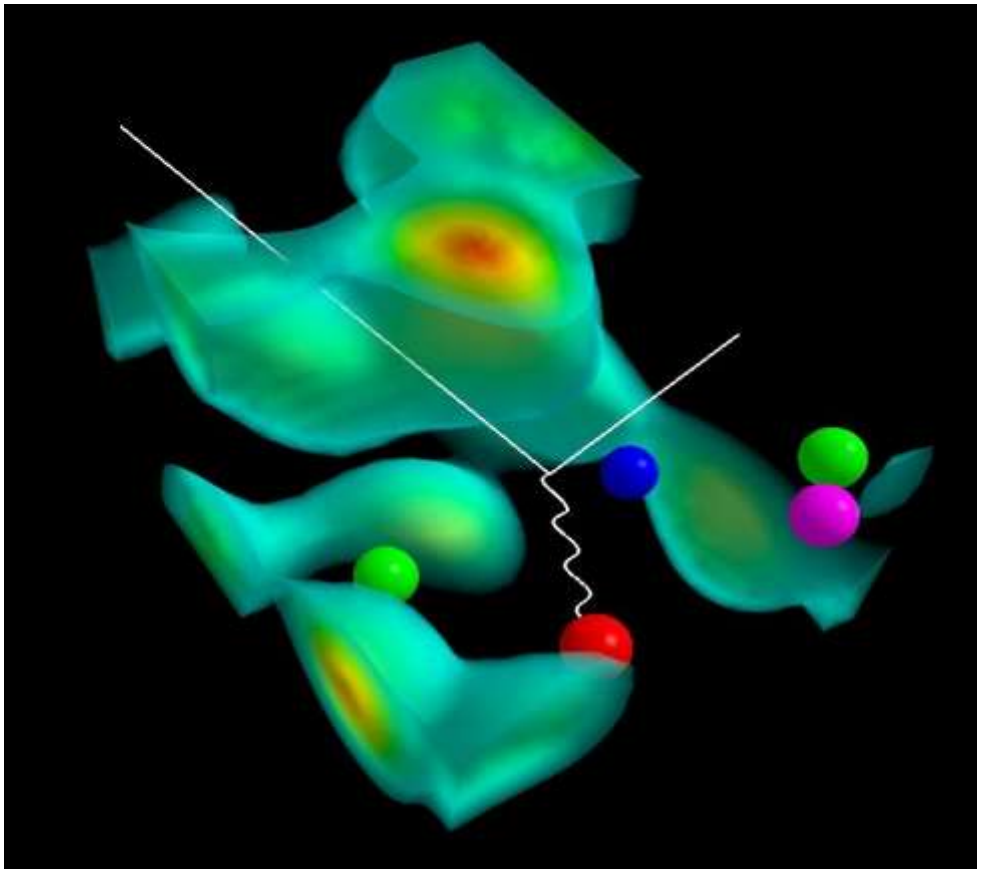
Positrons at JLab



Anthony W. Thomas

International Workshop : March 25th 2009

Elastic Proton Form Factors

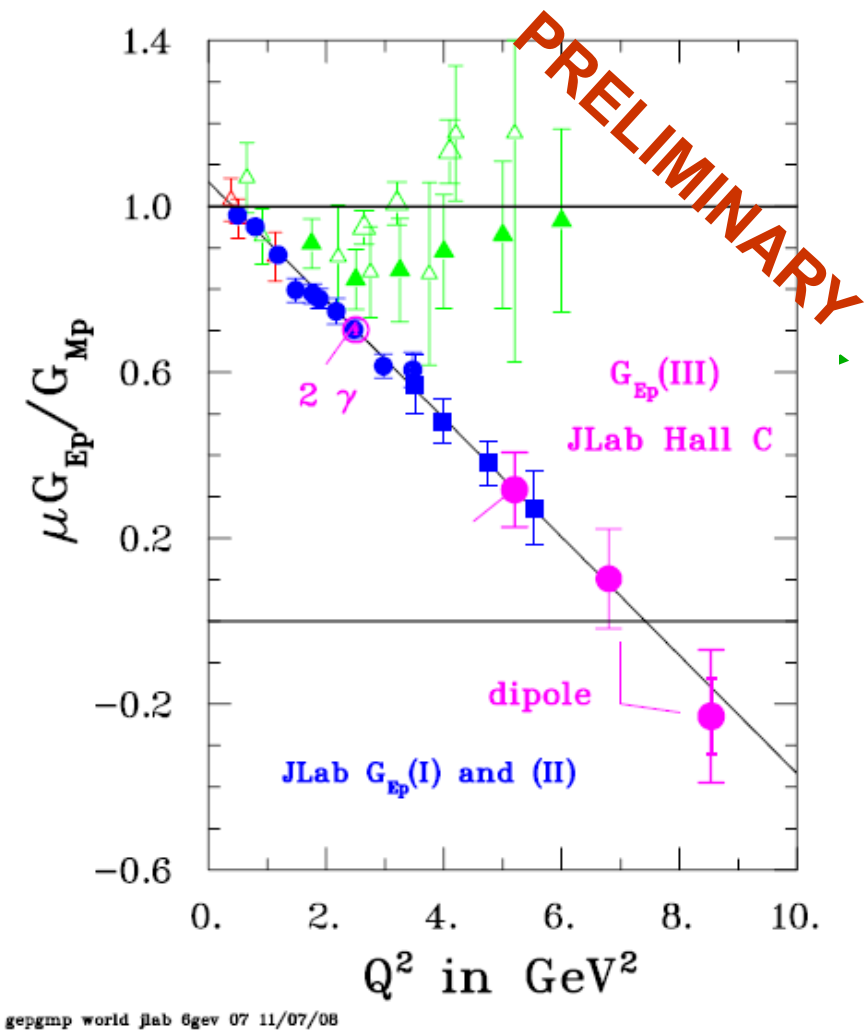
The preliminary results of E04_108 and 04-019 at Jlab.

At 2.49 GeV^2, weighted average of 3 measurements at ε=0.14, 0.63 and 0.785. 0.01 statistics, very small point-to-point systematics

At 5.2 GeV^2, chosen for χ=180^0 spin precession, hence Pn=Pℓ*sin χ ≈0;a check point.

At 6.8 GeV^2, final error

At 8.54 GeV^2, current and proposal error bars shown; systematics not known yet.

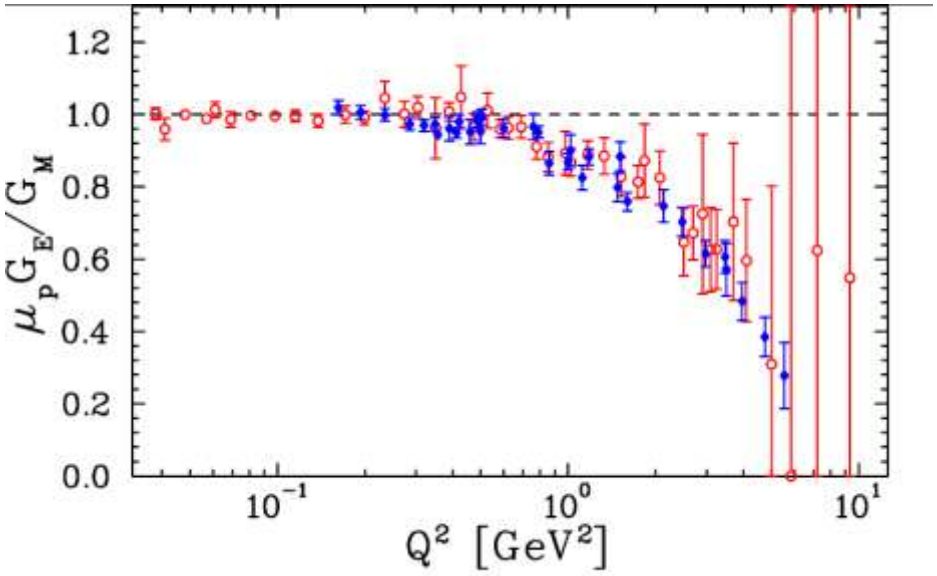


- from Perdrisat PANIC 08

2- γ exchange

- **Theoretical studies seem unambiguous:**

  - 2-γ exchange explains the difference from Rosenbluth

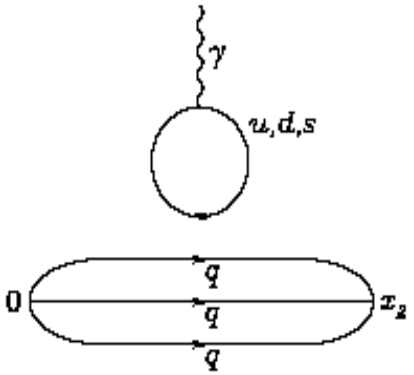


Arrington, Melnitchouk and Tjon, 2007

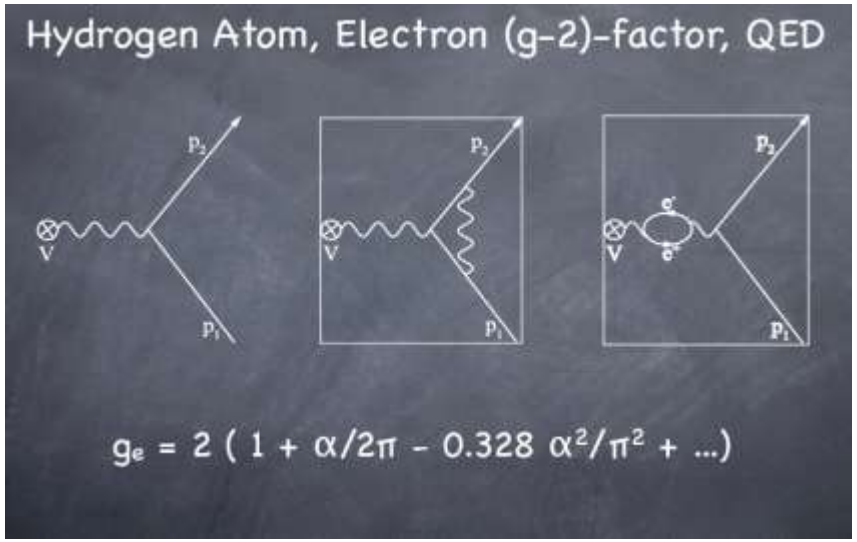
- **Change of sign of interference with e^+ would provide unambiguous experimental confirmation**

Strangeness & Electromagnetic Form Factors

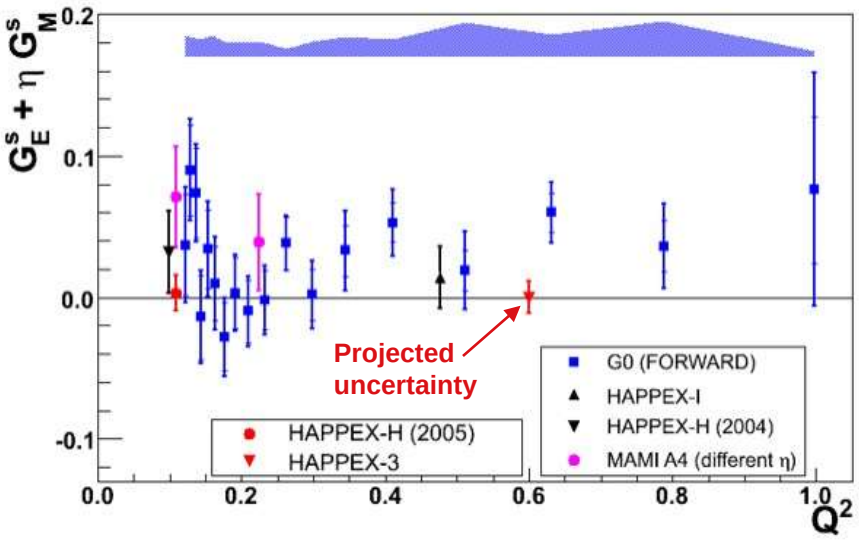
Experiment: Need Parity Violation



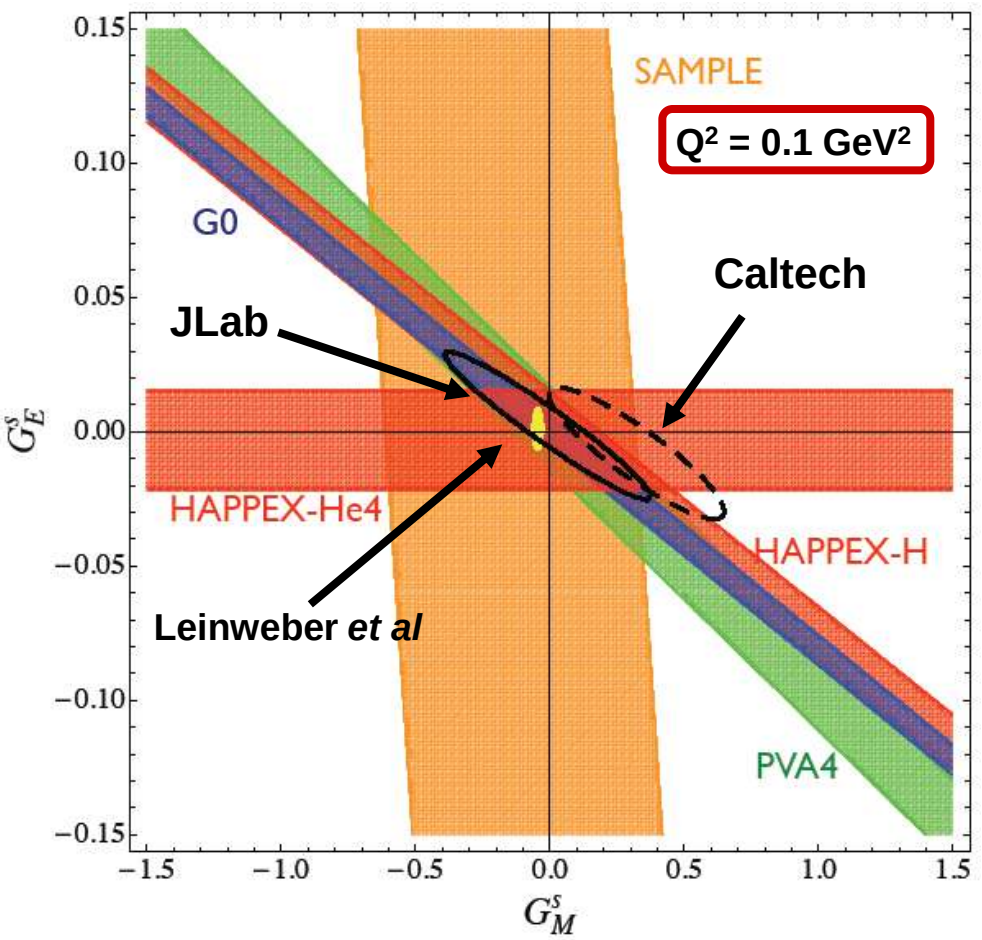
Theory: Disconnected diagram



Strangeness Content of the Proton from PVES



- Proton not all that strange
- Separation possible at 0.1 GeV^2
- New data coming at 0.23 and 0.6 GeV^2 (PVA4, G0, HAPPEx III)

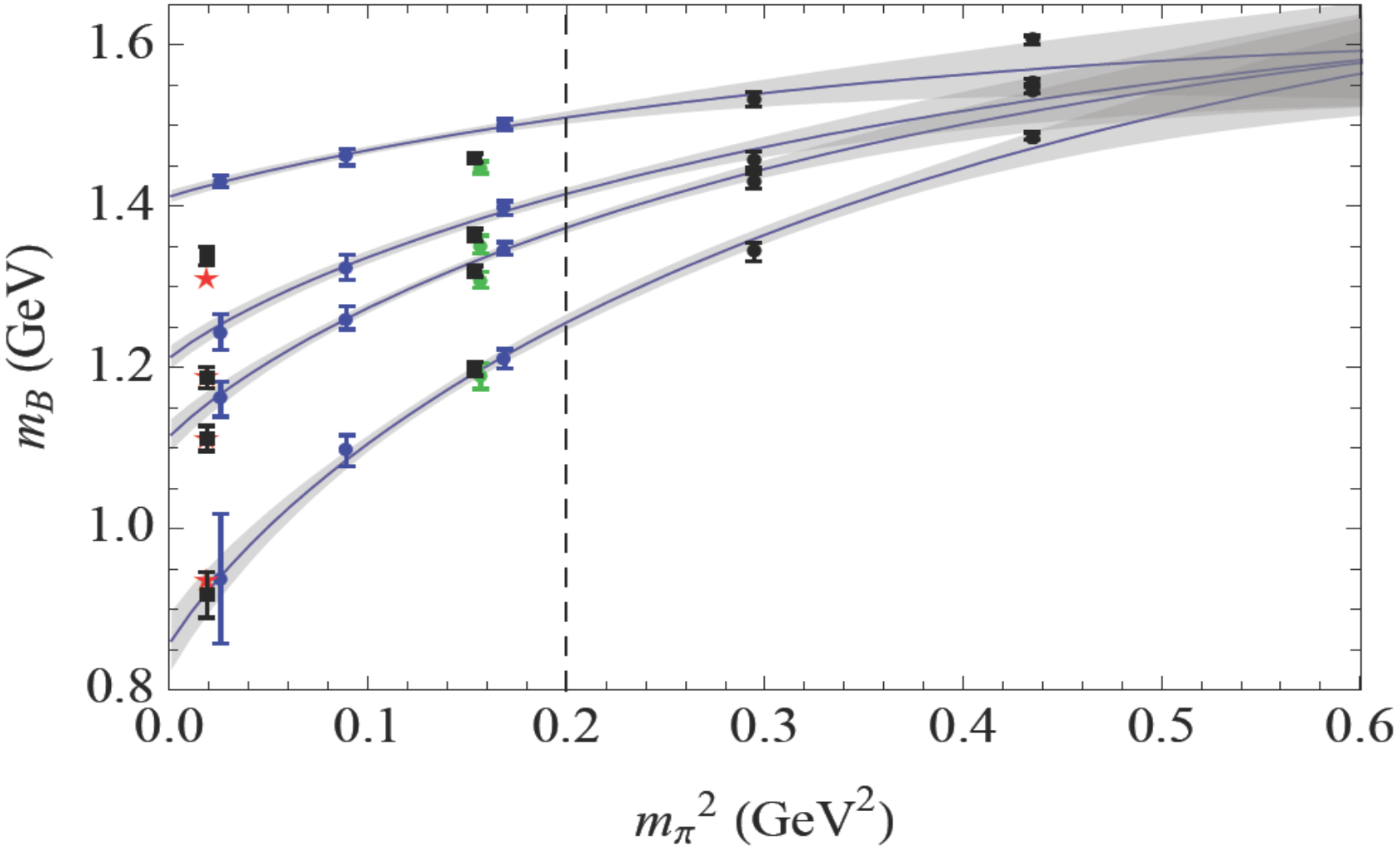


Courtesy of R. McKeown, R. Young, J. Liu

from NSAC Long Range Plan

PACS-CS Data

(Aoki et al., arXiv:0807.1661[hep-lat])



Young & Thomas, arXiv:0901.3559 [nucl-th]

Summary of Results of Combined Fits
(of 2008 LHPC & PACS-CS data)

B	Mass (GeV)	$\bar{\sigma}_{Bl}$	$\bar{\sigma}_{Bs}$
N	$0.939(19)(4)(2)$	$0.054(7)(2)(2)$	$0.020(11)(7)(3)$
Λ	$1.108(11)(10)(1)$	$0.0296(31)(5)(10)$	$0.138(11)(2)(2)$
Σ	$1.185(9)(2)(1)$	$0.0221(20)(7)(7)$	$0.176(11)(6)(2)$
Ξ	$1.321(9)(20)(0)$	$0.0095(7)(4)(0)$	$0.236(11)(4)(3)$

$$\bar{\sigma}_{Bq} = (m_q/M_B)\partial M_B/\partial m_q$$

Of particular interest:

σ commutator well determined : $\sigma_{\pi N}$= 51 (6) (2) (2) MeV

and strangeness sigma commutator small

$m_s\, \partial M_N / \partial\, m_s$ = 18 (10) (6) (3) MeV

NOT several 100 MeV !

Profound Consequences for Dark Matter Searches

Hadronic Uncertainties in the Elastic Scattering of Supersymmetric Dark Matter

John Ellis,[1,*] Keith A. Olive,[2,†] and Christopher Savage[2,‡]

CERN-PH-TH/2008-005
UMN–TH–2631/08
FTPI–MINN–08/02

We find that the spin-independent cross section may vary by almost an order of magnitude for 48 MeV $< \Sigma_{\pi N} <$ 80 MeV, the ± 2-σ range according to the uncertainties in Table I. This uncertainty is already impacting the interpretations of experimental searches for cold dark matter. Propagating the ± 2-σ uncertainties in $\Delta_s^{(p)}$, the next most important parameter, we find a variation by a factor ~ 2 in the spin-dependent cross section. Since the spin-independent cross section may now be on the verge of detectability in certain models, and the uncertainty in the cross section is far greater, *we appeal for a greater, dedicated effort to reduce the experimental uncertainty in the π-nucleon σ term $\Sigma_{\pi N}$*. This quantity is not just an object of curiosity for those interested in the structure of the nucleon and non-perturbative strong-interaction effects: it may also be key to understanding new physics beyond the Standard Model.

$$\mathcal{L} = \alpha_{2i}\bar{\chi}\gamma^{\mu}\gamma^{5}\chi\bar{q}_i\gamma_{\mu}\gamma^{5}q_i + \alpha_{3i}\bar{\chi}\chi\bar{q}_i q_i$$

spin

σ terms

Neutralino (0.3 GeV / cc :WMAP)

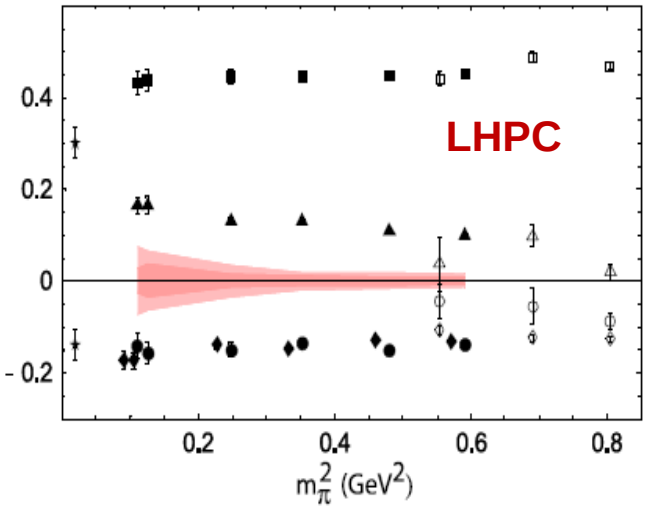
Strange quark parton distributions unknown

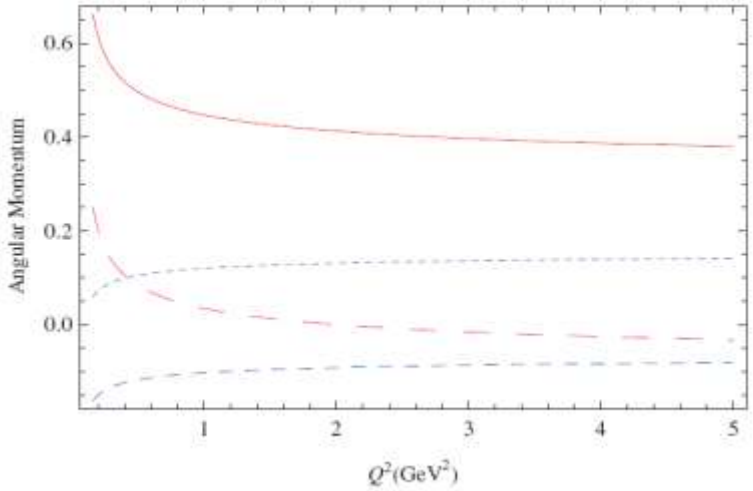
- **Sign of s – sbar as a function of x important for NuTeV**
- **Must be non-zero in general because of chiral symmetry**
- **Charge current measurements (μ^+ or μ^- in final state) would be unambiguous**

  - probably ELIC rather than 12 GeV

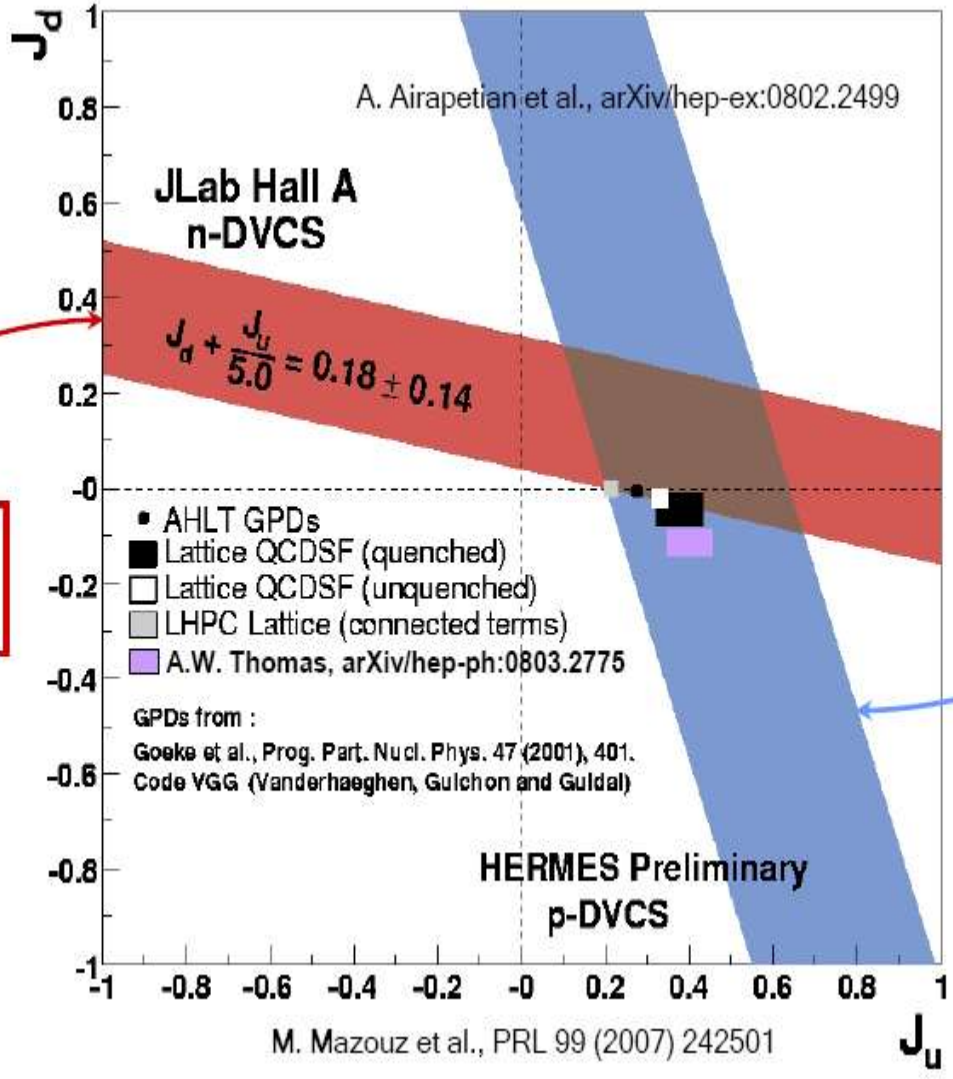
Distribution of Proton Spin

- **Polarized gluons play little or no role**
- **Modern analysis suggests that a significant fraction of the spin is carried as orbital angular momentum of quarks and anti-quarks**
- **DVCS at 12 GeV an important tool to identify this**





DVCS – promising *model dependent* results



Measurements off **neutron** are sensitive to J_d (**u** quark in the neutron)

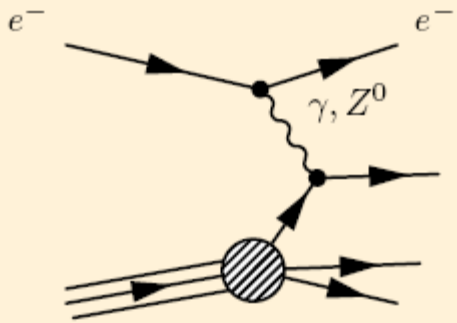
From Eric Voutier (ECT* June 08)

Measurements off **proton** are sensitive to J_u (**u** quark in the proton)

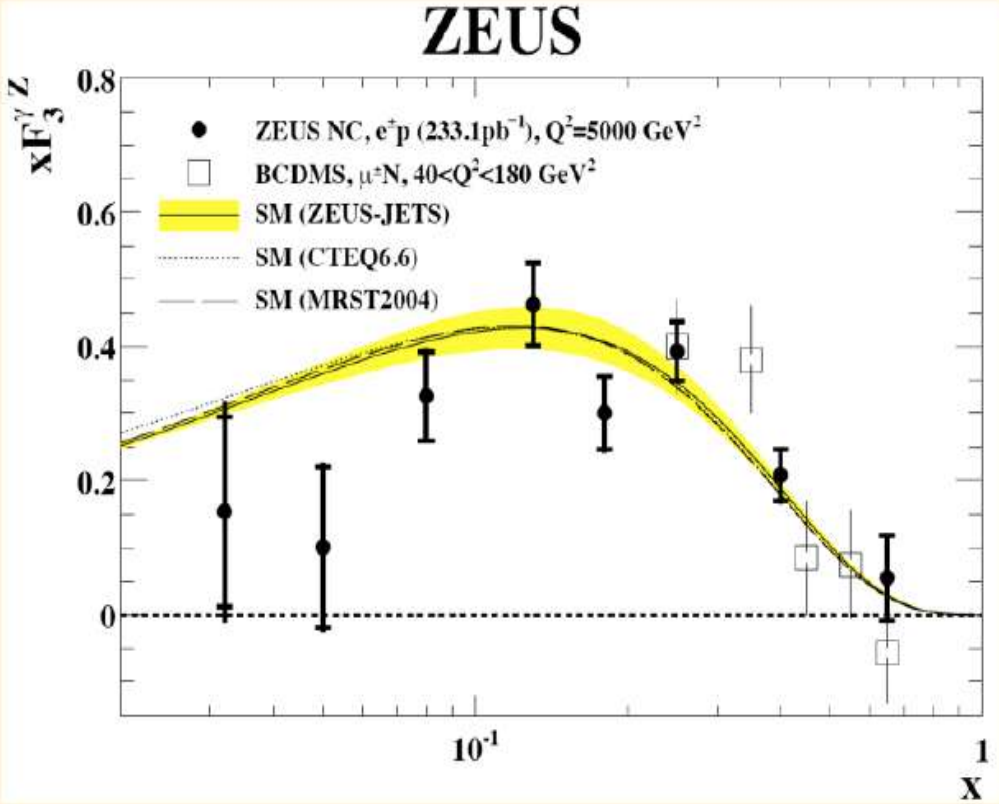
Electromagnetic Calorimeter

Theory MUST reproduce the absolute σ – hence e^+ vs e^-

HERA results for DIS



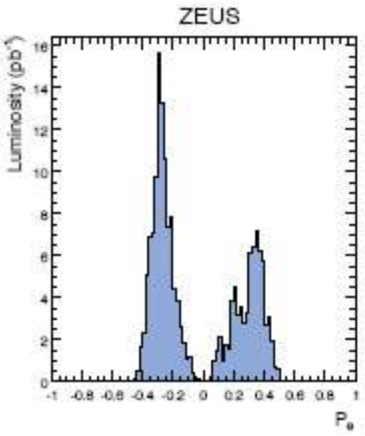
- e^- final results
- γ/Z^0 interference
- e^+ vs e^- $\Rightarrow$ xF_3

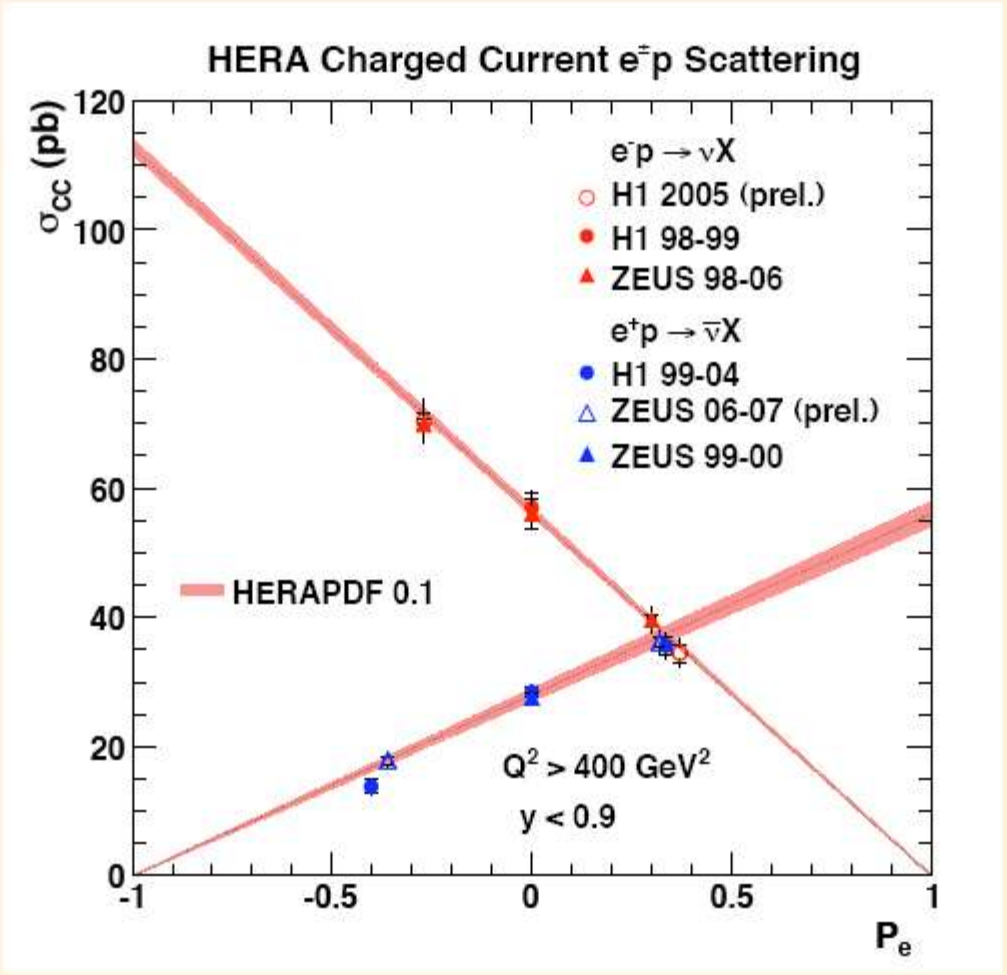


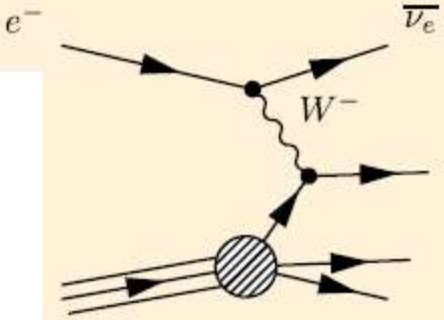
$$xF_3 \propto \sum_{i=u,d,\ldots} (q_i - \overline{q_i})$$

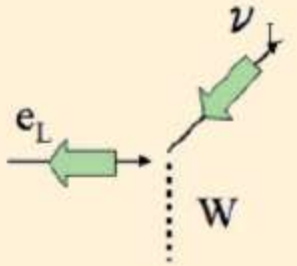
Valence quarks

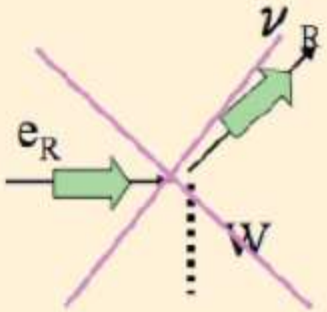
High Q^2 charged currents





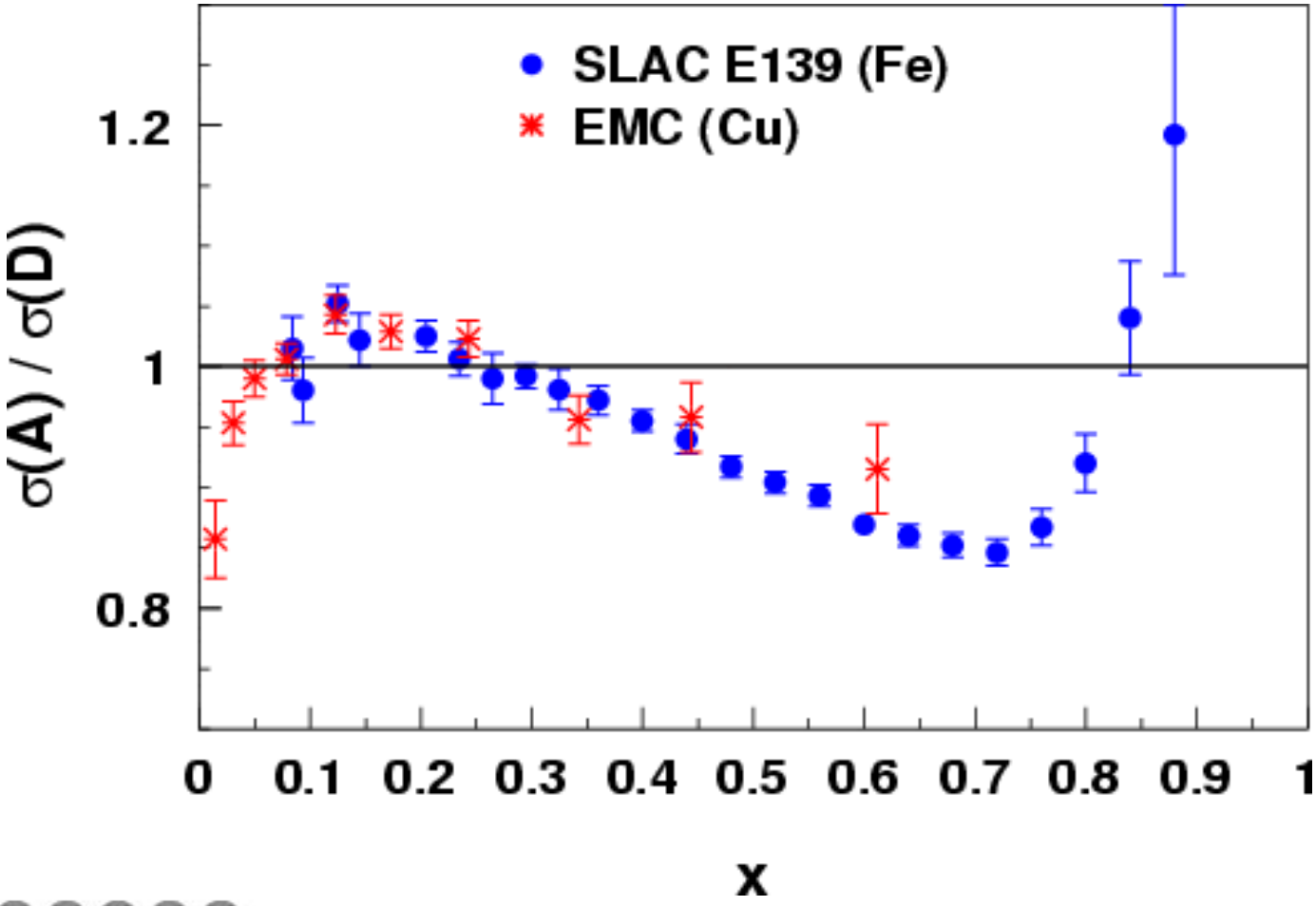






The EMC Effect: Nuclear PDFs

- Observation stunned the nuclear & particle communities 20 years ago
- Nearly 1,000 papers have been generated…..



J. Ashman *et al.*, Z. Phys. C57, 211 (1993)

J. Gomez *et al.*, Phys. Rev. D49, 4348 (1994)

What is the significance?

- Only prediction (Krzywicki, Phys.Rev.D14:152,1976) modeled nucleus as bag of 168 quarks – not at all "realistic" as a description of nuclear structure

- BUT correctly realized:

$$H_{QCD} |N\rangle = m(N) |N\rangle$$
$$H_{QCD} |^{208}Pb\rangle = m(^{208}Pb) |^{208}Pb\rangle \ldots \text{etc.}$$

i.e. nuclei are *different* eigenstates of the QCD Hamiltonian and any relation between them is model dependent

- Why description of nucleon structure as "structure of building blocks of atomic nuclei" is unappealing….

Explanations

- **Binding and Fermi motion corrections do *not* work**

- **All descriptions which describe data and satisfy basic theoretical constraints involve a *fundamental change in the structure of bound "nucleon"***

- **Discovering how the structure is modified and the role this plays in nuclear structure (and structure of dense matter) is *one of the most fundamental issues facing nuclear physics and a task for which JLab is ideally suited*…. but has not yet delivered**

- **Any successful theory must describe free nucleon structure and observables, describe properties of nuclear matter & finite nuclei and ideally explain effective NN forces**

Effect of Isovector-Vector Potential in DIS

- Recall: $q_A(x_A) = \frac{\overline{M}_N}{\hat{M}_N}\, q_{A0}\left(\frac{\overline{M}_N}{\hat{M}_N} x_A - \frac{V_q}{\hat{M}_N}\right)$
- $N \neq Z \implies u$- and d-quarks feel different V_q
- $N > Z \implies V_u < V_d\ ,\ \langle x\, u^- \rangle < \langle x\, d^- \rangle$
- Therefore: $\langle x\, u_A^- \rangle < \langle x\, u_0^- \rangle,\ \langle x\, d_A^- \rangle > \langle x\, d_0^- \rangle$
  - Vector fields maintain momentum sum rule!!
- Isoscalarity: $\langle x\, u_0^- - x\, d_0^- \rangle = 0,\ \langle x\, u_A^- - x\, d_A^- \rangle < 0$
- Recall $\Delta R_{PW}^{CSV} \simeq \left(1 - \frac{7}{3}\sin^2\Theta_W\right) \frac{\langle x\, u_A^- - x\, d_A^- \rangle}{\langle x\, u_A^- + x\, d_A^- \rangle}$
- Therefore ΔR_{PW}^{CSV} is negative – after isoscalarity
- ρ_0 vector field reduces anomaly – Model Independent!!

Isovector EMC Effect Eliminates NuTeV Anomaly

NuTeV: $\sin^2\theta_W = 0.2277 \pm 0.0013 \pm 0.0009$

: with isovector EMC* $\rightarrow$ 0.2245 (2σ)

: with CSV $\rightarrow$ 0.2228 (1σ)

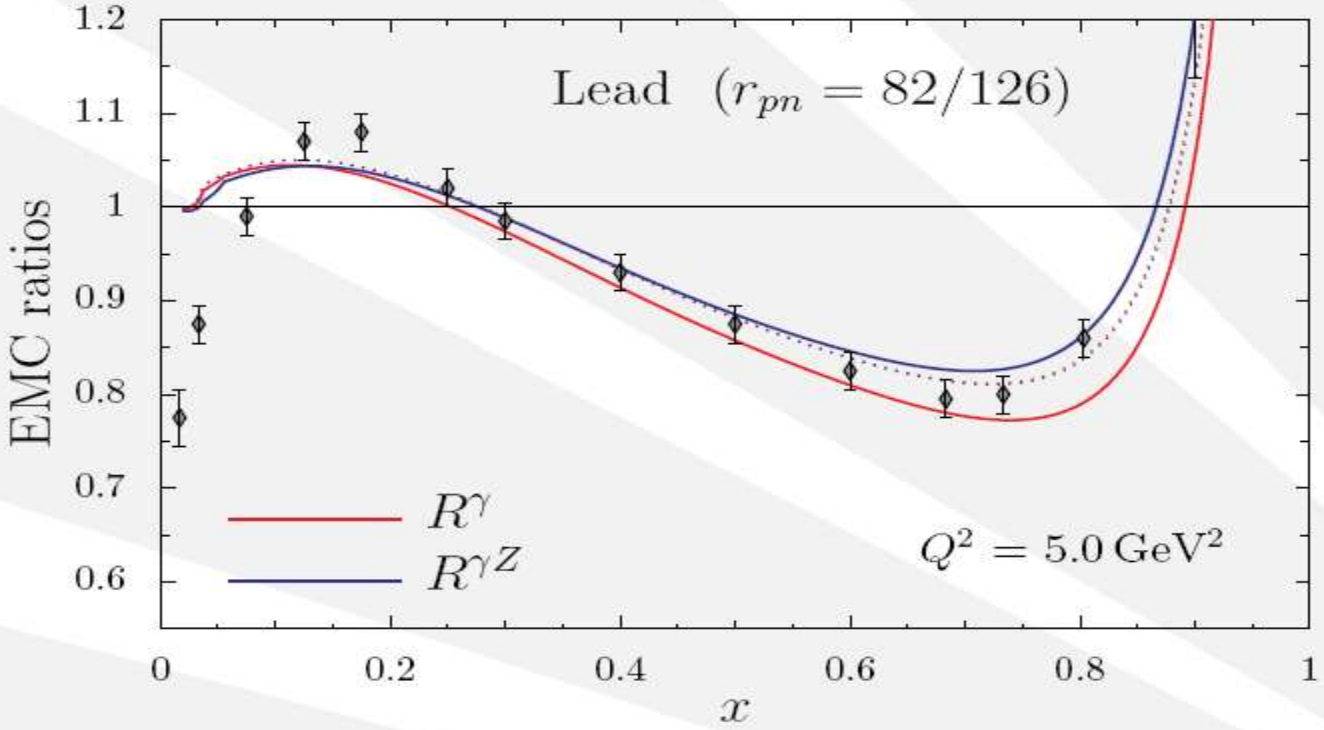
c.f. Standard Model: 0.2227 ± 0.0004

- Thus, with additional (almost model independent) effect of charge symmetry violation (Londergan et al.), NuTeV agrees perfectly with Standard Model

- Alternatively, given Standard Model (c.f. PVES) NuTeV may be seen as a remarkable confirmation of the in-medium modification of nucleon structure!
  - within nuclear physics equally significant!!

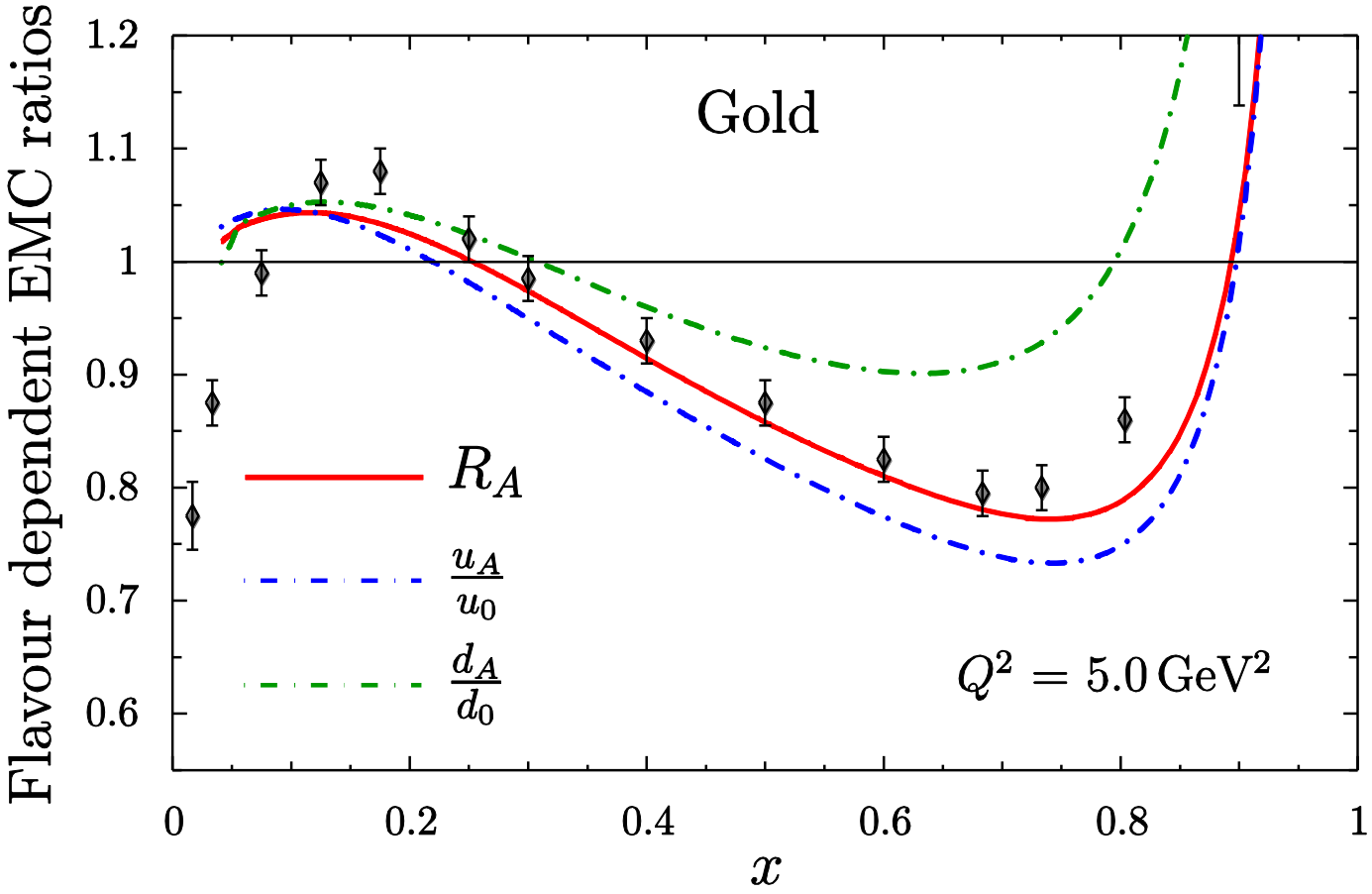
*Cloet et al., nucl-th/0901.3559

PV DIS



- $R^\gamma \sim \frac{4\,u_A(x)+d_A(x)}{4\,u_0(x)+d_0(x)}$ & $R^{\gamma Z} \sim \frac{1.16\,u_A(x)+d_A(x)}{1.16\,u_0(x)+d_0(x)}$
- $\frac{Z}{N} < 1 : u_A(x) < d_A(x)$, V_u decreases, V_d increases
- ρ_0-field $\Longrightarrow R^{\gamma Z} > R^\gamma$ – Model Independent

Isovector EMC Effect ⇒ Clean Test



Light Dark Matter

- **Talk of Bogdan Wojtsekhowski….**
- **Motivated by intense signal of 511 keV X-rays from galactic centre – INTEGRAL satellite**
- **Possible source (e.g. Fayet 1980) U-boson mass ~ few to 10's of MeV coupling to e^+ e^-**