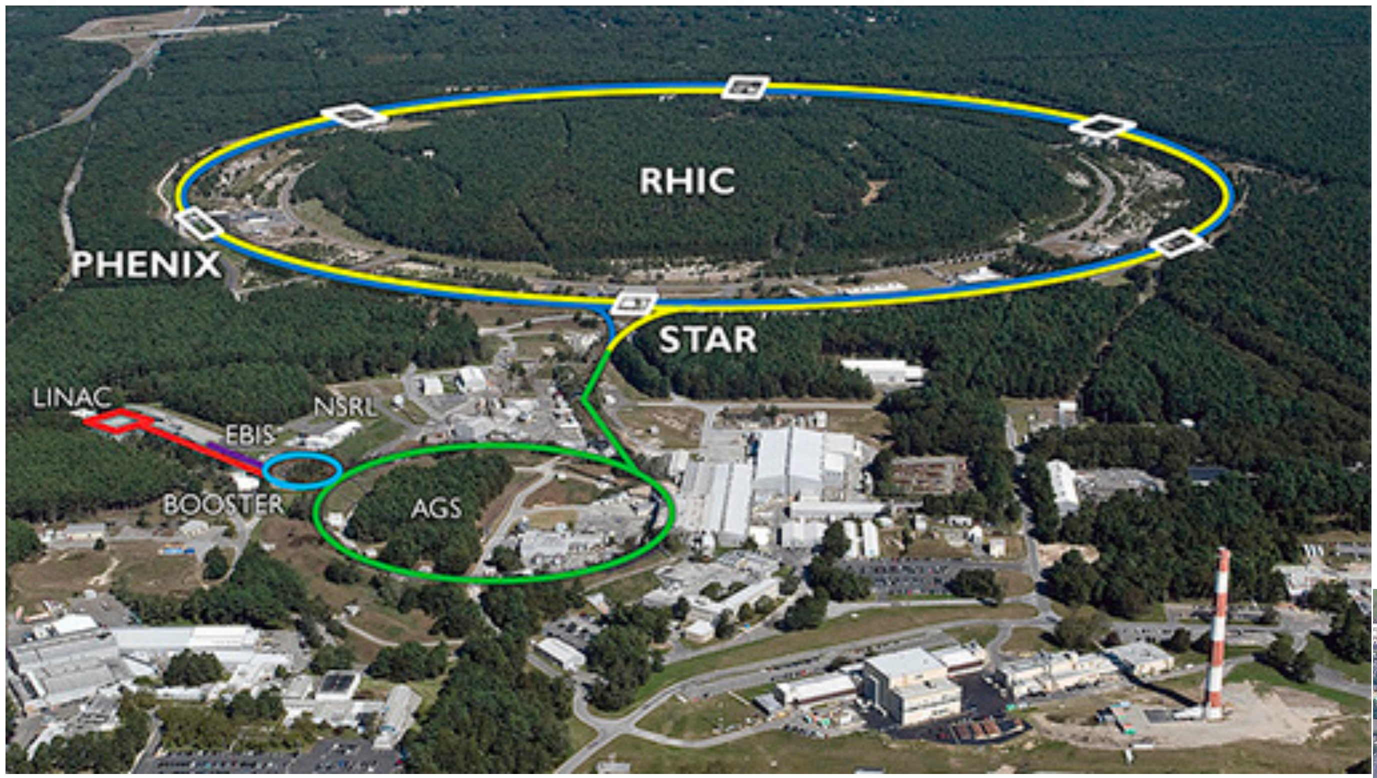
Inside of the nucleon: Zooming in and out

Sanghwa Park
(Stony Brook University)

From p+A to e+N



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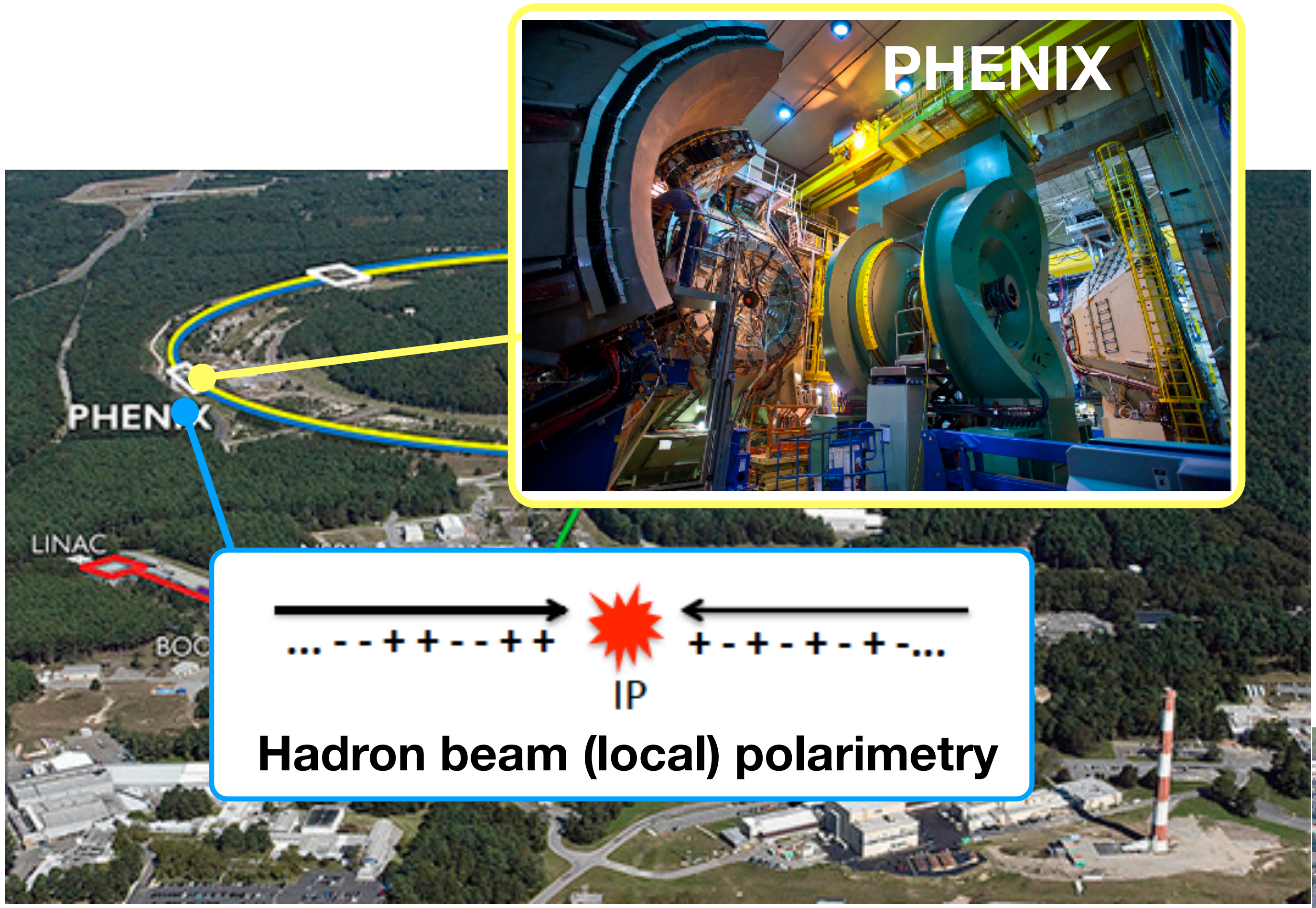

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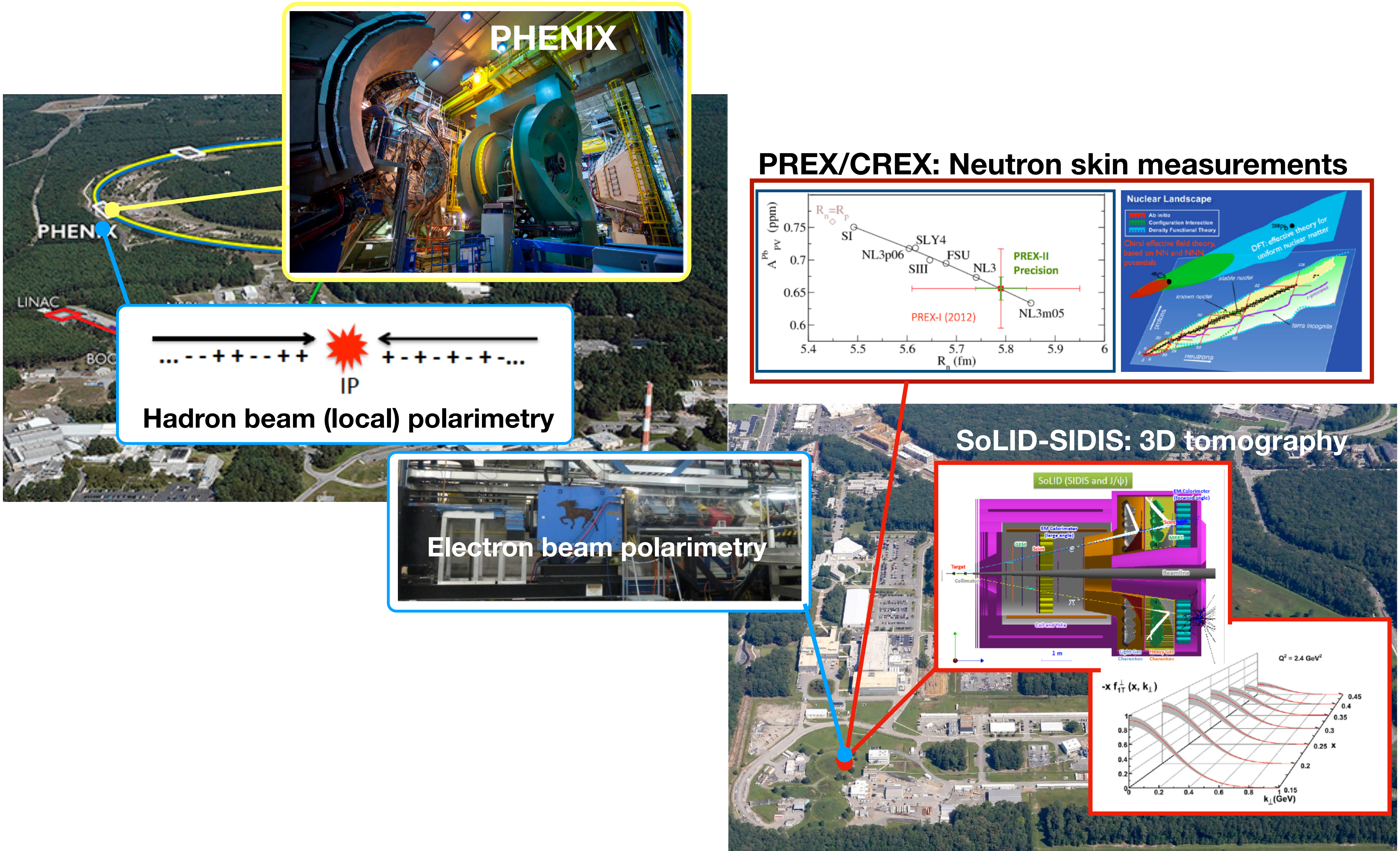
PHENIX
PHENIX
LINAC
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IP
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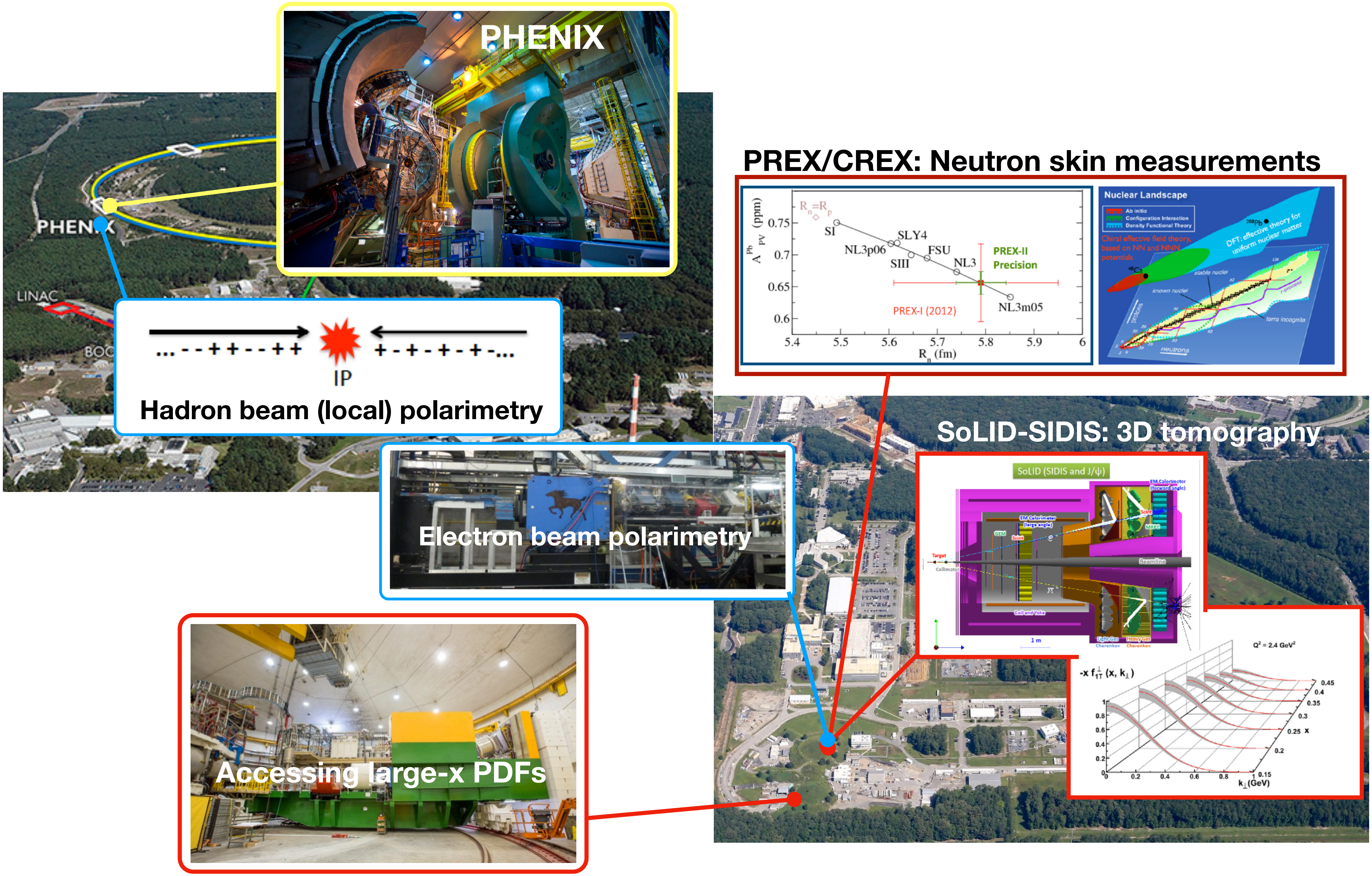
Hadron beam (local) polarimetry
Electron beam polarimetry
PREX/CREX: Neutron skin measurements
$R_n=R_p$
SI
SLY4
NL3p06
FSU
SIII
NL3
PREX-II Precision
PREX-I (2012)
NL3m05
A_{PV}^{Pb} (ppm)
R_n (fm)
Nuclear Landscape
SoLID-SIDIS: 3D tomography
SoLID (SIDIS and J/ψ)
Q² = 2.4 GeV²
$-x\, f_{1T}^{\perp}(x, k_\perp)$
$k_\perp$(GeV)

From p+A to e+N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RHIC Spin Program: Key questions

- **How do gluons contribute to the proton spin?**
- **What is the landscape of the polarized sea in the nucleon?**
- **What do transverse spin phenomena teach us about proton structure?**

PHENIX pi0: access gluons

RHIC data: direct access to gluons

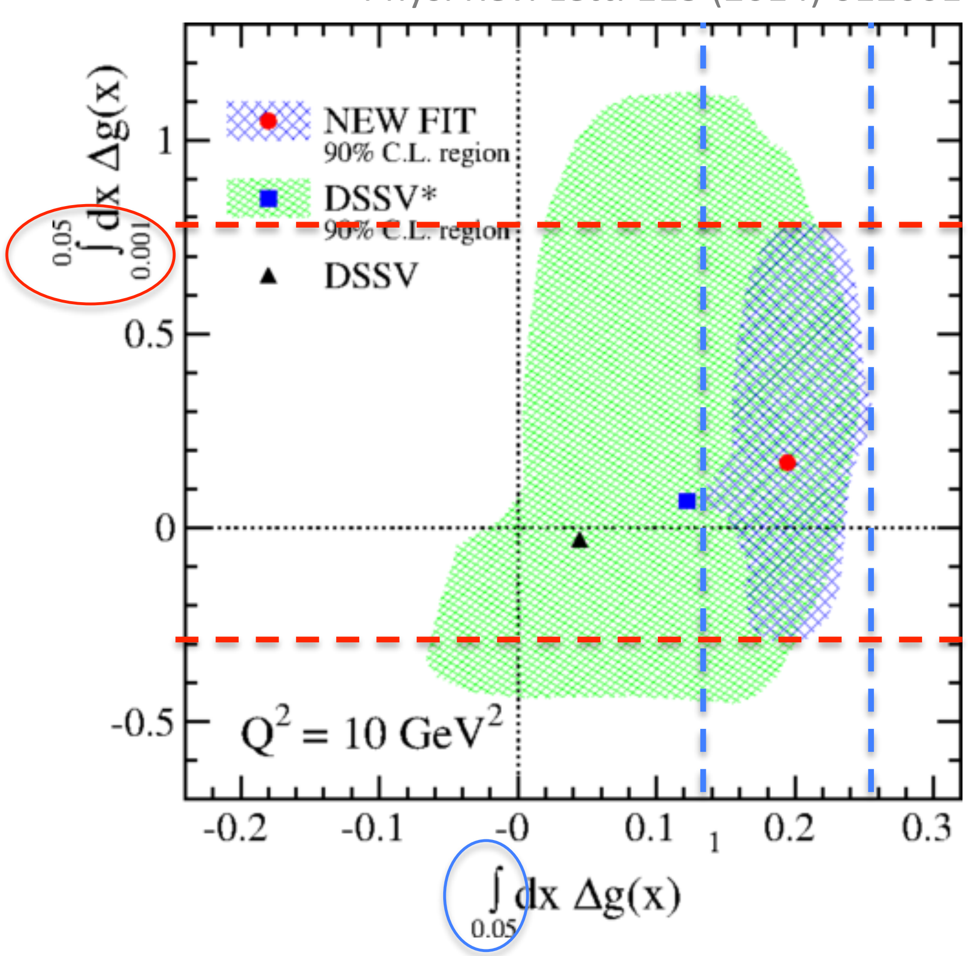
PHENIX pi0 and STAR jets confirm non-zero gluon spin for x > 0.05

$$\int_{0.05}^{1} dx \Delta g(x) = 0.2^{+0.06}_{-0.07} (Q^2 = 10 \text{GeV}^2)$$

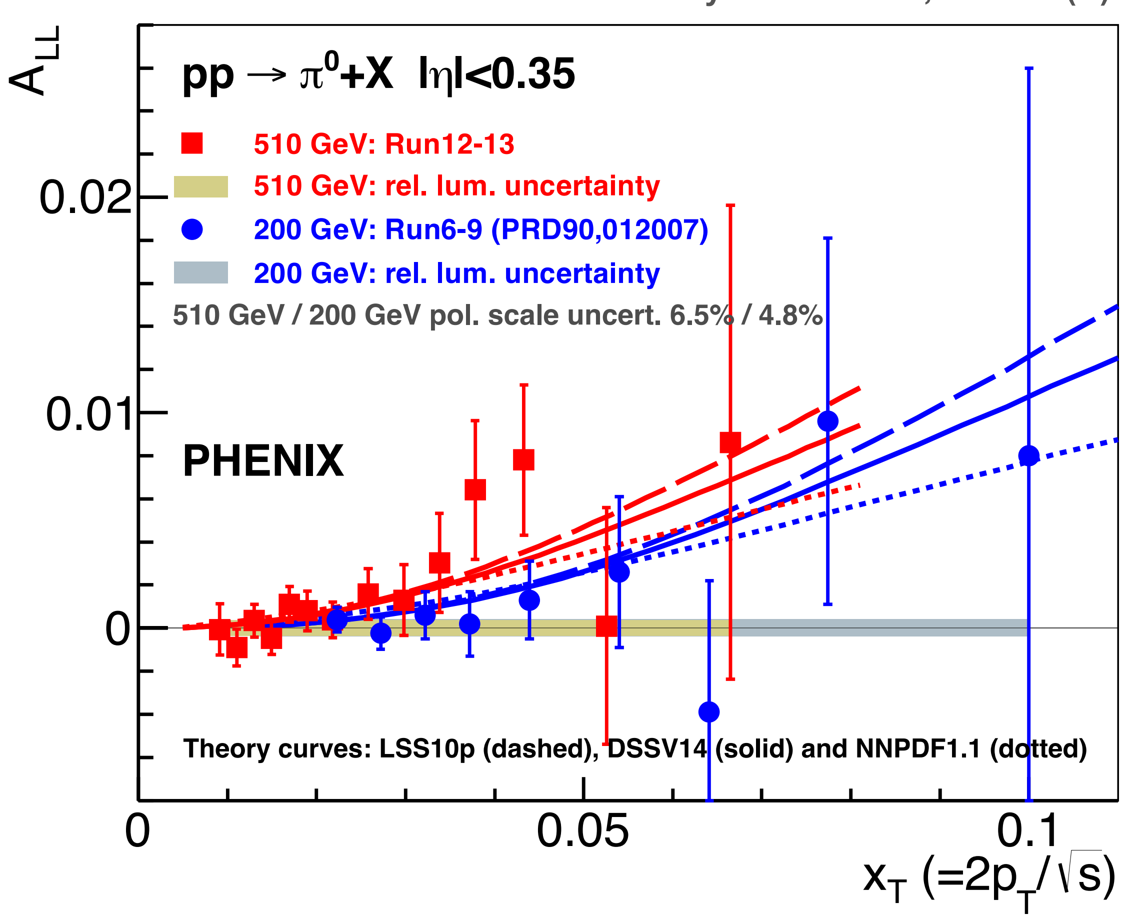
Access low-x by higher energy (x down to ~10^{-2}) or going forward

More forward p+p measurements, EIC!

Phys. Rev. Lett. 113 (2014) 012001

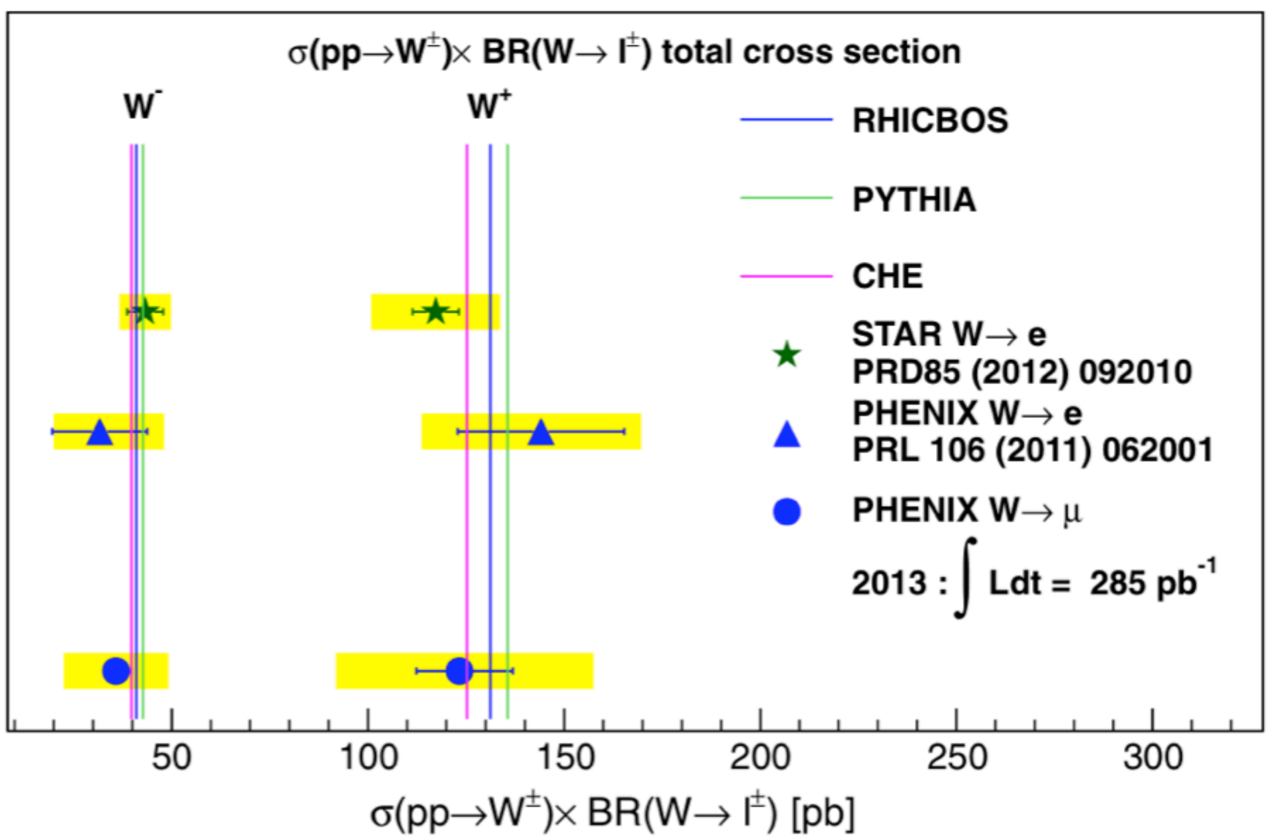


Phys. Rev. D 93, 011501(R)

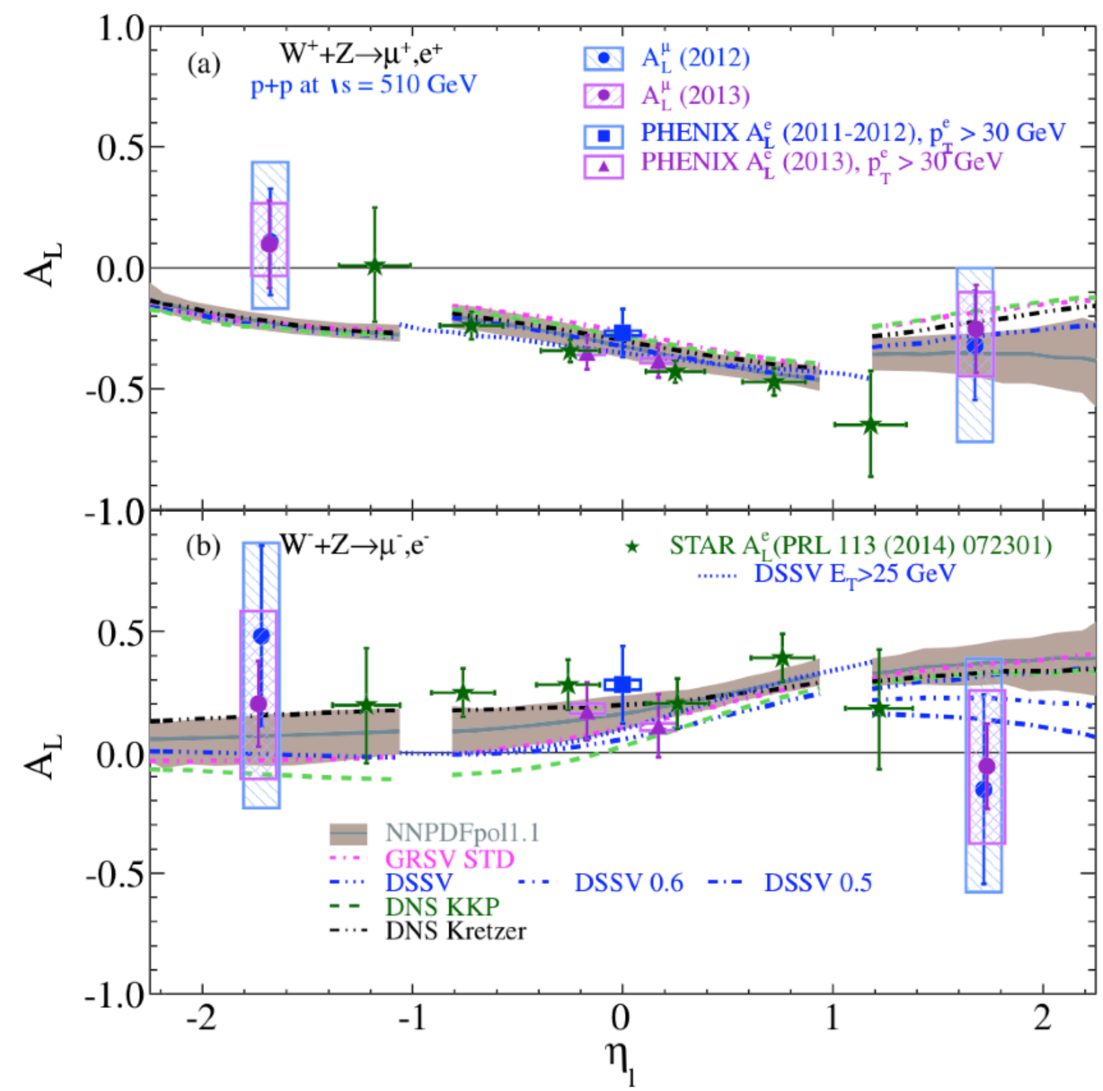


W measurements: separating quark flavor

- **Clean and direct sensitivity to (anti)quark helicity PDFs via parity violating W production**
- **Flavor asymmetry of the sea: unpolarized sea asymmetry**
  -> is polarized sea asymmetric? NNPDFpol1.1 arXiv:1406.7122

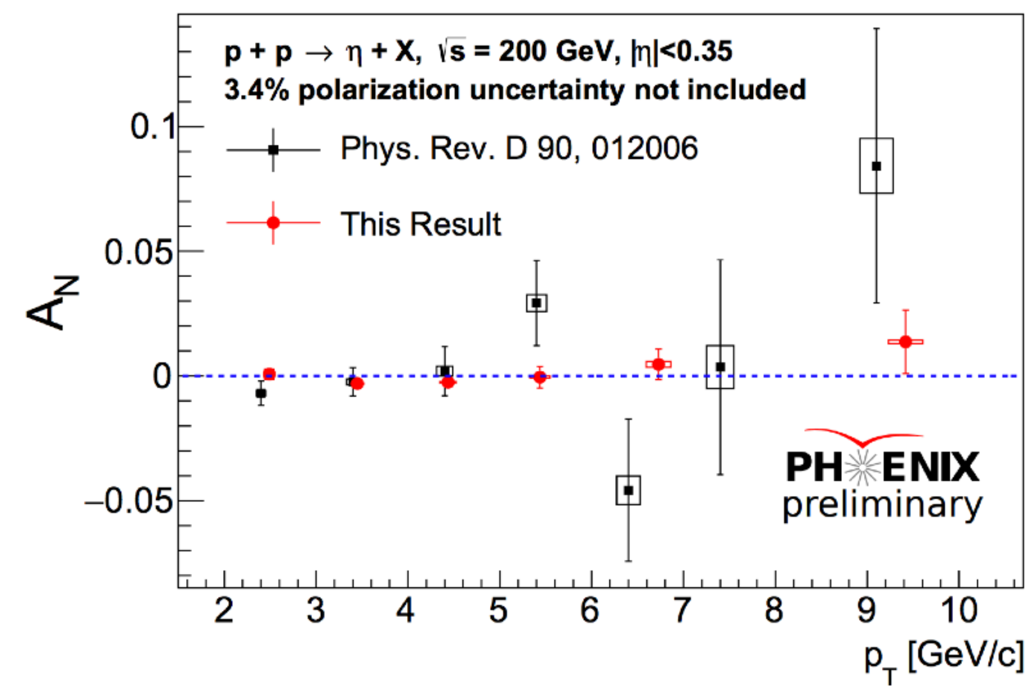


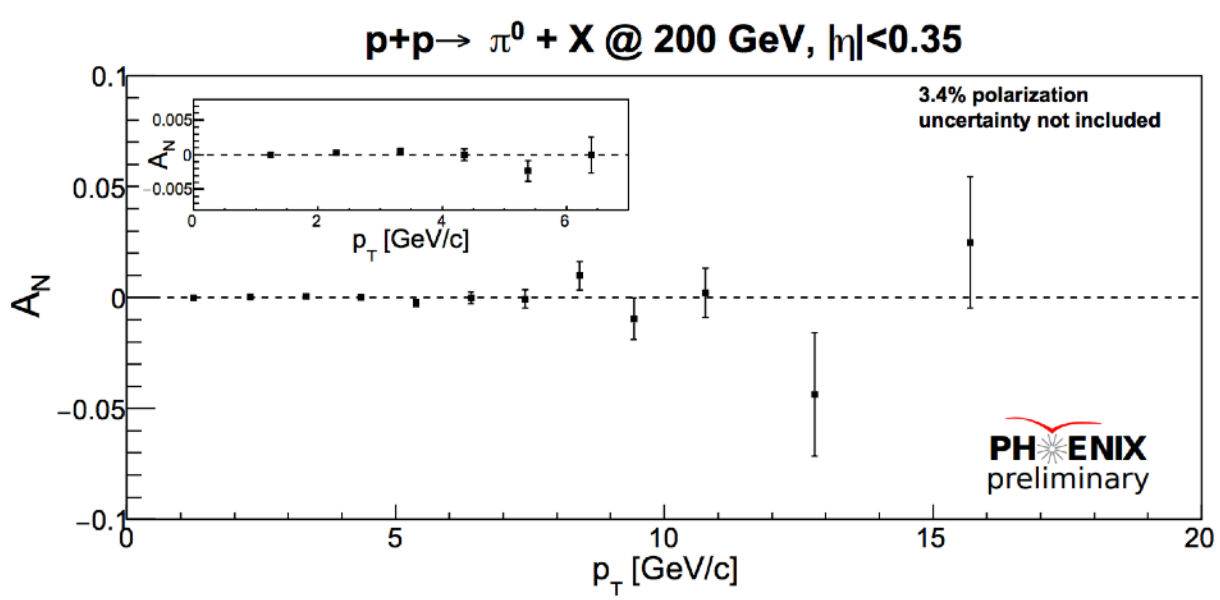
Phys. Rev. D 98, 032007 (2018)

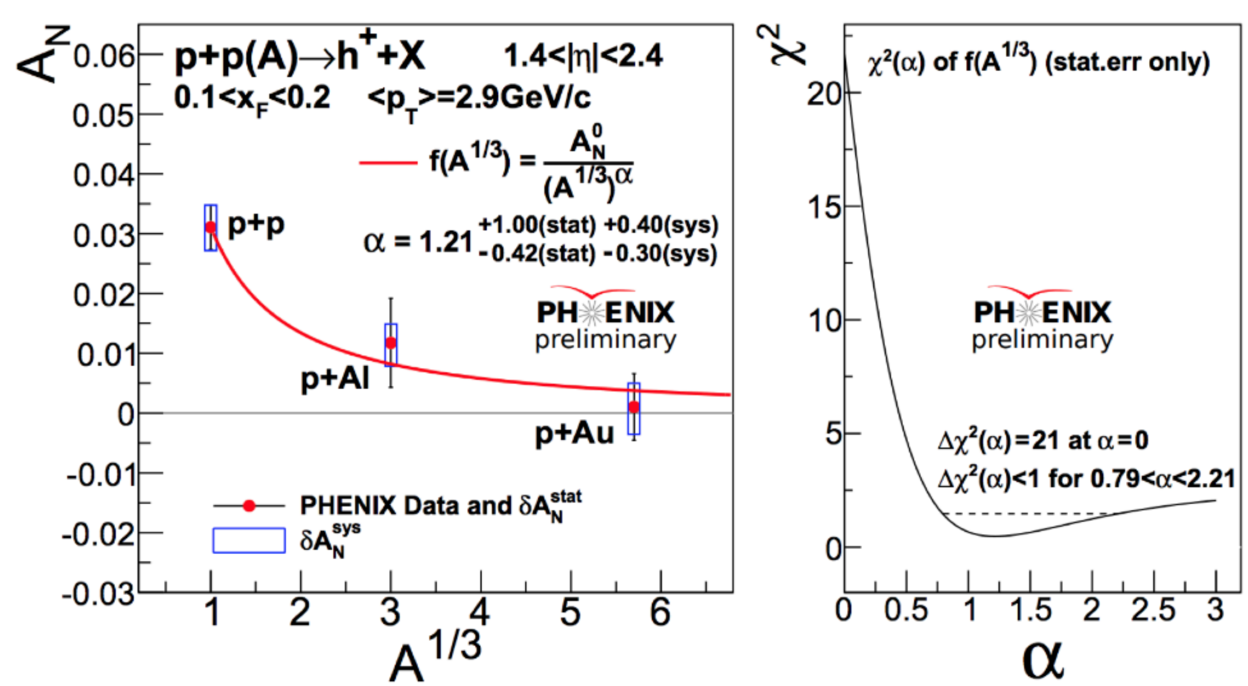


Transverse Spin Phenomena

- **Lead to surprises and new insights**
- **Development of theoretical frameworks and a lot of experimental effort recently**
- **Recent PHENIX measurements - heavy flavor, precise pi0 and eta results at mid-rapidity and more.**
- **Unique pA datasets to study nuclear effects**





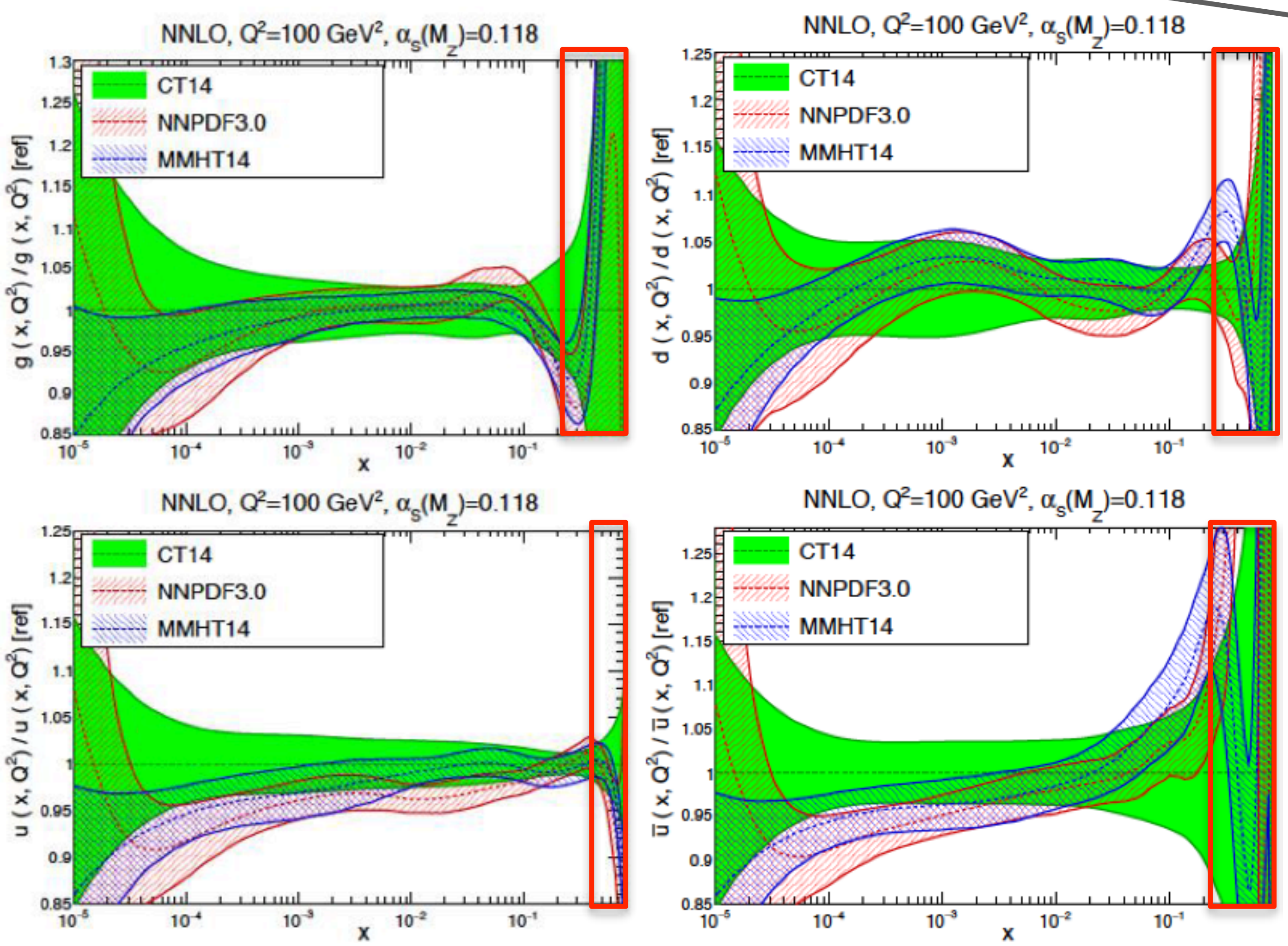


Accessing Large-x PDFs

- **Global analyses to extract PDFs: Regular DIS + Neutrino DIS + Hadron collider data**

Precision mapping in wide range of x and Q^2

Poorly constrained at small and large x



Higher energy -> EIC!

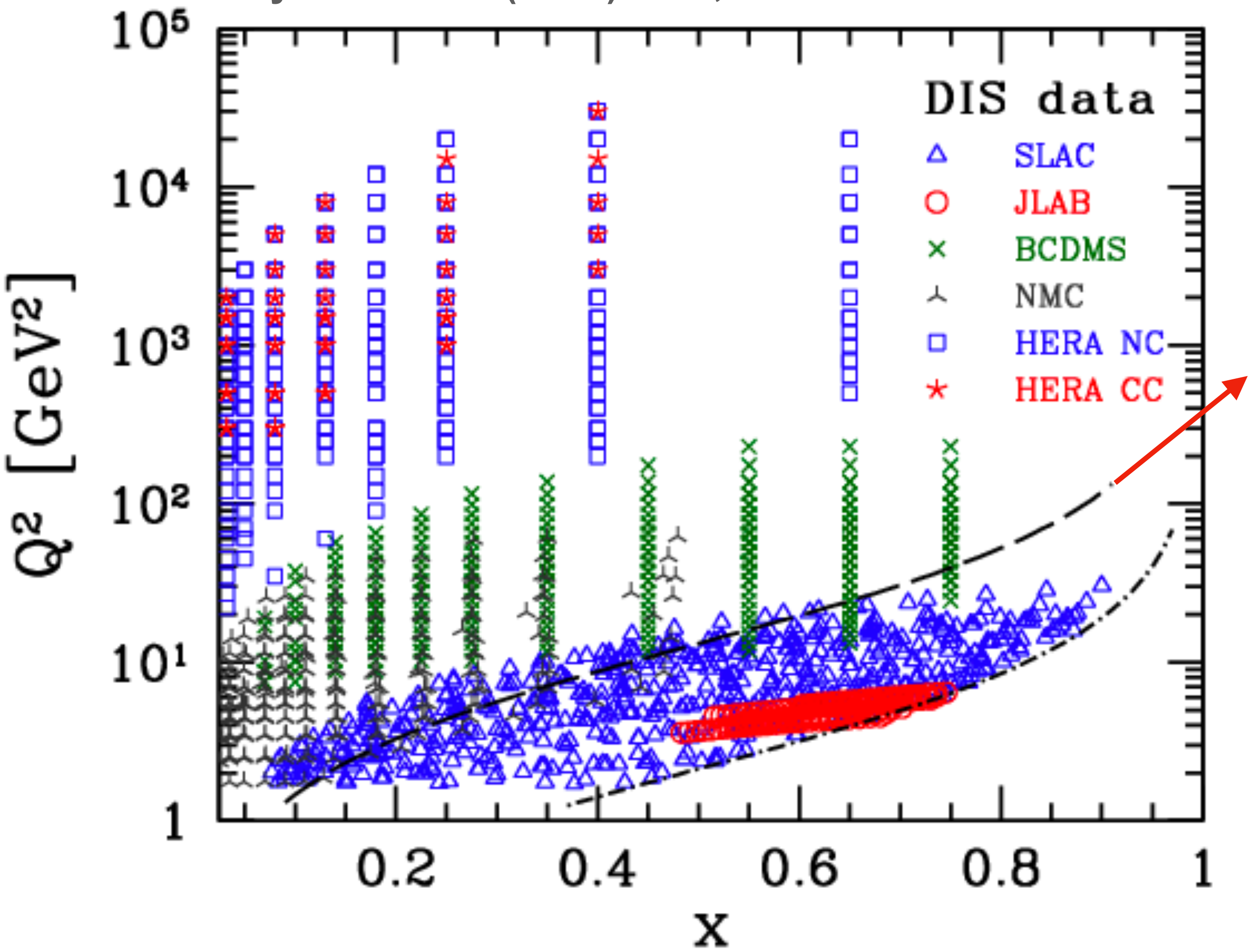
Parton dynamics at high gluon density

Large-x:

Study non-perturbative dynamics of nucleon
Improve low-x PDFs
High energy cross sections at collider

Precision F2 measurements in the resonance region and beyond

Phys.Rev. D87 (2013) no.9, 094012



Standard global PDF analysis used stringent cuts on W^2 and Q^2
(Large amount of data not used)

$Q^2 > 4$ GeV^2 $W^2 > 12.25$ GeV^2

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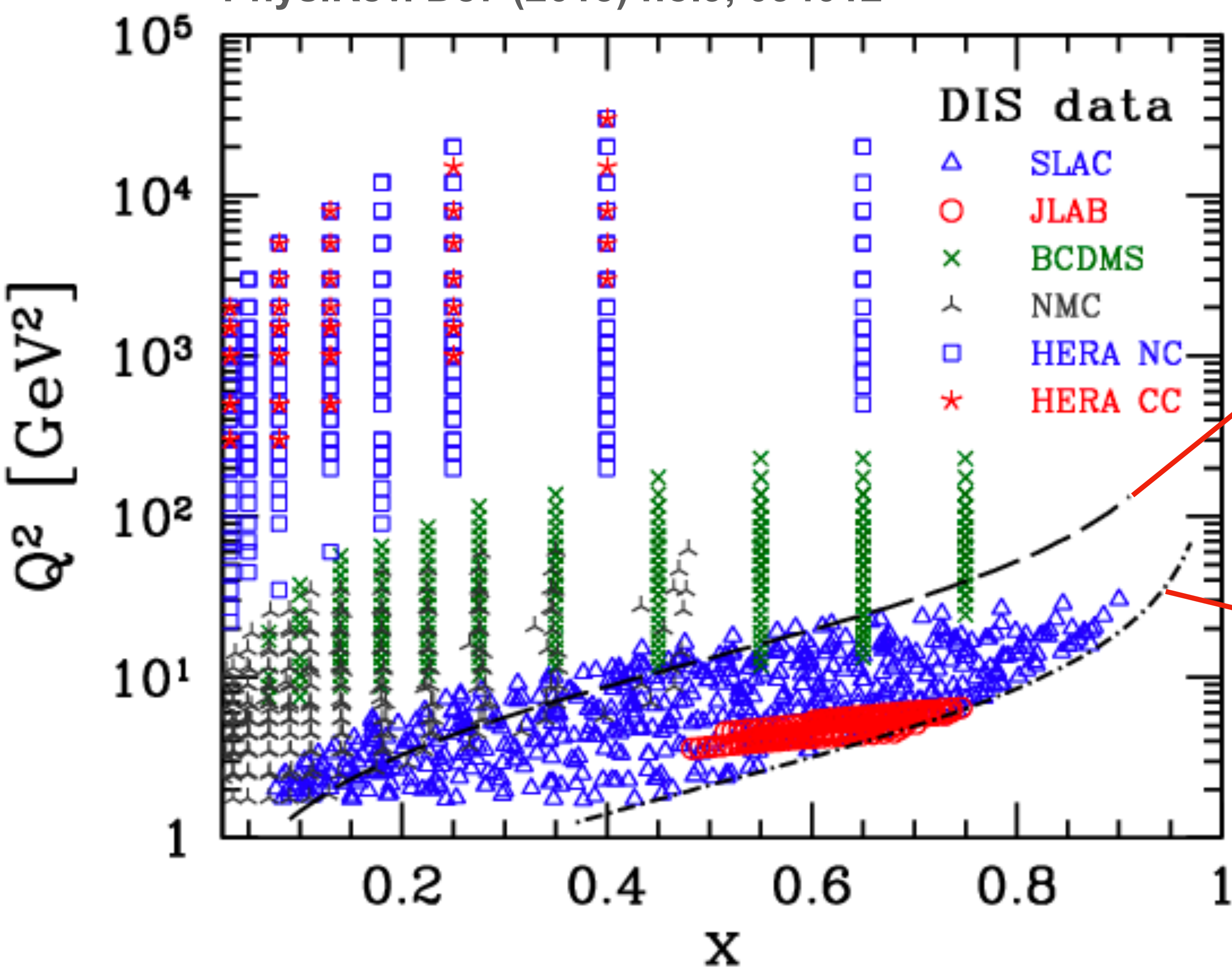

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Significantly improved constraints on d PDF at large x

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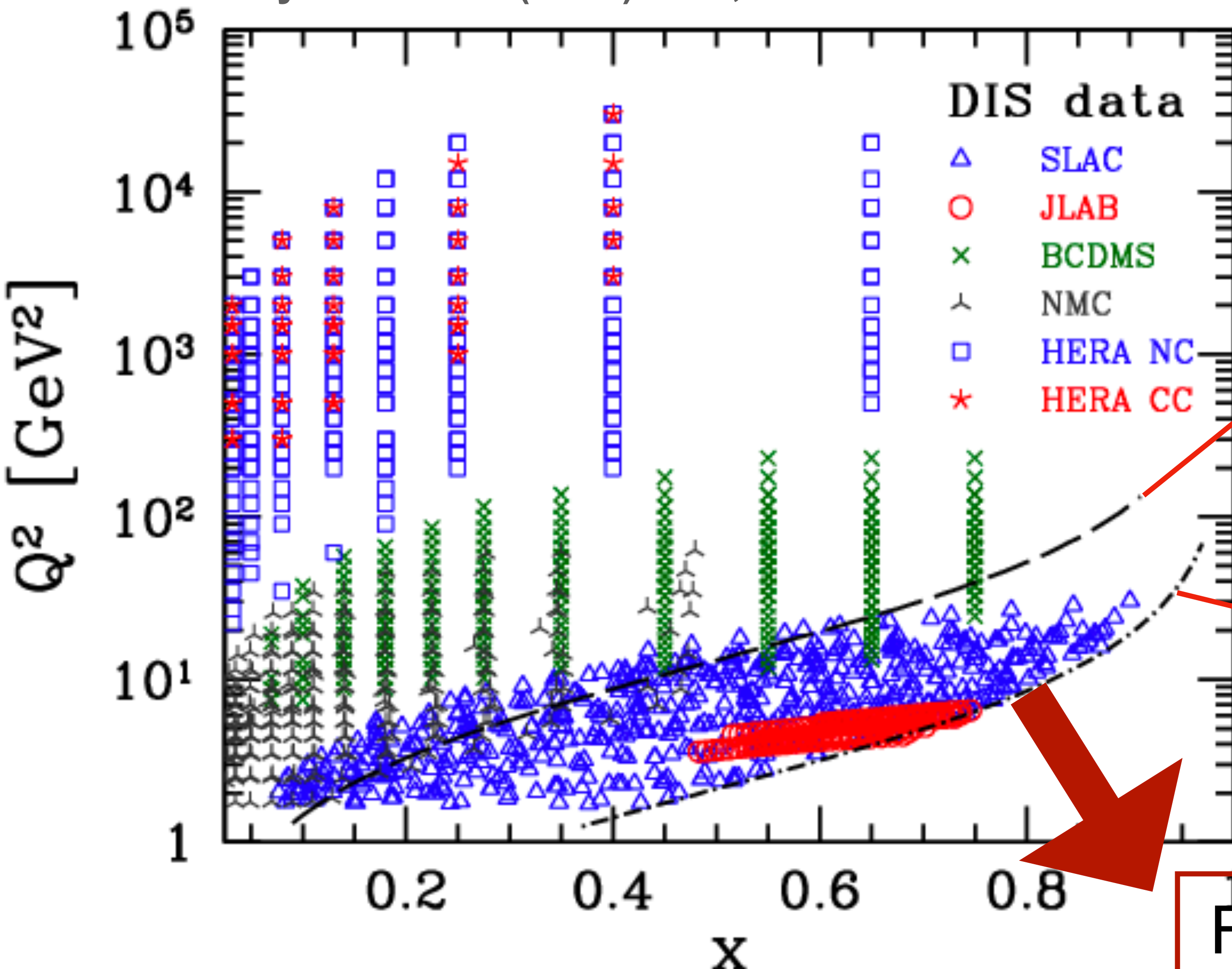

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Further relax W^2_{min} to explore large x region
-> data from resonance region

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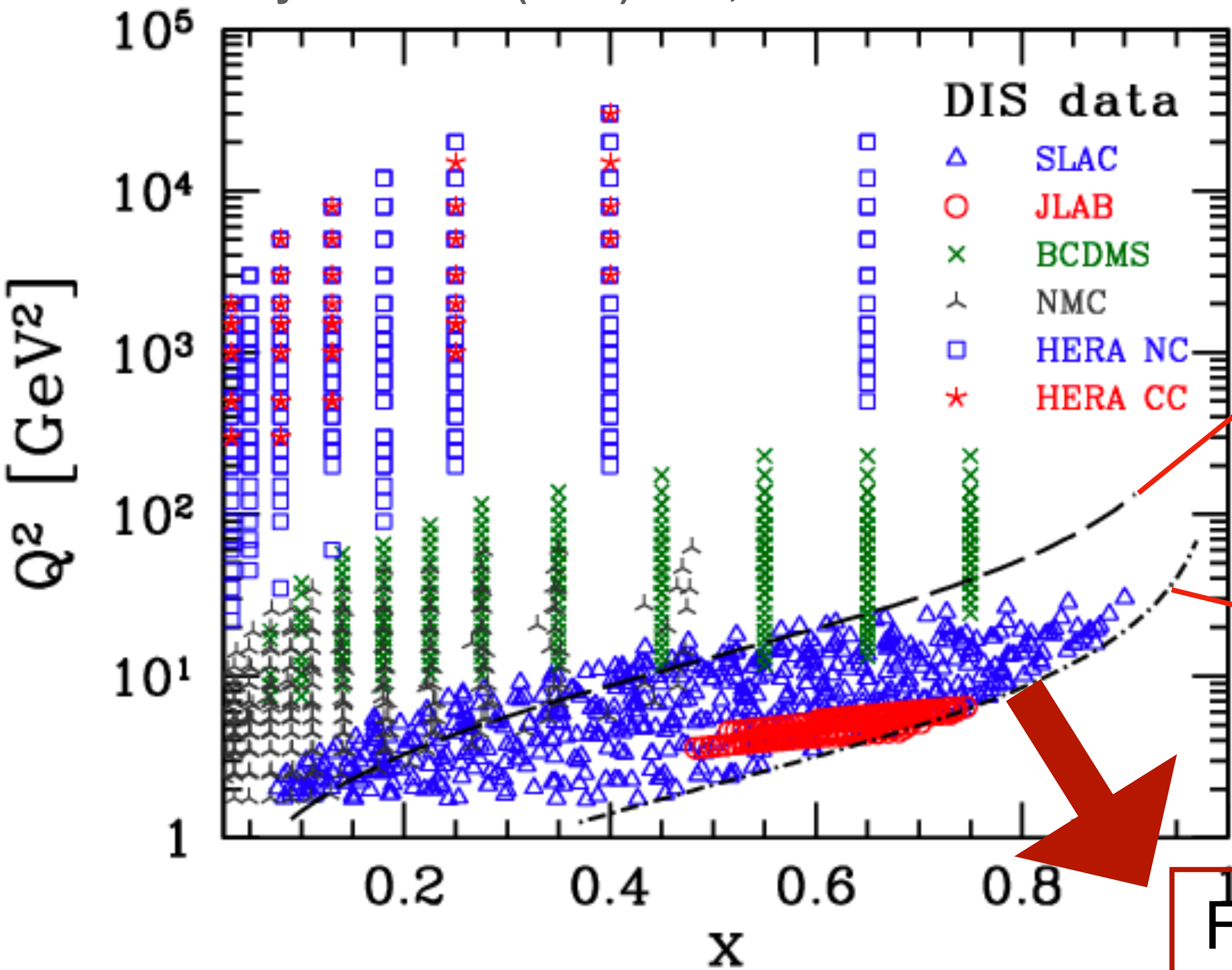

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Further relax W^2_{min} to explore large x region -> data from resonance region

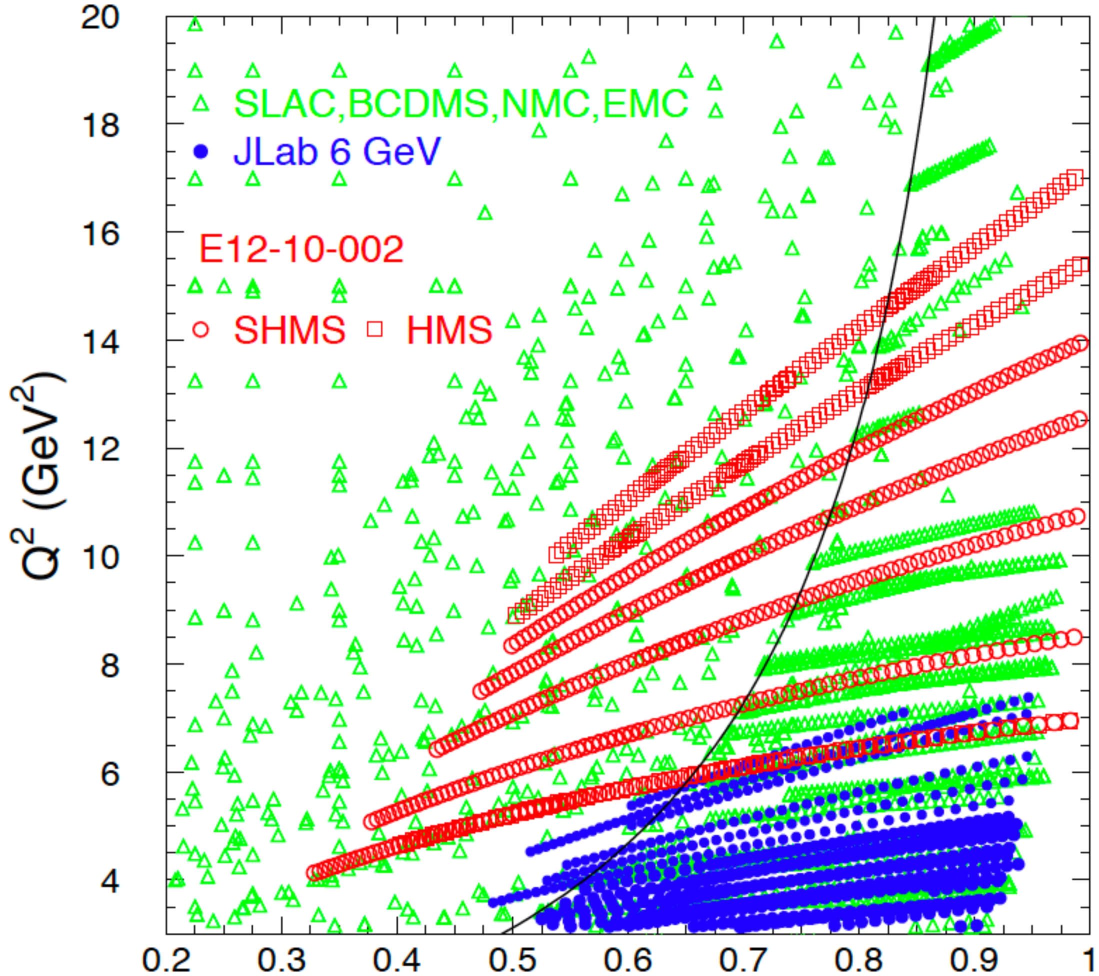
Quark-hadron duality:

SLAC (1969) Integrated F_2 in nucleon resonance region resemble the strength under scaling curve

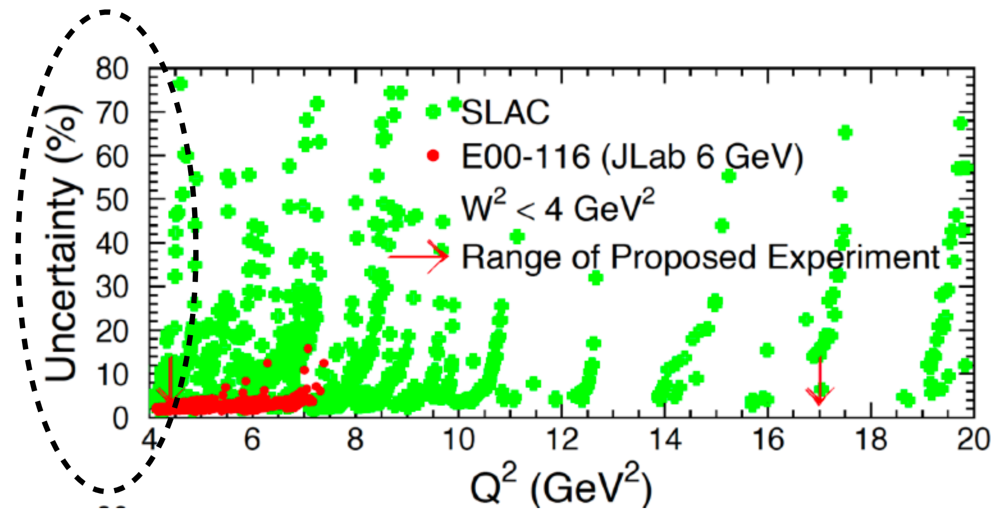
Could use averaged resonance data to access large x region

Precision F2 measurements in the resonance region and beyond

$W^2 > 4$ GeV^2



DIS **Resonance**



SLAC data - limited statistics, low Q^2

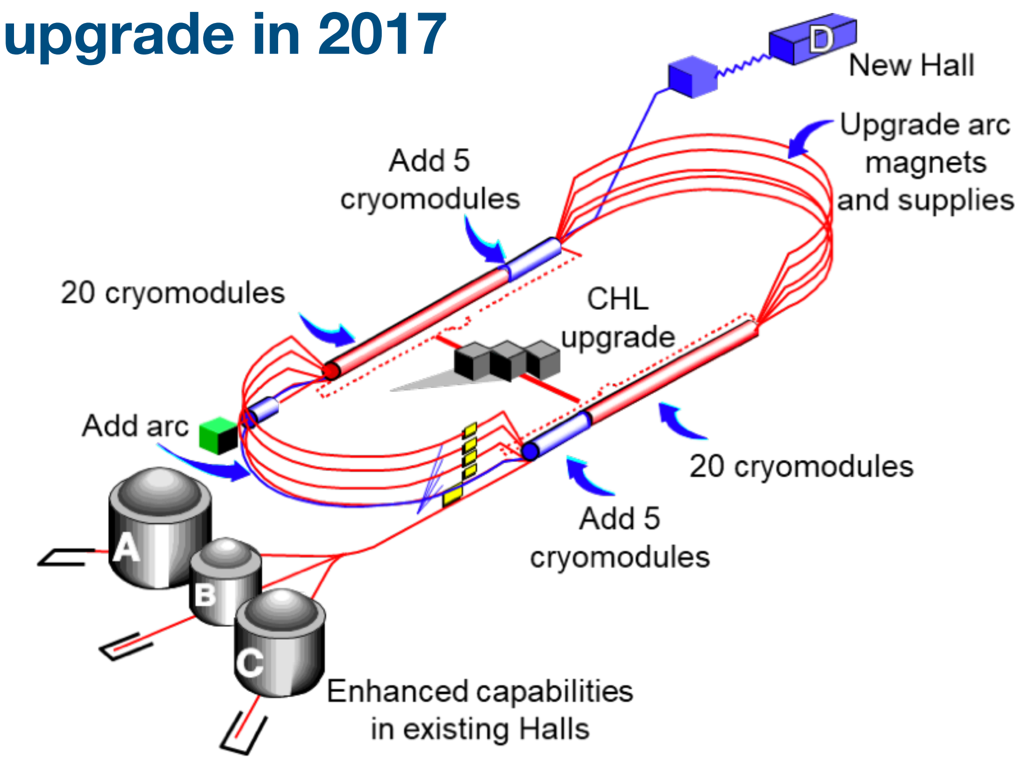
-> JLab 12 GeV can extend Q^2 coverage with high precision

Experimental setup

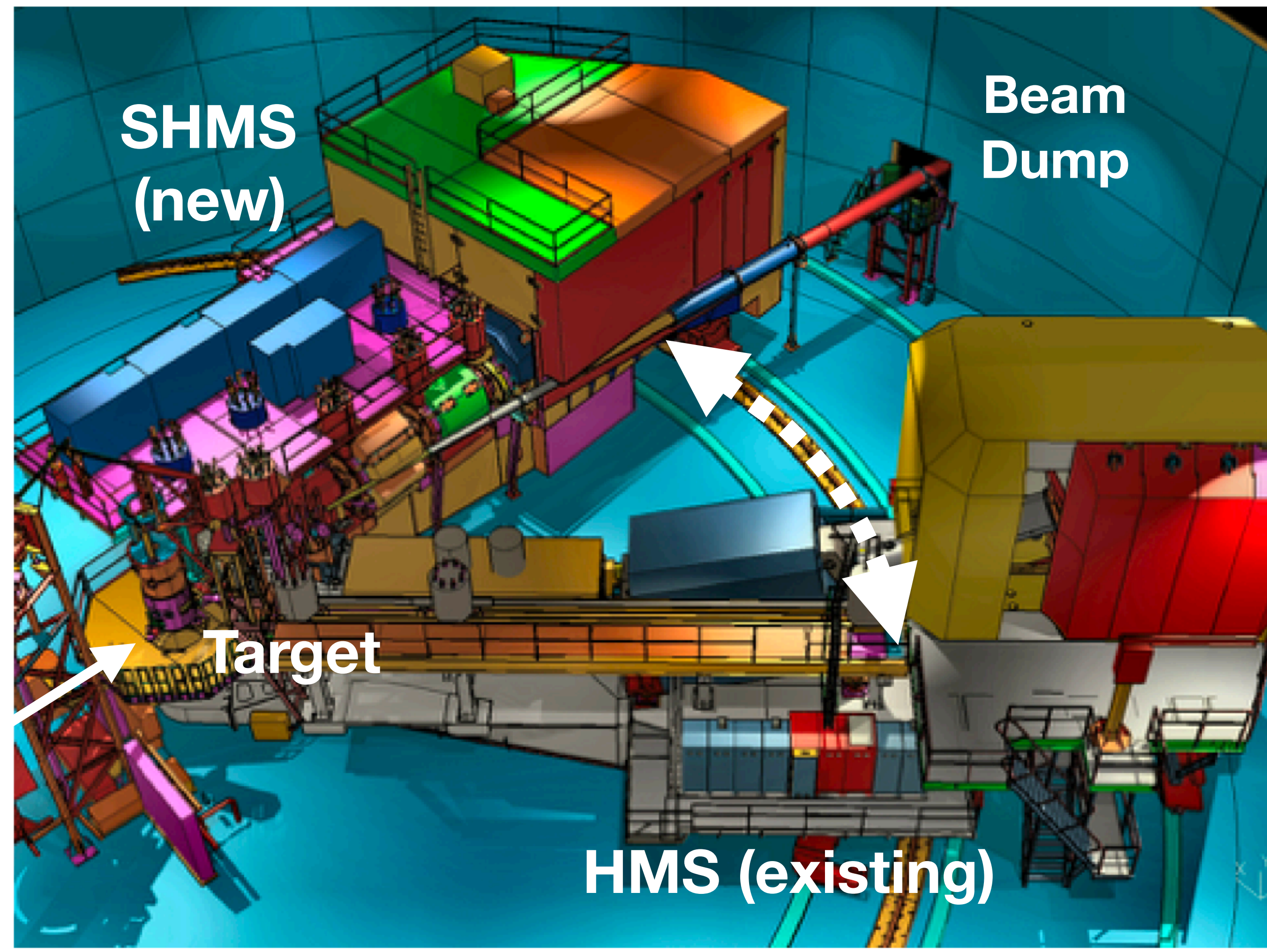
Inclusive H(e,e') and D(e,e') measurements

CEBAF electron beam

Successfully completed 12 GeV upgrade in 2017



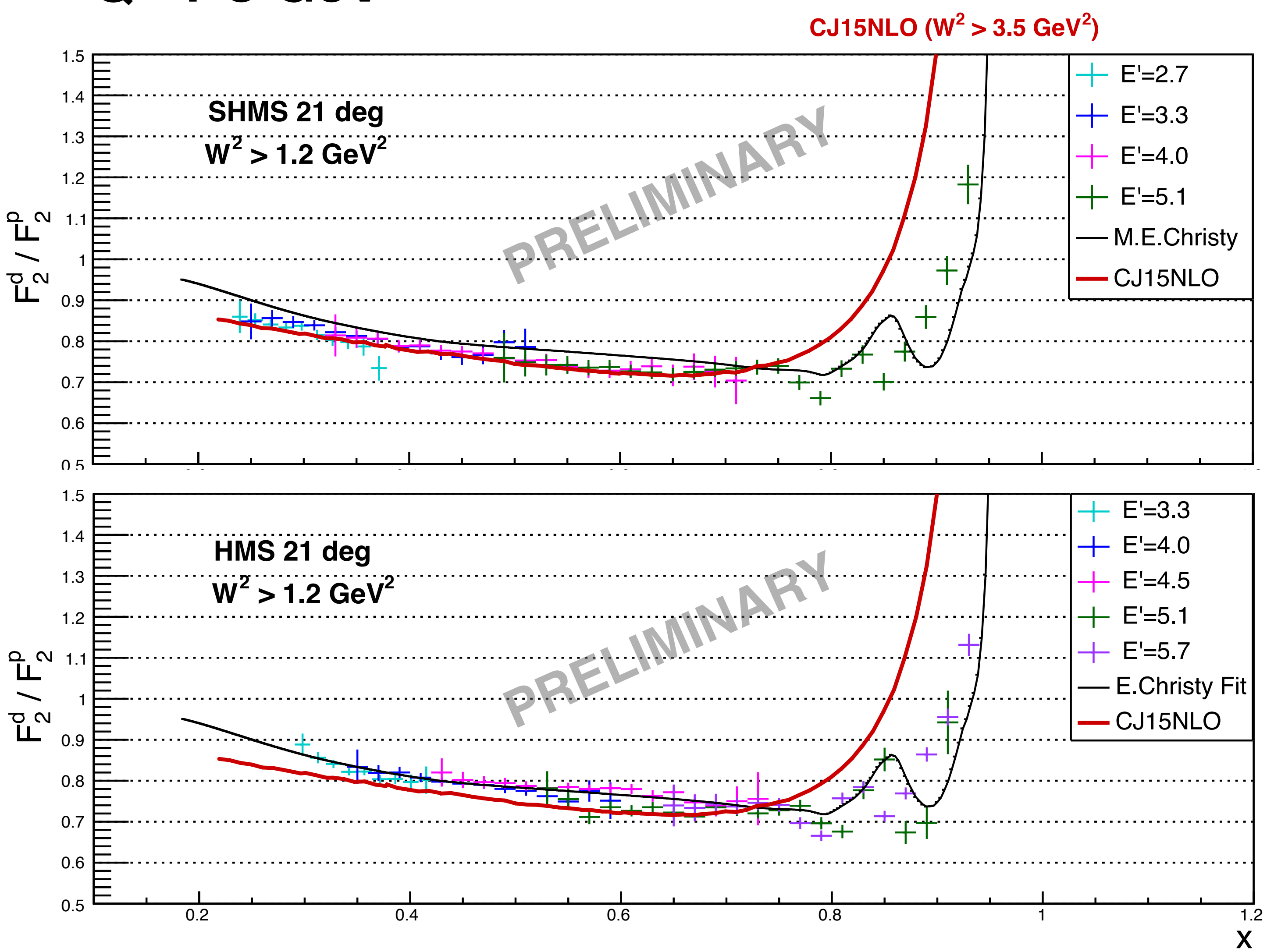
Hall C High Momentum Spectrometers



- **High current 10.6 GeV electron beam**
- **New Super High Momentum Spectrometer (SHMS) expands central momentum range**
- **LH2 and LD2 targets (F2p, F2d measurements)**
- **Al target (target cell background subtraction)**

F_2^d/F_2^p Ratio

Q^2 4-8 GeV^2



(* Statistical uncertainty only)

Very first look of our structure function ratio

Assume Rd = Rp $\frac{\sigma^d}{\sigma^p} \approx \frac{F_2^d}{F_2^p}$

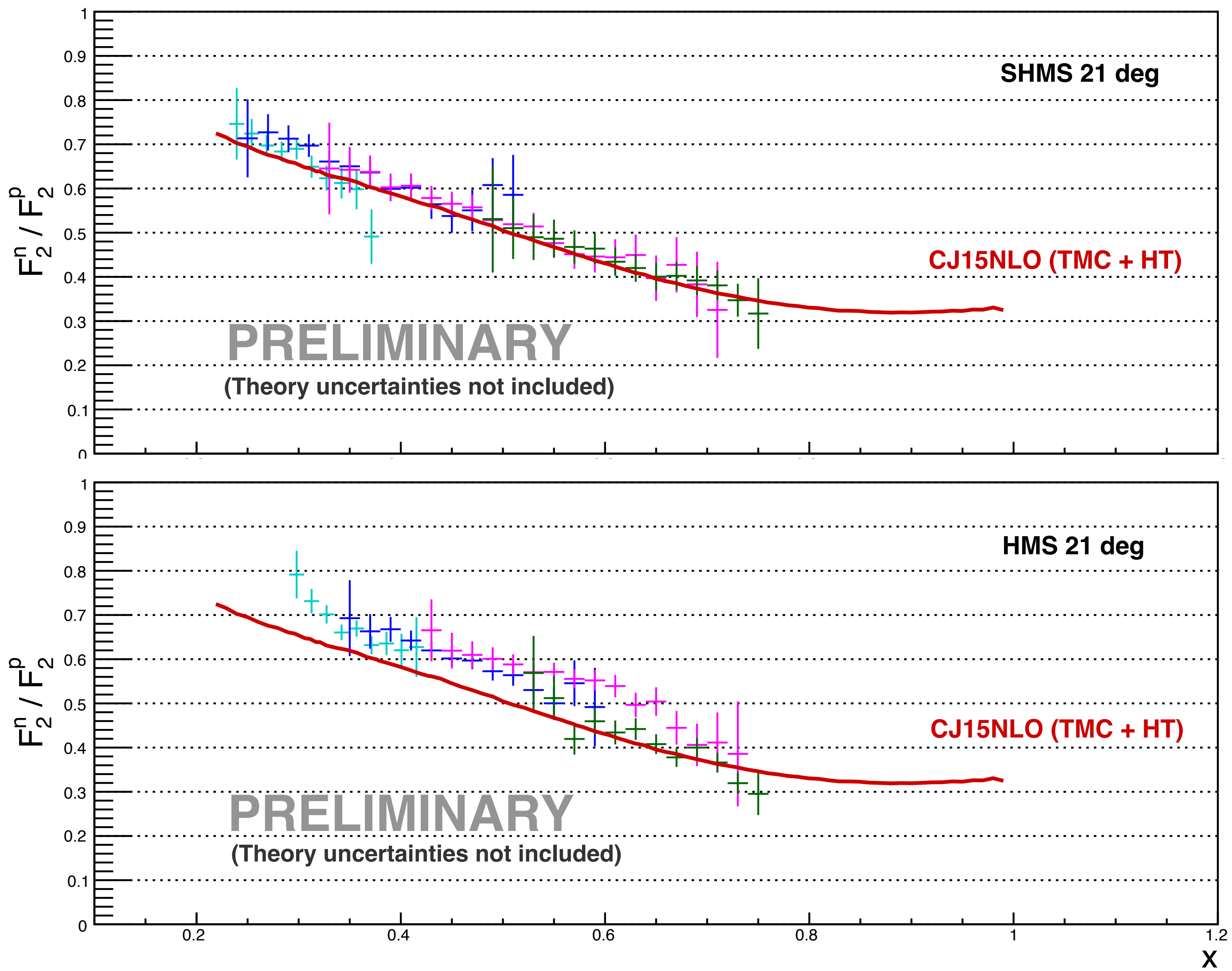
Compared with the fit and CJ NLO analysis:

M.E. Christy and P.E. Bosted fit: Phys. Rev. C 81, 055213 (2010) includes resonance data

CJ15NLO: https://www.jlab.org/theory/cj/ DIS only

F_2^n/F_2^p Ratio

(* W^2 > 3.5 GeV^2 applied to the data)



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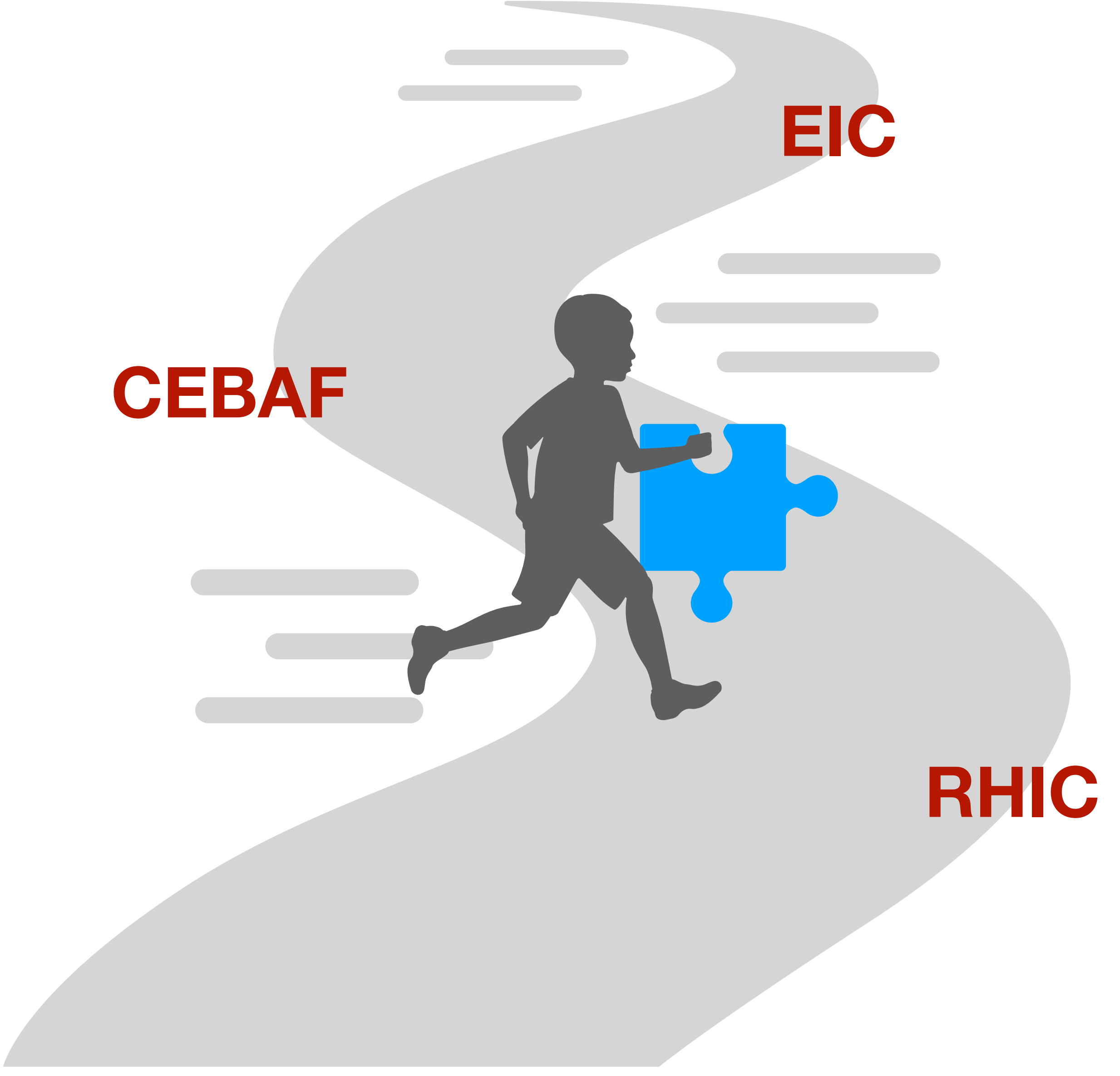
Very first look of our structure function ratio

- CJ PDF extraction includes state-of-the-art deuteron nuclear corrections
- Use CJ corrections to extract $F2^n/F2^p$ ratio

$$\left(\frac{F_2^n}{F_2^p}\right) = \left(\frac{F_2^d}{F_2^p}\right)_{Data} \times \left(\frac{F_2^n + F_2^p}{F_2^d}\right)_{CJ} - 1$$

- Can compare with MARATHON data

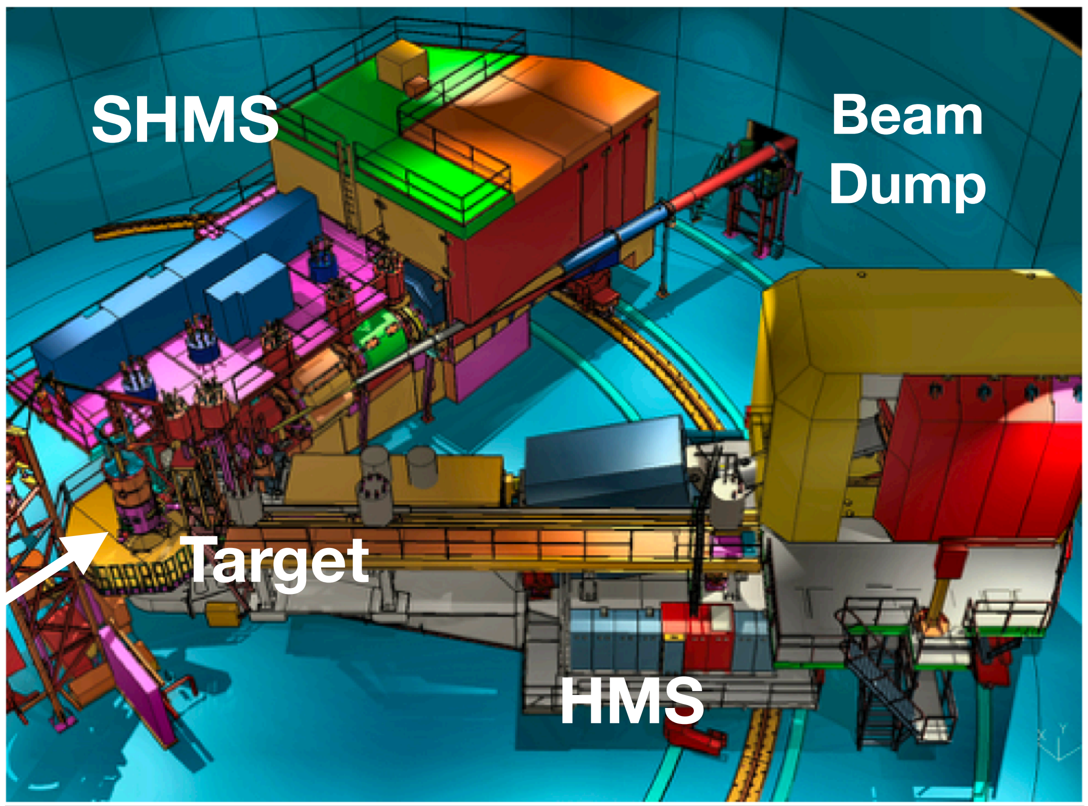
Summary



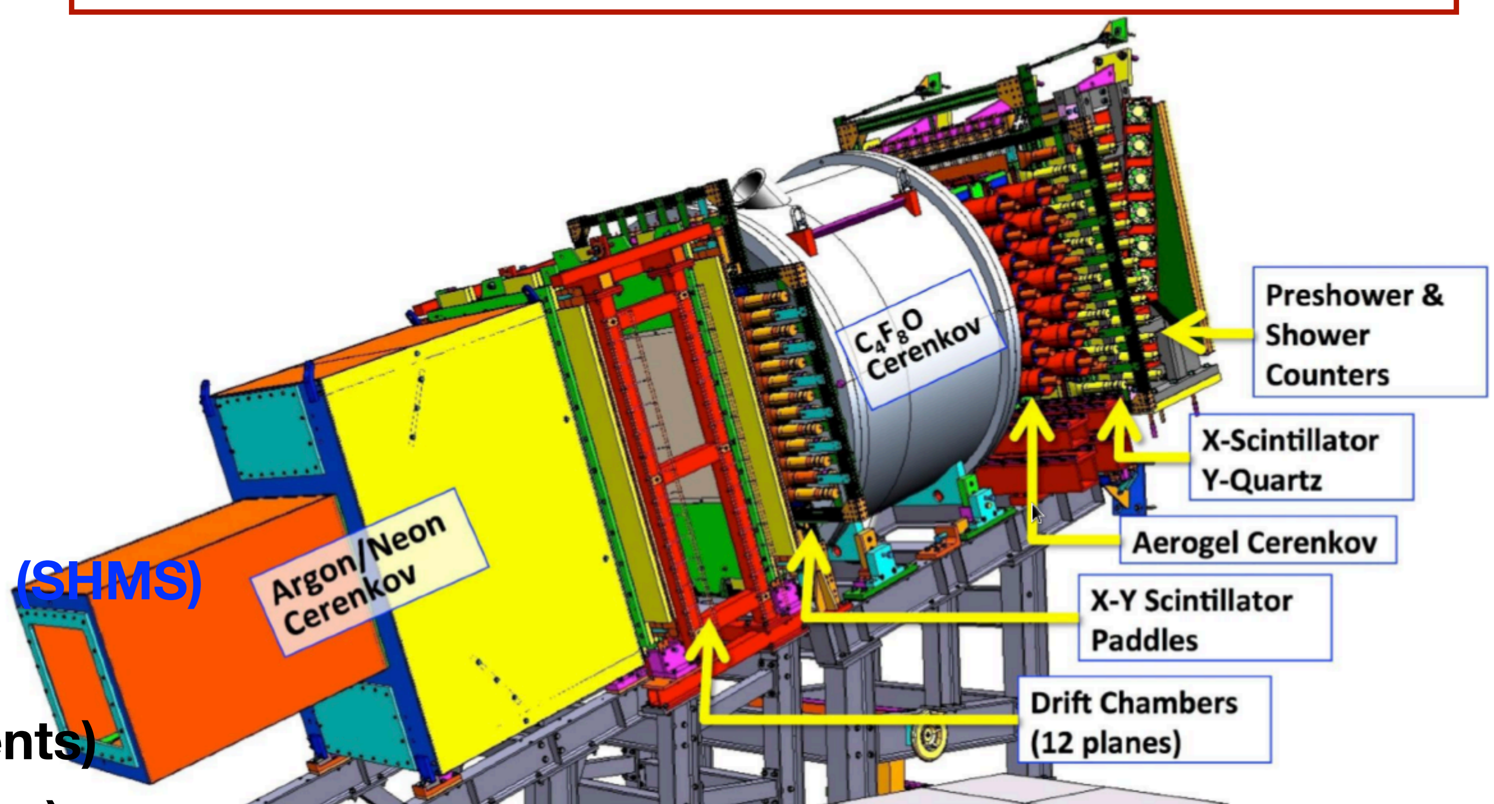
Backup

Experimental setup

Hall C High Momentum Spectrometers



- **Calorimeter based electron PID + pion rejection using Cherenkov detectors**
- **Drift chambers for tracking**
- **Scintillator hodoscopes provide timing and form triggers**



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