Polarimeter Systematic Errors

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dEDM Collaboration
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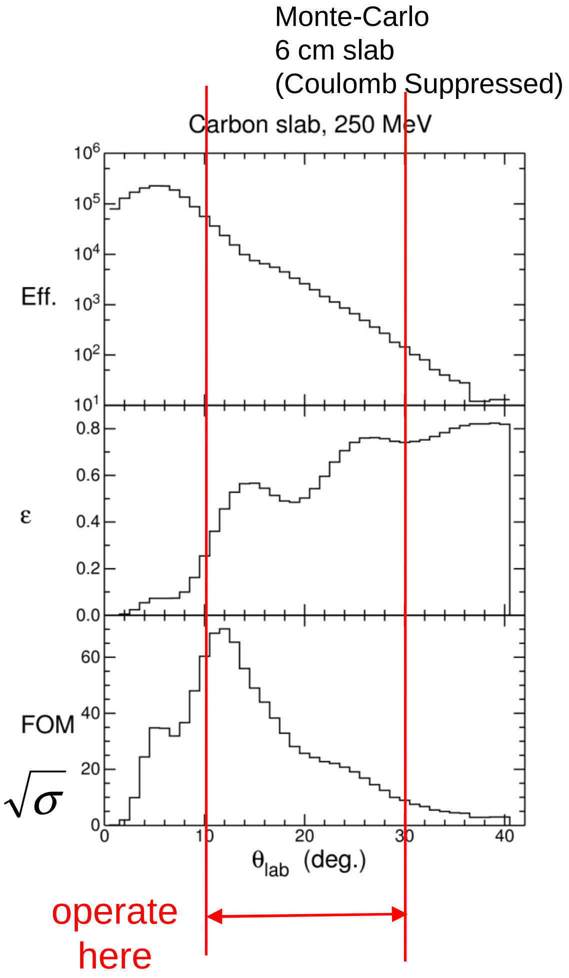
Signal: Appearance of p_y from component of polarization along velocity.
In 100 s, ω_{EDM} = 1.7 μrad for d = 10^{-29} e·cm.

Method: Scatter deuteron from carbon.
Monitor at forward angles where L·S effects are large.
OK to include low Q-value reactions; exclude breakup.

Polarimeter should be high efficiency:
Watch EDM signal grow from early to late in store.
Track (and use for feedback) g−2 precession in ring.
Use tensor polarization for verification.

During this talk: Issues

Tools

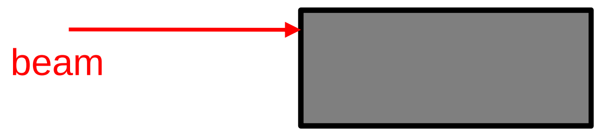


$$FOM = A_y\sqrt{\sigma}$$

Target

Gas or pellets lead to too much loss compared to scattered flux.

Bring particles from beam in just under edge of thick target (as opposed to slow extraction onto a slab).



Goal is to get near 1% of deuterons scattered into detectors in a range of angles useful to measure p_y.

Quality of surface.
How far particles hit below surface.
Asymmetry of scattering up and out rather than down and in (with energy loss in material)

Detectors

Scintillator arrays in original concept. All flux that passes an absorber (Fe) could be counted.

Also considering Multi-Resistive Plate Chambers (used on ALICE) from Frascati-Rome group (would add TOF to each event).

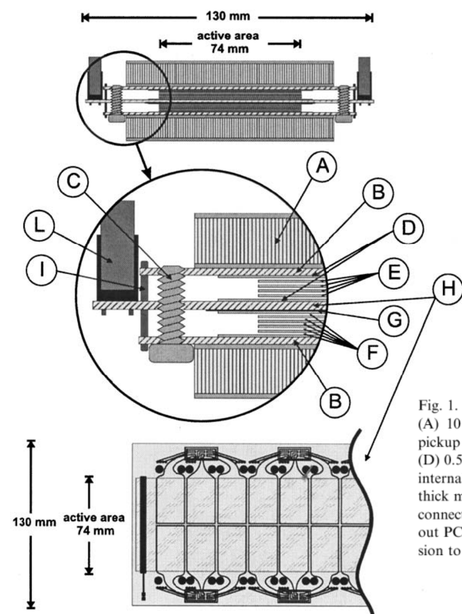


Fig. 1. Schematic cross-section of a double-stack MRPC strip. (A) 10 mm thick honeycomb panel; (B) PCB with cathode pickup pads; (C) M5 nylon screw to hold the fishing-line spacer; (D) 0.55 mm thick external glass plates; (E) four 0.4 mm thick internal glass plates; (F) five gas gaps of 250 μm; (G) 250 μm thick mylar film; (H) central PCB with anode pickup pads; (I) connector (pin) to bring the cathode signal to the central read-out PCB; (L) flat cable connector (for MRPC-signal transmission to the interface card).

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Available asymmetries:

$$\varepsilon_{EDM} = \frac{L-R}{L+R} \qquad \varepsilon_{g-2} = \frac{D-U}{D+U} \qquad \varepsilon_{tensor} = \frac{L+R-D-U}{L+R+D+U}$$

To examine errors, expand asymmetry as Taylor series about ideal point.
Use departures from ideal as small parameters.

Examples: x, y, θ, φ, $p^{+}-p^{-}$, width, halo, etc.

Features:

"drivers", small error terms (ρ)

"sensitivities" $\frac{\partial^N(\sigma, A)}{\partial\rho^N}$

analysis method

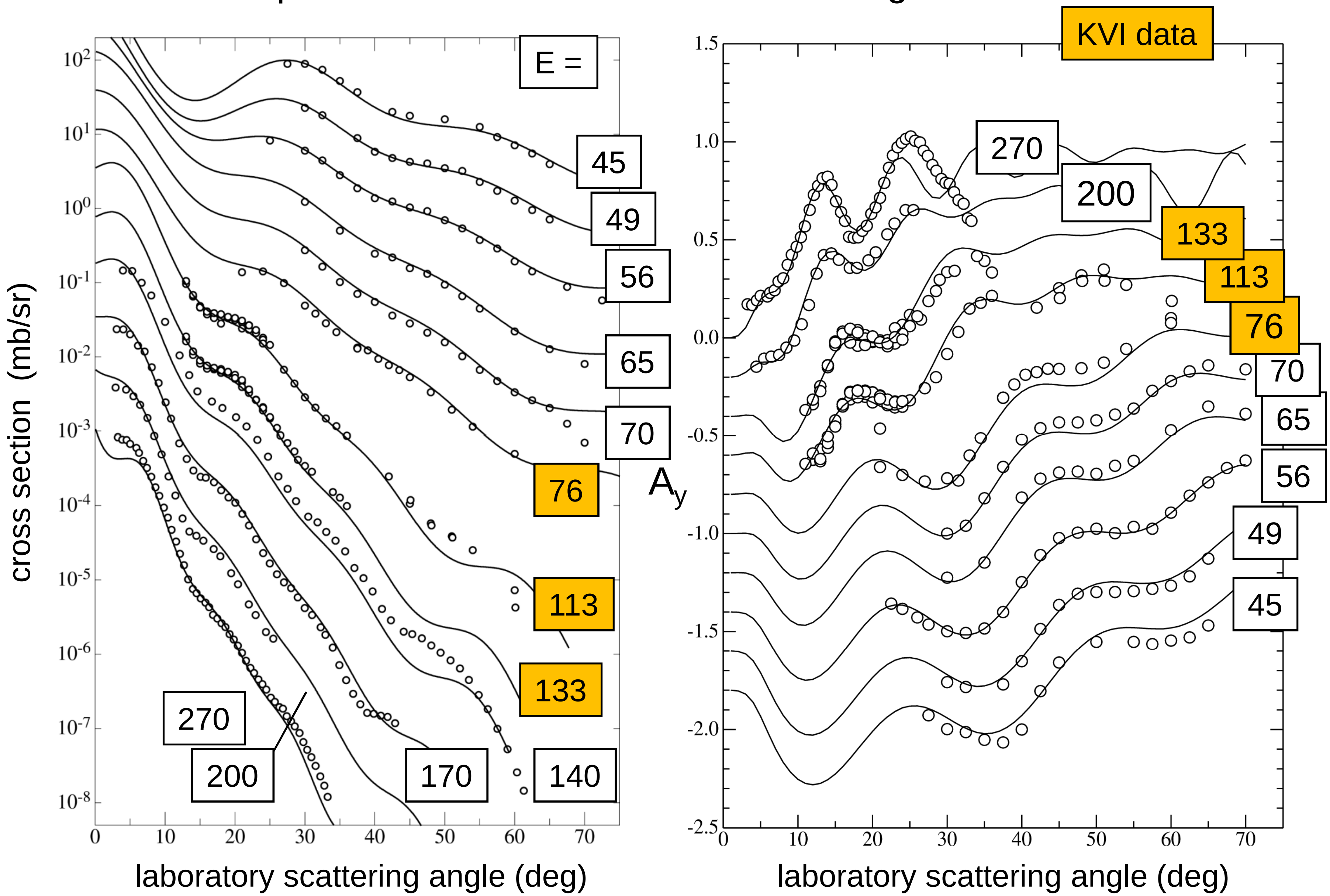
Comes from database on d+C scattering with polarization

Database weak for reactions or breakup. Elastic OK.

Typical choice: Cross Ratio robust against changes in intensity (+/−) or solid angle (L/R)

Ring will contain (+) and (−) polarization bunches. "Flips" also come from CW-CCW rings, and reversal of rings.

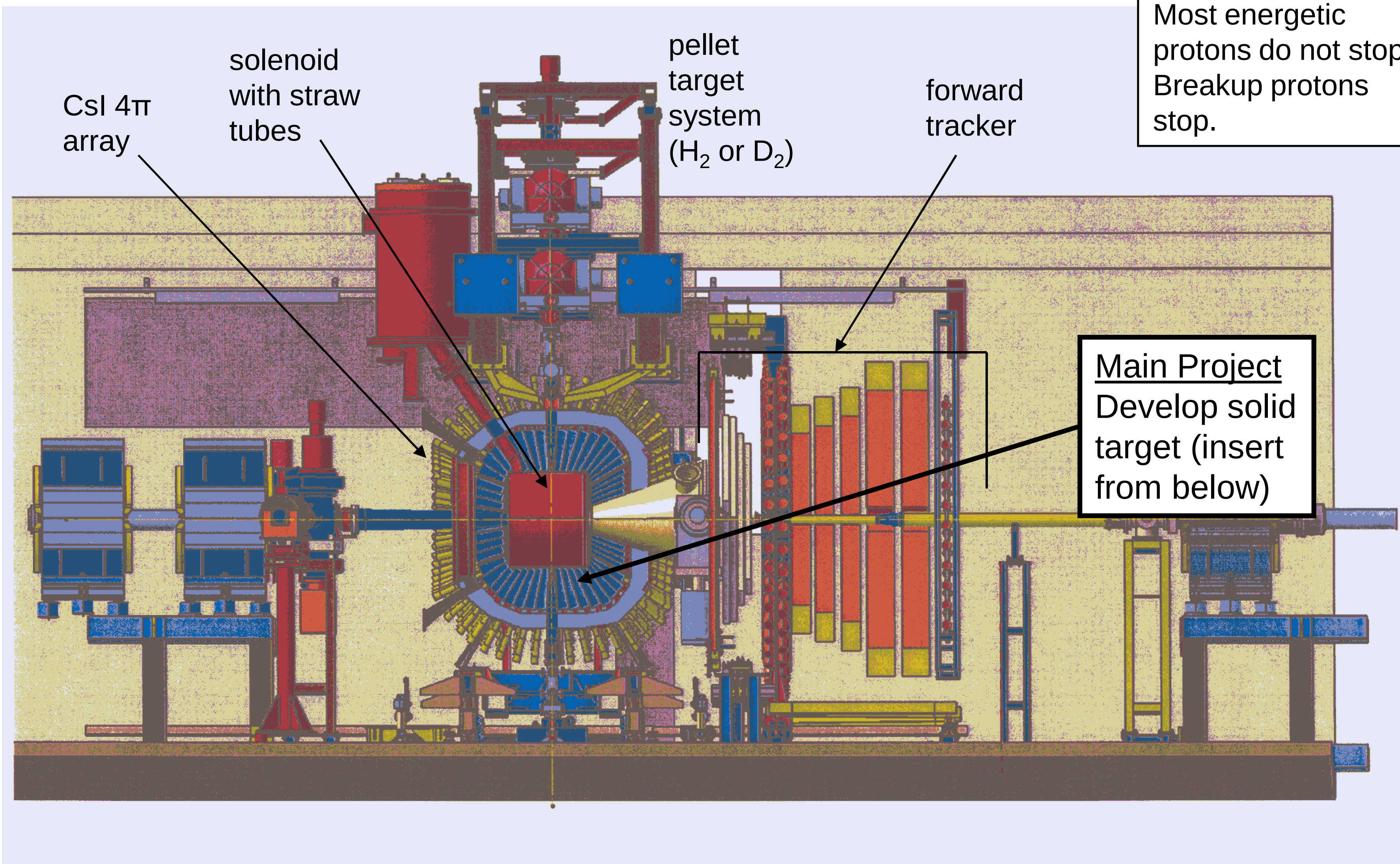
Database and parametrization for elastic scattering



Acquiring an adequate data base

Best prospect: use forward tracking detectors in WASA
Need to develop solid targets.

NOTE: The stack stops deuterons in next to last element. Most energetic protons do not stop. Breakup protons stop.



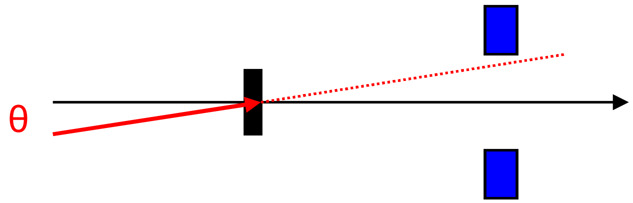
Second-order errors in Cross Ratio

Minimize problem with spin-flip and cross ratio:

$$p_y = \frac{1}{\sqrt{3}\langle iT_{11}\rangle}\frac{r-1}{r+1} \qquad r^2 = \frac{L_+ R_-}{L_- R_+}$$

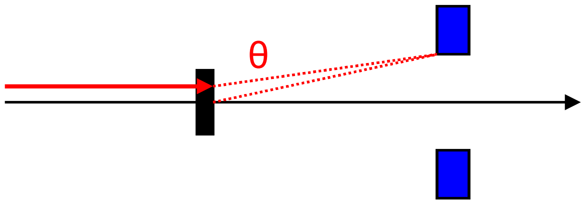
An illustration:

angle error



Systematic effects come at second order and constrain allowed size of θ.

position error



both represented by θ

contribution to EDM asymmetry:

$$\Delta\varepsilon = \varepsilon^3 u^2 + 2\varepsilon^2 \frac{1}{iT_{11}}\frac{\partial iT_{11}}{\partial\theta} u\theta + \varepsilon \frac{1}{iT_{11}}\frac{\partial^2 iT_{11}}{\partial\theta^2}\theta^2$$

asymmetry ~ 0.01 (residual p_y)

$u = p_+ + p_-$

~0.146

~ –0.015

requires θ < 1.3 mrad

Tube target enhances sensitivity;
2 cm diameter limits θ < 0.078 mrad.

Are such estimates credible?

Run was completed at KVI (11/07) to measure effects using in-beam polarimeter.

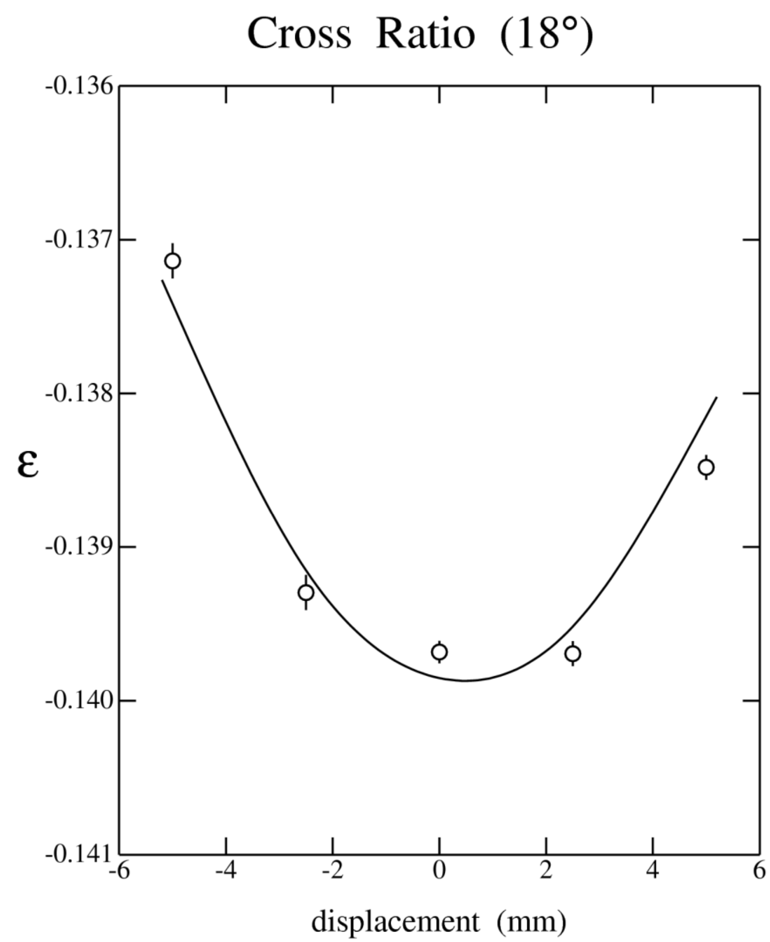
Detector pairs set at 18°, 28°, 38°, 48°.

1-mm carbon strip target moved horizontally to generate “error”.

Vector up and down data analyzed with cross ratio.

Curvature measures θ^2 term;
Slope measures $u\theta$ term.

Coefficients for these terms taken from model of elastic scattering. Average analyzing power matched to data.



Plan is to use a rod target at the edge of the beam and to sweep the beam into it through the store.

Polarization in halo may differ from core of beam.

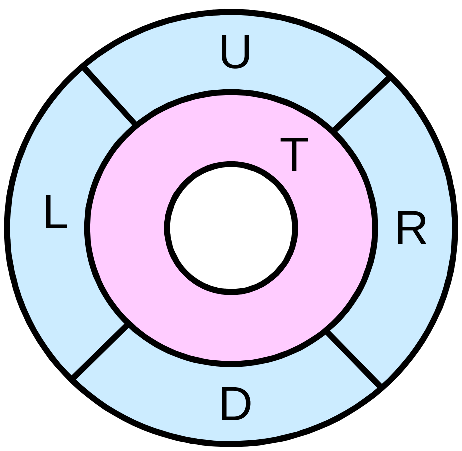
Pattern for store:

Cool beam in AGS
Inject into EDM ring (up and down bunches)
Rotate polarization into plane with RF solenoid
Take data

Because of imperfectly matched **E** and **B** field magnitudes, polarization direction will slowly drift in horizontal plane.

Measurements of radial “g−2” component in intervals of several ms could provide feedback to hold polarization in place.

If polarization direction is allowed to rotate, each of the asymmetries will sweep out a characteristic curve. These data can be fit to a model of the process to extract the EDM signal.



If a separate ring in the detector acceptance is set aside to yield t_{20}, the these observables are available

$$S = L + R + D + U + 4T$$

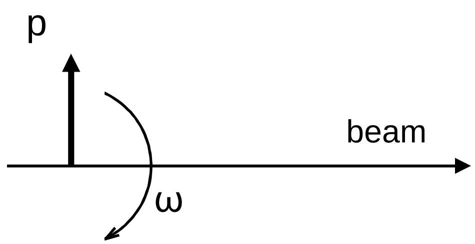
$$\Delta_{LR} = (L - R) / S$$

$$\Delta_{DU} = (D - U) / S$$

$$\Delta_{20} = (L + R + D + U - 4T) / S$$

$$\Delta_{22} = (L + R - D - U) / S$$

Data Generator



Inject P sideways (in ring plane)
Allow to precess at ω for 1 second
EDM precession is added by
integrating longitudinal component (p_z)
Take polarization shapshot at regular
intervals (say every 10 ms)
Compute count rate in each detector
Change count rate randomly based on
statistics for that rate

$$it_{11} = \tau_{10} \tfrac{1}{\sqrt{2}} \sin\beta \cos\phi$$

$$t_{20} = \tau_{20} \tfrac{1}{2} (3\cos^2\beta - 1)$$

$$t_{21} = \tau_{20} \sqrt{\tfrac{3}{2}} \sin\beta \cos\beta \sin\phi$$

$$t_{22} = \tau_{20} \sqrt{\tfrac{3}{8}} \sin^2\beta \cos 2\phi$$

where

$$\tau_{10} = \sqrt{\tfrac{3}{2}} (f_+ - f_-)$$

$$\tau_{20} = \sqrt{\tfrac{1}{2}} (1 - 3 f_0)$$

Count rates:

$$C_L = C_0 \, (1 + 2\, it_{11}\, iT_{11} + t_{20}\, T_{20} + 2\, t_{21}\, T_{21} + 2\, t_{22}\, T_{22})$$

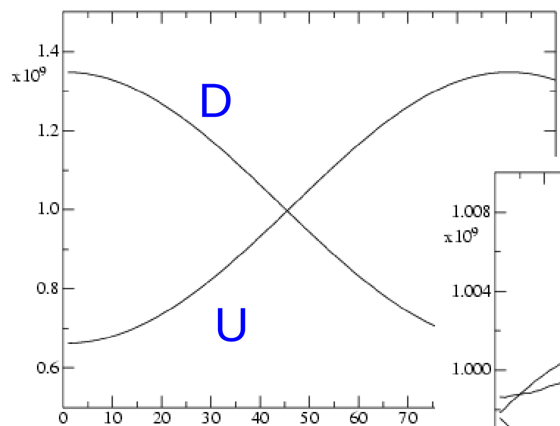
$$C_R =$$

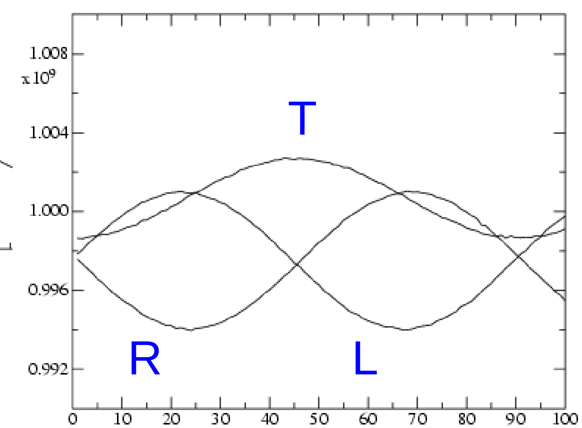
$$C_D =$$

$$C_U =$$

$$C_T =$$

etc. with angles rotated as
needed for each detector





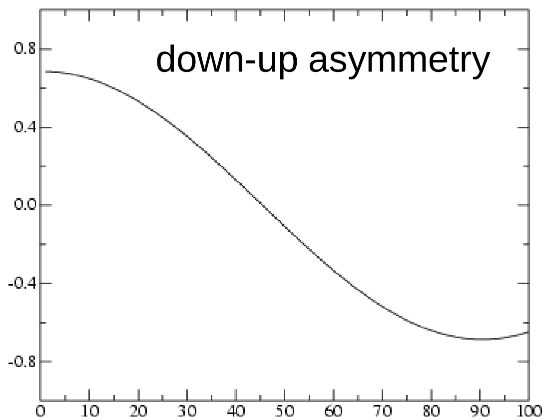
Typical Output

function of time

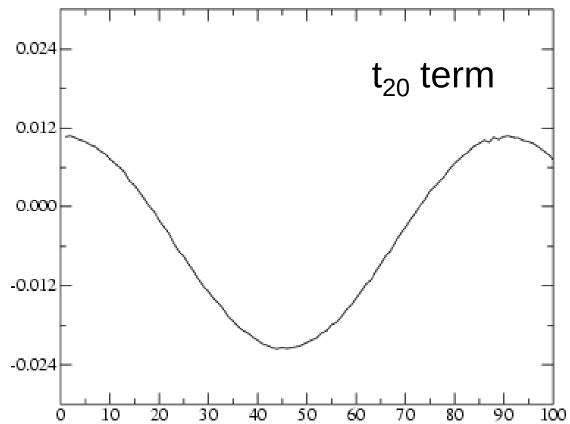
$$\vartheta = \theta_0 + \bar{\theta} t$$

θ_0: spin injection angle

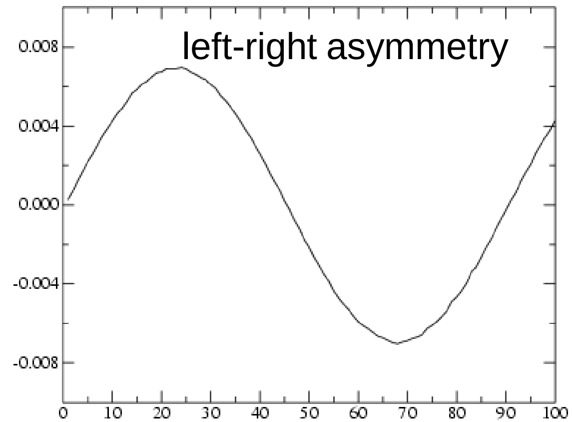
$\bar{\theta}$: spin precession rate



$$\Delta_{DU} = A_1 \cos\vartheta + A_2 + A_3 \sin 2\vartheta$$



$$\Delta_{20} = A_7 (3\sin^2\vartheta - 1)/2$$

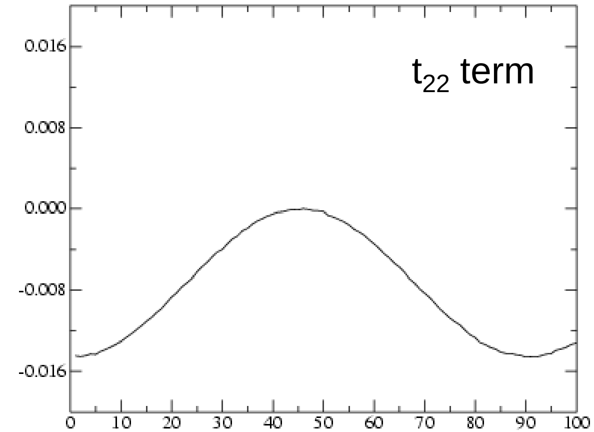


$$\Delta_{LR} = A_4 10^{-4} \cos\vartheta + A_5 10^{-4} + A_6 \sin 2\vartheta$$

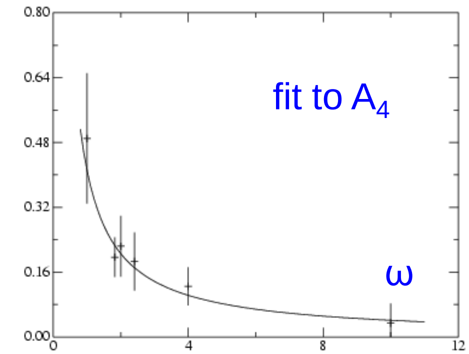
A_4: EDM term

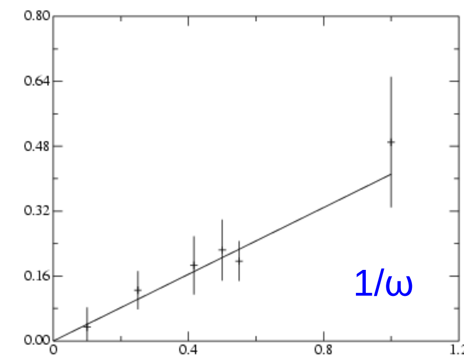
A_6: t_{21} term

A_5: constant term needed because EDM grows from zero



$$\Delta_{22} = A_8 \cos^2\vartheta$$





A_4 at several precession rates

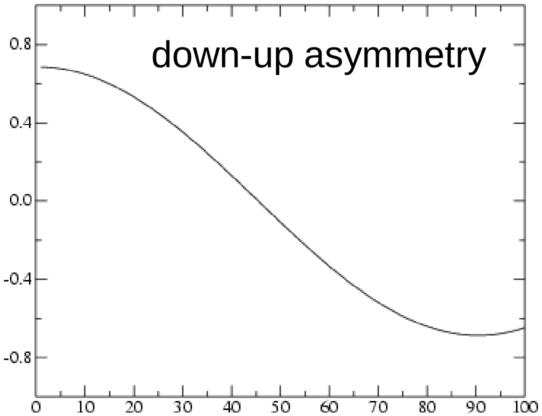
Typical Output

function of time

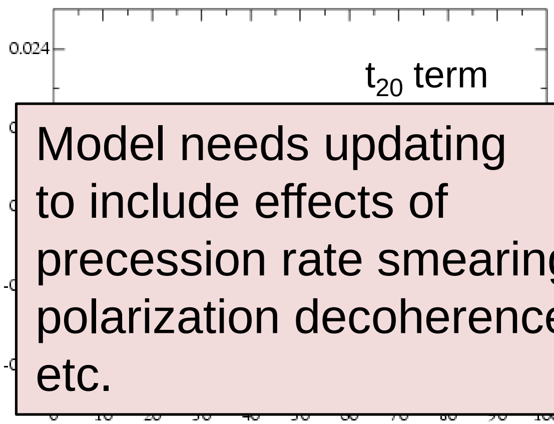
$$\vartheta = \theta_0 + \bar{\theta} t$$

spin injection angle (θ_0)

spin precession rate ($\bar{\theta}$)

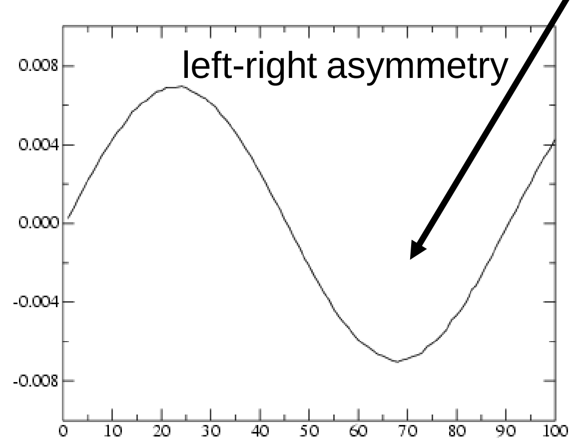


$$\Delta_{DU} = A_1 \cos\vartheta + A_2 + A_3 \sin 2\vartheta$$



Model needs updating to include effects of precession rate smearing, polarization decoherence, etc.

$$\Delta_{20} = A_7 (3\sin^2 \vartheta - 1)/2$$



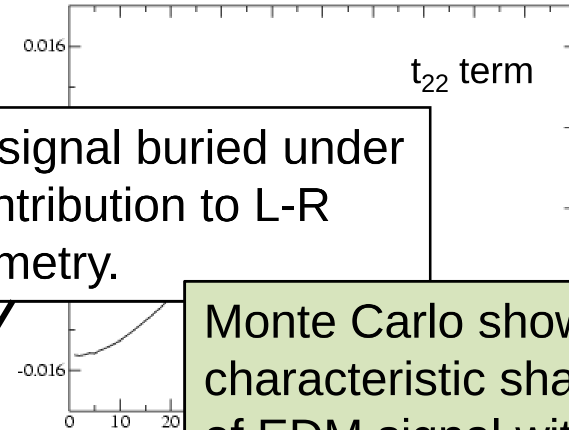
EDM signal buried under t_{21} contribution to L-R asymmetry.

$$\Delta_{LR} = A_4 10^{-4} \cos\vartheta + A_5 10^{-4} + A_6 \sin 2\vartheta$$

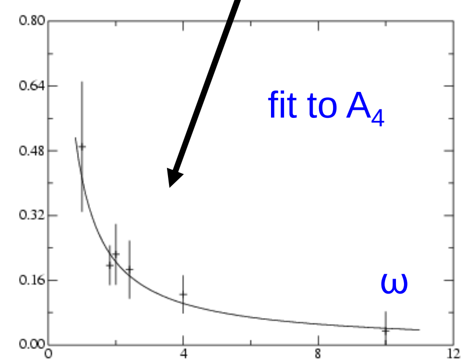
EDM term (A_4)

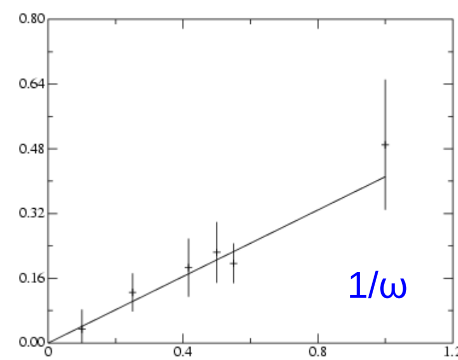
t_{21} term (A_6)

constant term needed because EDM grows from zero (A_5)



Monte Carlo shows characteristic shape of EDM signal with g−2 precession rate.





A_4 at several precession rates

Summary Table

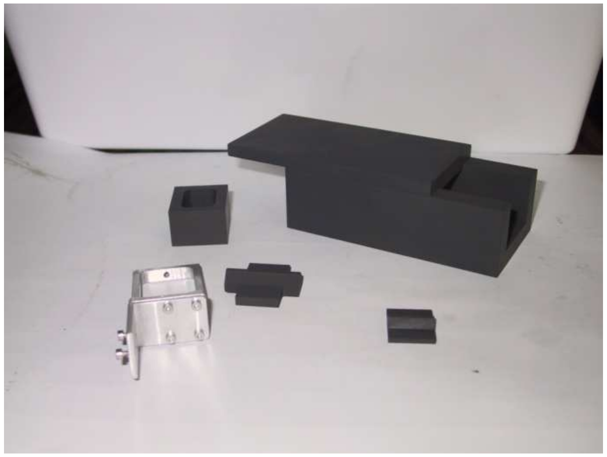
item	signal	flips w/ spin		flips w/ ω_a		goes as		new location		
		yes	no	yes	no	const.	$1/\omega_a$	same	opp.	diff.
EDM	$\sin\theta$	X		X			X	X		
self-polarization	$\cos 2\theta$		X	X			X	X		
residual p_{zz}	$\sin 2\theta$		dif		X	X		X		
residual p_y	const.	X	.		X	X		X		
polarimeter rotation	$\sin\theta$	X			X	X				X
off-axis/angle	const.		X		X	X				X
geom. phs. (wobble)	θ	X		n/a		n/a			X	
geom. phs. (running)	$\sin\theta$	X			X	X			X	
non-linear resp.	$\sin\theta$	X			X	X				X

Plans for COSY running:

8 weeks of time approved

First run scheduled for June 9-16, 2008

- Commission new electronics for EDDA detector.
- Try tube and rod targets for greater polarimeter efficiency.
- Study sensitivities to beam-target interaction.
- Look at systematic effects of beam errors.
- If possible, try to precess beam with RF solenoid.



Additional running includes:

- Further studies with horizontal polarization.
- Studies of things that affect polarization lifetime (emittance, momentum spread, beam-target interactions, etc.)
- Development of WASA solid target capability; run d+C database.

Modeling work to continue.

Ad out for LDRD funded polarimeter post-doc.

- May obtain funding for COSY post-doc.