EHM4 – Dec.2 discussion session

1. Experimental tools: access the PDFs of the pion/kaon.

2. Theoretical tools: determine PDFs from the measured cross sections

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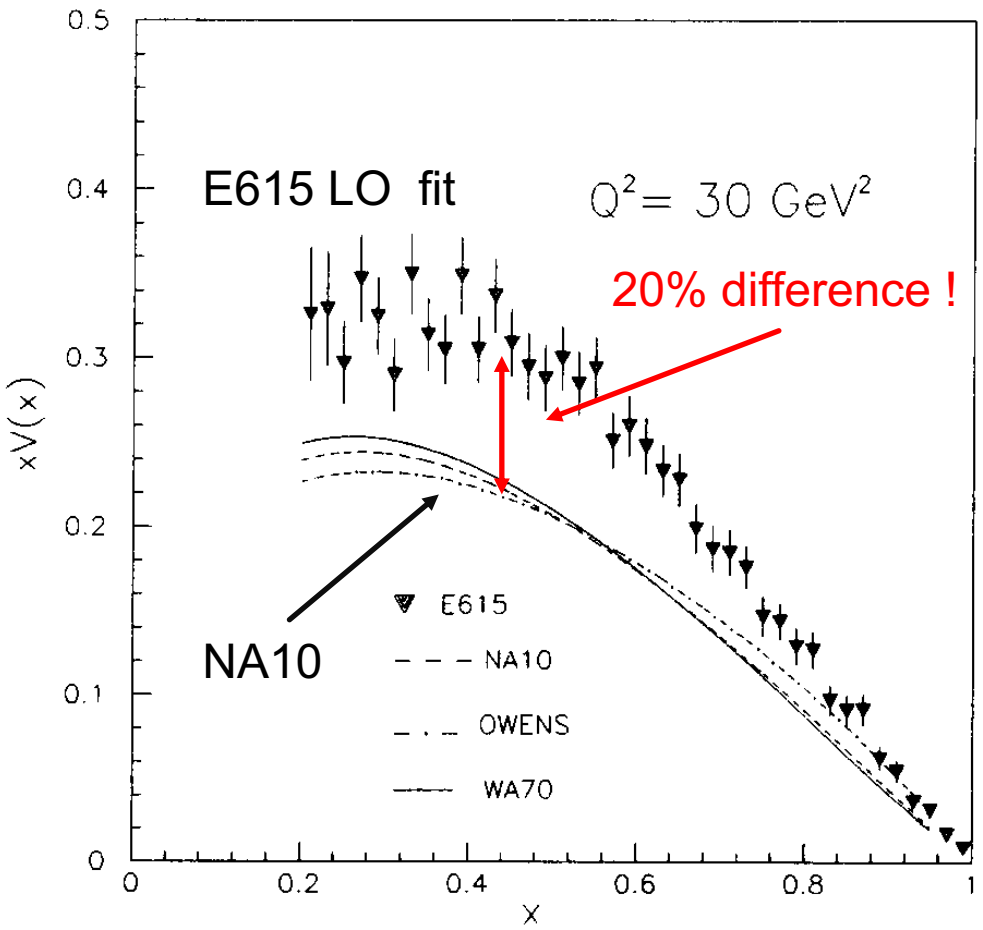
Pion valence and sea PDFs

- Drell-Yan experiments
  - Pion-induced DY experiments (1979-1989)
  - Mainly data from heavy ^{184}W or ^{195}Pt targets
  - Val/sea separation: only with $\pi+$ / $\pi-$ beams
    - New data to come

☞ talk by C. Quintans

- Sullivan process
  - Scattering from nucleon-meson fluctuations

☞ talks by R. Ent, T. Keppel



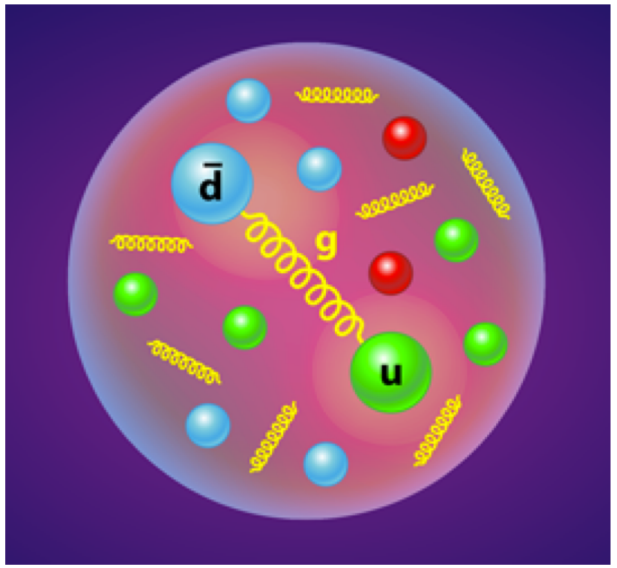
Pion PDF "data" from E615 are pseudo-data: LO, no NLL, no Cold Nuclear Effects

Pion gluon PDF

☞ AMBER (talk by C. Quintans)

- Direct-photon production using pion beams:
  - $gq \to q\gamma$ and $q\bar{q} \to q\gamma$.
  - Only two experiments: NA24 (1987), WA70 (1987).
    - No new data since 1987! Foreseen in Amber Phase-2
- J/ψ production
  - A number of pion-induced experiments (1980-2000)
  - H to ^{195}Pt targets ☞ talk by J.-C. Peng
    - Large cross sections, production mechanism
- Sullivan process at the energies of HERA/EIC

  ☞ talks by R. Ent and T. Keppel

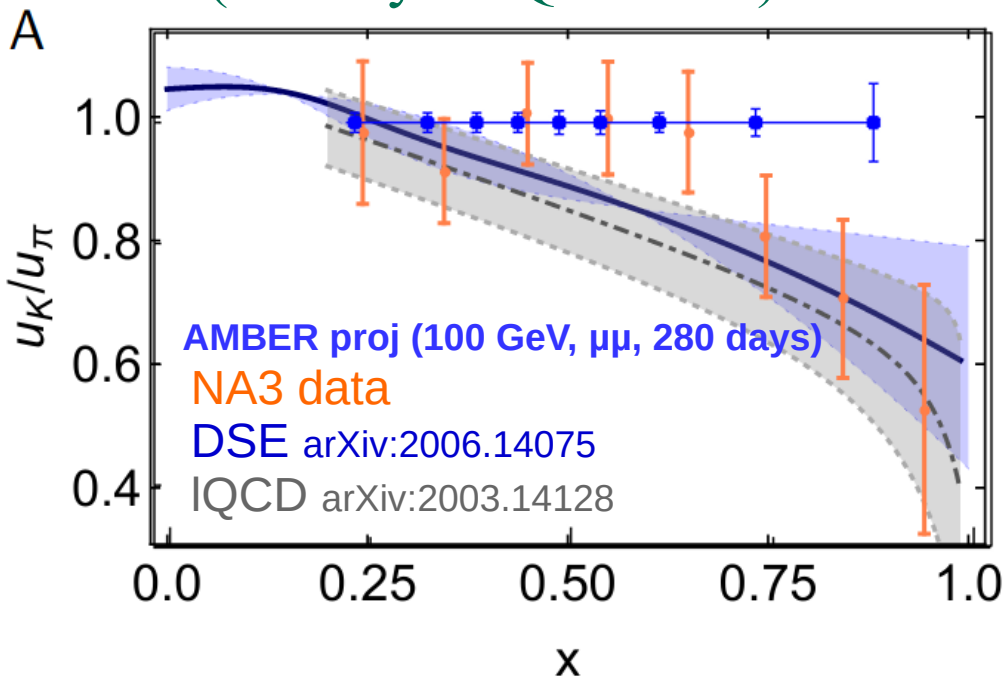


from PRL, Barry, Sato, et al., 2018

Kaon PDFs

- Valence PDF:
  - using Drell-Yan data
    - (only the pion/kaon ratio is known)
- Gluon PDF:
  - Direct-photon production using kaon beams
    - No data
  - J/ψ production with kaon beams (K^+, K^-)
    - Nice J/psi production data from NA3 (1983)
  - Sullivan process at the energies of EIC

☞ AMBER (talk by C. Quintans)



Available global fits: nice progress in the last two years!

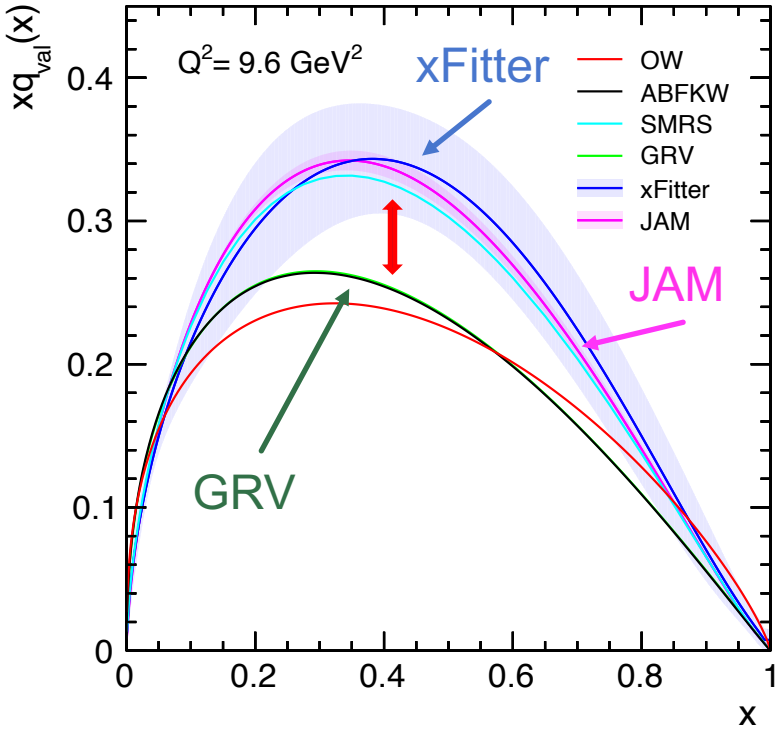
- Older fits:
  - Owens (1984), Aurenche et al., (1988)
  - GRV/GRS (1992/1999): NLO
  - SMRS (1992): NLO

- Recent fits (on old data!)
  - JAM (2018): includes (for the first time) leading neutron HERA data ☞ talk by N. Sato
  - xFitter (2020): includes direct photon data from CERN (80's) ☞ talk by F. Olness

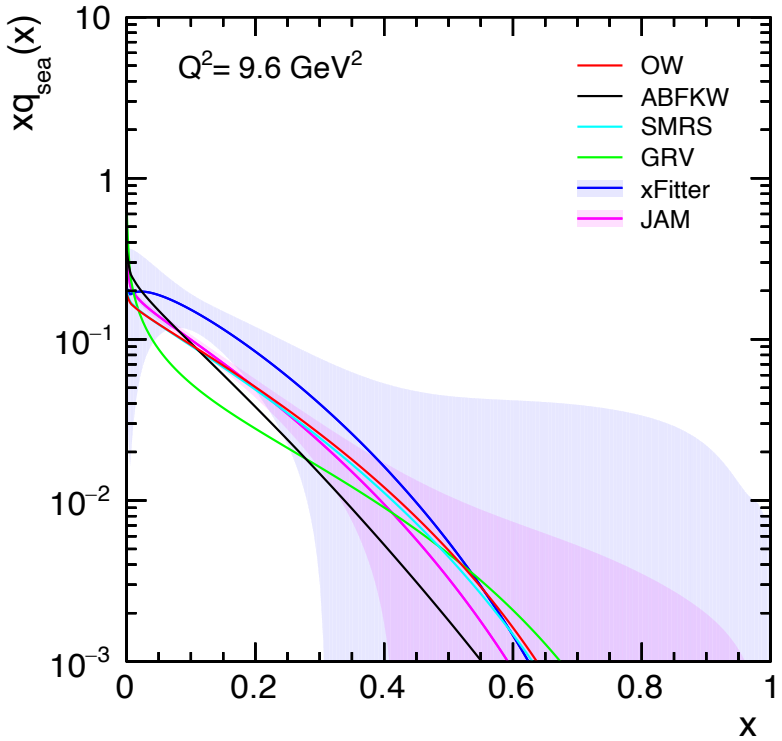
Comparison of the global fit PDFs – shapes and magnitudes

Chang, Peng, SP, Sawada, PRD 102 (2020) 054024

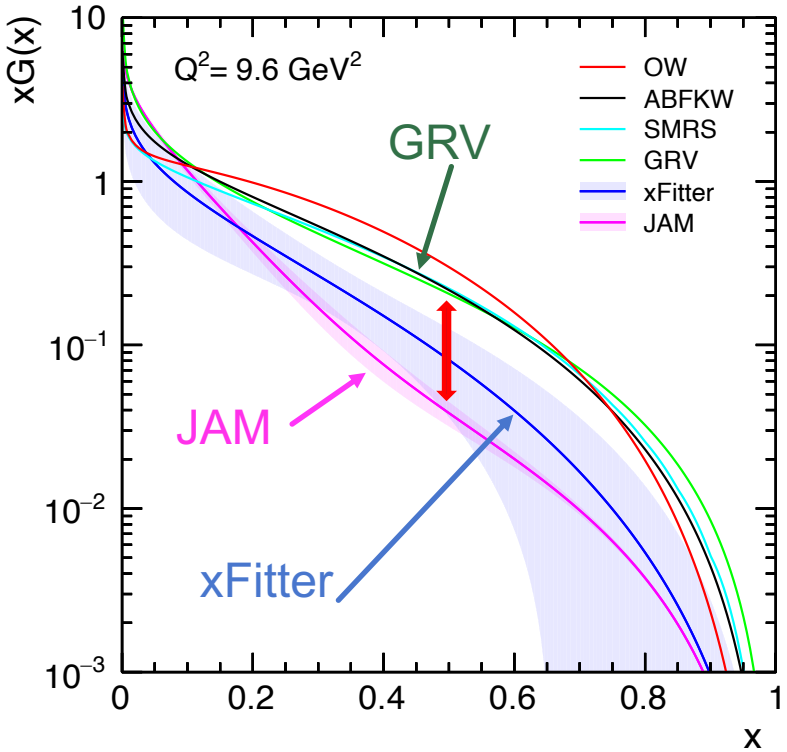
valence



sea



gluons



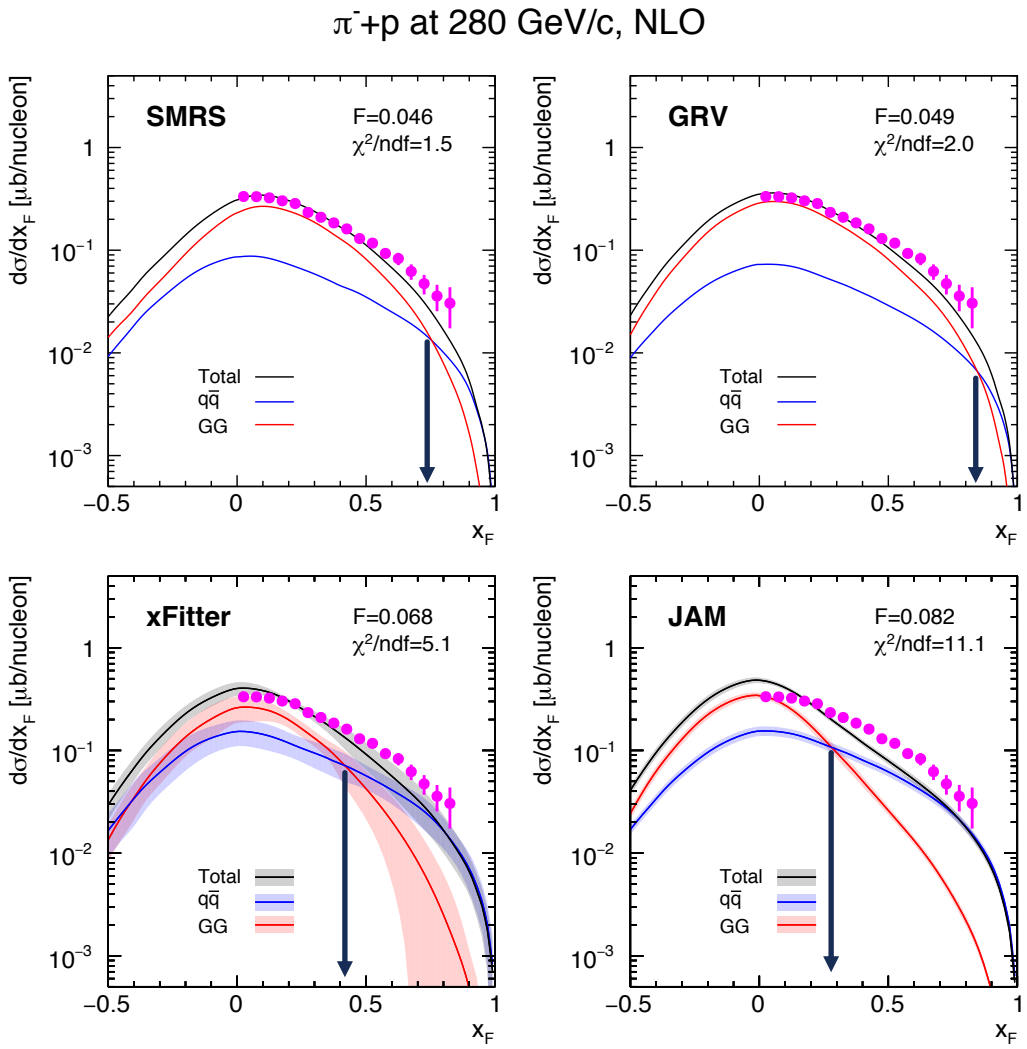
Chang, Peng, SP, Sawada, PRD 102 (2020) 054024

Pion-induced J/psi production: Global fit differences

☞ talk by J.-C. Peng

- The large differences are observed come from the different shapes of the valence and gluon PDFs.
- Crossover in x_F between *qq* and *gg* terms:
  - SMRS: 0.75
  - GRV: 0.85
  - xFitter: 0.45
  - JAM: 0.30

The J/psi production cross section is extremely sensitive to the shapes of the pion PDFs.

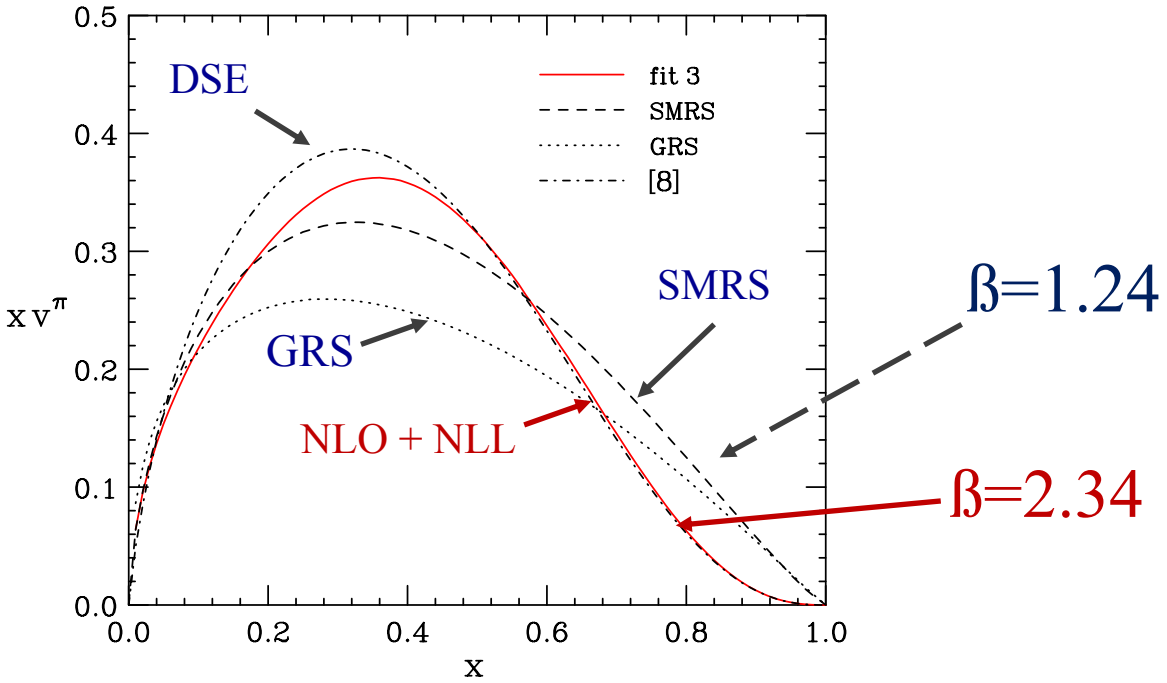


Pion valence PDF: reanalysis with NLL resummation (2010)

Aicher, Schäfer and Vogelsang, PRL 105, 252003 (2010).

- Fit of E615 data: NLO, NLL
  - valence PDF:

$$x\, v^{\pi}(x) = N v x^{\alpha}(1-x)^{\beta}(1+\gamma x^{\delta})$$



Slope at large x: Agreement with pQCD, DSE

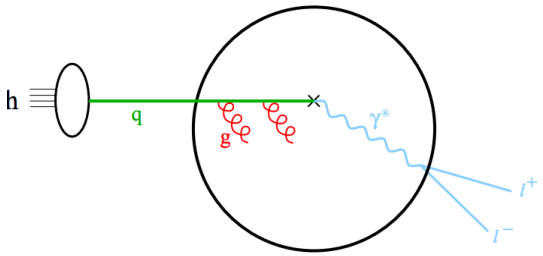
NLL: makes the valence distribution softer at high x

Yet another large-x effect: parton energy loss

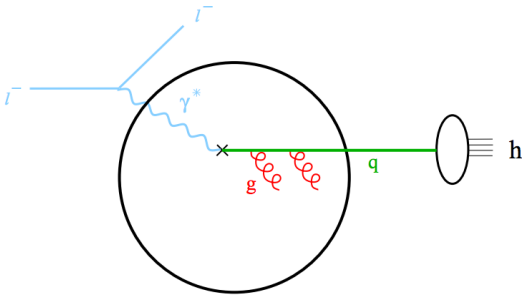
Arleo, Naim, SP, JHEP 01 (2019) 129

During the scattering process, partons lose energy via soft gluon radiation in the nuclear medium:

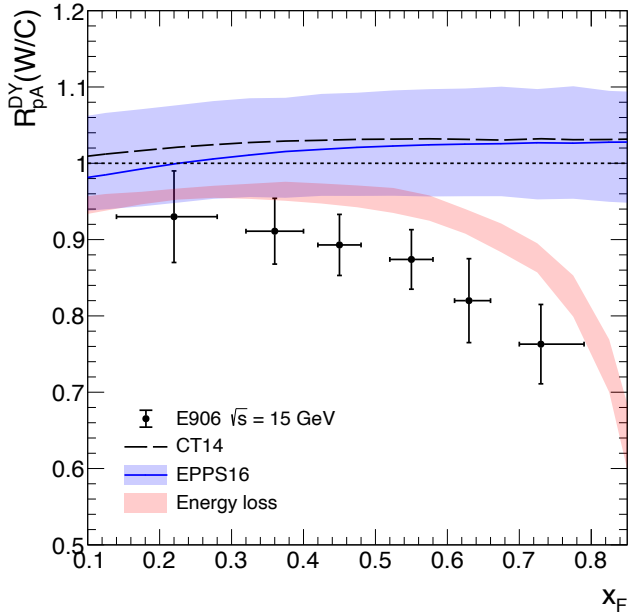
Drell-Yan



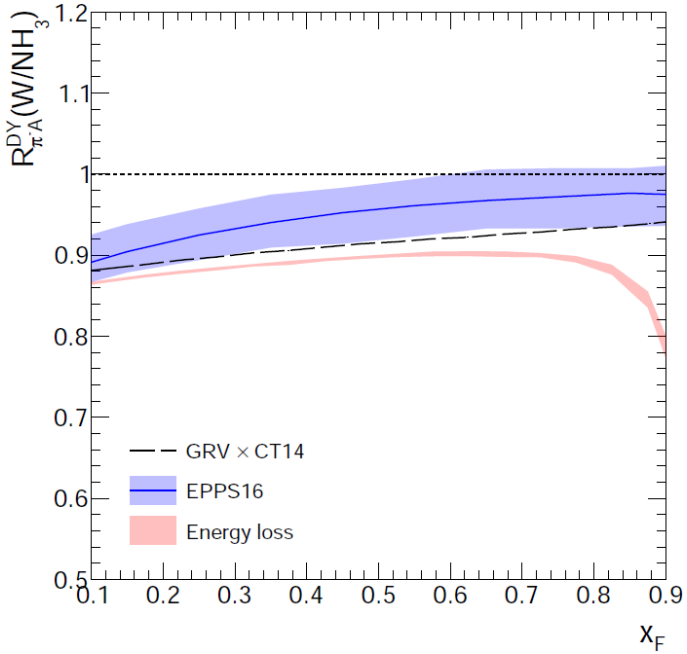
SIDIS



Sea Quest, preliminary
P.-J. Lin, PhD, 2017
Protons, 120 GeV



Eloss prediction
Pions, 190 GeV



Effect smaller than NLL; for heavy targets should also be considered.

Some additional (theory…) questions

- Meson-induced J/psi production
  - Very powerful tool, as cross sections are large (typically 30-50 times larger than DY).
  - However, production mechanism is not well understood… How do we make further progress?
    - AMBER : could provide a benchmark measurement with an antiproton beam…
- Meson-induced direct-photon production
  - Complementary tool. Theoretical calculations are 3 decades old (to my knowledge).
  - Is this process fully understood, or do we need further improvements?
- Sullivan process
  - Pion/kaon in the cloud are off-shell. Is the necessary correction under control?

A benchmark measurement? antiproton- vs proton-induced J/psi production

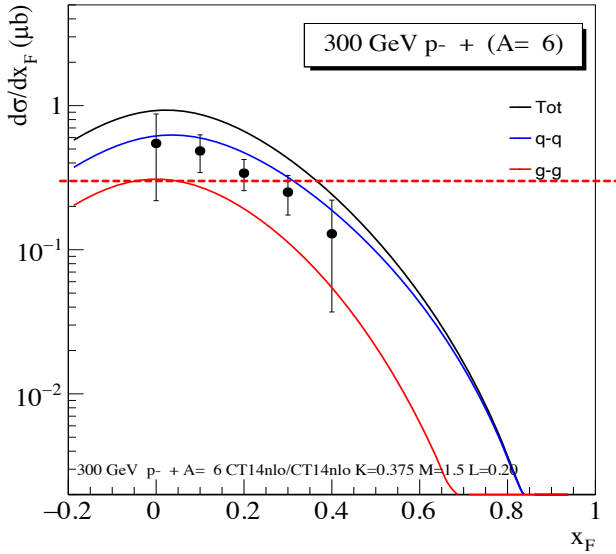
- E705 experiment (1992):
  - p and pbar on ^{6}Li, 300 GeV

$$p^+(uud)+p^+(uud)=gg+(--.--.--.-)_{val-val}+(u_v^p\bar{u}_s^p+d_v^p\bar{d}_s^p)_{val-sea}+(\bar{u}_s^p u_v^p+\bar{d}_s^p d_v^p)_{sea-val}+(.....)_{sea-sea}$$

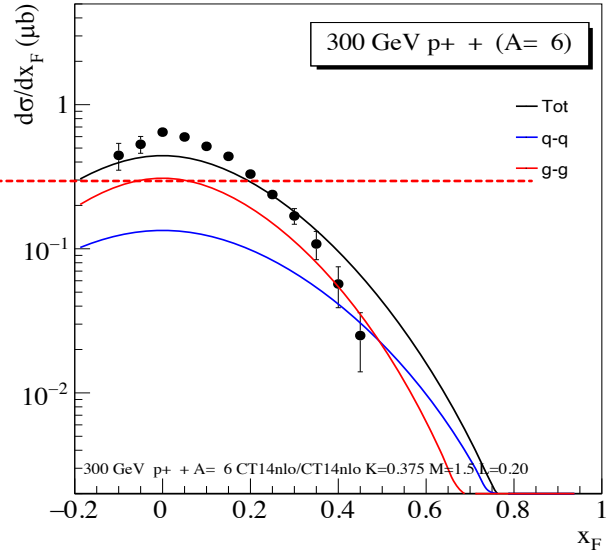
$$p^-(\bar{u}\bar{u}\bar{d})+p^+(uud)=gg+(\bar{u}_v^{\bar{p}}u_v^p+\bar{d}_v^{\bar{p}}d_v^p)_{val-val}+(\bar{u}_v^{\bar{p}}u_s^p+\bar{d}_v^{\bar{p}}d_s^p)_{val-sea}+(\bar{u}_s^{\bar{p}}u_v^p+\bar{d}_s^{\bar{p}}d_v^p)_{sea-val}+(.....)_{sea-sea}$$

The valence quarks in the antiproton provide the main contribution to the $q\bar{q}$ term.
The gg terms are identical, as all other contributions

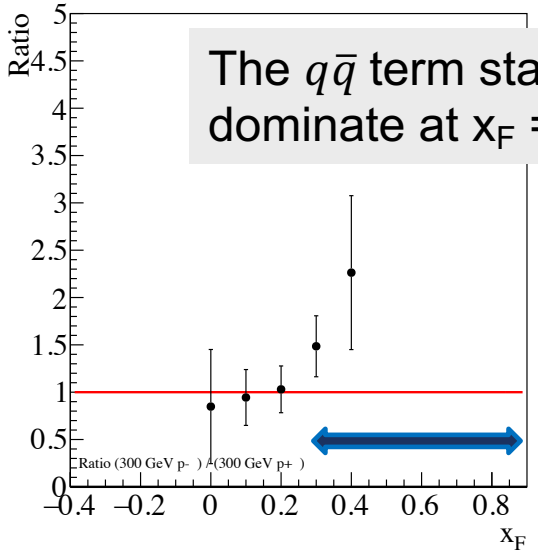
antiproton beam



proton beam



ratio



The $q\bar{q}$ term starts to dominate at x_F = ~0.3

AMBER (Phase2) could measure antiproton-induced cross sections much high statistics (> x100 !)