



The very powerful UCN source at the reactor TRIGA Mainz - Application for precise measurements of the neutron half-life

Institut für Physik, Johannes Gutenberg Universität Mainz:

M. Beck, W. Heil, J. Karch, Th. Lauer¹, Th. Zechlau¹

Institut für Kernchemie, Johannes Gutenberg Universität Mainz:

Ch. Düsing, K. Eberhardt, G. Hampel, Ch. Plonka-Spehr, T. Reich, Yu. Sobolev, N. Trautmann

¹ now Technische Universität München, Forschungs-Neutronenquelle Heinz Maier-Leibnitz

For NRC 8 –International Conference on Nuclear and Radiochemistry, Como, Italy, 16-21.09.2012

Yury Sobolev



Content

- Motivation
- TRIGA Mark II reactor Mainz
- Cryogenic system of the UCN source at beamport D
- UCN density measurements
- Neutron half-life measurement at the reactor TRIGA Mainz: concept of an experiment
- Conclusion and outlook

Motivation

Ultracold Neutrons (UCN) to test the Standard Model

- neutron electric dipole moment
- neutron lifetime
- quantum states in gravitational field
- ...

Ultracold neutrons (UCN): $E_n < 300 \text{ neV}$ ($T_n \sim \text{mK}$)

- can be stored in material bottles
- can be magnetically stored : 60 neV/Tesla
- gravitational storage: 102 neV/m

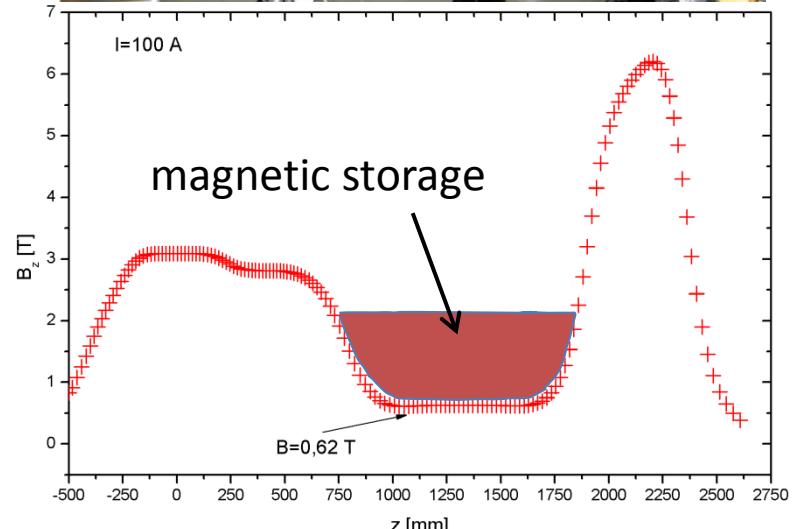
UCN-source in pulse mode operation:

- ideal for UCN storage experiments

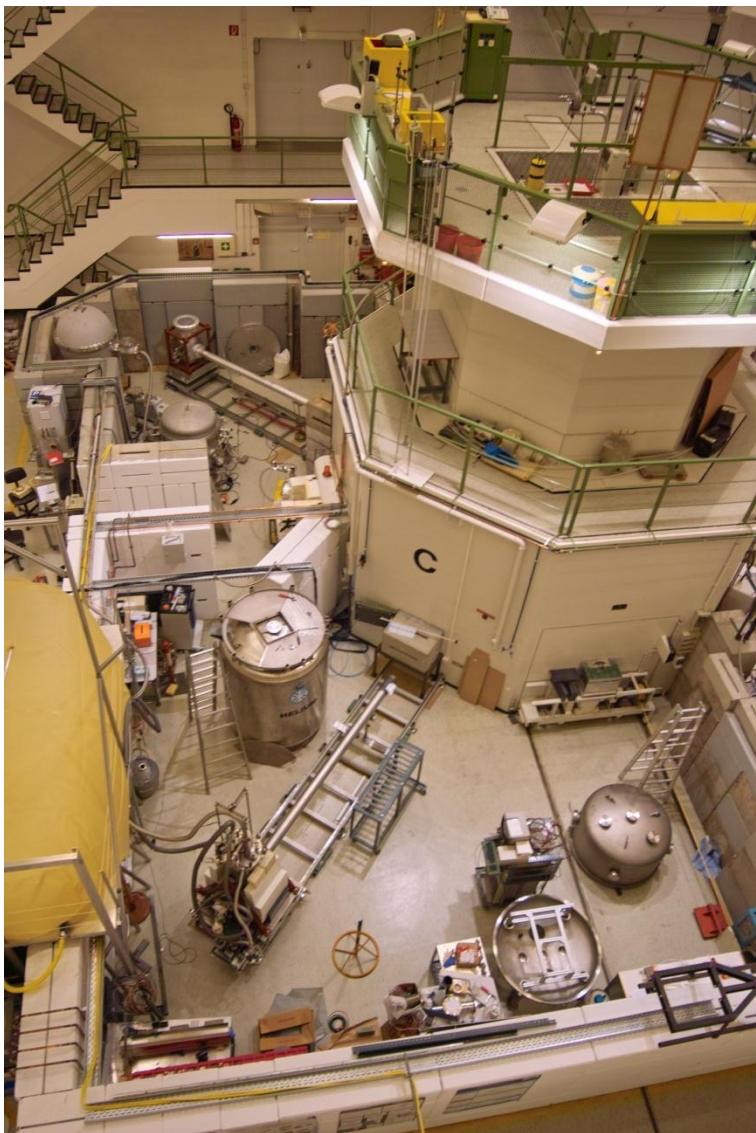
UCN source at TRIGA reactor Mainz:

- max. 12 pulses / hour

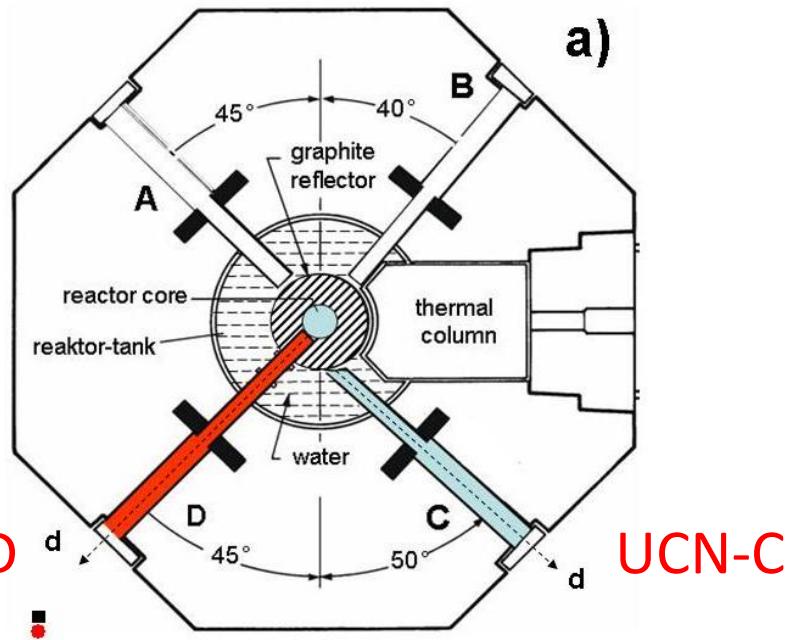
example: Mainz n-lifetime experiment



TRIGA Mark II reactor Mainz



UCN-D



UCN-C

two operation modes:

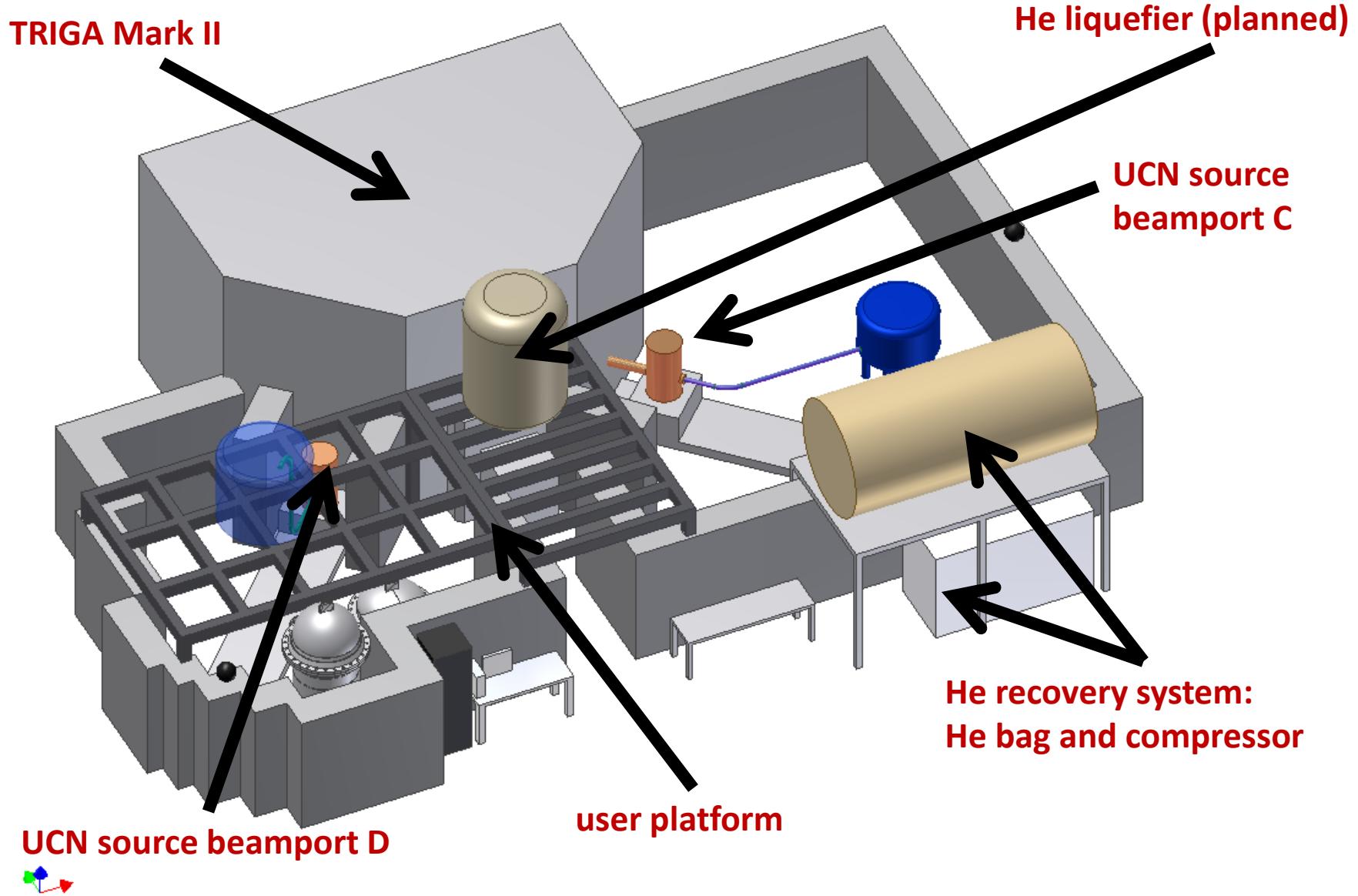
steady state:

$100 \text{ kW}_{\text{th}}, 10^{12} \text{ n/cm}^2\text{s}$

pulse mode:

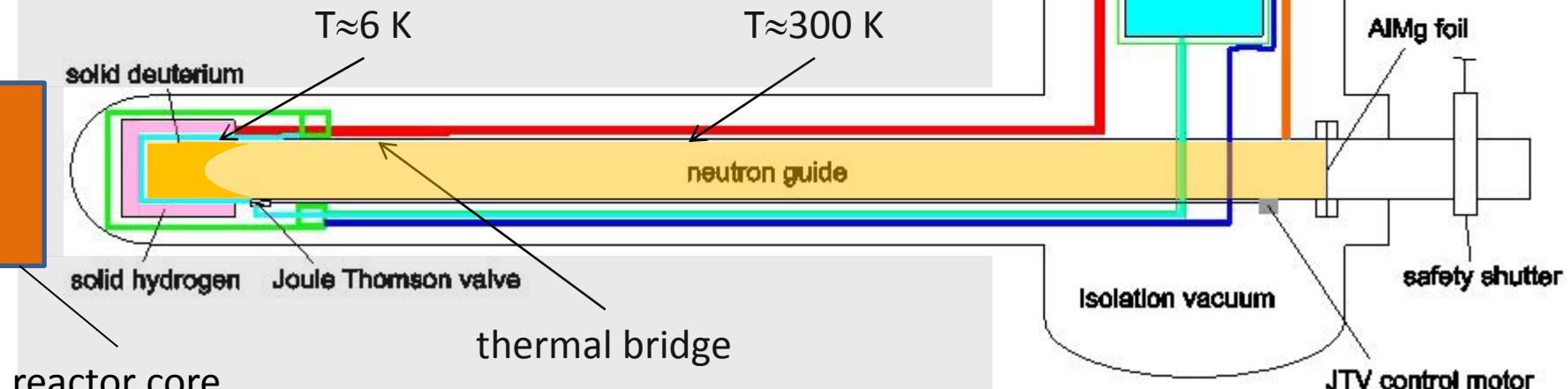
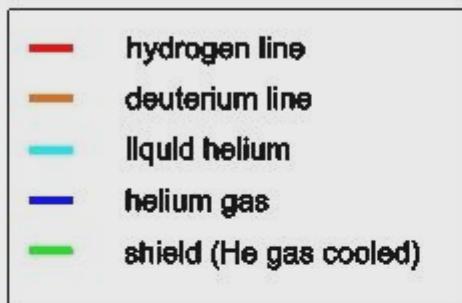
$250 \text{ MW}_{\text{th}} (30 \text{ ms}),$
 $2 \cdot 10^{15} \text{ n/cm}^2\text{s}$

UCN sources at the TRIGA Mainz



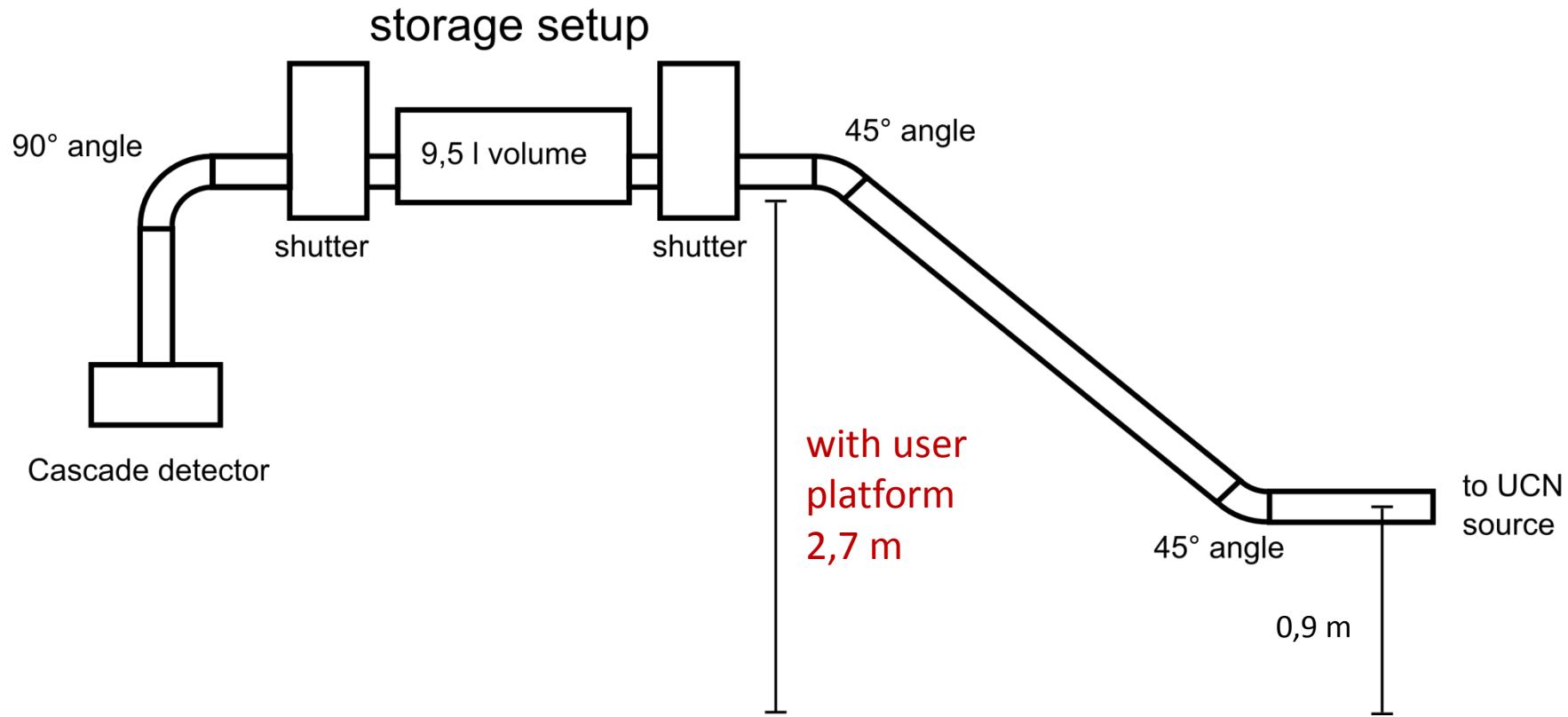
Cryogenic system of UCN source at beamport D

biological shield

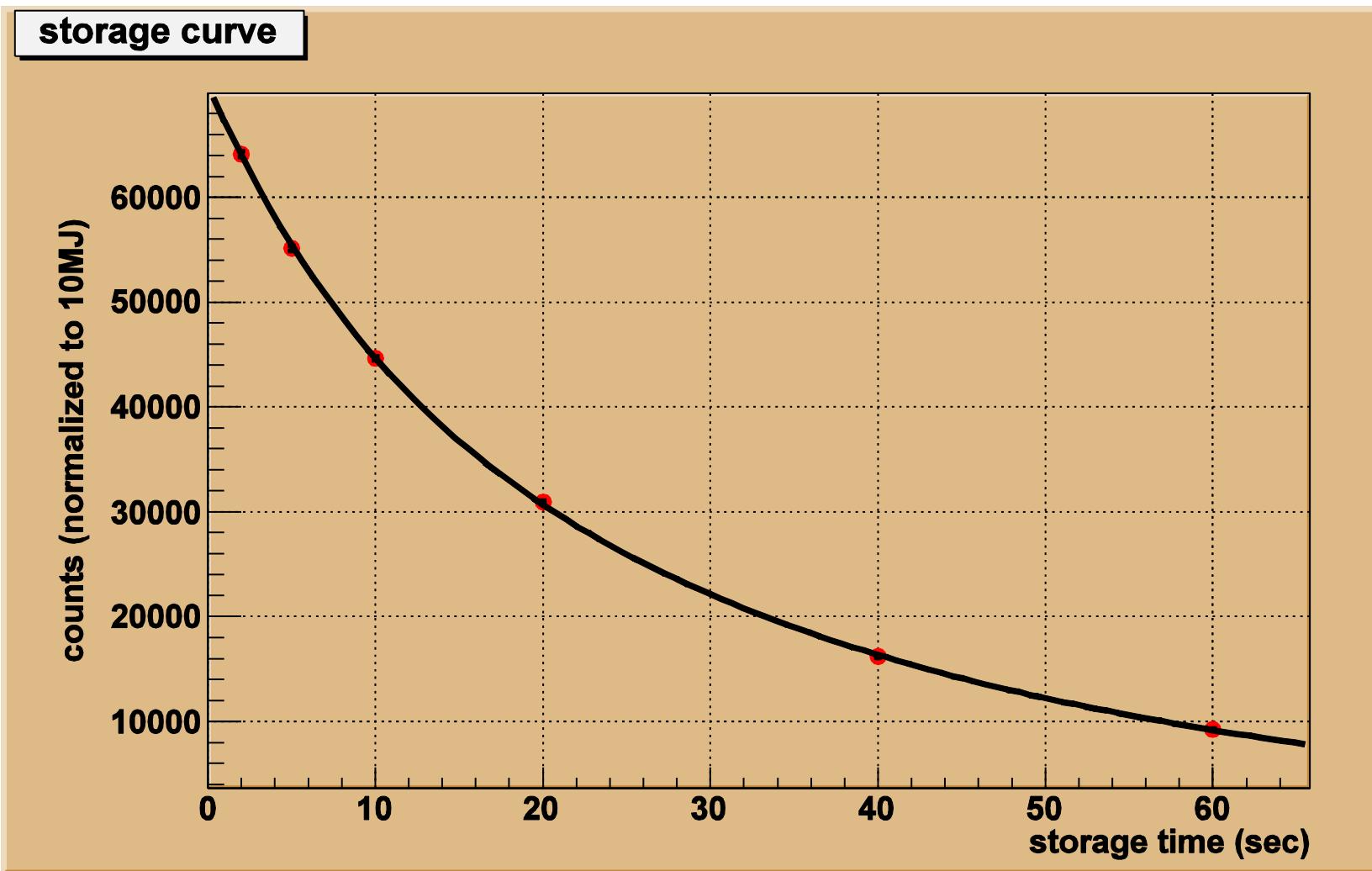


UCN density measurement

Setup



UCN D: results of UCN storage experiment



UCN storage curve (red points, stat. error bar are too small to be visible) with two exponents fit:
UCN density $\rho(0) = 7 \text{ UCN/cm}^3$



Neutron half-life measurement at the reactor TRIGA Mainz: *concept of an experiment*

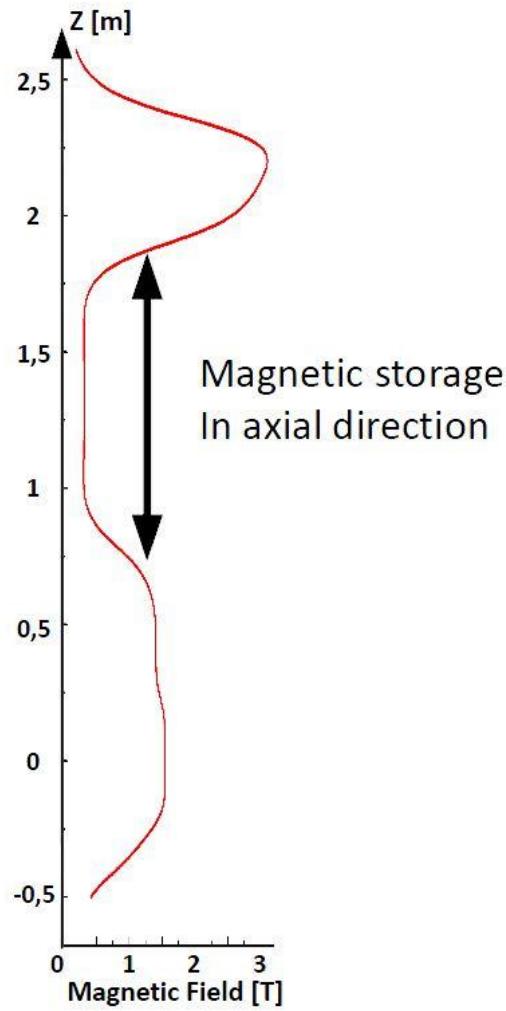
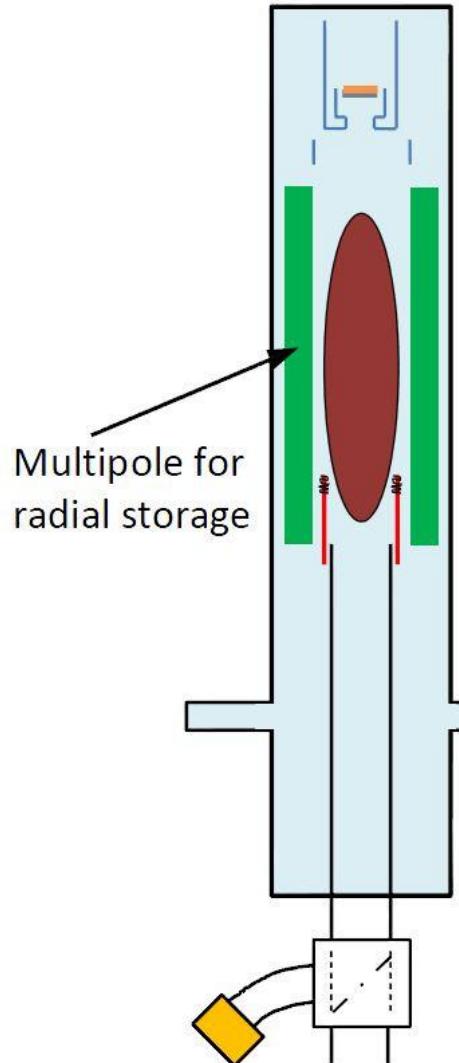
The full concept

- TRIGA reactor in Mainz with existing UCN source
- Axial storage: B-field of α SPECT
in horizontal arrangement
- Radial storage: multipole inside α SPECT
- Fast adiabatic spin flip
retractable guide tube with rf-flipper
- 4π decay proton measurement with α SPECT detection system
continuous monitoring!
background measurements
- Monitoring of neutron losses
with GEM detector,
n-sensitive Li-glass scintillators
n-sensitive Si-Photodiode

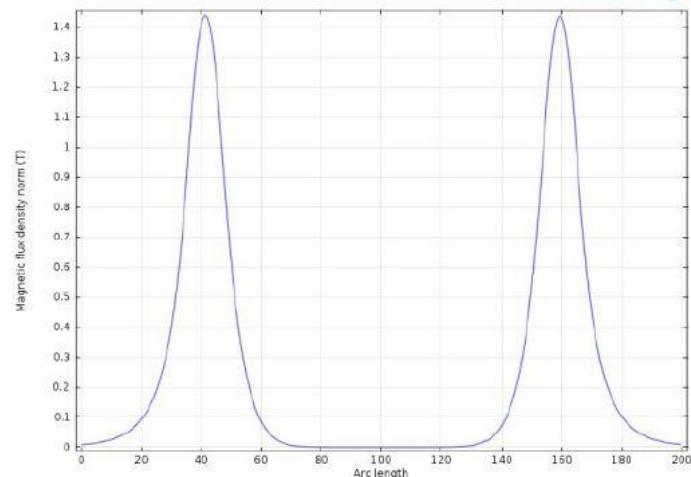
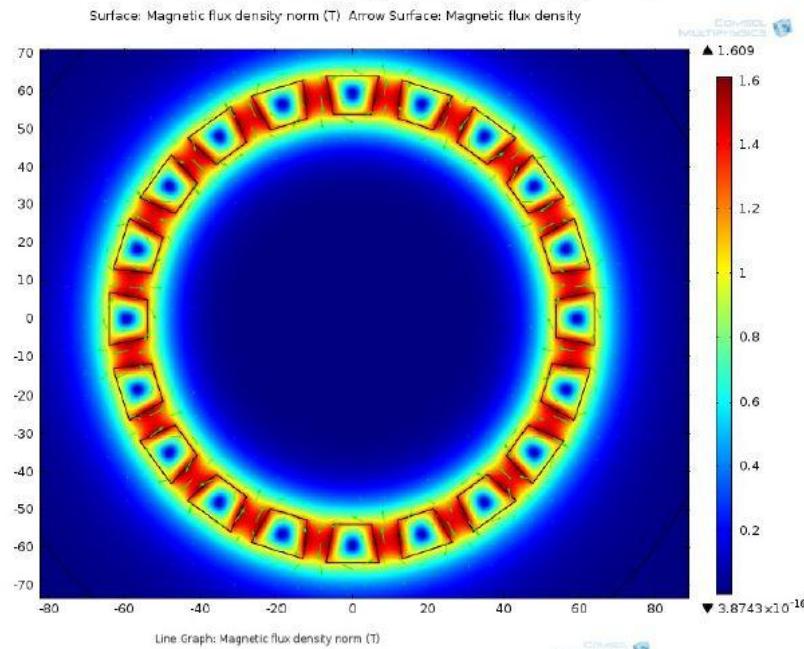


The concept

Magnetic storage in axial and radial direction



Field of magnetic multipole





The concept

Statistics at the TRIGA Reactor

$$\text{Storage volume } (|B| \leq 1 \text{ T}): \quad \left. \begin{array}{l} l = 1110 \text{ mm} \\ \emptyset = 100 \text{ mm} \end{array} \right\} \quad V = 8.7 \text{ l}$$

Present UCN density at platform level: $\rho \approx 6 \text{ UCN/cm}^3$ for $E_n < 55 \text{ neV}$

Loss due to

Polarization: factor 2

Storage and detection efficiency 70%

=> Initial number of UCN in storage volume $N \sim 18500$ UCN/filling
Corresponds to a statistical uncertainty $\Delta N/N = 7 \cdot 10^{-3}$

Goal: $\Delta\tau_{n,\text{stat}} = 0.3 \text{ s}$



The concept

Advantages:

- Reduced losses due to magnetic storage
- Online detection of the decay protons
 - measurement of the decay curve
 - relative measurement
 - $\sim 4\pi$ detection
- Many components already available
 - cryostat system (50K)
 - UHV system
 - magnets for axial storage
 - proton detection
- Energy-dependent measurement to study neutron losses
- Pulsed source at TRIGA ideal for lifetime measurement

Conclusion and outlook:

- *Construction of UCN D is completed and source can currently be operated in the test regime*
- *UCN density of 7 cm^{-3} was achieved in a storage volume of 10 liters (preliminary)*
- *Steps towards a UCN user facility at TRIGA Mainz- on-site:*
He-liquifier for long-term runs with UCN sources,
 - *experimental platform*
 - *additional reactor staff (operators) to provide long-term reactor operation*
- *Concept of a new experiment for the neutron half-life with the aSPECT setup at the TRIGA Mainz UCN source is developed*