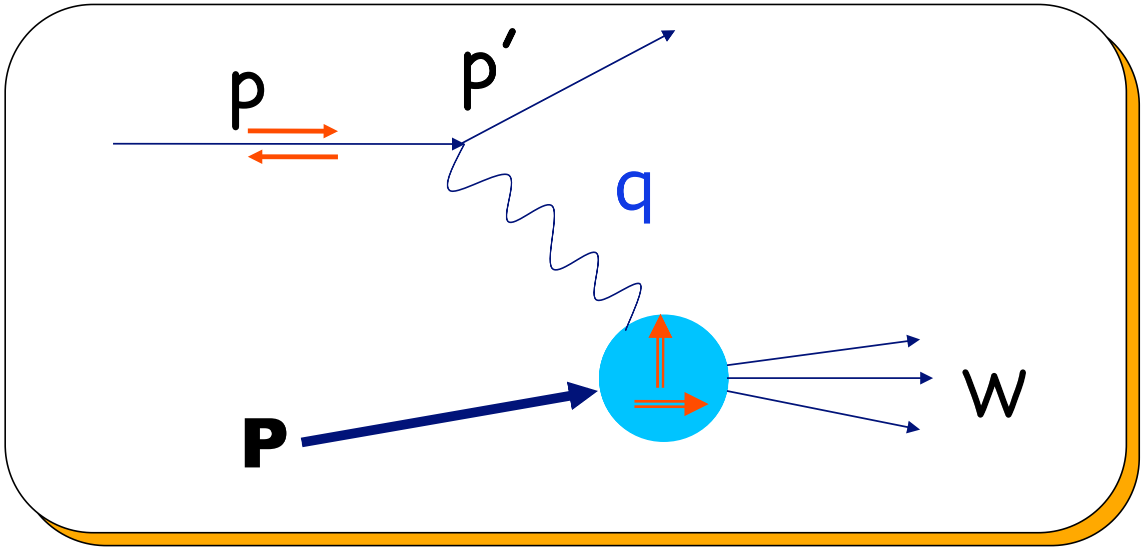
Physics Goals
&
Overview

E08-027/007 Collaboration meeting

K. Slifer, UNH
Sept. 30, 2010

Inclusive Scattering



Construct the most general Tensor W consistent with Lorentz and gauge invariance

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

$$+\gamma\, g_1(x,Q^2) + \delta\, g_2(x,Q^2)$$

Inclusive **Polarized** Cross Section

SFs parameterize everything we don't know about hadron vertex

E08-027 : Proton g_2 Structure Function

Fundamental spin observable has never been measured at low or moderate Q^2

A$^-$ rating by PAC33

Camsonne, Crabb, Chen, Slifer*

BC Sum Rule : violation suggested for proton at large Q^2, but found satisfied for the neutron & ^{3}He.

Spin Polarizability : Major failure (>8σ) of χPT for neutron δ_{LT}. Need g_2 isospin separation to solve.

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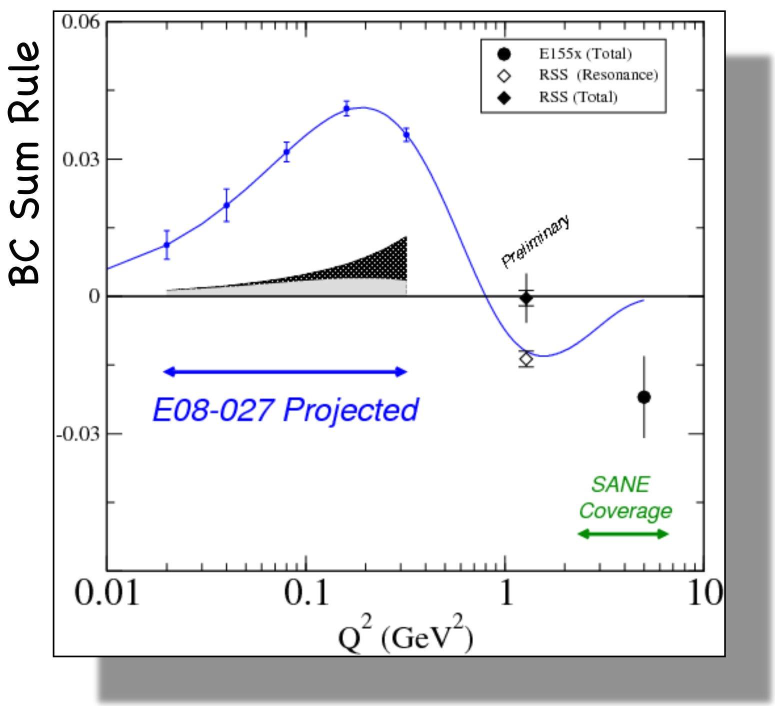

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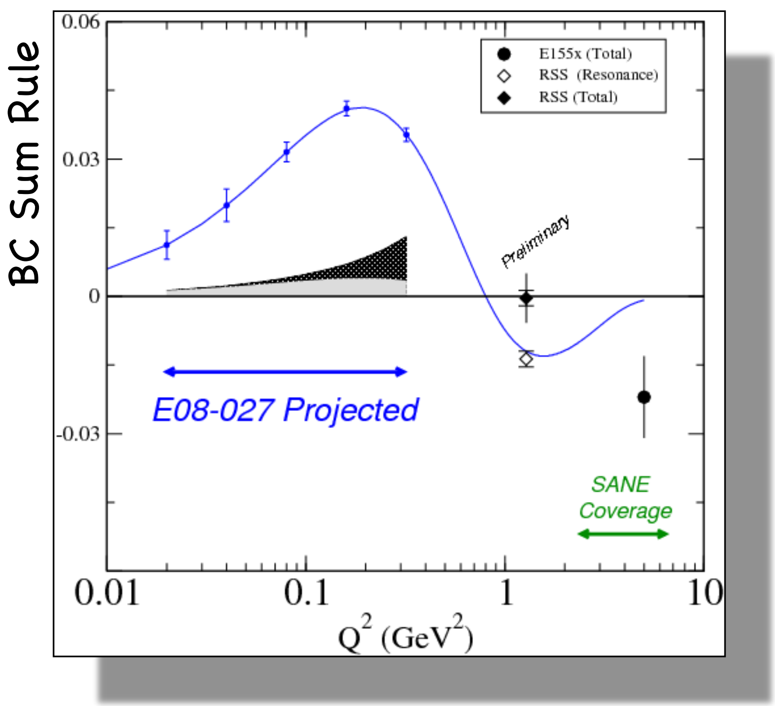

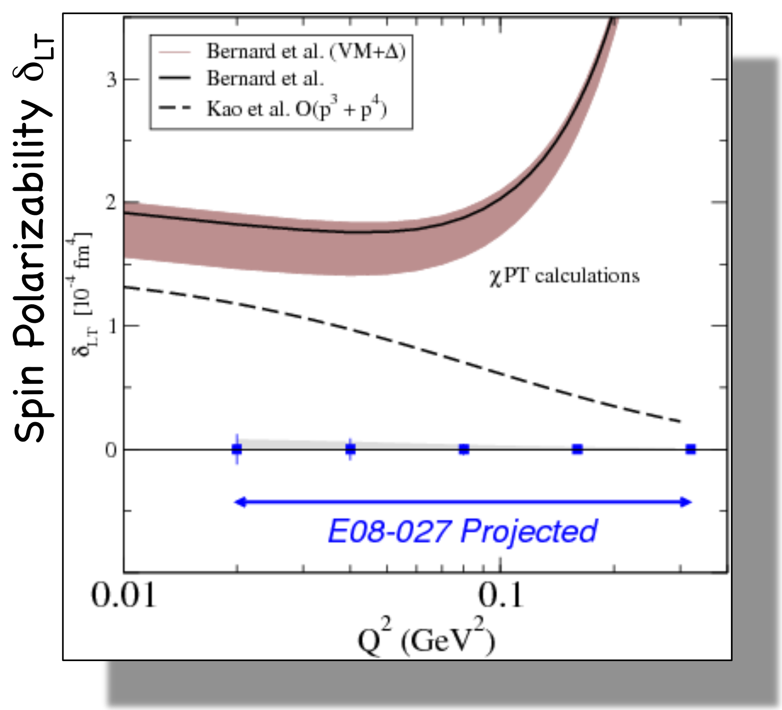

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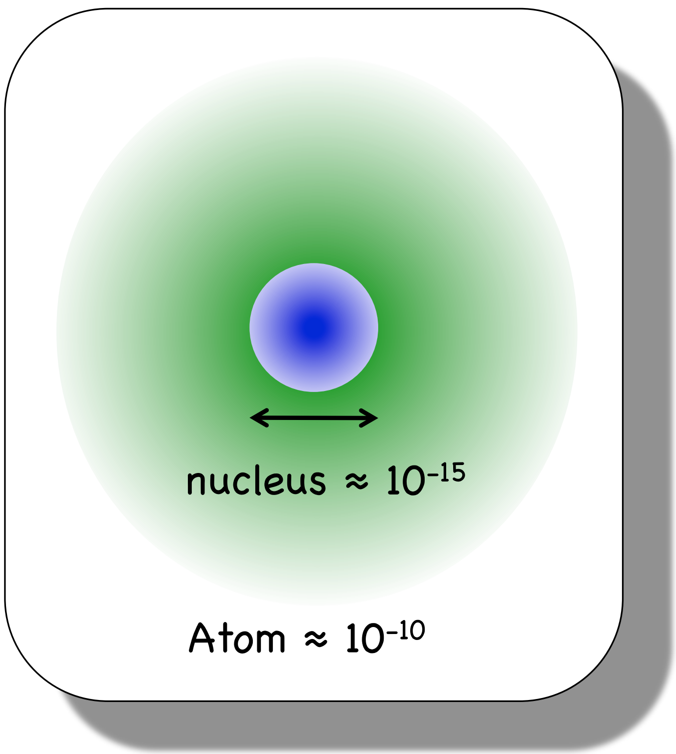
Hydrogen HyperFine Splitting : Lack of knowledge of g_2 at low Q^2 is one of the leading uncertainties.

Proton Charge Radius : also one of the leading uncertainties in extraction of $\langle R_p \rangle$ from μ–H Lamb shift.



The finite size of the nucleon (QCD) plays a small but significant role in calculating atomic energy levels in QED.

Proton Charge Radius from μP lamb shift disagrees with eP scattering result by about 6%

$\langle R_p \rangle = 0.84184 \pm 0.00067$ fm — Lamb shift in muonic hydrogen
R. Pohl *et.al Nature, July 2010*

$\langle R_p \rangle = 0.897 \pm 0.018$ fm — World analysis of eP scattering
I. Sick PLB, 2003

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$\langle R_p \rangle = 0.8768 \pm 0.0069$ fm — CODATA world average

Possible Implications :

Some experimental mistake ? Fairly straightforward spectroscopy.

Rydberg constant off by 5σ ? Really unlikely.

We don't know how to calculate in QED ? Missing some terms?

Something about muons we don't understand ?

Underestimating finite size effect uncertainties?

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nature

LETTERS

The size of the proton

Randolf Pohl[1], Aldo Antognini[1], François Nez[2], Fernando D. Amaro[3], François Biraben[2], João M. R. Cardoso[3], Daniel S. Covita[3,4], Andreas Dax[5], Satish Dhawan[5], Luis M. P. Fernandes[3], Adolf Giesen[6]†, Thomas Graf[6], Theodor W. Hänsch[1], Paul Indelicato[2], Lucile Julien[2], Cheng-Yang Kao[7], Paul Knowles[8], Eric-Olivier Le Bigot[2], Yi-Wei Liu[7], José A. M. Lopes[3], Livia Ludhova[8], Cristina M. B. Monteiro[3], Françoise Mulhauser[8]†, Tobias Nebel[1], Paul Rabinowitz[9], Joaquim M. F. dos Santos[3], Lukas A. Schaller[8], Karsten Schuhmann[10], Catherine Schwob[2], David Taqqu[11], João F. C. A. Veloso[4] & Franz Kottmann[12]

The proton is the primary building block of the visible Universe, but many of its properties—such as its charge radius and its anomalous magnetic moment—are not well understood. The root-mean-square charge radius, r_p, has been determined with an accuracy of 2 per cent (at best) by electron–proton scattering experiments[1,2]. The present most accurate value of r_p (with an uncertainty of 1 per cent) is given by the CODATA compilation of physical constants[3]. This value is based mainly on precision spectroscopy of atomic hydrogen[4-7] and calculations of bound-state quantum electrody- of the trailing digits of the given number). An H-independent but less precise value of r_p = 0.897(18) fm was obtained in a recent reanalysis of electron-scattering experiments[1,2].

A much better determination of the proton radius is possible by measuring the Lamb shift in muonic hydrogen (μp, an atom formed by a proton, p, and a negative muon, μ^-). The muon is about 200 times heavier than the electron. The atomic Bohr radius is correspondingly about 200 times smaller in μp than in H. Effects of the finite size of the proton on the muonic S states are thus enhanced. S

> The main uncertainties originate from the proton polarizability, and from different values of the Zemach radius.

deviations from the CODATA value[3] of 0.8768(69) fm. Our result implies that either the Rydberg constant has to be shifted by ... and spin–spin interactions) are an order of magnitude smaller than the Lamb shift (Fig. 1c). The uncertainty of 0.0049 meV in ΔE is

<u>Polarizability</u> : Integrals of g_1 and g_2 weighted by $1/Q^4$

<u>Zemach radius</u> : Integral of $G_E G_M$ weighted by $1/Q^2$

Dominated by Kinematic region of E08-027 and E08-007

General Announcements

Mailing lists:

g2p@jlab.org : general collaboration information
g2p_ana@jlab.org : Analysis and day-2-day info

Subscribe at mailman.jlab.org

g2p wiki : https://hallaweb.jlab.org/wiki/index.php/g2p

g2p analysis logbook: https://hallaweb.jlab.org/dvcslog/g2p

Weekly Meetings (join in!) :

Tues 8:30 : Instrumentation/Beamline @MCC
Weds 2:30 : Analysis and experiment preparation
Thurs 1:30 : Target preparations (bi-weekly)

Lessons learned, courtesy O. Rondon

Subsystem	SANE/RSS	Suggestions for g2p/gep
Beam line	Chicane Beam Geometry drawing is very helpful http://hallcweb.jlab.org/experiments/sane/general/beamline/RSS-chicane.pdf	Request equivalent drawings as for RSS/GEn https://hallcweb.jlab.org/experiments/sane/wiki/index.php/Upstream_Beam_Line
	Slow raster Wavetek waveform generators and PCM amplifiers needed repeated replacement. Circular shape stability: X-Y phase drifted. Phase shifter limited to 45°.	Procure new generators (now Fluke 271), refurbish amplifiers. 90° capable phase shifter or other method of setting X-Y phases
	No SEM. Rely on slow raster ADC for event-by-event beam position. Large out-of-plane (vertical) beam position affects HMS momentum reconstruction.	Effect of vertical beam offset on HRS should be understood, single arm elastic data with peak near center of momentum acceptance is useful.
Target	Target rotation was restricted to one direction (CW from above) due to OVC protrusions, total angle 80°.	Check clearances, plan for rotation sense.
	Full target system not ready before beam delivery: issues not detected until beam was in Hall, limited operator training.	Target should polarize material (do TE's) 1-2 weeks before beam delivery.
	Magnet had only been ramped with the same polarity for years. Quench protection failed due to bad diode that was only needed for the opposite polarity.	Ramping with both polarities should be tested (parallel field at 0° vs 180°; only one polarity – down-bending - is possible for 90°)

Lessons learned, courtesy O. Rondon

Subsystem	SANE/RSS	Suggestions for g2p/gep
Target (continued)	Multiple subsystem failures: leaks in refrigerator, overheated mechanical pumps, target movement freezes (two damaged inserts), hard disk crash, no He nose level readout	Current planing is on track to avoid repeats. Plan for unexpected, consider redundant systems, e.g. additional nose He level readout would have allowed for much better anneals, no polarization drops, nose overfills, frozen inserts, ...
	Operator training: data lost to operators not tracking microwave frequency	Seriously consider automating microwave frequency control
DAQ/Analysis	No redundant scalers for helicity-dependent signals	Record scalers for both helicities for all helicity dependent signals (triggers, beam charge, ..)
	Half-wave plate setting changes requested by other Halls added unnecessary variable to analysis.	Use other methods other than HWP to control false asymmetries (not needed for our polarized target).
Detectors	BETA was novel, untested detector. Takes a long time and lots of effort to understand.	Reconstruction with septa-HRS and target field should be simulated extensively as early as possible. Single arm elastic peak is key.
Installation	Scheduling multiple projects in parallel in Hall resulted in conflicts, lead to delays.	Single top priority project should have veto power over parallel ones.
	Installation of untested/not well understood/understaffed equipment lead to unexpected issues (target, SEM,)	Test all equipment to be fully operational and have experts totally familiar with operation/readout before installing in Hall.

runplan / Schedule

Major Milestones

May 14, 2011 : Start of 6 month down. Installation begins in 100 days.

Nov 19, 2011 : Beam to hall. Commissioning begins in 289 days.

Dec 03, 2011 : Production data @ 6 degrees.

Jan 23-Mar 16, 2012 : Septa removed.

Mar 17, 2012 : Start Production data @ 12.5 degrees.

April 26, 2012 : Completion of production data.

May 14, 2012 : Start of 12 month upgrade.

Target Milestones

Magnet arrival. Soon?

Magnet cooldown in EEL :

Quench test.

Demonstrate Ramping in both polarities.

Full cooldown.

All subsystems operational: uwaves,NMR, fridge+pumps.

Demonstrate material Polarization.

T.E.'s

Target Fully Operational in Hall A

T.E. in Hall A atleast 2 weeks before experiment starts.

much sooner would be better ☺

g2p and Gep

E0 (GeV)	Angle (deg)	Time (phys+overhead)
2.2 (commisioning)	6	14
2.2	6	12
1.1	6	8
1.6	6	8
3.3	6	10
2.2 (no commissioning)	12.5	19
3.3	12.5	20 days

Overhead

Table 3: Overhead

Overhead	Number	Time Per (hr)	(hr)
Target anneal	35	2.5	87.5
Target rotation	11	8.0	88.0
Target swap	3	8.0	24.0
Target T.E.	6	4.0	24.0
Pass change	6	4.0	24.0
Packing Fraction	37	0.50	18.5
Linac change	2	8.0	16.0
Momentum change	74	0.25	18.5
Moller measurement	6	2.0	12.0
Septum angle change	0	8.0	0.0
Elastic calibration	5	8.0	40.0
Arc Energy Meas.	6	2.0	12.0
BCM calibration	2	3.0	6.0
Beamline survey	6	8.0	48.0
			360.5

More Overhead

Calibrations

BPM

Tungsten Calorimeter : 3 shifts (beginning, mid, end)

Compton

tune difficult, and incompatible with Moller tune

1 shift: perform once at end of 6deg running

FOM best for 3.3 GeV

Moller

Once per energy.

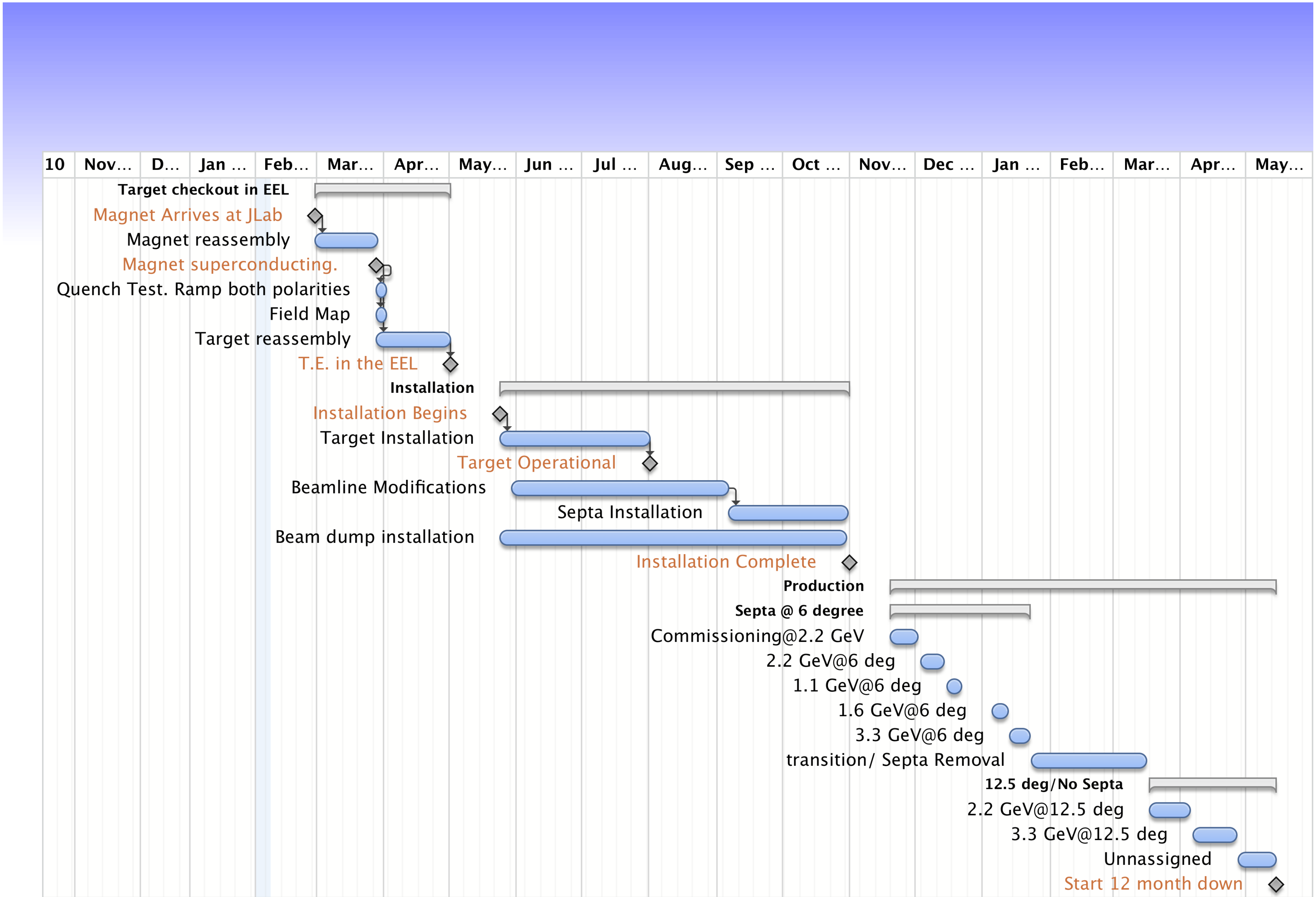
Optics

Once per energy

Dummy Runs

(carbon,empty, helium, nitrogen?)

Very frequently.



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Target checkout in EEL
Magnet Arrives at JLab
Magnet reassembly
Magnet superconducting.
Quench Test. Ramp both polarities
Field Map
Target reassembly
T.E. in the EEL
Installation
Installation Begins
Target Installation
Target Operational
Beamline Modifications
Septa Installation
Beam dump installation
Installation Complete
Production
Septa @ 6 degree
Commissioning@2.2 GeV
2.2 GeV@6 deg
1.1 GeV@6 deg
1.6 GeV@6 deg
3.3 GeV@6 deg
transition/ Septa Removal
12.5 deg/No Septa
2.2 GeV@12.5 deg
3.3 GeV@12.5 deg
Unassigned
Start 12 month down

Task	Start
1) **Target checkout in EEL**	**2/28/11**
1.1) Magnet Arrives at JLab	2/28/11
1.2) Magnet reassembly	2/28/11
1.3) Magnet superconducting.	3/28/11
1.4) Quench Test. Ramp both polarities	3/28/11
1.5) Field Map	3/28/11
1.6) Target reassembly	3/28/11
1.7) T.E. in the EEL	5/1/11
2) **Installation**	**5/24/11**
2.1) Installation Begins	5/24/11
2.2) Target Installation	5/25/11
2.3) Target Operational	8/1/11
2.4) Beamline Modifications	5/29/11
2.5) Septa Installation	9/6/11
2.6) Beam dump installation	5/24/11
2.7) Installation Complete	10/31/11
3) **Production**	**11/19/11**
3.1) **Septa @ 6 degree**	**11/19/11**
3.1.1) Commissioning@2.2 GeV	11/19/11
3.1.2) 2.2 GeV@6 deg	12/3/11
3.1.3) 1.1 GeV@6 deg	12/15/11
3.1.4) 1.6 GeV@6 deg	1/5/12
3.1.5) 3.3 GeV@6 deg	1/13/12
3.2) transition/ Septa Removal	1/23/12
3.3) **12.5 deg/No Septa**	**3/17/12**
3.3.1) 2.2 GeV@12.5 deg	3/17/12
3.3.2) 3.3 GeV@12.5 deg	4/6/12
3.3.3) Unassigned	4/27/12
4) Start 12 month down	5/14/12

tasks/manpower discussion

Physics Manpower

Post-Docs
Jixie Zhang (JLab)
Kalyan Allada (JLab)
Post-doc (UNH) onsite by 5/11

Part-time
Vince Sulkosky (MIT)
Narbe K. (UVa)
Hovannes B. (UVa)

Graduate Students
Melissa Cummings (W&M)
Chao Gu (Uva)
Min Huang (Duke)
Pengjia Zhu (USTC)
Ryan Zielinski (UNH)

Expected
Student (Temple University)
Student (Jerusalem)
Tobias Badman (UNH)

JLAB Staff

Jian-Ping Chen
Alexandre Camsonne
Doug Higinbothan

Faculty

Guy Ron

Karl Slifer onsite fulltime 5/11-1/12
onsite partime 1/12-end

Tasks in progress

Geant4 Simulations : Jixie

3rd Arm Detector : Kalyan, Min

Beamline oversight : Alex?

BPM: Pengjia

Compton : Alex

Target: J.P., Pengjia, Karl

Radiative Tails: Karl, Jixie

Optix: Jixie, Min

Runplan: Karl, Guy, Doug

SNAKE/MUDIFI: Min

Target Stick : Chao Gu

GEM Trackers: Nilanga

Energy loss in Irradiations : Penjxia

Additional manpower

Melissa Cummings (W&M)
Student (Temple University)
Ryan Zielinski (UNH)
Tobias Badman (UNH)*
Post-doc (UNH)
Chao Gu (Uva)

Unassigned Target Tasks

Need atleast 2 dedicated students and one post-doc. As many more trained as possible.

Target Field Alignment:

Target Field Map:

NH_3 Material budget:

Heat load (400W) from beam dump. Target fridge ok with this?

NMR coil placement: in material vs. saddle coil
- effect on radiative tails
- effect on NMR precision

Realistic estimate of necessary carbon/empty/helium runs.

Ceramic cups:

Microwave feedback:

Target operator training:

Unassigned analysis tasks (pre-run)

Specific

Saftey Docs : modify SANE docs for g2p.

Analysis coordinator: scripts, replay, workspace…

Optix : Kalyan?

Detector Calibrations and efficiencies
- calorimeter
- cerenkov
- hodoscopes

Online PbPt:

Target polarimetry :

do we need nitrogen dummy target.

Ensure UNAMBIGUOS HWP status

Unassigned analysis tasks (long term)

Radiative Corrections

PbPt:

Target polarimetry :

Analysis (PhD) Topics

Target polarimetry:

Spin Asymmetries:

g2p, A2, structure functions:

Polarizabilities :

δ_{LT}

γ_0

Sum rules:

Burkhardt-Cottingham

GDH

Finite size effects:

Hyperfine Splitting

Charge radius

Much more physics.
Let's start thinking about it.

Date of next Collaboration Meeting

March 14-18? Spring break, but only 6 weeks from now

March 21-25? 7 weeks

March 28-31 8 weeks.

Possible Conflicts

CLAS PARIS : March 7-11
Spring break : March 14-18
DIS11: April 11-15
April 4 rb
April 30-May 3 : GHP Annaheim
May 14 : 6mo down starts
May 17-20 : NSTAR @ jlab
Jun1-3 : Hall A Meeting

147-162 K in confirmed user contributions

(as of June 24)

Argonne : 10K parts or machining.
+ 2 tech staff that can help with design work.

Rutgers : 25-30K machining in Rutgers shop (CNC available).

Tel Aviv : 10-20K machining of beamline components.

Temple : 10K in beamline parts or machining.

UVa : 60K in target magnet repairs at Oxford.
5K to repair target refrigerator.

UVa(2) : 10K in machining and parts (+tungsten beam dump).

UNH : 10K in parts or machining.
2K in target stick repair.

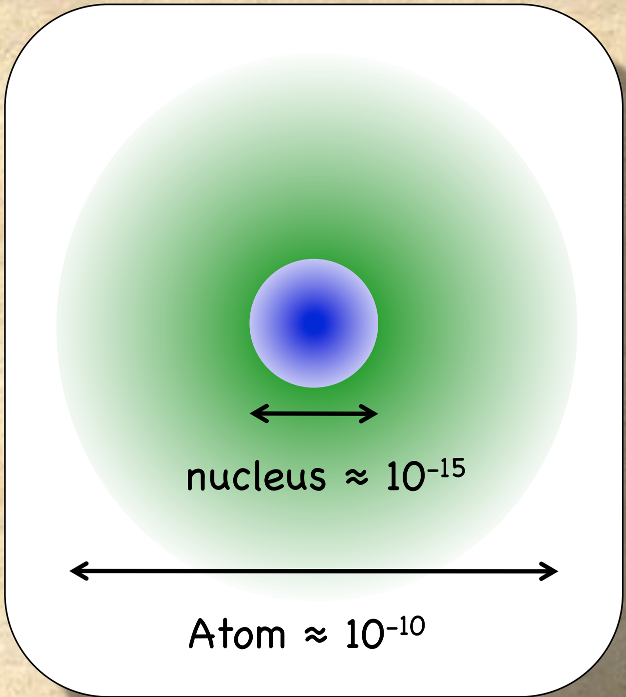
William&Mary : 5K in parts or machining + manpower.

Additional anticipated contributions

UNH : 20K supplemental request for parts/machining.

Spokesman Guy Ron will move from post-doc to faculty position with associated startup funding within the next few months.

Applications to Atomic Physics



The finite size of the nucleus plays a small but significant role in atomic energy levels.

Hydrogen HF Splitting

$$\begin{aligned} \Delta E &= 1420.405\ 751\ 766\ 7(9) \quad \text{MHz} \\ &= (1+\delta)E_F \end{aligned}$$

$$\delta = (\delta_{QED} + \delta_R + \delta_{small}) + \Delta_S$$

≈1ppm ≈5ppm <1ppm ≈40ppm

Friar & Sick PLB **579** 285(2003)

Structure dependence of Hydrogen HF Splitting

$$\Delta_S = \Delta_Z + \Delta_{POL}$$

Elastic Scattering

Inelastic

Nazaryan,Carlson,Griffieon
PRL **96** 163001 (2006)

Δ_Z=-41.0±0.5ppm

$\Delta_{pol}\approx$ 1.3±0.3 ppm

Elastic piece larger but with similar uncertainty

$$\Delta_Z = -2\alpha m_e r_Z (1 + \delta_Z^{\text{rad}})$$

$$r_Z = -\frac{4}{\pi}\int_0^\infty \frac{dQ}{Q^2}\left[G_E(Q^2)\frac{G_M(Q^2)}{1+\kappa_p} - 1\right]$$

$$\Delta_{POL} = 0.2265\ (\Delta_1 + \Delta_2)\text{ppm}$$

Δ_1 well determined from F_2,g_1 data

Δ_2 Not well determined at all, assumed small.

If assume Maid Model instead of Eg1 model, the uncertainty on g_2 would be 2X uncertainty from g_1