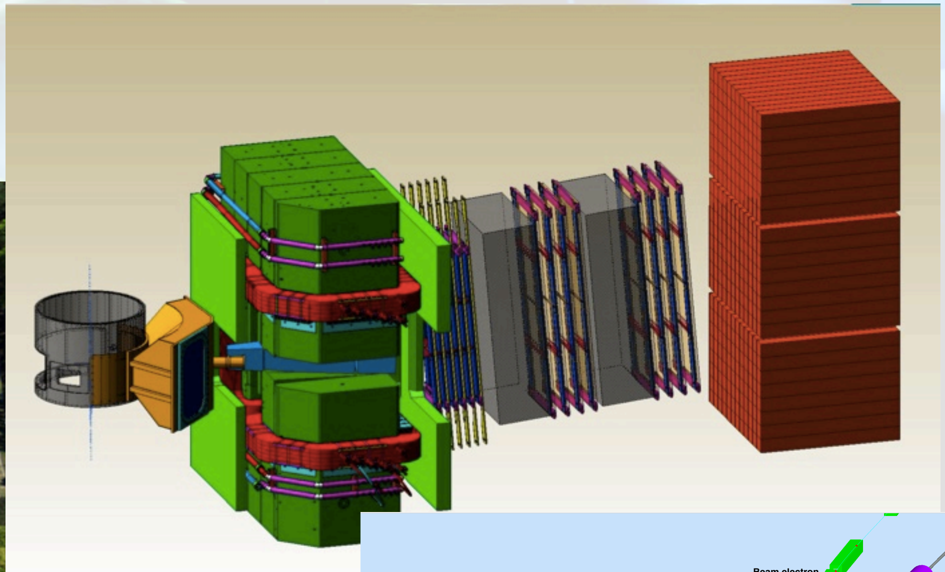
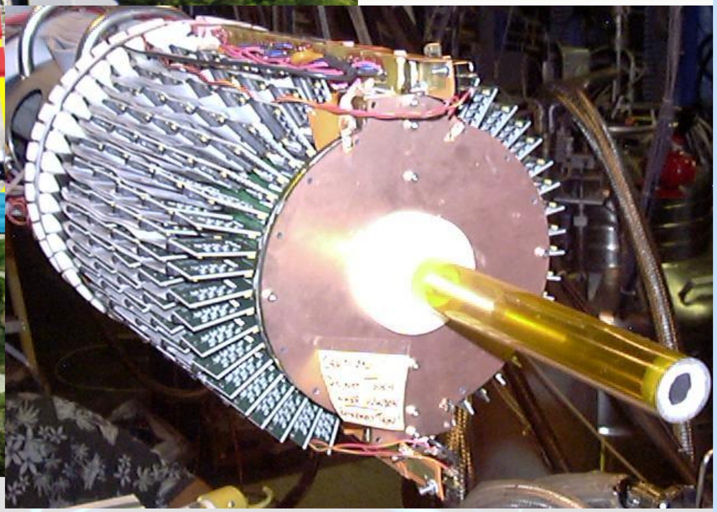
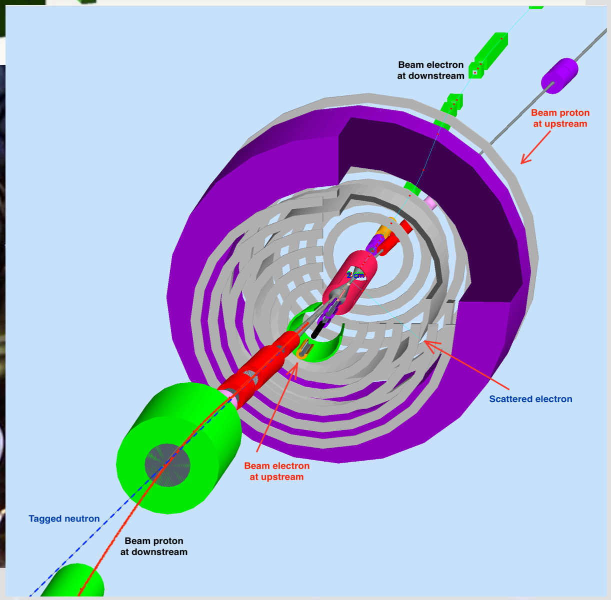
Tagged Deep Inelastic Scattering

Thia Keppel







Tagged Deep Inelastic Scattering (TDIS)

- Semi-inclusive deep inelastic scattering technique
  - but *not* to access the current regime

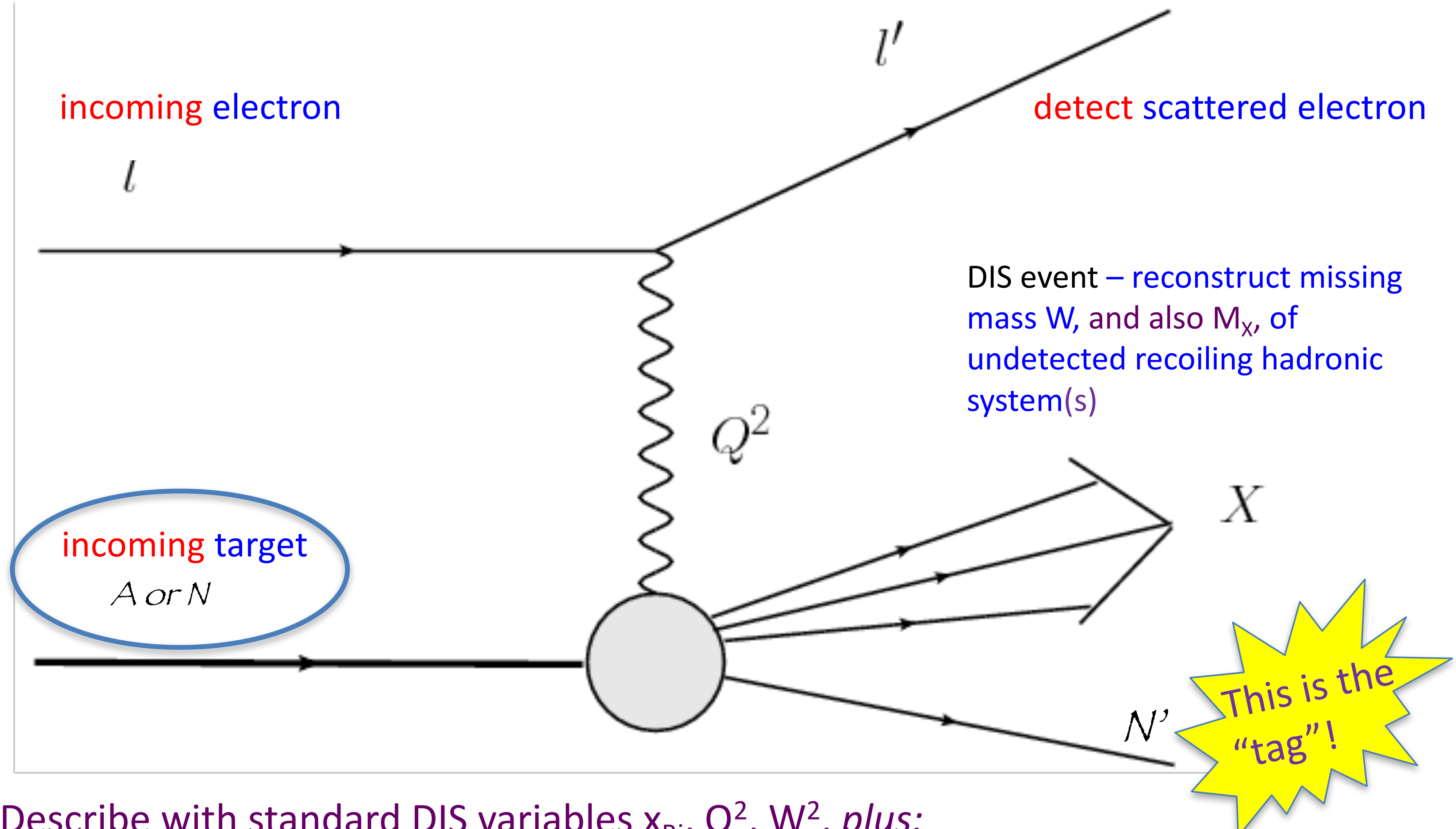
- “Tagging” facilitates effective *targets* not readily found in nature

- Tagged DIS provides novel probe of partonic structure of these effective targets

- Three examples:
- Neutron
- Pion
- Kaon

Will discuss pioneering efforts

Tagged Deep Inelastic Scattering:
Basic Experimental Approach



detect outgoing target nucleon

Describe with standard DIS variables x_{Bj}, Q^2, W^2, *plus:*

M_x = mass of system X

t = four-momentum transfer squared at the nucleon vertex

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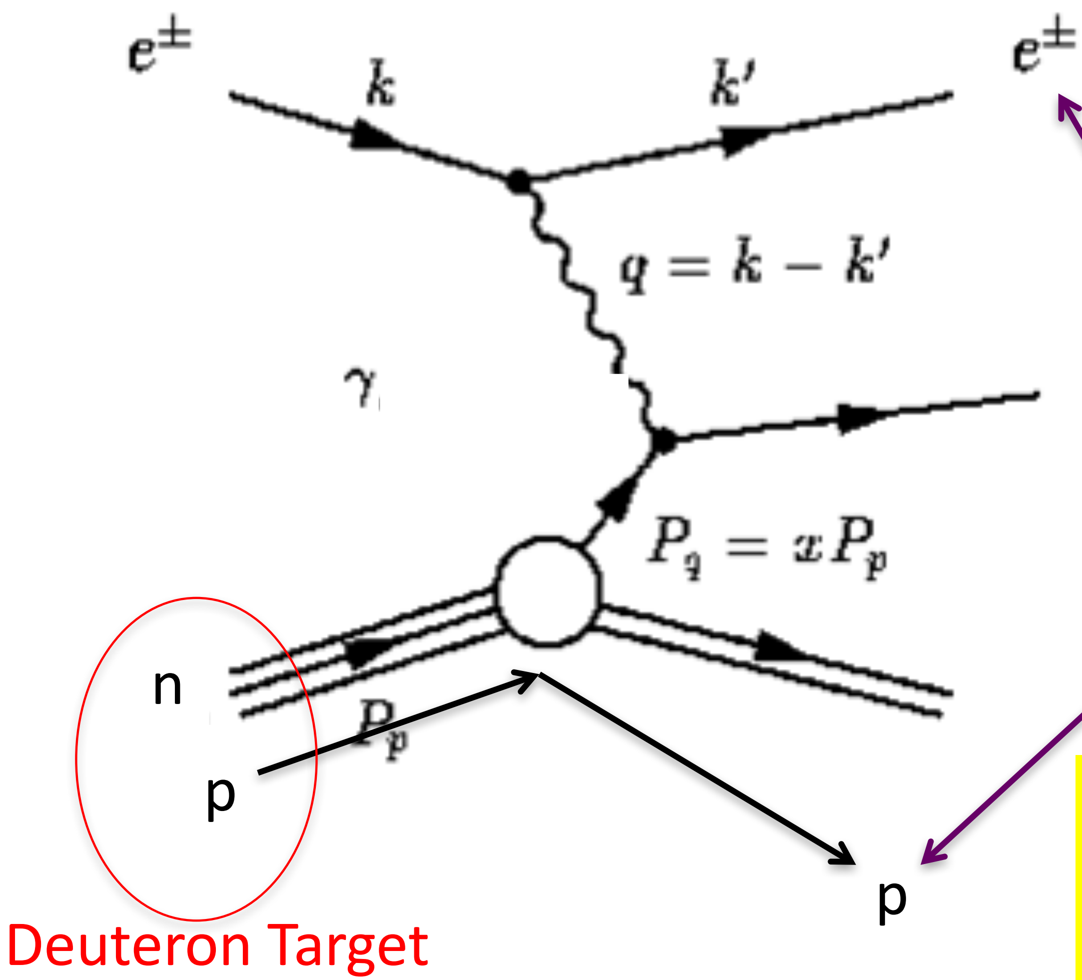
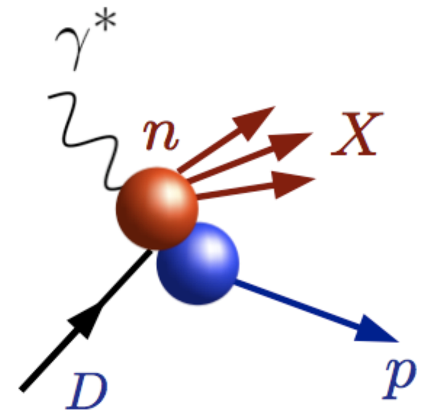
- Three examples:
  - ***Neutron***
  - Pion
  - Kaon

Will discuss pioneering efforts

Example 1: **TDIS to access neutron valence structure**

"BONUS" Experiment at Jefferson Lab – use fixed target tagging to create an effective ***free neutron*** target



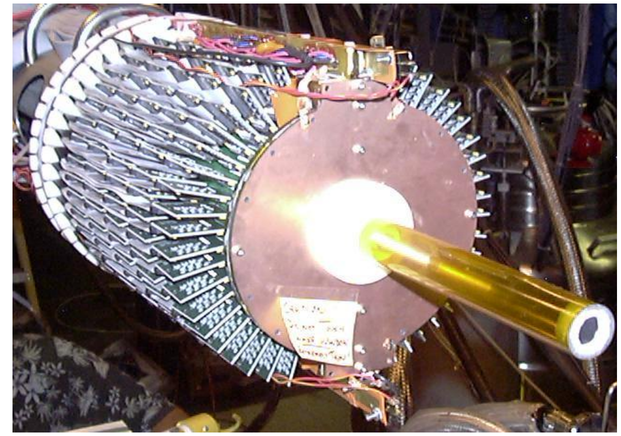


Measure DIS electron in coincidence with proton tag

- "Hard" scattering inelastic event (high Q, W)
- Proton remains intact
- Low momentum proton = nucleons barely off shell
- ✓ Neutron target!

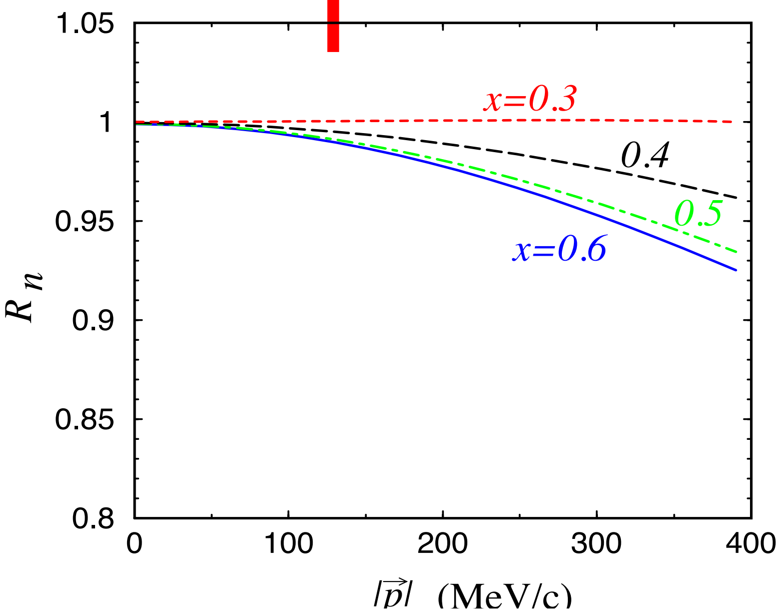
The BONUS experimental approach:

use low mass radial TPC detector / target in magnetic field to TAG "spectator" proton at (very) low momenta (~65 MeV/c) and large angles (> 90^o in lab) ***....difficult but doable***

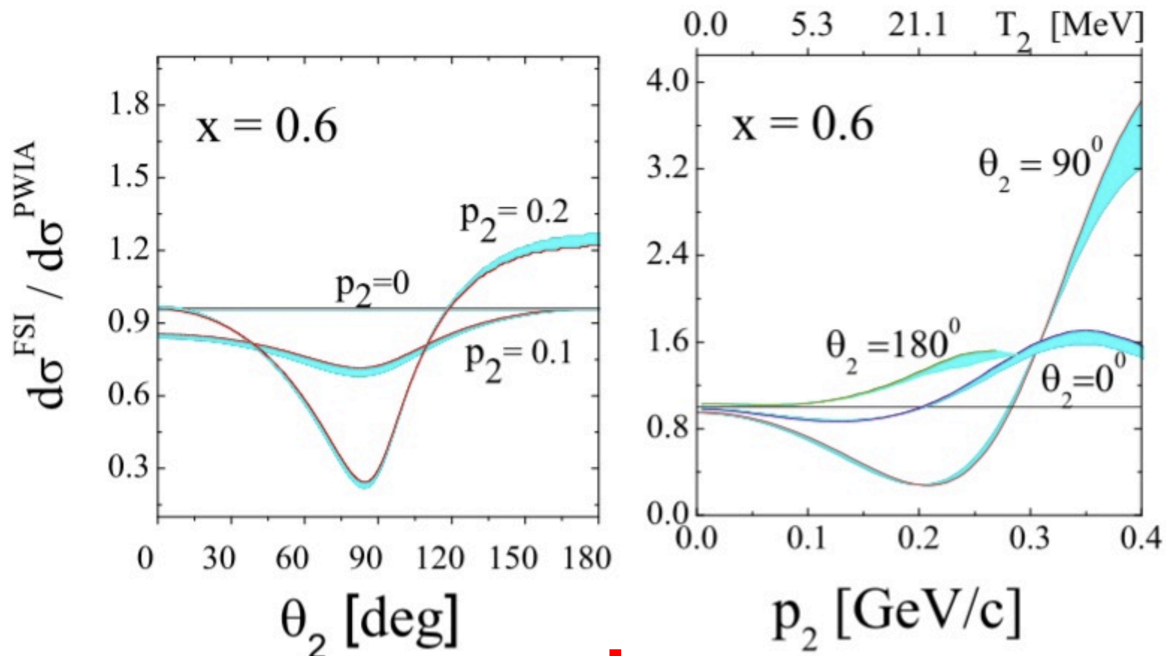


Bound / free neutron structure

O **(1%)**



W. Melnitchouk et al, Phys. Lett. B 335(1994) 11 (updated 2010)



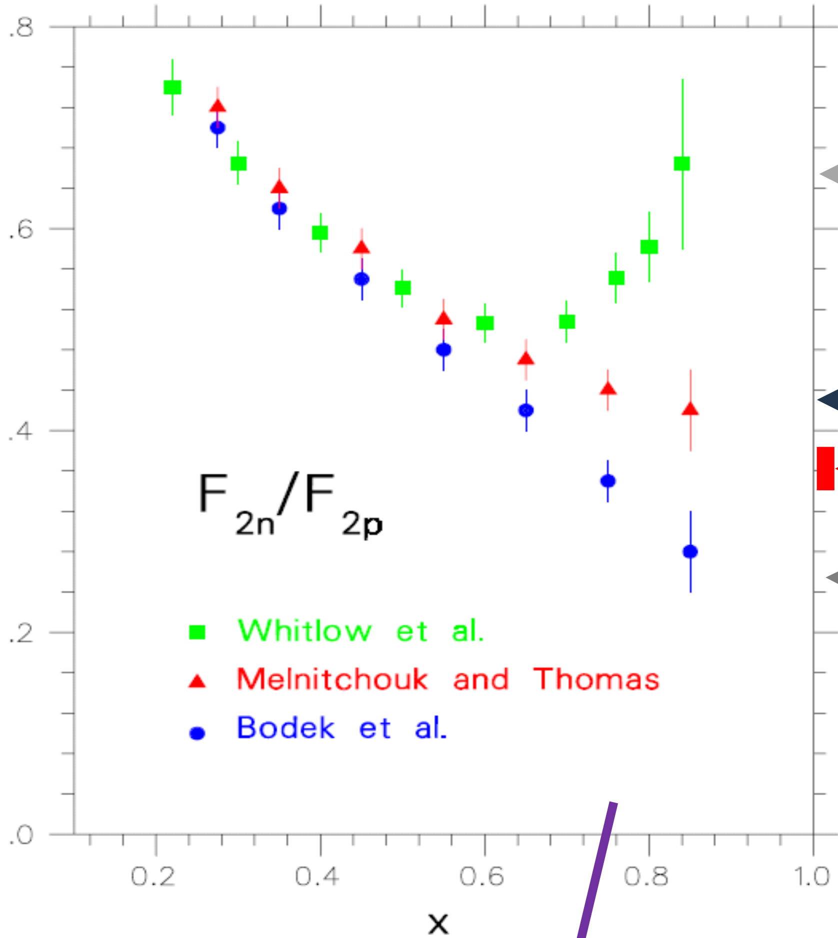
Final state interactions

O **(5%)**

V. Palli, C. Ciofi degli Atti, L.P. Kaptari, C.B. Mezzetti, M. Alvioli Phys.Rev. C80 (2009) 054610

F_2^n not well known at large x:

- Conflicting fundamental theory expectations
- Data inconclusive due to uncertainties in deuterium nuclear corrections



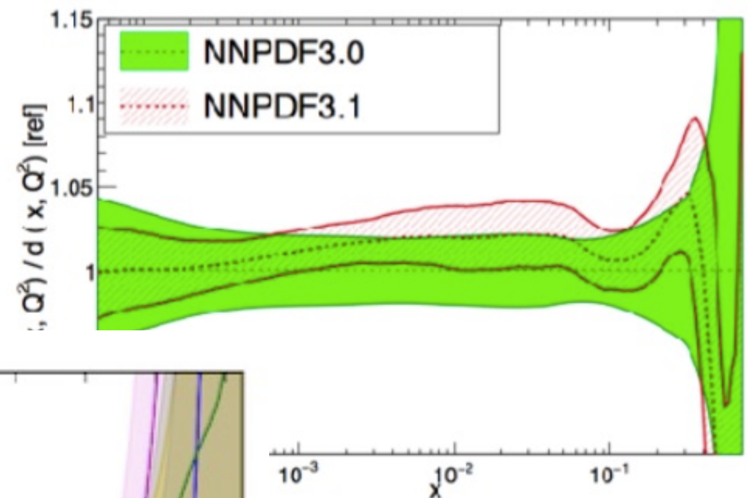
SU(6) symmetry

pQCD

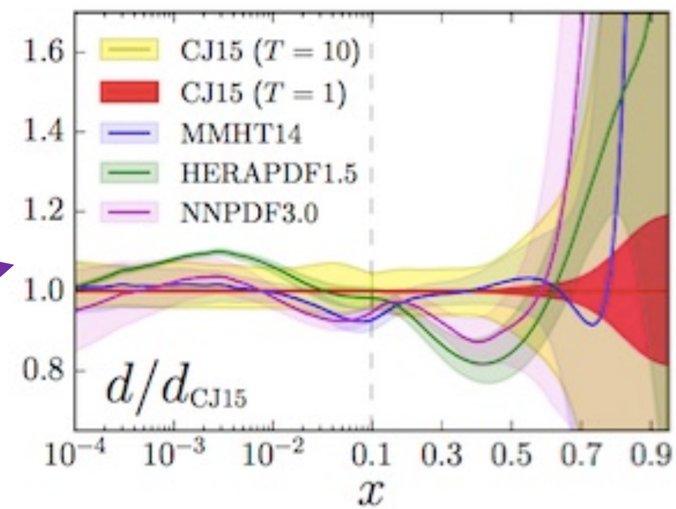
DSE:
0^+ & 1^+ qq

0^+ qq only

Review Articles:
N. Isgur, PRD **59** (1999),
S Brodsky et al NP **B441** (1995),
W. Melnitchouk and A. Thomas PL **B377** (1996) 11,
R.J. Holt and C. D. Roberts, Rev. Mod. Phys. **82**, 2991 (2010)
I. Cloet et al, Few Body Syst. **46** (2009) 1.



Translates directly to uncertainty on d/u, d(x), and indirectly to g(x),…



d(x) has large uncertainty in all global PDF extractions

Polarized quark distributions

In the parton model:

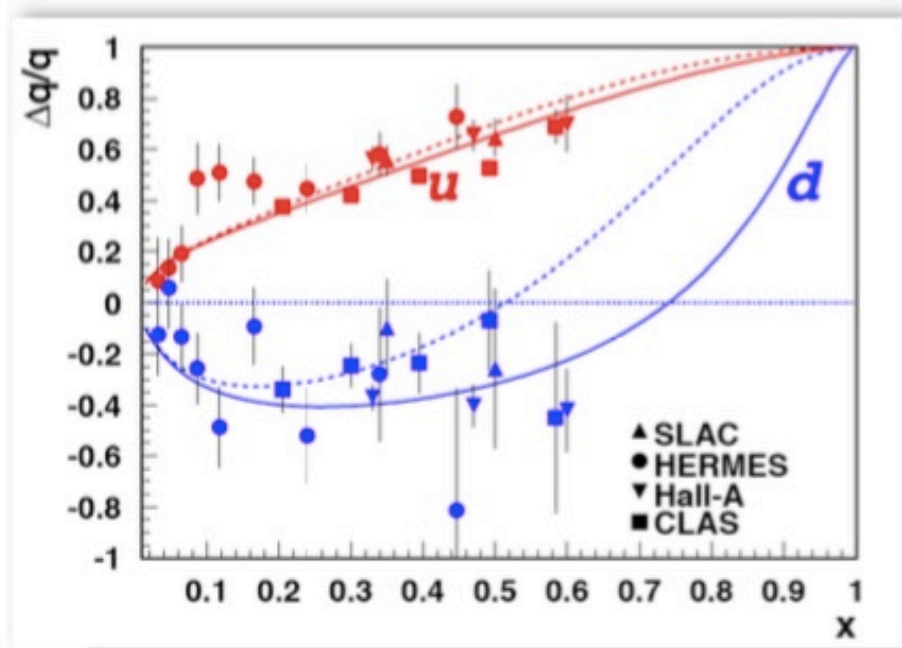
$$F_1(x) = \frac{1}{2}\Sigma_i e_i^2[q_i(x)]$$

$$g_1(x) = \frac{1}{2}\Sigma_i e_i^2[\Delta q_i(x)]$$

At high Q^2, $A_1=g_1/F_1$ and:

$$\frac{g_1^n}{F_1^n} = \frac{\Delta u + 4\Delta d}{u+4d}$$

$$\frac{g_1^p}{F_1^p} = \frac{4\Delta u + \Delta d}{4u+d}$$



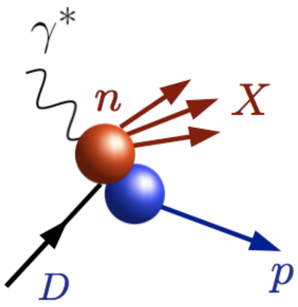
$$\frac{\Delta u}{u} = \frac{4}{15}\frac{g_1^p}{F_1^p}\left(4+\frac{d}{u}\right) - \frac{1}{15}\frac{g_1^n}{F_1^n}\left(1+4\frac{d}{u}\right)$$

$$\frac{\Delta d}{d} = \frac{4}{15}\frac{g_1^n}{F_1^n}\left(4+1/\frac{d}{u}\right) - \frac{1}{15}\frac{g_1^p}{F_1^p}\left(1+4/\frac{d}{u}\right)$$

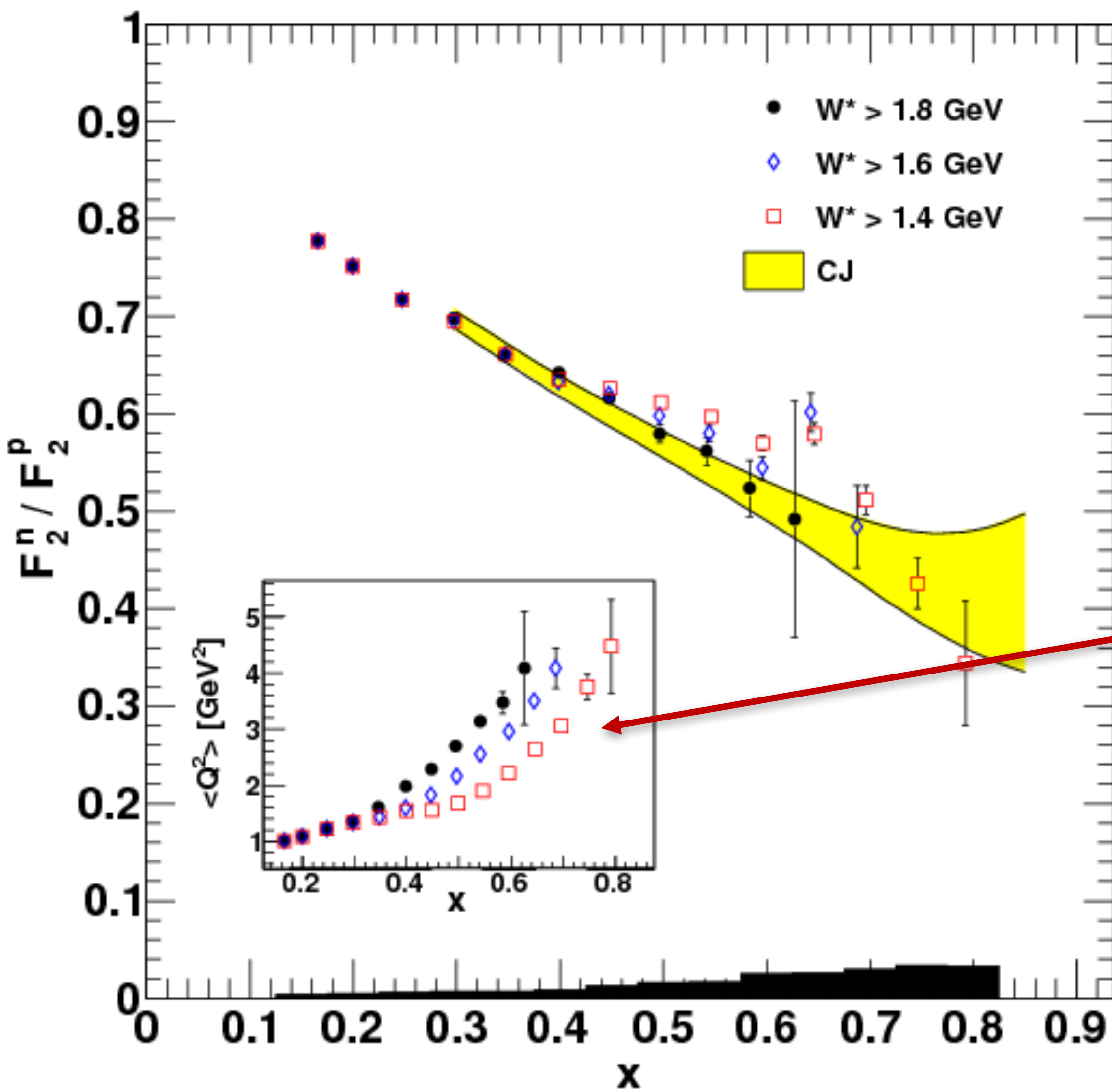
JAM Jefferson Lab Angular Momentum Collaboration

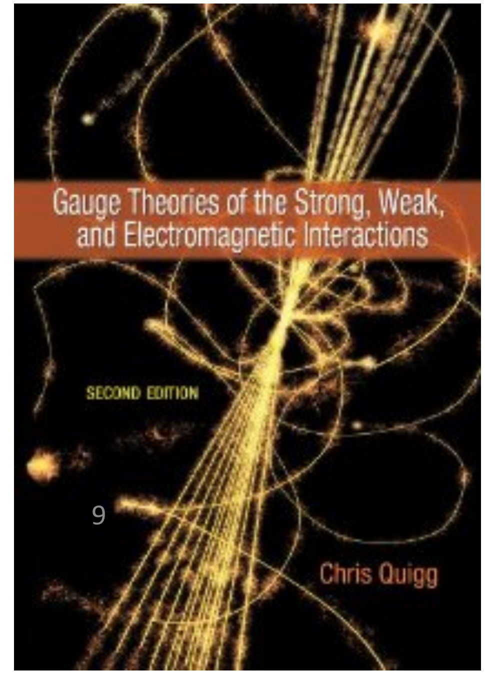
Effort launched to do a *simultaneous* fit of polarized, unpolarized PDFs (and fragmentation functions) - particularly tailored for studies of the large x region

BONUS effective neutron target via TDIS *achieved!*



Phys.Rev. C92 (2015) no.1, 015211
Phys.Rev. C91 (2015) no.5, 055206
Phys. Rev. C89 (2014) 045206 – editor's suggestion
Phys. Rev. Lett. 108 (2012) 199902
Nucl. Instrum. Meth. A592 (2008) 273-286





- Not quite high enough x, Q^2
- Nonetheless still powerful as input for global PDF fits…

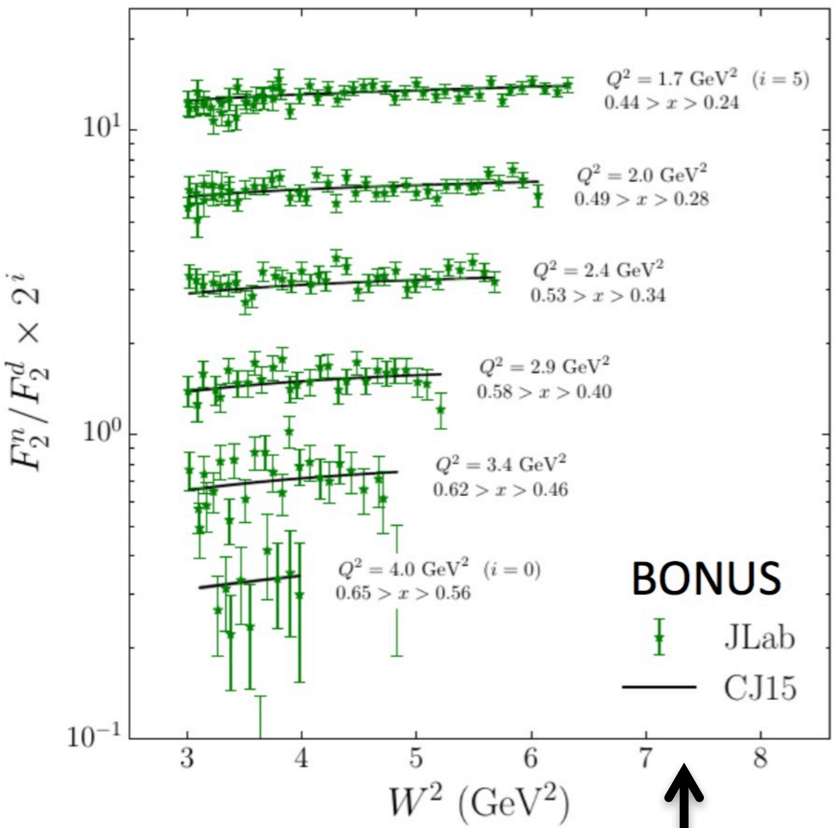
CTEQ-Jefferson Lab Collaboration

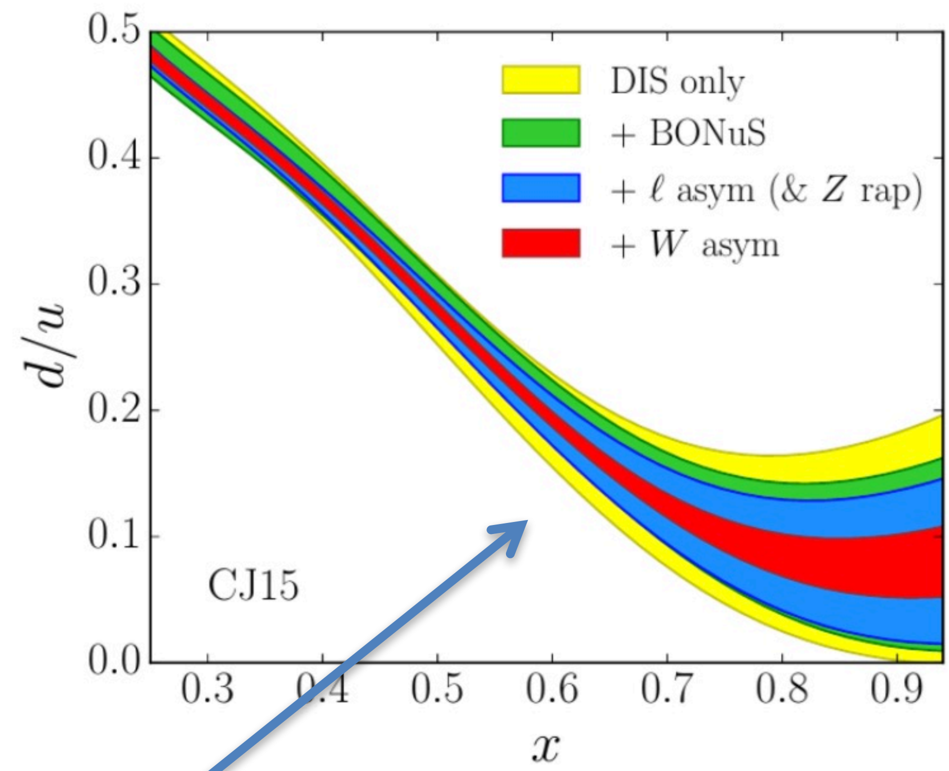
Global PDF fits *including the non-perturbative regime*

Accardi, Melnitchouk, Owens, Sato, CK, friends…
See www.jlab.org/theory/cj/

	10/2014	12/2014	06/2015	06/2015	06/2016	01/2017
April 2017	**NNPDF3.0**	**MMHT2014**	**CT14**	**HERAPDF2.0**	**CJ15**	**ABMP16**
Fixed Target DIS	✔	✔	✔	✘	✔	✔
JLAB	✘	✘	✘	✘	✔	✘
HERA I+II	✔	✔	✔	✔	✔	✔
HERA jets	✘	✔	✘	✘	✘	✘
Fixed Target DY	✔	✔	✔	✘	✔	✔
Tevatron W,Z	✔	✔	✔	✘	✔	✔
Tevatron jets	✔	✔	✔	✘	✔	✘
LHC jets	✔	✔	✔	✘	✘	✘
… or boson	✔	✔	✔	✘	✘	✔
… top	✔	✘	✘	✘	✘	✔
… ment	Monte Carlo	Hessian $\Delta\chi^2$ dynamical	Hessian $\Delta\chi^2$ dynamical	Hessian $\Delta\chi^2=1$	Hessian $\Delta\chi^2=1.645$	Hessian $\Delta\chi^2=1$
Parametrization	Neural Networks (259 pars)	Chebyshev (37 pars)	Bernstein (30-35 pars)	Polynomial (14 pars)	Polynomial (24 pars)	Polynomial (15 pars)
HQ scheme	FONLL	TR'	ACOT-χ	TR'	ACOT-χ	FFN (+BMST)
Order	NLO/NNLO	NLO/NNLO	NLO/NNLO	NLO/NNLO	NLO	NLO/NNLO

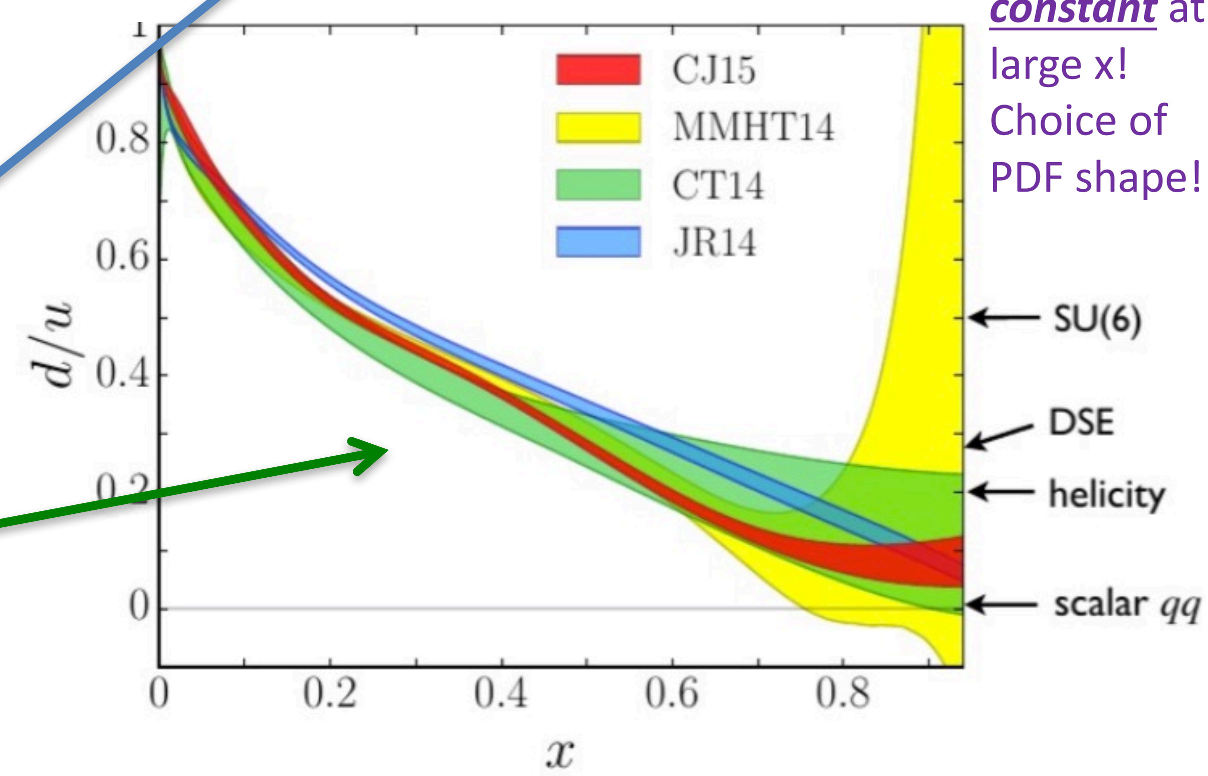
chart from M. Ubiali plenary talk DIS 2017





- BONUS data well fit by CJ
- Effect of adding BONUS (also W, l asymmetries from D0)
- **Substantial reduction in d/u uncertainty at large x!**

Important to let d/u -> ***constant*** at large x! Choice of PDF shape!



www.jlab.org/theory/cj/index.html

CTEQ-Jefferson Lab Collaboration

Global PDF fits *including the non-perturbative regime*

Accardi, Melnitchouk, Owens, Sato, CK, friends…

See www.jlab.org/theory/cj/

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Fixed Target DY	✔	✔	✔	✘	✔	✔
Tevatron W,Z	✔	✔	✔	✘	✔	✔
jets	✔	✔	✔	✘	✔	✘
LHC jets	✔	✔	✔	✘	✘	✘
LHC vector boson	✔	✔	✔	✘	✘	✔
LHC top	✔	✘	✘	✘	✘	✔
Stat. treatment	Monte Carlo	Hessian $\Delta\chi^2$ dynamical	Hessian $\Delta\chi^2$ dynamical	Hessian $\Delta\chi^2=1$	Hessian $\Delta\chi^2=1.645$	Hessian $\Delta\chi^2=1$
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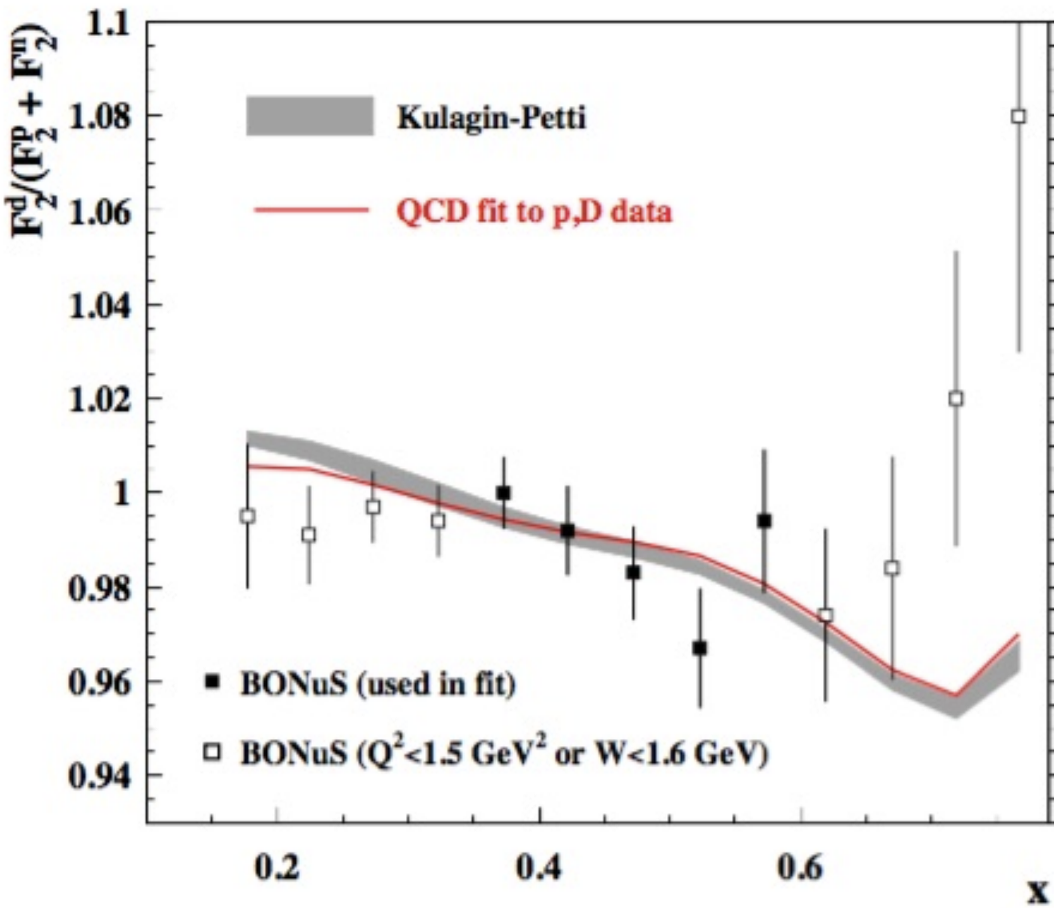
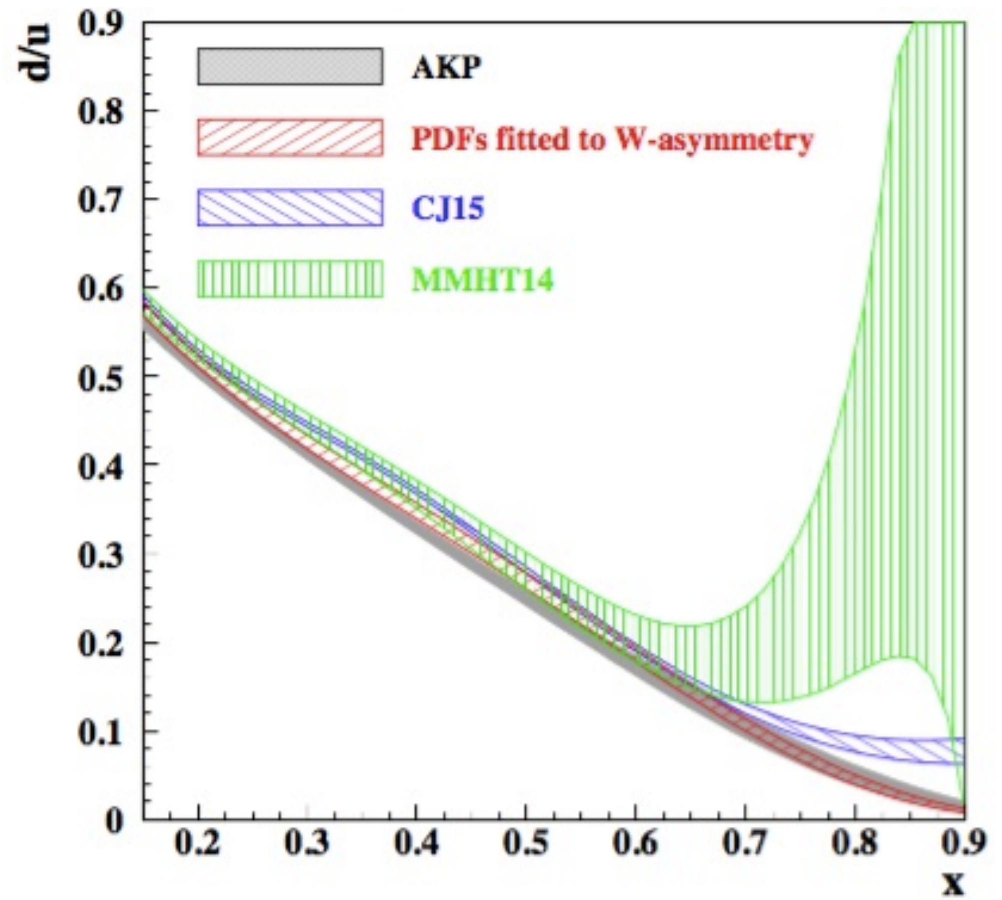
(my) 2018 update

EMC effect in deuterium – correction for nPDFs

$F_2^D/(F_2^n + F_2^p)$ with F_2^n from BONUS

Alekhin, Kulagin, Petti
Phys. Rev. D 96, 054005 (2017)



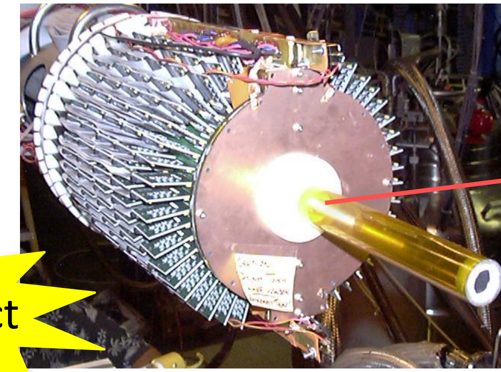


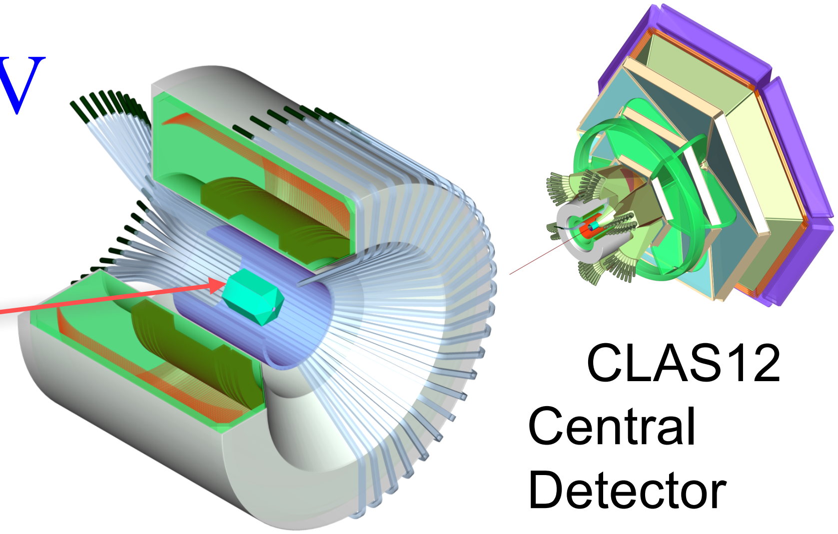
"…the recent direct measurement of the ratio F2D/F2N from the BONuS experiment contributes to constrain the overall normalization of the nuclear corrections in our fits."

Approved for Jefferson Lab 12 GeV

E12-06-113
"BONUS12"

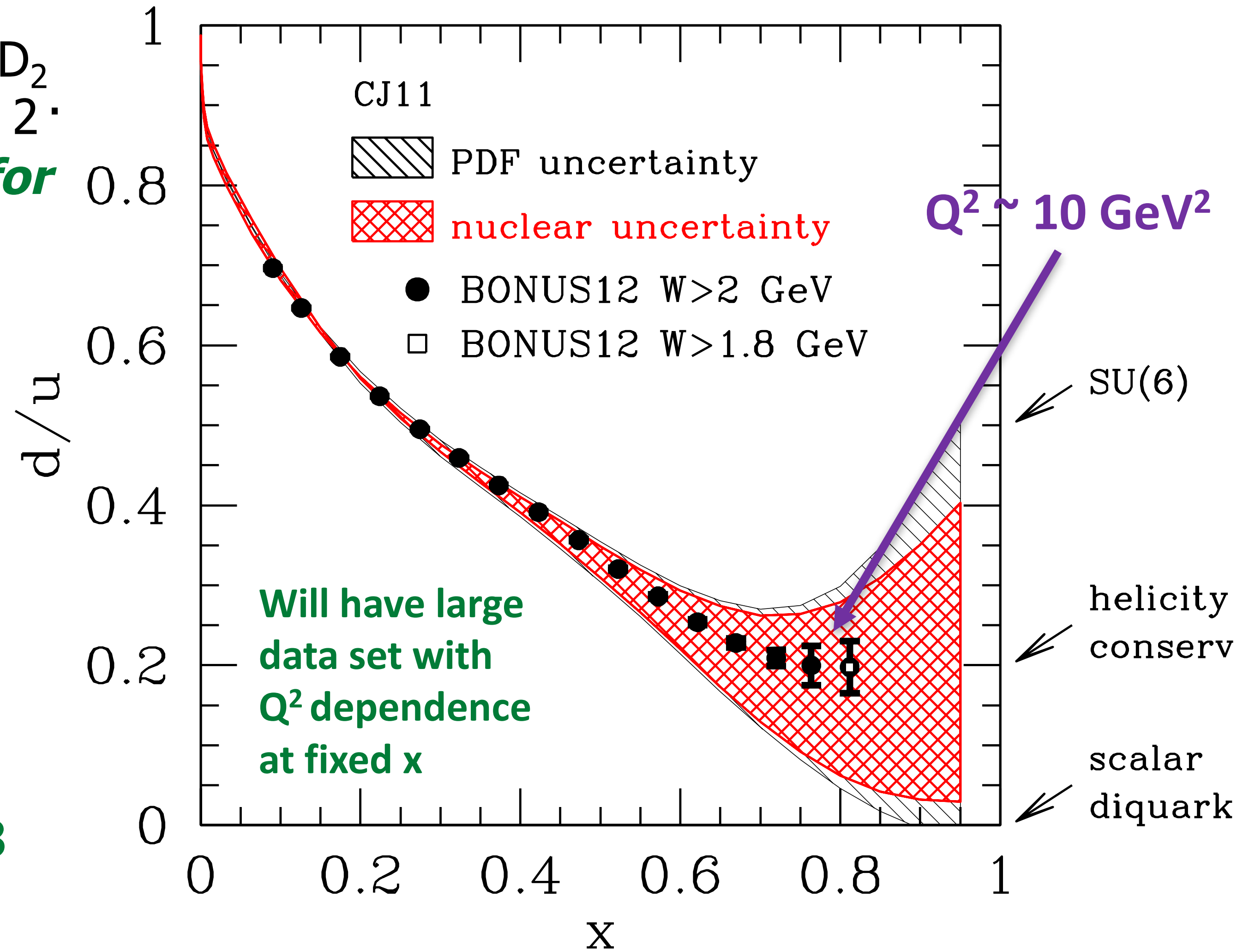
High Impact



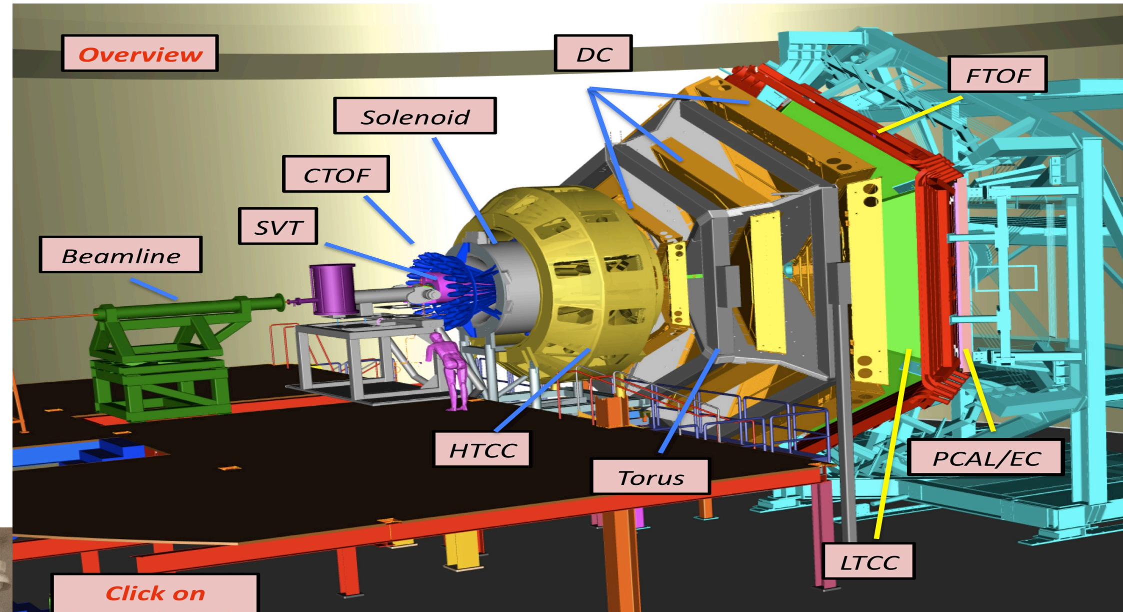


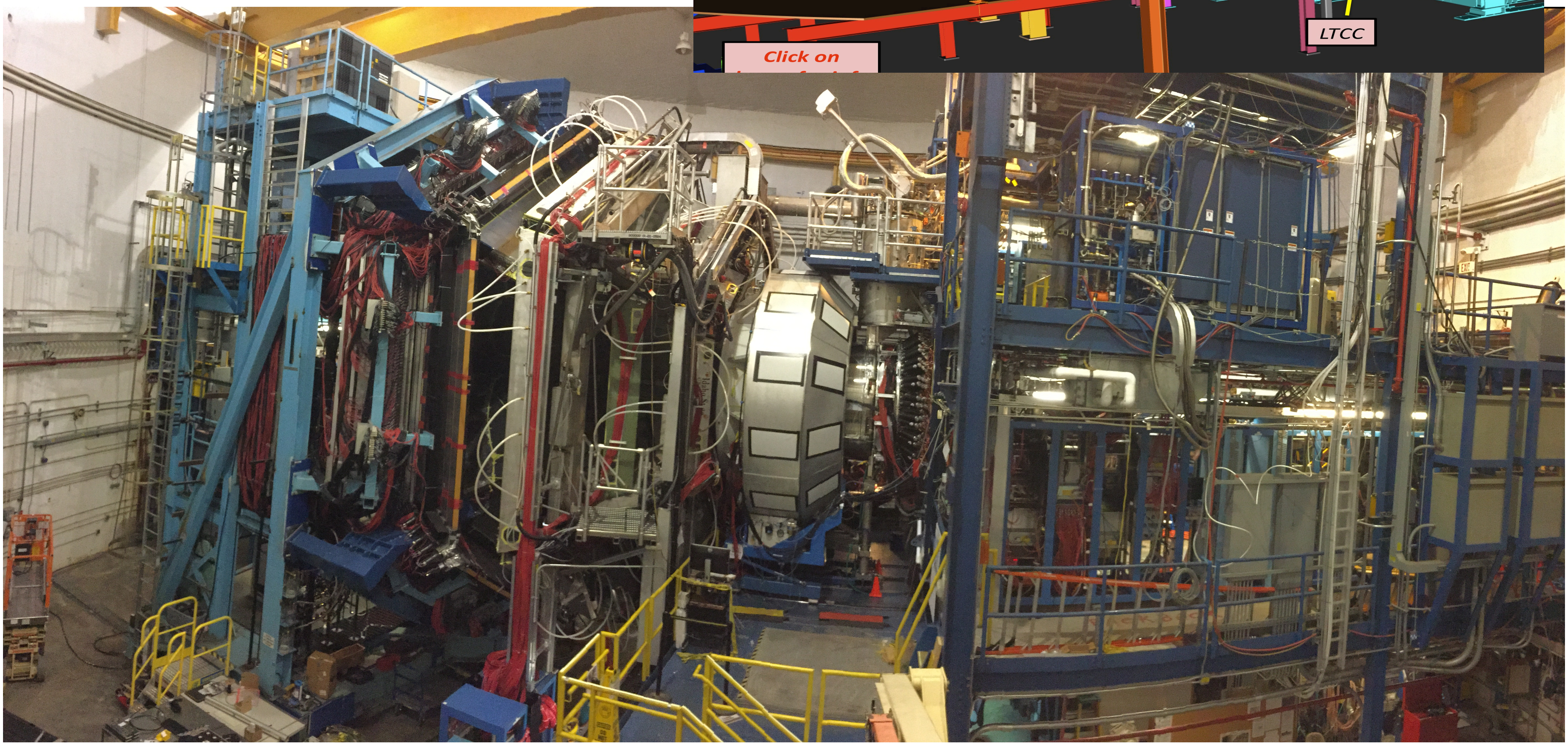
CLAS12
Central
Detector

- Data taking of 35 days on D_2 and 5 days on H_2 with $L = 2 \cdot 10^{34}$ cm^{-2} sec^{-1} ***planning for 2019 installation***
- BoNuS detector DAQ and trigger upgrade
- DIS region with
  - $Q^2 > 1$ GeV$^2/c^2$
  - $p_s < 100$ MeV/c
  - $\theta_{pq} > 110°$
- Largest value for $W^* > 1.8$ GeV gives max. $x^* = 0.83$

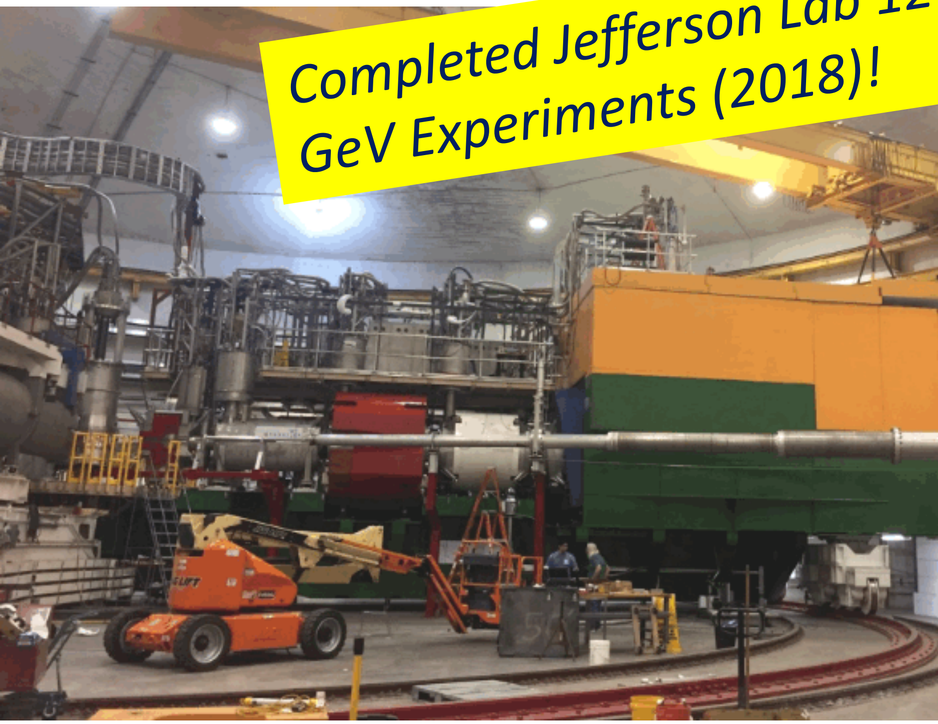


CLAS12 (JLab Hall B) now taking first data!

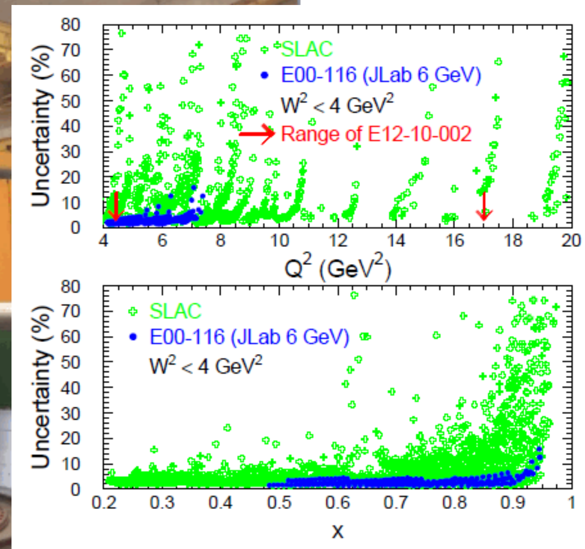


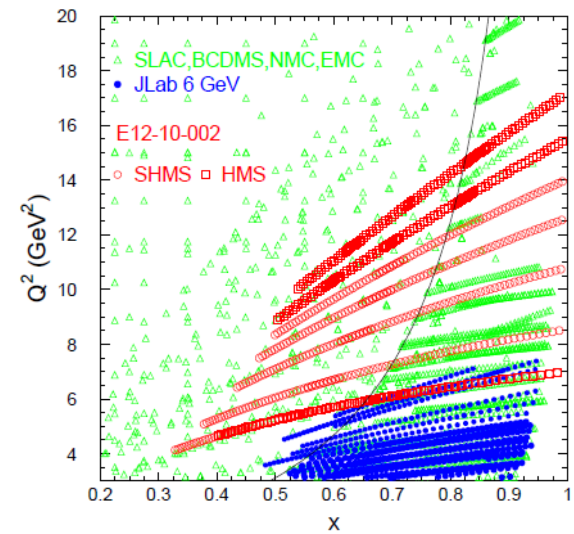


Completed Jefferson Lab 12 GeV Experiments (2018)!

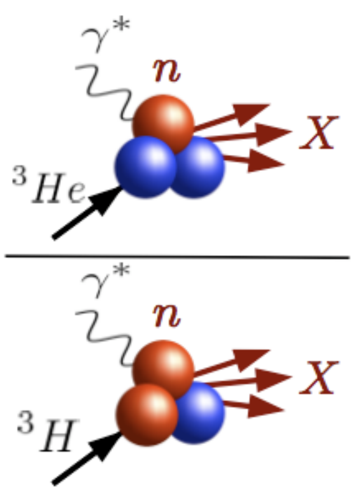


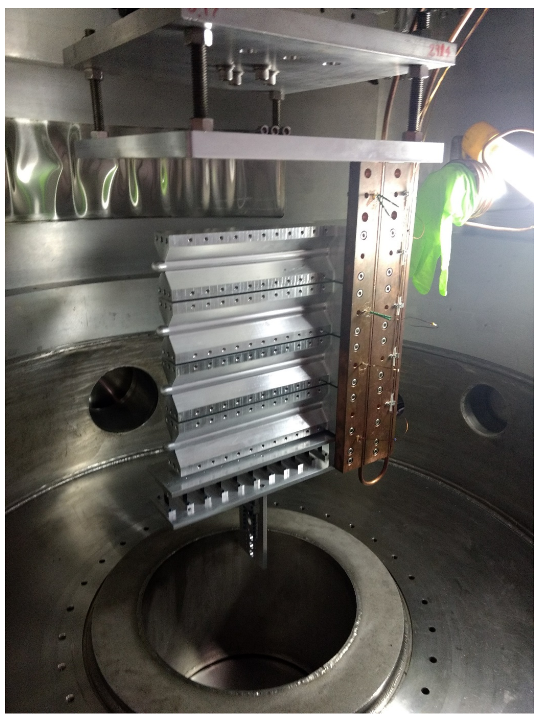
F_2^p, F_2^D at Large x in Hall C

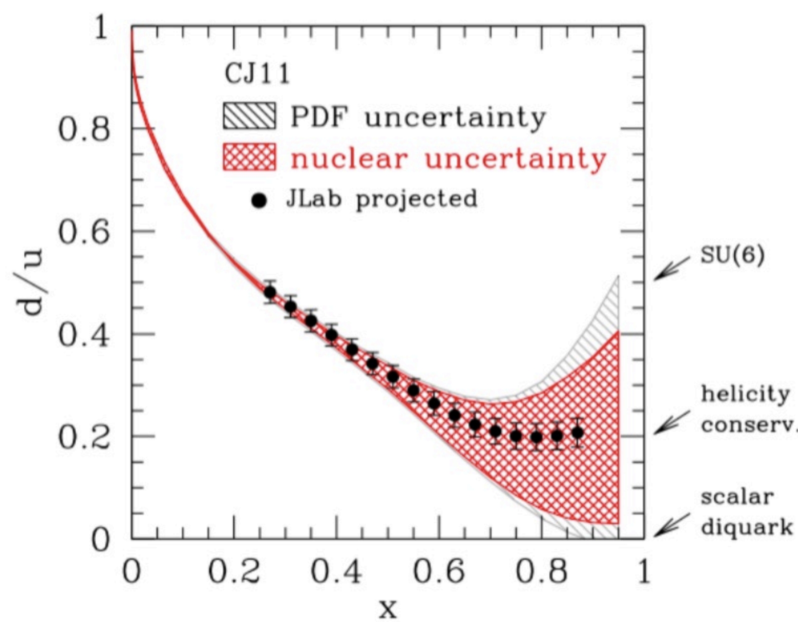




F_2^n/F_2^p using $^3H/^3He$ Mirror Nuclei in Hall A

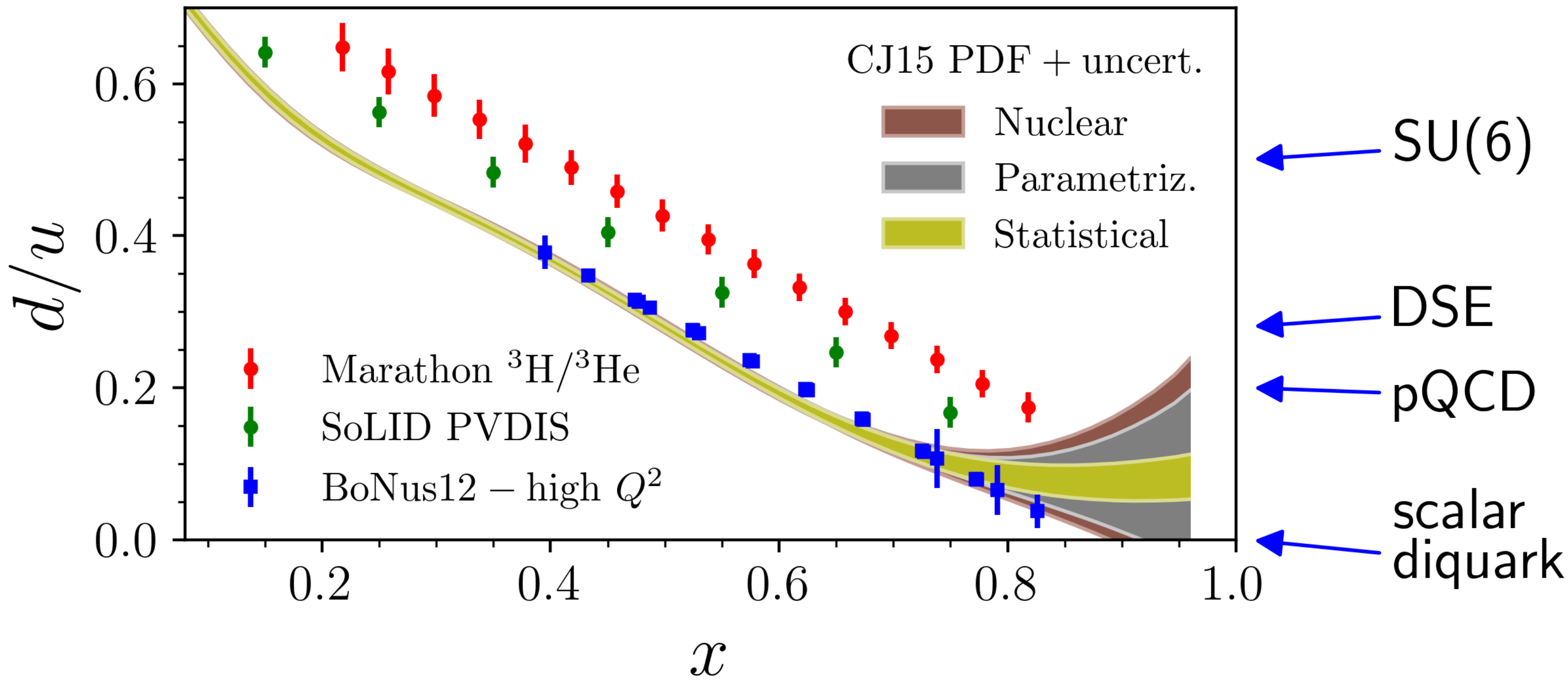






First tritium target for nuclear physics in ~3 decades!

Probing the Nucleon Valence Regime at Jefferson Lab



- New generation of experiments at JLab at 12 GeV will access the regime where valence quarks dominate
- First experiments *completed!*
  - Hall C F2p,d
  - Hall A 3H/3He
- Dedicated theory efforts also underway
  - "CJ", (CTEQ-Jefferson Lab) – and also "JAM" (polarized pdf) collaborations

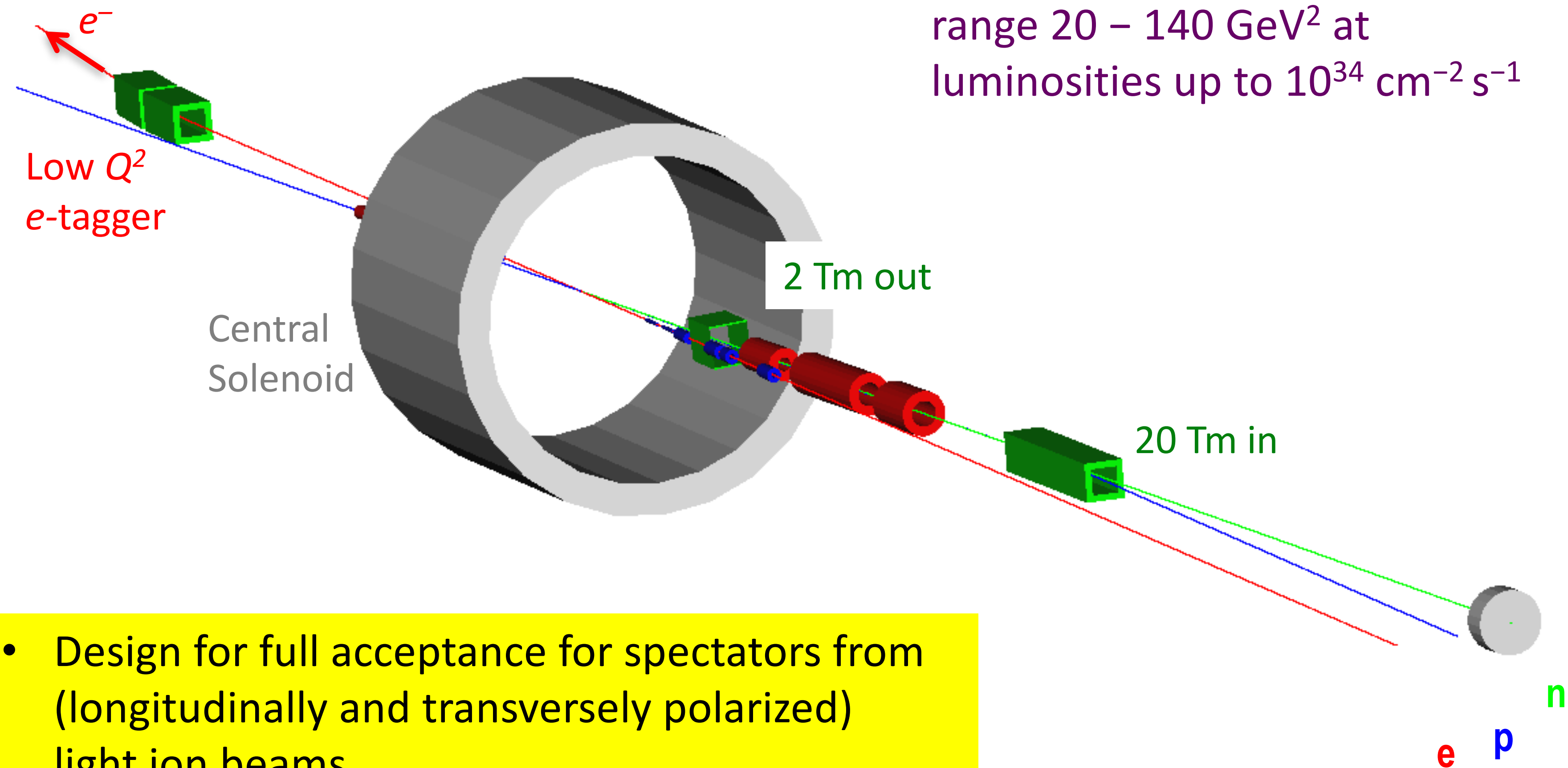
See also P. Reimer talk

Expect large improvements in our understanding of PDFs in the the valence regime in the next 1-2 years!

Tagged Neutron Structure at the Electron Ion Collider

The TDIS technique is better suited to colliders: no target material absorbing low-momentum nucleons, forward acceptance only!

The EIC designs provide electron–nucleon squared center–of–mass energies in the range 20 – 140 GeV^2 at luminosities up to 10^{34} cm^{-2} s^{-1}



- Design for full acceptance for spectators from (longitudinally and transversely polarized) light ion beams

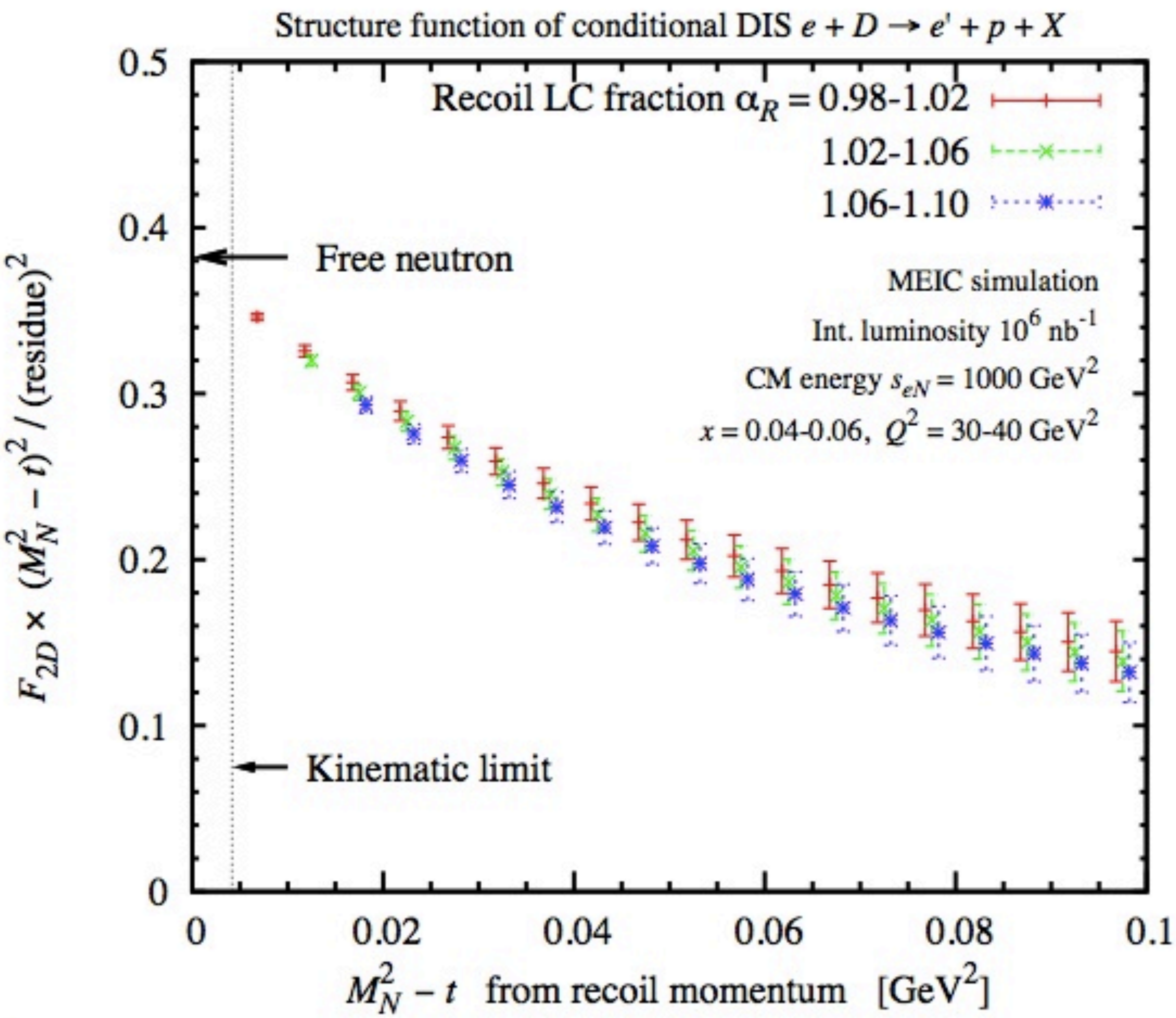
Tagged Neutron Structure at the Electron Ion Collider

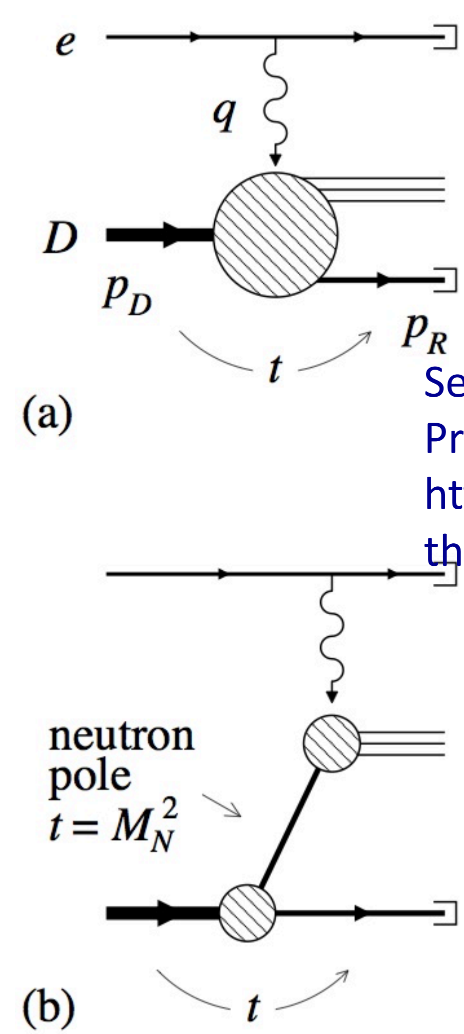
TDIS measurements require coverage for [protons] with:

- low momenta (pT/pbeam ~ 0.8 – 1.2)
- good momentum resolution (ΔpT ~20 MeV, < Fermi momentum)
- small intrinsic momentum spread in the ion beam for accurate reconstruction

EIC being designed with this physics in mind
– neutron structure functions up to $Q^2 = 40\ GeV^2$

e + D → e′ + p + X *a la BONUS*





See Spectator Tagging Project at https://www.jlab.org/theory/tag/

Determining Large-x Parton Distributions with EIC

First look at projected EIC data in CTEQ-Jefferson Lab "CJ" PDF Fits

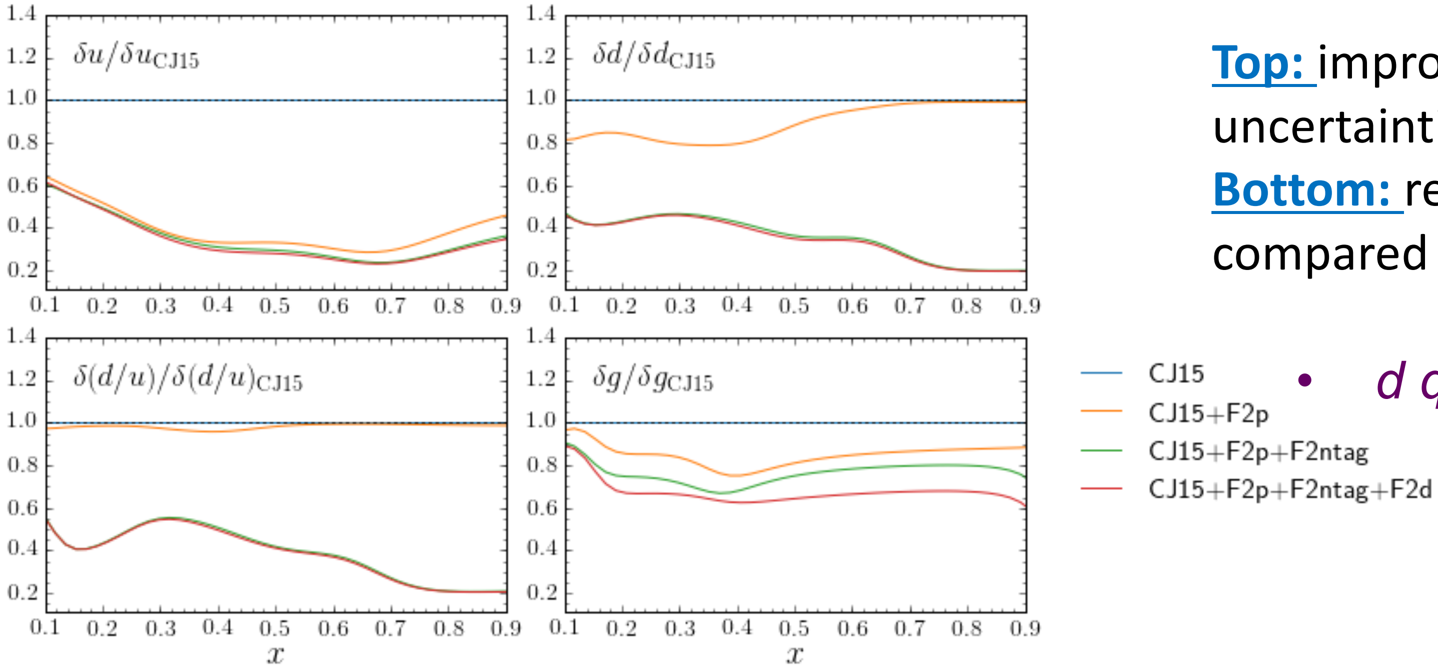
So far, have used JLEIC 10x100 GeV^2 projections in bins $0.1 < x < 0.9$ for:

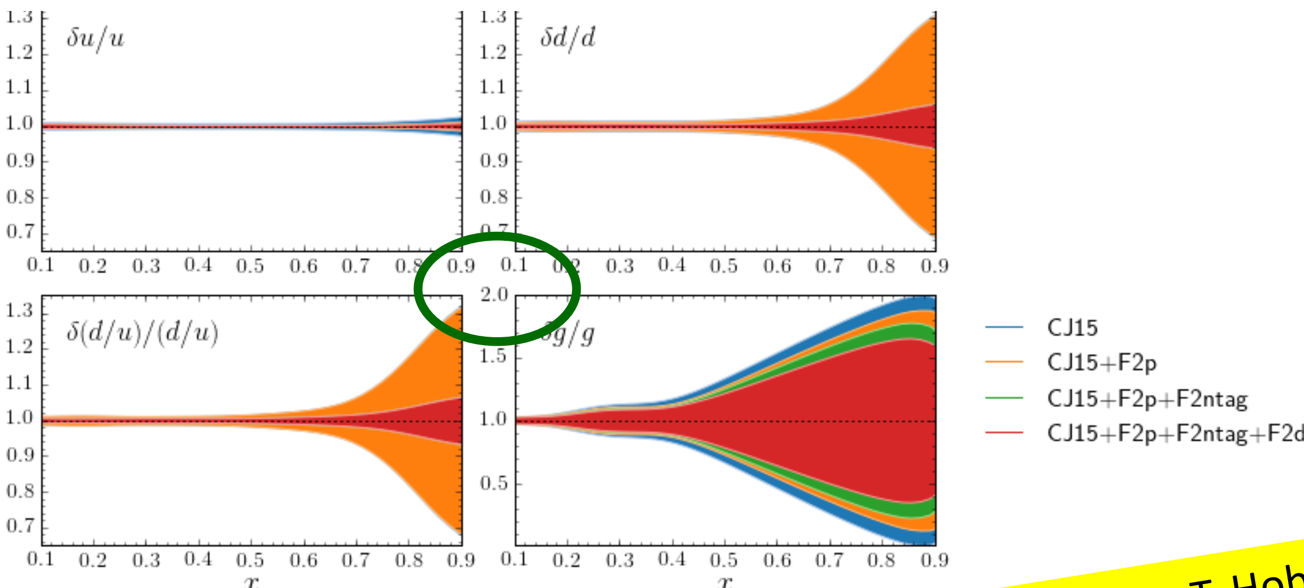
- ✓ F_2^p
- ✓ F_2^n from deuterium with ***tagged proton spectator***
- ✓ F_2^d

- Measurements ranging up to high Q^2 will enable studies of target mass, higher twist, pert/nonpert transition
- Can check on-shell extrapolation by measuring F_2^p from deuterium with tagged neutron spectator, comparing to proton target data
  - Validation of TDIS technique
- Can check nuclear corrections to F_2^d against $F_2^{n\ (\text{tagged})}$

A. Accardi, R. Ent, J. Furletova,
C. Keppel, K. Park,
R. Yoshida, M. Wing

EIC e-d (with n_{tag}) projection with 100/fb luminosity





Top: improvement in relative PDF uncertainties compared to CJ15
Bottom: relative uncertainties compared to CJ15

- *d quark precision will become comparable to current u!! (becomes ~5% at x = 0.9)*
- d/u tracks d
- ~20% improvement in g(x), accessed by F_2 shape in Q^2 – lever arm in Q^2 matters most
- The u quark uncertainty becomes less than ~1%; may be important for large mass BSM new particles.

See also T. Hobbs talk!

- Semi-inclusive deep inelastic scattering technique
  - but *not* to access the current regime

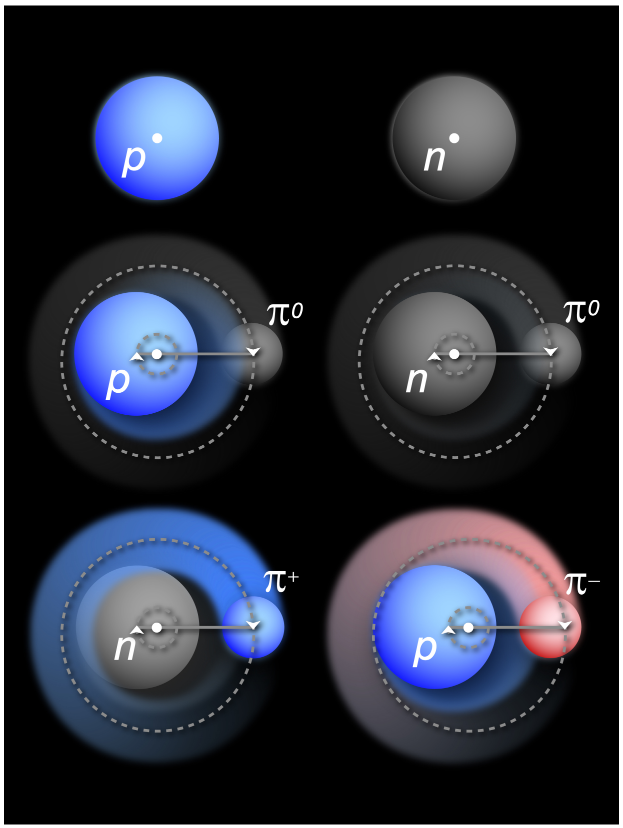
- "Tagging" facilitates effective *targets* not readily found in nature

- Tagged DIS provides novel probe of partonic structure of these effective targets

- Three examples:
  - Neutron
  - ***Pion***
  - Kaon

Will discuss pioneering efforts

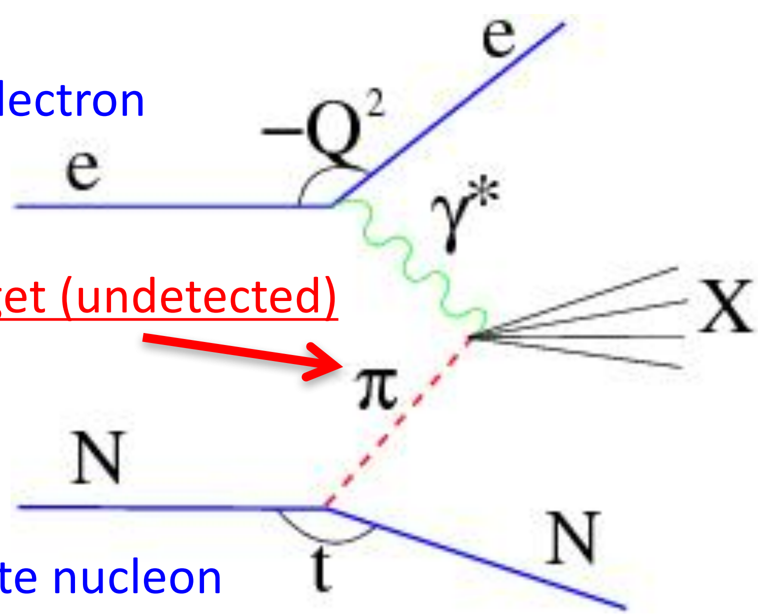
Example 2: TDIS to access **pion** structure function
- use **Sullivan process** scattering from **nucleon-pion** fluctuation



detect scattered electron

incoming electron

pion target (undetected)



DIS event –
reconstruct x, Q^2, W^2, also M_X (W_π) of undetected recoiling hadronic system

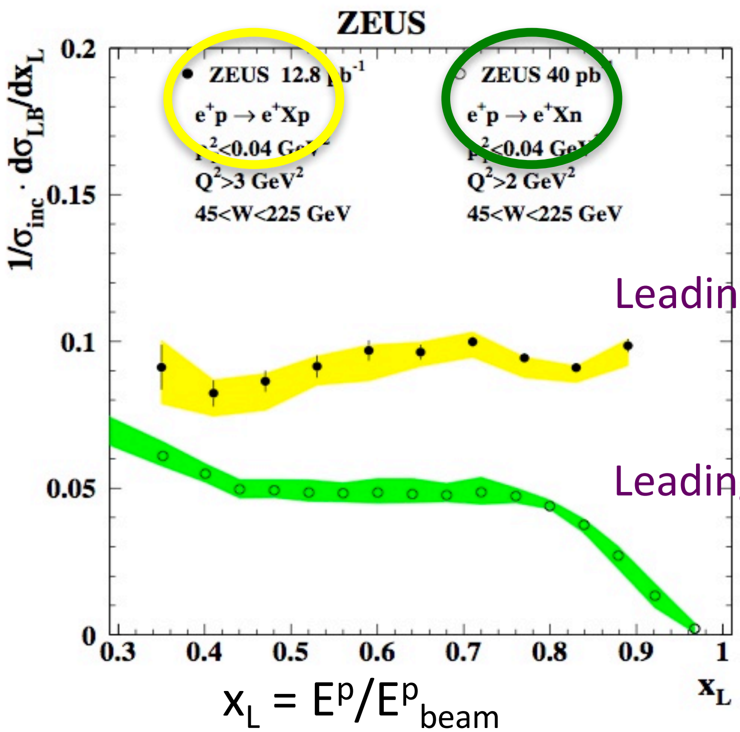
Initial state nucleon

tagged outgoing target nucleon

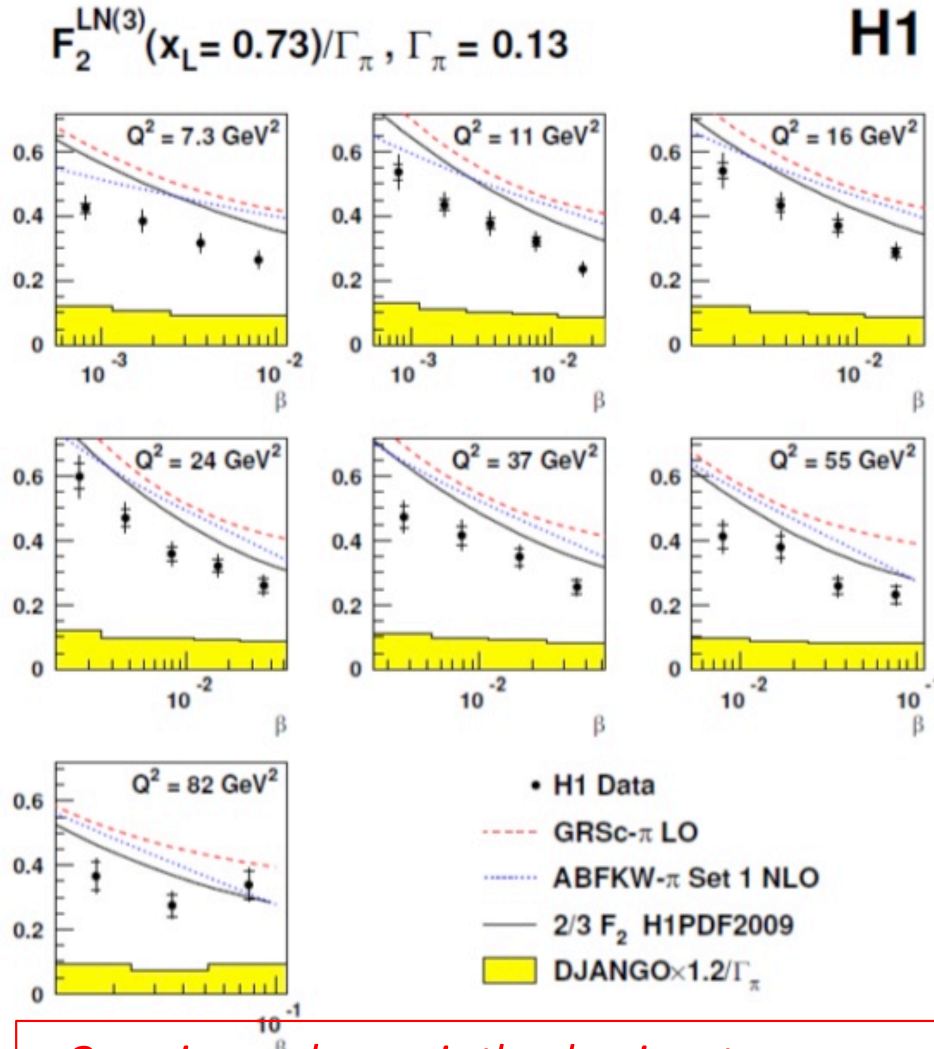
- t = four-momentum transfer squared at the nucleon vertex

Pion Structure Function from TDIS Measurements at HERA

Total yield for $0.35<x_L<0.9$



$x_L = E^p/E^p_{beam}$



Pure isovector exchange

$\Rightarrow$ Lp= ½ Ln (isospin Clebsch-Gordon)

Data: Lp ≈ 2Ln

$\Rightarrow$ additional isoscalar exchanges for Lp

Proton isoscalar events include diffractive scattering – *the neutral pion is buried*

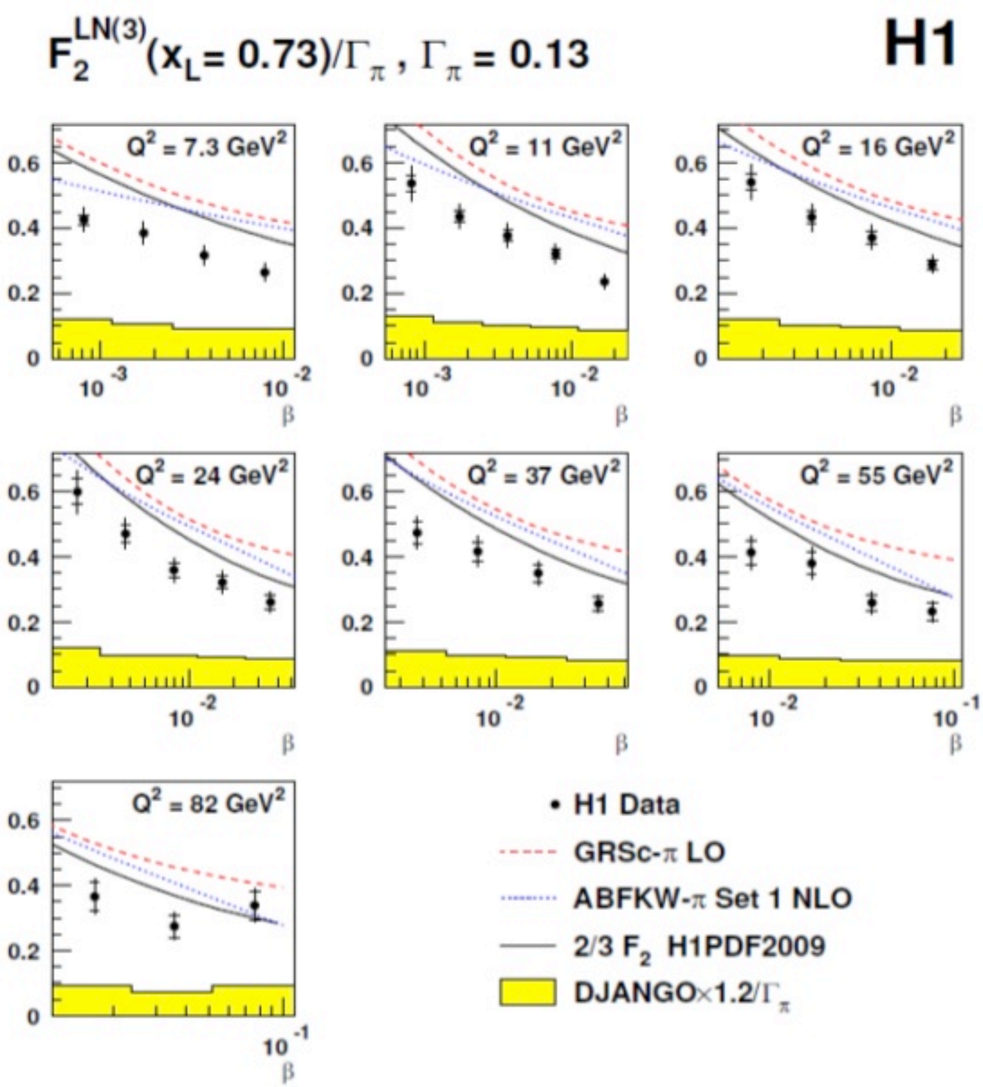
Neutron events isovector only, charged pions dominate

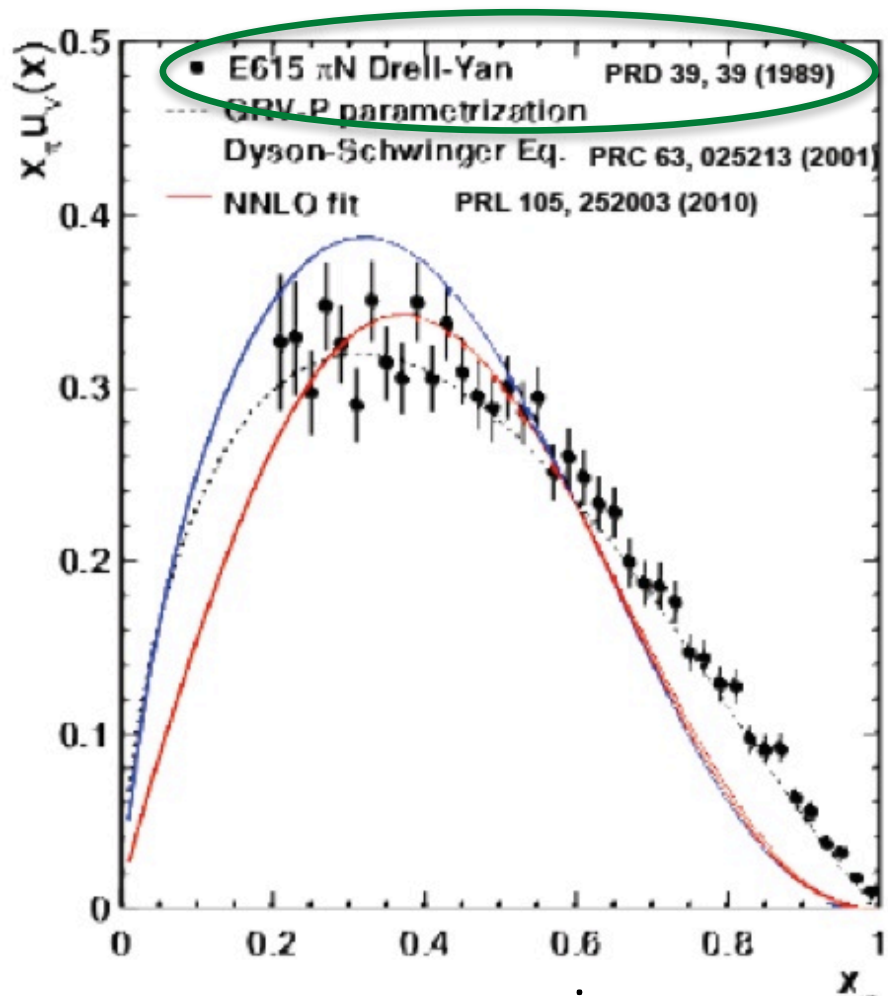
- *One pion exchange is the dominant mechanism.*
- *Can extract pion structure function*
- *Fine print disclaimer! Oversimplified (rescattering, absorption,…), requires in-depth model and kinematic studies*

DESY 08-176 JHEP06 (2009) 74

Pion Structure Function Measurements

- Knowledge of the pion structure function is ***very limited:***
  - HERA TDIS data - at low x
  - Pionic Drell-Yan from nucleons in nuclei - at large x



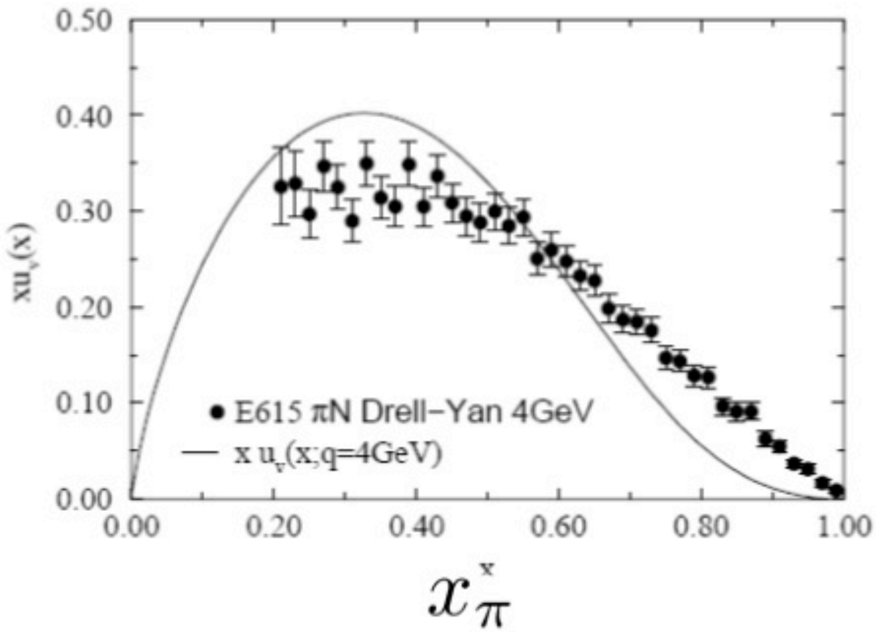


x_pi

Pion Structure Function from Drell-Yan: Large x Concerns

Large x Structure of the Pion

Initial observations:
- PDF ~ $(1-x_\pi)$ as $x_\pi \to 1$
- Agrees with structureless model
- Differs from pQCD prediction of $(1-x_\pi)^2$

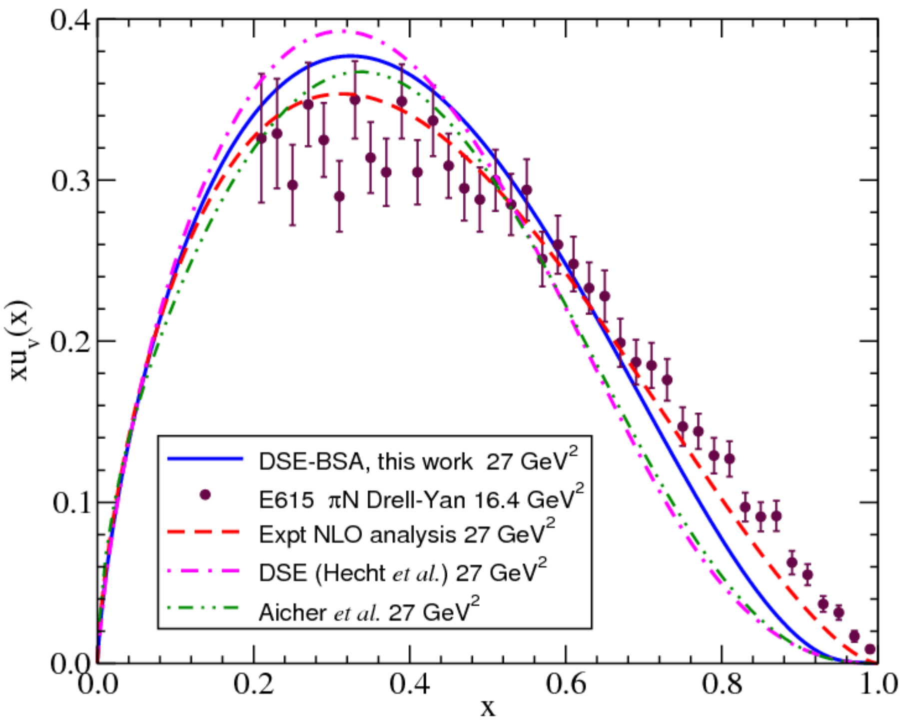


FNAL E615, CERN NA3,10

$$\pi^- W \to \mu^+ \mu^- X$$

$$\sigma \propto \bar{u}(x_{\pi^-}) u(x_N)$$

See also S. Platchkov, C.D. Roberts, R. Sandapen talks



C.D. Roberts, arXiv:1203.5341 [nucl-th]

- Data do not agree with pQCD, Dyson-Schwinger, Light Front, Instanton,….*numerous models!*
- Problem with data analysis?
  - NLO fit
  - Improved proton PDFs
  - Sea quark contribution
  - More flexible extractions of PDFs
- Nuclear corrections needed?
- Only soft gluon resummation shows "convex" shape

(Aicher, Schäfer, Vogelsang, Phys. Rev. Lett. 105, 252003 (2010))

Jefferson Lab TDIS can provide important verification….

Web-based Self-Serve Pion PDF: More Large x Concern

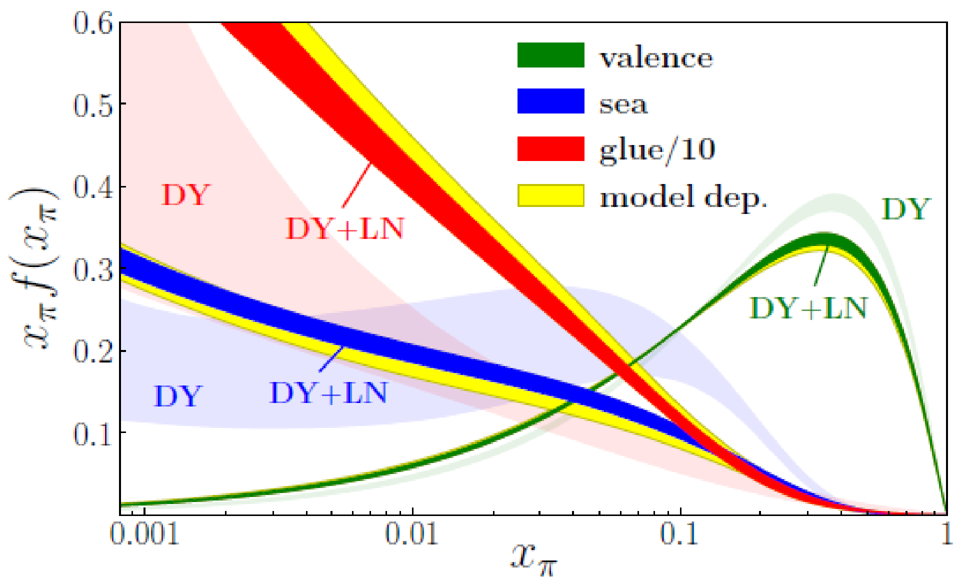
From combined HERA TDIS Leading-Neutron and Drell-Yan analysis…

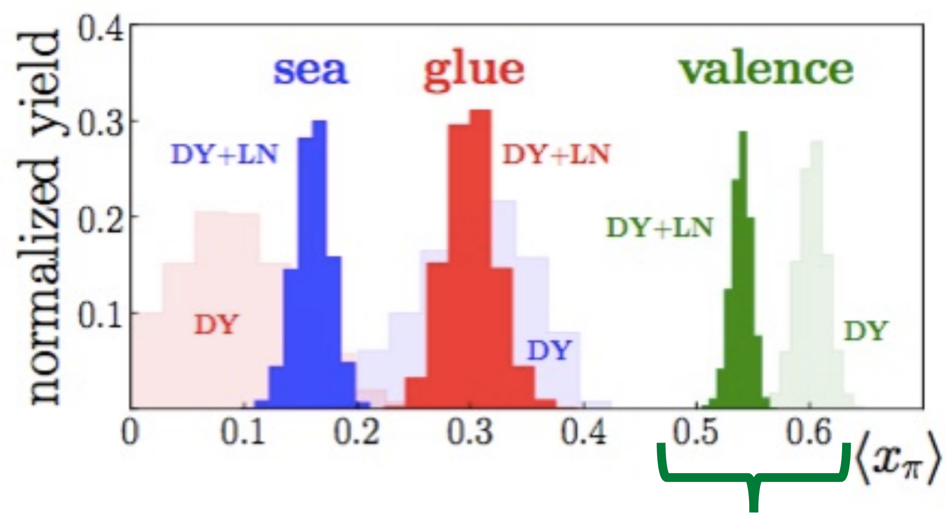
Web-based self-server performs a combined data analysis – can test sensitivity to new data

Github: https://github.com/JeffersonLab/jamfitter

Jupyter notebook: https://jupyter.jlab.org/

P.C. Barry, **N. Sato**, W. Melnitchouk, C-R Ji
arXiv: 1804.01965 (2018)





Tension at large x!
Need new data!

TDIS+BONUS Technique Provides Potential for HERA-type Experiments at JLab

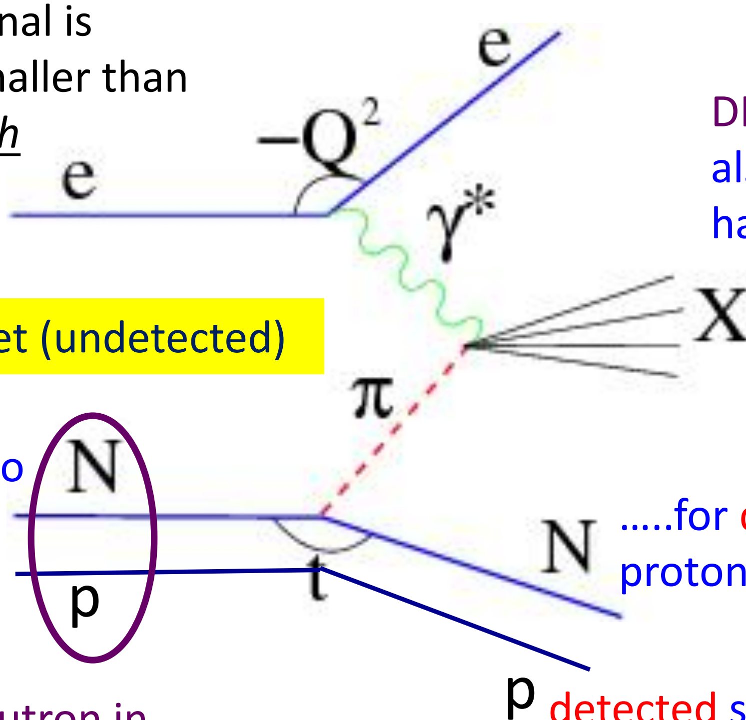
Sullivan Process scattering from neutron-pion fluctuation

detect scattered electron –
large acceptance a plus

Incoming electron – Signal is orders of magnitude smaller than inclusive DIS – *need high luminosity*

DIS event – reconstruct x, Q^2, W^2, also M_X of undetected recoiling hadronic system

Want *charged* pion target (undetected)



need fluctuating nucleon to be a neutron…….

…..for detected nucleon to be a proton

neutron in deuteron target

detected spectator proton tags neutron target (BONUS experiment technique)

Detected protons need to be *low* momentum
- Tag target hadron
- Extrapolate to pole
- Barely off-shell neutron

detecting two protons with common vertex in coincidence tags “pion” target!
Note: only need one p for hydrogen target

Extrapolation to the pole

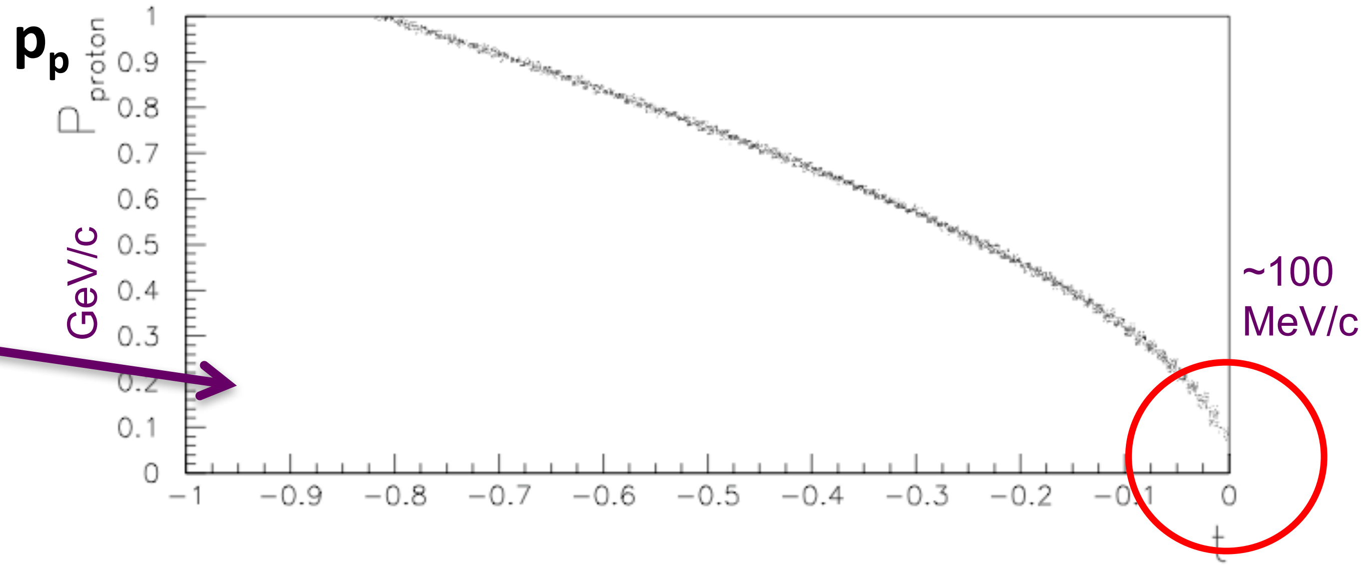
Need range of low momentum protons

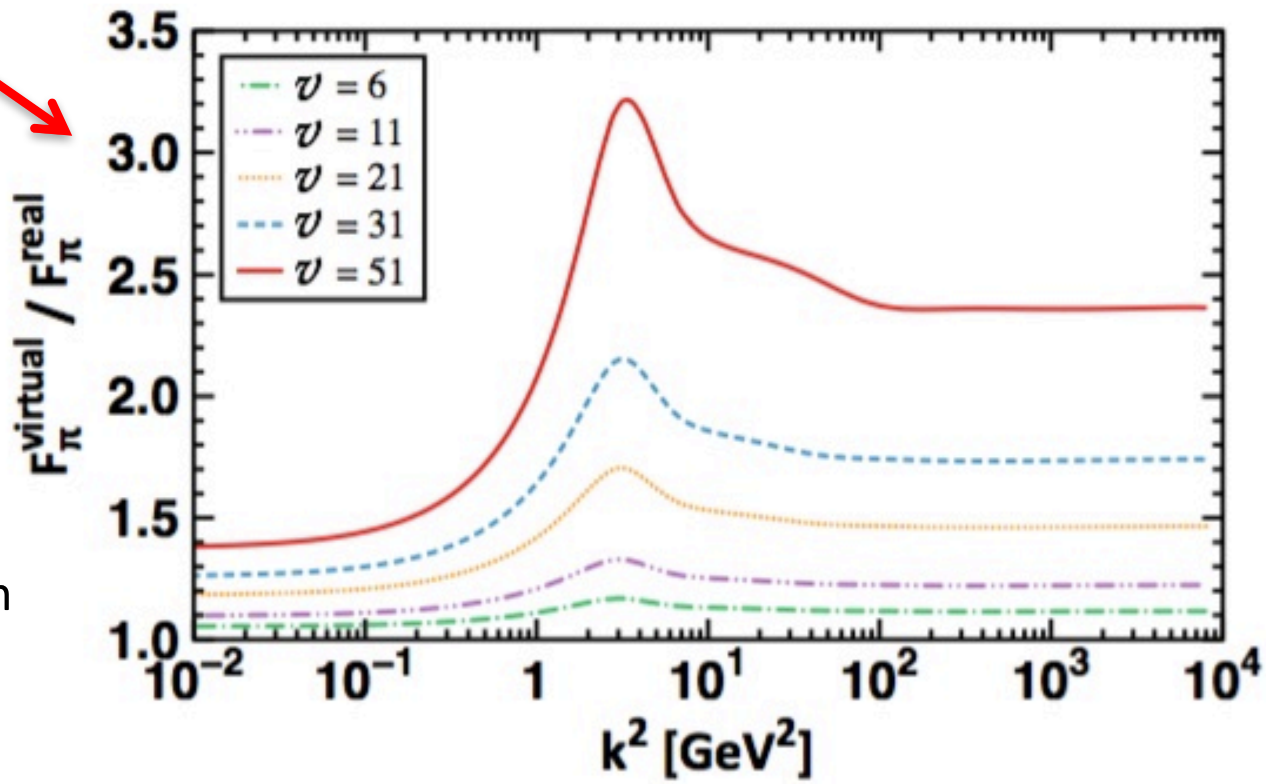
The ratio of off-shell to on-shell pion electromagnetic form factor

Si-Xue Qin, Chen Chen, Cedric Mezrag, Craig D. Roberts
Phys.Rev. C97 (2018) no.1

"…we demonstrated that for $v < v_S \sim 31$, which corresponds to $-t < \sim 0.6$ GeV^2….the off-shell correlation serves as a valid pion target."

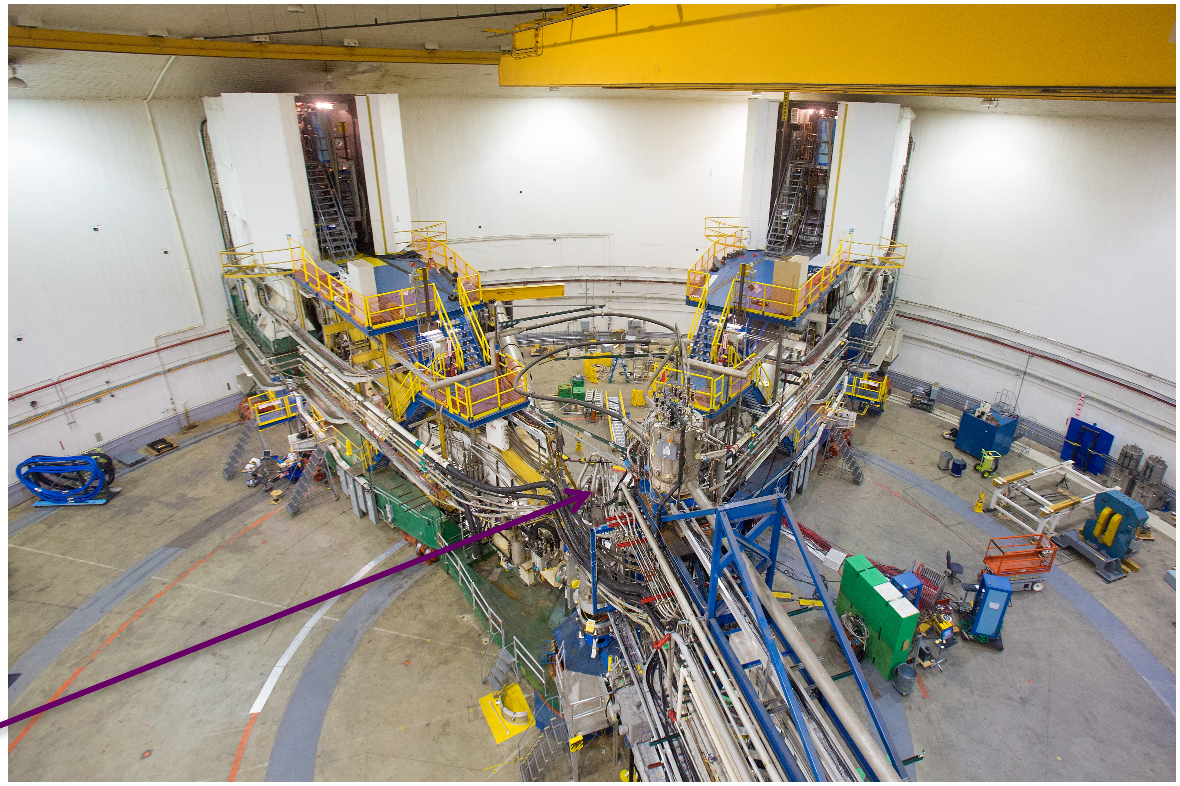
Within ~10% at JLab TDIS kinematics, best at lowest t values





Like BONUS, a challenging low p proton tag experiment

JLab Hall A TDIS Experiment



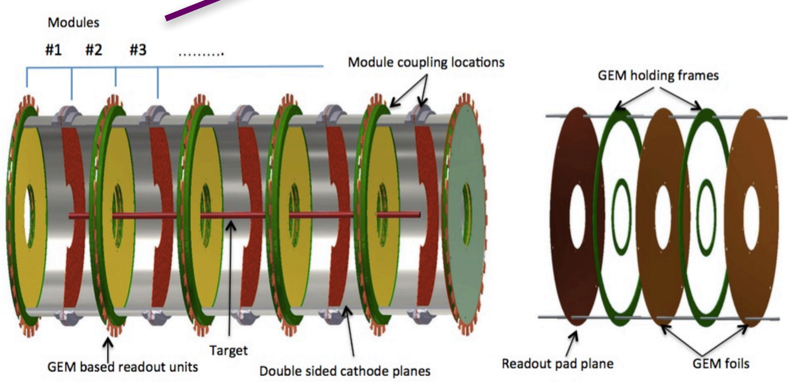
Hall A with SBS:

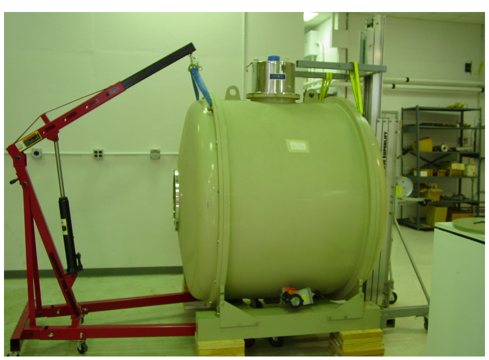
- ✓ High luminosity,
  50 μAmp,
  $\mathcal{L} = 3\text{x}10^{36}/\text{cm}^2\ \text{s}$
- ✓ Large acceptance
  ~70 msr

Important for small cross sections

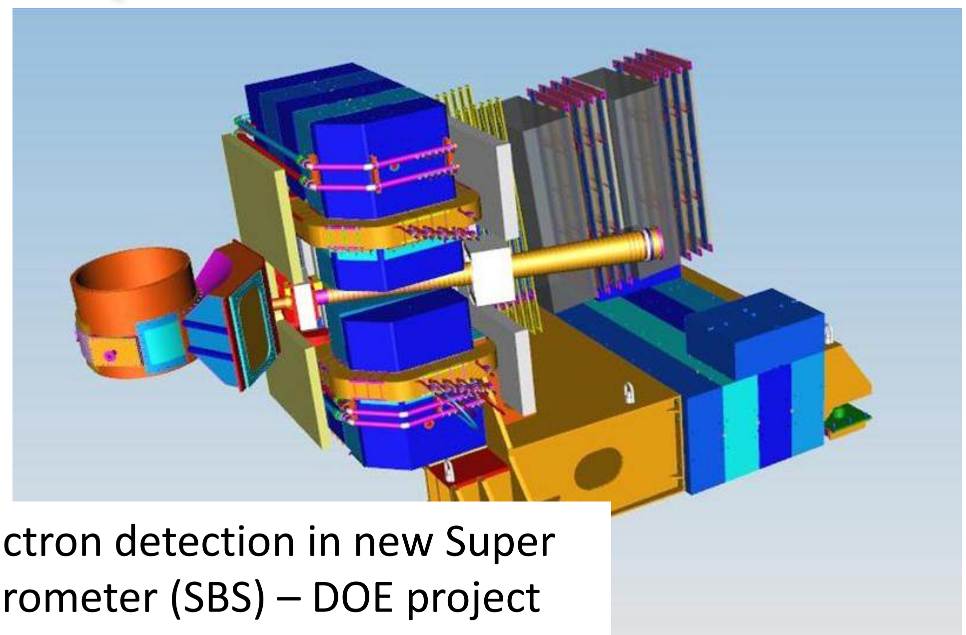
proton tag detection in GEM-based mTPC at pivot

e- beam





mTPC inside superconducting solenoid

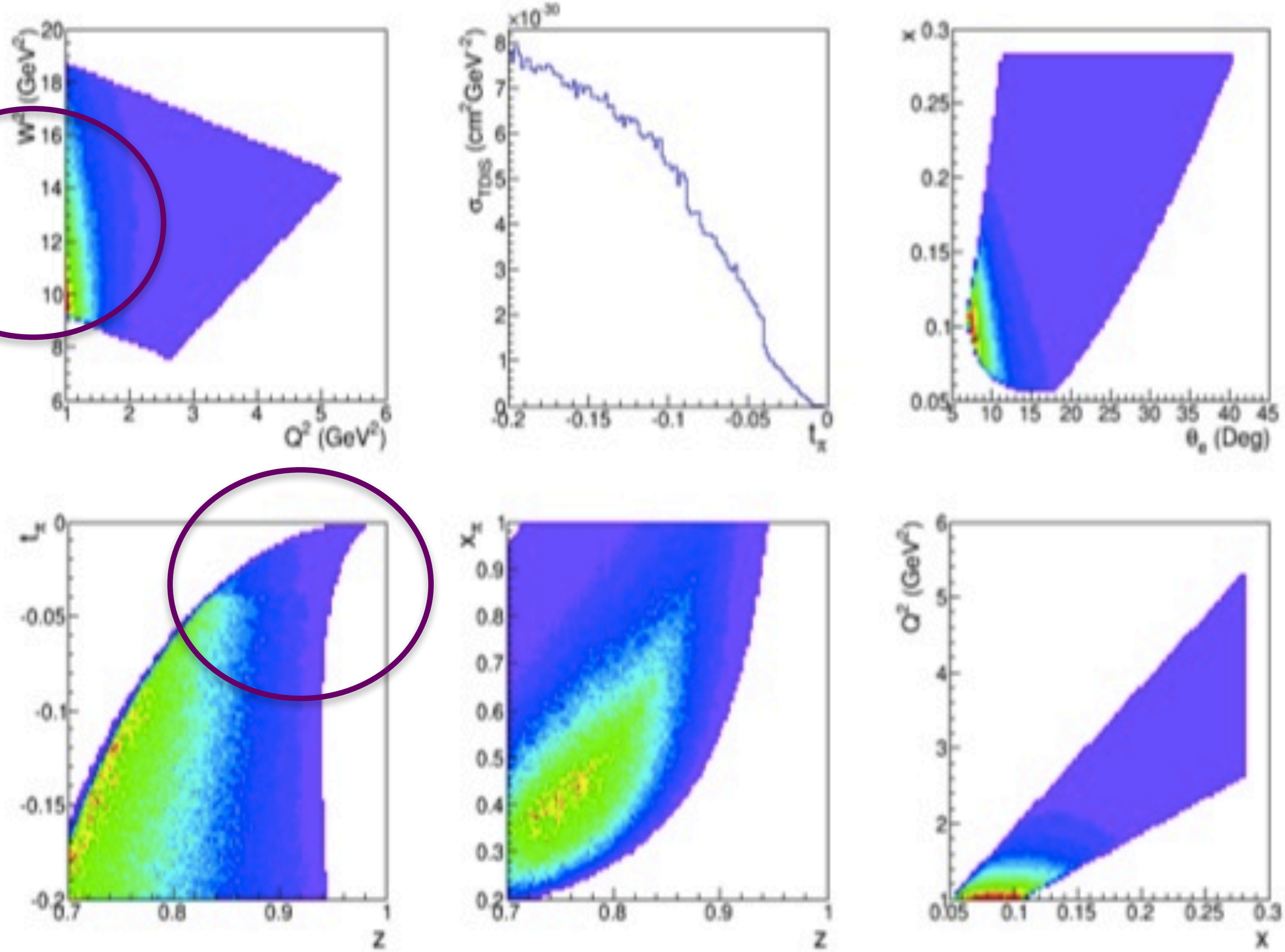


Scattered electron detection in new Super Bigbite Spectrometer (SBS) – DOE project complete

TDIS Kinematics – *optimized for meson cloud*

High W^2
- High M_x^2
- DIS!

All data obtained *simultaneously* at one E = 11 GeV setting, only a target change – will run hydrogen and deuterium (neutron)

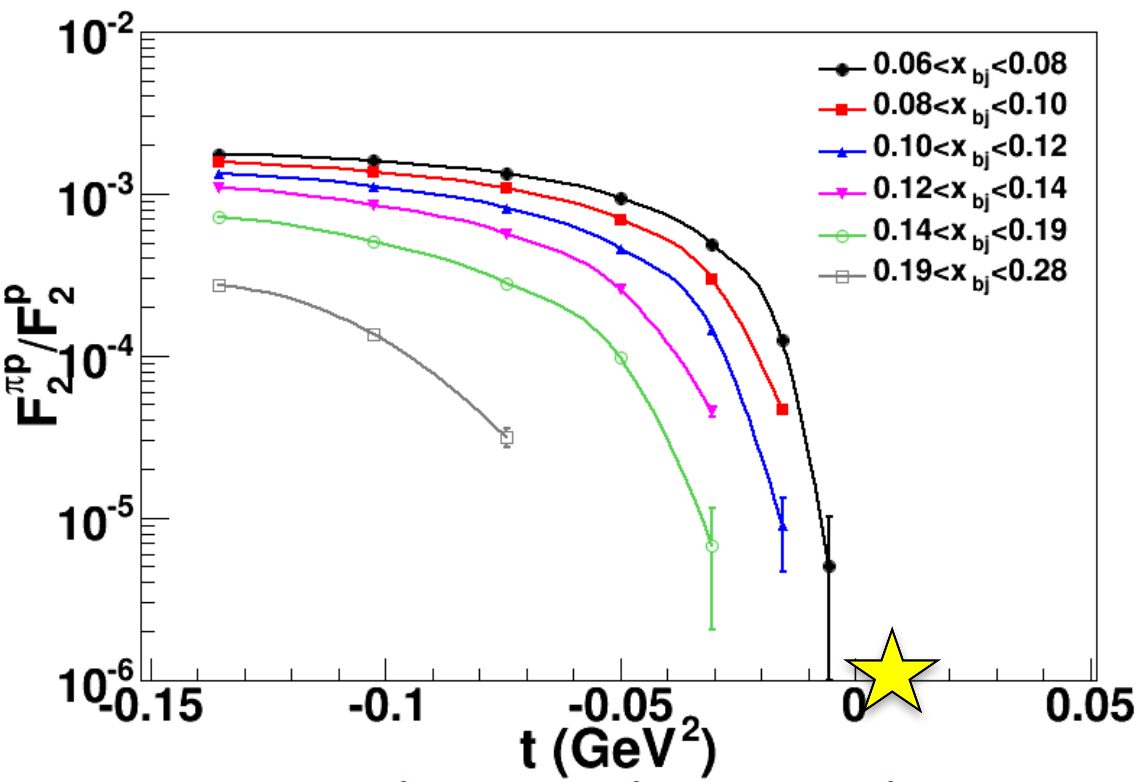


Low t, high (1-z)

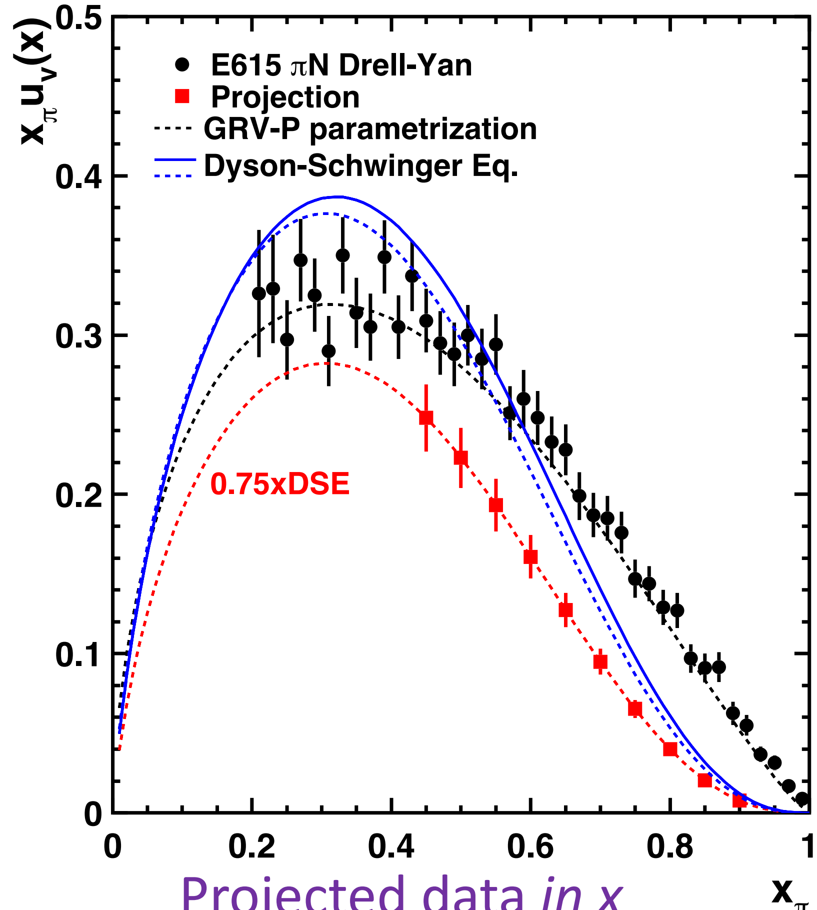
x range ~ 0.1
$1 < Q^2 < 2$ GeV^2

Projected Results – Pion Structure Function from TDIS at JLab

- Large x structure of the pion is of particular interest, verify (?) resummed Drell-Yan results
- Large x, low Q complementary to HERA low x, high Q via evolution



Low t extrapolation to the pion pole



Projected data *in* x_π

J. R. McKenney, et al., Phys. Rev. D93 (2016), 054011

T. J. Hobbs et al, Few Body Syst. 56 (2015) no.6-9

Tagged Deep Inelastic Scattering (TDIS)

- Semi-inclusive deep inelastic scattering technique
  - but *not* to access the current regime

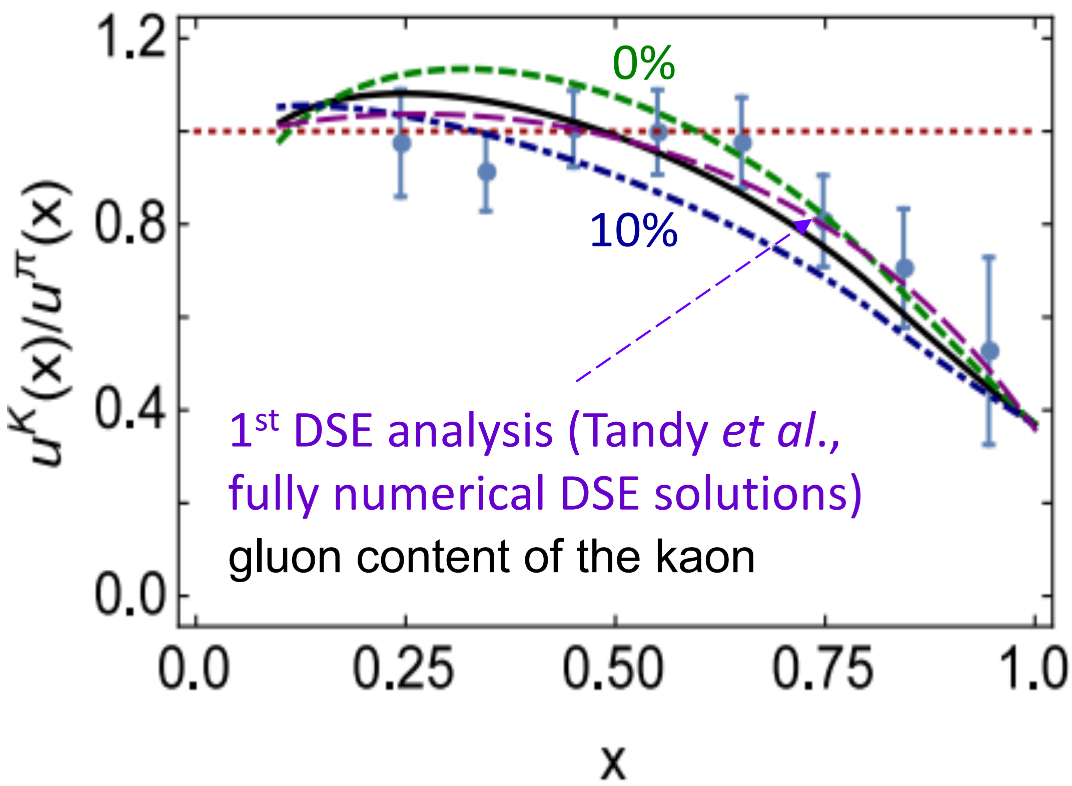
- "Tagging" facilitates effective *targets* not readily found in nature

- Tagged DIS provides novel probe of partonic structure of these effective targets

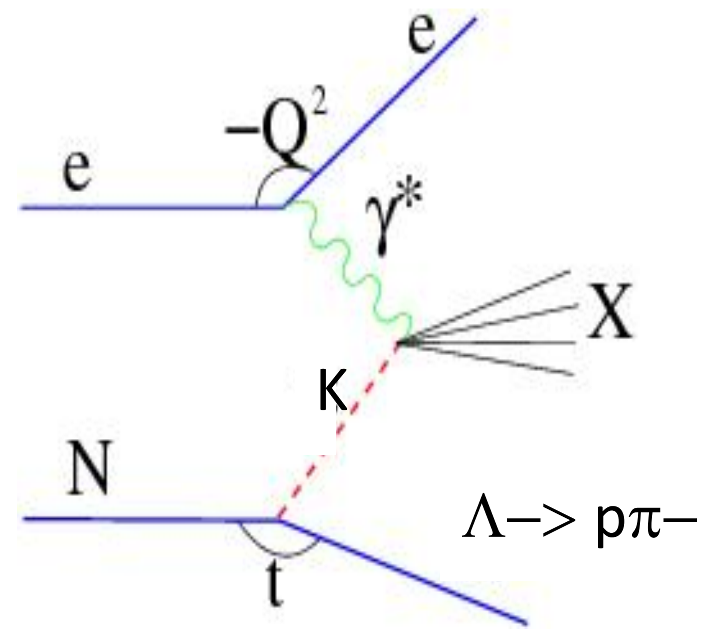
- Three examples:
- Neutron
- Pion
- ***Kaon***

A pioneering effort

But wait, there's more…!…. (***Example 3:*** **TDIS to access kaon structure function**)



Approved TDIS rungroup experiment – get "for free"
- Very difficult
- *A first preliminary look*, en -> (eKΛ) –> epπ–



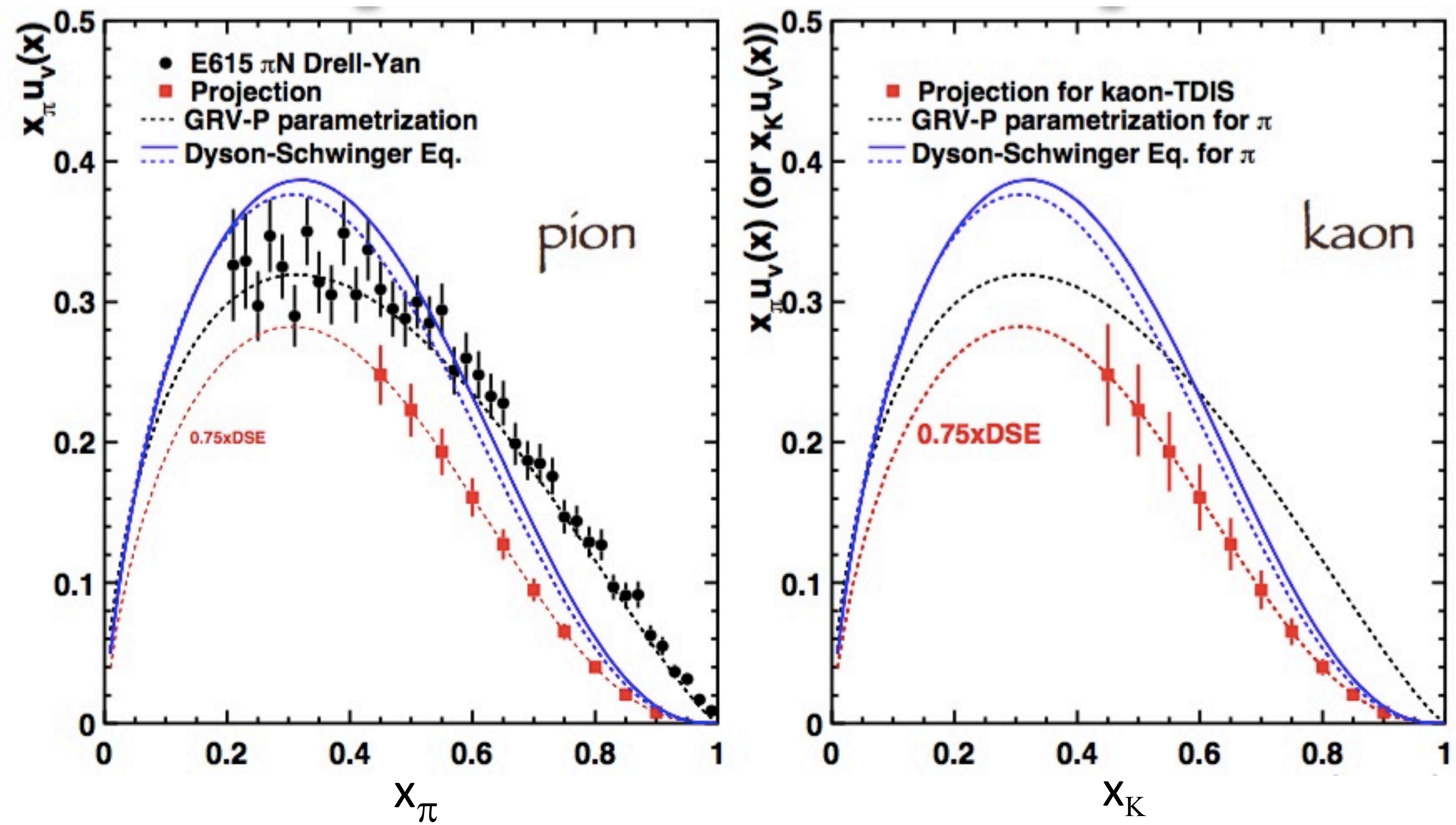
Based on Lattice QCD and DSE:

- Valence quarks carry some 52% of the pion's momentum at the light front, at the scale used for LQCD calculations, or ~65% at the perturbative hadronic scale
- At the same scale, valence-quarks carry ⅔ of the kaon's light-front momentum, or roughly 95% at the perturbative hadronic scale
- **Less glue in the kaon than in the pion**

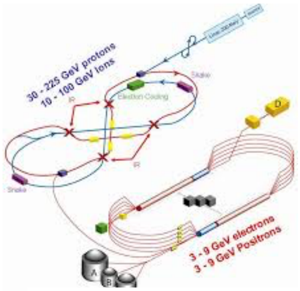
At high x, the shapes of valence u quark distributions in pion, kaon and proton are different, and so are their asymptotic x→1 limits

S-S Xu, L. Chang, C.D. Roberts, H-S Zong, Phys. Rev. D 97 (2018) no.9, 094014

Projected JLab TDIS Results for π, K Structure Functions



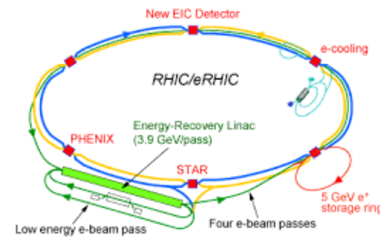
Essentially no data currently



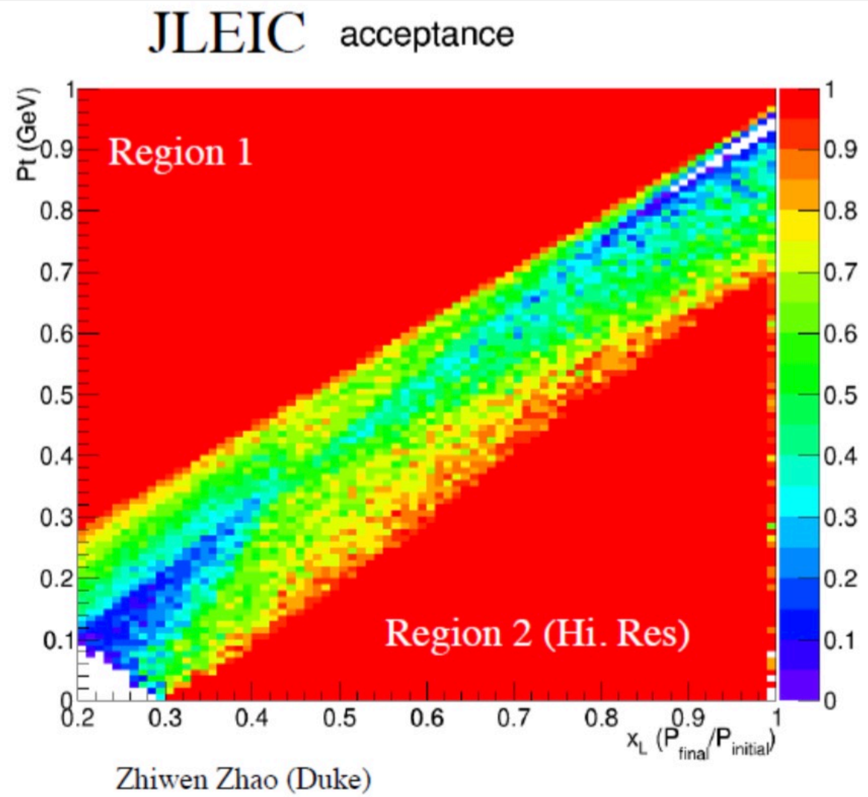
Meson Structure Functions at the EIC

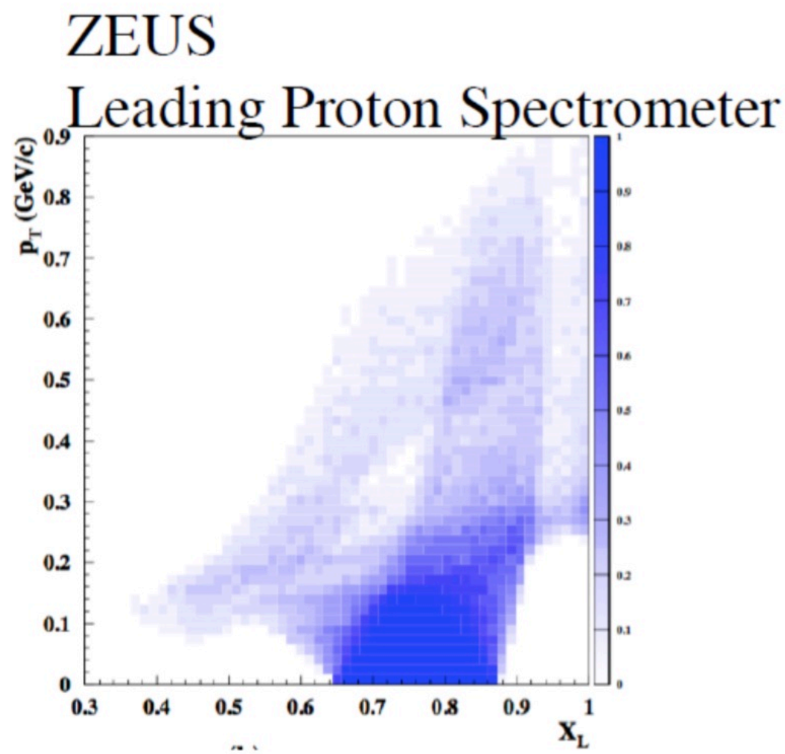
Good Acceptance for TDIS-type Forward Physics!

Low momentum nucleons ***easier*** to measure!



Example: acceptance for p' in e + p → e' + p' + X





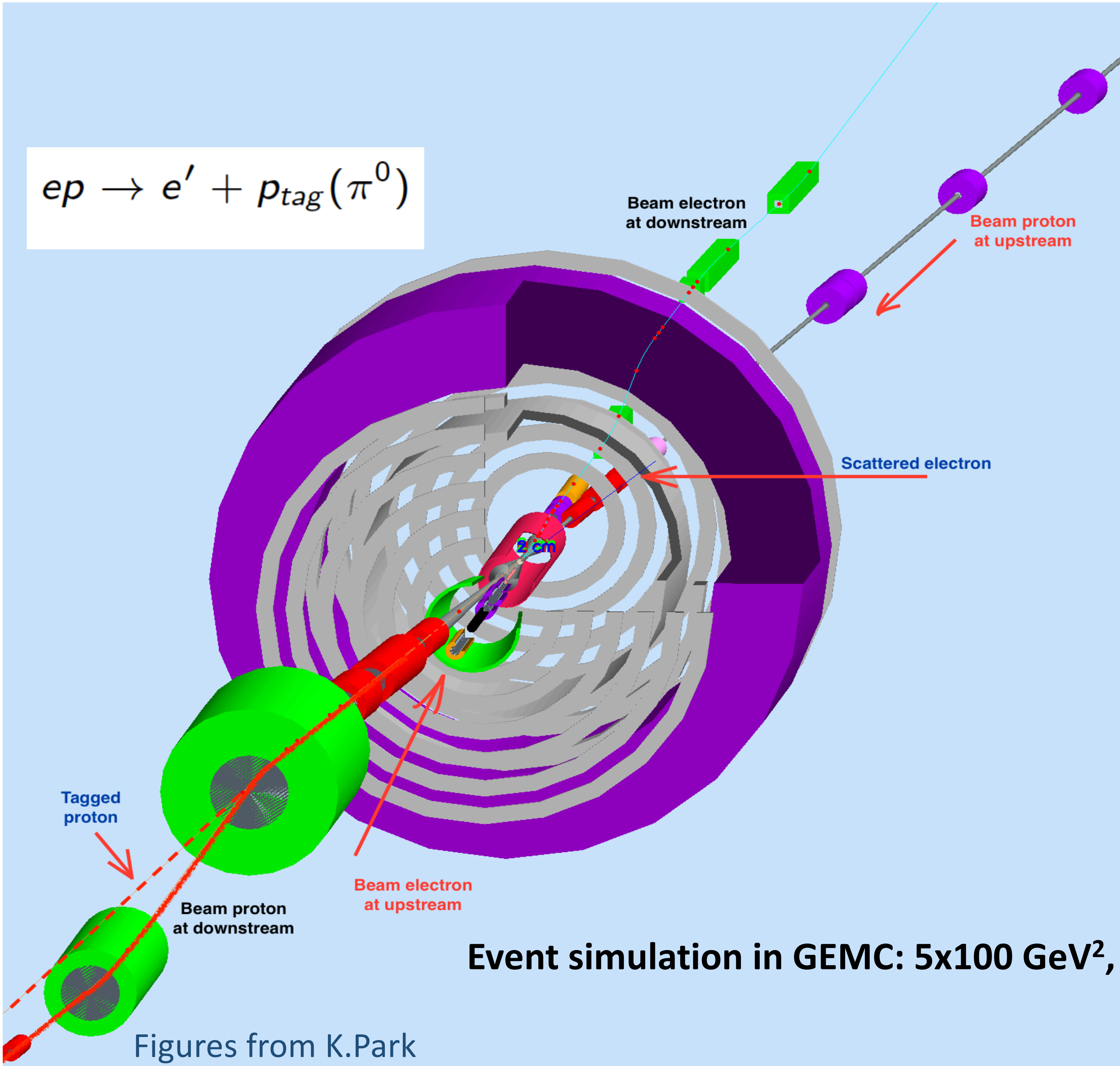
Acceptance in diffractive peak (X_L>~.98)

ZEUS: ~2%

JLEIC: ~100% (also covers much higher X_L than ZEUS)

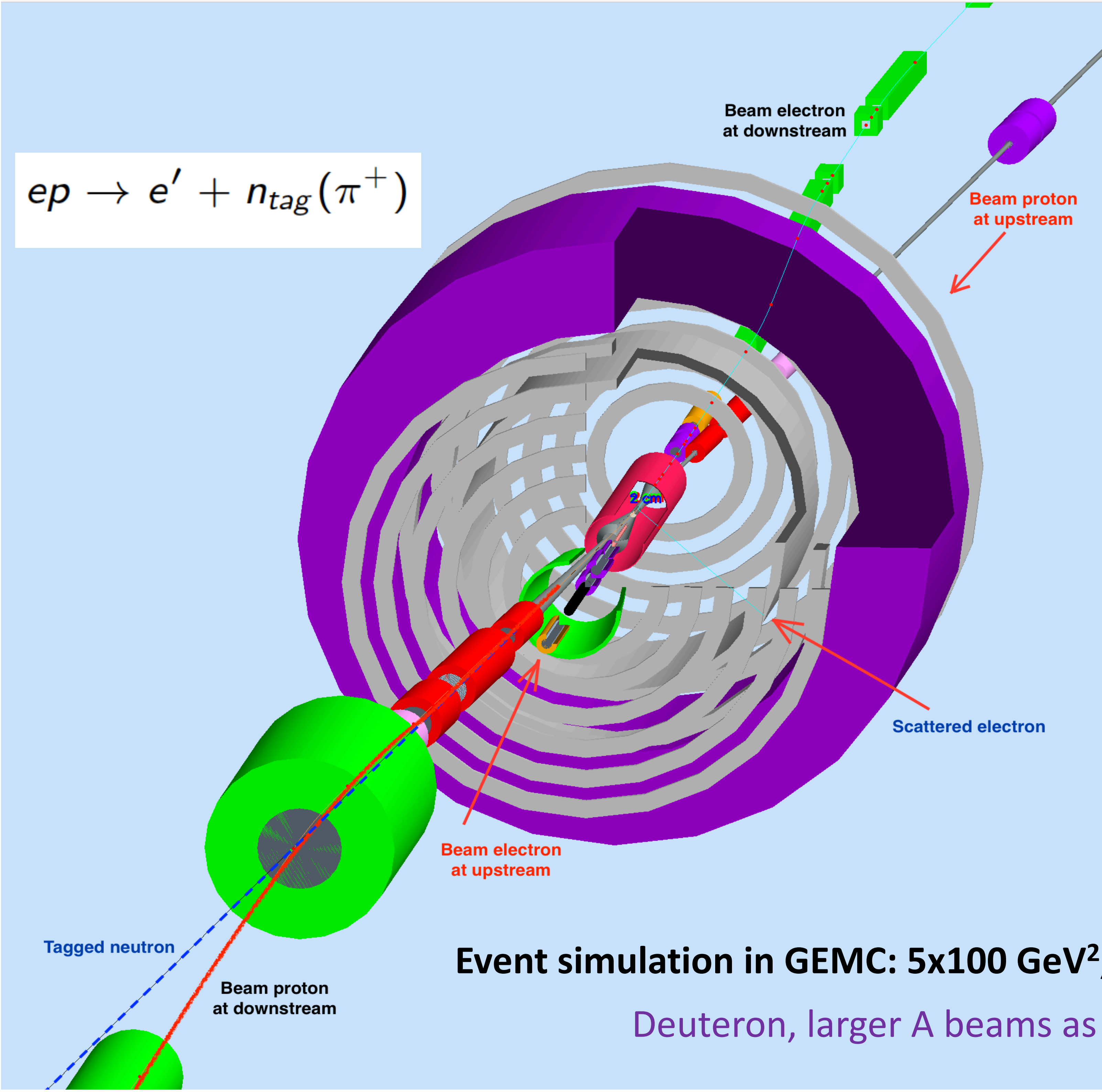
Huge gain in acceptance for forward tagging….

$$ep \rightarrow e' + p_{tag}(\pi^0)$$



Event simulation in GEMC: 5x100 GeV^2, e/p beams

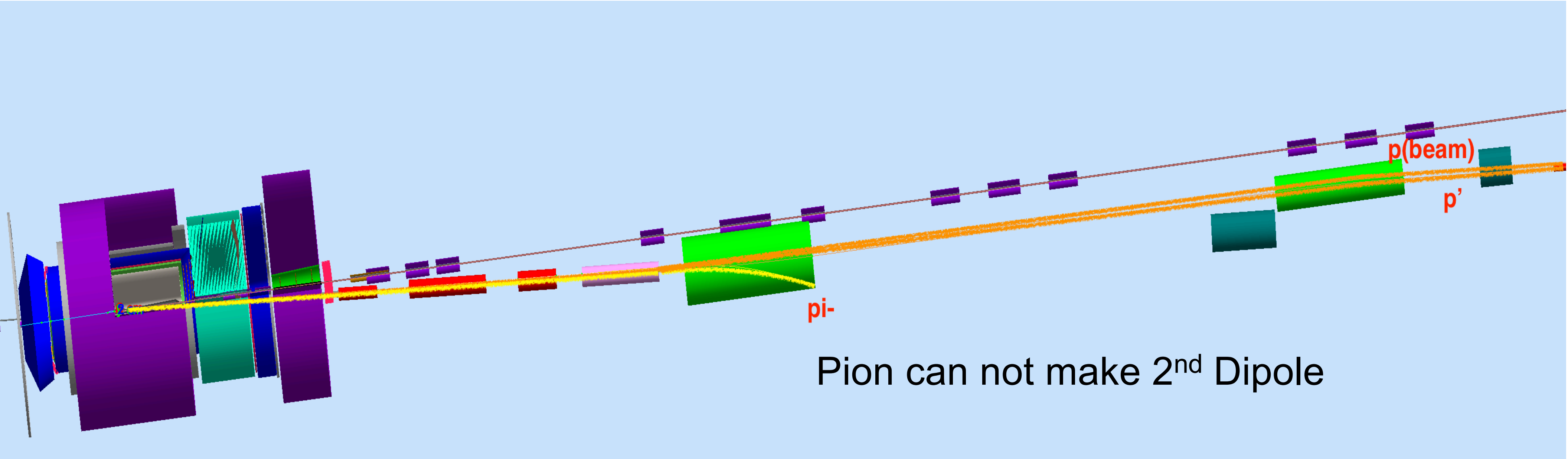
Figures from K.Park



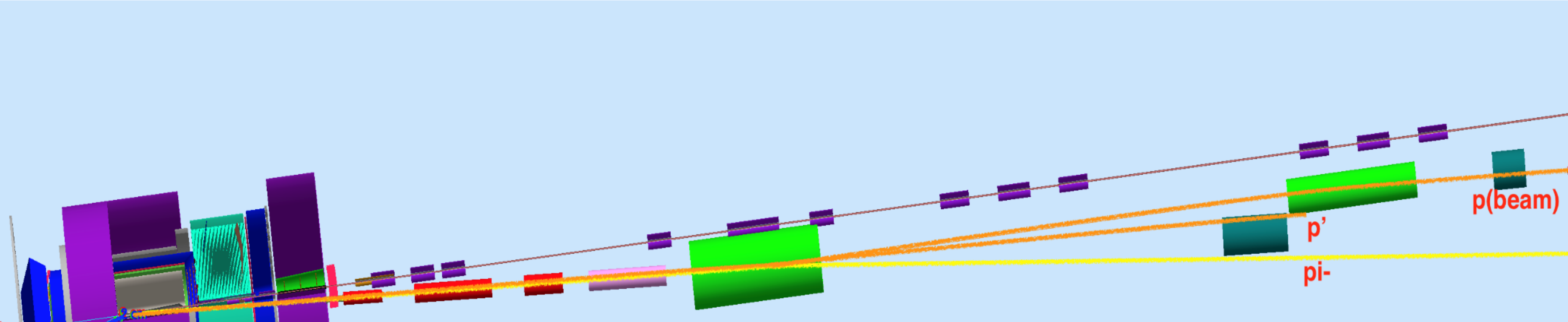
Event simulation in GEMC: 5x100 GeV^2, e/p beams

Deuteron, larger A beams as well

Detection of $^{1}H(e,e'K^{+})\Lambda$, Λ decay to $p + \pi^{-}$



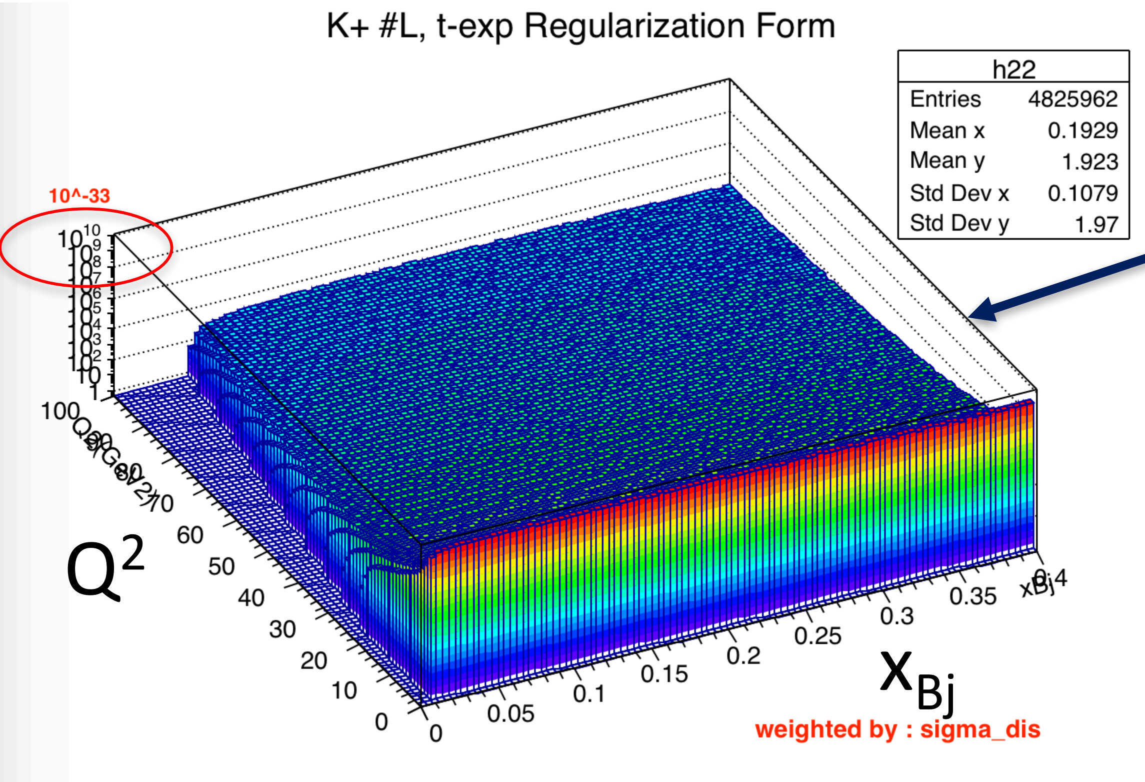
Pion can not make 2nd Dipole



Proton can be detected before 3rd Dipole

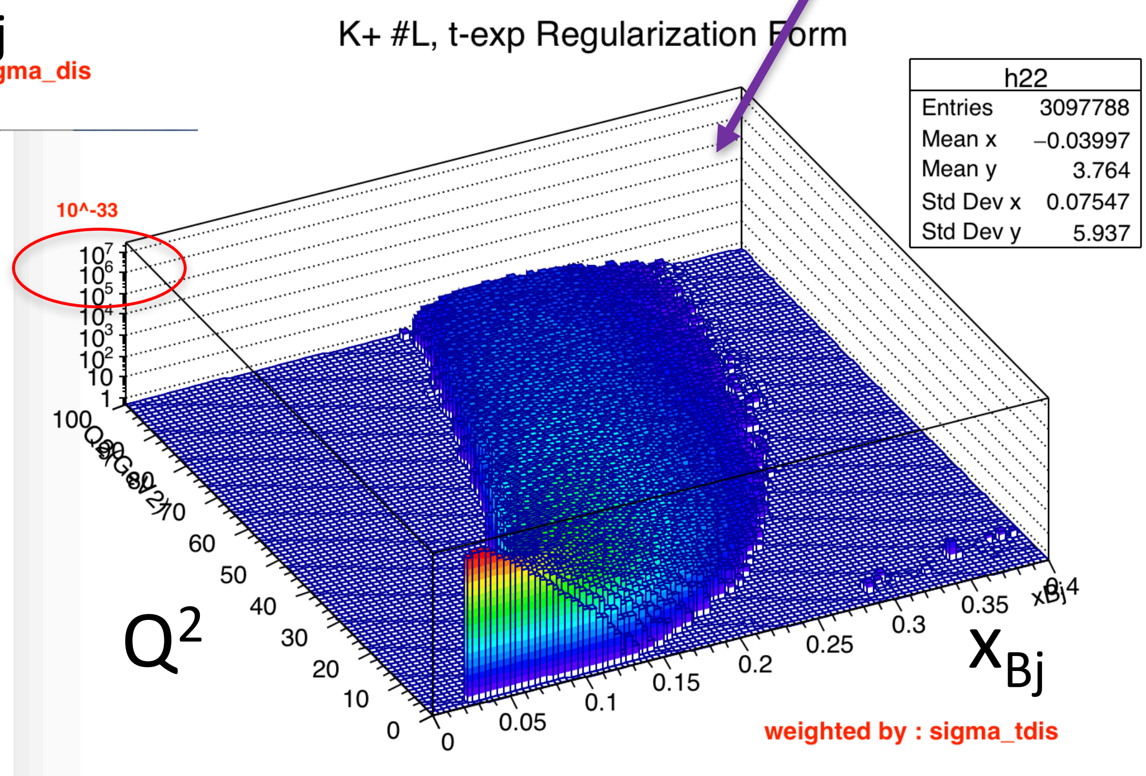
Pion can be detected before 3rd Dipole

Tagged events weighted by cross-section



Monte Carlo events weighted by DIS e-p cross section

Monte Carlo events weighted by tagged DIS e-p cross section
~3 orders of magnitude smaller - ***luminosity critical***



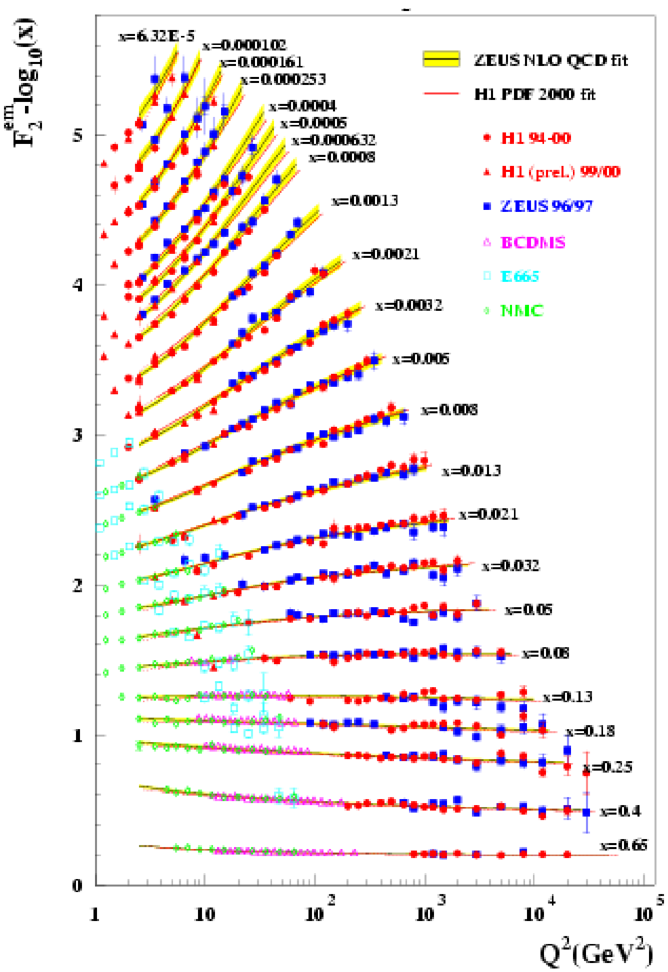
J. R. McKenney, et al., Phys. Rev. D93 (2016), 054011
T. J. Hobbs et al, Few Body Syst. 56 (2015) no.6-9

Landscape for n, π, K Structure Functions after EIC

Proton: large existing data set

EIC will add:

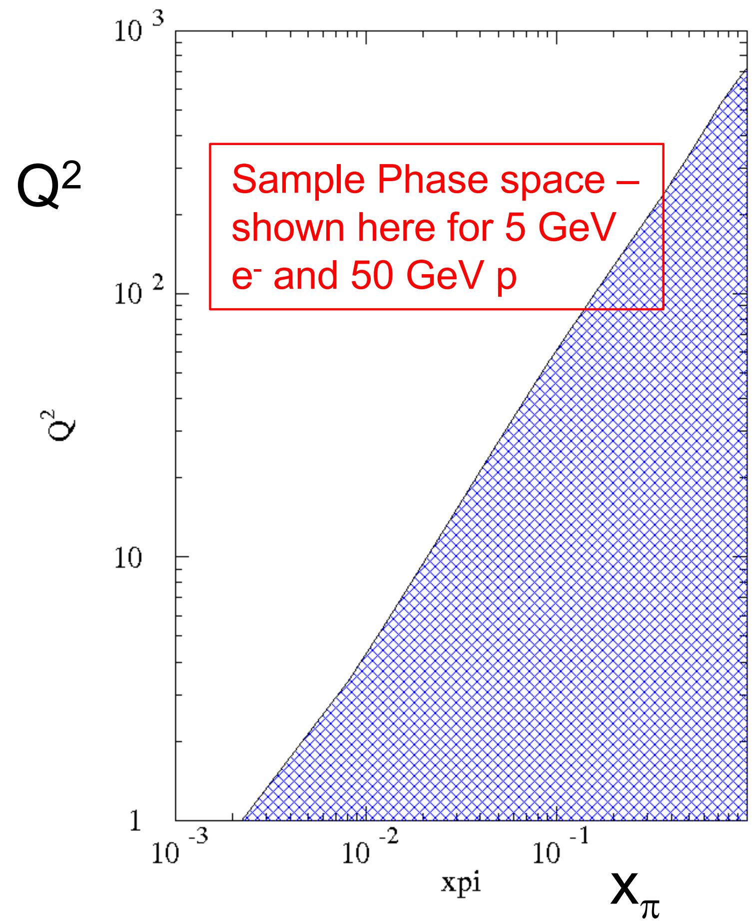
- Better constraints at large-x
- Precise F_2^n neutron SF data



Pion and kaon - limited data from:

- Drell-Yan experiments
- Some pion SF data from HERA

EIC will add large (x,Q^2) landscape for both pion and kaon!



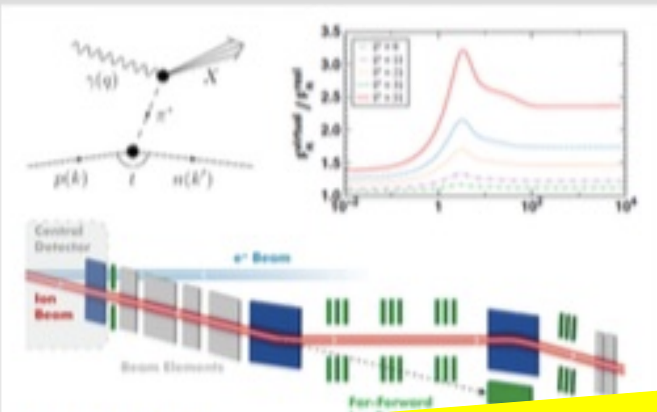
….and some shameless advertisements

Pion and Kaon Structure at an Electron-Ion Collider

1–2 June 2017, Physics Division, Argonne National Laboratory

Argonne NATIONAL LABORATORY

HOME ACCOMMODATION PARTICIPANTS PROGRAM REGISTRATION



Introduction

This workshop at Argonne Nation[al] explore opportunities provided by quark and gluon structure of the p[ion and] kaon.

Invited Speakers:

Navigate

- Home
- Accommodatio[n]
- Participants
- Program
- Pion and Kaon

White paper in the works!! (R. Ent, T. Horn, C.D. Roberts, et al)

Jefferson Lab > Events > PIEIC2018 Privacy and Security Notice

Jefferson Lab EXPLORING THE NATURE OF MATTER

LINKS print version

- Circular
- Registration
- Program
- Transportation
- Lodging
- Participants List

PIEIC2018

Workshop on Pion and Kaon Structure at an Electron - Ion Collider
May 24-25, 2018
The Catholic University of America
Washington, D.C.

Circular

This workshop will explore opportunities provided by the Electron - Ion Collider to study the quark and gluon structure of the pion and kaon. It follows and will stake stock of the progress since the earlier June 1-2, 2017 workshop at Argonne National Lab: http://www.phy.anl.gov/theory/pieic2017

Organizing Committee

Ian Cloet - ANL
Tanja Horn – CUA
Cynthia Keppel – Jlab
Craig Roberts - ANL

Sponsors:

CUA Jefferson Lab JSA

12000 Jefferson Avenue, Newport News, VA 23606
Phone: (757) 269-7100 Fax: (757) 269-7363

contact Stephanie Schatzel
updated April 3, 2018

Workshop on Parton distributions as a bridge from low to high energies

November 8 and 9, 2018
[before the Fall CTEQ meeting]
Jefferson Laboratory, Newport News, VA

- **Multi-dimensional PDFs (TMDs and GPDs)**
- **Collinear parton distributions at JLab 12, EIC, and LHeC**
- **QCD and Nuclear PDFs in electron-nucleus and neutrino-nucleus scattering**

Jefferson Lab
Thomas Jefferson National Accelerator Facility

C T E Q

Consider yourself invited!

- TDIS provides unique access to effective neutron, pion, kaon.. targets
  - Nucleons and mesons are the basic building blocks of matter.
  - *Critical, fundamental hadron structure measurements!*
- TDIS can directly probe the meson cloud of the nucleon
  - Direct measurement of nucleon-meson fluctuation component of DIS
  - Access pion and kaon structure functions
- ***Very*** few experiments to date
  - Neutron at JLab BONUS, pion at HERA
  - Neutron and pion, also kaon, at JLab12
  - *EIC will open up a new TDIS era*

TDIS can also provide a new, precision window on the EMC effect
Also neutron DVCS,….

Thanks