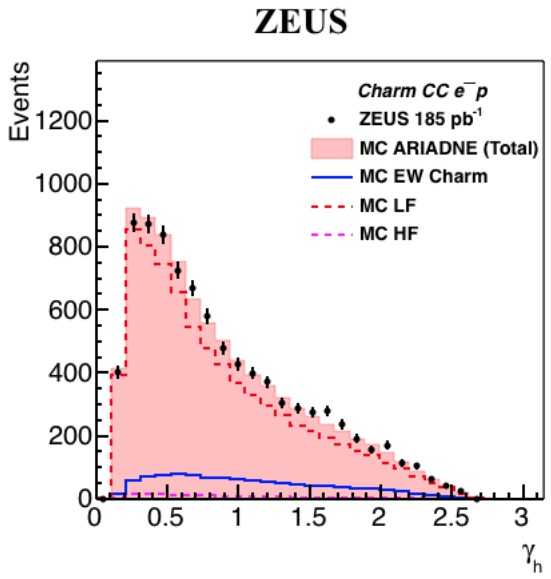












Charm Identification

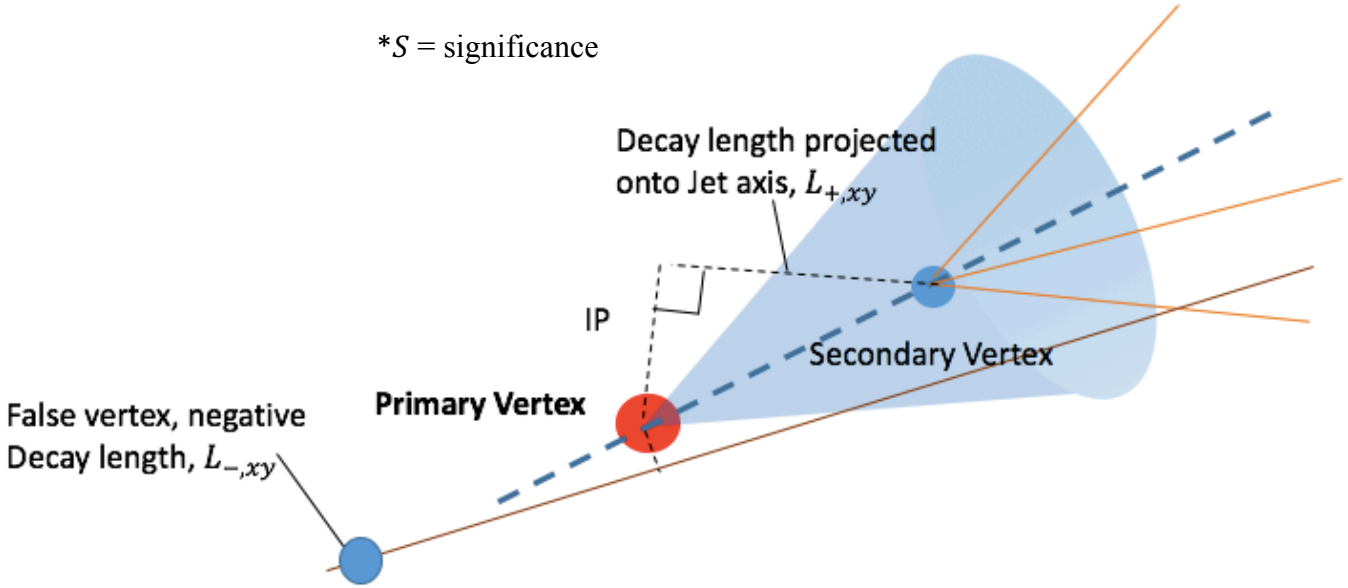
Lifetime-tagging Method

- 2D decay length (L_{xy}) projected onto Jet axis.
  - LF → Short-lived, Symmetric decay length.
  - Charm → Long-lived, Asymmetric.

- LF contribution (background) suppressed by mirroring decay length distribution about $L_{xy} = 0$.

  $(M_{L+} - M_{L-}\,, M_{S+} - M_{S-})$

*S = significance

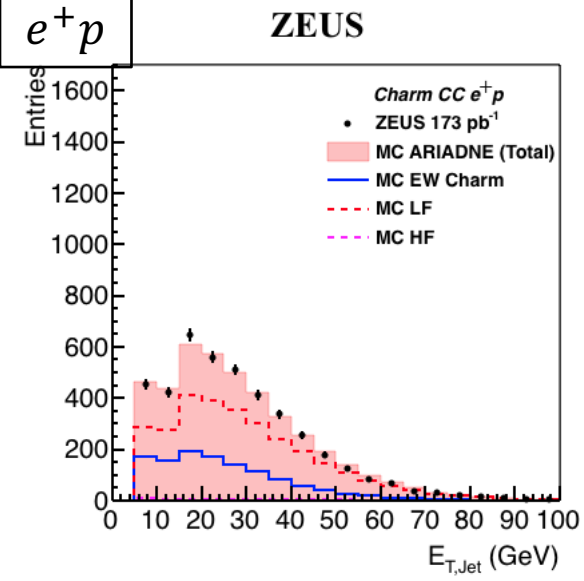


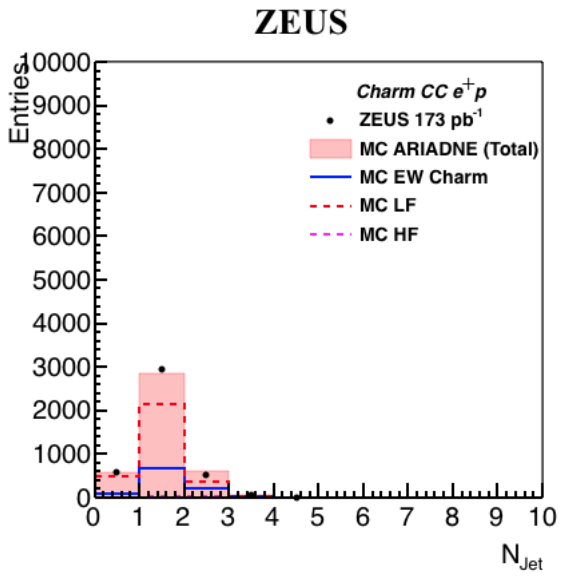
Jet Selection	Reconstructed by using kT algorithm in massive mode.
	$E_T^{jet} > 5\ GeV$
	$\mathbf{-2.5 < \eta^{jet} < 2.0\ (1.5\ for\ 05e)}$ **** backup slide 29**
SecVtx Selection	$\chi^2/N_{dof} < 6$
	$\lvert Z_{secvtx}\rvert < 30\ cm$
	Distance to beam spot $\sqrt{\Delta x^2 + \Delta y^2} < 1\ cm$
	$\mathbf{M_{secvtx} < 6\ GeV}$
	$\mathbf{N_{secvtx}^{trk} > 2}$ **** backup slide 30**

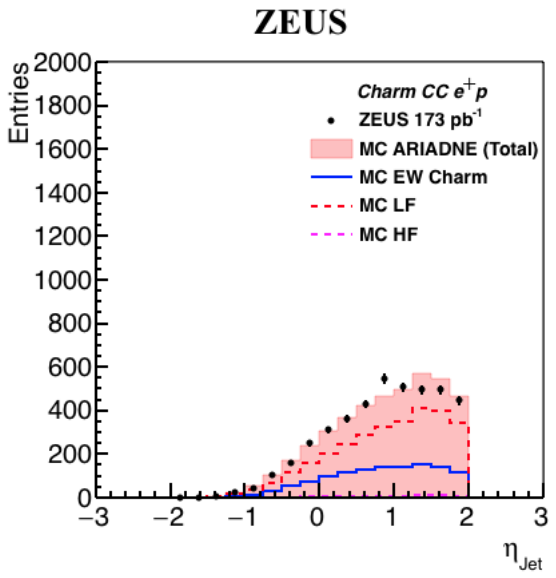
- E_T^{jet} and η^{jet} cuts further define the kinematic phase space of the measurement.

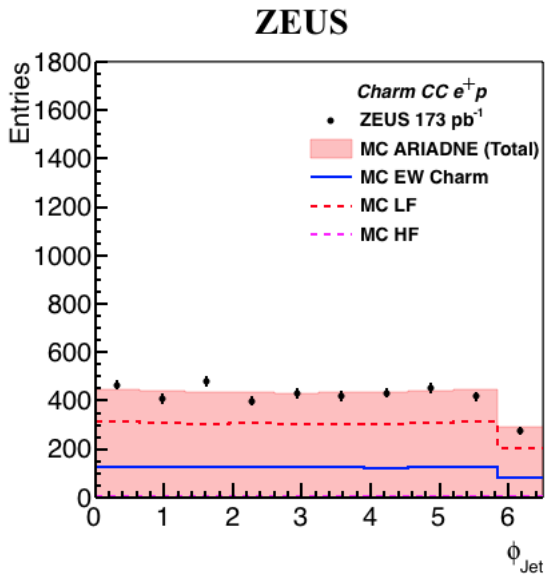
Control Plots – Jet

e^+p

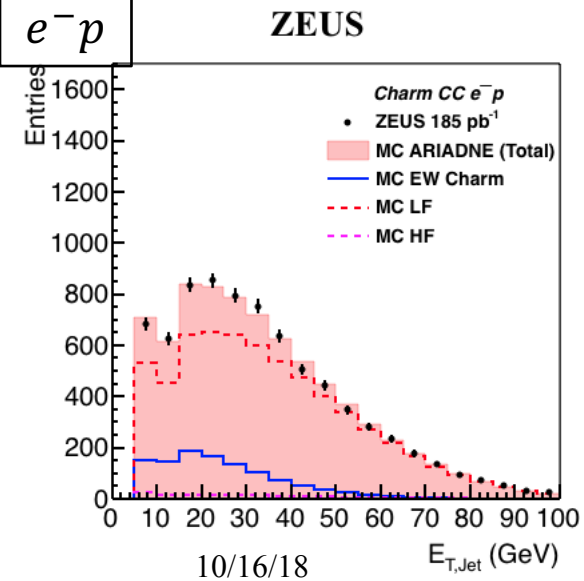


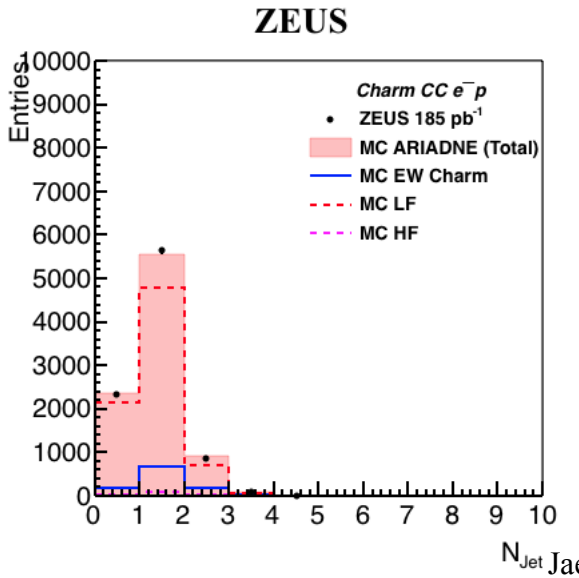


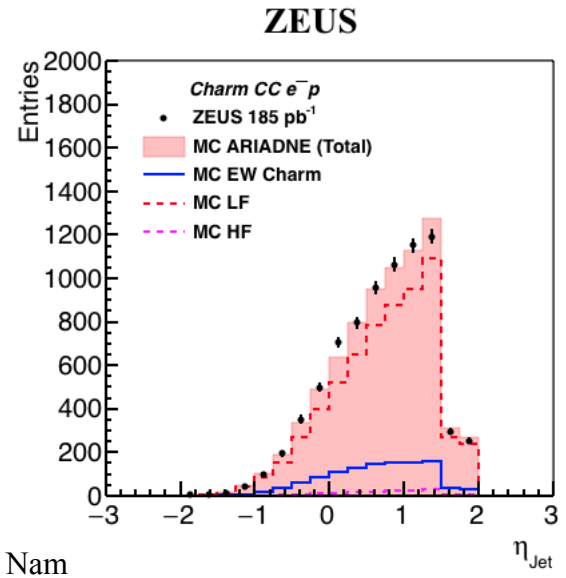


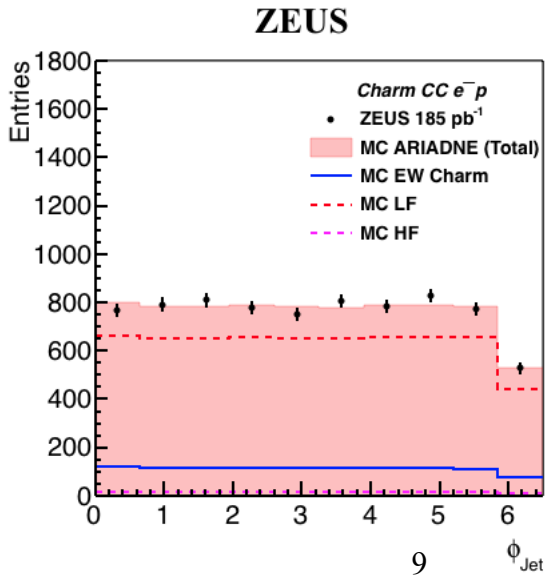


e^-p



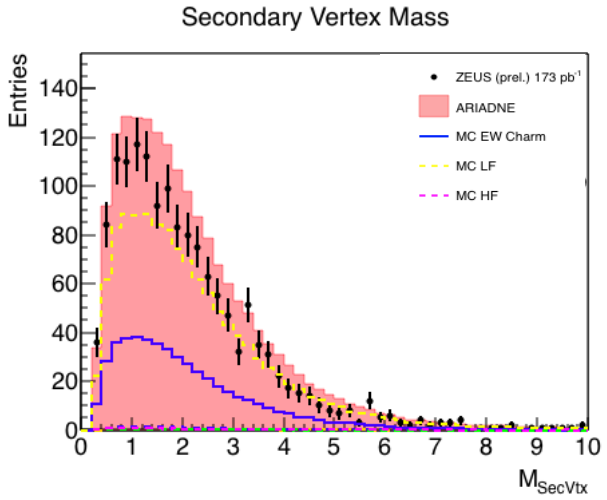


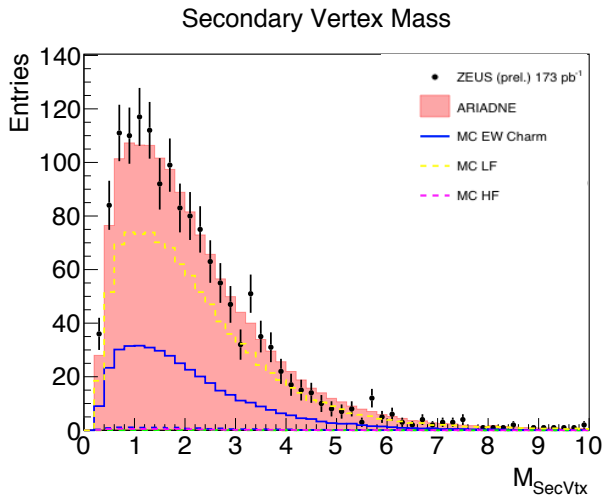


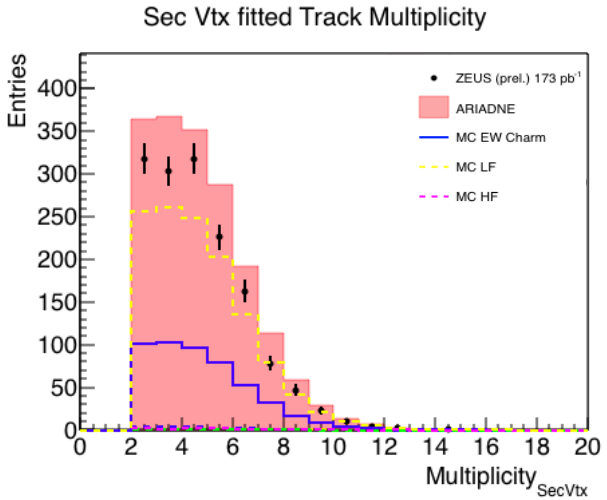


Secondary Vertex Scaling

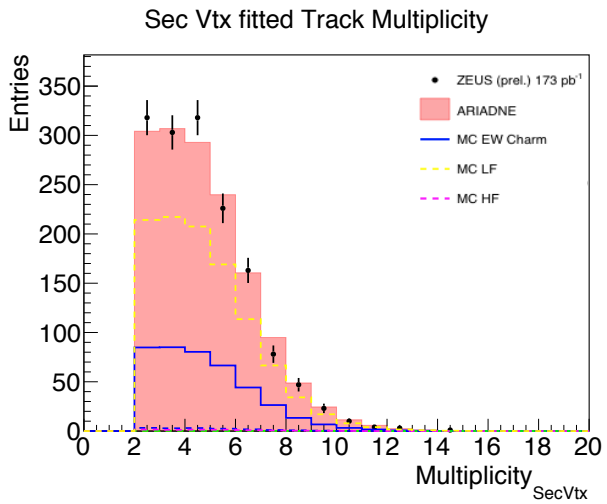
(0607p)







MC scaling factor
$= 0.830$

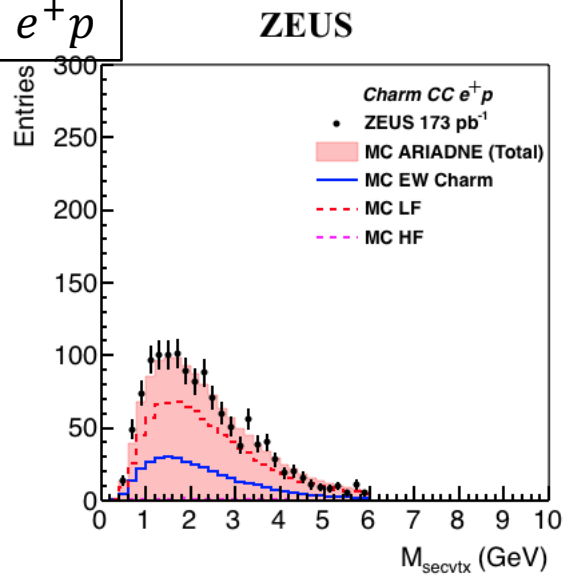


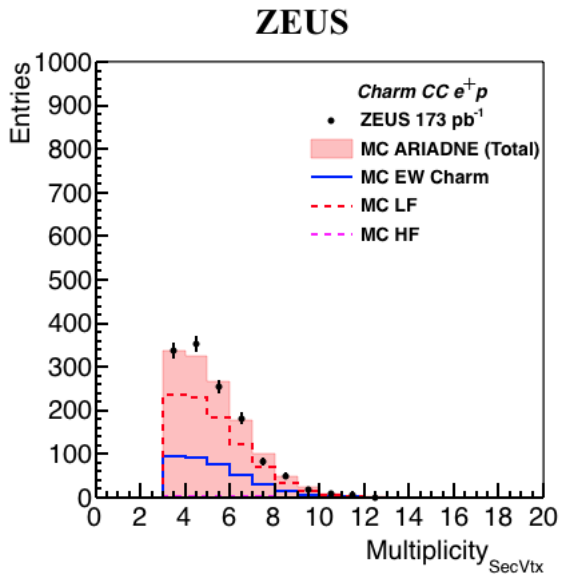
- MC overestimates trackings & secondary vertices.
- A secondary scaling applied to MC to match Data.

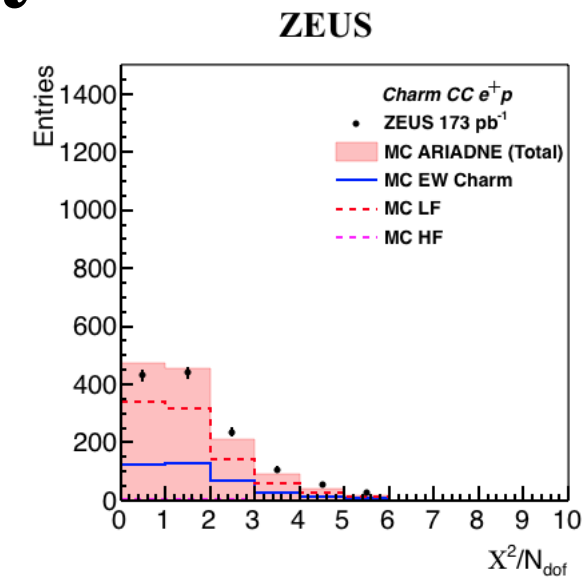
$$N_{SecVtx}^{DATA}/N_{SecVtx}^{MC} = 0.708 \ (0304p)$$
$$= 0.810 \ (05e)$$
$$= 0.807 \ (06e)$$
$$= 0.830 \ (0607p)$$

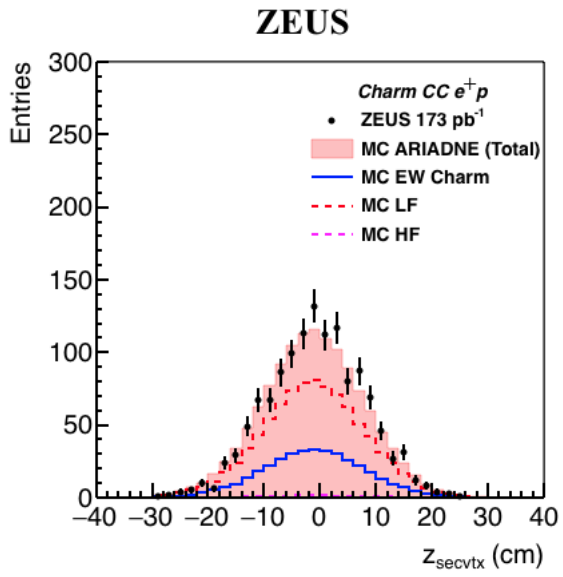
Control Plots – Secondary Vertex

e^+p

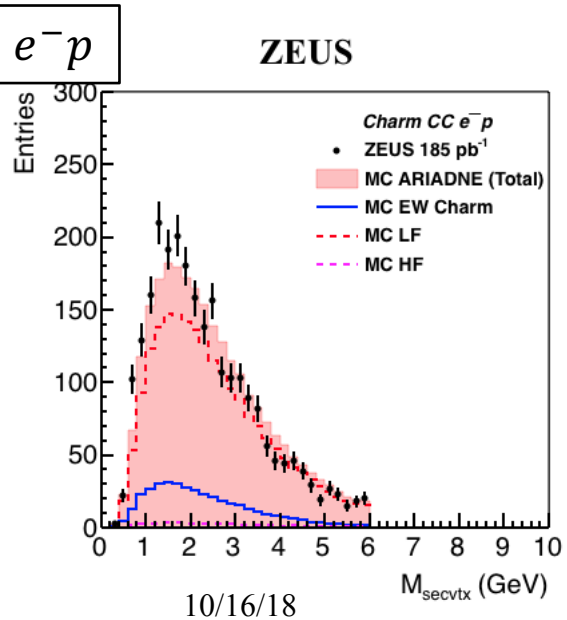


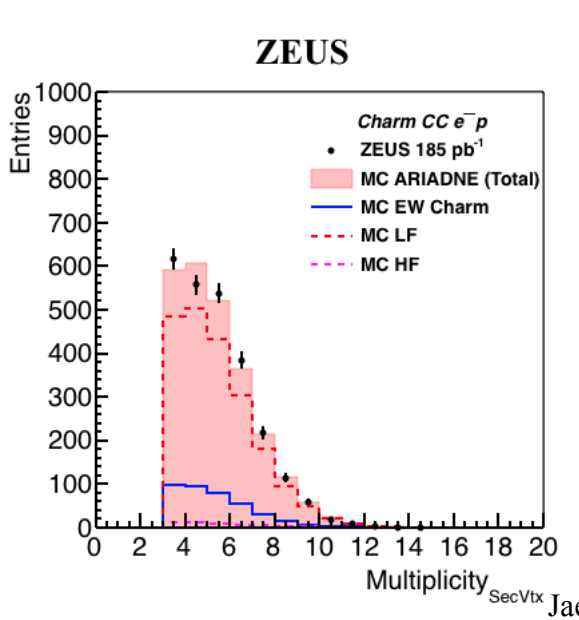


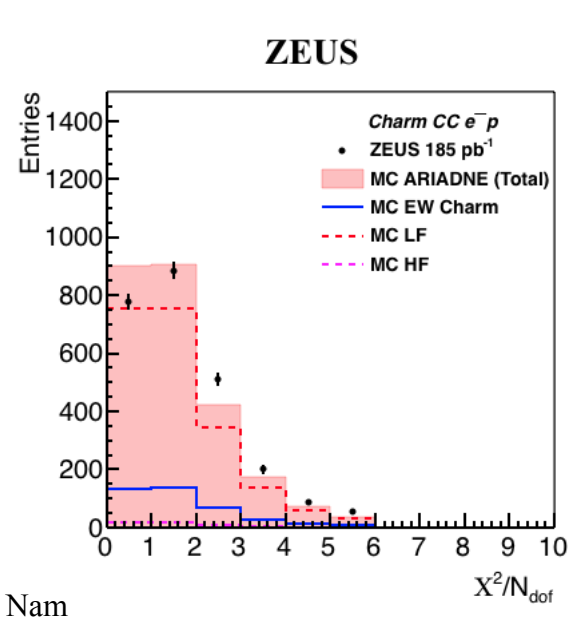


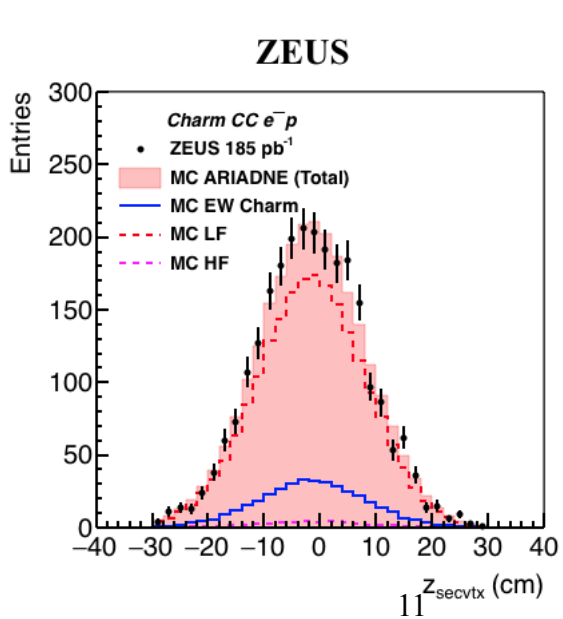


e^-p

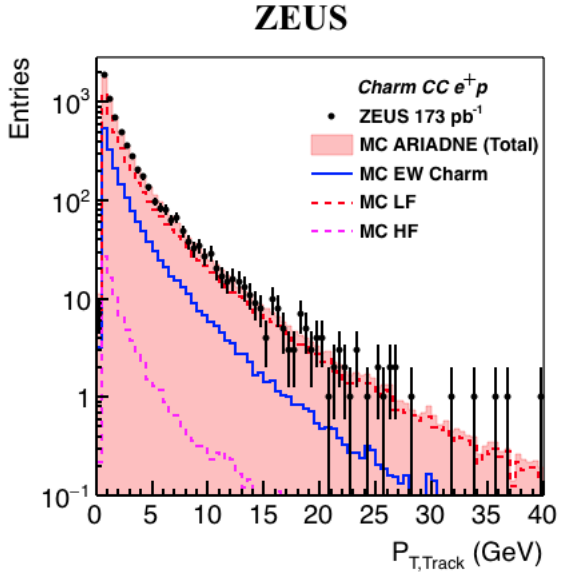


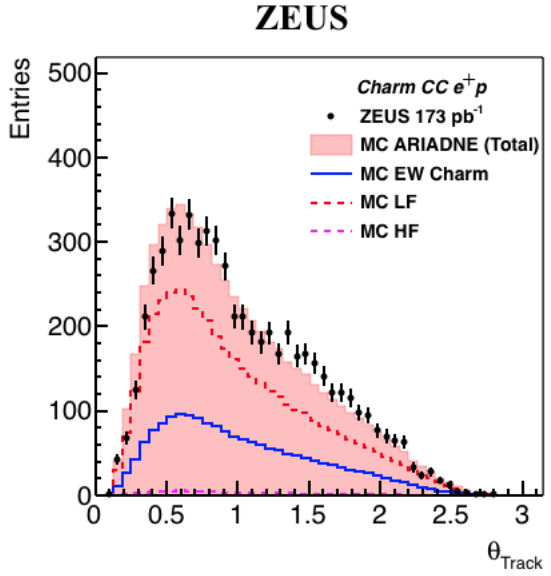


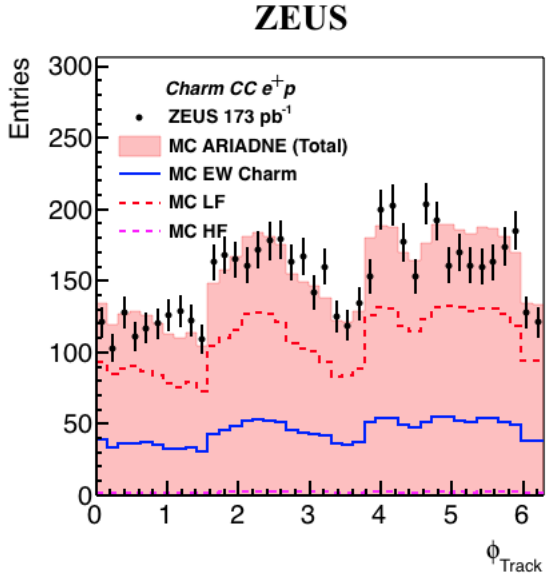


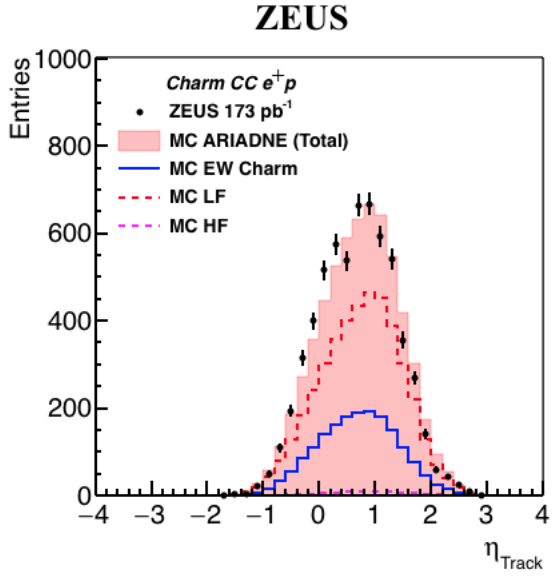


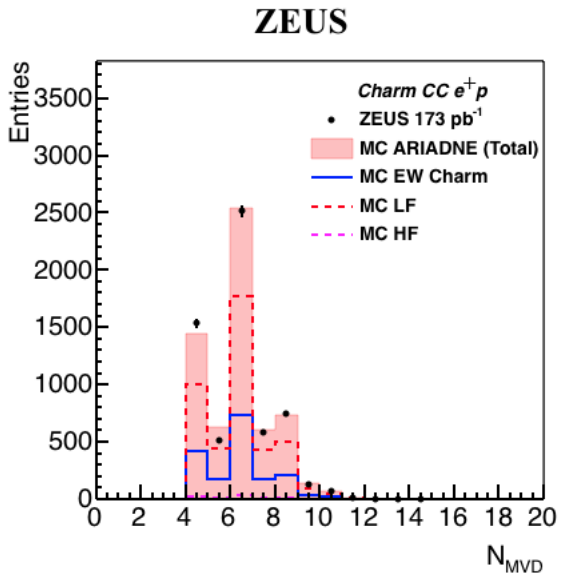
Control Plots – Tracks (e^+p)

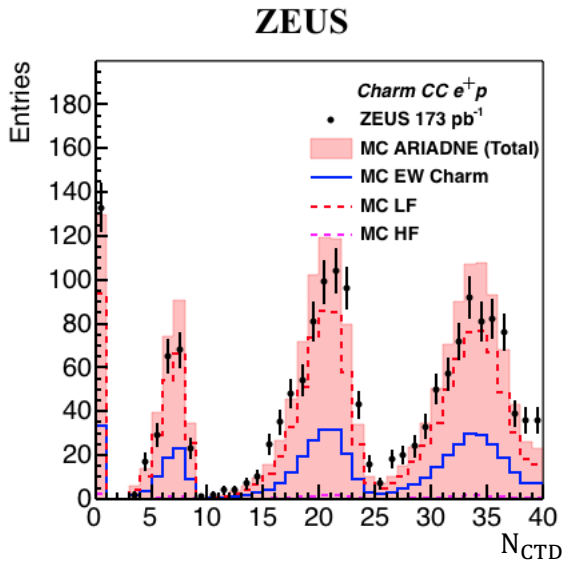


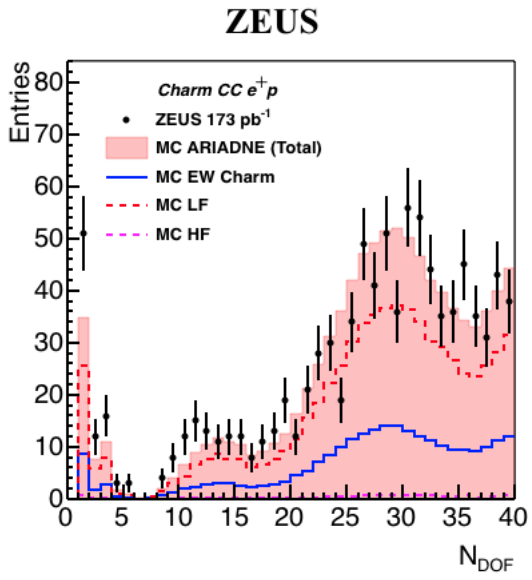


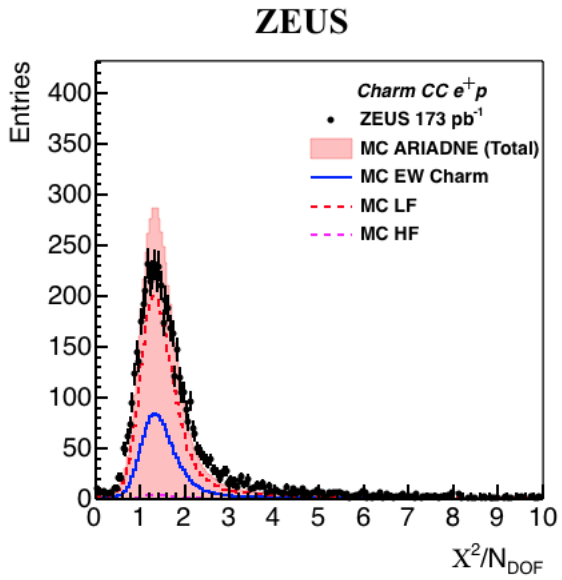




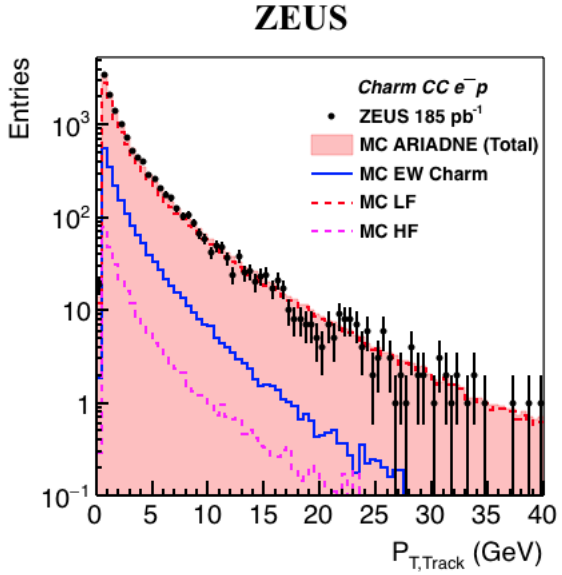


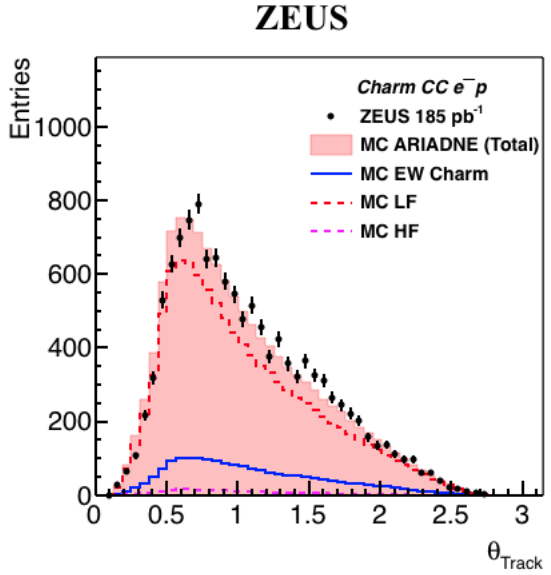


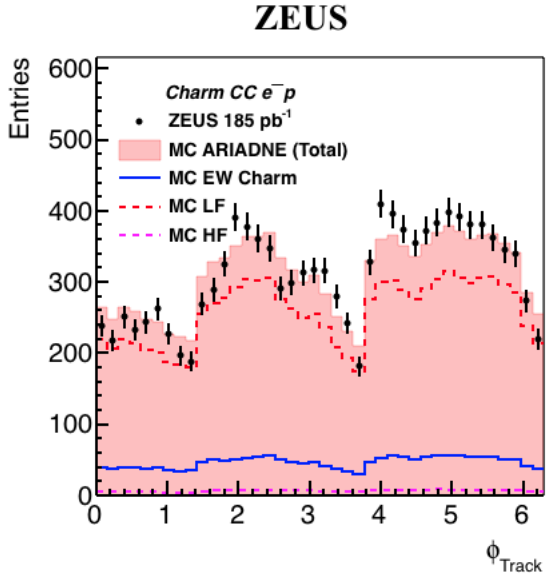


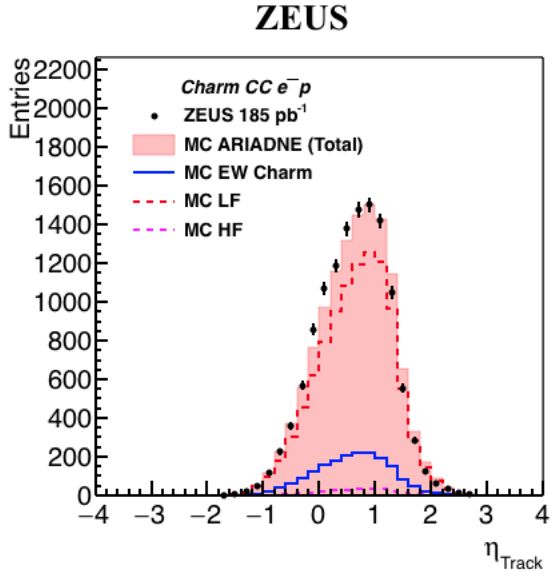


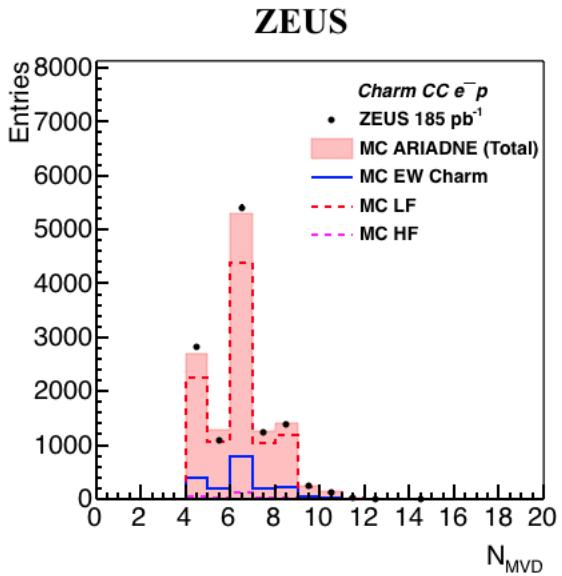
Control Plots – Tracks ($e^- p$)

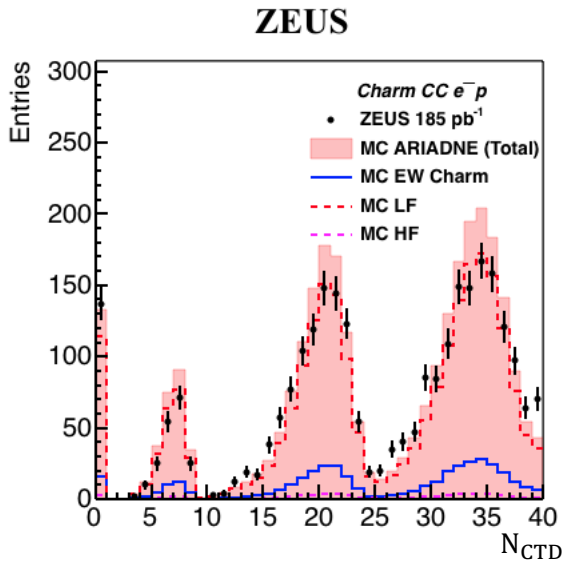


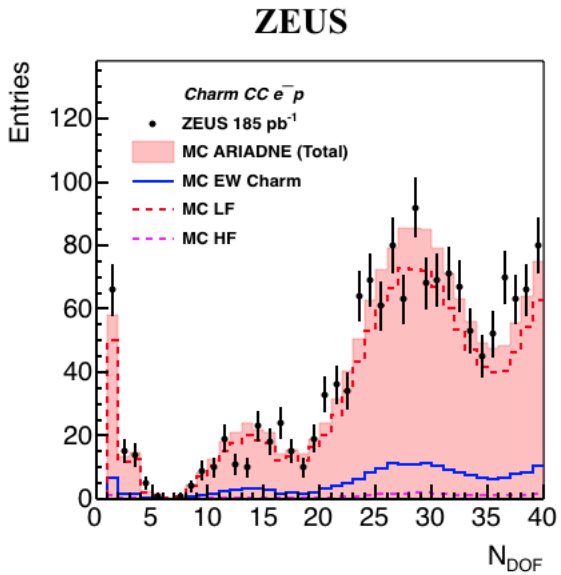


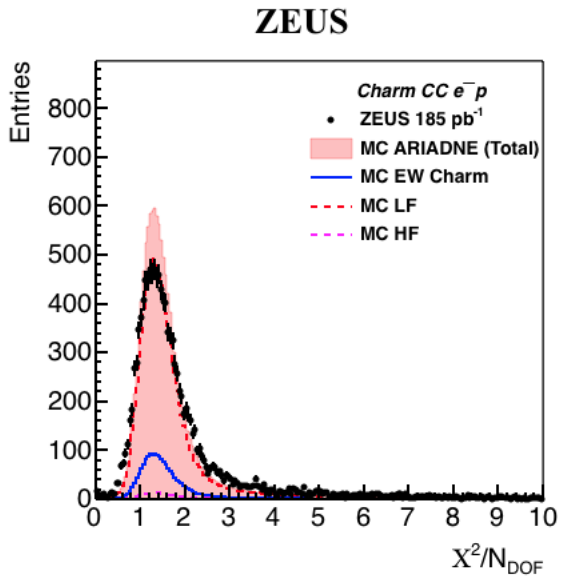






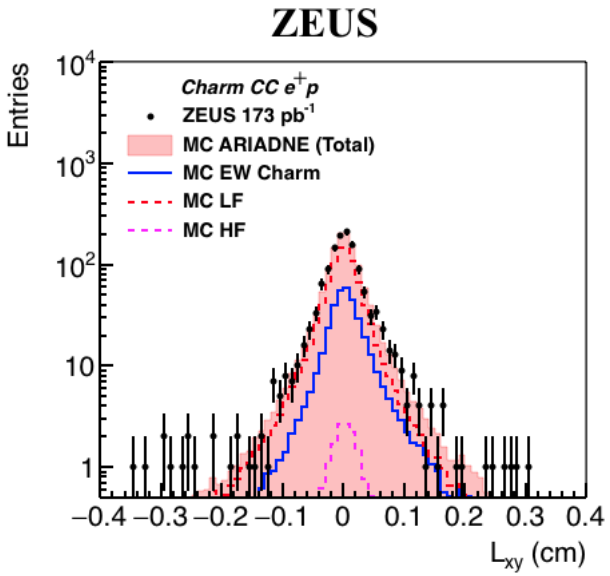


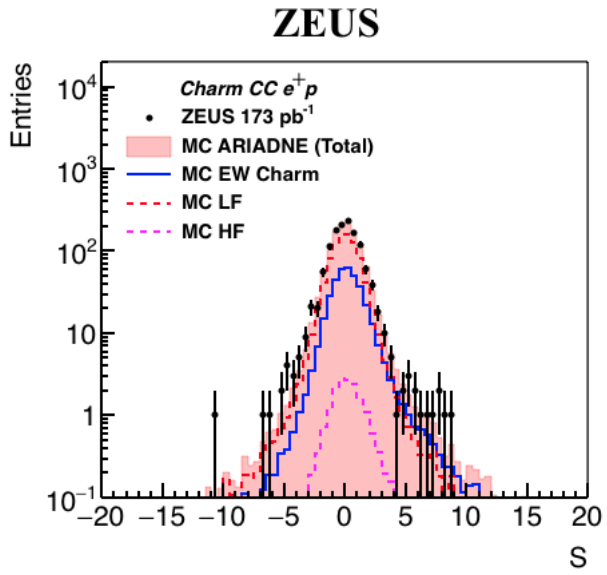




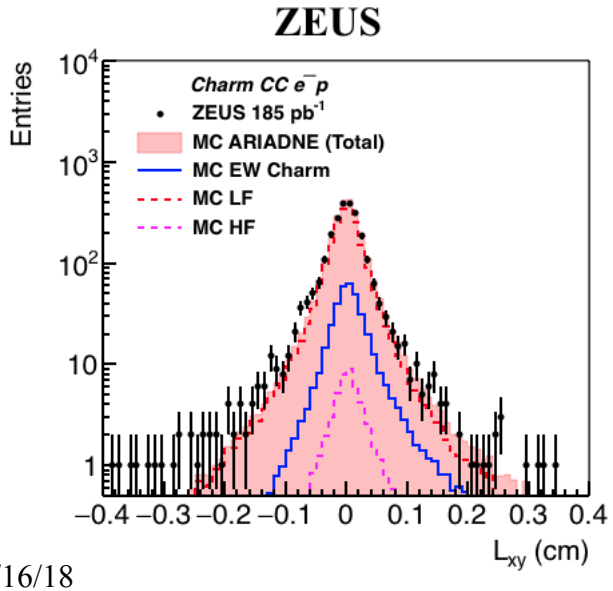
Decay Length Plots

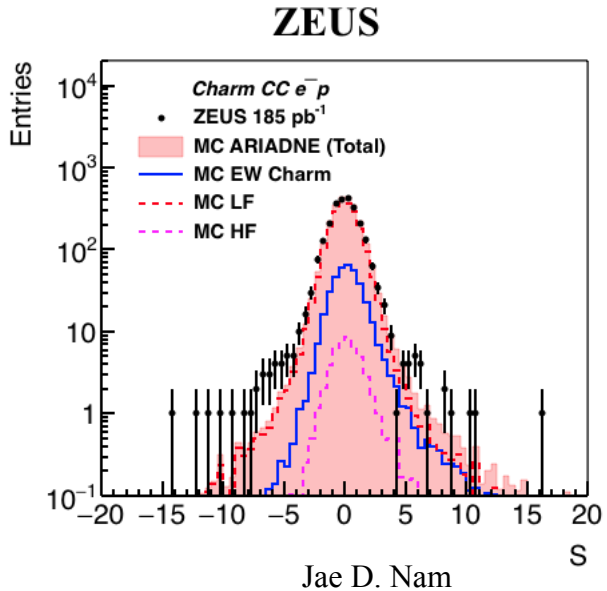
e^+p





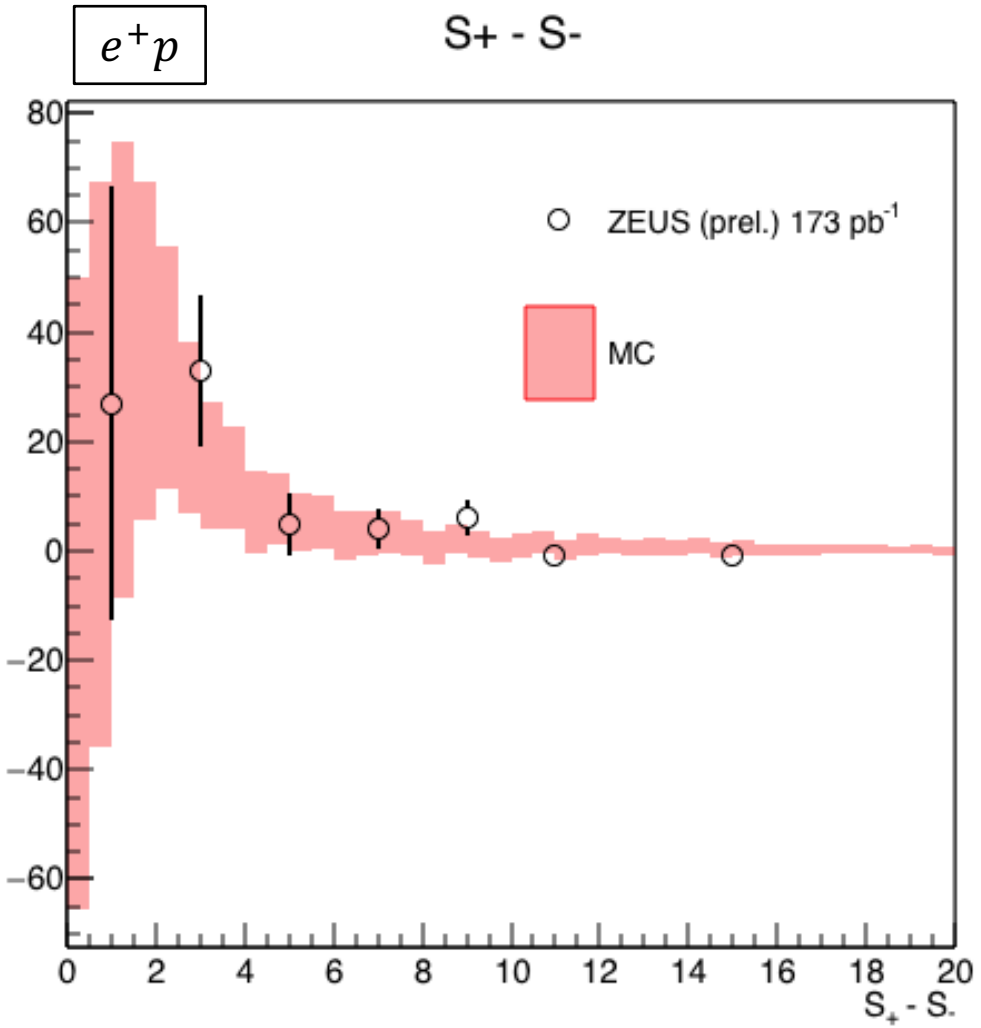
e^-p

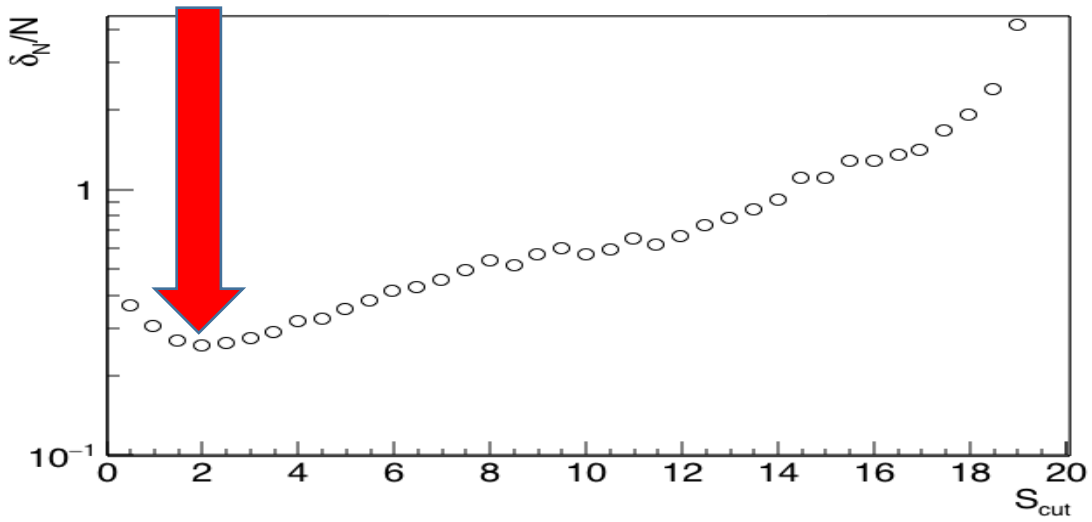




- Asymmetric charm signal observed.
- The high symmetry and large statistics around $S \sim 0$ contributes to a large statistical uncertainty in the low bin regions in S.
- A significance threshold cut was applied to reduce overall statistical uncertainty.

Determination of Significance Threshold

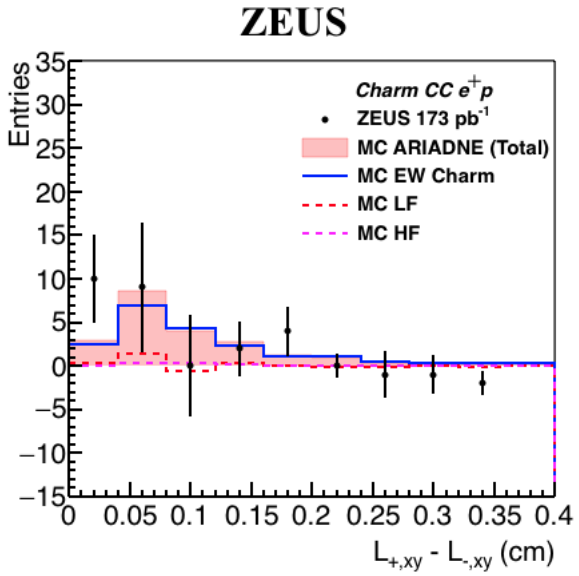


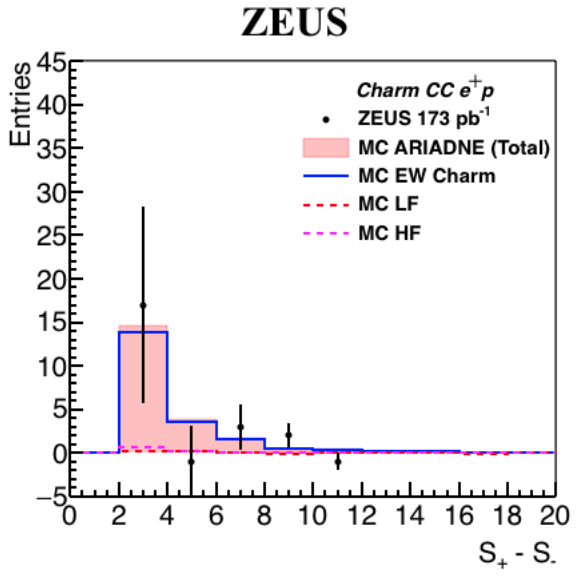


- The high symmetry and large statistics around $S \sim 0$ contributes to a large statistical uncertainty.
- A significance threshold cut was applied to reduce overall statistical uncertainty.
- From MC, the lowest δ/N is achieved if cut were to be applied at $S = 2$.

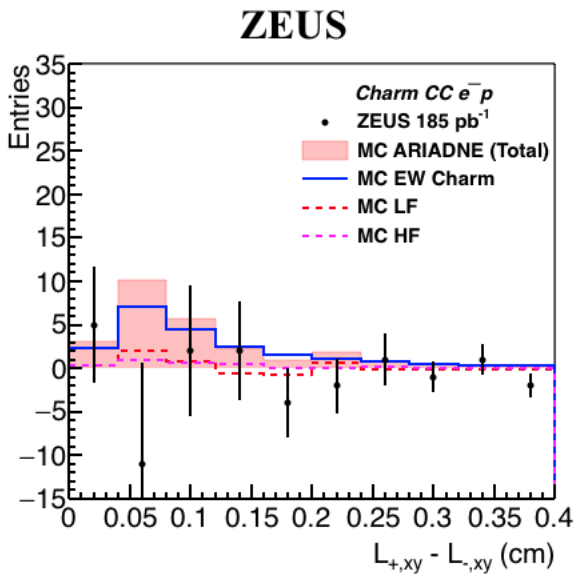
Mirrored Decay Length

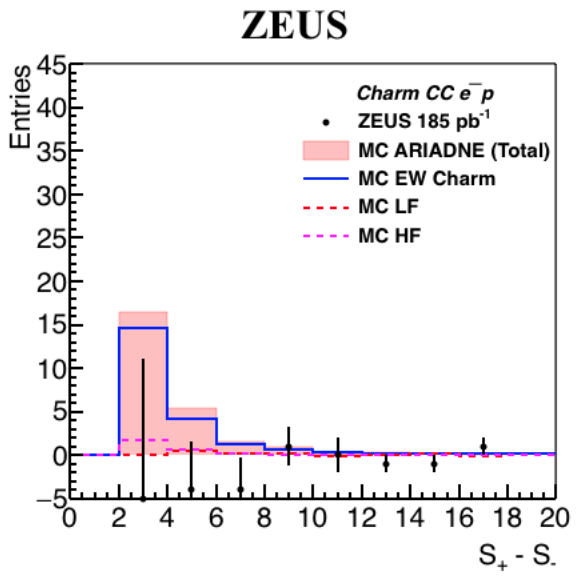
e^+p





e^-p



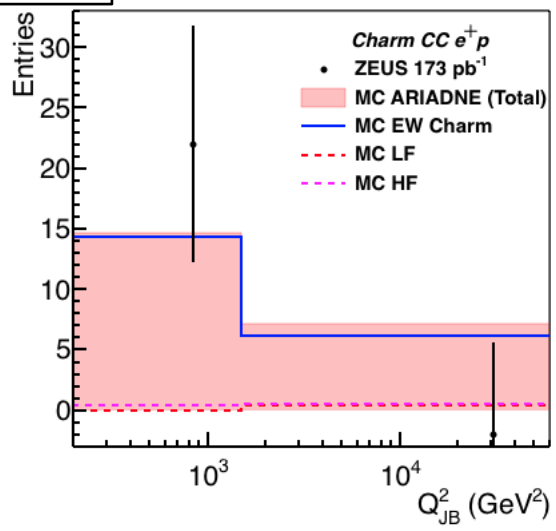


- Significance cut applied at $S > 2$.
- Charm signal observed with LF contribution (Background) suppressed.
- Surviving events are split into 2 bins in Q^2 to unfold charm production cross section, $\sigma_{charm,CC}$.

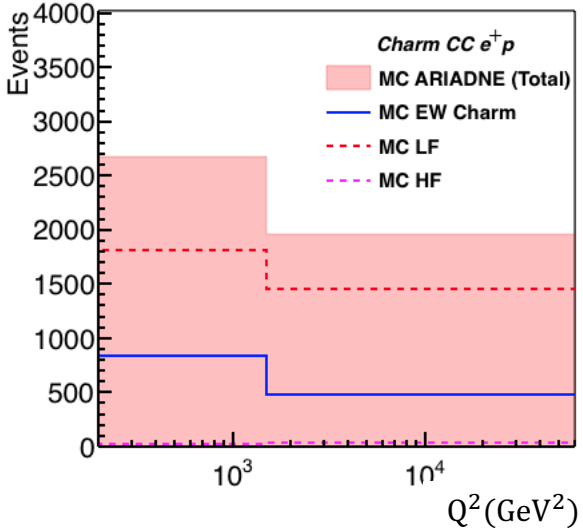
Charm signal & Charm generated

e^+p

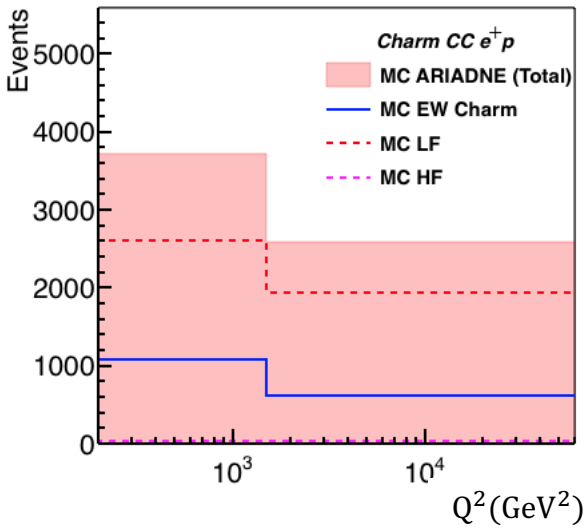
N_{signal}



$N_{gen,kin}$

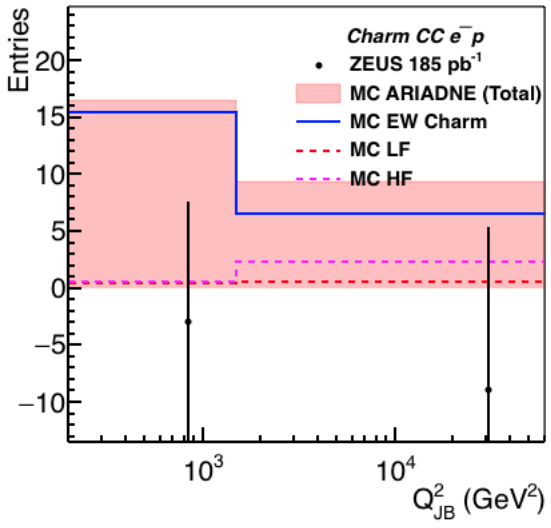


N_{gen}

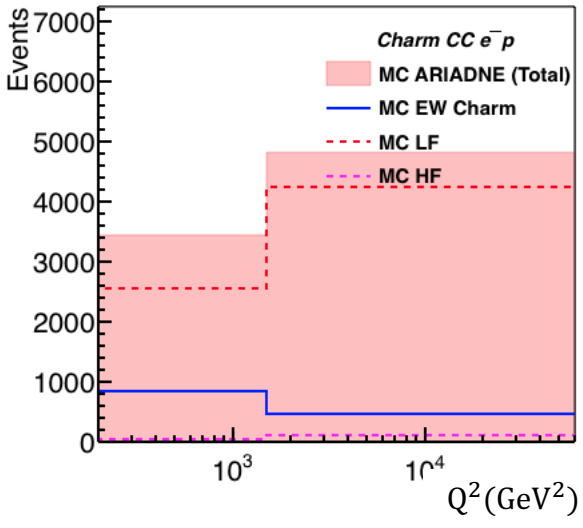


e^-p

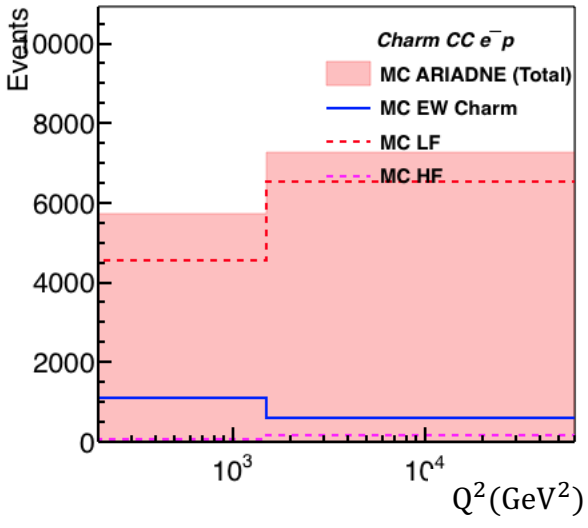
N_{signal}



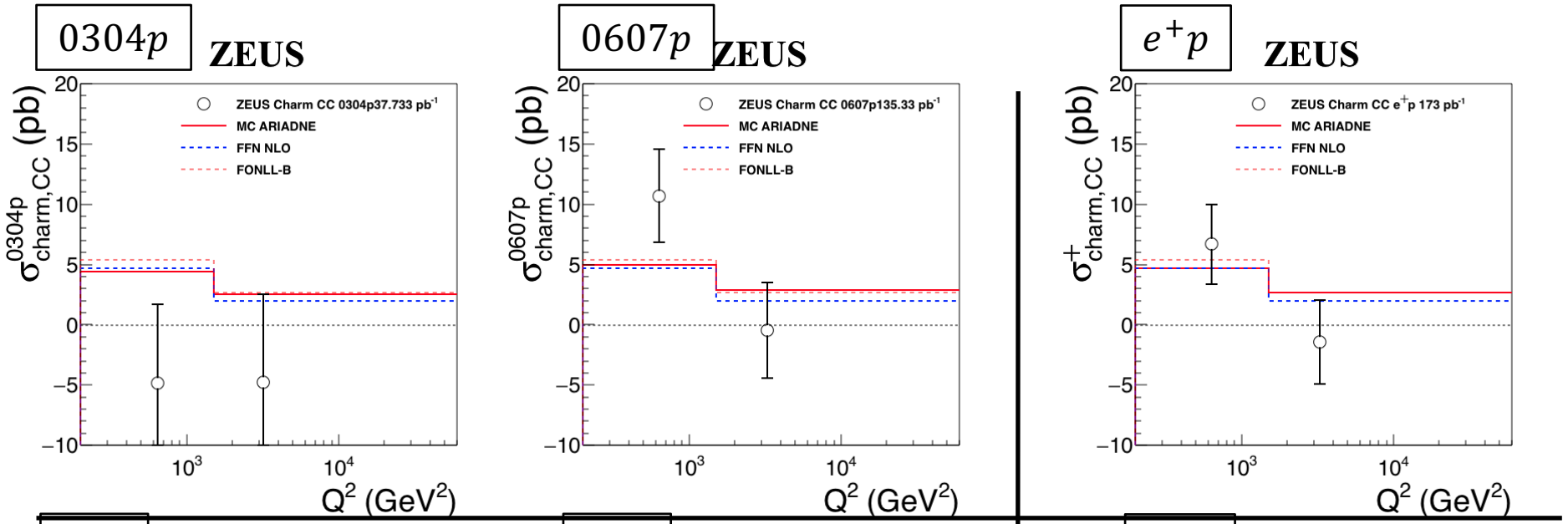
$N_{gen,kin}$

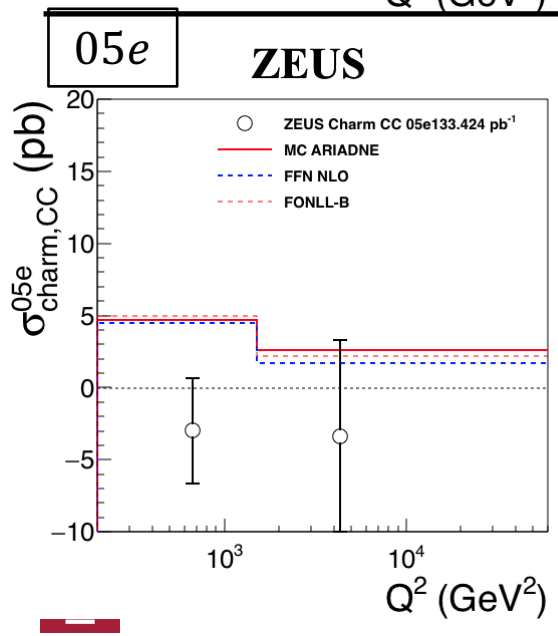


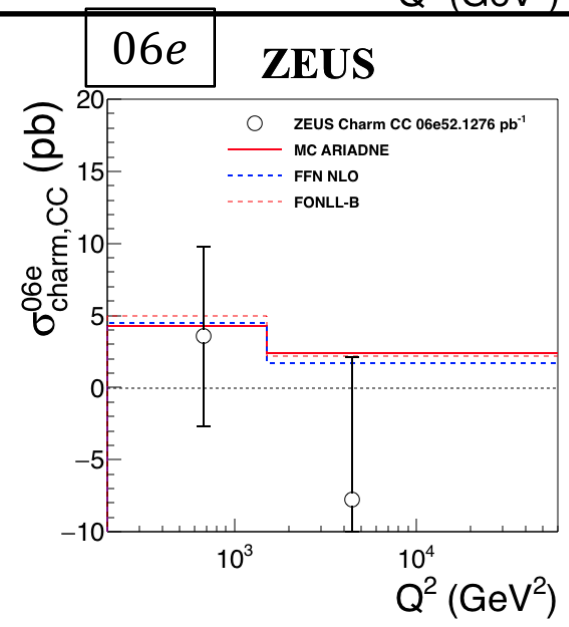
N_{gen}

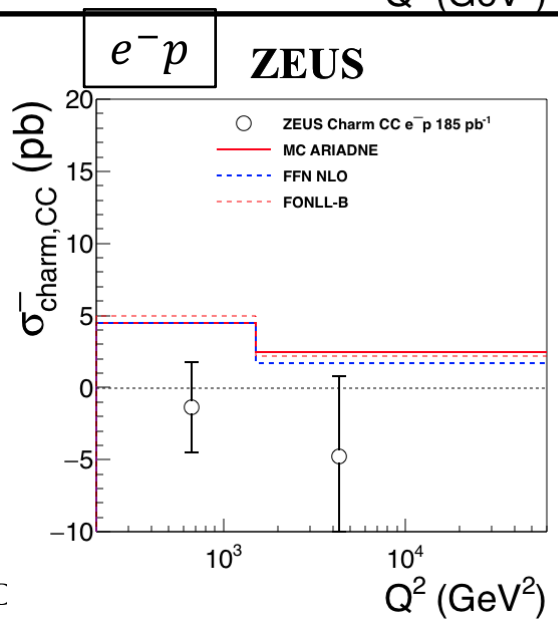


Results









- 0304p & 0607p, 05e & 06e combined at the cross section level.
- EW charm cross sections have been measured.
- MC & theory predictions suggest that the contributions from QI and BGF processes are about equal.

- Theory predictions
- FFN scheme:
  - ABMP16.3 NLO pdf set, OPENQCDRAD
- FONLL scheme:
  - NNPDF31 NLO pdf set, APFEL
- Both are interfaced in xFitter.

Systematic Uncertainties (for 2nd pres.)

δ_1 DIS Selection

- Uncertainty associated with the selection threshold values.

δ_2 Calorimeter

- Due to imperfect calibration of hadronic calorimeter (HAC). Uncertainty in E_T^{jet} is known to be $\pm 3\%$.

δ_3 Background

- Asymmetry in LF decay length due to long-lived LF particles.
- Uncertainty associated with HF will be assigned (status report)

δ_4 Secondary Vertex Rescaling

- More secondary vertices survive in MC than in data. Rescaling was only applied to the light-flavor signal to account for different causes of the discrepancy.

δ_5 Signal Extraction

- Due to the low statistics & high fluctuation in data, further study will be performed.

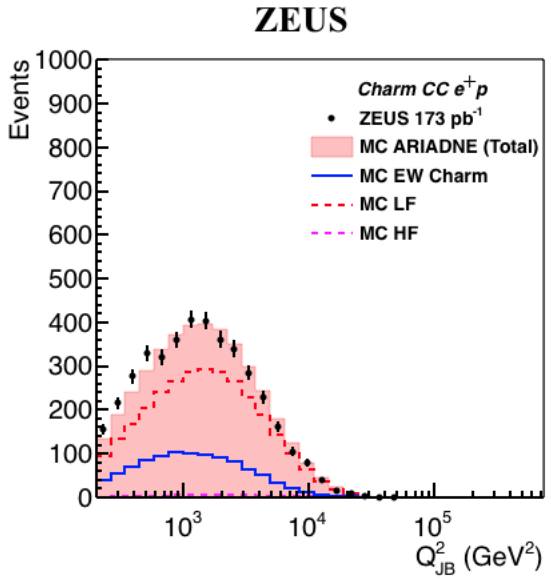
δ_6 Luminosity

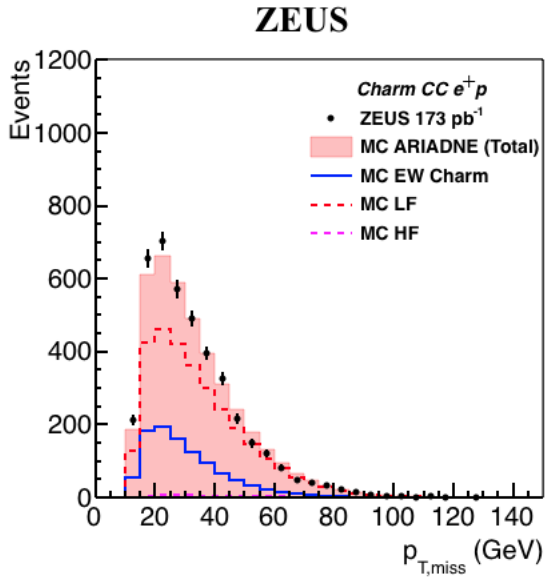
- Uncertainty in ZEUS luminosity measurement. Known to be $\pm 2\%$.

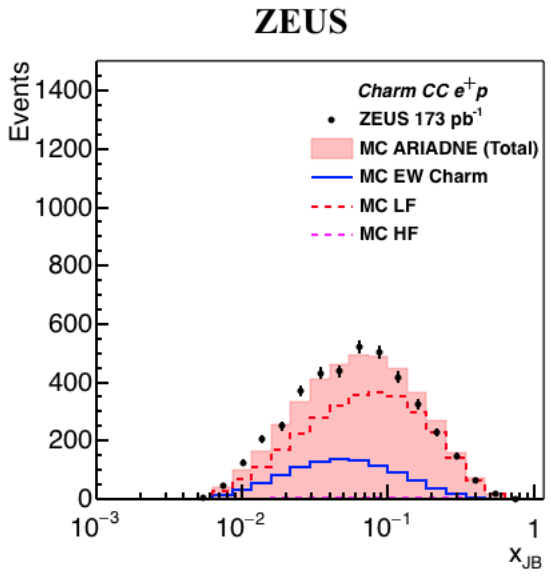
Summary

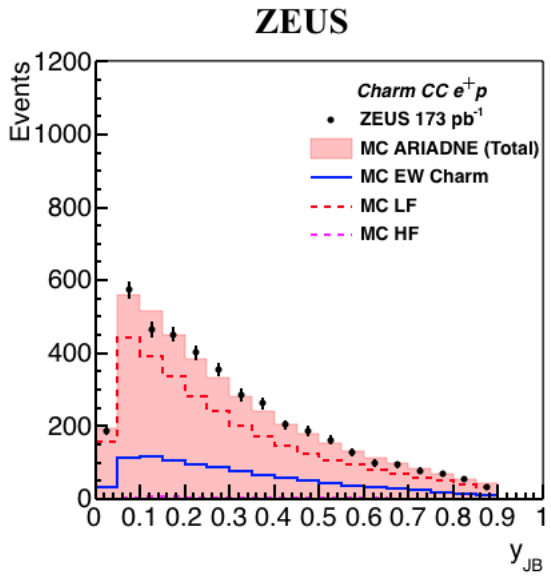
- Measurements on EW Charm production in CCDIS has been performed; separately for e^+p and e^-p.
  - Good agreement between MC, FFN, FONLL and possibly data within its large statistical uncertainty.
  - Two major contributors are LO Cabbibo-allowed transition ($s \to c$) and BGF ($g \to c\bar{c}$) sharing about equal contribution.
- Changes from preliminary includes…
  - New cuts introduced: $-2.5 < \eta^{jet} < \mathbf{2.0(1.5)}$, $N_{trk}^{secvtx} > 2$ and $M^{secvtx} < 6\ GeV$.
  - Cross sections are combined at the cross section measurement stage.
- Plan for second paper presentation
  - Verify the source of HF background in electron beam periods (to be discussed in the update).
  - Completion of systematic uncertainty.

Requested for Paper









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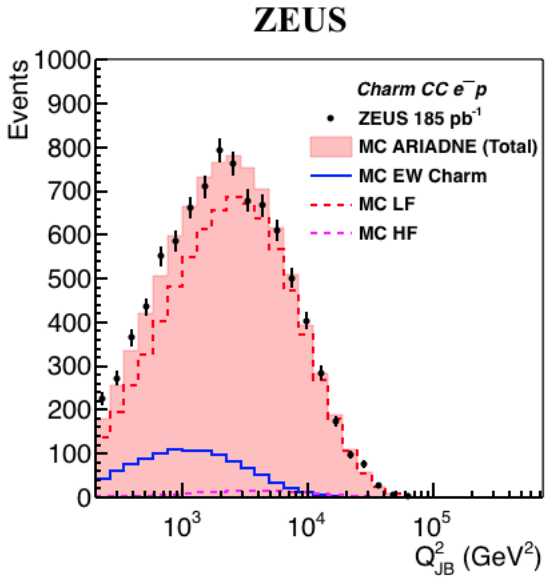

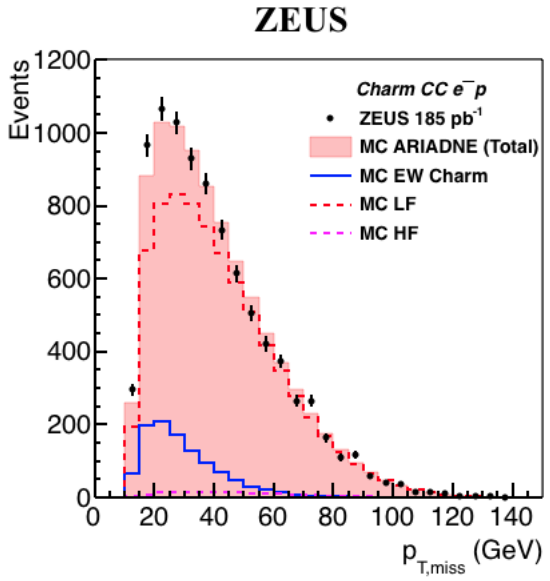

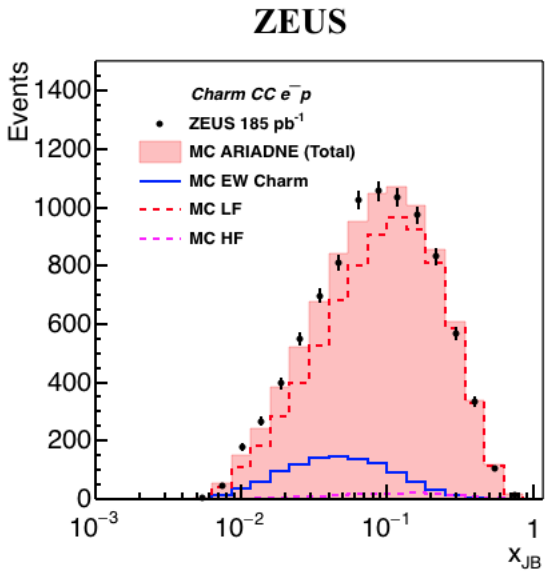

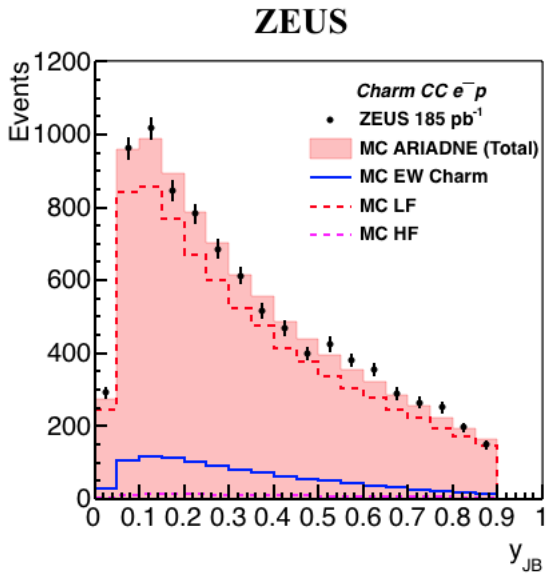

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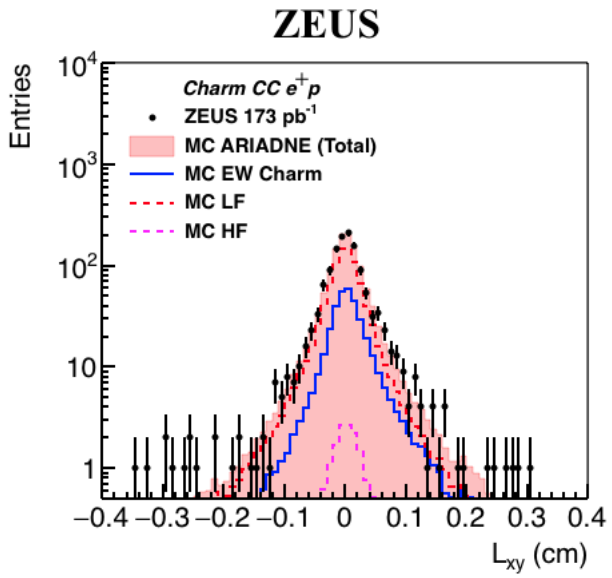

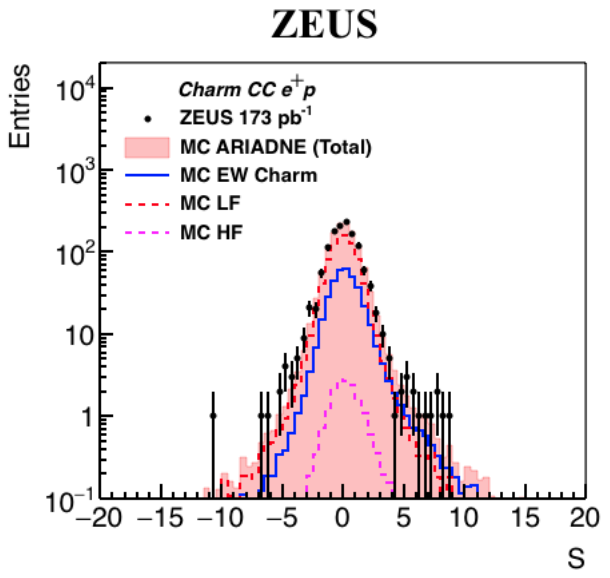

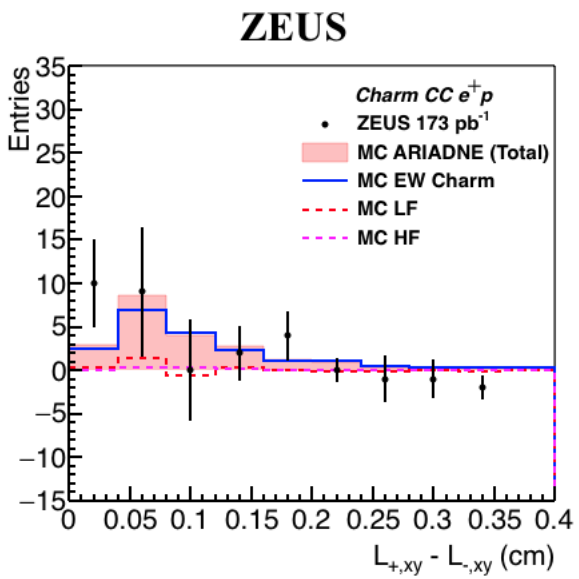

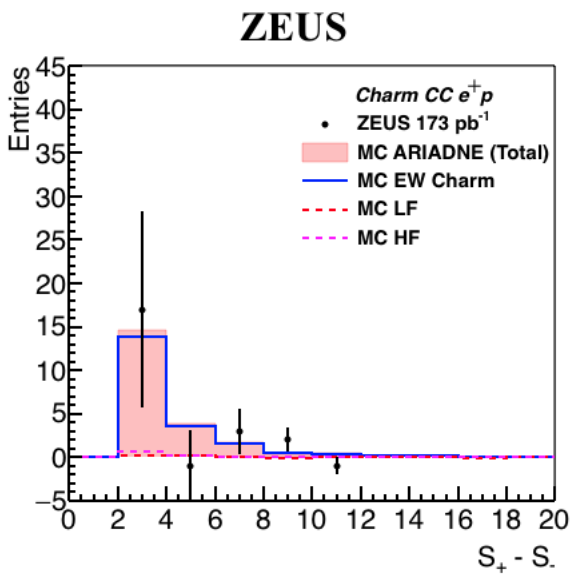

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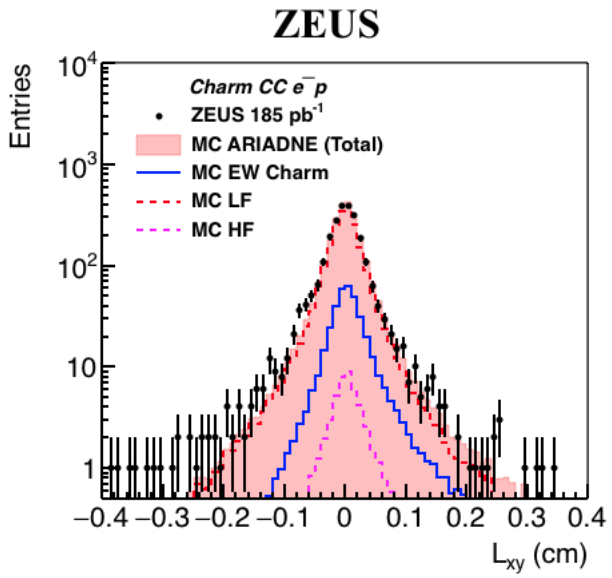

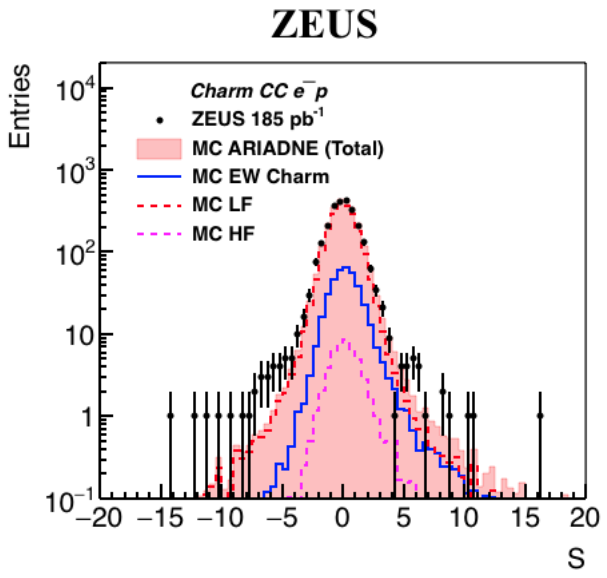

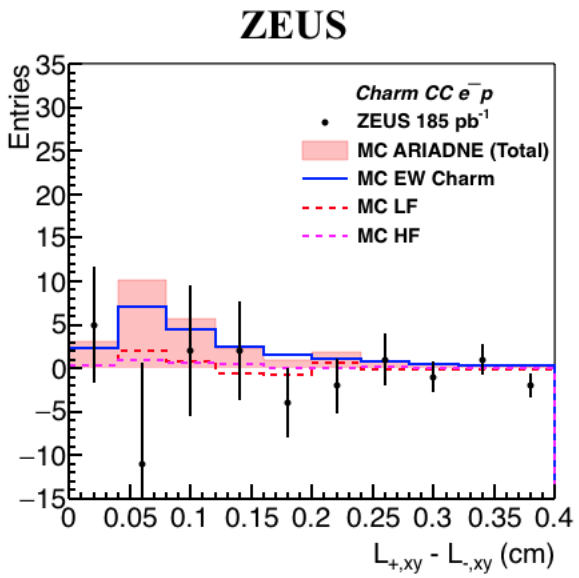

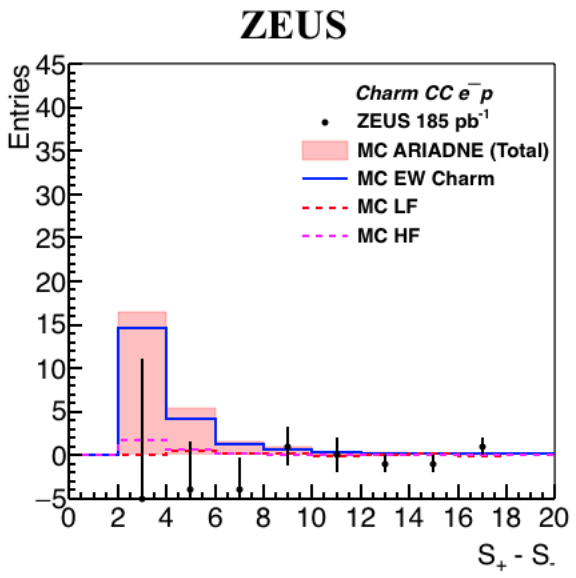

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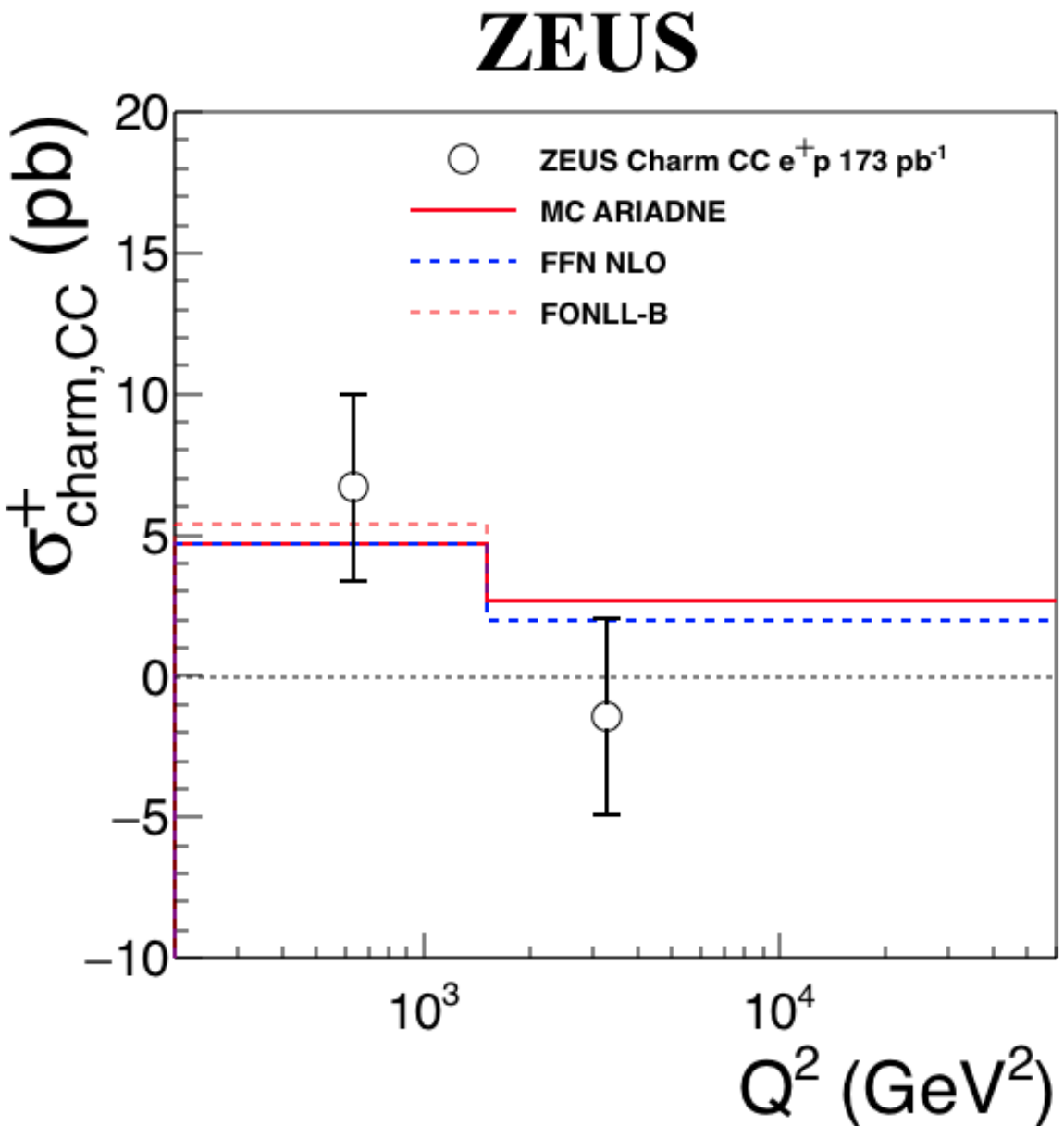
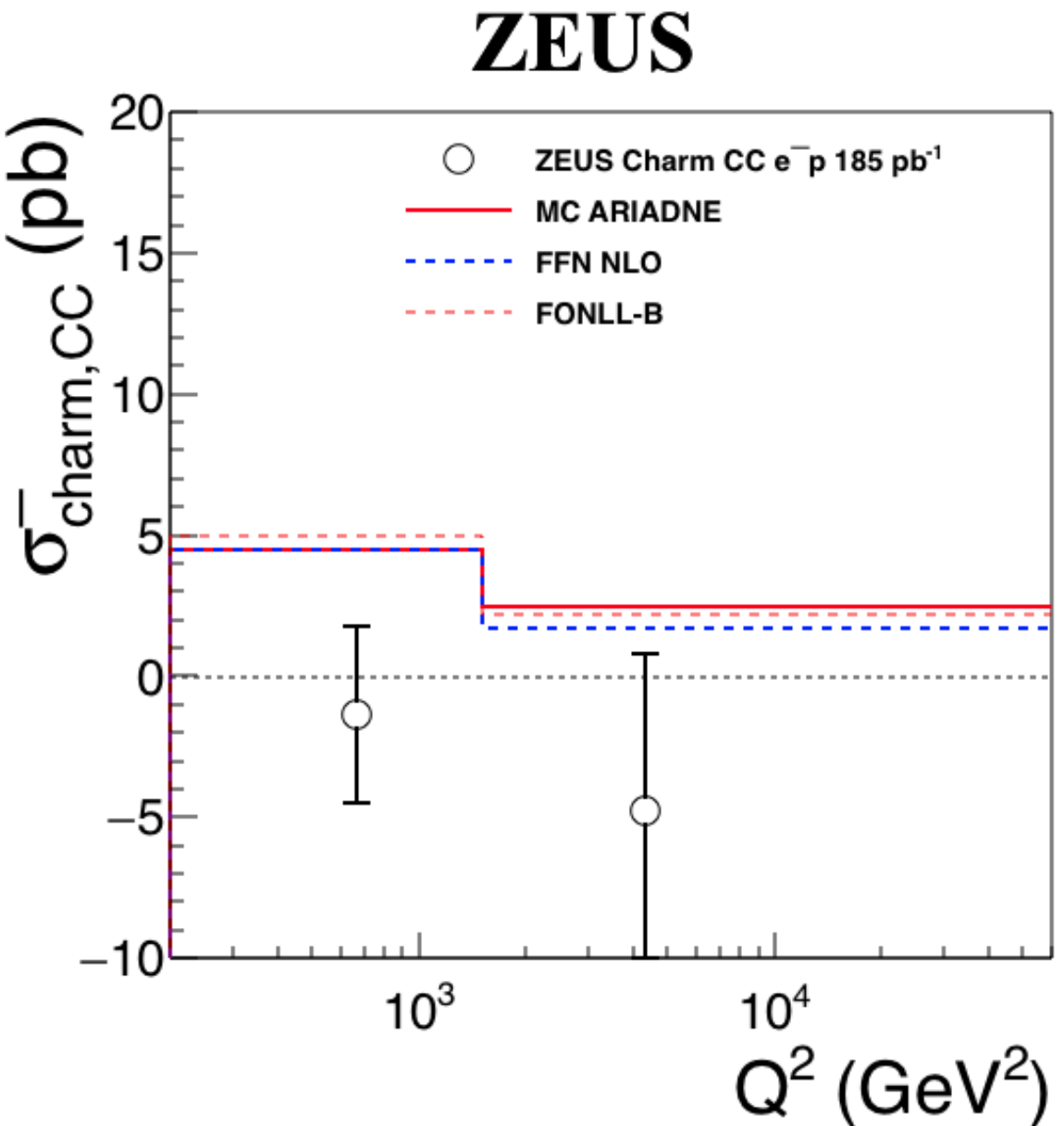




Requested for Paper

e^+p	$200 < Q^2 < 1,500\,\mathrm{GeV}^2$				
	$\sigma_{vis}(\mathrm{pb})$	$d \to c(\%)$	$s \to c(\%)$	$g \to c\bar{c}(\%)$	$\bar{c} \to \bar{s}/\bar{d}$
ARIADNE	5.23 ± 0.17	6	37	0	57
FFN	4.72 ± 0.05	8	49	43	0
FONLL	5.37 ± 0.21	8	43	-9	59

e^+p	$1,500 < Q^2 < 60,000\,\mathrm{GeV}^2$				
	$\sigma_{vis}(\mathrm{pb})$	$d \to c(\%)$	$s \to c(\%)$	$g \to c\bar{c}(\%)$	$\bar{c} \to \bar{s}/\bar{d}$
ARIADNE	2.93 ± 0.18	10	28	0	62
FFN	1.97 ± 0.03	16	43	41	0
FONLL	2.66 ± 0.23	12	37	-10	61

e^-p	$200 < Q^2 < 1,500\,\mathrm{GeV}^2$				
	$\sigma_{vis}(\mathrm{pb})$	$\bar{d} \to \bar{c}(\%)$	$\bar{s} \to \bar{c}(\%)$	$g \to c\bar{c}(\%)$	$c \to s/d$
ARIADNE	5.30 ± 0.21	3	38	0	59
FFN	4.50 ± 0.05	4	51	45	0
FONLL	4.98 ± 0.22	4	43	-10	64

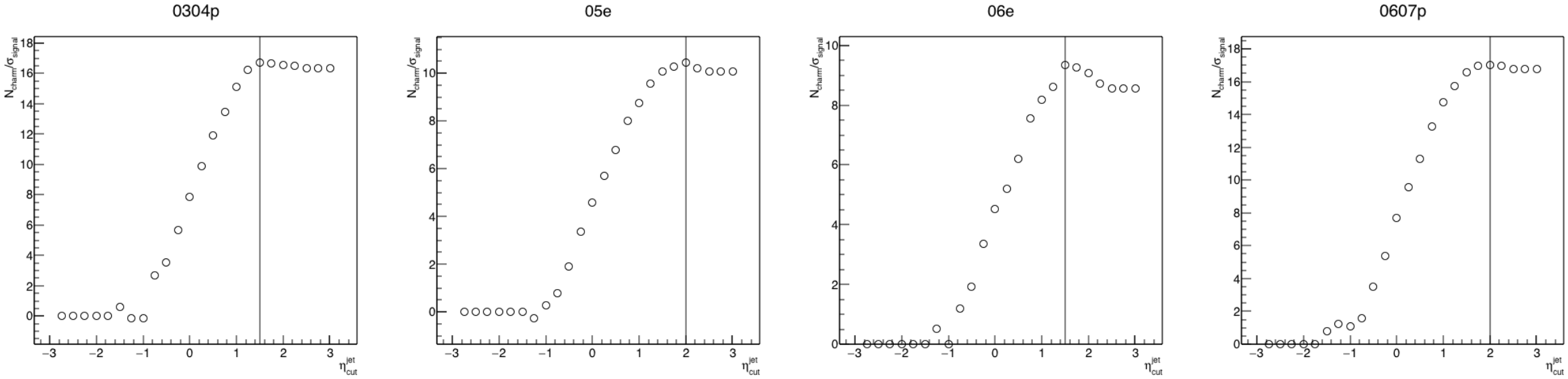
e^-p	$1,500 < Q^2 < 60,000\,\mathrm{GeV}^2$				
	$\sigma_{vis}(\mathrm{pb})$	$\bar{d} \to \bar{c}(\%)$	$\bar{s} \to \bar{c}(\%)$	$g \to c\bar{c}(\%)$	$c \to s/d$
ARIADNE	2.85 ± 0.20	2	31	0	66
FFN	1.73 ± 0.03	5	49	46	0
FONLL	2.16 ± 0.22	4	33	-12	75

~~Requested for Paper~~ (incomplete)

Q^2 range (GeV^2)	σ(pb)				
			e^+p		
200–1,500	6.7	± 3.3	(stat.)	$^{+0.0}_{-0.0}$	(sys.)
1,500–60,000	-1.5	± 3.5	(stat.)	$^{+0.0}_{-0.0}$	(sys.)
			e^-p		
200–1,500	-1.3	± 3.1	(stat.)	$^{+0.0}_{-0.0}$	(sys.)
1,500–60,000	-4.7	± 5.5	(stat.)	$^{+0.0}_{-0.0}$	(sys.)

Back Up

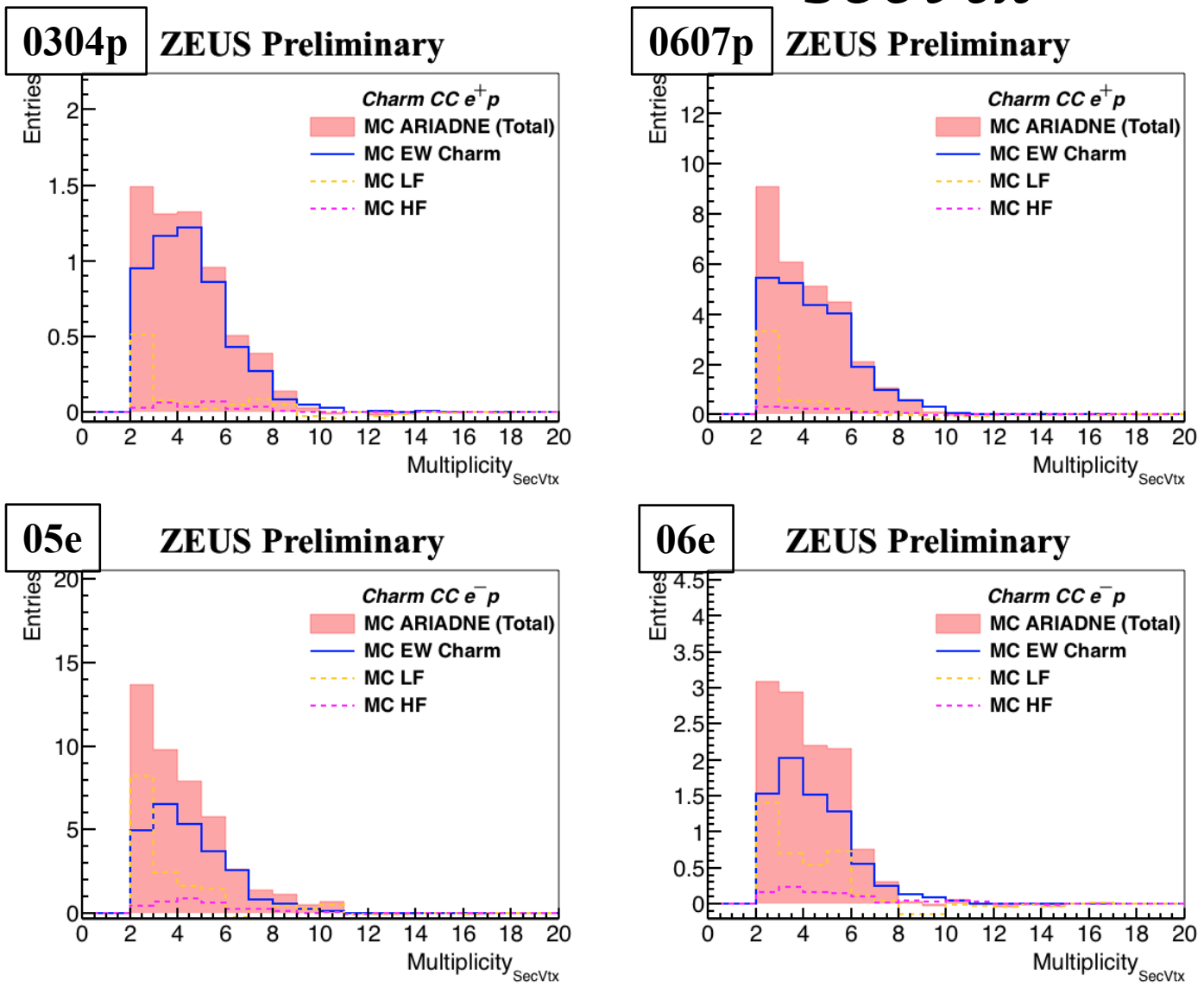
Determination of η^{jet} upper cut



- $\frac{N_{charm}^{MC,mir}}{\sigma_{signal}^{MC,mir}}$ projected from MC as functions of η_{cut}^{jet} per different run period.
  - Highlighted in red vertical lines are the cut locations that would yield the highest ratio.

- In this presentation, $\eta^{jet} < 1.5$ for 05e (STT coverage), $\eta^{jet} < 2.0$ for else.
  - If not placed on the optimal position, the new η^{jet} cut will not reduce statistical uncertainty significantly.

Determination of N_{secvtx}^{trk} cut



- A high concentration of LF background in low N_{secvtx}^{trk} region is observed across all run periods.
- A LF rejection cut was applied at $N_{secvtx}^{trk} > 2$.

Reconstructed variables

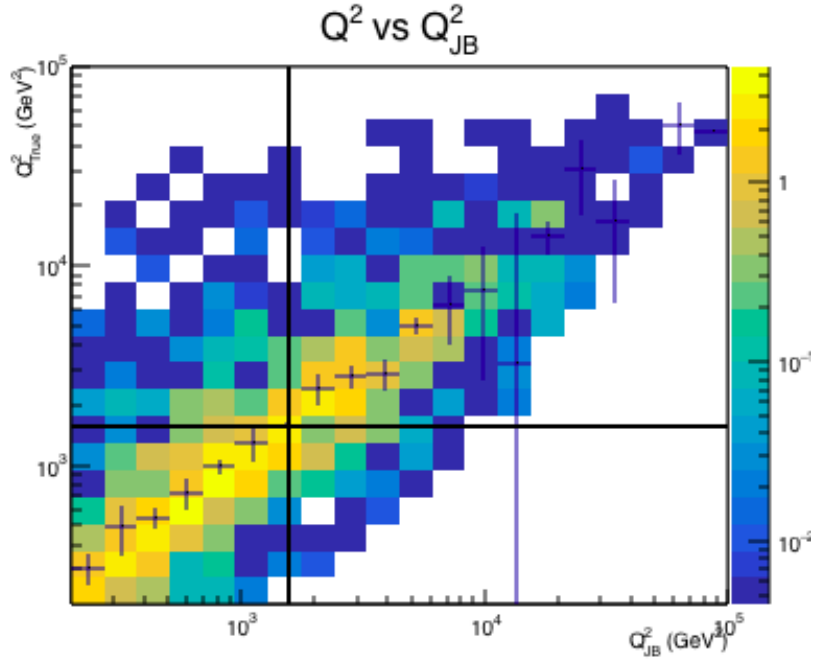
- Good agreement between True and Reconstructed Q^2

$$N_i = \sum_j C_{ij} M_j$$

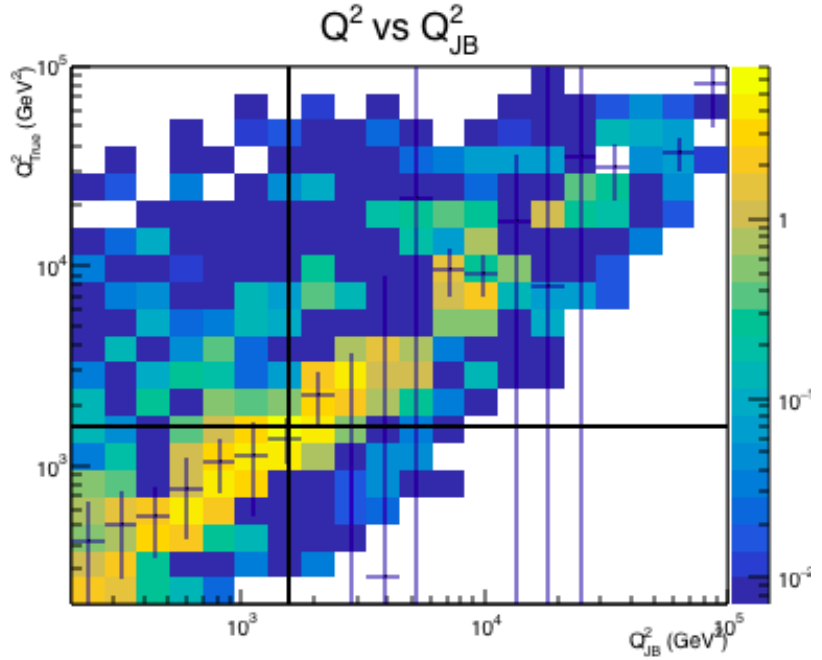
$N_i = true\ number\ of\ entries\ in\ bin\ i$
$M_i = reconstructed\ number\ of\ entries\ in\ bin\ i$
$C_{ij} = correlation\ matrix\ element\ for\ bin\ i,j$

Collision	C_{11}	C_{22}
e^+p	0.99	1.01
e^-p	0.98	1.02

$e^+ p$

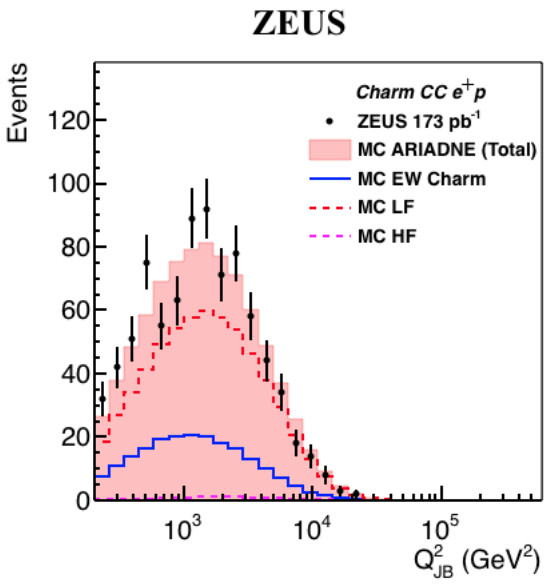


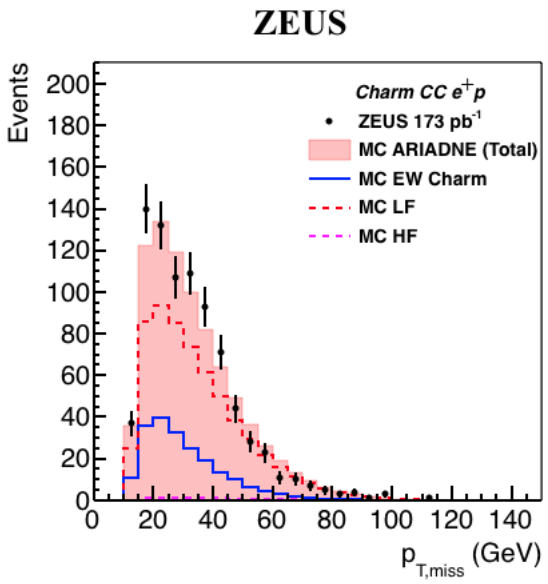
$e^- p$

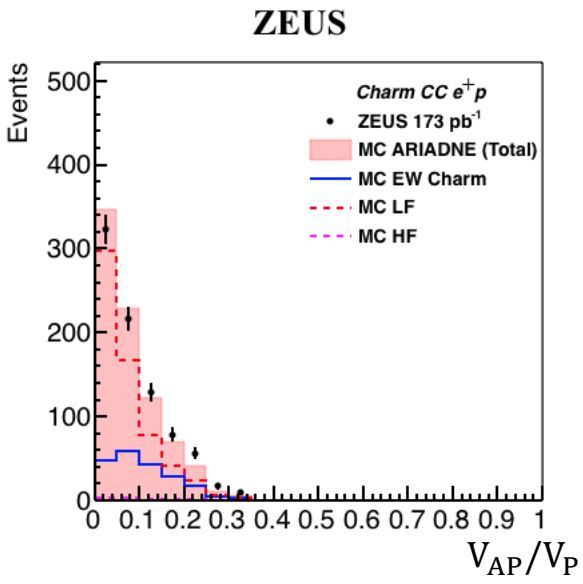


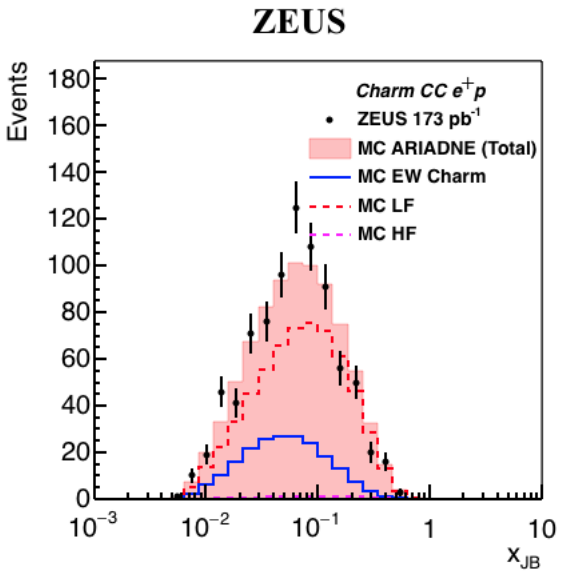
0304p

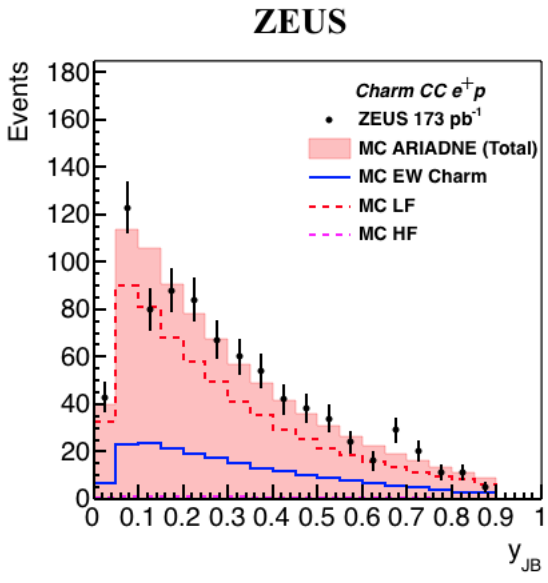
Event

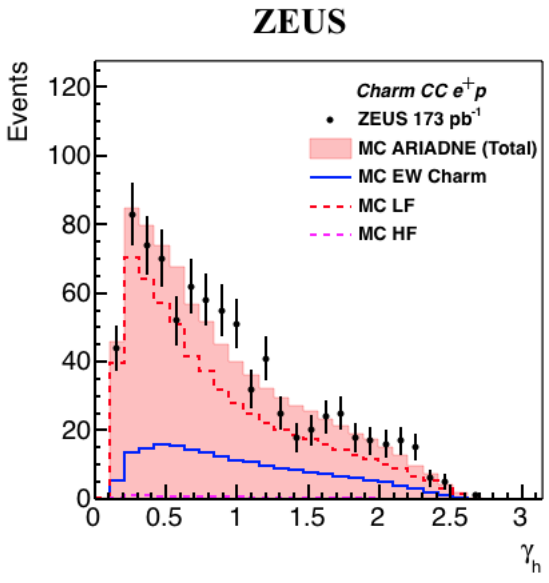

ZEUS
Charm CC e+p
ZEUS 173 pb-1
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
Q2JB (GeV2)


ZEUS
Charm CC e+p
ZEUS 173 pb-1
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
pT,miss (GeV)

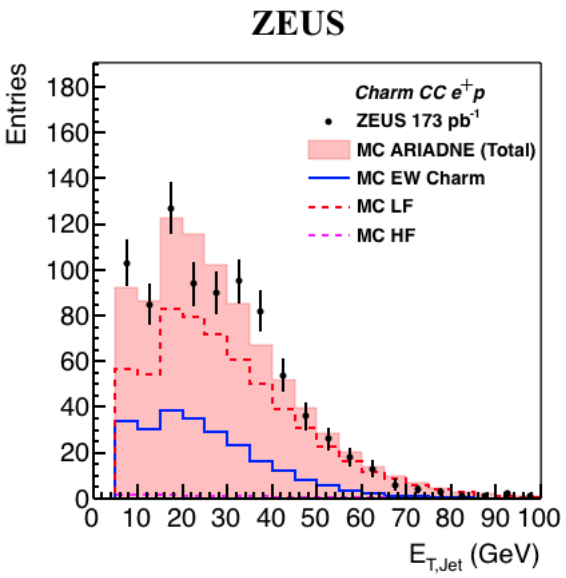

ZEUS
Charm CC e+p
ZEUS 173 pb-1
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
VAP/VP

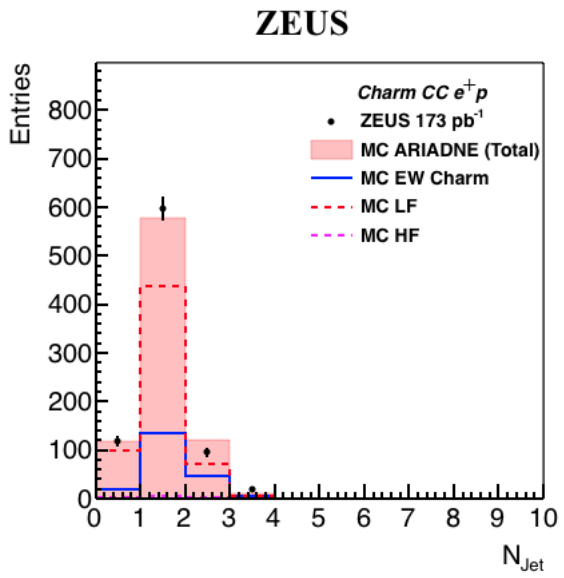

ZEUS
Charm CC e+p
ZEUS 173 pb-1
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
xJB

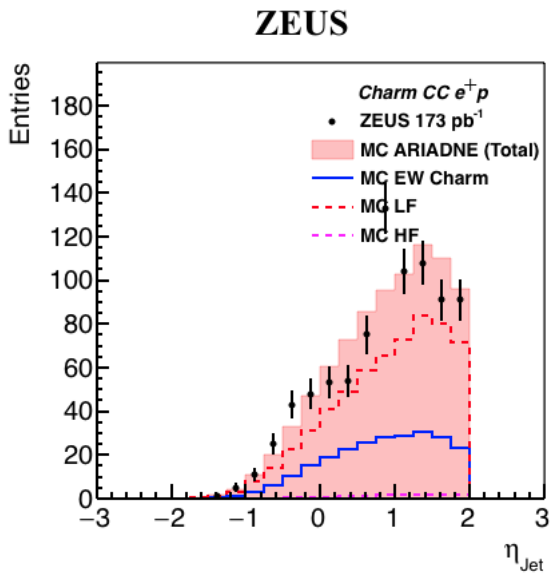

ZEUS
Charm CC e+p
ZEUS 173 pb-1
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
yJB

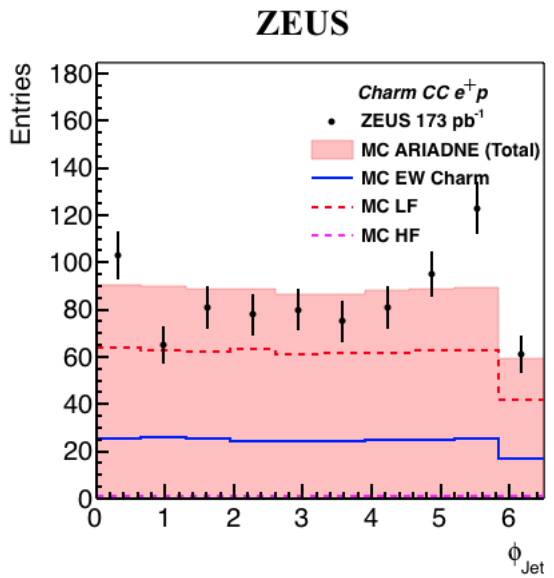

ZEUS
Charm CC e+p
ZEUS 173 pb-1
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
γh

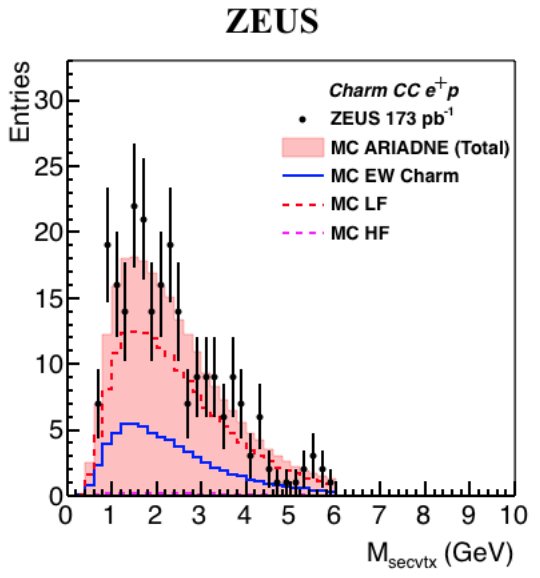
Jet & SecVtx

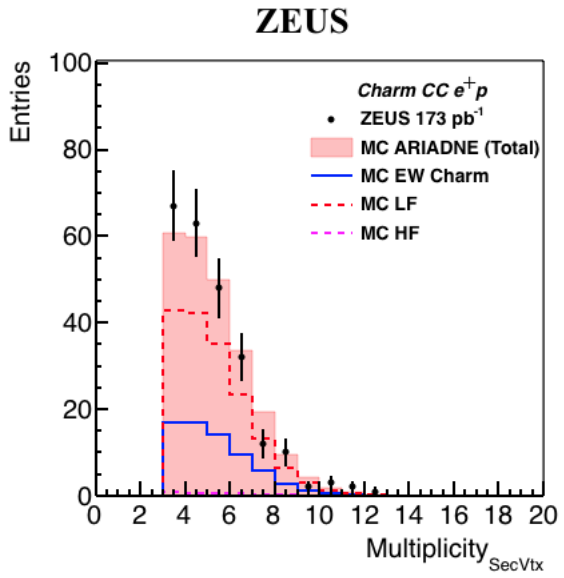

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
$E_{T,Jet}$ (GeV)

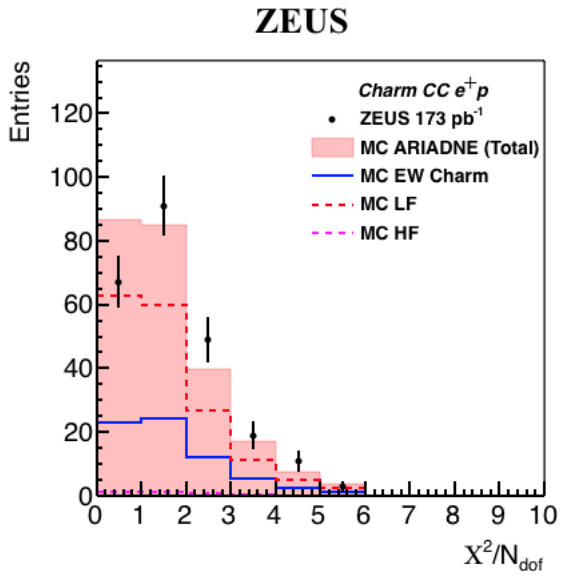

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_{Jet}

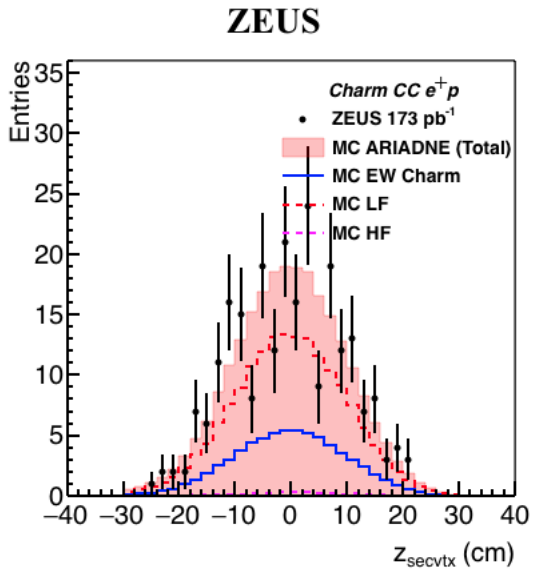

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
η_{Jet}


ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
ϕ_{Jet}

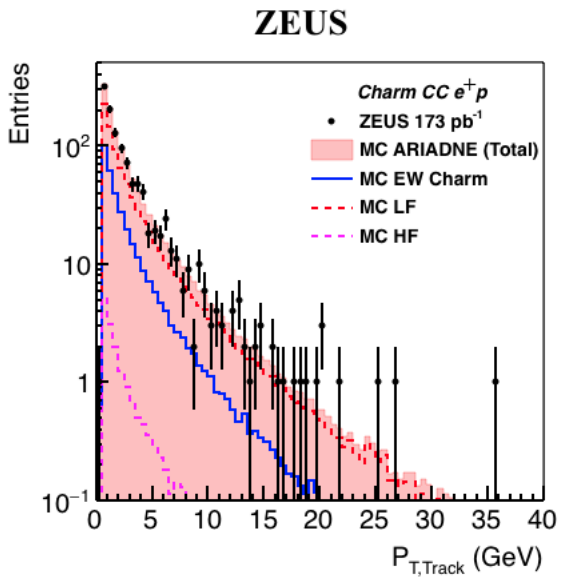

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
M_{secvtx} (GeV)

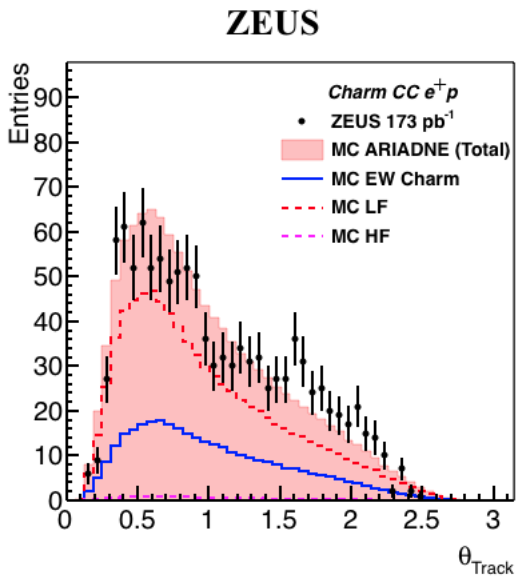

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
Multiplicity$_{SecVtx}$

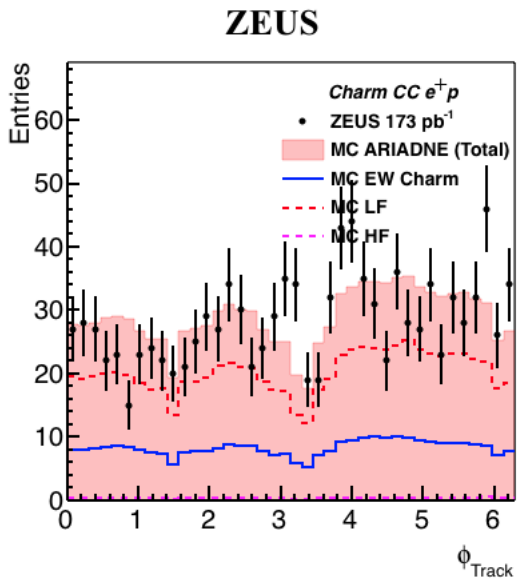

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
X^2/N_{dof}

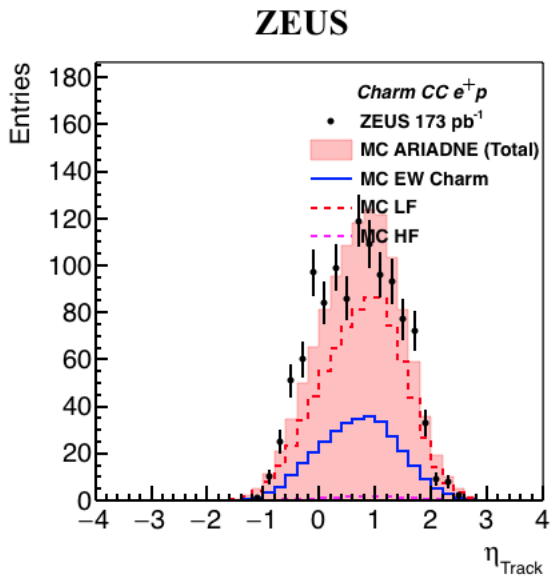

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
z_{secvtx} (cm)

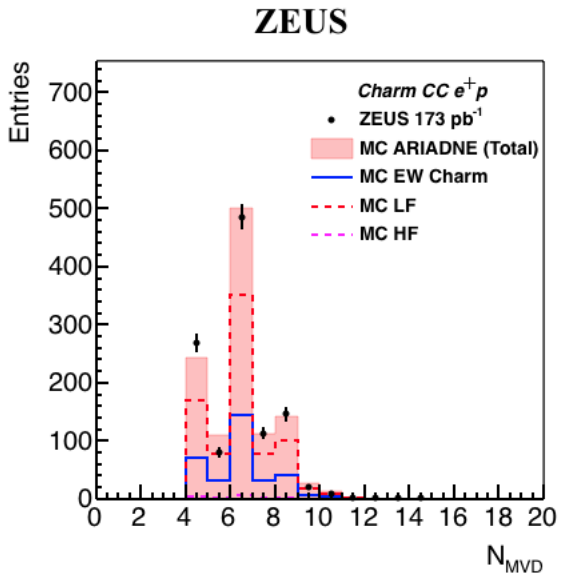
Track

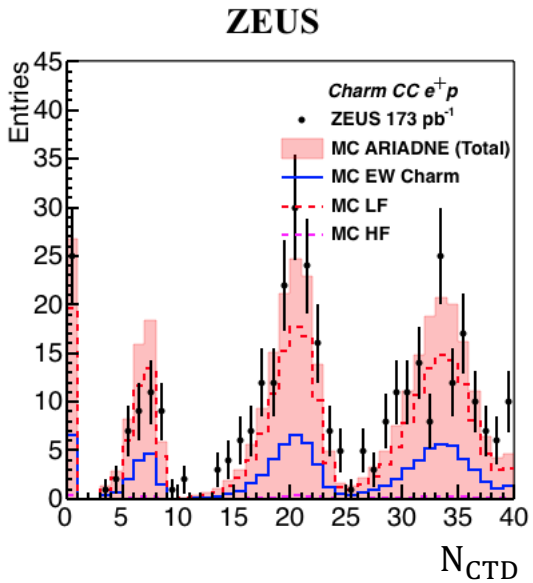

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
$P_{T,Track}$ (GeV)

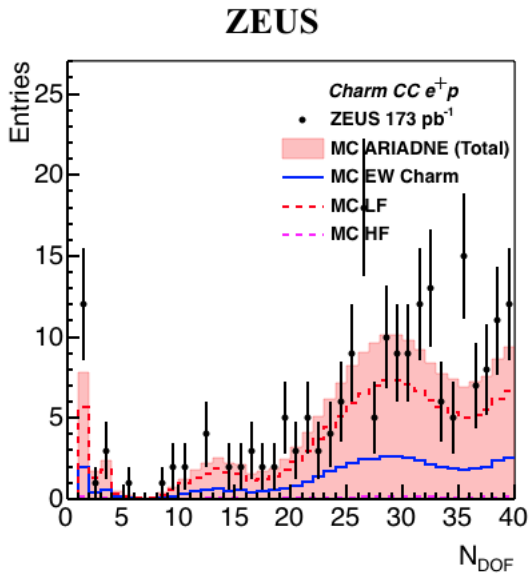

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
θ_{Track}

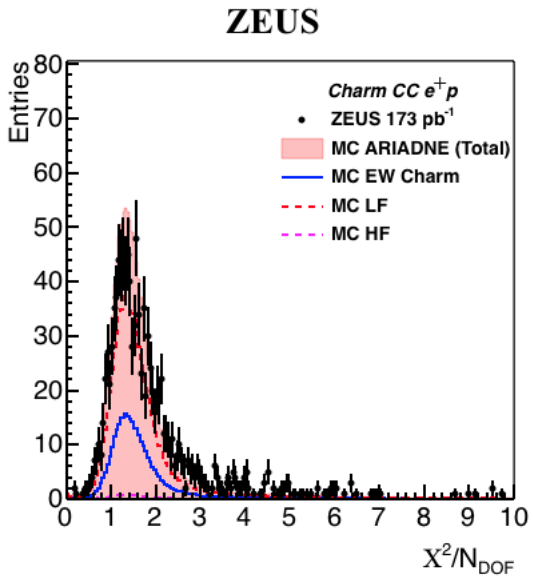

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
ϕ_{Track}


ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
η_{Track}

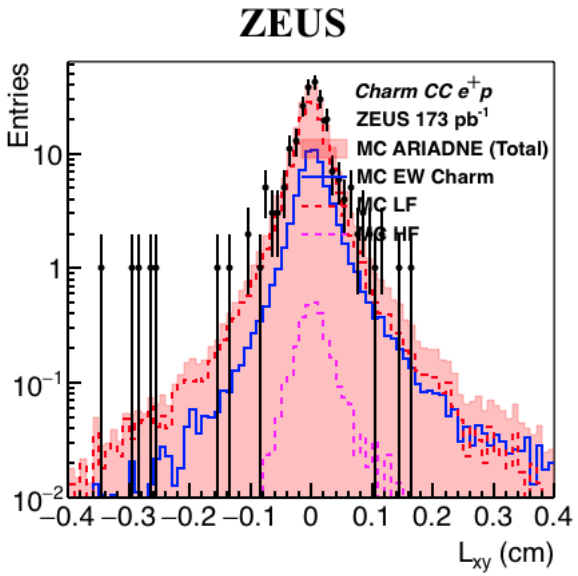

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_{MVD}

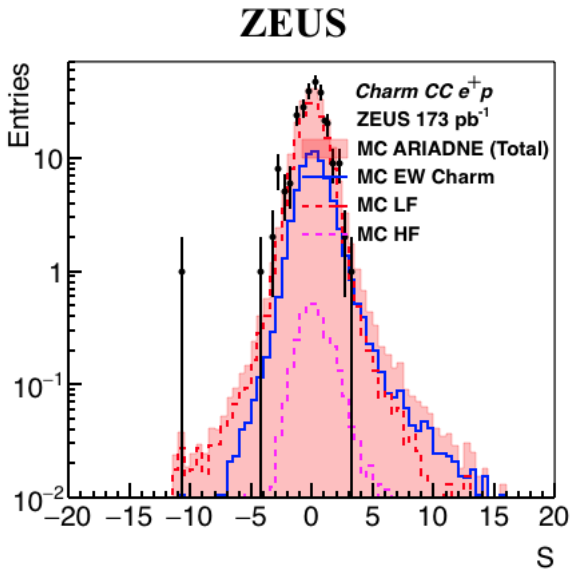

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_{CTD}

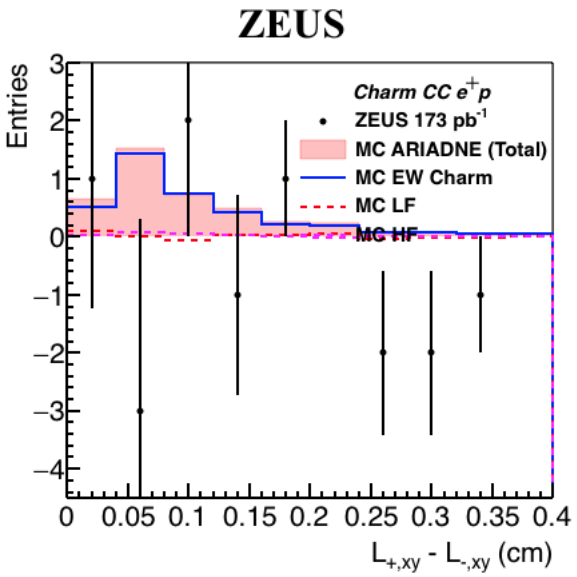

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_{DOF}

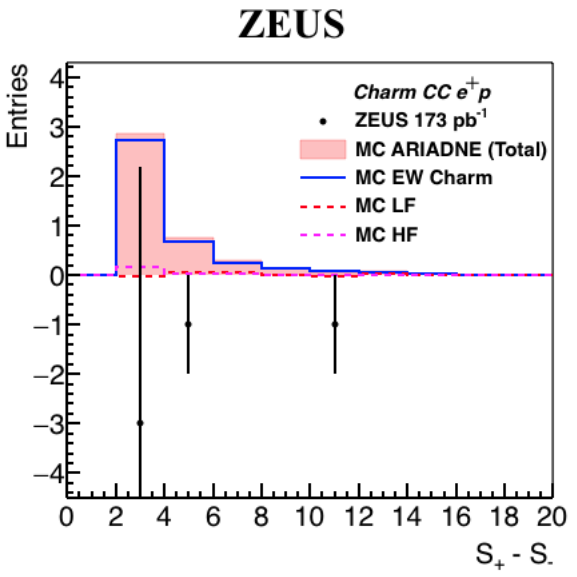

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
X^2/N_{DOF}

Decay Length



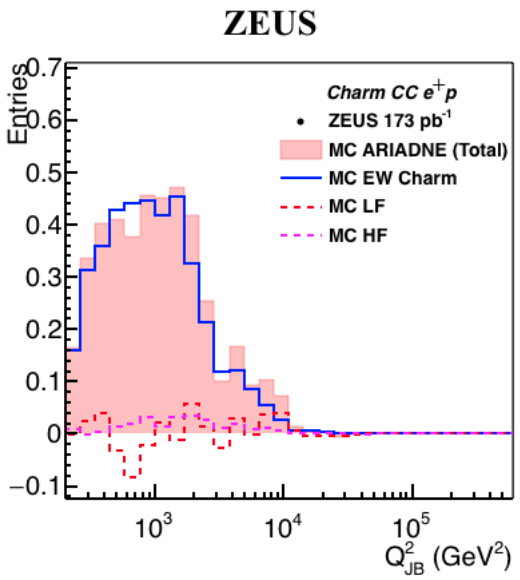


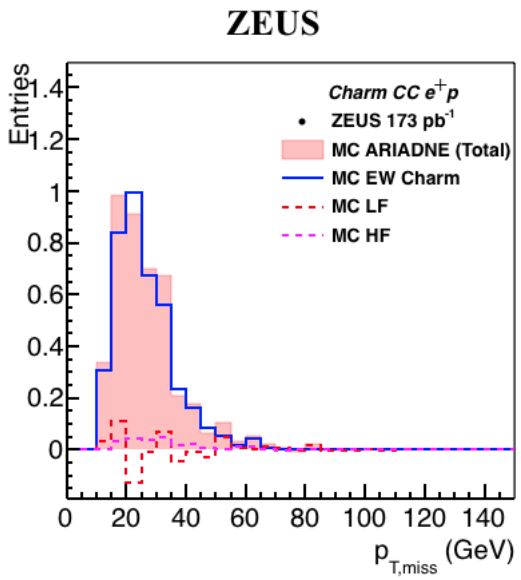


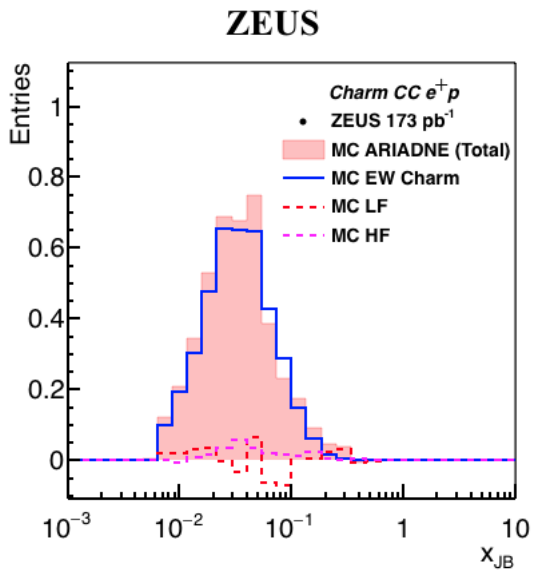


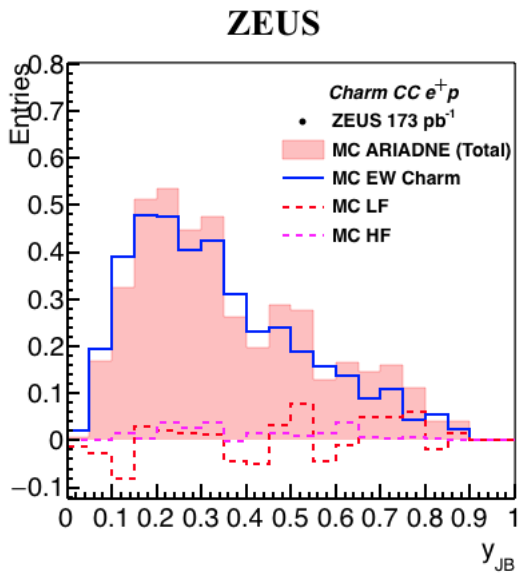
m

Mirrored Event

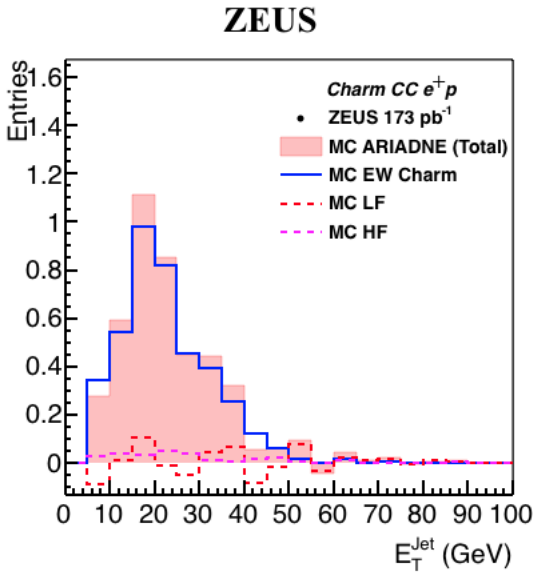


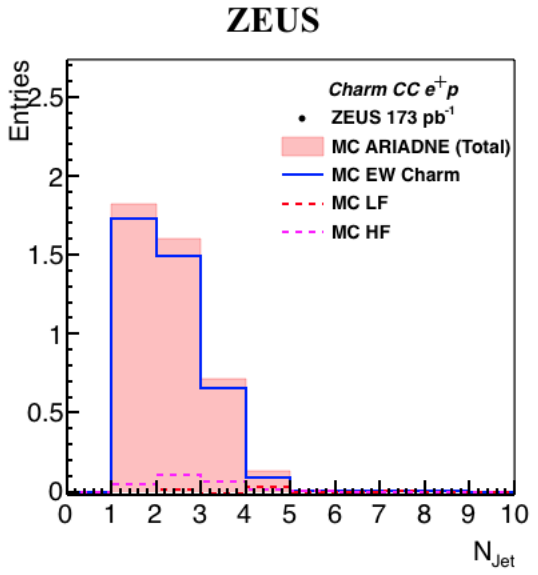


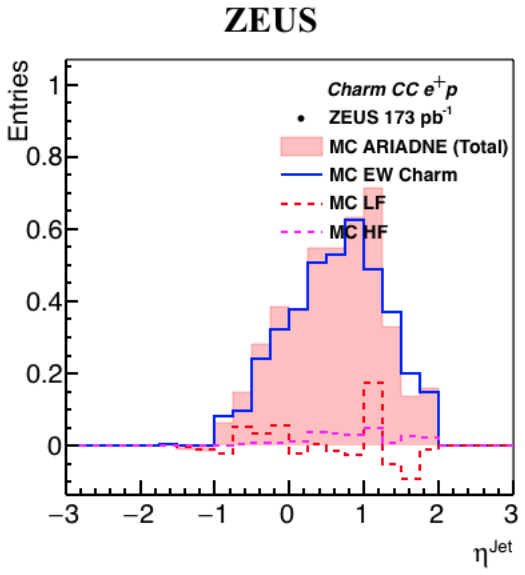


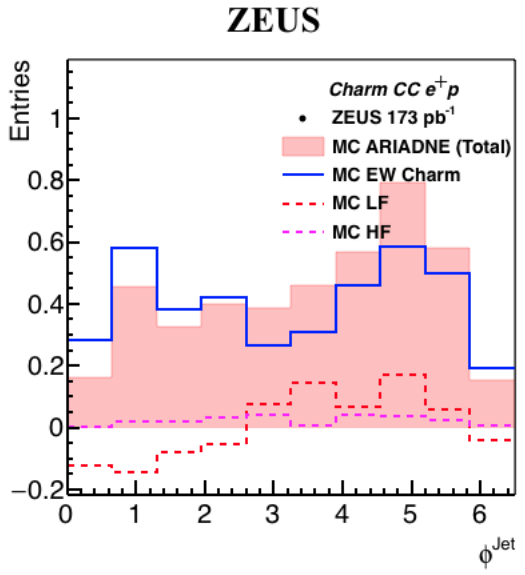


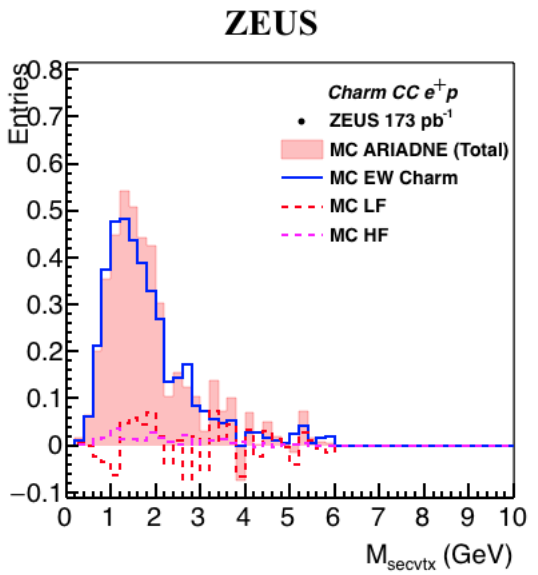
Mirrored Jets & SecVtx

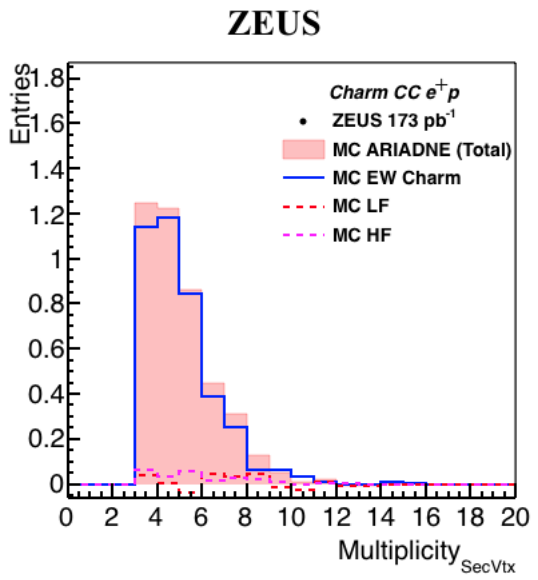


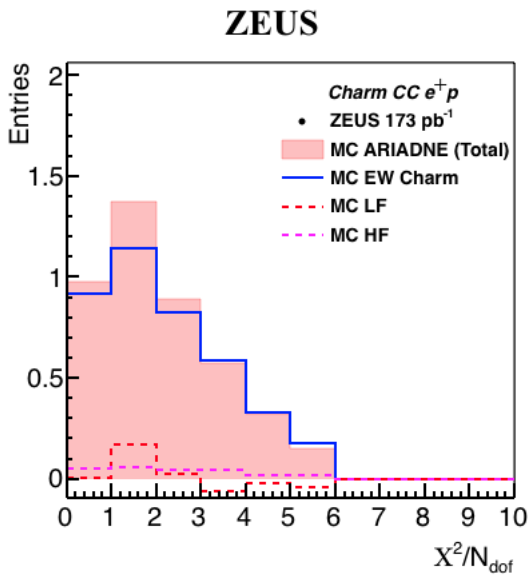




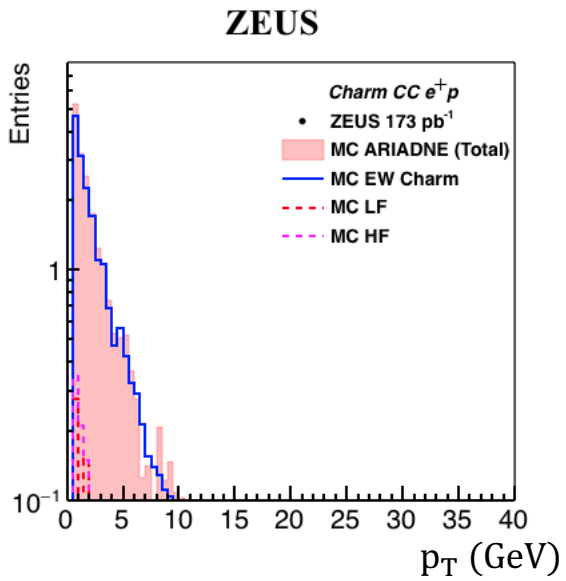


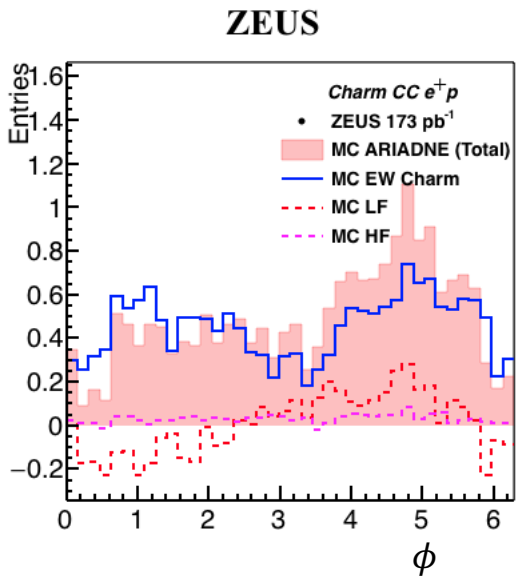


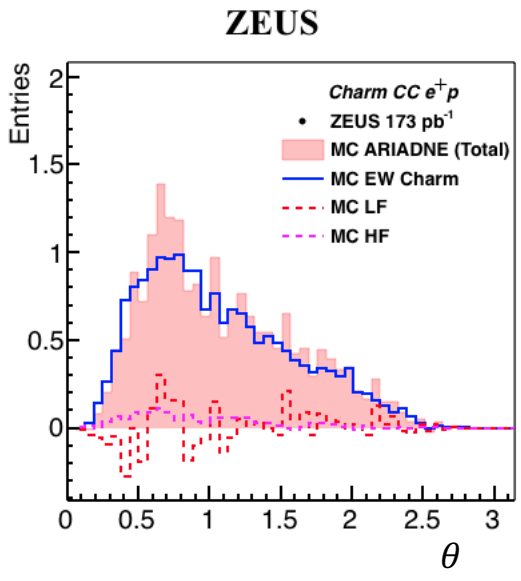


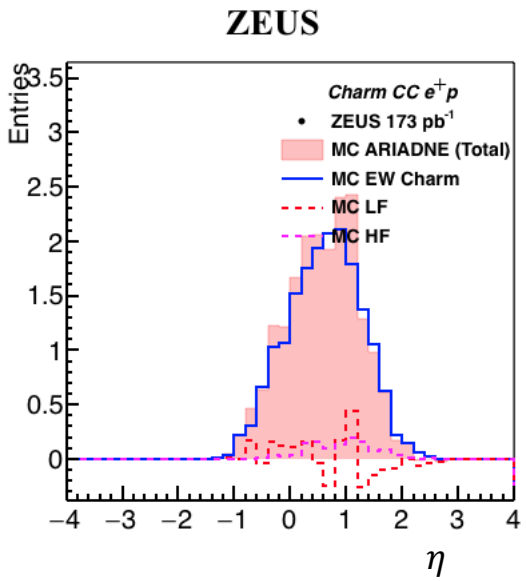


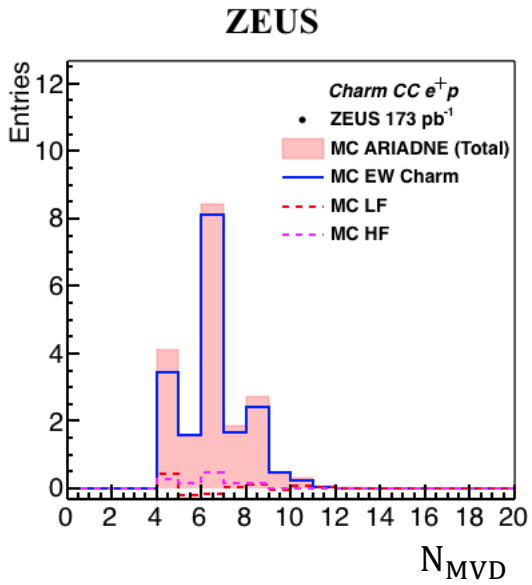
Mirrored Tracks

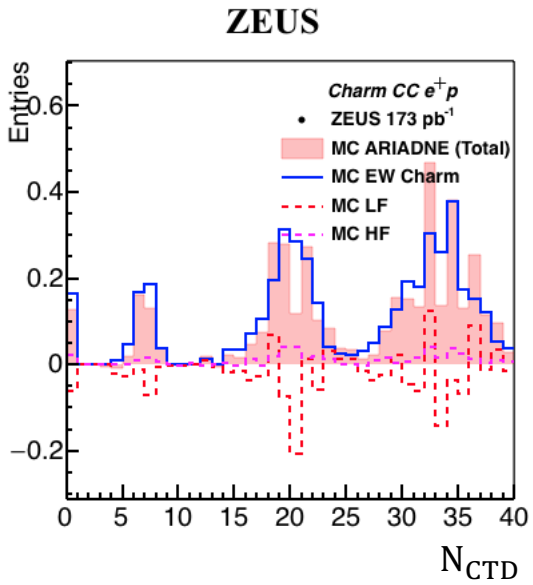


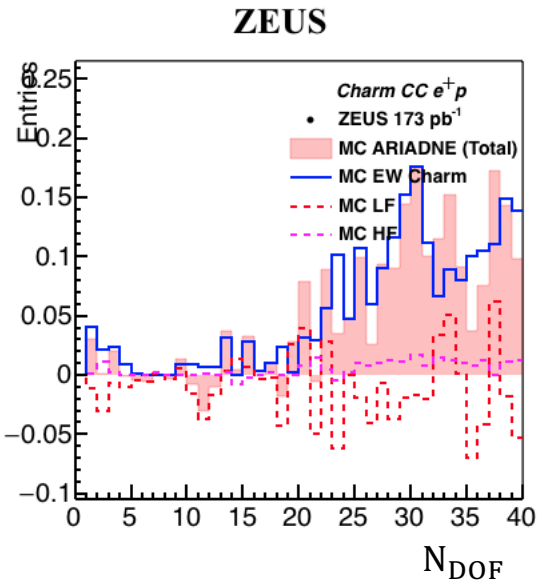


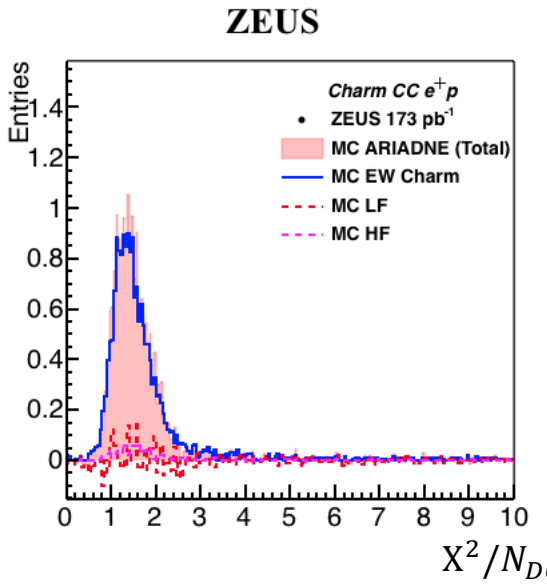






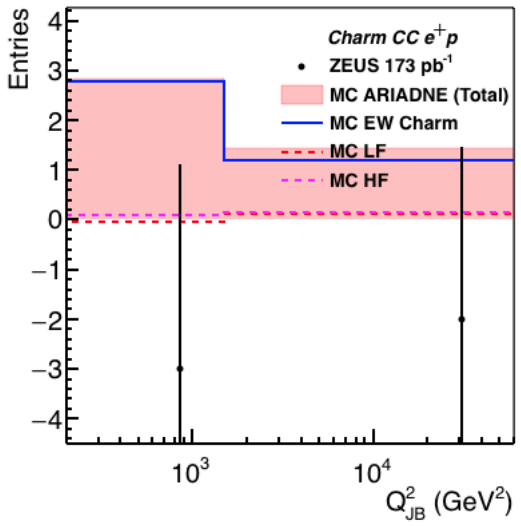




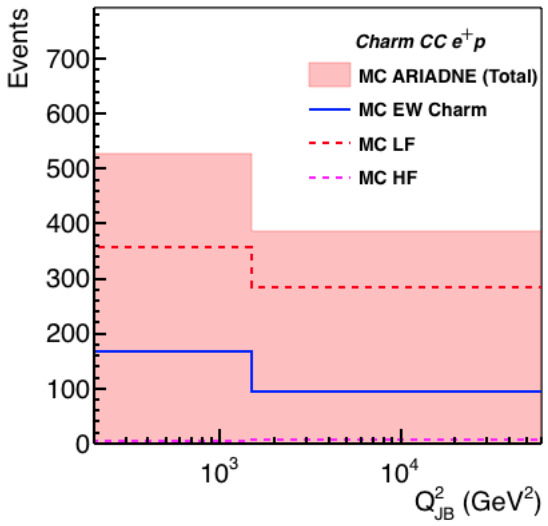


Charm signal and generated charm

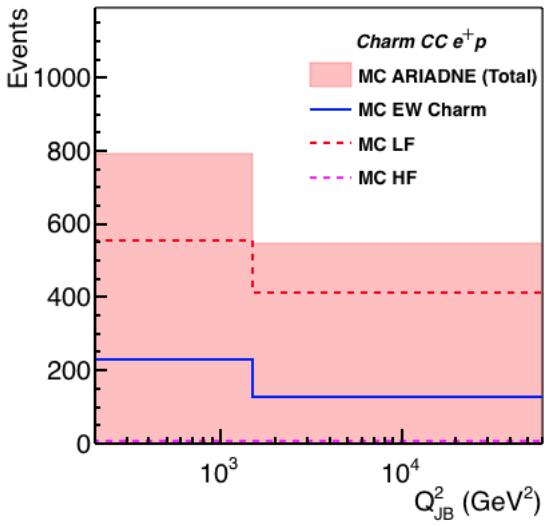
N_{signal}



$N_{gen,kin}$

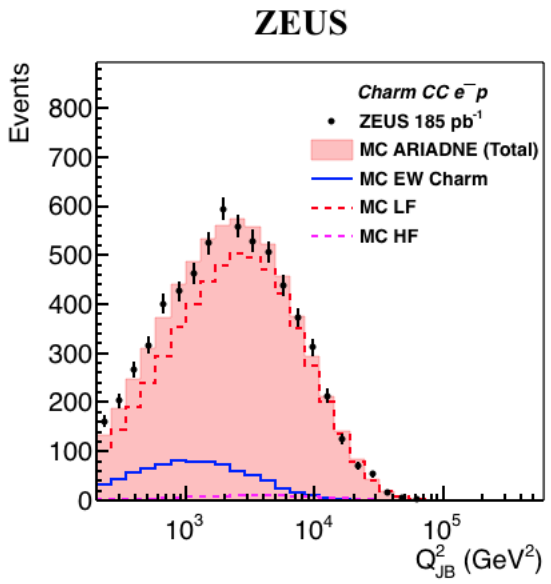


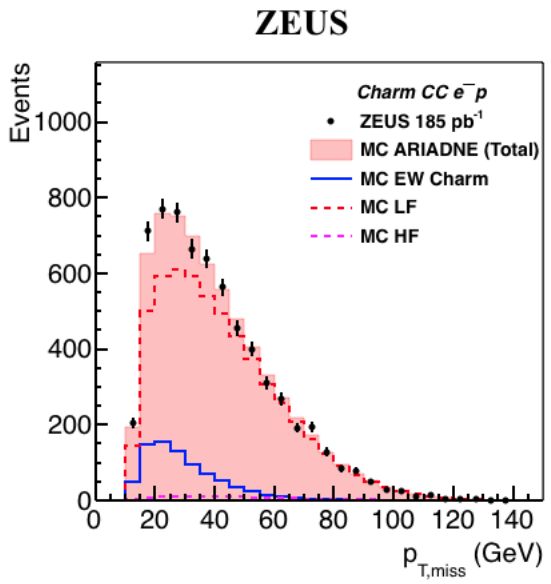
N_{gen}

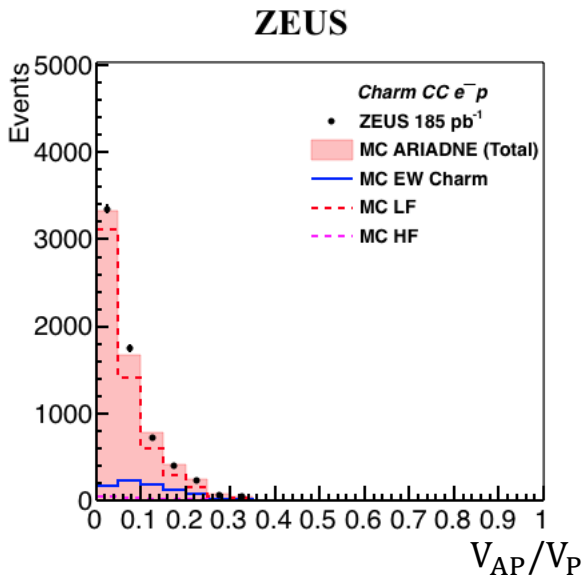


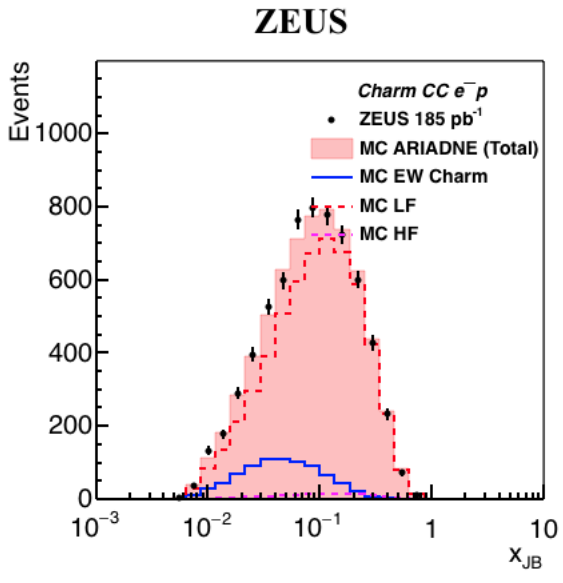
05e

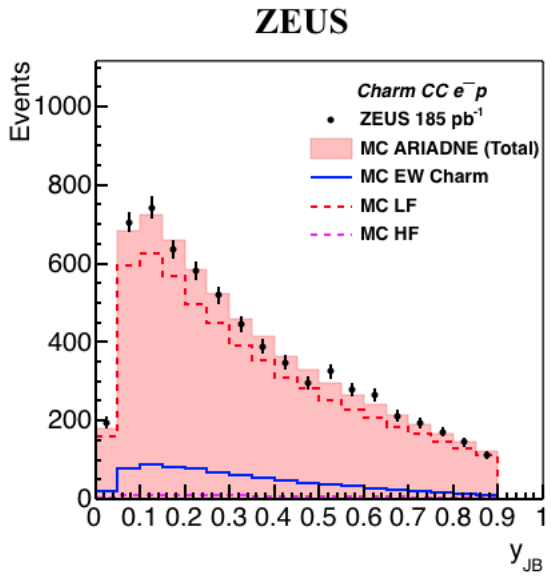
Event

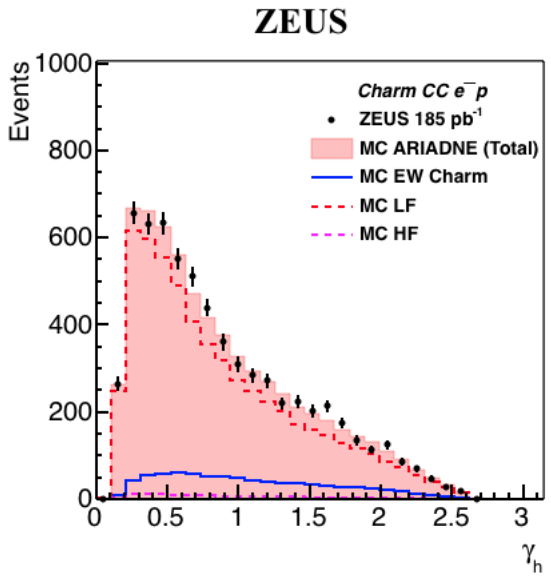

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
Q²JB (GeV²)


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
pT,miss (GeV)

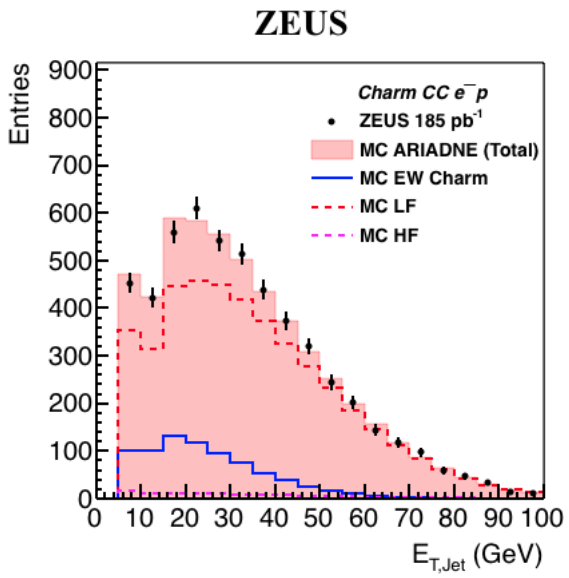

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
VAP/VP


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
xJB


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
yJB


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
γh

Jet & SecVtx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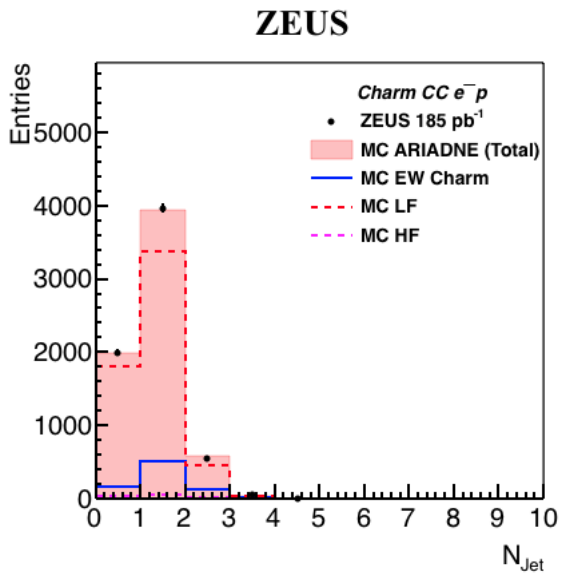
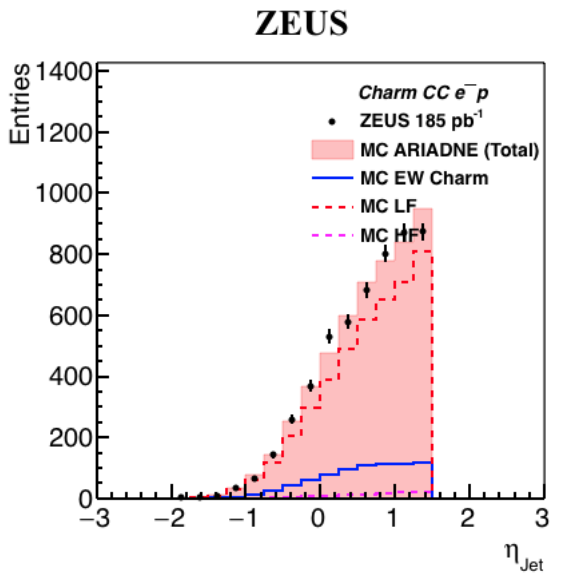
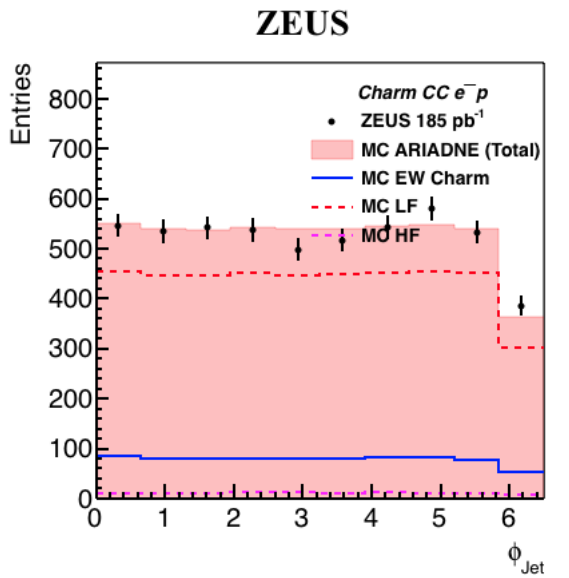
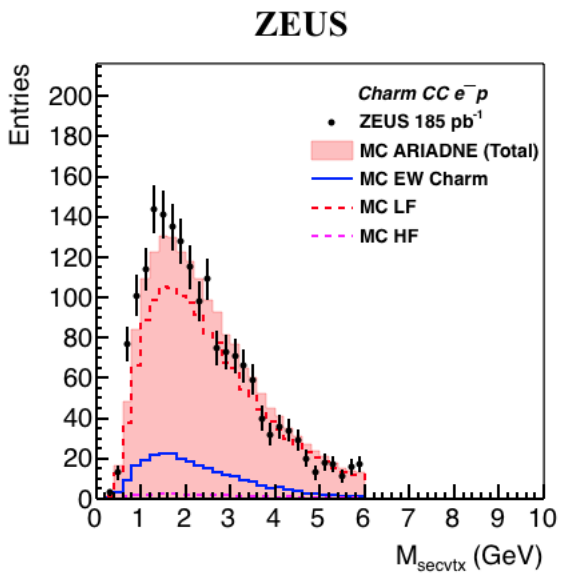
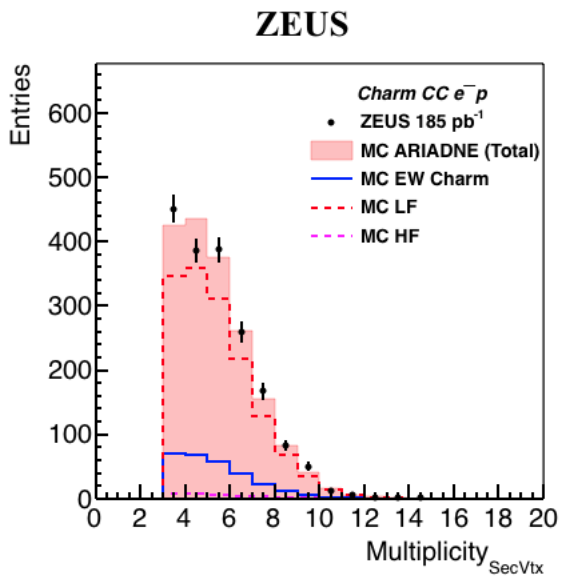
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
E_T,Jet (GeV)

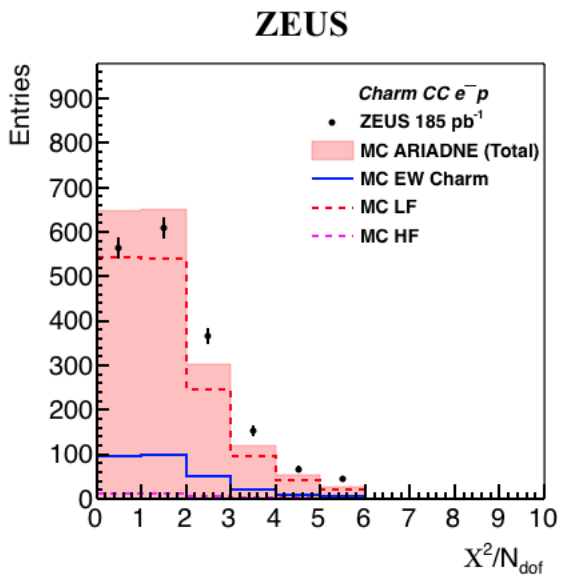

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_Jet

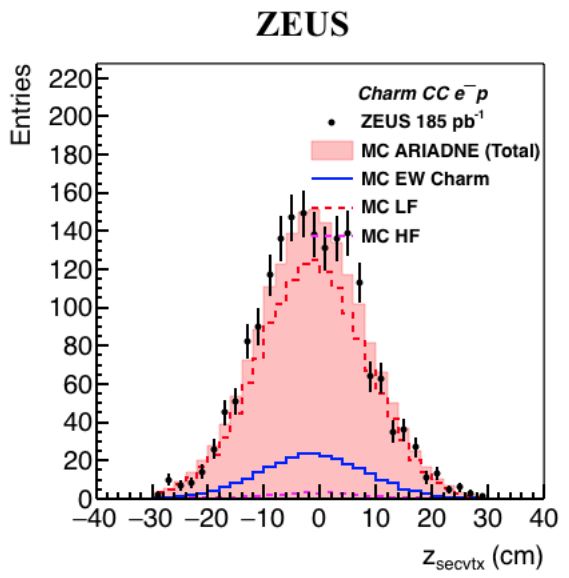

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
η_Jet


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
φ_Jet

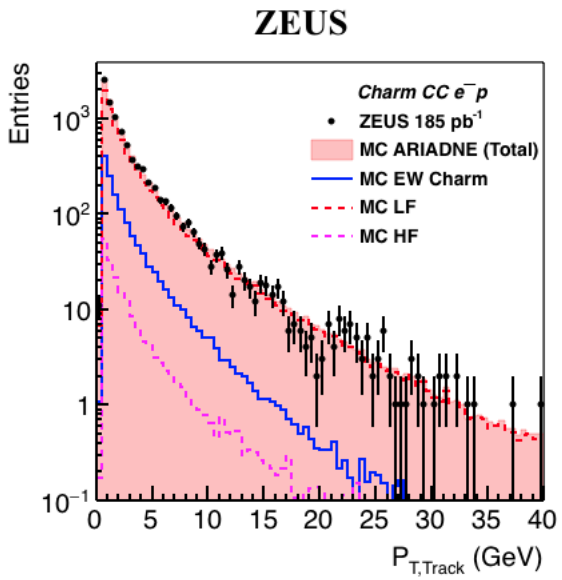

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
M_secvtx (GeV)

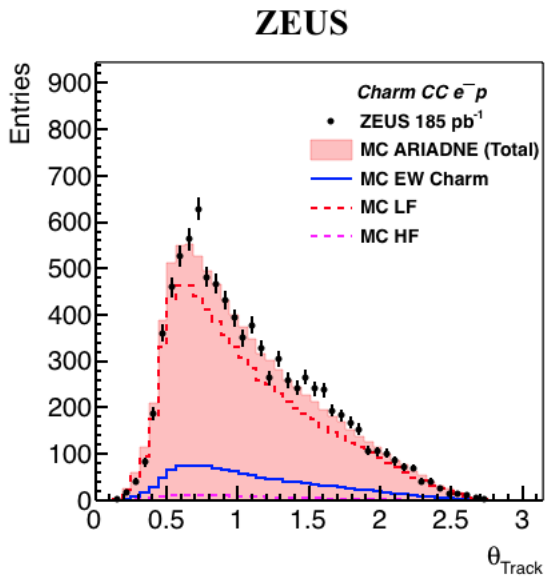

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
Multiplicity_SecVtx

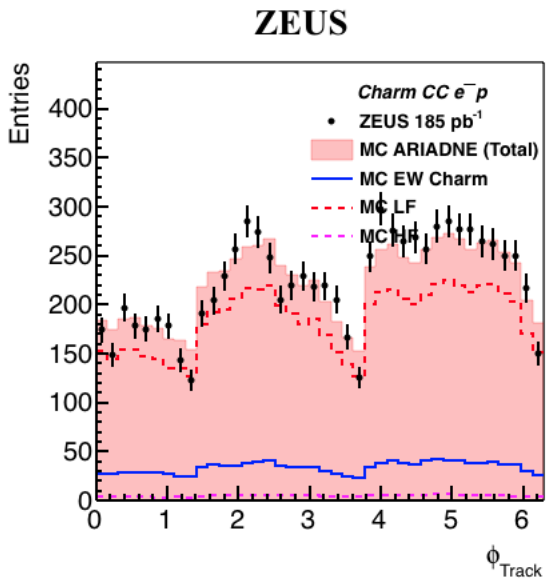

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
X²/N_dof

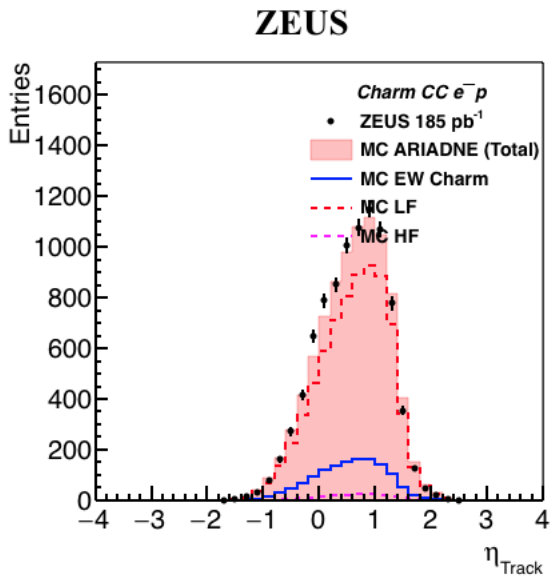

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
z_secvtx (cm)

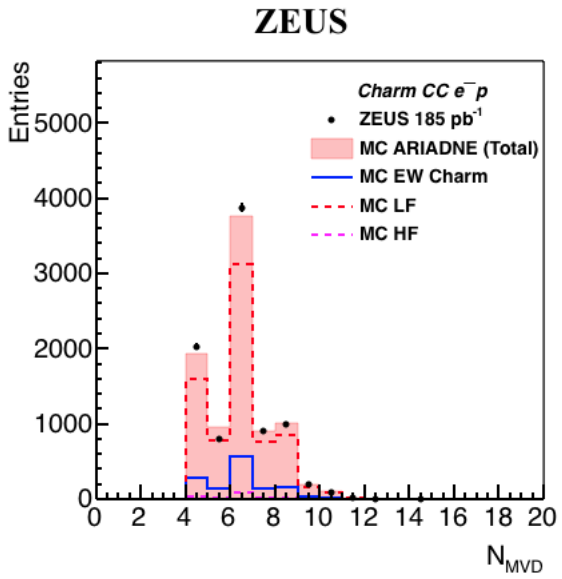
Track

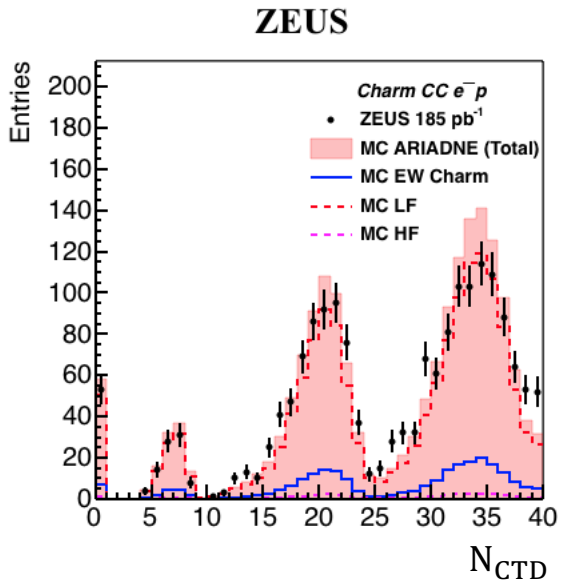

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
P_T,Track (GeV)

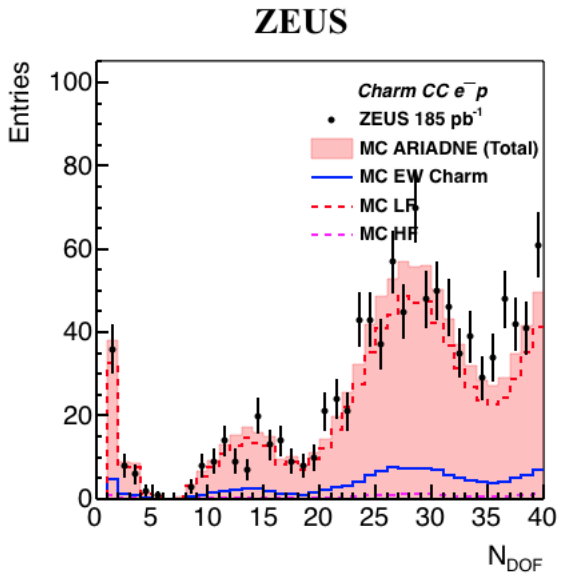

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
θ_Track

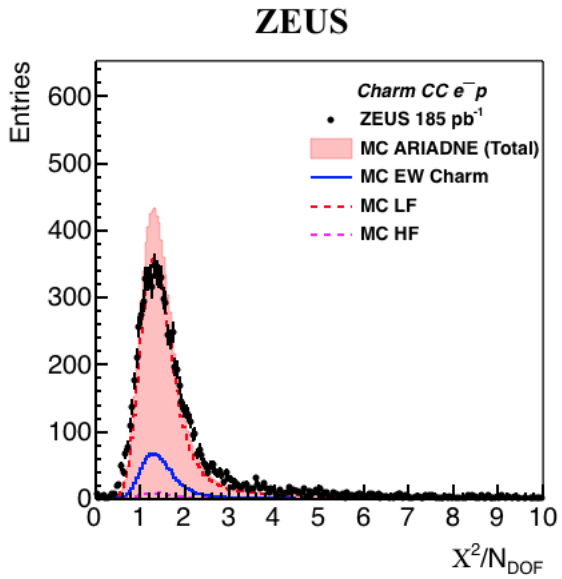

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
φ_Track


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
η_Track

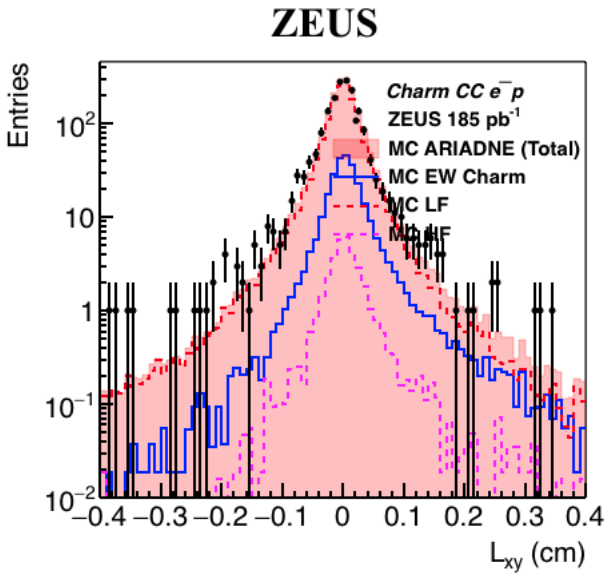

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_MVD

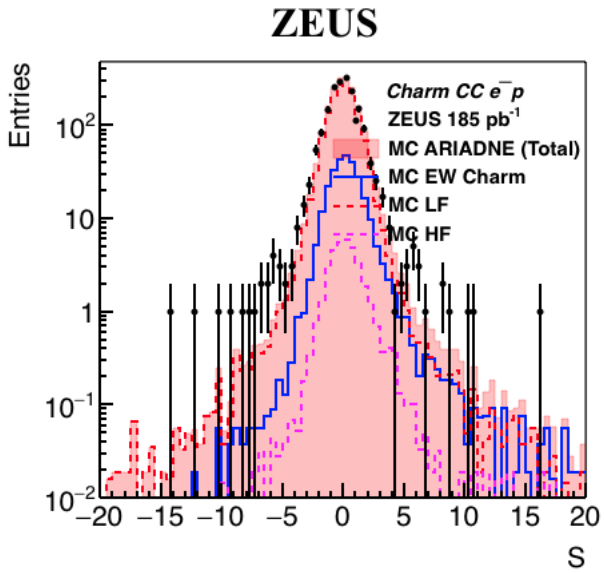

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_CTD

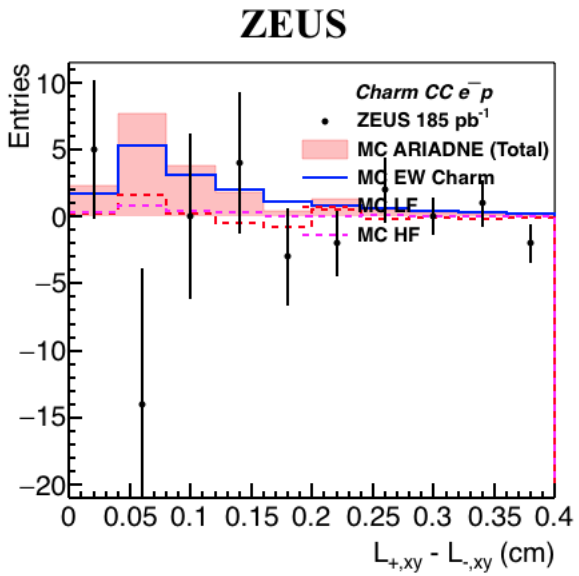

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_DOF

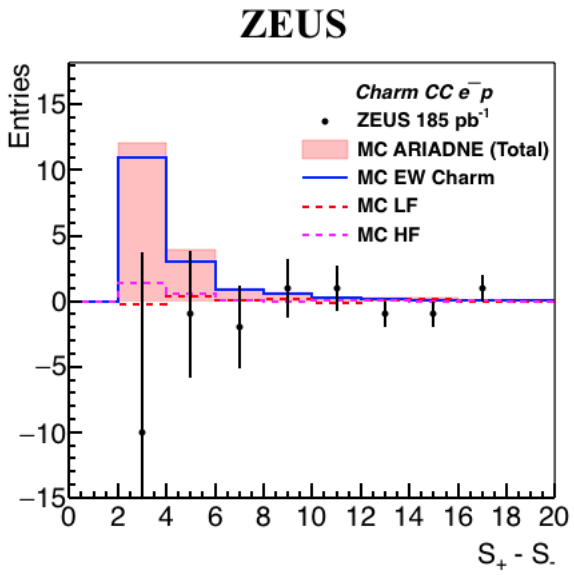

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
X²/N_DOF

Decay Length



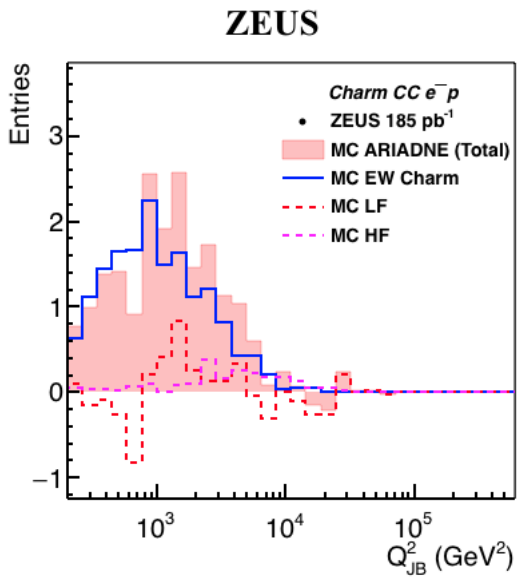


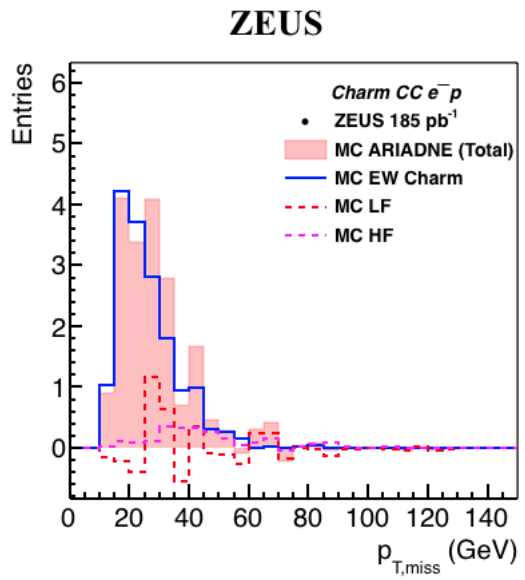


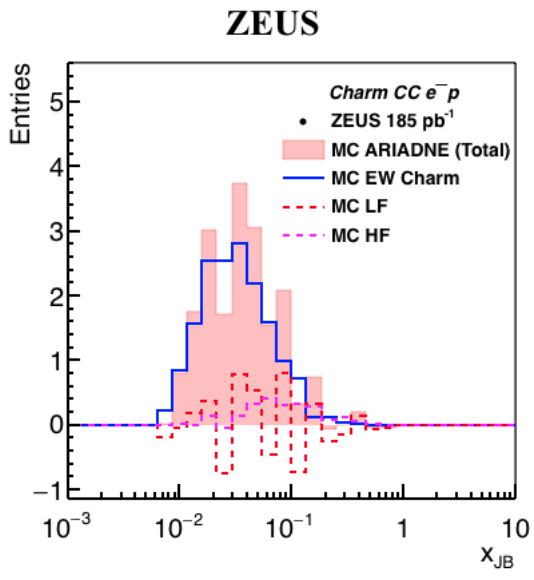


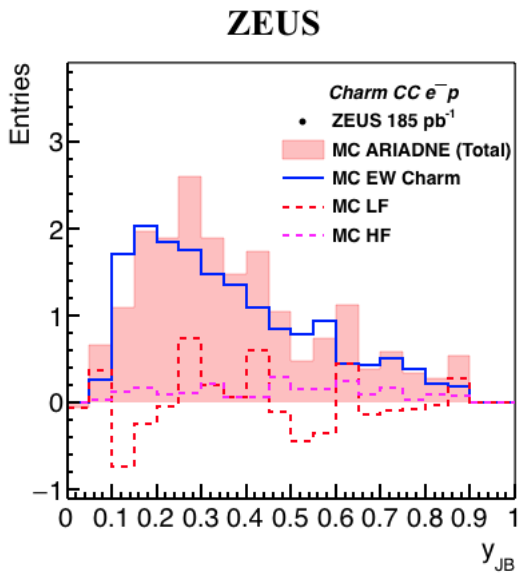
m

Mirrored Event

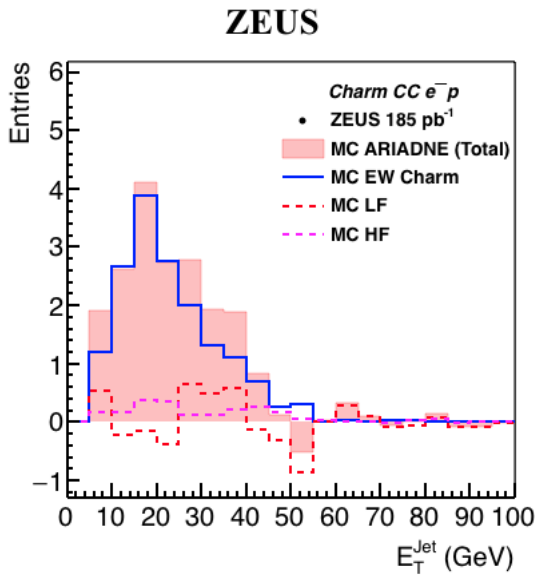


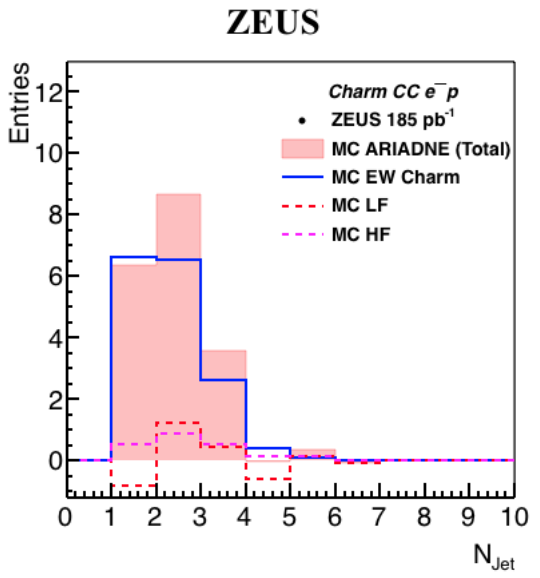


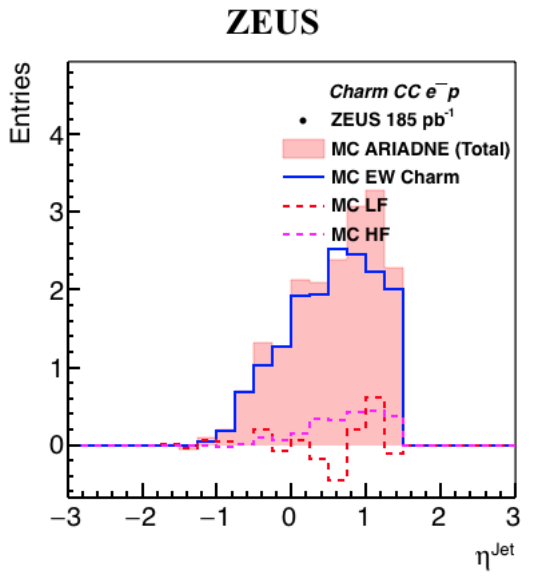


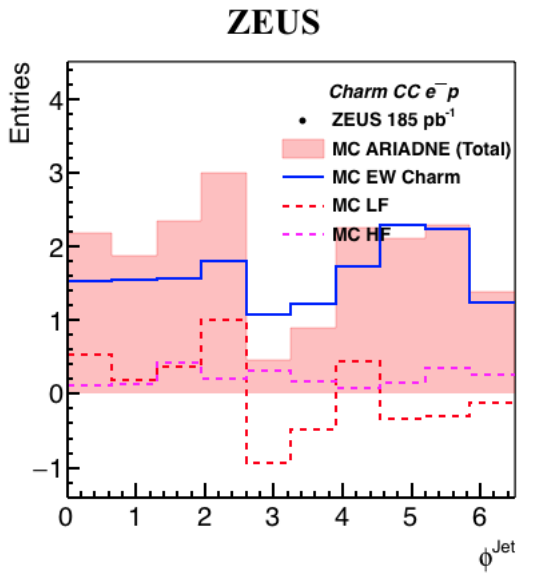


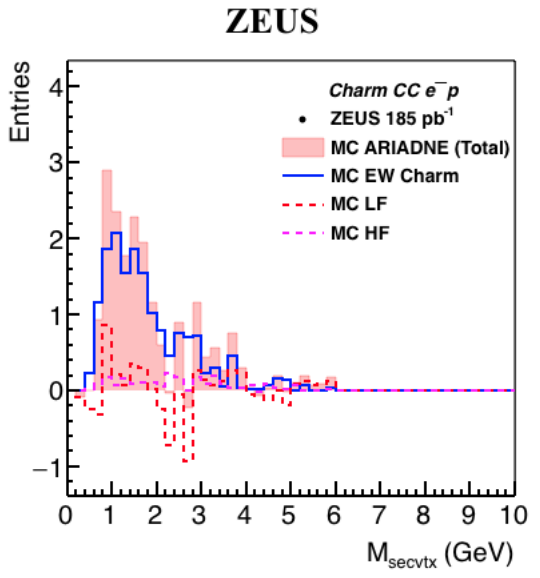
Mirrored Jets & SecVtx

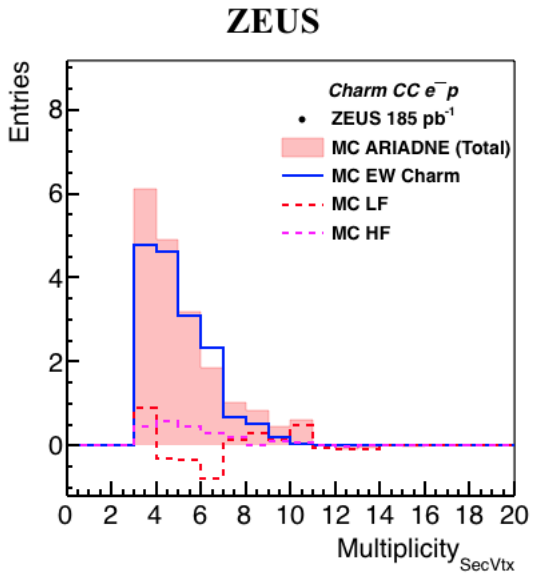


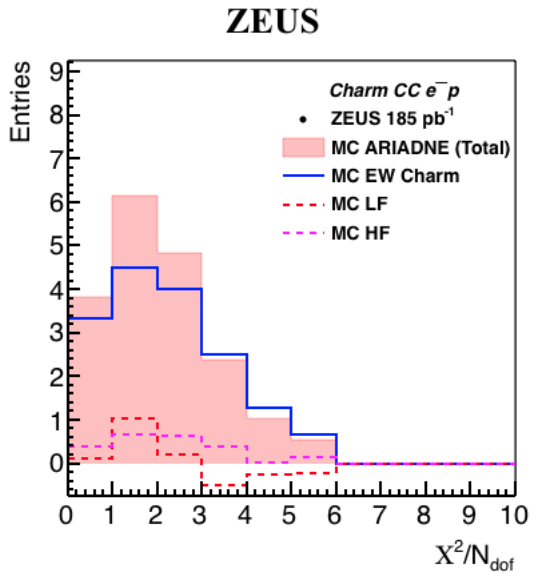




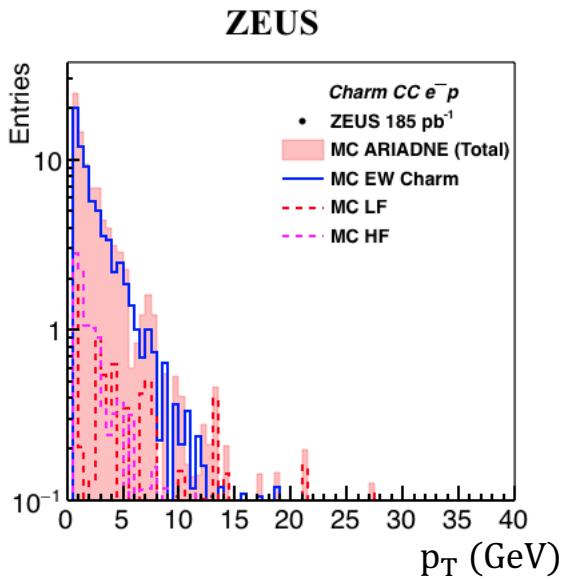


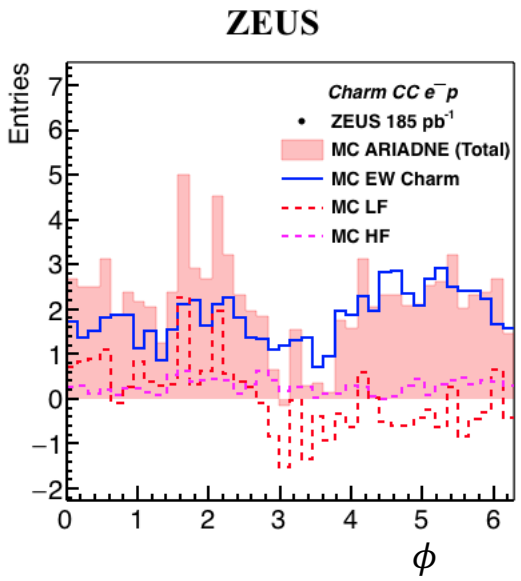


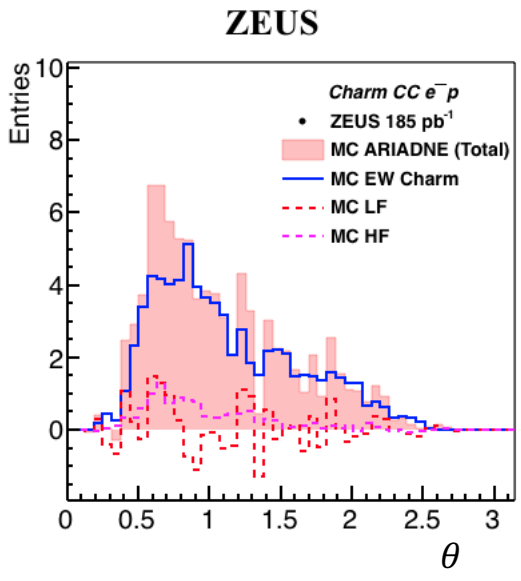


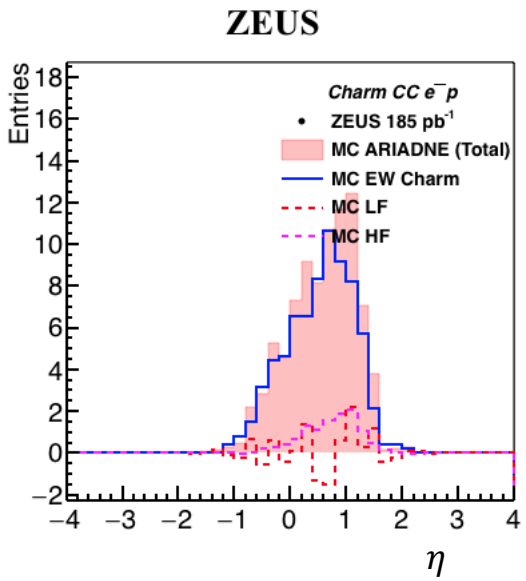


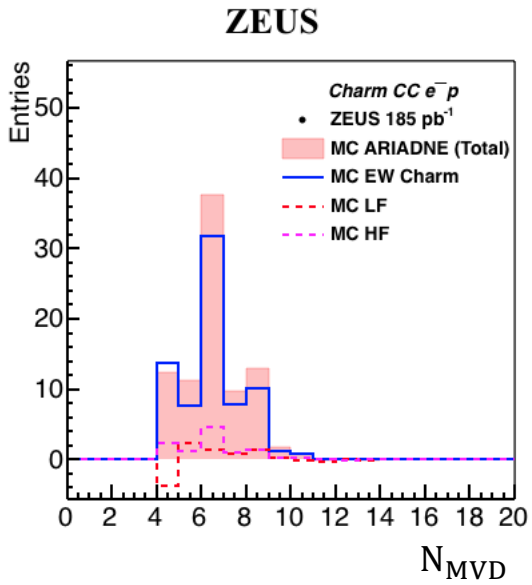
Mirrored Tracks

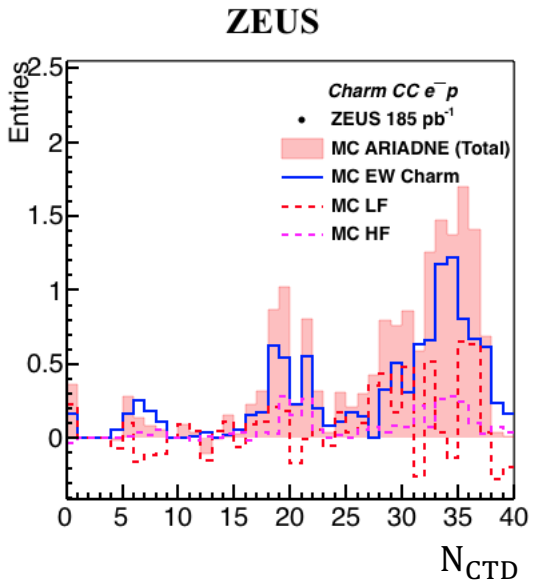


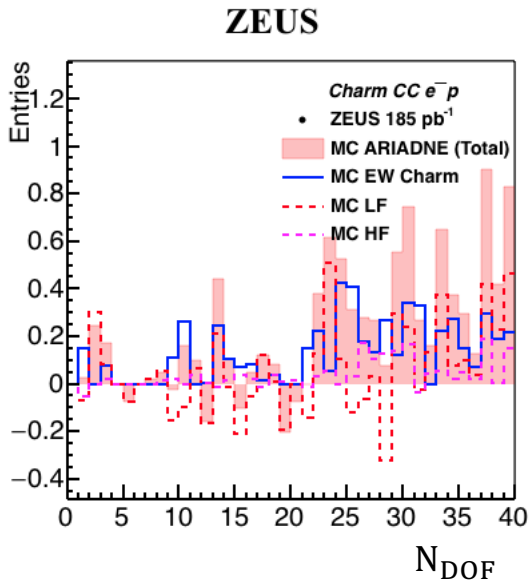


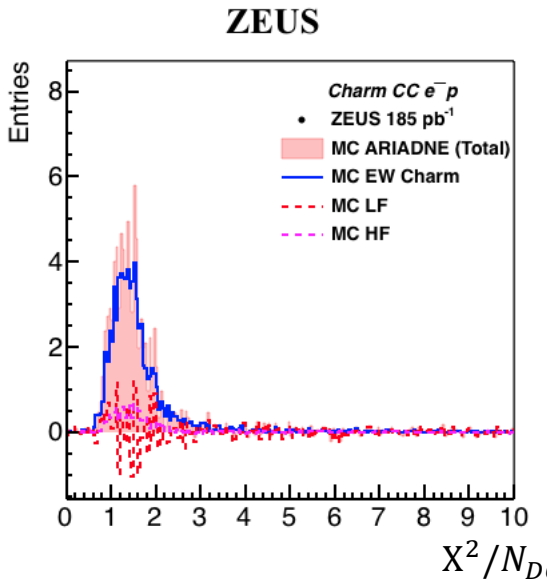






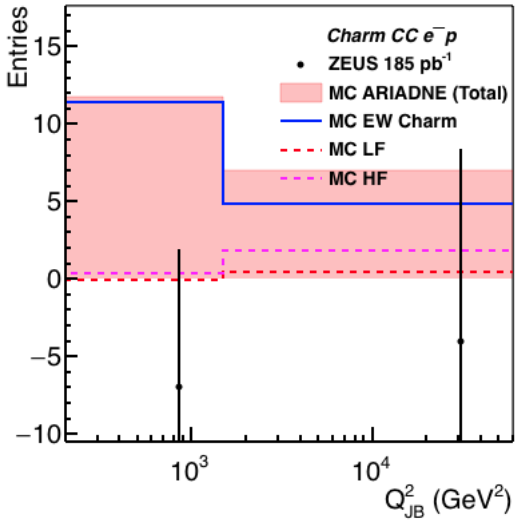




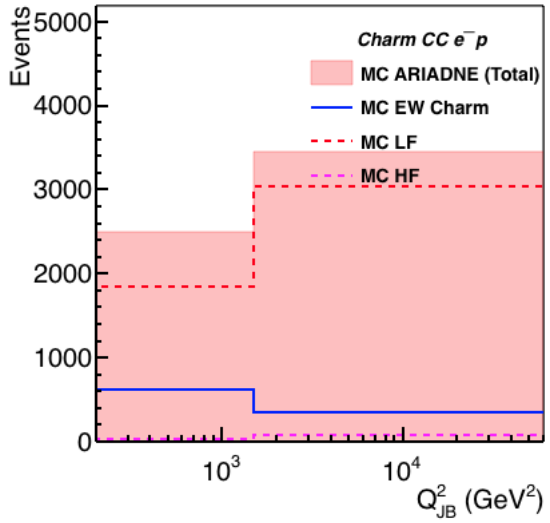


Charm signal and generated charm

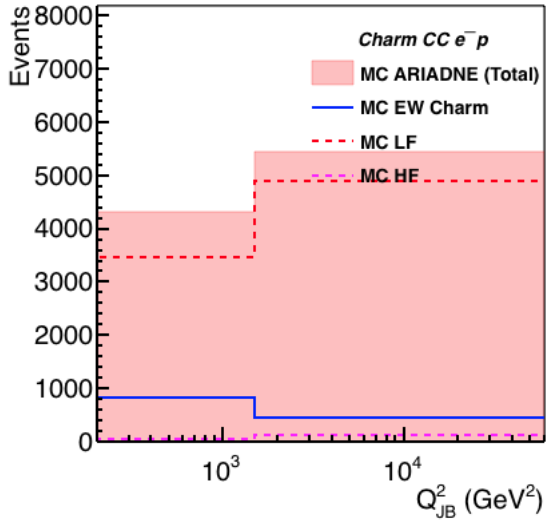
N_{signal}



$N_{gen,kin}$

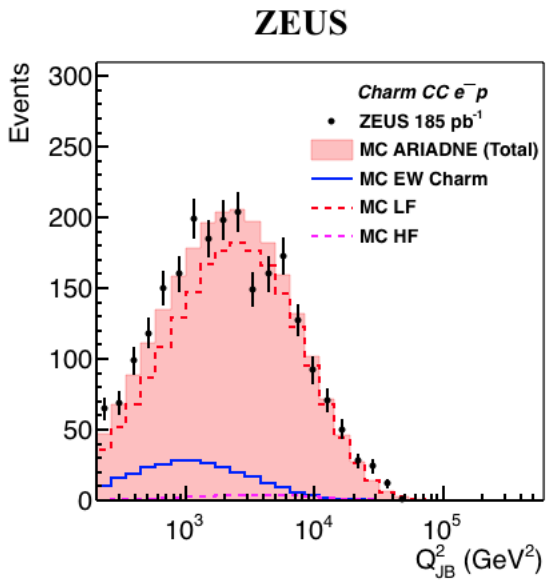


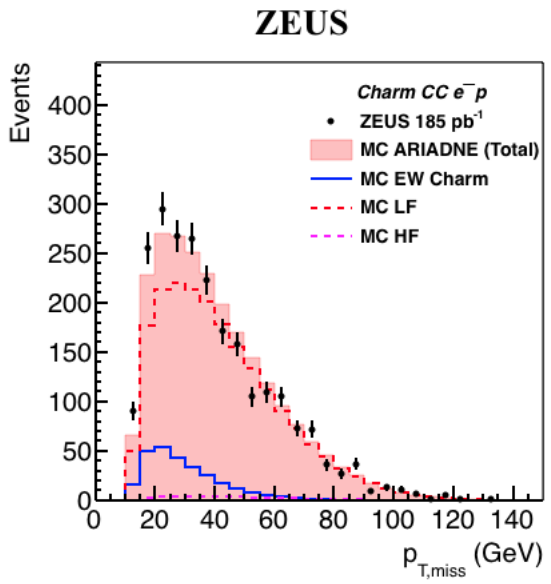
N_{gen}

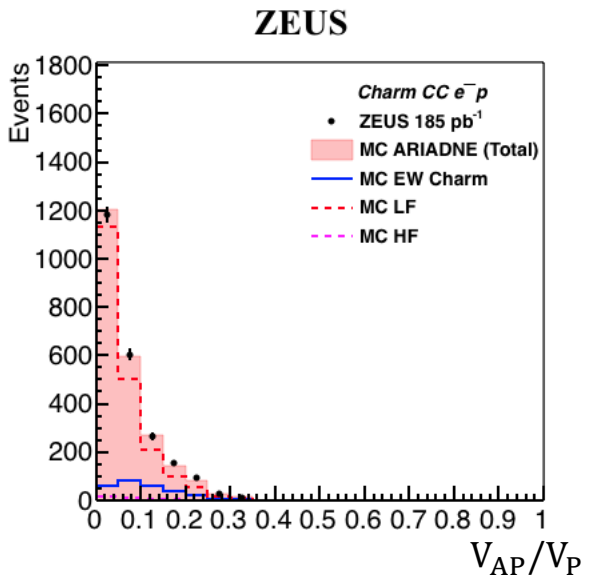


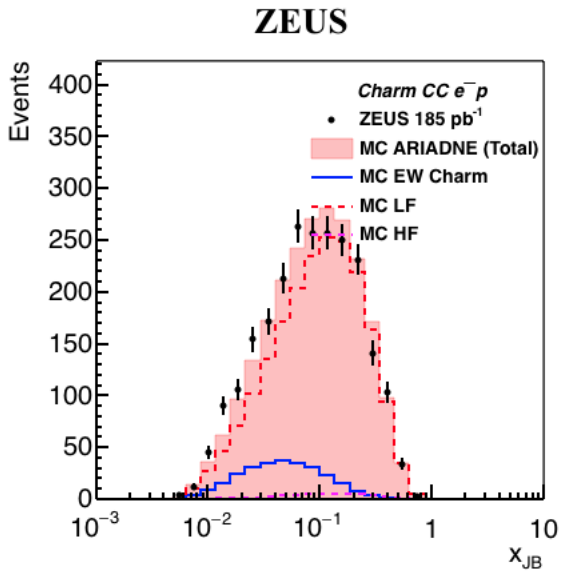
06e

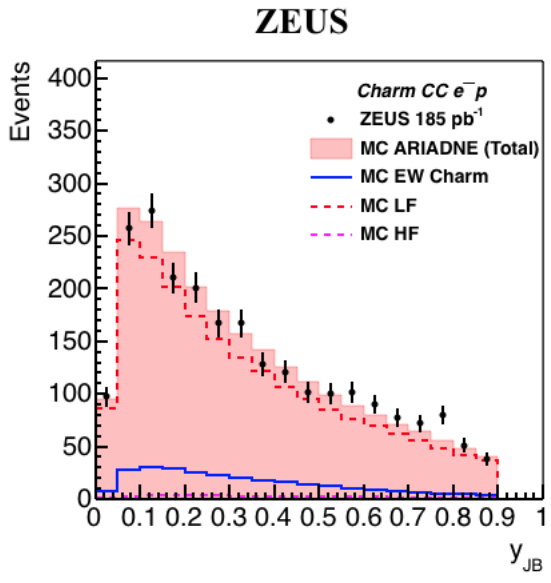
Event

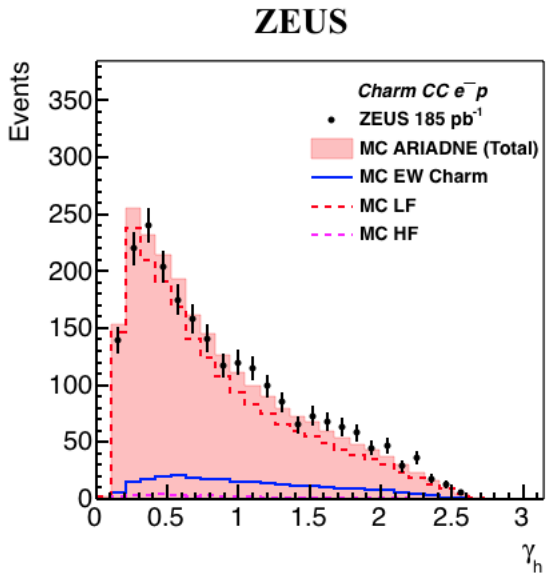

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
Q²JB (GeV²)


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
pT,miss (GeV)

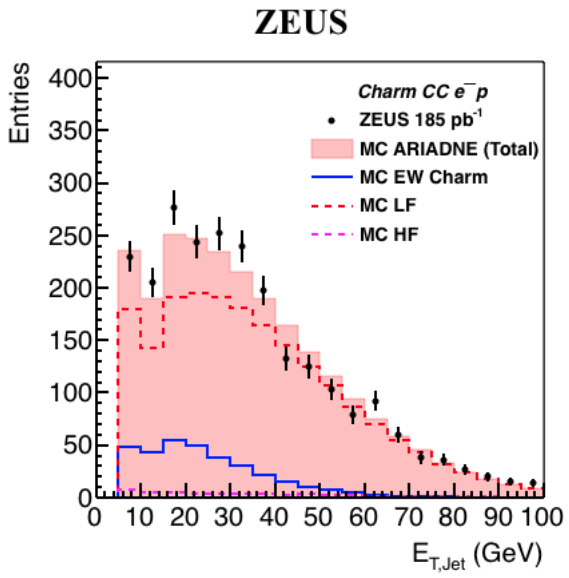

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
VAP/VP


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
xJB


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
yJB


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
γh

Jet & SecVtx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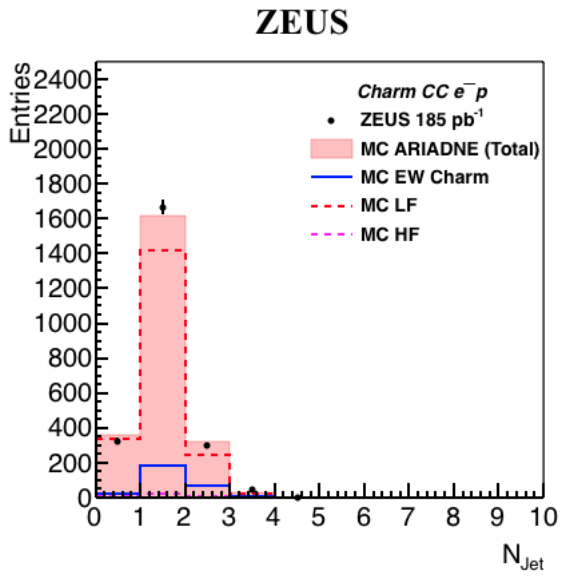
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
E_T,Jet (GeV)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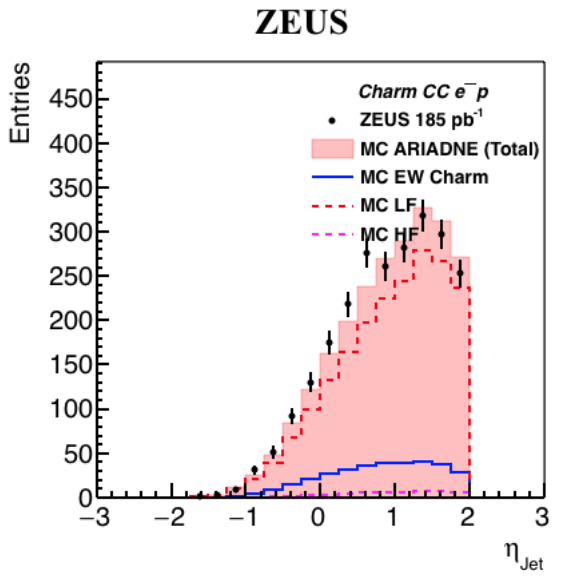
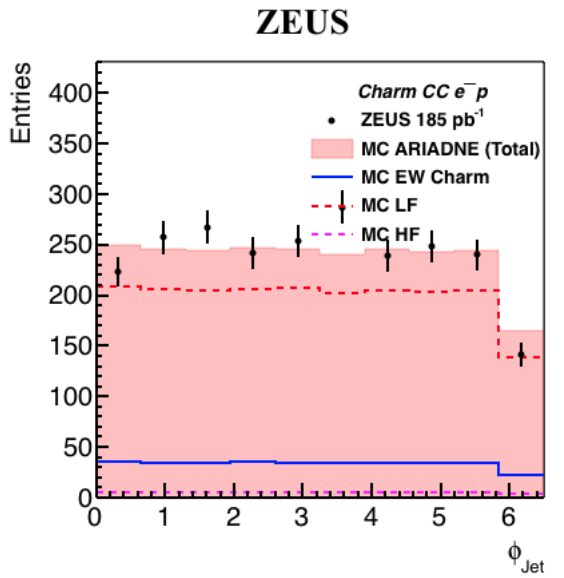
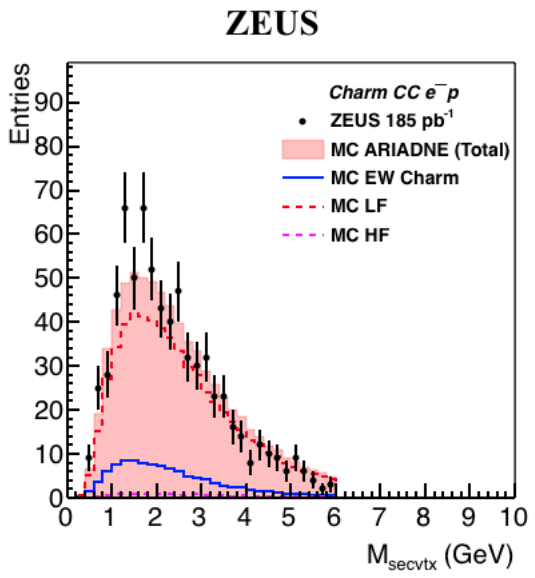
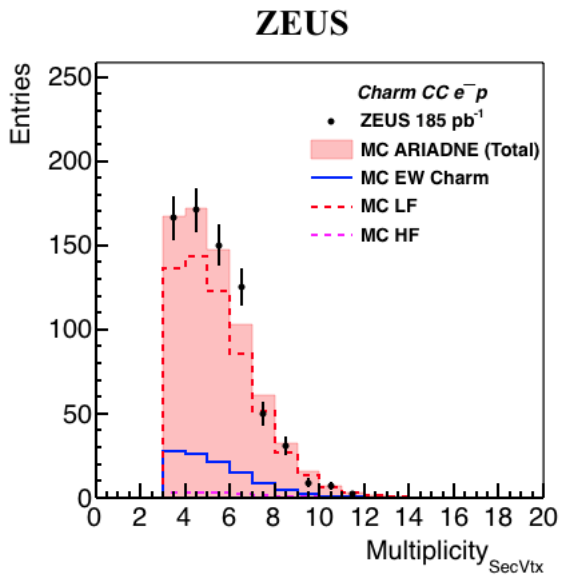
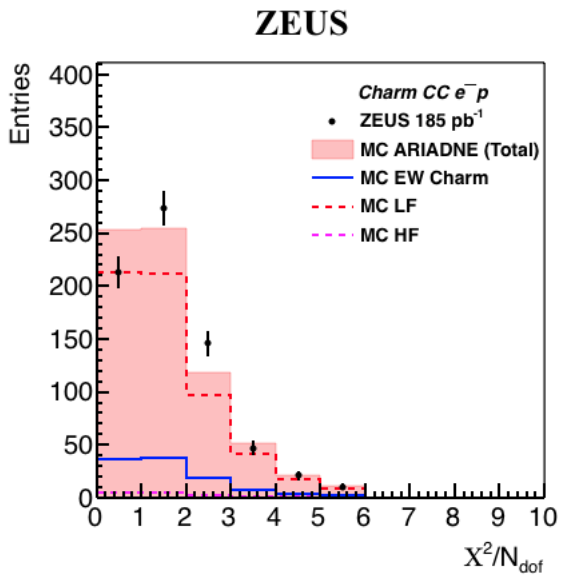
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_Jet

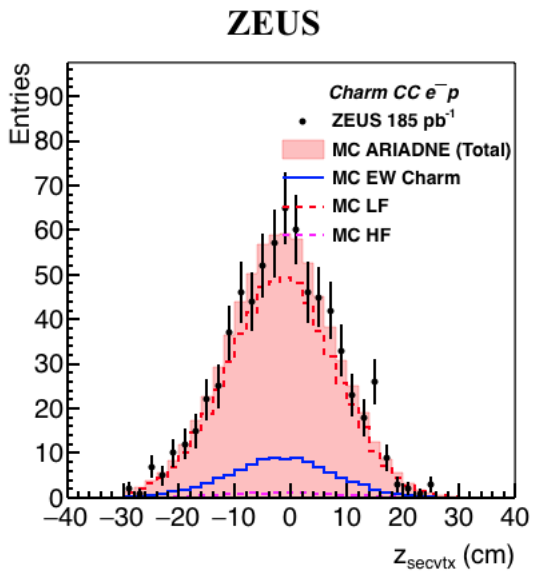

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
η_Jet


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
φ_Jet

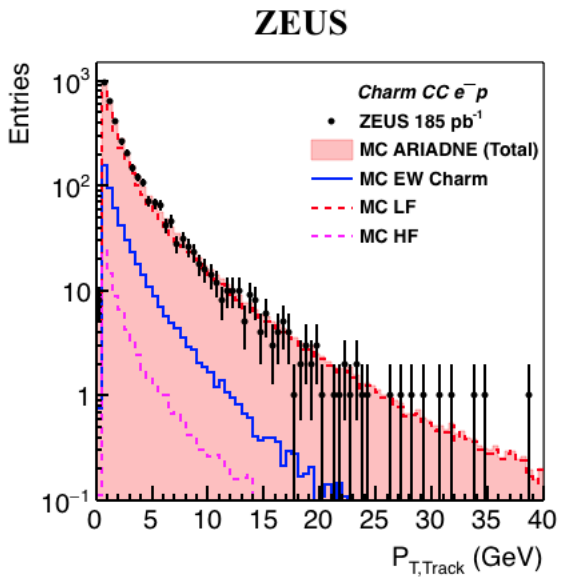

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
M_secvtx (GeV)

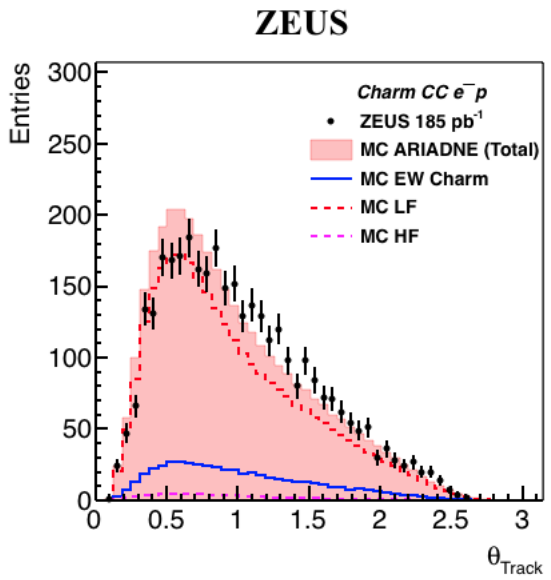

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
Multiplicity_SecVtx

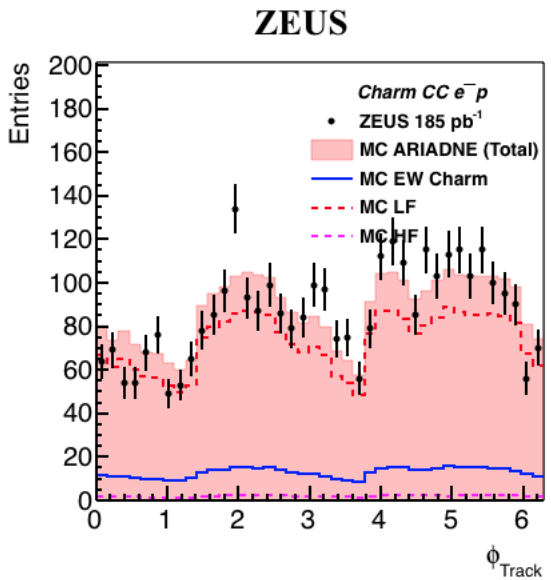

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
X²/N_dof

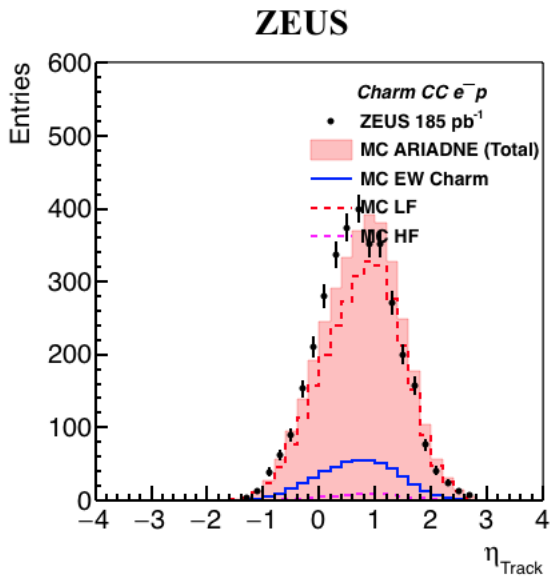

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
z_secvtx (cm)

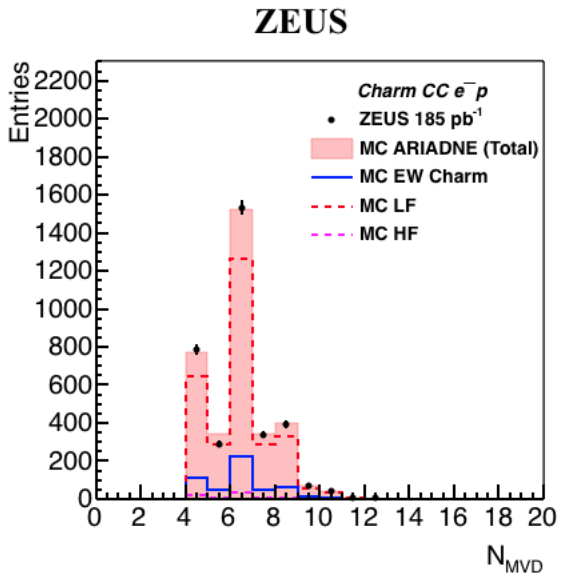
Track

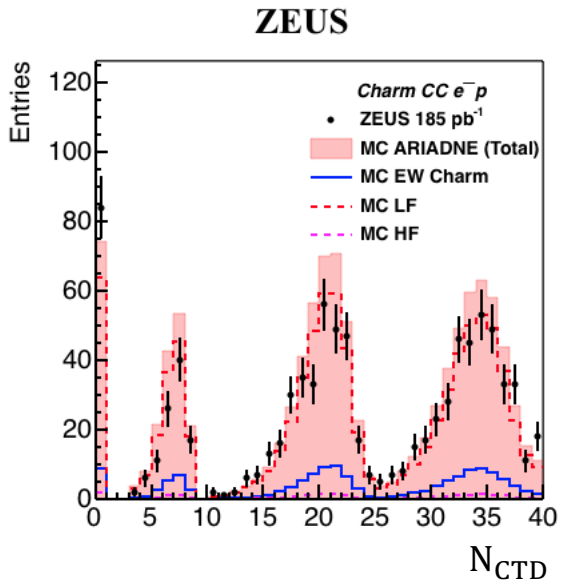

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
P_T,Track (GeV)

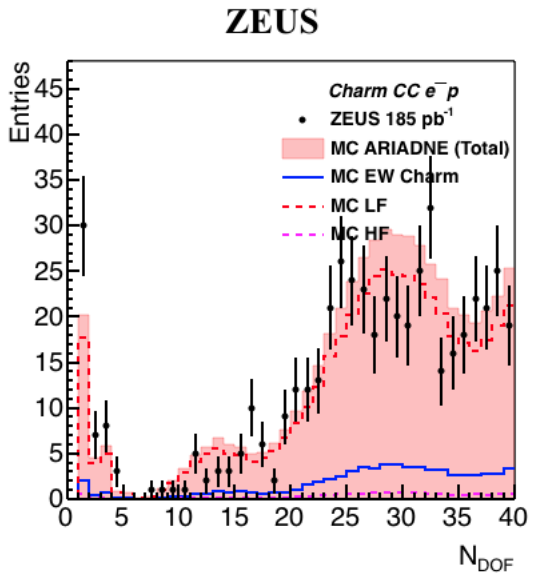

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
θ_Track

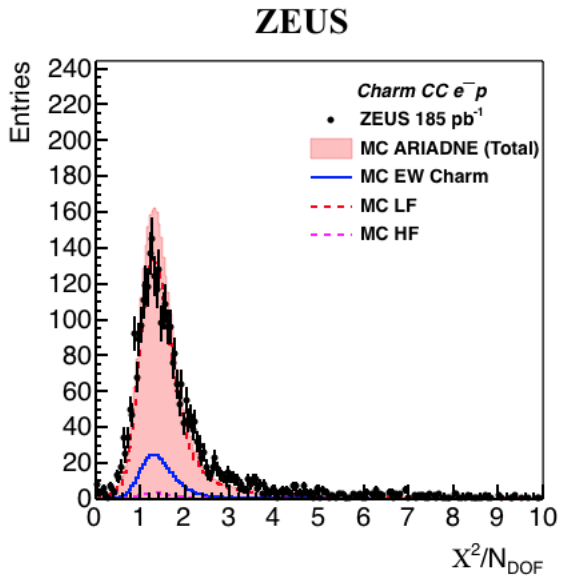

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
φ_Track


ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
η_Track

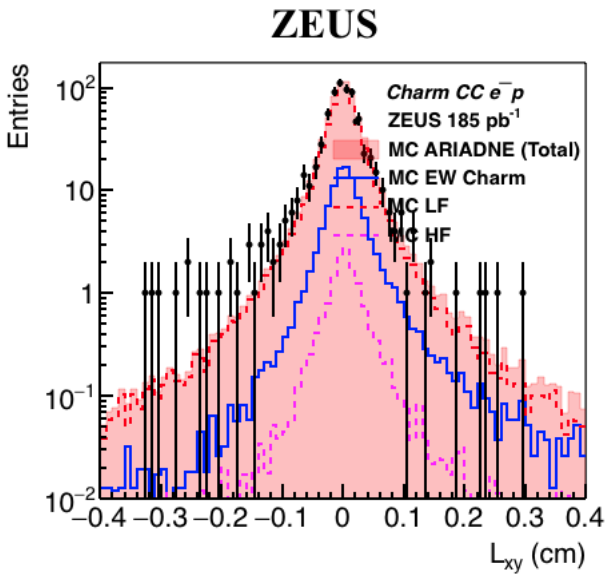

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_MVD

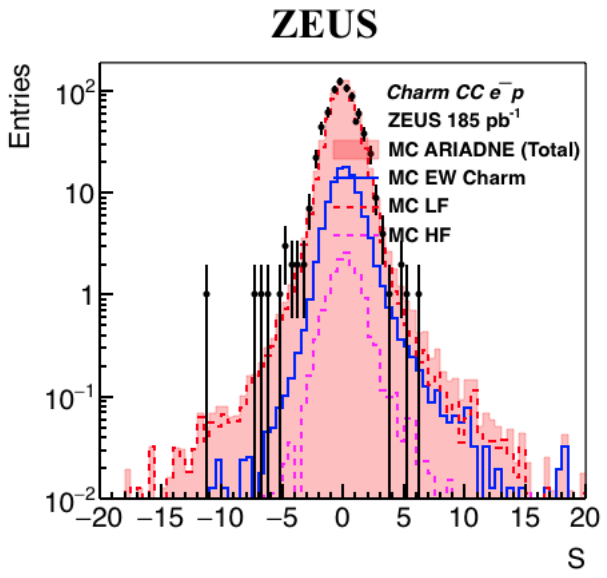

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_CTD

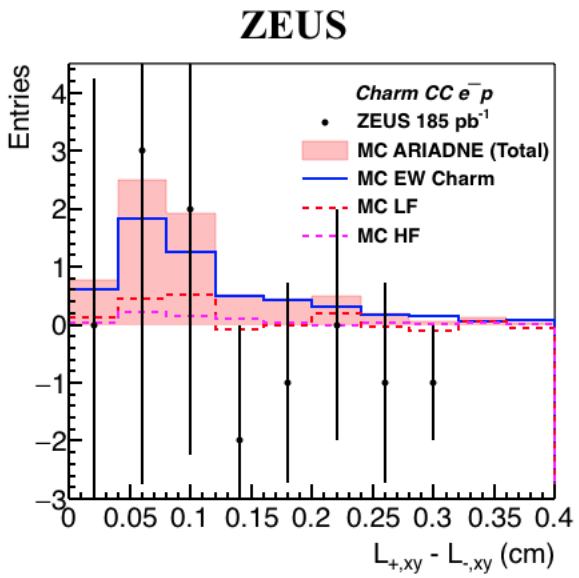

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_DOF

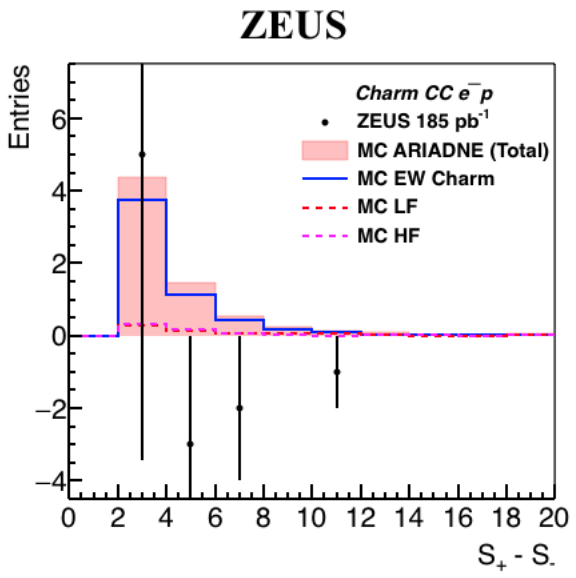

ZEUS
Charm CC e⁻p
ZEUS 185 pb⁻¹
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
X²/N_DOF

Decay Length



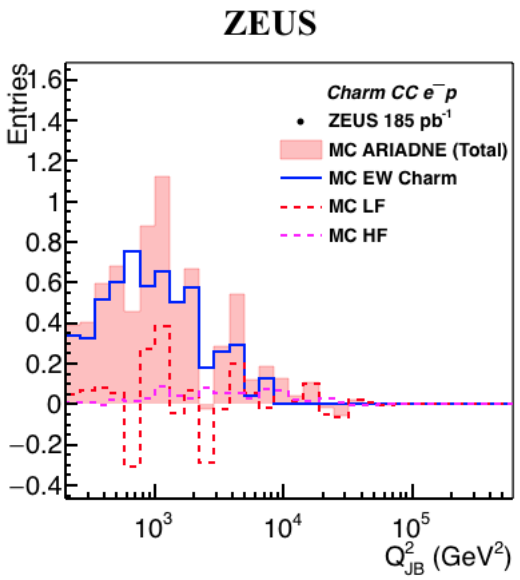


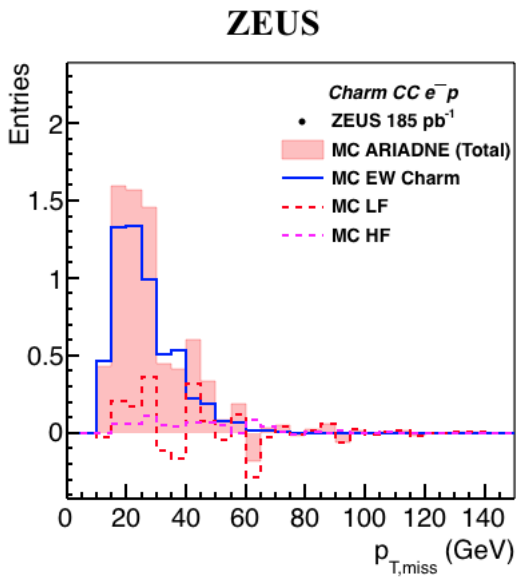


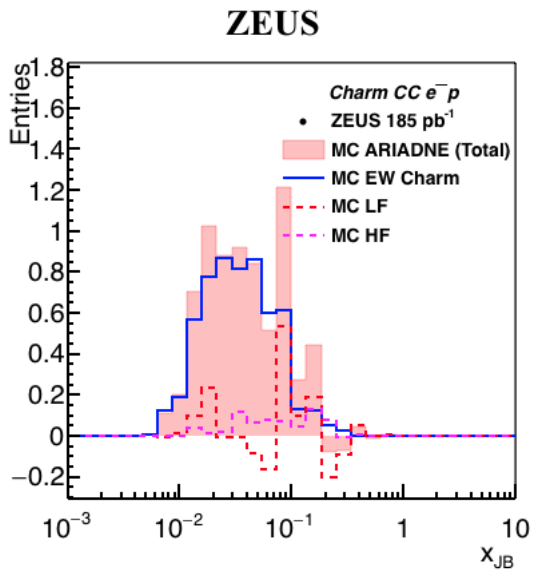


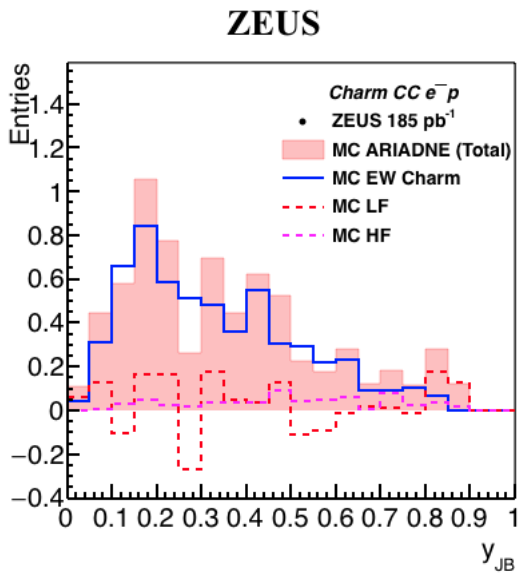
m

Mirrored Event

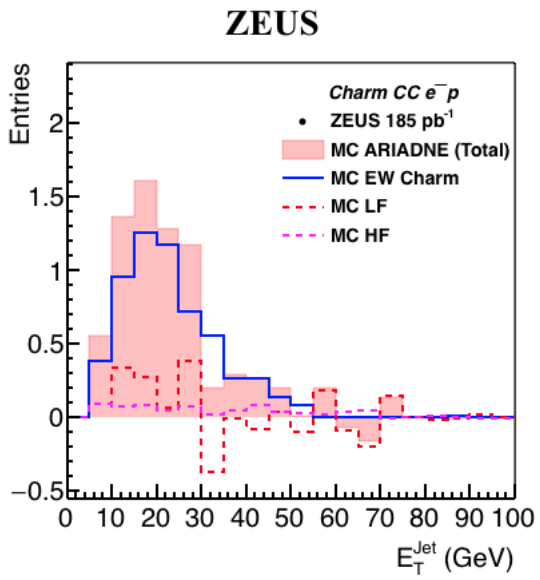


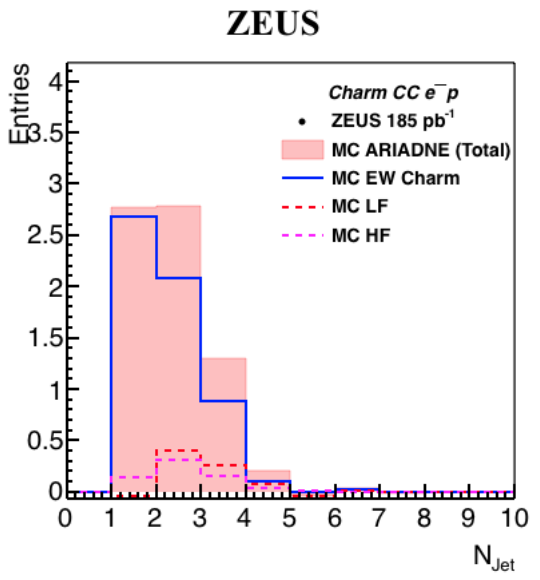


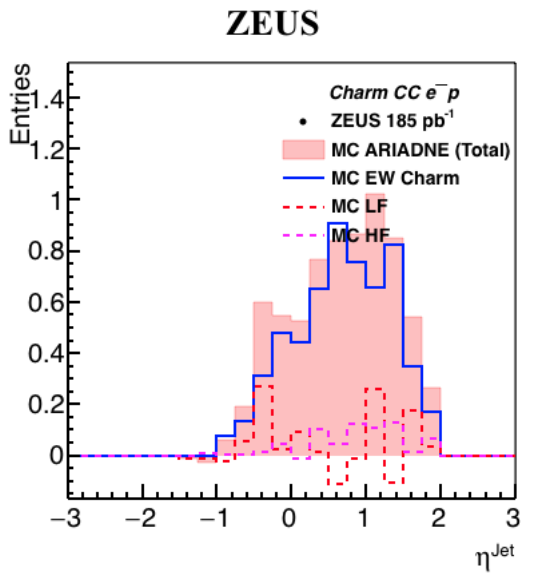


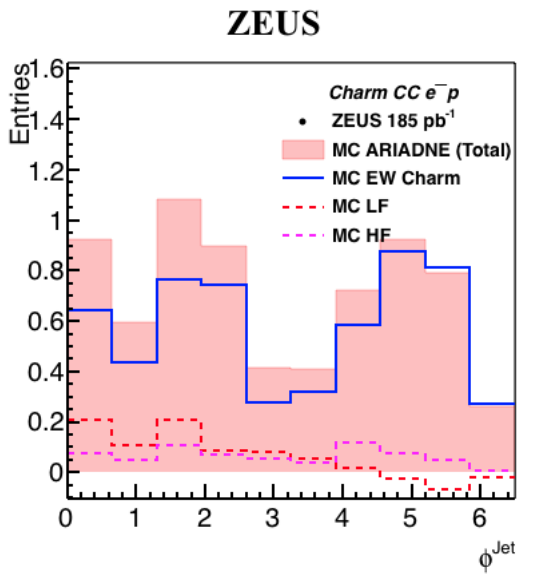


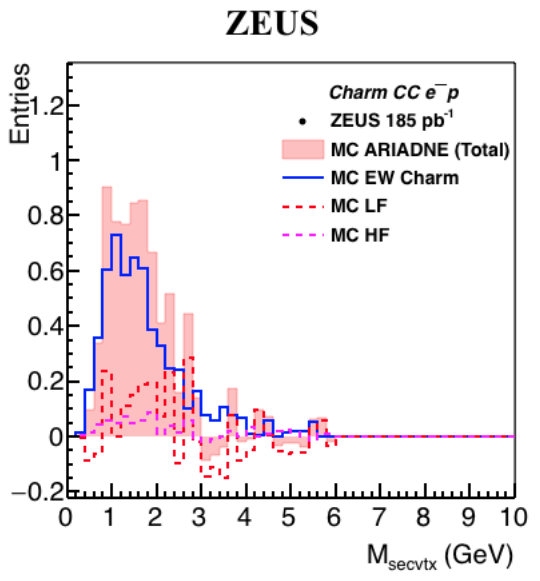
Mirrored Jets & SecVtx

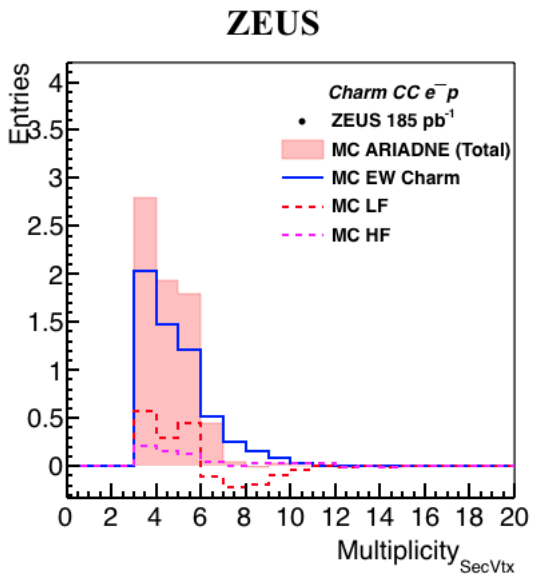


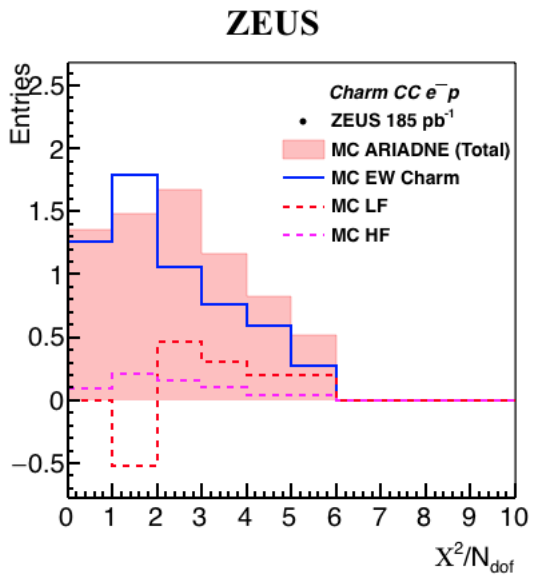




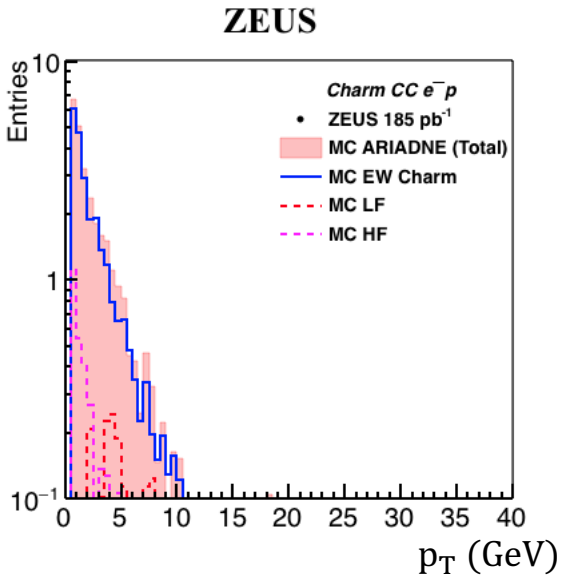


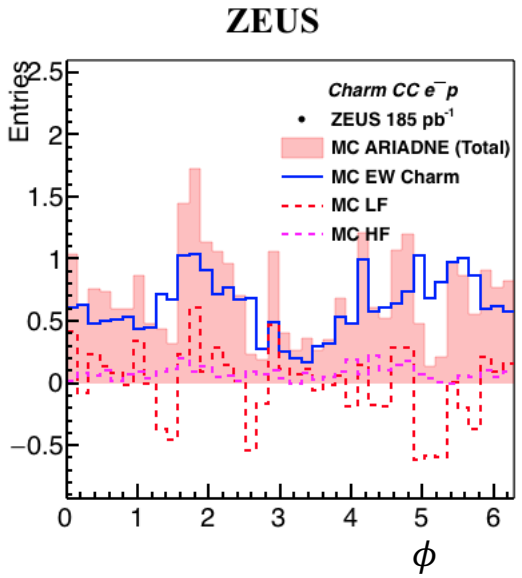


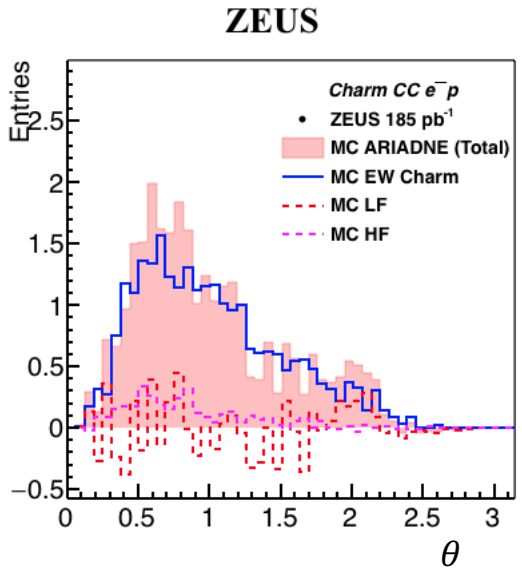


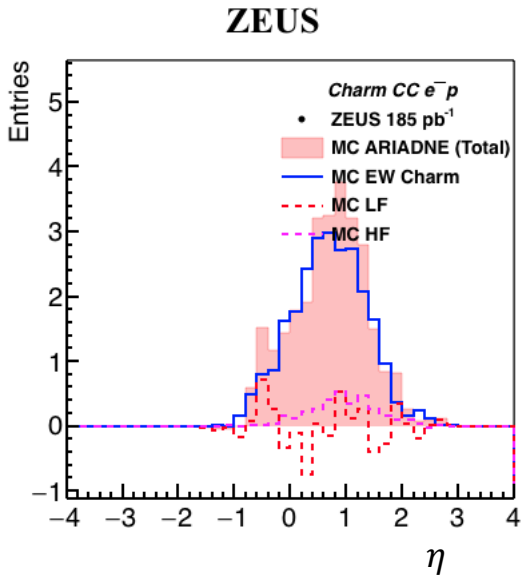


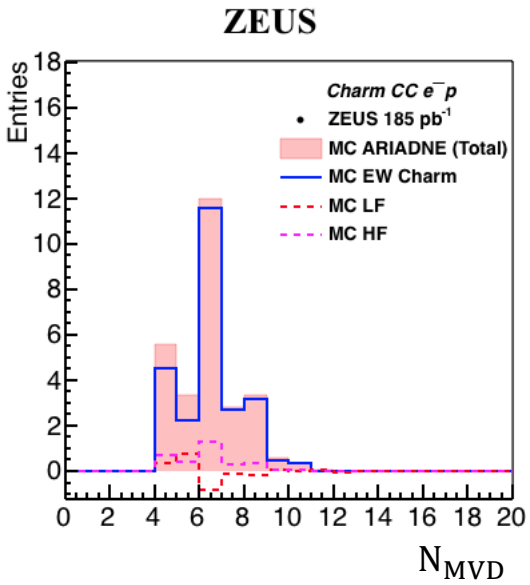
Mirrored Tracks

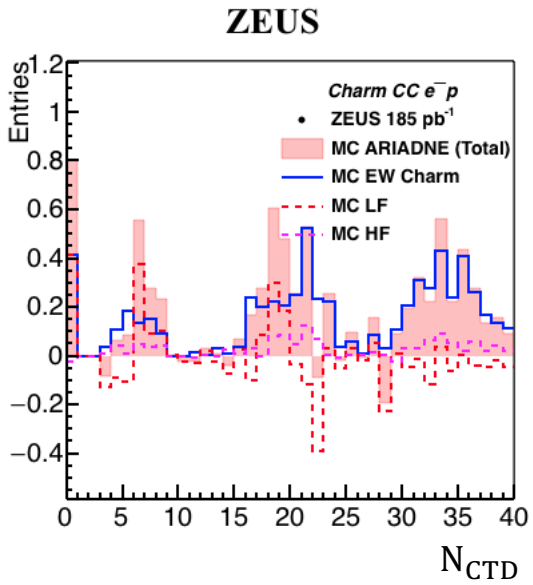


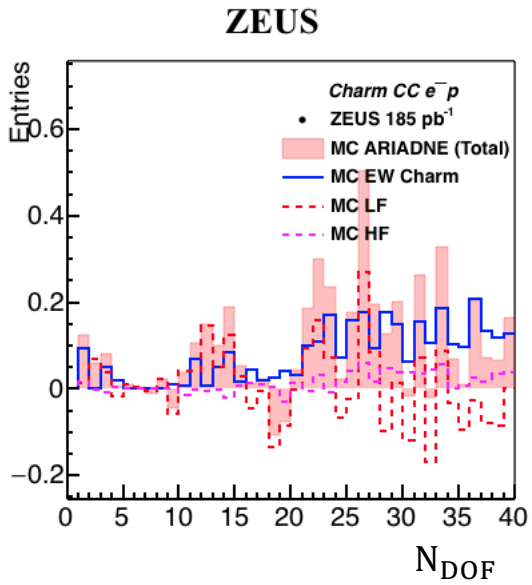


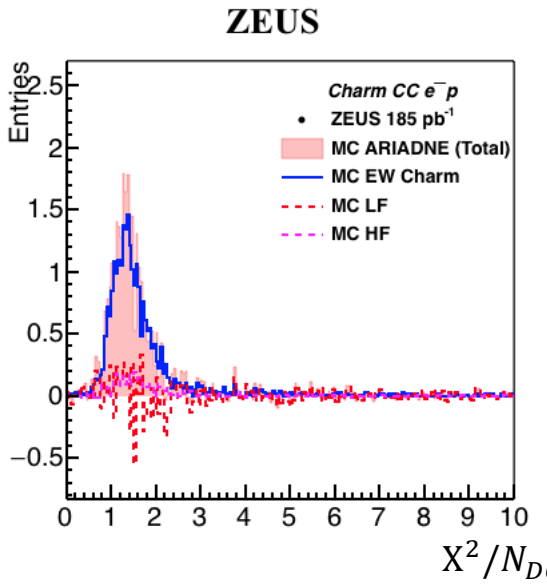






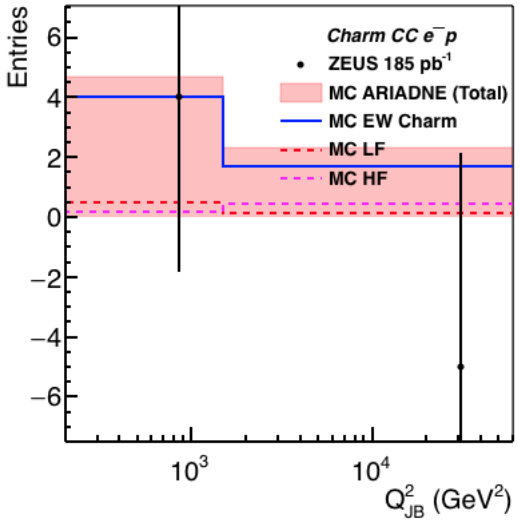




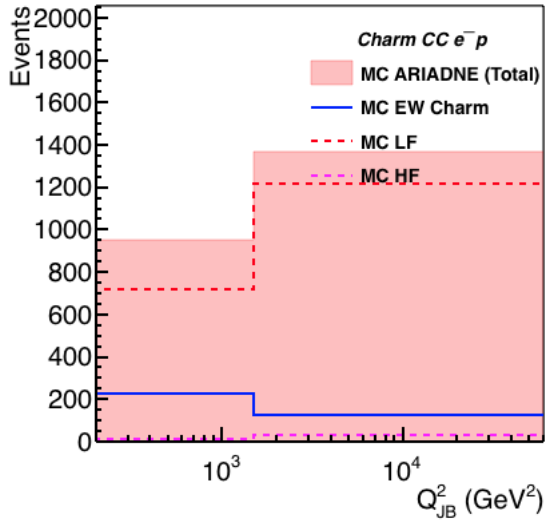


Charm signal and generated charm

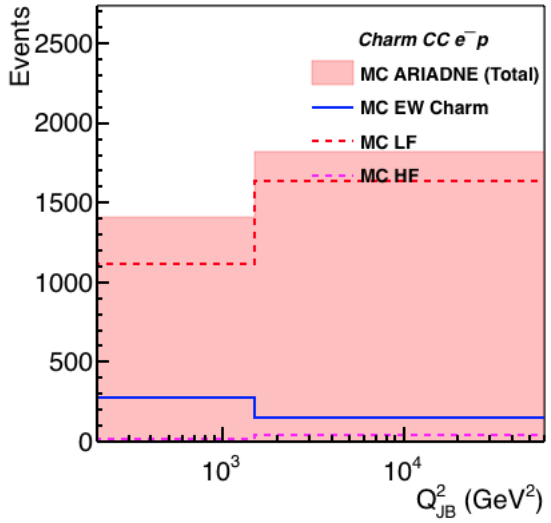
N_{signal}



$N_{gen,kin}$

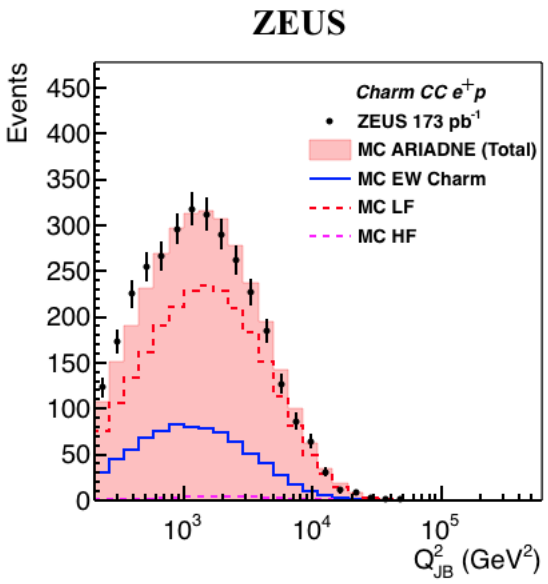


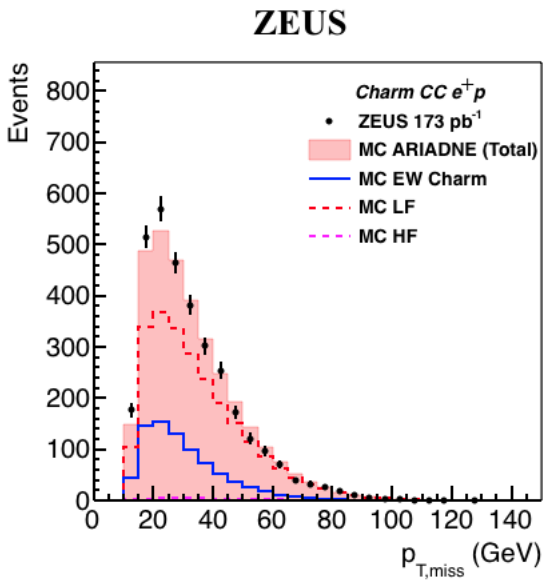
N_{gen}

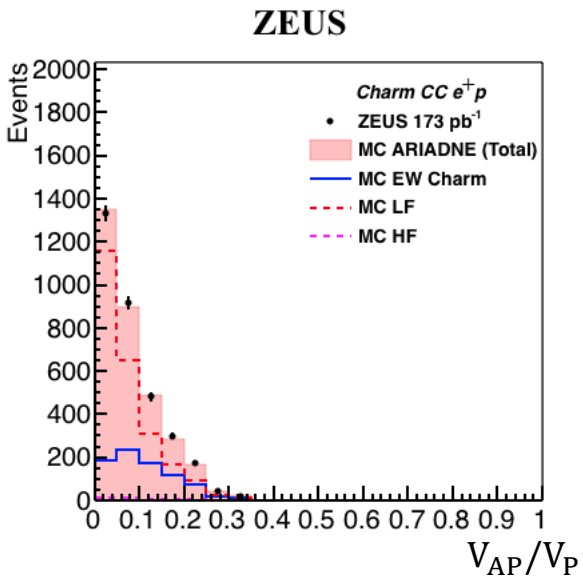


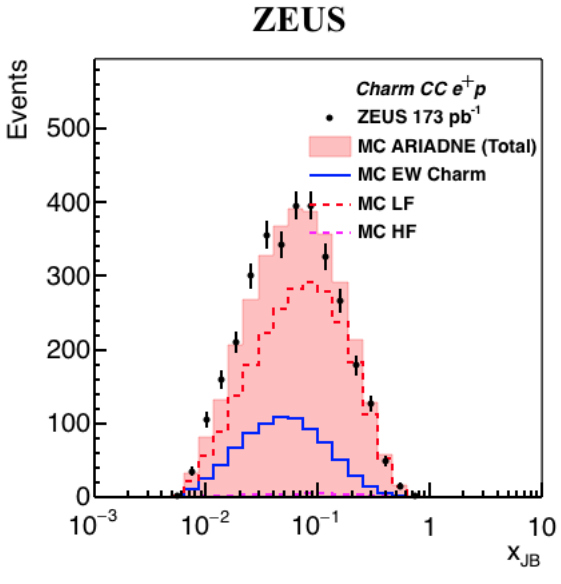
0607p

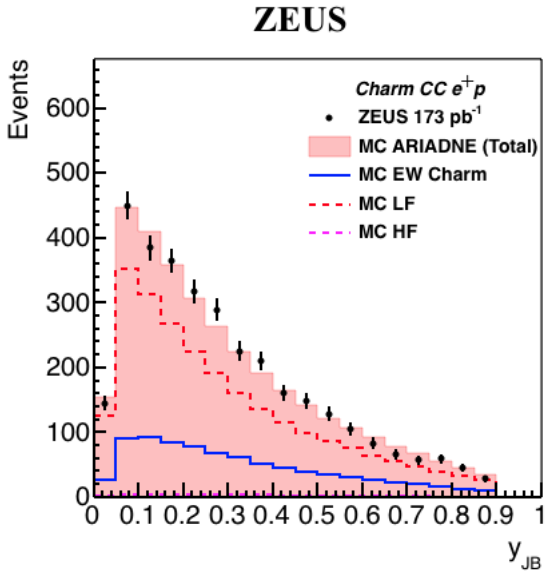
Event

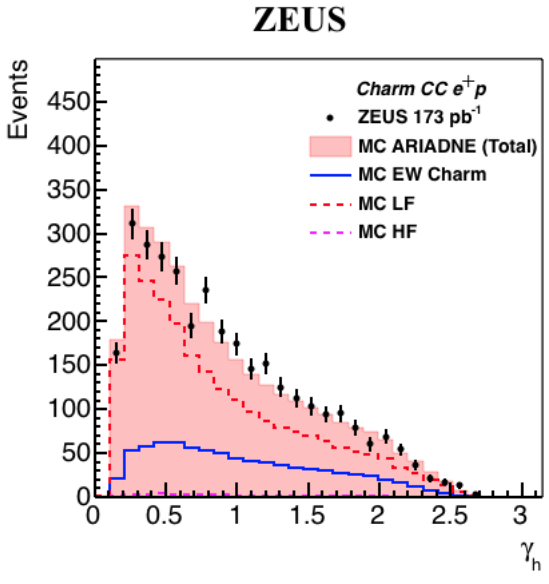

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
Q^2_{JB} (GeV^2)


ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
$p_{T,miss}$ (GeV)

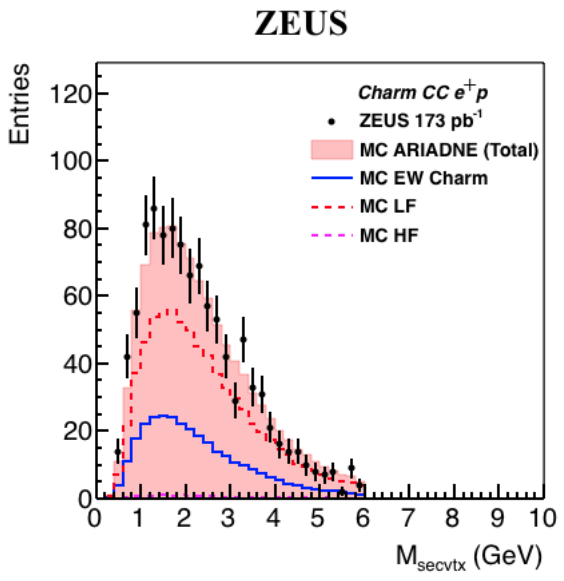

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
V_{AP}/V_P

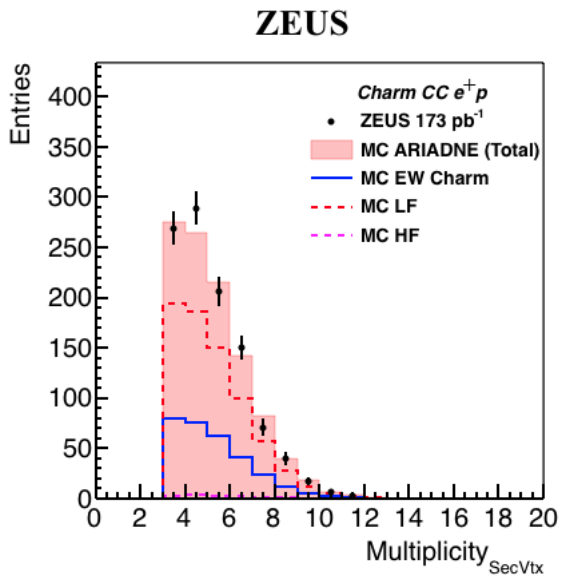

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
x_{JB}

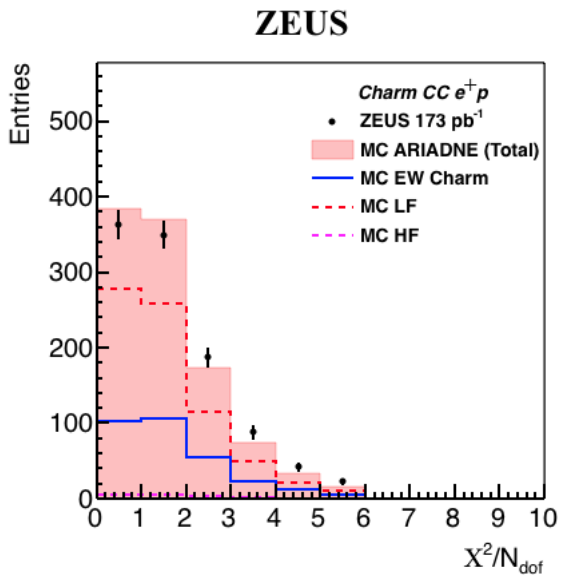

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
y_{JB}

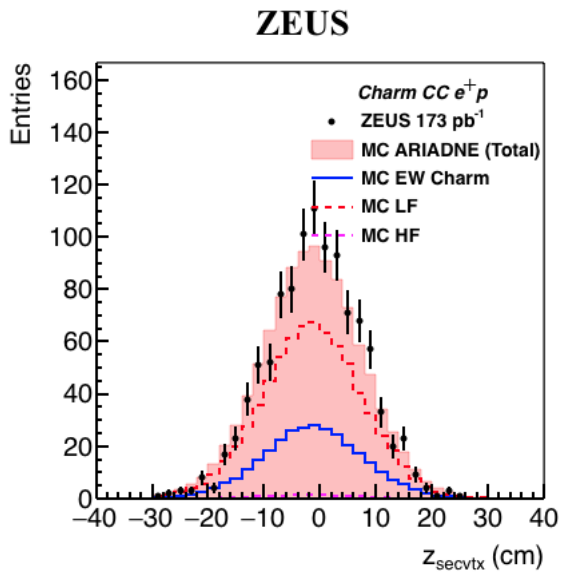

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Events
γ_h

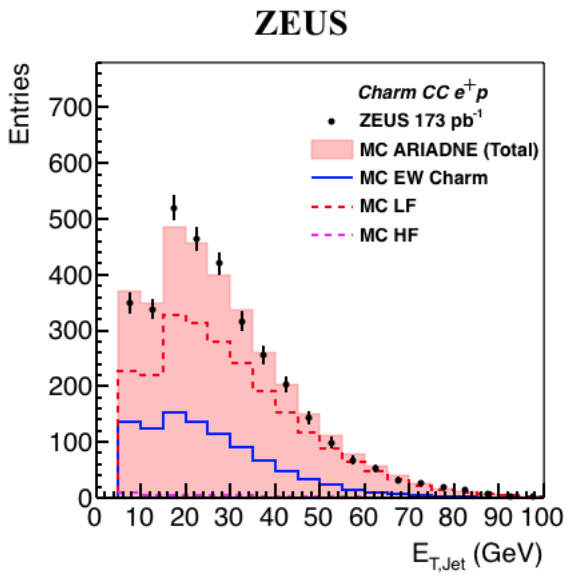
Jet & SecVtx

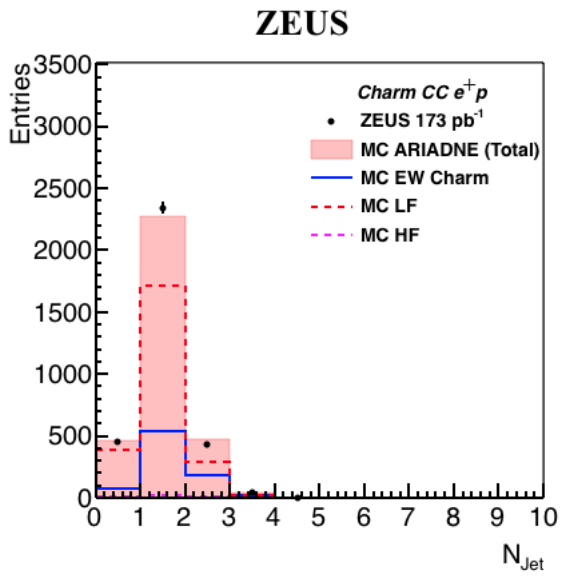

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
M_{secvtx} (GeV)

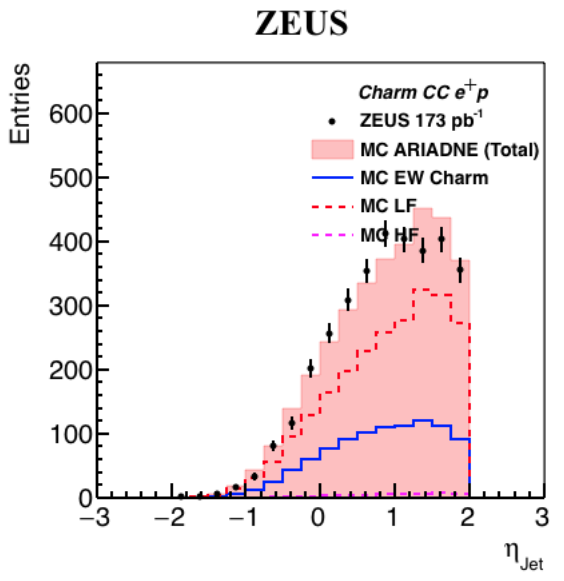

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
Multiplicity$_{SecVtx}$

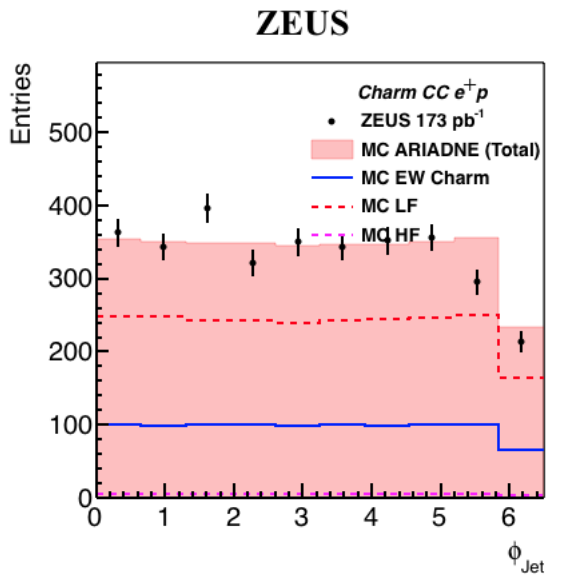

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
X^2/N_{dof}


ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
z_{secvtx} (cm)

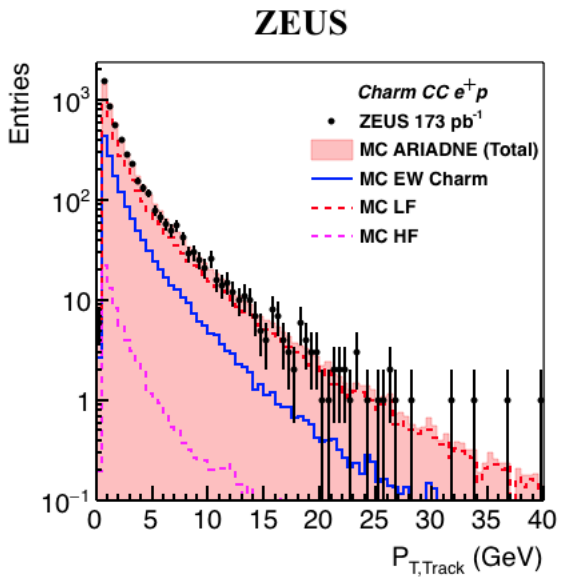

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
$E_{T,Jet}$ (GeV)

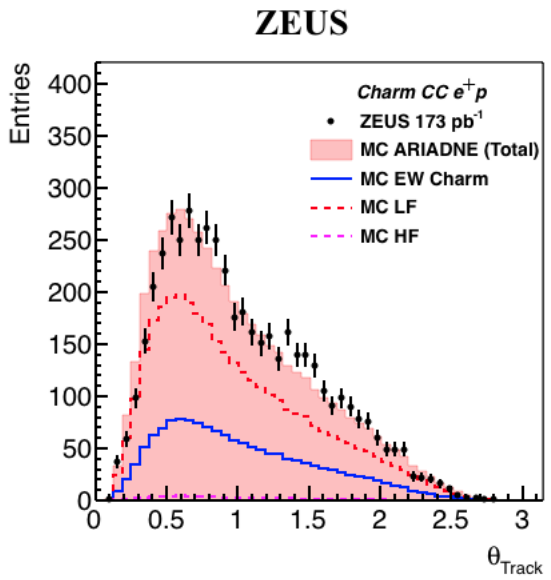

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_{Jet}

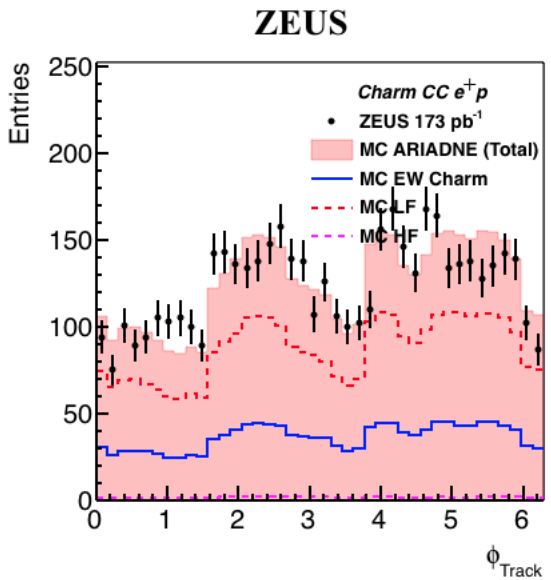

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
η_{Jet}

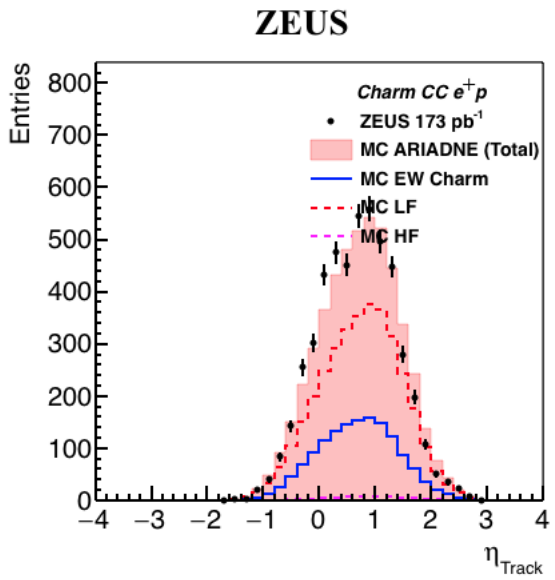

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
ϕ_{Jet}

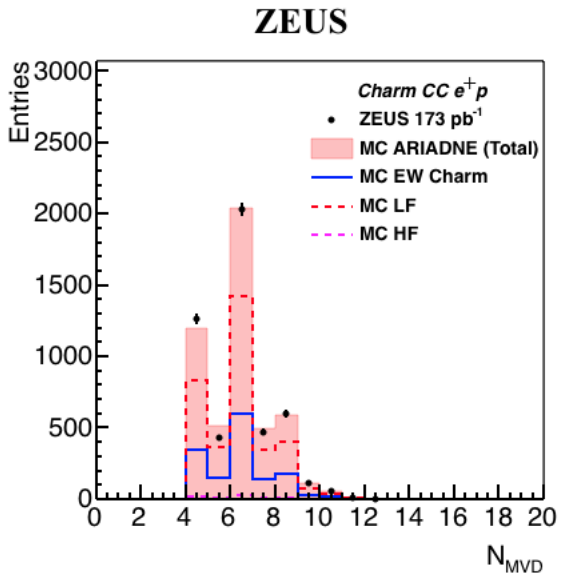
Track

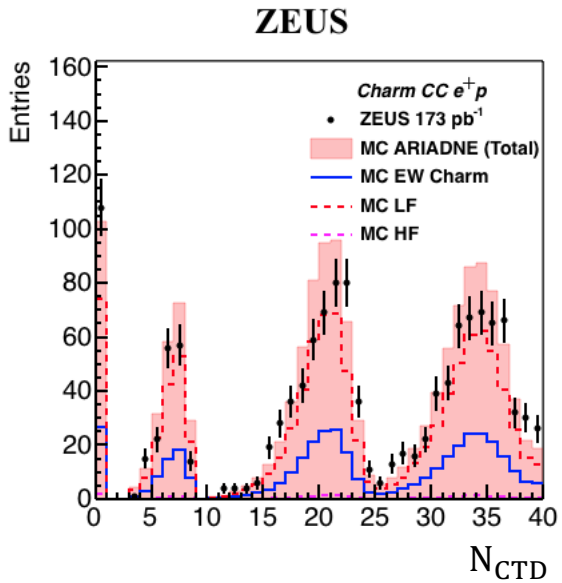

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
$P_{T,Track}$ (GeV)

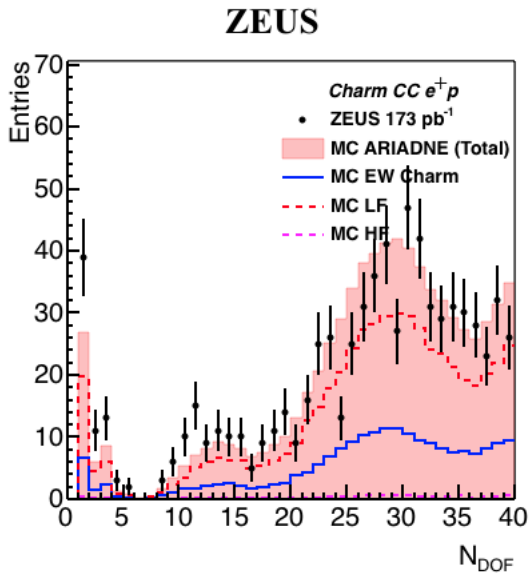

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
θ_{Track}

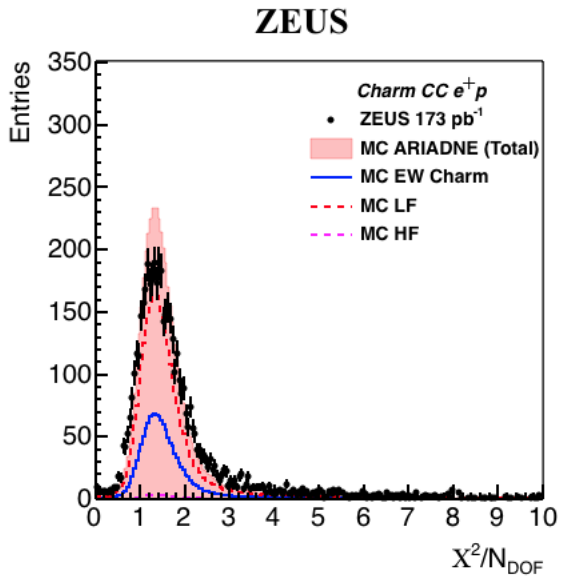

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
ϕ_{Track}


ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
η_{Track}

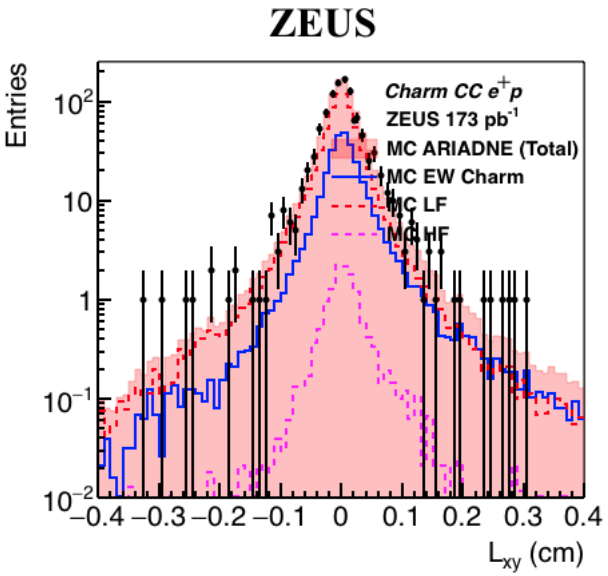

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_{MVD}

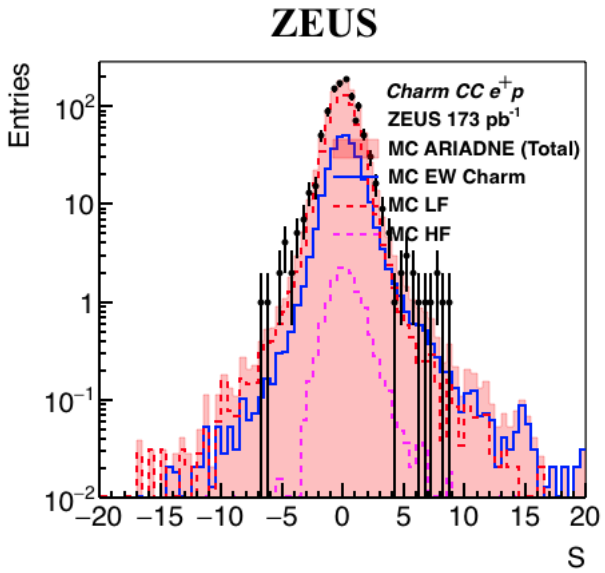

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_{CTD}

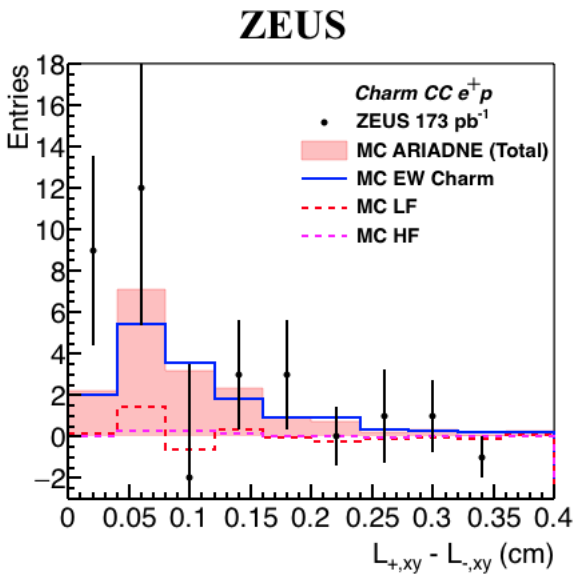

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
N_{DOF}

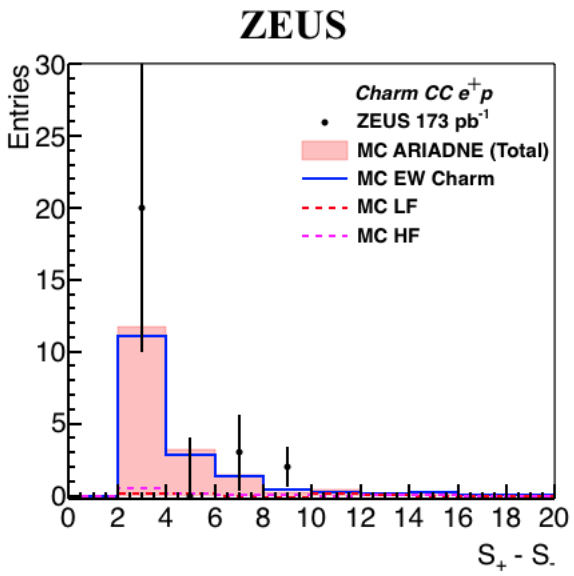

ZEUS
Charm CC e^+p
ZEUS 173 pb^{-1}
MC ARIADNE (Total)
MC EW Charm
MC LF
MC HF
Entries
X^2/N_{DOF}

Decay Length



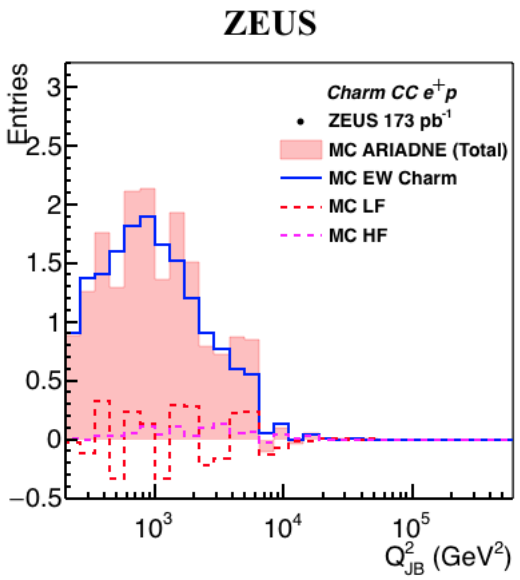


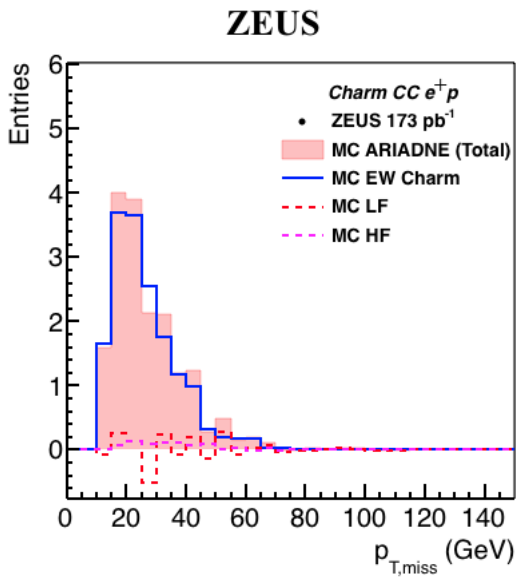


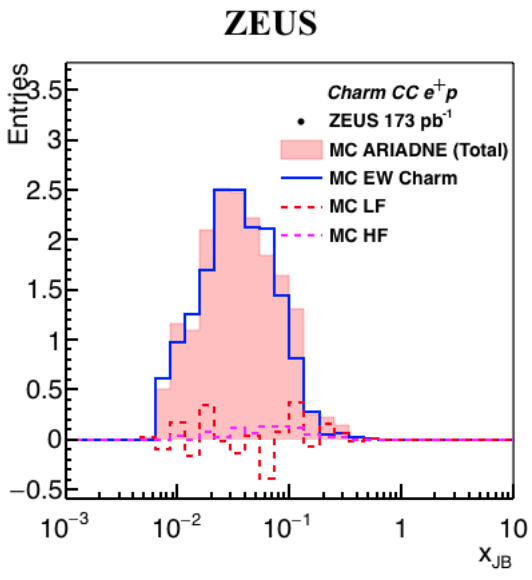


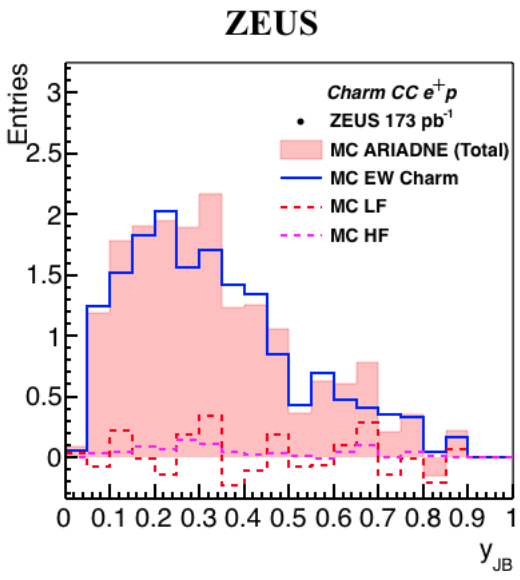
m

Mirrored Event

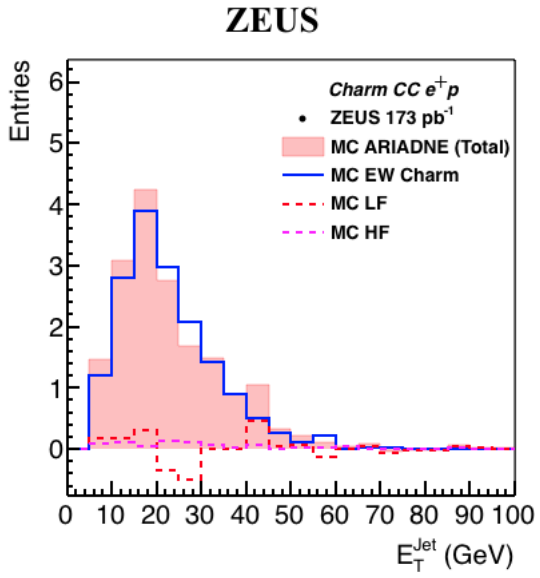


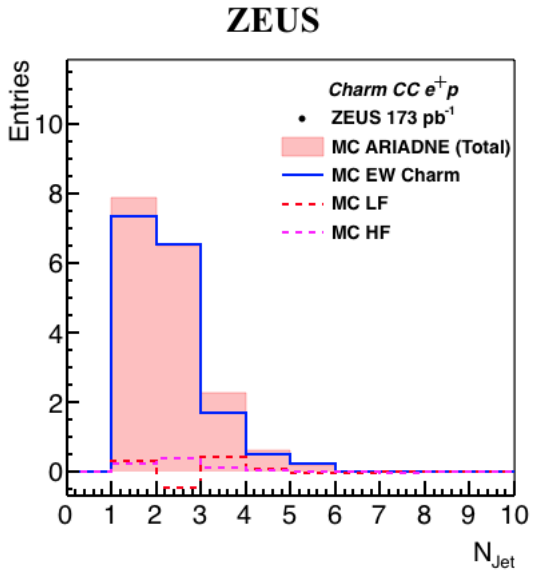


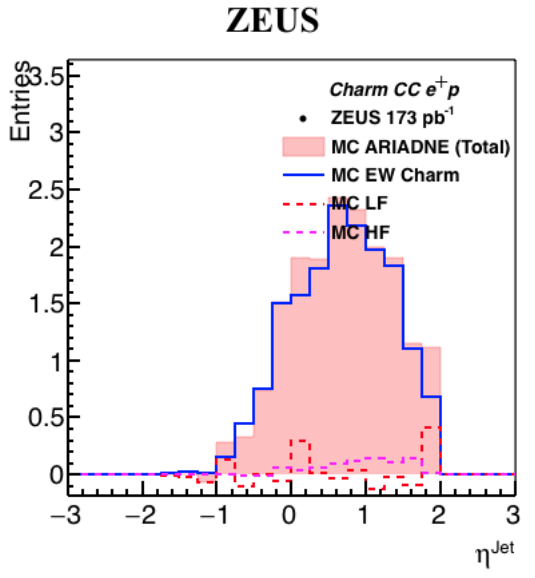


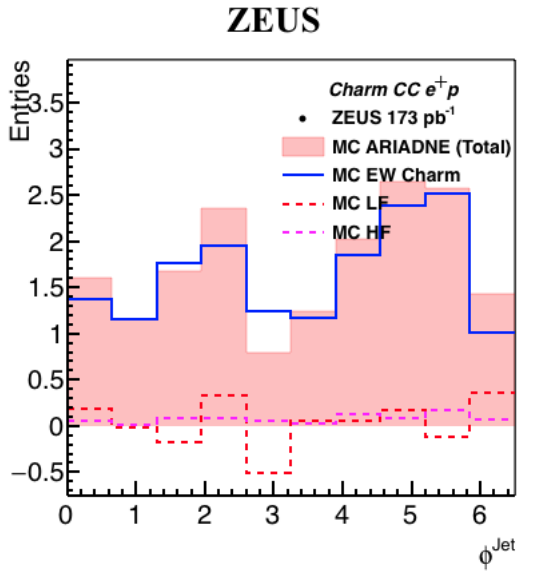


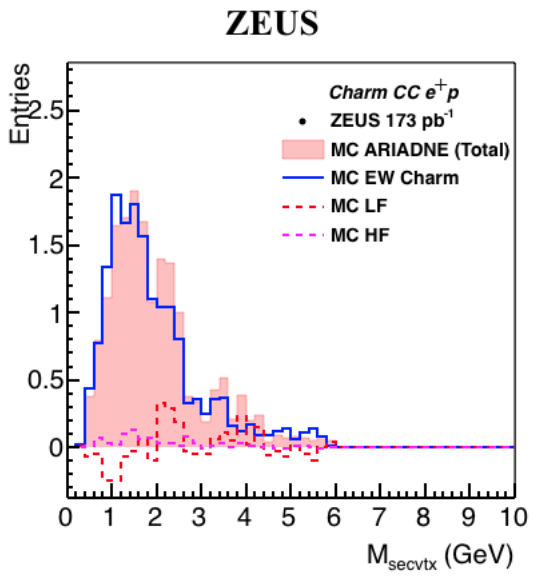
Mirrored Jets & SecVtx

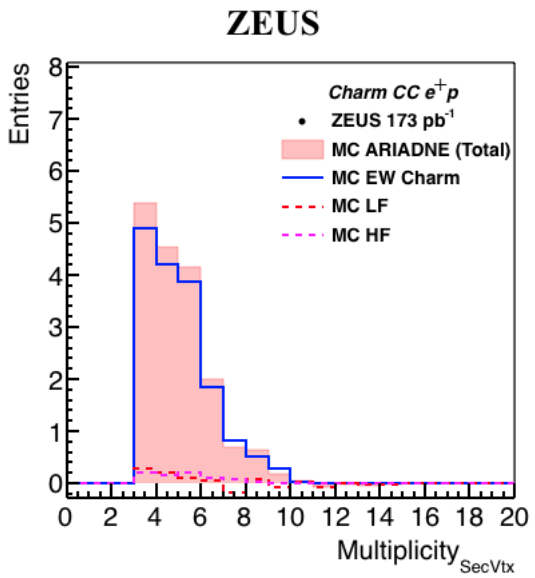


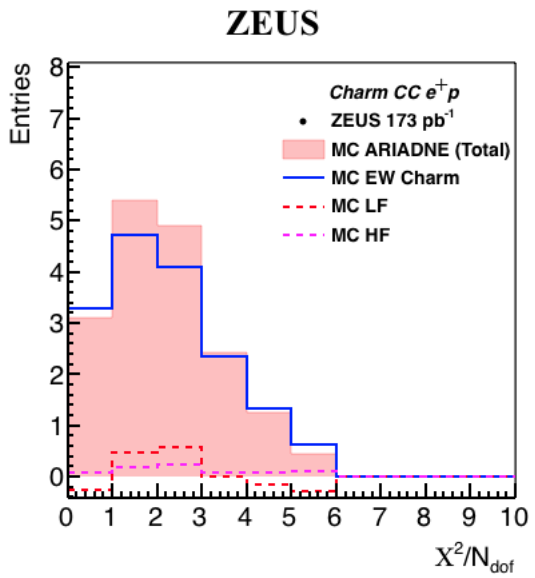




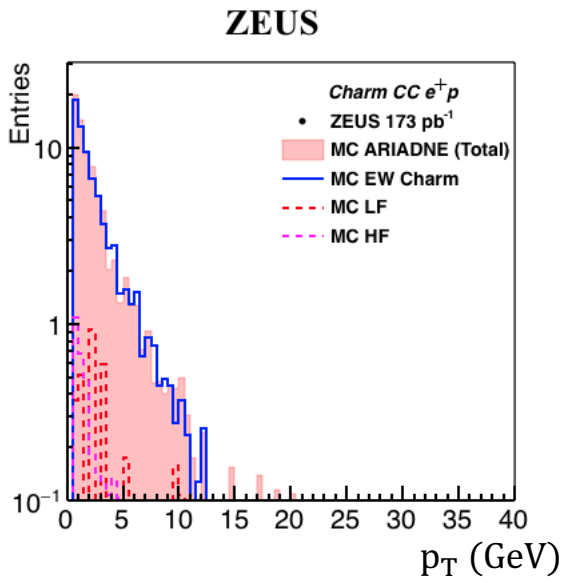


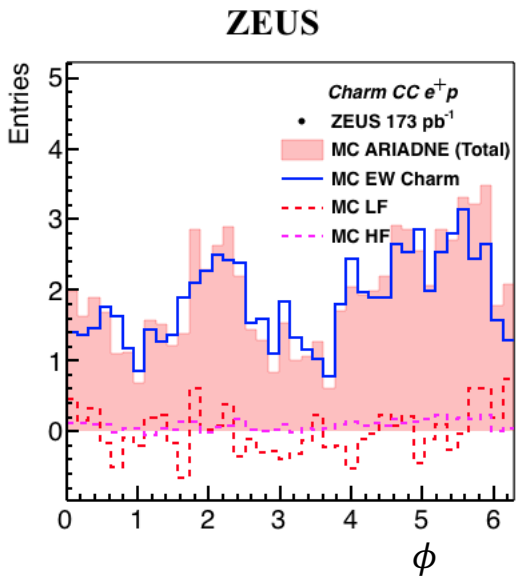


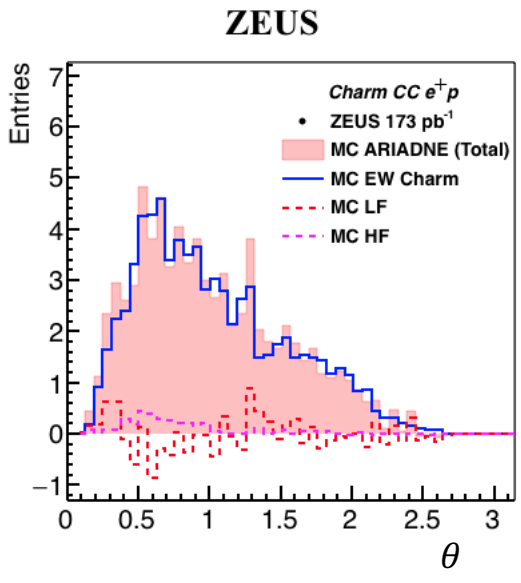


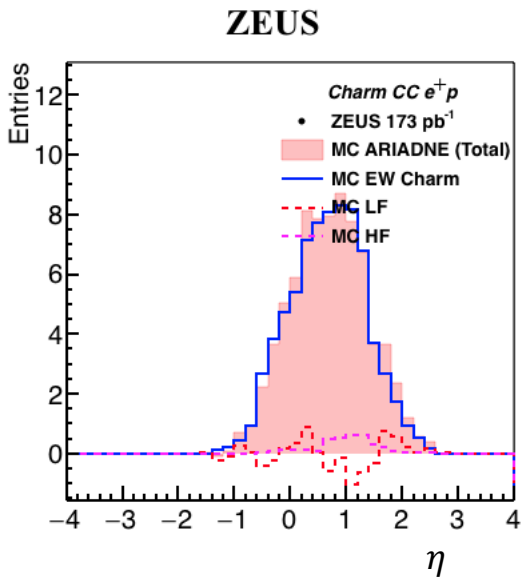


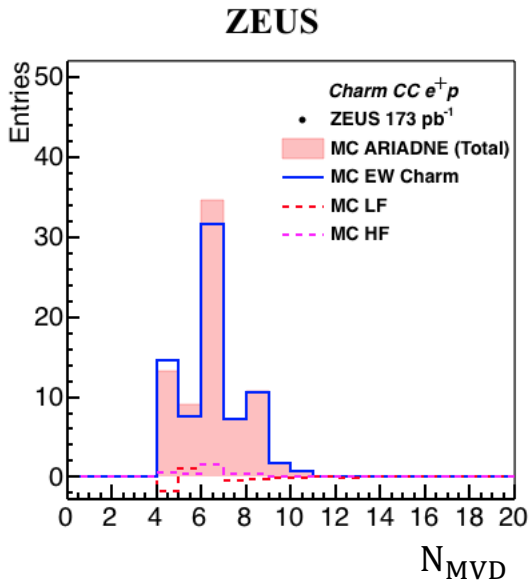
Mirrored Tracks

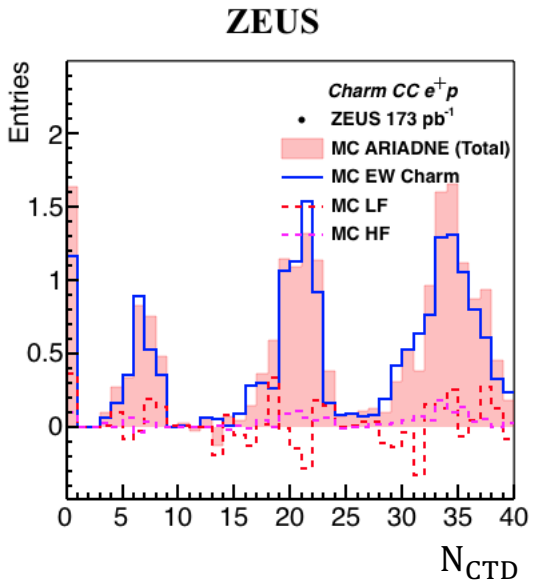


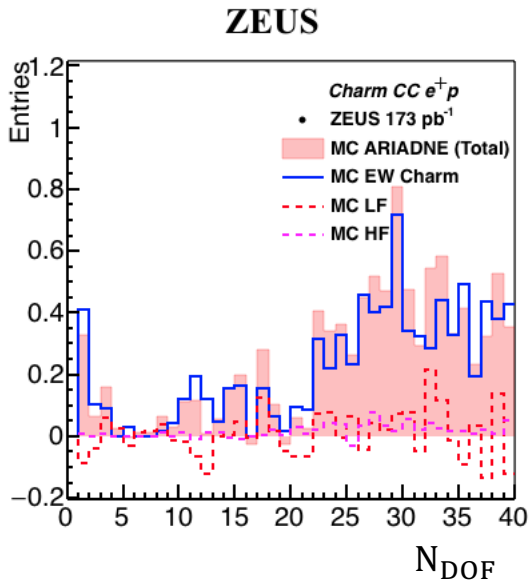


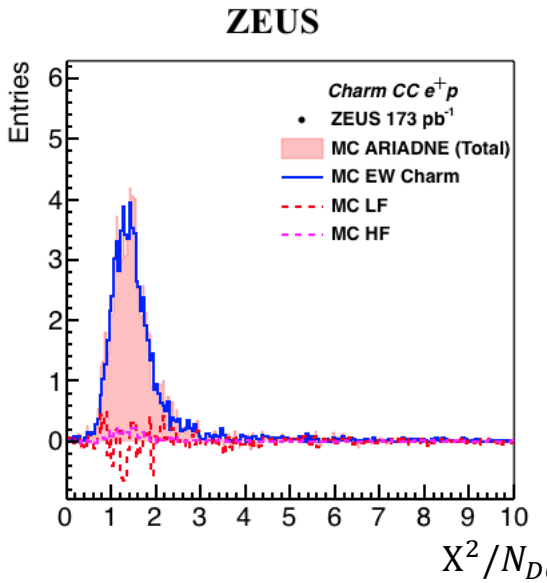






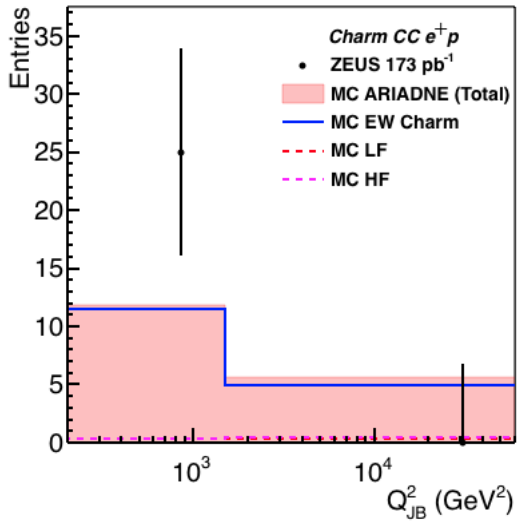




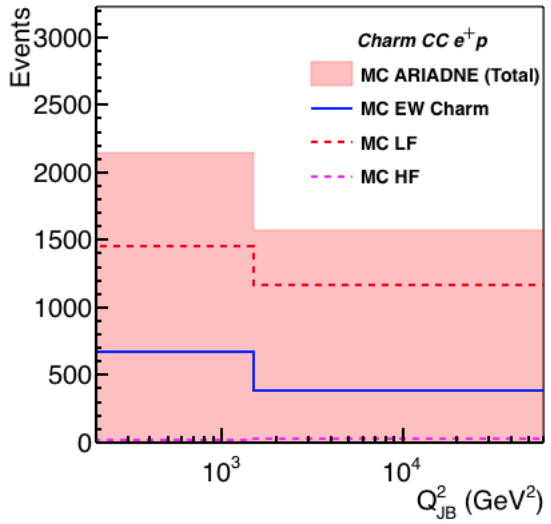


Charm signal and generated charm

N_{signal}



$N_{gen,kin}$



N_{gen}