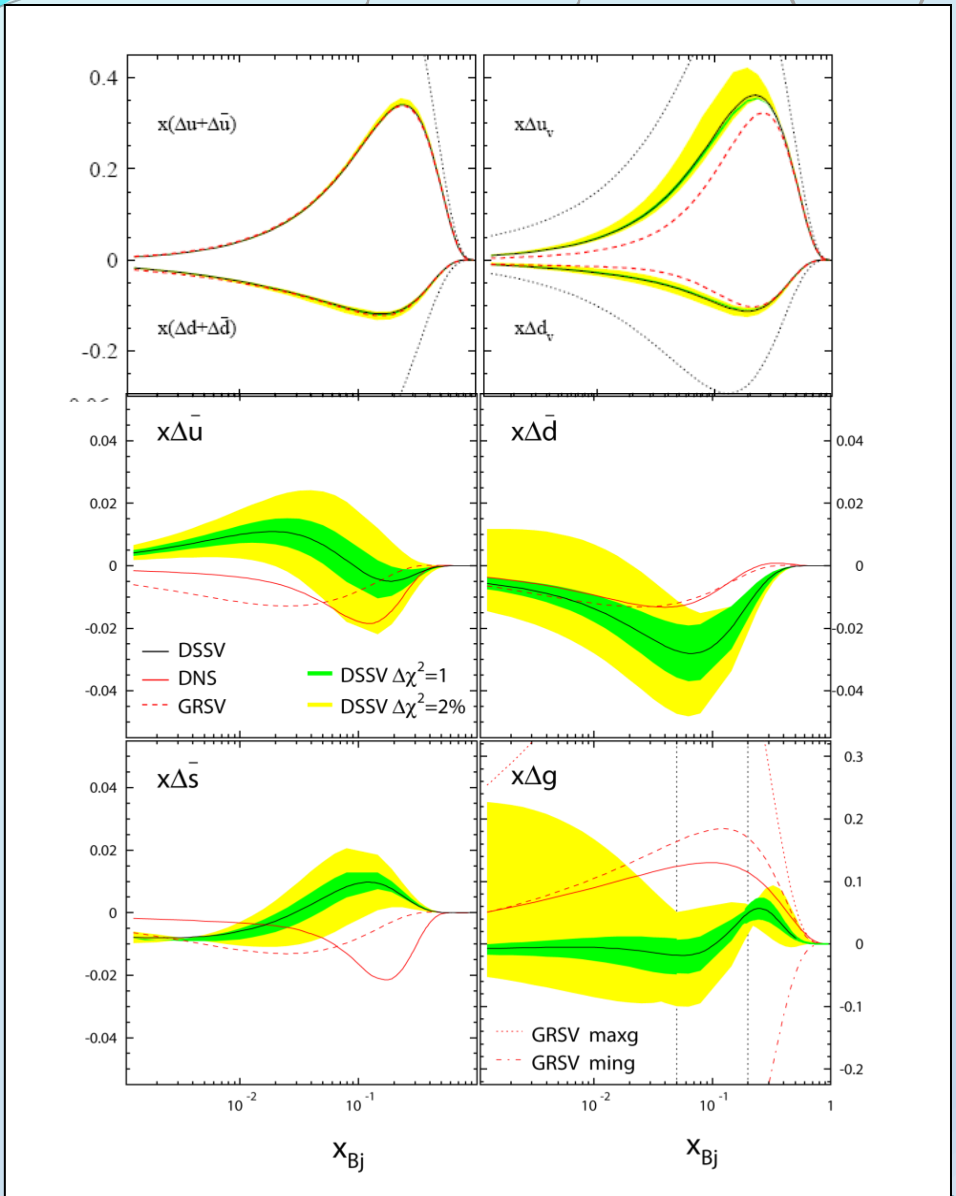
W→μ measurements at PHENIX

DIS 2014, Warsaw, Poland,
May 29, 2014

Ralf Seidl
(RIKEN)
For the PHENIX collaboration

Most recent global analysis : DSSV

de Florian et al., PRL101, 072001 (2008)



- NLO analysis
- Inclusion of SIDIS data before COMPASS
- Inclusion of RHIC A_{LL} data(from 200GeV)
- Using most recent NLO fragmentation functions (DSS)
- Large uncertainties still for sea quarks
- Decay data forces Δs to become negative at small x
- RHIC data results in node to Δg

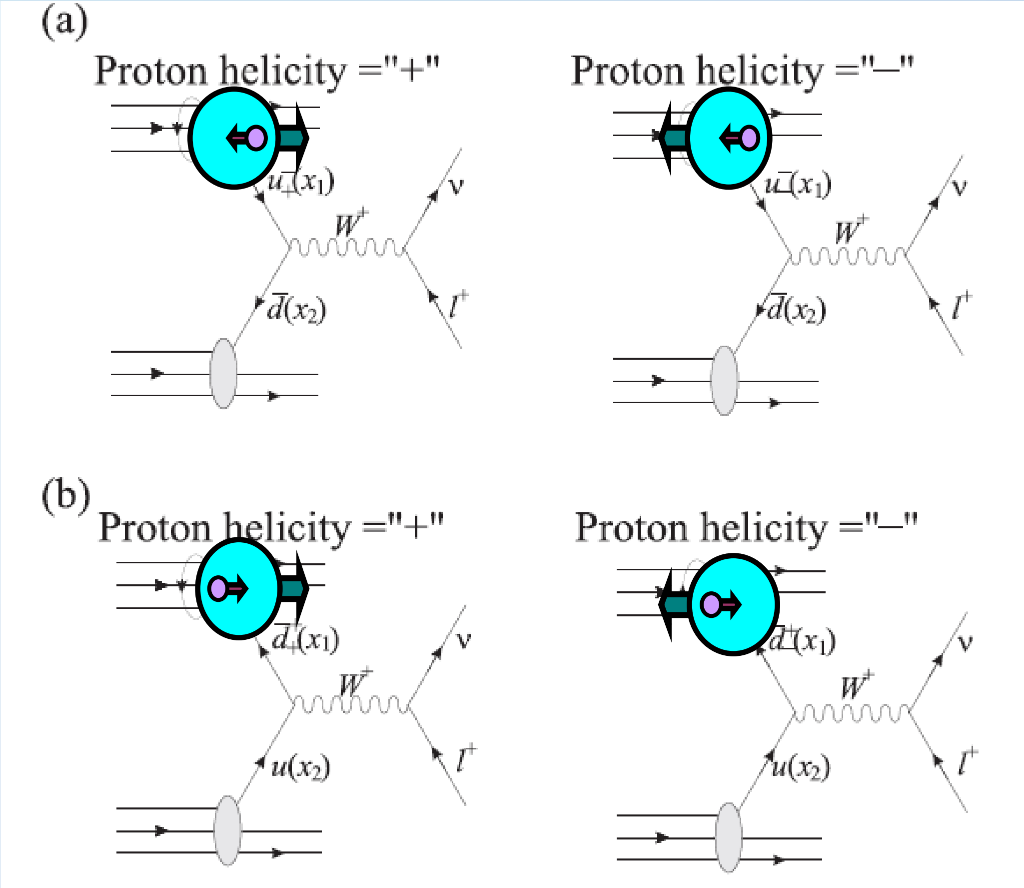
Real W production as access to quark helicities

- Maximally parity violating V-A interaction selects only lefthanded quarks and righthanded antiquarks:

➔Having different helicities for the incoming proton then selects spin parallel or antiparallel of the quarks

➔Difference of the cross sections gives quark helicities $\Delta q(x)$

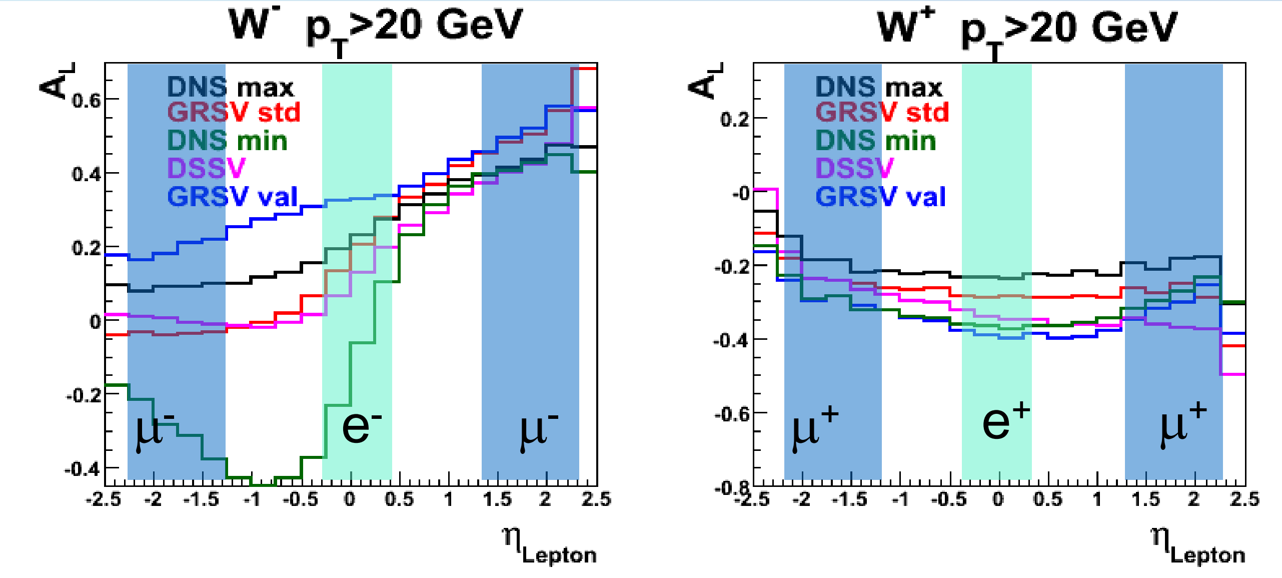
- No Fragmentation function required
- Very high scale defined by W mass



Bourrely , Soffer
Nucl.Phys. B423 (1994) 329-348

Sea quark polarization via W production

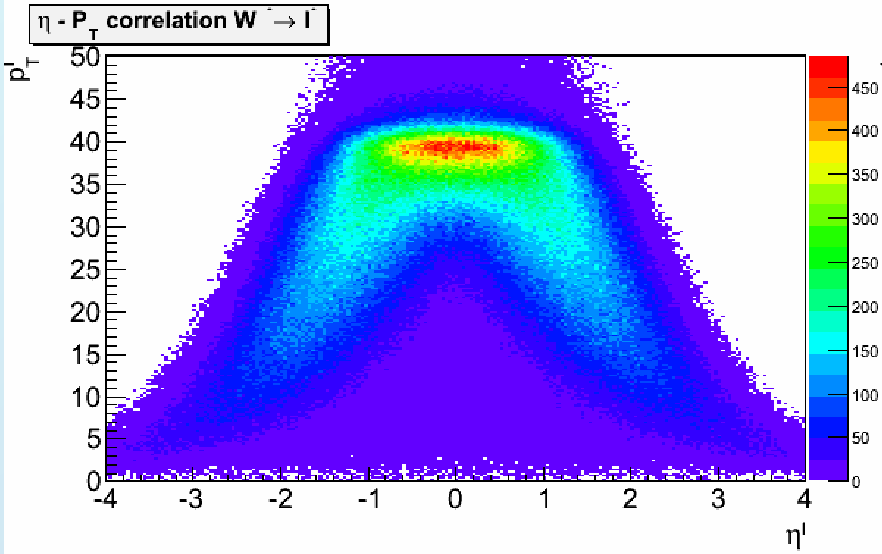
- Single spin asymmetry proportional to quark polarizations
- Large asymmetries
- Forward/backward separation smeared by W decay kinematics

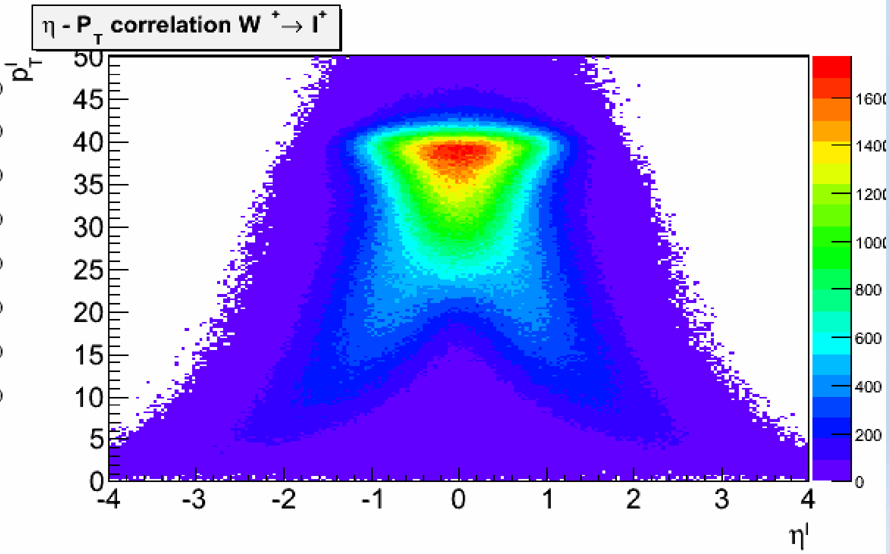


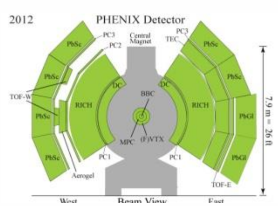
$$A_L^{W^+} \approx \frac{-\Delta u(x_1)\bar{d}(x_2)(1-\cos\theta)^2 + \Delta\bar{d}(x_1)u(x_2)(1+\cos\theta)^2}{u(x_1)\bar{d}(x_2)(1-\cos\theta)^2 + \bar{d}(x_1)u(x_2)(1+\cos\theta)^2}$$

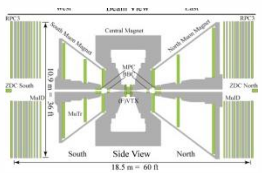
$$A_L^{W^-} \approx \frac{-\Delta d(x_1)\bar{u}(x_2)(1+\cos\theta)^2 + \Delta\bar{u}(x_1)d(x_2)(1-\cos\theta)^2}{d(x_1)\bar{u}(x_2)(1+\cos\theta)^2 + \bar{u}(x_1)d(x_2)(1-\cos\theta)^2}$$

W kinematics

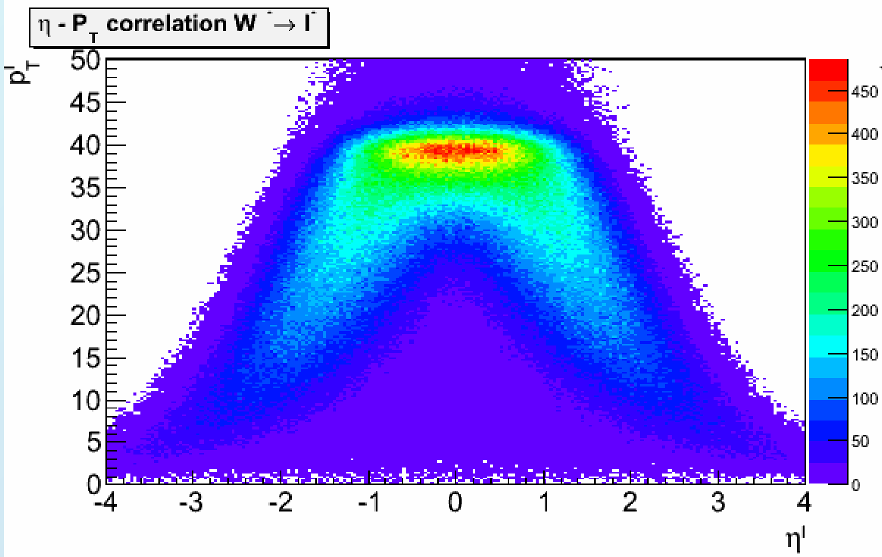


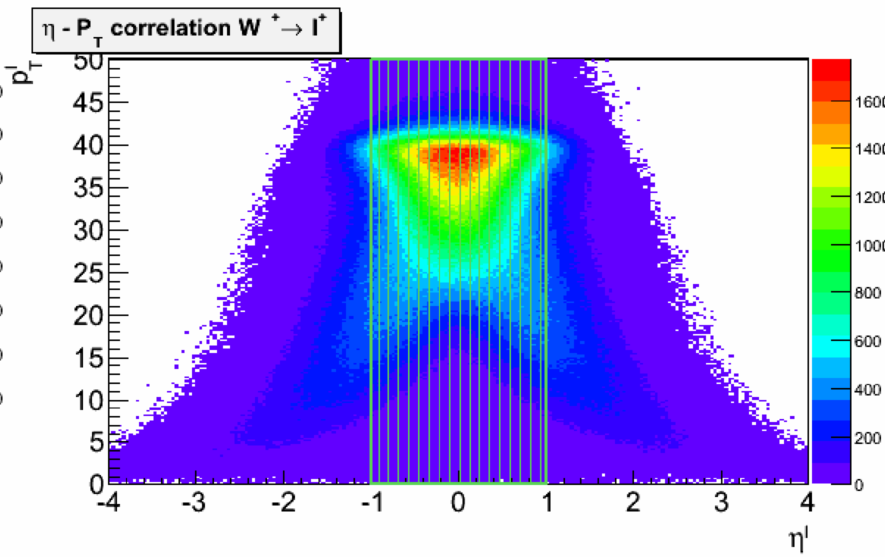


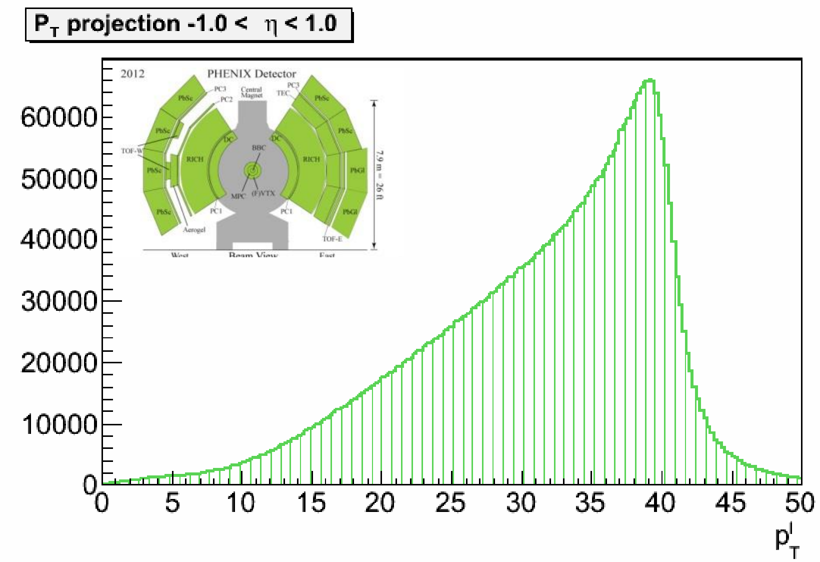


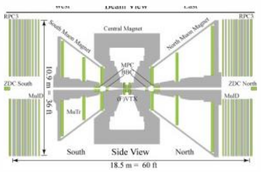


W kinematics

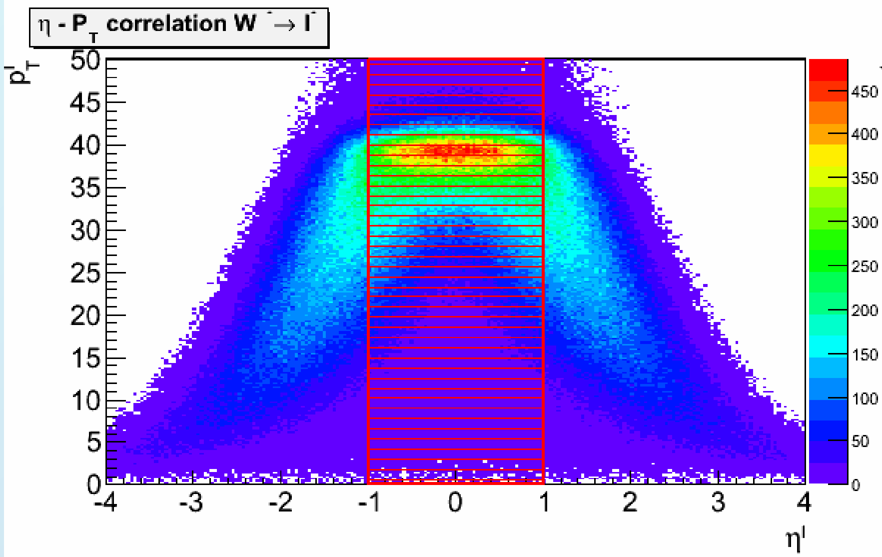


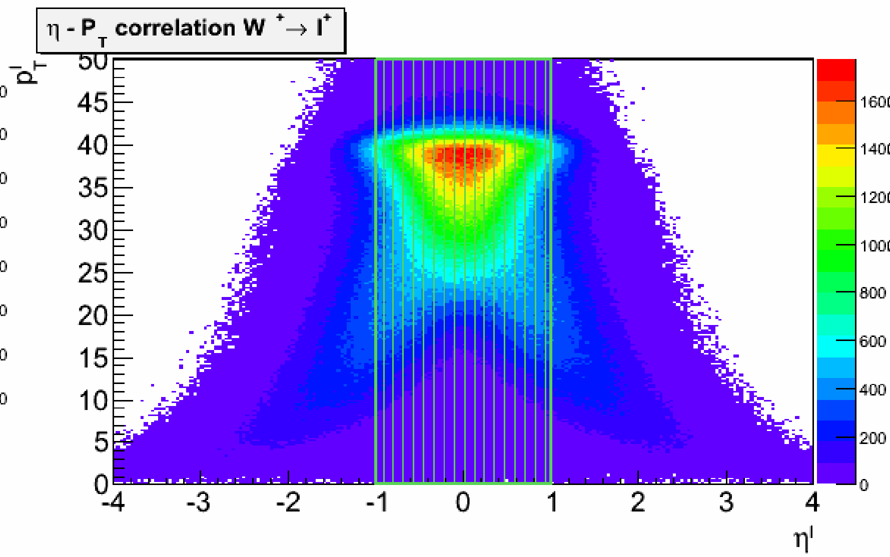


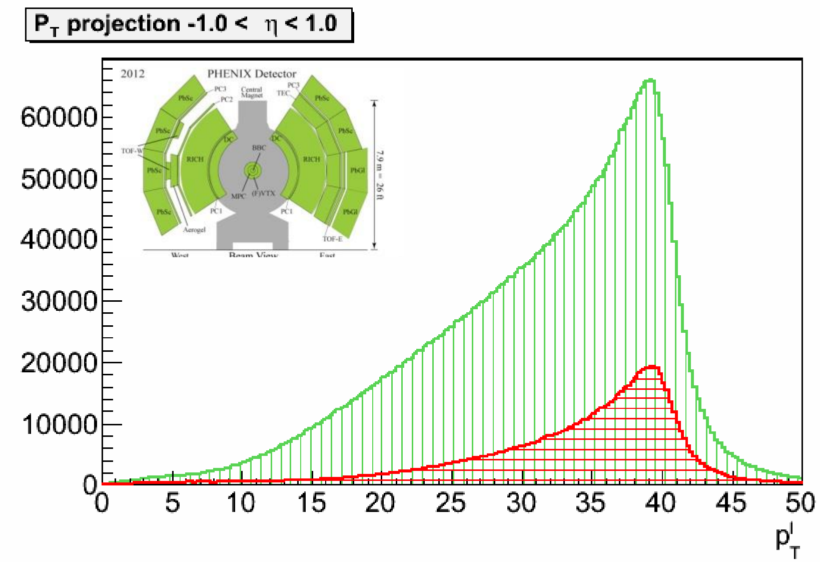


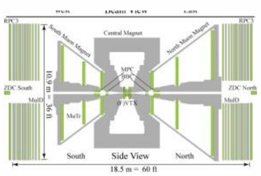


W kinematics

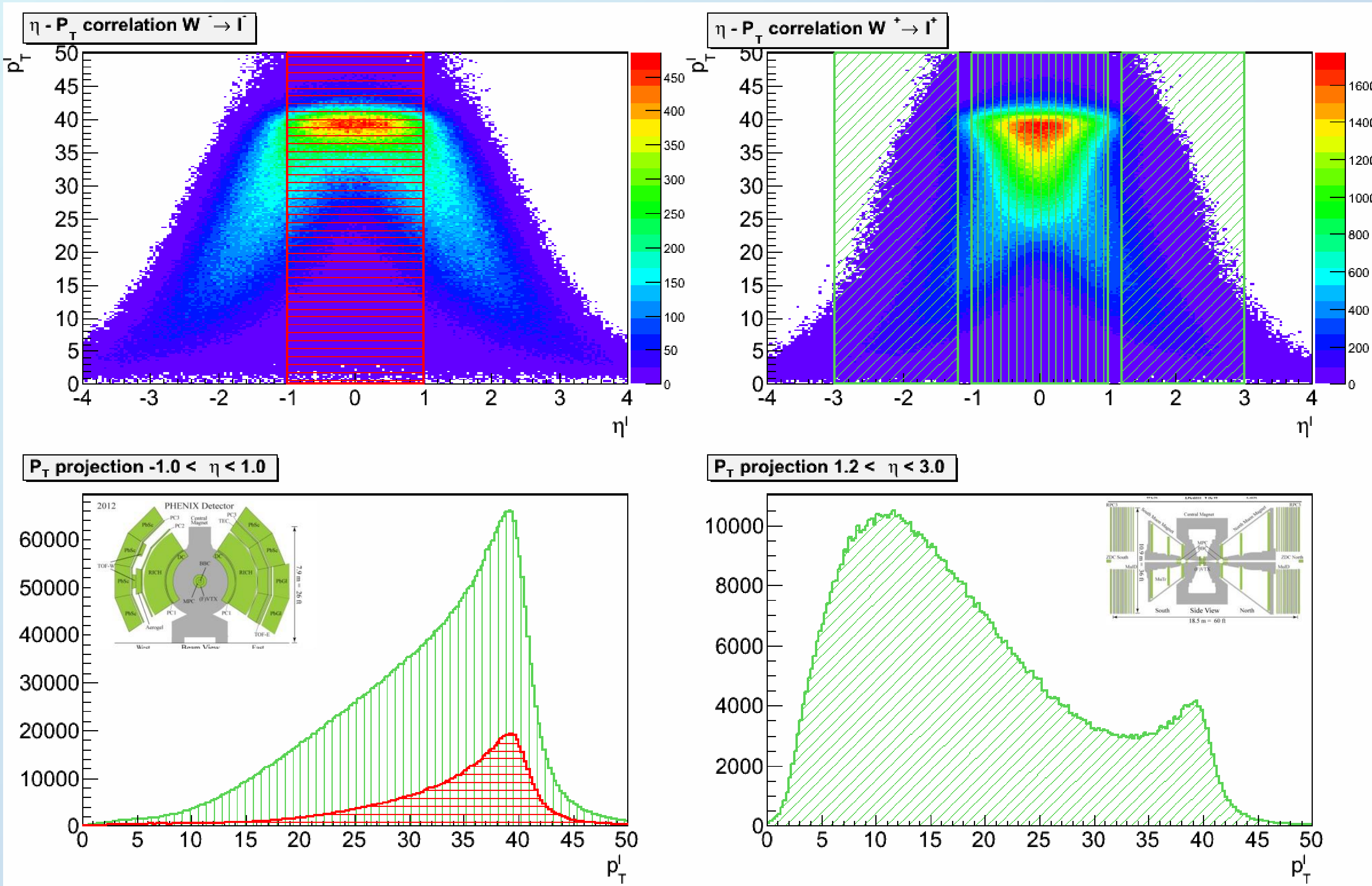




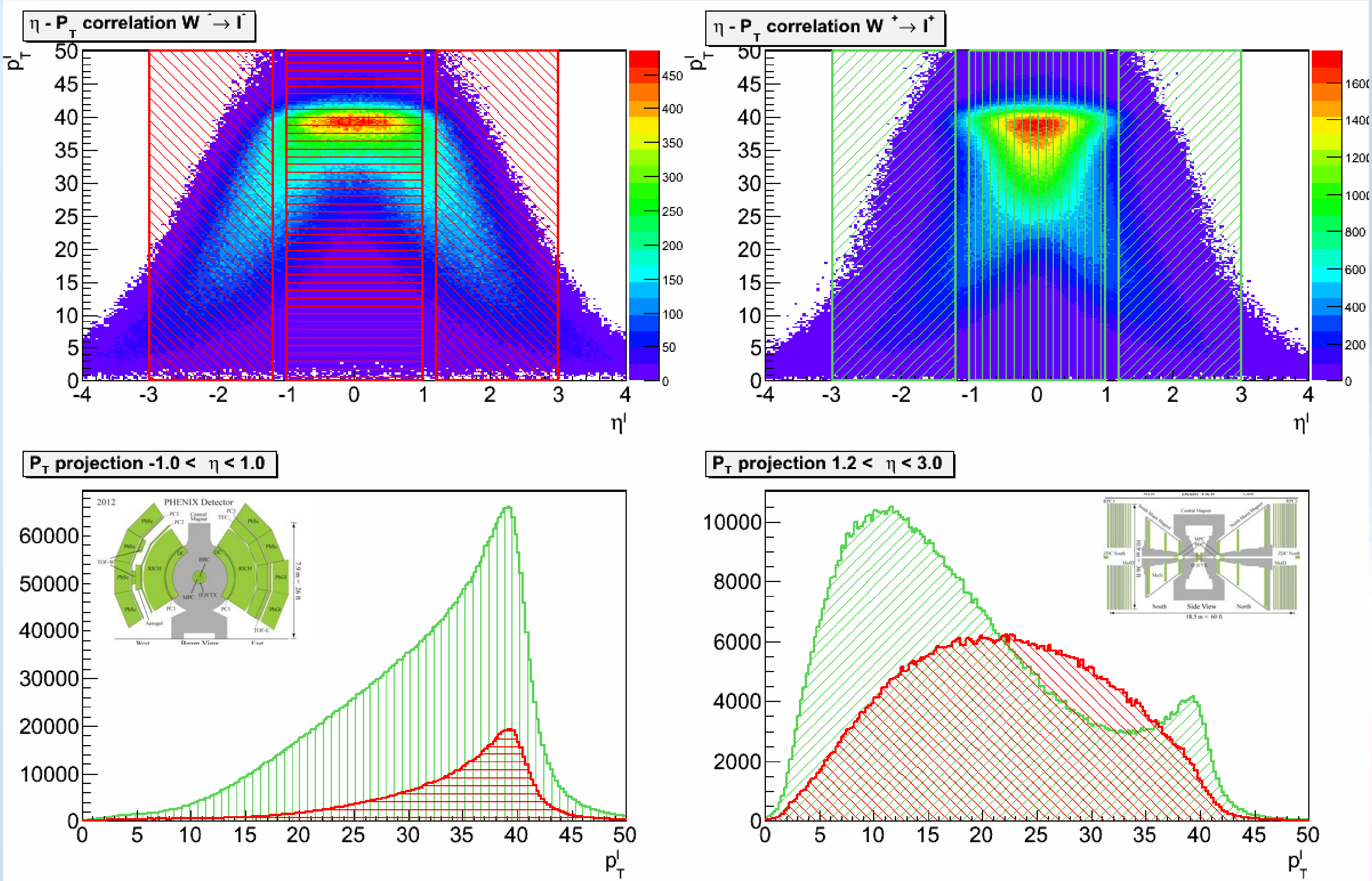




W kinematics



W kinematics

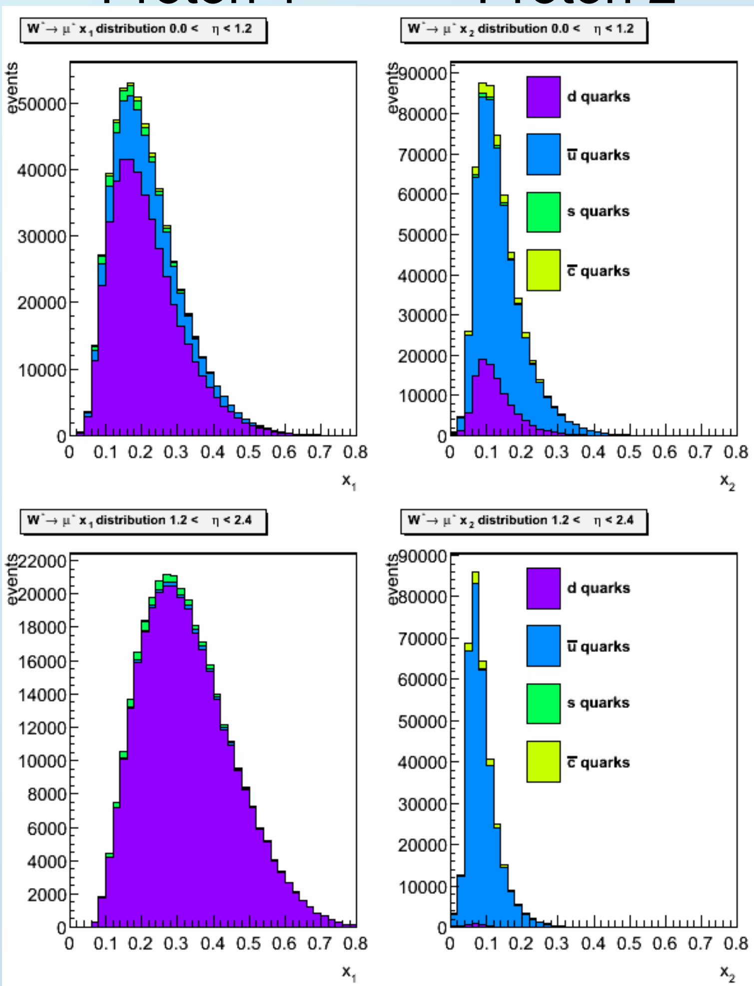


Pythia: quark flavors and x ranges

Proton 1 Proton 2 Proton 1 Proton 2

Central

Forward



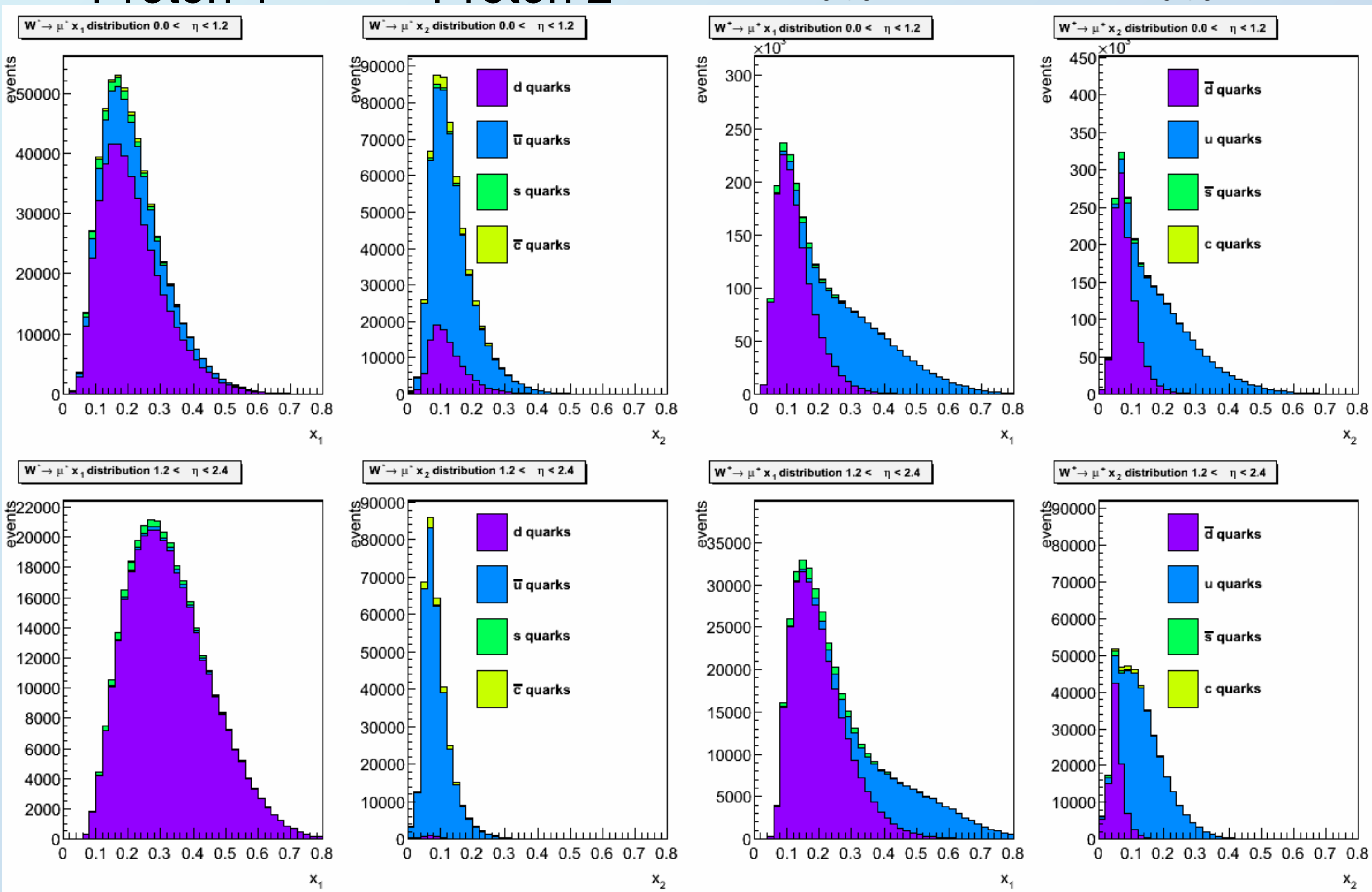
W^- →μ case: almost entirely forward d quarks and backwards $\bar{u}$

Pythia: quark flavors and x ranges

Proton 1 Proton 2 Proton 1 Proton 2

Central

Forward

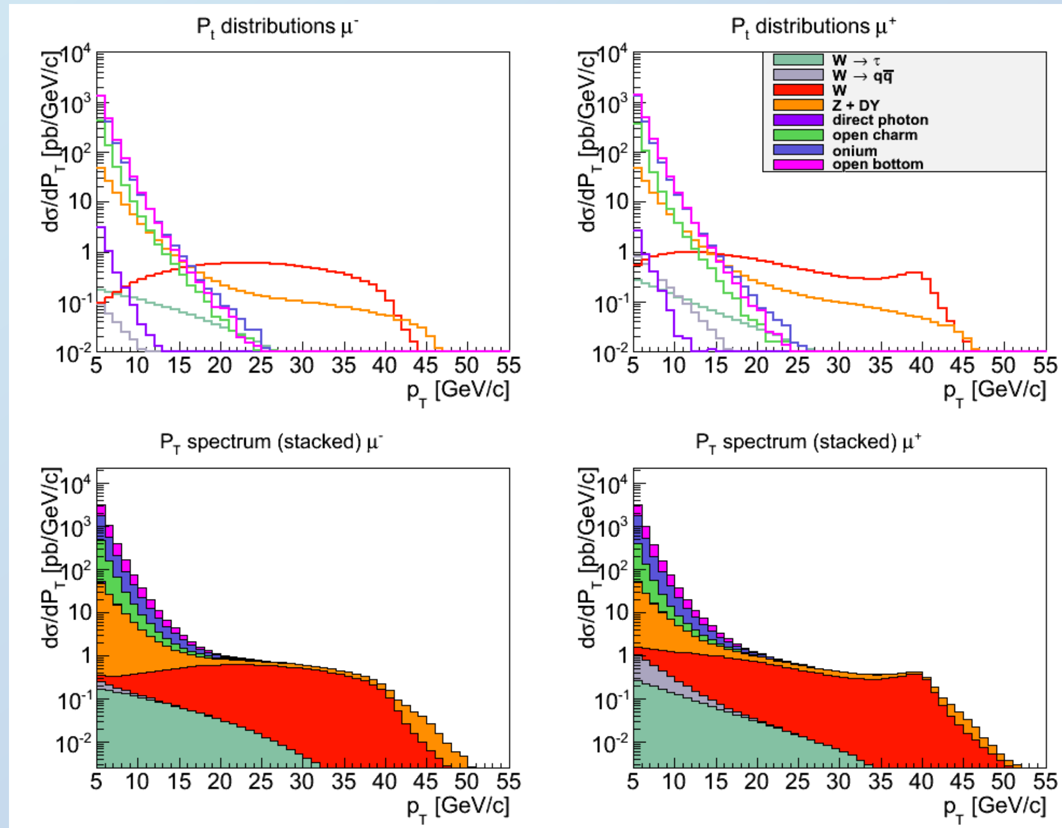


W⁻ → μ case: almost entirely forward d quarks and backwards $\bar{u}$

W⁺ → μ case: predominantly forward $\bar{d}$ quarks and backwards u

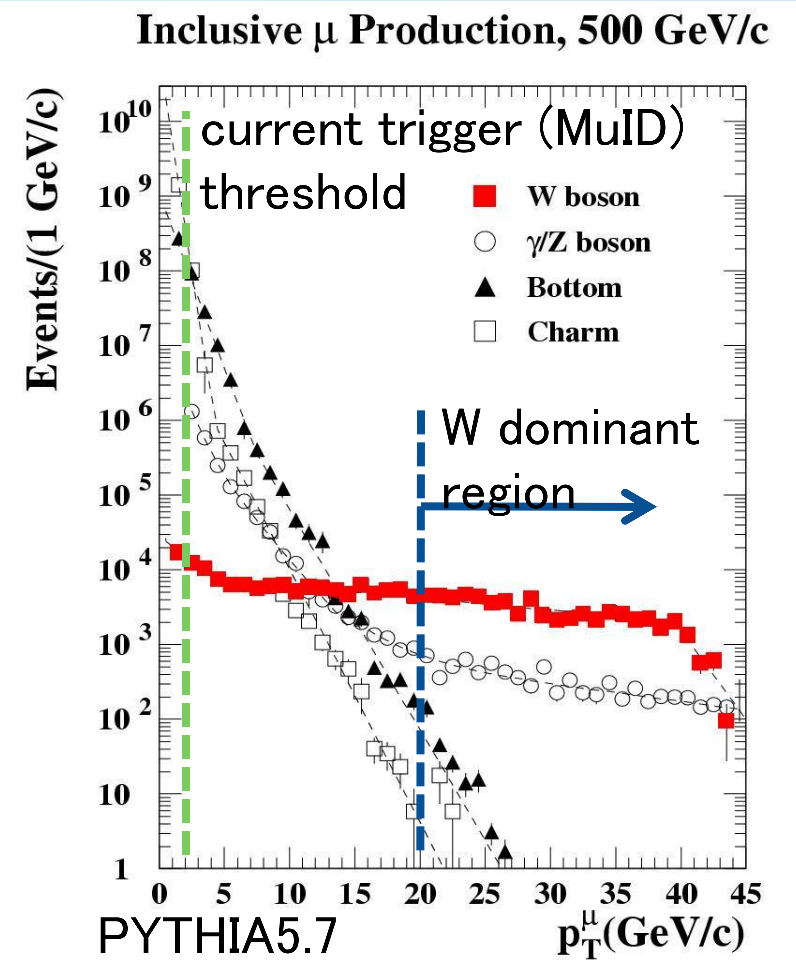
Forward W analysis

- W momentum cannot be ignored
- Jacobian peak only visible for forward moving W^+ decaying at close to 90 degrees
- Need to understand and suppress backgrounds lacking distinct signal signature



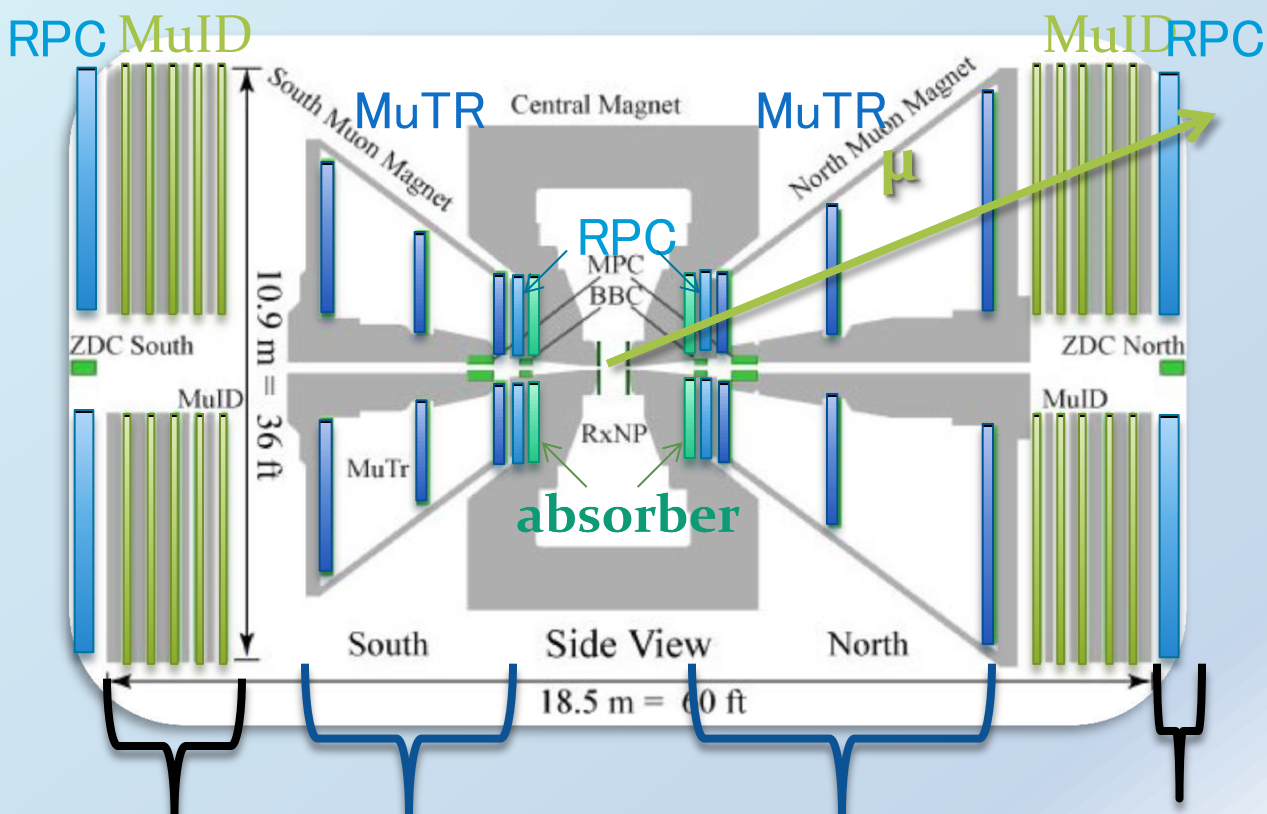
Pythia 6.4, muons in rapidities 1.2 – 2.4

PHENIX Muon trigger upgrade



- σ(tot)=60mb, L=$3\times10^{32}cm^{-2}s^{-1}$ (500GeV)
  - collision rate = 18MHz
  - (after luminosity upgrade)
- DAQ rate limit < 2kHz (for muon Arm)
- Therefore, required rejection ratio
  - > 9000
- But, MuID-trigger rejection ratio (500GeV)
  - < 100
- **A higher momentum trigger was needed**

PHENIX Muon Trigger Upgrade detectors



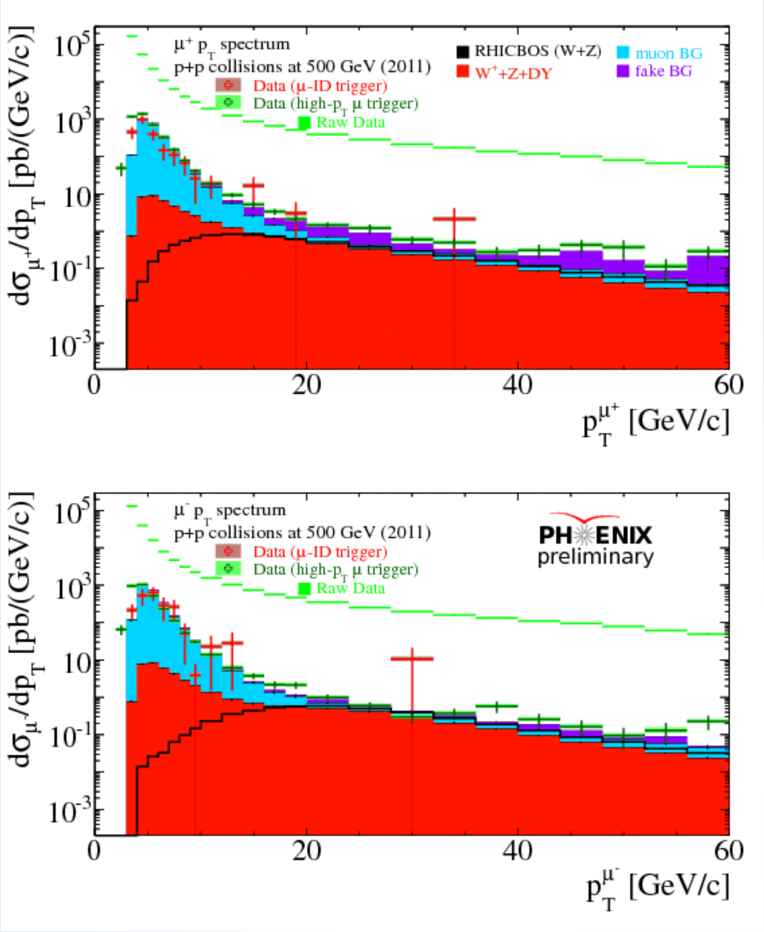
MuID trigger
selecting muon momentum > 2GeV/c

MuTR FEE upgrade
fast selection of high-momentum-tracks

RPC
provide timing information and rough position information

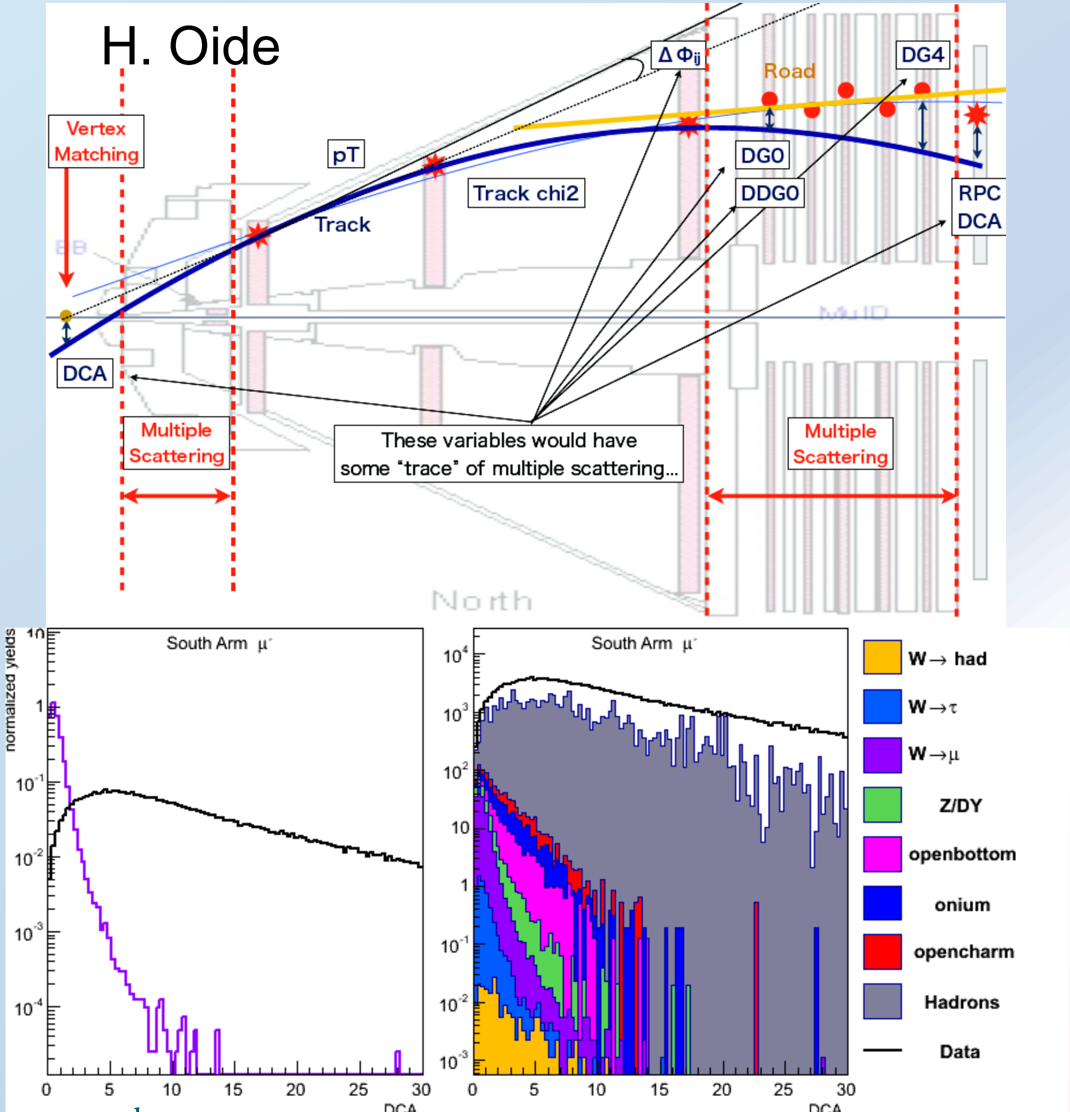
Forward Muon Backgrounds

- Real muons from heavy flavor and DY decays get smeared to higher transverse momenta
- Low energetic hadrons (huge cross section) decay within the muon tracker, mimicking a straight track
- Raw yields 3 orders above signal

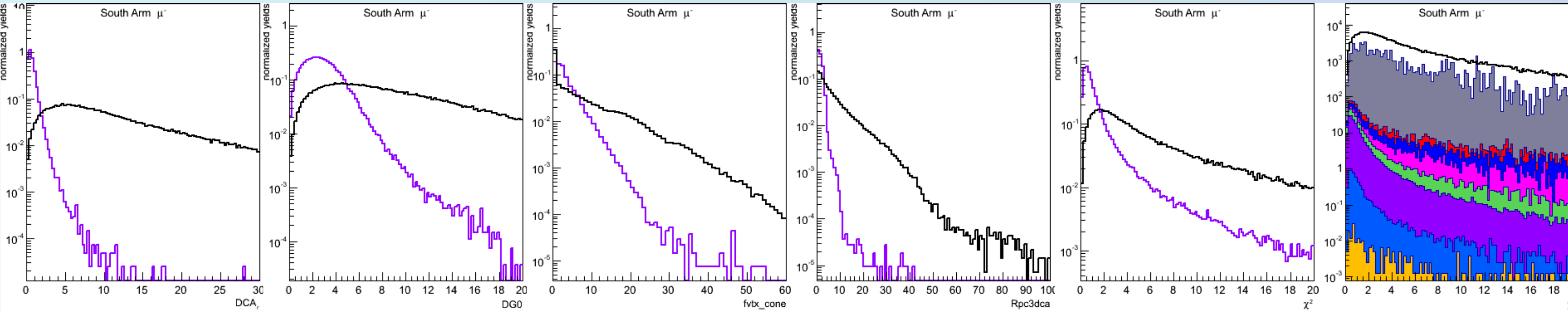


Reducing the background components

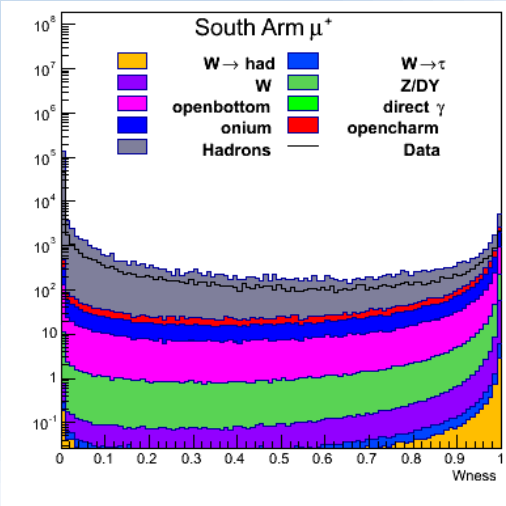
- Apply sensitivity to multiple scattering to reduce hadronic backgrounds
- Initially (2011) cut based removal of backgrounds
- Improved by using likelihood based pre-selection and unbinned max likelihood fit



Multivariate analysis



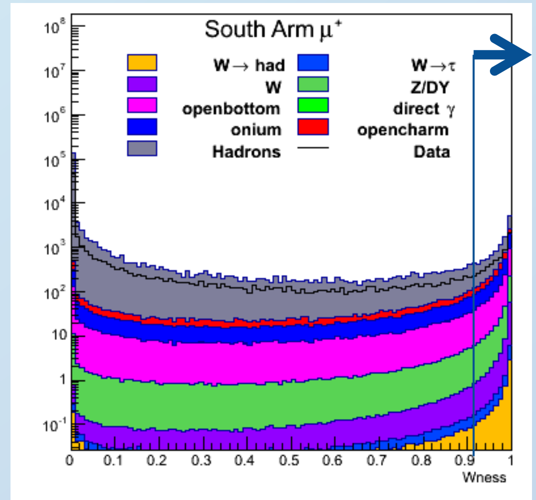
- Define Wness likelihood using 5-9 kinematic variables based on signal MC and data (= mostly BG)

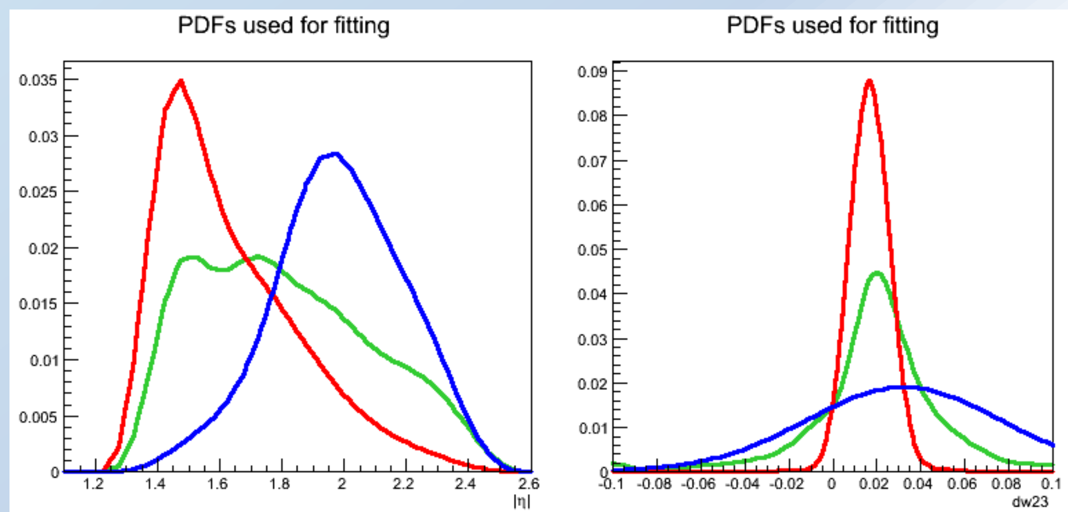


$$
\begin{aligned}
Wness &= \frac{\lambda_{(SIG)}}{\lambda_{SIG} + \lambda_{BG}} \\
\lambda &= [p(DG0, DDG0), p(DCA_r), p(\chi^2), \\
&\quad p(RPC1, 3\_DCA), p(FVTX\_Match), p(FVTX\_Cone)]
\end{aligned}
$$

W signal fit

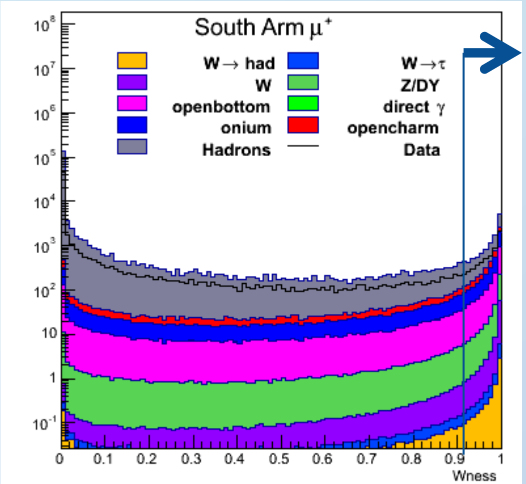
- After preselecting W like events (>0.92) perform unbinned max likelihood fit in independent variables rapidity and effective bending angle
- Shapes for fit are extracted from:
  - Hadron Background: extrapolation from lower wness data
  - Muon from MC (fixed)
  - Signal MC

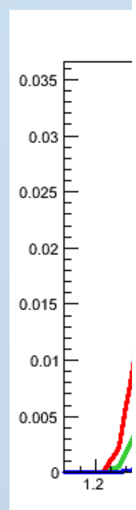


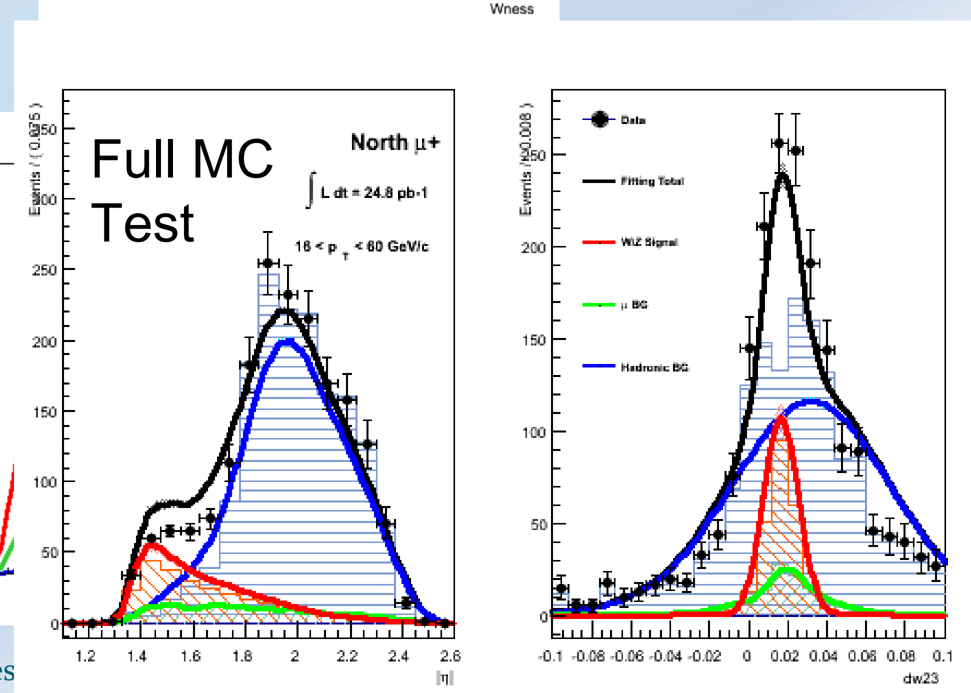


W signal fit

- After preselecting W like events (>0.92) perform unbinned max likelihood fit in independent variables rapidity and effective bending angle
- Shapes for fit are extracted from:
  - Hadron Background: extrapolation from lower wness data
  - Muon from MC (fixed)
  - Signal MC

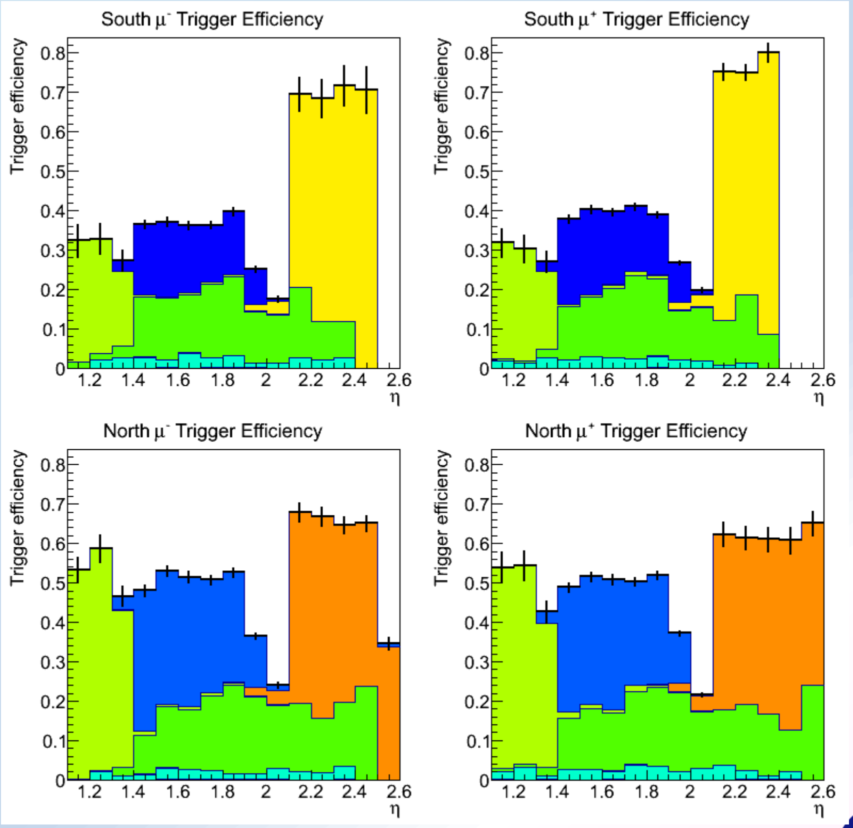




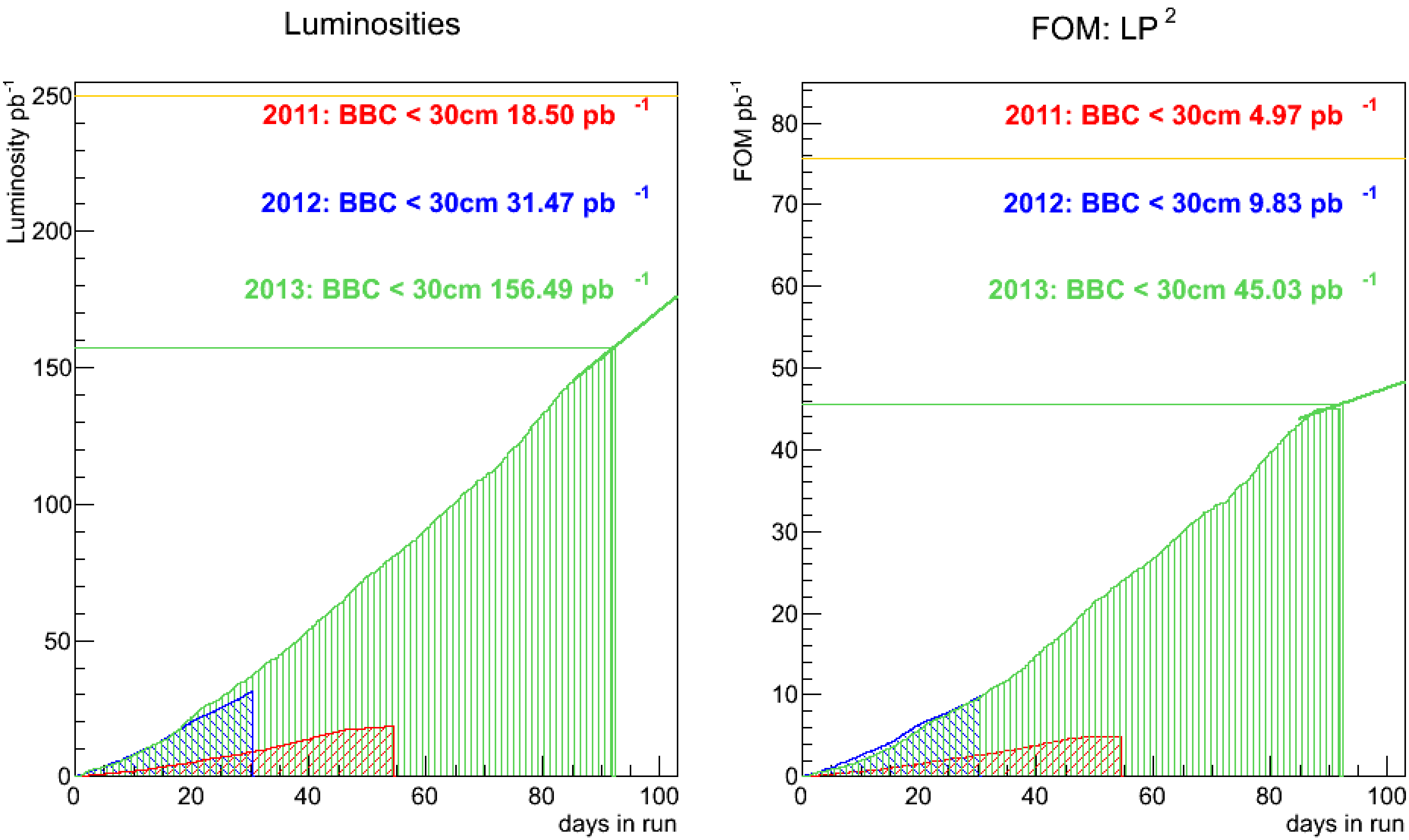


Analysis status - efficiencies

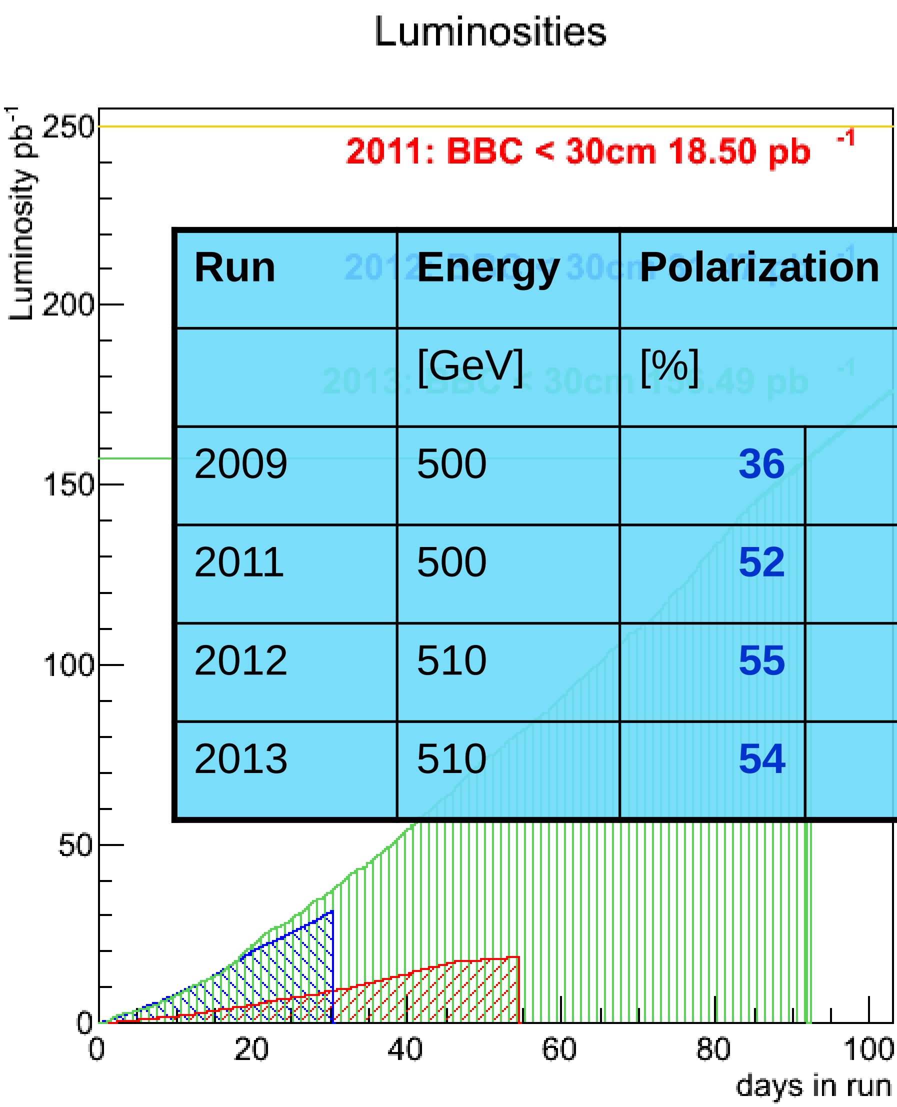
- All relevant efficiencies have been calculated
  - Trigger efficiencies
  - Detector and reconstruction efficiencies and their rate dependence
  - Pile-up luminosity correction in progress

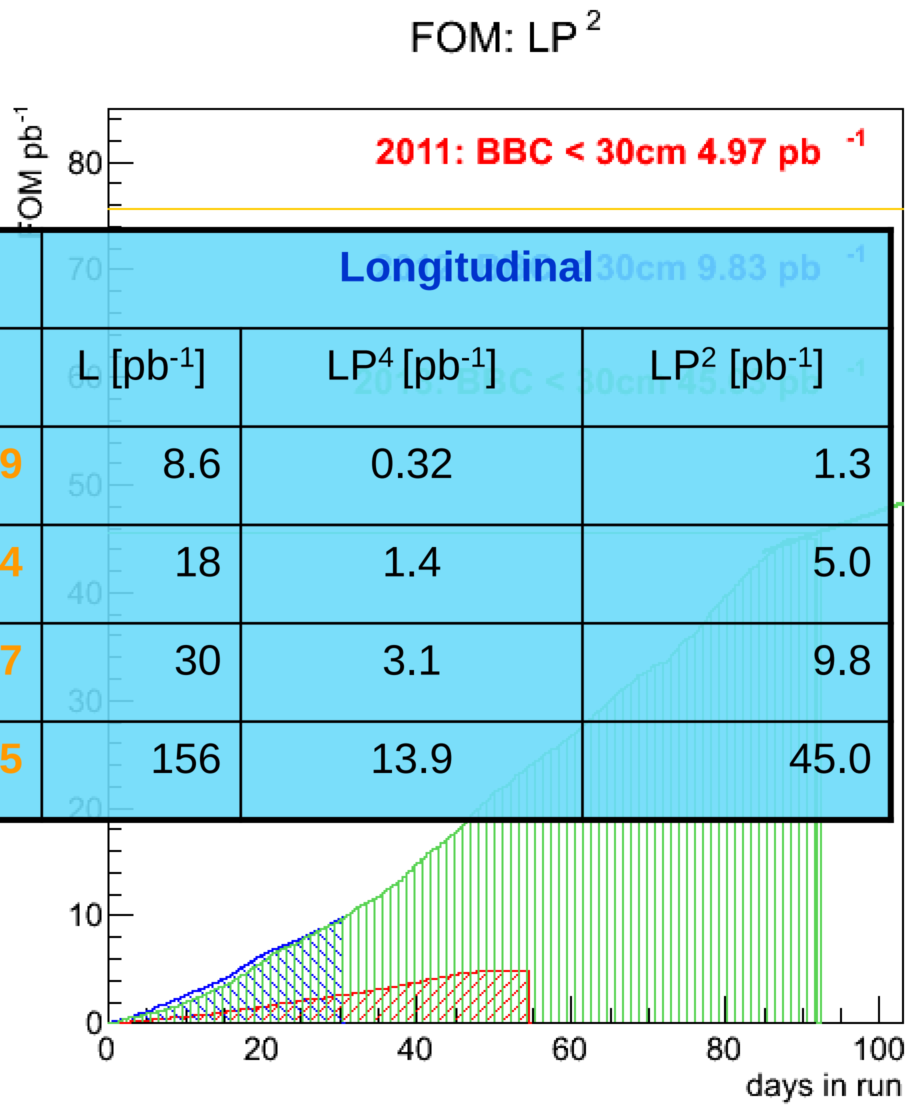


PHENIX luminosities



PHENIX luminosities

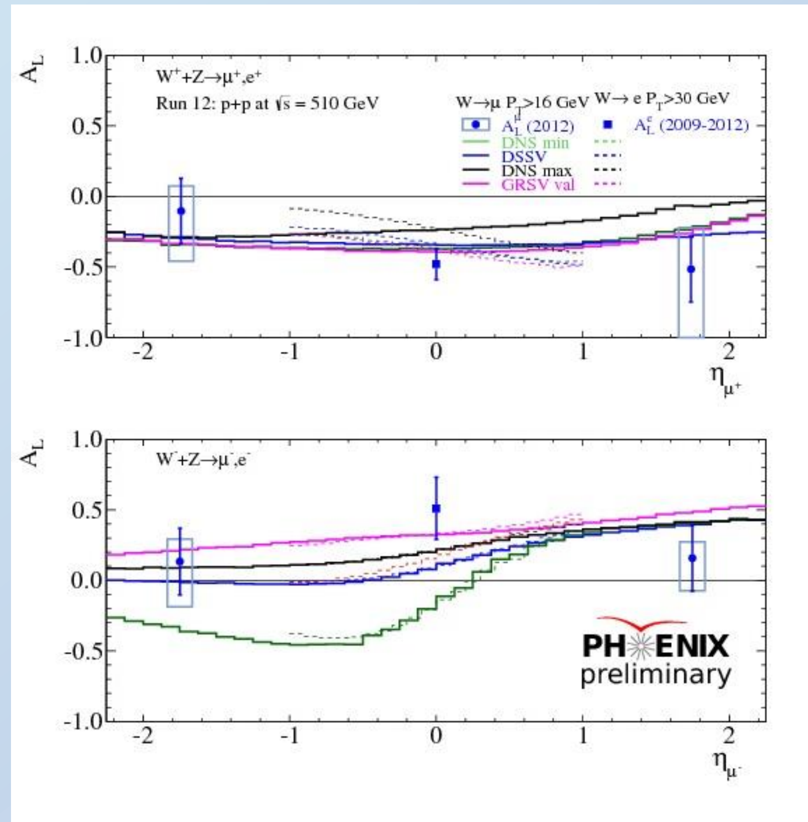




Run	Energy [GeV]	Polarization [%]		Longitudinal L [pb^{-1}]	LP^4 [pb^{-1}]	LP^2 [pb^{-1}]
2009	500	36	39	8.6	0.32	1.3
2011	500	52	54	18	1.4	5.0
2012	510	55	57	30	3.1	9.8
2013	510	54	55	156	13.9	45.0

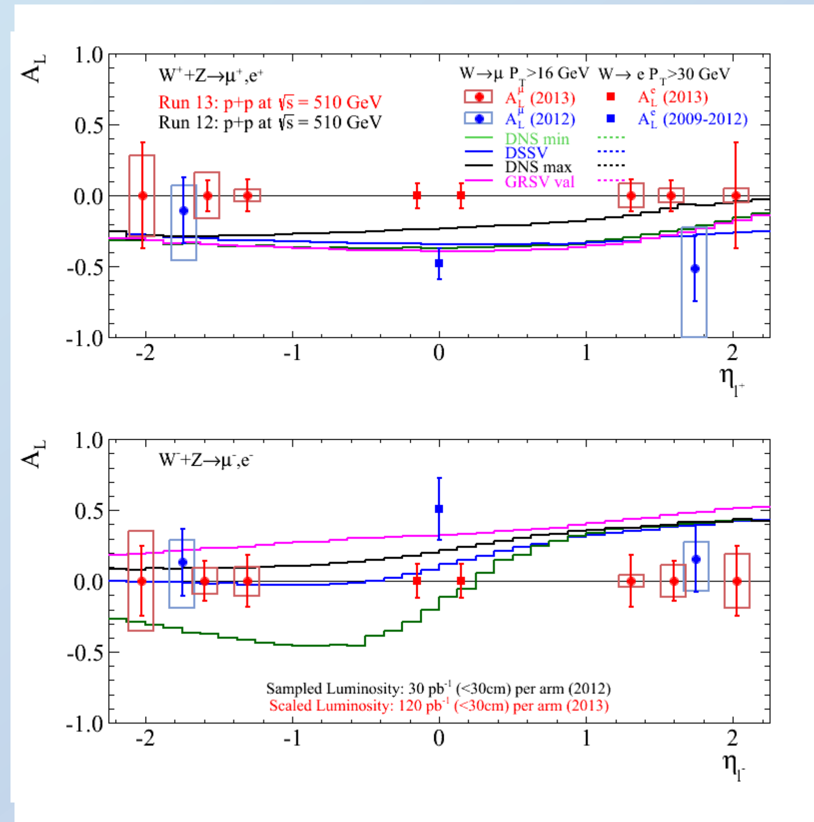
Forward W asymmetries

- After extracting S/BG ratios (in 2012 preliminary data ~0.3) extract asymmetries and correct for BG (BG asymmetries are consistent with zero)
- Inclusion of FVTX information will improve BG rejection (isolation, multiple scattering)
- 2011 and 2012 Analysis will be finalized soon
- 2013 data analysis is ongoing



Forward W asymmetries

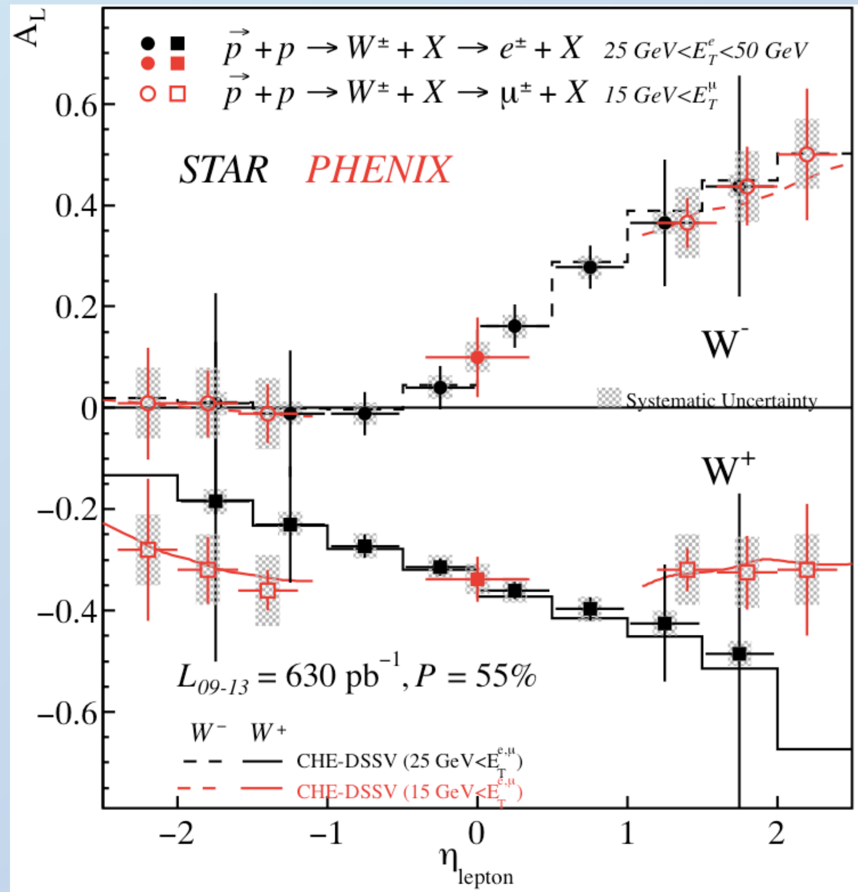
- After extracting S/BG ratios (in 2012 preliminary data ~0.3) extract asymmetries and correct for BG (BG asymmetries are consistent with zero)
- Inclusion of FVTX information will improve BG rejection (isolation, multiple scattering)
- 2011 and 2012 Analysis will be finalized soon
- 2013 data analysis is ongoing



Outlook

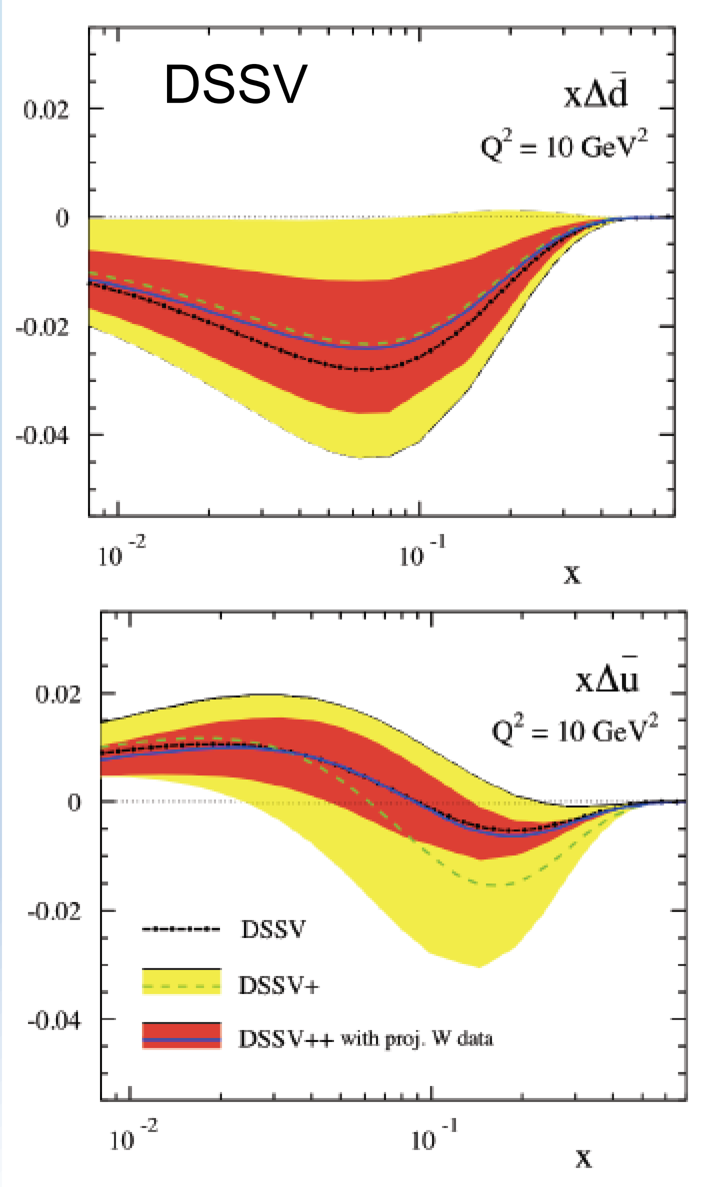
RHIC Spin NSAC write-up:
Aschenauer et. al: arXiv:1304.0079

- Real W boson production as clean access to sea quark helicities
- RHIC has delivered 510 GeV polarized pp collisions from 2009-2013
- Run 13 analysis will significantly improve sea quark helicity knowledge



Expected impact of full data set

- Substantial uncertainty improvement of the sea quark helicities
- DSSV framework ready to include W asymmtries
- NNPDF in the process of including W asymmetries

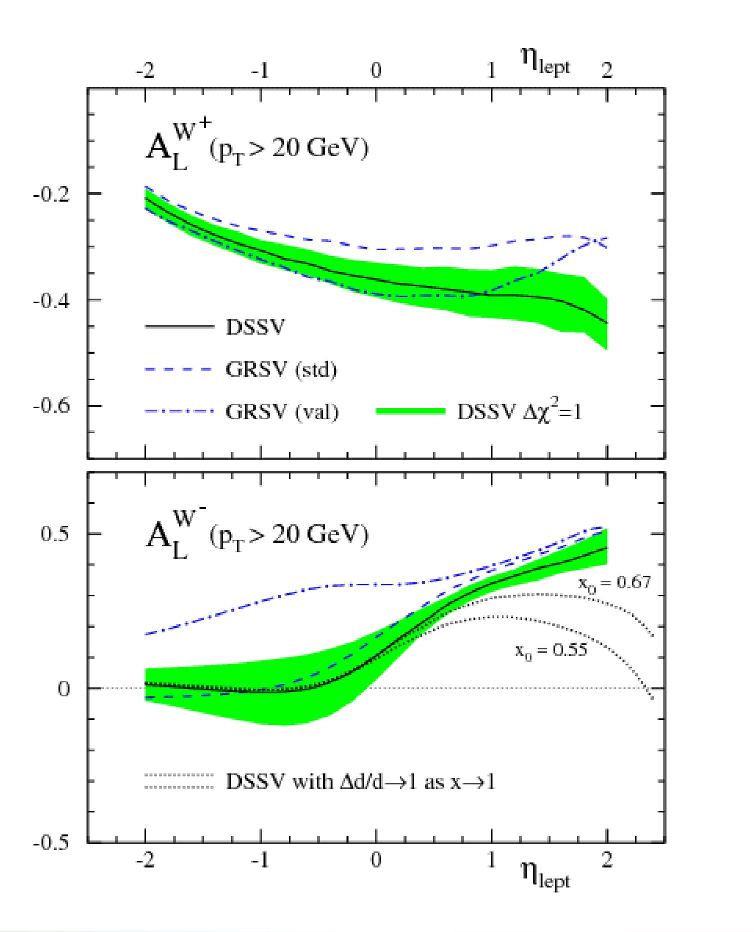


Backup

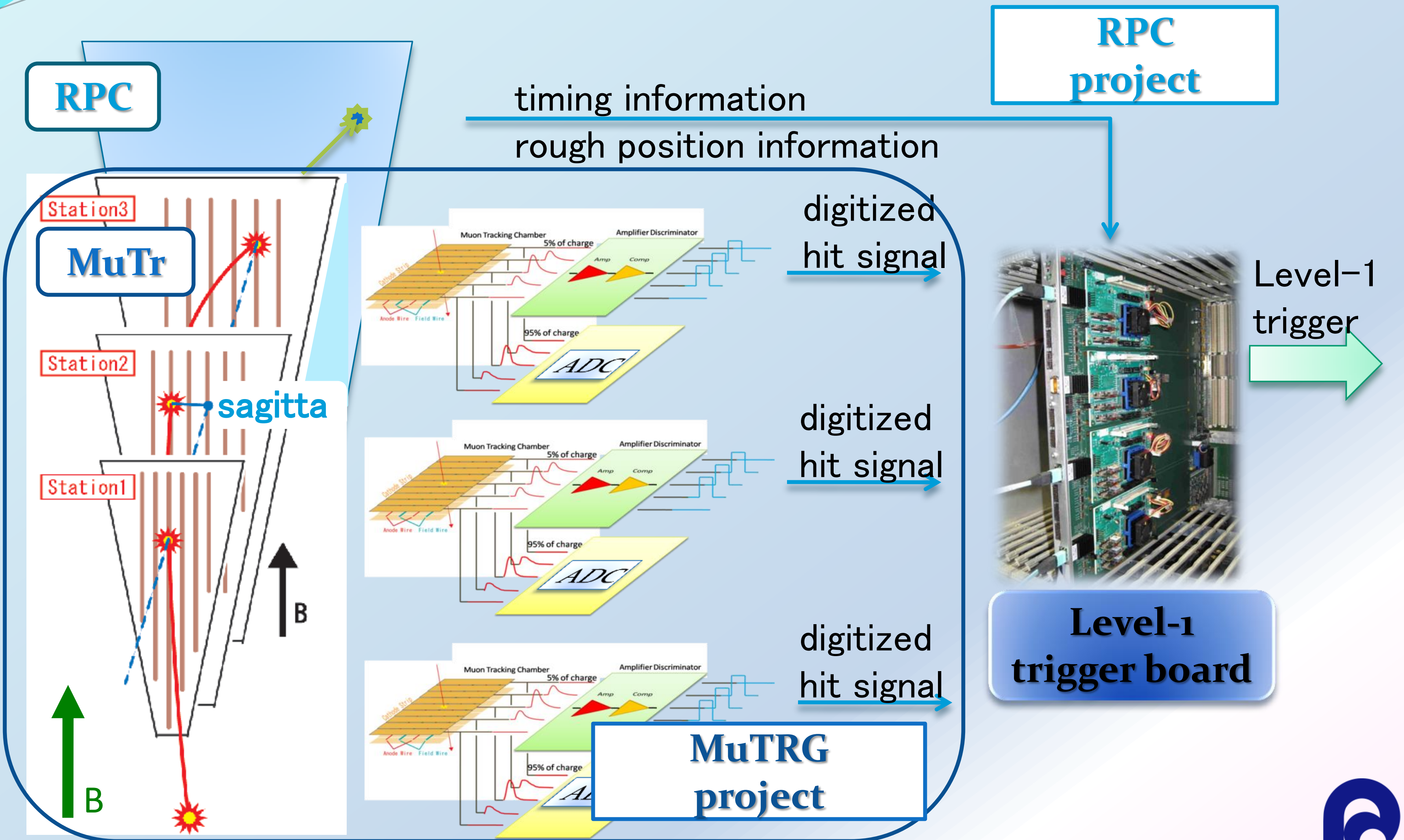
DSSV/CHE predictions

- Only 1% uncertainties shown, actual uncertainties larger
- Potential impact of turnaround of Δd at high x visible in forward W-asymmetries

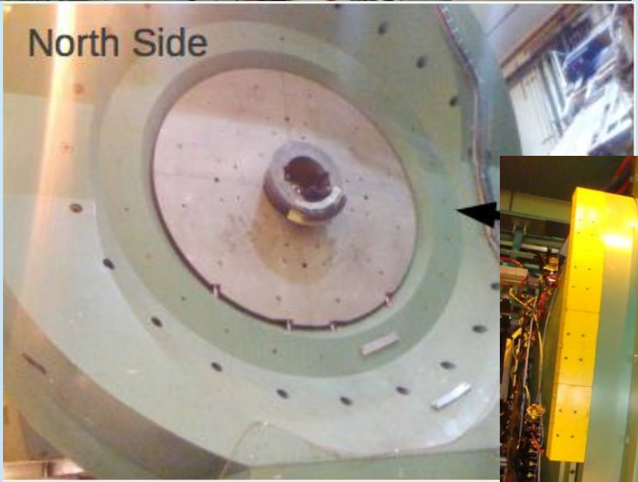
DSSV, PRD80 (2009) 034030

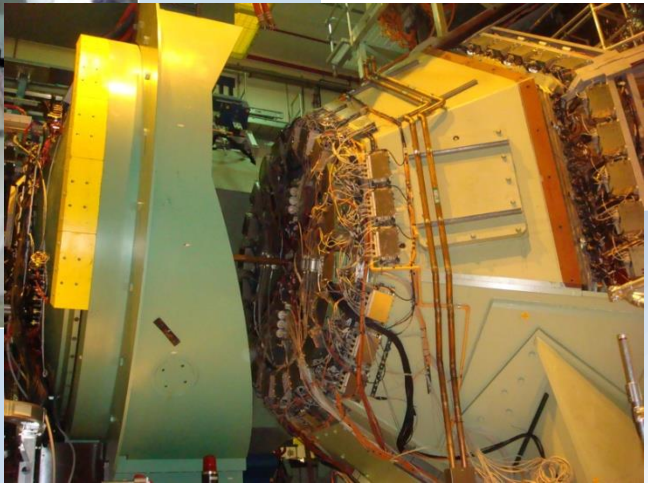


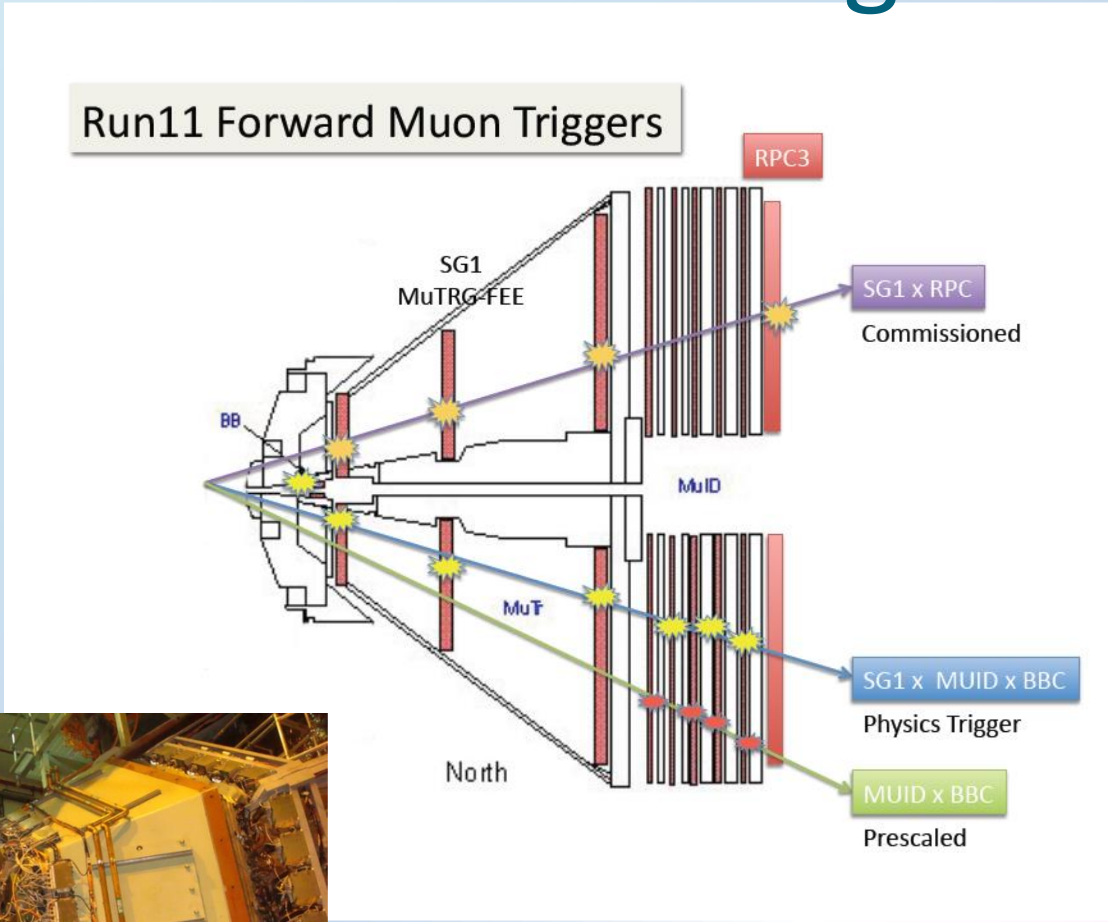
Muon Trigger Upgrade



PHENIX Forward W trigger upgrade installation and commissioning

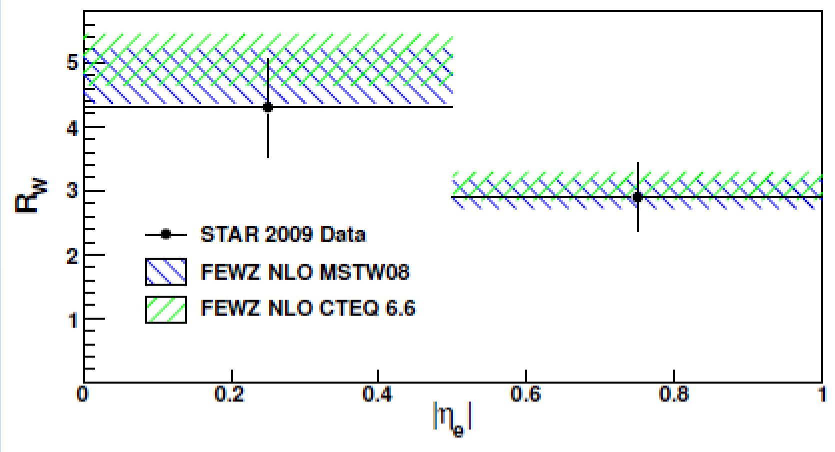


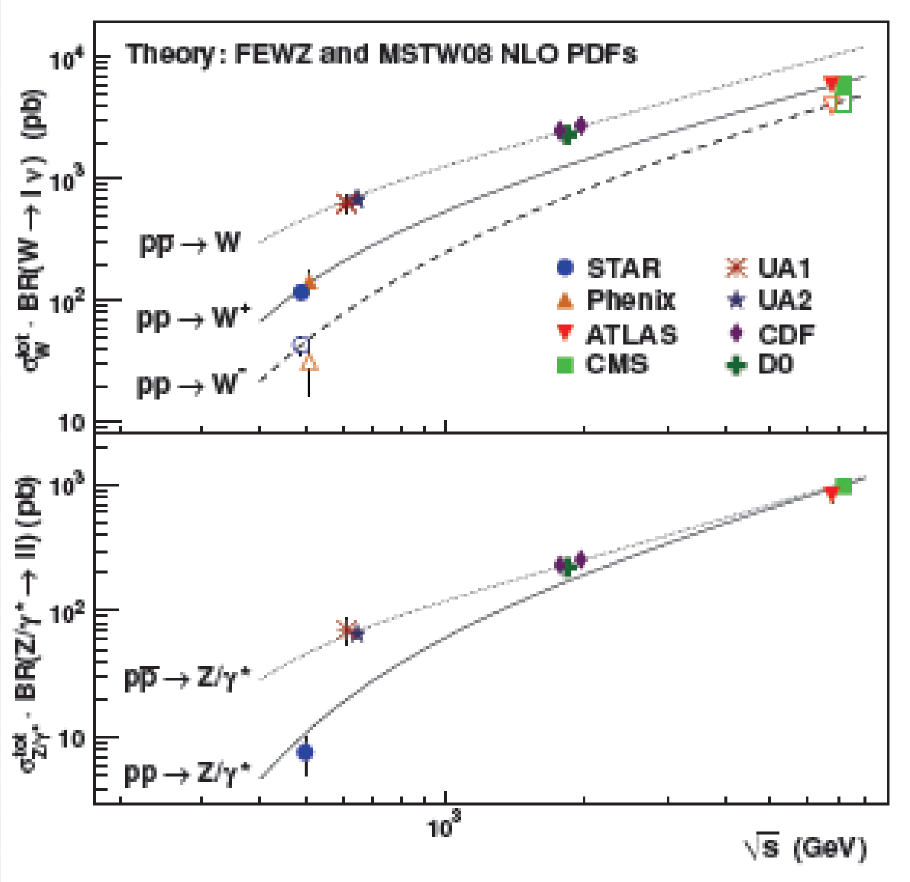




W Cross sections

- Correcting acceptance and efficiencies one can obtain the absolute W/Z cross sections:
- Excellent agreement of the scale dependence from RHIC to LHC



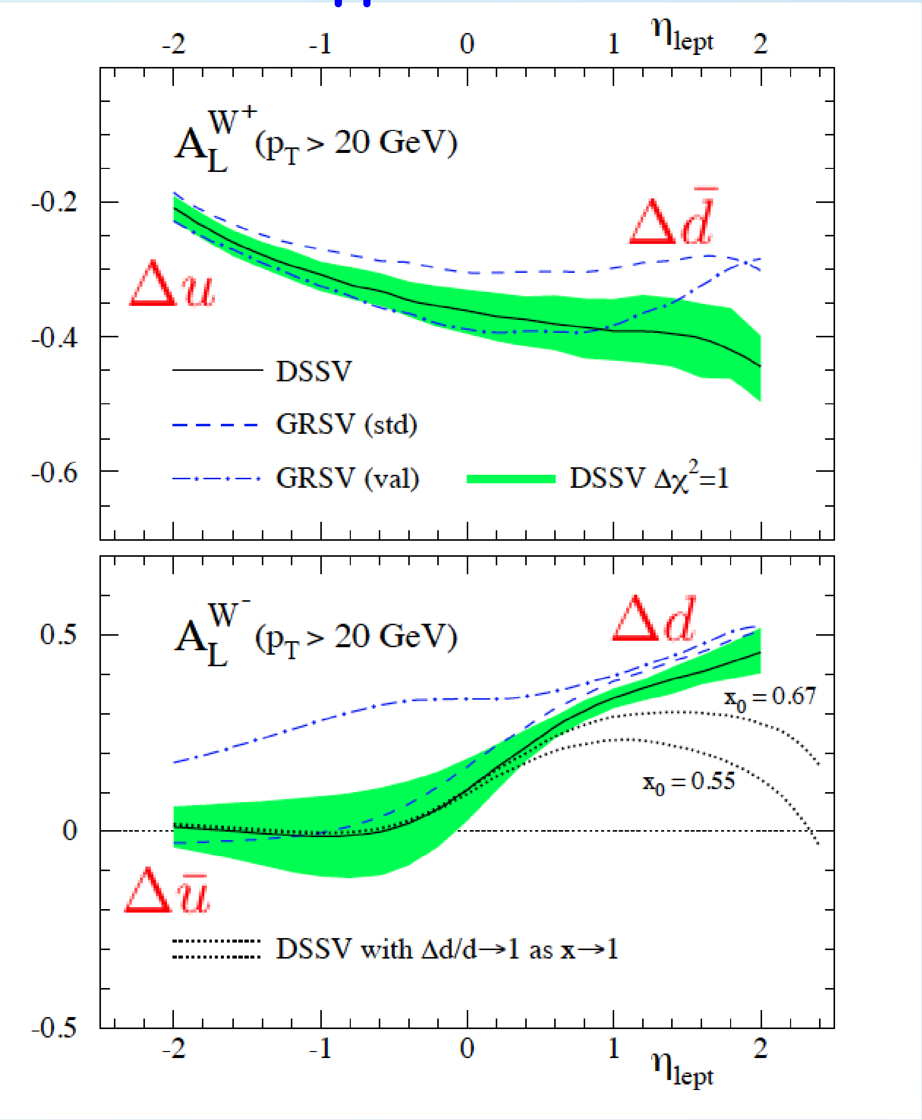


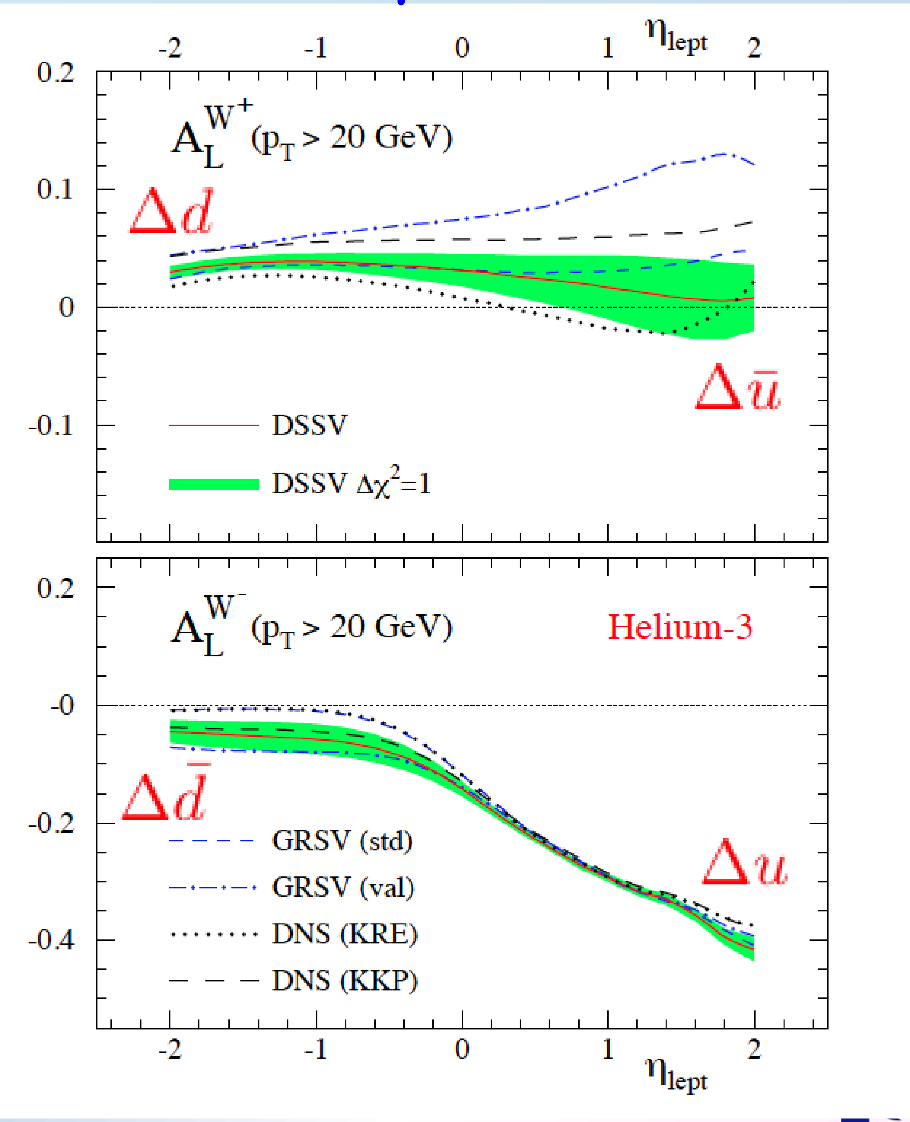
PRL 106:062001(2011)
PRD 85 (2012) 092010

W Outlook ^{3}He p collisions

Marco Stratman (BNL)

pp @ 500 GeV | **^{3}He p @ 432 GeV**

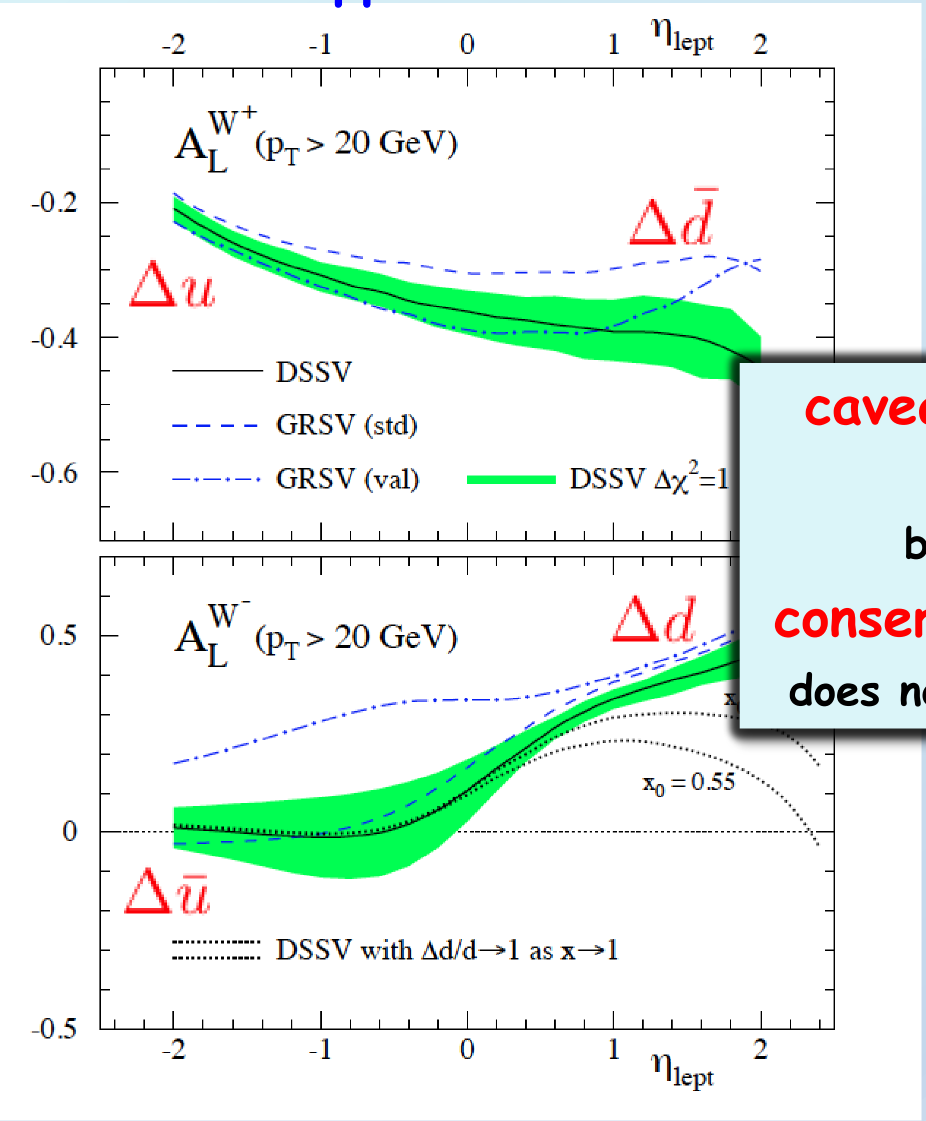




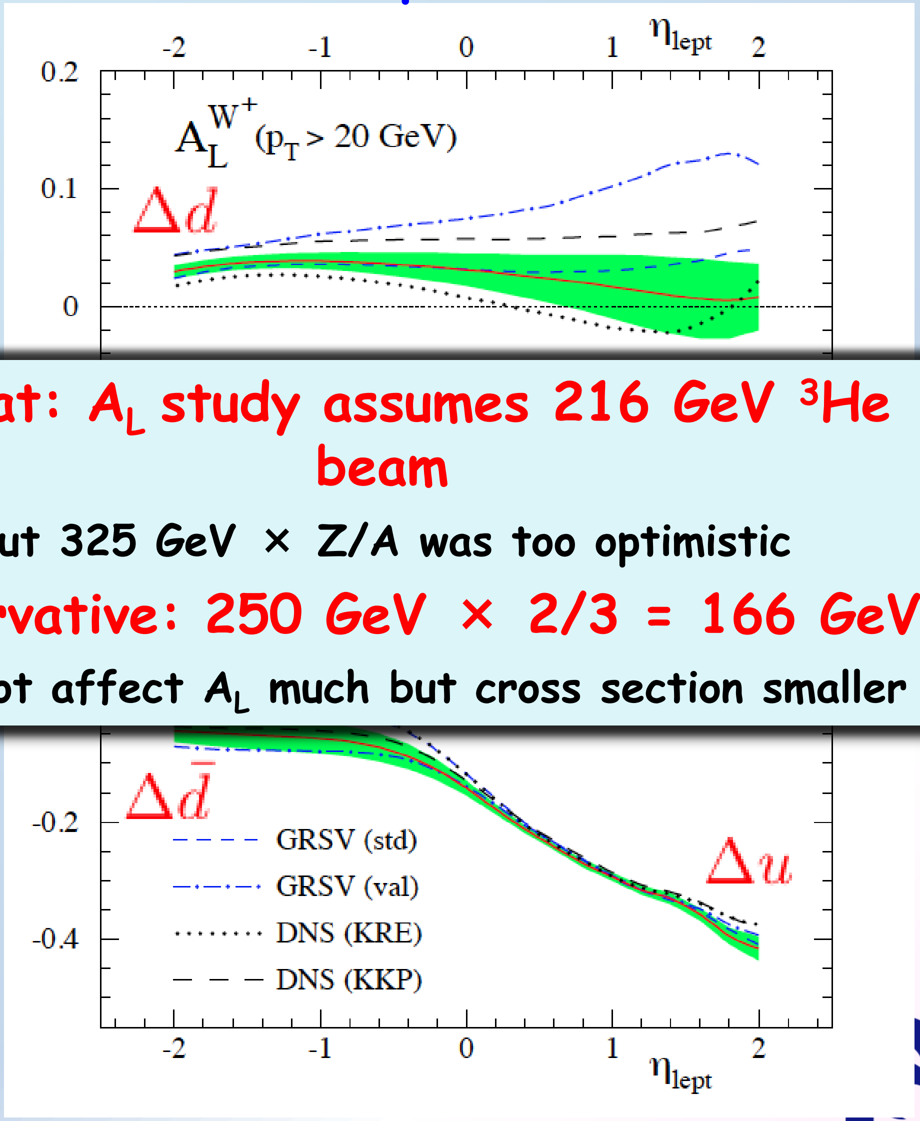
W Outlook ^{3}He p collisions

Marco Stratman (BNL)

pp @ 500 GeV



^{3}He p @ 432 GeV



caveat: A_L study assumes 216 GeV ^{3}He beam

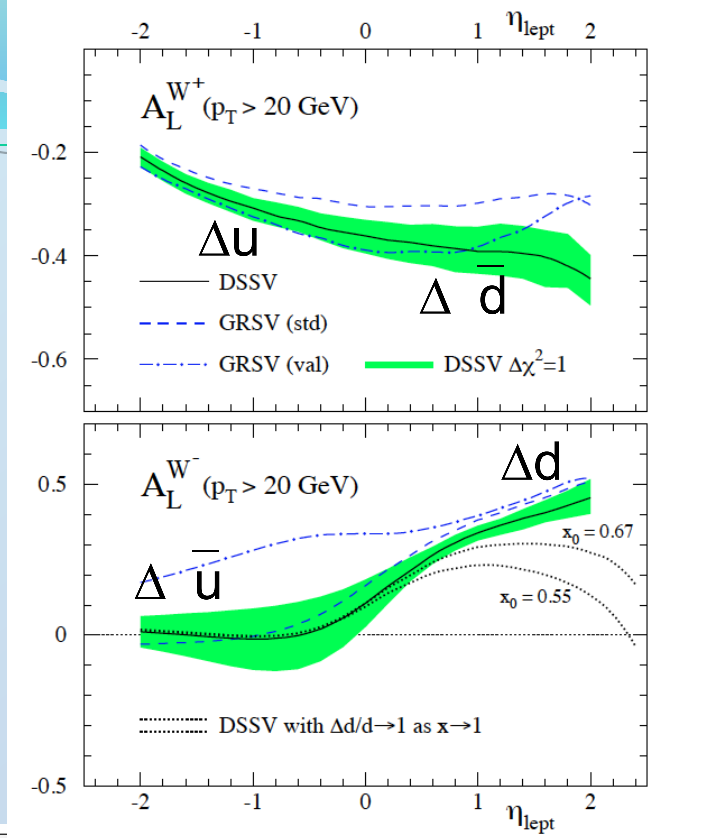
but 325 GeV × Z/A was too optimistic

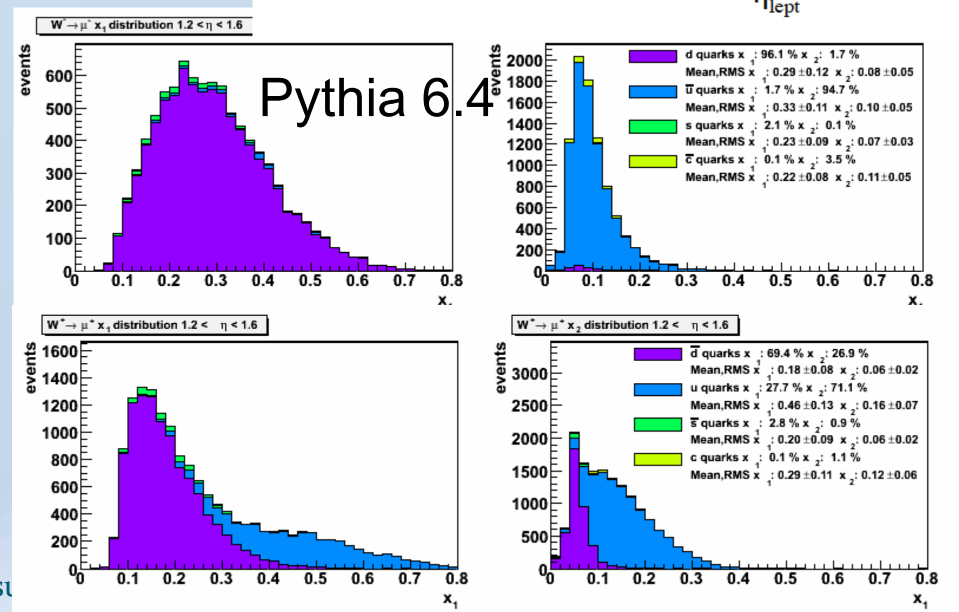
conservative: 250 GeV × 2/3 = 166 GeV

does not affect A_L much but cross section smaller

Forward W decays

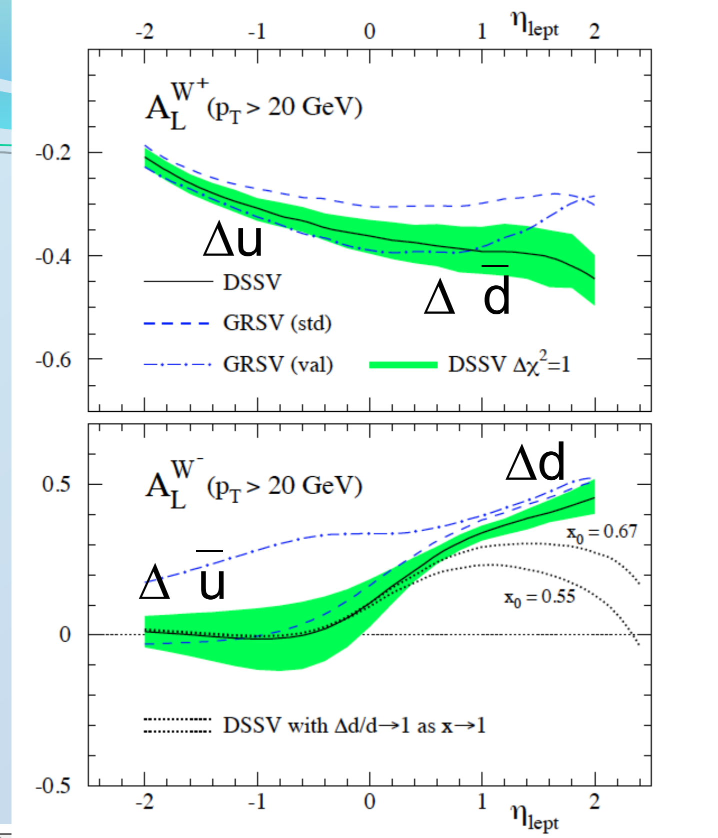
- Forward W decays advantages:
  - largest sensitivity to the anti-u quark polarization
  - some sensitivity to the anti-d quark polarizaiton (due to decay kinematics)
  - With high statistics possibility to test d pol sign change
- But no Jacobian peak, experimentally more difficult

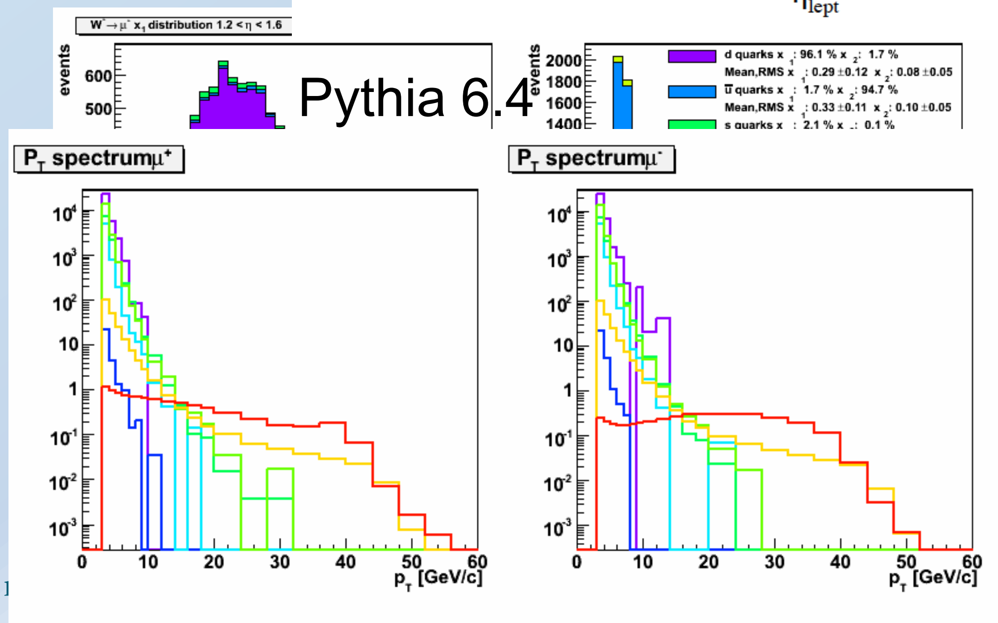




Forward W decays

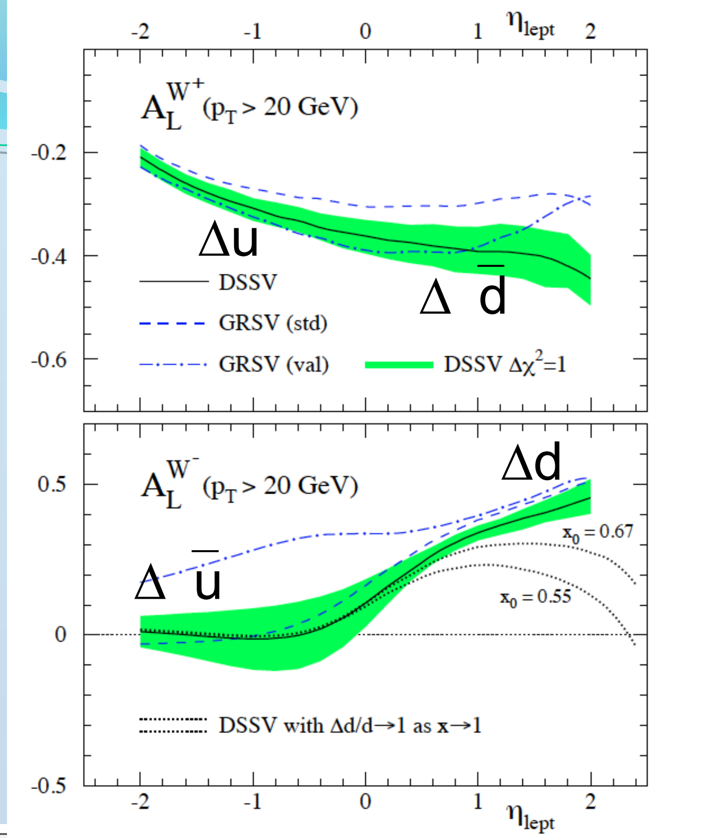
- Forward W decays advantages:
  - largest sensitivity to the anti-u quark polarization
  - some sensitivity to the anti-d quark polarizaiton (due to decay kinematics)
  - With high statistics possibility to test d pol sign change
- But no Jacobian peak, experimentally more difficult

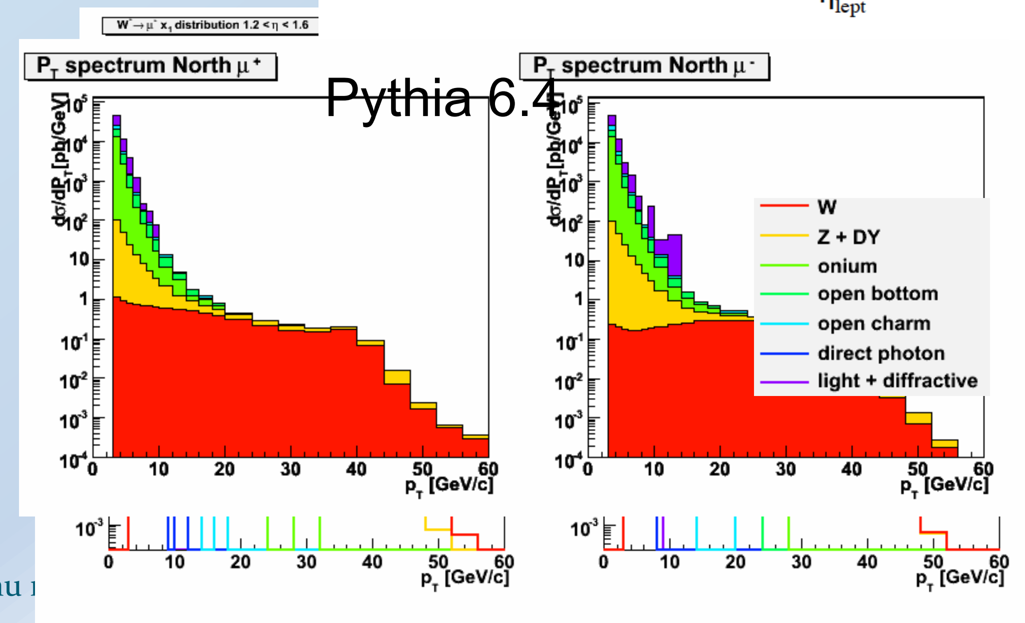




Forward W decays

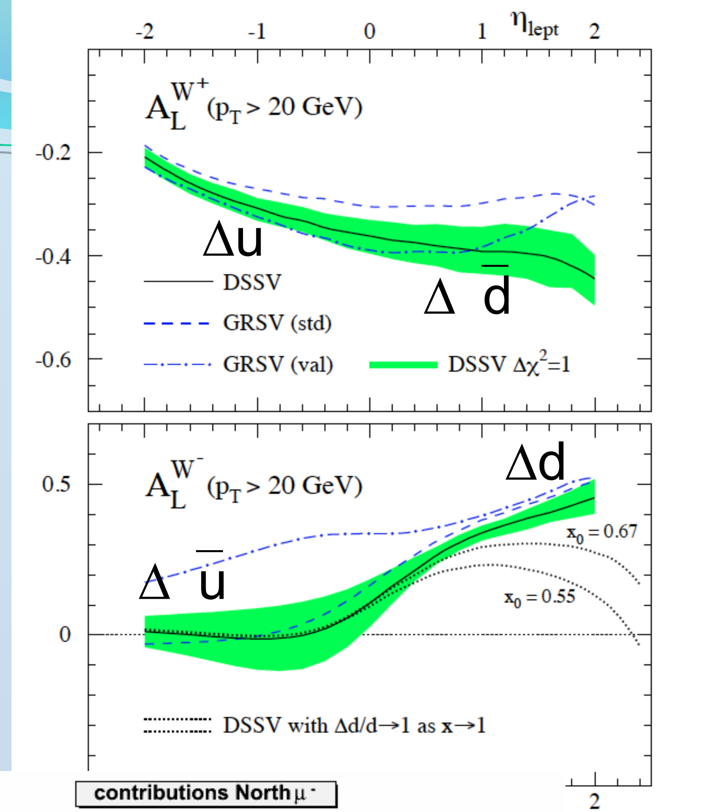
- Forward W decays advantages:
  - largest sensitivity to the anti-u quark polarization
  - some sensitivity to the anti-d quark polarizaiton (due to decay kinematics)
  - With high statistics possibility to test d pol sign change
- But no Jacobian peak, experimentally more difficult

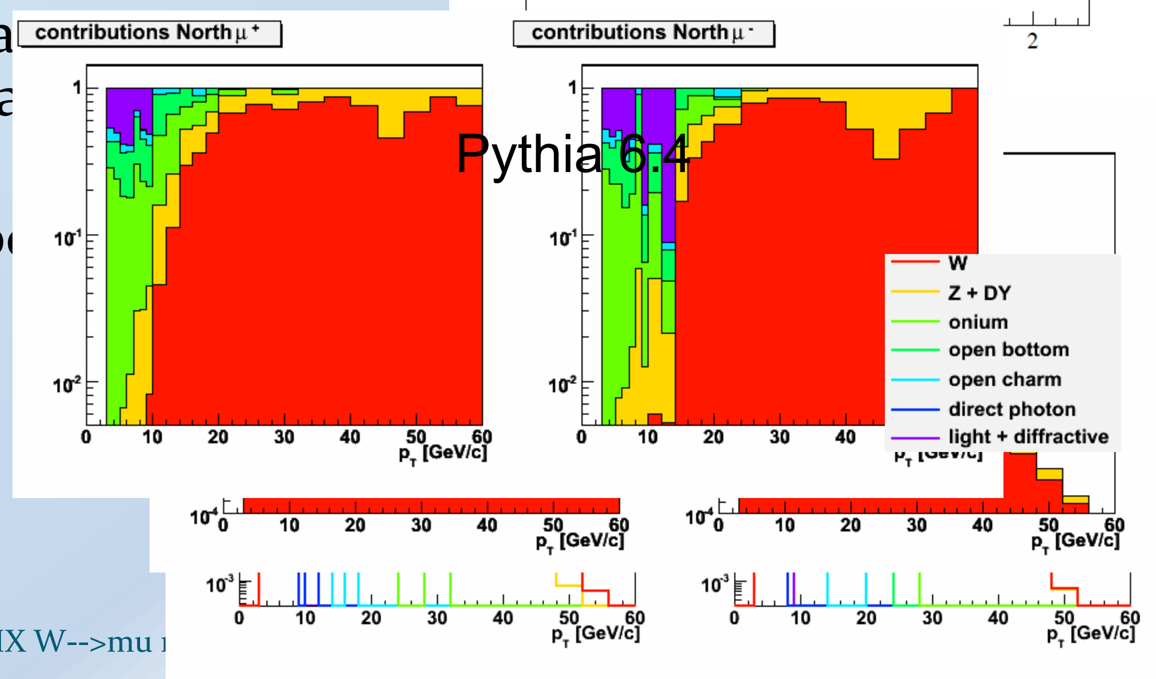




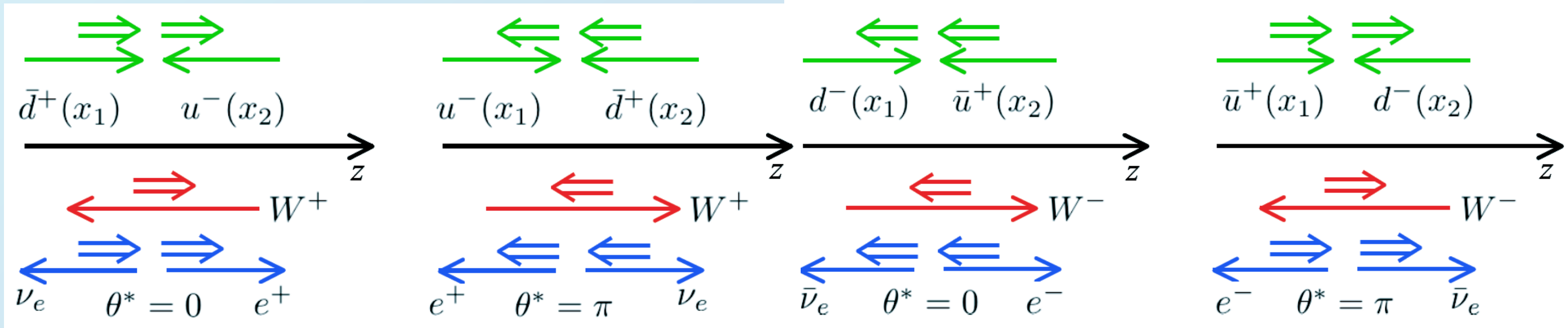
Forward W decays

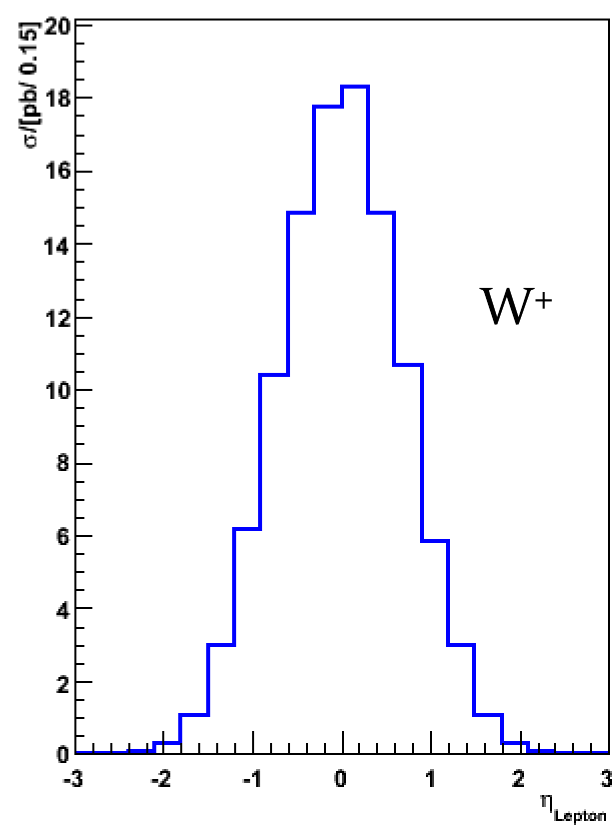
- Forward W decays advantages:
  - largest sensitivity to the anti-u quark polarization
  - some sensitivity to the anti-d quark polariza
    (due to decay kinema
  - With high statistics possibility to test d p
    sign change
- But no Jacobian peak, experimentally more difficult

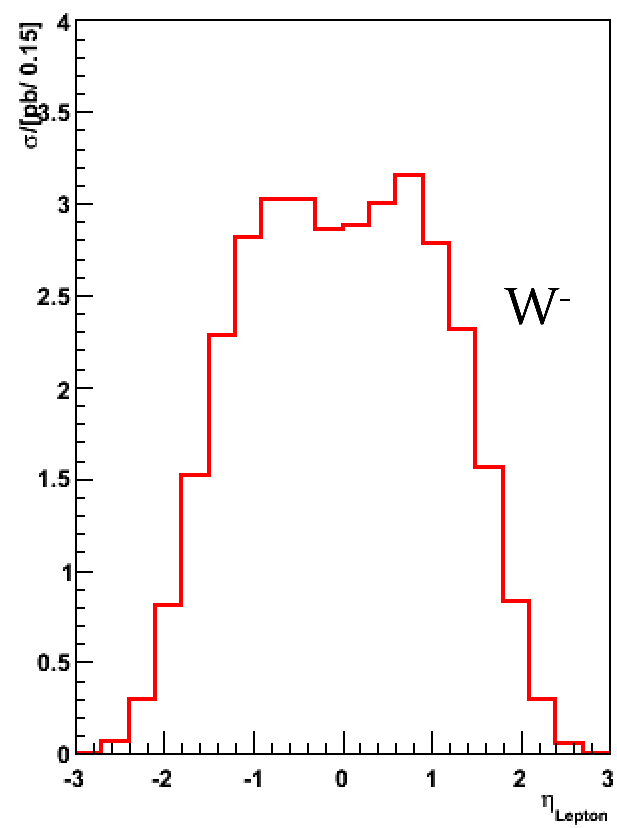




Decay kinematics due to helicity conservation







W vs lepton asymmetries

- Clear correlation for W: valence quark polarization→forward sea quark → backward
- However, not for decay muon/electron: enhanced for W^-, mixed for W^+
- reversed effect for neutrino asymmetry
- neutron target reverses that due to isospin asymmetry →run He3 collisions eventully?
- x is not affected by this; still forward is larger x, backward smaller x