RC Input Cross Section Models Study

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Motivation

For each $(E_0,\ E_p,\ \theta)$ set:

- calculate born cross section $\sigma(E_0, E_p, \theta)$
- calculate radiative cross section $\sigma^*(E_0, E_p, \theta)$ by formula:

$$\sigma^*(E_0, E_p, \theta) = \int_0^T \frac{dt}{T} \int_{E_{0min}(E_p)}^{E_0} dE_0' \int_{E_p}^{E_p max(E_s')} dE_p' I(E_0, E_0', t) \sigma_r(E_0', E_p', \theta) I(E_p', E_p, T - t) \quad (1)$$

  where $\sigma_r(E_0', E_p', \theta)$ is calculated from born cross section $\sigma(E_0', E_p', \theta)$
- radiative correction factor: $RC = \sigma(E_0, E_p, \theta)/\sigma^*(E_0, E_p, \theta)$

We need an input model to provide reliable born cross sections in MARATHON kinematics region.

Outline

- INEFT (Bodek Model)
  - Fit functions and data sets;
  - Nuclei cross section (DIS and Resonance);
- F1F217 (Eric Christy Model)
  - Fit functions and data sets;
  - Nuclei cross section (DIS and Resonance);
- Two models comparison on Deuterium and proton with Data

Bodek Model

- Data sets: SLAC e-p and e-d scattering experiments A, B, C; [1]
- F_{2p} and F_{2d} are extracted from proton cross section and deuterium cross section by assuming $R_p = R_d = 0.18$
- The F_{2p} and F_{2d} are parametrized as follows:

$$F_2(\nu, Q^2) = A(W, Q^2) f(\omega_w)/\omega \tag{2}$$

where

$$f(\omega_w) = \omega_w \sum_{n=3}^{7} C_n (1 - 1/\omega_w)^n \tag{3}$$

and

$$\omega_w = \frac{2M\nu + a^2}{Q^2 + b^2} \tag{4}$$

- $f(\omega_w)$ in the "INEFT" is the same as what's given in [1]
- No corresponding paper is found for $A(W, Q^2)$ used in "INEFT". While $A(W, Q^2)$ describes resonance region, it's close to unity for $W > 2.0 GeV$

[1] A. Bodek *et al.* Phys. Rev. D20, 1471 (1979)

Nuclei cross section by using INEFT

- Get W_{1p}, W_{2p}, W_{1d}, W_{2d} from INEFT by assuming $R_p = R_d = 0.18$;
- Neutron structure functions:

$$W_{1n} = 2W_{1d} - W_{1p}, \quad W_{2n} = 2W_{2d} - W_{2p} \tag{5}$$

- Nuclei ${}^A_Z N$ structure functions:

$$W_1 = Z \times W_{1p} + (A - Z) \times W_{1n}, \quad W_2 = Z \times W_{2p} + (A - Z) \times W_{2n} \tag{6}$$

- Cross section: $\sigma = \sigma_{mott}(W_2 + 2W_1 tan^2(\frac{\theta}{2})) \times emcfac(x, A)$
- emcfac(x, A) is the EMC effect correction factor, which has x and A dependence.

Eric Christy Proton Model

- Proton data sets:
- Proton fitting procedure [2]:
  - Get reduced cross section σ_r from data:

$$\sigma_r = \frac{1}{\Gamma}\frac{d\sigma}{d\Omega dE'} = \sigma_T(W^2, Q^2) + \epsilon\sigma_L(W^2, Q^2) \tag{7}$$

  - Fit σ_r by parametrizing $\sigma_T(W^2, Q^2)$ and $\sigma_L(W^2, Q^2)$ simultaneously

$$\sigma_{T,L}(W^2, Q^2) = \sigma^R_{T,L} + \sigma^{NR}_{T,L} \tag{8}$$

    where $\sigma^R_{T,L}$ is the resonant contribution and $\sigma^{NR}_{T,L}$ is the non-resonant contribution;
  - It's valid for $W^2 \geq 1.159 GeV^2$

[2] M.E. Christy, P.E. Bosted, arXiv:0712.3731 [nucl-ex] (2007)

F1F217 free proton σ_T and σ_L

- In "F1F217", to get free proton σ_T and σ_L:
  - when $W^2 \leq 8.0 GeV^2$, using Eric's proton fit;
  - when $8 < W^2 \leq 10 GeV^2$,
    1. get F_2 from Whitlow's proton fit and R from R1998; calculate σ_L^{dis} and σ_T^{dis} using F_2 and R;
    2. get σ_T^{res} and σ_L^{res} using Eric's proton fit;
    3. the σ_T and σ_L are calculated by:

$$\sigma_T = \frac{1}{2}(10.0 - W^2) * \sigma_T^{res} + (W^2 - 8.0) * \sigma_T^{dis} \tag{9}$$

$$\sigma_L = \frac{1}{2}(10.0 - W^2) * \sigma_L^{res} + (W^2 - 8.0) * \sigma_L^{dis} \tag{10}$$

  - when $W^2 > 10.0 GeV^2$, using Whitlow's proton fit;

Eric Christy Neutron Model

- Deuterium data sets: E94-110, E00-116, E00-002, E99-118, ROSEN07, Spring03, SLAC DIS, BONUS
- Neutron model fitting procedure:
  - $\sigma^p_{L,T}$ is known from the proton fit $\longrightarrow F^p_{1,2,L}$
  - $\sigma^n_{L,T}$ have almost the same parameterization form as $\sigma^p_{L,T} \longrightarrow F^n_{1,2,L}$
  - The Fermi motion of the nucleons in deuteron is taken into account based on theory as:

$$F_2^{d(smear)}(x, Q^2) = \int f_2(y, \gamma) \sum_{N=p,n} F_2^N(y/x, Q^2) dy \quad (11)$$

$$F_1^{d(smear)}(x, Q^2) = \int [f_{11}(y, \gamma) \frac{2x}{y} \sum_{N=p,n} F_1^N(y/x, Q^2) + f_{12}(y, \gamma) \sum_{N=p,n} F_2^N(y/x, Q^2)] dy \quad (12)$$

$$F_L^{d(smear)} = \gamma^2 F_2^{d(smear)} - 2xF_1^{d(smear)} \quad (13)$$

Eric Christy Neutron Model

- Off-shell correction $\delta^{(off)}$ is obtained by a modified Kulagin and Petti model. The corrected deuteron structure function is: [3]

$$F^d_{1,L} = F^{d(smear)}_{1,L} / (1 - \delta^{(off)}) \tag{14}$$

- Deuterium cross section from fit is expressed by

$$\sigma^d = \Gamma(\sigma^d_T + \epsilon\sigma^d_L) \propto (F^d_1 + \frac{\epsilon}{2x} F^d_L) \tag{15}$$

- By minimizing the difference of σ^d constructed from eq. (15) with respect to data, the neutron parameters are decided

- No R_n or R_p assumption is made; "CD-Bonn" potential is used when doing smearing;
- The deuterium cross section in "F1F217" is calculated in the same procedure
- It's a fit in region $Q^2 < 13.75 Gev^2$ and $W^2 < 14 Gev^2$

[3] CJ11, A. Accardi *et al.*, arXiv:1102.3686 [hep-ph] (2011)

A>2 nuclei cross section in F1F217

- Get free nucleon structure function F_1^p, F_L^p, F_1^n, F_L^n;
- Apply EMC and off-shell corrections:

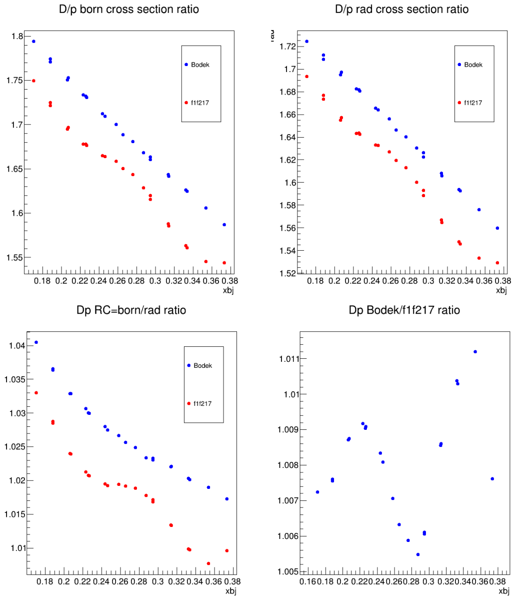
$$F_1^N = F_1^N * emcfac, \quad F_L^N = F_L^N * emcfacL \quad (N = p, n) \tag{16}$$

- Smear F_1^p, F_L^p, F_1^n, F_L^n by gaussian function;
- The nuclei structure function:

$$F_1 = Z \times F_1^{p/A} + (A - Z) \times F_1^{n/A}, \quad F_L = Z \times F_L^{p/A} + (A - Z) \times F_L^{n/A} \tag{17}$$

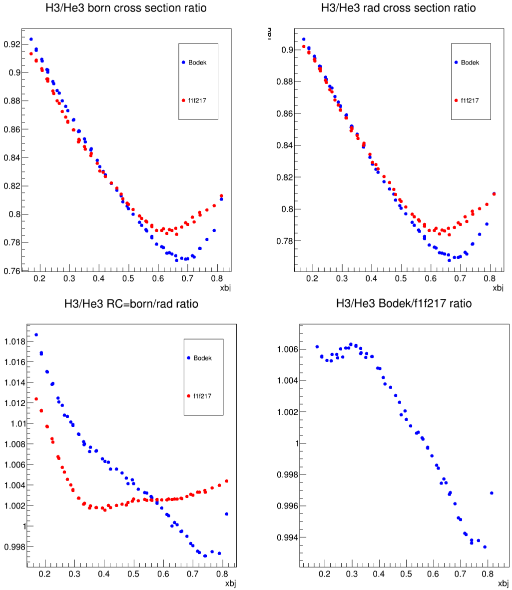
- Cross section: $\sigma = \Gamma(\sigma_T + \epsilon\sigma_L)$

RC factor comparison in marathon kinematic settings

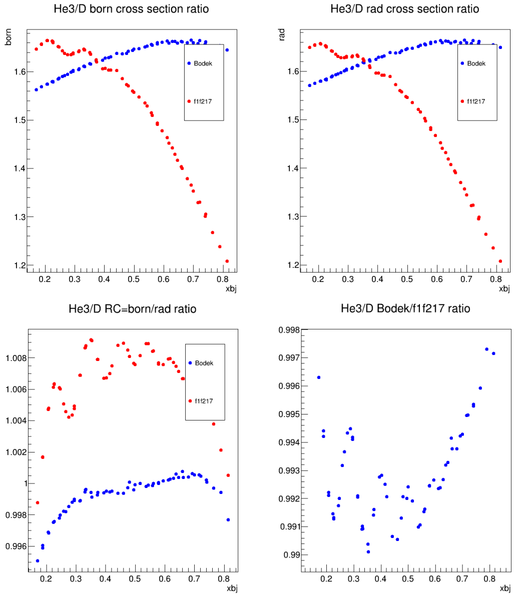


- born cross section ratio $= \frac{\sigma_{D2}}{\sigma_p}$
- rad cross section ratio $= \frac{\sigma^*_{D2}}{\sigma^*_p}$
- RC $= \frac{\sigma_{D2}/\sigma_p}{\sigma^*_{D2}/\sigma^*_p}$
- RC_{bodek}/RC_{f1f217}

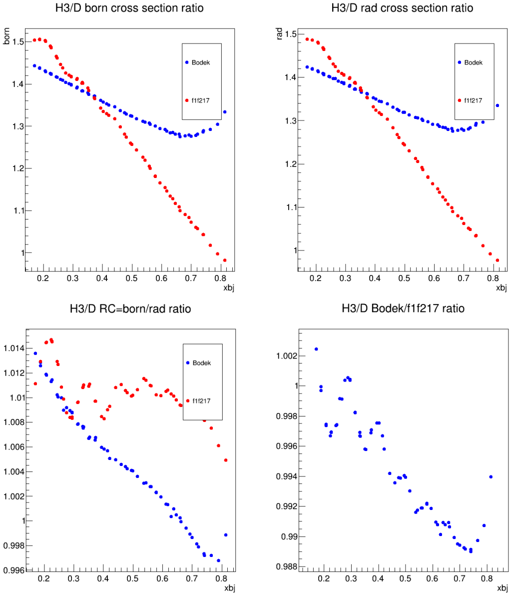
RC factor comparison in marathon kinematic settings



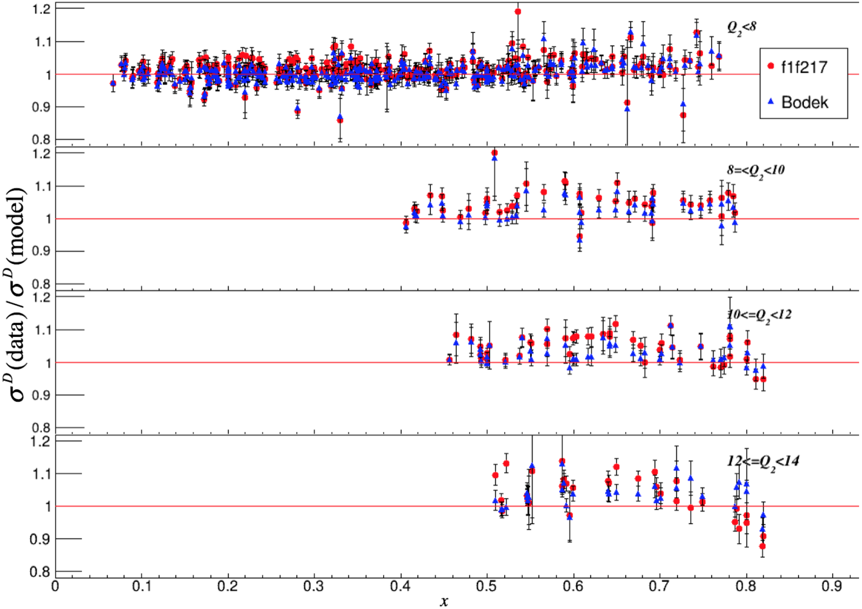
RC factor comparison in marathon kinematic settings



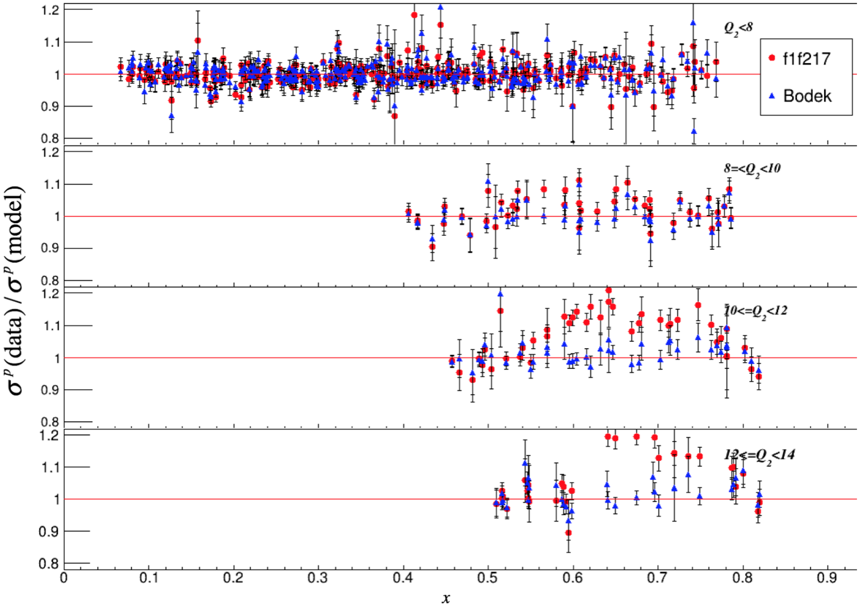
RC factor comparison in marathon kinematic settings



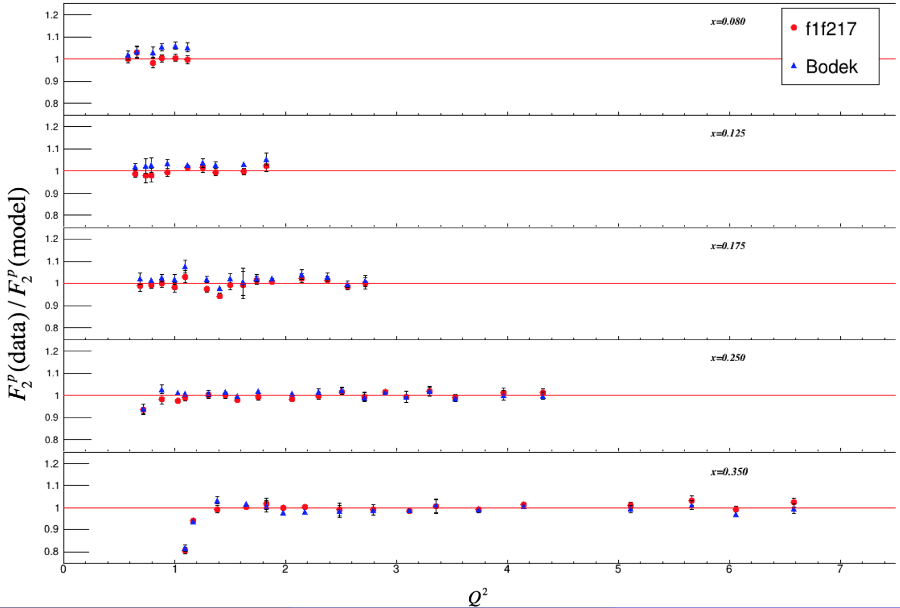
σ^D comparison with Whitlow σ^D



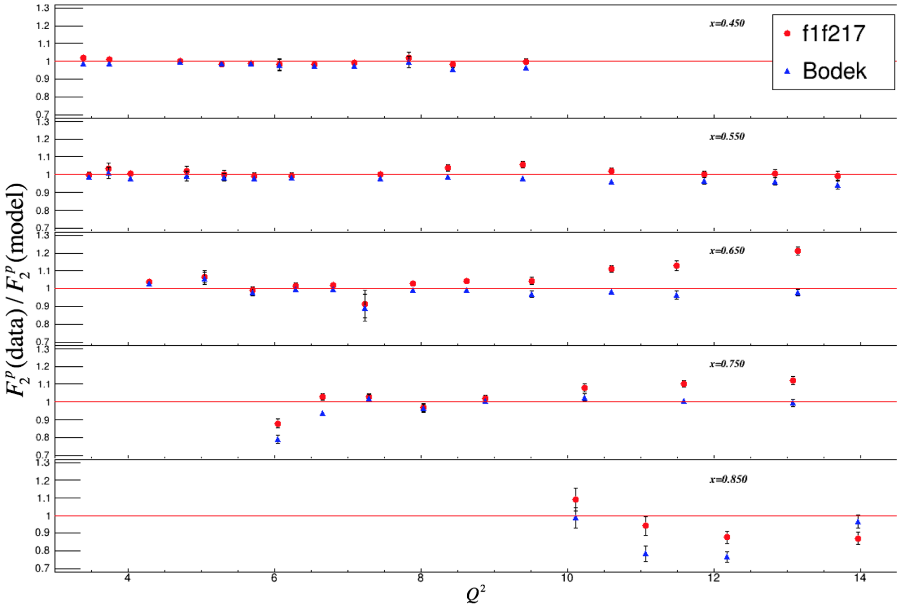
σ^p comparison with Whitlow σ^p



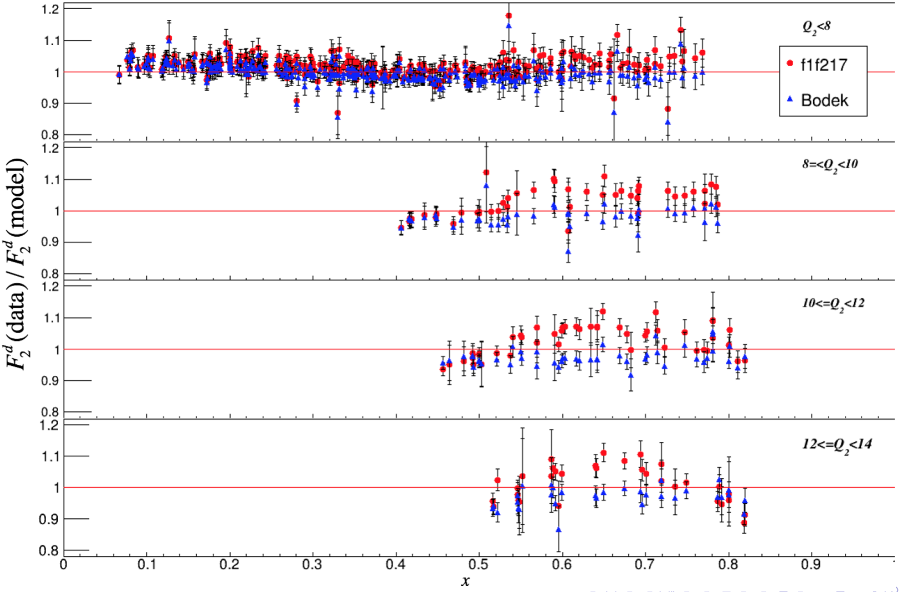
F_2^p comparison with SLAC F_2^p



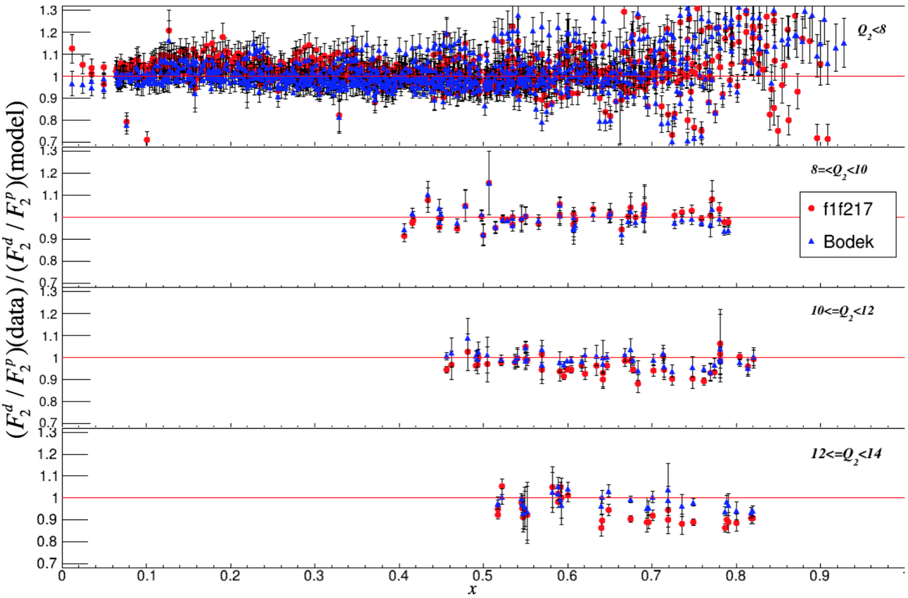
F_2^p comparison with SLAC F_2^p



F_2^d comparison with Whitlow F_2^d

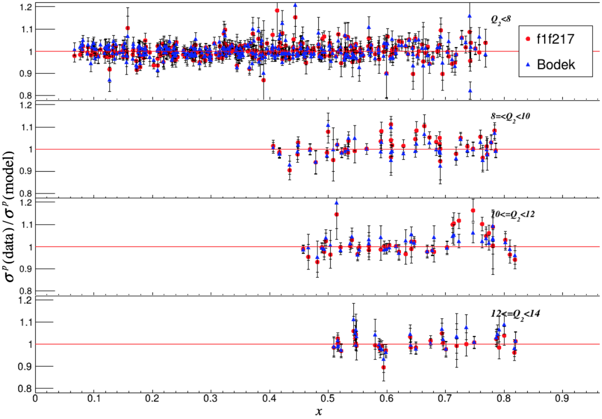


F_2^d / F_2^p comparison with Global data



Current status

- Change the W^2 region used in combining with Whitlow's fit as a function of Q^2



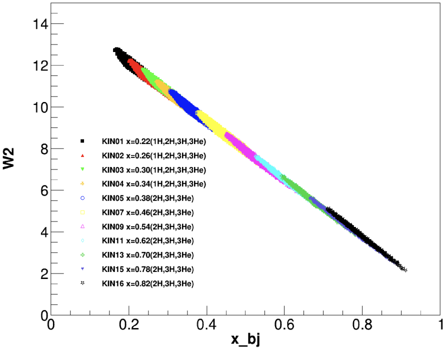
- Since the proton fit has changed, need to refit neutron. I'm waiting for Eric's new neutron fit.

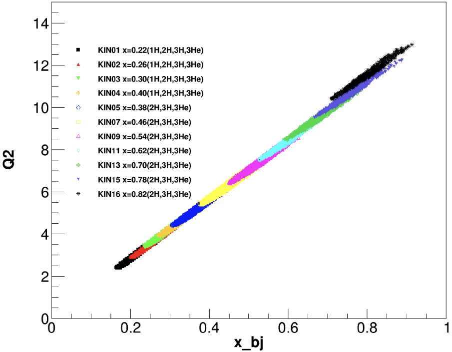
Conclusions

- The proton and deuterium cross sections from both models look good when $Q^2 < 8$;
- "f1f217" proton starts to fail when $Q^2 > 10$, and it's solved by combining with Whitlow's fit at lower W^2;
- Both of them are good as a start model for Deuterium and proton;
- Next steps:
  - go through the full procedure of bin centering and radiative correction to get D/p result with Bodek model or f1f217, then compare D/p data ratio and model ratio to tune the model;
  - check the A>2 nuclei model and the EMC correction they use;

backup

Marathon kinematics settings





F_{2p} and F_{2n} comparison

- F2p and F2n in marathon kinematics settings from two models