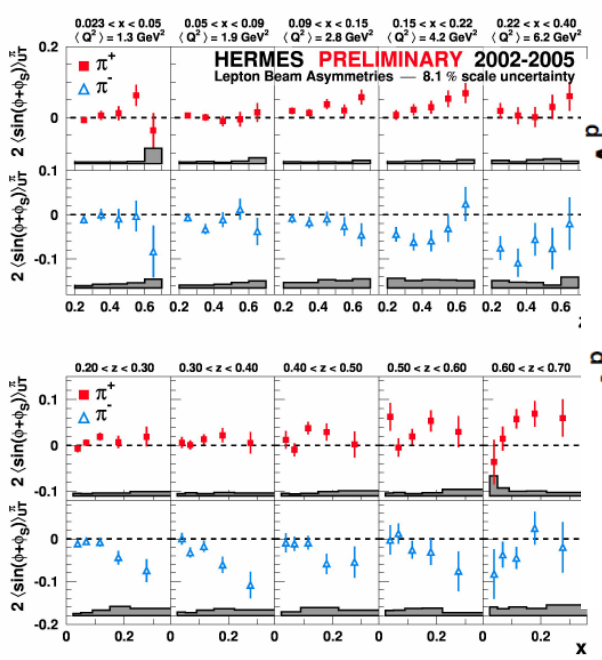
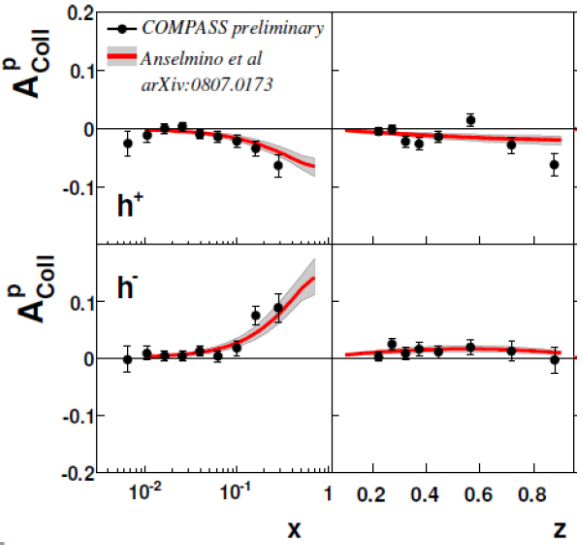
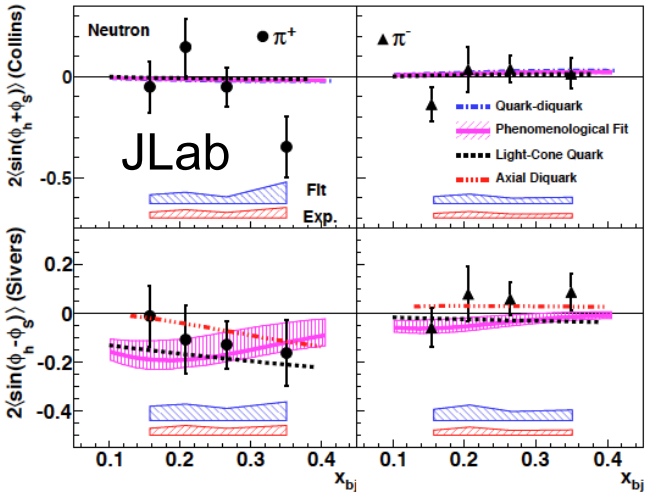
THE PRESENT SITUATION - TMDS

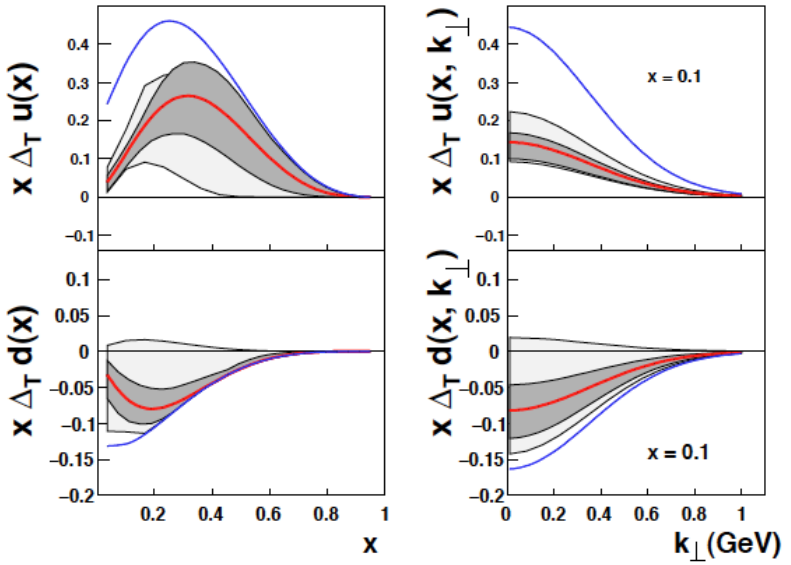




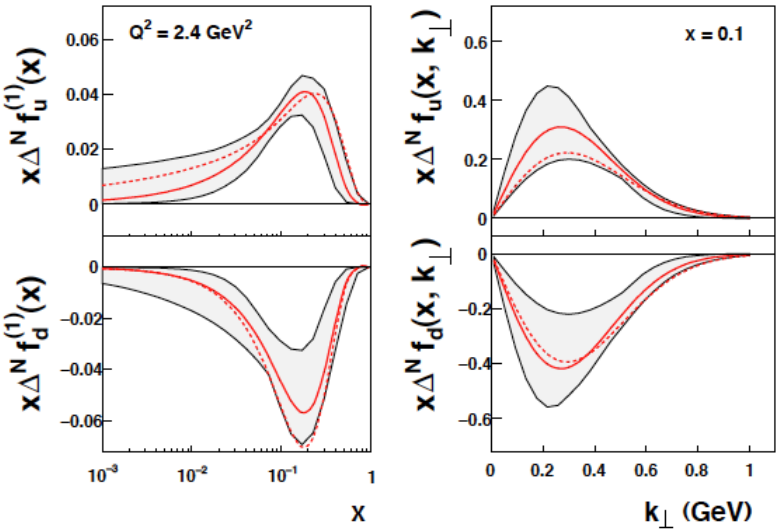


A full program to measure 8 TMDs has just begun…

Fit by Anselmino et al.



Transversity



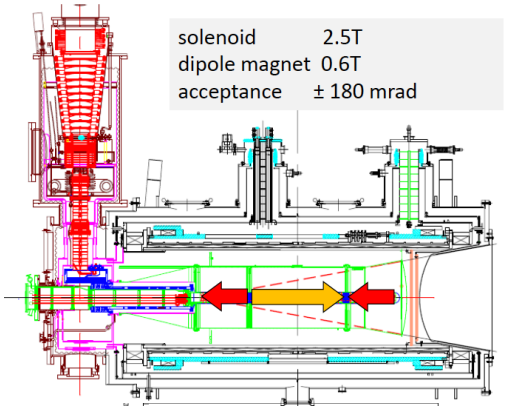
Sivers Functions

WHAT'S MISSING?

- Tensor charge of the nucleon (analog to vector and axial charges)
- Full mapping of all 11 TMD PDFs as a function of quark flavor in the valence region
- Test of universality
- Test of prediction that time-odd TMDs (e.g., Sivers asymmetry) change sign in Drell-Yan processes
- TMDs of sea quarks and gluons
- Towards a "wave function" of the nucleon including angular orbital momentum
  (Wigner distribution? Lattice comparison?)

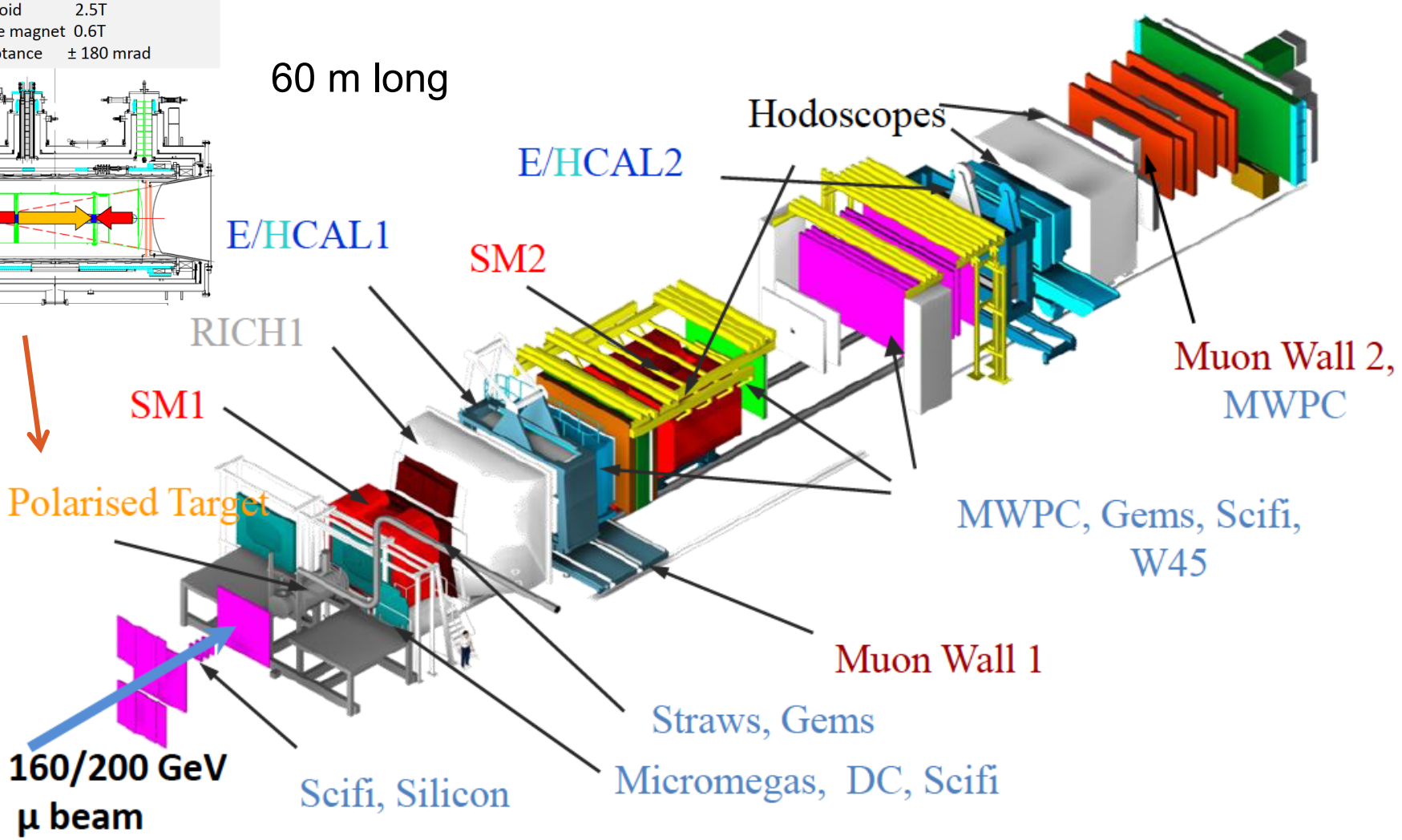
THE COMPASS SPECTROMETER

upgraded for COMPASS II



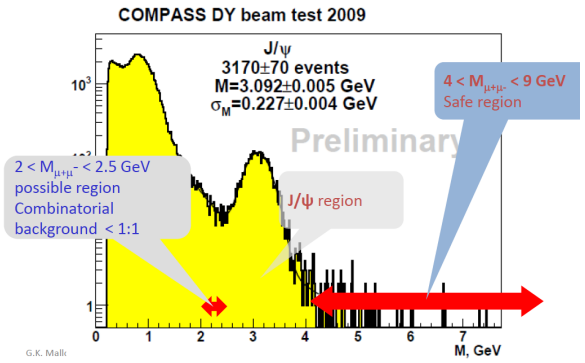
60 m long

50% d
90% p



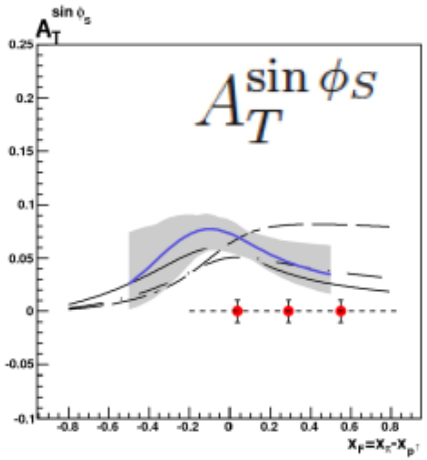
Polarization ≈ 75% from weak pion decay

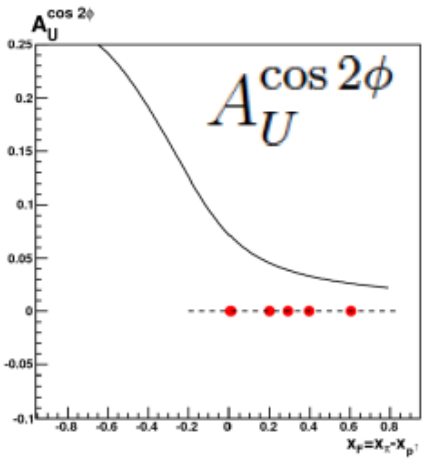
DRELL-YAN

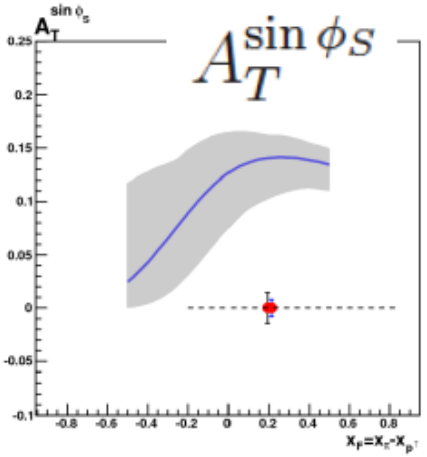


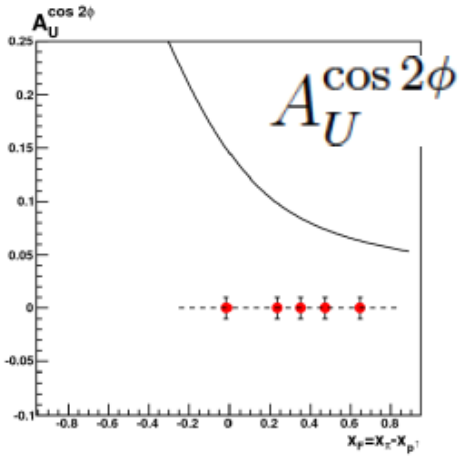
$2.0 \leq M_{\mu\mu} \leq 2.5\ \mathrm{GeV}/c^2$

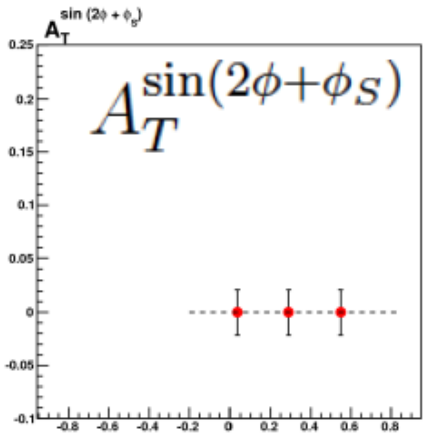
$4. \leq M_{\mu\mu} \leq 9.\ \mathrm{GeV}/c^2$

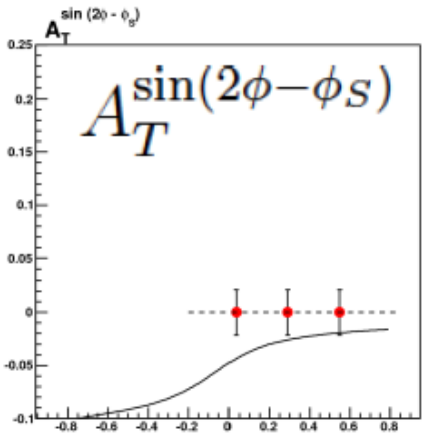


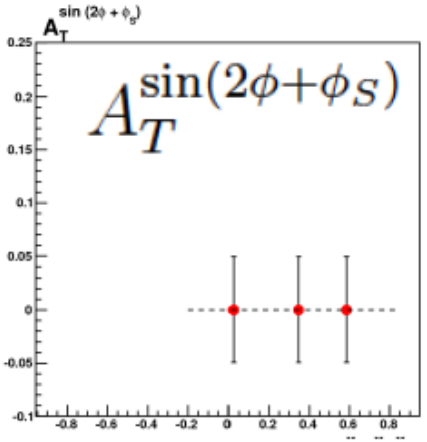


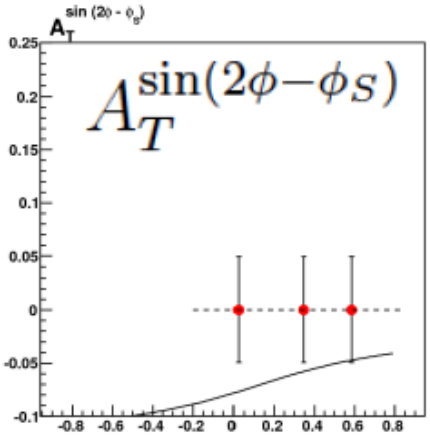


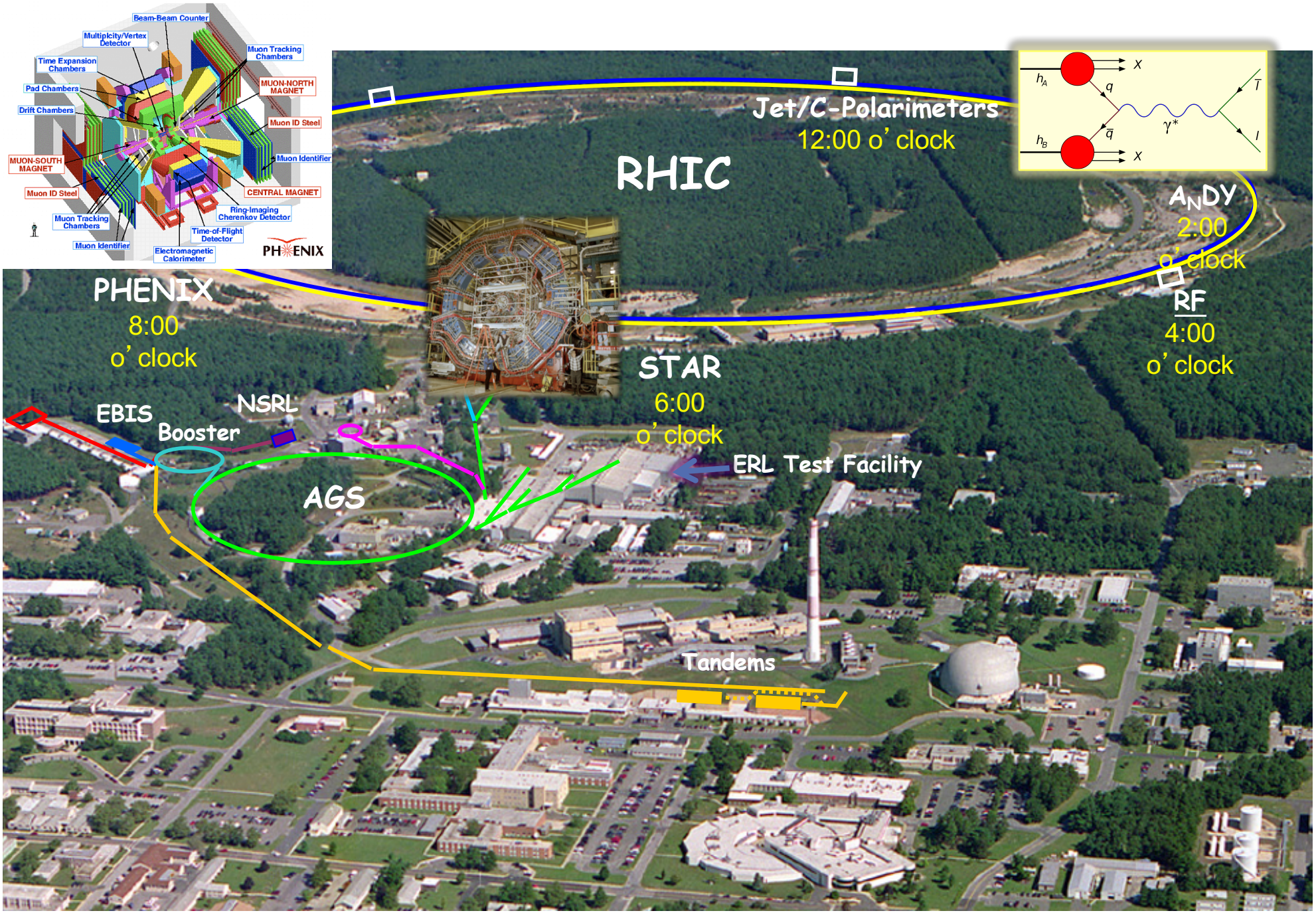






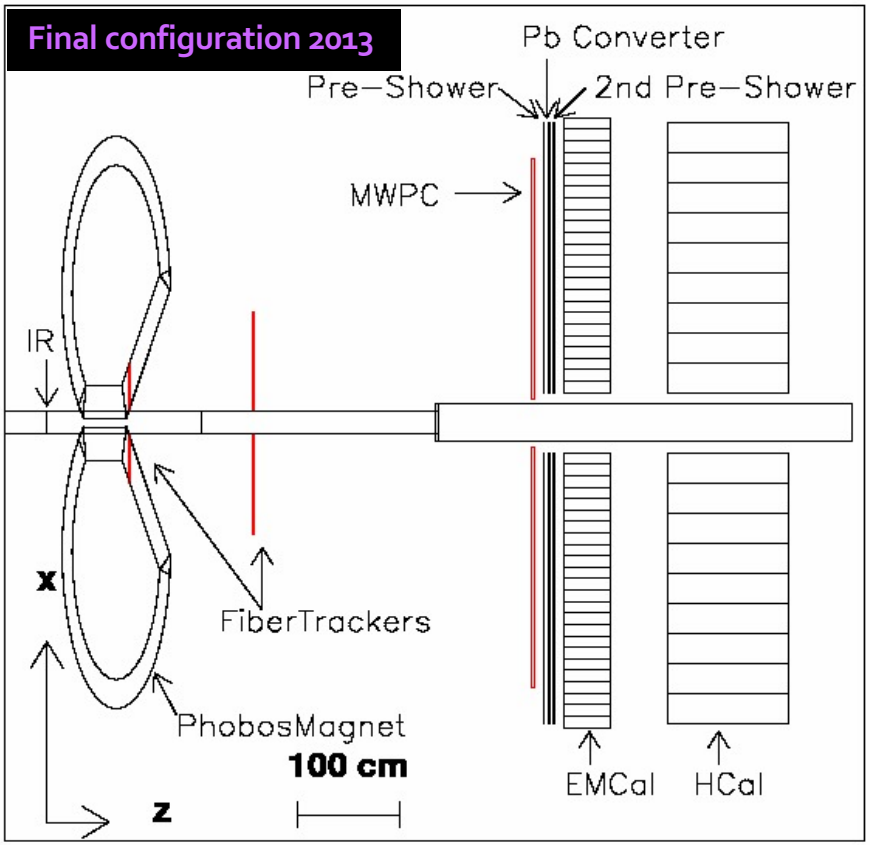


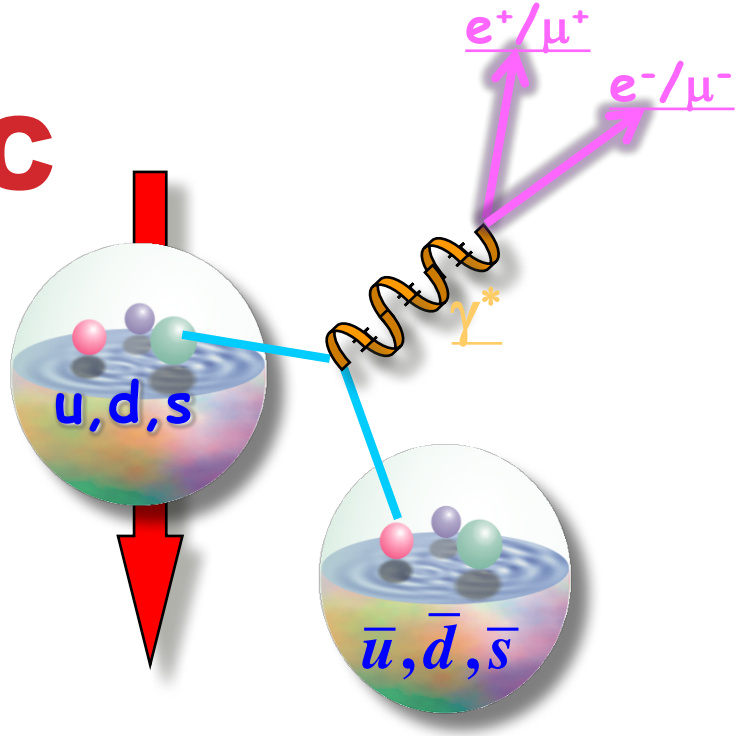



Beam-Beam Counter
Multiplicity/Vertex Detector
Time Expansion Chambers
Pad Chambers
Drift Chambers
Muon Tracking Chambers
MUON-NORTH MAGNET
Muon ID Steel
Muon Identifier
MUON-SOUTH MAGNET
Muon ID Steel
CENTRAL MAGNET
Muon Tracking Chambers
Ring-Imaging Cherenkov Detector
Time-of-Flight Detector
Muon Identifier
Electromagnetic Calorimeter
PHENIX
RHIC
Jet/C-Polarimeters
12:00 o' clock
A_NDY
2:00
o' clock
RF
4:00
o' clock
PHENIX
8:00
o' clock
STAR
6:00
o' clock
EBIS
Booster
NSRL
AGS
ERL Test Facility
Tandems

DRELL YAN AT RHIC

A_NDY @ IP-2





- Idea: have DY feasibility test at IP-2
  - staged measurements over 3 years
  - re-use as much detector equipment as possible to finish till summer 2014
- Measurement:
  - why IP-2
    - ✓ transverse polarization
    - ✓ measure parallel to $\sqrt{s}$ = 500 GeV W-program
  - η > 3, M>4 GeV $0.1<x_f<0.3$
  - → optimizes Signal / Background & DY rate
  - → measure δA_N^{DY} ~0.015 for $\int L \sim 100$ pb^{-1}
- Proposal approved June 2011 BNL PAC

JEFFERSON LAB

CLOSE-OUT 6 GeV

- **Finish analysis on CLAS eg1-DVCS (SSAs + DSAs in $\pi^{+/0/-}$ production with longitudinally polarized H and D targets) and EG4 (SSFs at low Q^2)**
- **g_{2p} at low Q^2 (Hall A)**
- **Test electron run on HD-ICE**

12 GEV PROGRAM (6.6, 8.8 and 11 GeV in Halls A/B/C)

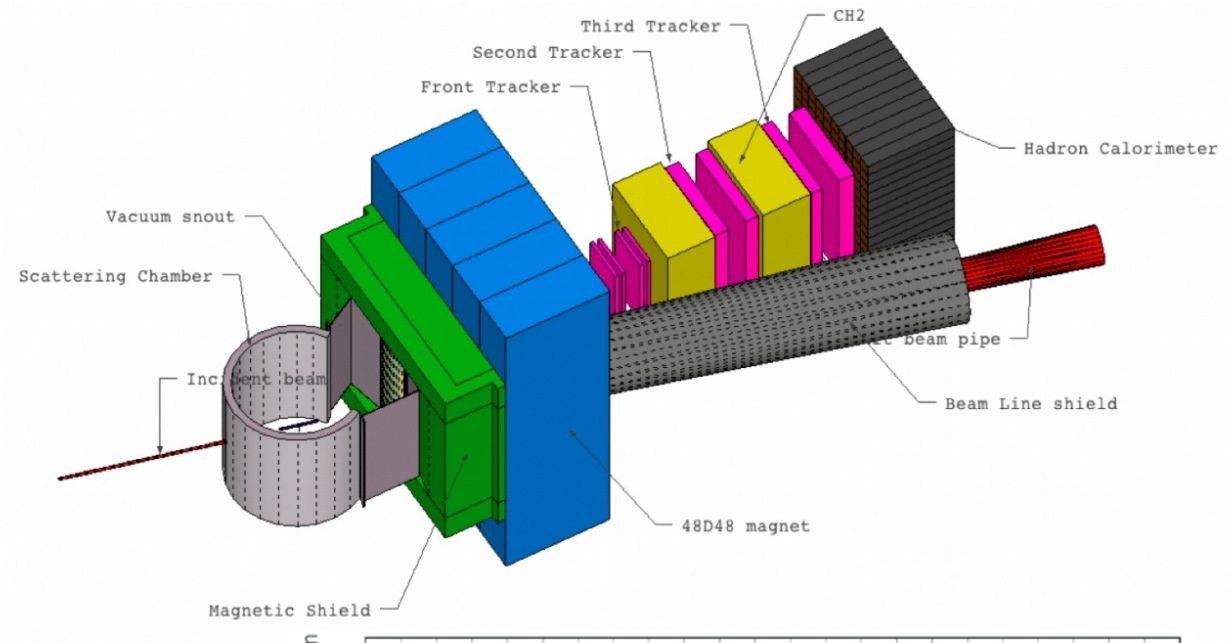
- **Inclusive SSFs on p, d, n (^{3}He) in all 3 Halls**
- **Tagged SSFs and TMDs on p, d, n (^{3}He) in all 3 Halls (including Kaons)**

GOAL: Complete map of all PDFs in the valence region $x > 0.1$

NEW CAPABILITIES – HALL A

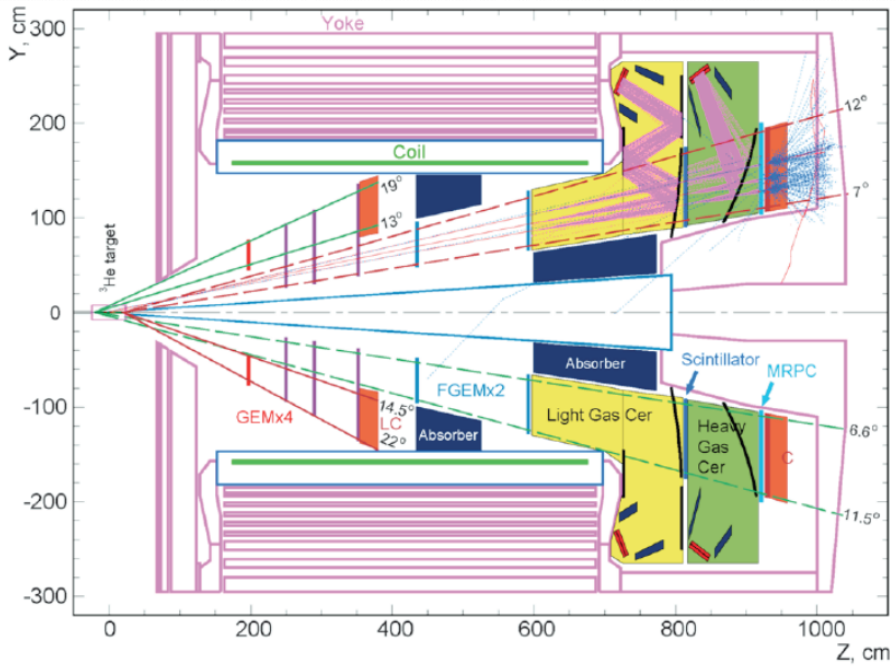
Super Big Byte

- (Moderately) large acceptance
- Full PID (K and π)
- Well-matched to high-luminosity ^{3}He target

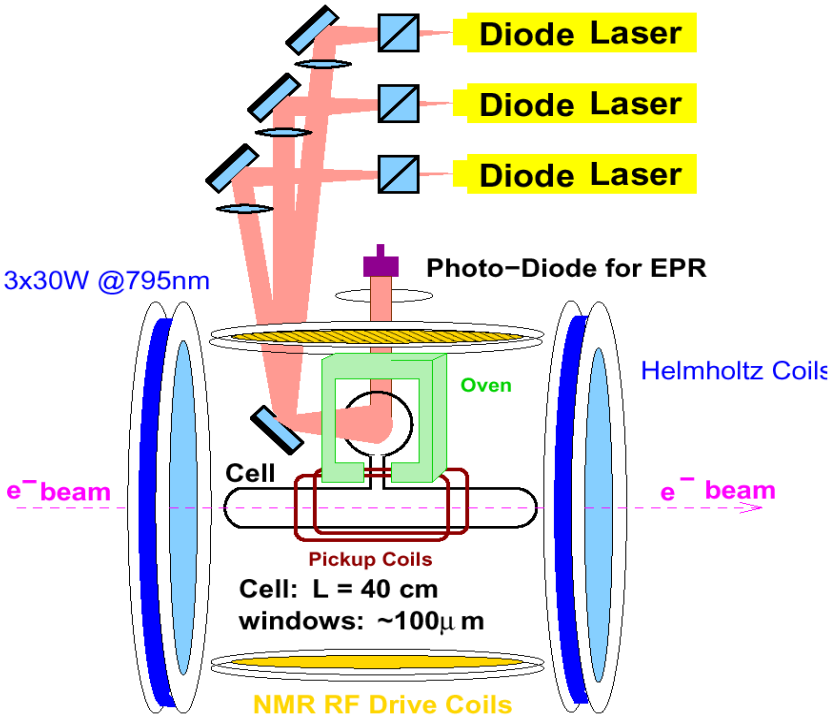


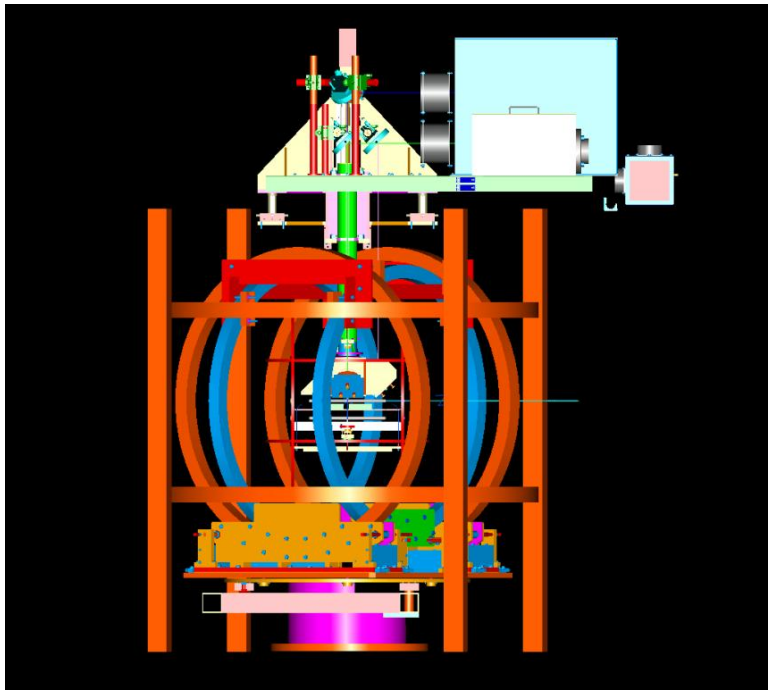
SoLID

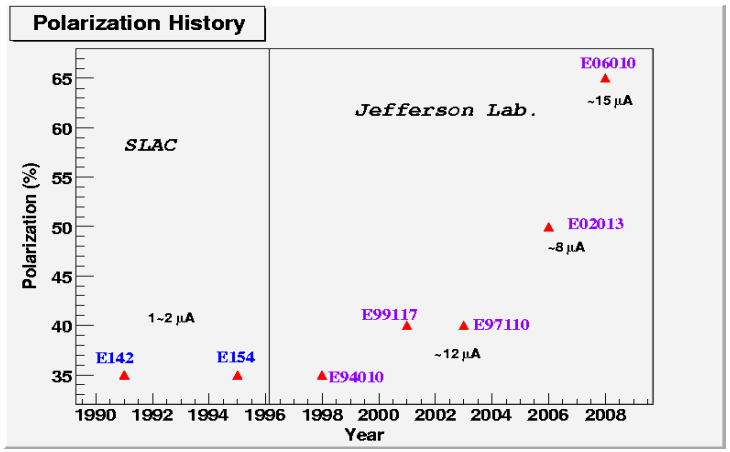
- Large acceptance (2π)
- Kinematic coverage out to moderately large P_T
- Capable of quite high luminosity (10^{36} cm^{-2}s^{-1})
- Requires major new funds

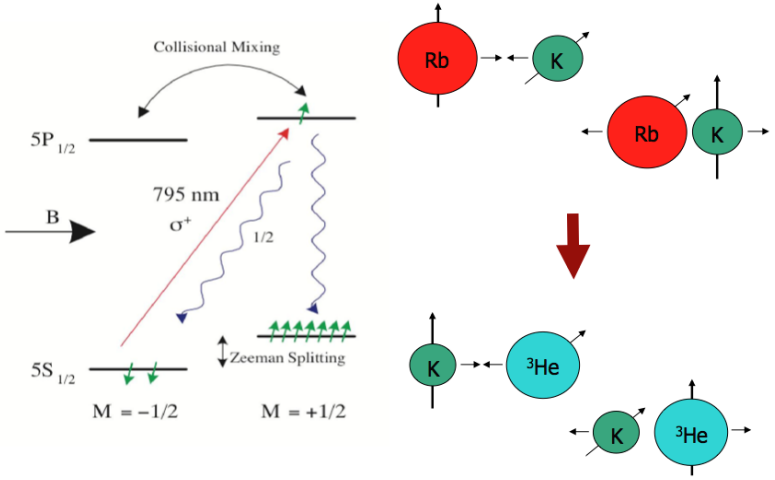


POLARIZED 3HE TARGETS (APPROX. POL. NEUTRON)









NEW CAPABILITIES – HALL B

CLAS12
(see next slide)

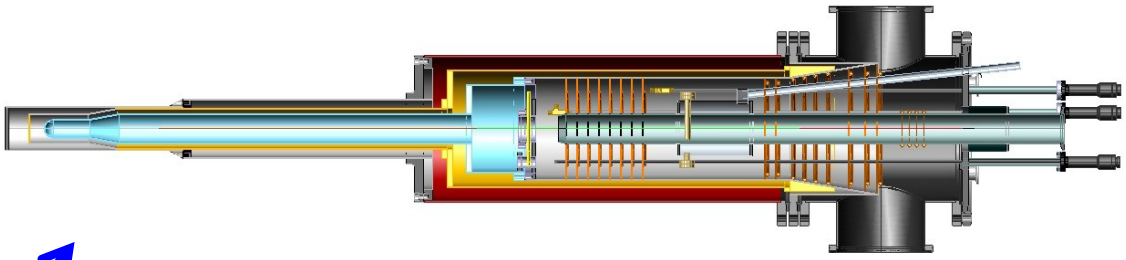
- VERY large acceptance
- Full PID (K and π)
  (K ID requires major new funds for RICH)
- Moderately high luminosity (10^{35} $cm^{-2}s^{-1}$)
  (matched to NH_3, ND_3)

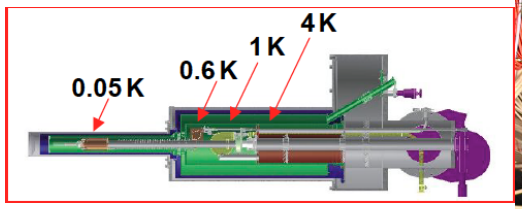
Polarized Targets

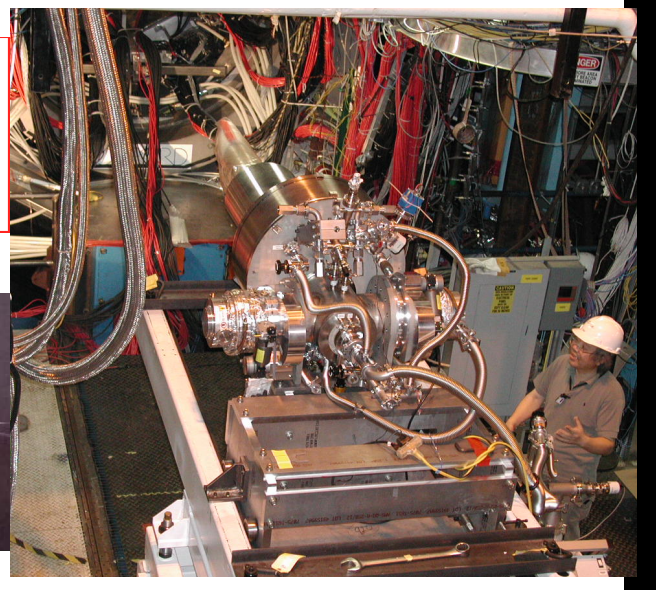
- Standard DNP longitudinal NH_3, ND_3 targets
  (funded by NSF MRI, under construction)
- HD-Ice target
  (suitability for e^- beam remains to be demonstrated)

Future longitudinally polarized target for CLAS12 (11 GeV program at Jefferson Lab)

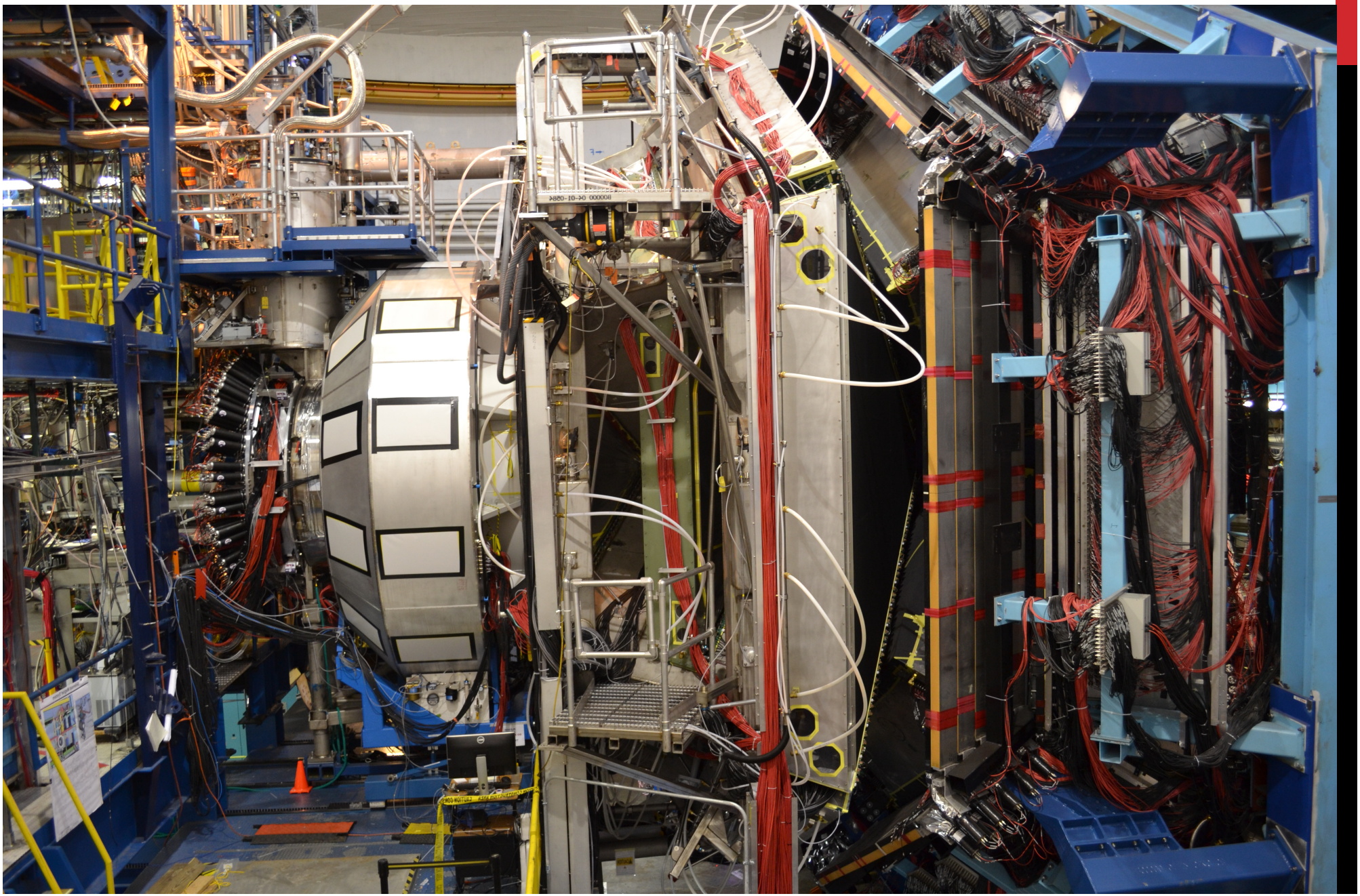
- Horizontal ^{4}He evaporation cryostat
- 5 T B-field provided by central detector







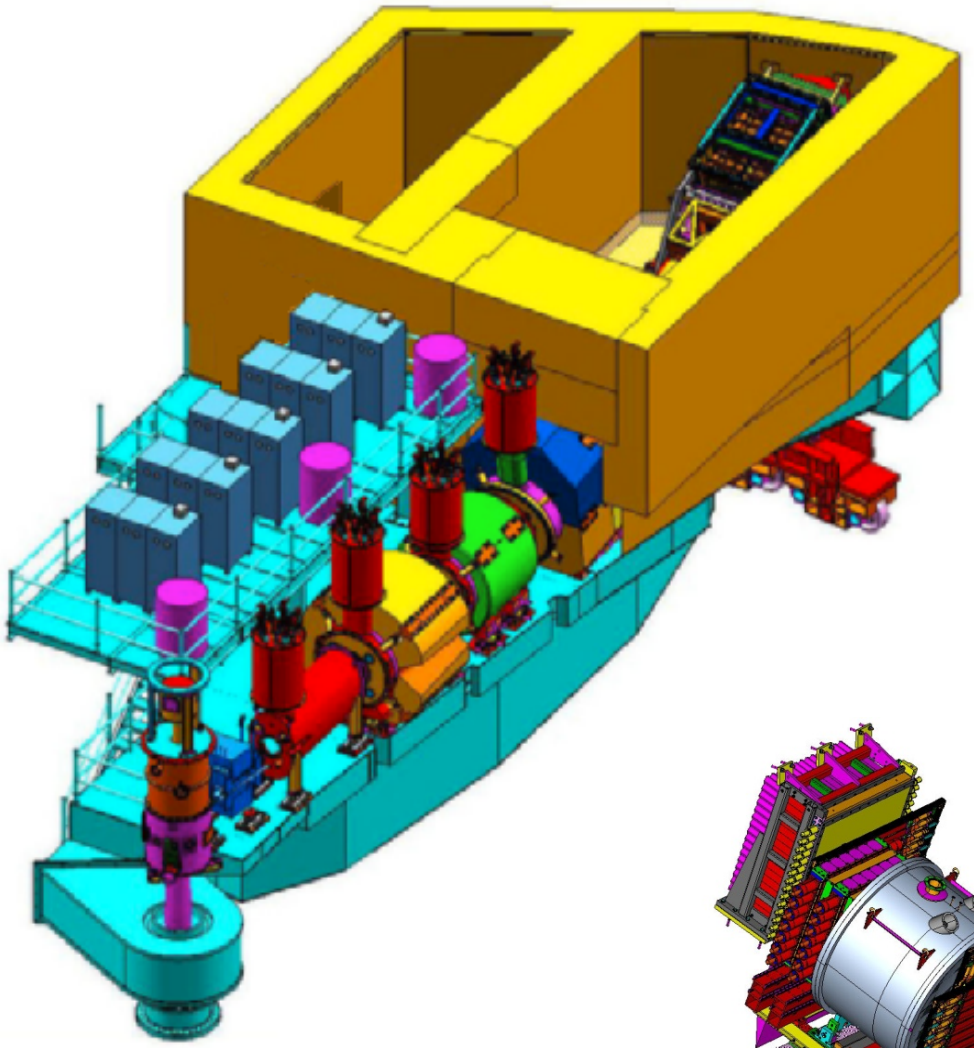
CLAS12

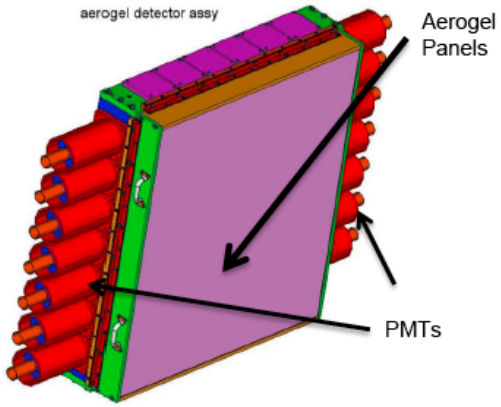


NEW CAPABILITIES – HALL C

Super HMS

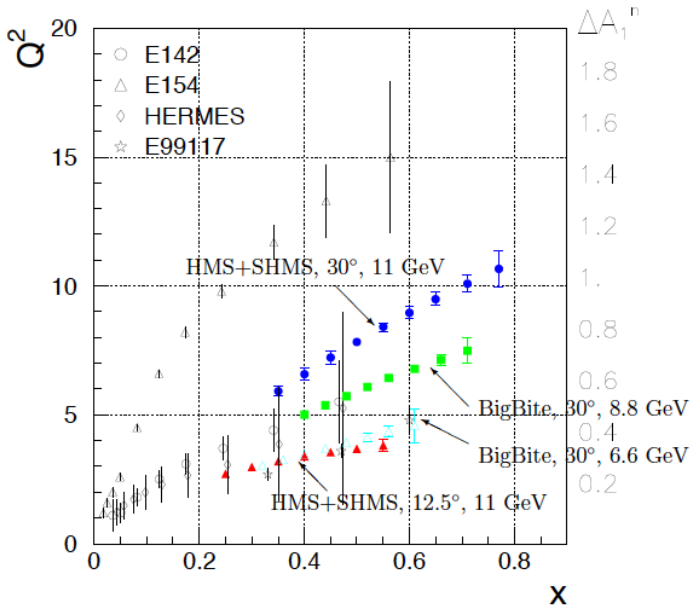
- High momentum capability and resolution
- Full PID
- High luminosity polarized ^{3}He target (as in Hall A)



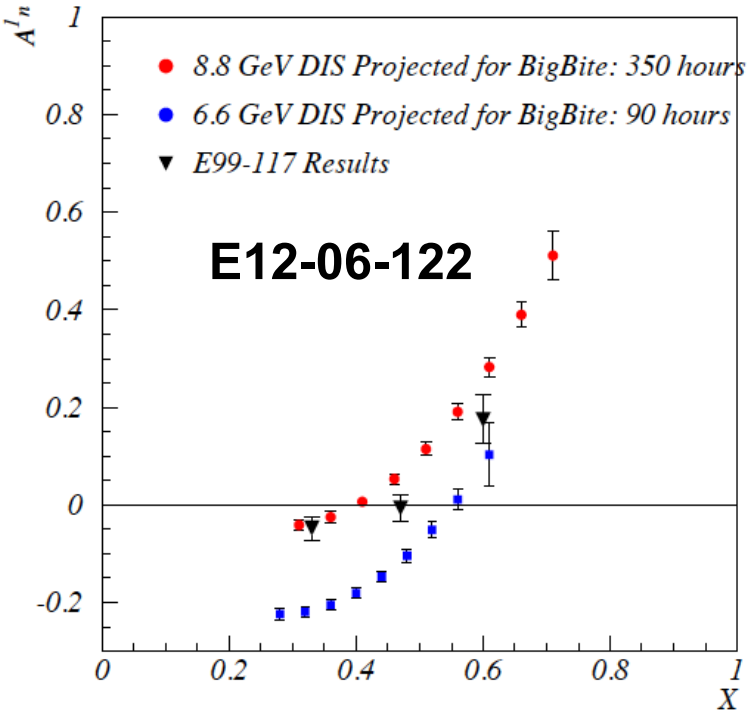


INCLUSIVE SSF – HALLS A/C

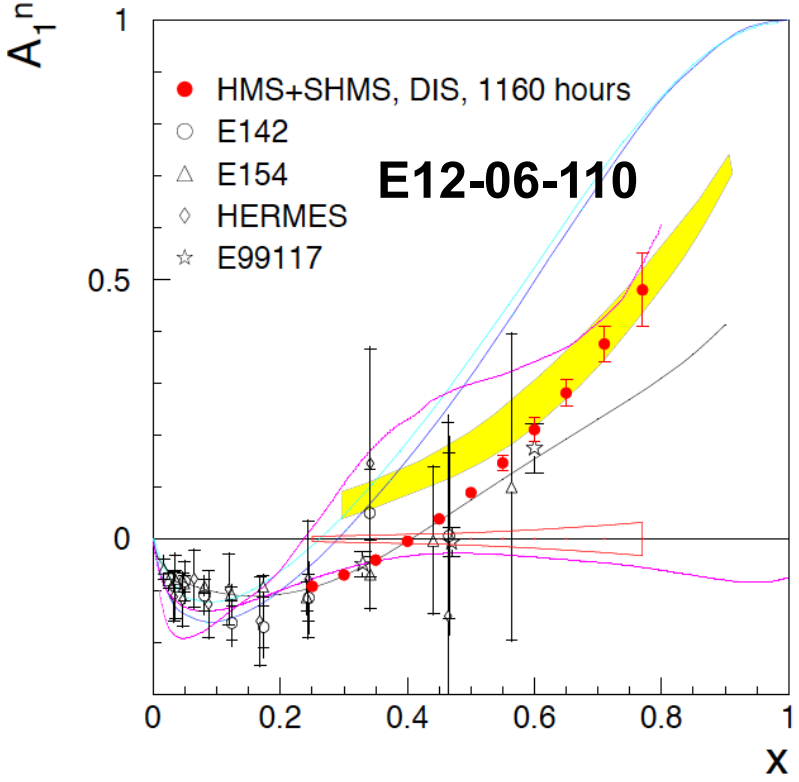
^{3}He -> A_{1n}, g_{1n}
Important constraint on Δd at large *x*



Hall A – BigByte

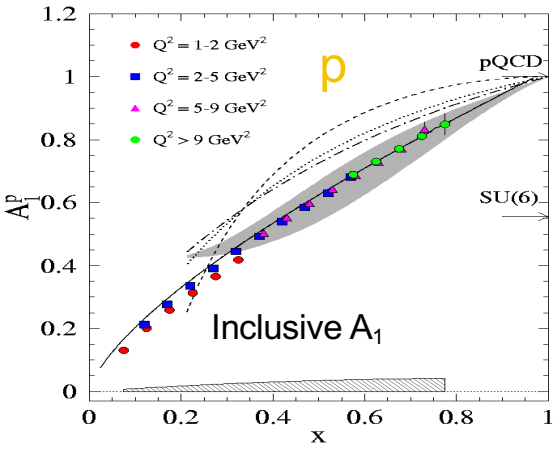


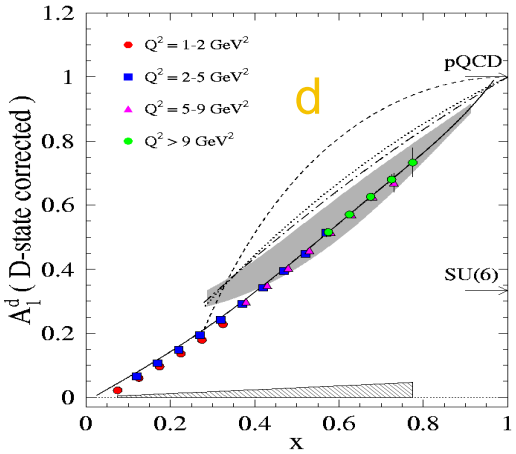
Hall C – SHMS+HMS



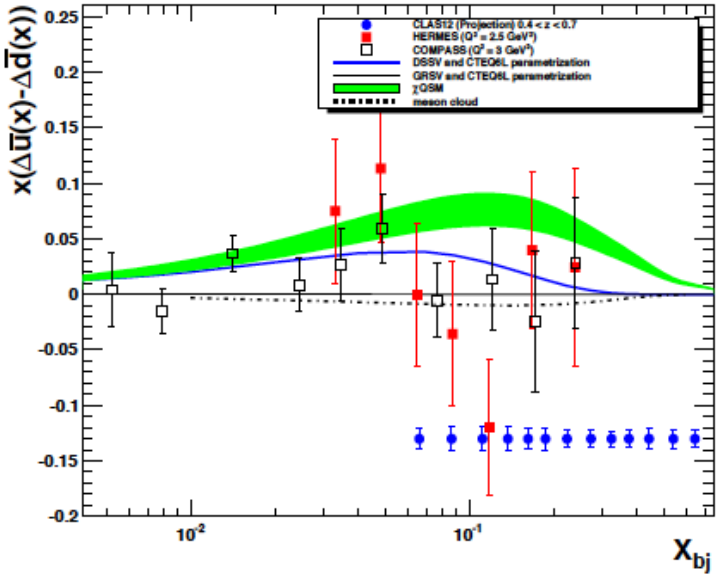
…+ g_{2n}

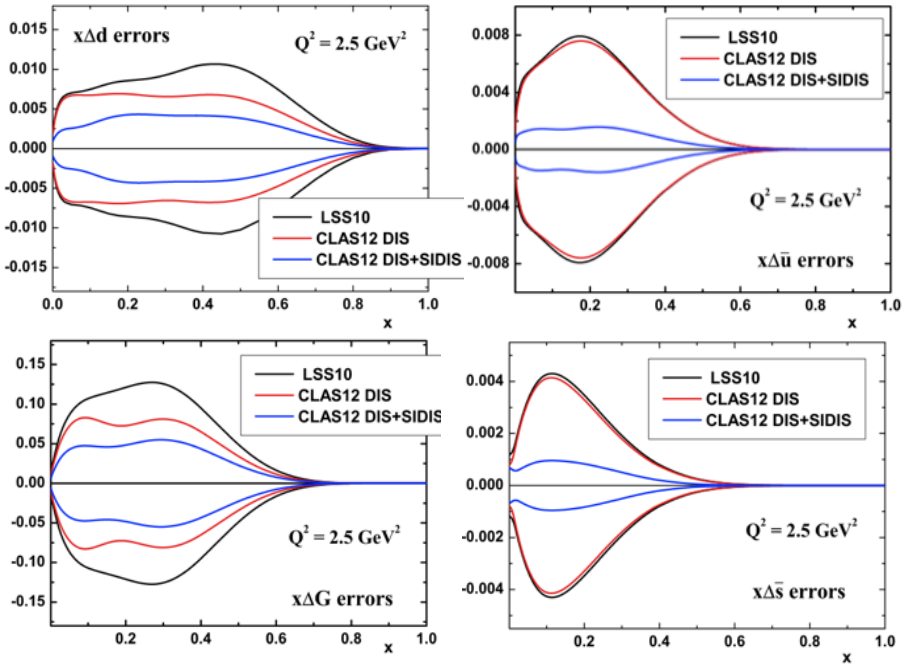
INCLUSIVE + TAGGED SSF – HALL B



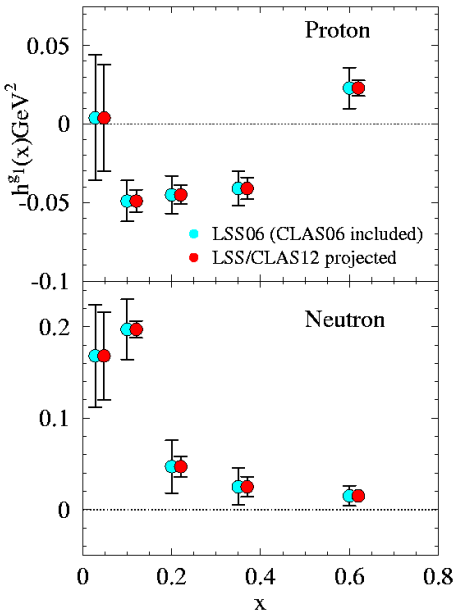


SIDIS A_1

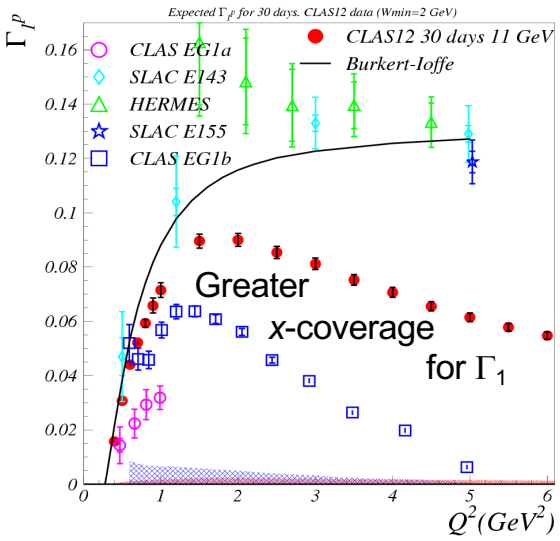




Improved PDFs from NLO analyses



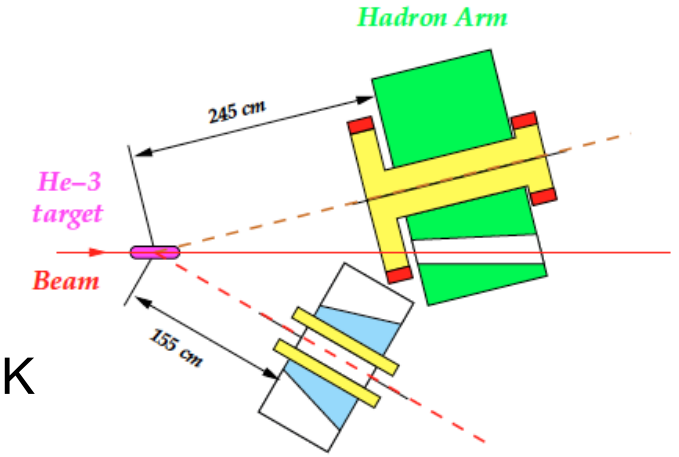
Better determination of Higher Twist vs. *x*



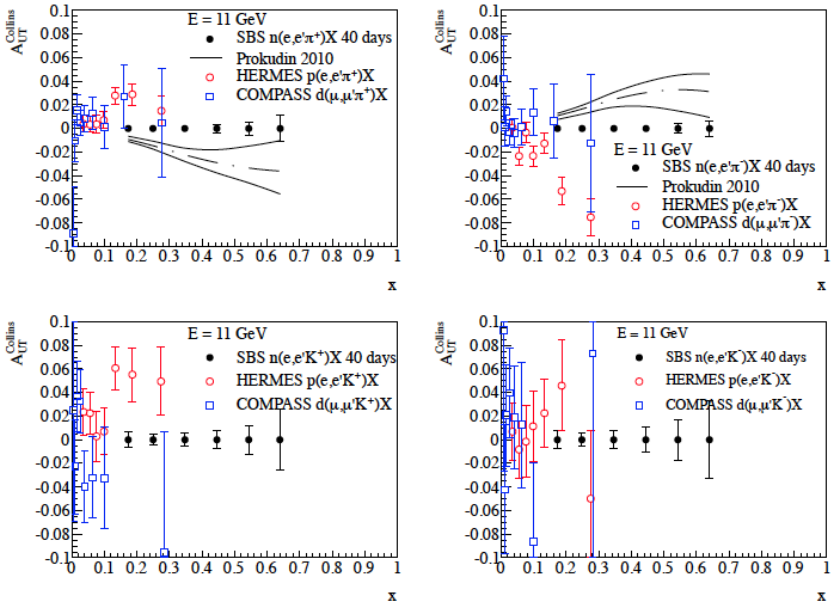
Improved coverage to evaluate moments

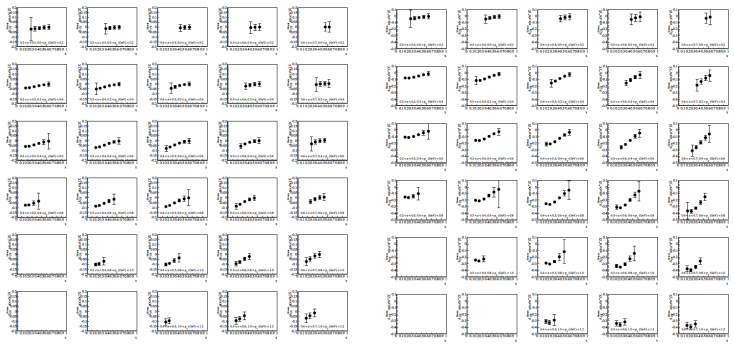
TMDS – HALL A

First generation: Use transverse ^{3}He target with Bigbite and Super Bigbite to measure Sivers, Collins (transversity), "worm-gear" and "pretzelosity" SSAs for π and K



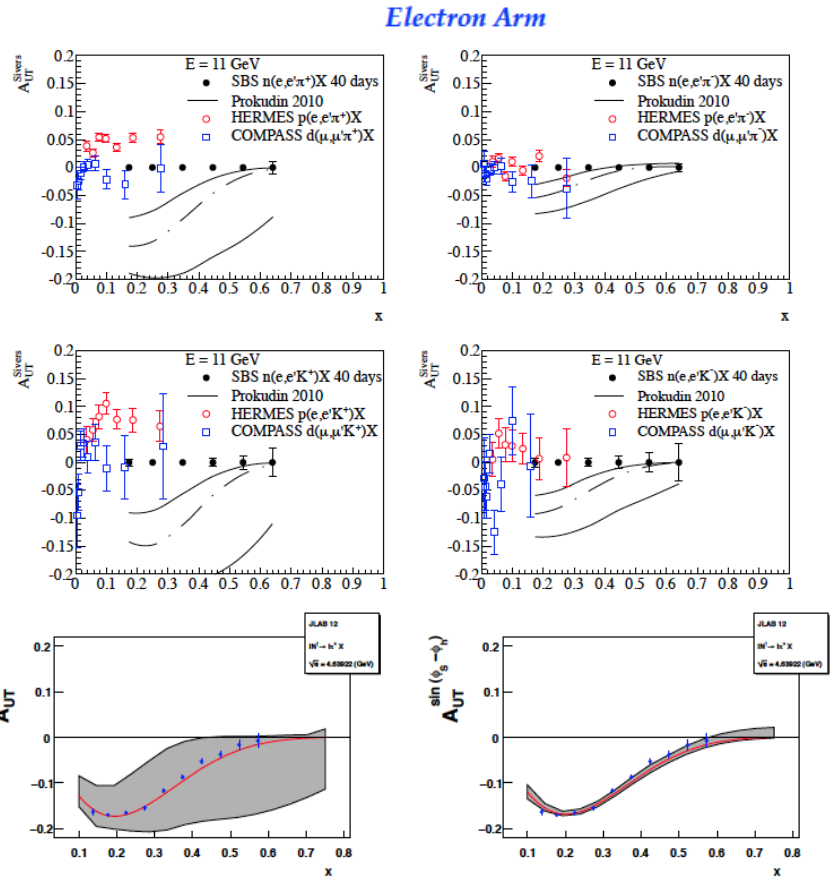
Collins





...

Sivers



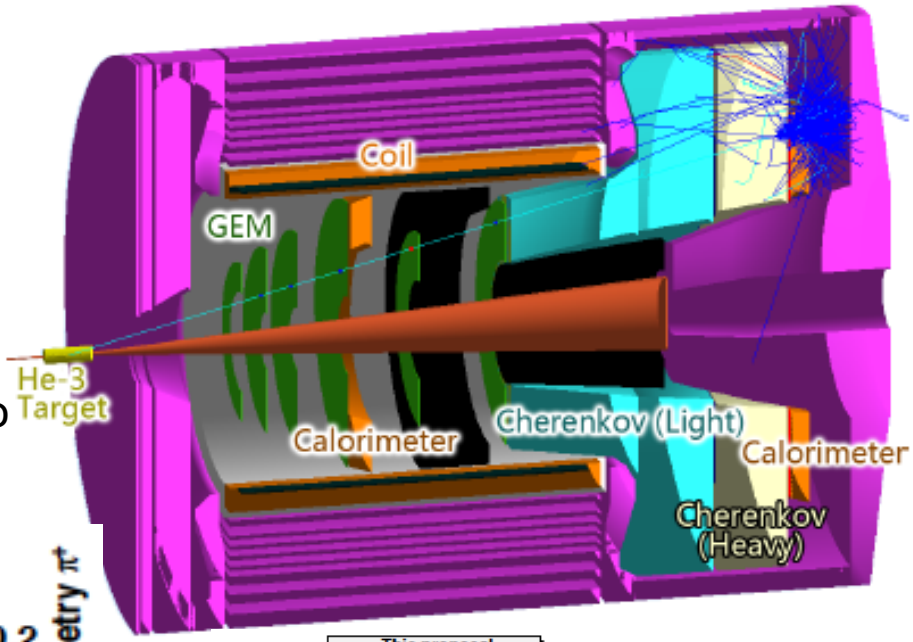
P12-09-018

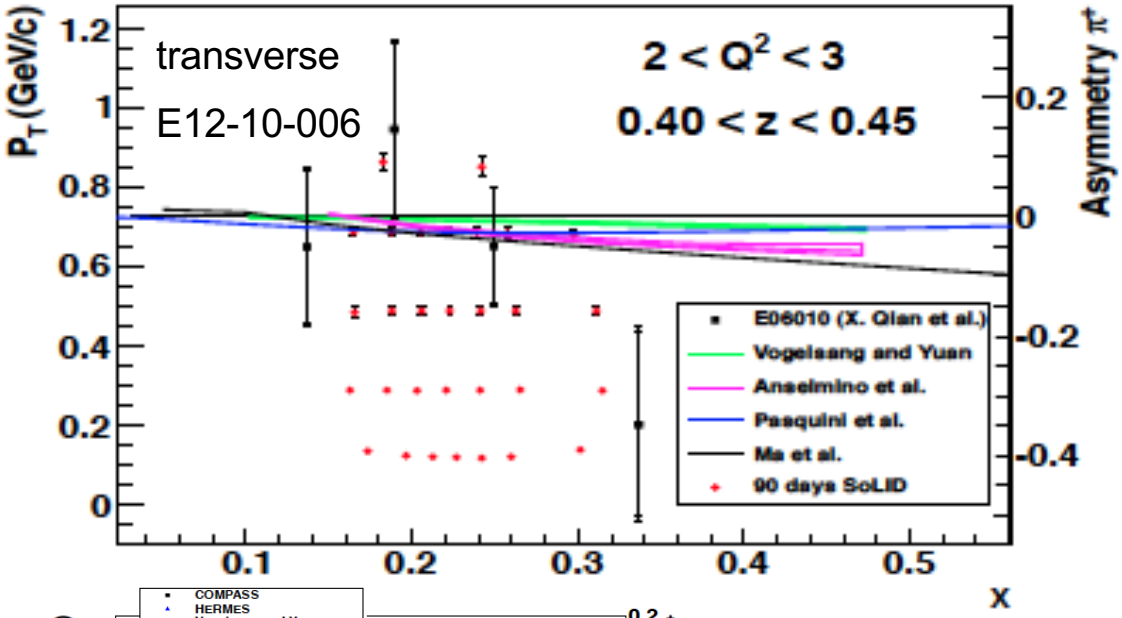
(a) A. Prokudin, 2010 best fit.

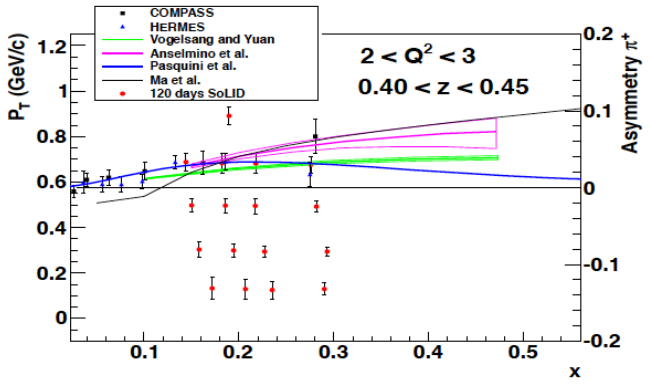
(b) Projected uncertainty band, *20* days $n(e,e'\pi^+)X$ at $E = 11$ GeV.

TMDS – HALL A

Later on: Use longitudinal and transverse ^{3}He target (and perhaps transverse p) with SoLID to measure all SSAs (TMDs) for π



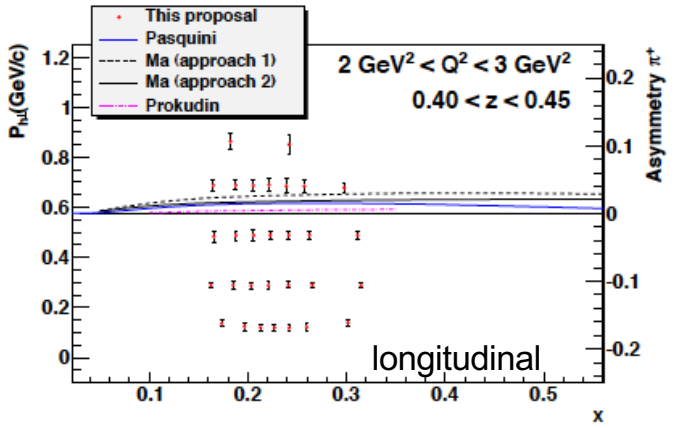


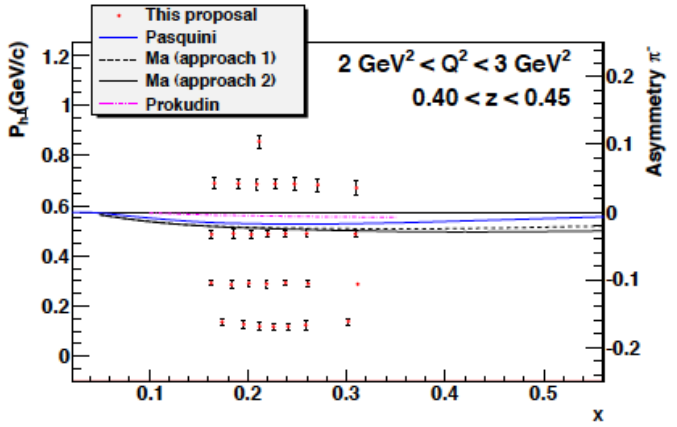


Proton

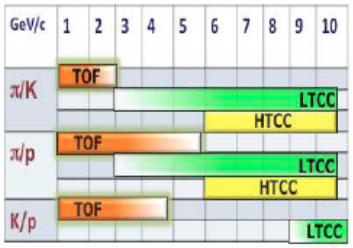
P12-11-108

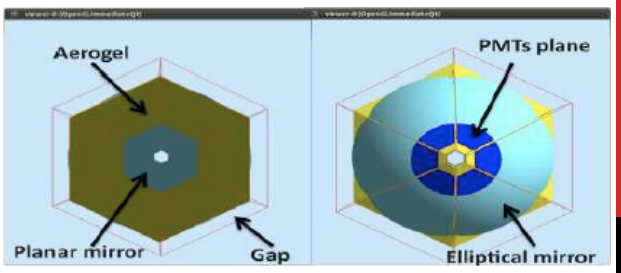
P12-11-007





TMDS – CLAS12





Comprehensive Program with **Longitudinal** and **Transverse** H, D targest

Worm gear, HT

Flavor tagging (Δq); pT dep.

Kaons Worm gear

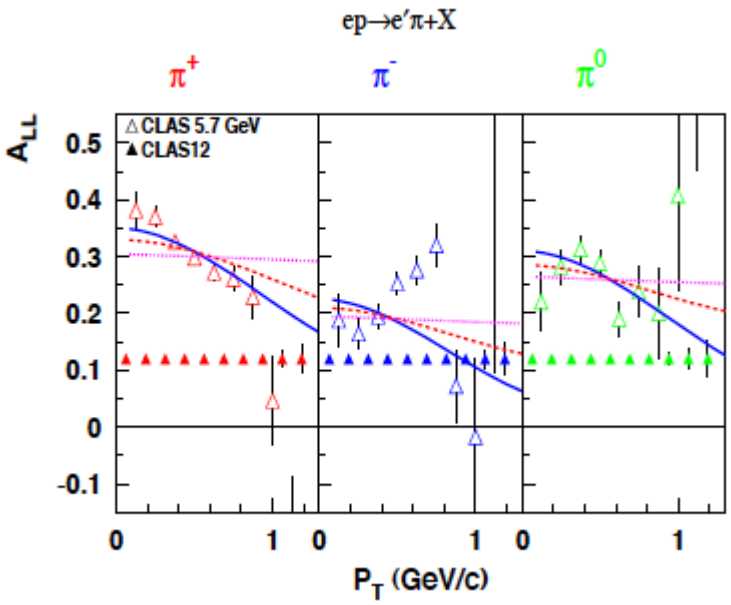
Two-Hadron (Deferred)

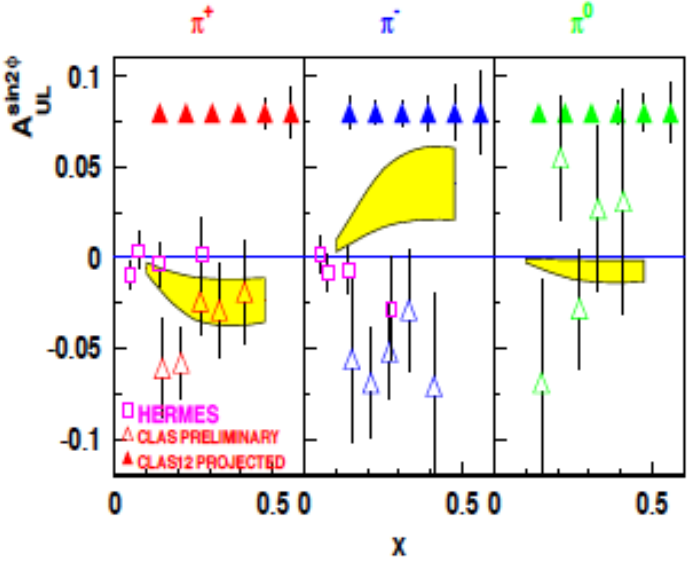
Transversity, Sivers, Worm Gear, Pretzelosity

Experiment	Quantity	Physics	Target	particle species	Kinematics	beam request	run group
E12-07-107	$A_{UL}^{\sin\phi}$ $A_{UL}^{\sin 2\phi}$		NH_3 ND_3	π^+, π^-, π^0	x= 0.1-0.7 P_T=0.1-1.2	30 days 50 days	
E12-09-007b	Δu, Δd, Δs Δu, Δd, Δs	x(Δu-Δd)	NH_3 ND_3	π^+, π^-, π^0 K^+, K^-, K^0_s	x=0.1-0.7	30 days 50 days	**170 days**
E12-09-009	A_1 $A_{UL}^{\sin\phi}$ $A_{UL}^{\sin 2\phi}$		NH_3 ND_3	π^+, π^-, π^0 K^+, K^-, K^0_s	Q^2= 1 - 9 x=0.1-0.7 P_T= 0.1-1.2	30 days 50 days	
PR12-11-109b	A_{UL}	h_L	NH_3 ND_3	$\pi\pi$, KK	x=0.05-0.6	30 days 50 days	
PR12-11-111	SIDIS A_{UT}	Sivers, Transversity Pretzelosity	HD	π^+,π^-,π^0 K^+, K^-, K^0_s	Q^2=1-10GeV^2 x=0.1-0.7 P_T=0.2-1.5	100 days	**100 days**

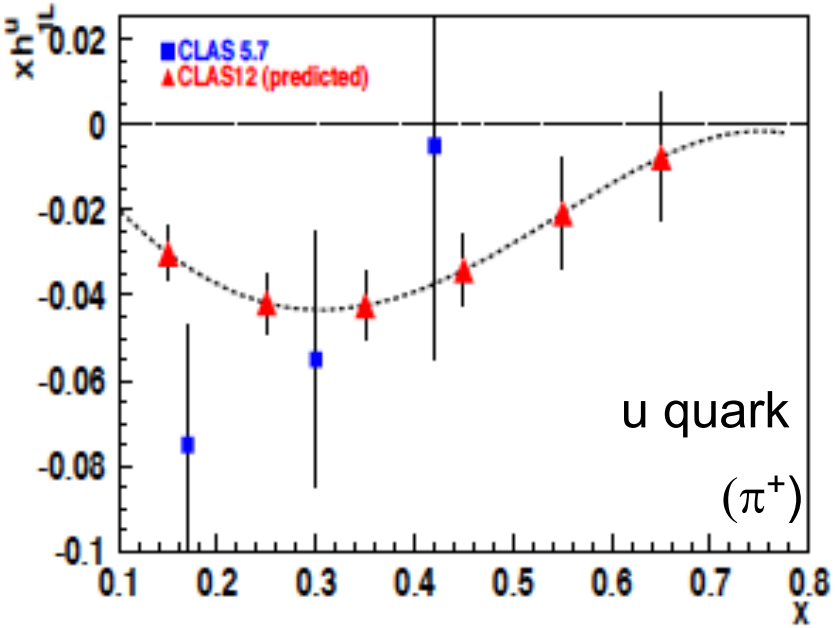
TMDS – CLAS12 (LONG. POL. P,D)

A_1 p_T distr.

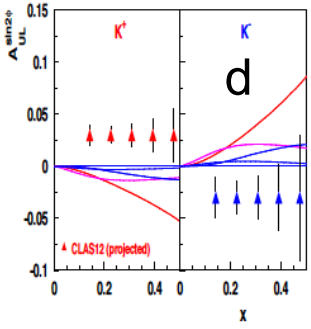


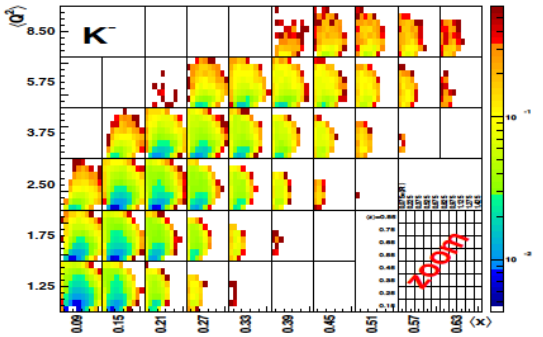


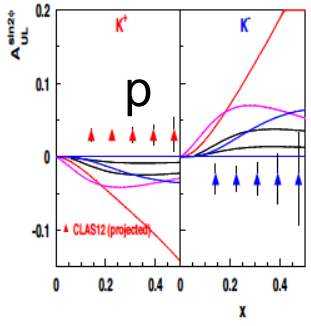
…+sinϕ
(Higher Twist)

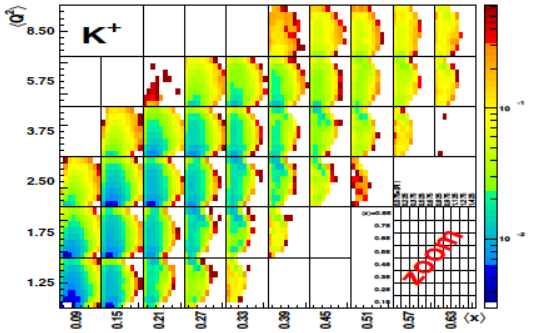


Worm Gear

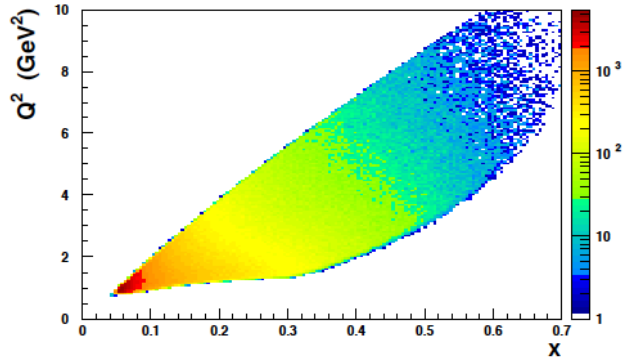




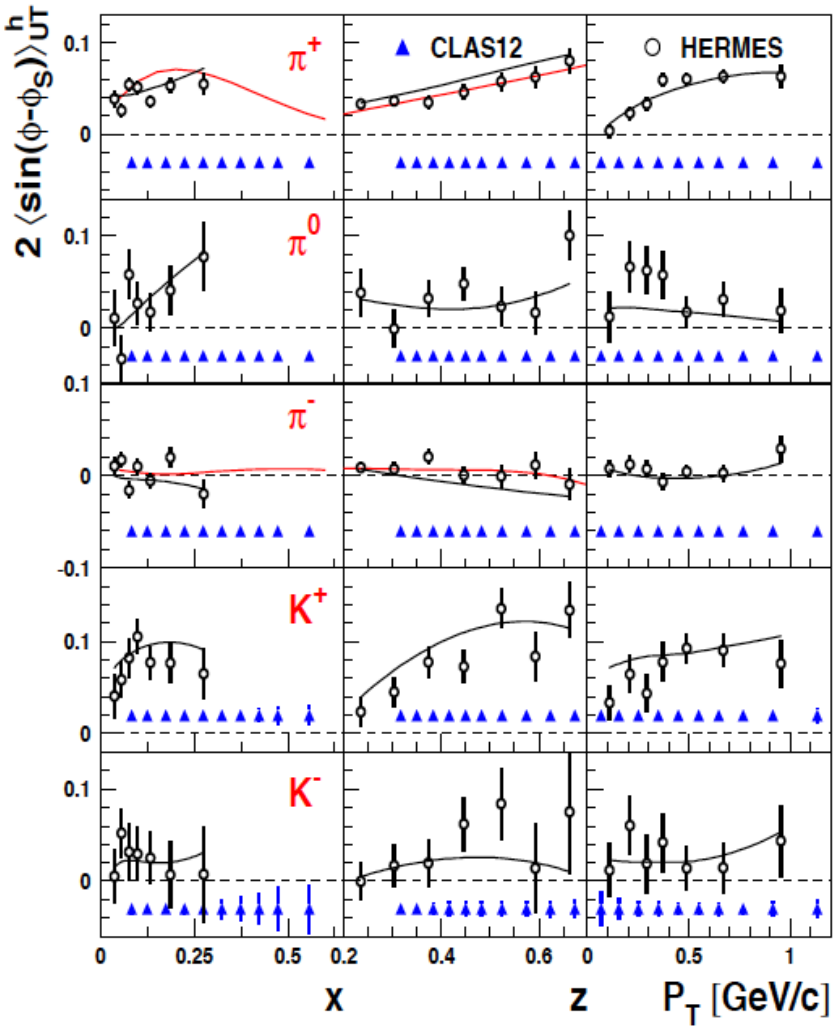




TMDS – CLAS12
TRANSVERSE HD-ICE (?)



Sivers



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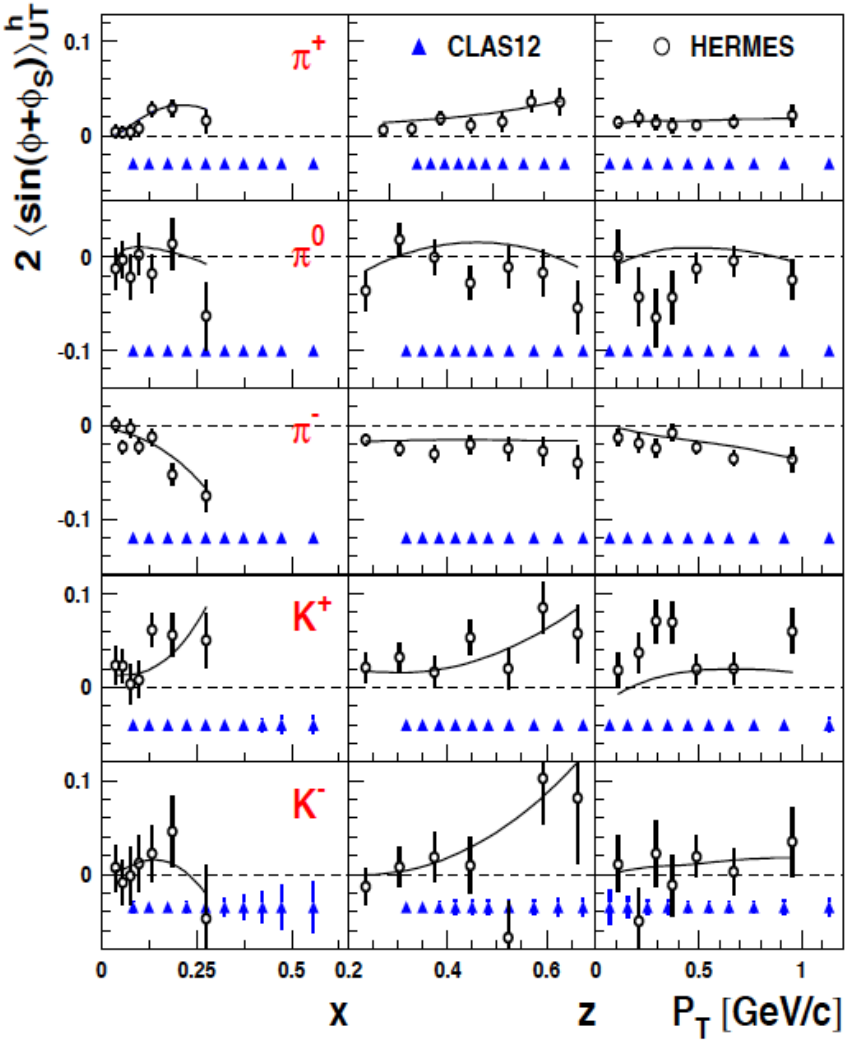
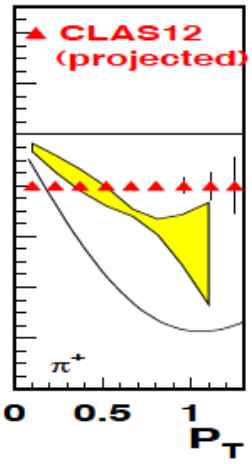


+

worm gear,



pretzelosity