The FINESSE beamline at ESS

Linus Persson, linus.persson@fysik.lu.se

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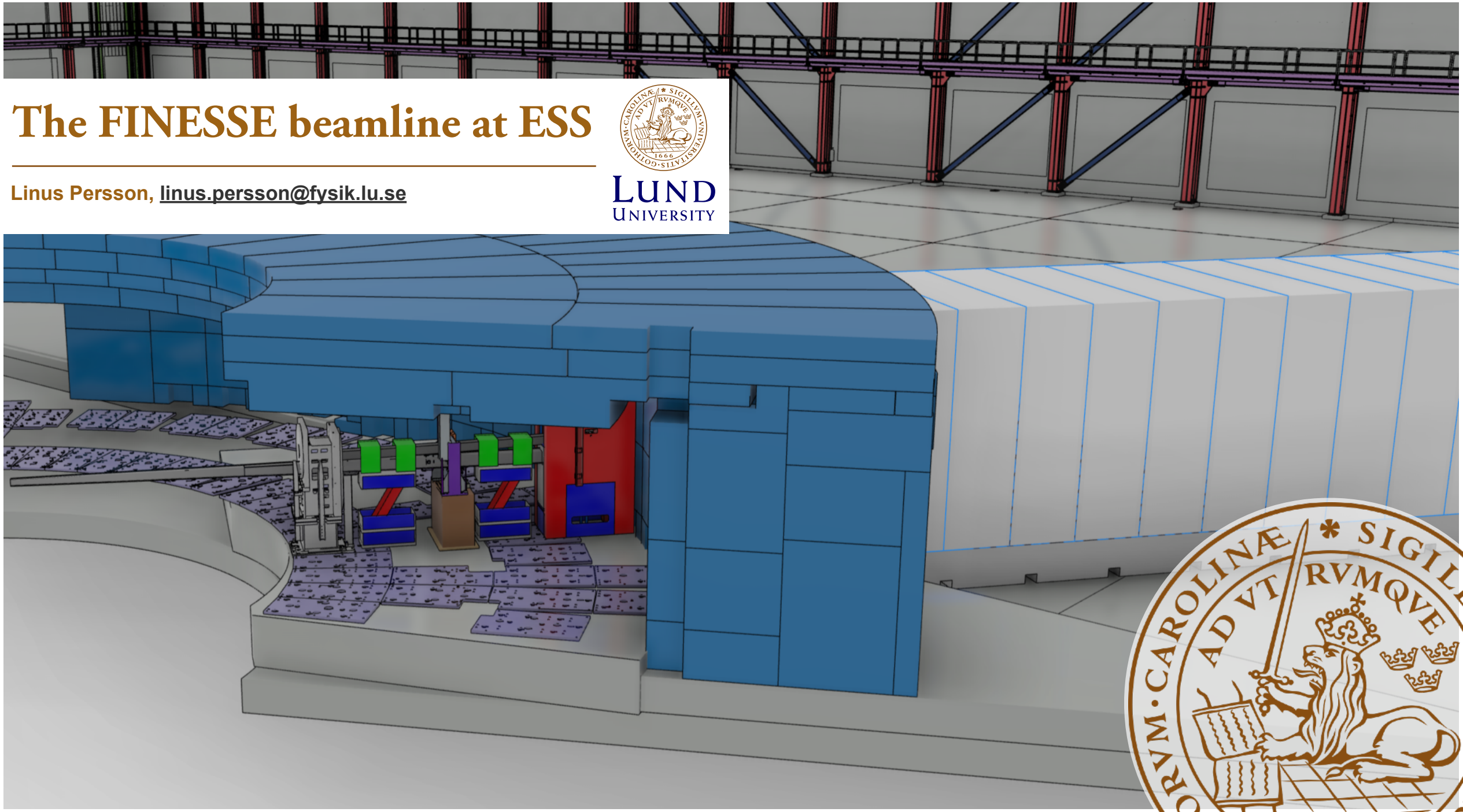

The European Spallation Source

- Designed to become the world's brightest spallation neutron source.
- 13 European member states, construction cost of about ~€3B.
- First neutrons by mid-2027, routine user operations from 2028.
- Currently 15 neutron beamlines approved for construction, no particle physics yet!

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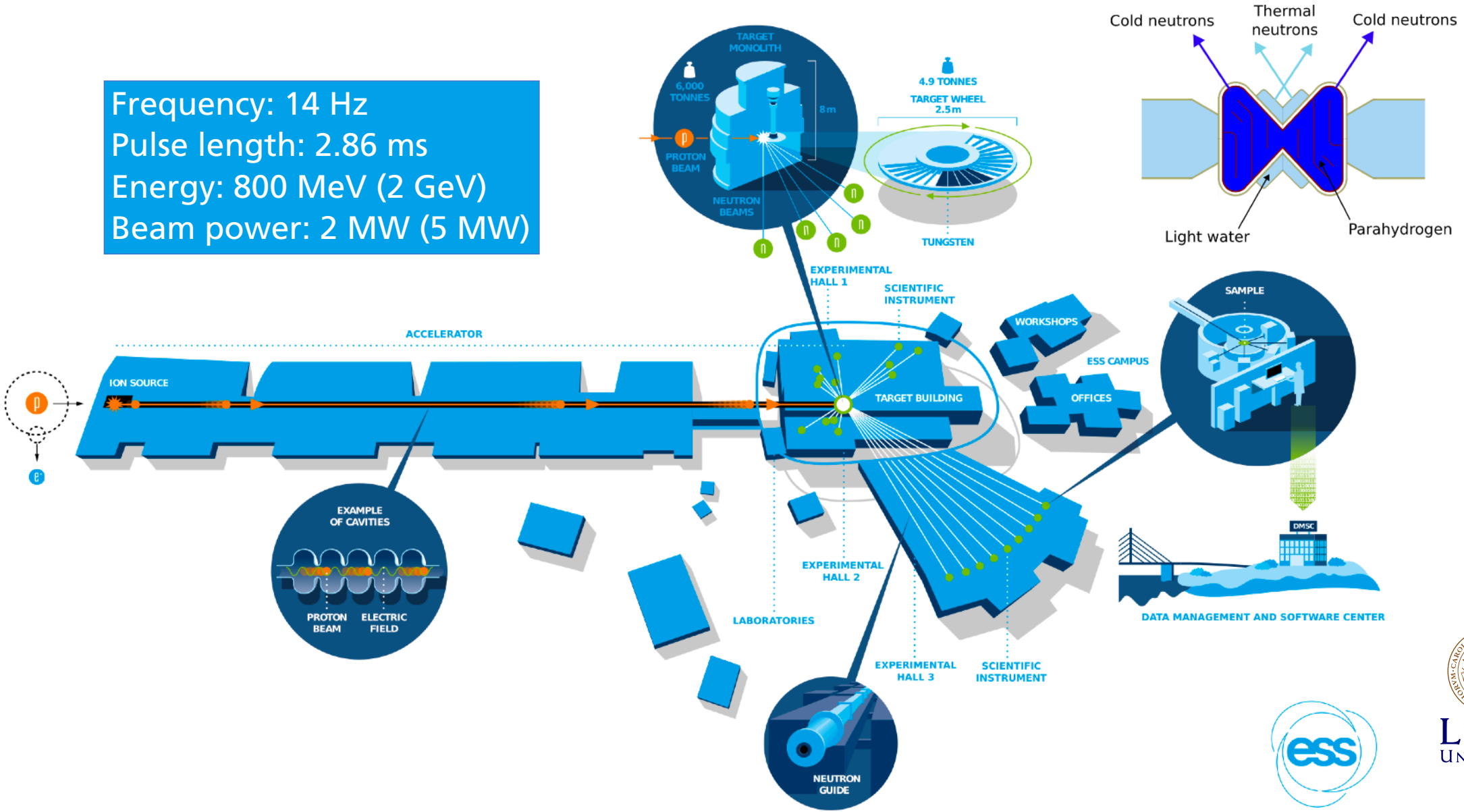
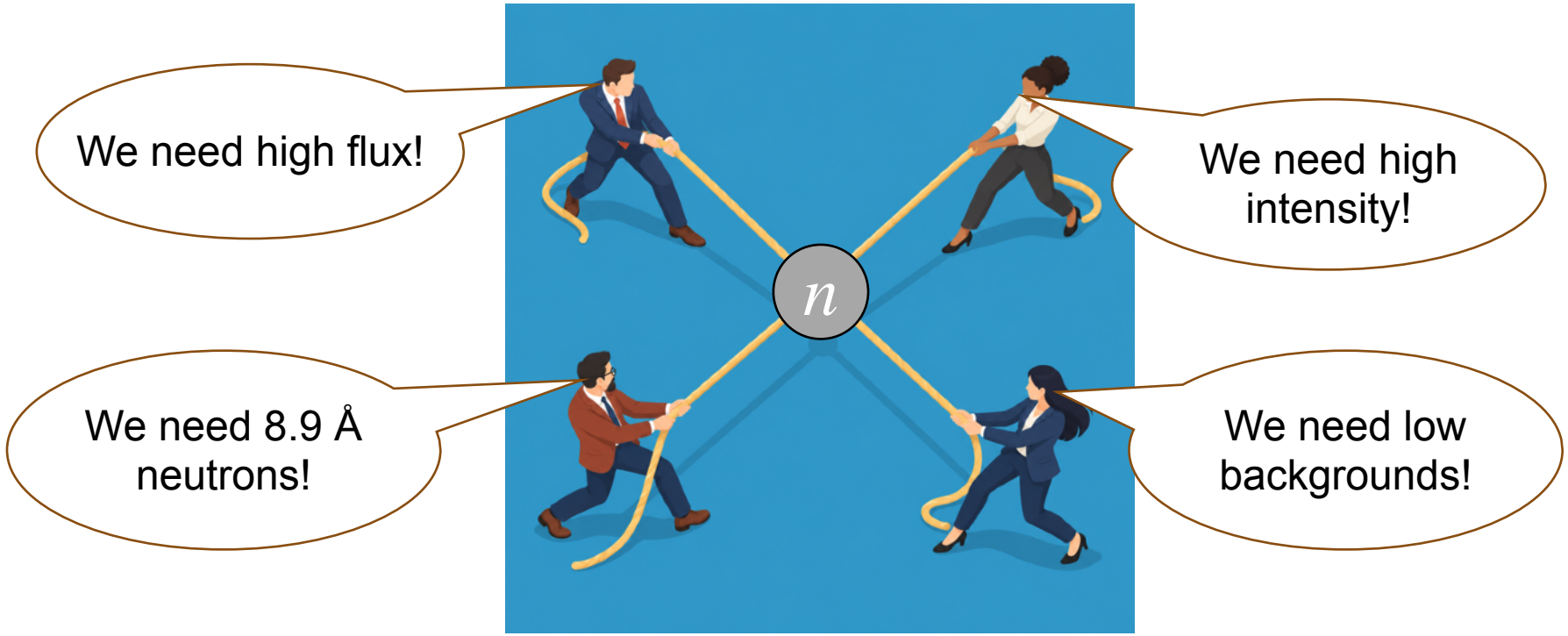
ESS overview

Frequency: 14 Hz
Pulse length: 2.86 ms
Energy: 800 MeV (2 GeV)
Beam power: 2 MW (5 MW)



What is FINESSE?

- **F**undamental **I**nteractions with **N**eutrons at the **E**uropean **S**pallation **S**ourc**E**.
- A versatile beamline for fundamental physics.
- The crux: Different experiments want different neutron beam properties.



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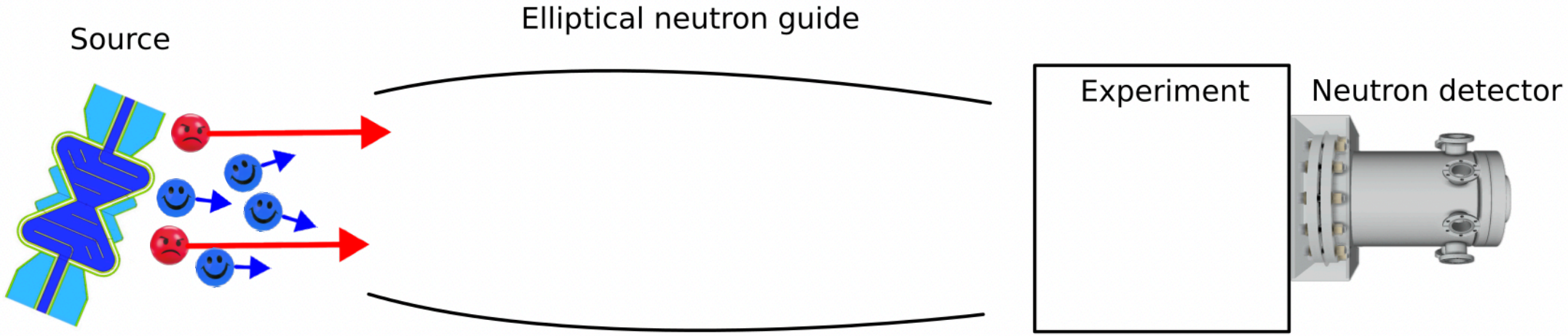
What determines the beam properties?

- The neutron beam properties are largely decided by the neutron guide close to the source.



High-flux configuration

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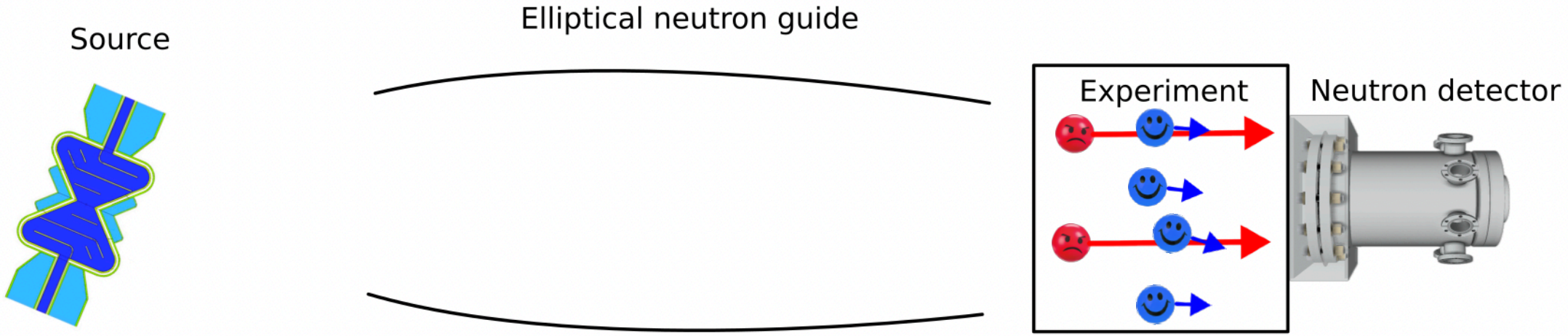

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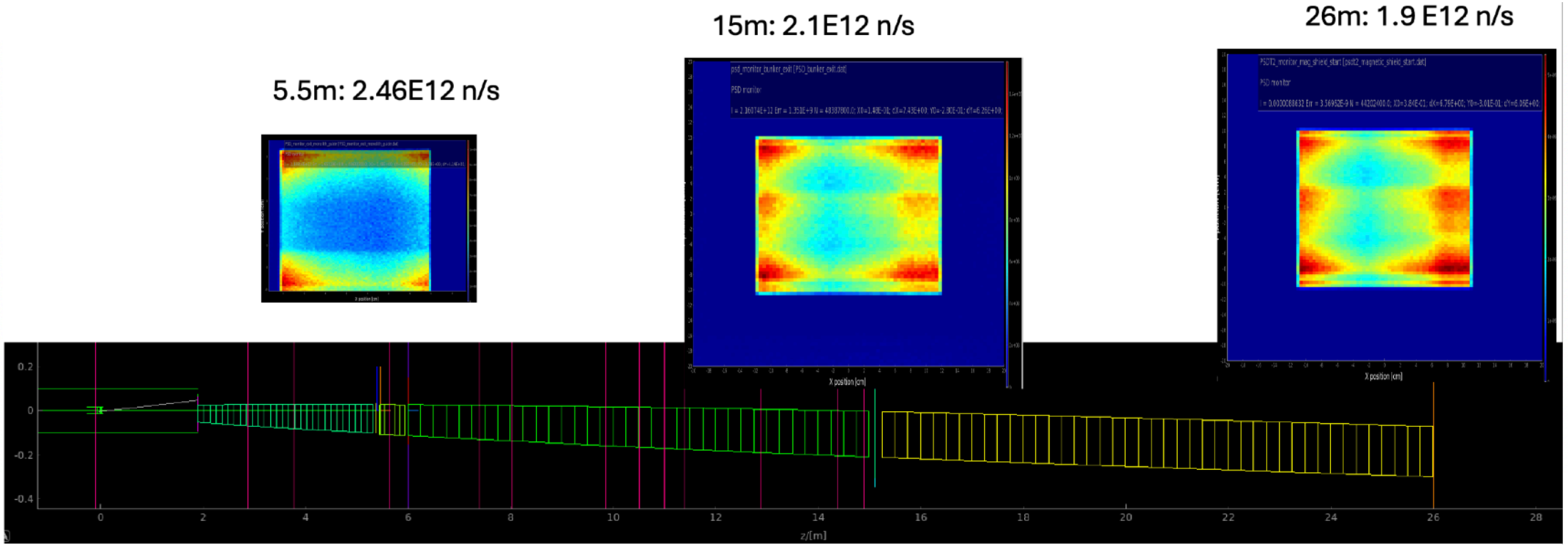

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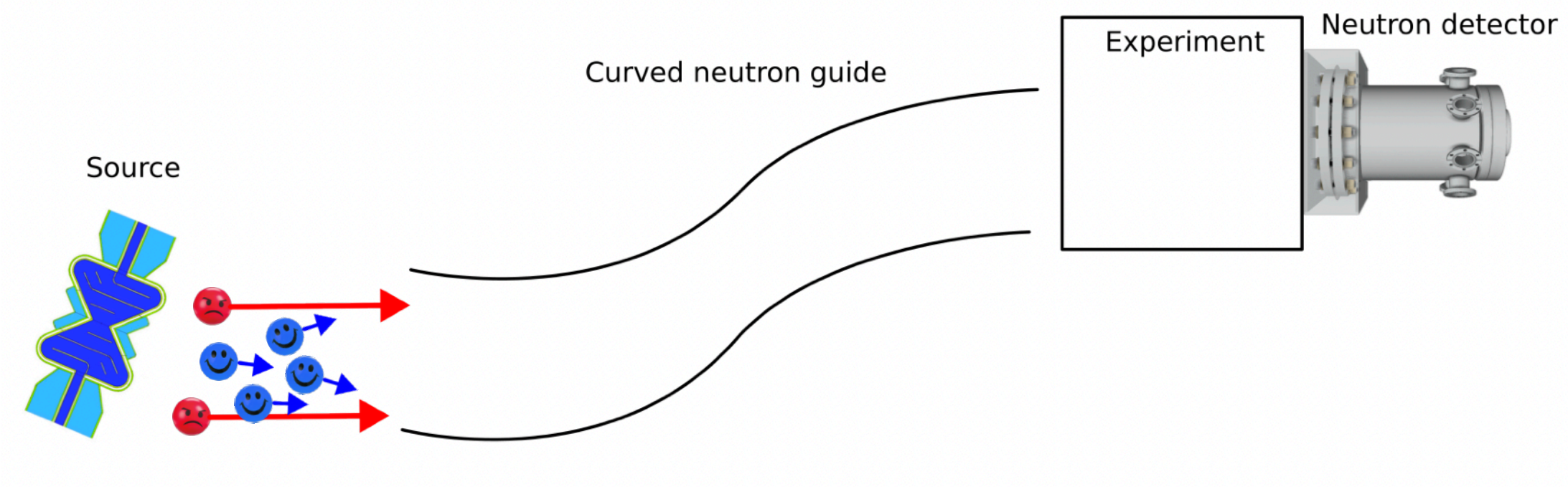

Low-background configuration

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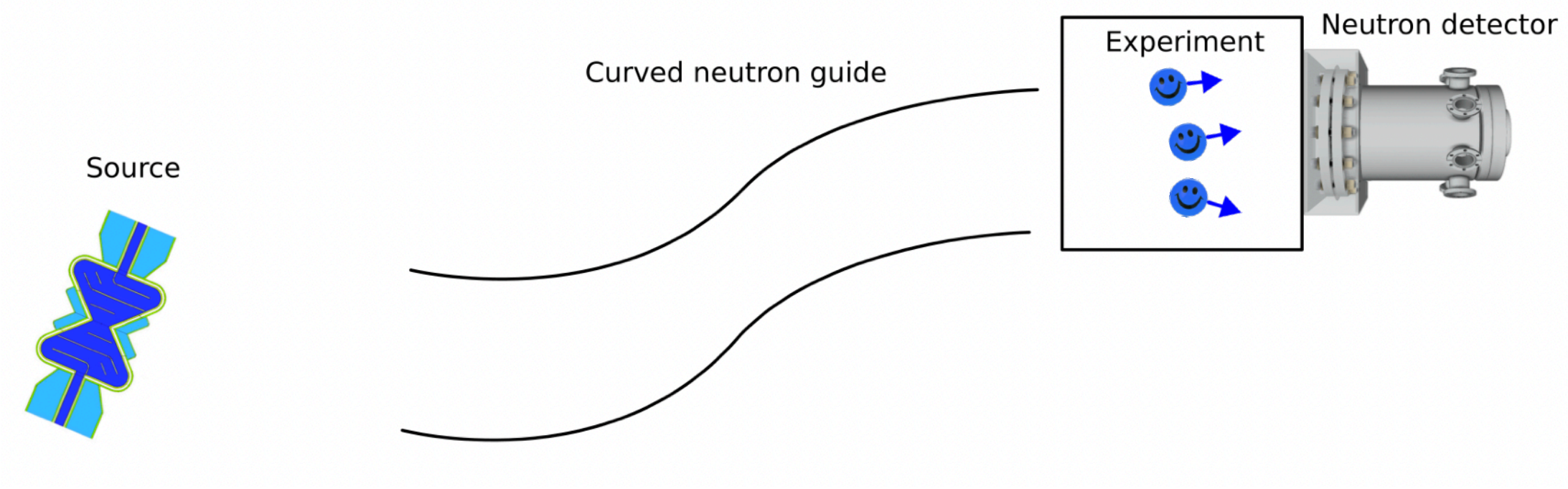

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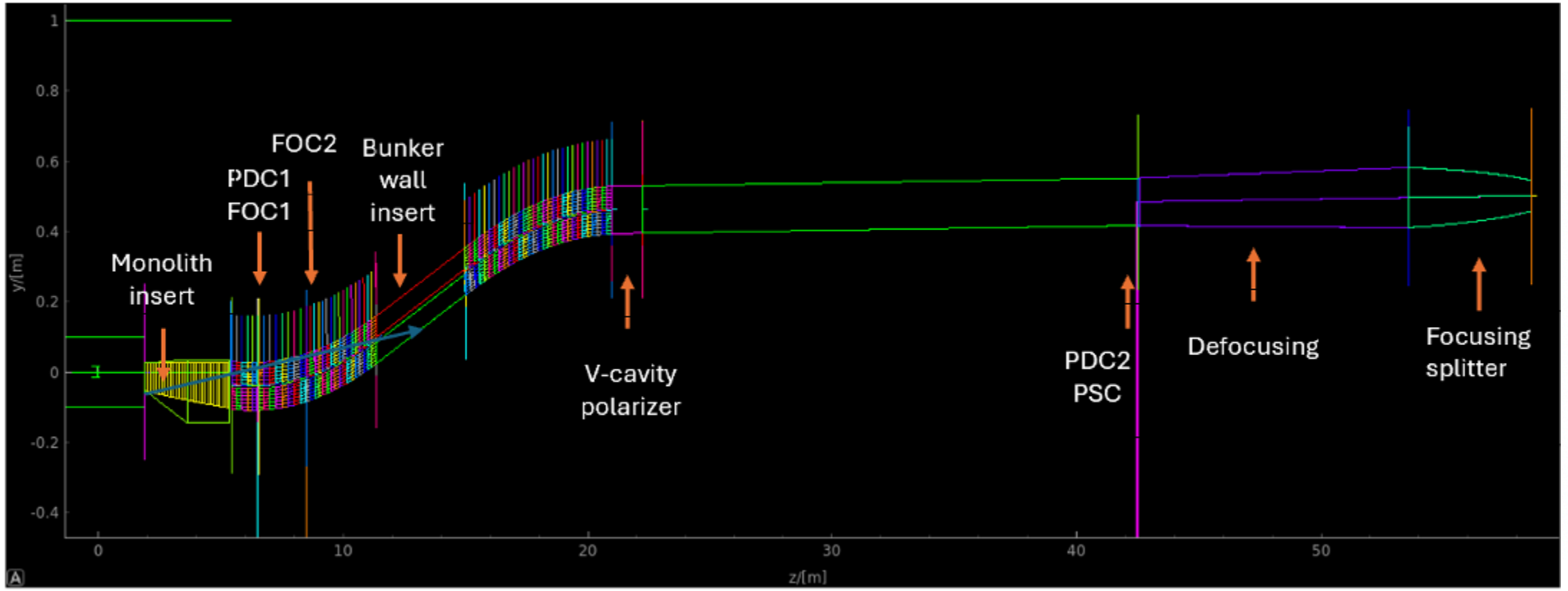
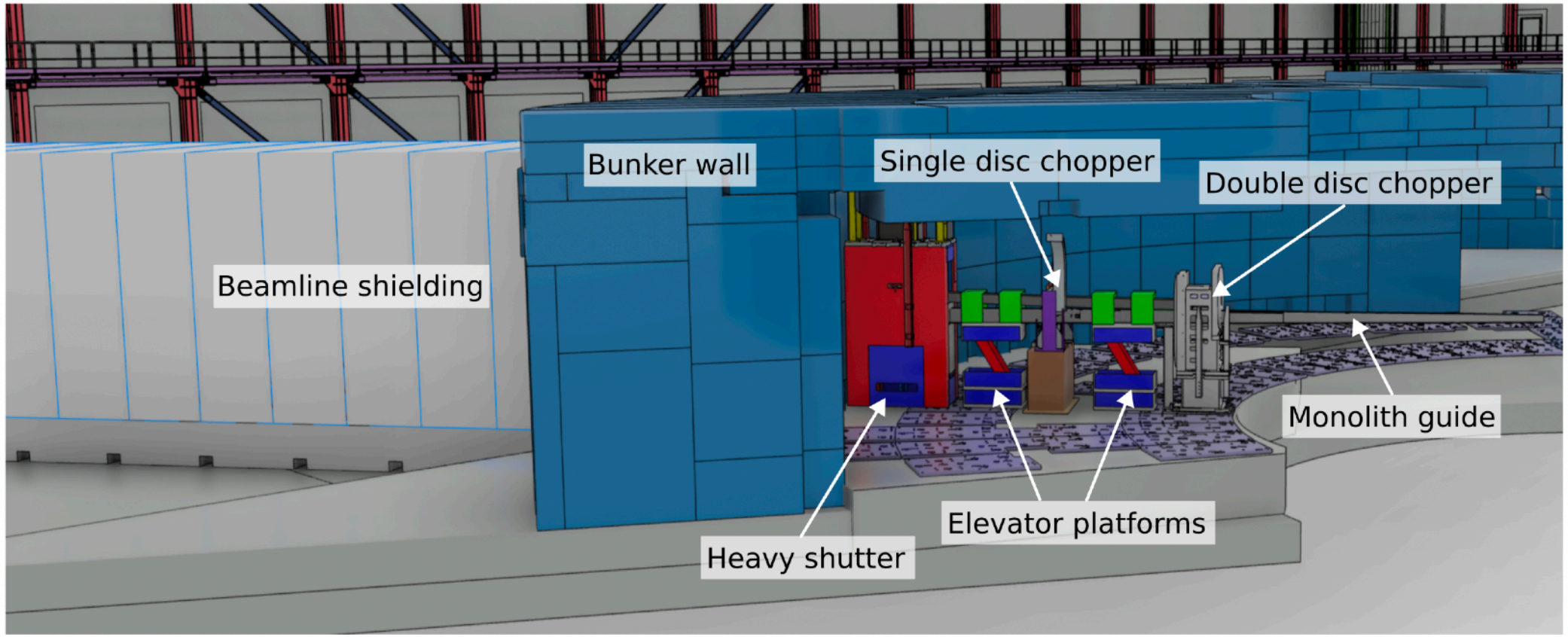


One beamline, two configurations

- We can switch between the two configurations without needing to wait for a long shutdown to access the space inside the bunker.



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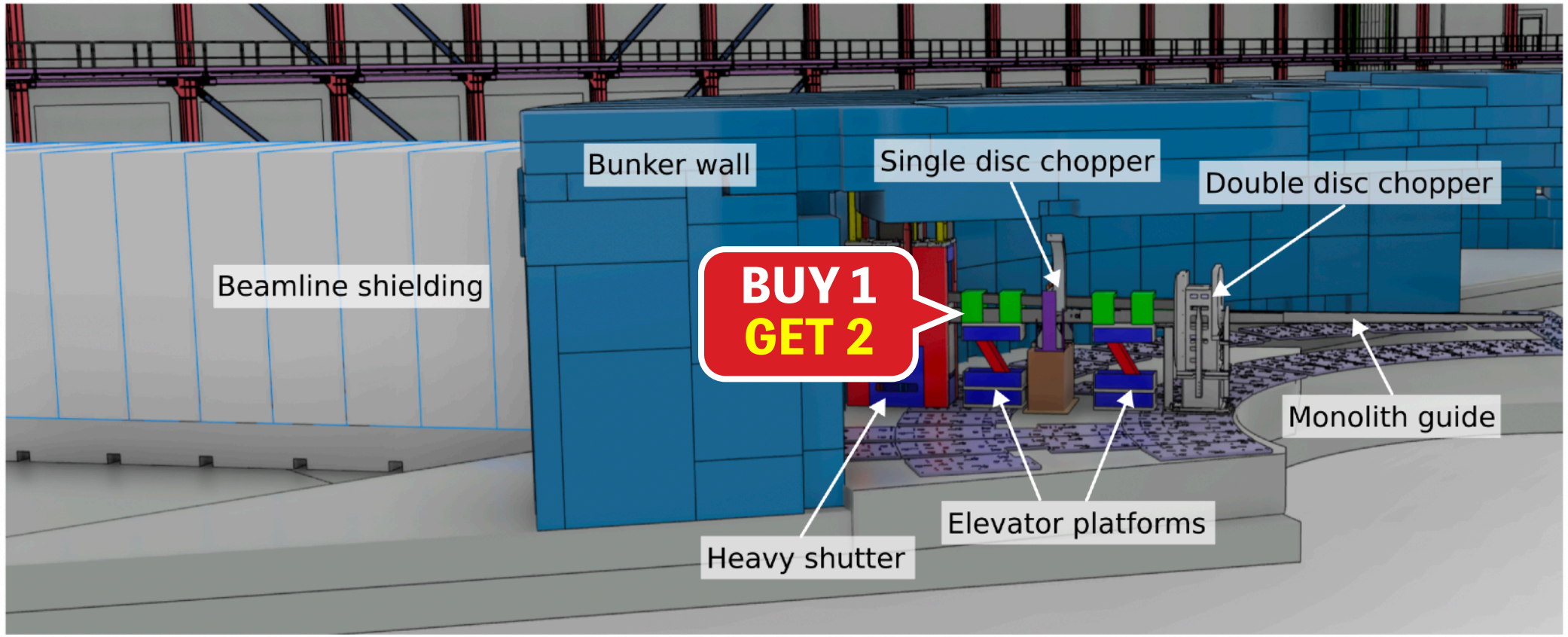

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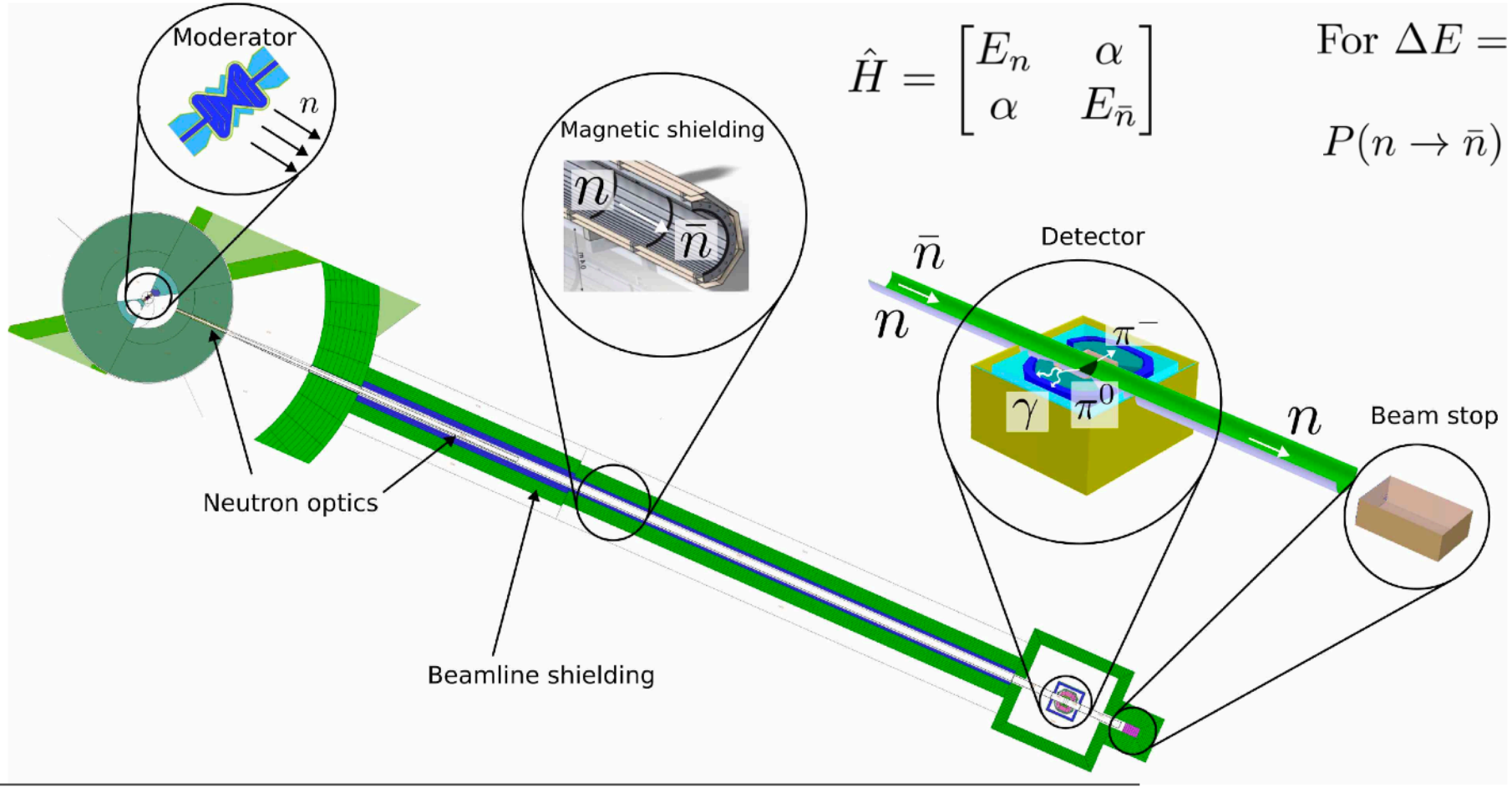
Neutron-antineutron oscillation

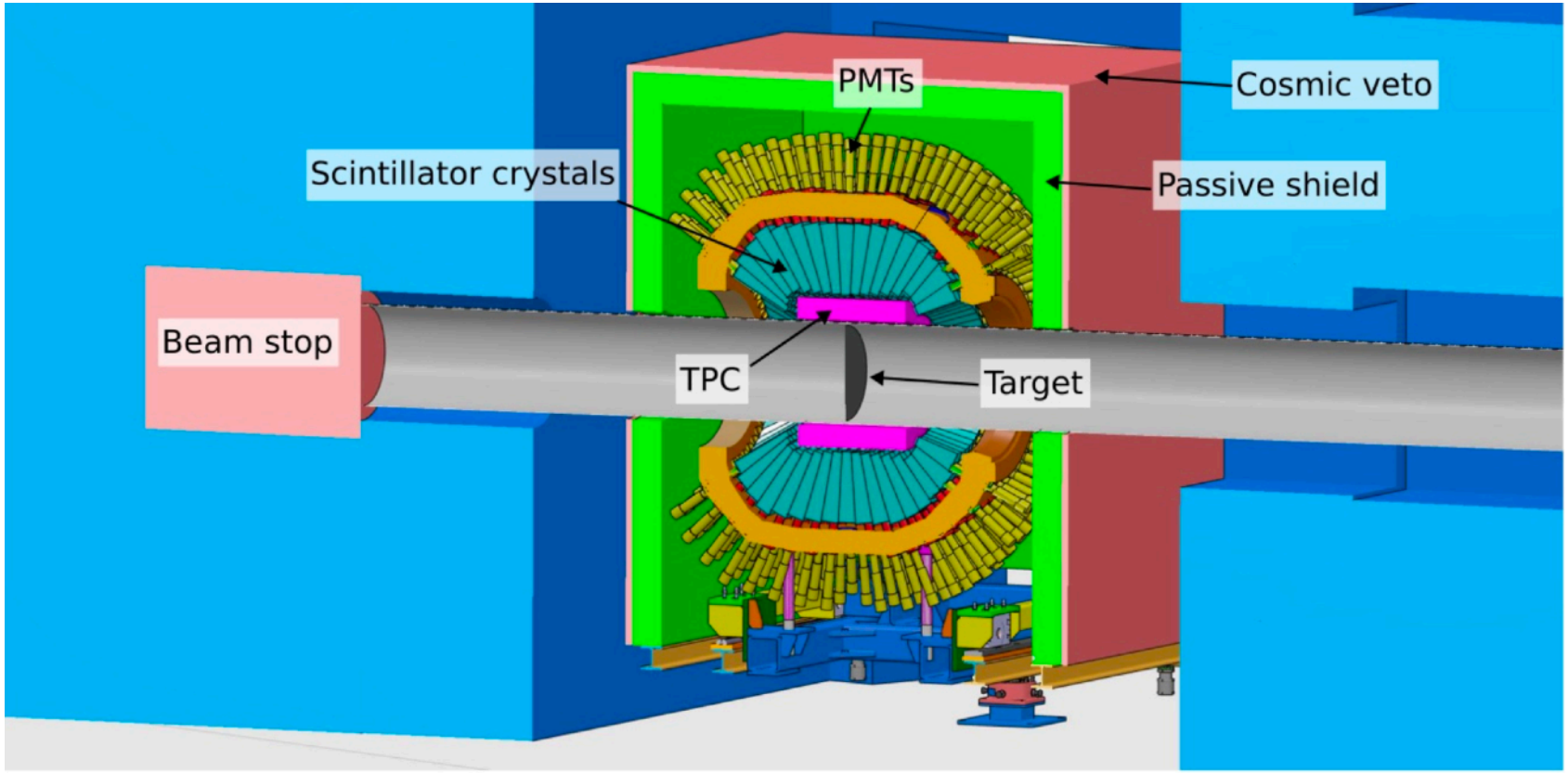
- Baryon number violation is a key condition for explaining the matter-antimatter asymmetry.



Further reading: V. Santoro *et al*. *J. Phys. G: Nucl. Part. Phys.* **52** 040501 (2025).

Annihilation detector

- To claim a discovery, we need full background rejection.
- Detector combines tracking, calorimetry and cosmic veto.



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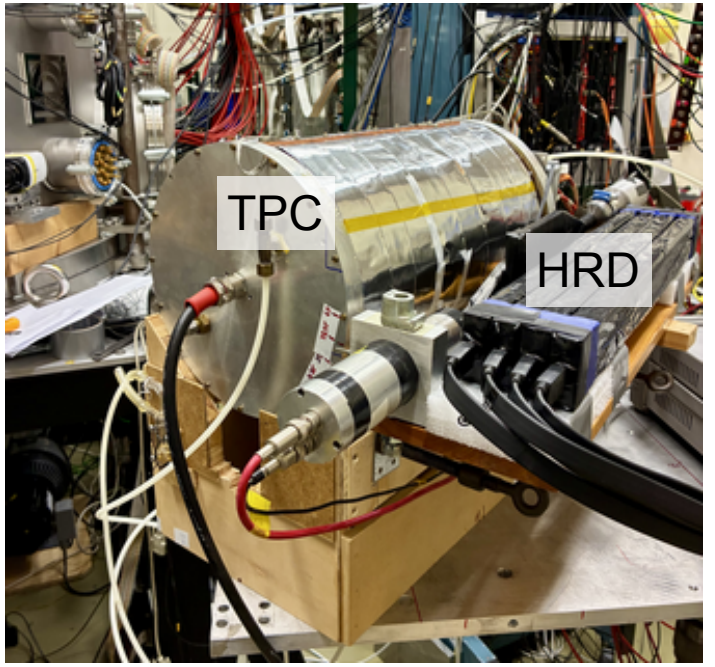
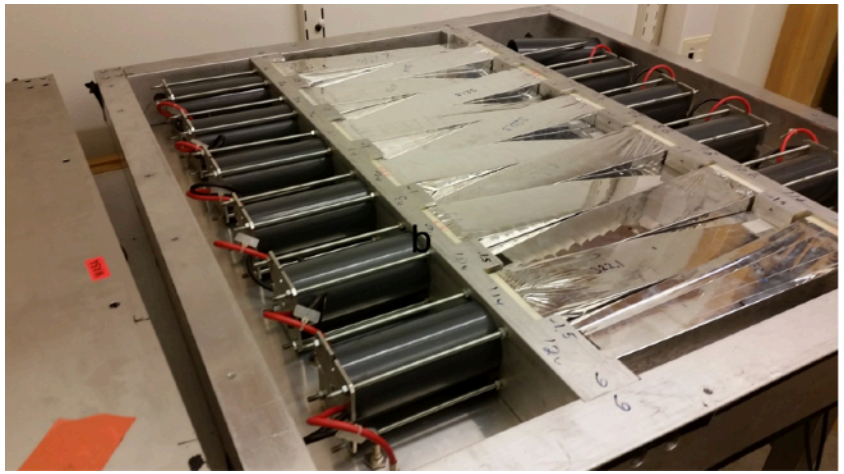
Prototype and simulation work in Sweden

- LU: TPC prototype, tracking algorithm, background characterisation and simulation.
- SU: HRD/LEC prototypes, front-end electronics, vertexing algorithms (see A. Burgman's talk today at 14:45).
- UU: WASA crystal characterisation with furbished light guides.

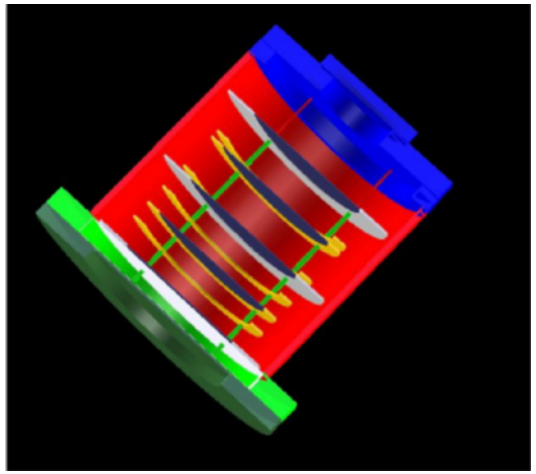


Prototype test at CCB, Dec. 2025

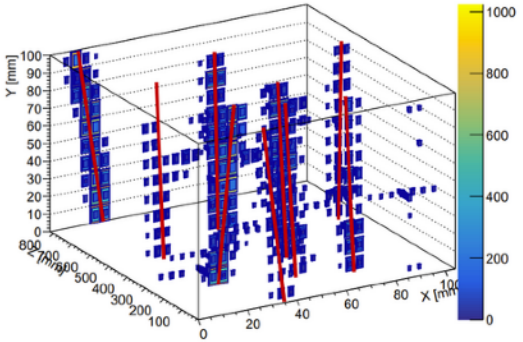
WASA crystal characterisation setup



Geant4 detector simulation



TPC track reconstruction



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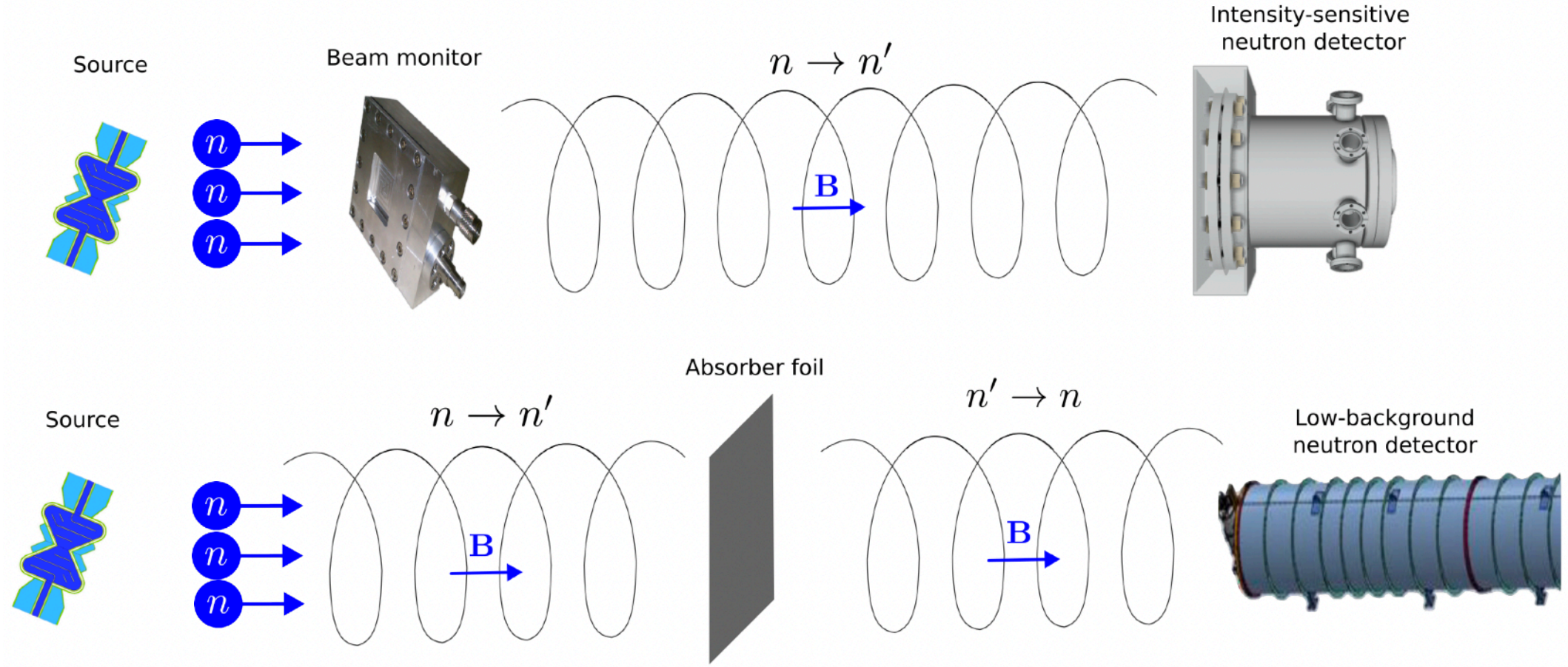
Sterile neutron oscillation

- What if the dark sector is a copy of the Standard Model?
- Can search for sterile neutrons by disappearance or regeneration experiments.



Further reading: J. Rogers *et al*. arXiv:2608.21120 (2026).

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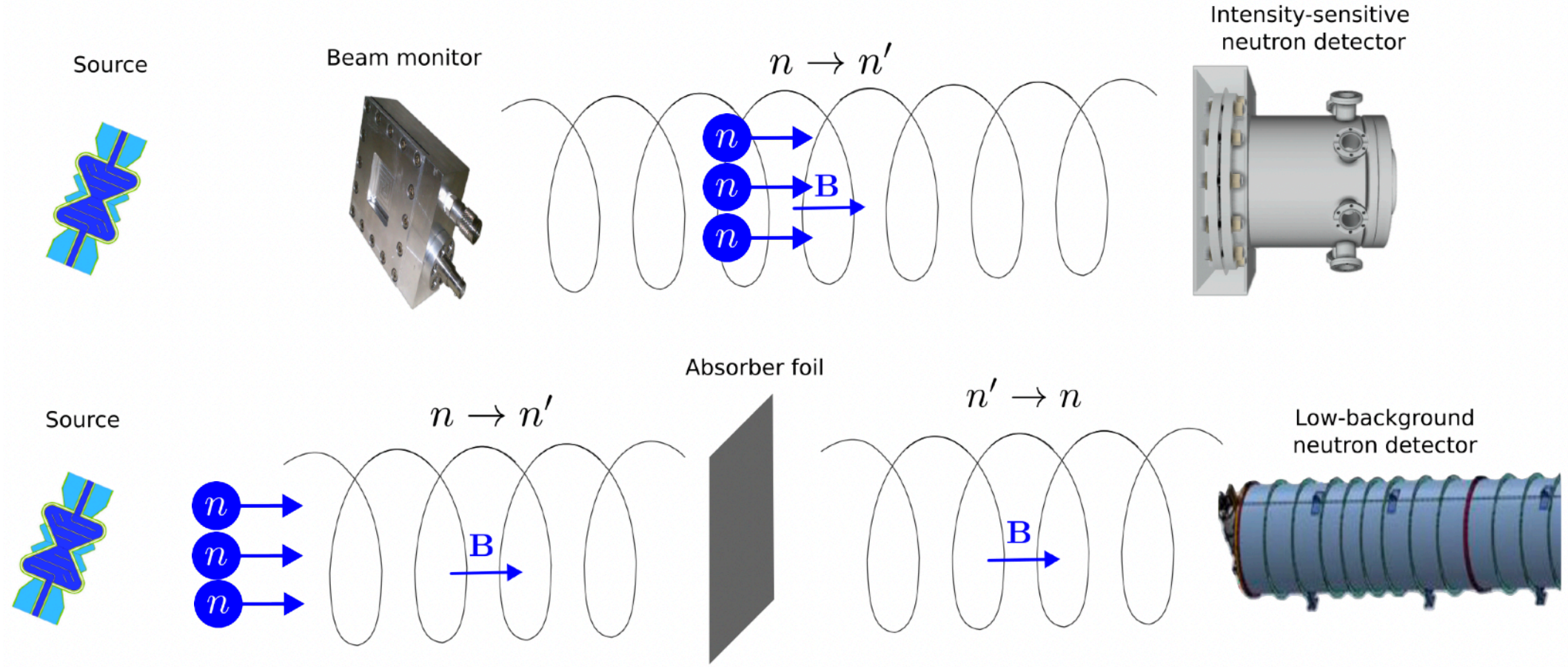

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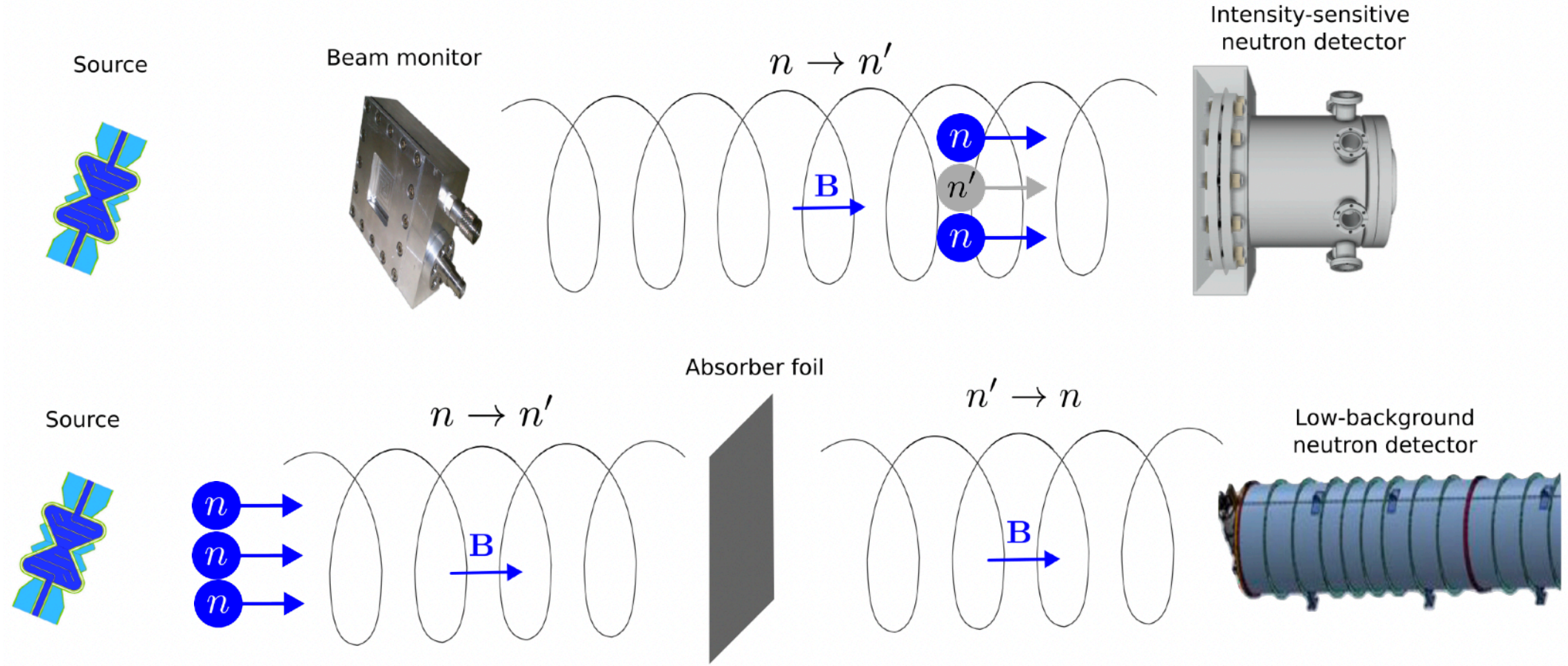

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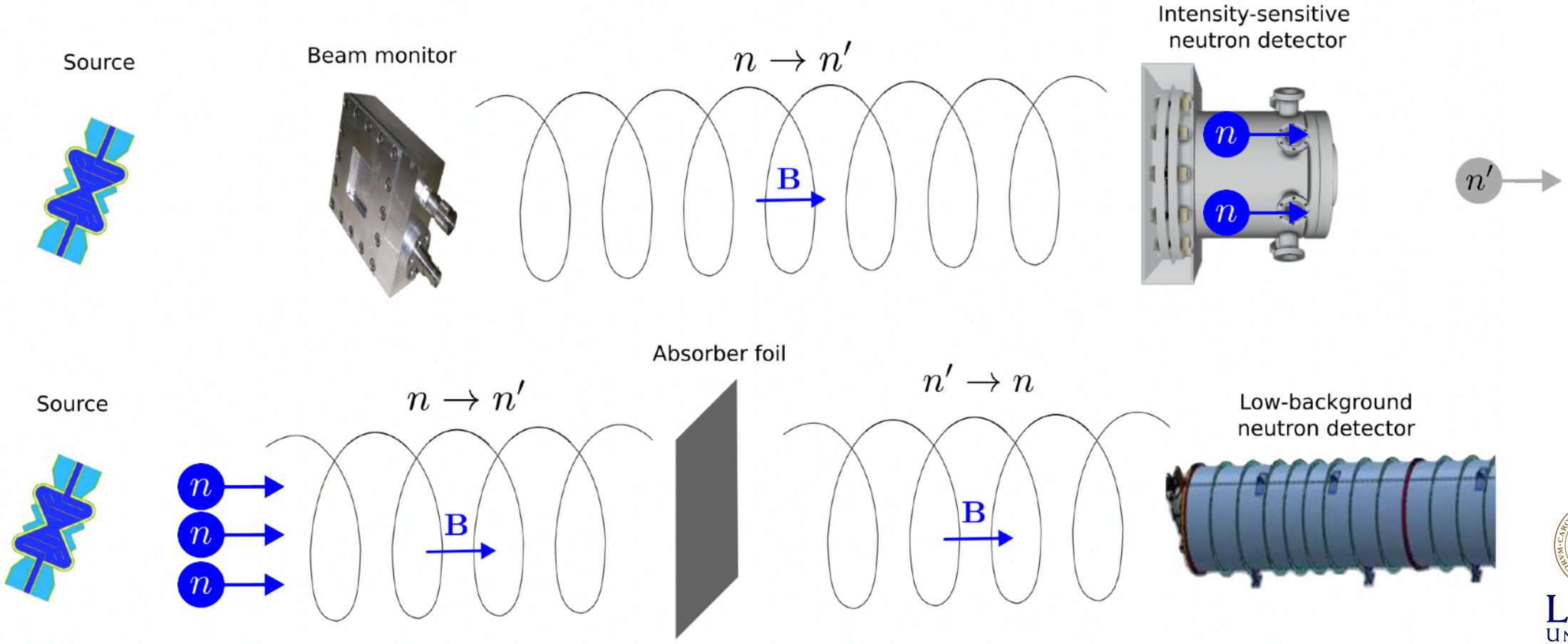

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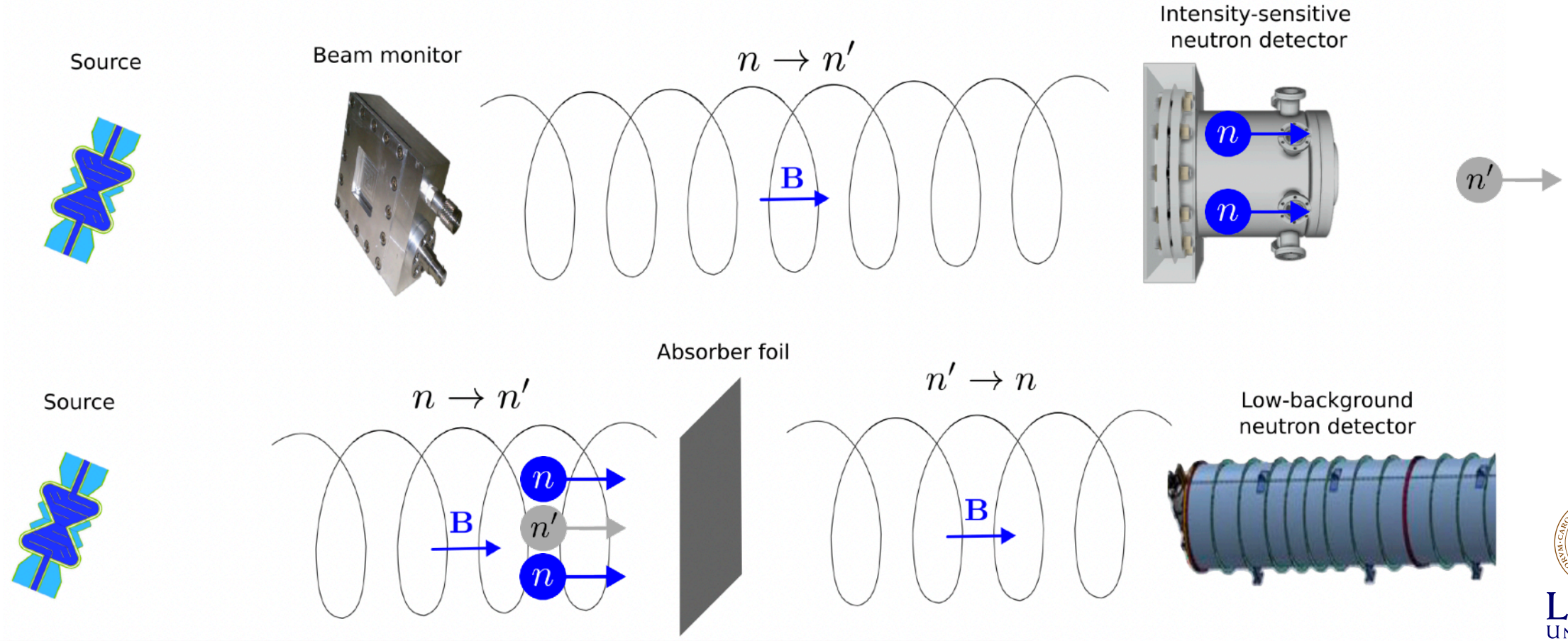

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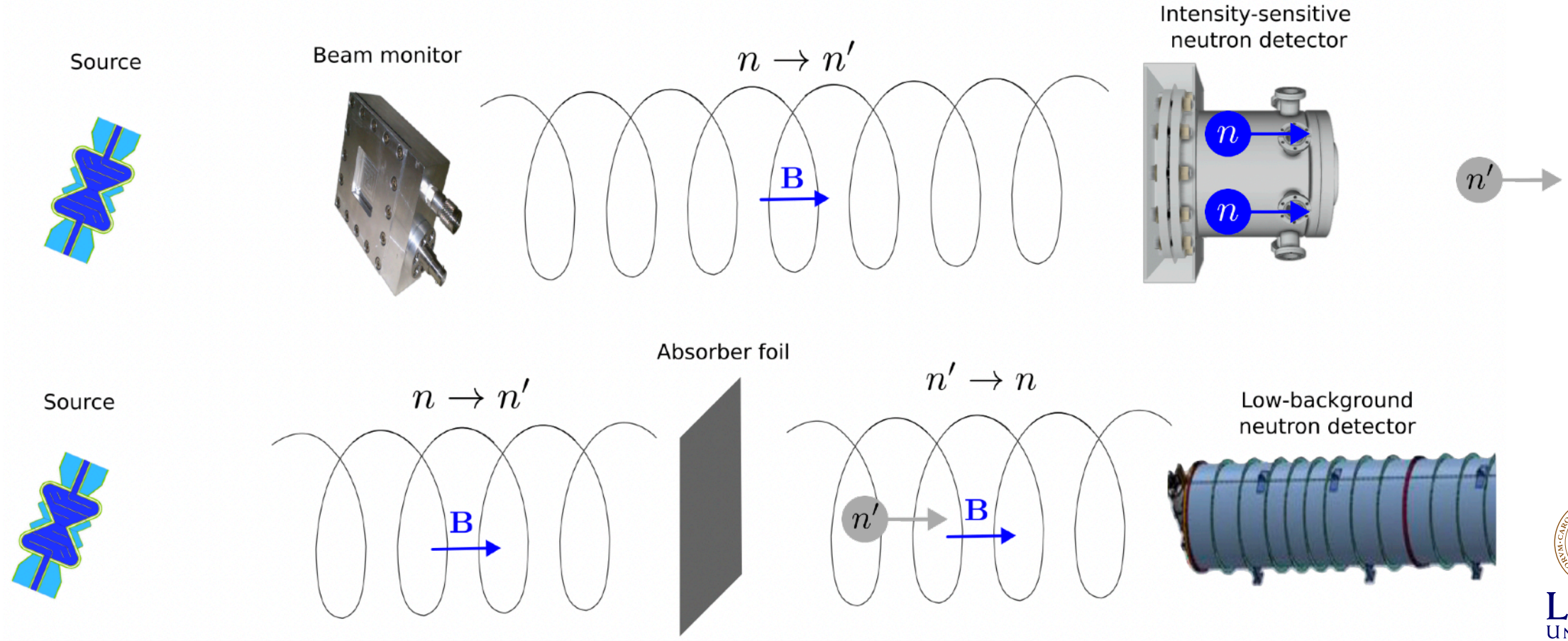

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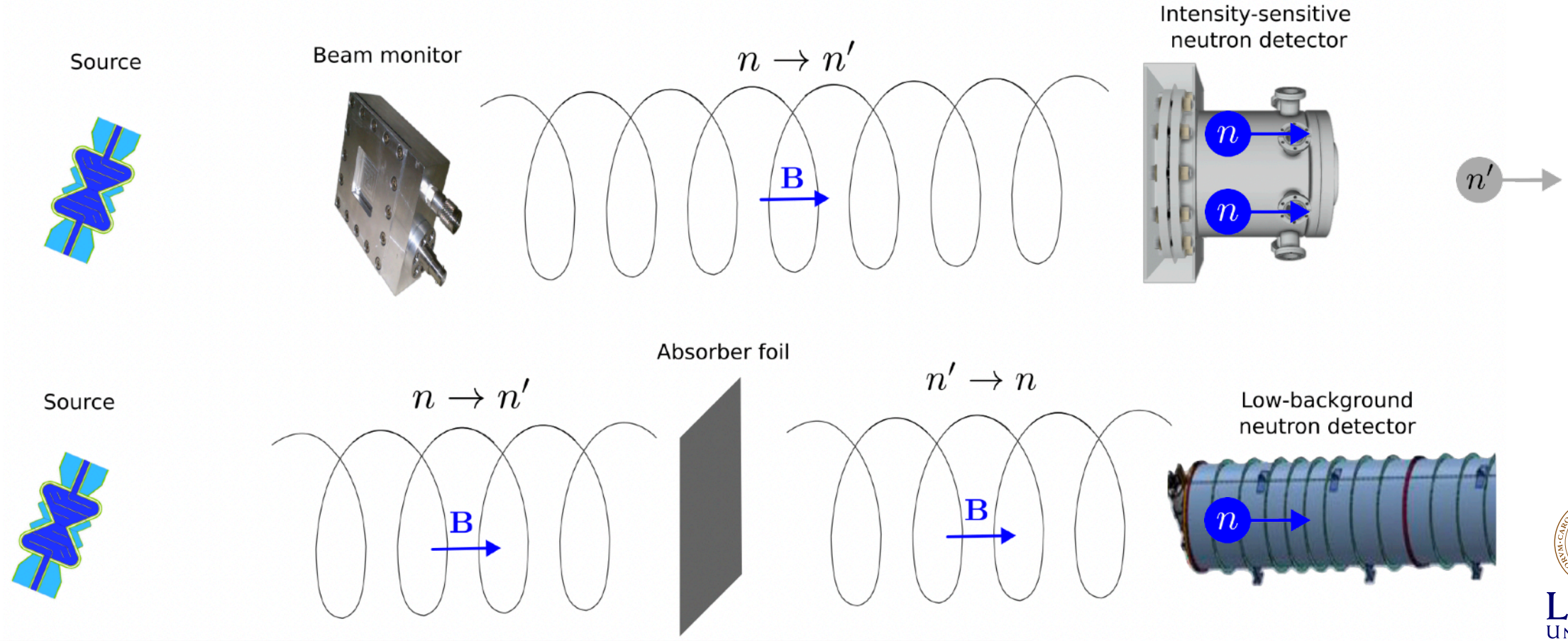

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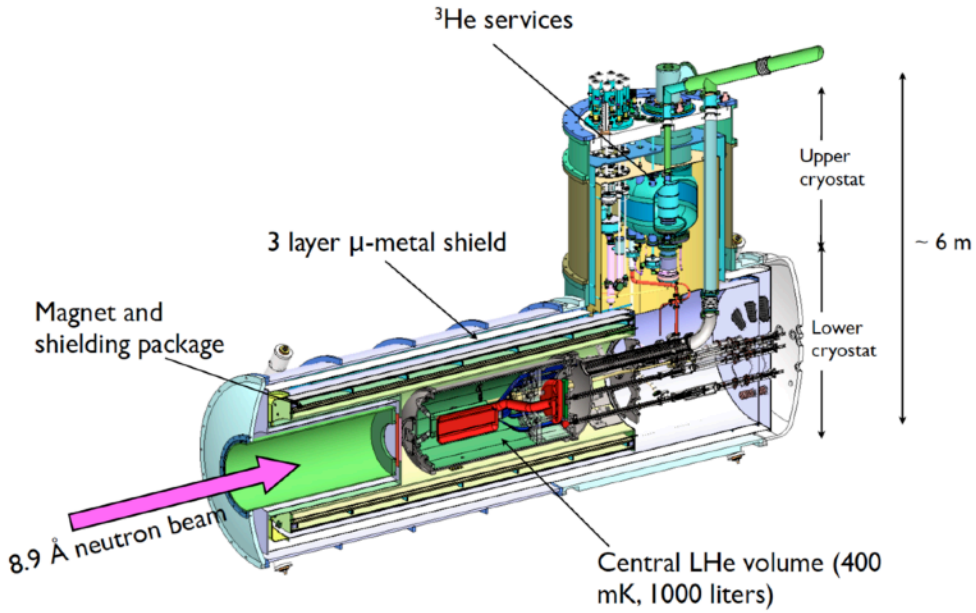
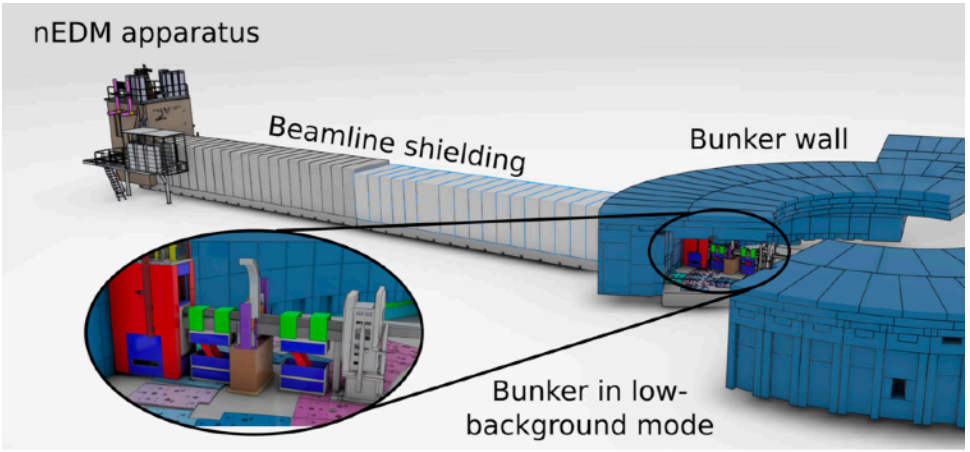
Search for neutron electric dipole moment (nEDM)

- A non-zero nEDM is T-violating and thus CP-violating. The known CP-violation is insufficient to explain the matter-antimatter asymmetry.
- Superfluid ^{4}He converts 8.9 Å neutrons to UCN, which precess in strong electric and controlled magnetic fields.
- Equipment designed for the cancelled SNS experiment could be transferred to ESS.

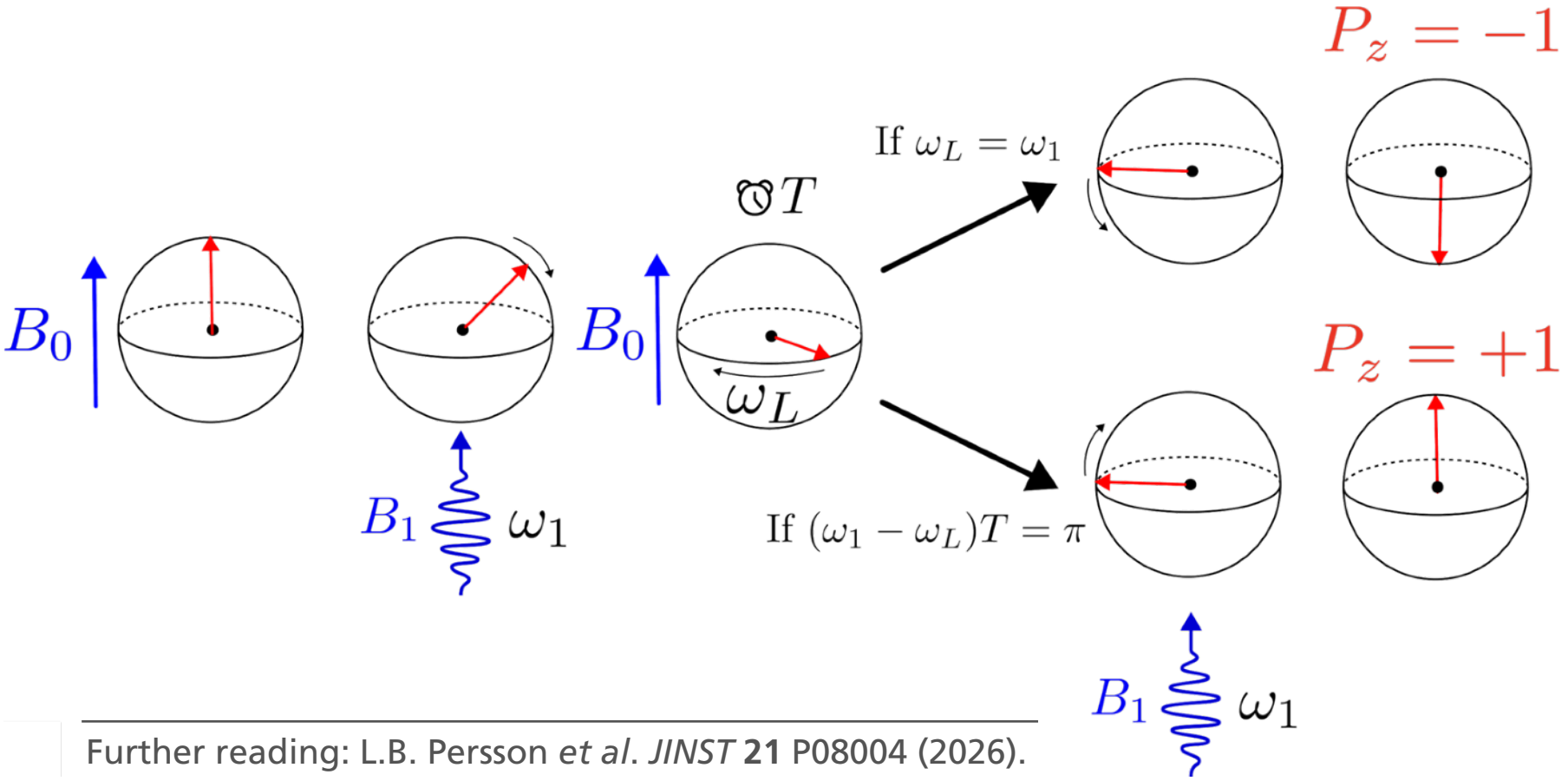




Further reading: M.W. Ahmed *et al*. *JINST* **14** P11017 (2019).

Axion-like particle search

- Ultralight axion-like particles interact with neutron spins as a pseudo-magnetic field.
- Measurable phase shift through Ramsey interferometry.



Further reading: L.B. Persson *et al*. *JINST* **21** P08004 (2026).

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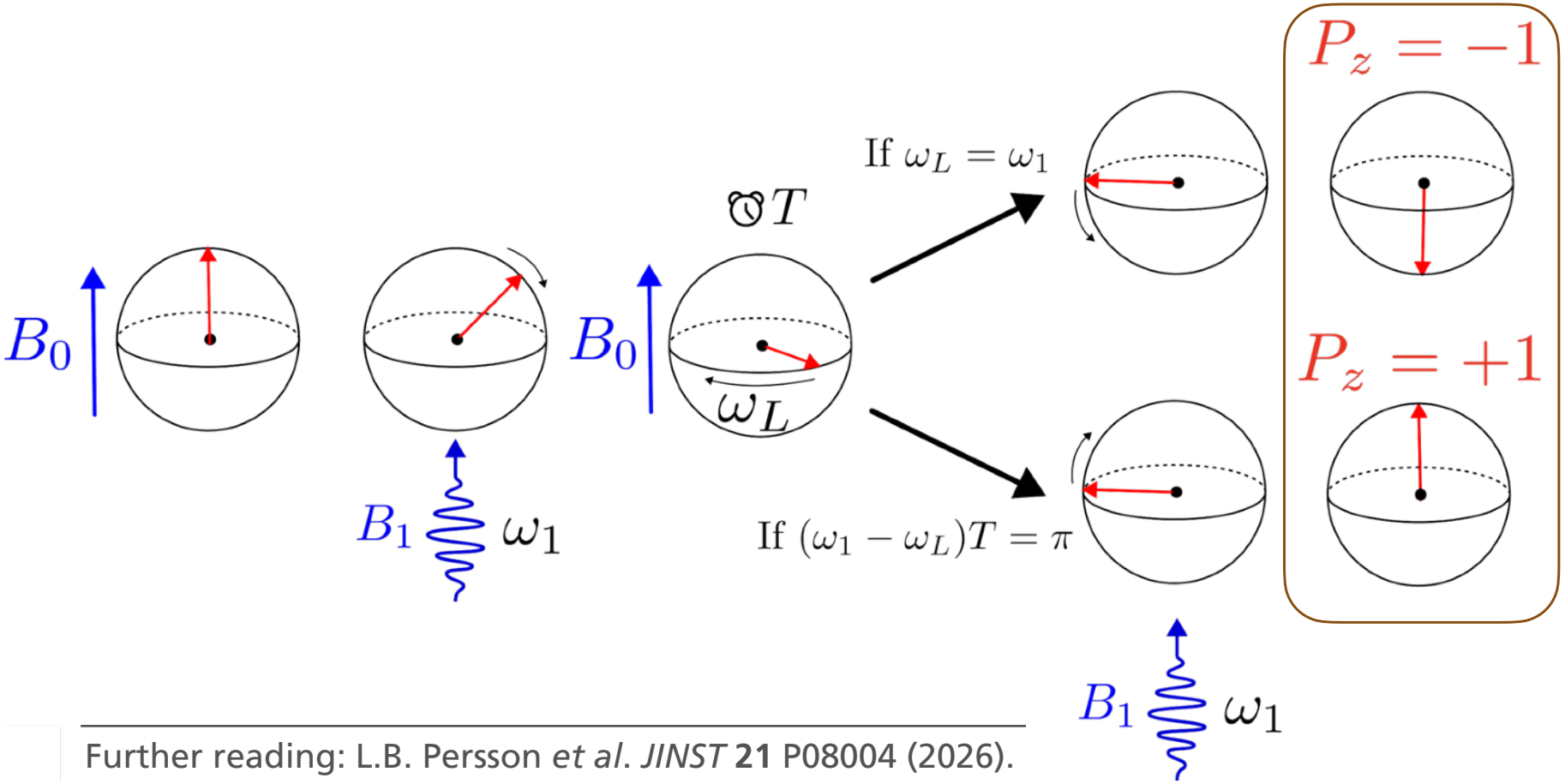

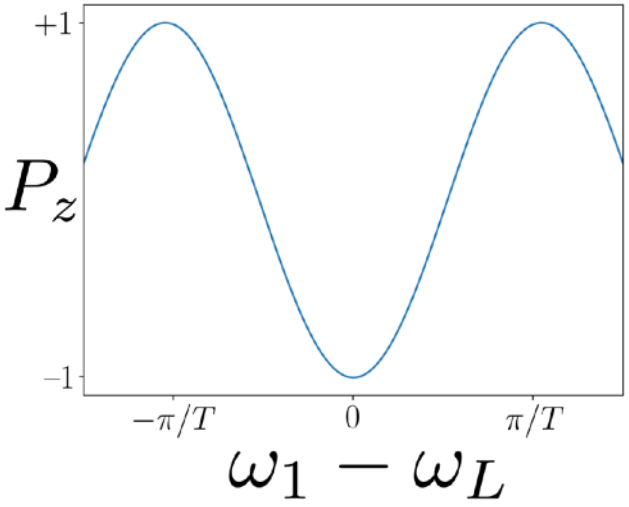

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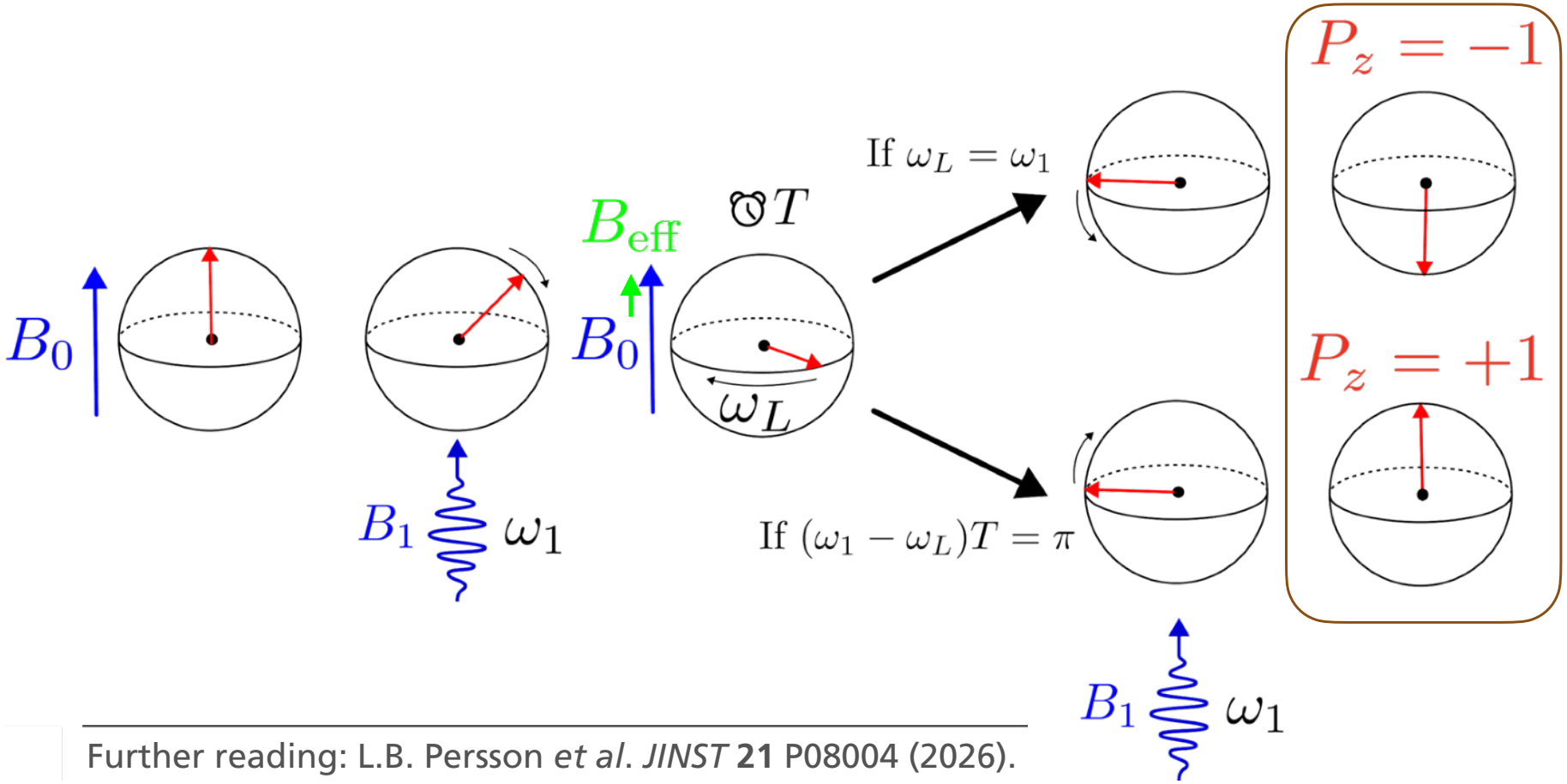

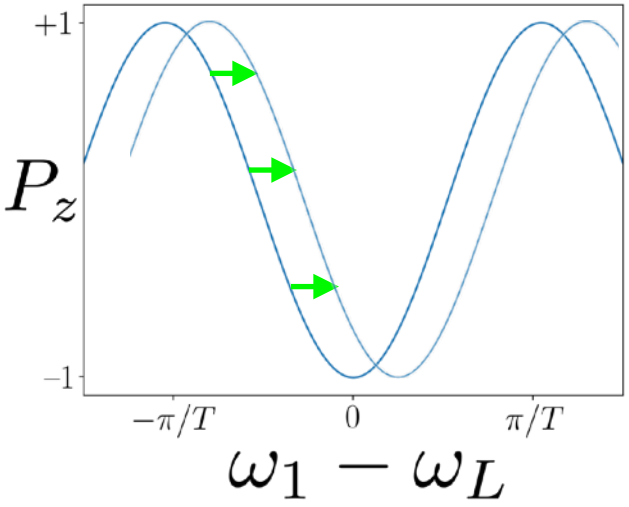

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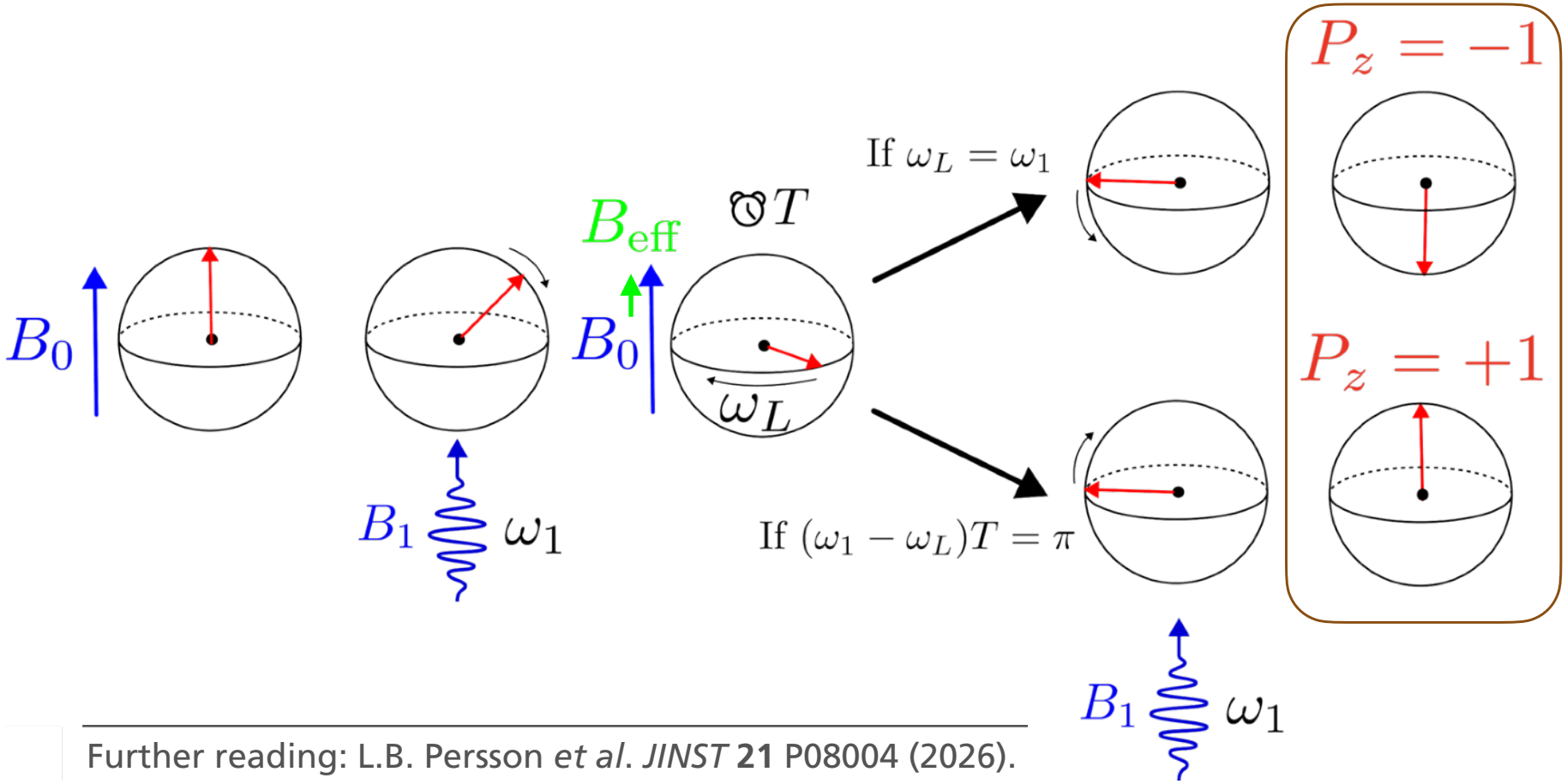
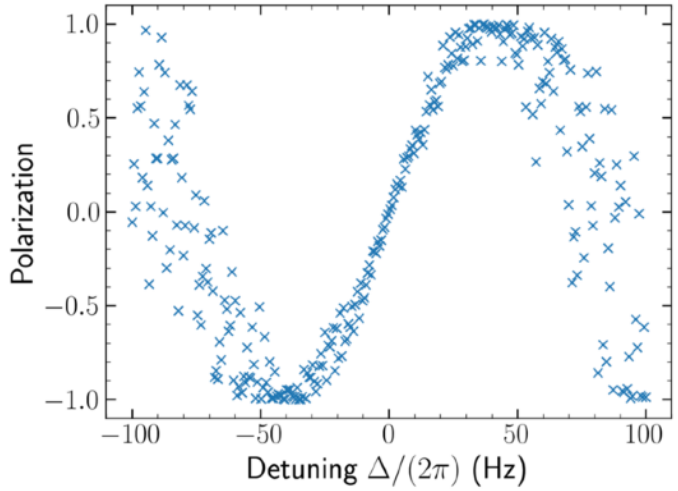


Simulated in RamseyProp



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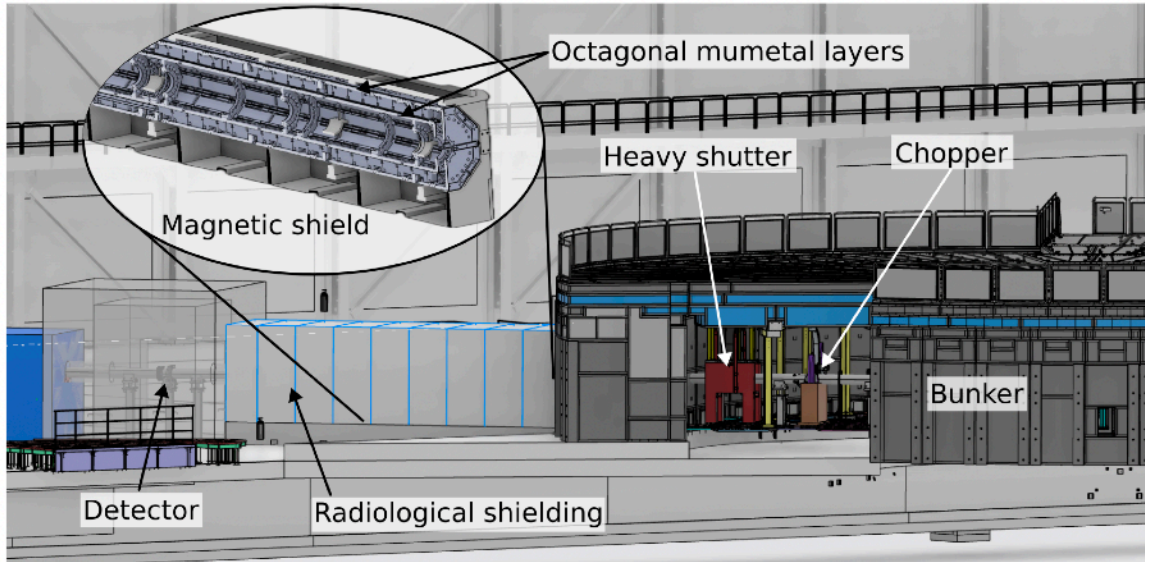
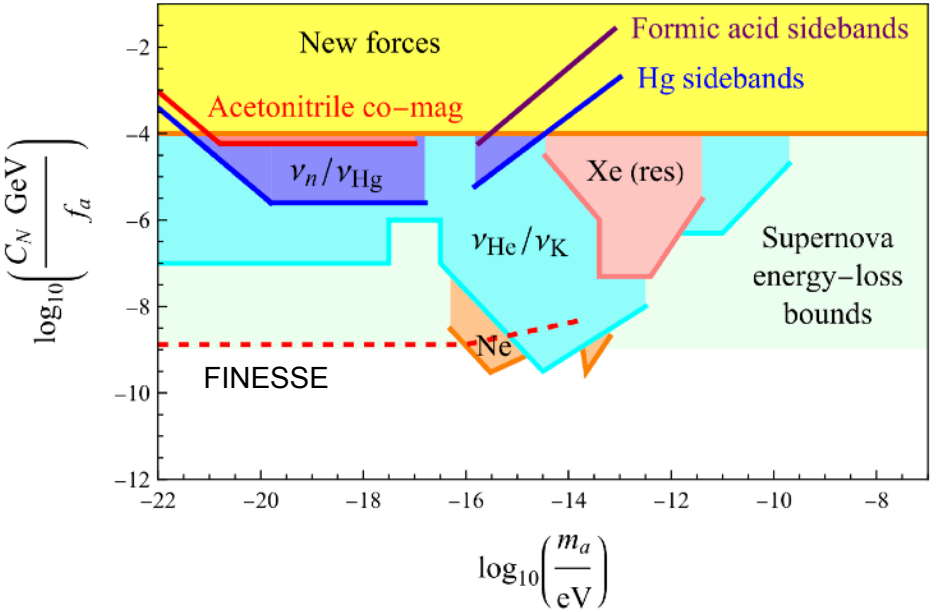
Short FINESSE

- The axion experiment can be performed at a 10-meter version of the beamline.
- Funded by the Swedish Foundation for Strategic Research (15 MSEK) and Swedish Research Council (4.7 MSEK).
- A 10-meter magnetic shield prototype soon to be procured and tested in Lund.





The FINESSE proposal

+ many more…

- 95 scientists from 51 institutions signed a proposal on 27 March for the ESS Instrument Roadmap.
- Currently being evaluated by external committees, first step to become an approved instrument.
- New collaborators are welcome!

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Summary

- FINESSE is a proposed particle physics beamline at ESS with two operating modes, one for high flux and one for low background.
- The high-flux configuration allows searches for neutron oscillation ($n \rightarrow \bar{n}$, $n \rightarrow n'$), axion-like particles and rare neutron decays.
- The low-background allows searches for the neutron EDM, hadronic parity violation and neutron beta decay experiments.
- With a single (Swedish-led) beamline, we can address fundamental issues including the matter-antimatter asymmetry, dark matter and the nature of the weak interaction.

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