n_TOF (facility) performance upgrade strategy
Joint accelerator Performance Workshop
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Outlook

- n_TOF facility, main components and challenges (a bit of historical background as well…)
- Spallation target – performances and expected lifetime
- Neutron beamlines
- Wishes for the future…
n_TOF facility at CERN

- Neutron time-of-flight facility for **high accuracy neutron-induced cross-section measurements**
  - Focused on neutron astrophysics & nuclear technology & medical applications

- Spallation source based on 20 GeV/c proton pulse, 7 ns $1\sigma$, $8.5 \times 10^{12}$ ppp

Beam kinetic energy = $n_b \times I \times E_b = 1 \times 8.5 \times 10^{12} \times 20 = 27 \text{ kJ}$

Beam inst. power = $27 \text{ kJ}/7 \text{ ns} = 3.8 \text{ TW}$

![Diagram of n_TOF facility](image.png)
Neutron target area

- Target installed in a vertical shaft
- Access and handling from the service gallery (10 m above)
- Between 1999 and 2018, n_TOF operated with 2 different neutron production targets, with evolutionary designs
- Since 2021, operating with a third-generation “revolutionary” target design
Neutron target area

Target area in 1999 → 20 years of radiation → Target area 2020

±50-100 MGy
First generation n_TOF spallation target
1999-2004

- Facility was conceived in 2000 and operated with a Pb target immersed in a pool with cooling water
- First generation n_TOF spallation target

Lessons learnt:
- Must guarantee enough cooling and beam spot
- Surface oxidation due to rupture of protective layer (flushing)
- Water chemistry must be controlled
- Pure Pb blocks require mechanical stabilization

Prior to installation
After target removal in 2013
Water cooling was maintained with the 2nd generation target, but monolithic block inserted in a pressurized vessel resulted in full chemistry control.

Prior to installation (2008)  
During removal operation (2019)

Lessons learnt:

- Water contamination due to contact between $\text{H}_2\text{O}$ and Pb is a major operational challenge
- Operational optimisation for vertical flight path
- Complex Al geometries a challenge for radioactive waste disposal
Dismantling of 2\textsuperscript{nd} generation spallation target

- Removing and packaging a contaminated neutron spallation target & related ancillaries is not straightforward – but \textbf{fully successful}

- Combined mix of well-prepared procedure, remote handling and robotics

\textbullet\ NB: spallation target exchange can happen only in a LS
Third generation n_TOF spallation target

2021-2032

- 3rd generation spallation target, pure Pb based, N_2-gas cooled, water moderated, operational since July 2021 – incorporating operational feedbacks

- Providing improved physics performance (more neutrons, less background)


Focus – reliability & physics performances
Pb is a non-structural material, low melting point, very low yielding point (hence \textbf{low $\Delta T$ is key for reliability} $\rightarrow$ hence the efforts for large beam spot on target)

(listen for $\pm$kJ impacting on Pb)

2.6 MPa vs. 1 MPa (plastic flow onset)
6 type-K thermocouples to monitor Pb surface temperature

Beam size on target

On axis

Off axis

Cooling station parameters
Thanks to the excellent work done by ABT, OP, BI and RP (+STI), **large beam spot on target** (and its continuous monitoring via SEM grid) is now available (→ Y. Dutheil’s talk)

This optimisation, coupled with efficient (gas) cooling systems and target thermocouples, **allows for target average power increase** (166*10^{10} p/s to 220*10^{10} p/s) (→ N. Patronis/D. Cotte’s talk)

Facility “homologation” with Tripartite Authority (ASN/OFSP) in the pipeline (TOF-L-SF-0005)
What is the lifetime of the spallation target?

- If the n_TOF Facility is to continue with its physics/technological programs, a target exchange must be foreseen not later than LS4
  - Limitations induced by Pb plastic creep, corrosion aspect of Al & bimetallic transition (TOF-TAR-ES-0003)
- EoL foreseen around 2032, hence hopefully should stretch until LS4
- Considering the project timelines, Consolidation Project shall start right after LS3 (O(2028-2029))
- Extra information will be extracted from the Target #2 packaging & autopsy – foreseen in mid 2023 (TOF-PM-MG-0004)
H primary neutron beam line

- Spallation target
- Neutron shielding
- 1st collimator
- 2nd "shaping" collimator
- Filter station
- SmCo sweeping magnet
V primary neutron beam line

1st collimator

2nd “shaping” collimator

Filter station

SmCo sweeping magnet

Spallation target

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Neutron primary beamlines

- No major upgrades in the beamlines foreseen for the time being
- Latest upgrade (LS2) were two equipment in the horizontal beam line

SmCo “sweeping” magnet

2nd “shaping” collimator

Thanks to TE/MSC
NEAR facility and infrastructure

- In 2020 n_TOF Collaboration proposed the realization of a "near" target area for neutron activation measurements (CERN-INTC-2020-073, INTC-I-222)

- Enabled by the Target #3 works during LS2 and the modification of the target shielding to ease target installation and (future) dismantling of the infrastructure (TOF-J-EC-0001)

- During 2021, already several measurements led to physics results (coordinated and presented at INTC) as well as new experimental proposals (INTC-P-623, INTC-P-641)

- Employed also for mixed-field radiation testing of commercial equipment and lubricants (in the R2E/M context) for CERN-wide applications (Phys. Rev. Accel. Beams 25, 103001)
What future for NEAR?

- n_TOF Collaboration interested in **further exploring options for further development of NEAR**
  - i.e., rabbit systems for short irradiation inside the spallation target and subsequent irradiation

- Extra funding may be available from specific member states for ”special projects” – still under discussion now (hence no commitment yet from CERN side…)

- Staged project could be foreseen, **strong synergies with ISOLDE sought** from both physics' communities
  - Dream: production of radioactive material, irradiation in n_TOF target & gamma measurements post activation
Conclusions

- Large facility consolidation (target, horizontal beam line) has taken place during LS2
- Physics production full steam ahead, guarantee by new spallation target and efficient and reliable beam delivery
- No major upgrade foreseen during LS3, but to be prepared in advance in view of LS4
- New ideas and proposals from n_TOF Collaboration being proposed that may have an impact on infrastructure, but no commitment yet
Spallation target ready for installation

Cooling and moderator station
Neutron production at CERN

- Facility requires **low-γ background** conditions and **high n/p yield**
- Pb best possible target material:
  - High elastic neutron cross-section
  - (very) Low inelastic neutron cross-section, reducing reabsorption