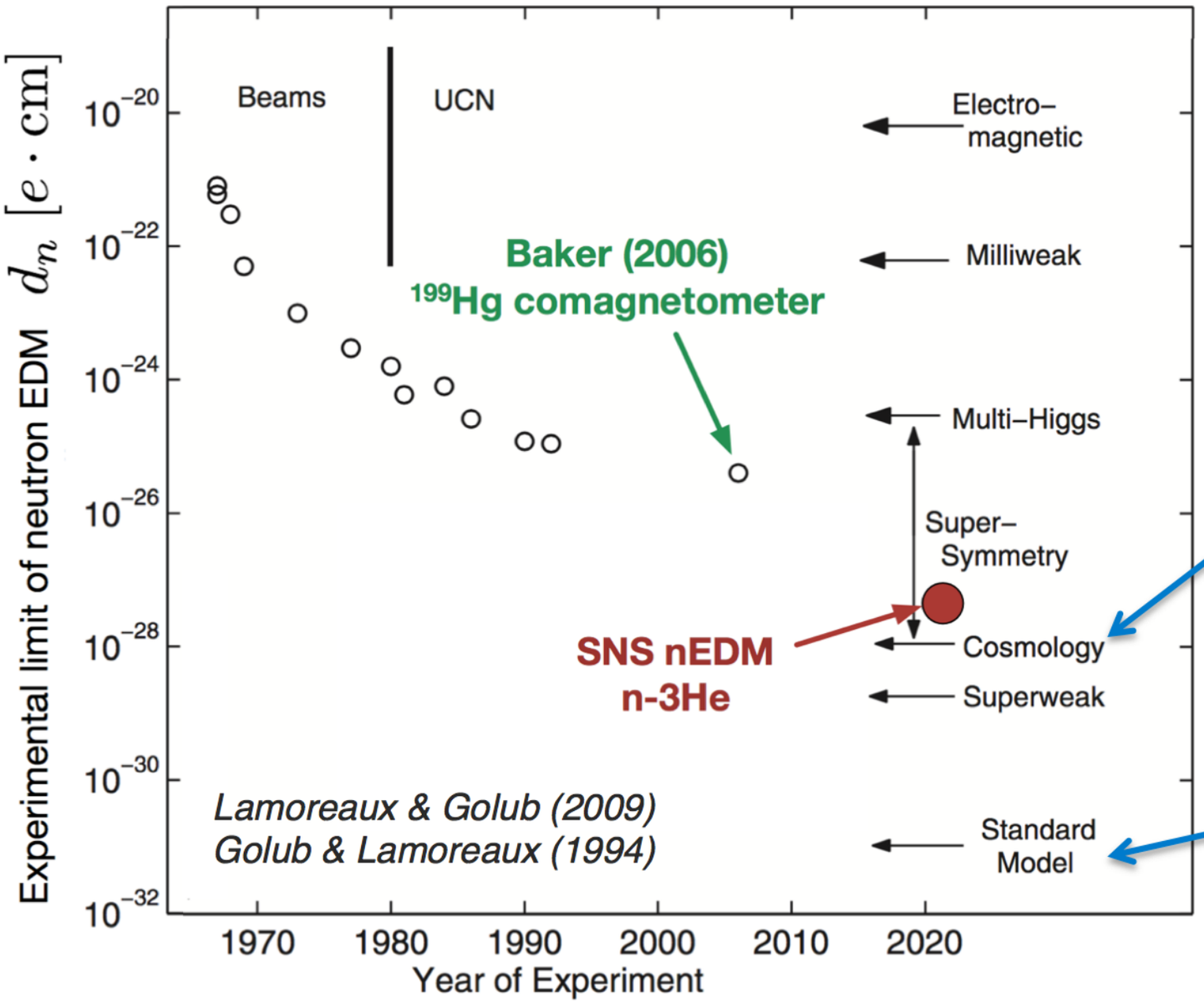
nEDM Panda Payload Development for OLCF

BigPanda Technical Interchange Meeting, BNL
April 25, 2018

Jed Leggett
Contributions From nEDM@SNS Simulations Team

Overview of nEDM@SNS Experiment



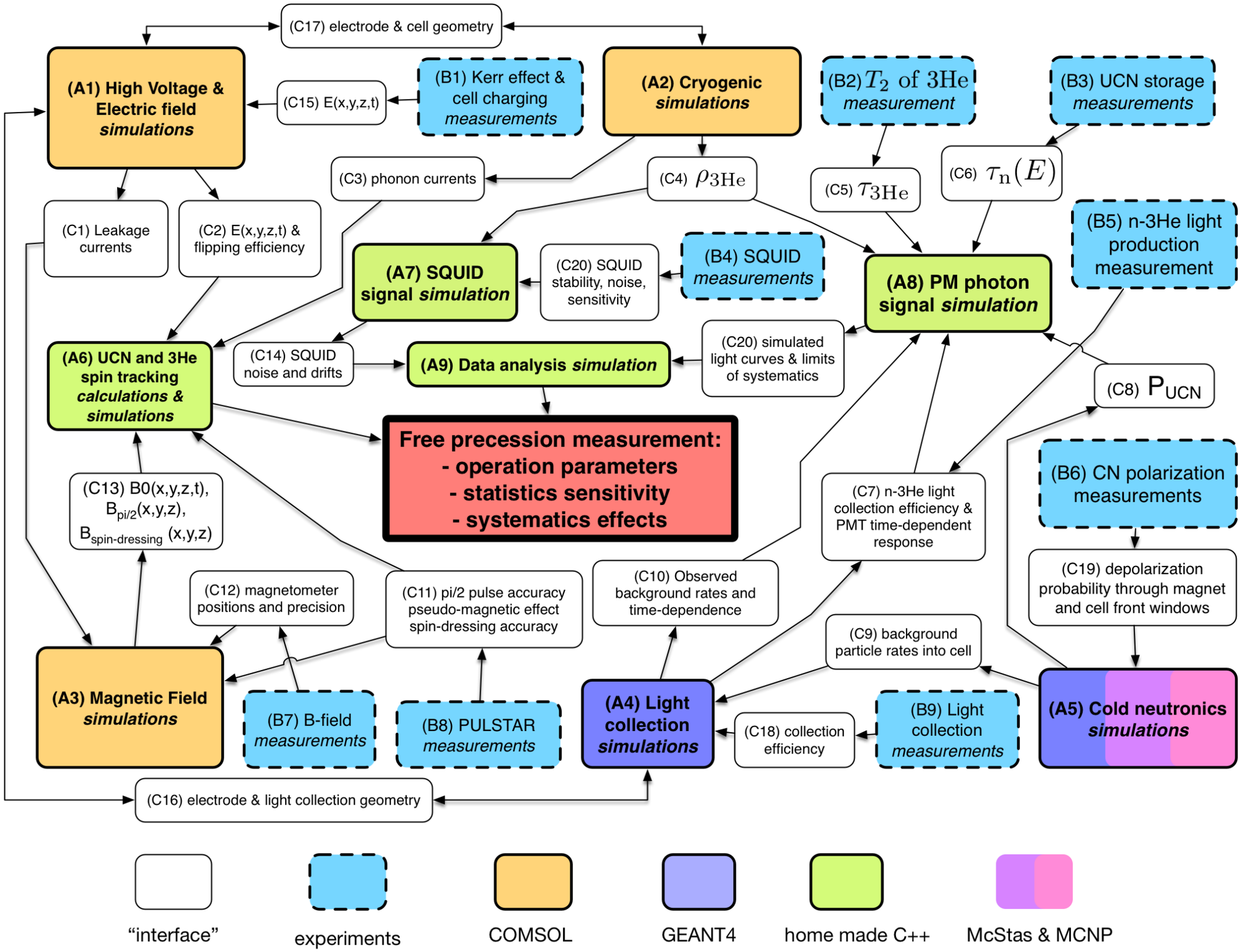
Rich History of nEDM Measurements, Started at ORNL in 1950

minimum neutron EDM that produce observed baryon-asymmetry due to known CP-violation along with baryon nonconservation. *Ellis et al. (1981)*

The size of nEDM predicted from known amounts of *CP*-violation in the standard model.

*Slide from Ken Leung.

nEDM Simulations Framework



K Leung (NCSU), B Plaster (UKy), L Broussard (ORNL)

Largest Computational Needs

Data Challenge 2.0

- Experiment runs at Spallation Neutron Source 2020+
- We want to have data analysis workflows in place when data collection begins.
- Previous Data Challenge produced 10^9 simulated events with backgrounds.
- Current iteration produces 10^{11} events per production run: 100k Titan node-hours, or 1.6M core-hours and 20 TB of data.

Systematic Studies

- Detailed tracking of spin propagation in magnetic field is needed to understand systematic uncertainties.
- On the order of 10^8 core-hours and 100 TB required for these studies.
- Stand alone C++ application with ROOT dependency (R. Shmid Dissertation)
- Currently being investigated for GPU vectorization.

nEDM on Panda

Minimize extra workforce requirements needed to utilize available computational resources.

- No nEDM collaborators work full time on simulations, but many make intermittent contributions.

Take advantage of fine grained backfill potential.

- nEDM Central Cell Simulation can utilize as little as a few node-minutes in an efficient manner.
- Results for Data Challenge can be accumulated over time.

Current Status

- In January, a few preliminary nEDM payloads were successfully submitted through PanDA.
- When attempting to submit a full production run, a bug was encountered that resulted in over-limit stdout files.
- With Pavlo's help, the problem was fixed and we have verified successful submission of new Payloads.
  - After spending time looking for something complicated, we realized that the problem was the file permissions on the output directory.
- In the interim, one full production run was tested on Titan manually.
  - Data from this run is currently being analyzed offline and will inform the upcoming parametric studies.

Next Steps

- The nEDM simulations team will meet for a 2-day Hackathon at the end of May.
- We plan to have our simulations workflow completely migrated to PanDA by that point. Leah and I will train other team members on using PanDA.
- During this meeting, the team will decide on the 1st round of parametric studies.
  - At least 10 production runs to be submitted in 2018.
  - ~1 million Hours.

Longer Term

- As the nEDM simulations team is making plans, questions have been raised regarding the availability of computing resources for the 2019-2021 time frame.

- Will we need to host our own PanDA server?

- What are the prospects of extending our current DD project for another 2-3 years?

nEDM Collaboration

Thank You!

Arizona State University

Bartoszek Engineering

Brown University

California Institute of Technology

Duke University

University of Illinois

Indiana University

University of Kentucky

Los Alamos National Laboratory

Massachusetts Institute of Technology

National Autonomous University of Mexico

Mississippi State University

North Carolina State University

Oak Ridge National Laboratory

Simon Fraser University

Tennessee Tech University

University of Tennessee

Valparaiso University

University of Virginia

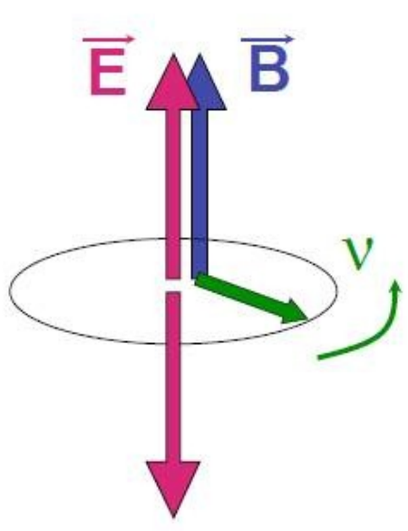
Extra Slides

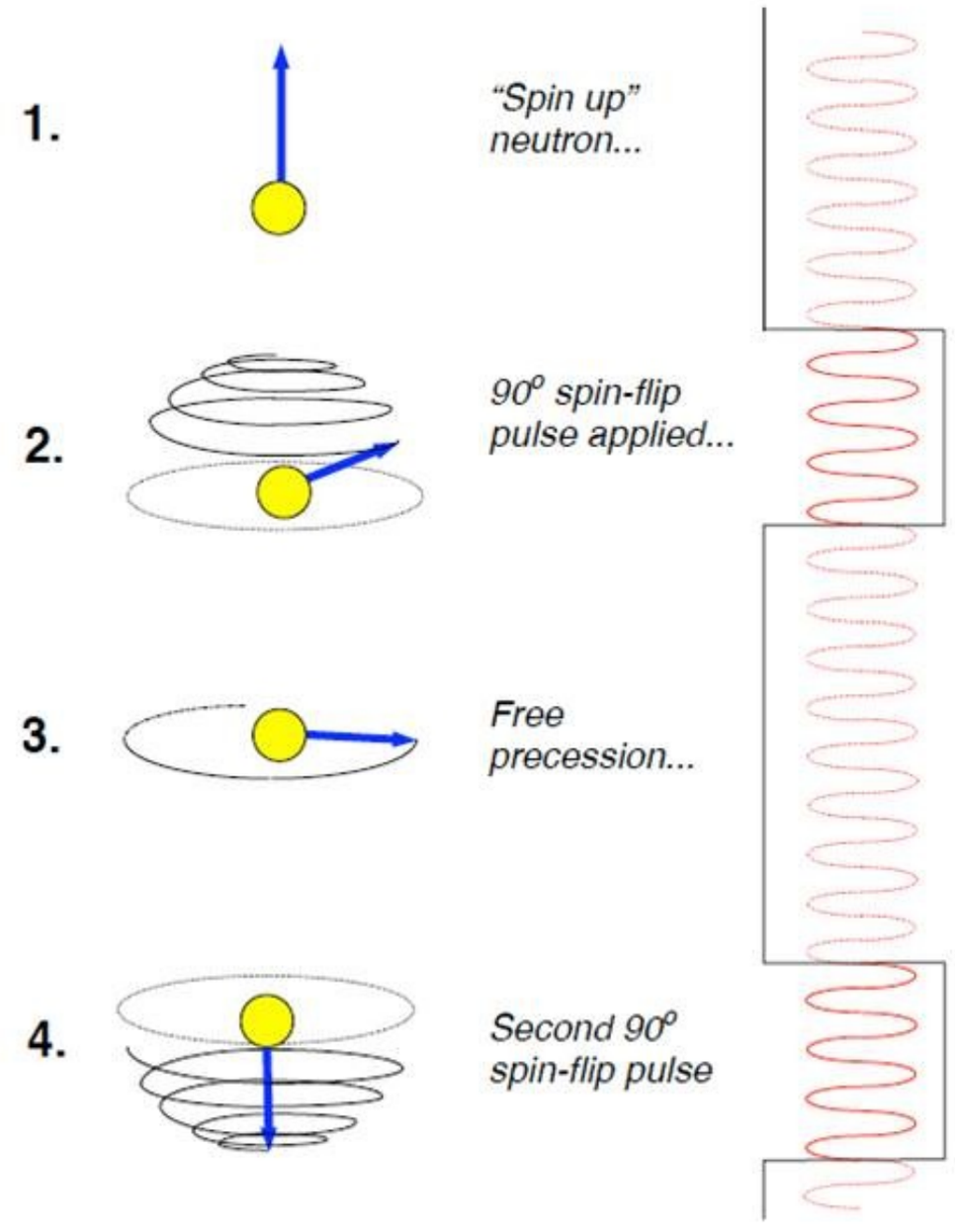
EDM Measurement Technique

- Measure change in precession frequency with parallel vs antiparallel **E**, **B** fields

$$\omega = \frac{2\vec{\mu}\cdot\vec{B} \pm 2\vec{d}\cdot\vec{E}}{\hbar}$$

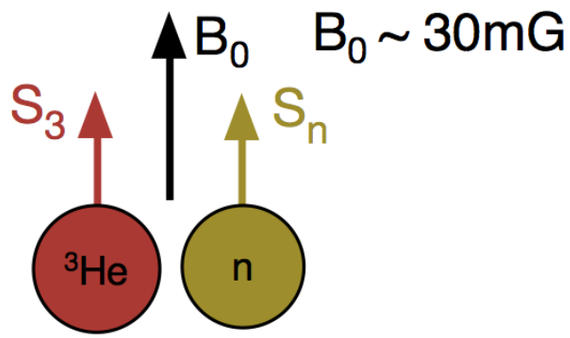
$$\Delta\omega = \frac{4dE}{\hbar}$$

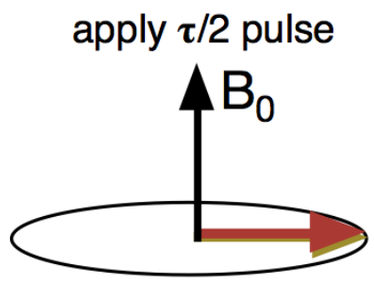


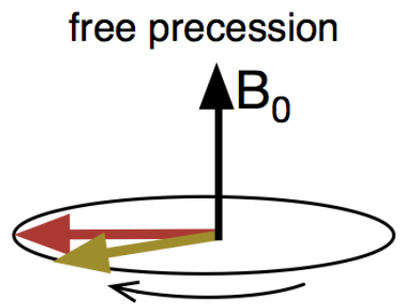


*Slide from Leah Broussard.

EDM Measurement Technique







^{3}He + n → p + ^{3}T (Q=764keV) has **spin-dependent** cross-section (@2200m/s):

Parallel spins: $\sigma_{\uparrow\uparrow} < 10\,\mathrm{b}$ Anti-parallel spins : $\sigma_{\uparrow\downarrow} \approx 11\,\mathrm{kb}$

Scintillation light signal: $1 - P_n\,P_3\,\cos\theta_{\mathrm{n3}}(t)$

← angle between n & ^{3}He spins

Effects of He-3 EDM suppressed by Schiff screening so that:

$$\theta_{\mathrm{n3}} = |\gamma_n - \gamma_3|B_0 t \pm \frac{e d_n |E|}{\hbar} t \qquad \gamma_3 \approx 1.1\,\gamma_{\mathrm{n}} \qquad \gamma_3 B_0/(2\pi) \approx 100\,\mathrm{Hz}$$

Measure ^{3}He precession $\gamma_3 B_0/(2\pi)$ with SQUIDS => sensitivity $\approx 5 \times 10^{-28}\,e.\mathrm{cm}$

Alternative dressed-spin technique: apply strong RF ($B_{\mathrm{rf}} \sim 1\,\mathrm{G}$ $\omega_{\mathrm{rf}}/(2\pi) \sim 3\,\mathrm{kHz}$) and increase sensitivity of exp.

*Slide from Ken Leung.