

The search for neutron to mirror neutron oscillations at PSI

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On behalf of the nn' collaboration at PSI
ETH Zürich
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Introduction

What is mirror matter?

- Mirror symmetry was proposed by Lee & Yang (1956) to restore Parity in the weak sector.
- Each left-handed SM particles gets a right-handed mirror equivalent.
- Mirror matter interacts with ordinary matter only through gravity [1].
- Neutral particles can oscillate into their mass-degenerate mirror partner [2].
 - requires $E_{\text{pot}}(n) = E_{\text{pot}}(n')$, therefore $B = B'$
 - Earth could have a mirror magnetic field $B' \neq 0$ [3]

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Why else is it interesting?

- Mirror matter is dark matter candidate [4].
- $n - n'$ mixing violates baryon number conservation.
- Consequences for high energy cosmic rays [2, 5].

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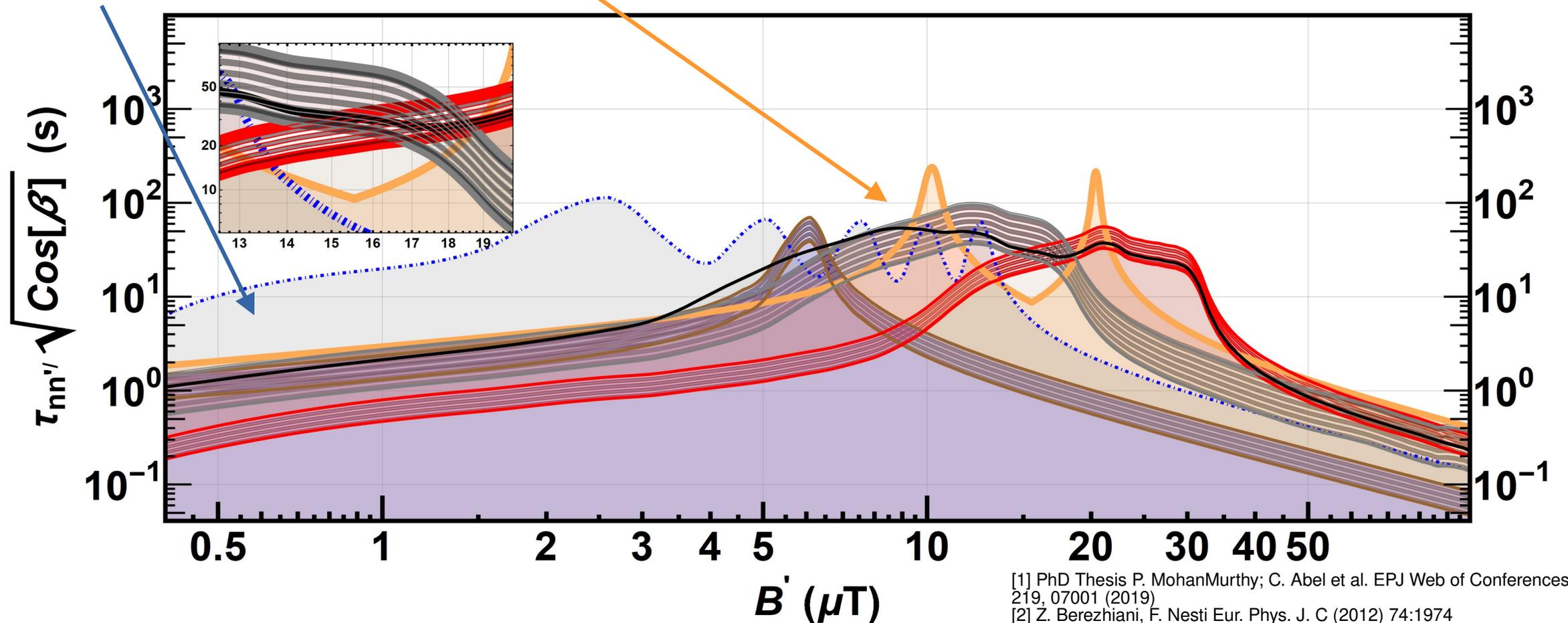
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Previous experimental efforts

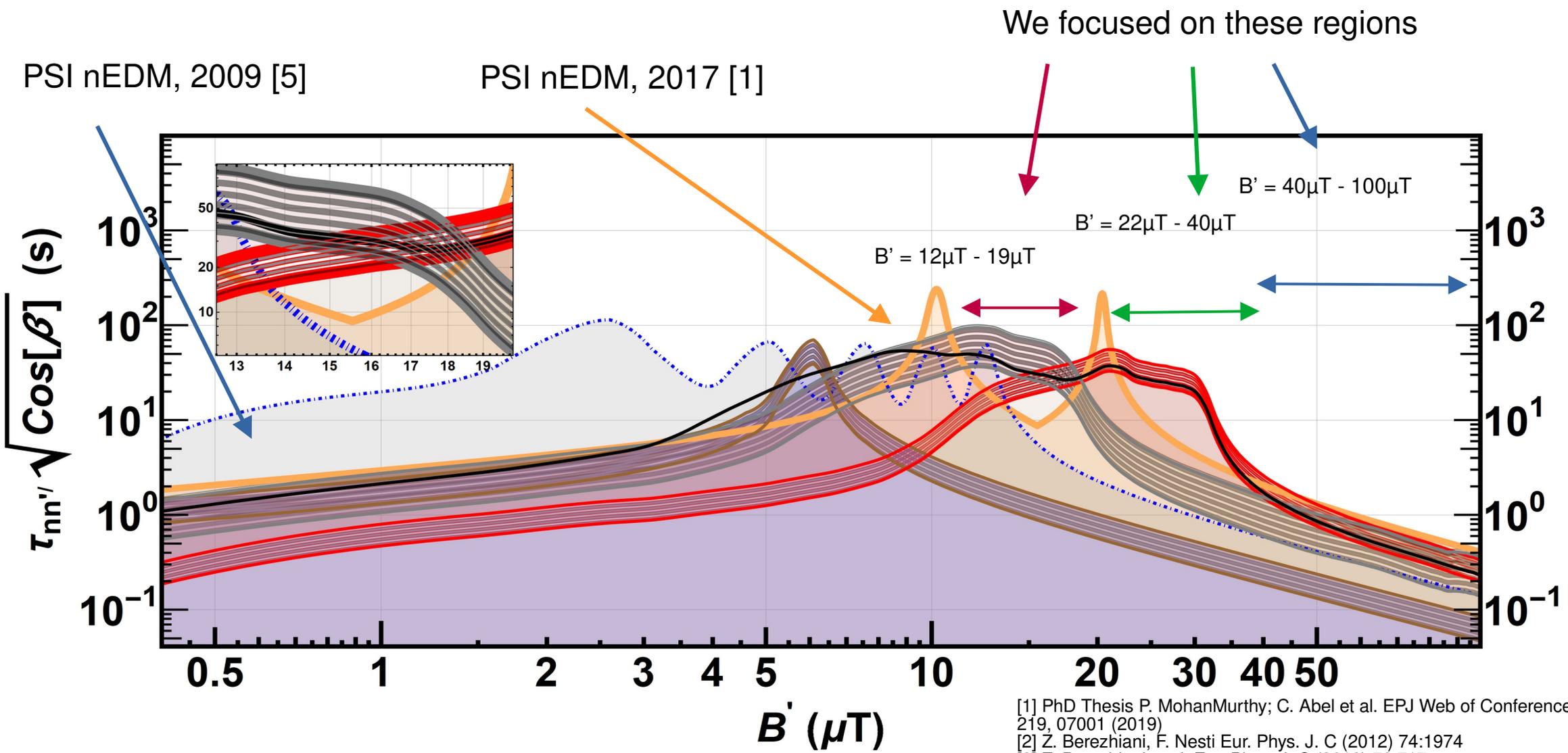
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We focused on these regions

$B' = 40\mu\text{T} - 100\mu\text{T}$

$B' = 22\mu\text{T} - 40\mu\text{T}$

$B' = 12\mu\text{T} - 19\mu\text{T}$

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Measurement principle

1. Store Neutrons.

→ Ultracold neutrons can be confined for hundreds of seconds in storage volumes with adequate surface coating.

2. Apply magnetic field.

→ Set of 6 Helmholtz coils to generate a homogeneous field in any direction inside the storage volume.

→ Simultaneously scan applied magnetic field for better tuning.

→ $B' = 0$ is already well constrained.

3. Observe if neutron count changes as a function of B .

$$\tau_{nn'}(B, B') = \sqrt{\frac{t_s}{\langle t_f \rangle A_{\uparrow\downarrow}}} \sqrt{f(B, B') \cos \beta}$$

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Asymmetry between B up and B down

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The diagram shows the equation for the neutron count rate $\tau_{nn'}(B, B')$ with several terms annotated by red arrows:

- $n \rightarrow n'$ oscillation time: points to the entire equation.
- Storage time: points to the t_s term in the numerator of the square root.
- Mean free neutron time: points to the $\langle t_f \rangle$ term in the denominator of the square root.
- Asymmetry between neutron counting for B up and B down: points to the $A_{\uparrow\downarrow}$ term in the denominator of the square root.
- Angle between B and B' : points to the $\cos\beta$ term in the second square root.

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- $n \rightarrow n'$ oscillation time: points to the t_s term in the numerator of the square root.
- Storage time: points to the t_s term in the numerator of the square root.
- Lineshape, peak at $B = B'$: points to the $f(B, B')$ term in the second square root.
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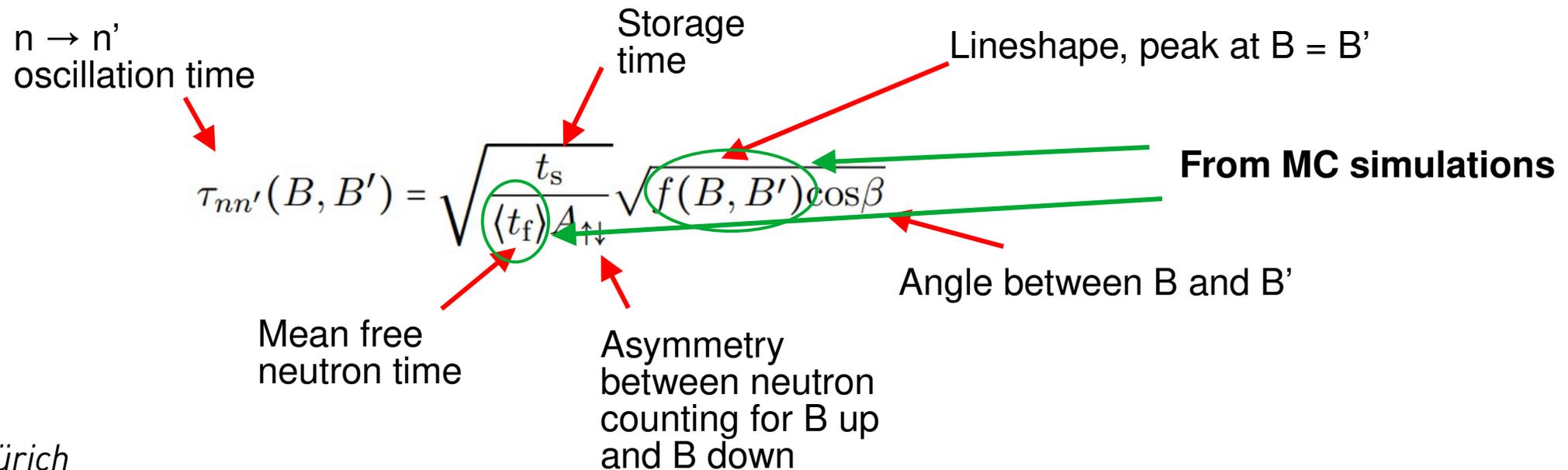
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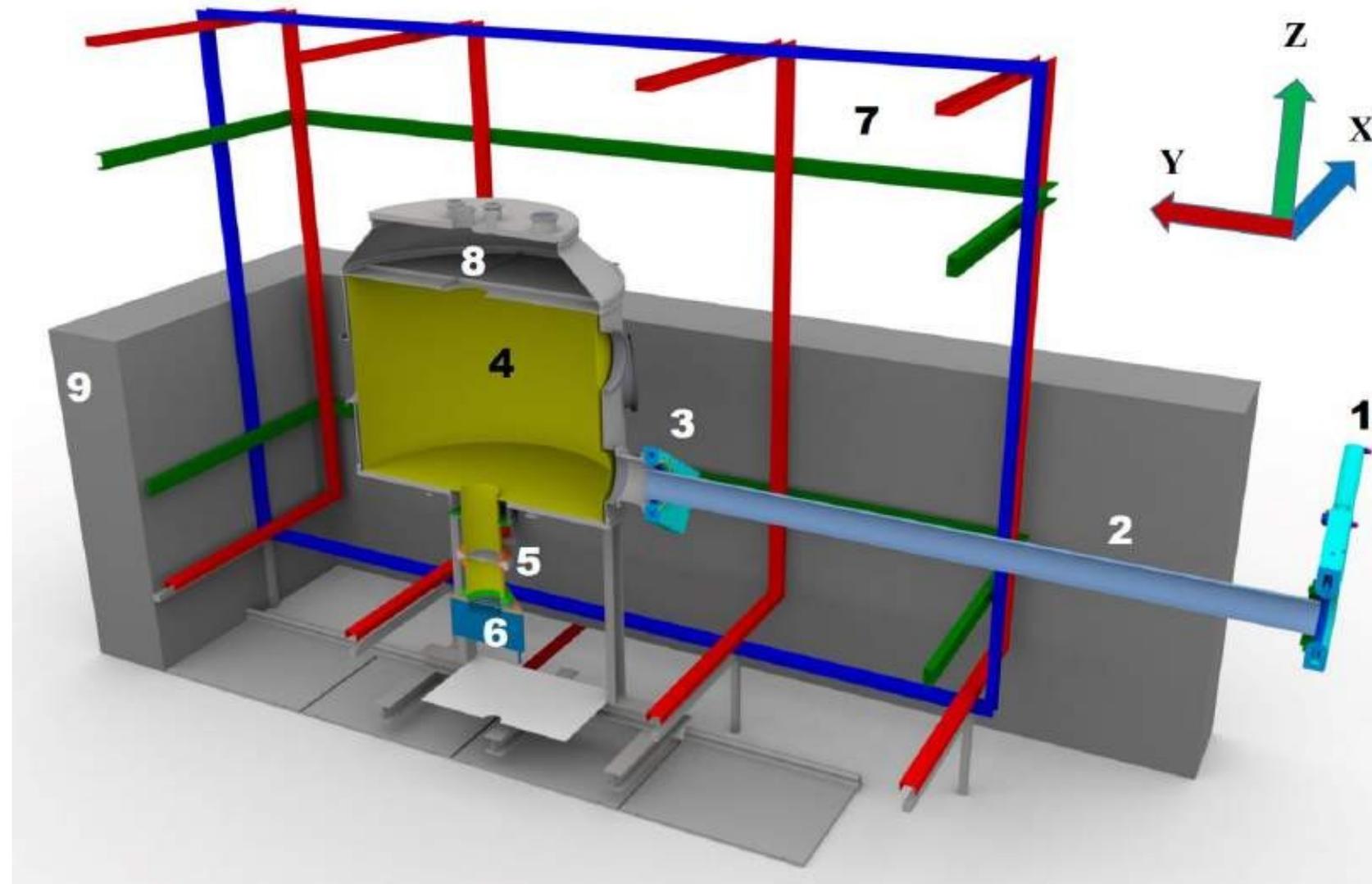
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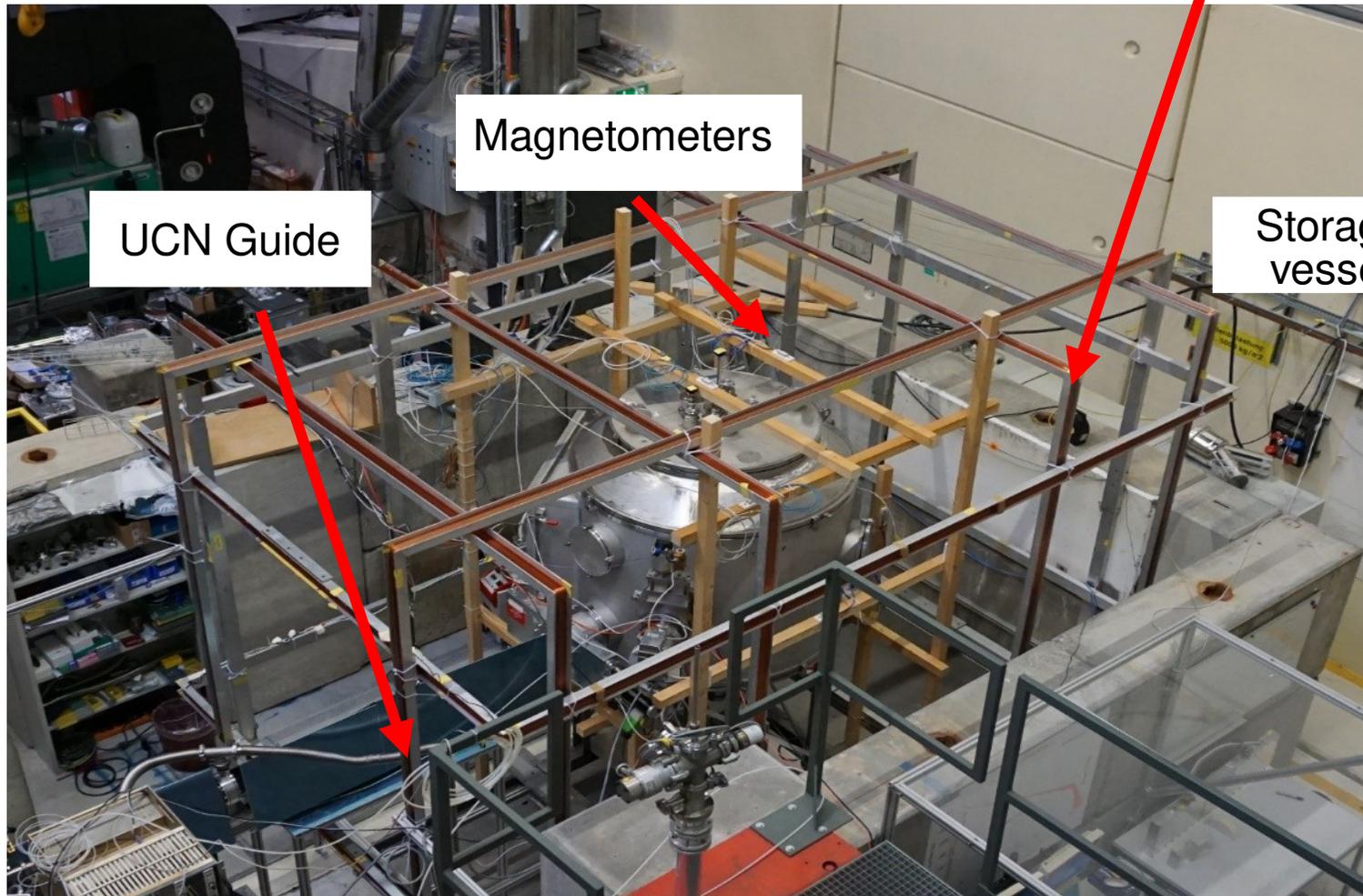


Experimental setup

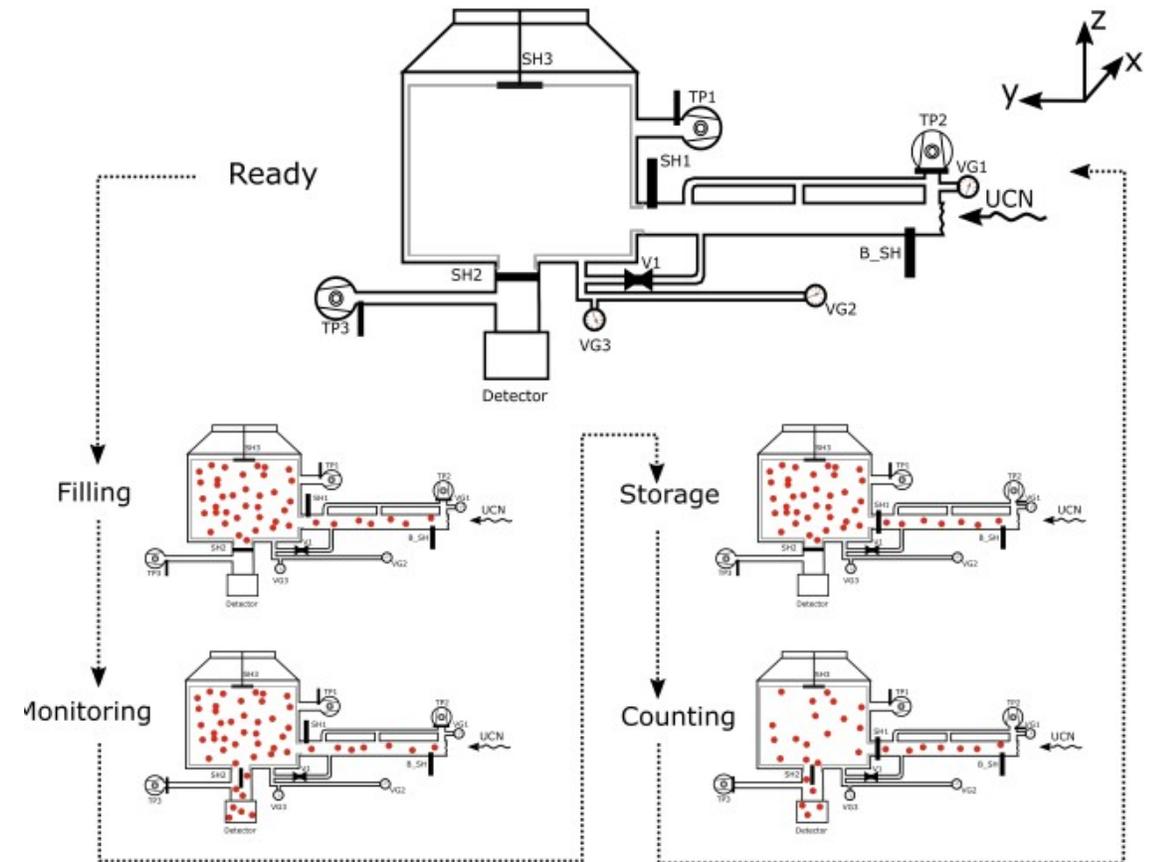
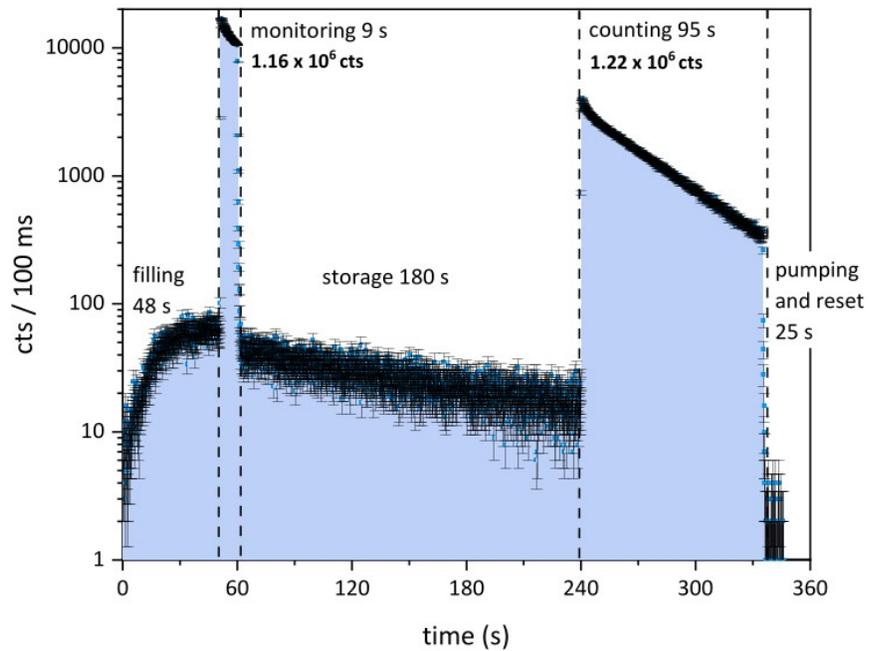
- 1) Beamport shutter
- 2) UCN Guide
- 3) SH1
- 4) Vacuum vessel
- 5) SH2
- 6) UCN detector
- 7) Bfield generating coil system
- 8) SH3
- 9) Concrete shielding



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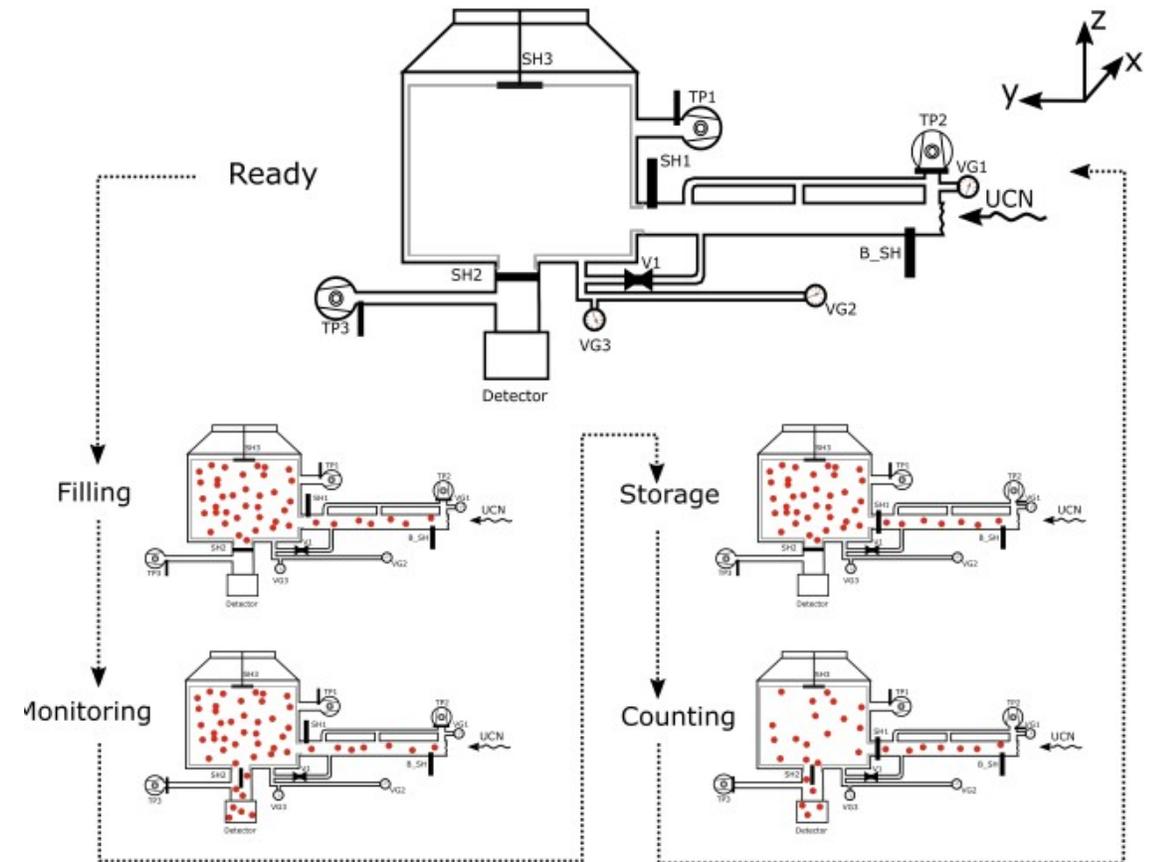
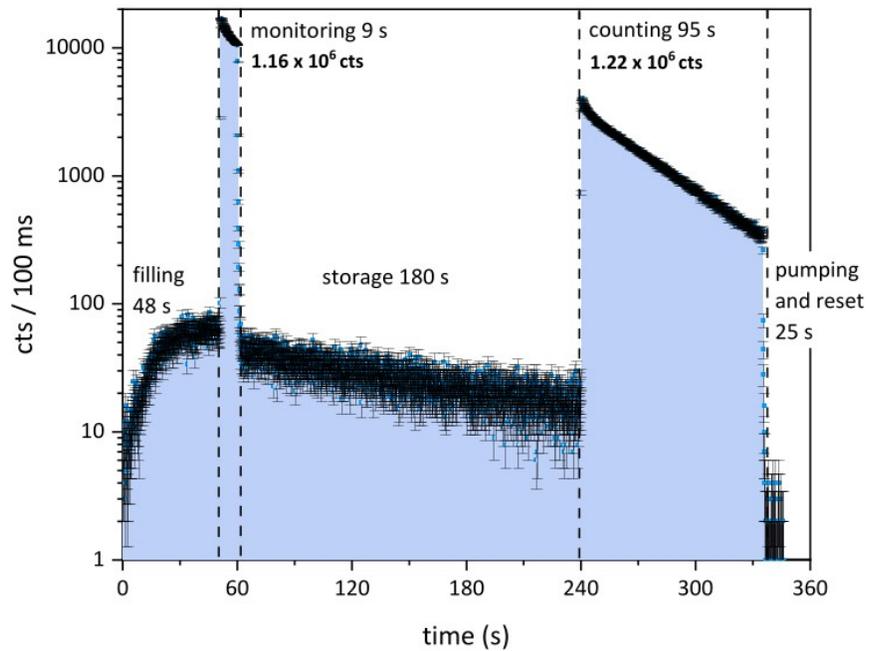


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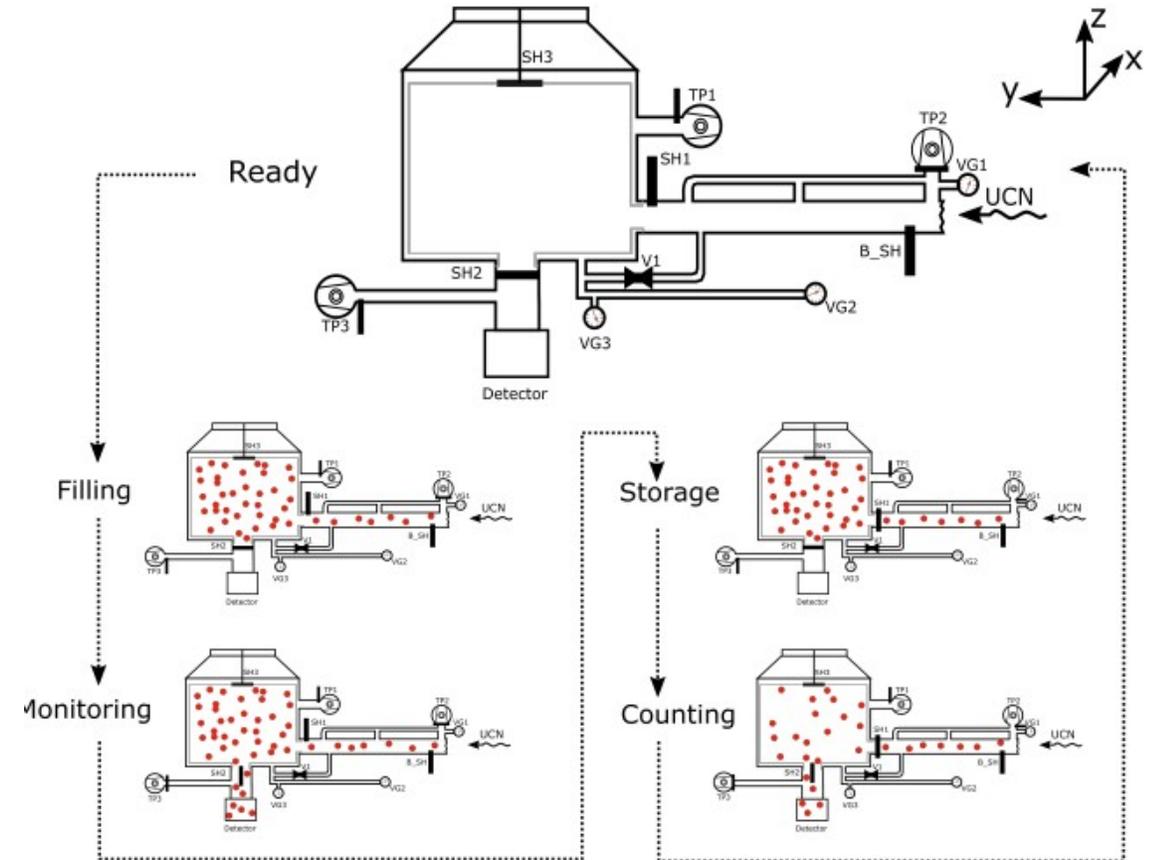
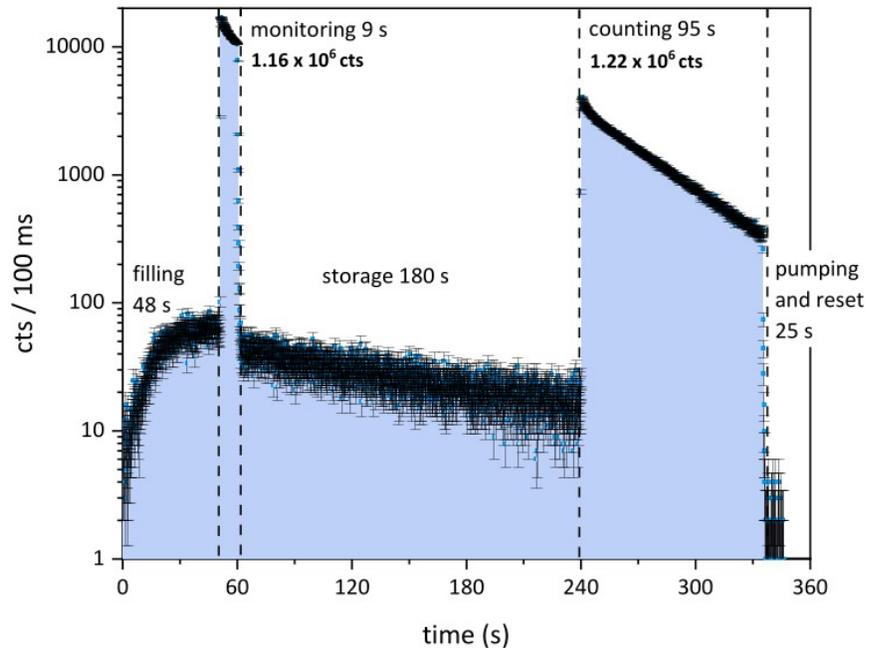
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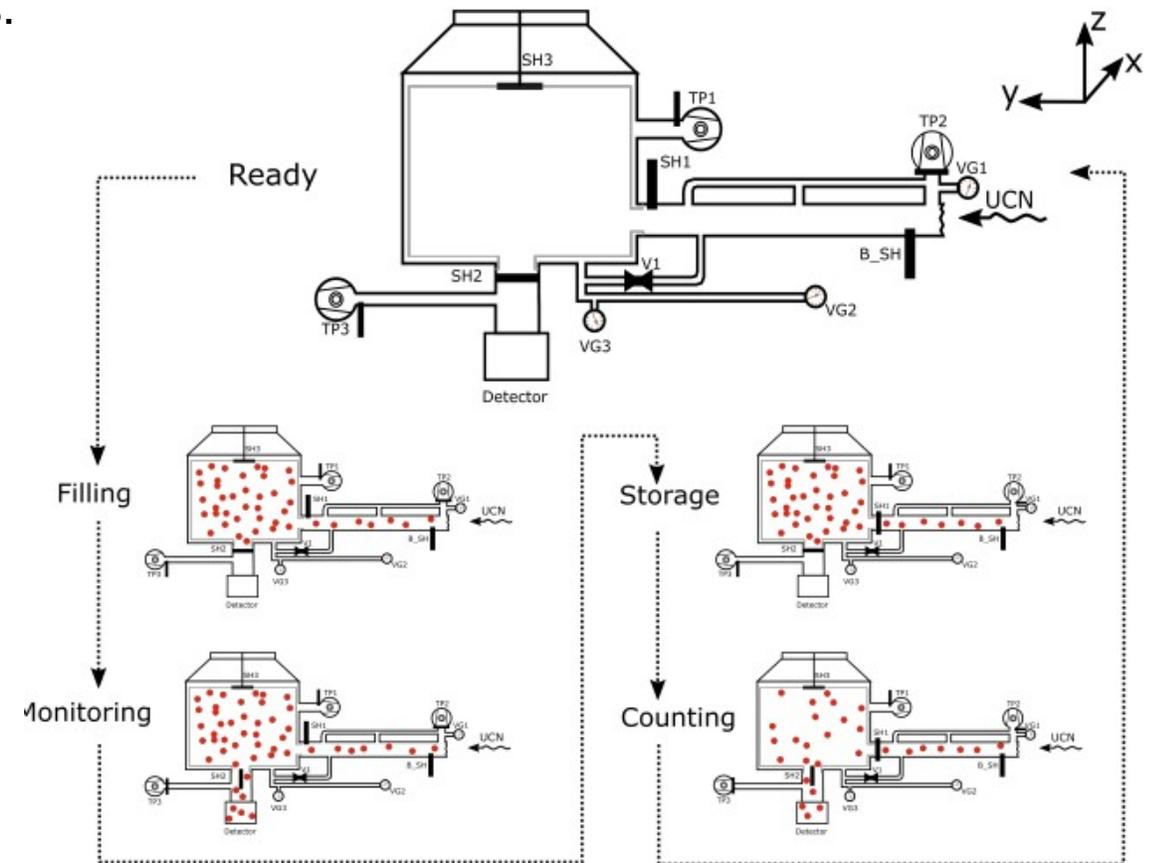
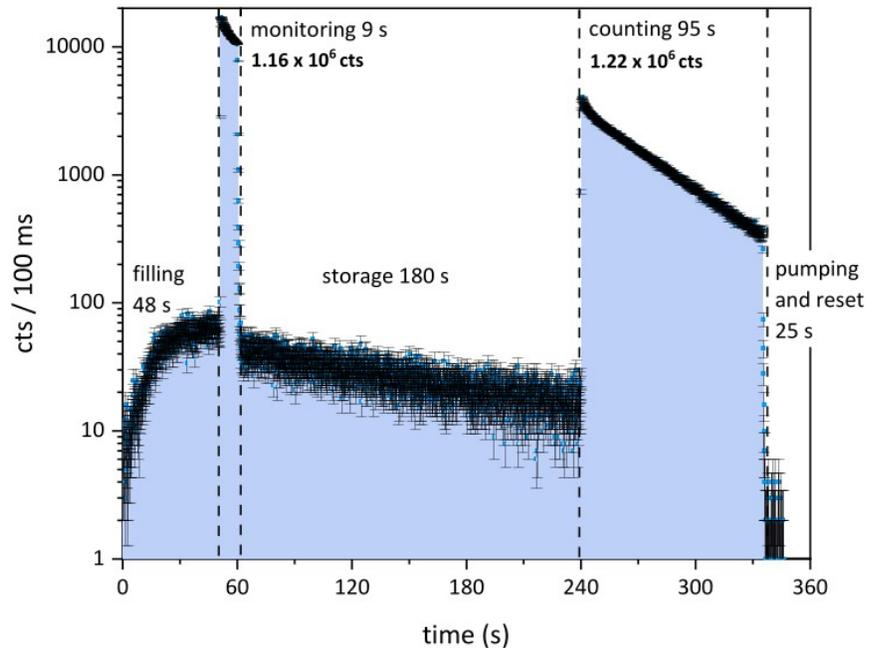


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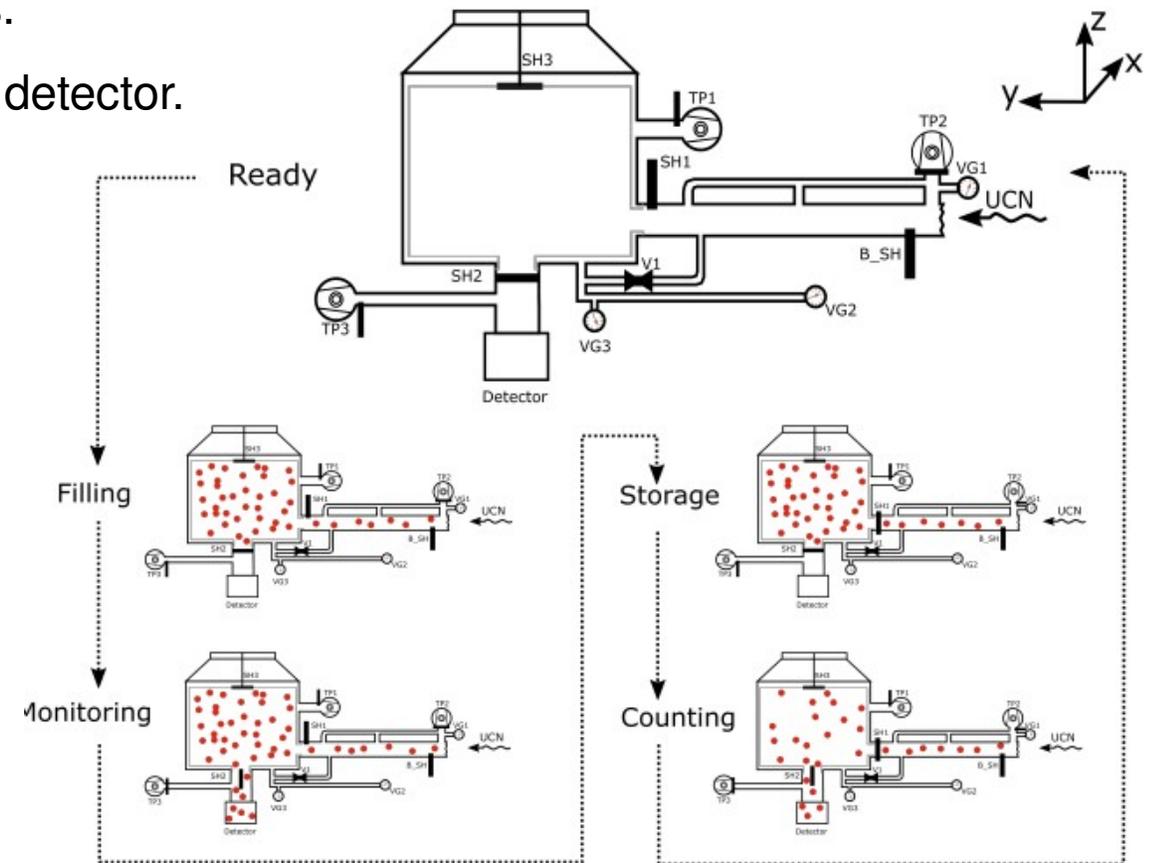
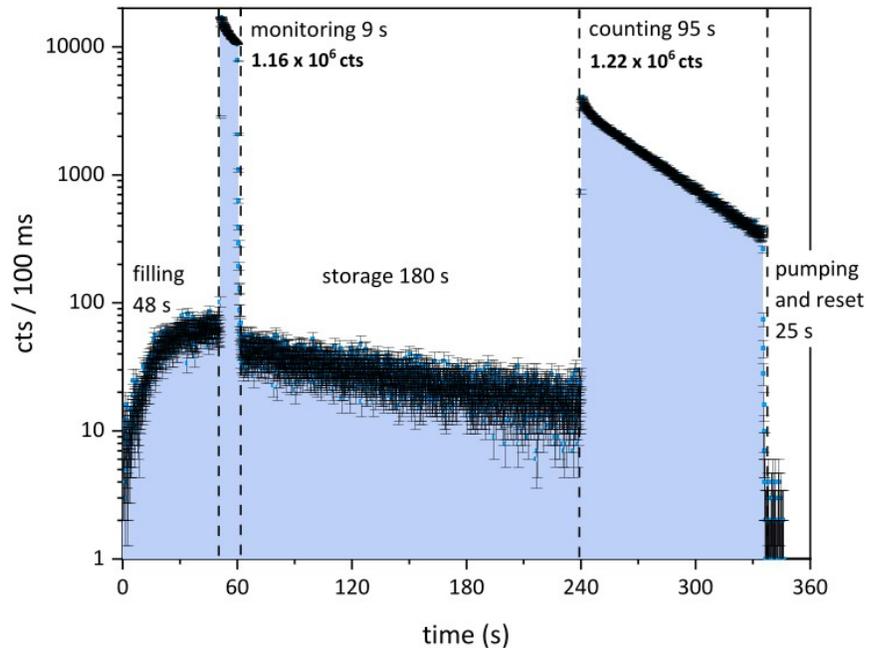
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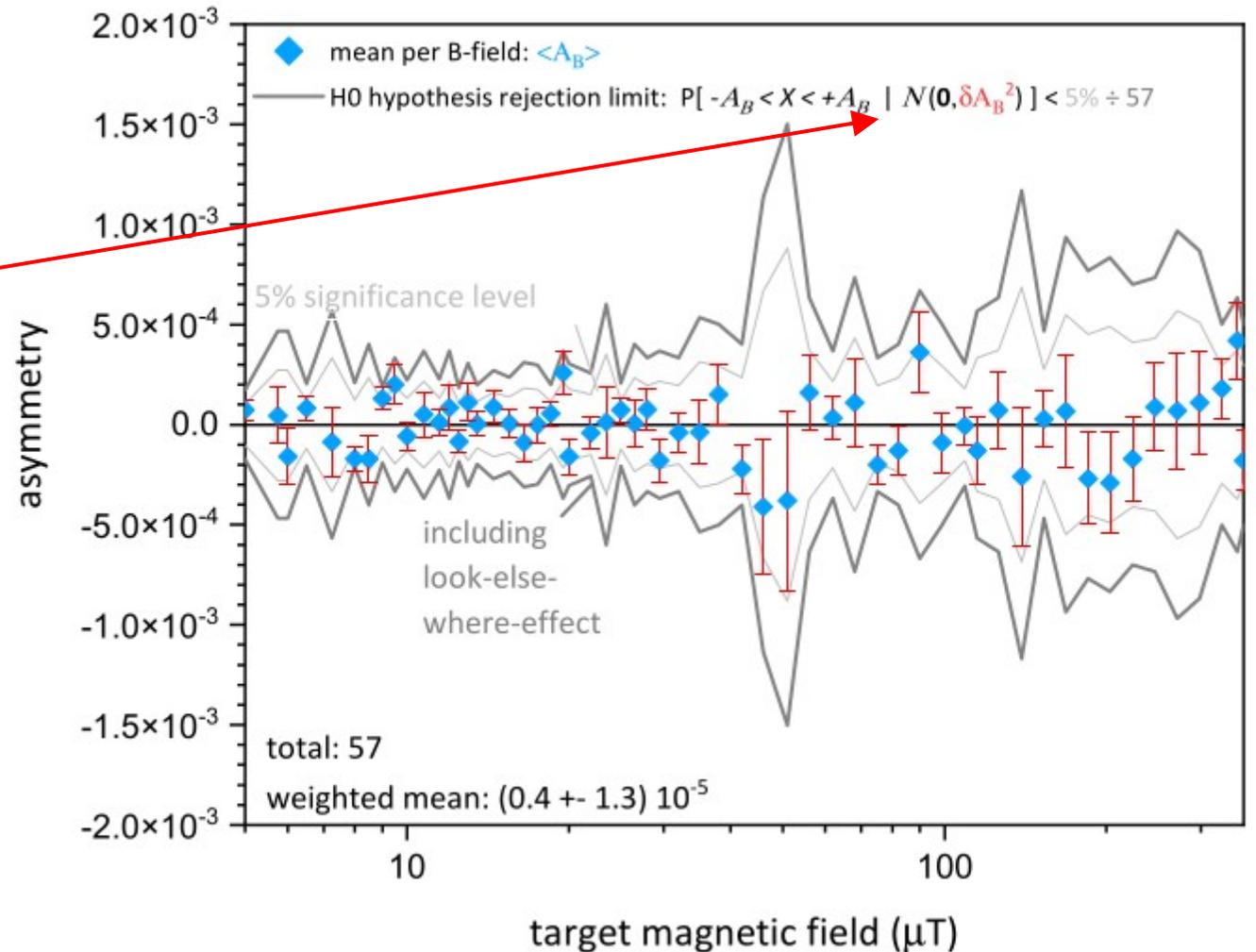
Counting: SH2 is opened and UCNs are counted in the detector.



Results

Null hypothesis:

For each applied magnetic field value the measured mean asymmetry is a random draw from a Gaussian distribution centred around 0. The width is equal to the experimental uncertainty.

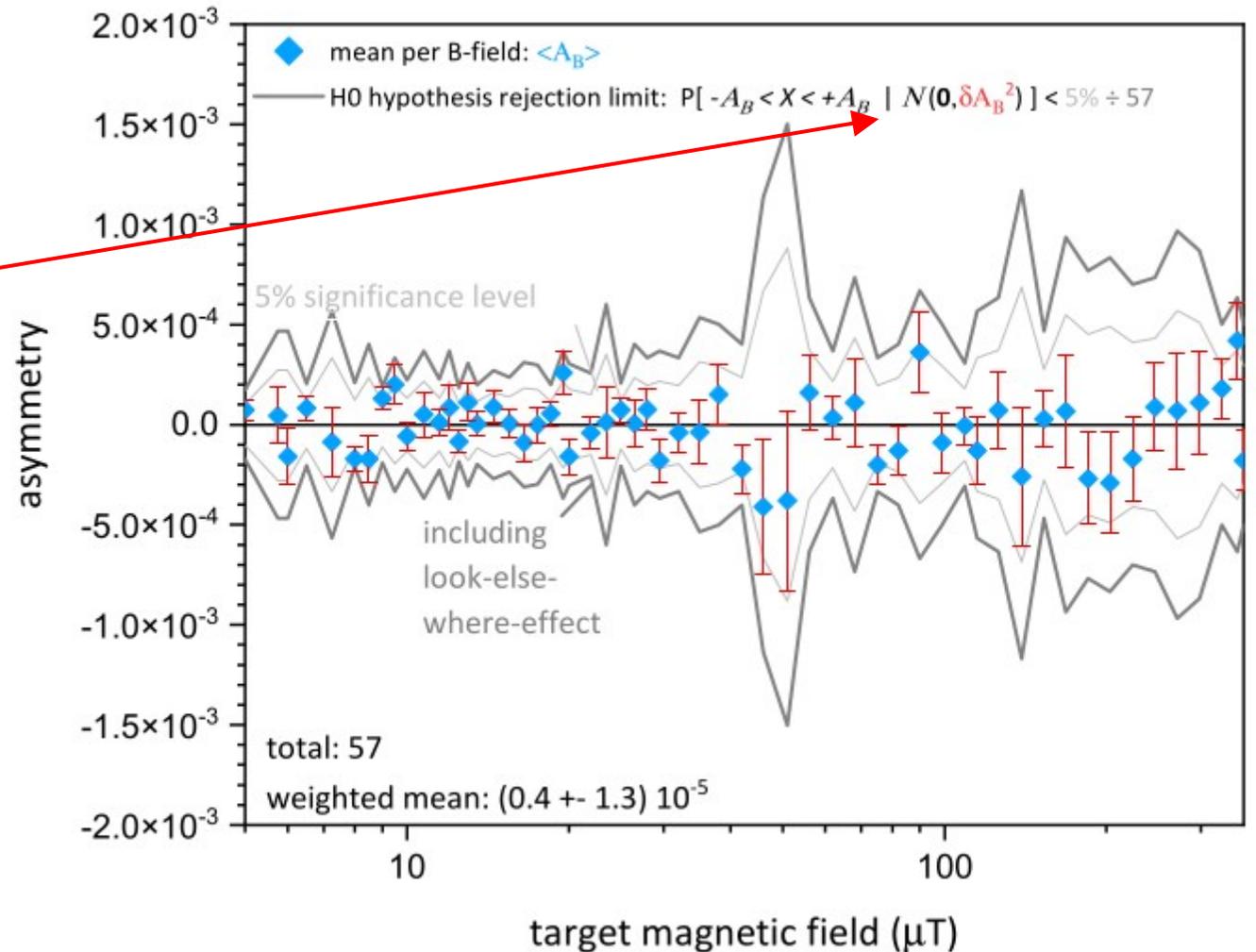


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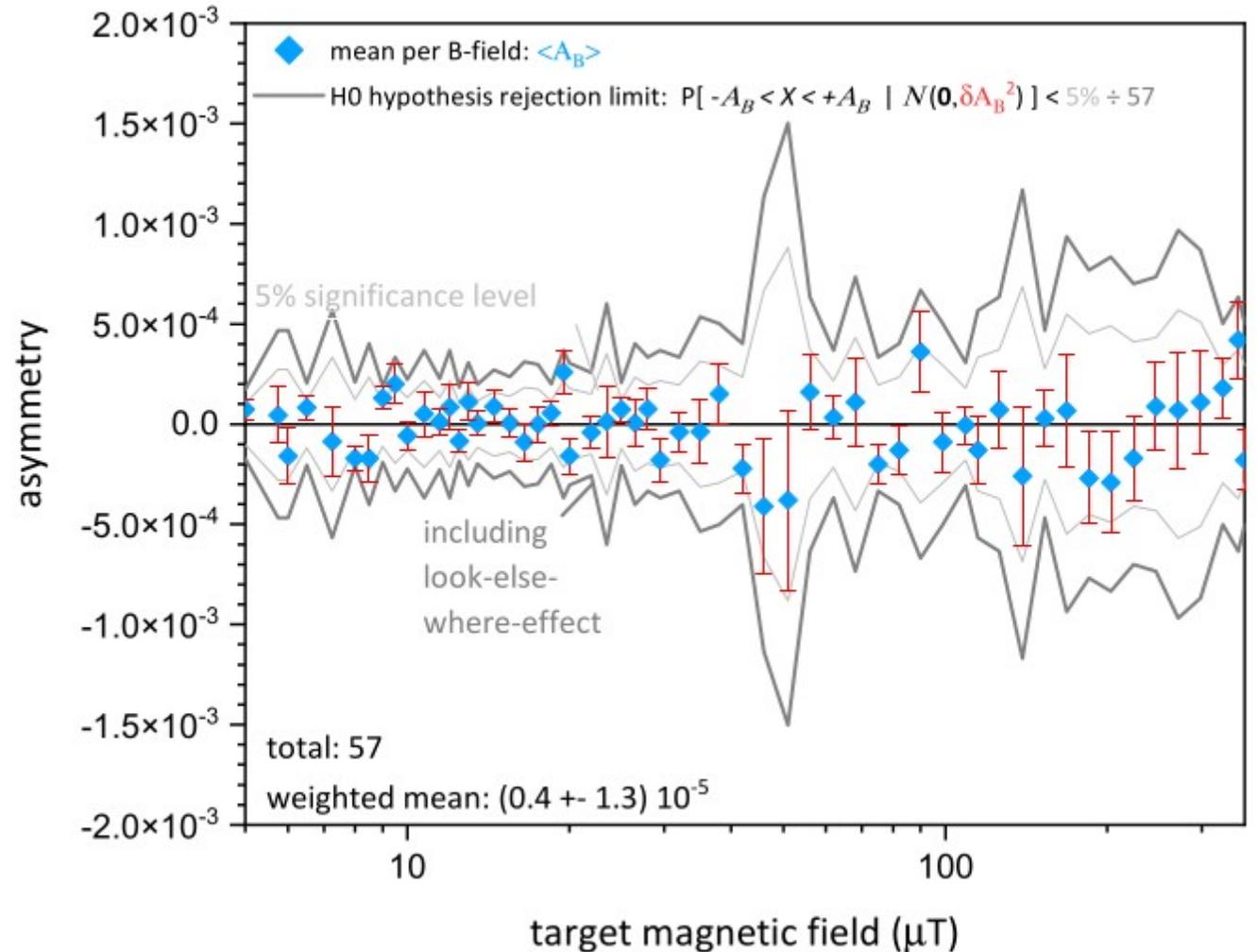
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Preliminary result:

Further analysis of the dataset may reveal that we have to apply cuts to the dataset.

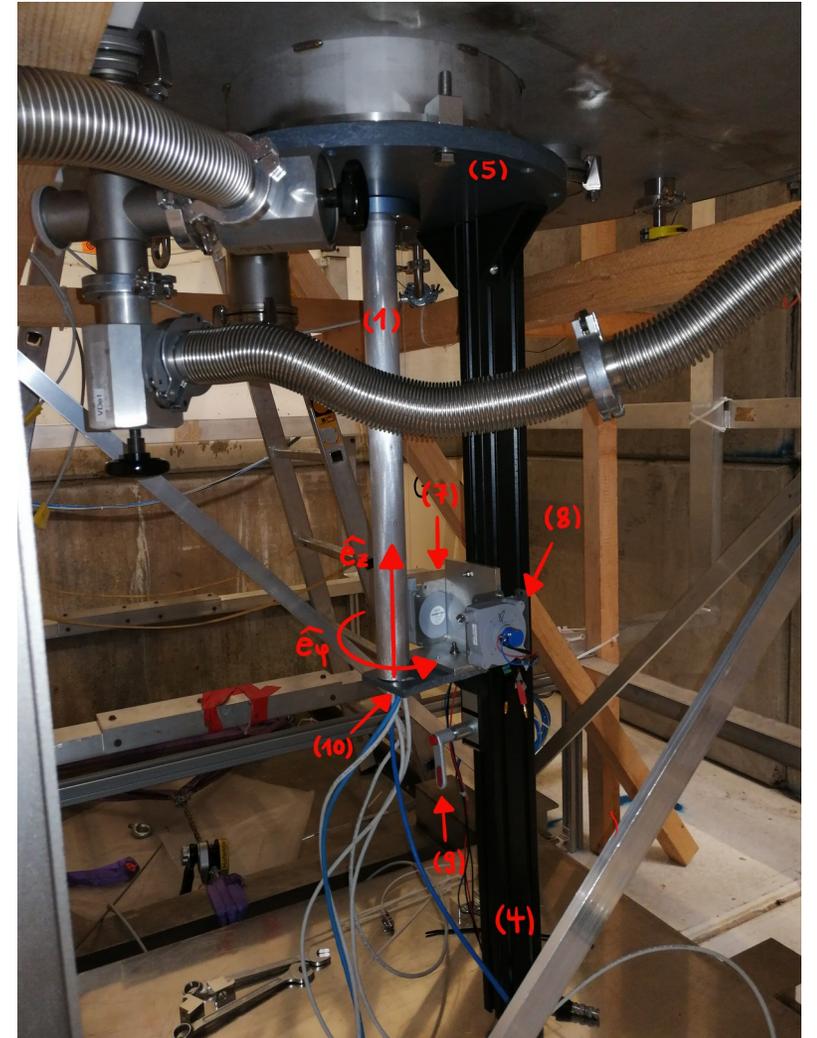
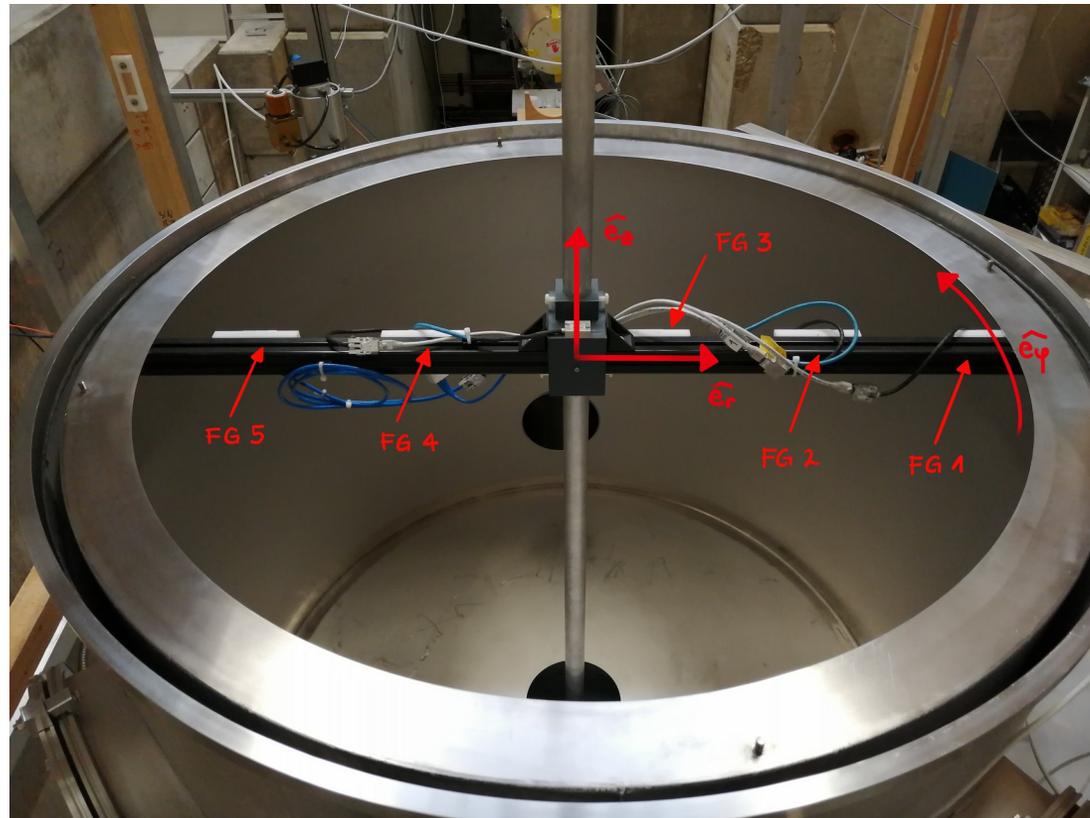
Work in progress!



Magnetic field mapping

What was the actual magnetic field inside the storage vessel during the experiment?

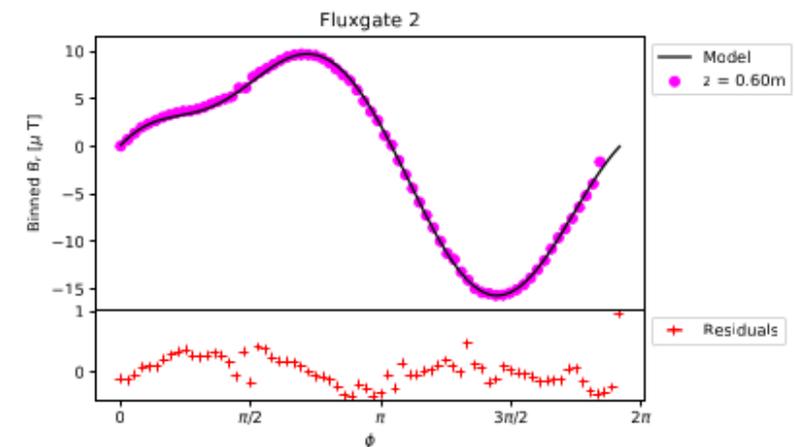
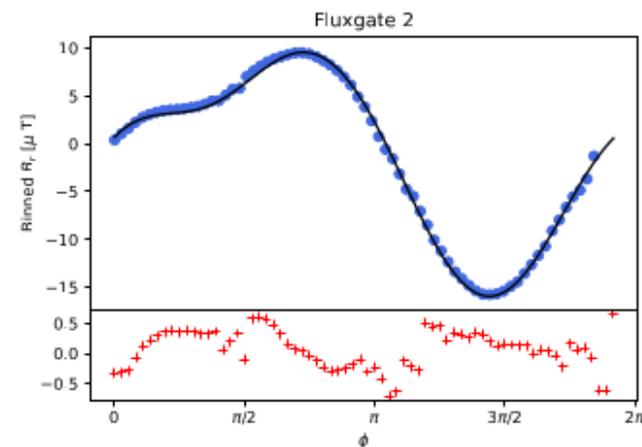
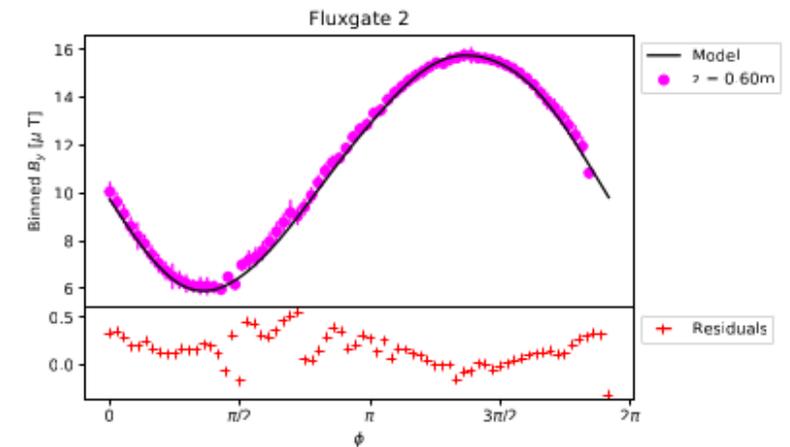
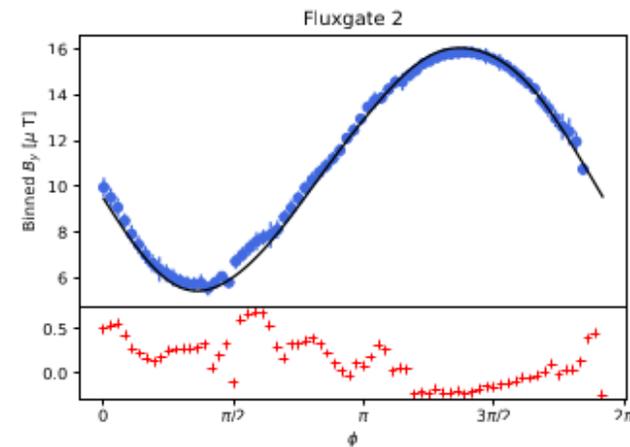
→ Scan Field inside storage vessel with manual mapper.



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Obtain map of the storage tank with known external magnetic field.



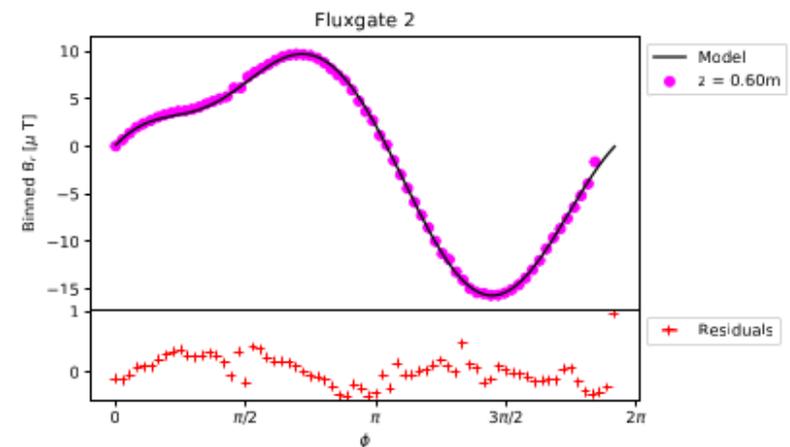
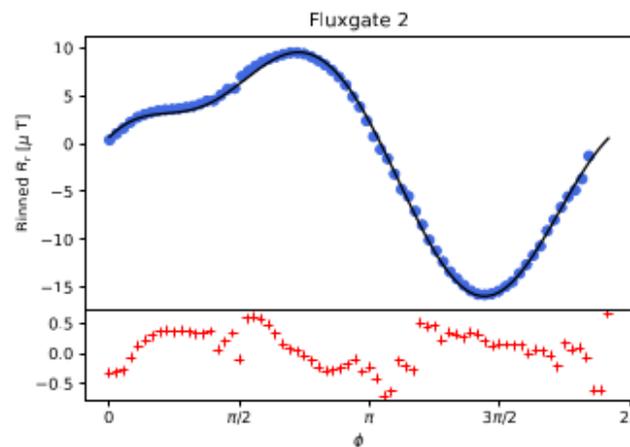
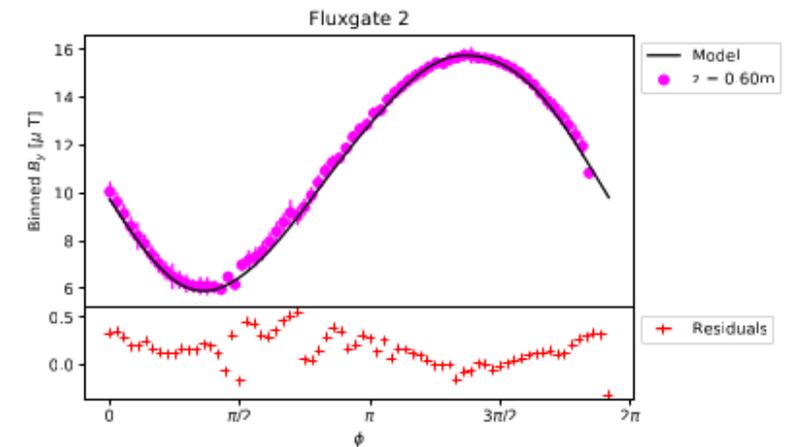
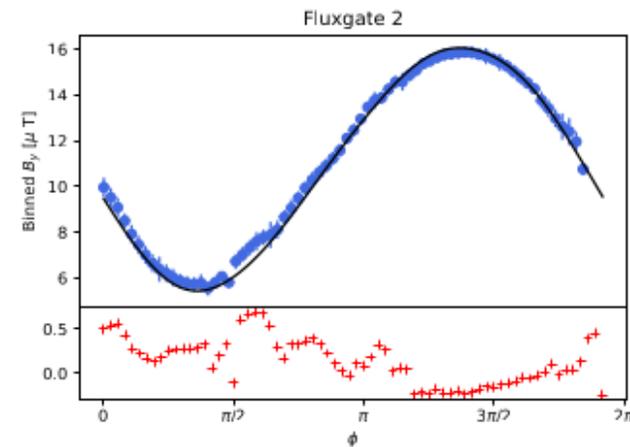
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Idea: recover internal field from measurement of external field.

Work in progress!



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