# The MCUCN simulation model for the n2EDM experiment

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# Outline

- Scope of n2EDM simulations
- Benchmarks of the PSI UCN source model (MCUCN)
- n2EDM model
- Detected counts estimation
- Ramsey curves and depolarization estimations
- Conclusions and outlook

# Scope of n2EDM simulations

$$\sigma(d_n) = \frac{\hbar}{2\alpha E T \sqrt{N}}$$

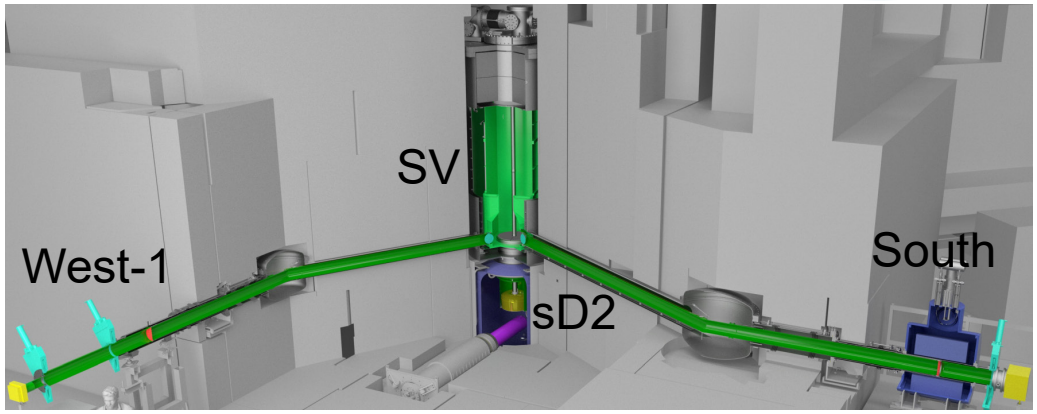
- The technical design supported by detailed simulations of the UCN optics system with MCUCN (NIM A 881, 16 (2018))
- Maximize the UCN density in the precession chambers as a function of the geometry and surface parameters
- Verify the asymmetry between the TOP and BOTtom chambers: *N*, energy spectrum and UCN center-of-mass offset
- Depolarization estimates by using realistic energy spectra in the TOP/BOT chambers in inhomogeneous magnetic field configurations
- Check conditions of depolarization effects during filling and emptying using detailed field maps

# Benchmarks of the PSI UCN source model

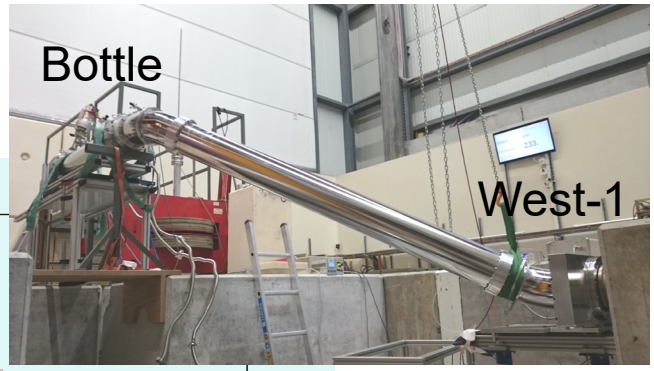
- The n2EDM model includes the PSI source and beam guides for the UCN filling phase, benchmarked up to the BP with various test measurements
- UCN transmission from BP West-1 to South after pre-storage, to constrain the loss and diffuse reflection parameters of the guides
- UCN storage at different heights above BP level to constrain the energy spectrum exiting the sD2
- TOF spectra at BP,

  foil and guide transmissions
- Paper on global benchmark to be submitted early 2021

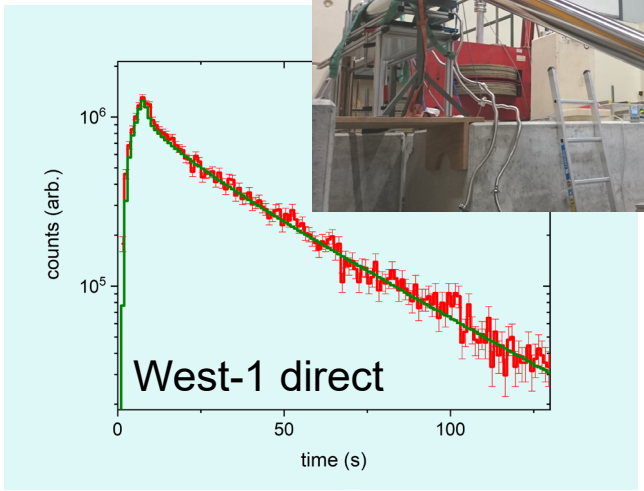
  see also Eur. Phys. J. A 56, 33 (2020)




Phys. Rev. C 95 045503 (2017)

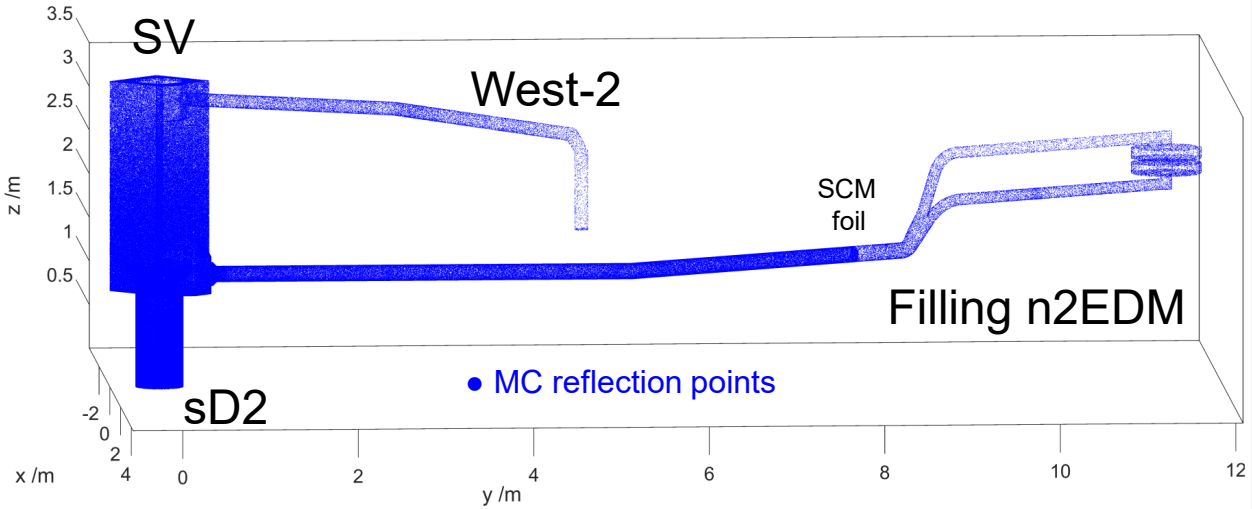


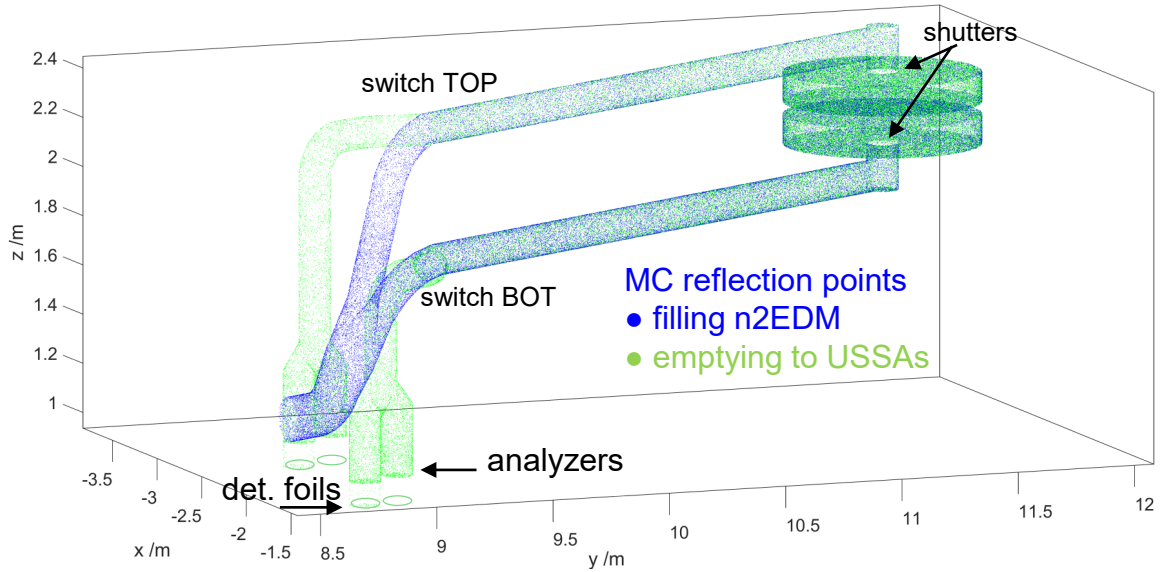

D. Ries, Dissertation, ETH Zürich, 2016



# n2EDM model and input data

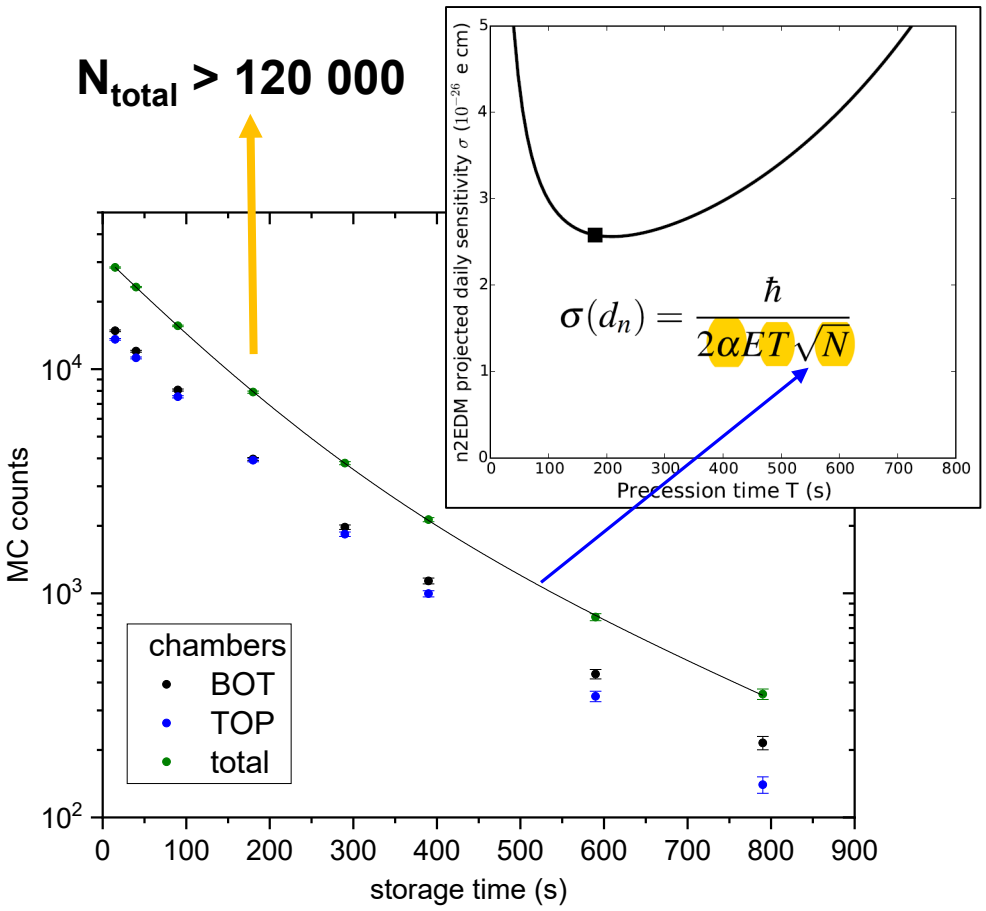
- Optimized geometry (UCN)
- Surface parameters
  - $V_F$, $\eta_{loss}$, $p_{diff}$ , loss in windows:
- NiMo coated guides:
  220 neV, 3x10$^{-4}$, 2%
- Prec. chambers:
  - Electrodes 230 neV, 2%
  - Insulator 165 neV, 100%
  - Common 2.8x10$^{-4}$
- Analyzer Fe: 90↓, 330↑ neV
- Details in n2EDM tech. design paper (submitted to EPJ C)
  **arXiv: 2101.08730**

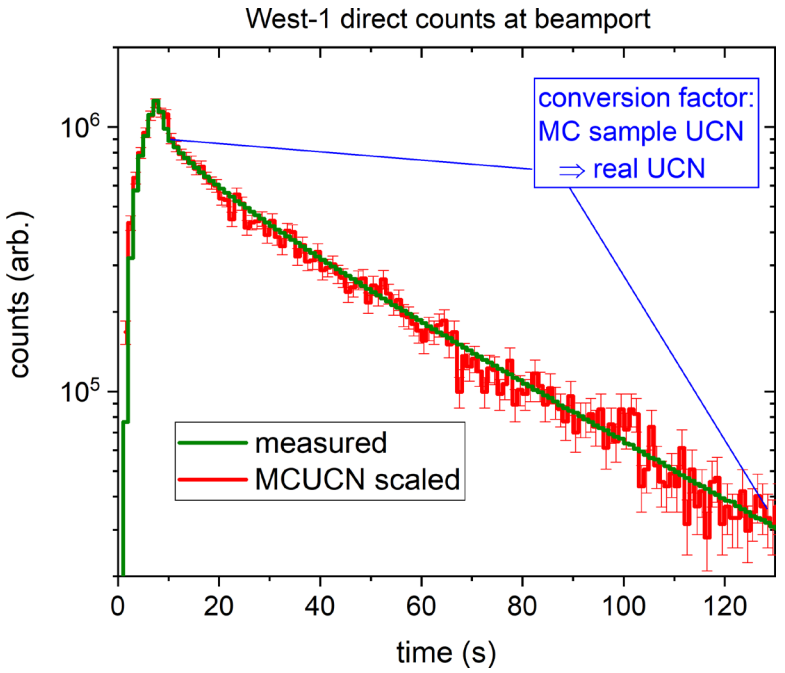


# n2EDM storage properties and detected counts

- Storage curves TOP and BOT chambers
  - Optimize precession time T = $T_{store}$ – 8s
  - Estimate final UCN counts $N_{total}$




- West-1 2016 best 3.5x10$^7$ UCN per pulse gives conversion factor:

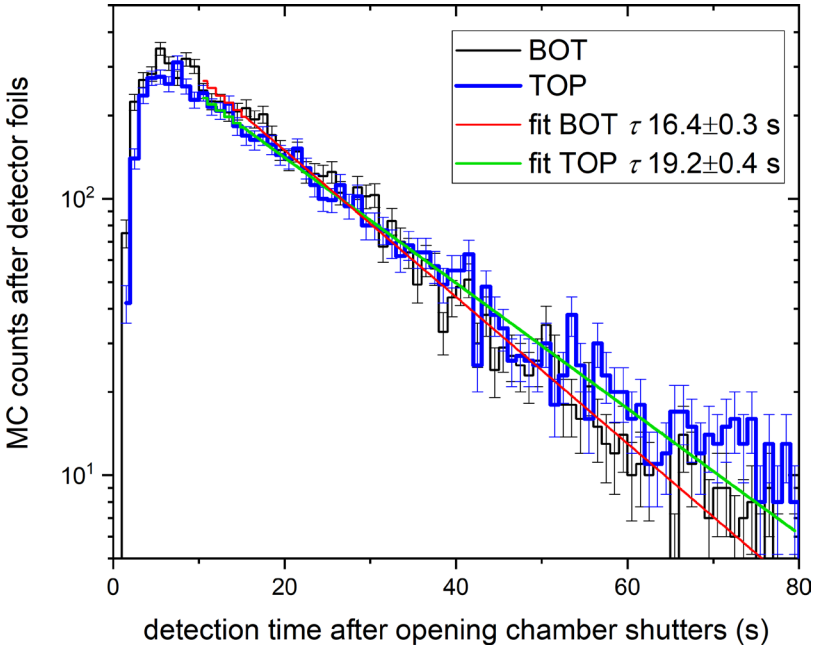
  **UCN_real / UCN_MC**

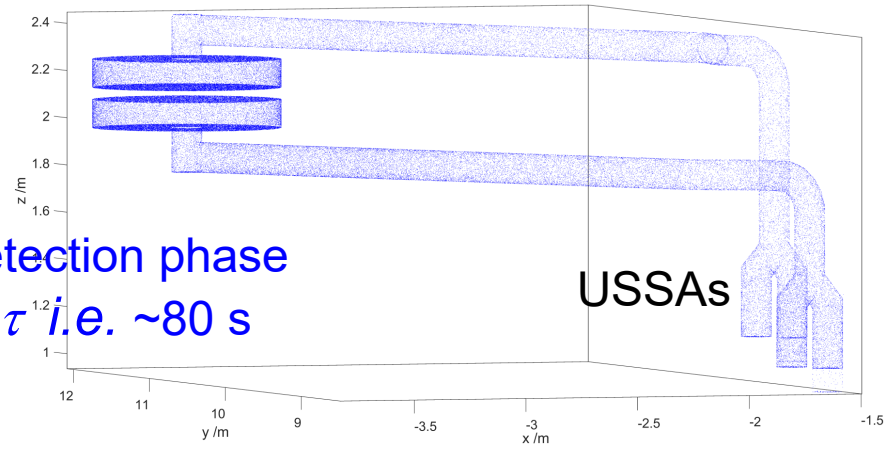
- Reference: 2016 nEDM average

  Average 15000 / Best: 20000 UCN

- **UCN_MC from n2EDM → $N_{total}$**
- MC uncertainty obtained from reproducing the steel bottle measurements ±15%

# Detected spectra from TOP/BOT in the USSAs




Detection phase
~4$\tau$ *i.e.* ~80 s

USSAs

**Center-of-mass offsets h/cm:**

TOP: -0.098

BOT: -0.130

**Difference Δh TOP-BOT: -0.032 cm**

**Stability**: Check $p_{diff}$ 8% in n2EDM guides

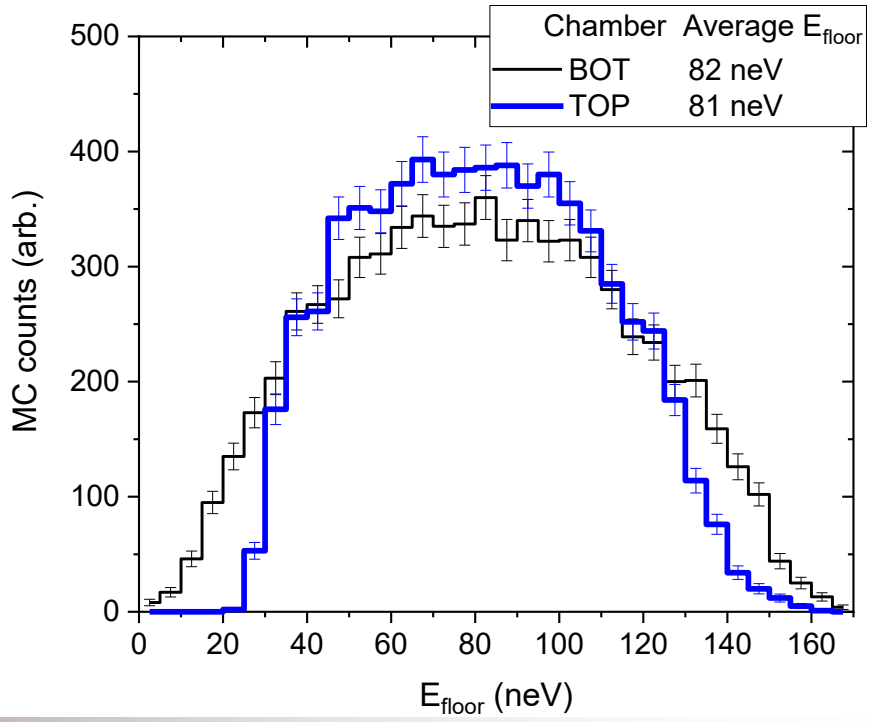
TOP: - 0.093

BOT: - 0.129

Check 8% and beamline guide 10%

TOP: -0.094

BOT: -0.134

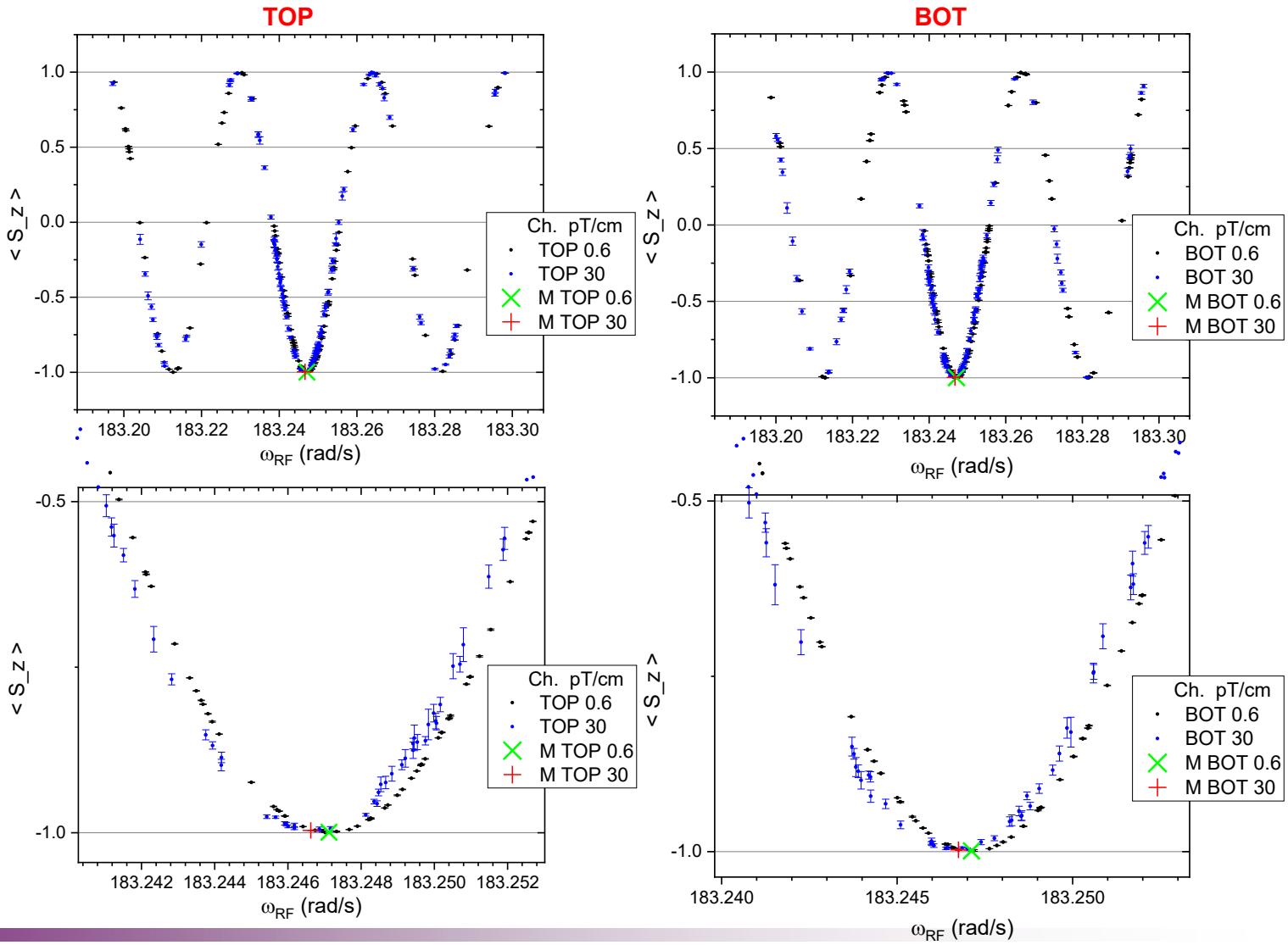


# Ramsey cycles in TOP and BOT chambers

$$G_{1,0} = \partial_z B_z = -\partial_x B_x - \partial_y B_y$$

- Used energy spectra detected from the BOT and TOP chambers, **by the USSA detectors**
- MC of Ramsey cycles

Shifted for TOP / BOT chambers



# MC of neutron depolarization in TOP/BOT

- Decay of polarization during storage

$$\frac{d\alpha}{dt} = -\frac{\alpha}{T_{\text{wall}}} + \dot{\alpha}_{\text{grav}} - \frac{\alpha}{T_{2,\text{mag}}}$$

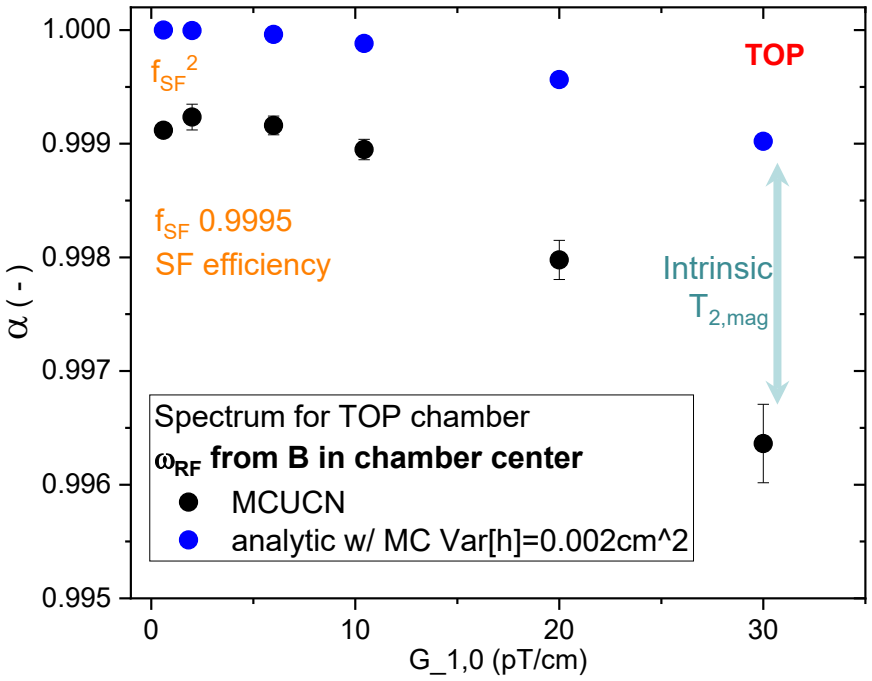
- *E* spectra TOP and BOT are slightly different

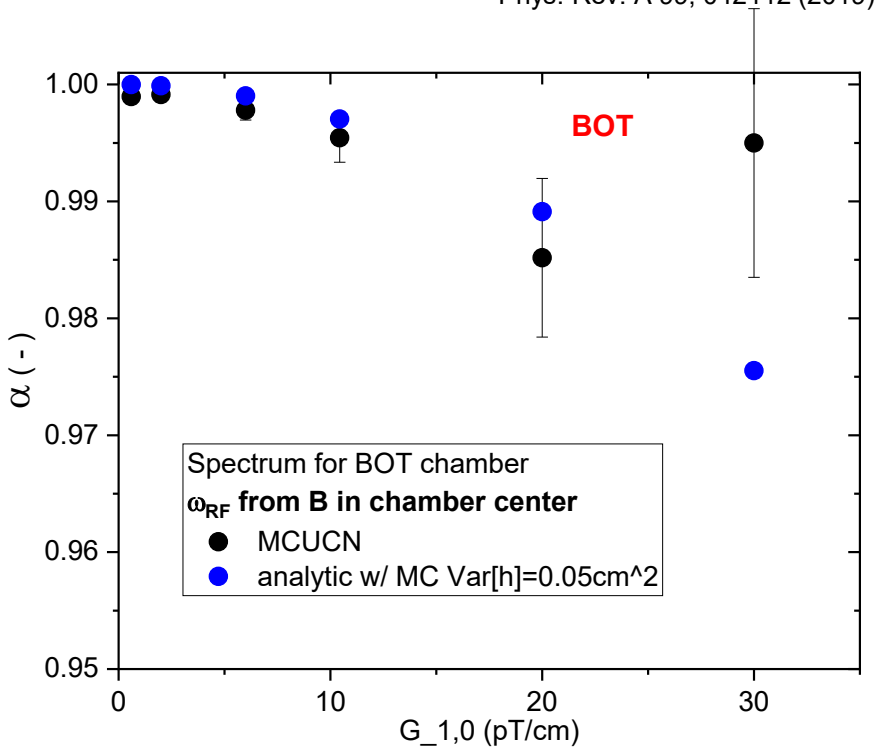
Gravitationally enhanced:

$$\dot{\alpha}_{\text{grav}} = -\gamma_n^2 G_{1,0}^2 \text{Var}[\bar{z}]\, T$$

$$\text{Var}[\bar{z}] = \int (\bar{z}(\epsilon) - \langle z \rangle)^2 n(\epsilon) d\epsilon$$

Phys. Rev. A 99, 042112 (2019)



# Conclusions and outlook

- The design process of the n2EDM experiment was supported by detailed simulations of its UCN optics system
- Estimated important parameters: *N* and energy spectra in TOP and BOT chambers
- MC with realistic energy spectra confirm a very low degree of depolarization. Further MC checks planned for higher order $G_{l,m}$.
- Implementation of reading a magnetic field map along the full path of the UCN started. The map was generated by the Univ. of Kentucky group. We will check e.g. conditions of depolarization effects located in the guides