Study of Meson Structure at EICC

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Sullivan Process

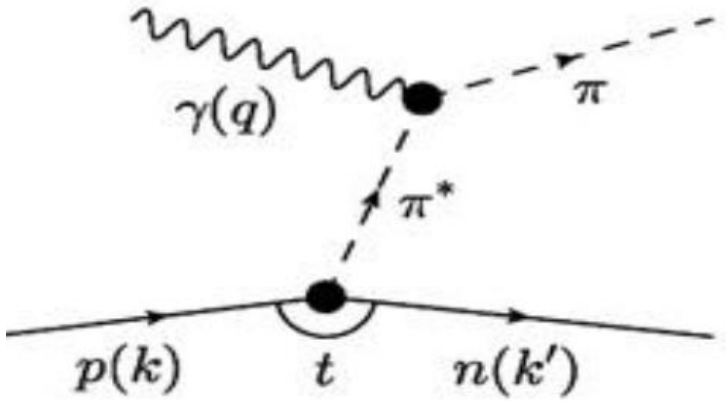
Definition: the electron DIS off the meson cloud of a nucleon target is called Sullivan process.

$q = e - e`$

$\pi^* = k - k`$

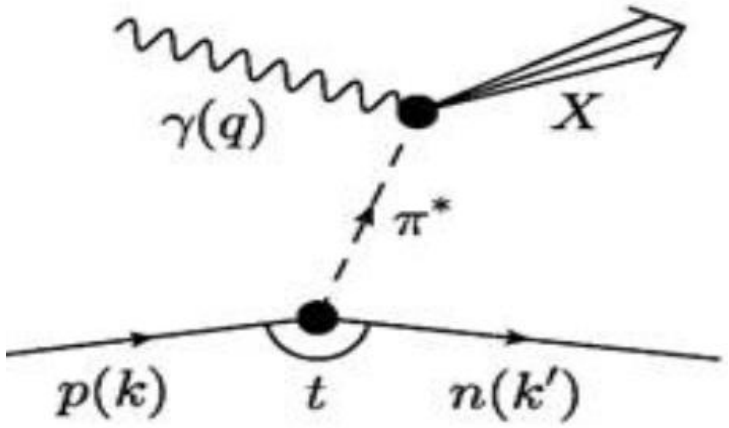
$t = (k - k`)^2$

$x_L = k \cdot q \,/\, k` \cdot q$



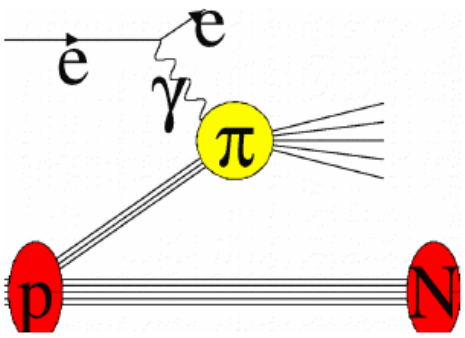
The Sullivan process can provide reliable access to a meson target if -t is small (-t<0.6|0.9 GeV^2 for pion|kaon).

To ensure a quasi-free pion target, we choose a cut of $x_L > 0.9$.

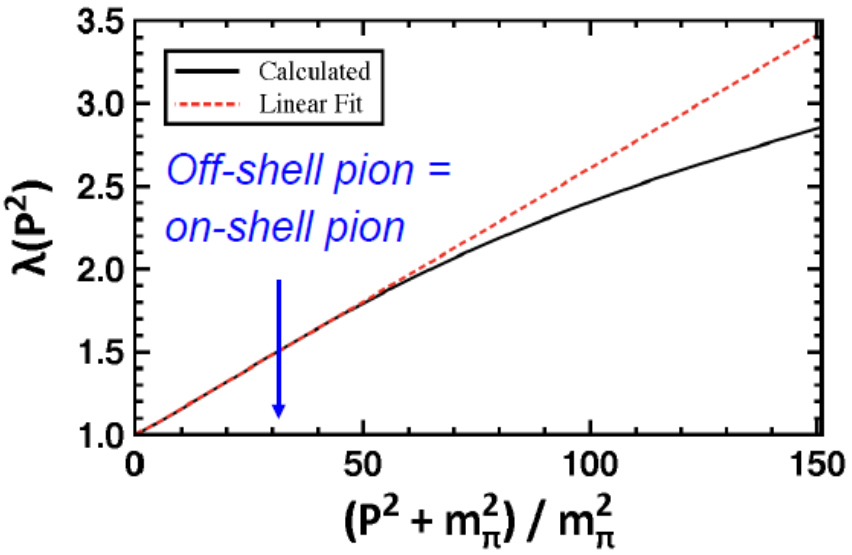


Experimental consideration: Off-shellness effects

S-X Qin, C.Chen, C. Mezrag, C.D. Roberts, arXiv:1702.06100 (2017)



In the Sullivan process, the mesons in the nucleon cloud are virtual (off-shell) particles



- Recent calculations estimate the effect in the BSE/DSE framework – as long as $\lambda(\nu)$ is linear in ν the meson pole dominates
  - Within the linearity domain, alterations of the meson internal structure can be analyzed through the amplitude ratio
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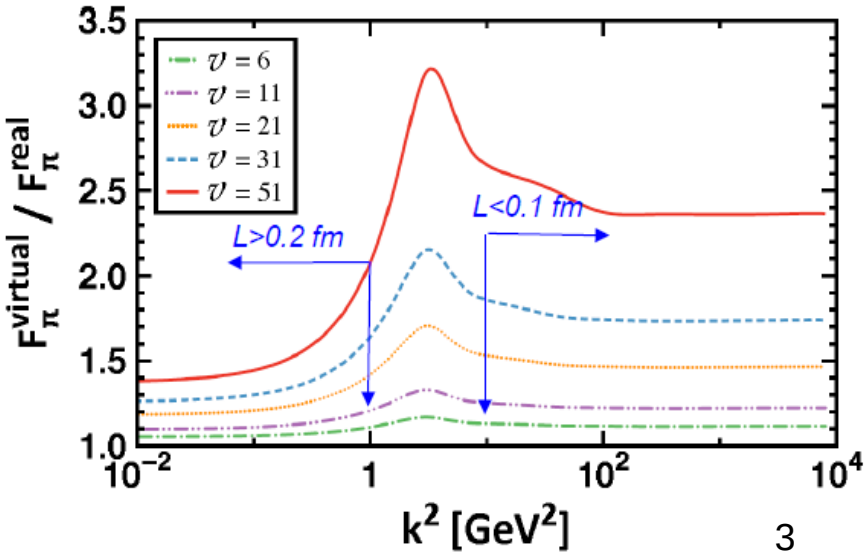
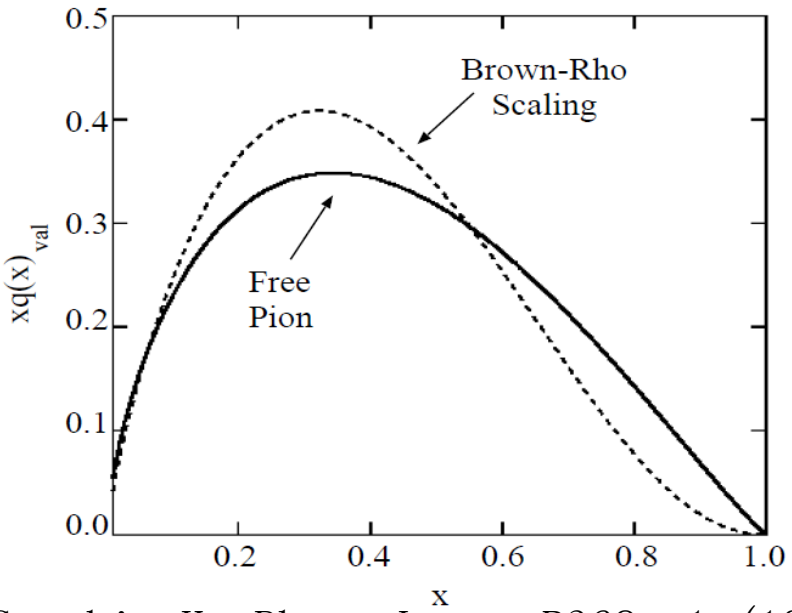


This means that pion and kaon structure functions can be accessed through the Sullivan process

Pion Structure Function in the Nuclear Medium



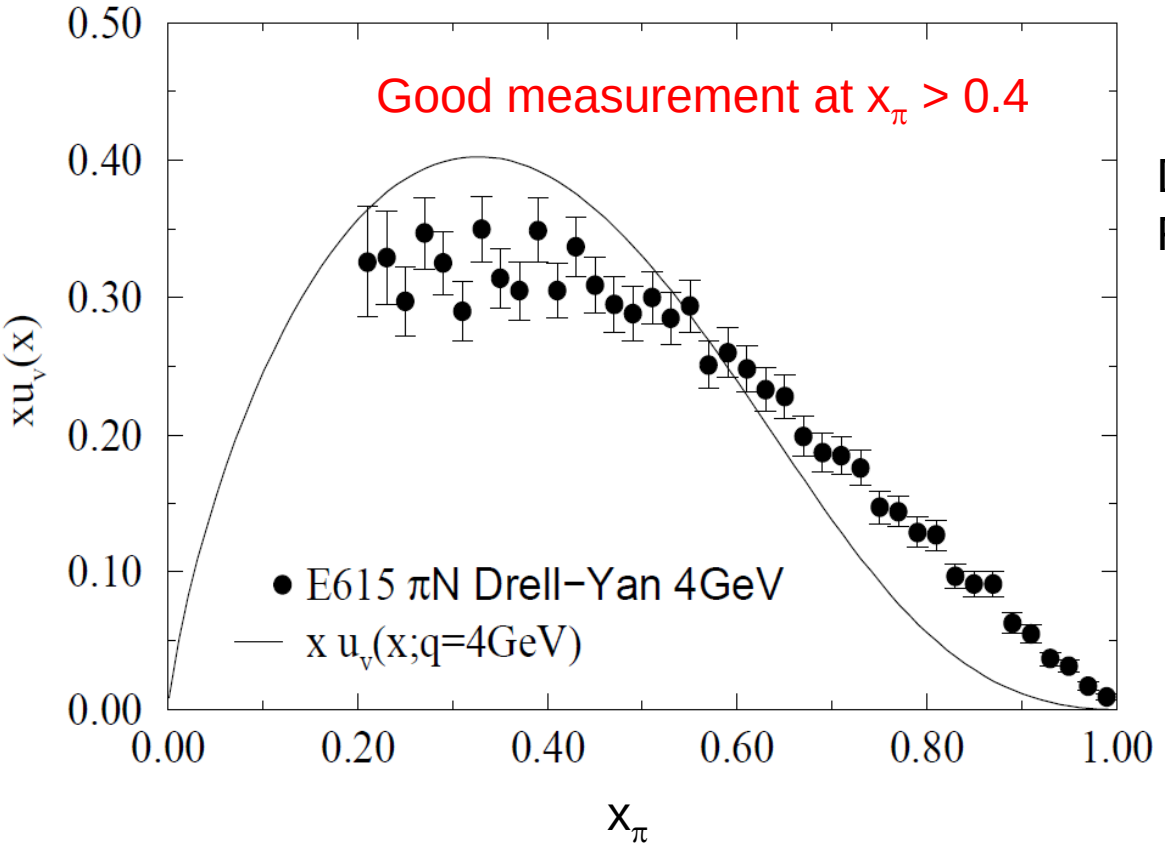
Suzuki, K. Phys. Lett. B368, 1 (1996).

Solid curve: the Nambu Jona-Lasinio (NJL) model in nuclear matter
Dashed curve: the effect of Brown-Rho scaling in nuclear matter

The nuclear binding correction can be done using data.

Off-shellness correction also need to be determined (by binning t up to the on-shell|off-shell limits.

Existing Pion Structure Function Data

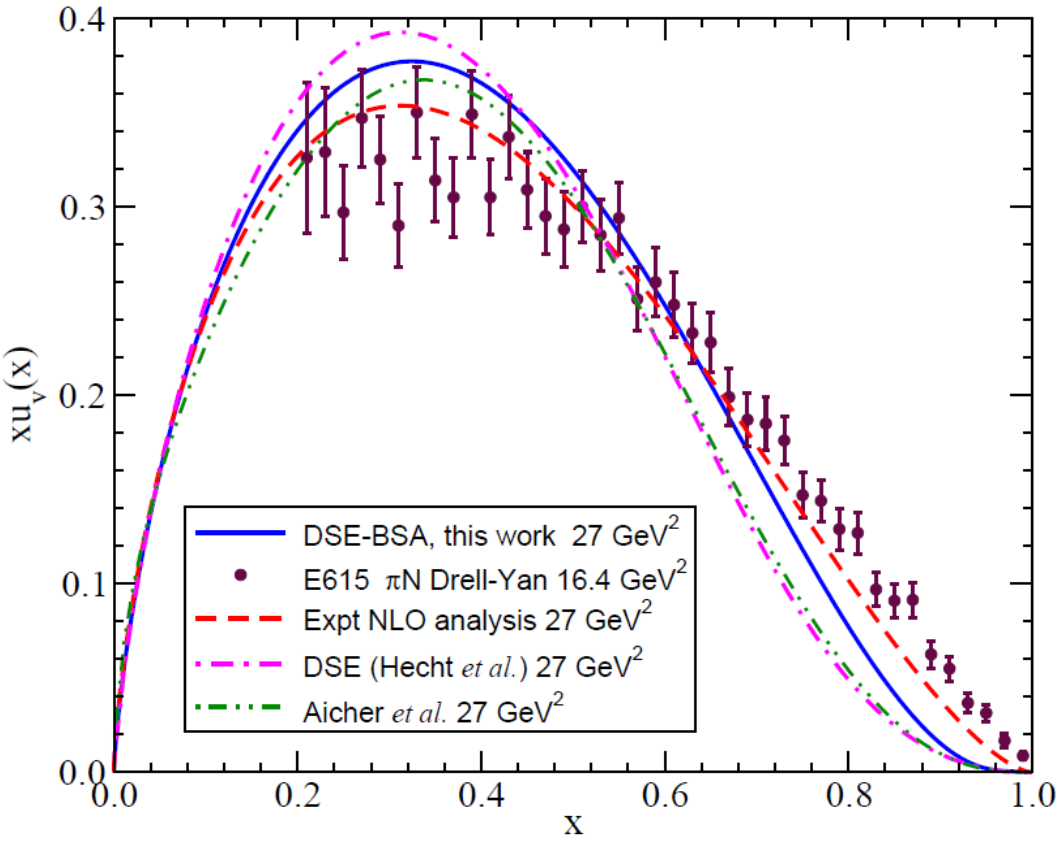


Drell-Yan,
FNAL E615

J. S. Conway et al. PRD 39,92 (1989).

Dyson-Schwinger Model: M. B. Hecht, C. D. Roberts, S. M. Schmidt, nucl-th/0008049 (2000).

Existing Pion Structure Function Data

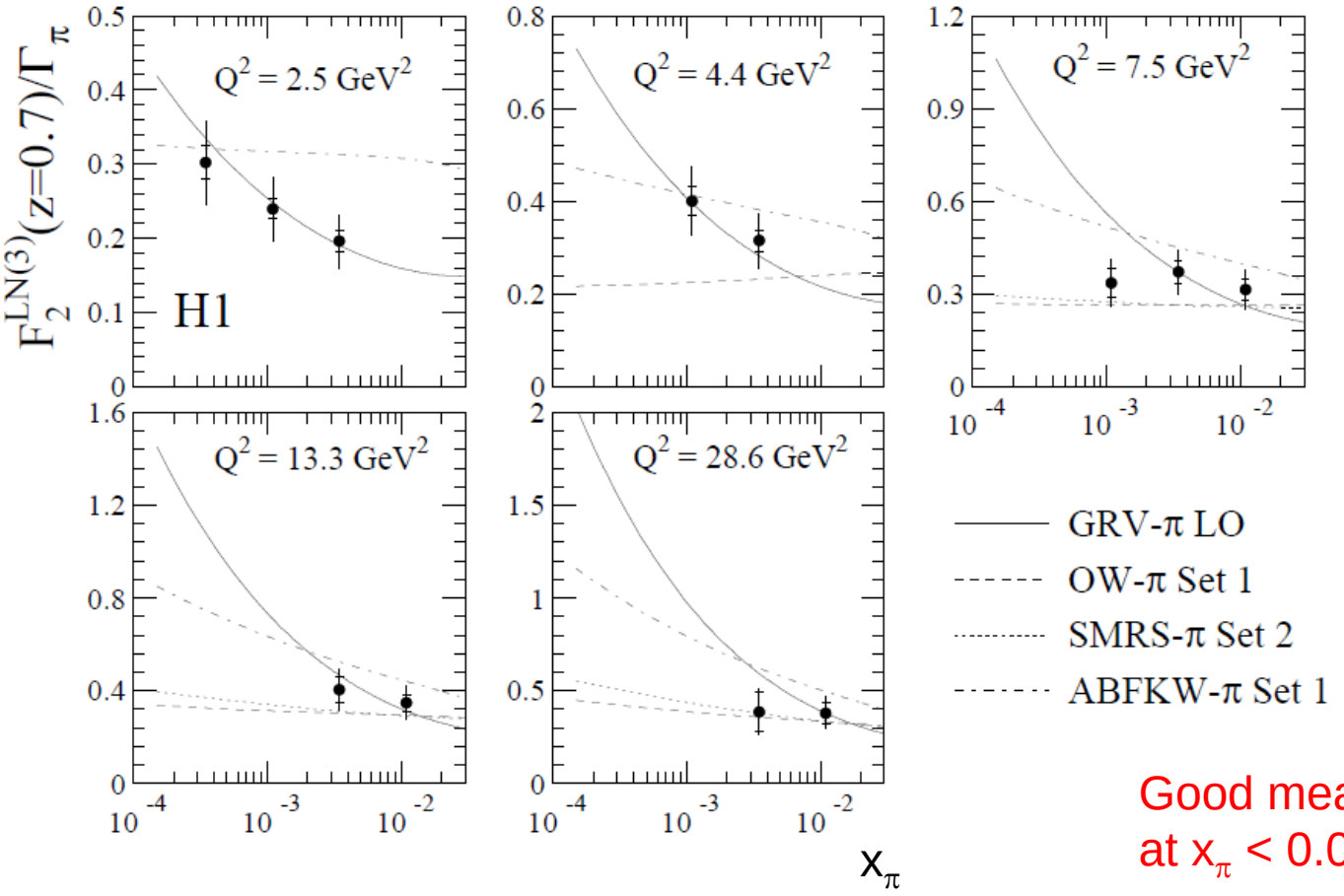


Drell-Yan,
FNAL E615

C. D. Roberts, arXiv:1203.5341v1 [nucl-th]

Good measurement at $x_\pi > 0.4$

Existing Pion Structure Function Data From H1



HERA

Good measurement at $x_\pi < 0.02$

Figure 9: $F_2^{LN(3)}/\Gamma_\pi$ at $z = 0.7$ plotted as a function of β for fixed values of Q^2. The quantity Γ_π is the p_T integrated pion flux factor. Within the framework of the Regge model, $F_2^{LN(3)}/\Gamma_\pi$ can be interpreted as being equal to the pion structure function F_2^π. The data are compared to different parametrizations of F_2^π which are only shown in the Q^2 regions in which they are valid.

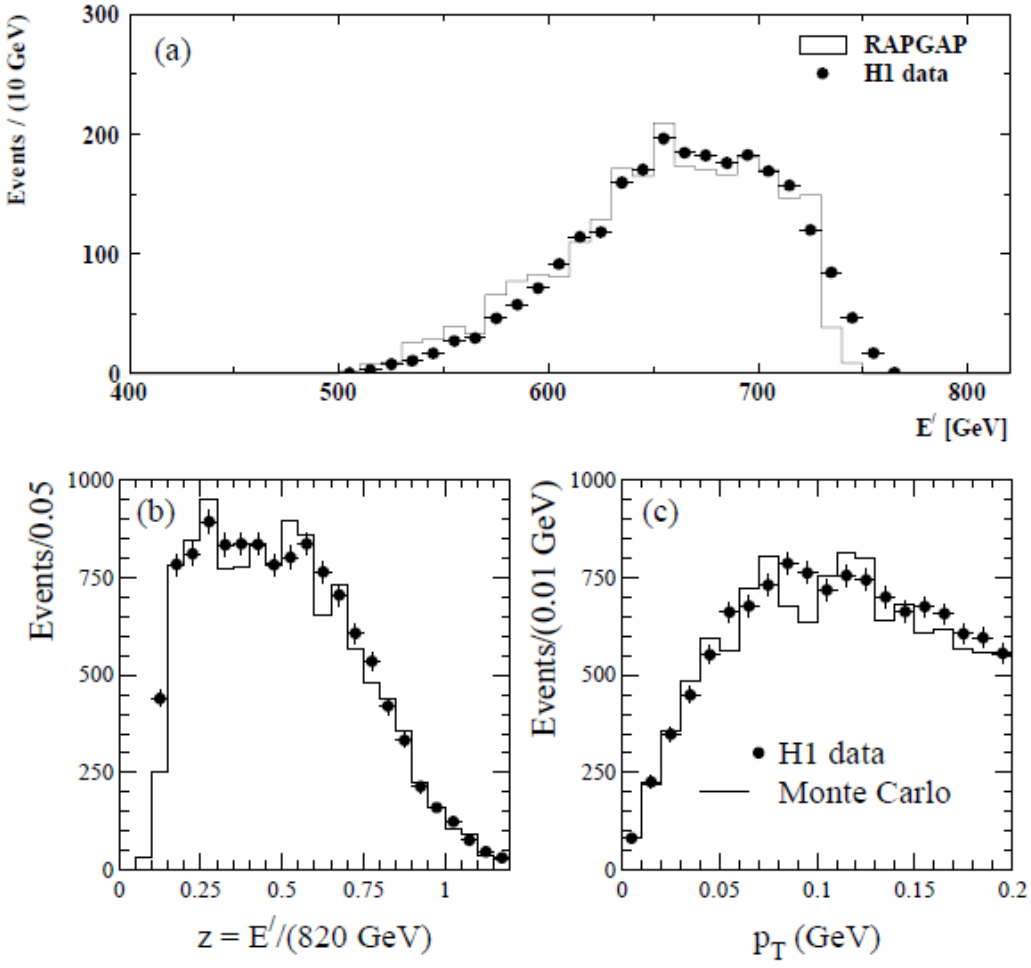
C. Adloff et al. (H1 Collaboration), Eur. Phys. J. C 6, 587 (1999).

RAPGAP Simulation

RAPGAP v3.2, hard-coded **pion structure** functions from LEPTO and PYTHIA v6.4, including LUND string fragmentation model. Radiation process included. It calls several other packages, for example, BASE5.1, LHAPDF, SOPHIA…etc.

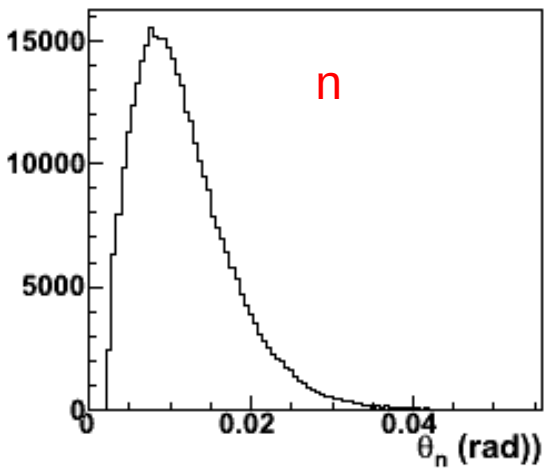
It was tuned to simulate H1 experiment. It agrees with H1 experiment data pretty well.

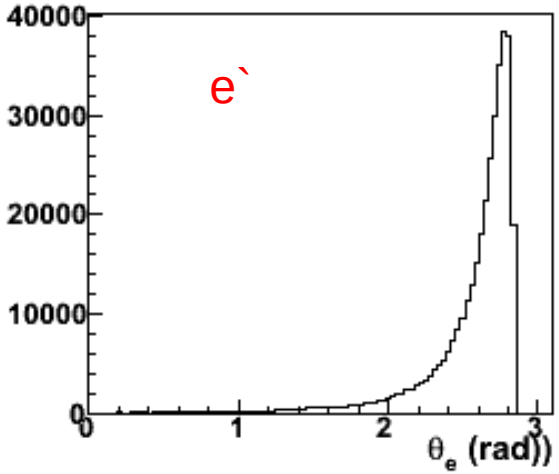
I use it to simulate DIS ep scattering with charged pion exchange.

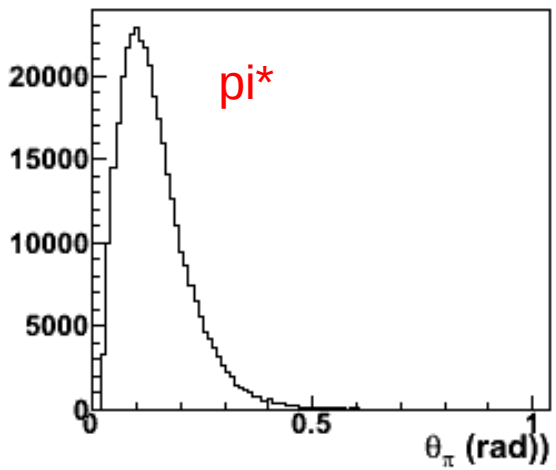


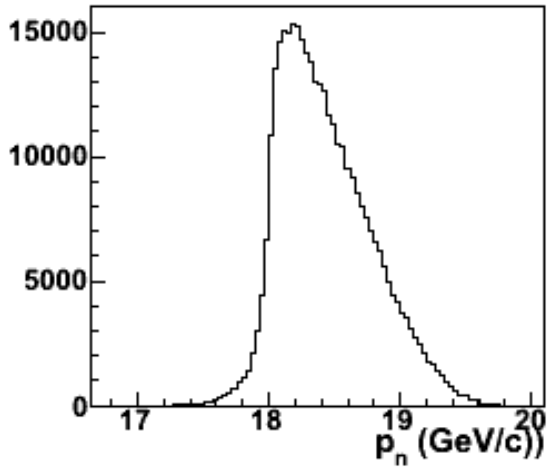
Eur. Phys. J. C 6, 587 (1999).

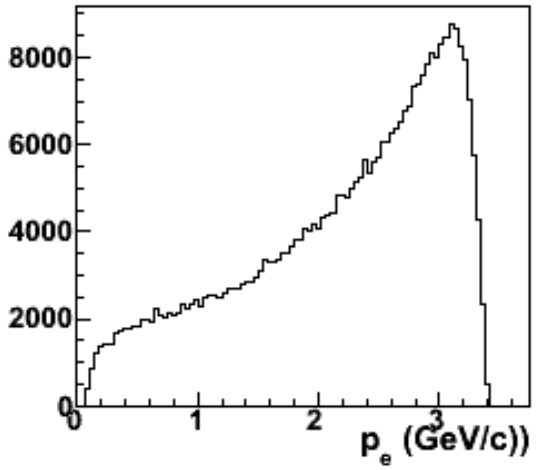
Kinematics Coverage

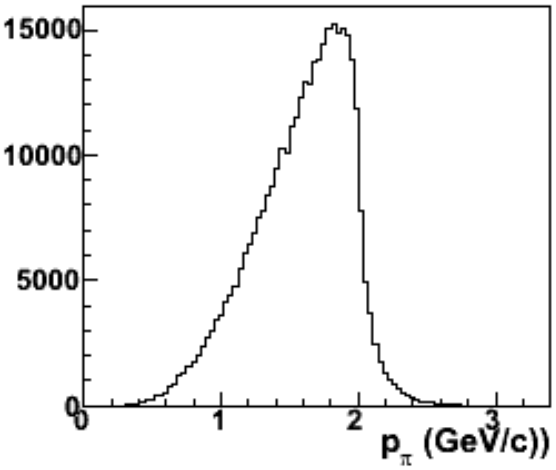








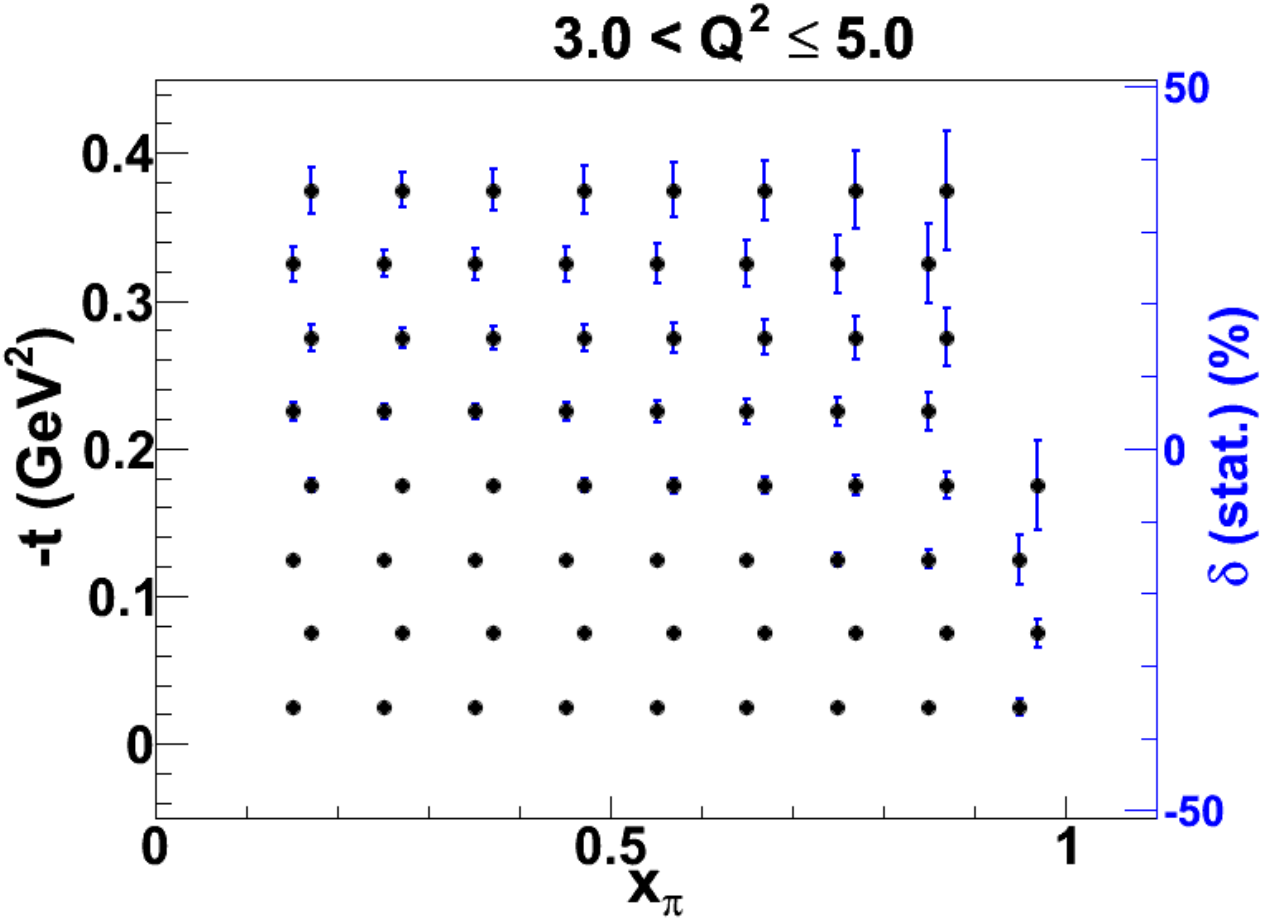




3.5(e-) x 20 (p), Lumi=1.0 fb^{-1}

Cuts: $x_L > 0.9$ and $Q^2 > 1.0$, NO detector acceptance or efficiency cut yet

Projected Result

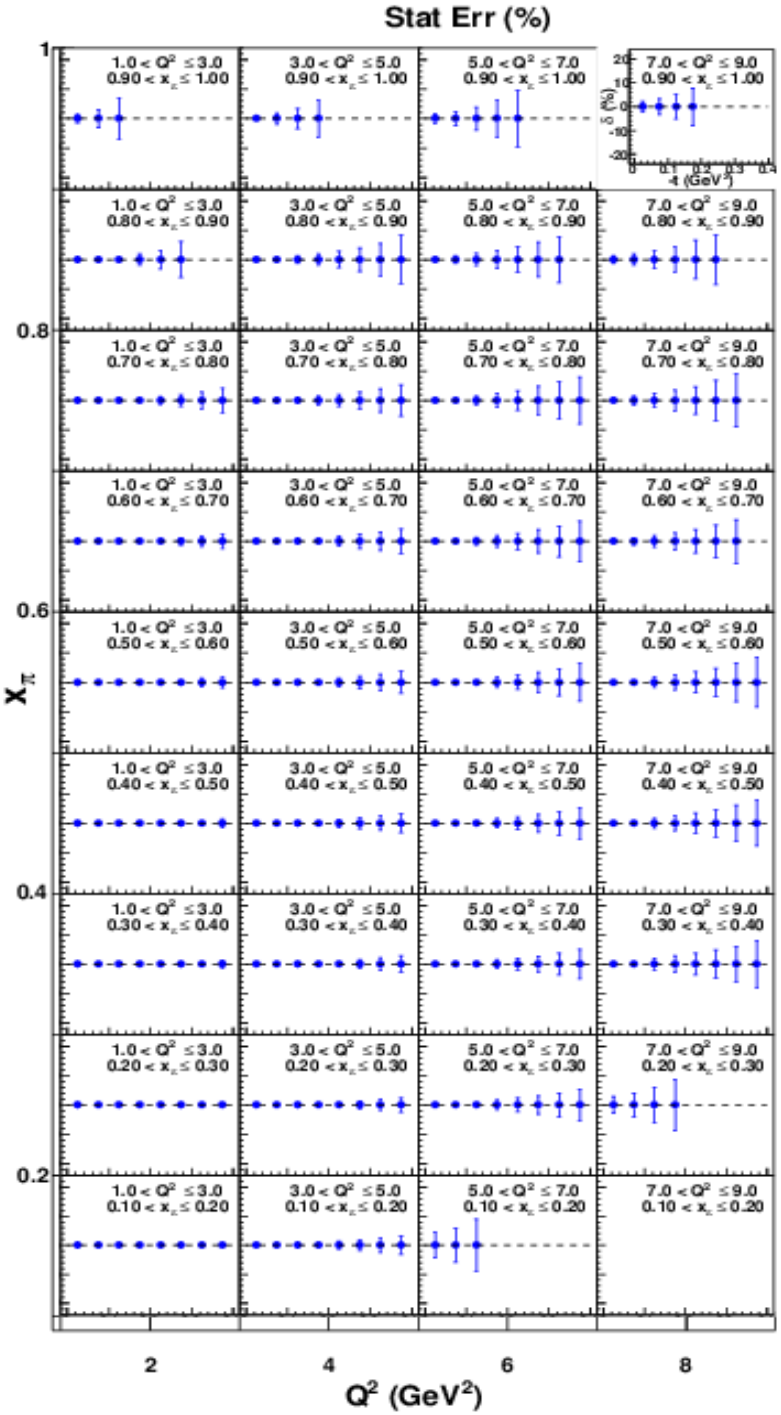


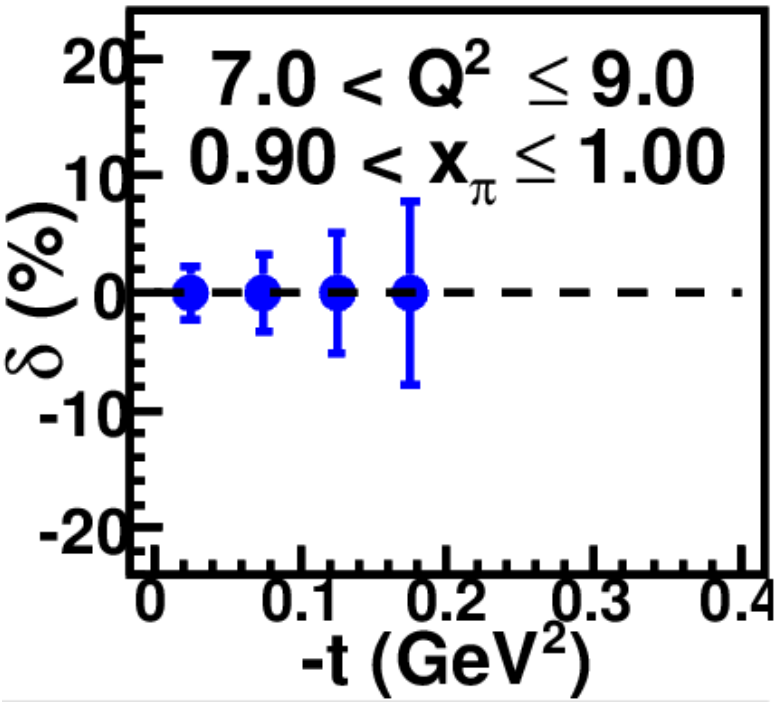
3.5(e-) x 20 (p), Lumi=50fb^{-1}

Cuts: $x_L > 0.9$

NO detector acceptance or efficiency cut

Projected Stat Err





3.5(e-) x 20 (p), Lumi=50fb^{-1}

Cuts: $x_L > 0.9$

NO detector acceptance or efficiency cut

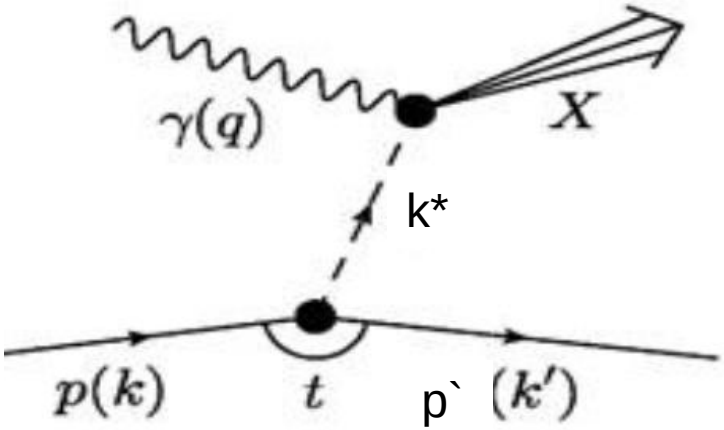
Kaon Structure Function

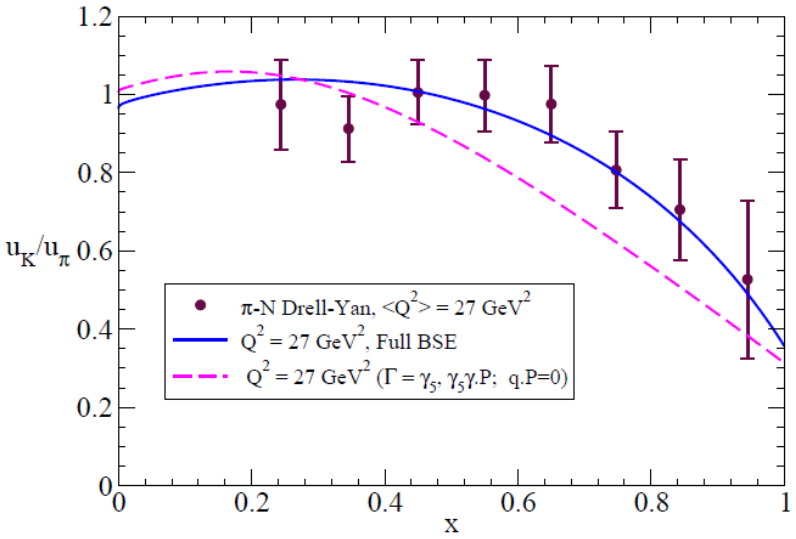
The K+ structure function can be measured by considering DIS off the kaon+ cloud surrounding a lambda core.

DIS from the K+ cloud should be comparable to that for the π+ since the KNΛ coupling constant is comparable to that of the πNN vertex.

The difficulty with this process is in the detection of the Λ. The Λ decays predominantly (63.9%) to $p\pi^-$, or to $n\pi^0$ (35.8%). For $p\pi^-$ production, a special forward proton detector and a forward pion detector would be needed. ($n\pi^0$ will be even harder to detect)

Sim. status: still in progress



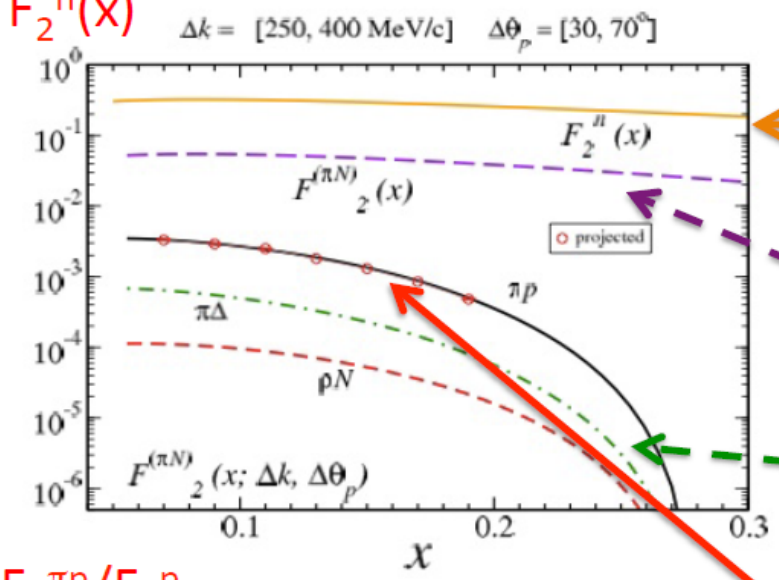


Bethe-Salpeter models: full (solid) and reduced (dash). C. D. Roberts, arXiv:1203.5341

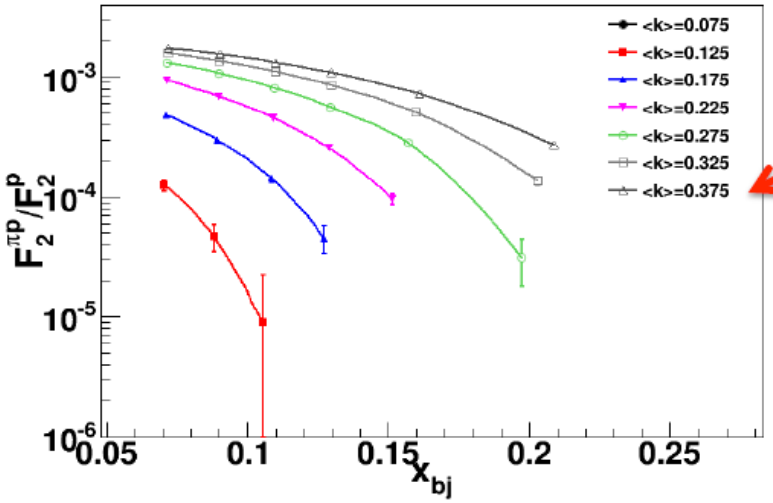
Jlab TDIS Experiment Projected Result, Neutron

Projected Results I - neutron

$F_2^n(x)$



$F_2^{\pi p}/F_2^p$



$F_2^n(x)$ is inclusive DIS – neutron target tagged by low momentum, backward angle p

$F_2^{(\pi N)}(x)$ is total *pion* contribution to structure function

Colored lines are expected *total* Delta and rho contribution for $250 < p_{proton} < 400$ MeV/c

Data for pion contribution are a subset to show uncertainty

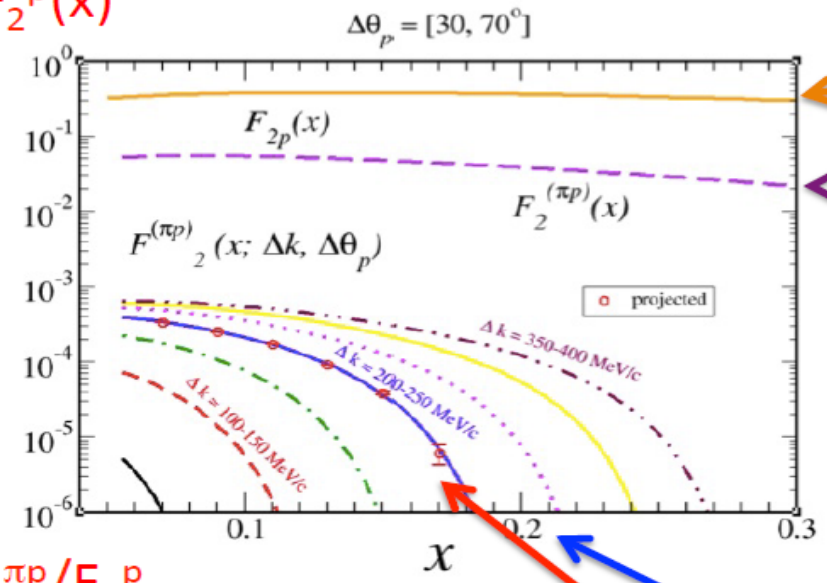
Full data set shown here

- Assuming $F^T \sim F_2^{(\pi p)}(x) / F_2^p(x)$
- Statistical uncertainty only
- Error bars largest at highest x (lowest t) points
- 6.5 % systematic uncertainty not shown

Jlab TDIS Experiment Projected Result, Proton

Projected Results II - proton

$F_2^p(x)$



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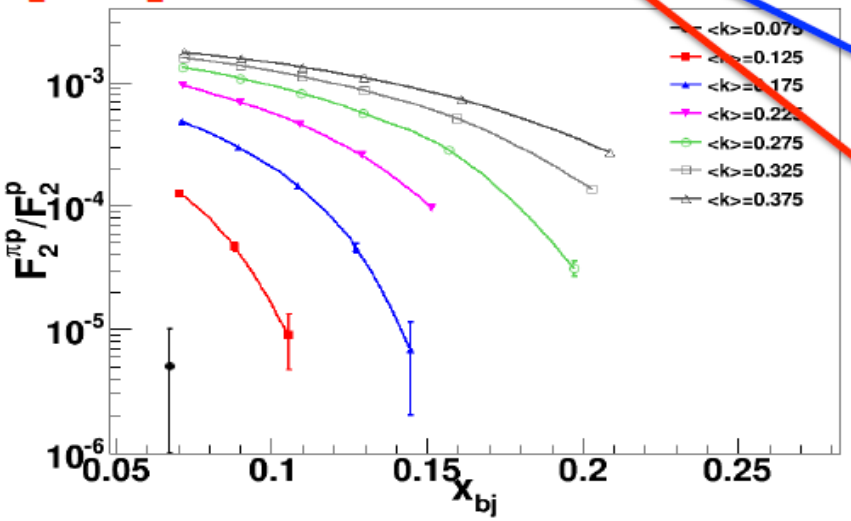

$F_2^p(x)$ is well-known inclusive DIS

$F_2^{(\pi p)}(x)$ is total pion contribution to structure function. ***Note:***

- HERA p tag understood in terms of Pomeron, Reggeon, isoscalar, isosinglet
- Will ratio of n/p tag reflect same physics at JLab kinematics?
- How to evolve HERA diffractive to JLab kinematics unknown
- *Unique* role for this experiment!

Colored lines are pion contribution for different bins in p_{proton}

Data for $200 < p_{proton} < 250$ MeV/c are representative to show uncertainty

Full data set shown here

- Assuming $F^T \sim F_2^{(\pi p)}(x) / F_2^p(x)$

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Summary and Outlook

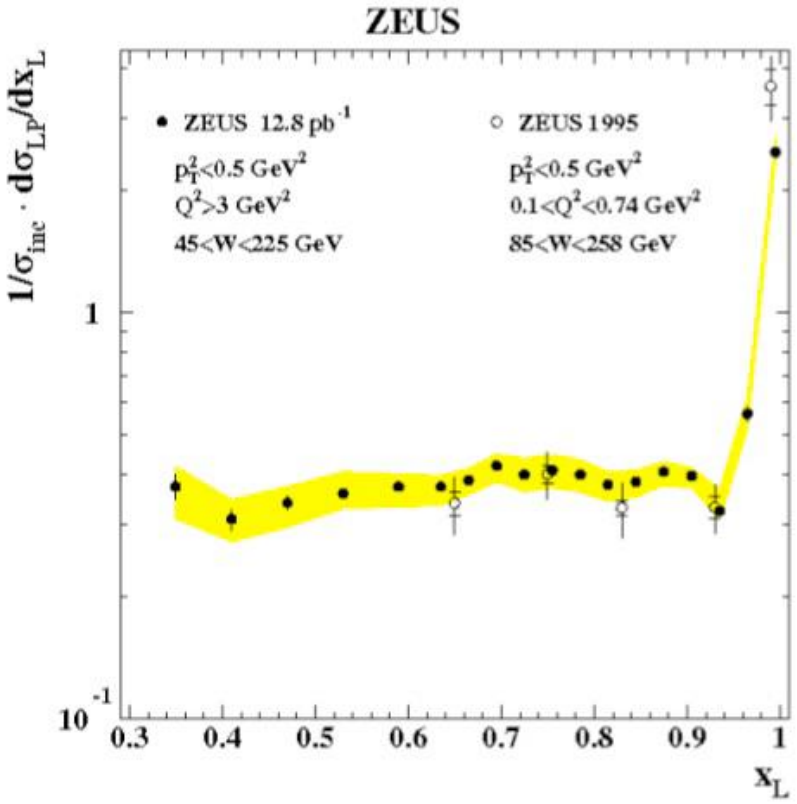
- Simulation has been perform using RAPGAP for eq->e`q` DIS process with charged pion exchange.
- Both pion and kaon structure function measurement are doable at EICC.
- EICC can provide very precise measurement for pion structure function at $0.02 < x_p < 0.4$, which other facility can not.
- Kaon structure function simulation is still in progress. Rapgap is not able to perform this simulation. Need to work out our own packages.

- Pion form factor measurement is also doable at EICC.

Back up

HERA: Tag Leading Baryon Production: ep → eXN

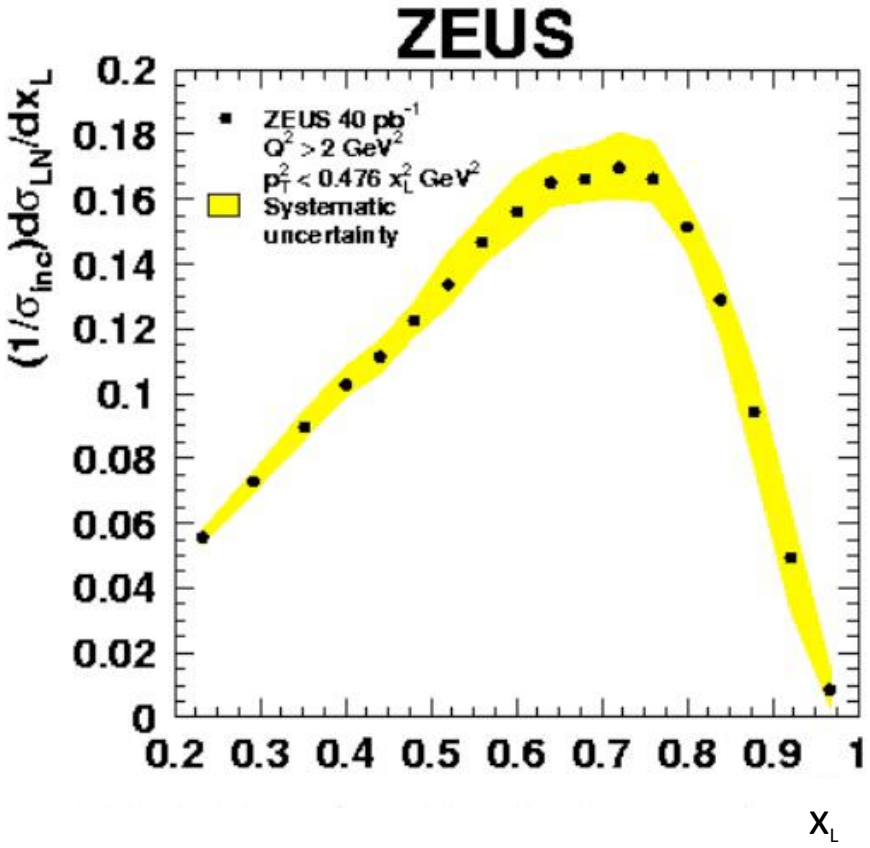
$x_L = |P(k`)| / |P(k)|$



Tagged forward proton

Dramatic increase as $x_L \rightarrow 1$

- Diffractive peak, large rapidity gap



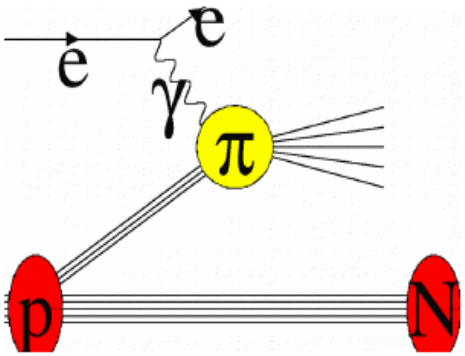
Tagged forward neutron

Yield → 0 as as $x_L \rightarrow 1$

- *Isovector* contributions → 0 as limit $x_L \rightarrow 1$

Meson Structure Function at EICC

S-X Qin, C.Chen, C. Mezrag, C.D. Roberts, arXiv:1702.06100 (2017)



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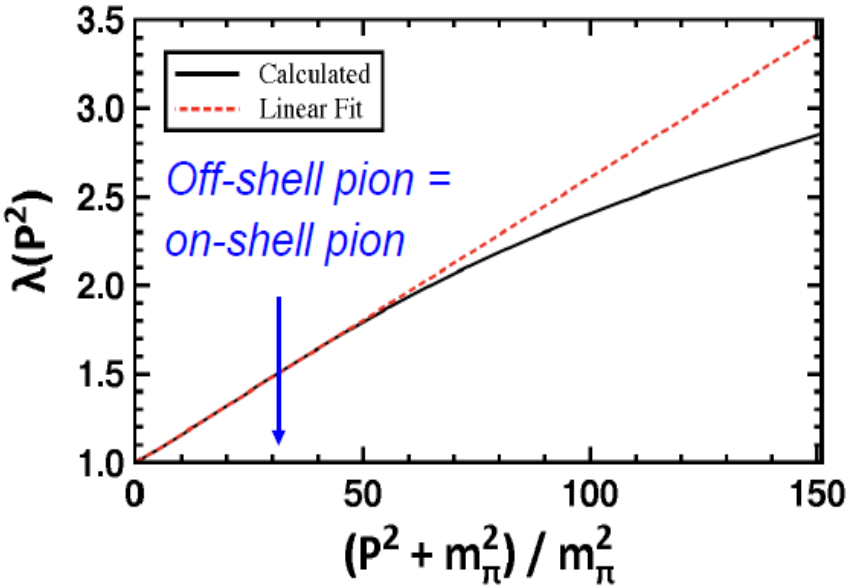

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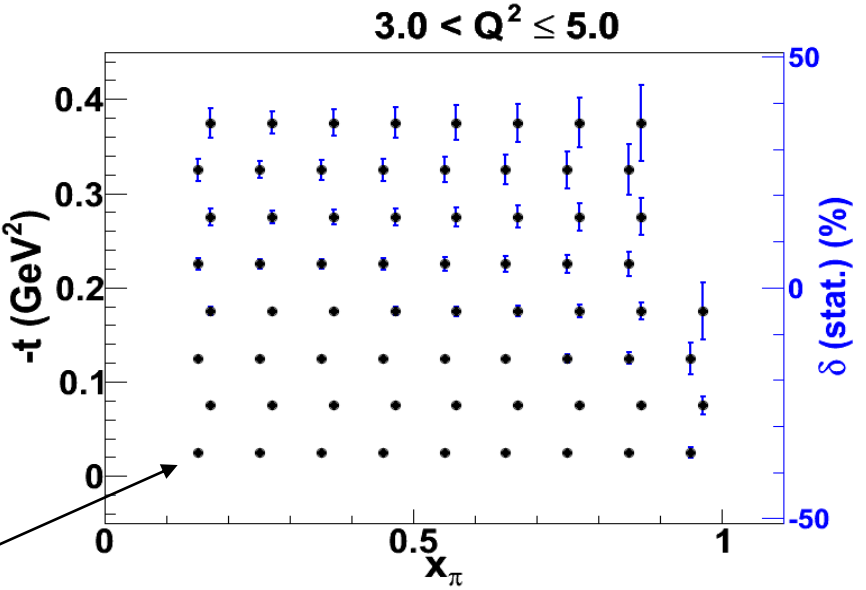

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3.5(e−) x 20 (p), Lumi=50 fb^{-1} , X_L > 0.9