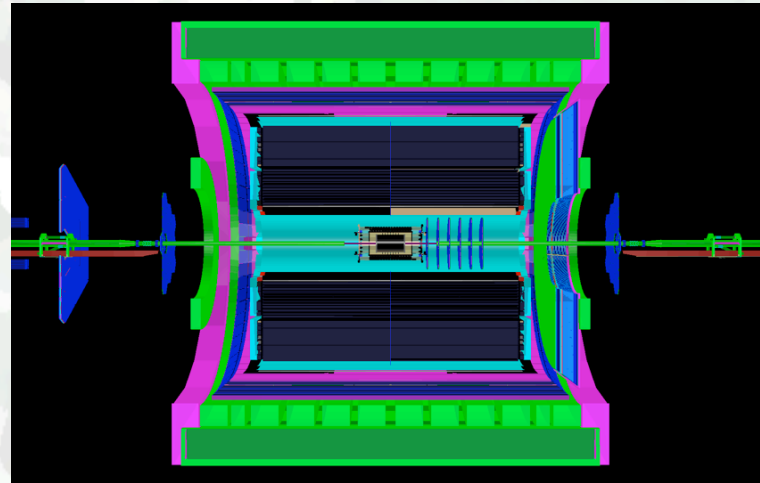


# The STAR W Physics Program - Recent results and Future Plans -

Bernd Surrow



Massachusetts  
Institute of  
Technology





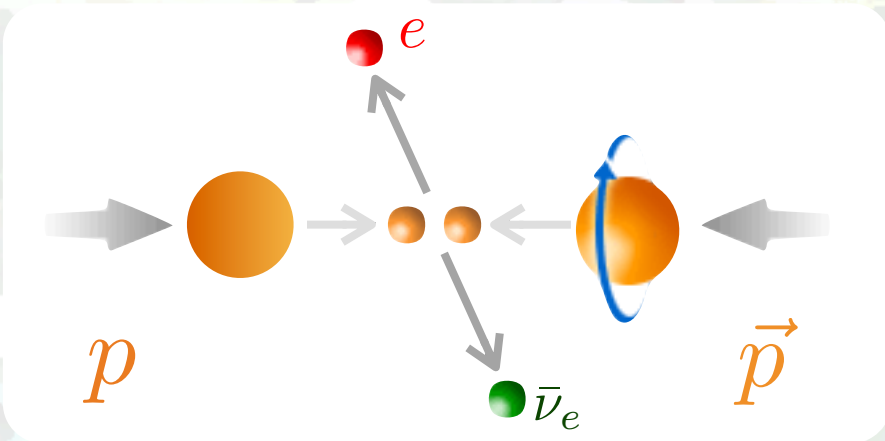
# Outline

## □ Run 9 W Physics Analysis

- First Observation of W bosons at STAR
- Further plans: Cross-section and  $A_L$

## □ Future Plans - STAR W Program

- Overview of the STAR Forward GEM Tracker
- Projections of future forward/backward rapidity measurements
- Projections of future mid-rapidity measurements



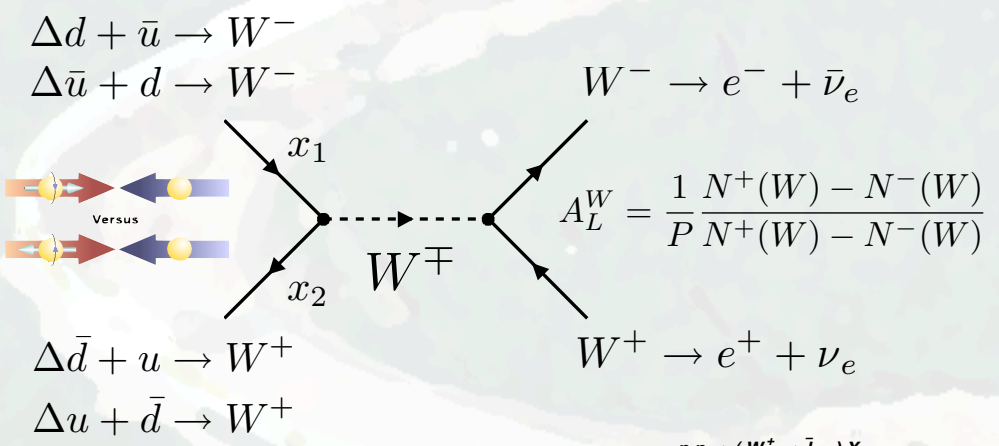
## □ Theoretical foundation - STAR W Program

## □ Summary and Outlook



# Theoretical foundation - STAR W Program

## Brief review of kinematics



In the limit of zero transverse W momentum  $q_T$ :

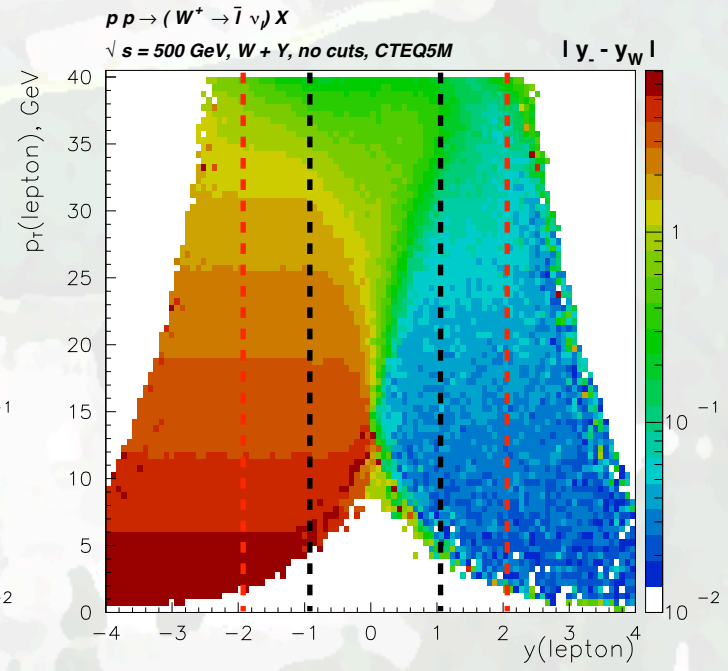
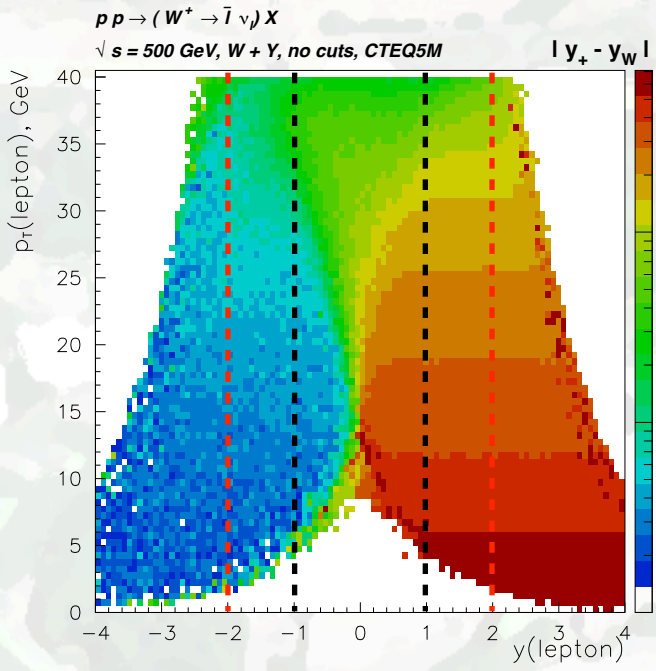
$$y_l = y_W + \underbrace{\frac{1}{2} \ln \frac{1 + \cos \theta^*}{1 - \cos \theta^*}}_{y_l^*}$$

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

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

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

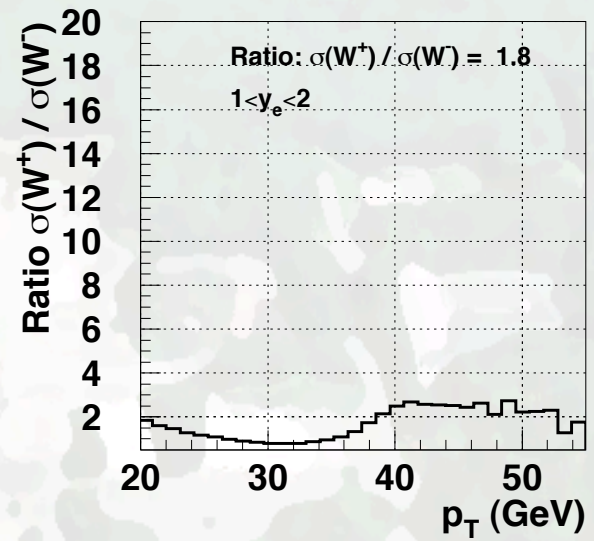
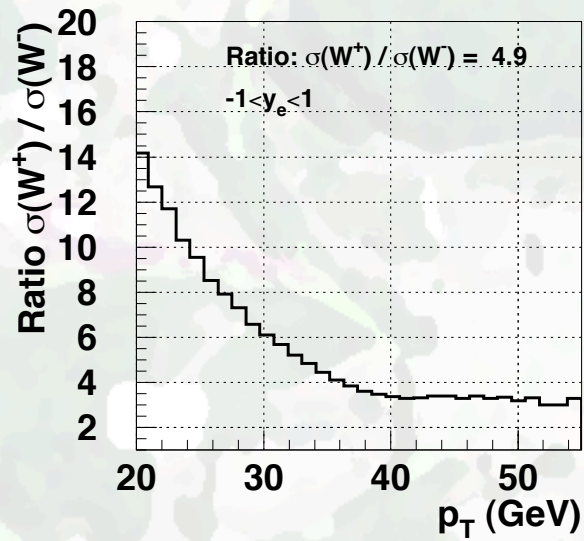
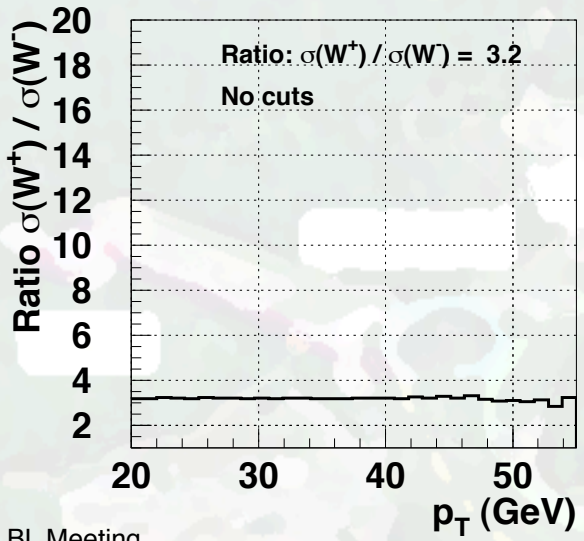
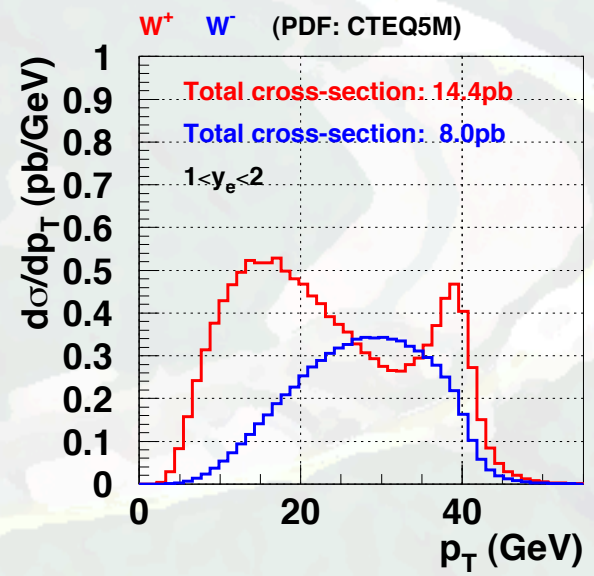
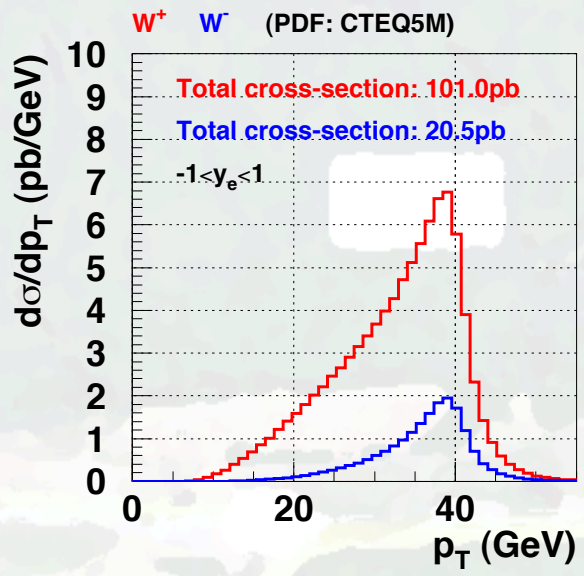
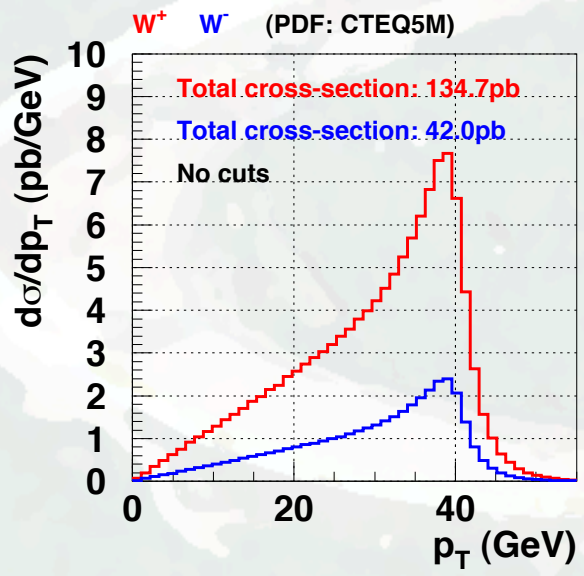
With:  $\frac{M_W}{\sqrt{s}} = 0.16$





# Theoretical foundation - STAR W Program

□ Cross-section: STAR mid-rapidity and forward rapidity (RHICBOS  $\sqrt{s}=500\text{GeV}$ )

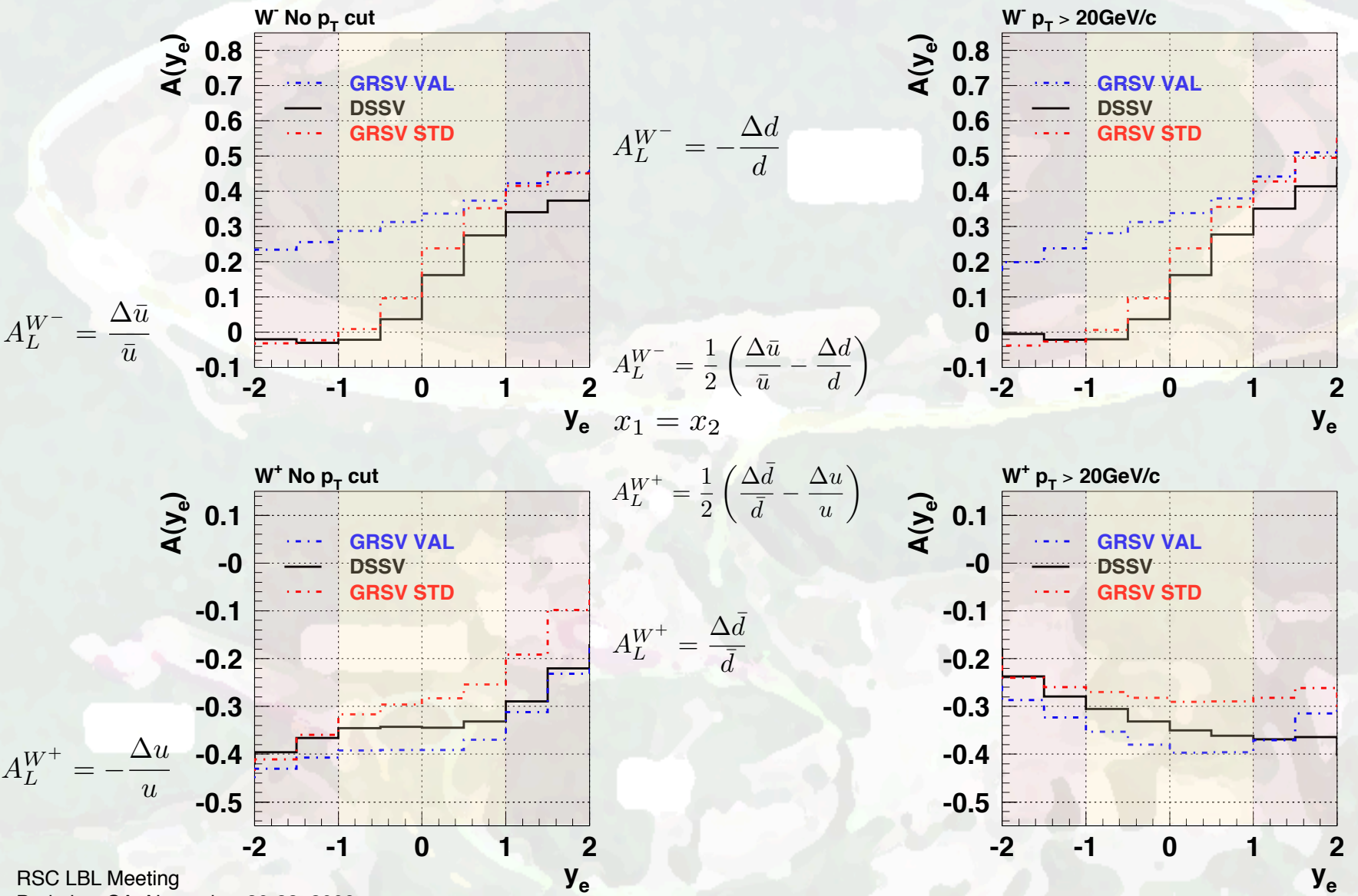






# Theoretical foundation - STAR W Program

□  $A_L$ : STAR mid-rapidity and forward rapidity (RHICBOS  $\sqrt{s}=500\text{GeV}$ )

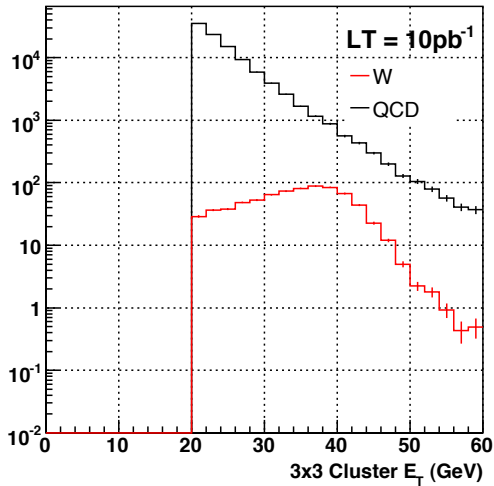




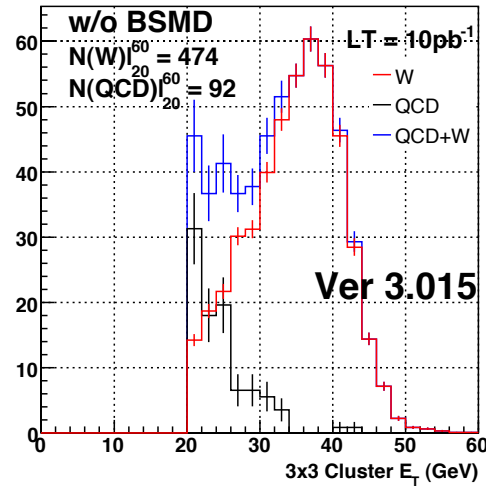
# Run 9 W Physics Analysis

## Expectations for Run 9 - First polarized pp run at 500GeV

QCD and W for mid-rapidity before cuts

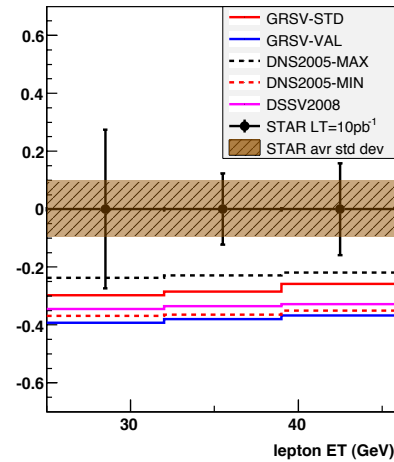


QCD and W for mid-rapidity after cuts

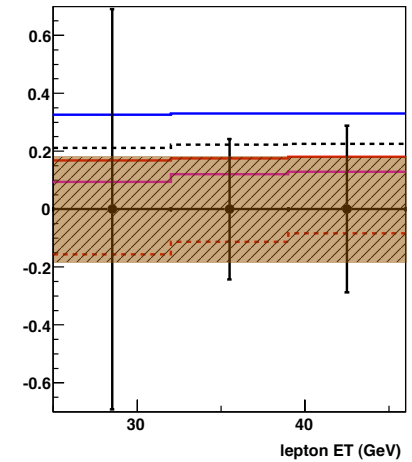


STAR projections for LT=10pb<sup>0</sup>, Pol=0.5, effi=70%, including QCD background, 2 beams, no vertex cut

A<sub>L</sub>(W+) for positron |η| < 1



A<sub>L</sub>(W-) for electron |η| < 1

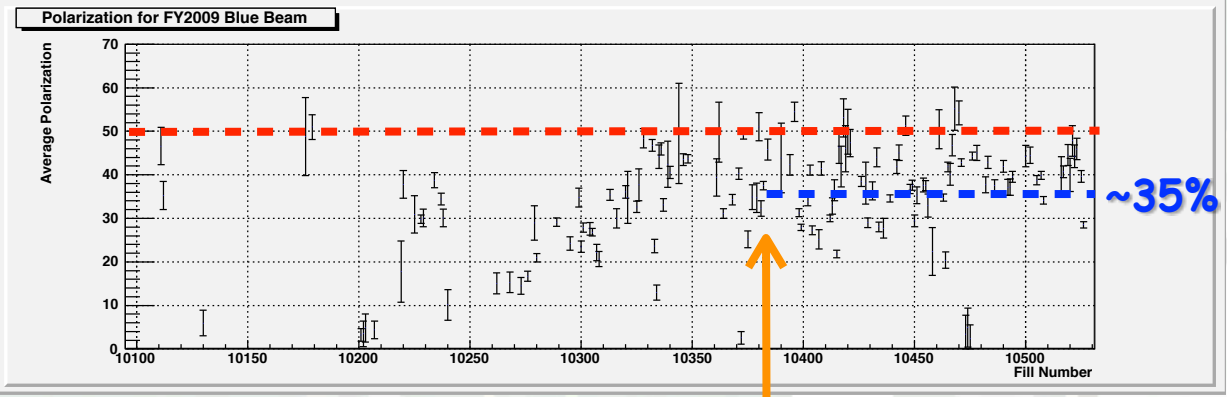
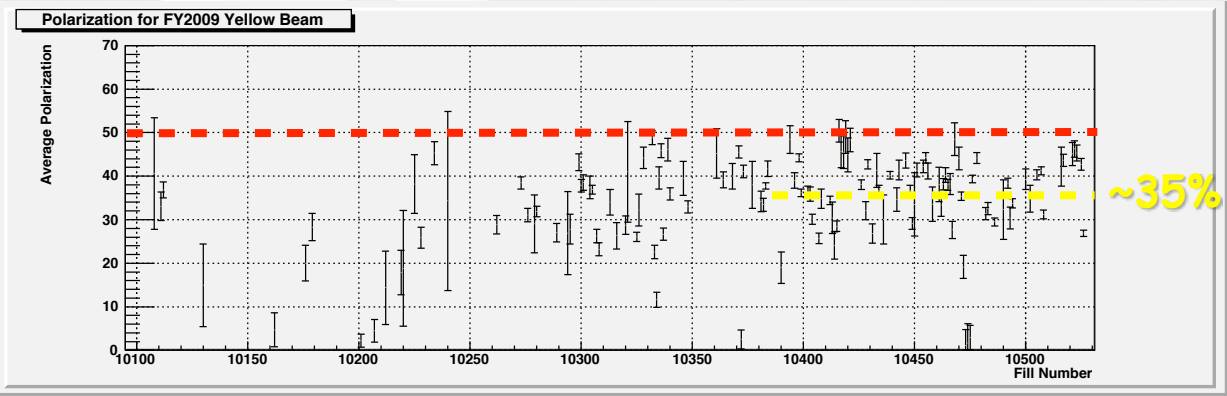


- Develop local polarimetry in STAR at 500GeV (⇒ ZDC)
- Physics Goal 1: First W measurement in STAR at mid-rapidity : Establish signal (Extensive full GEANT simulations completed of W signal and QCD background events in preparation of Run 9) a) Jacobian peak b) Cross section
- Physics Goal 2: First A<sub>L</sub> W measurement
- Other opportunities: Jets / Di-Jets at low x



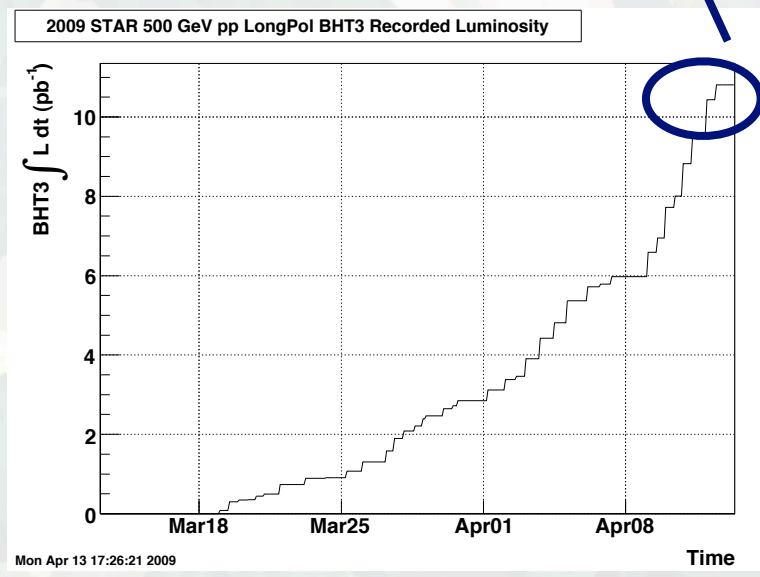
# Run 9 W Physics Analysis

## □ Polarization and Luminosity performance during Run 9 / 500GeV



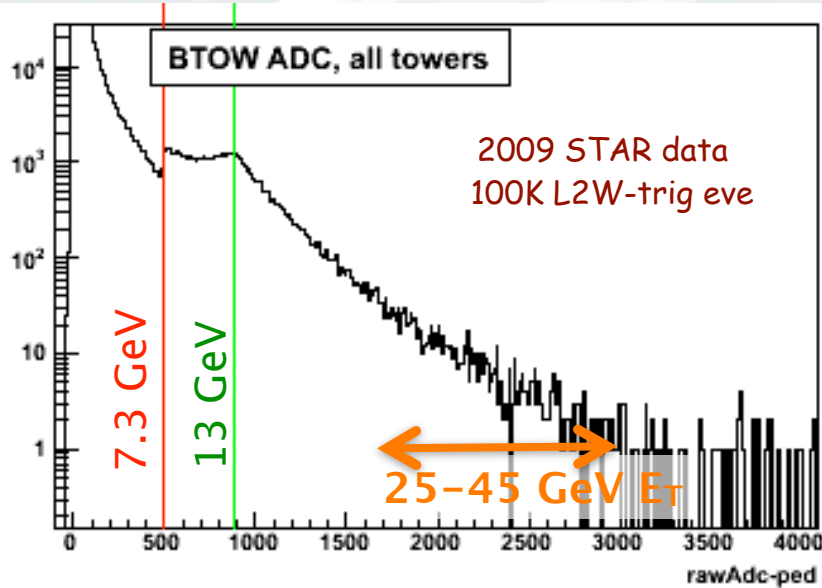
First long. fill (STAR): 10383

Recorded luminosity:  $\sim 10 \text{ pb}^{-1}$



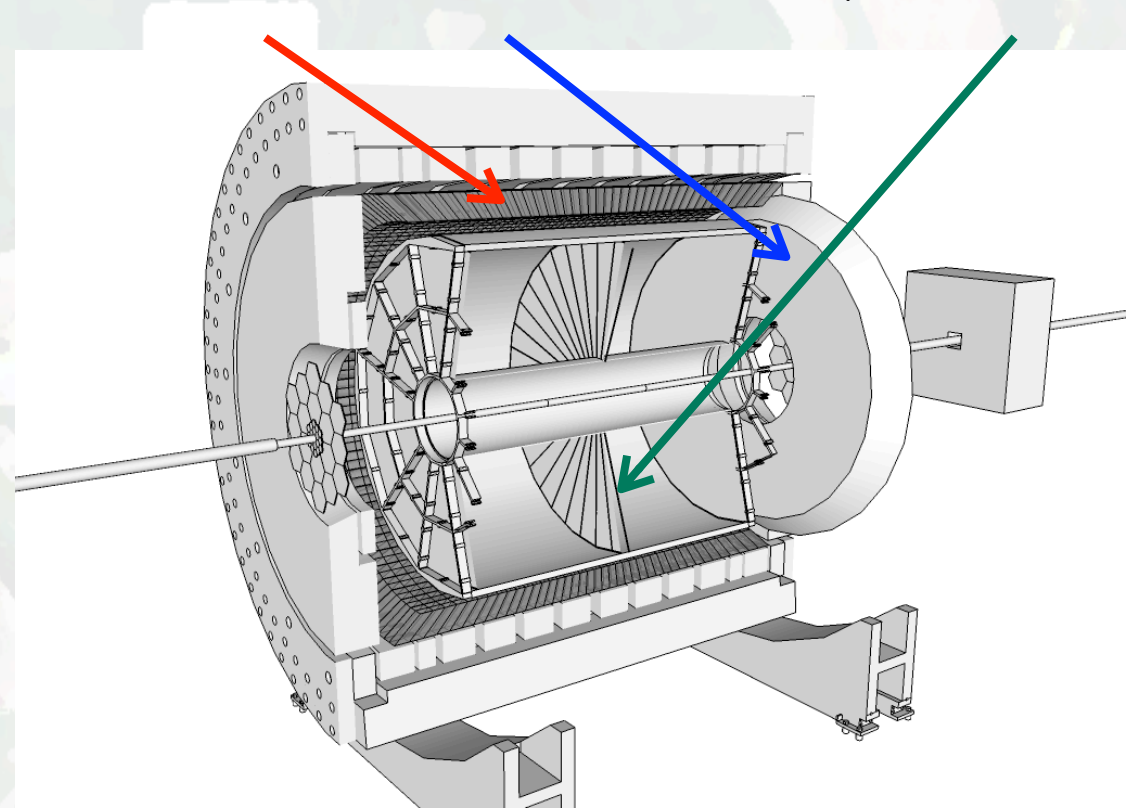
# Run 9 W Physics Analysis

## STAR Data sample Run 9 / 500GeV and W Trigger



First STAR W analysis based on:

**BTOW** and **ETOW** (Veto cut only) and **TPC**



**W-trigger:**  $HT > 7.3 \text{ GeV}$  ET &

L2:  $2 \times 2 > 13 \text{ GeV}$ , 2-3Hz

**Acquired since March 19**

**(longitudinal pol. @STAR)  $\sim 10 \text{ pb}^{-1}$**

- $\sim 103.3$  hours of STAR DAQ up time w/ W-trigger
- $\sim 1.6 \text{ M}$  W-trigger events

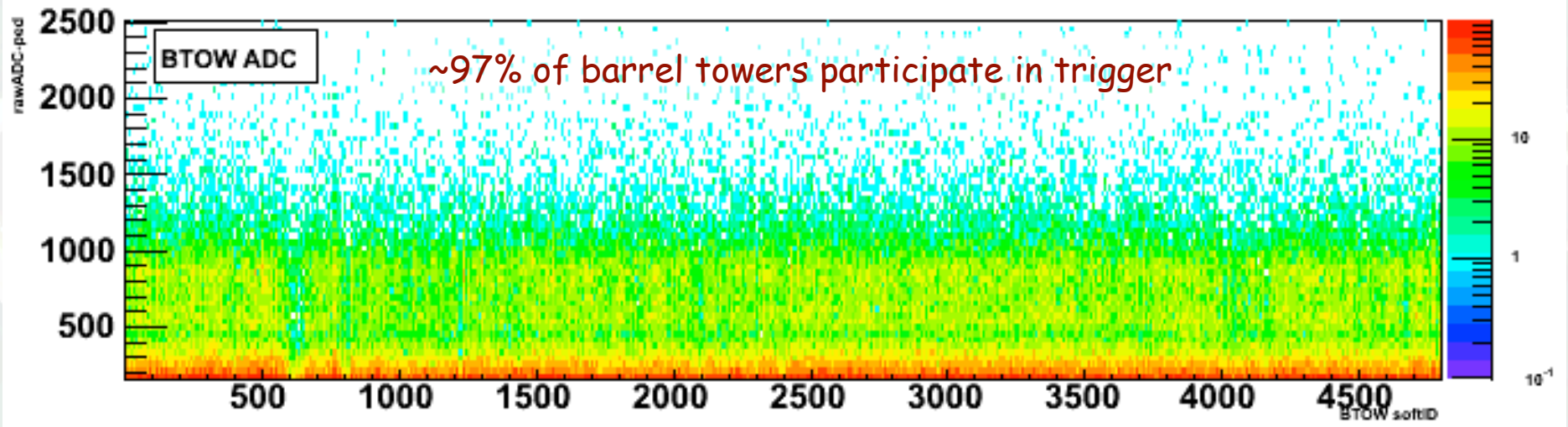
All events processed to muDst w/  
crude TPC calibration





# Run 9 W Physics Analysis

## □ Detector performance Run 9 / 500GeV : BTOW

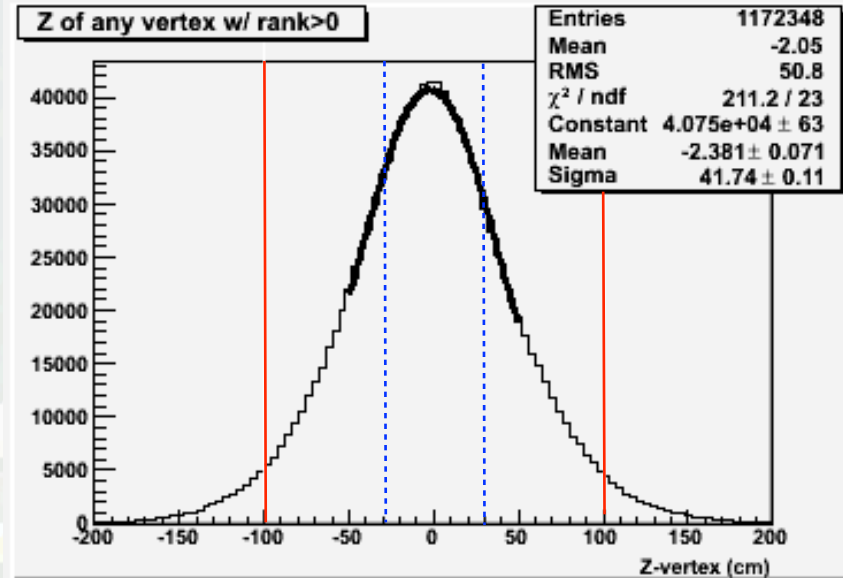
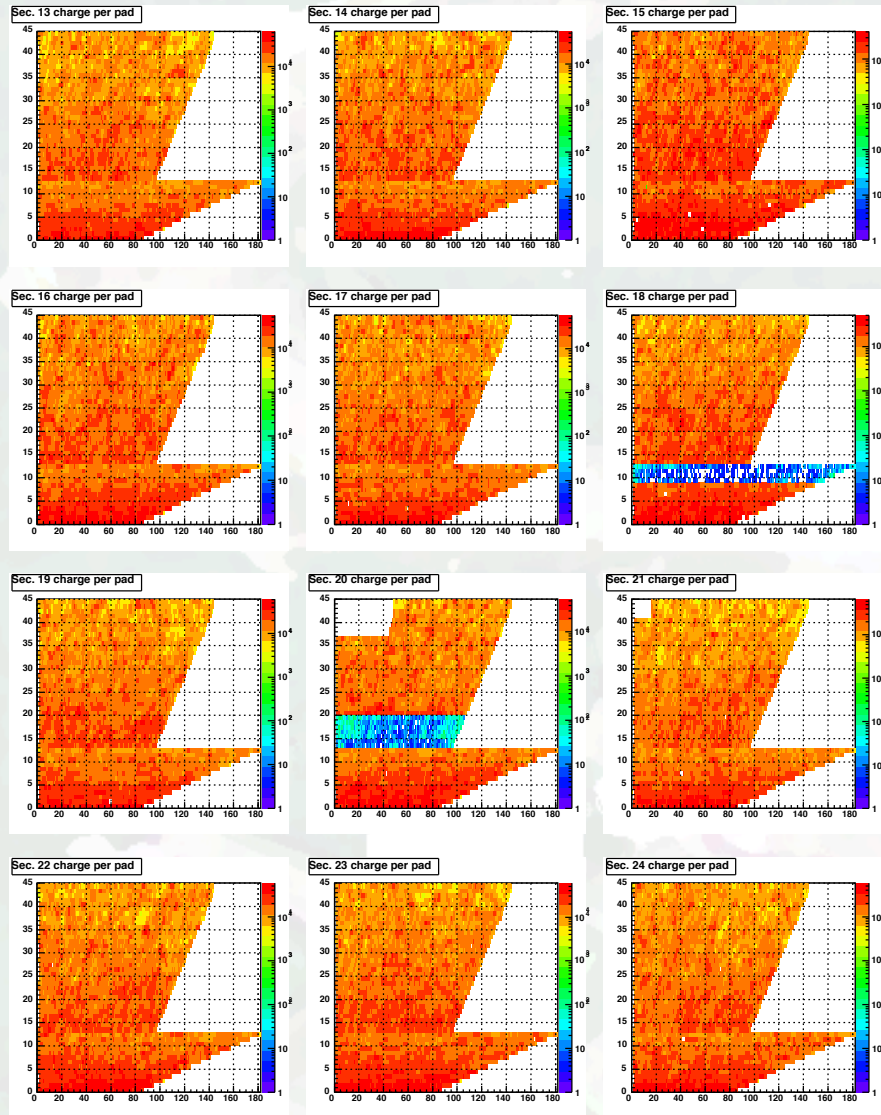


- Status tables and pedestals were generated online throughout the run and monitored
- Additional QA was done by calculating MIP peaks and slopes over the pp500 period
- Final production:
  - Relative calibration using tower energy spectra slopes
  - Absolute calibration: E/p method (electron calibration)



# Run 9 W Physics Analysis

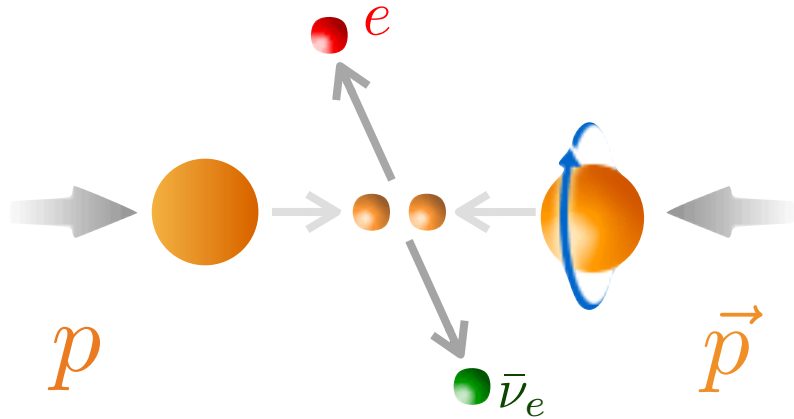
## Detector performance Run 9 / 500GeV : TPC



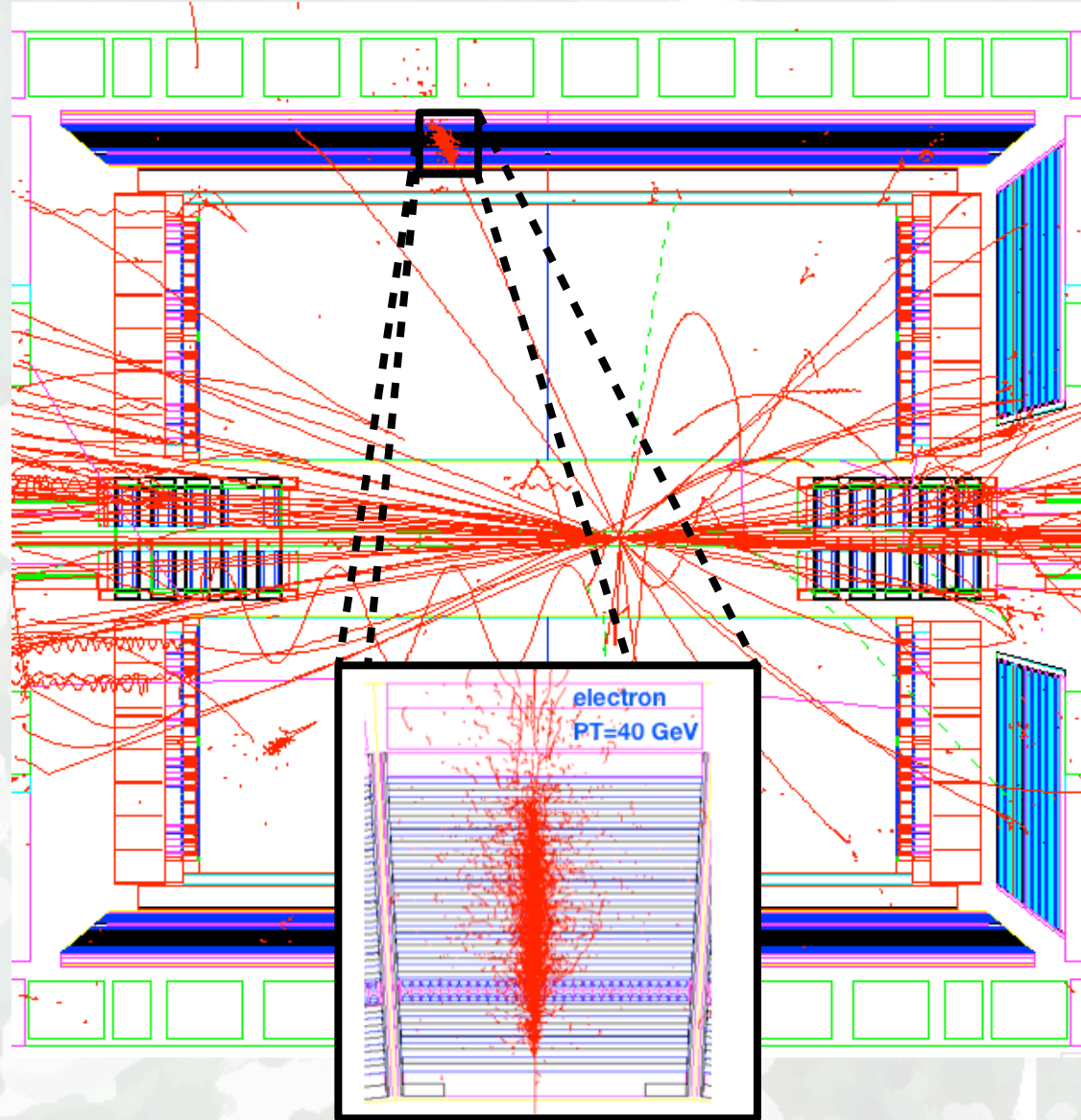
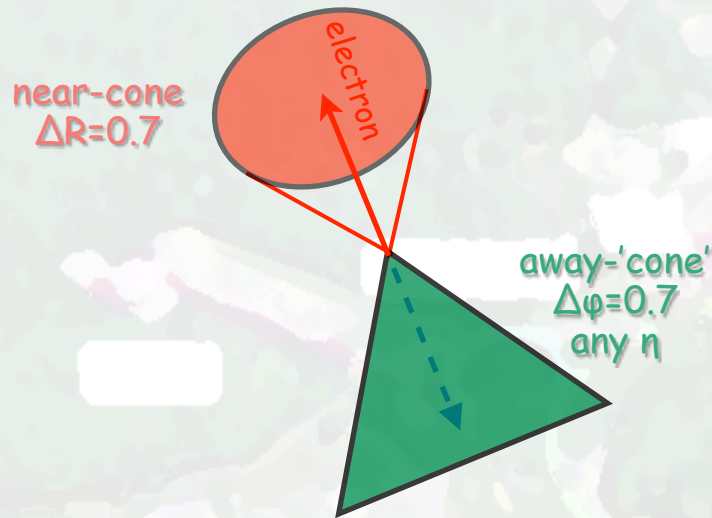
- TPC sector histograms (1-24)
- TPC pad-row vs. number of pads for a given pad-row (Change from inner [1-13] to outer [14-45] pad-rows)
- Fraction of TPC alive > 95%

# Run 9 W Physics Analysis

- W reconstruction - Algorithm : Idea



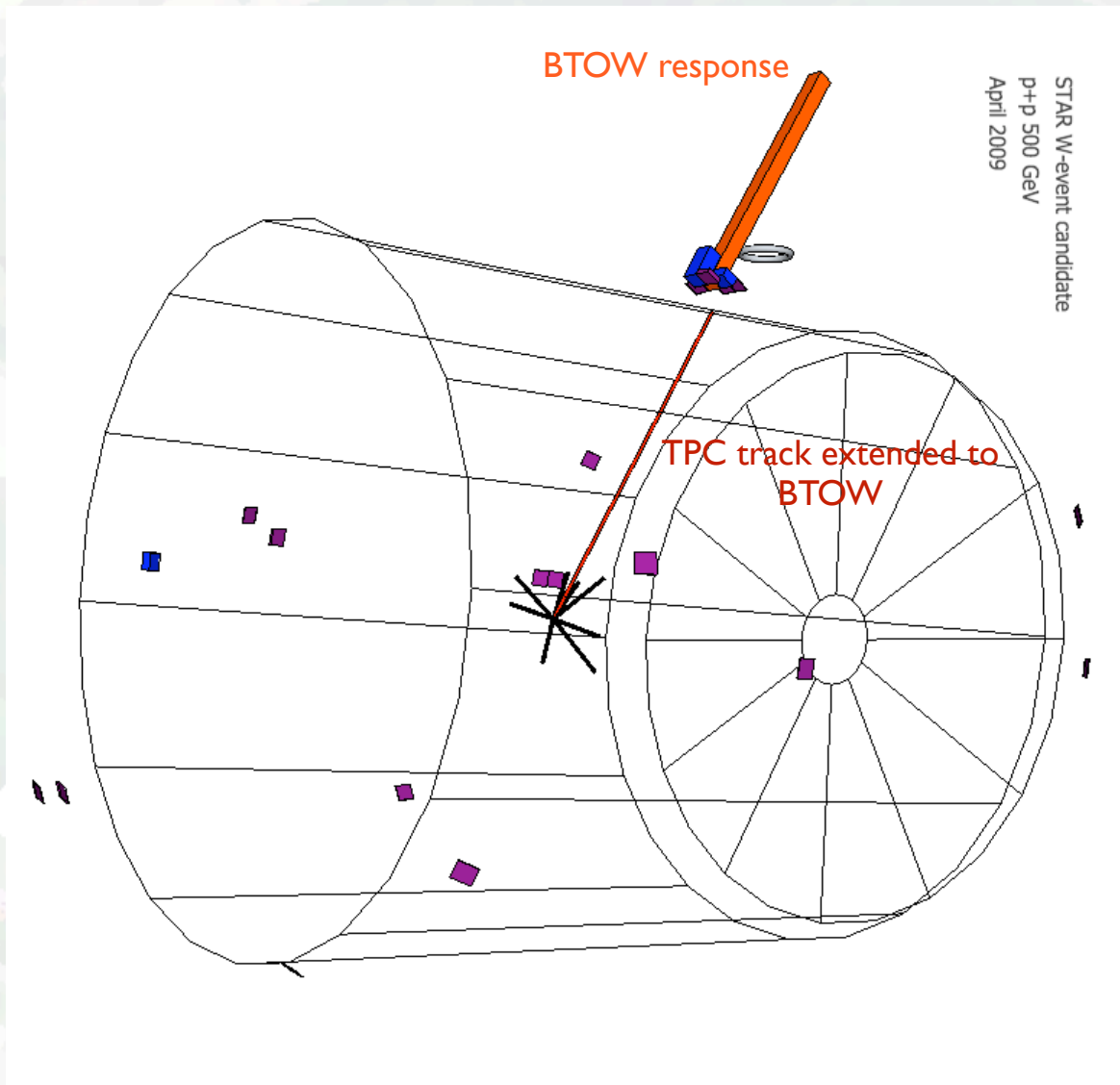
Transverse plane view





# Run 9 W Physics Analysis

- Event display ( $W$  event candidate) and detector signature (1)



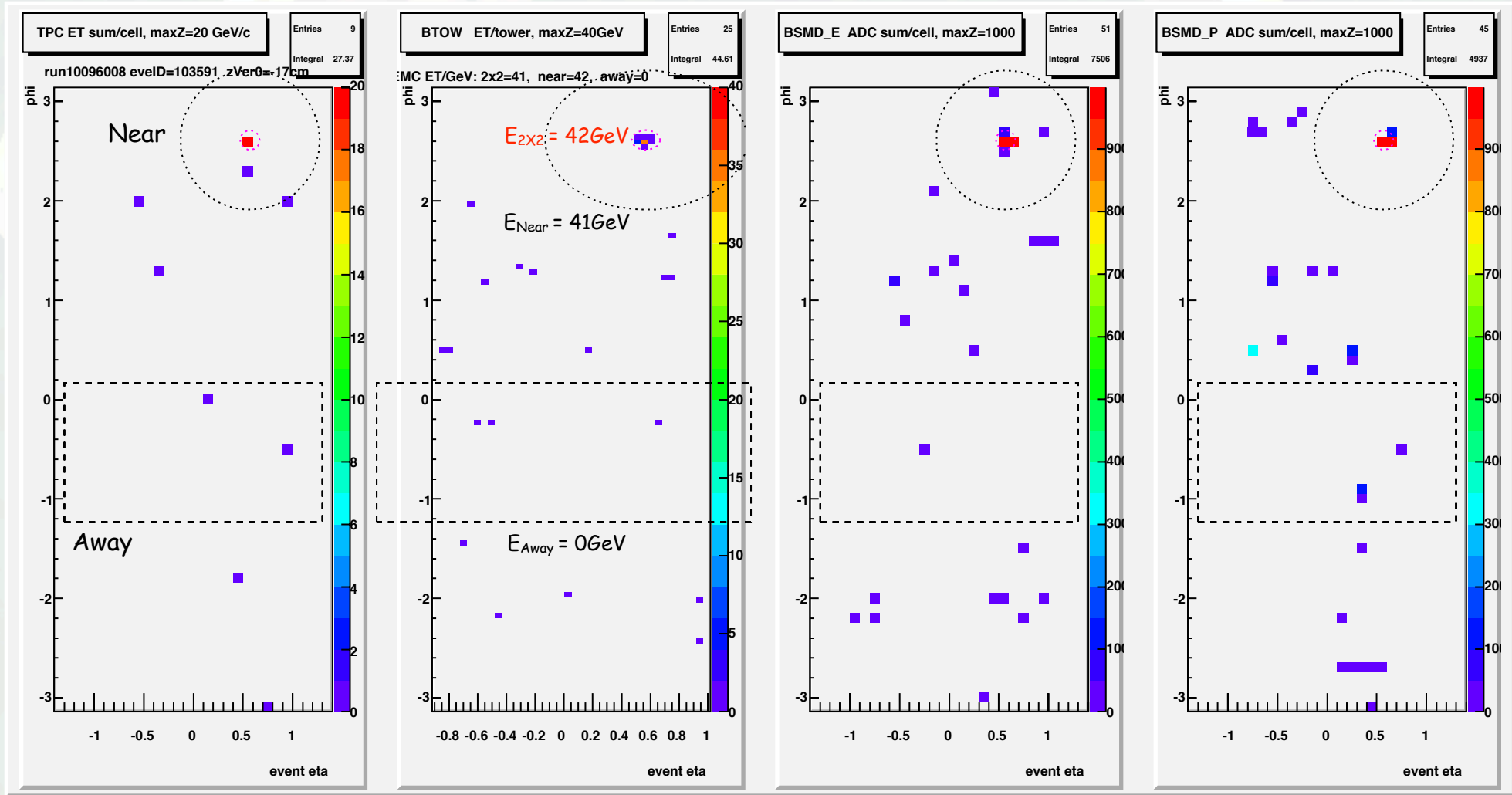
We found  
~400 of those  
kinds of  
events!





# Run 9 W Physics Analysis

## Event display (W event candidate) and detector signature (2)



TPC

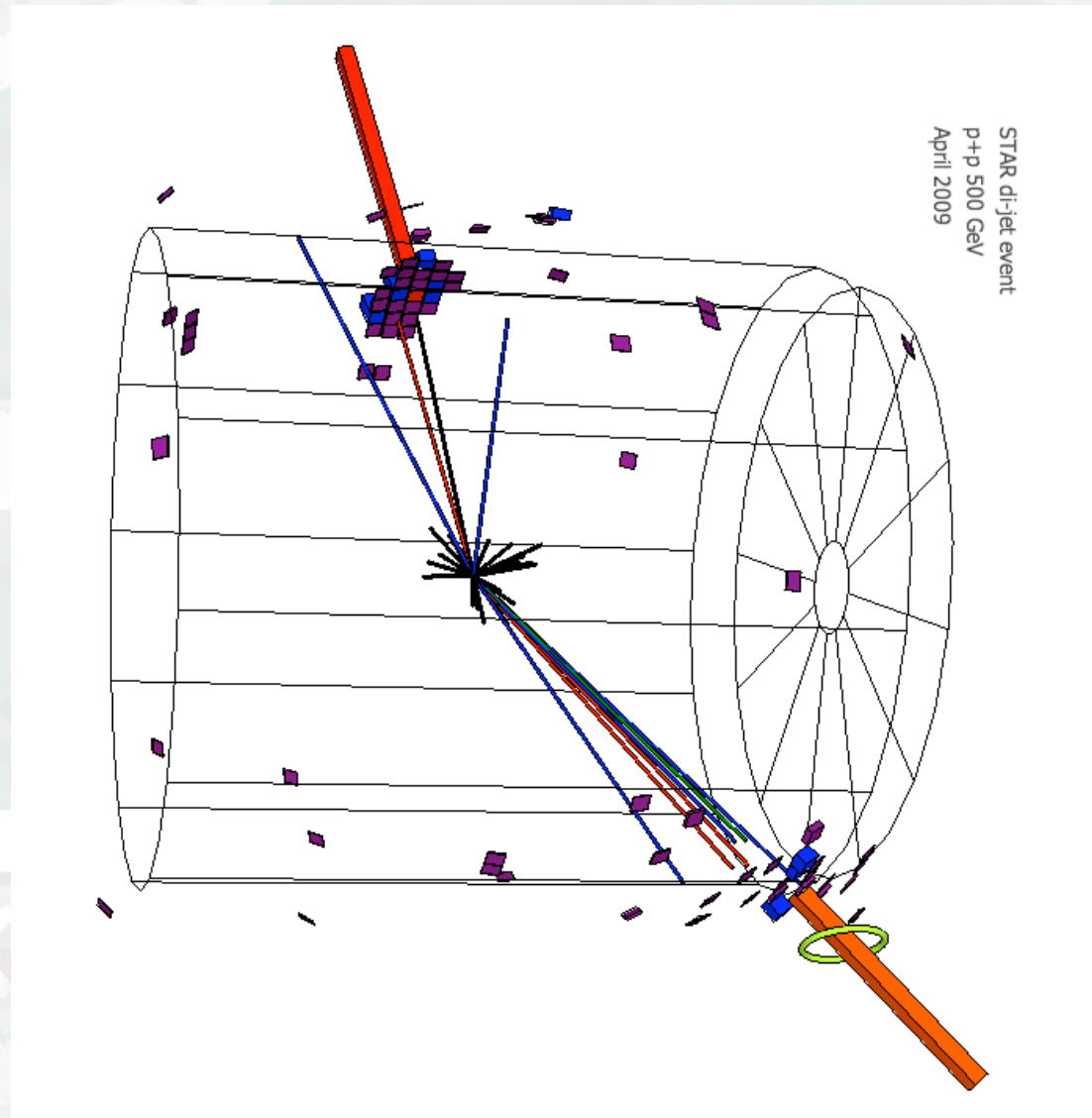
BTOW

BSMD\_E

BSMD\_P

# Run 9 W Physics Analysis

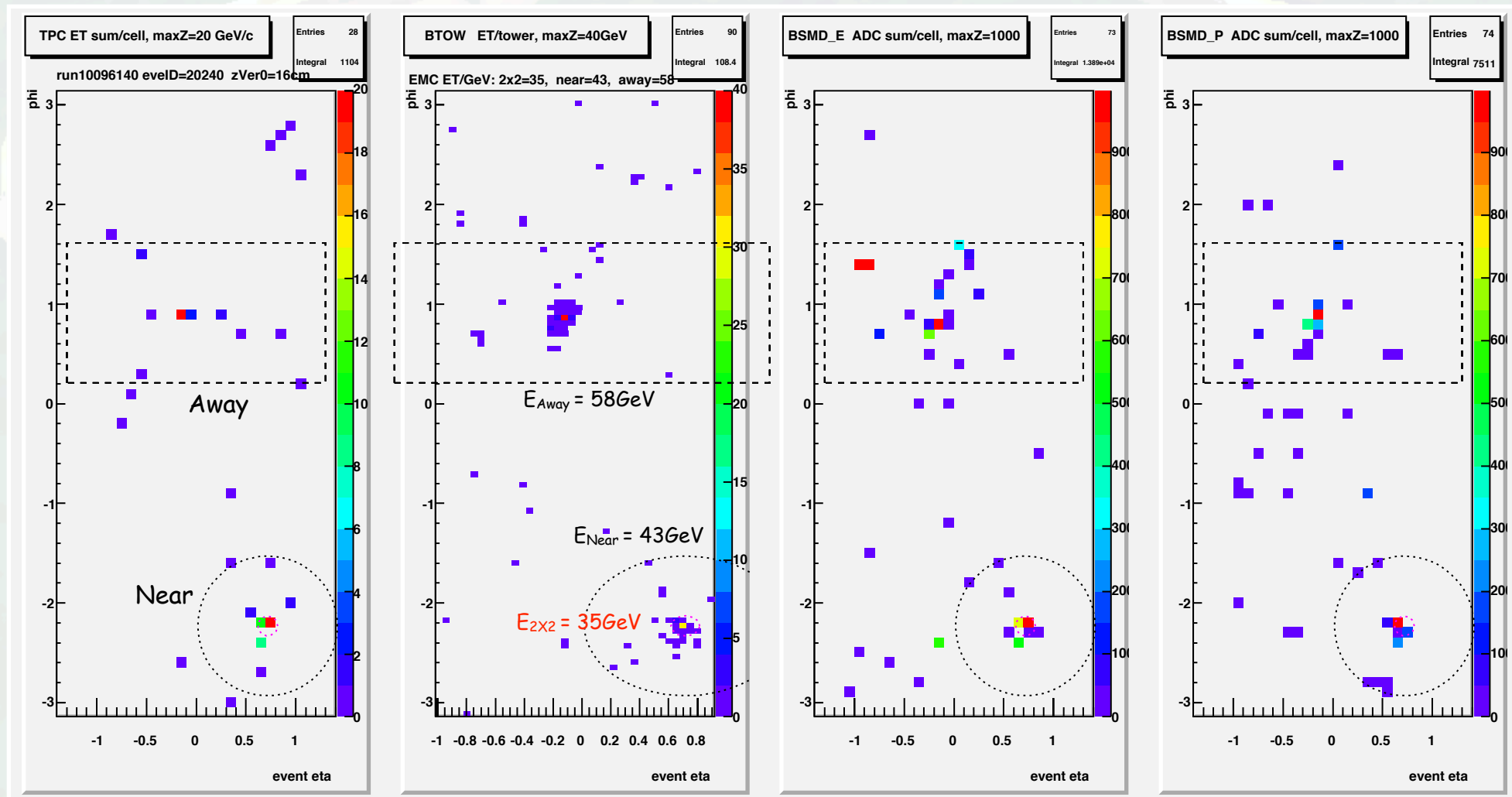
- Event display (Di-Jet event candidate) and detector signature (1)



We recorded  
and rejected  
~1.5M of those  
kinds of events!

# Run 9 W Physics Analysis

- Event display (Di-Jet event candidate) and detector signature (2)



TPC

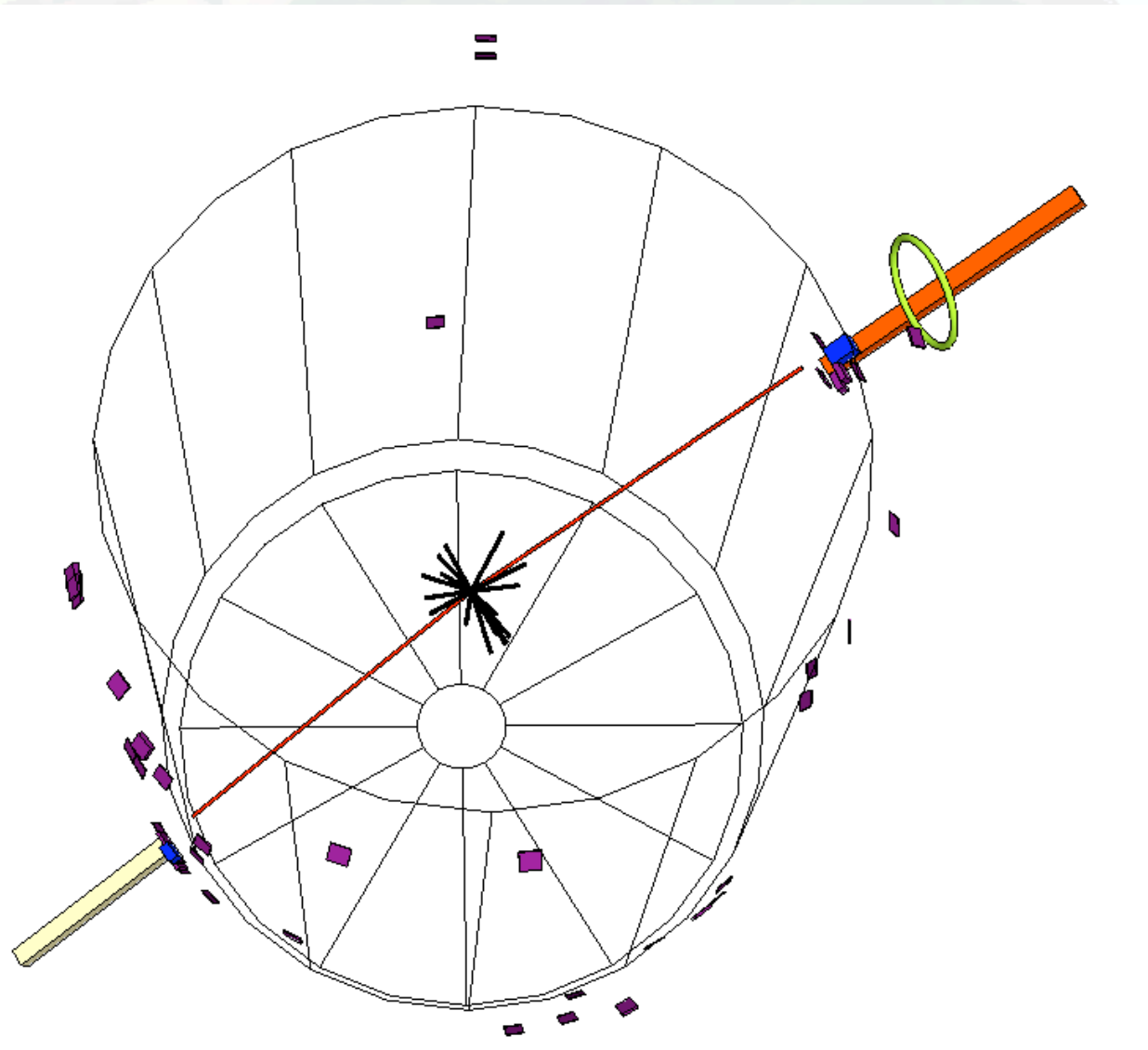
BTOW

BSMD\_E

BSMD\_P

# Run 9 W Physics Analysis

- Event display (Z event candidate) and detector signature (1)



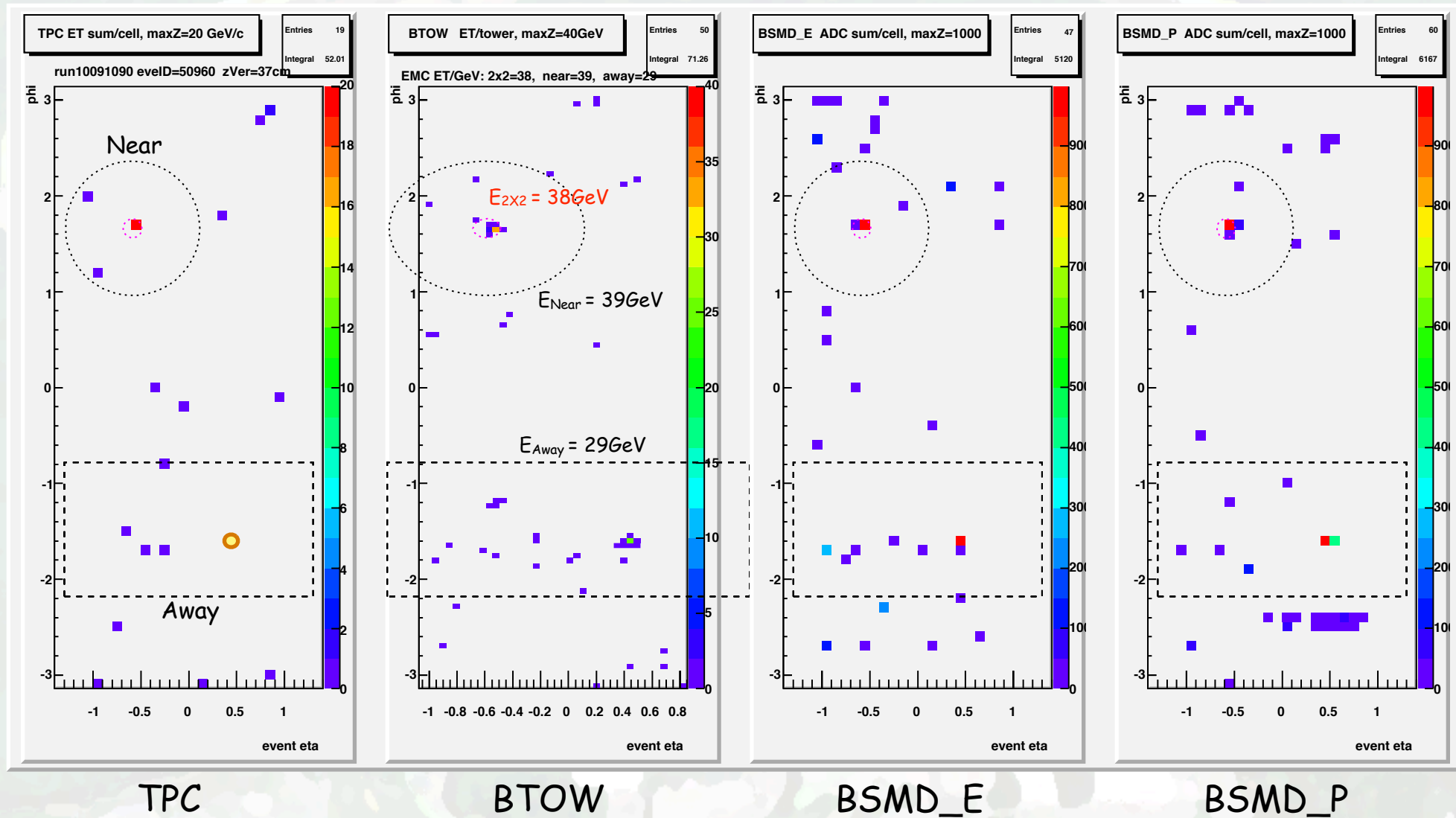
We found  
a handful  
of those  
kinds of  
events!





# Run 9 W Physics Analysis

- Event display (Z event candidate) and detector signature (2)



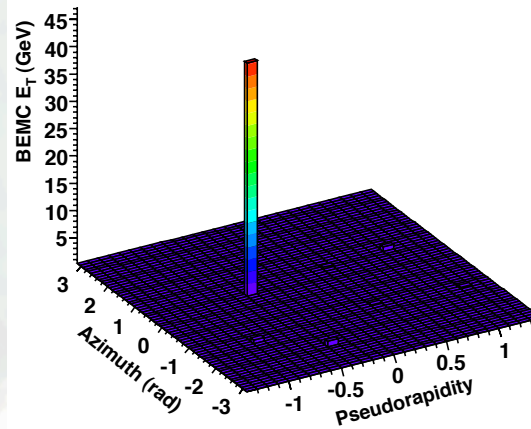


# Run 9 W Physics Analysis

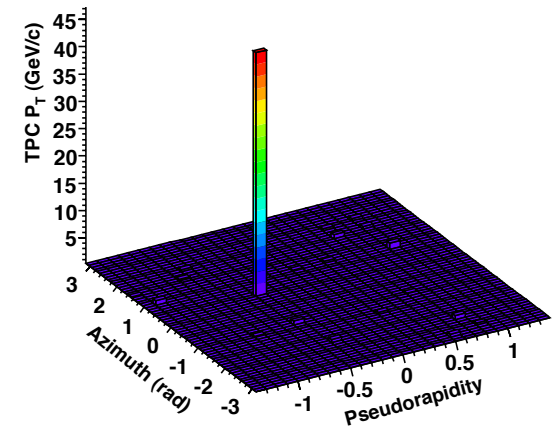
## □ Lego plots

W event

BEMC  $E_T$  Distribution (GeV)

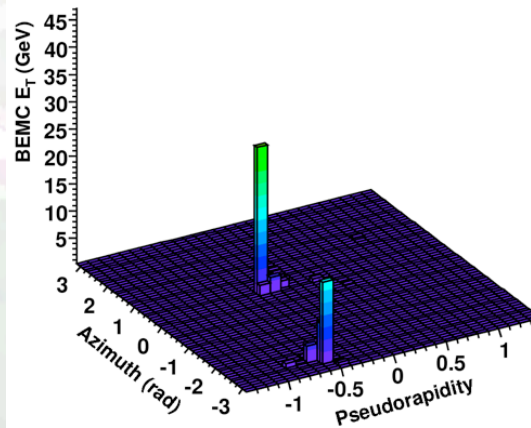


TPC  $p_T$  Distribution (GeV/c)

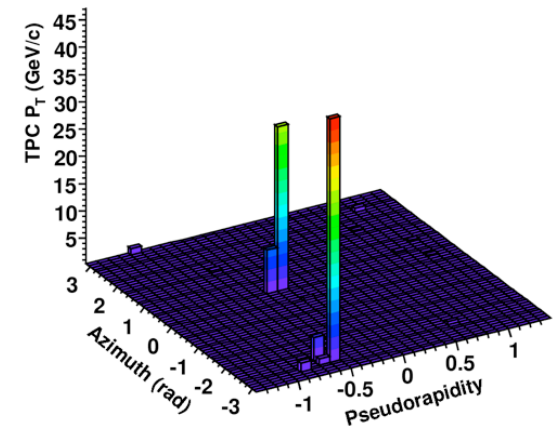


Di-Jet event

BEMC  $E_T$  Distribution (GeV)



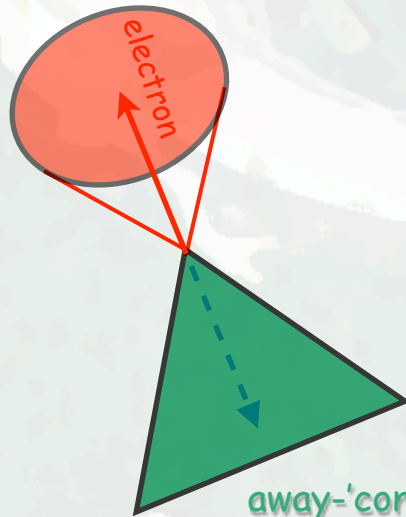
TPC  $p_T$  Distribution (GeV/c)



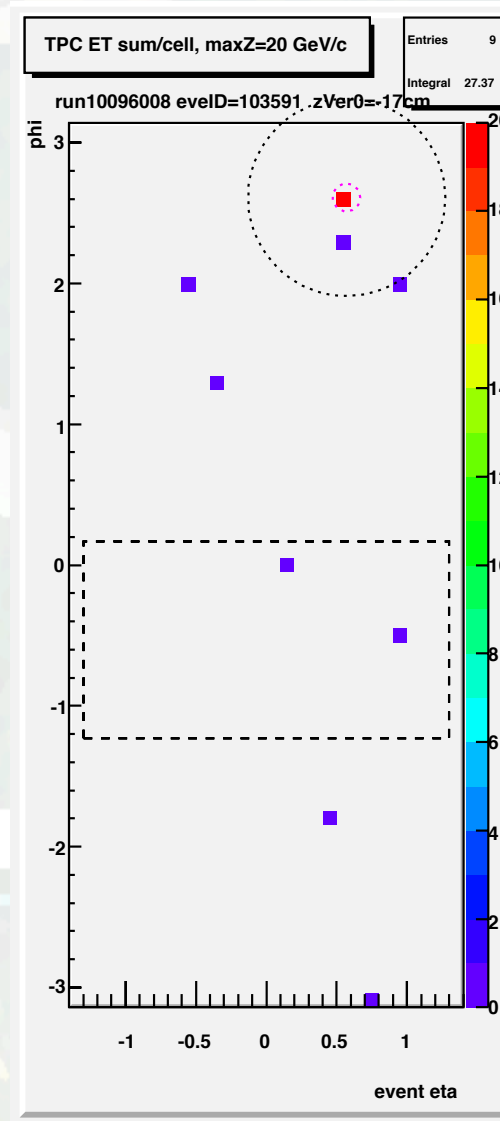
# Run 9 W Physics Analysis

## W reconstruction - Algorithm : Details

near-cone  
 $\Delta R=0.7$



away-'cone'  
 $\Delta\phi=0.7$   
any  $\eta$



General:

- Use BTOW ideal gains and actual peds, status tables from DB
- Select L2W- $E_T$  triggered events from SL09b production
- Select vertices with  $|Z| < 100$  cm

Electron isolation cuts:

- Electron candidate is any primary TPC track with global  $P_T > 10$  GeV/c
- Extrapolate TPC track to BTOW tower
- Compute  $2 \times 2$  tower cluster  $E_T$ , require  $E_T$  sum  $> 15$  GeV
- Require the excess  $E_T$  in  $4 \times 4$  tower patch over  $2 \times 2$  patch to be below 5%
- Require distance of  $2 \times 2$  cluster vs. TPC track below 7 cm

Near-cone veto:

- Compute near-cone  $E_T$  sum of BEMC+TPC over  $\Delta R=0.7$  in eta-phi space
- Require near-cone excess  $E_T$  below 12%

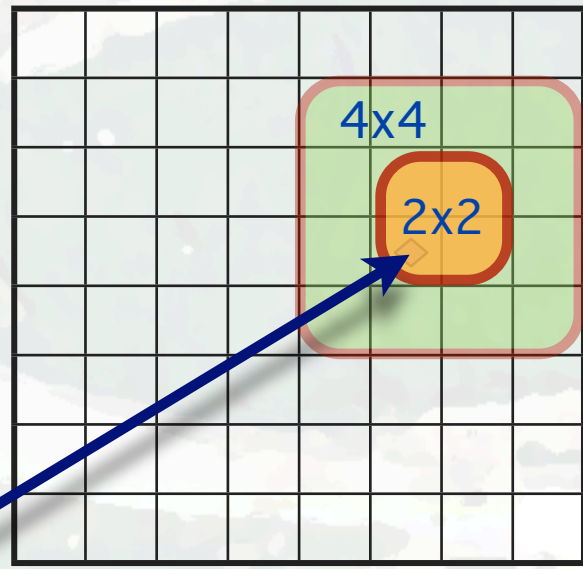
Away-'cone' veto:

- Compute away-'cone'  $E_T$  sum of BEMC+TPC over  $\Delta\phi=0.7$  and any eta (it is a rectangle)
- Require away-cone  $E_T$  below 8 GeV



# Run 9 W Physics Analysis

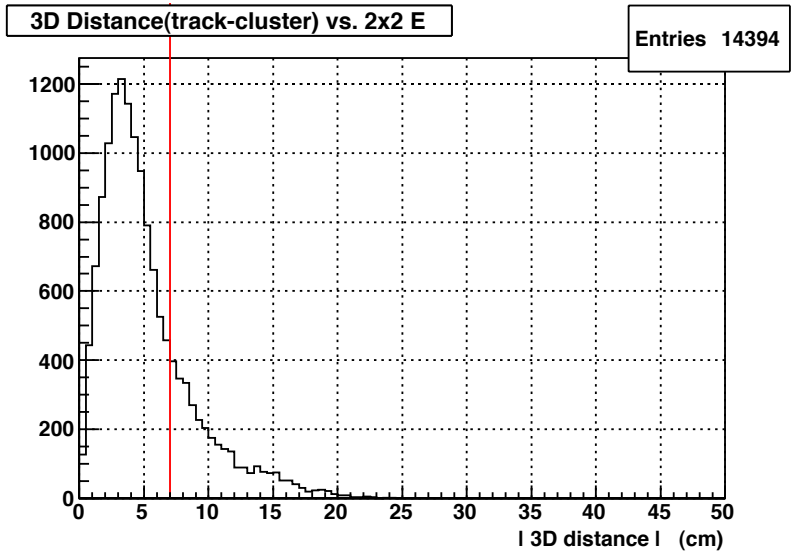
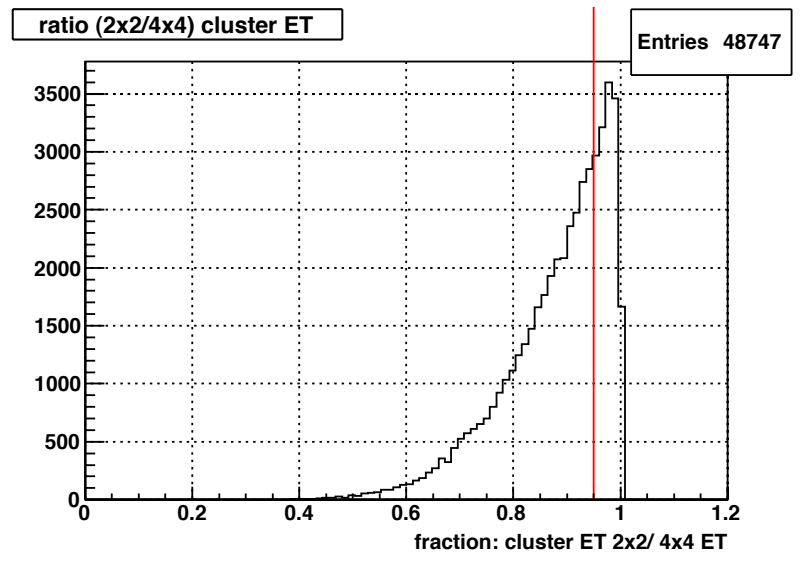
## Electron isolation cuts



TPC track extrapolated to BTOW tower grid

4x4 patch centered on 2x2 patch

Select 2x2 cluster with highest  $E_T$  sum, must contain tower pointed by the track



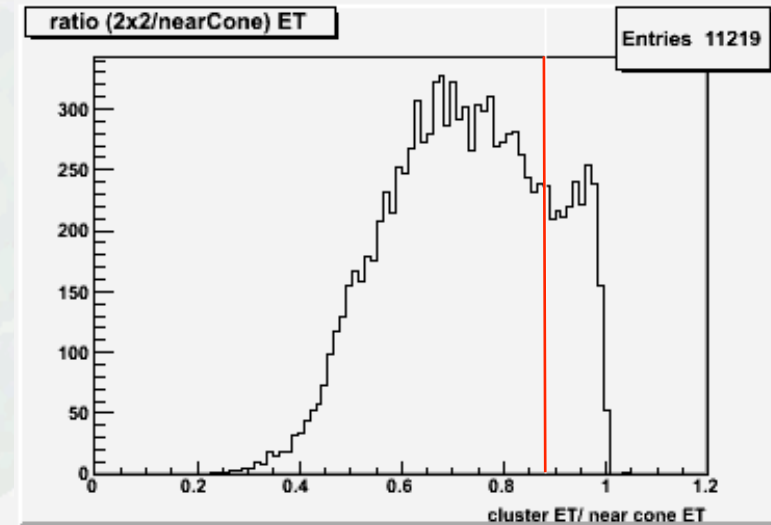


# Run 9 W Physics Analysis

## □ Near and away-side cone Veto on $E_T$

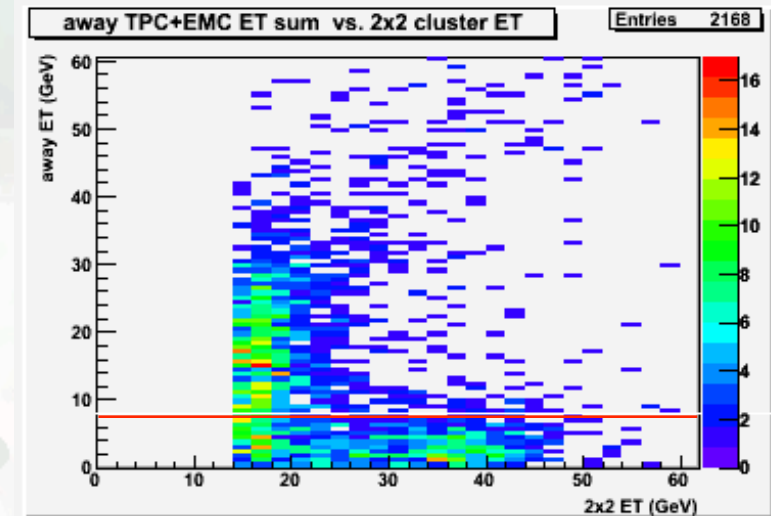
### Near-cone $E_T$ sum

- Defined by electron track
- $\Delta R(\eta, \phi) = 0.7$
- BTOW: Sum  $E_T$
- TPC: Sum glob  $p_T$ , if  $p_T > 10 \text{ GeV}/c$  use 10  $\text{GeV}/c$
- Total = BTOW + TPC (Avoid double counting)

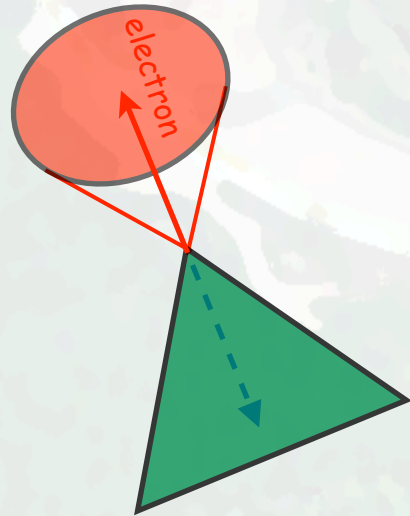


### Away-'cone' $E_T$ sum

- Defined by (-electron track) in  $\phi$
- $\Delta\phi = 0.7$ , any  $\eta$
- BTOW: Sum  $E_T$
- TPC: Sum glob  $p_T$ , if  $p_T > 10 \text{ GeV}/c$  use 10  $\text{GeV}/c$
- Total = BTOW + ETOW + TPC



near-cone  
 $\Delta R=0.7$

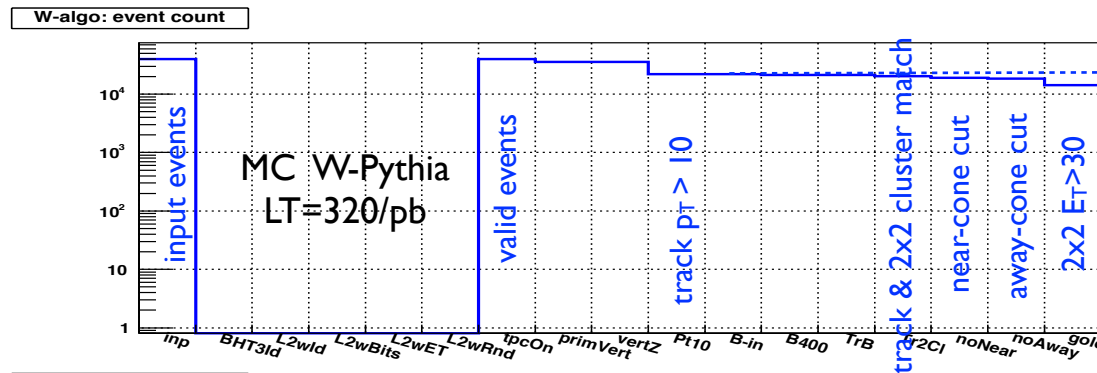
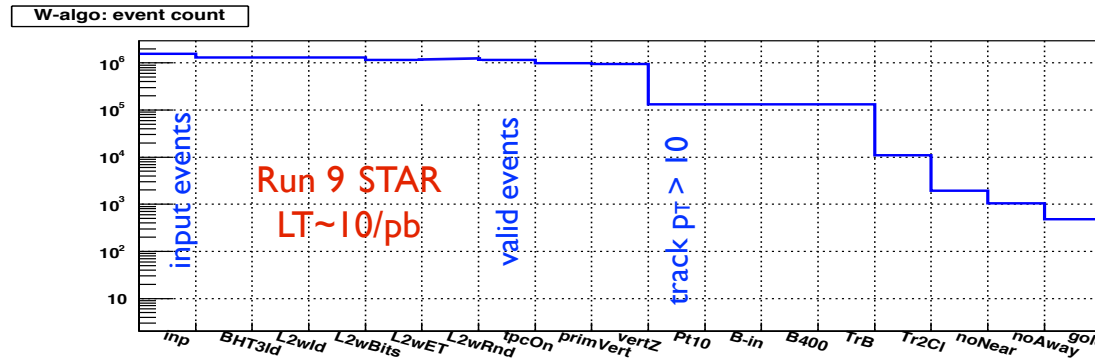


away-'cone'  
 $\Delta\phi=0.7$   
any  $\eta$

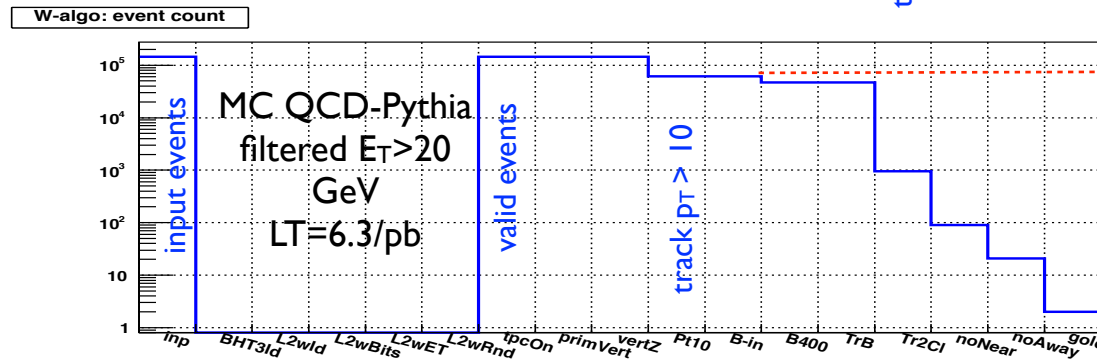


# Run 9 W Physics Analysis

- Event yield vs. cut ID - Data/MC (PYTHIA W Signal and QCD Background simulation)



W signal event loss in reconstruction: ~40%!



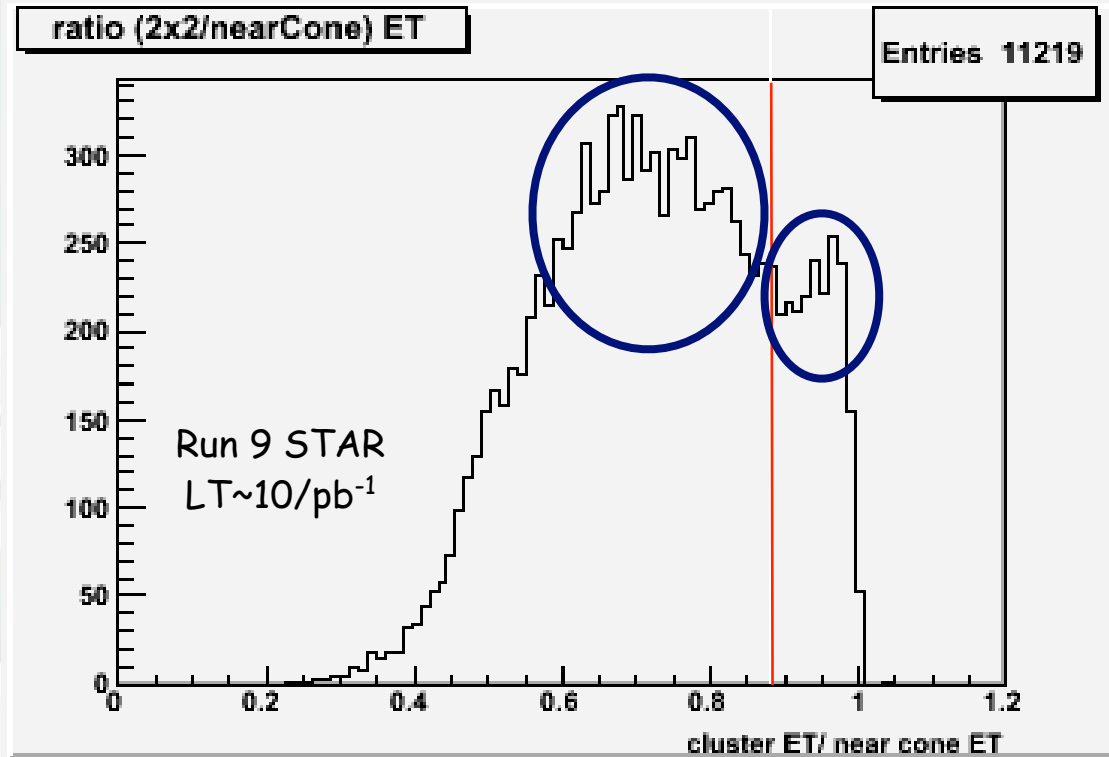
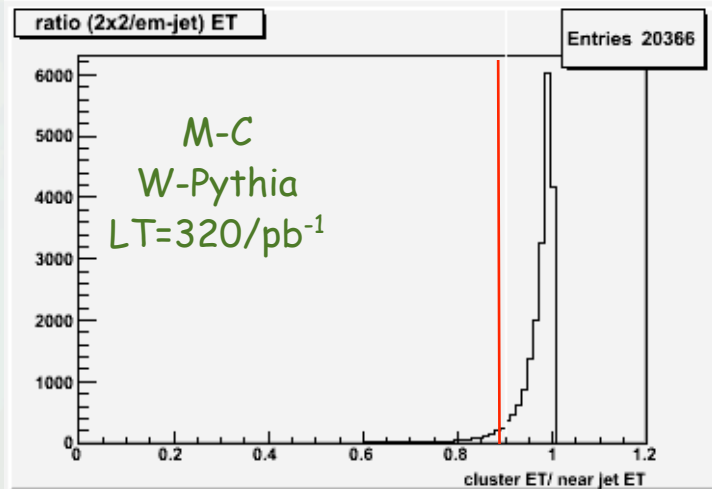
Large QCD suppression  $\sim 10^4!$



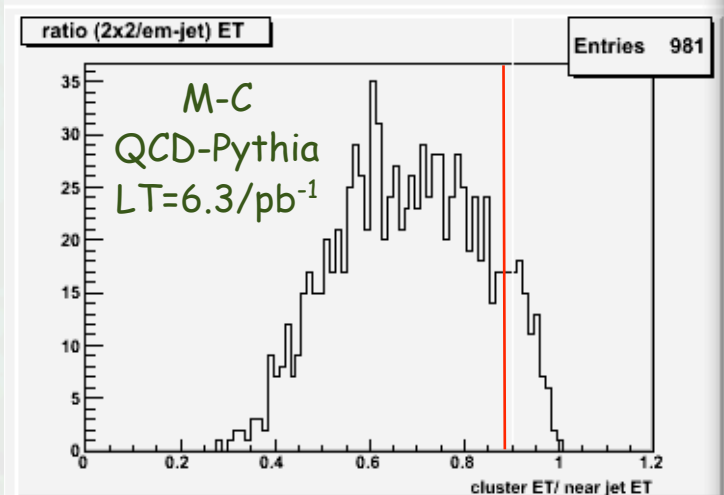
# Run 9 W Physics Analysis

## Correlation of $E_T(2X2) / E_T(\text{Near-side}) : \text{MC} / \text{Data}$

TPC+BTOW near jet ET, mcSetD1\_ppWp



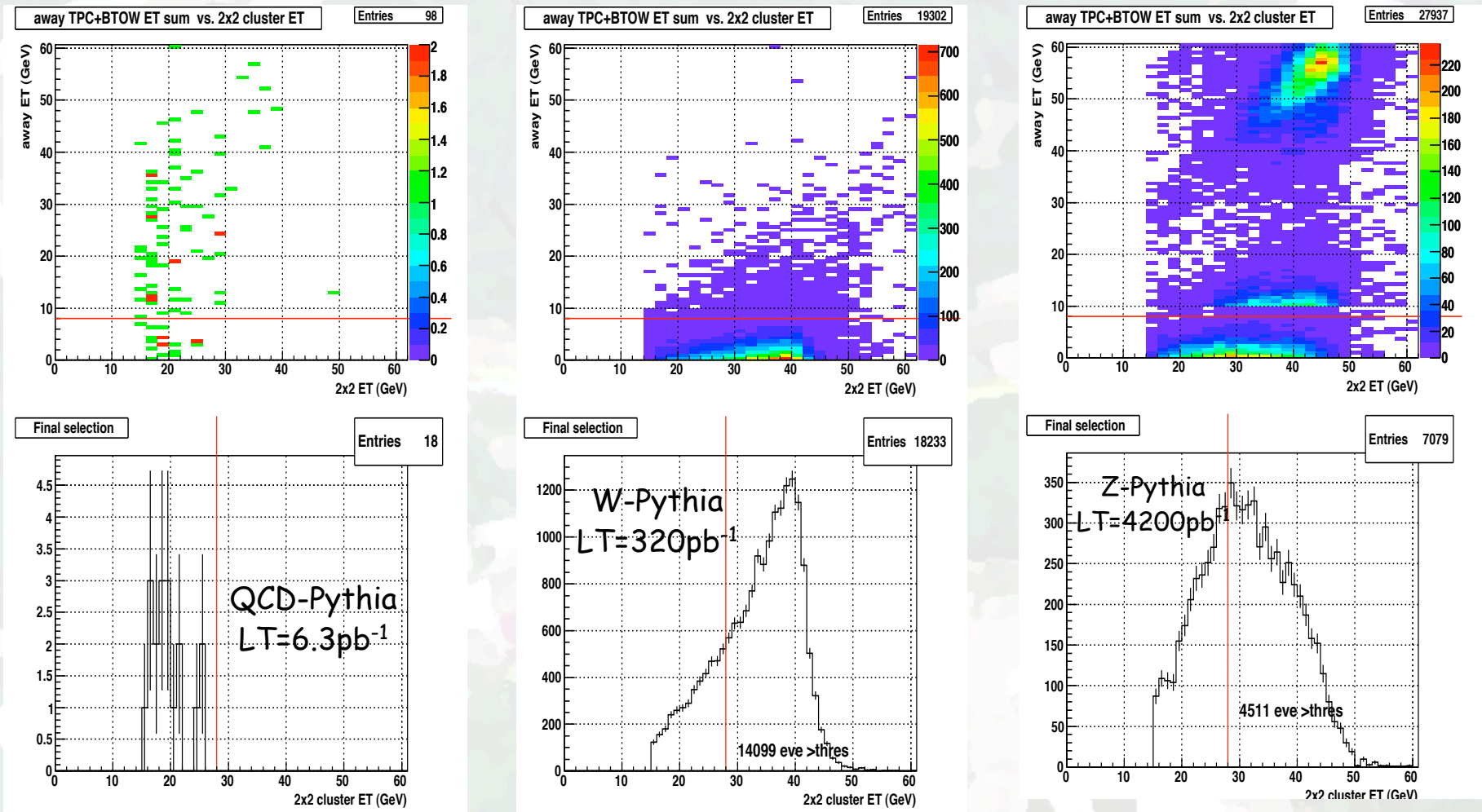
TPC+BTOW near jet ET, mcSetD2\_ppQCD10





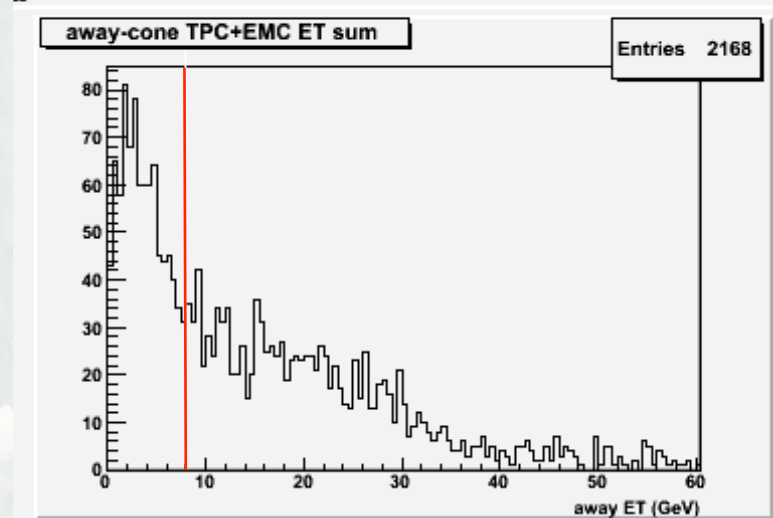
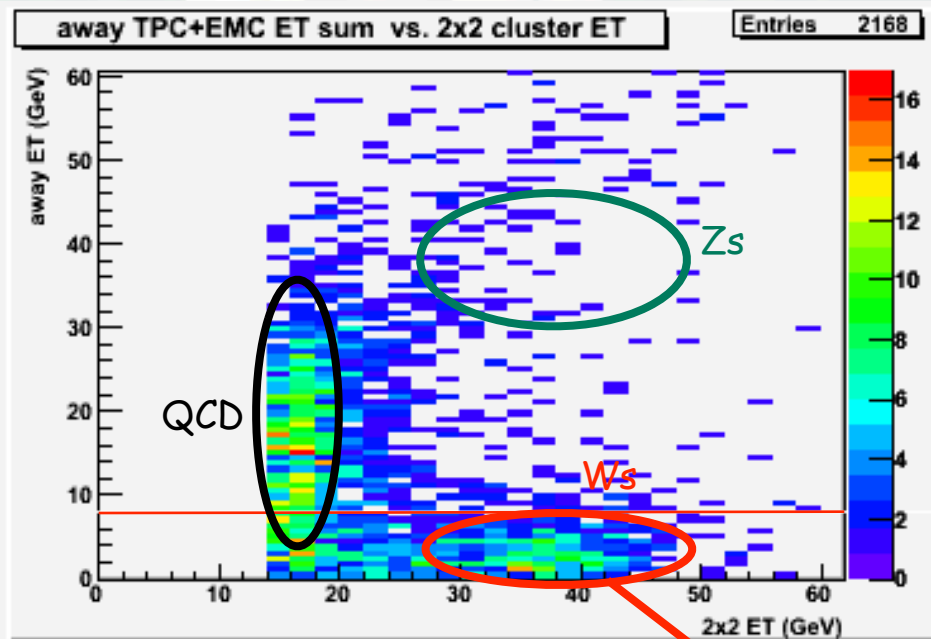
# Run 9 W Physics Analysis

## Correlation of $E_T(2X2) / E_T(\text{Away-side}) : MC$

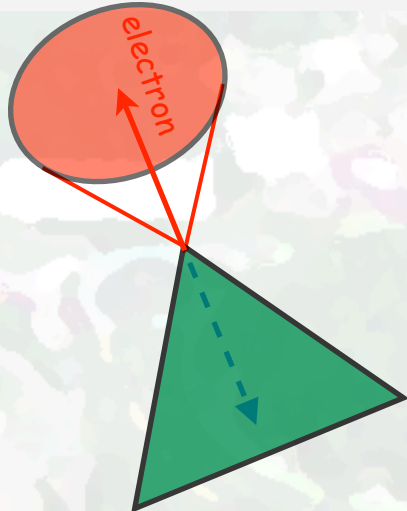


# Run 9 W Physics Analysis

## Correlation of $E_T(2X2) / E_T(\text{Away-side})$ : Data

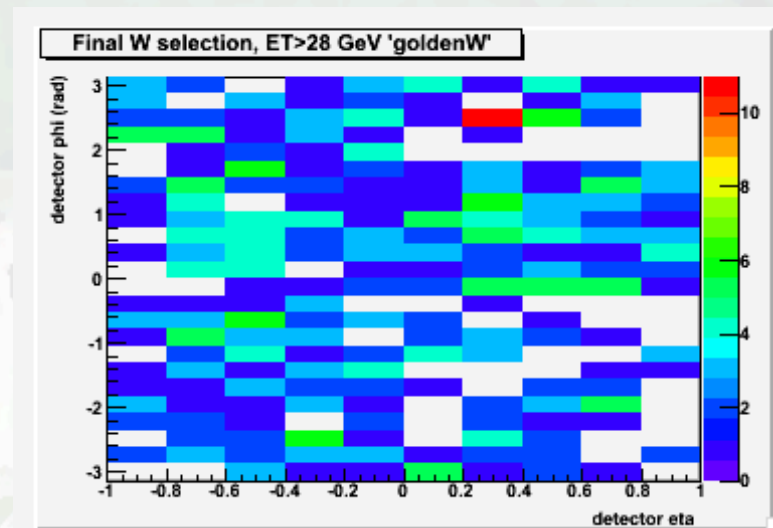


near-cone  
 $\Delta R=0.7$



$W_s$

away-'cone'  
 $\Delta\phi=0.7$   
any  $\eta$

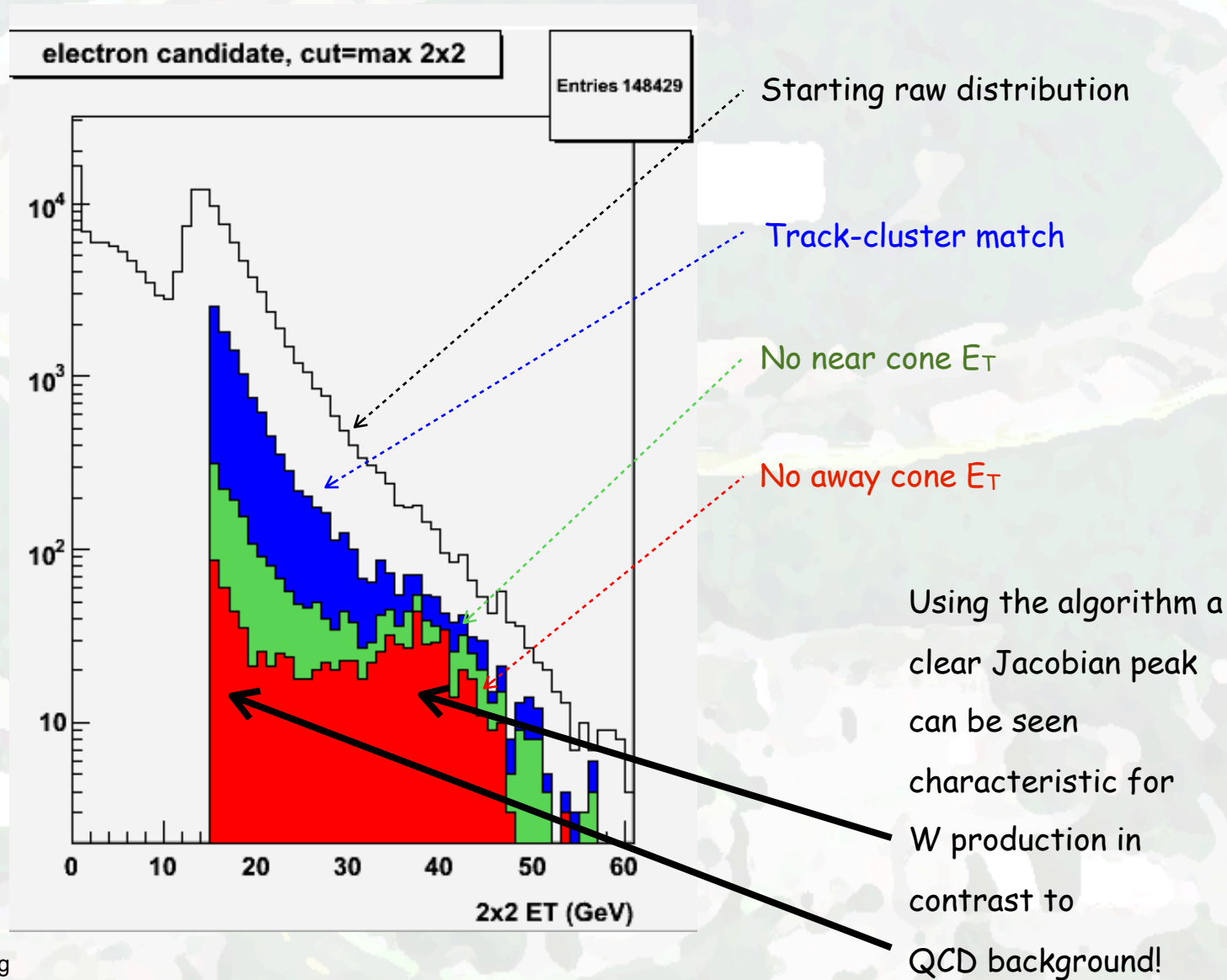






# Run 9 W Physics Analysis

## □ Evolution of $E_T$ distribution vs. cut ID

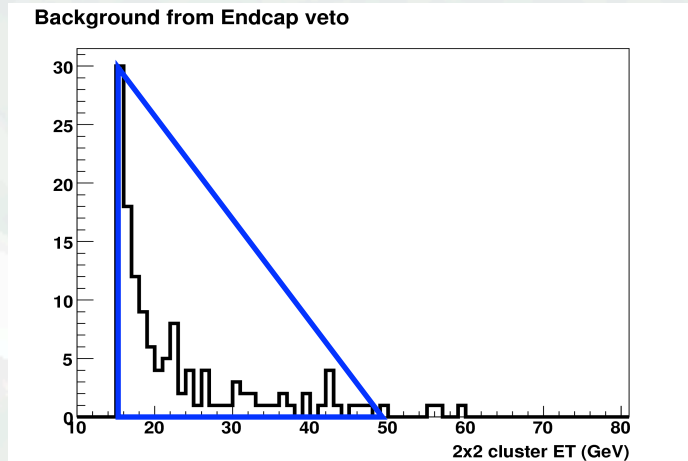
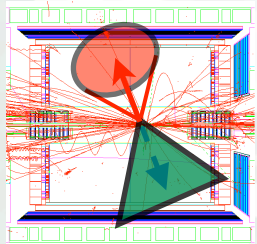


# Run 9 W Physics Analysis

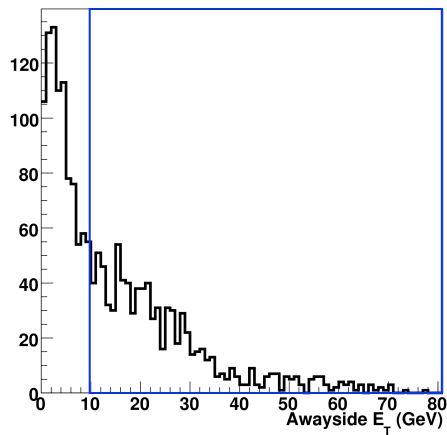
## QCD background treatment

Estimate QCD background in a fully data-driven manner

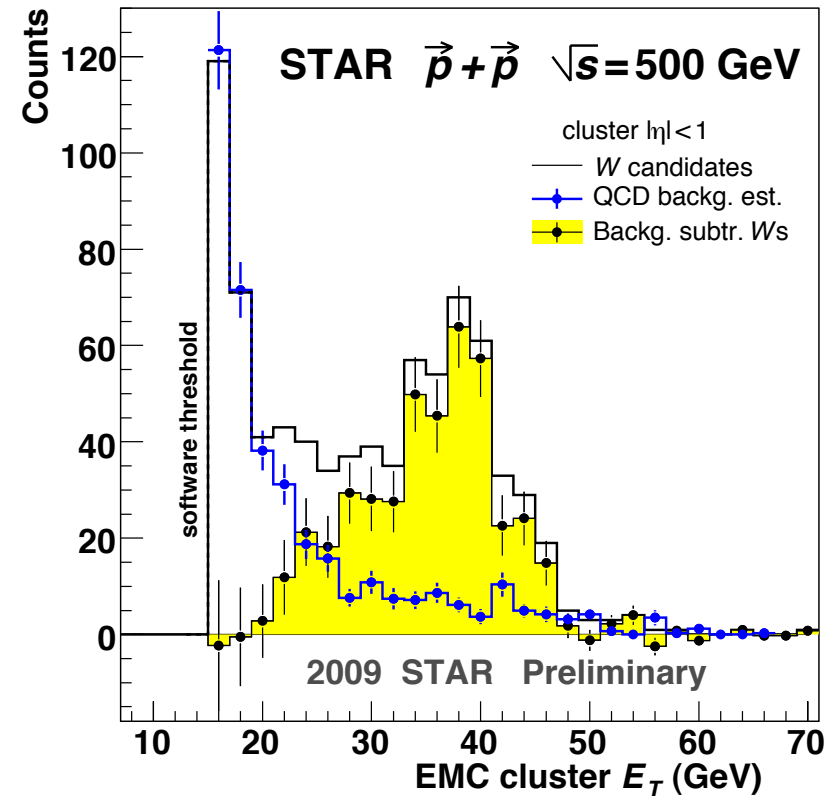
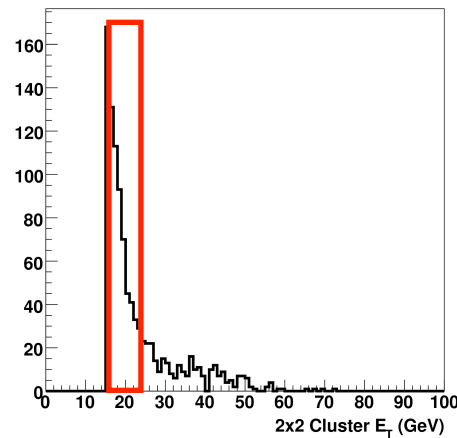
Background from "missing" endcap



Awayside Sum  $E_T$



Nearside  $E_T$  for Awayside  $E_T > 8$  GeV

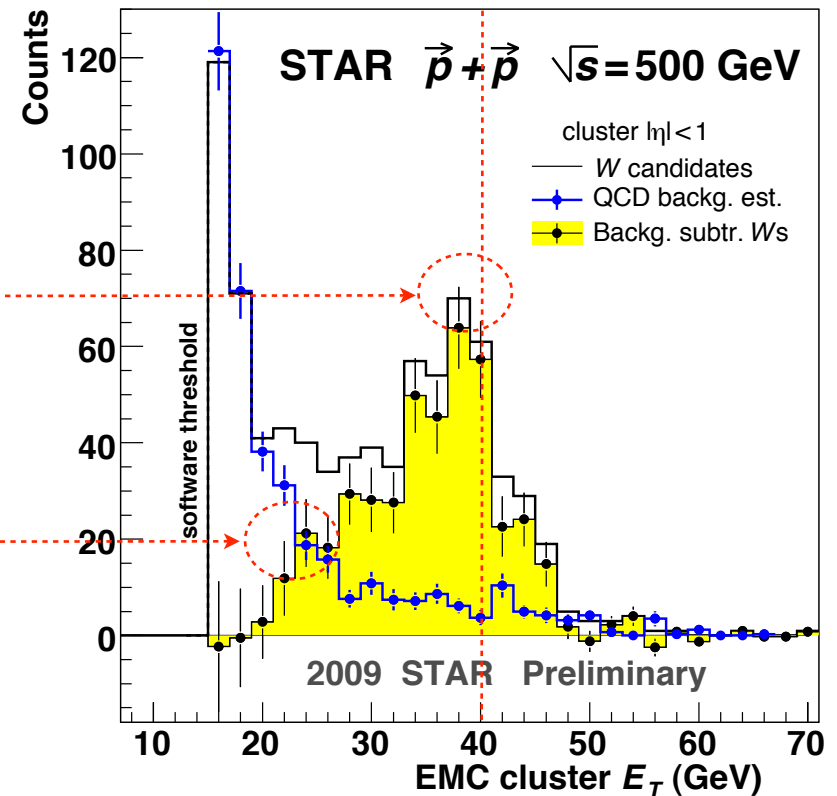
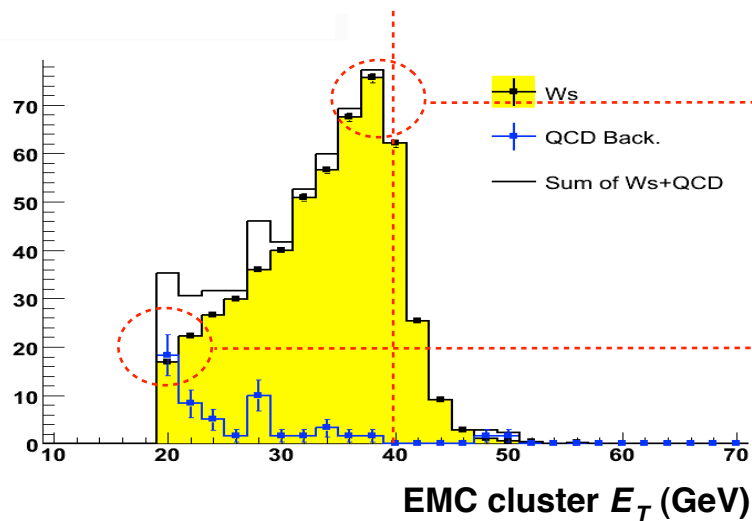




# Run 9 W Physics Analysis

- Final result and overall yield: First Observation of W boson production at STAR

## W PYTHIA MC Simulation (10pb<sup>-1</sup>)

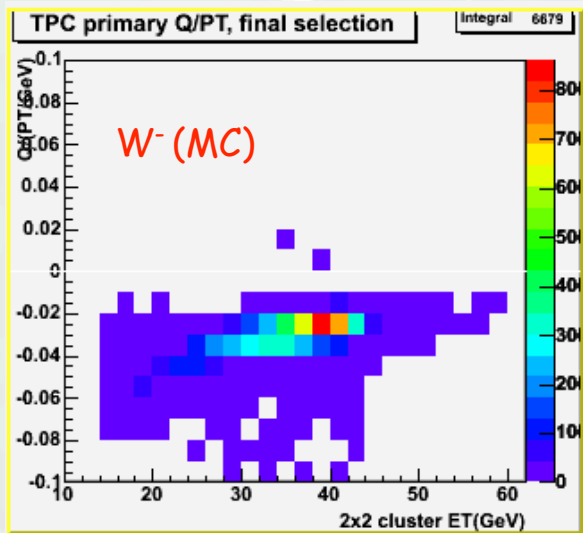
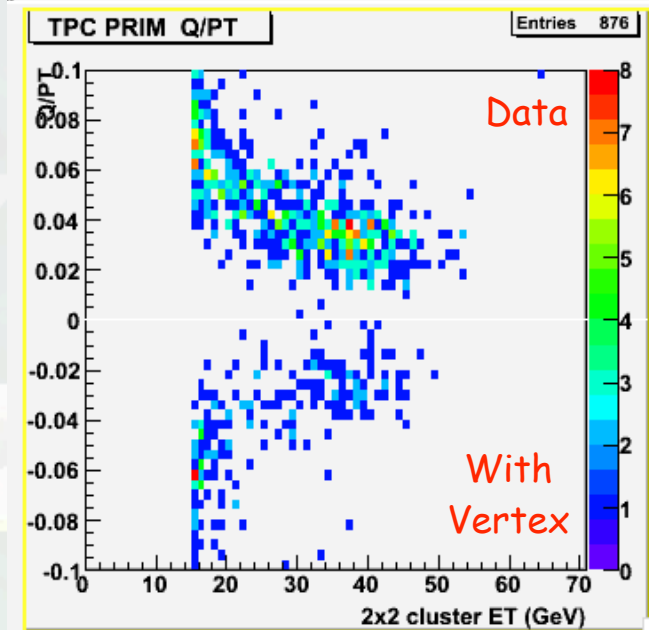
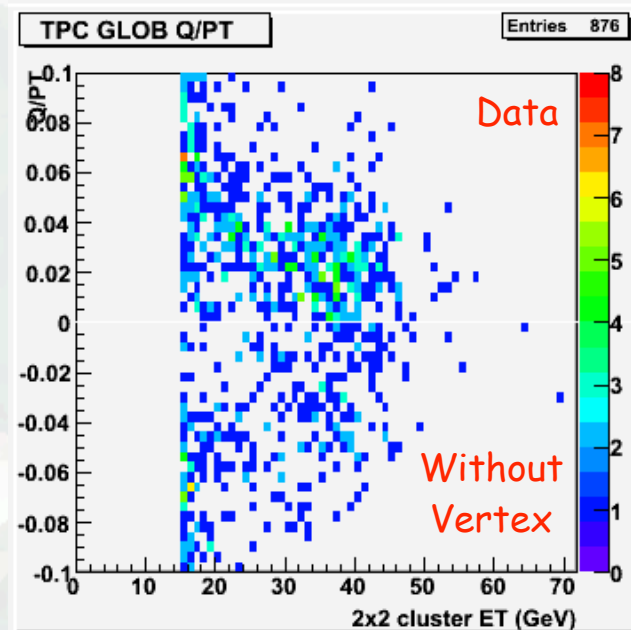
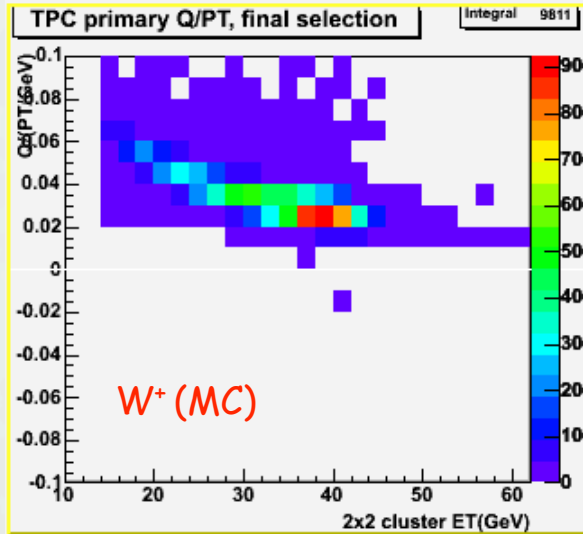


⇒ Comparable shape/yield of W PYTHIA MC  
Simulation and Data Run 9

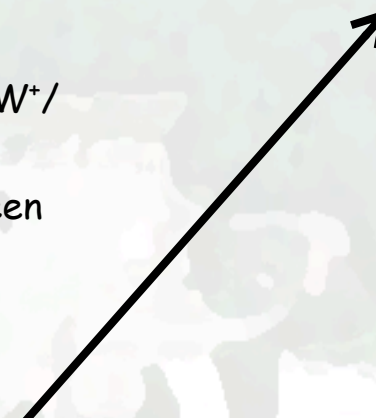


# Run 9 W Physics Analysis

- First look at charge-sign discrimination : Data/MC comparison



- Features as seen in MC for W<sup>+</sup>/  
W<sup>-</sup> in sign/p<sub>T</sub> vs. E<sub>2x2</sub> also seen  
in data
- Critical: Vertex constraint





# Run 9 W Physics Analysis

## Statistical precision in $A_L$ from Run 9

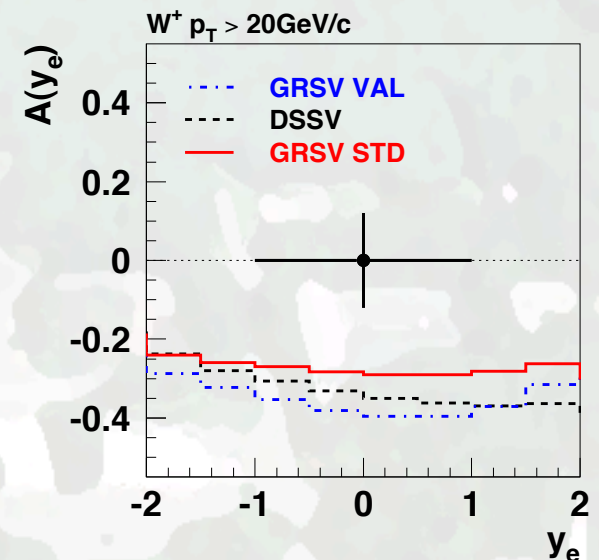
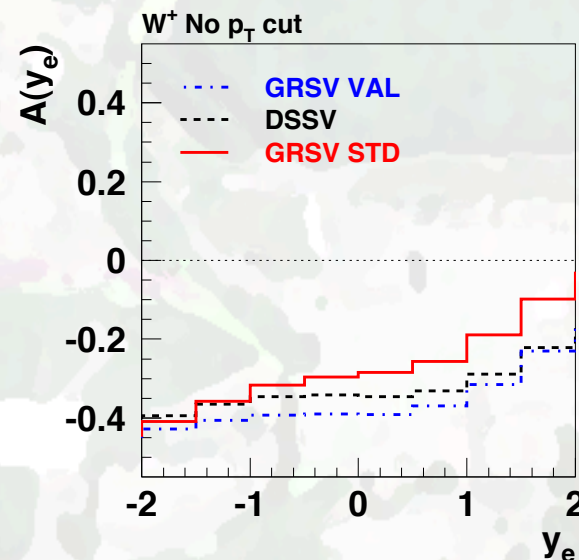
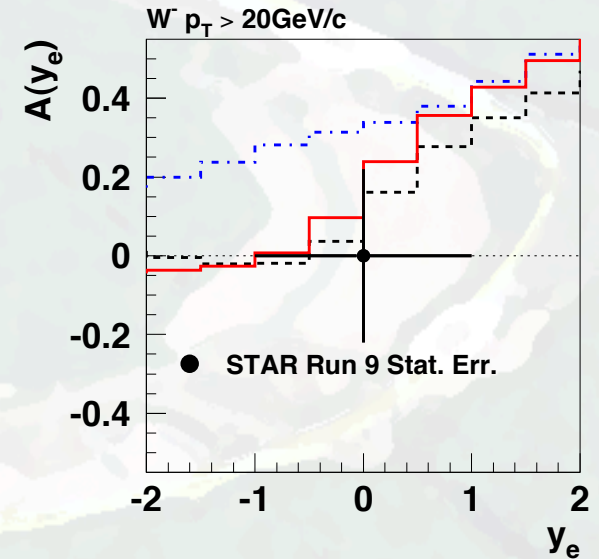
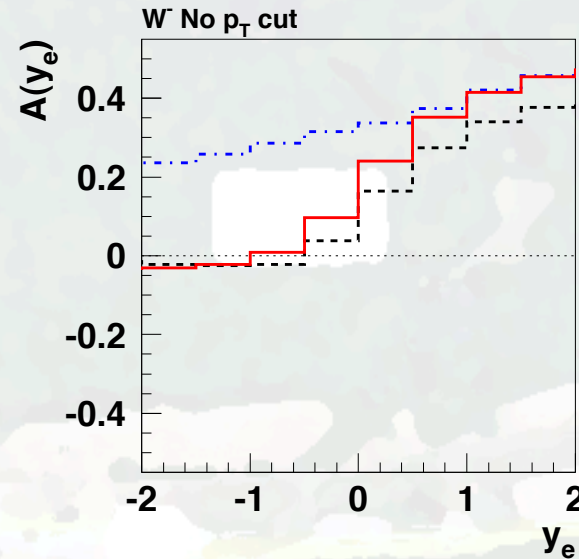
- Projected statistical uncertainties of  $A_L$  for  $W^-$  and  $W^+$  from Run 9 ( $E_T > 30\text{GeV}$ ) in comparison to RHICBOS predictions

Assumed mean

polarization:  $P = 35\%$

No background contribution

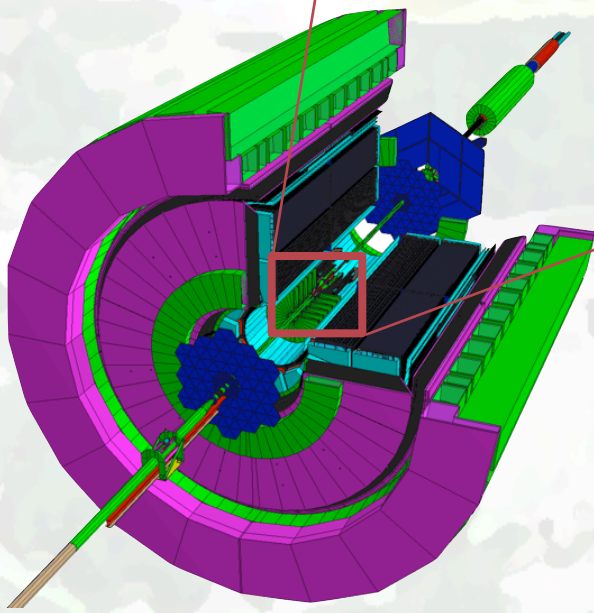
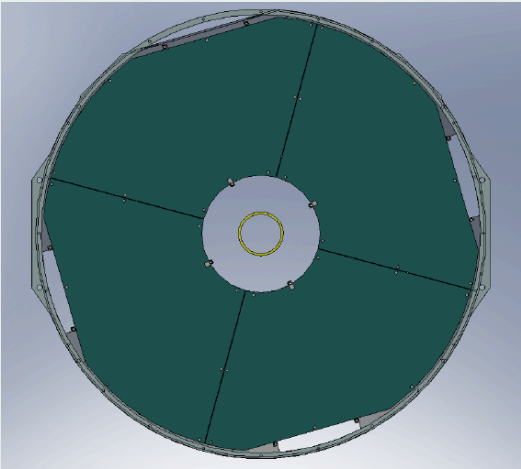
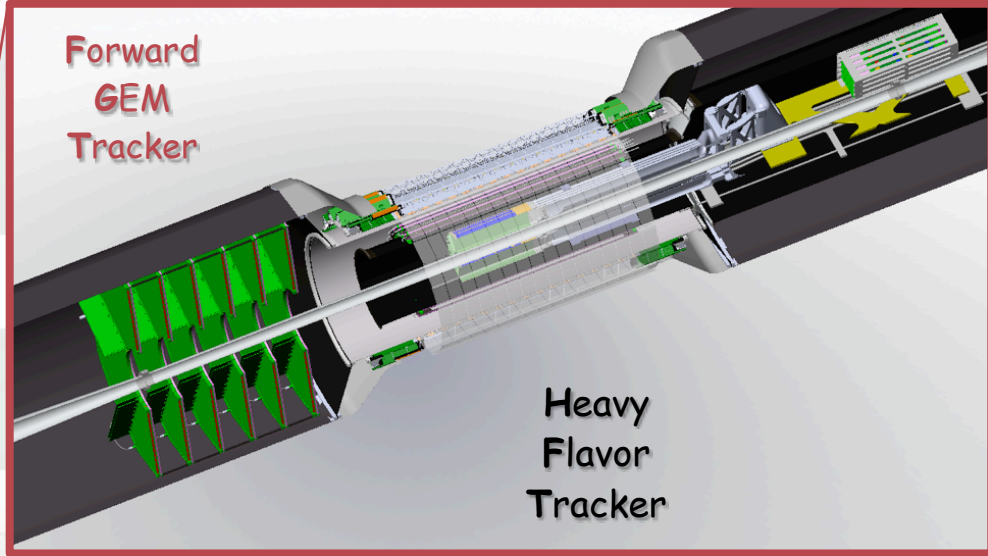
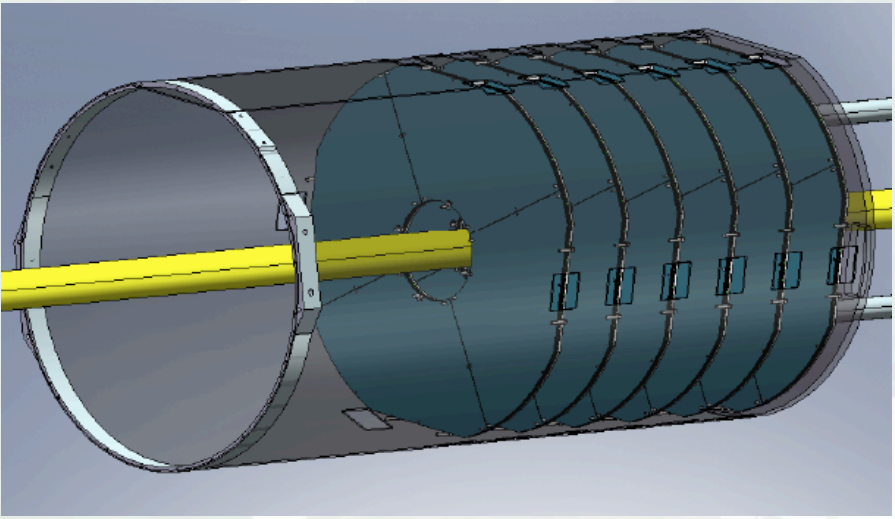
contribution





# Future Plans - STAR W Program

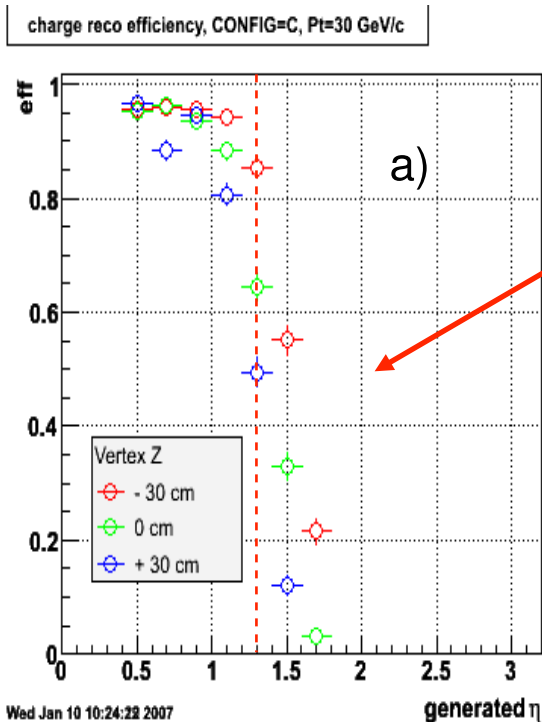
## FGT layout





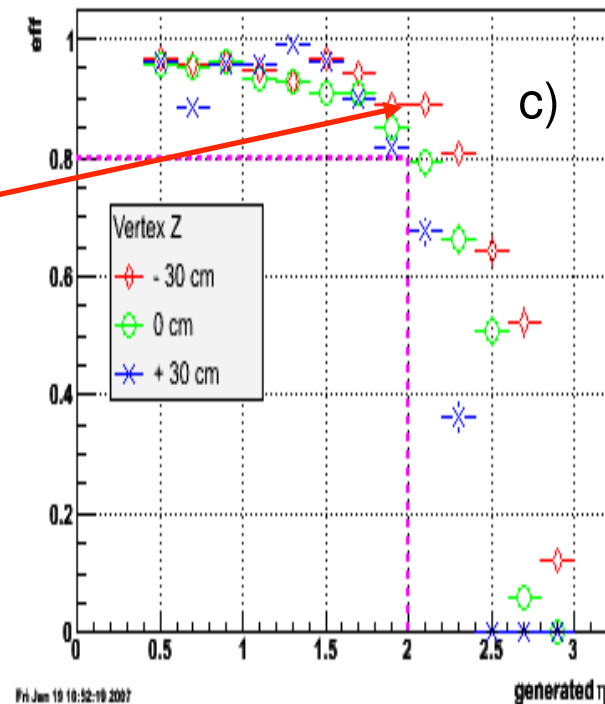
# Future Plans - STAR W Program

## FGT concept on charge-sign discrimination



Reach of EEMC Acceptance

TPC + FGT Tracking,  $p_T = 30 \text{ GeV}/c$



### Conclusion:

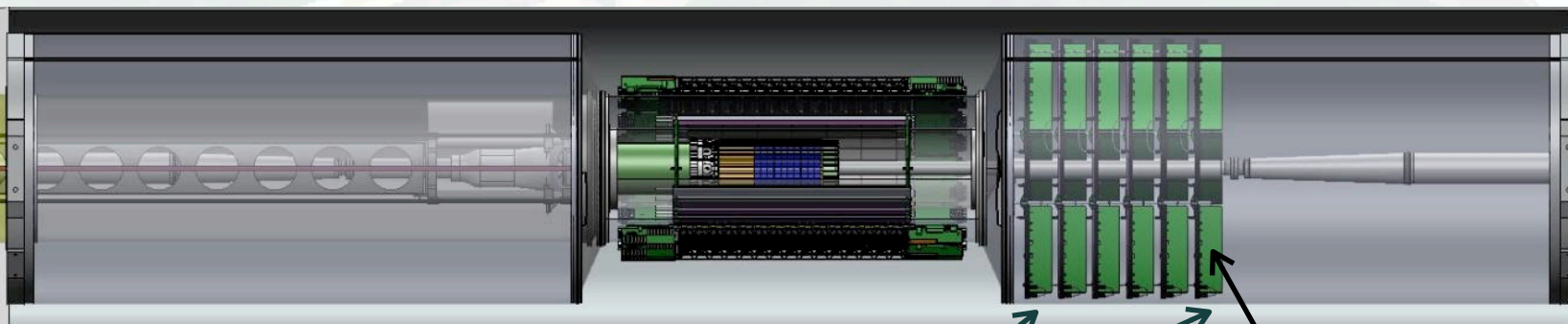
Charge sign reconstruction impossible beyond  $\eta = \sim 1.3$

6 triple-GEM disks, assumed spatial resolution 60 $\mu\text{m}$  in x and y (Fairly insensitive for 60-100 $\mu\text{m}$ )

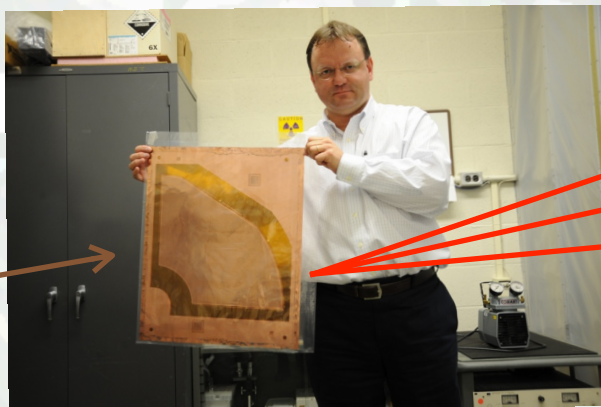
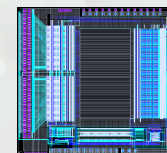
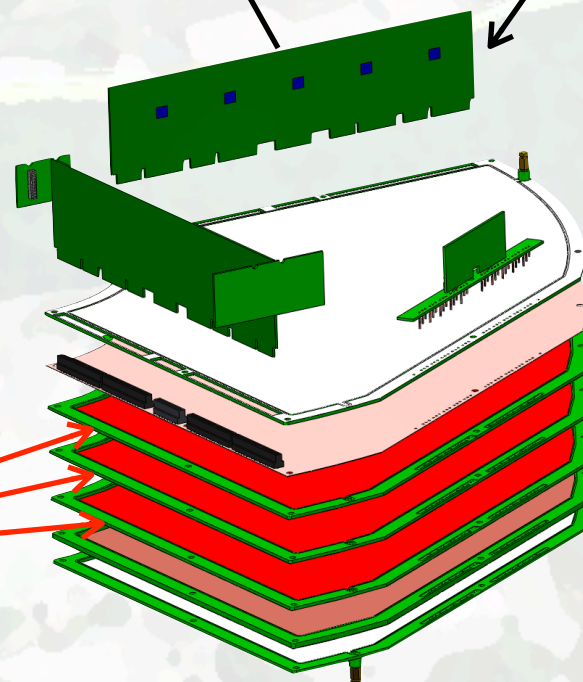
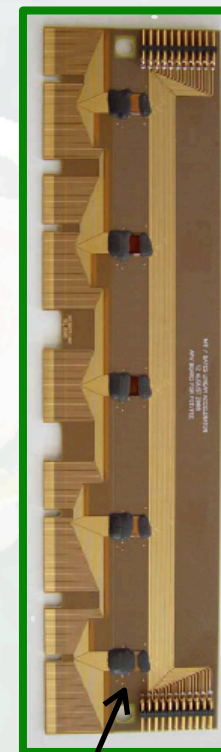
Charge sign reconstruction probability above 90% for 30 GeV  $p_T$  over the full acceptance of the EEMC for the full vertex spread

# Future Plans - STAR W Program

## FGT Status



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



FGT GEM foil





# Future Plans - STAR W Program

## □ $A_L$ projections: Forward/backward rapidity

### ○ Large asymmetries dominated by

quark polarization - Important

consistency check to existing DIS

data with  $100\text{pb}^{-1}$  (Phase I)

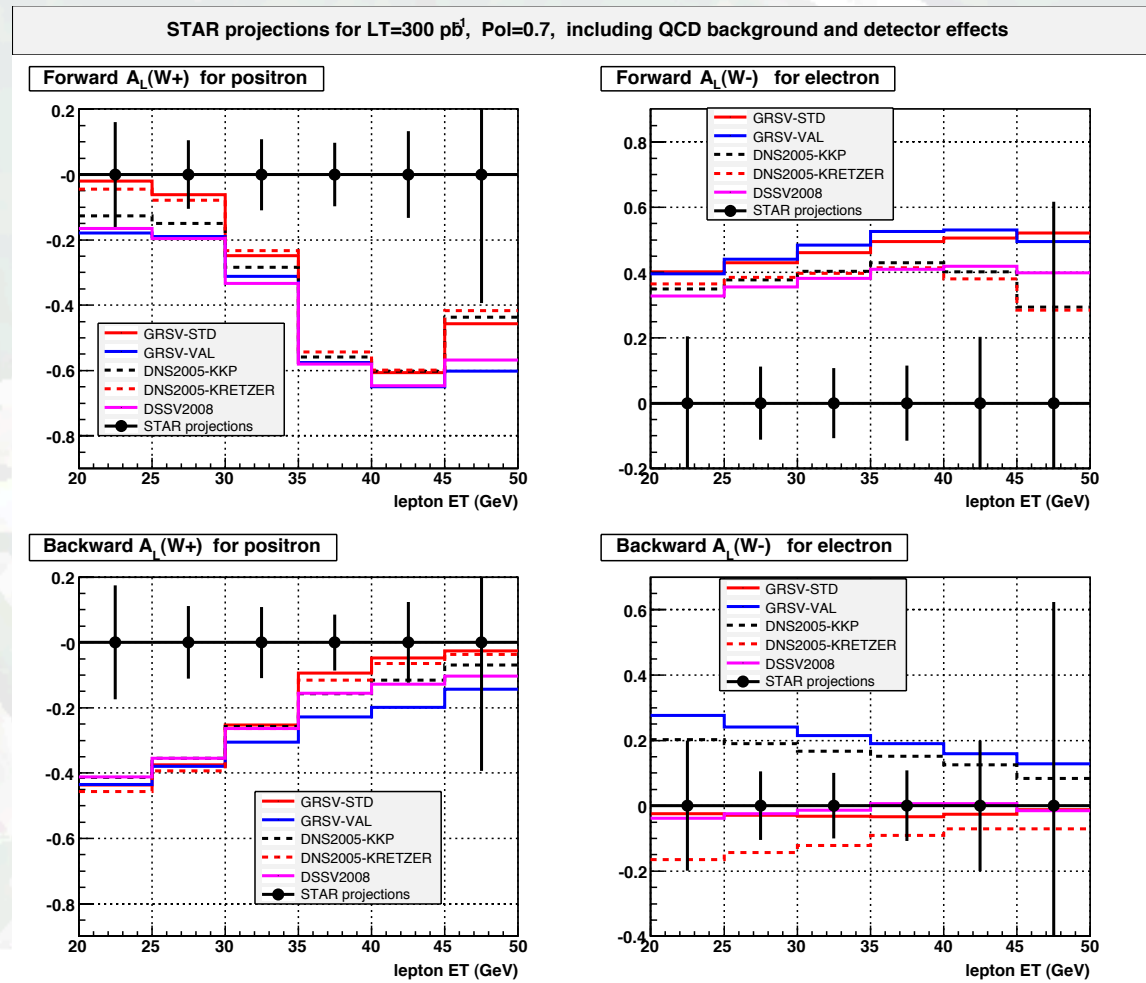
### ○ Strong impact constraining unknown

antiquark polarization requires

luminosity sample at the level of

$300\text{pb}^{-1}$  for 70% beam polarization

(Phase II)



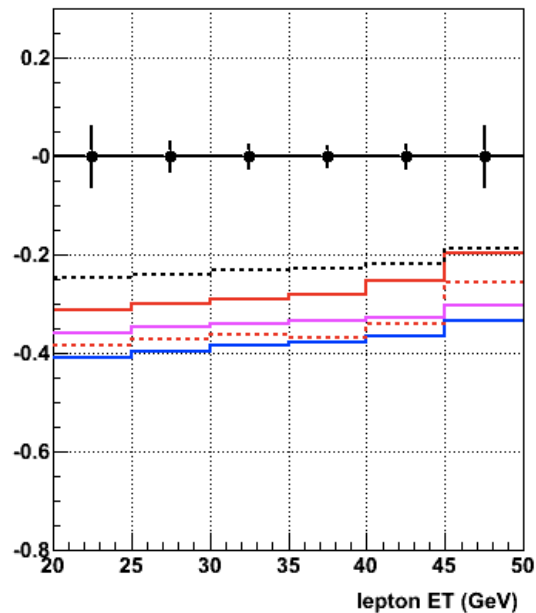


# Future Plans - STAR W Program

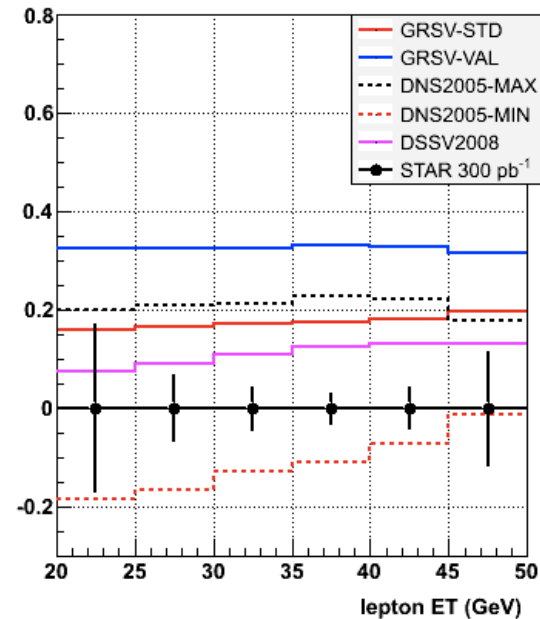
## □ $A_L$ projections: Mid-rapidity

STAR projections for  $LT=300 \text{ pb}^{-1}$ ,  $\text{Pol}=0.7$ ,  $\text{effi}=70\%$ , including QCD background, 2 beams, no vertex cut

$A_L(W^+)$  for positron  $|\eta| < 1$



$A_L(W^-)$  for electron  $|\eta| < 1$



- Mid-rapidity STAR W program will provide additional important constraint!





# Summary

- First  $W$  boson results at STAR
  - STAR has shown a first extraction of a **Jacobian peak of a  $W$  signal** in p+p collisions at  $\sqrt{s}=500$  GeV **confirming our expectations**
  - Next step: **Run 9 Cross-section** and  $A_L$  for  $W^+/W^-$  at **mid-rapidity**
- Outlook:
  - Goal: 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)
  - High-precision future measurements of  $A_L$  at STAR at mid-rapidity and forward rapidity are expected to play a critical role in our understanding of the polarized QCD sea!



# Thank You

## □ W Analysis Team

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BNL: Gene V. Buren

ANL: Hal Spinka

UC-Davis: Rosi Reed