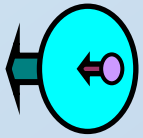
Ongoing and future spin analysis

R. Seidl

(RIKEN)

Spin goals in PHENIX (and pp)

Longitudinal spin physics



- What is the gluon spin contribution to the proton spin?
- Do also sea quarks contribute? If so are they symmetric?

Transvserse spin physics

- Can we understand the mechanisms to create these large left-right asymmetries?...and relate them to fundamental quantities (Sivers function, Transvserity, diffraction)?

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Next physics runs

- 2015:
  - Transversely polarized pp and pA at 200 GeV
- 2016:
  - 510 GeV pp running likely (strong case in STAR for transvsere W asymmetries) → Should we run transverse (low mass Drell Yan???) or longitudinal (Δg, W)
  - 62 GeV pp (longitudinal?)

The Spin sum rule

$$\frac{1}{2} = \frac{1}{2}\Delta\Sigma + \Delta G + L$$ Jaffe, Manohar

$$\Delta\Sigma = \int dx \left[(\Delta u(x) + \Delta\overline{u}(x)) + (\Delta d(x) + \Delta\overline{d}(x)) + (\Delta s(x) + \Delta\overline{s}(x))\right]$$

- Other decompositions exist
- $\Delta\Sigma$ and ΔG can be accessed in longitudinally polarized (SI)DIS and pp collisions
- more on orbital angular momentum later

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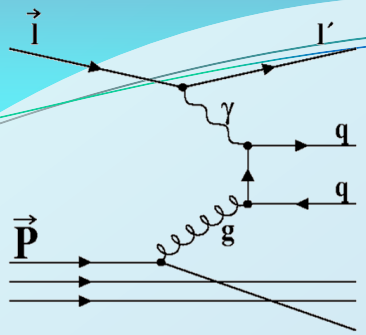
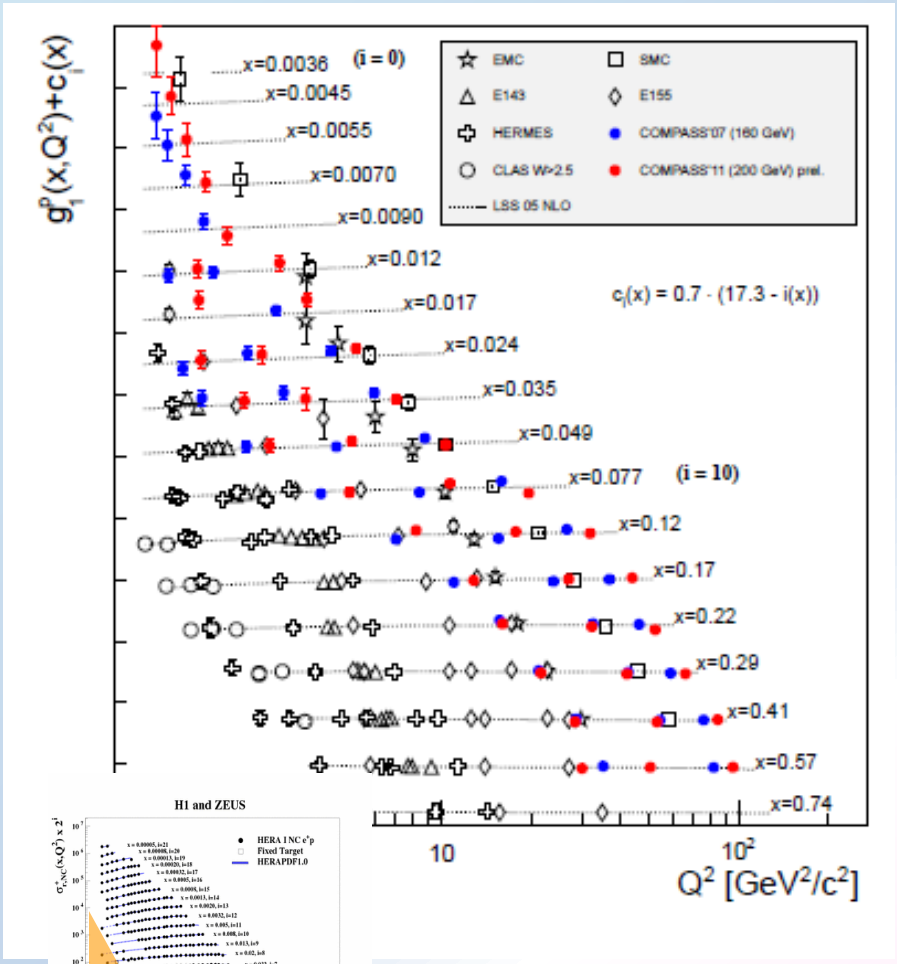
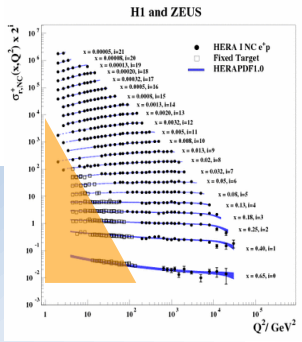


Gluon polarization

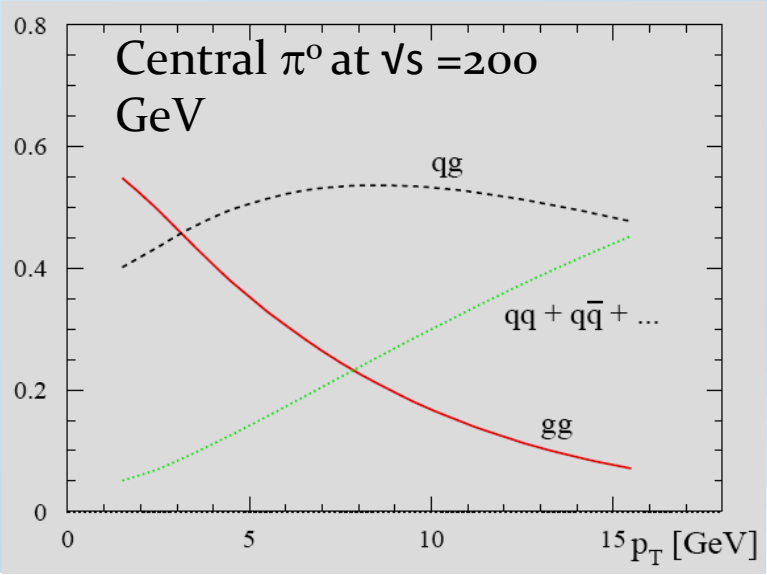
- Barely access via DIS data through DGLAP evolution (no large Q^2 lever arm)
- Some access in SIDIS through high Pt hadrons and charmed mesons

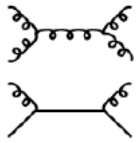
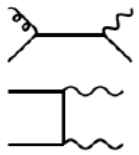
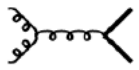




Gluon polarization

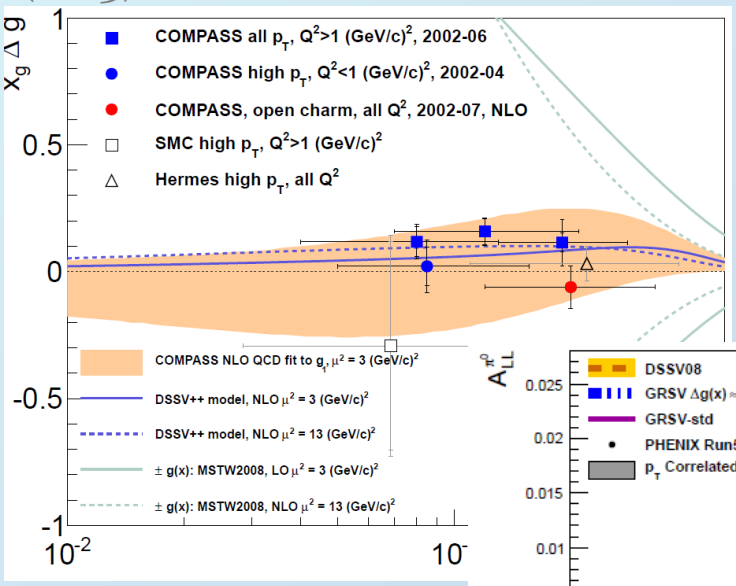
- Barely access via DIS data through DGLAP evolution (no large Q^2 lever arm)
- Some access in SIDIS through high Pt hadrons and charmed mesons
- Polarized pp collisions at LO in α_S sensitive to gluons

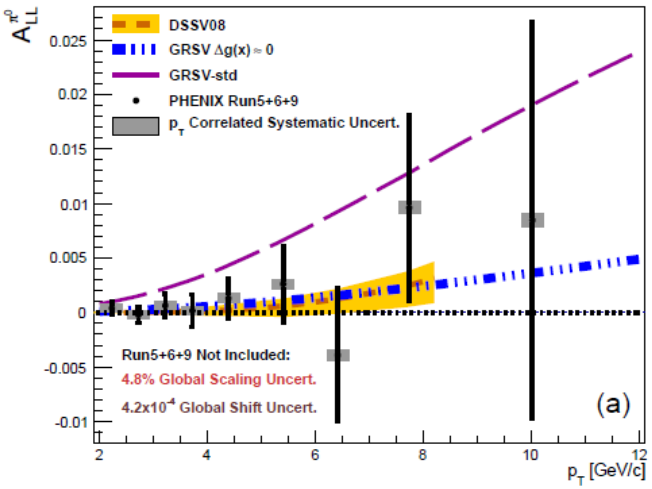


Reaction	Dom. partonic process	probes	LO Feynman diagram
$\vec{p}\vec{p} \to \pi + X$	$\vec{g}\vec{g} \to gg$ $\vec{q}\vec{g} \to qg$	Δg	
$\vec{p}\vec{p} \to \text{jet(s)} + X$	$\vec{g}\vec{g} \to gg$ $\vec{q}\vec{g} \to qg$	Δg	(as above)
$\vec{p}\vec{p} \to \gamma + X$ $\vec{p}\vec{p} \to \gamma + \text{jet} + X$	$\vec{q}\vec{g} \to \gamma q$ $\vec{q}\vec{g} \to \gamma q$	Δg Δg	
$\vec{p}\vec{p} \to \gamma\gamma + X$	$\vec{q}\vec{\bar{q}} \to \gamma\gamma$	$\Delta q, \Delta\bar{q}$	
$\vec{p}\vec{p} \to DX, BX$	$\vec{g}\vec{g} \to c\bar{c}, b\bar{b}$	Δg	

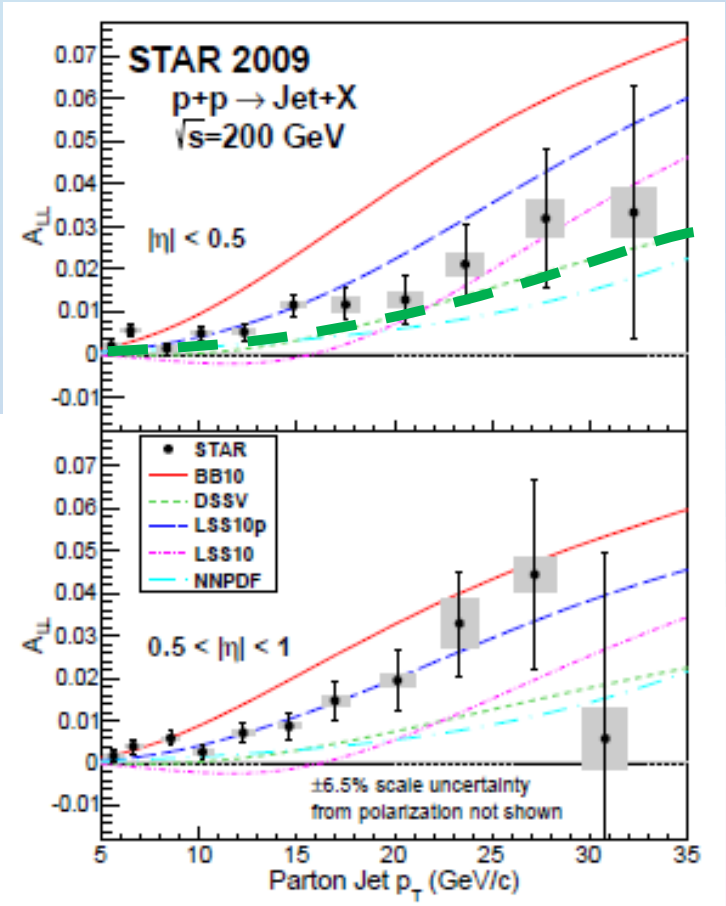
Current highlights: gluon helicities

COMPASS, PLB718(2013), PRD87 (2013)



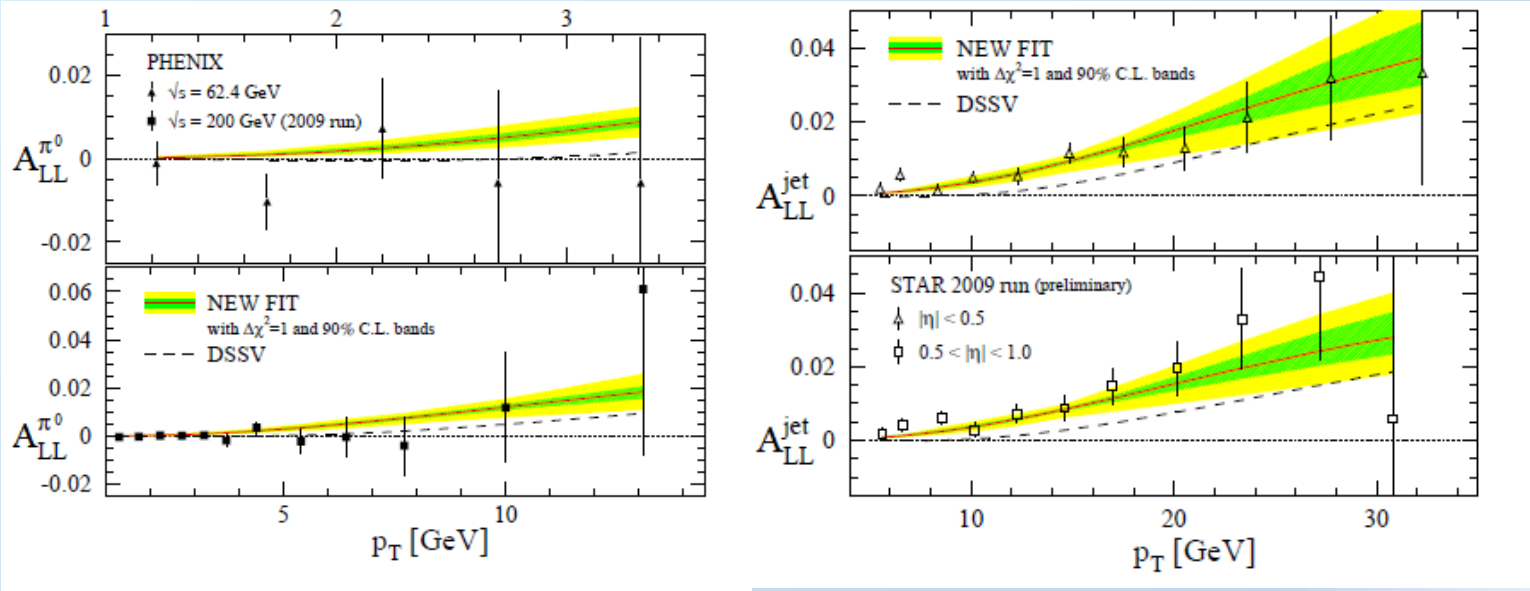


STAR: arXiv:1405.5134



PHENIX: Phys.Rev. D90 (2014) 012007

DSSV++



- DSSV:Phys.Rev.Lett. 113 (2014) 012001

- Nonzero gluon spin in measured x range
- Similar conclusion from NNPDFpol1.1 arXiv:1406.5539

- Pions at slightly smaller x and smaller Pt → Δg smaller due to evolution

Press interest in nonzero gluon spin

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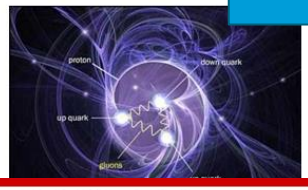
Proton Spin Mystery Gains a New Clue

Physicists long assumed a proton's spin came from its three constituent quarks. New measurements suggest particles called gluons make a significant contribution

Jul 21, 2014 | By Clara Moskowitz

Protons have a constant spin that is an intrinsic particle property like mass or charge. Yet where this spin comes from is such a mystery it's dubbed the "proton spin crisis." Initially physicists thought a proton's spin was the sum of the spins of its three constituent quarks. But a 1987



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2014

Gluons get in on proton spin

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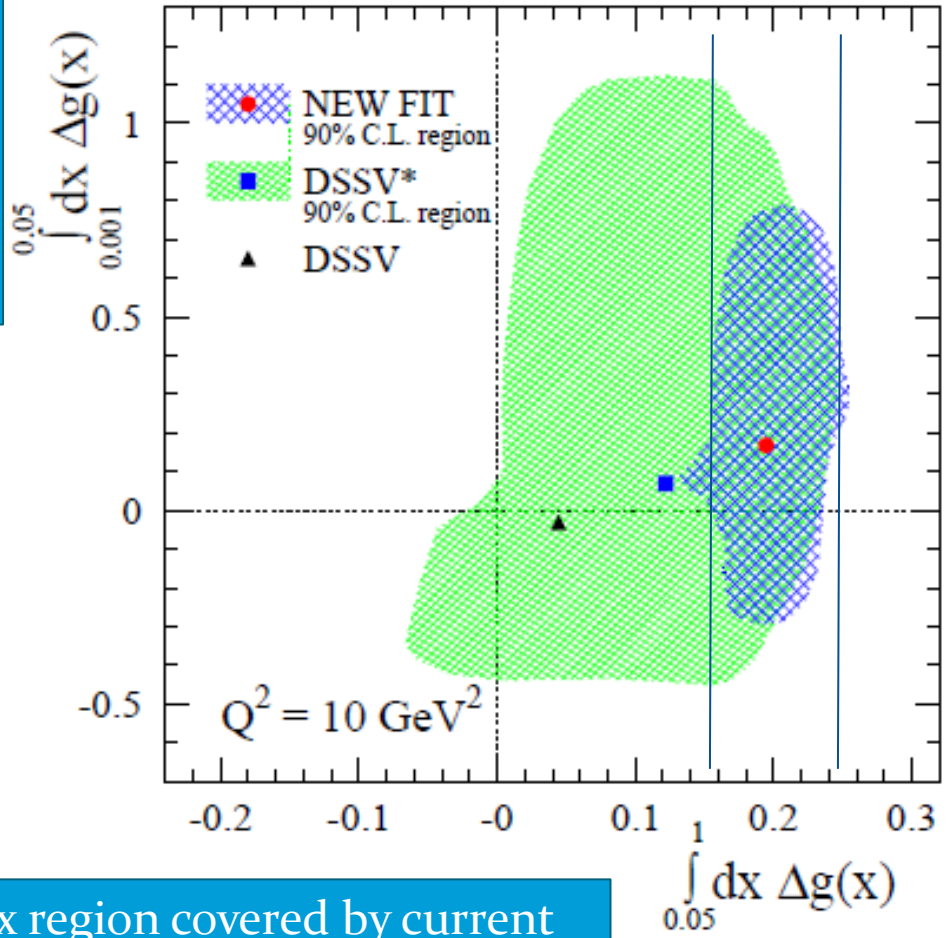
Synopsis: Gluons Chip in for Proton Spin

Low x, not covered so far →more forward pp, EIC



x region covered by current RHIC and DIS results

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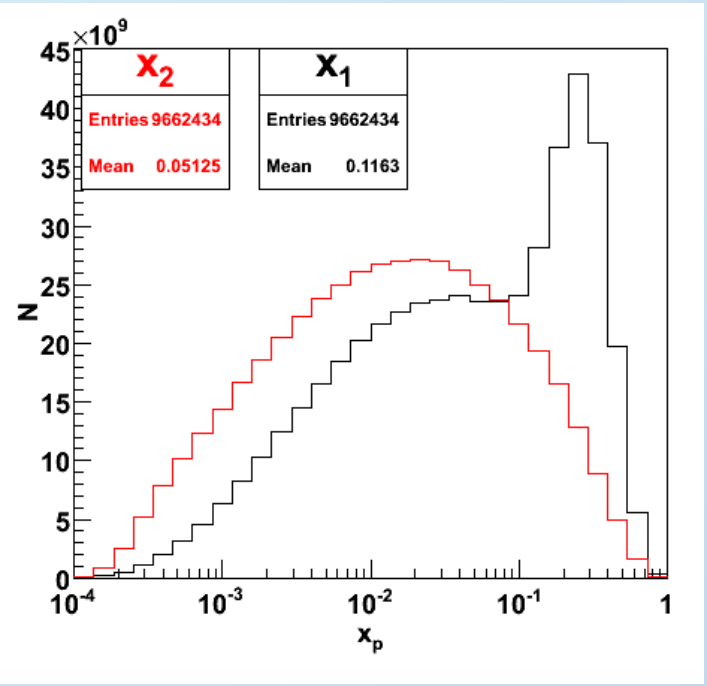
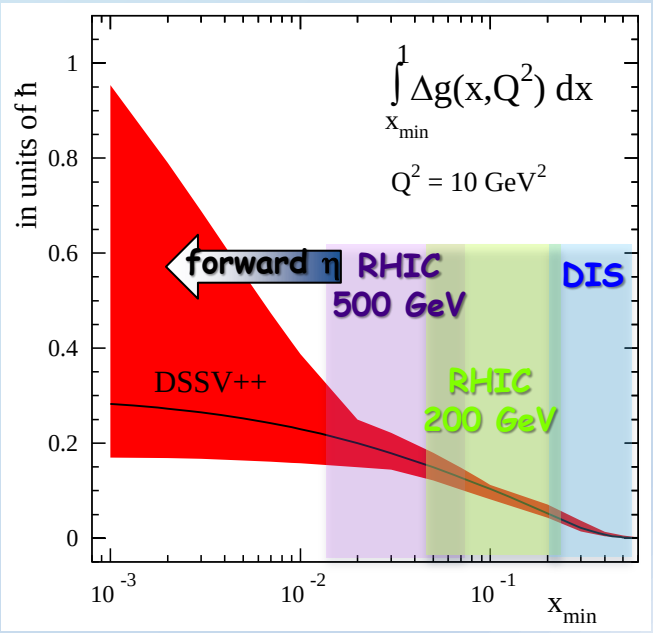
Near future: extend gluon x range

Forward π^0 in $3.1<\eta<3.9$, $p_T>1$GeV

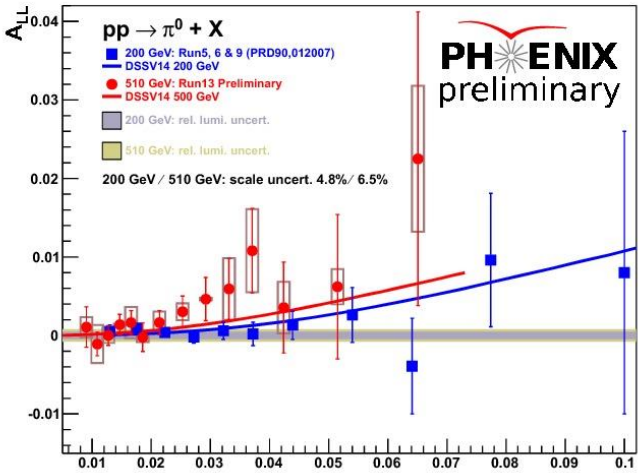




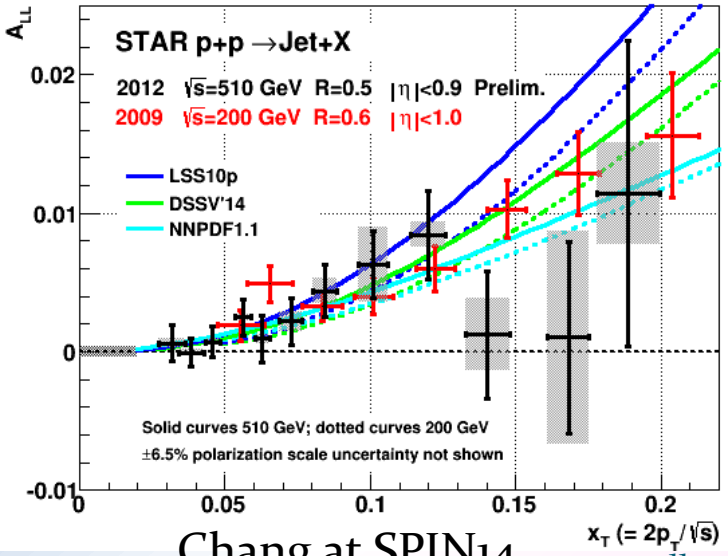
- Existing 2013 + future data will extend gluon x coverage below $x=10^{-2}$ in forward pion and jet measurements
- Di-jets to scan x range
- Improved precision in central jet and pion measurements

First 510 GeV results

- Run 9 STAR Jet and PHENIX po results show nonzero gluon polarization
- Confirmed by 500 GeV results by both experiments
- Next steps → lower x, more channels

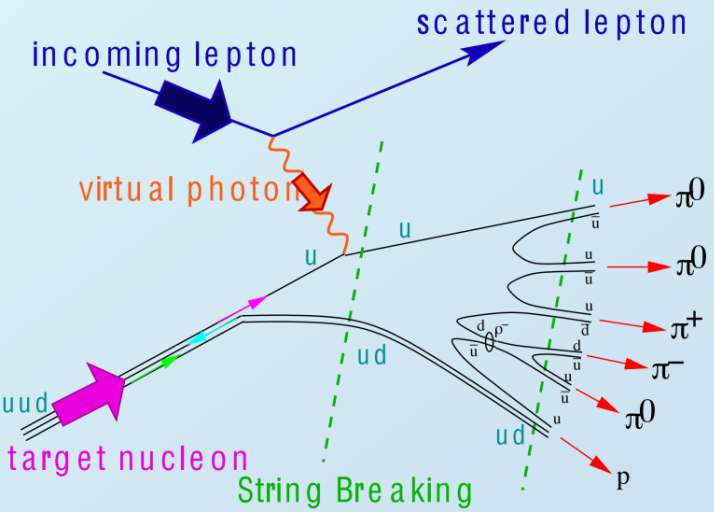


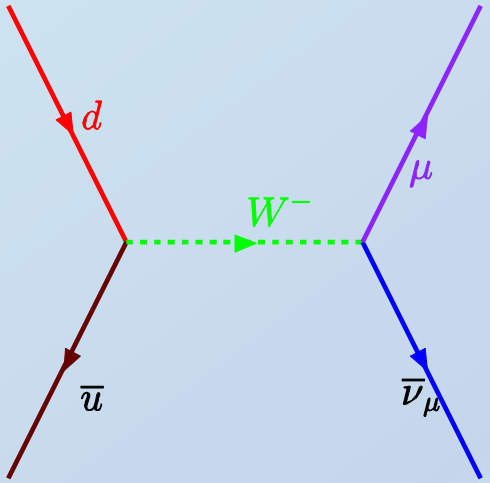
Inseok at SPIN14



Chang at SPIN14

Flavor information via SIDIS and W production in pp



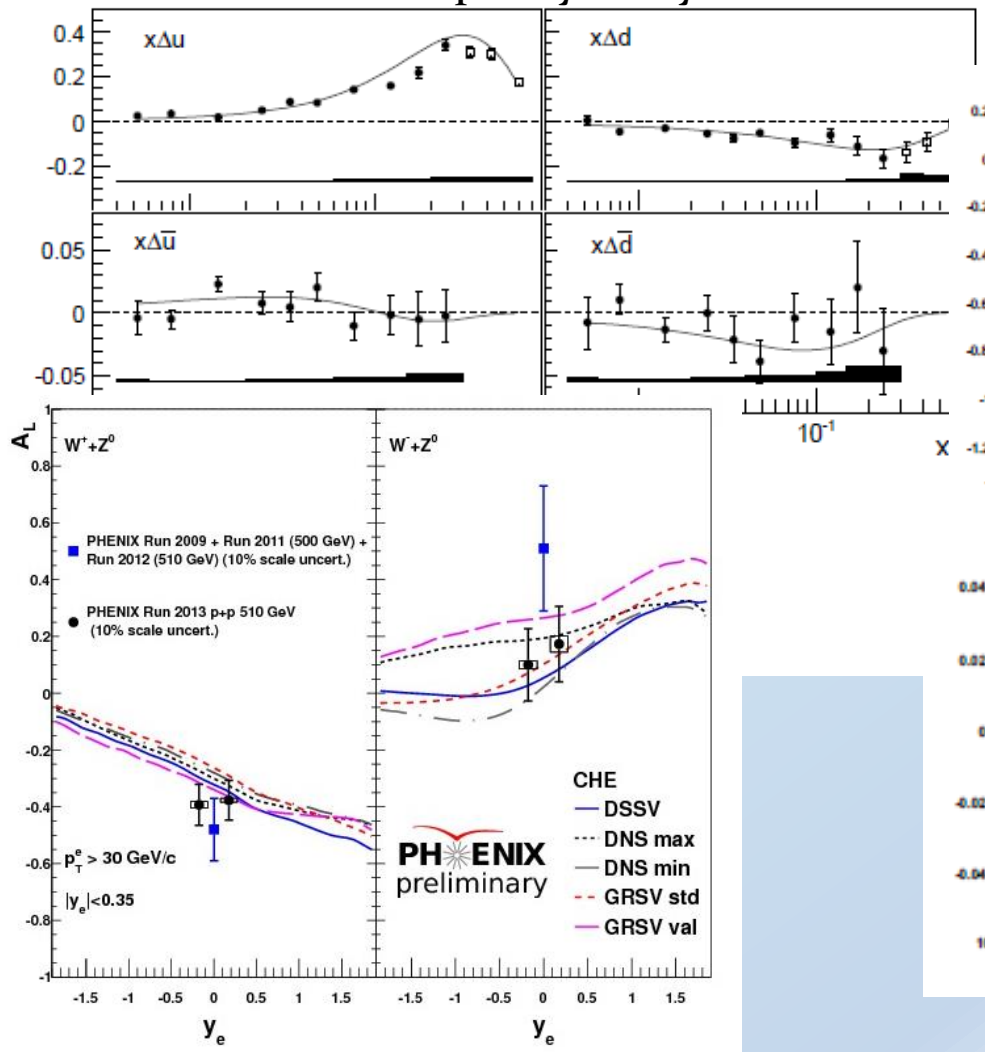


- Semi-inclusive DIS: detect at least one final state hadron
- Hadron type relates to initial parton via fragmentation functions (important new results from Belle, Babar, RHIC, LHC and SIDIS)

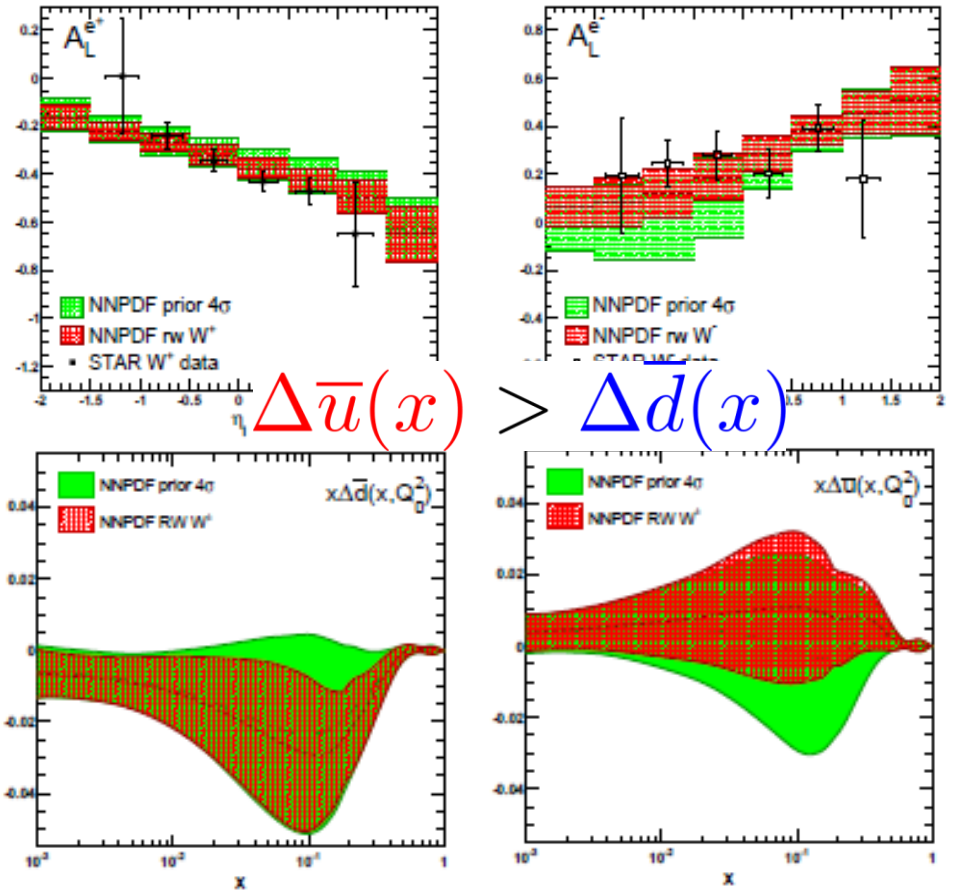
- W production in pp collisions selects participating quark and antiquark flavors and its helicity

Current highlights: sea quark helicities

COMPASS purity analysis



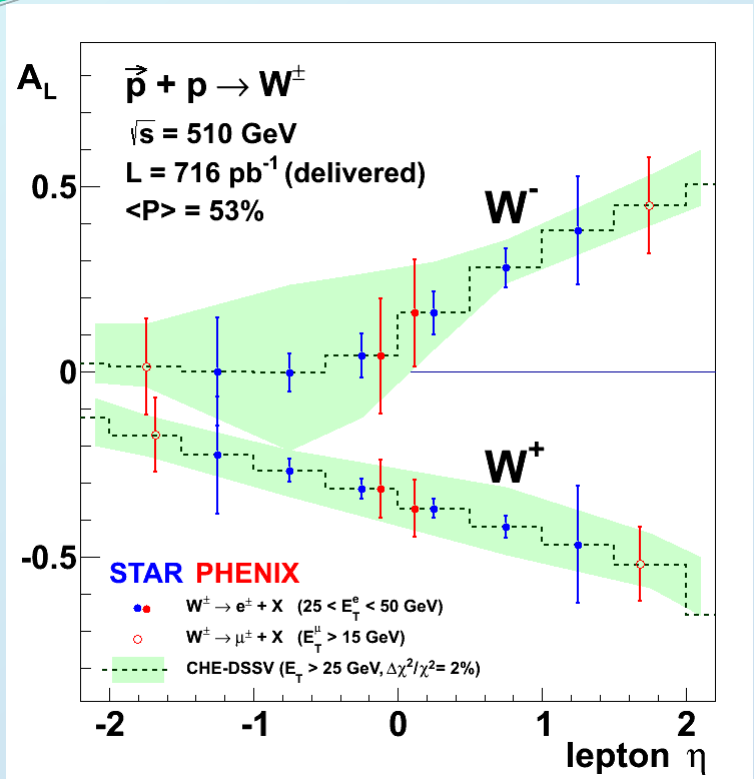
STAR: PRL 113 (2014) 072301

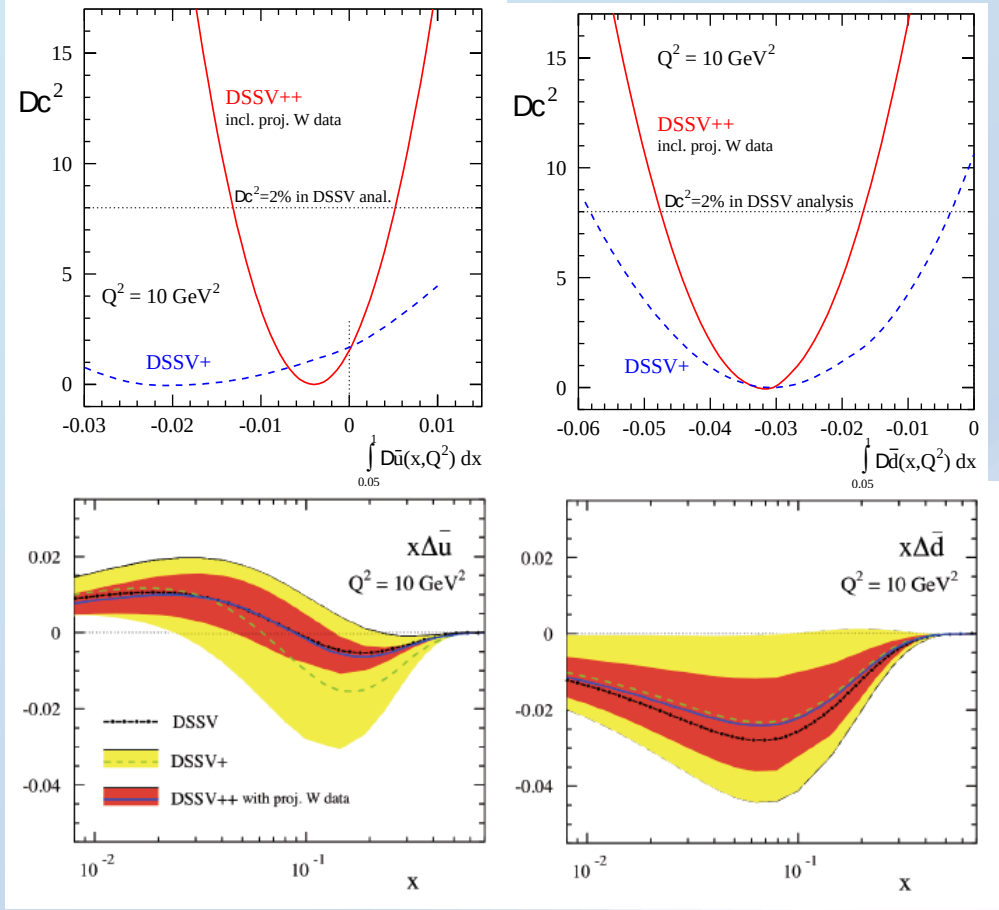


$$\Delta\bar{u}(x) > \Delta\bar{d}(x)$$

NNPDFpol1.1: E. Nocera et al..
arXiv:1406.5539

Near future: is polarized sea symmetric?





- Total 2011-2013 RHIC W data:
  - Substantial uncertainty improvement of the sea quark helicities
  - DSSV framework ready to include W asymmetries
  - NNPDF ready for Ws (but still need to include SIDIS)

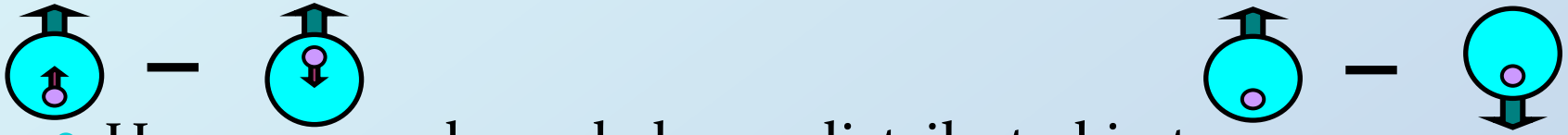
arXiv:1304.0079

Longitudinal analysis

Published
Preliminary
Else

	Run 9 (200)	Run11 (500)	Run12 (510)	Run13 (510)
Central π^0 A_{LL} +xsec	Andrew/Kieran Sasha(xsec)		Iseok/Hari (xcheck)	Inseok/Hari
Central η A_{LL} +xsec	Murad(xsec)			Murad/Hari
Central $\pi^{\pm}$ A_{LL} +xsec	SookHyun			Minjung
Central Direct γ A_{LL} +xsec	Paul			???
MPC cluster A_{LL}	Scott	Cameron	Cameron	Pedro
MPC η A_{LL}				???
J/ψ A_{LL} (μ)				Haiwang/Aaron
J/ψ A_{LL} (e?)				Amaresh
e (HF) A_{LL}	Katsuro			?
μ(HF) A_{LL}				Jeongsu
Di-pion A_{LL}	Kimiaki			
Jet A_{LL}?				ISU(+Arbin)
DY($\mu\mu$) A_{LL}				Darshana

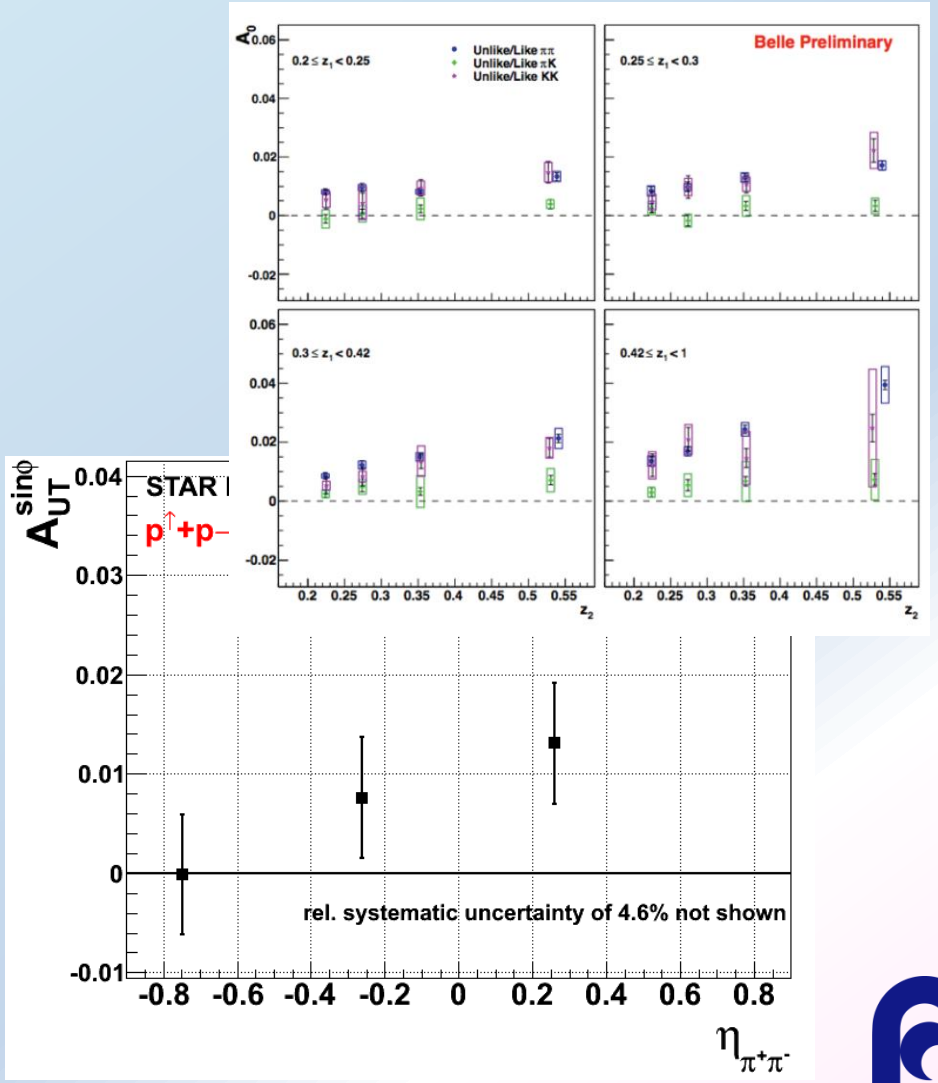
Transverse spin: Main questions



- How are quarks and gluons distributed in transverse momentum space?
- What do we learn from all the different spin and orbit correlations (obviously OAM needed for nonzero Sivers function, but so do anomalous magnetic moments)
- Is our understanding of TMDs via gauge links correct? → universality, sign change of Sivers and Boer-Mulders function
- How do Transversity distributions differ from helicity distributions?
  - connection to lattice calculations via tensor charge
  - Any sizeable sea?
- what is the connection between SIDIS and pp?

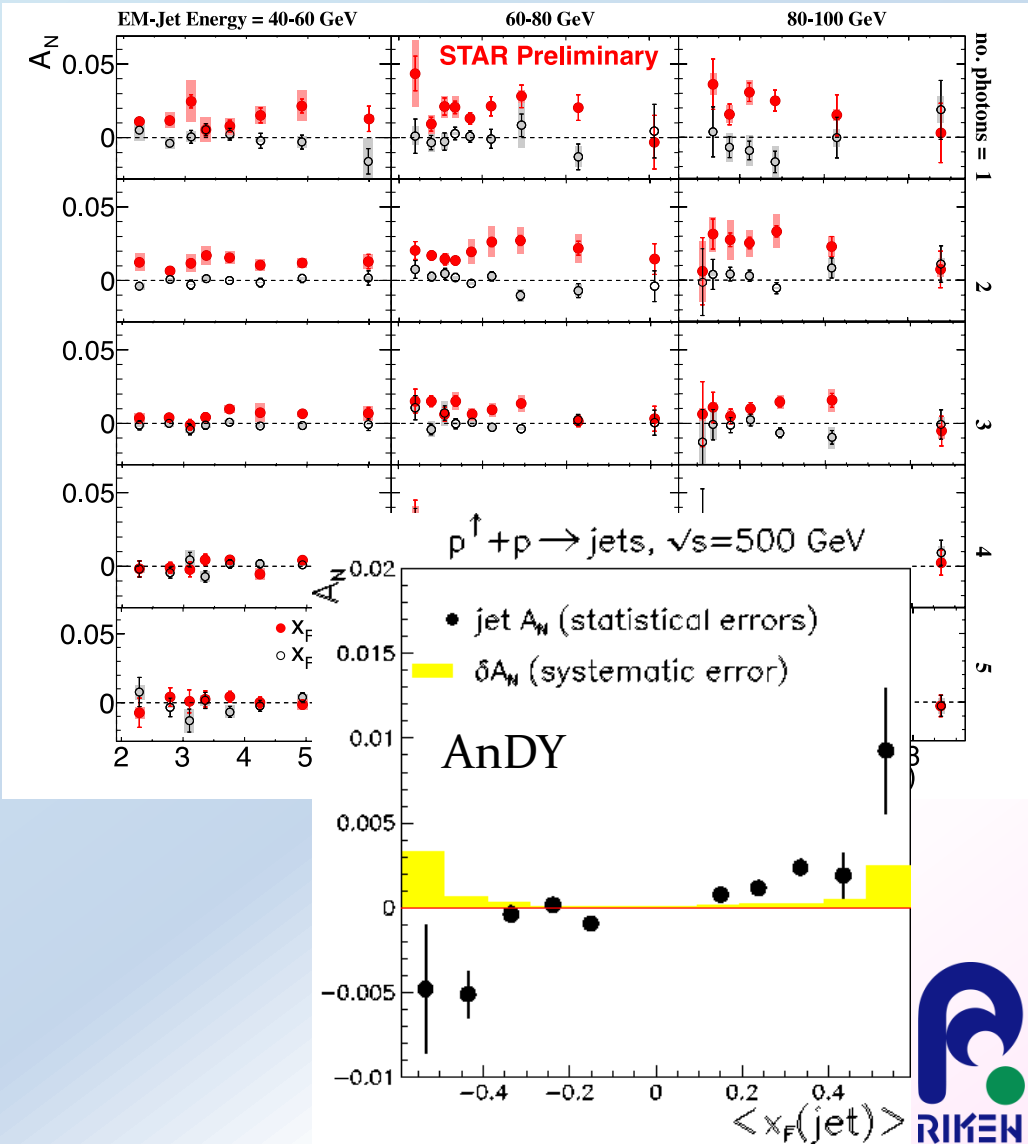
Transversity

- Collins and dihadron SIDIS (HERMES,COMPASS, HallA) and Collins FF (Belle, BABAR) results very consistent,
- "global" fits to pion Collins (Torino) and di-hadron (Pavia) with similar transversitites
- Still need to be included in fits:
  - First Collins and di-hadron results from RHIC.
  - Kaon SIDIS results
  - preliminary Kaon FF from Belle



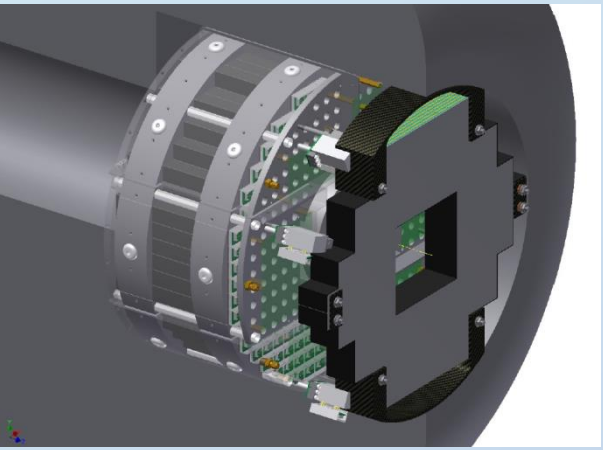
Connection to pp A_Ns

- higher twist contributions related to Sivers and Collins kt moments
- However, more higher twist functions exist
- Initial assumptions of Sivers-like only contributions not correct or at least of wrong sign
- Indications of smaller asymmetries in more "jetty" events could point to other mechanism such as diffraction
- All backward and central asymmetries zero (pions, eta, jets) --indication of small forward jets



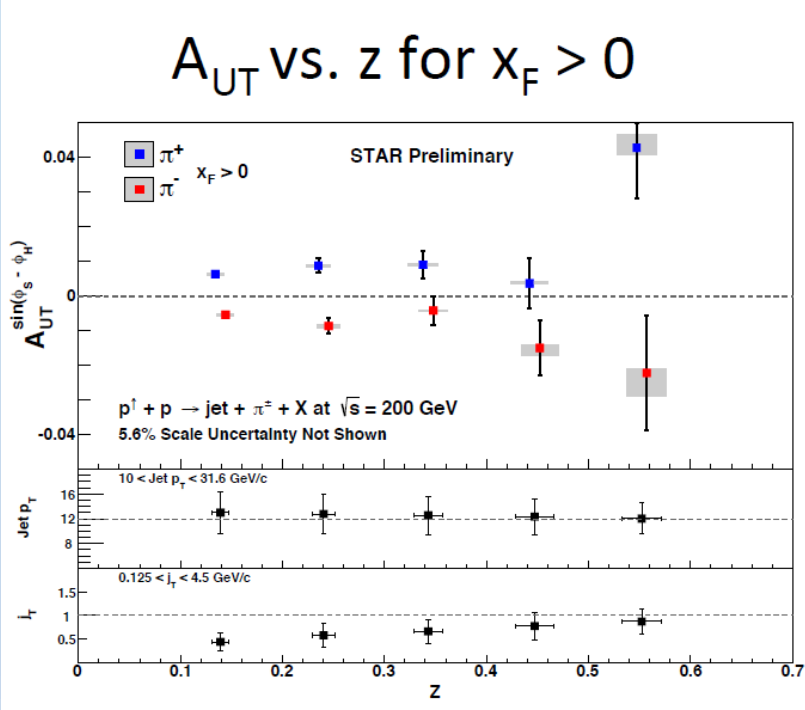
Transverse background

- In SIDIS confirmed existence:
  - Transversity x Collins
  - Transversity x IFF
  - Sivers, other TMDs
- Large A_Ns in pp with some (but not complete) connections to TMDs via kt moments, indication of other mechanisms (diffraction)
  - Any clean access to remaining final state contributions? (Pitonyak)
  - Any access to processes information?
- Sign change – already interesting for direct photons?



Forward Preshower (MPC-EX), currently being installed

- STAR has clearly seen nonzero Collins and IFF asymmetries
  - Can we access them as well?



Adkins (KU) at SPIN14

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Transverse analysis I

Published
Preliminary
Else

	Run 8 (200)	Run12 (200)	Run15 (200)
Central π^0 A_N	John Koster		?
Central η A_N	John Koster		?
Central $\pi^{\pm}$ A_N			?
Direct γ A_N	Imran	?	?
MPC cluster A_N	John Koster	(Mickey)	?
MPC η A_N	David Kleinjan	Richard Hollis	?
J/ψ A_N (μ)	Hussein,Imran,Xiaorong	Oleg	Chen Xu
J/ψ A_N (e?)		?	?
e (HF) A_N		?	?
μ(HF) A_N	Feng	Feng	?
Flip and Swap (Collins)		Josh/Milap	???
DY($\mu\mu$)			(NMU 500)
IFF(central+muon)	Ruizhe(+Oleg)		

Transverse analysis II

Published
Preliminary
Else

	Run12 (200)	Run15 (200)
MPC EX π^0 A_N		Liankun
MPC EX Direct γ A_N		Milap
pA MPC EX π^0 A_N (+cluster)		Liankun, Stacy Karthas
pA ZDC A_N		Junsang
MPC cluster AN w/ and w/o central activity?		
MPC cluster w ZDC/BBC coincidence		
MPC cluster w other same/away side MPC activity		

Summary

- We just found that the gluon contributes substantially to the proton spin
  - Now we need to confirm and study it in various channels and with different x regions

- Transvsere spin asymmetries are still not very well understood in pp collision
  - Measure various channels with different contributions and in different detector correlations