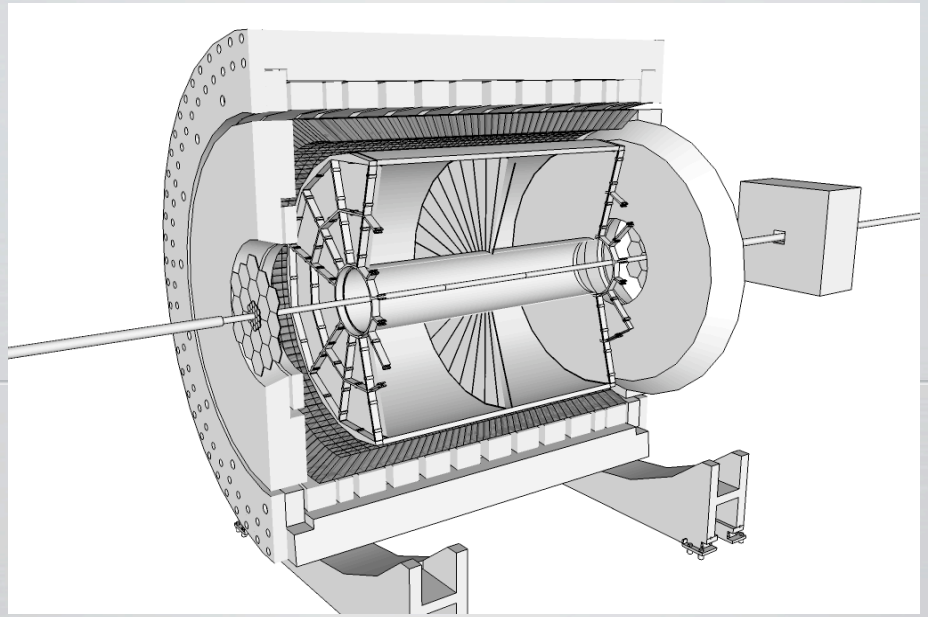
STAR Spin Status & Plans



Renee Fatemi

for

the STAR Collaboration

2012 - Productive run for RHIC & STAR

200 GeV Transverse (P^2L FOM = 7.7 pb^{-1})

- Mid-rapidity Collins Asymmetries
- Mid-rapidity Interference Fragmentation Function A_N
- Progress on Forward direct photon A_N
- FGT Commissioning

510 GeV Longitudinal (P^2L FOM = 25 pb^{-1} P^4L FOM = 6.3 pb^{-1})

- Extend low x reach of inclusive jet A_{LL}
- Increased statistics on dijet A_{LL}
- First run with substantial statistics for W A_L
- First data taken with FGT

STAR in 2012 and Near Future

Tracking: TPC

Particle ID: TOF

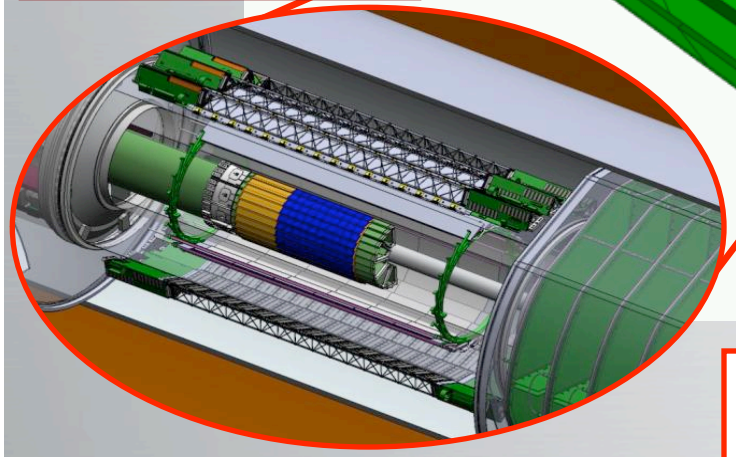
Electromagnetic Calorimetry: BEMC+EEMC+FMS ($-1 \leq \eta \leq 4$)

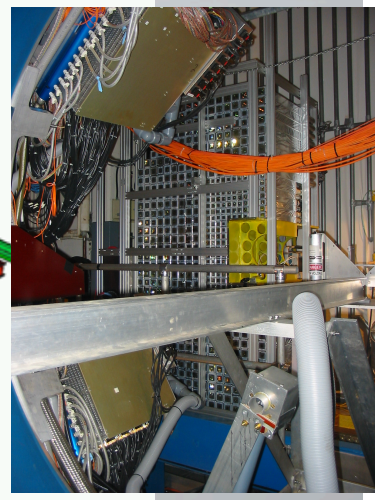
Recent upgrades: DAQ1000 TOF

Plus upgrades to Trigger and DAQ

Muon Telescope Detector (runs 13/14)

Heavy Flavor Tracker (run 14)





Forward GEM Tracker (runs 12/13)

Full azimuthal particle identification over a broad range in pseudorapidity

Future of STAR Spin?

Decadal Plan outlined two focus areas

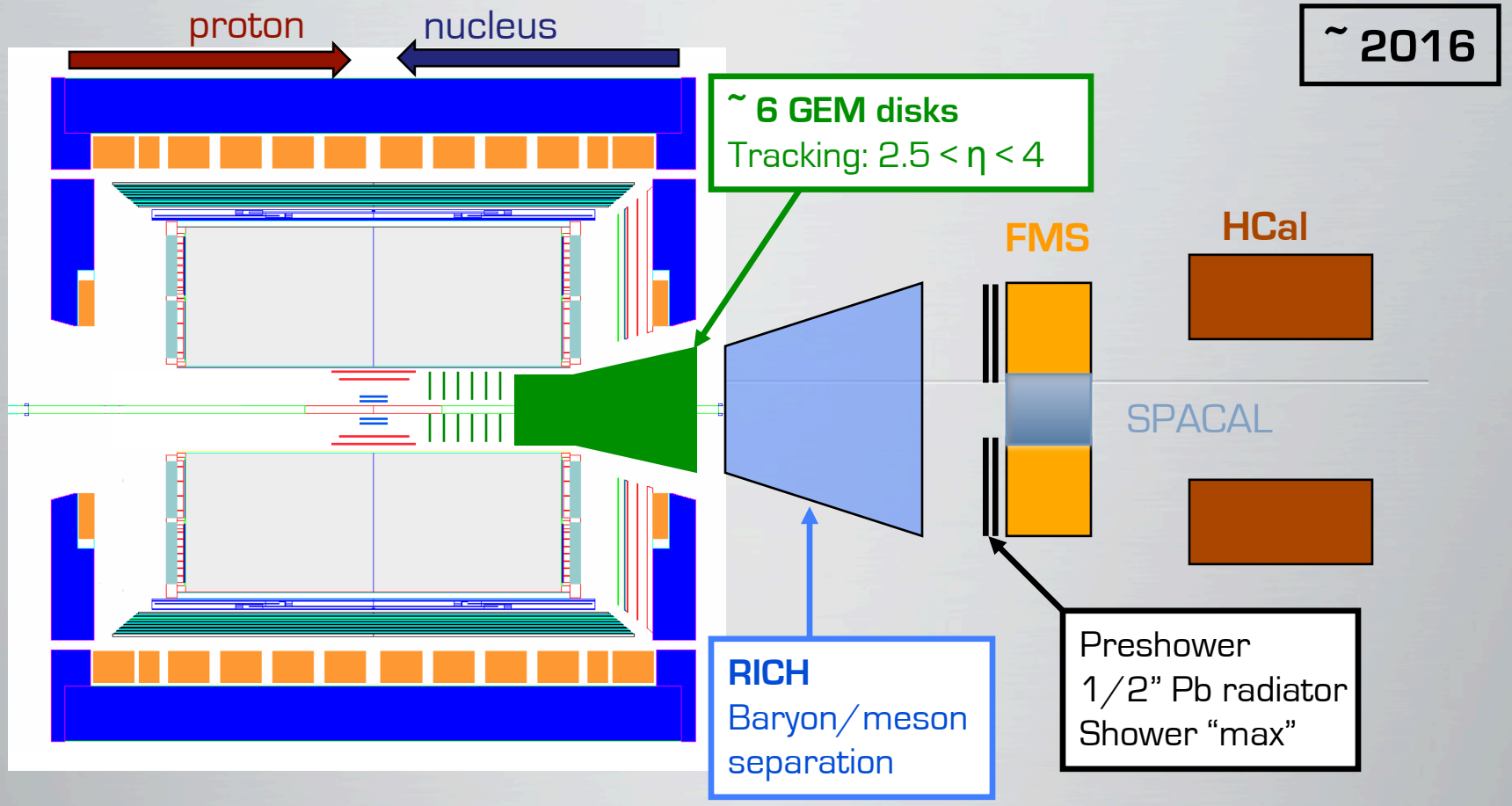
I. Spin structure of the nucleon

- Gluon Helicity
- Quark Helicity
- Quark Transversity

II. How to go beyond leading twist and collinear factorization?

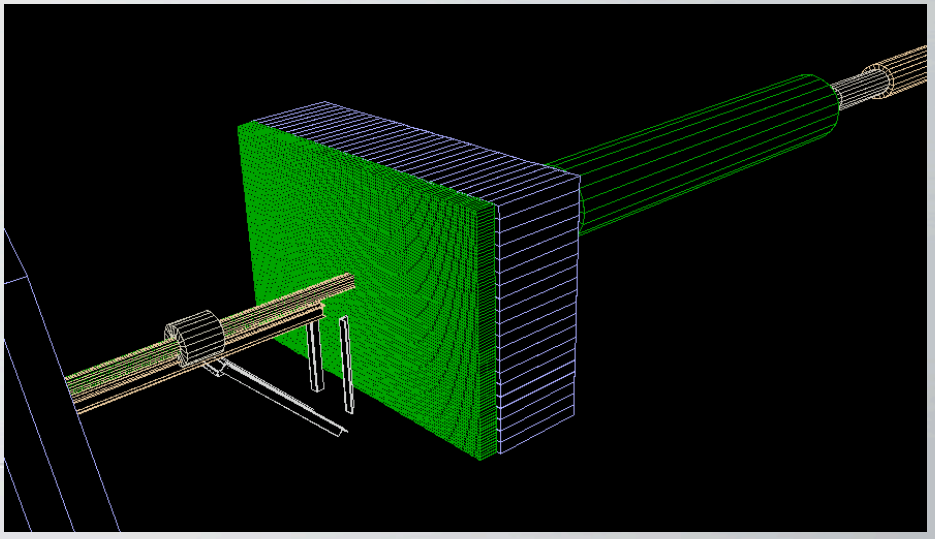
- Untangling source of large forward SSA
- Understanding process dependence of Sivers functions
- Probing differences in evolution of TMD and collinear FF

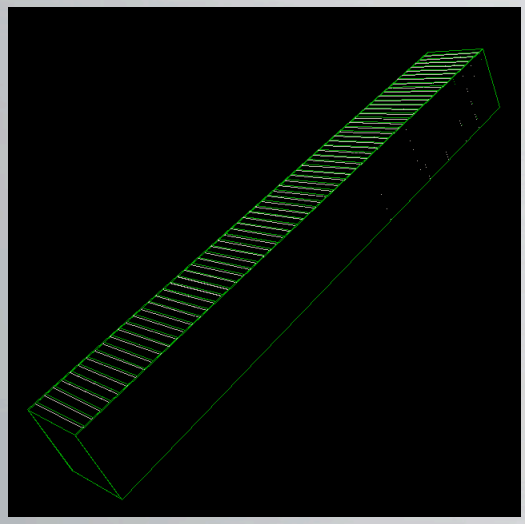
STAR Forward Instrumentation Possibilities



Calorimeters: SpaCal + HCAL

- SPACAL: Scintillating plastic fibers embedded in a lead matrix
- Efficient reconstruction of π^0 up to 100 GeV.
- Good e/h rejection at ~80 GeV. (x1000 @ 90%)
- Reasonably good electromagnetic energy resolution. (~15%/√E(GeV))





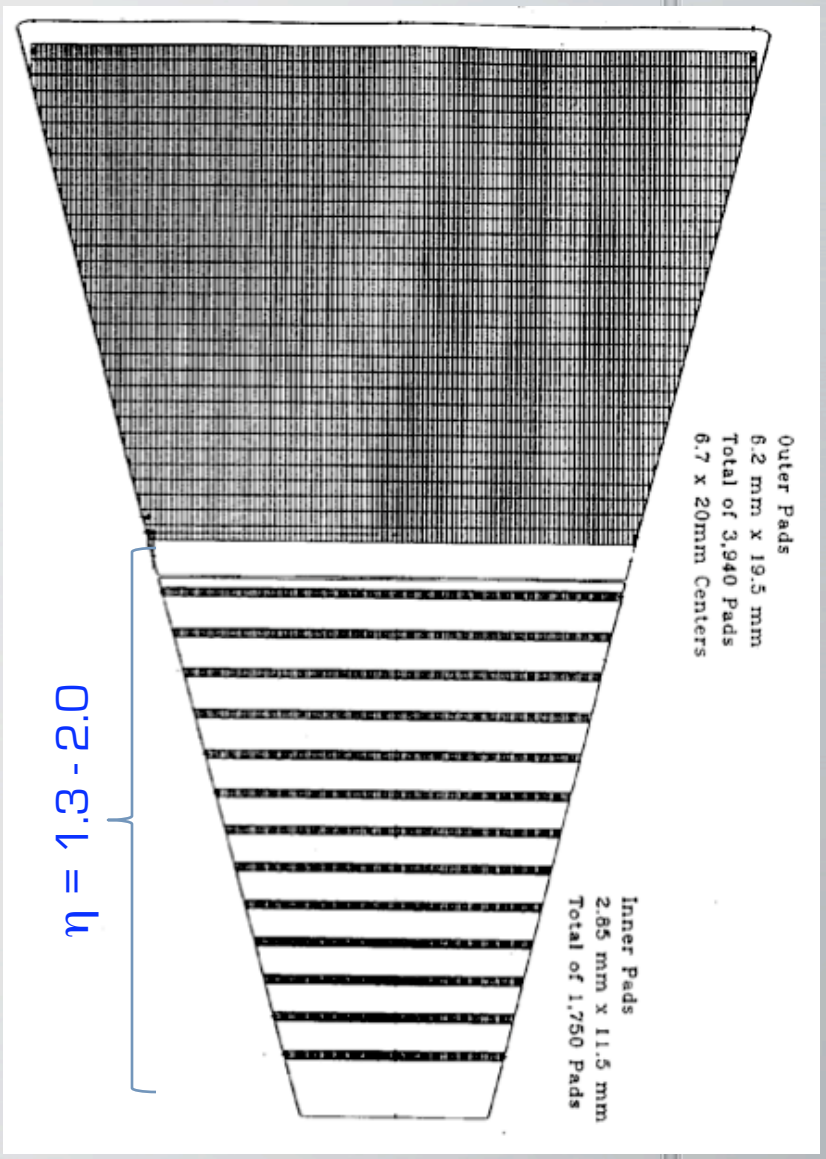
• HCAL follows ZEUS design of Pb/Sc compensated sampling calorimeter.

• For STAR, stack will consist of 65 layers of 10 mm thick lead plates with 2.5 mm scintillation tiles in between.

• The first and the last absorber tiles will need to be made of steel.

Also...a TPC inner sector upgrade!

- 24 sectors - 12 on each side
- Large pads for good dE/dx resolution in the outer sector
- Small pads for good two track resolution in the inner sector
- More pad rows and larger pads in the inner sector
- Current inner sector pads only cover ~20% of the area
- Individual pads are smaller than necessary (3.35 x 12 mm pitch)
- Redesign the inner sector pad planes with somewhat larger pads (e.g., 4.8 x 16 mm) covering the full plane

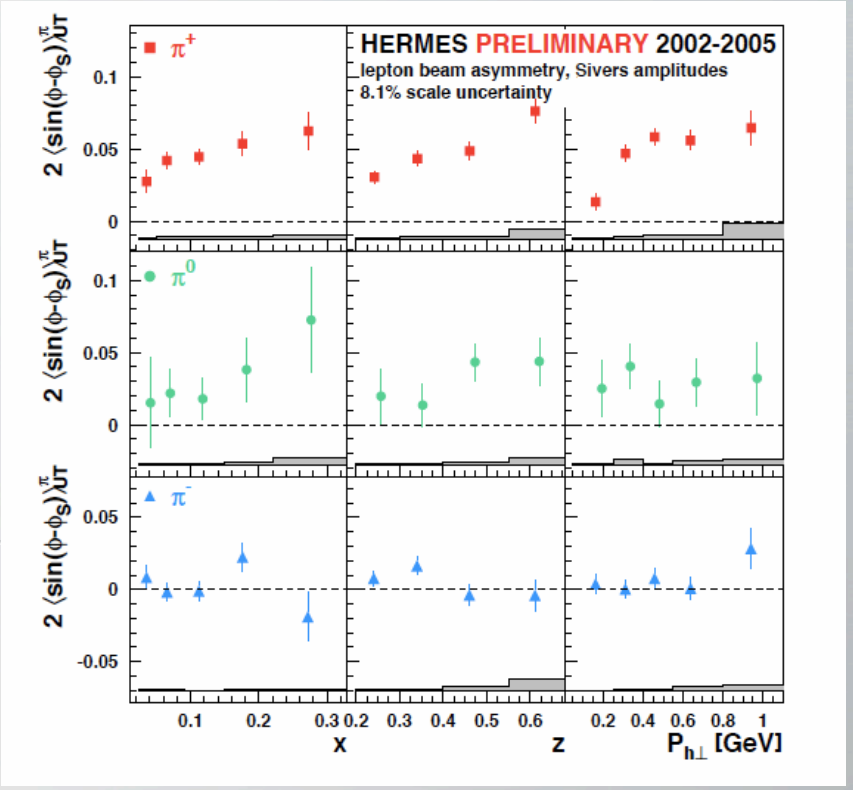


Process dependence of Sivers Effect

I. Non zero Sivers asymmetries have been measured @Hermes, Compass & JLAB

II. TMD factorization appropriate for SIDIS kinematics ($Q^2 \gg P_T^{\pi} \sim \Lambda_{QCD}$) so effects are attributed to "Sivers Functions".

III. Twist-3 collinear factorization appropriate for inclusive particle production at hadron colliders ($P_T^{\pi} \gg \Lambda_{QCD}$) so effects are attributed to "3 –Parton correlation functions".



$$gT_{q,F}(x,x) = -\int d^2k_\perp \frac{|k_T|^2}{M} f_{qT}^{\perp q}(x,k_\perp^2) \,|\, SIDIS$$

Collinear 3-parton function

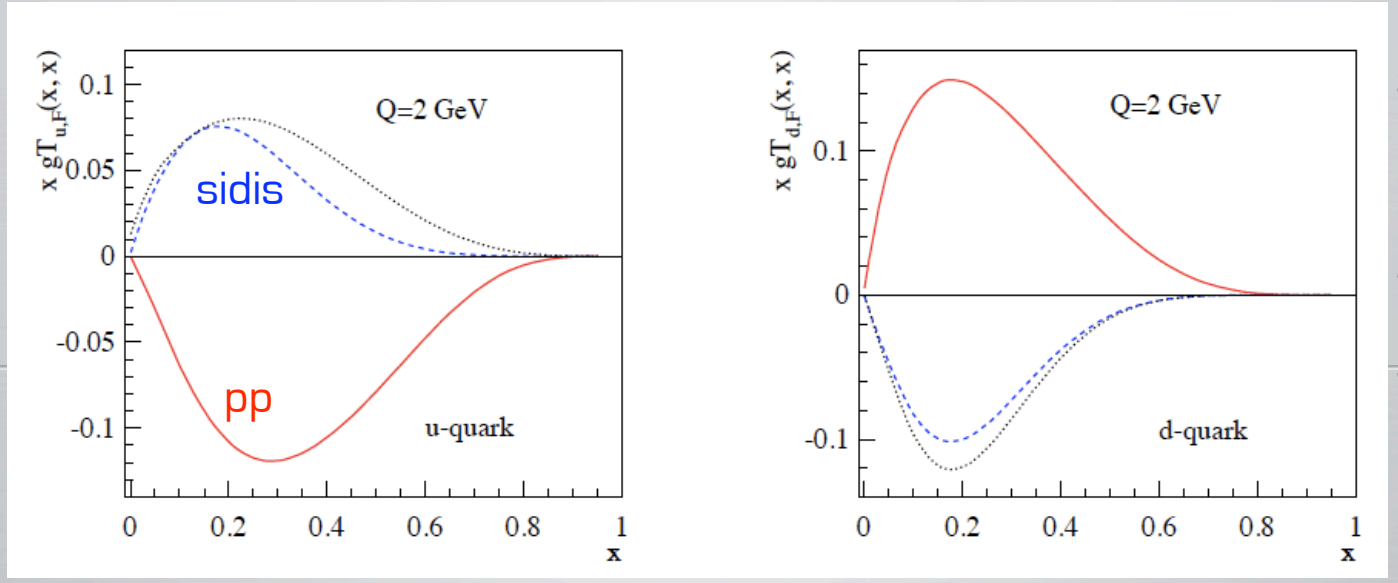
TMD Sivers function

IV. The relationship between the k_T integrated moment of Sivers' function to the twist-three parton correlation function is understood theoretically.

Phys.Rev.D83 (2011) 094001

Sign Mismatch!?

Extractions of correlation functions from SIDIS Sivers moments differ in sign compared to correlations functions from hadronic collision data!



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Three Possibilities:

I. Sivers not the driving mechanism behind large SSA in pp.

II. Instead Transversity x twist3 FF term dominates in pp.

III. k_T distribution not well constrained by SIDIS data and there is a node somewhere in x and kT that reverses sign

Accessing Sivers with Direct Photon and Inclusive Jet A_N

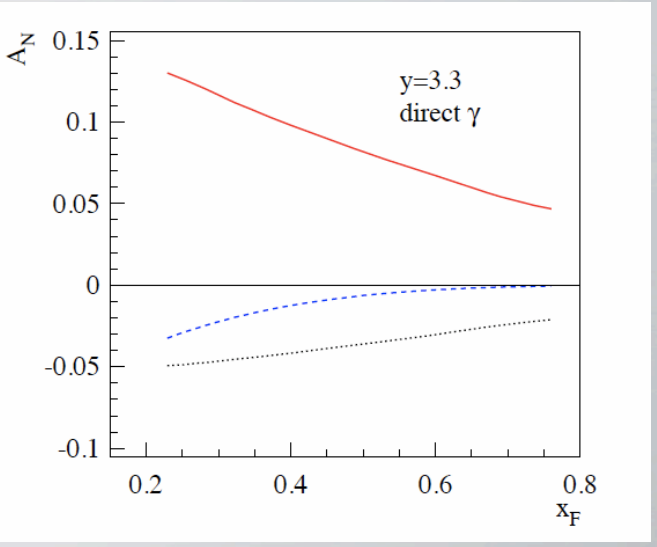
DIRECT PHOTON A_N

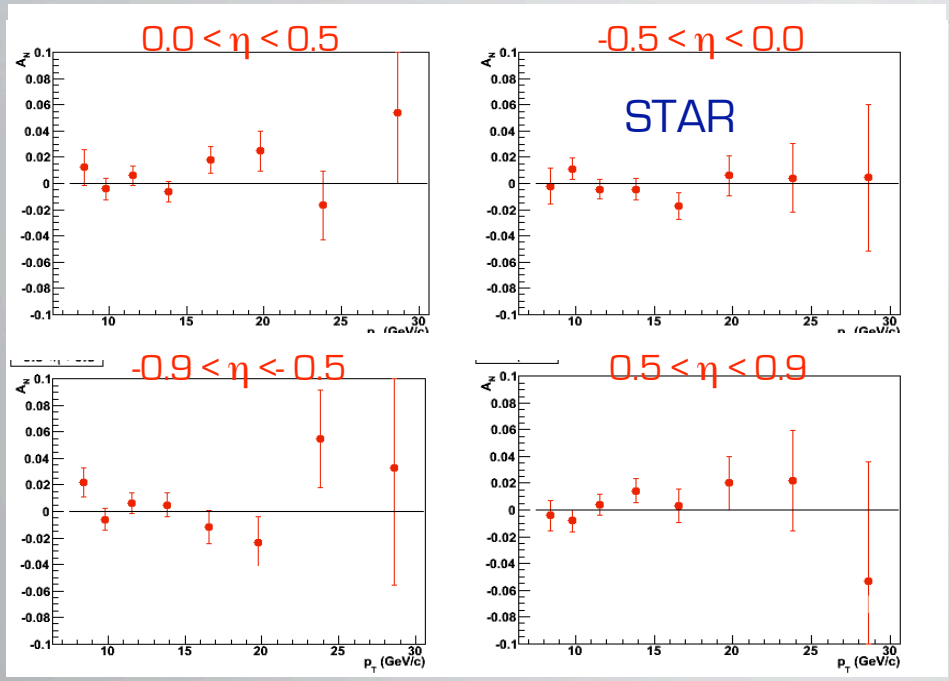
$1 < \eta < 2$

- Use EEMC for gamma reconstruction
- Use FGT and iTPC to veto jets

$2.5 < \eta < 4.0$

- Use FMS for gamma reconstruction
- Use vFGT and hadronic calorimeter to veto jets





INCLUSIVE JET A_N

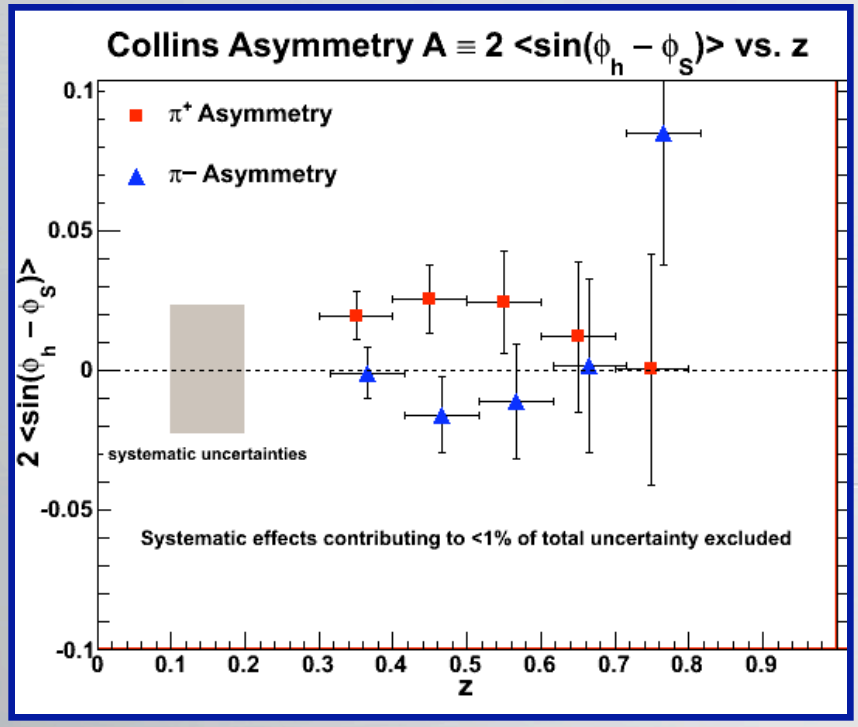
$1 < \eta < 2$

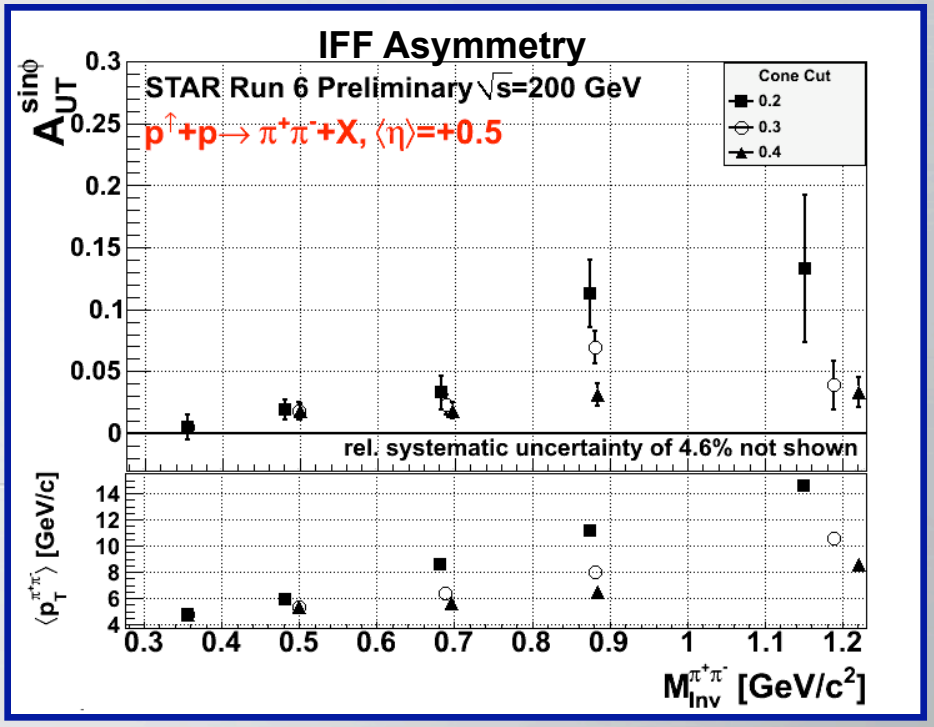
- EEMC for neutral E component
- iTPC for charged E component

$2.5 < \eta < 4.0$

- FMS for neutral E component
- HCAL for charged E component

Mid-rapidity Surprise!



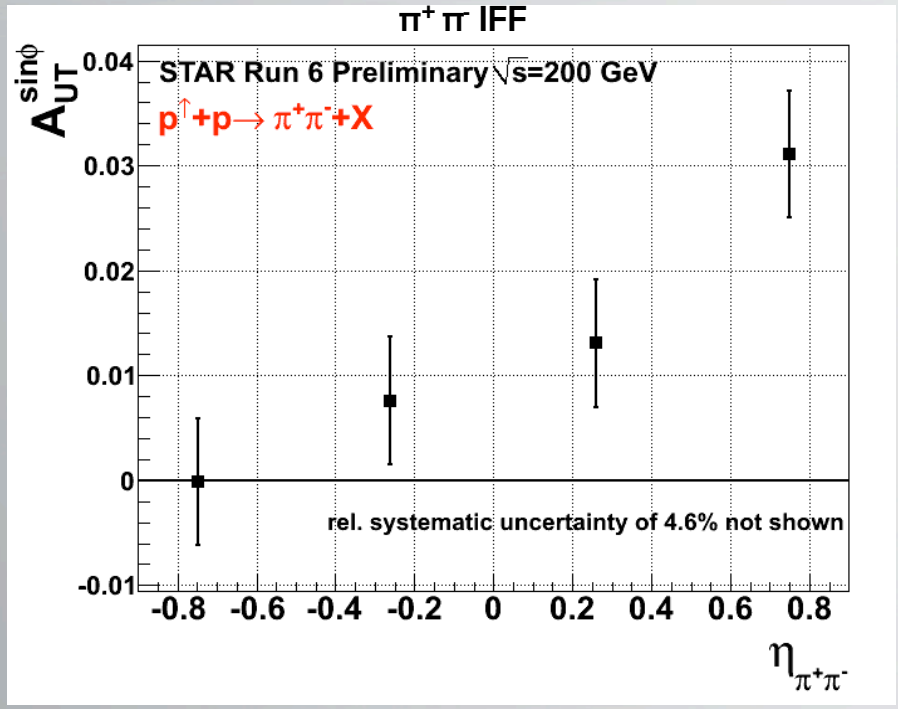


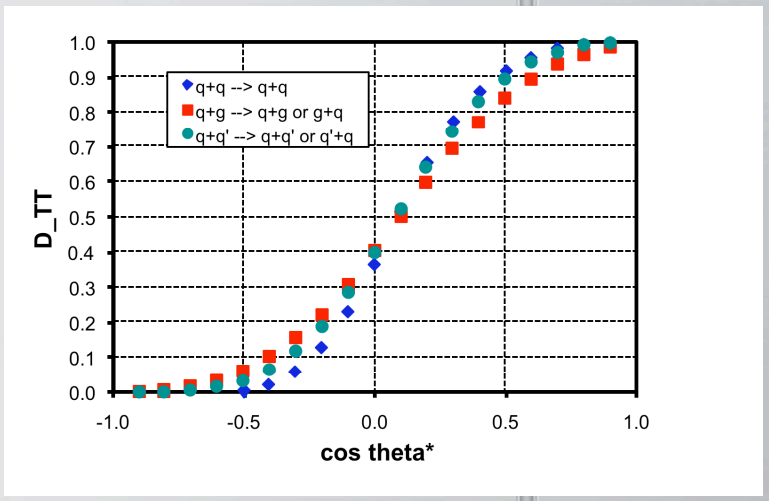
Exploratory Analysis from 200 GeV Transverse Running in 2006 show **first clear signal of transversity** in pp collisions at RHIC!

Push quark transversity to higher x

... which also means higher η

Partonic Polarization Transfer increases making IFF & Collins asymmetries grow in forward regions. Already demonstrated in existing data:





Comparison of IFF and Collins result will give insights into evolution of TMD vs collinear type of fragmentation function. It will also give some indication about size of Sudakov effects in Collins.

Move IFF & Collins SSA Forward

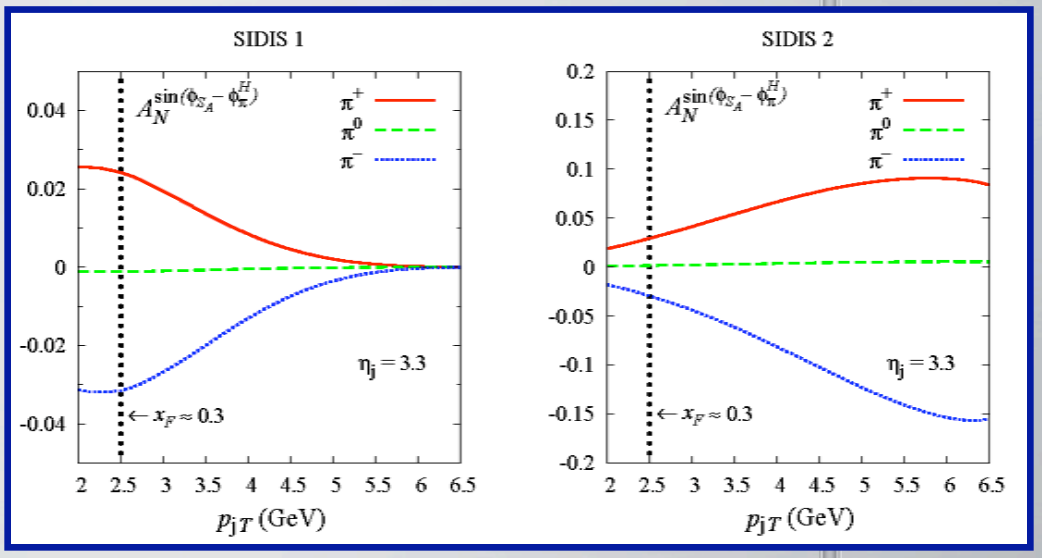
Interference Fragmentation Function

1 < η < 2

- iTPC dE/dx for charged pion ID
- FGT for additional charge sign discrimination
- EEMC for π^0 correlations

2.5 < η < 4.0

- vFGT for charge sign
- RICH for particle id
- FMS for π^0 correlations



Collins Asymmetry

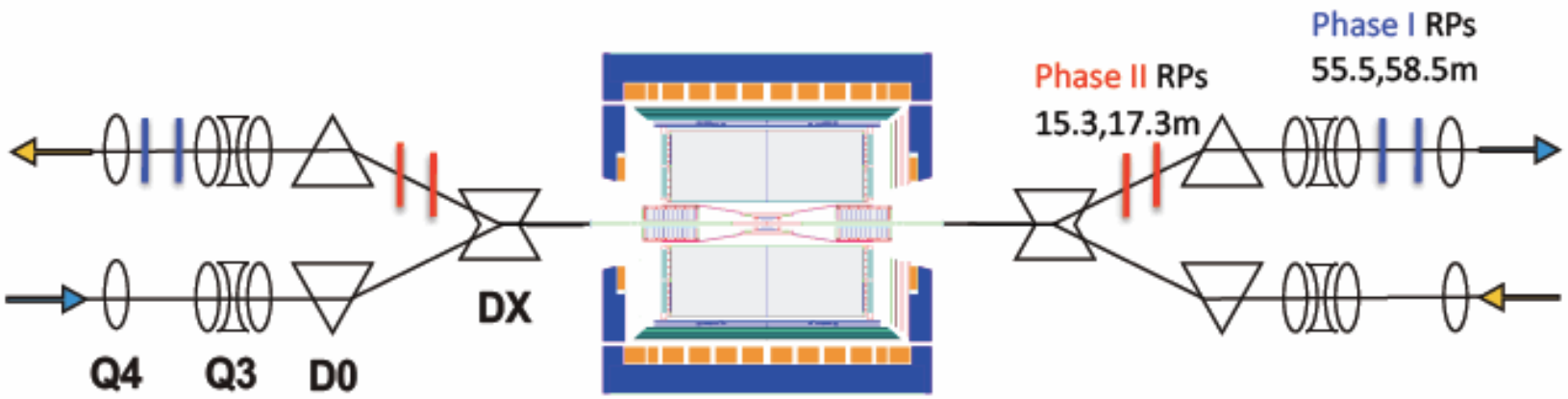
1 < η < 2

- iTPC dE/dx for charged pion ID
- FGT for additional charge sign discrimination
- EEMC for π^0 correlations
- EEMC for neutral E component of jet
- iTPC for charged E component of jet

2.5 < η < 4.0

- vFGT for charge sign
- RICH for particle id
- FMS for π^0 correlations
- FMS for neutral E component of jet
- HCAL for charged E component of jet

Roman Pots: Phase II



RPs for Phase II are located between DX – D0

New vacuum chamber is required to accommodate the RPs

Diffraction

What if Sivers and Fragmentation asymmetries don't add up to total SSA magnitude at forward rapidities? Investigate correlations between SSA and diffractive events!

Characteristics:

- Small Energy transfer is small
- Single Diffraction (SD) – Detect one proton in East Roman Pot and rapidity gap between proton and forward jet. FGT and TPC used for rapidity gap veto and VFGT used to detect forward tracking cluster.
- Double Diffraction (DD) – two jets with one central rapidity gap. Would look like SD (no FGT/VFGT on East STAR) without elastically scattered proton on east side Roman Pot.

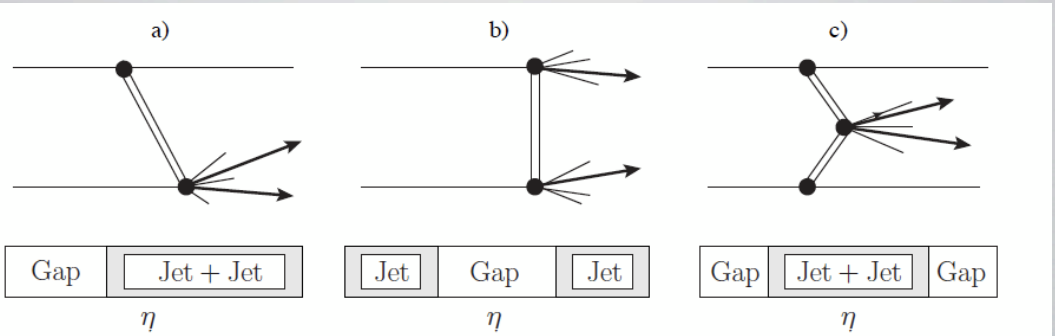
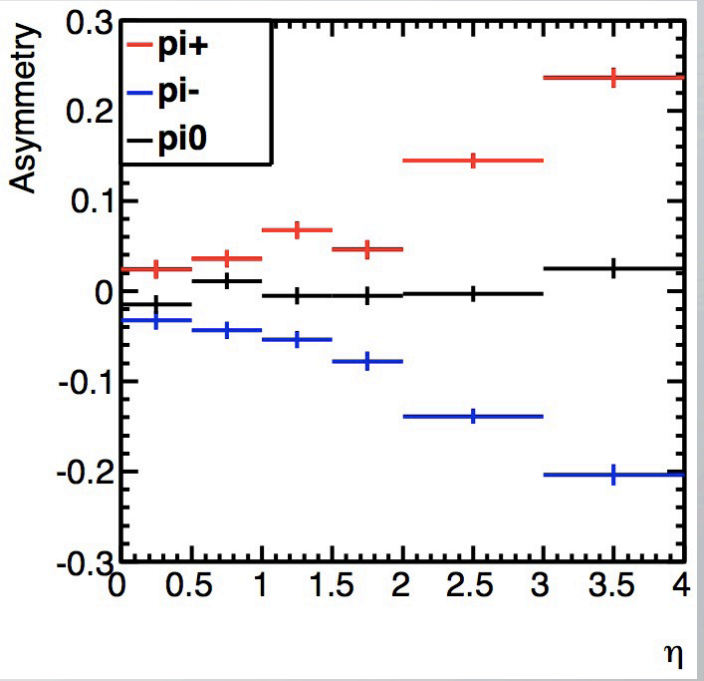


Figure 2.6: Three main colorless exchanges at hadron-hadron collider: a) single diffractive dissociation (or single diffraction), b) double diffractive dissociation c) double pomeron exchange. See text for further description.

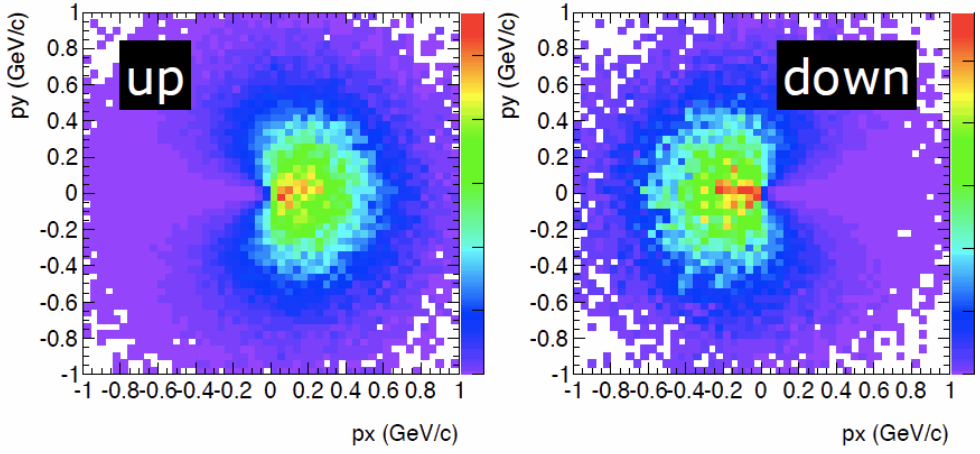
Transversely Polarized Proton MC

- Developed by Tom Burton
- Sivers and Collins asymmetries included
- IFF and DY/ W A_N need to be still included
- Details: http://drupal.star.bnl.gov/STAR/system/files/burtonAnalysisMeeting20110418.pdf

Collins with positivity bounds as input



Sivers Mechanism



$$PDF(x,k_T) = f(x,k_T) + Sivers(x,k_T)\vec{S}(\vec{p}\times\vec{k}_T)$$

Fast smearing generator
tool to smear generator particle responses in p and energy and to include PID responses, "detectors" can be flexible defined in the acceptance

Summary

Upgrades in forward direction will allow STAR to:

- Constrain Sivers Function via direct photons and inclusive jets
- Push measurements of quark transversity PDFs into high x region
- Help isolate mechanism behind large SSA in forward direction

Proposed forward detector suite:

- vFGT - Extension of FGT to FMS region.
- HCAL – Hadron Calorimeter behind FMS.
- iTPC – TPC Inner sector upgrade for improved dE/dx and momentum resolution in front of EEMC
- RICH - Baryon/meson separation in front of the FMS

Next Step is quantifying detector specifications by simulation physics channels.

- Transversely Polarized Proton MC developed and tested
- vFGT and HCAL are implemented into STAR GEANT framework