TDIS meson production – a theory perspective

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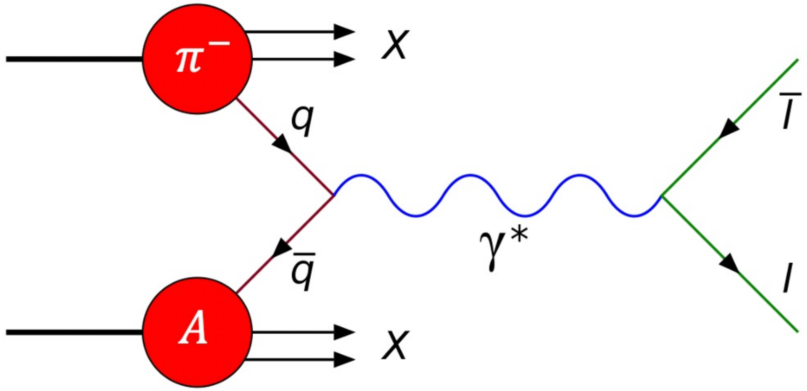
Science at Mid x, July 23rd, 2022

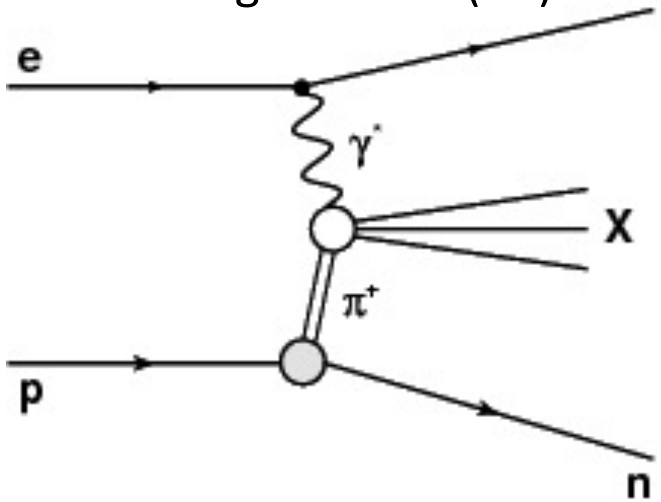
In collaboration with Chueng-Ryong Ji, Wally Melnitchouk, and Nobuo Sato

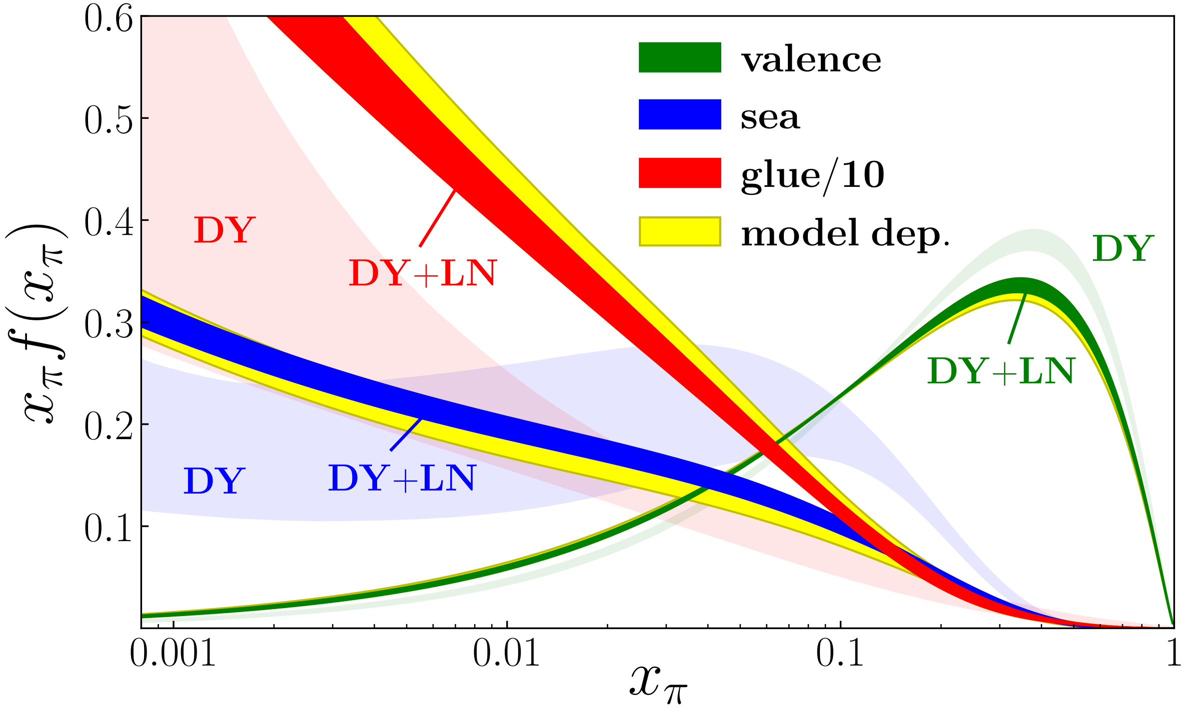
Pion PDFs in JAM

Drell-Yan (DY)



Leading Neutron (LN)





PHYSICAL REVIEW LETTERS **121,** 152001 (2018)

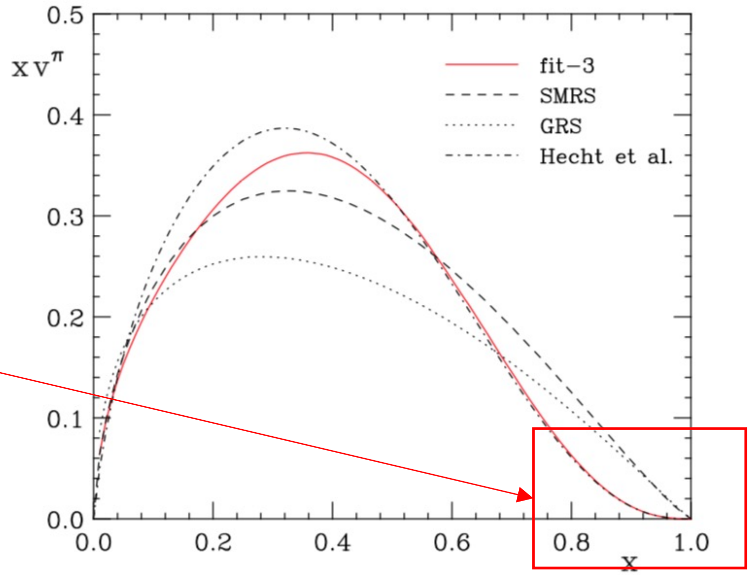
Featured in Physics

First Monte Carlo Global QCD Analysis of Pion Parton Distributions

P. C. Barry,[1] N. Sato,[2] W. Melnitchouk,[3] and Chueng-Ryong Ji[1]

Large-x_π behavior

- Generally, the parametrization lends a behavior as $x \to 1$ of the valence quark PDF of $q_v(x) \propto (1-x)^\beta$
- For a fixed order analysis, analyses find $\beta \approx 1$
- Aicher, Schaefer Vogelsang (ASV) found $\beta = 2$ with threshold resummation



ASV valence PDF

Phys. Rev. Lett. **105**, 114023 (2011).

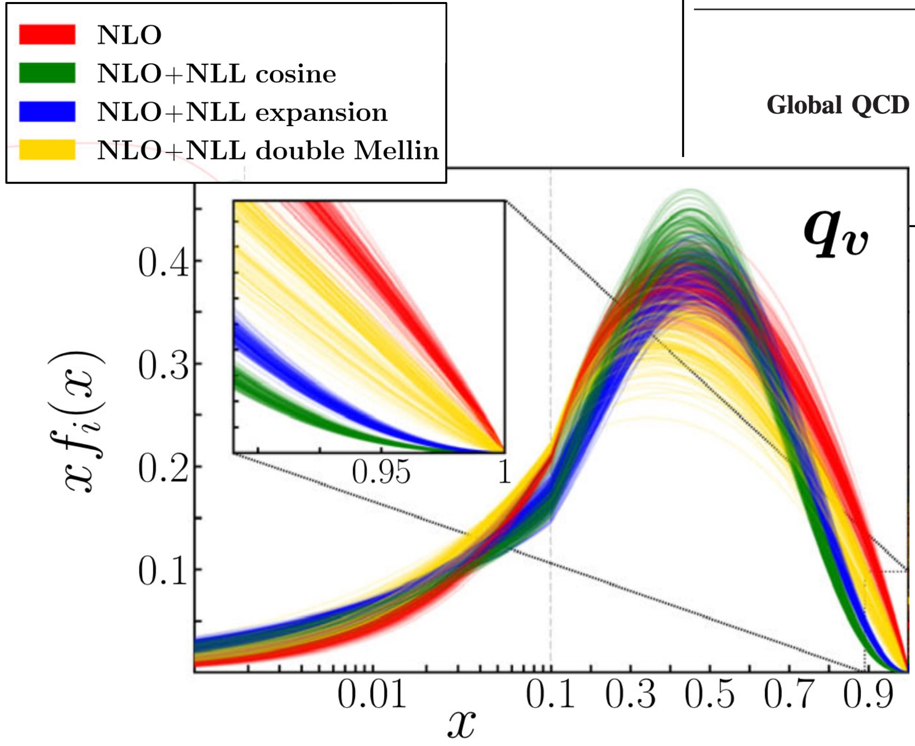
JAM analysis with threshold resummation

PHYSICAL REVIEW LETTERS 127, 232001 (2021)

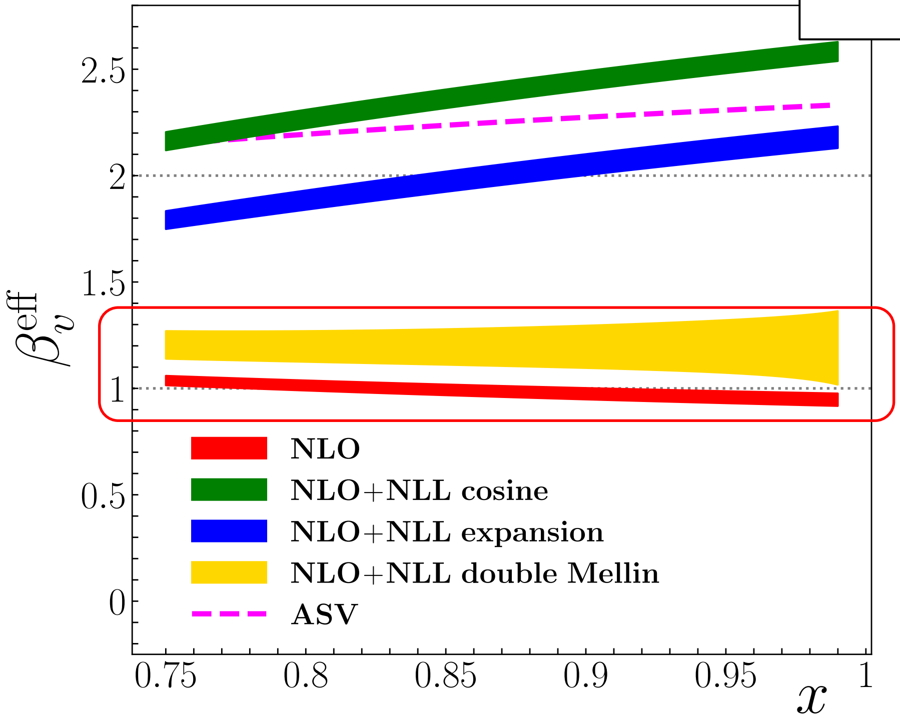
Global QCD Analysis of Pion Parton Distributions with Threshold Resummation

P. C. Barry,[1] Chueng-Ryong Ji,[2] N. Sato,[1] and W. Melnitchouk[1]

(JAM Collaboration)



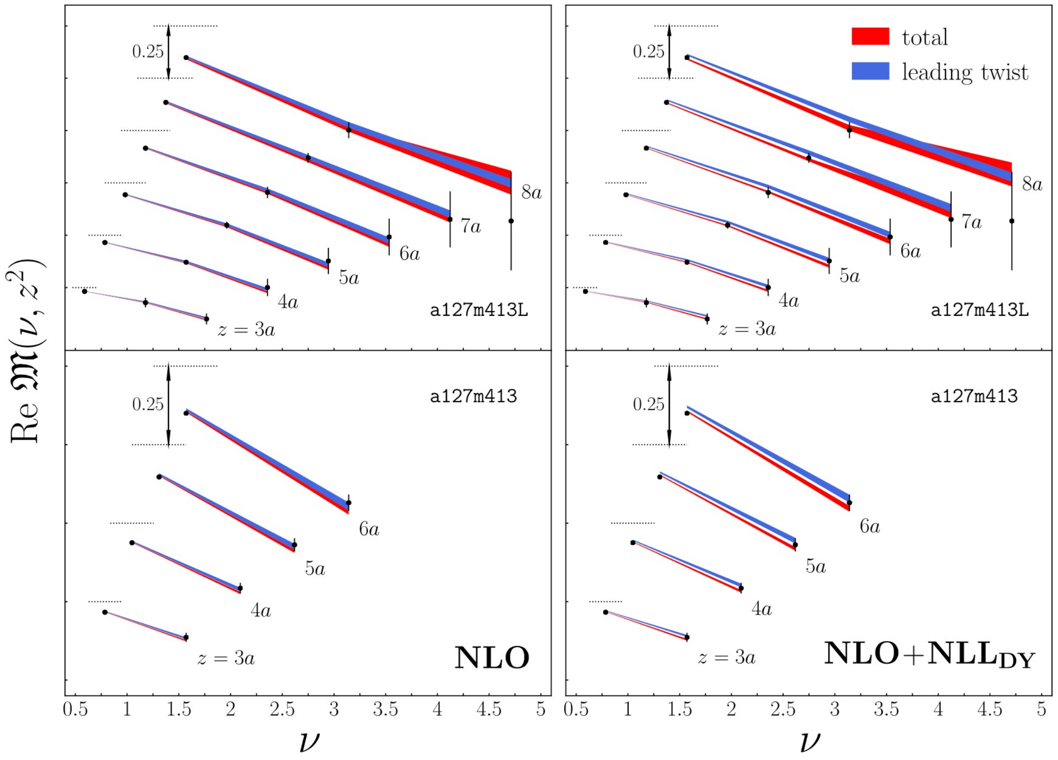
$$\beta_{\rm eff}(x,\mu) = \frac{\partial \log |q_v(x,\mu)|}{\partial \log(1-x)}$$



- Highly dependent on perturbative approach
- NLO and NLO+NLL double Mellin methods better on theoretical grounds

Introduction of lattice QCD data

- JAM has also included recent simulations on the lattice to constrain pion PDFs

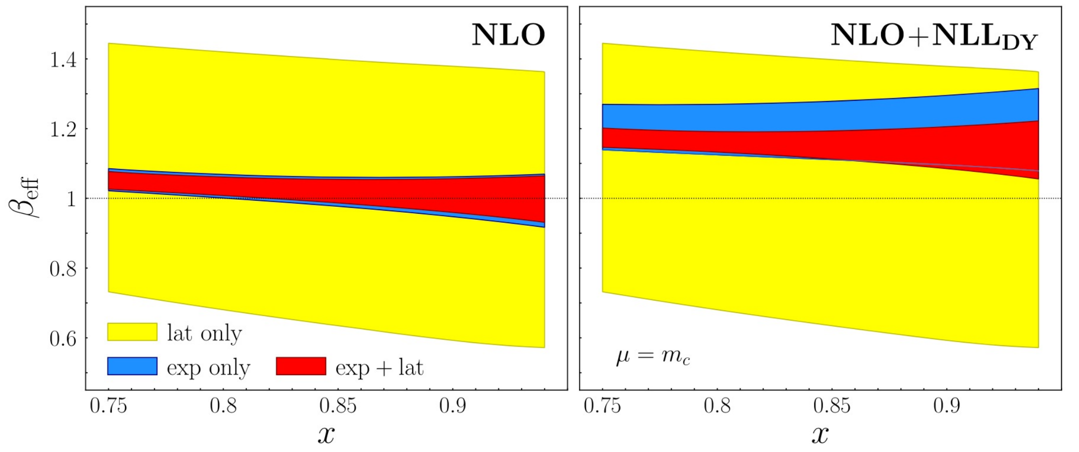


PHYSICAL REVIEW D **105,** 114051 (2022)

Complementarity of experimental and lattice QCD data on pion parton distributions

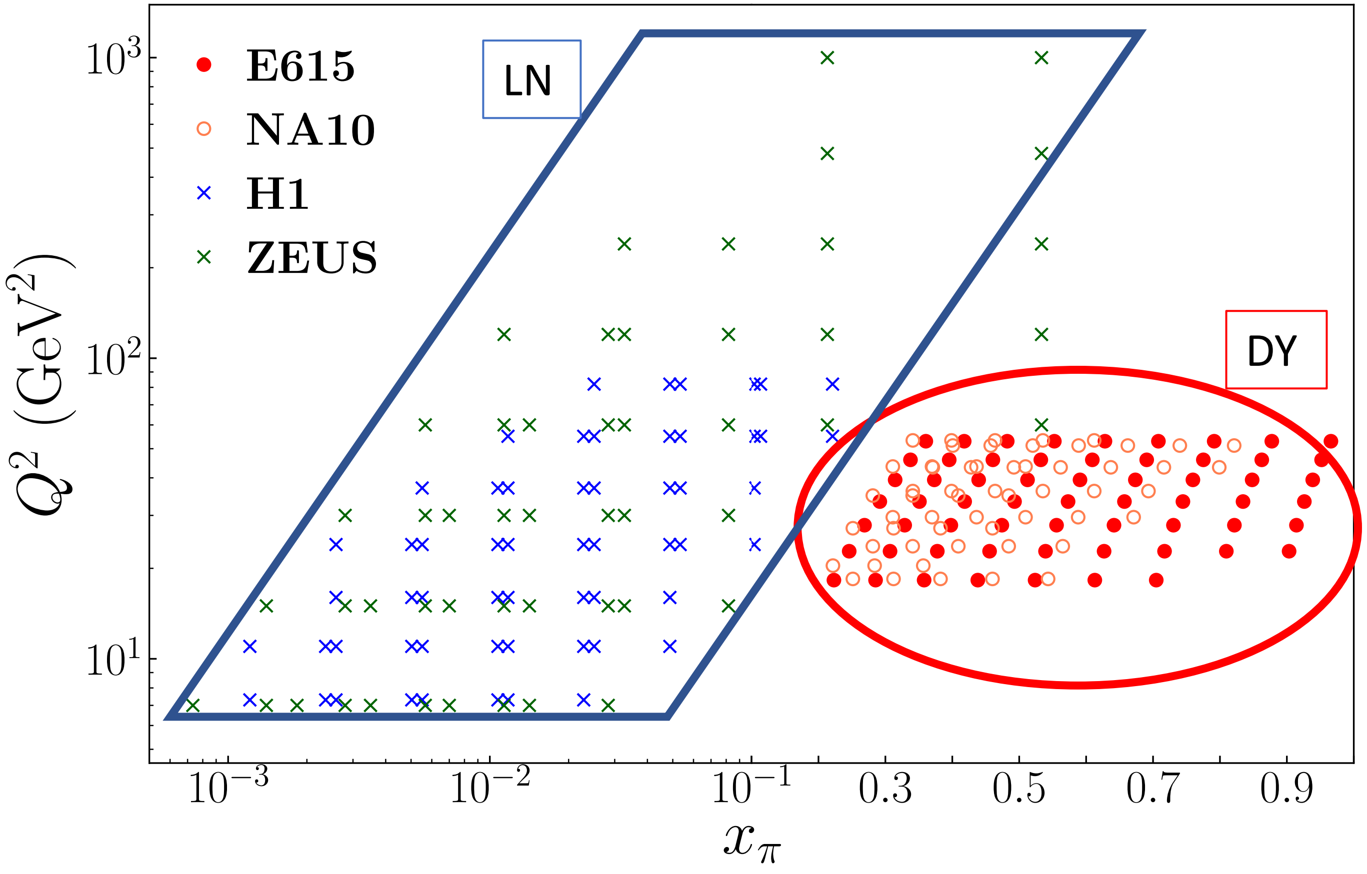
P. C. Barry,[1] C. Egerer,[1] J. Karpie,[2] W. Melnitchouk,[1] C. Monahan,[1,3] K. Orginos,[1,3] Jian-Wei Qiu,[1,3] D. Richards,[1] N. Sato,[1] R. S. Sufian,[1,3] and S. Zafeiropoulos[4]

(Jefferson Lab Angular Momentum (JAM) and HadStruc Collaborations)



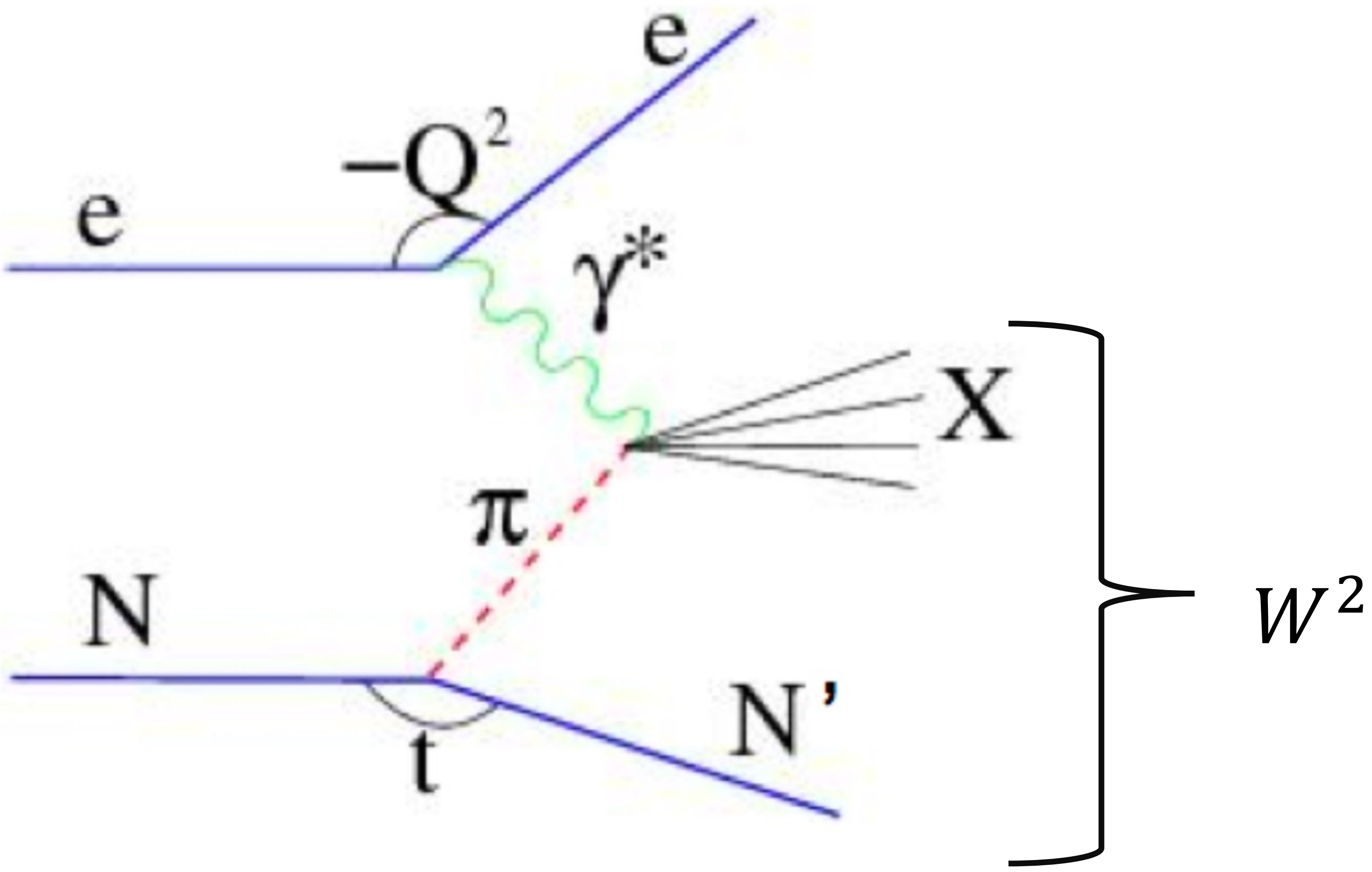
Datasets -- Kinematics

- Current experimental data is limited kinematically with little overlap
- Can JLab TDIS help us learn more about pion PDFs?



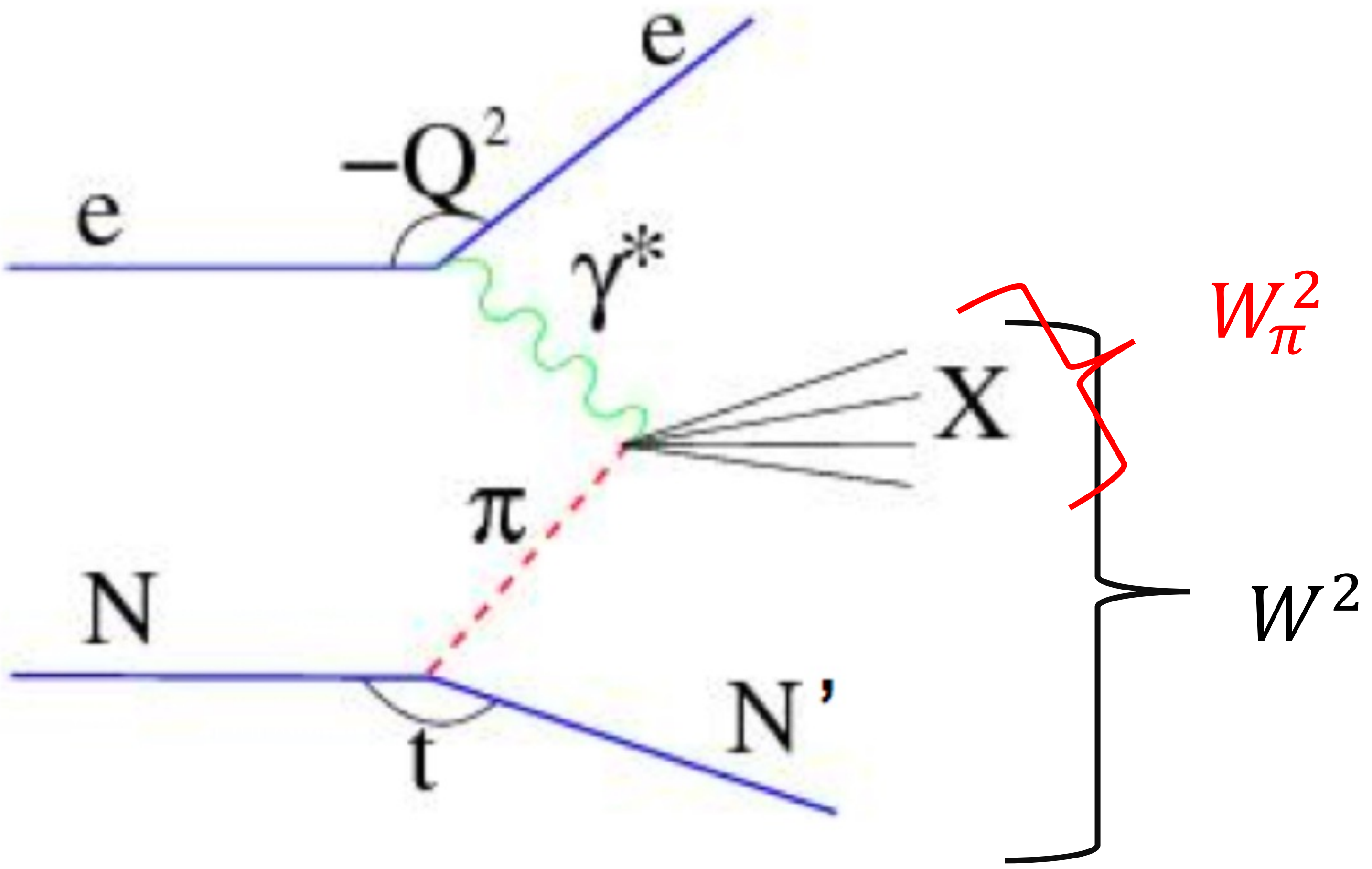
Sullivan process

- Impose kinematic cuts on experimental data
- Such as lower limit on the totally *inclusive* W^2



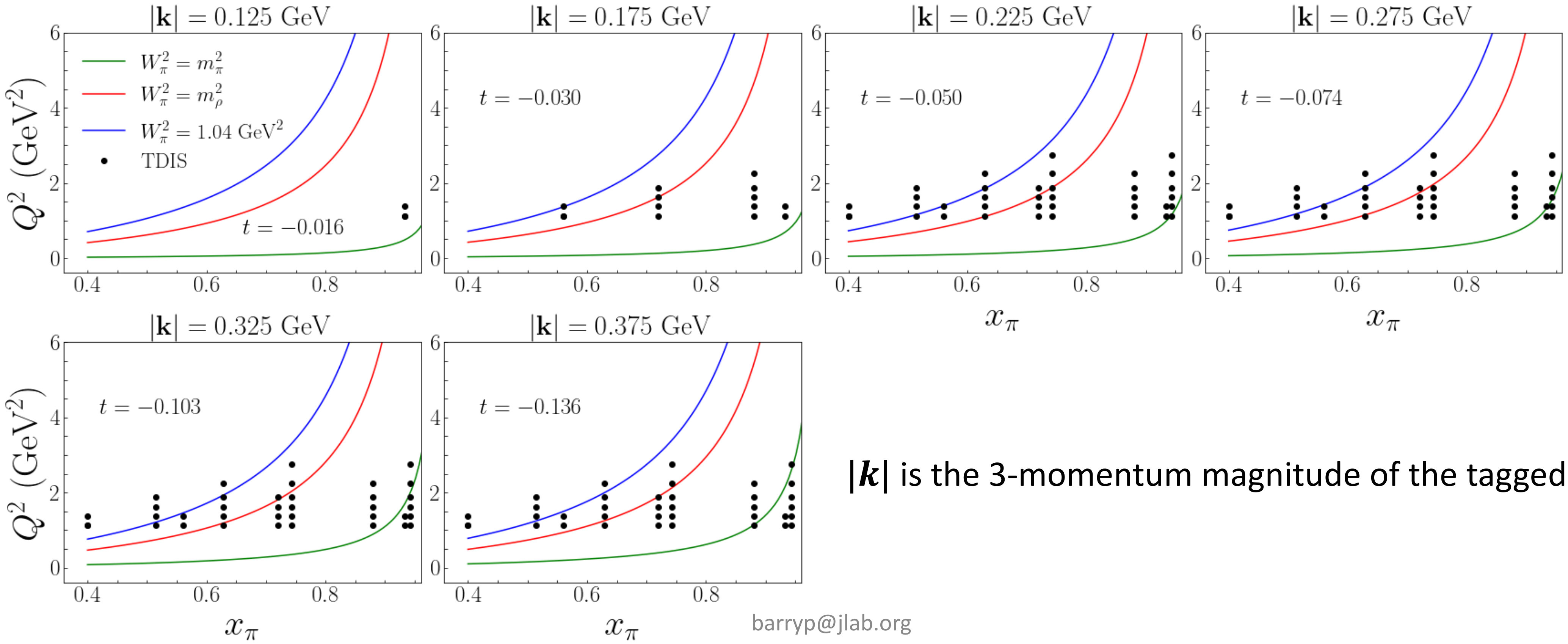
Sullivan process and W_π^2

- Impose kinematic cuts on experimental data
- Such as lower limit on the totally *inclusive* W^2
- What about the W_π^2?



Current 11 GeV TDIS kinematics

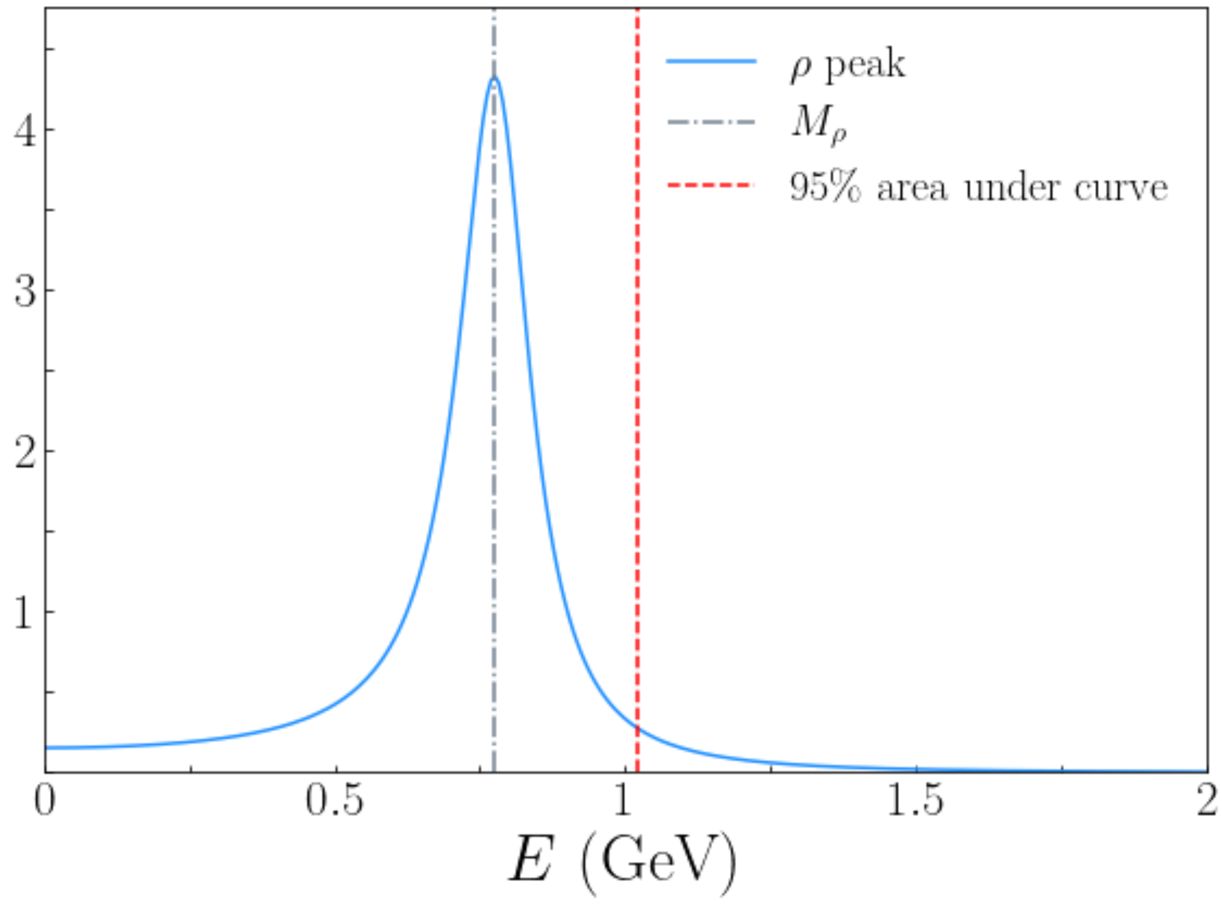
- Plotting available 11 GeV TDIS kinematics with a few representative W_π^2 curves



$|\boldsymbol{k}|$ is the 3-momentum magnitude of the tagged nucleon

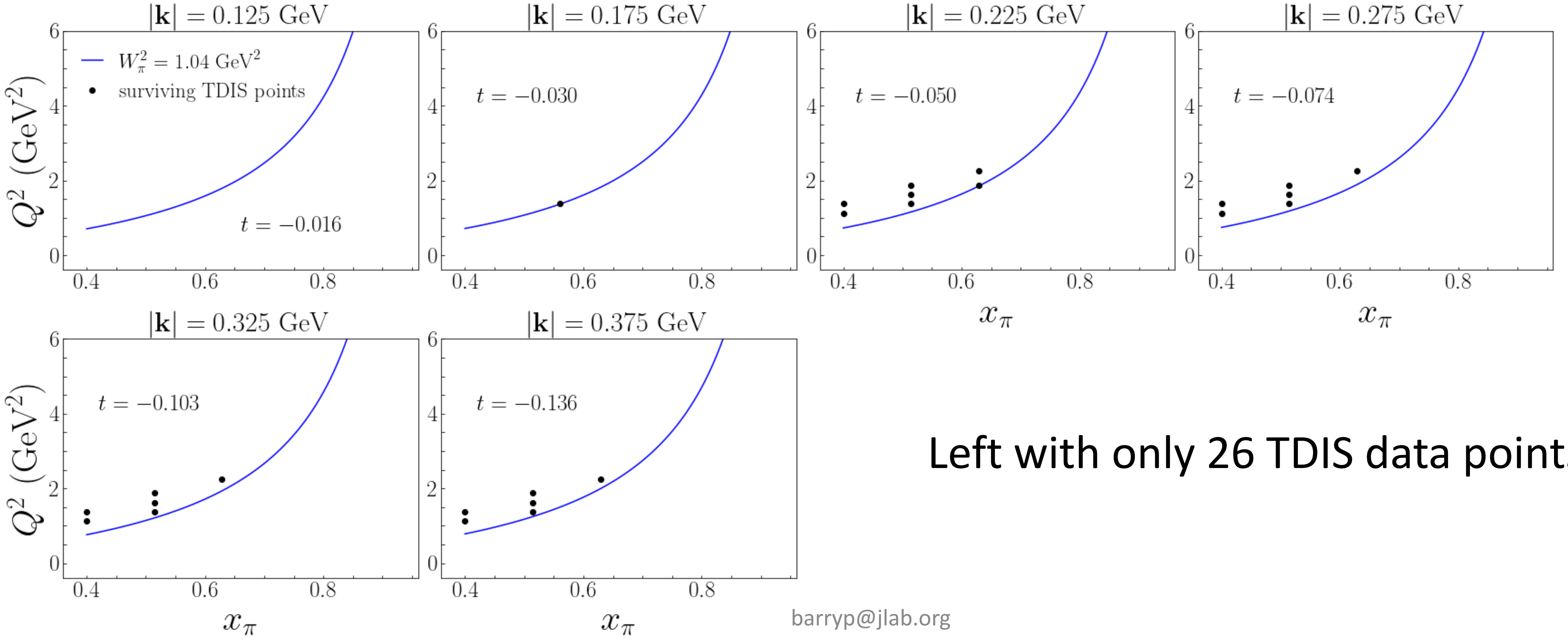
What to choose for W_π^2

- HERA did not measure the low-W_π^2 region
- Potentially largest resonance comes from the ρ-meson
- Must be well above the peak of the resonance
- Estimating the safe region to be an energy above 95% of the area under the curve



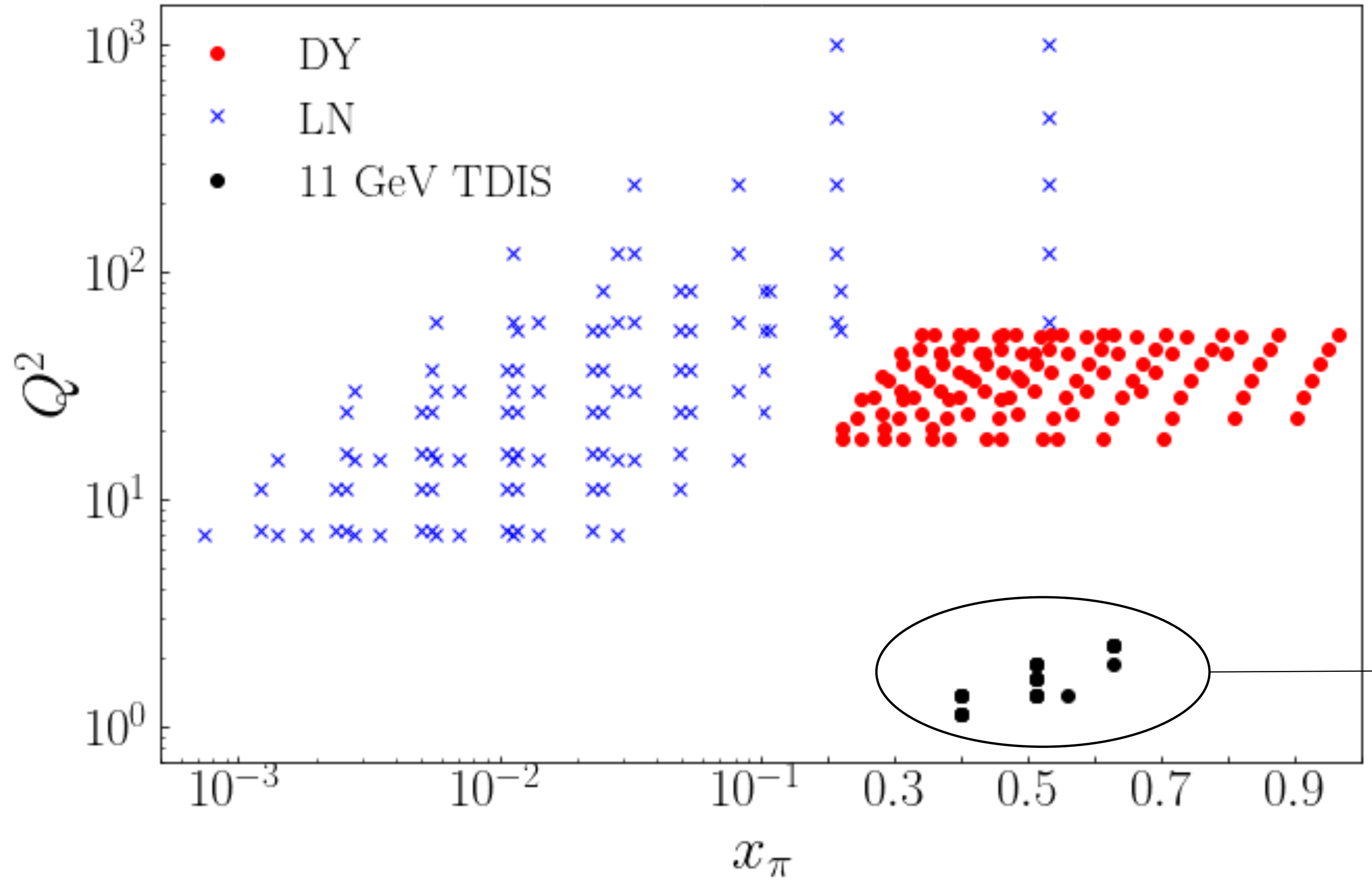
Choosing $W^2_{\pi,\max} = 1.04\ \text{GeV}^2$

- Removing all data points that could be contaminated by resonance regions



Left with only 26 TDIS data points

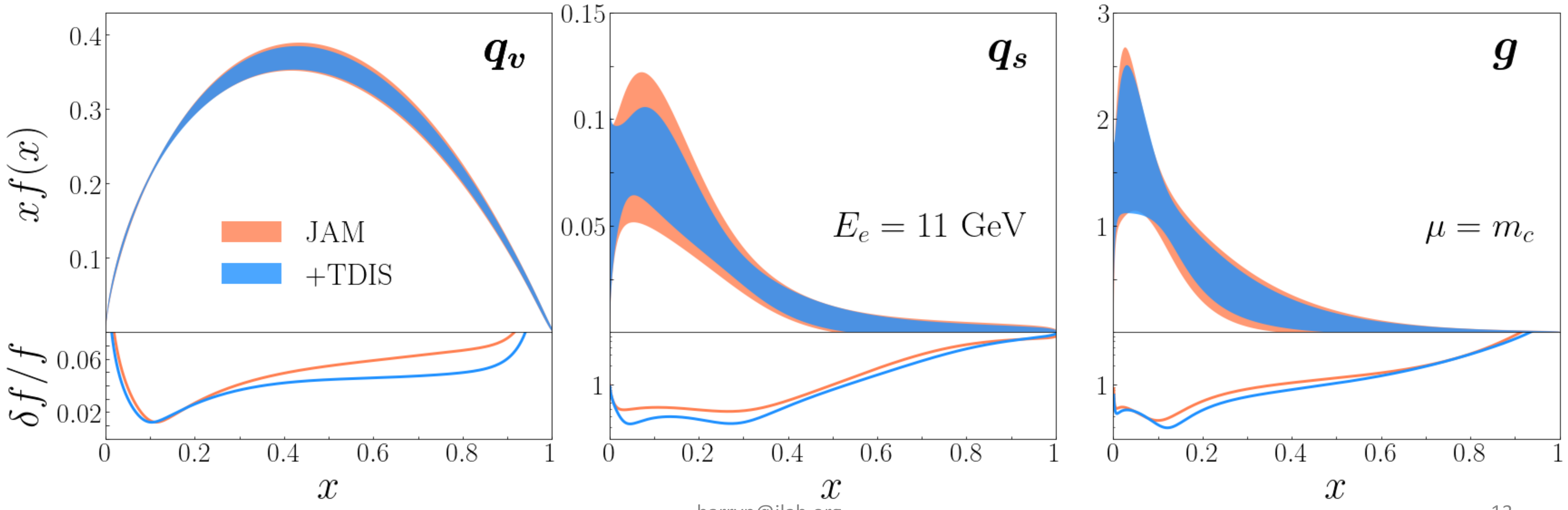
Total pion kinematics



Higher twist effects and potentially non-perturbative effects could be relevant

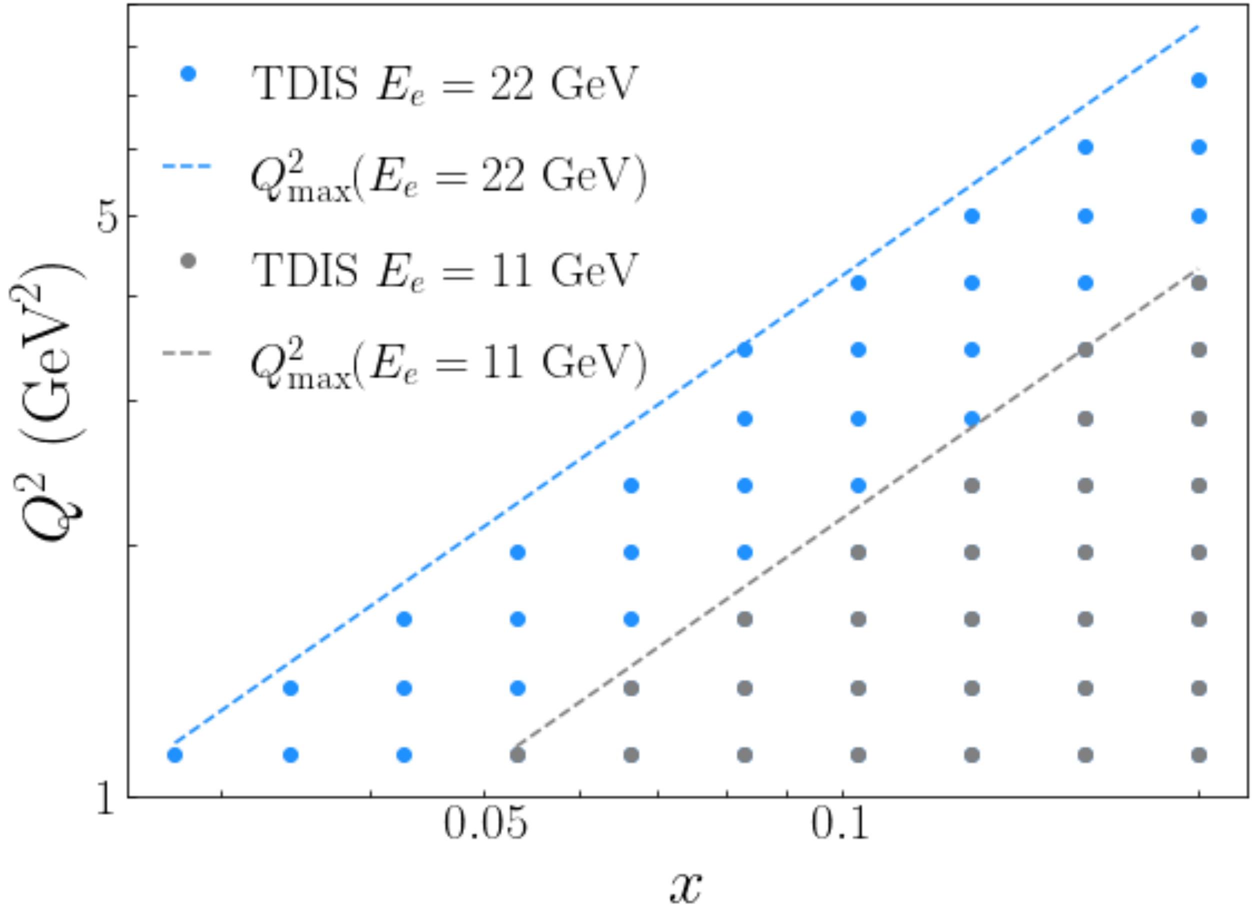
Performing impact study with 11 GeV

- Create pseudodata from these points and perform global analysis with available experimental data



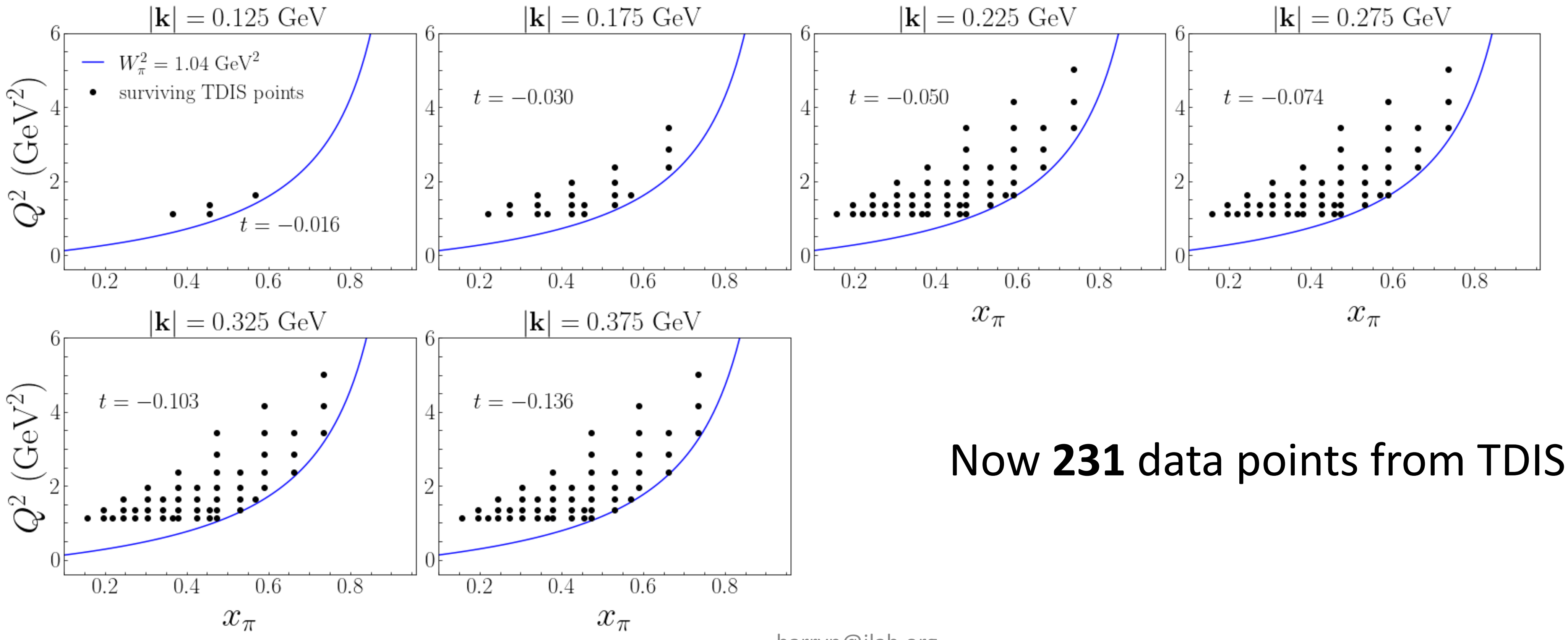
Upgrade to 22 GeV

- Much more available kinematic range in (x, Q^2)
- Recall the W_π^2 cut removed large x_π and small Q^2 data
- New blue points will survive the cut



Kinematics with 22 GeV

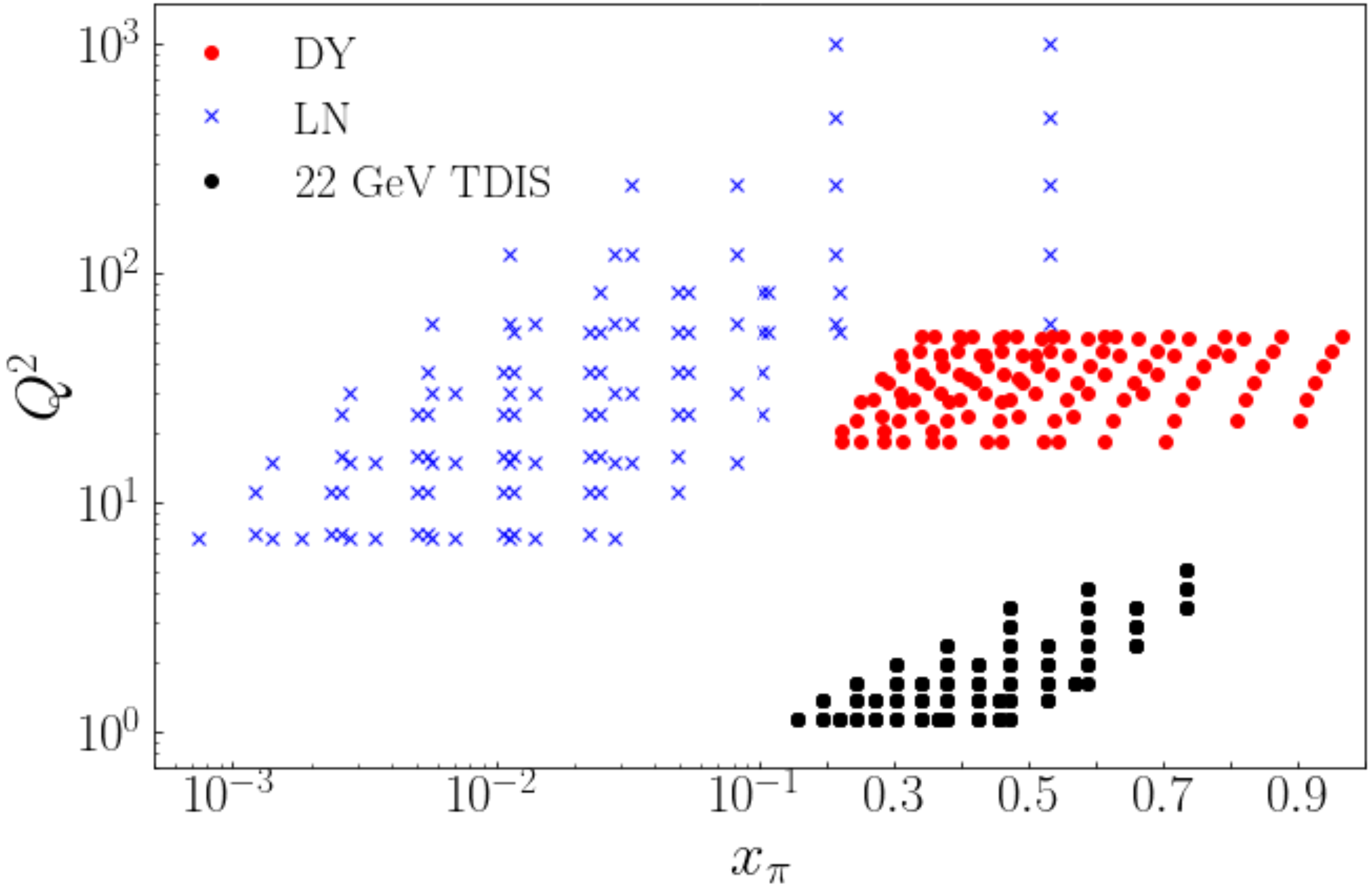
- MASSIVE increase in available data points



Now **231** data points from TDIS

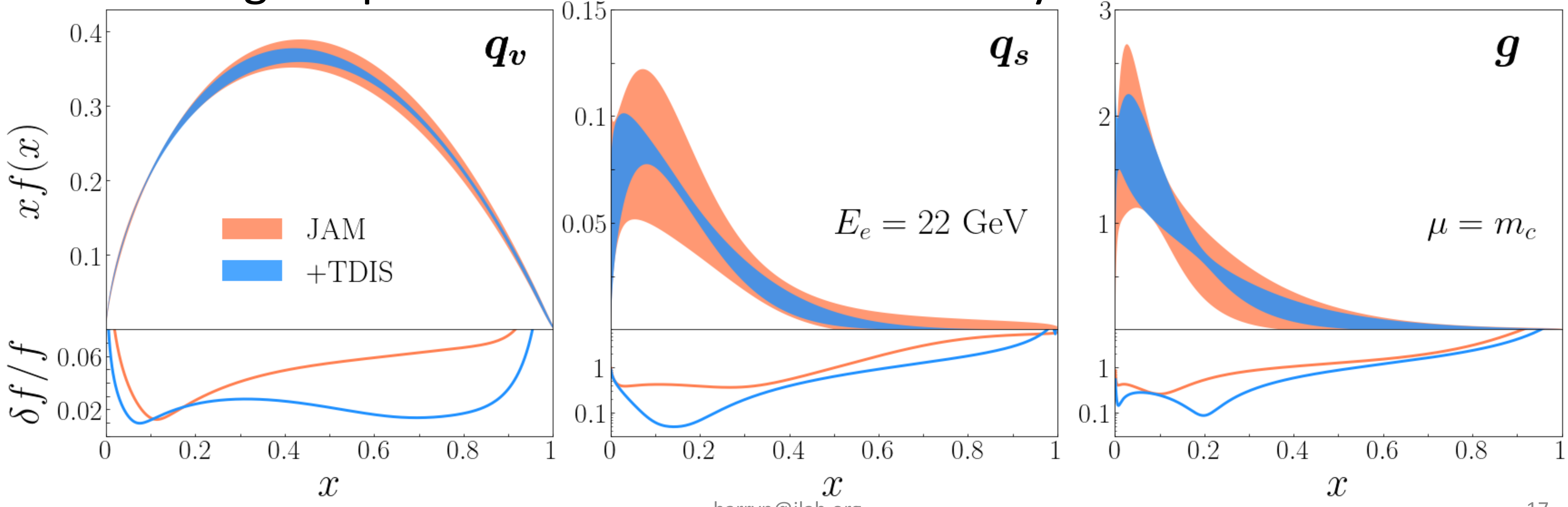
Total kinematics

- Much larger range in x_π and Q^2



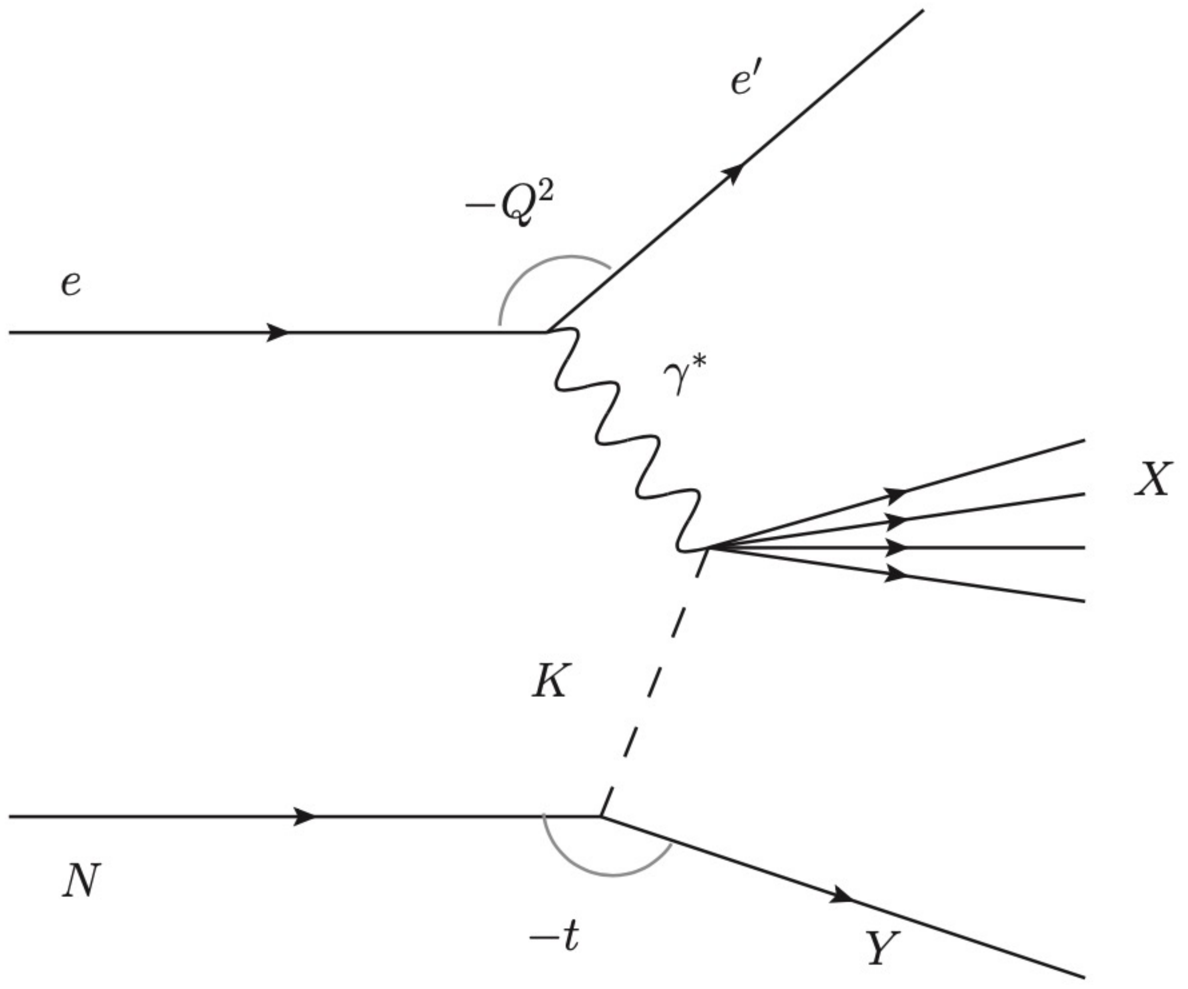
Impact on pion PDFs with 22 GeV

- Sizable impact on pion PDFs, especially compared with the 11 GeV beam
- Knowledge of pion PDFs increases dramatically with 22 GeV beam



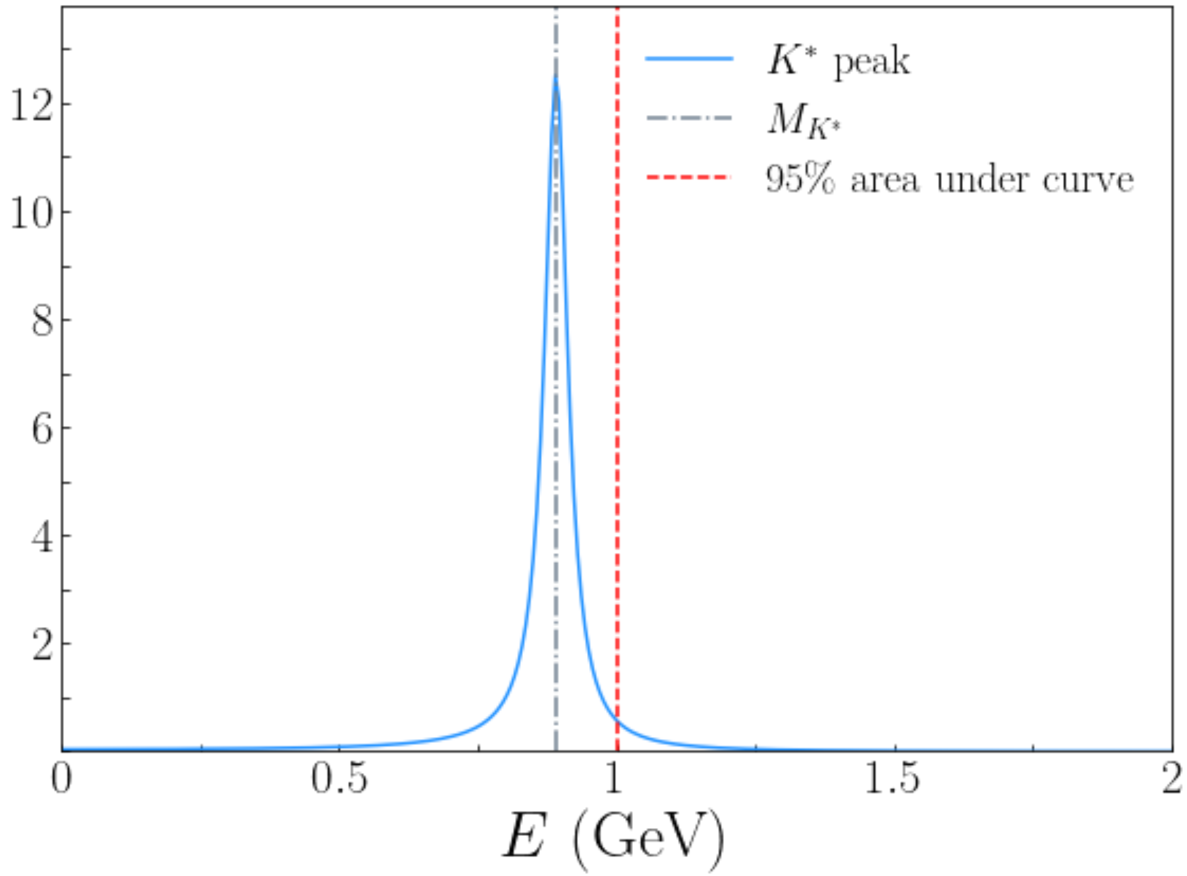
Brief words on kaon TDIS

- Sullivan process applies, but a *hyperon* must be tagged
- Consider again, not only inclusive W^2 but W_K^2



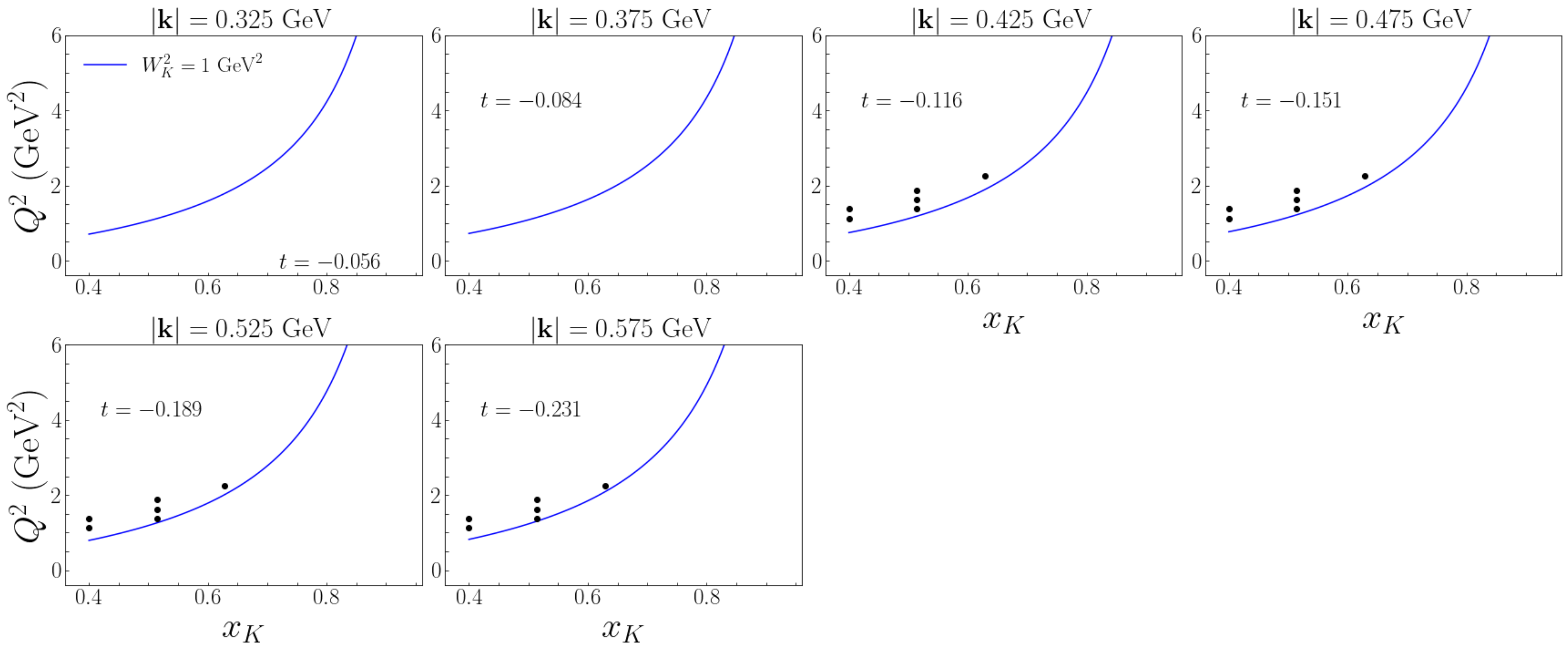
Resonance from K^*

- The K^* resonance is much more narrow than for ρ meson
- $W_{K,\max}^2 = 1\ \mathrm{GeV}^2$



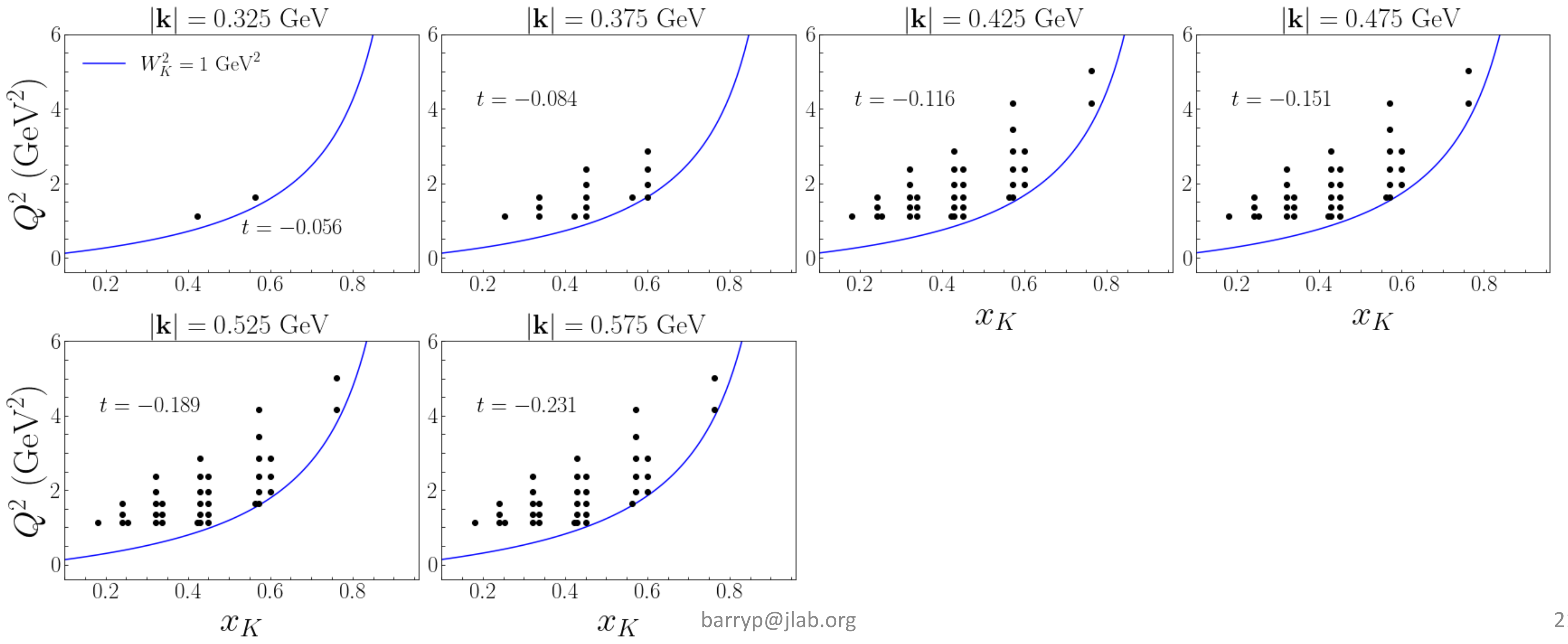
Kinematics for 11 GeV Kaon TDIS

- Beware of such large $|t|$ further away from kaon pole



Kinematics for 22 GeV Kaon TDIS

- Accepting of more points at smaller $|\boldsymbol{k}|$



Conclusion

- Impacts from the 11 GeV TDIS experiment on pion PDFs will be limited, but can test the large-x_π behavior inferred from the Drell-Yan data
- The 11 GeV TDIS can measure the low-W_π pion structure function
- **Much** more constraints will come from larger 22 GeV upgrade
- Kaon PDF analysis may be more realistic with energy upgrade

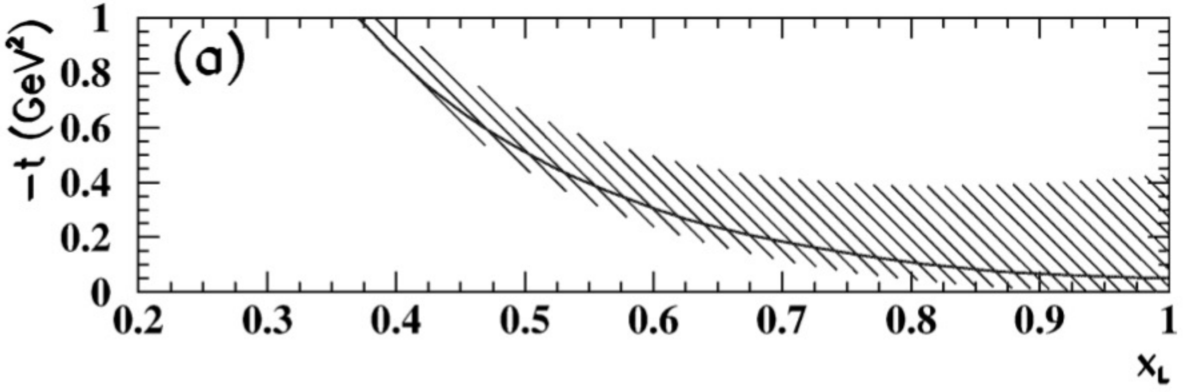
Backup slides

Formula for W_π^2

- Dependent on the external tagged kinematics

$$W_\pi^2 = t - Q^2\left(1 - \frac{\bar{x}_L}{x}\right)$$

Range in t from HERA



EIC impact

- How much will EIC give relative to JLab 22 GeV upgrade?