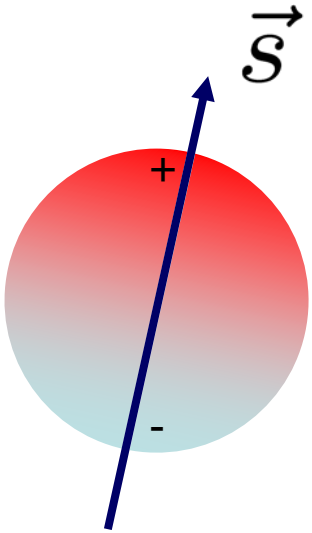
The Proton EDM: the single ring option



Yannis Semertzidis, BNL
APEX meeting, Nov 12, 2009

Electric Dipole Moments: P and T-violating when $\vec{d}$// to spin

$$\vec{\mu} = g\left(\frac{q}{2m}\right)\vec{s},$$

$$\vec{d} = \eta\left(\frac{q}{2mc}\right)\vec{s}$$

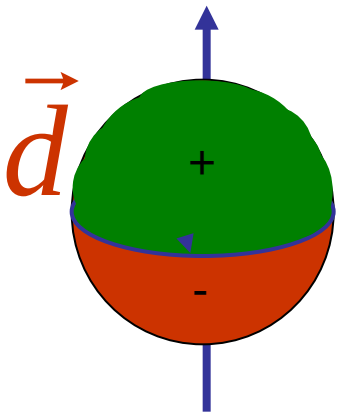
$$\mathcal{H} = -\vec{\mu}\cdot\vec{B} - \vec{d}\cdot\vec{E}$$

	$\vec{E}$	$\vec{B}$	$\vec{\mu}$ or $\vec{d}$
P	$-$	$+$	$+$
C	$-$	$-$	$-$
T	$+$	$-$	$-$

T-violation (under CPT conservation) implies CP-violation, which is needed to explain why matter is dominating over anti-matter in our universe

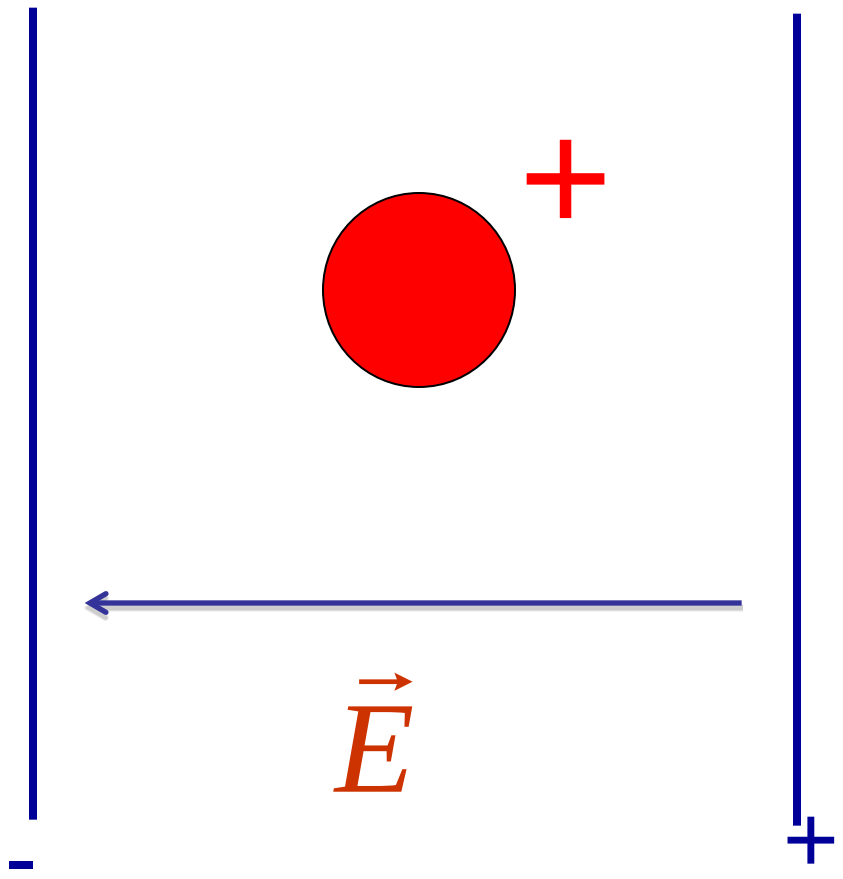
The Electric Dipole Moment precesses in an Electric field

The EDM vector *d* is along the particle spin direction

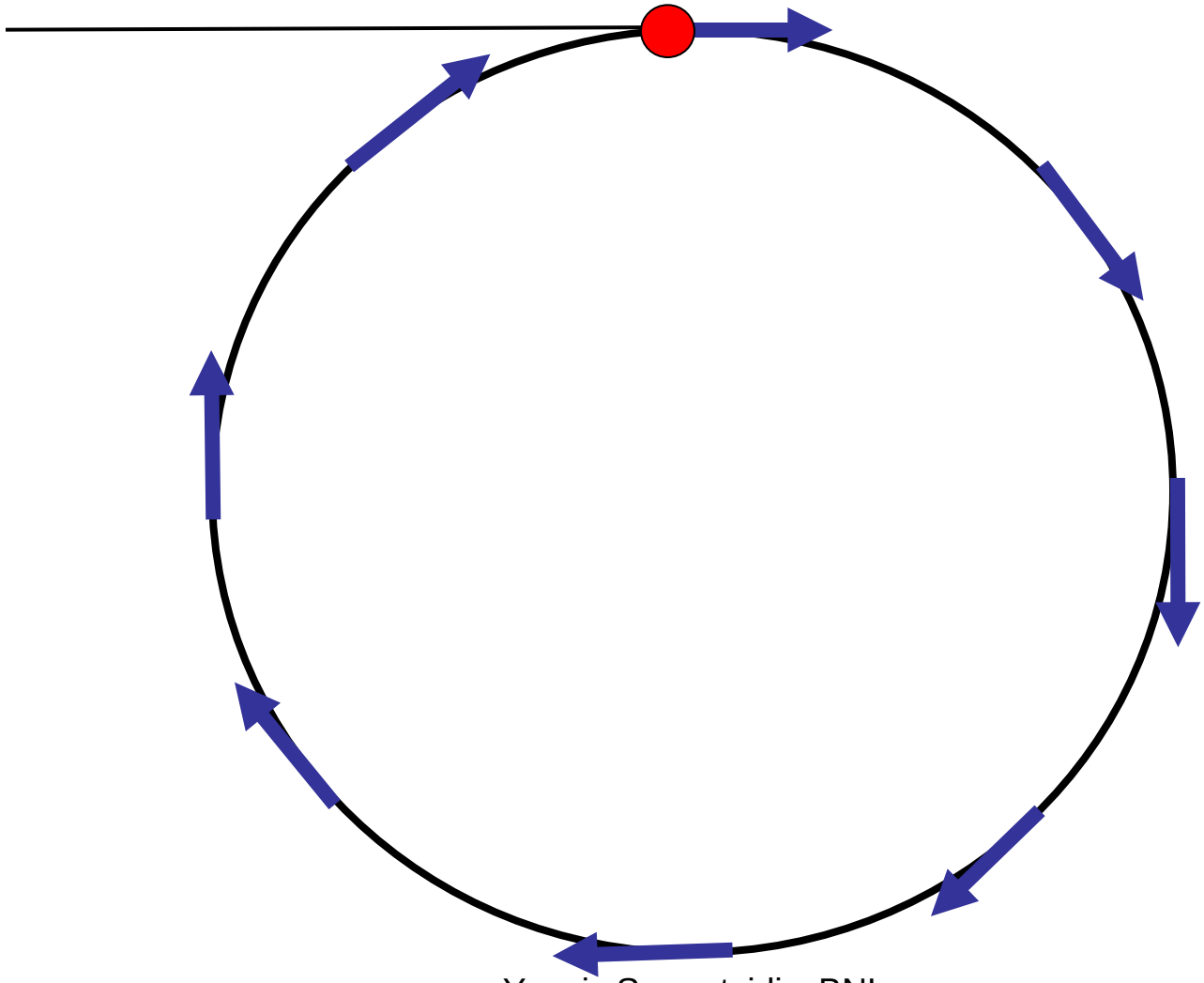


$$\frac{d\vec{s}}{dt} = \vec{d} \times \vec{E}$$

A charged particle between Electric Field plates would be lost right away…



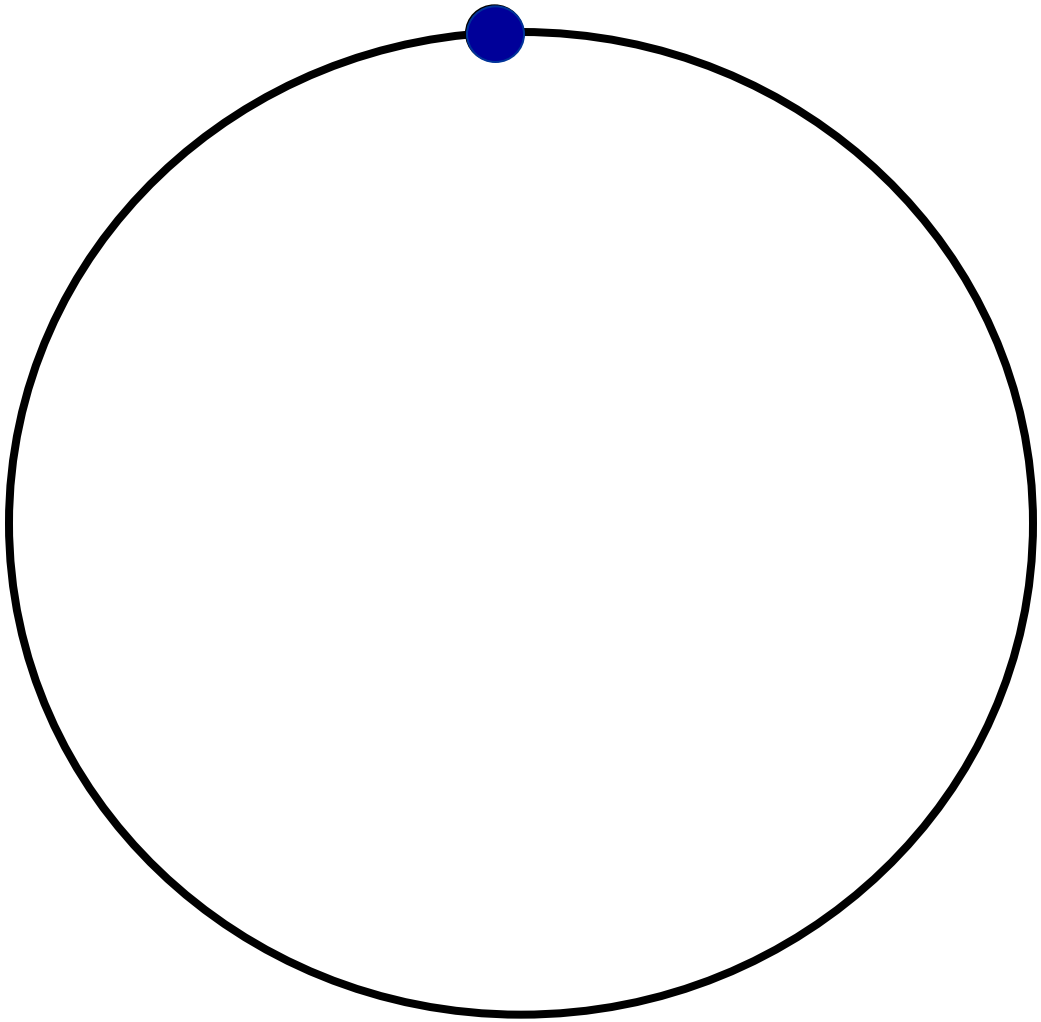
…but can be kept in a storage ring for a long time



For systematic error considerations we need CW & CCW beam storage. Certain (main) systematic errors easier to handle if CW & CCW is done at the same time (collision beams: CBS)

In a ring with Electric field bending it is possible to store protons CW & CCW at the <u>same time in the same place</u>

CW and CCW injections



Proton EDM parameters during storage

1. Proton EDM with a statistical goal of 10^{-29} e cm within ~1year.
2. Proton momentum 0.7 GeV/c, kinetic energy: 232 Mev, beta~0.6.
3. Two simultaneously counter-rotating beams in one ring (same place).
4. 2×10^{10} particles per CW and CCW
5. Injected with vertical polarization in one bunch. The bunch is captured by barrier buckets and first it is split into two bunches with opposite polarization using an RF-dipole magnet. Then they split into many bunches with a 0.5-2 GHz RF cavity (frequency to be defined).
6. We will have resonant cavities as BPMs as well as striplines and/or buttons for position monitoring.
7. The focusing in the EDM ring is going to be either magnetic or electric but not mixed. The systematic errors are very different. After the R&D period we will decide the electric or magnetic focusing for the experiment.

For this option to work the two beams need to highly overlap

- The overlap needs to be monitored with BPMs each with *relative* beam-position resolution of <10nm and 1 Hz BW.
- Issue for absolute beam position resolution is mechanical and temperature stability. This issue goes away when requiring only the relative beam position.

We request beam time at RHIC and use BPMs at an intersection point

- We need to observe the signals with single beam present and compare them to those with both counter-rotating beams present.

- Under certain conditions the signal from the counter-rotating beams cancel, potentially improving the dynamic range of the system.

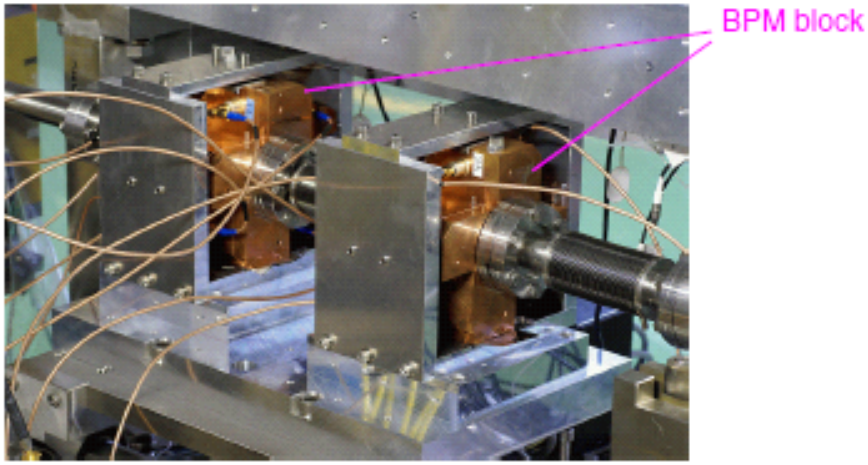
Motivation (Peter Cameron's slide)

- pEDM Coincident Beam Scheme (CBS) requires
  - one picometer measurement of relative positions of the two beams
  - with a bandwidth of one year
  - see BNL pEDM web site for further details
- This can be accomplished with (obsolete, cumbersome, and expensive) COTS electronics (Libera Brilliance)
- We want to get to 1pm in the first month, refine the experiment from there
- In principle, and as the problem is presently understood, this can be accomplished
- Development effort for pickups and electronics is underway
- As a first step in exploring possible unknown systematics of the measurement we propose an APEX experiment

(Peter Cameron's slide)

Beam Experiment Title:	pEDM position monitoring
Spokesperson(s):	Y. Semertzidis
Status:	proposed
Team:	Y. Semertzidis et.al
Experiment Goal:	1. Demonstrate viability of pEDM position measurement 2. Explore measurement systematics
Benefits:	Strengthens viability of CBS pEDM proposal
Experiment Description:	1. At injection, beam in both rings. 2. RF phase is shifted to bring beams into collision in the sector 2 DX BPM adjacent to IP2. 3. Beam steering and RF phase are varied in small increments. 4. Data taken in time domain with scope and frequency domain with FFT box, as well as RHIC BPMs.
Resources:	
Instrumentation:	BPMs, Fast scope and FFT box
Application:	The usual Apps for each system
Time:	4 periods of 2 hrs each at injection Prefer consecutive weeks early in the run
Personnel:	Team + MCR personnel
Intentional Beam Loss?	no
Plan for Data Analysis:	Partial on-line, the balance completed within 1 week

Prior work



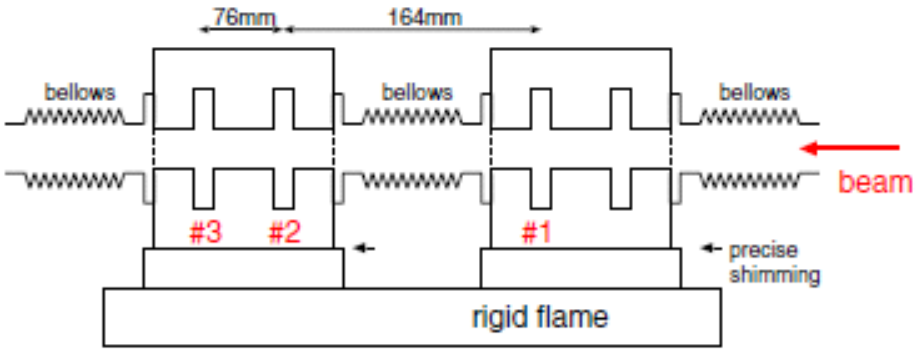


FIG. 6. (Color) BPM support system installed in the beam line. Two blocks were rigidly mounted in the system. The three cavities named 1, 2, and 3 were used in this test. Distances between cavities were 164 and 76 mm. They determine the geometrical factor that appears in the resolution analysis to be 0.799.

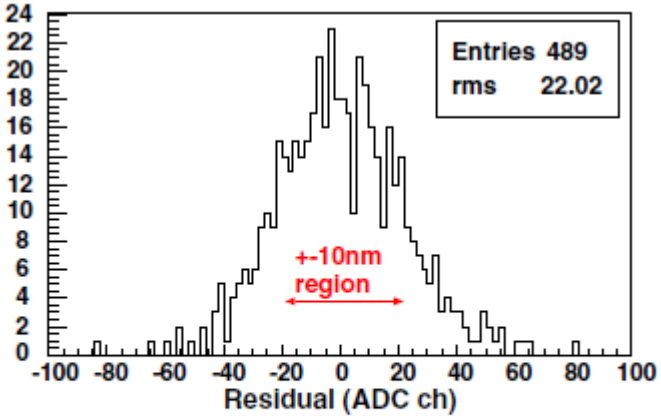


FIG. 17. (Color) Resolution measurement data. The top figure shows a scatter plot of the prediction and measurement. The bottom figure is the distribution of the residual of the prediction.

PRST , Accel & Beams, 11, 062801 (2008).
Achieved res. ~8nm per ~10^10 electrons/bunch

Summary

- The success of the proton EDM experiment hangs on our ability to develop BPMs with a relative position resolution better than 10 nm for 1 Hz BW.
- We need to develop experience with monitoring counter-rotating beams at a collision point in RHIC.

- At 10^{-29} e-cm the proton EDM experiment will have the best sensitivity for beyond the SM CP-violation.