The STAR W Physics Program - Status and Future Plans -

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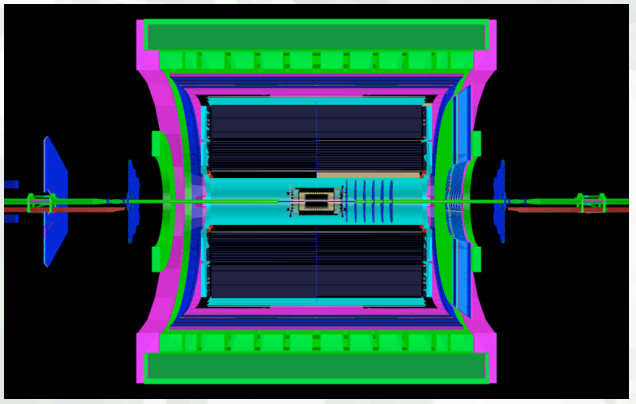
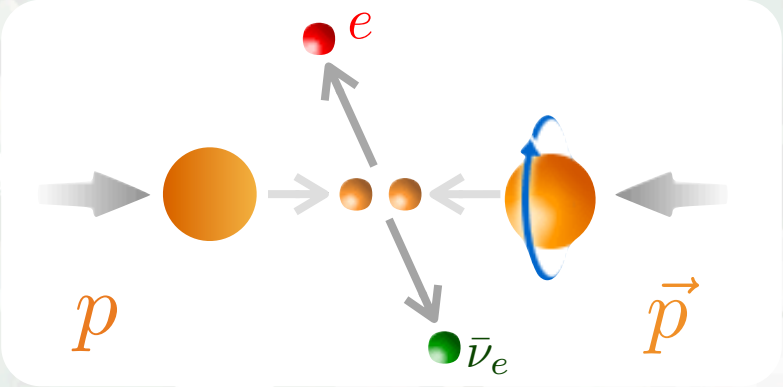
(On behalf of the STAR Collaboration)



Outline

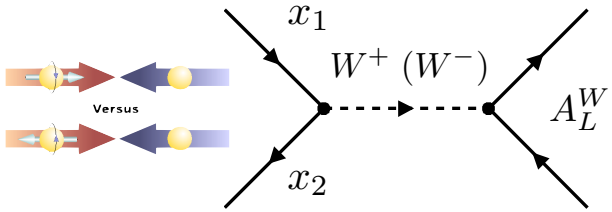
- Introduction
- Run 9 Lessons and Expectations: STAR W Results
- The STAR Forward GEM Tracker
  - Layout
  - Technical realization
  - Schedule
- Future Plans - STAR W Program
  - Plans
  - Projections of future mid-rapidity measurements
  - Projections of future forward/ backward rapidity measurements
- Summary and Outlook



Introduction

- STAR W program in e-decay mode at mid-rapidity and forward/backward rapidity

$u\,/\Delta u\;(d\,/\Delta d)$



$\Delta\bar{d}\,/\bar{d}\;(\Delta\bar{u}\,/\bar{u})$

$\nu_e\;(\bar{\nu}_e)$

$e^+\;(e^-)$

$$A_L^W = \frac{1}{P}\frac{N^+(W) - N^-(W)}{N^+(W) + N^-(W)}$$

$$y_l = y_W + \underbrace{\frac{1}{2}\ln\frac{1+\cos\theta^*}{1-\cos\theta^*}}_{y_l^*}$$

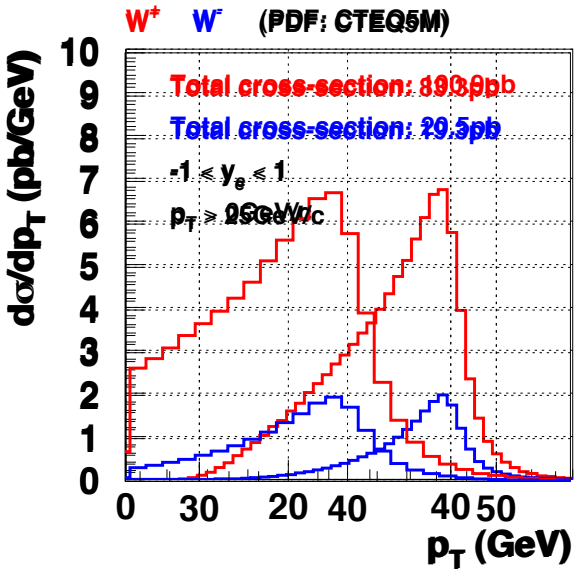
$$p_T = p_T^* = \frac{M_W}{2}\sin\theta^*$$

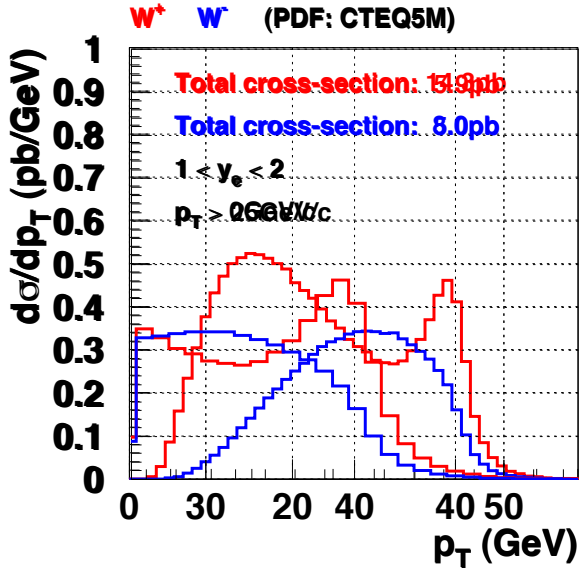
$$x_1 = \frac{M_W}{\sqrt{s}}e^{y_W}$$

$$x_2 = \frac{M_W}{\sqrt{s}}e^{-y_W}$$

$$\frac{M_W}{\sqrt{s}} = 0.16$$

- Key signature: High p_T lepton (e^-/e^+)(Max. $M_W/2$) - Selection of W^+/W^- : Charge sign discrimination of high p_T lepton
- Required: Lepton/Hadron discrimination



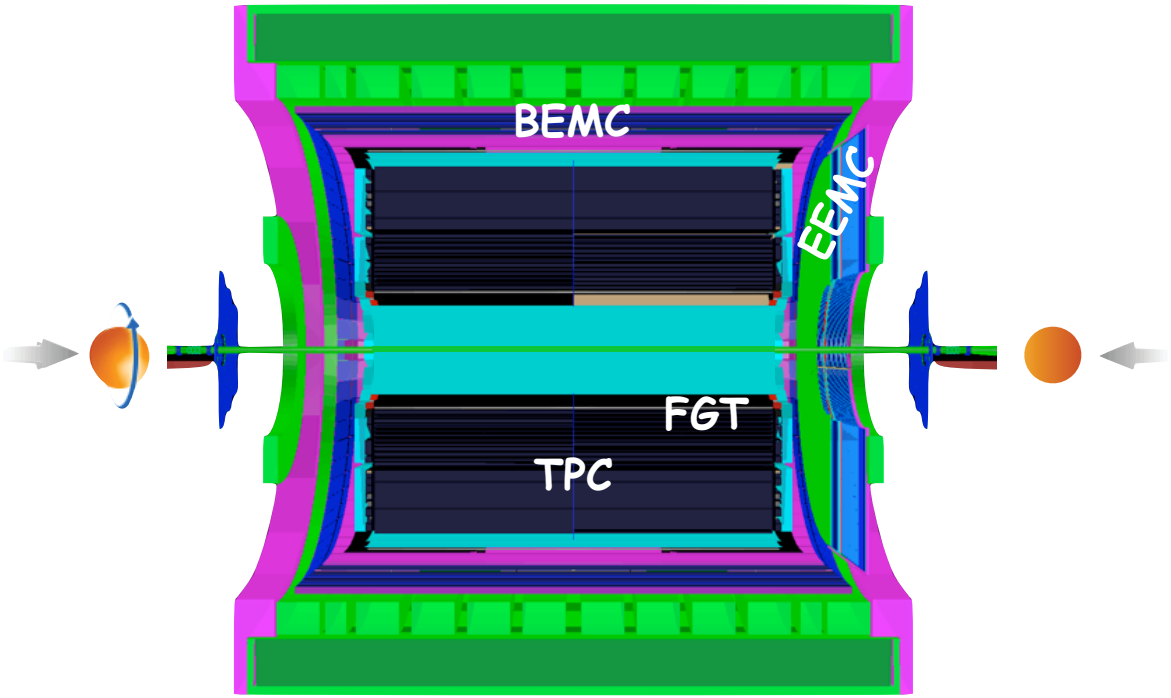


Total (√s=500GeV) σ(W⁺)=135pb and σ(W⁻)=42pb

Introduction

- STAR Overview

First collisions of polarized proton beams at STAR at $\sqrt{s}$ = 500GeV: Run 9 (P~40% / L~14pb^{-1})

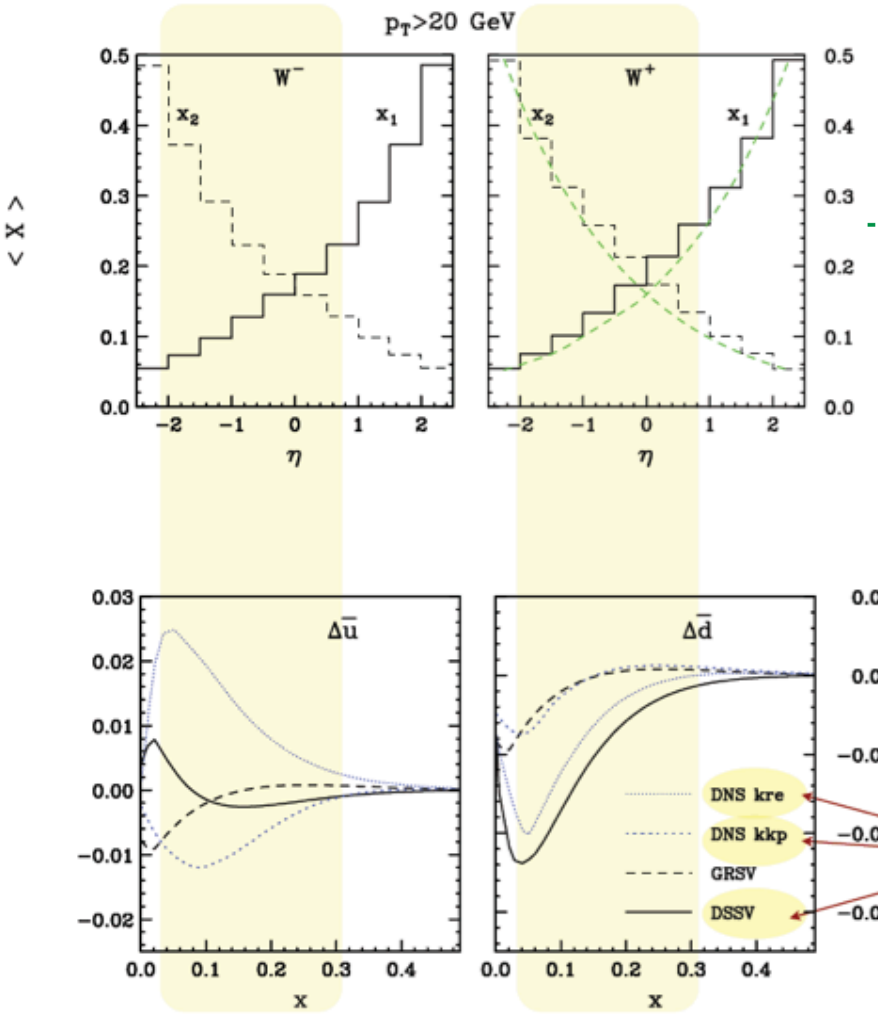


- Calorimetry system with 2π coverage: BEMC (-1<η<1) and EEMC (1<η<2)
- TPC: Tracking and particle ID
- ZDC: Relative luminosity and local polarimetry (500GeV)
- BBC: Relative luminosity and Minimum bias trigger

- STAR Mid-rapidity W program (|η|<1): BEMC and TPC
- STAR Forward/Backward W program (1<|η|<2): EEMC and TPC / FGT (Installation in summer 2011)

Introduction

- W boson kinematics relevant for STAR rapidity acceptance
  - Leptonic rapidity inherits relation to mean x
  - Forward rapidity:
    - $\eta > 0$
    - $\langle x_1 \rangle$ larger than $\langle x_2 \rangle$
  - Backward rapidity:
    - $\eta < 0$
    - $\langle x_1 \rangle$ less than $\langle x_2 \rangle$
  - Mid-rapidity:
    - $\eta \sim 0$
    - $\langle x_1 \rangle$ similar to $\langle x_2 \rangle$



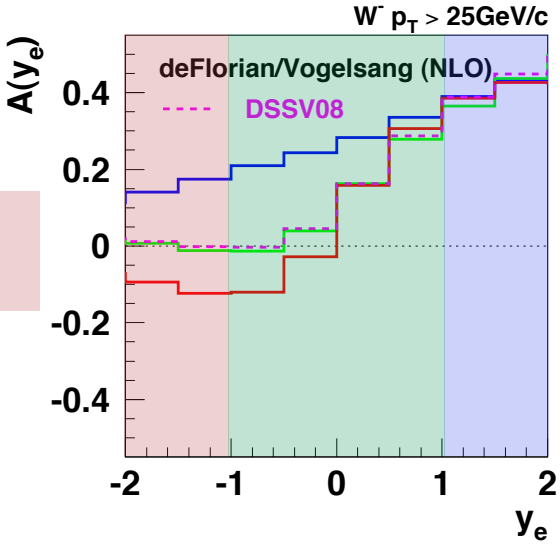
$$< X_{1,2} > \simeq \frac{M_W}{\sqrt{S}} e^{[\mp \eta/2]}$$

D. de Florian, LBL, RHIC Spin Workshop, November 2009

Introduction

- A_L behavior for STAR mid-rapidity and forward/backward rapidity region

$$A_L^{W^-} = \frac{\Delta\bar{u}}{\bar{u}} \qquad x_1 \ll x_2$$



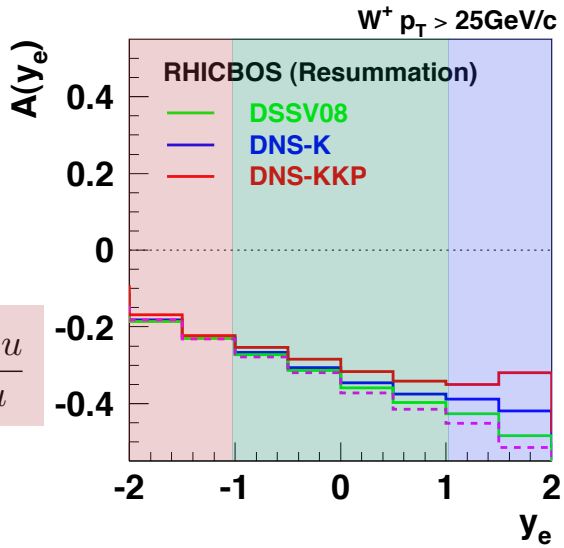
$$A_L^{W^-} = -\frac{\Delta d}{d} \qquad x_1 \gg x_2$$

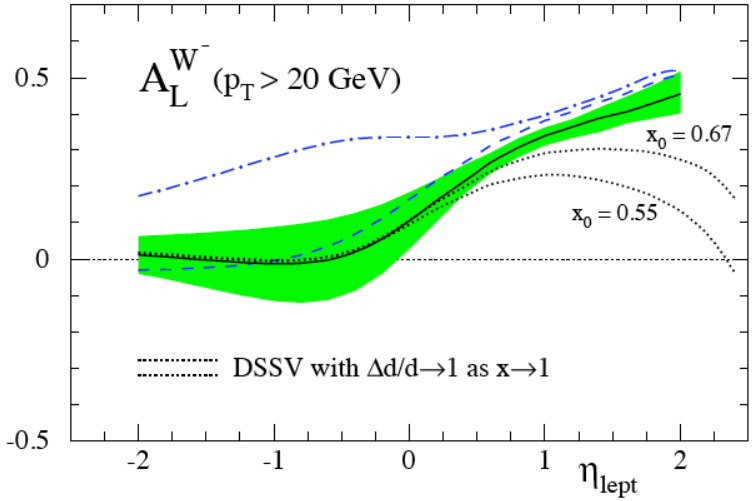
$$A_L^{W^-} = \frac{1}{2}\left(\frac{\Delta\bar{u}}{\bar{u}} - \frac{\Delta d}{d}\right) \qquad x_1 = x_2$$

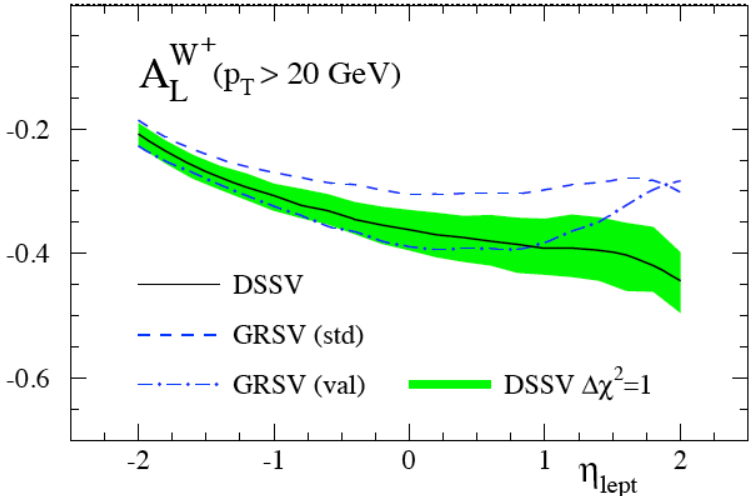
$$A_L^{W^+} = \frac{1}{2}\left(\frac{\Delta\bar{d}}{\bar{d}} - \frac{\Delta u}{u}\right)$$

$$A_L^{W^+} = \frac{\Delta\bar{d}}{\bar{d}} \qquad x_1 \gg x_2$$

$$A_L^{W^+} = -\frac{\Delta u}{u} \qquad x_1 \ll x_2$$







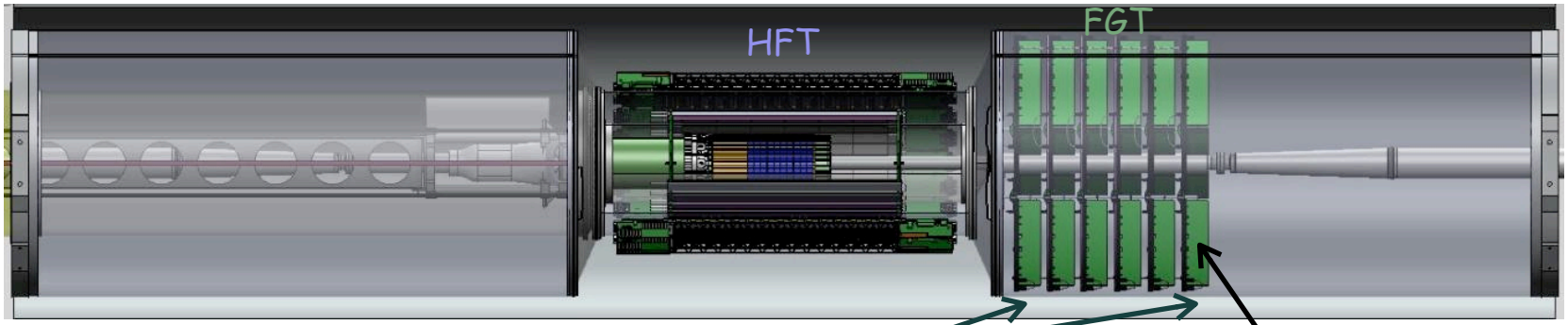
Calculations:

1) RHICBOS: P.M. Nadolsky and C.-P. Yuan, Nucl. Phys. B666 (2003) 31.

2) deFlorian / Vogelsang: D. deFlorian, private communications.

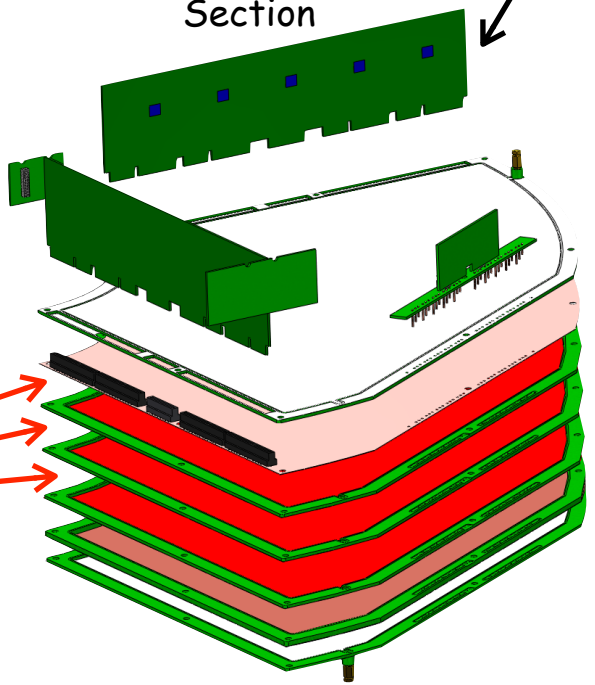
The STAR Forward GEM Tracker

- FGT layout

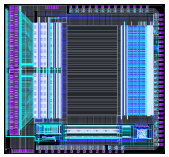


- FGT: 6 light-weight triple-GEM disks using industrially produced GEM foils (Tech-Etch Inc.)
- New mechanical support structure
- Expected installation: Summer 2011

FGT Quarter Section

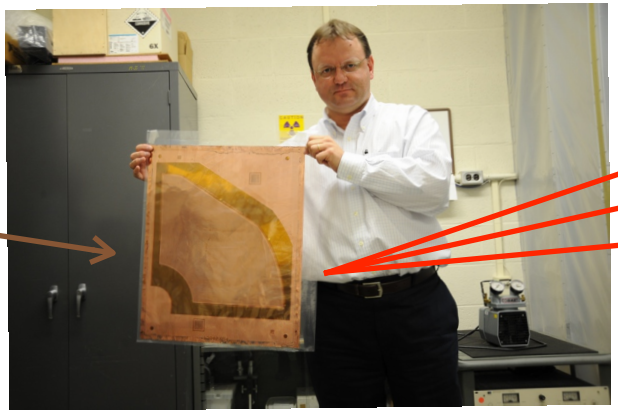


APV module



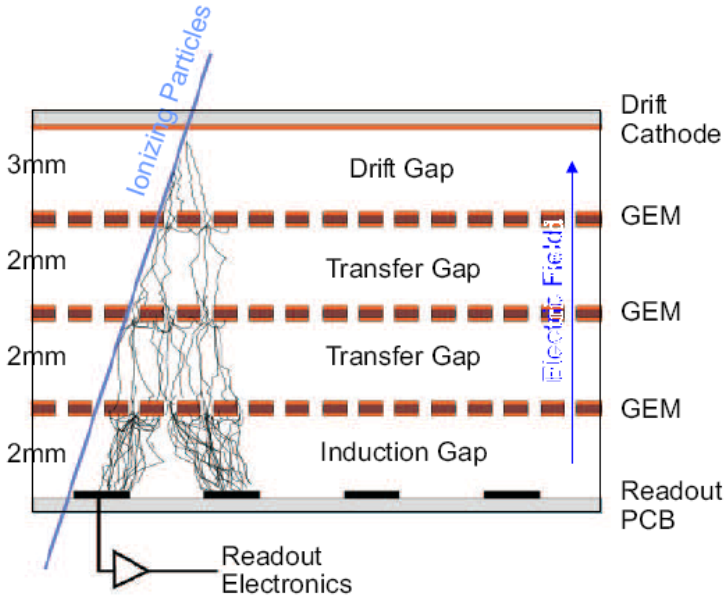
APV chip

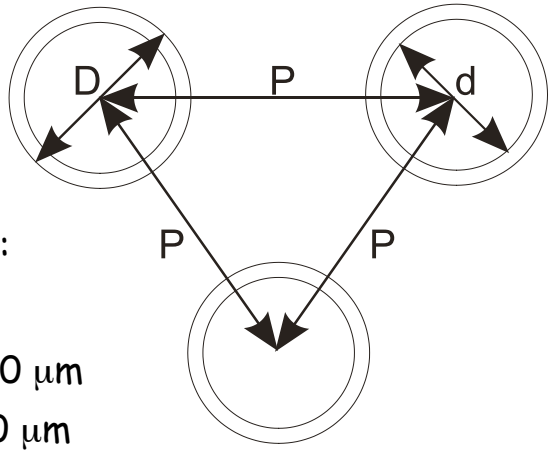
FGT GEM foil



The STAR Forward GEM Tracker

- GEM technology
  - Example: Triple-GEM application at COMPASS
  - Advantages:
    - Reliable (COMPASS, multi-year experience)
    - High gas amplification (Multiple GEMs: up to ~10^6)
    - Fast (< 20 ns FWHM, rate capability up to 10^5 Hz/mm)
    - Low mass (50μm Kapton + 10μm Cu; Thin low Z read-out plane)
    - Good spacial resolution (1D and 2D) (~60μm)
    - Simple construction and in-expensive





Standard GEM foil hole layout:

- Pitch (P) 140 μm
- Outer diameter (D) 70 μm
- Inner diameter (d) 50 μm

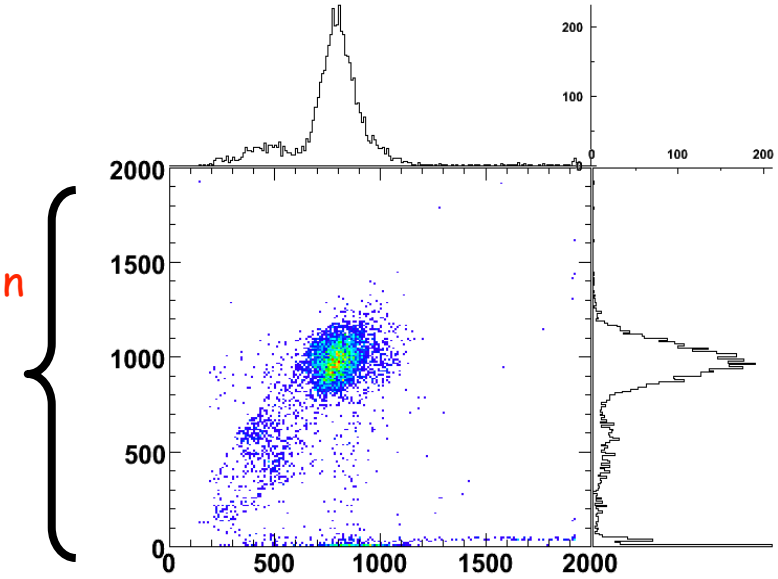
F. Sauli, Nucl Instr. and Meth. A386 (1997) 531.

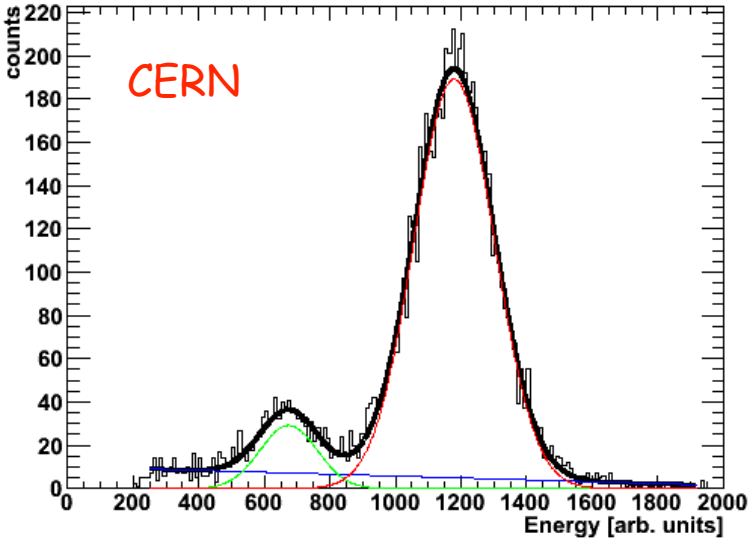
C. Altunbas et al., Nucl Instr. and Meth. A490 (2002) 177.

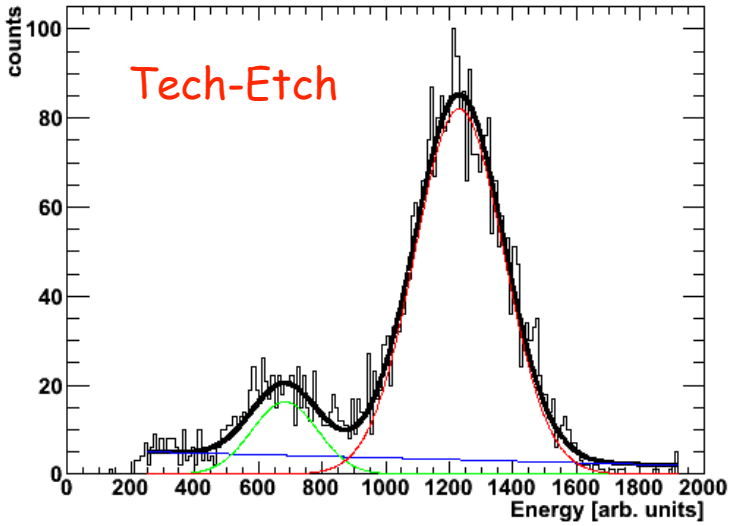
The STAR Forward GEM Tracker

- Source tests
  - Two identical detectors, one with CERN foils, one using Tech-Etch foils
  - Both detectors give reasonable X-Ray spectrum using ^{55}Fe source with comparable energy resolution (~20%)

Correlation of X-Y readout plane

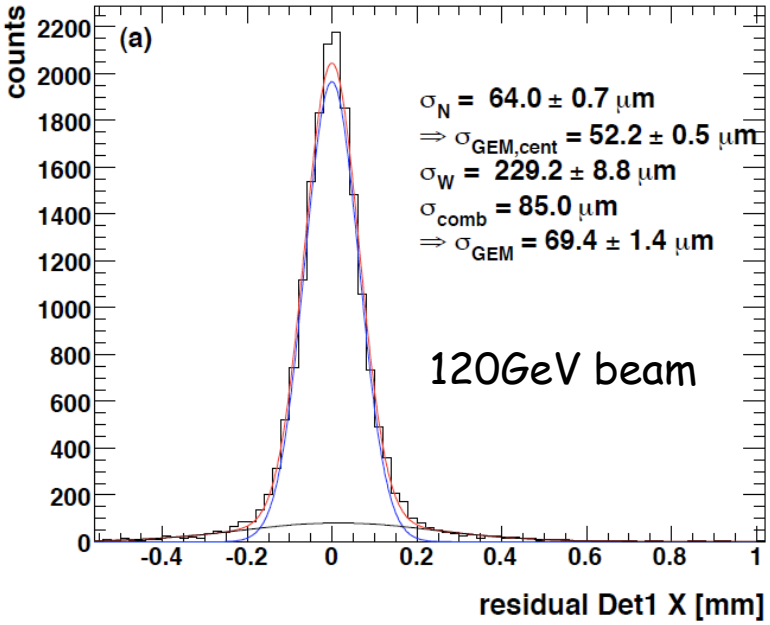


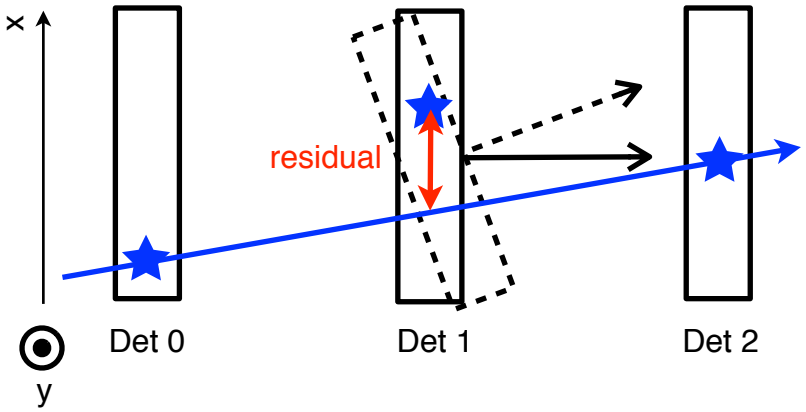


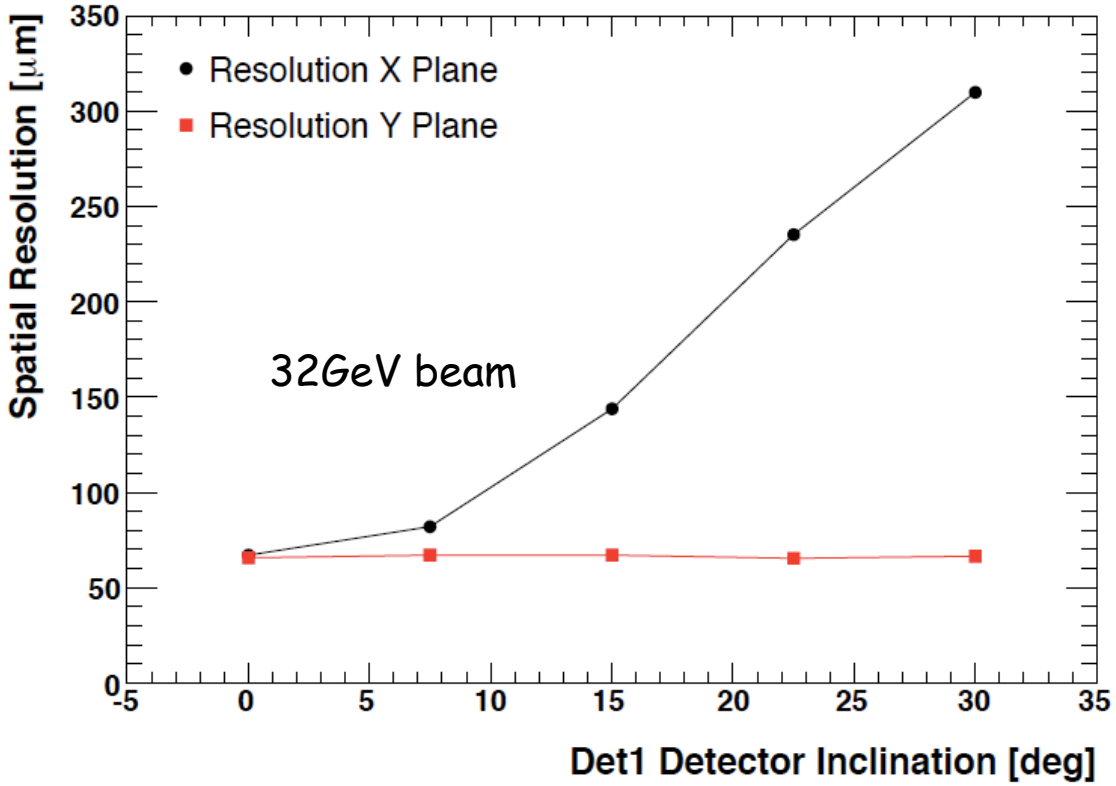


The STAR Forward GEM Tracker

Testbeam results - Results





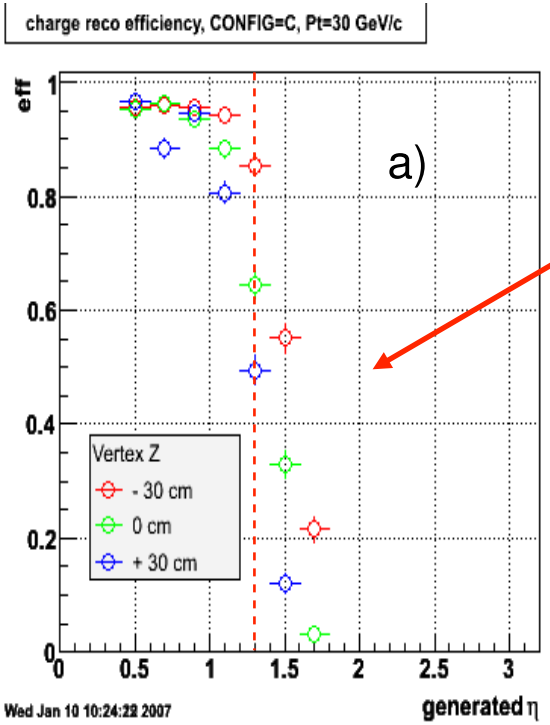


- Study of inclination by up to 30°: Only X (horizontal) resolution is affected, not so for Y (vertical) coordinate as expected!

F. Simon et al., NIM A598 (2009) 432.

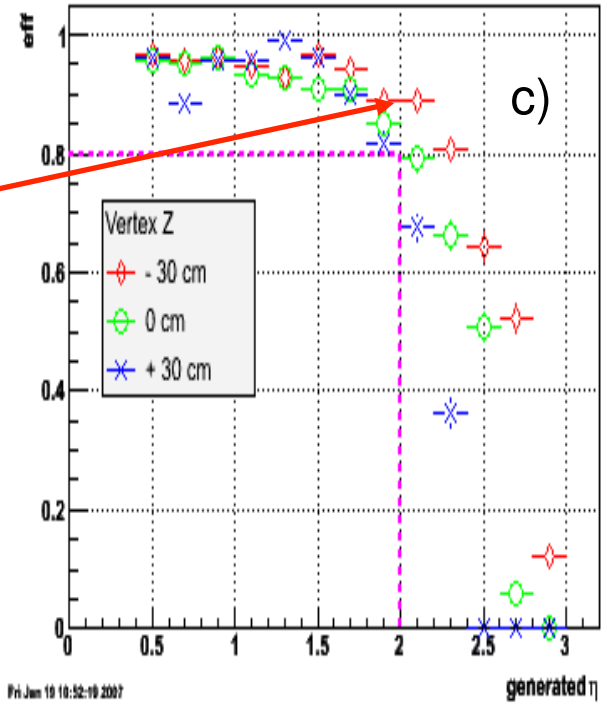
The STAR Forward GEM Tracker

- Charge-sign discrimination - Simulation results



Reach of EEMC Acceptance

TPC + FGT Tracking, p_T = 30 GeV/c



Conclusion:

Charge sign reconstruction impossible beyond η = ~1.3

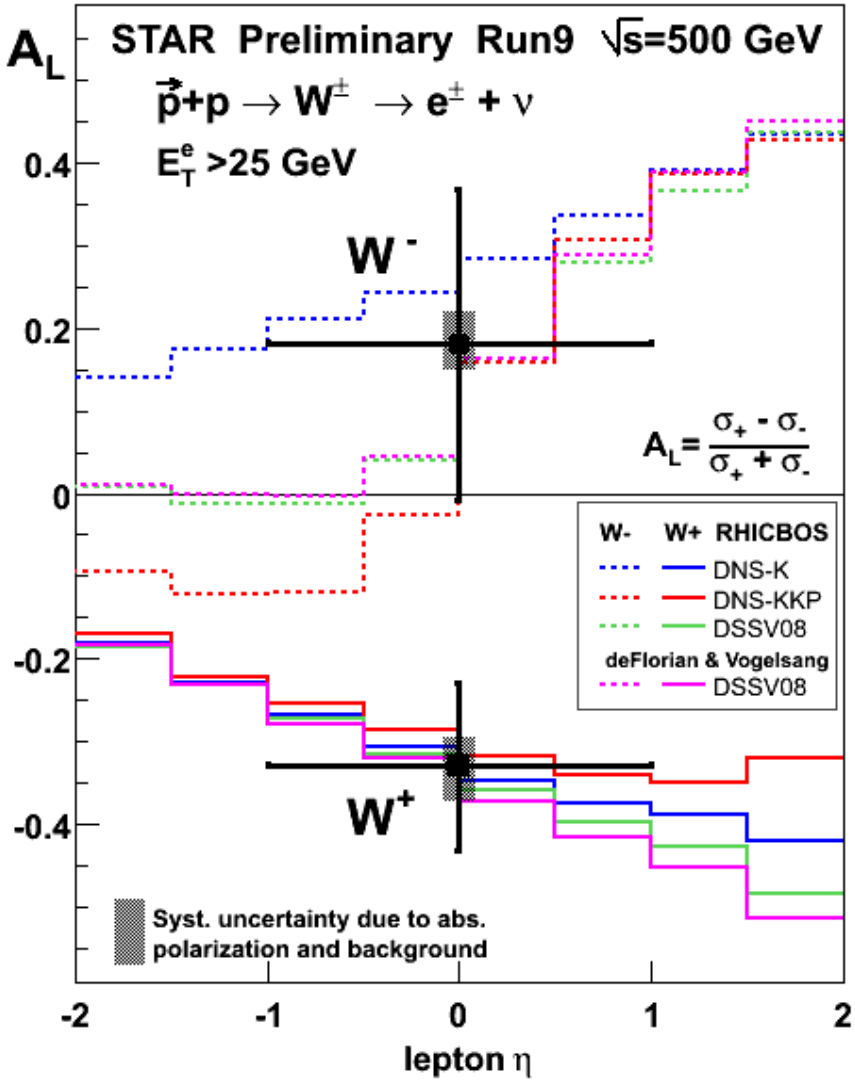
6 triple-GEM disks, assumed spatial resolution 60μm in x and y (Fairly insensitive for 60-100μm)

Charge sign reconstruction probability above 90% for 30 GeV p_T over the full acceptance of the EEMC for the full vertex spread

Future plans: Run 9 Lessons and Expectations

Overview

J. Balewski (MIT), Spring APS Meeting 2010



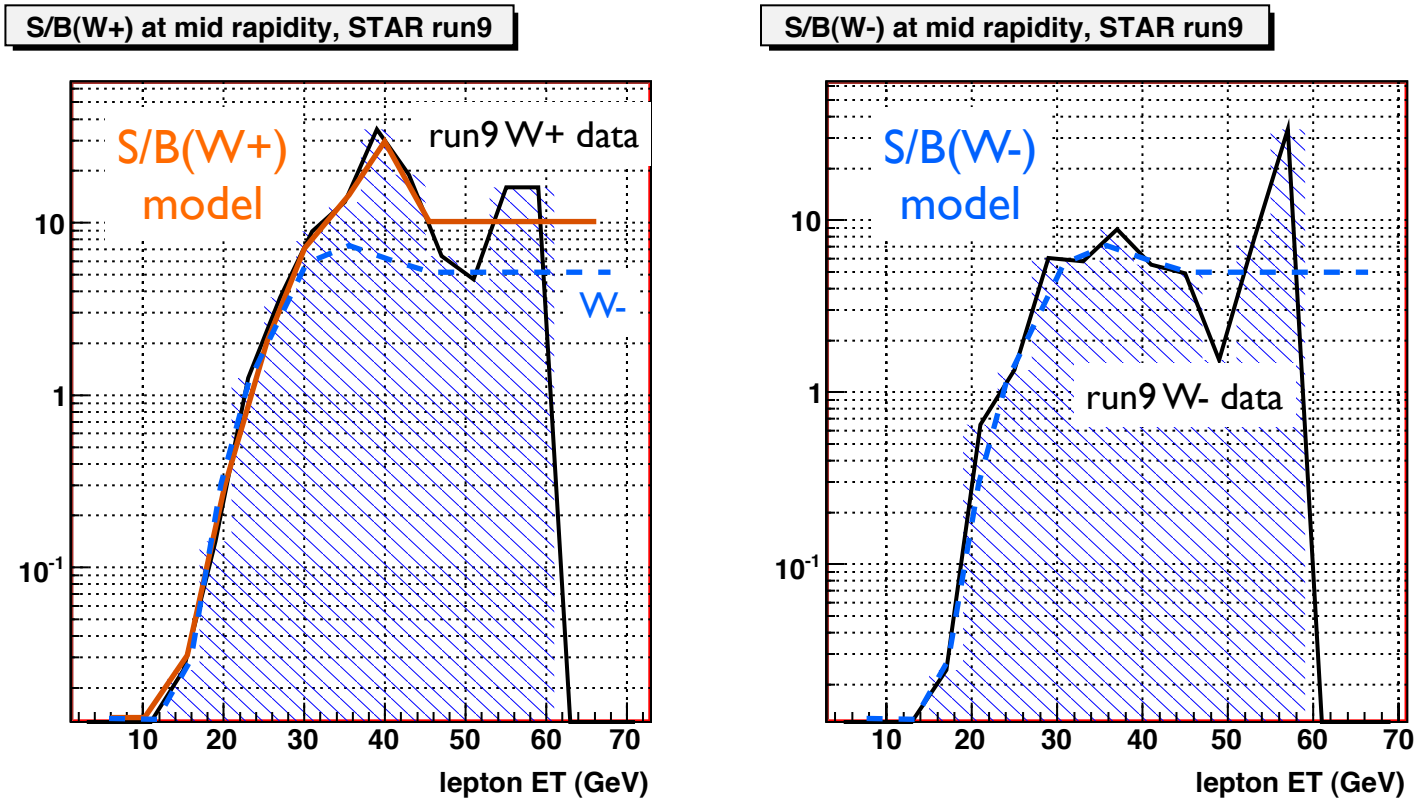
- W measurement:
  - Total efficiency: 0.56

Efficiency Component	$W^- \to e^- + \bar{\nu}_e$	$W^+ \to e^+ + \nu_e$
Trigger: ϵ_{trig}	0.86 ± 0.04	0.88 ± 0.04
Vertex: ϵ_{vertex}	0.91 ± 0.03	0.91 ± 0.03
Reconstruction: ϵ_{reco}	$0.72\ ^{+0.13}_{-0.11}$	$0.71\ ^{+0.14}_{-0.11}$
Total: ϵ_{total}	$0.56\ ^{+0.11}_{-0.09}$	$0.56\ ^{+0.12}_{-0.09}$

  - Signal (S) / Background (B):
    - S/B = 6 for W^-
    - S/B = 11 for W^+
  - Charge sign separation demonstrated to high-p_T ~50GeV/c
- Global variables:
  - Luminosity: ~14pb^{-1} (Large sys. uncertainty: ~23%)
  - Polarization: ~40%
  - Polarization uncertainty (Sum of Y+B beams): 9.2%

Run 9 Lessons and Expectations: STAR W Results

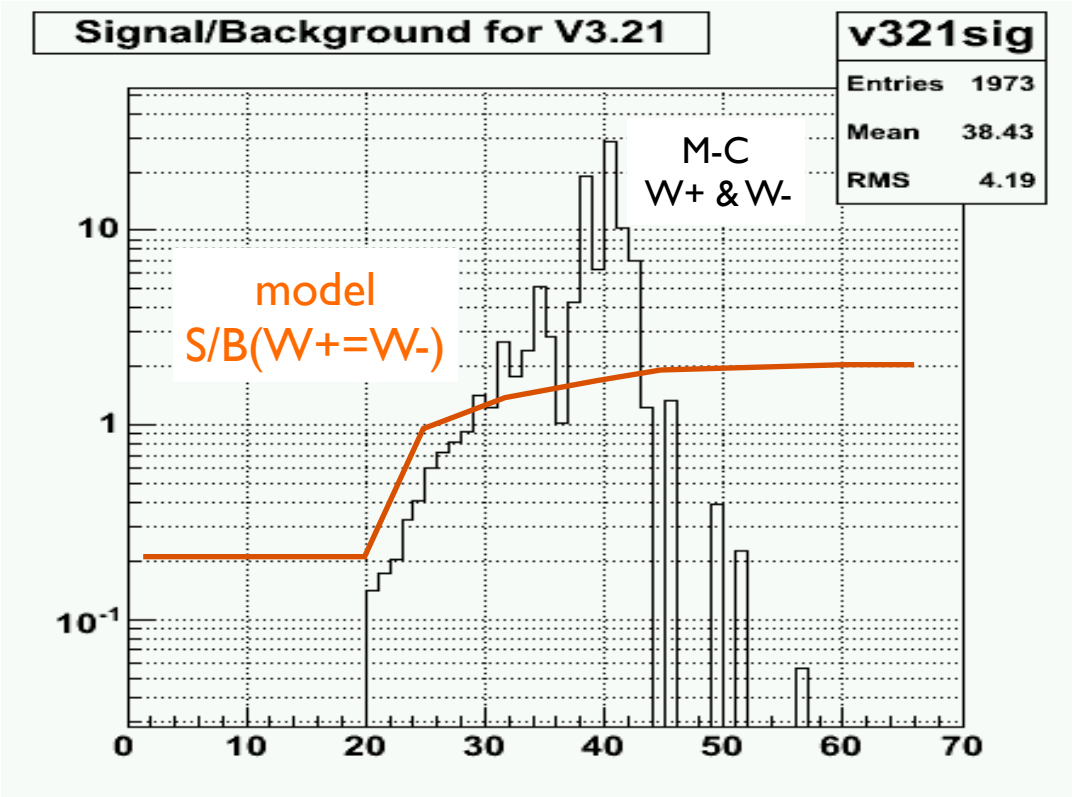
- Background (1): W signal (S) vs. QCD background (B)



- Run 9 serves as benchmark for mid-rapidity QCD background treatment: S/B=11 for W^+ and S/B=6 for W^- (Integrated for $E_T > 25$GeV)
- Future projections: Assume Run 9 background performance

Run 9 Lessons and Expectations: STAR W Results

- Background (2): W signal (S) vs. QCD background (B)

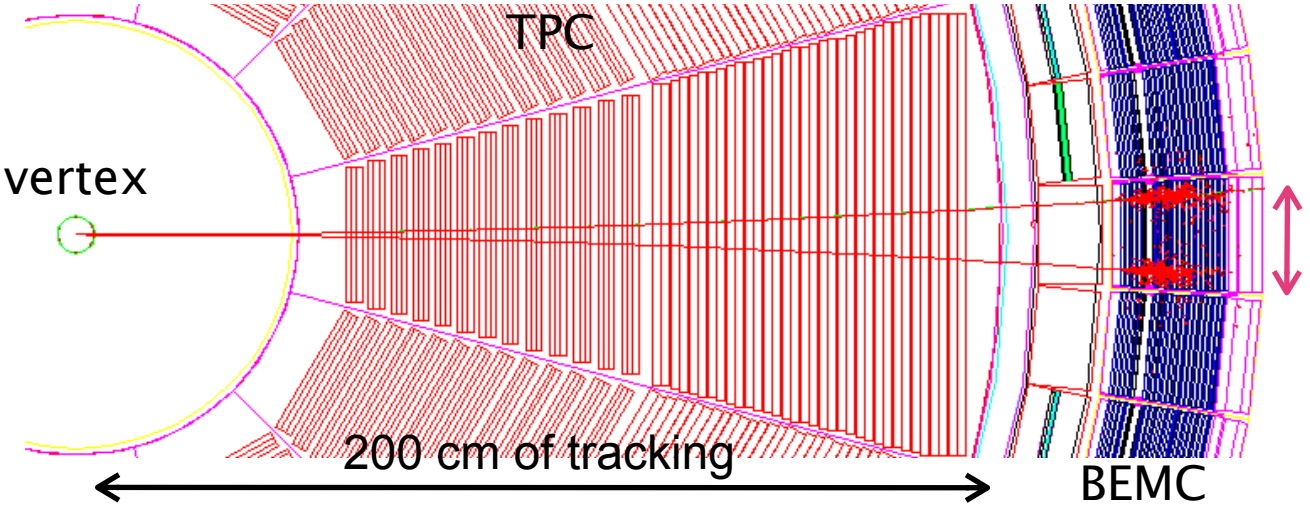


- QCD MC simulations used for forward rapidity QCD background treatment
- Future projections: Assume S/B (W^+=W^-) = ~1.1 as shown above (Same as for 2008 DOE RHIC Spin Report)

TPC

Run 9 Lessons and Expectations: STAR W Results

- TPC performance: Mid-rapidity high p_T $e^{\pm}$ charge separation (1)



positron p_T = 5 GeV

electron p_T = 5 GeV

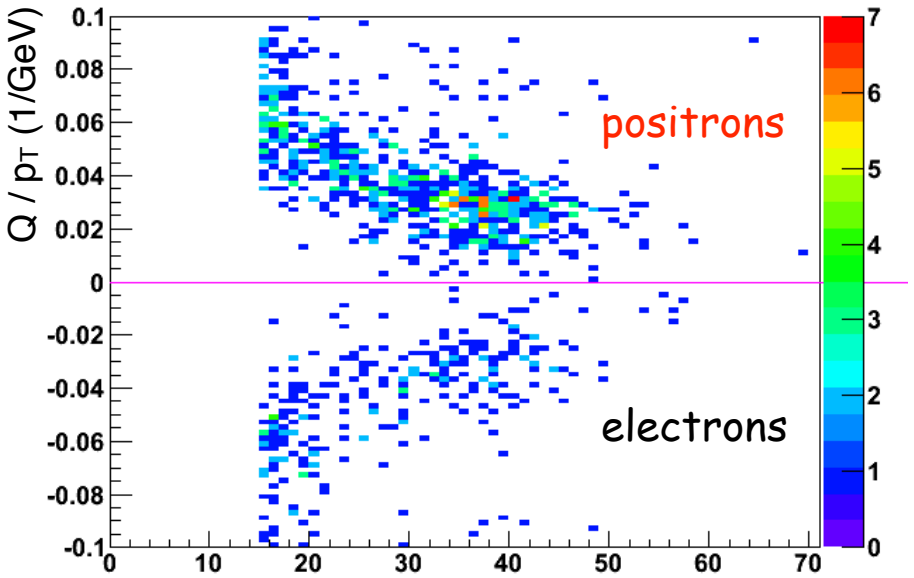
+/- distance D: ~1/P_T

p_T = 5 GeV : D ~15 cm

p_T = 40 GeV : D ~2 cm

Successful separation of different charge states!

Q: Charge-sign of reconstructed track



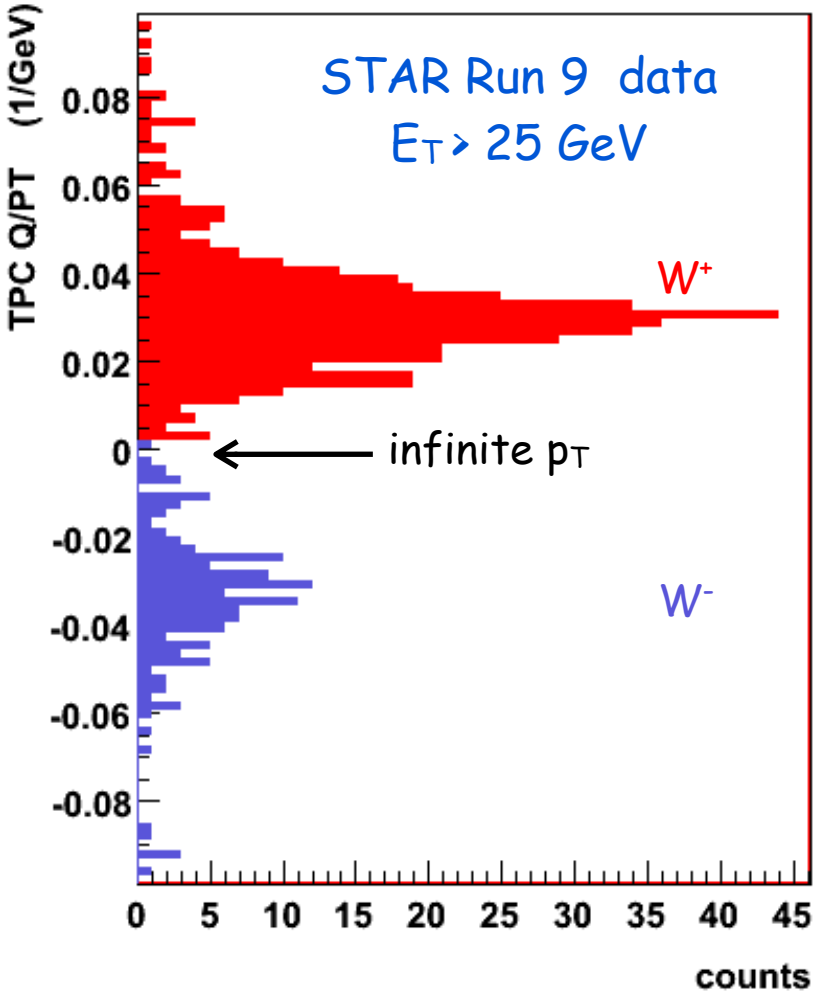
Assign:

Q/p_T > 0 positrons

Q/p_T < 0 to be electrons

Run 9 Lessons and Expectations: STAR W Results

- TPC performance: Mid-rapidity high p_T $e^{\pm}$ charge separation (2)
  - TPC Running experience:
    - TPC currents in Run 9 / 500GeV higher than previously observed
    - Frequent HV trips resulted in lowering TPC inner-sector HV
      ⇒ Stable running
    - New TPC electronics with S/N~30 compared to old electronics S/N~20 can handle lower TPC gains due to lower HV of inner sectors ⇒ Efficiency not affected
  - TPC calibration: Extensive effort following Run 9 resulting in successful charge-sign separation at high-p_T (~50GeV/c)
  - TPC long-term performance:
    - Careful monitoring required in particular at higher luminosity operations
    - W program (⇒ Low W trigger rate) expected not to be affected!

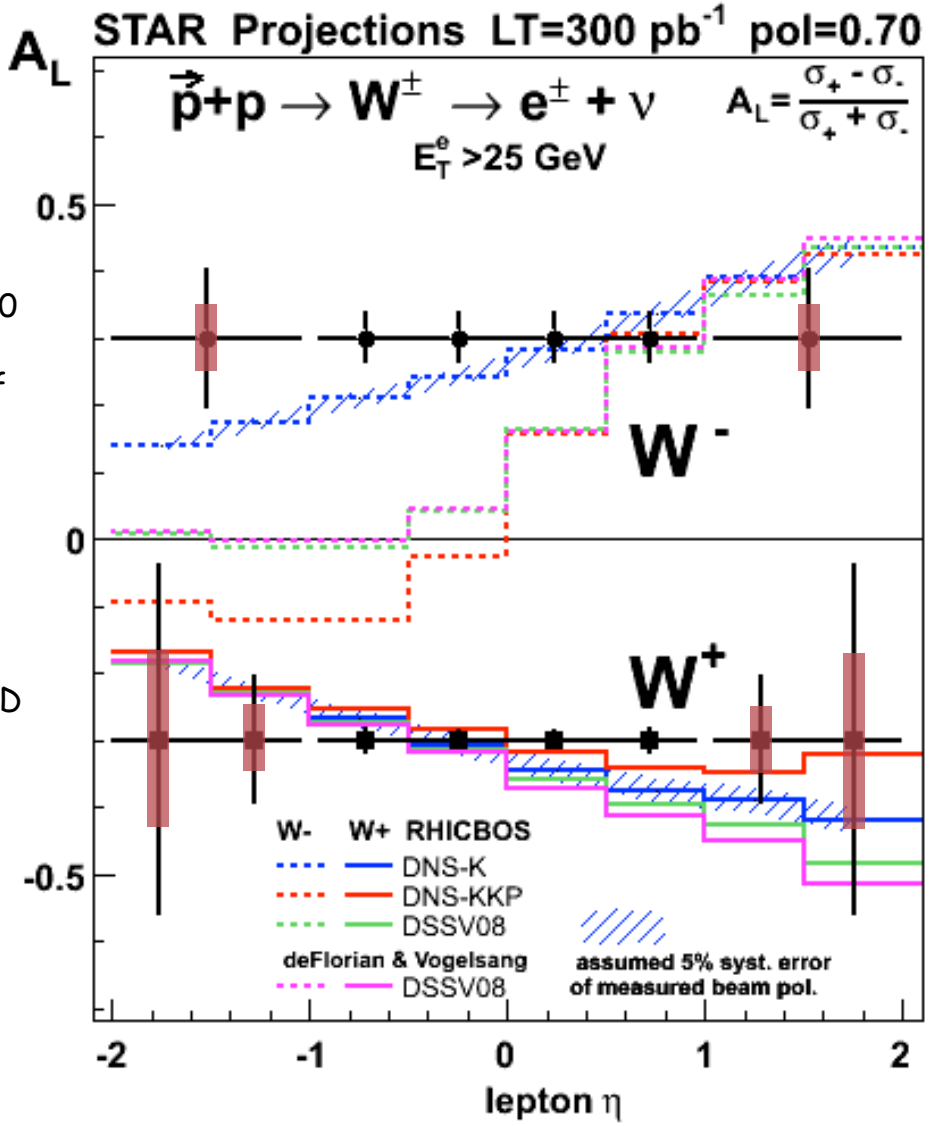


Future plans: Projections

- A_L projections

lepton $|\eta|<1$: 2 beams, eff=0.65 w/ 9MHz RF, Run9 QCD bckg, rhicbos $\sigma W^{+},W^{-}$=82, 19 pb
lepton $|\eta|\in[1,2]$: 1 beam, eff=0.60 w/ 9MHz RF, M-C QCD bckg, rhicbos $\sigma W^{+},W^{-}$=5.3, 4.7 pb

- Assumptions:
  - Efficiency:
    - Mid-rapidity: 0.65
    - Forward rapidity: 0.60
    - Assume availability of 9MHz RF
  - Background:
    - Mid-rapidity: Run 9
    - Forward rapidity: QCD MC simulations
  - Full charge-sign discrimination at high-p_T



- Conclusions:
  - W Program at RHIC is a multi-year program - Initial sample of ~100pb^{-1} / ~50% is only a step along the way!
  - Critical:
    - Design polarization performance of 70% to collect at least 300pb^{-1}
    - Polarization uncertainty ~5%

Summary

- STAR W program
  - First Run 9 STAR W result (Cross-section and A_L for W^+/W^- at mid-rapidity) important milestone!
  - Mid-rapidity:
    - Charge sign discrimination: Demonstrated at high-p_T (~50GeV/c)
    - Signal (S) / Background (B): S/B = 6 for W^- and S/B = 11 for W^+ (Integrated for E_T>25GeV)
  - Forward rapidity: Complete FGT construction in ~fall 2010 followed by full system test and subsequent full installation in ~summer 2011

    ⇒ Ready for anticipated long 500GeV polarized pp run in FY12 (Run 12)
  - Critical: Design polarization performance of 70% with ~5% absolute polarization uncertainty (⇒ Required by eRHIC program!) to collect at least 300pb^{-1}!
  - Future measurements of A_L at STAR at mid-rapidity and forward rapidity (Wide rapidity coverage!) are expected to play an important role in our understanding of the polarized QCD sea!