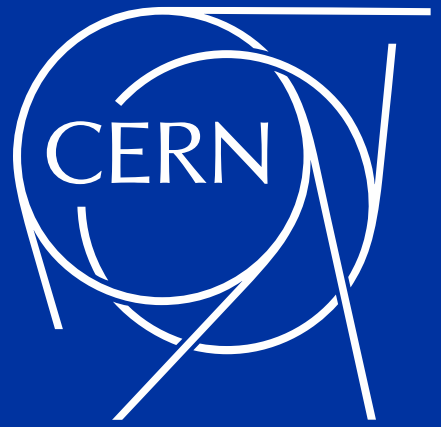


n_TOF Facility at CERN

NSTAPP – Neutrons in Science, Technology and Applications

M. Calviani (SY-STI)

for the n_TOF team (past & present)

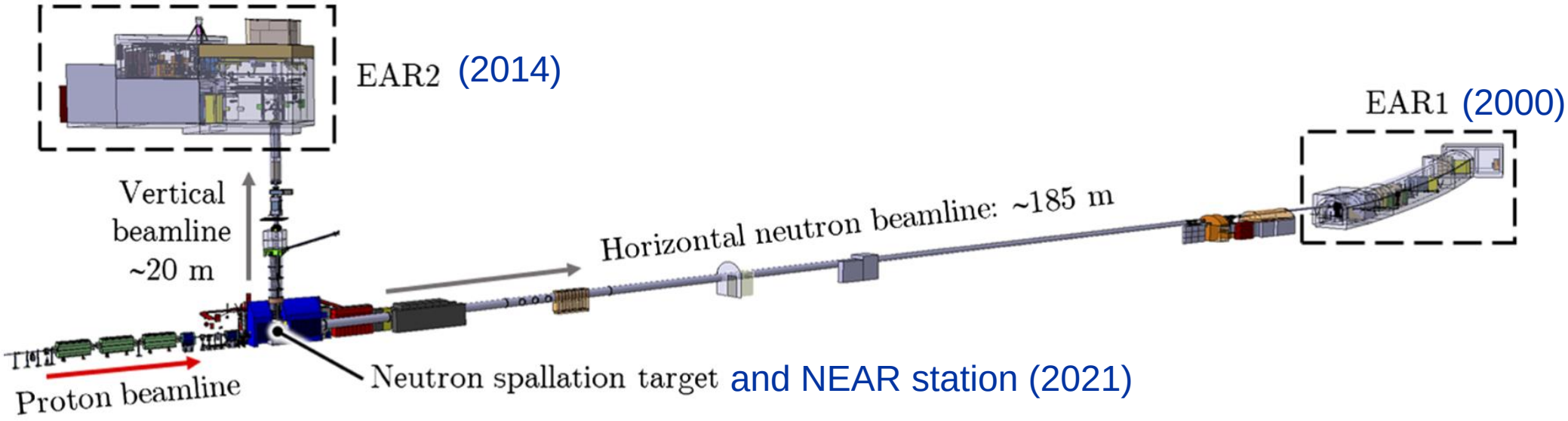
22nd November 2021

Outline

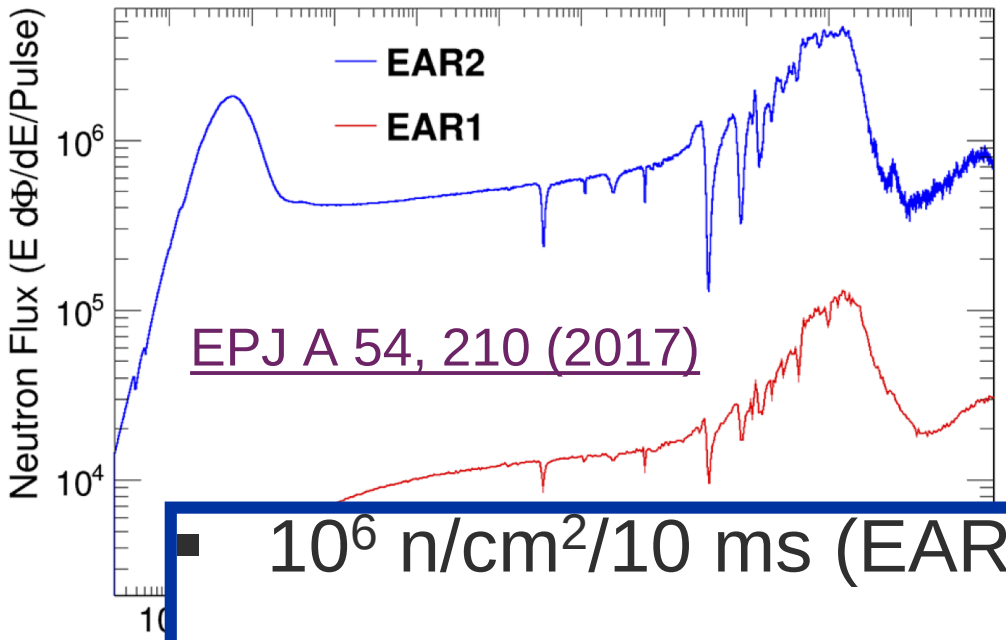
- Introduction to the n_TOF Facility
- History of spallation targets and infrastructure
- Horizontal and vertical neutron beam lines
- Experimental Stations
- Conclusions

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
- Original idea from C. Rubbia (CERN-LHC-98-002-EET, 1998)
- Spallation source based on 20 GeV/c proton pulse, 7 ns 1σ, 8.5*10^{12} ppp



Neutron production at n_TOF Facility



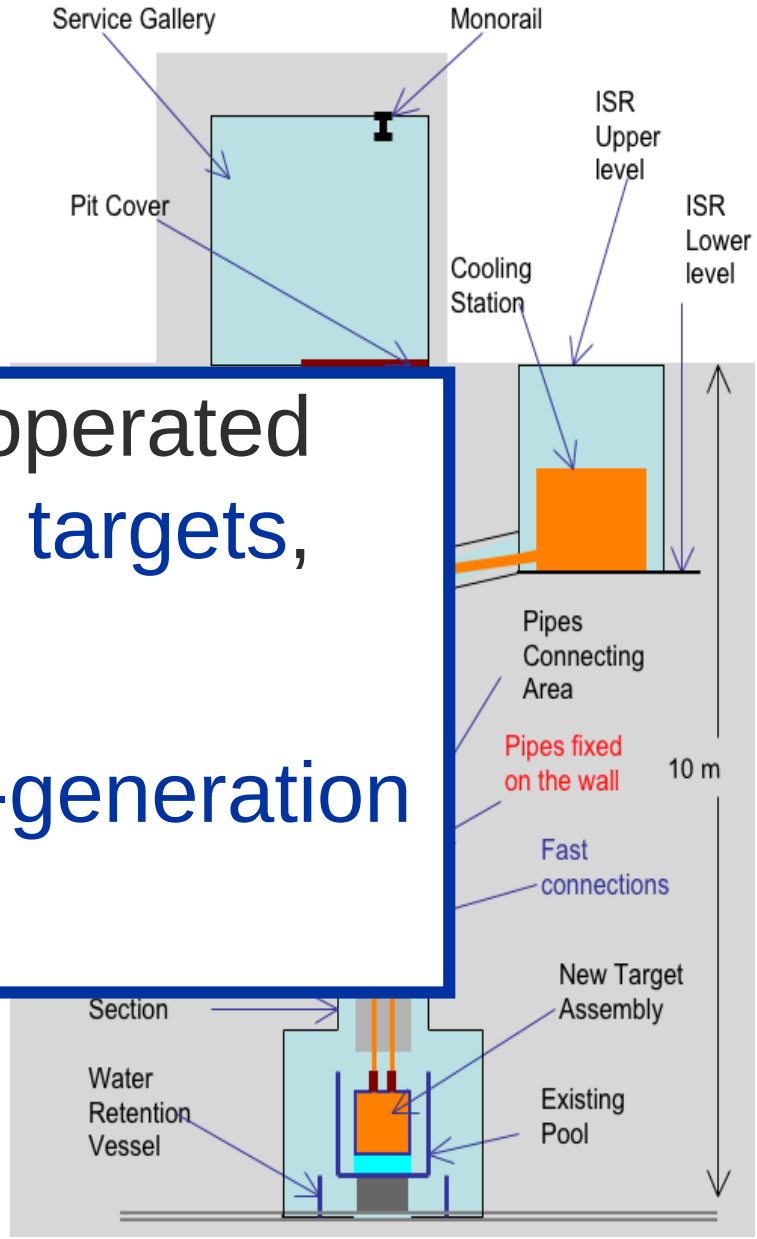
- Facility requires:
  - Very high instantaneous neutron fluence
  - Very low prompt and delayed photon flux
- From a physics standpoint, **pure Pb** is the best possible target material

- 10^6 n/cm^2/10 ms (EAR2) – unique for radioactive isotopes
- High energy resolution (~10^{-4})
- Large energy range (~meV to few GeV)
- Low repetition rate (<0.8 Hz)

Neutron target area

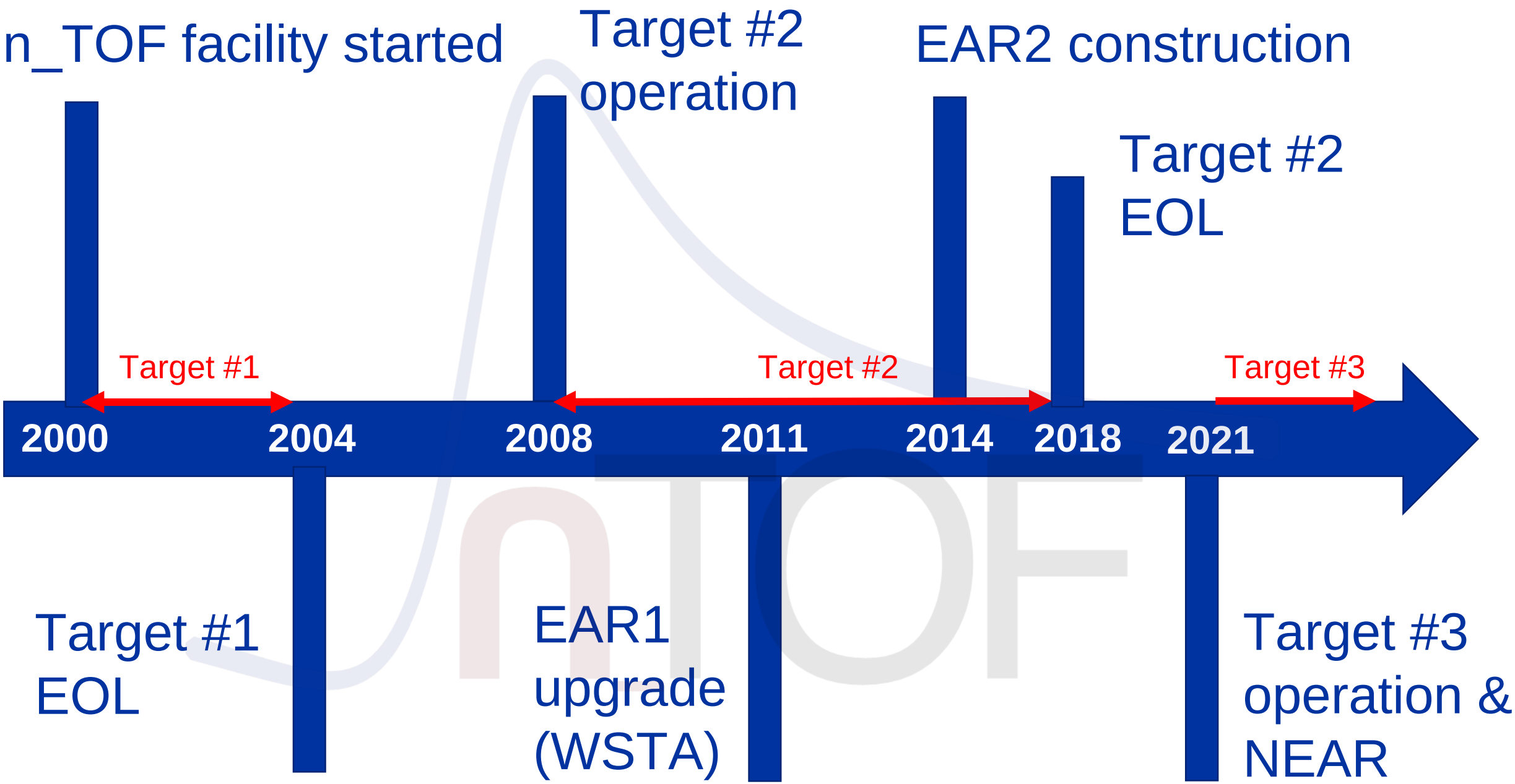
- Target installed in a vertical shaft
- Acces
(10 m

- 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 1999 → 20 years of radiation → Target area 2020

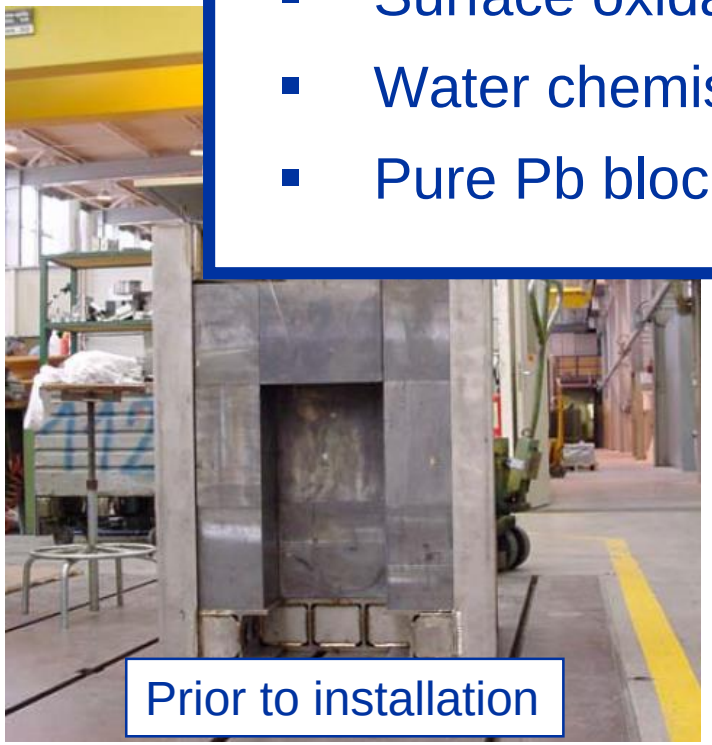

n_TOF facility started
Target #2 operation
EAR2 construction
Target #2 EOL
Target #1
Target #2
Target #3
2000
2004
2008
2011
2014
2018
2021
Target #1 EOL
EAR1 upgrade (WSTA)
Target #3 operation & NEAR

First generation n_TOF spallation target

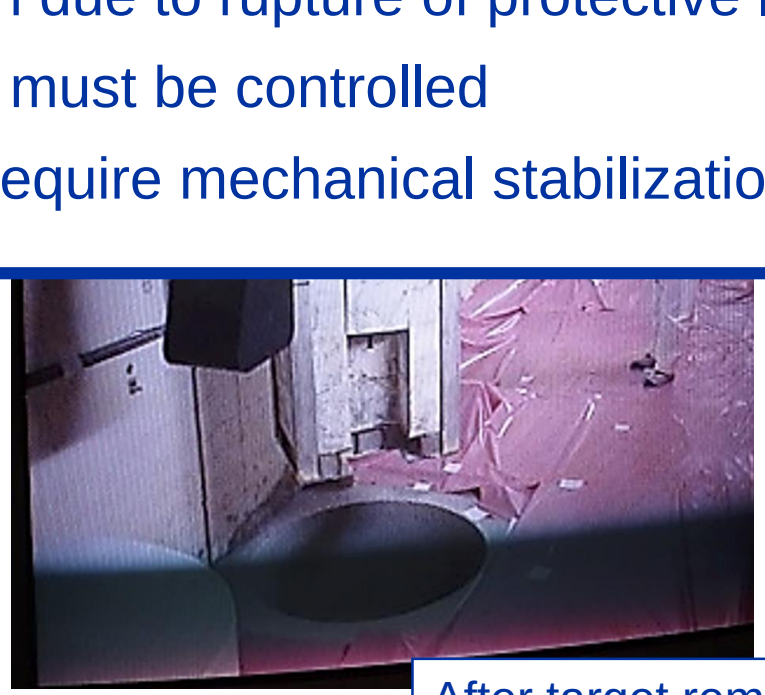
1999-2004

- Facili
  imme

- **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

Second generation n_TOF spallation target
2008-2018

- Wate
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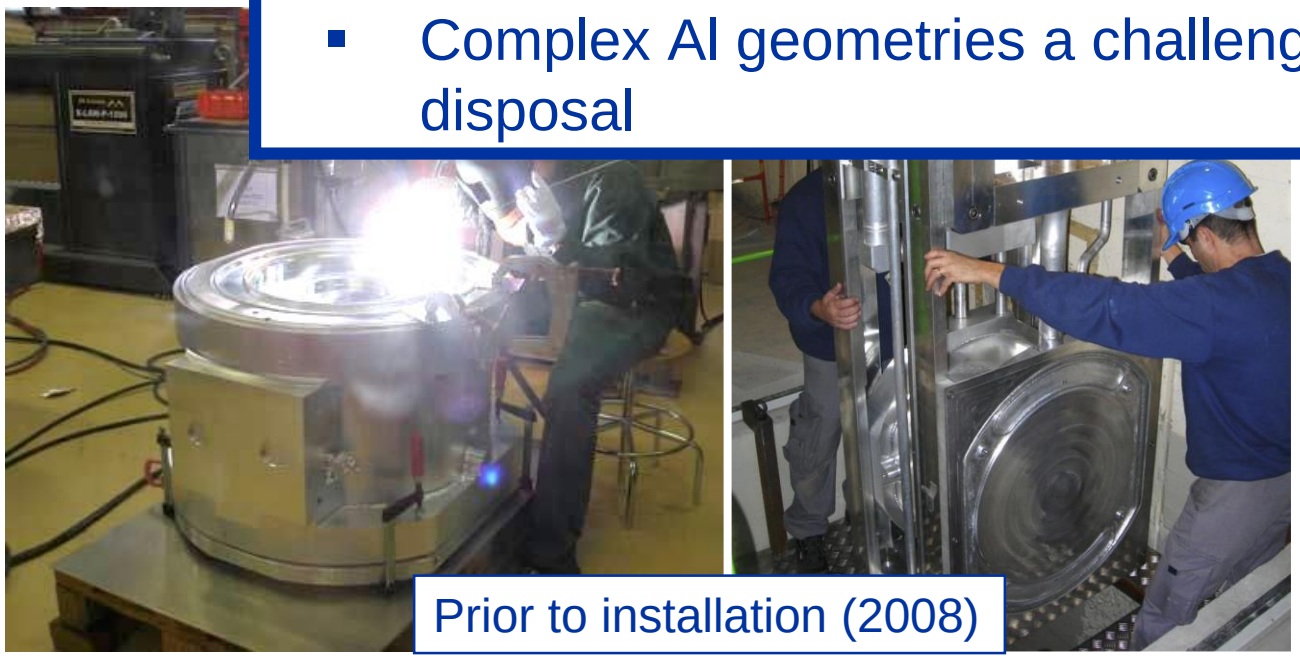
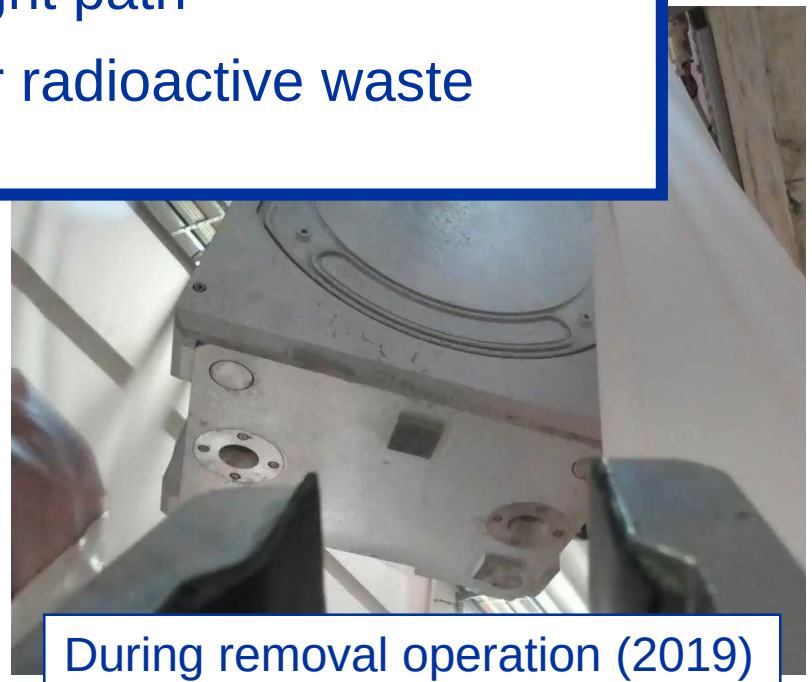
but
stry

- Lessons learnt:
  - Water contamination due to contact between H_2O and Pb is a major operational challenge
  - Operational optimisation for vertical flight path
  - Complex Al geometries a challenge for radioactive waste disposal



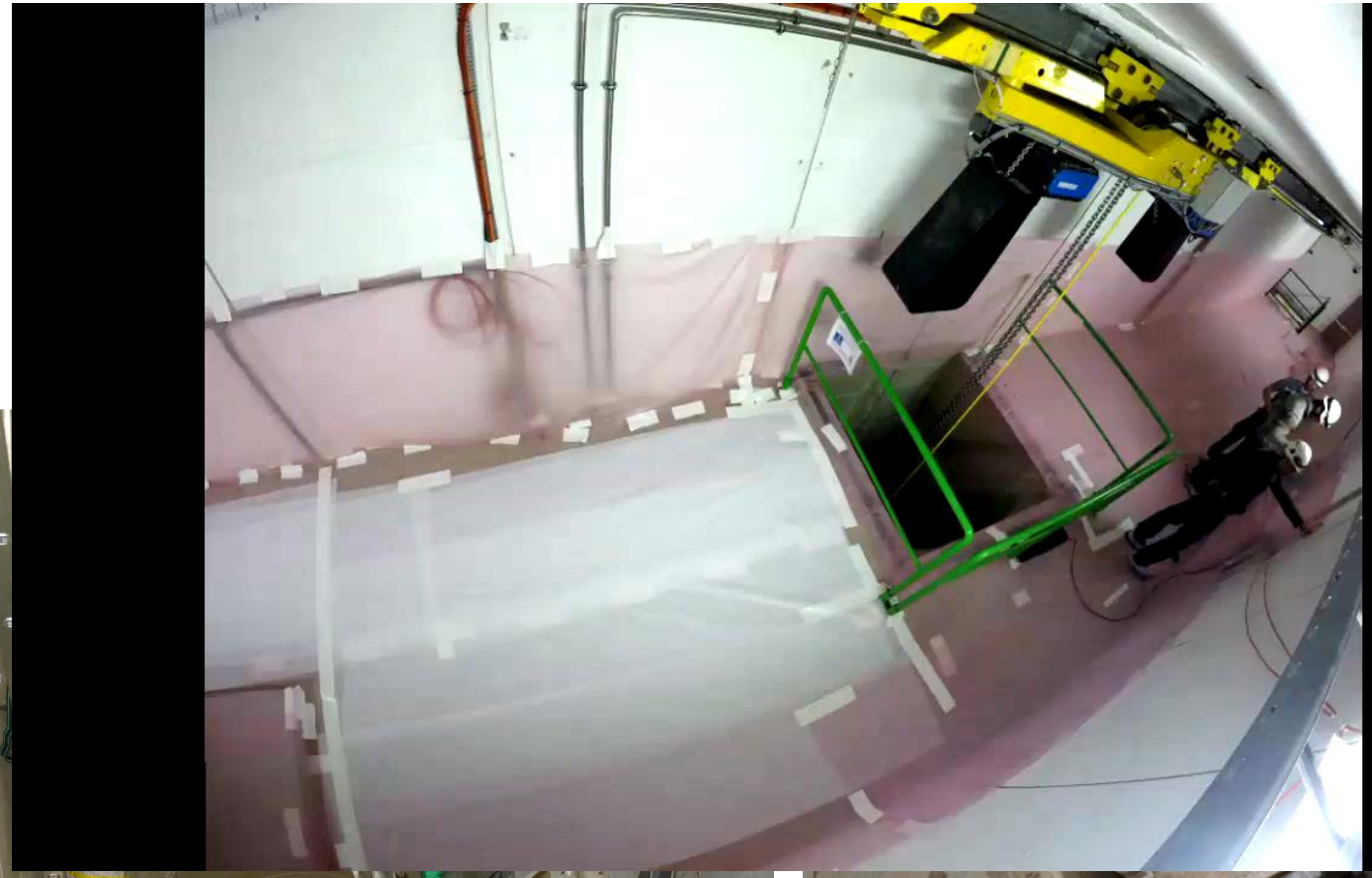
Prior to installation (2008)



During removal operation (2019)

Dismantling of 2nd generation spallation target

eutron spallation target &



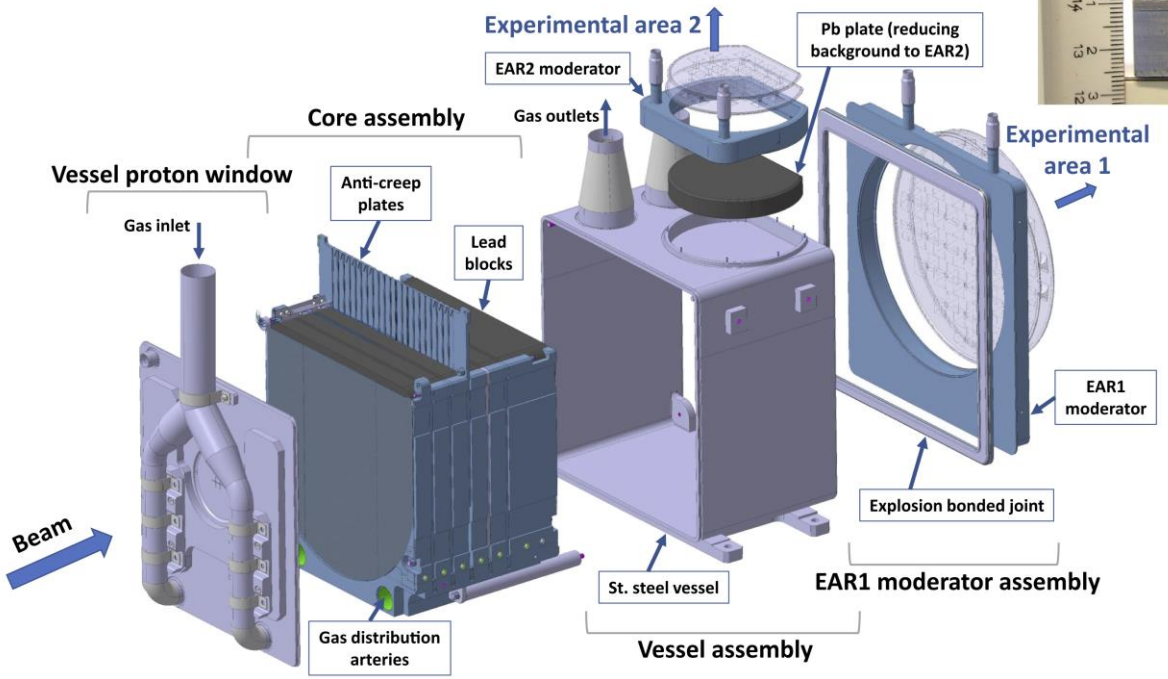
Third generation n_TOF spallation target

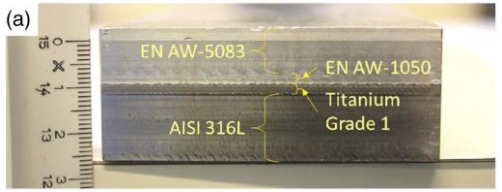
2021-

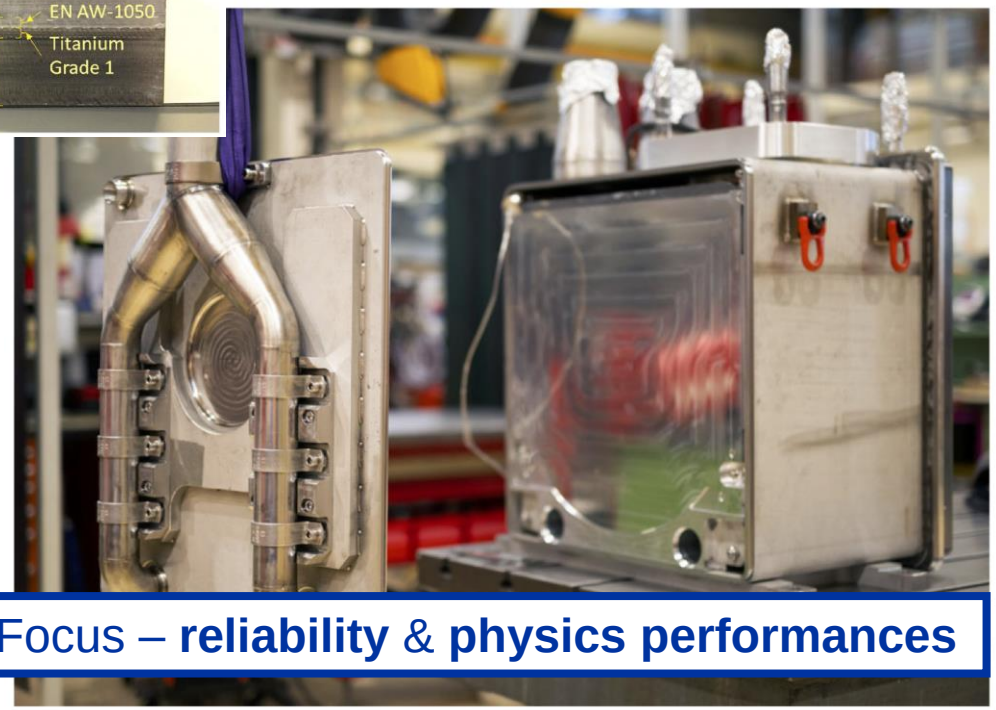
Phys. Rev. Accel. Beams 24, 093001 (2021)

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

- Several innovations have been introduced, including bimetallic transitions & nitrogen gas cooling







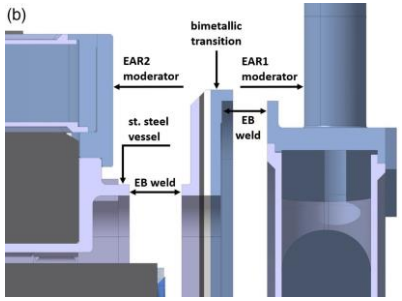
Focus – **reliability** & **physics performances**

Spallation target ready for installation

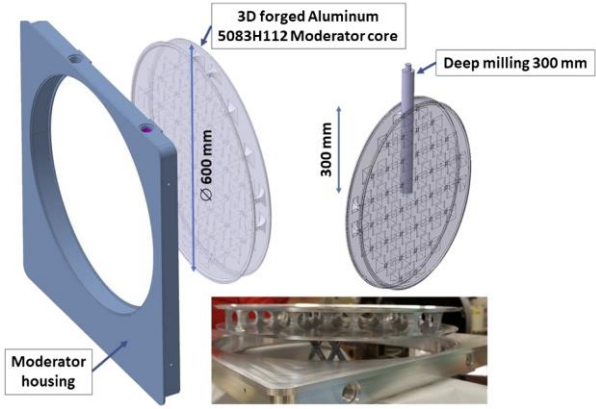
Cooling and moderator station

Physics/engineering design process

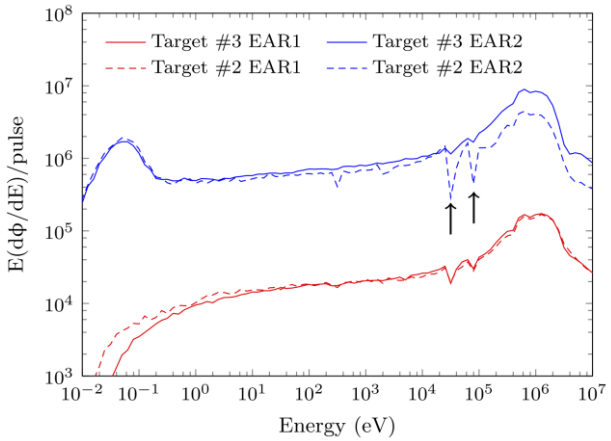
Design and **integration** impacts (CATIA v5)



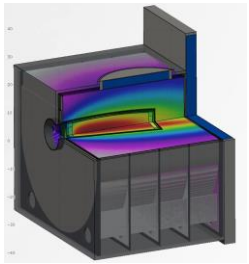
Machinability / reliability / feasibility (Workshop)



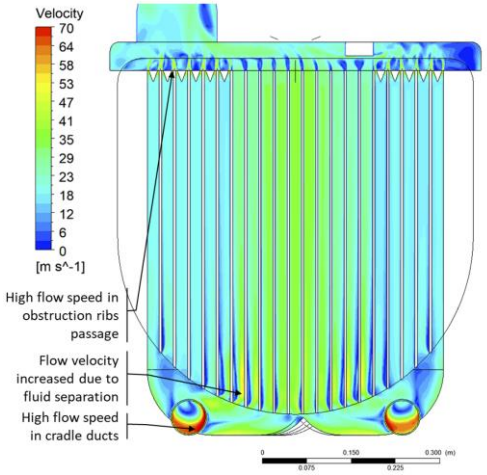
Physics performances (FLUKA)



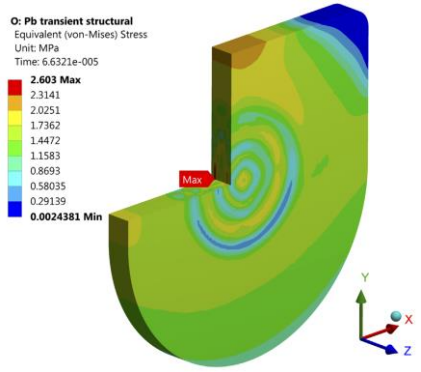
Heat loads (FLUKA)



Thermal management (ANSYS CFX)



Mechanical performances (ANSYS)

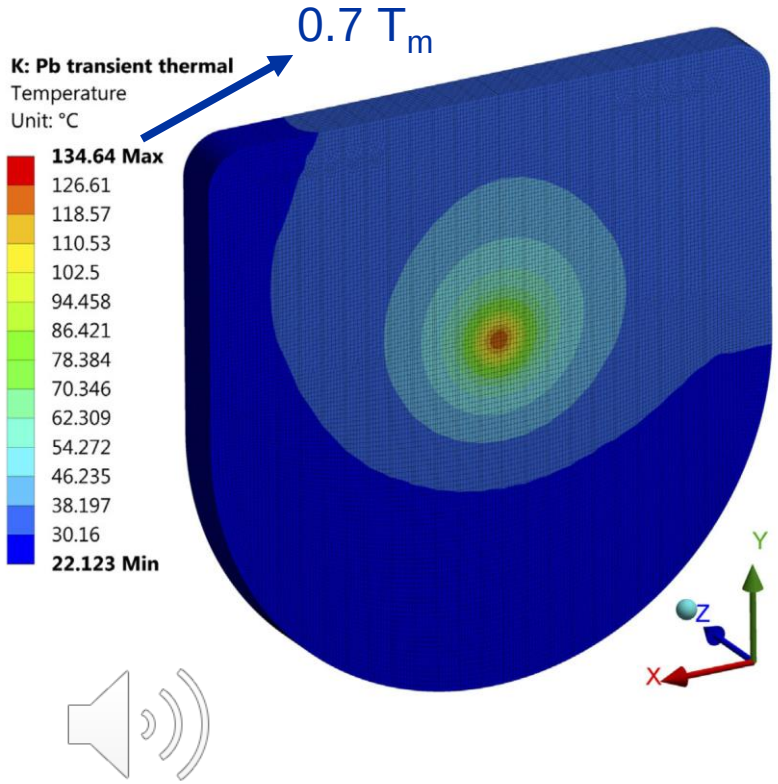


Target (BID) design progression

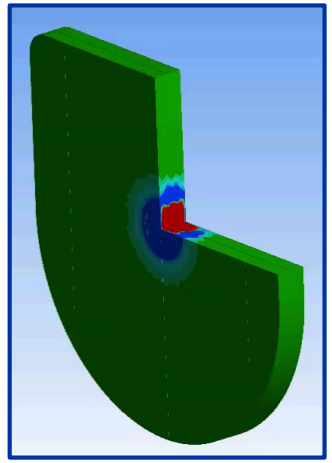
n_TOF neutron spallation target

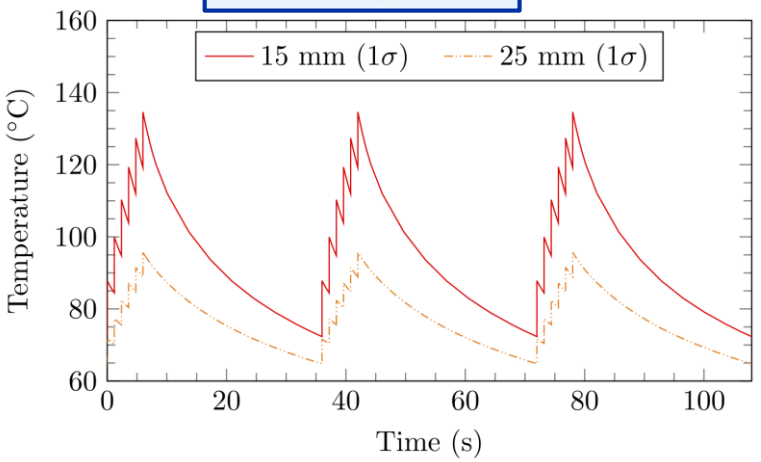
Phys. Rev. Accel. Beams 24, 093001 (2021)

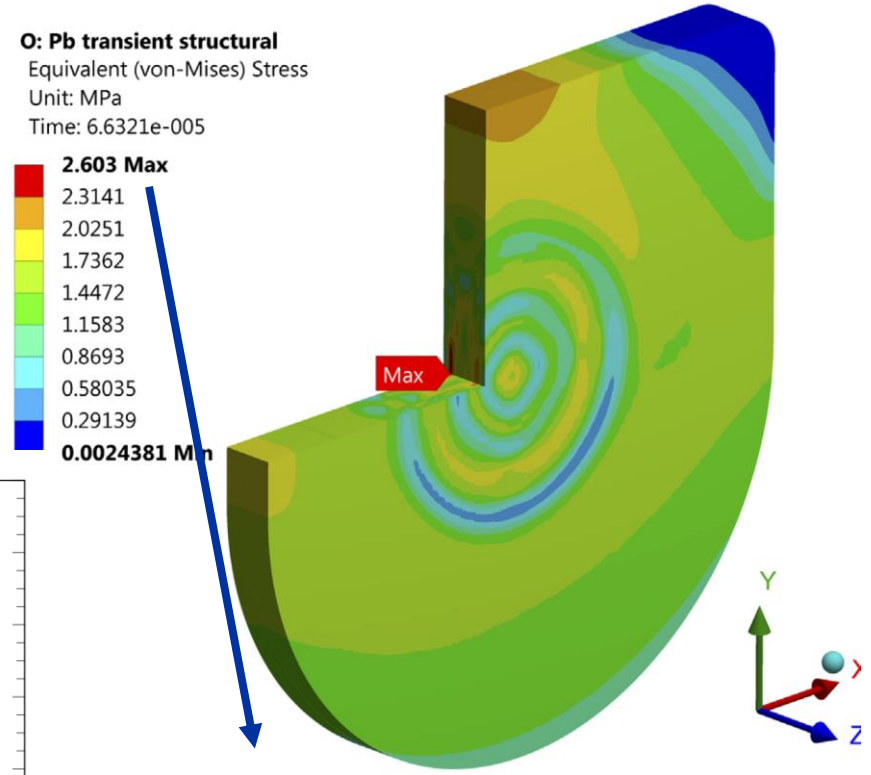
- Pb is a non-structural material, low melting point, very low yielding point



(listen for ±kJ impacting on Pb)



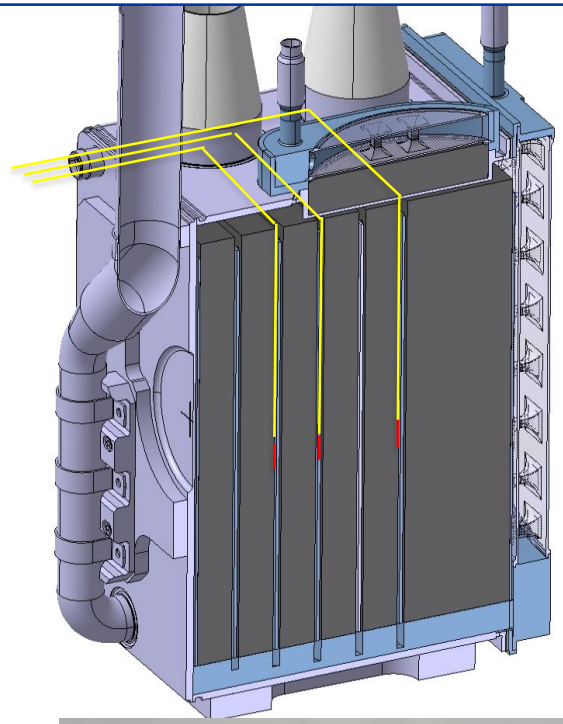




2.6 MPa vs. 1 MPa (plastic flow onset)

Target monitoring system

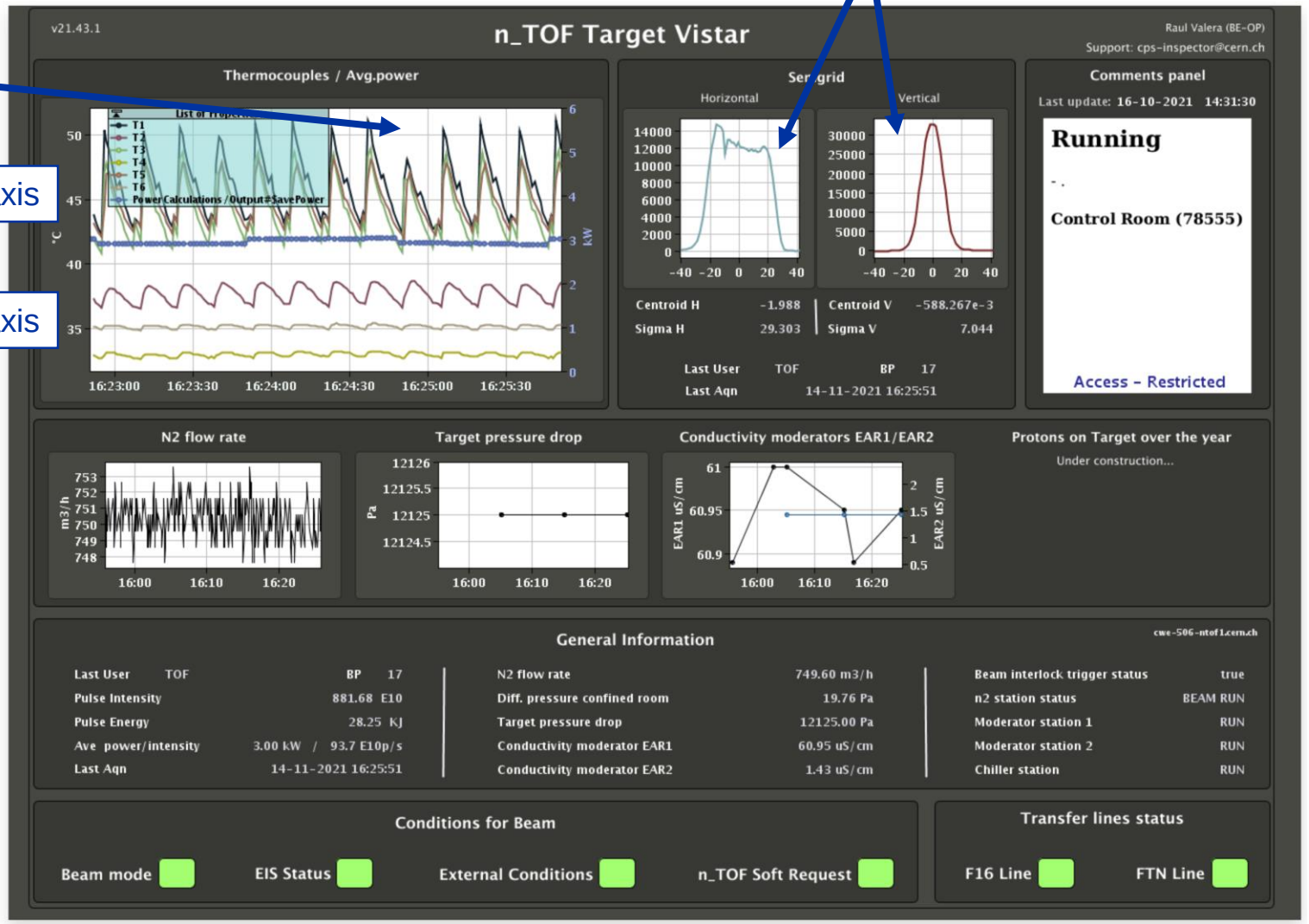
6 type-K thermocouples to monitor Pb surface temperature



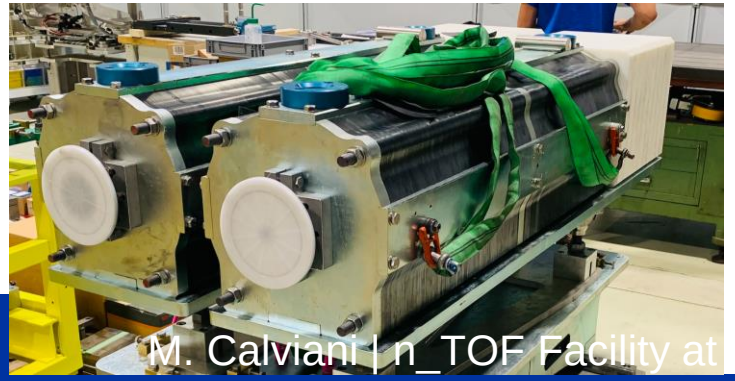
Beam size on target

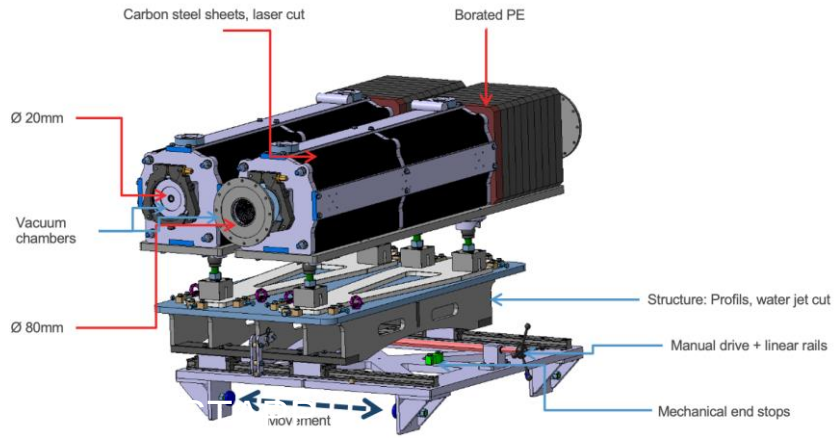
On axis

Off axis

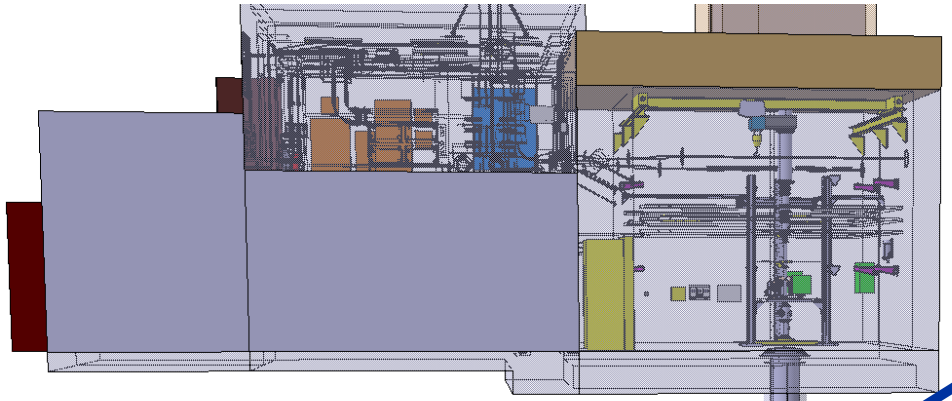


Horizontal neutron beam line





Vertical neutron beam line



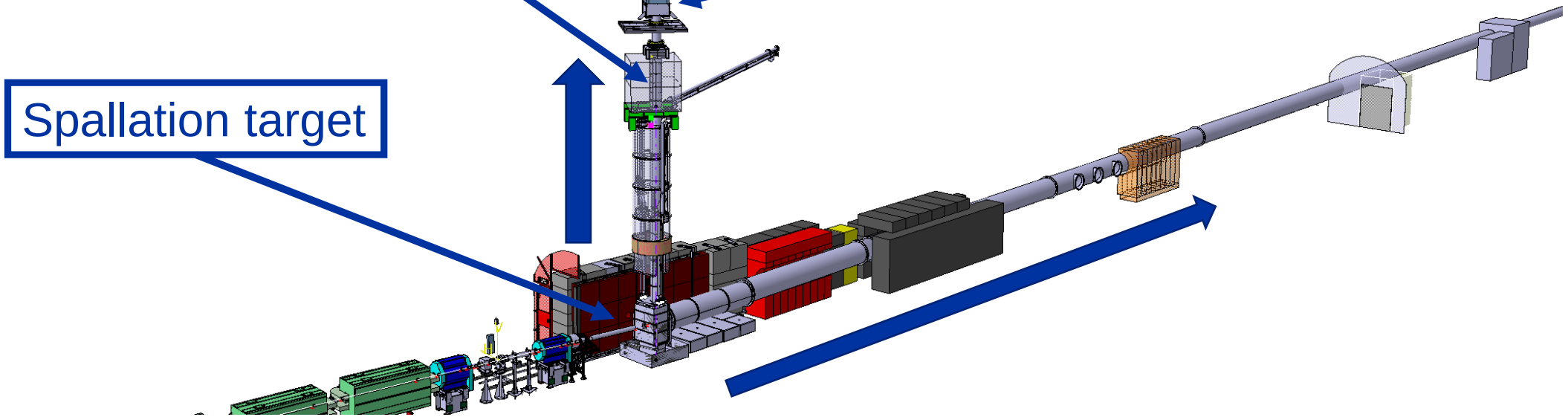
2nd "shaping" collimator

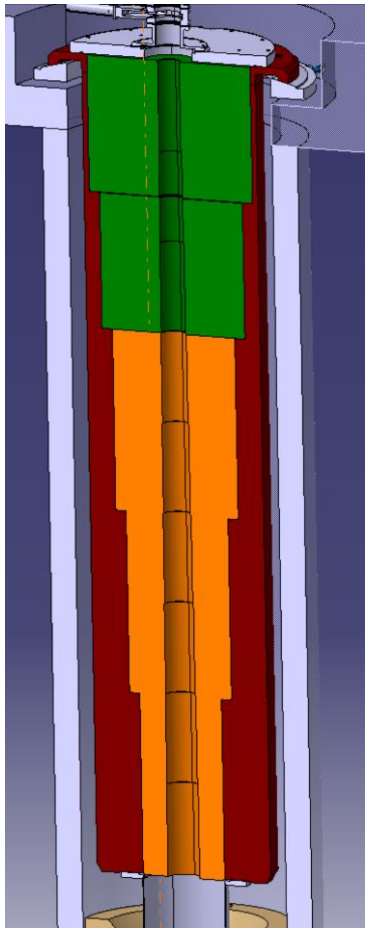
Filter station

1st collimator

SmCo sweeping magnet

Spallation target

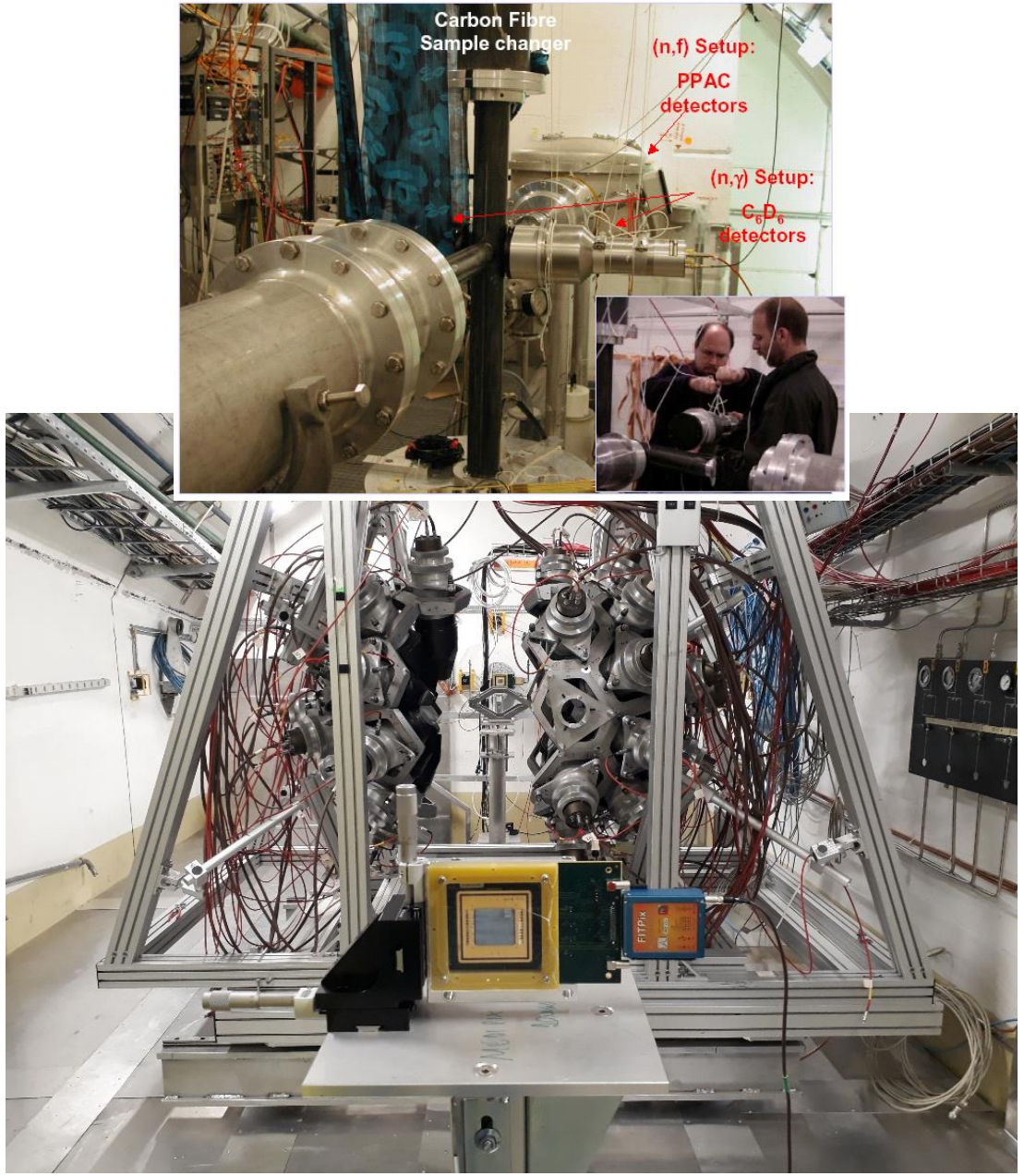




n_TOF Experimental stations
EAR1

- Original experimental area (1999), optimal neutron energy resolution
- Updated in 2010 in order to handle unsealed radioactive sources (Work Sector Type A) and therefore expand the physics reach
  - Enhanced safety features – fireproof, dedicated ventilation, access system, decontamination possibilities

➔ Talks from n_TOF colleagues

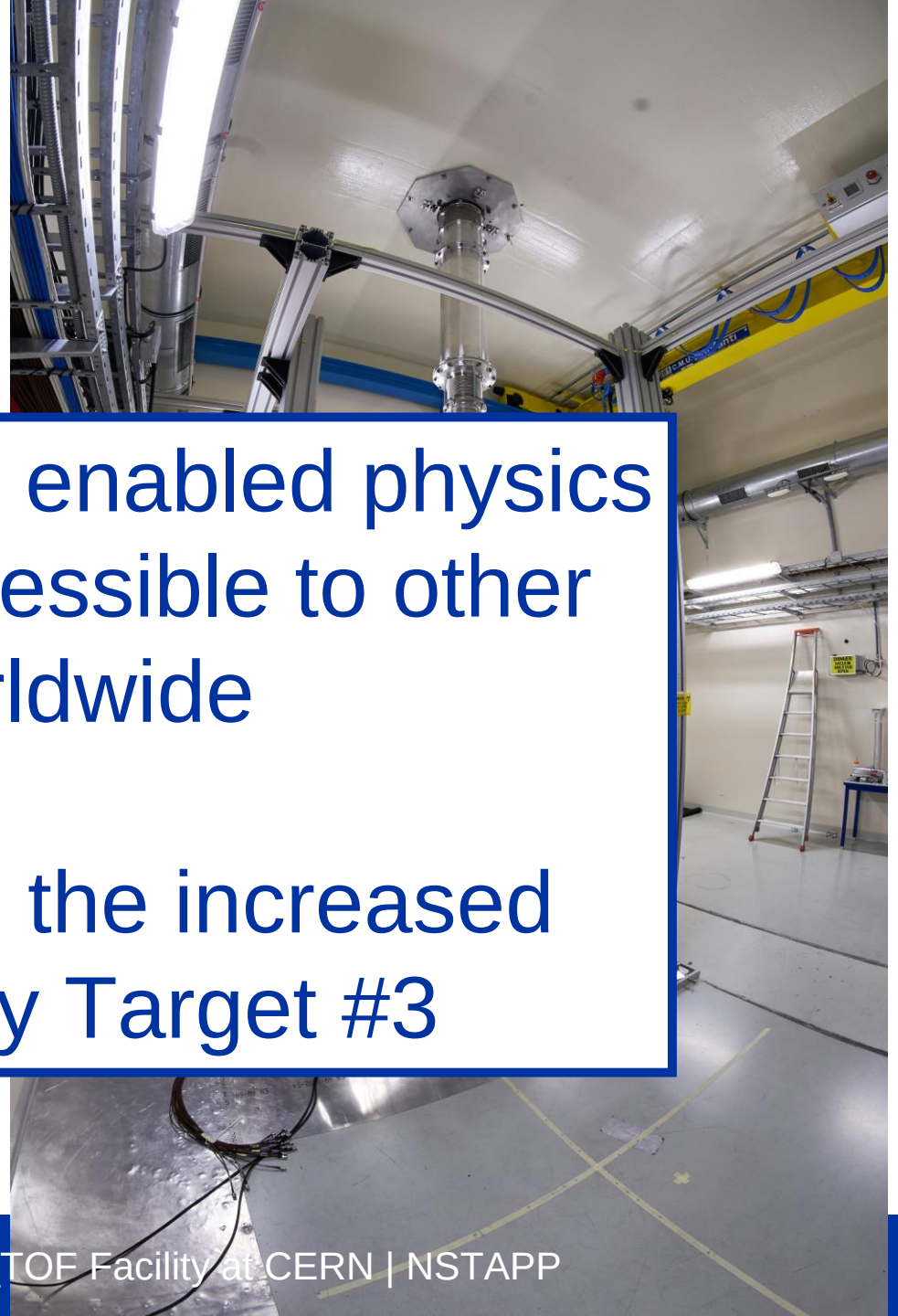


n_TOF Experimental stations
EAR2

- A major addition to the facility has been the creation of the 2nd experimental area 20 meters on top of the spallation target
- **Major fluence increase**, further enhancing the physics reach on radioactive samples and samples available only with little mass
- Also equipped as a Work Sector Type A & dedicated ad-hoc beam shaping collimators and low-background beam dumps

➔ Talks from n_TOF colleagues

n_TOF Experimental Area 2



The new infrastructure enabled physics measurements inaccessible to other facilities worldwide

➔ Bright future with the increased reach provided by Target #3

n_TOF Experimental stations
NEAR

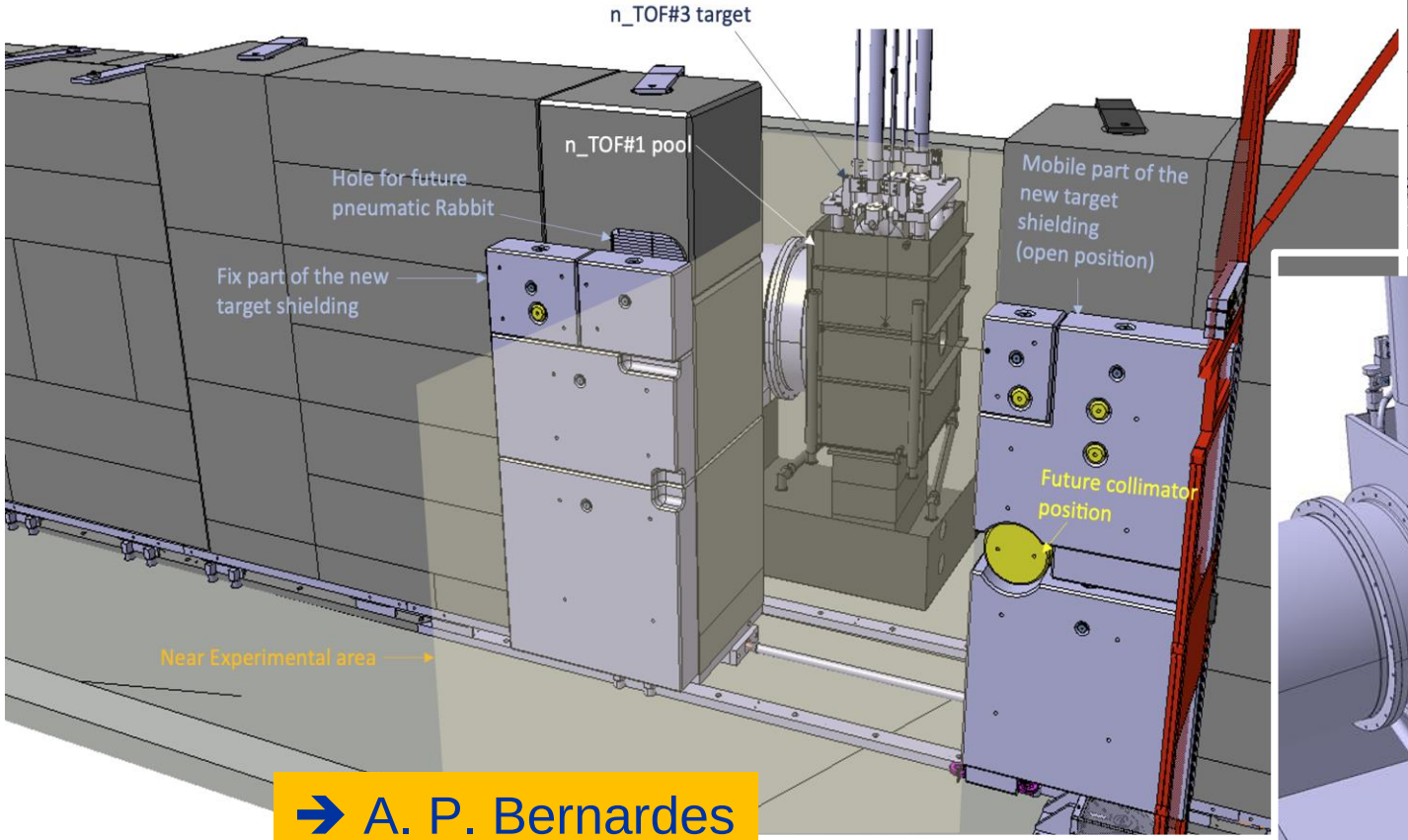
- During CERN's Long Shutdown 2 – together with the exchange of the spallation target – a major target shielding pit upgrade took place
- This created the opportunity to further enhance the capabilities of the facility, with the creation of a **near-target experimental station (NEAR)**
- **In-target irradiation station** (up to 1 MGy/y mixed field, radiation damage studies)
- **Out-target irradiation station** (irradiation station for physics measurements, radiation-to-electronics)

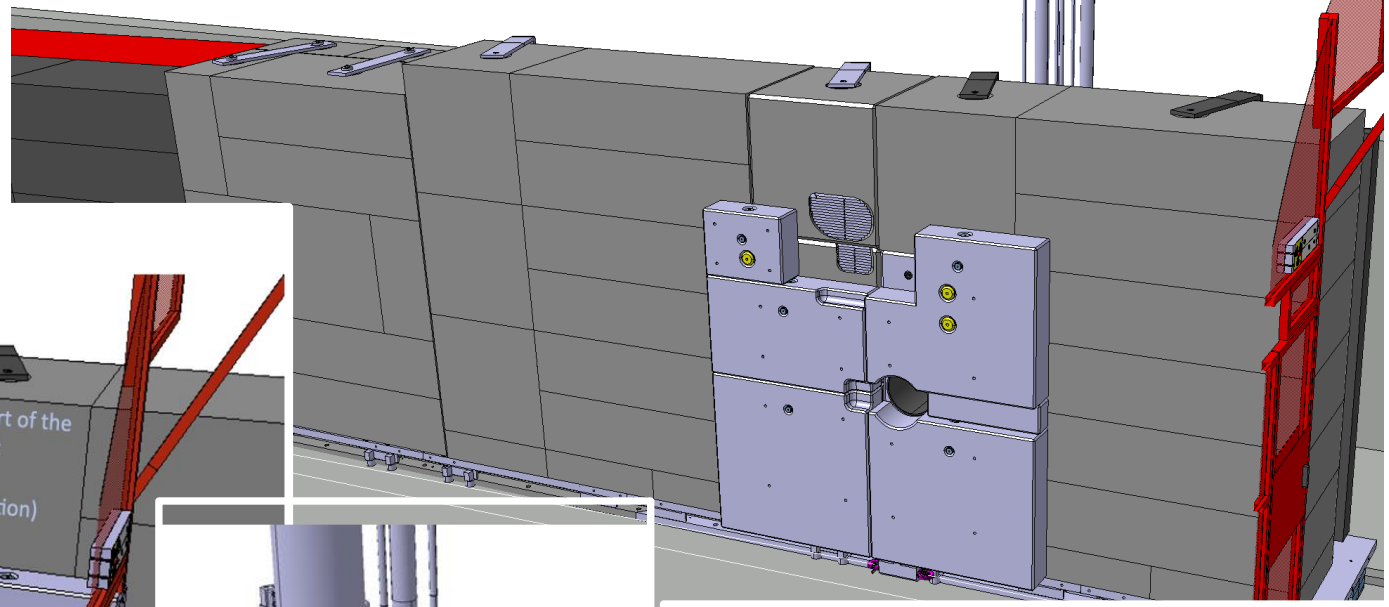
n_TOF Experimental stations

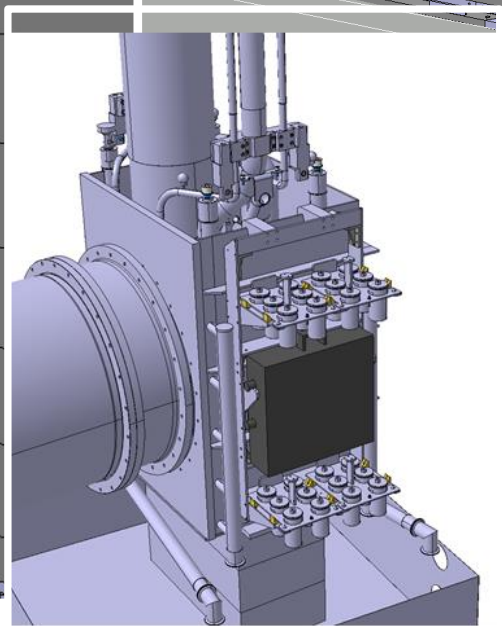
NEAR

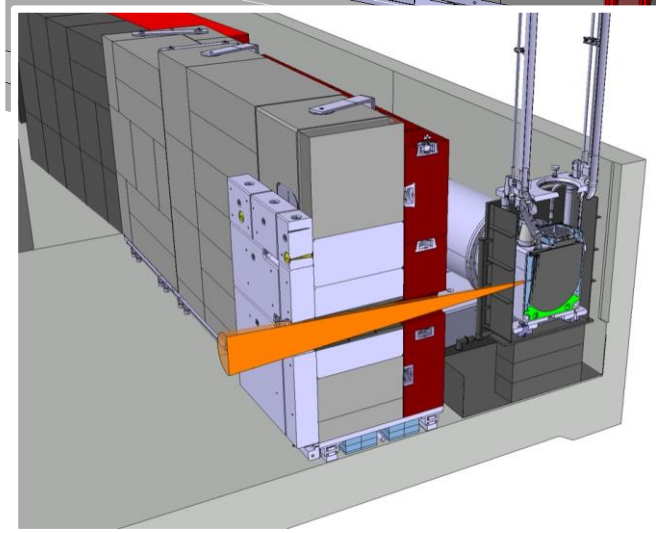
Closed configuration

Open configuration









➔ A. P. Bernardes

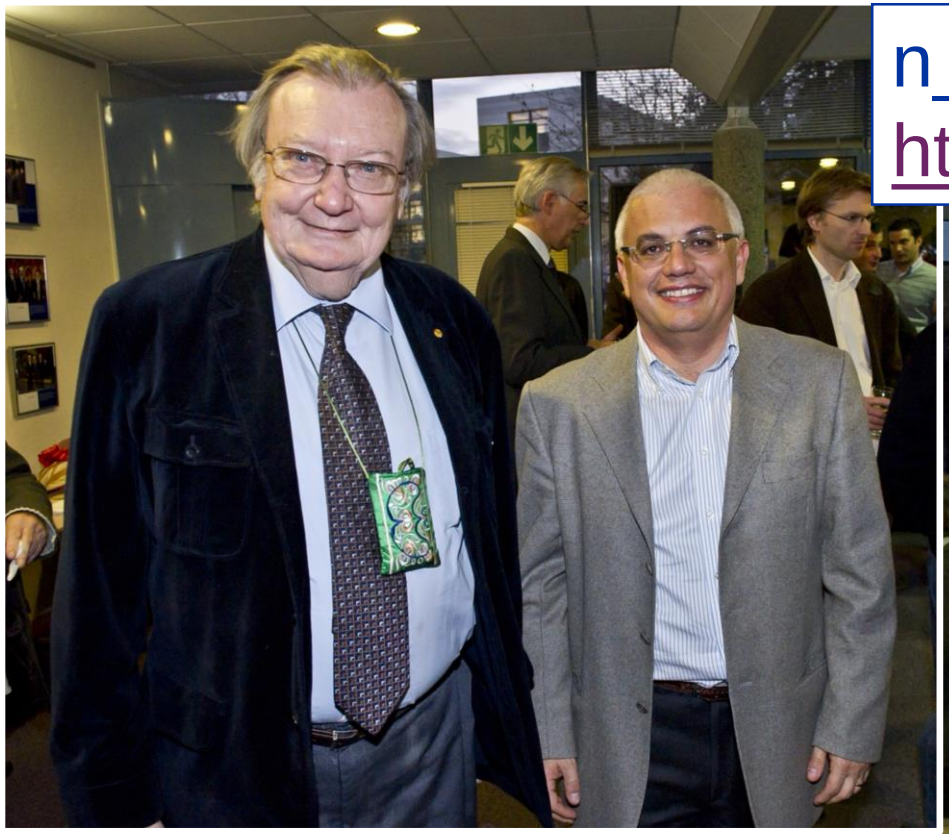
We’ve built, operate, upgrade and continue to do our best on the shoulders of giants!

R. Magnin, E. Radermacher, P. Cennini, R. Cappi (July 2000)

CERN-EX-0011025

n_TOF 10 years celebration (Dec. 2010)

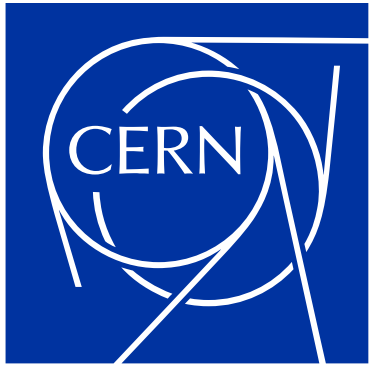
http://cdsweb.cern.ch/record/1312612



CERN-GE-1011313

Conclusions

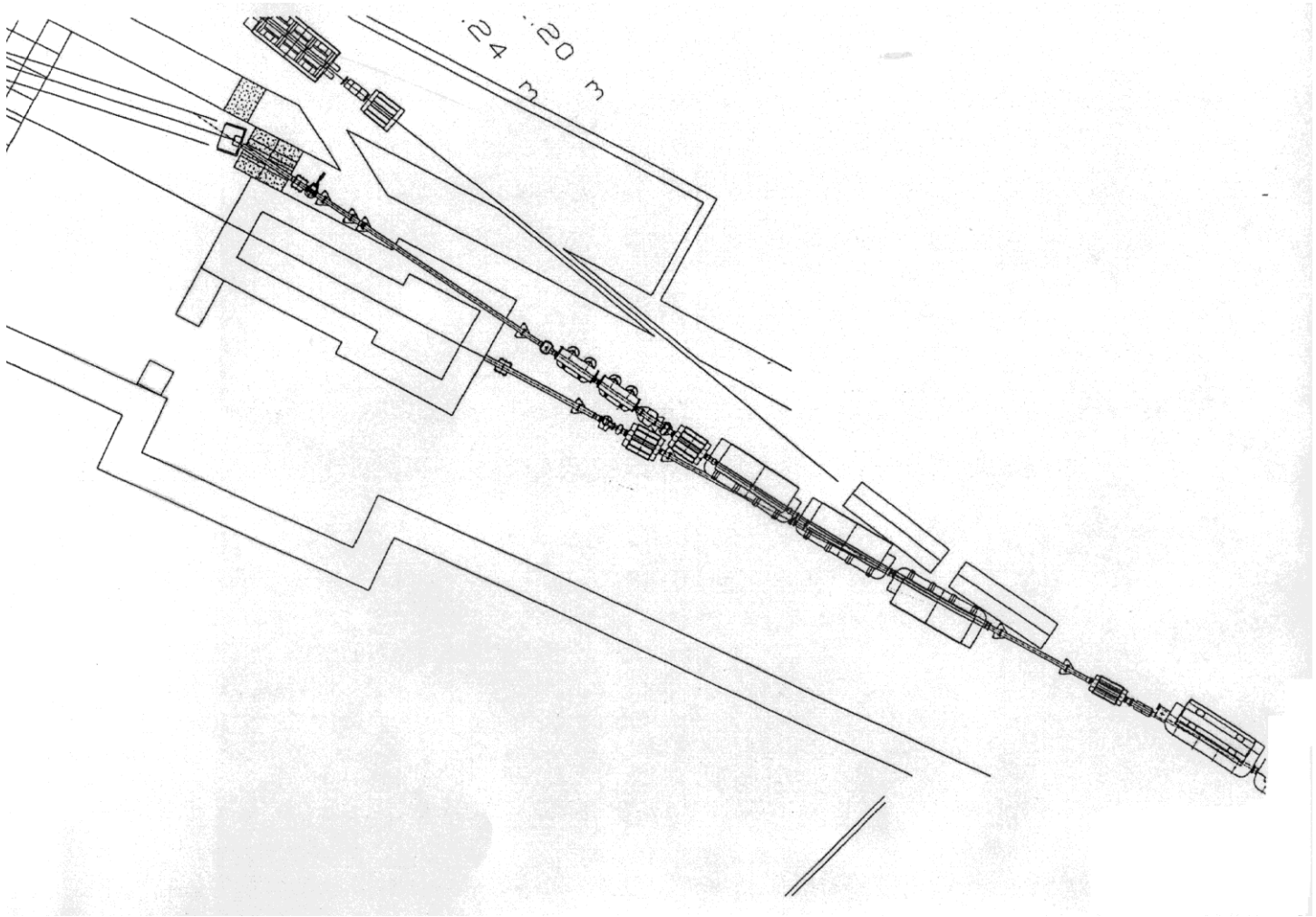
- n_TOF recently turned 20!
- Facility has been constantly updated over the years in order to improve and enlarge its physics reach
- 3rd generation spallation target & addition of NEAR are paving the way for a bright future
- Synergies will be strengthened with ISOLDE and AD infrastructure

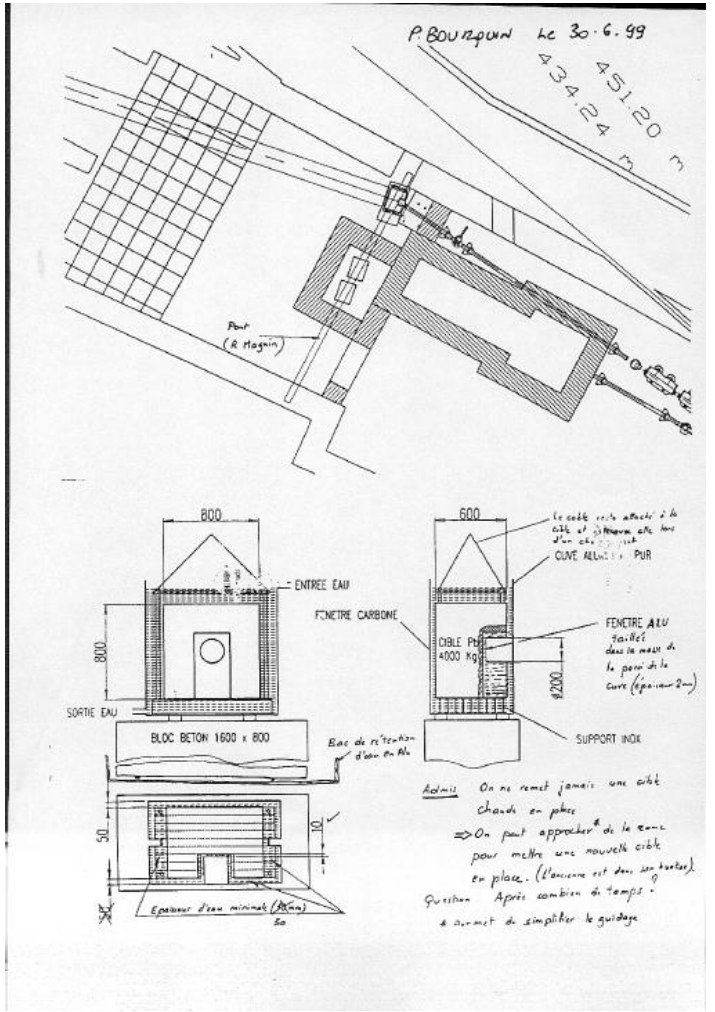


home.cern

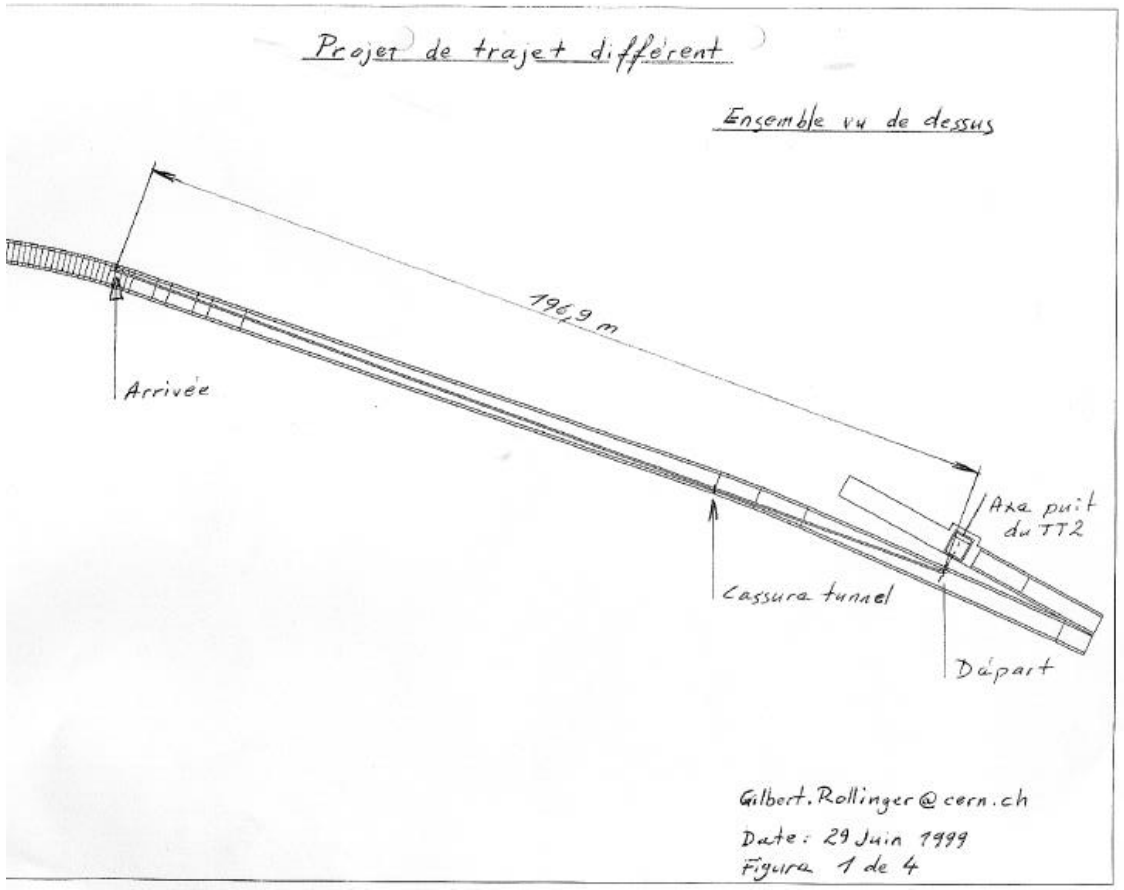
Early ideas for n_TOF

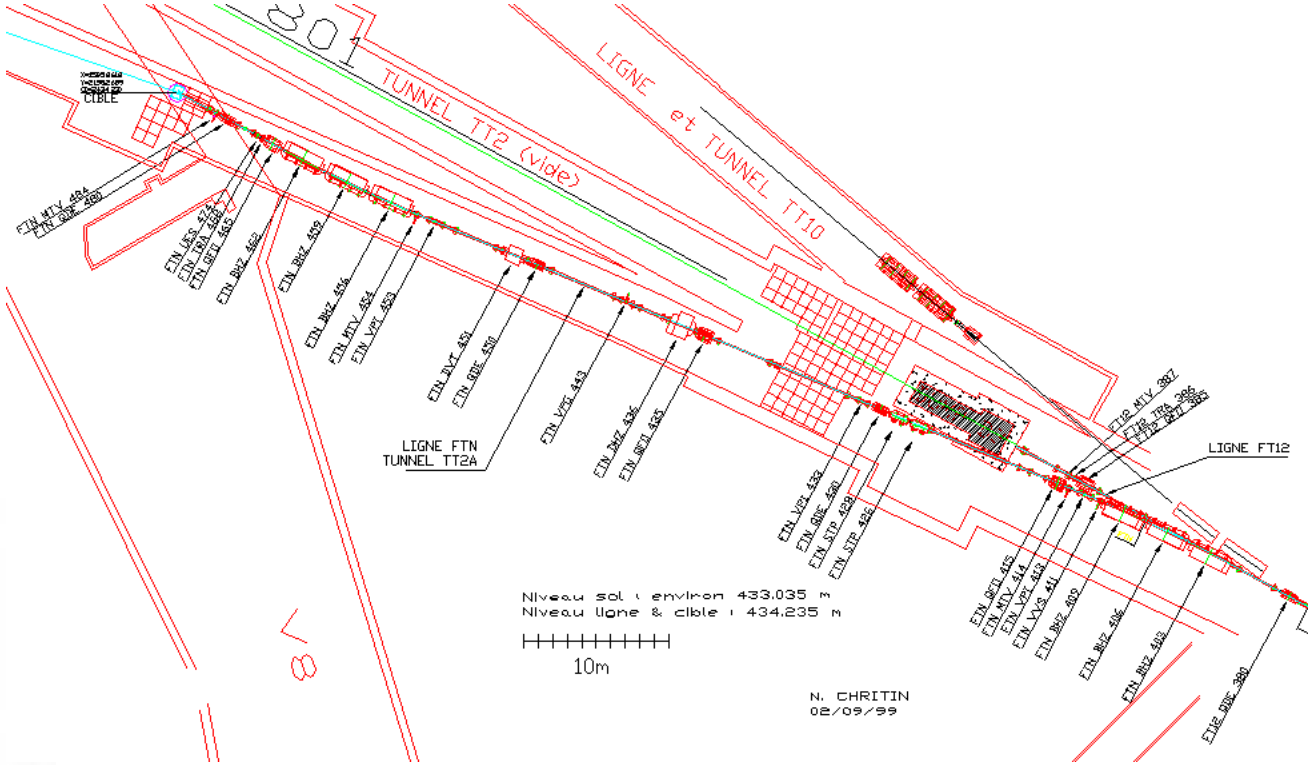
Target close to D3

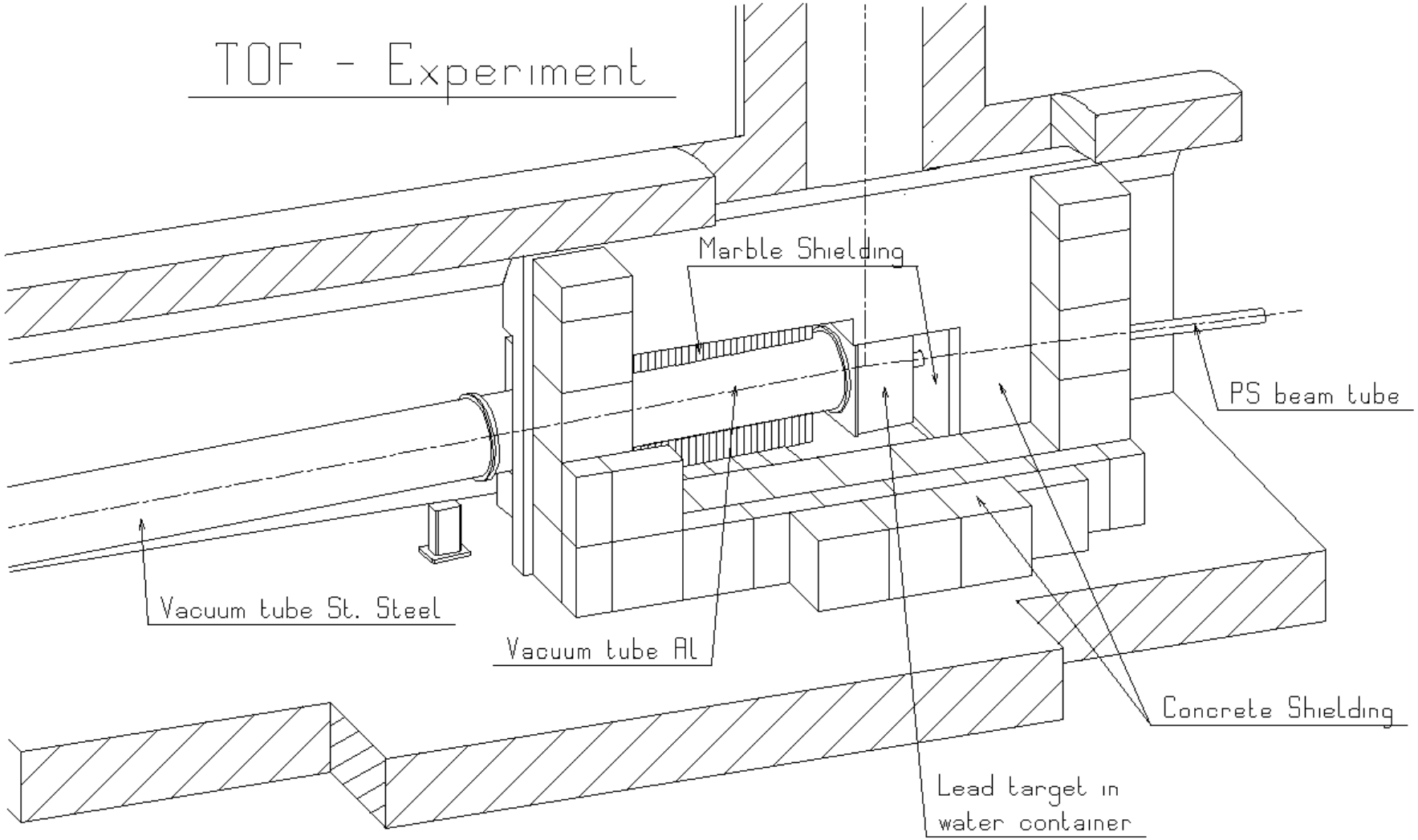




Early ideas for n_TOF
Final configuration (mid 1999)






TOF - Experiment
Marble Shielding
PS beam tube
Vacuum tube St. Steel
Vacuum tube Al
Concrete Shielding
Lead target in
water container