Measurement of Nuclear Effects with Drell-Yan Scattering at Fermilab, Now and in the Future

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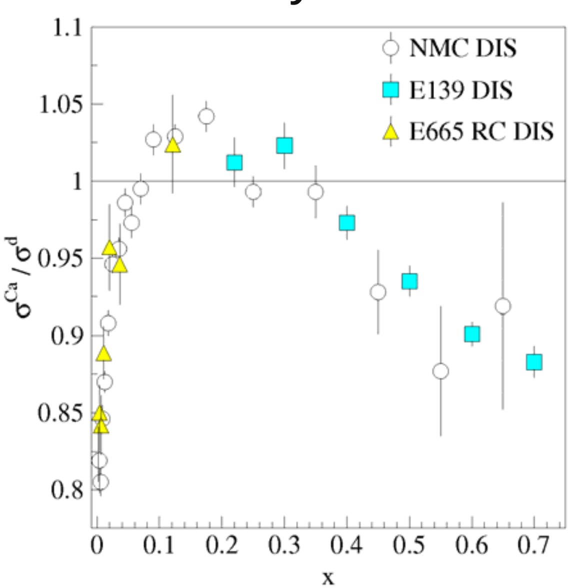
- EMC effect in the valence and the sea
- Partonic energy loss
- Future directions

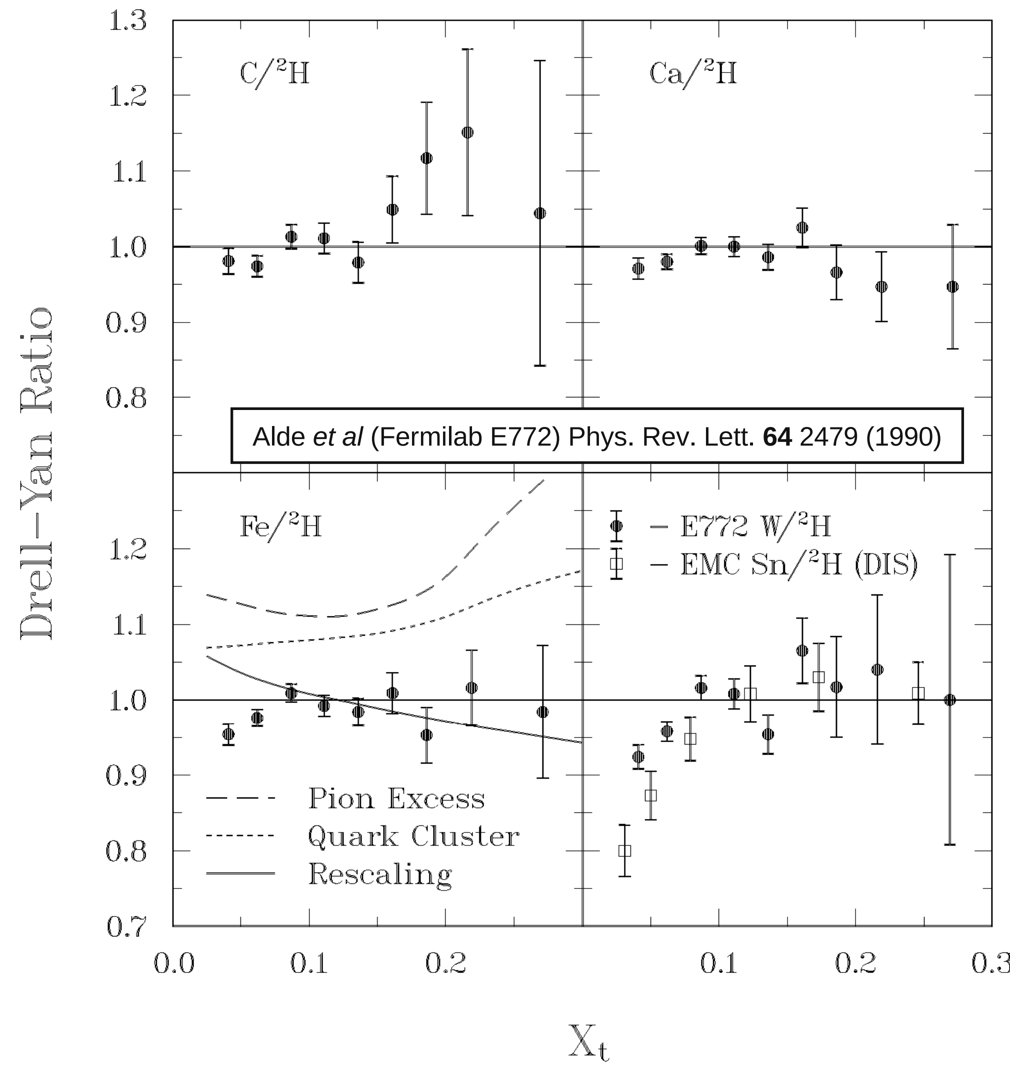
Structure of nucleonic matter:
How do sea quark distributions differ in a nucleus?

Comparison with

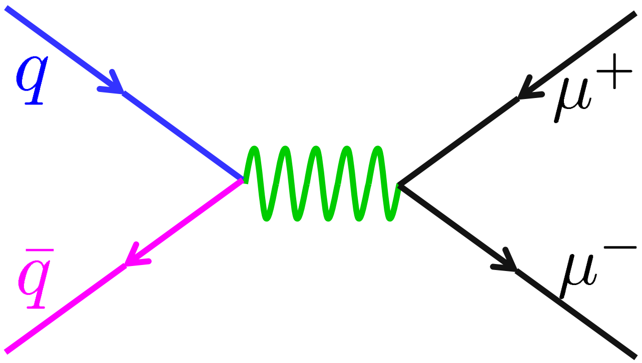
Deep Inelastic Scattering (DIS)

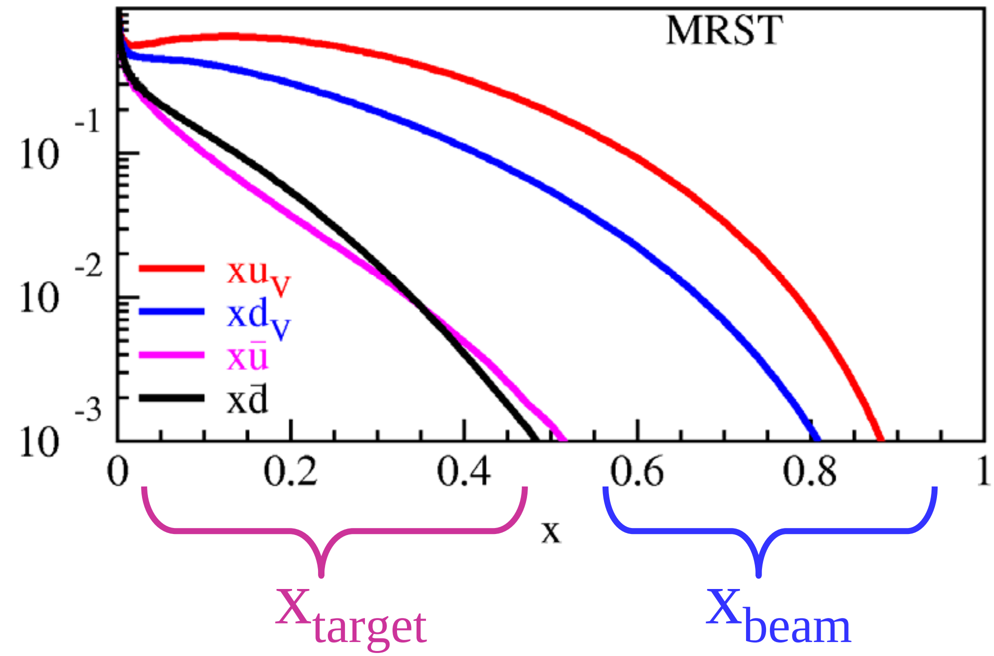
- EMC: Parton distributions of bound and free nucleons are different.
- Antishadowing not seen in Drell-Yan—Valence only effect





Drell-Yan scattering:
A laboratory for sea quarks





$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9x_1x_2}\frac{1}{s}\sum e^2\left[\bar{q}_t(x_t)q_b(x_b) + q_t(x_t)\bar{q}_b(x_b)\right]$$

Detector acceptance chooses range in x_{target} and x_{beam}.

- Fixed target ⇒ high $x_F = x_{beam} - x_{target}$
- Valence *Beam* quarks at high-x.
- Sea *Target* quarks at low/intermediate-x.

$$x_F = \frac{2p_L}{\sqrt{s}} = \sqrt{1+\frac{p_T^2}{M^2}}\,(x_1 - x_2)$$

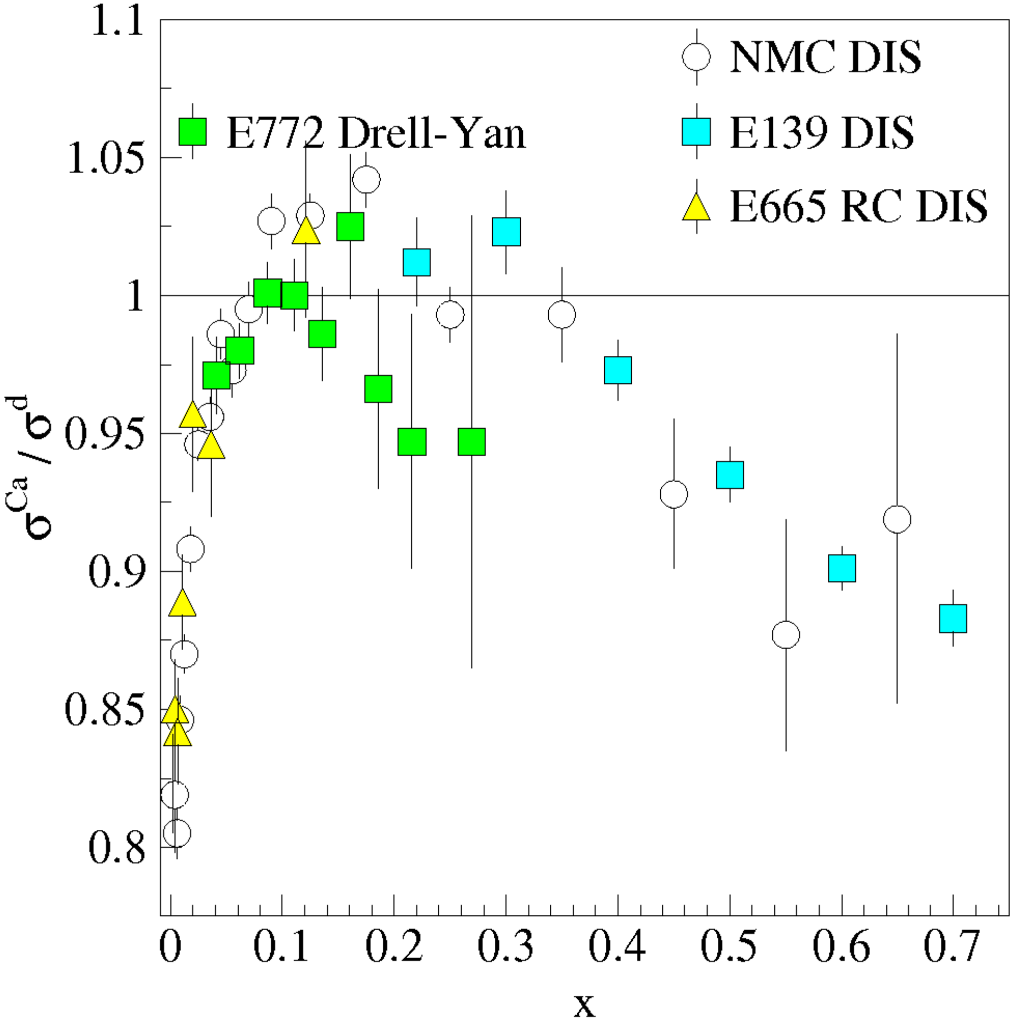
$$M^2 = x_1 x_2 s$$

Structure of nucleonic matter:
How do sea quark distributions differ in a nucleus?

Comparison with

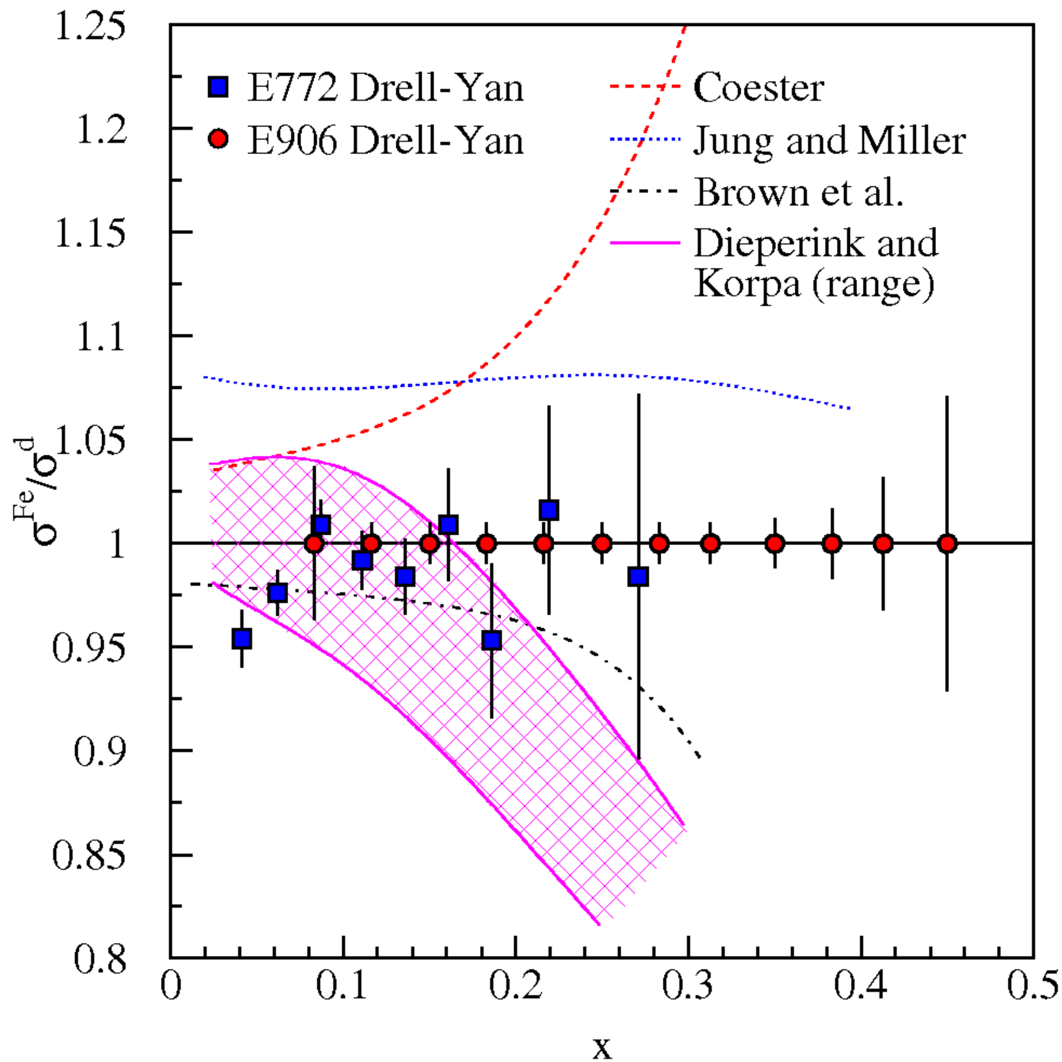
Deep Inelastic Scattering (DIS)

- EMC: Parton distributions of bound and free nucleons are different.
- Antishadowing not seen in Drell-Yan—Valence only effect?—better statistical precision needed—E906.
- Intermediate-*x* *sea* PDF's set by ν-DIS on iron—Are nuclear effects with the weak interaction the same as electromagnetic?
- What can the sea parton distributions tell us about the effects of nuclear binding?



Structure of nucleonic matter: Where are the nuclear pions?

- The binding of nucleons in a nucleus is expected to be governed by the exchange of virtual “Nuclear” mesons.
- No antiquark enhancement seen in Drell-Yan (Fermilab E772) data.
- Contemporary models predict large effects to antiquark distributions as x increases.



How can we do better with Drell-Yan?

The past:

FNAL E866/NuSea and E772

- 800 GeV proton beam

The future:

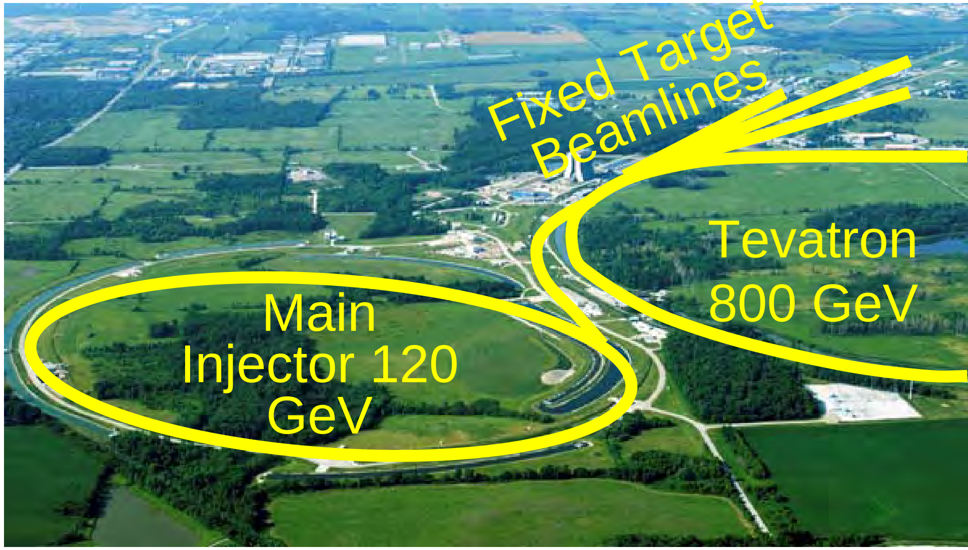
FNAL E906

- 120 GeV proton Beam

$$\frac{d^2\sigma}{dx_1 dx_2} = \frac{4\pi\alpha^2}{9x_1x_2}\frac{1}{s} \times \sum_i e_i^2 \left[q_{ti}(x_t)\bar{q}_{bi}(x_b) + \bar{q}_{ti}(x_t)q_{bi}(x_b)\right]$$

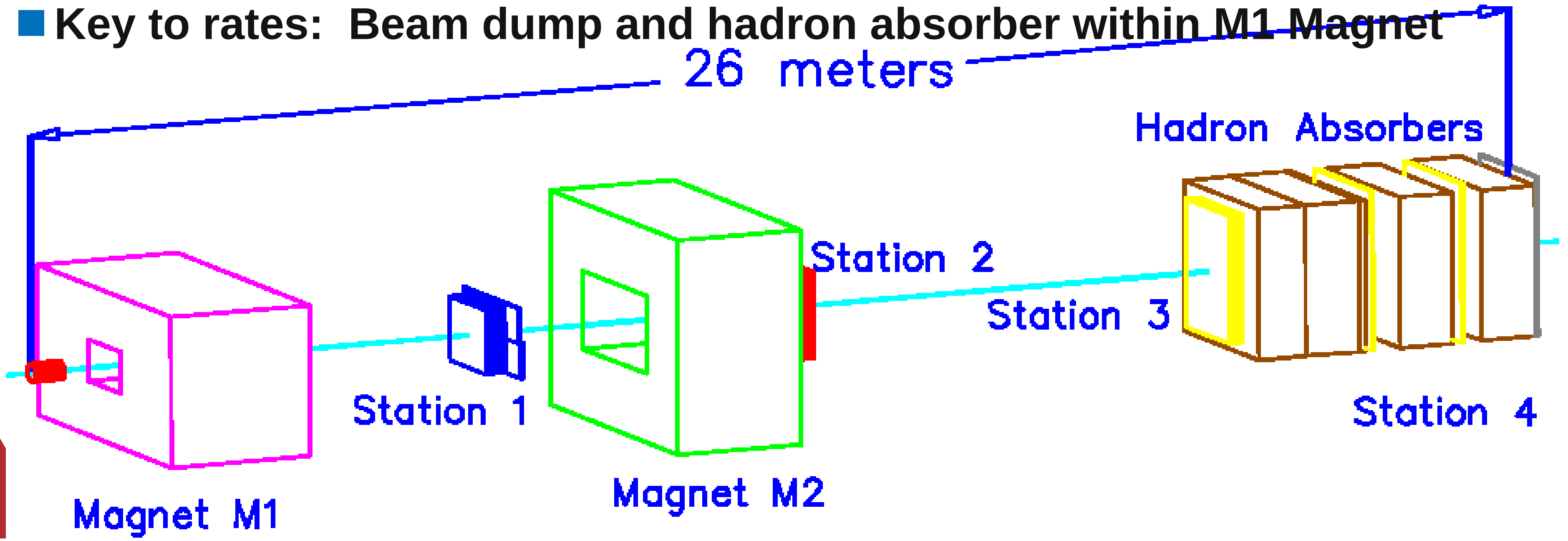
- Cross section scales as 1/s
  - *7× that of 800 GeV beam*
- Backgrounds, primarily from J/ψ decays scale as s
  - *7× Luminosity for same detector rate as 800 GeV beam*

50× statistics!!

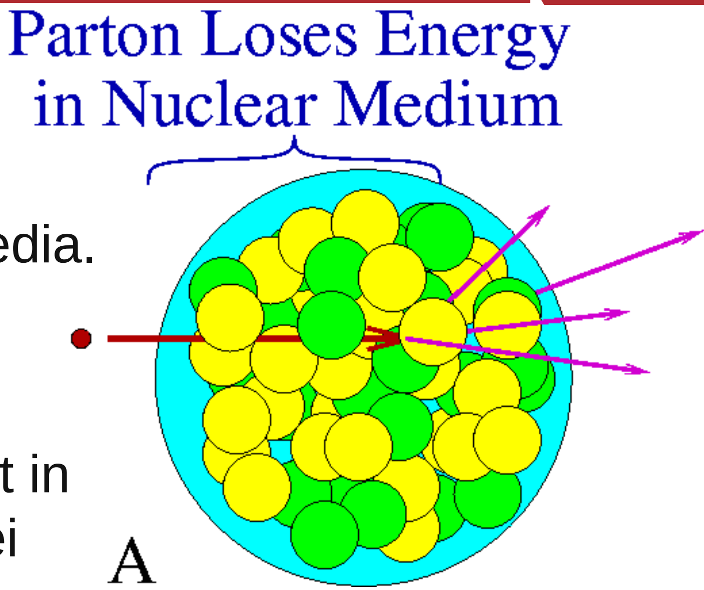


E906 Apparatus

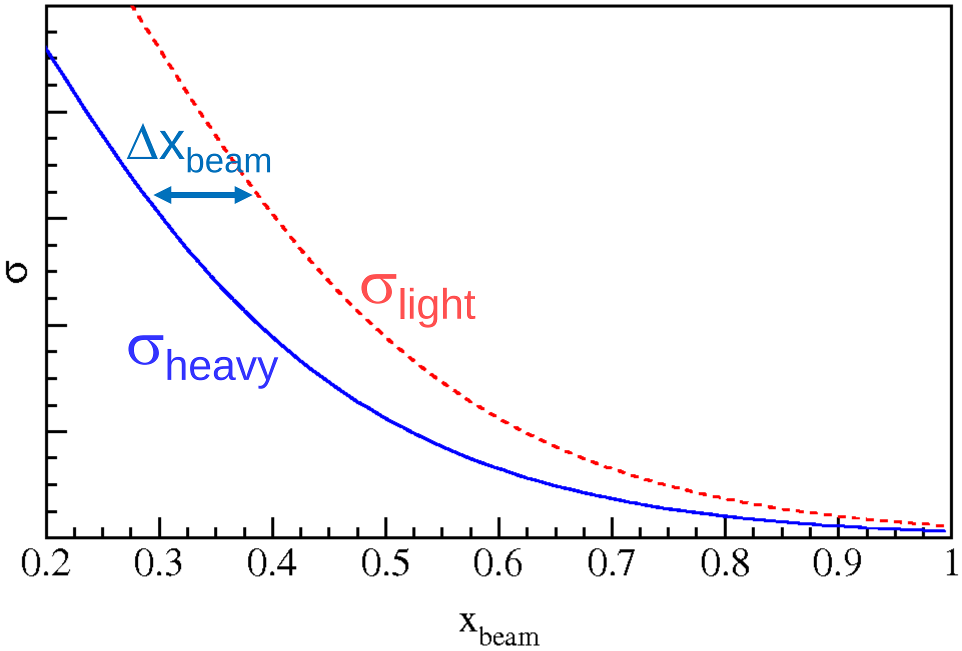
- Fermilab committed to running the experiment in 2009 (or sooner)
- Boost difference between 800 and 120 GeV requires shorter experiment.
  - Previous (E866) spectrometer was over 60m long; E906 spect. is only 26m long
  - Fabrication of new coils for M1 magnet (was 14.5 m long new M1 is only 4.8 m)
  - Complications with π decays between target and absorber
- Other items:
  - New Station 1 to handle higher rate
  - Replace some *very old* scintillators, additional phototubes
- Key to rates: Beam dump and hadron absorber within M1 Magnet



Parton Energy Loss



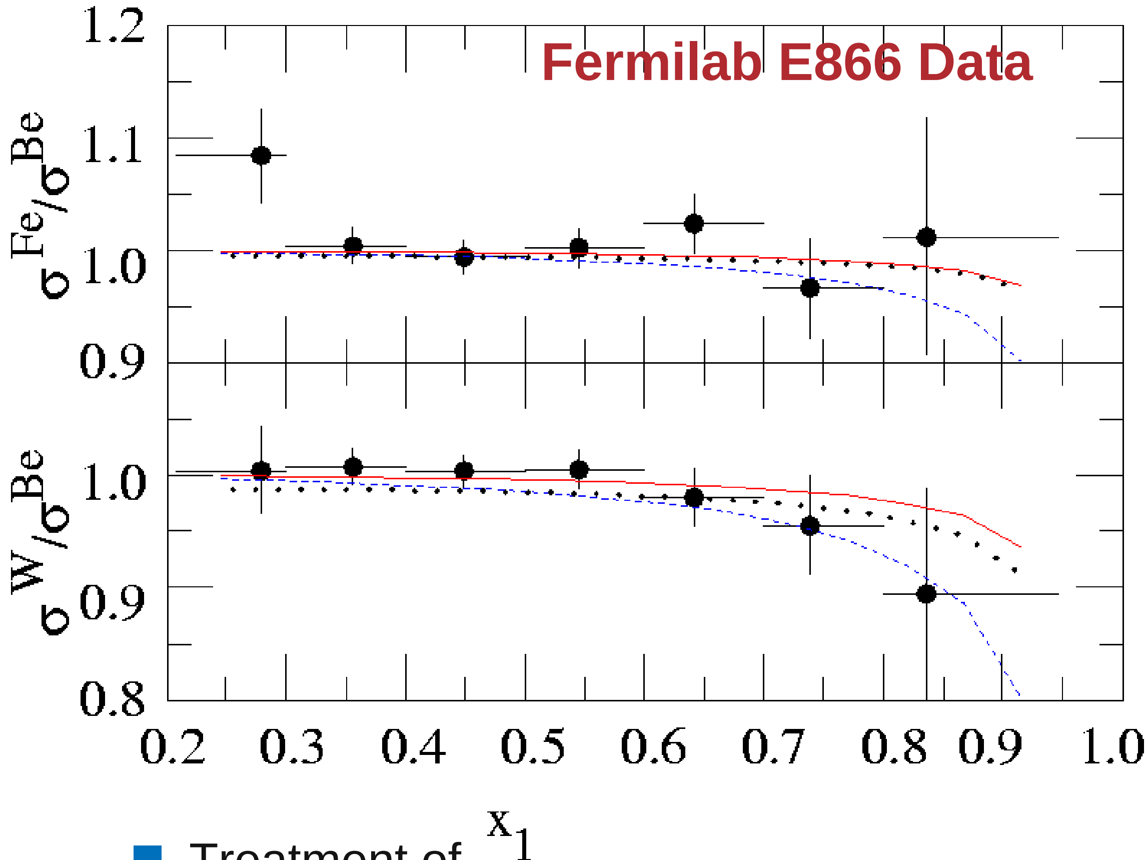
- **Important to understanding RHIC data.**
- Colored parton moving in strongly interacting media.
- Only initial state interactions
  - *no final state strong interactions*.
- In Drell-Yan, energy loss results in apparent shift in x_{beam} in a heavy nuclei compared with light nuclei



- Measure relative cross section in light and heavy nuclei
- Extract partonic energy loss

Parameterization of Energy Loss

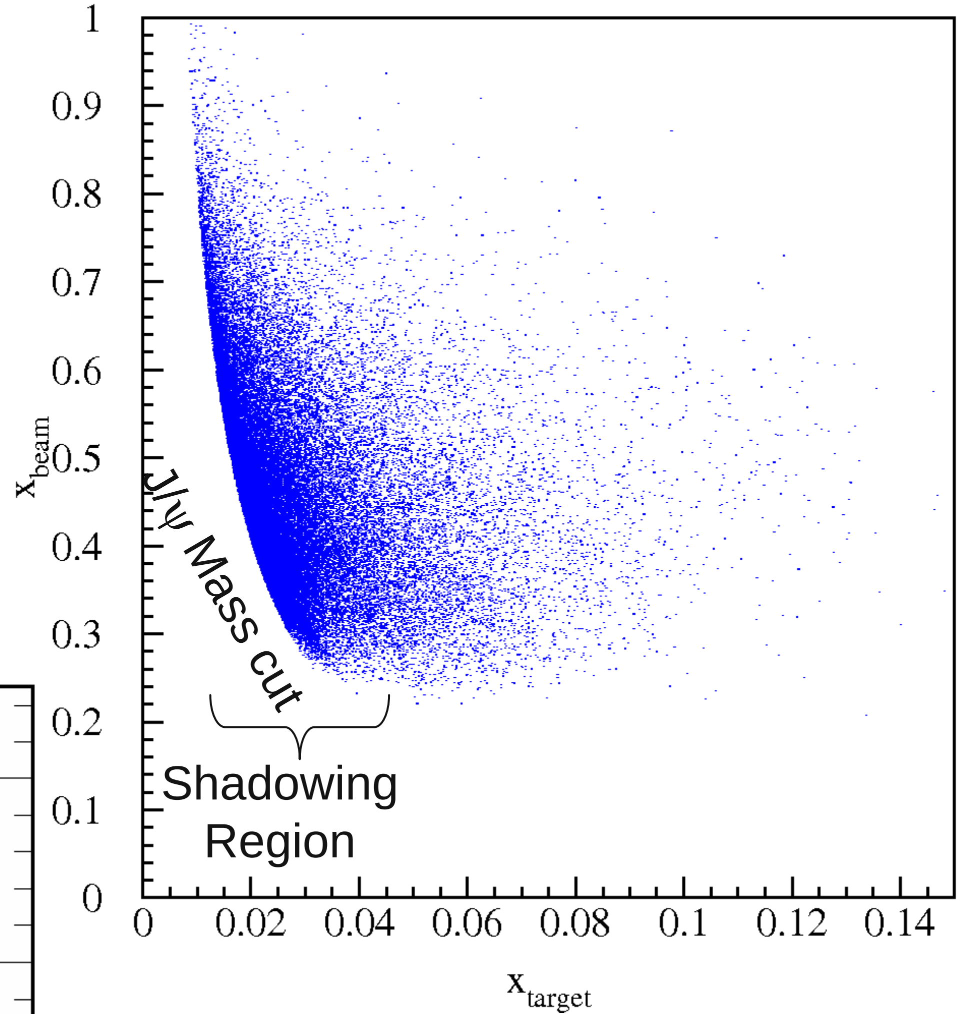
- $\Delta x_1 = -\kappa\, x_1\, A^{1/3}$
  Galvin and Milana,
  Phys. Rev. Lett. **68**, 1834 (1992)
  dE/dz < 0.014 fm
- $\Delta x_1 = -\kappa/s\, A^{1/3}$
  Brodsky and Hoyer,
  Phys. Lett. B **298**, 165 (1993)
  dE/dz < 0.044 GeV/fm
- $\Delta x_1 = -\kappa/s\, A^{2/3}$
  Baier *et al.*,
  Nucl. Phys. **B484**, 265 (1997)
  dE/dz < 0.046 GeV/fm$^2 \times$ L
- **E866 analysis consistent with no energy loss**



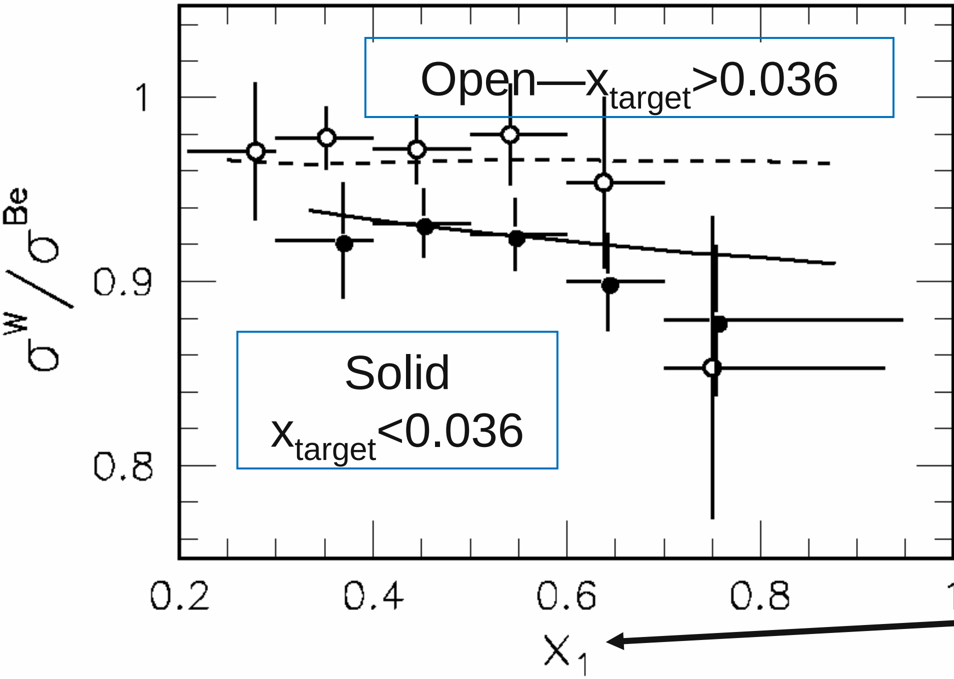
- Treatment of
  - **parton propagation length** and
  - **shadowing are critical**
  - Johnson *et al.*—2.2 GeV/fm from same data
- Energy loss $\propto$ 1/s—larger at 120 GeV

Partonic Energy Loss: Shadowing

- E866 Acceptance correlates x_{beam} and x_{target}
- Correct (event by event) for DIS shadowing (EKS)
- Look for partonic energy loss in residual nuclear dependence

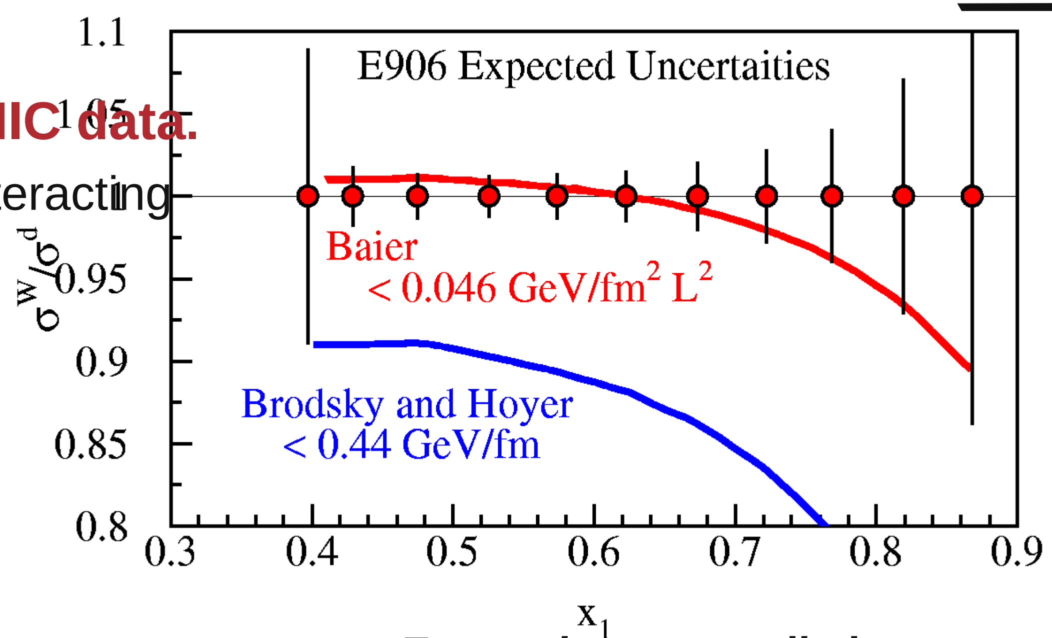


- DIS Shadowing describes Drell-Yan shadowing well



Function of x_{beam}

Parton Energy Loss



Energy loss upper limits based on E866 Drell-Yan measurement

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Drell-Yan at Fermilab

- **Fixed-Target Drell-Yan is the … the quark sea.**
- **What is the structure of nucleonic matter?**
  - Is antishadowing a valence effect?
  - Where are the nuclear pions?
- **Do partons lose energy in th…**
- **What is the structure of the nucleon?**
  - d-bar/u-bar at intermediate-x
  - Large-x valence distributions
- **Answers from Fermilab**
  - Significant increase in phys…
  - Scheduled to run in 2009