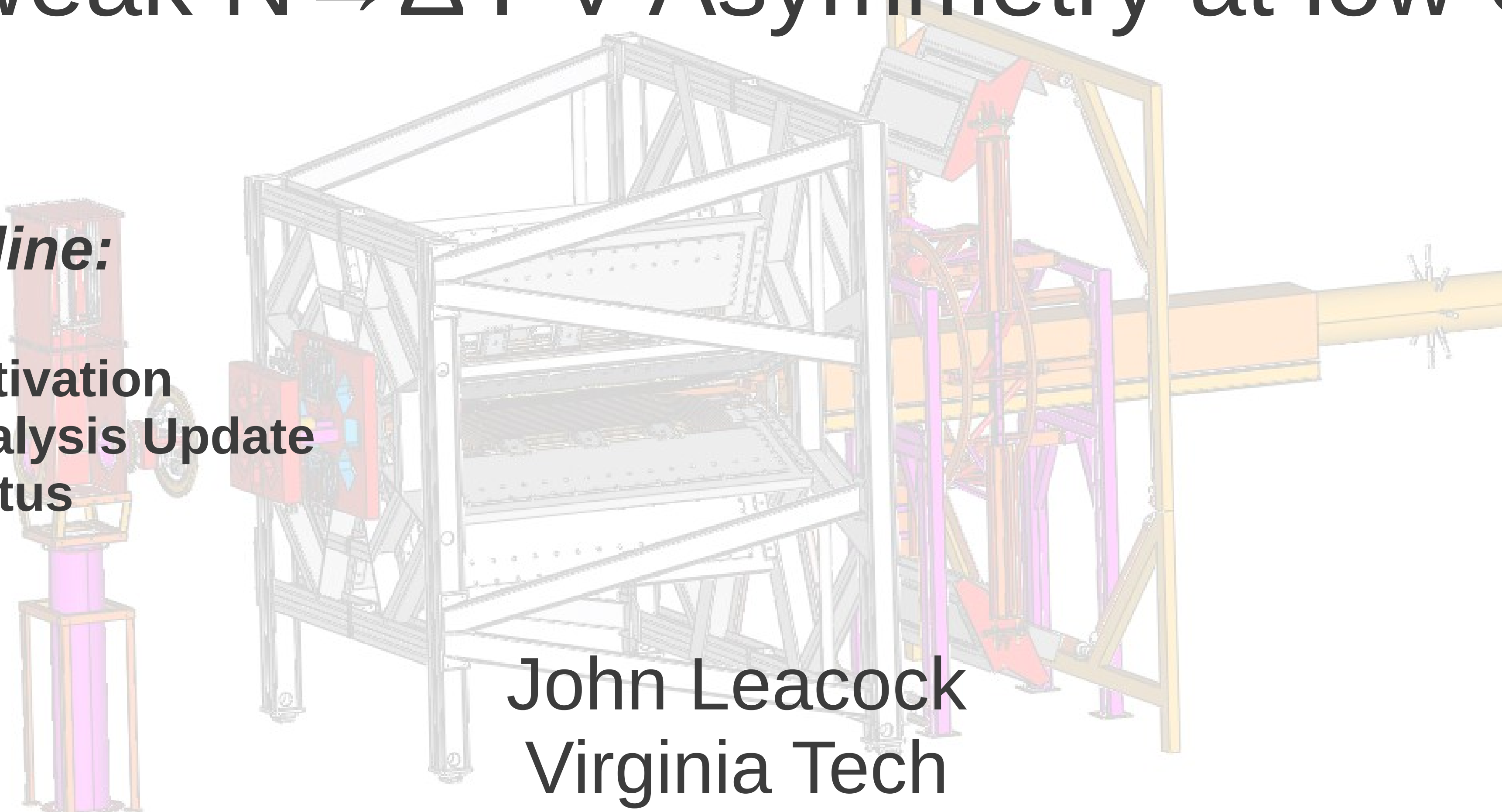
Qweak N → Δ PV Asymmetry at low Q^2

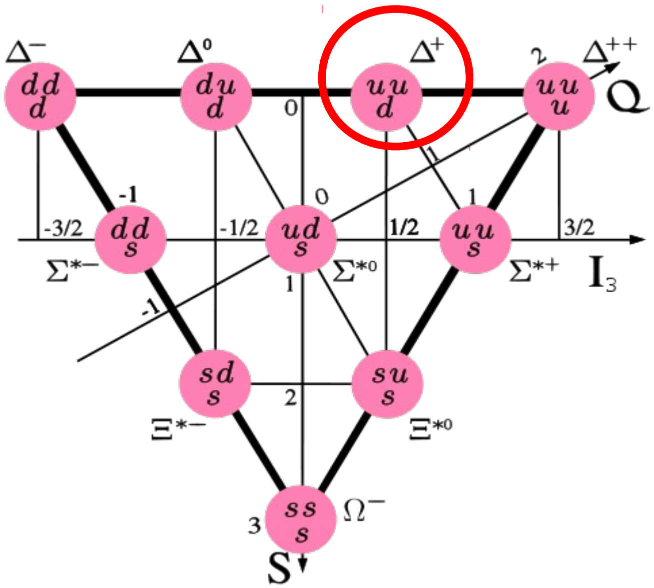


Outline:

- **Motivation**
- **Analysis Update**
- **Status**

John Leacock
Virginia Tech
20 October 2011
SESAPS, Roanoke, Virginia

What is the Δ?



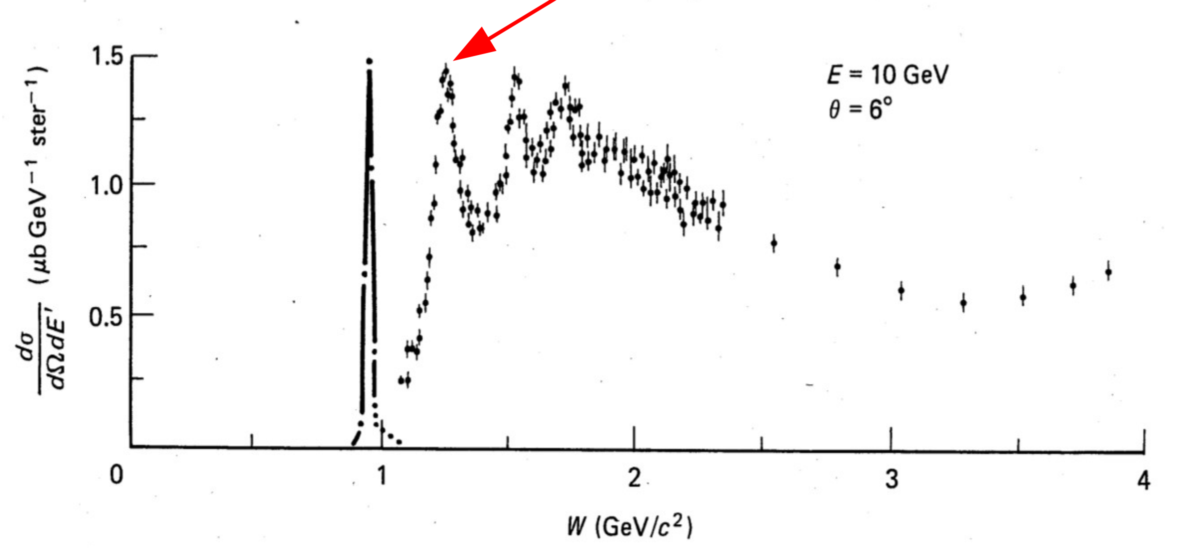
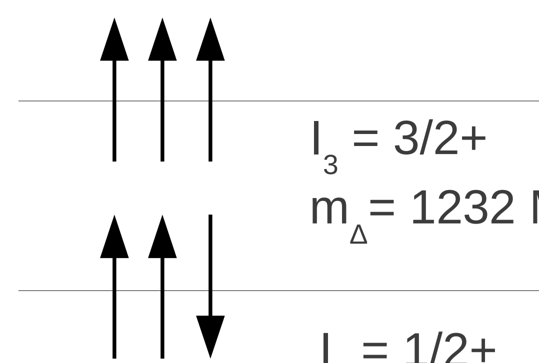


Image from Annual Review of Nuclear and Particle Science, Volume 22, 1972

Qweak N → Δ Interaction

$$\vec{e} + p \rightarrow \Delta^{+} + e'$$
$$\rightarrow N + \pi + e'$$

quark spin state



$I_3 = 3/2+$

$m_{\Delta} = 1232$ MeV

$I_3 = 1/2+$

q q q

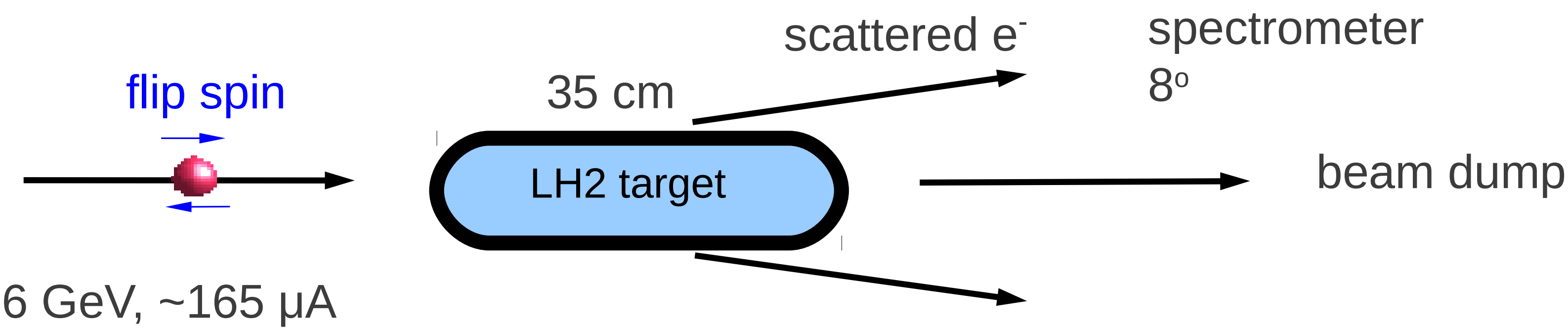
$m_p = 938$ MeV

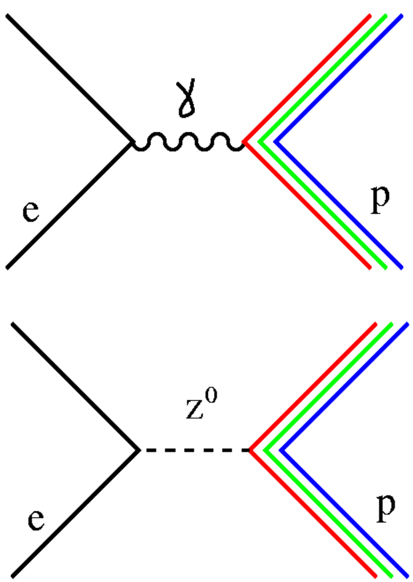
What is Qweak?

$\vec{e}^- + \color{red}{p} \rightarrow e^- + \color{red}{p}$

Qweak is the measurement of <u>elastically</u> scattered longitudinally polarized electrons at forward angles.

Overview talk by Mark Pitt session EA





	Q^γ	Q^Z	
u	$+2/3$	$1 - 8/3\sin^2\theta_W$	
d	$-1/3$	$-1 + 4/3\sin^2\theta_W$	
p(uud)	$+1$	$1 - 4\sin^2\theta_W$	≈ 0.07
n(udd)	0	-1	

suppressed

$N \rightarrow \Delta$ Measurement Motivation

1% - 10% correction to Qweak

$A_{N\Delta}$ *gives DIRECT ACCESS to* $G^A_{N\Delta}$

- *Axial transition form factor of the proton in* $N \rightarrow \Delta^+$
- *Reaction Mechanism (CQM)*
  - Z^0 *induces "quark spin flip" (Neutral Current)*

    $\rightarrow$ *c.f. M1 from* γ *induced quark spin flip*

Hadronic PV - d_Δ *– Weak Lagrangian Coupling Constant*

- d_Δ *characterizes the hadronic parity violation in the* $N \rightarrow \Delta^+$ *transition*
  - *c.f.* h_π, h_ρ *in parity violating N-N interactions*

QCD Symmetry Breaking Effects

$N \rightarrow \Delta$ Theory

$$A_{N\Delta}^{PV} = \frac{G_F}{\sqrt{2}} \frac{Q^2}{2\pi\alpha} \left(\Delta_{(1)}^{\pi} + \Delta_{(2)}^{\pi} + \Delta_{(3)}^{\pi} \right)$$

vector current terms

$\Delta_{(1)}^{\pi}$: resonant standard model term $\left(1 - 2\sin^2\theta_W\right)$

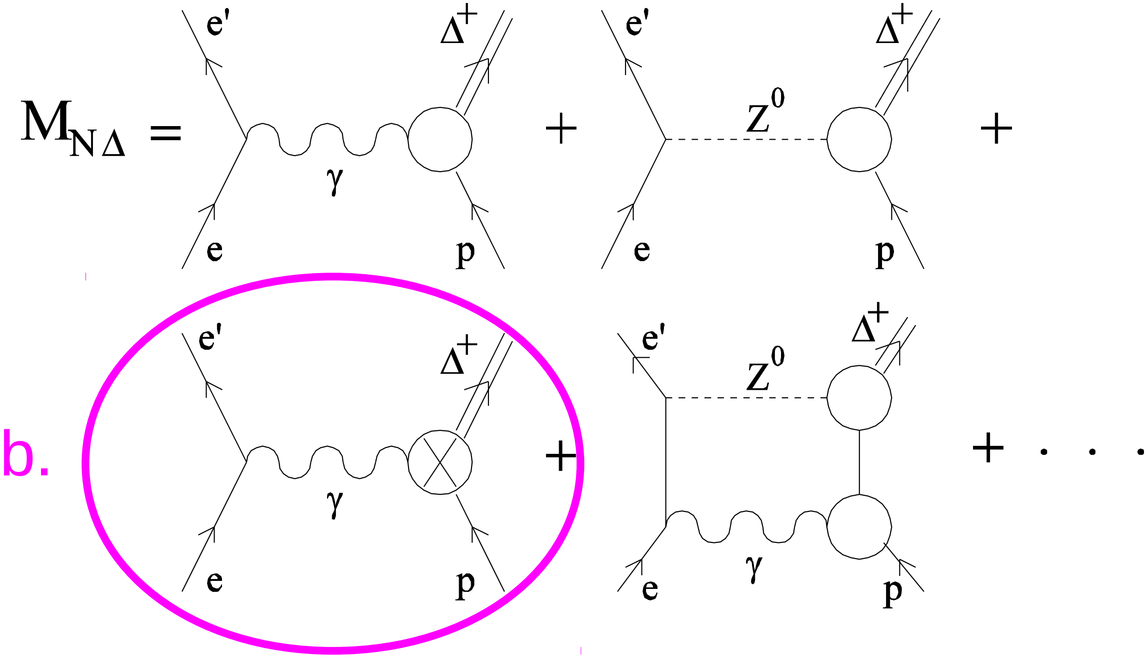
$\Delta_{(2)}^{\pi}$: non-resonant contributions — constrained by models

$\Delta_{(3)}^{\pi}$: axial vector nucleon response $\propto G_{N\Delta}^{A}$

M.J. Musolf et al., Phys. Rept. 239:1-178, 1994

N → Δ Radiative Corrections

Siegert Contrib.

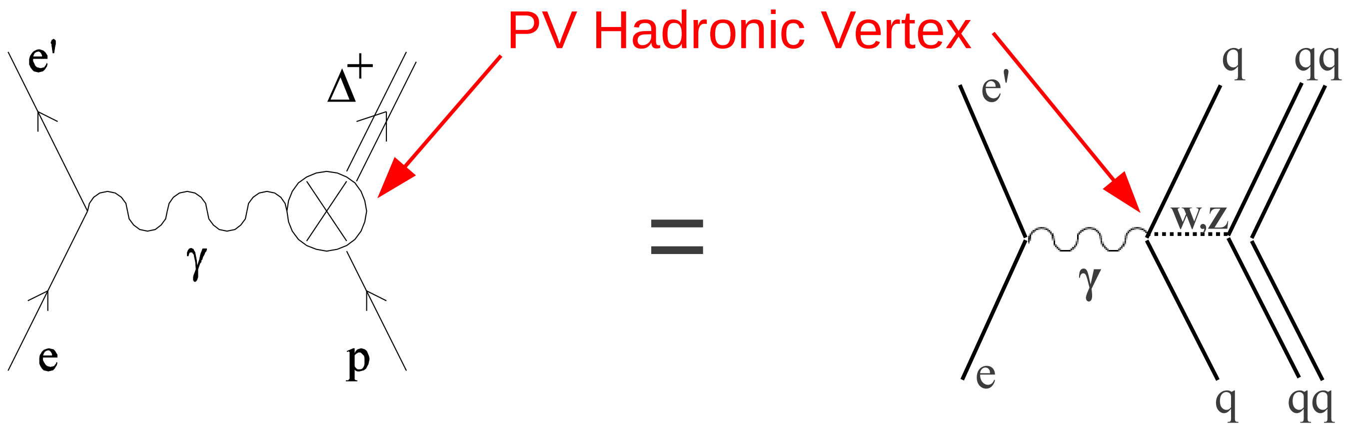


$$\Delta^{\pi}_{(3)} \propto (1+R^{\Delta}_{A})\, G^{A}_{N\Delta}$$

$$R_A^{\Delta} = R_A^{ewk} + R_A^{Siegert} + R_A^{Anapole} + R_A^{Box} + \cdots$$

S.-L. Zhu et al., Phys. Rev. D65:033001, 2002

Siegert Contribution



γ couples to q-q weak interaction inside nucleon

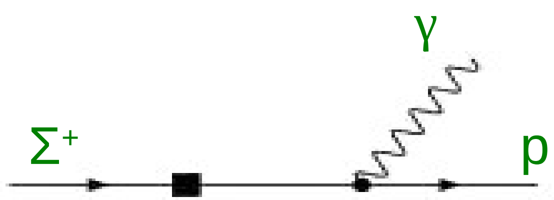
$$A_{PV}^{\gamma}\left(q^2=0\right) \approx -\frac{d_{\Delta} M_N}{\Lambda_X} \neq 0\,!$$

"natural scale" for this PV asymmetry is g_π = 3e-8

g_π is the hadronic PV coupling constant for *charged current* interactions

same matrix element drives Weak Hyperon Decay (e.g. $\Sigma^+ \to p\gamma$)

Radiative Hyperon Decay Problem



ΔS=1

Expected SU(3) symmetry breaking

$$\frac{m_s - m_u}{\Lambda_X} \approx 0.15$$

$$\frac{d\omega}{d\Omega} \propto 1 + \alpha_j P \cos\theta$$

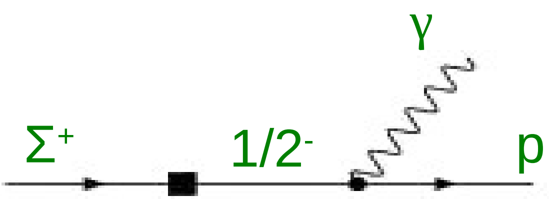
Experimentally determined asymmetry: $\alpha_j = -0.76$

~ 5X Larger than normal SU(3) Symmetry Breaking predicts

B. Borasoy and B.R. Holstein, Phys. Rev. D59:054019, 1999

Radiative Hyperon Decay Possible Solution

Dynamical Solution: Include heavy $1/2^-$ intermediate state resonances which couple to hyperon and daughter nucleon



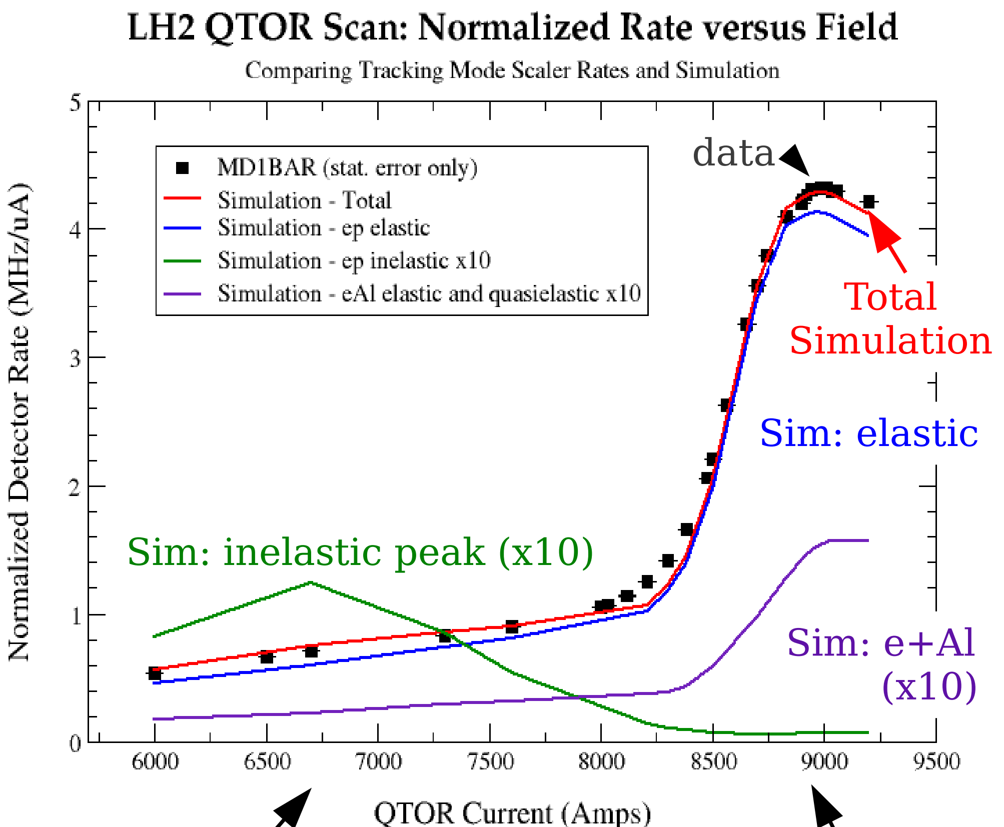
→ *pushes α_γ large and negative!*

→ *better agreement with experiment*

A similar model in the $\Delta S=0$ channel suggests a possible enhanced d_Δ with a range of $0 \rightarrow 100\ g_\pi$

Qweak N → Δ Transition Measurement

Use Qweak apparatus
- reduce bending magnet to 75% nominal
- increases inelastic event fraction from ~0.1% to ~30%



$$A_m = P[(1-f_{inel})A_{ep} + f_{inel}A_{inel}] + A_{false}$$

simulate dilution factor, f_{inel}

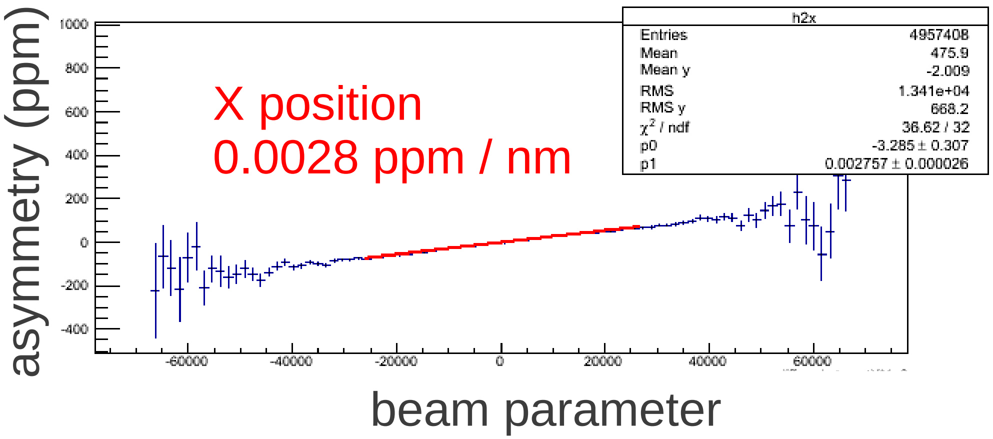
correct for false asymmetries using regression

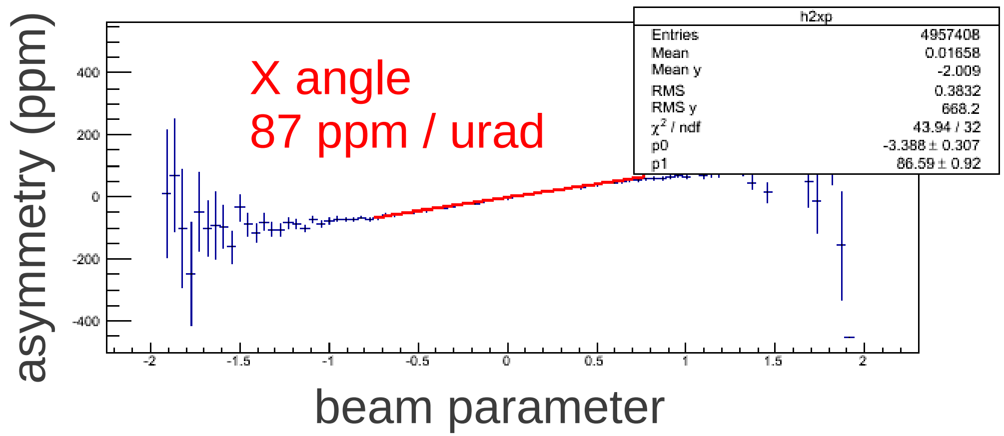
extract A_{inel} from measured asymmetry

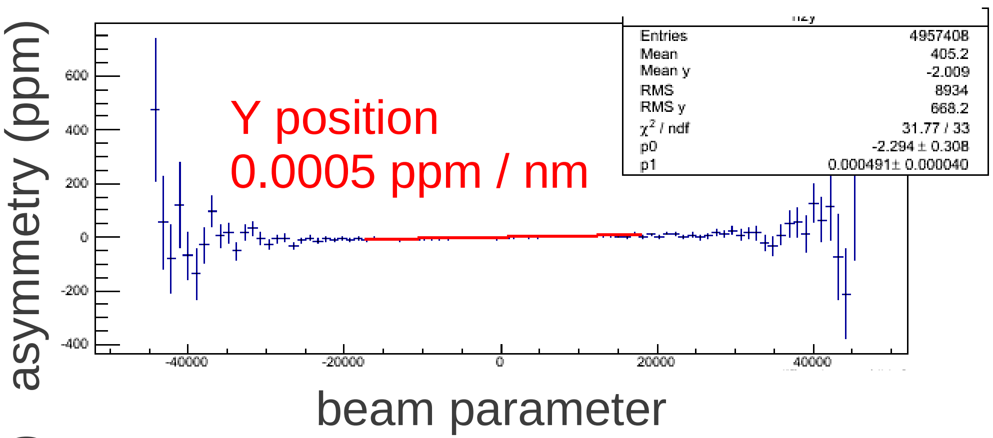
Inelastic peak
rate = 30% inelastic
QTOR = 6700 A
Q^2 = 0.022 GeV^2

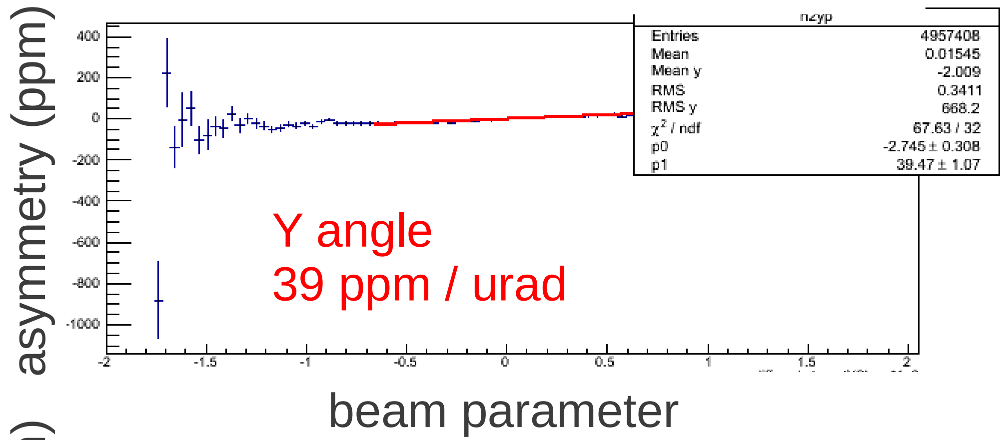
Normal Qweak running
rate = 0.1% inelastic
QTOR = 8921 A
Q^2 = 0.027 GeV^2

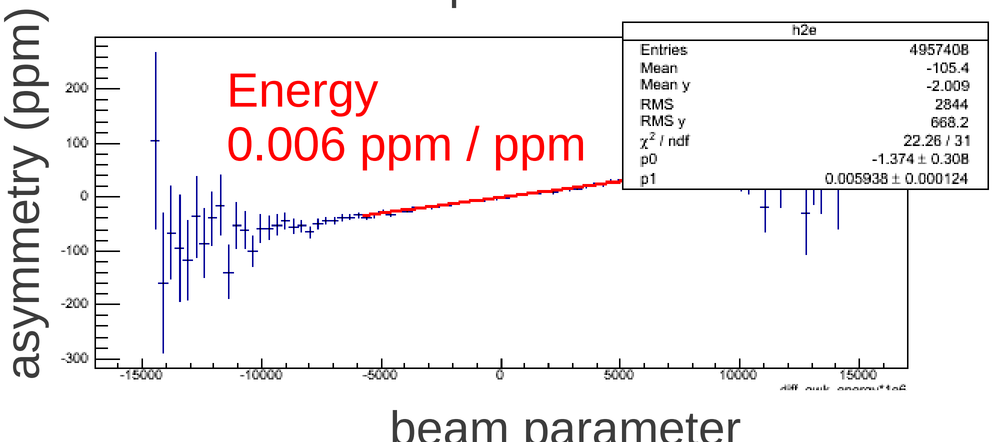
Beam parameter correlations before regression

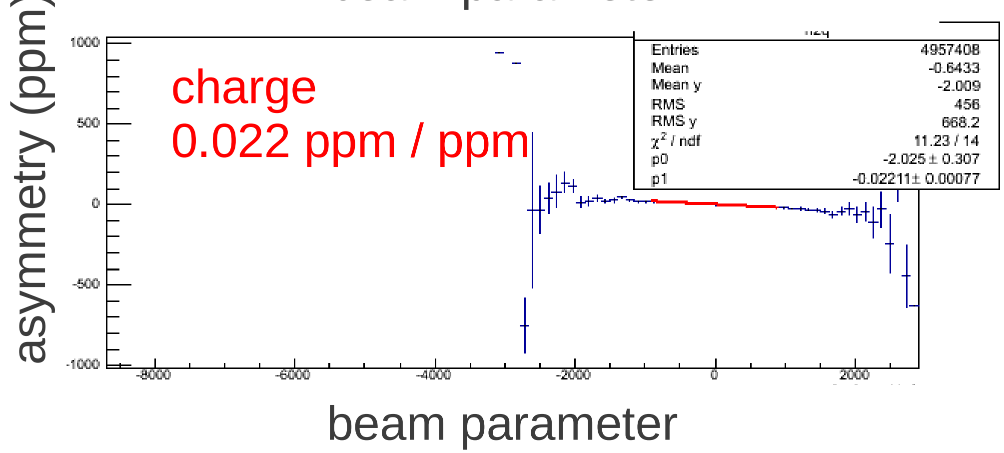




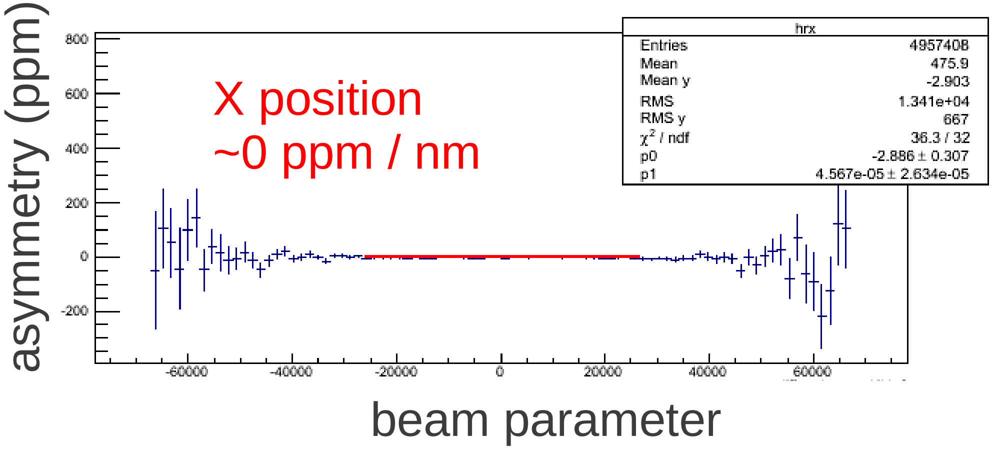


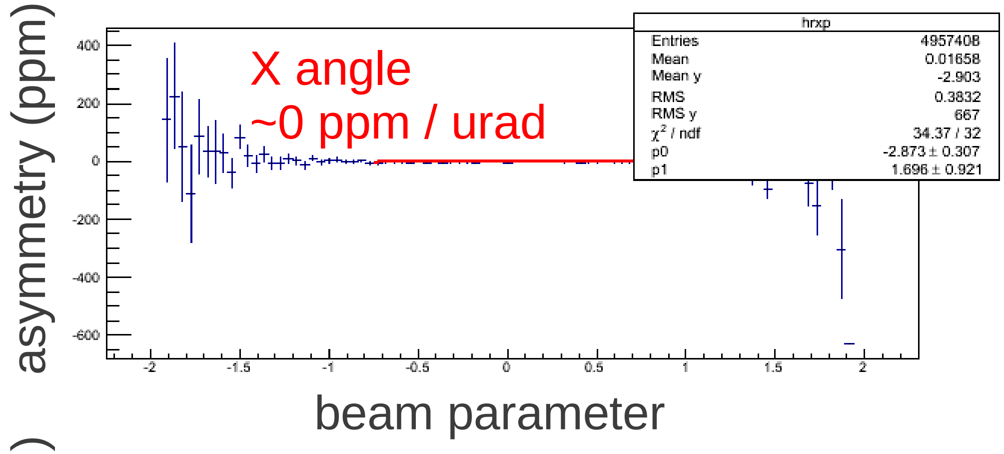


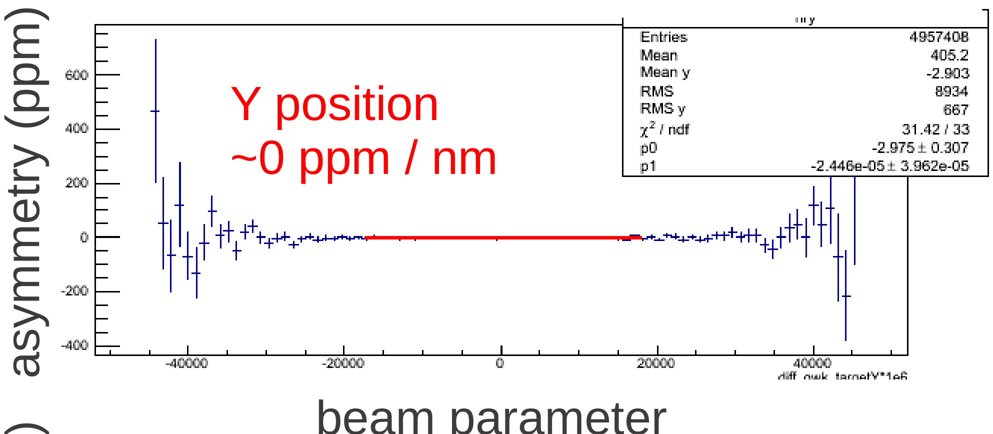


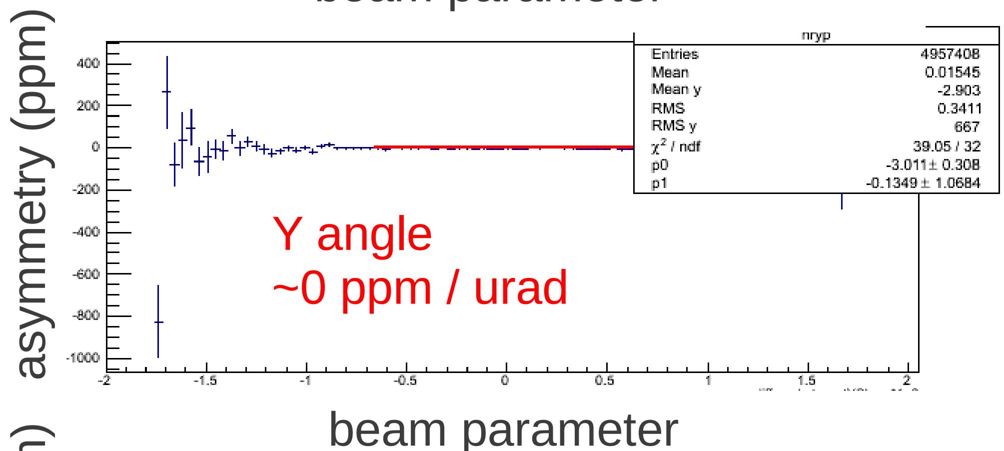


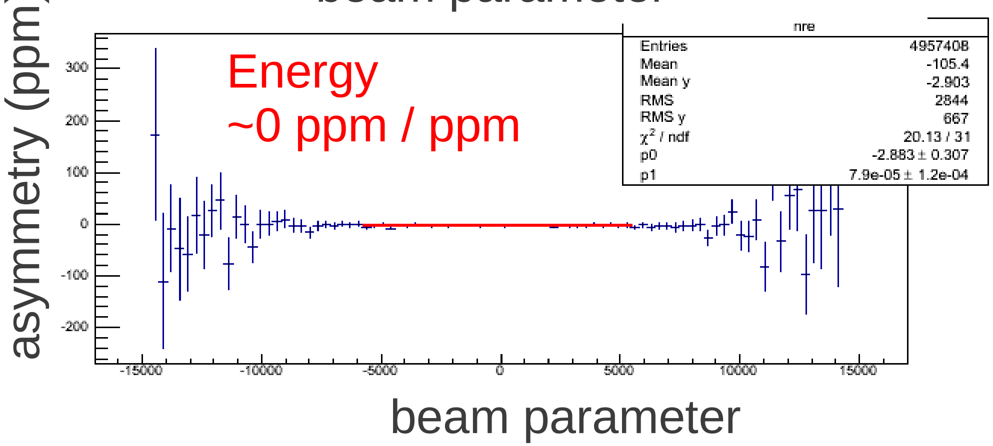
Beam parameter correlations after regression

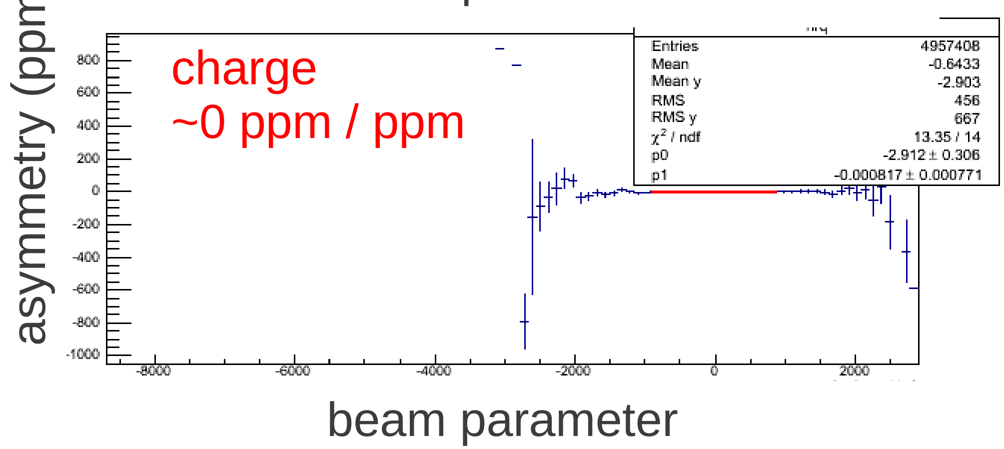




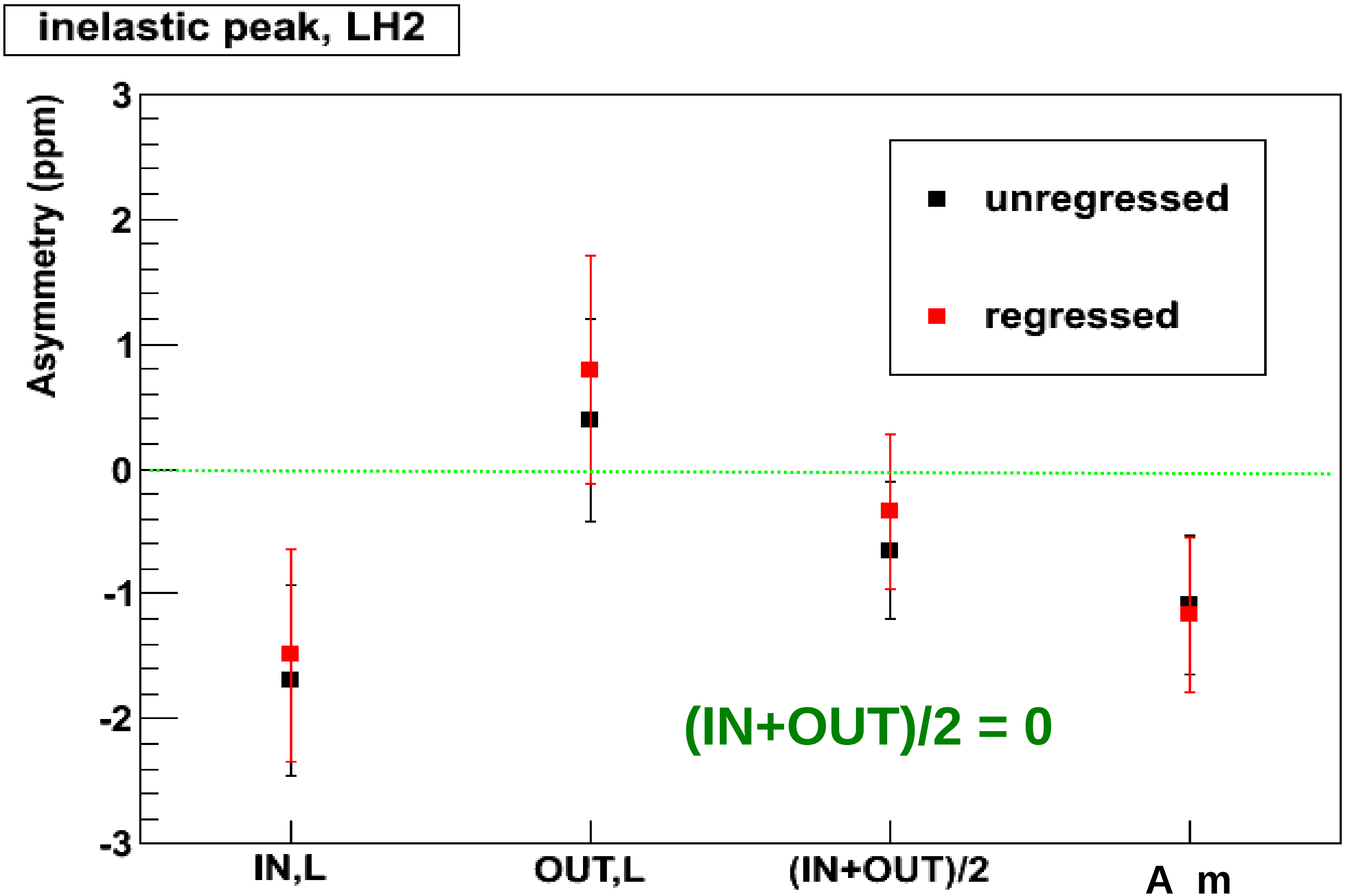








Qweak N→Δ Initial Measurement Data Quality

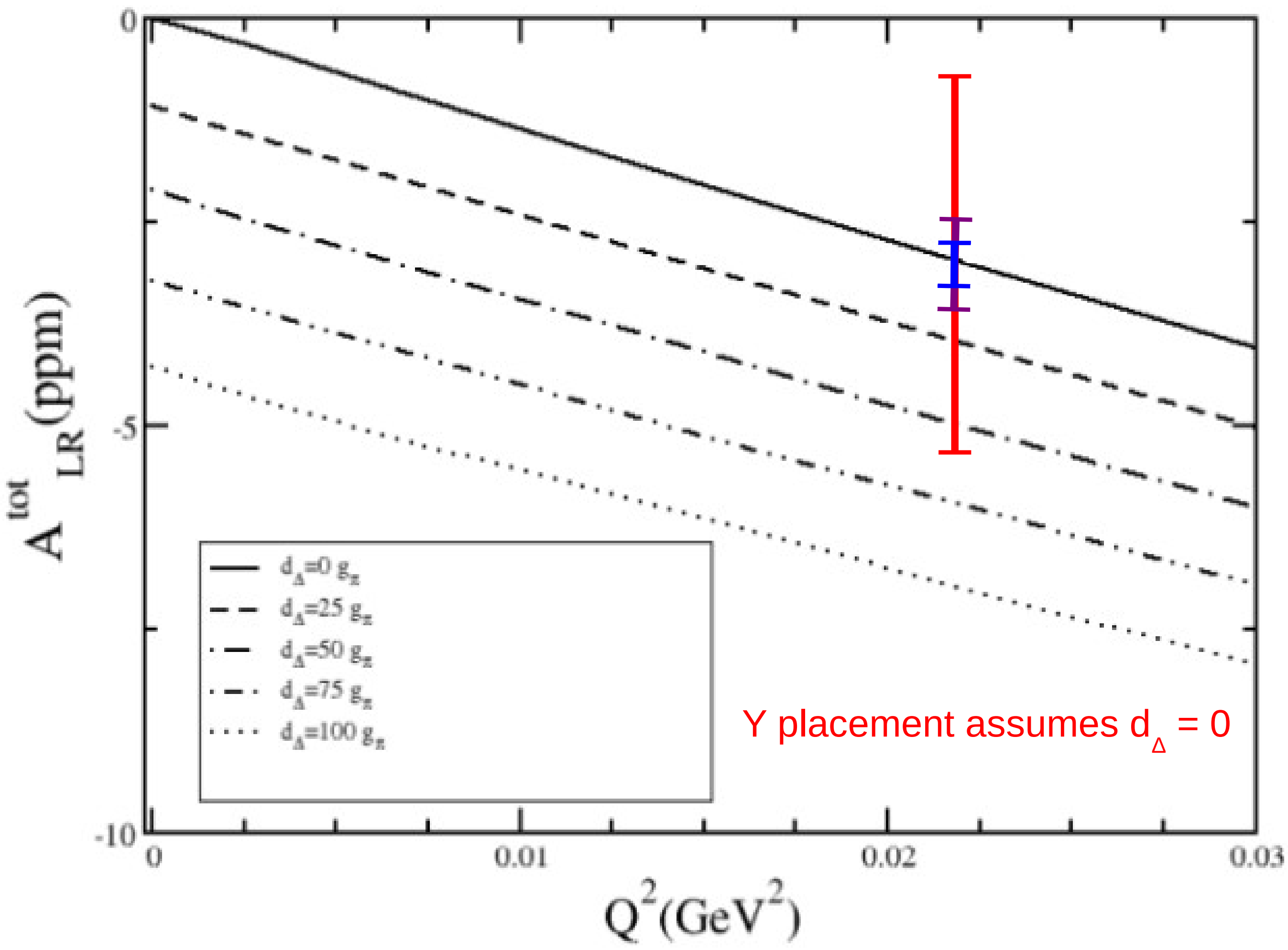


$A_{measured}$ = -1.2 +/- 0.6 ppm

Expected constraint on d_Δ

Expected error bars:

- initial measurement +/- $50g_\pi$
- enough data to constrain inelastic background to Qweak +/- $13g_\pi$
- proposed Qweak $N \rightarrow \Delta$ measurement +/- $7g_\pi$



Status

Dilution factor simulation ongoing

More beam time scheduled for early January

Nonresonant contribution modeling beginning soon

+/- $50g_{\pi}$ constraint by December 2011

+/- $13g_{\pi}$ constraint by February 2012

+/- $7g_{\pi}$ constraint by June 2012

The Collaboration

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S. Kowalski
S.A. Page

Project Manager:
G. Smith

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Extra Slides

Models for N → Δ interaction

1) "Default" model:

- MAID for $\Delta_{(2)}$
- use dipole form for $G^A_{N\Delta}(Q^2)$ with
- $F(Q^2)$ from Adler parameterization (S.L. Adler PRD **12**(1975)2644)

  parameters from N. Mukhopadhyay et al. (Nucl. Phys. A **633**(1998) 481.)

3) Dynamical Model of electroweak pion production:

K. Matsui, T. Sato & T.S.H. Lee, Phys. Rev. C **72,** 025204 (2005).
and T.S.H. Lee (private communication)
- hadronic effective chiral Lagrangian; field operators: N,Δ,π,ω,ρ and
effective Lagrangians for πNN,πNΔ,ωNN…

- $\Delta_{(3)}$ uses alternate form: $G^A_{N,\Delta}(Q^2) = (1 + aQ^2)\exp(-bQ^2)G_A(Q^2)$.