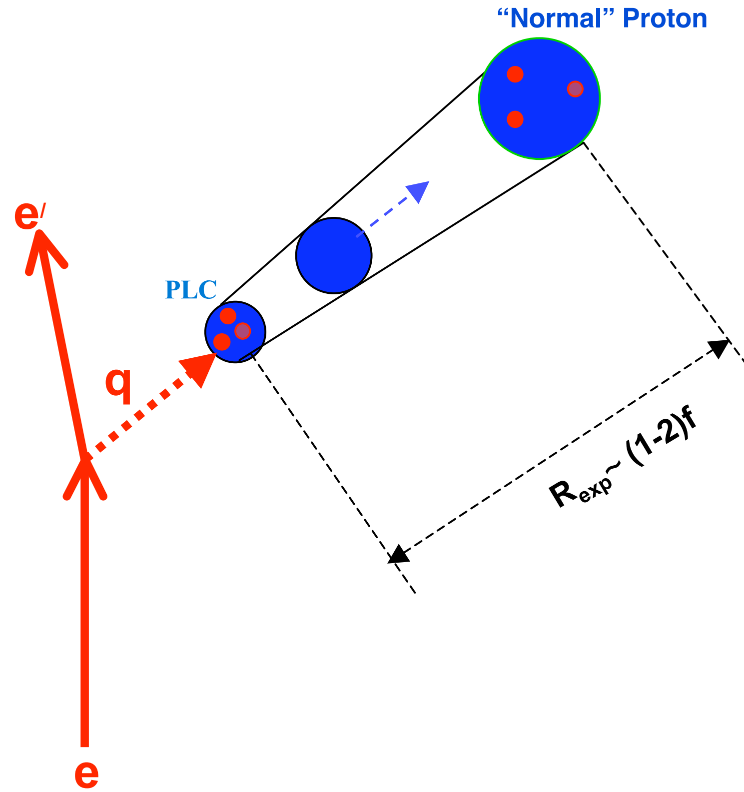
Search for color screening of protons in the exclusive d(e,e'p)n reaction with $1.75 < Q^2 < 6.5$ GeV^2

K. Egiyan, K. Griffioen, J-M. Laget

Point Like Configurations of the proton

- QCD predicts the production of small color-singlet objects in hard elastic electron-nucleon scattering.
- These are called point-like configurations (PLCs).
- Due to its small transverse size (and **quark screening**), the PLC interaction cross section should be lower than for a normal nucleon.
- PLCs expand rapidly to normal nucleon size.
- The expansion length R_{exp} depends strongly on Q^2, and for Jlab we expect $R_{exp} \approx 1\text{–}2$ fm.
- But how can we identify a PLC?

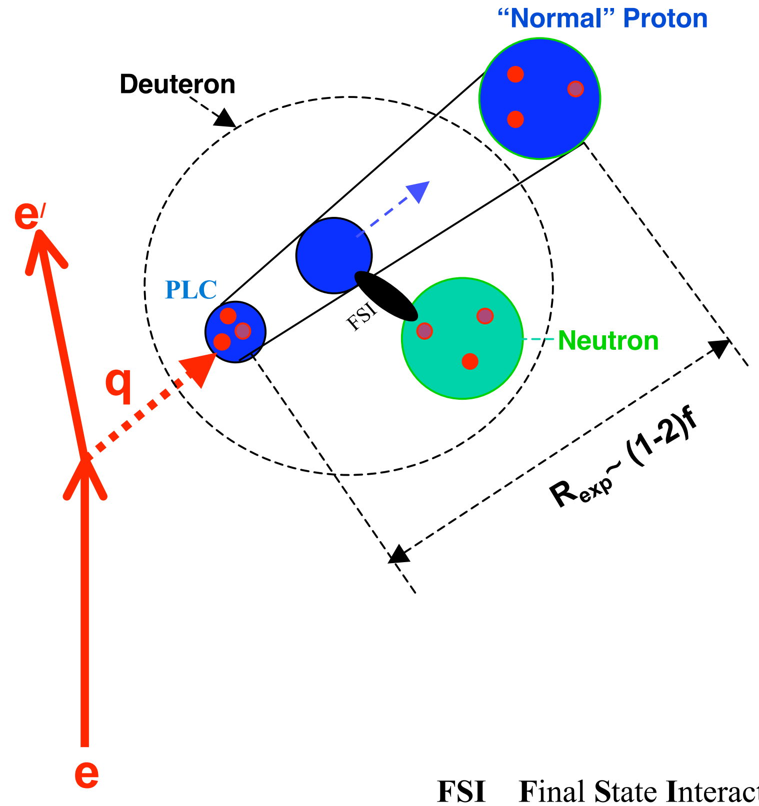


Identifying a PLC

- Measure a reduced hadronic interaction cross section.
- Use nucleon placed less than R_{exp} away (i.e. use a nucleus)
- Use light nuclei (small radii R_A) and high Q^2 (large R_{exp}) such that

$$R_{exp} > R_A$$

- This eliminates interactions once the PLC has expanded to normal size.
- Measure final-state interactions (FSIs).
- Reduced FSIs indicate a PLC.



FSI _ Final State Interaction

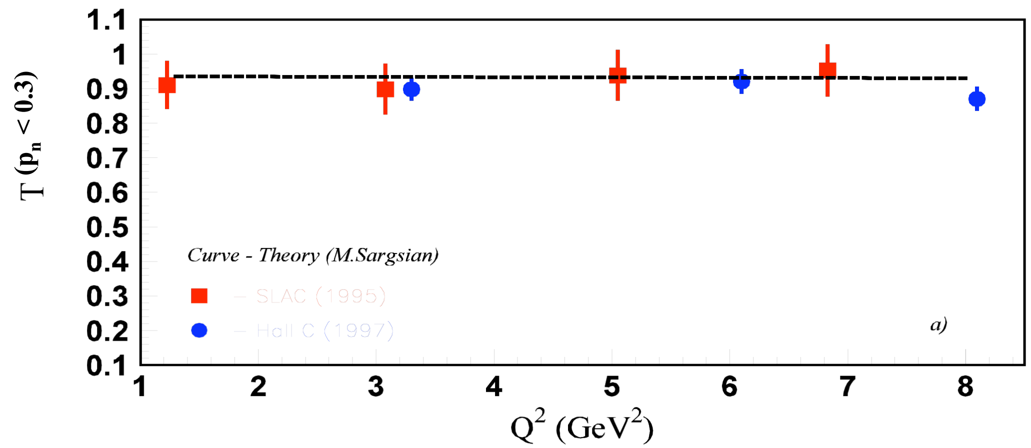
Existing data on color screening for protons in deuterium

- Color screening (CS) was investigated at SLAC (1995) and at JLab (1997).

- Conclusions from these data:
  - No CS is observed for $Q^2 < 8$ GeV^2

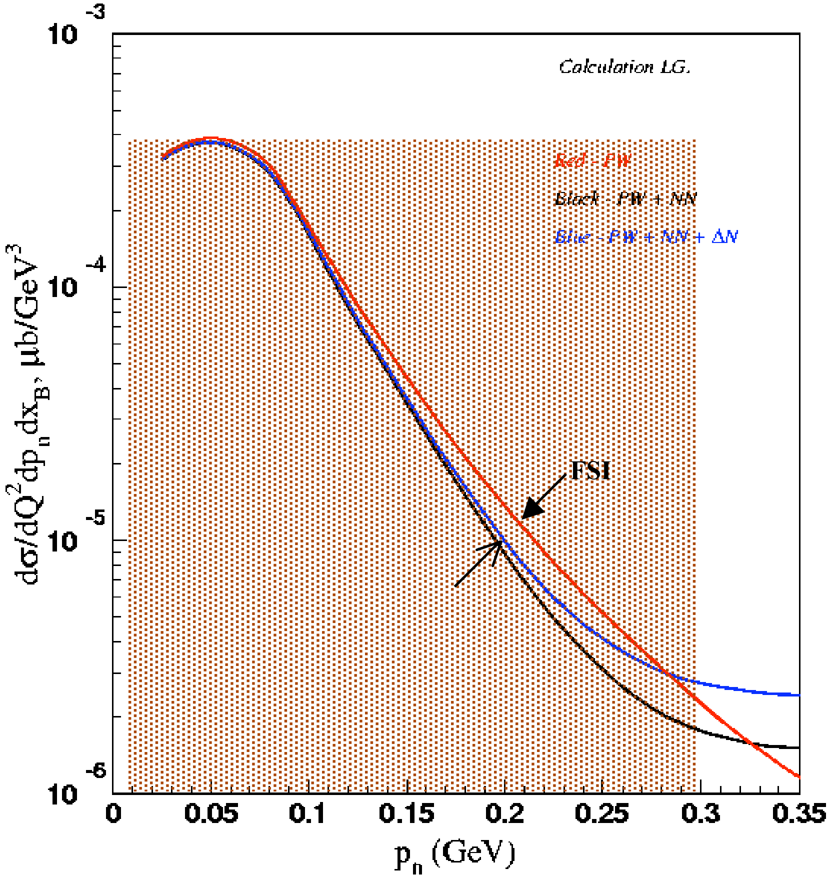
- However:
  - Integration over **$0<p_n<0.3$** GeV strongly reduces the FSI and therefore the CS contribution.
  - Expected CS effect has the same order of magnitude as the experimental errors.
  - New data are needed:
    - with better accuracy
    - without the integration over $0 <p_n<0.3$ GeV, using instead the kinematics most sensitive to FSIs.

$$T = \sigma_{exp}(p_n<0.3)/\sigma_{PWIA}(p_n<0.3)$$

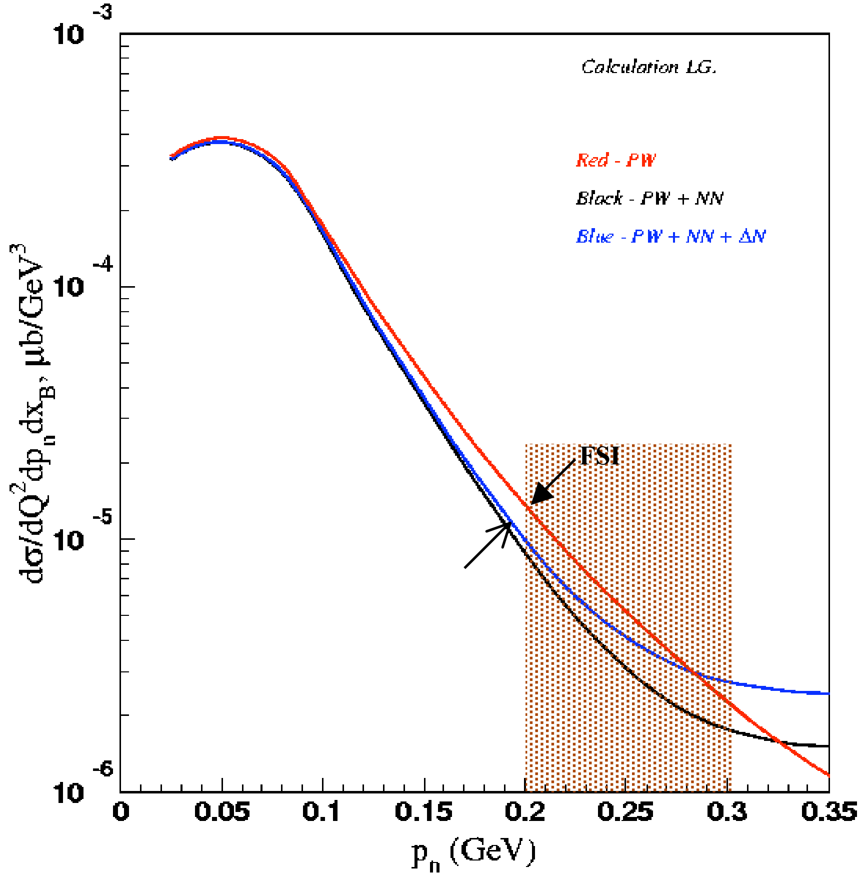


Integration over spectator nucleon momentum

Integration over $0<p_n<0.3$ GeV
reduces sensitiveity to CS (existing data)



Integration over $0.2 <p_n<0.3$ GeV
increases sensitivity to CS (our data)



Enhancement of FSIs at $\alpha_n = 1$

$$\alpha_n = \frac{E_n - p_n\cos\theta_n}{M_n}$$

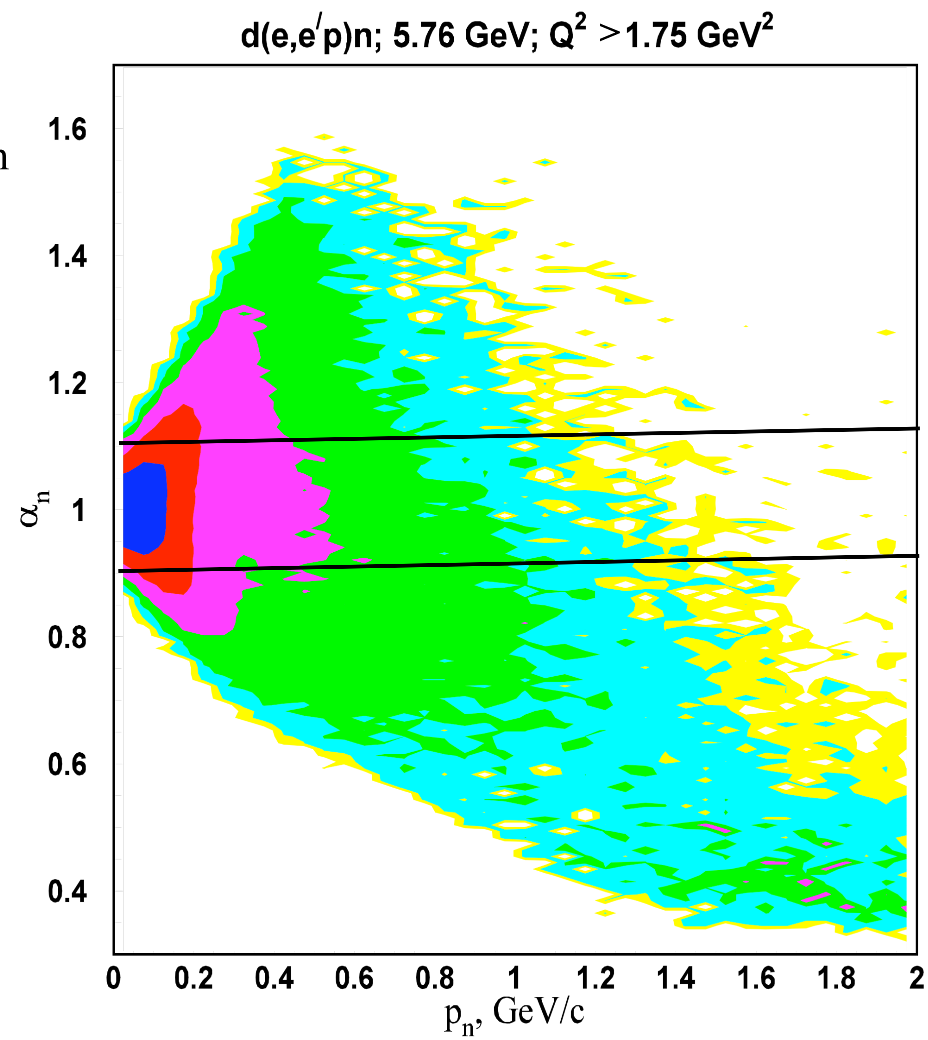
- Light-cone fraction of the deuteron momentum carried by the neutron.
- At $\boldsymbol{\alpha_n = 1}$, either

  $p_n=0$,

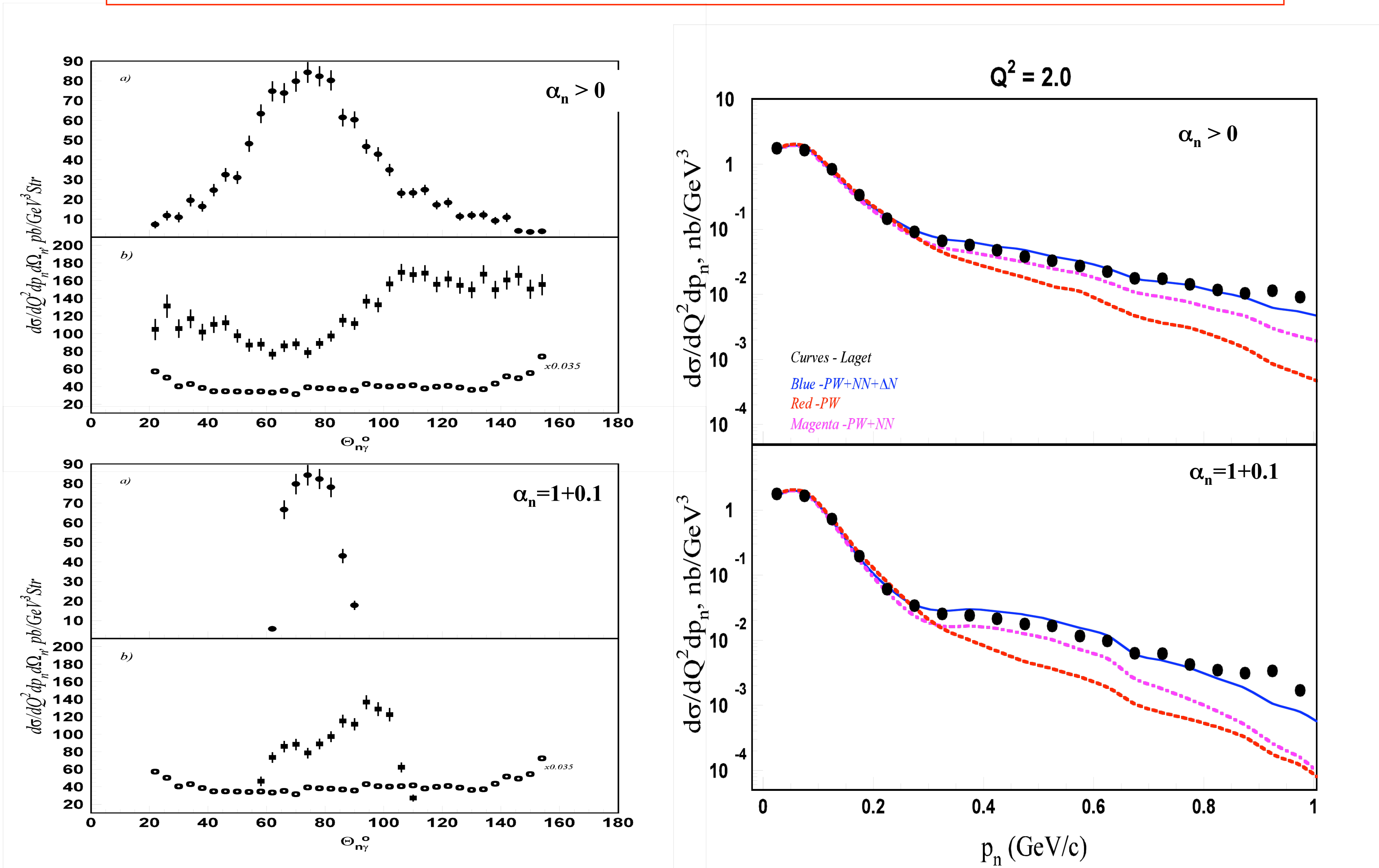
  or

  $p_n=2M.\cos\theta_n/\sin^2\theta_n/2$
- Neutron momentum range is $p_n \geq 0$
  - ♣ Very low momentum (including $p_n=0$) is dominant, which enhances FSIs
- We choose the cut

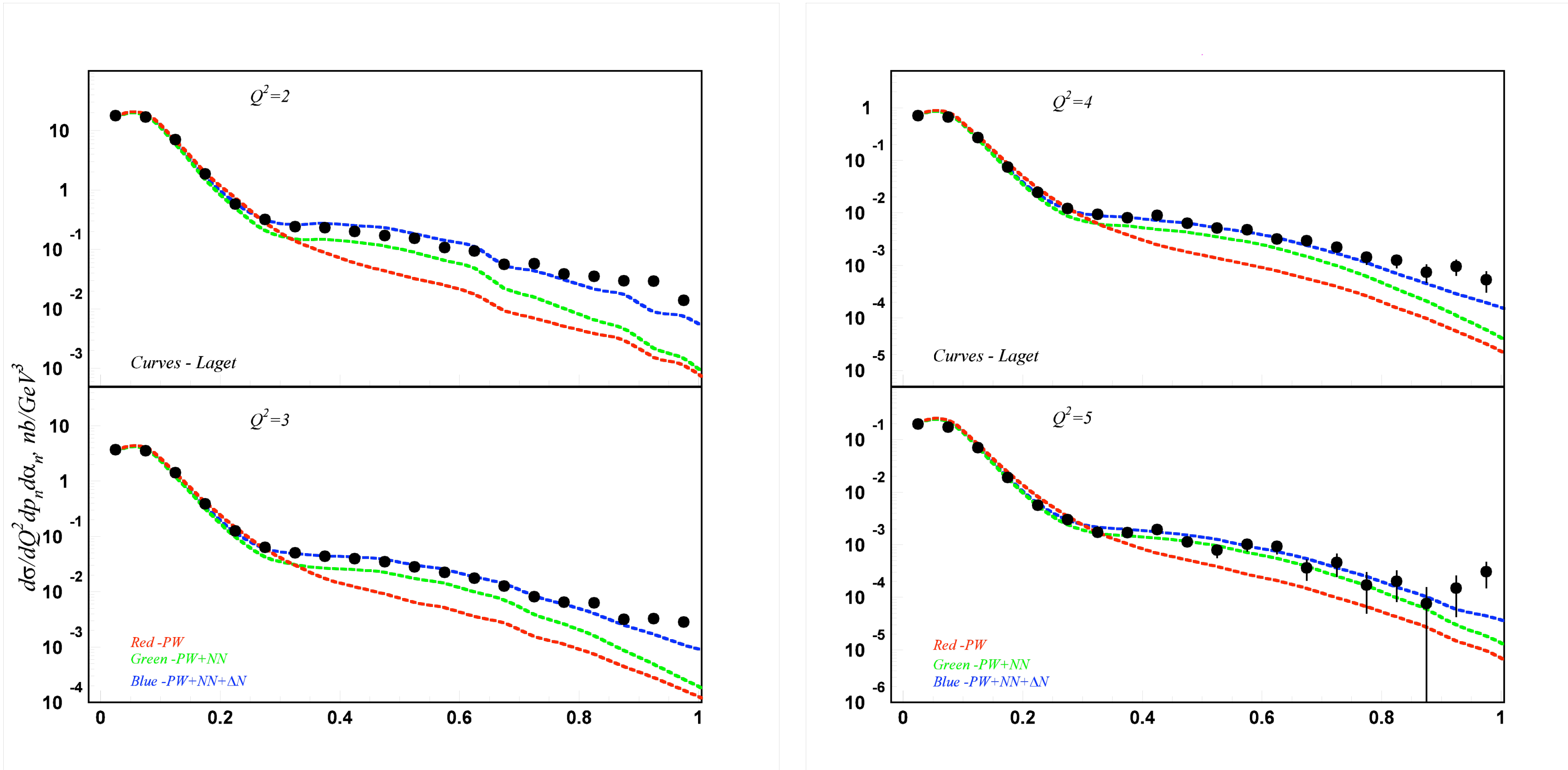
  $\alpha_n = 1\pm0.1$



Data at $\alpha_n = 1$

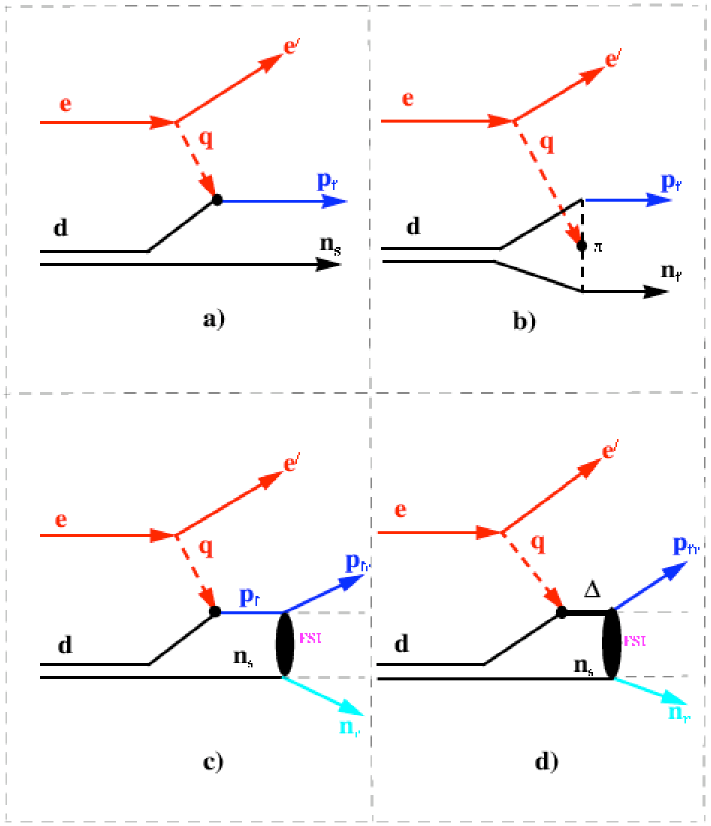


Recoil neutron momentum distributions with α=1±0.1, compared with MC calculations by Laget. There is with good agreement, especially for $p_n < 0.8$ GeV/c.



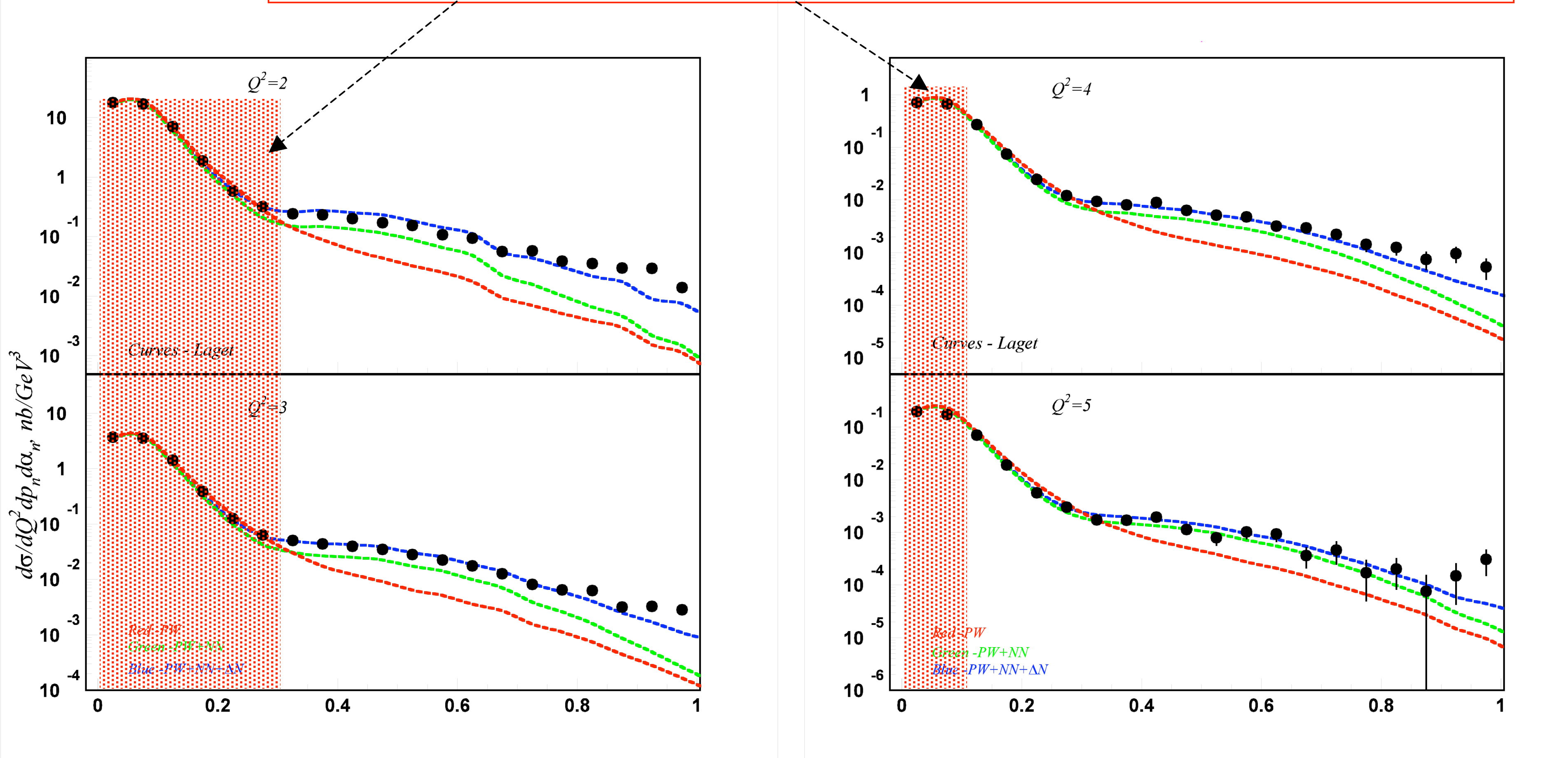
Contributing Feynman diagrams

- Paris potential used for the deuteron wave function.
- a) PWIA – (ep) interaction for on-shell proton
- b) MEC – small for our Q^2 range
- c) FSI = p + n → p + n (elastic)
- d) FSI = Δ + n → p + n
- For c) – world's data on (pn) and (pp) total cros sections and angular distributions are used.
- For d) – existing data on the Q^2-dependence of the N-Δ transition form factor are used.



High-accuracy data from CLAS

- Define a new variable sensitive to CS
- For $p_n < 0.1$, no expected FSIs and no CS
- $\mathbf{T = \sigma_{exp}(p_n<0.3)/\sigma_{exp}(p_n<0.1)}$ ⟶ significantly reduces systematic errors



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CLAS data integrated over regions of p_n vs. Q^2

Black - $0<p_n<0.1$ GeV/c

Red - $0<p_n < 0.3$ GeV/c

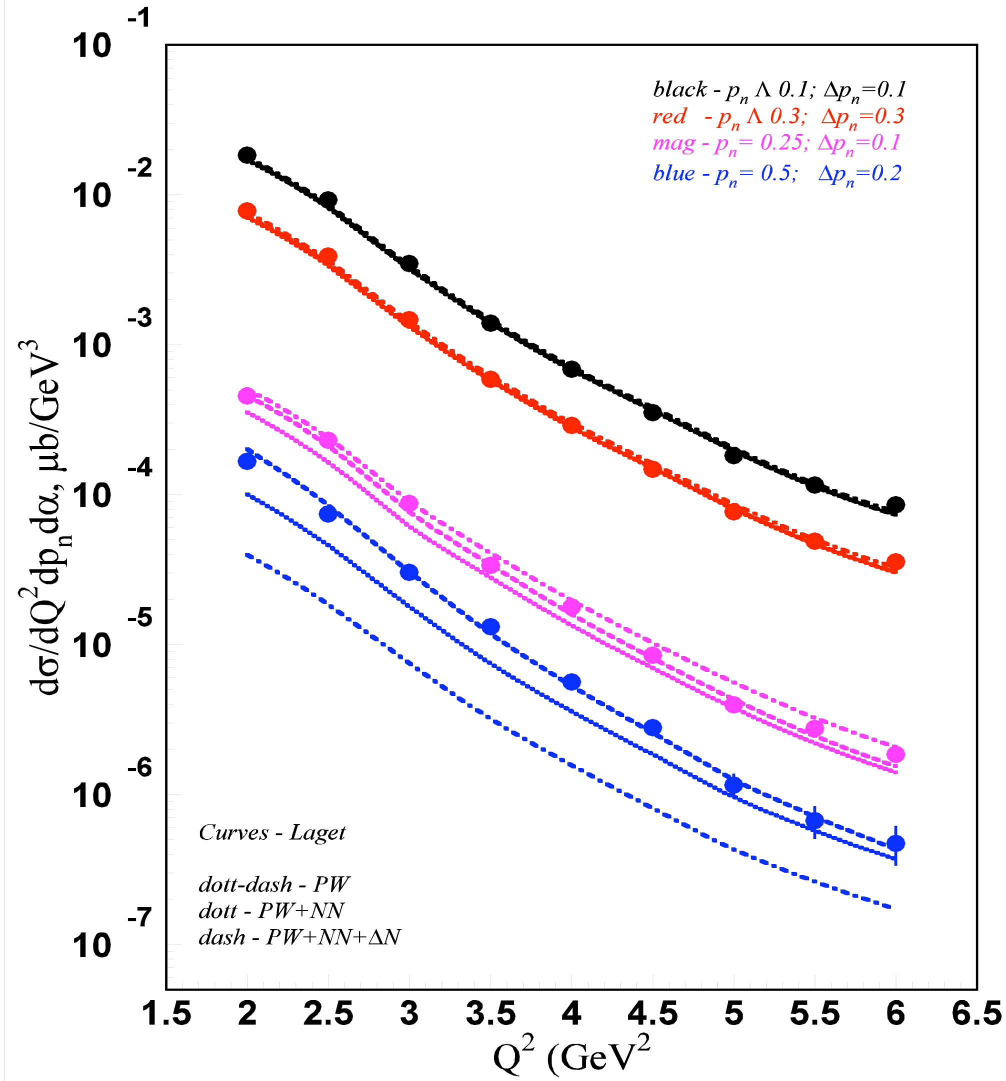
Magenta - $0.15<p_n<0.35$ GeV/c

Blue - $0.3<p_n<0.7$ GeV/c

Dot-dashed - PWIA

Dotted - PWIA + NN

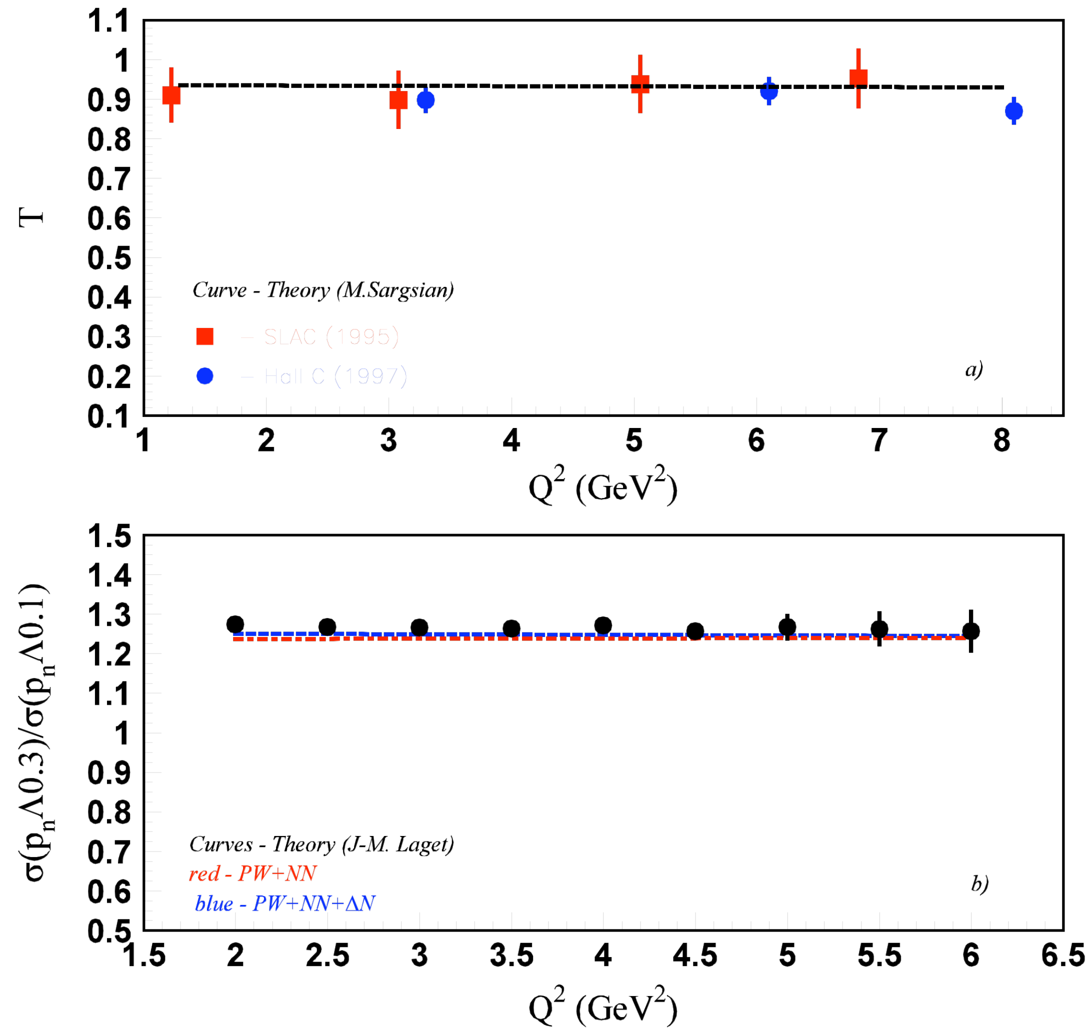
Dashed - PWIA + NN + ΔN



Two transparency ratios

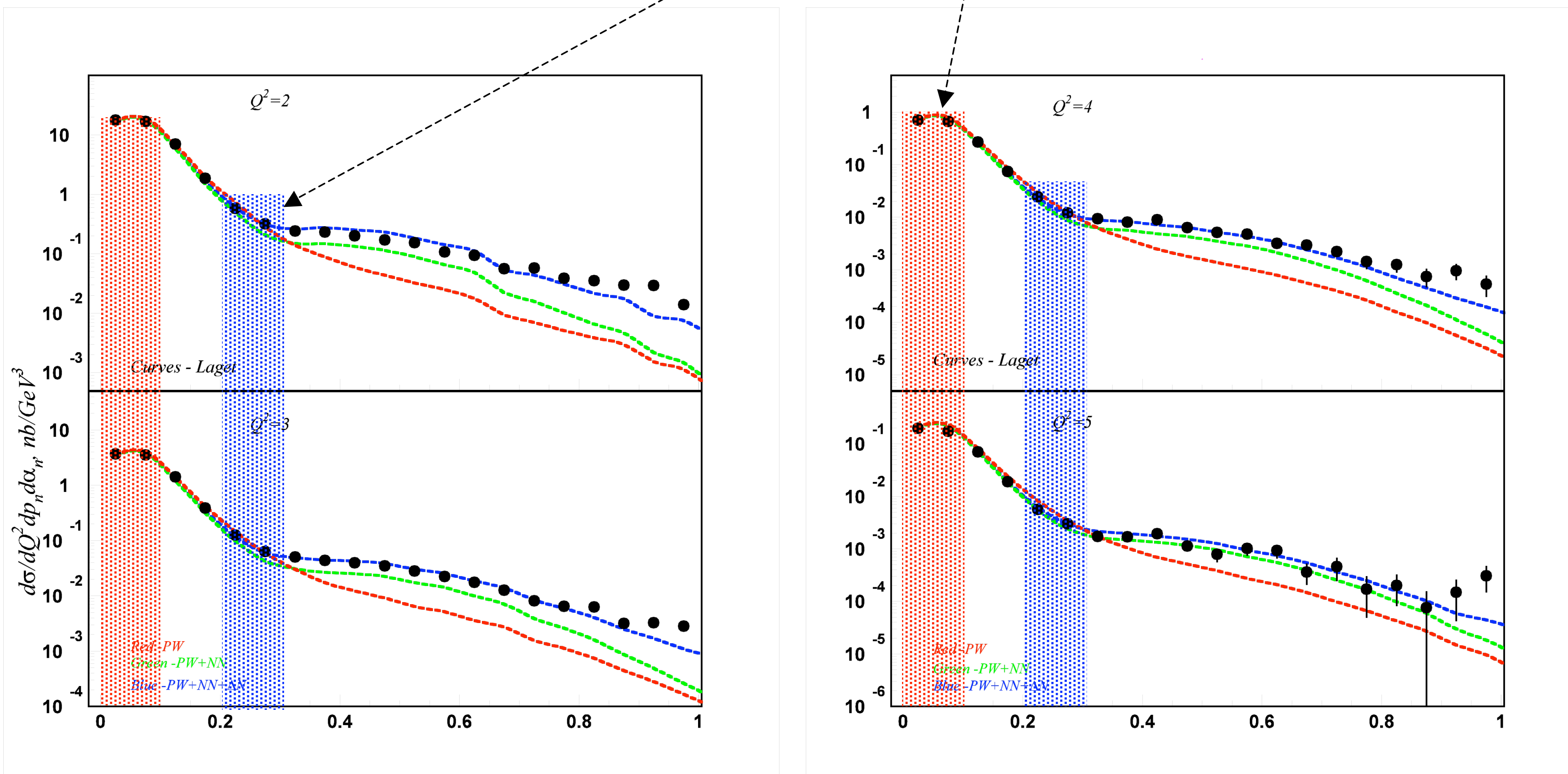
¬ Existing SLAC and JLab data with
T = measured / PWIA ratios.
No CS is observed for $Q^2 < 8$ GeV^2

¬ Our CLAS data with
T = measured/measured ratios.
No CS is observed for $Q^2 < 6$ GeV^2



FSI enhanced kinematics I

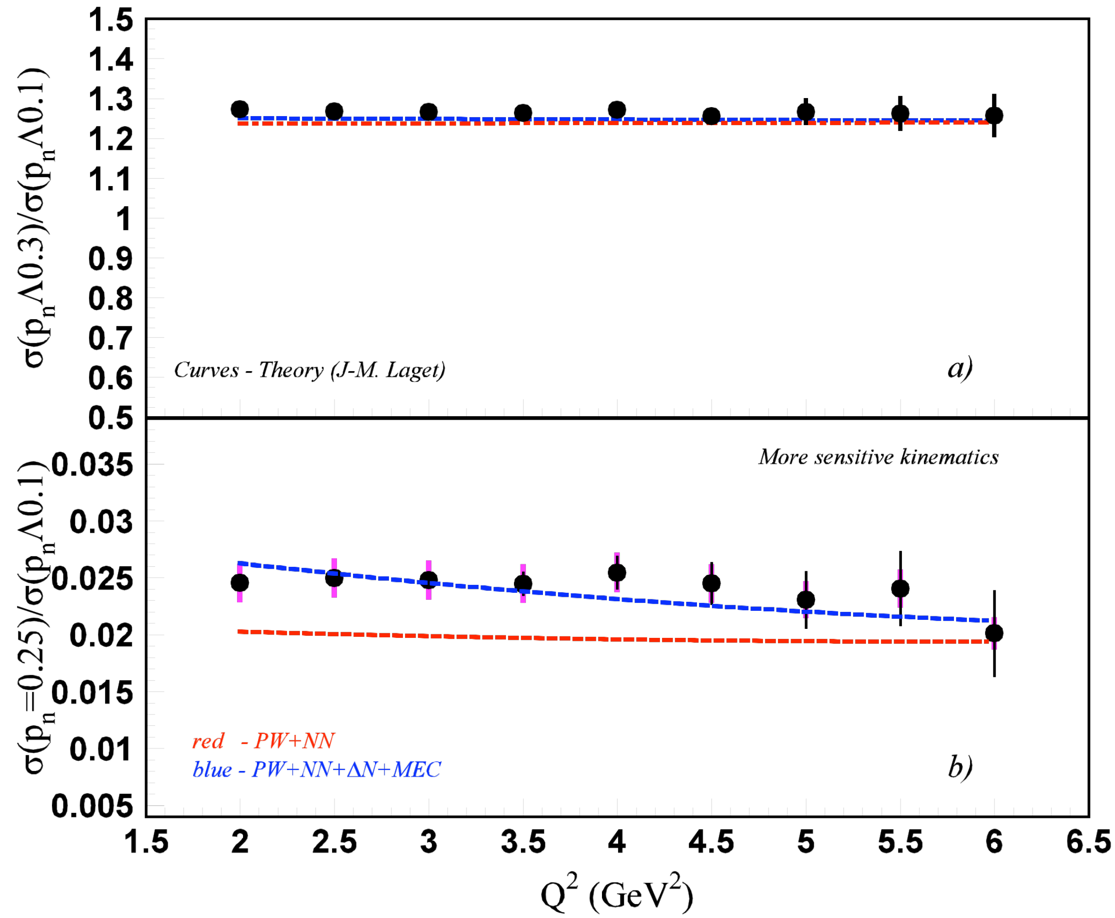
- For $p_n < 0.,1$ no FSIs and no CS
- **T = $\sigma_{exp}(p_n=0.25\pm0.05)/\sigma_{exp}(p_n<0.1)$**



Data for kinematics I

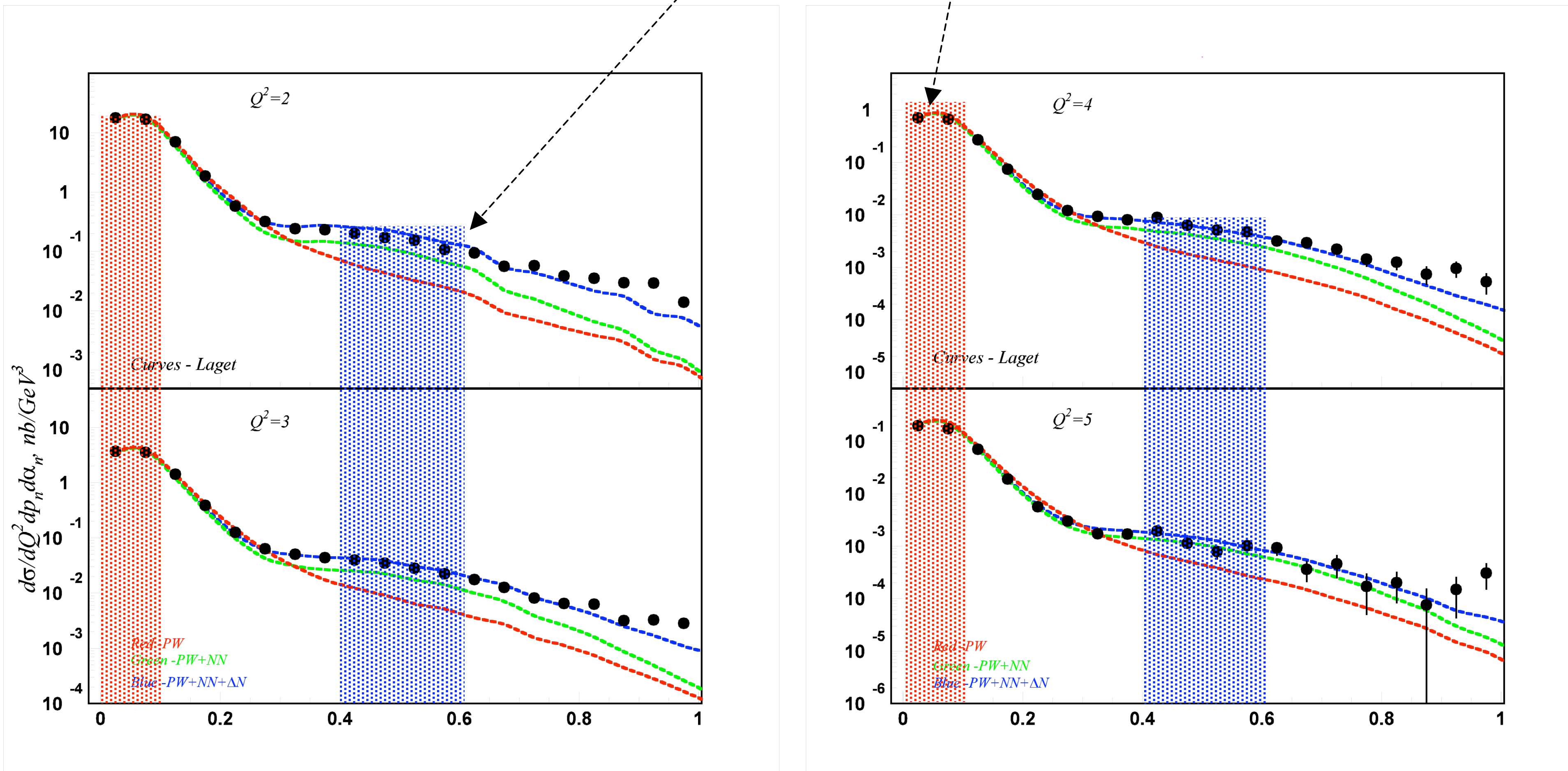
¬Ratio comparing p_n<0.3 with p_n<0.1

¬Kinematics I with enhanced FSIs.
Ratio comparing p_n=0.25 with p_n<0.1



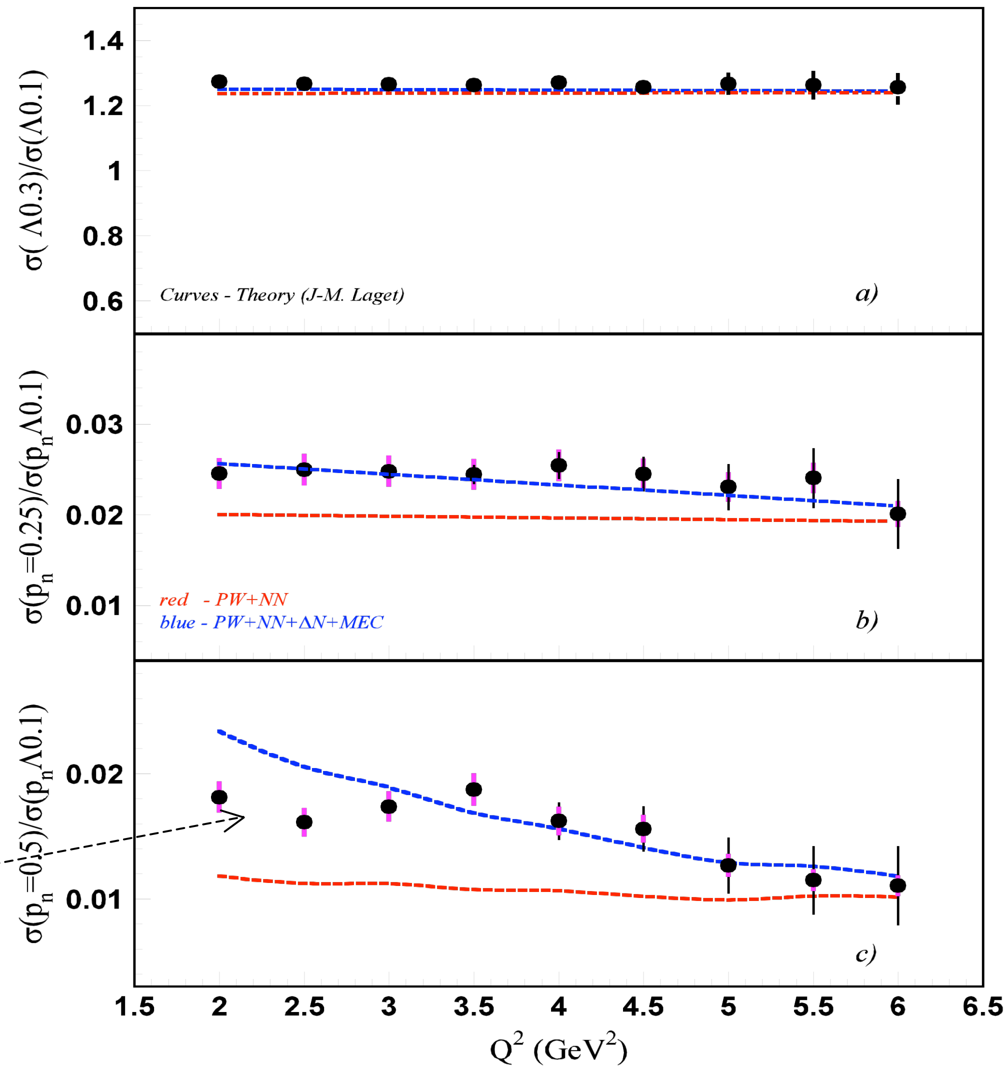
Data for kinematics II

- For $p_n < 0.1$ no FSIs and no CS
- **$T = \sigma_{exp}(p_n=0.5\pm0.1)/\sigma_{exp}(p_n<0.1)$**



Data with enhanced FSIs for Kinematics I and II

- Ratio comparing $p_n<0.3$ with $p_n<0.1$
- Kinematics **I** with enhanced FSIs. Ratio comparing $p_n=0.25$ with $p_n<0.1$
- Kinematics **II** with enhanced FSIs. Ratio comparing $p_n=0.5$ with $p_n<0.1$



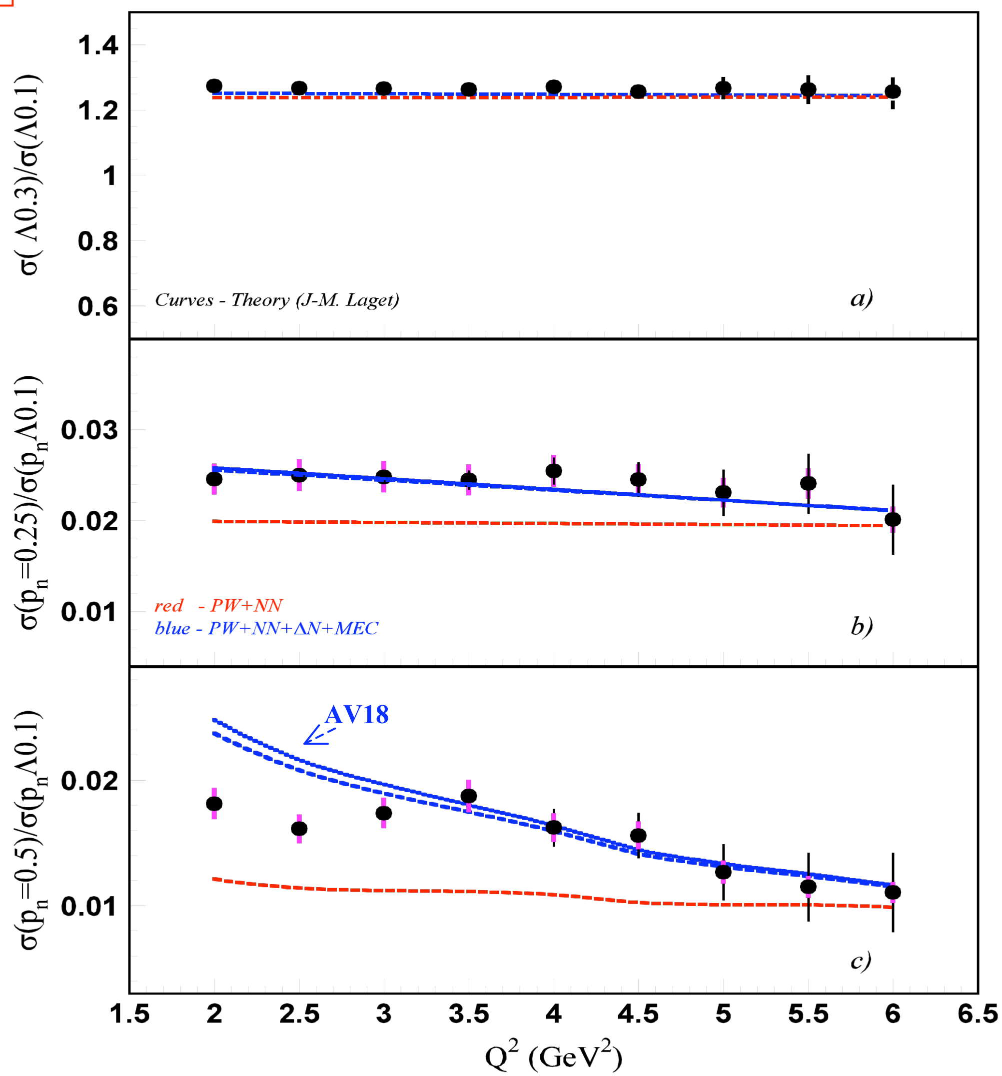
- Within the statistical uncertainties no CS is observed for $Q^2 < 6$ GeV^2

- There is large discrepancy for $Q^2 < 3$ GeV^2 between calculations and experiment.
  - Check other deuterium WFs
  - Check (**NΔ**) transition form factor

Data with enhanced FSIs for Kinematics I and II

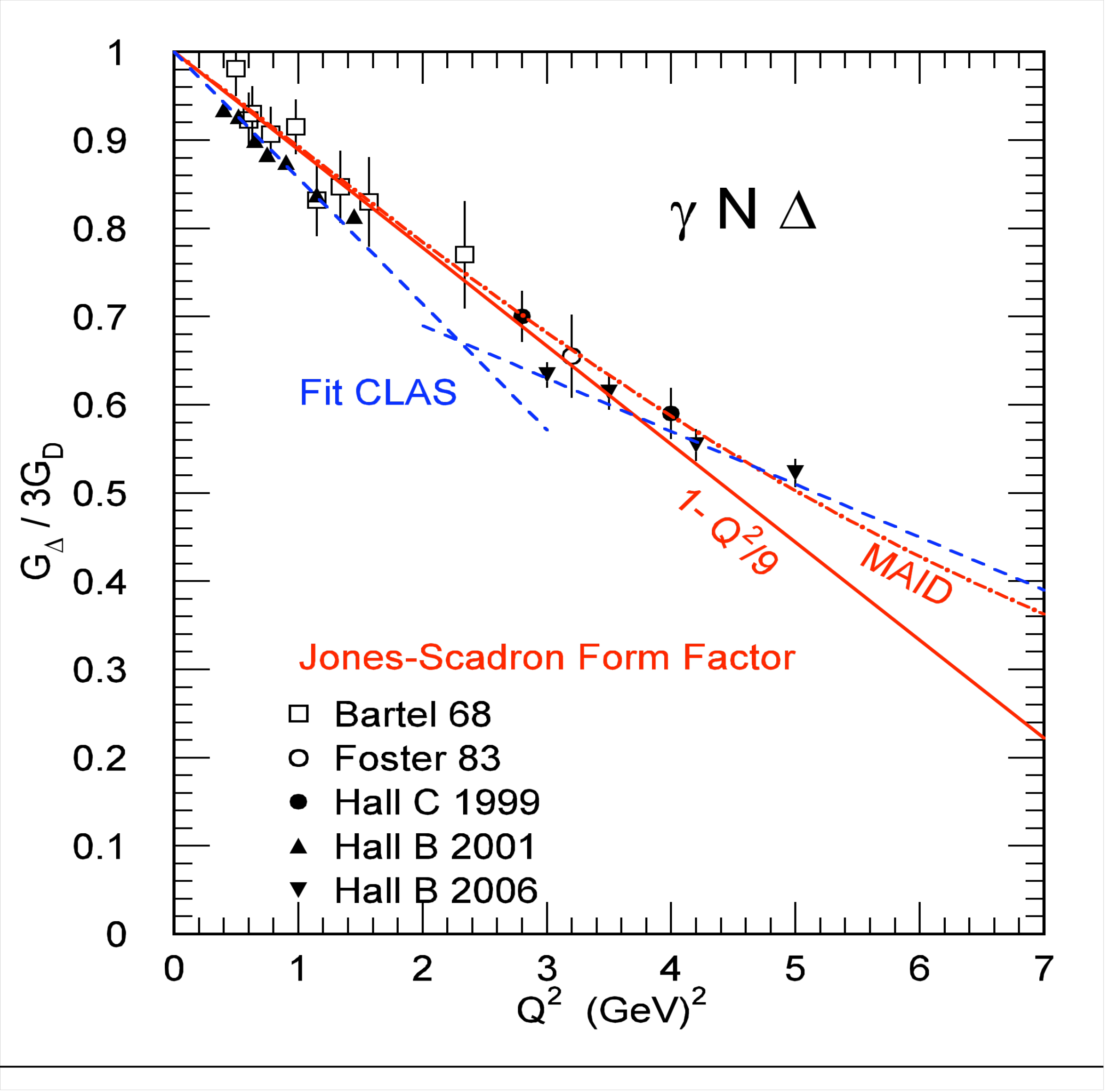
¬ Ratio comparing p_n<0.3 with p_n<0.1
¬Kinematics **I** with enhanced FSIs.
Ratio comparing p_n=0.25 with p_n<0.1
¬Kinematics **II** with enhanced FSIs.
Ratio comparing p_n=0.5 with p_n<0.1

¬ Change from Paris to AV18 wave function has a small effect.



N – Δ transition Form Factor

Several fits to existing data are possible.

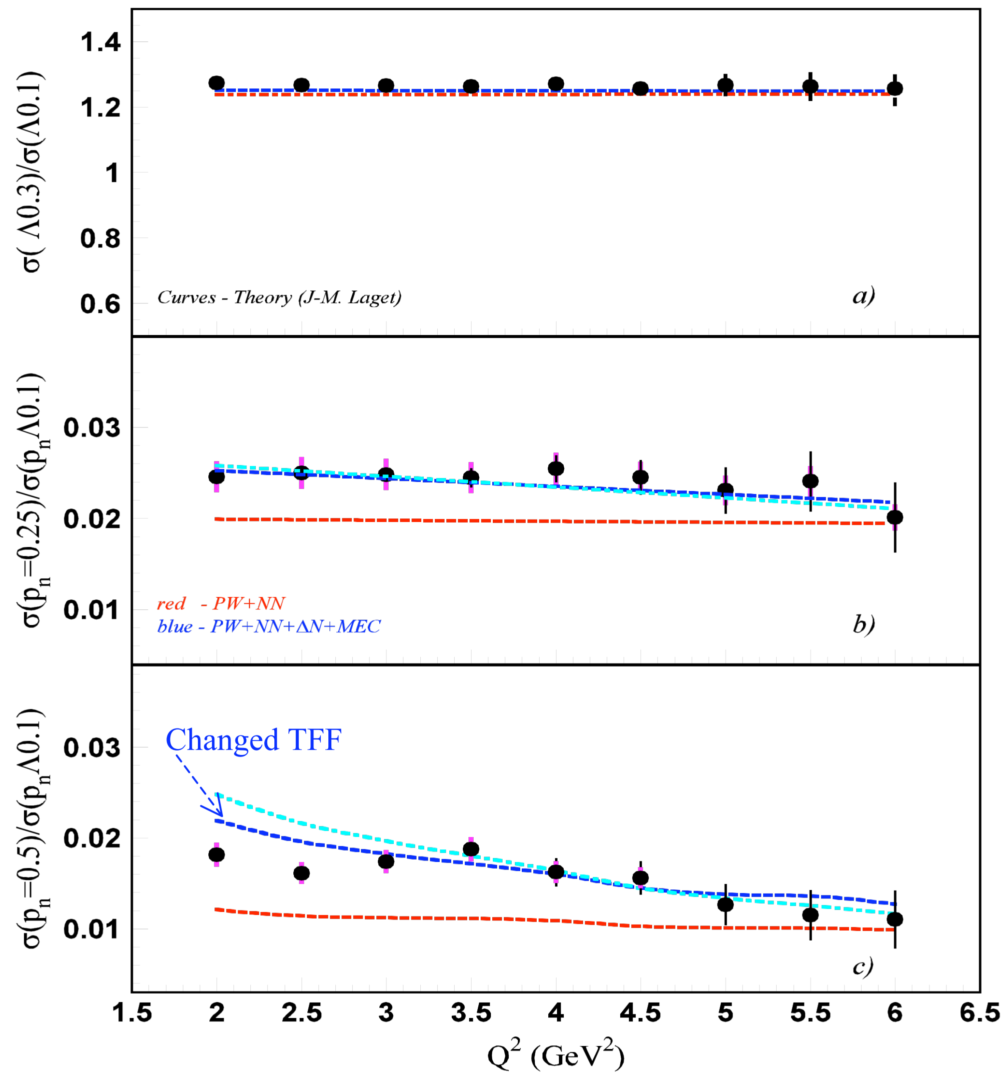


Data with enhanced FSIs for Kinematics I and II

- ¬ Ratio comparing $p_n<0.3$ with $p_n<0.1$
- ¬Kinematics **I** with enhanced FSIs. Ratio comparing $p_n=0.25$ with $p_n<0.1$
- ¬Kinematics **II** with enhanced FSIs. Ratio comparing $p_n=0.5$ with $p_n<0.1$

- ¬ New transition form factor improves low Q^2 region, but it's not enough.

Effect from changed NΔ transition FF



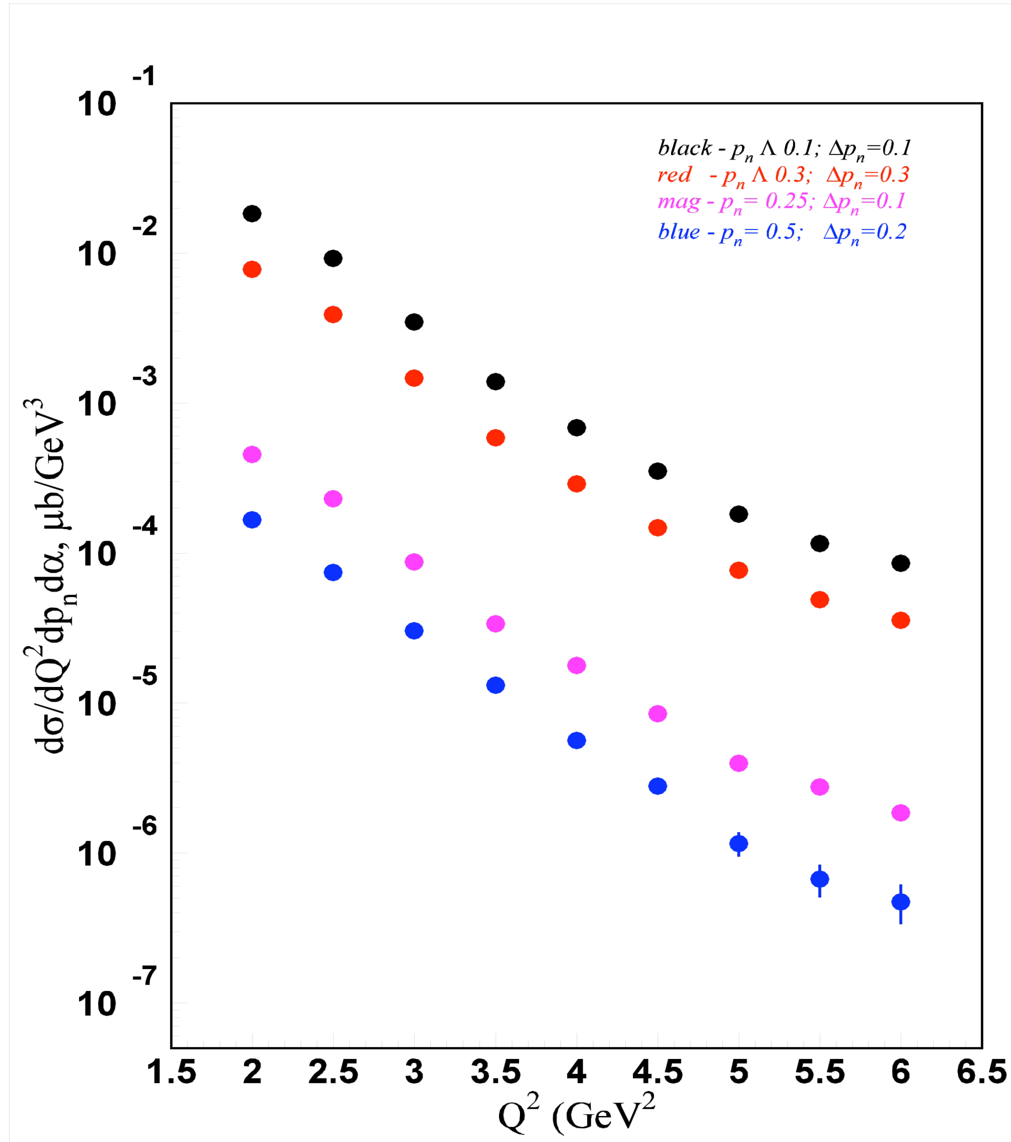
SUMMARY

High-quality CLAS data for D(e,e'p) have been measured.

Kinematics have been selected that enhance final-state interactions.

No reduction in these is seen compared to conventional calculations, which indicates we see no color screening.

A diagrammatic treatment of final-state interactions, meson exchange currents and isobar contributions describes the data well except near Q^2=2 GeV^2.


black - p_n Λ 0.1; Δp_n=0.1
red - p_n Λ 0.3; Δp_n=0.3
mag - p_n= 0.25; Δp_n=0.1
blue - p_n= 0.5; Δp_n=0.2
$d\sigma/dQ^2dp_nd\alpha$, $\mu b/GeV^3$
Q^2 (GeV^2
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
1.5
2
2.5
3
3.5
4
4.5
5
5.5
6
6.5

N – Δ transition Form Factor data used in calculations