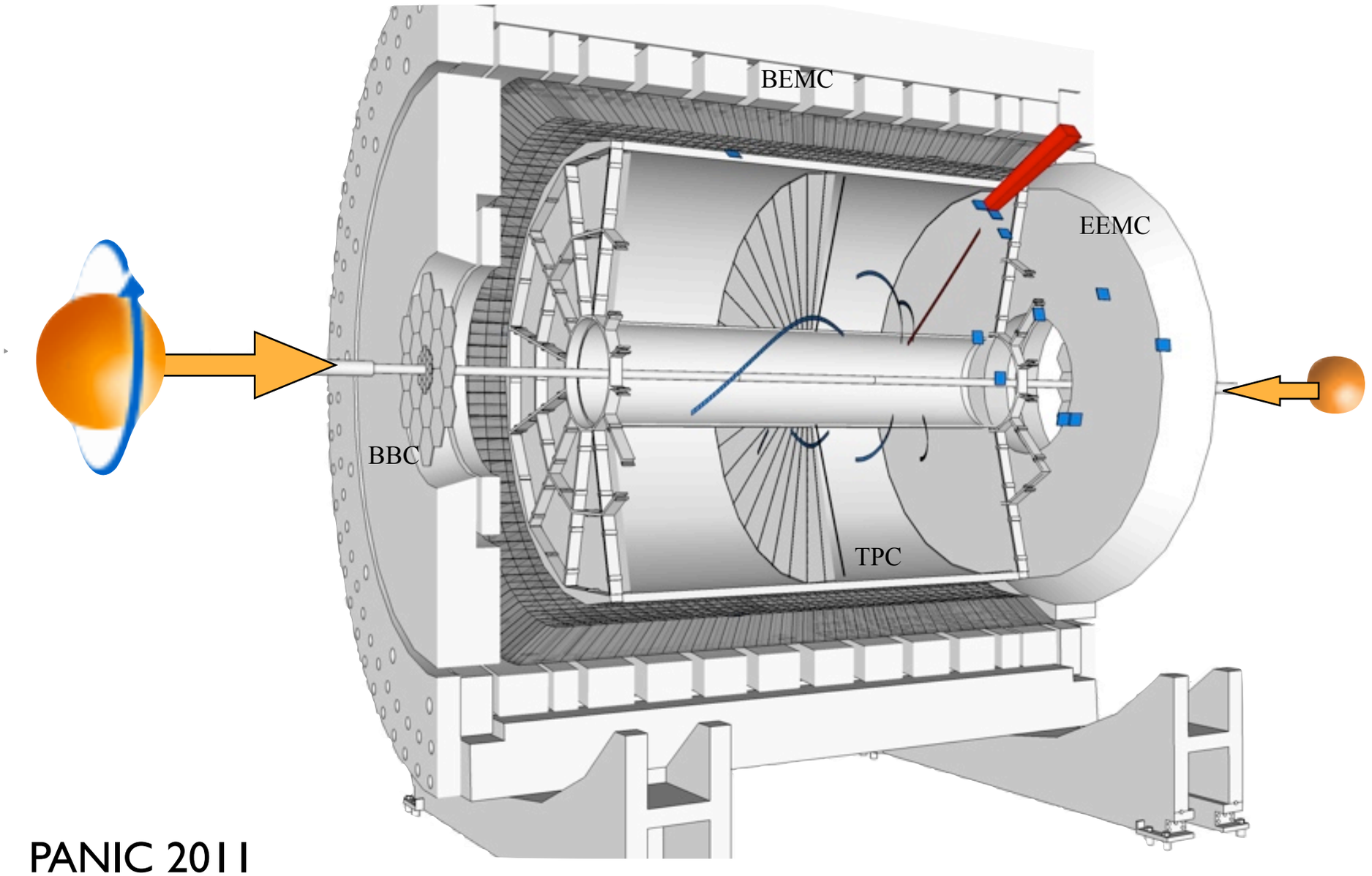
Recent STAR results on W boson production in polarized p+p collisions at √s=500 GeV



PANIC 2011
July 24-29
Cambridge

Jan Balewski
for STAR Collaboration

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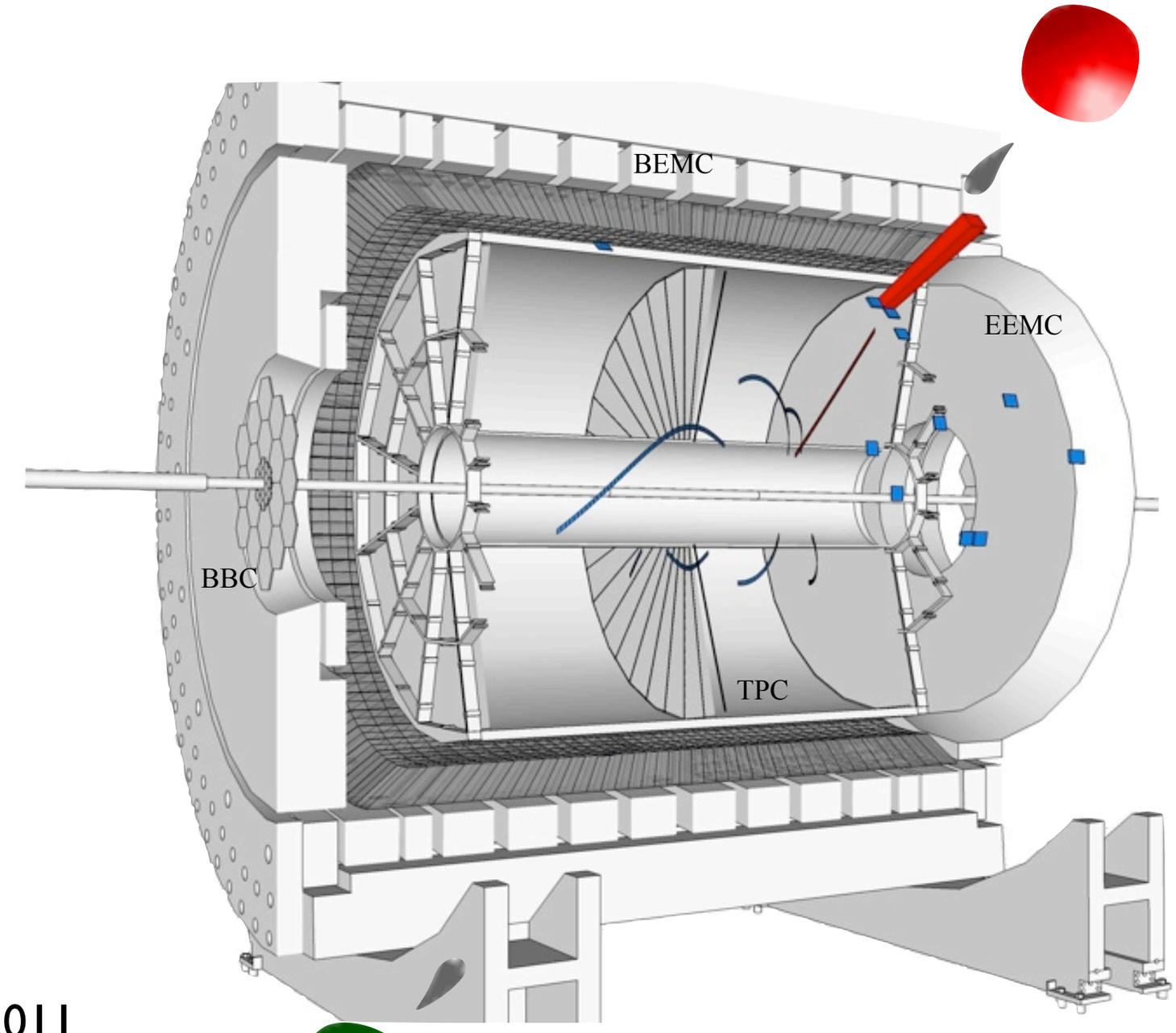

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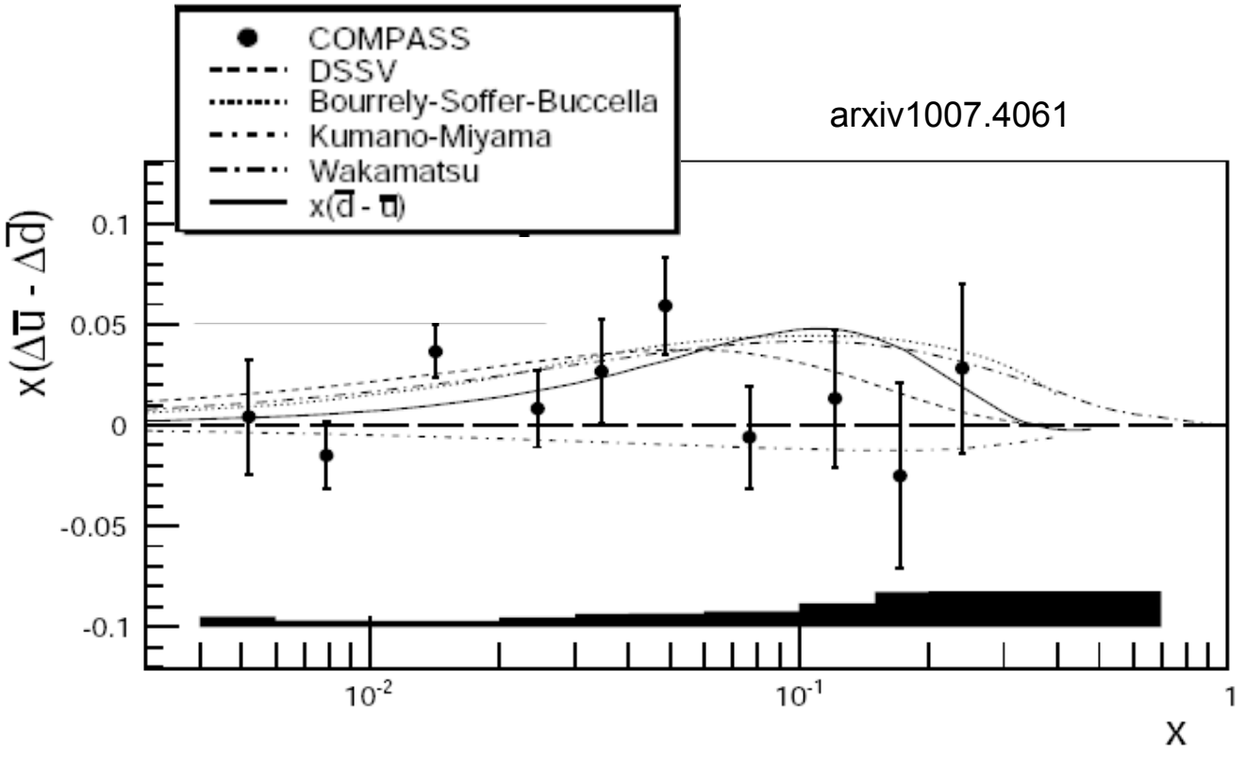
Asymmetry in the sea quarks: STAR W program

$$S_z = \tfrac{1}{2} = \tfrac{1}{2}\Delta\Sigma + \Delta G + L_z^g + L_z^q \qquad (L = L_z^g + L_z^q)$$

$\Delta\Sigma$: u, d, s; $\bar{u}$, $\bar{d}$, $\bar{s}$ — ΔG: J_g

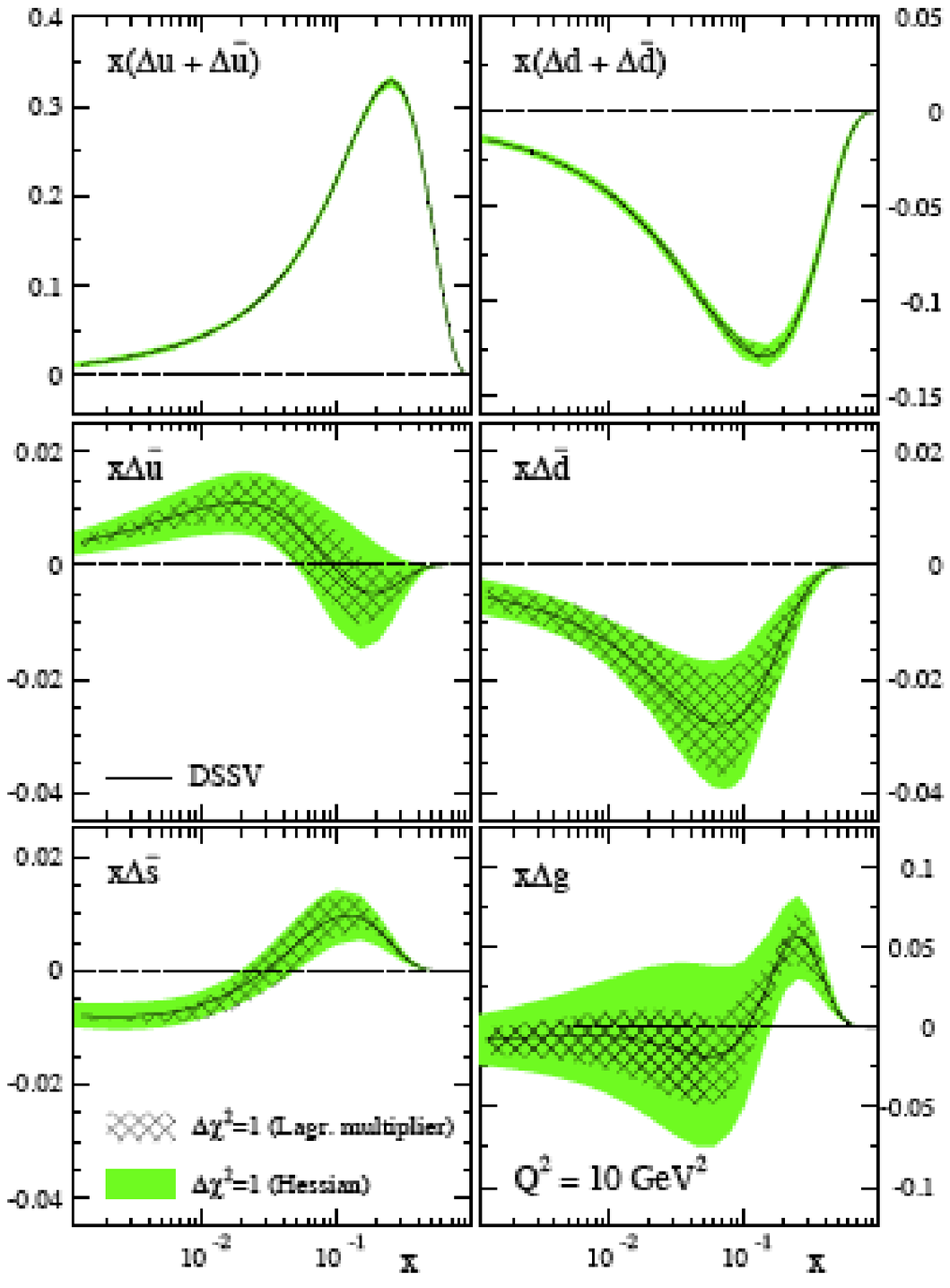
Global analysis predicts positive net helicity difference



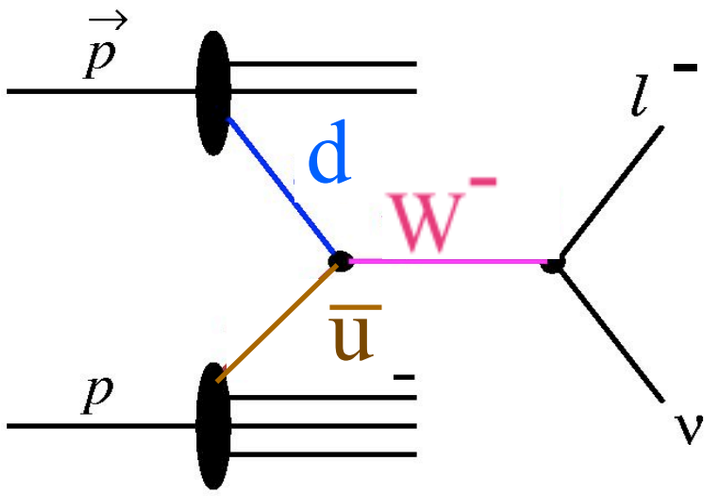
arxiv1007.4061

Recent global fit of polarized u,d anti-quarks distributions to DIS and SI-DIS measuremnt

de Florian: http://arxiv.org/pdf/0904.3821v1



Probing quark flavor structure using W boson



STAR measures $W^{\pm}$ through $e^{\pm}$ decays:

$$u + \bar{d} \rightarrow W^{+} \rightarrow e^{+} + \nu$$

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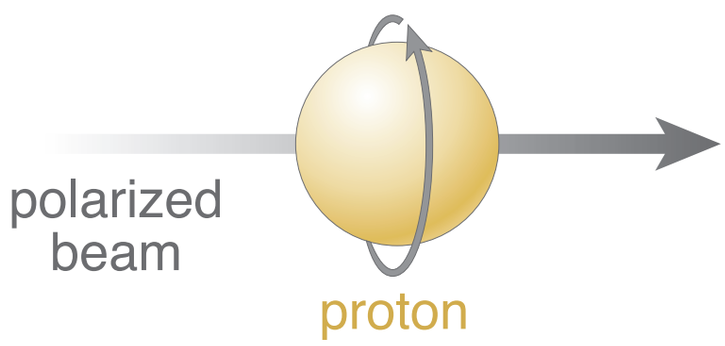
Neutrino helicity gives preferred direction of W decay



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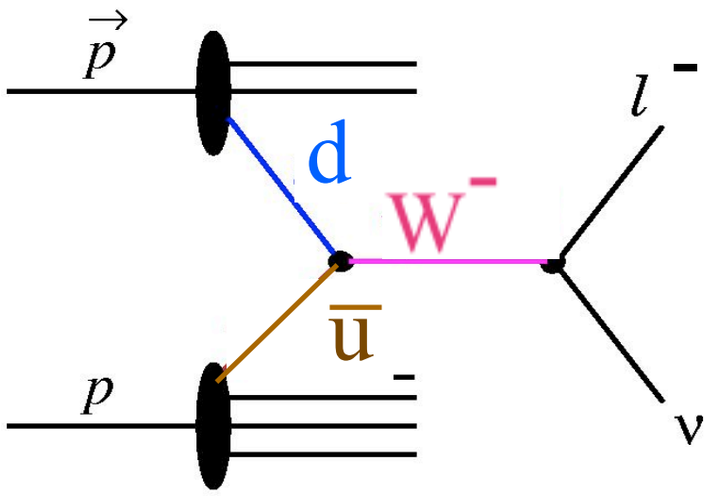

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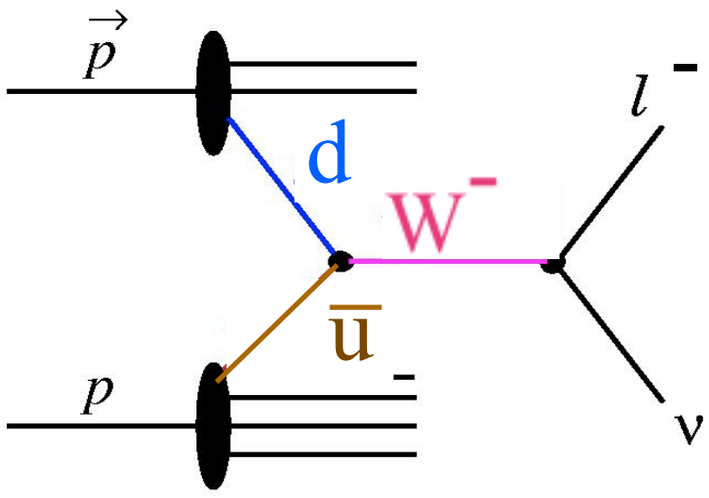

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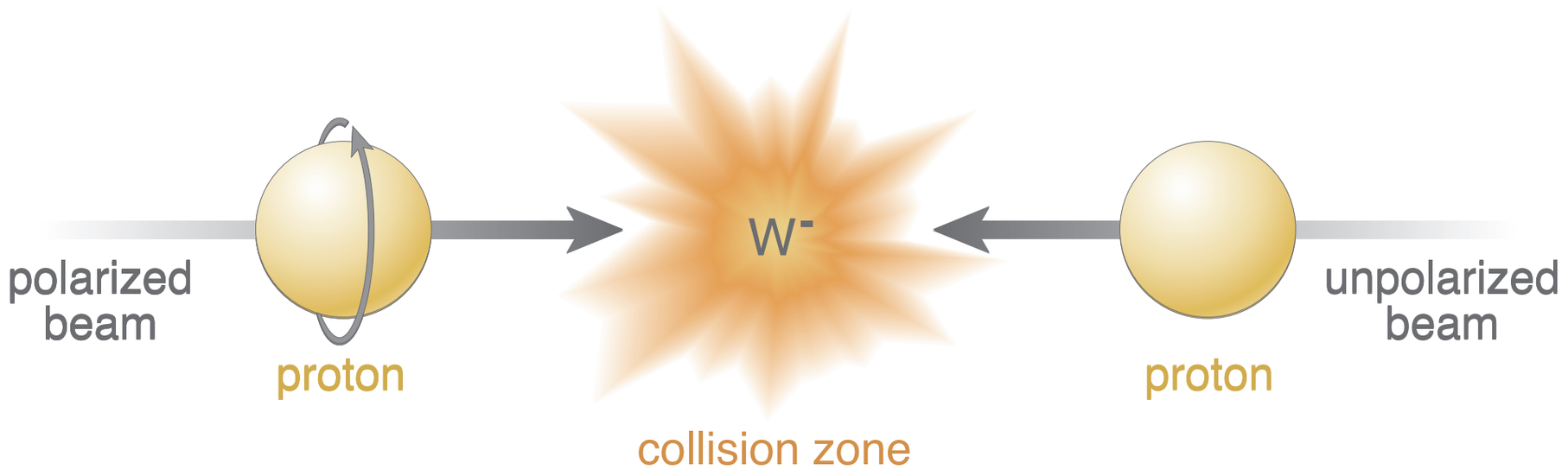

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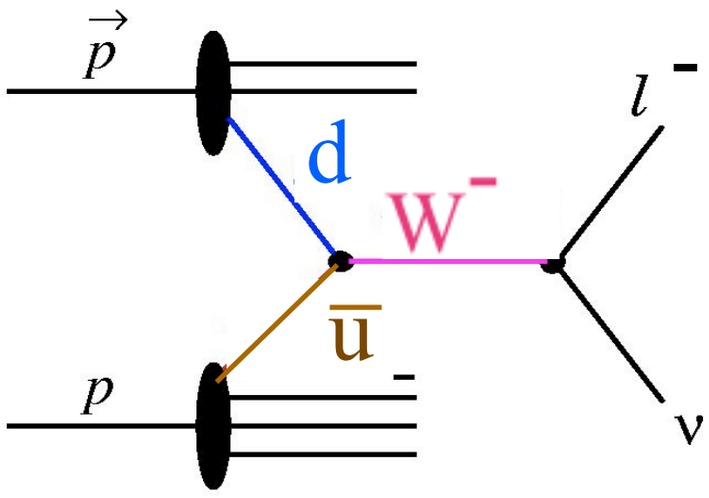

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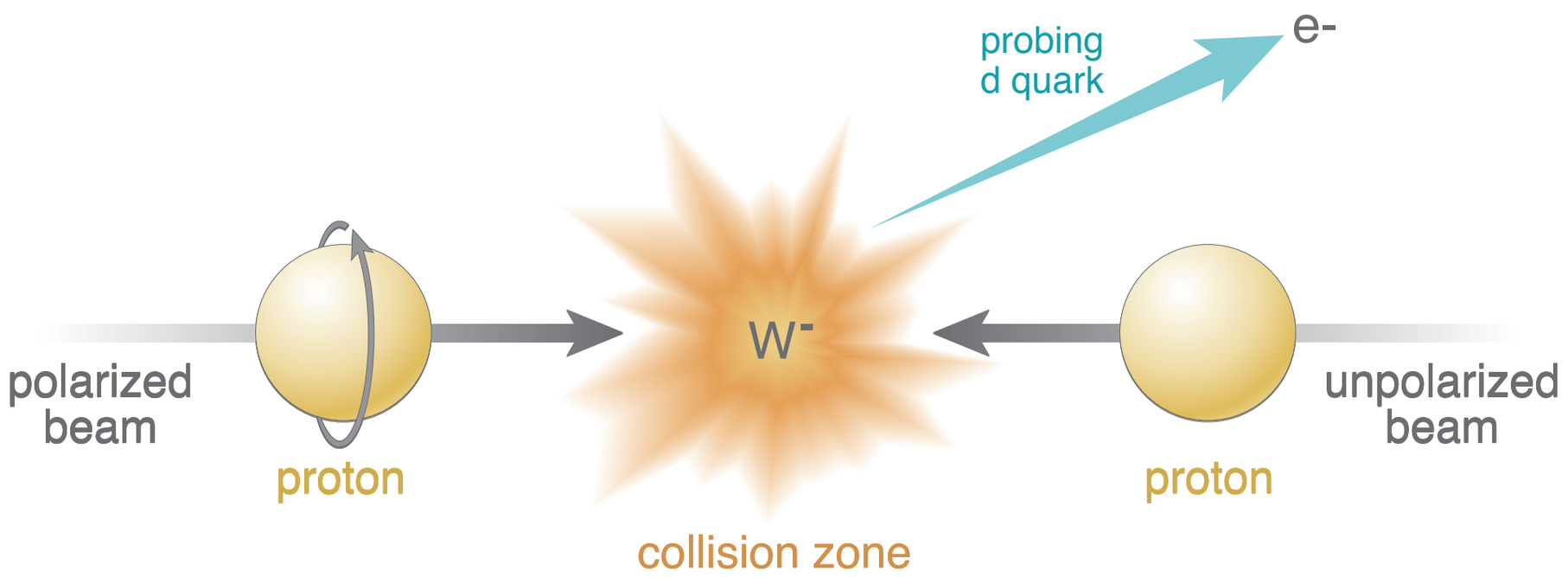

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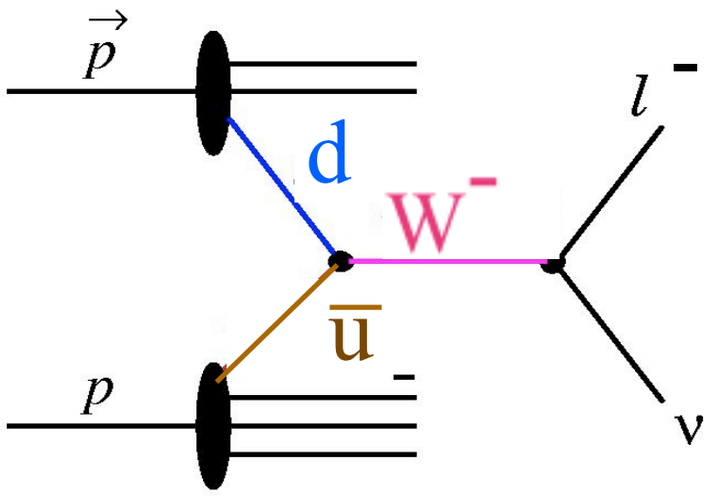

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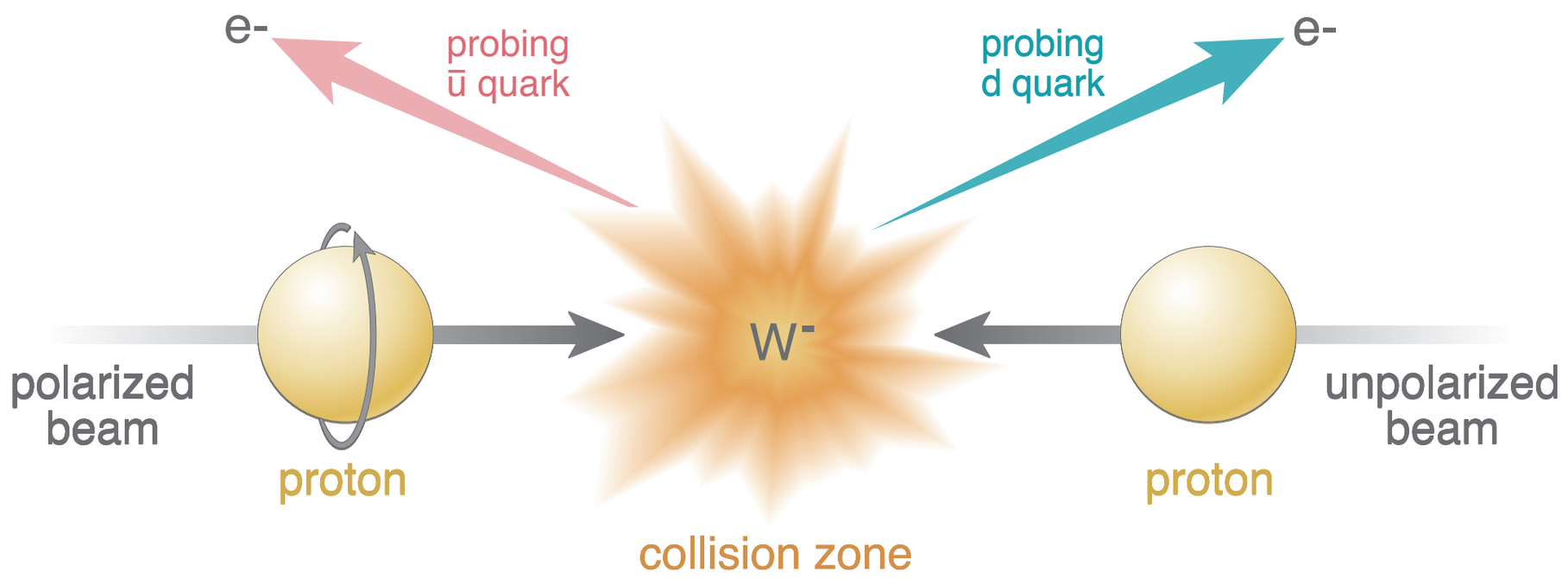

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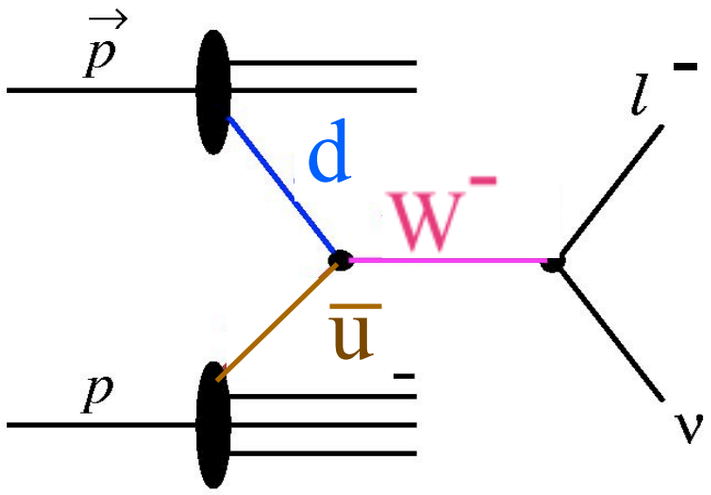

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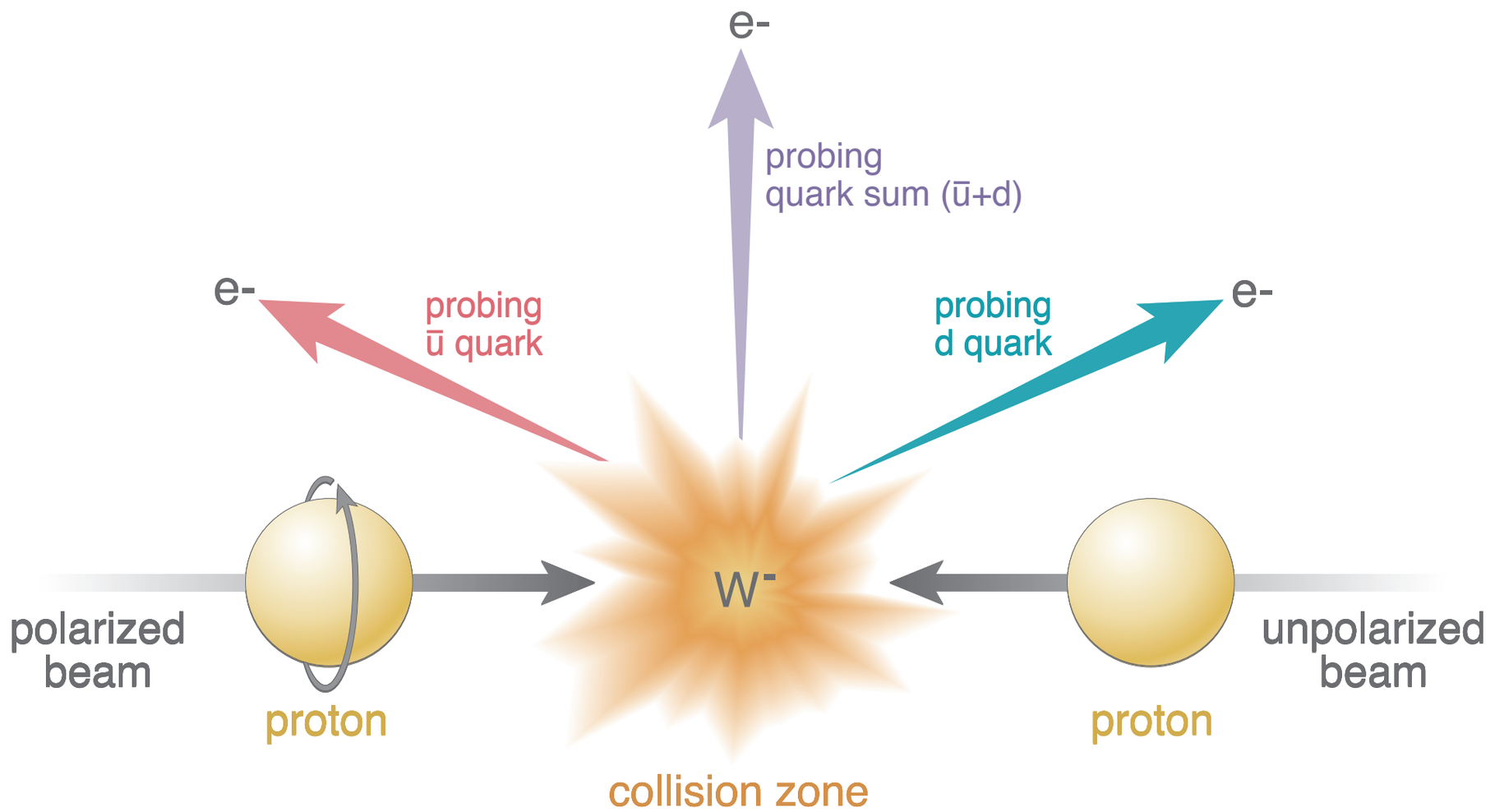
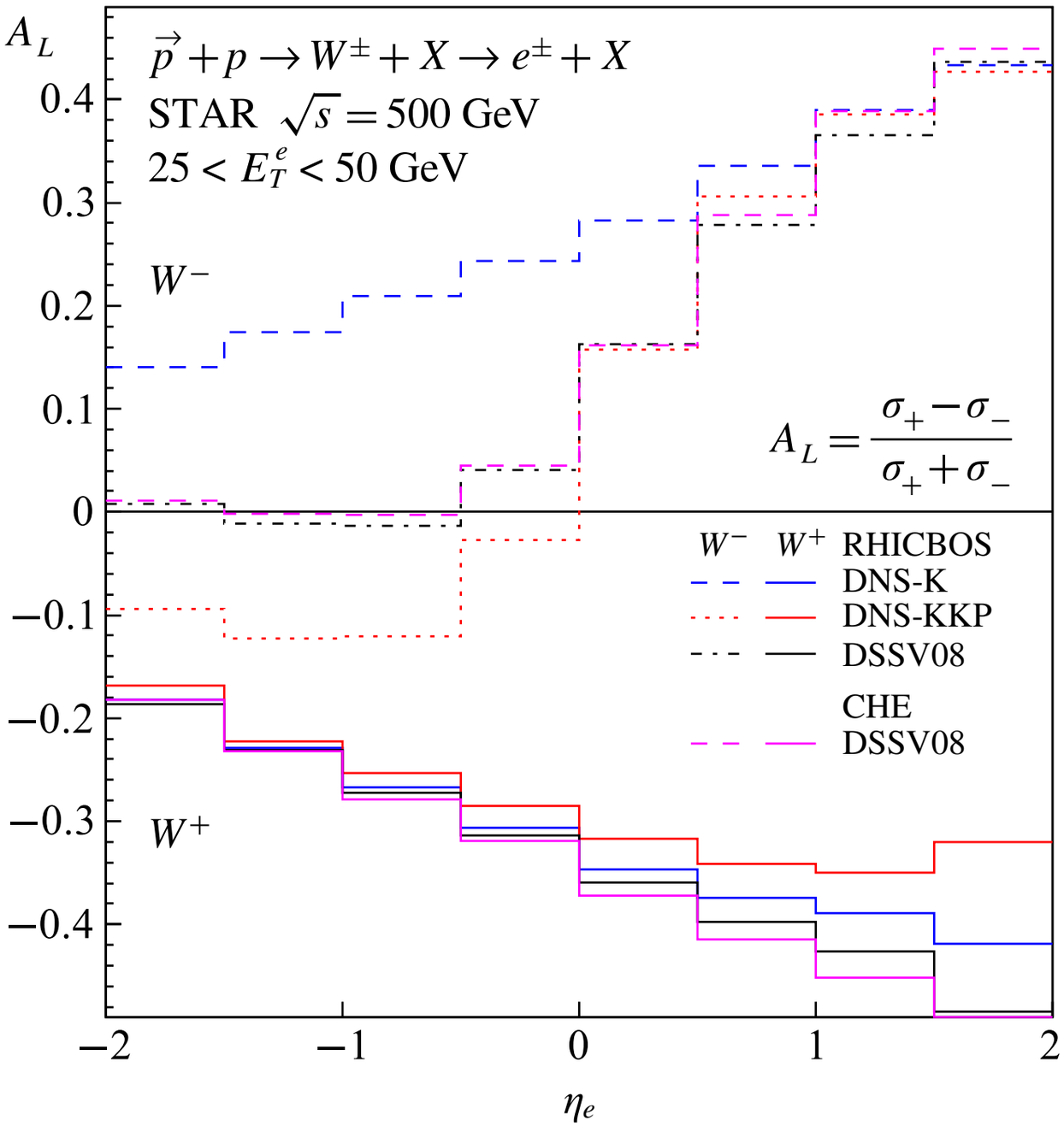
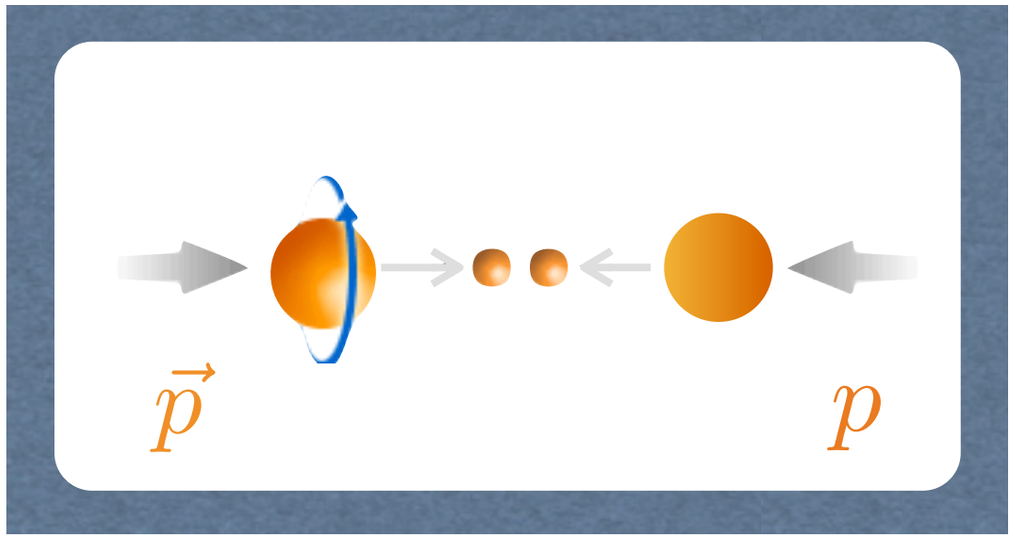


Predictions for W A_L



$$A_L = \frac{\sigma_+ - \sigma_-}{\sigma_+ + \sigma_-}$$



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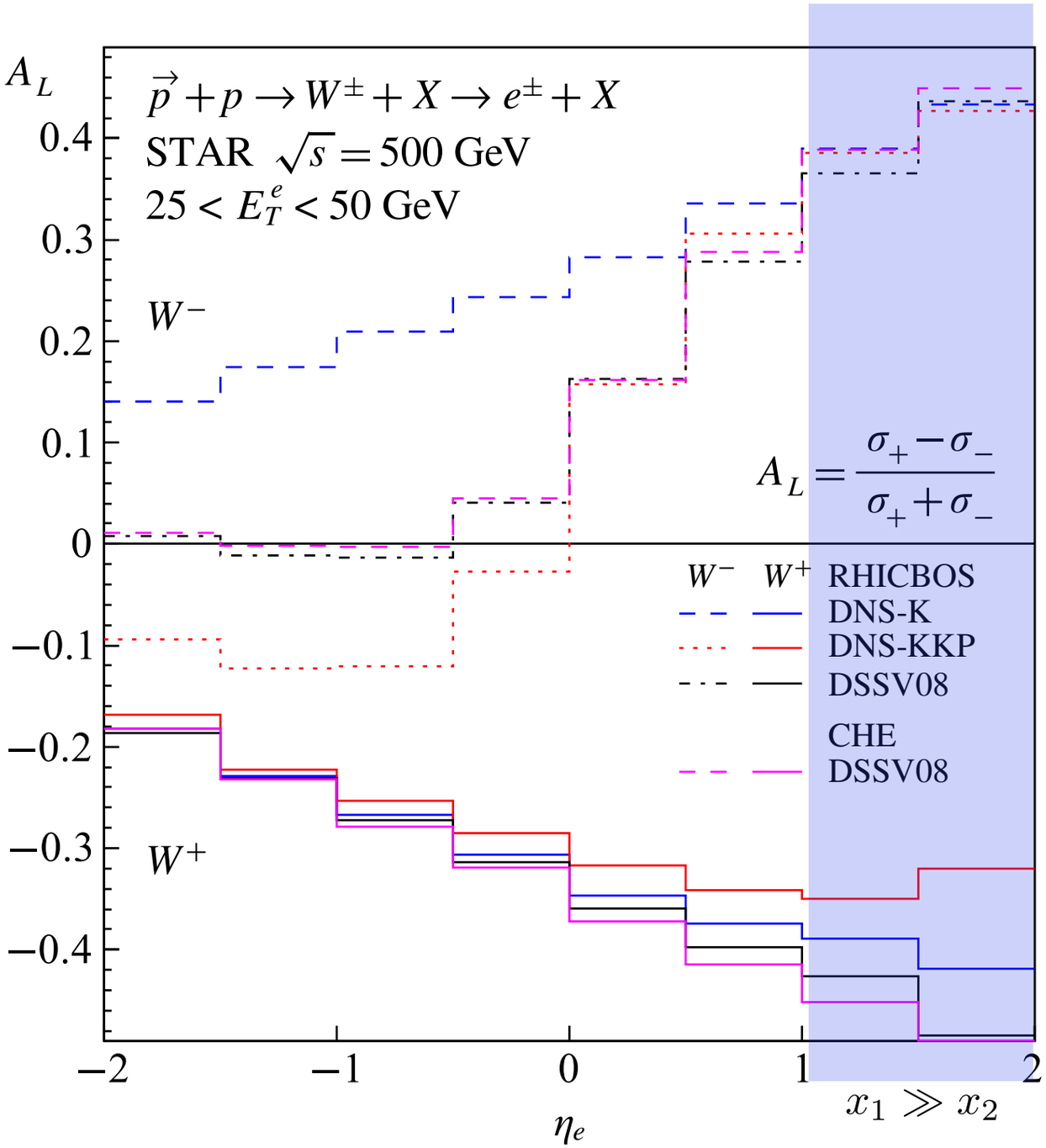

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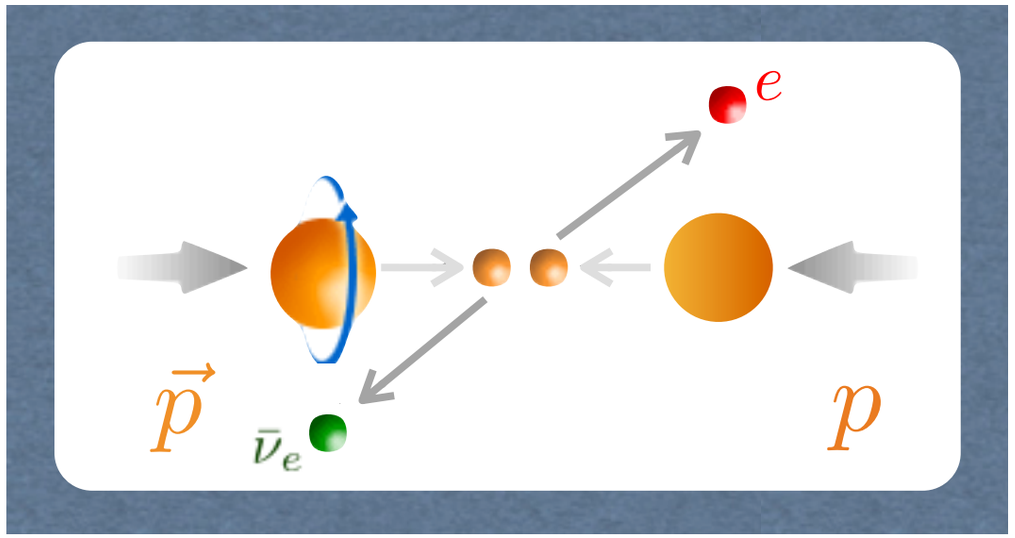

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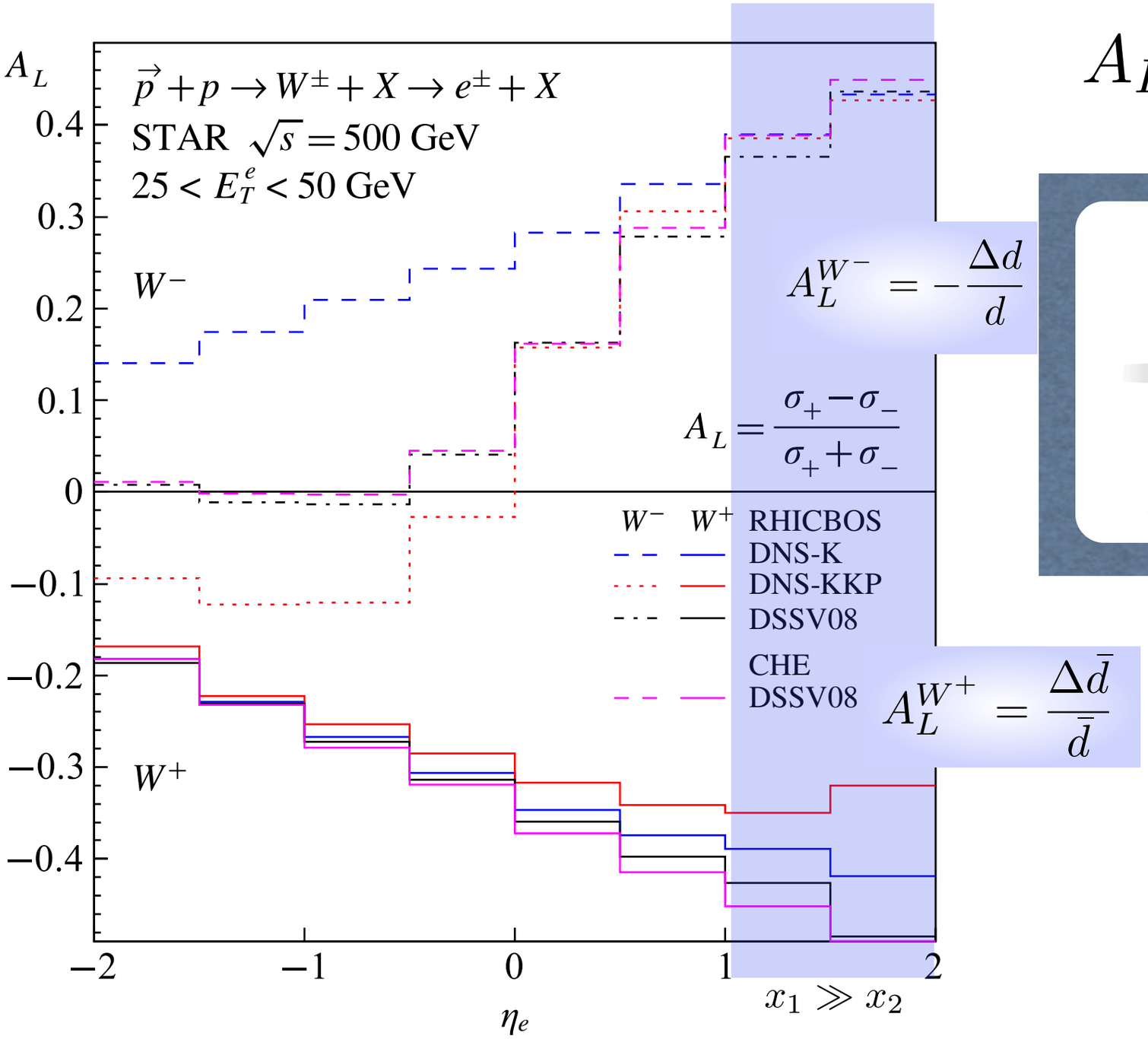

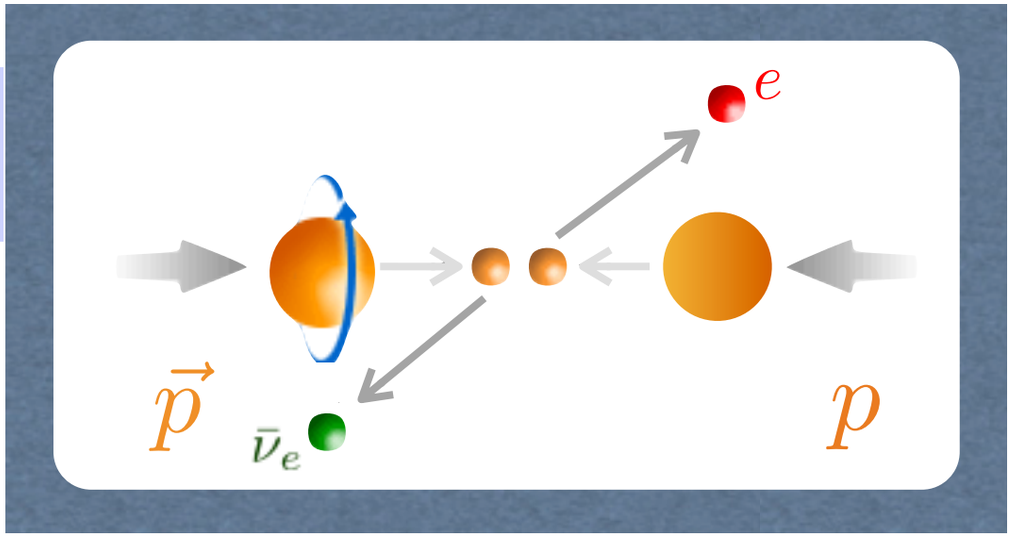

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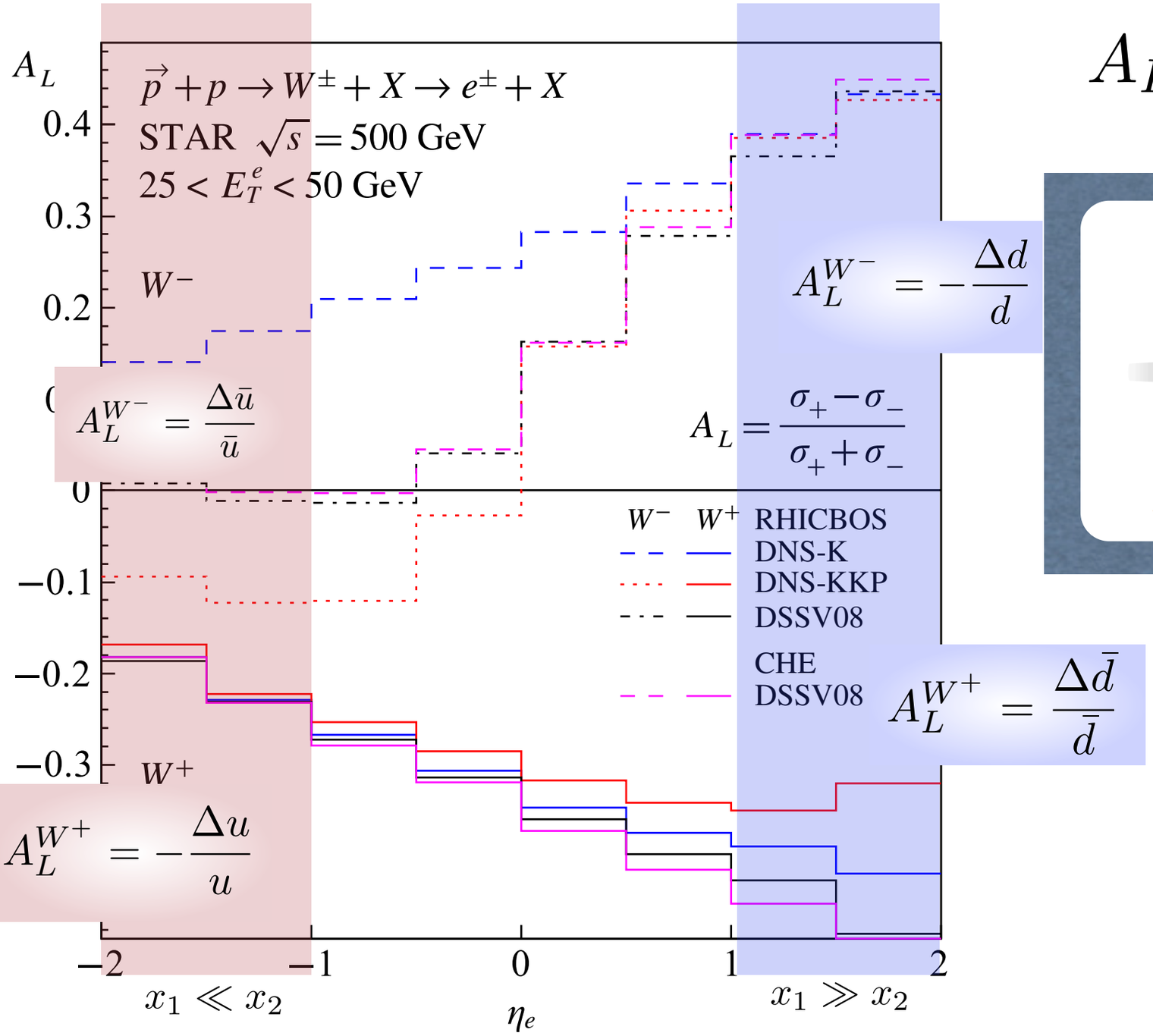

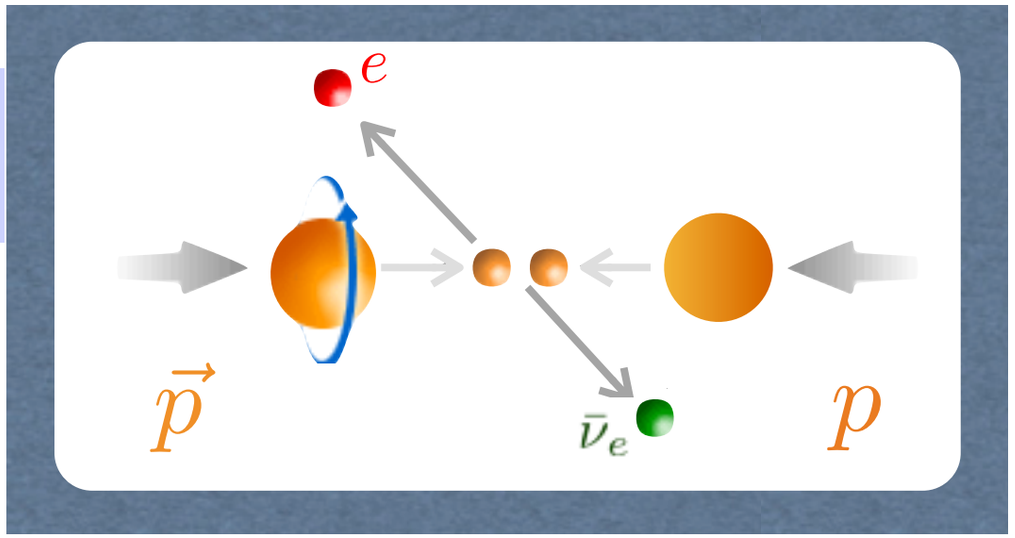

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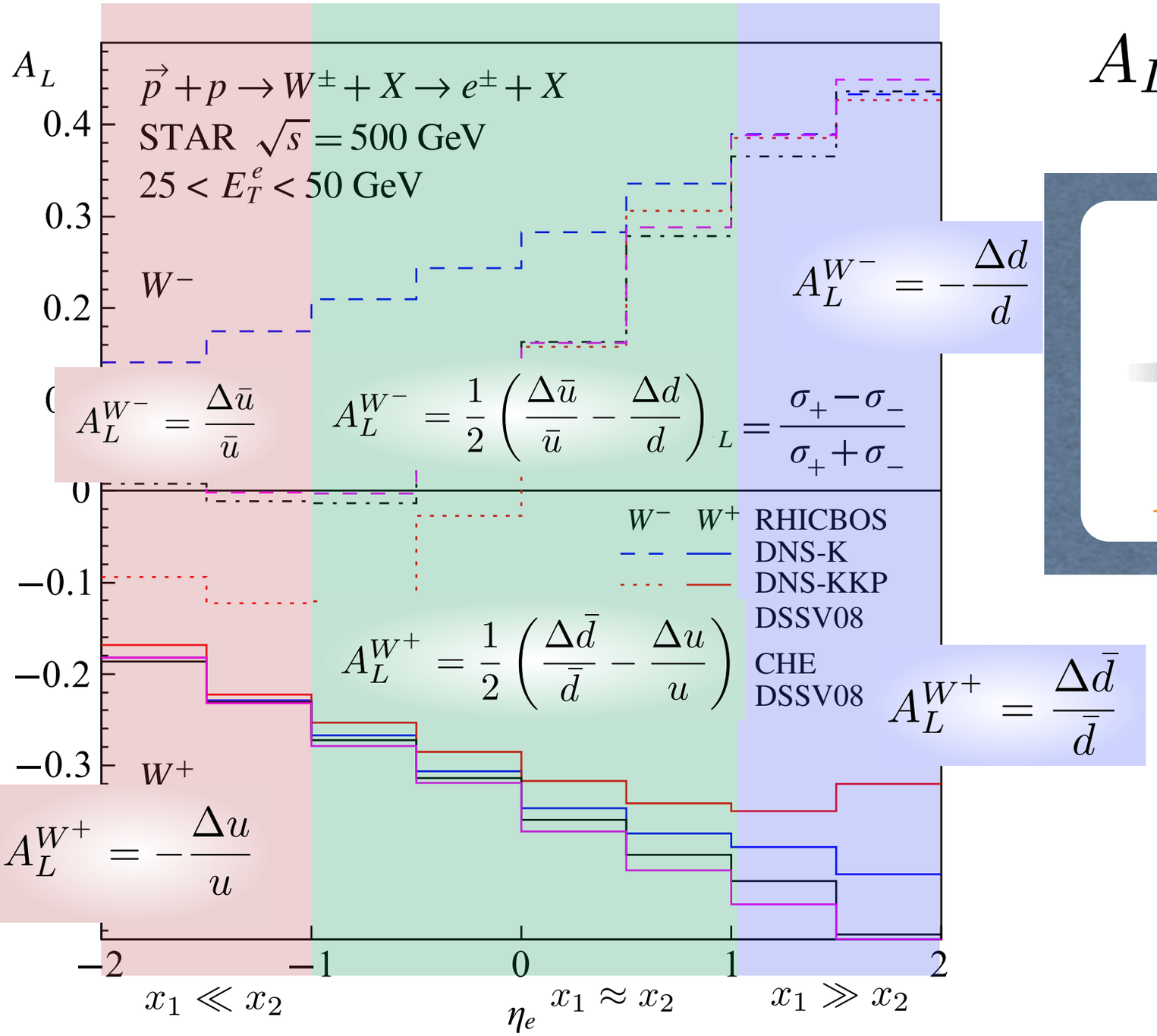

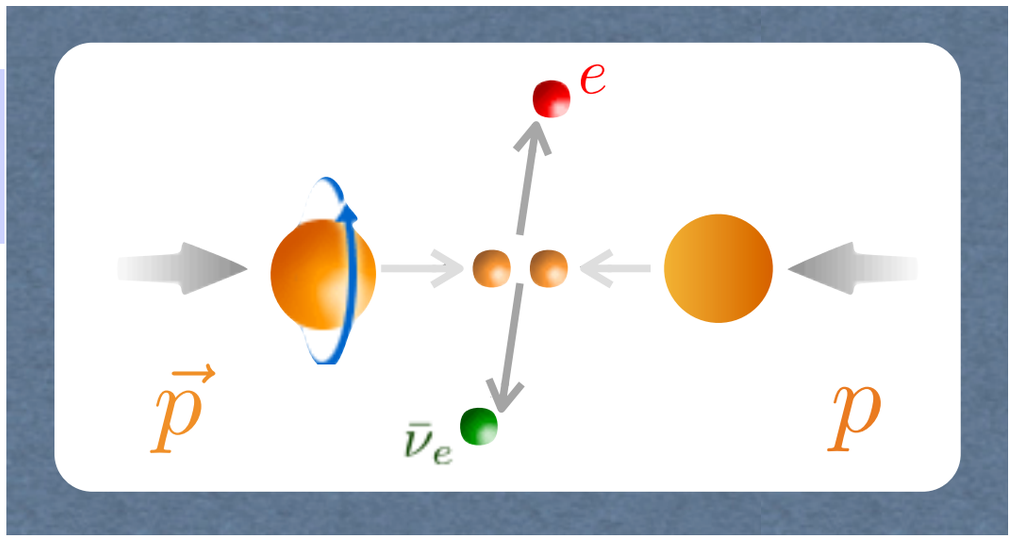

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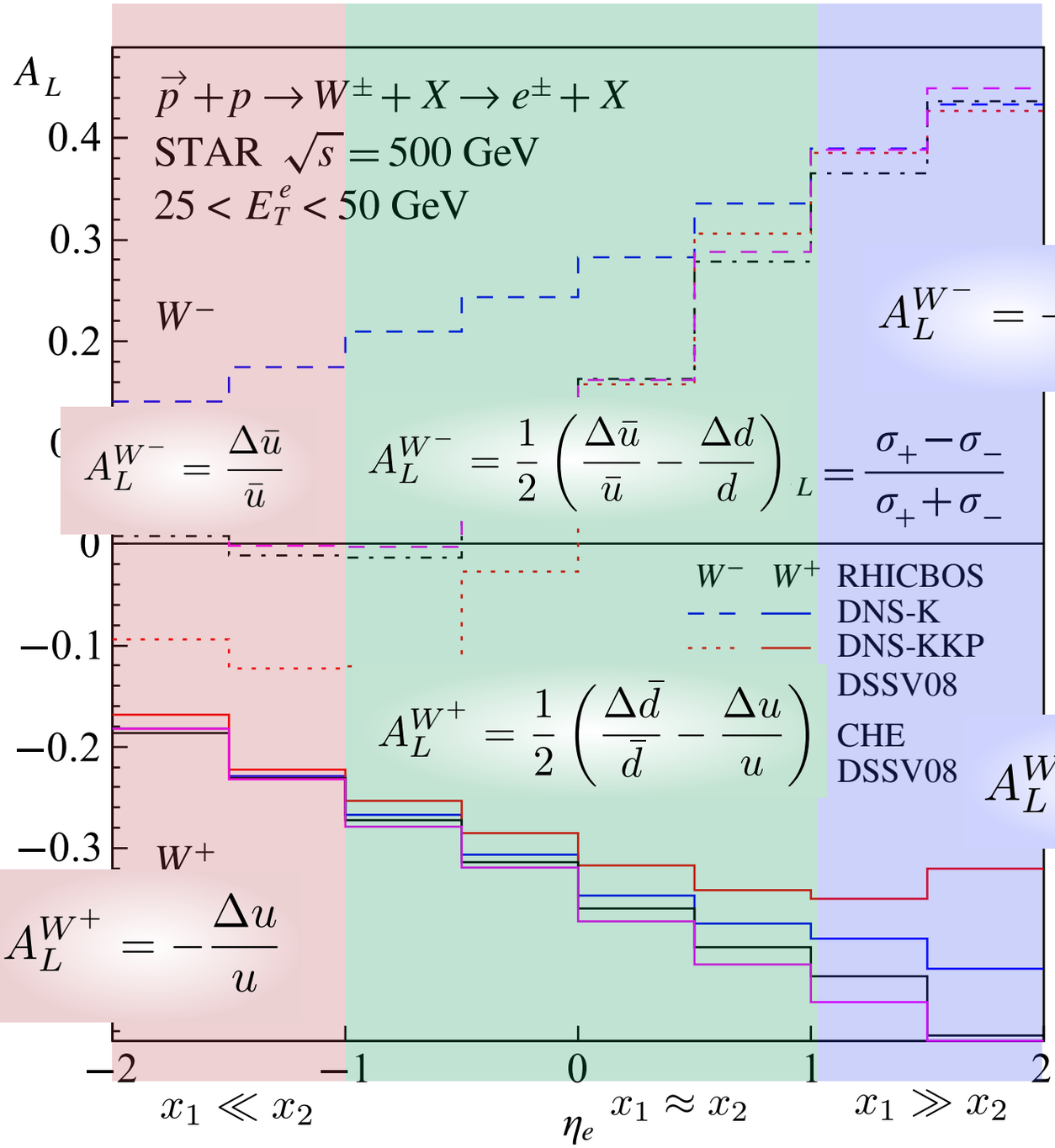
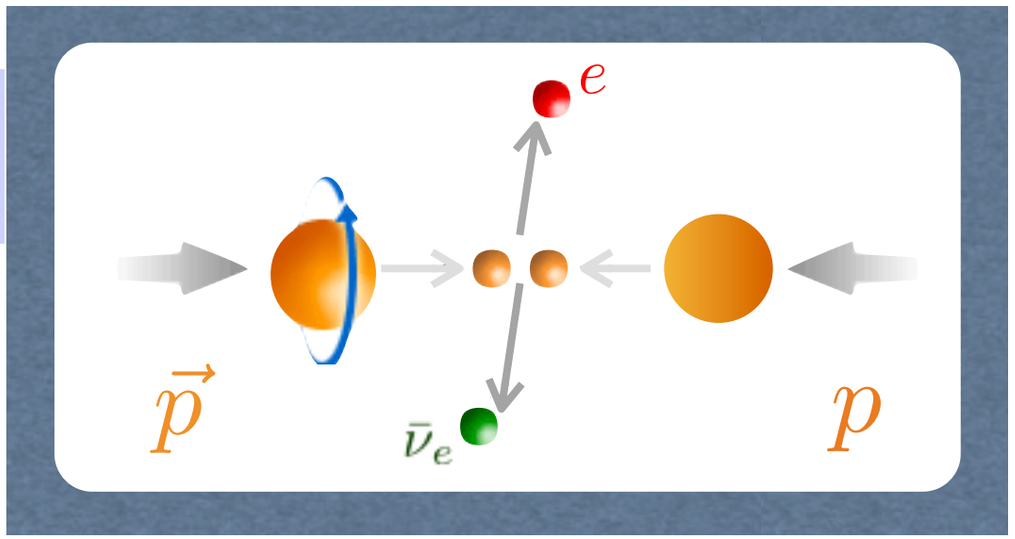




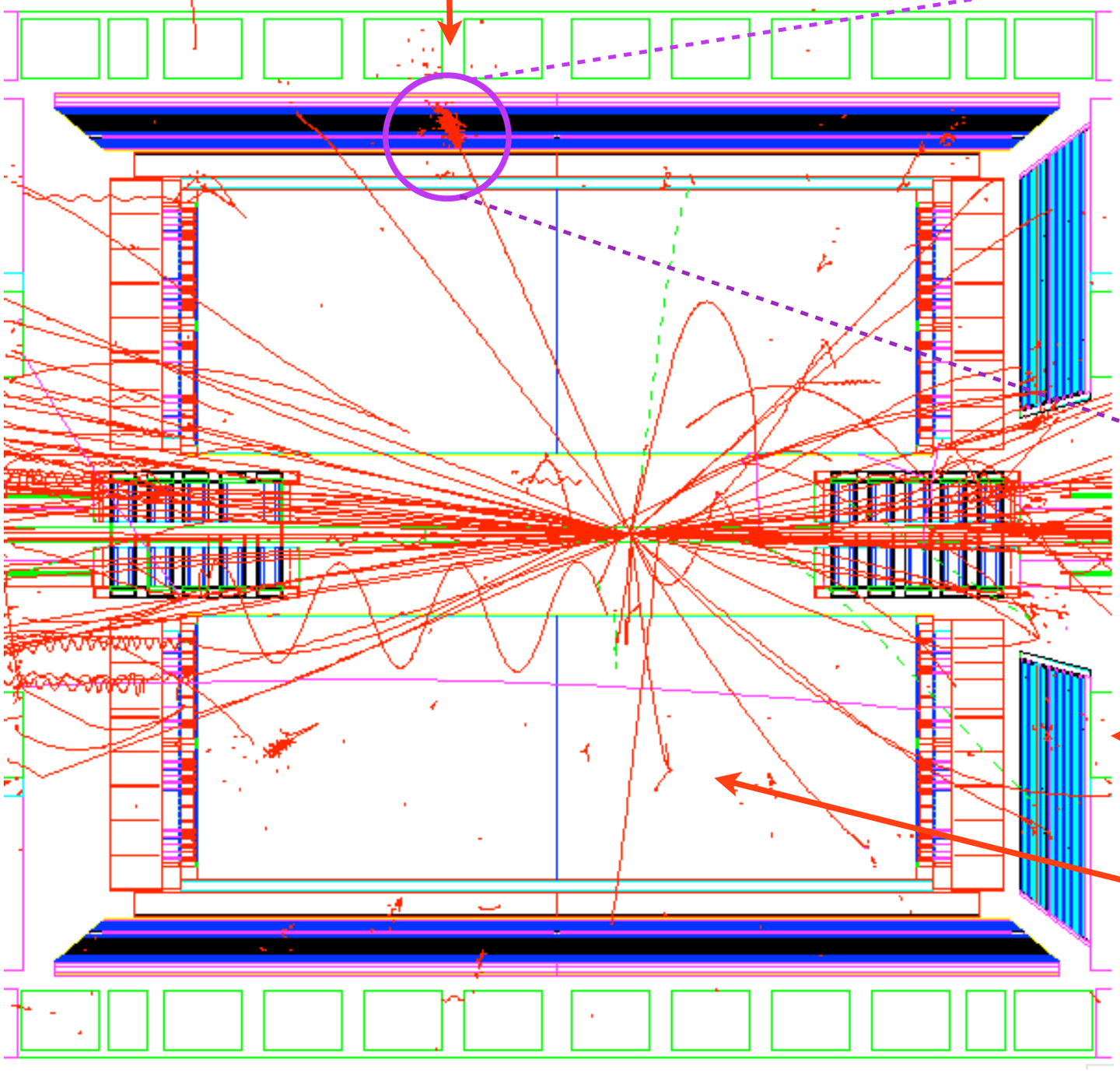
$$A_L^{W^-} = \frac{1}{2}\left(\frac{\Delta \bar{u}}{\bar{u}} - \frac{\Delta d}{d}\right)$$

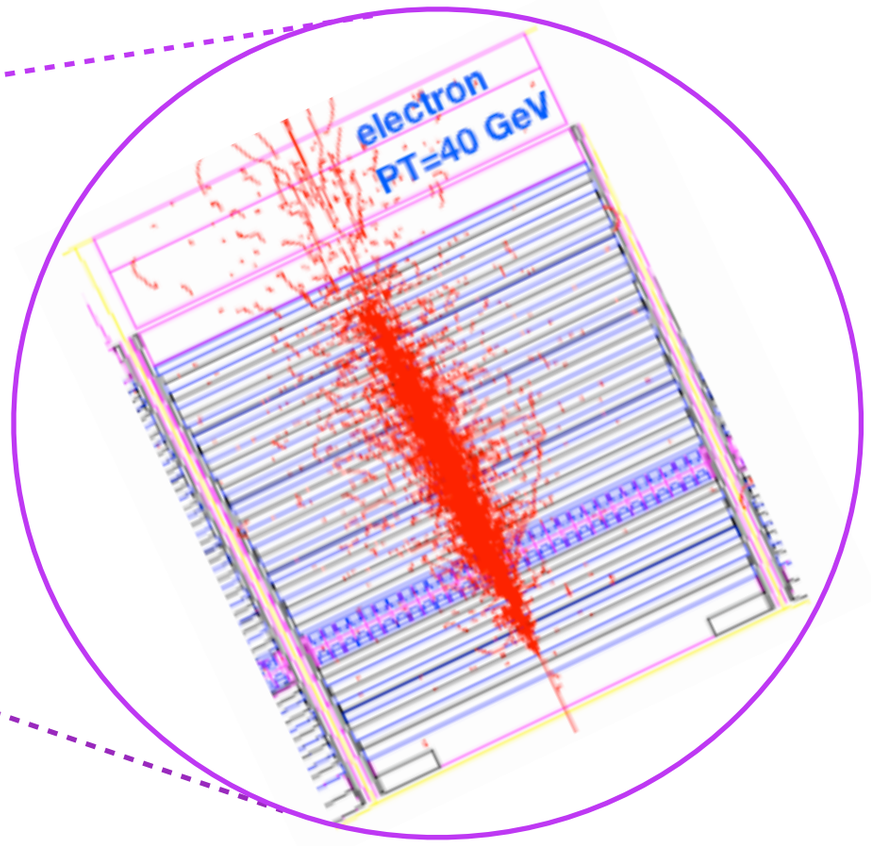
$$A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta \bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$$

STAR Barrel EMC

W event at STAR Detector

Barrel EM Calorimeter:
Lepton Energy
Veto jets



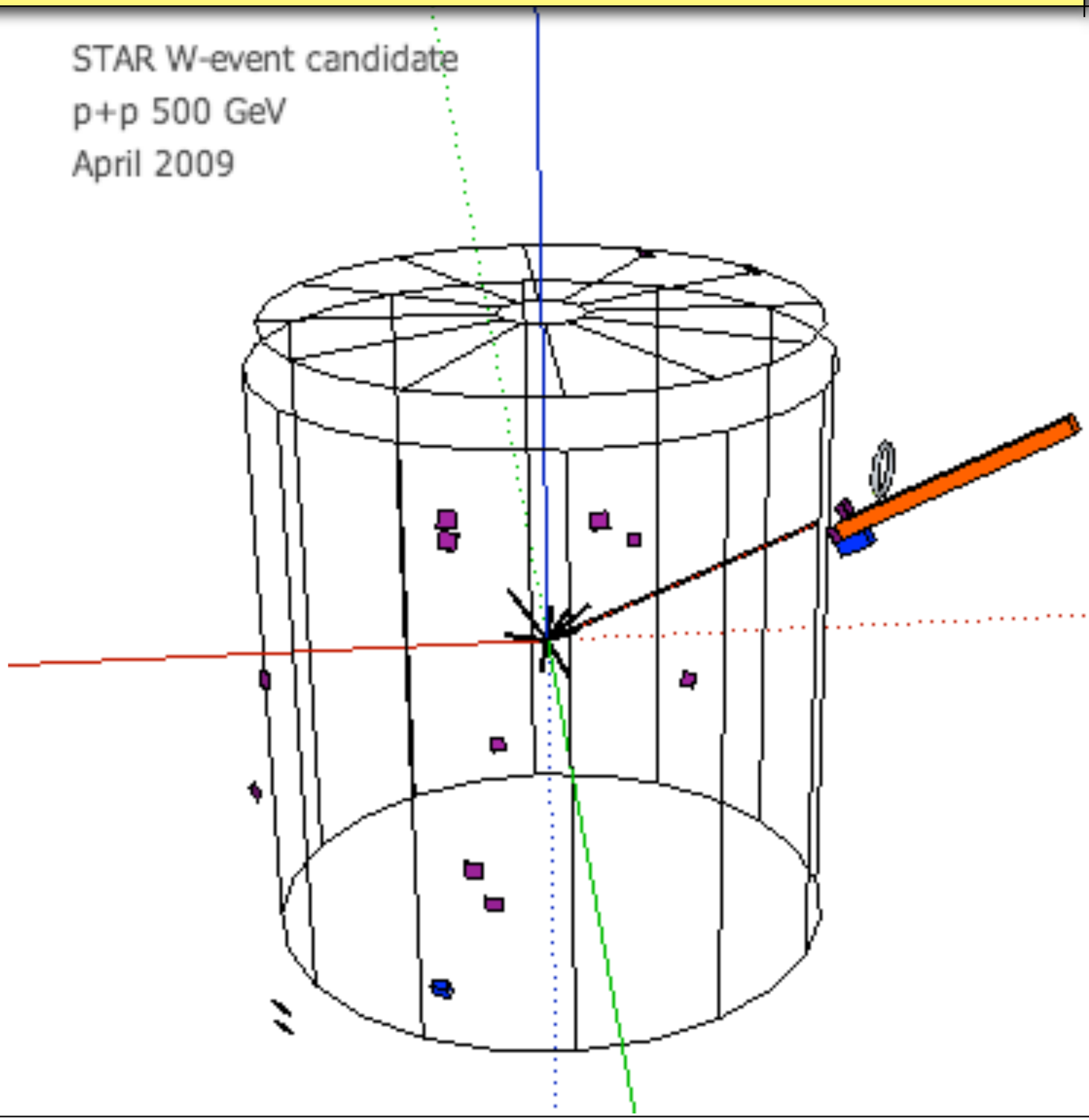


Endcap EM Calorimeter:
Veto jets

Time Projection Chamber (TPC):
Vertex
Charge Separation
Veto jets

Pythia+Geant p+p→W→e+ν event @ 500 GeV

Reconstructed W→e+ ν Event (movie)



Reconstructed Di-jet Event (movie)

1.4 million di-jet events
dominant physics background for 600
W extracted events

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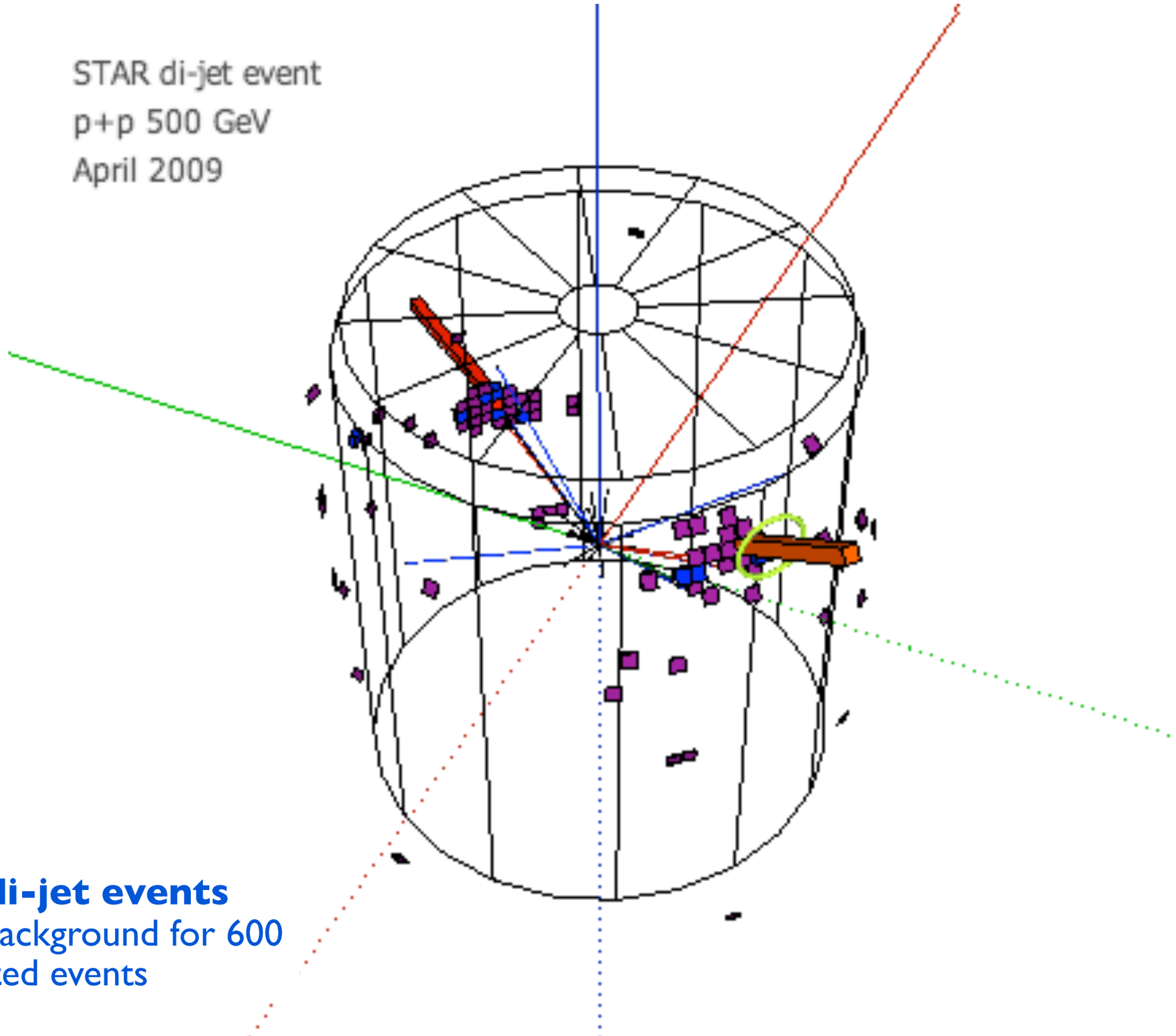

1.4 million di-jet events
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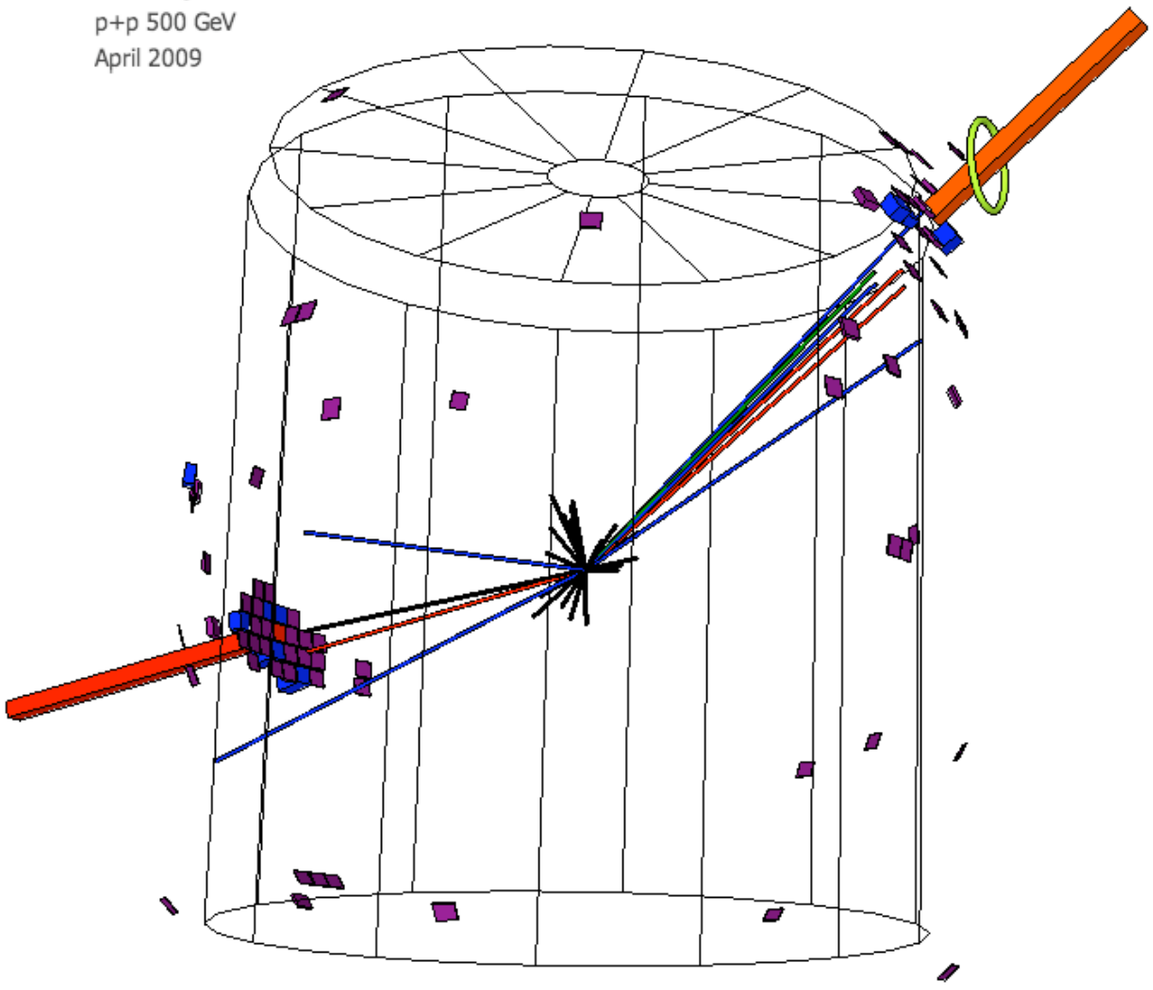
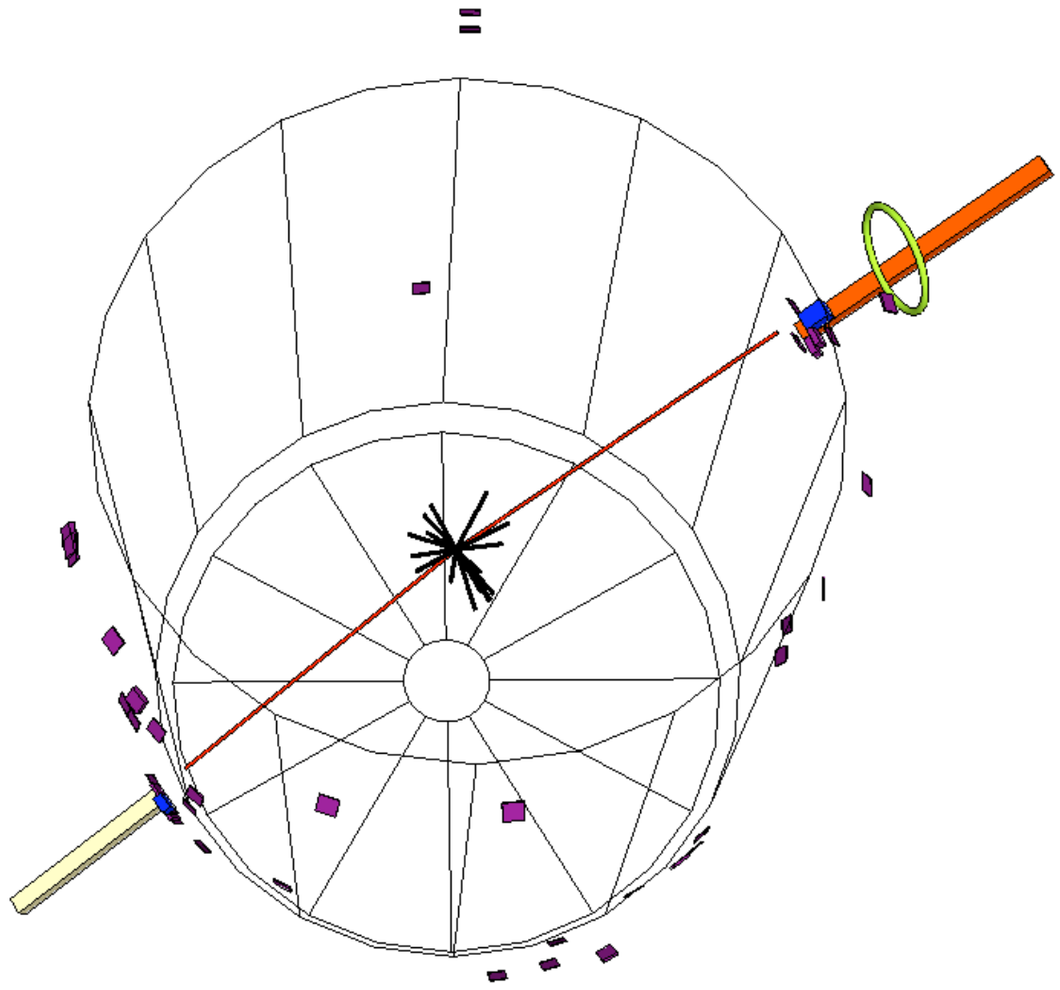
Other Reconstructed Events

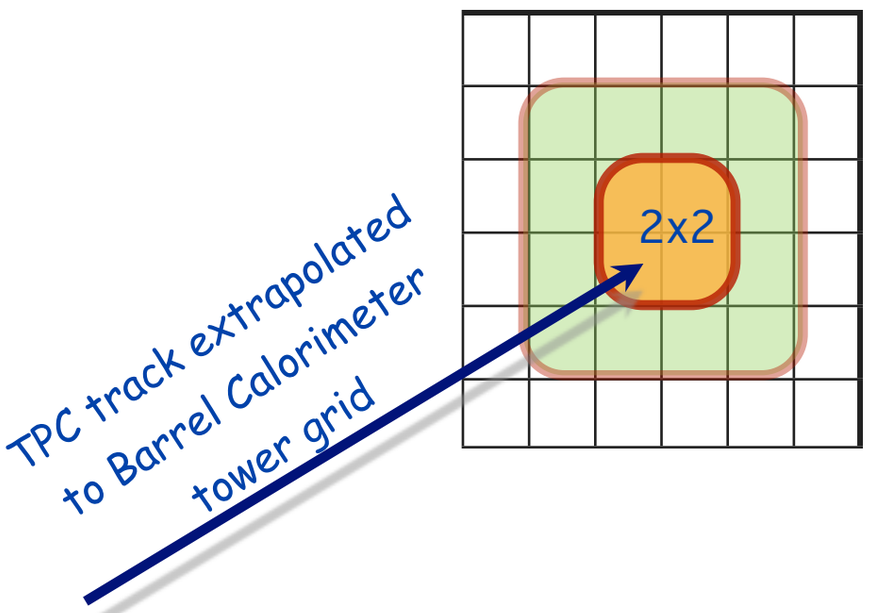
1,400,000 di-jet events were dominant physics background for Ws



Example of reconstructed
p+p →Z →e+ e−
reco Zmass=94 GeV

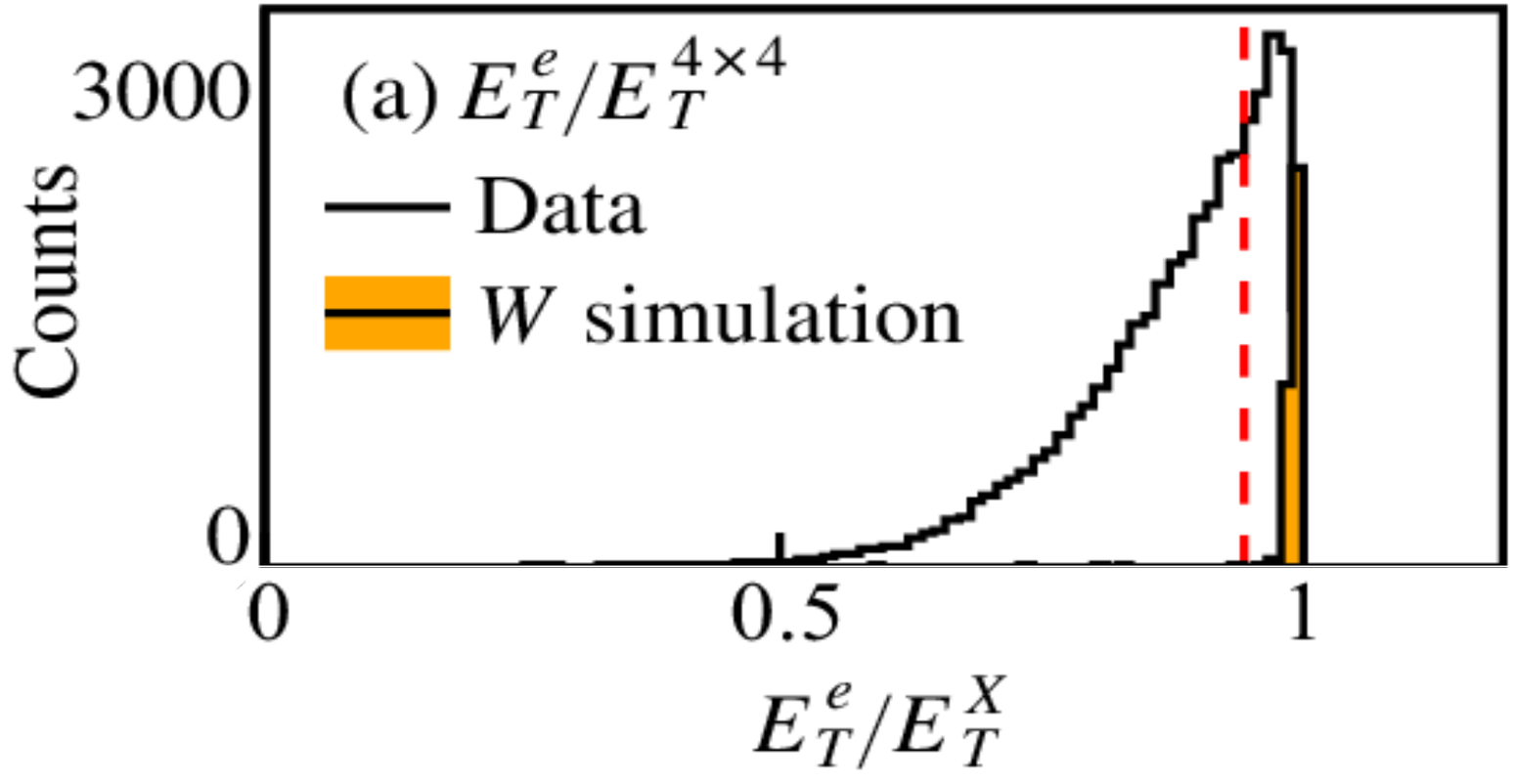


W reconstruction: Lepton Isolation

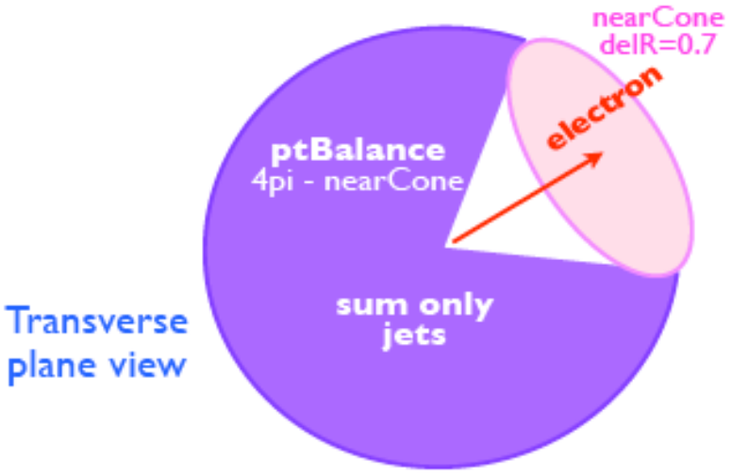


Lepton Isolation Cuts:

- Require TPC track with $p_T > 10$ GeV
- Extrapolate track to Barrel Calorimeter
- Require highest 2x2 cluster around pointed tower sum $E_T > 15$ GeV
- Require excess E_T in 4x4 cluster < 5%
- Match track to 2x2 cluster position



W reconstruction: Suppress QCD Background

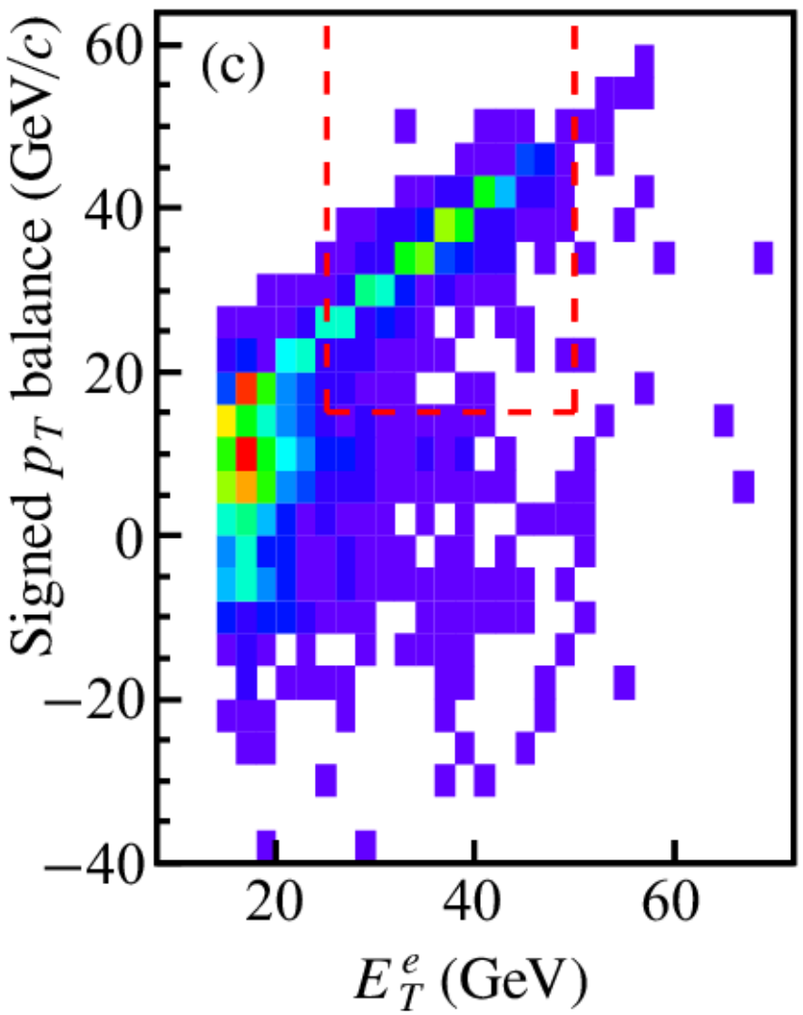


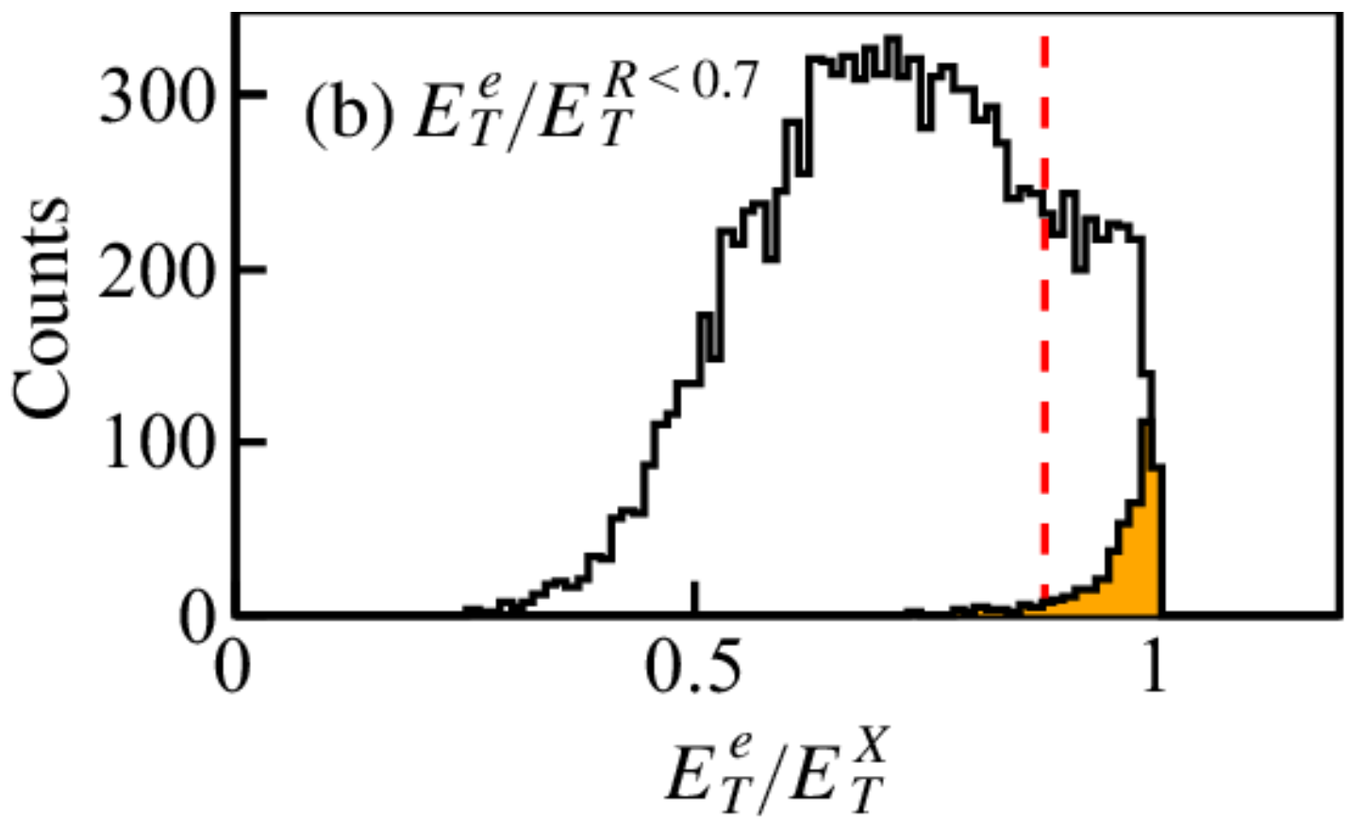
Suppress jets with leading hadron

- Near side jet-cone veto

Suppress di-jets and multi-jet events

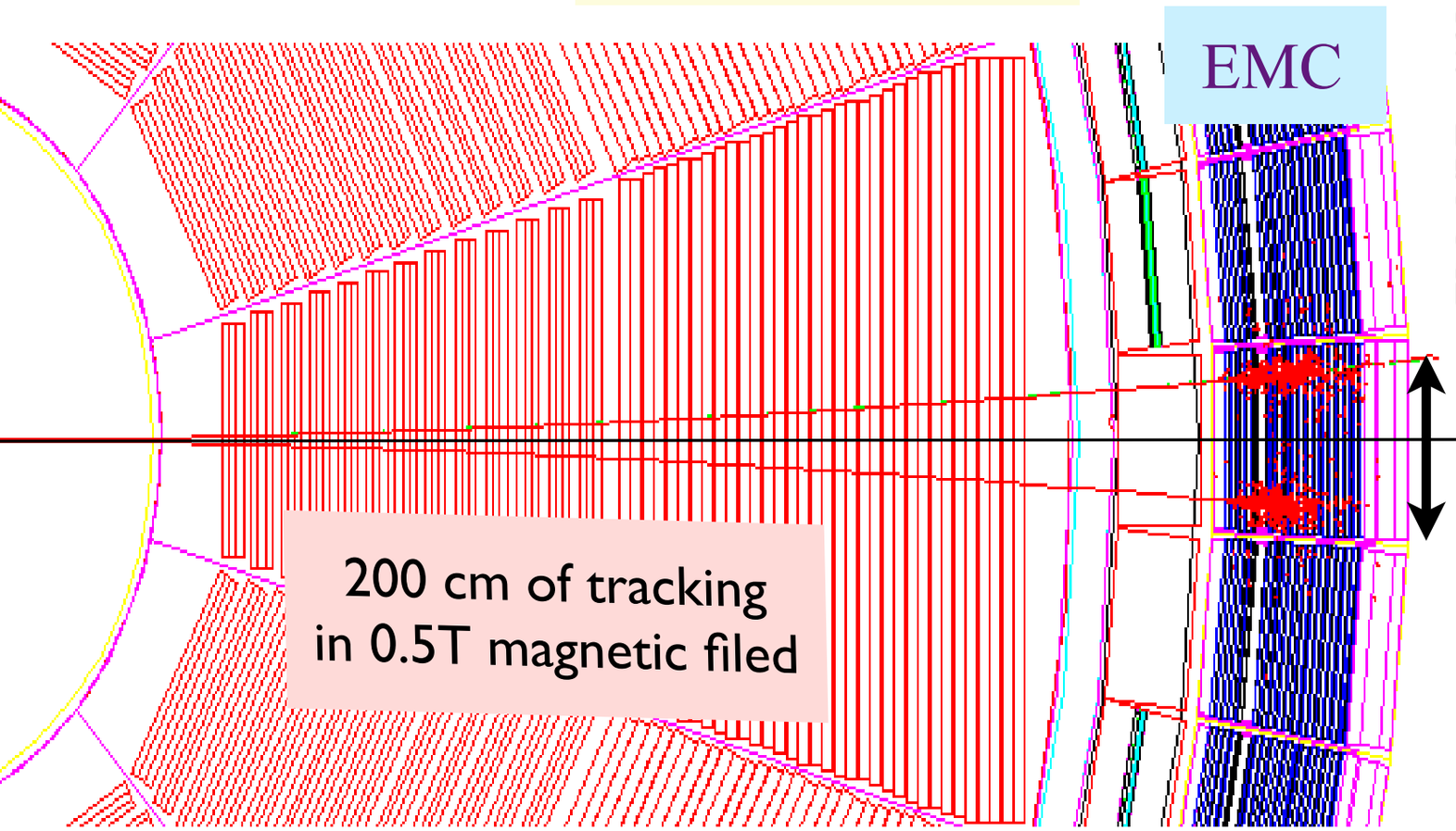
- Require an imbalance in p_T of the lepton cluster and any jets reconstructed outside the near side jet cone



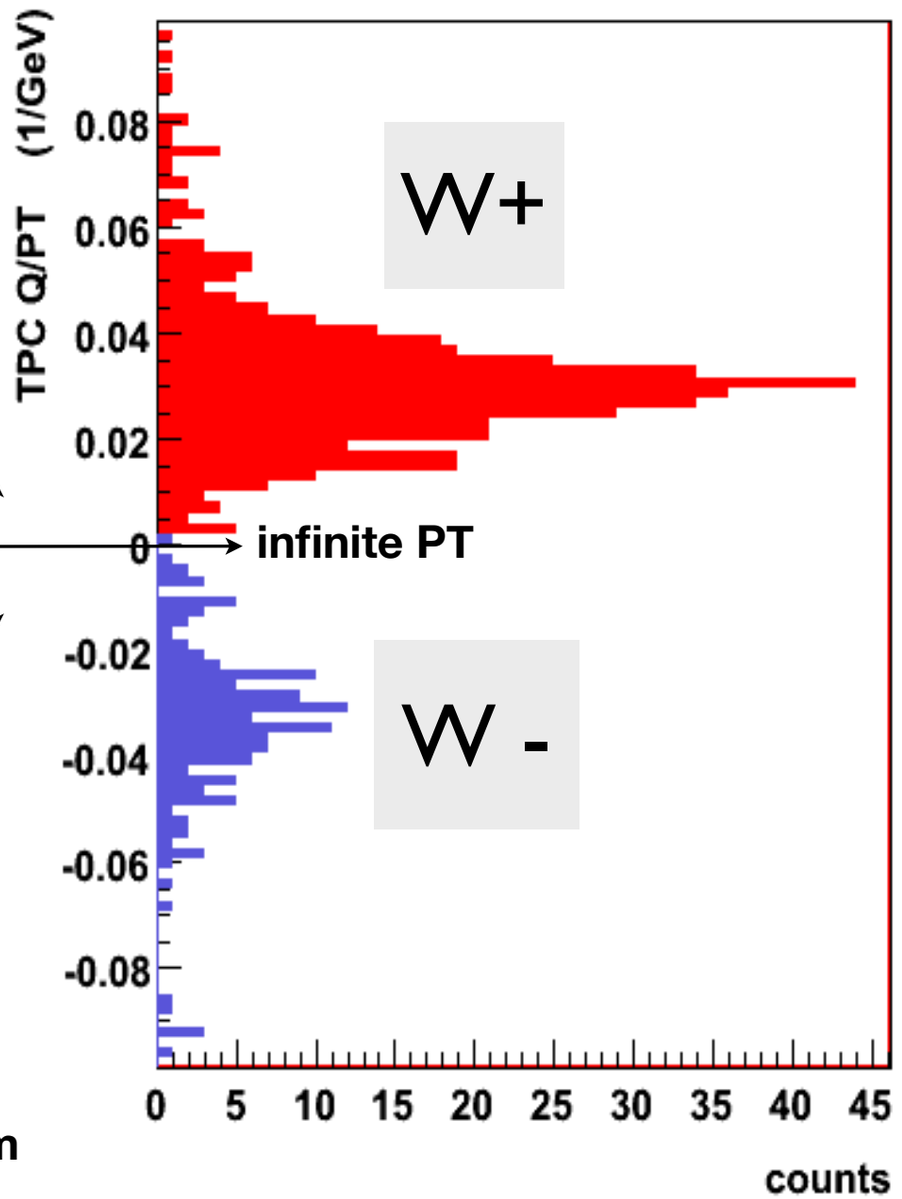


e+/ e- charge separation in STAR TPC

shown
electron & positron
PT= 5 GeV/c

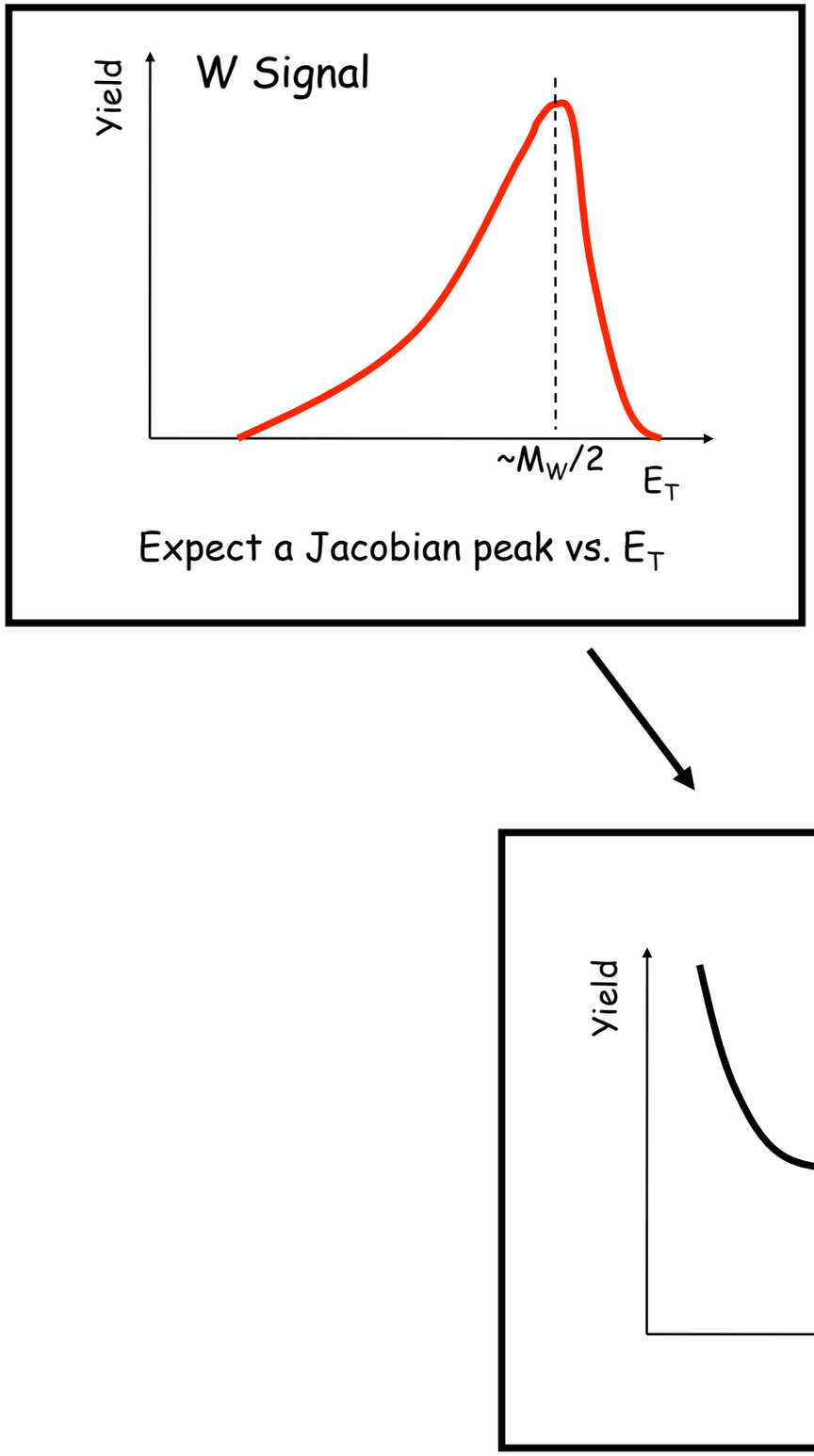


STAR Run 9 data
ET>25 GeV



distance D ~ 1/PT
PT=5 GeV/c D~15 cm
PT=40 GeV/c D ~2 cm

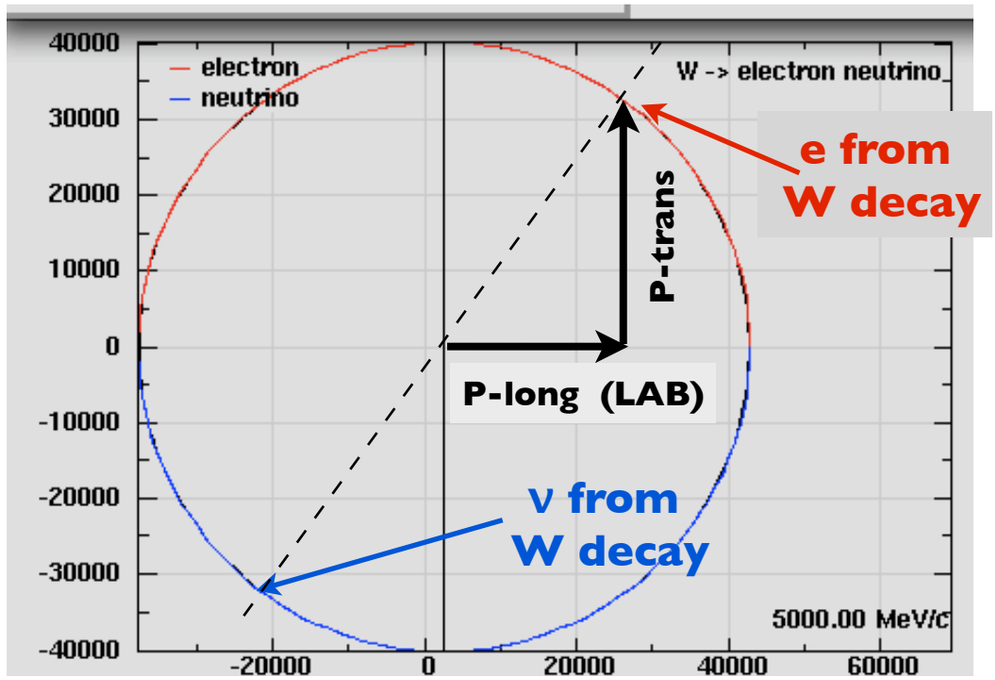
Expected Reconstructed $W \rightarrow e + \nu$ spectrum



We expect to see a peak in the E_T spectrum at $M_W/2$

Jacobian peak shape: 2 Body Decay & K_T-smearing

Isotropic decay $W \rightarrow e + \nu$
prob. density: $f_\Omega(\phi, \cos\theta) = const$,
electron $P_T = P_0 * \sin\theta$, where $P_0 = 40$ GeV/c.
Hence, prob. density: $f_{P_T}(P_T) = \frac{const}{\sqrt{1-(P_T/P_0)^2}}$
has singularity at $P_T = 40$ GeV/c



Assumed P-long of W of 5 GeV/c,
no K_T smearing

$$u + \bar{d} \rightarrow W^+$$

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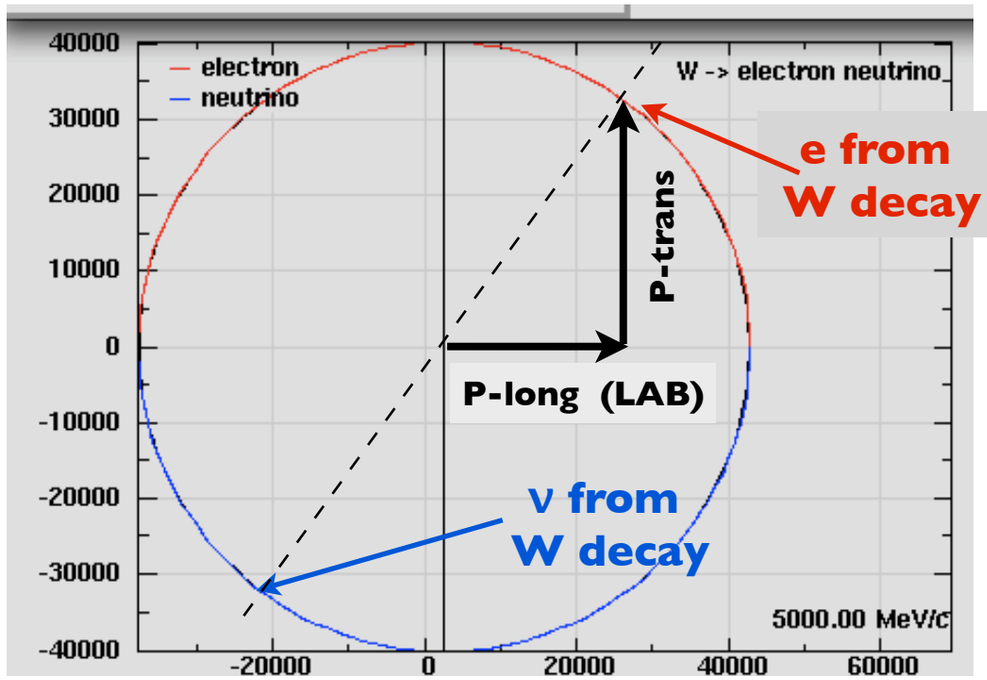

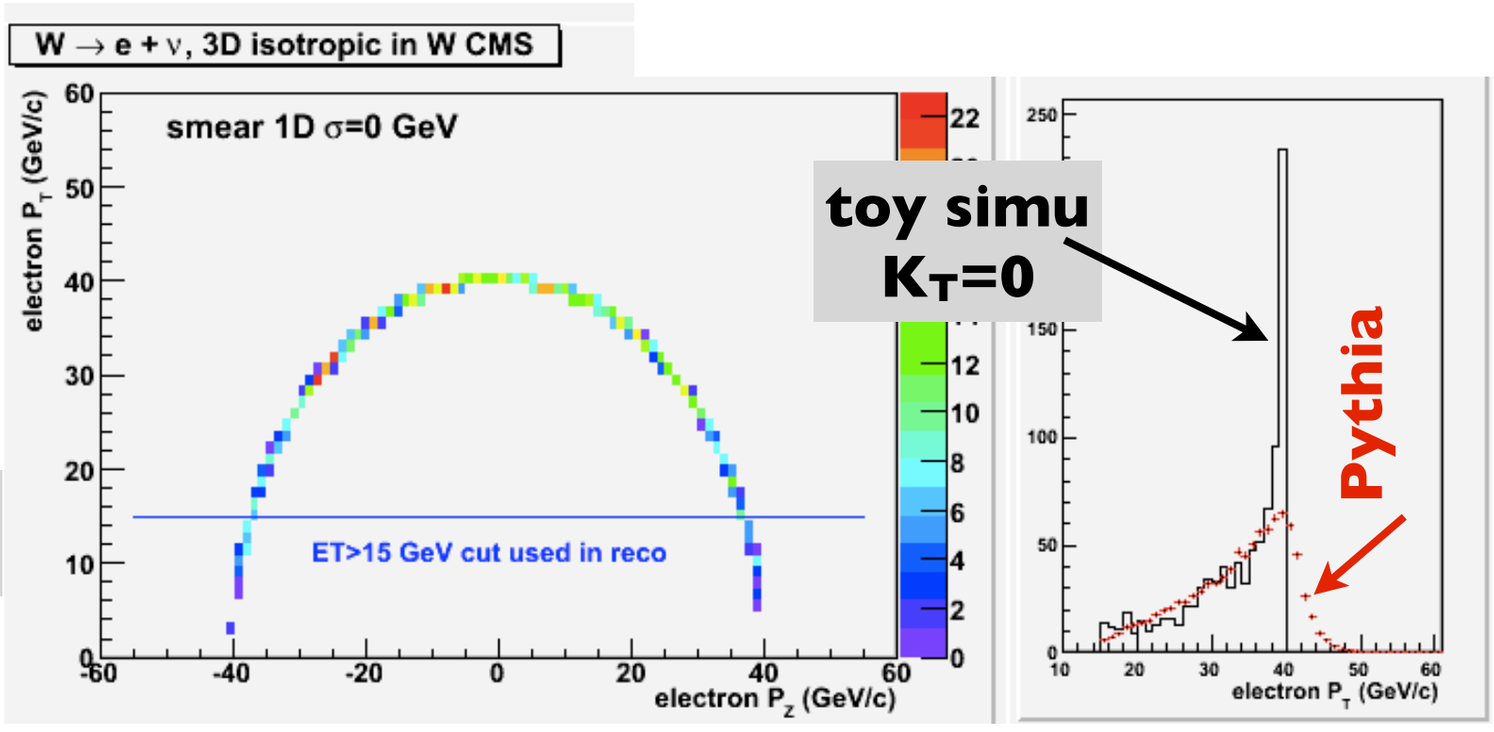

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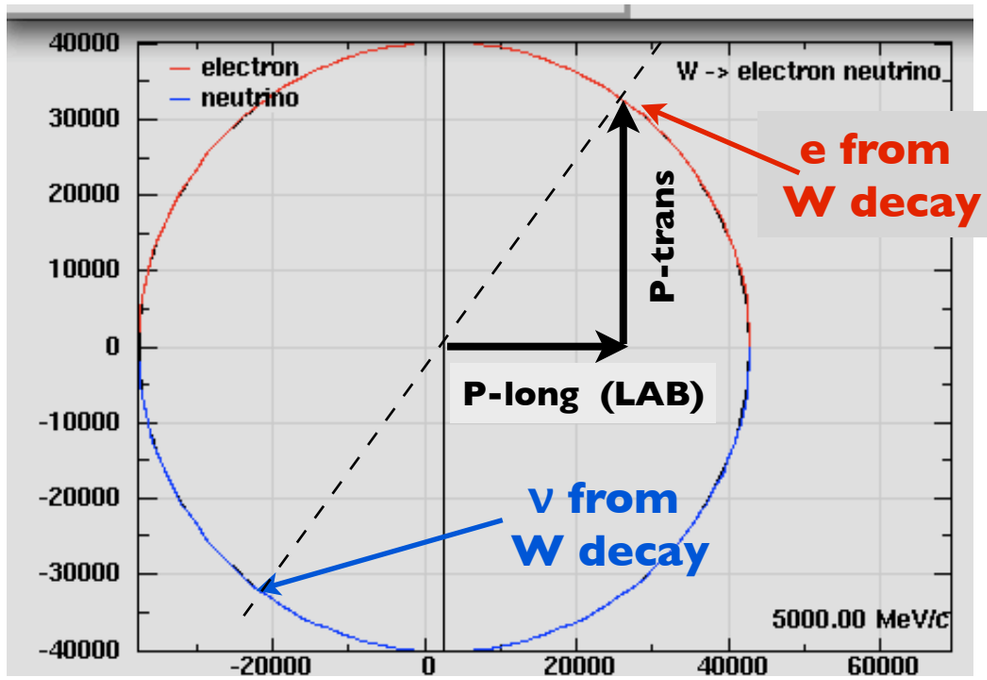

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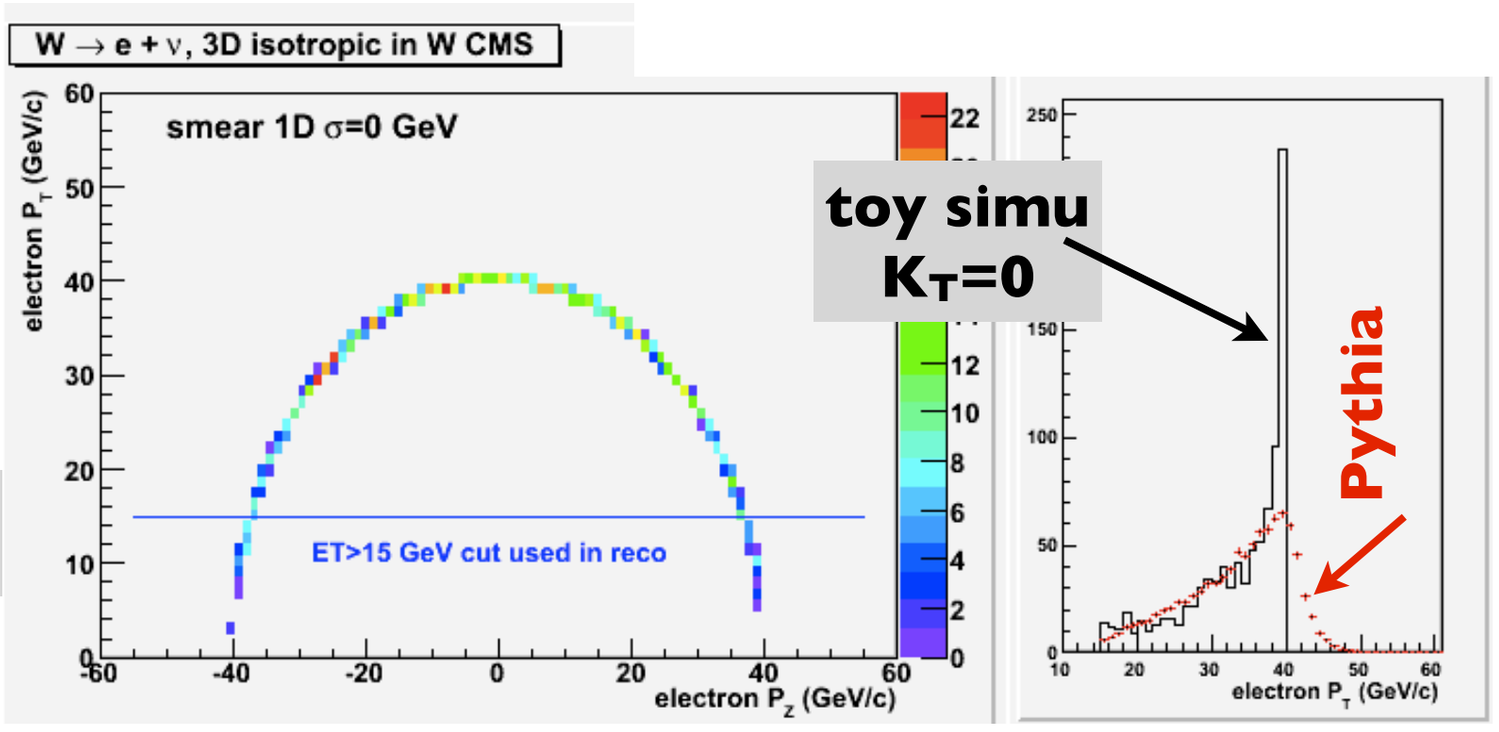
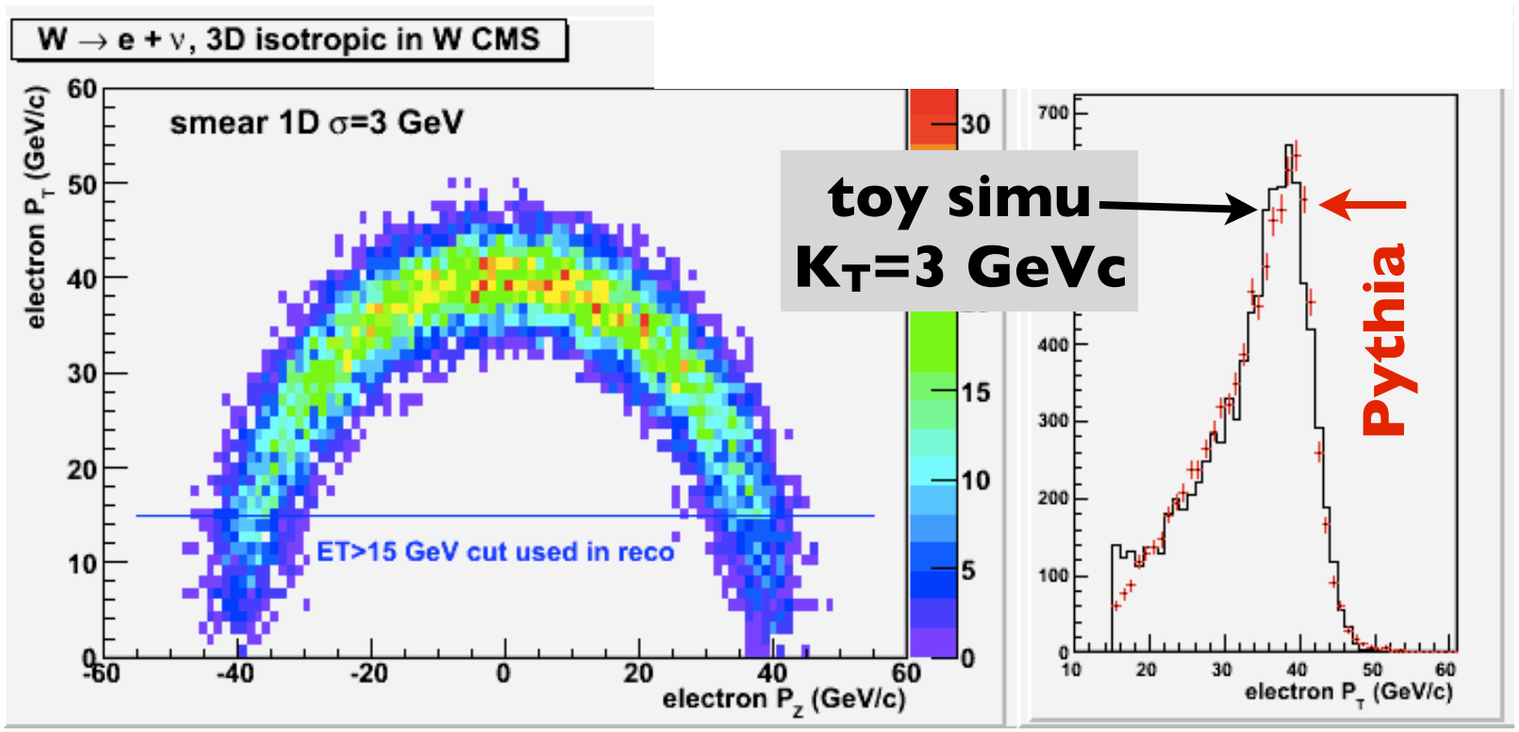
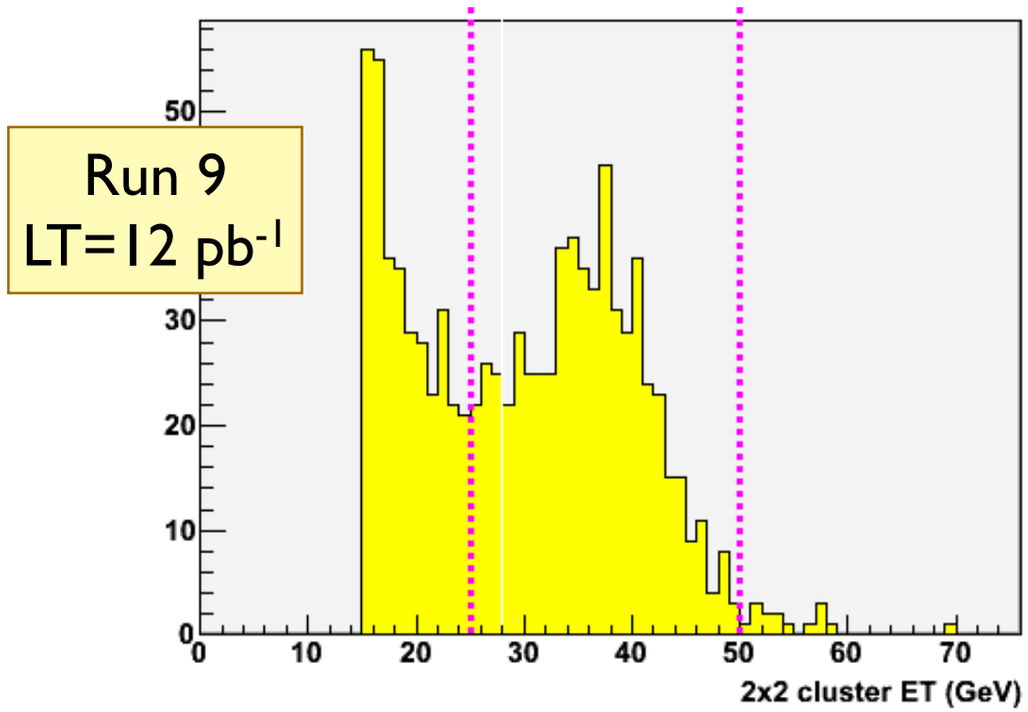
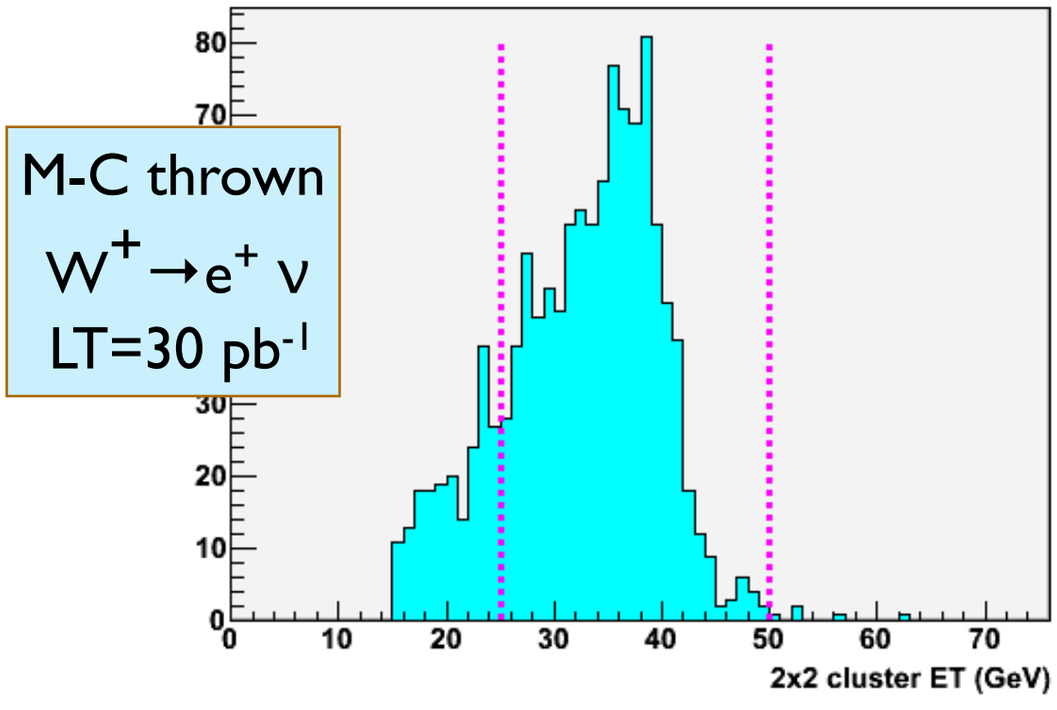


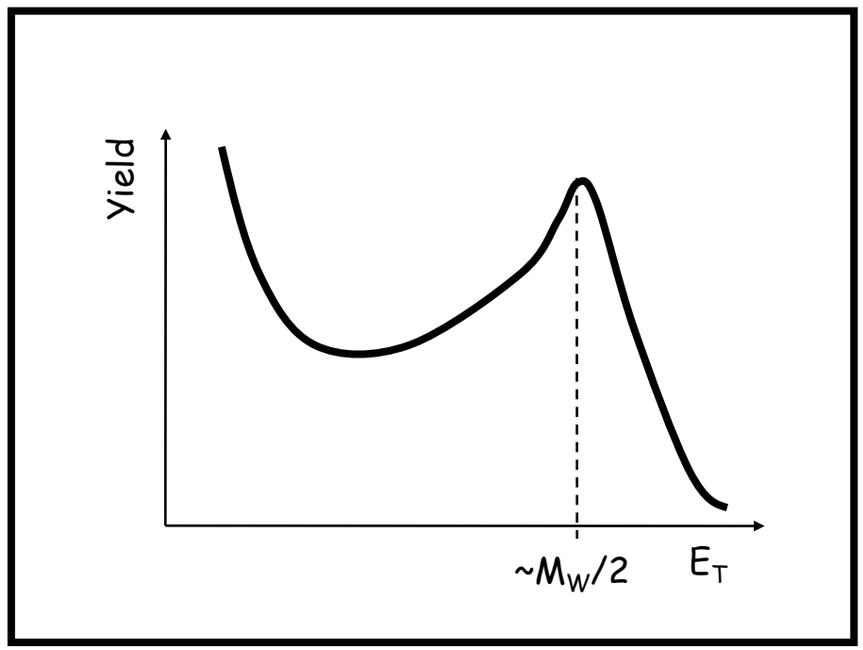


Data/MC Comparison

reco p+p → $W^{\pm}$ → $e^{\pm}$ ν (W± added)

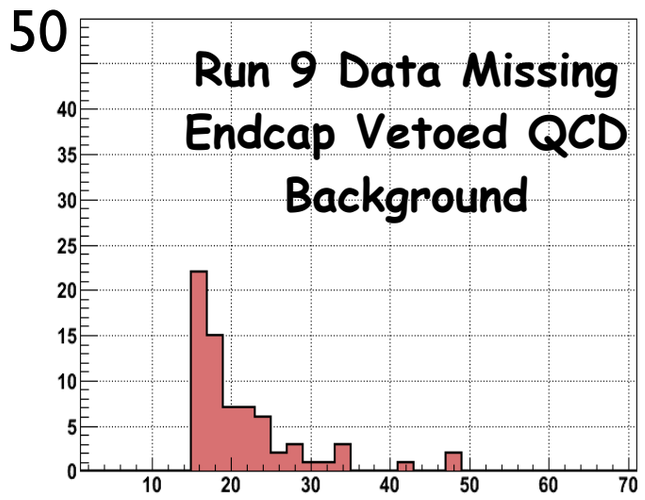


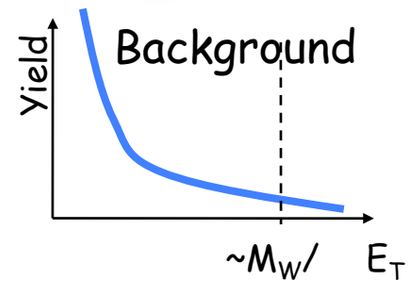


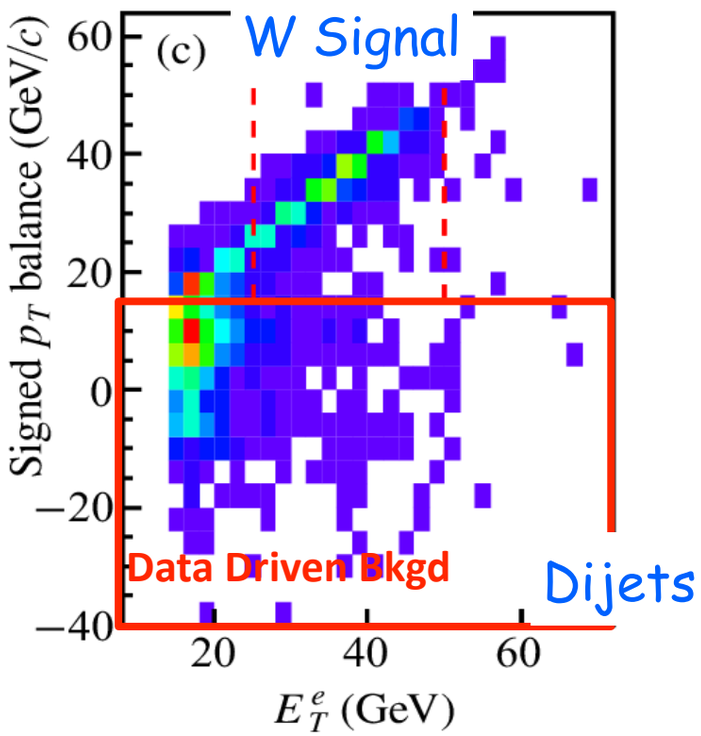


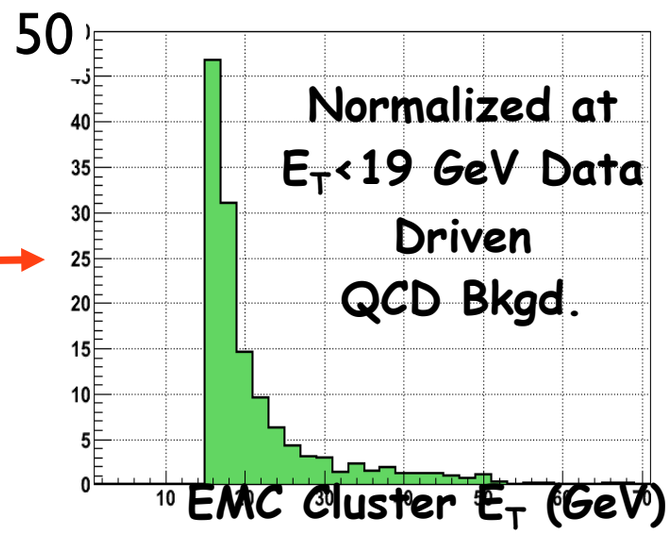
Extracting the W Signal

1. Run analysis with EEMC in veto cuts
2. Run analysis without EEMC in veto cuts
3. Subtract two raw signals









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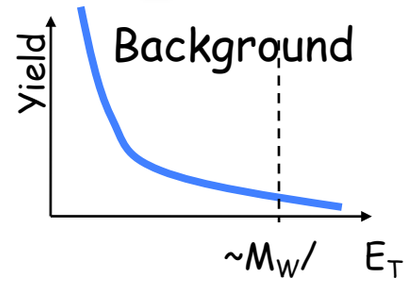
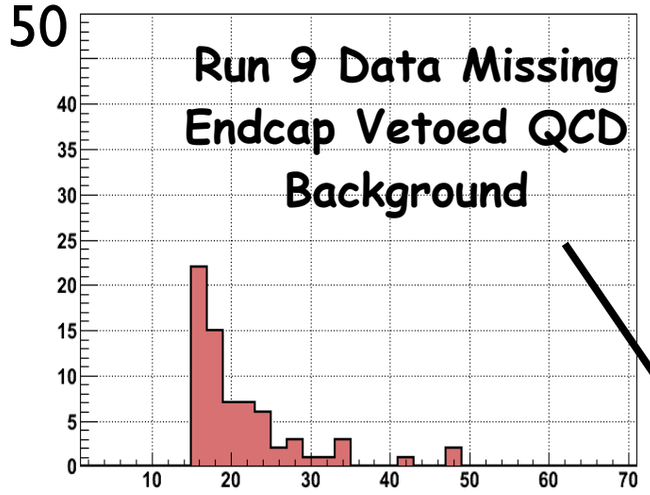
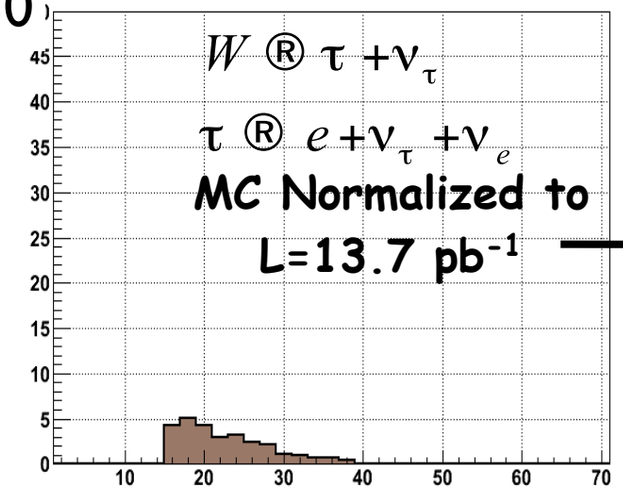
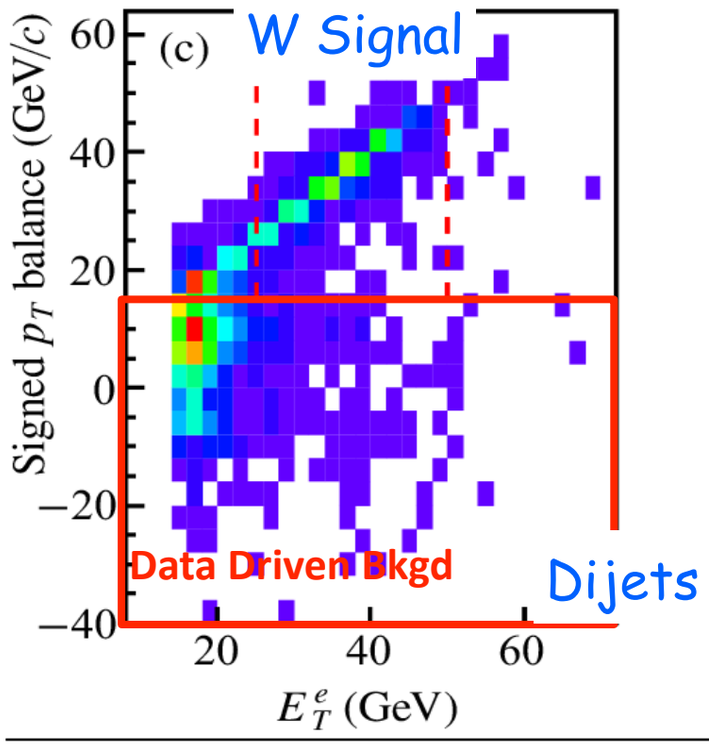
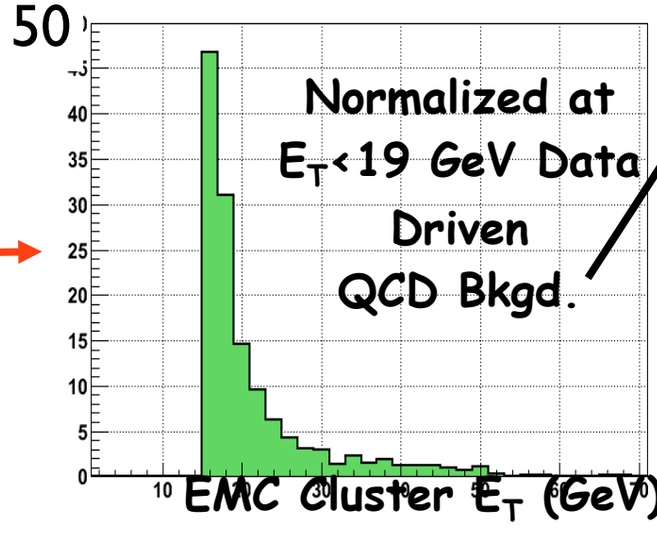


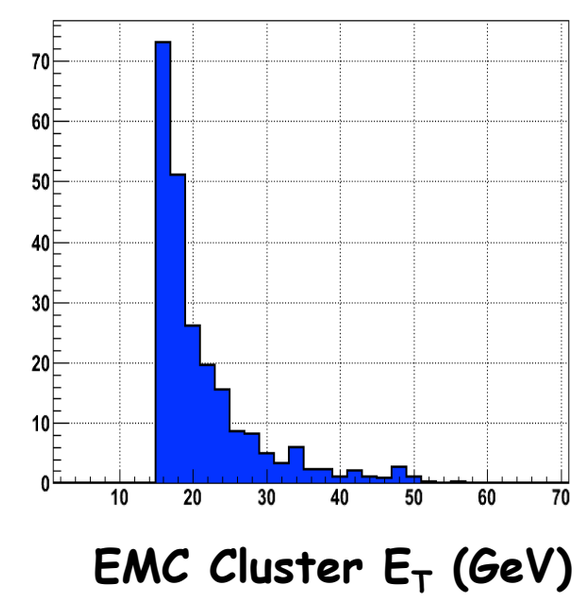


PYTHIA+GEANT MC

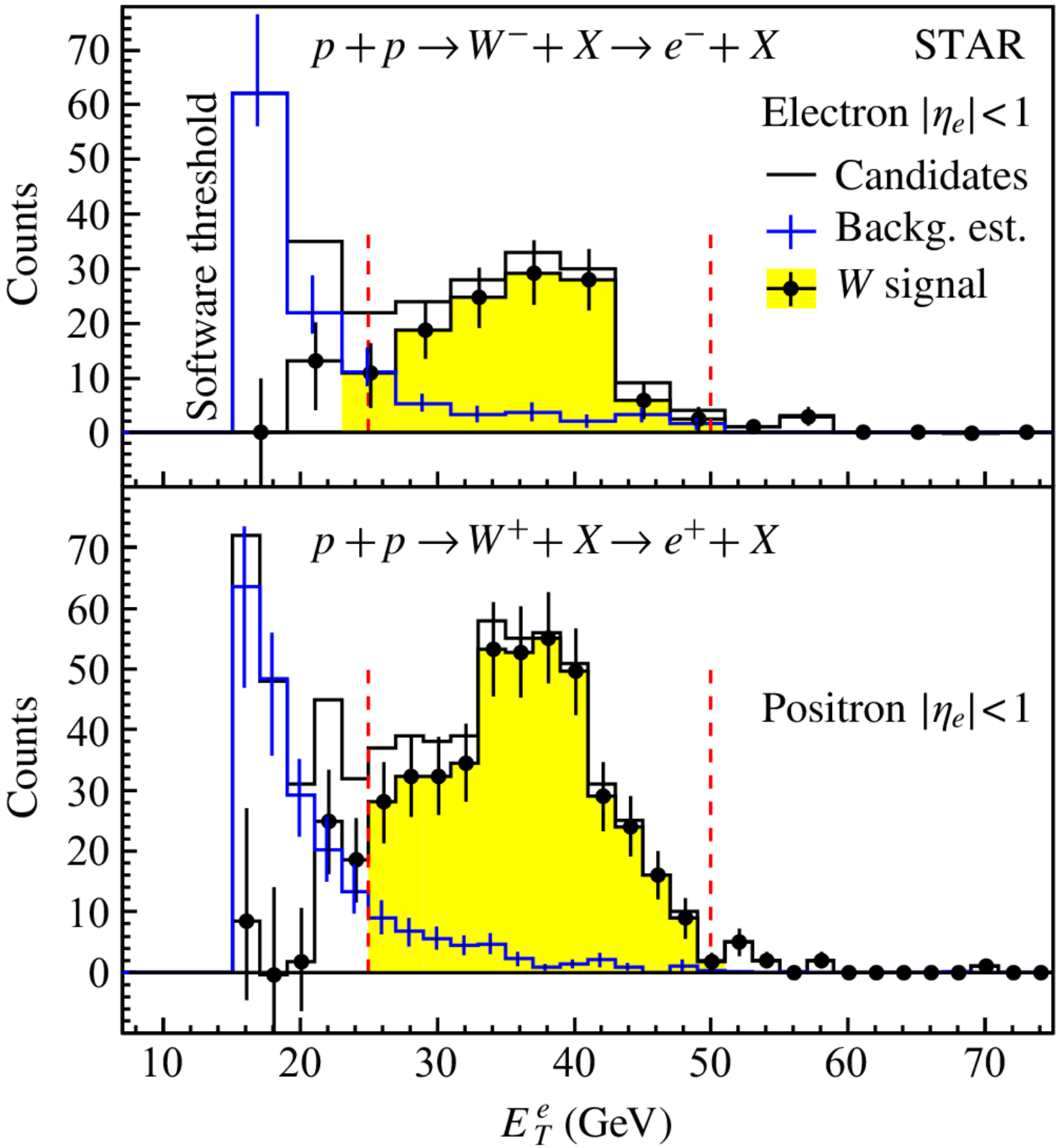








Reconstructed Jacobian Peak for W+/- Run 9



W Signal

– **"Jacobian Peak"**

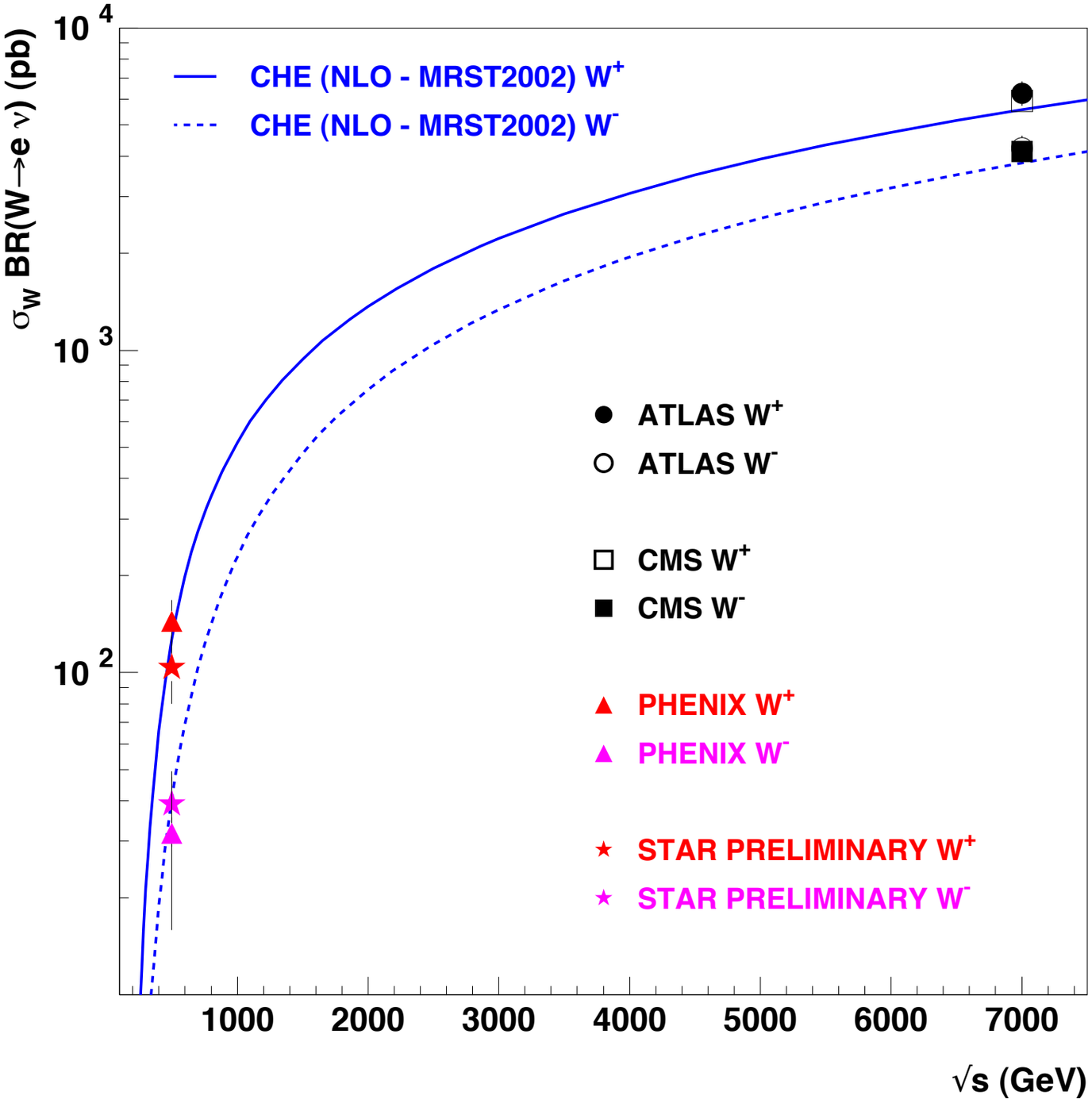
Background Estimation

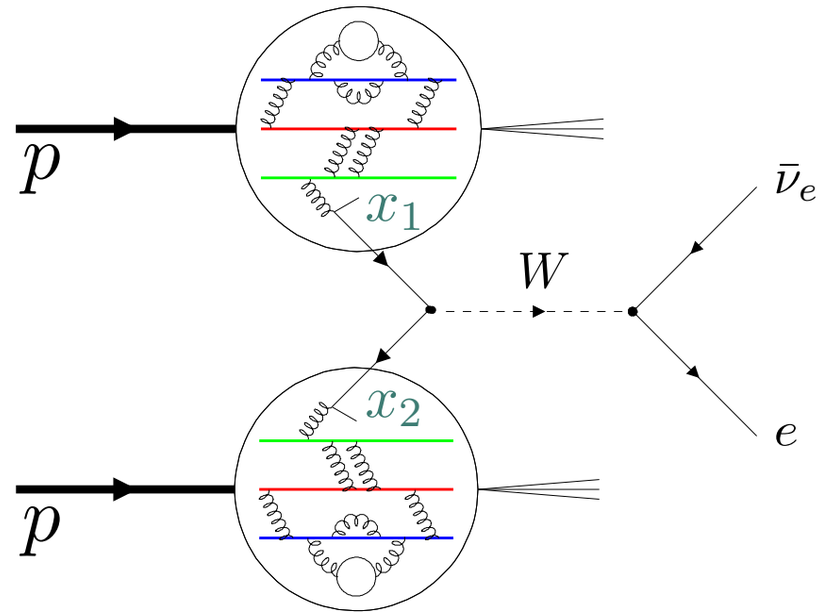
– **Electroweak**

– **QCD :**

- **Data-driven**

Measured W+/- cross section Run 9

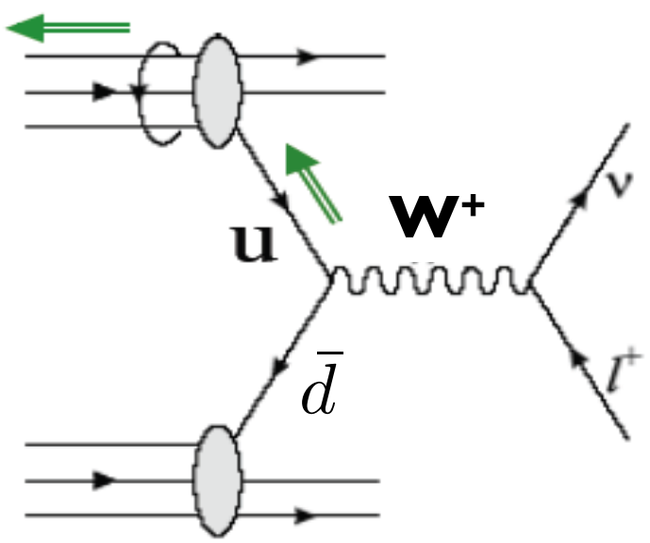




- Measured and theory evaluated cross-sections agree within uncertainties
- Theory calculations: Full NLO framework

u-quark polarization seen with 'naked eye'

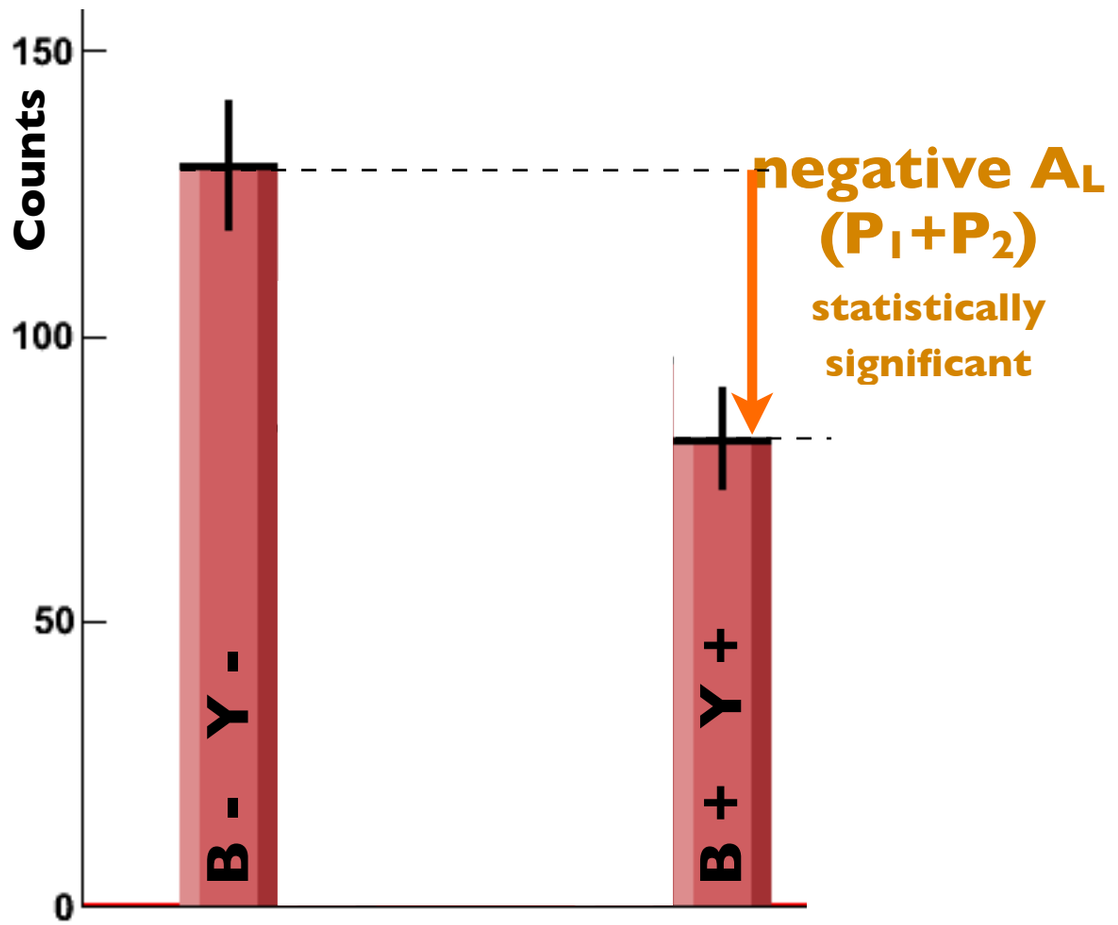
negative helicity



unpolarized proton

W+ yields integrated over |eta|<1

$$\mathcal{N}_{++} \simeq \sigma_0 \mathcal{L}_{++} [\, 1 + A_L P_1 + A_L P_2 \,]$$
$$\mathcal{N}_{--} \simeq \sigma_0 \mathcal{L}_{--} [\, 1 - A_L P_1 - A_L P_2 \,]$$



'naked eye' means big detector + 2 counters + a hand calculator

u-quark polarization seen with 'naked eye'

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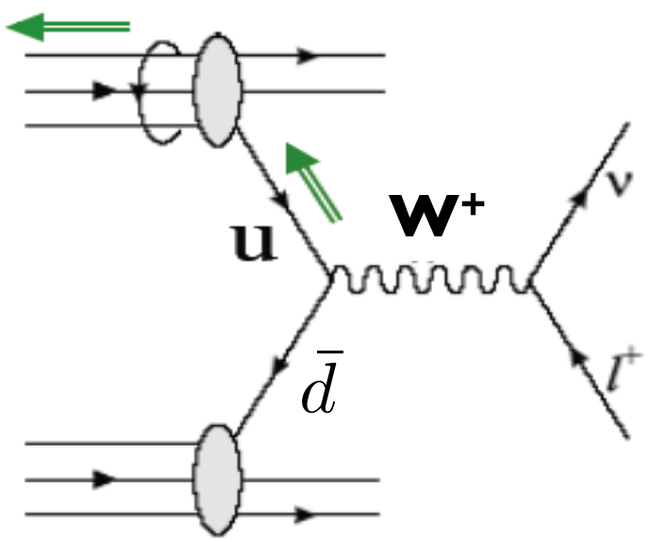

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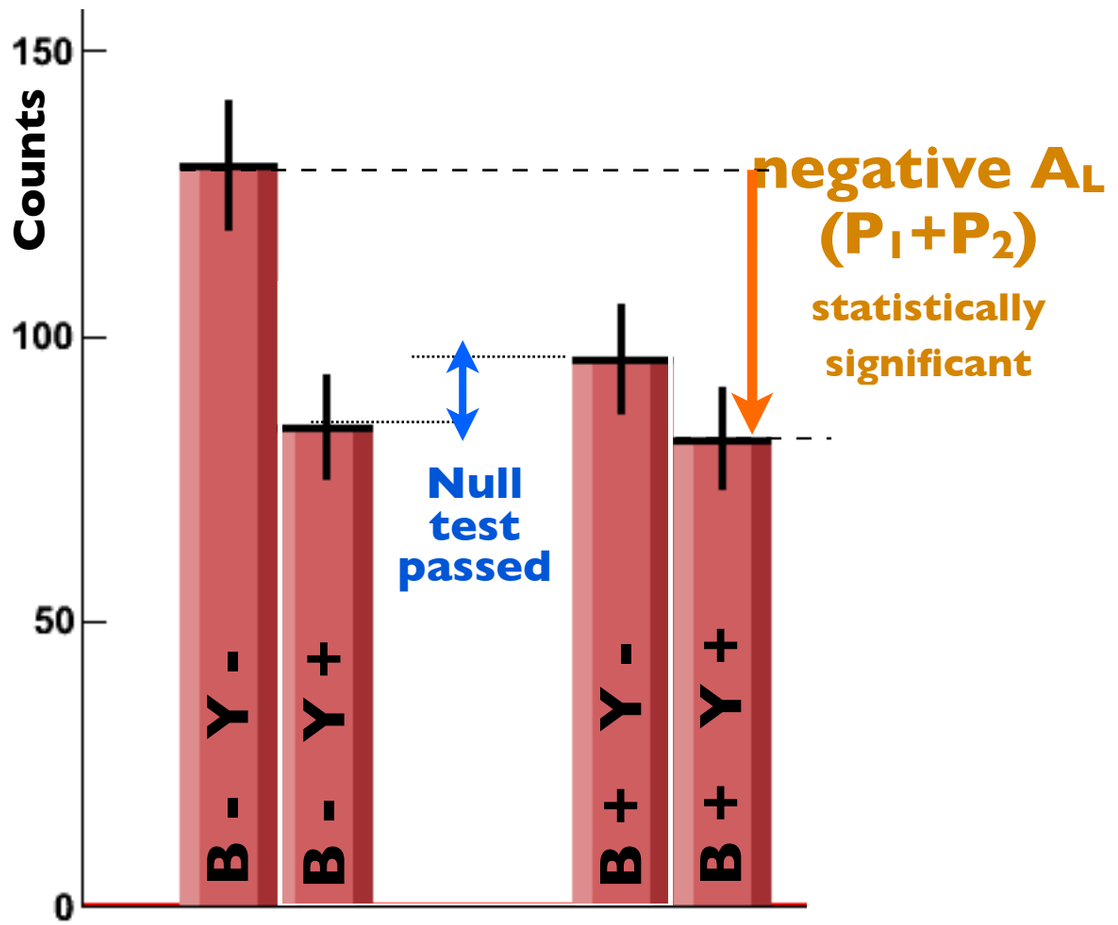

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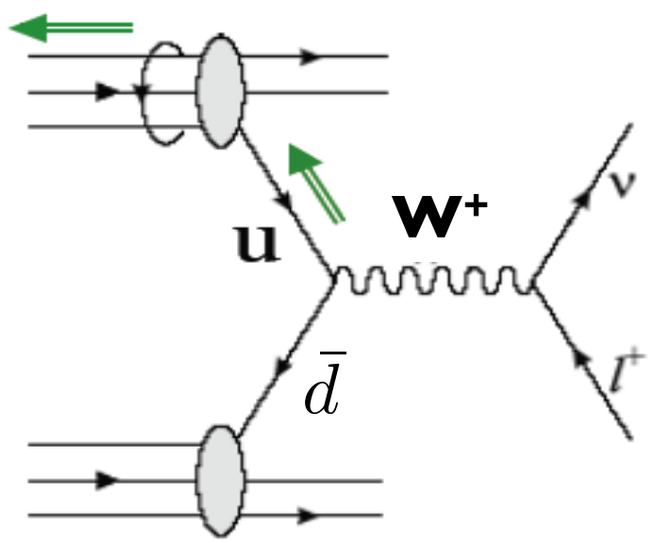

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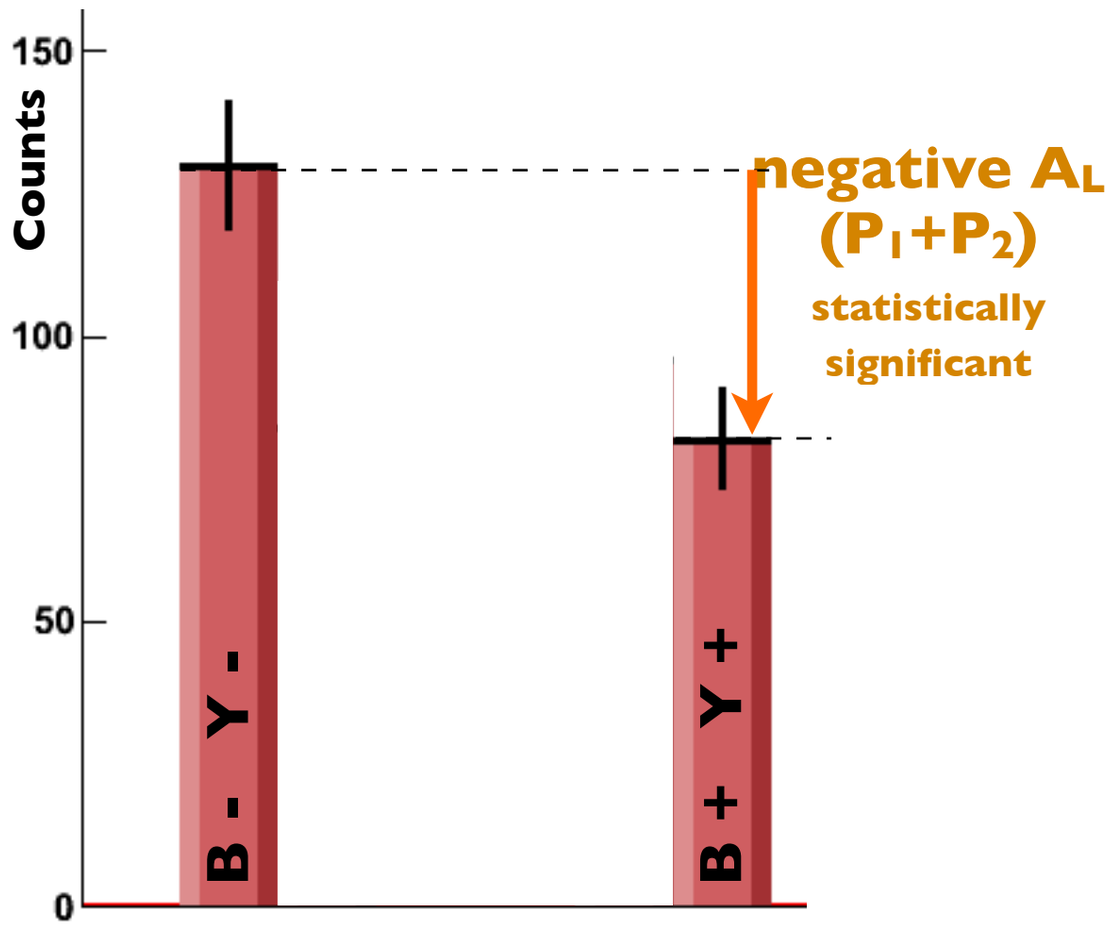
W+ yields integrated over |eta|<1

$$A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta\bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$$



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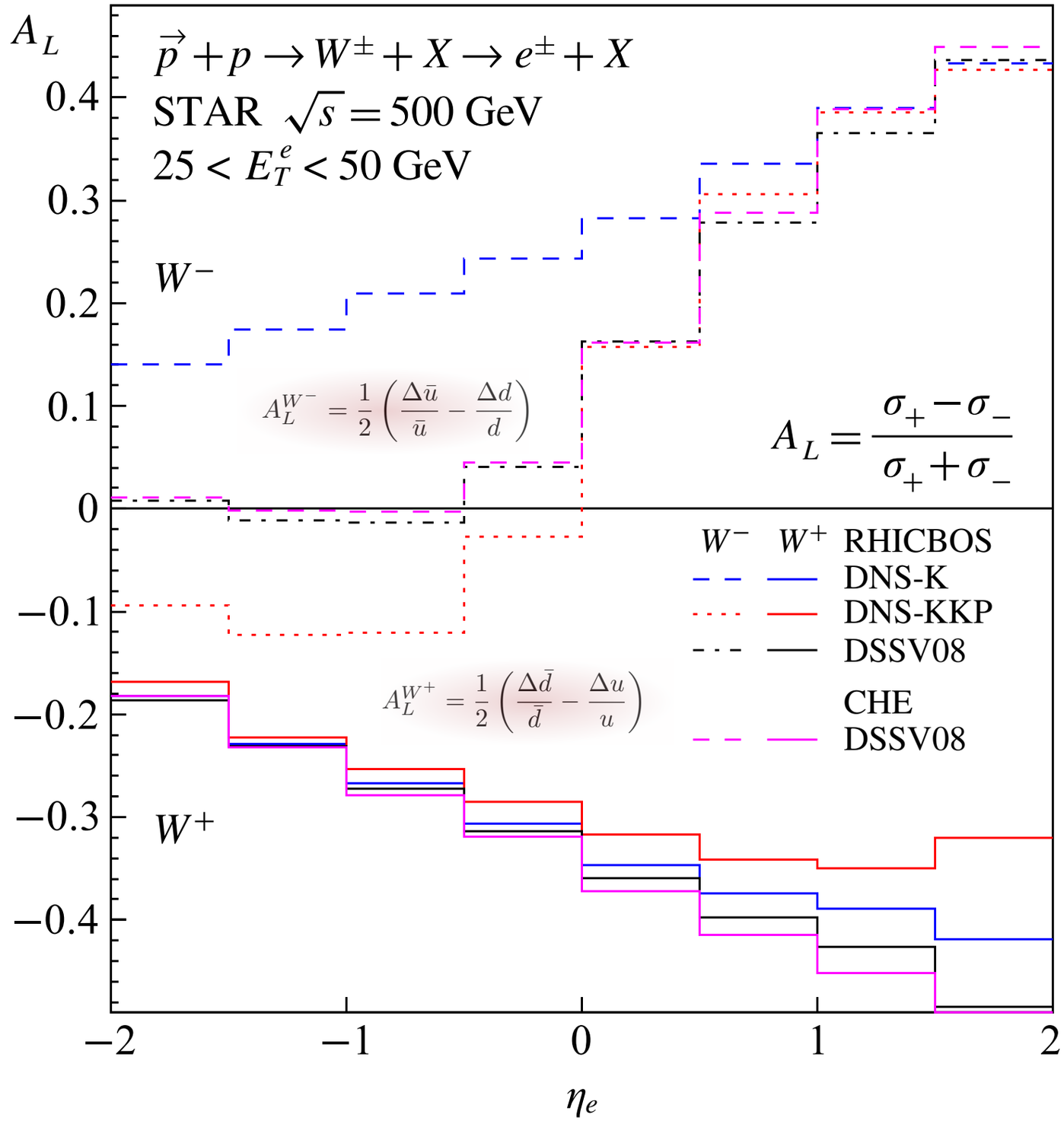
Measured W+/- Spin asymmetry A_L Run 9



Measured W+/- Spin asymmetry A_L Run 9

$$A_L^{W^-} = 0.14 \pm 0.19\ (\text{stat.}) \pm 0.02\ (\text{syst.}) \pm 0.01\ (\text{norm.})$$

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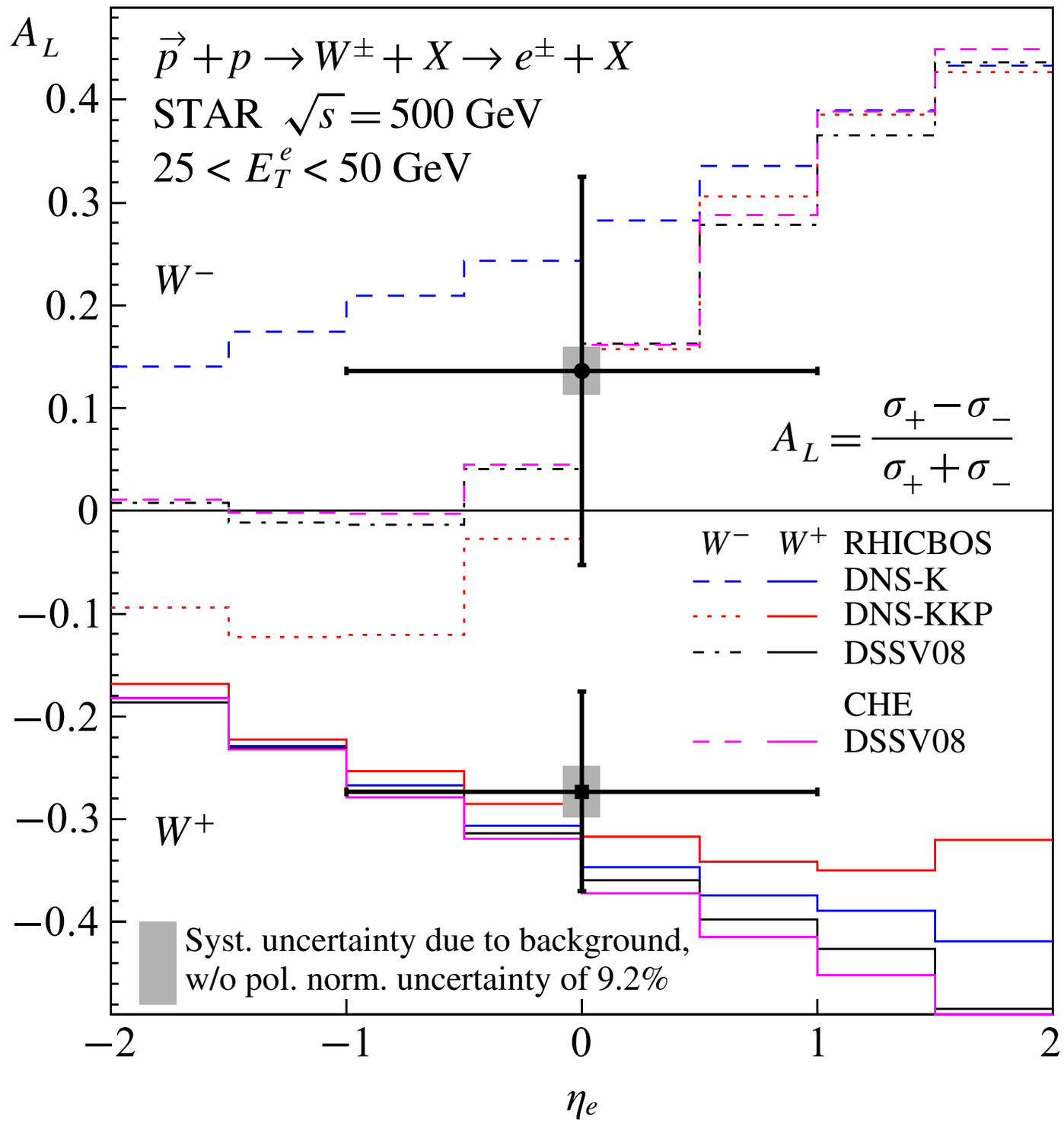

STAR Collaboration, PRL 106, 062002 (2011)

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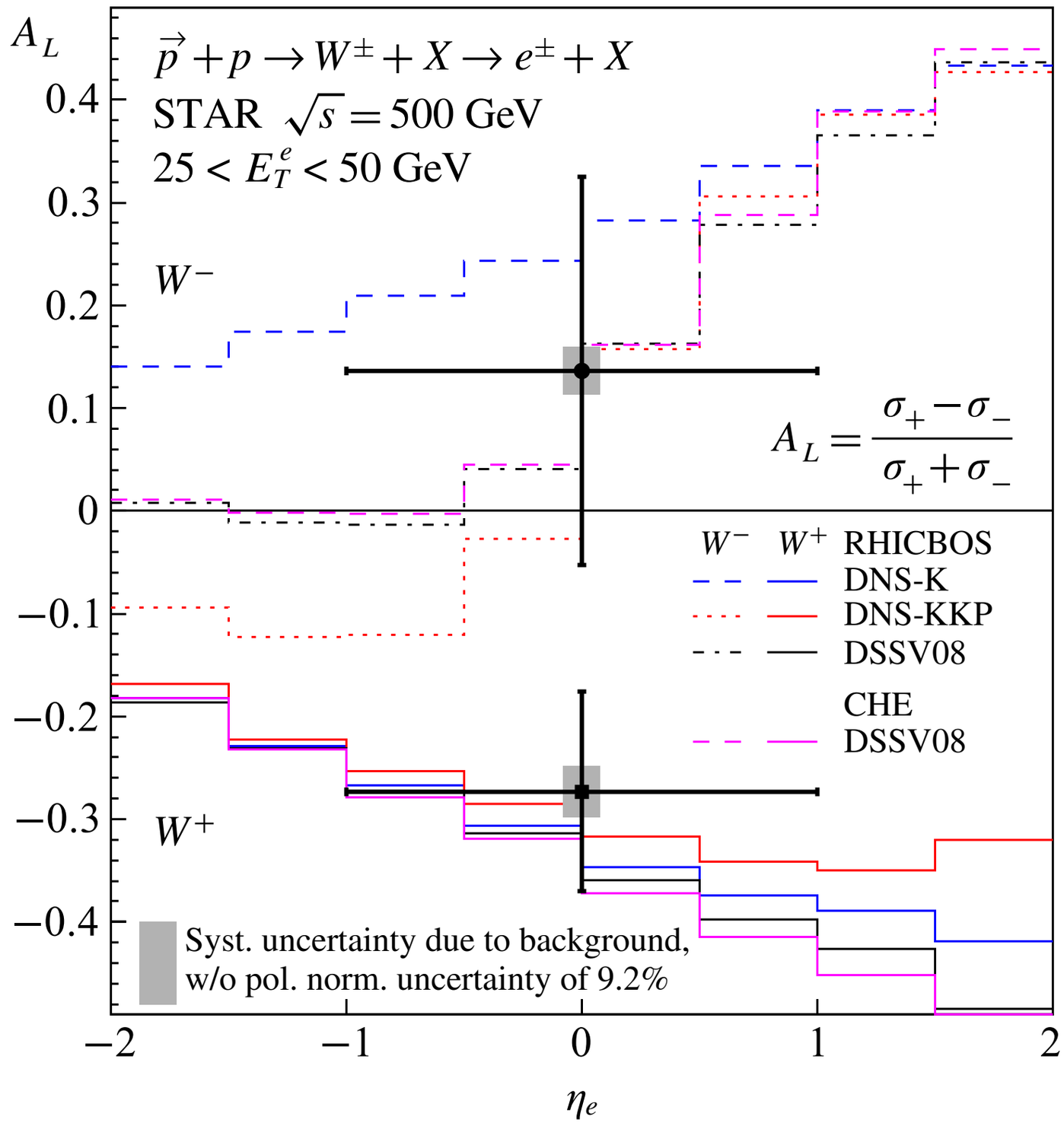
- $A_L(W^+)$ negative with a significance of ~3 σ
- $A_L(W^-)$ central value positive
- Measured asymmetries are in agreement with theory evaluations using polarized pdf's (DSSV) constrained by polarized DIS data

  ⇒ Universality of helicity distr. functions!



STAR Collaboration, PRL 106, 062002 (2011)

Projections for future W+/- A_L

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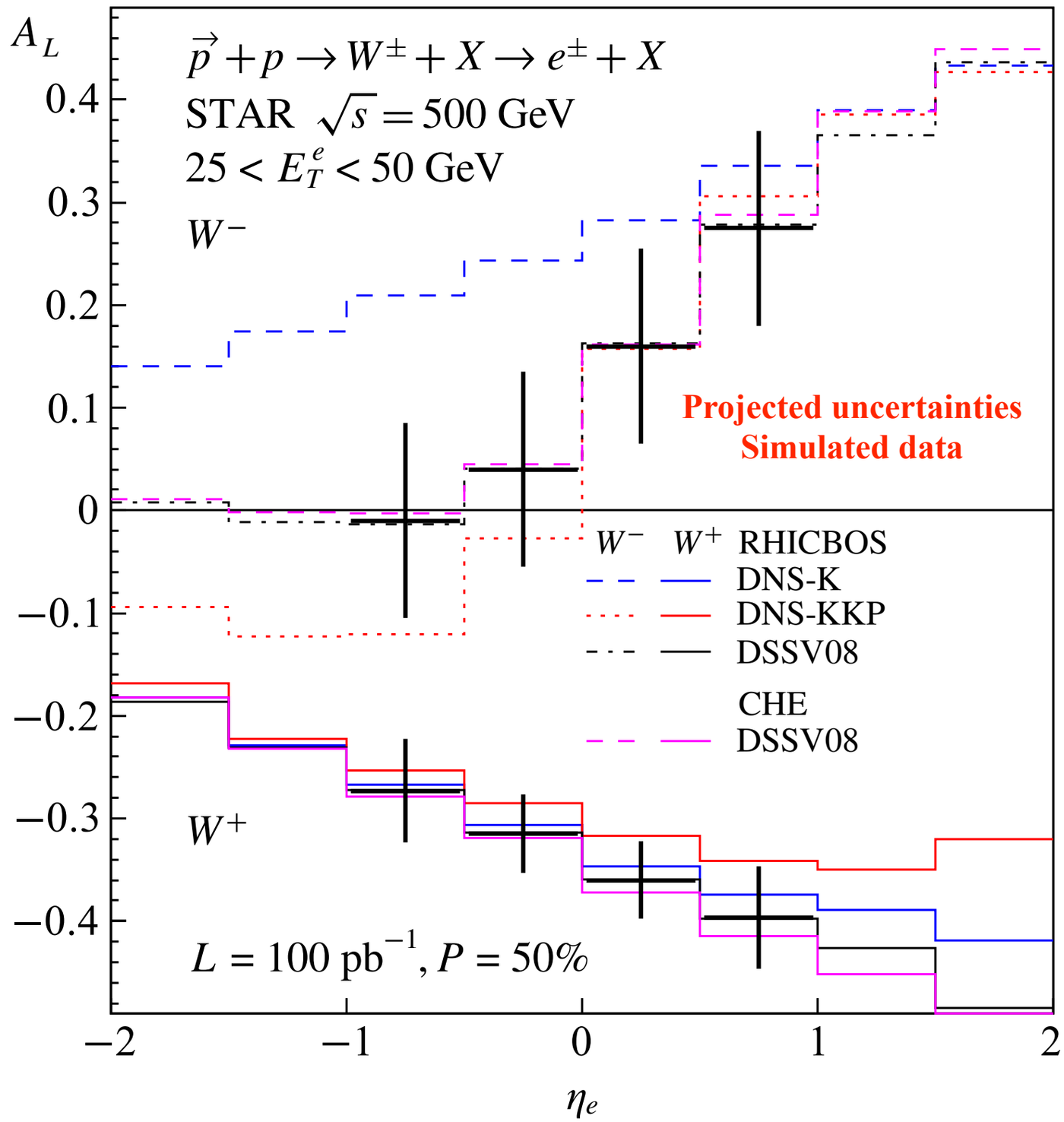

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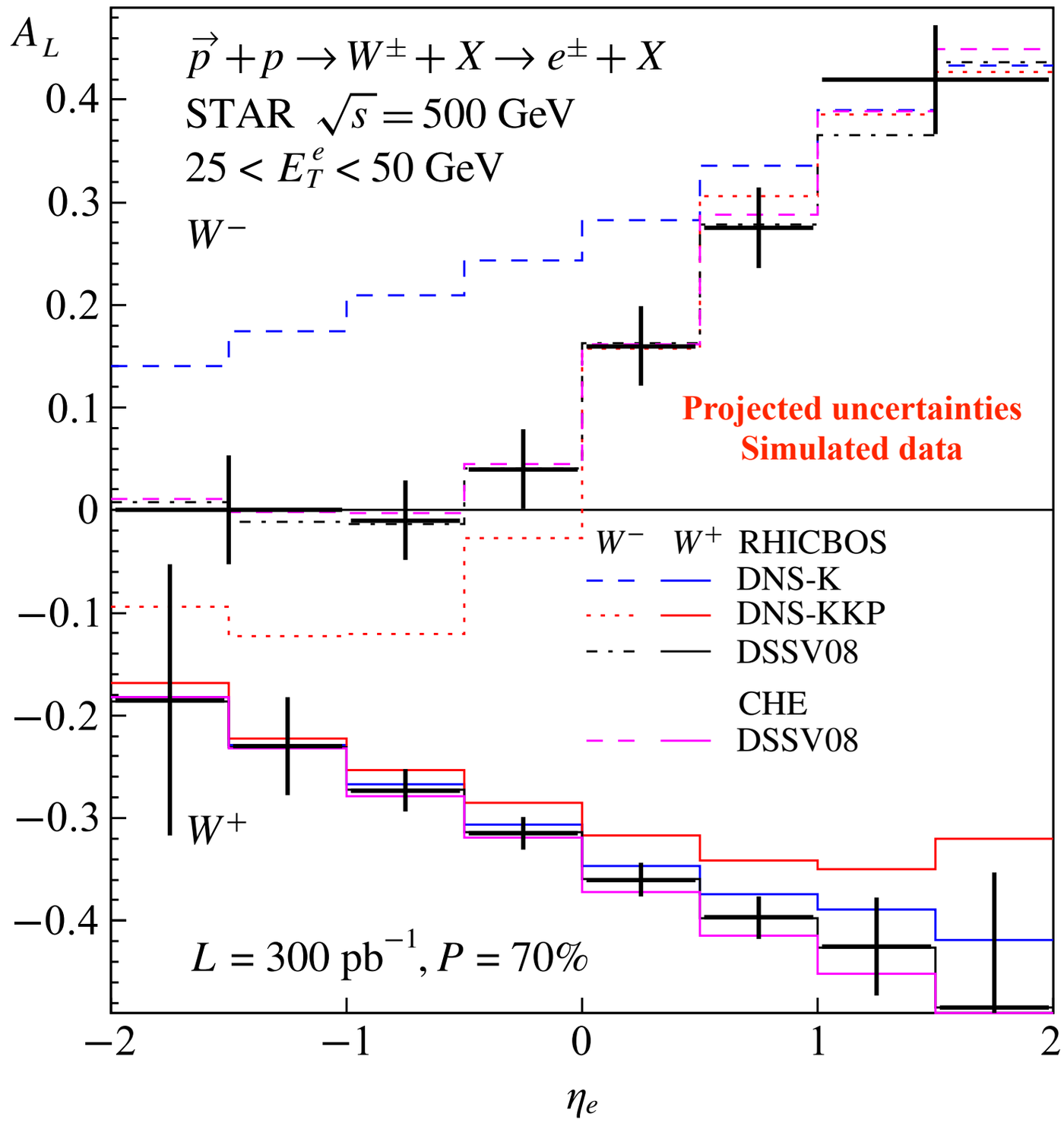
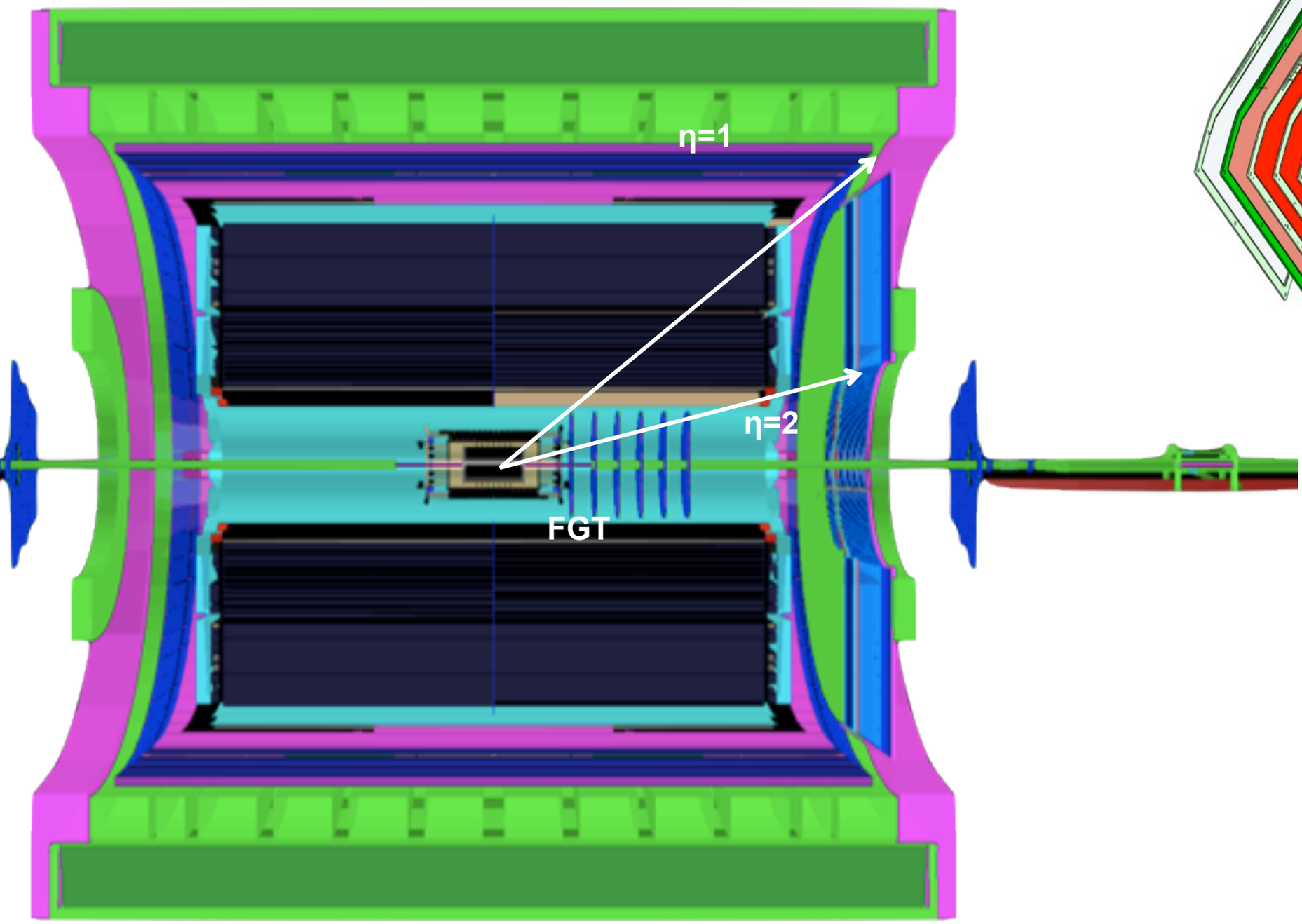
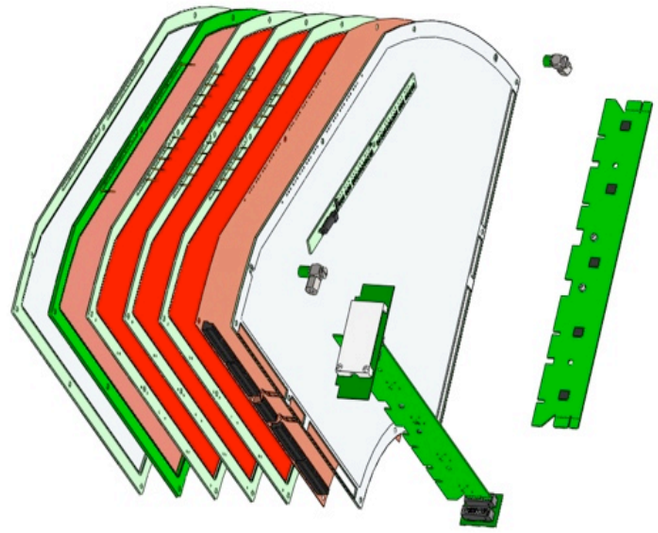


Forward tracking upgrade

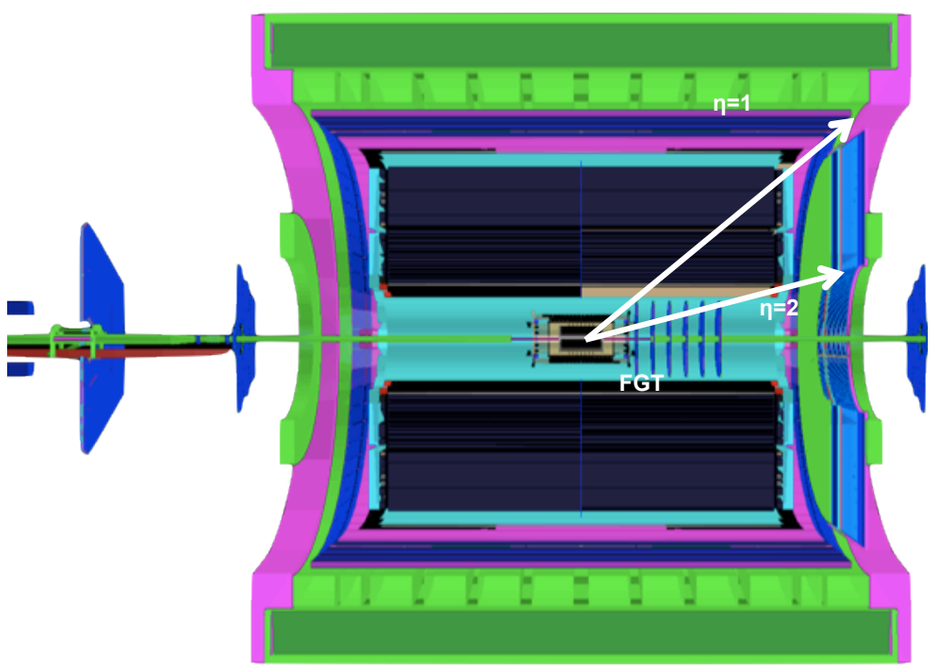


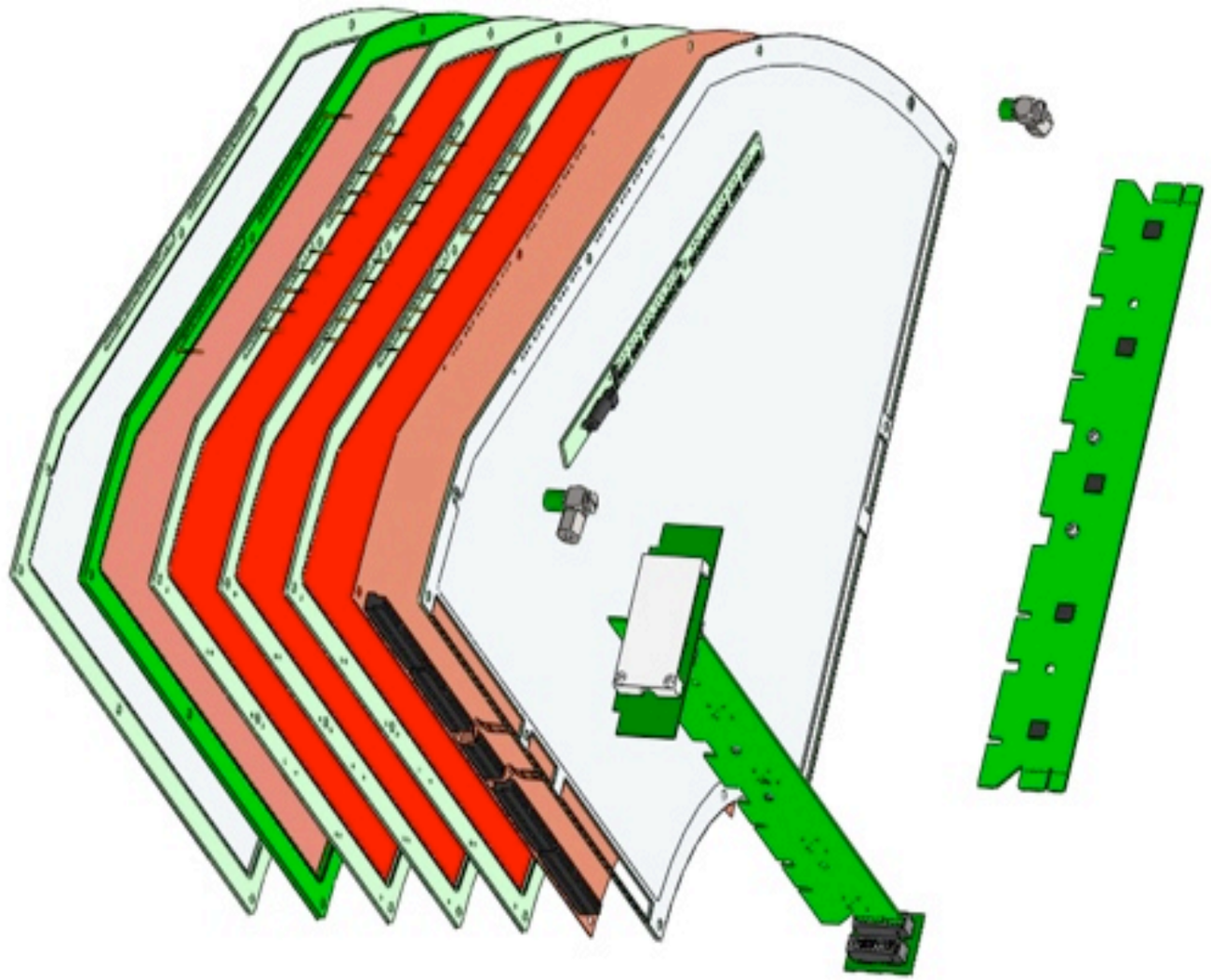


- FGT: 6 light-weight triple-GEM disks using industrially produced GEM foils (Tech-Etch Inc.)

Forward tracking upgrade

FGT quadrant



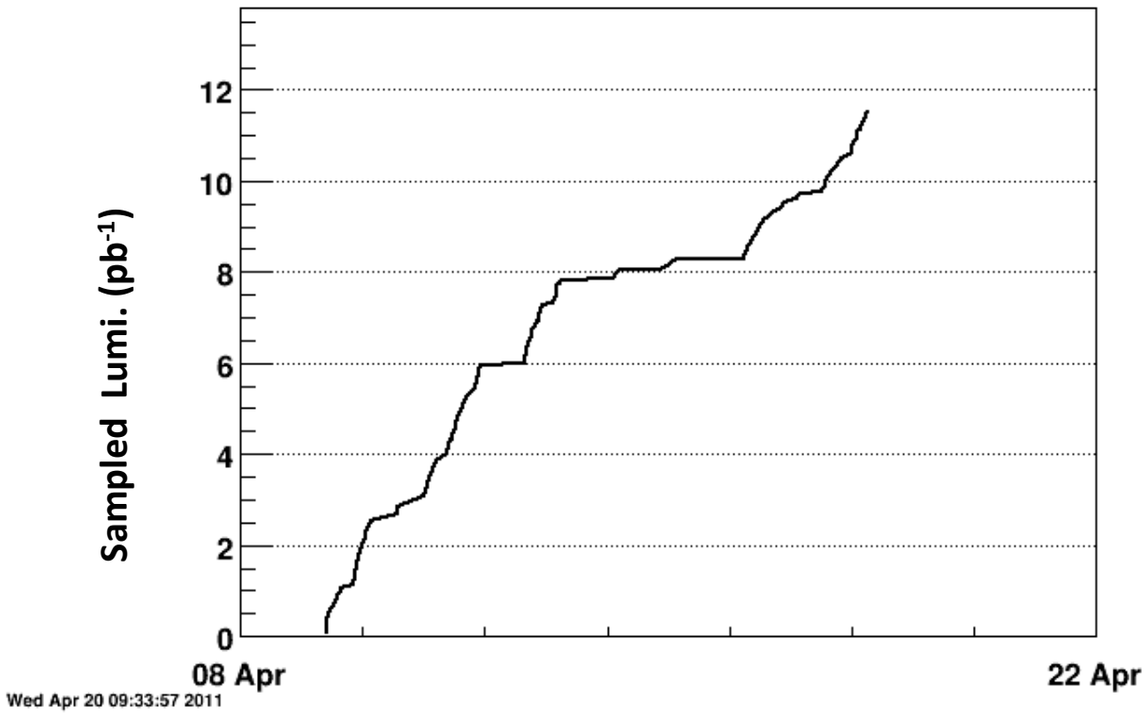


•FGT: 6 light-weight triple-GEM disks using industrially produced GEM foils (Tech-Etch Inc.)

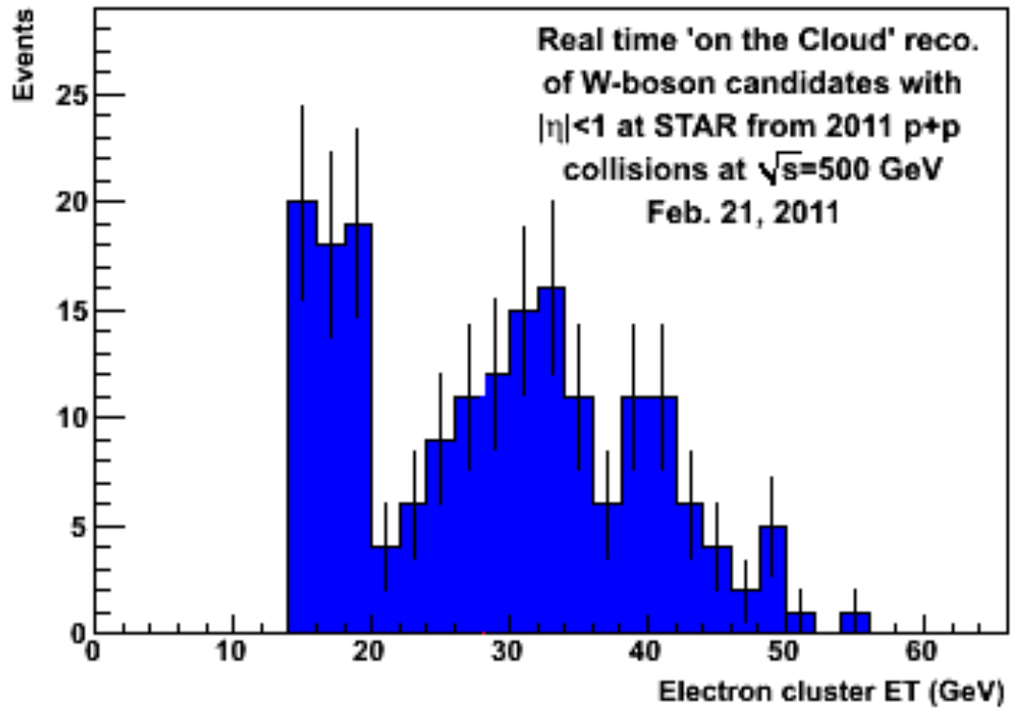
Run 11 Data Set (Spring 2011)

- Transverse Dataset (8 weeks of data taking):
  - W Trigger Sampled: L ~ 25 pb^{-1}, P ~50%
  - Possible feasibility studies for W A_N?
- Longitudinal Dataset (9 days of data taking):
  - W Trigger Integrated: L ~ 12 pb^{-1}, <P> ~ 43% (online)
  - Similar to Run 9 dataset with slight increase in polarization

Run 11 Longitudinal W Trigger



Run 11 "Online"Analysis: L~3.5 pb^{-1}



Summary

- Run 9: First observation of W production at STAR
  First collision of polarized proton beams at $\sqrt{s}$ = 500GeV (P~40% / L~14pb-1)
  W± Cross-section and Parity violating single-spin asymmetry measurement

- Critical analysis aspects:
  Charge-sign discrimination at high pT
  Rejection and treatment of QCD background

- W A_L paper published, W cross section paper in preparation

- Forward tracking upgrade, large luminosity & polarization
  allow STAR to access helicity of the sea quarks