Charm Production in CC

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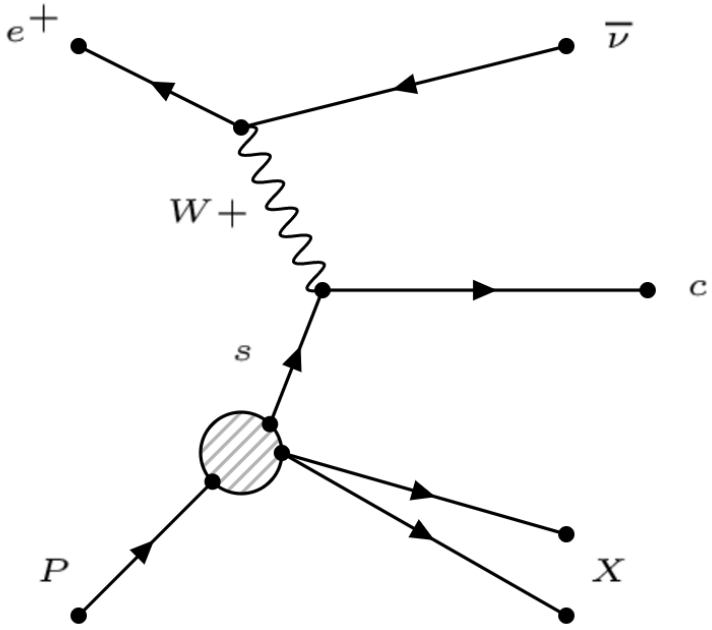
Reminder

- Charm cross section measurement ($d\sigma_{s\to c}^{CC}/dQ^2$) from CC events.

  $\rightarrow$ Constraints on $s(x, Q^2)$
- Data : HERA II, CN v08b, $L = 358.6\, pb^{-1}$
- MC : Inclusive CC DIS, Amadeus 2006a, DJANGOH 1.6, ARIADNE 4.12, CTEQ-5D.
- Jacquet-Blondel Method used to reconstruct kinematic variables



$$y_{JB} = \frac{\sum_h (E - p_z)_h}{2E_{e,beam}}$$

$$Q^2_{JB} = \frac{p^2_{T,h}}{1 - y_{JB}}$$

$$x = \frac{Q^2}{sy}$$

DIS selection

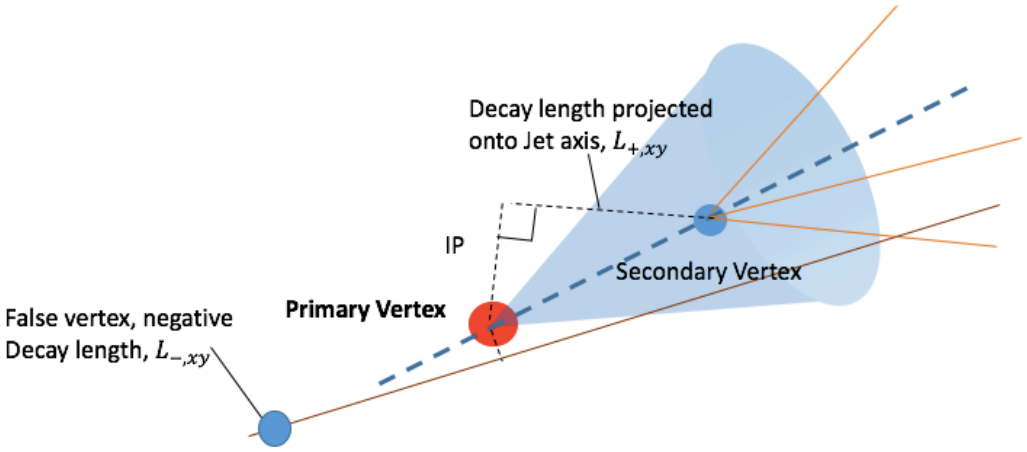
- CC DIS

Katie Oliver and Robert Ciesielski 06/07 e+p CC selection

- FLT 60 || 63 || 39 || 40 || 41 || 43 || 44, SLT EXO 4, TLT EXO 2 || EXO 6, DST 34
- $Q^2 > 200\ GeV^2, y < 0.9$
- STTAKE = 0 for 05e data
- FLT 63 active after run 54115
- Sparks Rejection Not implemented due to empty tree

*complete list in the backup slides

Lifetime-tagging Method & SecVtx Selection



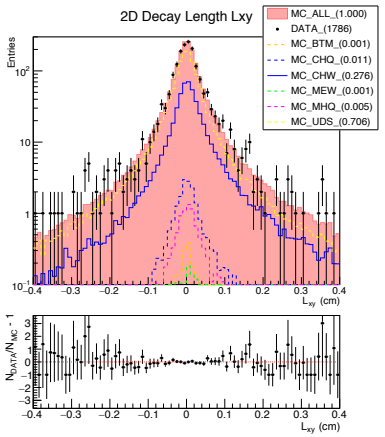
- Short-lived light flavour → Symmetric dec. len.
- Charmed particle → Asymmetric
- LF contribution (BG) suppressed by subtracting negative decay length events from positive

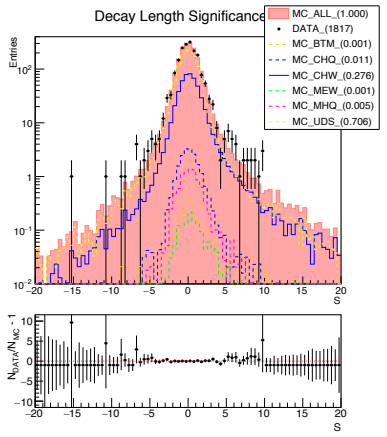
Jet Selection	ORANGE : Kt_jet_a
	At least 1 jet, each with $E_T > 5\ GeV$
	$-2.5 < \eta < 2.5$
Track Selection	ZTT tracks $P_T > 0.5\ GeV$
	$(N_{CTD} \geq 3 \,||\, N_{STT} \geq 1) \&\& N_{MVD} \geq 4$
	Distance to closest jet $R = \sqrt{\Delta\varphi^2 + \Delta\eta^2} < 1$
SecVtx Selection	ORANGE : Vtxsec_type[secvtxID] = 1
	$\chi^2/N_{dof} < 6$
	$\lvert Z_{secvtx} \rvert < 30\ cm$
	Distance to beamspot $\sqrt{\Delta x^2 + \Delta y^2} < 1\ cm$

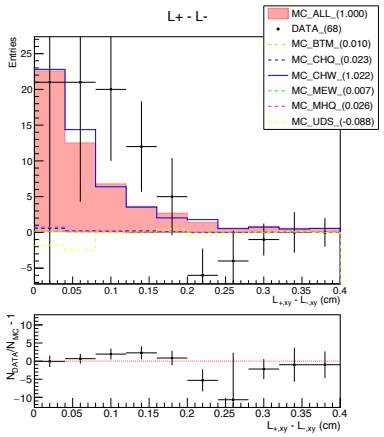
Previous

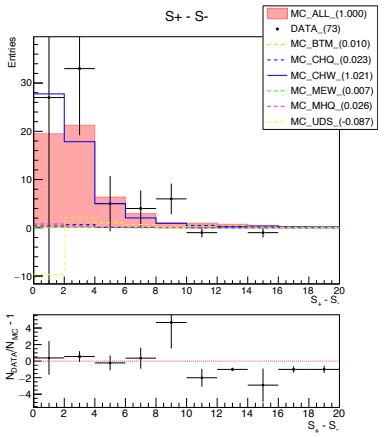
- Good agreement between Data and MC in QA plots
- Charm in CC observed in mirrored decay length plot (significance)

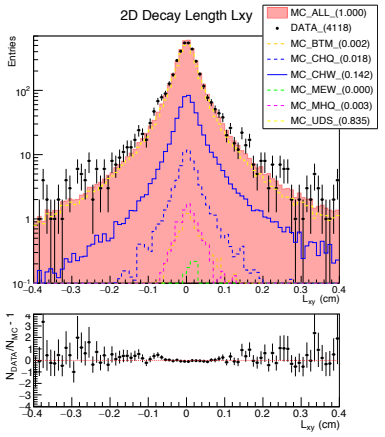
e+ p
(0304 + 0607)

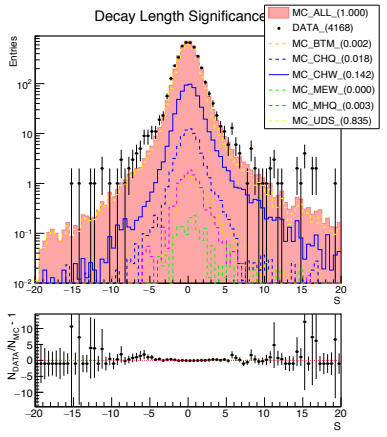


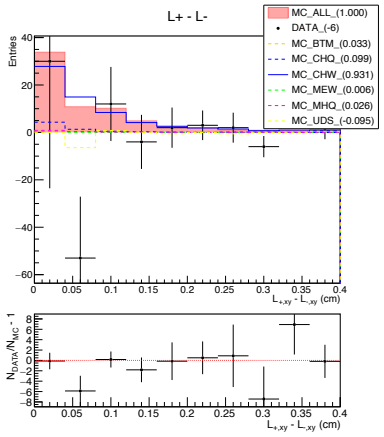


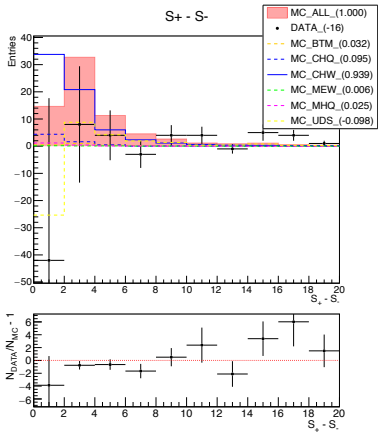






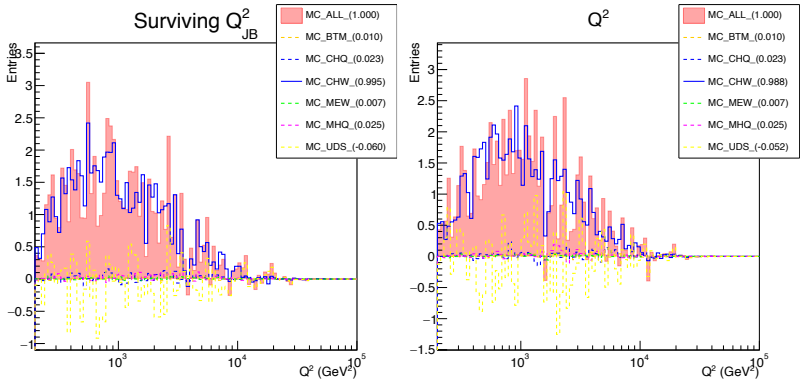




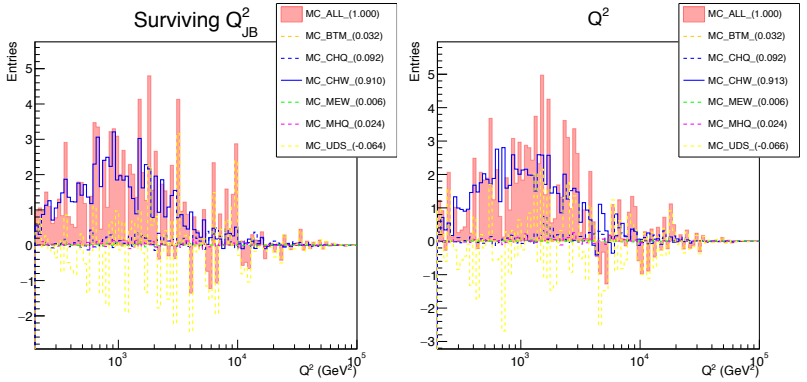


e- p
(05 + 06)

Q2 recon (Left) & particle level (Right)



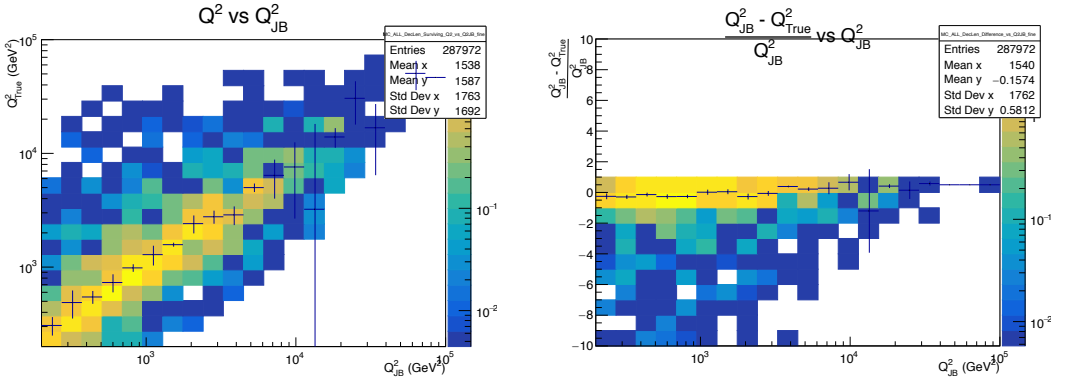
e+ p
(0304 + 0607)



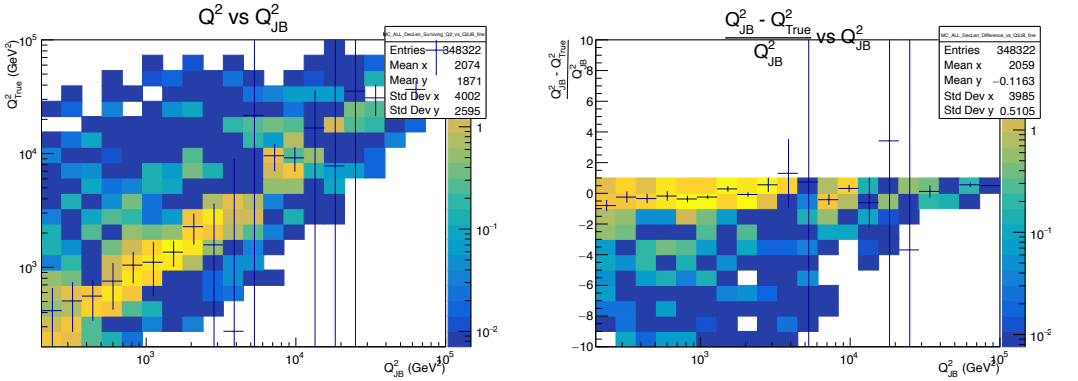
e- p
(05 + 06)

- Separated into two bins having approx. the same charm sensitivity.
- Separation point determined at 1554.9 GeV2
- Corresponding bin-widths
  bin1 : 1354.9 GeV2
  bin2 : 9982 GeV2

True vs Reconstructed Q2



e+ p
(0304 + 0607)



e- p
(05 + 06)

- Good agreement between True and Reconstructed Q2
- Bin-by-bin correction to account for small discrepancy

$$N_i = \sum_j \tilde{C}_{ij} M_j$$

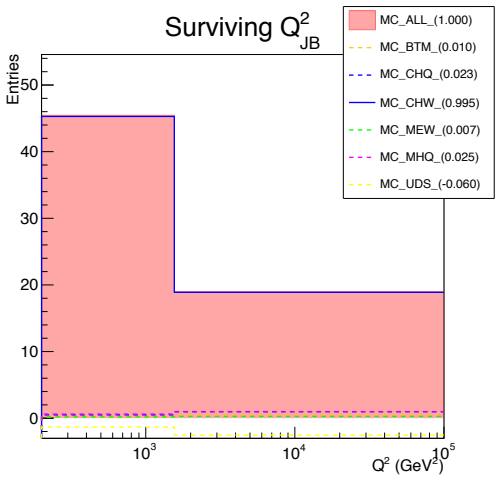
$$N_i = C_i M_i$$

$N_i = "true"\ number\ of\ entries\ in\ bin\ i$
$M_i = measured\ number\ of\ entries$
$C_{ij} = correlation\ matrix$
$\tilde{C}_i = correlation\ constant$

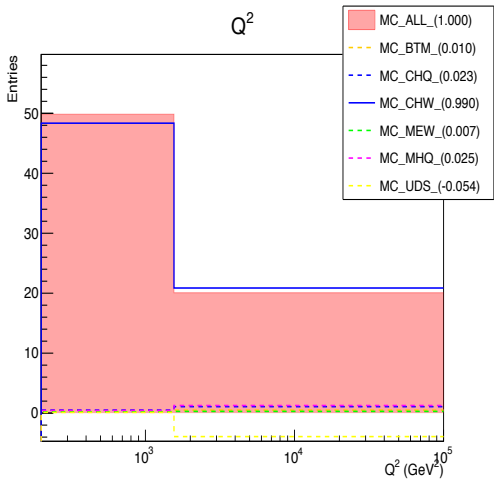
Rebinned

e+ p Collision (0304 + 0607)

Reconstructed

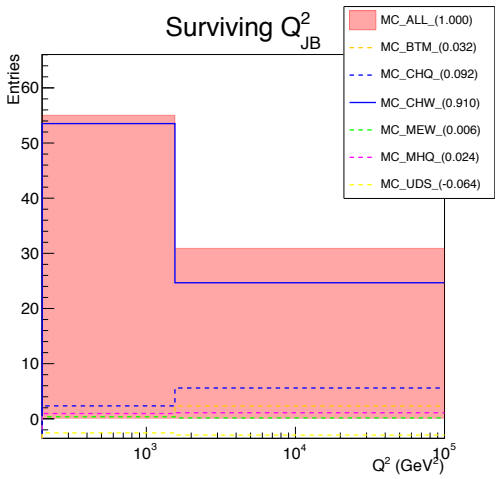


True

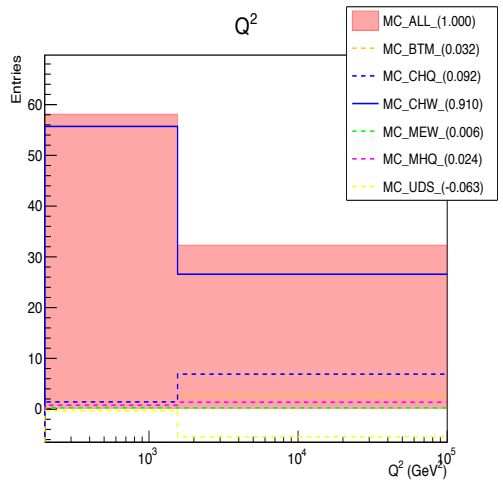


e- p Collision (05 + 06)

Reconstructed



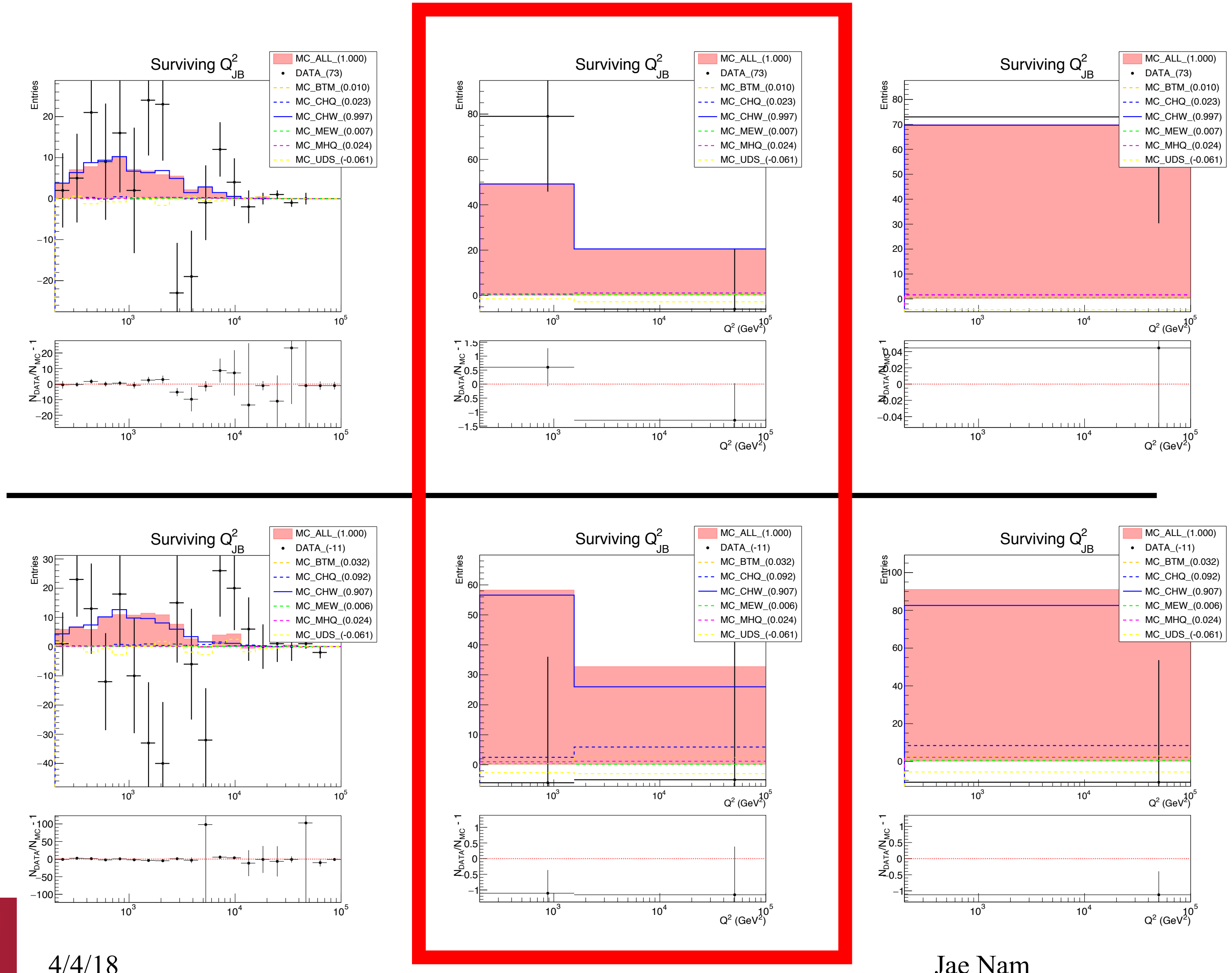
True



$C_i = 1.011\ (i = 1), 0.975\ (i = 2)$

$C_i = 0.997\ (i = 1), 0.986\ (i = 2)$

MC + Data



- Reasonable agreement with MC with large stat. unc.

Cross Section Calculation

$$\left(\frac{d\sigma_{charm}^{CC,data}}{dQ^2}\right)_i = \frac{N_i^{data} - N_i^{bg}}{N_i^{MC}} * \left(\frac{d\sigma_{charm}^{CC,MC}}{dQ^2}\right)_i$$

$$** \left(\frac{d\sigma_{charm}^{CC,MC}}{dQ^2}\right)_i = C_i \frac{1}{A_i\, L} \frac{N_i^{MC}}{\Delta Q_i^2}$$

$$** N_i^{bg} = LF\ background\ estimated\ from\ MC$$

$$** A_i = acceptance = \frac{N_{i,measured}^{MC}}{N_{i,charm\ generated}^{MC}}$$

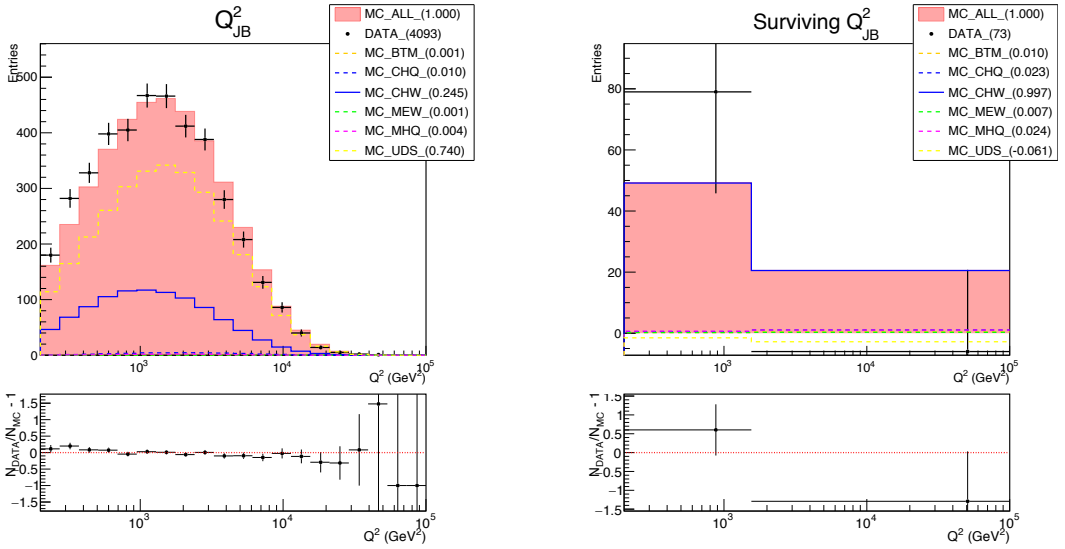
e^+p	DATA		MC	
Bin	1	2	1	2
A_i	0.0437	0.0359	0.0437	0.0359
$d\sigma/dQ^2$ $(10^{-3}pb * GeV^{-2})$	7.77 ± 3.27	-0.096 ± 0.425	4.85 ± 0.364	0.326 ± 0.050
$\sigma\ (pb)$	9.58 ± 6.11		9.79 ± 0.70	
e^-p	DATA		MC	
Bin	1 ($560\ GeV^2$)	2 ($4240\ GeV^2$)	1 ($560\ GeV^2$)	2 ($4240\ GeV^2$)
A_i	0.0517	0.0594	0.0517	0.0594
$d\sigma/dQ^2$ $(10^{-3}pb * GeV^{-2})$	-0.591 ± 3.22	-0.106 ± 0.445	4.34 ± 0.488	0.235 ± 0.067
$\sigma\ (pb)$	-1.85 ± 6.19		8.20 ± 0.938	

Systematic Uncertainties

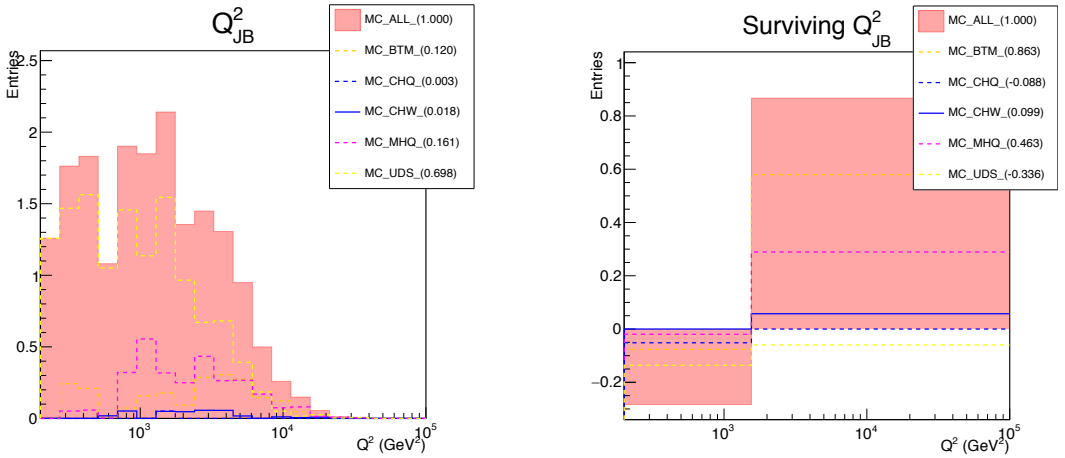
Source	Note	$\delta_{relative}$
Tracking Efficiency	The MC has a higher tracking efficiency than data and this should be accounted for. It is done by randomly rejecting MC tracks (~1%, Libov).	
LF Background	Asymmetry in decay length due to long-lived LF hadrons. (~2%, Libov)	
Non CC Background	The remaining NC and PhP events may contaminate the signal. However, their contributions are reported to be negligible. (Tapper)	In progress
DIS selection	Uncertainty in the event selection criteria (both event/jet/secvtx/track selections). This can be analyzed by varying the cut value of each criterion.	Next Step
Luminosity	The uncertainty in the luminosity measurement ~2%.	$\pm 2\%$

Non-CC Background (NCDIS, e+)

CC



NC

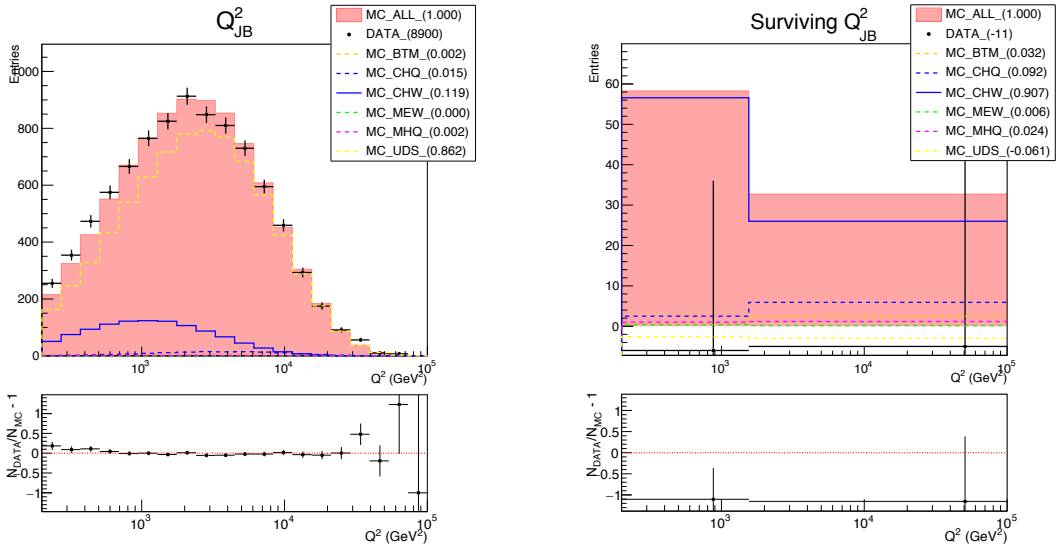


e^+p	N_{CC}^{DATA}	N_{CC}^{MC}	N_{NC}^{MC}
Q^2_{JB}	4093	4092.81	17.87
$Q^2_{JB,mir}$	73 ± 42.6	69.89	0.58
Bin 1	79 ± 33.2	49.31	-0.28
Bin 2	-6 ± 26.8	20.58	0.87

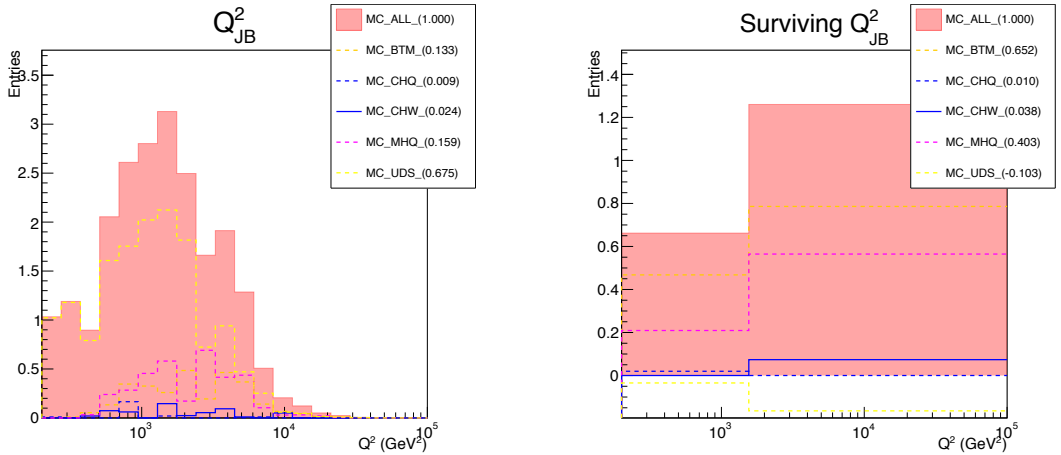
- Inclusive NC DIS, DJANGOH 1.6, ARIADNE 4.12, CTEQ-5D.
- MC scaled to Data luminosity.
- NC contribution negligible in general.
- Bin 2 might need a further quantification.

Non-CC Background (NCDIS, e-)

CC



NC

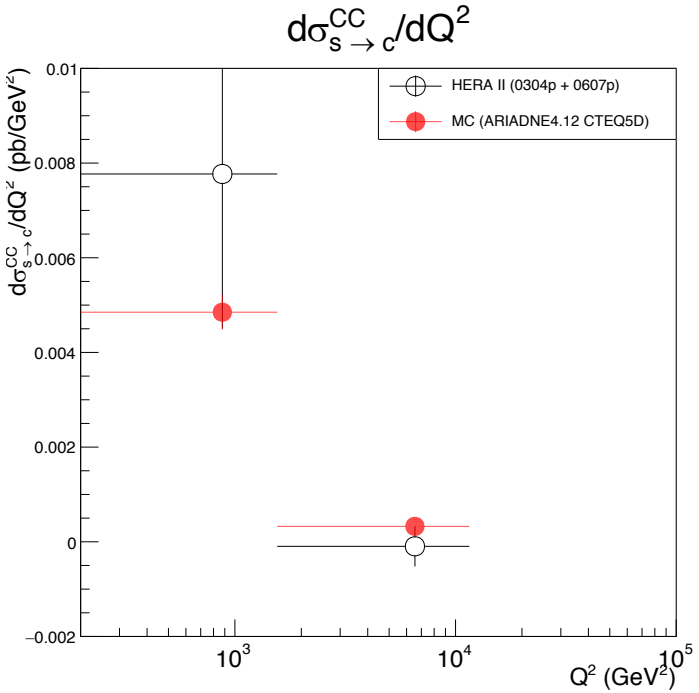


e^-p	N_{CC}^{DATA}	N_{CC}^{MC}	N_{NC}^{MC}
Q^2_{JB}	8900	8900.14	21.99
$Q^2_{JB,mir}$	-11 ± 64.63	91.05	1.92
Bin 1	-6 ± 42	58.29	0.66
Bin 2	-5 ± 49.1	32.76	1.26

- Pretty much the same as e+ case. NC contribution negligible in general with a potential exception of Bin 2.

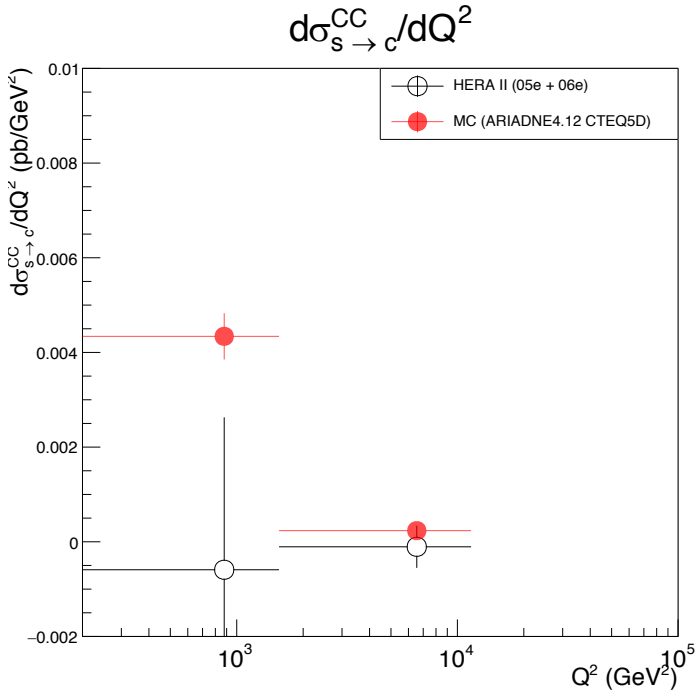
- PhP MC samples need to be normalized.
  HERWIG, resolved & direct (05e+06e, 0607p)

Results (so far)



$e^+p\ (0304p + 0607p)$

$\sigma_{tot}^{DATA} = 9.58 \pm 6.11(stat)\ pb$
$\sigma_{tot}^{MC} = 9.79 \pm 0.7(stat)\ pb$



$e^-p\ (05e + 06e)$

$\sigma_{tot}^{DATA} = -1.85 \pm 6.19(stat)\ pb$
$\sigma_{tot}^{MC} = 8.20 \pm 0.938(stat)pb$

- Missing : Systematic Uncertainty, Theory curve
- Possibly put a constraint on Strange content by varying the theory curve input? (does the theory curve takes strange content as input?)

Summary & Future Plan

Summary

- Charm cross section in CC has been quantified for both e+ and e-.
  - Large stat. unc. observed as expected.
- Evaluation of syst. unc. has been initiated.
  - Negligible contribution from NC contamination (except in bin 2).
  - PhP MC sample needs to be normalized.

Future Plan

- Detector efficiency & visible cross section will be measured.
- Syst. unc. from DIS selection will be quantified.
- Constraint on Strange content

Thank you!

Backup Slides

Event Selection Summary

Katie Oliver and Robert Ciesielski 06/07 e+p CC selection

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
Pt	Pt > 12 GeV P't > 10 GeV
Kinematic	Q2 > 200 GeV2 y < 0.9
Tracking Based Selection	
Vertex	|Zvtx| < 30 cm
ϕcal - ϕtrk	dϕ < 90 degree
Beam Gas Trk	Ntrkvtx > 0.125 * (Ntrk - 20)

Calorimeter Based Selection	
Timing	Consistent with ep interaction
PhP, Beam Gas	VapVp < 0.25 if (Pt < 20 GeV) VapVp < 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)
Sparks	ET_MaxEtCell / ET < 0.5 and PT_-MaxEtCell / PT > 0.4

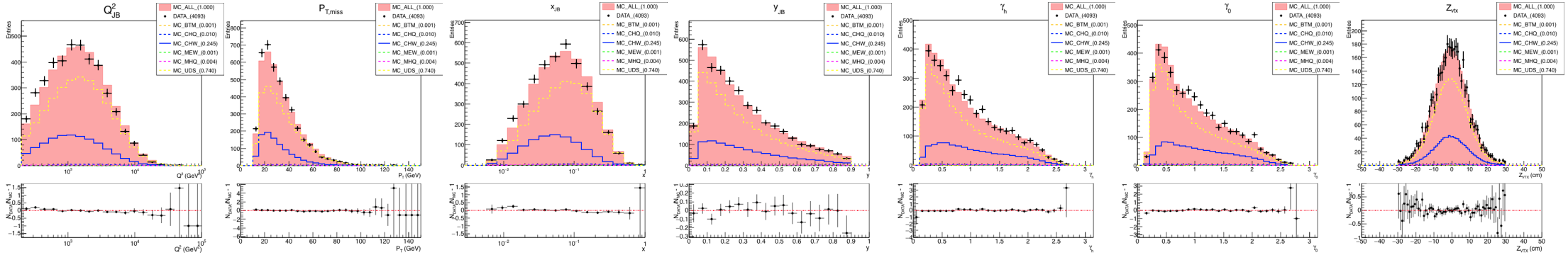
yellow – Varies between run periods.
-STTTAKE = 0 for 05e data
-FLT 63 active after run 54115

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

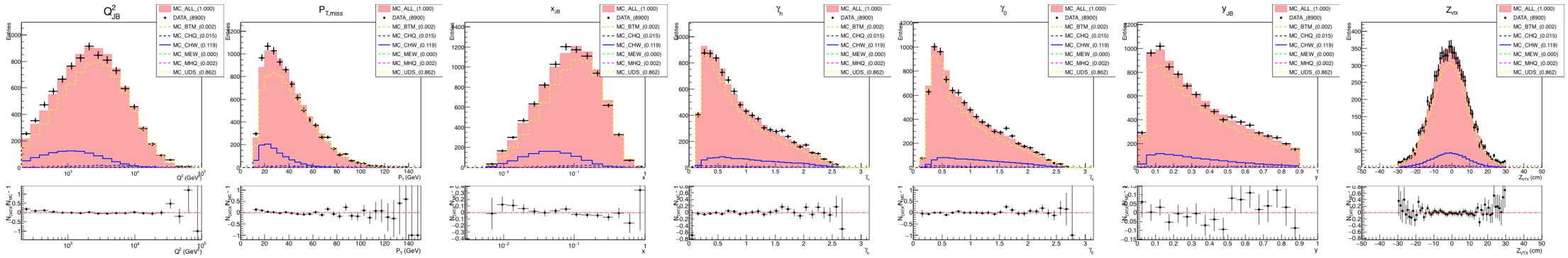
red – Not implemented
-Associated variables empty

QA Plots (CC DIS)

e+

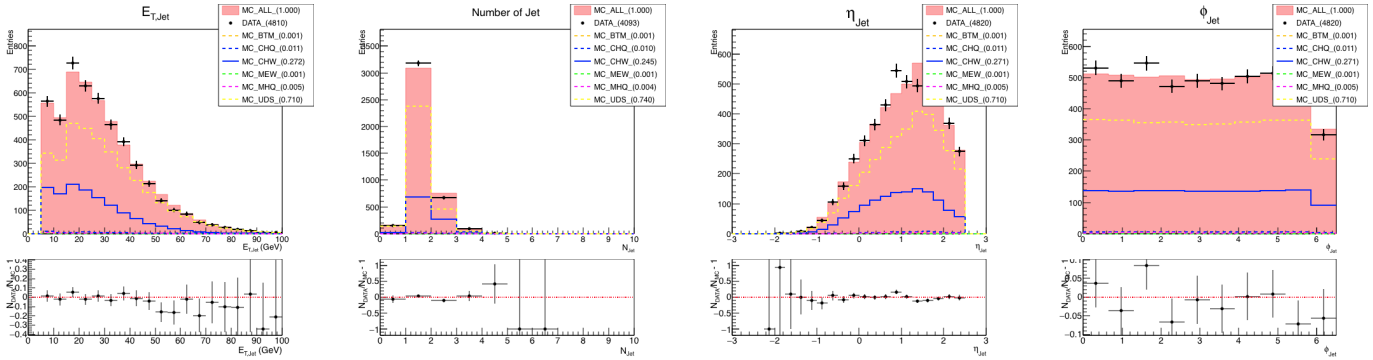


e-

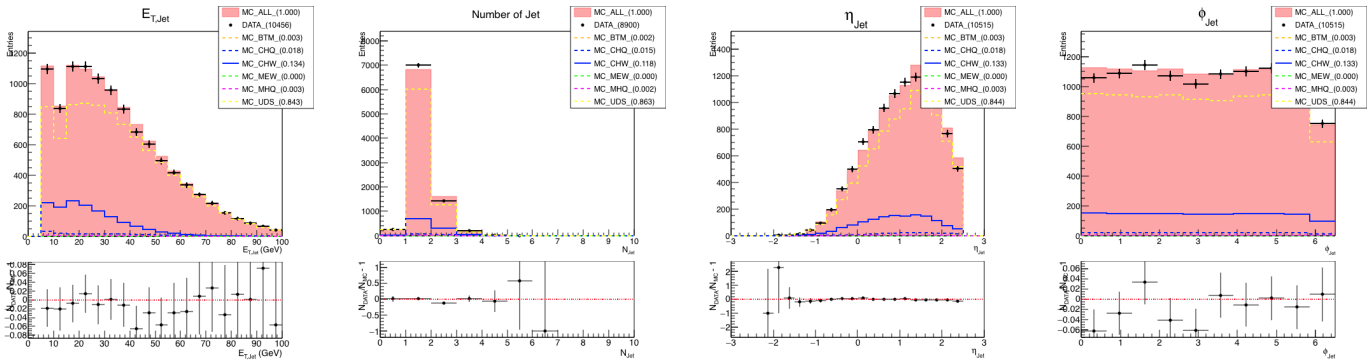


Jet

e+

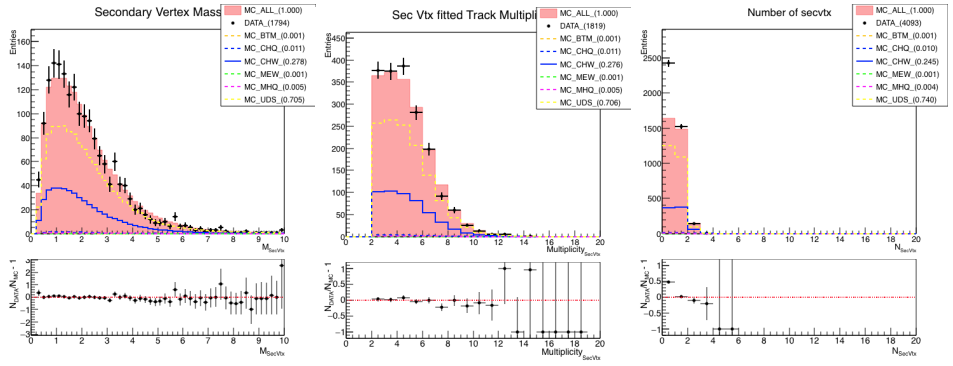

E_T,Jet
MC_ALL_(1.000)
DATA_(4810)
MC_BTM_(0.001)
MC_CHQ_(0.011)
MC_CHW_(0.272)
MC_MEW_(0.001)
MC_MHQ_(0.005)
MC_UDS_(0.710)
Number of Jet
DATA_(4093)
MC_BTM_(0.001)
MC_CHQ_(0.010)
MC_CHW_(0.245)
MC_MEW_(0.001)
MC_MHQ_(0.004)
MC_UDS_(0.740)
η_Jet
DATA_(4820)
MC_BTM_(0.001)
MC_CHQ_(0.011)
MC_CHW_(0.271)
MC_MEW_(0.001)
MC_MHQ_(0.005)
MC_UDS_(0.710)
φ_Jet
DATA_(4820)
MC_BTM_(0.001)
MC_CHQ_(0.011)
MC_CHW_(0.271)
MC_MEW_(0.001)
MC_MHQ_(0.005)
MC_UDS_(0.710)

e-

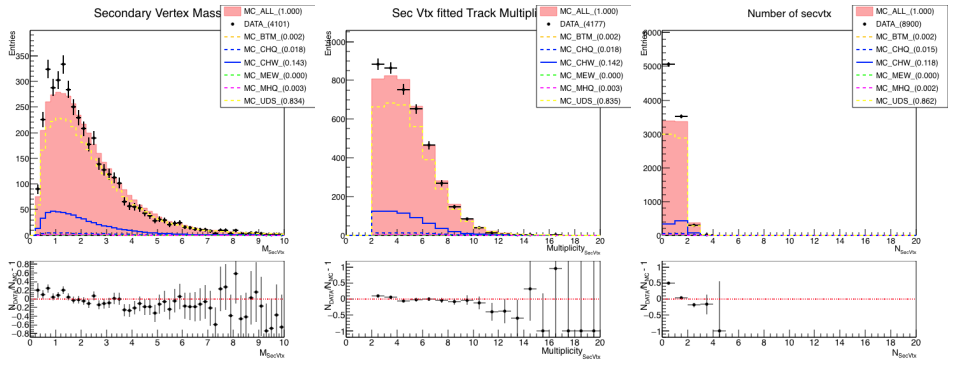

E_T,Jet
MC_ALL_(1.000)
DATA_(10456)
MC_BTM_(0.003)
MC_CHQ_(0.018)
MC_CHW_(0.134)
MC_MEW_(0.000)
MC_MHQ_(0.003)
MC_UDS_(0.843)
Number of Jet
DATA_(8900)
MC_BTM_(0.002)
MC_CHQ_(0.015)
MC_CHW_(0.118)
MC_MEW_(0.000)
MC_MHQ_(0.002)
MC_UDS_(0.863)
η_Jet
DATA_(10515)
MC_BTM_(0.003)
MC_CHQ_(0.018)
MC_CHW_(0.133)
MC_MEW_(0.000)
MC_MHQ_(0.003)
MC_UDS_(0.844)
φ_Jet
DATA_(10515)
MC_BTM_(0.003)
MC_CHQ_(0.018)
MC_CHW_(0.133)
MC_MEW_(0.000)
MC_MHQ_(0.003)
MC_UDS_(0.844)

Secondary Vertex

e+



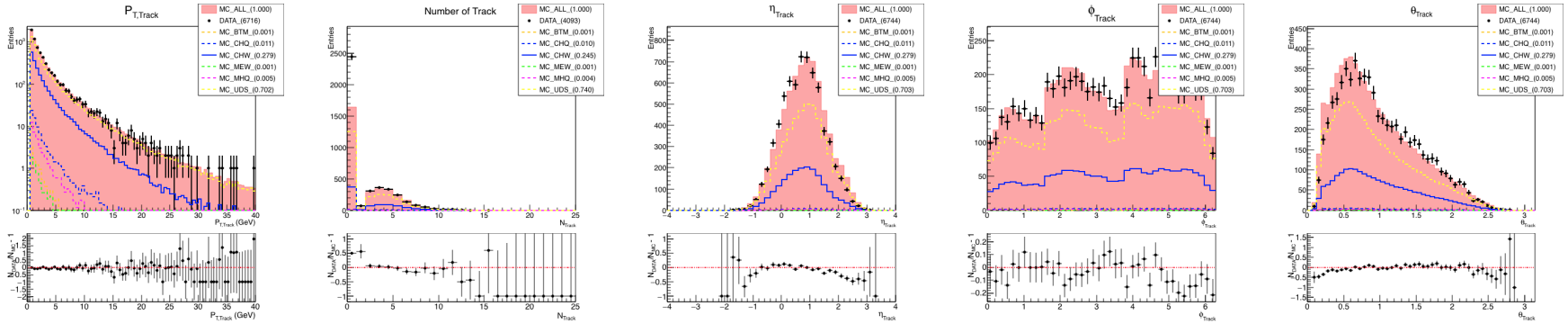
e-



-Secondary Vertex plots rescaled to match the data (due to higher tracking efficiency for MC)

Tracking

e+


P_T,Track
MC_ALL_(1.000)
DATA_(6716)
MC_BTM_(0.001)
MC_CHQ_(0.011)
MC_CHW_(0.279)
MC_MEW_(0.001)
MC_MHQ_(0.005)
MC_UDS_(0.702)
Number of Track
MC_ALL_(1.000)
DATA_(4093)
MC_BTM_(0.001)
MC_CHQ_(0.010)
MC_CHW_(0.245)
MC_MEW_(0.001)
MC_MHQ_(0.004)
MC_UDS_(0.740)
η_Track
MC_ALL_(1.000)
DATA_(6744)
MC_BTM_(0.001)
MC_CHQ_(0.011)
MC_CHW_(0.279)
MC_MEW_(0.001)
MC_MHQ_(0.005)
MC_UDS_(0.703)
φ_Track
MC_ALL_(1.000)
DATA_(6744)
MC_BTM_(0.001)
MC_CHQ_(0.011)
MC_CHW_(0.279)
MC_MEW_(0.001)
MC_MHQ_(0.005)
MC_UDS_(0.703)
θ_Track
MC_ALL_(1.000)
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MC_MHQ_(0.005)
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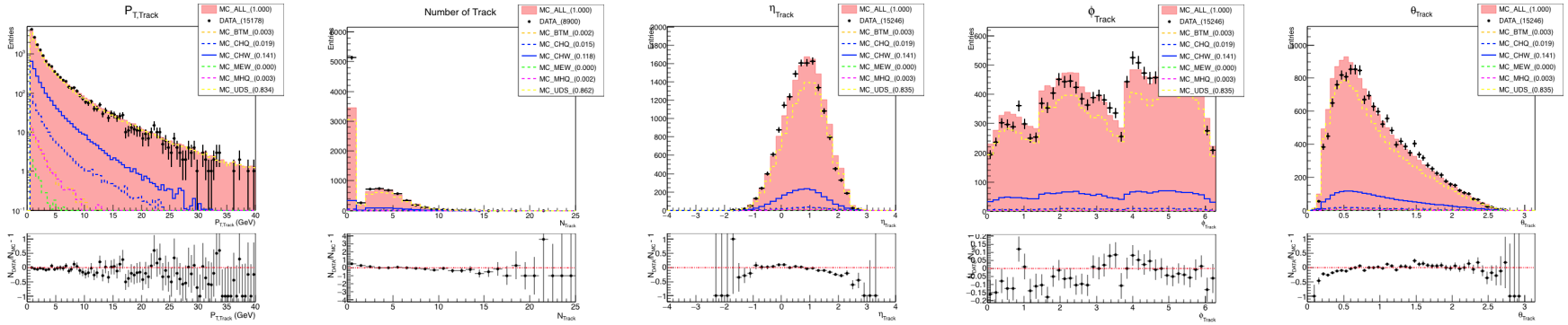
e-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Number of Track
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η_Track
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φ_Track
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MC_MHQ_(0.003)
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θ_Track
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MC_CHQ_(0.019)
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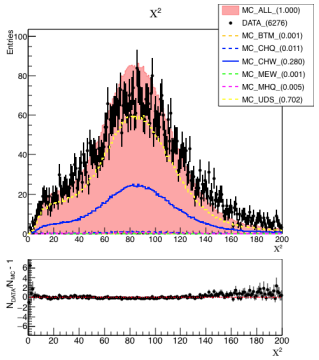
Tracking

e+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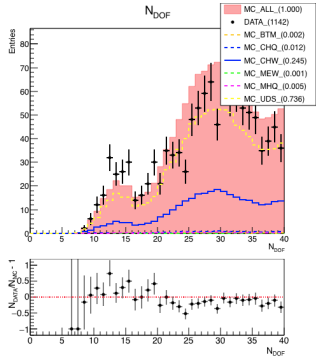
Entries
X²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Entries
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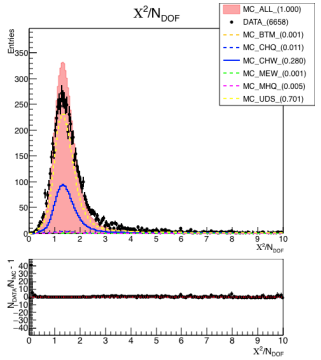
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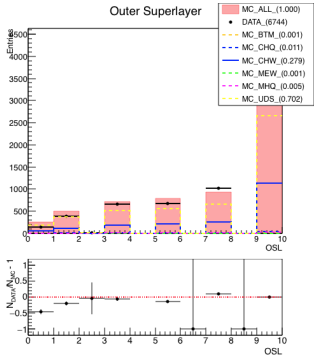
Entries
X²/N_DOF


Outer Superlayer
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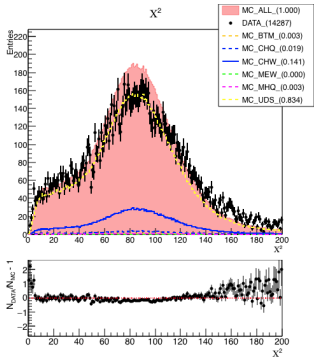
Entries
OSL

e-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MC_MHQ_(0.003)
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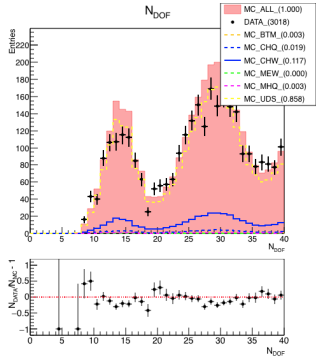
Entries
X²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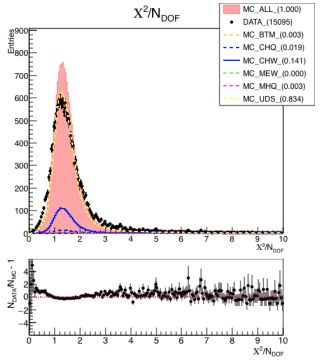
Entries
N_DOF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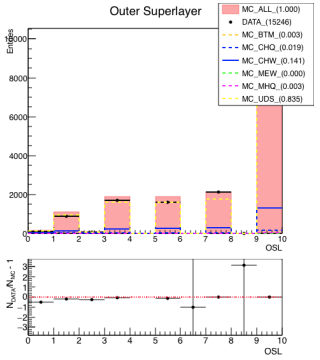
MC_MEW_(0.000)
MC_MHQ_(0.003)
MC_UDS_(0.834)
Entries
X²/N_DOF


Outer Superlayer
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MC_CHQ_(0.019)
MC_CHW_(0.141)
MC_MEW_(0.000)
MC_MHQ_(0.003)
MC_UDS_(0.835)
Entries
OSL