ψ' and J/ψ in photoproduction: **muon corrections revisited**

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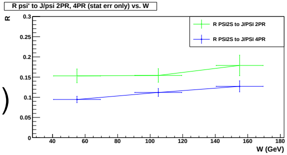
Outlook: R : *psi'* to J/ψ cross section ratio



- ψ' discrepancy in 2-prong ($\mu^+\mu^-$) and 4-prong ($\mu^+\mu^-\pi^+\pi^-$) channels
- can be just fluctuation ($2 \div 2.5\sigma$ in 3 W bins) (?)
- can be due to systematics of muon corrections $\rightarrow$ some effects do not cancel in $\psi'/J/\psi$ ratio

- **this analysis is entirely driven by muons** starting from trigger level
- reliable muon corrections are crucial
- trigger muon corrections were never before developed for HERA II (only off-line corrections for GMUON do exist)

Muon corrections: old approach

- single muon corrections it $(p_t, p_z; \eta)$ bins
  p_t in Barrel, pz in Endcaps
- extracted for DATA and MC
  using elastic di-muon sample (J/ψ, ψ' and Bethe-Heitler)
- TAG and PROBE method
  (second muon as independent tagger)
- separate set of corrections for each trigger level
  and off-line muon reconstruction
- ... and for each muon detector:
  FMUON, BRMUO, BAC and CAL (off-line only)
- ... and for each HERA II data taking period
  (0304p, 05e, 06e, 0607p)
- applied using "hit and miss" method

Old approach: pros and cons

- textbook approach, no simplified assumptions
- can account for cross-triggers

- to complicated scheme
  (taking into account limited statistic of data)
- subject to statistical fluctuations
  (at extraction and application stage)
- hard to control systematics
- additional technical problems in regions
  where standard MC is already overcorrected (like FMUON)
  "hit and miss" cannot create new events...

Muon corrections: new approach

- use weighted muon corrections
- single muon corrections it $(p_t, p_z; \eta)$ bins
  p_t in Barrel, pz in Endcaps
- extracted for DATA and MC
  using elastic di-muon sample (J/ψ, ψ' and Bethe-Heitler)
- TAG and PROBE method
  (second muon as independent tagger)

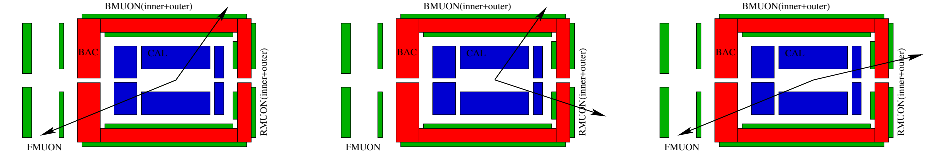
- one set of corrections for all trigger levels and off-line
- ... and for all HERA II data taking periods
- still separate corrections for each muon detector:
  MUON chambers, BAC and CAL (off-line only)
- applied by reweighting the MC events

New approach: pros and cons

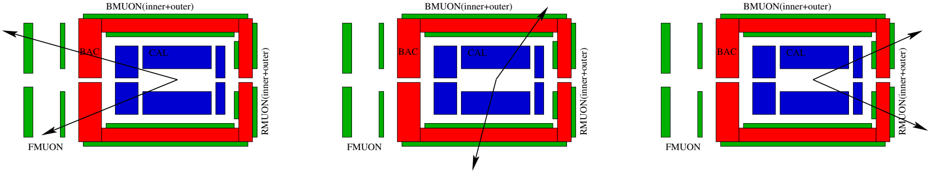
- deterministic approach (no intristic MC gambling)
- simple control of corrections uncertainties
- DATA statistic still limited but much bigger now:
  one set of (averaged) corrections for all HEAR II data taking periods
- straightforward treatment of overcorrected MC samples
  (weight > 1.0)
- in addition:
  - new software framework $\rightarrow$ major work during last months
  - instead of Common Ntuples (CN) a “micro-DST” used
    (extracted from CN, 115 variables)
  - very fast : 15 min. on BIRD (all DATA and MC)
    instead of $\sim$ 36 hours for CN
- for a given muon correct the whole chain: FLT-SLT-TLT-REC

TAG and PROBE: di-muon configurations

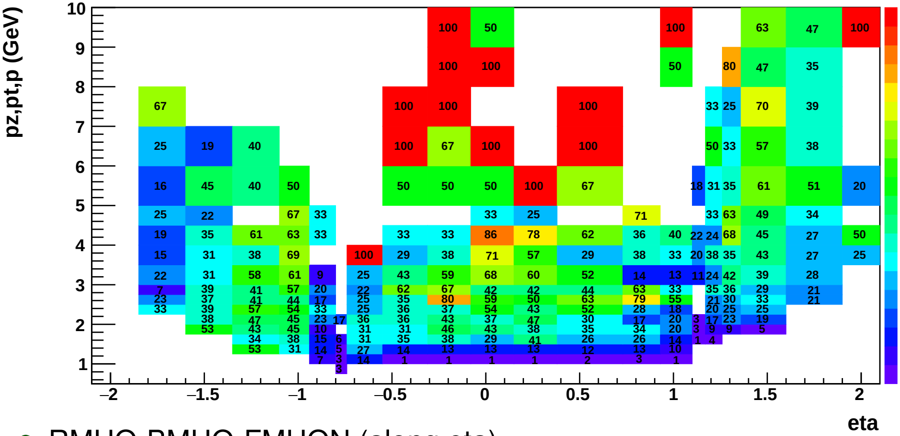
- (almost) non ambiguous: 1F1B, 1B1R, 1F1R (used)



- ambiguous: 2F, 2B, 2R (not used)

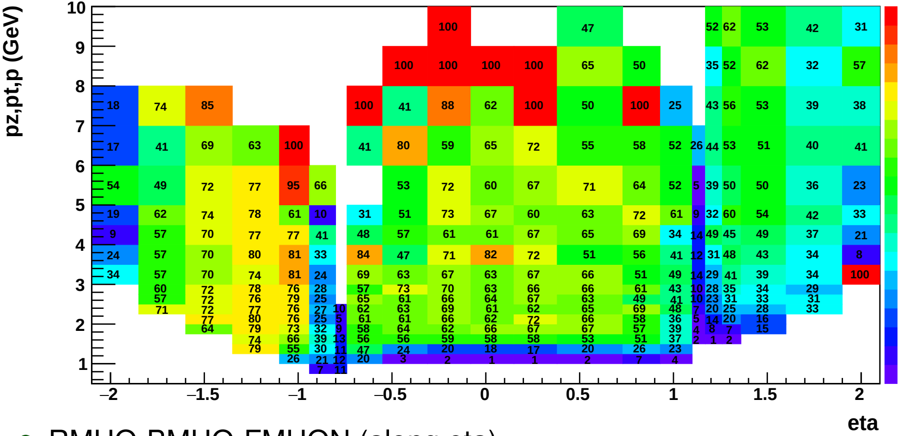


New corrections: example of $(p_z, p_t; \eta)$ maps - DATA



- RMUO-BMUO-FMUON (along eta)
- probability (%) to fire FLT-SLT-TLT-REC by muon on $(p_z, p_t; \eta)$ grid
- current choice for small p_t, p_z: 250 MeV per bin
- size of the grid is subject to systematics

New corrections: example of $(p_z, p_t; \eta)$ maps - MC

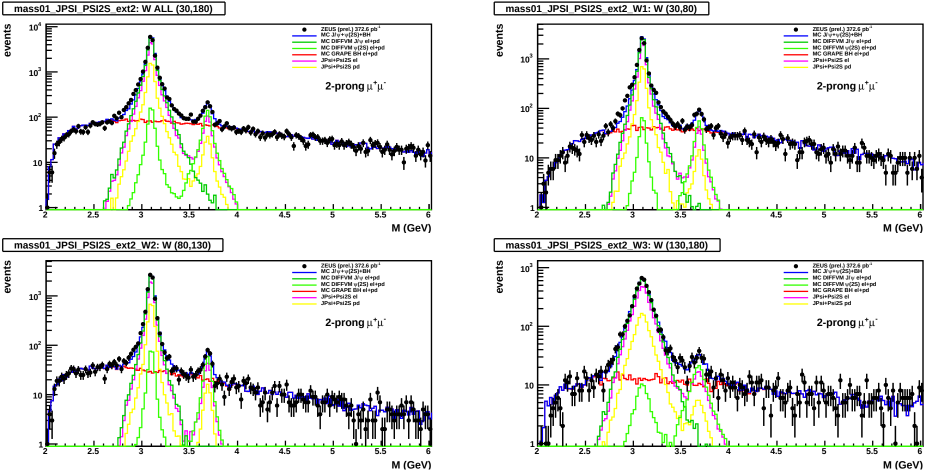


- ~~RMUO-BMUO-FMUON (along eta)~~
- different composition of J/ψ, ψ', Bethe-Heitler MC was tested
- current choice: reweight the MC samples
  keep the J/ψ : ψ' : BH ratio as in DATA

Control plots: no muon corrections

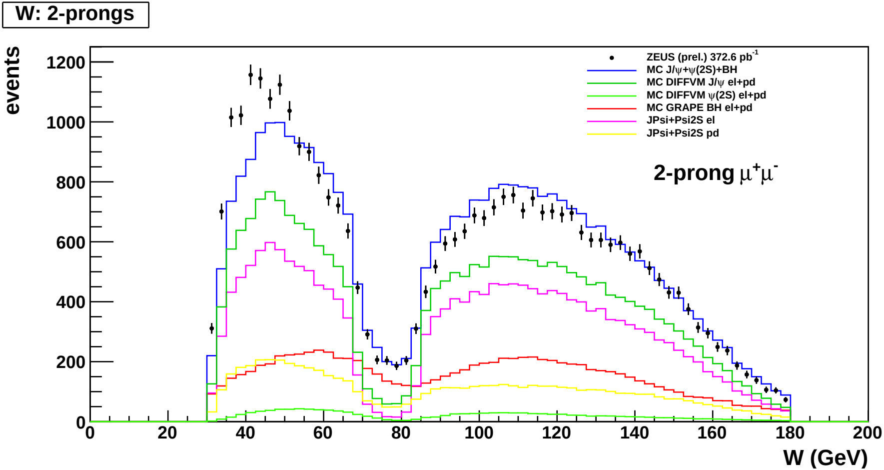
- no muon corrections
- DIFFVM reweighted:
  - W^δ: $\delta = 0.67$ for elastic, $\delta = 0.42$ for p-diss. (both J/ψ and ψ')
  - $\exp(-b|t|)$: $b = 4$ GeV^{-2} elastic J/ψ
  - $\exp(-b|t|)$: $b = 5$ GeV^{-2} elastic ψ'
  - $\exp(-b|t|)$: $b = 1$ GeV^{-2} p-diss. (both J/ψ and ψ')
  - $f_{p-diss} = 0.25$ (both J/ψ and ψ')
  - no reweighting of BH sample
    keep (elastic $\div$ p-diss. $\div$ DIS) xsec ratio as predicted by GRAPE
- all above parameters are subject to systematics
- J/ψ : ψ' : BH ratio from `root` `TFractionalFitter`
  to di-muon mass spectrum
- final (overall) MC normalization to total number of DATA events

Control plots, no corrections: $M(\mu^+, \mu^-)$



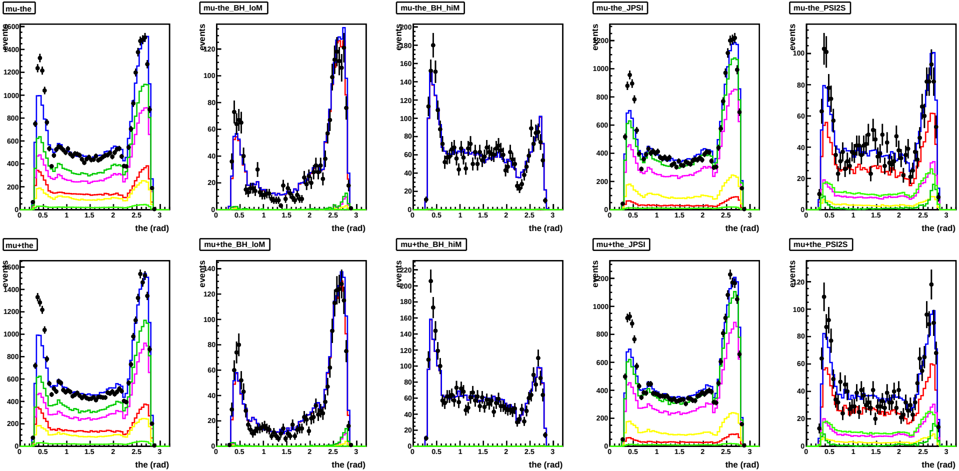
- ALL events and 3 W bins (30-80), (80-130), (130-180) GeV
- $M(\mu^+, \mu^-)$ is insensitive for muon corrections

Control plots, no corrections: W



- excess of events for low W (FMUON)

Control plots, no corrections: $\theta_{\mu^\pm}$ in mass bins



- top: θ_{μ^-}, bottom: θ_{μ^+}
- ALL events, BH-loM, BH-hiM, J/ψ peak, ψ' peak

Control plots: weighted muon corrections

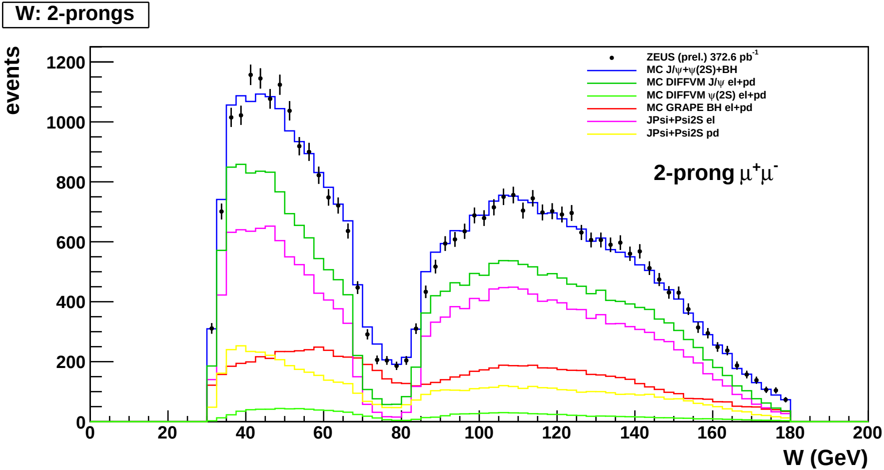
- weight is the DATA/MC ratio of probabilities on $(p_z, p_t; \eta)$ grid
- final weight:
  product of all individual weights for AND'ed independent conditions
  (two muon confirmed by CAL VM finder)
- if OR between two muons required
  (at least one muon in muon chambers):

$$P^{DATA} = P_1^{DATA} + P_2^{DATA} - P_1^{DATA} * P_2^{DATA}$$

$$P^{MC} = P_1^{MC} + P_2^{MC} - P_1^{MC} * P_2^{MC}$$

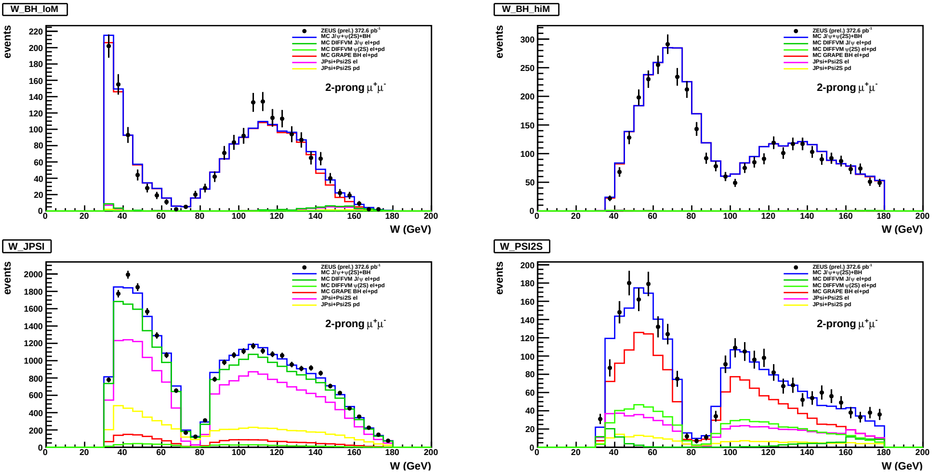
$$w = P^{DATA} / P^{MC}$$

Control plots, after muon corrections: W



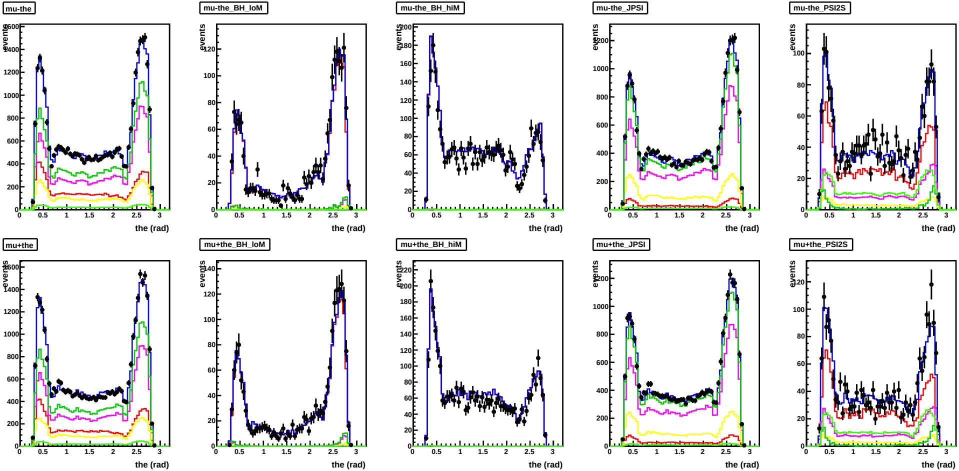
- good agreement

Control plots, after muon corrections: W in mass bins



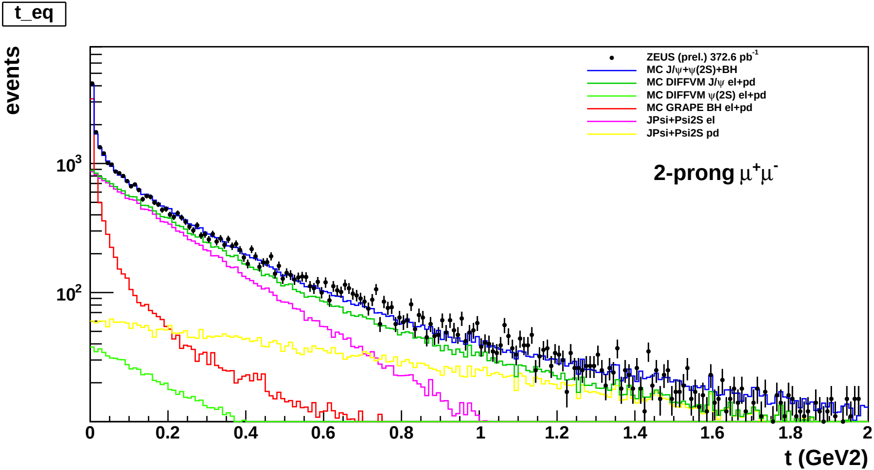
- good agreement
- BH-loM, BH-hiM, J/ψ peak, ψ' peak

Control plots, after muon corrections: $\theta_{\mu^\pm}$ in mass bins



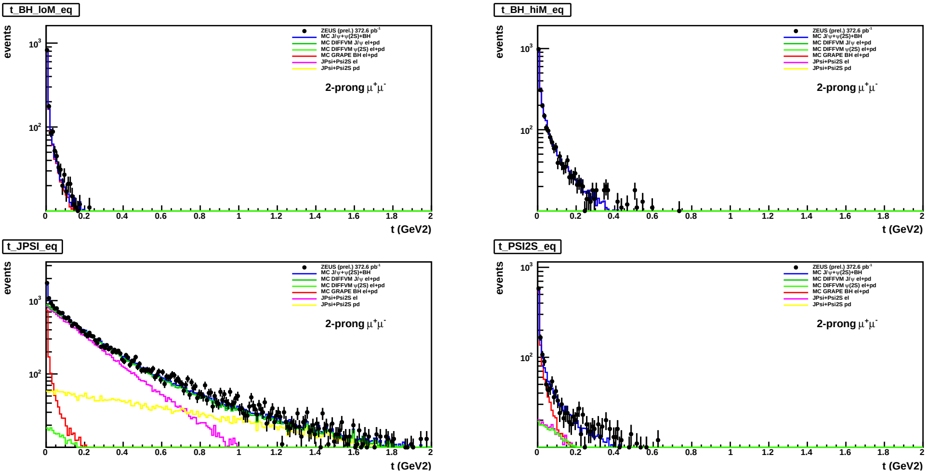
- ALL events, BH-loM, BH-hiM, J/ψ peak, ψ' peak
- good agreement in all mass windows
- (different processes, different $\mu^\pm$ angular/momentum distributions)

Control plots, after muon corrections: $|t|$



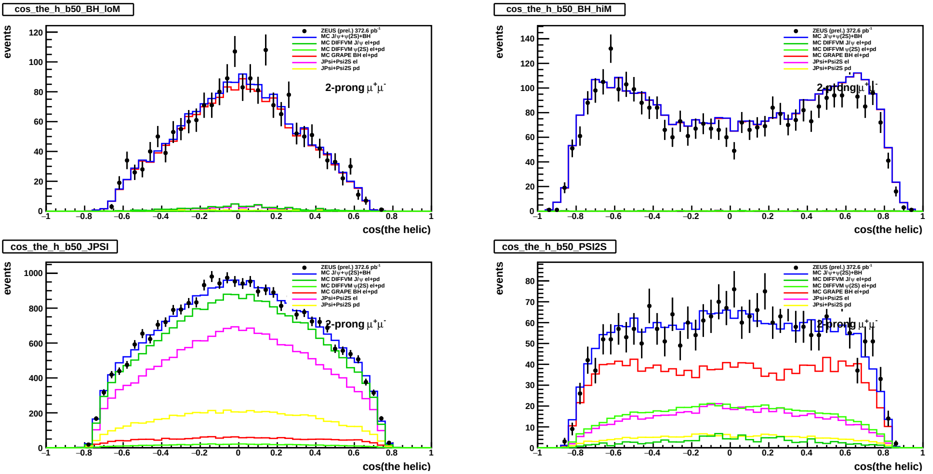
- good agreement
- Magenta: elastic contribution, Yellow: p-dissociation, Red: BH
- assuming $f_{p-diss} = 0.25$ (no fit)

Control plots, after muon corrections: $|t|$ in mass bins



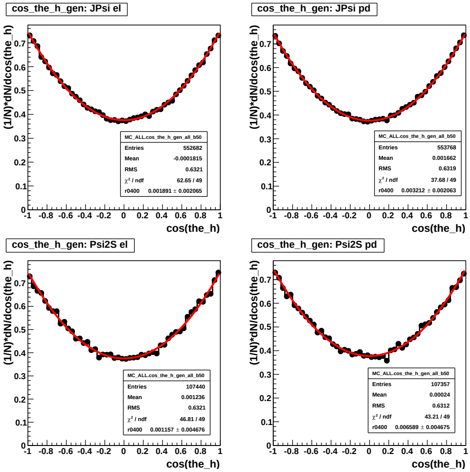
- BH-loM, BH-hiM, J/ψ peak, ψ' peak
- Magenta: elastic contribution, Yellow: p-dissociation, Red: BH
- assuming $f_{p-diss} = 0.25$ (no fit)

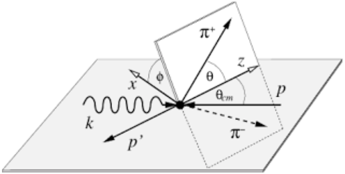
Control plots, after muon corrections: helicity: $\cos(\theta_h)$



- BH-loM, BH-hiM, J/ψ peak, ψ' peak
- Magenta: elastic contribution, Yellow: p-dissociation, Red: BH
- SCHC: s-channel helicity is conserved for VM !

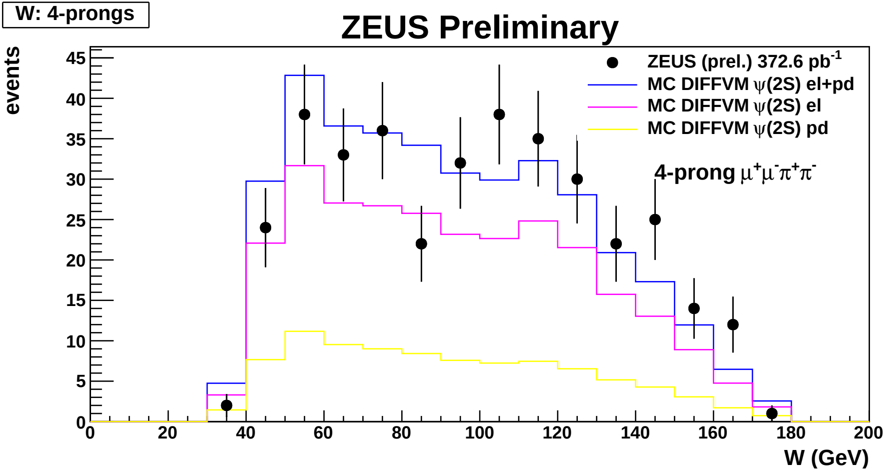
2-prong: helicity on generator level (before cuts)



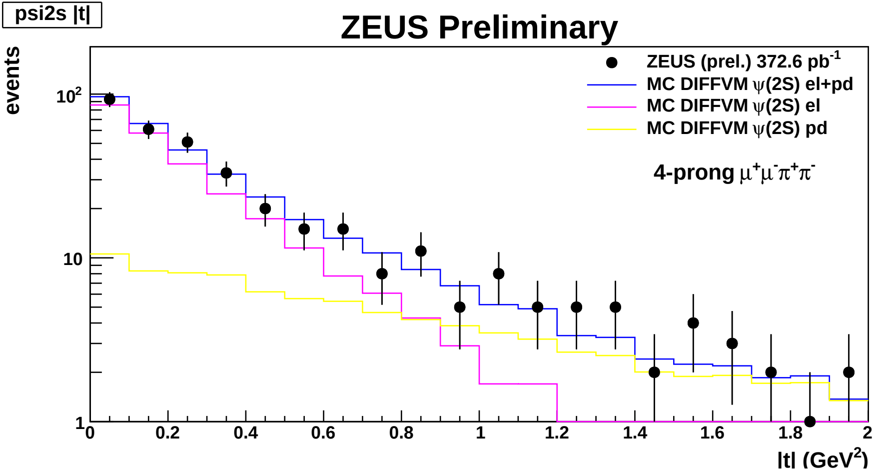


- $\frac{1}{N}\frac{dN}{dcos\theta_h} = \frac{3}{8}(1 + r^{04}_{00} + (1 - 3r^{04}_{00})cos^2\theta_h)$
- for J/ψ and $\psi(2S)$ (el and pd) r^{04}_{00} is 0.0 within errors (as for SCHC)

Control plots, after muon corrections: 4-prong W



- good agreement, no background
- Magenta: elastic contribution, Yellow: p-dissociation
- assuming $f_{p-diss} = 0.25$ (no fit)



- good agreement, no background
- Magenta: elastic contribution, Yellow: p-dissociation
- assuming $f_{p-diss} = 0.25$ (no fit)

Conclusions

- new muon correction scheme (weighted corrections) was developed
- works very well (for full FLT-SLT-TLT-REC chain)
- tested on 2-prong and 4-prongs samples
- no DATA/MC discrepancy found
- ready to calculate selection acceptance and efficiency
- deliver ψ' / J/ψ ratio R
- micro-DST approach very useful for fast systematic evaluation