Spin physics with PHENIX upgrades

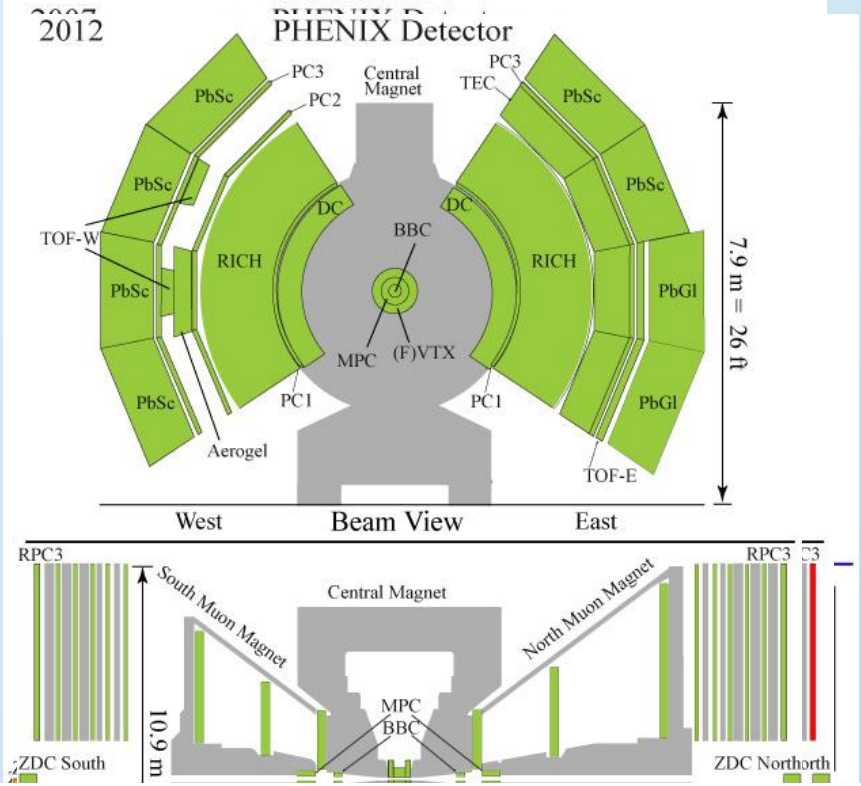
Future directions in High Energy QCD
RIKEN
October 20, 2011

Ralf Seidl
(RIKEN)
For the PHENIX collaboration

Outline

- Near term PHENIX upgrades
- Access to Sea quark polarization via W production
- Transverse spin phenomena – link to orbital angular momentum

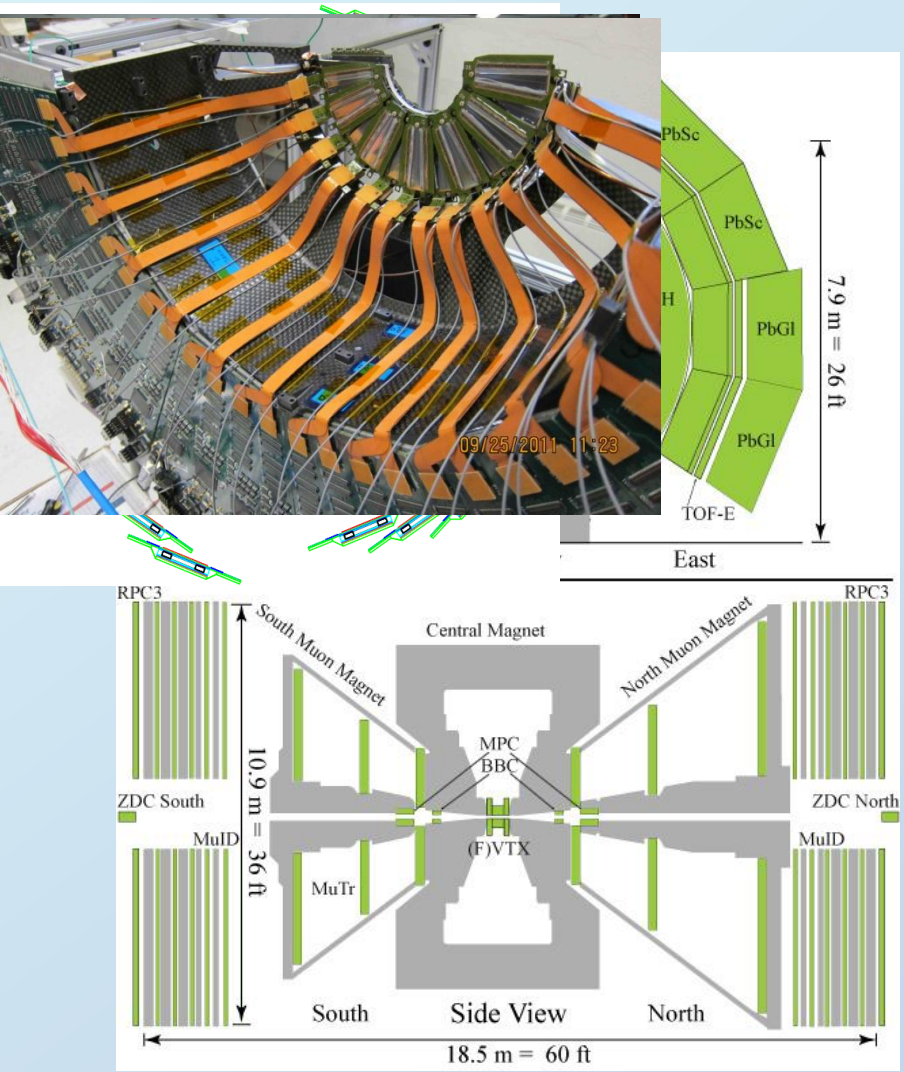
PHENIX upgrades past



- PHENIX has a history of constant detector improvements
- Some detectors recently removed for latest upgrades
  - Reaction plan
  - Hadron Blind Detector

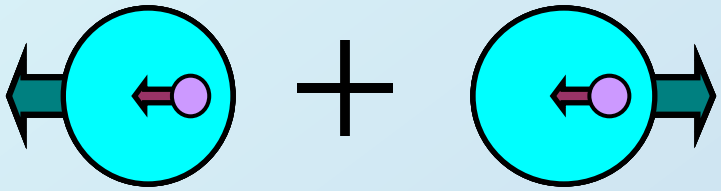
2006	2007	2008	2009	2010	2011	2012	2013	2014
	MPC							
	Reaction Plane							
		HBD						
					VTX			
				Muon Trigger				
						FVTX		
						current	MPC-EX	

Most recent Additions



- VTX detector (2011):
  - Central vertexing, b/c separation
- FVTX detector(2012):
  - Forward b/c separation
  - W→μ S/BG improvement
- Muon Trigger
  - W→μ triggering capabilities

Quark distributions



Unpolarized distribution function q(x)

Sum of quarks with parallel and antiparallel polarization relative to proton spin
(well known from Collider DIS experiments)

q(x),G(x)

Helicity distribution function $\Delta q(x)$

Difference of quarks with parallel and antiparallel polarization relative to longitudinally polarized proton
(known from fixed target (SI)DIS experiments)

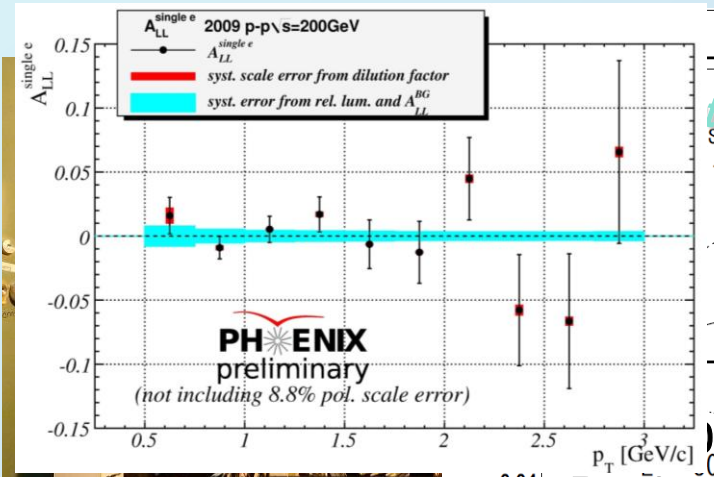
$\Delta q(x), \Delta G(x)$

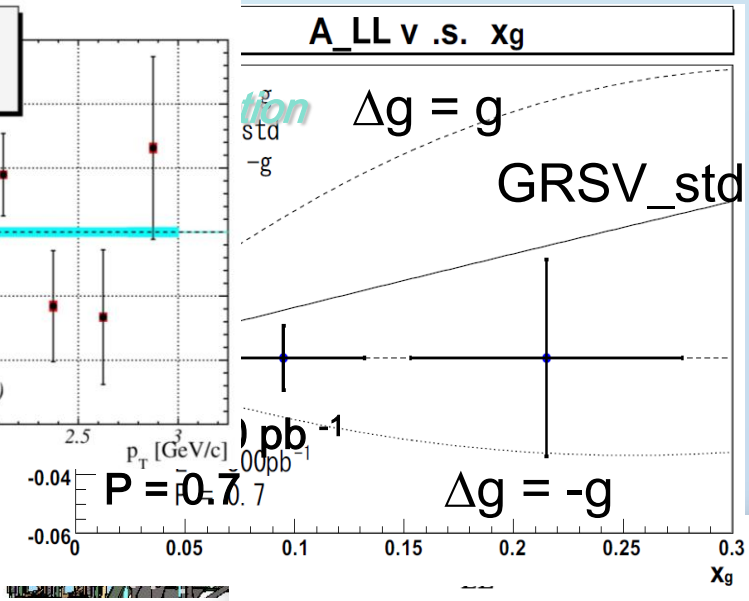
$\delta q(x)$

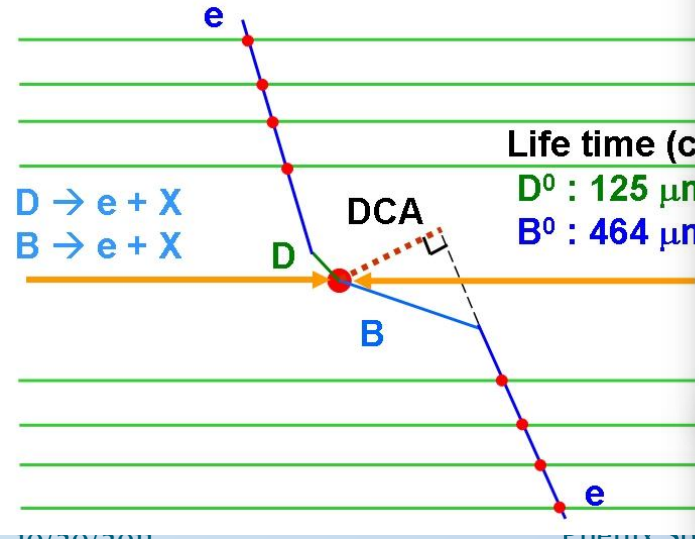
Transversity distribution function $\delta q(x)$

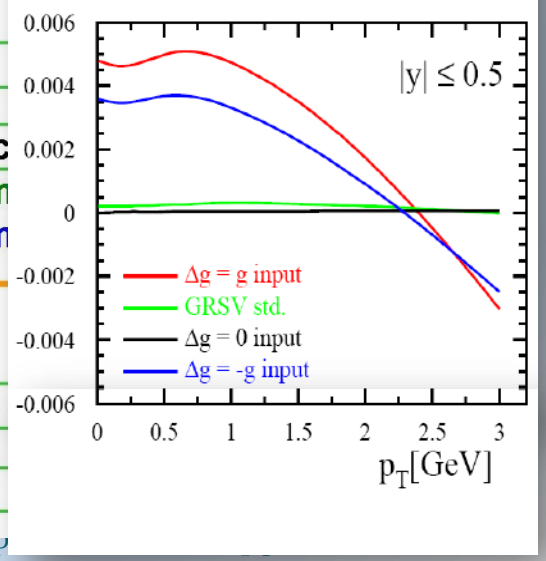
RIKEN

Δ G related improvements









- VTX detector increases acceptance for charged particles
  ➔ improved access to γjet and γhadron correlations
- FVTX/VTX sensitivity to heavy flavor decays via displaced vertices
  ➔ improved heavy flavor A_{LL}s (gg dominant process), but only feasible with several 100pb-1 and excellent control of systematics
  ➔Background reduction for DrellYan and forward W physics
- Better Vertex reconstruction

Sea quark polarization via W production

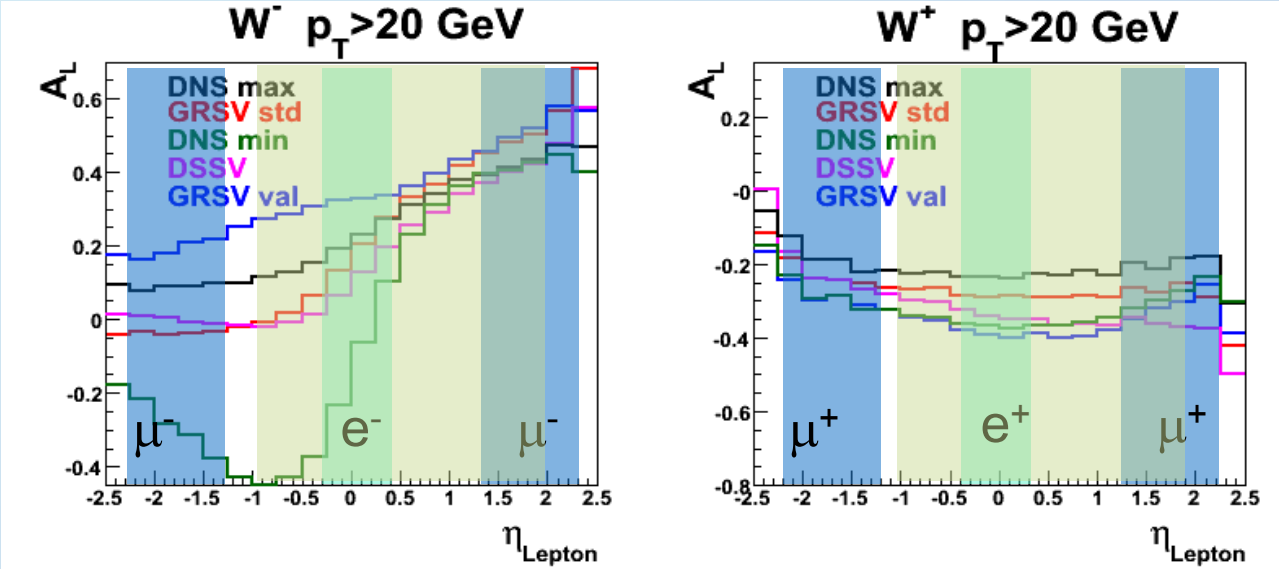
- Parity violation of weak interaction selects:

  lefthanded quarks and righthanded antiquaks

➔proton spin selects (anti)parallel quark/antiquark spins

➔ Single spin asymmetry proportional to quark polarizations

- Large asymmetries



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

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

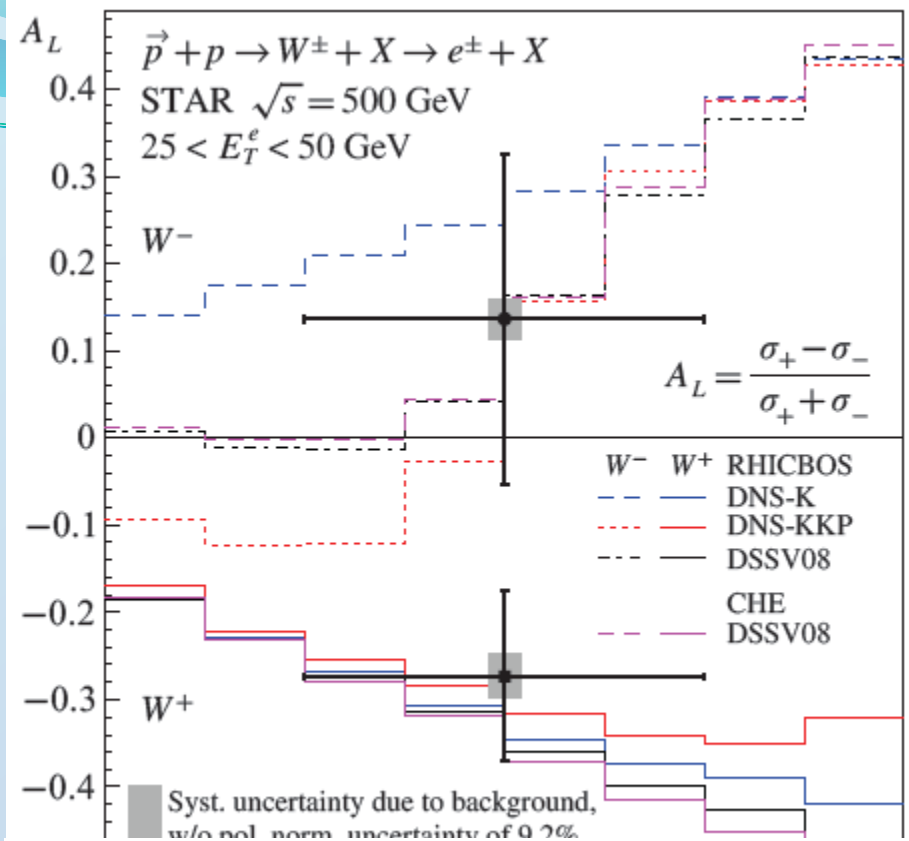
$$A_L^W \approx \frac{-\Delta u(x_1)\bar{d}(x_2) + \Delta\bar{d}(x_1)u(x_2) - \Delta d(x_1)\bar{u}(x_2) + \Delta\bar{u}(x_1)d(x_2)}{u(x_1)\bar{d}(x_2) + \bar{d}(x_1)u(x_2) + d(x_1)\bar{u}(x_2) + \bar{u}(x_1)d(x_2)}$$

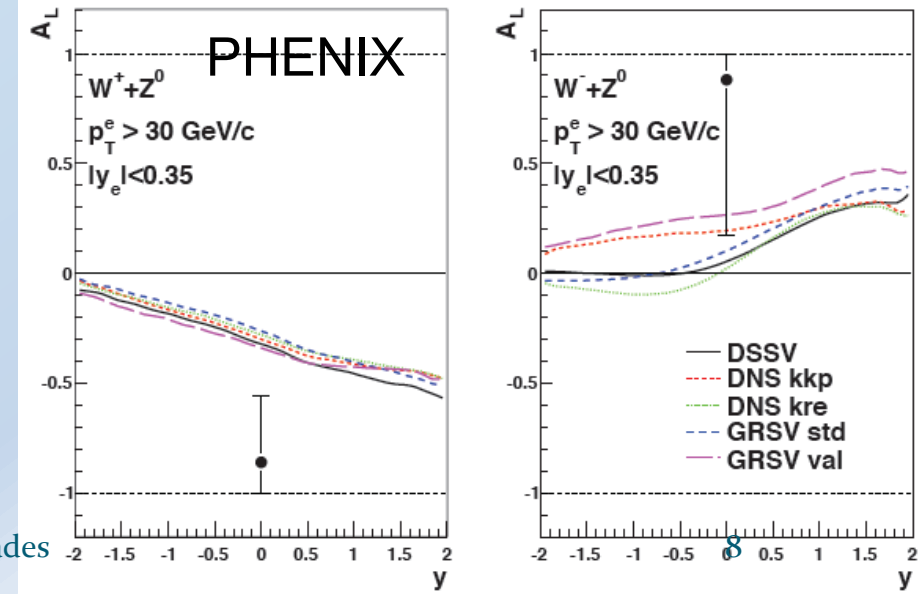
First W results

- In 2009: First exploratory RHIC run at 500 GeV
- Both PHENIX and STAR have first central rapidity results,

  PRL 106:062001(2011)

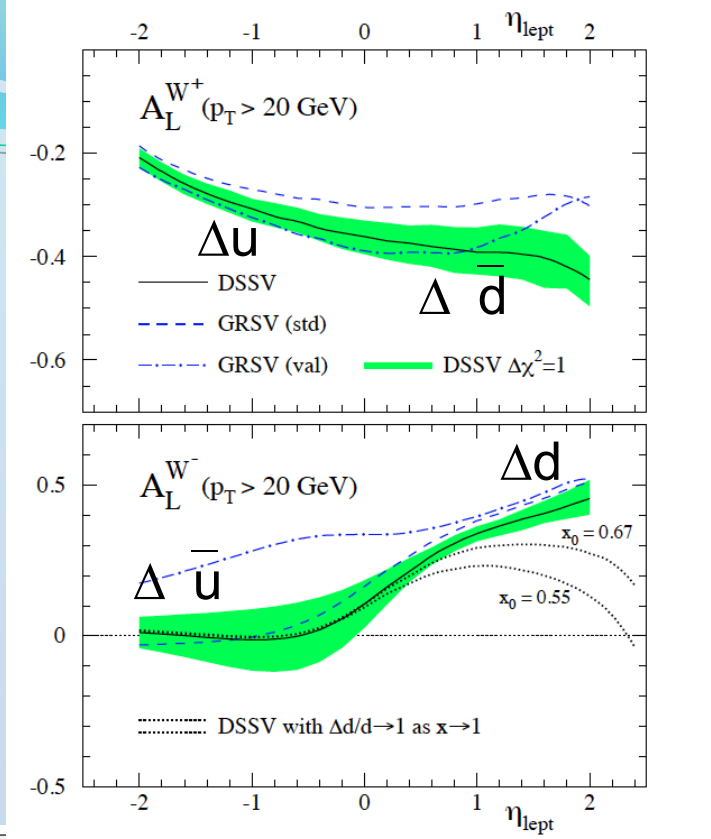
  PRL 106:062002(2011)
- Difficulty: Both detectors not hermetic – cannot use missing transverse momentum techniques for neutrino → inclusive measurement

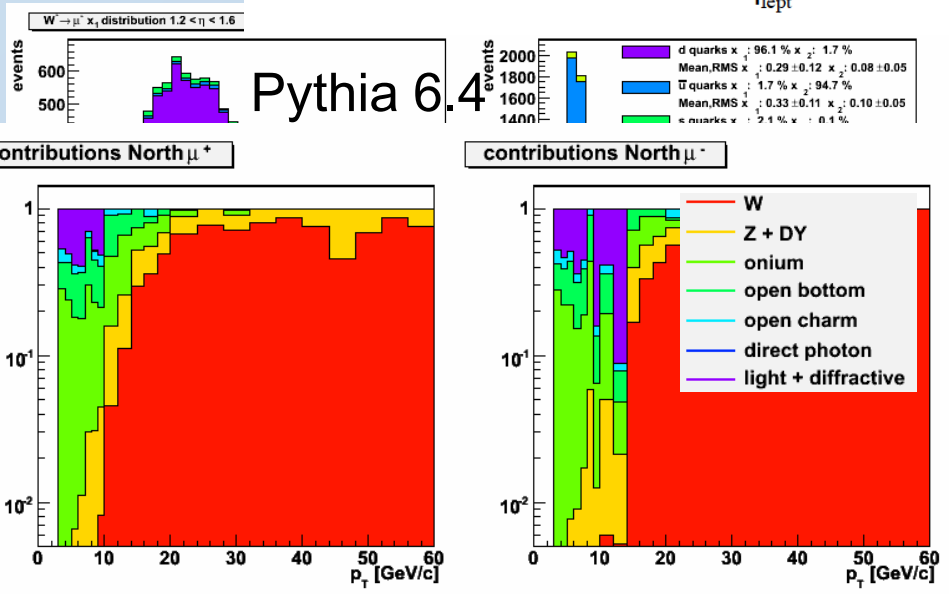




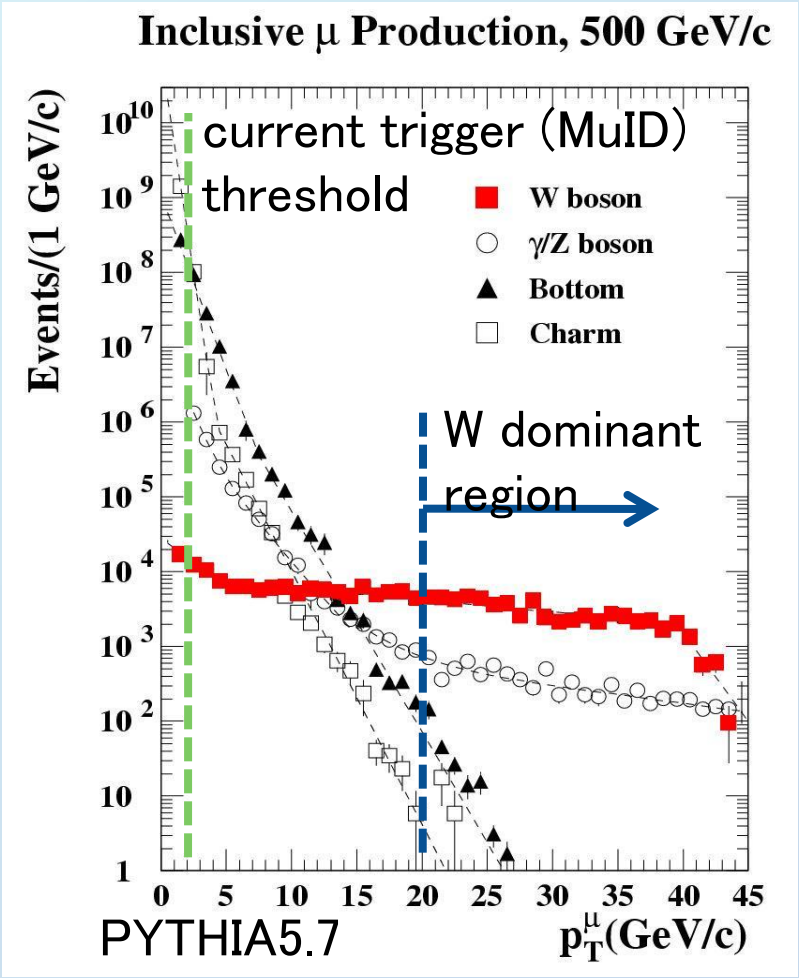
Forward W decays

- 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



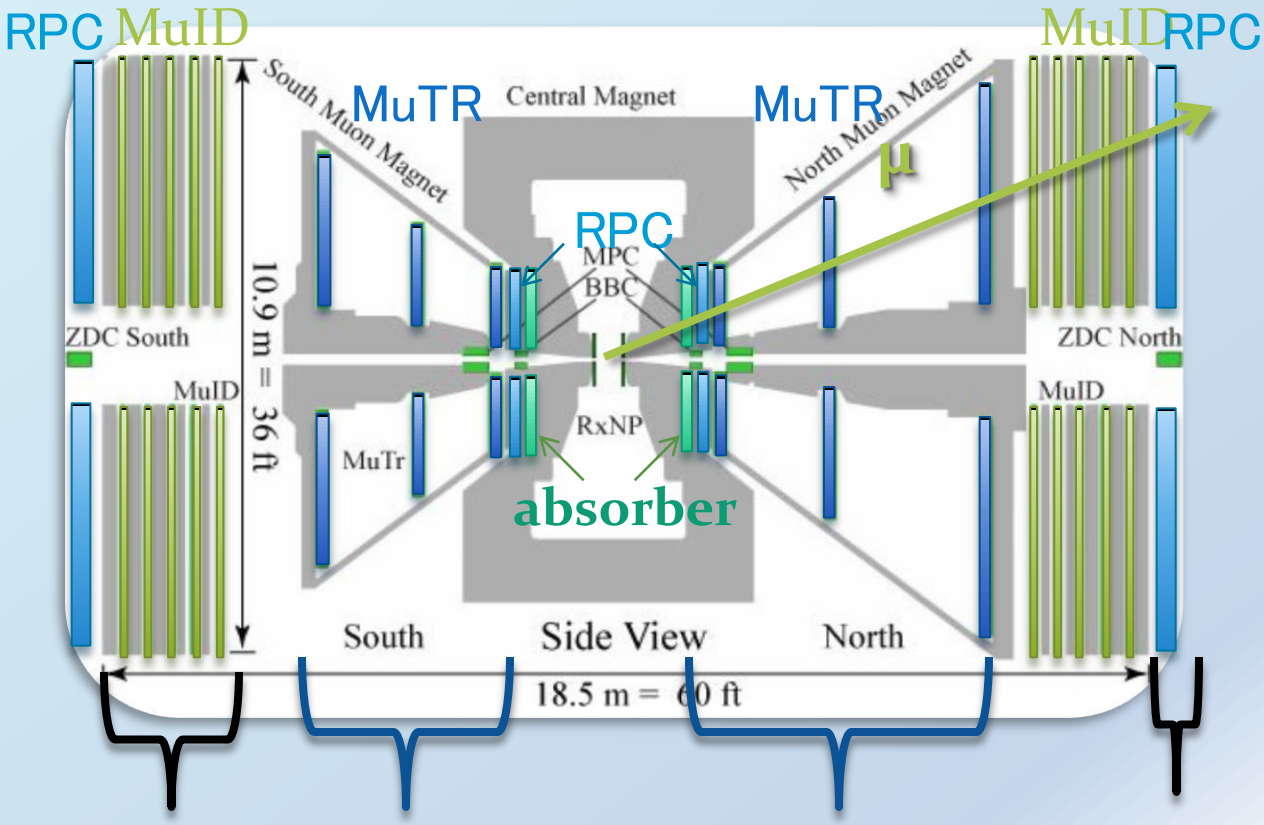


Muon trigger upgrade



- σ(tot)=60mb, L=3x10^{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
- *We need a momentum dependent trigger !*

PHENIX Muon Trigger Upgrade Project



MuID trigger
selecting muon momentum > 2GeV/c

MuTR FEE upgrade
fast selection of high-momentum-tracks

RPC
provide timing information and rough position information

Muon Trigger Upgrade

RPC

RPC project

timing information

rough position information

Station3

MuTr

Station2

sagitta

Station1

B

B

Muon Tracking Chamber

5% of charge

Amplifier Discriminator

Amp

Comp

95% of charge

ADC

digitized hit signal

digitized hit signal

digitized hit signal

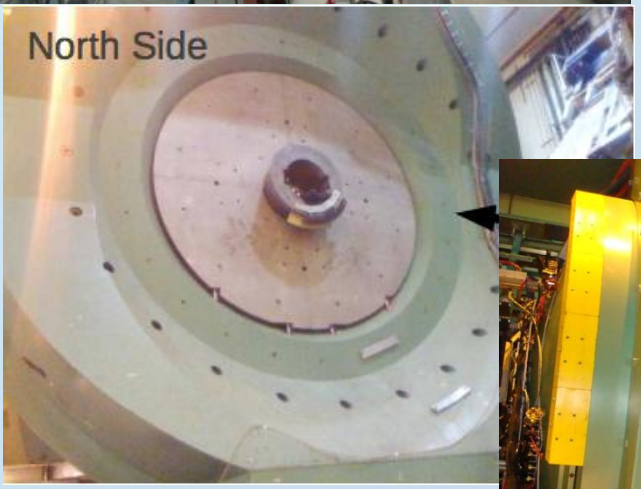
MuTRG project

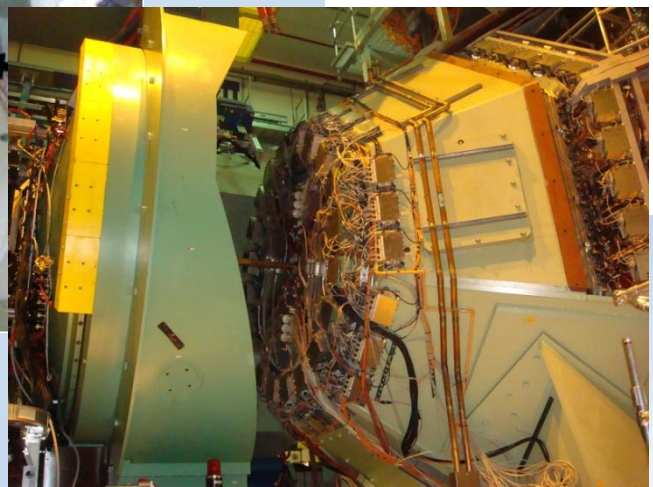
Level-1 trigger board

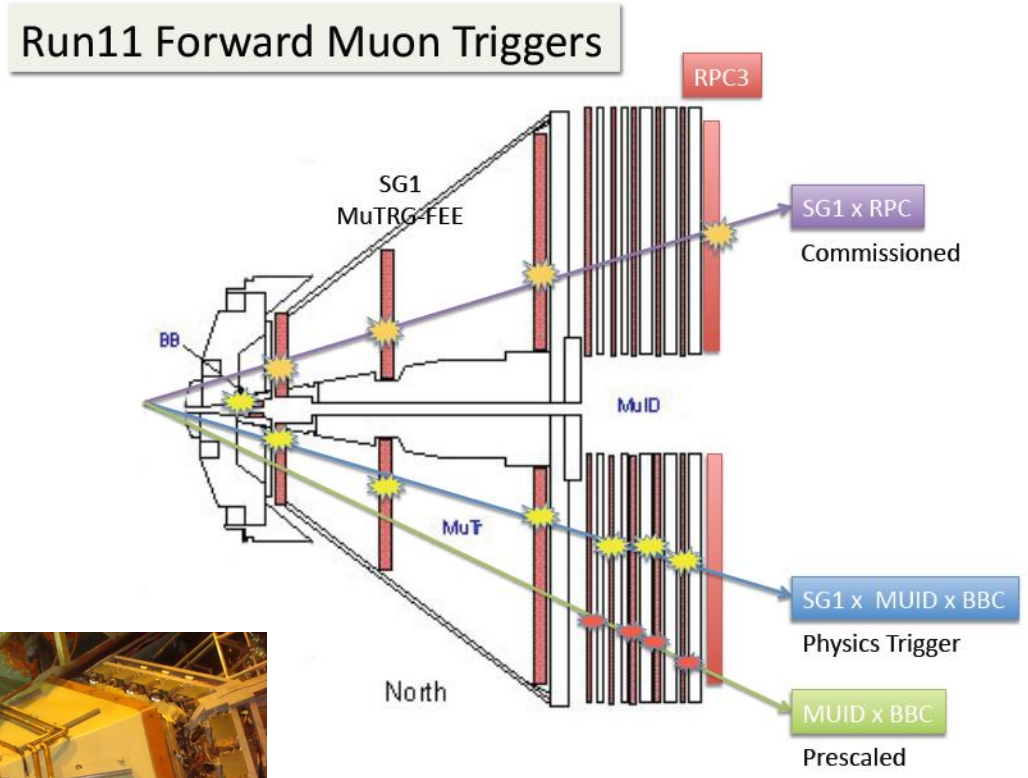
Level-1 trigger

RIKEN

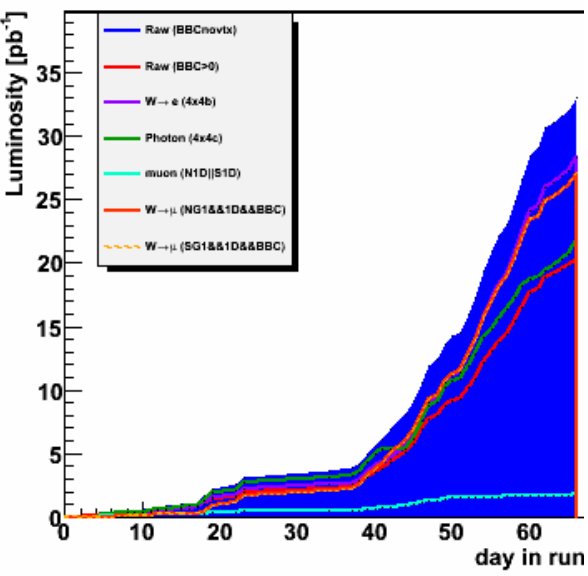
PHENIX Forward W trigger upgrade installation and commissioning

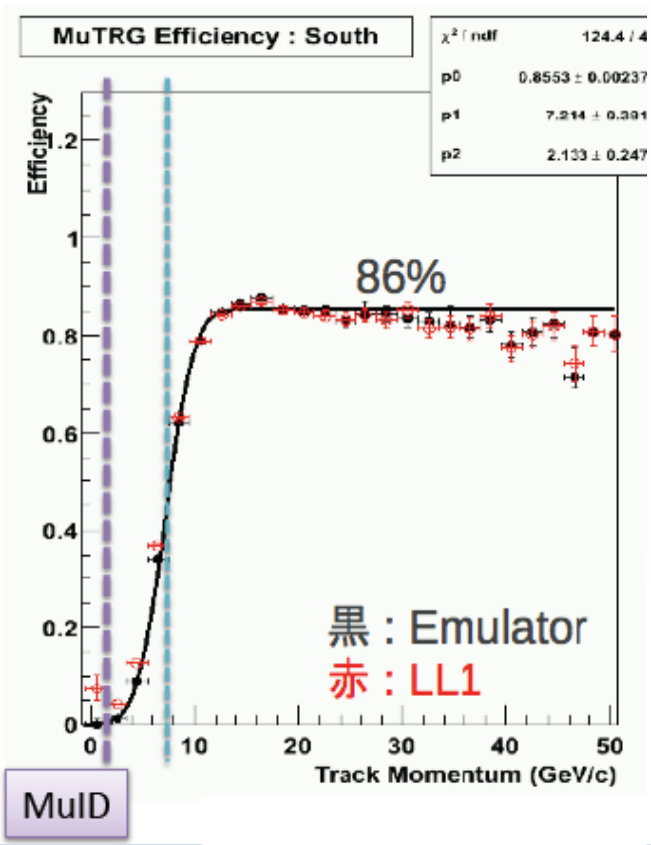


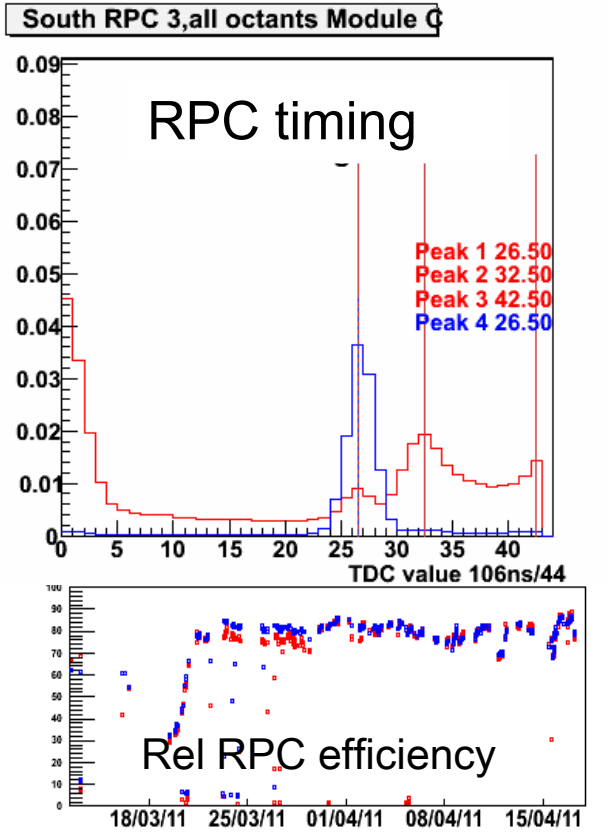




PHENIX run11 Trigger commissioning status



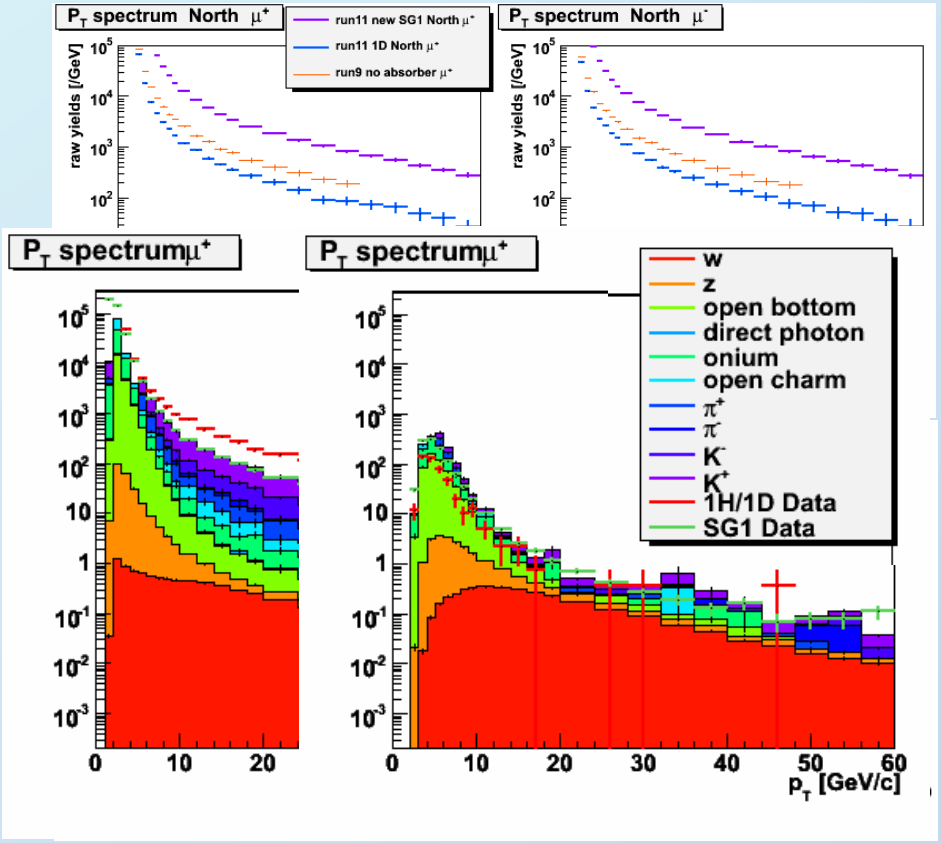




- New SG trigger un-prescaled →~25 pb^{-1} each arm w/o vertex restriction

Actual LL1 and RPC efficiencies higher due to contamination with fake tracks

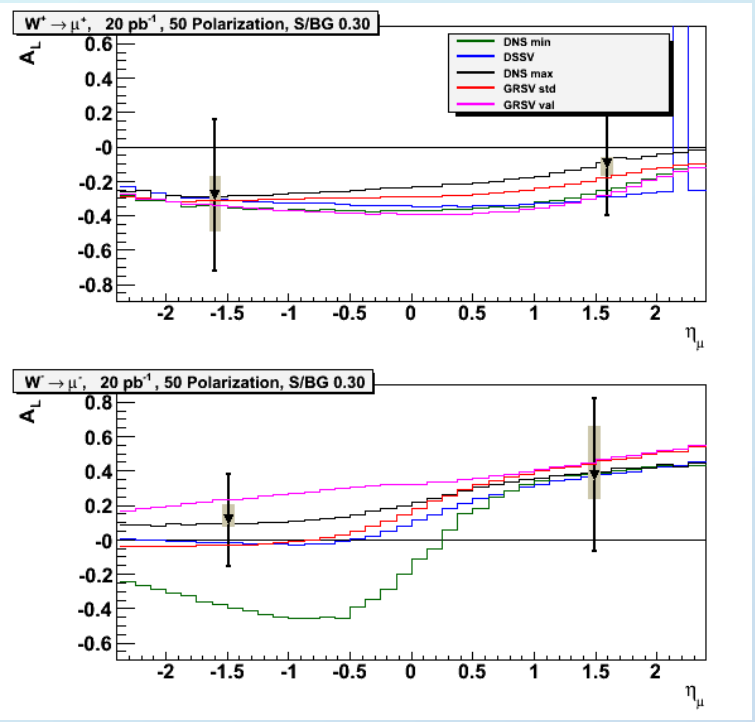
W analysis status

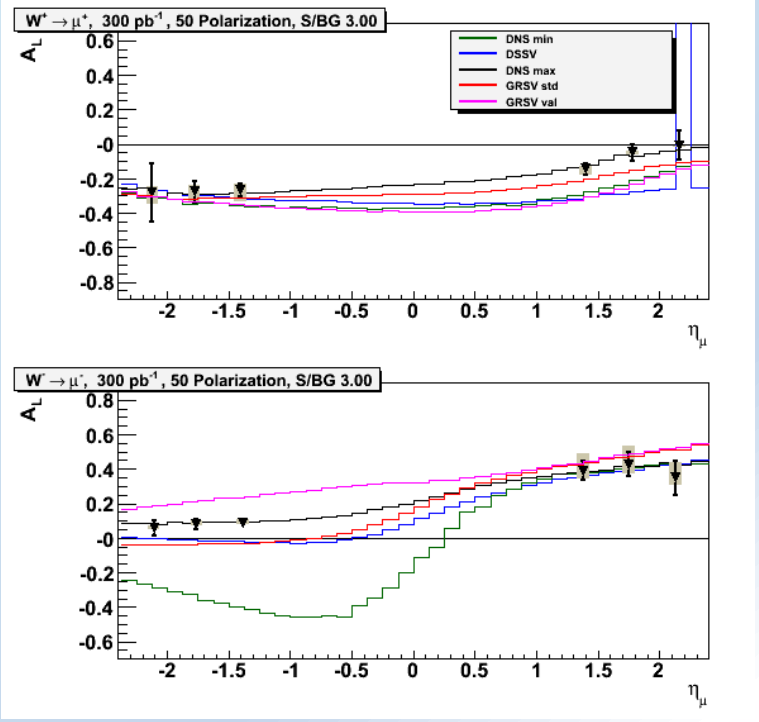


Work in progress

- Large improvement in raw muon candidates:
  - 2009 ~ 0.8 pb $^{-1}$ both arms
  - 2011 1.6 both arms combined
  - 2011 new trigger ~25 in each arm
- Absorber reduced amount of fake muons significantly
- Analysis and BG estimation ongoing

Currently and future expected sensitivities

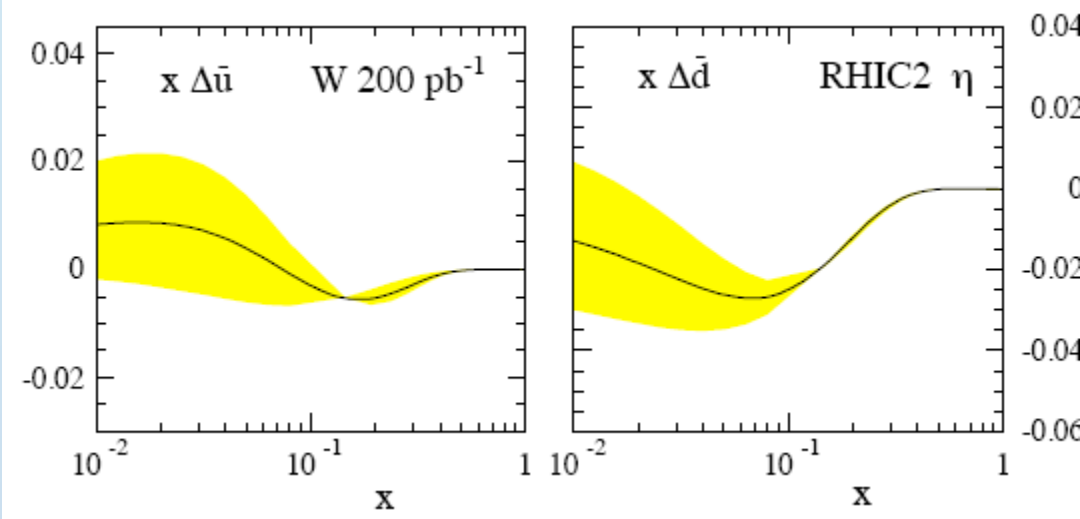




- Not shown similar improvements at PHENIX central rapipity
- 2009/2011 were just the beginning towards the total accumulated luminosities of 300^{-1} in each experiment

Expected sea quark sensitivities

- Inclusion of W channels into global analysis DSSV (deFlorian) prepared
- Expected impact with about 200 pb^{-1} in PHENIX and STAR in $-2 < \eta < 2$ estimated

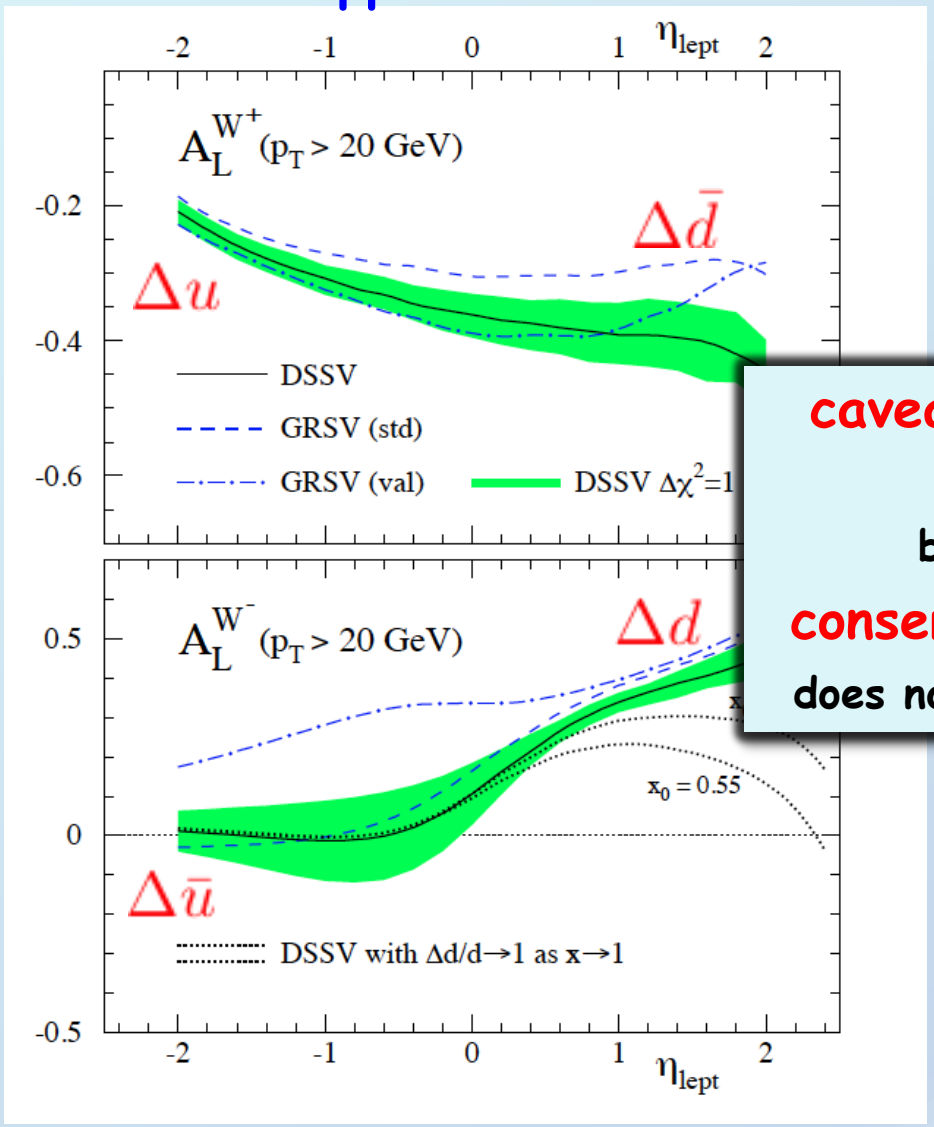


- Reduction of uncertainties in sea quark polarizations of above x~0.1 substantial

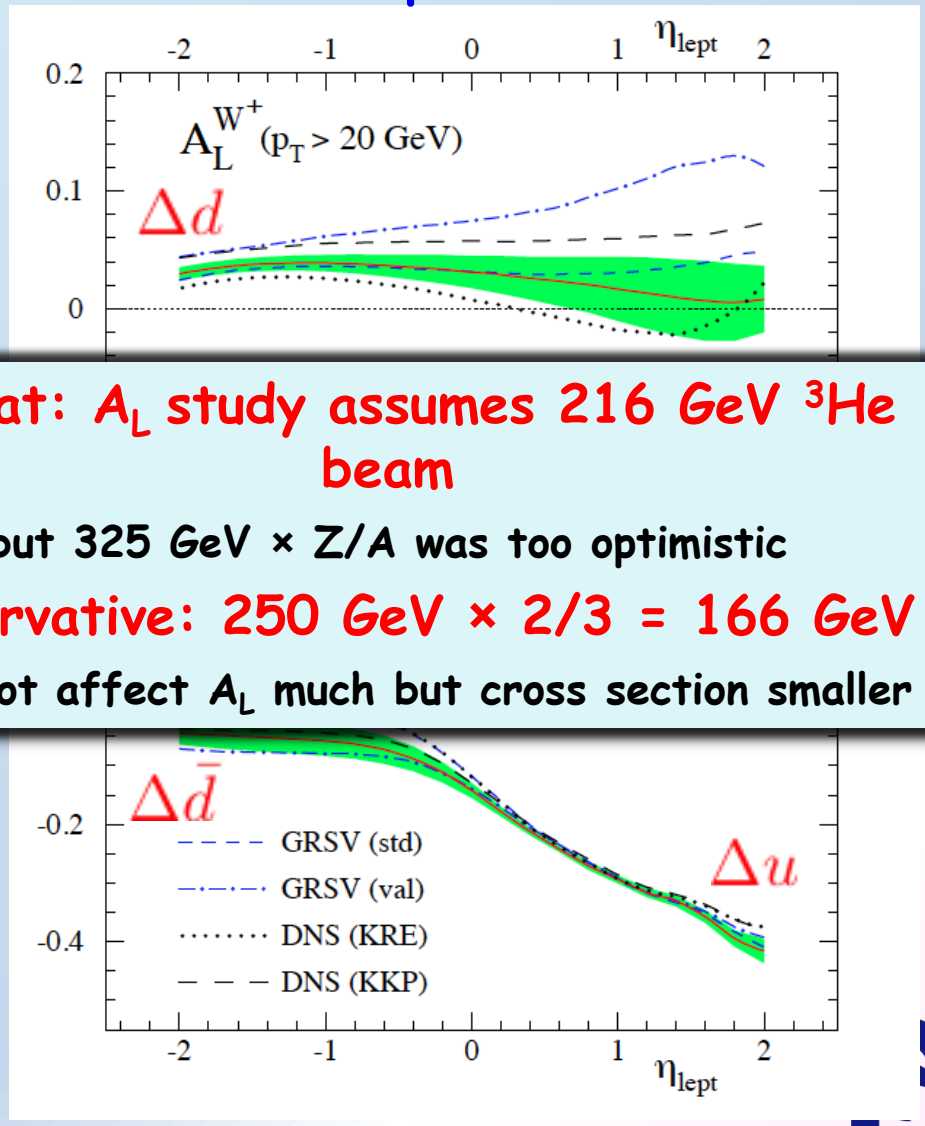
W Outlook ^{3}He p collisions

Marco Stratman (BNL)

pp @ 500 GeV



^{3}He p @ 432 GeV



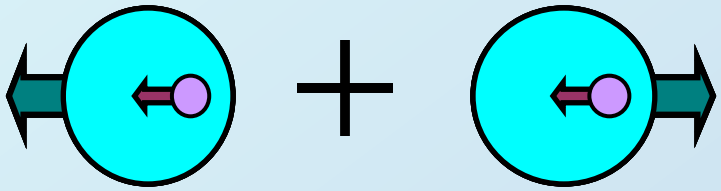
caveat: A_L study assumes 216 GeV ^{3}He beam

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

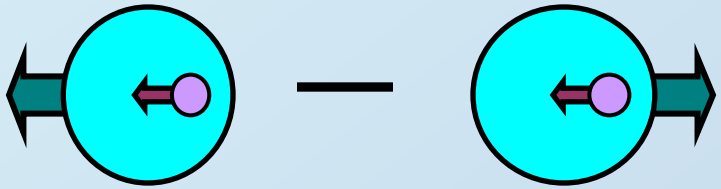
Transverse quark polarization



Unpolarized distribution function q(x)

Sum of quarks with parallel and antiparallel polarization relative to proton spin
(well known from Collider DIS experiments)

q(x),G(x)



Helicity distribution function $\Delta q(x)$

Difference of quarks with parallel and antiparallel polarization relative to longitudinally polarized proton
(known from fixed target (SI)DIS experiments)

$\Delta q(x), \Delta G(x)$

Difference of quarks with parallel and antiparallel polarization relative to transversely polarized proton
(first results from HERMES and COMPASS – with the help of Belle)

$\delta q(x)$

Transversity distribution function $\delta q(x)$

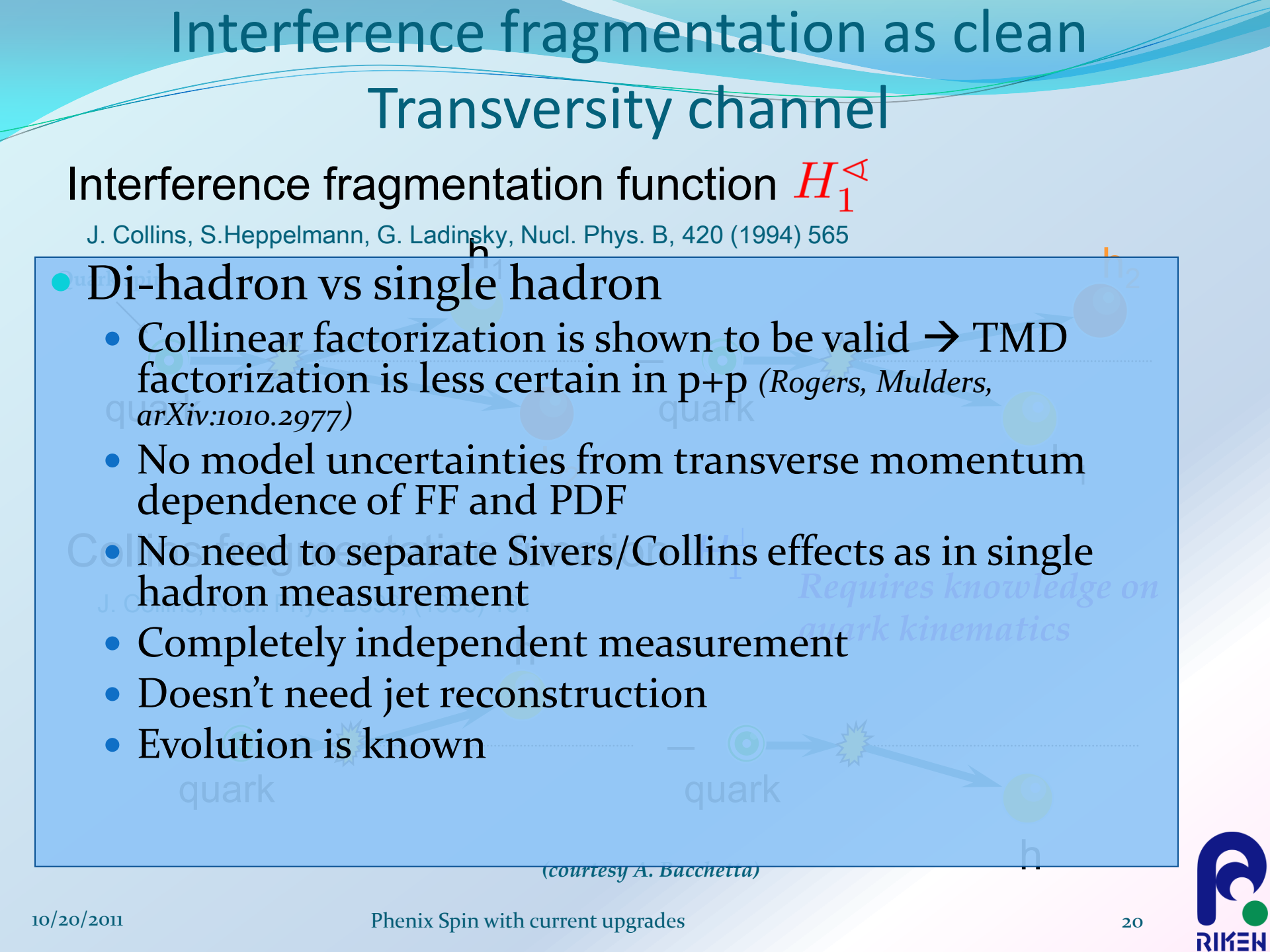
RIKEN

Interference fragmentation as clean Transversity channel

Interference fragmentation function $H_1^{\sphericalangle}$

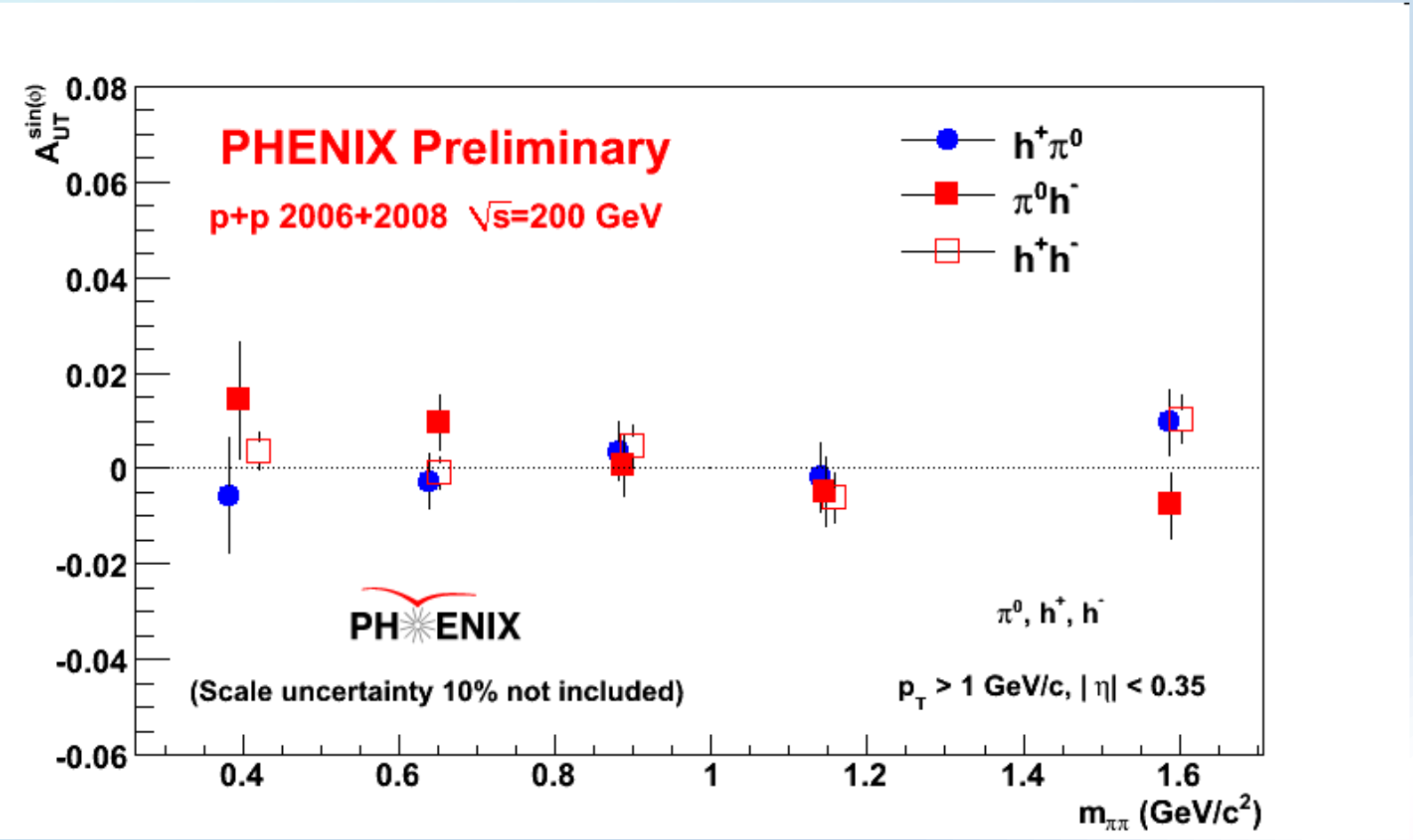
J. Collins, S.Heppelmann, G. Ladinsky, Nucl. Phys. B, 420 (1994) 565

- Di-hadron vs single hadron
  - Collinear factorization is shown to be valid → TMD factorization is less certain in p+p *(Rogers, Mulders, arXiv:1010.2977)*
  - No model uncertainties from transverse momentum dependence of FF and PDF
  - No need to separate Sivers/Collins effects as in single hadron measurement
  - Completely independent measurement
  - Doesn't need jet reconstruction
  - Evolution is known



(courtesy A. Bacchetta)

Interference FF Measurement at PHENIX

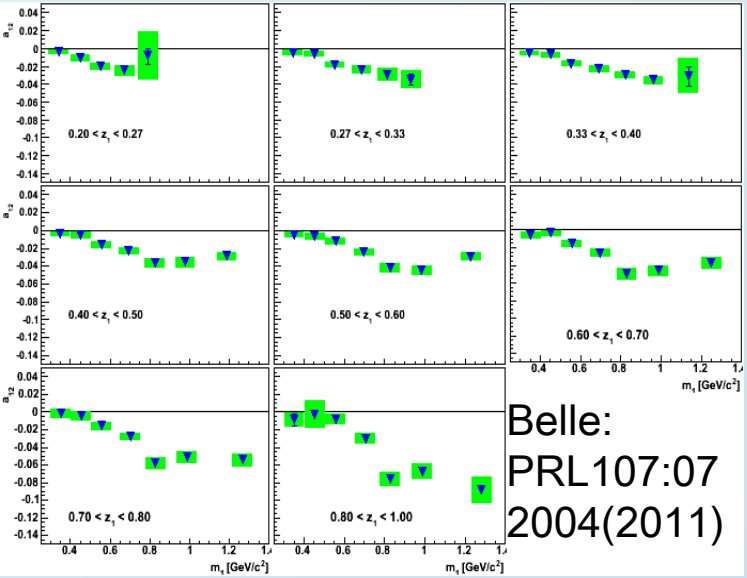


No significant asymmetries seen at mid-rapidity, so far

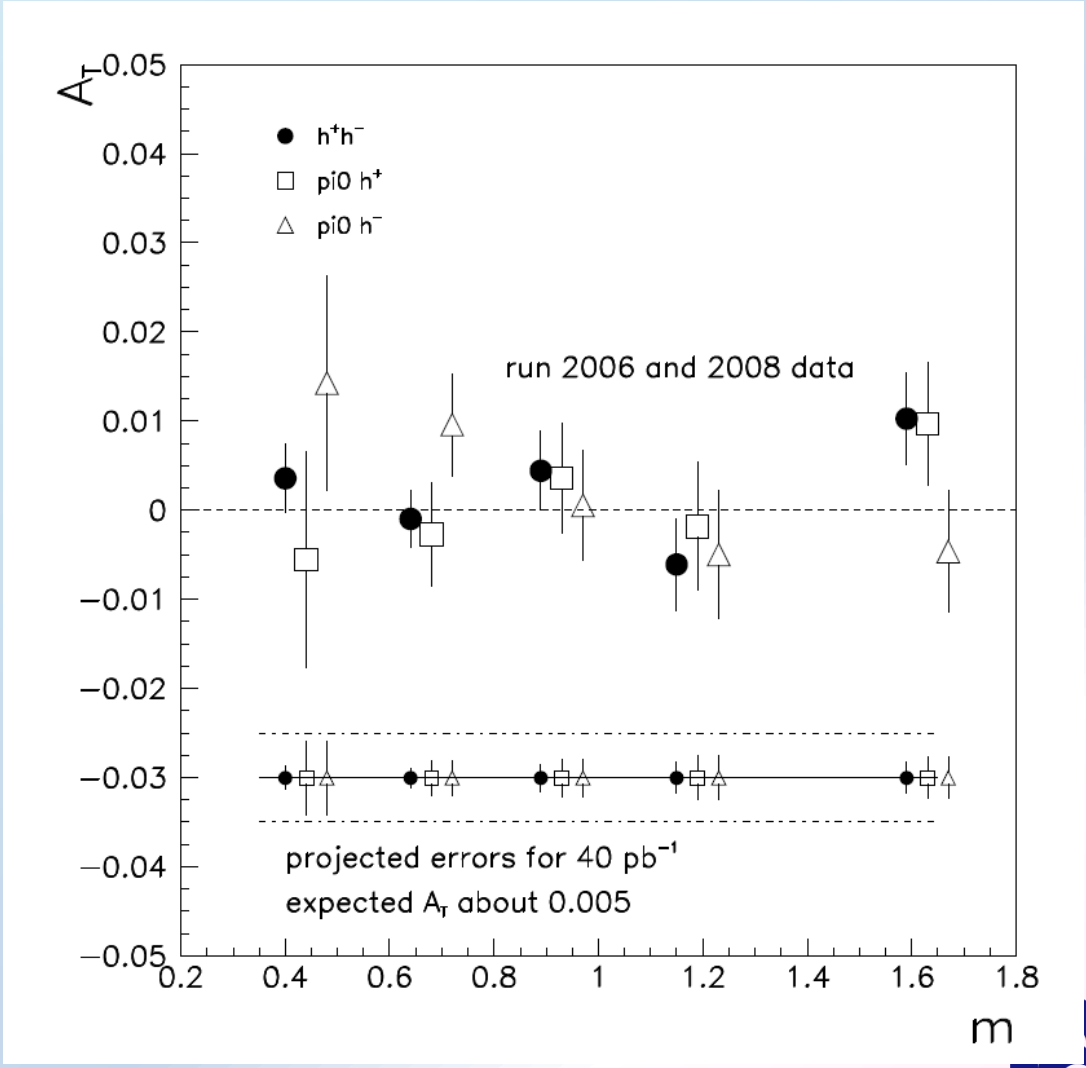
Analysis in rapidities < 2 ongoing in PHENIX

RIKEN

IFF Projected Error Bars

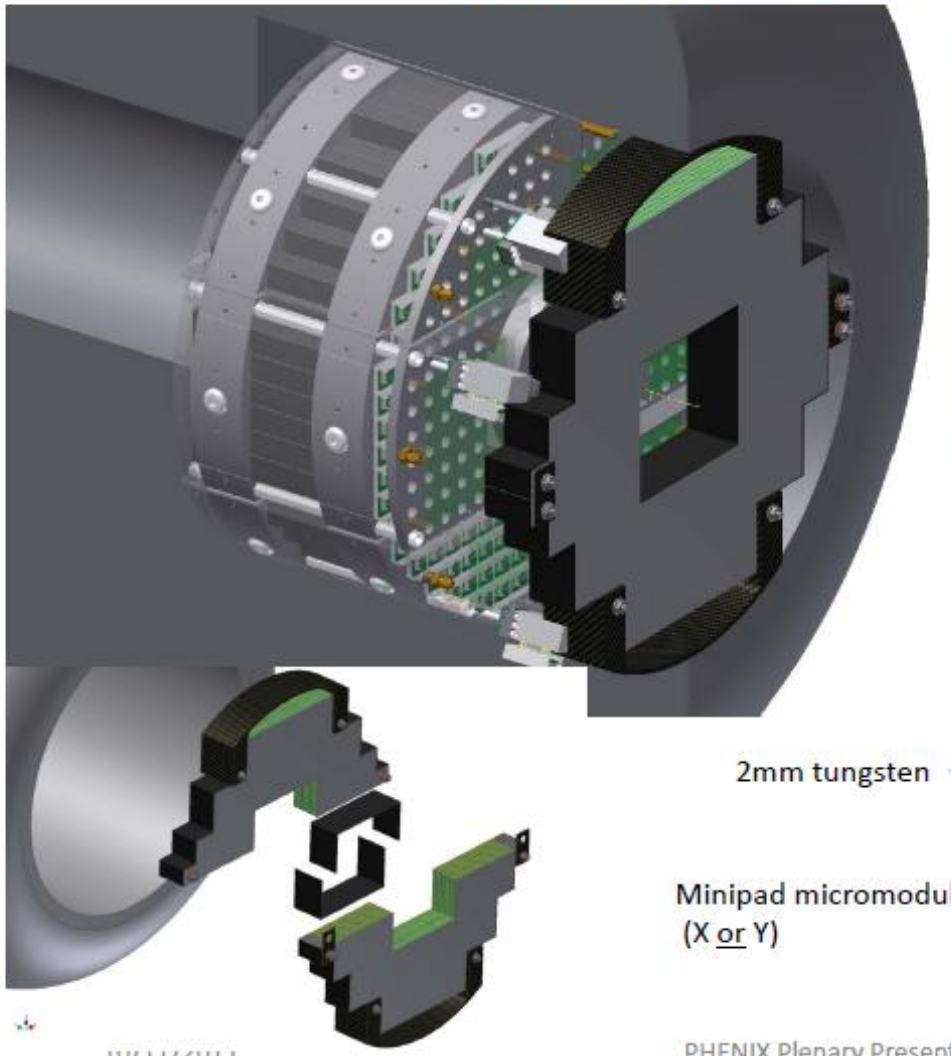


Belle: PRL107:07 2004(2011)



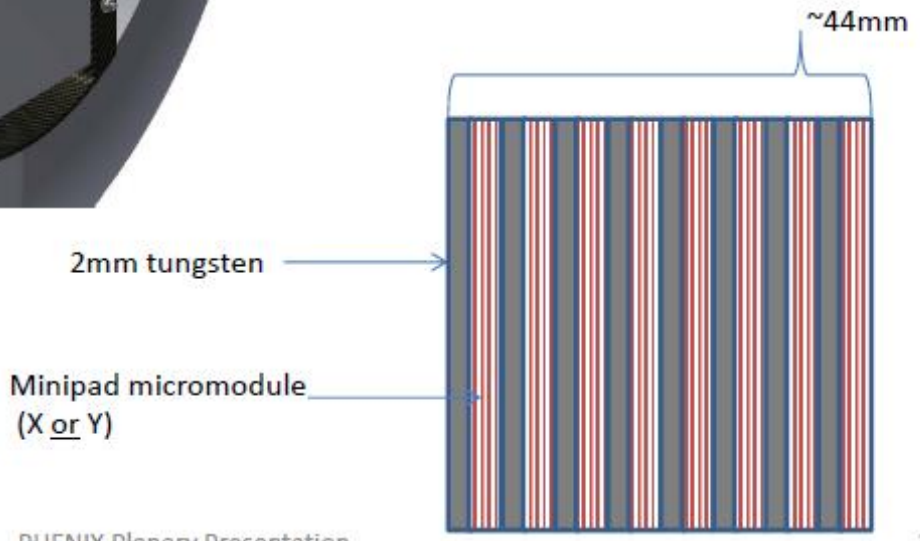
Analysis in Muon arm and MPC will improve the situation at larger x

The MPC-EX Detector Proposal

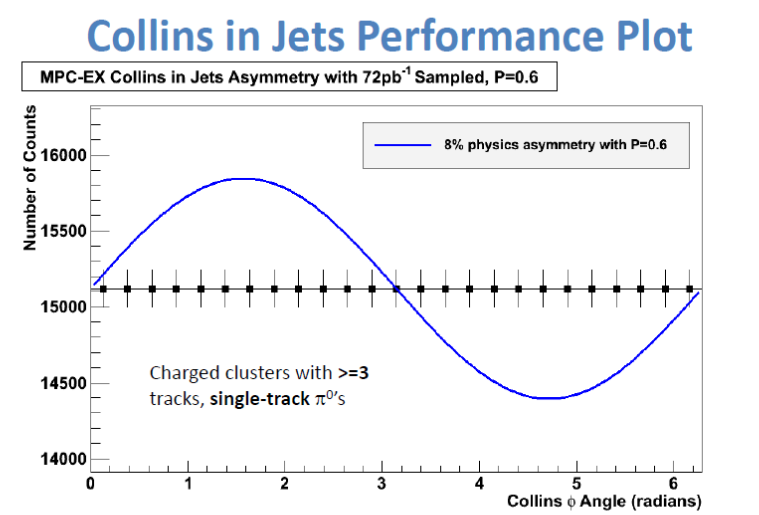


A combined charged particle and EM preshower detector – dual gain readout allows sensitivity to MIPS and full energy EM showers.

- Charged track identification
- π^0 reconstruction out to >80GeV



Azimuthal asymmetries in MPC EX



- Jet reconstruction possibility allows to disentangle of A_N mechanisms :
  - Jet A_N, direct photon A_N – Sivers-like mechanism, sign between ep and pp
  - Pion inside Jet – Collins mechanism

Summary and outlook

- Several years to come to improve sensitivity to gluon polarization by better localizing x
  - Correlation measurements to gain x sensitivity in gluon measurements
- Improve understanding of sea quark polarizations via W boson measurements
  - Upgrades finished, first results from 2009 run, analysis of 2011 run ongoing
- Many puzzling transverse spin effects seen, more sensitive measurements to disentangle them