Why we should do the deuteron Resonance EDM experiment at BNL

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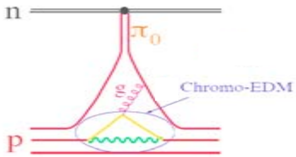
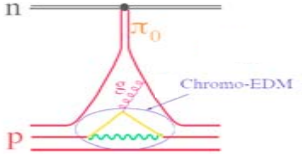
- Why BNL? It's the physics!
- Physics of Hadronic EDMs
- Experimental Technique
- Systematic errors
- Schedule/Summary



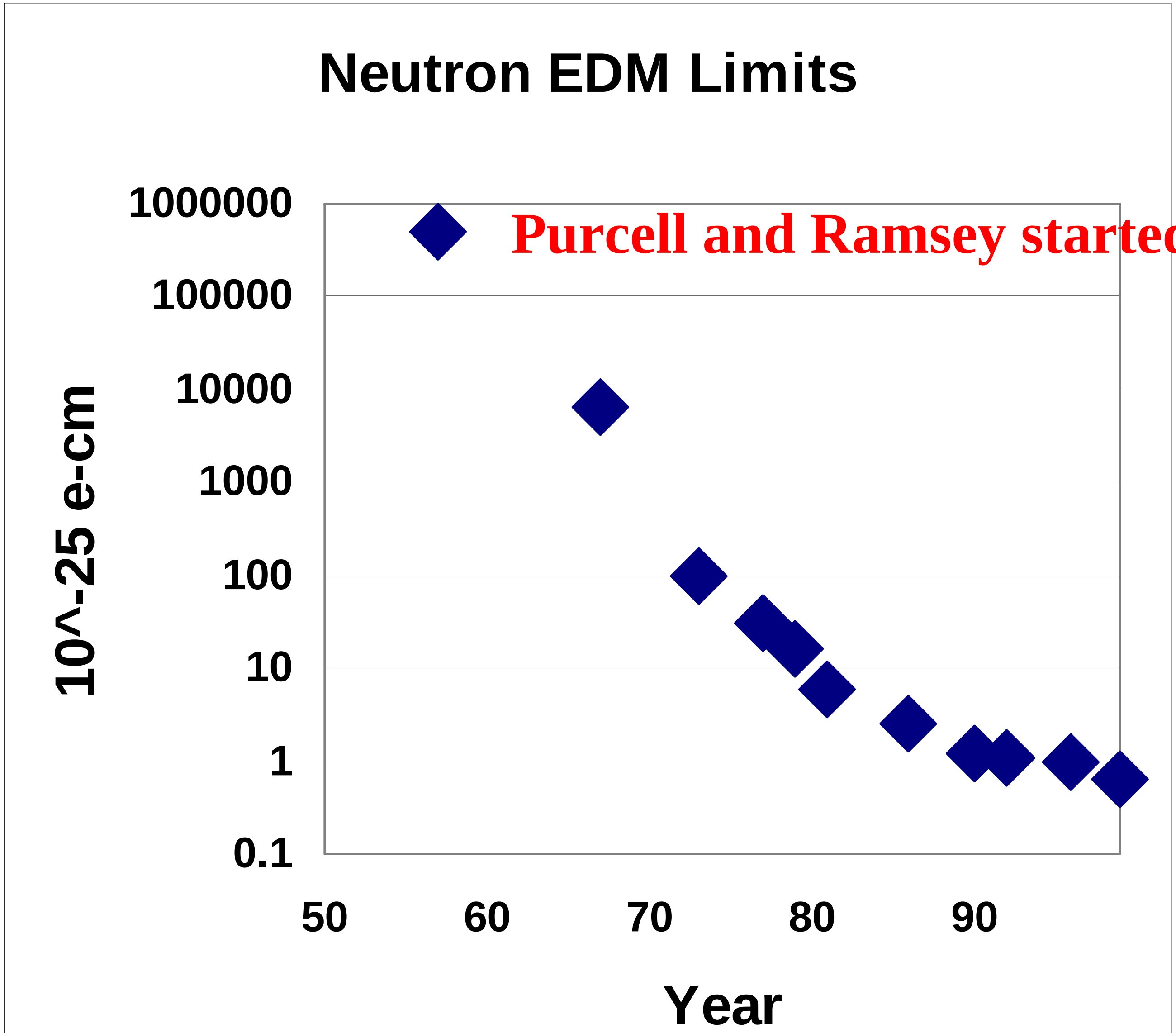
Resonance Electric Dipole Moment

- D @ 10^{-29} e·cm would be the best EDM sensitivity over *present* or *planned* experiments for θ_{QCD}, quark, and quark-chromo (T-odd Nuclear Forces) EDMs.

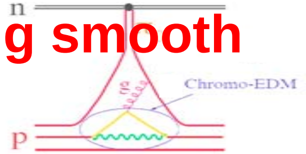
- D, P, ^{3}He, etc., i.e. a facility to pin down the CP-violation source.



Neutron EDM Vs Year



"…at 6 x 10^{-26} e cm, it is analogous to the Earth's surface being smooth and symmetric to less than 1 μm" (John Ellis).

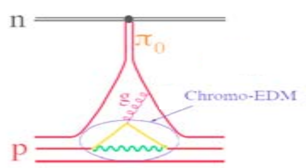


neutron EDM exps in preparation

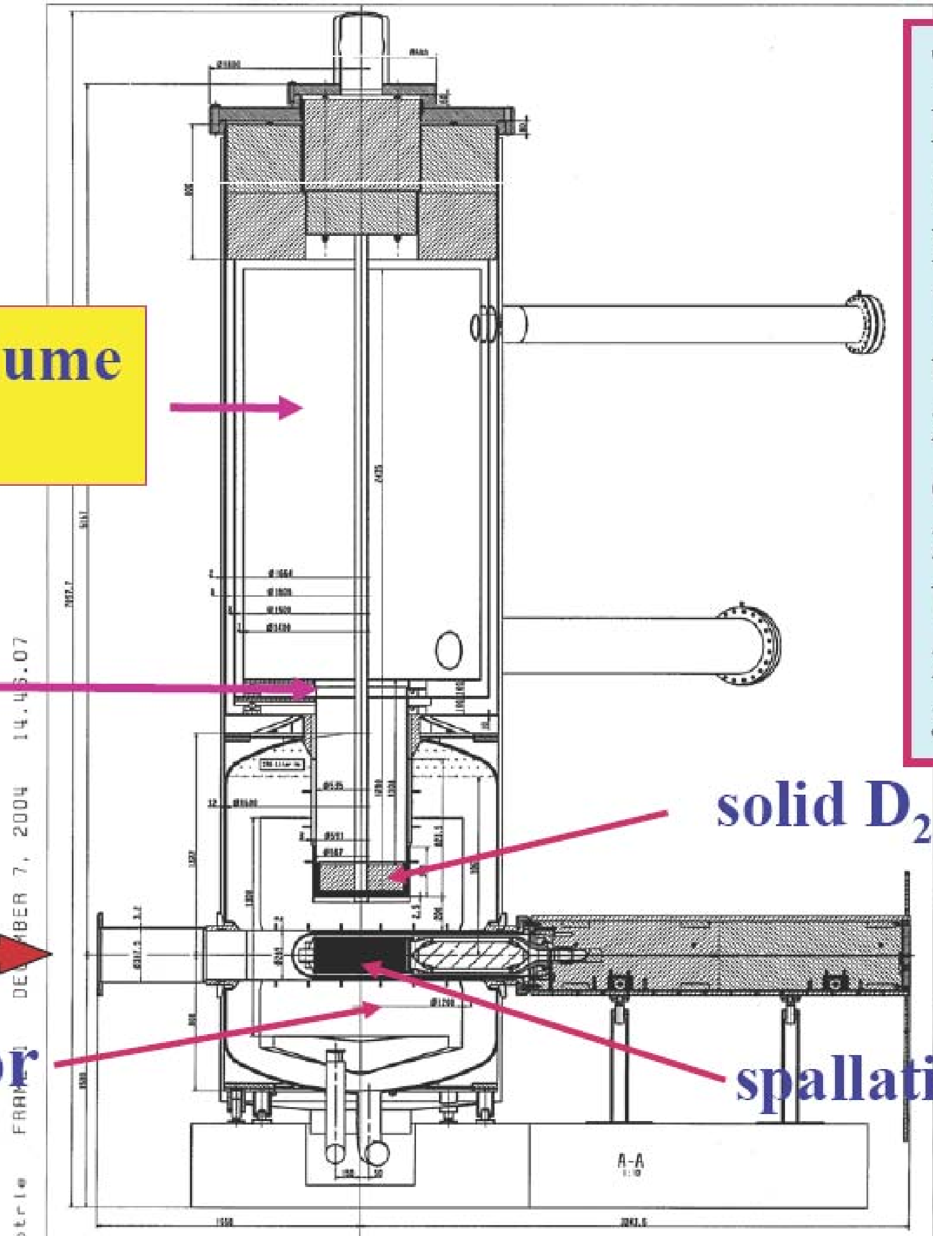
- UCN at PSI: Ramsey's method of separated oscillatory fields. First goal 1×10^{-27}e·cm, begin data taking ~2008.

- UCN at ILL (Sussex, RAL,…): Ramsey's method of separated oscillatory fields. Goal 2×10^{-28}e·cm/year, begin data taking 2009.

- Ultra-Cold Neutrons (UCN), at SNS (LANL,…): Polarized ^{3}He stored together in a superfluid ^{4}He. Goal 1×10^{-28} e·cm, begin data taking ~2011.



UCN tank system (5 m high)

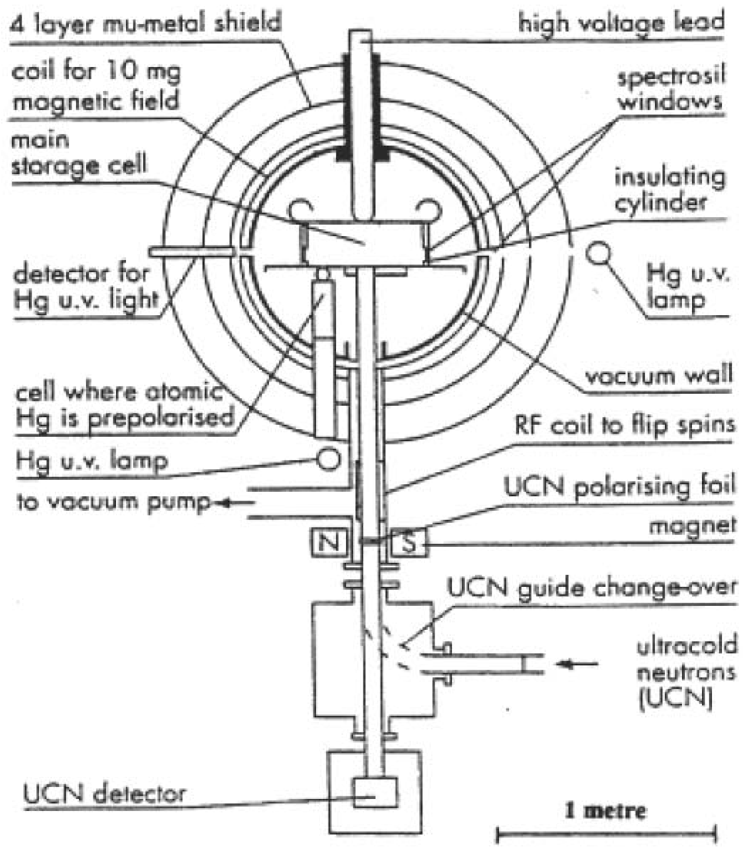


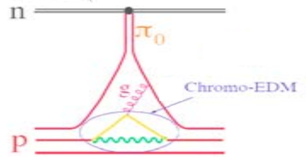
T_p = 600MeV
I_p = 2mA
10n/p
Per pulse:
10^{17}p $\rightarrow 10^{18}$n
thermal flux:
$2 \cdot 10^{14}$ s^{-1} cm^{-2}
cold flux:
$2 \cdot 10^{13}$ s^{-1} cm^{-2}
UCN:
$2 \cdot 10^{5}$ s^{-1} cm^{-3}
$3 \cdot 10^{3}$ cm^{-3} stored

UCN experiment at ILL:

Expect a factor of ~100 improvement in sensitivity due to

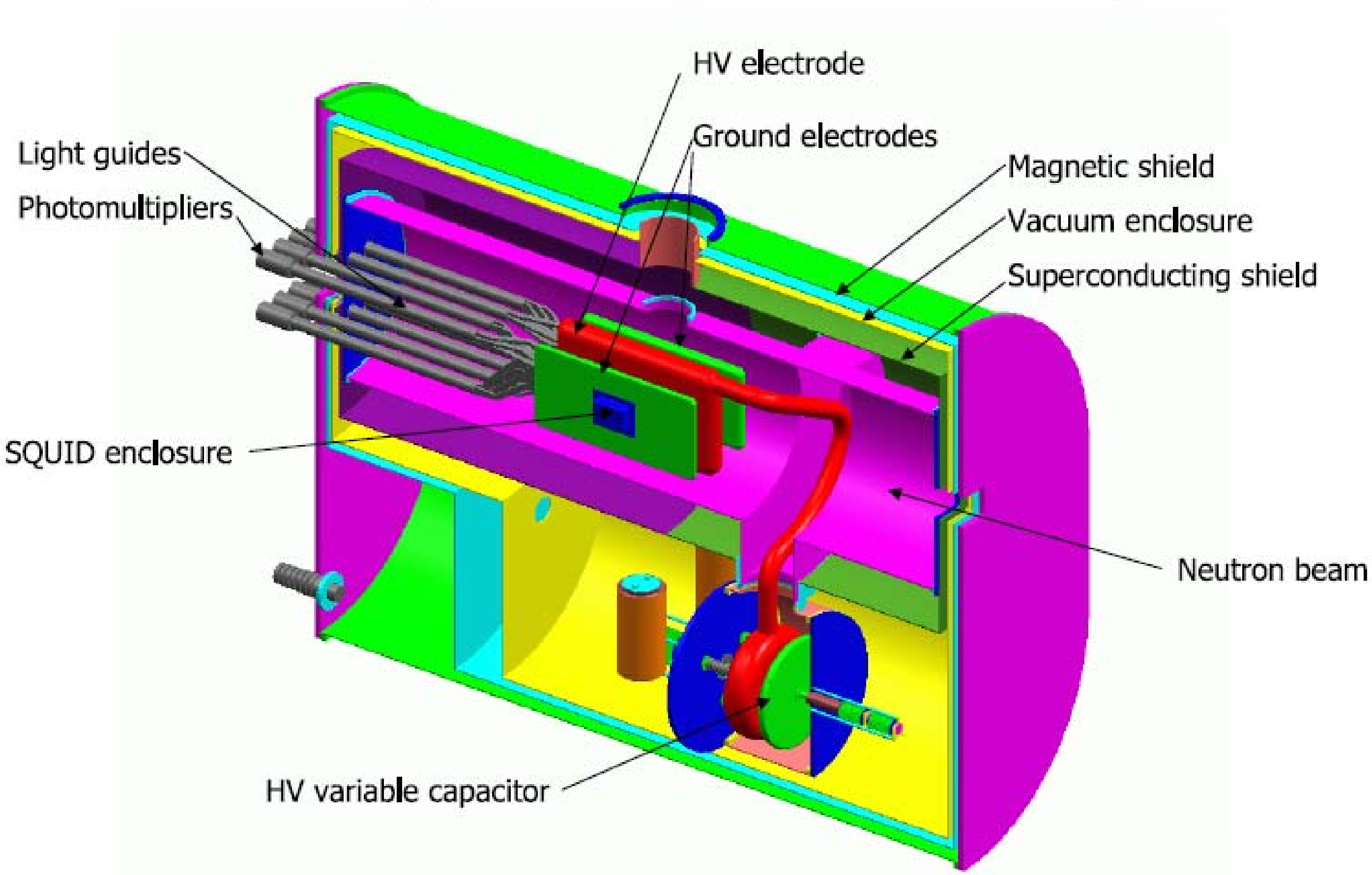
- Neutrons in 0.5 K He bath
- ~50× more neutrons
- E-field: 4-6× at cryo temp.
- Longer coherence times

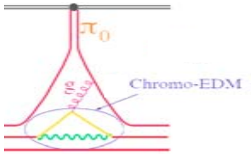




Neutron EDM at SNS. Aiming at 1×10^{-28}e·cm, begin construction 2007, begin data taking 2011

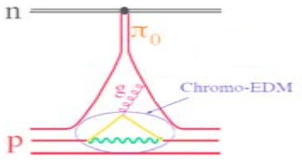
Proposed Experimental Design





Neutron EDM Timeline

	Exp begin data taking	Exp goal
2005		
2007		
2008	UCN-PSI	10^{-27}e·cm
2009	UCN-ILL	2×10^{-28}e·cm/yr
2011	UCN-LANL/SNS	1×10^{-28}e·cm



Hadronic EDMs

$$L_{\not{CP}} = \bar{\theta}\,\frac{\alpha_s}{8\pi}GG$$

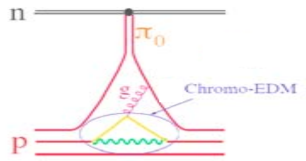
Order of magnitude estimation of the neutron EDM:

$$d_n\left(\bar{\theta}\right) \sim \bar{\theta}\,\frac{e}{m_n}\frac{m_*}{\Lambda_{QCD}} \sim \bar{\theta}\cdot\left(6\times10^{-17}\right)\mathrm{e\cdot cm}, \quad m_* = \frac{m_u m_d}{m_u + m_d}$$

M. Pospelov,
A. Ritz, Ann. Phys.
318 (2005) 119.

$$d_n\left(\bar{\theta}\right) \simeq -d_p\left(\bar{\theta}\right) \simeq 3.6\times10^{-16}\,\bar{\theta}\ \mathrm{e\cdot cm} \rightarrow \bar{\theta} \leq 2\times10^{-10}$$

Why so small? Axions? CAST, ADMX,…

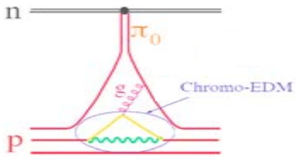


Deuteron EDM

$$d_D = (d_n + d_p) + d_D^{\pi NN}$$

$$d_D(\bar{\theta}) \simeq -10^{-16}\,\bar{\theta}\ \mathrm{e\cdot cm}$$

i.e. @ 10^{-29}e·cm: $$\bar{\theta} \leq 10^{-13}$$

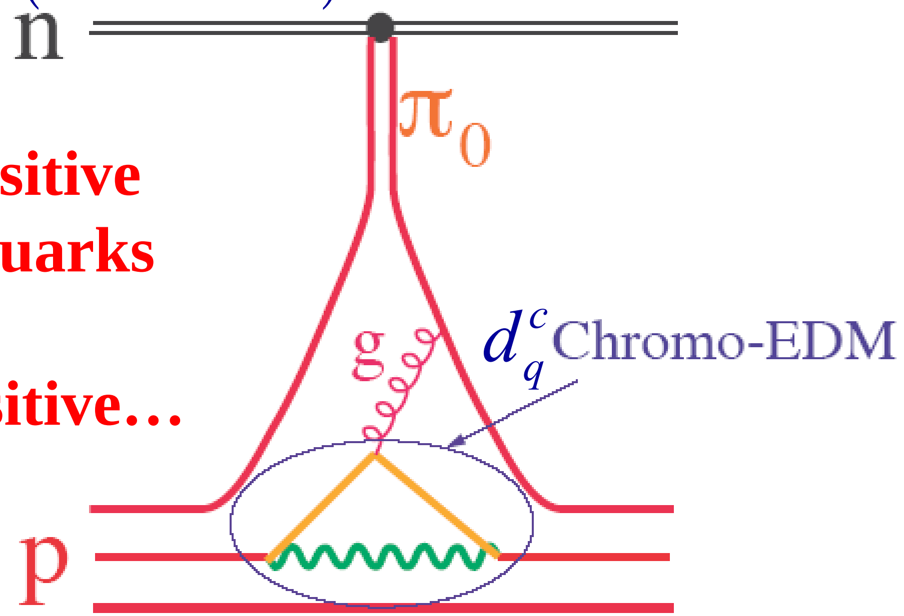


Quark EM and Color EDMs

$$L_{\not{CP}} = -\frac{i}{2}\sum_q \bar{q}\left(d_q \sigma_{\mu\nu} F^{\mu\nu} + d_q^c \sigma_{\mu\nu} G^{\mu\nu}\right)\gamma_5 q$$

$$d_D\left(d_q, d_q^c\right) \simeq 0.5\left(d_u + d_d\right) - 5.6e\left(d_u^c - d_d^c\right) - 0.2e\left(d_u^c + d_d^c\right)$$

$$d_n\left(d_q, d_q^c\right) \simeq 0.7\left(d_d - 0.25 d_u\right) + 0.55e\left(d_d^c + 0.5 d_u^c\right)$$



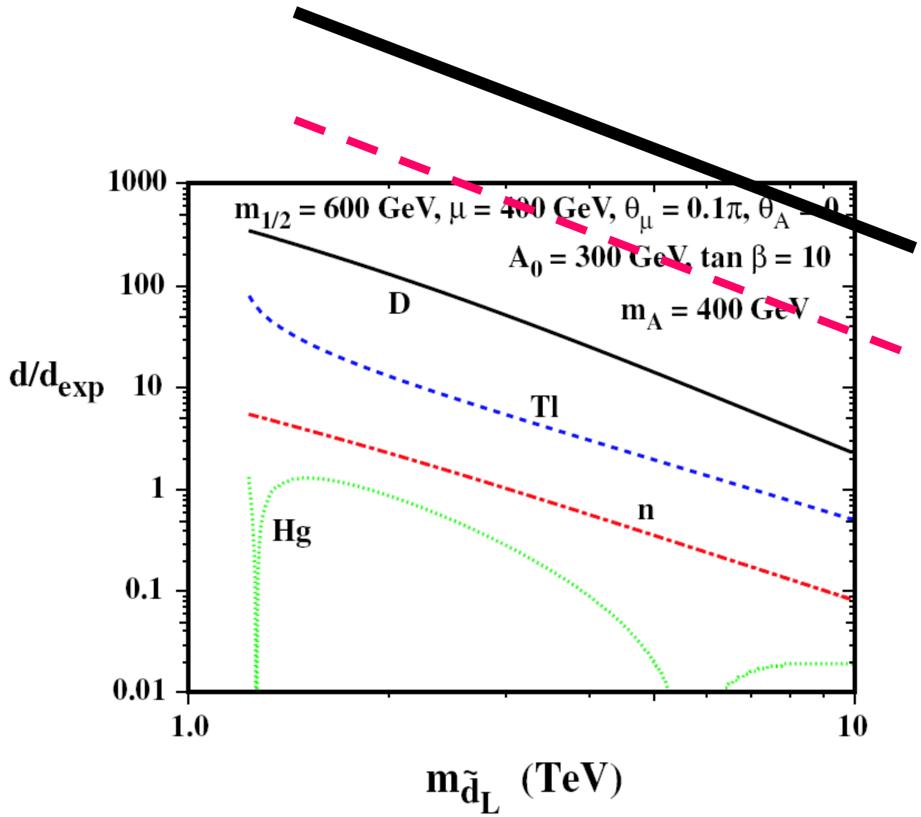
i.e. Deuterons and neutrons are sensitive to different linear combination of quarks and chromo-EDMs…

The Deuteron is 10 times more sensitive…

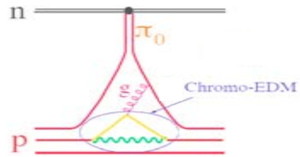
Sensitivity to SUSY models

d EDM at ~10^{-29}e·cm

n EDM at ~10^{-28}e·cm



Relative strength of various EDM limits as a function of left handed down squark mass (O. Lebedev, K. Olive, M. Pospelov and A. Ritz, PRD **70**, 016003 (2004) hep-ph/0402023)



Sensitivity to *right-handed* ν_τ mass

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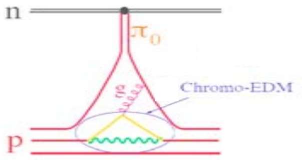
Hadronic EDMs in SUSY SU(5) GUTs with right-handed neutrinos

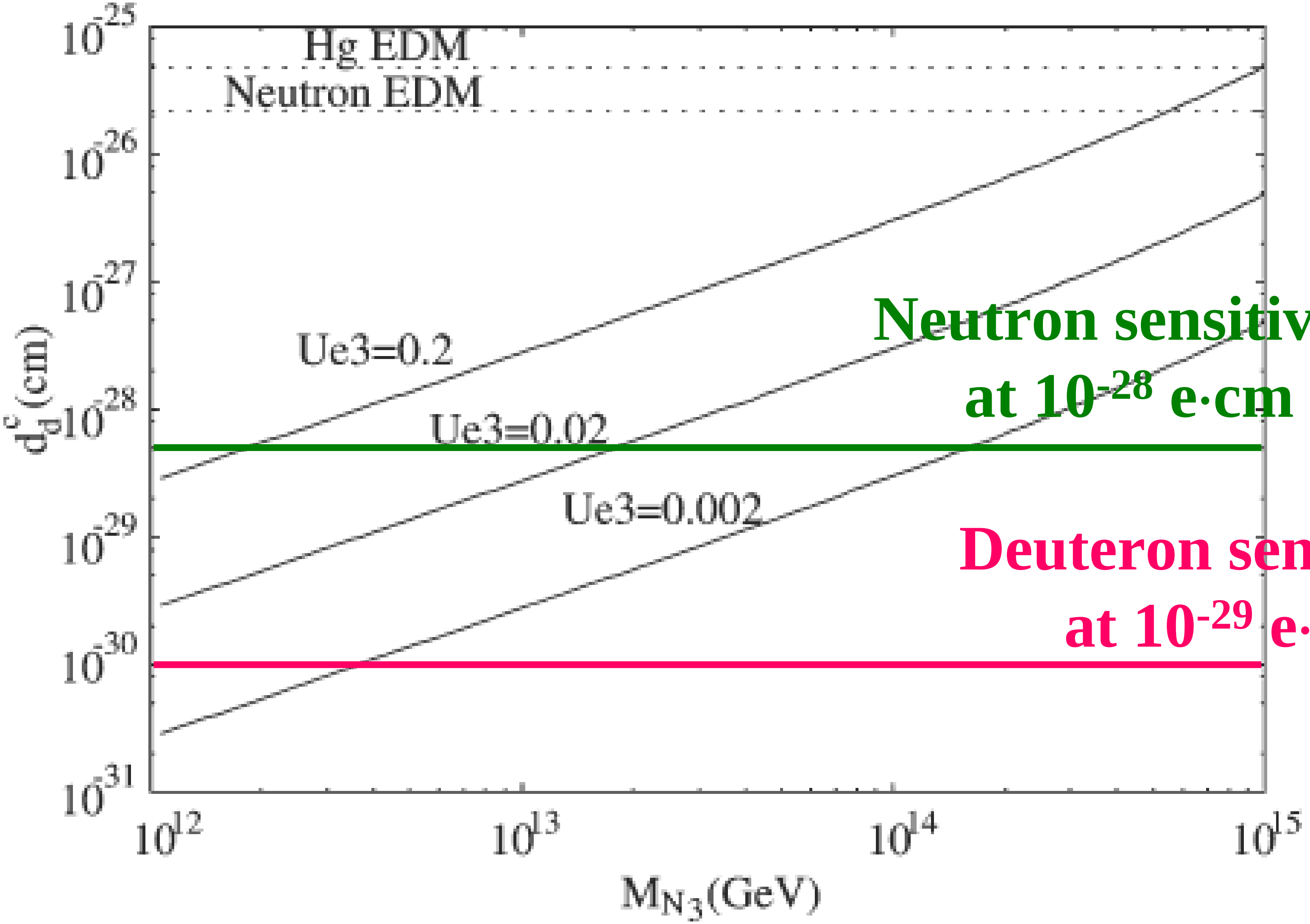
Junji Hisano [a], Mitsuru Kakizaki [a], Minoru Nagai [a], Yasuhiro Shimizu [b]

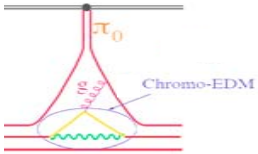
[a] *ICRR, University of Tokyo, Kashiwa 277-8582, Japan*
[b] *Department of Physics, Tohoku University, Sendai 980-8578, Japan*

"… The supersymmetric grand unified models (SUSY GUTs) are ones of the well-motivated models after discovery of the gauge coupling unification at the LEP experiment. Non-vanishing light neutrino masses shown in the neutrino oscillation experiments might also suggest existence of the SUSY GUTs since the right-handed neutrino masses expected from the measurements are near the GUT scale in the seesaw mechanism [1]. Nowadays many efforts are devoted to search for the next signature from both theoretical and experimental sides. …"



CEDMs for the down quark vs M_{N_3}



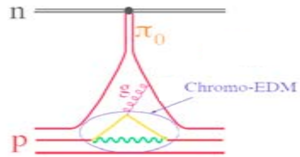


Deuteron vs. neutron sensitivity

…it depends on the source

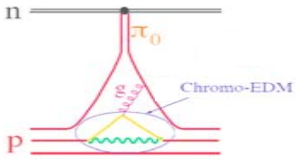
Color EDM: $$d_D\left(d_q^c\right)\approx 10\times d_n\left(d_q^c\right)$$

$\bar{\theta}_{QCD}$: $$d_D\left(\bar{\theta}\right)\approx \frac{1}{3}\times d_n\left(\bar{\theta}\right)$$



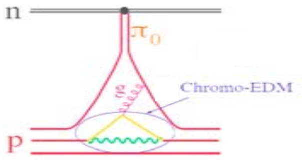
WHY BNL?

- Great physics opportunity; it will not be done at LHC
- The Infrastructure is here (polarized source, spin manipulating devices, …).
- The human factor: Hadron and spin expertise, the best in the world.
- Compatible with the lab mission: The nuclear physics lab of US, QCD Lab, θ_{QCD}

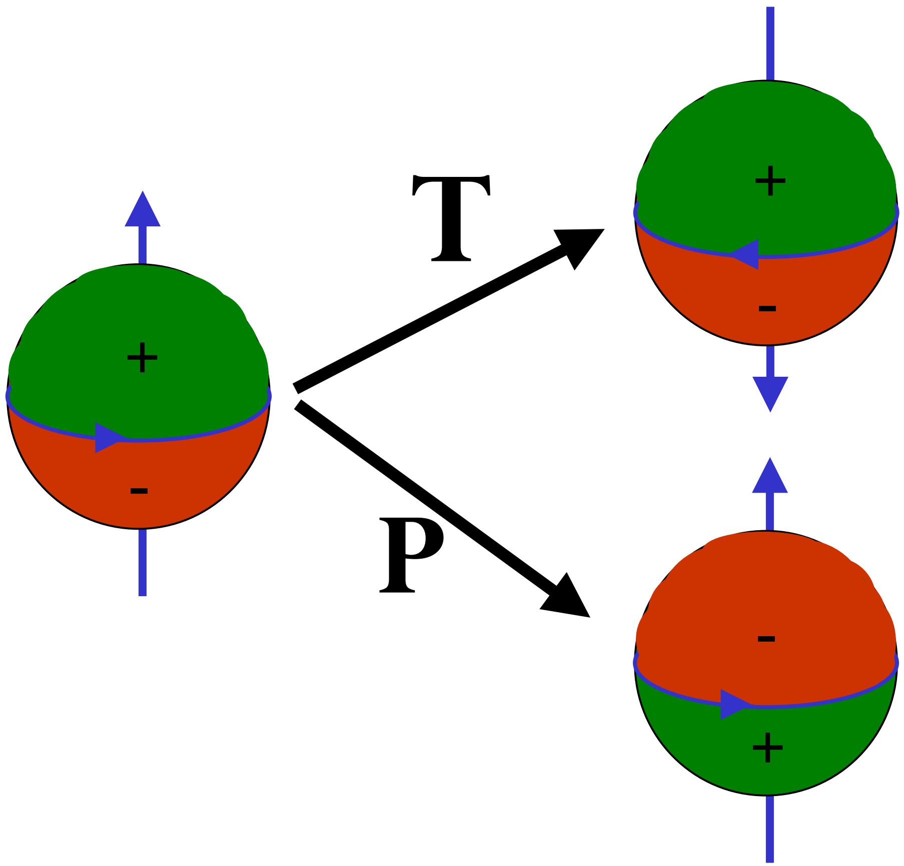


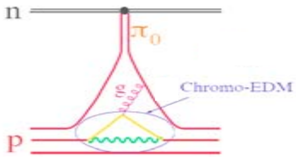
WHY BNL?

- Home of the successful (and sophisticated) muon g-2 experiment.
- Moderate cost to build a 5m by 10m ring
- Moderate Intensity, NO AGS/Booster rehab needed.
- Moderate power cost for running it: ~1.5GeV/c. One pulse every ≈100s-1000s.



A Permanent EDM Violates both T & P Symmetries:

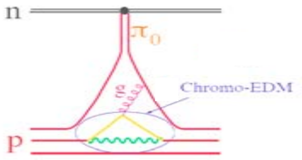




A Permanent EDM Violates both T & P Symmetries:

$$H = -d\vec{\sigma}\cdot\vec{E} \xrightarrow{\mathbf{T}} H = -d\left(-\vec{\sigma}\right)\cdot\vec{E} = d\vec{\sigma}\cdot\vec{E}$$

$$H = -d\vec{\sigma}\cdot\vec{E} \xrightarrow{\mathbf{P}} H = -d\vec{\sigma}\cdot\left(-\vec{E}\right) = d\vec{\sigma}\cdot\vec{E}$$



How about Induced EDMs?

$$\vec{d} \propto d\vec{E}$$

$$H = -d\vec{E}\cdot\vec{E} \quad \xrightarrow{\quad \mathbf{T} \quad} \quad \textbf{OK}$$

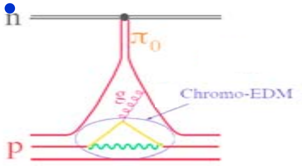
$$H = -d\vec{E}\cdot\vec{E} \quad \xrightarrow{\quad \mathbf{P} \quad} \quad \textbf{OK}$$

$$H = -d\vec{\sigma}\cdot\vec{E}$$

1st order Stark effect. T, P Violation!

$$H = -d\vec{E}\cdot\vec{E}$$

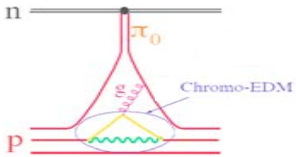
2nd order Stark effect. Allowed!



MDMs are Allowed…

$$H = -\mu\vec{\sigma}\cdot\vec{B} \xrightarrow{\mathbf{T}} H = -\mu\left(-\vec{\sigma}\right)\cdot\left(-\vec{B}\right) = -\mu\vec{\sigma}\cdot\vec{B}$$

$$H = -\mu\vec{\sigma}\cdot\vec{B} \xrightarrow{\mathbf{P}} H = -\mu\left(\vec{\sigma}\right)\cdot\left(\vec{B}\right) = -\mu\vec{\sigma}\cdot\vec{B}$$

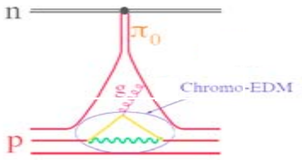


CPT

T-Violation → CP-Violation

<u>Andrei Sakharov 1967:</u>

CP-Violation is one of three conditions to enable a universe containing initially equal amounts of matter and antimatter to evolve into a matter-dominated universe, which we see today....

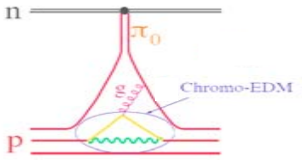


EDM Searches are Excellent Probes of Physics Beyond the SM:

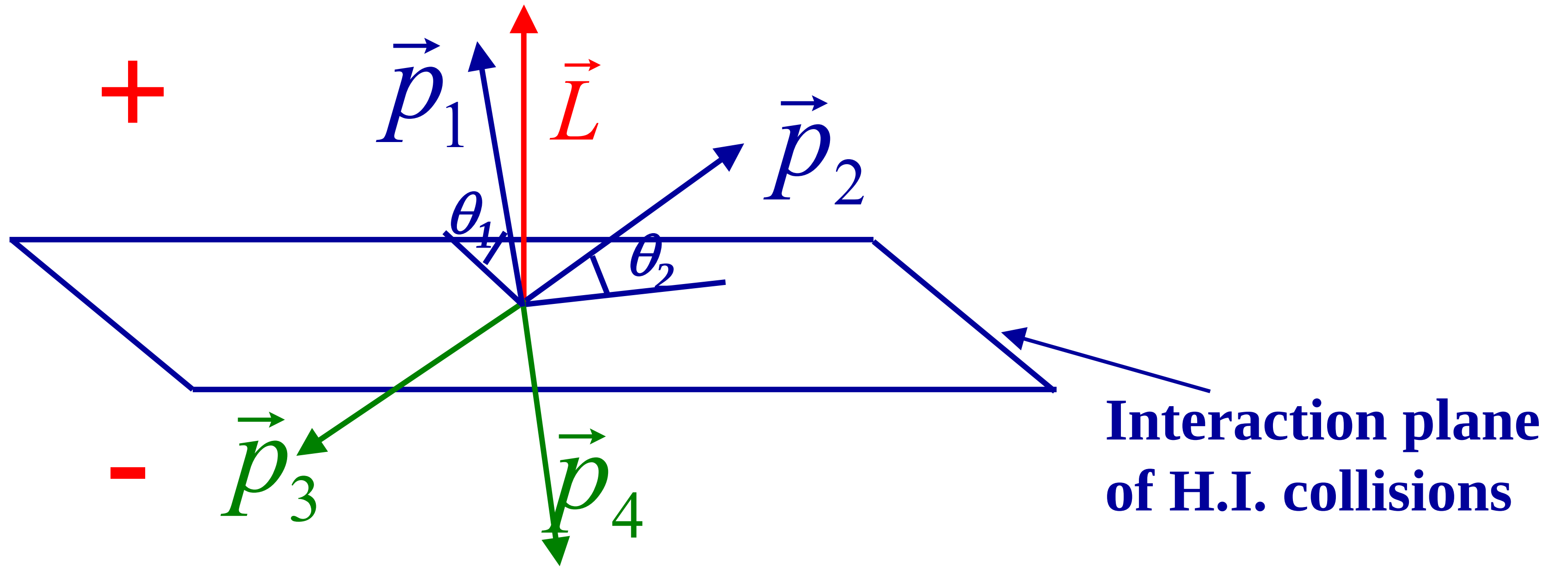
Most models beyond the SM predict values within the sensitivity of current or planned experiments:

- SUSY
- Multi-Higgs
- Left-Right Symmetric …

SM background negligible…



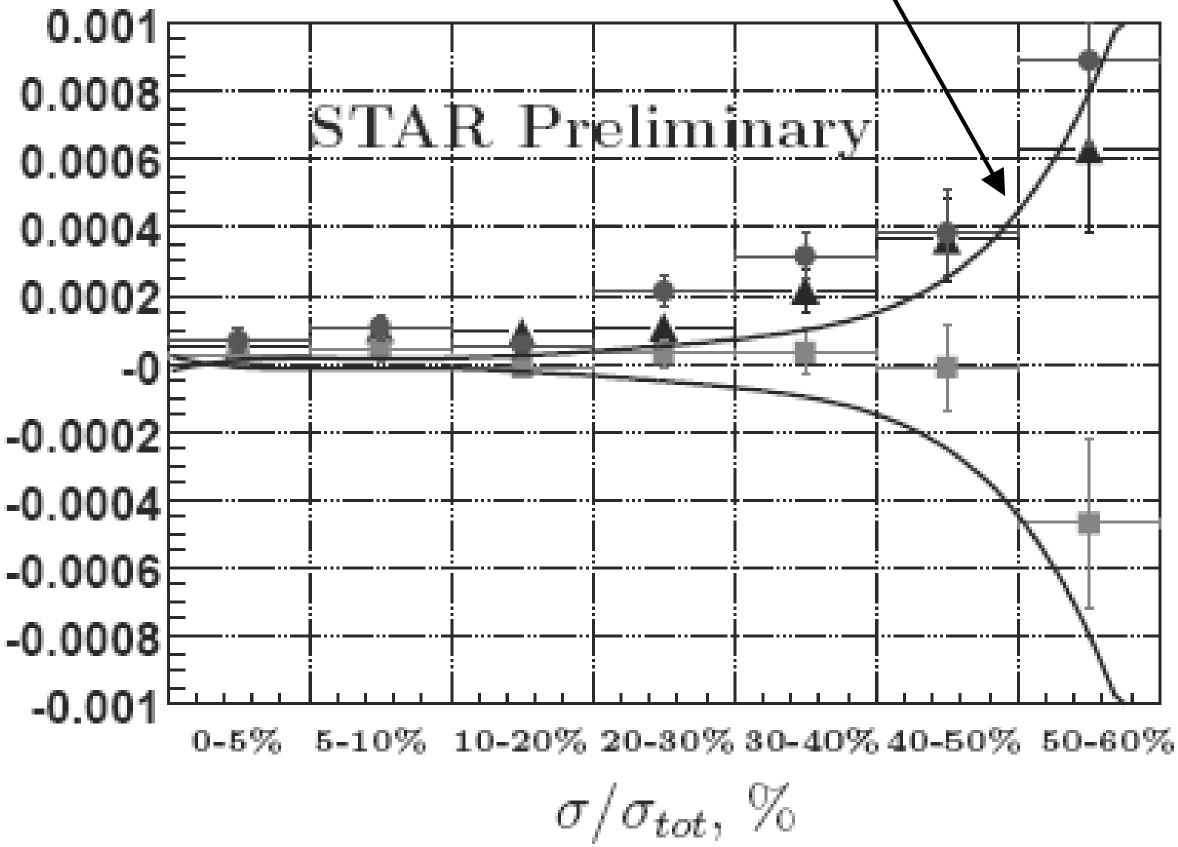
…In the vicinity of the deconfinement phase transition θ_{QCD} might not be small: P & T-violating bubbles are possible at H.I. collisions. **D. Kharzeev, R. Pisarski, M. Tytgat, PRL81, (1998) 512;**
D. K., R. P., PRD 61 (2000) 111901;
D. K., hep-ph/0406125.



Where p_1 and p_2 are the momenta of the positive pions and p_3 and p_4 those of the negative pions.

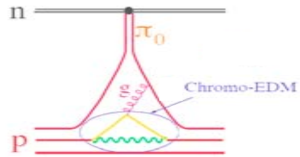
prediction

(Charge Asymmetry)



CP-violation (EDM) at RHIC!! (preliminary) Nucl-ex/0510069

(Centrality of Collisions)

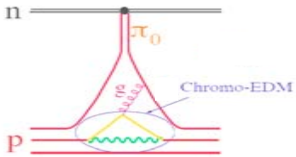


Comments

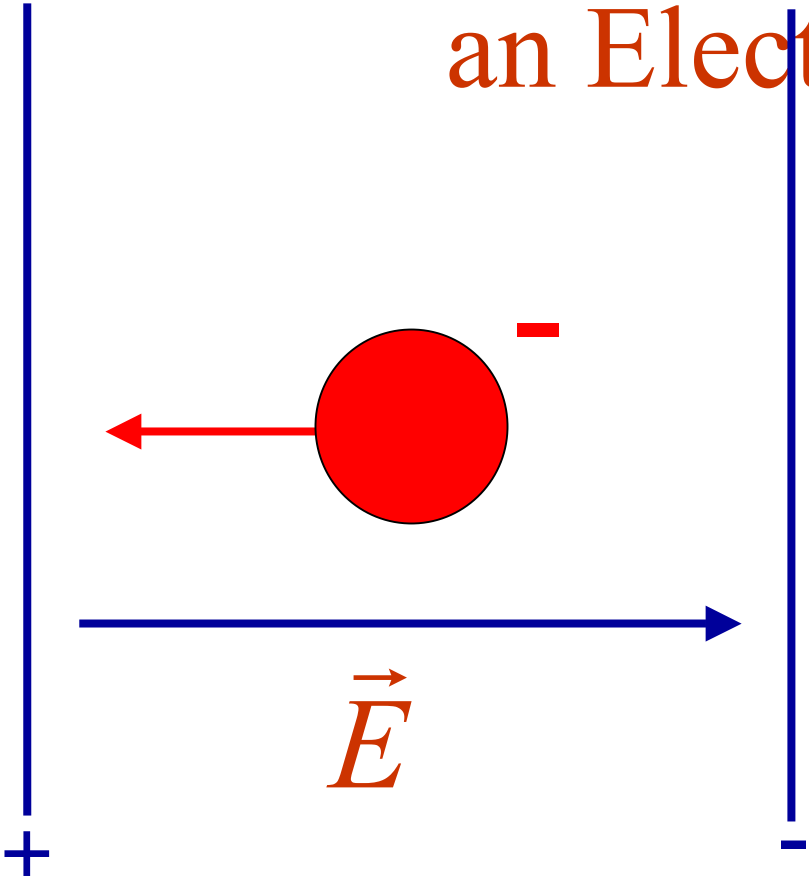
- If it survives the systematics checks it will be a phenomenal, earthshaking discovery

- Discovery of EDM in the plasma probes θ_{QCD} in hot matter

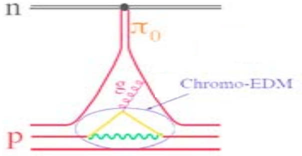
- Deuteron EDM probes θ_{QCD} in cold matter



How about charged particles in an Electric Field…



How about an electron in an atom…



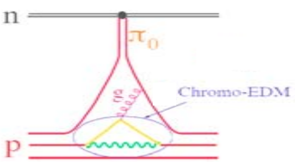
Schiff Theorem:

A Charged Particle at Equilibrium Feels no Force…

…An Electron in a Neutral Atom Feels no Force Either:

$$\left\langle \vec{F}_{Total} \right\rangle = q \left\langle \vec{E}_{Total} \right\rangle = q \left\langle \vec{E}_{ext} + \vec{E}_{\text{int}} \right\rangle = 0$$

…Otherwise it Would be Accelerated…



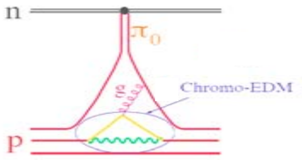
<u>Schiff Theorem:</u>

A Charged Particle at Equilibrium Feels no Force…

…An Electron in a Neutral Atom Feels no Force Either. <u>However:</u>

$$\left\langle \vec{F}_{Tot} \right\rangle = \left\langle q\vec{E}_{ext} + q\vec{E}_{\text{int}} + Other\ Forces \right\rangle = 0$$

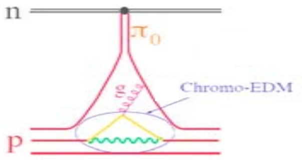
…the net E-field is not zero!



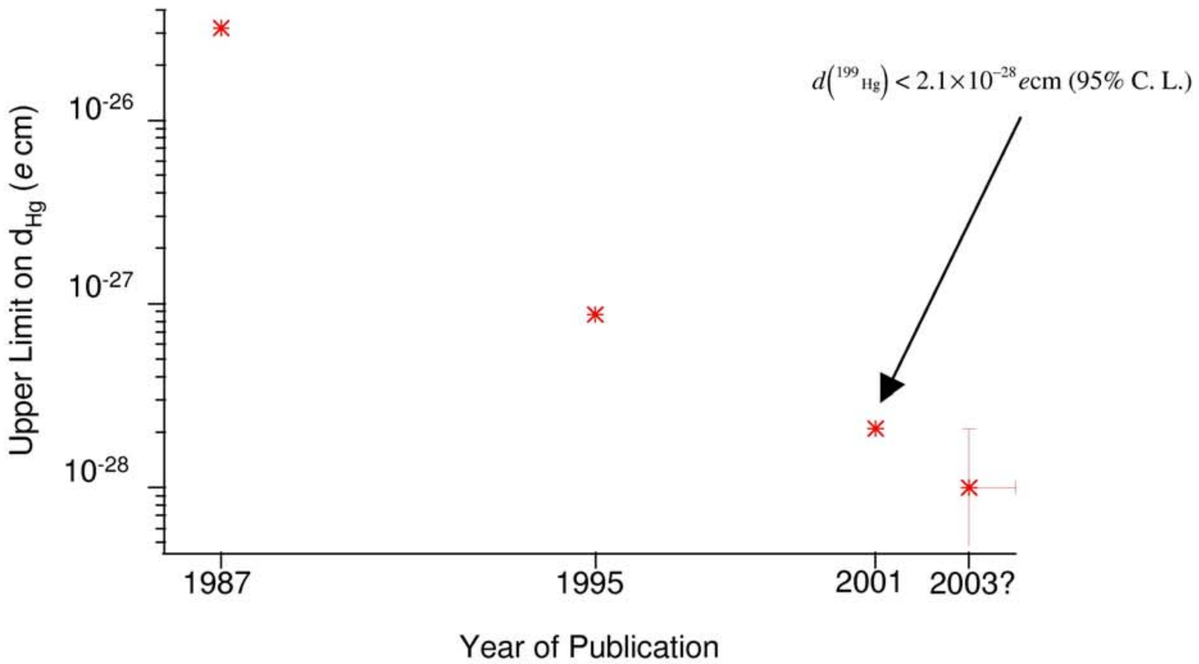
Current Atomic EDM Limits

- **Paramagnetic Atoms, ^{205}Tl: electron $|d_e| < 1.6\times10^{-27}$e·cm (90%CL) PRL 88, 071805 (2002)**

- **Diamagnetic Atoms, ^{199}Hg Nucleus: $|d(^{199}Hg)| < 2.1\times10^{-28}$e·cm (95%CL) PRL 86, 2505 (2001)**



UW ^{199}Hg EDM Limit —Historical Perspective



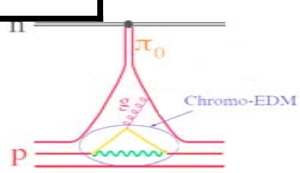
1987: S.K. Lamoreaux, J.P. Jacobs, B.R. Heckel, F.J. Raab, and E.N. Fortson, Phys. Rev. Lett. **59**, 2275 (1987).

1995: J.P. Jacobs, W.M. Klipstein, S.K. Lamoreaux, B.R. Heckel, and E.N. Fortson, Phys. Rev. A **52**, 3521 (1995)

2001: M.V. Romalis, W.C. Griffith, J.P. Jacobs, and E.N. Fortson, Phys. Rev. Lett. **86**, 2505 (2001).

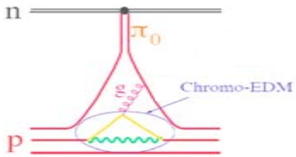
EDM Status

Particle	**System**	**Limit [e·cm]**
Electron	^{205}Tl (~10^{-24} e·cm)	1.5×10^{-27}
Mercury	^{199}Hg atom	2×10^{-28}
Proton	^{199}Hg atom	5×10^{-24}
Neutron	Ultra-Cold n	5×10^{-26}



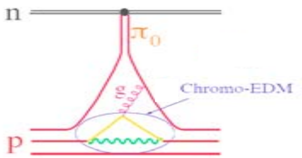
A value of $\theta_{QCD} = 10^{-13}$ would create an EDM of

System	EDM value
Proton	≈-3×10^{-29}e·cm
Neutron	≈3×10^{-29}e·cm
Deuteron	≈-1×10^{-29}e·cm
Tl atom	≈5×10^{-31}e·cm
Hg atom	≈1×10^{-32}e·cm

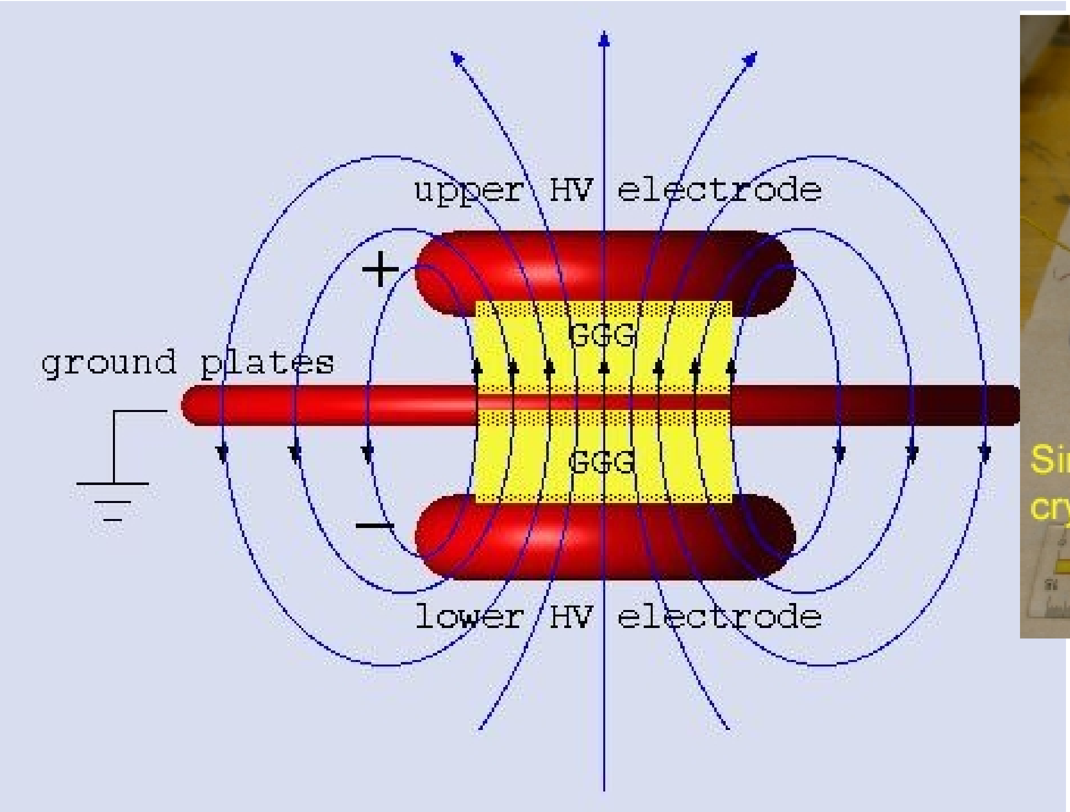


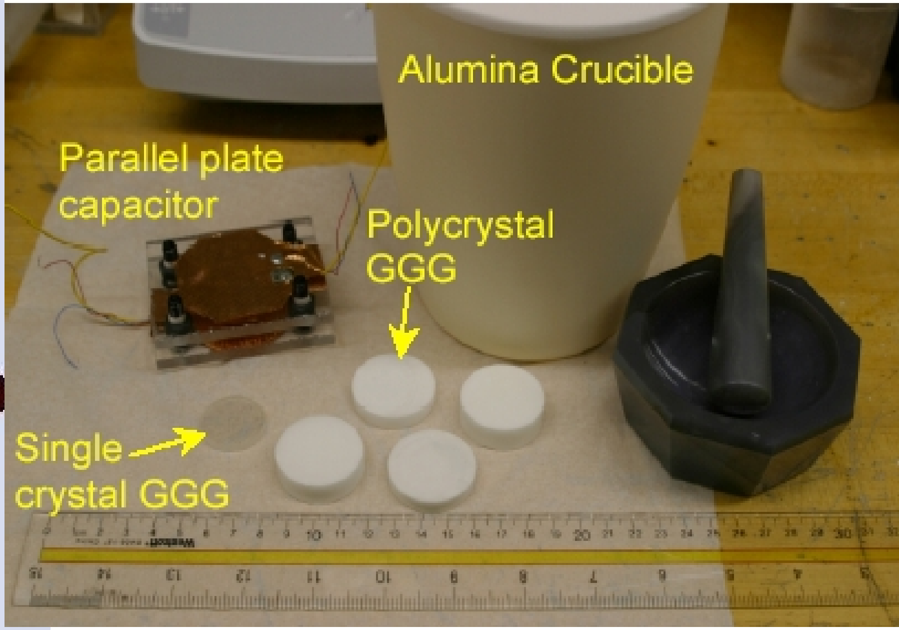
Future Prospects in electron EDM:

- Electron: YbF Ultra-cold molecules. Goal ~1000, B.E. Sauer *et al.*
- Electron: PbO^*, goal ~1000, D. DeMille *et al.*
- E. Commins: "It takes 15 years for the electron EDM Exps from start to end…"

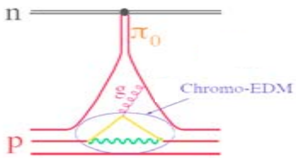


Solid State Electron EDM Search at 50mK

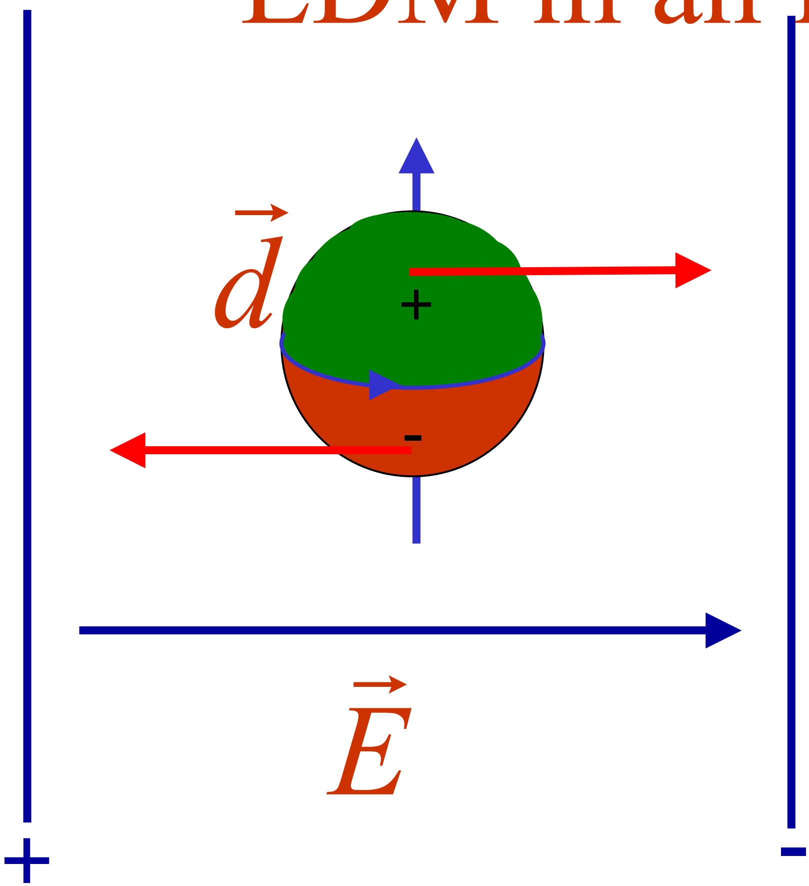




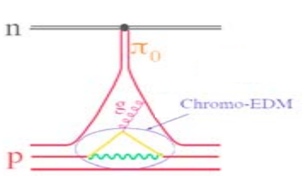
Estimated sensitivity 10^{-30}e·cm, no sensitivity to θ_{qcd}



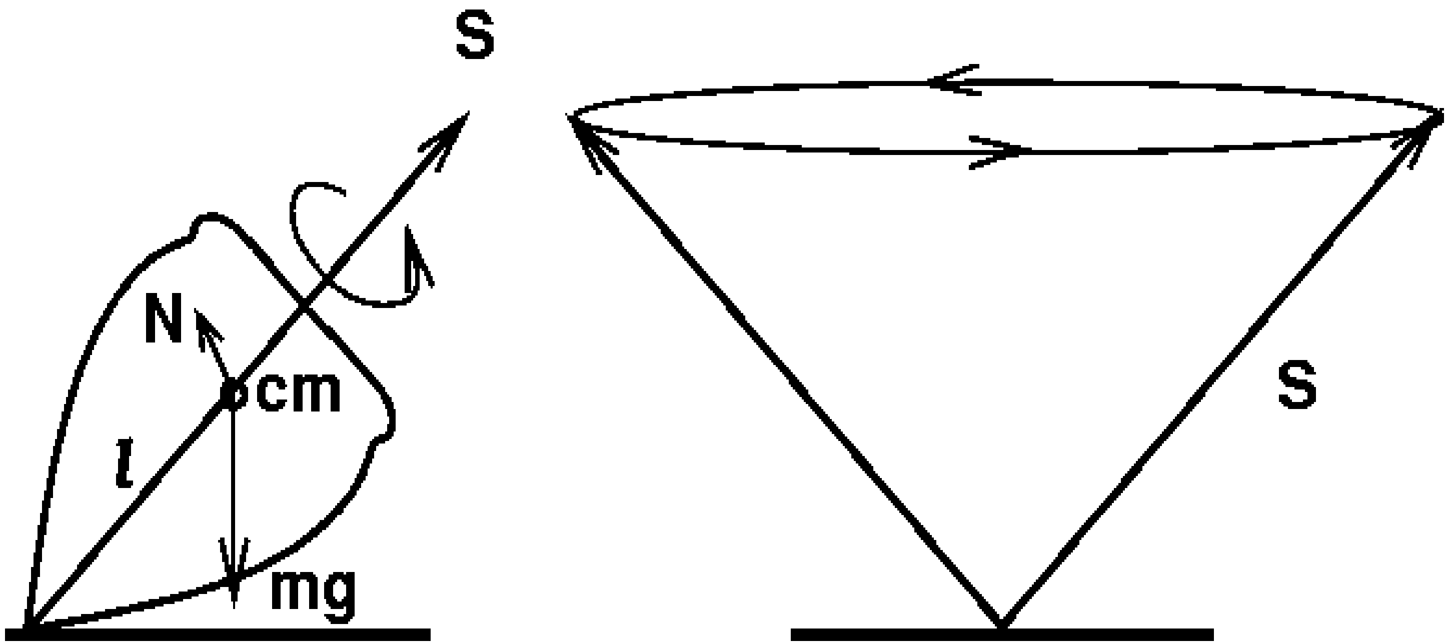
EDM in an Electric Field…



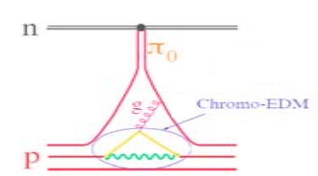
$$\frac{d\vec{s}}{dt} = \vec{d} \times \vec{E}$$



Precession of a Top in a Gravitational Field



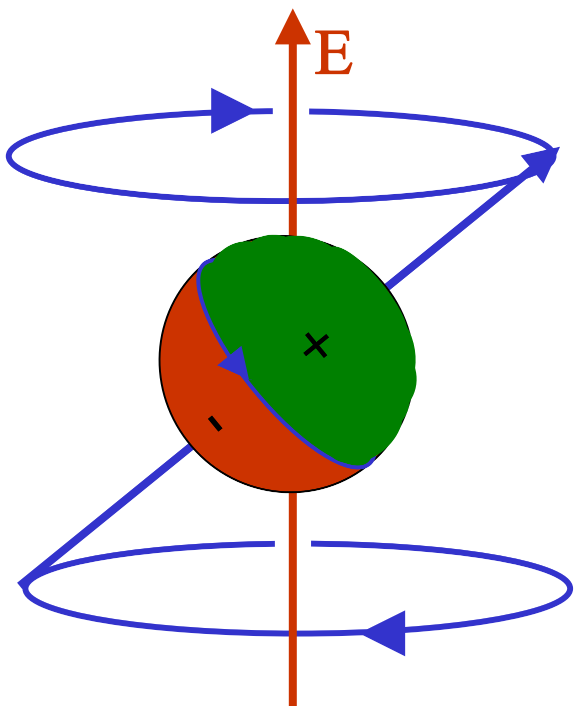
$$\omega = \frac{mgl}{L}, \quad \vec{L} = I\,\vec{S}$$



Usual Experimental Method

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

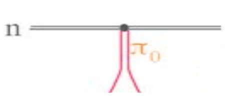
Small Signal



Compare the Zeeman Frequencies When E-field is Flipped:

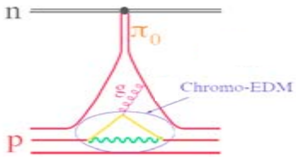
$$\hbar(\omega_1 - \omega_2) = 4dE$$

$$\sigma_d \propto \frac{1}{E} \frac{1}{\sqrt{N\tau T}}$$



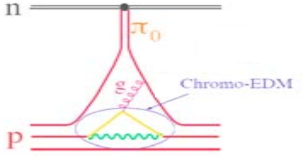
Experimental Principle of dEDM

- Polarize
- Interact with an E-field
- Analyze as a function of time



The deuteron is a winner

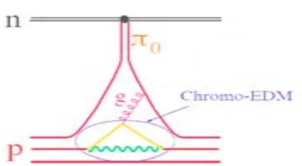
- High intensity deuteron polarized beams with high polarization are available
- Interact in a very strong E-field
- deuteron polarimeters are available, with very high analyzing power for ~1.5 GeV/c d-momentum



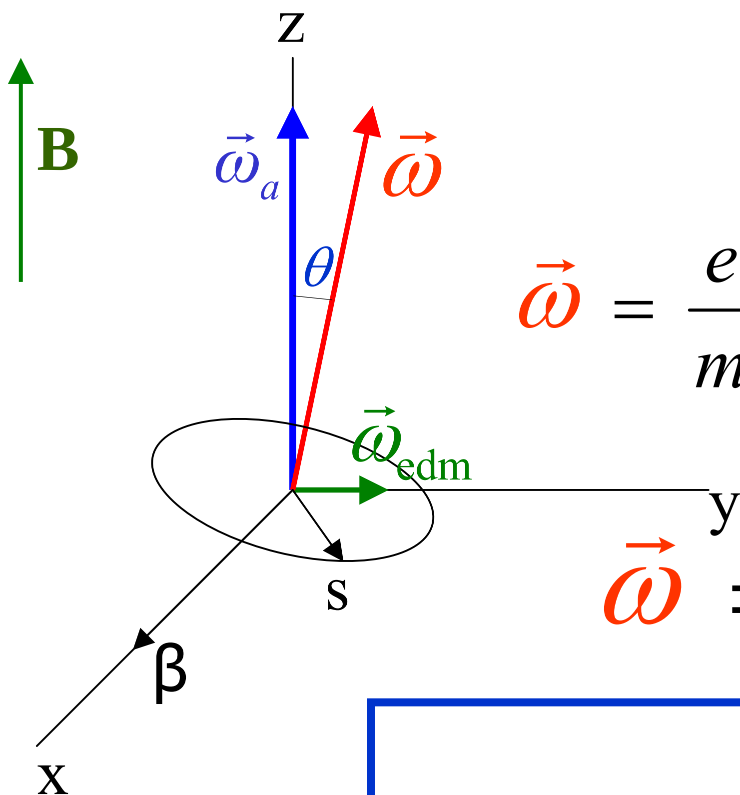
Electric Dipole Moments in Storage Rings

$$\frac{d\vec{s}}{dt} = \vec{d} \times \left(\vec{v} \times \vec{B} \right)$$

e.g. 1T corresponds to 300 MV/m for relativistic particles



Indirect Muon EDM limit from the g-2 Experiment

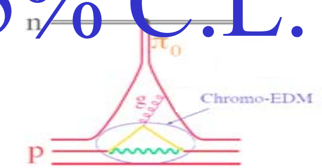


$$\vec{\omega} = \frac{e}{m}\left\{a\vec{B} + \frac{\eta}{2c}\left(\vec{u}\times\vec{B}\right)\right\}$$

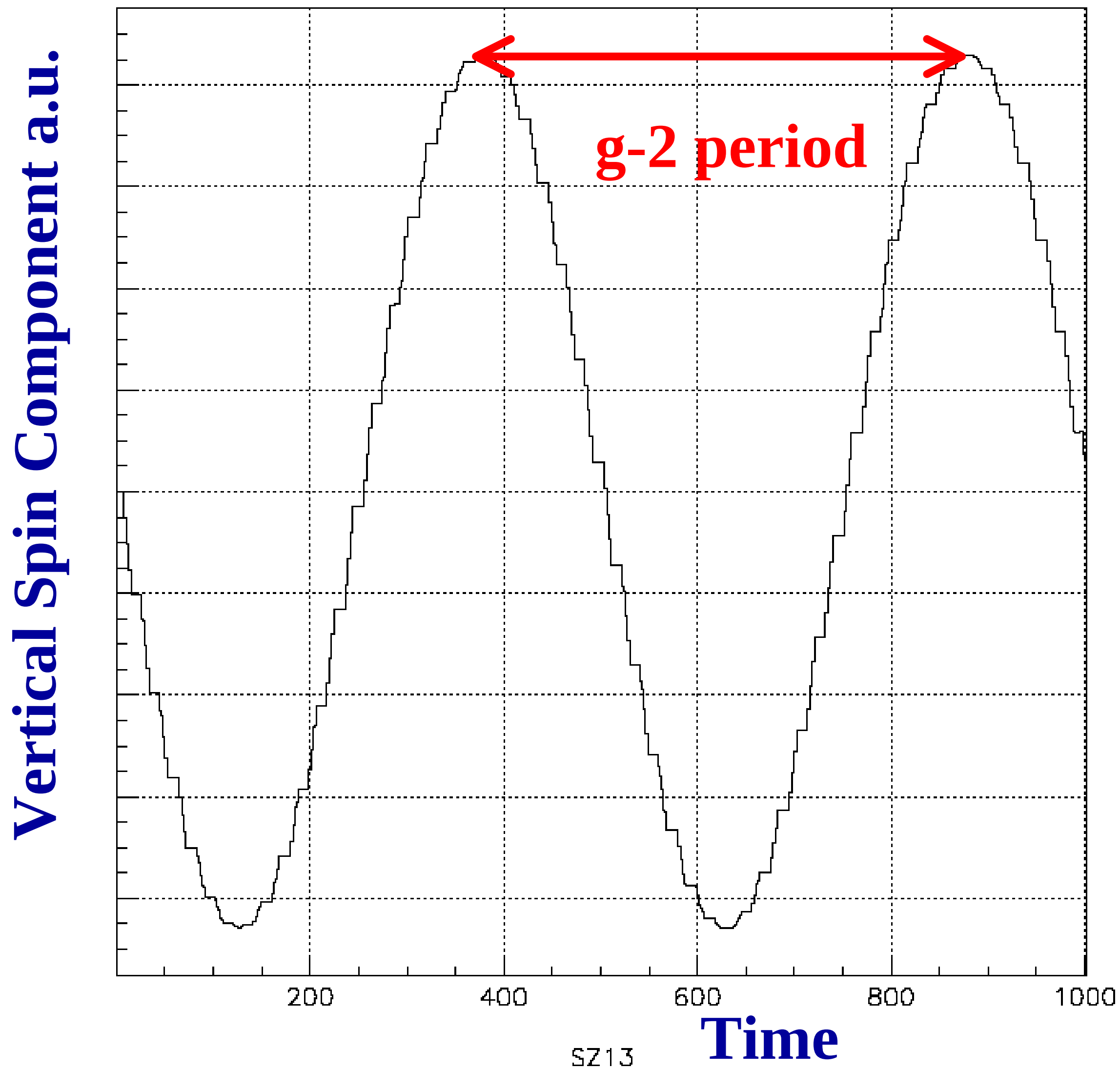
$$\vec{\omega} = \vec{\omega}_a + \vec{\omega}_{\mathrm{edm}}$$

$$\tan\theta = \frac{\omega_{edm}}{\omega_a}$$

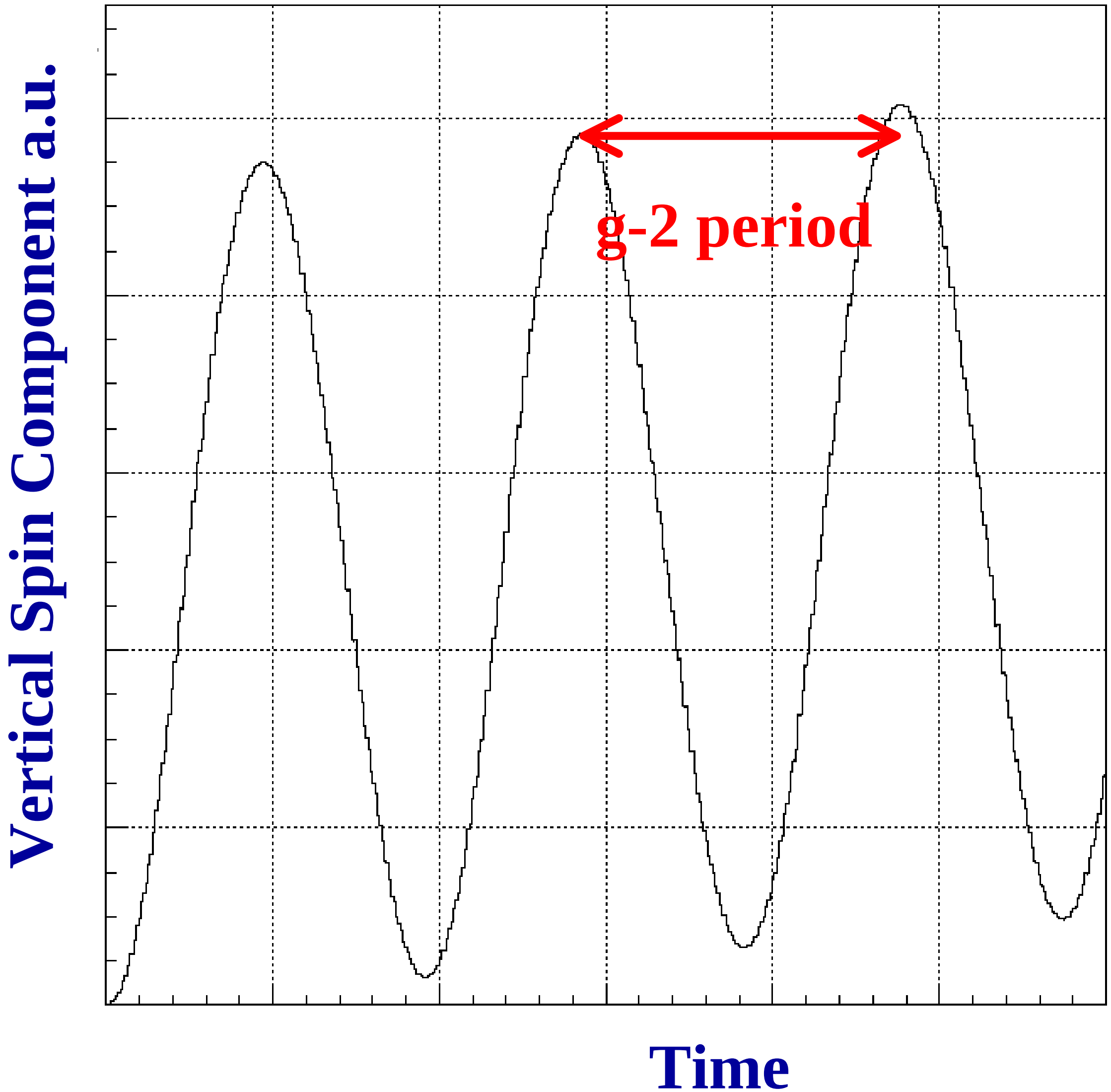
Ron McNabb's Thesis 2003: $< 2.7\times10^{-19}\,\mathrm{e}\cdot\mathrm{cm}$ 95% C.L.



Vertical Spin Component without Velocity Modulation

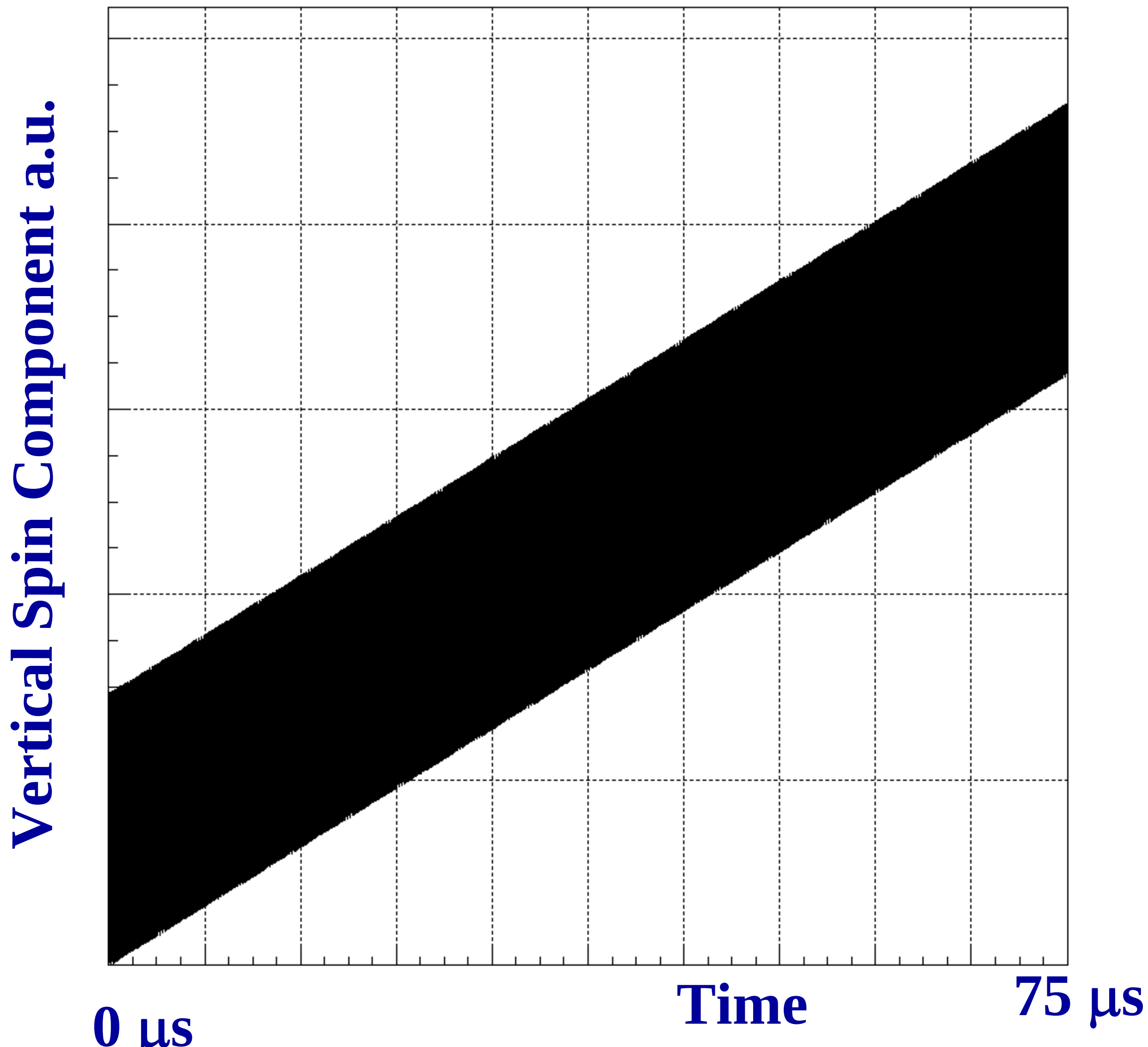


Vertical Spin Component <u>with</u> Velocity Modulation at ω_a

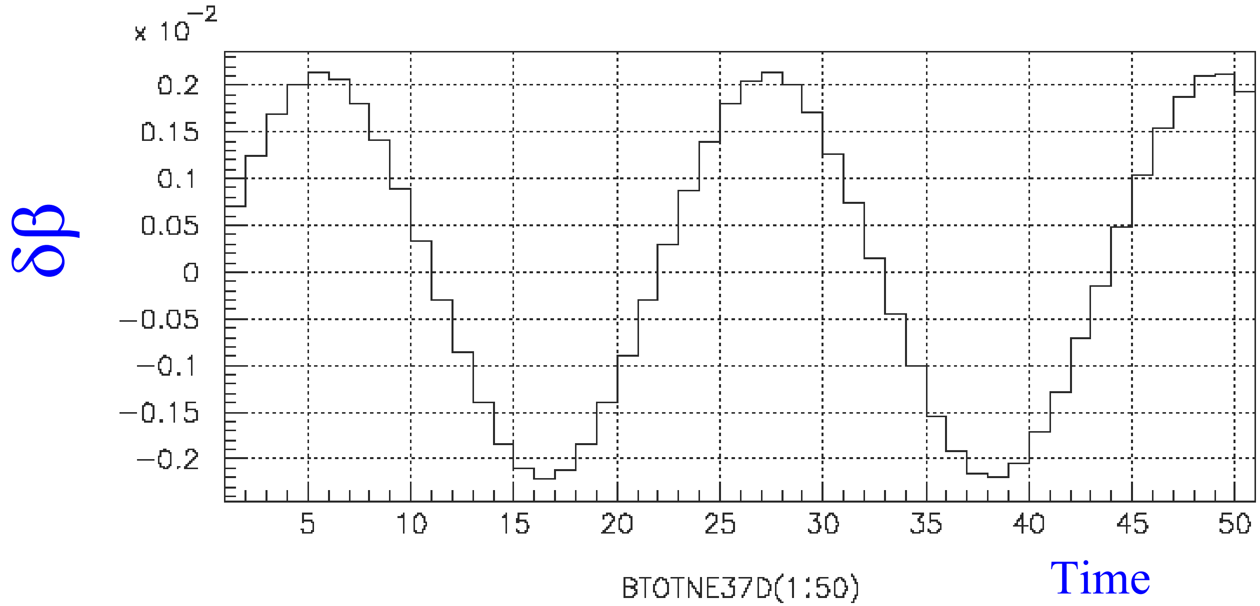


Storage

Vertical Spin Component with Velocity Modulation (longer Time)

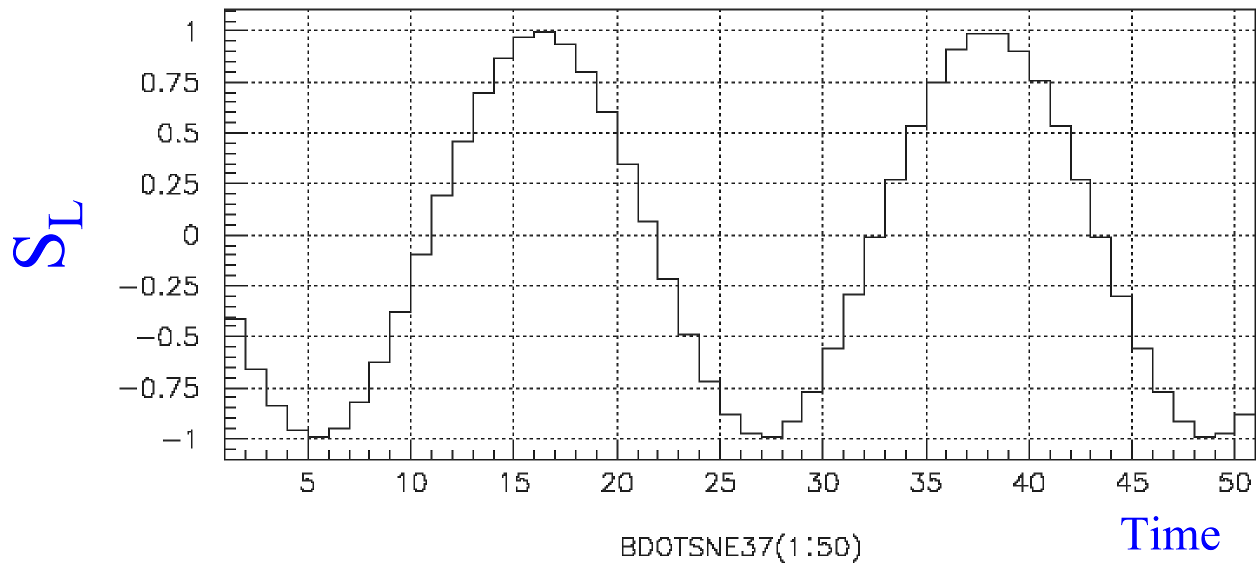


Velocity (top) and g-2 oscillations



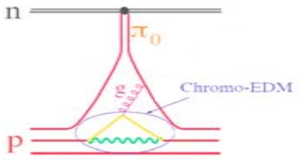
Yuri Orlov's new idea

Particle velocity oscillations



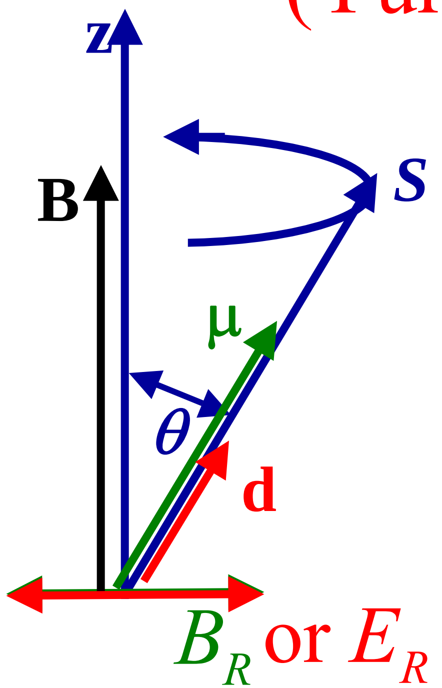
Particle S_L oscillations
(i.e. g-2 oscillations)

The synchrotron oscillation phase (top) compared to g-2 phase (bottom). ~5us total horizontal scale



Resonance spin-flip

(Yuri's picture)

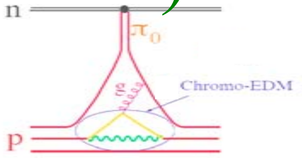


$$\cos\theta = \frac{s_z}{\sqrt{s(s+1)}}$$

$$B_R = B_0 \sin(\omega_a t)$$

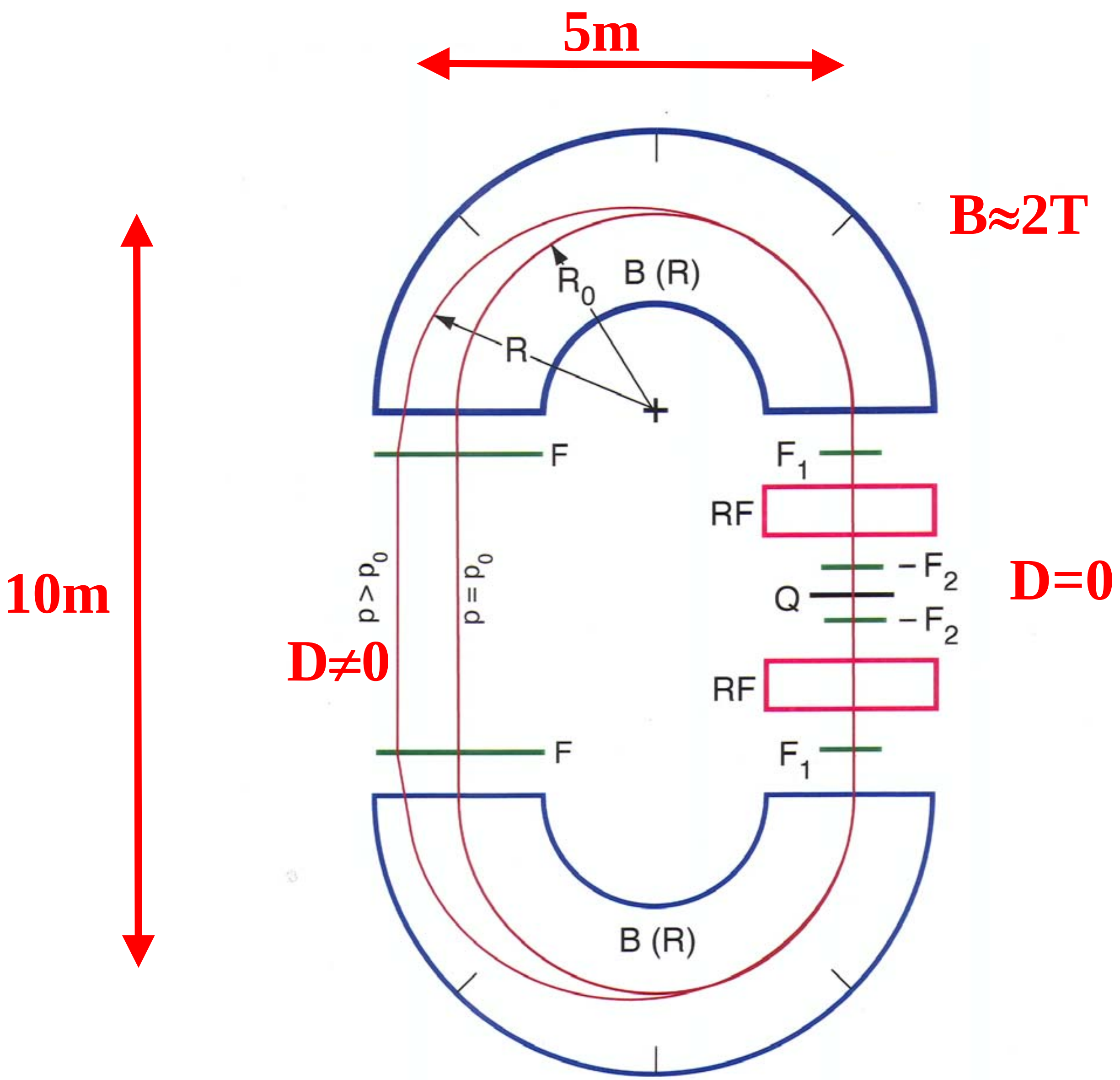
$$\vec{E}_R = \gamma\left(\vec{v}\times\vec{B}\right) = \gamma v B = \gamma B v_0 \sin(\omega_a t), \quad \omega_a = a\gamma\omega_c$$

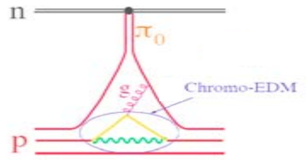
- E_R works on the EDM (signal)
- B_R works on the magnetic moment (background)



The Orlov ring

$P_0 \approx 1.5$GeV/c

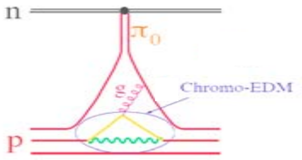




Deuteron Coherence Time

- B-fields stability
- Multipoles of B-fields
- Vertical (Pitch) and Horizontal Oscillations
- Finite Momentum Acceptance ΔP/P

I.B. Vasserman *et al.*, Phys. Lett. **B198**, 302 (1987); A.P. Lysenko, A.A. Polunin, and Yu.M. Shatunov, Particle Accelerators **18**, 215 (1986).



Deuteron Statistical Error:

$$\sigma_d \approx \frac{16\hbar}{\delta\beta_0 c \langle B \rangle A P \sqrt{N_c f \tau_p T_{Tot}}}$$

τ_p : 1000s **Polarization Lifetime (Coherence Time)**

A : 0.6 **The left/right asymmetry observed by the polarimeter**

P : 0.95 **The beam polarization**

N_c : 4×10^{11}d/cycle **The total number of stored particles per cycle**

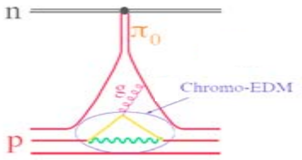
T_{Tot}: 5000h/yr. **Total running time per year**

f : 0.05 **Useful event rate fraction**

$\delta\beta_0$: 0.01 **Velocity modulation**

$<B>$: 1T **The average magnetic field around the ring**

$$\sigma_d \approx 3\times10^{-29}\, \mathrm{e\cdot cm\, /\, year}$$



Resonance EDM systematic errors

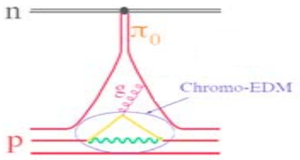
Examples: 1) Radial B-field or skew quadrupole where D≠0,

2) RF-cavity (vertical offset or misalignment), …

3) …

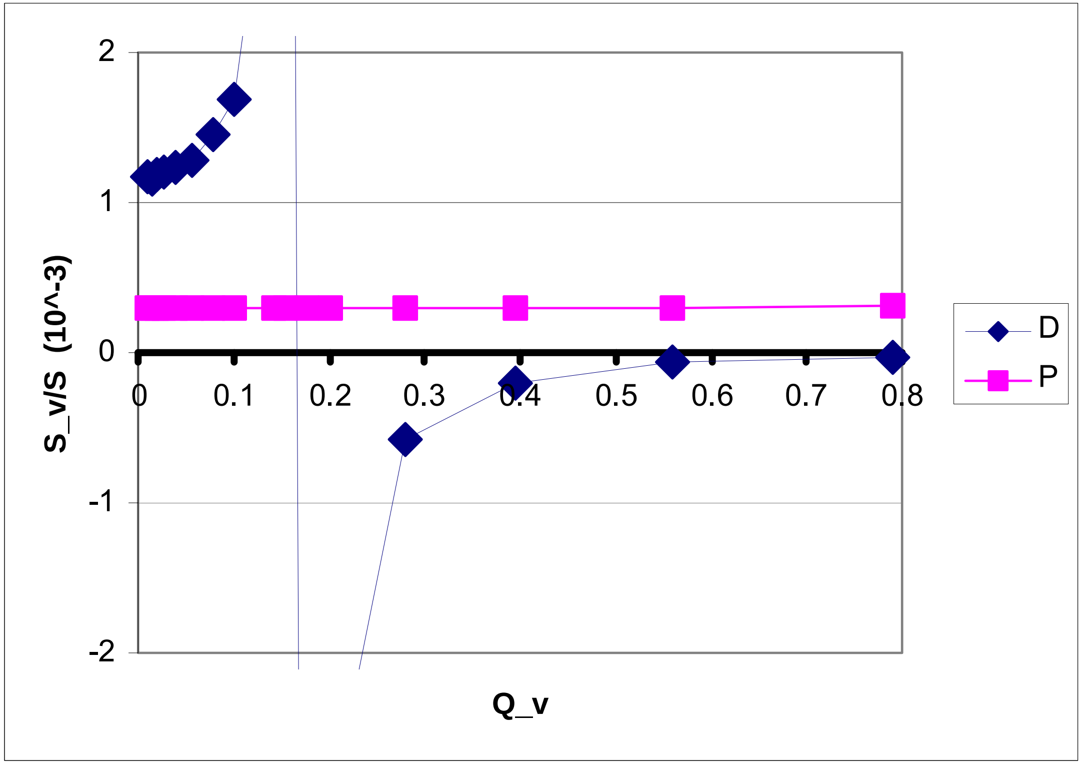
Remedy: They depend on the vertical tune…

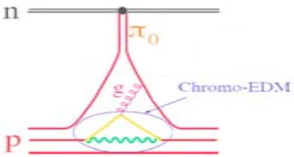
They all do!



Backgrounds are vertical tune dependent; EDM signal is not!

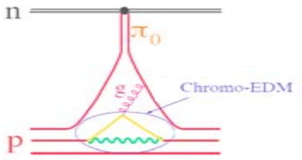
$$\frac{ds_v}{dt} \propto \frac{1}{Q_v^2 - Q_s^2}$$





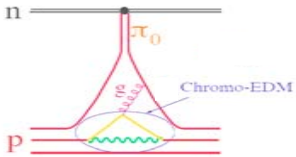
EDM Collaboration Meetings

- January 2006: decide the lab(s) to send the LOI to.
- February 2006: finalize the ring parameters for the LOI.



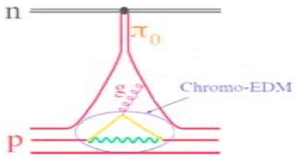
Deuteron EDM Timeline

- February 2006 Letter of Intent
- We need to develop the final ring lattice and tolerances on parameters
- Goal for a proposal by the end of next year



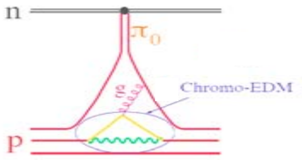
Neutron/deuteron EDM Timeline

Year	Exp begin data taking	Exp goal
2005		
2007		
2008	UCN-PSI	10^{-27}e·cm
2009	UCN-ILL	2×10^{-28}e·cm/yr
2011	UCN-LANL/SNS	1×10^{-28}e·cm



Neutron/deuteron EDM Timeline

	Exp begin data taking	Exp goal
2005		
2007		
2008	UCN-PSI	10^{-27}e·cm
2009	UCN-ILL	2×10^{-28}e·cm/yr
2010	Deuteron in Storage Ring	10^{-29}e·cm
2011	UCN-LANL/SNS	1×10^{-28}e·cm



Overview

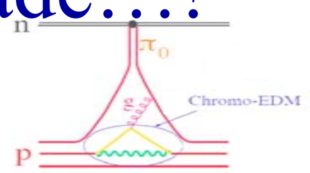
- Neutron, and deuteron EDM experiments are sensitive probes of physics beyond the SM and of CP-violation in particular.

Unique sensitivity to

- θ_{QCD}
- Quark EDM
- Quark-color EDM

with the deuteron at 10^{-29}e·cm holding the best EDM sensitivity over *present* or *planned* experiments.

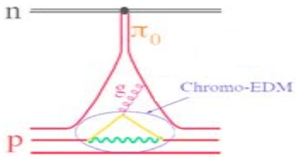
Together n (p) and deuteron EDM exp: pinpoint EDM source, promising a very exciting decade…!



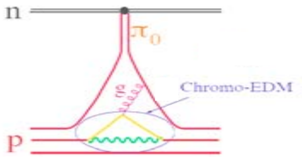
Summary

BNL could and should play a major role in the deuteron EDM experiment. BNL should host the experiment:

1) First rate physics
2) It will not be done at LHC
3) Compatible with the mission and present infrastructure and expertise of the lab
4) Moderate cost to build the 5m by 10m orlov ring; and a moderate power cost to run it (~1.5 GeV/c deuterons)

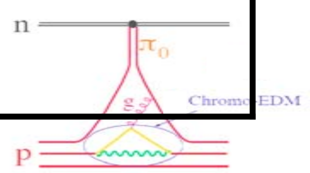


Extra Slides



Possible labs for 0.7-2GeV/c EDM Exps

Lab	D, P, ^{3}He (Polarized)	Equipment needed	Comment
BNL	Y, Y, Y	OK!	US funding cuts
CERN	N, N, N	Polarized Source, Spin manipulating devices	LHC +
COSY	Y, Y, N	Spin manipulating devices	Intensity, commitment to GSI, Funding
Frascati	N, N, N	IUCF's front end, Spin manipulating devices	New direction, Intensity
KVI	Y, Y, ?	Accumulator, Spin manipulating Dev.	Funding?
KEK/ JPARC			Interested!

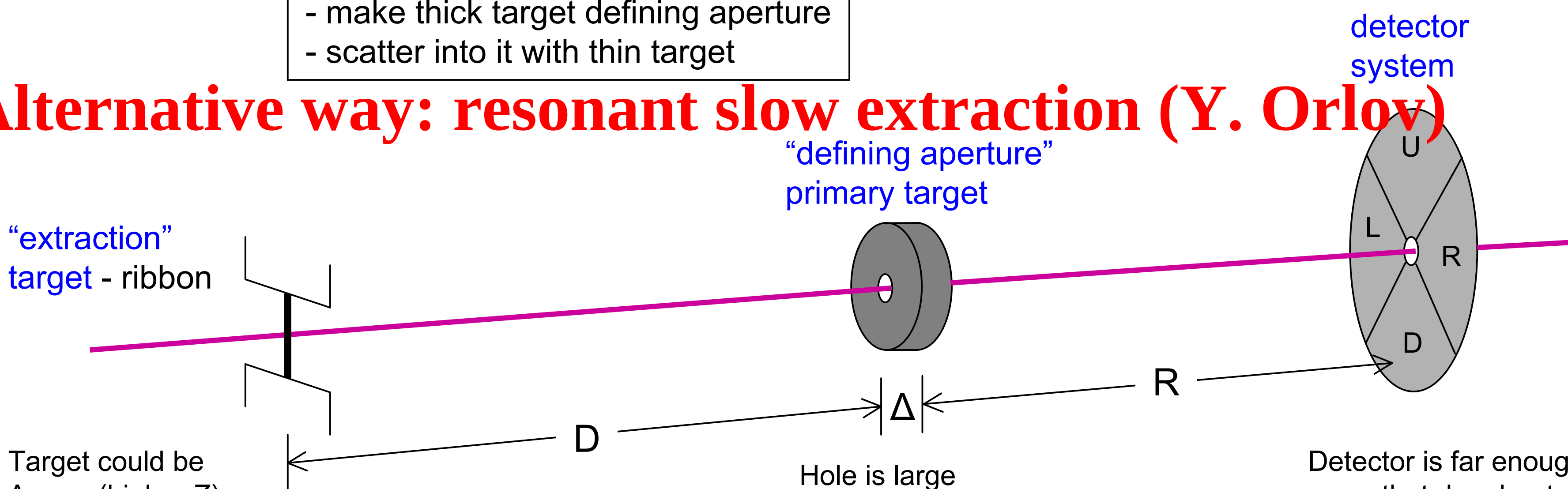


Nuclear Scattering as Deuteron EDM polarimeter

Ed Stephenson's

IDEA:
- make thick target defining aperture
- scatter into it with thin target

Alternative way: resonant slow extraction (Y. Orlov)



Target could be Ar gas (higher Z).

Target "extracts" by Coulomb scattering deuterons onto thick main target. There's not enough good events here to warrant detectors.

Hole is large compared to beam. Every-thing that goes through hole stays in the ring.

Detector is far enough away that doughnut illumination is not an acceptance issue: $\Delta < R$.

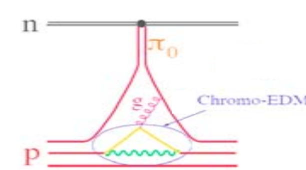
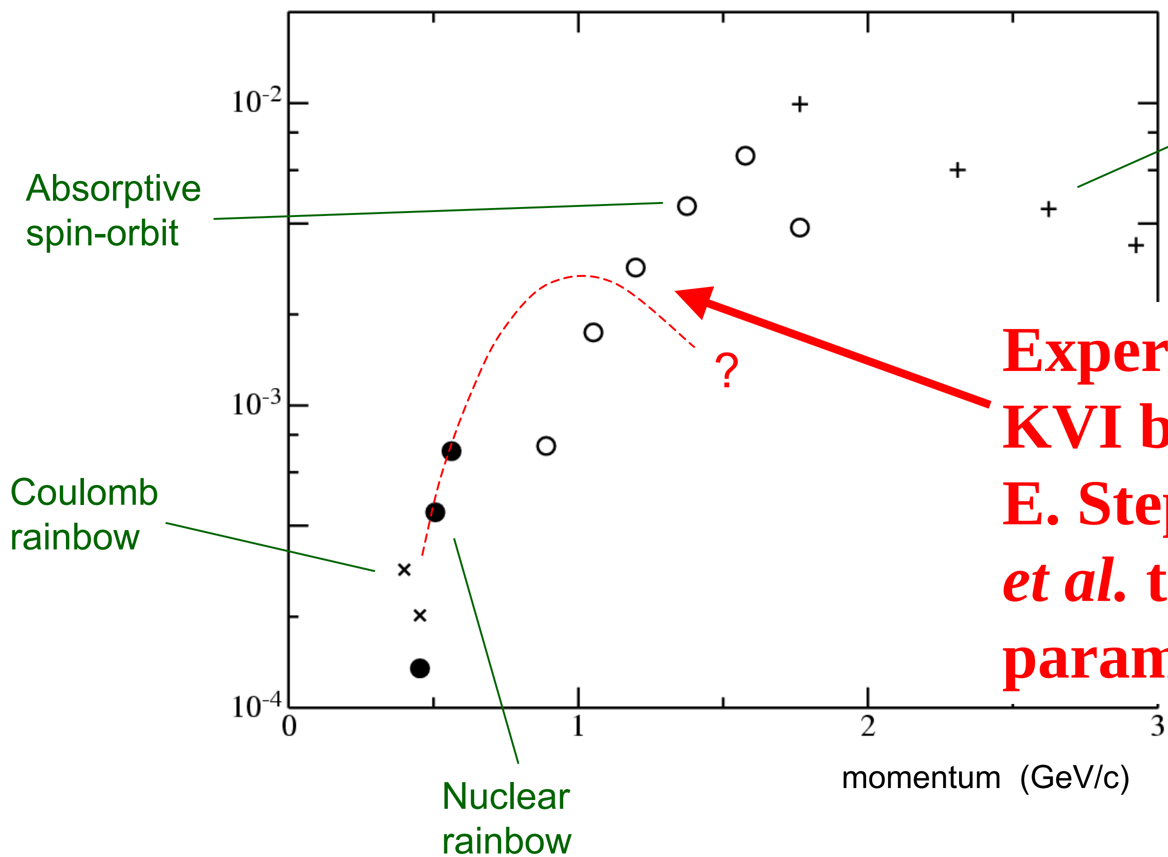
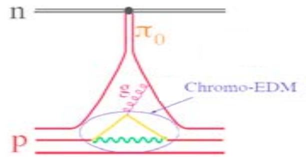


Figure of merit = effiency $\times \langle iT_{11} \rangle^2$

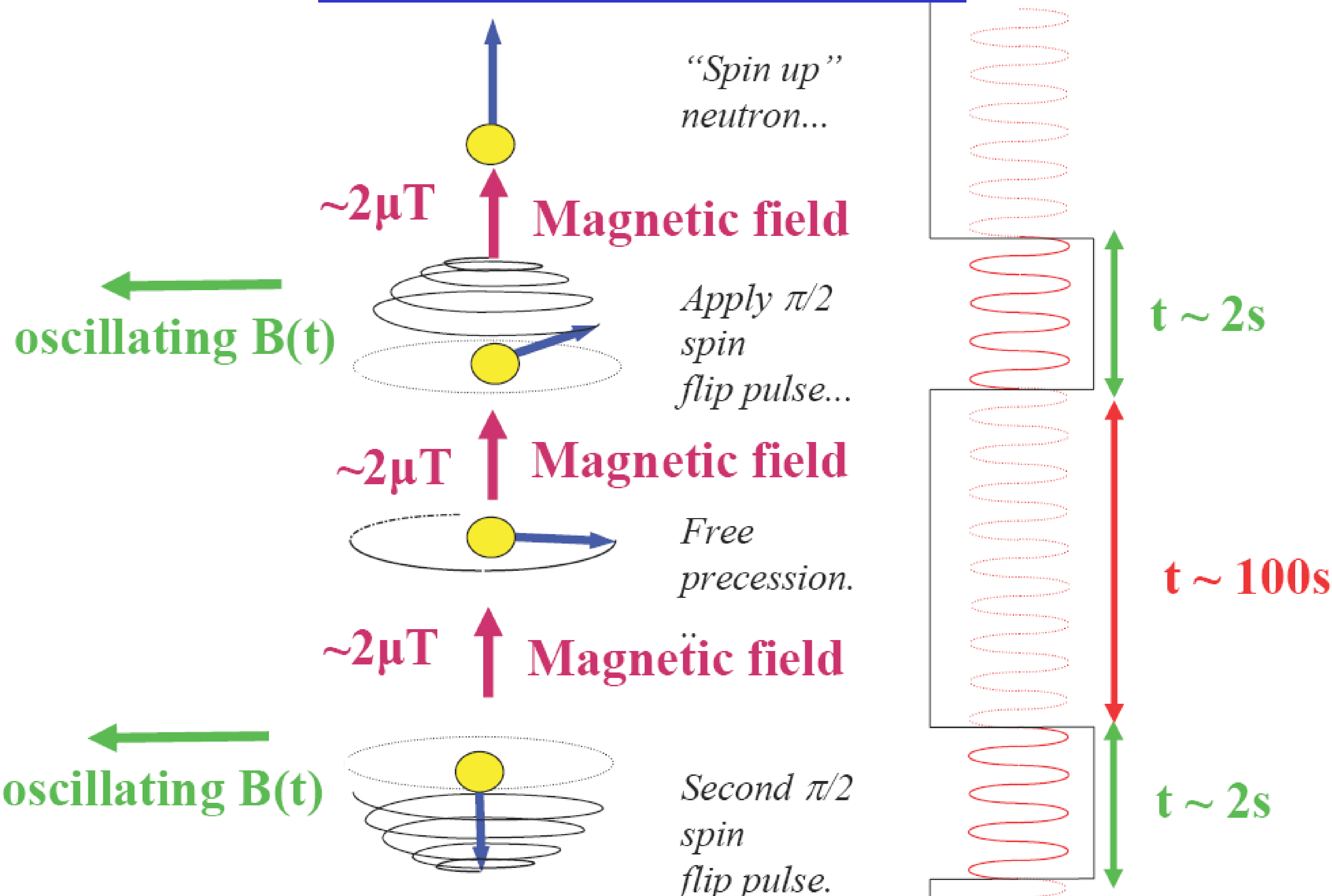


Experimental Work at KVI by G. Onderwater, E. Stephenson (IUCF), *et al.* to explore this parameter space.

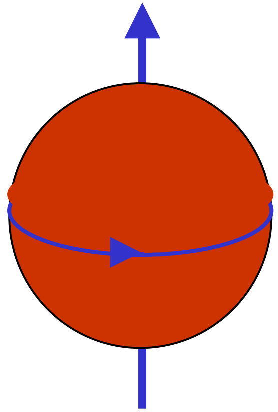
Extrapolation of nuclear rainbow effect is not known.



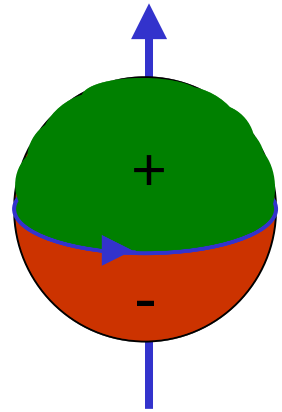
Ramsey’s method



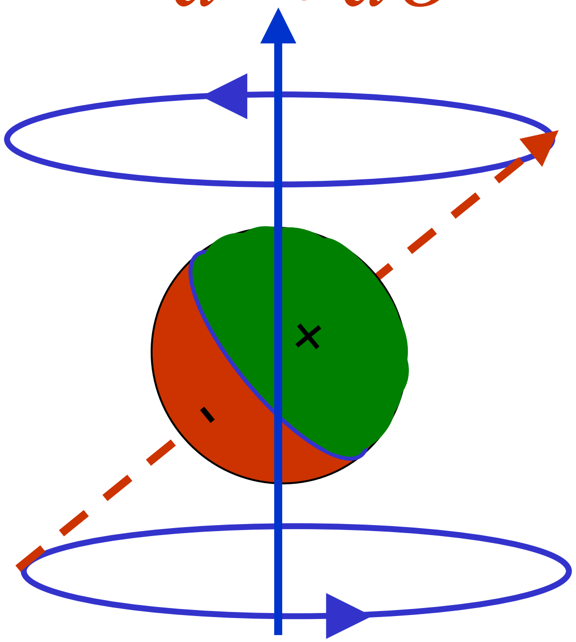
EDM: Particles with Spin…



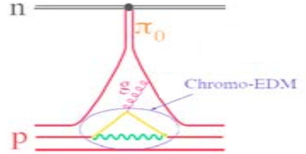
$$\vec{d} = 0$$



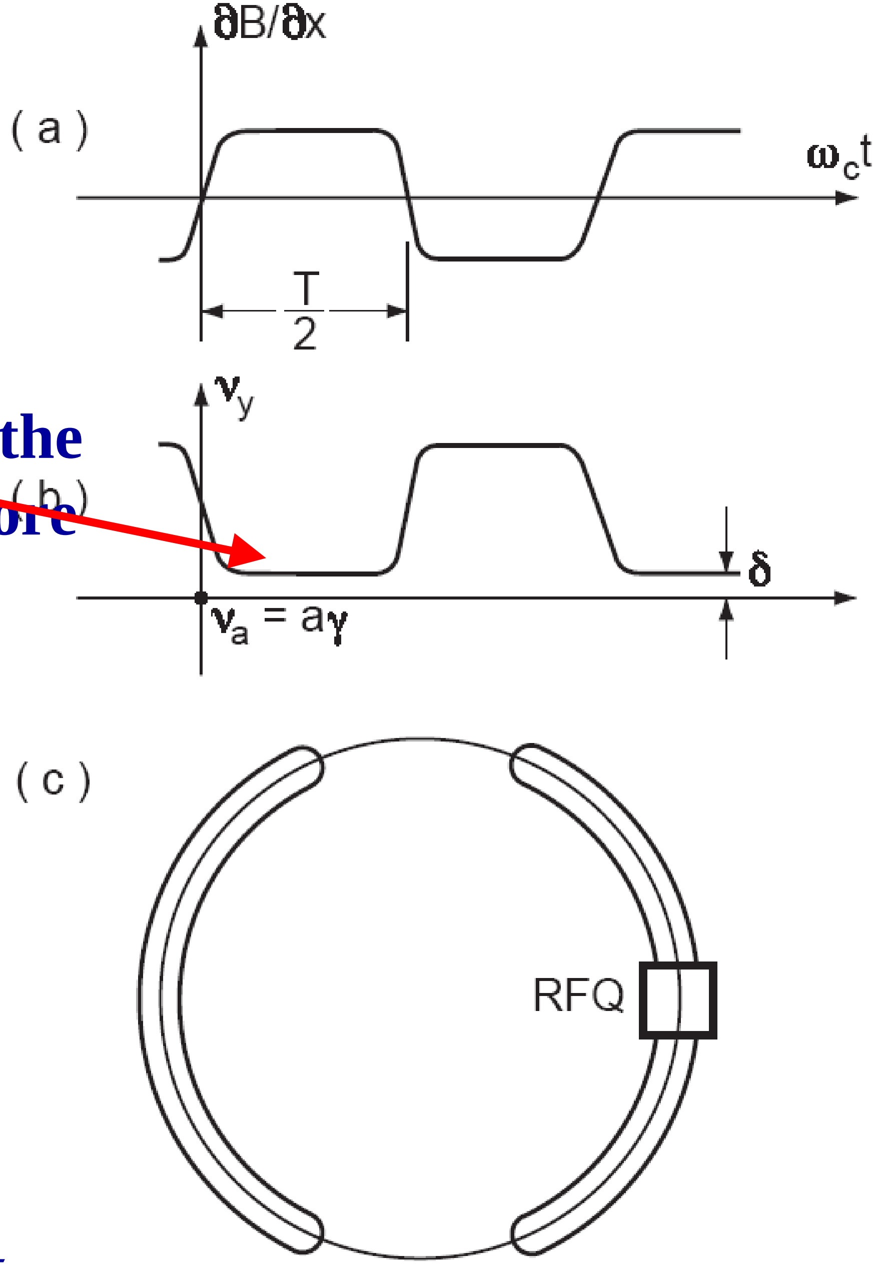
$$\vec{d} \propto d\hat{\sigma}$$



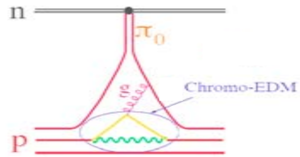
For a particle with a spin, only the EDM component along the spin survives.



Two half beam technique



This tune makes the Deuteron spin more Sensitive to background



Yuri Orlov's EDM note #70

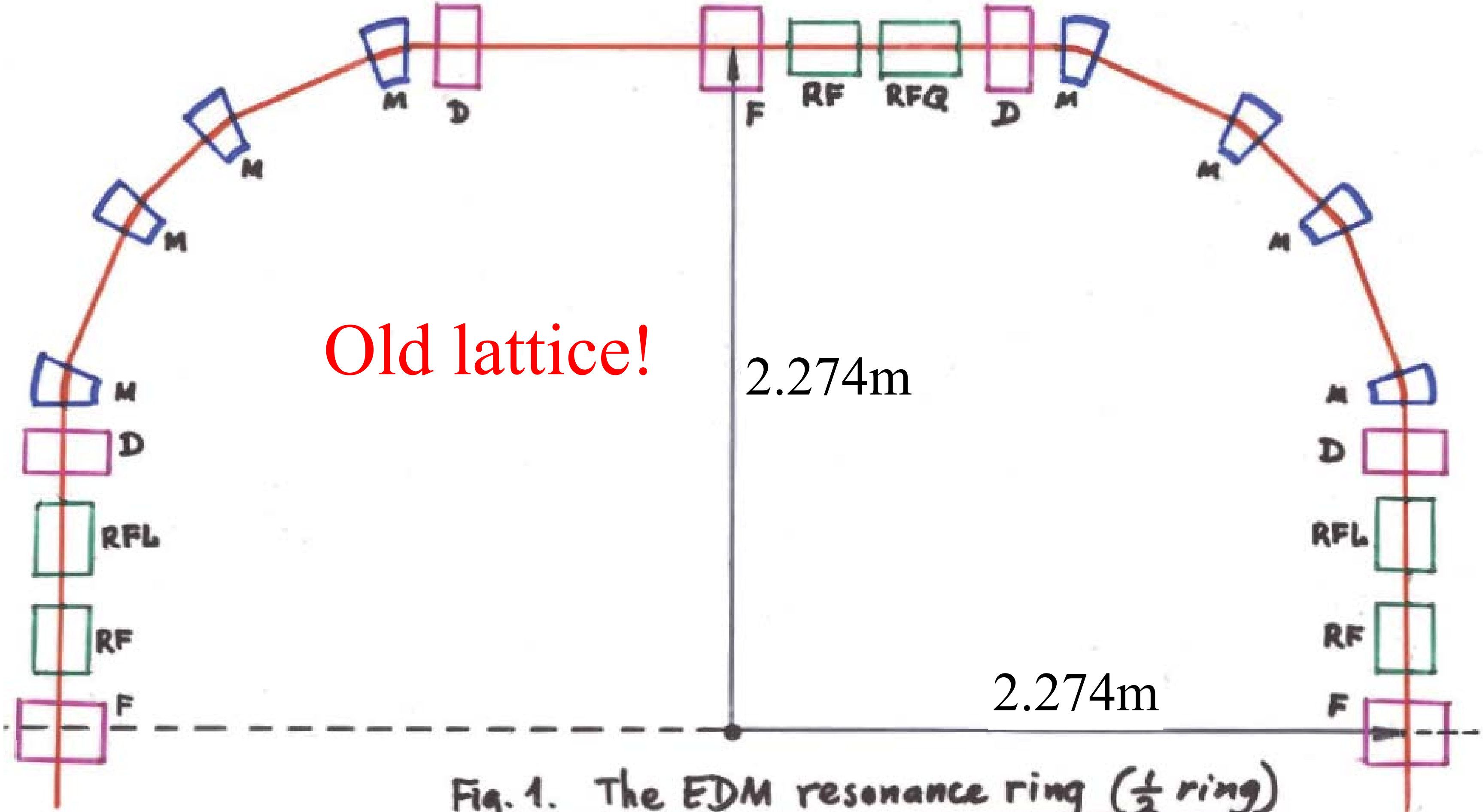


Fig. 1. The EDM resonance ring (½ ring)

M – dipole magnets
F – focusing quadrupoles
D – defocusing quads

RF – usual RF cavities
RFQ – RF quadrupoles
RFL – RF cavities for linearization

Scale 1:20

Effect of the vertical offset, YkS note #85

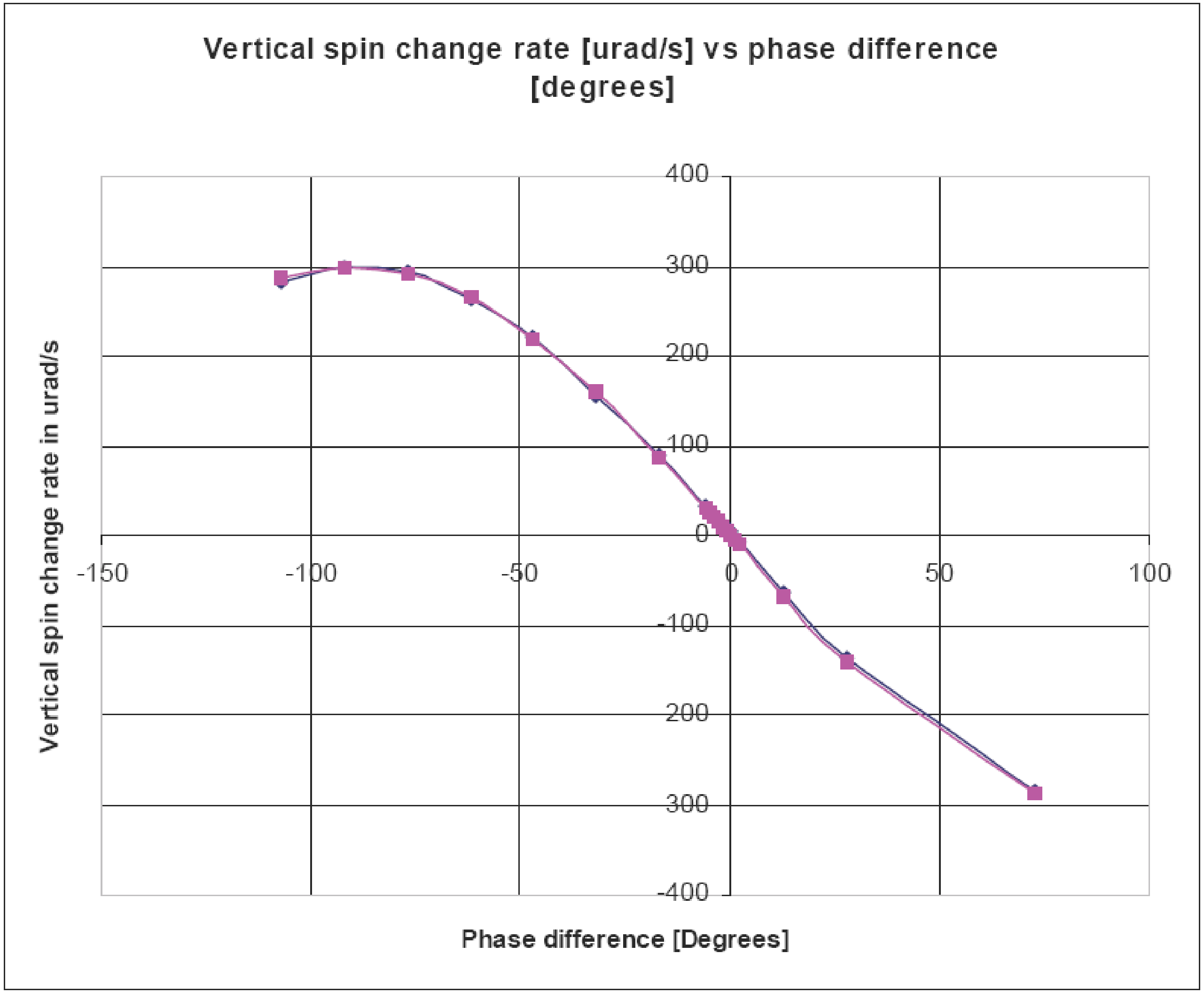
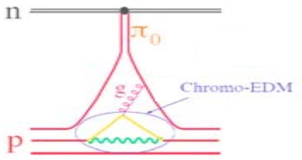


Figure 1. The vertical spin precession rate in μrad/s versus the phase difference (ϕ) between the synchrotron oscillations and the g-2 precession in degrees (modulo 180°) for an RF-cavity offset of 10μm is shown. An overlay of the function 300 μrad/s * sin(ϕ) is also shown.



Effect of the angular offset, YkS note #92

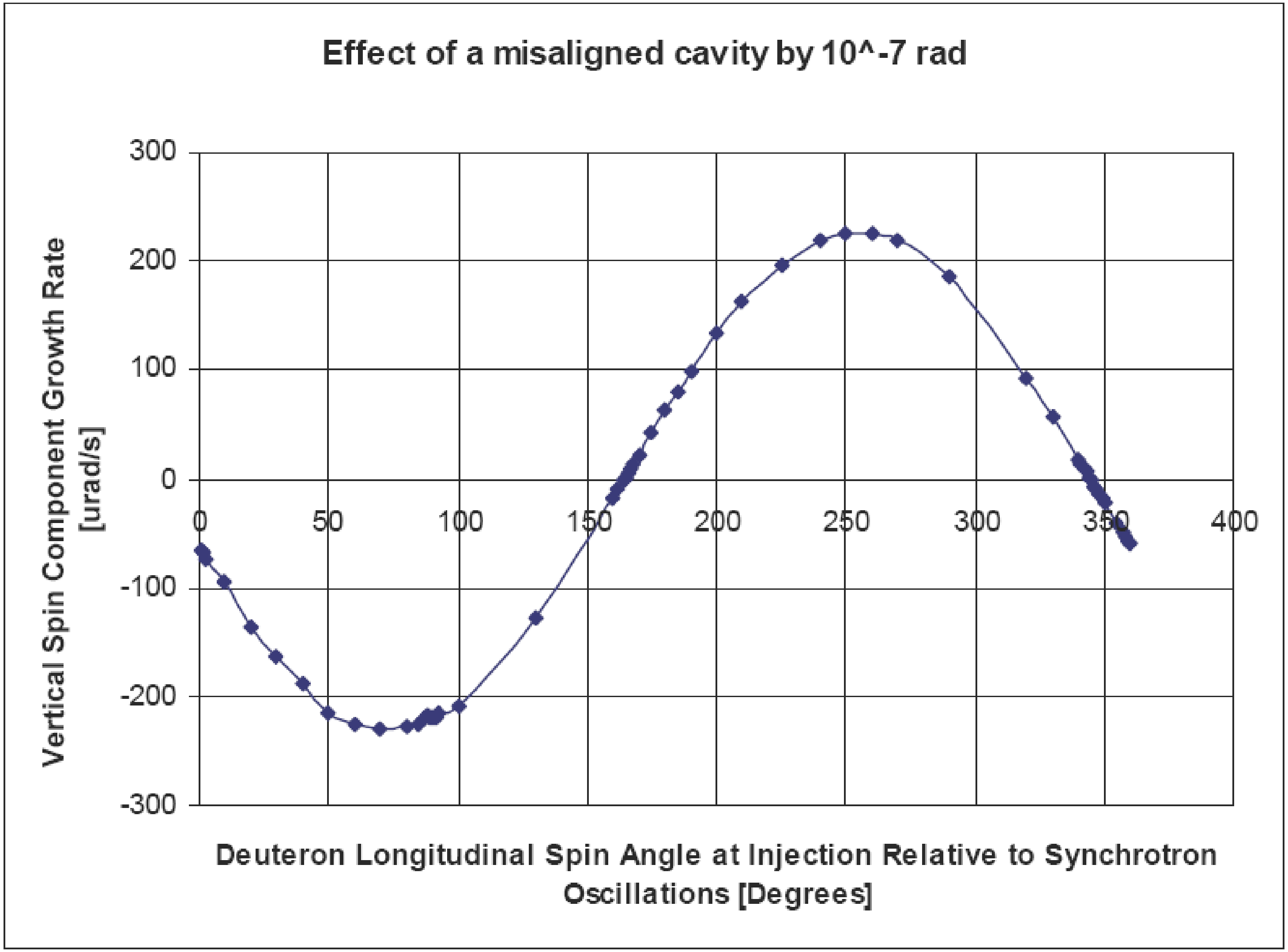
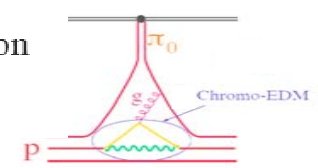
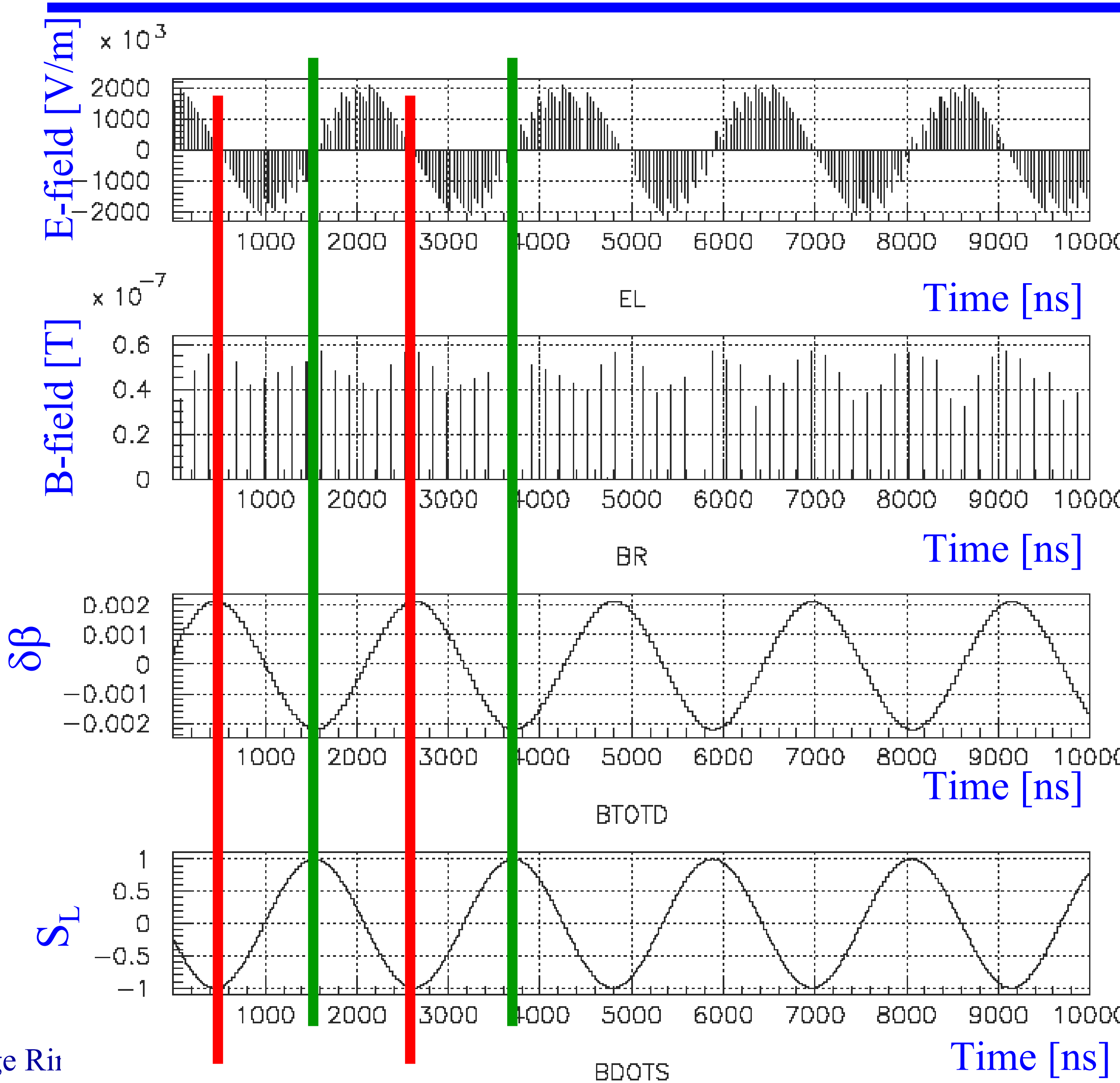


Figure 1. The effect of a misaligned cavity depends on the relative phase between the synchrotron and g-2 oscillations. This dependence is very different from the EDM effect dependence.



RF-fields and oscillation phases

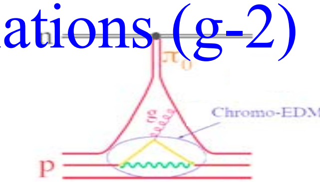


E-field in RF-cavity

B_R-field in RF-cavity

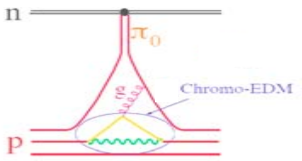
Particle velocity oscillations

Particle S_L oscillations (g-2)



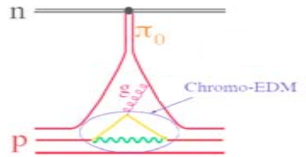
List of things to do…

1. Compaction factor: $\alpha_p=1$ or $\alpha_p\neq1$ Graziano Venanzoni, and Yuri Orlov
2. Low beta (=0.6) Super-Conducting Cavities with one mode having $\omega=3\omega_{RF}$ Alberto Facco, …
3. Space Charge, Impedance, etc. Mikhail Zobov?
4. Polarimetry M.C. Anna Ferrari, Ed Stephenson
5. Slow Extraction coupled with polarimetry
6. Spin Coherence Time Yuri Orlov
7. Polarimetry measurements G. Onderwater, E.S.

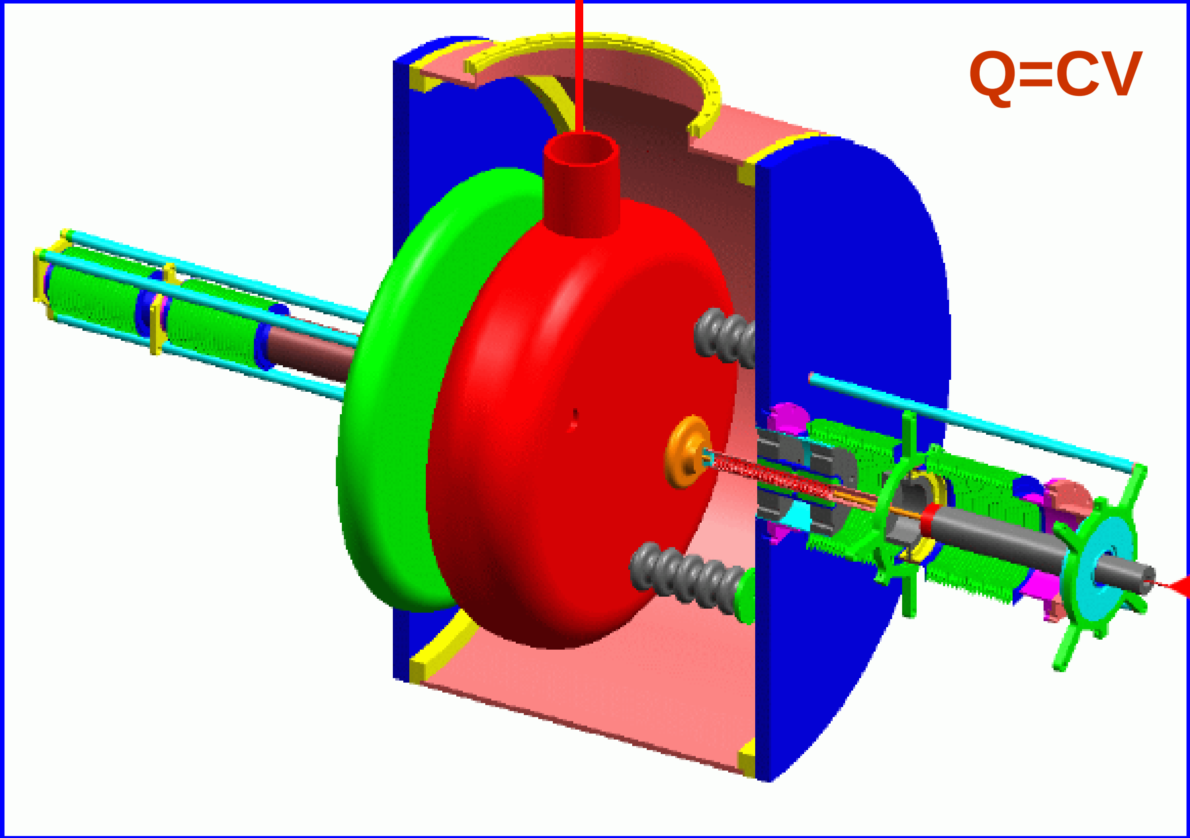


BNL as QCD lab

- Leading role in QCD studies with RHIC
- Lattice QCD leading role with QCD-OC
- θ_{QCD} plays a vital role in the question why strong interactions respect P, T symmetries. The value of θ_{QCD} is probed with highest sensitivity with the storage ring deuteron EDM method.



Concept for HV generator

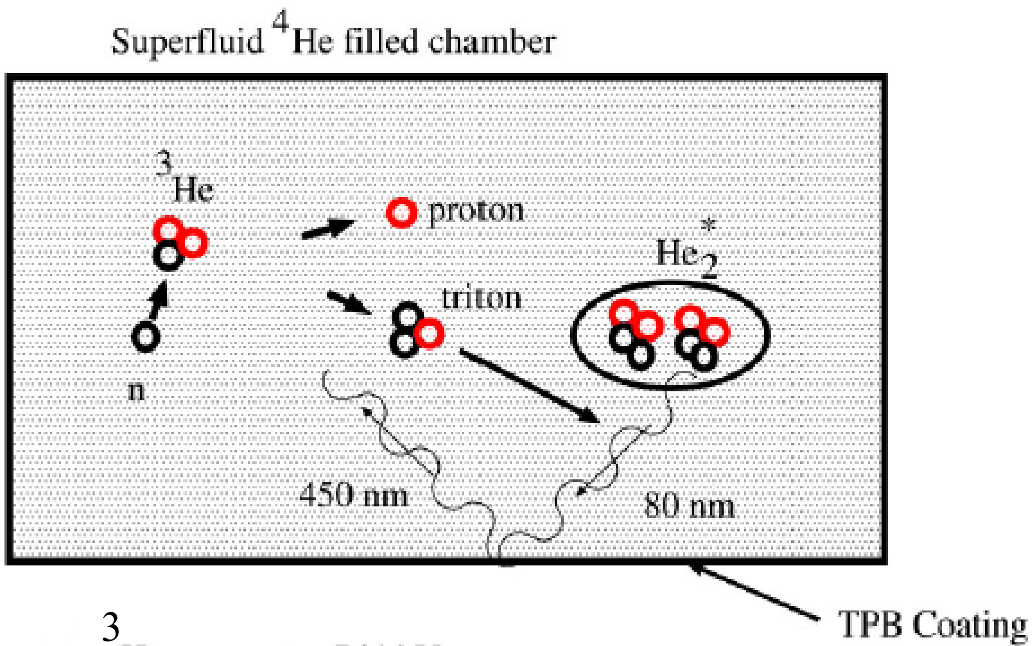


500 kV

50 kV

Variable capacitor in LHe volume

SUPERFLUID HELIUM AS A DETECTOR



$$n + {}^{3}He \rightarrow p + t + 764\ kV$$

The energetic charged particles produced excited state helium molecules, He_2^*

The excited state decays in a few nsec (triplet) and produces 80 nm light for which the superfluid helium is transparent.

The 80 nm light is converted to 450 nm (visible) that can be detected by a photomultiplier tube. Approximately 1 photon/keV deposited is produced.

^{3}He-DOPANT AS AN ANALYZER

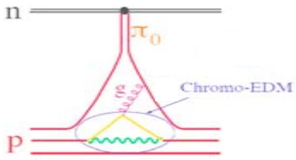
$^3\vec{He} + \vec{n} \rightarrow t + p$

$\sigma(\text{parallel}) < 10^2$ b

$\sigma(\text{opposite}) \sim 10^4$ b

UCN loss rate ~

$1-\vec{p}_3 \bullet \vec{p}_n = 1-p_3 p_n \cos[(\gamma_n-\gamma_3)B_0+2dE]t$



S. Lamoreaux at "Lepton Moments", June 2003

HV Effects on SQUIDs

1. Sparks will likely destroy a SQUID; however, a sudden change in electric field will likely destroy the experiment due to expansion associated with the electrostriction effect for superfluid ^{4}He
2. ^{3}He signal: 0.2 pG, 1 nA leakage in a 10 cm loop: 60 pG (at least 100 X expected field)
3. Dressed spin technique is an alternative method and a profitable goal

E=5MV/m, T=10^8s

R&D