# dEDM

deuteron electric dipole moment

# Progress on a Polarimeter for the Deuteron EDM Search

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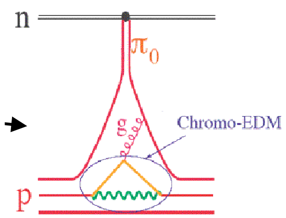
## Summary of the Motivation

EDM (aligned along spin) violates parity and time reversal symmetries.
Standard Model predictions are very small.
Any observation would indicate new physics processes (SUSY).
New source of CP-violation needed to explain matter excess in universe.

## Deuteron is a good candidate for a search.

It is particularly sensitive to chromo-EDMs; couple to P-wave.
It has a small anomalous magnetic moment (= −0.14).
It is easily polarizable and measurable (scattering from carbon).
Goal for search is statistical limit of $10^{-29}$ e·cm.



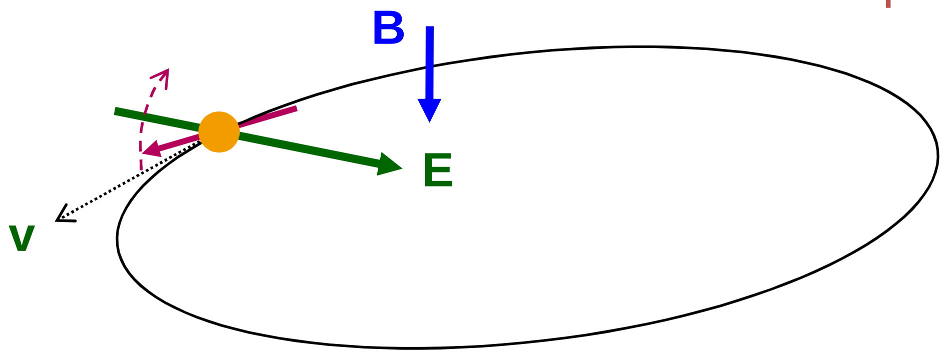

## Use large electric field (= $\gamma \mathbf{v} \times \mathbf{B}$) in frame of storage ring beam to search for EDM.

## Project Status

Letter of Intent (2006) received favorable PAC review.
LDRD funding made available to begin R&D.
Technical feasibility review to be held in fall, 2009. Test ideas at COSY-Jülich.
[polarization lifetime, polarimetry, electric field, systematic errors]

# What is the method?

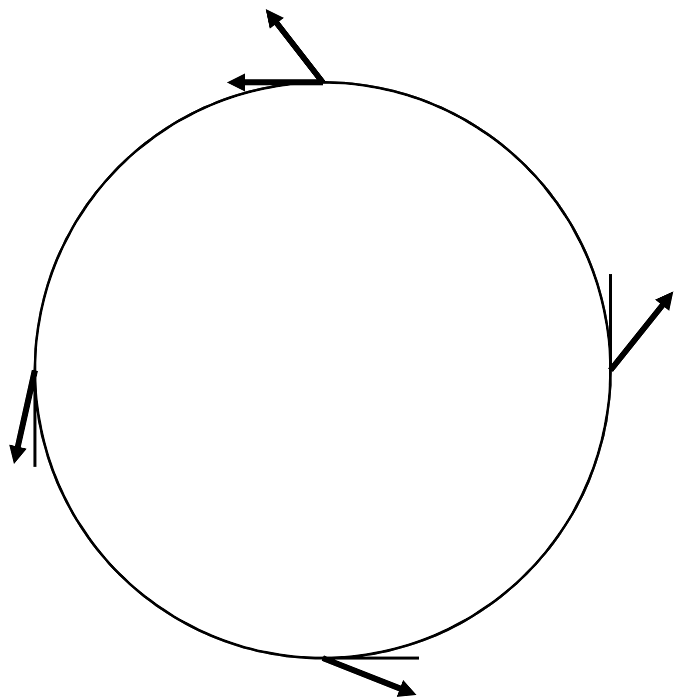
EDM Signal: observe precession of spin in large electric field.




Technique: create large E field from $\gamma \mathbf{v} \times \mathbf{B}$ on polarized beam circulating in a ring.

Experiment: watch for spin that starts out along **v** to acquire a vertical component.

Technical challenge: rotation of particle due to magnetic moment precession in ring **B** field cancels any accumulation of EDM effect.



# What is the method?

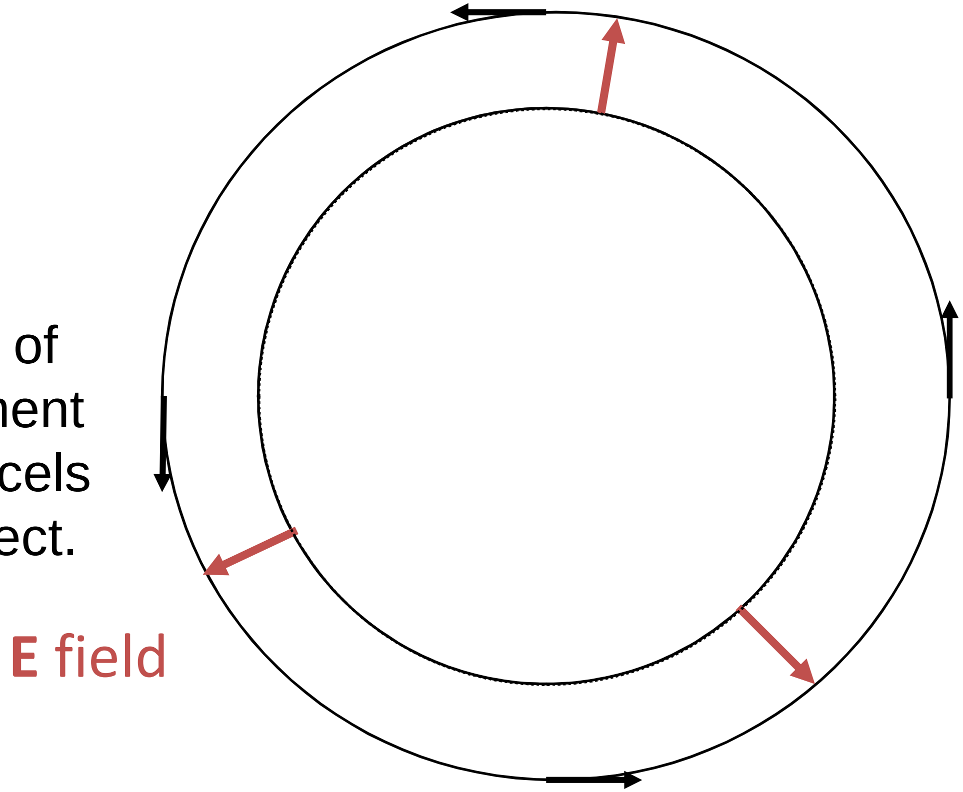
Deuteron anomalous moment = – 0.14.
In one revolution, spin lags momentum.

Idea: Use electric field to enlarge orbit and revolution time while keeping B constant.

For some ratio of **E** and **B**, the lengthened path will be just right for the spin to track the velocity.

(Small precessions will be used for systematic checks.)

Technical challenge: rotation of particle due to magnetic moment precession in ring **B** field cancels any accumulation of EDM effect.



# COSY floor plan

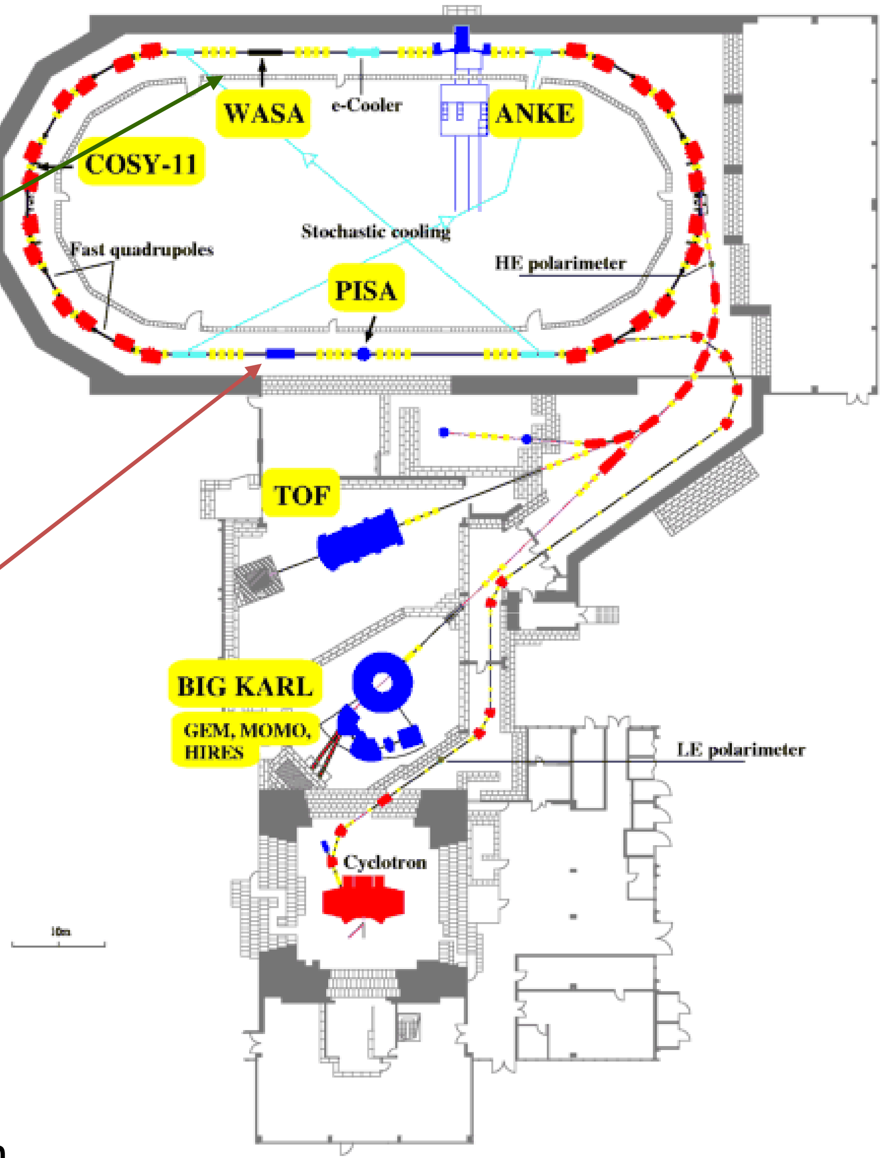
## Database:

Use forward angle tracking scintillation detectors of WASA 4-π system to look at broad range of charged particles from deuteron+ carbon scattering.

## Polarimeter demonstration:

Use scintillators from EDDA experiment as a substitute polarimeter to demonstrate principles for dEDM use.

high efficiency
precess vertical to in-plane
measure in-plane precession



# Use EDDA detectors as test polarimeter

Install annular carbon target in holder.

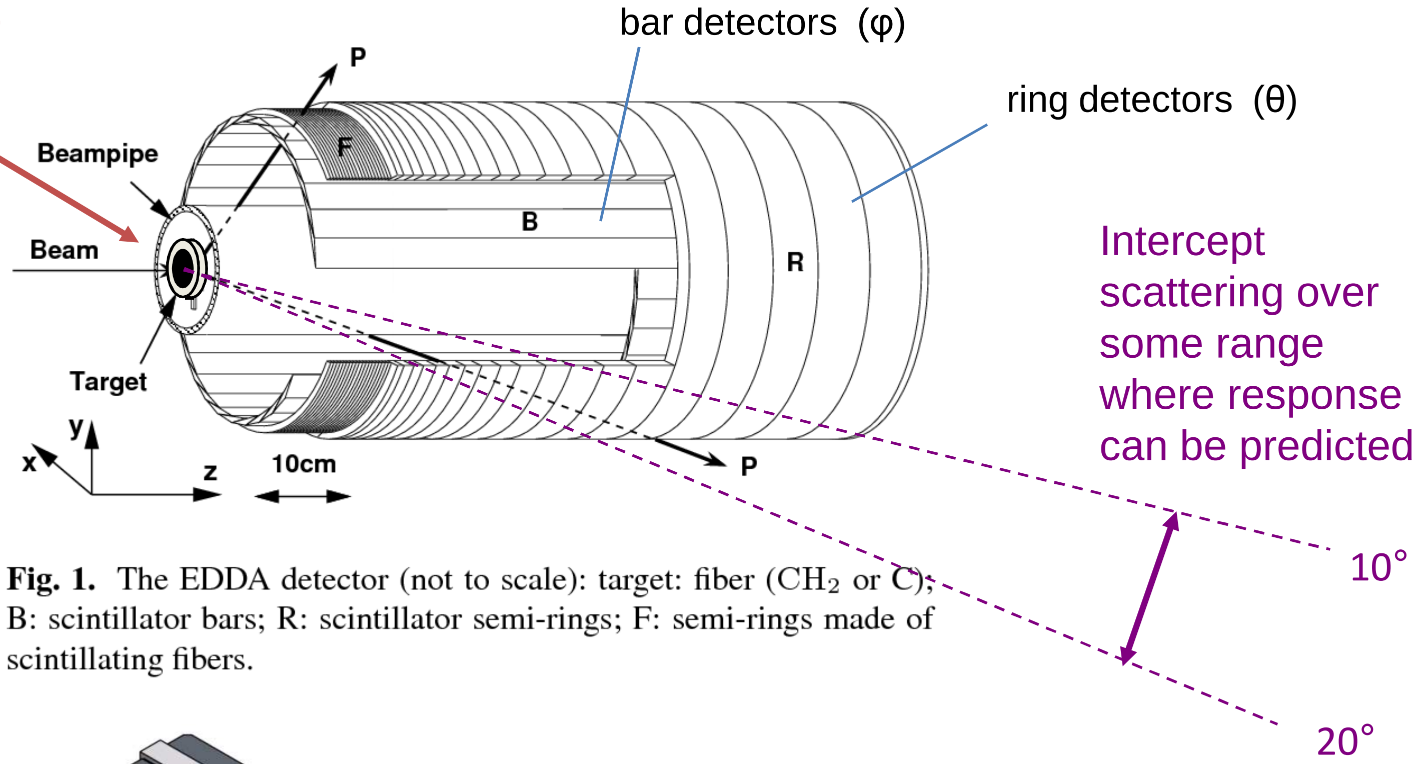
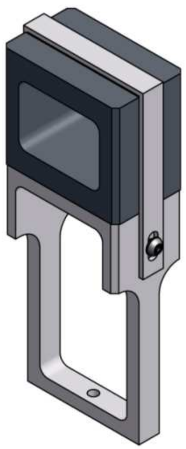



**Fig. 1.** The EDDA detector (not to scale): target: fiber ($CH_2$ or C); B: scintillator bars; R: scintillator semi-rings; F: semi-rings made of scintillating fibers.

Intercept scattering over some range where response can be predicted.

Tube and bar targets made at COSY and installed in EDDA carousel.

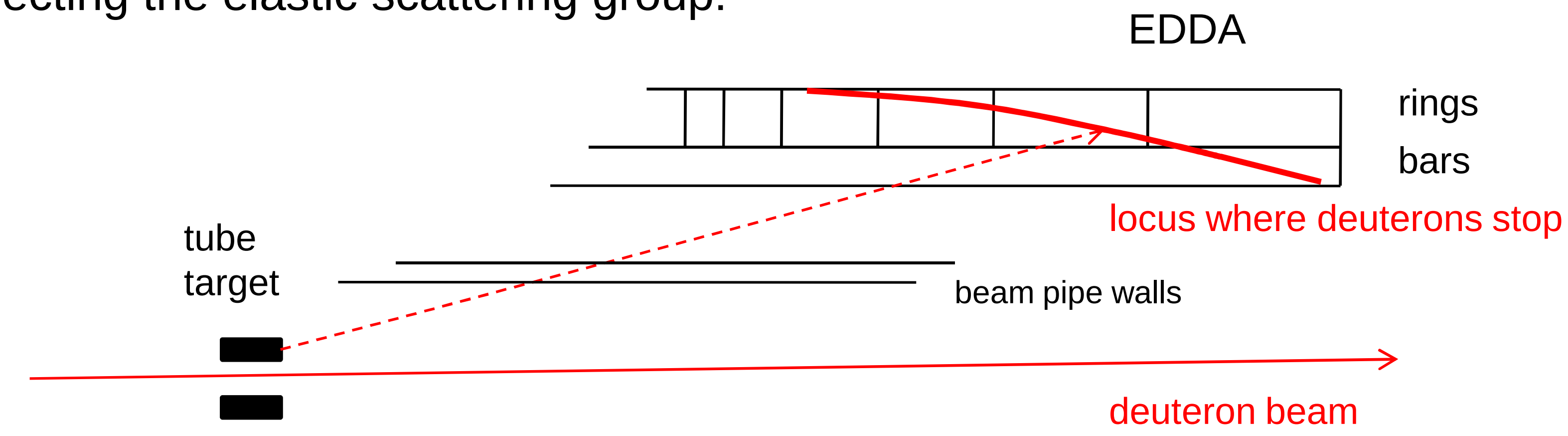


<u>Beam Extraction</u>:

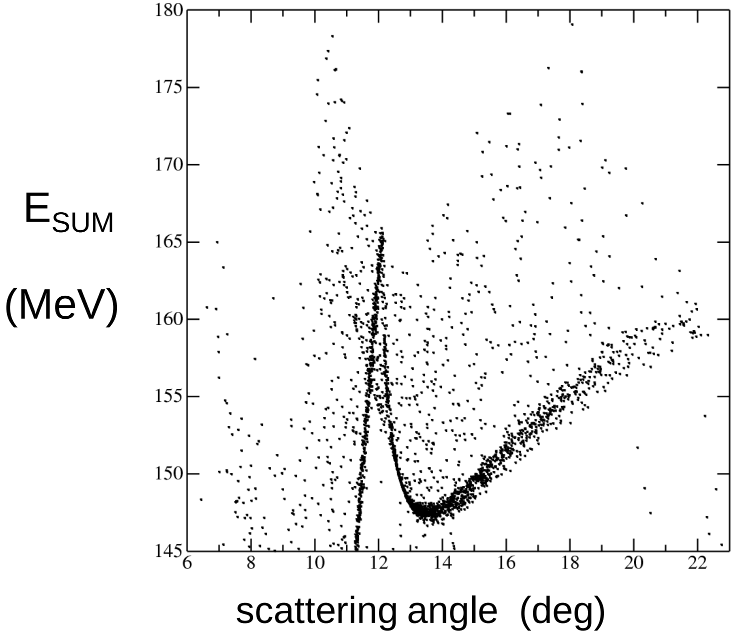
spread beam with gas target (too slow)
move beam to target edge (introduces error)
heat beam with white noise on stochastic
cooling plates (include betatron frequency)

may touch only one point on tube target

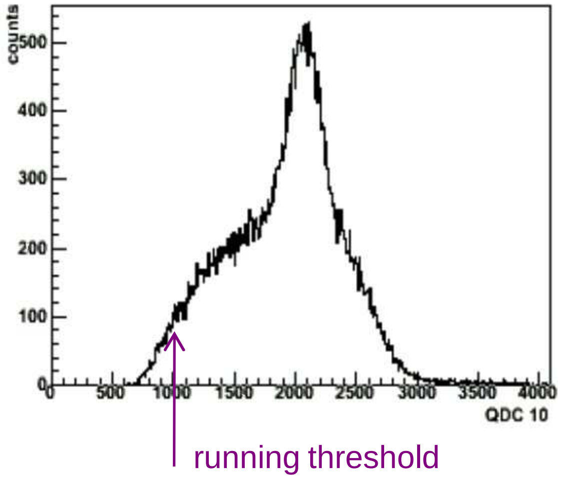
Selecting the elastic scattering group:




Monte Carlo simulations say that forming $E_{SUM} = 1.8\ E_{BAR} + E_{RING}$ yields narrow elastic peak over stopping angle range.




Resulting energy spectrum for third EDDA ring $E_{SUM}$ signal.



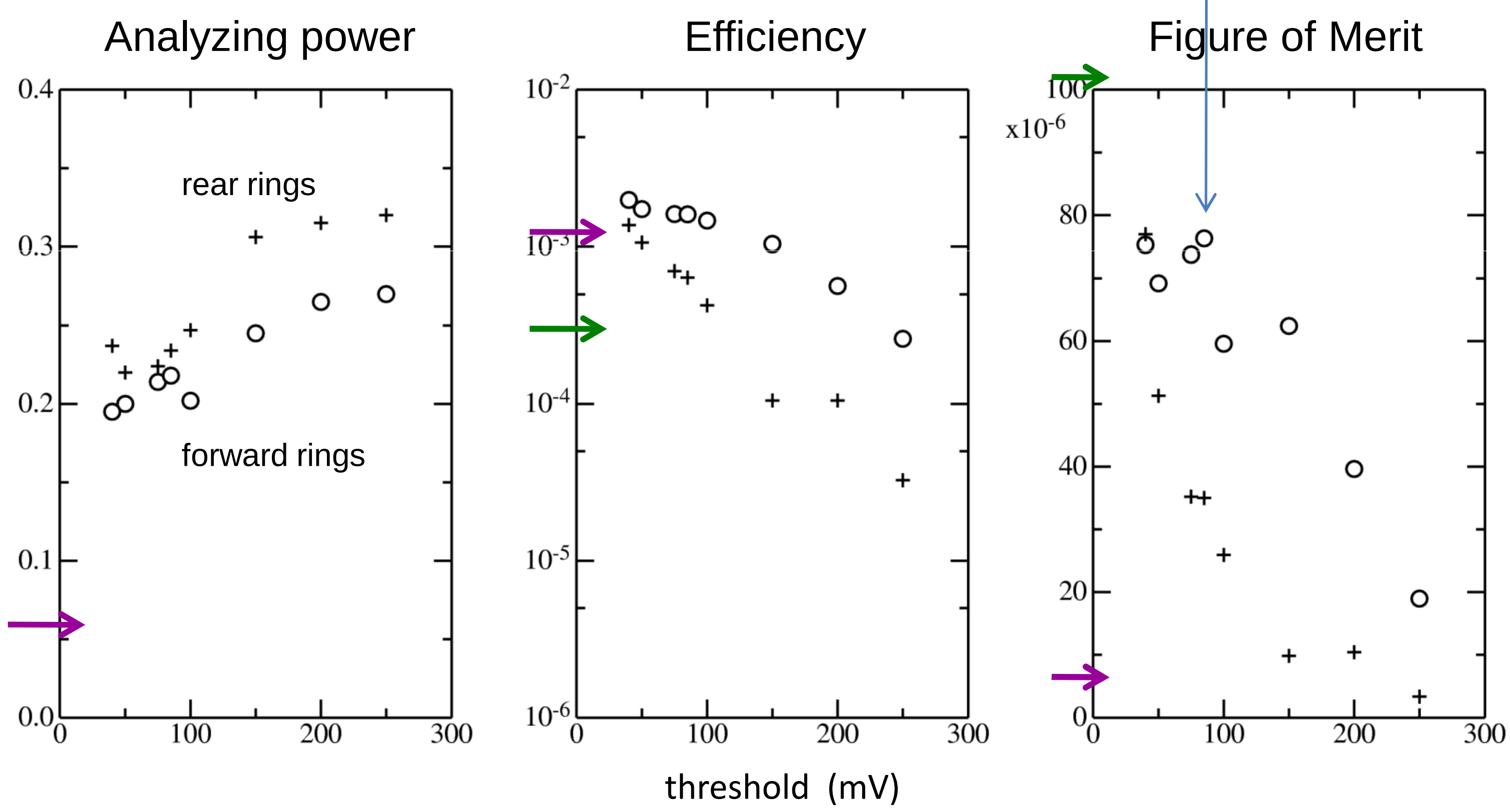
# Optimization

Run here:
Largest (not by much)
of the analyzing powers
on the high FOM plateau

Expectation from Monte Carlo model:

Elastic only: A = 0.55 Eff. = 0.33 × $10^{-3}$

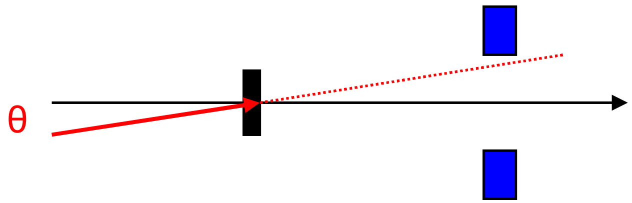
All (breakup): A = 0.06 Eff. = 1.1 × $10^{-3}$



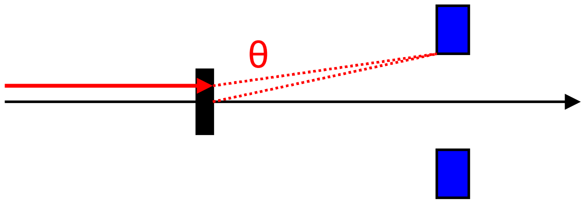
# Second-order errors in Cross Ratio

An illustration:

angle error




position error




both represented by θ

The usual asymmetry $\varepsilon = \dfrac{L-R}{L+R}$

changes in first order due to errors.

The cross ratio $\varepsilon_{CR} = \dfrac{r-1}{r+1}$ $\quad r^2 = \dfrac{L_+ R_-}{L_- R_+}$

cancels first-order errors.

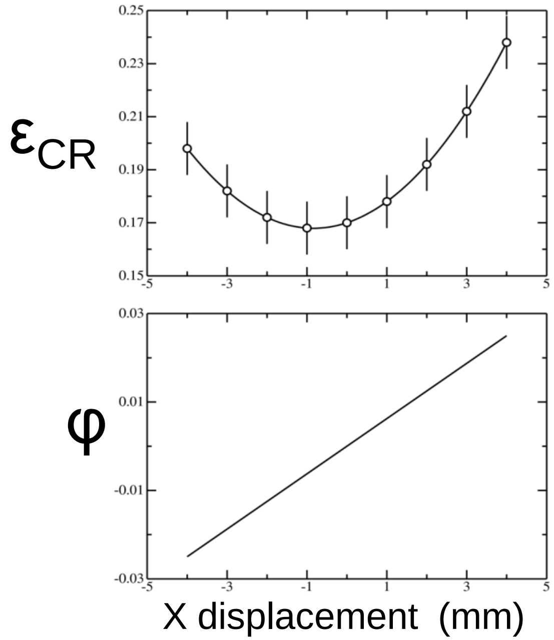
But there are second-order contributions:

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

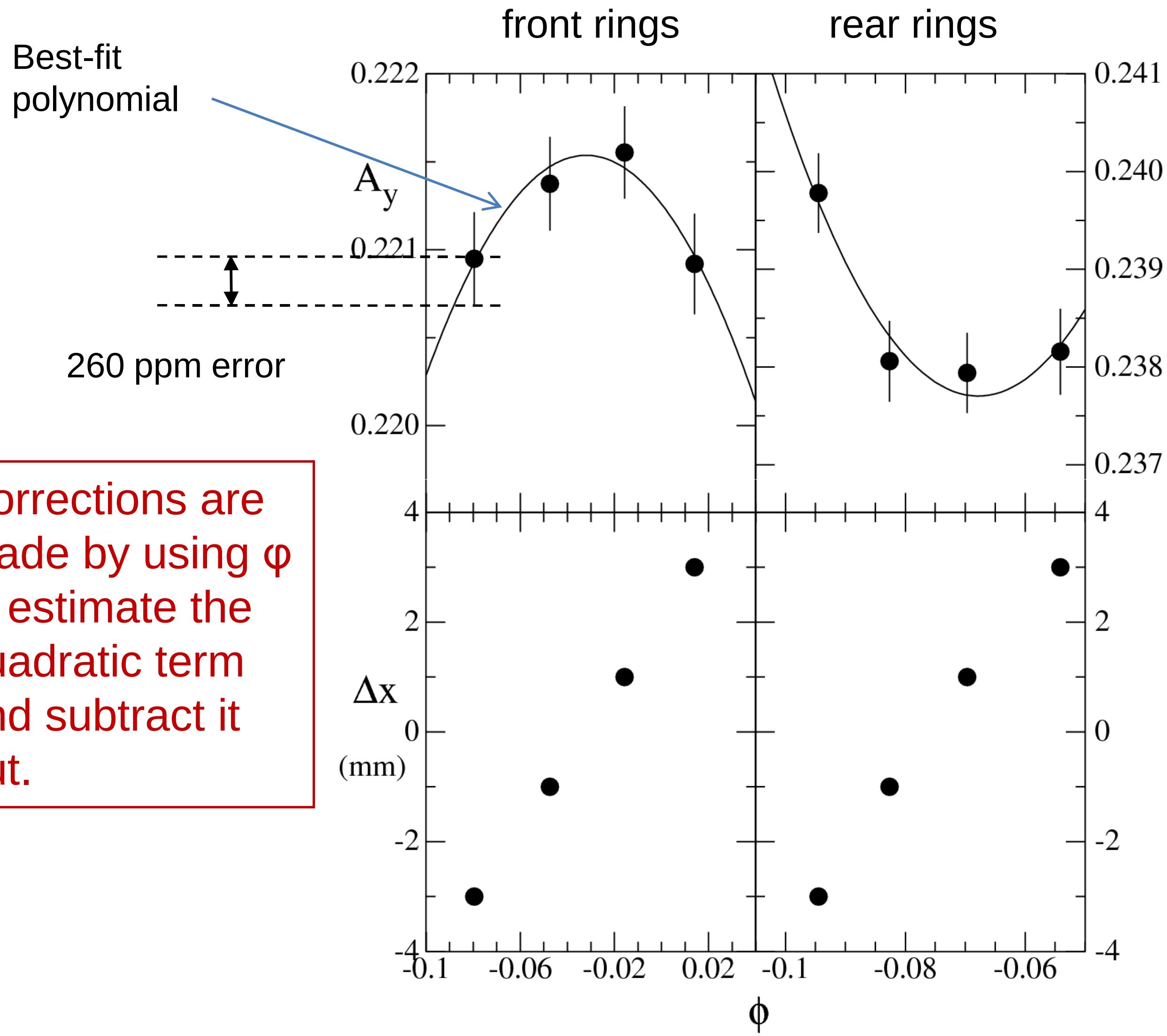
where $u = p_+ + p_-$

Use an index parameter to measure the error term:

$$\varphi = \frac{s-1}{s+1} \quad s^2 = \frac{L_+ L_-}{R_+ R_-}$$



Sample of data from the September run




Corrections are made by using φ to estimate the quadratic term and subtract it out.

Curves should be predicted from Monte Carlo model of target and EDDA detector.

Next run at COSY will be used to improve statistics.

## Run participants

*Indiana University:* Ed Stephenson*
*KVI:* Klaas Brantjes, Wilbert Kruithof, Gerco Onderwater,* Marlène de Silva a Silva, Oscar Versolato
*COSY:* Ralf Gebel, Andreas Lehrach, Bernd Lorentz, Dieter Prasuhn, Hans Stockhorst
*BNL:* Vasily Dzhordzhadze, Astrid Imig, Don Lazarus, Bill Morse, Yannis Semertzidis
*Frascati:* Paolo Levi Sandri, Graziano Venanzoni
*University of Rome:* Roberto Messi and Dario Moricianni

* spokespersons

Crossing a depolarizing resonance (+ sideband) with an RF solenoid.