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Discovery, accelerated

First high voltage breakdown measurements in a test setup for the TUCAN neutron EDM experiment

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Motivation

TUCAN EDM project goal is to measure the neutron electric dipole moment (EDM) with a sensitivity of 10^{-27} ecm

Non-zero EDM violates CP symmetry
→ sensitive direct probe of new physics

Future plan is to use a dual comagnetometer setup using ^{199}Hg and ^{129}Xe co-located with ultra cold neutrons (UCN) in the EDM cell

Requires EDM of ^{129}Xe to be limited to at least a level of ~10^{-28} ecm
HeXeEDM: Thu, 14.00, DAC FT 1, Session R2-8

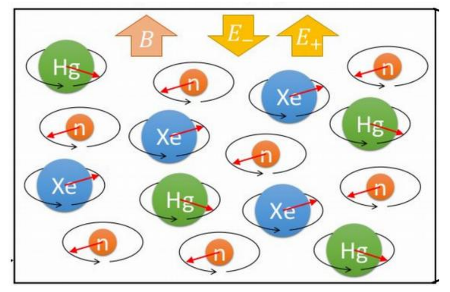
HV test setup main goal:
Determine xenon gas pressures compatible with optical readout, neutrons and E-fields

Neutron EDM dual co-magnetometer

Magnetometry is essential in EDM measurements, but adds systematics

$$\omega_i^{\uparrow\uparrow} = \gamma_i B_0 - \underbrace{\frac{1}{4c^2}\gamma_i^2 R^2 \frac{\partial B_{0z}}{\partial z}|E|}_{\text{shift due to geometric phase effect}}$$

Measurement of ^{199}Hg **and** ^{129}Xe inside same cell as UCN:



→ magnetic field **and** magnetic field gradient

→ removes dependence of magnetic field measurement on co-magnetometer geometric phase

	n	^{199}Hg	^{129}Xe
γ/2π [Hz/μT]	-29.16	7.65	-11.77
UCN capture σ [barns]		2150	21

^{129}Xe has 100x smaller neutron absorption cross section compared to ^{199}Hg

High voltage setup and cell

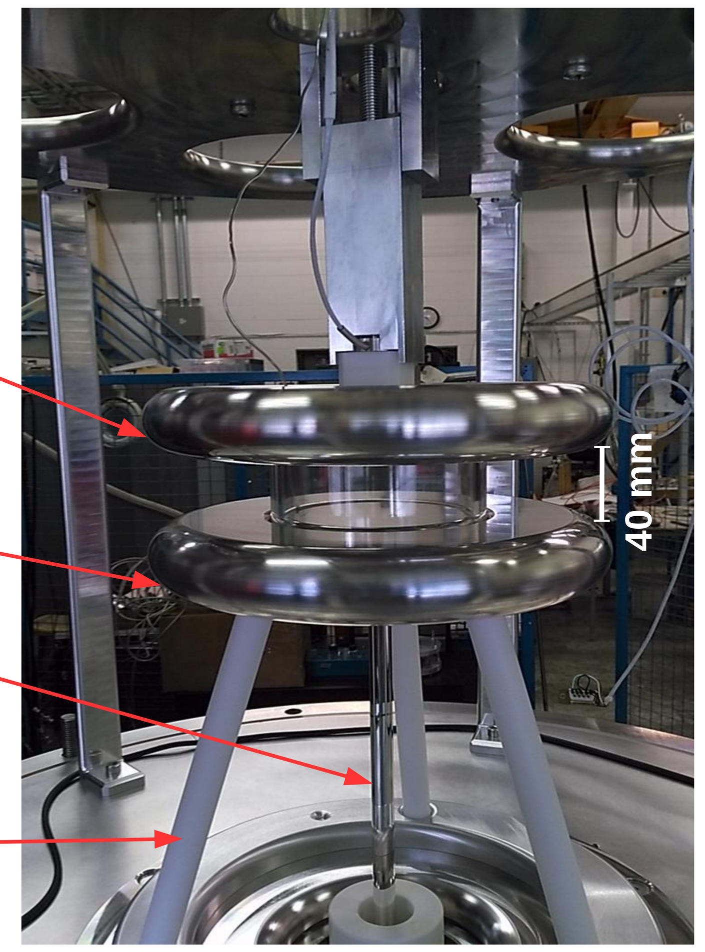
Inside vacuum chamber (typ 2e-6 Torr)

Ground electrode (aluminum)

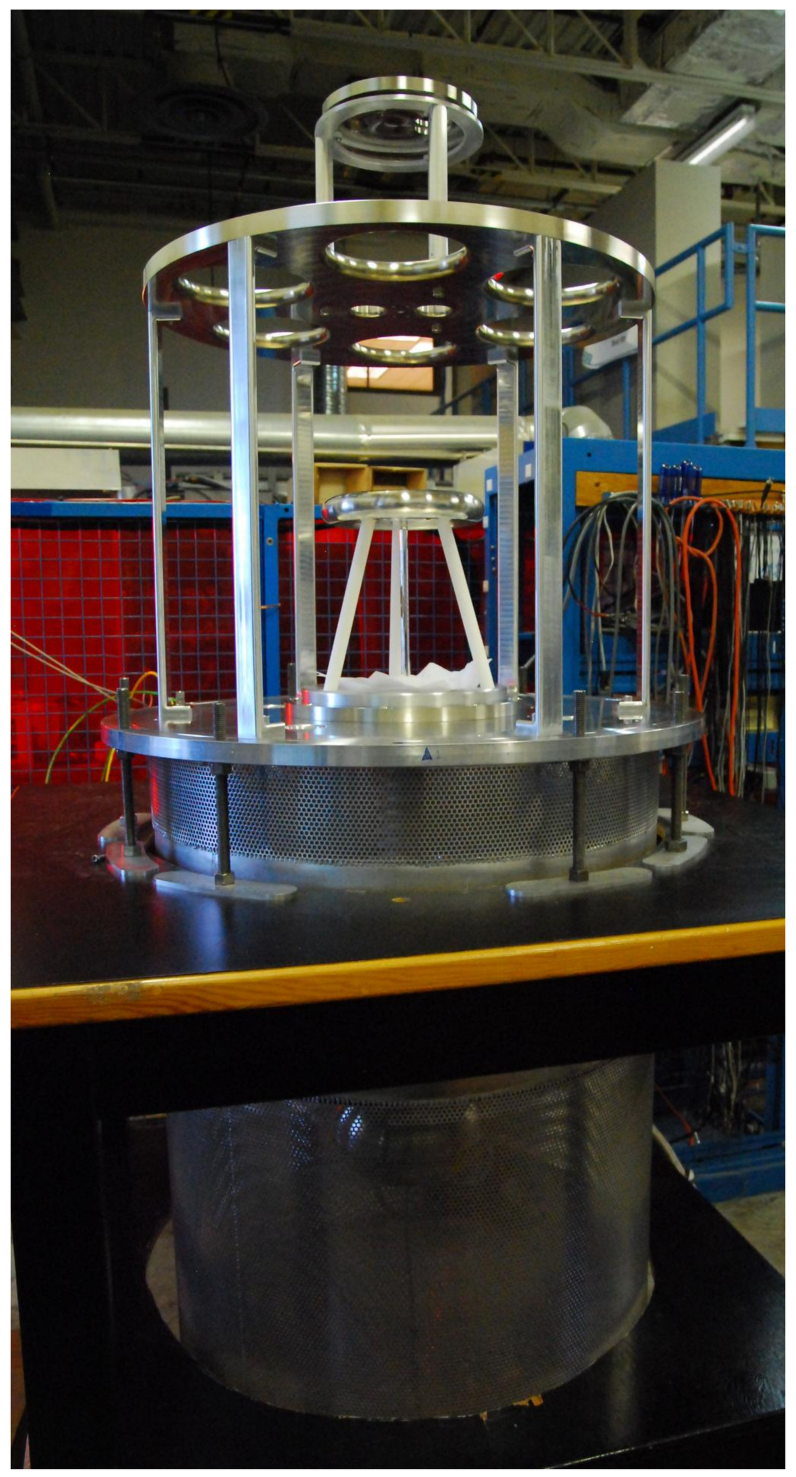
HV electrode (aluminum)

HV feed (up to -100 kV)

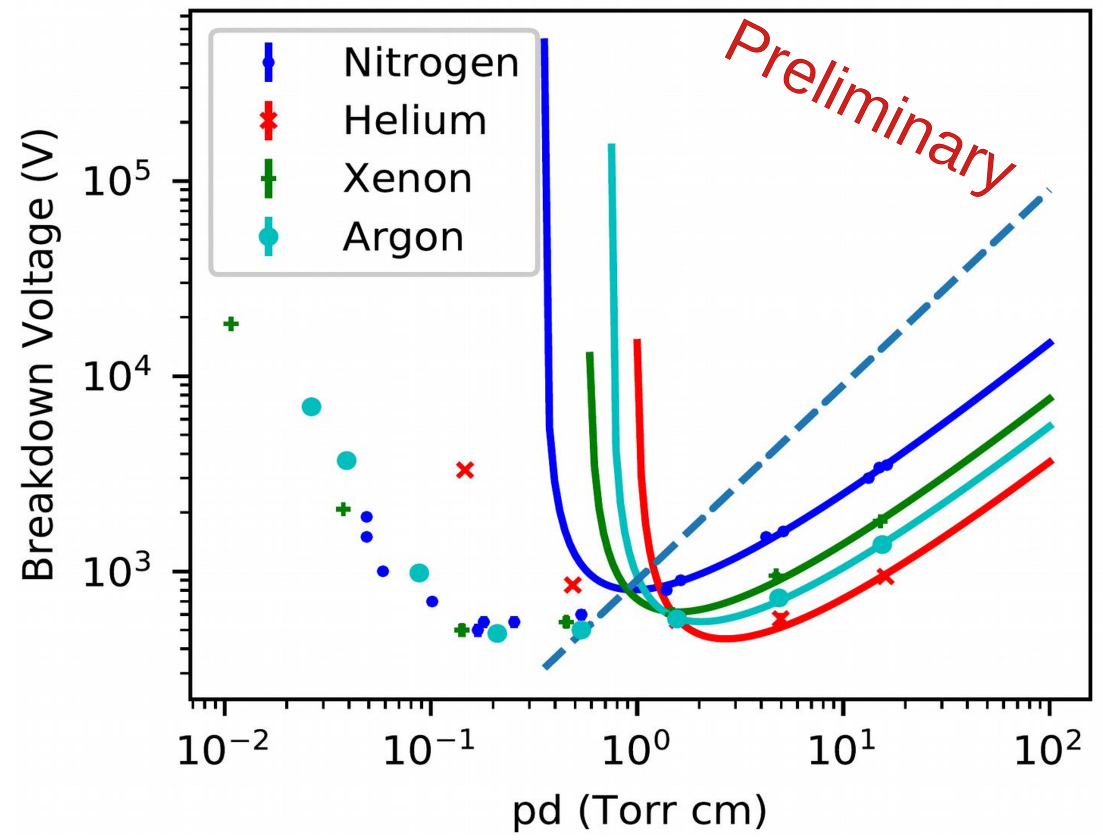
Supports (Macor/Delrin)



Successfully tested glass (d=40 mm, 65 mm) and polyethylene (d=75 mm) insulators >10kV/cm



Electric field breakdown results



High voltage breakdown results for different gases filled into the HV cell at pressures of 10^{-2} to 10^{2} Torr

Solid lines show fits to $V_B = \frac{Bpd}{\ln(A'pd)}$

A' includes parameters A and γ_{SE}. Only data in validity range of empirical parameters A', B (area right of dashed line) is used for the fit

Measurements show gas species dependence and qualitatively follow Paschen's model

Electric field breakdown in gases

Described by Paschen-law and empirical parameters:

$$V_B = \frac{Bpd}{\ln(Apd) - \ln(\ln(1+1/\gamma_{SE}))}$$

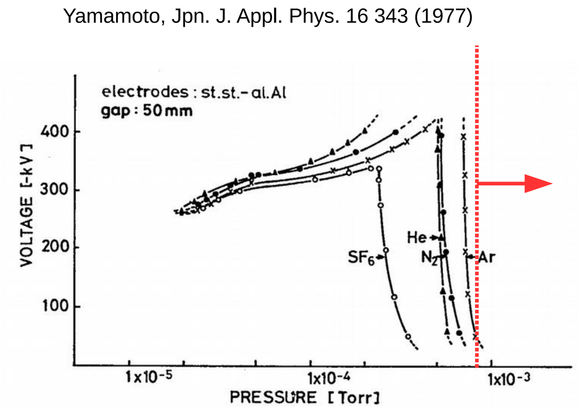
A saturation ionization in the gas
B related to excitation and ionization energies
γ_{SE} number of secondary electrons emitted

The validity range of literature values for A, B in terms of p*d is outside the parameters of TUCAN EDM

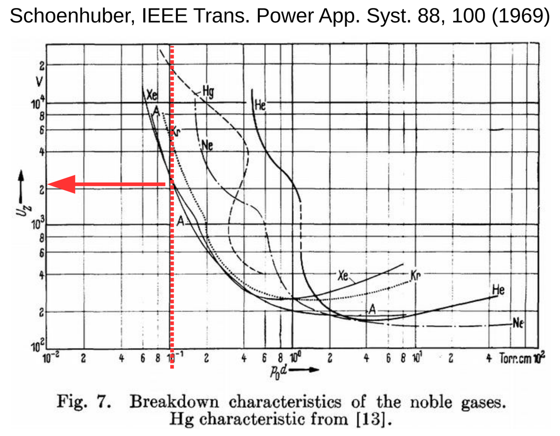
Electric field breakdown depends on electrode and cell geometries, electrode distance, electrode material

No xenon electric field breakdown data available in the pressure range 1 mTorr to 100 mTorr

Yamamoto, Jpn. J. Appl. Phys. 16 343 (1977)

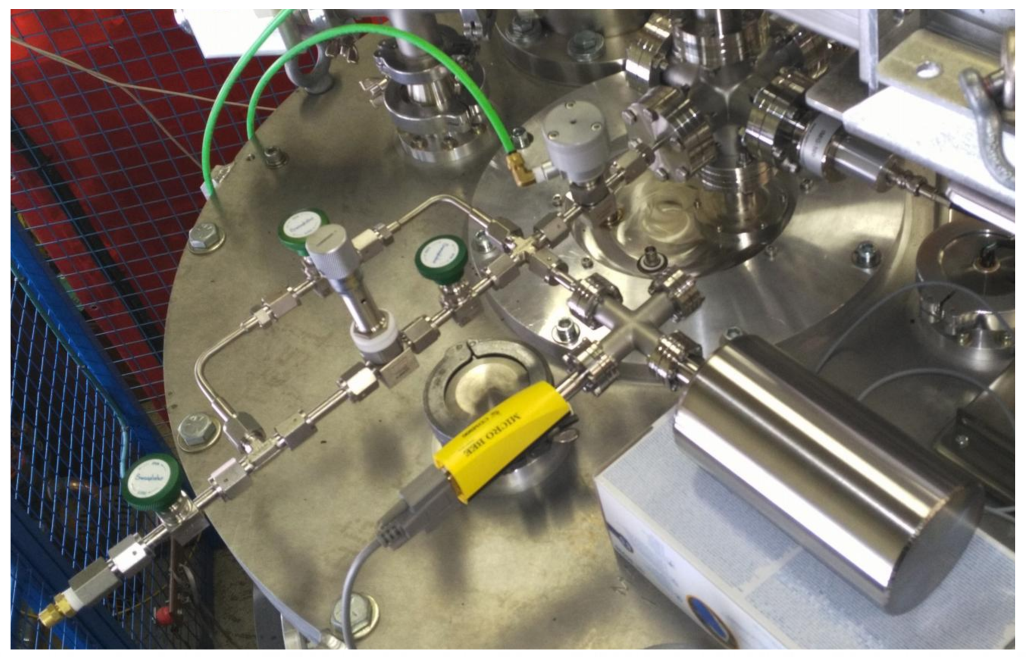


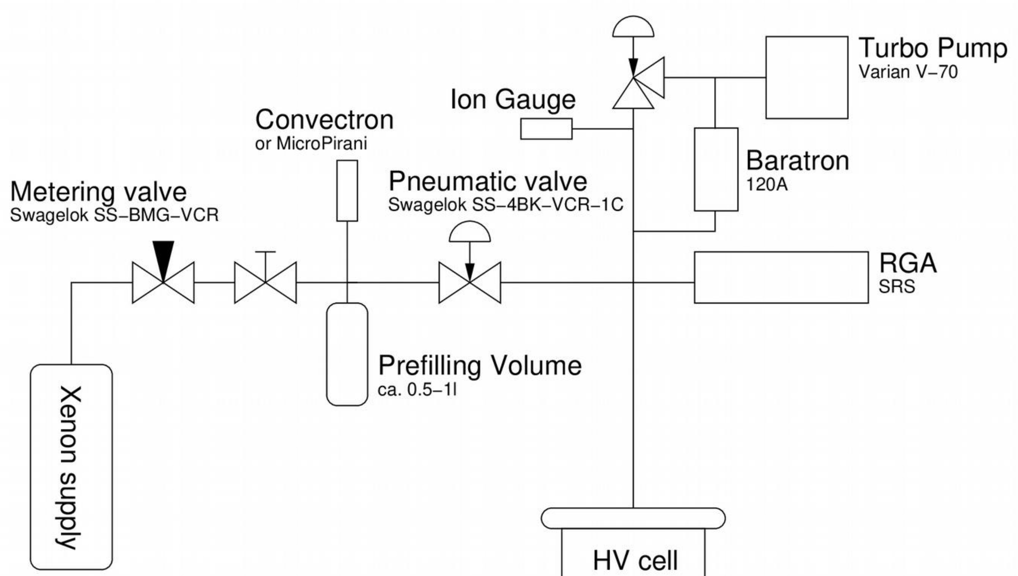
Schoenhuber, IEEE Trans. Power App. Syst. 88, 100 (1969)



Published electric field breakdown data for xenon is available for low pressures (<1 mTorr) and high pressures (>100 mTorr), but not in the range of interest for TUCAN EDM.

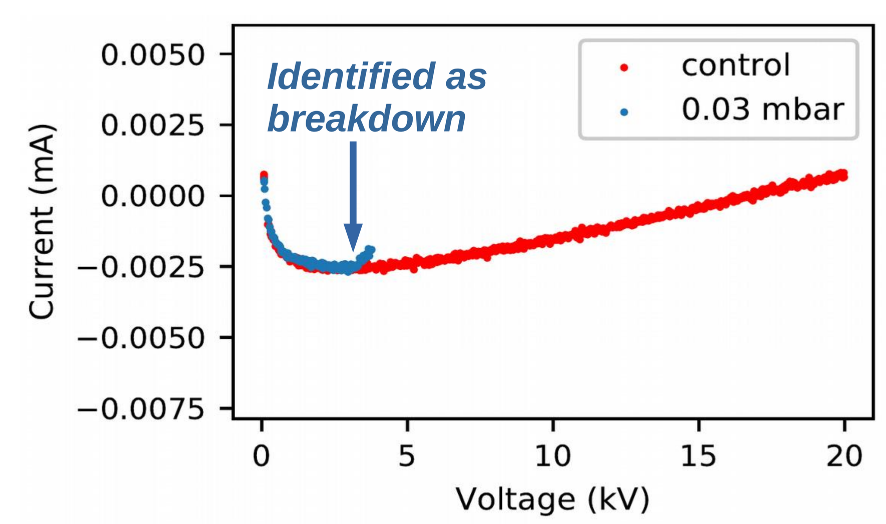
Gas filling setup





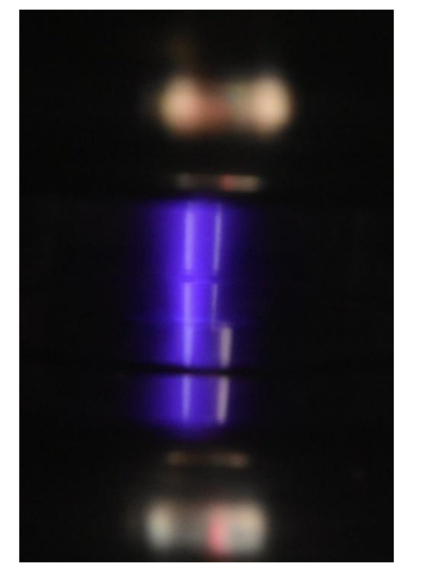
Scheme and picture of the gas filling setup. The pre-filling volume is filled with up to 20 Torr of gas. With subsequent filling and evacuation cycles of the HV cell the pressure range of 10^{-5} to 10 Torr can be covered for electric field breakdown tests

How to identify an electric field breakdown?



Left: High voltage power supply current monitor signal for vacuum (red) and 0.03 mbar of helium (blue)

Right: Nitrogen glow inside HV cell



- Electric field breakdown identified by deviation in I-V curve from vacuum baseline
- Improve on breakdown identification by using leakage current monitor
- Gas pressure inside HV cell needs to be confirmed in the low pressure range (pressure gradient is expected)

Next steps and goals

Extend measurements to lower pressures (10^{-5} to 10^{-2} Torr) and different cell geometries to study feasibility of dual co-magnetometer using xenon

Implement and test leakage current monitoring system for neutron EDM
- finish design of prototype
- 1kHz sampling rate, 1 pA – 100 nA sensitivity (selectable gain)
- HV compatible

Testing of insulator materials & cell coatings for high voltage compatibility