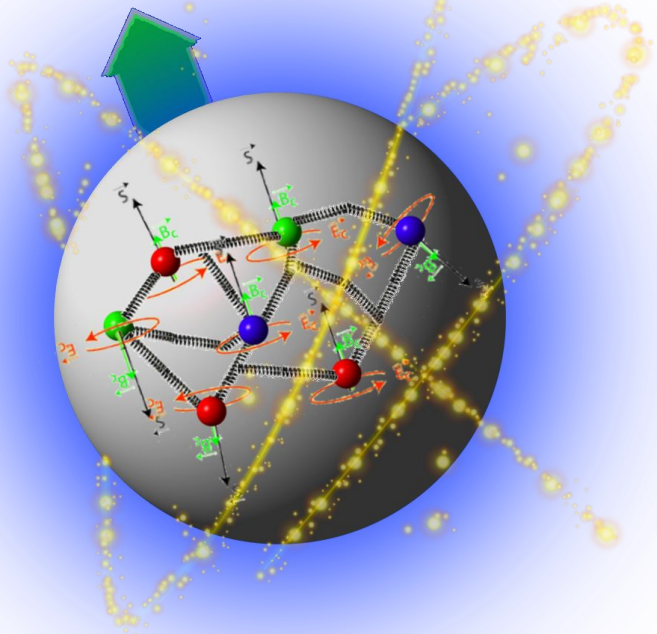
E12-06-121
Measuring the Neutron g_2 and d_2 at 12 GeV

- A cross section measurement on a *polarized* ^{3}He target in Hall C
- Directly measure the Q^2 dependence of the neutron $d_2^n(Q^2)$ at $Q^2 \approx 3, 4, 5, 6$ GeV^2 with the new polarized ^{3}He target.
  - ➡ The SHMS is ideally suited to this task!
- Doubles number of precision data points for $g_2^n(x, Q^2)$ in DIS region.
  - ➡ Q^2 evolution of g_2^n over $(0.23 < x < 0.85)$



- Spokespeople: T. Averett, W. Korsch, Z.E. Meziani, B. Sawatzky

d_2: A clean probe of quark-gluon correlations

- d_2 is a clean probe of quark-gluon correlations / higher twist effects

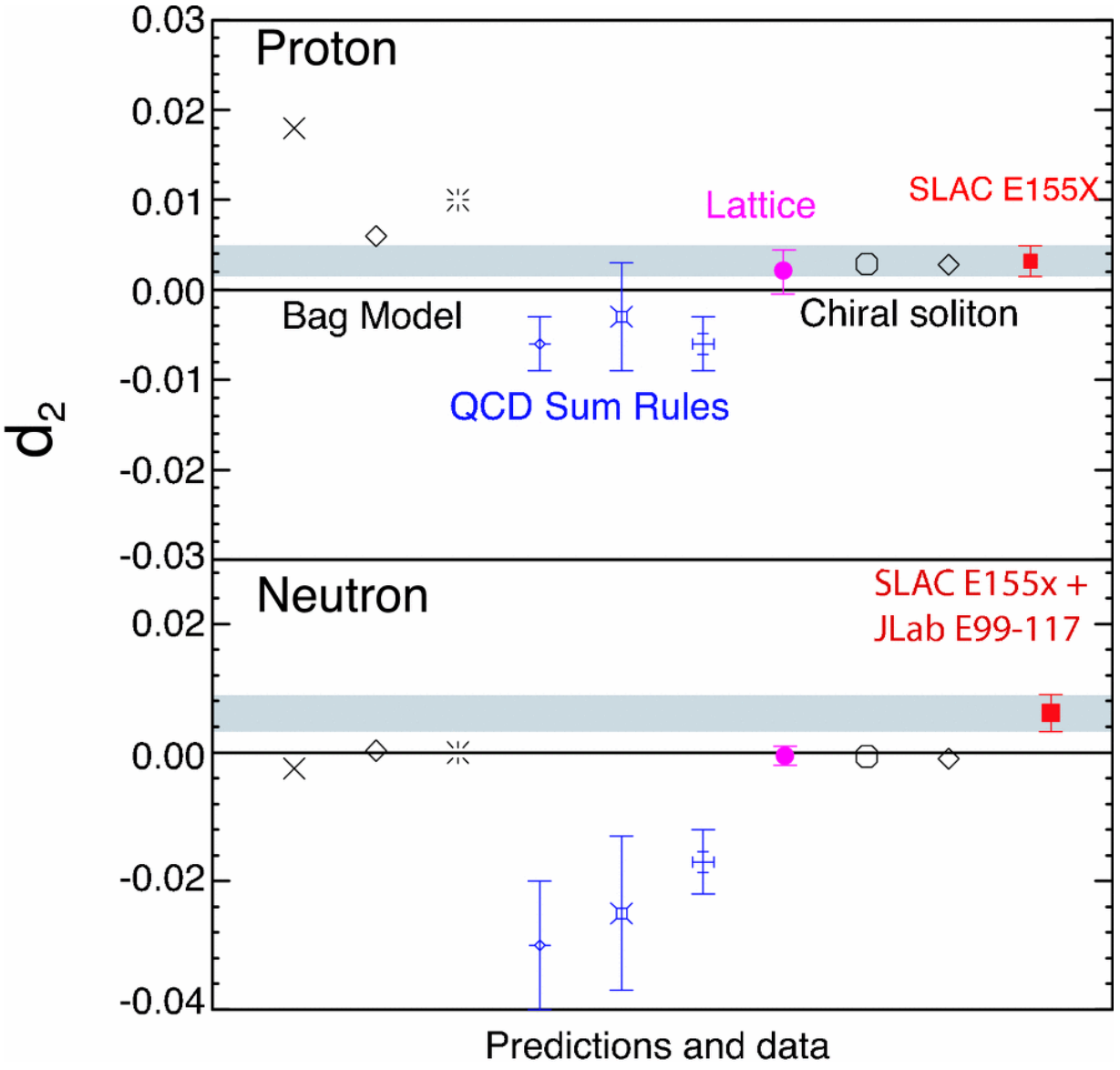
$$d_2(x,Q^2) = \int_0^1 x^2 [2g_1(x,Q^2) + 3g_2(x,Q^2)]\, dx$$

  - ➡ d_2 is the 2nd moment of a sum of the spin structure functions
  - ➡ matrix element in the Operator Product Expansion
    - ↳ *it is cleanly computable using Lattice QCD*

- Connected to the *color Lorentz force* acting on the struck quark (Burkardt)
  - ➡ same underlying physics as in SIDIS $k_\perp$ studies

- Investigate the present discrepancy between data and theories for the neutron d_2
  - ➡ Theory calcs consistent but have wrong sign, wrong value.
    - Spokespeople: T. Averett, W. Korsch, Z.E. Meziani, B. Sawatzky

Model evaluations of d_2



E12-06-121 for Hall C and SHMS/HMS

- A polarized electron beam of 11.0 GeV and *new* polarized ^{3}He target
  - ➡ Measure $\Delta\sigma_\perp = \sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}$, $\Delta\sigma_{||} = \sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}$ for $^3\vec{\mathrm{He}}(\vec{e},e')$ reaction using both the SHMS and HMS running in parallel for 4 kinematic settings of *125 hours* each
    - SHMS: (7.5 GeV/c, 11.0°), (7.0 GeV/c, 13.3°), (6.3 GeV/c, 15.5°), *(5.6 GeV/c, 18.0°)*
    - HMS: (4.3 GeV/c, 13.5°), (5.1 GeV/c, 16.4°), (4.0 GeV/c, 20.0°), *(2.5 GeV/c, 25.0°)*
- Polarized target will also be used with 12 GeV A1n, GeN experiments
- Determine d_2^n and g_2^n using the relations:

$$\tilde{d}_2 = x^2(2g_1+3g_2) = \frac{MQ^2\nu}{8\alpha_e^2}\frac{E}{E'}\frac{x^2(4-3y)}{(E+E')}\left[\Delta\sigma_{||} + \left(\frac{4-y}{(1-y)(4-3y)\sin\theta_e} - \cot\theta_e\right)\Delta\sigma_\perp\right]$$

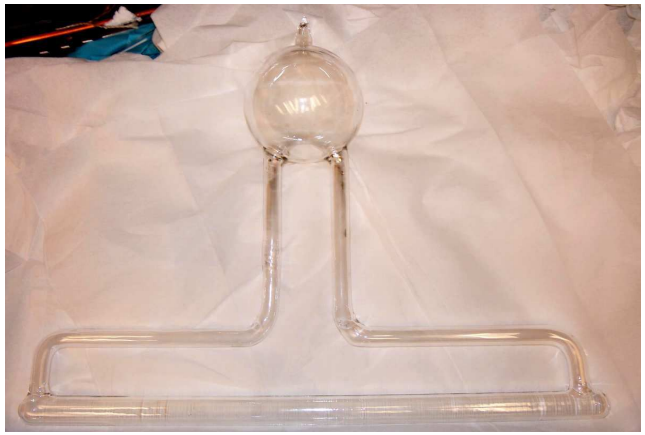
$$g_2 = \frac{MQ^2\nu^2}{4\alpha_e^2}\frac{1}{2E'(E+E')}\left[-\Delta\sigma_{||} + \frac{E+E'\cos\theta_e}{E'\sin\theta_e}\Delta\sigma_\perp\right]$$

where $\Delta\sigma_{||} = \sigma^{\downarrow\Uparrow} - \sigma^{\uparrow\Uparrow}$, $\Delta\sigma_\perp = \sigma^{\downarrow\Rightarrow} - \sigma^{\uparrow\Rightarrow}$ and $y = \nu/E$.

I_{beam} = 30 μA
P_{beam} = 0.8
P_{targ} = 0.55

Impact of Planned ^{3}He Target Upgrade

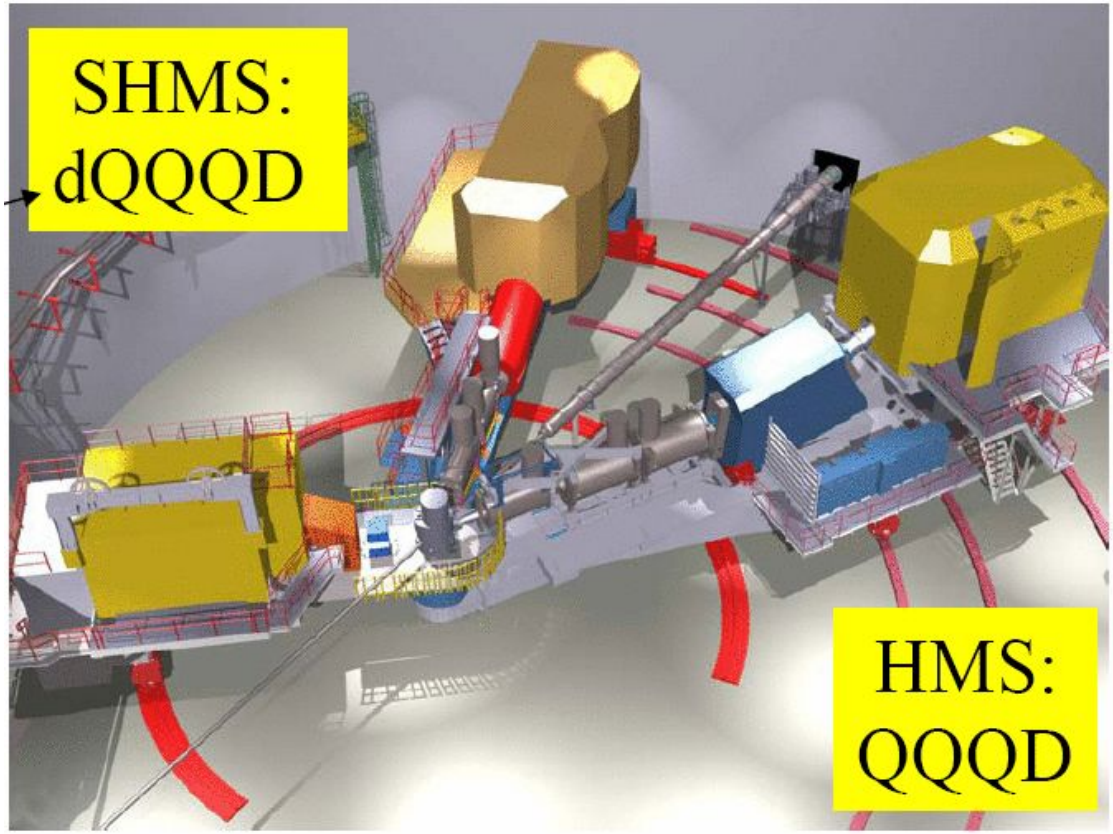
- Polarized ^{3}He target group has developed a new target design
  - ➡ "high-luminosity GEN-II" target cell
  - ➡ 60cm long target cell (2008 cell was 40cm)
  - ➡ dual transfer tube allowing active convective circulation of polarized gas
  - ➡ *Ultimate goal* for this design is to reach 60% polarization @ 60 *μA* (critical for GEN-II)



Prototype cell bench tested in 2010 (UVa)

- E12-06-121 collaboration assumed 55% polarization @ 30 *μA* for PAC36 (a "grading PAC" in Summer 2010)
  - ➡ 55% polarization @ 15 uA is sufficient to achieve original (PAC30) goals (even with original 40cm cell)
  - ➡ Extended cell + 30 *μA* operation allows significant extension of experimental reach. Additional kinematic points were added to take advantage of new design.
    - ↳ This measurement would be a good commissioning run for new target!
    - ↳ Moderate luminosity goal. Easily adapts to accommodate unforeseen issues, or add additional points if target perform to final spec.

Floor layout for Hall C

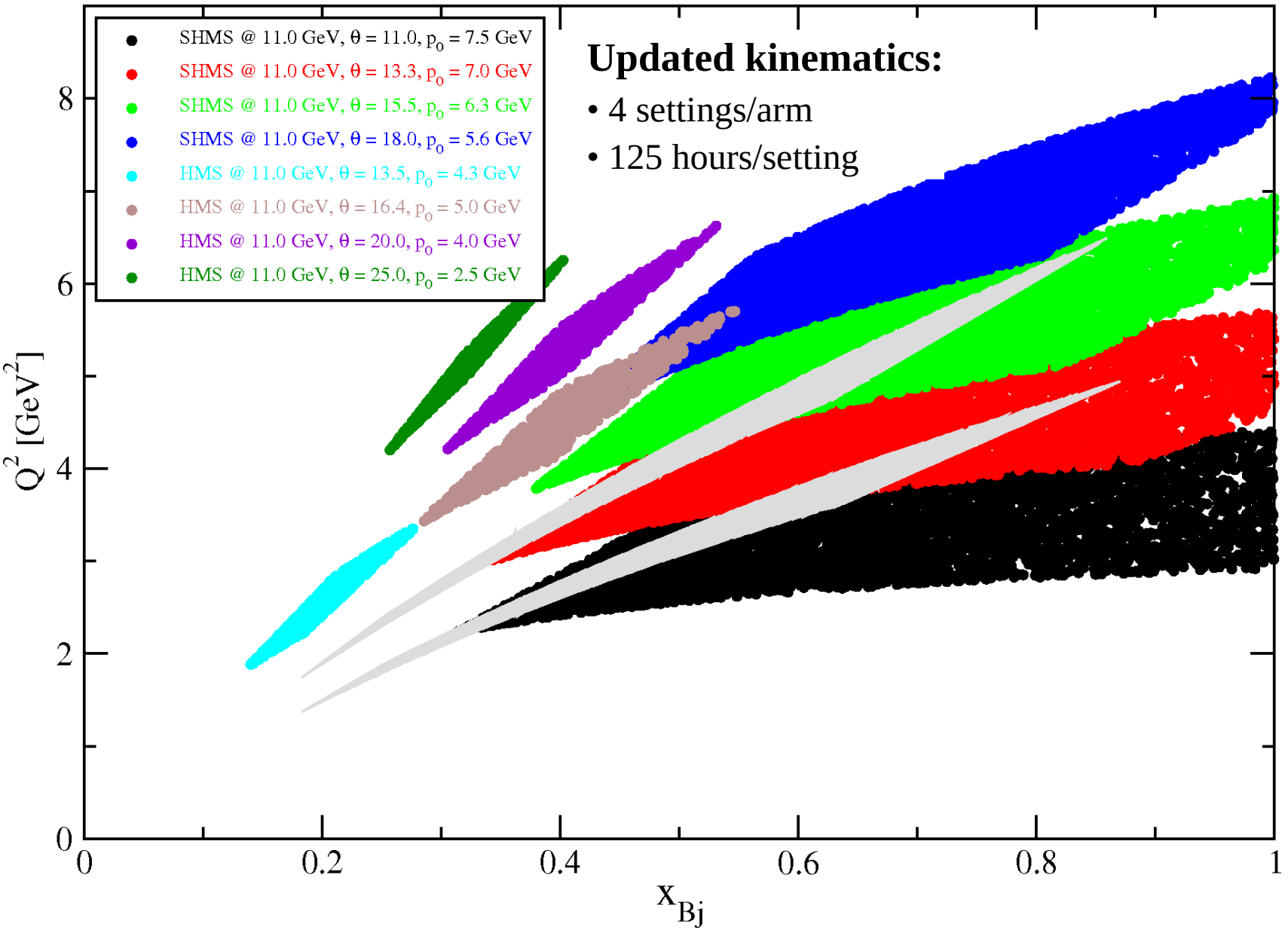


Hall C

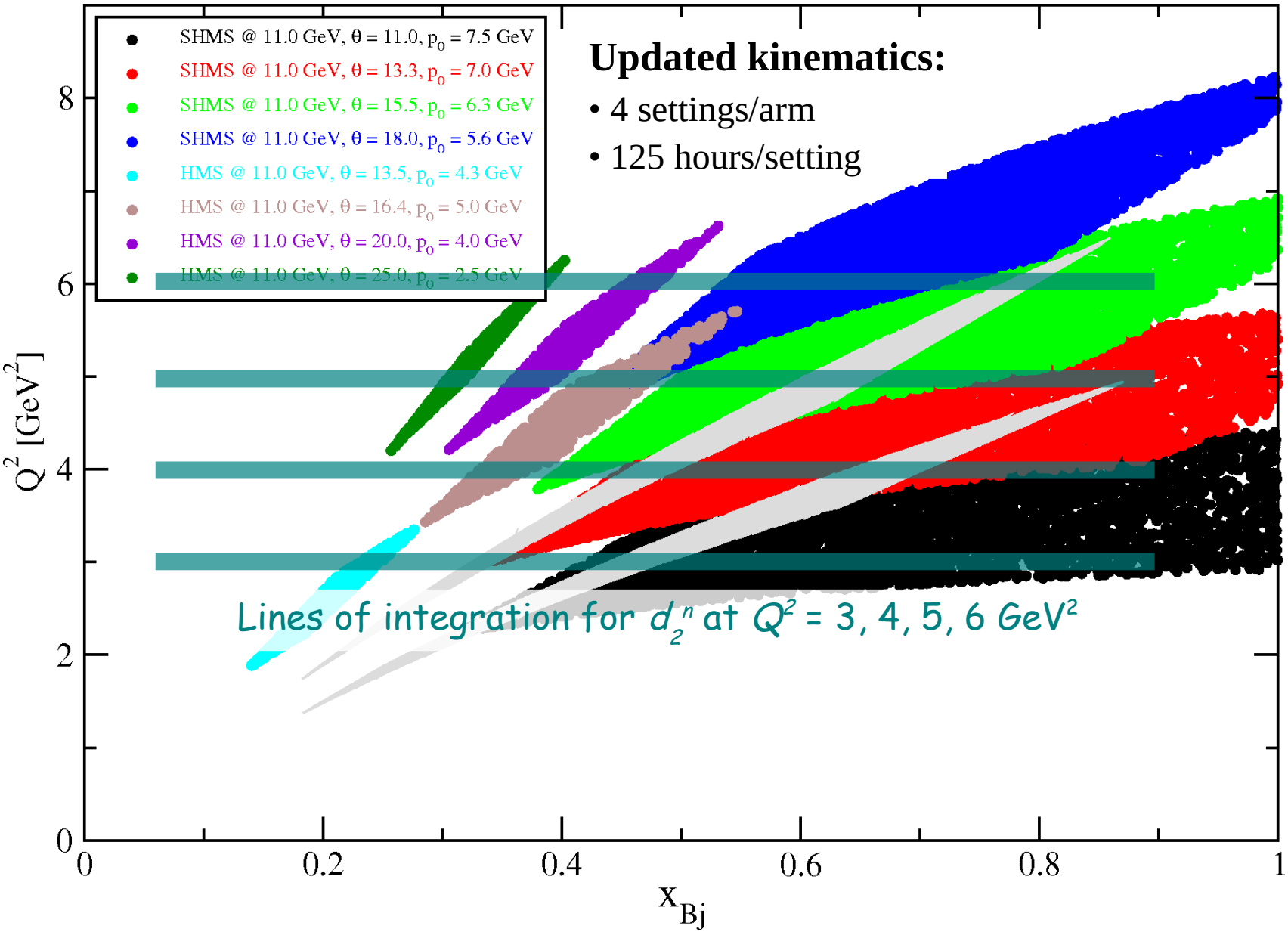
- One beam energy
  - ➡ 11 GeV
- Each arm measures a total cross section independent of the other arm.
- Experiment split into four pairs of 125 hour runs with spectrometer motion in between.

- SHMS collects data at Θ = 11°, 13.3°, 15.5° and 18.0° for 125 hrs each
  - ➡ data from each setting divided into 4 bins
- HMS collects data at Θ = 13.5°, 16.4°, 20.0° and 25.0° for 125 hrs each

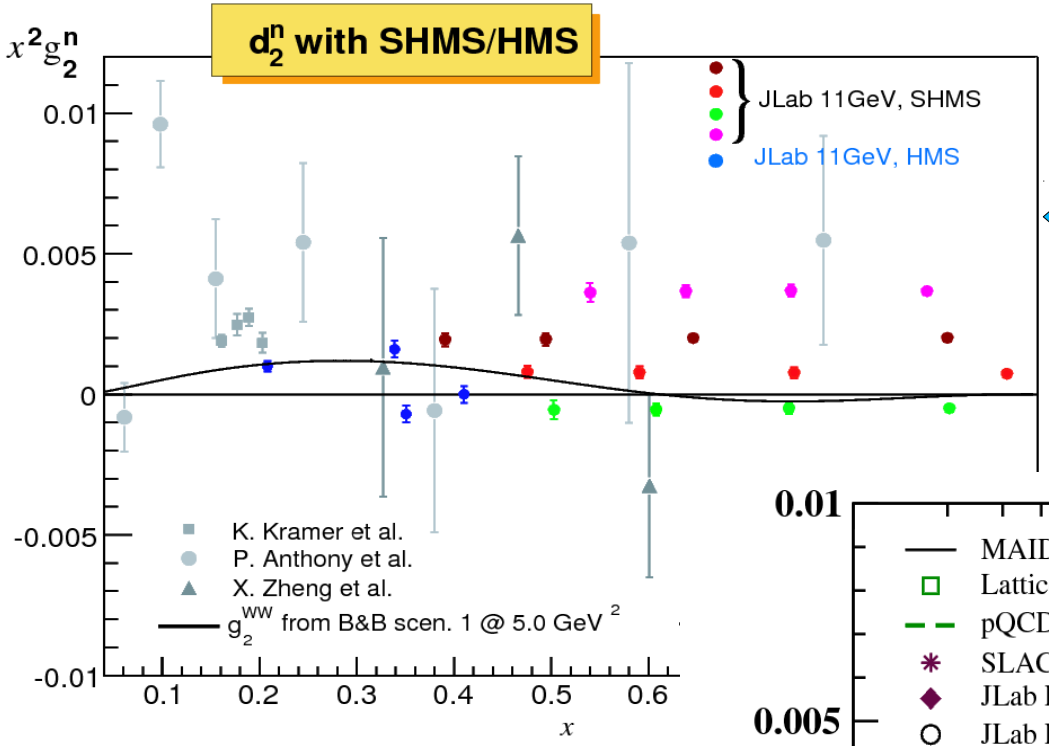
Updated Kinematics



Updated Kinematics

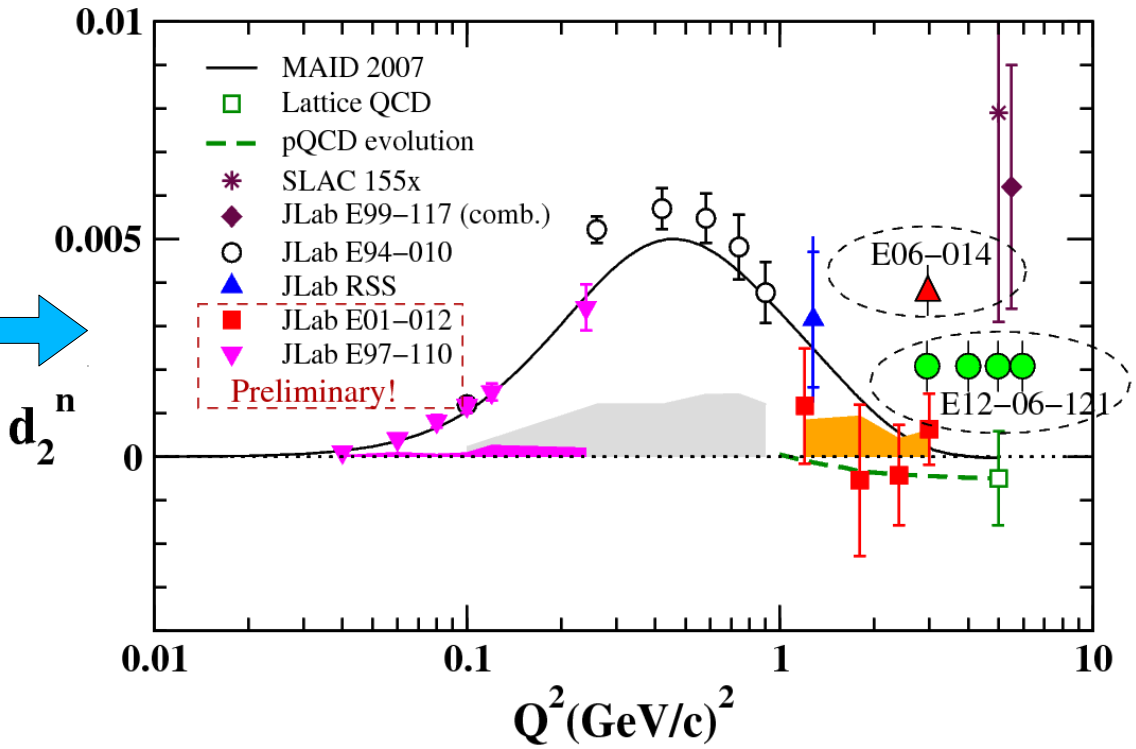


Projected results for E12-06-121



Projected g_2^n points are vertically offset from zero along lines that reflect different (roughly) constant Q^2 values from 2.5—7 GeV^2.

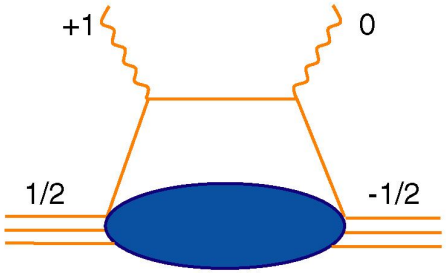
- Q2 evolution of d_2^n in a region where models are thought to be accurate.
- Direct overlap with 6 GeV Hall A measurement point.



Misc slide

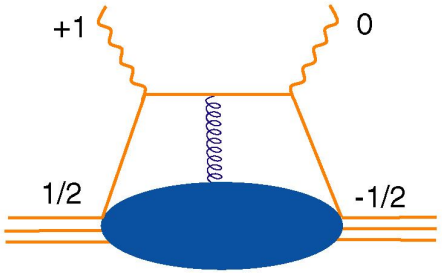
g_2 and Quark-Gluon Correlations

twist-2



QCD allows the helicity exchange to occur in two principle ways

twist-3



Carry one unit of orbital angular momentum

Couple to a gluon

$$g_2(x,Q^2) = g_2^{WW}(x,Q^2) + \bar{g}_2(x,Q^2)$$

- a twist-2 term (Wandzura & Wilczek, 1977):

$$g_2^{WW}(x,Q^2) = -g_1(x,Q^2) + \int_x^1 g_1(y,Q^2)\frac{dy}{y}$$

- a twist-3 term with a suppressed twist-2 piece (Cortes, Pire & Ralston, 92):

$$\bar{g}_2(x,Q^2) = -\int_x^1 \frac{\partial}{\partial y}\left(\frac{m_q}{M}h_T(y,Q^2) + \xi(y,Q^2)\right)\frac{dy}{y}$$

transversity

quark-gluon correlation