Study Quark Contribution to Proton Spin Structure at RHIC

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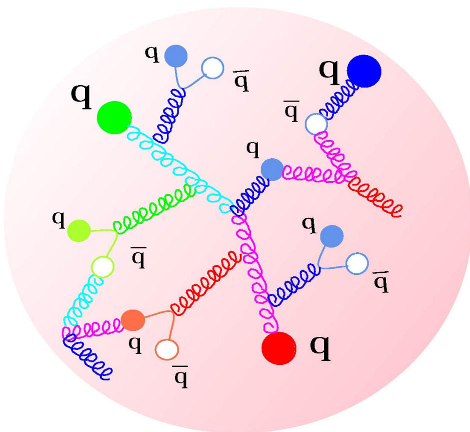
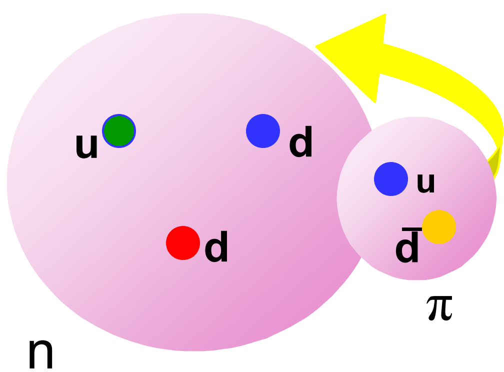
Content:

- Physics Motivation
- How RHIC will measure Quark Contribution to spin structure
- How well RHIC can measure the W-decay lepton with current detector configuration
- Upgrade for STAR tracking system and PHENIX forward spectrometer
- Summary

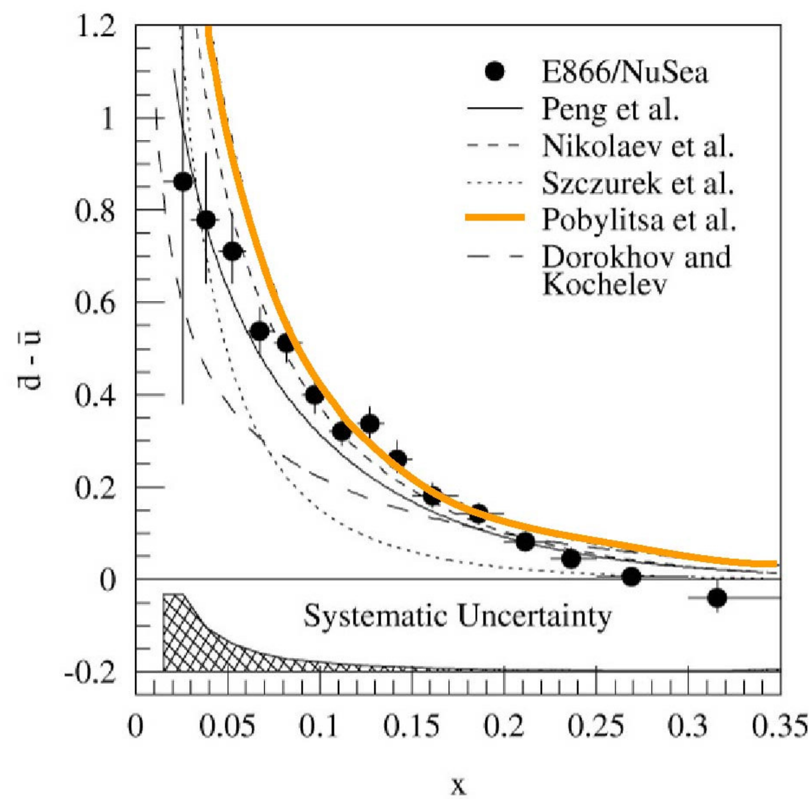
Spin Average Sea Quark Asymmetry



pQCD implies that
$\bar{u}(x) \sim \bar{d}(x)$

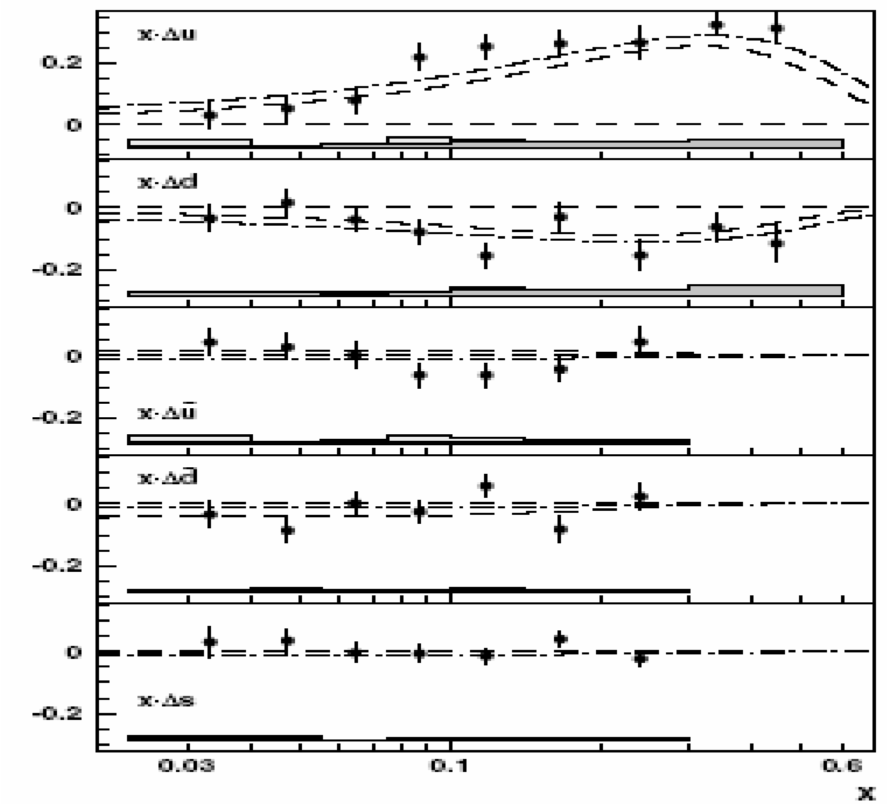


Virtual π's imply an excess of $\bar{d}$ over $\bar{u}$

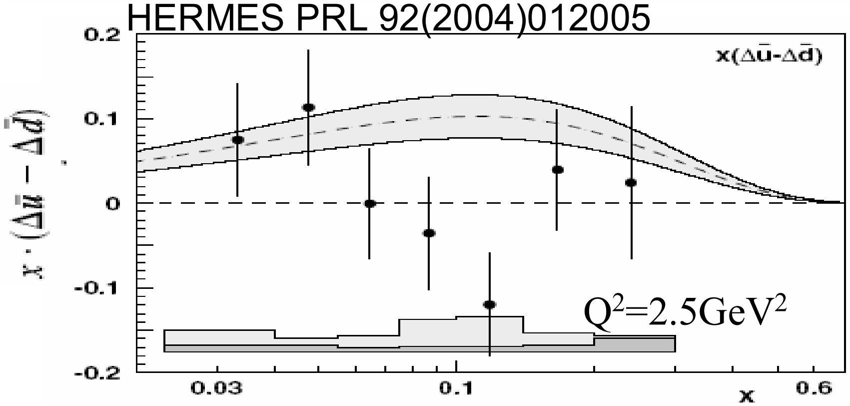


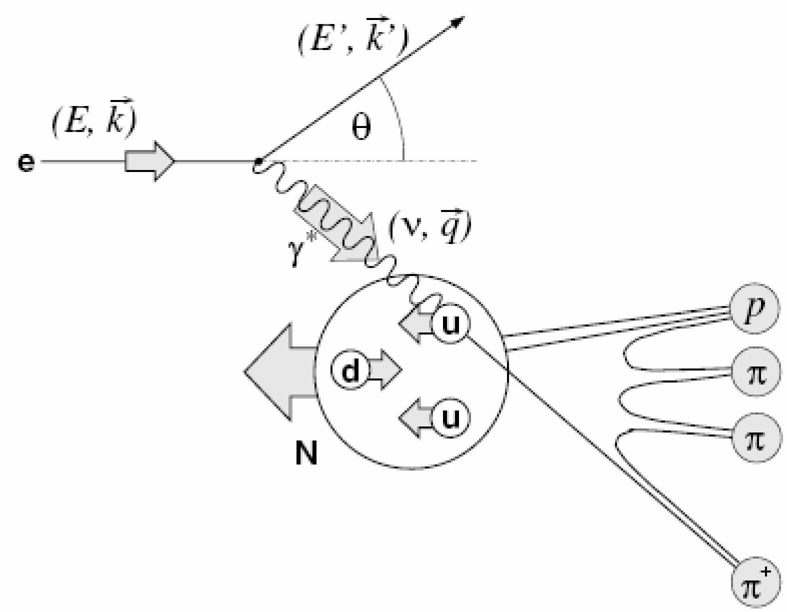
- Non-perturbative processes seem to be needed in generating the sea

Quark Flavor Structure Measurement at SIDIS



HERMES PRL 92(2004)012005

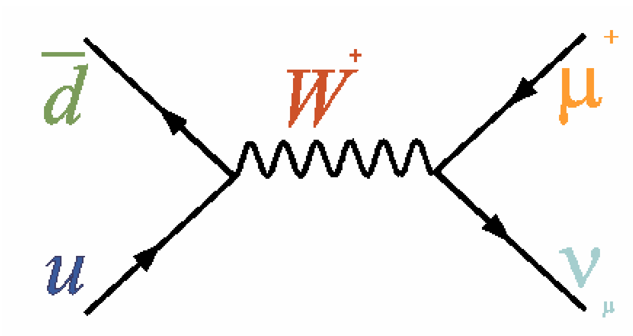


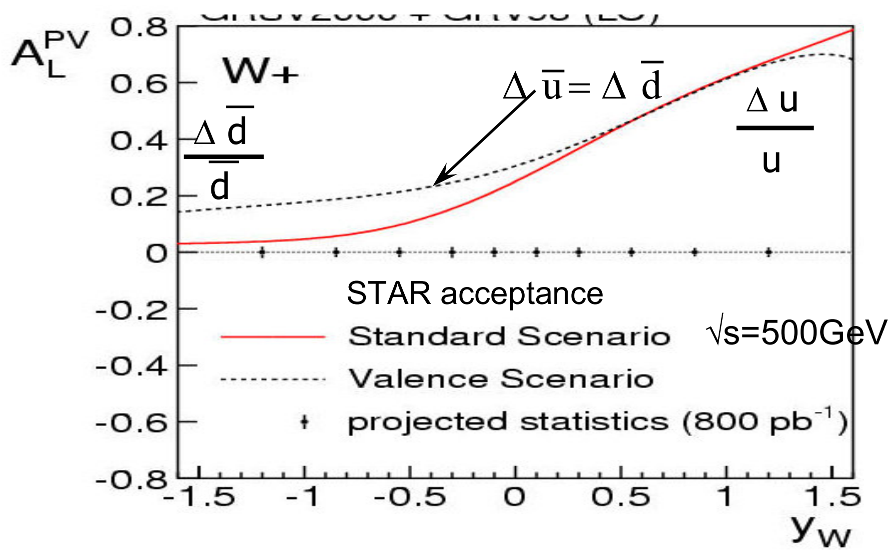


- Q^2 is low
- relies on knowledge of fragmentation functions

Quark Flavor Structure Measurement at RHIC

- Parity violating single-spin asymmetries at RHIC provide direct access to the quark flavor structure of the proton spin:

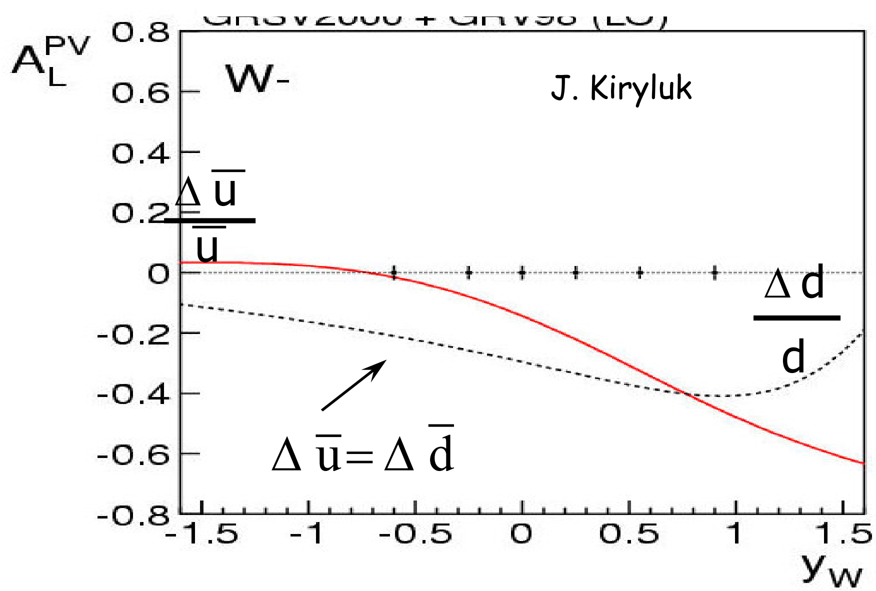




$$A_L^{W^+}(y) = \frac{-\Delta u(x_a)\bar{d}(x_b) + \Delta\bar{d}(x_a)u(x_b)}{u(x_a)\bar{d}(x_b) + \bar{d}(x_a)u(x_b)}$$

, $x_a >> x_b$

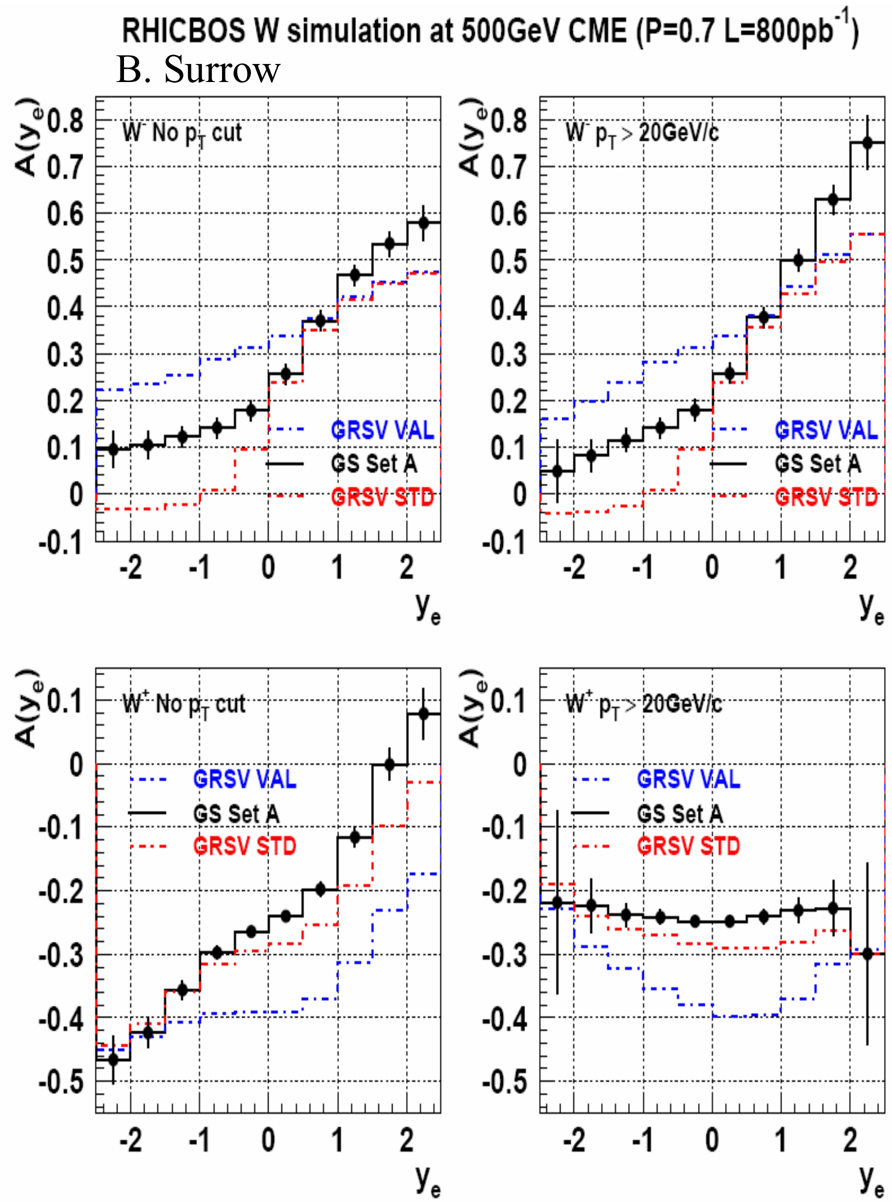
$$A_L(W^+) = \frac{\Delta\bar{d}(x_b)}{\bar{d}(x_b)}, \quad x_b >> x_a$$



RHICBOS predicted Sensitivity at RHIC

RHICBOS W simulation at 500GeV CME (P=0.7 L=800pb^{-1})

B. Surrow



- •STAR
  - central rapidity: $|\eta|<1$, $\Delta\phi=2\pi$, electon
  - forward rapidity: $1<\eta<2$, $\Delta\phi=2\pi$, electron
- •PHENIX
  - •central arm: $|\eta|<0.35$, $\Delta\phi=2\pi$, electron
  - •Muon arm: $1.2<|\eta|<2.4$, $\Delta\phi=2\pi$, muon

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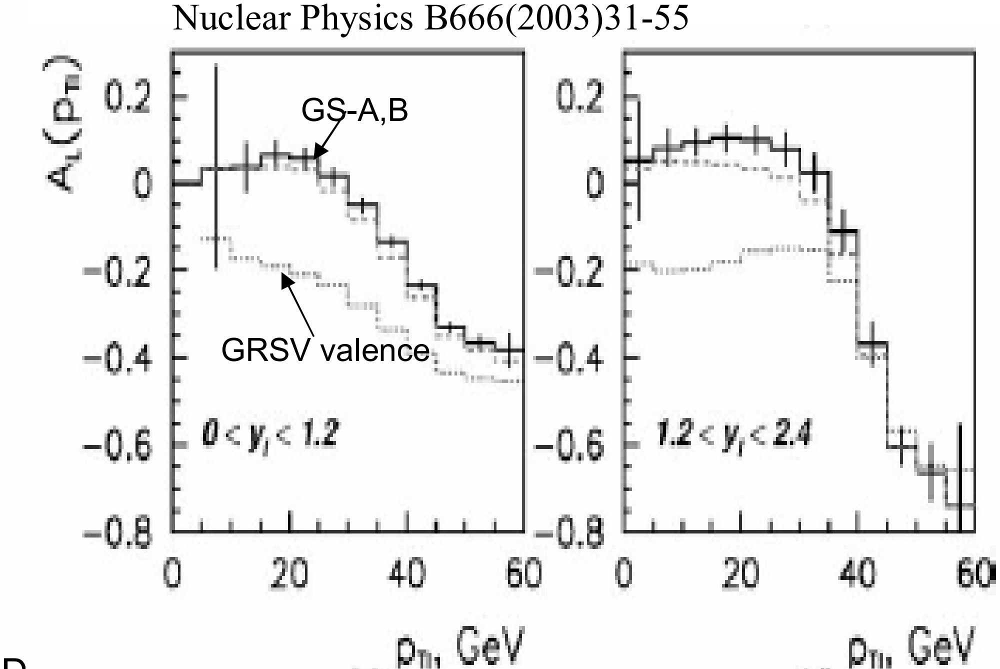
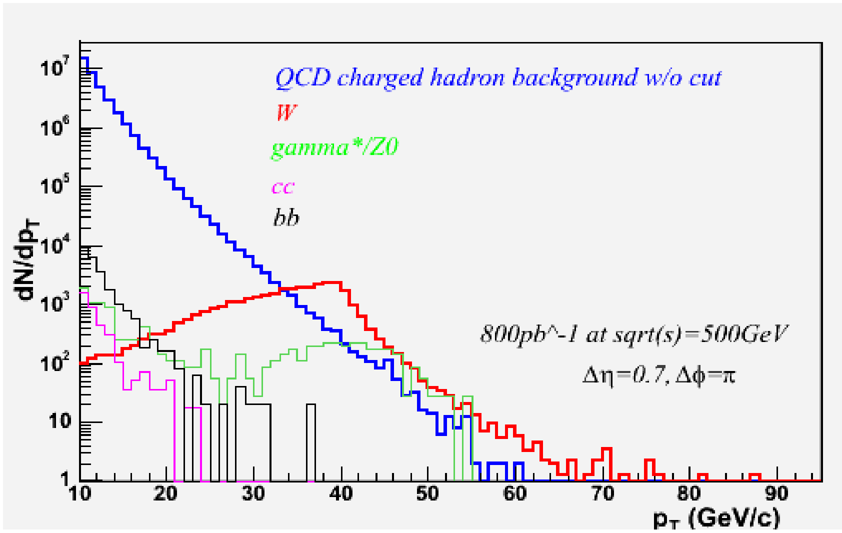


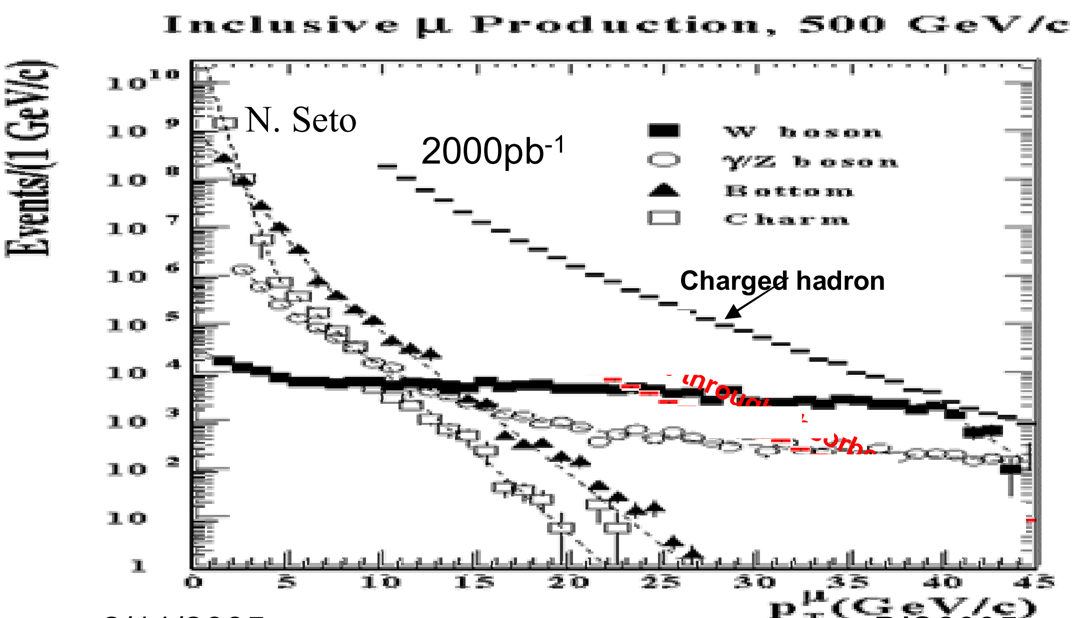
Background for the W-decay Lepton Measurement



PHENIX Central arms:

Major background: charged hadrons

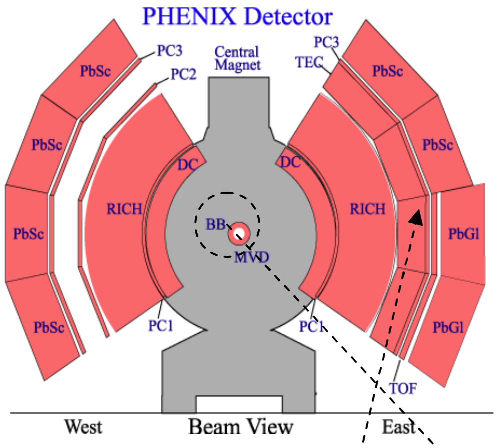
Similar for STAR experiment



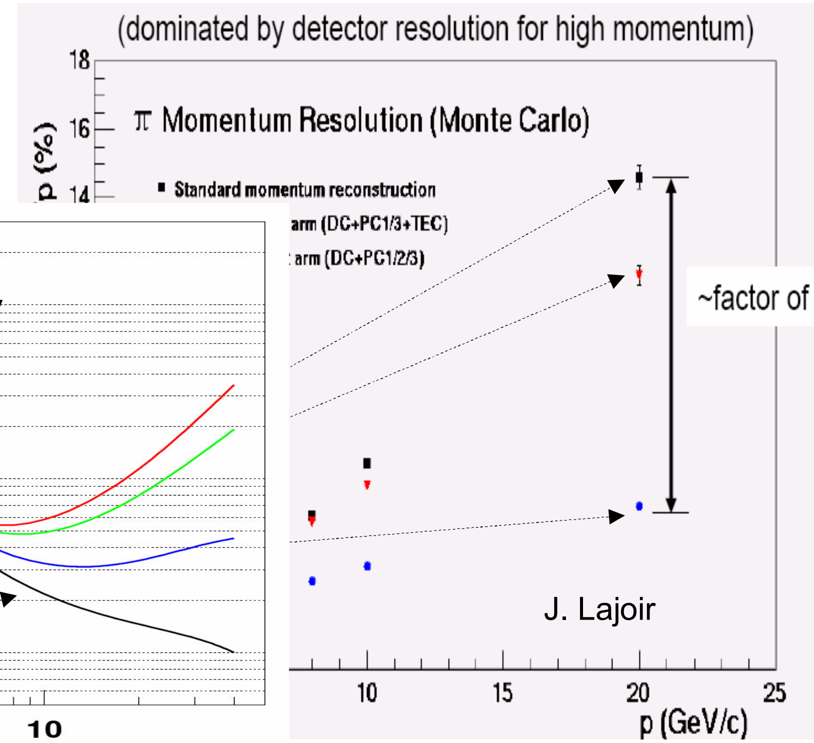
PHENIX muon arms:

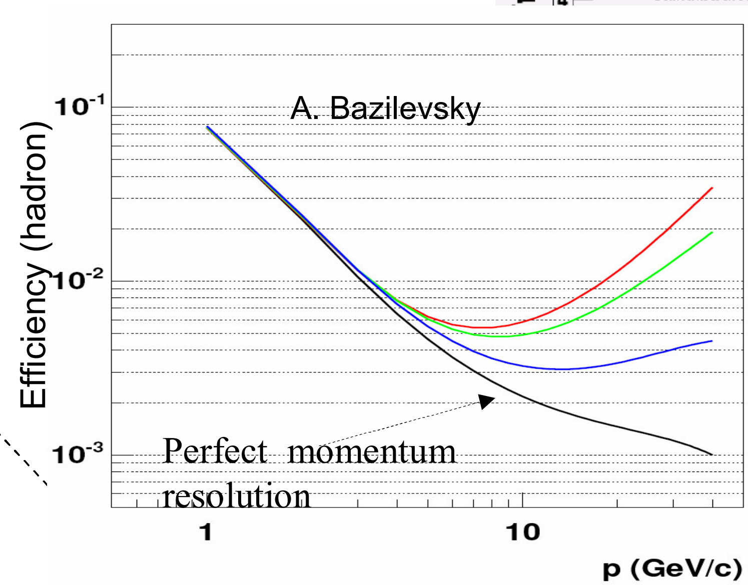
Major background: charged hadrons

Charged Hadron Rejection for PHENIX and STAR

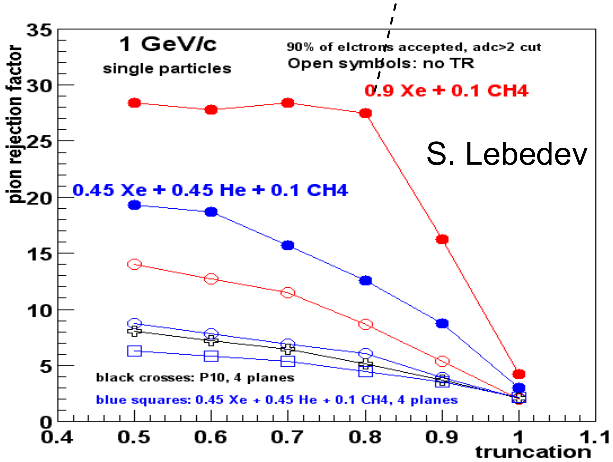


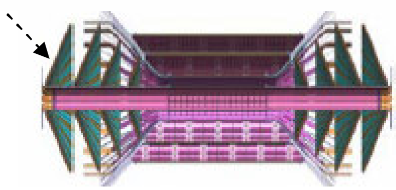
E/p cut:





TRD cut:





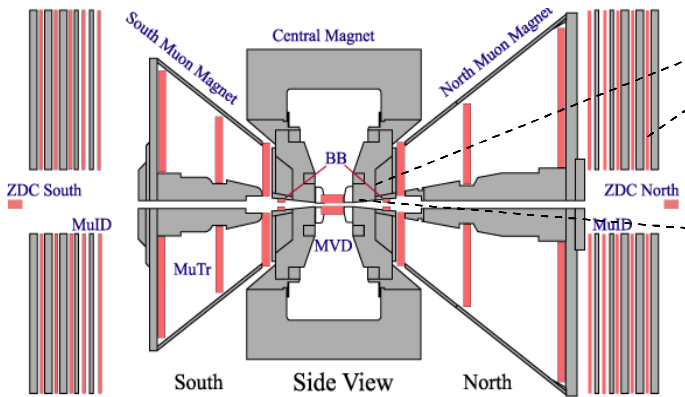
Improve resolution by ~2

Shower profile: ~10 rejection

Isolation cut: ~5 rejection

Total charged particle rejection: ~10^4

Charged Hadron Rejection for PHENIX and STAR

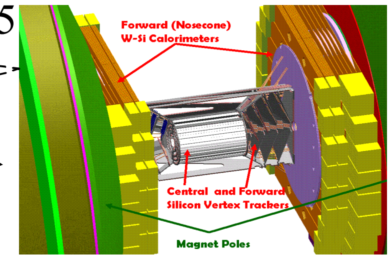


PHENIX Muon arms

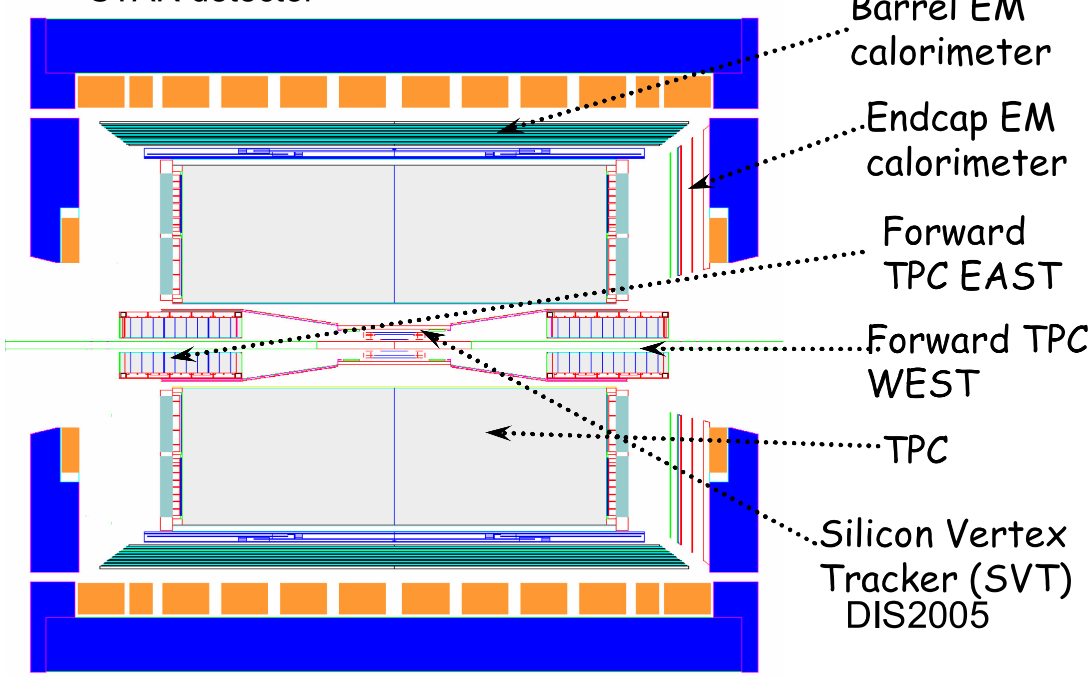
- Charged hadron rejection through absorber: ~100
- More rejection from the shower profile on the tube.
- More rejection from isolation cut: ~5
- more rejection from W

mt reconstruction via NCC (?)

Total rejection: ~10^3



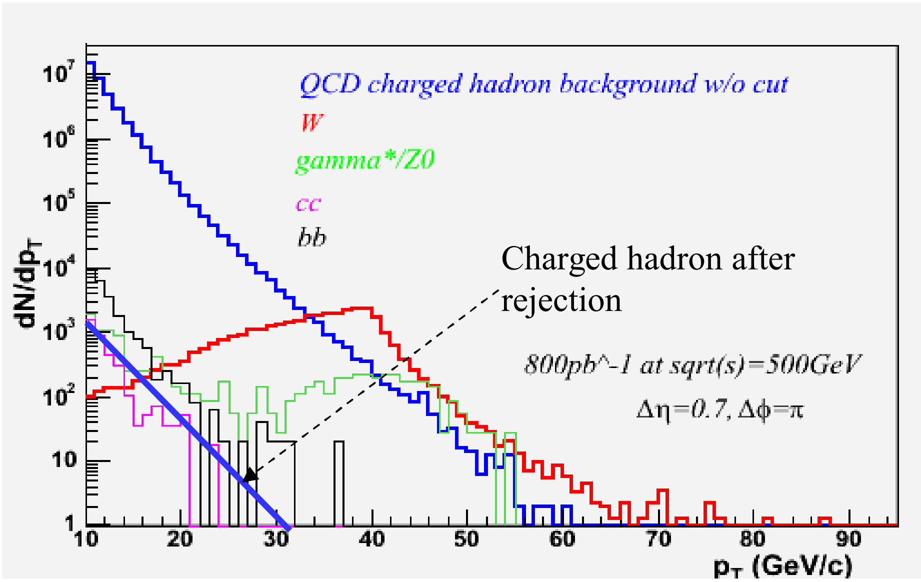
STAR detector



- E/p cut: ~10 rejection
- Isolation cut: ~10 rejection
- Large missing pt cut: ~10 rejection
- longitudinal shower profile cut: more rejection.

Total rejection: > 10^3

Charged Hadron Background after the Rejection

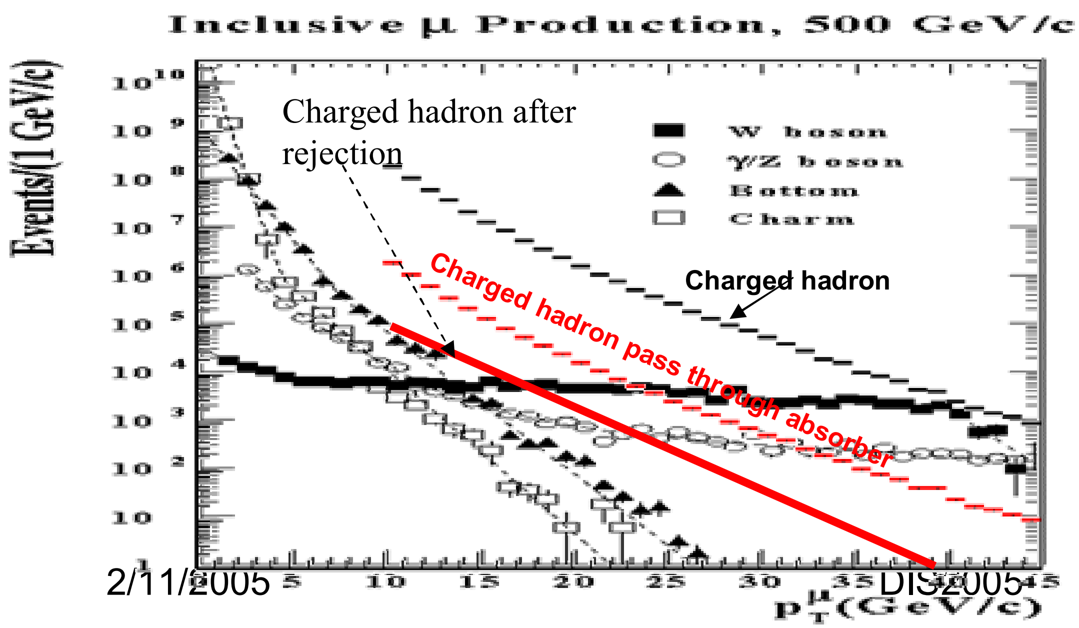


PHENIX Central arms:

Major background from Z0 decay. Should be correctable.

Measurement: pT> 20GeV/c

Similar for STAR experiment



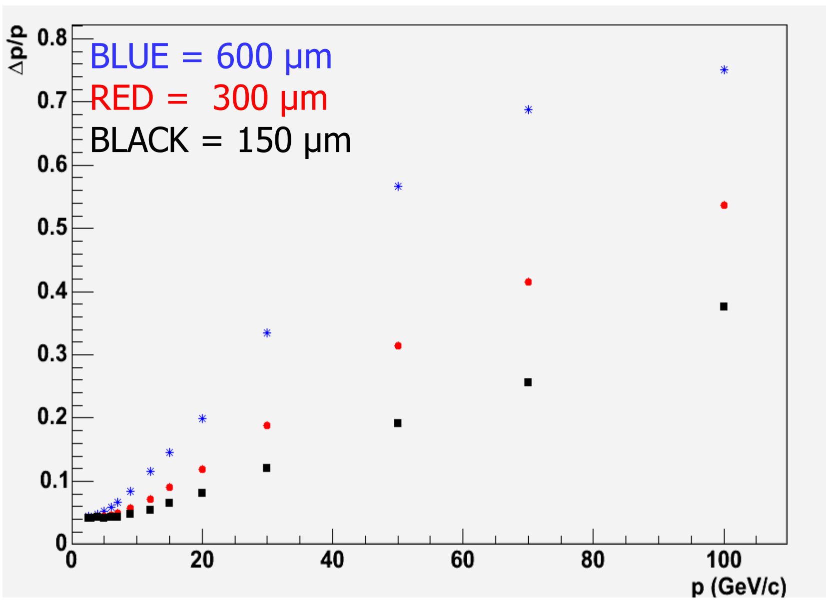
PHENIX muon arms:

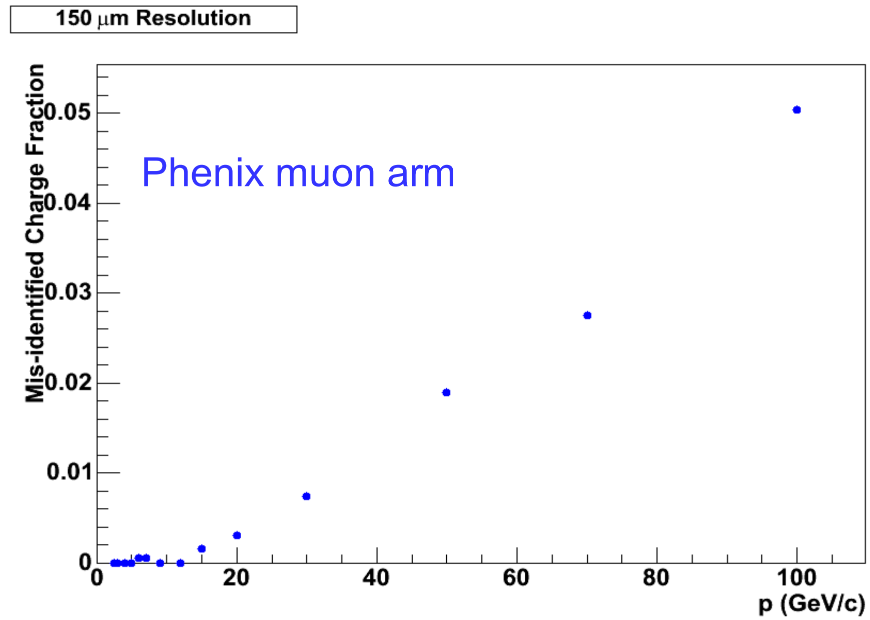
Major background from the pion punch through and Z0 decay.

Measurement: pT>20GeV/c

Charge Sign misidentification for PHENIX

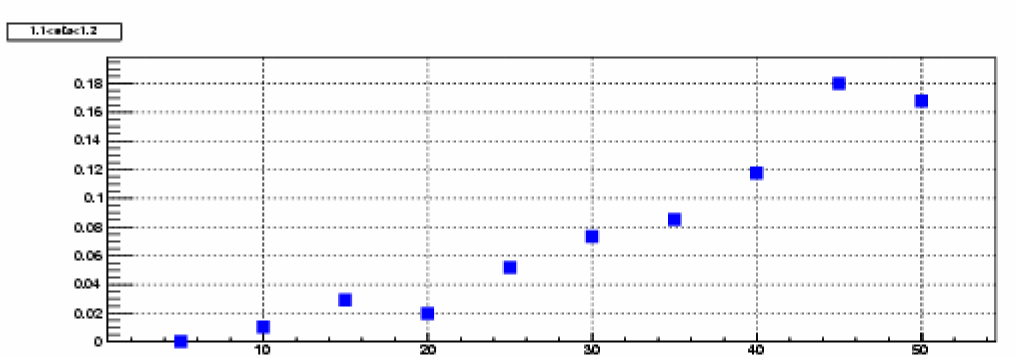
- **Need good charge sign separation for high pT tracks (> 20GeV)**
  - PHENIX: a few % mis-identification in *muon* arm



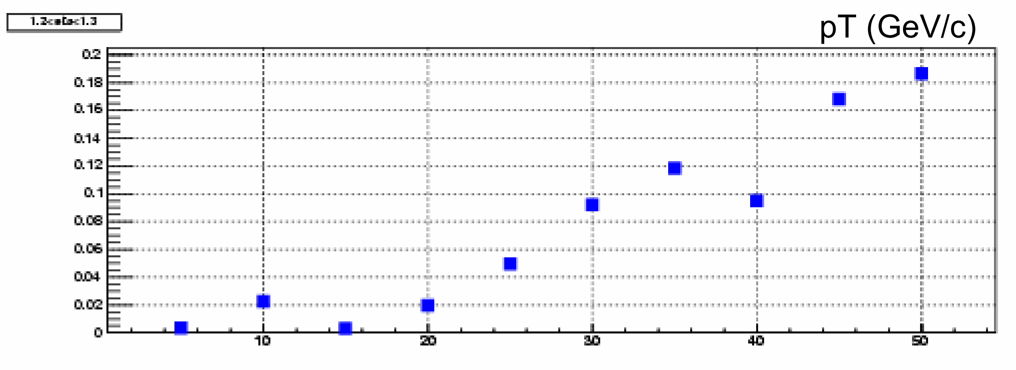


- Similar in central arm but will be much better after silicon tracker is installed

Charge Sign misidentification for STAR



pT (GeV/c)



pT (GeV/c)

- Simulation done without including event pile-up effect

Existing tracking degrades with η for η>1

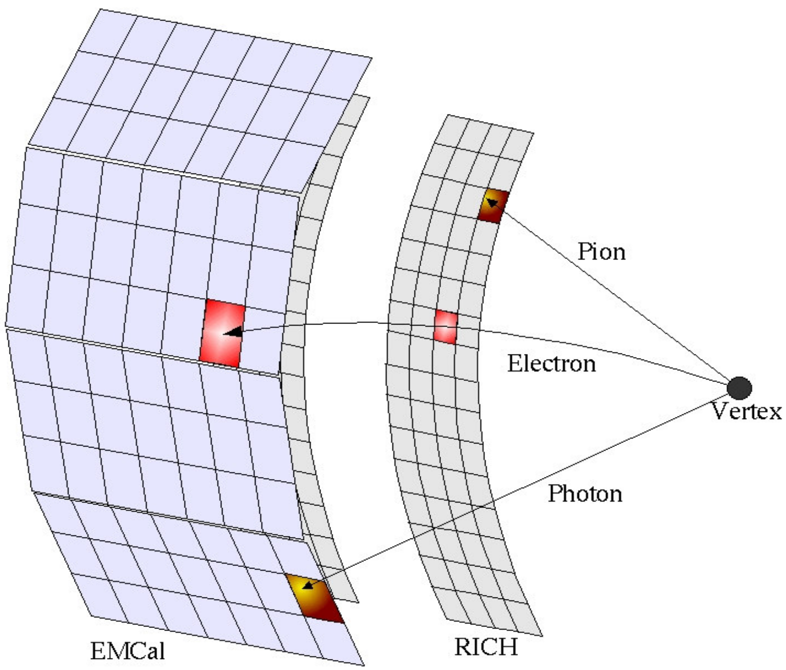
- Fewer pad rows hit as η increases
- Pad row density decreases for η>1.5
- Miss SVT

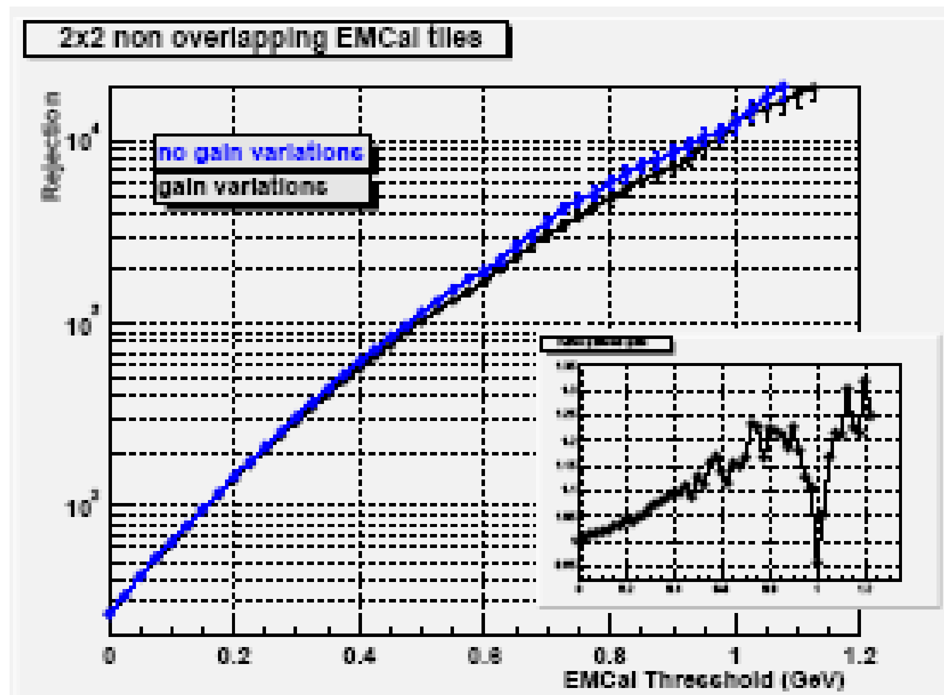
Need a tracking system upgrade

These are all crucial for tracking in the region -1 < η < 1 as well, where tracking upgr. also of use

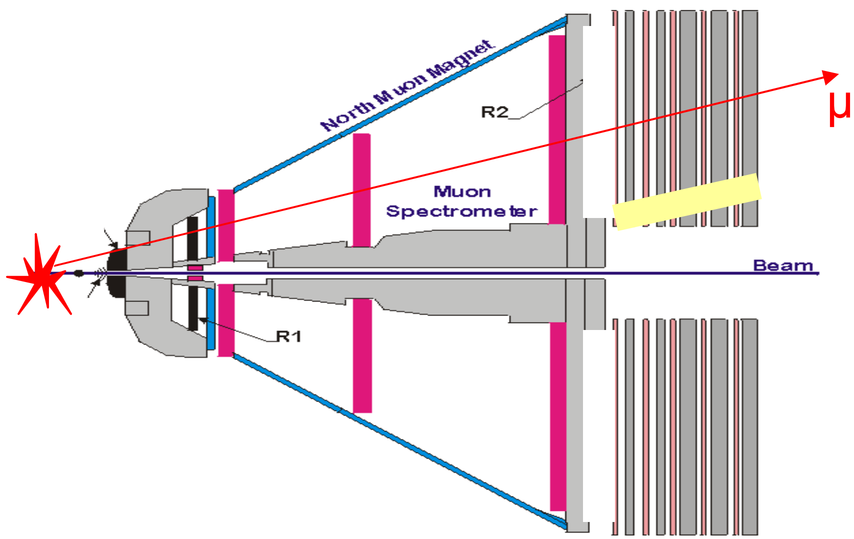
Level-1 Trigger Performance for PHENIX and STAR

- **Need a high performance trigger to handle the high collision rate:**
  - collision rates in 500GeV run: *~12MHz*
  - PHENIX DAQ bandwidth: *~10kHz*, i.e. need rejection factor of ~10^4.
    - PHENIX central arm has enough rejection power





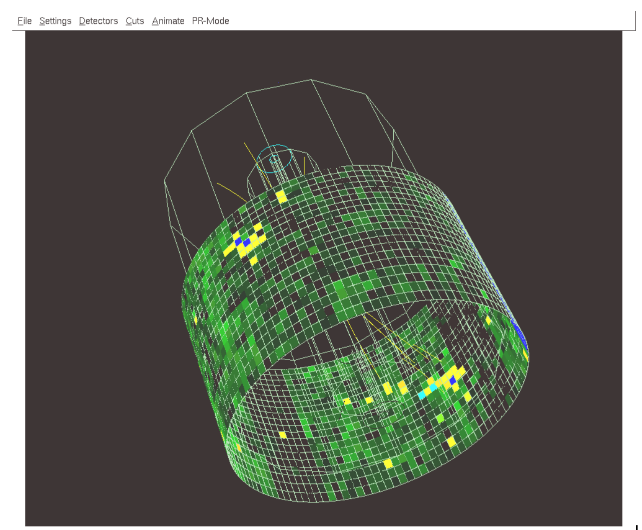
Level-1 Trigger Performance for PHENIX and STAR



PHENIX muon arm level-1 trigger: rejection factor ~500.

Need upgrade to increase a factor of ~20

- STAR DAQ bandwidth (upgrade): *~1kHz*, i.e. need rejection factor of >10000
  - threshold trigger using barrel and encap EMCal Huge rejection can be achieved.

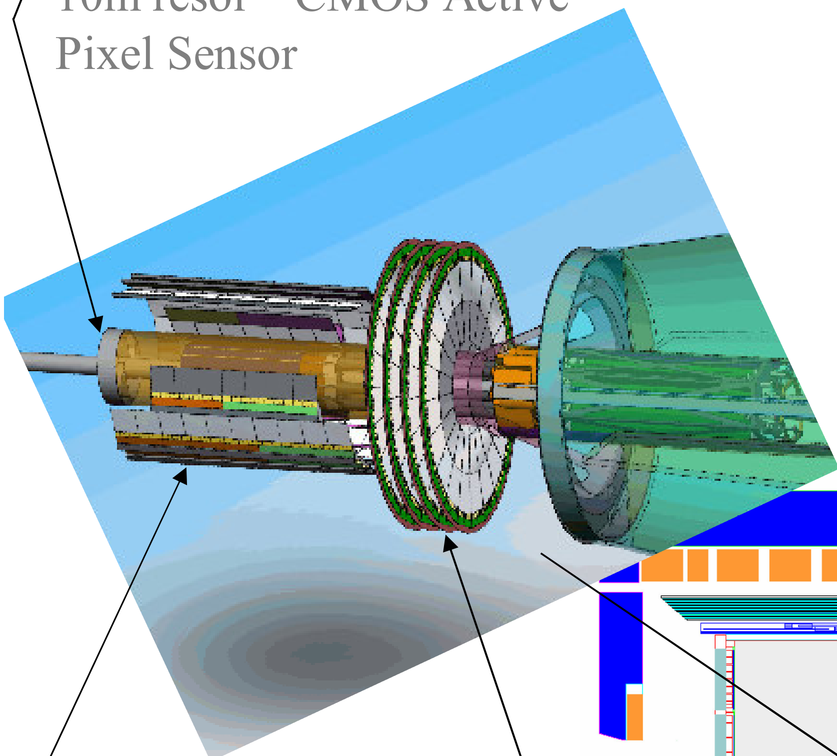


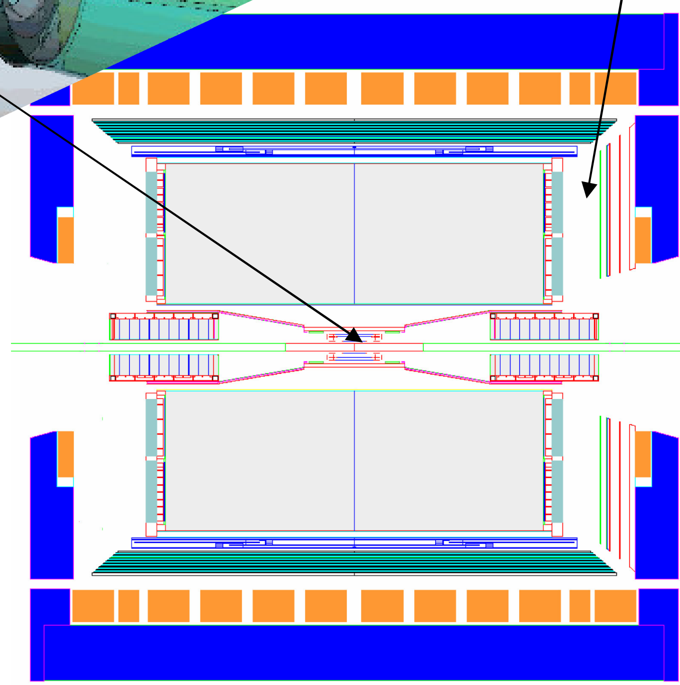
- In order to measure quark contribution to spin structure
  - PHENIX need forward spectrometer upgrade
  - STAR need Tracking system upgrade and DAQ upgrade.

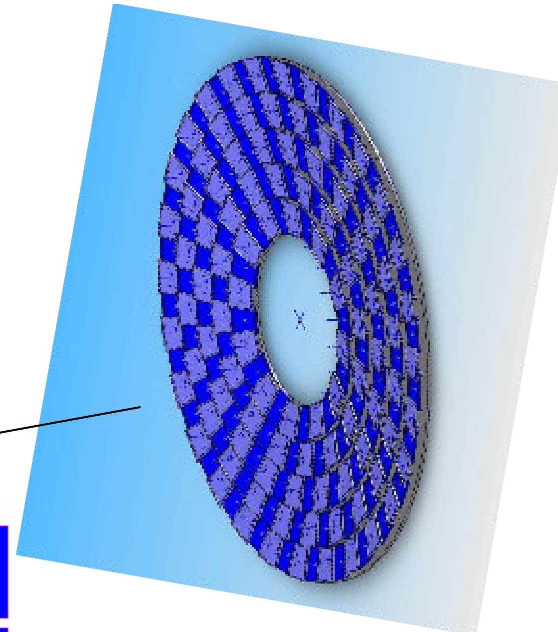
STAR Tracking Upgrade Concept

Inner Tracker

Heavy Flavor Tracker
10m resol – CMOS Active
Pixel Sensor







Integrated Silicon
Tracker – 50m res.

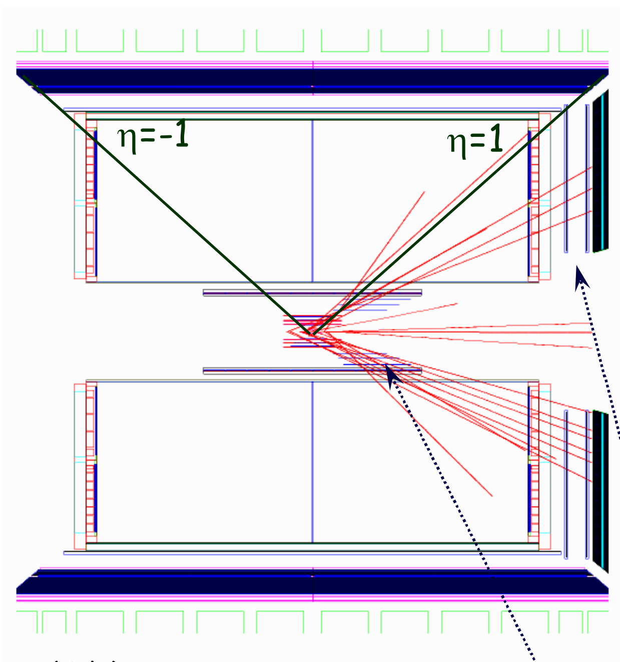
- 3 Barrel planes
- 4 Forward disks

Endcap Tracker

Tiled GEM chambers
100m resol.

Performance of STAR Forward tracking

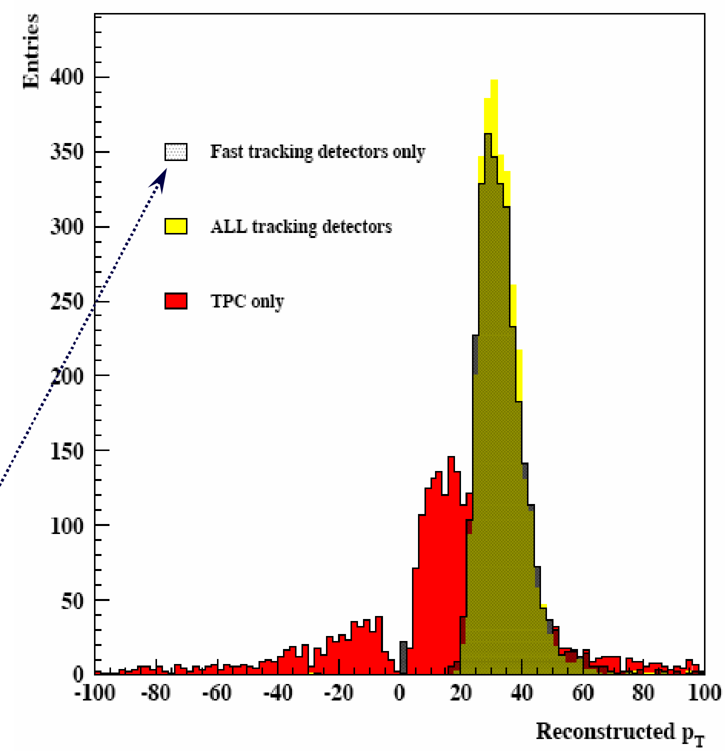
- Simulated forward p_T resolution ($1 < \eta < 2$)
  - Forward p_T reconstruction: π^-
    - True $p_T = 30$ GeV
    - Range in η: $1 < \eta < 2$



N. Smirnov (Yale)

- Simulated fast tracking configuration:
  - Inner (fast) configuration: 3 silicon layers
  - Outer (fast) configuration: 2 triple GEM layers

- Reconstructed p_T for various detector configurations:



STAR tracking upgrade
Integrated tracking approach of pixel upgrade and inner silicon upgrade in combination with forward GEM tracker!

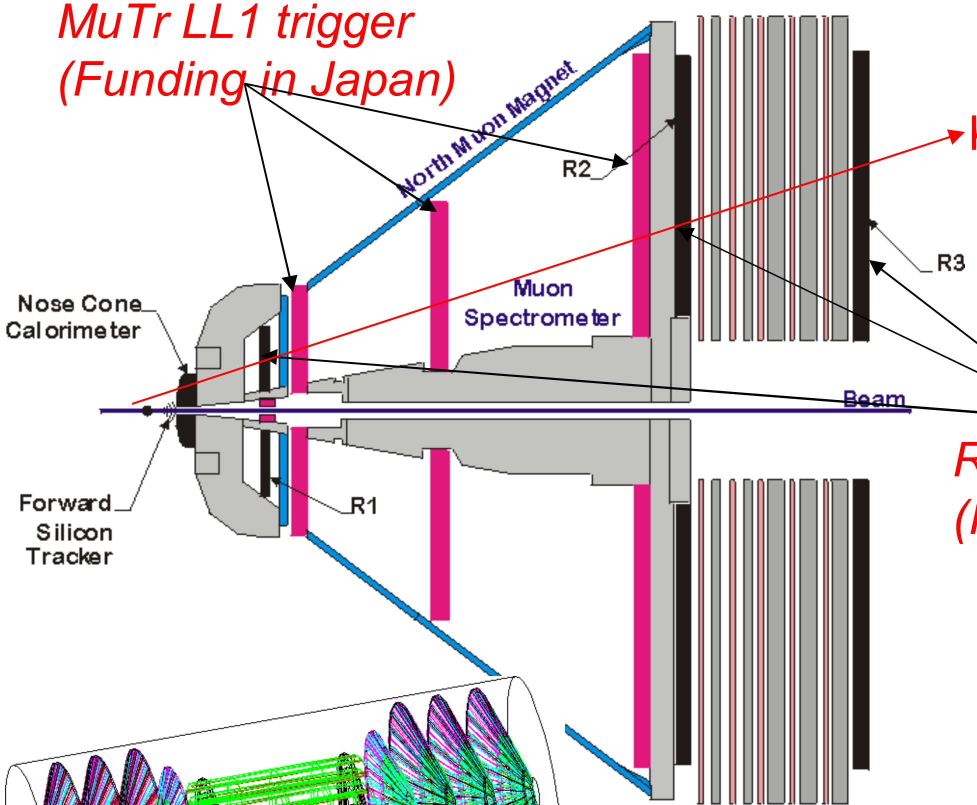
Status and timeline of STAR tracking upgrade

- The study of heavy flavors and W production: Upgrade of the STAR inner/forward tracking system
- Simulation work and design of detector layout based on silicon and triple-GEM technology (On-going R&D and prototyping effort) started
- Integrated tracking design of a new inner and forward STAR tracking system mandatory
- Staging of tracking upgrade in accordance with readiness of detector technology and beam development:

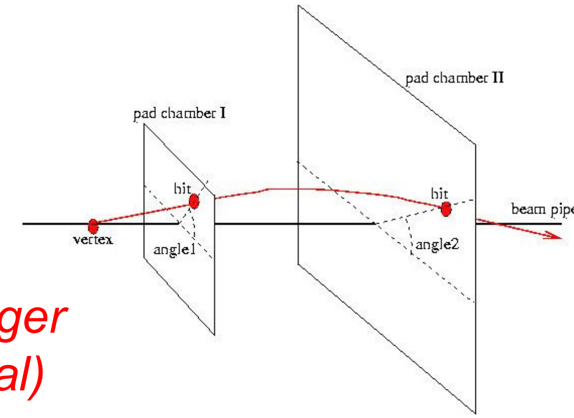
- Possible scenario:
  - Stage 1: Installation of STAR Micro-Vertex Detector together with a minimal new barrel tracking detector based on silicon technology ($-1 < \eta < 1$) (Heavy Flavor Physics)
    - Proposal APS Heavy Flavor Tracker early CY05
    - Proposal Barrel after FY05 run
    - Installation of new inner tracking system by summer 2008 (FY09 run)
  - Stage 2: Upgrade of the forward tracking system ($1 < \eta < 2$) (W physics)
    - Proposal after FY06 run
    - Installation of forward system by summer 2009 (FY10 run)
- Dedicated time for machine development with polarized protons to achieve high luminosity and high polarization is vital for the success of this novel program!

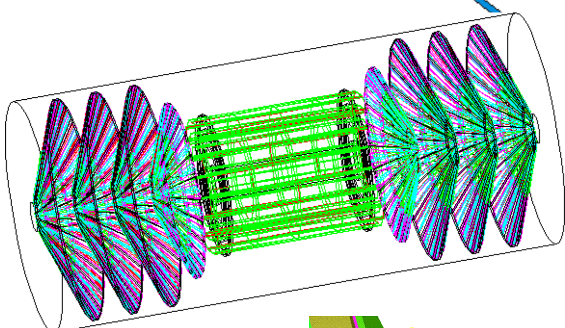
PHENIX forward upgrade

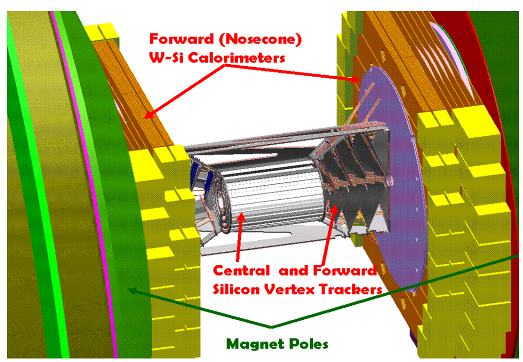
MuTr LL1 trigger
(Funding in Japan)



RPC LL1 trigger
(NSF proposal)





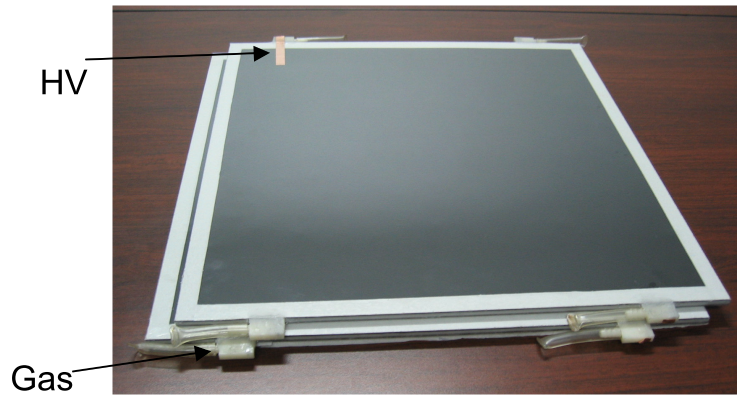


Achieved enough trigger rejection

δ(ϕ) deg	<0.7	<1.0	<2.0
rejection	36000	19980	10090

- increase of pion rejection via isolation cut
- possible background rejection via reconstructing W transverse mass.
- possible improve of momentum resolution with well defined determined vertex.

PHENIX forward upgrade plan

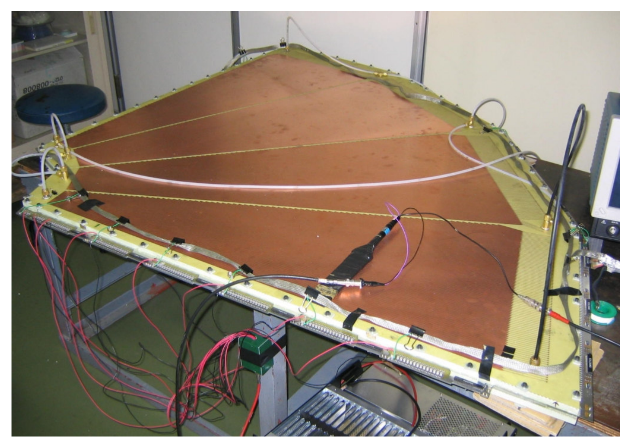


Picture of 2 chambers

courtesy of Y. Mao

- RPC hardware, FEE and Local level-1 trigger
  - R&D from 2005-2007
  - build RPC for half of the south muon spectrometer by September 2007, install for the run in winter 2007 and 2008.
  - build remaining modules for both spectrometers by September 2008
  - complete mechanical integration of RPCs into PHENIX by January 2009.

- **MuTr LL1 Trigger:**
  - R&D on fast readout FEE is ongoing at Kyoto University.
  - plan to have the final design in 2005 and mass production in start right after funding is avaliable.



Summary

- RHIC provide unique environment for direct measurement of quark contribution to proton spin through W boson decay.

- PHENIX will do the measurement through
  - Electron channel in central rapidity region
  - Muon channel in forward region with forward upgrade
    - Welcome to join the upgrade project

- STAR will do the measurement through
  - Electron channel in both central and forward rapidity region with new tracking system upgrade
    - Welcome to join the upgrade project

- First Measurement expected to be at 2009-2010.

Backup slide

PHENIX

Current collaborators on W-project

STAR

University of Colorado
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University of California at Riverside
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Iowa State University
John Lajoie, John Hill, Gary Sleege
Kyoto University
Kazuya Aoki, Ken-ichi Imai, Naohito Saito, Kohei Shoji
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And collaborators working on NCC upgrade

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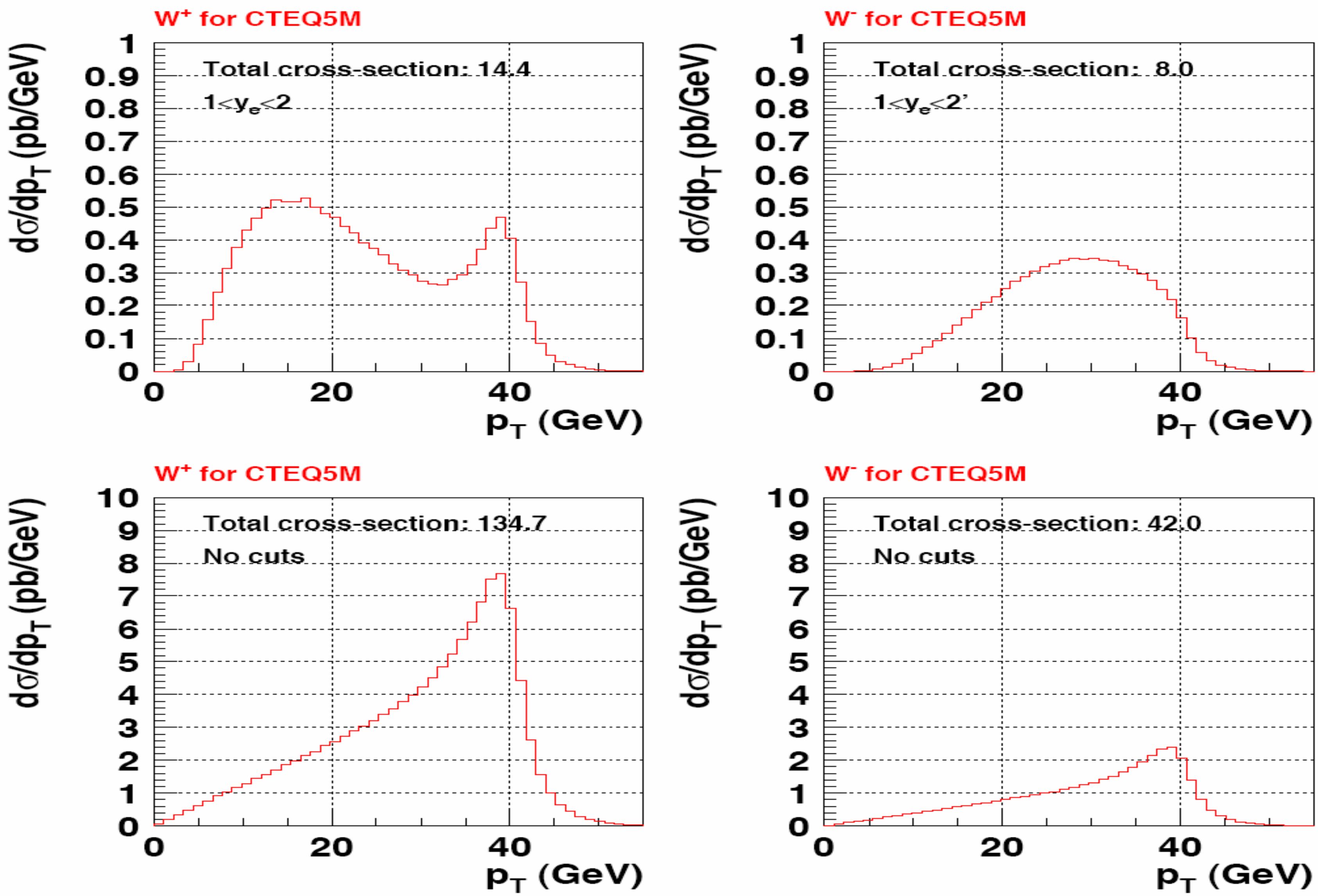
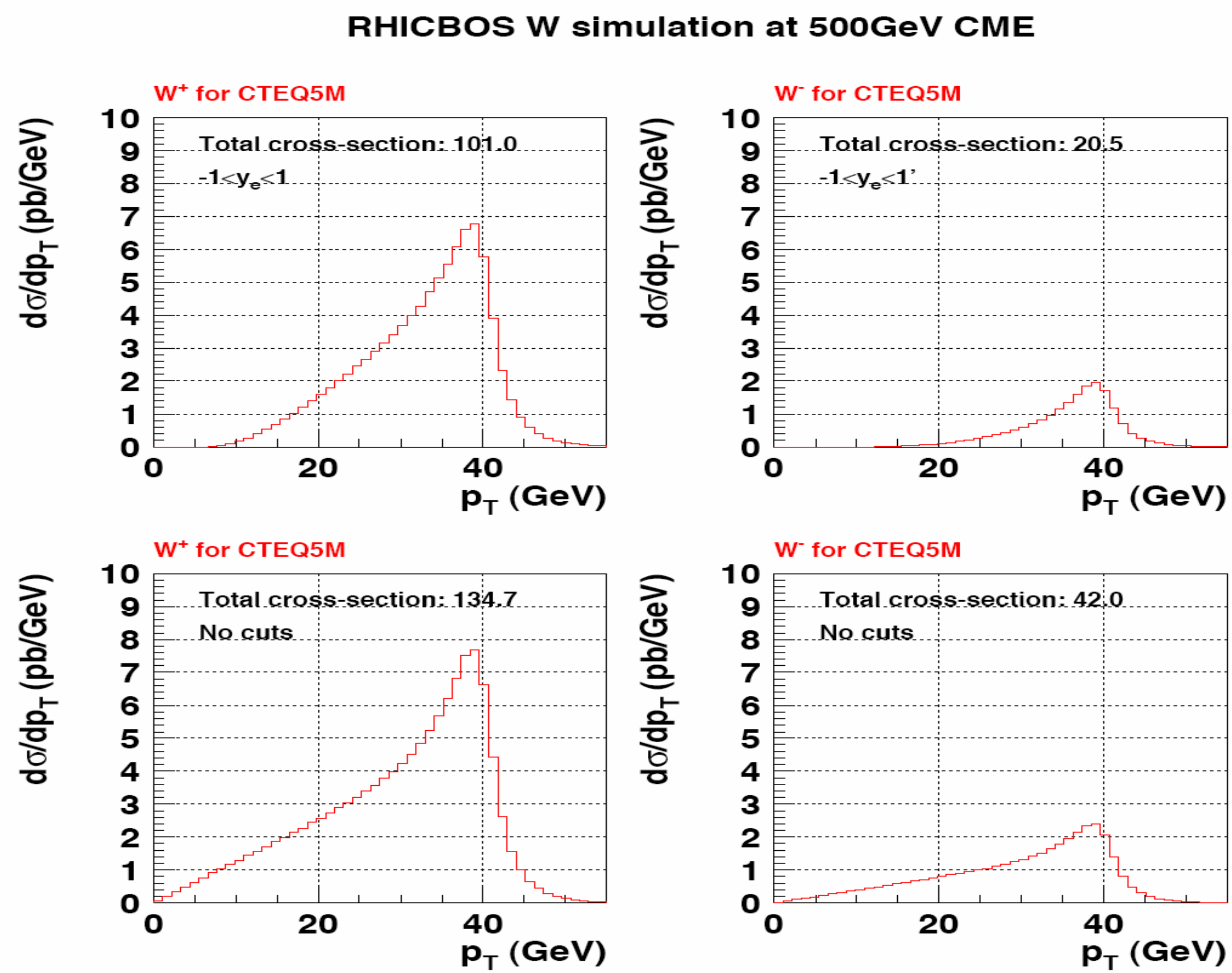
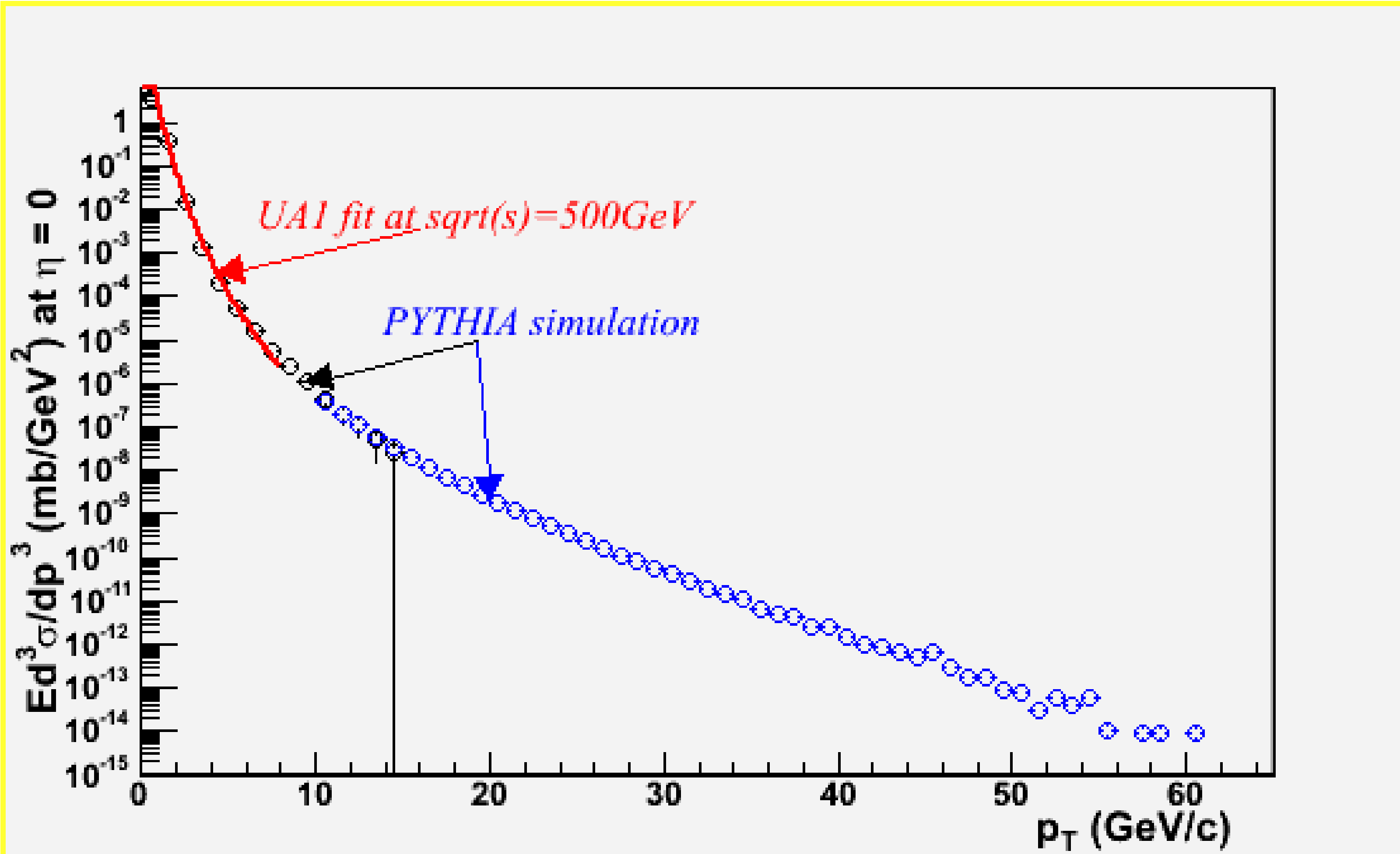
H. Mattis, H.-G. Ritter, K. Schweda, E. Sichtermann, H. Wieman, J. Thomas
MIT:
K. Dow, D. Hasell, J. Kelsey, J. Kiryluk, W. Leight, M. Miller, G. v. Nieuwenhuizen, M. Plesko, B. Surrow
Yale:
R. Majka, N. Smirnov
Zagreb: M. Planinic

RHICBOS W simulation at 500GeV CME

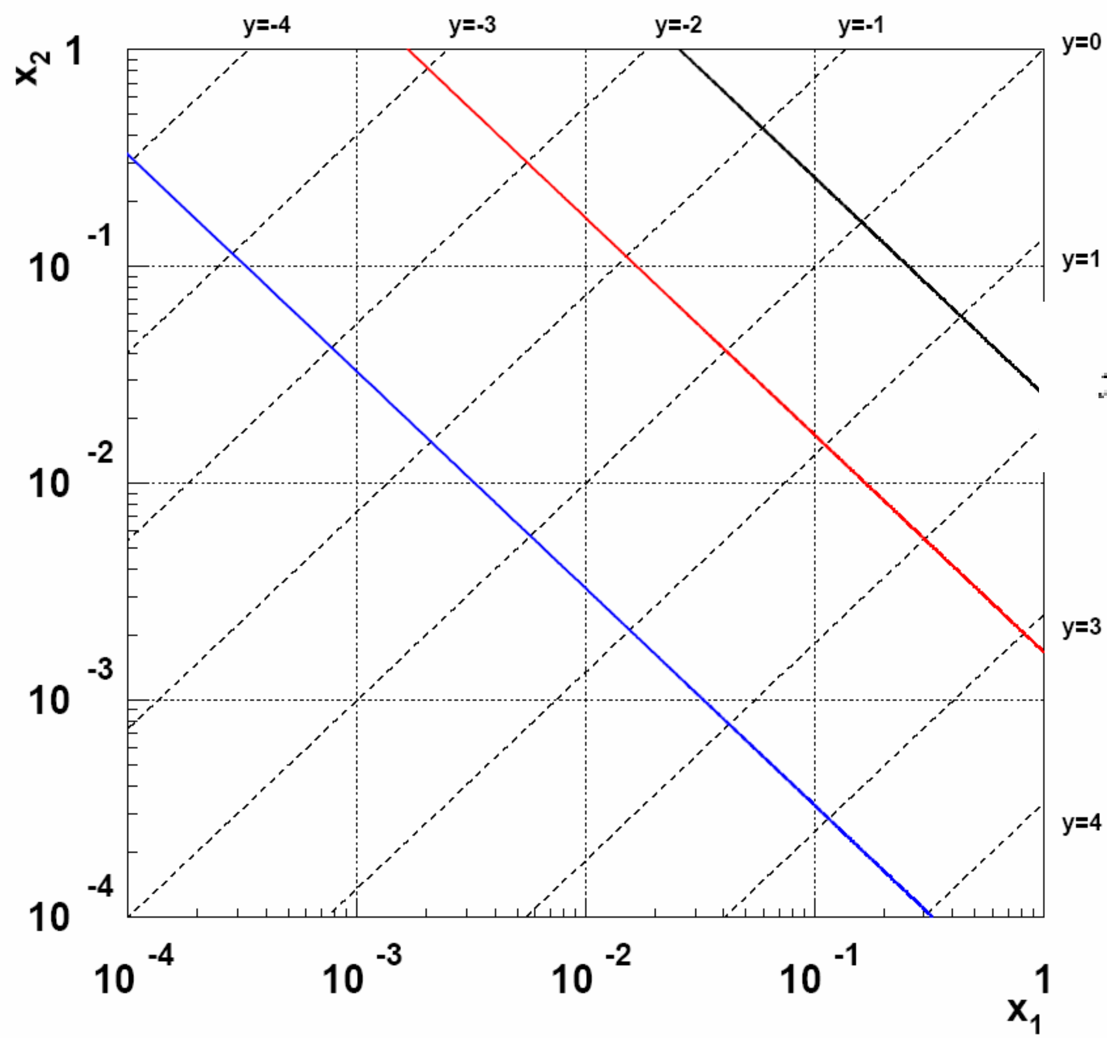



RHICBOS W simulation at 500GeV CME
W+ for CTEQ5M
Total cross-section: 101.0
-1<y_e<1
W- for CTEQ5M
Total cross-section: 20.5
-1<y_e<1'
W+ for CTEQ5M
Total cross-section: 134.7
No cuts
W- for CTEQ5M
Total cross-section: 42.0
No cuts
dσ/dp_T (pb/GeV)
p_T (GeV)

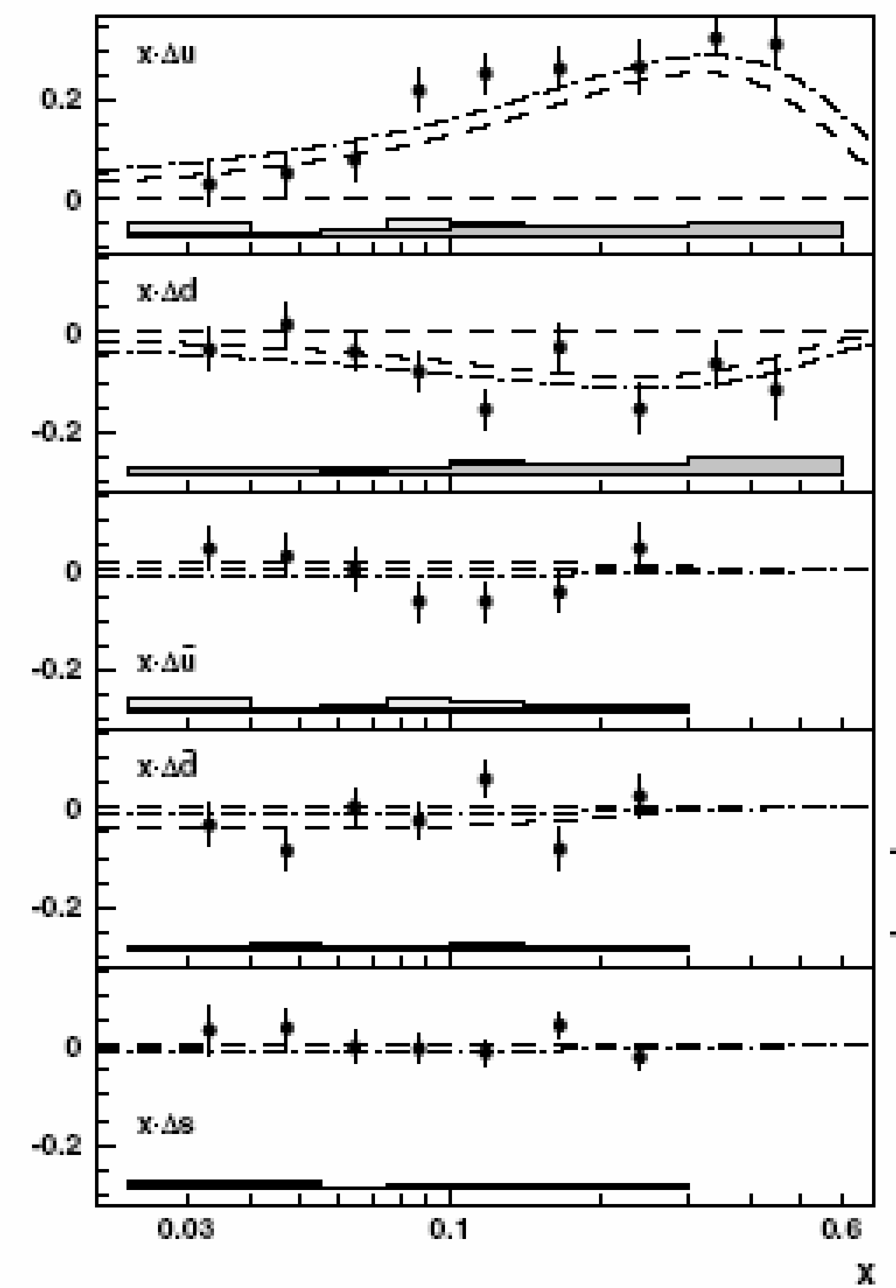
Inclusive charge hadron spectrum (PYTHIA and UA1)



W Kinematic Converage



$$x_1 = \frac{M_W}{\sqrt{s}} e^{y_W}, \quad x_2 = \frac{M_W}{\sqrt{s}} e^{-y_W}.$$

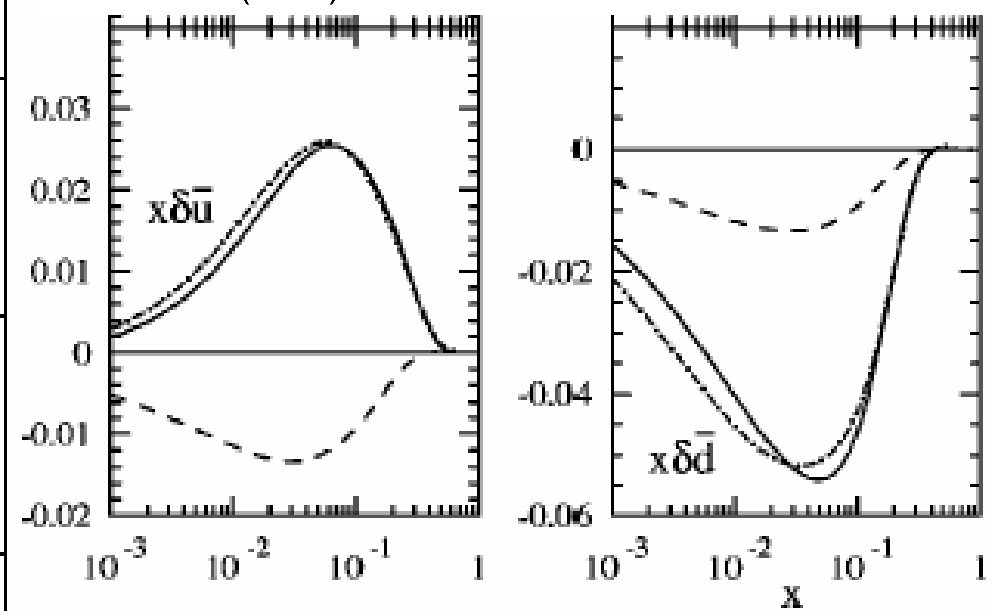


2005

PRD 71 (2005)012003

HERMES result comparison with GRSV-valence and BB

PRD63(2000) 094005



GRSV-valence at Q^2=5GeV