Work package 8

Objectives

The main objective of this WP is to provide a conceptual design of the NNBAR experiment

nnbar experiment

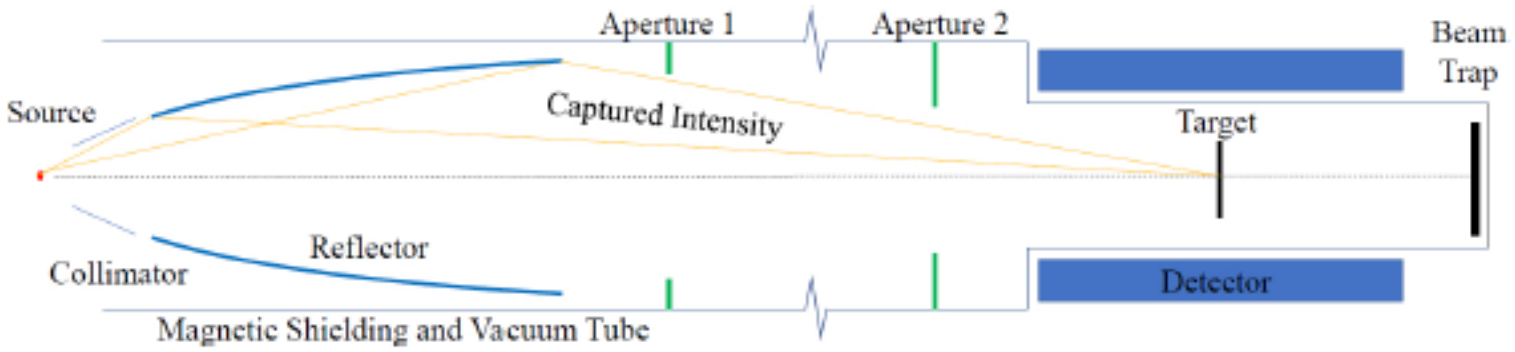
Search for $n \rightarrow \bar{n}$ with a precision improvement of 1000 wrt last experiment at ILL

Unique observable which addresses baryogenesis, dark matter..

Improvement made possible by advances in neutronics, cold ESS flux and ~200m beamline for ESS.

Basic principles of the nnbar experiment and WP8

Extract and focus neutrons from lower moderator to a distant (200m) carbon target.
Neutrons propagage in a field-free region to allow $n \rightarrow \bar{n}$
$\bar{n} + N \rightarrow \sim 5\pi$
Final state observed in annihilation detector



Coupled to WP4 (moderator design) and WP6 (advanced reflector)

Tasks and deliverables

Description of work

Task 8.1 Design of the NNBAR magnetic shield **SU** (M1-6)

Task 8.2 Development of a Geant-based model of different detector geometries and technologies. This includes, e.g., silicon-based tracking vs a Time Projection Chamber and a crystal calorimeter vs a sampling calorimeter **SU** (M1-12)

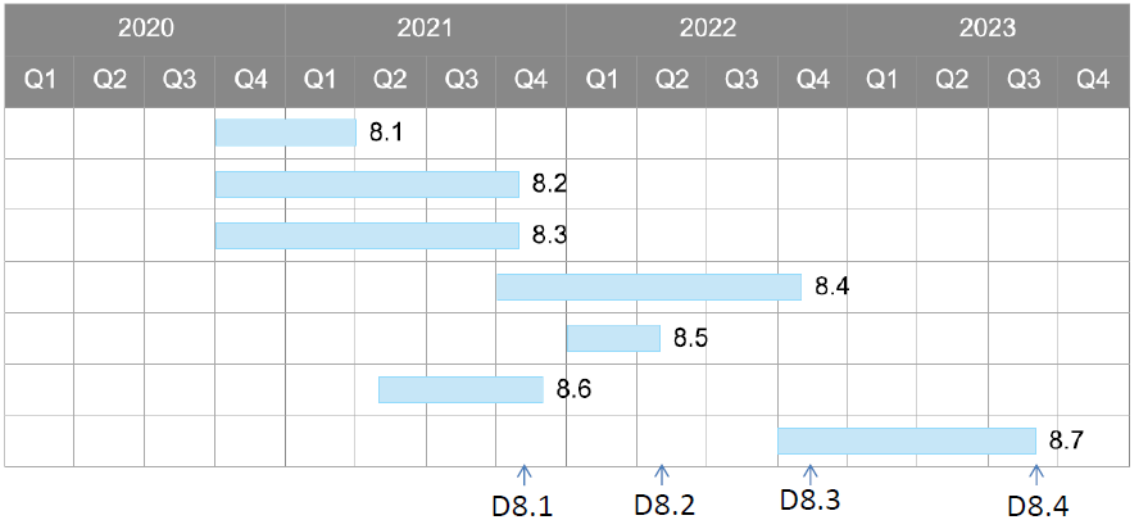
Task 8.3 Development of McStas components for single nested-mirror banks and Wolter optics **ILL** (M1-12)

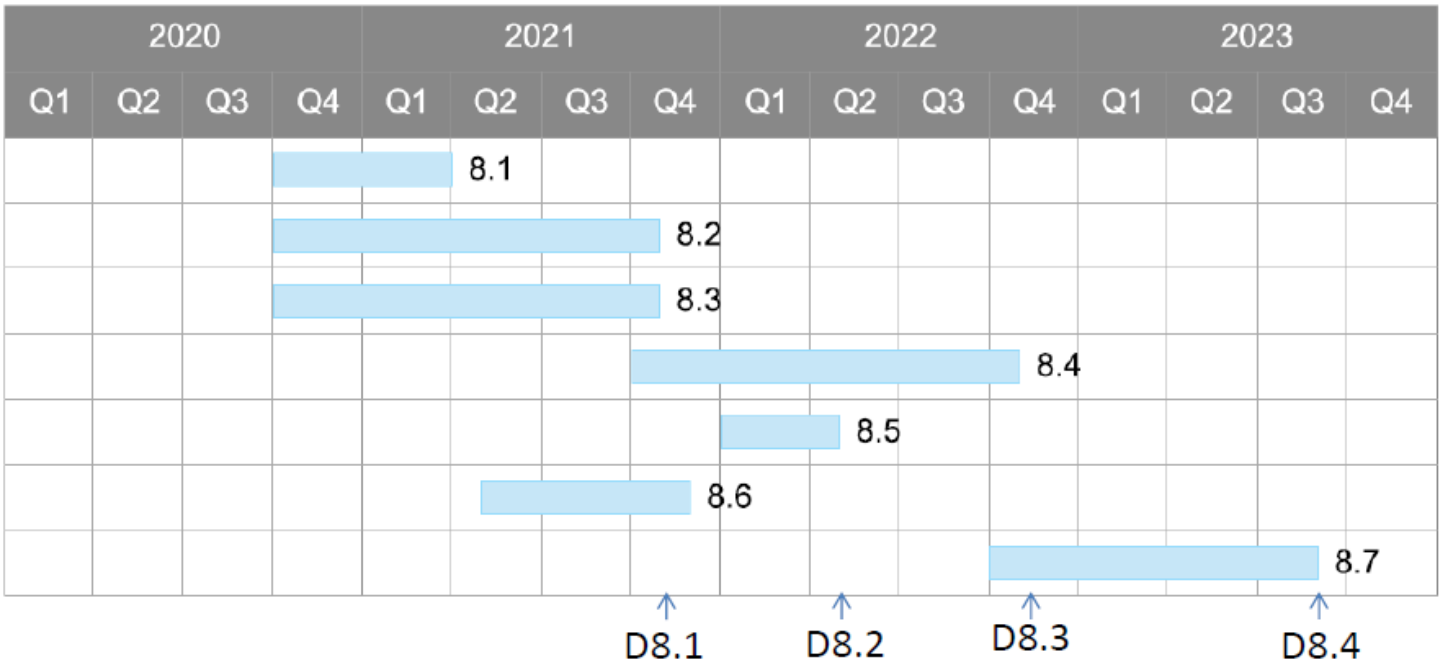
Task 8.4 Generation of a McStas model for nested mirror optics and a parabolic neutron trumpet, taking into account the neutron source and the NNBAR setup parameters; simulations comparing the different mirror systems; preparation of publication of simulation results **ILL, SU** (M12-24)

Task 8.5 Development of a full model of the NNBAR experiment incorporating the Geant-based detector model with simulations of antineutron annihilation and flux estimations based on McStas simulations **SU** (M15-18)

Task 8.6 Background estimations (spallation and non-spallation) together with the development of background-discrimination algorithms **SU** (M18-24)

Task 8.7 Optimization of a model of sensitivity for the NNBAR experiment for physics performance and cost, using the complete experiment model from beam extraction to detector response and incorporating background estimations; preparation of publication of results **SU** (M24-34)





Deliverables

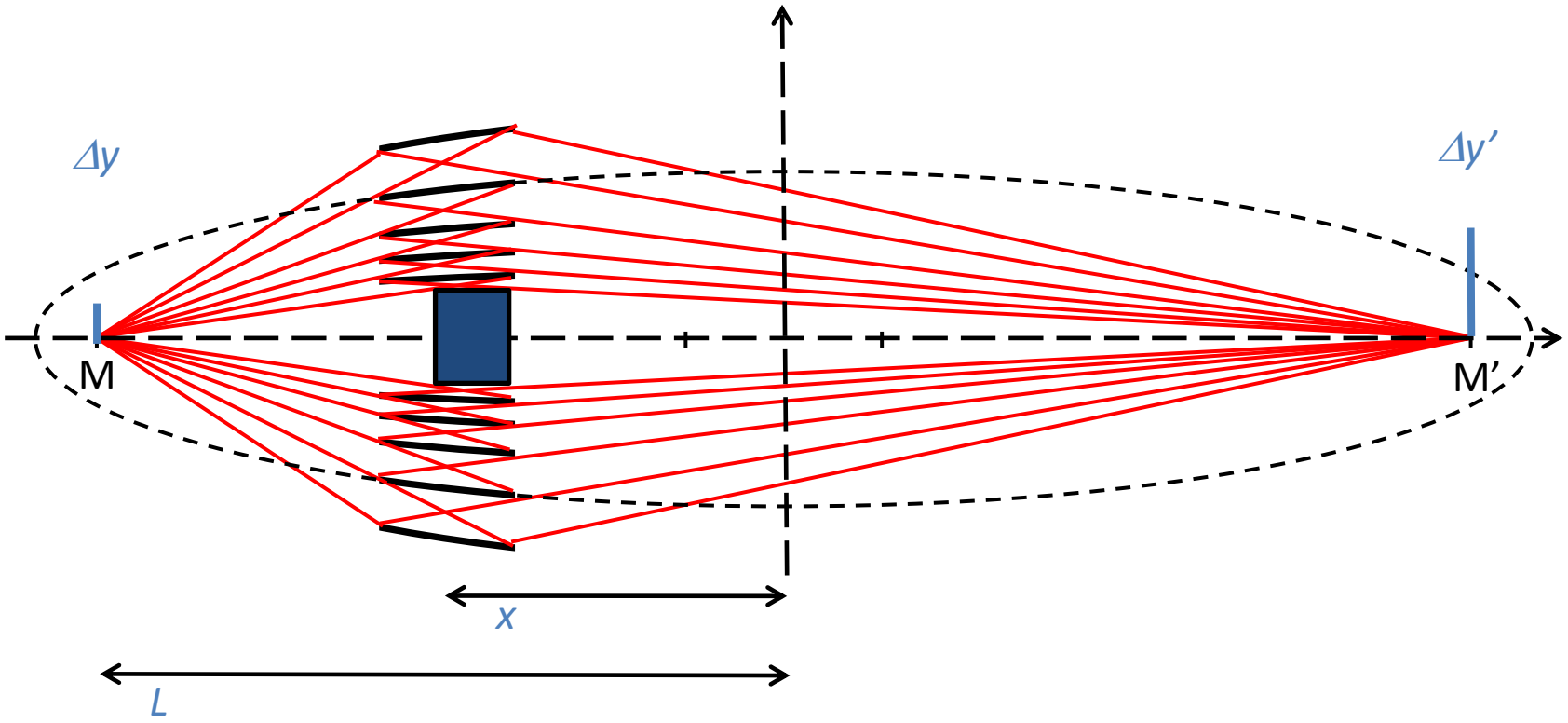
D8.1 McStas components of a single nested-mirror-bank and Wolter optic for general purpose neutron extraction from a moderator (M12)

D8.2 Paper submitted for publication on the development of a full model of the NNBAR experiment (M18)

D8.3 Paper submitted for publication on comparative McStas simulations of optimized nested-mirror neutron extraction systems and a parabolic neutron trumpet for NNBAR (M24)

D8.4 Conceptual design report paper on NNBAR design, expected physics performance and cost (M34)

Nested focusing super-mirror for nnbar:



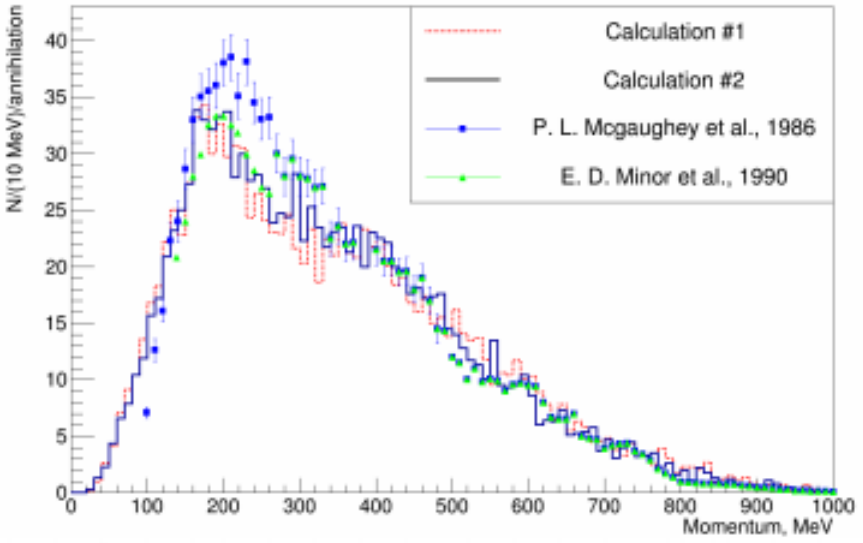
Larger viewable area of the lower moderator -> optimised imaging insturment to extract a large divergence neutron flow and focus over long distance (~200m).

Design nested mirror systems of a single set of elliptic/short mirrors and of Wolter-optic types.

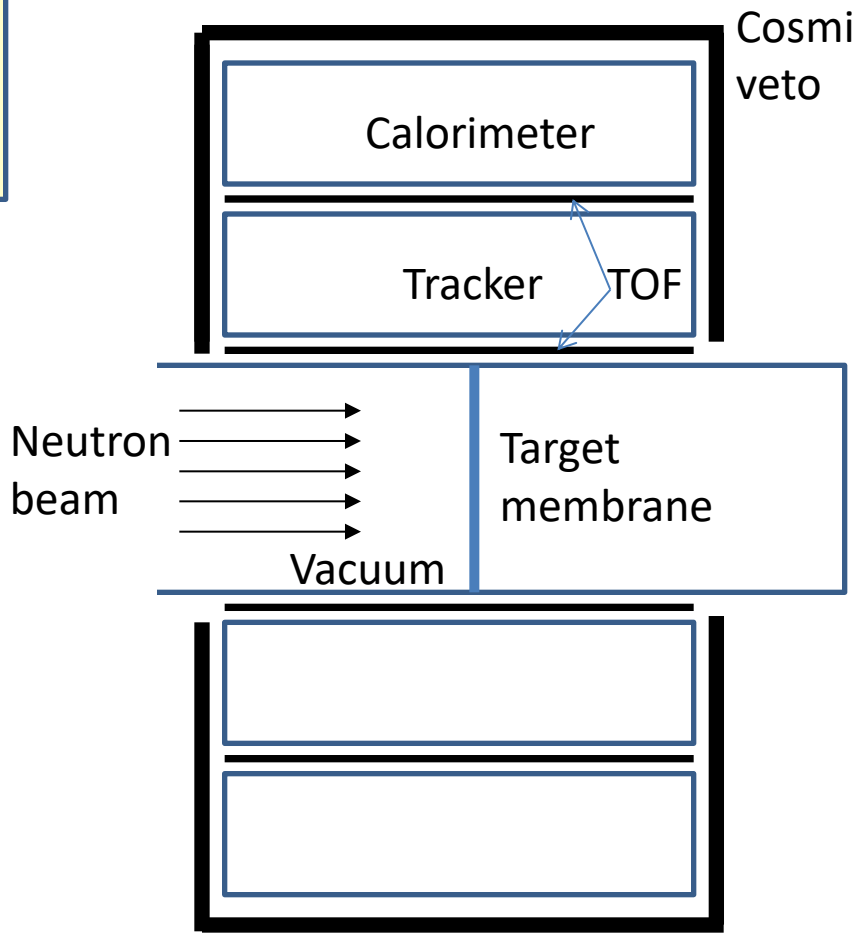
Annihilation detector

Expect $\bar{n} + N \rightarrow \sim 5\pi$ at $\sqrt{s} \sim 2$ GeV.

Detector design for high efficiency $(\varepsilon > 0.5)$ and low bg (~ 0).



Isotropic – order 100 MeV particles.

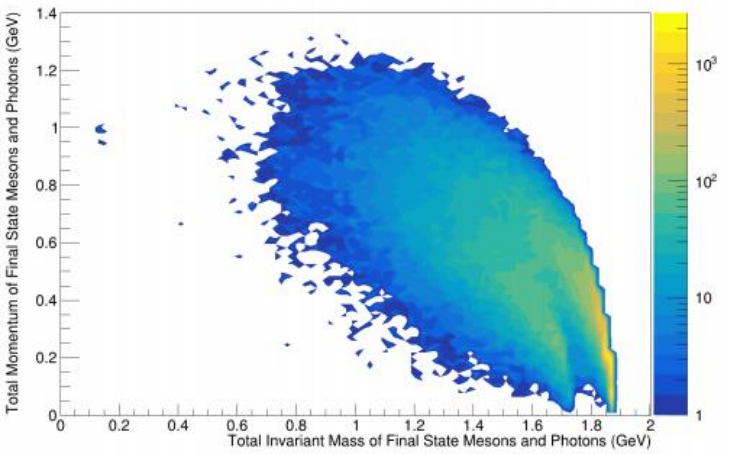


Detector technology choices

- Aim for optimal detector (technology and cost)
- Signal isotropic 4-5π at 100-300 MeV.
- Charged particle and photon reconstruction
- Pointing resolution precision vertex/target pointing + particle identification)
- Optimal Timing resolution

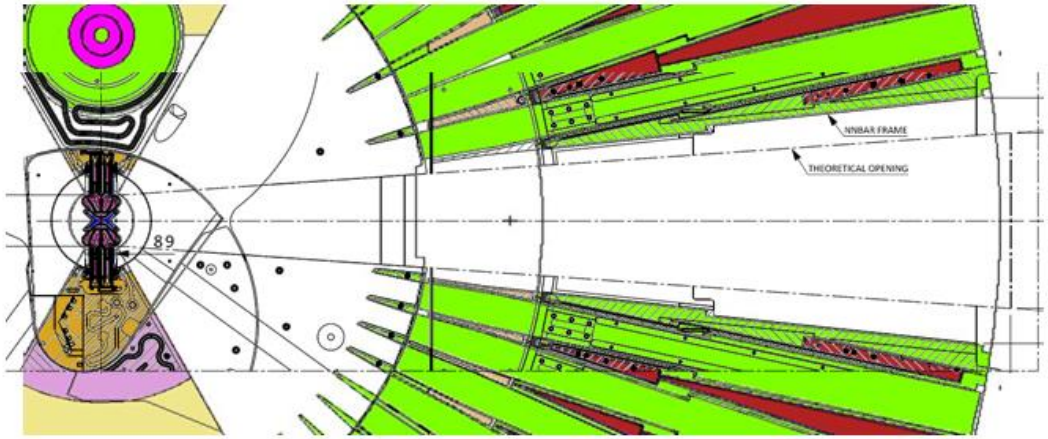
Subdivision of detector tasks

- Expansion of modules to full Geant-4 detector with basic TPC/silicon + scintillator/lead-glass
- Tentative estimates of worst case bg scenarios
- Characterisation and variation of detector parameters
  - Granularity, cell size
- Reconstruction algorithms for hit and energy clustering
- Identification of sensitive variables (invariant mass, track multiplicity, sphericity…)
- Triggering strategy (photon + scintillator)
- Performance and figure of merit for signal reconstruction.
- Investigate different technology choices with alternative Geant-4 model
  - Eg drift chamber + sampling calorimeter.
- Full optimisation of detector parameters with precision predictions of background sources.



Subdivision of background tasks

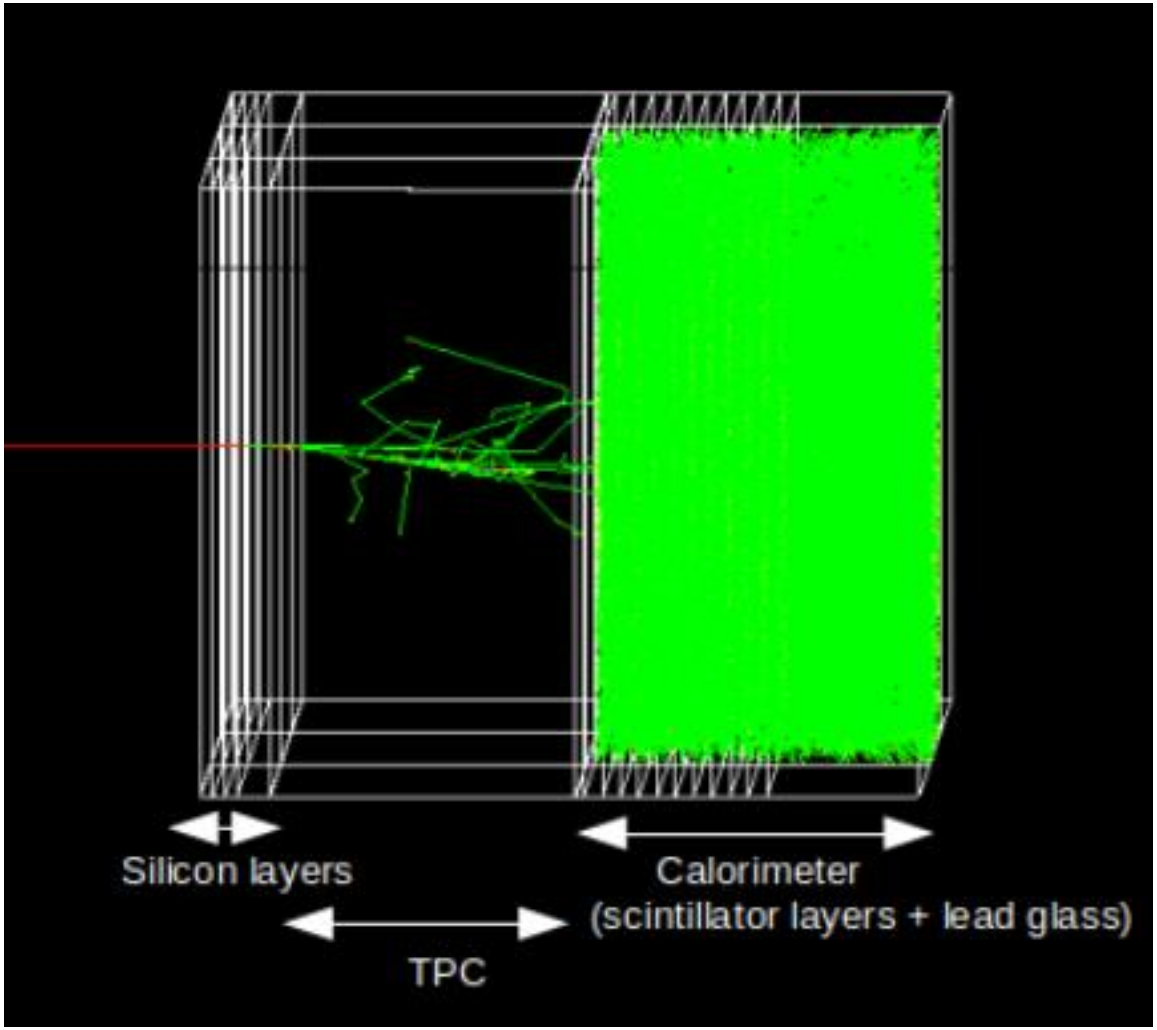
- Aim for a zero background experiment as for ILL
  - Previous search at ILL dominated by cosmics
  - NNBAR at a spallation source
- Cosmic background (charged and neutral)
- Spallation backgrounds – full NNBAR model from moderator to the target
- Background radiation (gamma, scattered fast and epithermal neutrons) also related to shielding
- Skyshine
- Activation of structure materials
- Shielding strategy
- Contribution of NNBAR to other experiments



Horizontal cut through the NNBAR opening in the monolith (overlap Monte Carlo model and drawing)

Current detector status

Geant-4 simulation implementing silicon layers, TPC volume and calorimeter.



Personpower plan

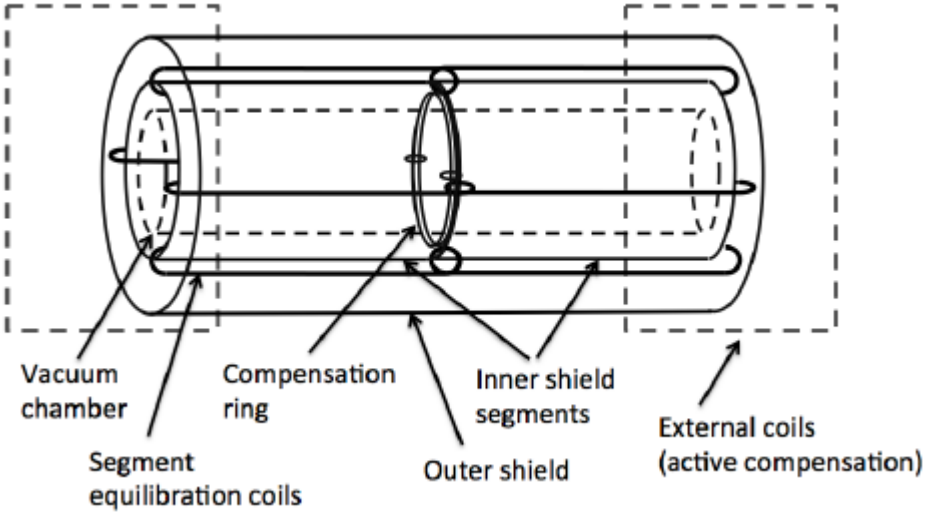
Work package number	8	**Lead beneficiary**			SU		
Work package title	Fundamental Physics						
Participant number	1	2					
Short name of participant	**SU**	ILL					
Person months per participant:	24	24					
Start month	1			**End month**	36		

ILL – senior scientist (O. Zimmer) and postdoctoral scientist who starts in January 2021.
SU – PhD student , senior scientist (D. Milstead) and a consultant/postdoc.

Summary

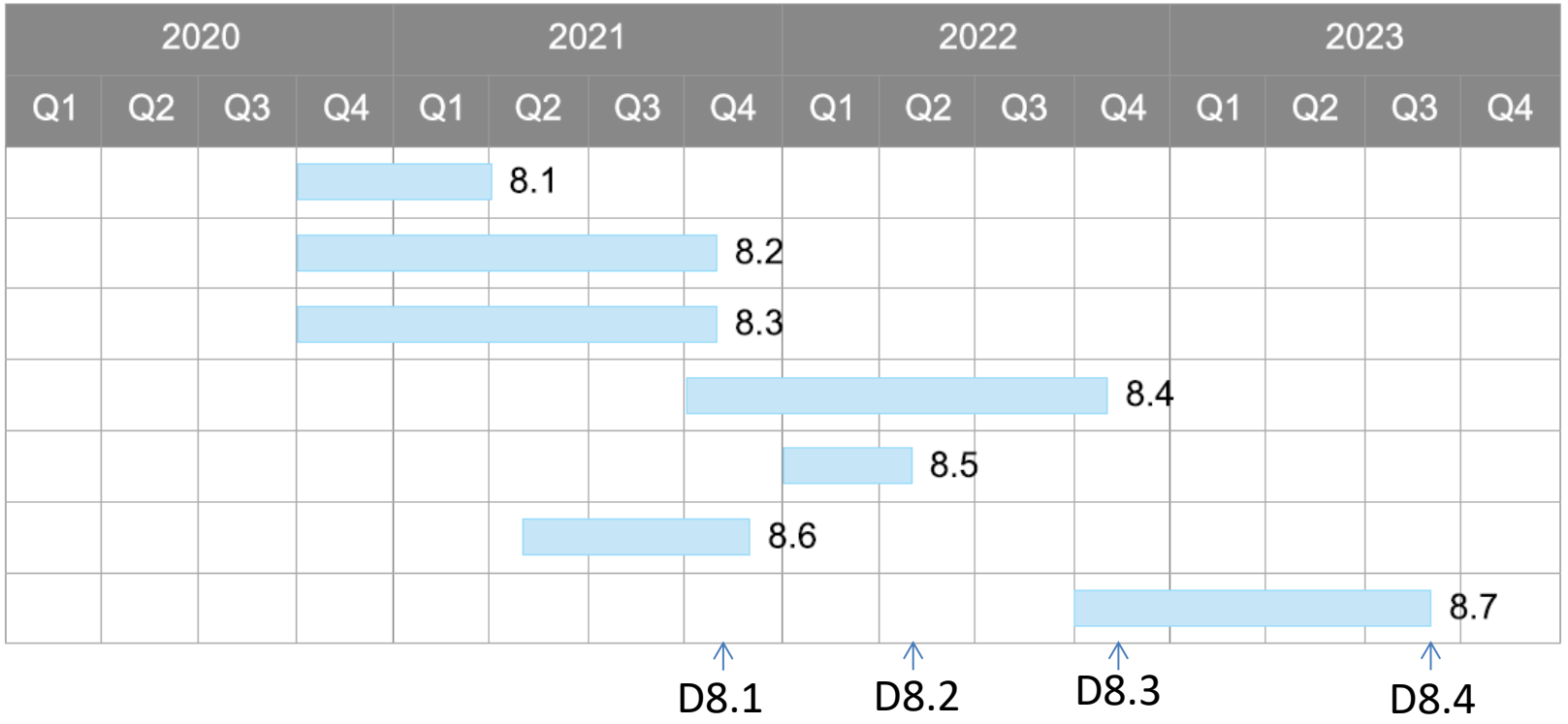
- Work package 8 underway
- Design of NNBAR experiment
- Principal tasks of neutron focusing and detector design.

Magnetic shielding



Basic design

- Passive shielding - multi-layer magnetisable material for passive.
- Active shielding by coils


2020
2021
2022
2023
Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4 Q1 Q2 Q3 Q4
8.1
8.2
8.3
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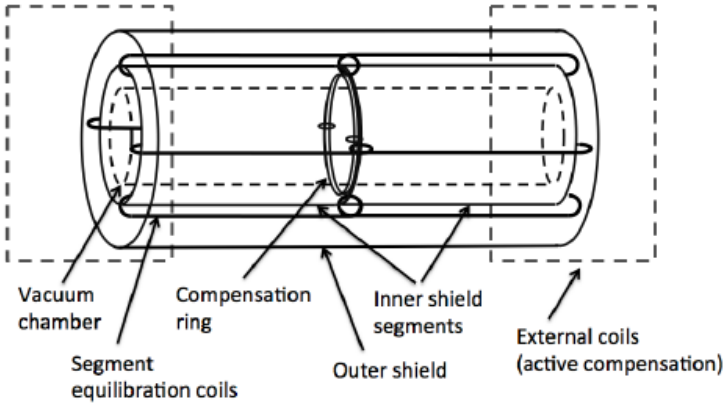
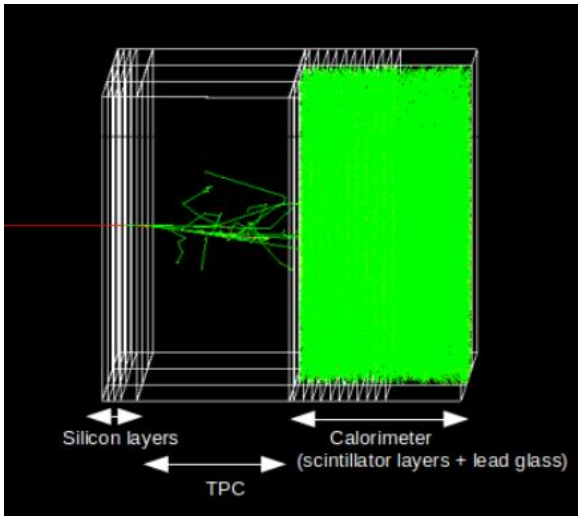
Status

Task 8.1 Basic design of magnetic shield



Task 8.2 First Geant simulations of basic detector modules.



Task 8.3 Basic McStas components set up which can be used for single-nested mirror banks