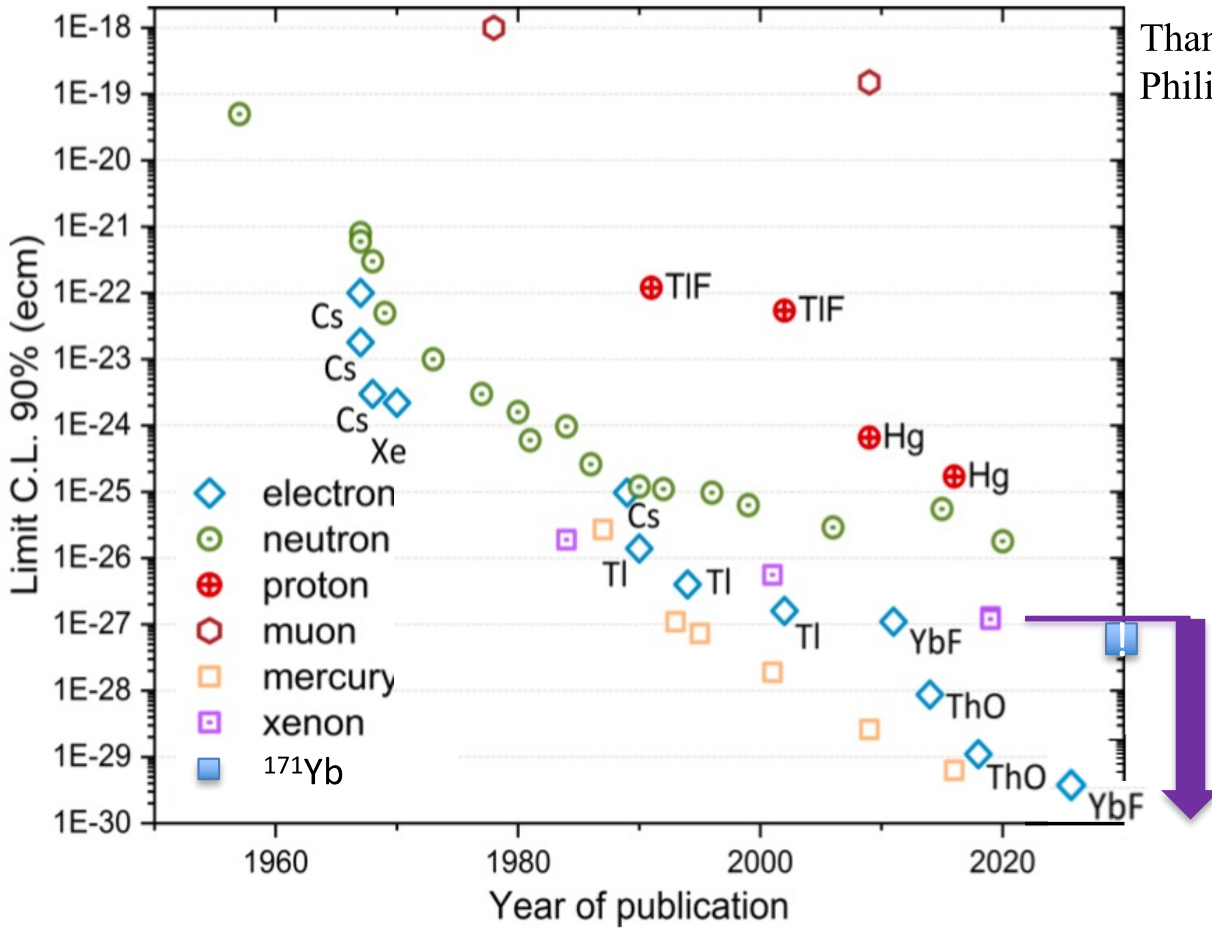
^{129}Xe EDM@LANL: Towards 10^{-30} e-cm:

Tim Chupp - University of Michigan (94, 95, 99, 14, 21, 26…)



Thanks to
Philipp Schmidt-Wellenberg

EDM experiments are well motivated!

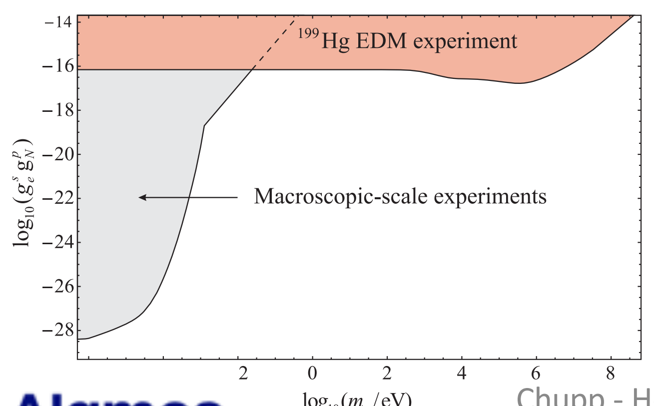
^{129}Xe too!!

Summary of ^{129}Xe Motivations

- Diamagnetic – nuclear spin system
- Alternative to ^{199}Hg, etc. for both theory and experiment
  – ^{199}Hg Theory is difficult/ambiguous – FOR NOW
- Xe comagnetometer for nEDM (e.g. TUCAN)
- Discovery potential: not ruled out (model INdependent)

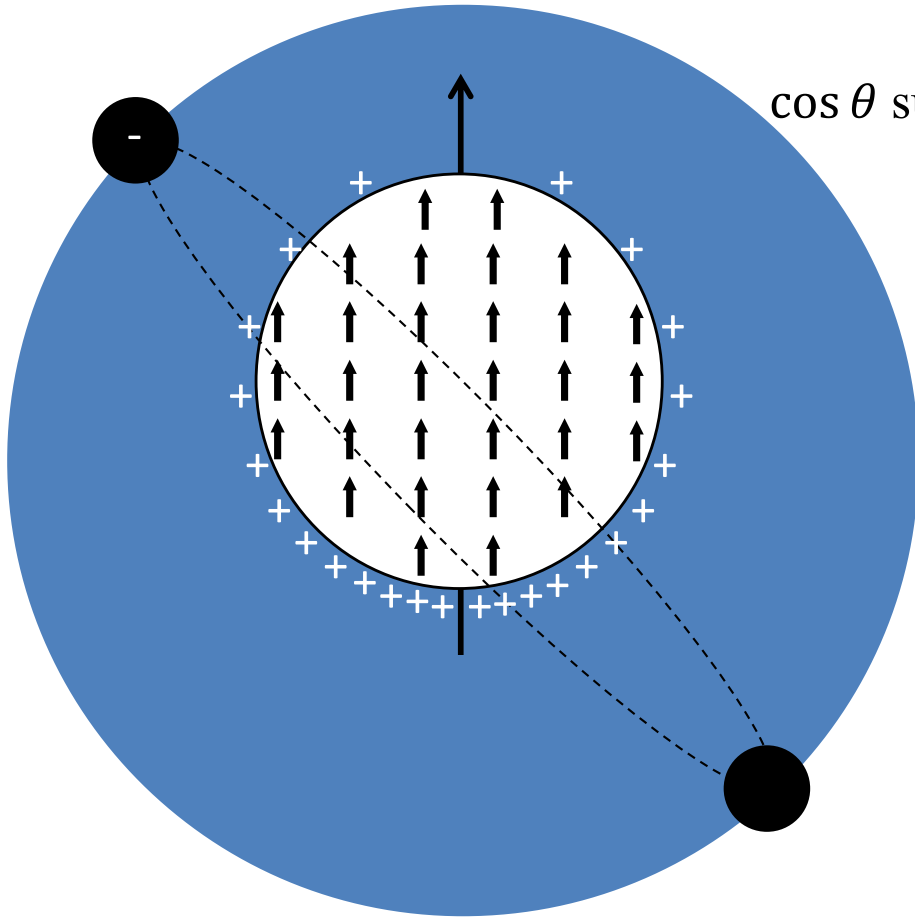
System	$\kappa_S = \frac{d}{S}$ (cm/fm^3)	$a_0 = \frac{S}{13.5\bar{g}_\pi^{(0)}}$ (e fm^3)	$a_1 = \frac{S}{13.5\bar{g}_\pi^{(1)}}$ (e fm^3)	$a_2 = \frac{S}{13.5\bar{g}_\pi^{(2)}}$ (e fm^3)	s_N (fm^2)
^{129}Xe	0.27×10^{-17} (0.27–0.38)	−0.008[−0.005 – (−0.05)]	−0.006[−0.003 – (−0.05)]	−0.009[−0.005 – (−0.1)]	0.63
^{199}Hg	-2.8×10^{-17} [−4.0 – (−2.8)]	0.01 (0.005–0.05)	±0.02 (−0.03 – 0.09)	0.02(0.01–0.06)	1.895 ± 0.035
^{225}Ra	-8.5×10^{-17} [−8.5 – (−6.8)]	−1.5[−6 – (−1)]	+6.0 (4–24)	−4.0[−15 – (−3)]	
TlF	-7.4×10^{-14}	−0.0124	0.1612	−0.0248	0.62

- Can be more sensitive to axions (Stednik&Flambaum)



$\lvert d\rvert$, $e \cdot$ cm	$m_a \lesssim 10^3$ eV	$m_a \gtrsim 10^8$ eV
^{129}Xe	$1.5 \times 10^{-13}\ g_e^s g_N^p$	$1.7\ g_e^s g_N^p (\frac{\mathrm{eV}}{m_a})^2$
^{199}Hg	$3.2 \times 10^{-14}\ g_e^s g_N^p$	$7.3\ g_e^s g_N^p (\frac{\mathrm{eV}}{m_a})^2$
^{211}Rn	$9.3 \times 10^{-14}\ g_e^s g_N^p$	$8.5\ g_e^s g_N^p (\frac{\mathrm{eV}}{m_a})^2$
^{225}Ra	$1.3 \times 10^{-13}\ g_e^s g_N^p$	$25\ g_e^s g_N^p (\frac{\mathrm{eV}}{m_a})^2$

Particle Interactions Polarize Particles, Atoms, Molecules



$\cos\theta$ surface charge distribution
Ginges&Flambaum
deMille

Diamagnetic atoms: Schiff moment $\propto Z^2$

$$\vec{S} = S\vec{J} = \frac{1}{10}\left\langle r^2 \vec{r}_p \right\rangle - \frac{1}{6} Z \left\langle r^2 \right\rangle \left\langle \vec{r}_p \right\rangle$$

Brief history

- 1963: Schiff's theorem/violations

  Motivated by Fairbank's ^{3}He idea
- 1980/4: Ramsey's ^{3}He comagnetometer proposal (nEDM)
- 1984: Fortson/Vold: single species ^{129}Xe at UWashington
- **1990: Oteiza – first He-Xe comagnetometer EDM experiment**
- **2001: Rosenberry* – dual He-Xe maser**
- **2019: HeXe @TUM – PTB (MSR test while waiting for UCNs)**
- 2019: MIXed (next talk)

Other efforts:

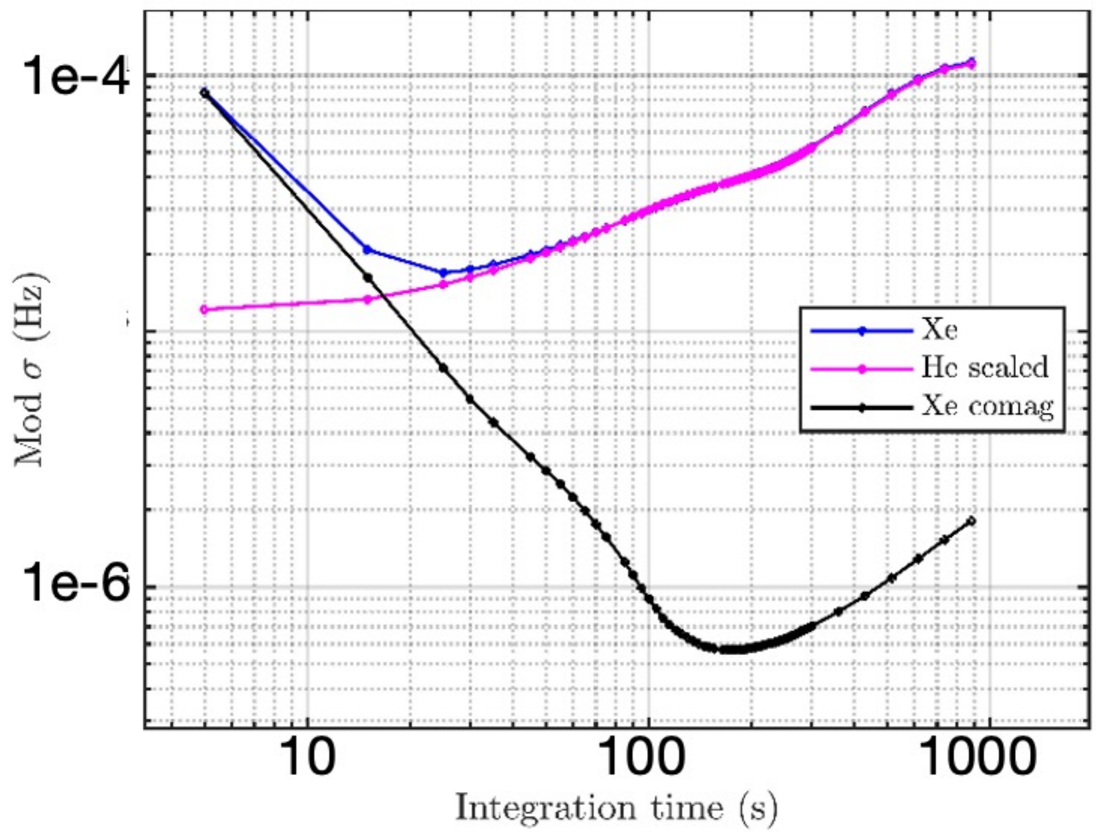
- Romalis – LXe
- Active maser: Tokyo
- TRIUMF Xe (comagnetometer)

Comagnetometry

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

$$\omega_{co} = \omega_{\mathrm{Xe}}^{meas} - R\omega_{\mathrm{He}}^{meas}$$

$$R \rightarrow \frac{1}{2.7540816} \approx \frac{\gamma'_{\mathrm{Xe}}}{\gamma'_{\mathrm{He}}}$$



Other comagnetometers

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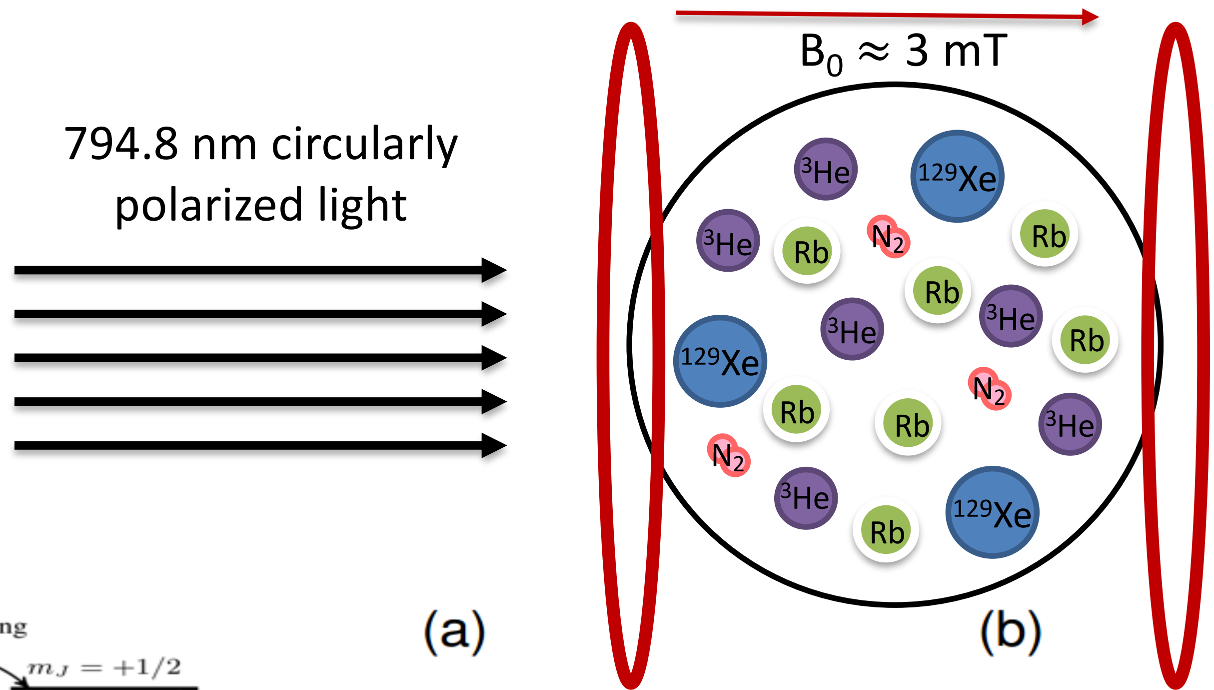
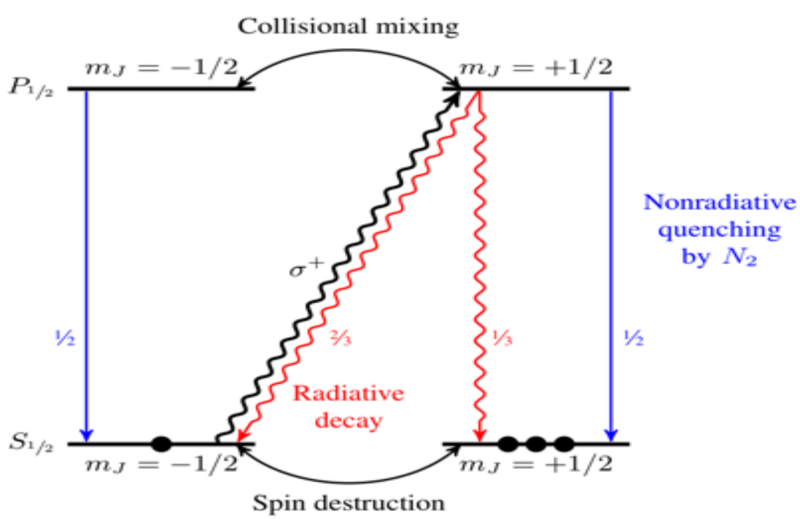
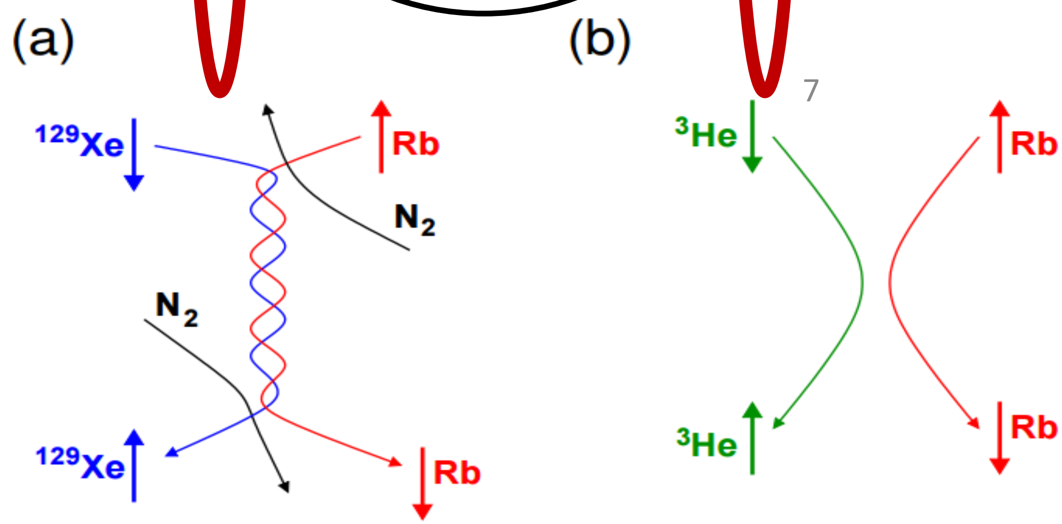
- $^{3}He/^{21}Ne$ (I=3/2)
- Alkali-noble gas, e.g. K-^{3}He (Romalis)
- Na/Cs (Sandars)
- Na/Tl (Commins)
- Neutron/^{199}Hg (Pendelbury/ILL)
- Neutron/^{129}Xe (TRIUMF/TUCAN: proposed)

$^3He/^{129}Xe$ Spin-exchange optical pumping







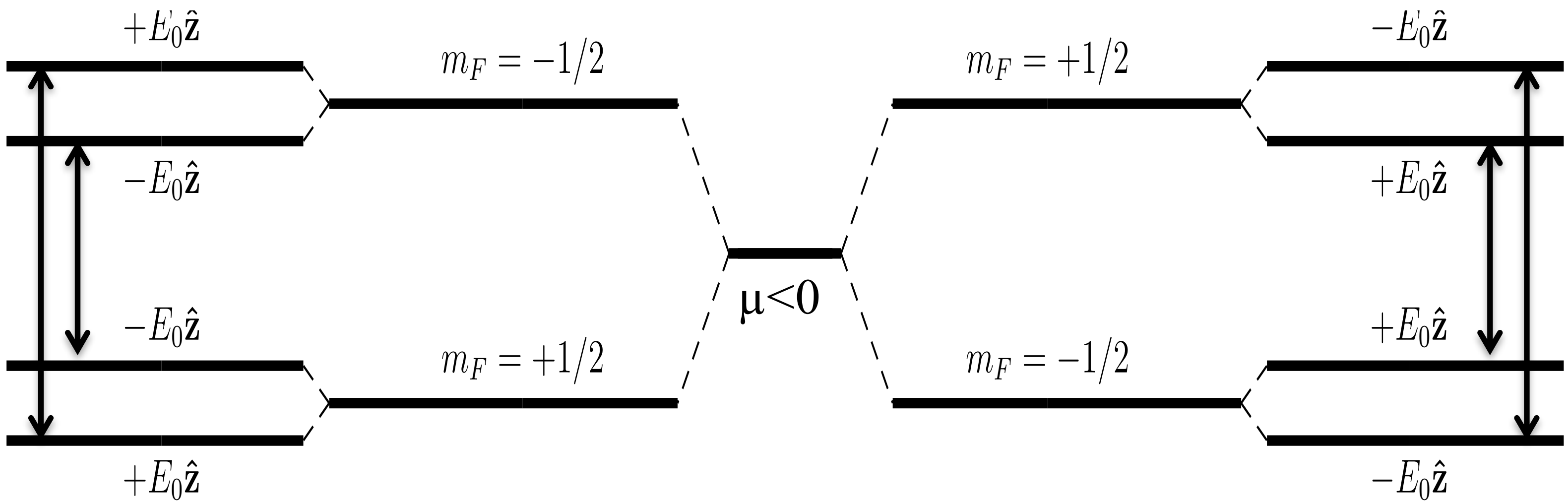
M. A. Bouchiat, T. R. Carver, and C. M. Varnum. Phys. Rev. Lett., 5:373 (1960).
Happer et al.; TC et al.; Walker et al.

Move on … 7

Frobidden Transition

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

- Strong electric field (static): need neutral particles (or confined ion)
- Large signal needs POLARIZATION **$\vec{\mu}$ negative, $\vec{d}$ positive**.



- MEASURE FREQUENCIES:

$$\sigma_d \approx \frac{1}{2E}\frac{\hbar}{T_2}\frac{1}{S/N}$$

$$\frac{1}{2E}\frac{\hbar}{T_2}\frac{1}{\sqrt{\varphi_n T_2}}$$ Phase-noise limit

$$\frac{1}{2E}\frac{\hbar}{T_2}\frac{1}{\sqrt{N_\gamma}}$$ Count-rate limit

- **AND MAGNETIC FIELDS**

Oteiza (1992)

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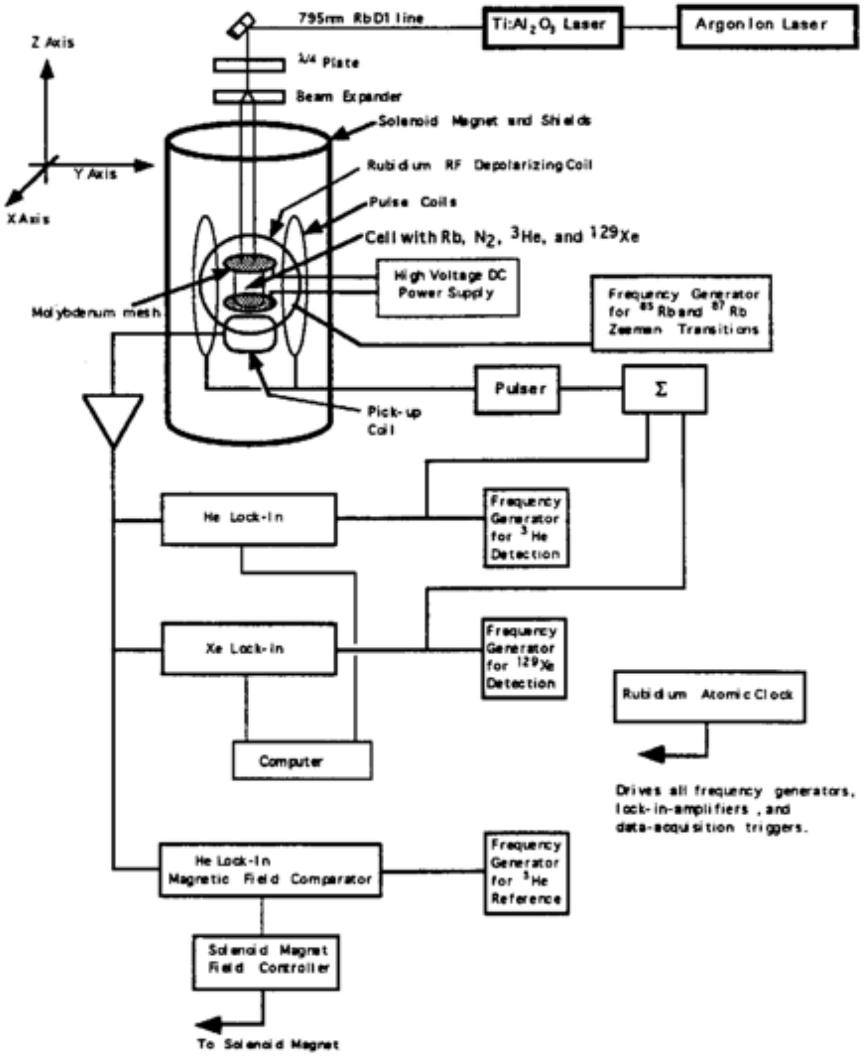

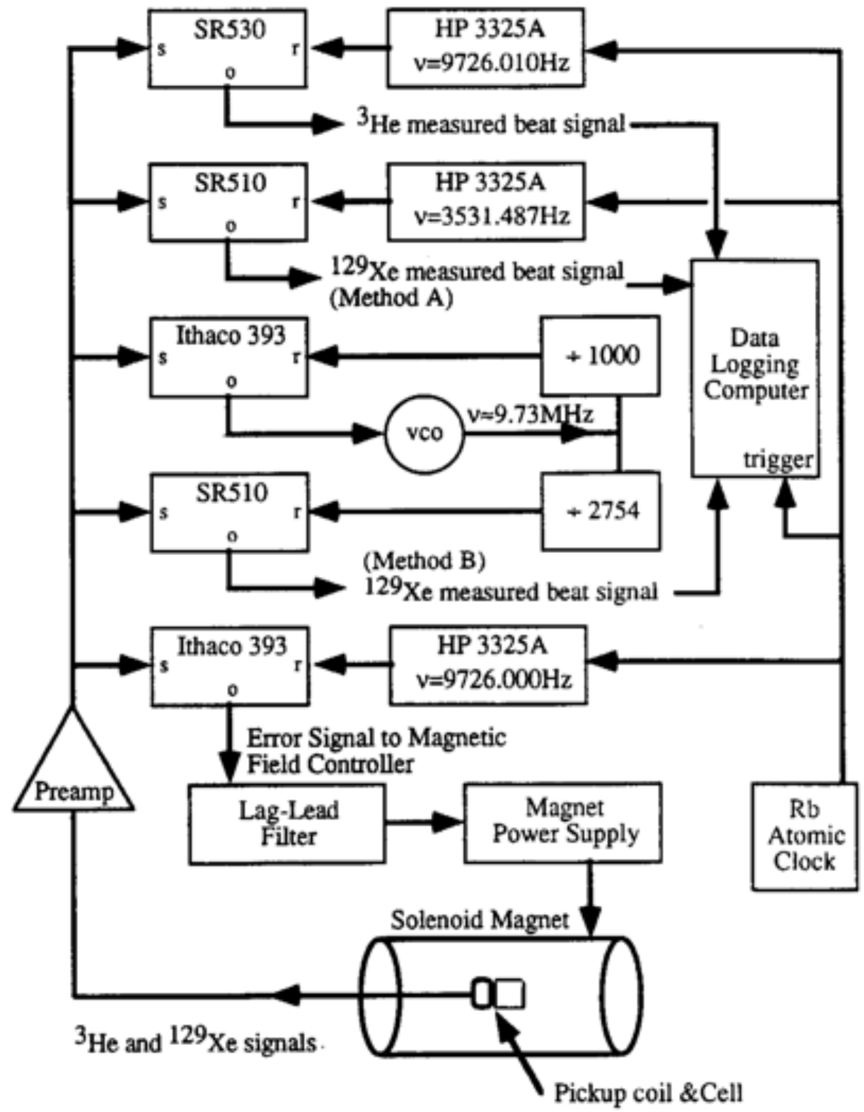

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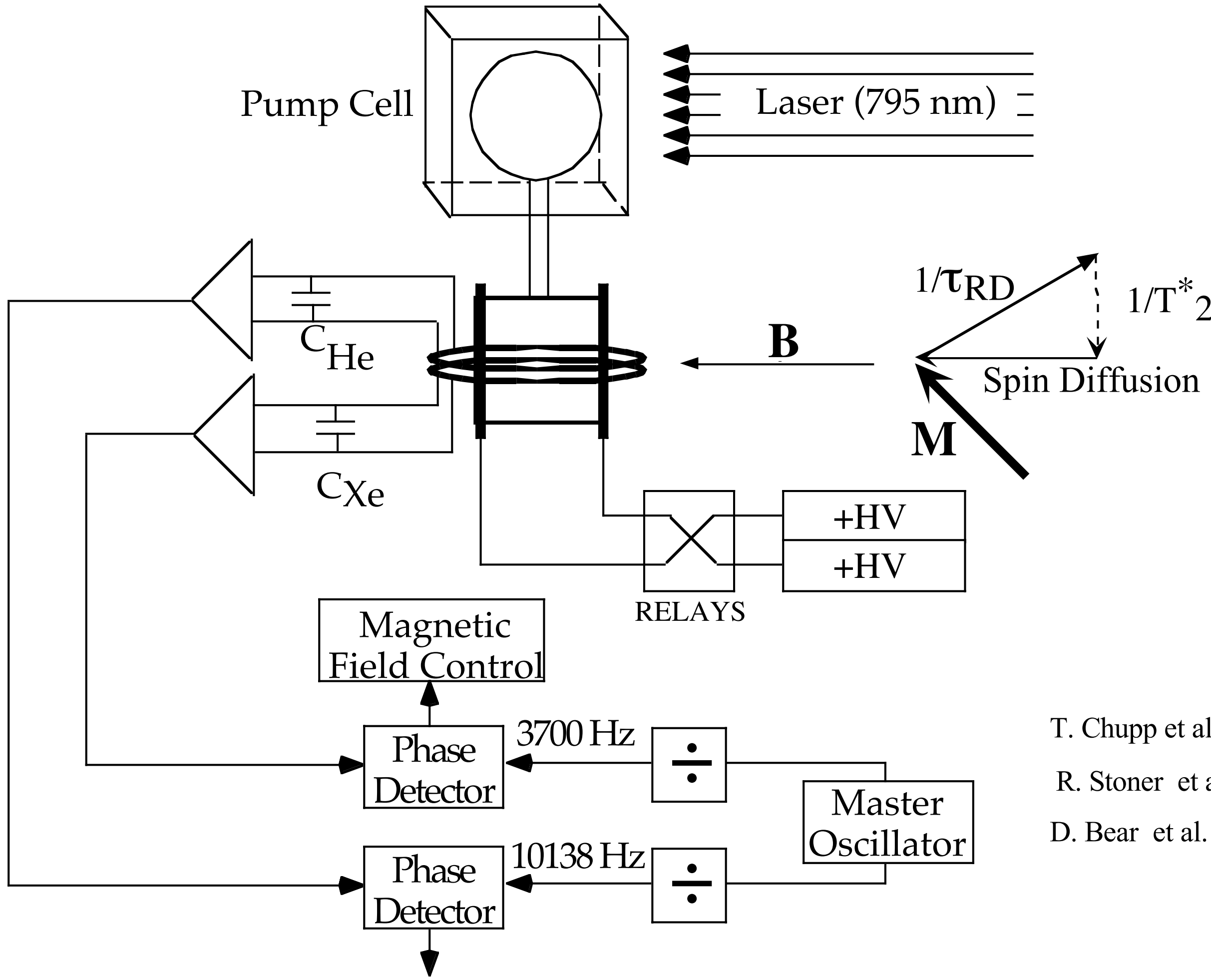
VOLUME 86, NUMBER 1 PHYSICAL REVIEW LETTERS 1 JANUARY 2001

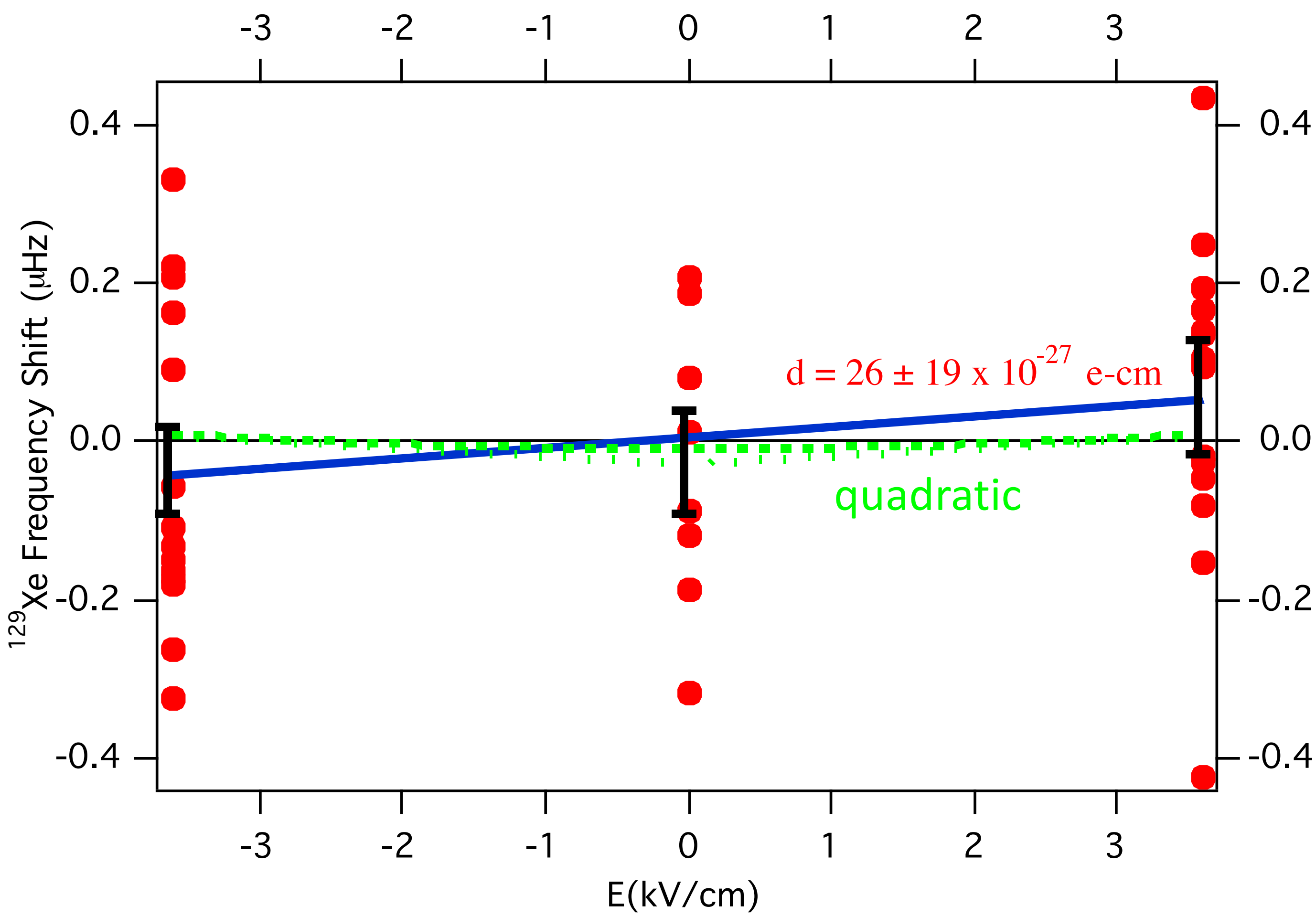
Atomic Electric Dipole Moment Measurement Using Spin Exchange Pumped Masers of ^{129}Xe and ^{3}He

M. A. Rosenberry* and T. E. Chupp
University of Michigan, Ann Arbor, Michigan 48109
(Received 1 August 2000)



T. Chupp et al. PRL 72, p 2363 (1994)
R. Stoner et al. PRL 77, p 3971 (1996)
D. Bear et al. PRA 57, p 5006 (1998)

EDM Run



Final: d_{Xe}=(0.7±3.3)x10^{-27} e-cm

(<6.6x10^{-27} e-cm 95%)

^{129}Xe EDM with He Comagnetometry

TUM
Peter Fierlinger
Florian Kuchler
Stefan Stuber
Mike Marino
Jonas Meinel

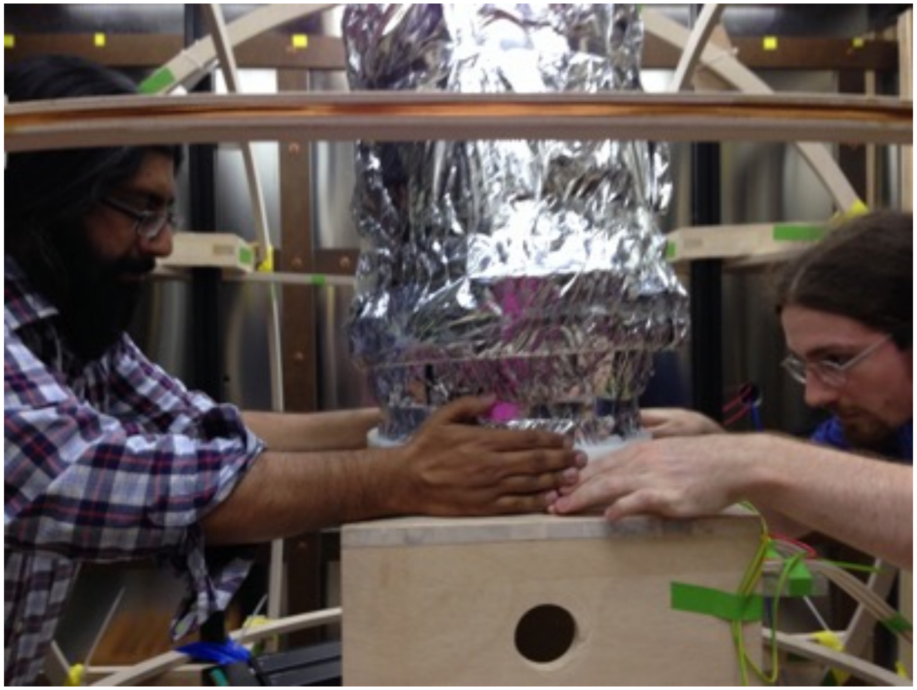
PTB
Wolfgang Kilian
Issac Fan
Allard Schnabel
Sylvian Knappe
Martin Burghoff
Lutz Trahms
Tianhao Liu

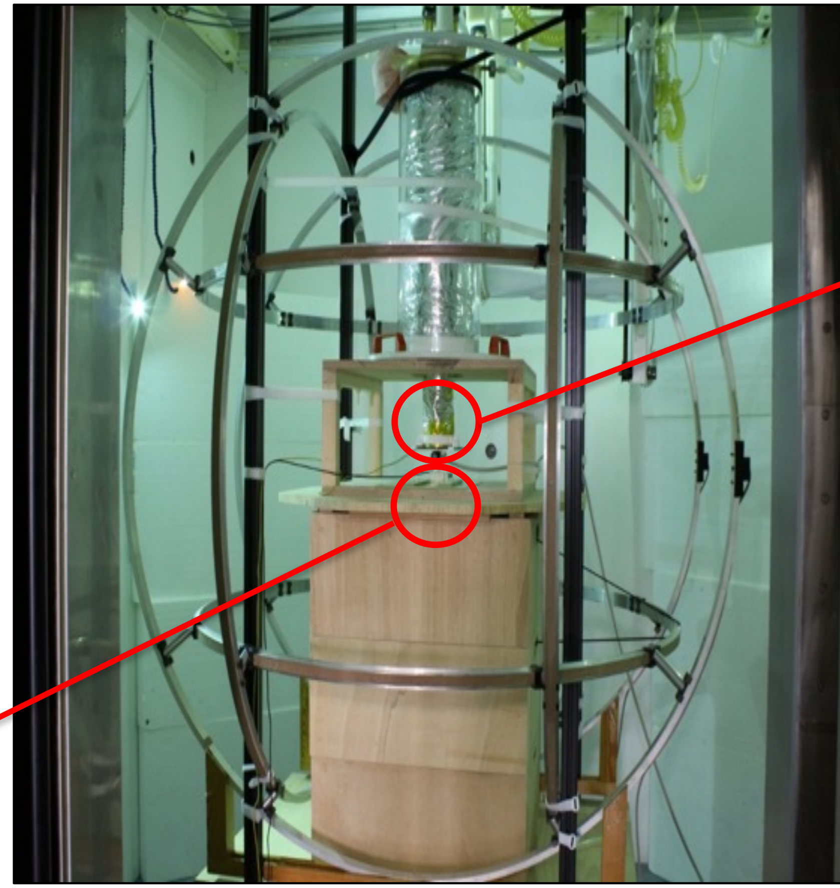
MSU
Jaideep Singh

Julich FZ
Earl Babcock

UM
Natasha Sachdeva
Skyler Degenkolb
Fei Gong
T.C.

HeXe at PTB





MRX SQUID system in the BMSR-2 at PTB Berlin.

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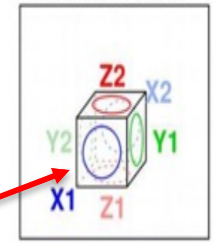
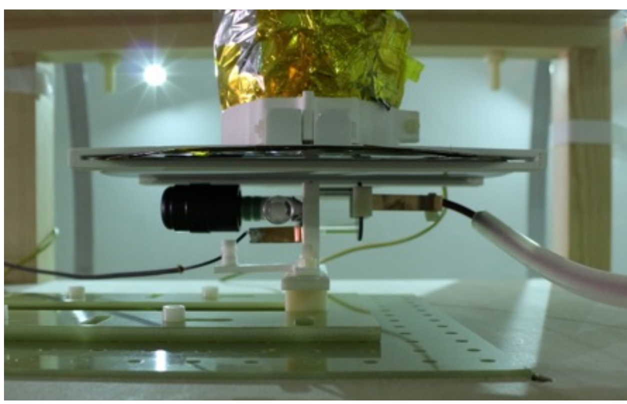
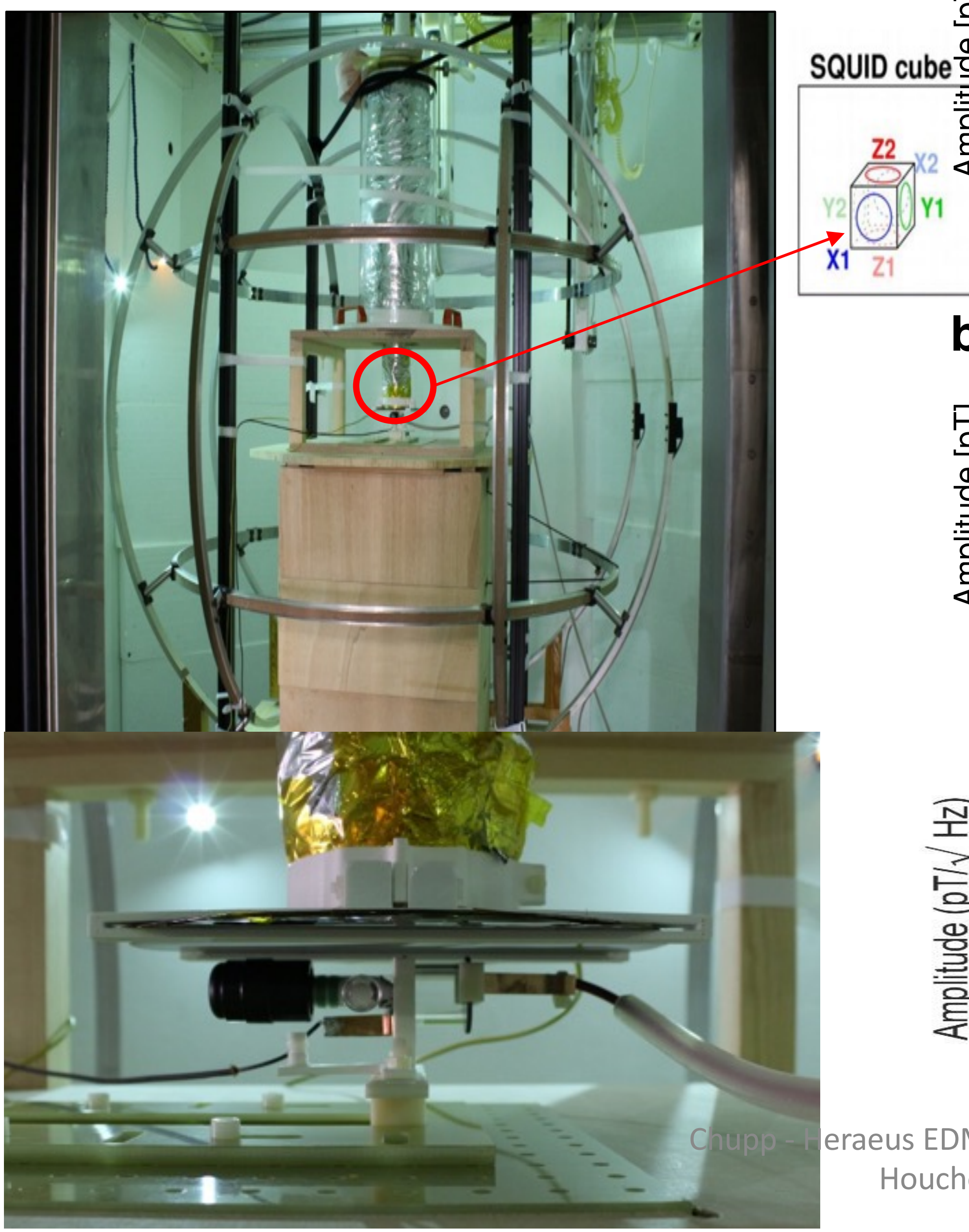
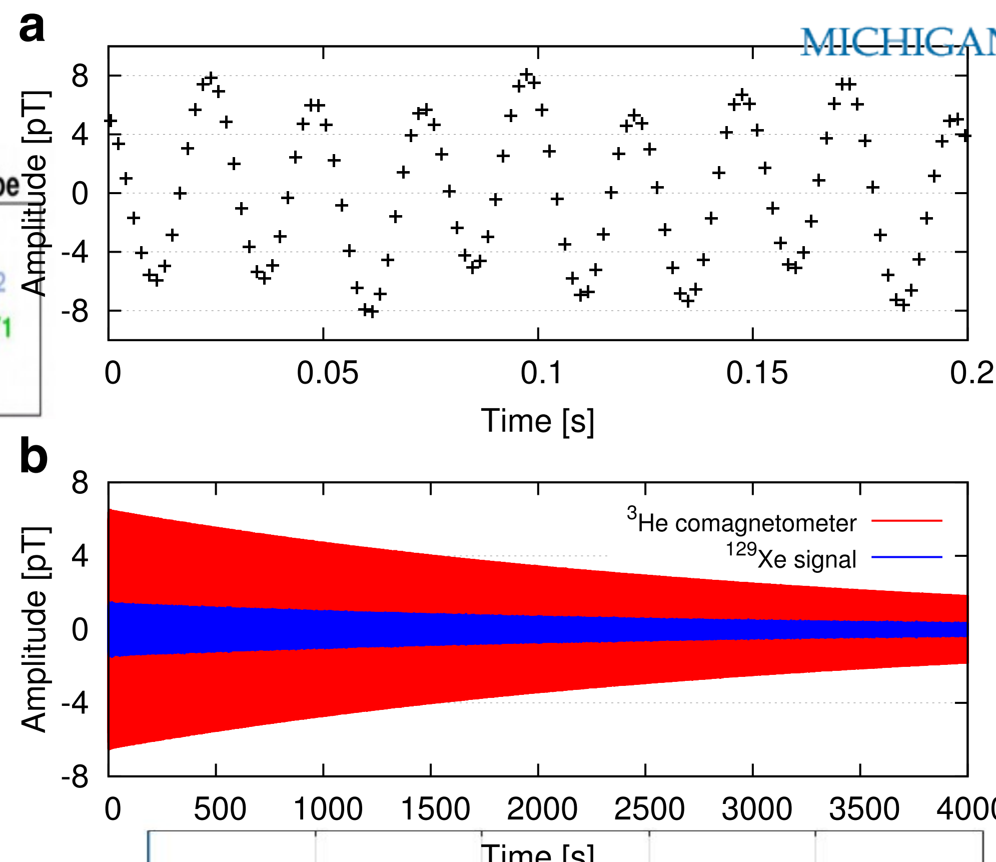
SQUID cube

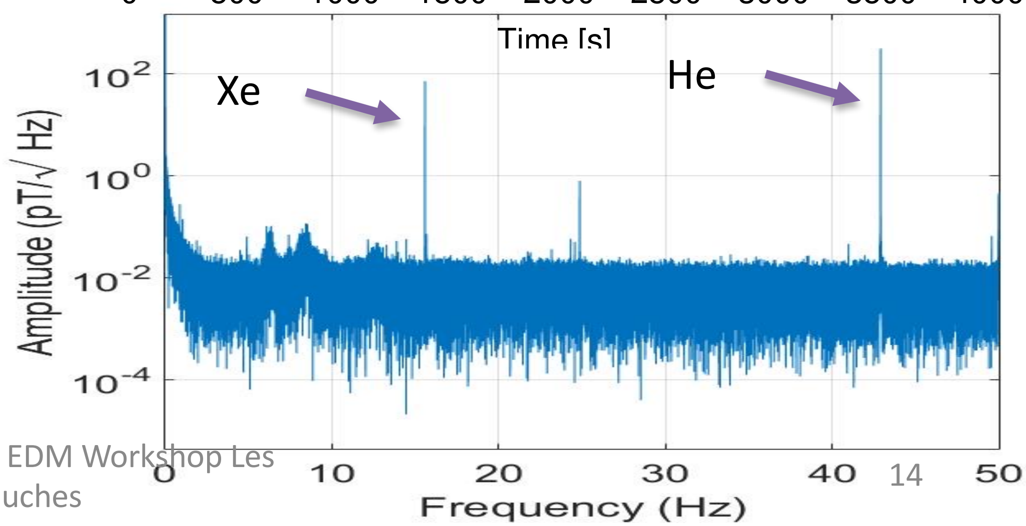




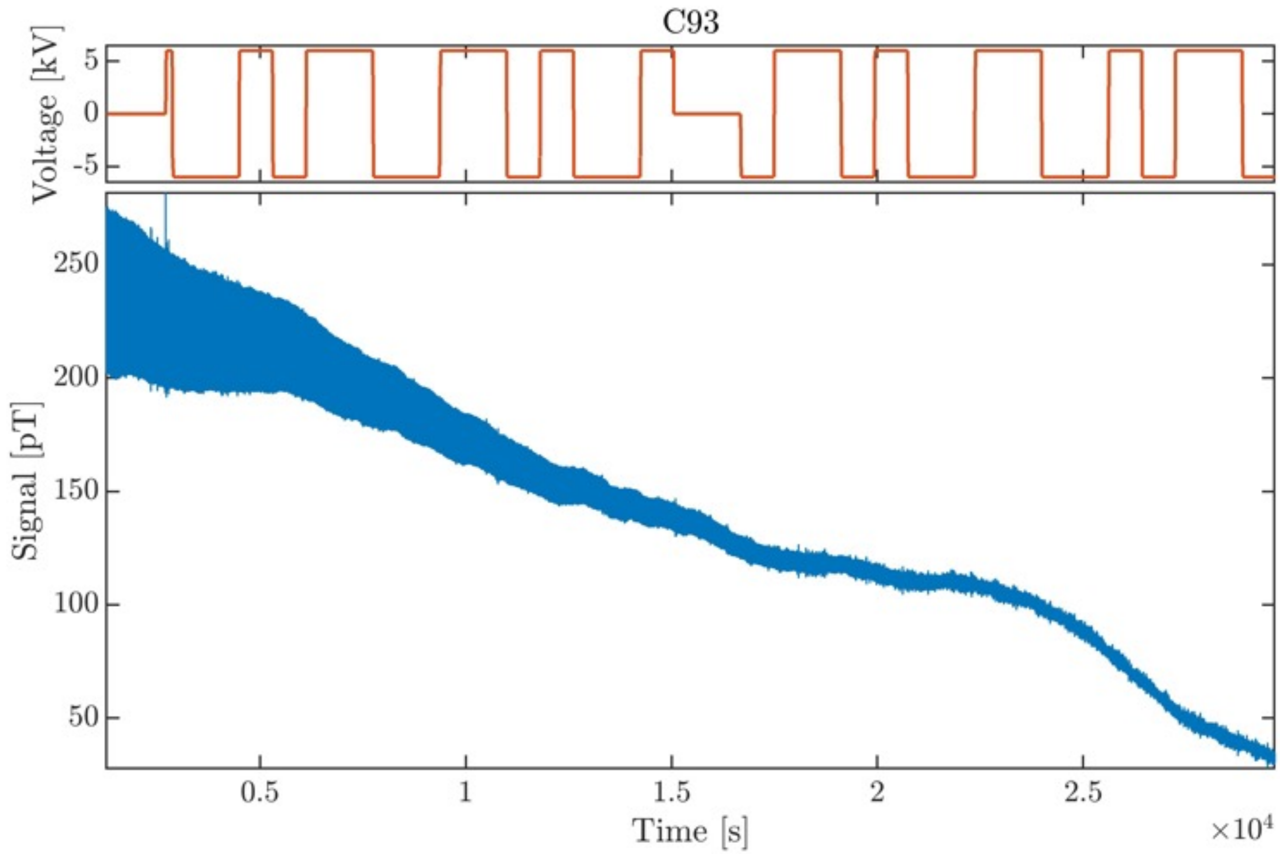
SQUID Detection







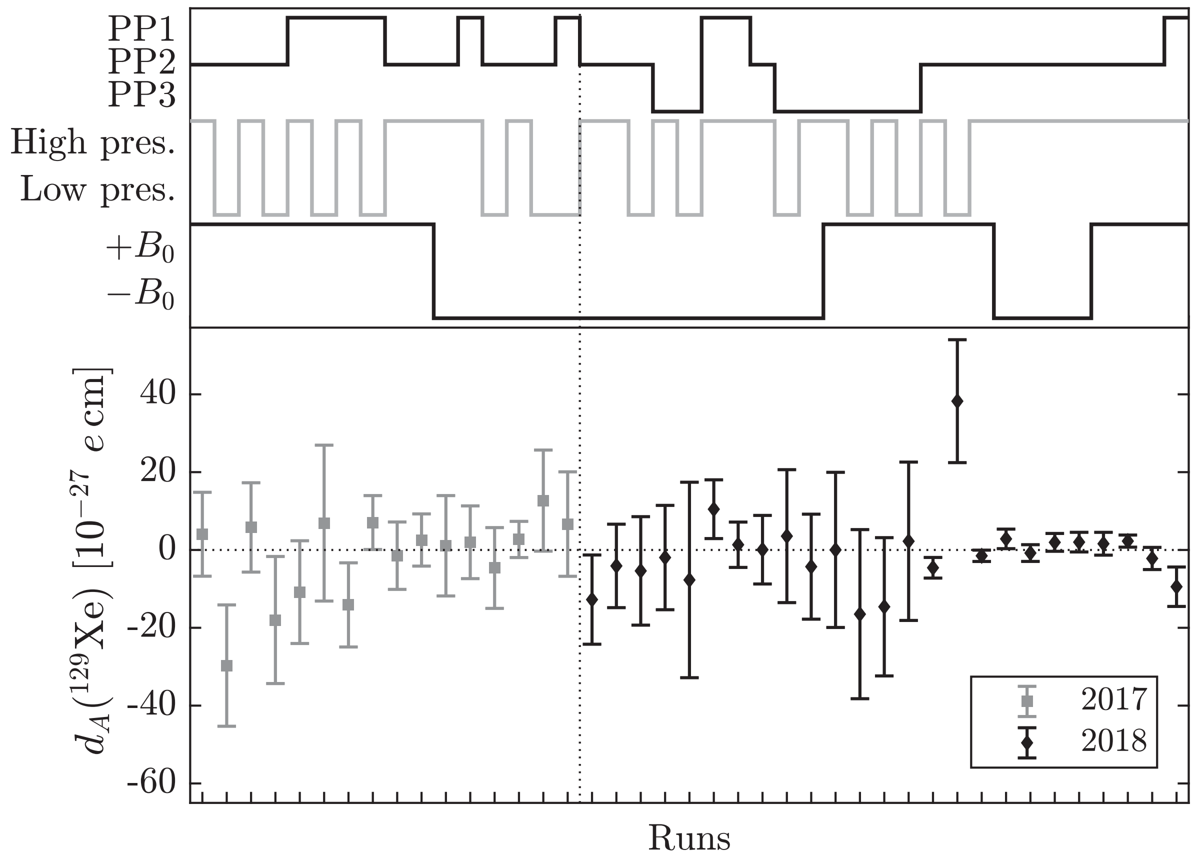
Data Reduction



1. High pass filter – removes offset and slow drift (B)
2. Fit 20s blocks to $A_X\cos(w_Xt)+B_X\sin(w_Xt)+A_H\cos(w_Ht)+B_H\sin(w_Ht)$ (6 param.)
3. Find phase by block: $\Phi_{X=}\mathrm{atan}(B_X/A_X)+N_X\pi$; $\Phi_H=\mathrm{atan}(B_H/A_H)+N_H\pi$: removes B drift
4. Fit comagnetometer phase vs time for each 400(800) second segment; **ADD BLIND**

All 2017-18 EDM Data

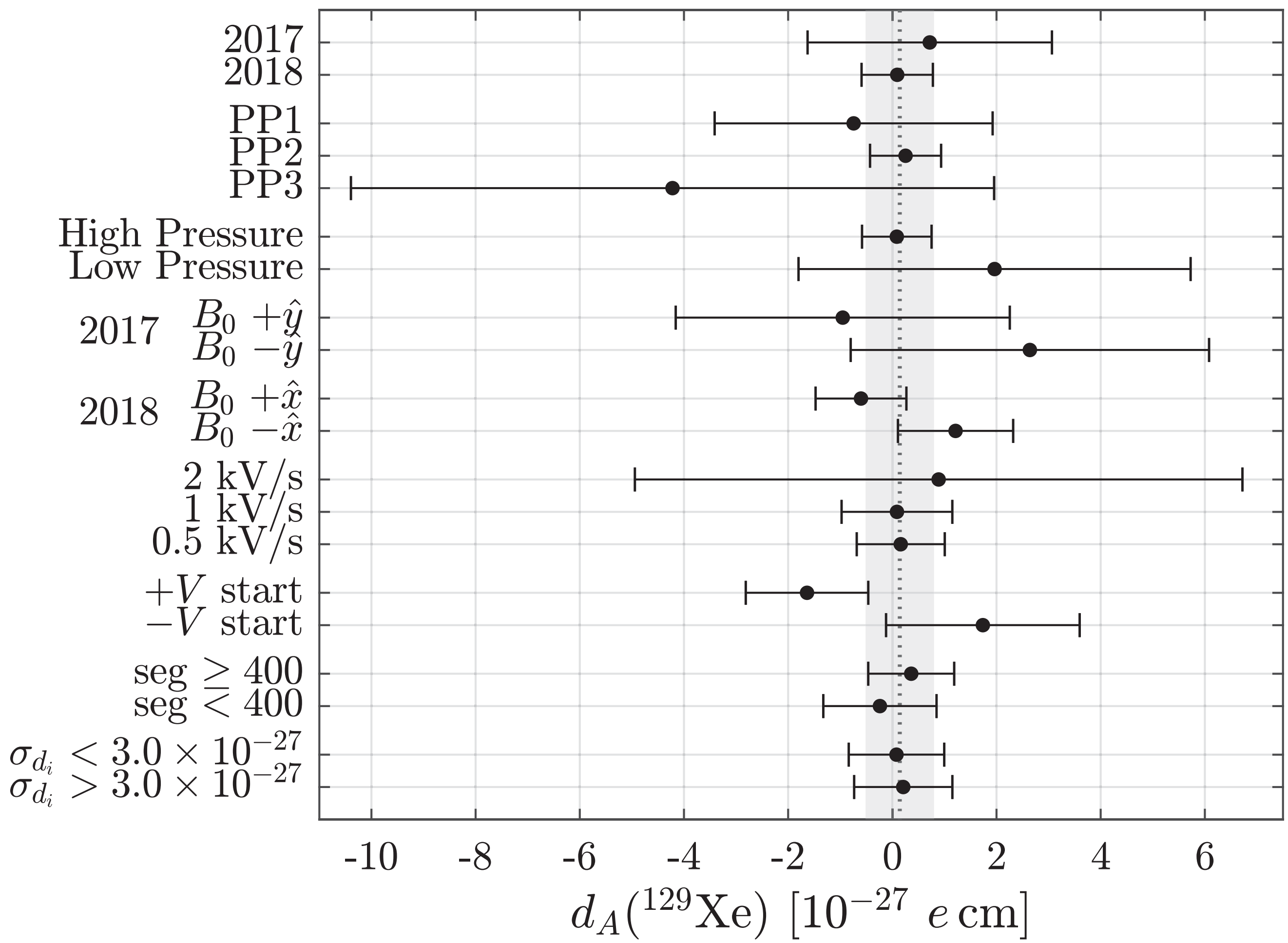
PRL 123, 143003 (2019)



$$d_A(^{129}\mathrm{Xe}) = (1.4 \pm 6.6_{\mathrm{stat}} \pm 2.0_{\mathrm{syst}}) \times 10^{-28}\ e\,\mathrm{cm}$$

$$|d_A(^{129}\mathrm{Xe})| < 1.4 \times 10^{-27}\ e\,\mathrm{cm}\ (95\%\ \mathrm{C.L.}),$$

Experimental condition dependence



Systematic effects

Systematic error	**2017 (*e*-cm)**	**2018 (*e*-cm)**
Leakage current	1.2×10^{-28}	4.5×10^{-31}
Charging currents	1.7×10^{-29}	1.2×10^{-29}
$\vec{E}$-correlated cell motion (rotation)	4.2×10^{-29}	4.0×10^{-29}
$\vec{E}$-correlated cell motion (translation)	2.6×10^{-28}	3.2×10^{-28}
Comagnetometer drift	2.6×10^{-28}	2.6×10^{-28}
$\lvert\vec{E}\rvert^2$ effects	1.2×10^{-29}	2.2×10^{-28}
$\lvert\vec{E}\rvert$ uncertainty	7.2×10^{-29}	$0.1 d_A$
Geometric phase	$\leq 2 \times 10^{-31}$	$\leq 1 \times 10^{-31}$
Total Systematic error	4.0×10^{-28}	2.0×10^{-28}
Statistical error	2.35×10^{-27}	6.8×10^{-28}
Result	7.2×10^{-28}	0.9×10^{-28}

Systematic effects

studied with auxiliary measurements

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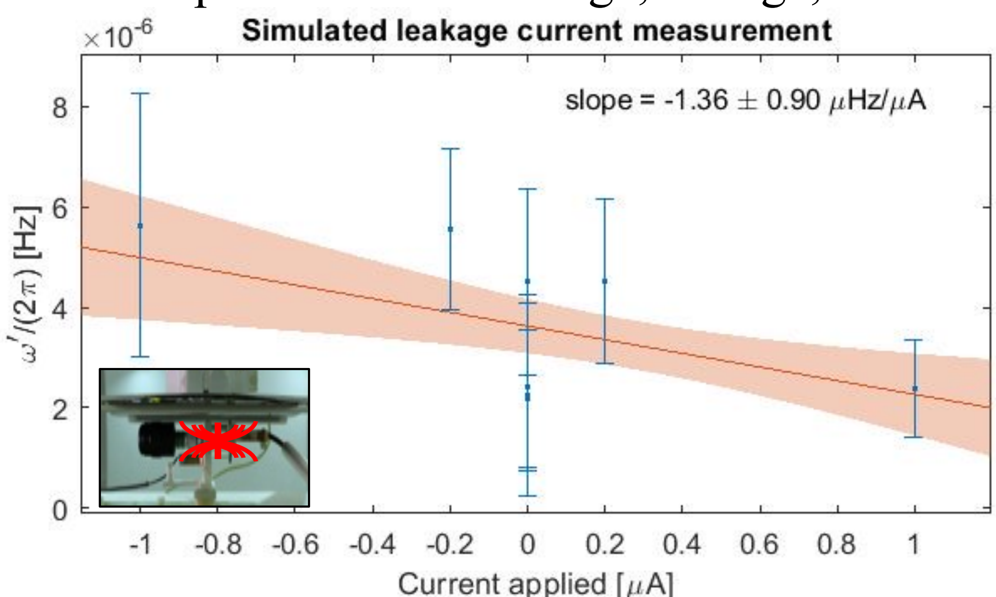
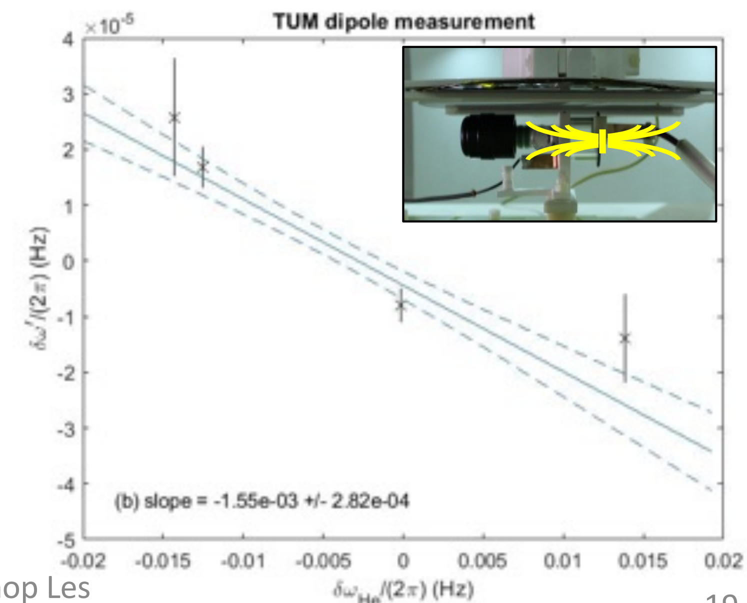
		Leakage current	Charging current	Cell rotation	Cell translation: Linear Gradient	Cell translation: External Dipole (Loop Test)
Auxiliary measurement		Single turn ± 0.1–$1\ \mu$A	± 10–$20\ \mu$A	$\pm 5^\circ$	N/A	Loop attached to electrode 0–100 μA
Measured linear dependence		$\frac{1}{2\pi}\frac{\partial \omega_{co}}{\partial I}$	$\frac{1}{2\pi}\frac{\partial \omega_{co}}{\partial I}$	$\frac{1}{2\pi}\frac{\partial \omega_{co}}{\partial \theta}$	$\frac{1}{2\pi}\frac{\partial \omega_{co}}{\partial z}$	$\frac{1}{2\pi}\frac{\partial \omega_{co}}{\partial \omega_{He}}$
	2017	$= (1.32 \pm 0.93)$ Hz/A	$= (-0.3 \pm 1.2)$ mHz/A	$\leq 1.6\ \mu$Hz/rad	≤ 90 nHz/m	$= (-1.55 \pm 0.28) \times 10^{-3}$
	2018	$= (-8.6 \pm 7.6)$ mHz/A			≤ 100 nHz/m	
Observed HV-correlated maximum	2017	$I_{leak} = 97$ pA	$I_{charge} = 19$ nA	$\delta\theta \leq 33\ \mu$rad	$\delta z \leq 200\ \mu$m	$\frac{\delta\omega_{He}^{HV}}{2\pi} = (-181.4 \pm 124.4)$ nHz
	2018	$I_{leak} = 73$ pA	$I_{charge} = 19$ nA			$\frac{\delta\omega_{He}^{HV}}{2\pi} = (-82.5 \pm 226.8)$ nHz
False EDM ($e$cm)	2017	1.2×10^{-28}	1.7×10^{-29}	4.2×10^{-29}	1.3×10^{-29}	2.6×10^{-28}
	2018	4.5×10^{-31}	1.2×10^{-29}	4.0×10^{-29}	1.0×10^{-29}	1.9×10^{-28}

Note loop test covers Leakage, Charge, and MOTION wrt external dipole.





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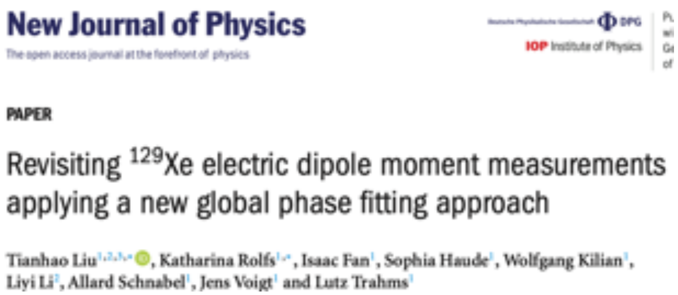
HeXe Data Phase Analysis (T. Liu) Instrinsic 2x more sensitive


New Journal of Physics
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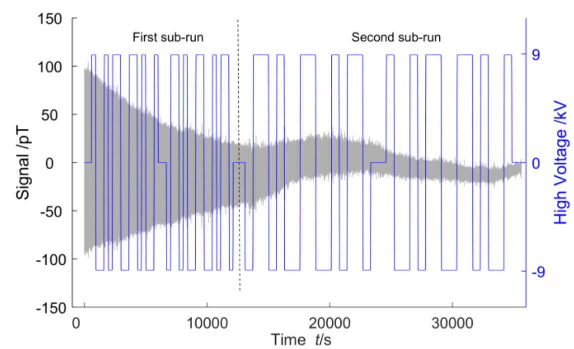
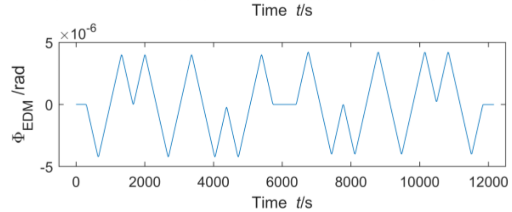
IOP Institute of Physics

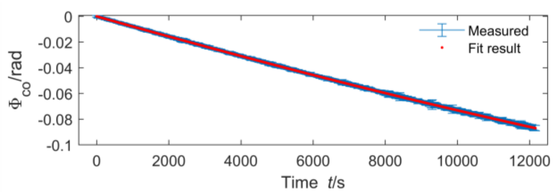
PAPER

Revisiting ^{129}Xe electric dipole moment measurements applying a new global phase fitting approach

Tianhao Liu, Katharina Rolfs, Isaac Fan, Sophia Haude, Wolfgang Kilian, Liyi Li, Allard Schnabel, Jens Voigt and Lutz Trahms







	d_{Xe}	δd_{Xe}	Reduced χ^2
HeXe	1.43	6.56	0.87
Phase fit	0.251	3.06	1.28

Fitting for this phase pattern

<u>2x smaller σ_d</u>

BUT also need to fit drift:

Polynomial up to 13th order

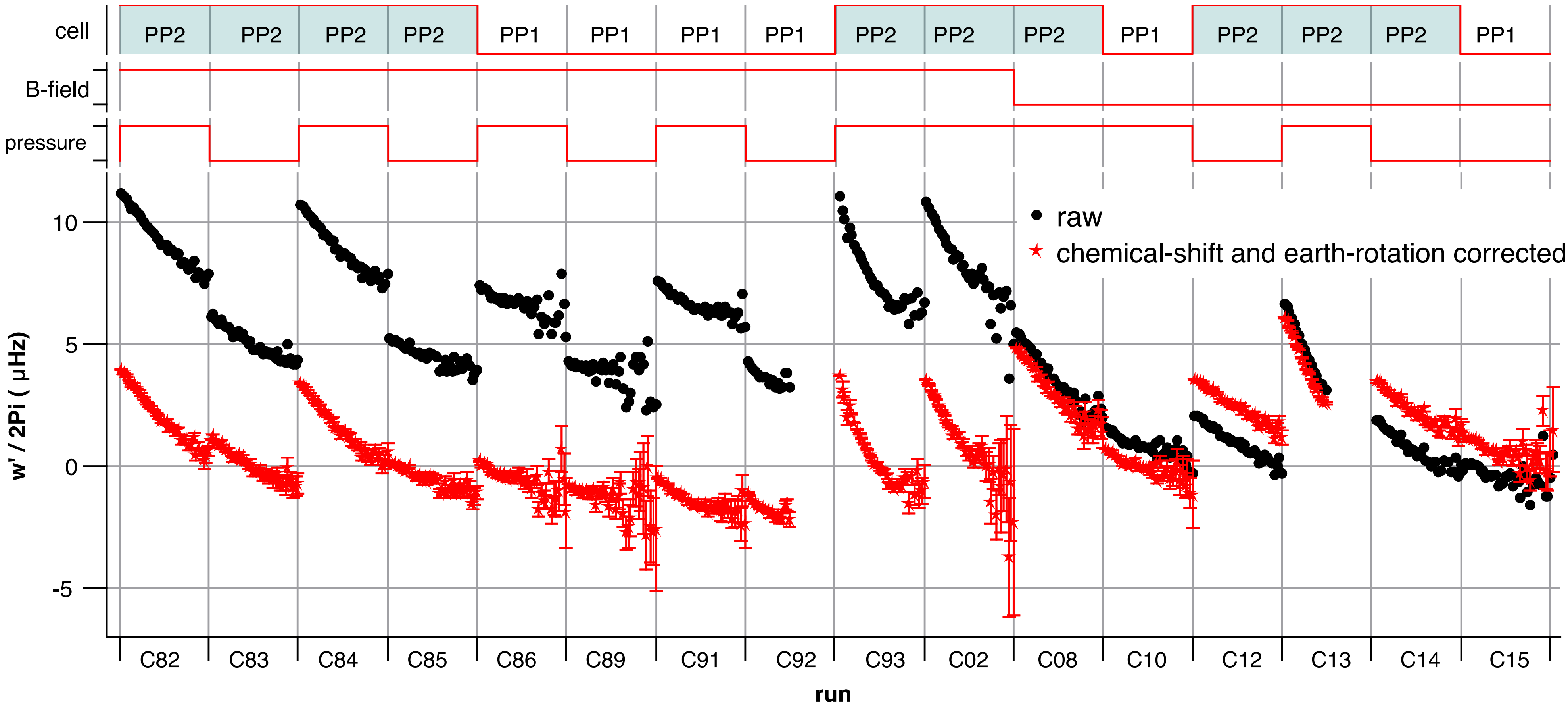
$$\Phi_{\text{fit}}[k] = a \cdot \Phi_{\text{EDM}}[k] + p_0 + p_1 \cdot t_k + p_2 \cdot t_k^2 + \cdots p_g \cdot t_k^g$$

	a	p_0	p_1	p_2	p_3	p_4	p_5	p_6
a	**1.0**	**0.2**	**-0.2**	**0.1**	**-0.1**	**0.1**	**-0.1**	**0.1**
p_0	**0.2**	1.0	-0.9	0.7	-0.7	0.6	-0.5	0.5
p_1	**-0.2**	-0.9	1.0	-1.0	0.9	-0.9	0.8	-0.8
p_2	**0.1**	0.7	-1.0	1.0	-1.0	1.0	-0.9	0.9
p_3	**-0.1**	-0.7	0.9	-1.0	1.0	-1.0	1.0	-0.9
p_4	**0.1**	0.6	-0.9	1.0	-1.0	1.0	-1.0	1.0
p_5	**-0.1**	-0.5	0.8	-0.9	1.0	-1.0	1.0	-1.0
p_6	**0.1**	0.5	-0.8	0.9	-0.9	1.0	-1.0	1.0

$P_{\min}$	Average order	EDM d_{Xe}	Uncertainty	Reduced- χ^2	***P*-value**	Upper limit (95% C.L.)
0.2	13.2	-0.35×10^{-28}	2.96×10^{-28}	1.39	0.01	7.8×10^{-28}
0.4	9.4	1.81×10^{-28}	2.88×10^{-28}	1.36	0.02	8.3×10^{-28}
0.6	6.6	1.08×10^{-28}	2.81×10^{-28}	1.24	0.07	7.4×10^{-28}
0.8	5.5	-1.13×10^{-28}	2.76×10^{-28}	1.26	0.05	7.4×10^{-28}

Dependence on polynomial order

Comagnetometer drifts



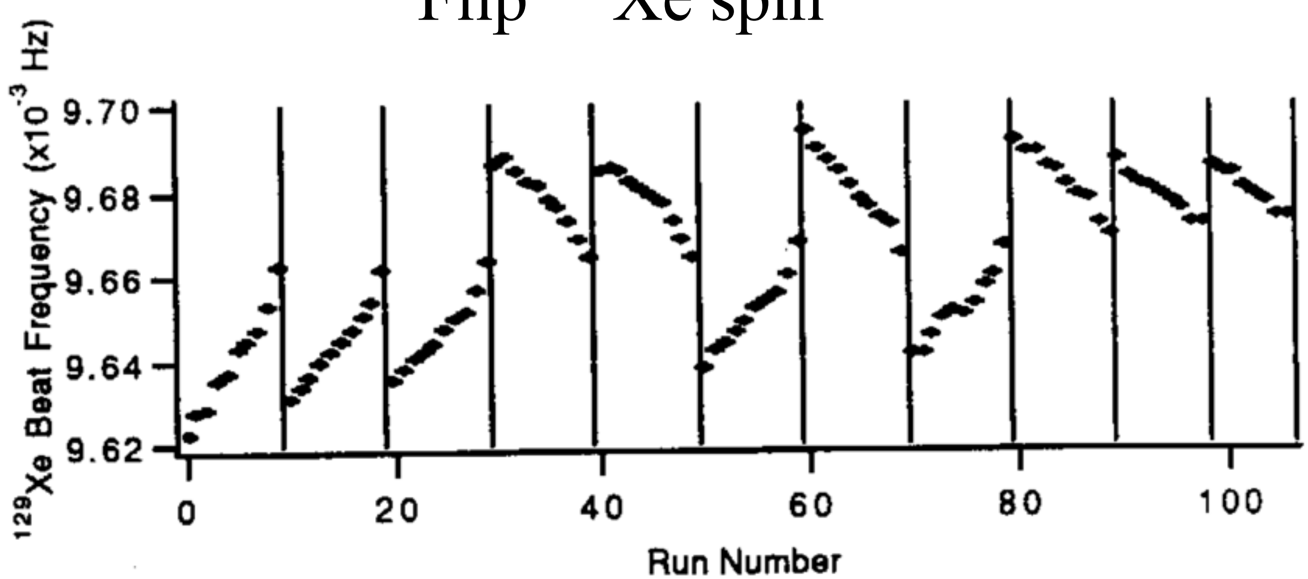
1. Combinations of 4 segments compensate linear drifts
2. Non-linear drift correction determined from polynomial parameterization (fits) by run
3. Check: 8 segment and 16 segment EDMS
4. CORRECTION: $(-0.08\pm0.66)\times10^{-27}$ e-cm

Oteiza (1992)

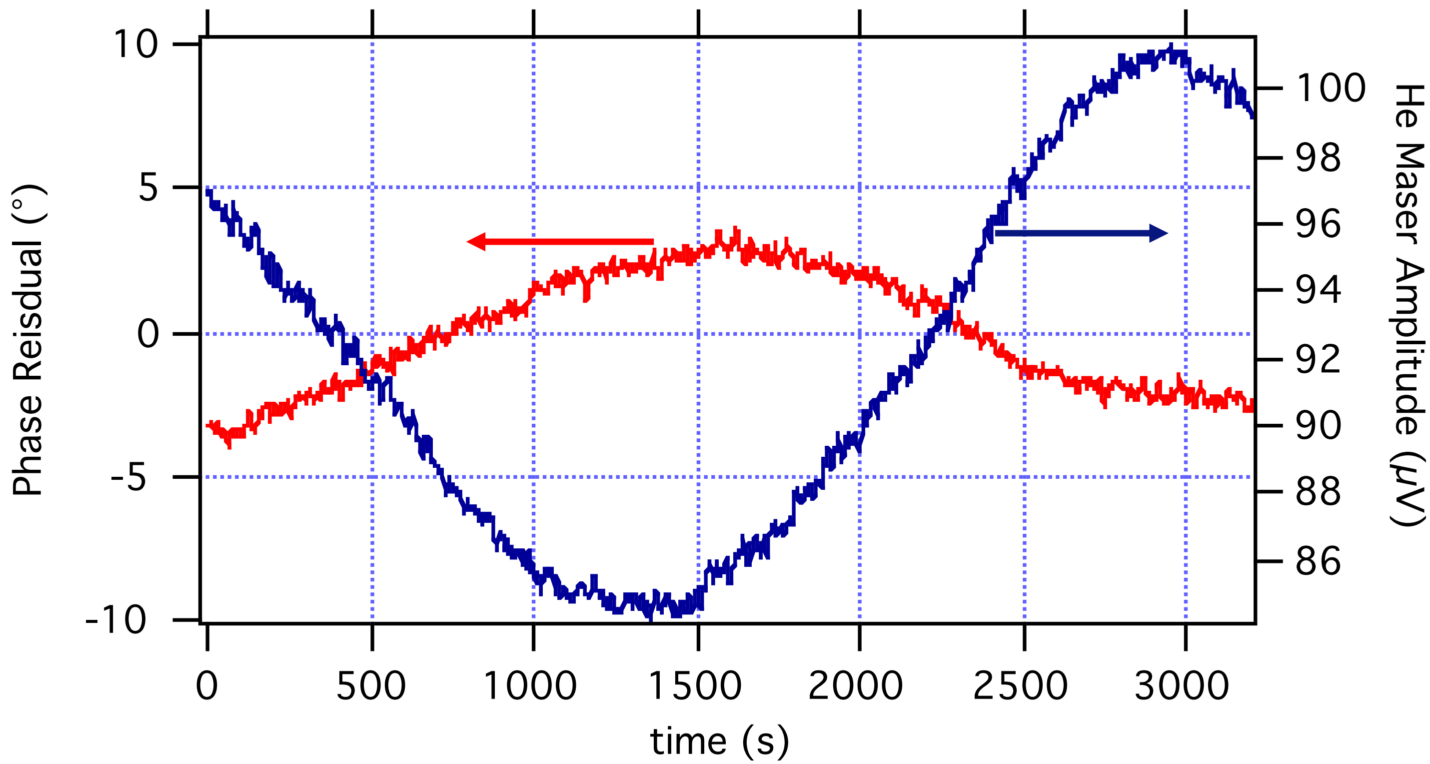
Run Number	0	1	2	3	4	5	6	7	8	9
Pulse Angle	11.9°	13.2°	14.8°	16.6°	19.0°	21.9°	25.9°	31.9°	42.6°	90°

Table 5.1: ^{3}He pulse angle sequence for a ten-run cycle where T_1 for ^{3}He is 6 Hours and Δt is 0.5 Hours.

Flip ^{129}Xe spin



Rosenberry 2001



Comagnetometer drift

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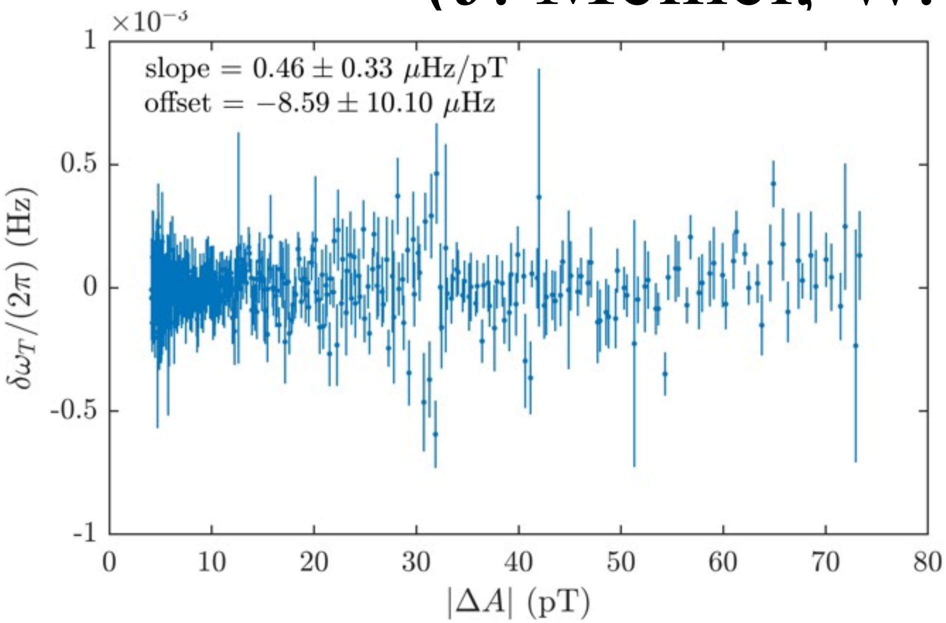
$$\omega_{\rm Xe} = \omega_{d_{\rm Xe}} + \gamma'_{\rm Xe}(1-\delta_{\rm Xe})\langle B\rangle_{\rm Xe} + \omega^{sd}_{\rm Xe} + \vec{\Omega}\cdot\hat{B}$$
$$\omega_{\rm He} = \omega_{d_{\rm He}} + \gamma'_{\rm He}(1-\delta_{\rm He})\langle B\rangle_{\rm He} + \omega^{sd}_{\rm He} + \vec{\Omega}\cdot\hat{B}$$

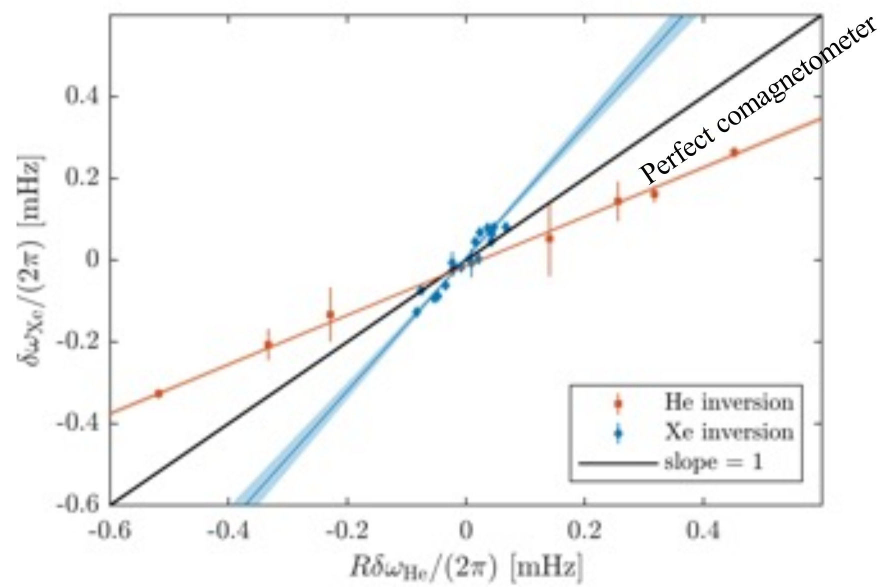
$\omega_{\rm co} \approx \ \omega_d$	EDM
$+ (1-R)\,\vec{\Omega}\cdot\hat{B}$	Earth's rotation
$-\gamma'_{\rm He}\Delta RB$	Residual B-dependence (chemical shifts)
$+\gamma'_{\rm Xe}\left(\Delta B_{\rm Xe} - \Delta B_{\rm He}\right)$	Diffusion affects averaging of B: $\frac{\partial^2\vec{B}}{\partial z^2}$...
$+\left(\omega^{sd}_{\rm Xe} - R\omega^{sd}_{\rm He}\right).$	Species-dependent drifts

1. HV correlated change of $\vec{B}$ can produce a false EDM signal
2. Uncompensated time dependence (drift): false EDM

$$\omega_{\rm co} = \omega_{d_{\rm Xe}} + \left[\gamma'_{\rm Xe}(1-\delta_{\rm Xe})\langle B\rangle_{\rm Xe} - R\gamma'_{\rm He}(1-\delta_{\rm He})\langle B\rangle_{\rm He}\right] + (\omega^{sd}_{\rm Xe} - R\omega^{sd}_{\rm He}) + (1-R)\vec{\Omega}\cdot\hat{B}$$

Species dependent drift (J. Meinel, W. Terrano et al.)





Transverse (RBS) dependence *very small*

Oteiza PhD Dissertation (1992)

D. Sheng, A. Kabcenell, and M. V. Romalis. Phys. Rev. Lett., 113:163002 (2014).

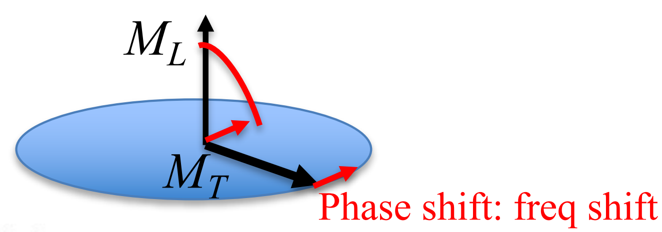
M. E. Limes, N. Dural, M. V. Romalis, E. L Foley, T. W. Kornack, A. Nelson, L. R. Grisham, and J. Vaara. Phys Rev A 100, 010501 (2019).

W. A. Terrano, J. Meinel, N. Sachdeva, T. Chupp, S. Degenkolb, P. Fierlinger, F. Kuchler, and J. T. Singh. Phys Rev A 100, 012502 (2019)

Longitudinal dependence *dominant*

Xe-He scalar contact

Rotation of M_L by resonant transverse field ~ radiation damping



$$\ddot{M}^{x'} = -(\gamma\mu_0\Gamma_{\rm cell}M^{z'})^2 M^{x'}$$
$$\delta\omega_k = \gamma\mu_0\Gamma_{\rm cell}M^{z'}$$

From 10^{-27} to 10^{-30} *e*-cm

$$\sigma_d \approx \frac{1}{2E}\frac{\hbar}{T_2}\frac{1}{S/N} \propto \frac{1}{\tau^{3/2}}$$ Per HV dwell time τ

Increase *S/N*	
Quieter SQUID →3 fT/√Hz	3x
Coupling to cell (cold-warm)+4 loops	5x
Improved polarizer	2x
Larger *E*	
Optimize gas mixture	1.5x
Longer HV dwell (τ)	
Cell shape, π/2 pulse ($\tau^{-3/2}$)	8x
Phase analysis	2x
Duty factor and integration (1 year)	5x
	3600

XeEDM@LANL
Expertise from HeXe/SNS nEDM

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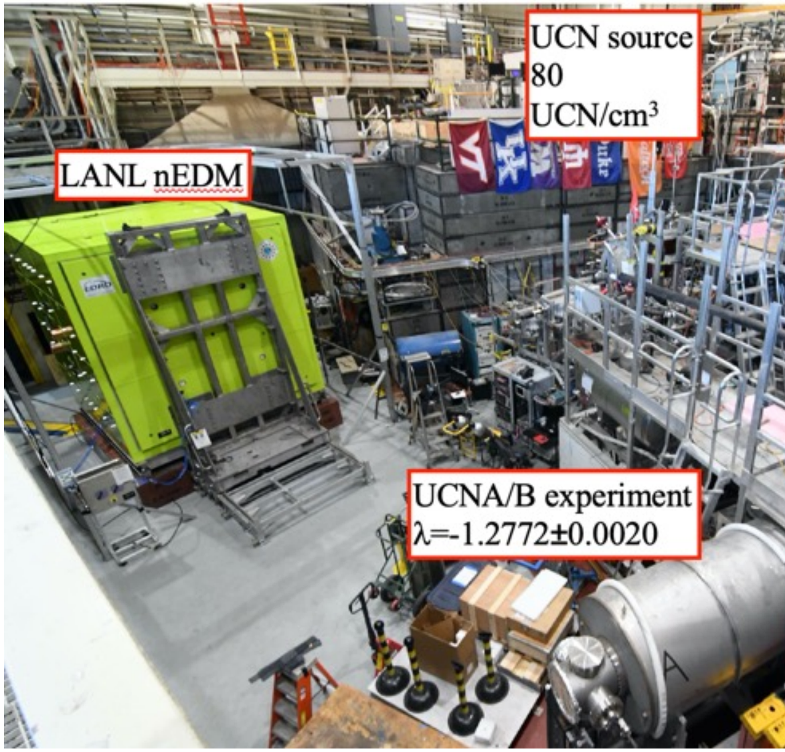

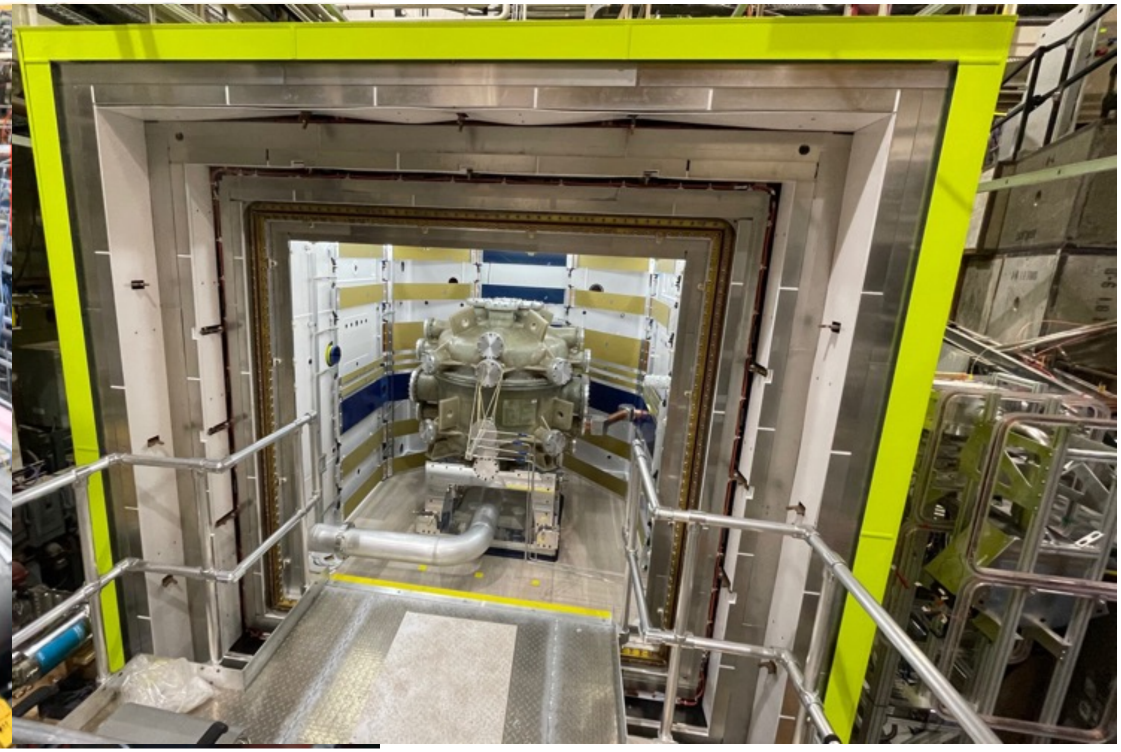

Arizona State University (DOE Early Career): Alec Epstein, **<u>William Terrano</u>**, Keaten Wood

Los Alamos National Lab (LANL LDRD): Steven Clayton, Takeyasu Ito, **<u>Young Jin Kim</u>**, T. J. Schaub, Mark Makela, Christopher O'Shaugnessy, Wade Uhrich

University of Heidelberg: Skyler Degenkolb

University of Michigan (NSF): Tim Chupp, Henry Sottrel, Jamison Starr

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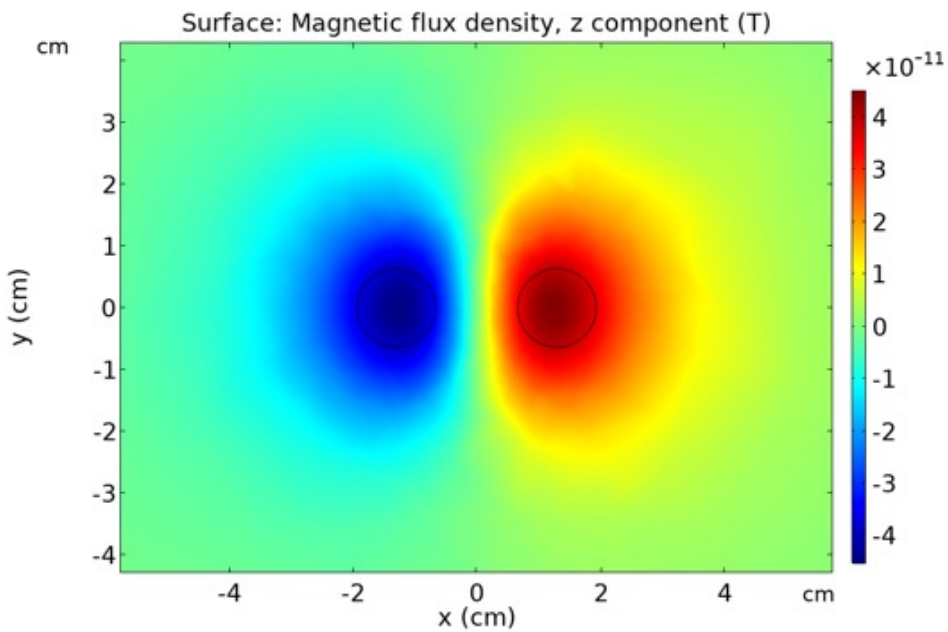
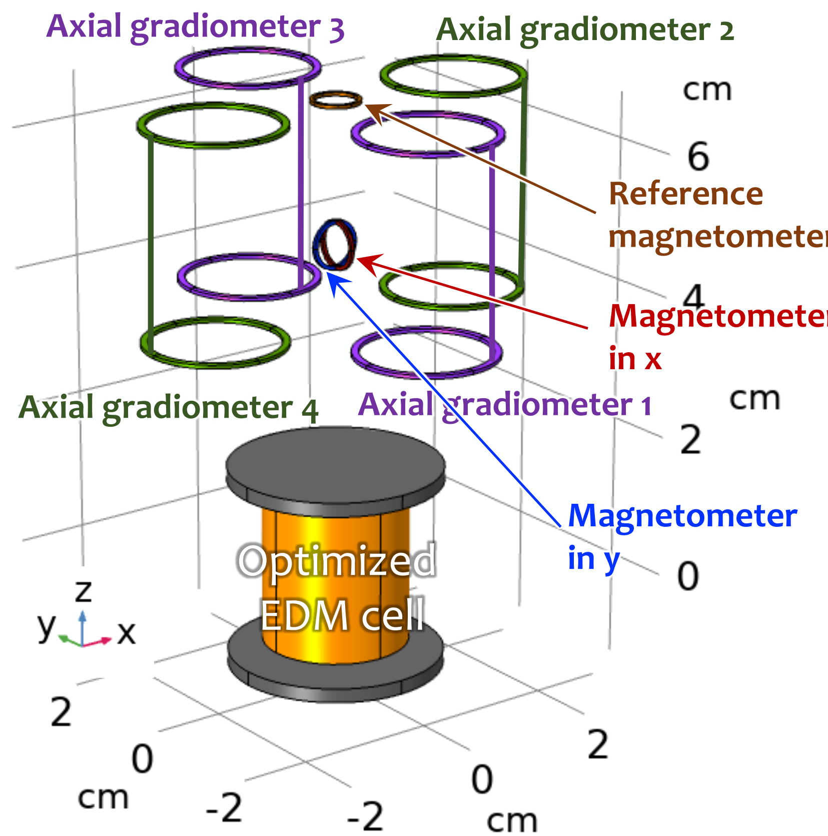
Increase S/N
Young-Jin Kim, S. Clayton (LANL)

Small Tristan Low-noise Dewar (Dewar inner diameter = 4.1 cm)

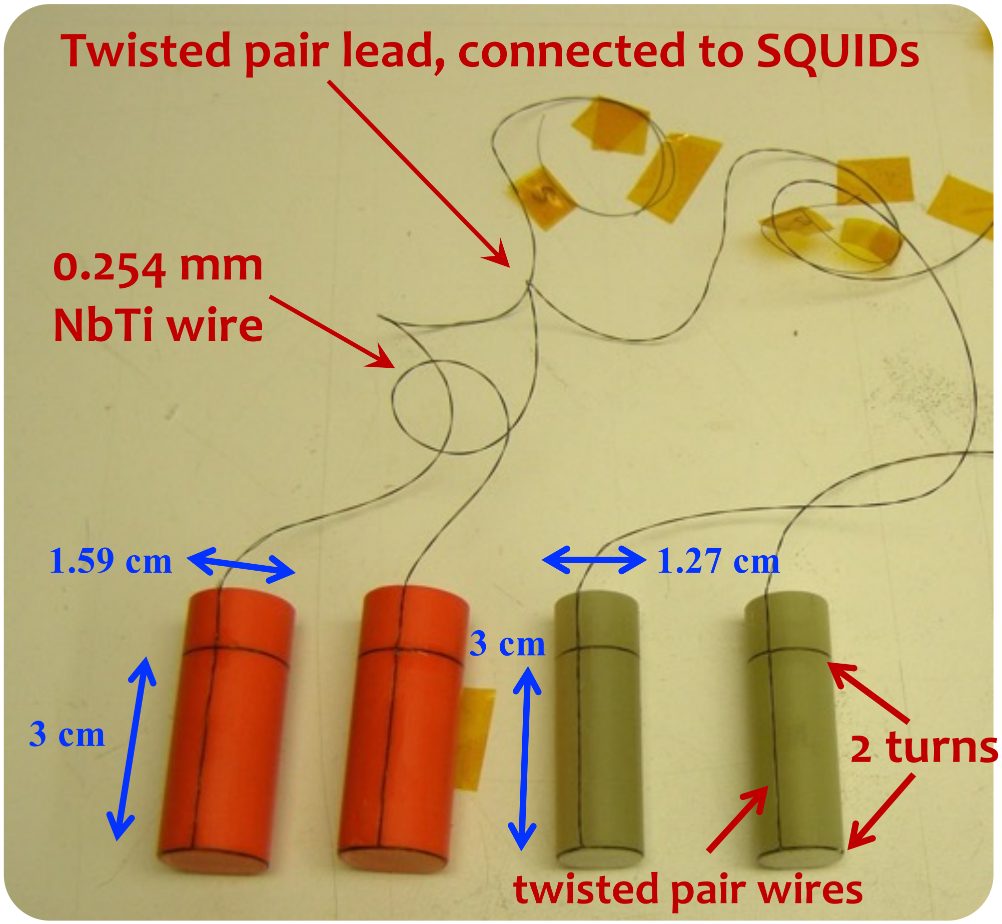


Numerical simulation of EDM signal at the bottom pickup loops

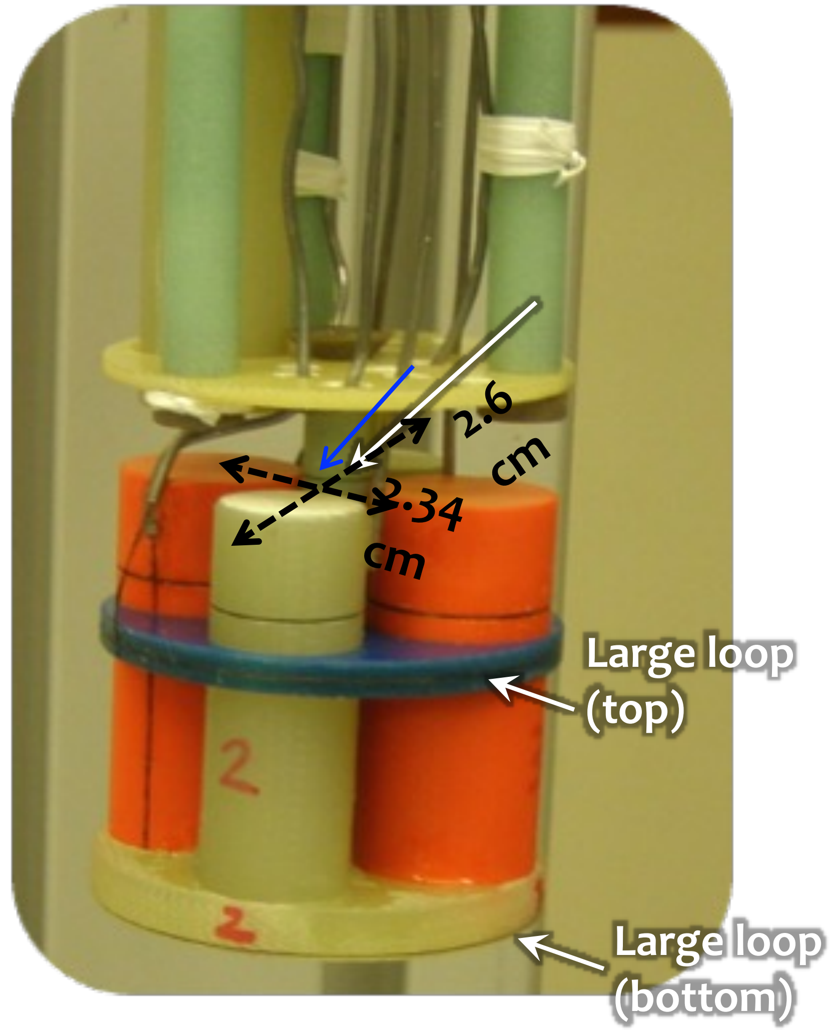


- Paired axial gradiometer (e.g., 1 and 3) serves as synthetic planar gradiometer.
- Effectively less susceptible to vibration-induced and ambient noises.

Increase S/N
Young-Jin Kim, S. Clayton (LANL)



Two diameters for comparison



Increase S/N
Young-Jin Kim, S. Clayton (LANL)

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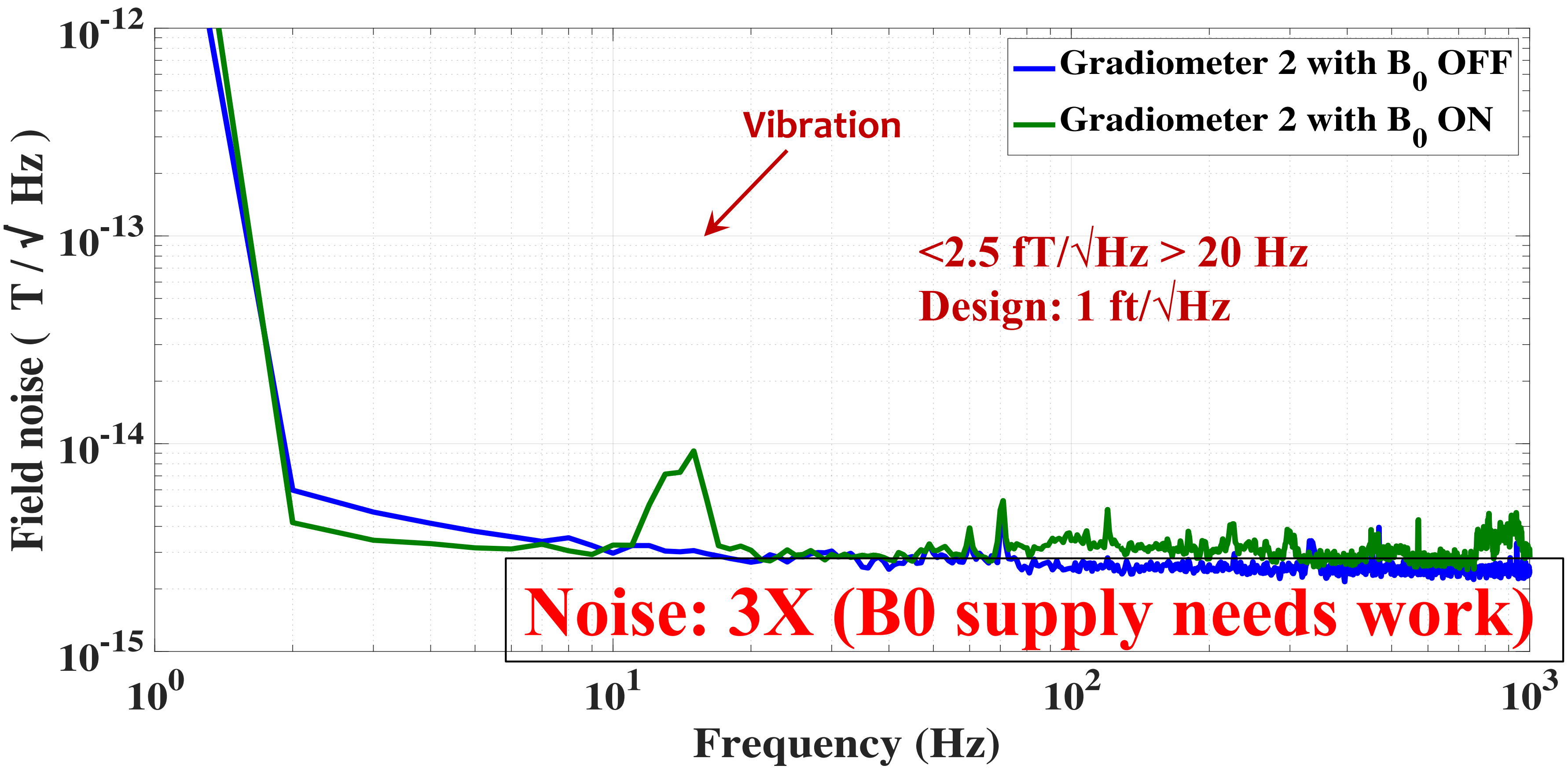
- **Gradiometer 2 Field Noise with/without B0 field**



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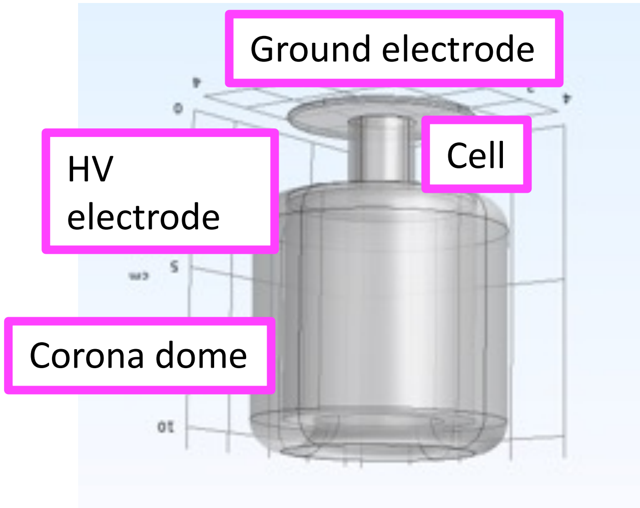
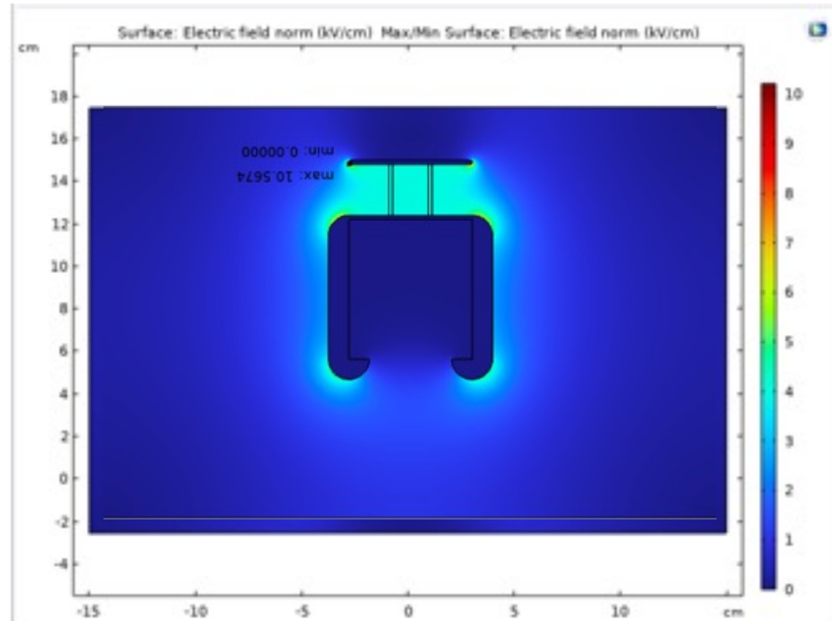
Reduce cold-warm distance





Electrodes and <u>corona dome</u> made of high resistivity material to suppress magnetic Johnson noise 1 fT/sqrt(Hz) at 100 Hz (at SQUID), e.g. SiC.

Fluctuation-Dissipation theorem and a finite element tool (COMSOL).

$$\delta B(f) \equiv \sqrt{S_B(f)} = \frac{\sqrt{4kT}\sqrt{2P(f)}}{ANI\omega}.$$ < 0.5 ft/√Hz (flat over freq.)

N. S. Phan, S. M. Clayton, Y. J. Kim, T. M. Ito, J. Appl. Phys. **136**, 124901 (2024).

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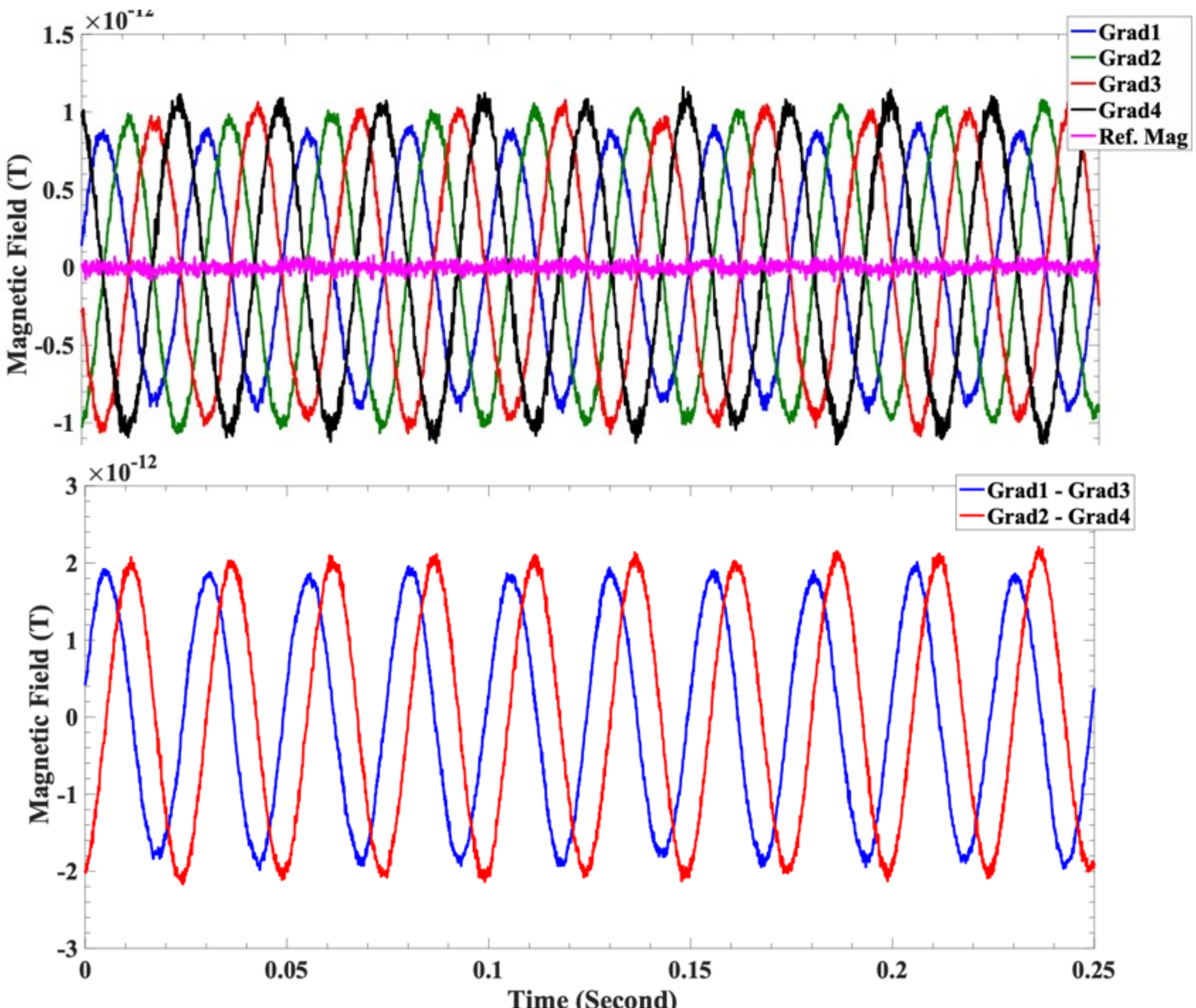
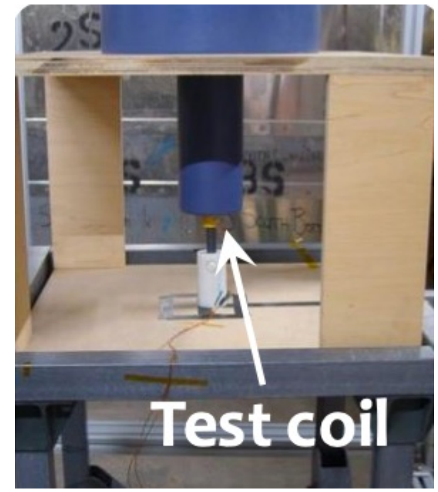
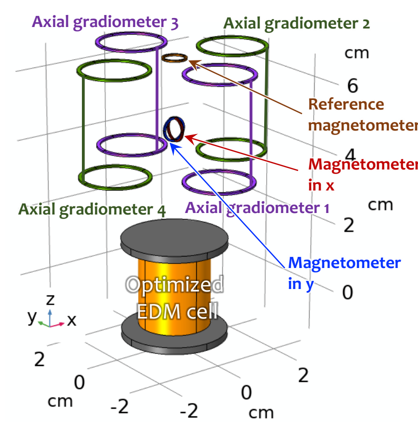
Rotating-field test coil
Henry Sottrel (UMich)

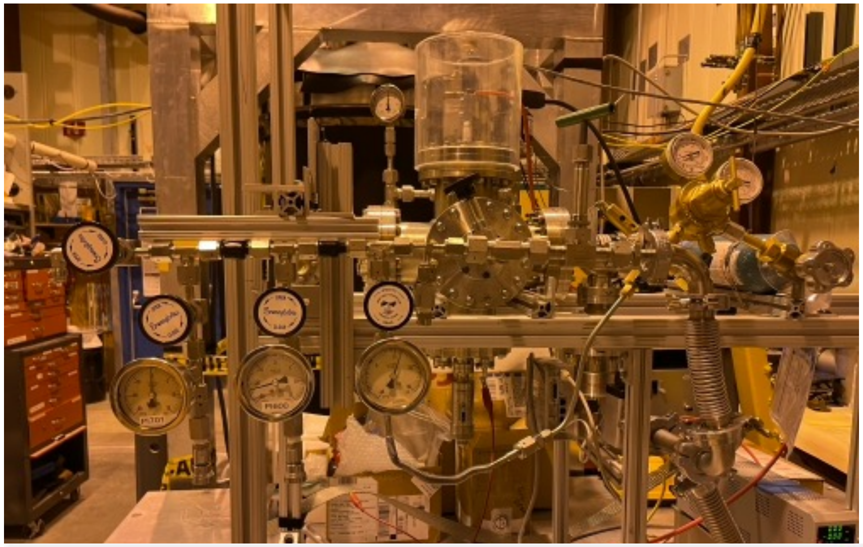


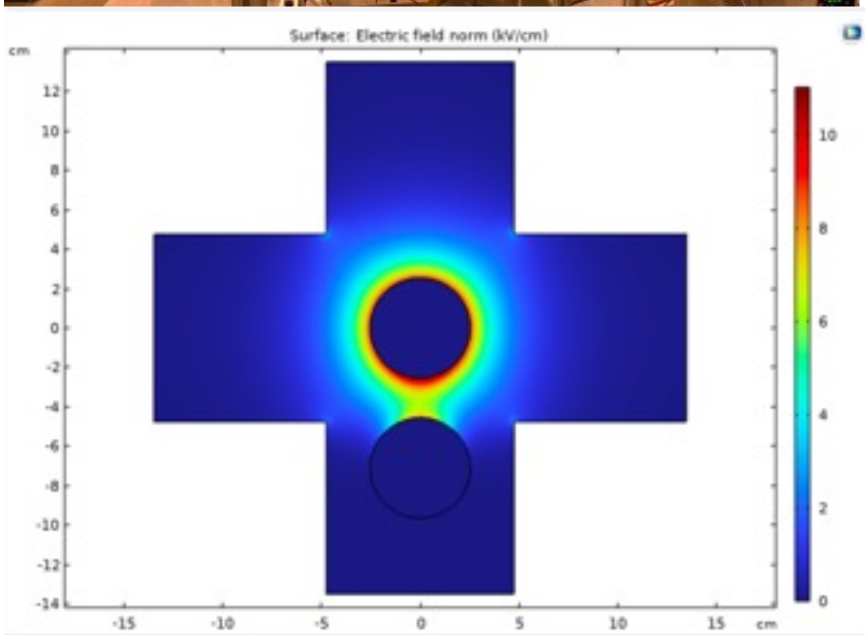




Signal: 5X

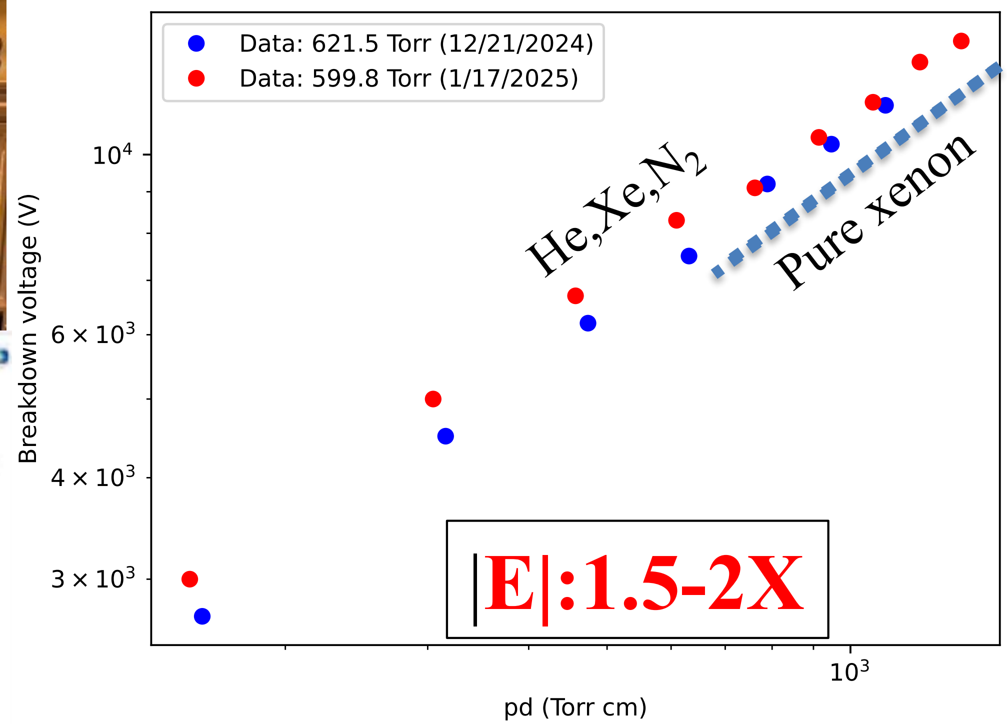
Increase E
T. Ito (LANL)





2” diameter SS sphere electrodes

Paschen-curve measurement of breakdown Xe, He, and N_2 mixture



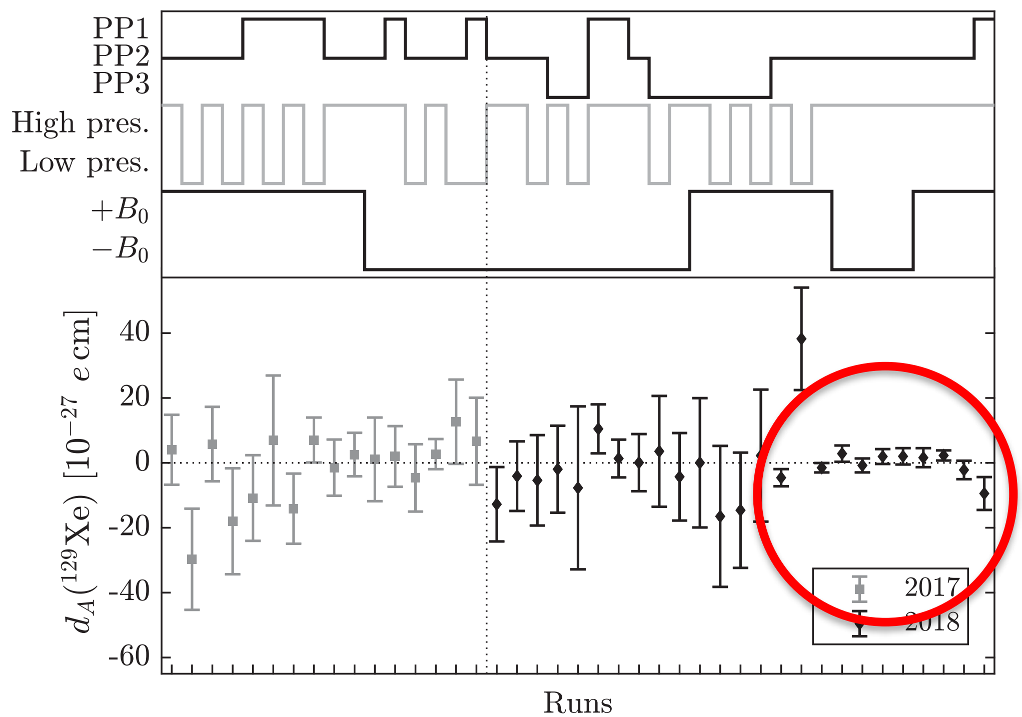
Optimize gas mixture for ***E***

<u>AND</u> ^{129}Xe/^{3}He polarization

Longer τ
W. Terrano (ASU)

$$\sigma_d \approx \frac{1}{2E}\frac{\hbar}{T_2}\frac{1}{S/N} = \frac{1}{2E}\frac{\hbar}{T_2}\frac{1}{\sqrt{\varphi_n T_2}}$$

Phase-noise limit



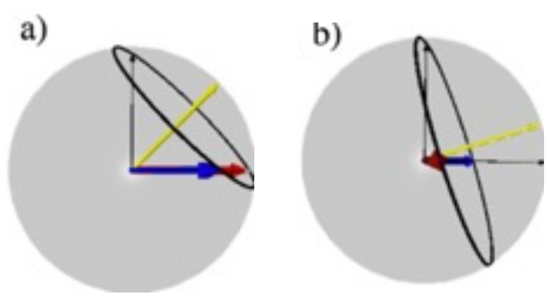
Longer τ
W. Terrano (ASU)

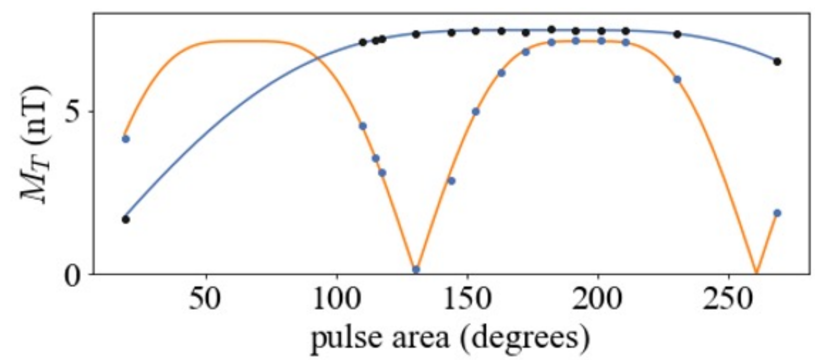
depends on cell shape

$$\frac{\omega_{\mathrm{co}}}{\mu_0\gamma_{\mathrm{Xe}}} = \Gamma^{\mathrm{T}}\left(M^{\mathrm{L}}_{\mathrm{He}} - M^{\mathrm{L}}_{\mathrm{Xe}}\right) + \frac{2\kappa_{\mathrm{He,Xe}}}{3}\left(M^{\mathrm{L}}_{\mathrm{He}} - M^{\mathrm{L}}_{\mathrm{Xe}}\right).$$

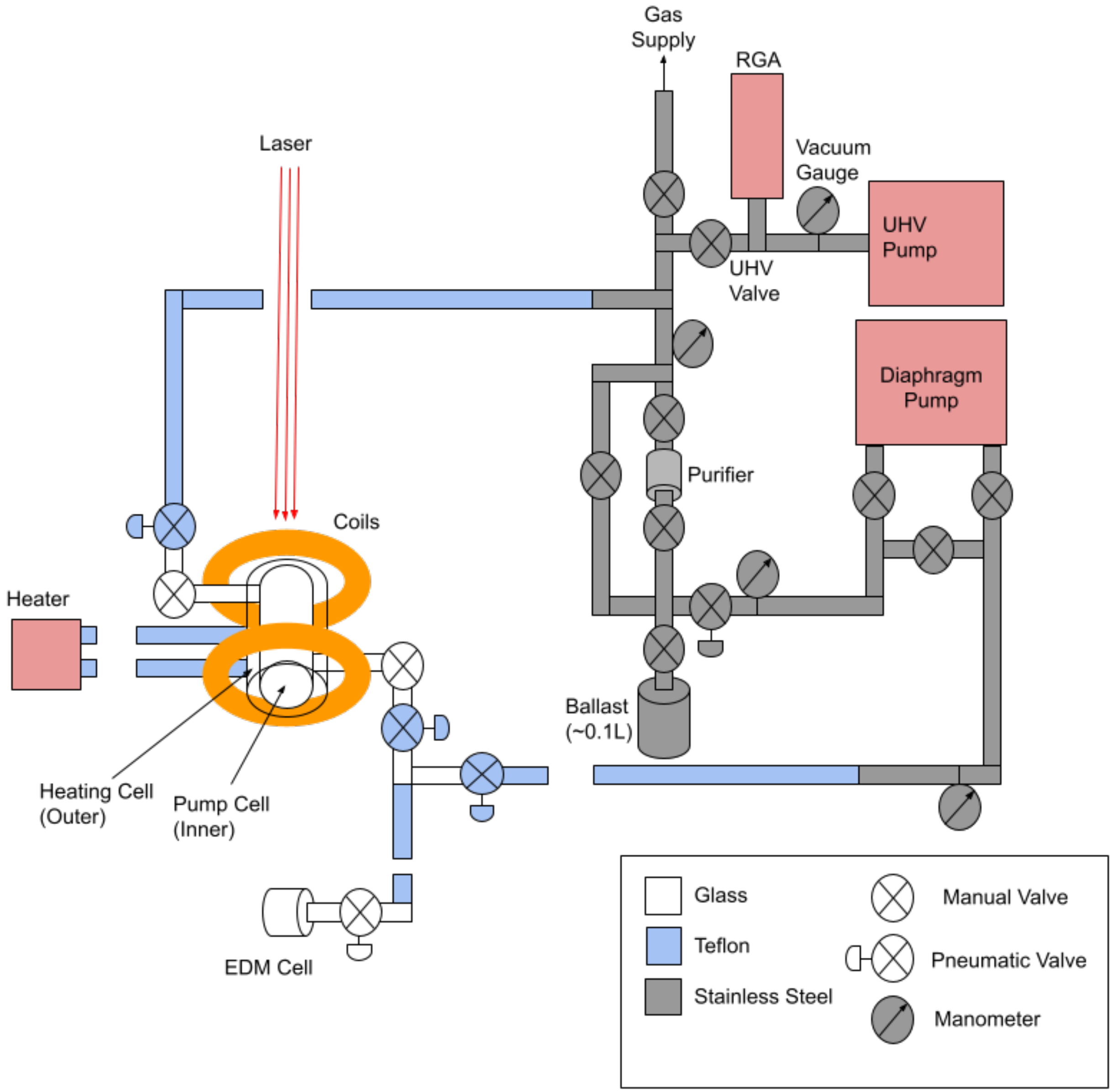
1. $M^{L}_{He} = M^{L}_{Xe}$ (varies over time)
2. $\Gamma^{T} = -\frac{2\kappa_{He,Xe}}{3}$ (cell shape h/t=0.875)
3. $M^{L} = 0$ ("perfect" π/2 rotation)

Compound (robust) pulse sequence - tilted axes

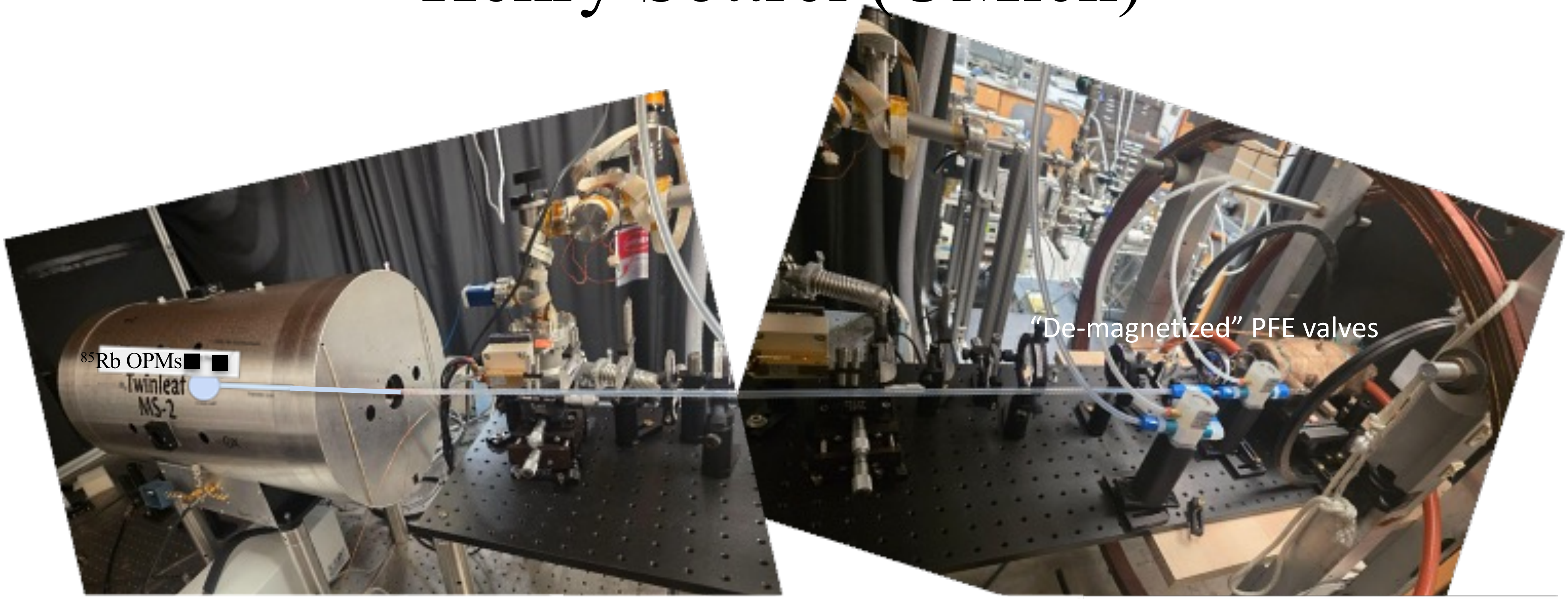


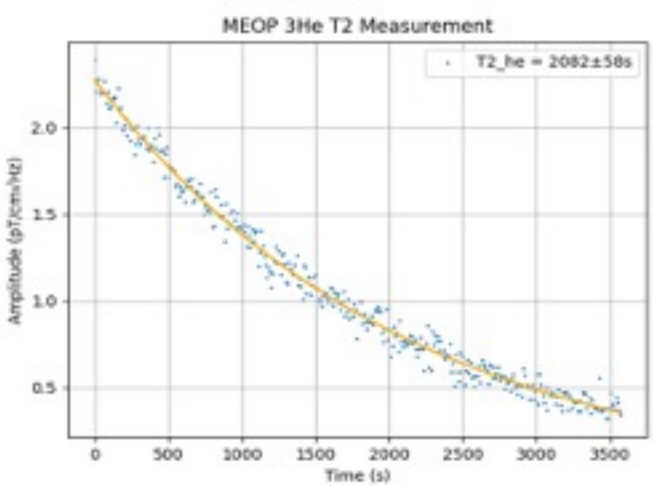


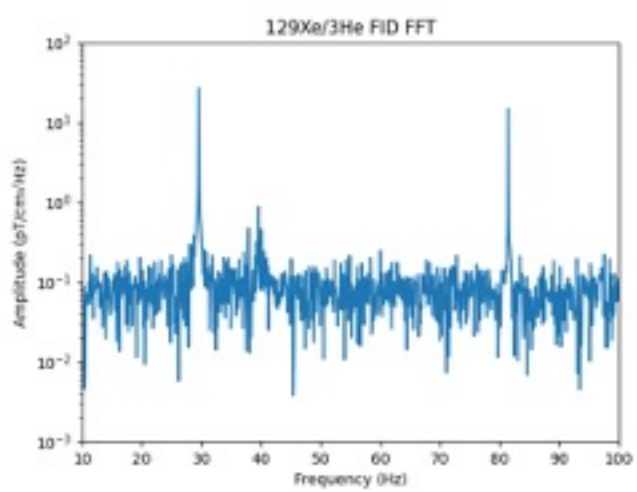
Duty-factor: Full time polarizer
Henry Sottrel (UMich)

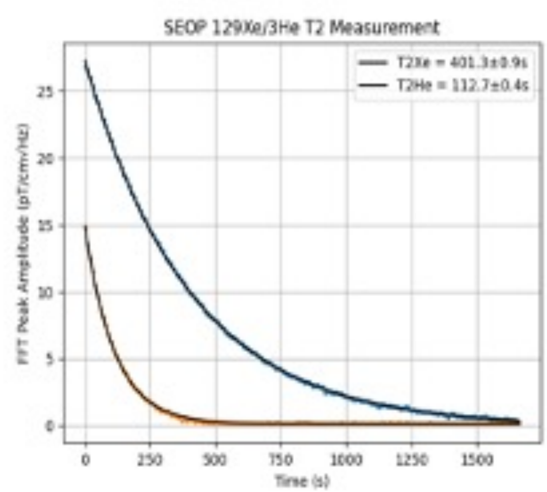


Duty-factor: Full time polarizer
Henry Sottrel (UMich)









From 10^{-27} to 10^{-30} *e*-cm

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$$\sigma_d \approx \frac{1}{2E}\frac{\hbar}{T_2}\frac{1}{S/N} \propto \frac{1}{\tau^{3/2}}$$ Per HV dwell time τ

<u>Increase *S/N*</u>			
Quieter SQUID →3 fT/√Hz	3x	✓	B0 supply
Coupling to cell (cold-warm)+4 loops	5x	✓	
Improved polarizer	2x		Need to optimize
<u>Larger *E*</u>			
Optimize gas mixture	1.5x	✓	
<u>Longer HV dwell (τ)</u>			
Cell shape, π/2 pulse ($\tau^{-3/2}$), $M_{Xe/He}$	>8x	✓	π/2 tests underway
<u>Phase analysis</u>	2x	✓	
<u>Duty factor and integration (1 year)</u>	5x		
	1200-3600		

Towards 10^{-30} e-cm

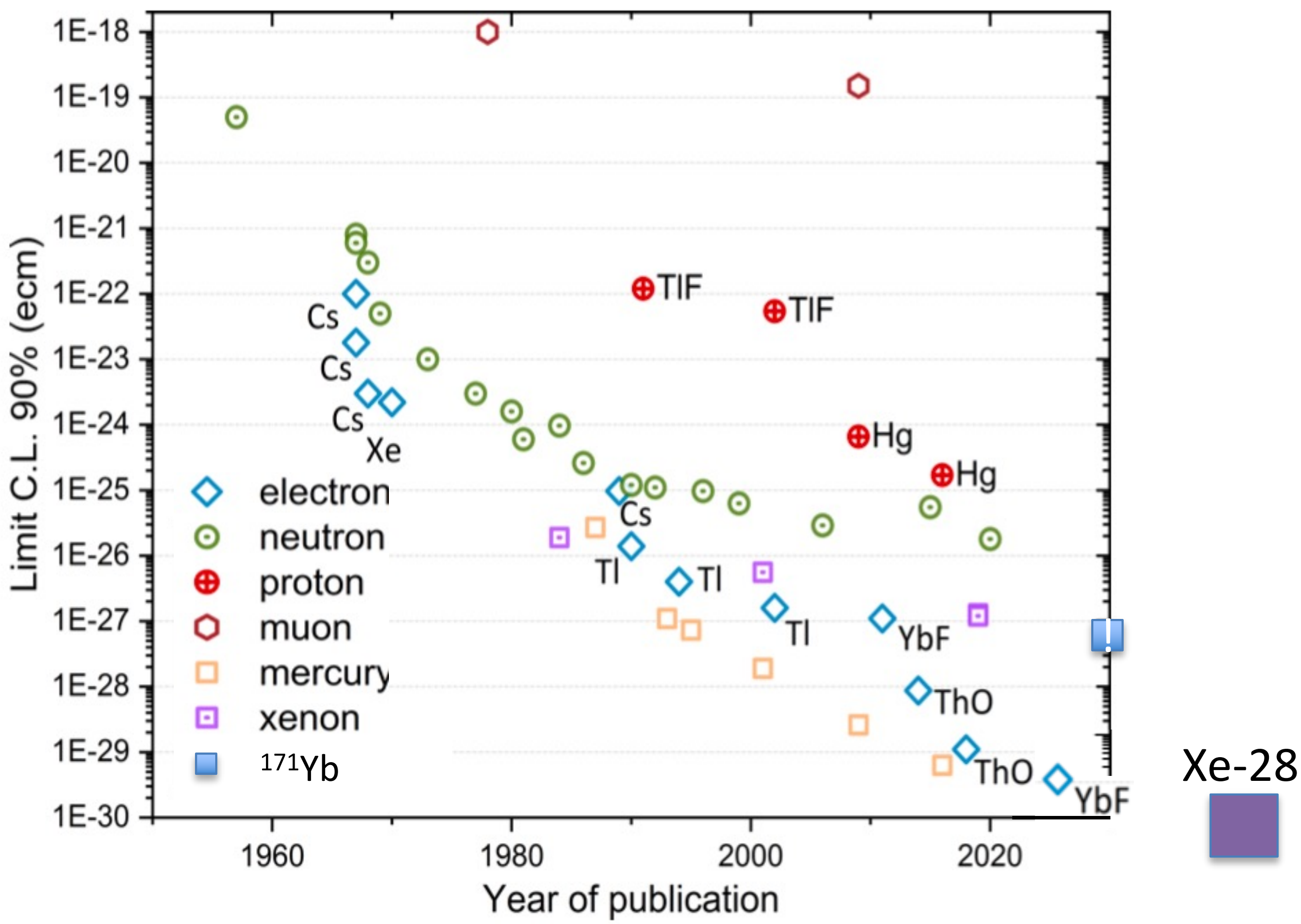
Source	2018 Sys. Error (e cm)
Leakage current	4.5×10^{-31}
Charging currents	1.2×10^{-29}
$\vec{E}$-correlated cell motion (rotation)	4.0×10^{-29}
$\vec{E}$-correlated cell motion (translation	3.2×10^{-28}
Comagnetometer drift	2.6×10^{-28}
$\lvert\vec{E}\rvert^2$ effects	(Needs final EDM freqs.)
$\lvert\vec{E}\rvert$ uncertainty	$0.1 d_A$
Geometric phase	$\leq 1 \times 10^{-31}$
Total	(4.1×10^{-28})

}Monitor B (OPMs)

- M_L suppression

?

Thank you!



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