Status of the $g-2$ EDM Analysis

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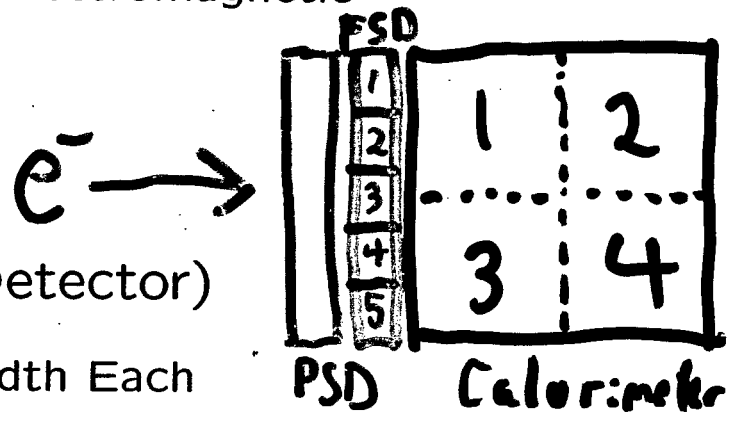
Calorimeter

- 24 Lead/Scintillating Fiber Electromagnetic Calorimeters
- Readout Through 4 PMTs



FSD (Front Scintillator Detector)

- 5 Tiles, 2.8 cm Vertical Width Each
- 1999: 6 Stations 2000-2001: 12 Stations

PSD (Position Sensitive Detector)

- Tile-Fiber Hodoscopes on 5 Stations
- 7mm Width Tiles
- 20 Vertical $\times$ 32 Horizontal Segments
- Systematic Studies

Traceback

- 4 Planes of Horizontal and Vertical Straw Tubes
- Direct Sensitivity to Electron Decay Angle

$\Delta\overline{y}$ Method

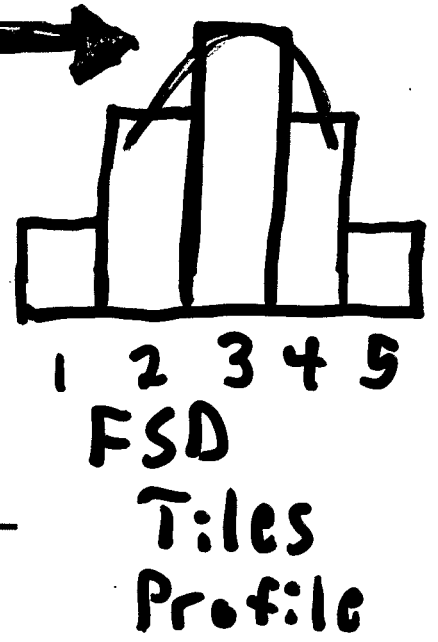
An EDM causes a vertical oscillation of the profile with the g-2 frequency, but 90° out of phase. This effect is greatest for electrons of energy 1.2-2.4 GeV. The simplest analysis method is to look at the mean of the distribution vs time in the g-2 cycle. We can use 3 tiles or all 5.

Parabolic Method

Using tiles 2-4 assume the profile is a parabola $N(y) = A(y - y_o)^2 + C$.

Solving for the peak (y_o) we obtain:

$$y_o = \frac{\Delta}{2}\frac{N_2 - N_4}{2N_3 - N_2 - N_4}$$



$\Delta\phi$ Method

An EDM would cause a difference in the phase of the g-2 oscillation from the top to the bottom of the detector.

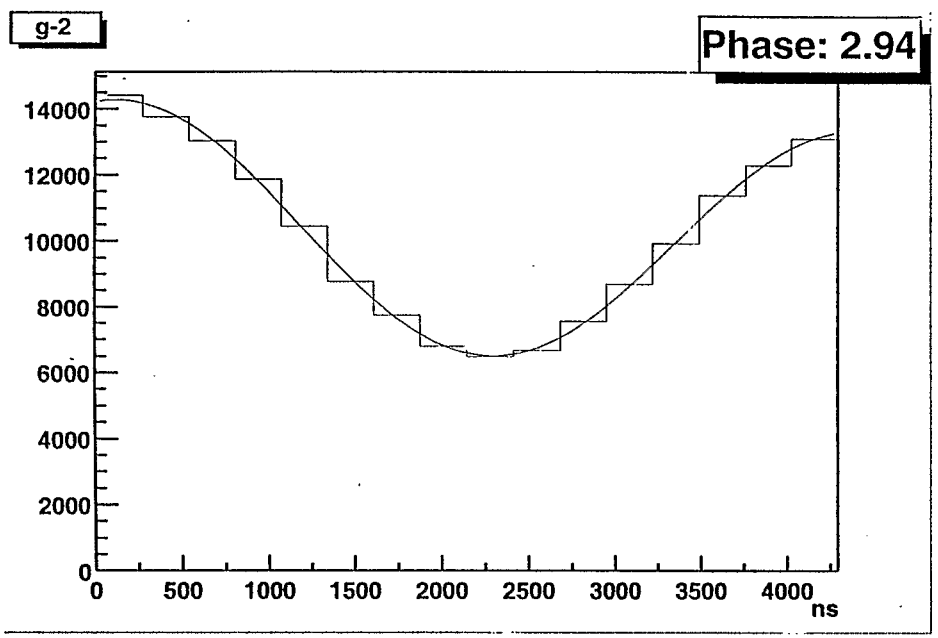
$\Delta\omega$ Method

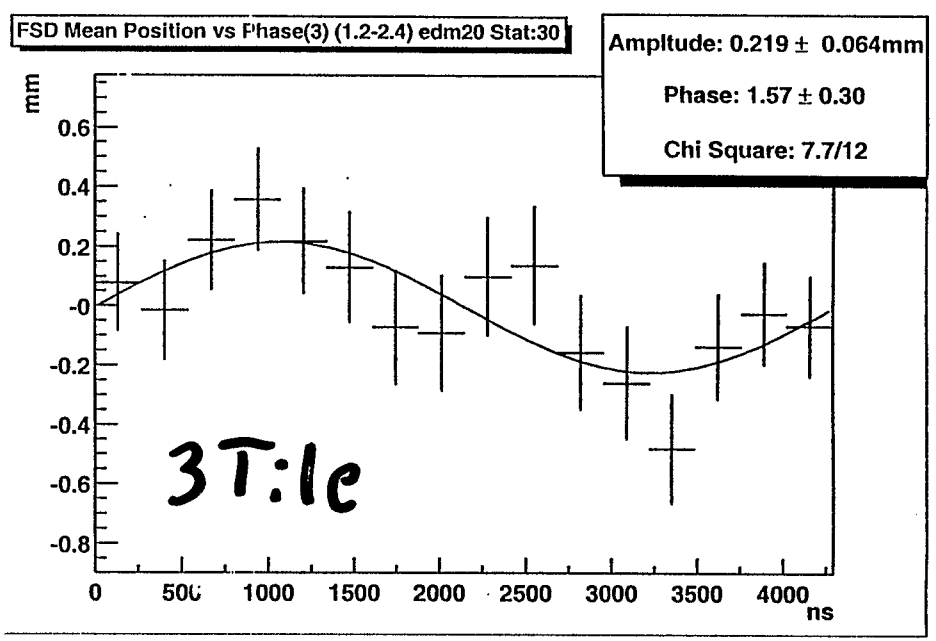
In addition to tilting the plane of precession an EDM will also change the g-2 frequency.

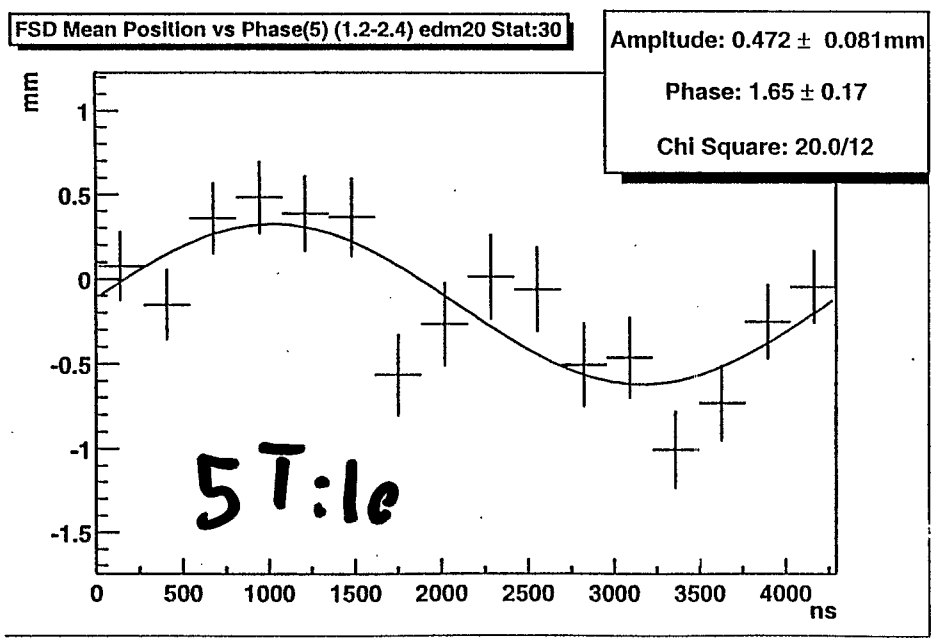
A CERN level EDM would cause a 6ppm shift in the g-2 frequency. The change in frequency scales as the square of the EDM.

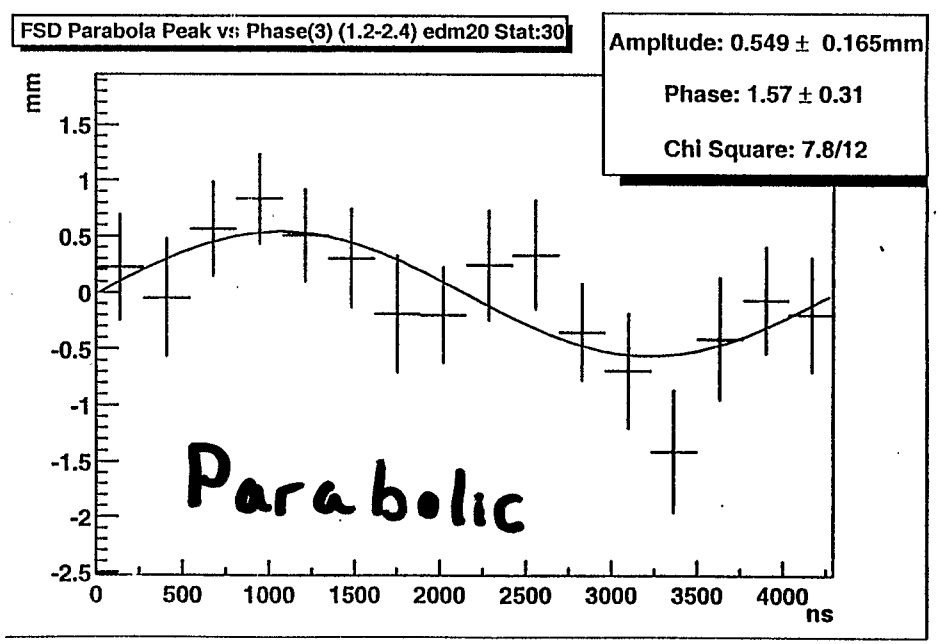
Based on the 1999 g-2 result we can place a 95% confidence level limit of 3.9×10^{-19} e-cm on the muon EDM.

GEANT Simulation: 7.4×10^{-18} e-cm EDM





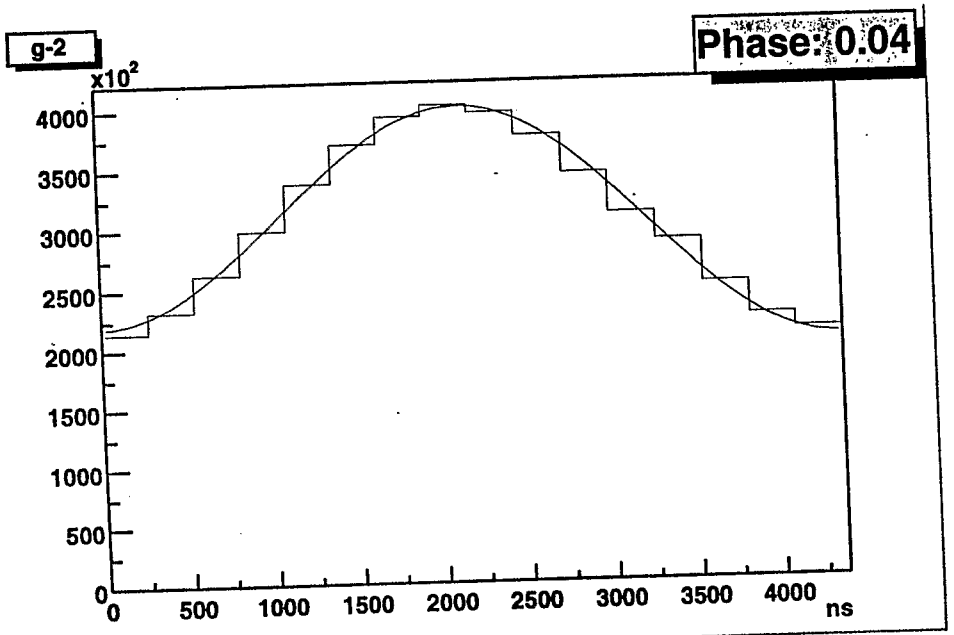


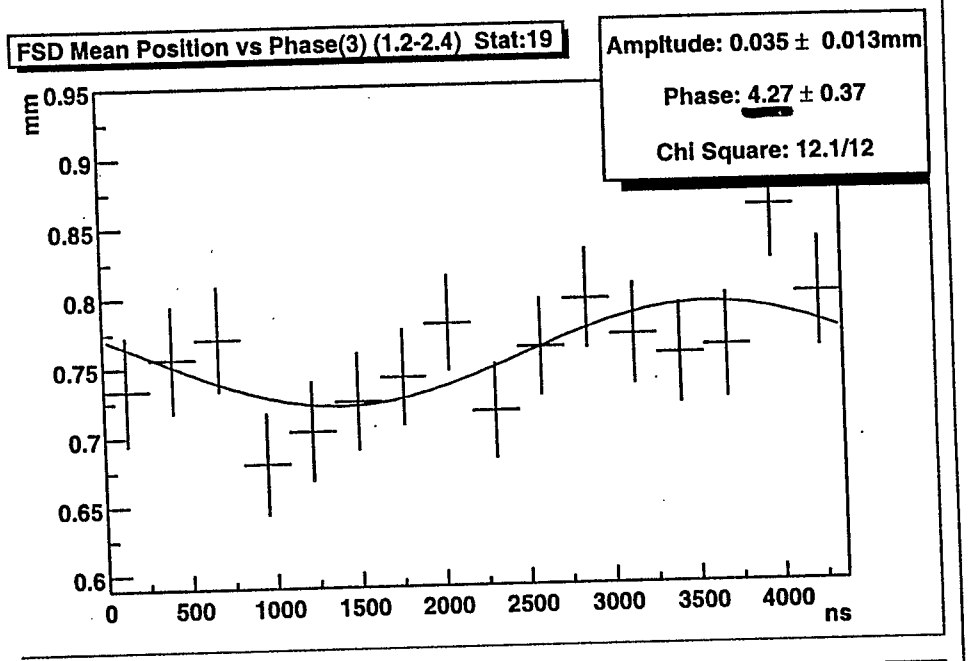


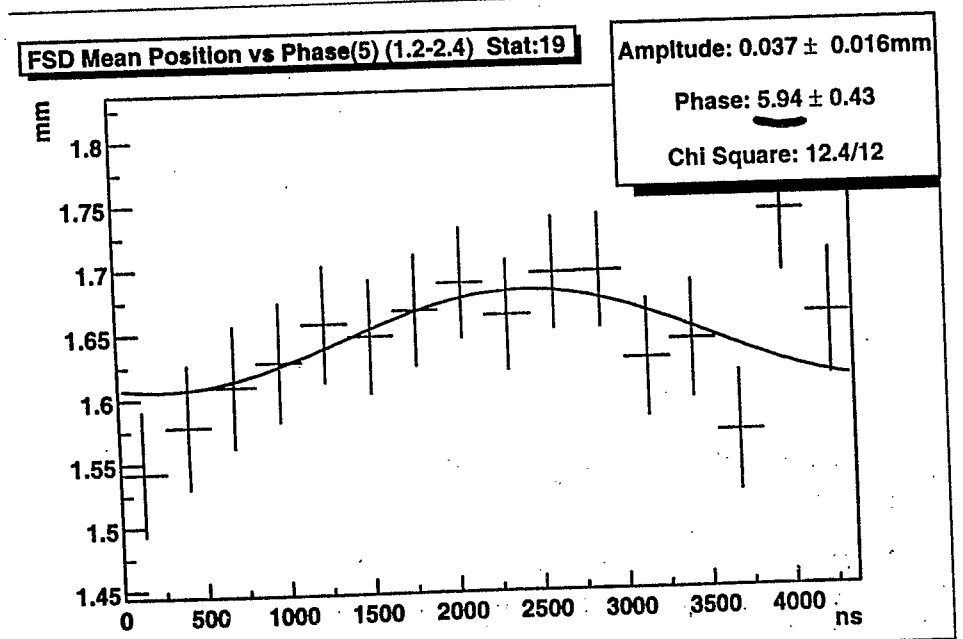
EDM Statistical Errors

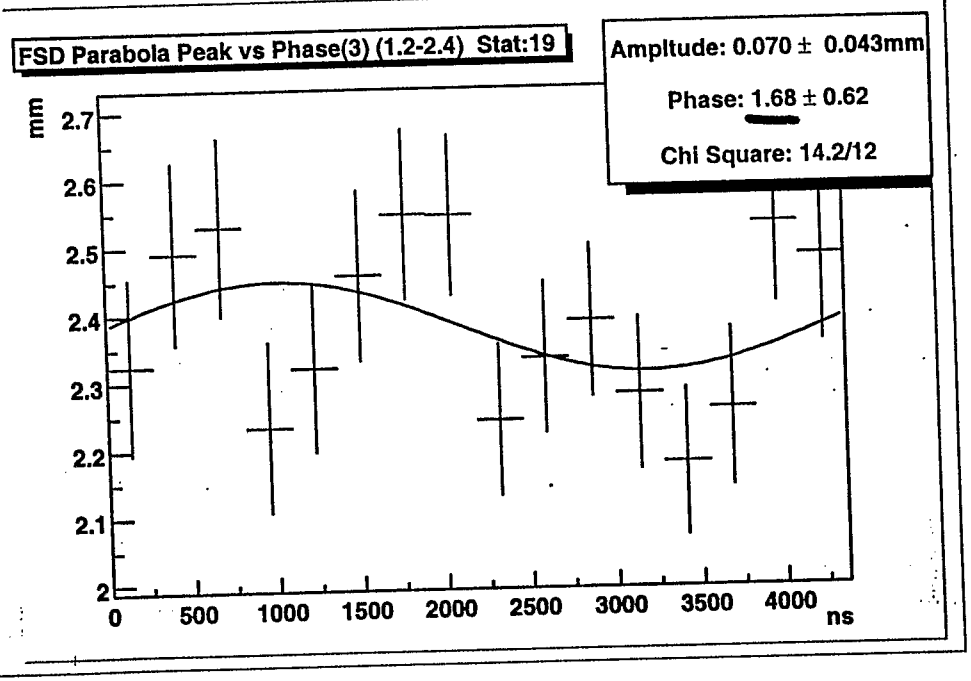
	3 Tile Mean	5 Tile Mean	Parabolic
CERN EDM	$11\mu m$	$30\mu m$	$35\mu m$
1999 Statistics	$5.5\mu m$	$6.9\mu m$	$19\mu m$
1999/CERN	1/2	1/4	1/2
2000/CERN	1/6	1/12	1/6

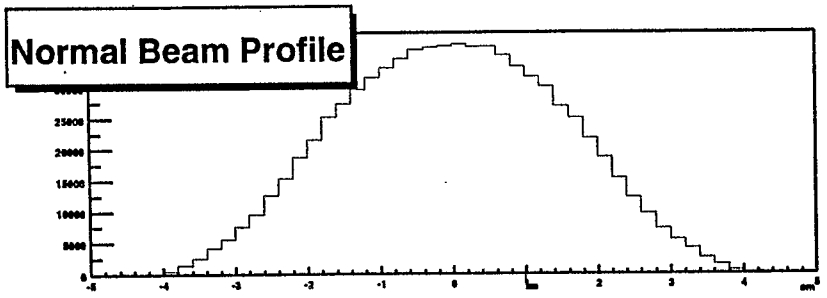
1999 Data - Station 19 preliminary

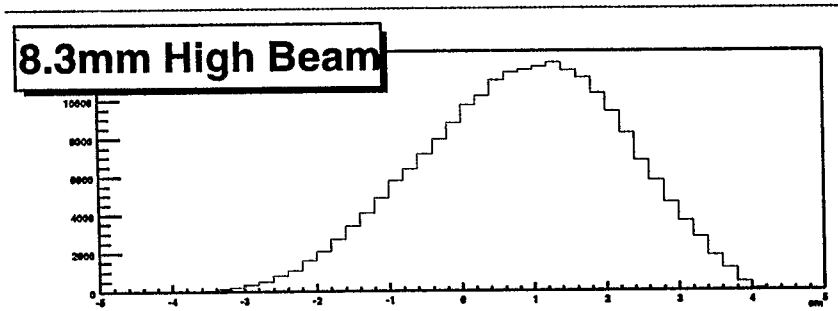


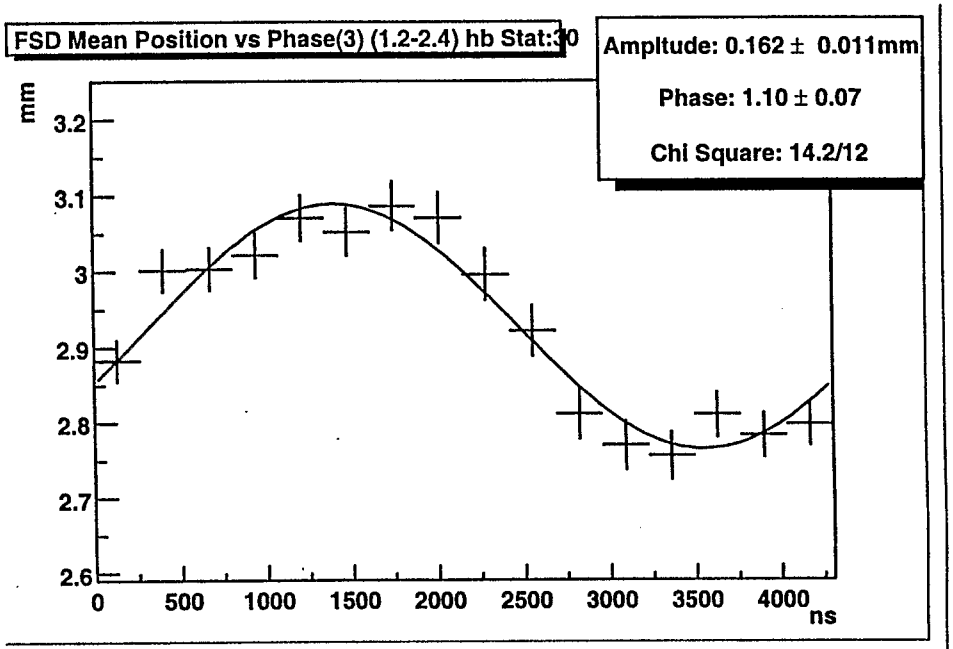


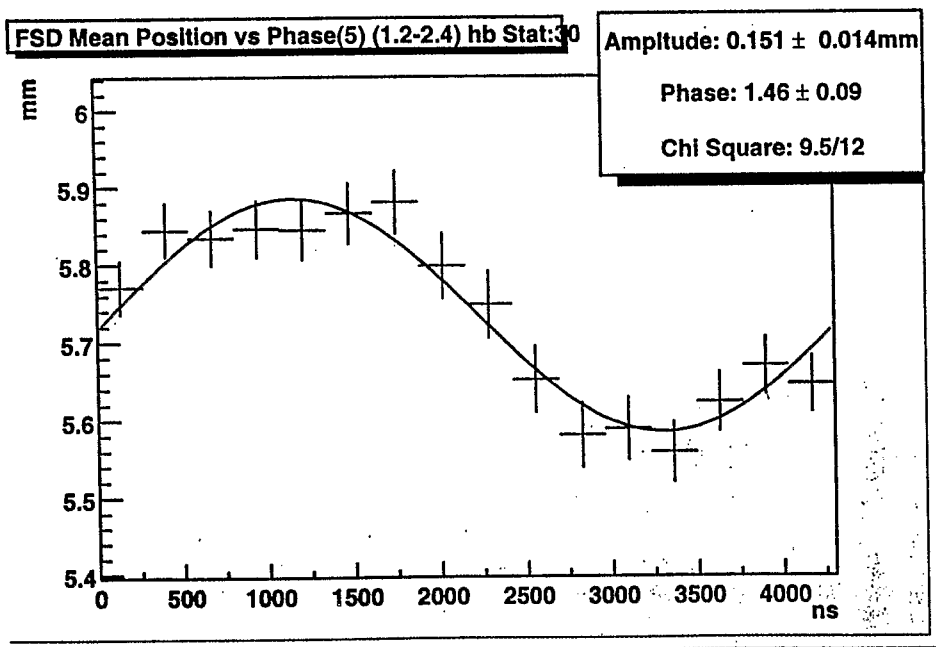


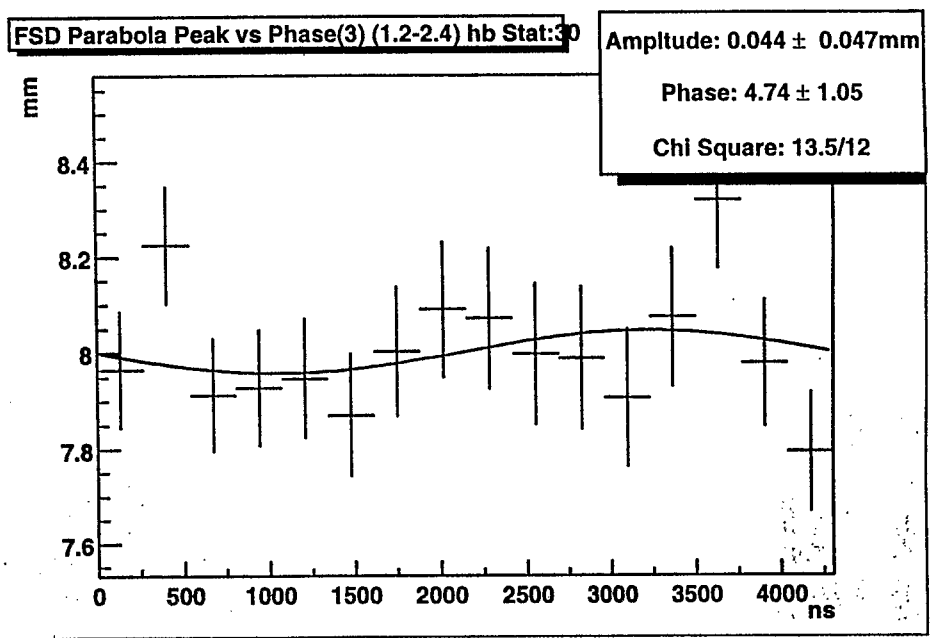



Normal Beam Profile


8.3mm High Beam

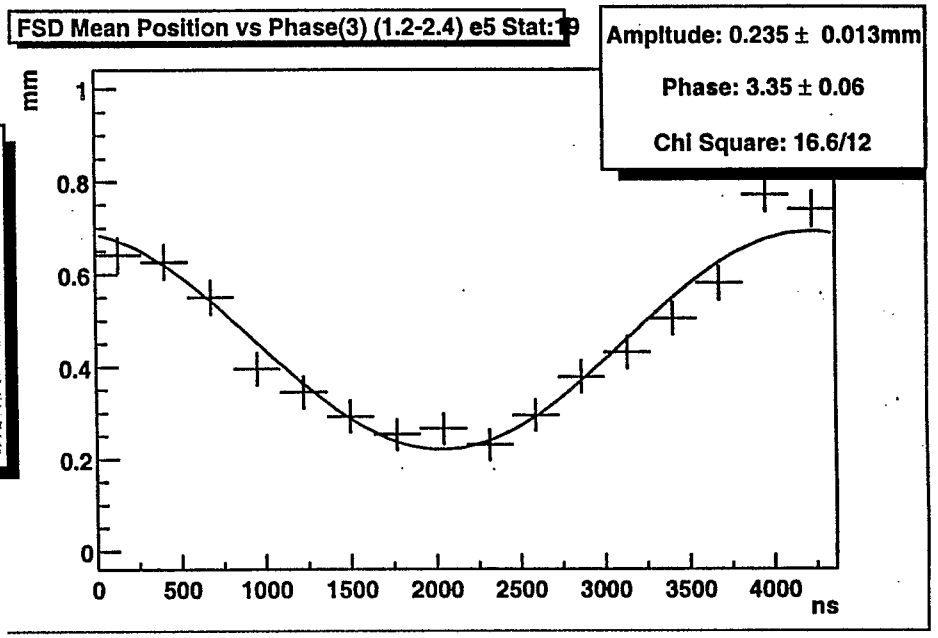

FSD Mean Position vs Phase(3) (1.2-2.4) hb Stat:30
Amplitude: 0.162 ± 0.011mm
Phase: 1.10 ± 0.07
Chi Square: 14.2/12
mm
3.2
3.1
3
2.9
2.8
2.7
2.6
0
500
1000
1500
2000
2500
3000
3500
4000
ns

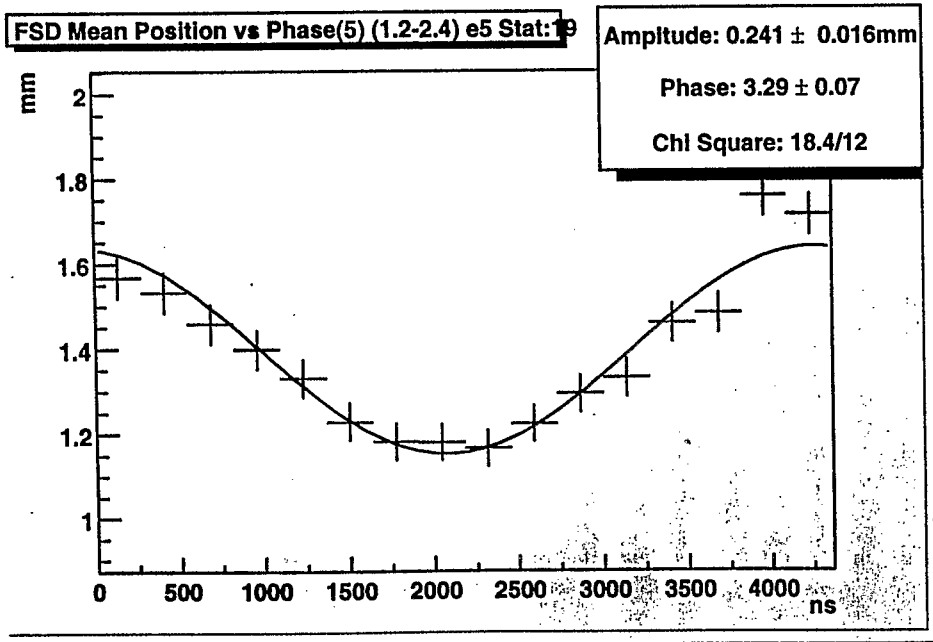

FSD Mean Position vs Phase(5) (1.2-2.4) hb Stat:30
Amplitude: 0.151 ± 0.014mm
Phase: 1.46 ± 0.09
Chi Square: 9.5/12
mm
6
5.9
5.8
5.7
5.6
5.5
5.4
0
500
1000
1500
2000
2500
3000
3500
4000
ns

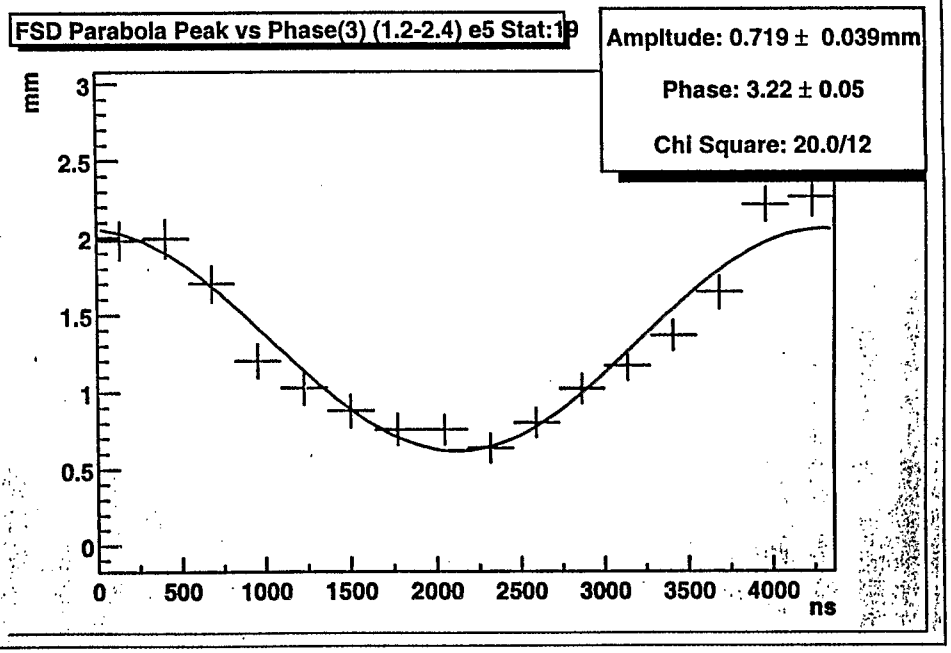

FSD Parabola Peak vs Phase(3) (1.2-2.4) hb Stat:30
Amplitude: 0.044 ± 0.047mm
Phase: 4.74 ± 1.05
Chi Square: 13.5/12
mm
8.4
8.2
8
7.8
7.6
0
500
1000
1500
2000
2500
3000
3500
4000
ns

Top/Bottom 5% Energy Miscalibration

Systematic Study on Data







Effect on Muons

A radial magnetic field can cause a tilt in the muon precession plane in the same way that an EDM would. An EDM of 3.7^{-19} e-cm causes a 3.4mrad tilt in the precession plane. We know that the average radial field in the ring is less than 40ppm of the total field. This is therefore a negligible systematic error.

Effect on Positrons

The change in the vertical position of the profile due to a radial field is approximately equal to the change in trajectory length times the angle of the field. In simulation we see a change in average trajectory length of 54mm within the g-2 cycle. From measurements the maximum radial field sampled by electrons is less than 100ppm. So maximally we have a $5.4\mu m$ systematic.

Current Levels of Systematic Errors

Amplitude of vertical oscillation expected based on estimates of various sources of systematic error. This does not account for the phase of the oscillation.

Systematic	3 Tile Mean μm	5 Tile Mean μm	Parabolic μm
Energy Calibration (1%)	47	48	143
Tilt (1°)	5.7	8.7	20
Detector/Beam Alignment (2mm)	40	38	<12
Tile Eff. (1%)	< 1	< 1	19
Timing Offset ($1ns$)	2.0	2.7	5.4
Radial B Field ($100ppm$)	1.9	5.4	5.4
CERN EDM	11	30	35

Outlook for Improving Systematics

Top/Bottom Energy Scale

- 12 independent detectors.
- Out of phase with EDM.
- Instead of linear fit to spectrum, fit to Asymmetry vs Energy.

Detector/Beam Alignment

- Parabolic method much less sensitive than mean.
- CBO causes similar effect.

Tile Efficiencies

- 12 independent detectors.
- Better estimate using the calorimeter top/bottom segmentation.
- Tiles were in WFDs for part of the run in 2000 and 2001
- Mean much less sensitive than parabolic method.

Outlook for Improving Systematics

Detector Tilt

- 12 independent detectors.
- Use high energy electrons (insensitive to EDM).
- Partially out of phase with EDM.

Timing Difference

- Use cyclotron motion of early beam (before debunching) to get better relative timing.

Radial Magnetic Field

- Use high energy electrons (insensitive to EDM).
- Use CBO, which also causes changes in drift distance.
- MC studies.

Conclusions

- Several large sources of systematic error to be dealt with.
- Not statistics limited.
- I believe that a Muon EDM measurement 3-4 times better than CERN is possible.