Argonne NATIONAL LABORATORY

... for a brighter future

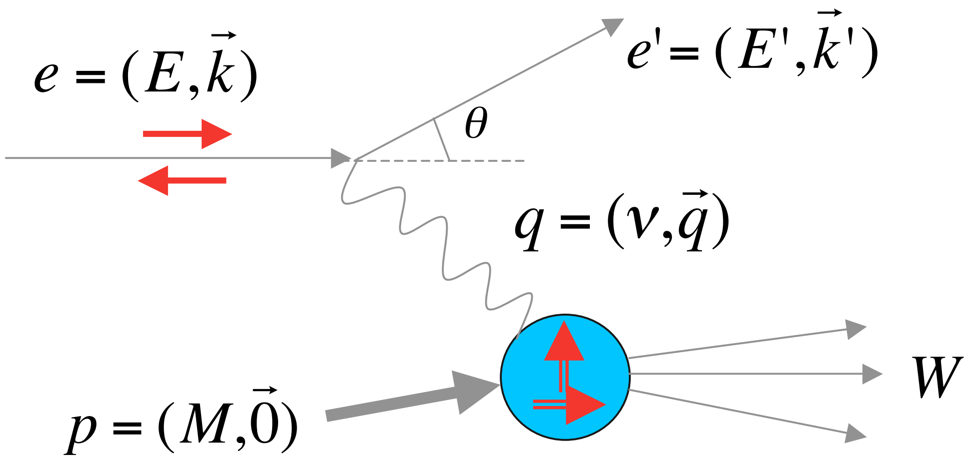
E01-012: Spin Duality Status report

Patricia Solvignon

Argonne National Laboratory

For E01-012 collaboration

Inclusive electron scattering



4-momentum transfer squared

$$Q^2 = -q^2 = 4EE'\sin^2\tfrac{\theta}{2}$$

Invariant mass squared

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

Bjorken variable

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

Unpolarized case

$$\frac{d^2\sigma}{d\Omega dE'} = \sigma_{Mott}\left[\frac{1}{\nu}F_2(x,Q^2) + \frac{2}{M}F_1(x,Q^2)\tan^2\tfrac{\theta}{2}\right]$$

Polarized case

$$\frac{d^2\sigma^{\uparrow\Uparrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Uparrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{\nu E Q^2}\left[(E + E'\cos\theta)g_1(x,Q^2) - 2Mxg_2(x,Q^2)\right]$$

$$\frac{d^2\sigma^{\uparrow\Rightarrow}}{d\Omega dE'} - \frac{d^2\sigma^{\downarrow\Rightarrow}}{d\Omega dE'} = \frac{4\alpha^2 E'}{\nu E Q^2}\sin\theta\left[g_1(x,Q^2) + \frac{2ME}{\nu}g_2(x,Q^2)\right]$$

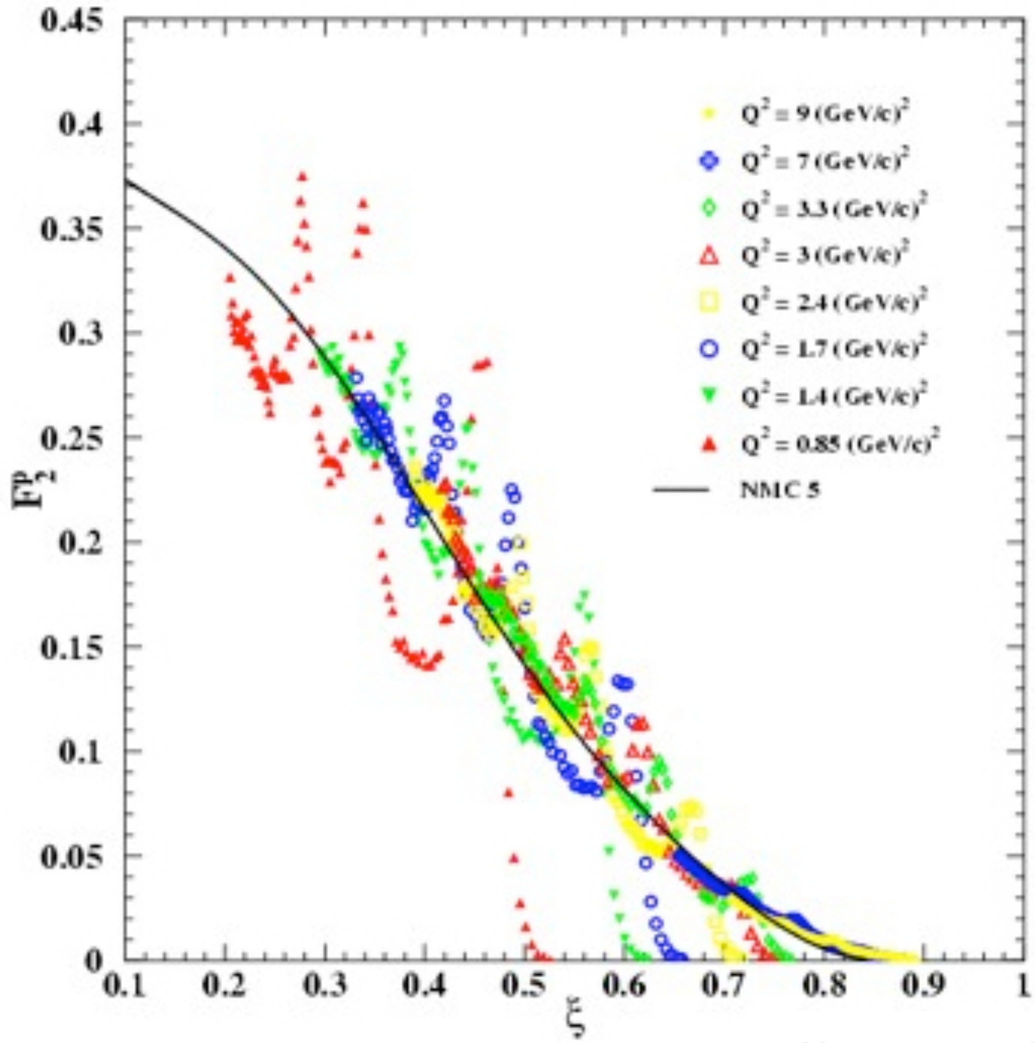
Argonne NATIONAL LABORATORY

Quark-hadron duality

- First observed by Bloom and Gilman in the 1970's on F_2

- Scaling curve seen at high Q^2 is an accurate average over the resonance region at lower Q^2

- Global and Local duality are observed for F_2

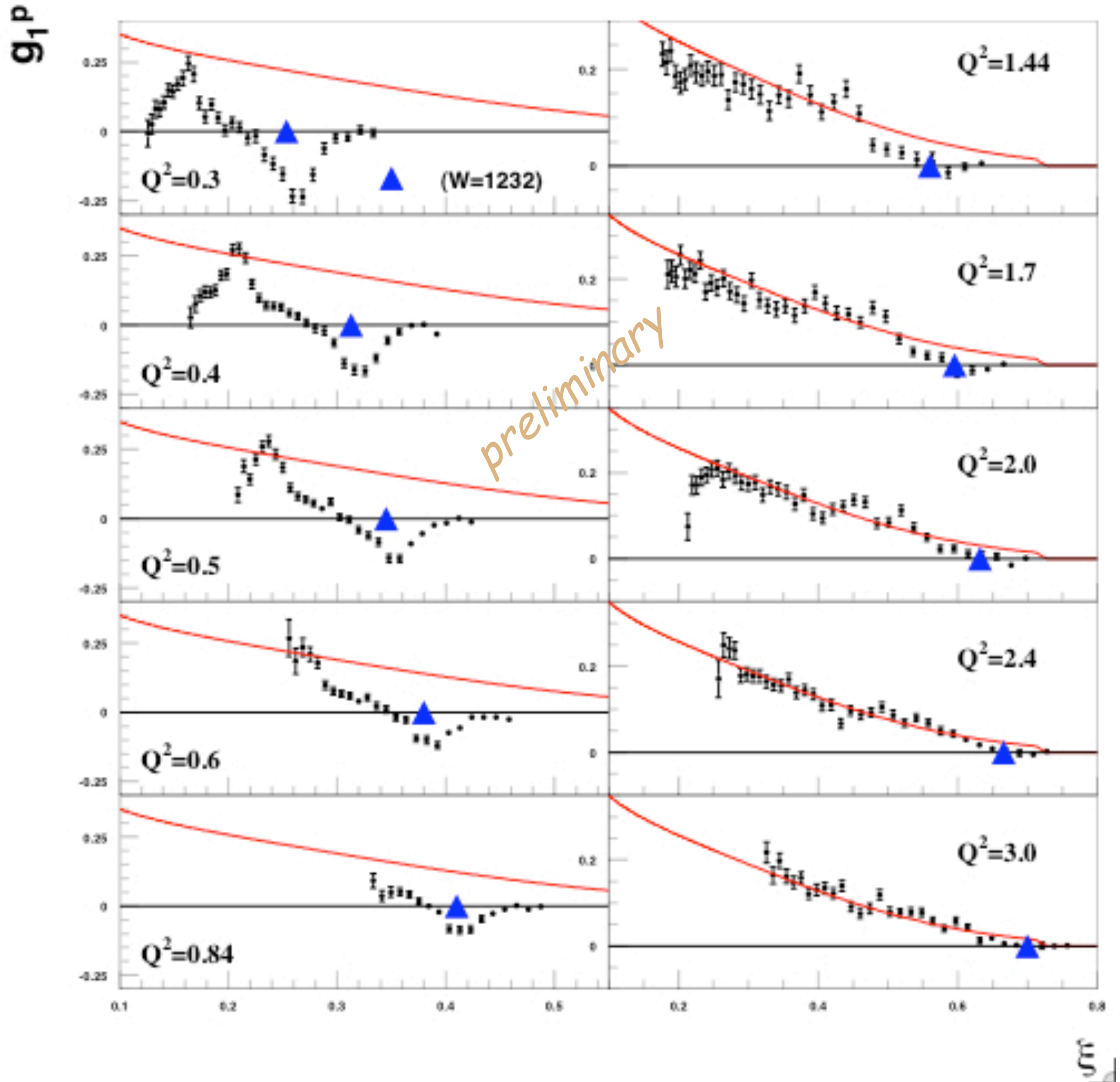


I. Niculescu et al., PRL 85 (2000) 1182

World data

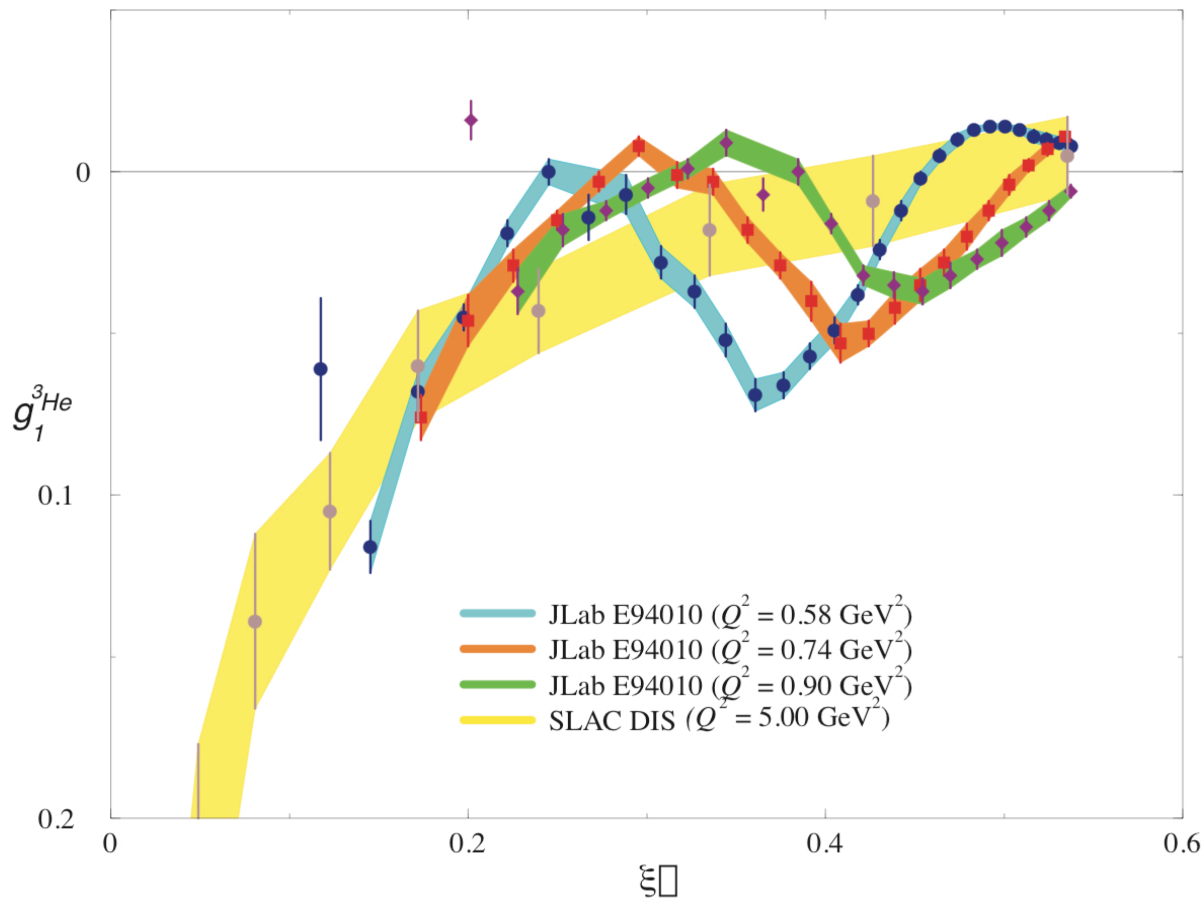
Jlab Hall B for g_1^p

From DIS 2005 proceedings



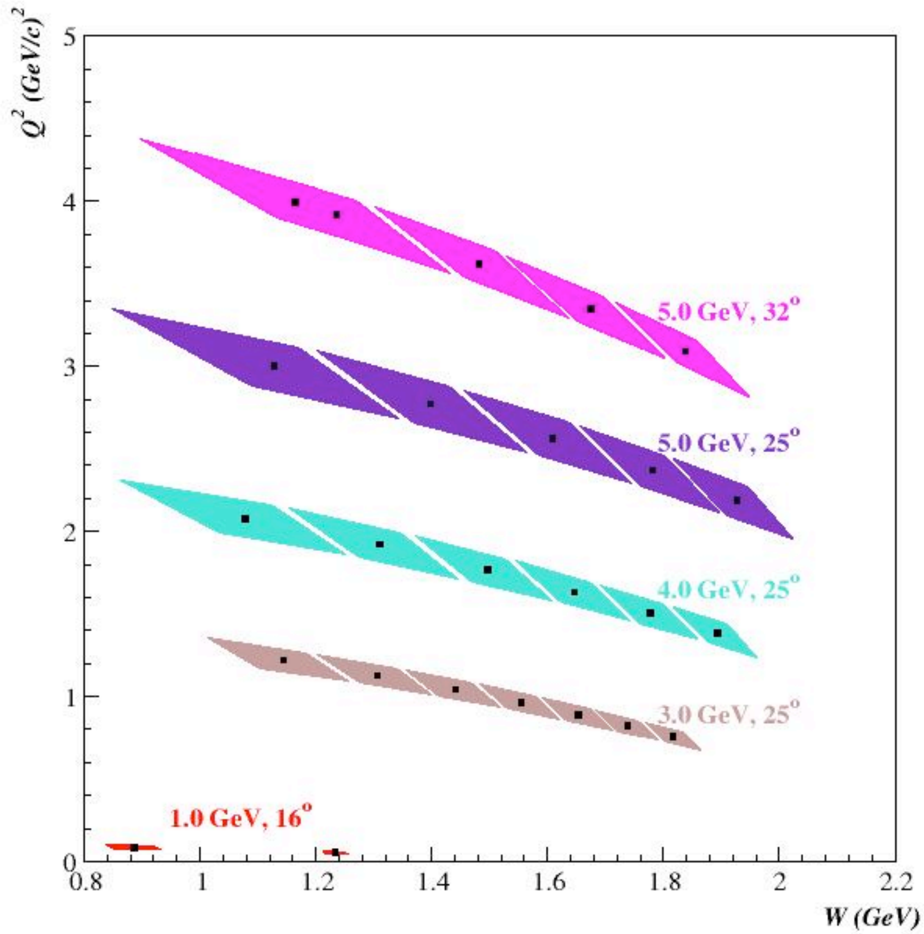
World data

Indication of duality from Jlab Hall A for g_1^{3He}



The experiment E01-012

- Ran in Jan.-Feb. 2003
- Inclusive experiment: $^3\vec{He}(\vec{e},e')X$
  - Polarized electron beam:
    $70 < P_{beam} < 85\%$
  - Hall A in standard equipment:
    - ↪ HRS in symmetric configuration
    - ↪ PID performance $\pi/e < 10^{-4}$
  - Pol. ^{3}He target (para and perp):
    $\langle P_{targ} \rangle = 37\%$
- Measured polarized cross section differences
- Form g_1 and g_2 for ^{3}He



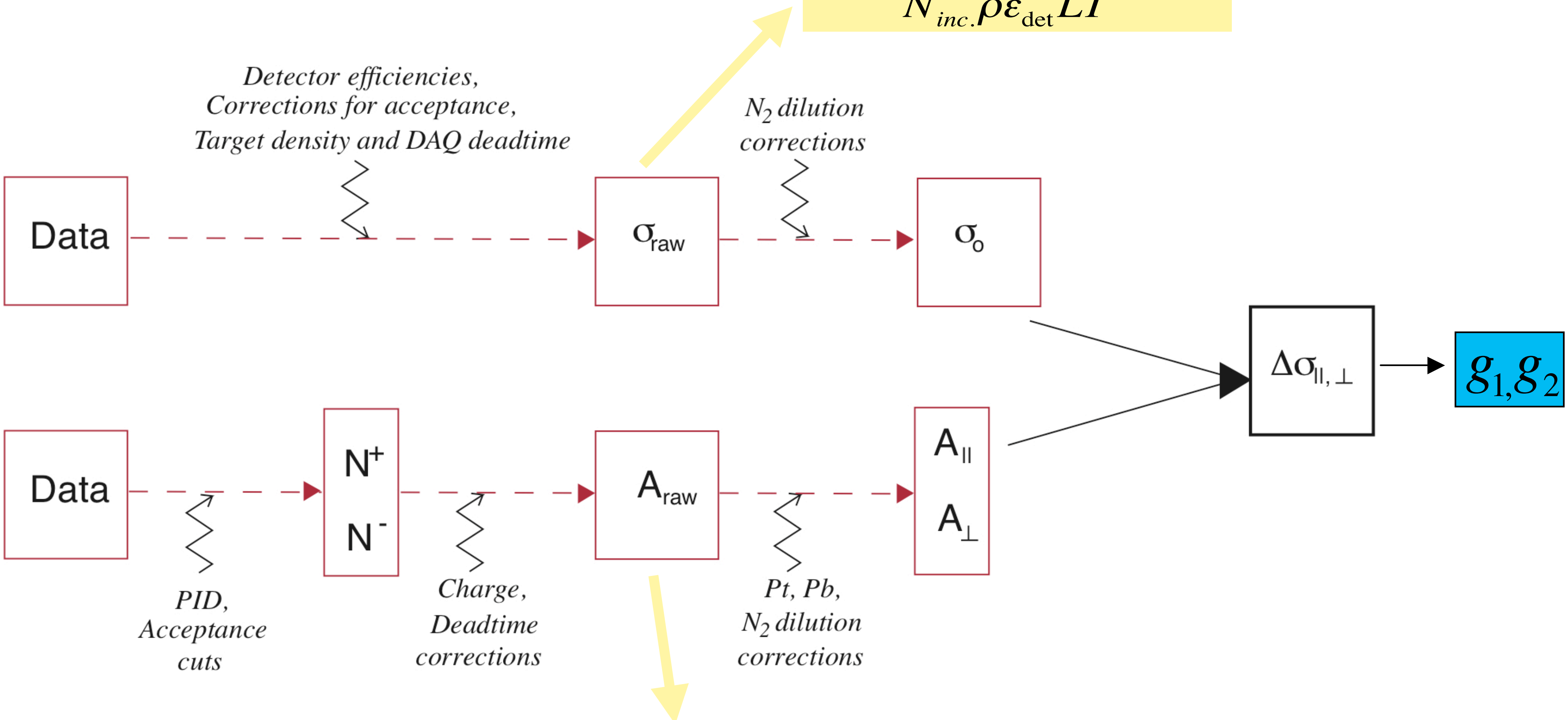
↪ **Test of spin duality on the neutron (^{3}He)**

The E01-012 Collaboration

K. Aniol, T. Averett, W. Boeglin, A. Camsonne, G.D. Cates,
G. Chang, J.-P. Chen, Seonho Choi, E. Chudakov, B. Craver,
F. Cusanno, A. Deur, D. Dutta, R. Ent, R. Feuerbach,
S. Frullani, H. Gao, F. Garibaldi, R. Gilman, C. Glashausser,
O. Hansen, D. Higinbotham, H. Ibrahim, X. Jiang, M. Jones,
A. Kelleher, J. Kelly, C. Keppel, W. Kim, W. Korsch,K. Kramer,
G. Kumbartzki, J. LeRose, R. Lindgren, N. Liyanage, B. Ma,
D. Margaziotis, P. Markowitz, K. McCormick, Z.-E. Meziani,
R. Michaels, B. Moffit, P. Monaghan, C. Munoz Camacho,
K. Paschke, B. Reitz, A. Saha, R. Sheyor, J. Singh, K. Slifer,
P. Solvignon, V. Sulkosky, A. Tobias, G. Urciuoli, K. Wang,
K. Wijesooriya, B. Wojtsekhowski, S. Woo, J.-C. Yang,
X. Zheng, L. Zhu

and the Jefferson Lab Hall A Collaboration

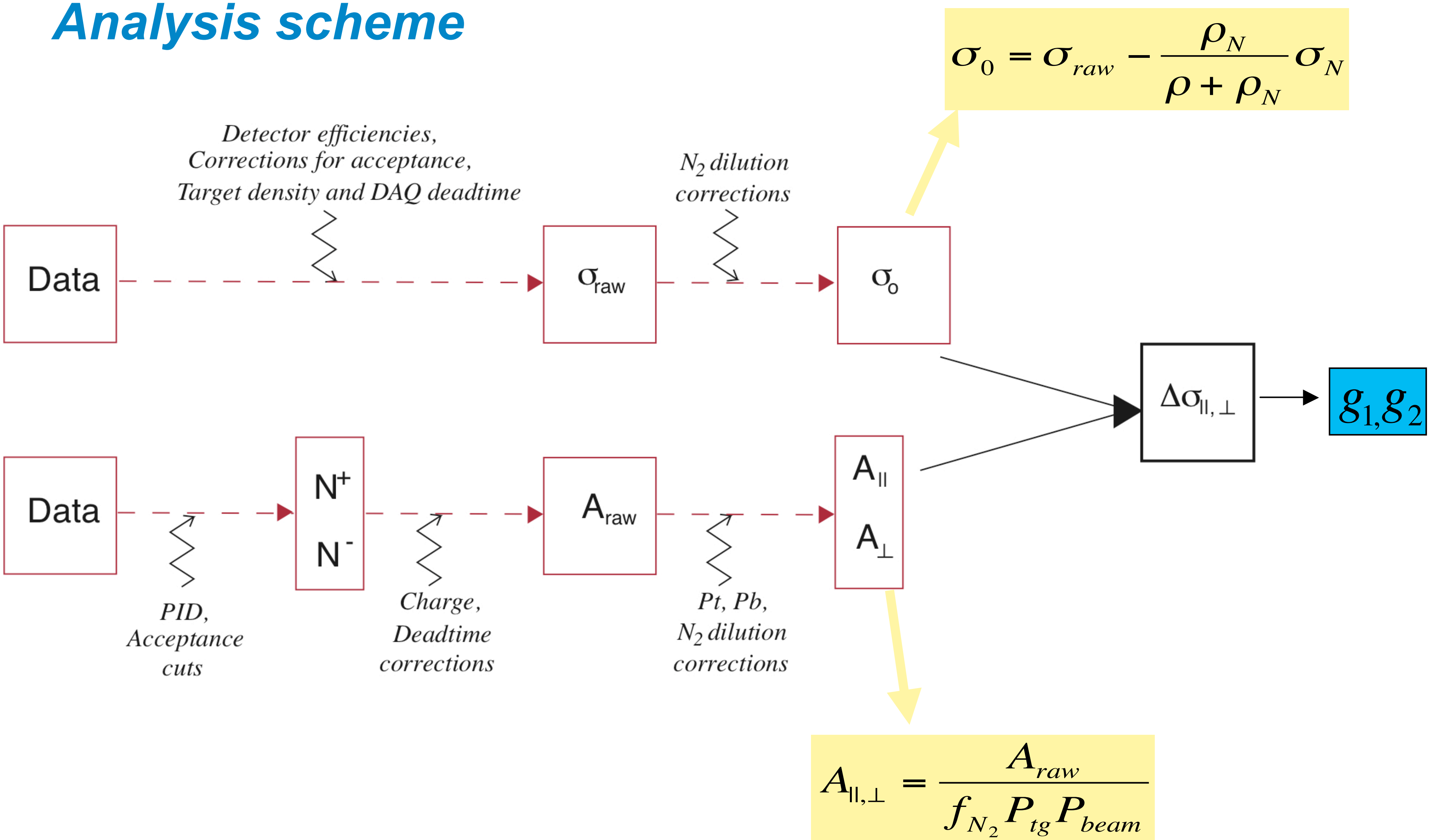
Analysis scheme



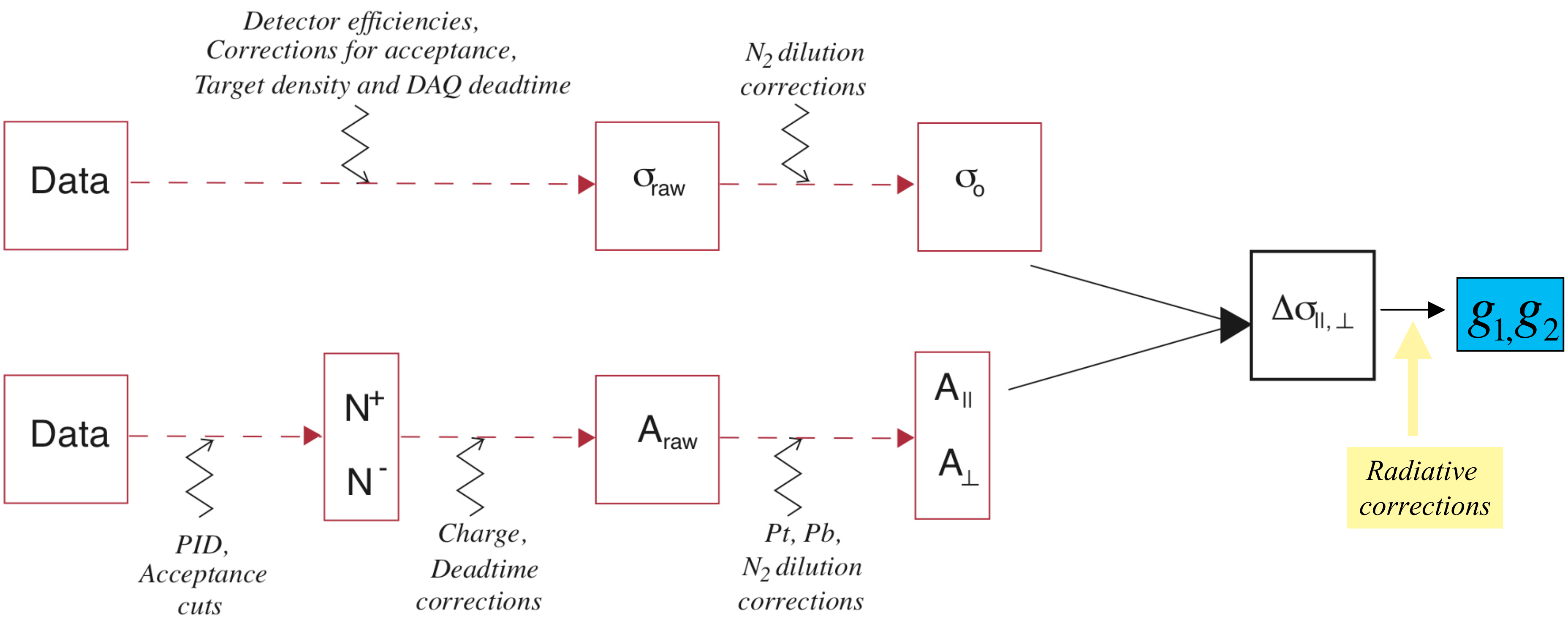
$$\sigma_0 = \frac{N_{cuts}}{N_{inc.}\rho\varepsilon_{\det}LT} * Acc.$$

$$A_{\parallel,\perp} = \frac{\dfrac{N^+}{Q^+LT^+} - \dfrac{N^-}{Q^-LT^-}}{\dfrac{N^+}{Q^+LT^+} + \dfrac{N^-}{Q^-LT^-}}$$

Analysis scheme

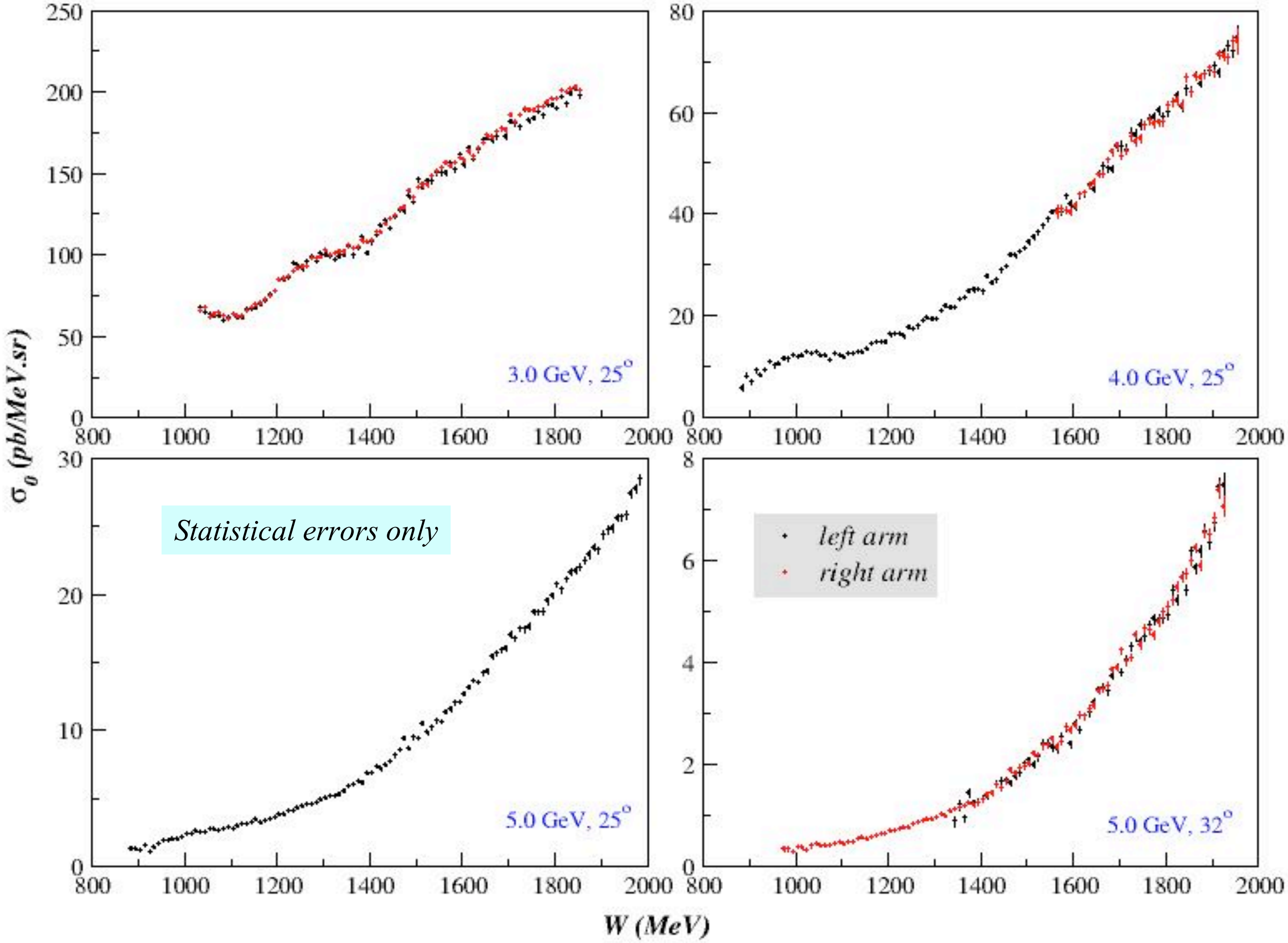


Analysis scheme

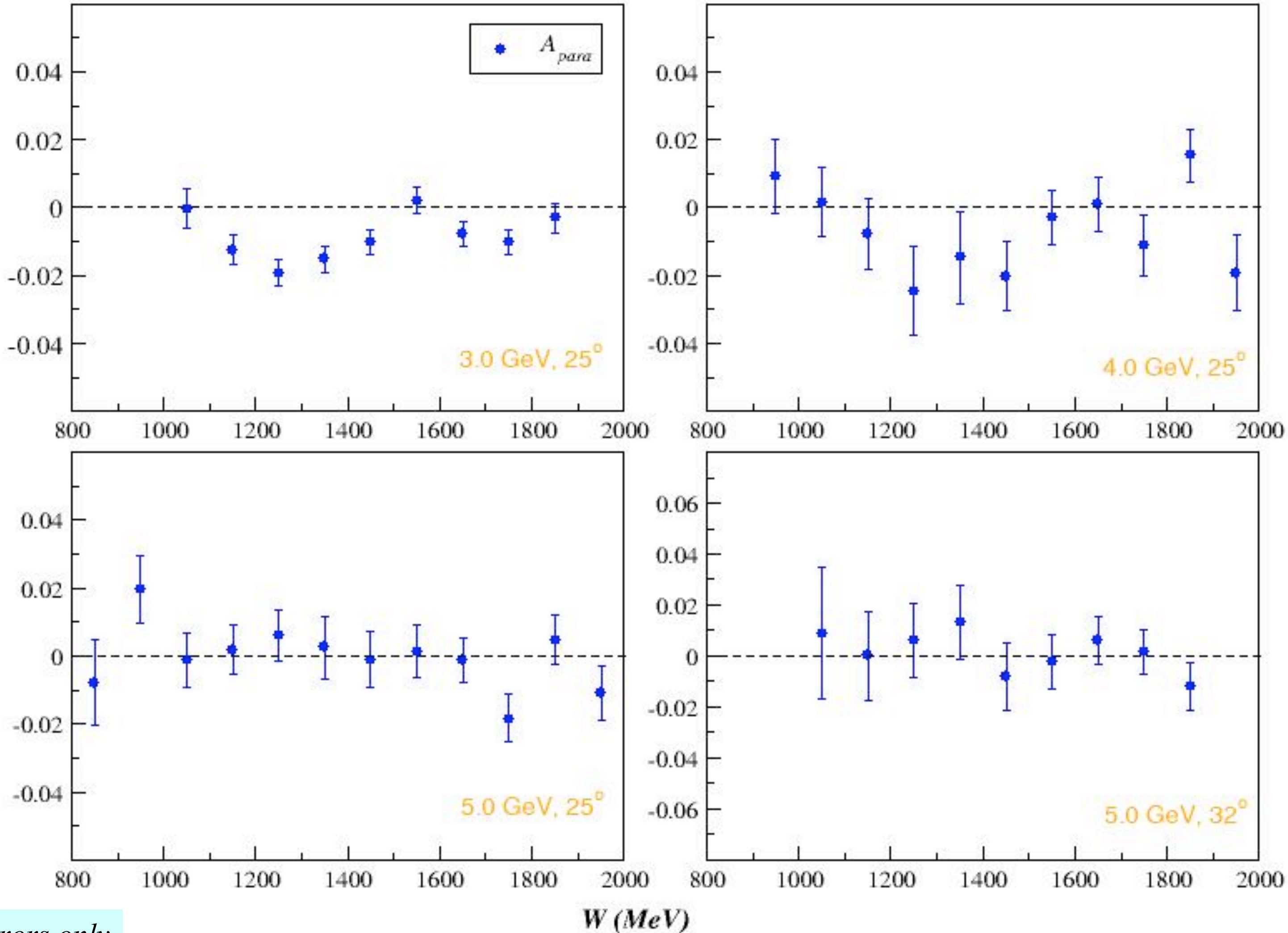


Unpolarized cross sections

Agreement between both HRS better than 2%

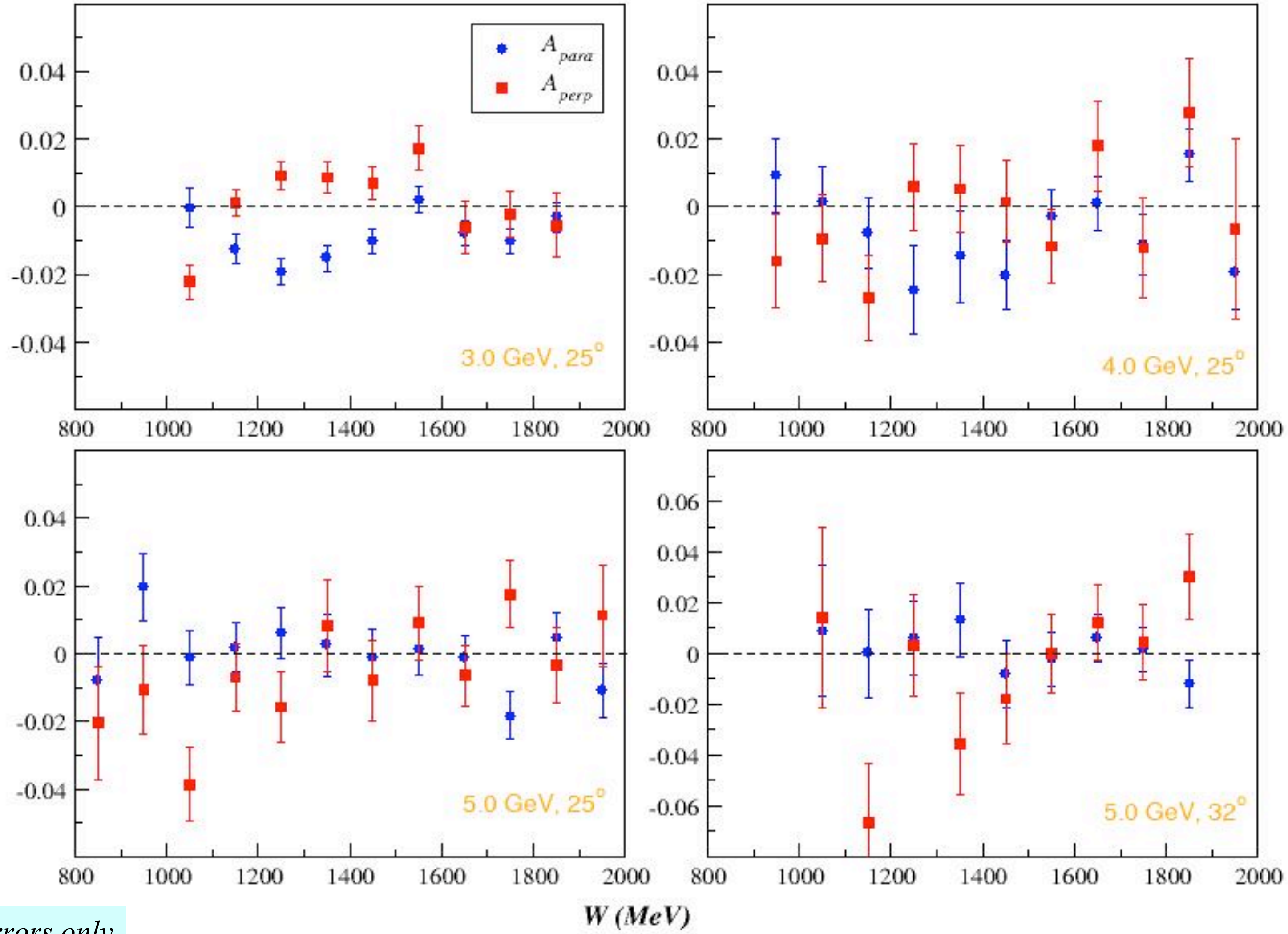


Asymmetries



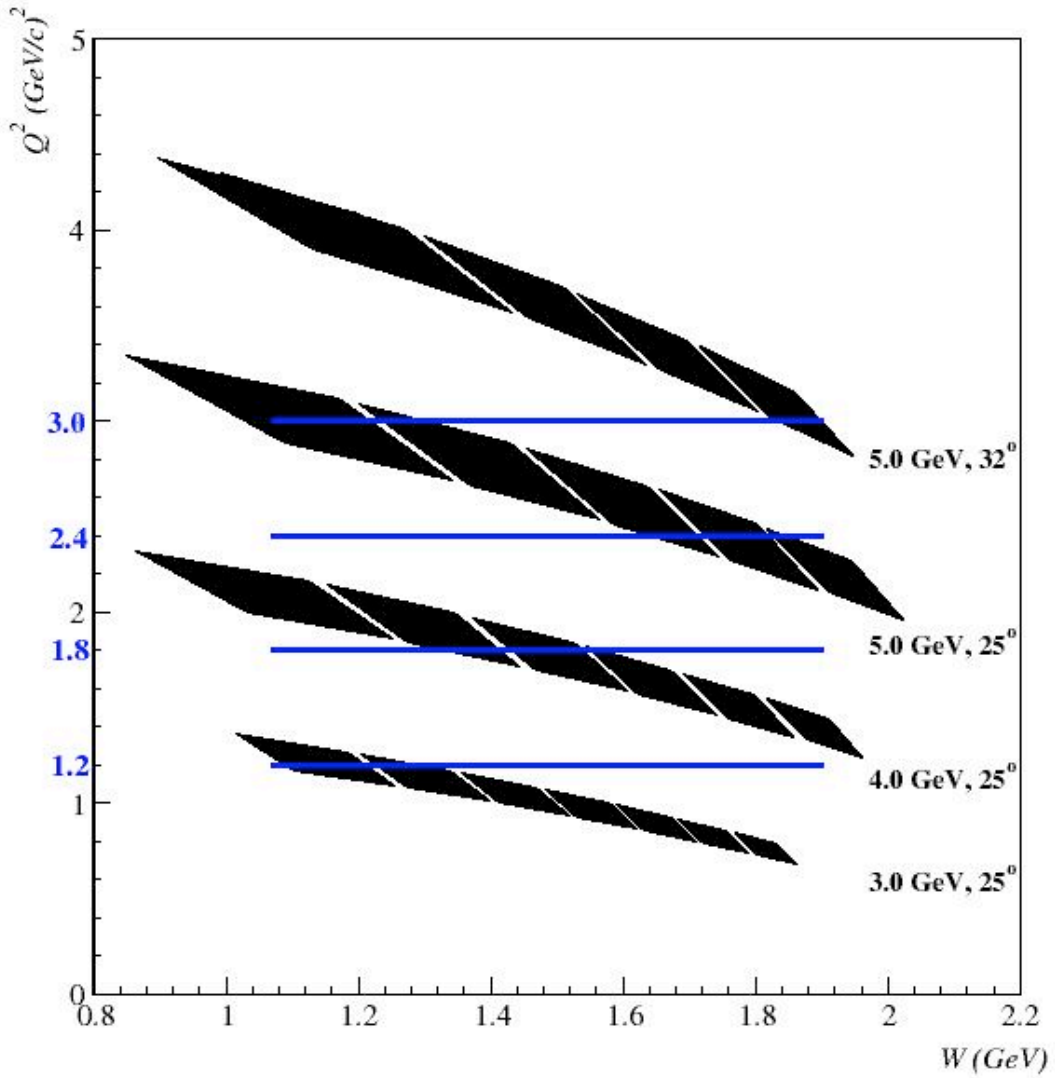
Statistical errors only

Asymmetries

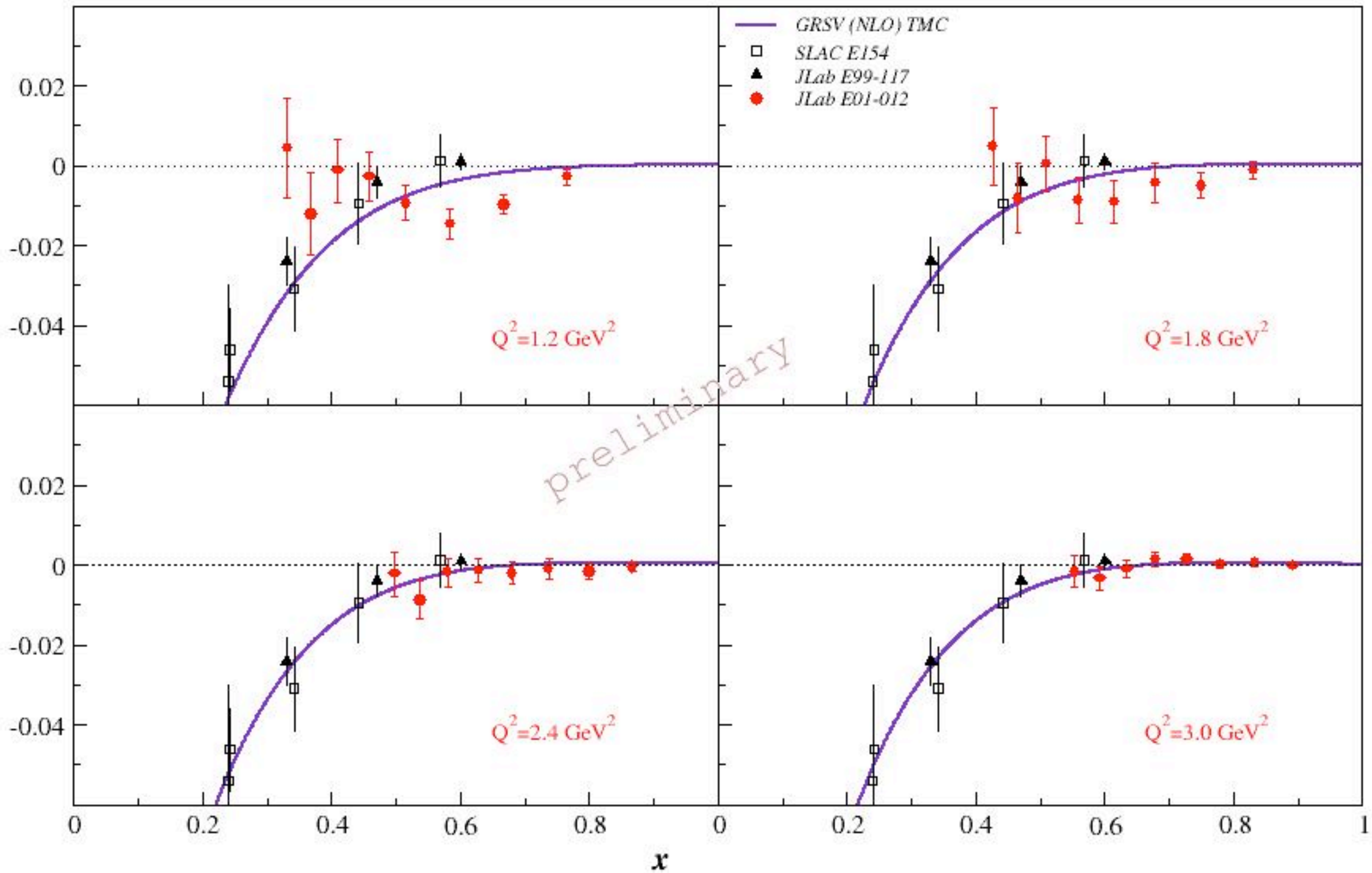


Statistical errors only

From constant E to constant Q^2



g_1^{3He} at constant Q^2



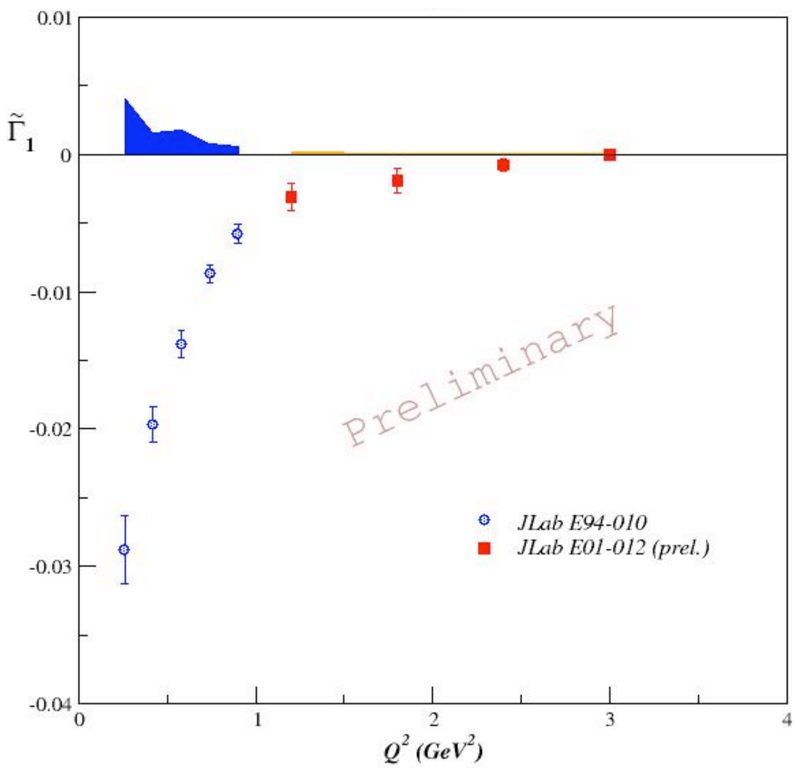
g_1 in the resonance region

Extract the neutron from effective polarization equation:

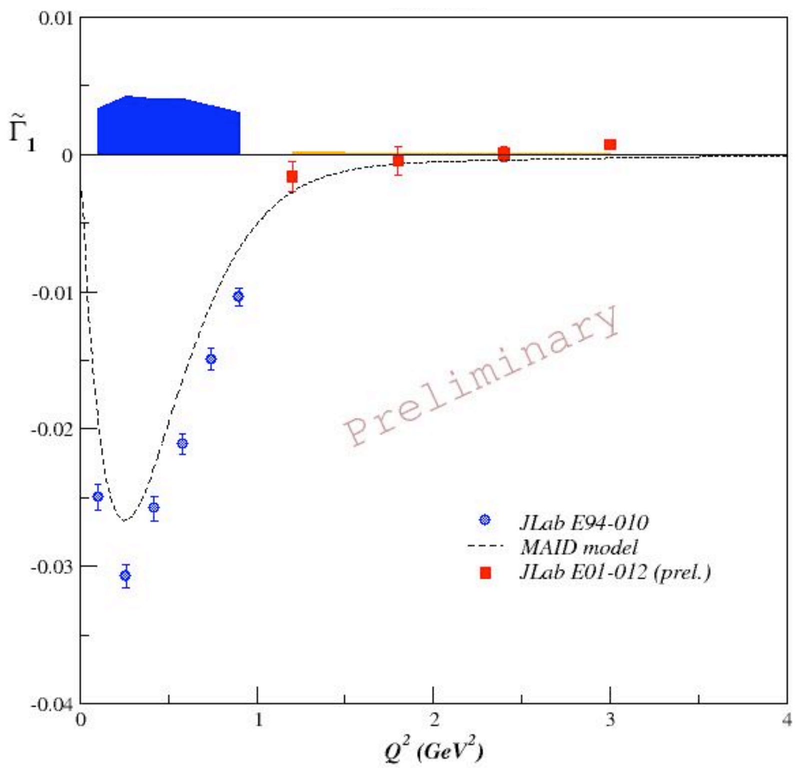
$$\tilde{\Gamma}_1^{\,^3He} = P_n \tilde{\Gamma}_1^n + 2P_p \tilde{\Gamma}_1^p$$

P_n=86%
P_p=-2.8%

^{3}He



neutron



Test of duality on the neutron and ^{3}He

Used method defined by N. Bianchi, A. Fantoni and S. Liuti on g_1^p

PRD 69 (2004) 014505

1. Get g_1 at constant Q^2
2. Define integration range in the resonance region in function of W
3. Integrate g_1^{res} and g_1^{dis} over the same x-range and at the same Q^2

$$\tilde{\Gamma}_1^{res} = \int_{x_{\min}}^{x_{\max}} g_1^{res}(x,Q^2)dx$$

$$\tilde{\Gamma}_1^{dis} = \int_{x_{\min}}^{x_{\max}} g_1^{dis}(x,Q^2)dx$$

If $\tilde{\Gamma}_1^{res} = \tilde{\Gamma}_1^{dis} \Rightarrow$ **duality is verified**

Target mass corrections

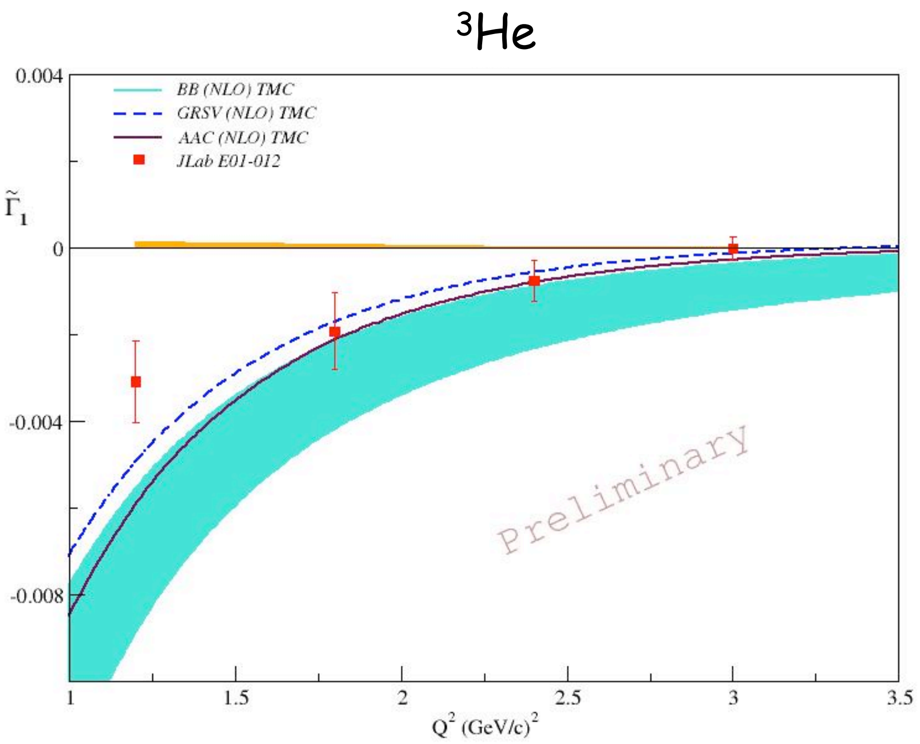
$$g_1(x,Q^2) = g_1(x,Q^2;M=0) + \frac{M^2}{Q^2} g_1^{(1)TMC}(x,Q^2) + \frac{h(x,Q^2)}{Q^2} + O(1/Q^4)$$

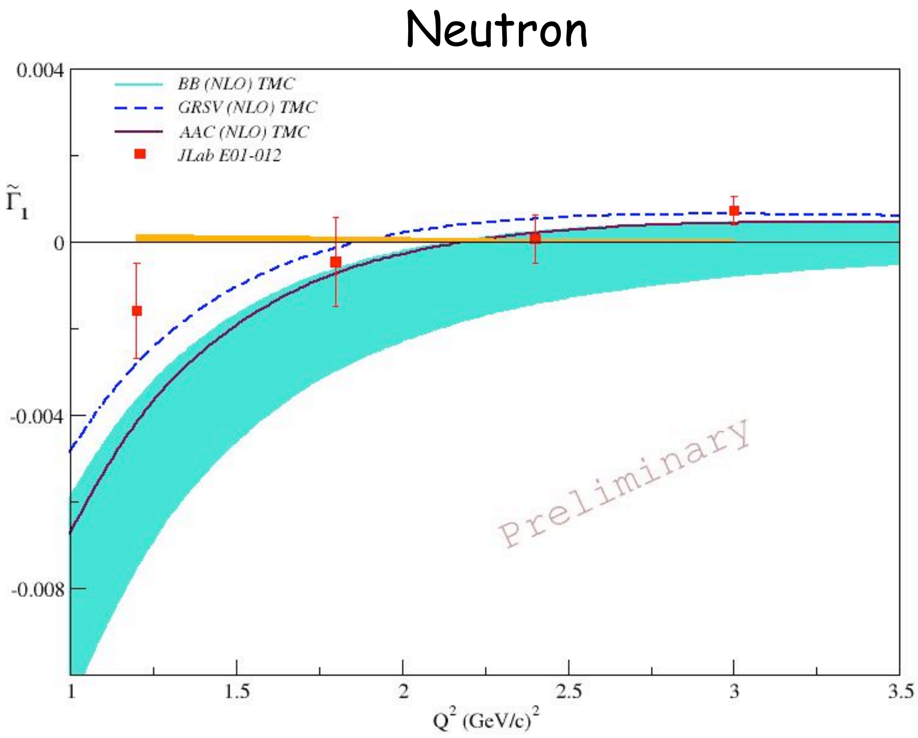
from experiments

from pQCD

- Purely kinematic effects: finite value of $4M^2x^2/Q^2$
- Need to be applied before calculating higher twist effects
- TMCs are expressed by higher moments of $g_1(x,Q^2;M=0)$

Test of duality on the neutron and ^{3}He





Integration range corresponding to 1.08<W<1.93GeV

Virtual photon-nucleon asymmetry

In the parton model:

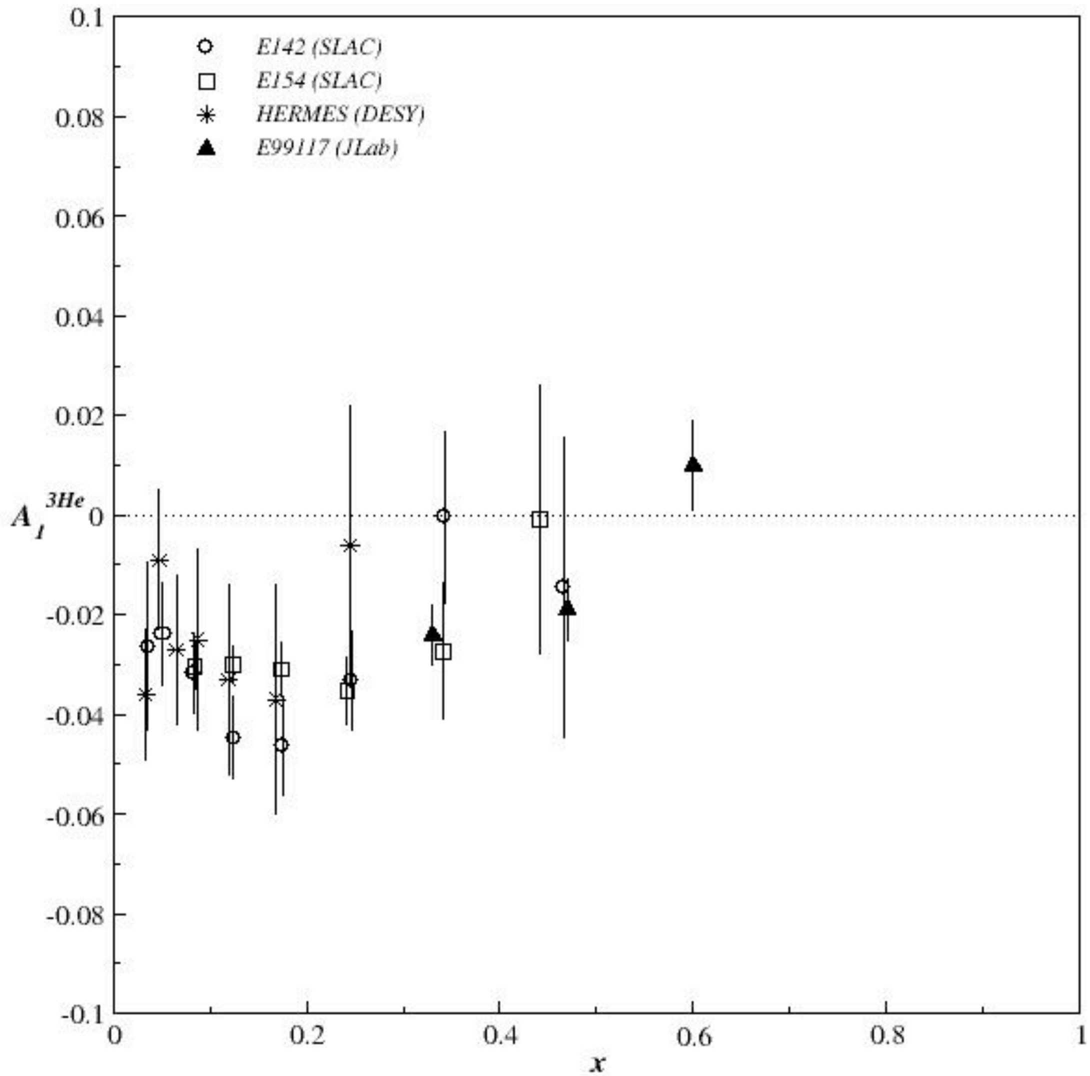
$$A_1(x,Q^2) \approx \frac{g_1(x,Q^2)}{F_1(x,Q^2)}$$

If Q^2 dependence similar for g_1 and for $F_1 \Rightarrow$ weak Q^2 dependence of A_1

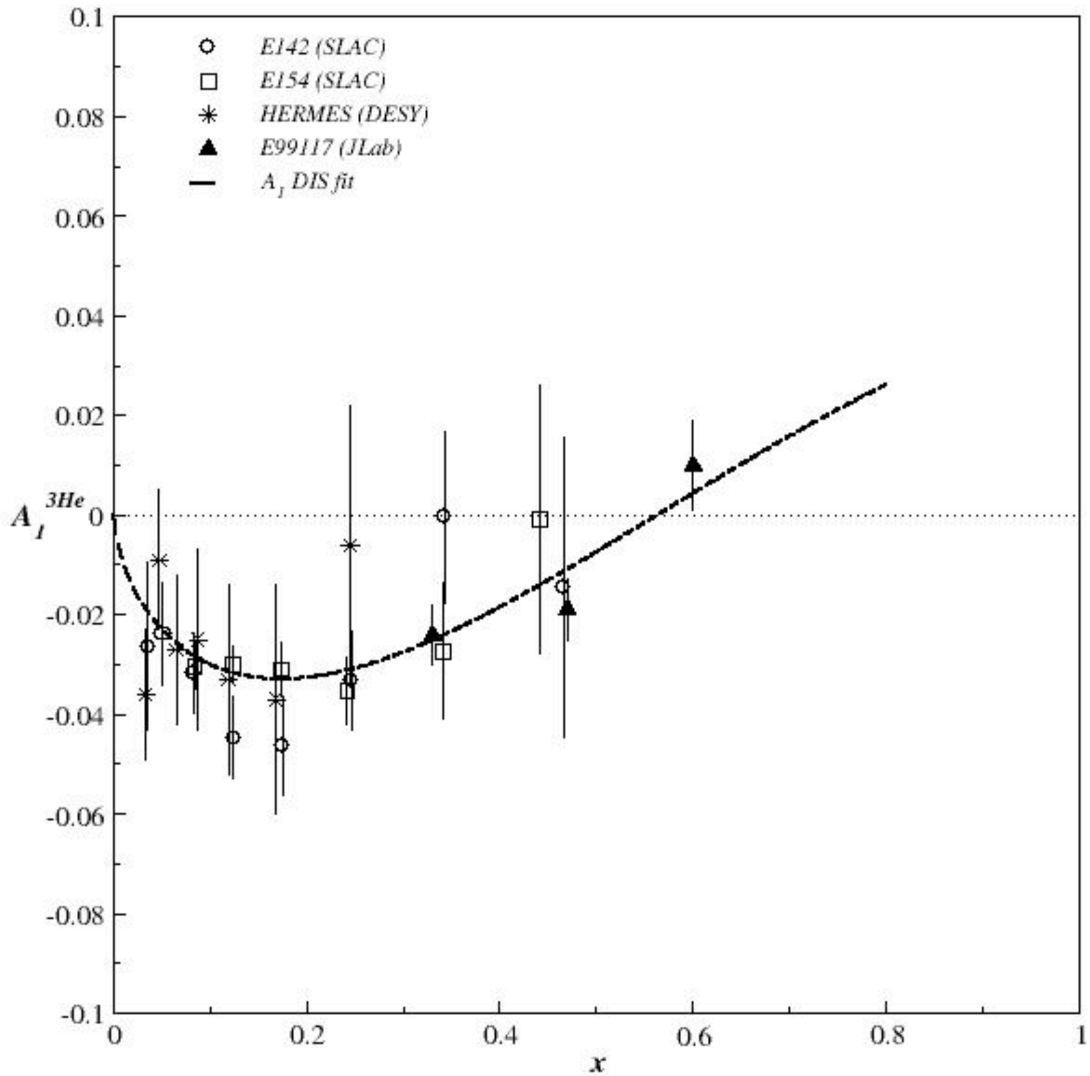
From the resonance:

If local duality observed in g_1 and F_1 → $A_1^{res} = A_1^{dis}$

A_1^{3He}

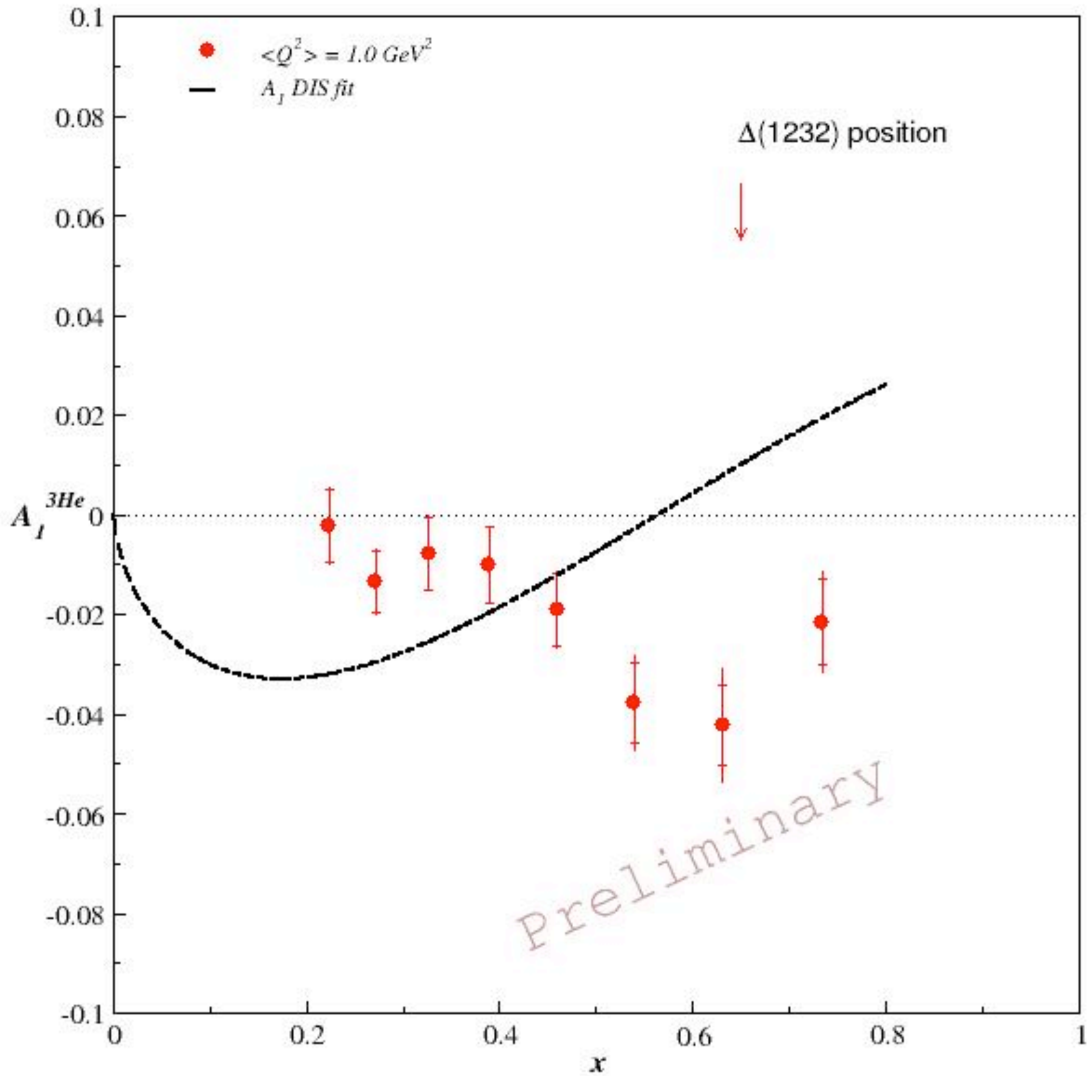

E142 (SLAC)
E154 (SLAC)
HERMES (DESY)
E99117 (JLab)
A1 3He
x
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0
0.2
0.4
0.6
0.8
1

A_1^{3He}



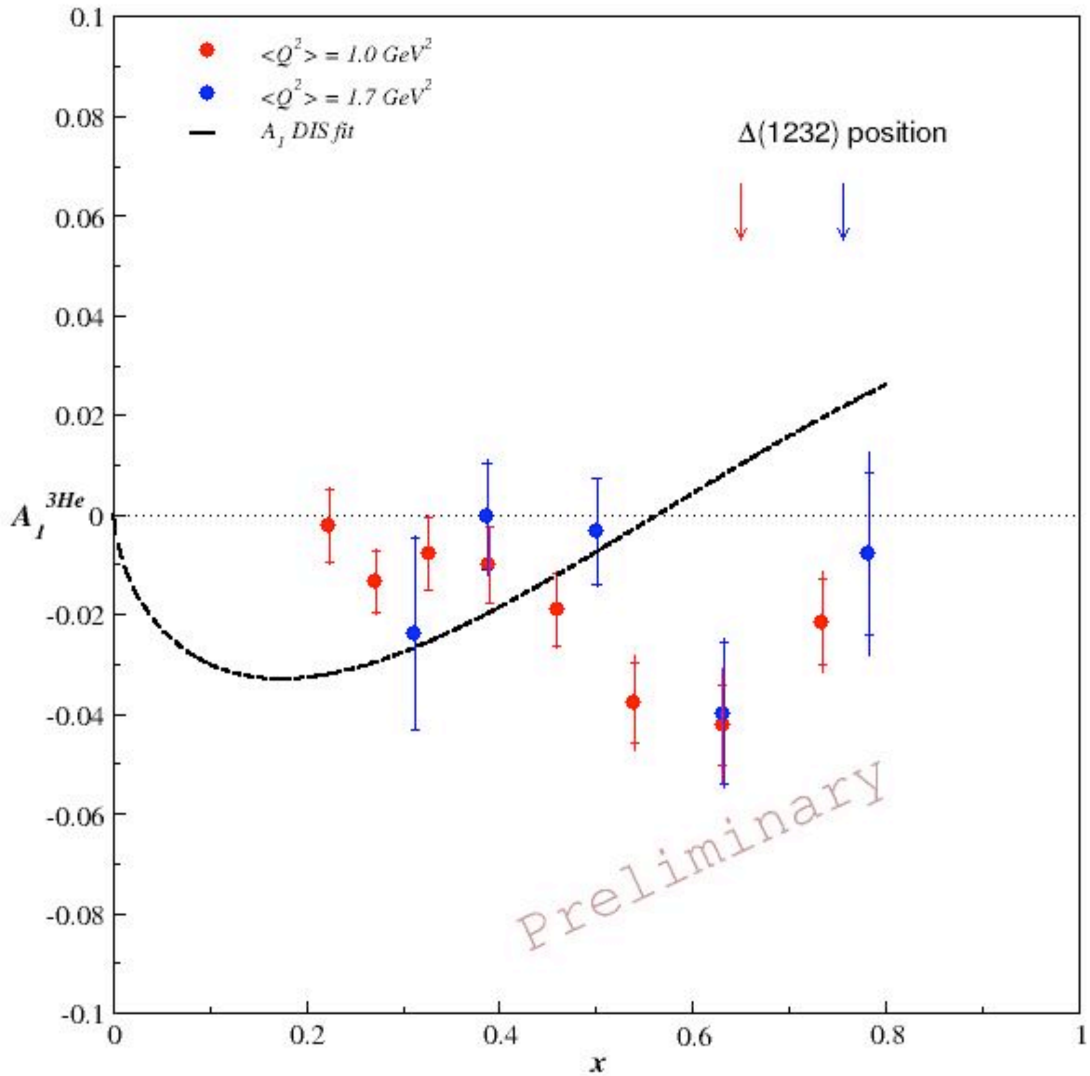
Argonne NATIONAL LABORATORY

A_1^{3He}



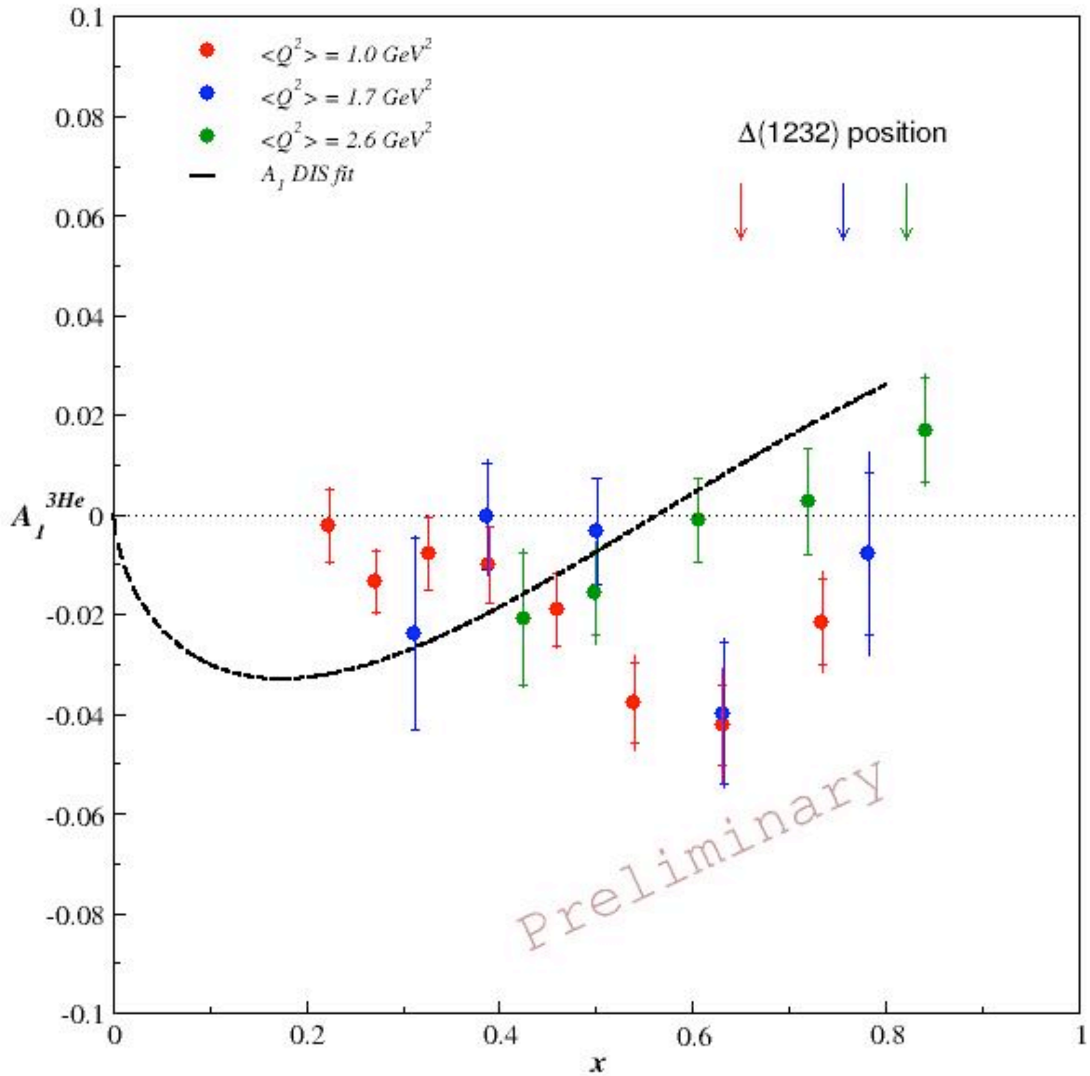
$<Q^2> = 1.0\ GeV^2$
A_1 DIS fit
Δ(1232) position
Preliminary
A_1^{3He}
x
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0
0.2
0.4
0.6
0.8
1

A_1^{3He}



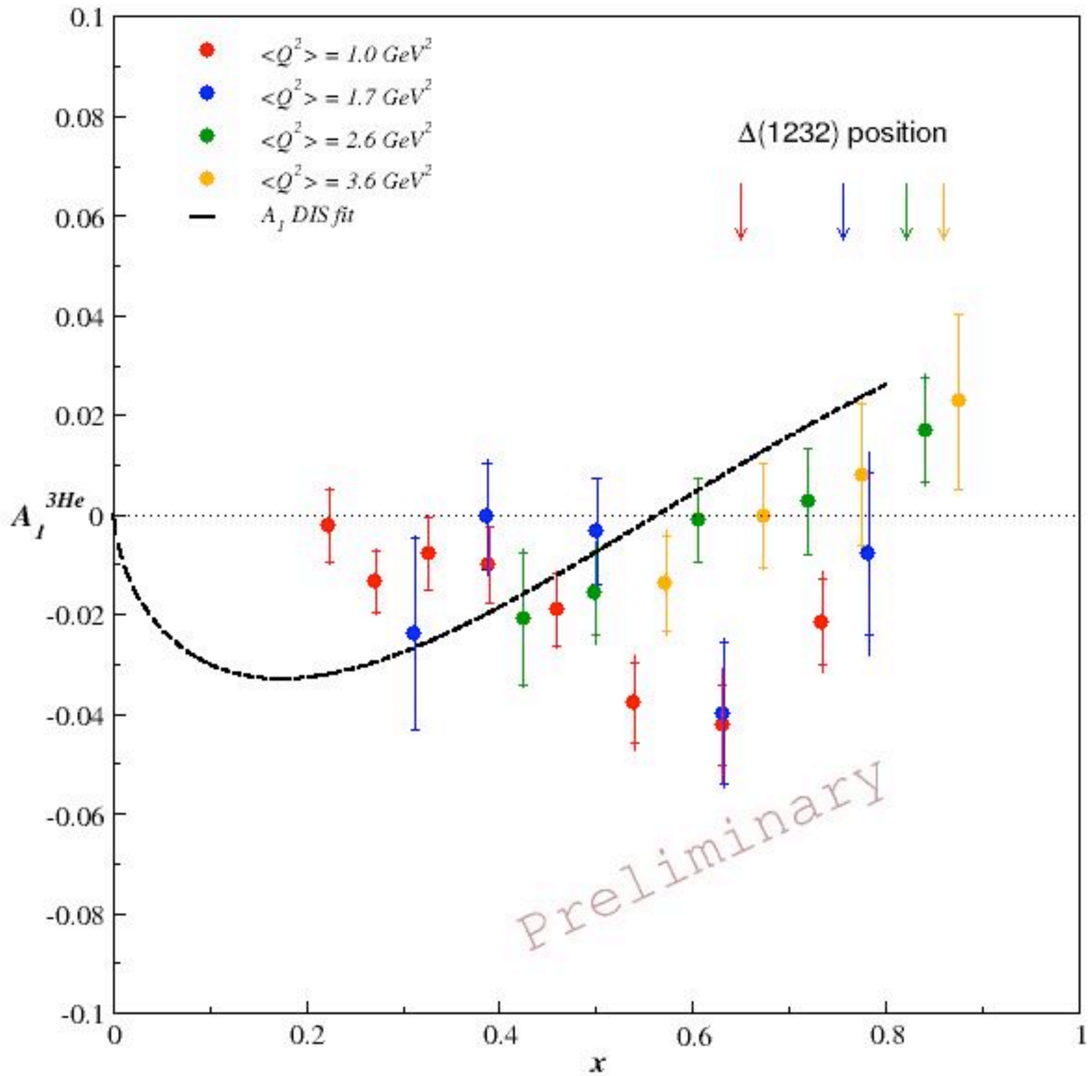
<Q²> = 1.0 GeV²
<Q²> = 1.7 GeV²
A1 DIS fit
Δ(1232) position
Preliminary
A1 3He
x
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0
0.2
0.4
0.6
0.8
1

A_1^{3He}



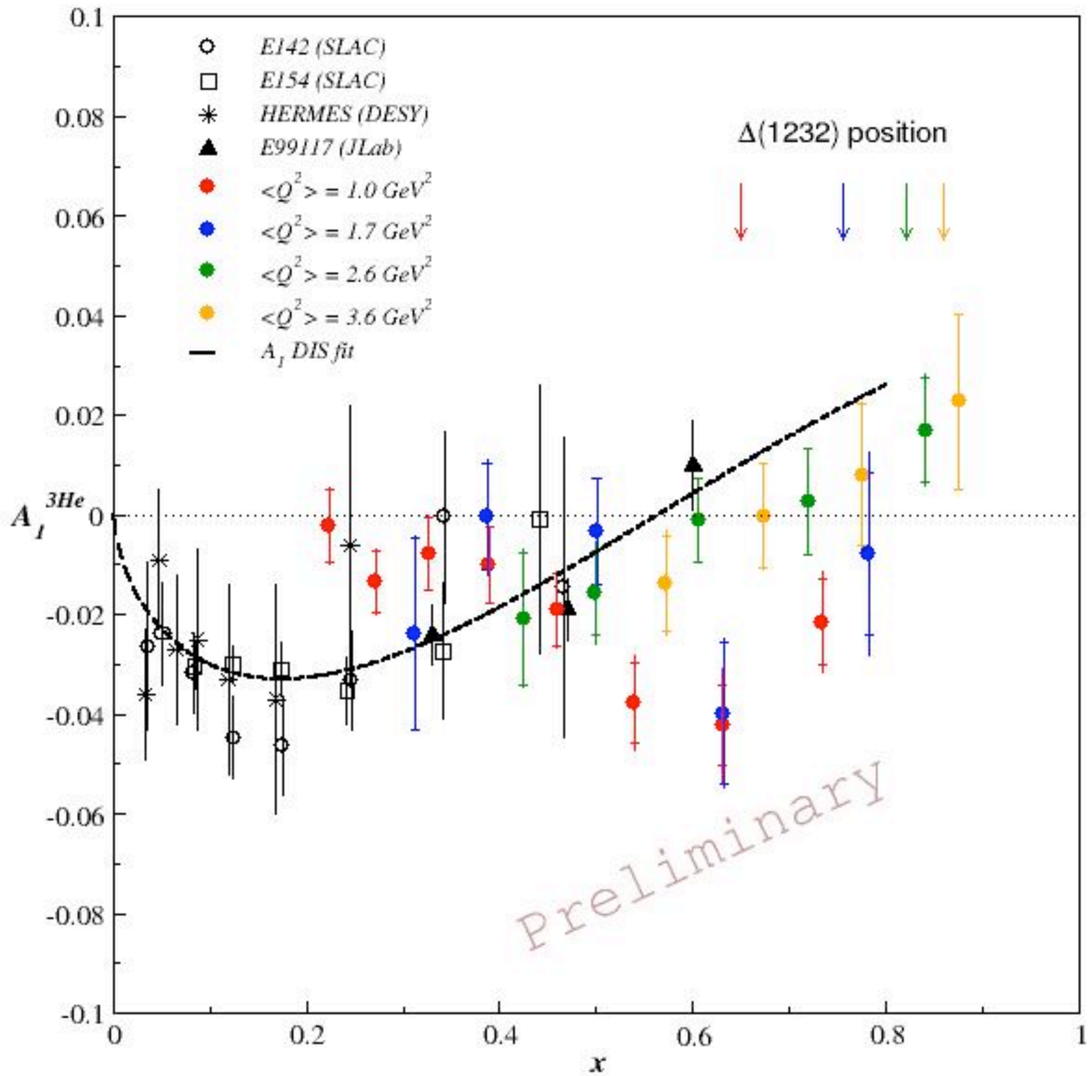
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
A_1^{3He}
0
0.2
0.4
0.6
0.8
1
x
<Q²> = 1.0 GeV²
<Q²> = 1.7 GeV²
<Q²> = 2.6 GeV²
A1 DIS fit
Δ(1232) position
Preliminary

A_1^{3He}



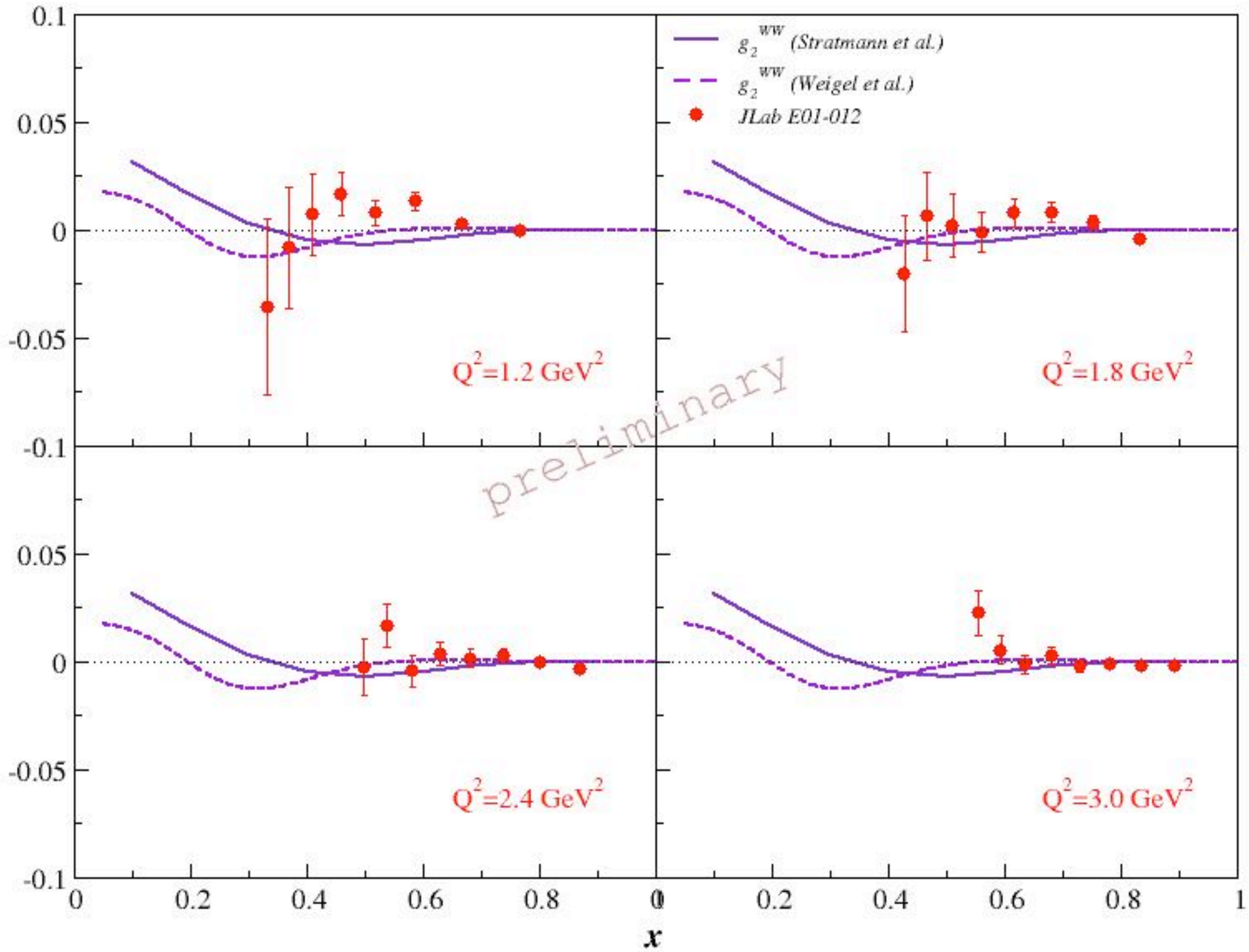
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
A_1^{3He}
$<Q^2> = 1.0\ GeV^2$
$<Q^2> = 1.7\ GeV^2$
$<Q^2> = 2.6\ GeV^2$
$<Q^2> = 3.6\ GeV^2$
A_1 DIS fit
Δ(1232) position
Preliminary
0
0.2
0.4
0.6
0.8
1
x

A_1^{3He}

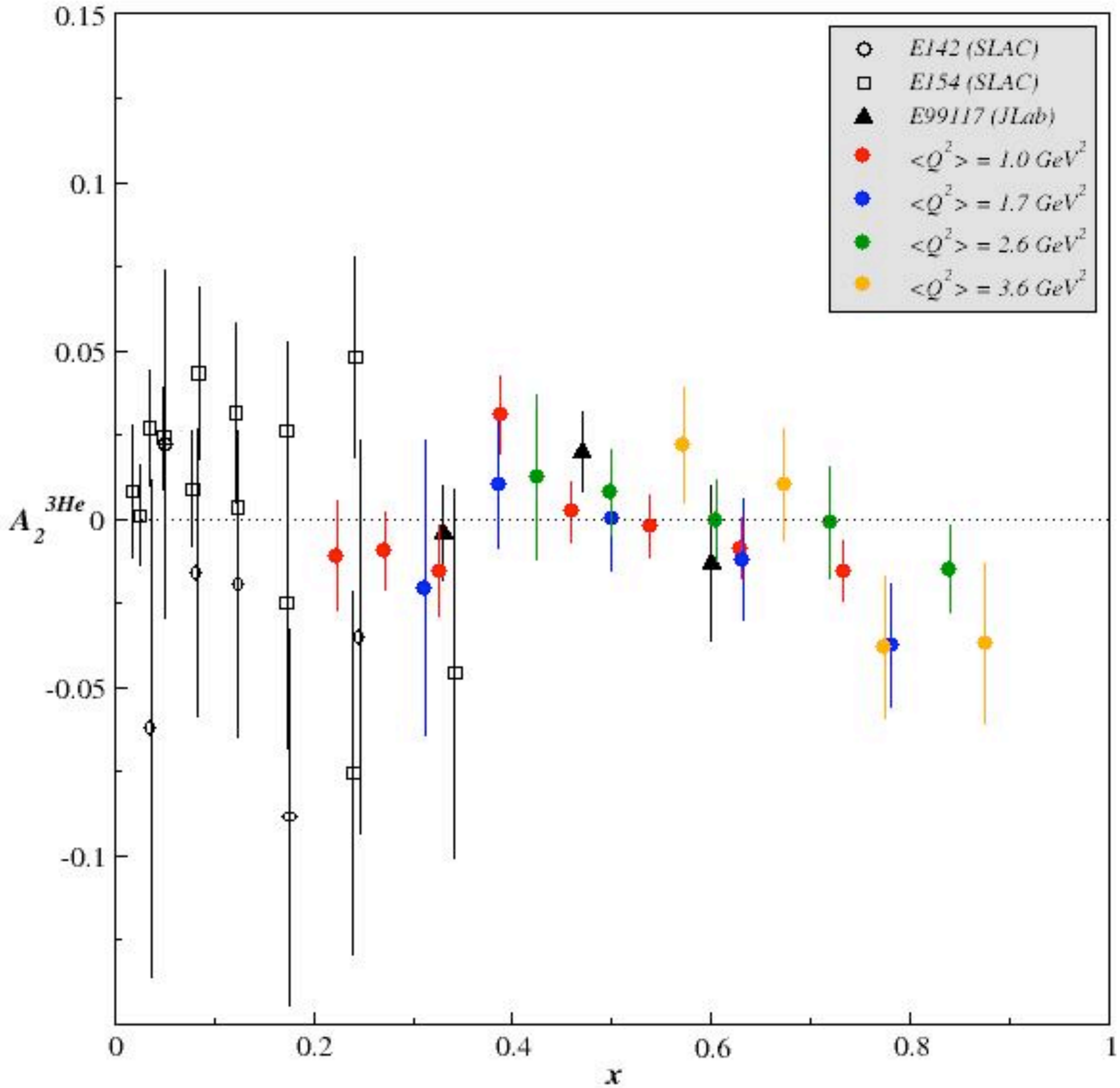


E142 (SLAC)
E154 (SLAC)
HERMES (DESY)
E99117 (JLab)
<Q²> = 1.0 GeV²
<Q²> = 1.7 GeV²
<Q²> = 2.6 GeV²
<Q²> = 3.6 GeV²
A₁ DIS fit
Δ(1232) position
Preliminary
A₁^3He
x
0.1
0.08
0.06
0.04
0.02
0
-0.02
-0.04
-0.06
-0.08
-0.1
0
0.2
0.4
0.6
0.8
1

$g_2^{^3He}$ at constant Q^2



A_2^{3He}



E142 (SLAC)
E154 (SLAC)
E99117 (JLab)
<Q²> = 1.0 GeV²
<Q²> = 1.7 GeV²
<Q²> = 2.6 GeV²
<Q²> = 3.6 GeV²
0.15
0.1
0.05
0
-0.05
-0.1
A₂³He
0
0.2
0.4
0.6
0.8
1
x

Summary

- E01-012 provides first data of Spin Structure Functions on neutron (^{3}He) in the resonance region for $1.0 < Q^2 < 4.0 GeV^2$

- Direct extraction of g_1 and g_2 from our data

- Overlap between E01-012 resonance data and DIS data:
  first dedicated test of Quark-Hadron Duality
  for neutron and ^{3}He SSF

In progress

- ^{3}He results are final but neutron extraction in the resonance region is not straightforward

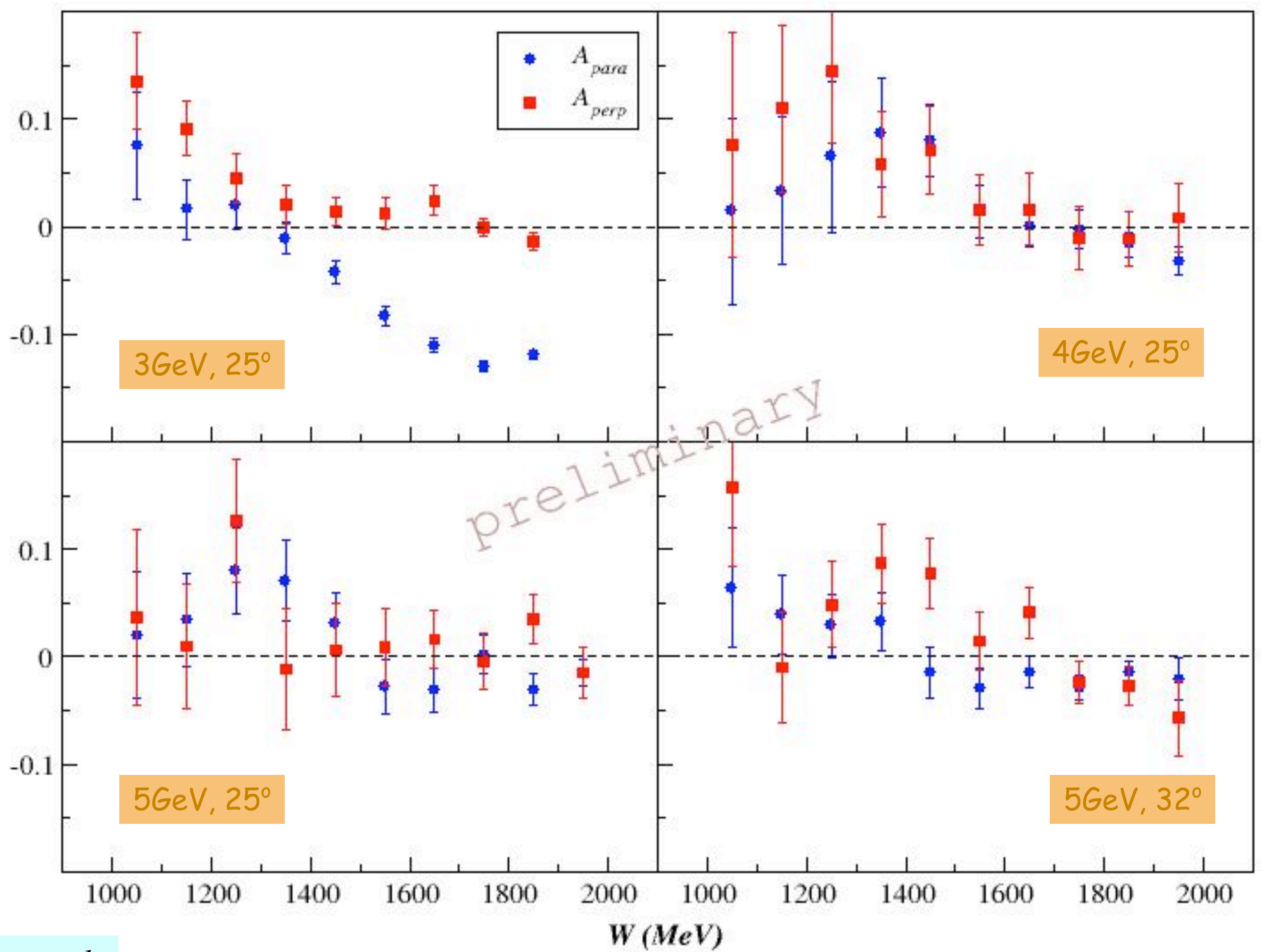
- 1st paper in preparation:
  still working on A_1^n extraction

- Efforts are ongoing to extract:
  d_2^n
  BC sum rule
  A_2^n
  → potential 2nd paper

Extra Slides

Systematics

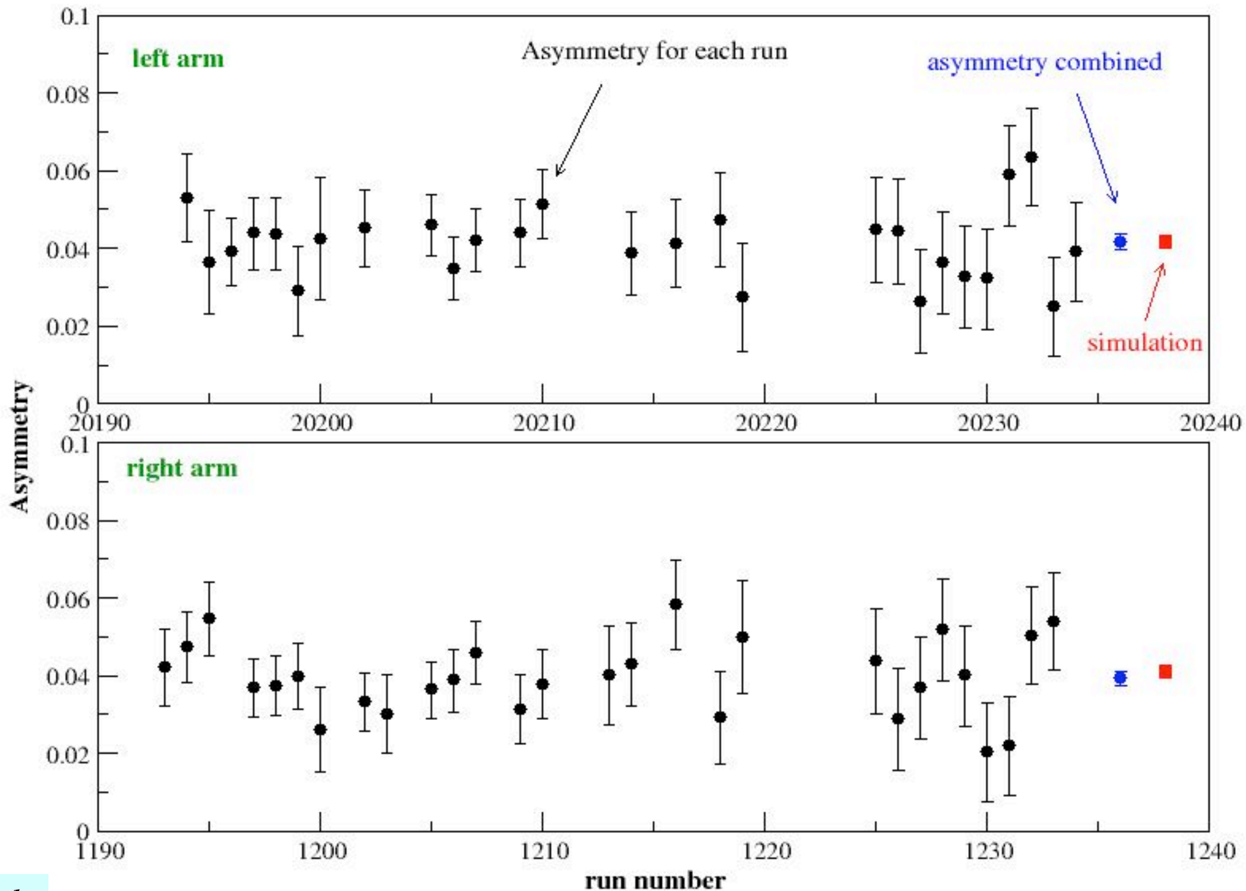
Pion asymmetries



Statistical errors only

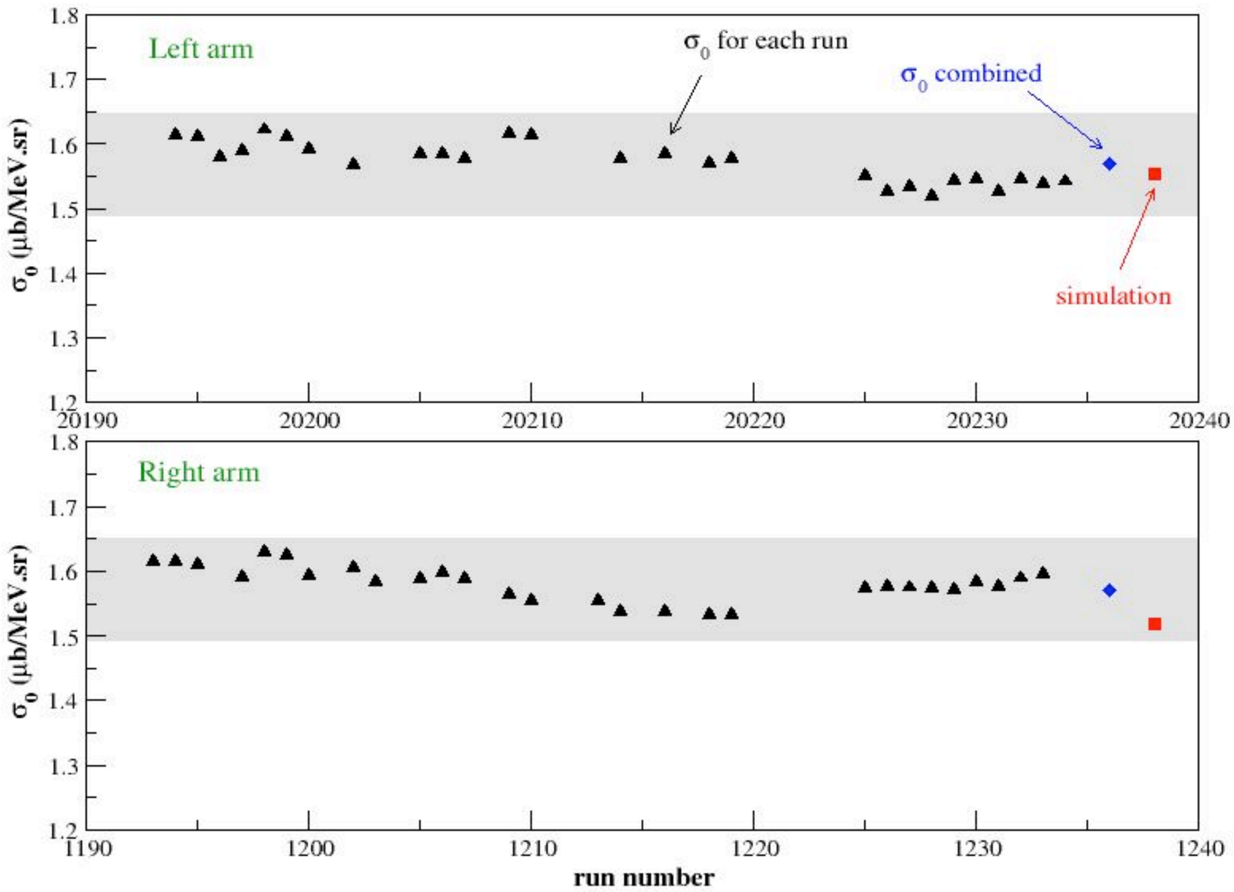
Elastic asymmetry

Check of the product: $f_{N_2} P_{tg} P_{beam}$



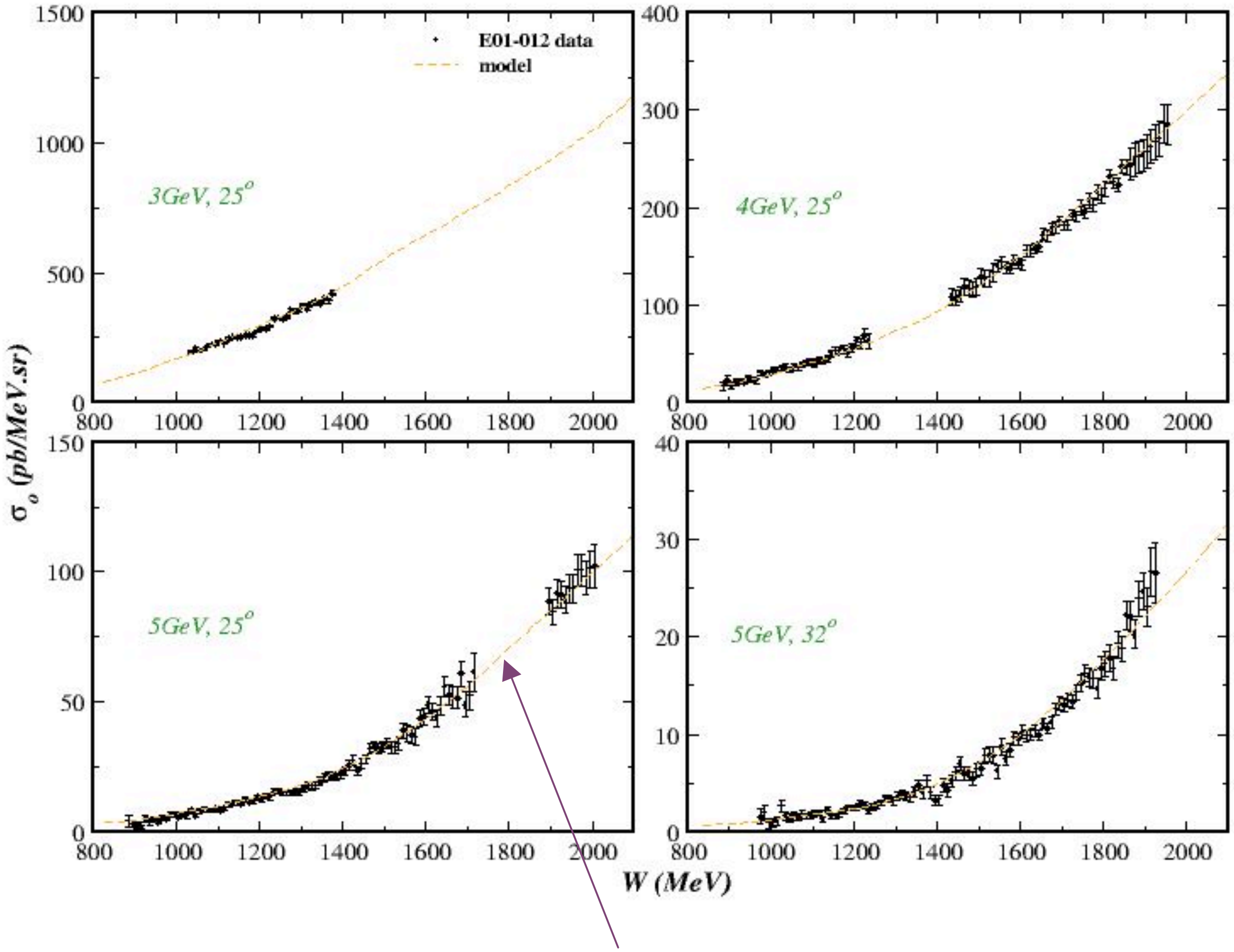
Statistical errors only

Elastic cross section



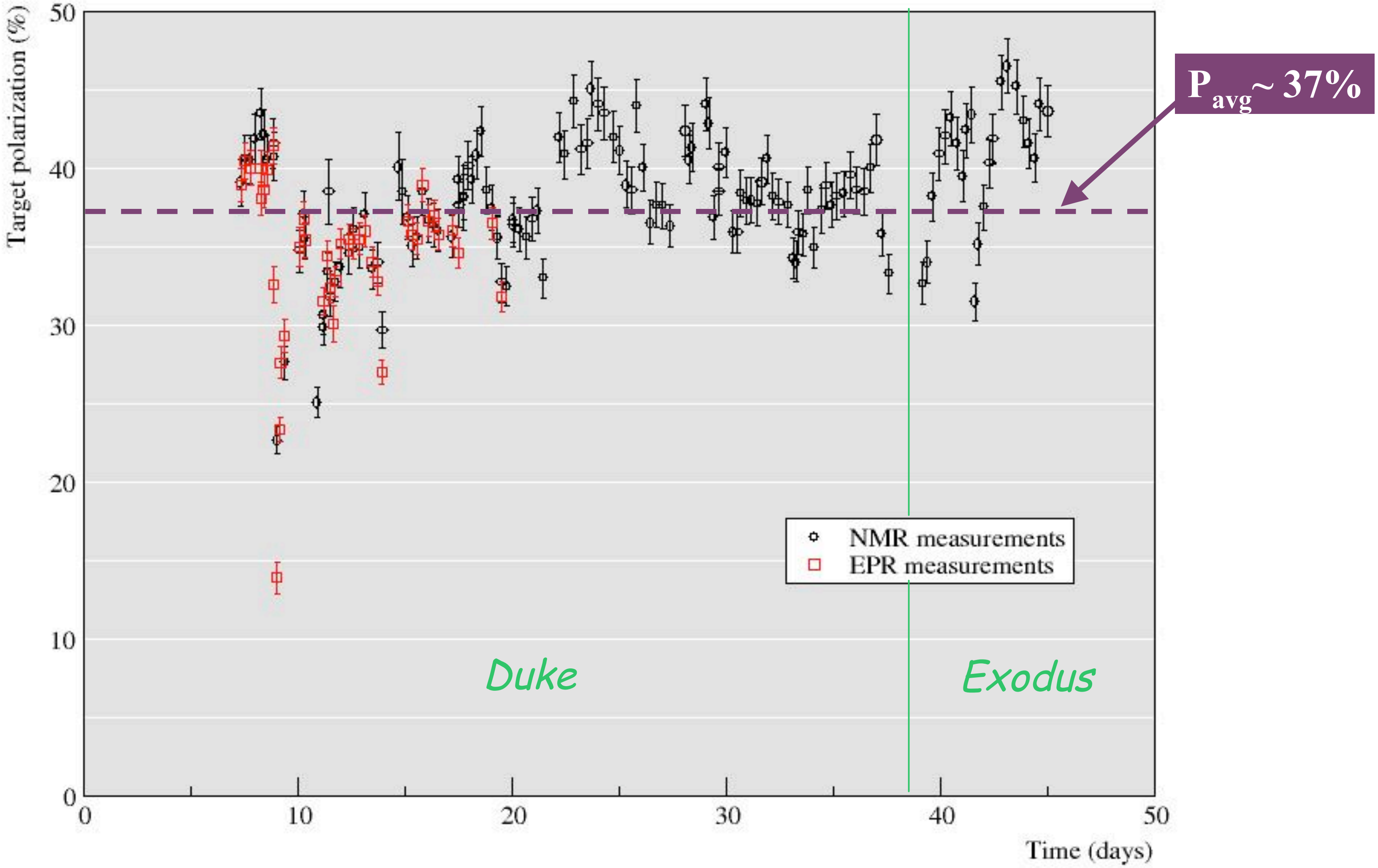
Statistical errors only

Nitrogen dilution



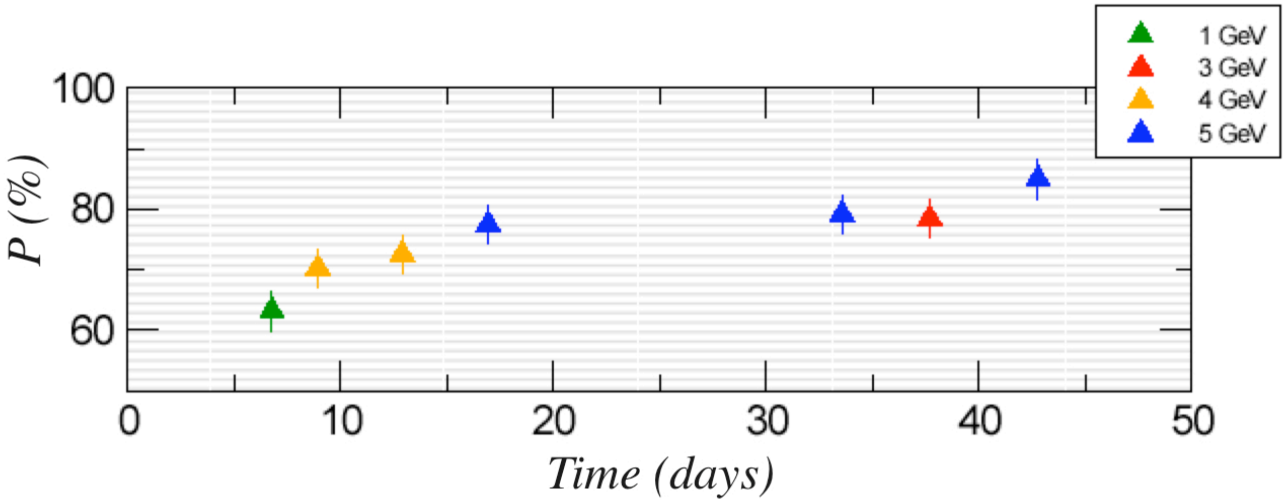
Modified the QFS model by adding energy dependence to the cross sections

Target performance



Electron beam polarization

- Used Moller Polarimeter
- $70 < P_{beam} < 85\%$ for production data

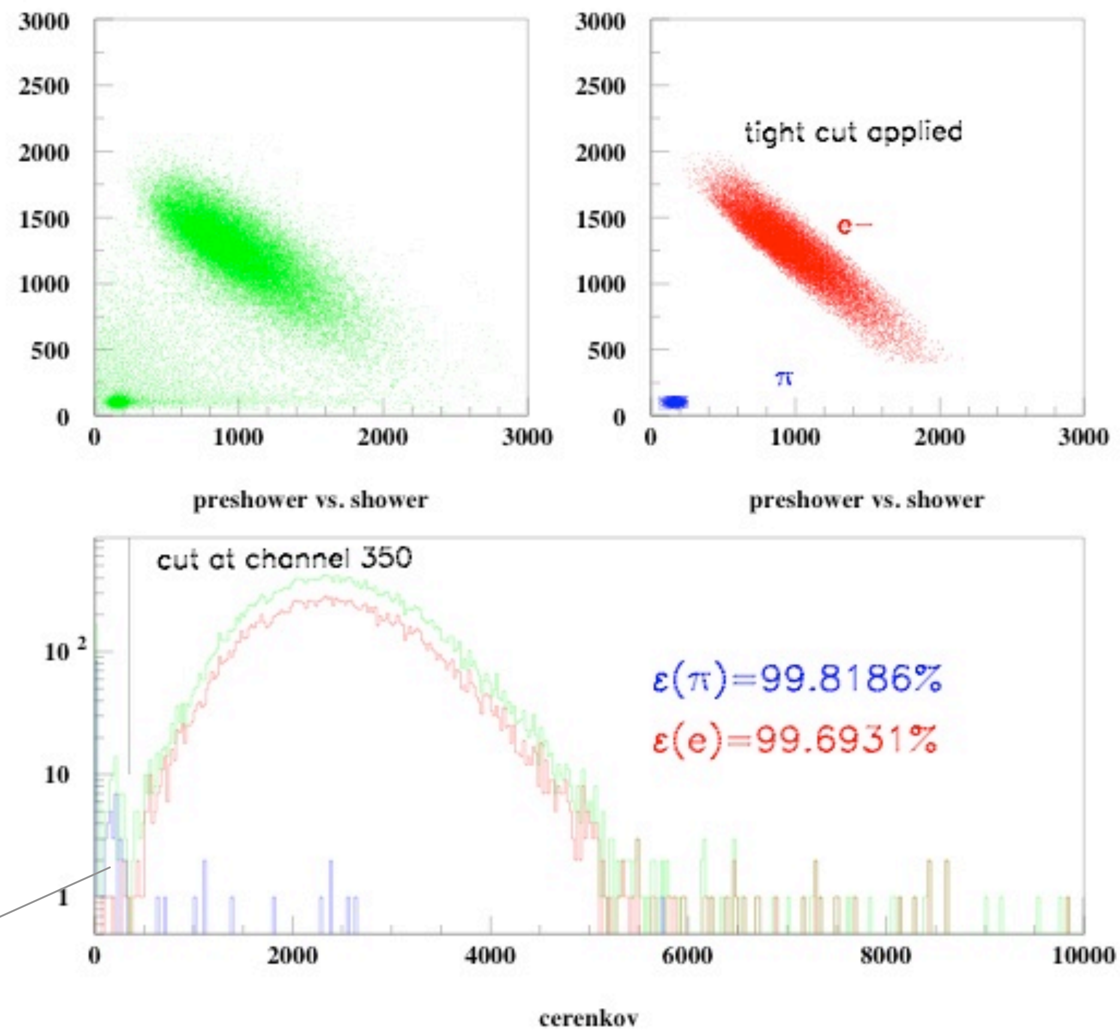


The CO_2 gas Cerenkov detector

Index of refraction:
n = 1.00041

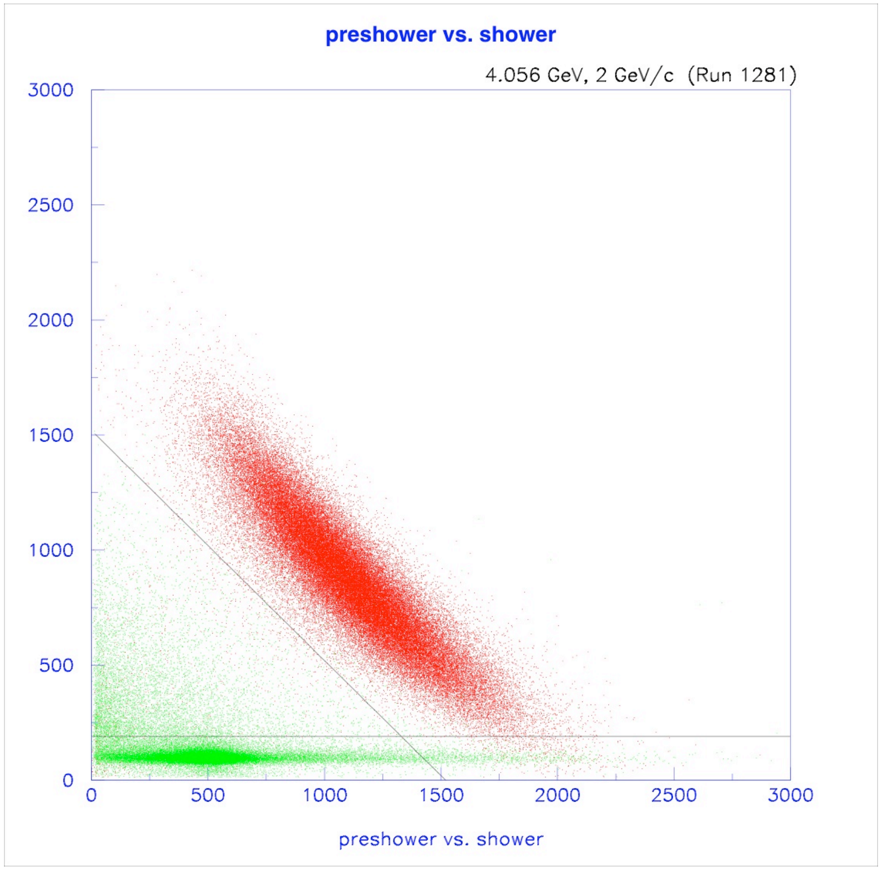
$$P^{e^-}_{thres.} = 18\,MeV$$

$$P^{\pi^-}_{thres.} = 4.9\,GeV$$



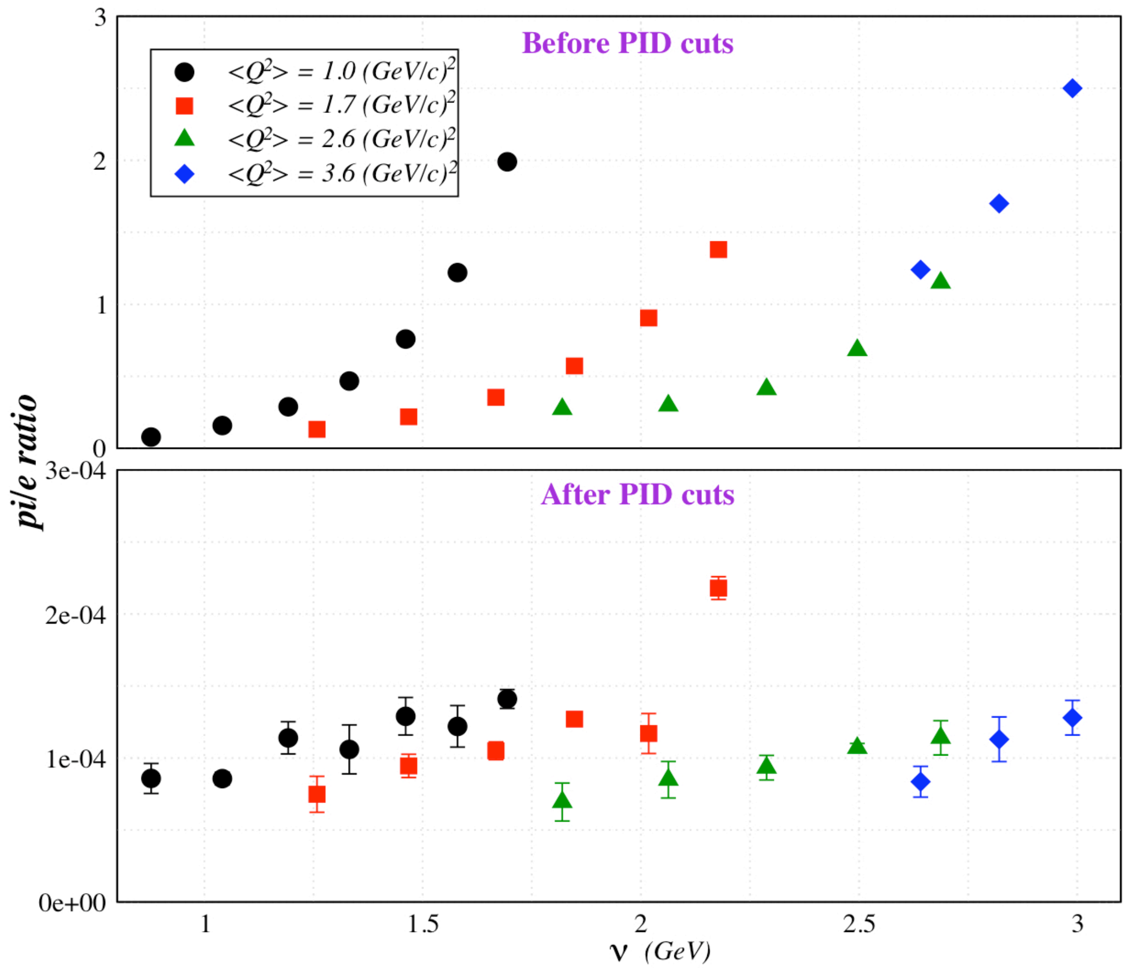
Knock-out e^-
&
Low energy e^-

Lead glass calorimeter



Cuts applied for electron efficiency > 99%

Particle identification performance



π/e reduced by 10^4 and electron efficiency kept above 98%