Difference of measured proton and He3 EDMs: a reduced systematics test of T−reversal invariance

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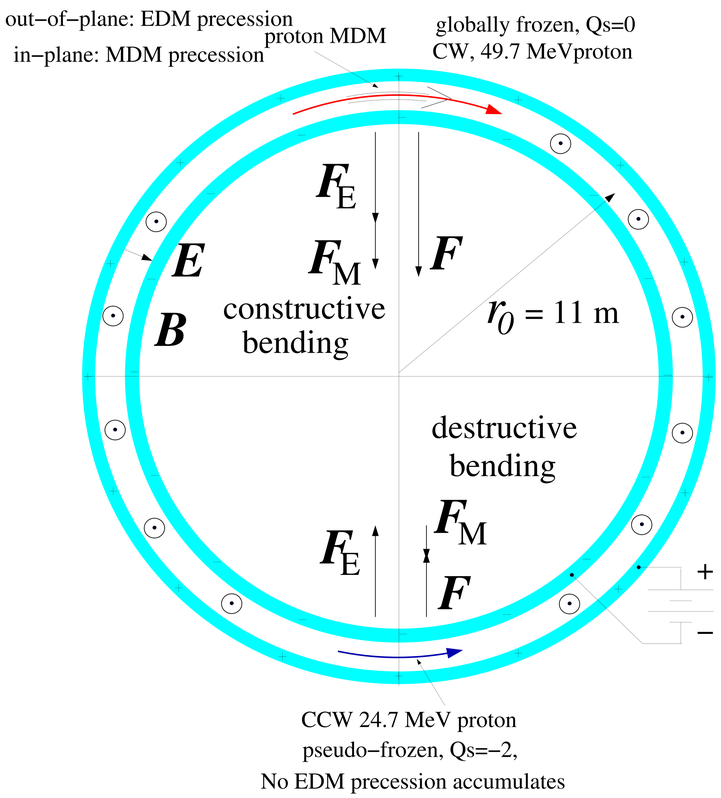
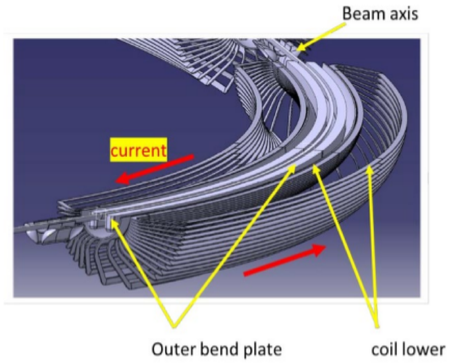
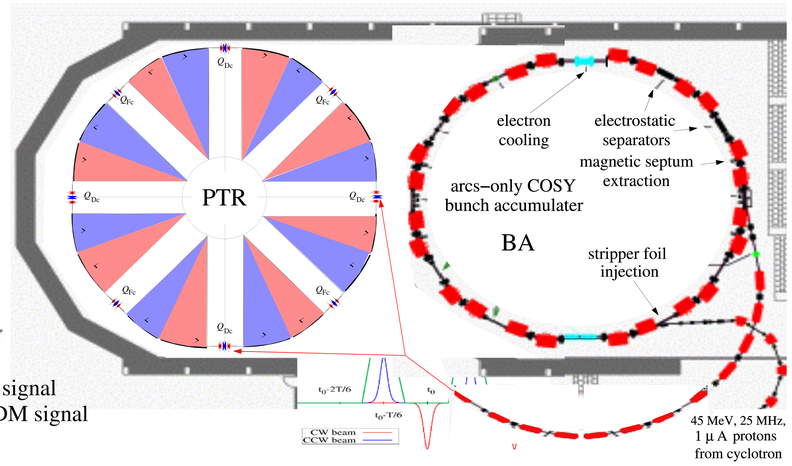
1. Simultaneous counter−circulating, frozen spin proton beams in MDM comparator ring PTR



2. Proposed proton EDM Prototype; COSY, Juelich, Germany



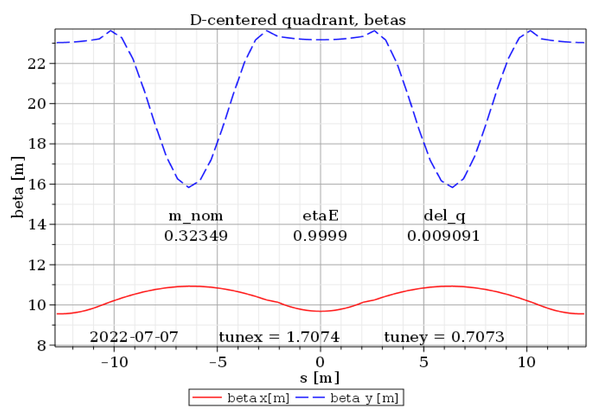


Toroidal two−way frozen spin storage ring
CW: 49.7 MeV "magic", Qs=0, protons, EDM signal
CCW 24.7 MeV pseudo−frozen, Qs=−2, no EDM signal

Table 1. PTR and COSY-arcs-only bunch accumulator (BA) parameters.

file name	variable name	unit	BA COSY-arcs-only	PTR
circumference	circum	m	102.250	102.250
bend radius	r0	m		11.0
E field., 30 MeV proton.	E	MV/m		5.370
long straight length	llsnom	m		4.142
totol available straight	16×llsh	m		32
electrodes/quadrant				4
bend/electrode	Thetah	radian		$2\pi/16$
electrode length	Leh	m		4.32
PTR stored p's no BA				0.6×10^7
COSY-arcs-only BA			0.6×10^{11}	0.6×10^{11}
min/max horizontal beta	β_x	m		9.60/10.83
min/max vertical beta	β_y	m		16.6/24.8
horizontal tune	Q_x			1.726
vertical tune	Q_y			0.673

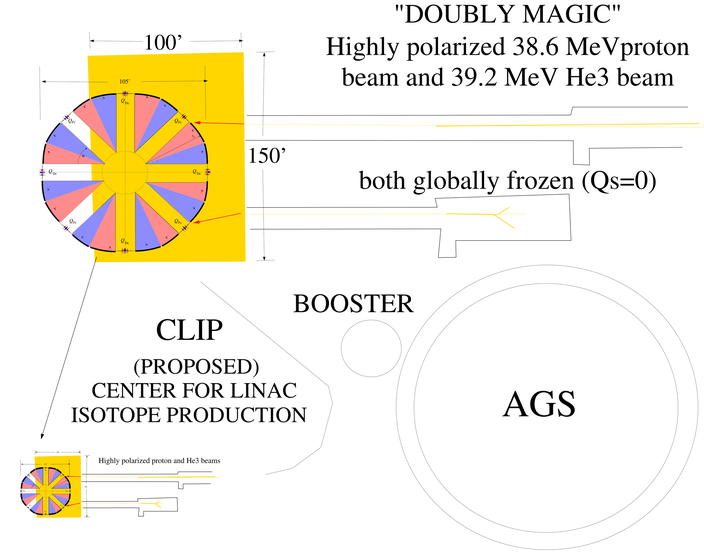
3. Distortion−free, Quadrupole−free, Doubly−magic, Two−way Tororoidal Optics



TOROIDAL OPTICS cancels distortion
Sum−resonance round beams
"Identical" forward/backward optics
Vert. exact, Horz. approximate
All spin decoherence modes cancelled
Long SCT
Discrete quads "not allowed"

4. Proposed proton, He3 EDM difference measurement at BNL

"DOUBLY MAGIC"
Highly polarized 38.6 MeVproton beam and 39.2 MeV He3 beam



The dominant systematic error cancels in the difference EDM[proton] − EDM[He3]

5. Cancellation of Systematic Error

EDM signature: out−of−plane MDM precession
Dominant systematic errorEDM−mimicks precession
only approximately cancelled by CW, CCW match
For the proton, He3 case: Measure the difference
Δ = EDM[proton] − EDM[He3].
Systematic error cancels.
NON−ZERO Δ IMPLIES BSM PHYSICS

6. Gyroscopic Phase−lockedCW/CCW reversal

Reversing CW/CCW requires reversing B−field
Setting, reversing, and resetting B−field
with frequency domain accuracy relies only on
MDM's acting as magneto−sensing gyroscopes
This avoids need for (unachievably precise)
magnetic field measurement
while allowing systematic error reduction
averaging over CW/CCW reversal

7. Counting Statistics

Run length = nominal week = 2x10^5 seconds
$\sigma_{stat} = +/- 10^{-29}$ e cm, in all cases
i.e. counting statistics error can "always" be neglected
for runs of one week or longer

8. Systematic Error

run sequencing	consecutive	concurrent	concurrent	Δ
	singly magic	singly magic	doubly magic	*p*-He3
	$\pm\sigma_{syst.}$	$\pm\sigma_{syst.}$	$\pm\sigma_{syst.}$	difference
	e cm	*e* cm	*e* cm	*e* cm
single run	10^{-26}	10^{-27}	10^{-28}	
polarization reversal	0.5×10^{-26}	0.5×10^{-27}	0.5×10^{-28}	
CW/CCW reversal	10^{-27}	10^{-28}	10^{-29}	$< 10^{-29}$

\href{https://github.com/jtalman/ual1/tree/master/examples/lattices}{Click Here}