Duality in Meson Electroproduction

(E00-108)

Tigran Navasardyan

Hall C Collaboration Meeting

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Outline

- The E00-108 Experiment
- Physics motivation
- Analysis status
- Simulation
- Current results
- Problems and what next to do.

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The Experiment

- **HMS** was detecting hadrons , $\pi^{\pm}$
- **SOS** was set for electrons , e^{-}
- **DAQ** in coincidence mode
- 3 groups of measurement have been conducted:
  - I. Z-scan → 8 different Z settings at fixed X_{Bj}
  - II. X-scan → 5 different X_{Bj} settings at fixed Z
  - III. P_t-scan → 5 different θ_{pq} settings at fixed Z and X_{Bj}.

$X_{Bj} = \frac{Q^2}{2M\nu}$ - Bjorken X

$Z = \frac{E_h}{\nu}$ - part of energy taken by hadron.

P_t - transverse momentum of the meson relative to virtual photon.

θ_{pq} - lab. angle between the virtual photon and outgoing meson.

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Quark-Hardon Duality

complementary between quark and hadron description

At high enough energy:

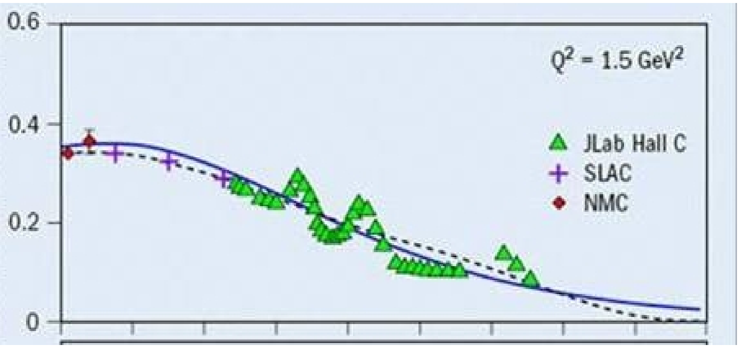
Hadronic Cross Sections averaged over appropriate energy range

Perturbative Quark-Gluon Theory

$$\Sigma_{hadrons} = \Sigma_{quark+gluons}$$

Can use either set of complete basis states to describe physical phenomena.
But why also in limited local energy ranges?

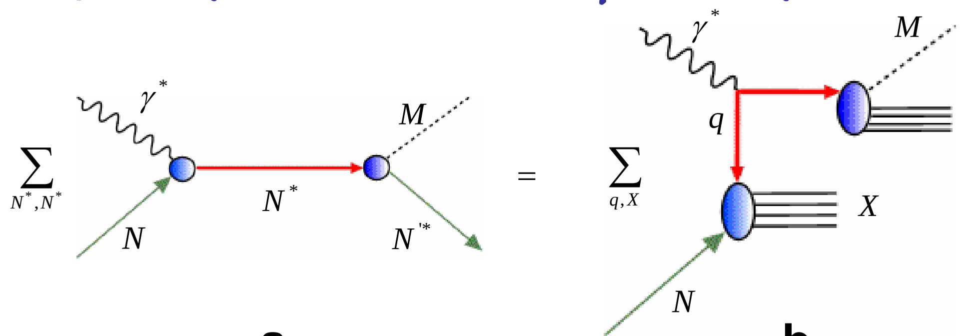
Duality works well.



Predicted to also appear in semi-inclusive scattering processes
(Carlson et al, 1998)

Duality in Semi-inclusive Reactions

- Duality description of semi-inclusive ($eN \rightarrow ehX$) meson production in terms of nucleon resonance excitation (a), and parton phenomenology (b).



a. b

- Cross section is given by a product of quark distribution and quark → hadron fragmentation function

$$\frac{d\sigma}{dxdz} \sim \sum_q e_q^2 \, q(x) \, D_{q\rightarrow h}(z)$$

and a little bit more complicated

$$\frac{\dfrac{d\sigma}{d\Omega_e dE_e dx dP_\perp^2 d\varphi}}{\dfrac{d\sigma}{d\Omega_e dE_e}} = \frac{dN}{dz} b \exp(-bP_\perp^2) \frac{1 + A\cos\varphi + B\cos 2\varphi}{2\pi}$$

At high energies:

1. *No φ dependence*
2. *Measured $P_\perp$ dependence*
3. *Cross section factorization*

The Analysis Procedure

Factors taken into account:

- All efficiencies and dead times;
- Decayed pion loss (~ 20 %);
- FSI corrections for Deuterium target (~4 %);
- Radiative corrections made with *SIMC* checked with POLRAD /HAPRAD/ (typically 5-10 %);
- Exclusive events radiative "tail" subtractions;
- Scale off ρ^o contribution;
- $k^{\pm}$ - mesons substraction (~2-9 %);
- Improved tracking pruning code and coincidence time path length correction.

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How Can We Verify Factorization?

$$\frac{d\sigma}{dxdz} \sim \sum_q e_q^2 q(x) D_{q\to h}(z)$$

Neglect sea quarks and assume no p_t dependence to parton distribution functions

→ Fragmentation function dependence drops out in Leading Order

→ $[\sigma_p(\pi^+) + \sigma_p(\pi^-)]/[\sigma_d(\pi^+) + \sigma_d(\pi^-)]$

$= [4u(x) + d(x)]/[5(u(x) + d(x))]$

$\sim \sigma_p/\sigma_d$ *independent of z*

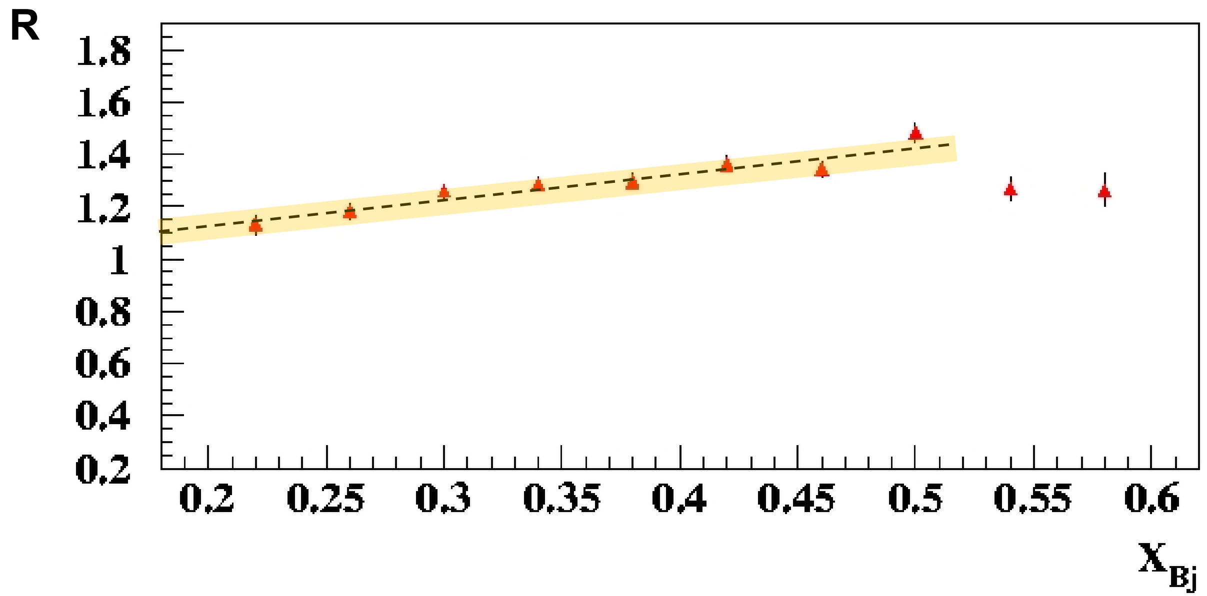
→ $[\sigma_p(\pi^+) - \sigma_p(\pi^-)]/[\sigma_d(\pi^+) - \sigma_d(\pi^-)]$

$= [4u(x) - d(x)]/[3(u(x) + d(x))]$

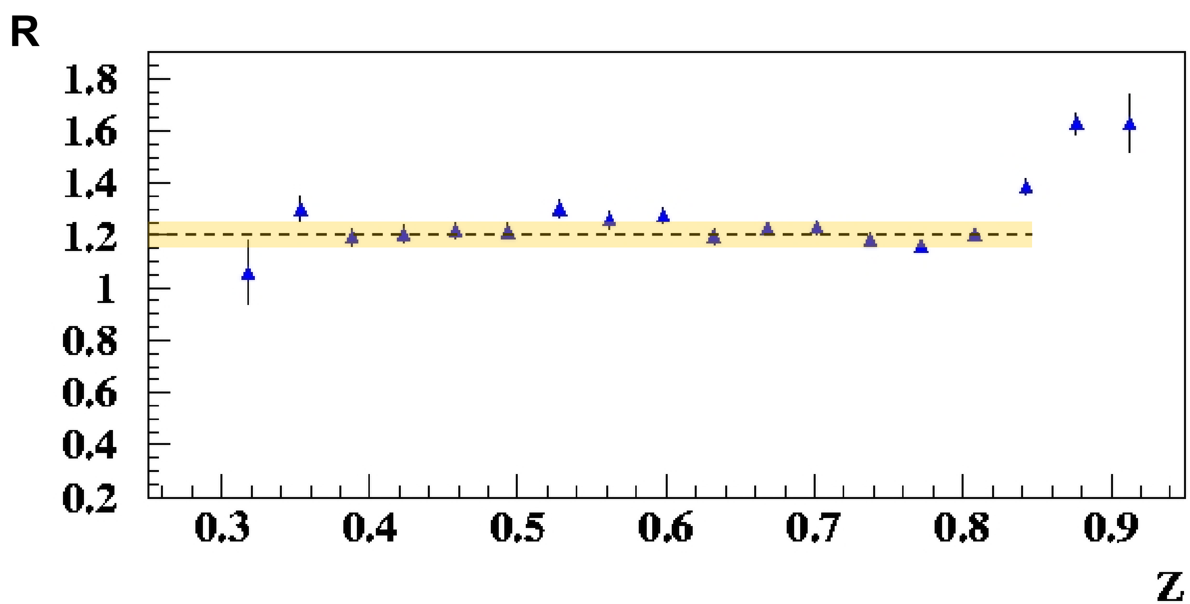
independent of z ,
but more sensitive to assumptions

$$R = \frac{\sigma_p(\pi^+)+\sigma_p(\pi^-)}{\sigma_d(\pi^+)+\sigma_d(\pi^-)}$$

Expected x dependence



independent of z



- Dotted line is LUND Monte-Carlo.

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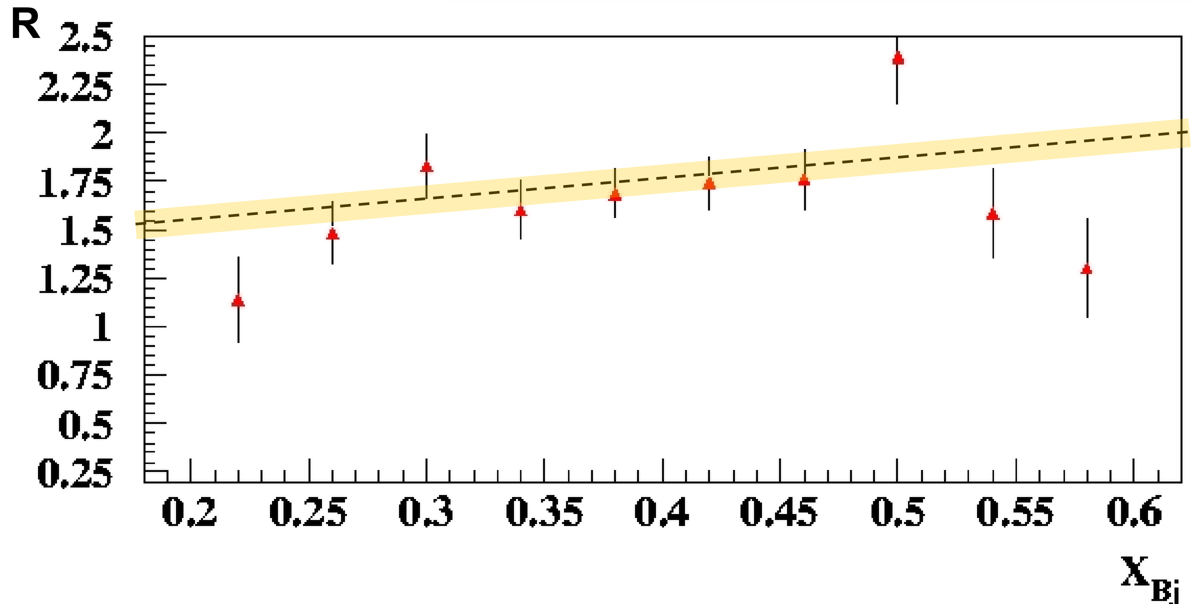
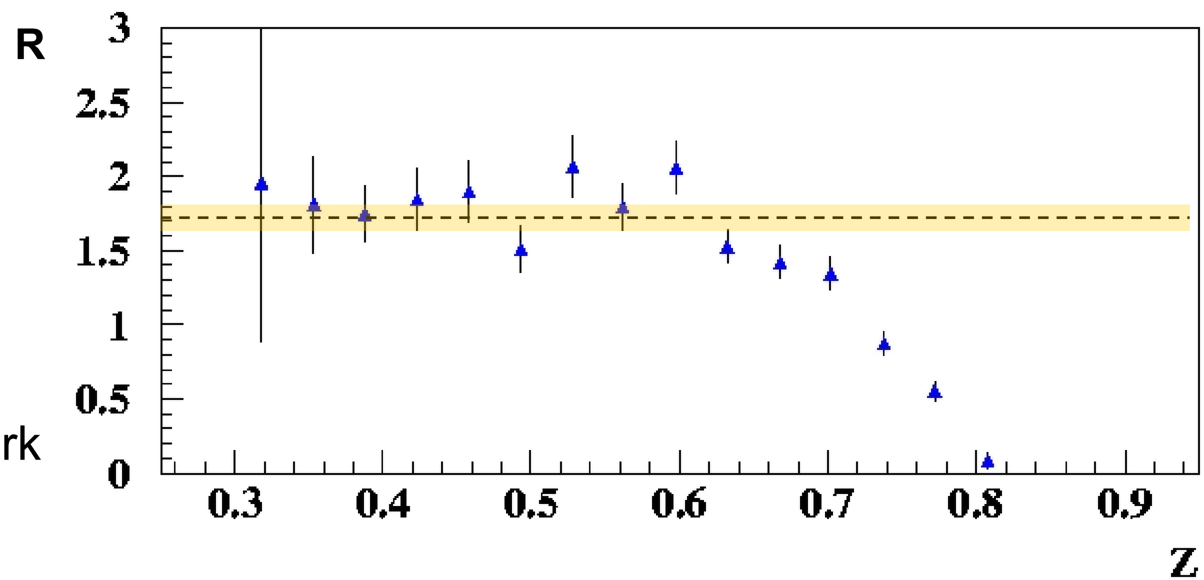
$$R = \frac{\sigma_p(\pi^+) - \sigma_p(\pi^-)}{\sigma_d(\pi^+) - \sigma_d(\pi^-)}$$

Expected x dependence



independent of z



Difference clearable more sensitive , but seems to work from z<0.65

Simulation

• For the simulation the standard SIMC package has been used with an addition of semi-inclusive cross section:

$$\sigma_{e,e'\pi x} \approx \sigma_{e,e'x} \frac{dN}{dz}(1 + A\cos\varphi + B\cos 2\varphi) b e^{-bP_t^2}$$

where

$$\frac{dN}{dz} \to \frac{\sum_i q_i^2 U_i(x,Q^2) D_i(z,Q^2)}{\sum_i q_i^2 U_i(x,Q^2)}$$

• CTEQ5 parametrization for parton distributions.

• BKK parametrization for the fragmentation functions.

• To separate favored and unfavored fragmentation functions a parametrizations of D^+/D^- from HERMES is used.

• DIS cross section was calculated through F_1 and F_2 structure functions.

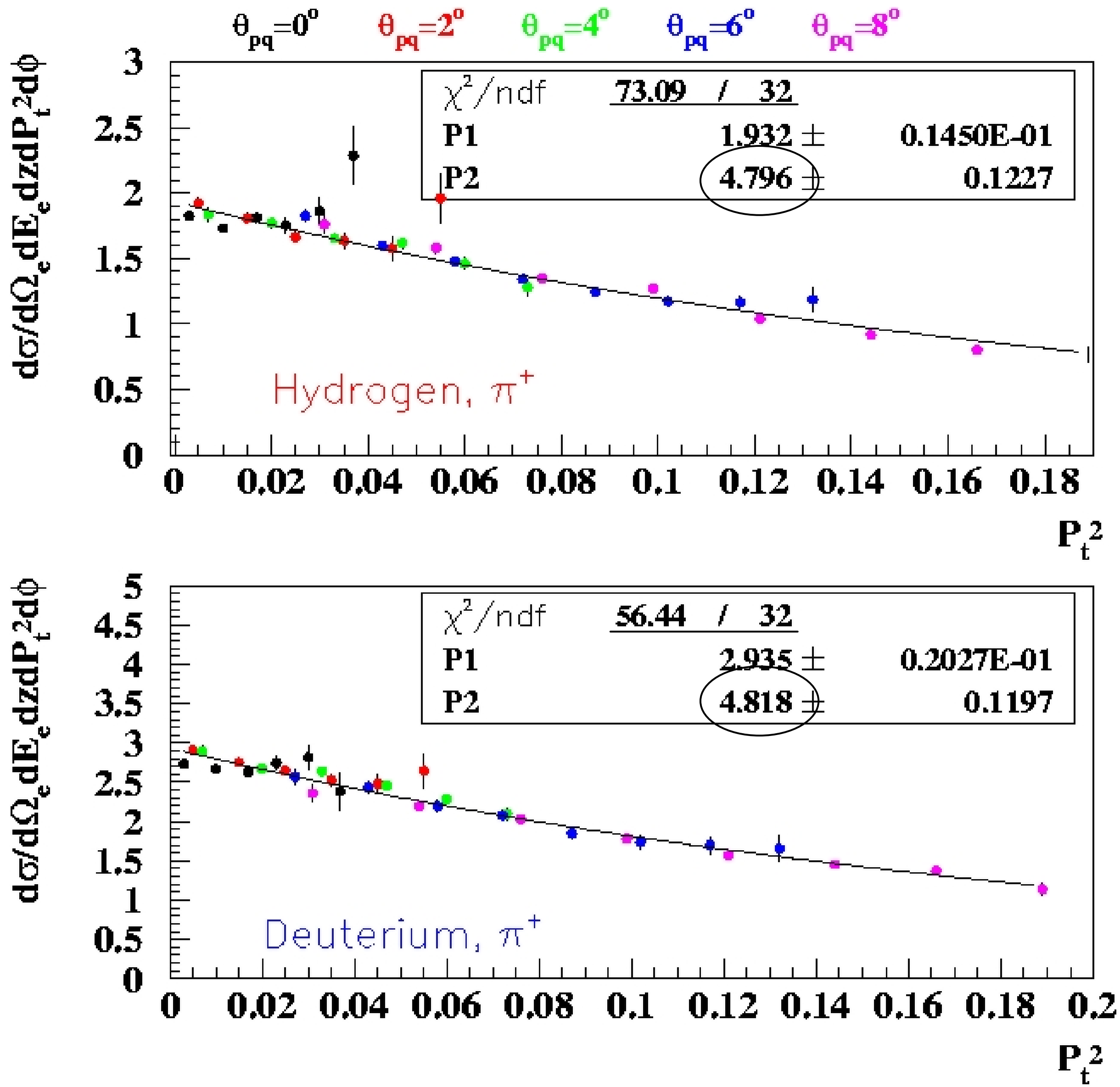
• Explicit φ and P_t^2 dependences are added in model.

• Q^2 dependence is included in the model to better describe experimental data

HERMES → b=4.69

SLAC → b=4.61

- Almost final ±10%



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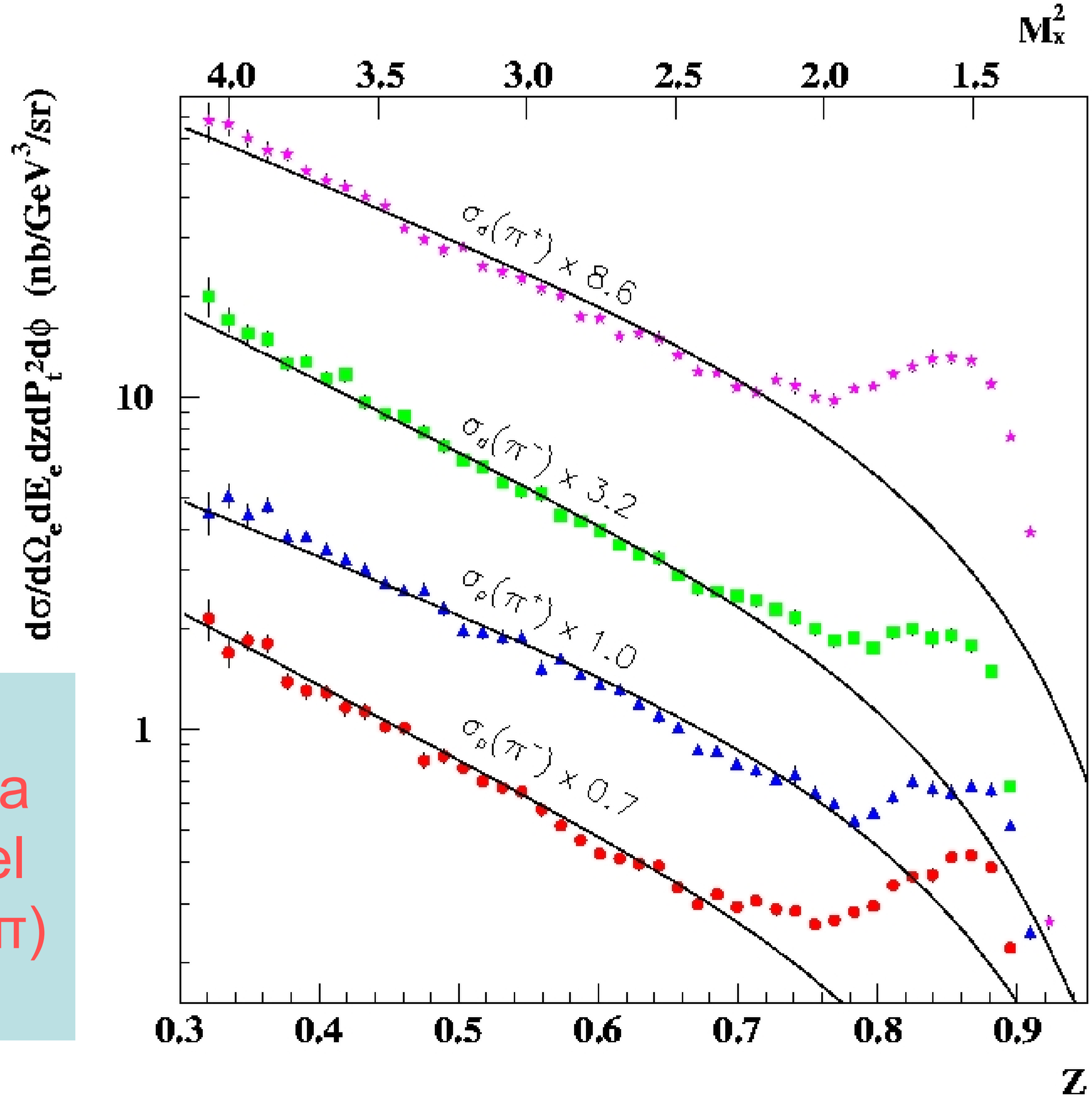
- Solid curves SIMC

$$\sigma_{\exp} = \frac{Y_{\exp}}{Y_{MC}} \sigma_{mc}$$

SIMC assume factorization and is a simple parton model assumption of (e,e/ π) process



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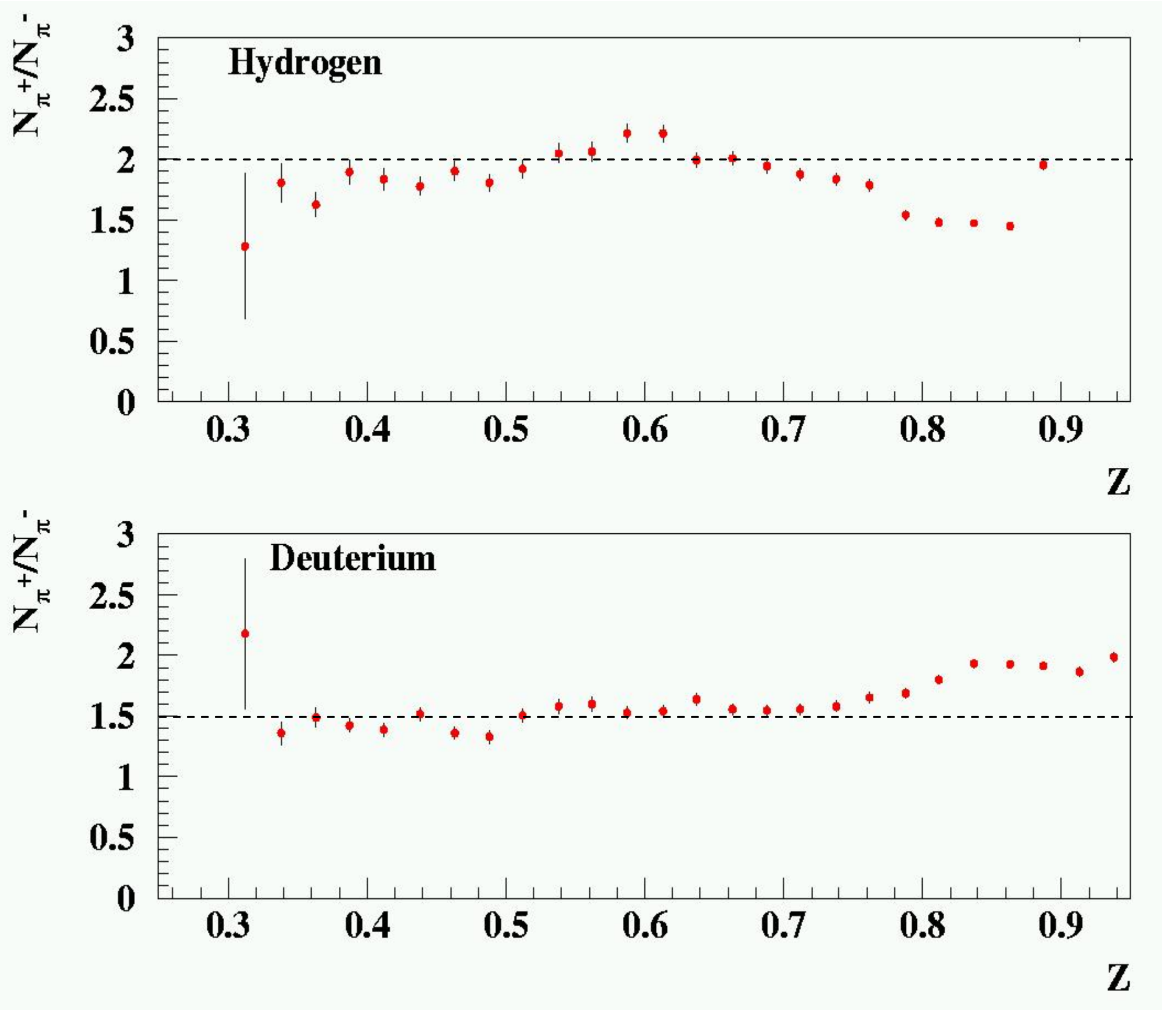
- Acceptance, kinematic and bin centering corrections are canceled in π^+/π^- ratios.

- π^+/π^- ratio expected to be flat in Z at the fixed X_{Bj} according to the previous experiments (SLAC, Cornell, DESY).



- From the simple quark count and SU(6) symmetry, ratio over ratio for Hydrogen should be at the level ~2, and for Deuterium 3/2 .

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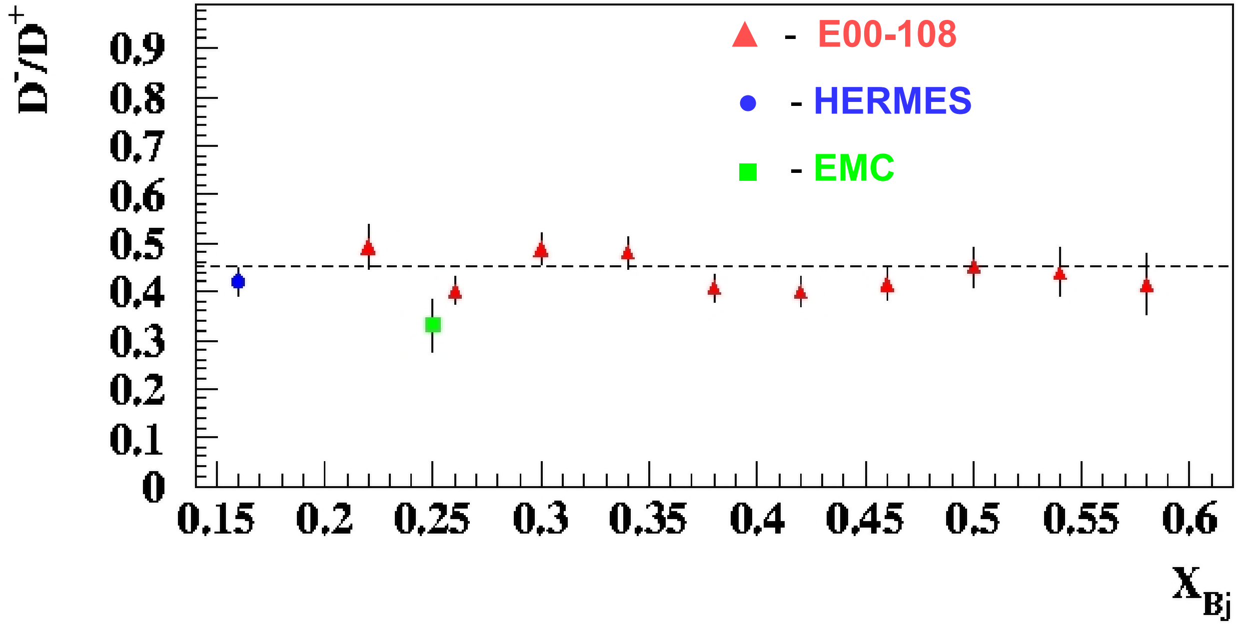
$$\frac{d\sigma}{dxdz} \sim \sum_q e_q^2 q(x) D_{q\to h}(z)$$

$$\frac{D^-}{D^+} = \frac{4 - N_{\pi^+}/N_{\pi^-}}{4 * \left(N_{\pi^+}/N_{\pi^-}\right) - 1}$$



D^- is the "favored" and D^+ is the "unfavored" fradmentation functions

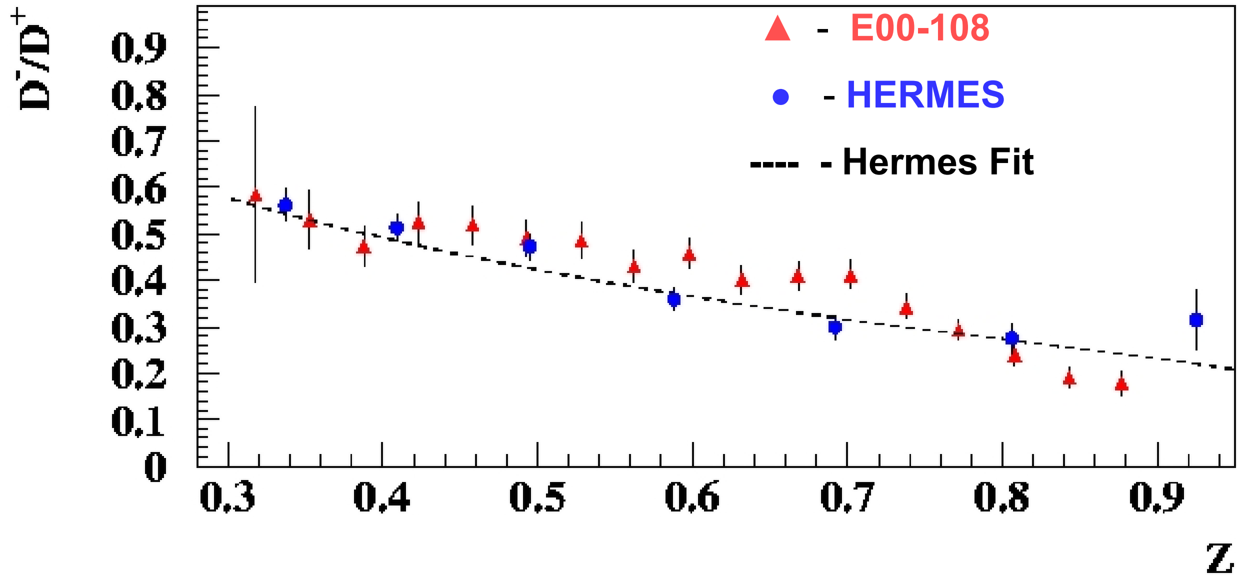
- Strange quark contribution neglected.

⟶ D^-/D^+ ratio should be independent from X_{Bj}

but ….

$$\frac{D^-}{D^+} = \frac{4 - R}{4 * R - 1}$$

where $R = \frac{N_{\pi^+}}{N_{\pi^-}}$



→ … should depend on Z

Similar slope versus Z at HERMES

Conclusion

- ***Data indicate a surprisingly smooth transaction from "Quark model physics" to "Parton Model Physics" at low Q^2***
- Evidence of cross-section factorization.
- Data seem to confirm the high energy physics predictions.
- Results are close to the data from experiments at higher energies.

What next ?

- Iterate the model.
- Calculate cross-sections.
- Estimate systematic errors.