# Further Exploration of Spin Dynamics Issues for the EDM Search

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(possible thesis project for student from India via Cracow)

COSY Beam Advisory Committee
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## Context:

COSY has been used for a series of EDM feasibility studies.
(polarimetry with error correction, long in-plane polarization lifetime, feedback control of in-plane polarization)

### Further questions left to address with impact on EDM experiment design:

| | |
|---|---|
| A | Is electron cooling needed? |
| B | Can the block polarimeter target be replaced by a fiber target? |
| C | What limits the practical beam current to $10^9$ /fill? |

### Requirements for long in-plane polarization lifetime:

See PRL **117**, 054801 (2016)

- Bunched beam
- Electron cooling
- Trimmed sextupole fields ($\zeta_{X,Y} = 0$)
- Stored currents less than $10^9$ /fill

Fixes depolarization due to betatron oscillations by either reducing phase space size or making all tracks same length.

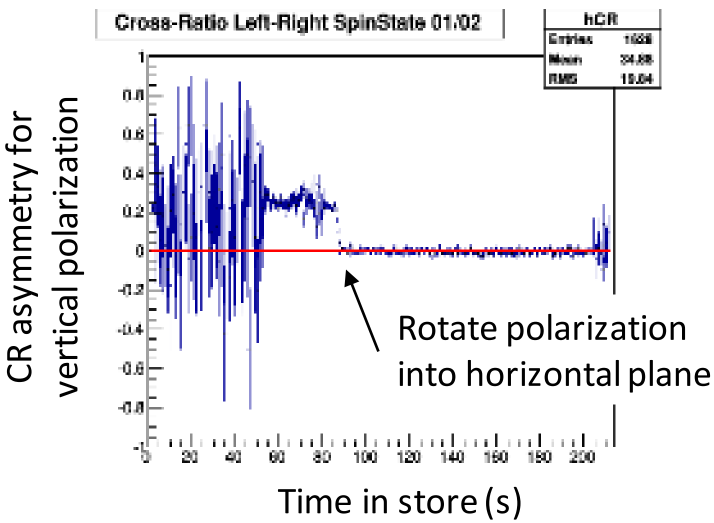
Electron cooling not sufficient, Do we need it at all?

Question C

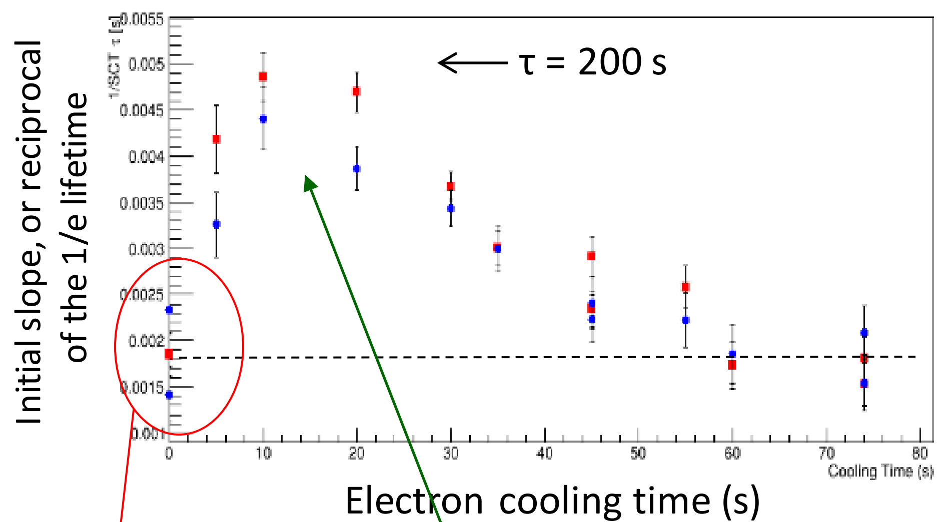
A

# Plan for 2015 test: Pick a good lifetime point, reduce electron cooling time to zero.

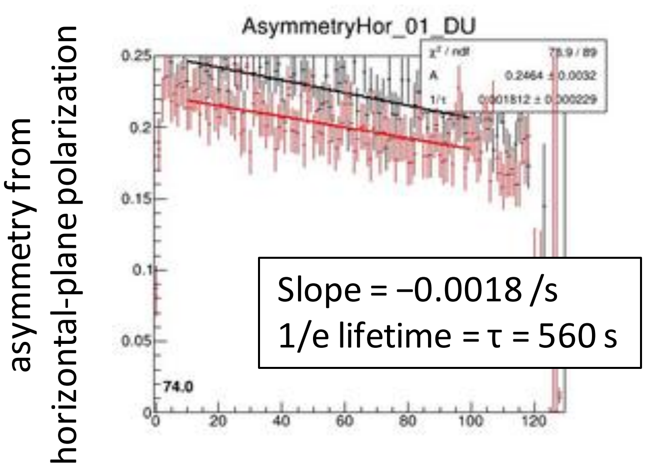
NOTE:
MXS = 12 %
MXG = 14 %




Scan from logbook:




Measure in-plane polarization lifetime

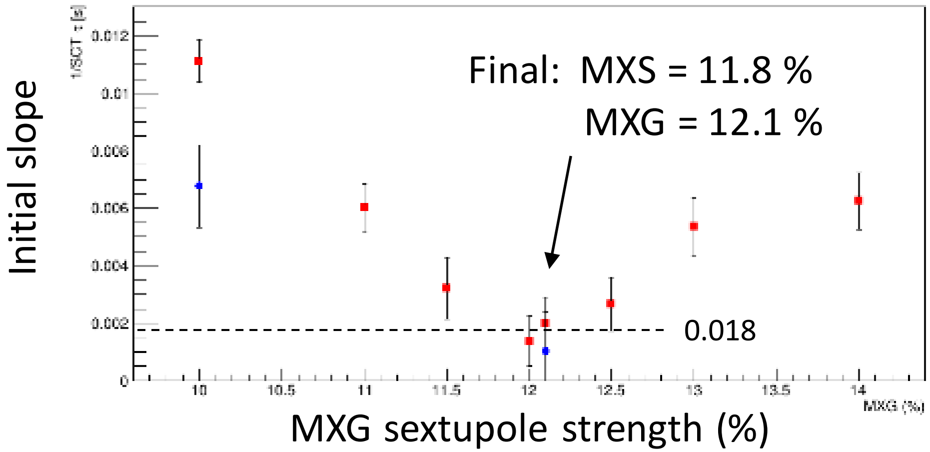



This looks like success.

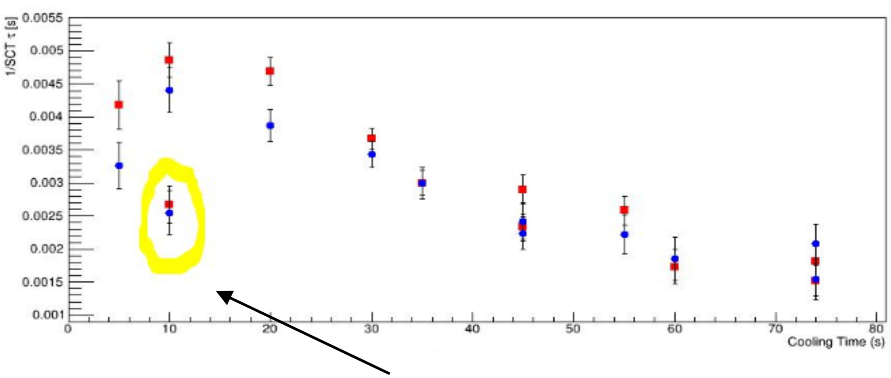
For the next few days (nights), attention turned to the question of whether the shorter lifetime could be repaired.

## Result of further sextupole scans:

Electron cooling time = 10 s

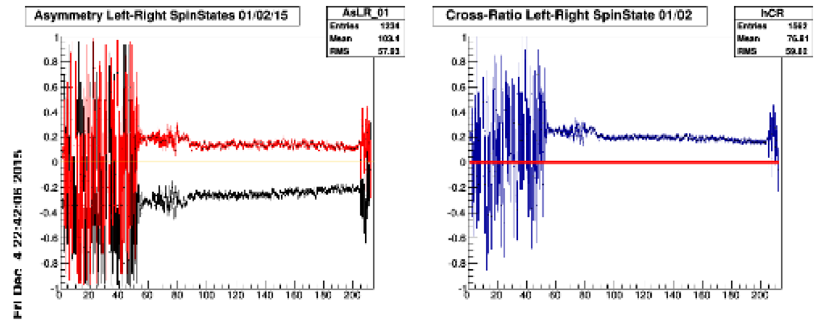



## Leads to:




New value (actually lower)

## But problems arose for lowest electron cooling time points:




These plots show a failure to rotate.

## Possible issues:

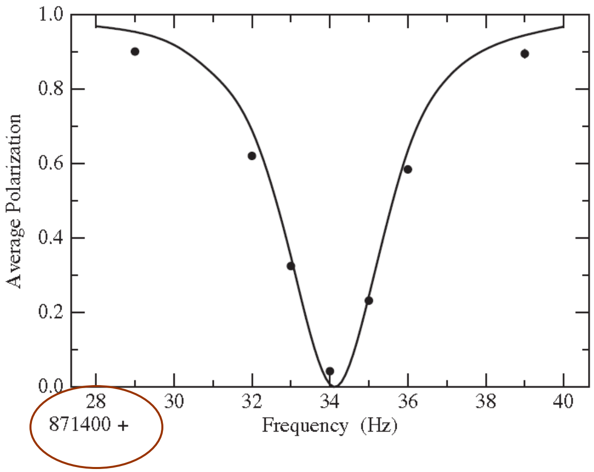
(f) Solenoid off resonance
(no evidence at other e-cool times)

(ϕ) Uncooled beam is too long
(outer parts out of resonance)

Beware low in-plane polarization yielding “fake” long lifetime.

This needs investigation.

Resonance for a cooled beam:
The RF solenoid must be this good…

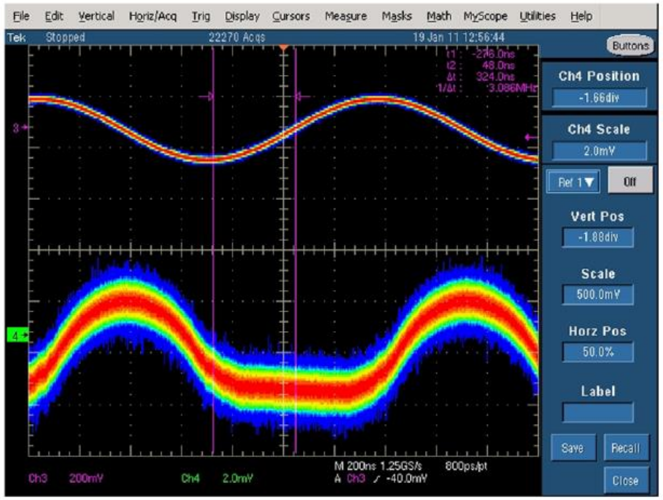



It usually is…

Beam oscilloscope traces:

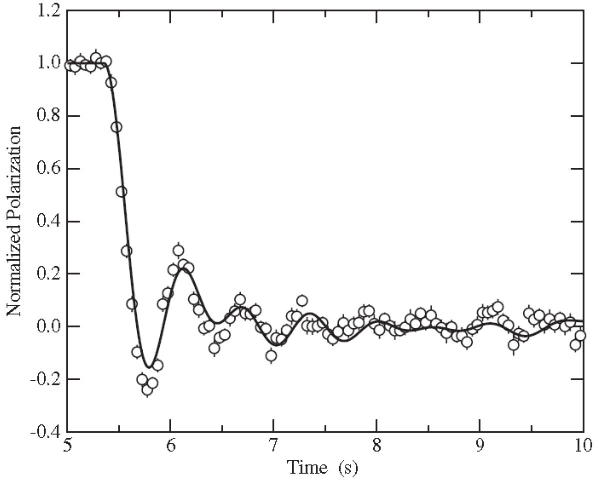
RF

Beam pickup



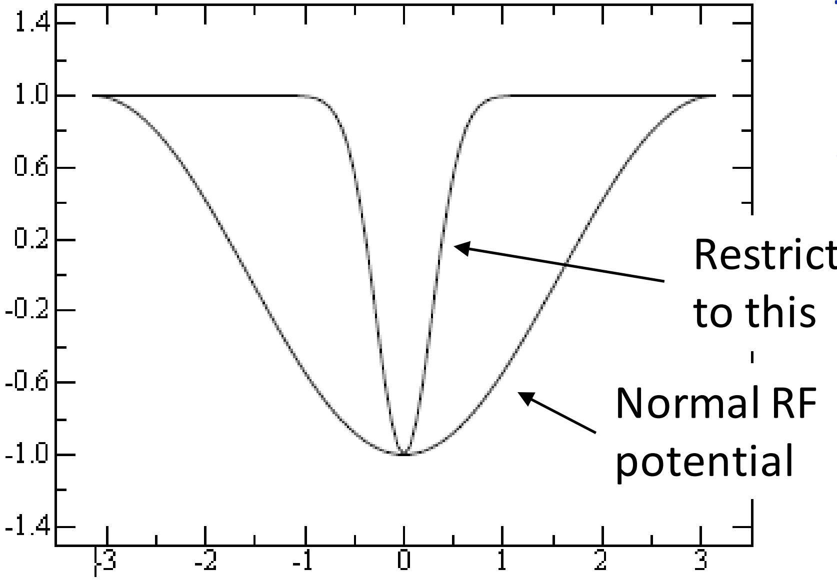

The beam is this long.

Attempts to make a driven oscillation fail to maintain the polarization. Early and late particles are out of phase with the solenoid.




Rotation set by solenoid on for a fixed time.
We probably just see this process get started.

The plan is to use a modified “barrier bucket” RF signal to narrow the allowed region for the beam.



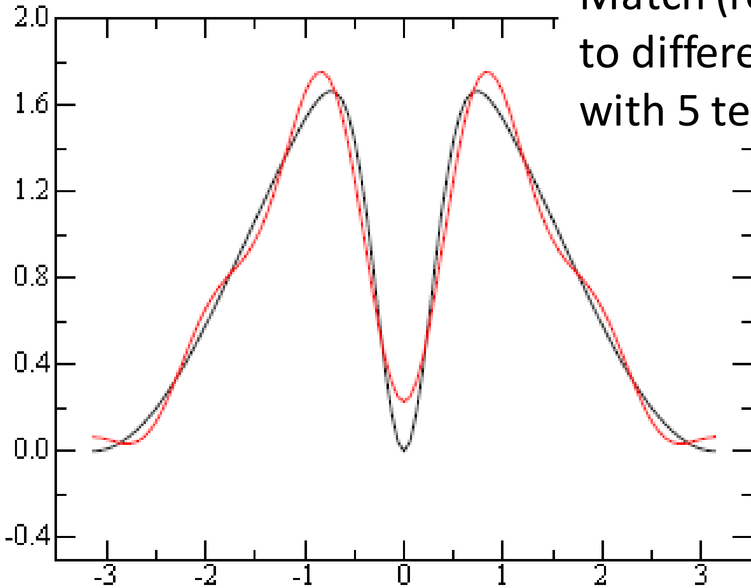

New tools to help with this:

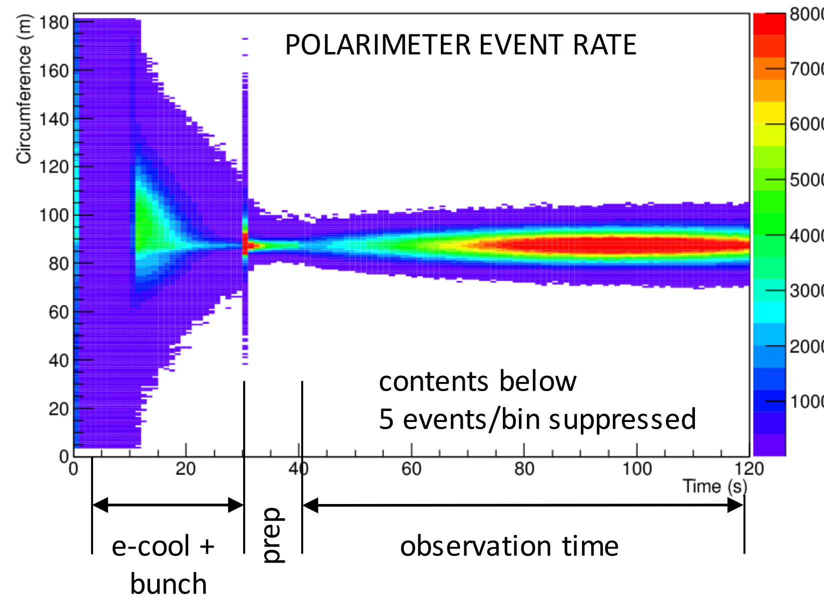
(May be useful for HESR.)

Main RF and barrier bucket cavity on same oscillator.

Use unfolded event rate to check quality of the bunching

Match (red) to difference with 5 terms



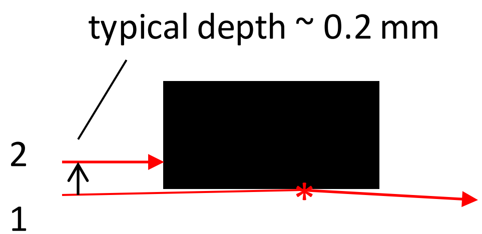
## B Can we use a fiber rather than a block target?

Original motivation: get efficiency as high as possible.

Disadvantages of block:

- Samples only from the halo, subject to profile issues.
- No way to sample profile.
- Requires manipulation to bring beam to target (heating, bump, etc.)

Block target (17 mm long)



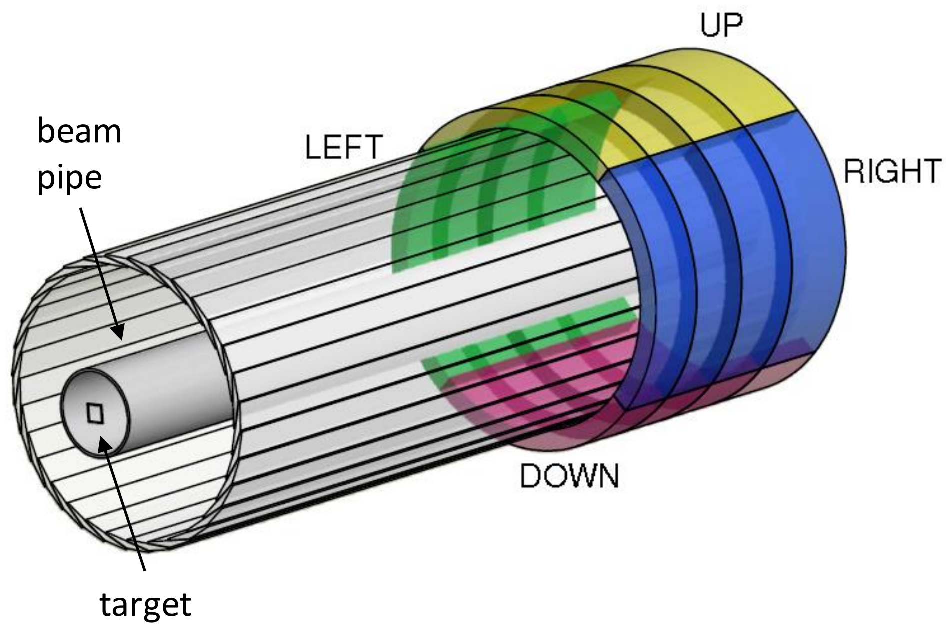

double-hit extraction?:
deflect at (1), then oscillate to (2)

$$\text{Efficiency} = \frac{\text{\# detected and useful}}{\text{\# lost from beam}}$$

$$= 7 \times 10^{-4}$$

(consistent with Monte Carlo)

Active EDDA scintillators



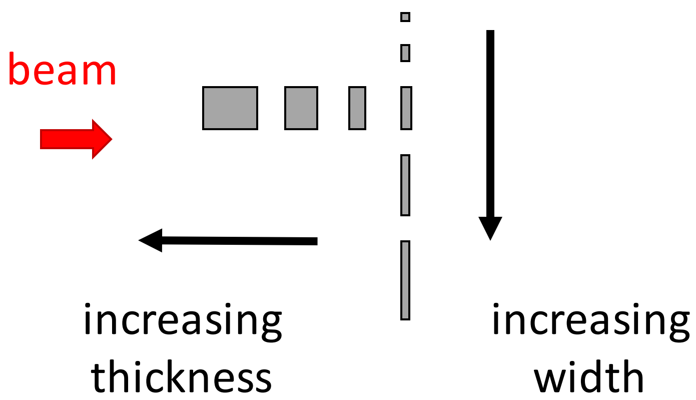
Fiber target mounted on fork at EDDA achieved an efficiency > $10^{-4}$ in multiple rapid passes through the beam.

This is possible only if particles that interact survive to interact again.

(A stationary target removes the beam in a few seconds.)

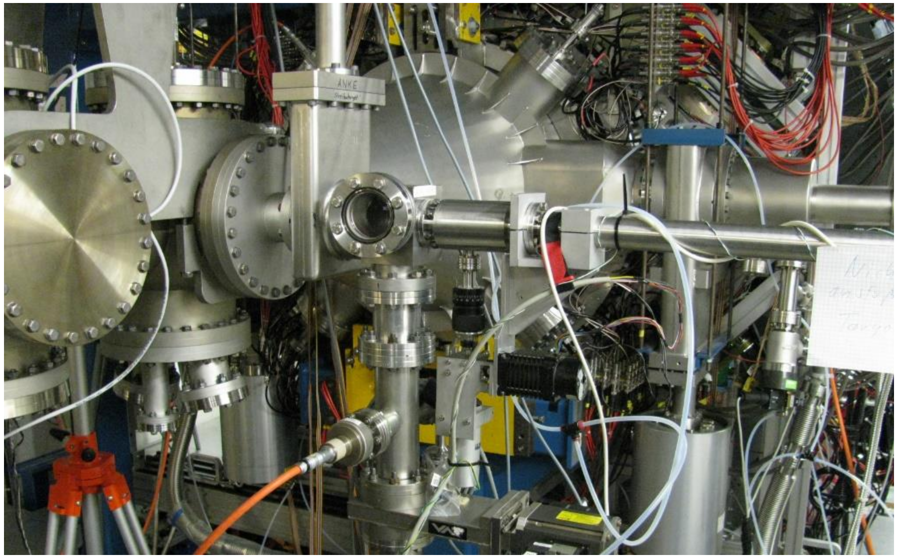
Can this be optimized?

Try an array of target configurations




Consider using aluminum instead of carbon.
Vary target speed.

New target ladder assembly for WASA

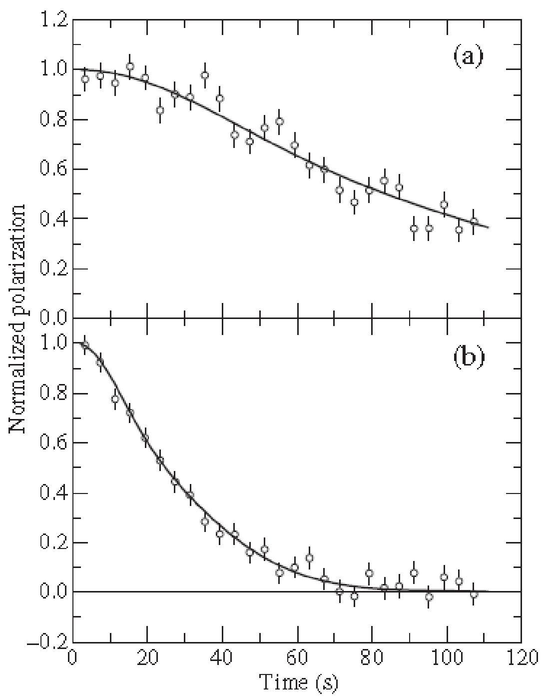


Will need to replace this with a moving (rotating) target holder.

## C Watch (and understand) what happens at higher beam currents

Lifetime curves at < $10^9$ /fill

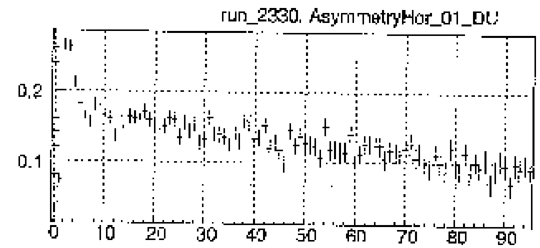
Fixed phase replay (to suppress false zero).



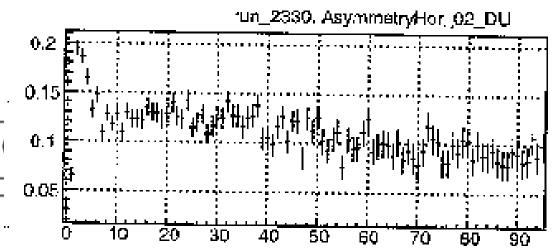

Fit to model template

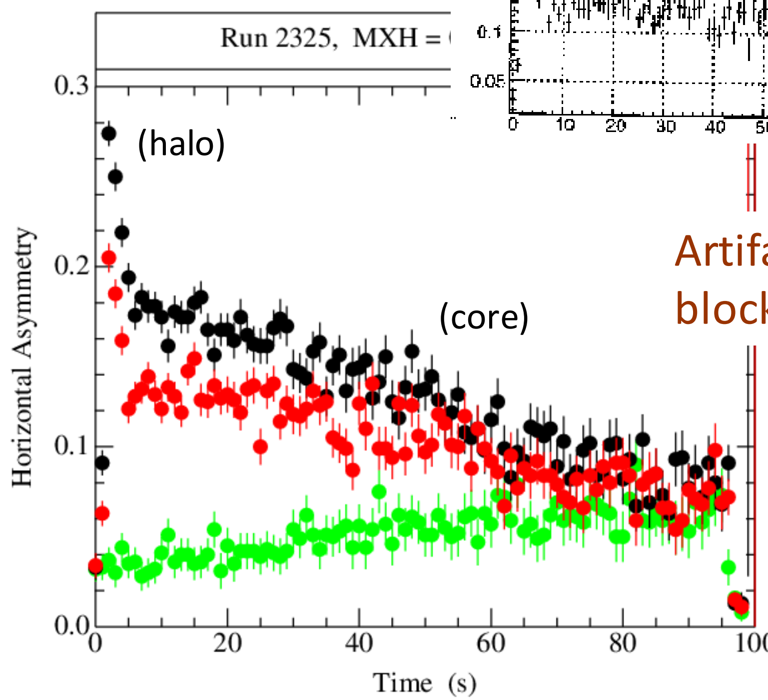
BUT…

2013 RUN
up to $10^{10}$ /fill




Double slopes

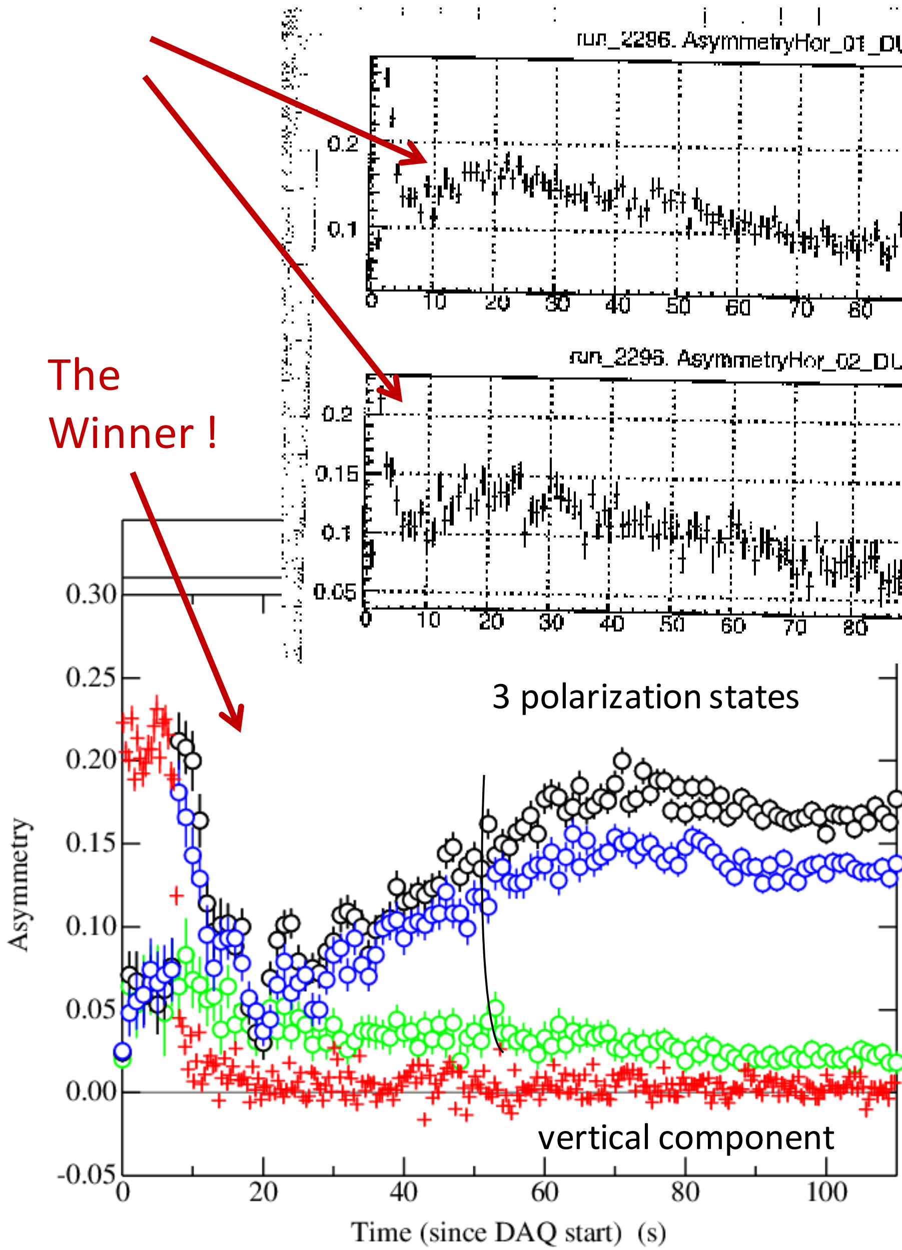


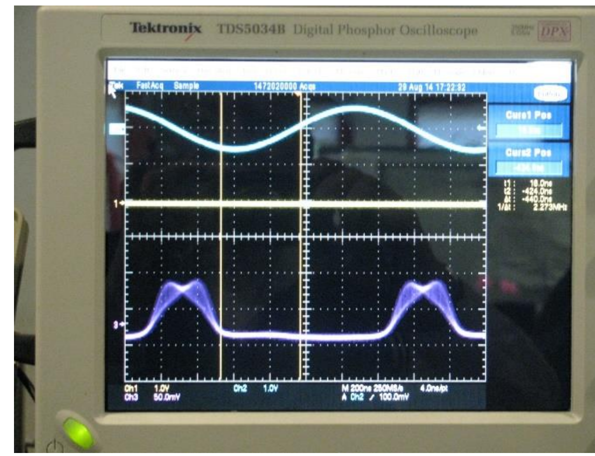

Artifact of block target?

# Polarization dips

The Winner !




We often see this accompanied by collective oscillations:




beam current monitor

## Plan:

Start with low current, good shapes.
Increase current, look for problems.
Correlate with beam changes, beam profiles, orbit changes, etc.

We request two weeks of machine time + MD.

Polarized deuterons, 0.97 GeV/c
WASA target station, WASA Forward Detector
Intensity: $3 \times 10^{8}$ to $10^{10}$ /fill

**THANK YOU**

# Extra pages

# New data acquisition procedure – time stamp every event

Count turn number (bunched beam) → distribution of turn number fraction yields beam distribution

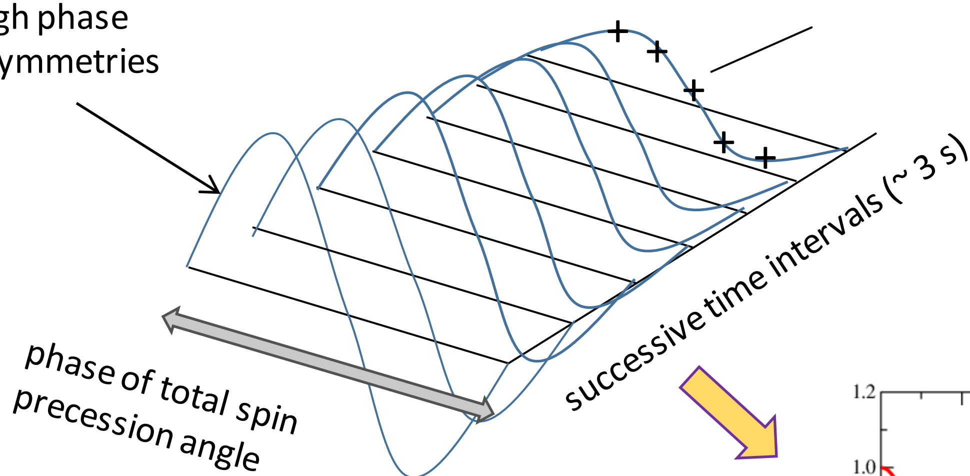
Compute total spin precession angle → based on integral part of turn number

Bin by phase around the circle

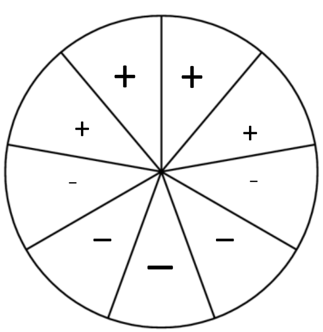
Compute asymmetry in each bin

these curves determined by asymmetry measurements for 9 angle bins

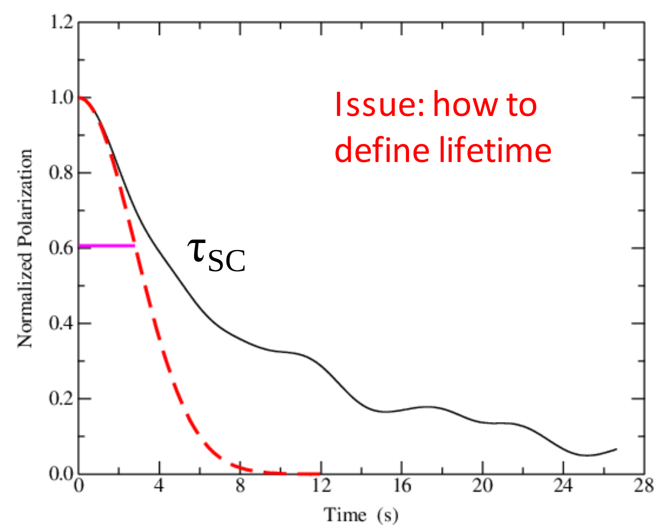
smooth curves through phase bin asymmetries




correcting phase slip from one bin to the next adjusts the spin tune



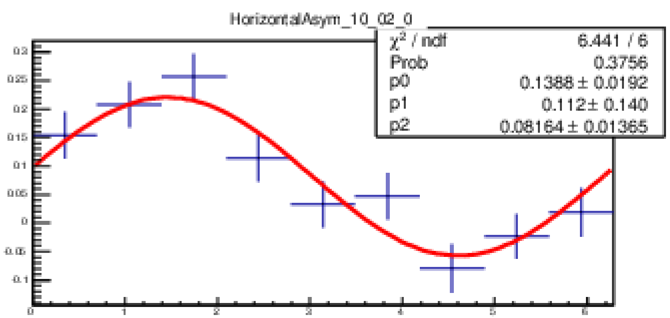
As the polarization rotates the down-up asymmetry reflects the sideways projection of the polarization.



# "POSITIVITY" PROBLEM:

Any random distribution of points fit to a sine wave with adjustable phase and offset will yield a non-zero amplitude.

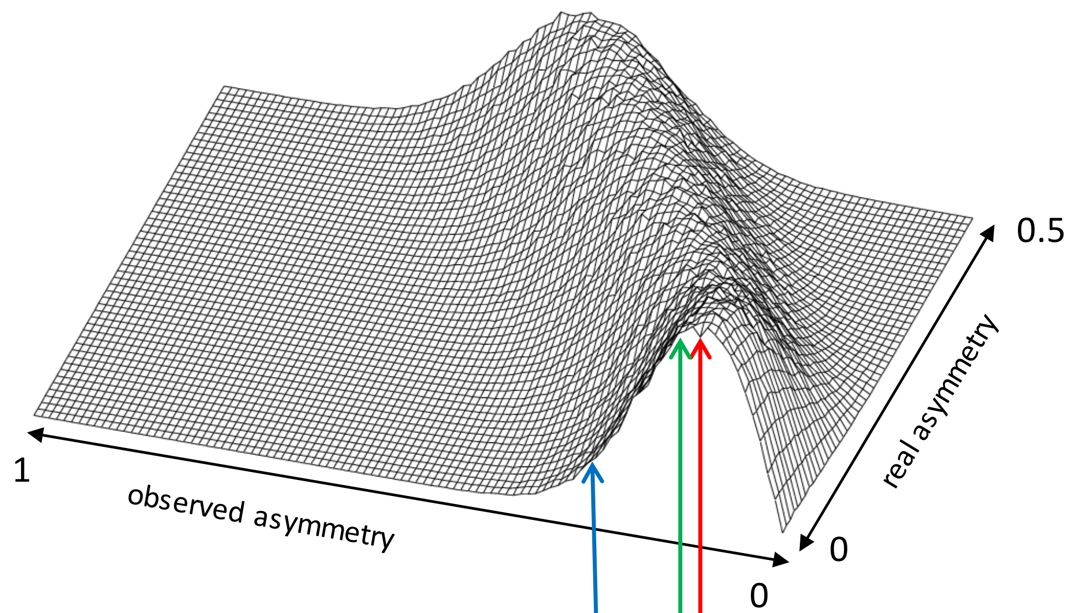
SAMPLE OF A GOOD DISTRIBUTION




You can model this (MC) by picking a typical error for the asymmetry at each point and adding (or not) some real signal to that.

PLAN: Add this effect to template.

For illustration, pick a case where the error is about the size of the typical signal.




mean = 0.14

most probable = 0.11

At ε = 0:

error = 0.25

(10 point circle average)

## As you adjust $a_1$ and $a_2$, include positivity correction.

Template:

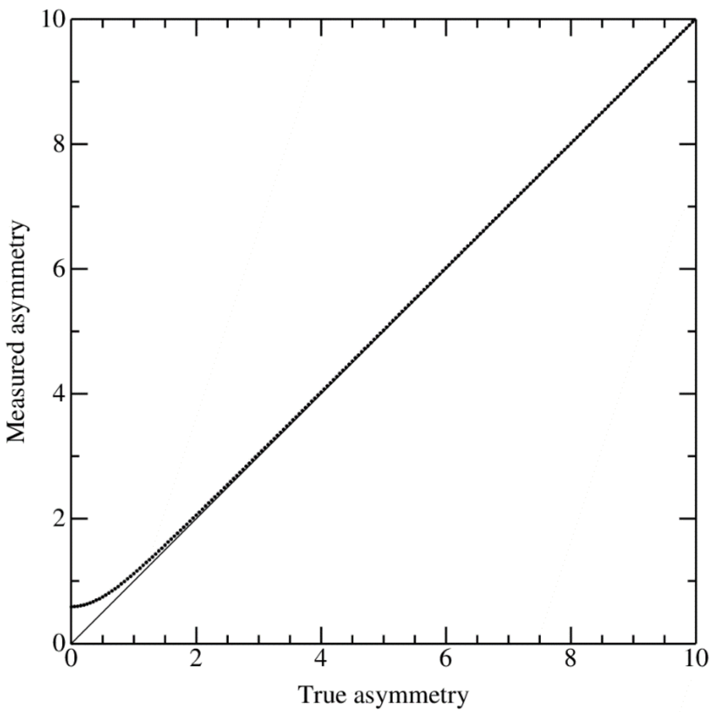
Calculated with σ = 1.

100,000 points used for each average.

(difference less than 1:1000 at ε = 0)

200 point table.

Values used from cubic spline fit.




Non-linear regression based on CURFIT from P.R. Bevington with numerical derivatives.

Run 1143:

Shape value interpolated at each data point.

Correction calculated based on σ (cycle error) deduced from individual error in average (δ).

$$\sigma = \sqrt{\frac{N_{slices} N_{cycles}}{2}}\ \delta$$

Fit made using corrected values (changed at each iteration).