Fitting (Semi) Inclusive Deuteron Data and Extraction of Neutron SF's

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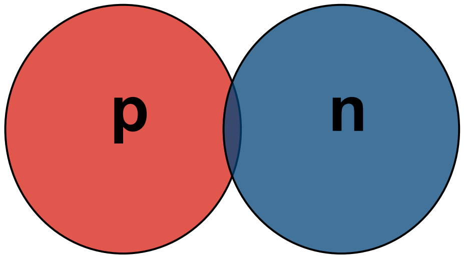
Outline

- Introduction
- Analysis
- Plans



Motivation

- How well do we understand the deuteron? Need to understand how to model deuteron from proton and neutron; *d =? p + n*
- How accurately can we describe the deuteron with in an independent nucleon impulse approximation?
- Extracting F_2^n from *d, p* DIS data.
- Fitting F_1^n, F_L^n
- Confronting modeling with data: F_2^n from BONuS*
- More reliable extrapolation to $\varepsilon = 1$.

$$\varepsilon = \left[1 + 2\left(1 + \frac{\nu^2}{Q^2}\right)\tan^2\frac{\theta}{2}\right]^{-1}$$

**Barely Offshell NeUtron Structure (E03-012)*

Analysis

- Fit Inclusive deuteron cross-sections;

$0.03 < Q^2 < 10.5$ GeV^2, $1.05 < W^2 < 11.5$ GeV^2

- Compare fit to BONuS data: $\sigma_{tag} / \sigma_{untag}$ (-> F_2^n/F_2^d @ $\varepsilon = 1$)
- Dependence of results on potential for deuteron wave function.
- Include BONuS result in fit and check consistency of model.

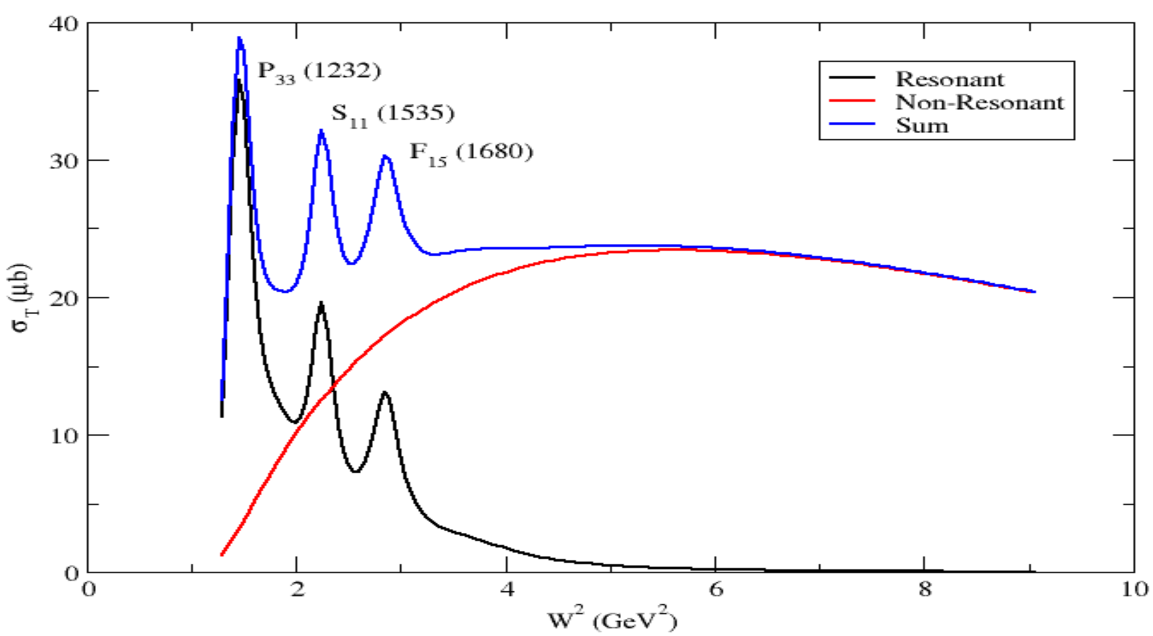
Data Fitting

$$\sigma_{T,L}(W^2,Q^2)=\sigma_{T,L}^{Res}(W^2,Q^2)+\sigma_{T,L}^{NonRes}(W^2,Q^2)$$

Fit Ingredients (Nucleon):

$$\sigma_{T,L}^{Res}(W^2,Q^2)\propto BW_{T,L}(W^2)\cdot\left[A_{T,L}(Q^2)\right]^2 \qquad \sigma_T^{Non\ Res}(W^2,Q^2)\propto C(Q^2)x'(W-m_\pi)^{1/2}$$

Proton $<Q^2> = 2.0$ GeV^2



Primary resonances

So, what about SF's?

$$\sigma_T \propto 2xF_1$$

$$\sigma_L \propto F_L$$

$$\sigma_T+\sigma_L \propto F_2$$

Resonance masses and widths fixed from proton result.

PRC 81, 055213 (Proton)

PRC 77, 065206 (Deuteron)

Corrections: PWIA

- 3 Smear functions to describe xF_2, F_1, F_L

Convolution Model (Nucleus)

- Using full AV18 potential for wave-function (includes 2-body forces).
- Theoretical smearing provided by W. Melnitchouk, J. Ethier.

Inelastic:

$$\int_x dy f_2(y,\gamma) F_2(\frac{y}{x},\gamma) = F_2^{smear}(x,Q^2)$$

$$\gamma = \left[1 + \frac{4m^2 x^2}{Q^2}\right]^{1/2}$$

$$\int_x dy f_{11}(y,\gamma) \frac{2x}{y} F_1(\frac{y}{x},\gamma) + f_{12}(y,\gamma) F_2(\frac{y}{x},\gamma) = F_1^{smear}(x,Q^2)$$

$$F_L^{smear} = \gamma^2 F_2^{smear} - 2xF_1^{smear}$$

Elastic:

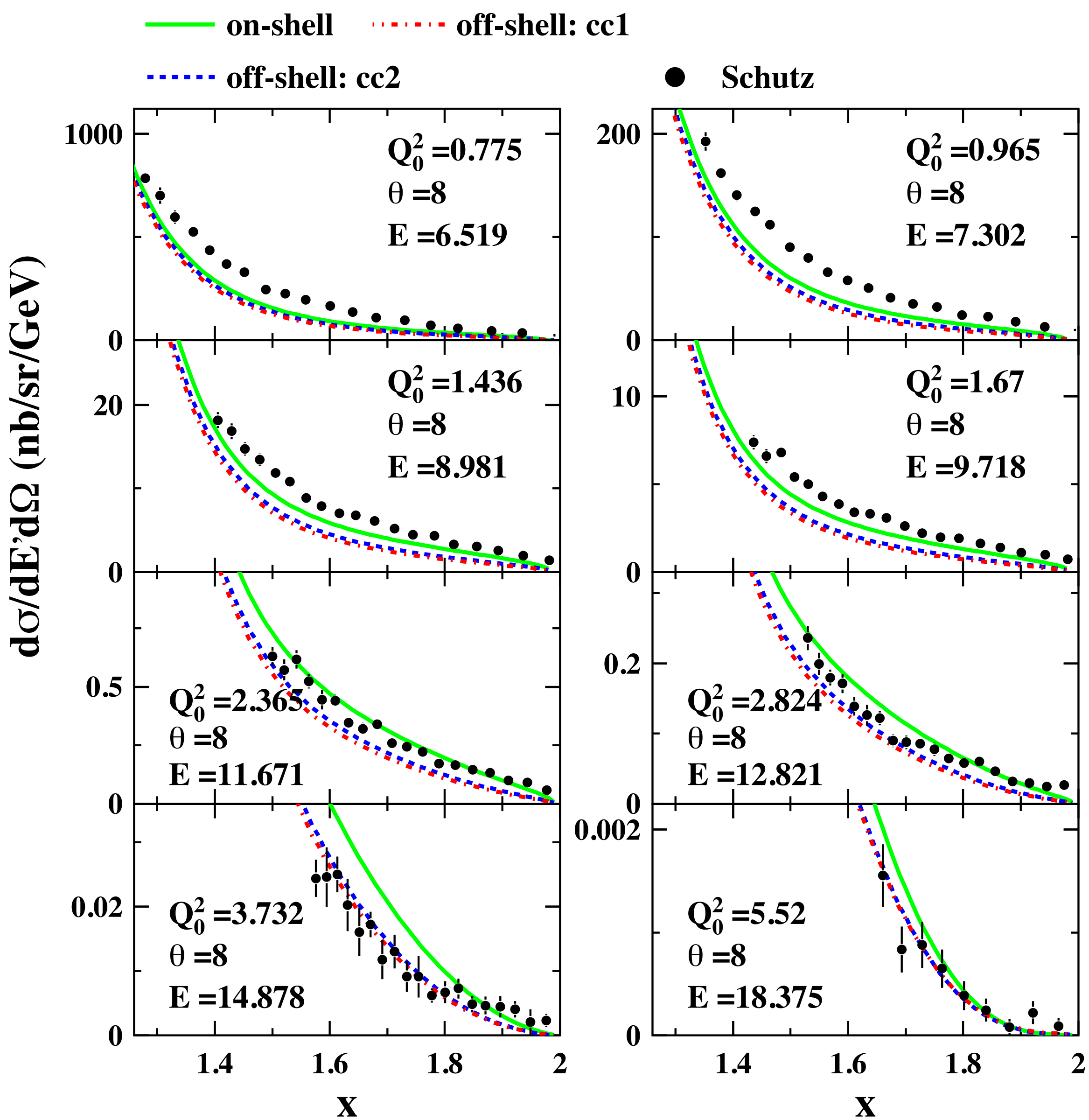
$$\tau = \frac{Q^2}{4M^2}$$

$$F_1 = \frac{G_M^2}{2}\delta(1-x) \qquad F_2 = \frac{\tau G_M^2 + G_E^2}{1+\tau}\delta(1-x) \qquad G_{M,E}^2 = (G_M^p)^2 + (G_M^n)^2$$

- Expressions above are for on-shell
- Used CJ12 for inelastic off-shell correction: assumed ~1.5% change in d_2 nucleon radius

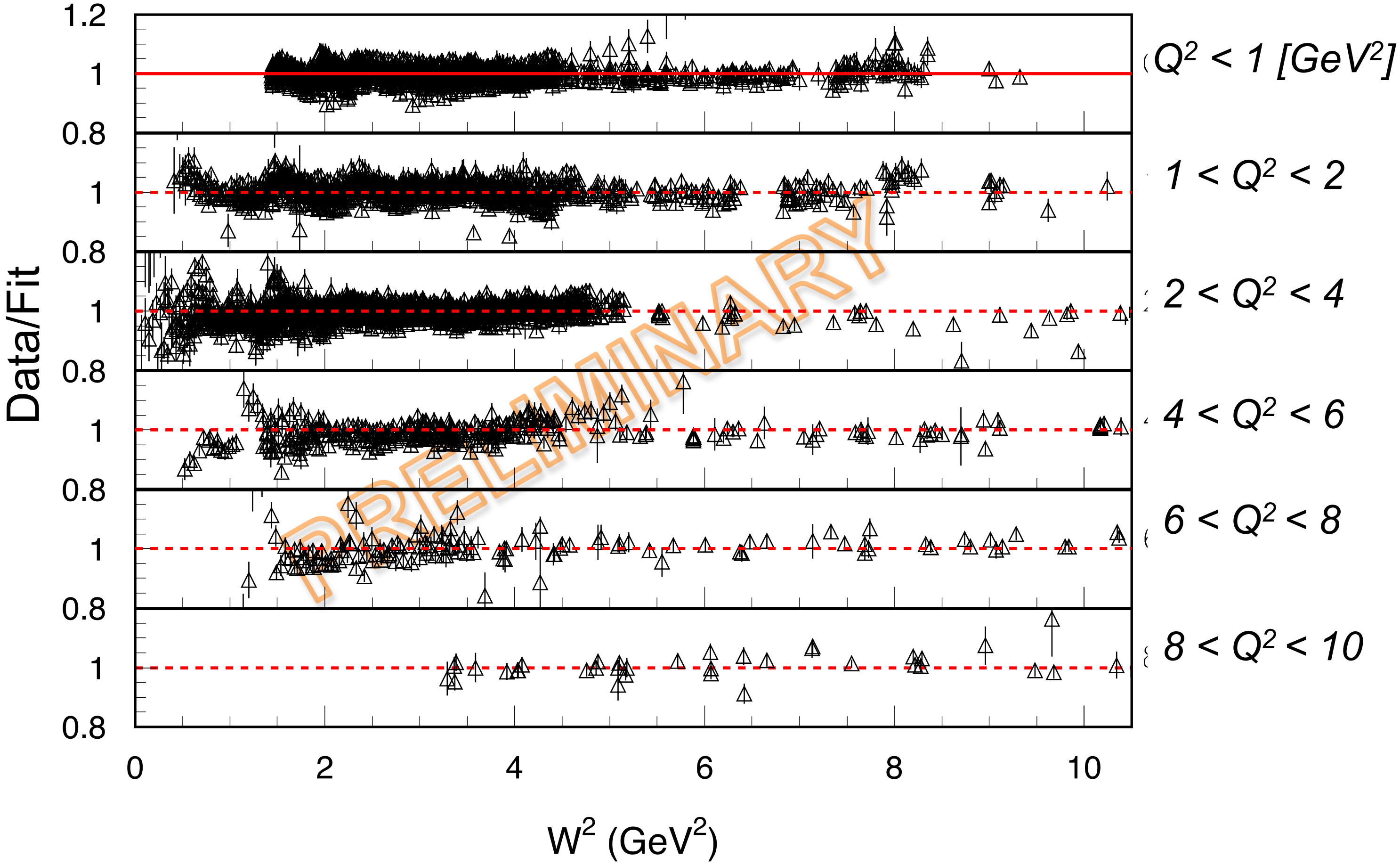
PRD 69, 114009 (2004), Sec. III
PRC 79, 035205 (2009), Sec. II
PRD 84, 014008 (2011), Sec. II

(Quasi)Elastic Corrections



- QE Off-Shell and smearing in De Forest cc1,2 formalism
- Worked out and provided by W. Melnitchouk, J. Ethier. [arXiv:1402.3910]

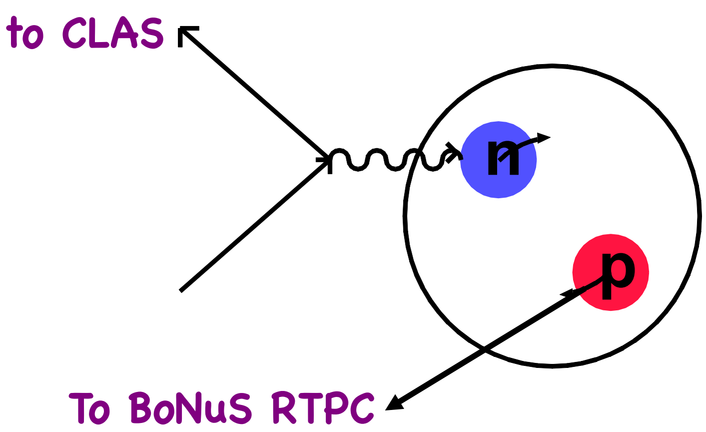
Comparison of Data/Fit

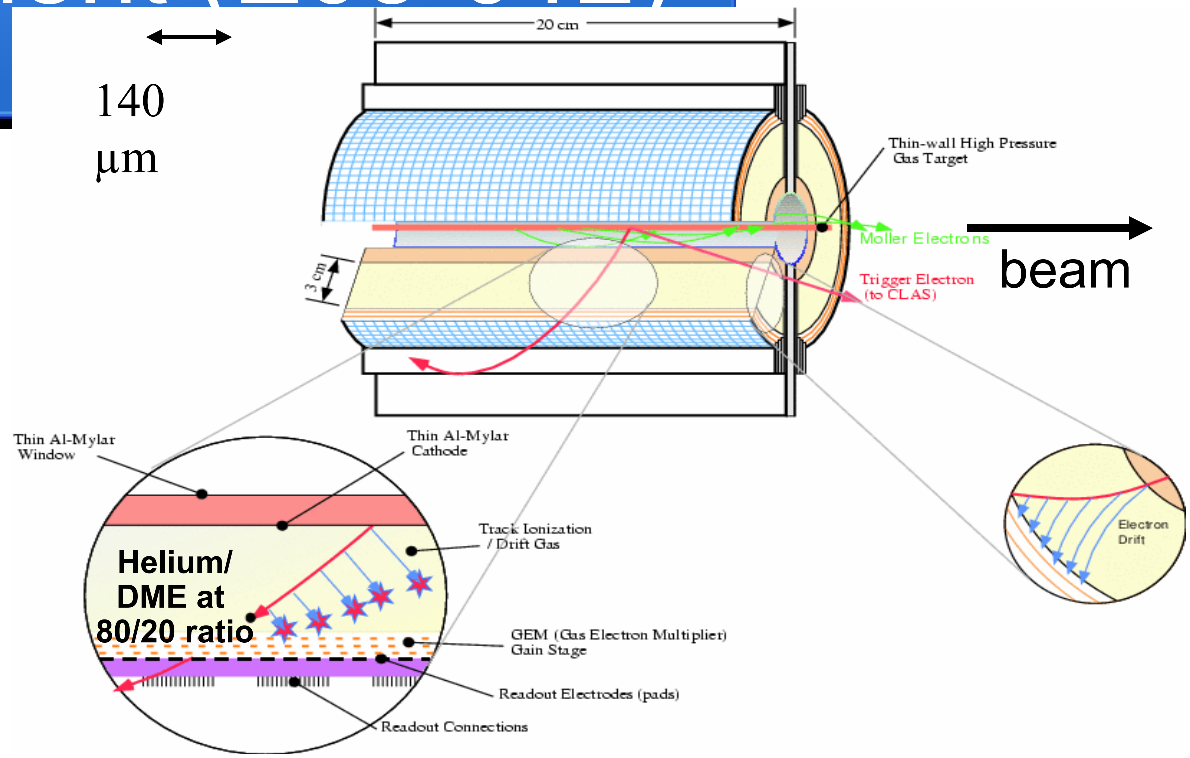


- ~5200 Data Points
- Data sets from JLab and SLAC (σ_d)
- ~1800 Data points from BONuS (σ_n/σ_d)
- Off-Shell corrections applied.

Data Sets Included:
E00-002
E00-116
E02-009
E06-109
E99-118
Whitlow-SLAC
NE11-SLAC

BONUS Experiment (E03-012)





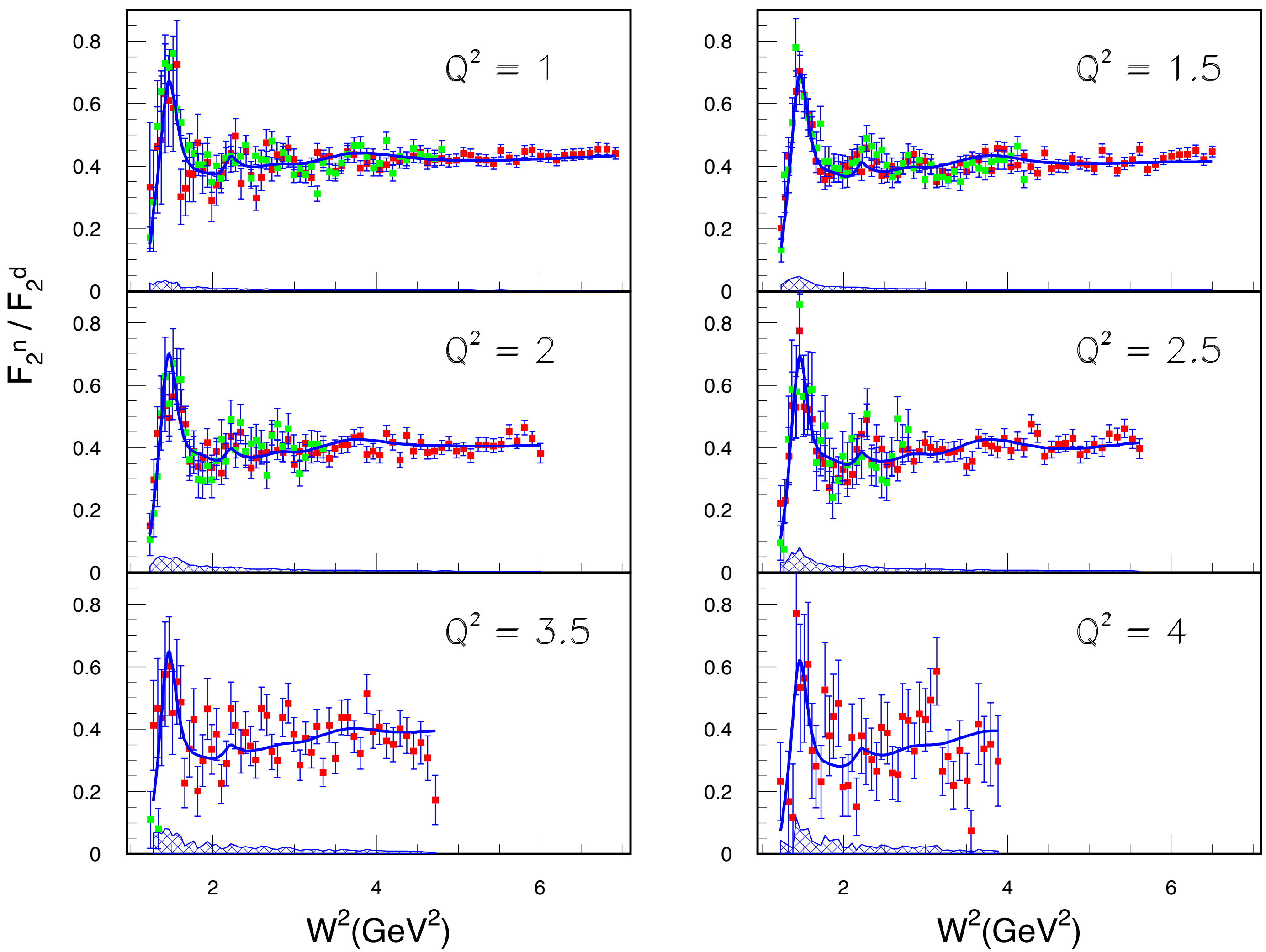
Thin walled deuterium gas target (7 atm) with 2, 4, and 5 GeV e-beam.

- Large acceptance spectrometer (CLAS) together with new detector capable of detecting spectator protons surrounding the target.

- Obtain virtually free neutron by tagging spectator protons with low momenta (66-200 MeV/c) and large scattering angles (> 90 deg.); minimize FSI + Off-shell effects

- Physics from (semi) inclusive and exclusive channels.

F_2^n/F_2^d

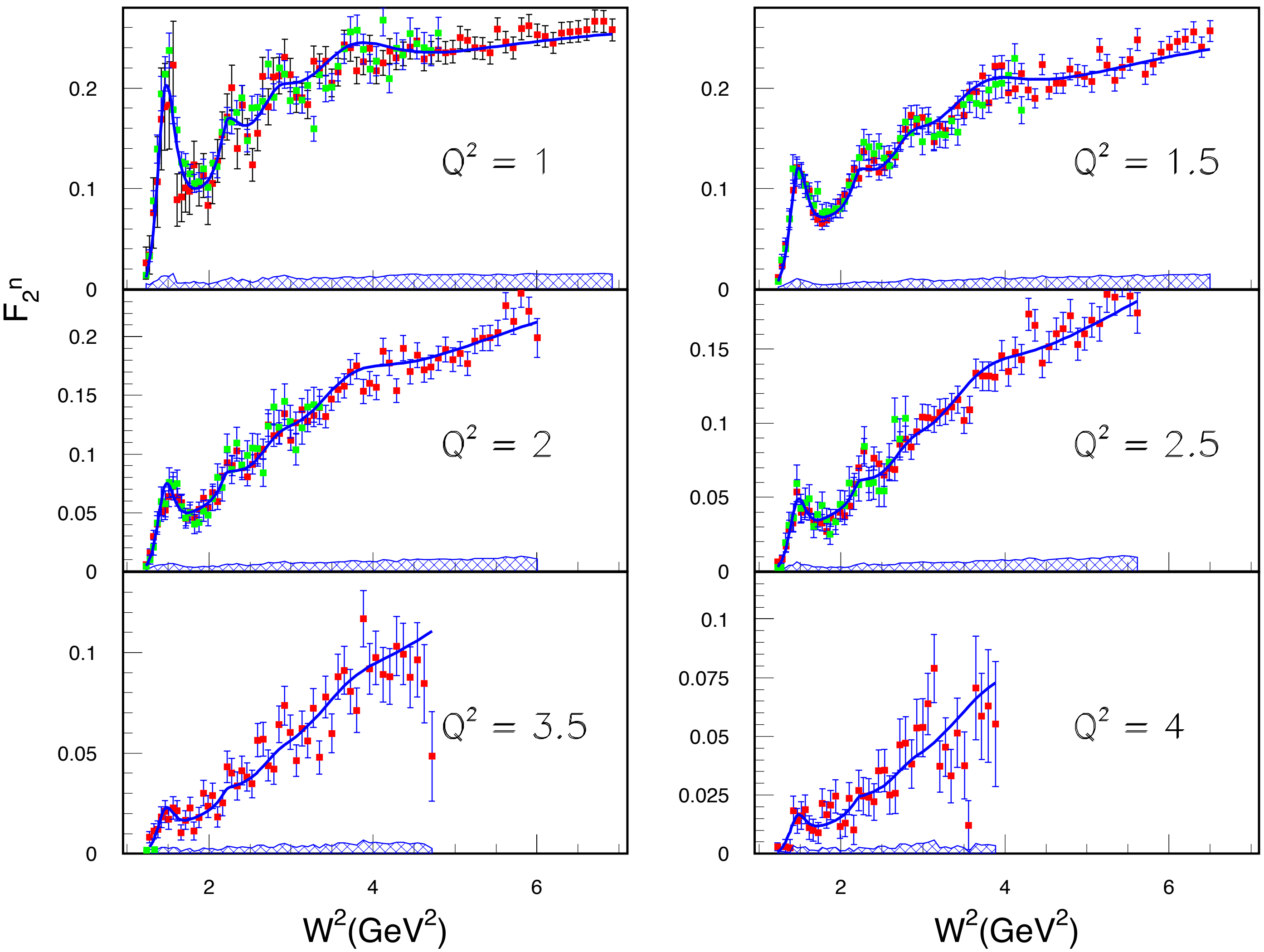


- Compare (normalized) BONuS result to fit
- Blue curve prediction from fit
- 5 GeV in red, 4 GeV in green.

PRC 89, 045206 (2014)

F_2^n

$(F_2^n/F_2^d)_{BONuS} \times (F_2^d)_{fit}$ -> F_2^n



- Compare (normalized) BONuS result to fit
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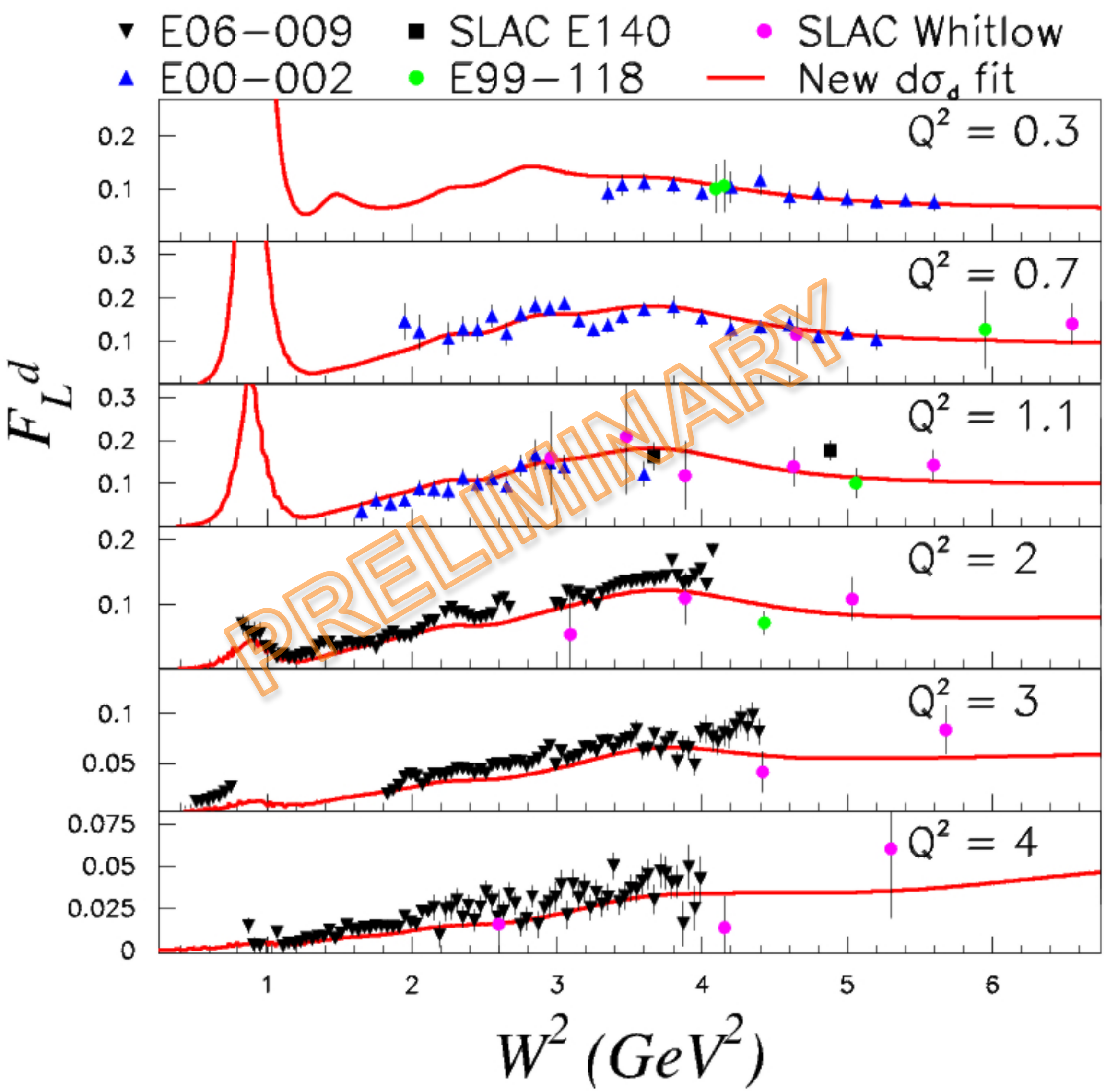
PRC 89, 045206 (2014)

F_2^n

From $(F_2^n/F_2^d)_{\text{BONuS}} \times (F_2^d)_{fit} \rightarrow F_2^n$

- Quark-Hadron Duality & Moments: [arXiv: 1501.02203]
- Study EMC effect for deuteron: $F_2^d/(F_2^n + F_2^p)$, under study
- …

Comparison of Data/Fit: F_L^d



- Reasonable global consistency within uncertainties.
- All sets shown are included in fit.
- Finalizing E06-009 (ROSEN07); use fit to redo RCs

Remaining

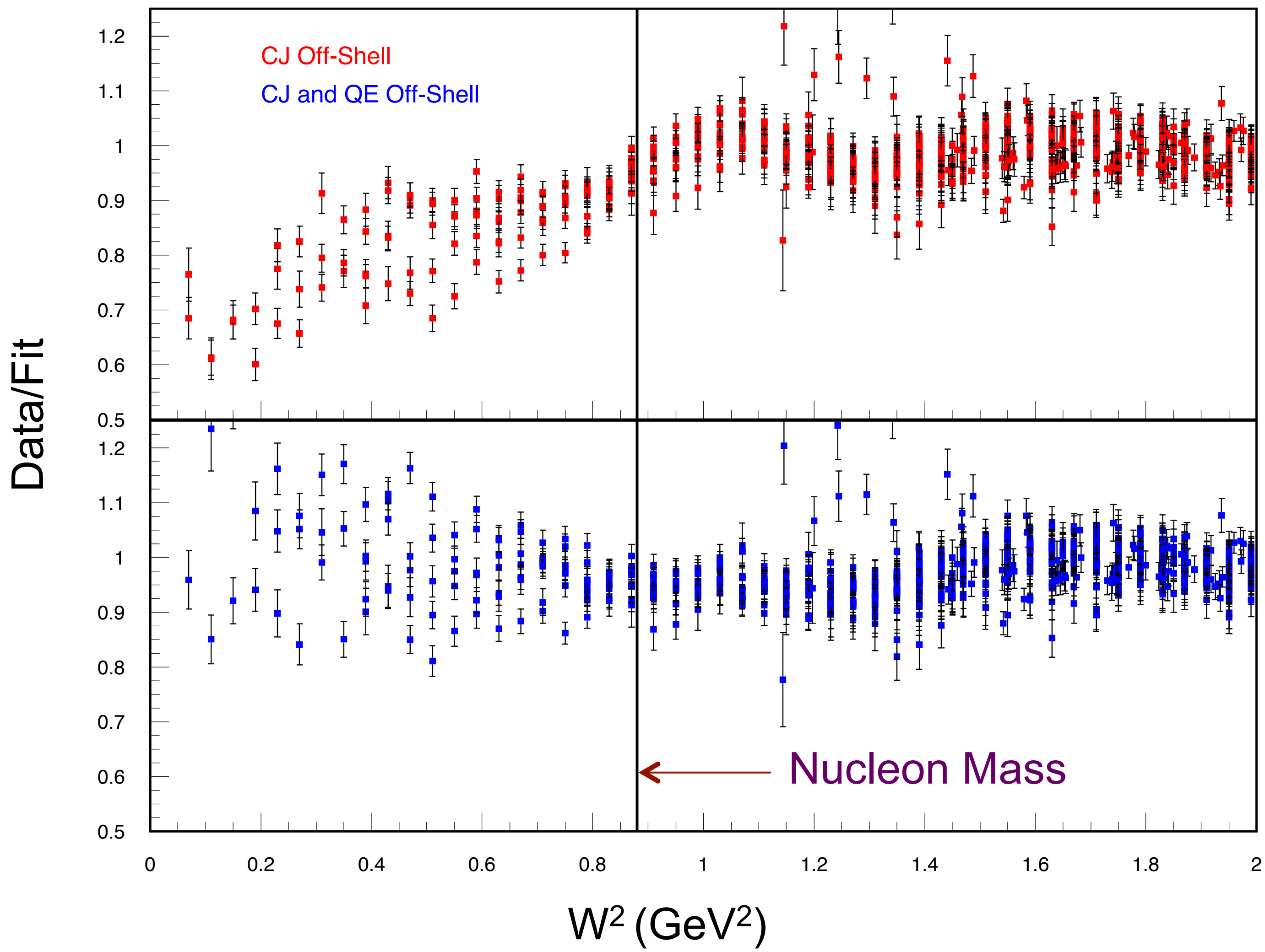
After current iteration:

- Include finalized ROSEN07 (F_L) and Jan05 data
- Check helicity amplitudes.
- Check dependence on wave-function –i.e. compare answer from AV18 to what other wv-fn's would say

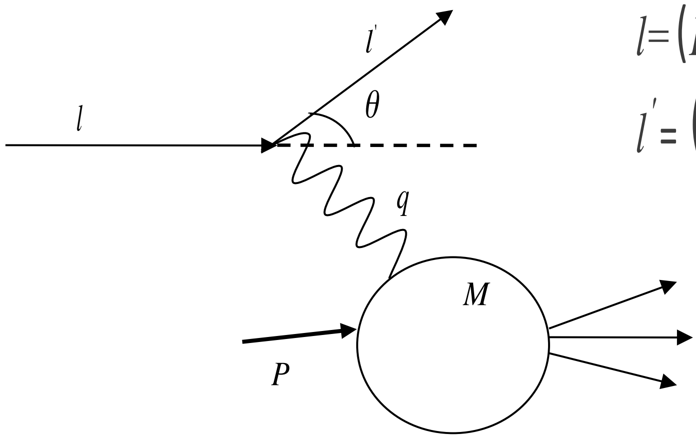
Summary

- Updating fit to deuteron, utilizing proton information, and including several more deuteron data sets.
- Including more deuteron. Replacing previous smear with convolution prescription.
- New QE off-shell correction.
- Using fit to model deuteron and extract F_2^n.
- Fit includes neutron (BONuS) data.

Comparison of Data/Fit



Lepton Scattering



$$l = \left(E, \vec{l}\right)$$

$$l' = \left(E', \vec{l'}\right)$$

$$q = l - l'$$

$$Q^2 = (-q)^2 = 4EE' \sin^2 \frac{\theta}{2}$$

$$x = \frac{Q^2}{2M\nu}$$

$$\nu = E - E'$$

$$y = \frac{\nu}{E}$$

$$W^2 = M^2 + 2M\nu - Q^2$$

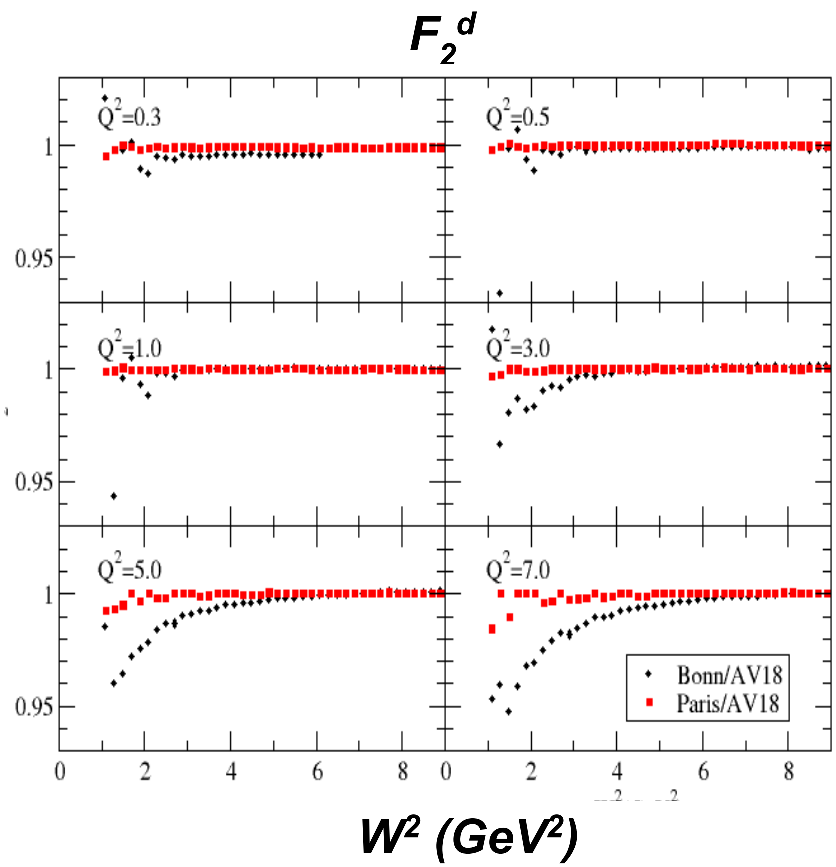
$$\Gamma = \frac{\alpha E' \left(W^2 - M^2\right)}{4\pi^2 Q^2 M E \left(1 - \varepsilon\right)}$$

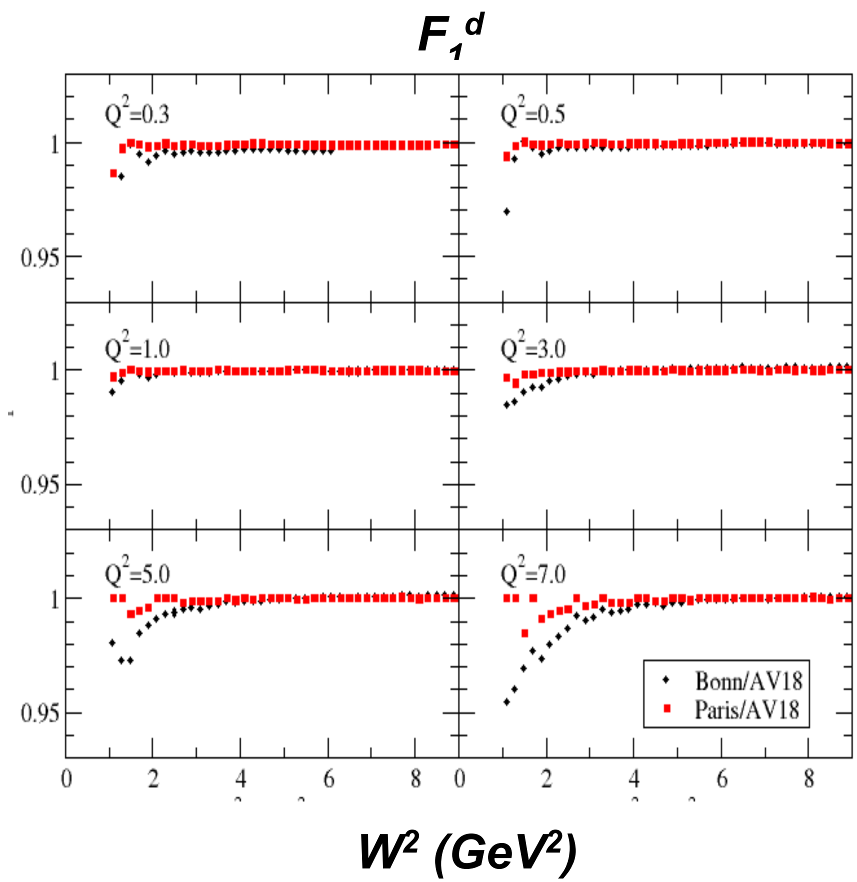
$$\frac{d^2\sigma}{d\Omega dE'} = \Gamma\left[\sigma_T(W^2, Q^2) + \varepsilon \sigma_L(W^2, Q^2)\right]$$

$$\varepsilon = \left[1 + 2\left(1 + \frac{\nu^2}{Q^2}\right)\tan^2 \frac{\theta}{2}\right]^{-1}$$

$$\sigma_{Reduced} = \frac{1}{\Gamma}\frac{d^2\sigma}{d\Omega dE'} = \sigma_T(W^2, Q^2) + \varepsilon \sigma_L(W^2, Q^2)$$

Comparison of Potentials



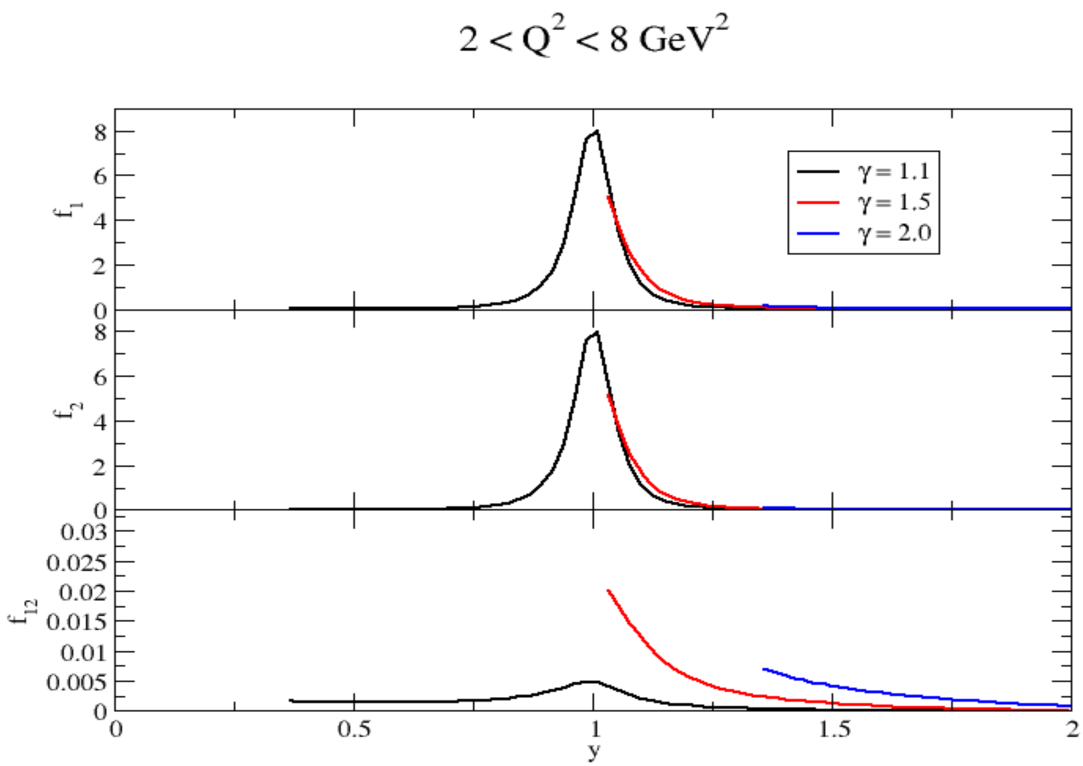


- Gives range of uncertainties from wave-function.
- Using AV18 in fit.
- AV18 more consistent with Paris than Bonn.
- QE region is included.

Plane Wave Impulse Approximation

- 3 Smear functions to describe and 2 of xF_2, F_1, F_L
- Using AV18 potential for wave-function.
- Theoretical smearing and off-shell calculations provided by W. Melnitchouk, J. Ethier.

Convolution Model (Nucleus)



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