PR05-004: A(Q) at low Q in ed elastic scattering

- R Gilman, D Higinbotham, X Jiang, and the Hall A Collaboration
- Jeopardy update of E02-004, approved by PAC 21 for 5 days at B+ priority

Physics motivation

Some experimental details

Run plan and time request

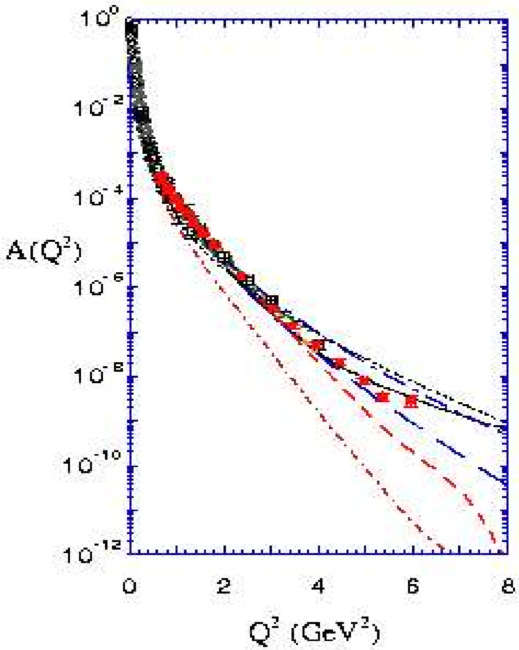
Overview

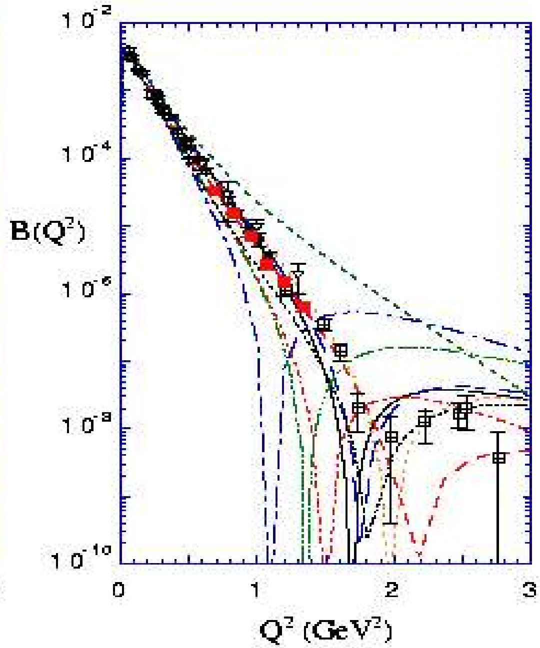
- Deuteron elastic scattering is a primary test case for predicting nuclear structure from NN interaction
- Many theoretical tools: conventional theory (NR, rel), no-π EFT, ChiPT, pQCD ...
- Spin 1 deuteron has 3 form factors:

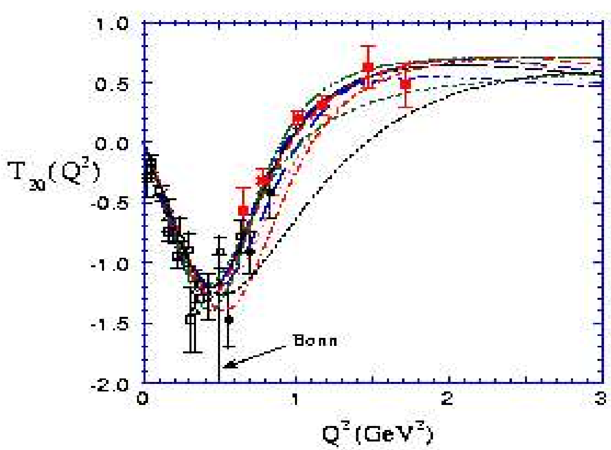
$$\sigma = \sigma_{NS}\,[A(G_C,G_Q,G_M) + B(G_M)\tan^2(\theta/2)]$$

- Our goal: high precision, low Q, to test ChiPT, relativistic corrections, old data

Overview of Data



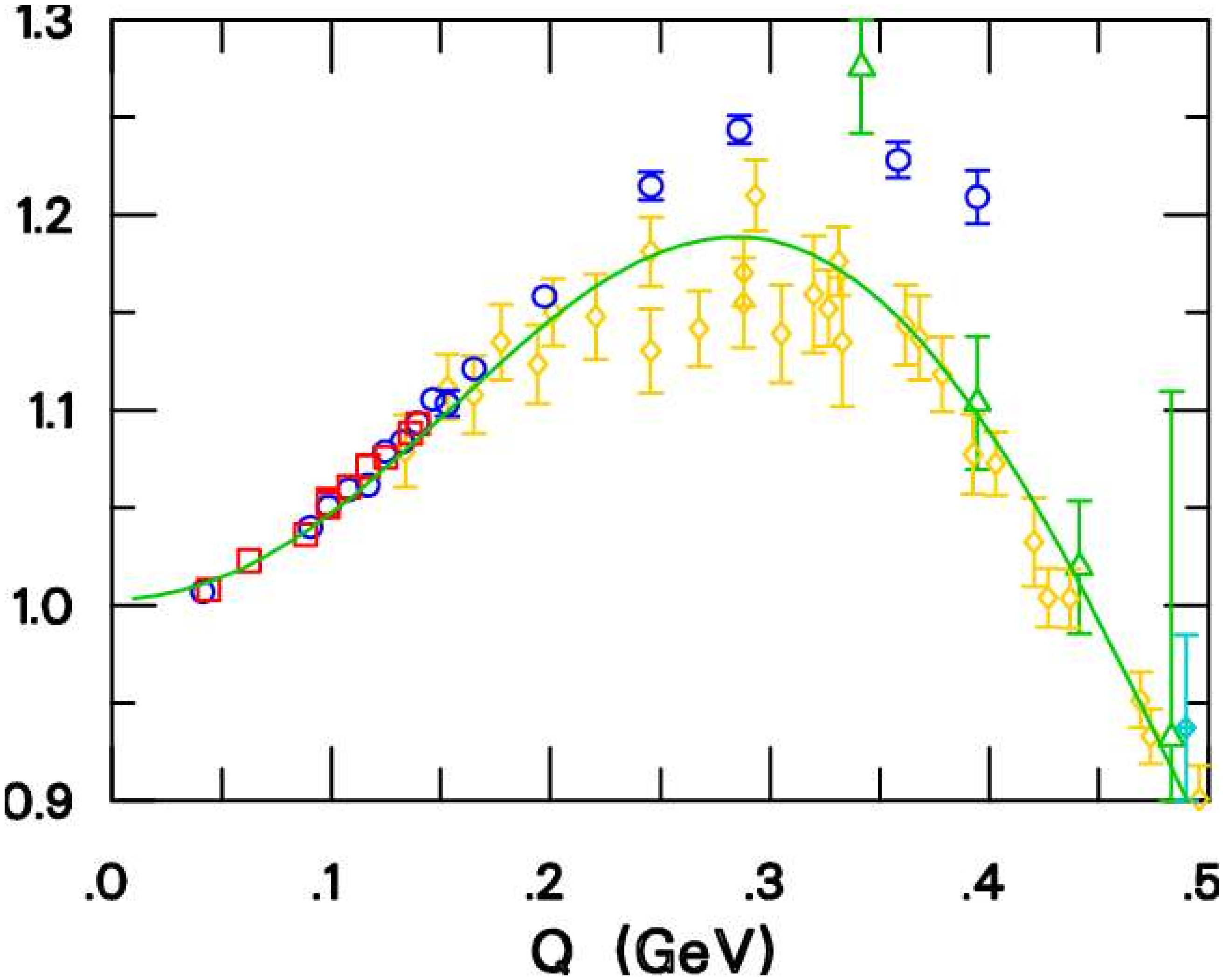




Overview suggests good agreement at low Q, need to better determine minimum of B and push all observabes to higher Q

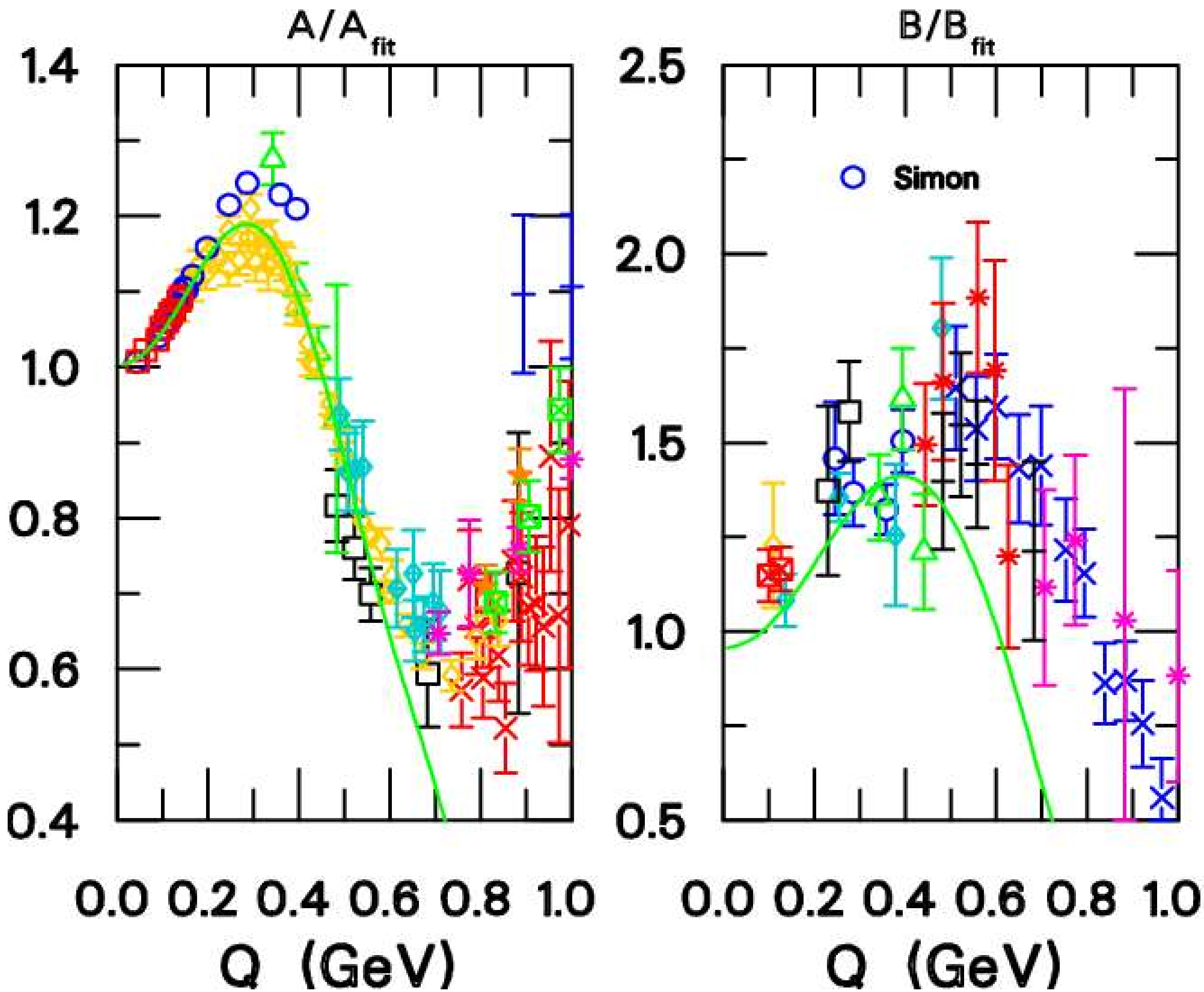
But semi-log plots hide problems.

Overview of Data: A/A_{fit}



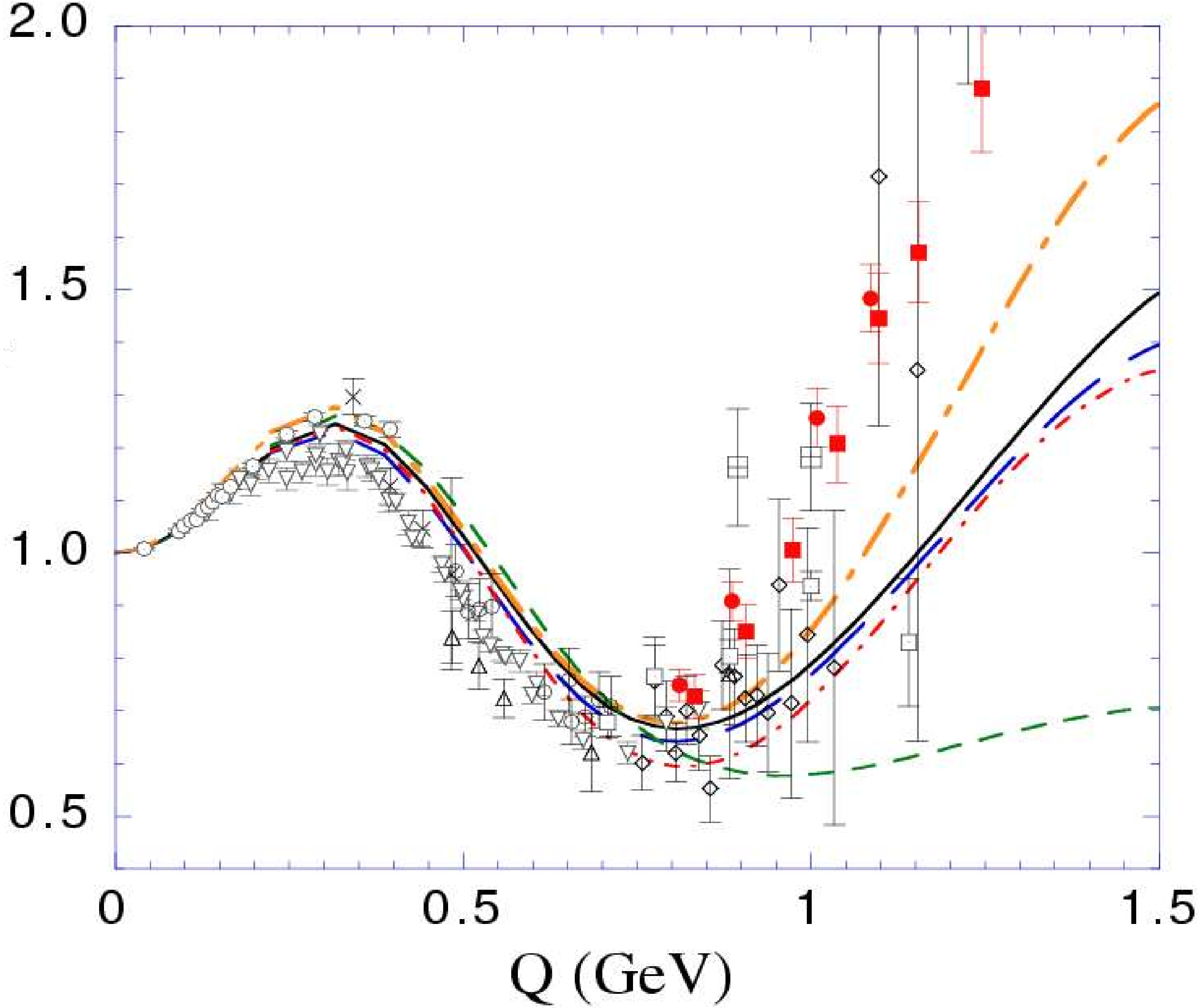
High precision Mainz and Saclay data do not agree as well as they should, chiPT closer to Saclay

Low Q and NNLO ChiPT



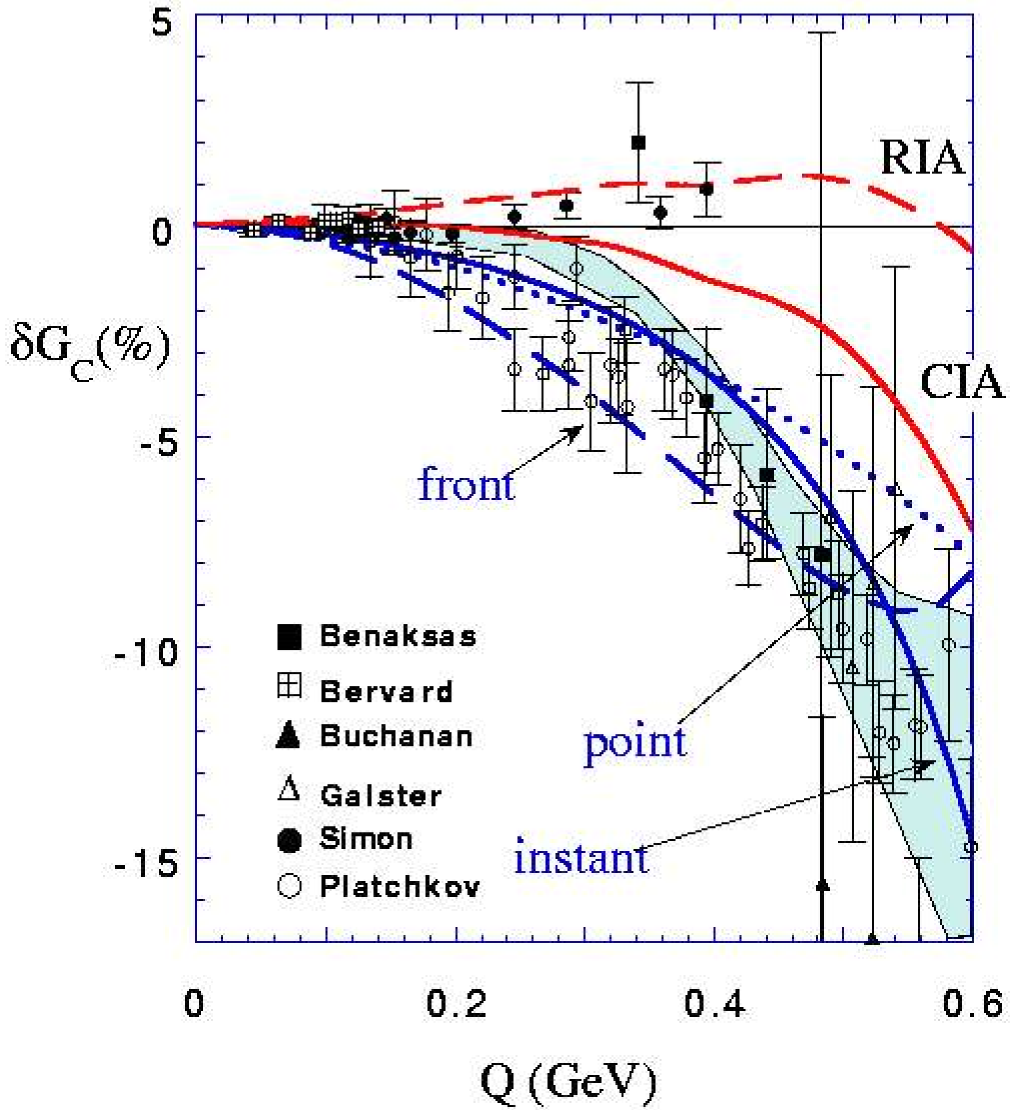
- B/Gm show greater short-range effects
- Hints of problems in each data set

Conventional nonrelativistic theory



NR theories consistent to ~ ±2% at low Q, so one can extract relativistic corrections reliably

Relativistic theory vs G_C



- Small corrections convert A to G_C
- Plot relative to NR AV18
- What are the relativistic corrections, at low Q where they are small?

Motivation Summary

- We are at a stage where there is improving precision in theoretical calculations
- A high-precision measurement of $A(Q)$ at low Q would be of great interest to many theorists, to determine how precisely we understand the deuteron
- Test relativistic corrections and ChiPT, and resolve discrepancy in data set

Experimental Overview

- Attempt high precision absolute measurement (2-3%), and even higher precision relative measurement (<1%)
- Use multiple cross checks to ensure knowledge of uncertainties under control
  - Measure ep, ed, $e^{12}C$ vs θ (Q) at fixed E_e
  - Measure with both HRS-L and HRS-R
  - Measure at 2 beam energies

E01-001 “Super-Rosenbluth”

- Recent high-precision Hall A experiment
- “Published” leading uncertainties:

Item	**absolute (%)**	**relative (%)**
Solid Angle	2	0.0
Radiative Correction	1	0.2
Background Subtraction	1	0.2
Luminosity	1	0.0
Tracking efficiency	0	0.2
Scattering Angle	0	0.2
Total	3	0.45

Kinematic Sensitivity

- Uncertainty in cross section and A due to knowledge of Q dominated by knowledge of scattering angle
- At 857 MeV, 0.3 mr uncertainty leads to 0.8% (0.3%) at Q=0.2 (0.8) GeV
- At 600 MeV, 0.3 mr uncertainty leads to 0.5% (0.2%) at Q=0.2 (0.8) GeV

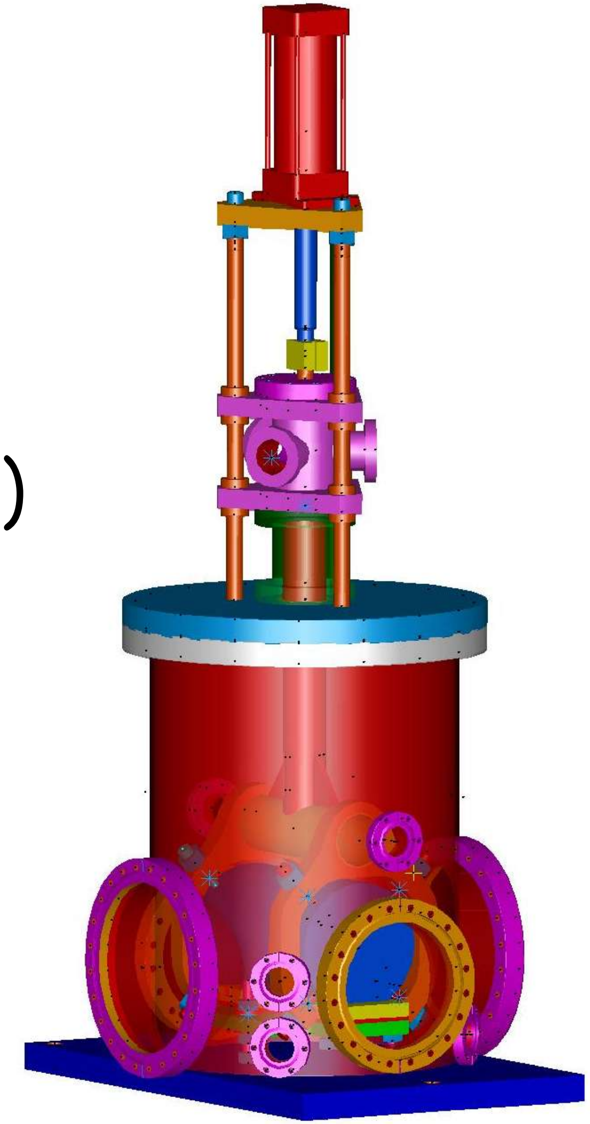
Luminosity

- Target areal density known to ~0.2%
- Relative luminosity (with monitor spectrometer) good to ~0.1%
- Hall A at present has no mechanism for calibrating absolute beam current at small currents
- In process of building beam calorimeter for these calibrations, copying and improving upon 1% SLAC silver calorimeter

Beam Calorimeter

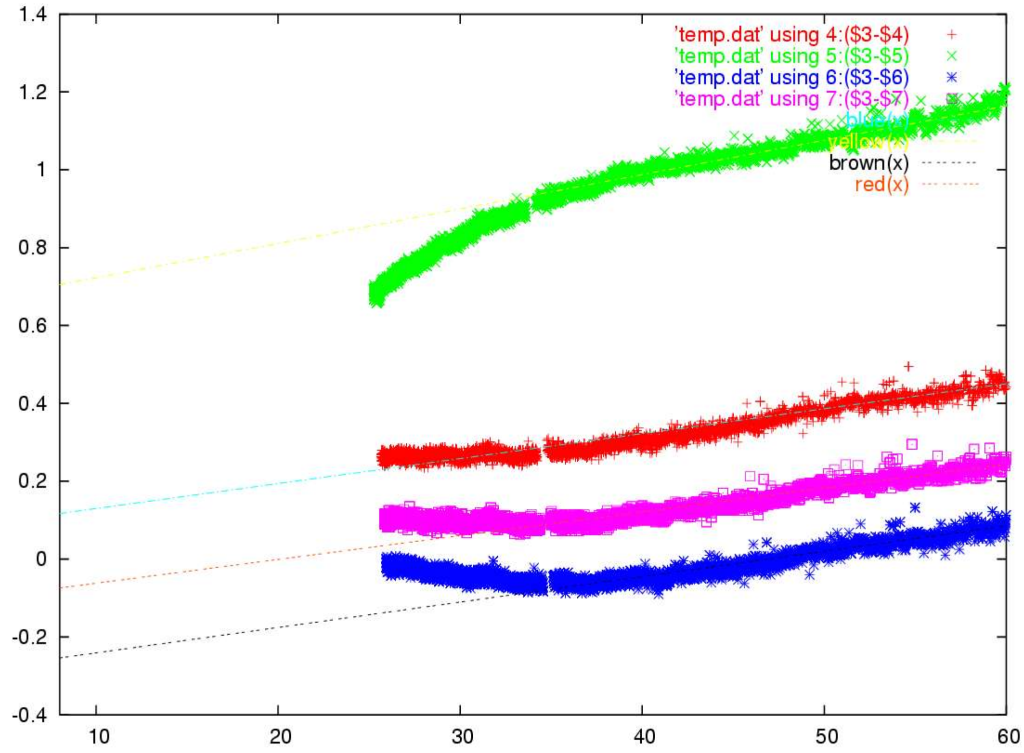
- Uncertainty estimate, from May 2004 design review

Item	Loss (%)	Uncertainty (%)
Beam Energy	0.0	0.02
Thermometry	0.0	0.2
Heat Capacity	0.0	0.2
Heat Losses	0.4	0.1
EM showers	0.15	0.05
Hadronic loss	0.3	0.15



Beam Calorimeter

- First cross comparison of four small surface mount RTDs to high precision NIST-traceable Omega probe (10 mK)



Beam Calorimeter

- Currently working with aluminum slug
- RTDs come good to ~200 mK (abs), good enough for ~1% current determination, but not good enough for our ambitions
- Working on cross-calibration procedure, moving to more robust RTDs
- Spent about 15/80 K, expect to finish this year once budget situation clears up

Systematic Uncertainties

- Estimated leading systematics

Systematic	Absolute (%)	Relative-d (%)	Relative-p (%)
Angle	0.5	0.7	0.1
Charge	0.5	0.1	0.1
Areal density	0.2	0.1	0.3
Solid angle	1.0	0.1	0.1
Rad. corr.	1.0	0.1	0.1
det. eff.	0.7	0.2	0.2
...			
Total	1.8	0.8	0.4

Kinematics / Rates

- Generally 0.1% statistics for data and for monitor spectrometer in Kin-4

Kin	Q (GeV)	I (muA)	Rate (Hz)	T (hrs)
1	0.20	1	70 k	0.5
2	0.25	1	16 k	0.5
3	0.30	1	4000	0.5
4	0.35	1	1300	0.5
5	0.40	3	1200	0.5
6	0.45	10	1400	0.5
7	0.50	10	500	1
8	0.60	50	350	1.5
9	0.70	50	60	3
10	0.80	50	11	4

Run Plan

- For each kinematic point, take data on elastic ^{181}Ta, C, C optics, Al empty cell, d, p targets
- Multiple nuclei calibrates E', θ
- Thin targets calibrate pointing, C optics calibrates y_{target}, sieve slit calibrates $\Delta\Omega$
- High precision C, d, p angular distributions
- Repeat 4 times, with both HRS-L&R, at 2 beam energies

Time Request

Item	Time (hrs, 0.85 GeV	Time (hrs, 0.6 GeV)
p,d data	34	17
empty cell	8	4
Carbon	15	7.5
Ta	2	1
Target changes	8	4
Angle/field changes	8	4
Access ($<15^{\circ}$)	6	6
Ee measurements	5	5
Q calibration	1	1
TOTAL	83	46.5

PAC 21 Report

- The measurement requires an improved knowledge of the HRS spectrometer, reduced uncertainties in the scattering angle and acceptance, as well as a more precise determination of the beam intensity.
- All these facets either demonstrated by other experiments or under development by us.

Summary

- Physics goal: determination of relativistic corrections and quality of NNLO ChiPT, not allowed with current data, and resolution of discrepancy in the data
- Technical elements needed either achieved or in process
- 6 days at ~850 and ~600 MeV