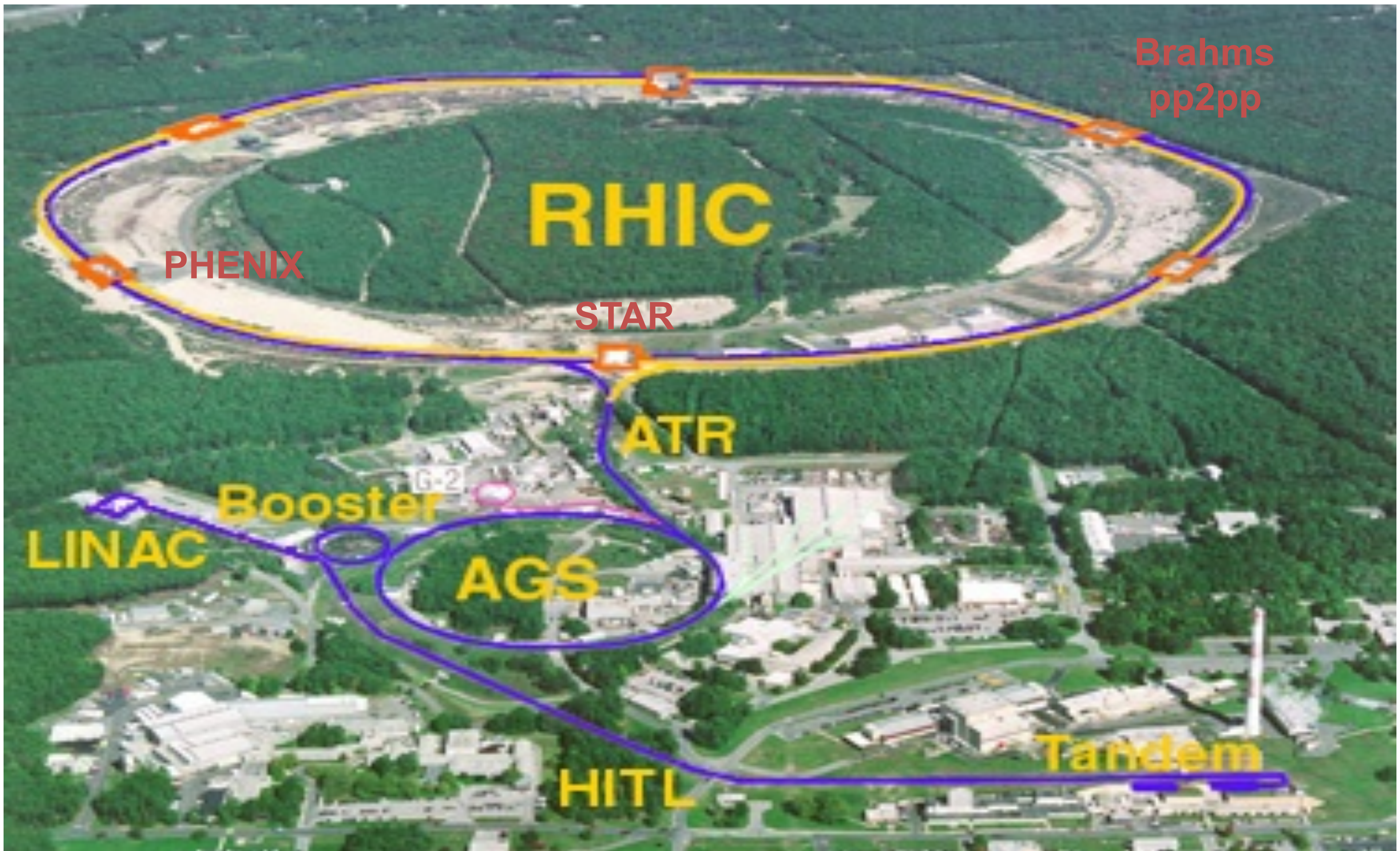
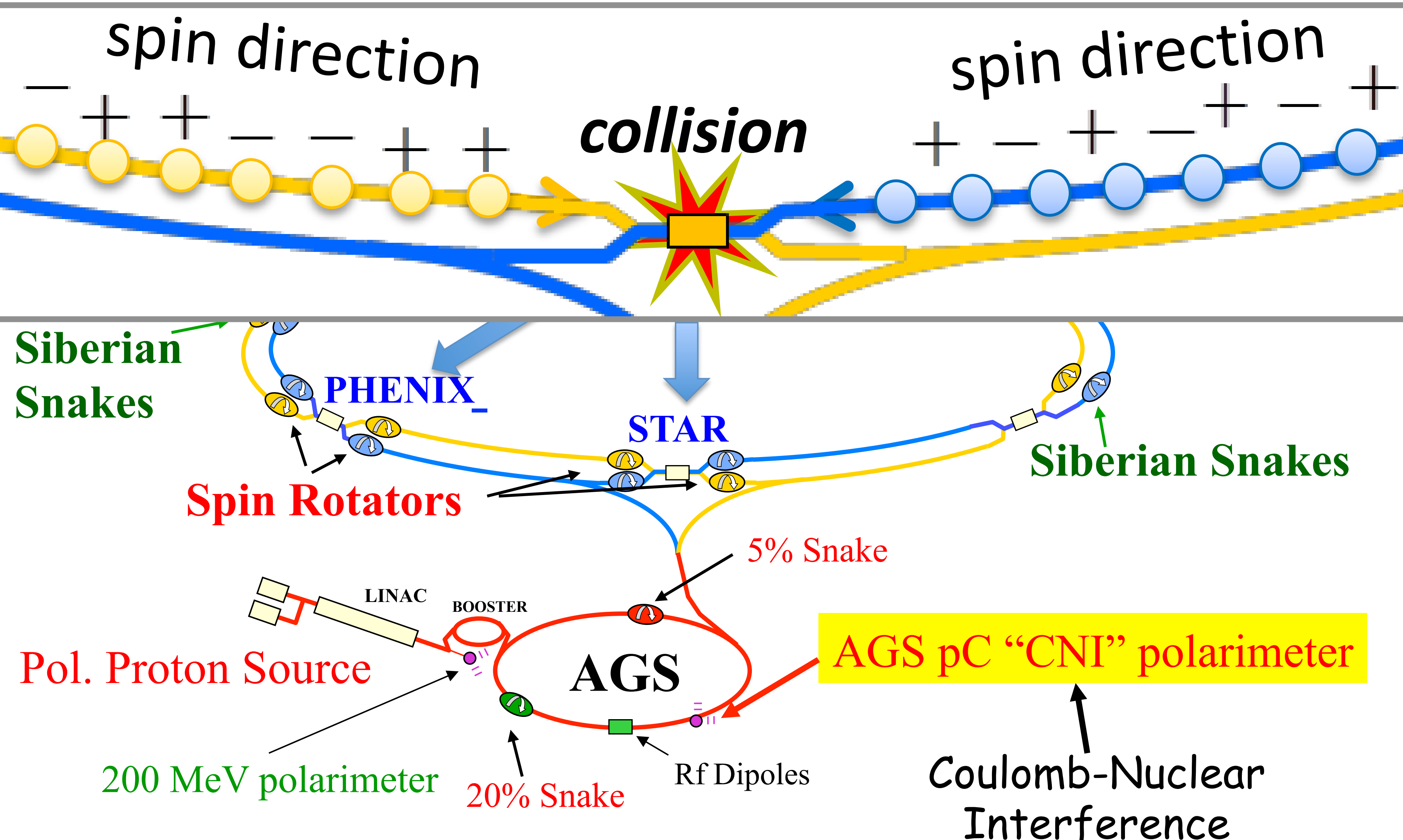
Recent Results on PHENIX Longitudinal Asymmetry Measurements

RIKEN/RBRC
Itaru Nakagawa

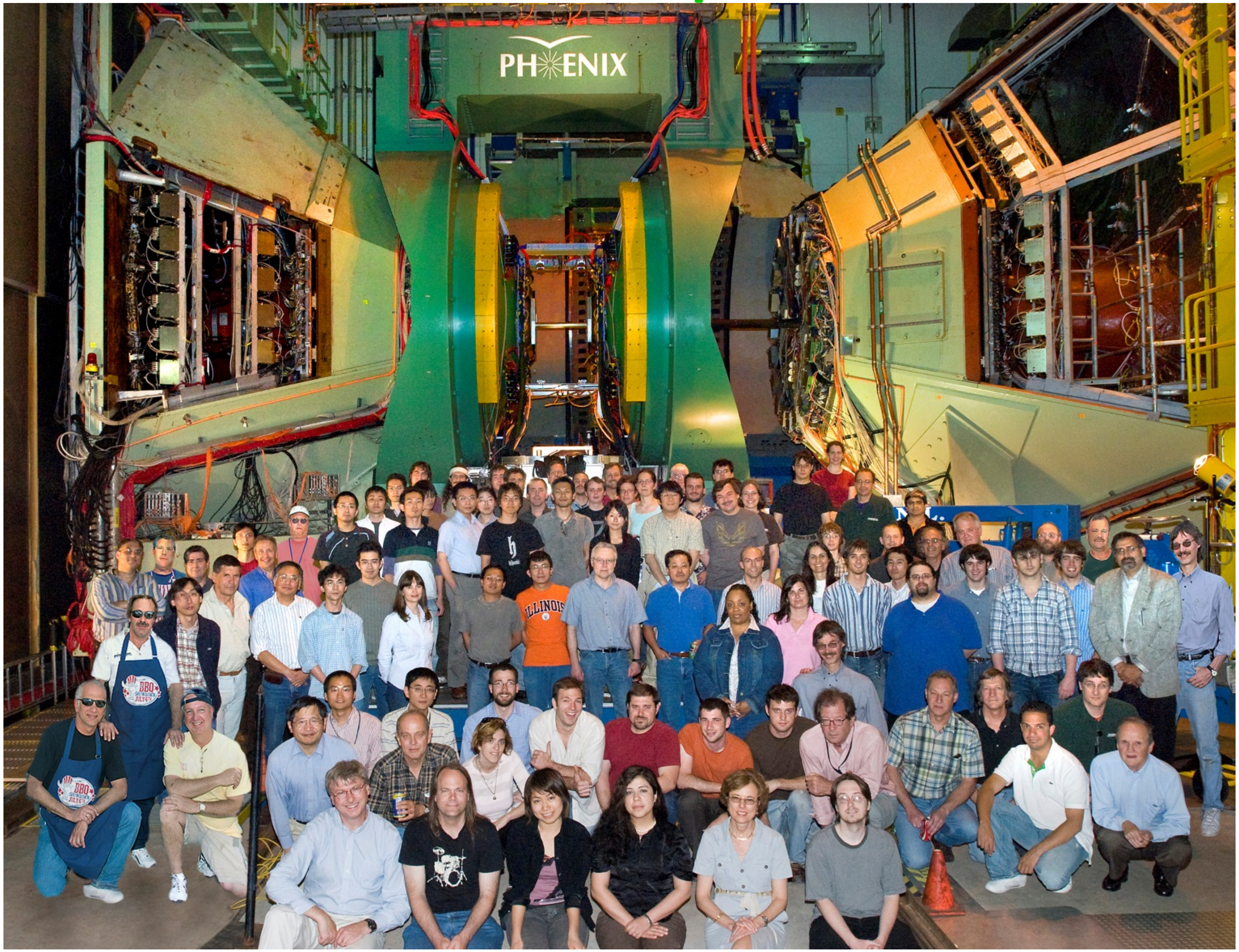
The Relativistic Heavy Ion Collider accelerator complex at Brookhaven National Laboratory



RHIC *p+p* accelerator complex



PHENIX Experiment



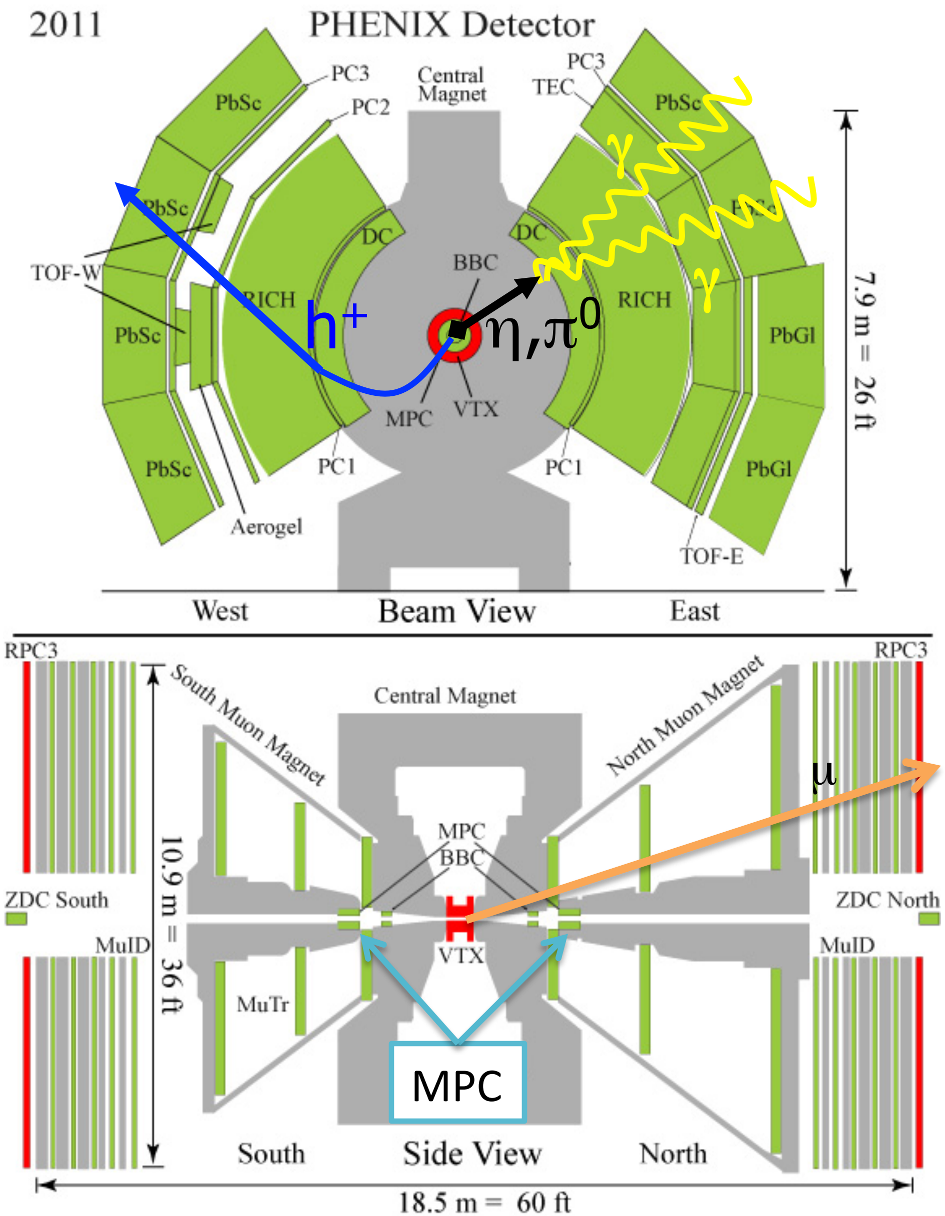
Pioneering High Energy Nuclear Interaction EXperiment

Universidade de São Paulo, Instituto de Física, Caixa Postal 66318, São Paulo CEP05315-970, Brazil
Institute of Physics, Academia Sinica, Taipei 11529, Taiwan
China Institute of Atomic Energy (CIAE), Beijing, People's Republic of China
Peking University, Beijing, People's Republic of China
Charles University, Ovocnytrh 5, Praha 1, 116 36, Prague, Czech Republic
Czech Technical University, Zikova 4, 166 36 Prague 6, Czech Republic
Institute of Physics, Academy of Sciences of the Czech Republic, Na Slovance 2, 182 21 Prague 8, Czech Republic
Helsinki Institute of Physics and University of Jyväskylä, P.O.Box 35, FI-40014 Jyväskylä, Finland
Dapnia, CEA Saclay, F-91191, Gif-sur-Yvette, France
Laboratoire Leprince-Ringuet, Ecole Polytechnique, CNRS-IN2P3, Route de Saclay, F-91128, Palaiseau, France
Laboratoire de Physique Corpusculaire (LPC), Université Blaise Pascal, CNRS-IN2P3, Clermont-Fd, 63177 Aubiere Cedex, France
IPN-Orsay, Universite Paris Sud, CNRS-IN2P3, BP1, F-91406, Orsay, France
Debrecen University, H-4010 Debrecen, Egyetem tér 1, Hungary
ELTE, Eötvös Loránd University, H - 1117 Budapest, Pázmány P. s. 1/A, Hungary
KFKI Research Institute for Particle and Nuclear Physics of the Hungarian Academy of Sciences (MTA KFKI RMKI), H-1525 Budapest 114, POBox 49, Budapest, Hungary
Department of Physics, Banaras Hindu University, Varanasi 221005, India
Bhabha Atomic Research Centre, Bombay 400 085, India
Weizmann Institute, Rehovot 76100, Israel
Center for Nuclear Study, Graduate School of Science, University of Tokyo, 7-3-1 Hongo, Bunkyo, Tokyo 113-0033, Japan
Hiroshima University, Kagamiyama, Higashi-Hiroshima 739-8526, Japan
KEK, High Energy Accelerator Research Organization, Tsukuba, Ibaraki 305-0801, Japan
Kyoto University, Kyoto 606-8502, Japan
Nagasaki Institute of Applied Science, Nagasaki-shi, Nagasaki 851-0193, Japan
RIKEN, The Institute of Physical and Chemical Research, Wako, Saitama 351-0198, Japan
Physics Department, Rikkyo University, 3-34-1 Nishi-Ikebukuro, Toshima, Tokyo 171-8501, Japan
Department of Physics, Tokyo Institute of Technology, Oh-okayama, Meguro, Tokyo 152-8551, Japan
Institute of Physics, University of Tsukuba, Tsukuba, Ibaraki 305, Japan
Chonbuk National University, Jeonju, Korea
Ewha Womans University, Seoul 120-750, Korea
Hanyang University, Seoul 133-792, Korea
KAERI, Cyclotron Application Laboratory, Seoul, South Korea
Korea University, Seoul, 136-701, Korea
Myongji University, Yongin, Kyonggido 449-728, Korea
Department of Physocs and Astronomy, Seoul National University, Seoul, South Korea
Yonsei University, IPAP, Seoul 120-749, Korea
IHEP Protvino, State Research Center of Russian Federation, Institute for High Energy Physics, Protvino, 142281, Russia
INR_RAS, Institute for Nuclear Research of the Russian Academy of Sciences, prospekt 60-letiya Oktyabrya 7a, Moscow 117312, Russia
Joint Institute for Nuclear Research, 141980 Dubna, Moscow Region, Russia
Russian Research Center "Kurchatov Institute", Moscow, Russia
PNPI, Petersburg Nuclear Physics Institute, Gatchina, Leningrad region, 188300, Russia
Saint Petersburg State Polytechnic University, St. Petersburg, Russia
Skobeltsyn Institute of Nuclear Physics, Lomonosov Moscow State University, Vorob'evy Gory, Moscow 119992, Russia
Department of Physics, Lund University, Box 118, SE-221 00 Lund, Sweden

PHENIX *13 Countries; 70 Institutions*

Abilene Christian University, Abilene, TX 79699, U.S.
Baruch College, CUNY, New York City, NY 10010-5518, U.S.
Collider-Accelerator Department, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
Physics Department, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
University of California - Riverside, Riverside, CA 92521, U.S.
University of Colorado, Boulder, CO 80309, U.S.
Columbia University, New York, NY 10027 and Nevis Laboratories, Irvington, NY 10533, U.S.
Florida Institute of Technology, Melbourne, FL 32901, U.S.
Florida State University, Tallahassee, FL 32306, U.S.
Georgia State University, Atlanta, GA 30303, U.S.
University of Illinois at Urbana-Champaign, Urbana, IL 61801, U.S.
Iowa State University, Ames, IA 50011, U.S.
Lawrence Livermore National Laboratory, Livermore, CA 94550, U.S.
Los Alamos National Laboratory, Los Alamos, NM 87545, U.S.
University of Maryland, College Park, MD 20742, U.S.
Department of Physics, University of Massachusetts, Amherst, MA 01003-9337, U.S.
Morgan State University, Baltimore, MD 21251, U.S.
Muhlenberg College, Allentown, PA 18104-5586, U.S.
University of New Mexico, Albuquerque, NM 87131, U.S.
New Mexico State University, Las Cruces, NM 88003, U.S.
Oak Ridge National Laboratory, Oak Ridge, TN 37831, U.S.
Department of Physics and Astronomy, Ohio University, Athens, OH 45701, U.S.
RIKEN BNL Research Center, Brookhaven National Laboratory, Upton, NY 11973-5000, U.S.
Chemistry Department, Stony Brook University,SUNY, Stony Brook, NY 11794-3400, U.S.
Department of Physics and Astronomy, Stony Brook University, SUNY, Stony Brook, NY 11794, U.S.
University of Tennessee, Knoxville, TN 37996, U.S.
Vanderbilt University, Nashville, TN 37235, U.S.

The PHENIX Detector



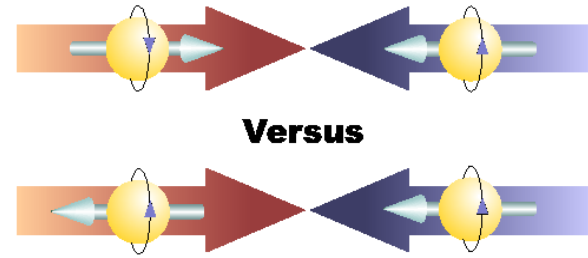
- Philosophy
  - high resolution & high-rate at the cost of acceptance
  - trigger for rare events
- Central Arms
  - $|\eta| < 0.35$, $\Delta\phi \sim \pi$
  - Momentum, Energy, PID
- Muon Arms
  - $1.2 < |\eta| < 2.4$
  - Momentum (MuTr)
- Muon Piston Calorimeter
  - $3.1 < |\eta| < 3.9$

ΔG

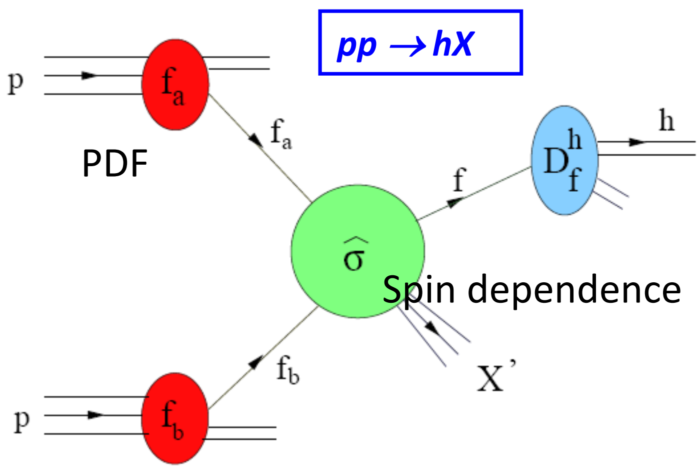
DOUBLE HELICITY A_{LL} RESULTS

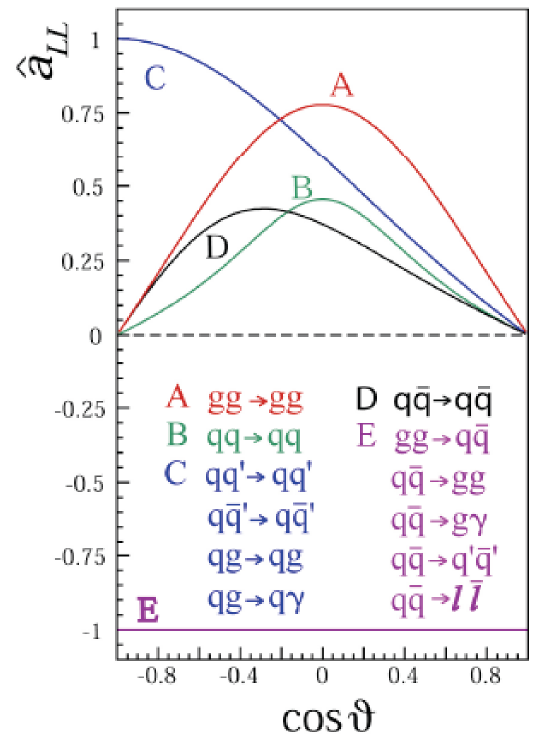
Probe	Advantage
π^0	Statistics
η	Different fragmentation
π^0 - π^0 correlation	Kinematic constraint, lower x
charged π	ΔG sign
heavy flavor decay e^-	Lower x, g-g dominant
MPC cluster	Lower x

ΔG Measurement at PHENIX



$$A_{LL} = \frac{d\sigma^{++} - d\sigma^{+-}}{d\sigma^{++} + d\sigma^{+-}} = \frac{\sum_{a,b} \Delta f_a \otimes \Delta f_b \otimes d\hat{\sigma}^{f_a f_b \to fX} \cdot \hat{a}_{LL}^{f_a f_b \to fX} \otimes D_f^h}{\sum_{a,b} f_a \otimes f_b \otimes d\hat{\sigma}^{f_a f_b \to fX} \otimes D_f^h}$$

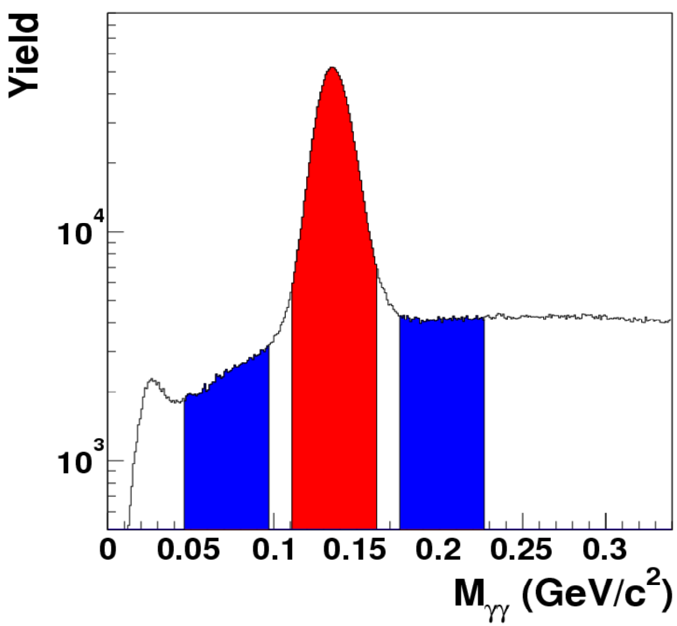




Central Arm π^0, η

- Production cross section is high and from gluon interaction
- PHENIX EMCal trigger friendly
- Found in 2 photons invariant mass

$$A_{LL}^{\pi 0} = \frac{A_{LL}^{\pi 0+BG} - w_{BG} A_{LL}^{BG}}{1 - w_{BG}}$$



Phys. Rev. Lett. 101, 072001(2008)

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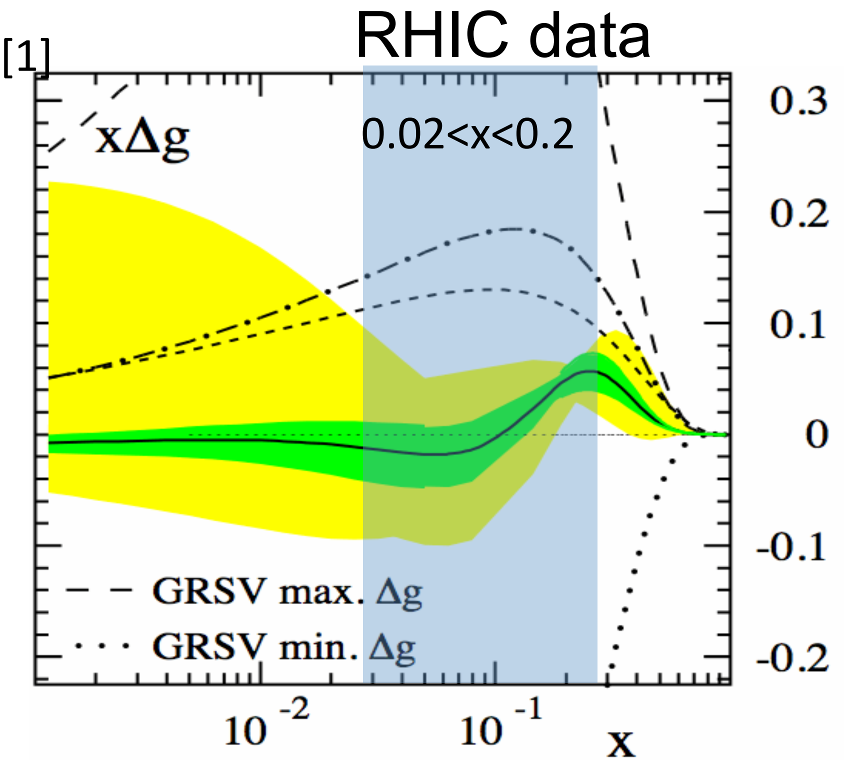
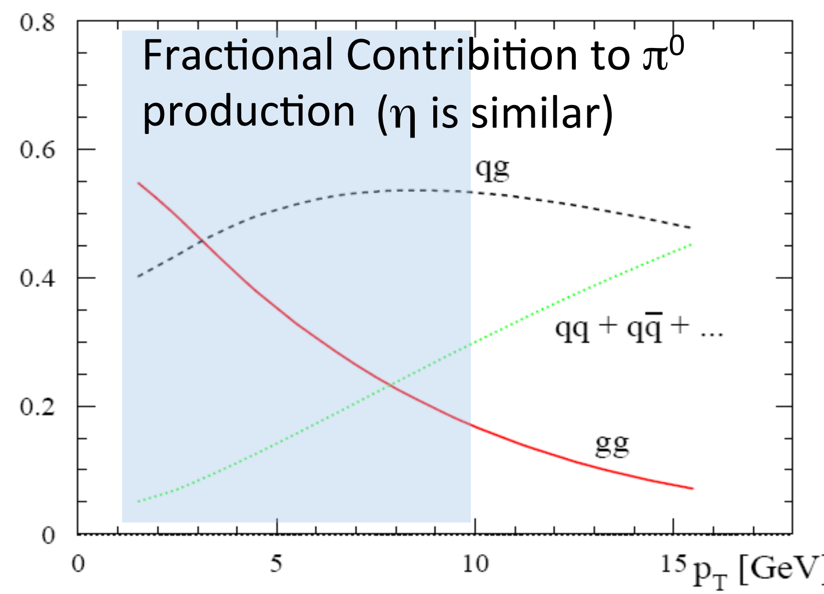
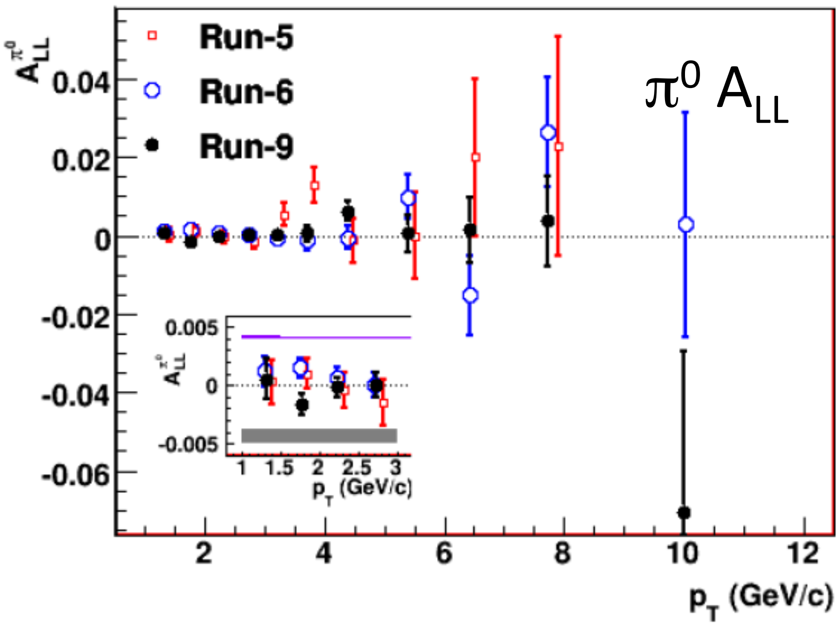
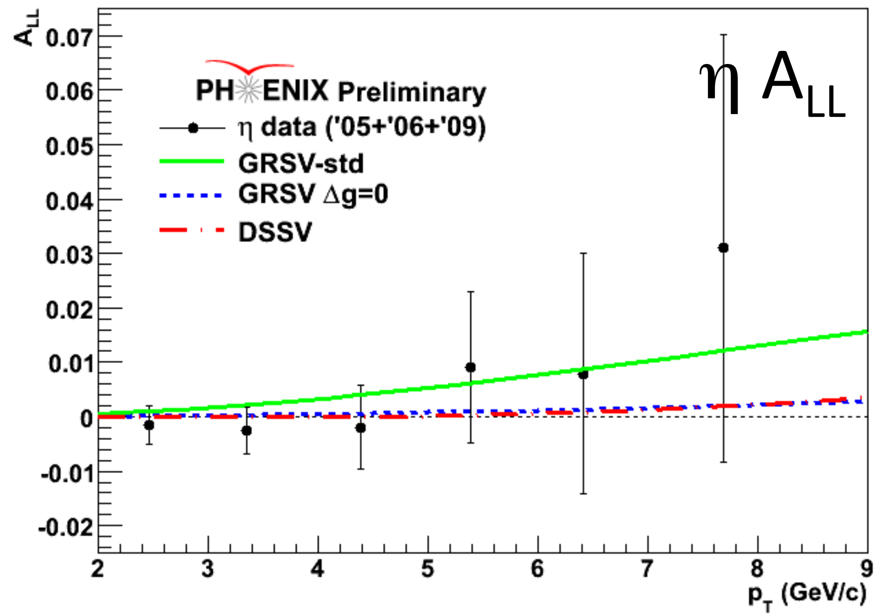




A_{LL} : Central Arm π^0, η





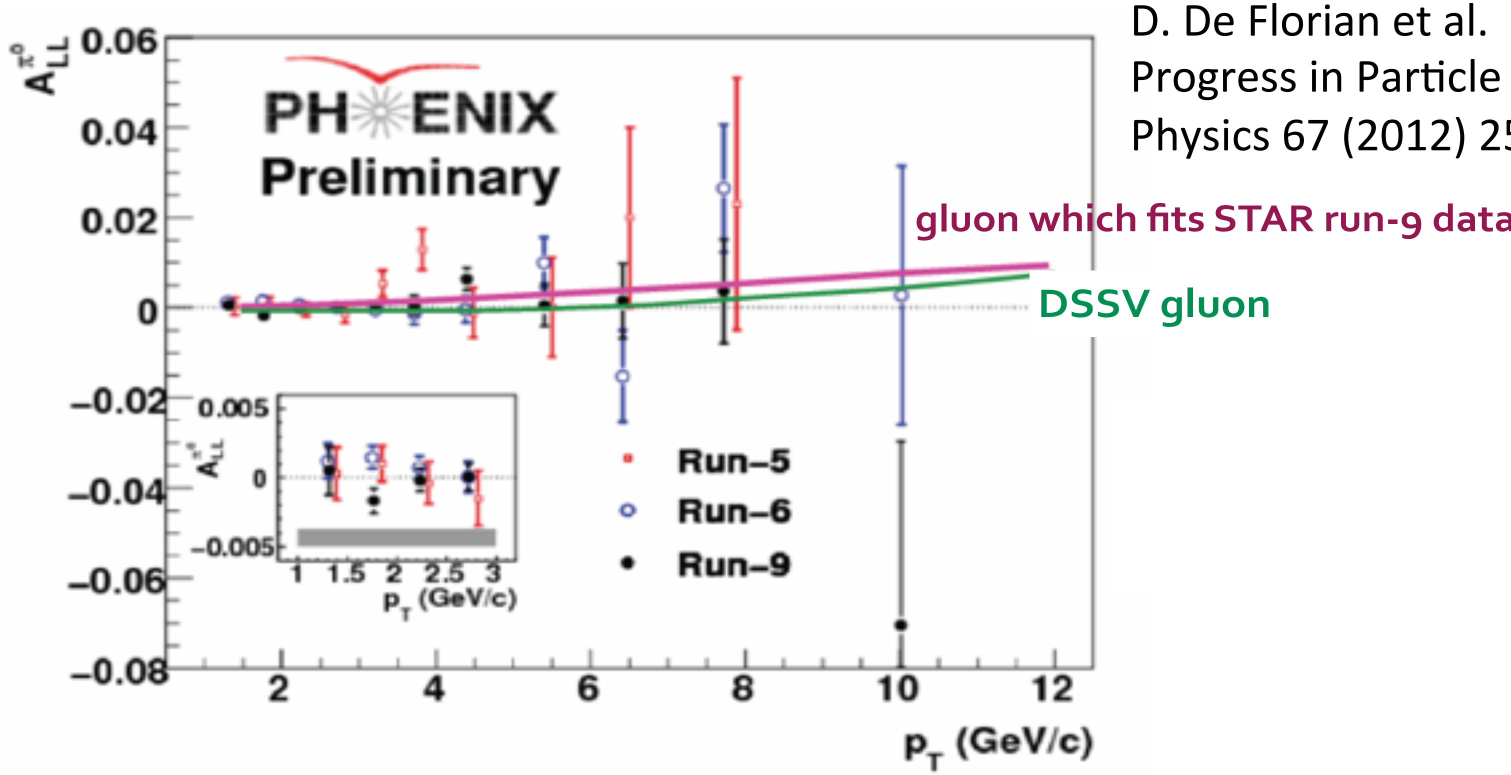
Statistically enriched observable

Need to control Systematic uncertainties (relative luminosity)

ΔG through
- a different flavor structure
- fragmentation function

Statistically Challenging

DSSV Interpretation of π^0 A_{LL}



D. De Florian et al.
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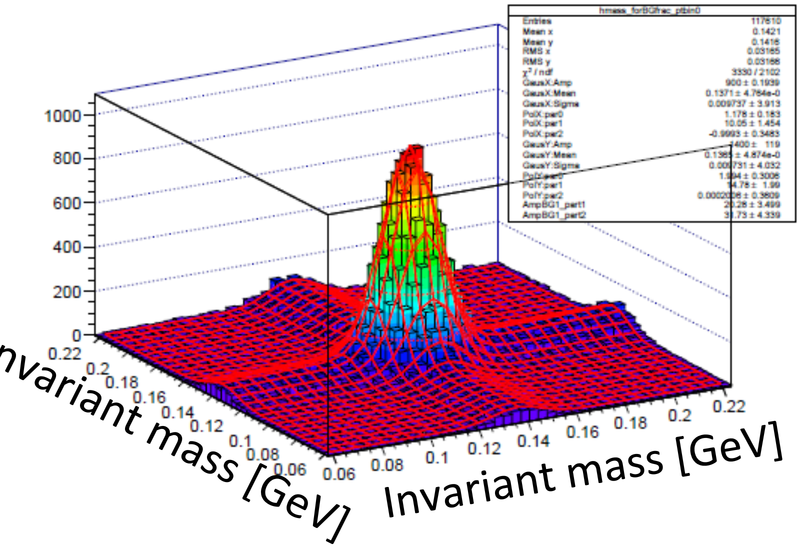
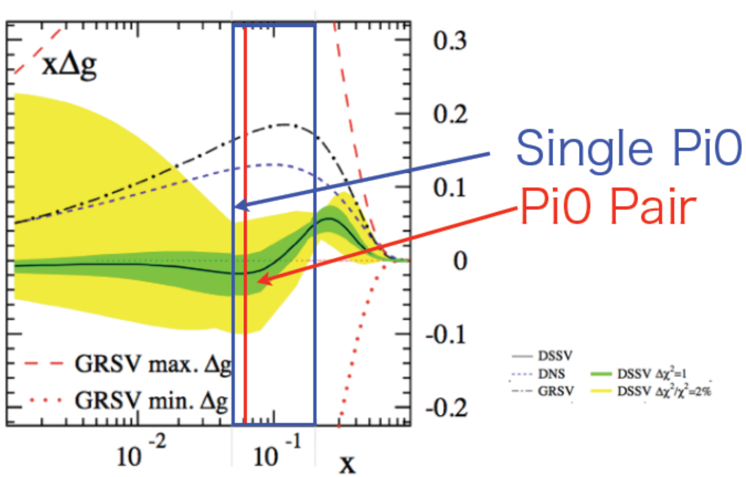
- Run5+Run6+Run9 Combined data constrain ΔG
- Consistent with small A_{LL}, but still compatible with STAR jet -> probes somewhat lower values of x

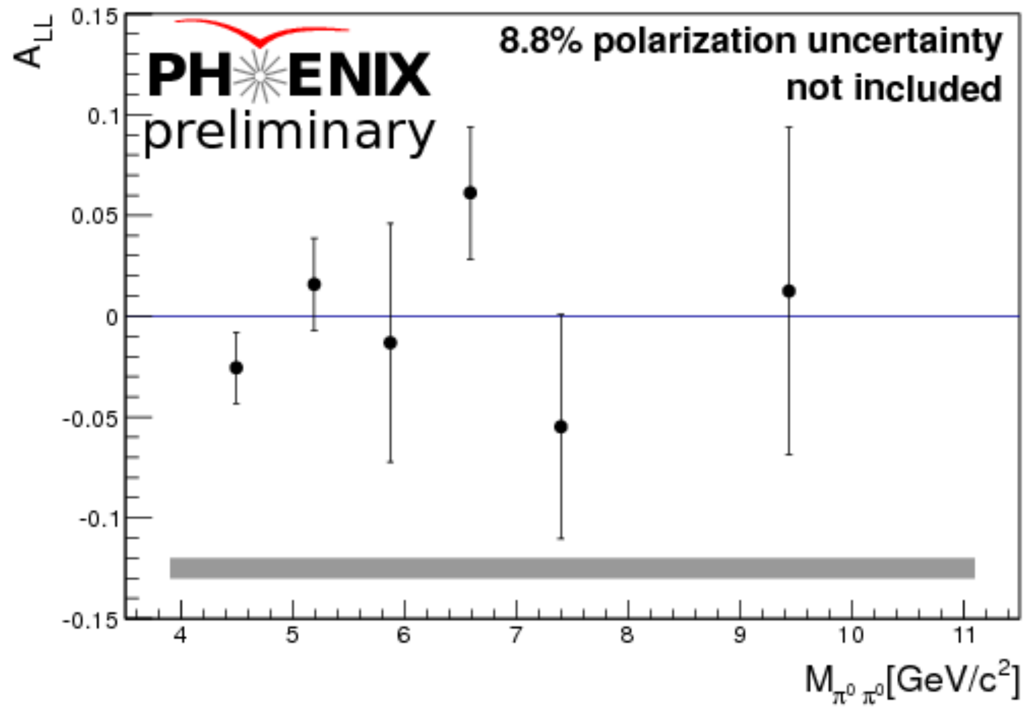
More Challenging Attempt : π^0-π^0 correlation



Constrains event kinematics further

Cost Statistics, need high P^4L



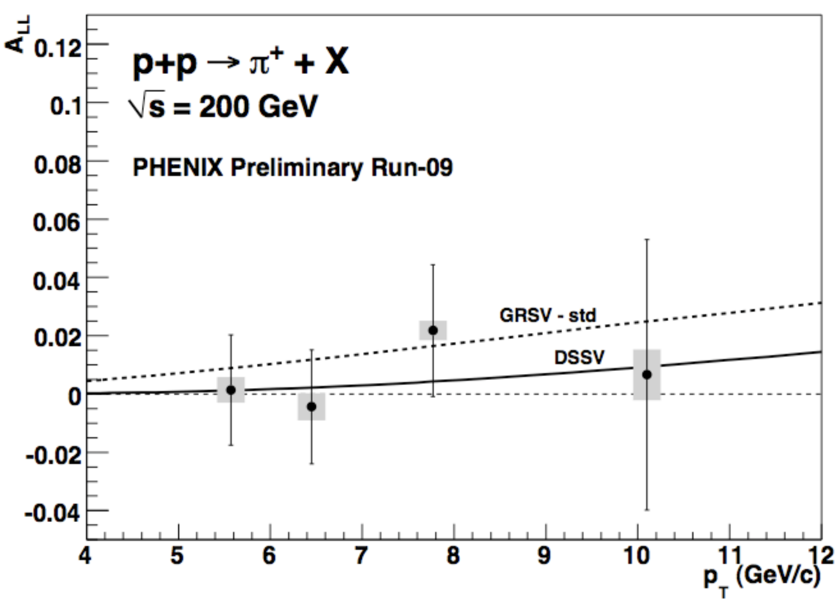


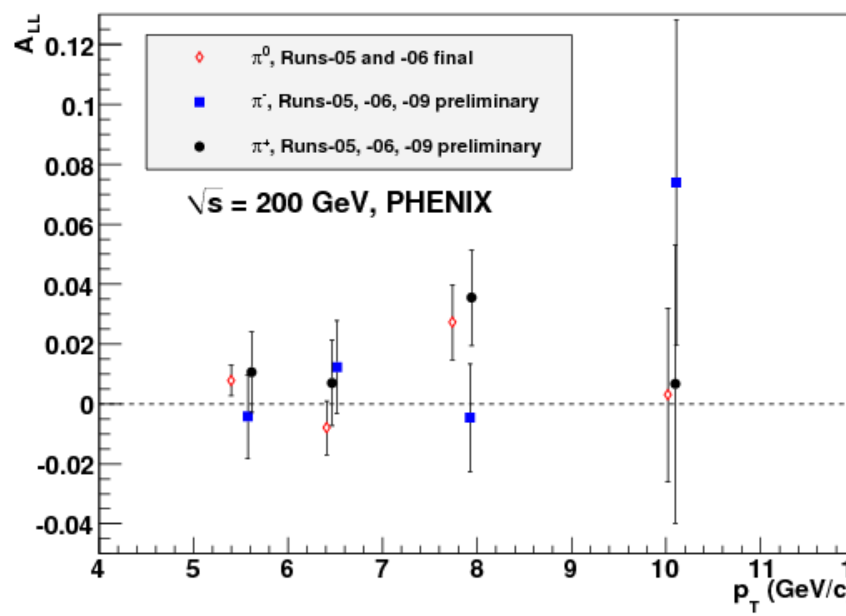
Preliminary Charged pion A_{LL}

- $\pi^{\pm}$ charge asymmetry is sensitive to sign of $\Delta g(x, Q^2)$:
  - $D_u^{\pi+} > D_u^{\pi 0} > D_u^{\pi-}$, $\Delta u > 0$
  - $D_d^{\pi+} < D_d^{\pi 0} < D_d^{\pi-}$, $\Delta d < 0$

  For positive Δg :

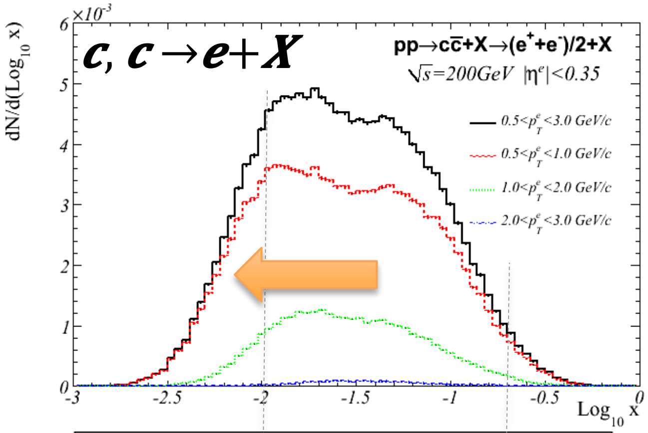
  $A^{\pi+}_{LL} > A^{\pi 0}_{LL} > A^{\pi-}_{LL}$

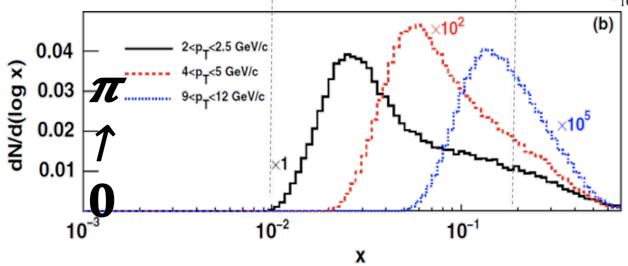




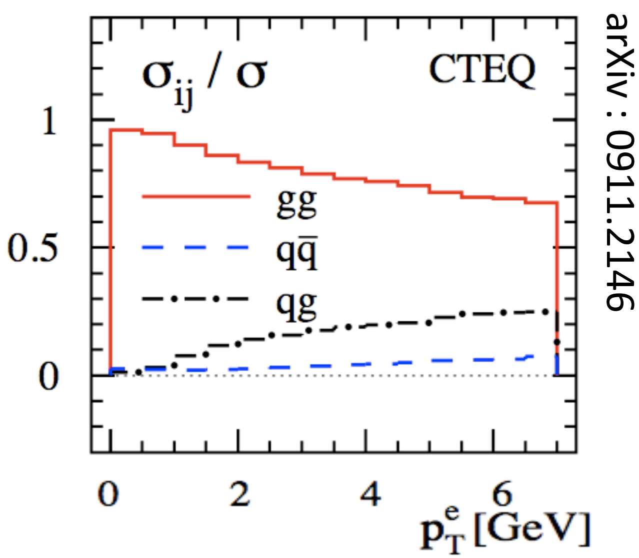
- p_T range of this analysis covers $<x_g>$~0.1

Heavy Flavor Decay Electrons





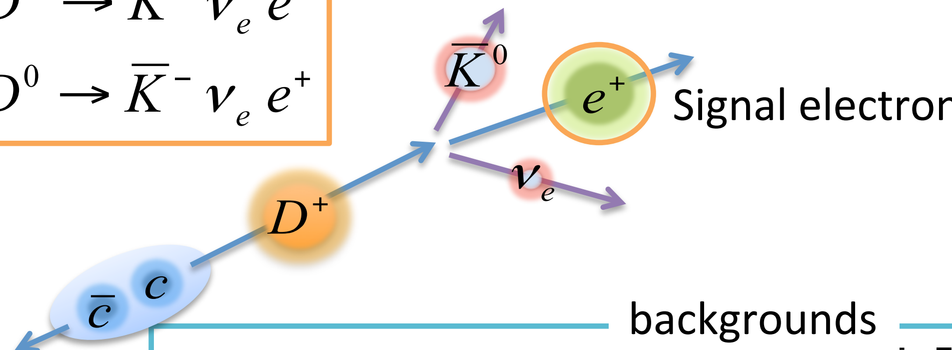
Subprocess fraction at NLO



signal

$$D^+ \to \bar{K}^0 \nu_e e^+$$

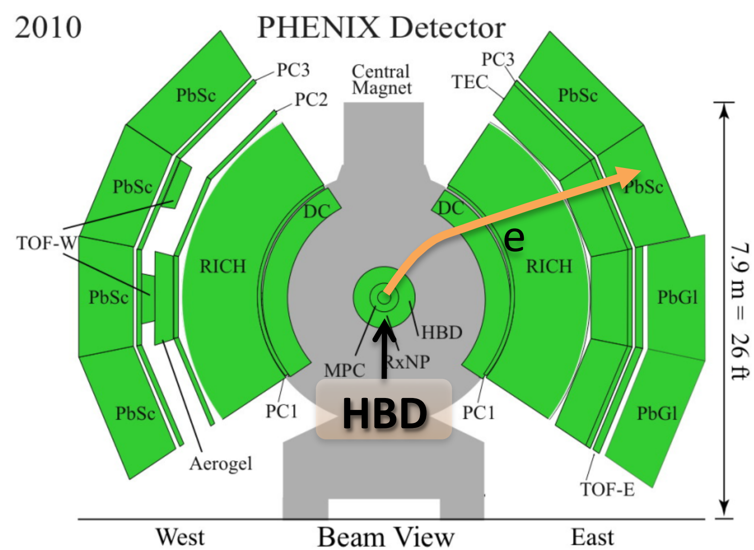
$$D^0 \to \bar{K}^- \nu_e e^+$$



backgrounds

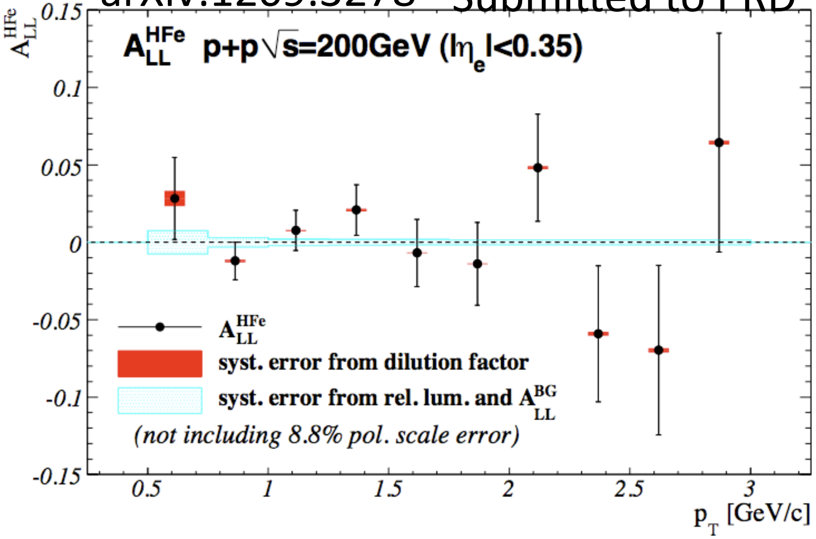
$$\pi^0(\eta) \to \gamma e^+ e^-$$

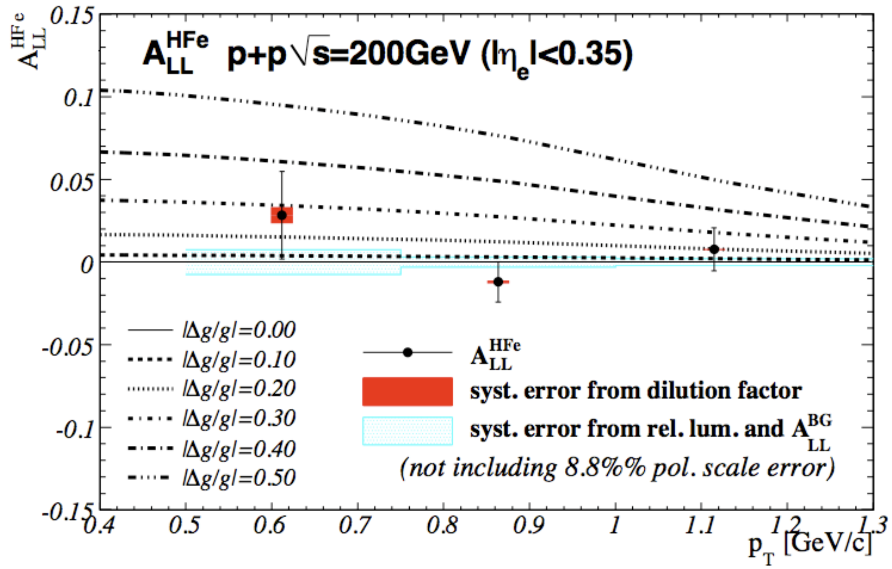
$$\pi^0(\eta) \to \gamma\gamma \quad \gamma \to e^+e^- \text{ (in material)}$$



ΔG Extraction from A_{LL}^{HFe}

arXiv:1209.3278 Submitted to PRD



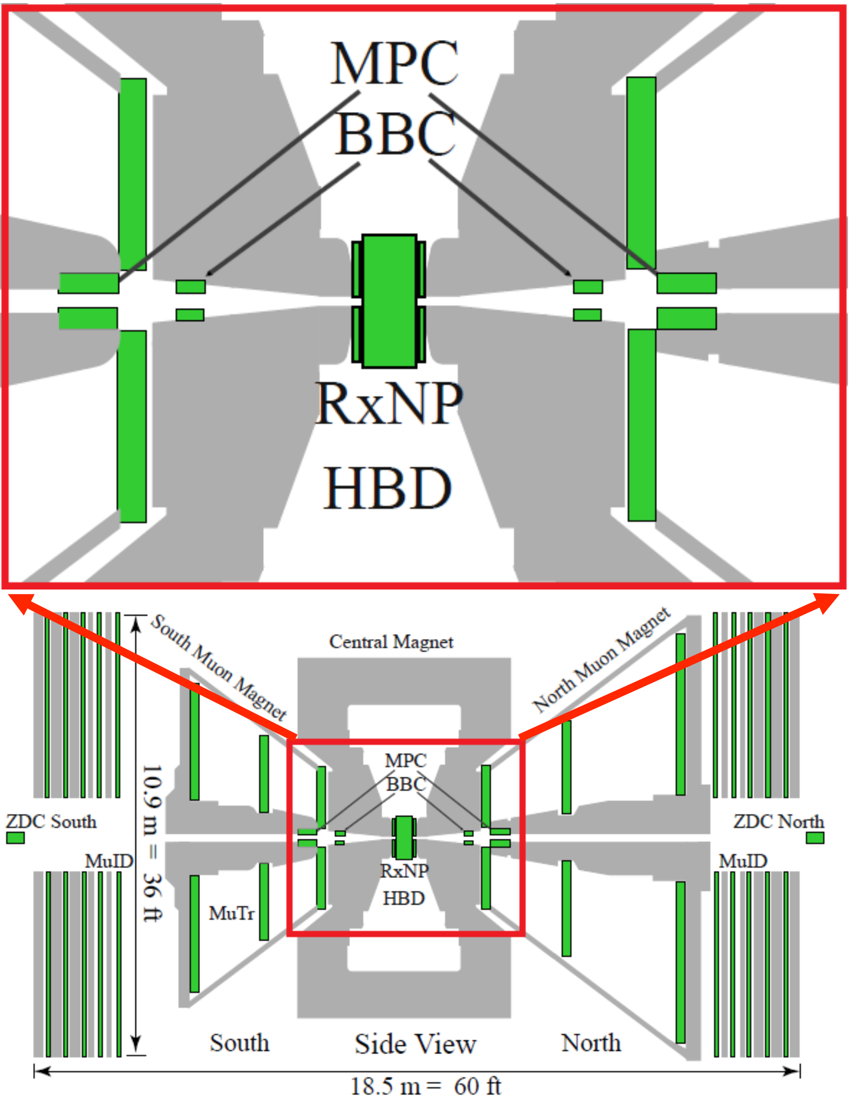


- ❑ This results largely benefited from using HBD in eliminating photo-conversion and Dalitz decay background.
- ❑ Decay electrons include J/ψ , bottom production and other vector meson as well as open charm contributions.
- ❑ Open charm production dominates in p_T range of 0.50 < pT < 1.25 GeV/c

  (J/ψ <2%, b quark<5%)
- ❑ $|\Delta g/g(\langle \log x \rangle,\mu)|^2 < 3 \times 10^{-2}$ (1σ)

  (0.01 ~ x ~ 0.08)

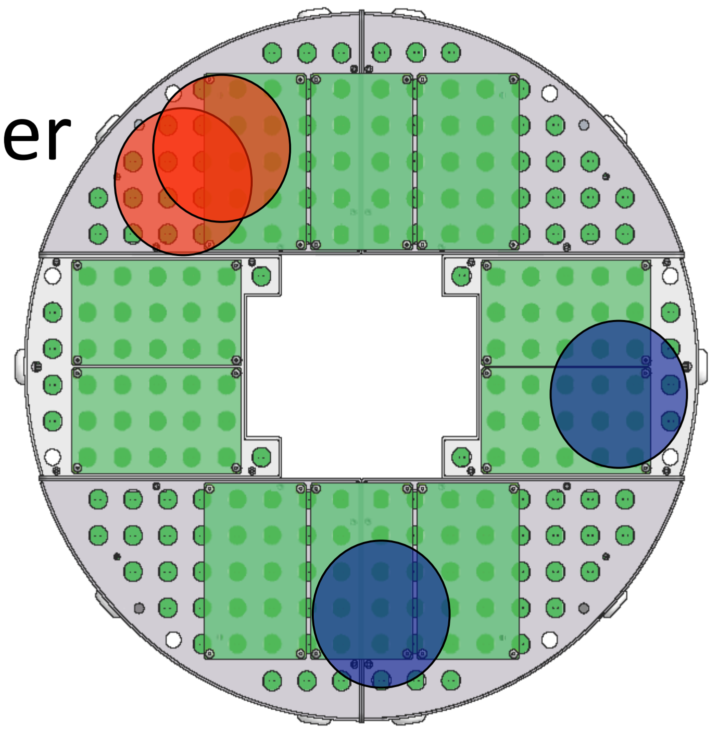
Exploring Lower-x by Forward MPC



<u>M</u>uon <u>P</u>iston <u>C</u>alorimeter
3.1<|η|<3.9

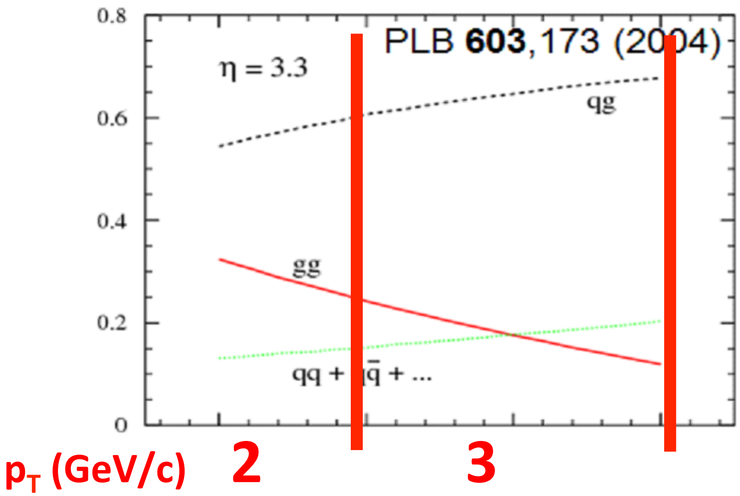
- **Low P_T Reconstructed π^0**
- **High PT Merged π^0**

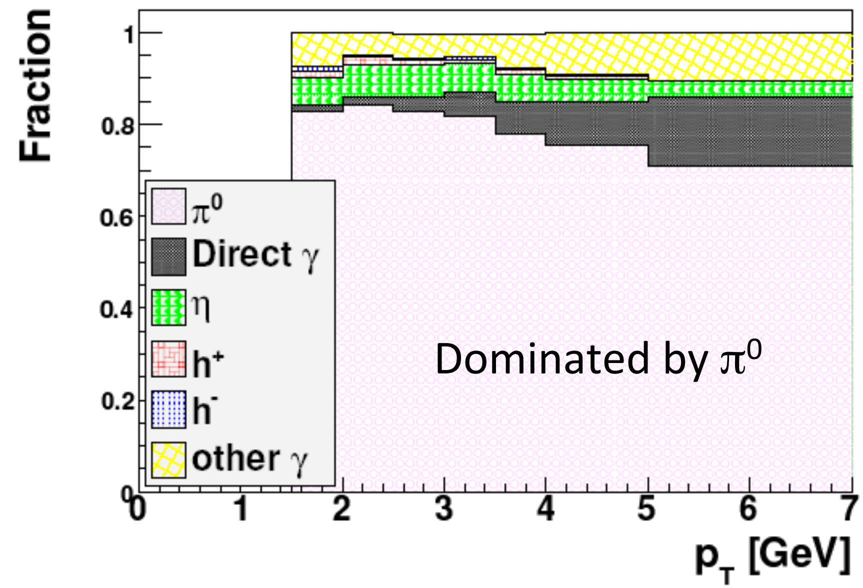
cluster

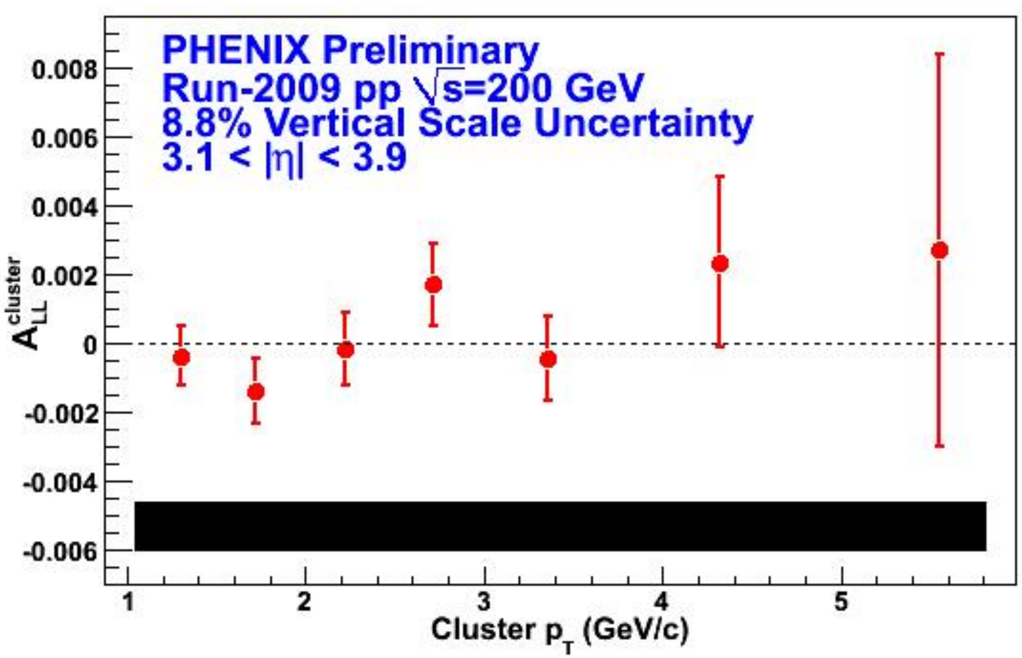


Range
0.05<x<0.2

Cluster A_{LL}







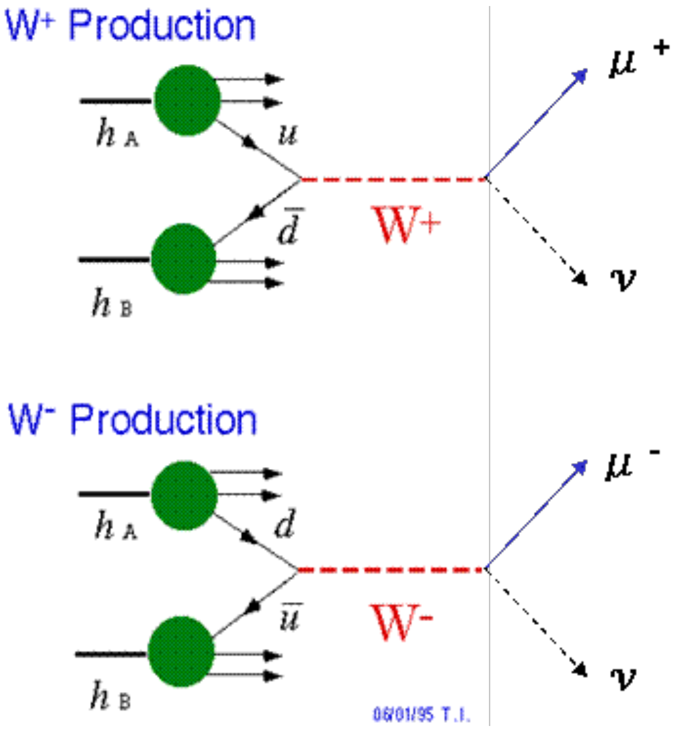
- Still consistent with zero at lower x
- Systematic error starts to defeat statistics
- Good control of relative luminosity required for better precision

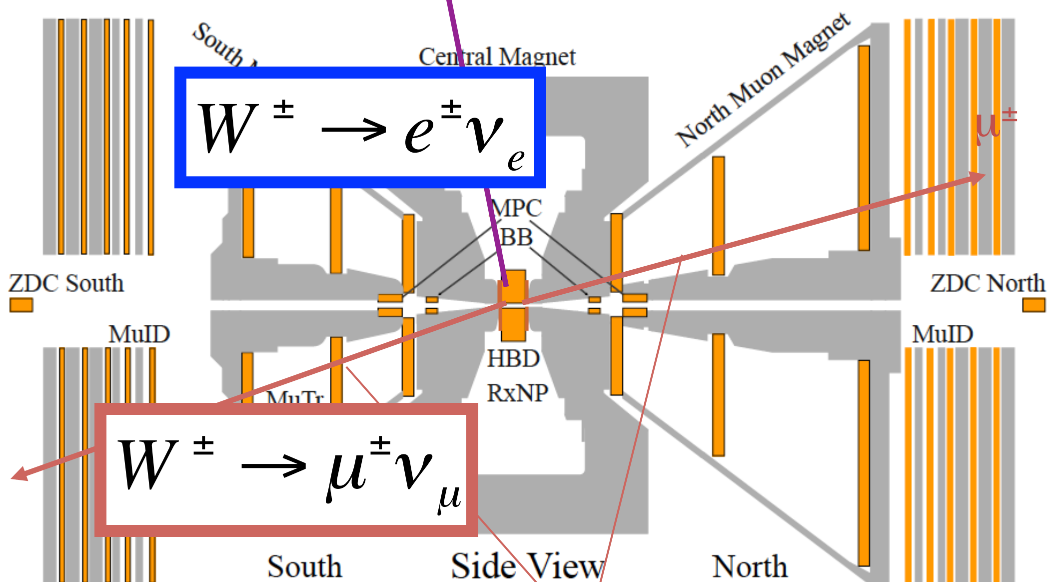
SEA QUARK POLARIZATION PRELIMINARY A_L^W FROM RUN11

Probe	Rapidity	Advantage
W->e	central	Good S/N
W->μ	forward	Enhanced sea quark

sqrt(s)=500 GeV @ RHIC

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



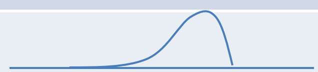
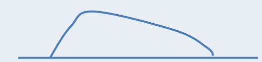


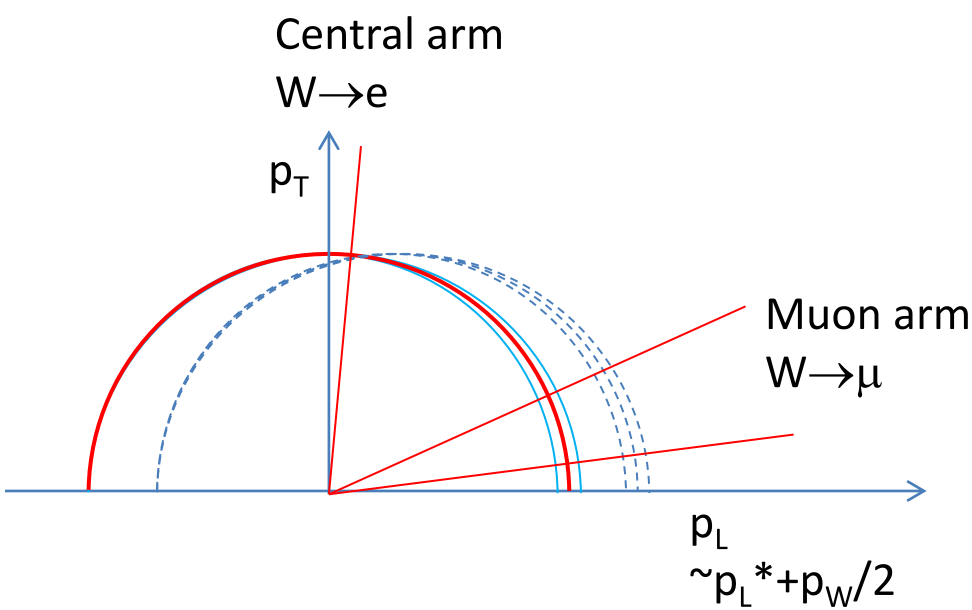
Parity Violation Asymmetry
Clean flavor separation
w/o fragmentation uncertainty

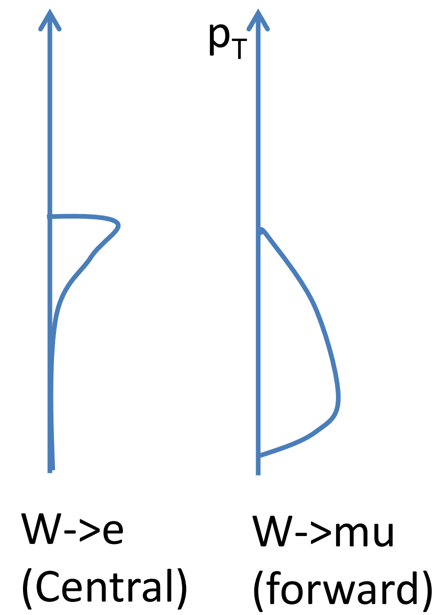
$$A_L^{W^+} \approx -\frac{\Delta u(x_1, M_W^2)}{u(x_1, M_W^2)}\ , \ x_1 > x_2 \ \ (y_W >> 0)$$

$$A_L^{W^+} \approx \frac{\Delta\bar{d}(x_1, M_W^2)}{\bar{d}(x_1, M_W^2)}\ , \ x_1 < x_2 \ \ (y_W << 0)$$

W→e (central), W→μ (forward)

	Central arm	Muon arm
Triggered by	energy	momentum
momentum	E_{dep} in EMCal	Tracking in B field
charge	Tracking in B field	Tracking in B field
pT shape		

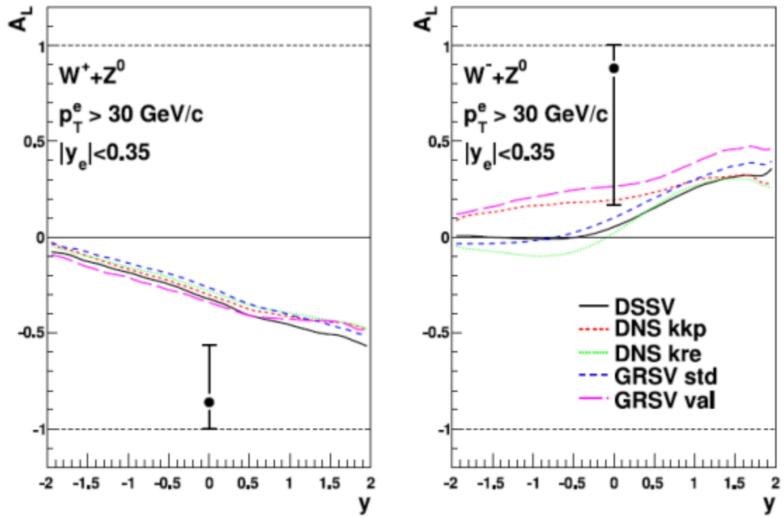




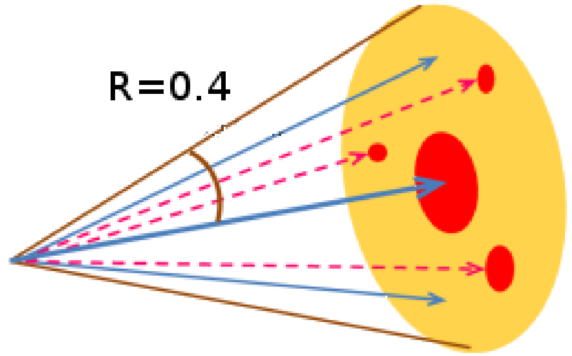
W→μ is more challenging.

Run11 Central Arm W->e

- Reducible Backgrounds
  - π, $\eta \rightarrow \gamma\gamma$, or direct photon, followed by conversions to $e^{\pm}$
  - Cosmic rays
  - Beam related backgrounds
- Irreducible Backgrounds (pass cuts)
  - $Z \rightarrow e^{+} + e^{-}$
  - Other W decays ($W \rightarrow \tau + \nu_{\tau} \rightarrow e + \nu_{e}\bar{\nu_{\tau}}\nu_{\tau}$) (very small)
  - charm, bottom decays to $e^{\pm} + X$ (very small)



Run9 PRL106,062001 (2011)

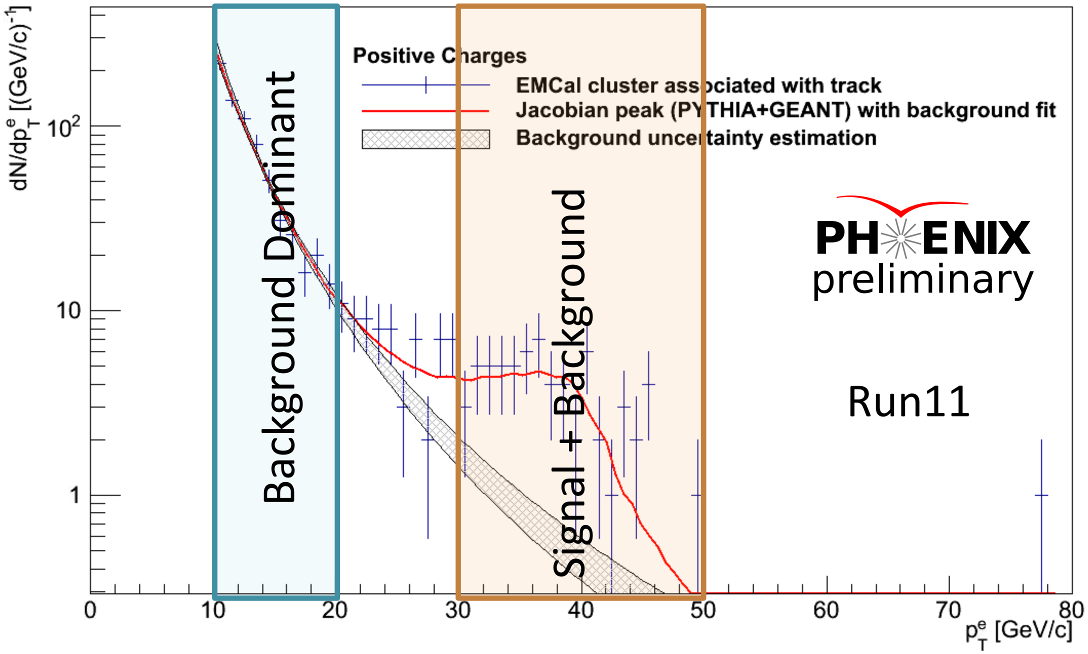


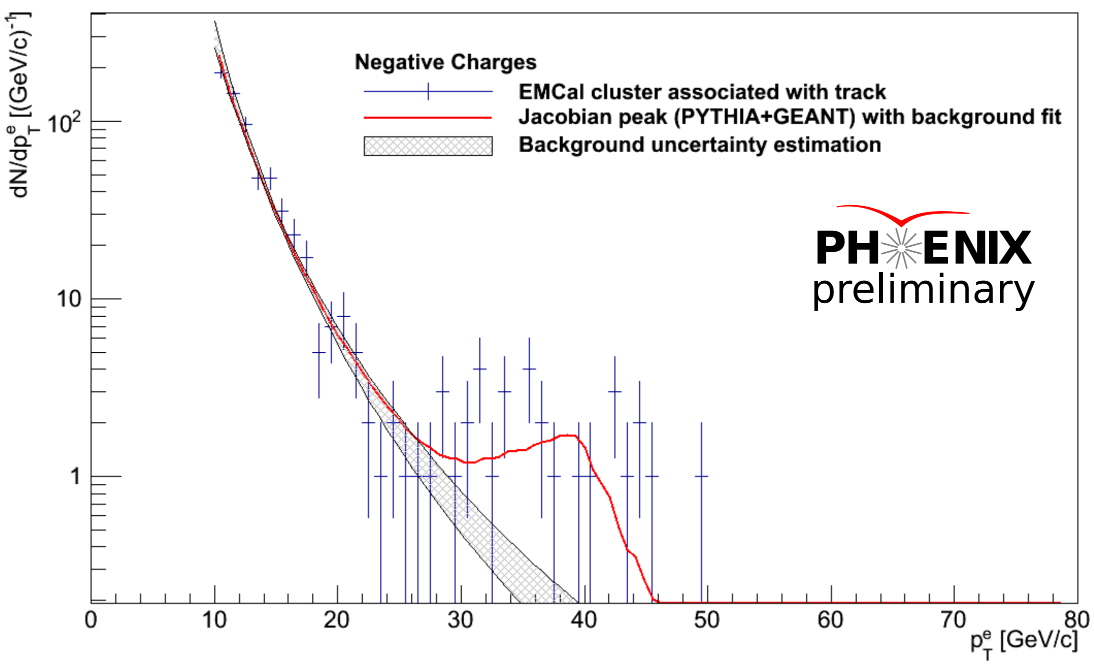
Backgrounds could be mitigated by relative isolation cut

Signal electron :

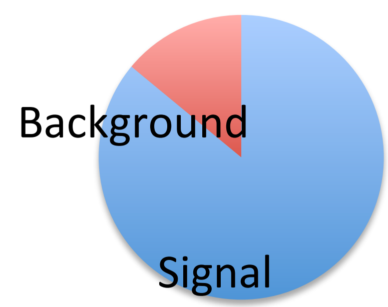
- High momentum electron
- Isolated

Single Electron P_T Spectra

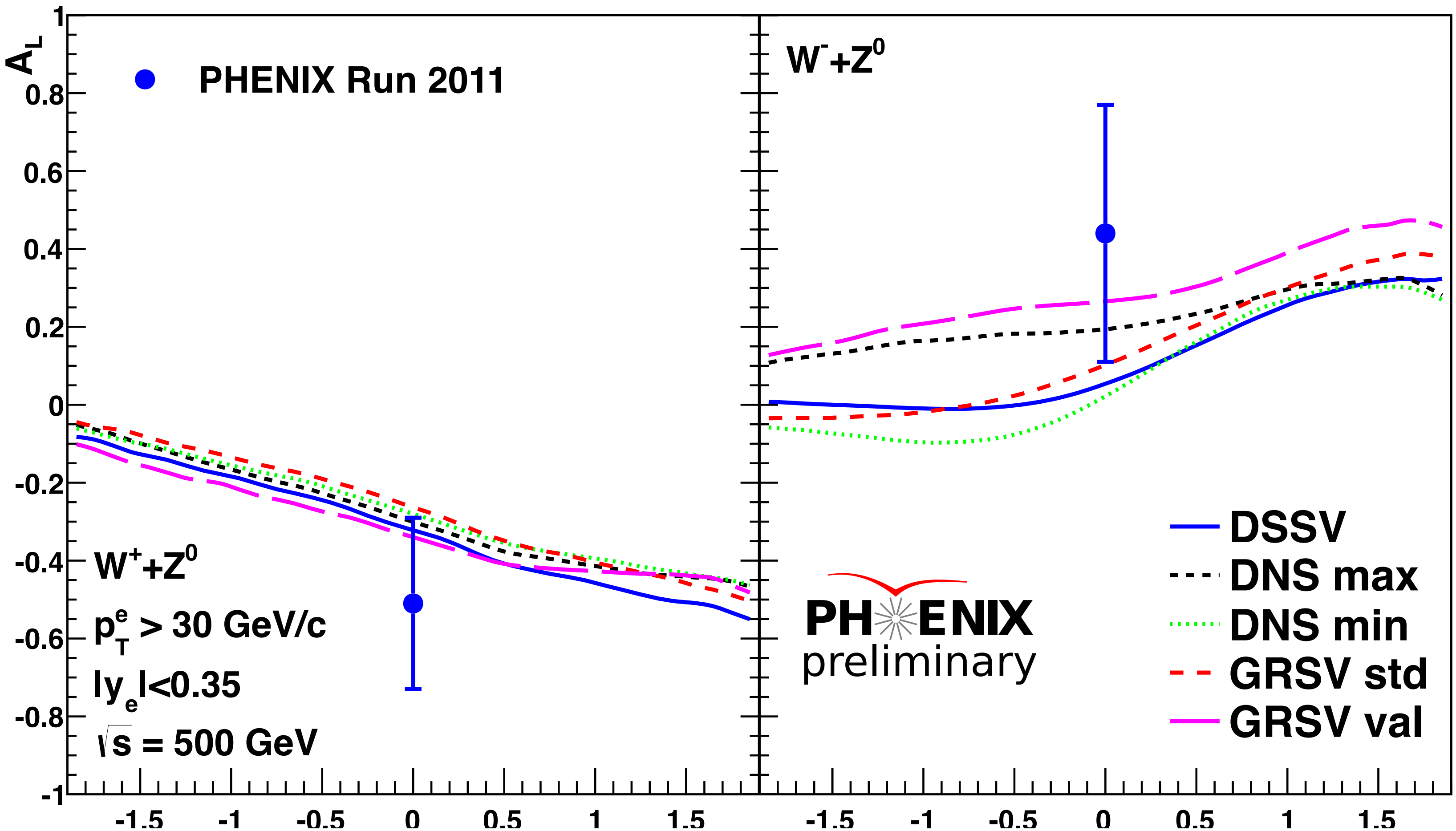




- Power Law Counting
  Background Shape Fixed in $10<P_T<20$ GeV/c
- Jacobian Peak (PYTHIA+GEANT) + Power Low Background Fitting
- Resulting Background contamination 14 ~ 17%.

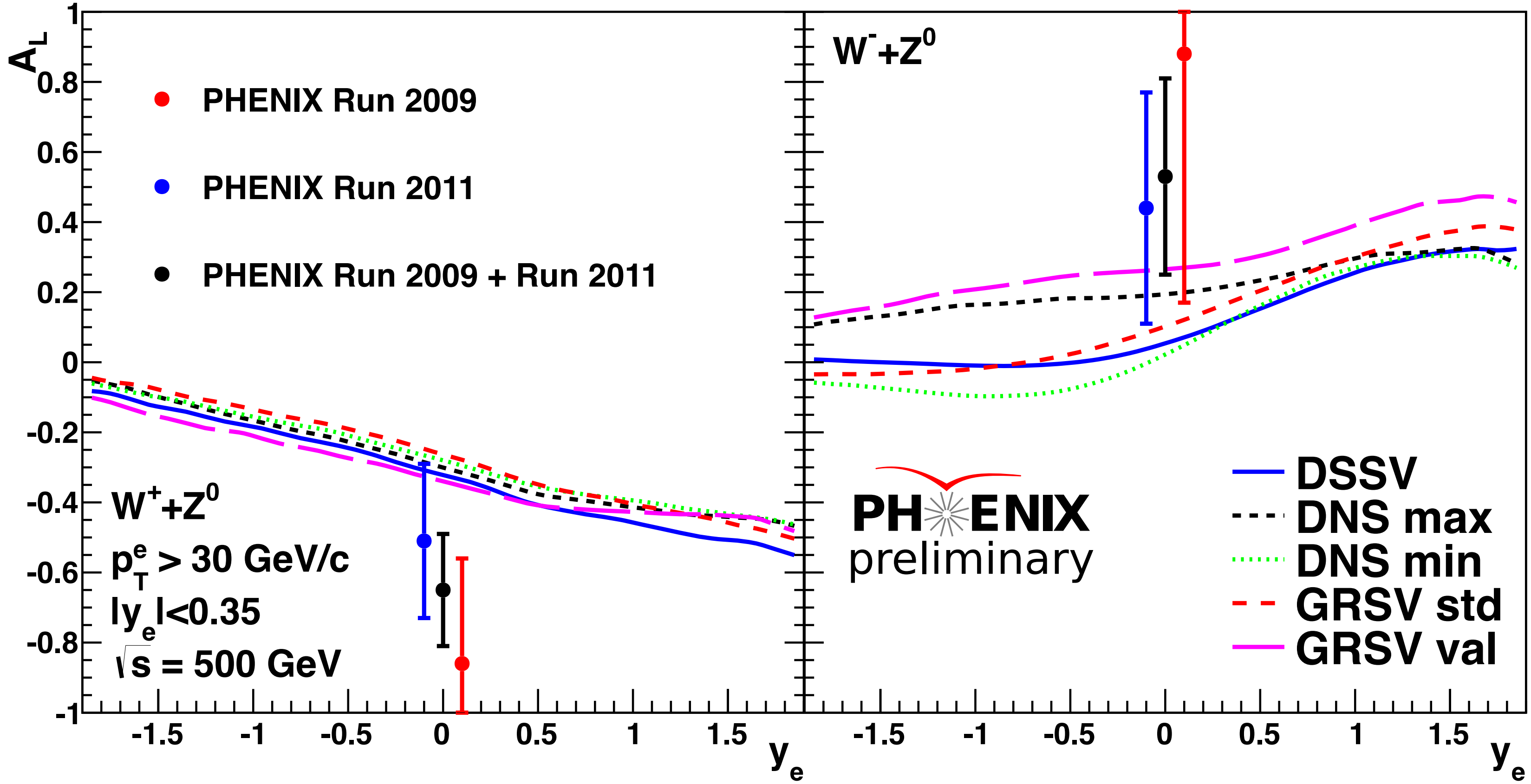


Central Arm A_L



Central Arm A_L

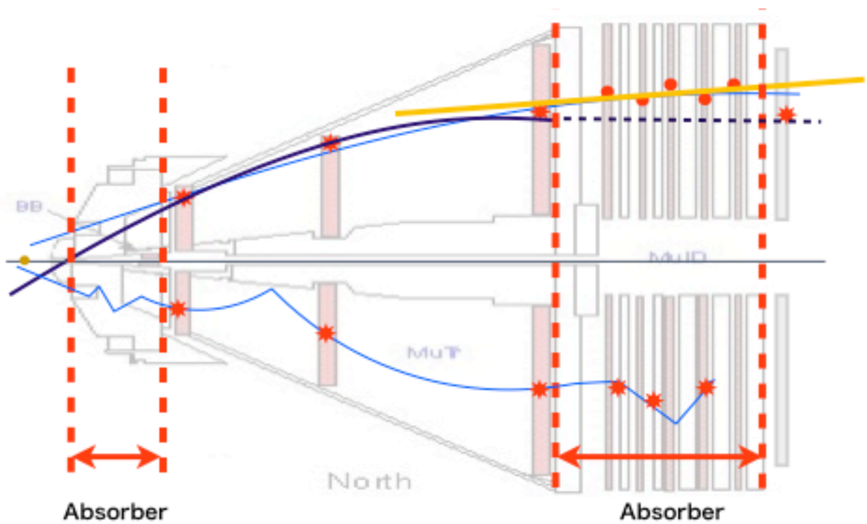
Run9 Phys. Rev. Lett. 106, 062001 (2011)

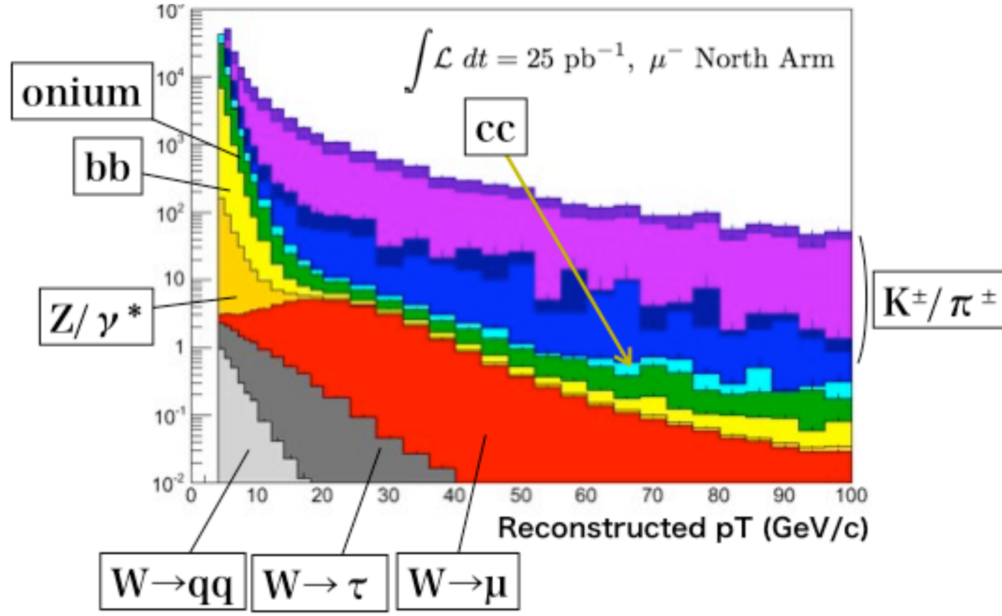


☑ Consistent With Run9 Results

☑ Consistent with Global Analyses Predictions within 2σ

Forward W-> μ Analysis





Signal: high pT single muon

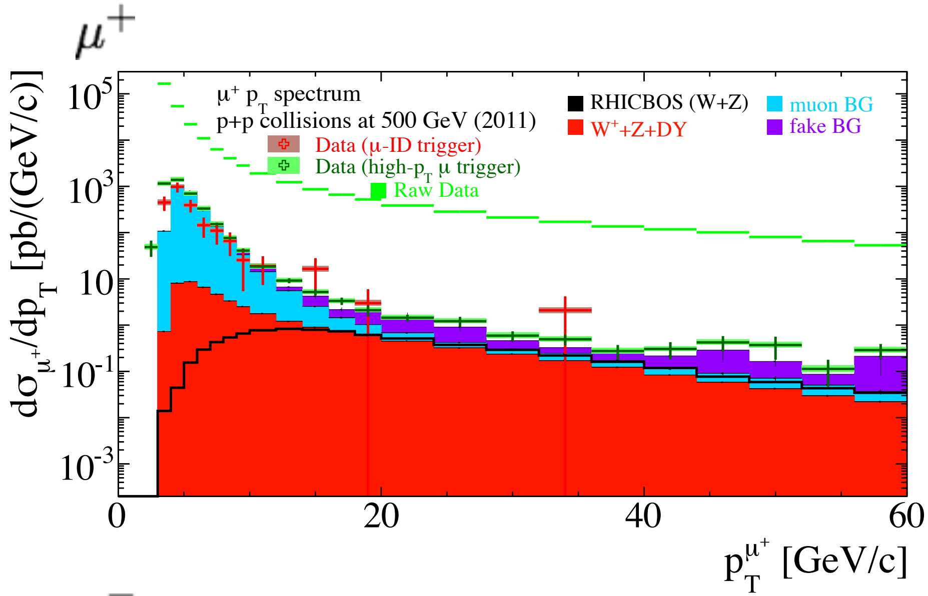
Backgrounds:

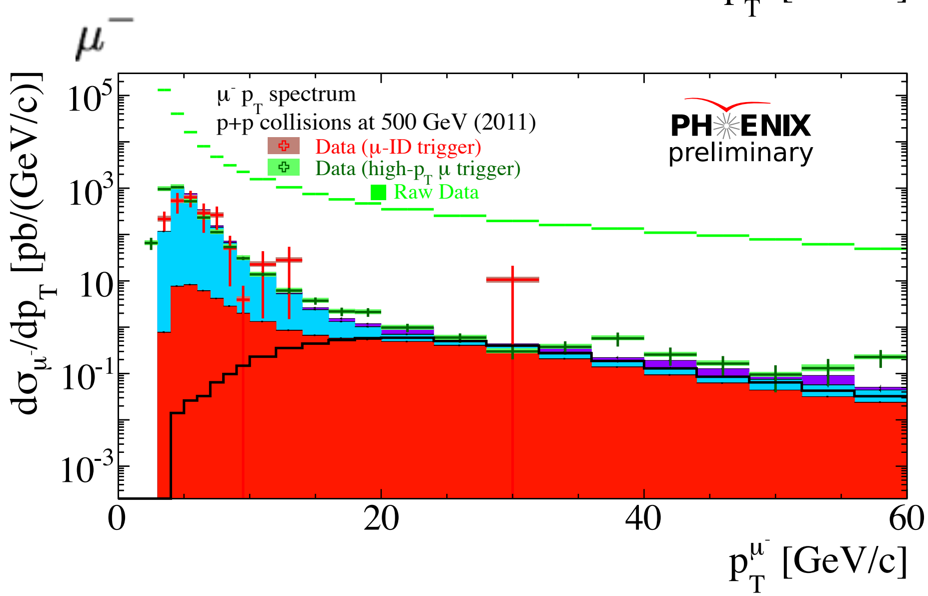
- Heavy flavor, onium (true muon, irreducible)
- "Fake high pT" caused by decayed hadrons

Tight cuts are applied for "consistency of true high pT muon".

- small multiple scattering : MuTr/MuID/RPC matching
- vertex requirement : Track/vertex(BBC) matching

Single Muon P_T Spectra



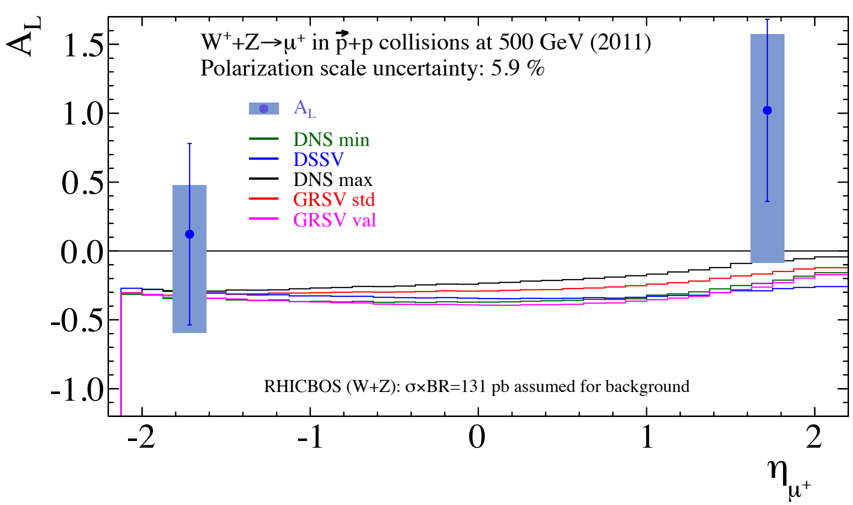


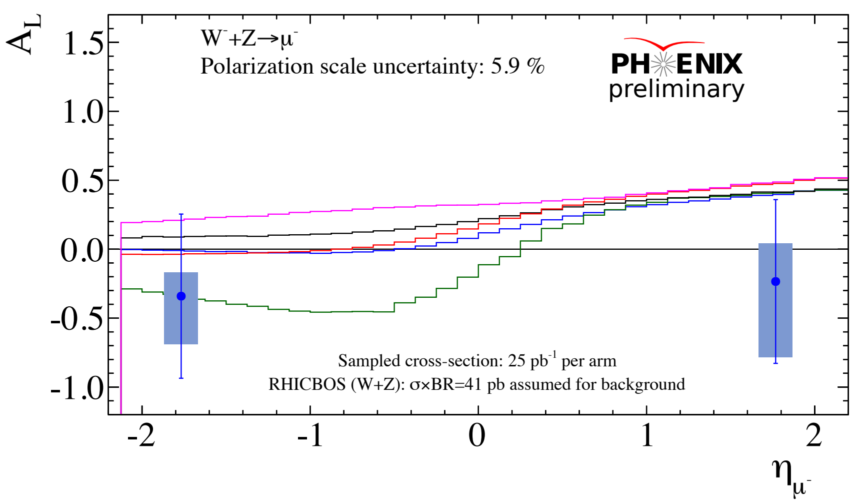
- ☑ Efficiency corrections
- ☑ W/Z cross section employed RHICBOS NLO
- ☑ S/B estimation from fixed W/Z cross section (RHICBOS NLO)

S/B ~ 1/3

- ☐ Background estimation in **data driven manner**
- ☐ Resolution Improvement for better S/N

The First Forward A_L^W Results





- $\sqrt{s}$ = 500 GeV
- Luminosity: ~25 pb-1
- Pol. : ~50%

First Forward W Asymmetry Results!

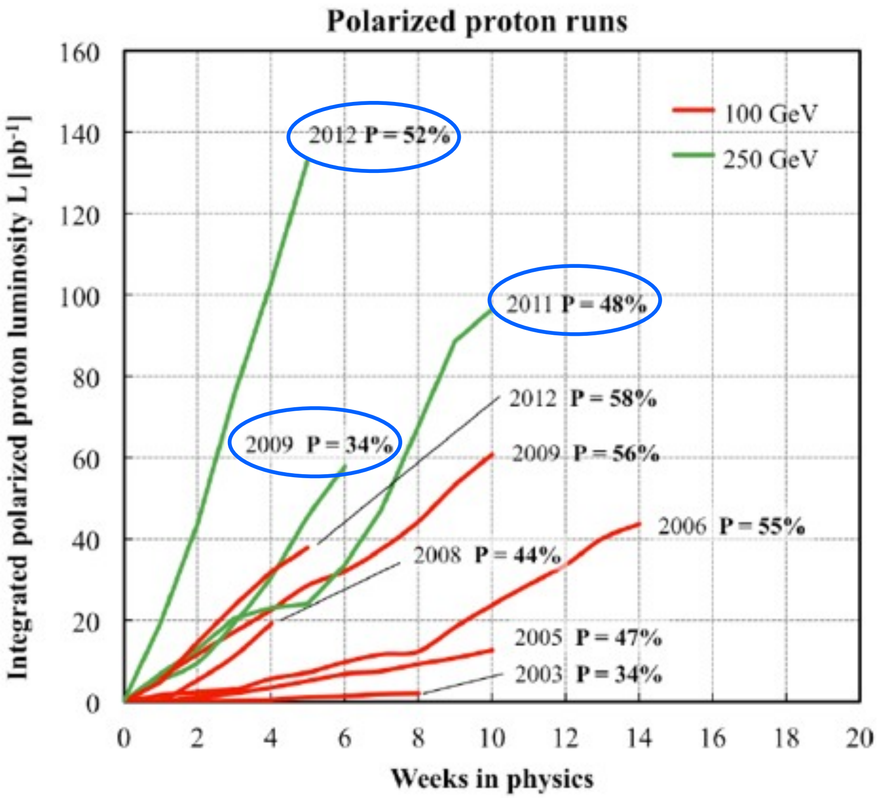
More to come!

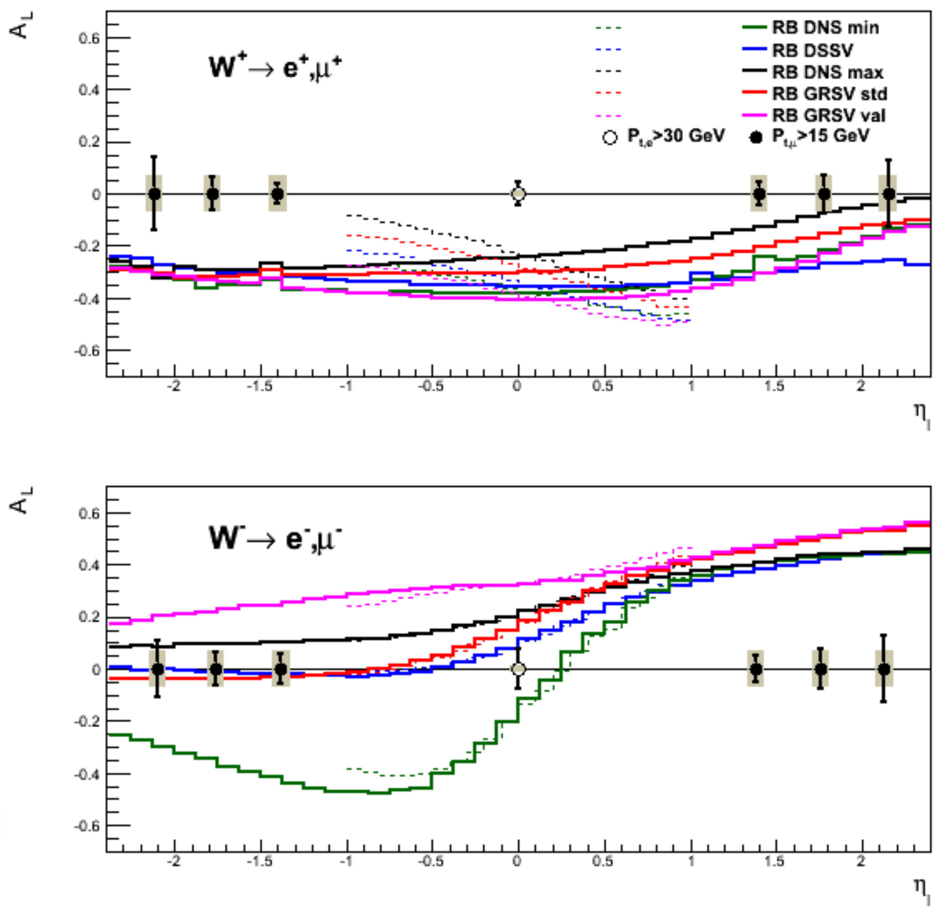
	Run11	Run12
Luminosity	25	50

W measurement Run13 Projections

Goal : 250 pb^{-1} on tape ($-30<z_{vtx}<30$cm)

Delivered Luminosity



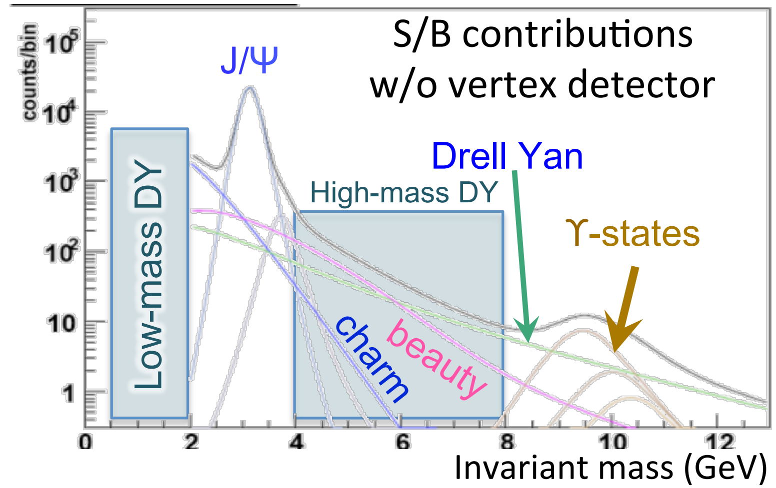


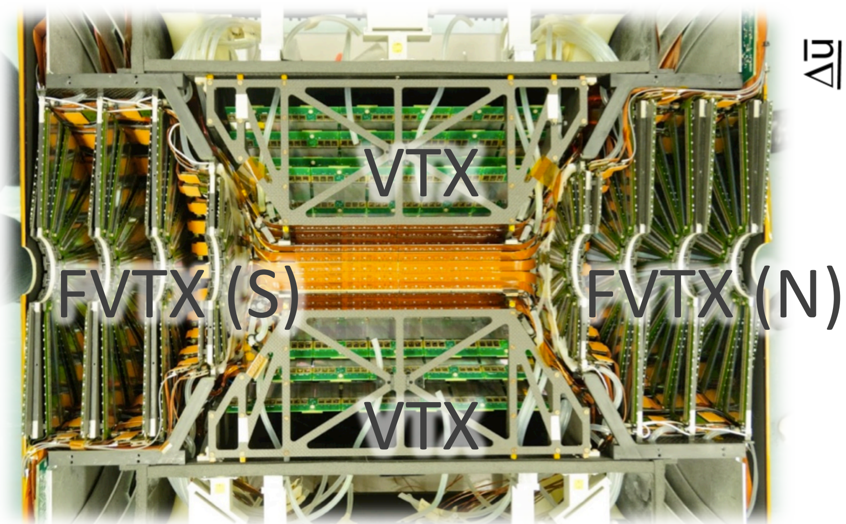
Improving Performance of RHIC

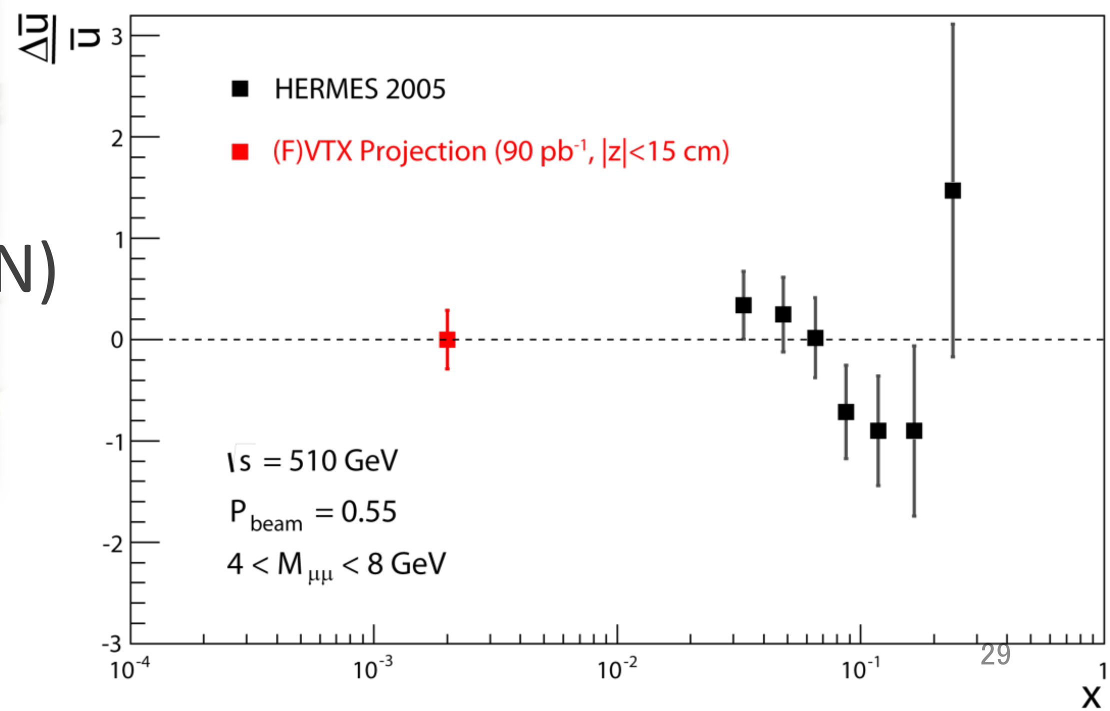
Further Sea Quark Measurement w/ DY

$$A_{LL}^{DY} = -\frac{\sum_q e_q^2\{\Delta q(x_1)\Delta\bar{q}(x_2) + \Delta\bar{q}(x_1)\Delta q(x_2)\}}{\sum_q e_q^2\{q(x_1)\bar{q}(x_2) + \bar{q}(x_1)q(x_2)\}}$$

$$\approx -\frac{\Delta u(x_1)}{u(x_1)} \cdot \frac{\Delta\bar{u}(x_2)}{\bar{u}(x_2)}$$







Extract DY events from heavy flavors using FVTX

Summary

- ☑ Presented latest ΔG and $\Delta\bar{q}$ measurements from PHENIX
- ☑ High statistics π^0 provides strict limit on present knowledge of ΔG
- ☑ Different probes constrain ΔG from various angles (purity, sign, low-x, etc…)
- ☑ First measurement of forward W A_L. Improving our knowledge on $\Delta\bar{q}$ in conjunction with W->e data.
- ☑ Higher statistics and smaller systematic in future measurements

BACKUP

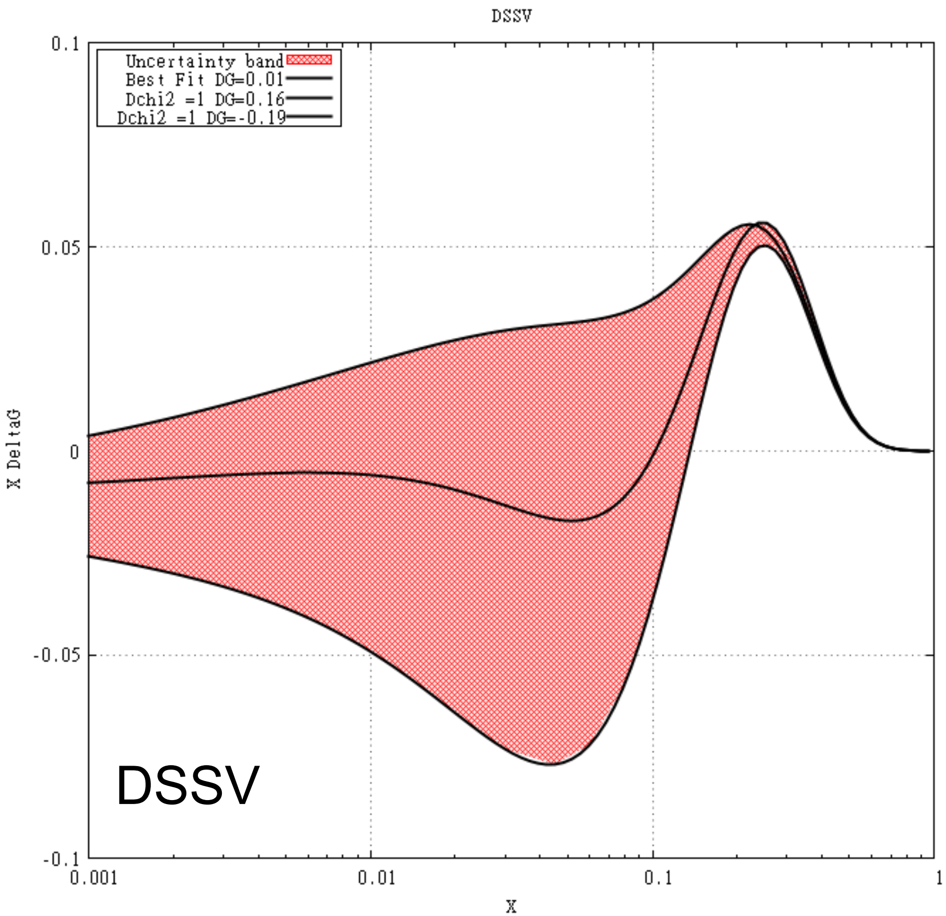
References

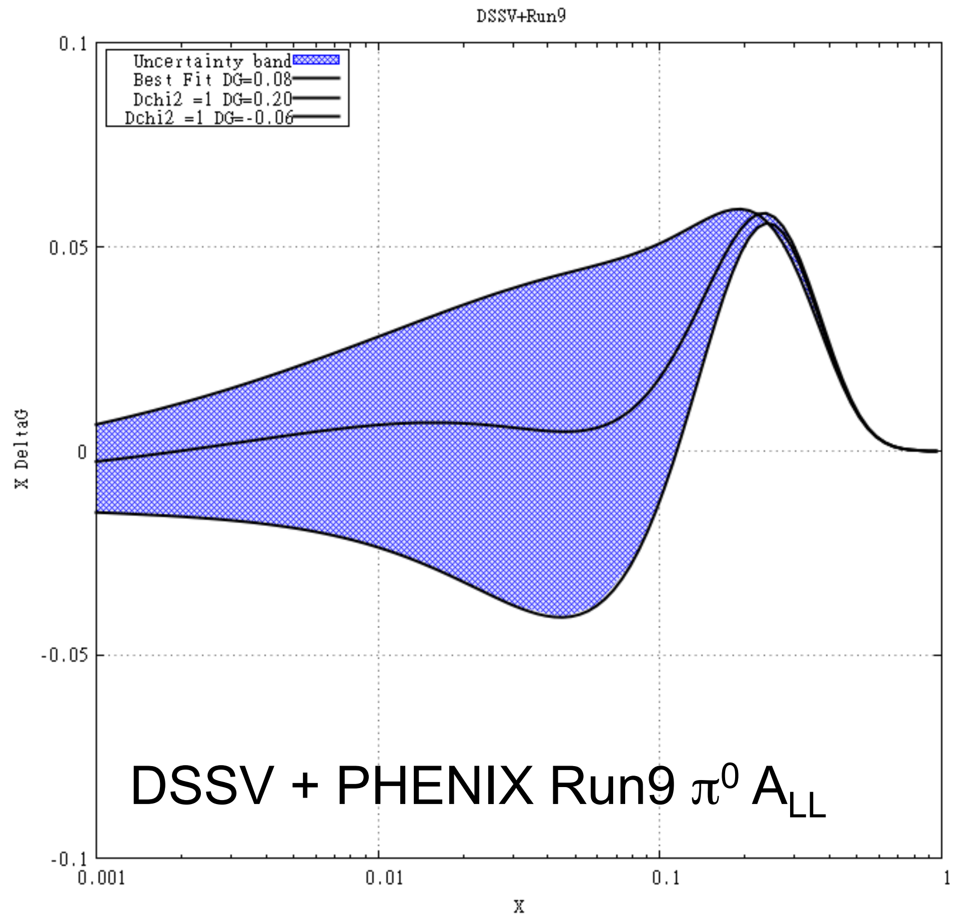
[1] Phys. Rev. Lett. 101, 072001 (2008);
Phys. Rev. D80 (2009) 034030.

Global Fit including Run9 π^0 A_{LL}

By S.Taneja et al (DIS2011)

ala DSSV with slightly different uncertainty evaluation approach



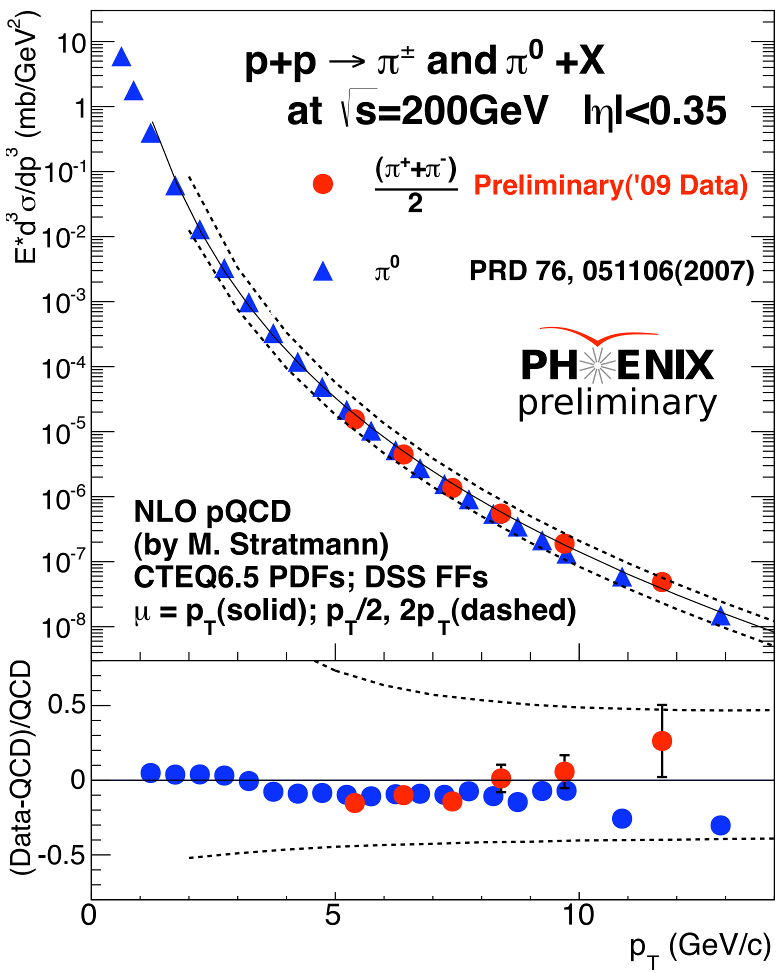


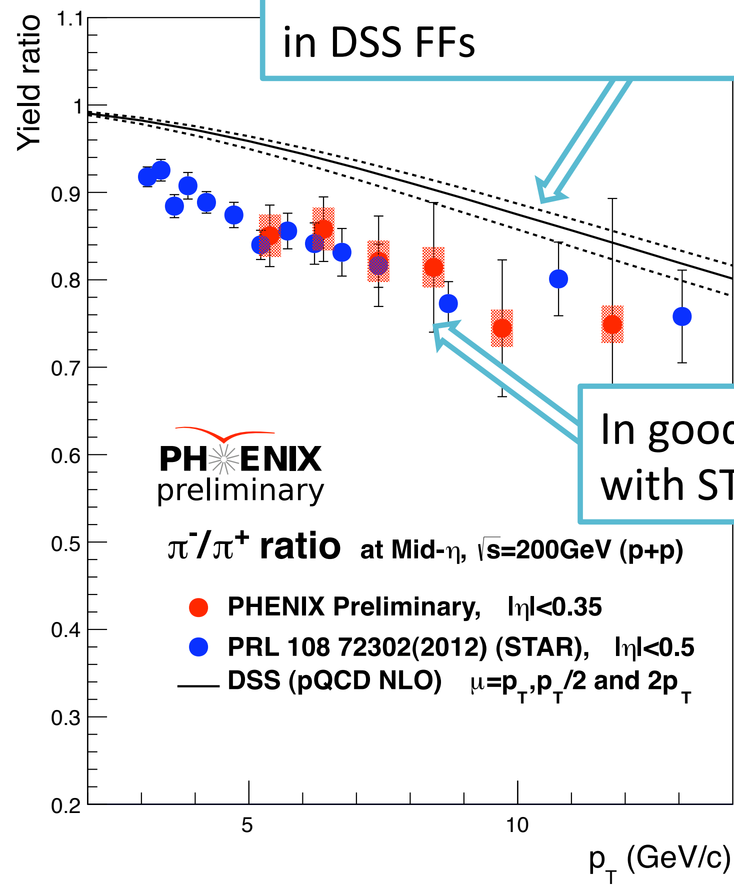
A node at x~0.1 ?

No node …

Uncertainties decreased

Charged pion Cross Section





Charge separated fragmentation functions are not well constrained in DSS FFs

In good agreement with STAR

PRD 83,032001 (2011)

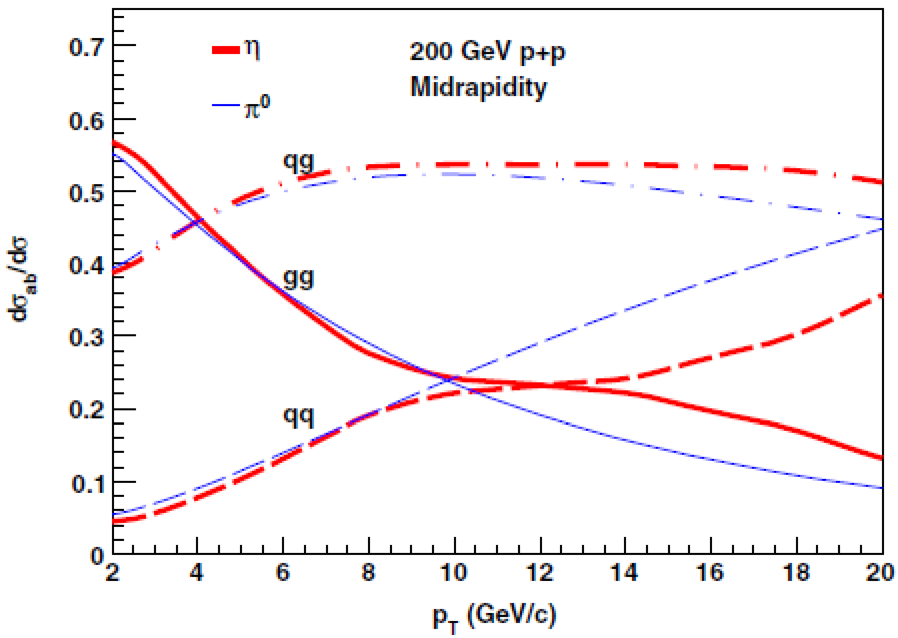


FIG. 4 (color online). The fractional contribution of gluon-gluon (gg), quark-gluon (qg), and quark-quark (qq) scattering to the η production in the pQCD calculation of Fig. 3, and to the π^0 production [24], as a function of p_T.

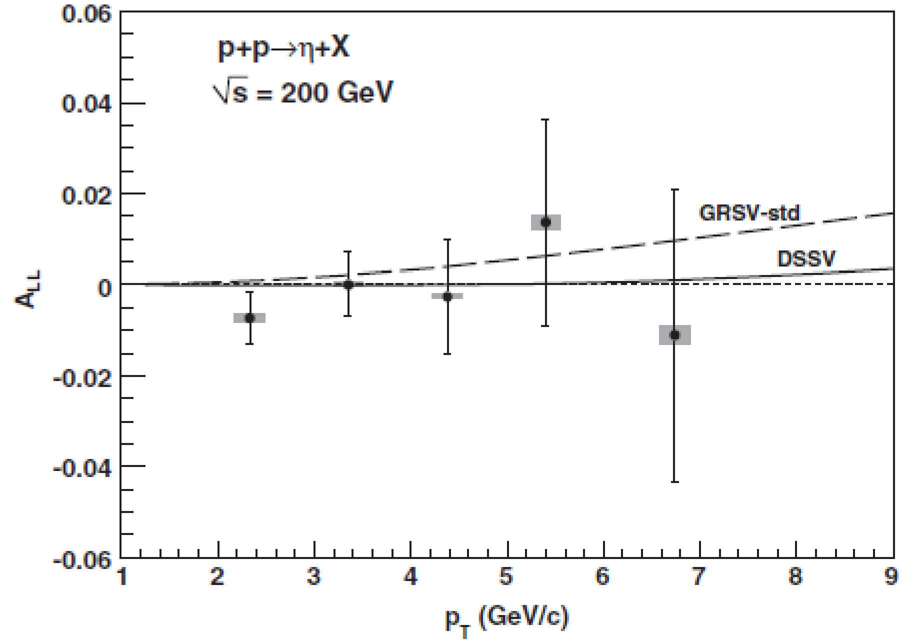
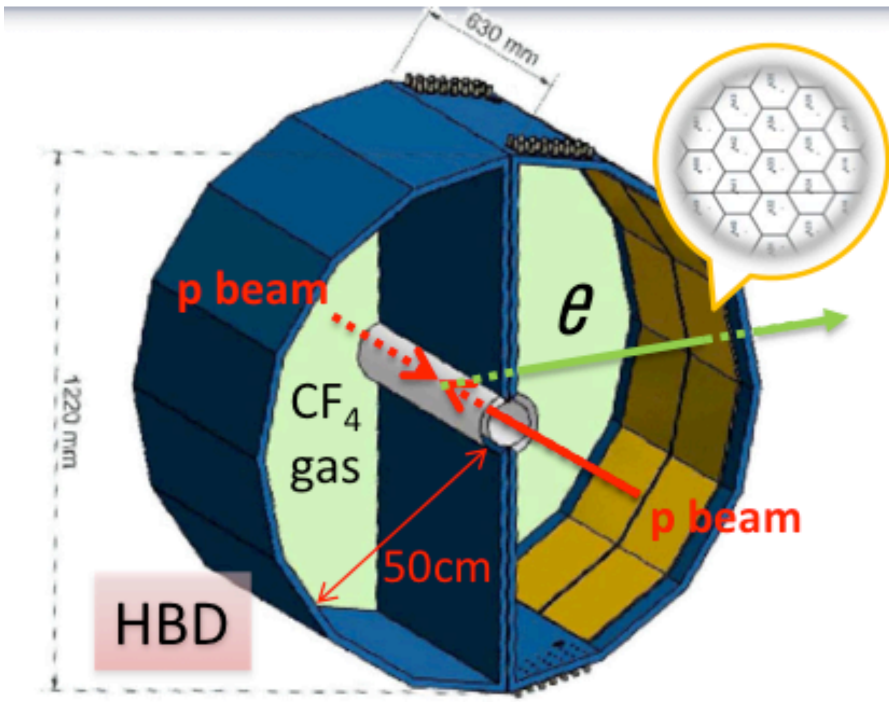
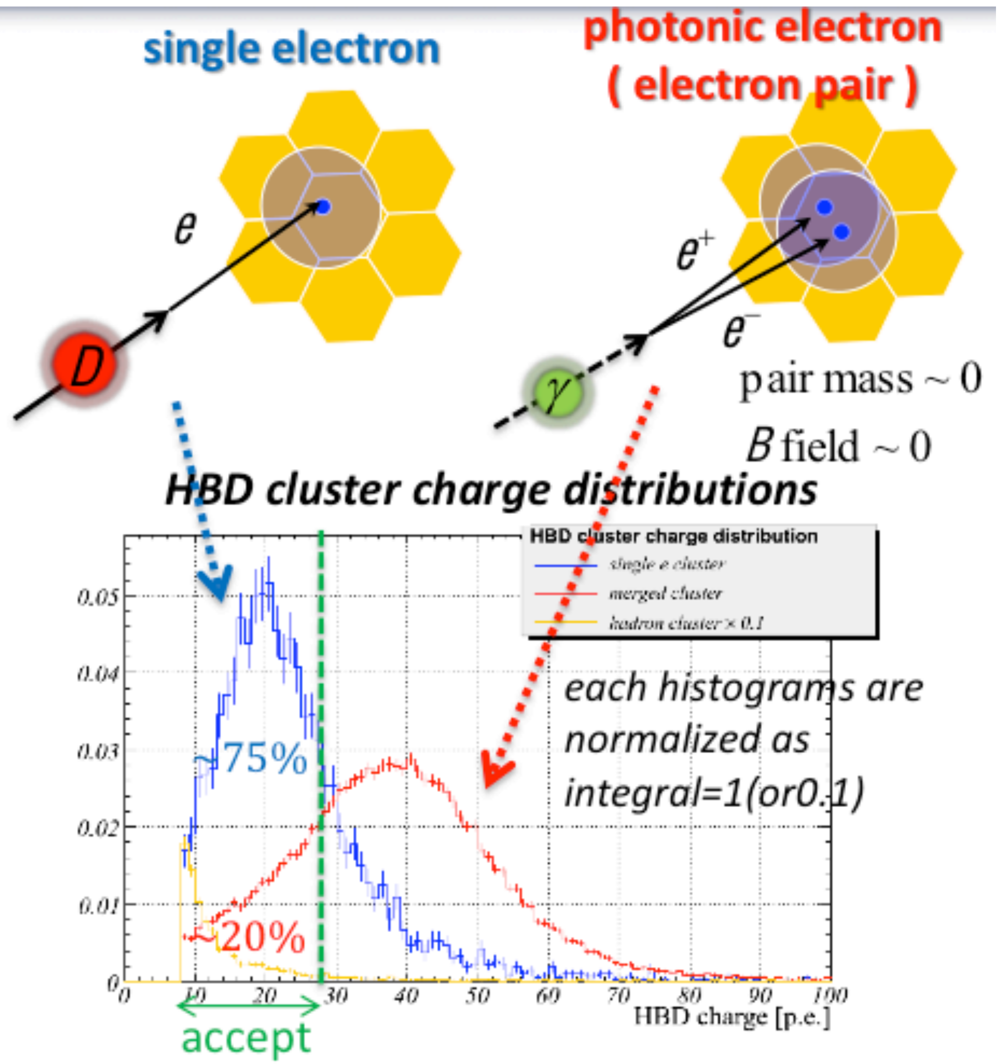


FIG. 6. The double-helicity asymmetry for midrapidity inclusive η production from the combined 2005 and 2006 data at $\sqrt{s} = 200$ GeV as a function of p_T. The gray boxes are point-to-point systematic uncertainties due to polarization and relative luminosity uncertainties and are correlated point-to-point, moving all points in the same direction but not by the same factor. An additional systematic uncertainty of 4.8% on the vertical scale due to the uncertainty in the beam polarizations is not shown. The results are compared to NLO pQCD calculations using two different sets of polarized PDFs [6,32]. See text for details.

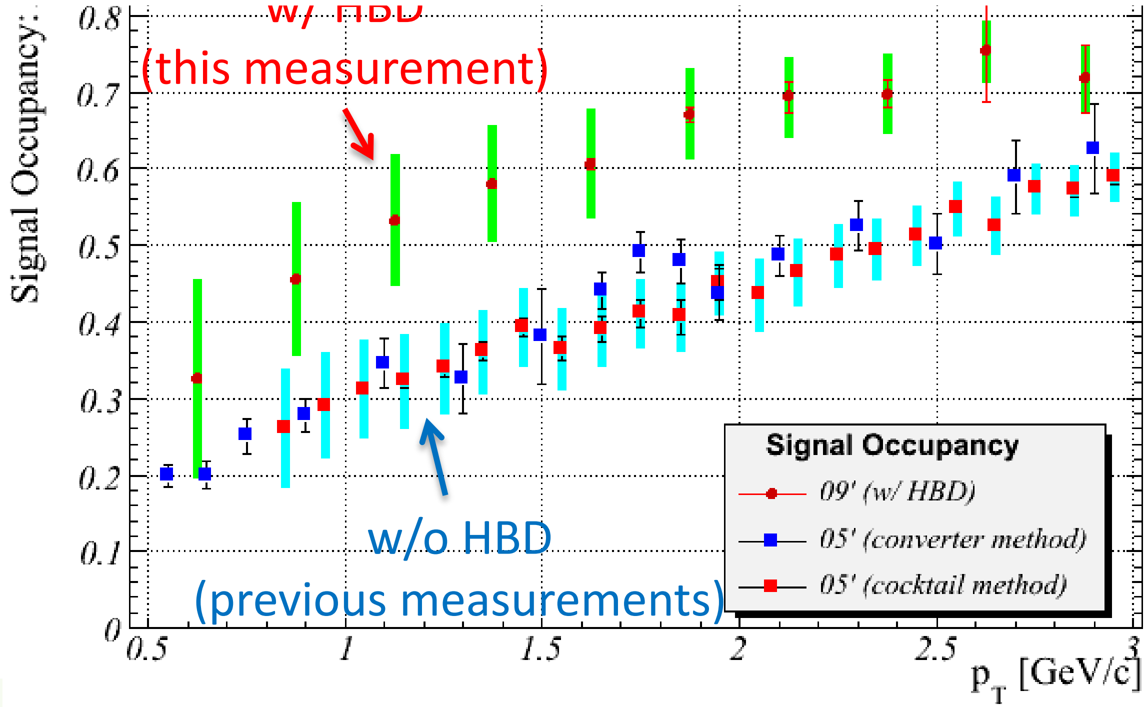
HBD Analysis for Heavy Flavor Decay e^-





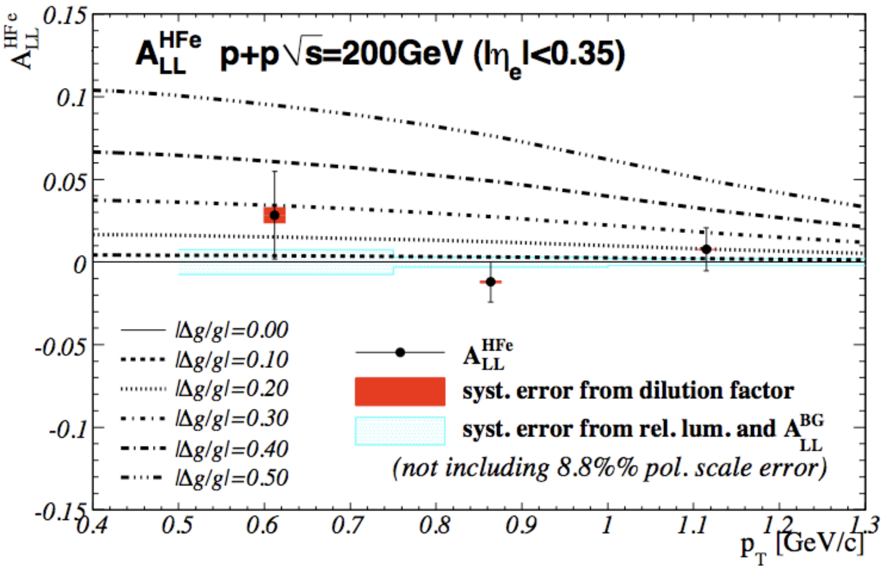
- **Hadron Blind Detector**
  - gas Cerenkov detector read out with CsI evaporated GEM
  - ***electron identification***
- **this analysis is the first time of physics measurement with HBD**

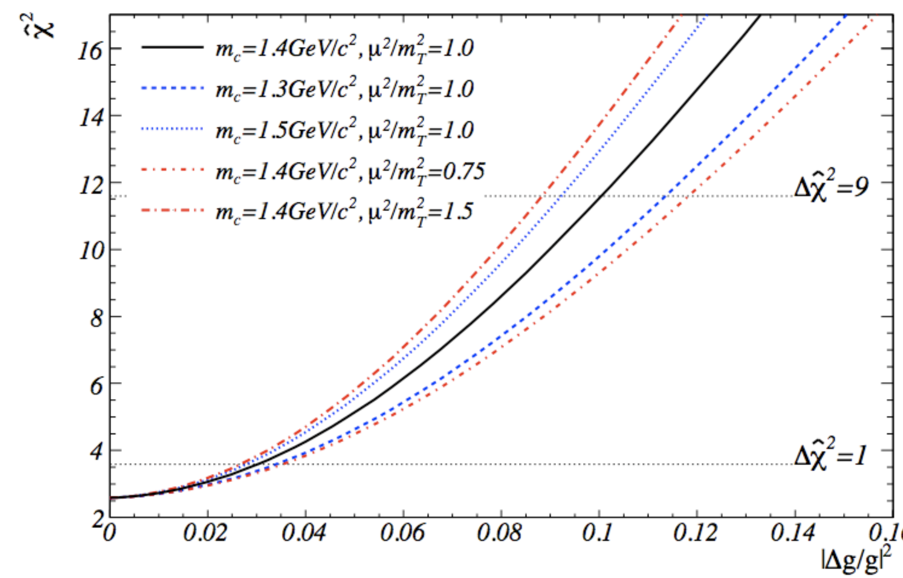
HBD Signal Occupancy



- **Signal Occupancy: *D***
  - the important value for the asymmetry measurement
  - increase by about ***factor of 1.5*** from previous

ΔG Extraction from A_{LL}^{HFe}





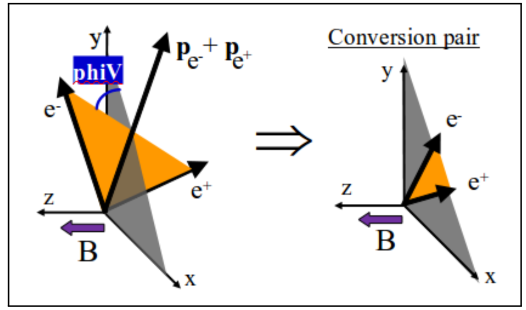
- Open charm production dominates in p_T range of 0.50 < pT < 1.25 GeV/c (J/ψ <2%, b quark<5%)
- pQCD prediction for $A_{LL}^{\text{open charm}}$ obtained from CTEQ6M PDFs + PYTHYA + LO hard scattering cross section

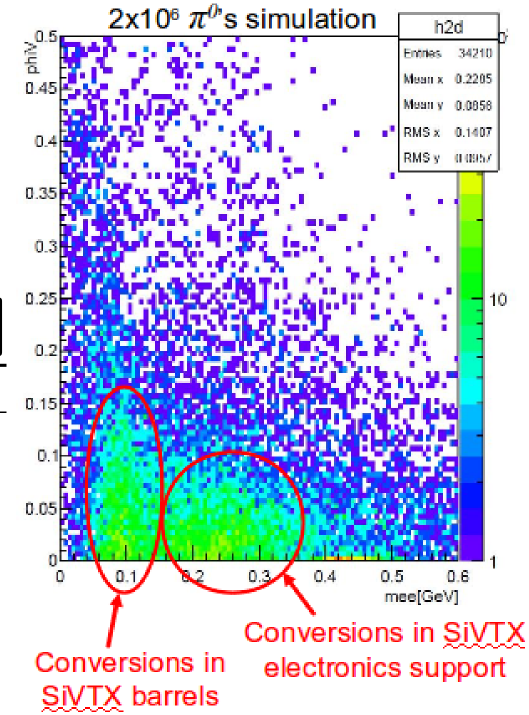
- $A_{LL}^{\text{open charm}} \sim |\Delta g/g(x, \mu)|^2$
- $|\Delta g(x, \mu)| = C\, g(x, \mu)$ is assumed
- Results:

$|\Delta g/g(\langle \log x\rangle,\mu)|^2 < 3.3 \times 10^{-2}$ (1σ) and 10.9×10^{-2} (3σ)

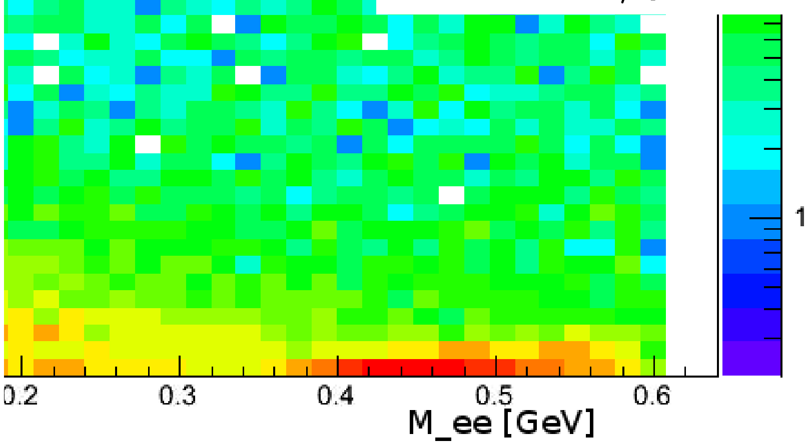
Central W Analysis

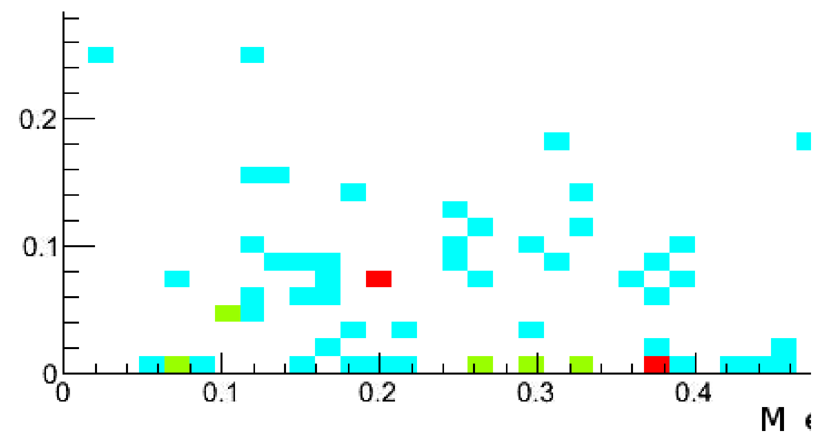
- phiV is a variable that describes the alignment between the plane of the electron/positron pair and magnetic field





- The conversions lie at small phiV (smaller than 0.15) and small invariant mass of the electron/positron pair





Central Arm A_L