EDM Polarimeter R&D

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Bold items run in 2007.

Response to PAC

The COSY program

- Technical demonstrations
  - **High efficiency polarimetry**
  - Rotation of polarization into horizontal plane
  - Observation of deuteron g-2 precession
  - (Forced synchrotron oscillations)
- Measurement of polarized d+C data
- Polarimeter prototyping

Proposal due March 21. Running starts fall, 2007.

The KVI program (**systematic error studies**)

Beam time available

Is this what we need to be doing?
What technical and human resources do we need?
How do we best coordinate with ring simulations?

Demonstrations, not discussions

Please find below the recommendation of the NPP PAC from September.

LoI: Search for a Deuteron Electric Dipole Moment Using a Charged Particle Storage Ring

This letter proposes a search for a deuteron electric dipole moment using a stored beam. The goal is a statistical precision of about 10^{-29} *e·cm; an appropriate level for an experiment we expect would take a number of years to develop. In this experiment, a longitudinally polarized beam develops a vertical spin component due to the torque of the motional electric field in the ring bending magnets acting on the electric dipole moment. The PAC is enthusiastic about this ingenious new approach to electric dipole moment searches. Because it is a new technique, however, there will be a daunting new set of false edm effects and associated systematic errors to consider. We believe it is very important to identify the most important of these difficulties and address them with a combination of simulation and measurement. We strongly encourage the collaboration to investigate the options for measurements in existing rings with polarized deuteron beams. Development of a program of simulations and tests should include, but not be limited to, complete characterization (intensity, size, energy, polarization) of the tails of the beam and their effects on the measurement, investigations of resonant extraction, considerations of correlations between energy and position in the 'extraction' region, and characterization of the effects of common lattice imperfections. Indeed, short of implementing the resonant enhancement of vertical polarization described in the proposal, measurements of zero left-right asymmetries at the requisite level must be demonstrated. A clear plan for near-term milestones including consideration of these issues (over perhaps a two-year period) should accompany any request to the laboratory for continued support.*

Clearly there is enthusiasm for your continuing development of this experiment and I look forward to a plan as suggested in the last sentence of the recommendation.

COSY has:
- storage ring
- polarized deuterons
- right energy
- polarimeters
- good equipment

Study systematics:
- drivers
- sensitivities
- suppression methods

Demonstration not possible (statistics and running time not there). Instead, show METHOD for systematics studies.

Is this experiment feasible?

Can we meet the critical tolerances required for this EDM search?

The COSY program
High efficiency polarimetry

Should we proceed assuming polarimeter is **in** the ring?

Use an existing polarimeter.

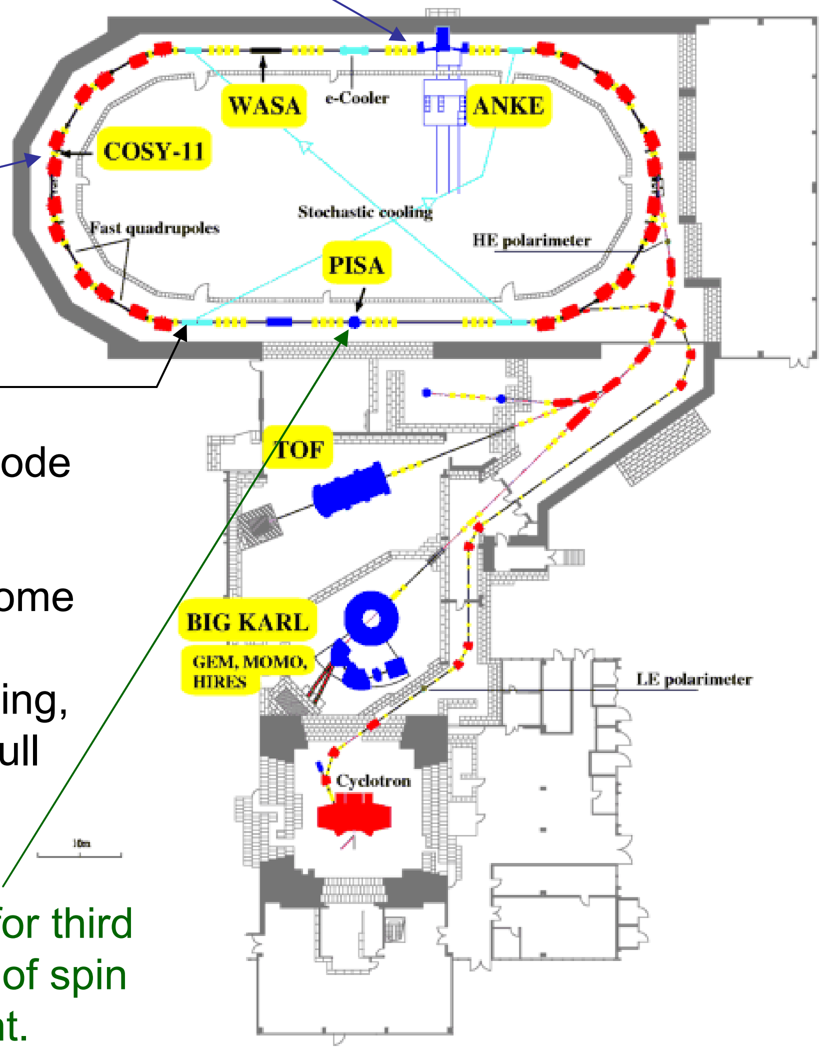
(Beam goes clockwise.)

Two gas targets in ring.

EDDA polarimeter is here.

Used by SPIN@COSY in scaler mode with carbon fiber target.

Targets are on motor drives that come in from top and bottom. We would split a carbon ring target so that filling, cooling, and ramping would have full ring aperture.



Possible location for third gas target as part of spin filtering experiment.

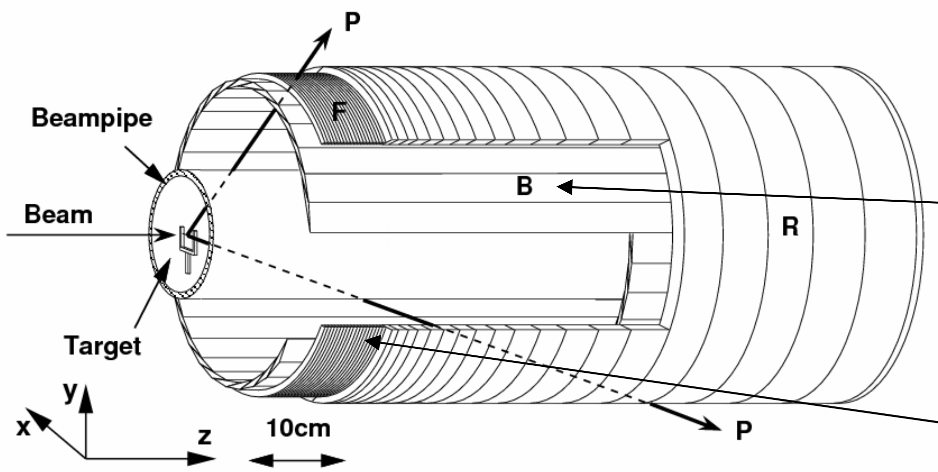
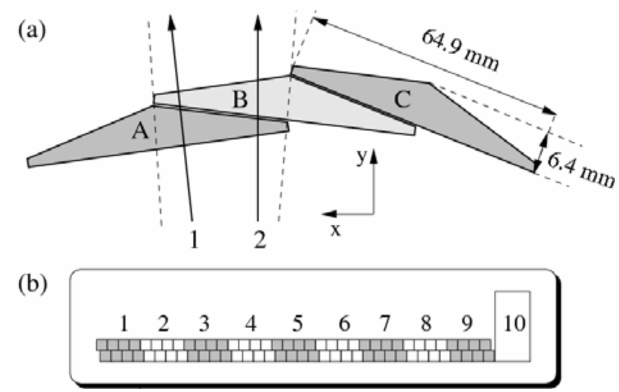


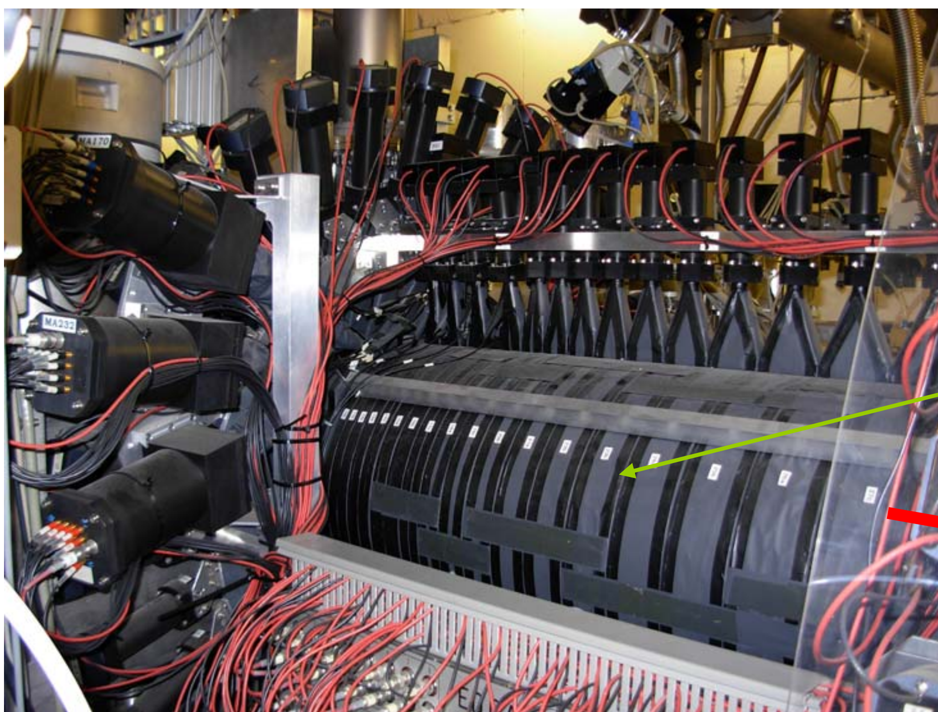
Fig. 1. The EDDA detector (not to scale): target: fiber (CH_2 or C); B: scintillator bars; R: scintillator semi-rings; F: semi-rings made of scintillating fibers.

overlapping B scintillators



large-angle fibers

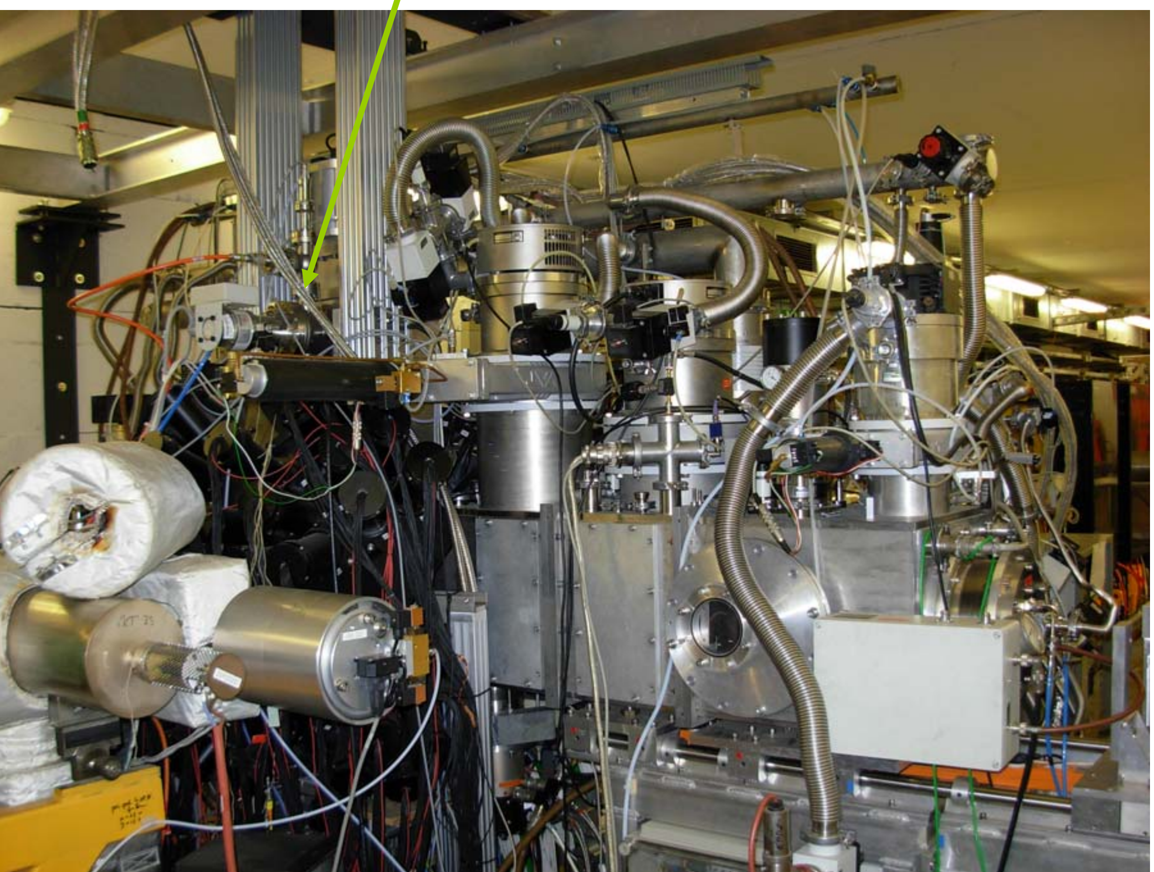
Not shown: an inner layer of fibers between beam pipe and B scintillators.

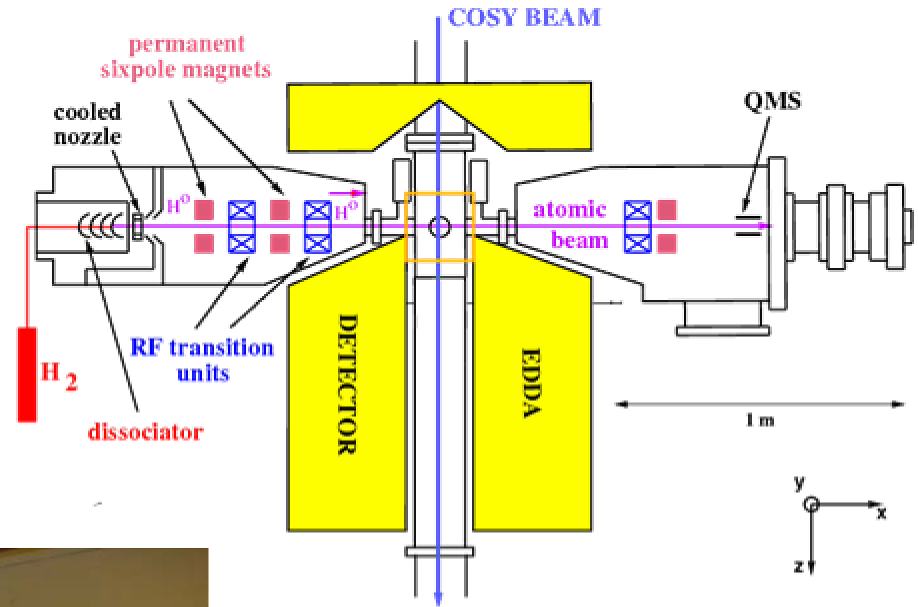


semi-rings (separate left and right)

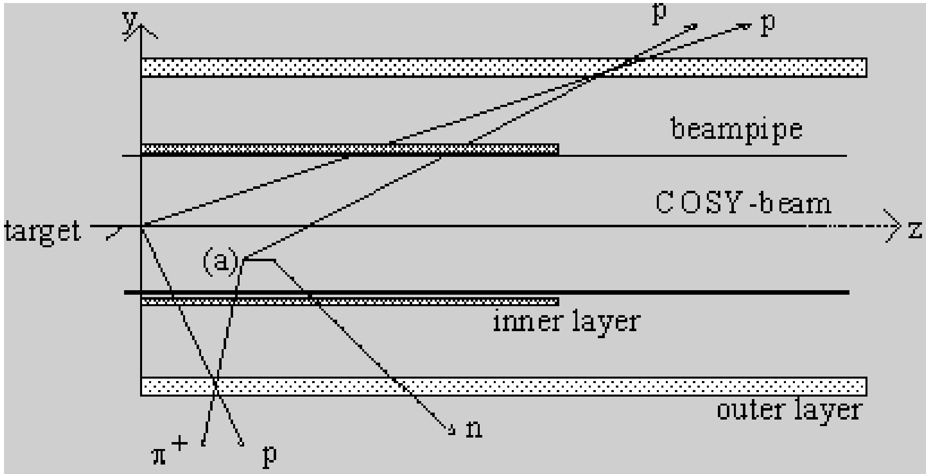
beam

Upper target motor drive





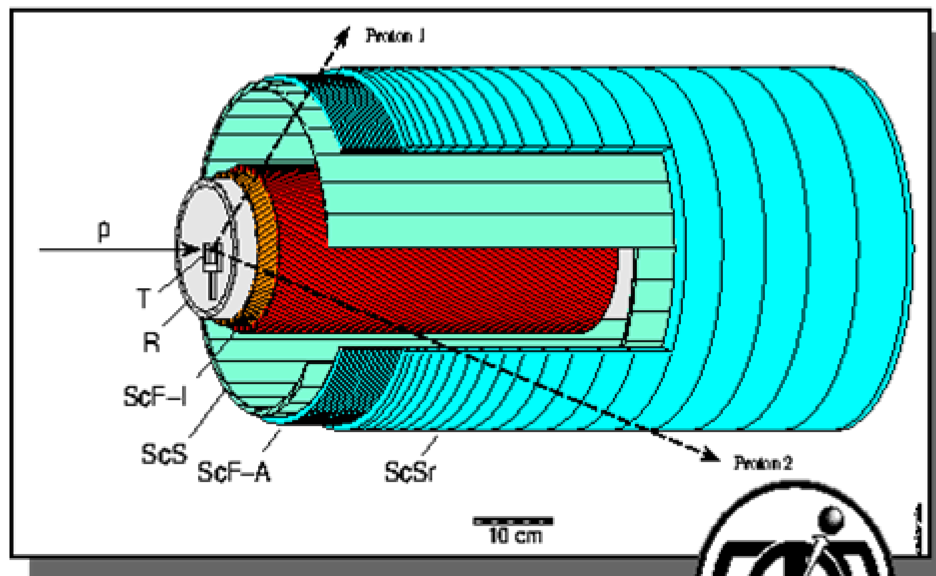
(All this other stuff is an old polarized atomic beam target.)



EDDA detector inner fiber layer

Introduced to be used with extended polarized atomic beam target, this feature permits ray tracing to the interaction point. This could add an important diagnostic capability for our tests.

Cut–Away View of the EDDA Detector



The picture shows the active parts of the EDDA detector with PP–fiber–target (T), beampipe (R), inner layer consisting of four scintillating fiber helices (ScF–I), and the outer layer made of scintillator bars (ScS), scintillator semi rings (ScSr) and scintillating fibers (ScF–A).

Preparation:

- engineer and build targets, test installation in summer shutdown
- become familiar with running system (SPIN@COSY run May 11-20)
- request about one week in fall

Tasks for run:

- learn to insert target, tune beam through target
- study beam lifetime with gas jet target on (regulate flow)
- run polarimeter, measure polarization during long store
- look for systematic issues (beam steering, high rates, etc.)

Things to consider:

- how to determine efficiency of target and polarimeter
- best operating conditions for annular target
  - acceptance cuts
  - beam energy
- ways to check polarization (CH_2 fiber, d+p scattering, other…)

There’s lots to do to get proposal ready…

What's next?

Use RF dipole or solenoid to precess polarization into ring plane.

Simulation needed before beam time request can go.

Note issues from SPIN@COSY experiments showing anomalous strengths for transverse RF dipole in spin flip studies.

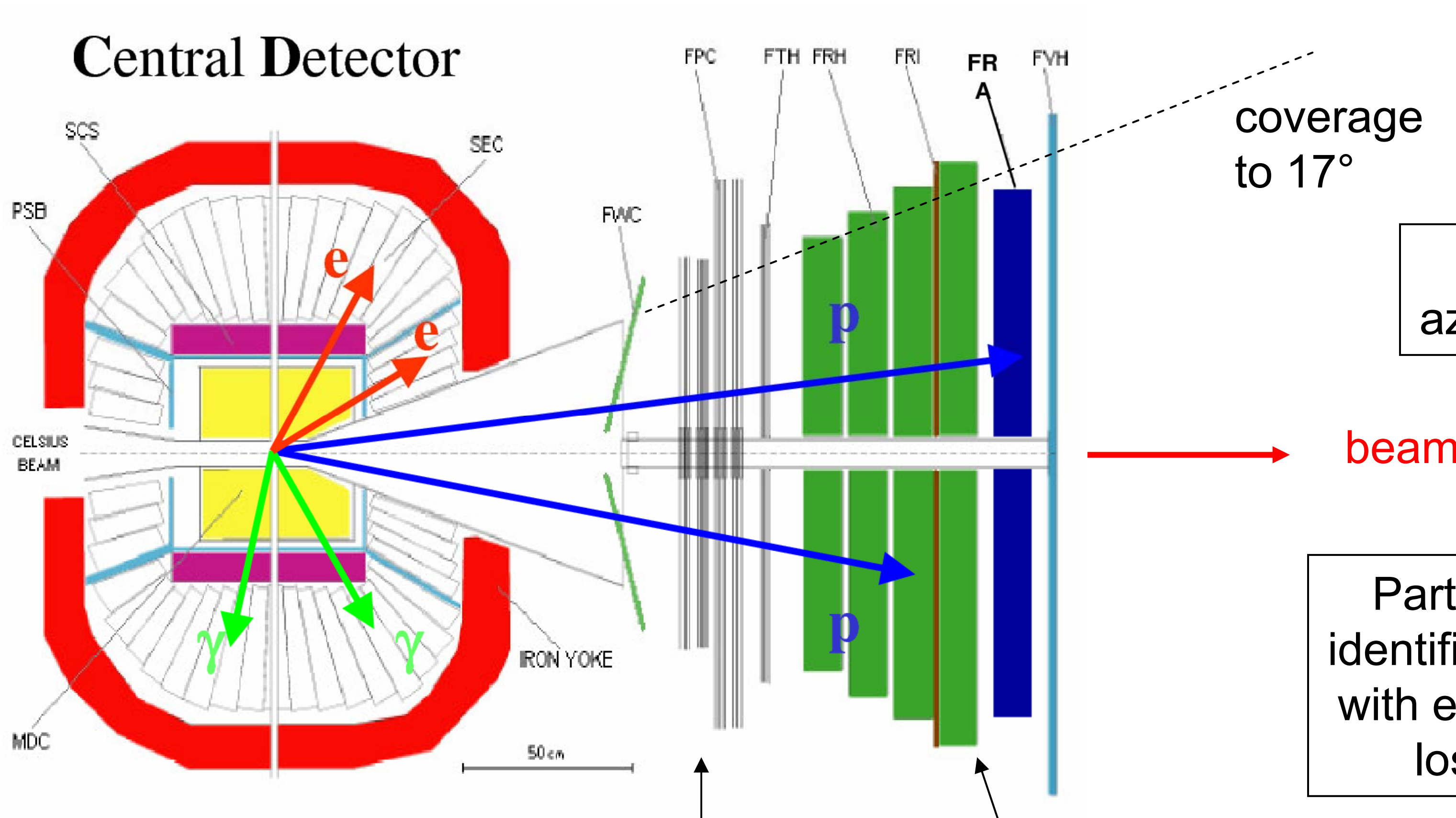
Consider polarization coherence time, beam bunching, corrections, etc. Can two-step precession protocol with variable time gap measure this?

Upgrade EDDA data acquisition to record bunch number. Consider how to process this information.

The COSY project

d+C data

The best option with an existing detector appears to be WASA.



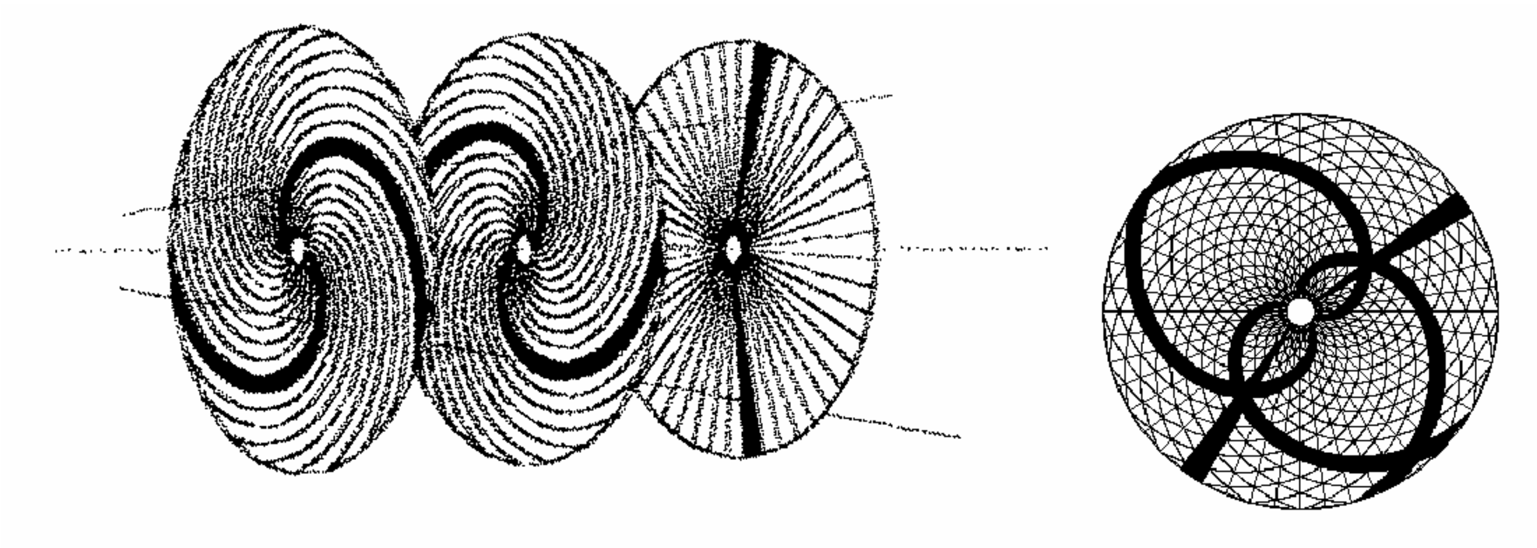
Full azimuth

Particle identification with energy loss

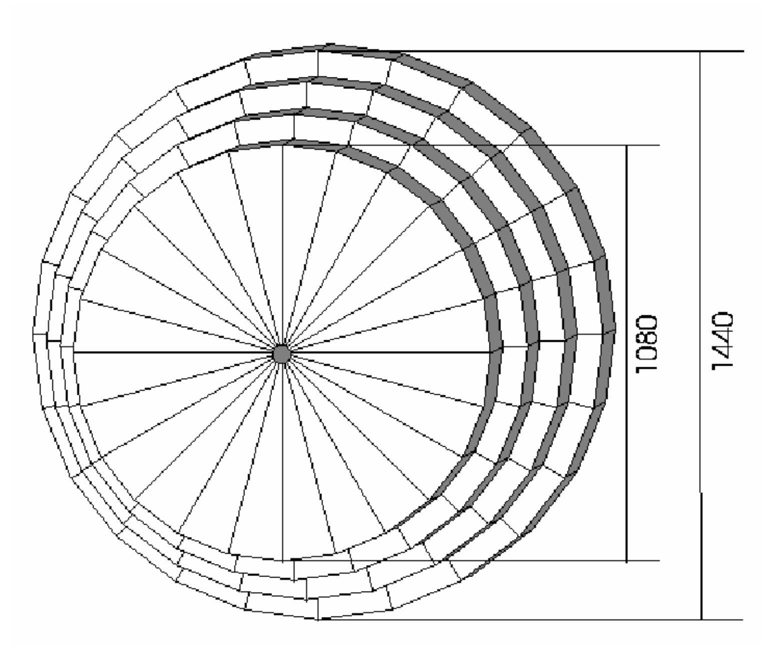
wire chambers for tracking

scintillator arrays that (mostly) stop deuterons

Forward trigger hodoscope is three "quirl" layers.



Forward range telescope



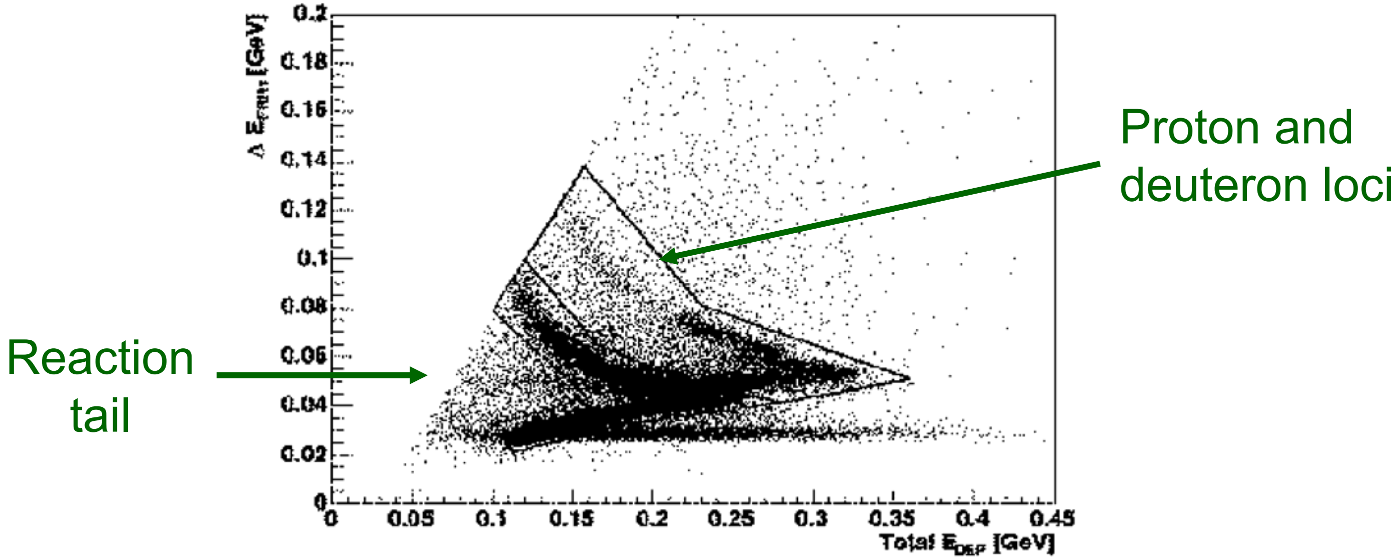
Issues:

System is presently a frozen H_2 or D_2 pellet target.
We need to replace this with carbon or CH_2 fibers.

- This is a significant change to target system.
- This must be justified to collaboration.
- Engineering will postpone run into 2008.

No luminosity monitor, compare to d+p scattering.

Stopping detectors may have 40% reaction losses.



Other options:

TOF

Provides information only on velocity.
Elastic deuterons and breakup protons have same velocity.
(Distinguishable only by width of peak)
Excitation of state and continuum contaminate separation.

Provides full azimuthal coverage.
No luminosity monitor.

ANKE chicane

Incomplete azimuthal coverage, bad range.

Good separation of elastic and breakup by rigidity.
No luminosity monitor.

The KVI program

Systematic Error Studies

Beam time still remaining from earlier d+C experiment.

Identify "drivers," error terms that are nominally zero.

This is the dangerous list.

	average	Δ with spin
centerline: x, y, θ, φ	●	●
spreading width: h, v	●	●
spreading skewness: f, g	●	●
vertical polarization: u		●
tensor polarizations: t_{kq}	●	●
data rate		●
dead time		●
background level		●
pileup		●
in-plane crosstalk	●	●

Dispersion or angular dispersion enters here.

Skewness:

$$[1+fx]\exp\left(-\frac{x^2}{2h^2}\right)$$

Baryshevsky self-polarization enters here.

There are also other effects, such as image charge, gravity, earth's rotation, etc.

Be careful of terms that are time dependent, particularly in an exponential way.

From the polarimeter properties:

$$\overline{\sigma} = \int_{acc} \sigma(\theta, p...) \qquad \overline{A} = \frac{\int_{acc} A(\theta, p...)\sigma(\theta, p...)}{\int_{acc} \sigma(\theta, p...)}$$

For any driver: δ

Calculate sensitivities:

$$\frac{\partial \overline{\sigma}}{\partial \delta} \qquad \frac{\partial^2 \overline{\sigma}}{\partial \delta^2}$$

$$\frac{\partial \overline{A}}{\partial \delta} \qquad \frac{\partial^2 \overline{A}}{\partial \delta^2}$$

etc.

Then choose method:

simple $\varepsilon = \frac{L - R}{L + R}$

cross-ratio

$$\varepsilon = \frac{r - 1}{r + 1} \qquad r = \sqrt{\frac{L_+ R_-}{L_- R_+}}$$

See results in a Taylor series.

NOTE: Terms may depend on powers of the asymmetry.

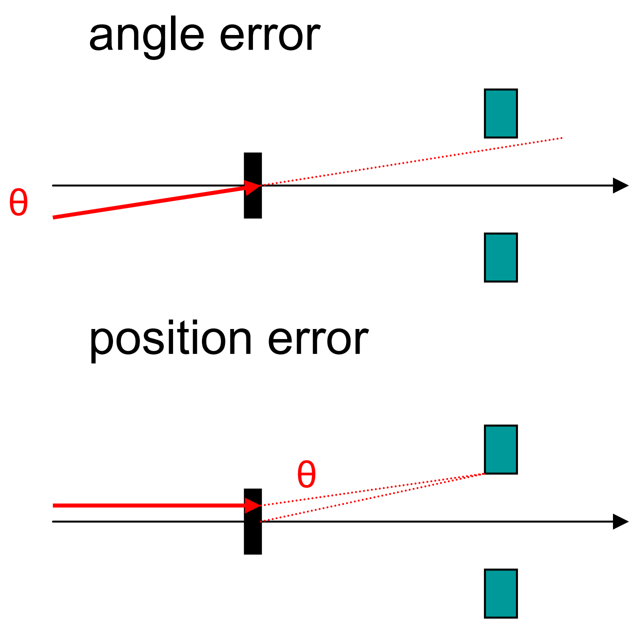
Dealing with systematic errors

The Toolbox:

- spin reversal (at source, in different bunches)
  - combined with cross-ratio calculations
- correct time dependence
  - depolarization confirmed from in-plane values

Challenge:
Predict these terms from Monte Carlo, then check in lab.
This demonstrates methodology.

An illustration:



both represented by θ

Fix problem with spin-flip and cross ratio:

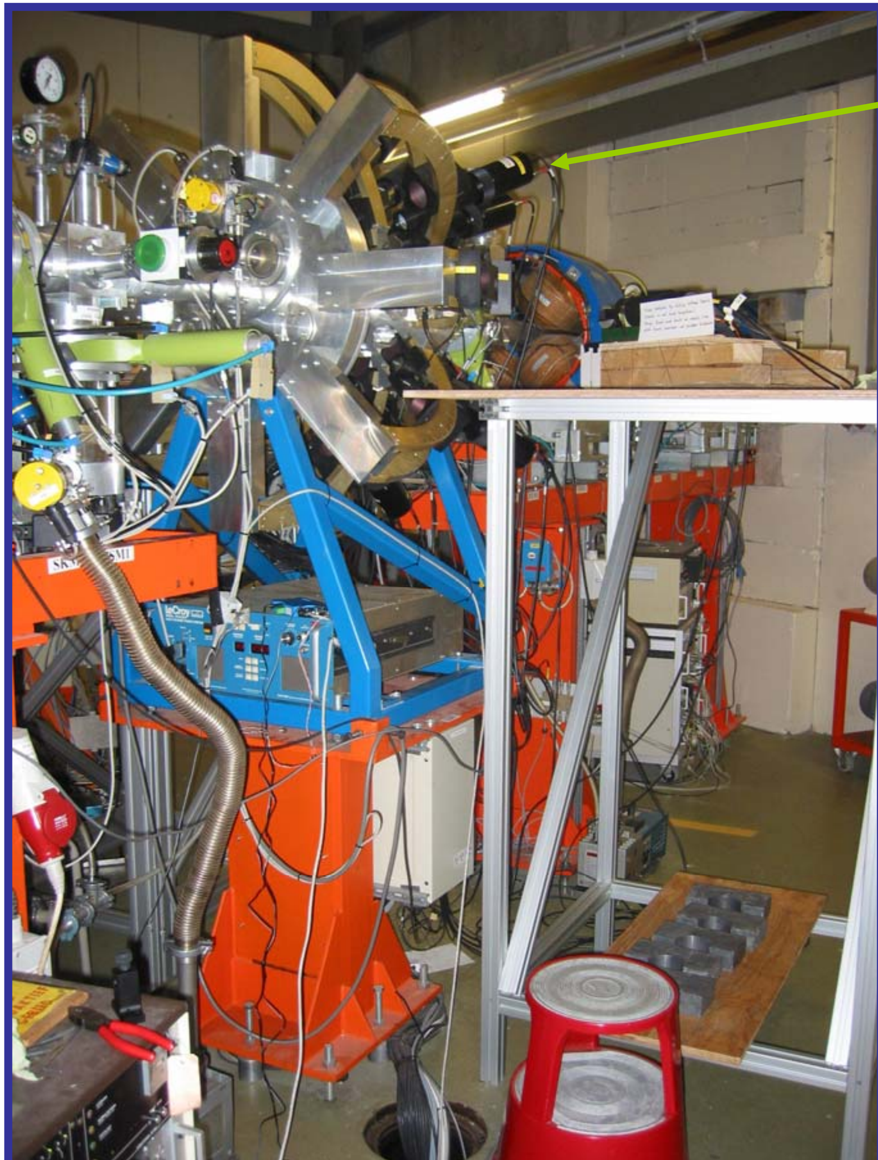
$$p_y = \frac{1}{\sqrt{3}\langle iT_{11}\rangle}\frac{r-1}{r+1} \qquad r^2 = \frac{L_+R_-}{L_-R_+}$$

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

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

- $\frac{\Delta\varepsilon}{\varepsilon}$: asymmetry ~ 0.01 (residual p_y)
- $u = p_+ + p_-$
- $\frac{1}{iT_{11}}\frac{\partial iT_{11}}{\partial\theta}$: ~0.1
- $\frac{1}{iT_{11}}\frac{\partial^2 iT_{11}}{\partial\theta^2}$: ~ –0.07
- requires θ < 0.02° difference + to –

Use the KVI in-beam polarimeter



16 Phoswich detectors mounted independently on 8 arcs

Use carbon target as mock polarimeter. Run detectors singly with iron absorbers. Check polarization by switching to CH_2 target and using 45° arcs.

We will probably use new data acquisition system being developed for TRIμP.

Running time is still available based on 2004 LOI.

COMMENTS:

Handling the size of the drivers requires good beam control and diagnostics.
Multiple steerers needed to separate “x” from “θ”.

Some errors can be investigated with unpolarized beam.

Quality of predictions depends on data and simulation quality.

This can be extended to COSY.

GOALS:

Demonstrate that systematic effects can be predicted quantitatively.

For selected drivers, obtain critical upper limit for design of EDM ring.

Expect two runs in 2007 (unpolarized and polarized)