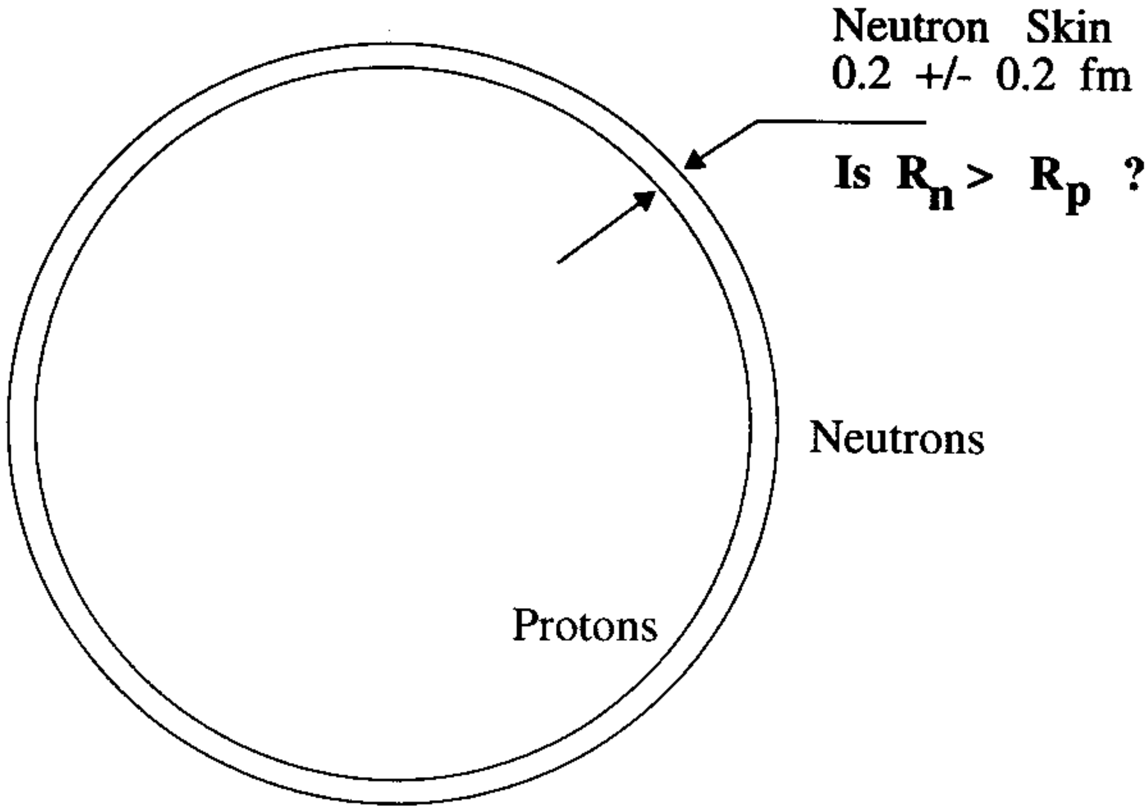
PR 00-003

A Clean Measurement of the Neutron Skin of ^{208}Pb Through Parity Violating Electron Scattering

PR - 99012 A Hall A Collaboration Proposal

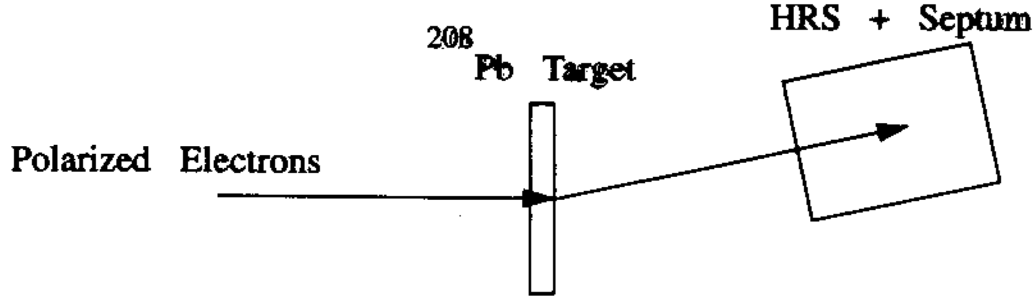


Electromagnetic Scattering -- Sees Mainly Protons

Z - Boson Probe (Parity Violation) -- Sees Mainly Neutrons

Measurements are Clean

LEAD PARITY



Elastic Scattering, 850 MeV, 6 degrees

Measure the Parity Violating Asymmetry

$$A = \frac{\sigma_R - \sigma_L}{\sigma_R + \sigma_L}$$

Parity is Violated due to Weak Interaction (Z Bosons)

PURPOSES OF EXPERIMENT

1. Establish Existence of "Neutron Skin"

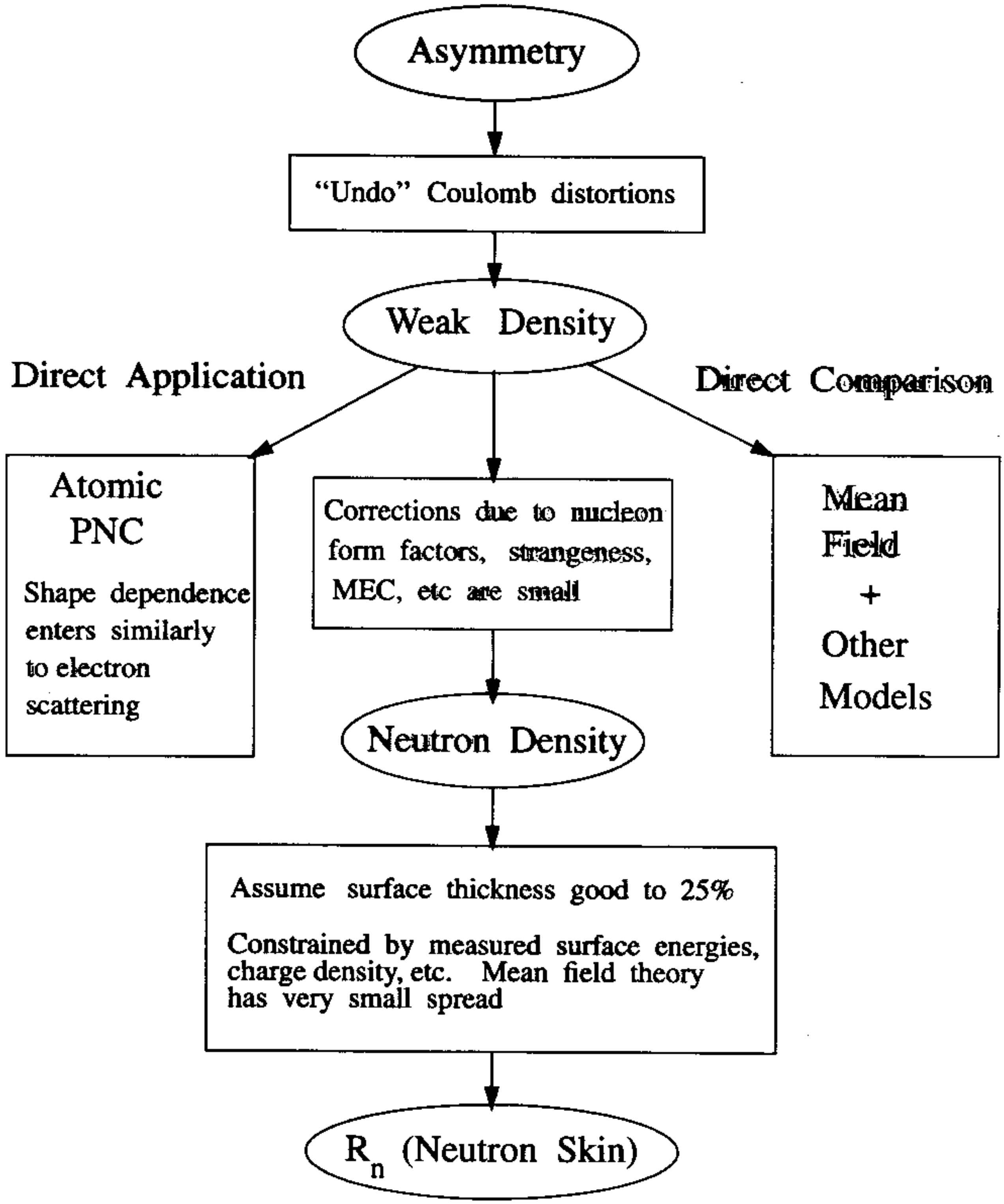
   Fundamental Feature of Heavy Nuclei

2. Compare Directly to Theory

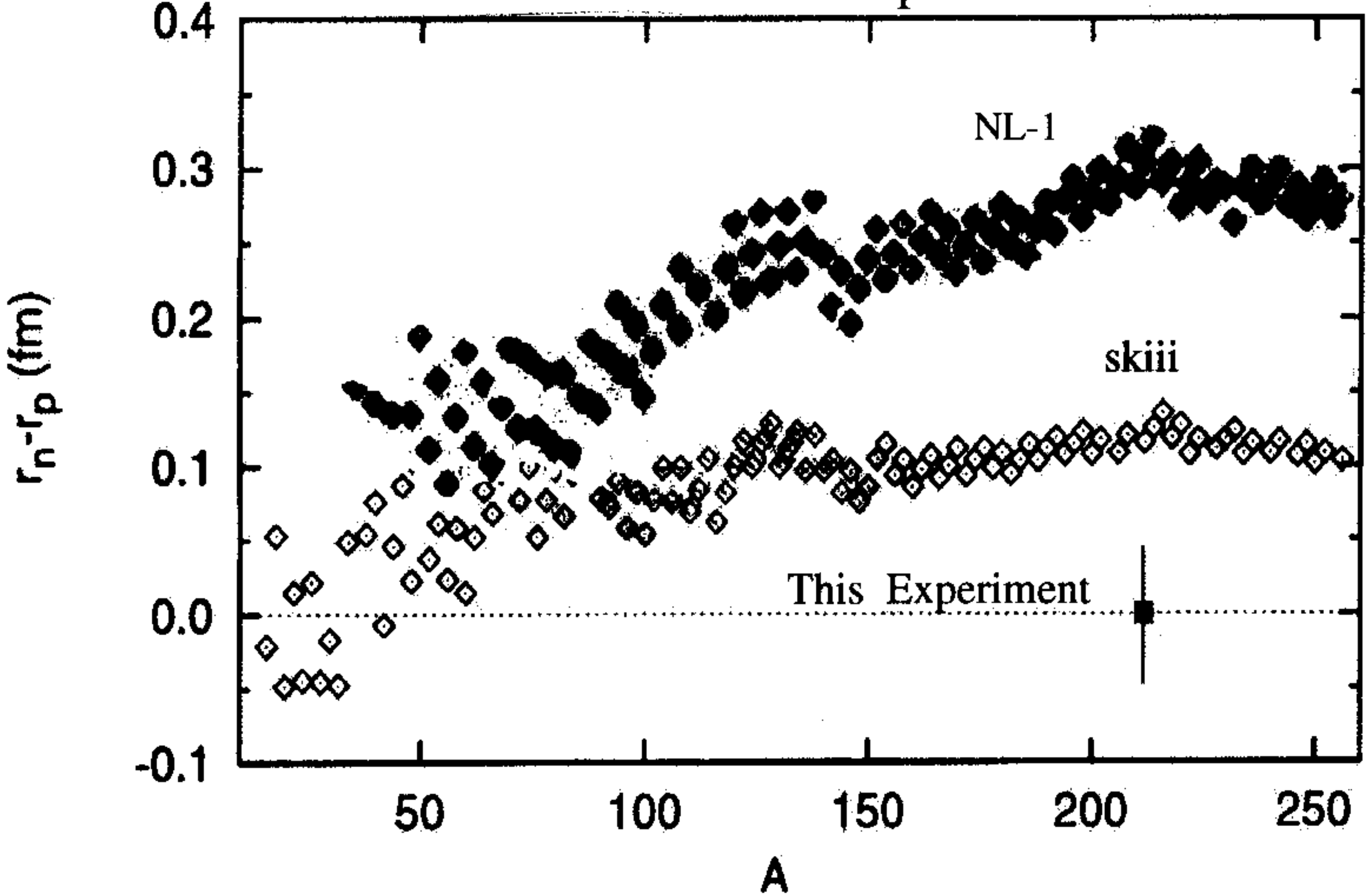
3. Direct Application to Atomic PNC Experiments

   Possibly the most precise low energy test of Standard Model in the future.

APPLICATIONS OF LEAD PARITY



Is $r_n > r_p$?



Difference between neutron radius and proton radius for two mean field calculations vs atomic number. Also shown is the projected error bar of this experiment

Calculations are from P. Ring, et. al. NPA 624 (1997) 349.

Impact on Atomic Parity Violation Experiments

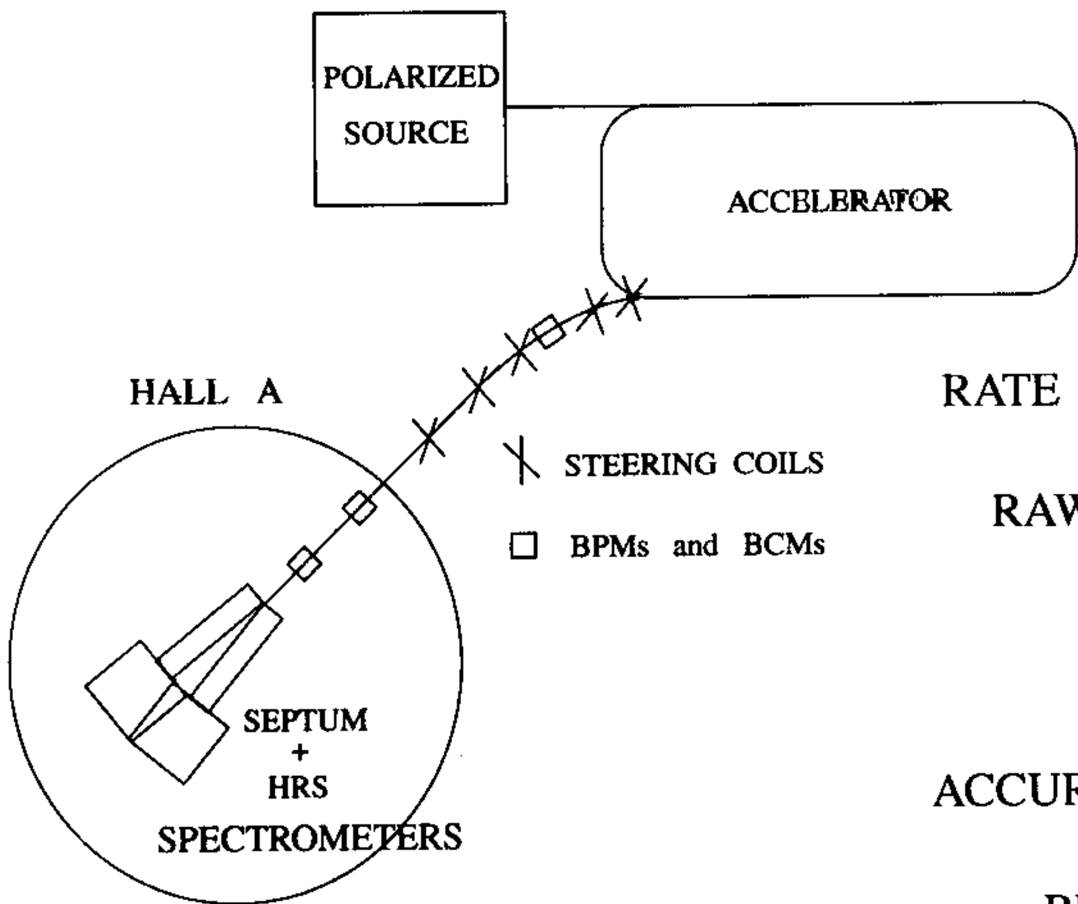
Atomic PNC aims at $\delta\left(\sin^2\theta_W\right) \leq 0.3\%$

Limitations:

- Atomic Theory 1% -- Improving, or Use Isotope Chains
- Experimental Techniques -- Improving to 0.3 %
- R_n/R_p needed to 1% → This experiment

Our one measurement will be a calibration of nuclear theory which will effectively give R_n to the desired accuracy.

OVERVIEW OF ^{208}Pb PARITY EXPERIMENT



E = 850 MeV

ANGLE = 6°

RATE = 860 MHz (each spectrometer)

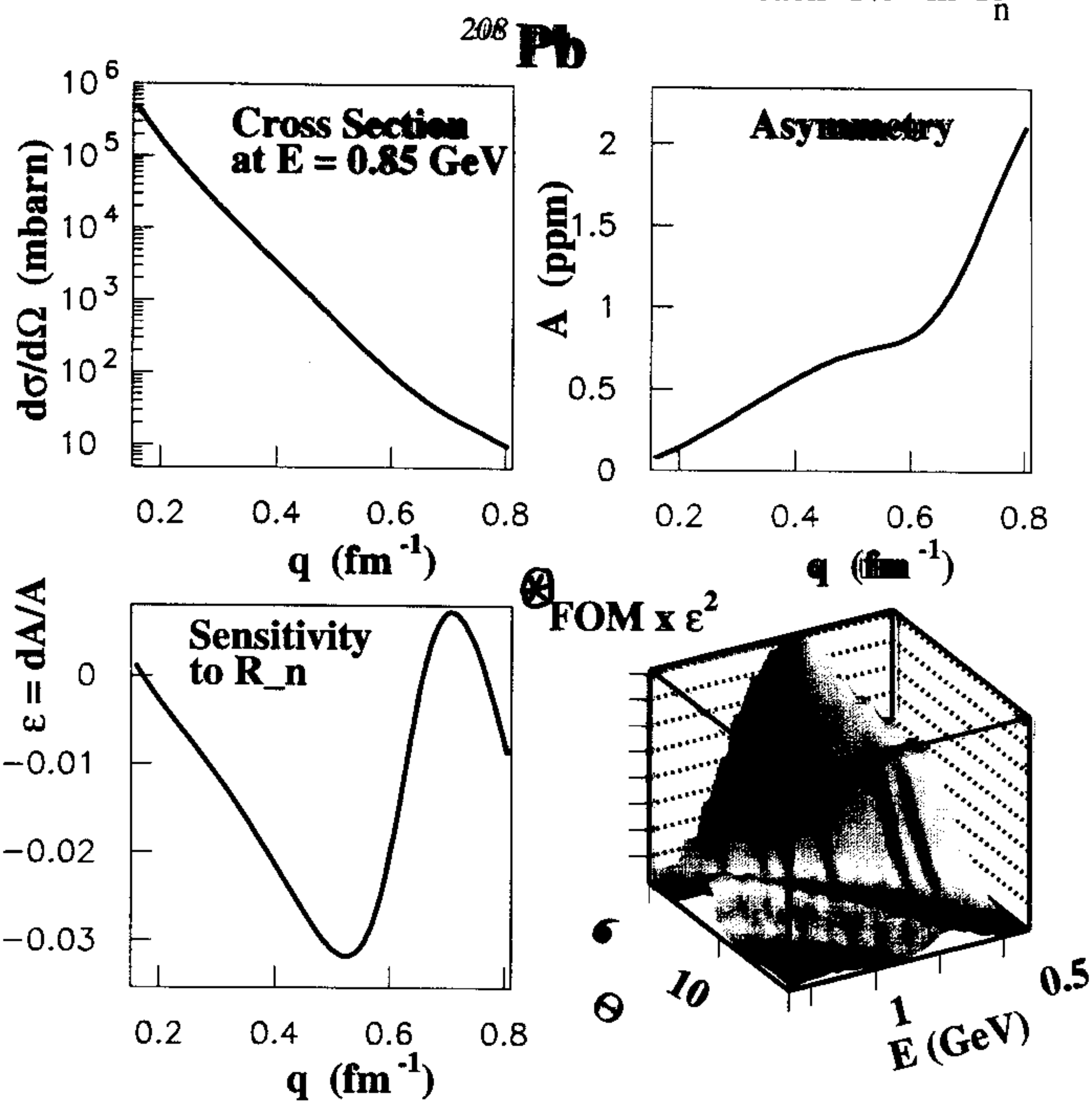
RAW ASYMMETRY = 0.51 ppm
($P_e * A_{physics}$)

ACCURACY in ASY 3%

ACCURACY IN NEUTRON RADIUS 1%

RUNNING TIME 30 DAYS

Max FOM --> Min Run Time to Reach 1% in R_n

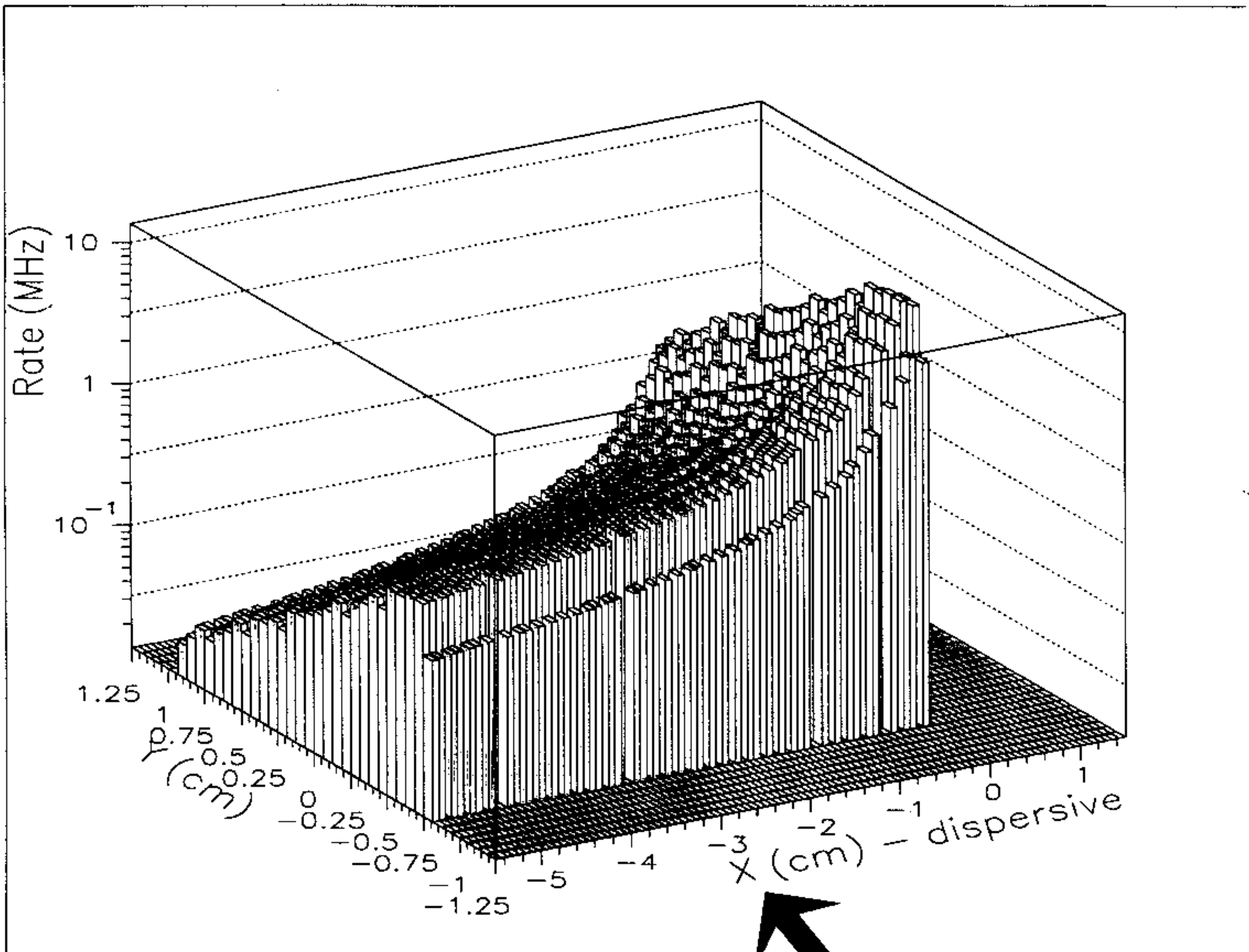


With Septum (6°) --> Best is 850 MeV
A JLab Energy

⊛ FOM ≡ Rate × A^2 ... we maximize FOM * ϵ^2
↳ $\propto \frac{d\sigma}{d\Omega}$

SCATTERING RATE IN SPECTROMETER

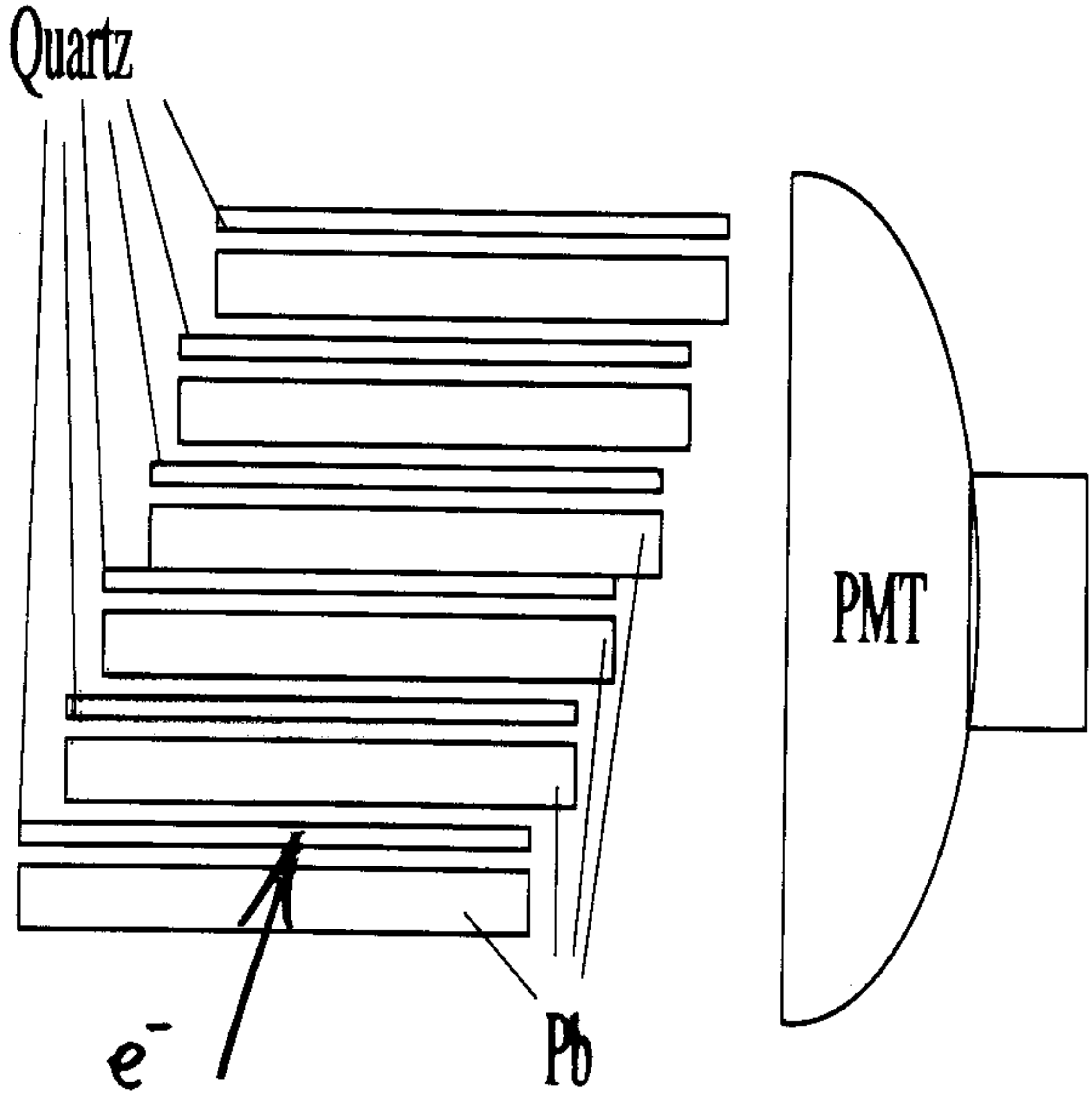
Distribution in Focal Plane



3 cm = 2 MeV

(1st State of Pb at 2.6 MeV)

Detector



Quartz/Pb Sandwich integrates e⁻

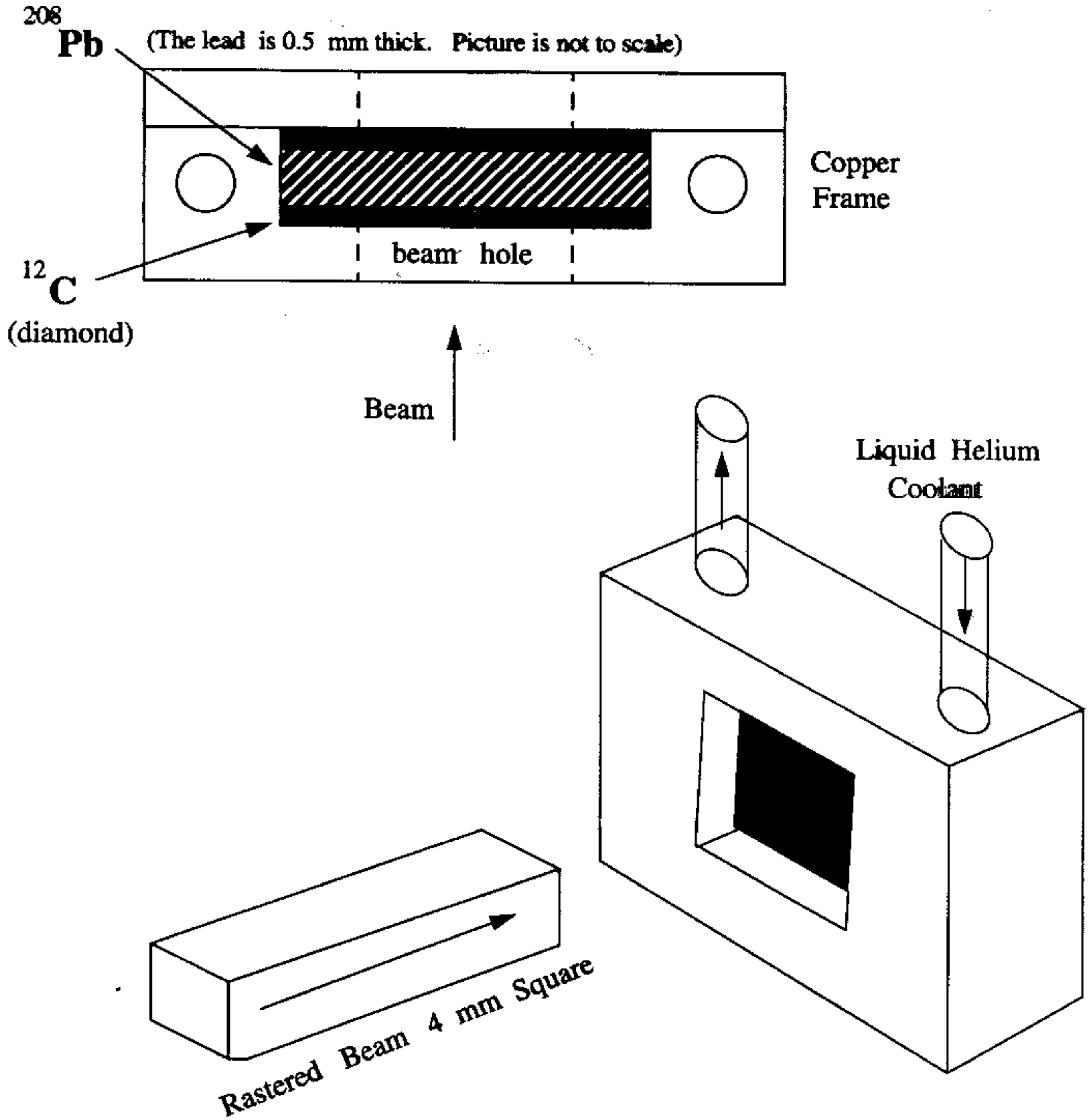
Choice of Target -- Lead

Advantages :

* Easy to Isolate Elastic Scattering --
  -- Largest Gap (2.6 MeV) of any Heavy Nucleus
* Doubly Magic -- Simple Structure
* Well-known Nucleus
* Large A, Good "Lever Arm" on Theory
* High Rate

High Power (40 Watt) ^{208}Pb Target

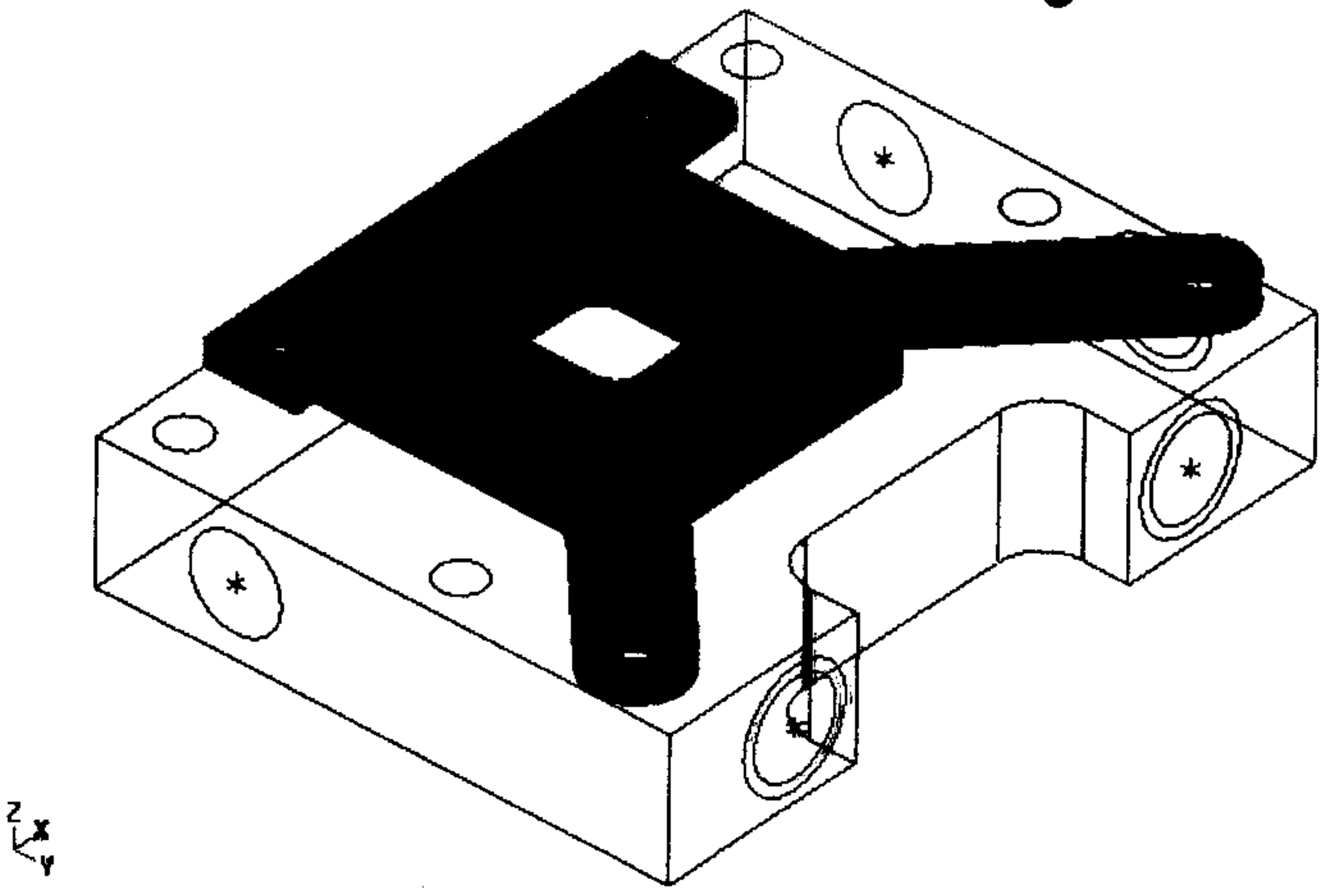
for JLab Parity Experiment



DIAMOND BACKING

- → Very High Thermal Conductivity
- → Negligible Systematic (^{12}C)

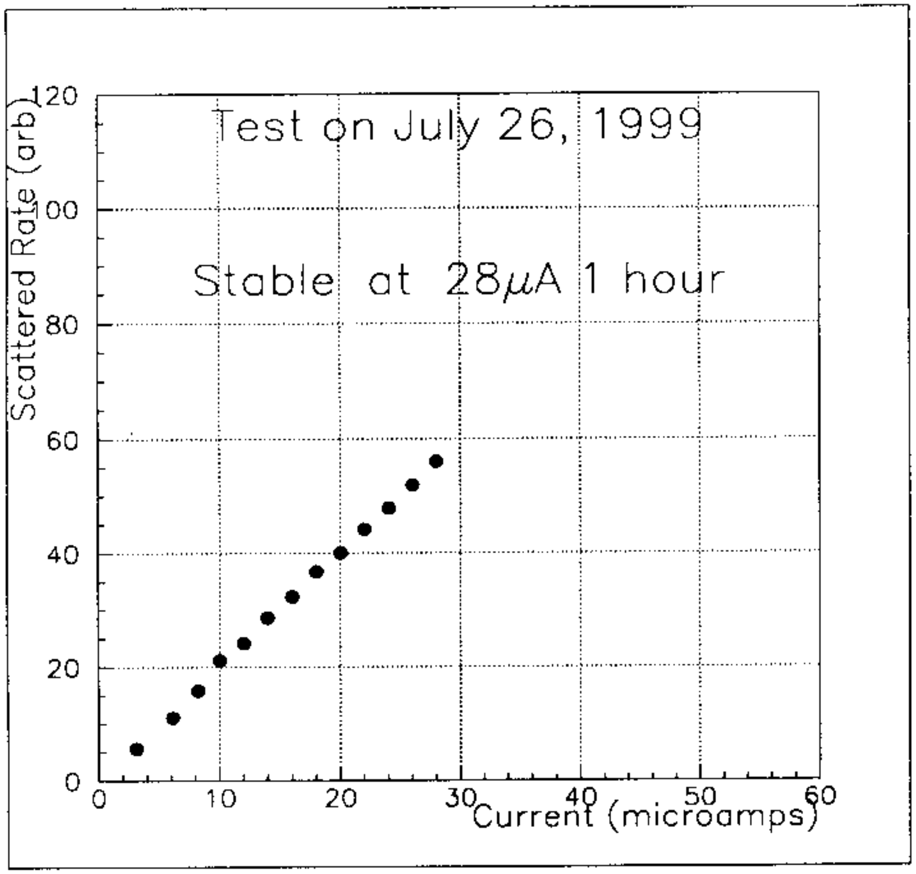
Lead Target Assembly

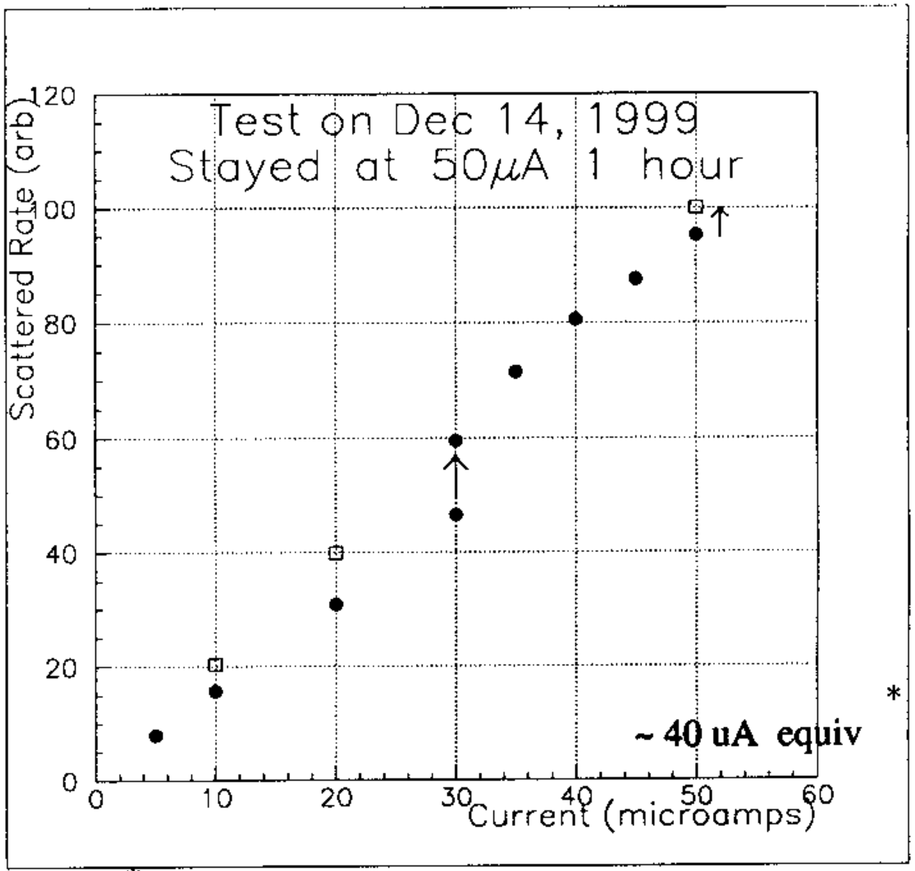


* Built by Cal State LA
* Fits on existing target ladder
* Probably installed ~~Jan~~ Aug. 2000 with Pb & Diamond.

Tests of Prototype Lead Target in Beam

0.5 mm LEAD sandwiched by 0.05 mm of Aluminum Foil





* Beam was, unfortunately, ~20 % occluded

* Target did not melt

* The Helium--cooled Lead / Diamond Target will be better.

SYSTEMATICS

Statistical Goal 15 ppb or 3%

→ 1. Want Systematics ~ 1 ppb
Helicity Correlated Beam Parameters, etc

2. Because of High Rates ,
need all noises << 140 ppm in 30 msec

3. Normalization to << 3%

* Q^2

→ * Polarization to 1% (at least 2%)

4. Backgrounds

5. Pedestals and Nonlinearities

→ 6. Theoretical Corrections

→ Will Discuss

Systematics -- Helicity Correlated Beam Parameters

Beam Parameter Corrections

HAPPEX 30 +/- 30 ppb

Different Target -- Different Sensitivity

Need a factor of ~10 better

Two Aspects :

1. Helicity Correlated Differences

   Too Large

   ⟶ New Controls at Polarized Source

   ⟶ New quadrupoles (Jan 2000) allow better tunes

2. Accuracy of Beam Position Measurements

   Intrinsic BPM accuracy ~1 micron ⟶ 1 ppb

   Need engineering runs to study:

   - BPM accuracy
   - Target sensitivity

   May need cavity monitors

POLARIMETRY

How polarization affects our result

Polarization Error	Total Expt Error
1 %	3.2 %
2 %	3.6 %

Systematics of Polarimeters

In Hall A		Presently Stated	Future Expectation
	Moller	3.2 %	2 %
	Compton	4.3 %	2 % (at 3.3 GeV)
Elsewhere (cross - checks)			
	Hall C Moller	~ 0.5 %	< 1 %
	Mott	~ 6 %	?

THEORETICAL CORRECTIONS

Addressed in a paper (to be submitted soon)

"Parity Violating Measurements of Neutron Densities"
C. J. Horowitz, S. J. Pollock, P. A. Souder, R. W. Michaels

1. Coulomb Distortions ~20% -- biggest correction
   Four Independent Codes
2. Strangeness < 0.5% Effect
   New data may reduce this
3. Parity Admixtures
4. MEC
5. Dispersion Corrections $\sim \frac{\alpha}{Z}$ negligible
6. Shape Dependence
7. Applicability to Atomic PNC
8. Inelastic Contributions
9. Isospin Violations (in nucleon)
10. Target Impurities (Diamond, Isotopes)

ERROR BUDGET

Source of Error	$\frac{\Delta A}{A}$ %	
Polarization	1.0	(2.0)
Q^2 Determination	0.3	
Finite Acceptance	0.3	
Beam Systematics	0.2	
Backgrounds	0.2	
Total Systematic Error	1.1	(2.1)
Statistics	3.0	
Total Experimental Error	3.2	(3.6)

BEAM TIME REQUEST

690 Hours (50 microamps, 80% pol)

1 hour Moller for each day "beam -on -target"

10 hours Setup and Checkout

Total: 30 Days