n_ACT @ BDF

A high intensity & high energy **n**eutron **act**ivation station at the CERN **B**eam **D**ump **F**acility

Michael Bacak

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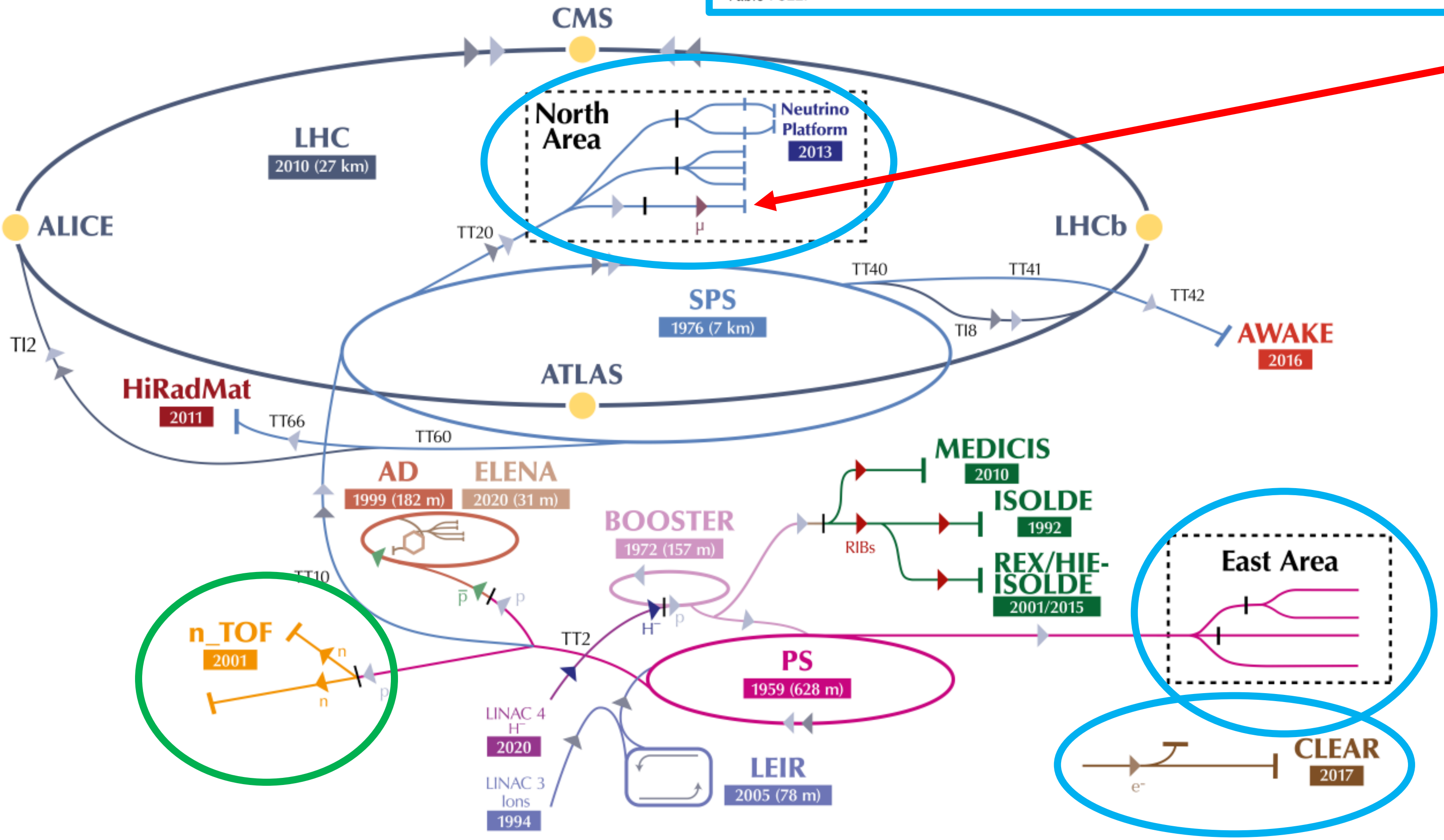
O. Aberle, M. Calviani, J.-L. Grenard, G. Humphreys, C. Mucher, L.S. Esposito
(CERN SY-STI-TCD/BMI)

C. Lederer-Woods, A. Mengoni, V. Becares & the n_TOF Collaboration

Neutrons @ CERN

10:35-11:10
Challenges and developments in neutron metrology for high energy workplace radiation fields
Speaker
Fabio Pozzi



11:30-11:45 The neutron Time-of-Flight facility, n_TOF at CERN: Status and perspectives
Speaker
Alice Manna

SHiP
Search for Hidden Particles

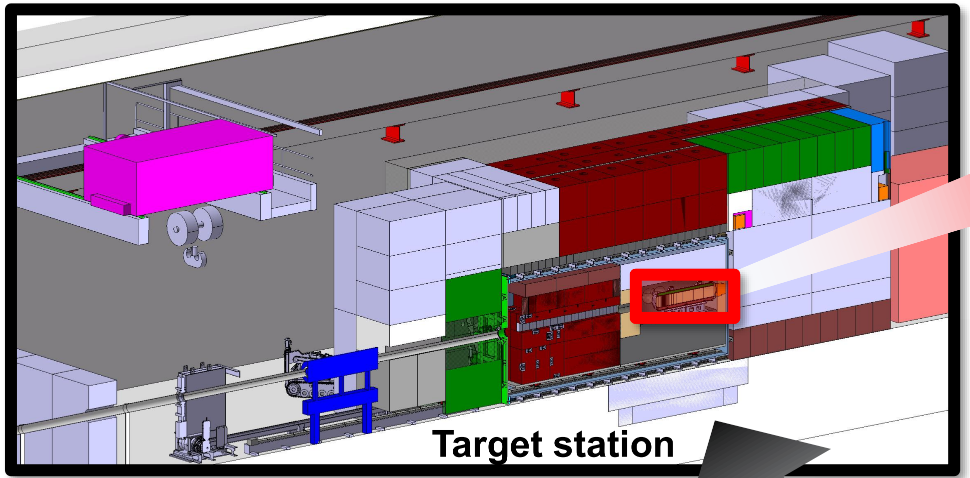
General-purpose experiment in to search for “hidden” particles (dark matter, neutrino oscillations, baryon asymmetry, …)

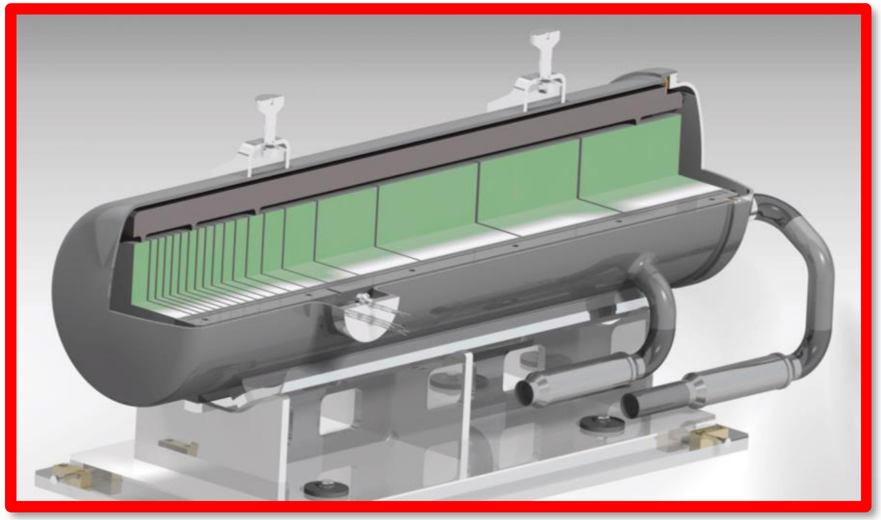
approved

start 2031

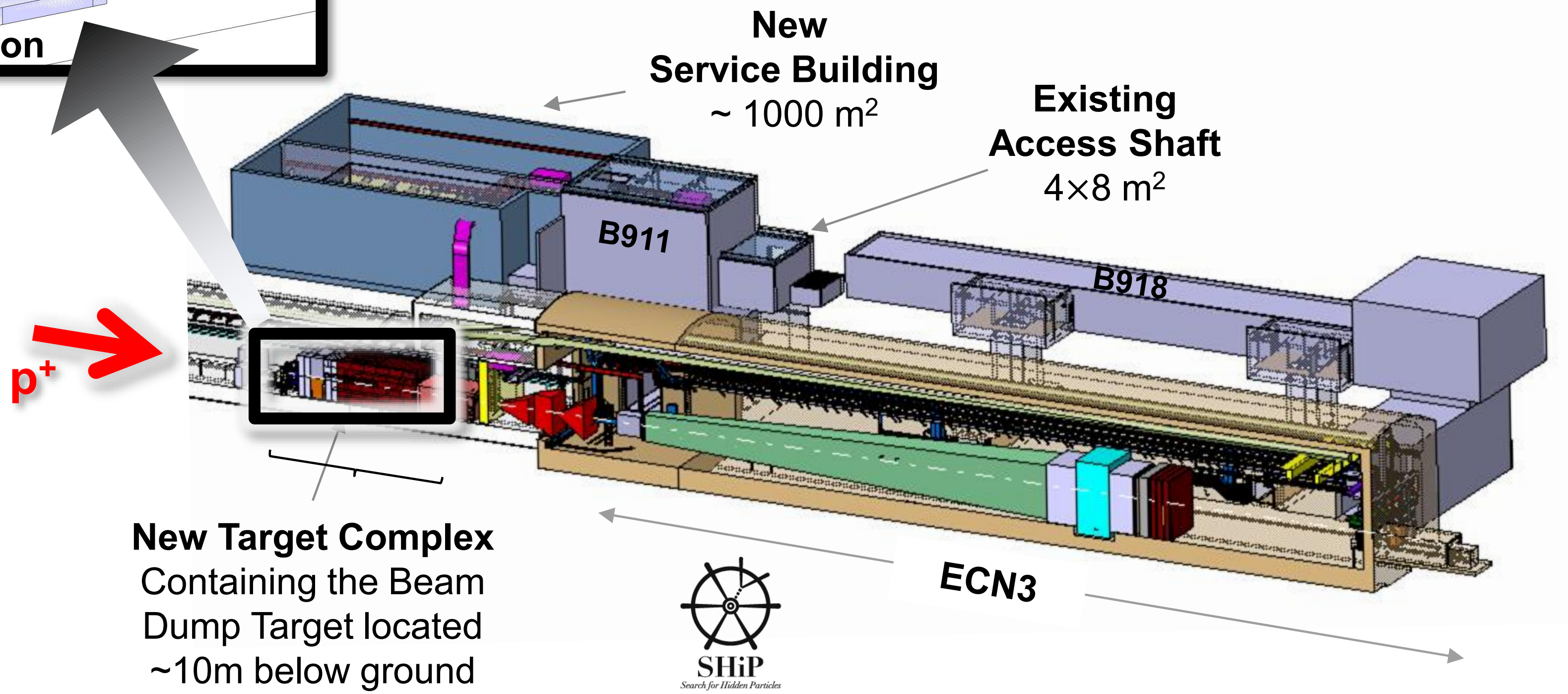
Neutrons from the target complex

BDF/SHiP Complex

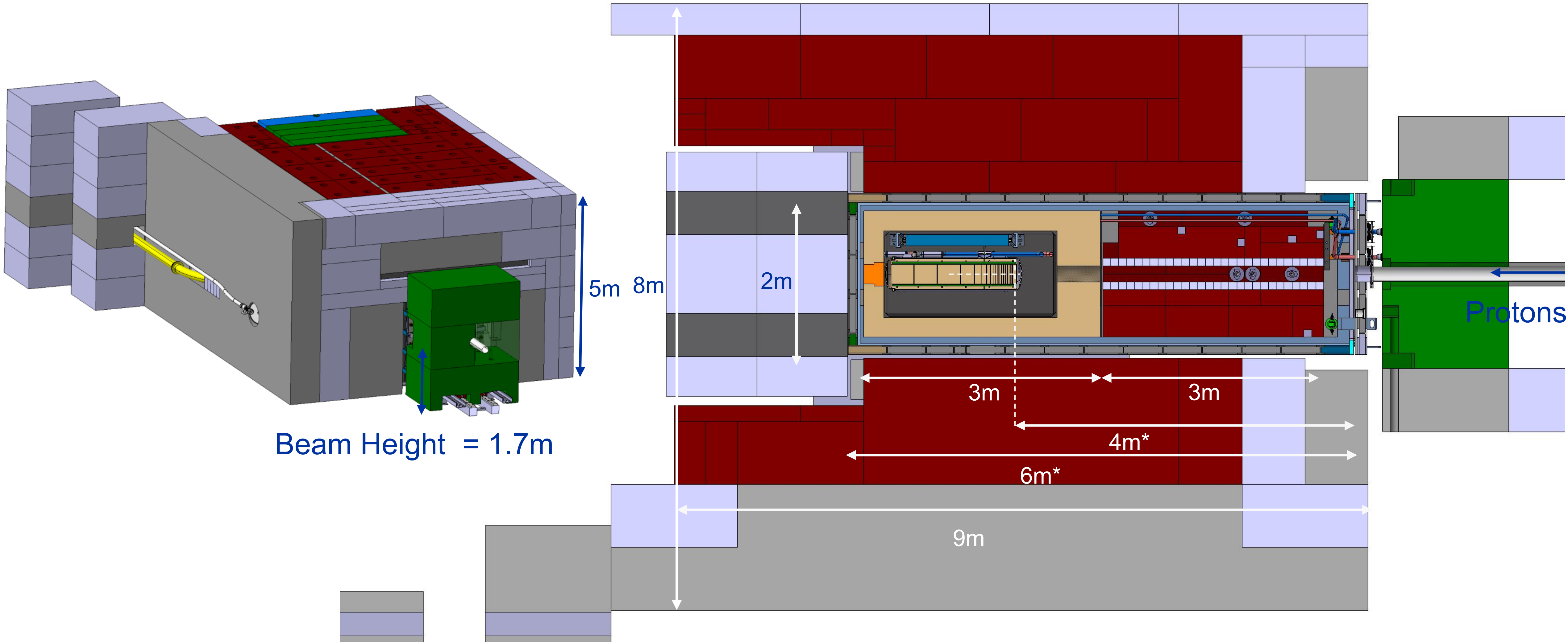




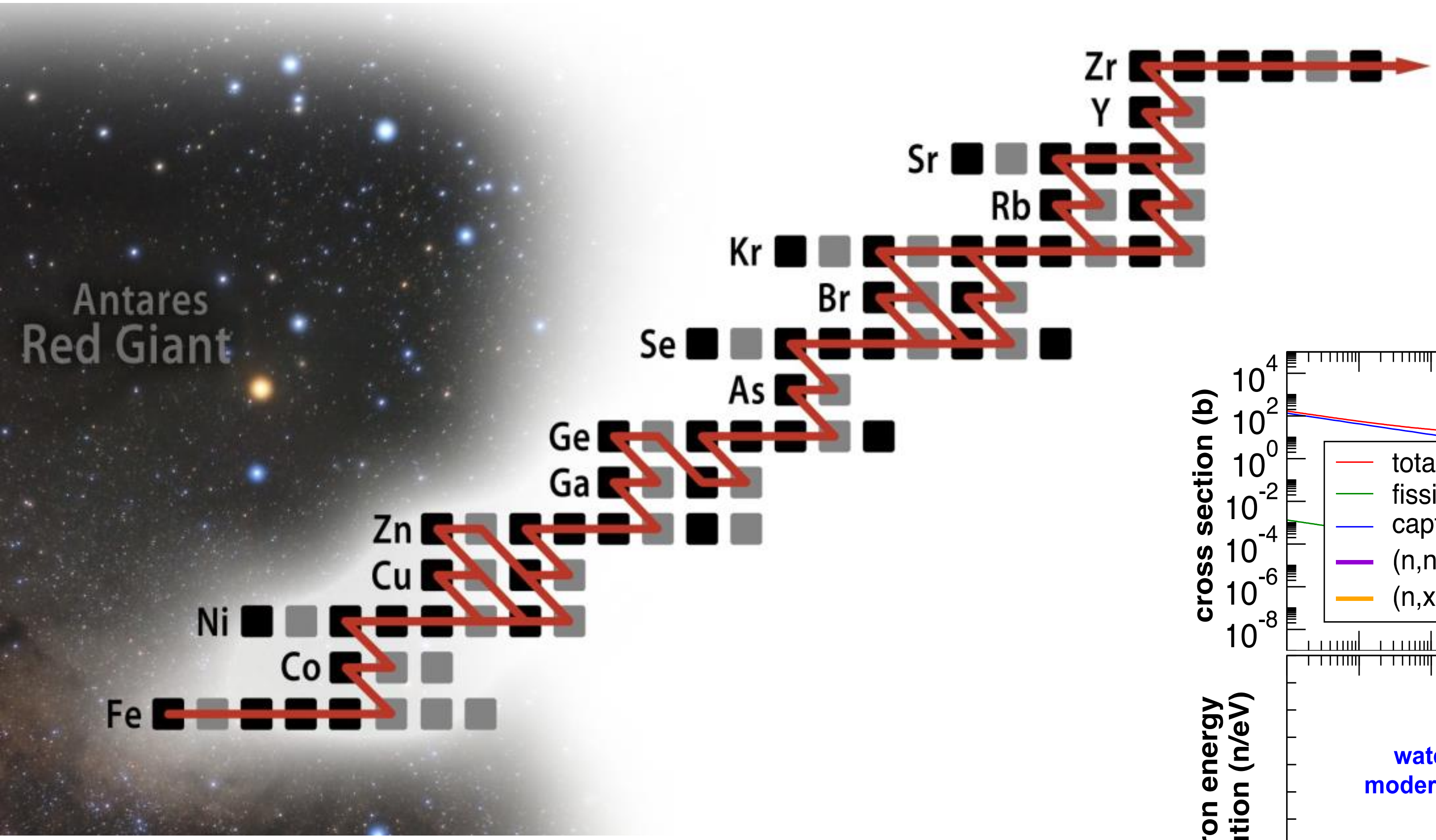
Nominal Design Parameter	Value
Beam type	proton
Beam momentum [GeV/c]	400
Beam pulse intensity [$\times 10^{13}$ p]	4.0
Spill length [s]	7.2
Beam pulse power [kW]	2560
Average beam power [kW] (7.2 s)	356
POT [$\times 10^{20}$ p over 15 years]	6.0



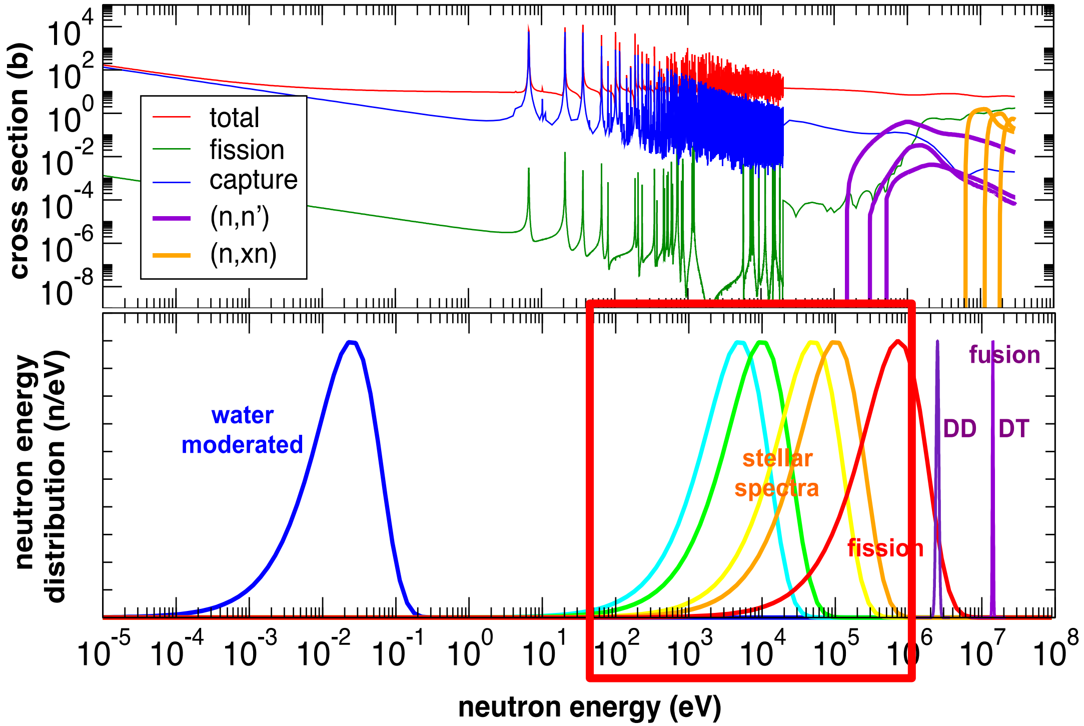
Target station – baseline configuration



Neutrons for nuclear Astrophysics

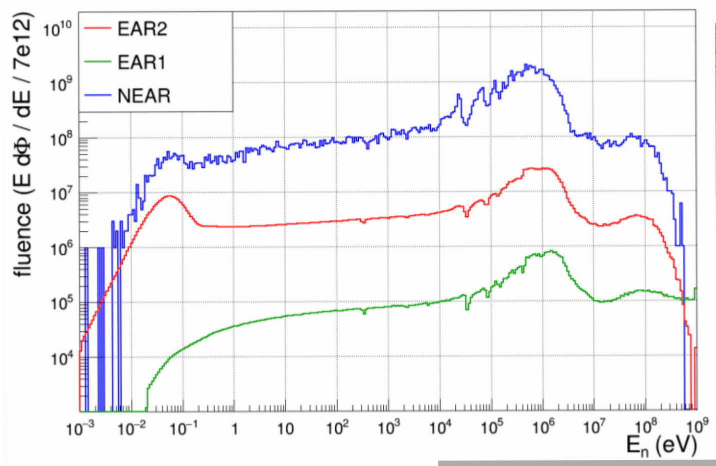


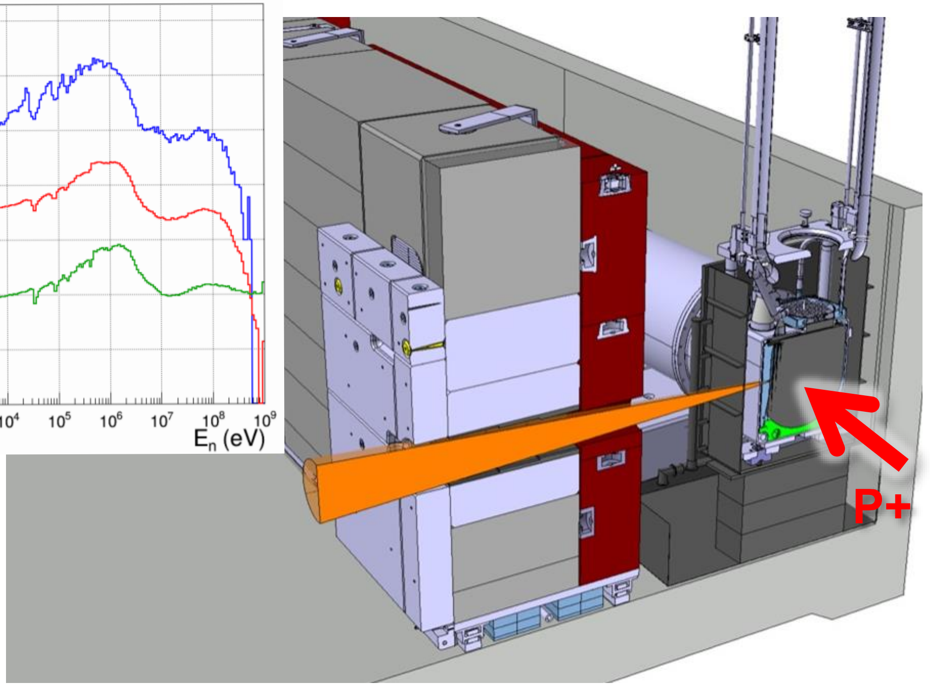
- Stellar nucleosynthesis
  - (n,g) Maxwellian Averaged Cross-Sections (**MACS**)
- **Activation technique**
  - High selectivity (no enriched materials necessary)
  - High flux = higher sensitivity = less mass

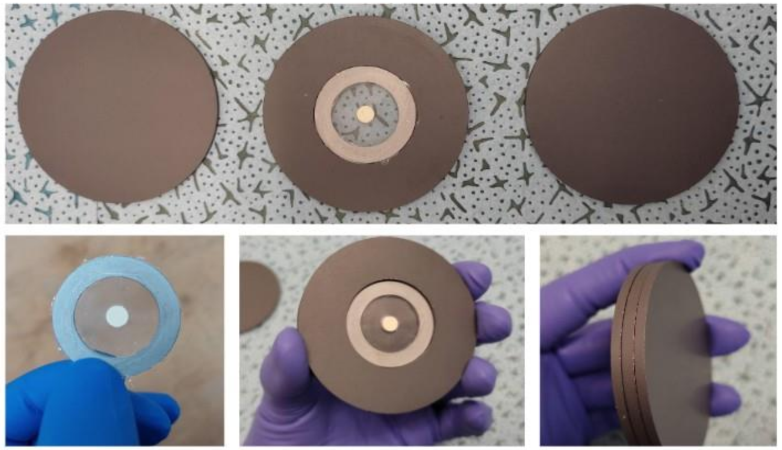


The n_TOF NEAR station

- Activation station at the n_TOF target
  - **Nuclear Astrophysics >> (n,g) via activation**
  - 2.5 m from spallation target **~1e9 n/cm²/pulse**
- Spectral beam tailoring
  - using ^{10}**B$_4$C filters**
  - Spectral-Averaged-Cross-Sections (**SACS**), ideally Maxwell-Boltzmann (MB) for MACS

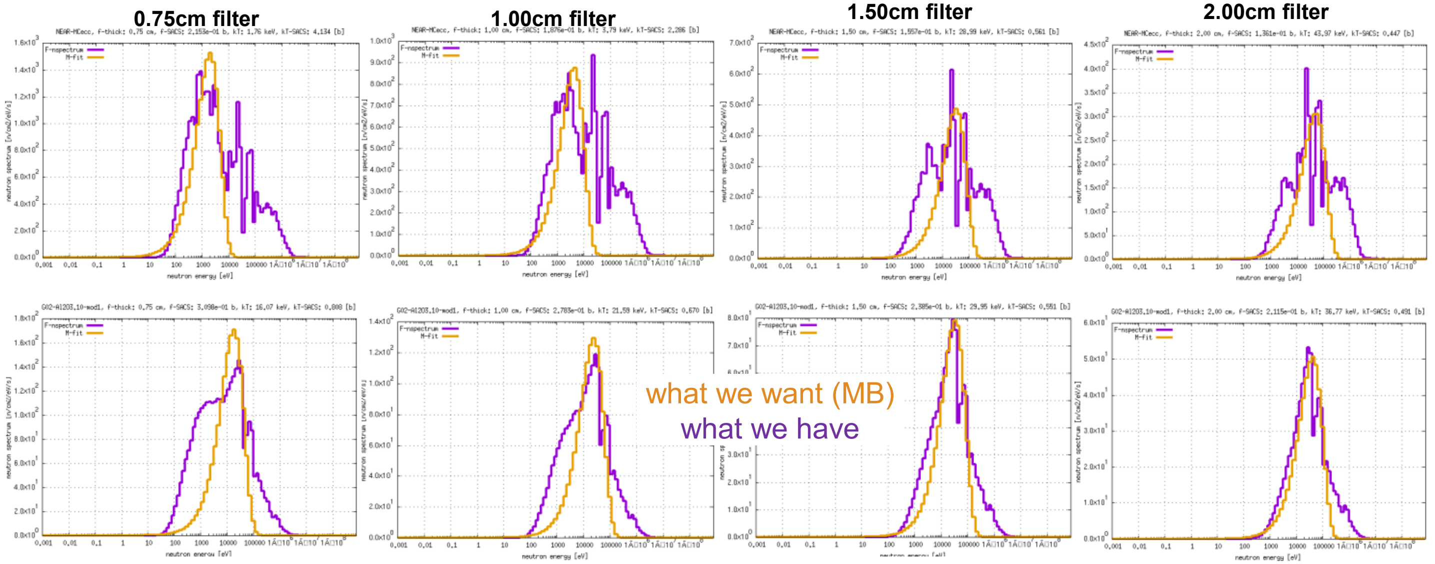






<2026

moderator (2026)

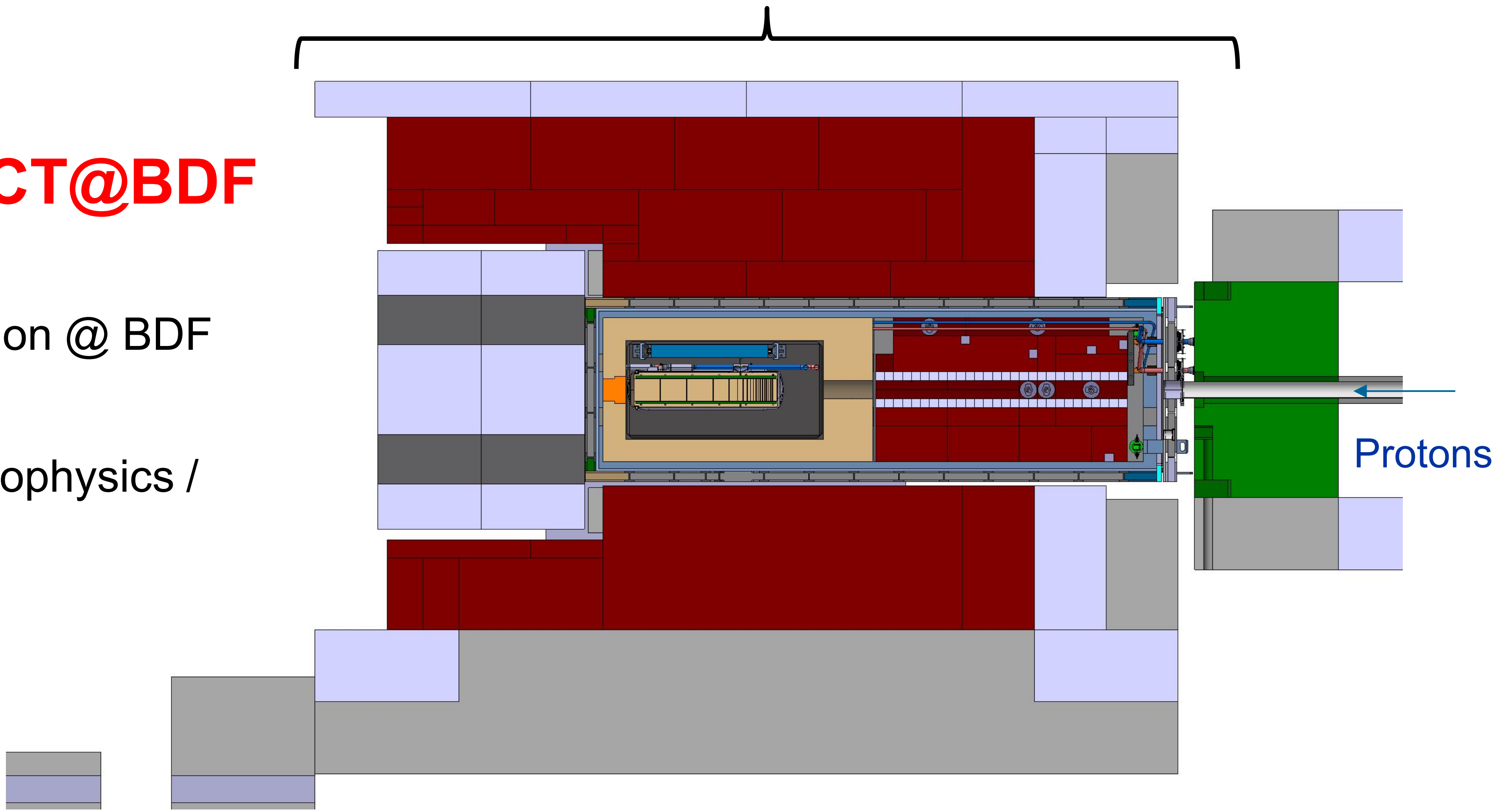


Target station

Proposed – n_ACT@BDF

A **n**eutron **act**ivation station @ BDF

Neutrons for nuclear astrophysics / stellar nucleosynthesis



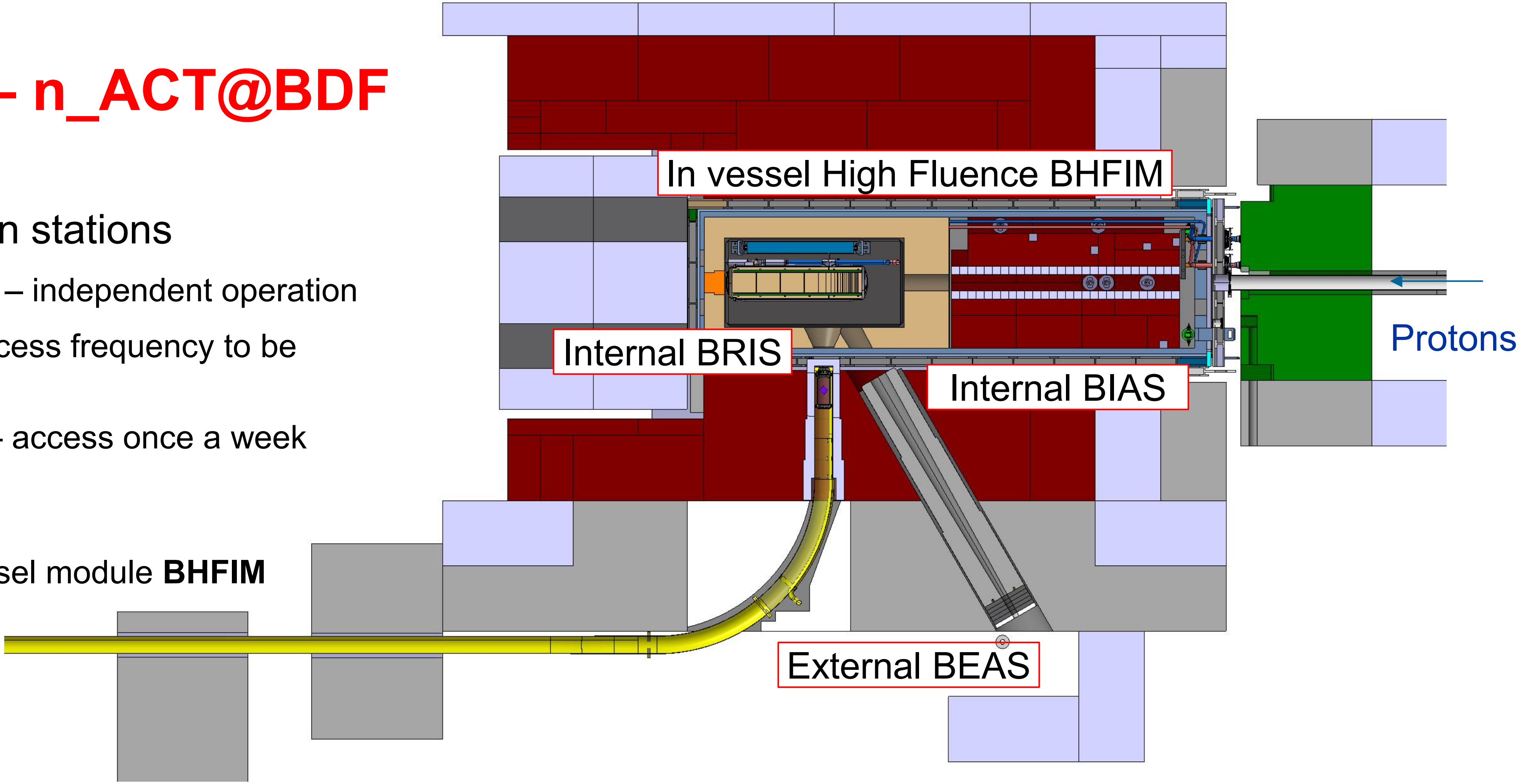
Baseline + n_ACT @ BDF

Proposed – n_ACT@BDF

Up to 3 activation stations

- **BRIS** with rabbit – independent operation
- **BIAS** static – access frequency to be defined
- **BEAS** external – access once a week

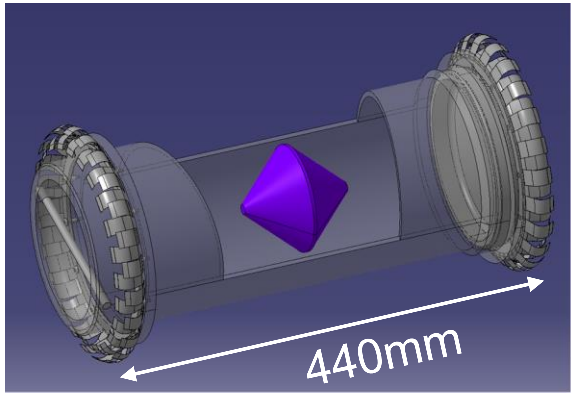
High Fluence In-vessel module **BHFIM**



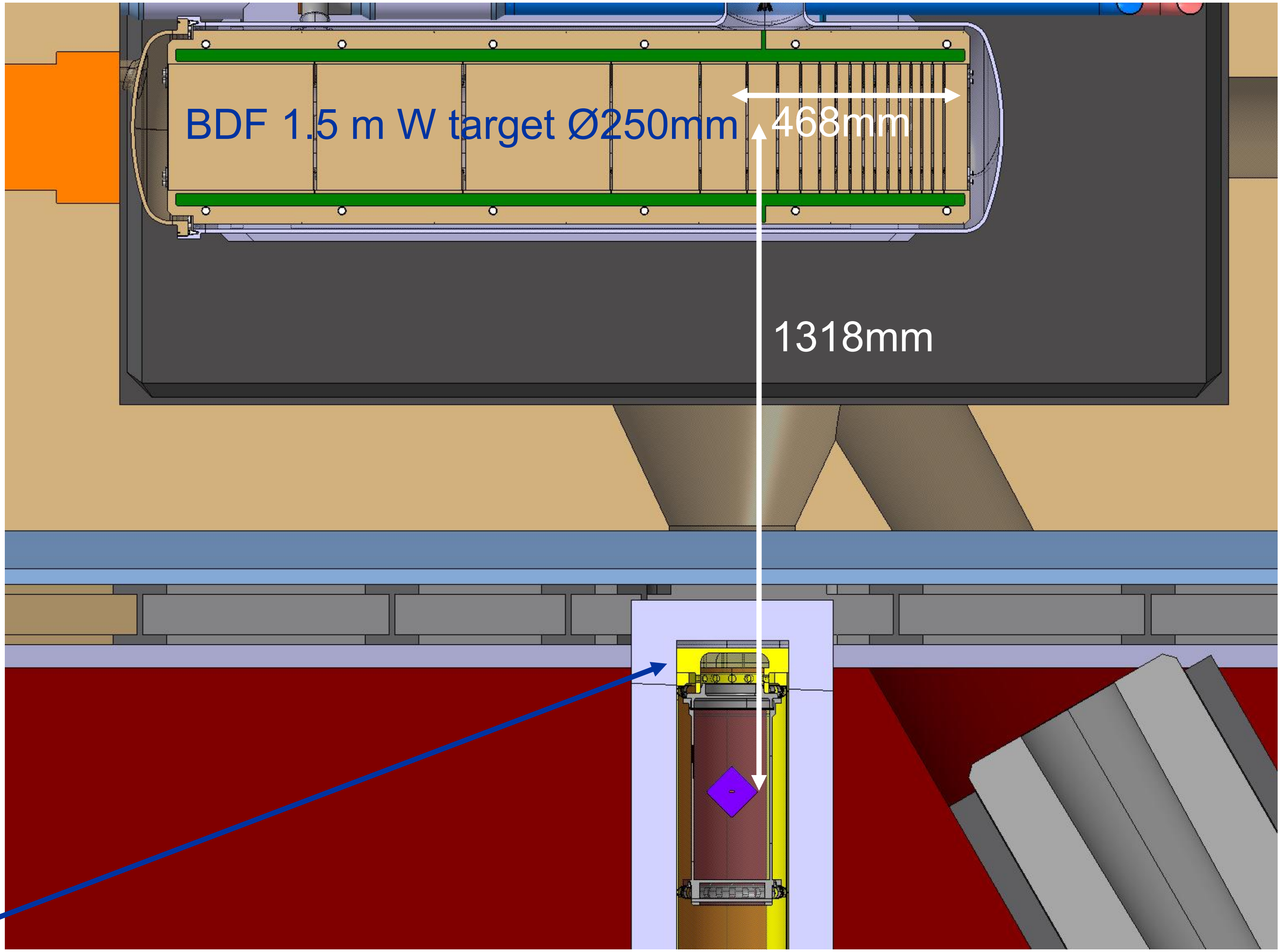
BRIS (internal flexible)

Equipped with a Rabbit system

BRIS Capsule
External Diameter: 200mm

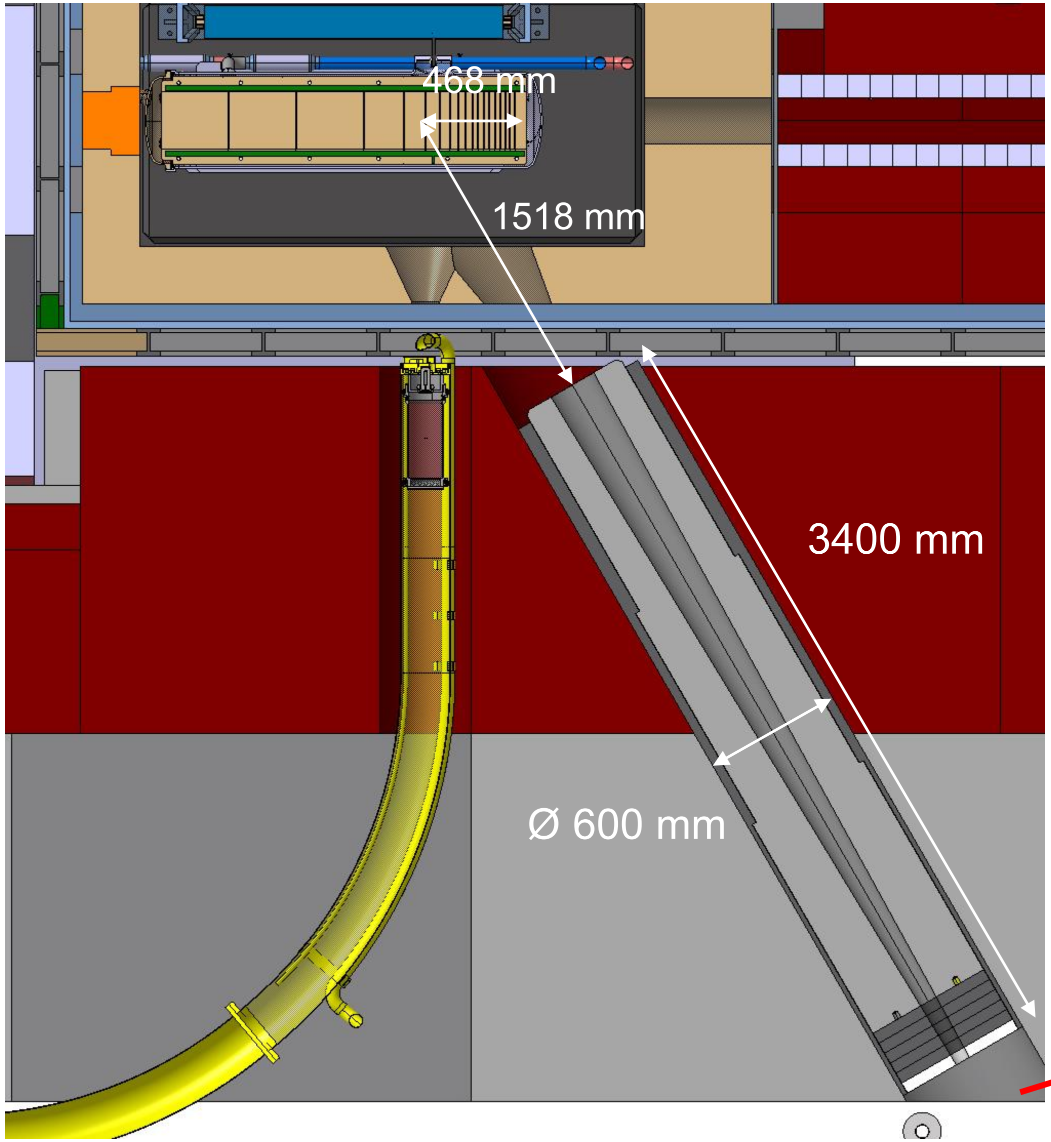


Internal: Ø 150mm x 360mm
Maximum weight ~1 kg
Polyethylene, Aluminium, Carbon fibre

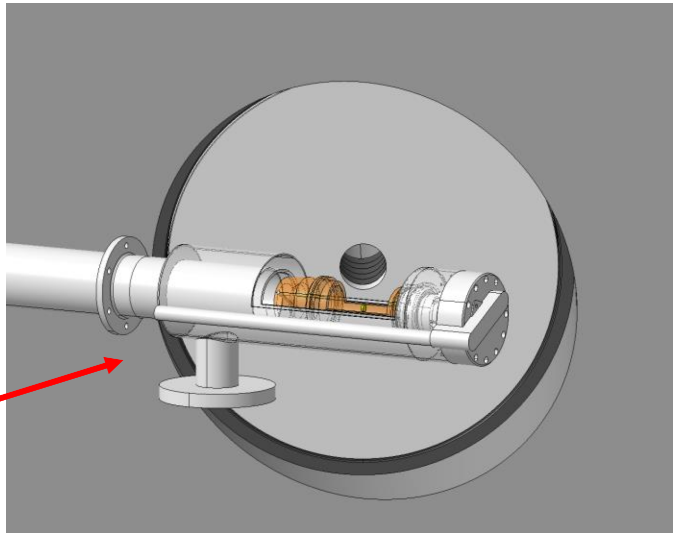


Moderator installed
around irradiation station

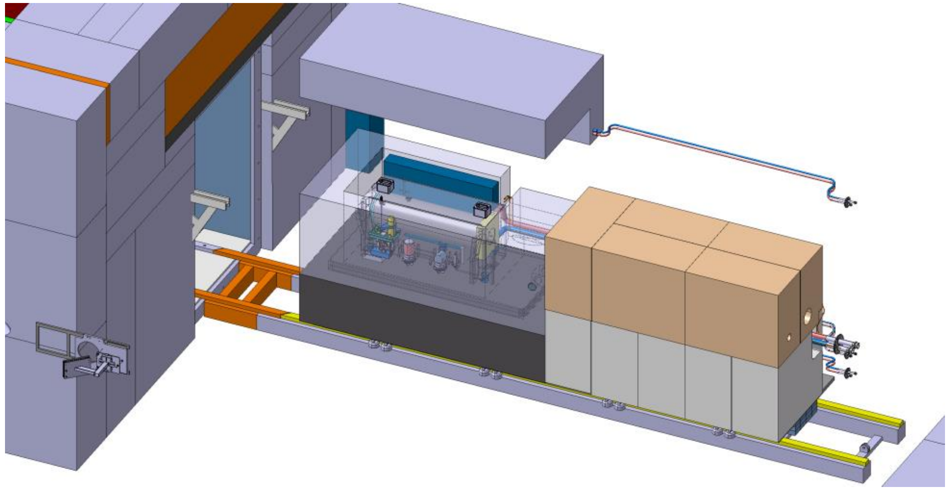
BIAS – BEAS (internal & external static)

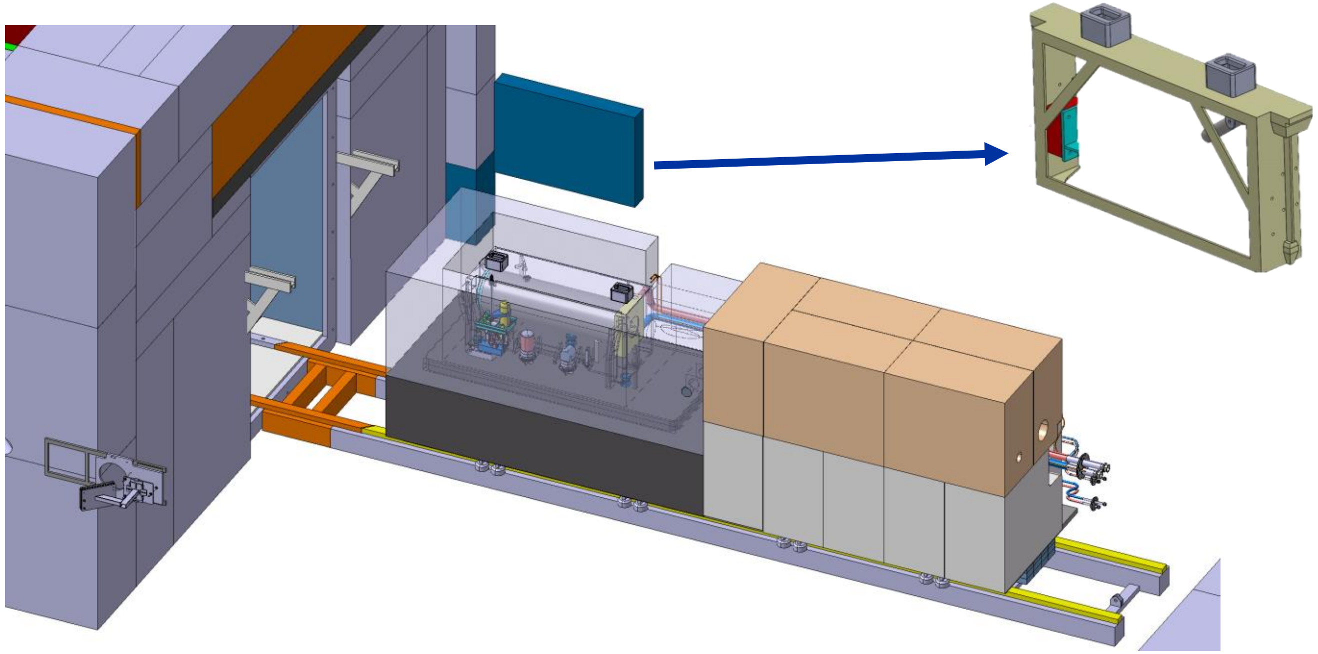


- Internal BIAS flux ~ BRIS
- Collimator system installed inside large ‘’plug’’ (Ø 600 mm)
- Access to retrieve samples and minor reconfiguration: once per week
- Potential extension with rabbit



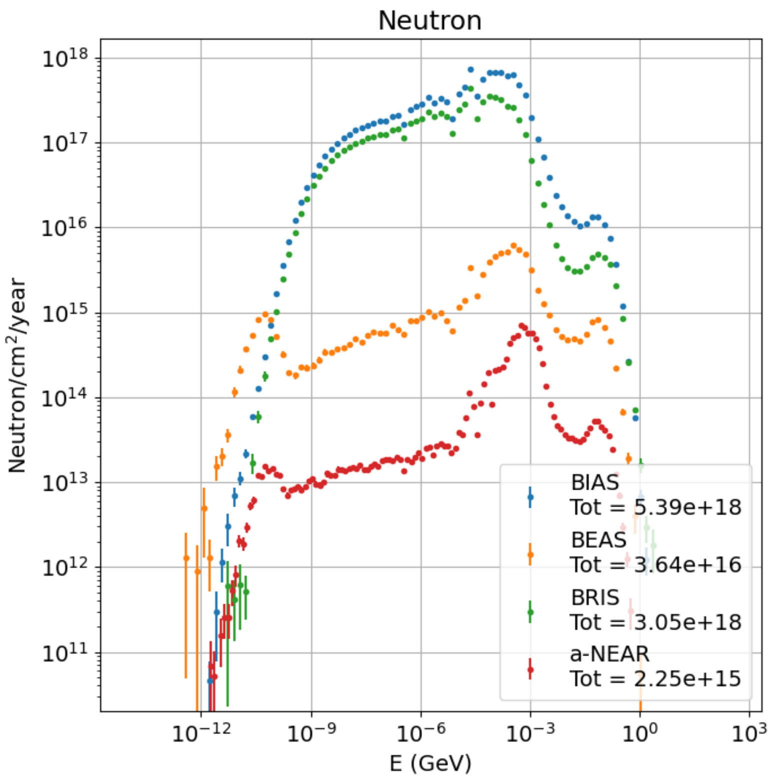
BHFIM



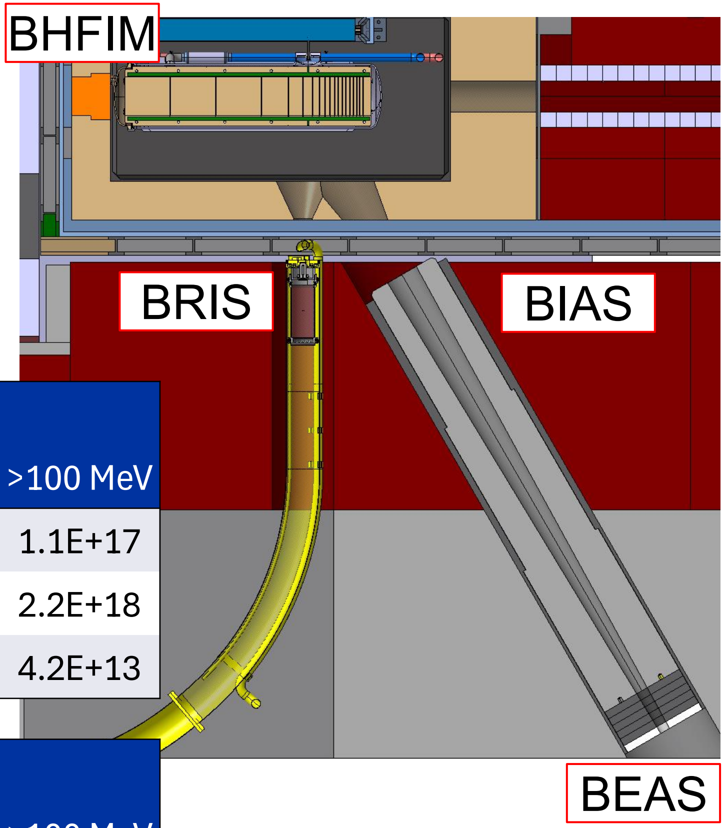


- In vessel module approximate overall size: **1 m (L) 150 mm (W) 900 mm (H)**
- Possible utilities could be connected via vacuum vessel door
- Accessibility once a year: **~1 month to extract** the module

Neutron fluxes



G. Mazzola, L. S. Esposito, Radiation levels for parasitic irradiation stations (2024/04)



position	neutron flux (/cm^2/year)					
	total	>1 eV	>1 MeV	>10 MeV	>20 MeV	>100 MeV
BHFIM1	2.6E+19	2.5E+19	1.9E+18	4.6E+17	4.0E+17	1.1E+17
BRIS/BIAS	2.2E+18	2.2E+18	2.2E+18	2.2E+18	2.2E+18	2.2E+18
BEAS	7.4E+15	7.4E+15	9.8E+14	3.1E+14	2.5E+14	4.2E+13

position	neutron flux (/cm^2/second)					
	total	>1 eV	>1 MeV	>10 MeV	>20 MeV	>100 MeV
BHFIM1	2.0E+12	2.0E+12	1.5E+11	3.5E+10	3.1E+10	8.5E+09
BRIS/BIAS	1.7E+11	1.7E+11	3.8E+09	1.1E+09	9.0E+08	2.2E+08
BEAS	5.7E+08	5.7E+08	7.6E+07	2.4E+07	1.9E+07	3.2E+06

assuming 4e19 PoT / year
150 days of operation / year

Pierre Pelissou, HI-ECN3 Irradiation Opportunities Workshop (6.10.2024)

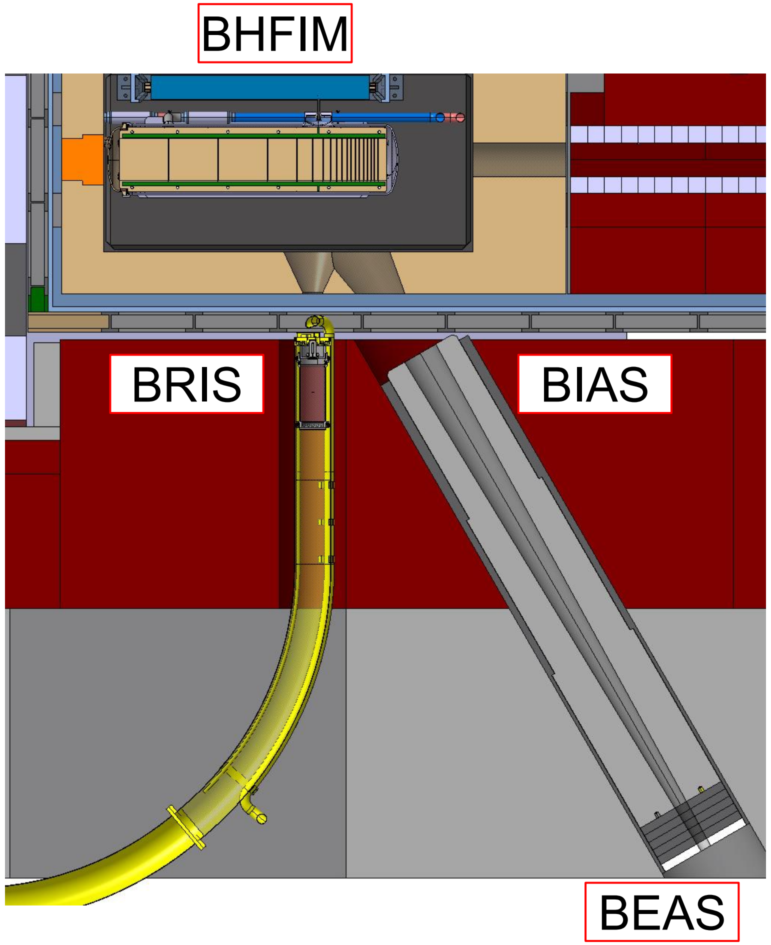
Position	TID (Gy/hour)	Si1MeVN$_{eq}$ (cm^{-2}/hour)	HEH$_{eq}$ (cm^{-2}/hour)
R2E@4m (2 x 10^{16} POT/hour)	10^1	10^{13}	10^{11}

Position	TID (Gy/year)	Si1MeVN$_{eq}$ (cm^{-2}/year)	HEH$_{eq}$ (cm^{-2}/year)
BHFIM1 (4 x 10^{19} POT/year)	10^7 - 10^8	10^{20}	10^{17}

all numbers indicative due to evolving design

Summary & Conclusions

- SHiP experiment in search for “hidden” particles
  - **CERN BDF@ECN3 facility**
  - **Approved**
- Modification of BDF design for complementary applications, i.e. **neutron activation & irradiation**
  - **n_ACT@BDF** for nuclear astrophysics – **proposed**
  - R2Electronics
  - R2Materials
  - …
- **n_ACT ongoing proposal** – next steps:
  - Proposal to SPSC
  - Acquiring funding



position	neutron flux (/cm^2/second)					
	total	>1 eV	>1 MeV	>10 MeV	>20 MeV	>100 MeV
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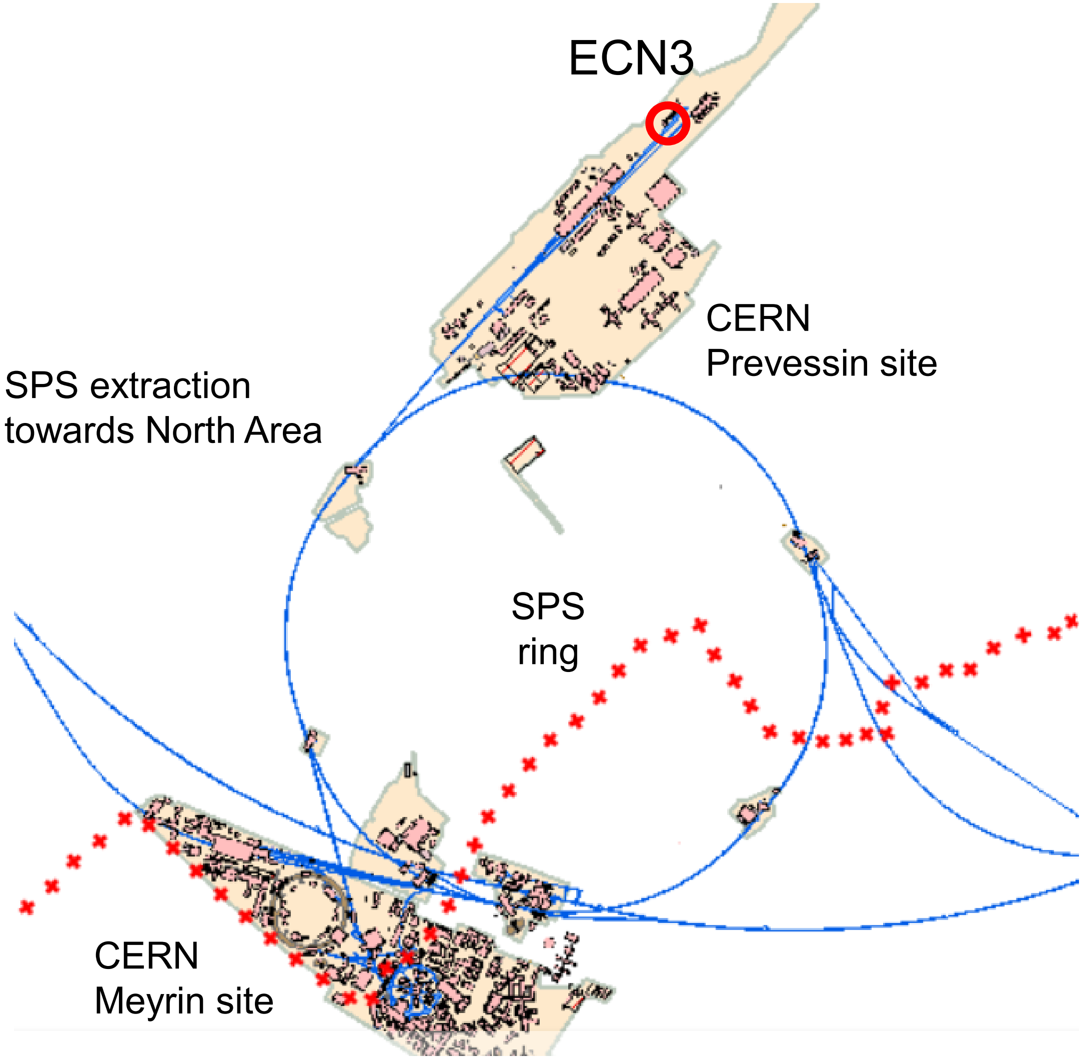
BRIS/BIAS	1.7E+11	1.7E+11	3.8E+09	1.1E+09	9.0E+08	2.2E+08
BEAS	5.7E+08	5.7E+08	7.6E+07	2.4E+07	1.9E+07	3.2E+06

Primary beam – SPS to ECN3



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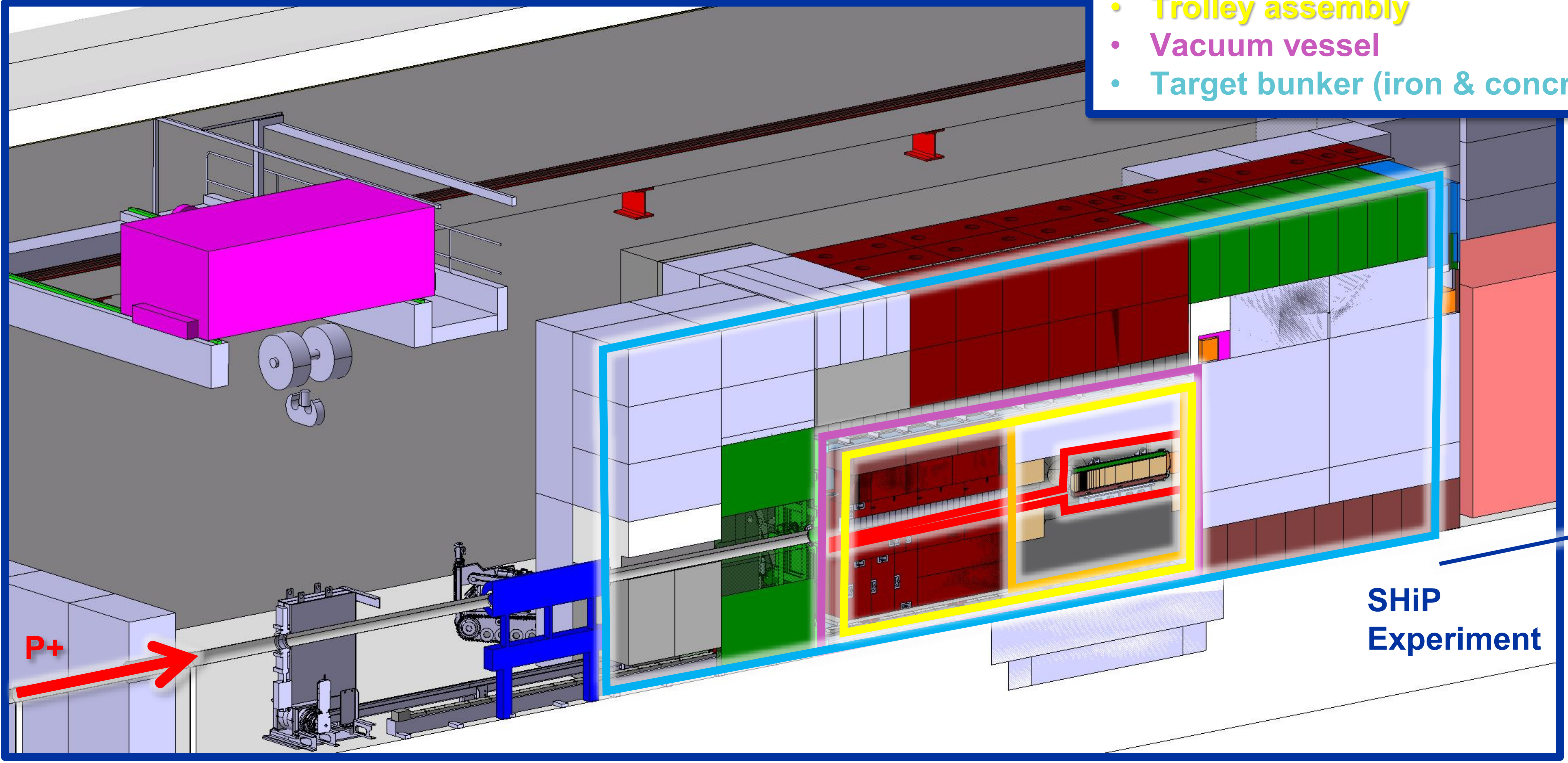
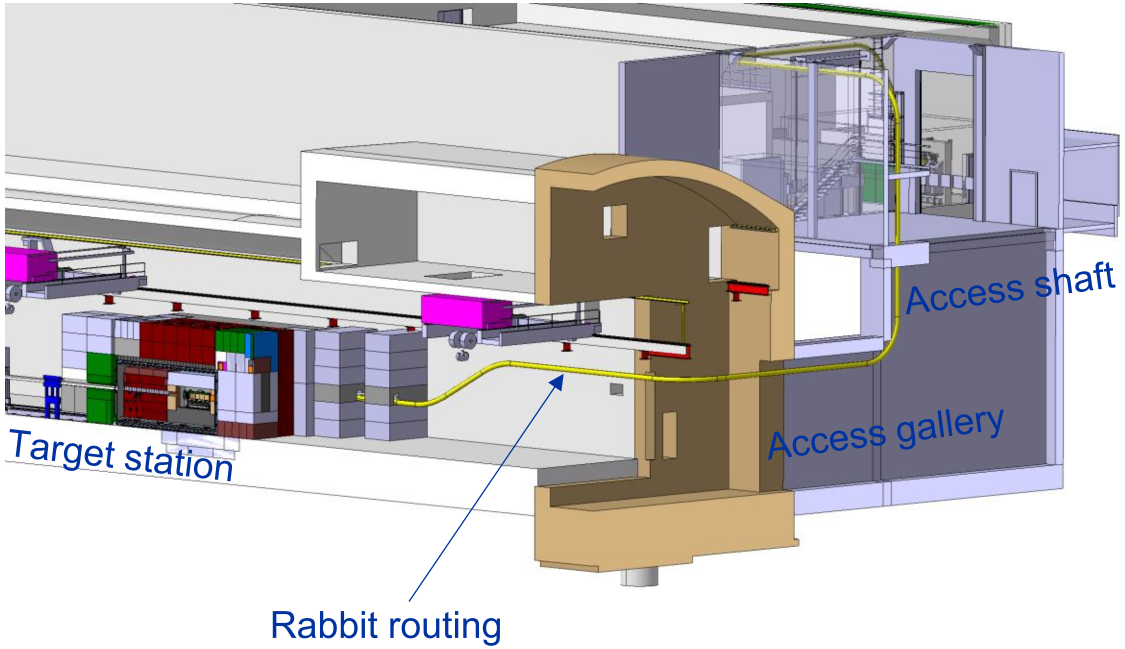
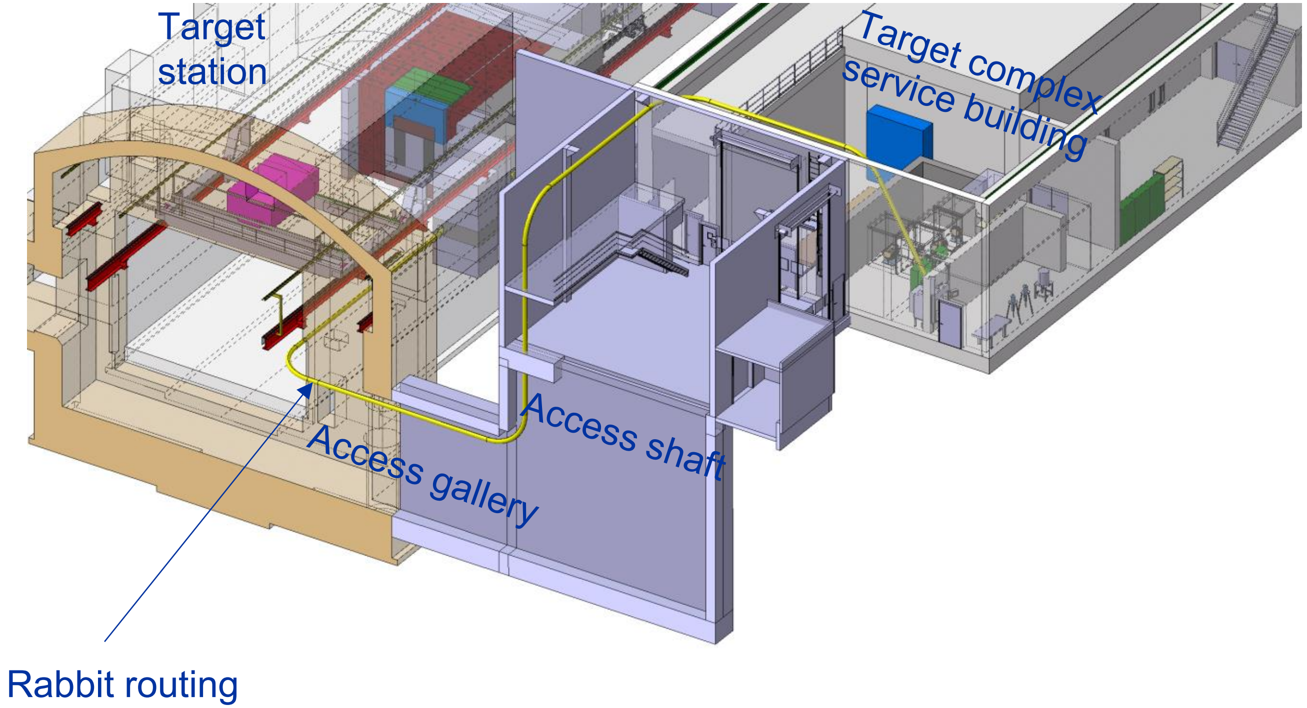
BDF/SHiP – Target Complex

- Target System
- Copper Proximity SS Shielding
- Trolley assembly
- Vacuum vessel
- Target bunker (iron & concrete)



BRIS rabbit routing

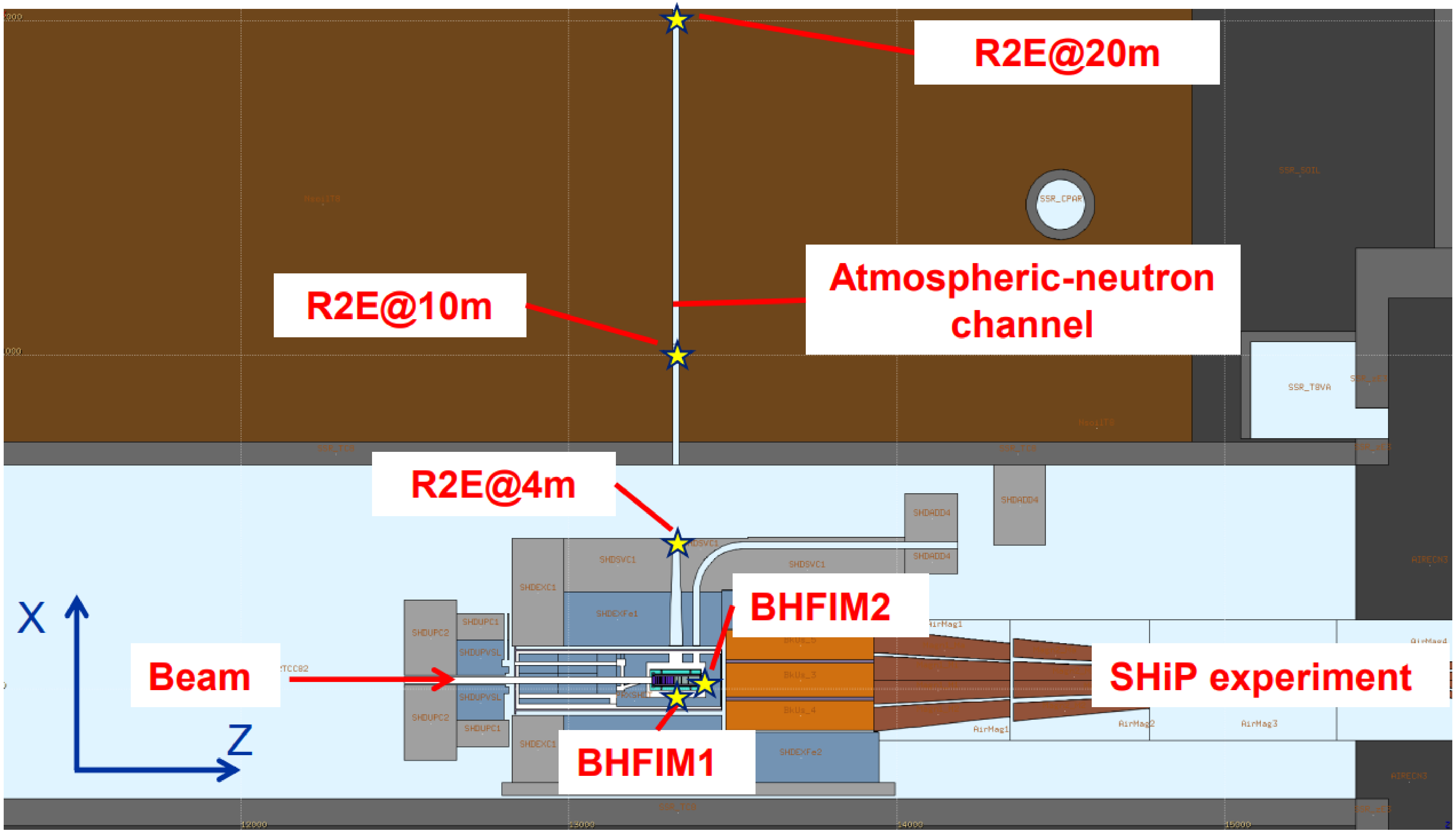




General particle fluxes – neutron dominated

Position	Proton (cm^{-2}/hour)	Photon (cm^{-2}/hour)	Pions (cm^{-2}/hour)	Muons (cm^{-2}/hour)	Neutron (cm^{-2}/hour)	Total (cm^{-2}/hour)
BHFIM1	1.54e+12 (0.01 %)	1.74e+15 (11.88 %)	2.59e+12 (0.02 %)	1.90e+11 (0.001 %)	1.29e+16 (**88.09 %**)	1.46e+16
BRIS	1.11e+11 (0.01 %)	1.85e+14 (10.85 %)	6.55e+10 (0.004 %)	1.13e+10 (0.001 %)	1.52e+15 (**89.14 %**)	1.71e+15
BIAS	1.99e+11 (0.007 %)	3.29e+14 (10.89 %)	2.63e+11 (0.009 %)	3.04e+10 (0.001 %)	2.69e+15 (**89.09 %**)	3.02e+15
BEAS	1.43e+10 (0.07 %)	2.88e+12 (13.63 %)	1.21e+10 (0.06 %)	4.65e+09 (0.02 %)	1.82e+13 (**86.23 %**)	2.11e+13

FLUKA Geometry – CDS target



Courtesy of G. Mazzola
More details can be found in his presentation: "FLUKA simulations and radiation field in potential irradiation locations"

Table of R2E parameters and particles' fraction (per hour)

Position	TID (Gy/hour)	Si1MeVN$_{eq}$ (cm^{-2}/hour)	HEH$_{eq}$ (cm^{-2}/hour)	Particles' fraction
R2E@4m (2 x 10^{16} POT/hour)	10^{1}	10^{13}	10^{11}	Neutrons (N): 99% Charged Hadrons (CH): <1%
R2E@10m (2 x 10^{16} POT/hour)	10^{0}	10^{12}	10^{11}	N: 99% CH: <1%
R2E@20m (2 x 10^{16} POT/hour)	10^{-1}	10^{11}	10^{10}	N: 99% CH: <1%
CHARM R10 (9 x 10^{13} POT/hour)	10^{-1} - 10^{0}	10^{9}	10^{8} - 10^{9}	/
CHARM R13 (1.2 x 10^{14} POT/hour)	10^{1}	10^{10}	10^{10}	N: 80% CH: 20%
NTOF_NEAR N1 and N4 (4 x 10^{15} POT/hour)	10^{-2} - 10^{0}	10^{10}	10^{9}	N (>20 MeV): 98% CH: 2%

Pierre Pelissou, HI-ECN3 Irradiation Opportunities Workshop (6.10.2024)

- The above figures are meant to give a reliable order of magnitude (qualitative study)