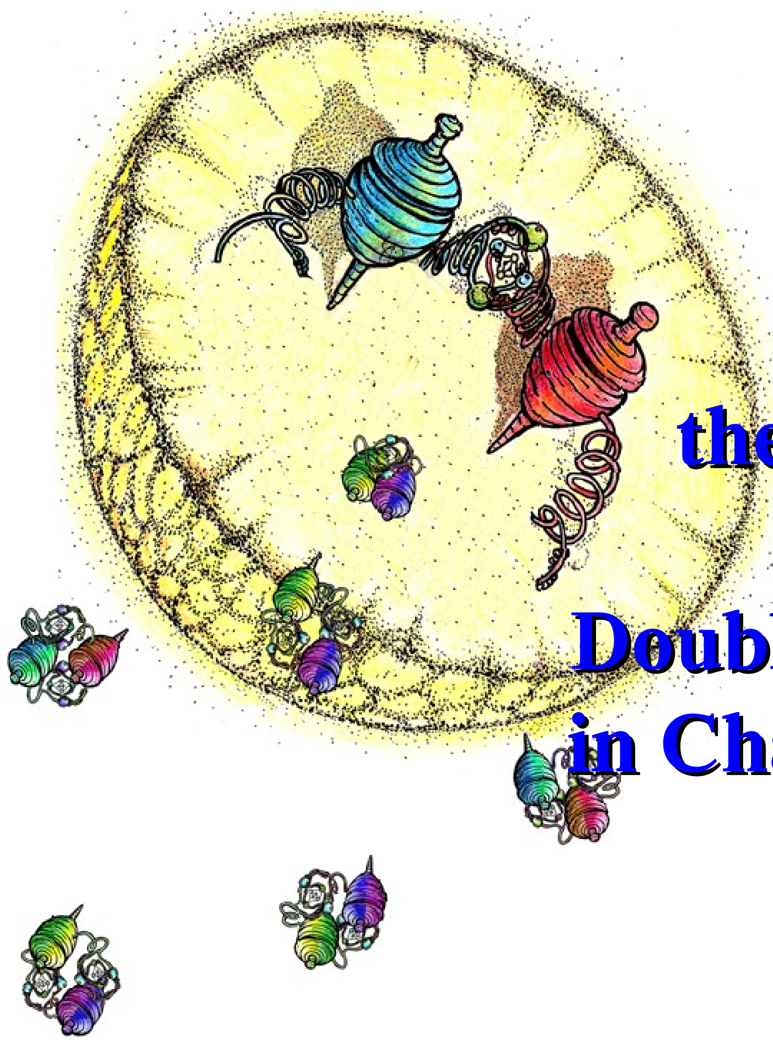
Illustration by Sebastien Pamentier & Astrid Morreale



Accessing the Gluon Polarization through the Double-Helicity Asymmetry in Charged Pion Production at PHENIX

Astrid Morreale

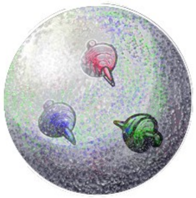
September 30th, 2006 RIKEN, Japan

Spin Structure of the Proton

Quarks and Gluons carry about 50% (each) of the longitudinal momentum

What about *spin*?

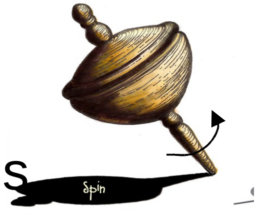
Valence quarks(QPM)



~30%

(QCD)

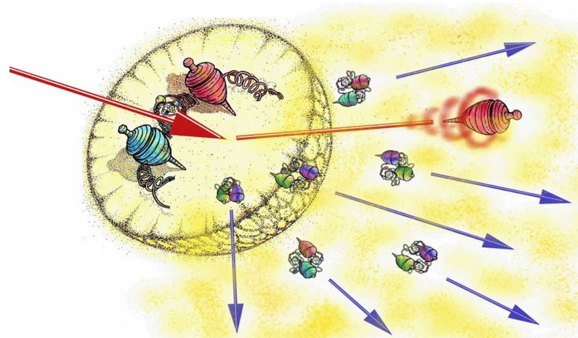
Gluons, sea quarks **~>,=,<0?**



~??

Orbital angular momentum contributions

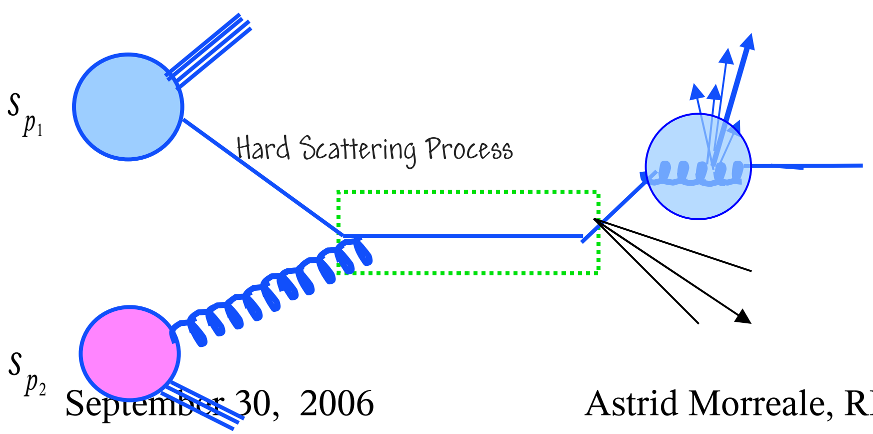
Hard Scattering Processes in PP collisions



FACTORIZATION:

It is assumed that a differential cross section section can be written as the convolution of a parton density and a hard scattering process

$$\sigma(pp \rightarrow hX) : f_q(x_1) \otimes f_g(x_2) \otimes \hat{\sigma}^{qg \rightarrow q\gamma}(\hat{s}) \otimes D_q^h(z)$$



- Structure functions (experimental input)
- pQCD hard scattering rates (calculable)
- Fragmentation functions (experimental input)

PARTONIC CONTRIBUTIONS AT MID-RAPIDITY

The pion's fragmentation function contains all long-distance interactions, they are not calculable but they are **universal:**

$$D^{\pi+}_{u} > D^{\pi 0}_{u} > D^{\pi -}_{u} \; , \; D^{\pi +}_{g} = D^{\pi -}_{g}$$

q-g starts to dominate for P_T>5GeV , pion production in this pT range is sensitive to both the gluon and the quark distributions, with different flavours having different weights for each pion species

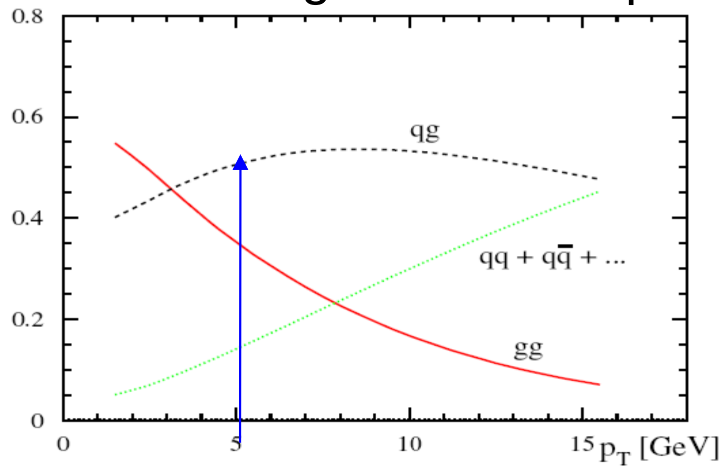
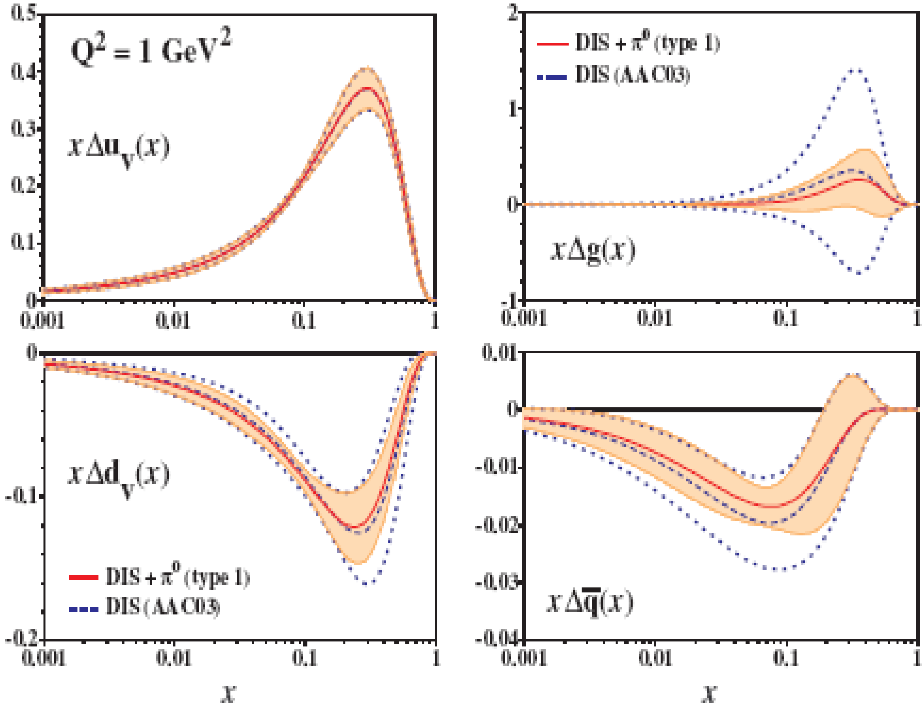


Figure 2: Relative fractional contributions of partonic processes to mid-rapidity pion production at $\sqrt{s} = 200$ GeV, calculated by W. Vogelsang.

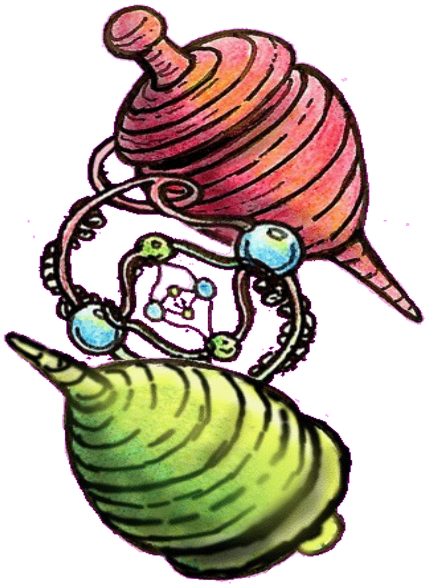
Polarized Parton Distribution Functions



arXiv:hep-ph/0603213 v2 28 Jun 2006
M.Hirai, S. Kumano, N.Saito

- Difference in probability between scattering off of a parton with one spin state vs. the other
- Function of $x_{Bjorken}$, -momentum fraction of the proton carried by the parton

PIONS



The **PI MESON** plays an important role in our quest:

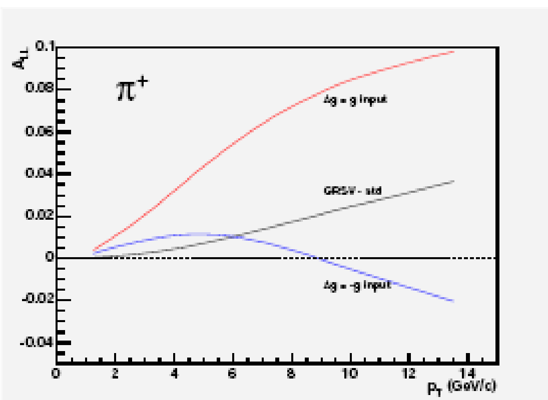
- Zero spin and composed of first generation quarks
- Pseudo scalar under a parity transformation: pion currents couple to the axial vector current.
- Production of pions proceed from **g-g** and **g-q** initiated sub processes on proton-proton collisions

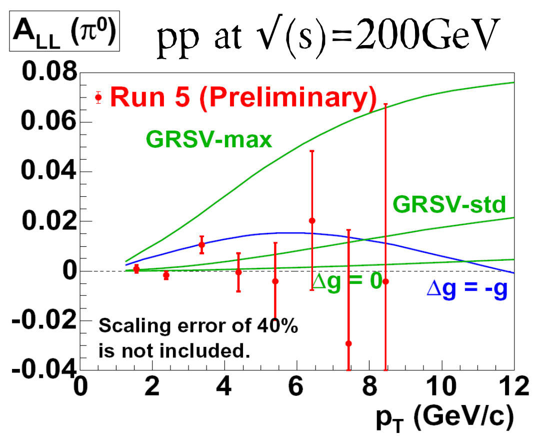
Charged Pion A_{LL}

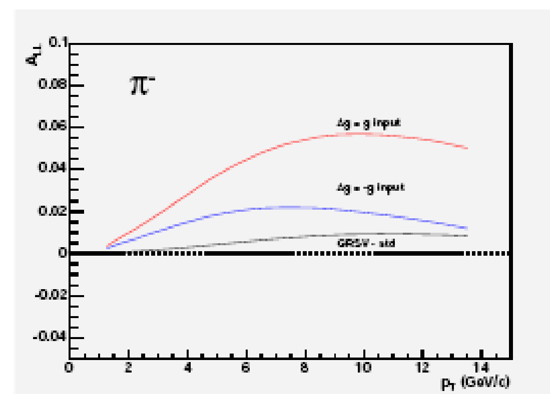
Charged Pion ALL has sensitivity to the sign of Δg

Just like in the pion's fragmentation functions the size of the asymmetries are ordered.

e.g, if $\Delta g>0$, then: $A^{\pi+}_{LL} > A^{\pi 0}_{LL} > A^{\pi -}_{LL}$







Predictions for A_{LL} of pi+ and pi- for various delta_g scenarios, from M. Stratmann(left and right) and preliminary neutral pion double asymmetries result(center)

CENTRAL SPECTROMETERS

Tracking

-Drift Chamber(DC),
 Pad Chambers(PC)

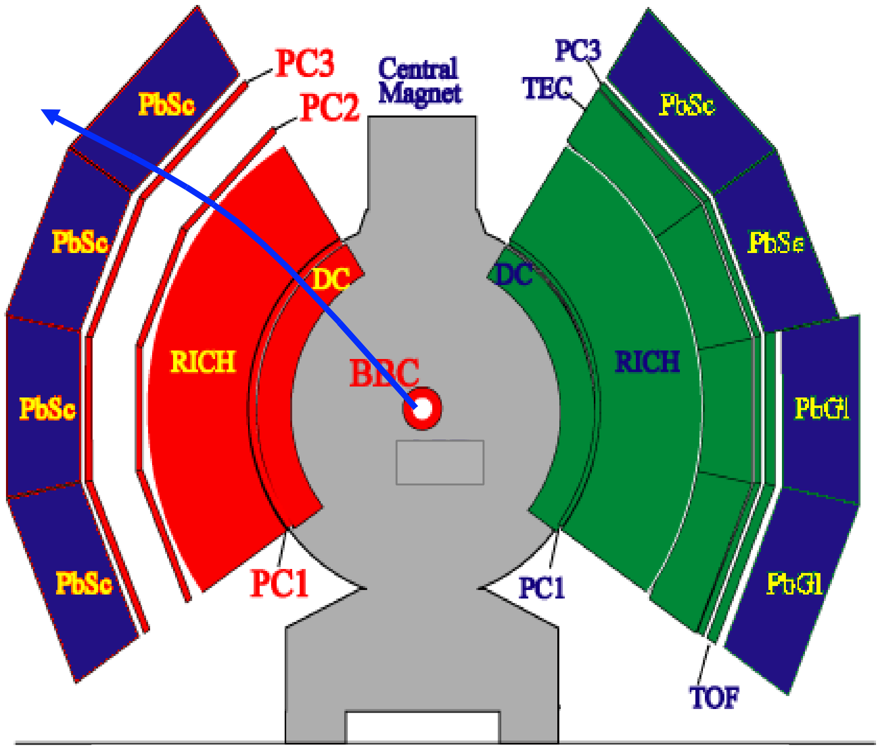
Electron and Hadron Identification

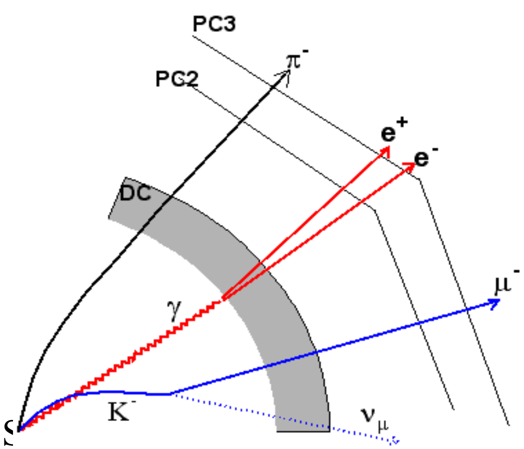
-Ring Imaging Cerenkov Counter(RICH

-ElectroMagnetic Calorimeter(EMCal)

Photons

-ElectroMagnetic Calorimeter (EMCal)



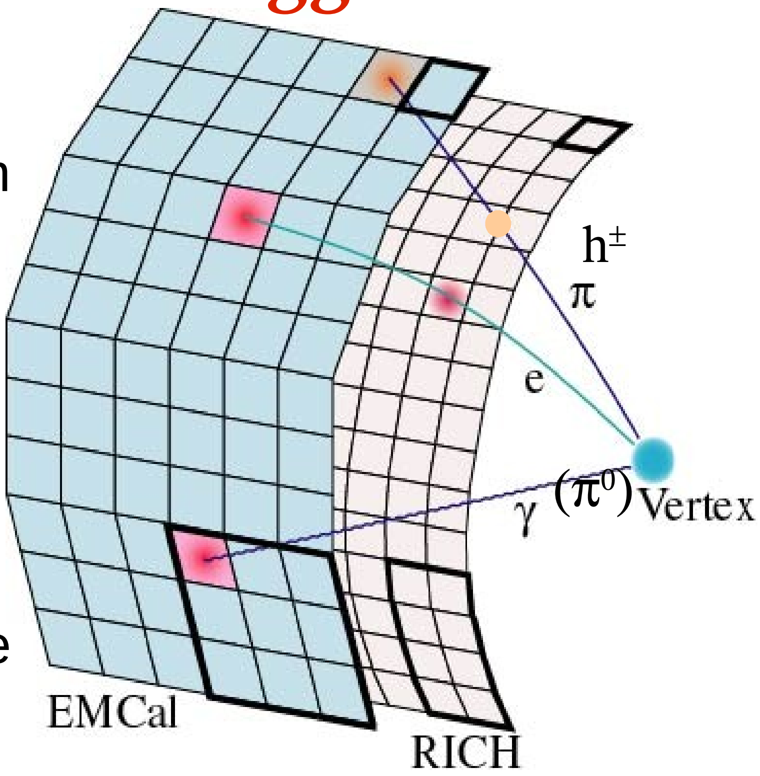


High-Energy EMCal trigger

RHIC's Massive detector PHENIX has a fine-grained calorimetry 100 times finer than previous collider detectors.

•Triggering in the central arms allow us to select high **pT** γ, e± and **charged pions** that produce a shower in the EMCal**.**

• We select the Pion signal and clean up the background created by other high Pt Particles by looking at different sub detector cuts and Identifying what Fast Particles produced Čerenkov light in the RICH.



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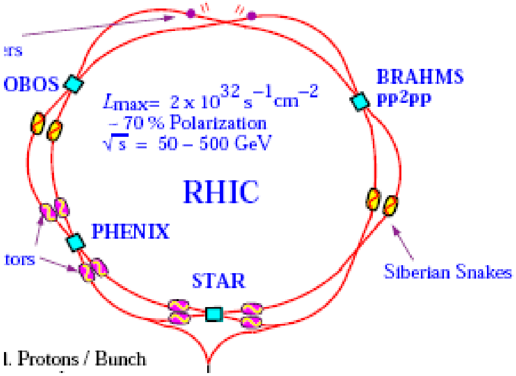
CALCULATING A_{LL}--Yields

After collecting all charged particles that passed our cuts, we then look at the number of particles detected with the polarized proton beams in different configurations



There are 120 bunch crossings, each bunch crossing has luminosity information and the spin pattern in each beam.

The charged pion yields are thus collected:

•By Transverse Momentum range(PT Bin)

•By Bunch Crossing.

A_{LL} is Finally calculated by Fill.

Double Longitudinal Asymmetries

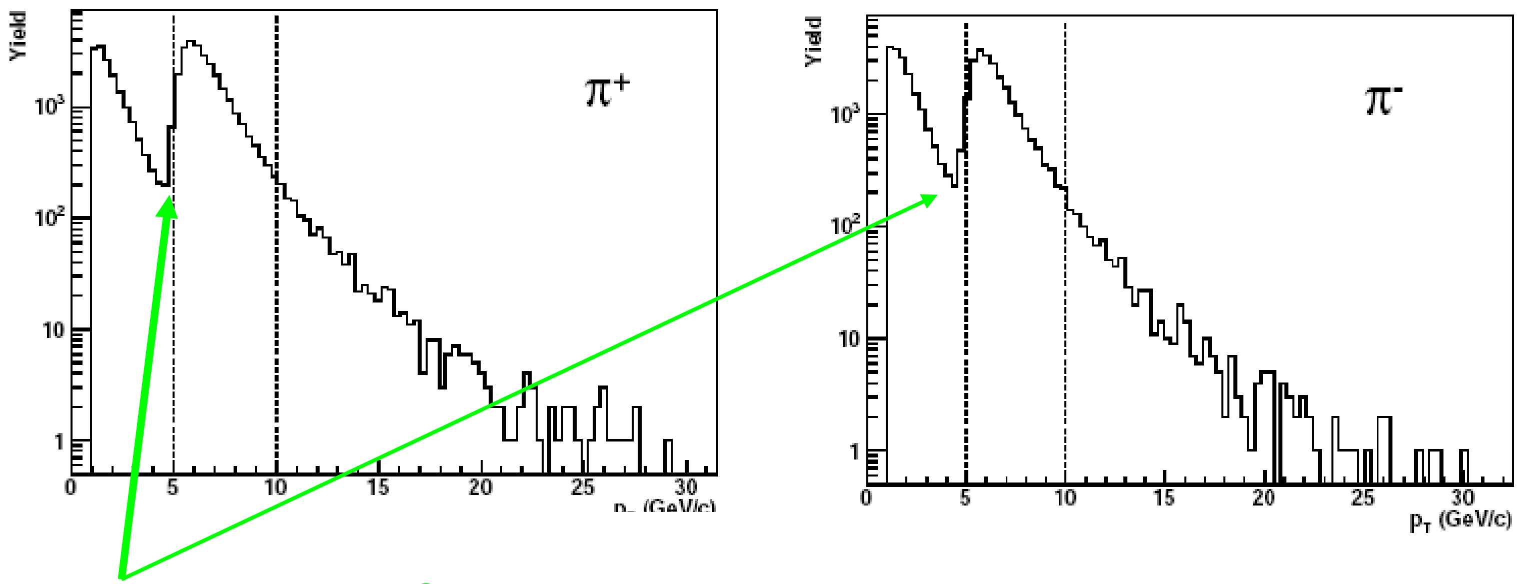
$$A_{LL}(p_T)=\frac{\sigma_{++}-\sigma_{+-}}{\sigma_{++}+\sigma_{+-}} \rightarrow \frac{1}{P^2}\frac{N_{++}(p_T)-RN_{+-}(p_T)}{N_{++}(p_T)+RN_{+-}(p_T)}, R=\frac{L_{++}}{L_{+-}}$$

$$\sim \frac{\Delta f}{f}$$

Where the N $_{\text{subscripts}}$ are the observed particle yields when the beams are polarized in different configurations P is the beam polarization ($P^2=P_1*P_2$) and R is the relative luminosity.

- Average Beam Polarization 49%.
- 0.89 billion triggered events analyzed, equivalent to 2.3 pb^-1,

PT SPECTRA OF PARTICLES

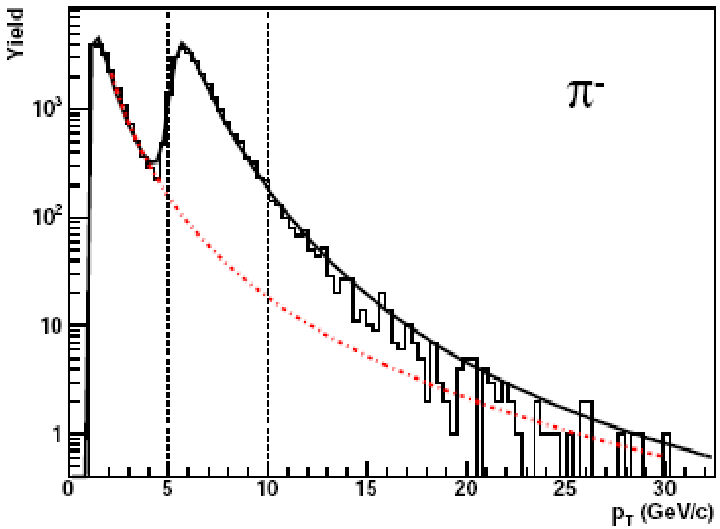


Pions start to fire RICH at 4.7 GeV.

PT spectra of positive(left) and negative(right) charged tracks passing detector cuts.

PT Spectrum Fit to power law.

-Conservative Estimate of Background



<~5% background

Background sources:

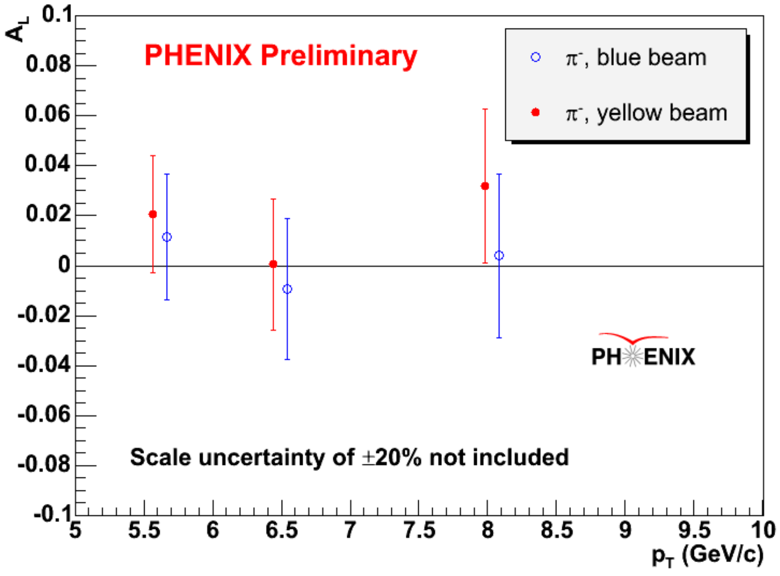
•charged hadron tracks randomly associated with a RICH ring.

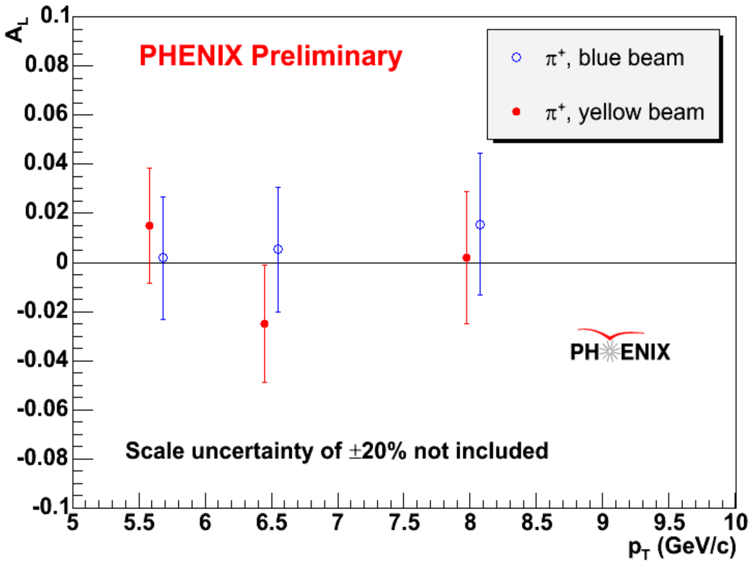
•conversion electrons with mis-reconstructed momentum (currently no PHENIX tracking close to the beam-pipe.)

RESULTS

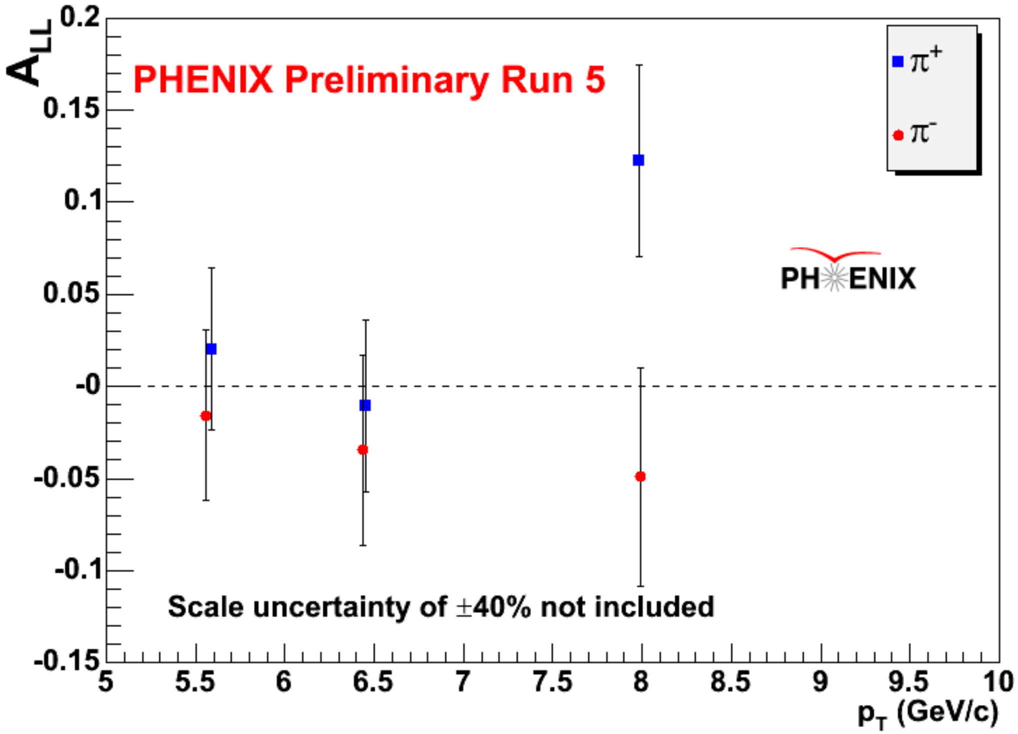
SINGLE SPIN ASYMETRIES

Parity-violating longitudinal spin asymmetries A_L are expected to be consistent with zero

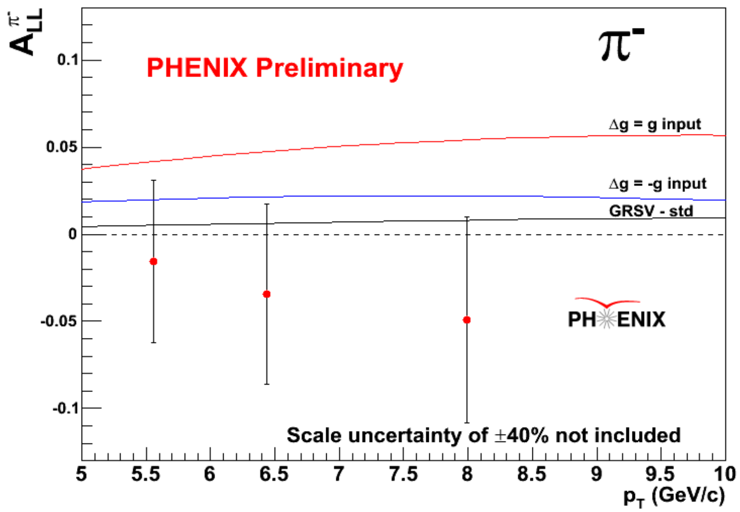


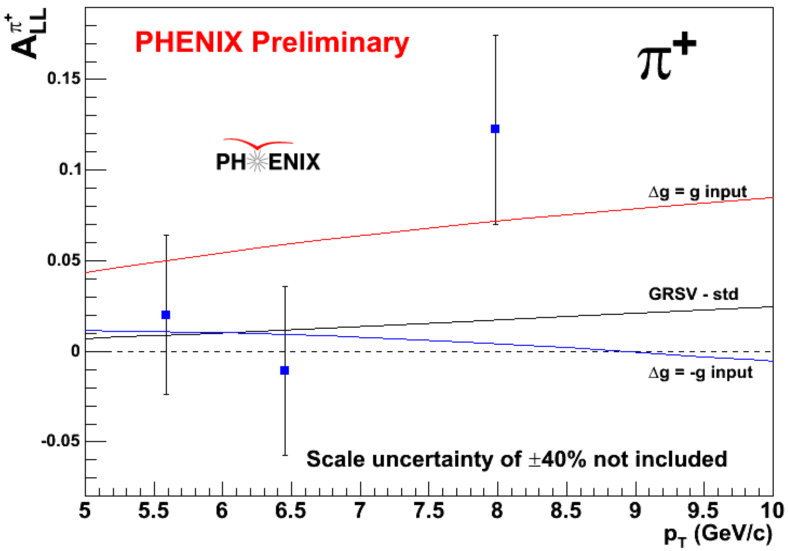


Double Spin Asymmetries for Both Charged Species

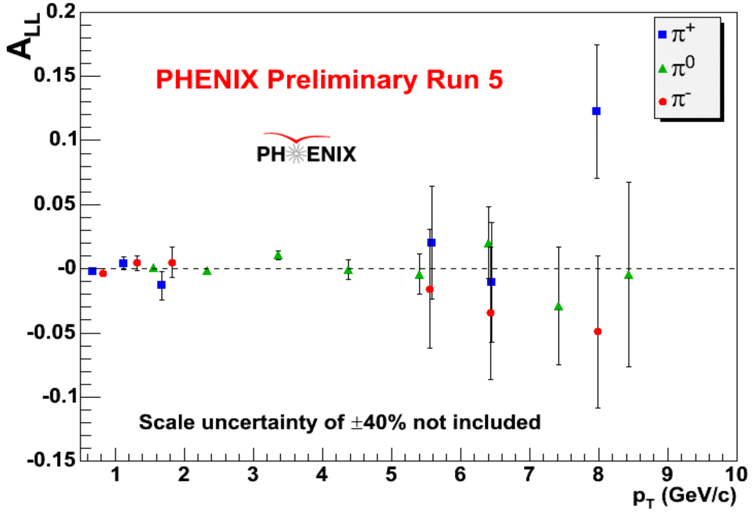


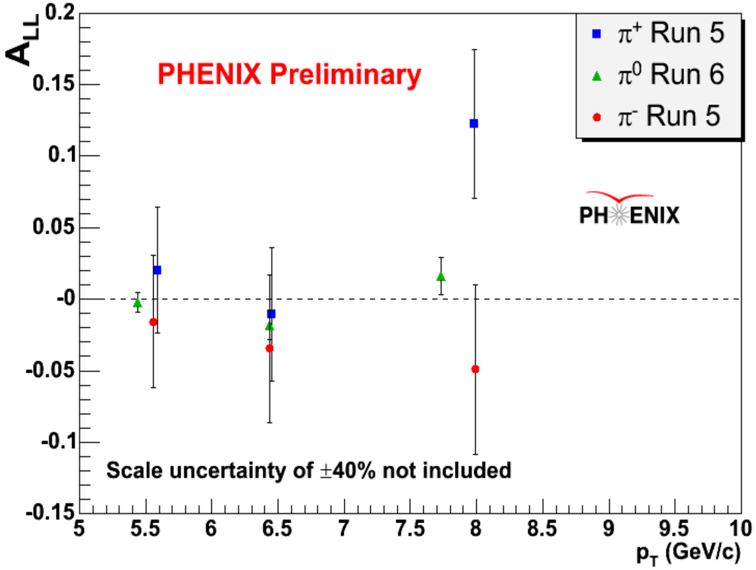
Results Compared to Theoretical Parametrizations





Combined Pion Species Results

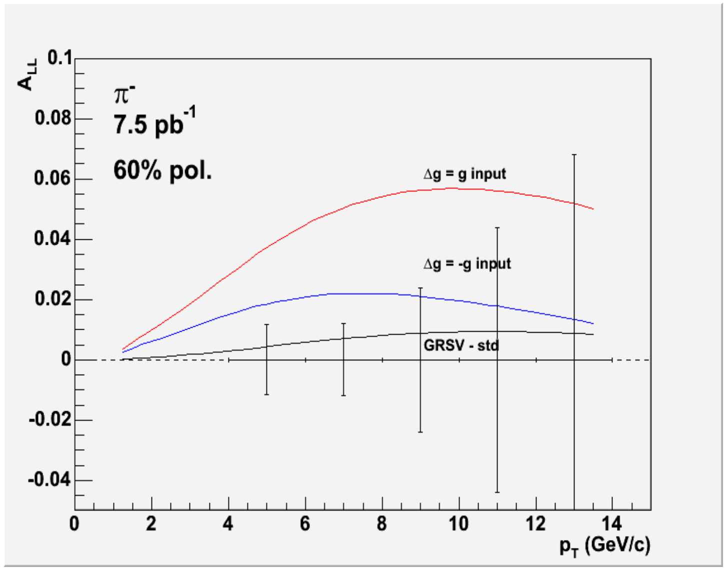


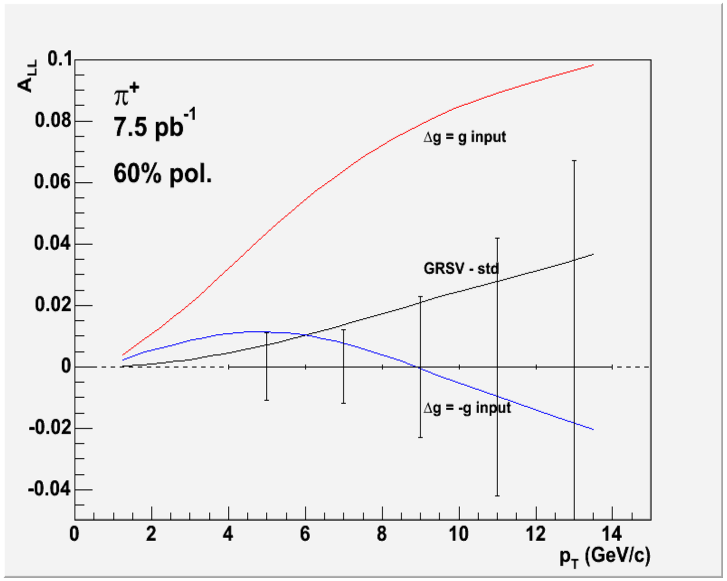


Asymmetries for charged pion in Run-05 are compared to neutral pion results.(Run-05 π^0 left, Run-06 level2 trigger π^0 Right)
*Left plot includes low PT charged pions.

Run-06 Projections

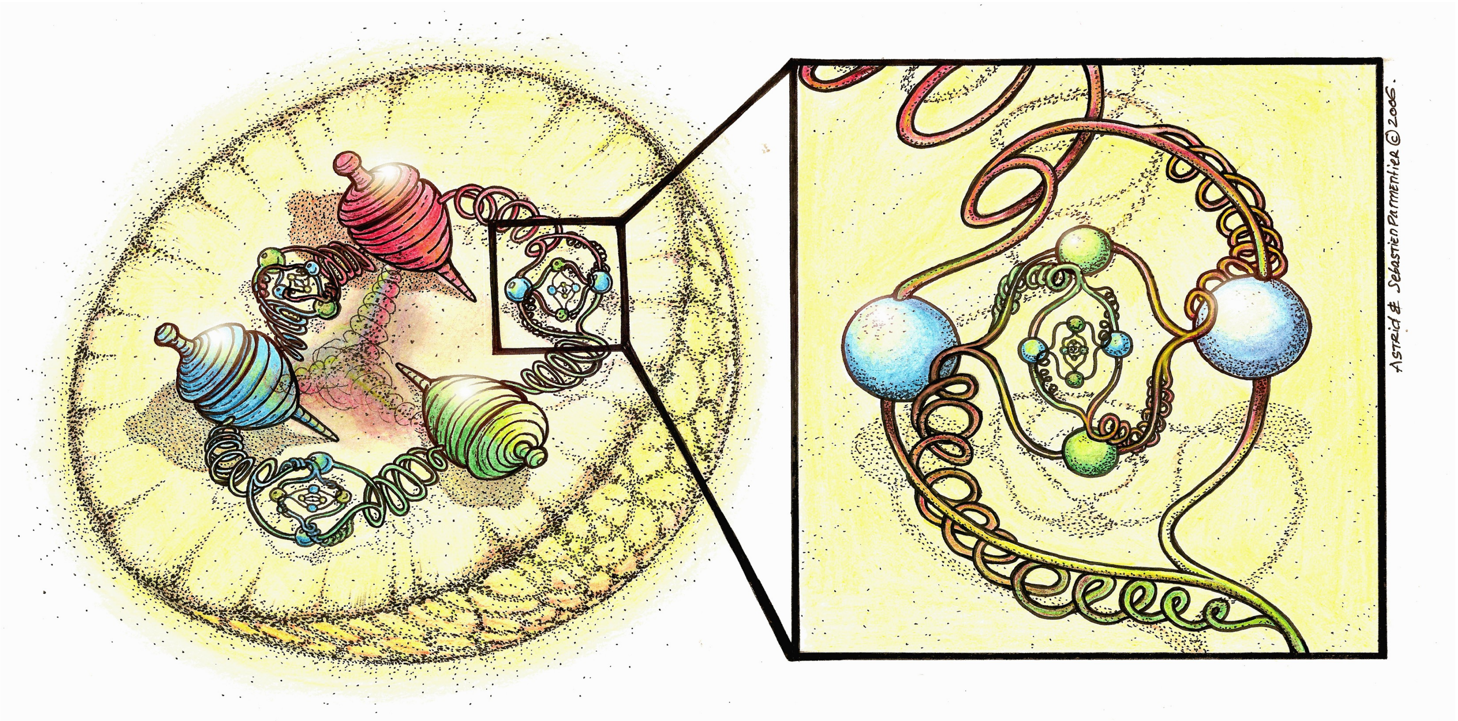
Run-06 PHENIX data with higher statistics and polarization will provide greater sensitivity





Projections for Run-06 for negative pions(left) and positive pions(right)

FINAL REMARKS



- **Global studies** aid in the understanding of the gluon's contribution to the proton spin.
- Combined analysis of all three pion species at RHIC can provide valuable information on both the sign and **magnitude of Delta-g**
- This analysis will be repeated for **run6 data** as this becomes available

BACKUP SLIDES

Cuts

- |BBC zvtx| < **30** cm
- Track quality **31** or **63**
- |zed| < **70** cm
- **5** < p_T < **10** GeV/c
- RICH hit (**n1** > 0)
- Shower-shape: prob < **0.2**
- e/momentum<0.9
- p_T-dependent energy cut:
- emce > 0.3 + 0.15p_T
- PC3 matching (< **3**sigma in z and phi)***
- EMCal matching (< **3**sigma in z, phi)

Sources of background

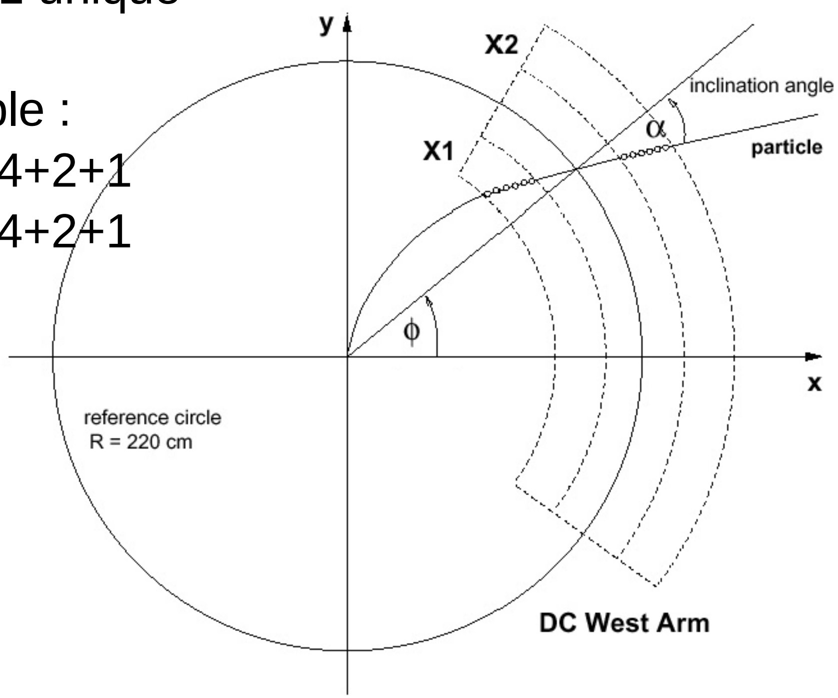
- RICH threshold $\gamma \sim 35$ → 0.017, 3.5, **4.7 GeV/c** for e, μ, π
- e/π and $\mu/\pi < 10^{-3}$ for primary e and μ
  - Small!
  - other non-primary background:
    - –Conversion electrons generated in front of the DC or inside the X1 layer, which fire the RICH and are often reconstructed with a (false) high momentum
    - –Decay or primary charged particles which don't fire the RICH but are randomly associated with a RICH ring. Found random assoc. probability ~0.4% in d+Au.

quality

Quality of the Drift Chamber tracks

0 (1)   X1 used
1 (2)   X2 used
2 (4)   UV found
3 (8)   UV unique
4 (16) PC1 found
5 (48) PC1 unique

For example :
63=48+8+4+2+1
31=16+8+4+2+1



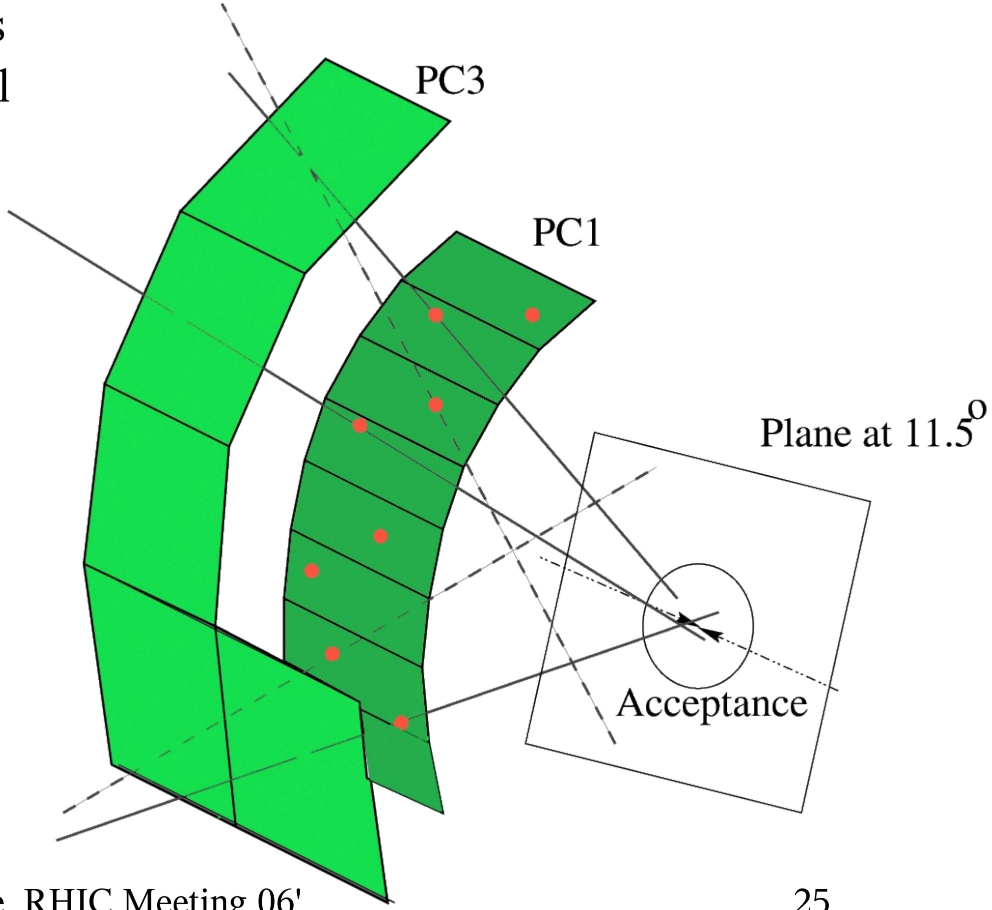
- First look for tracks with X1 and X2 hits
- Remaining unassociated hits go into X1 only and X2 only tracking
- Z coordinates of tracks are defined by PC1-UV-vertex tracking
- When PC choice is unique, stereo wires try to verify. If they do, then UV hits exist and are unique by construction. When they don't, there are no UV hits. If PC has more than one available choice, the UV are consulted for the "best match". In this case one either gets no UV, a best choice, or remaining ambiguity (tied).

zed

Z coordinate at which the track crosses PC1

The vertex position is determined by:

1) Combining all PC1 and PC3 hits to lines
2) Project the lines to the plane and save all within an appropriate X and Y window.
3) Calculate the peak position of the Z distribution.

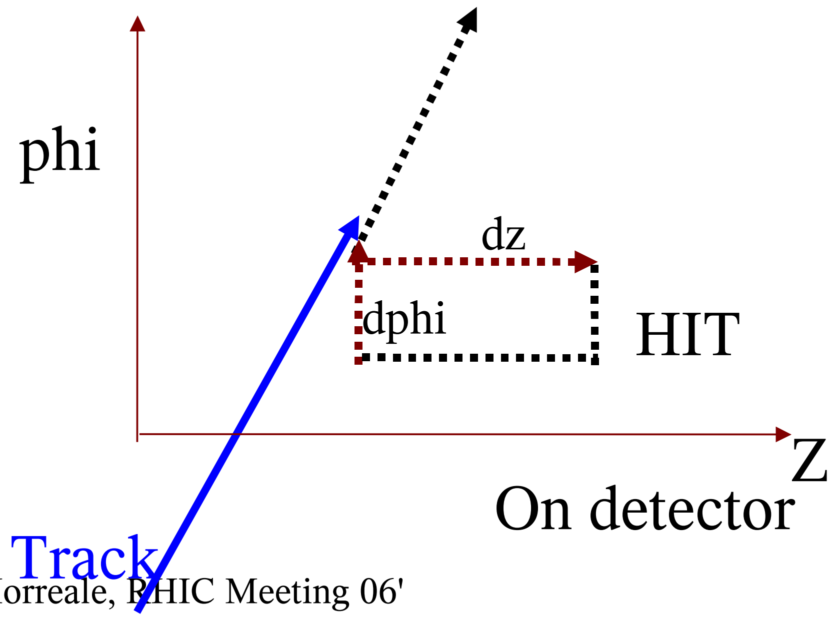


pc3sdz , pc3sdphi (emcsdz, emcsdphi)

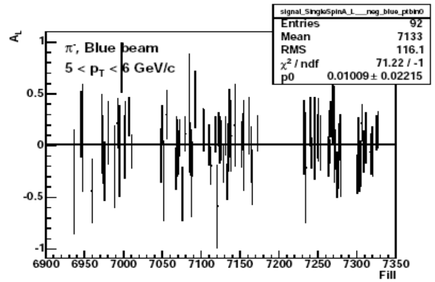
Difference in Z(cm)/phi(rads) between the track model projection and the hit in the pc3 (EMCal) normalized to sigmas. .

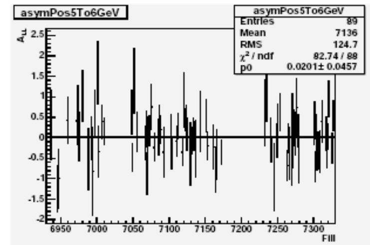
spc3sdphi

Difference between the track model projection and the measurement normalized to sigmas, but for the z-swapped projection.

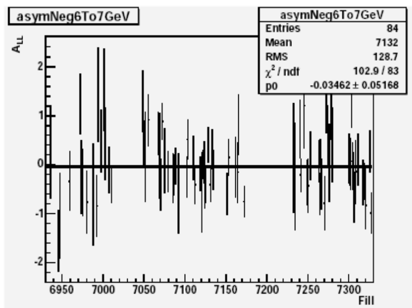


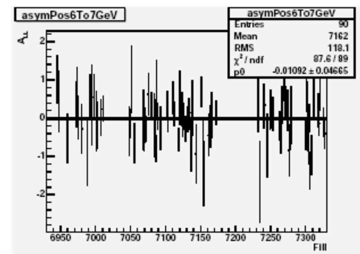
Double Spin Asymmetries vs Fill





Fill by Fill Asymmetries fitted to a constant

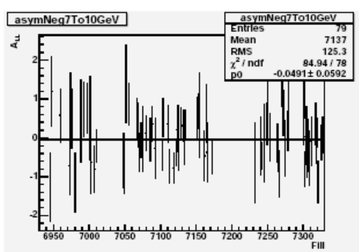


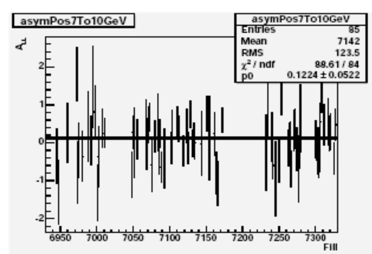


p_T 5-6 GeV Top

p_T 6-7 GeV Middle

p_T 7-10 GeV Bottom





Negative pions(Left)
Positive pions(Right)