YEARS / ANS CERN

CENF target station and secondary beam design

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on behalf of the CENF Secondary Beam Working Group

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Outlook

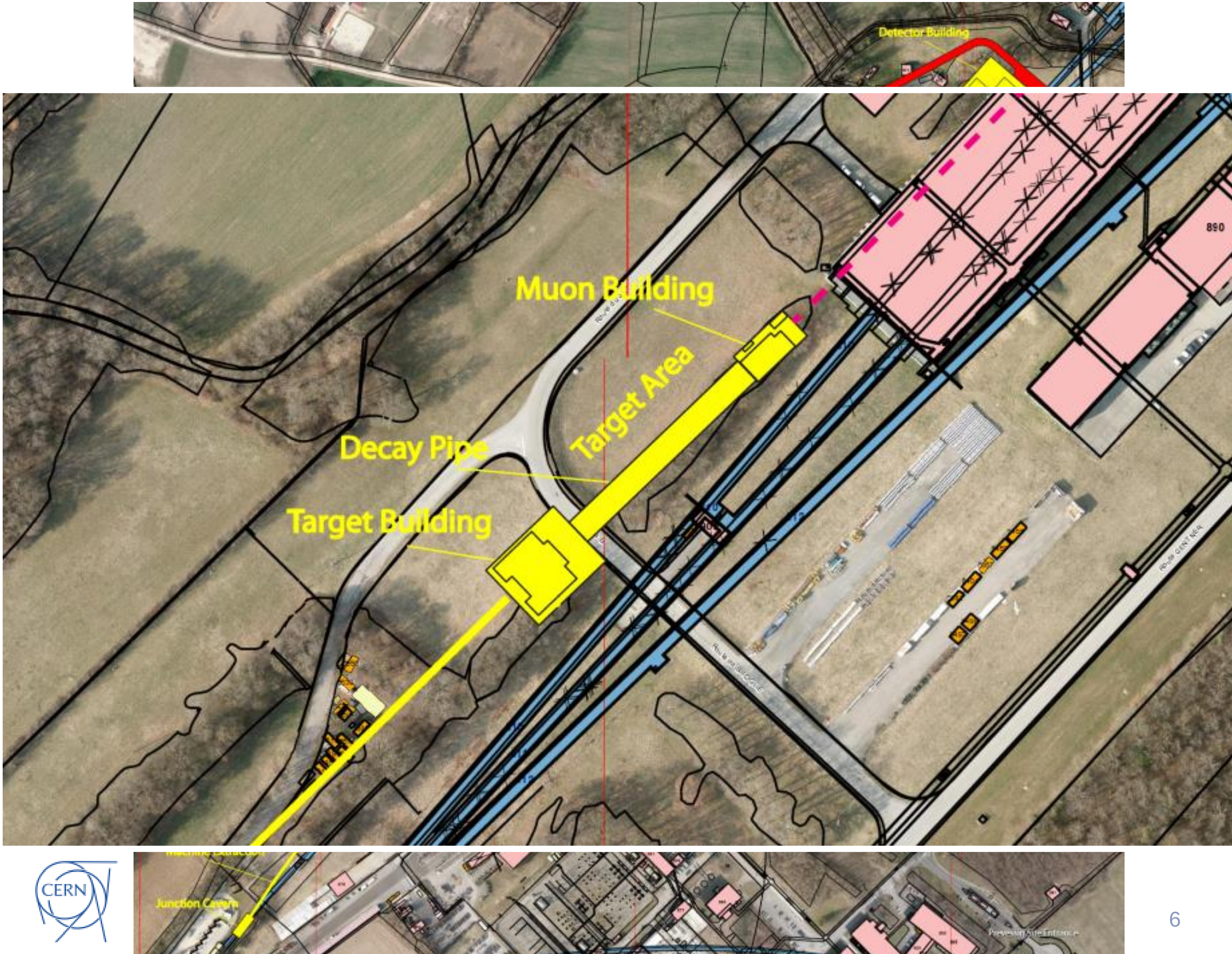
- Design of the CENF target facility and secondary beam
- Target R&D
- Cooling and ventilation design
- Thermo mechanical aspects
- Radioprotection and environmental releases
- Conclusions

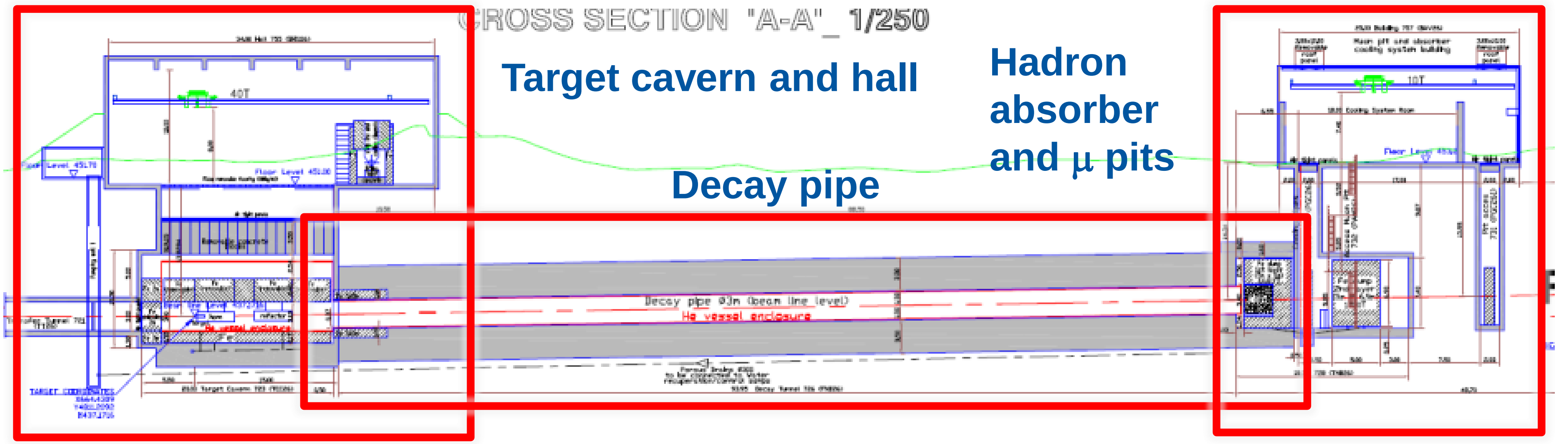
Target areas at CERN

- CERN target areas are generally halls, pits or long tunnels, far from the access points
  - Air has enough time to decay and stray radiation is not a problem for the public
  - Neutrino ones are generally deep in the molasse

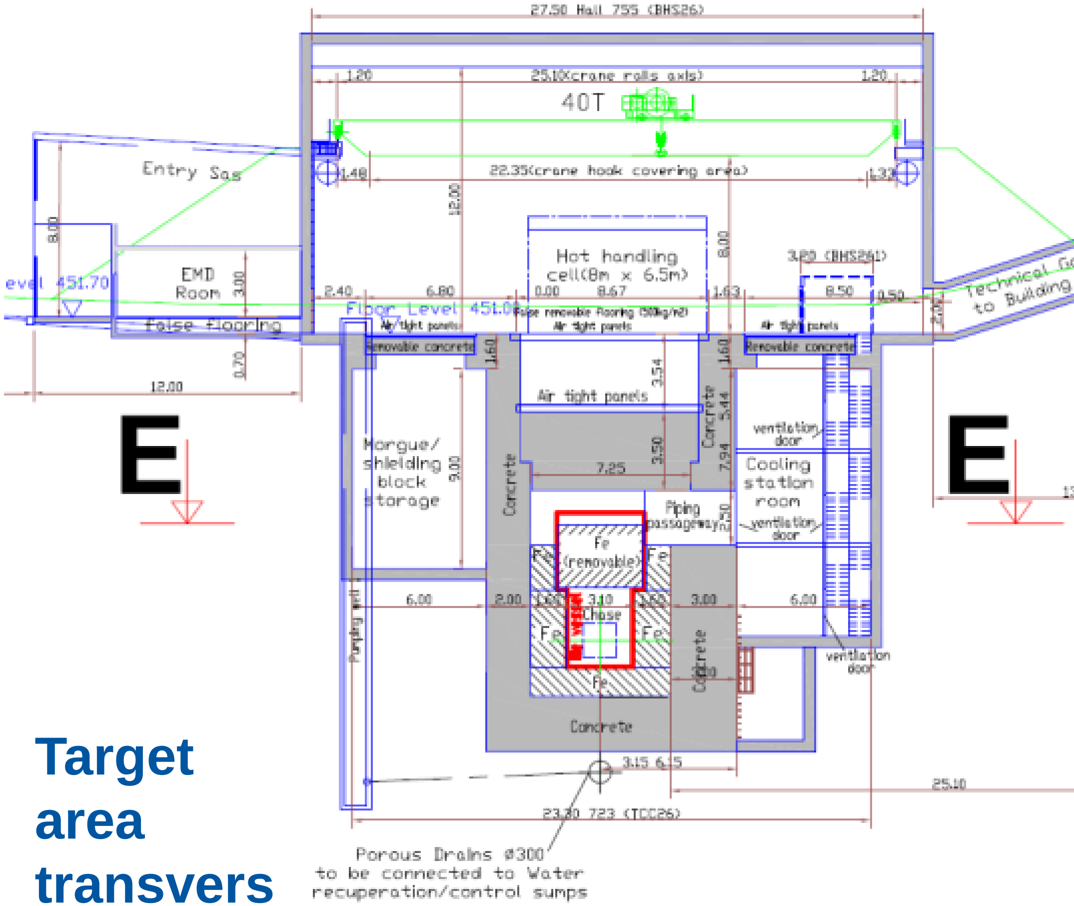
CENF target facility

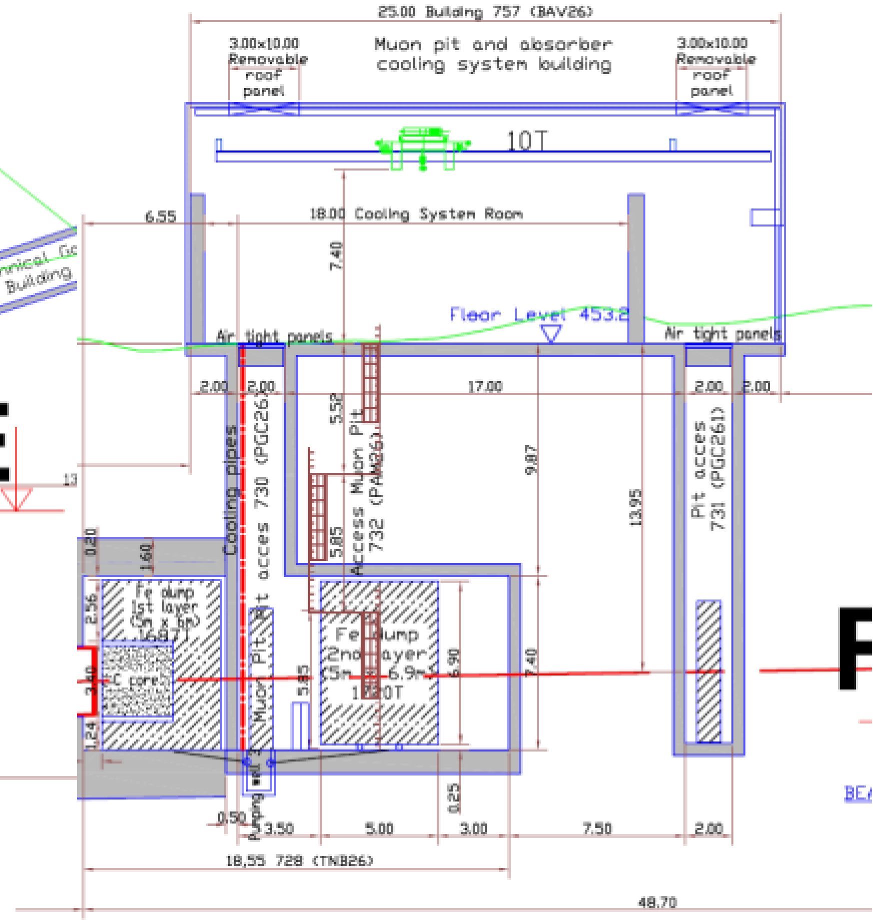
- Due to the shallow depth of the beam line (~14 meters), a target area approach based on long tunnels (i.e. CNGS, WANF, etc.) is <u>not</u> applicable
- A **multi-compartment solution** similar to T2K/NuMI has been therefore developed, taking into account the specificities of CERN
- **The proposed technical solutions and methods for the target station design are adaptable for other similar projects at CERN**


Detector Building
Junction Cavern
Muon Building
Target Area
Decay Pipe
Target Building
890



- **Beam line under He**, to avoid NO_x formation and to reduce air activation
- Angle, distance and depth optimised to keep dose rate in EHN1 <1 μSv/h and to allow ND at 460 m from target
- Target shielding adapted to H*(10) **<15 μSv/h**
- Air treatment and water recuperation
- Double muon pits to provide info on alignment, target "health" and μ flux for ν flux predictions



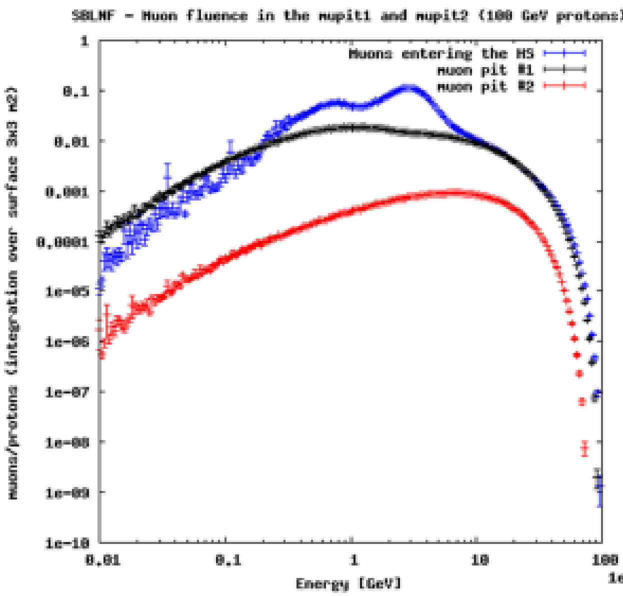


Target area transversal cross-cut

- Drawings essentially <u>ready</u> for CE tender

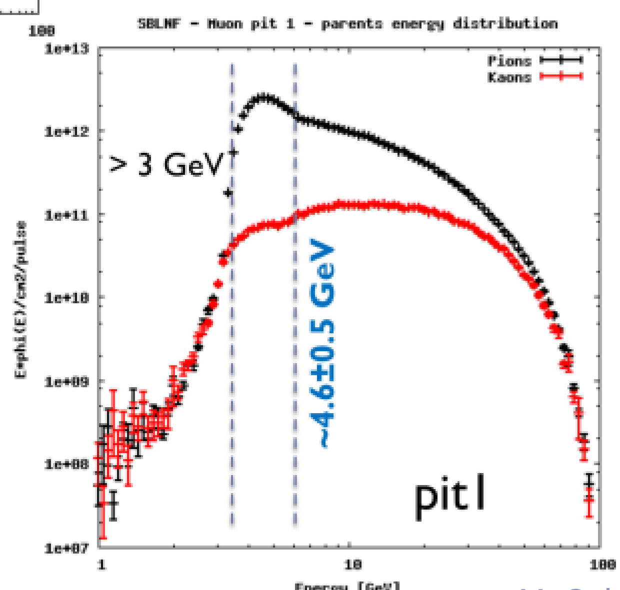
Hadron absorber / muon pits longitudinal cut

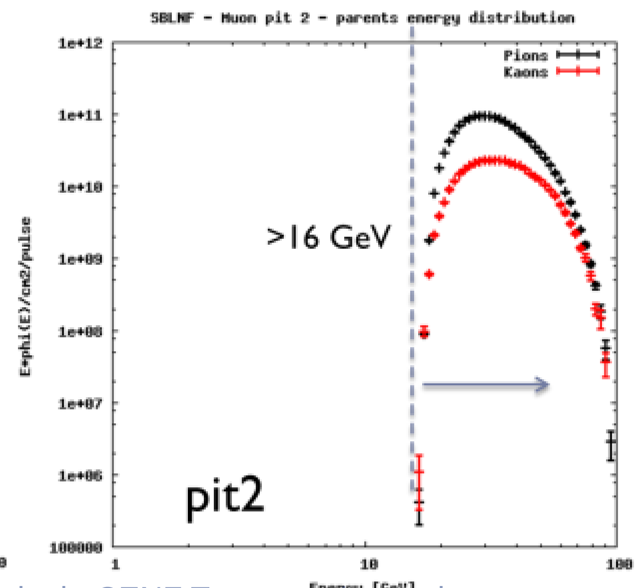
Importance of a double μ pit

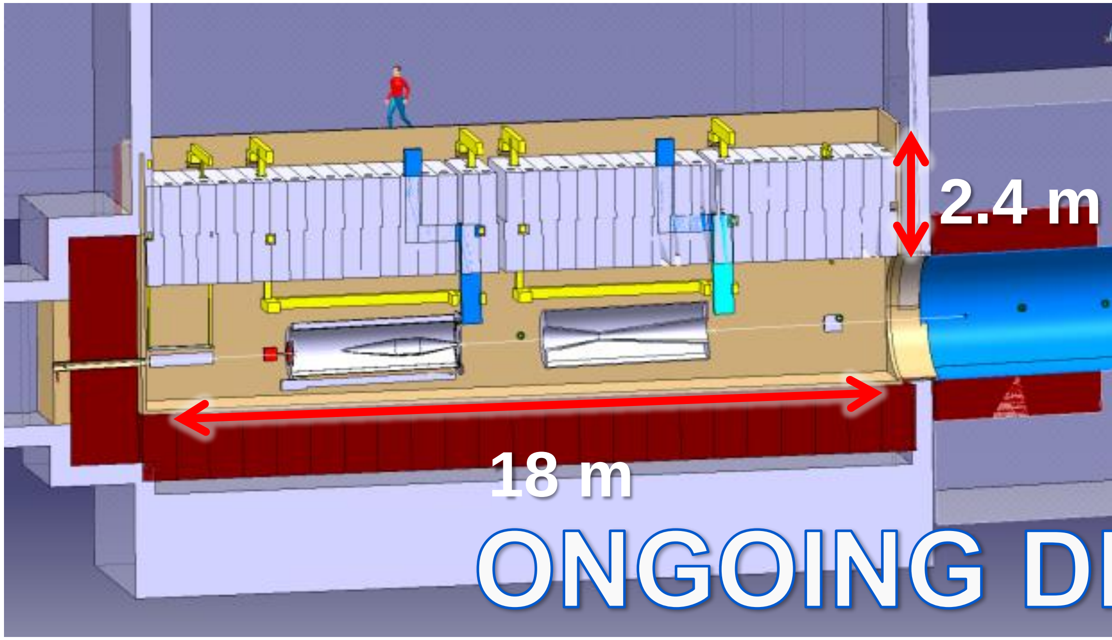


- **"thermalized" μ spectrum** in both pits
  - Impossible to know from which π these μ come from
- Shape remains the same as a function of depth

- Energy distribution of parents π/K, generating μ arriving in pit#1 and pit#2
- Pit1 sensitive to low energy μ



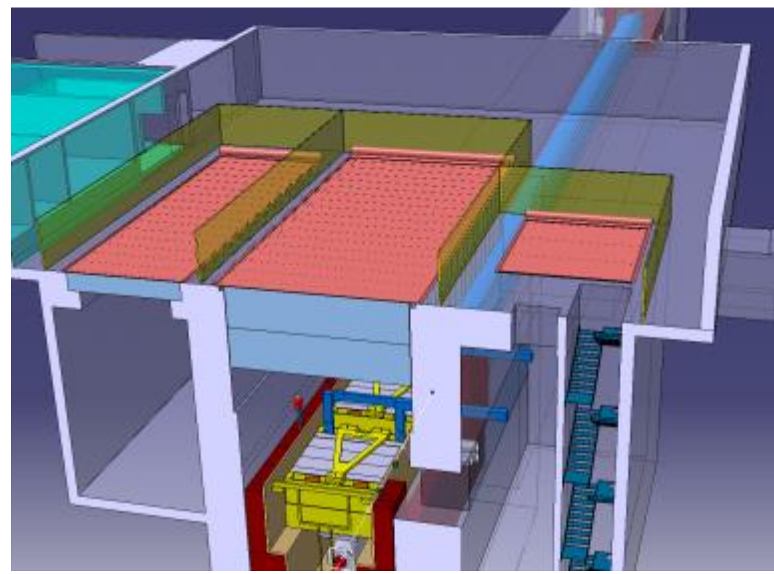




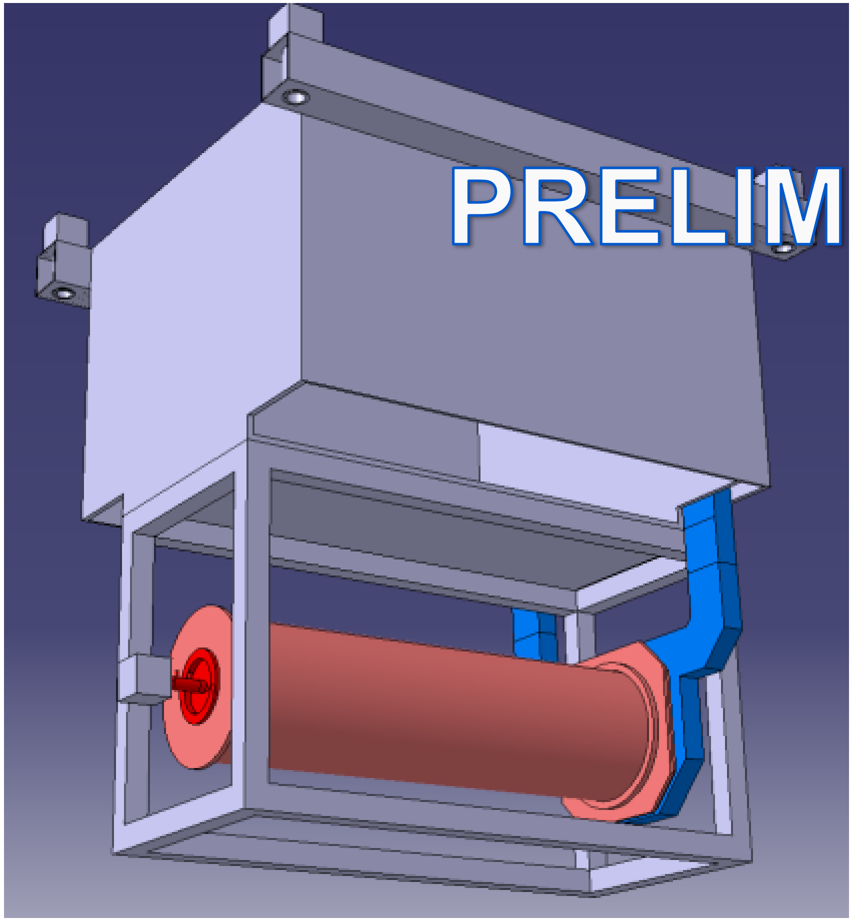
- Integration of target trench, 3x3 m^2
- Matches the DP diameter

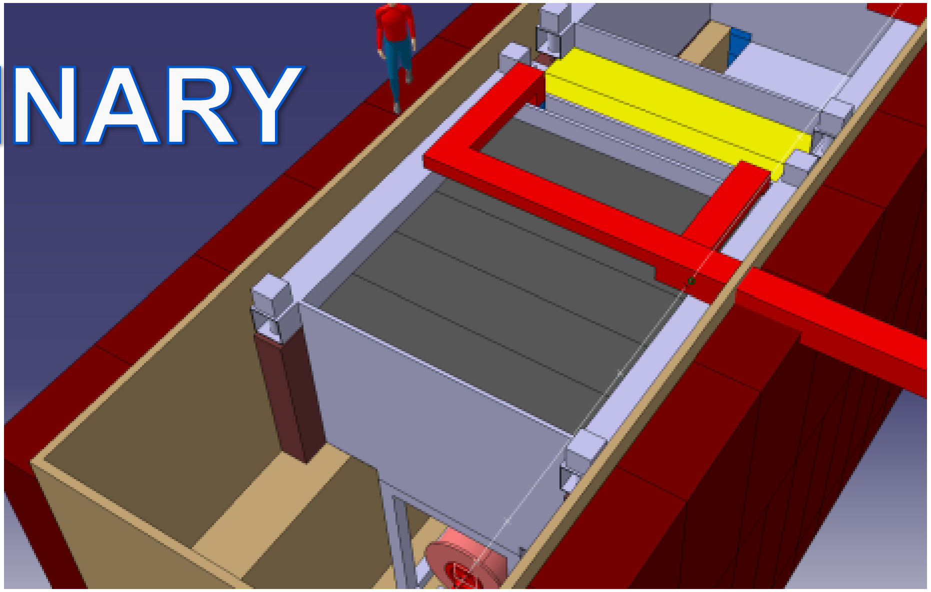
ONGOING DESIGN

- **Handling system design:**
  - 40 ton + 15 ton crane, redundant systems foreseen
  - Pure vertical movement system as baseline, respecting ITER Remote Handling Code of Practice
  - Support module fixed during operation (*under design*)



Horn/Reflector support module

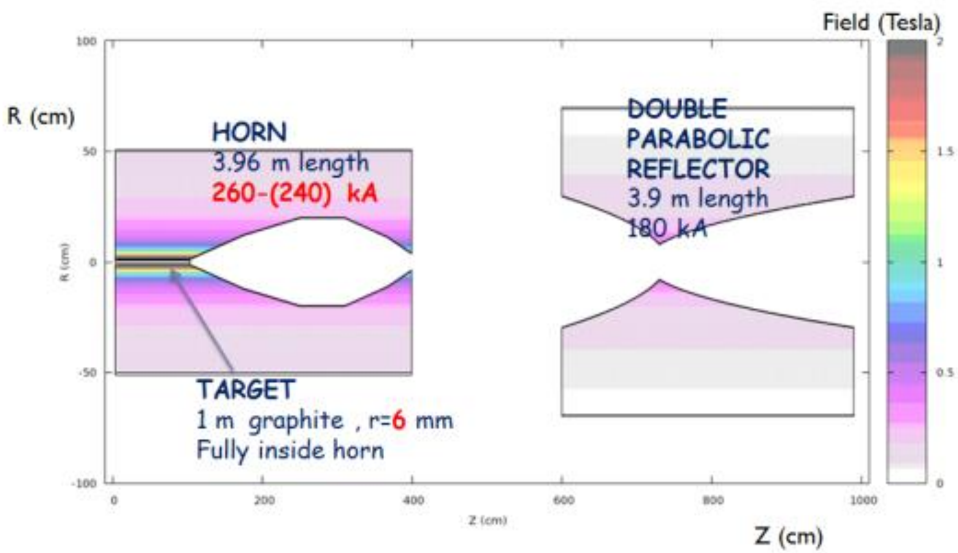


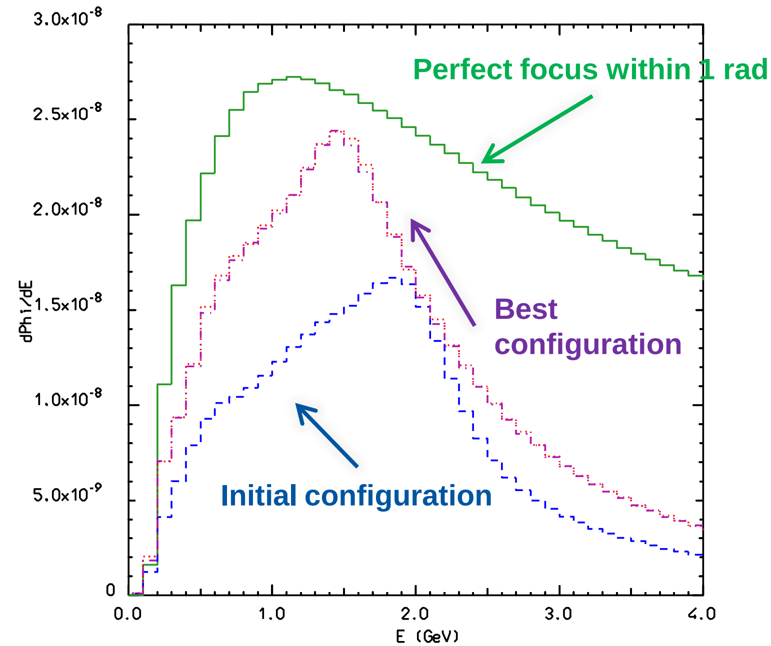


PRELIMINARY

Neutrino beam characteristics

- 5 GeV pion focusing – central ν_μ energy **~1.8 GeV**
- Target inside horn, followed by reflector

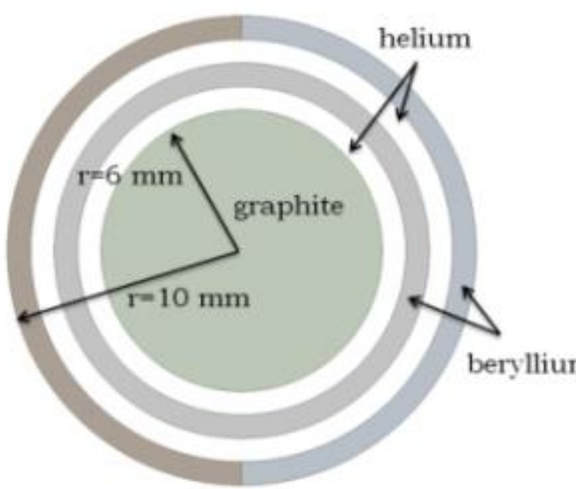


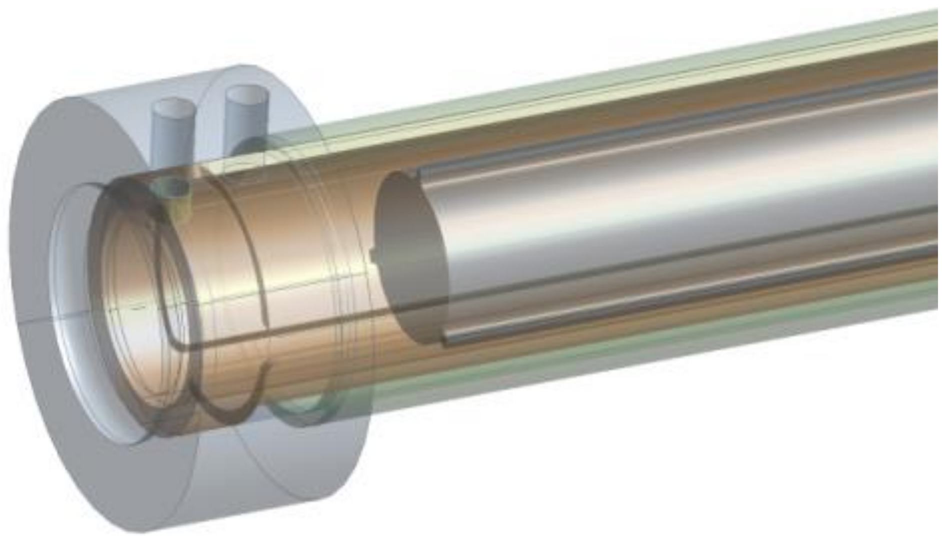


- Baseline DP radius of 150 cm

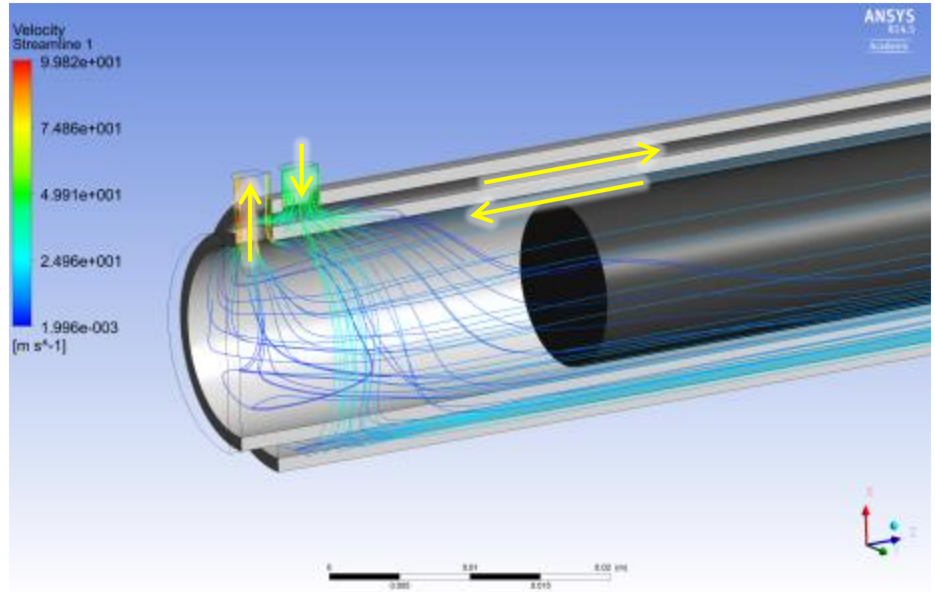
CENF target R&D

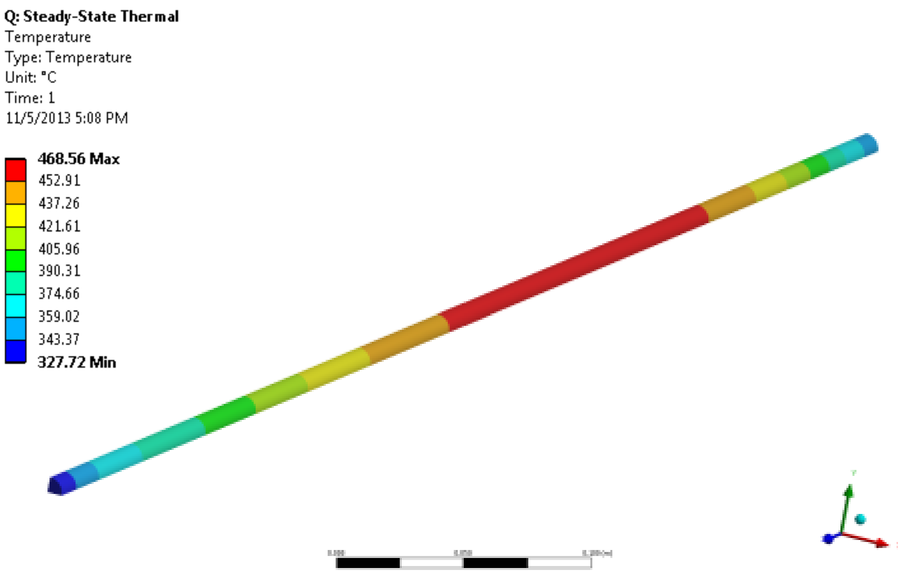
- 100 cm long, 12 mm Ø *→ challenging design*
  - ~2 kW dep. power, He-cooled graphite PT2020
- Graphite to be maintained around 600-700 K
  - Minimize mechanical properties change due to radiation effects
- Baseline fully inserted inside horn
- Complex design due to design IC Ø (24 mm – 30 mm)
  - Need low-Z but very rigid material to contain the graphite





VALUE	15 bar	20 bar
Max – Min T Graphite [K]	740 – 590	624 – 480 (-116)
Max temp Beryllium [K]	545	480 (-65)
P inlet [bar]- V outlet [m/s]	15 80	20 80
DP [kPa]	1.4	16.3
DT He [k]	230	180
He flow	0.4 g/ s	1.2 g/s

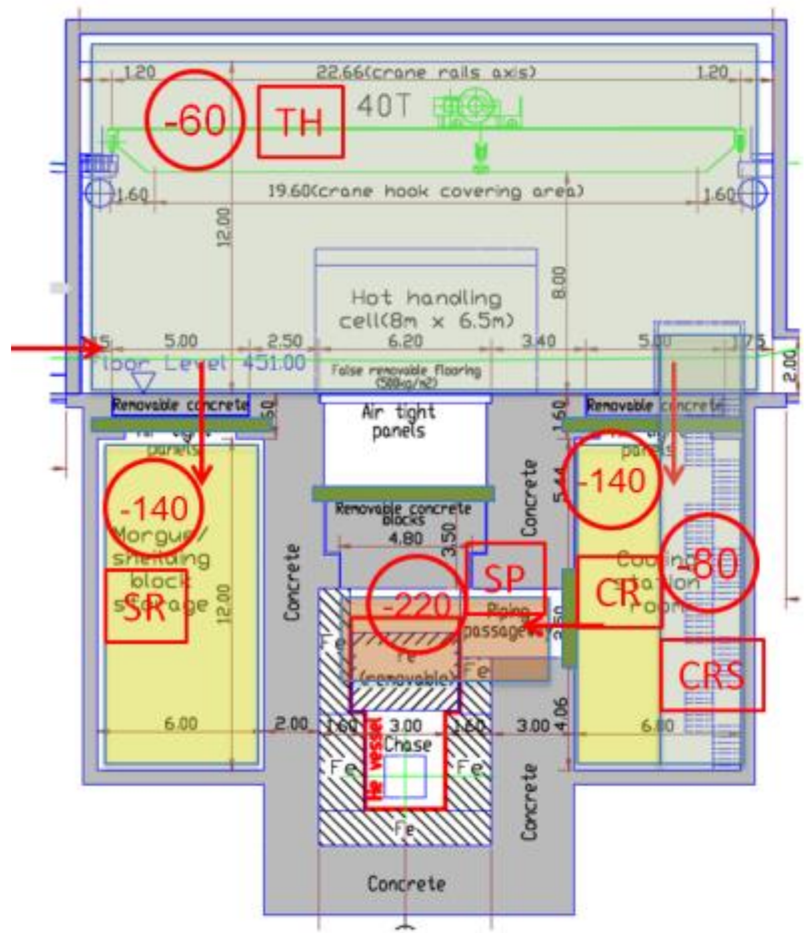




- Thermal compressive stress: **<2 MPa**
- Max graph. radial expansion: **~120 μm**
- Stresses due to pressure on Be structure (@20bar): **25 MPa** (max)

Ventilation system design

- CENF ventilation design respects ISO17873:2004*
- Pressure cascade of multi-compartments (from -60 to -220 Pa)
  - Flow rate: between 1 and 5 volumes/h
  - HEPA filters (F8+H14)
  - Low humidity control in the service pit



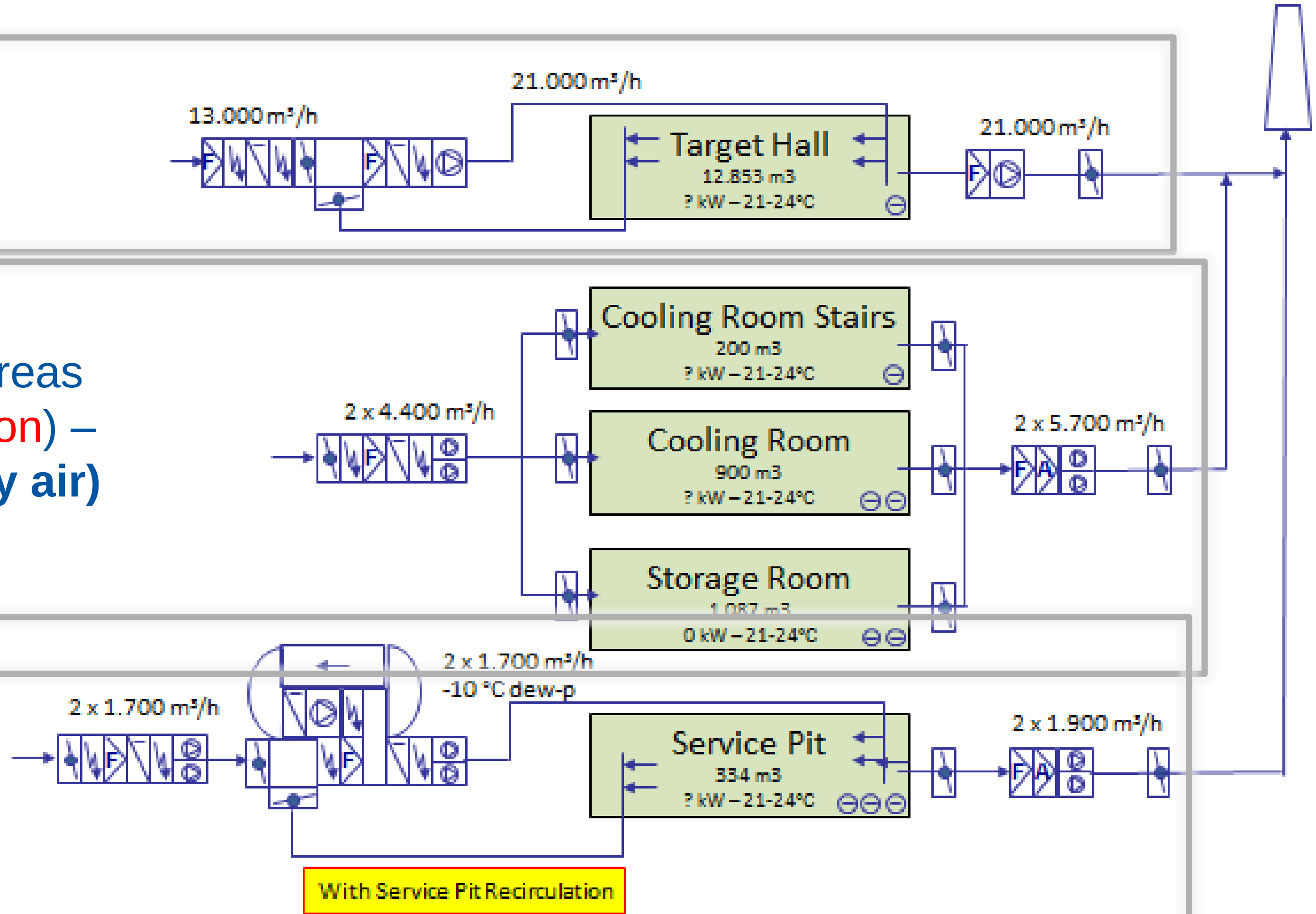
(*) adapted for nuclear instalallation other than nuclear reactors

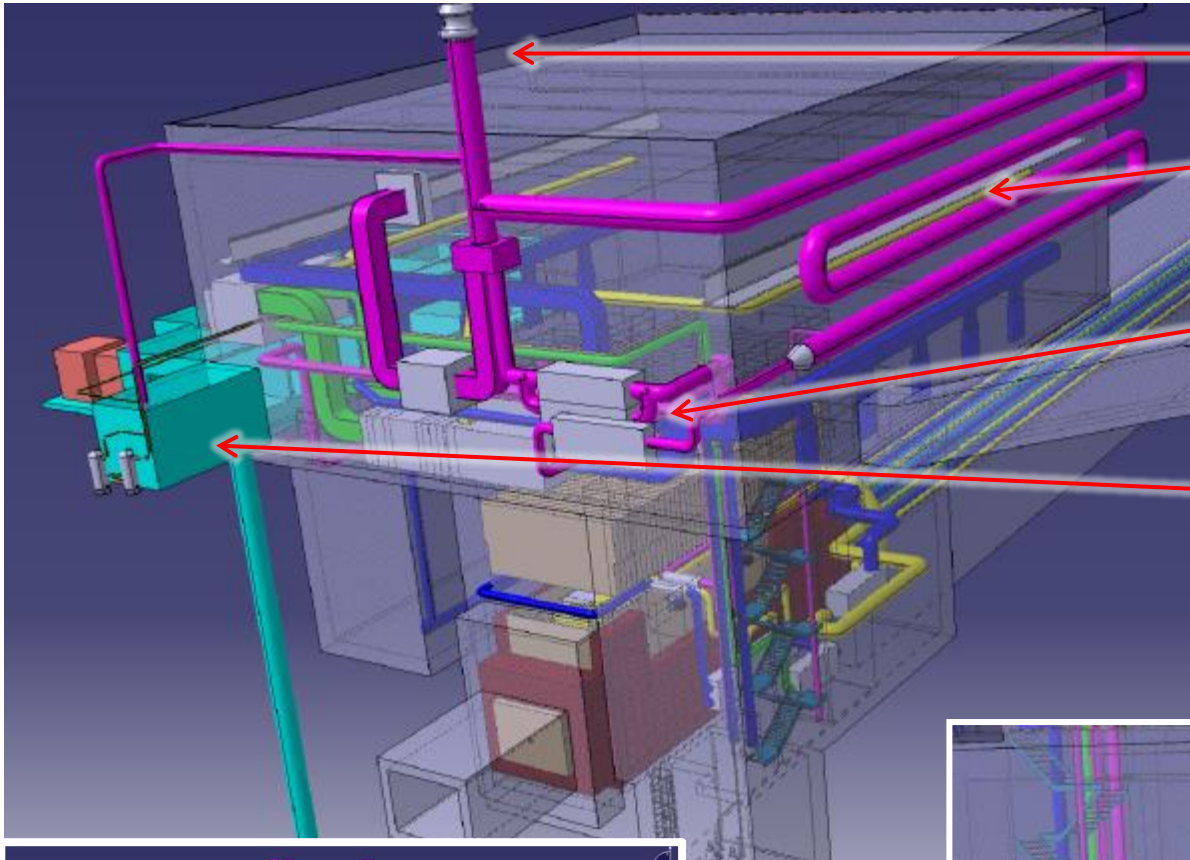
Ventilation system design

Surface hall – **partial recirculation**

Underground areas (limited activation) – **direct flow (dry air)**

Service pit (high activation) – **recirculation**





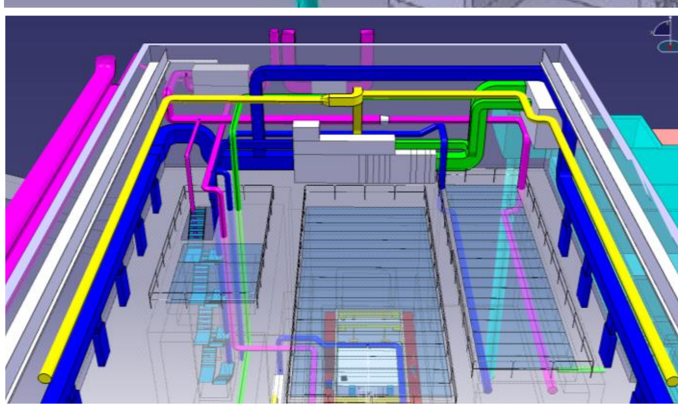
Main exhaust stack

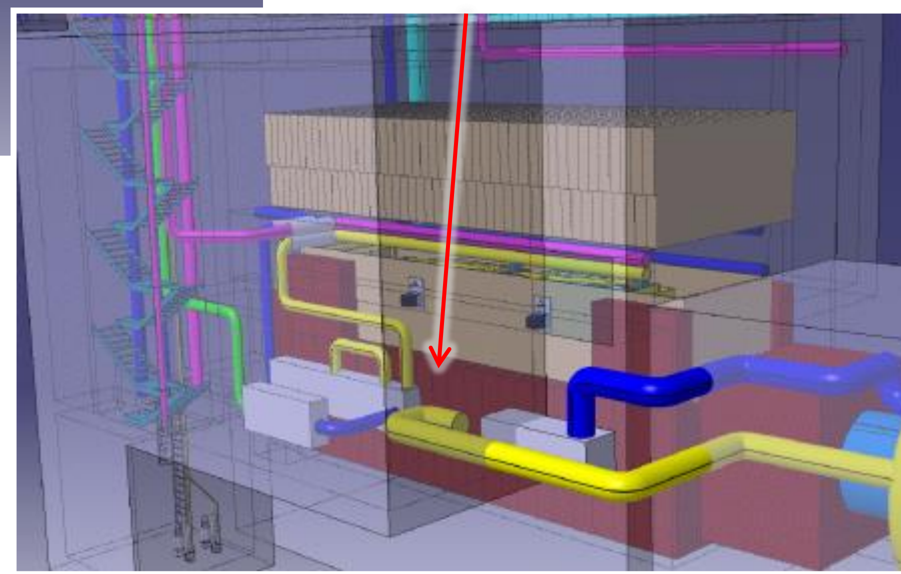
Delay line on the service pit extraction

Extraction units for underground areas

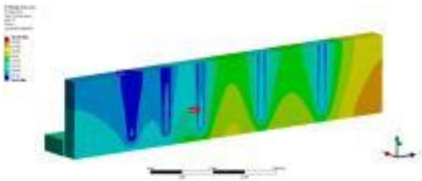
Evaporator for rising systems and water collection

Service pit circulation and DP cooling



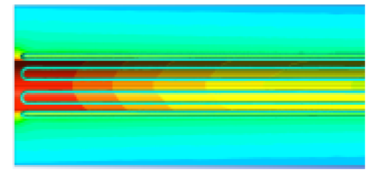


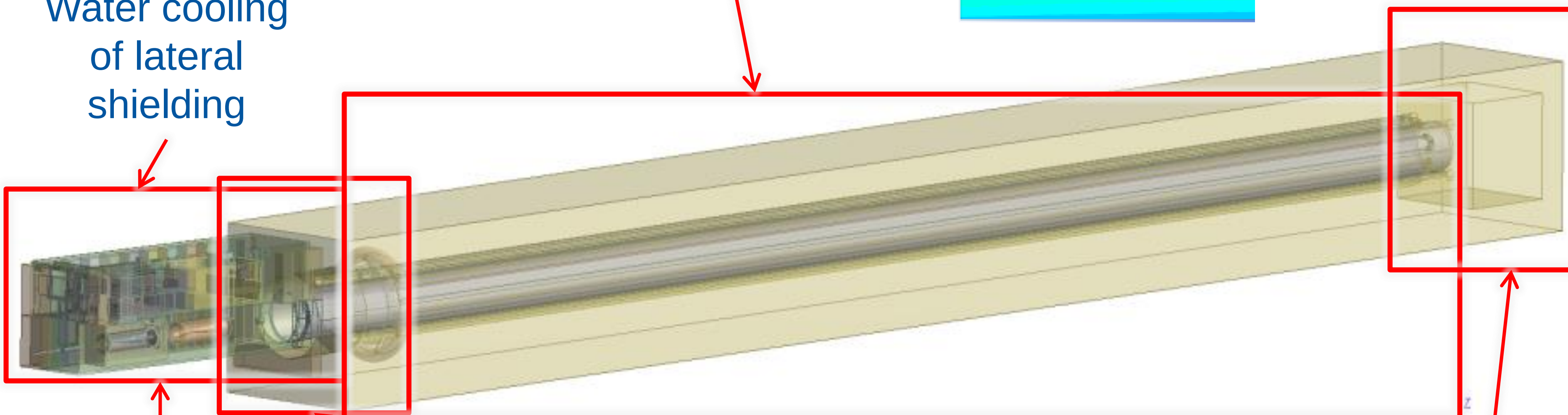
Summary of structural elements cooling



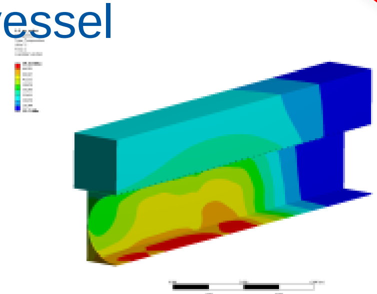
Water cooling of lateral shielding

DP steel/concrete air (or He-cooled)

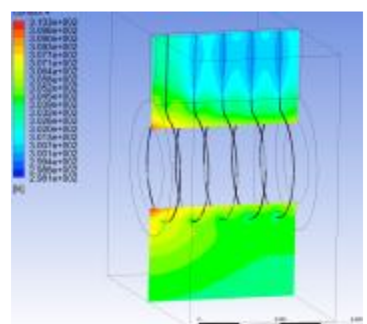




Helium forced circulation inside the He-vessel

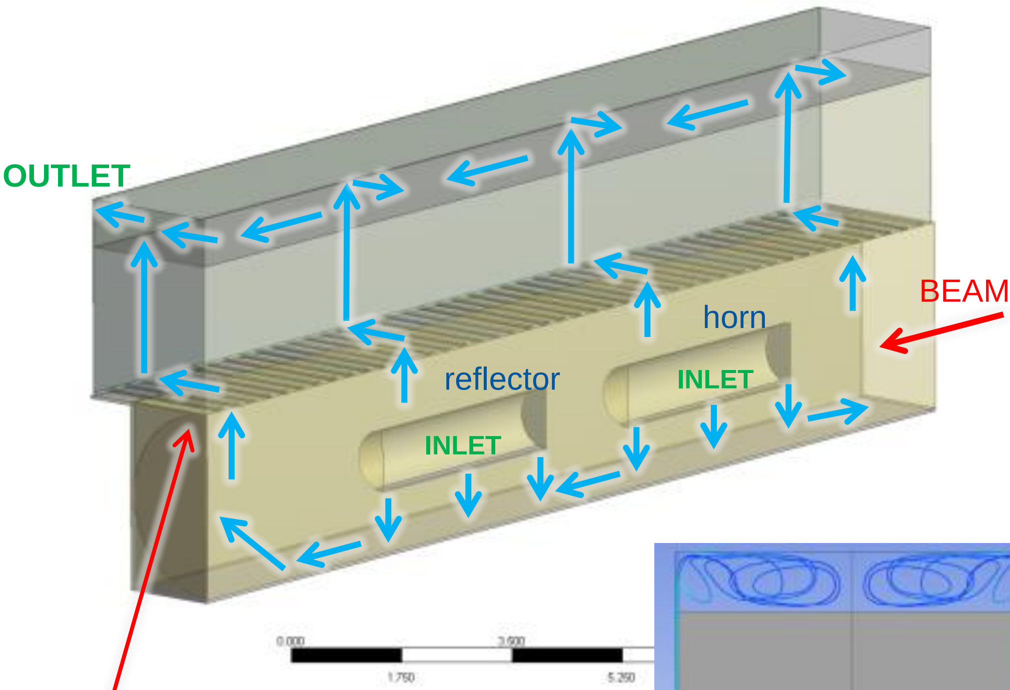


Water cooling of DP iron collar

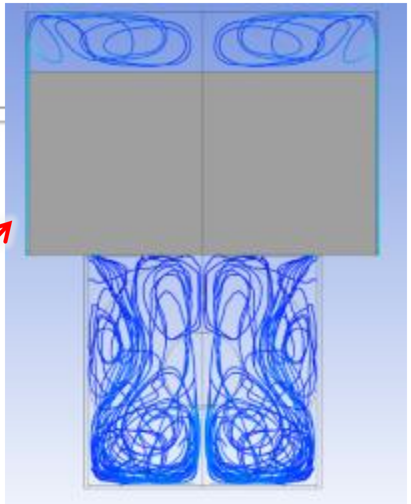


Water cooled hadron absorber

He-vessel + steel shielding cooling

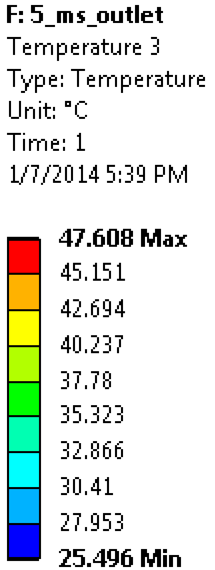


- Cooling of steel blocks and He-vessel via forced He-flow (~30 kW)

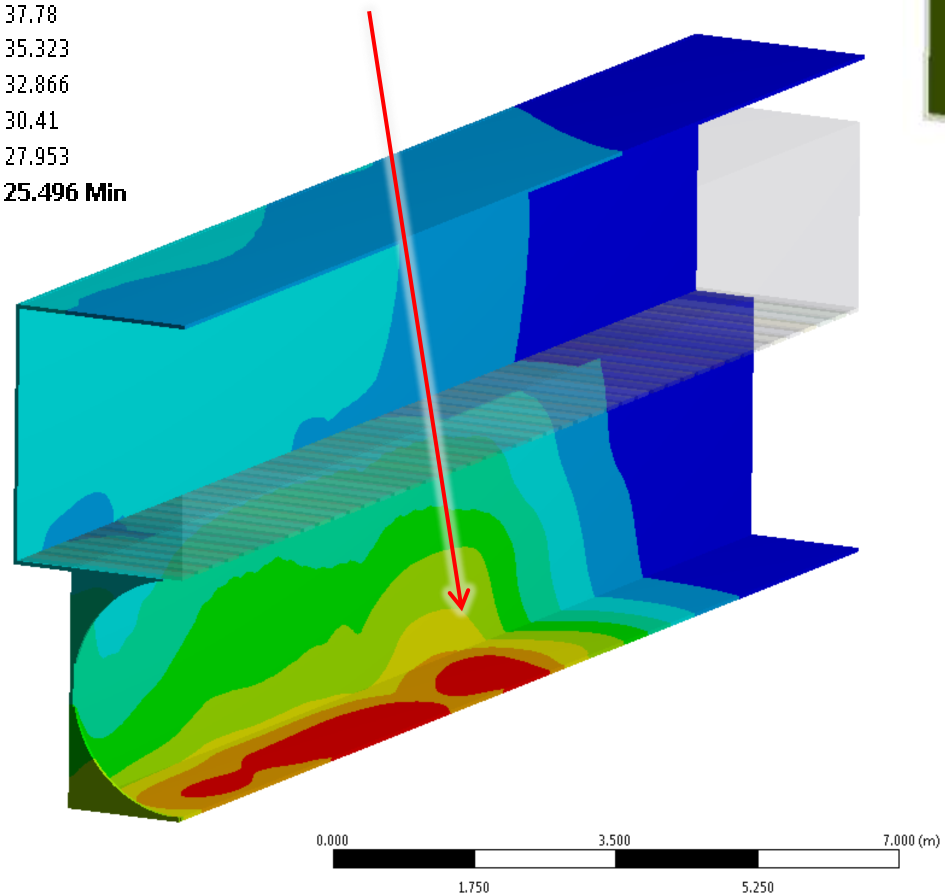


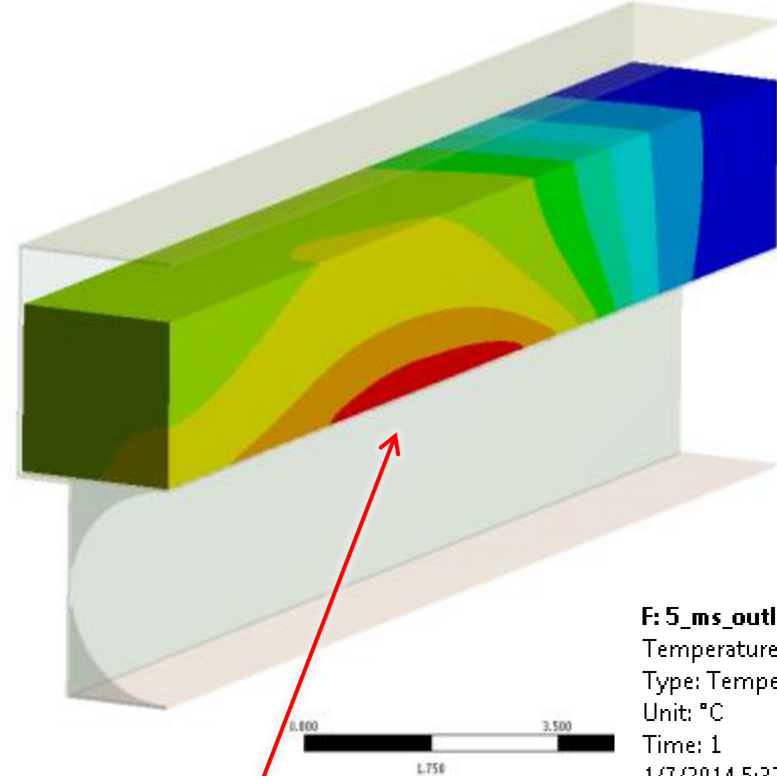
Steel blocks segmented in order to allow the flow of He

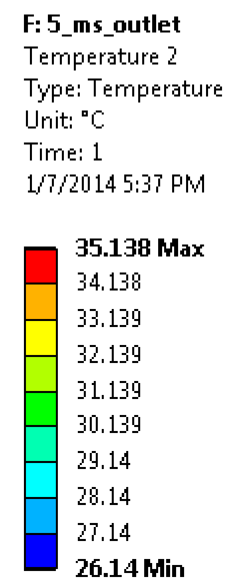
- Inlet @horn and reflector striplines (~0.7 m/s)
- Outlet symmetric upstream the He-vessel
  - ~5 m/s, 6000 m^3/h (ΔT~10 K)



Max He-vessel structure temperature at ~50 °C

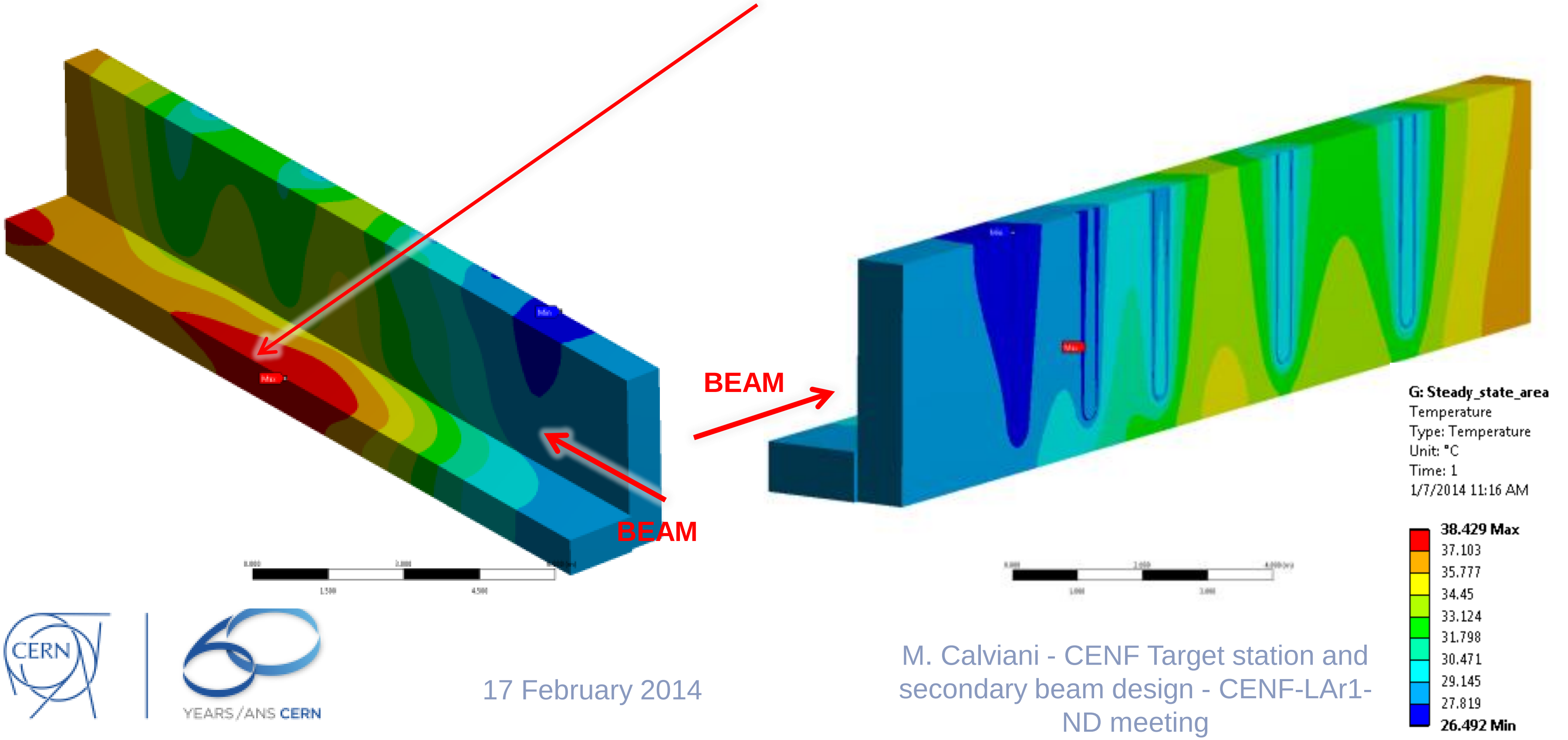






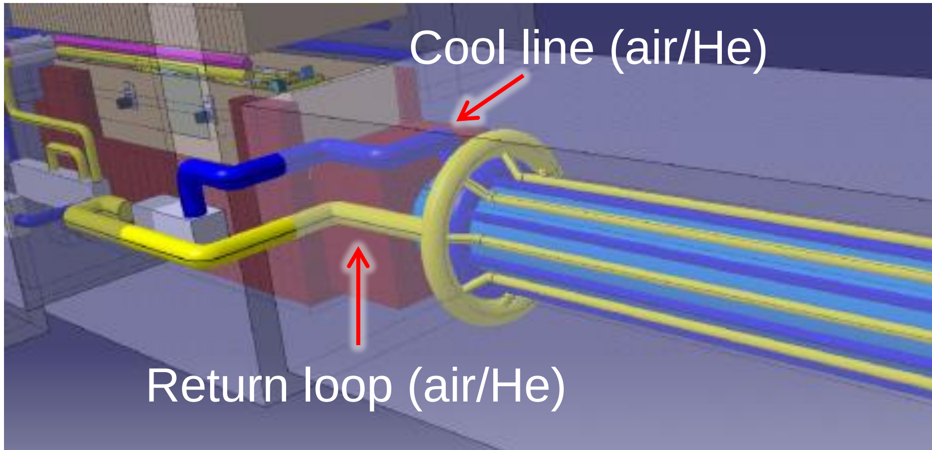
Max steel blocks temperature at ~35 °C

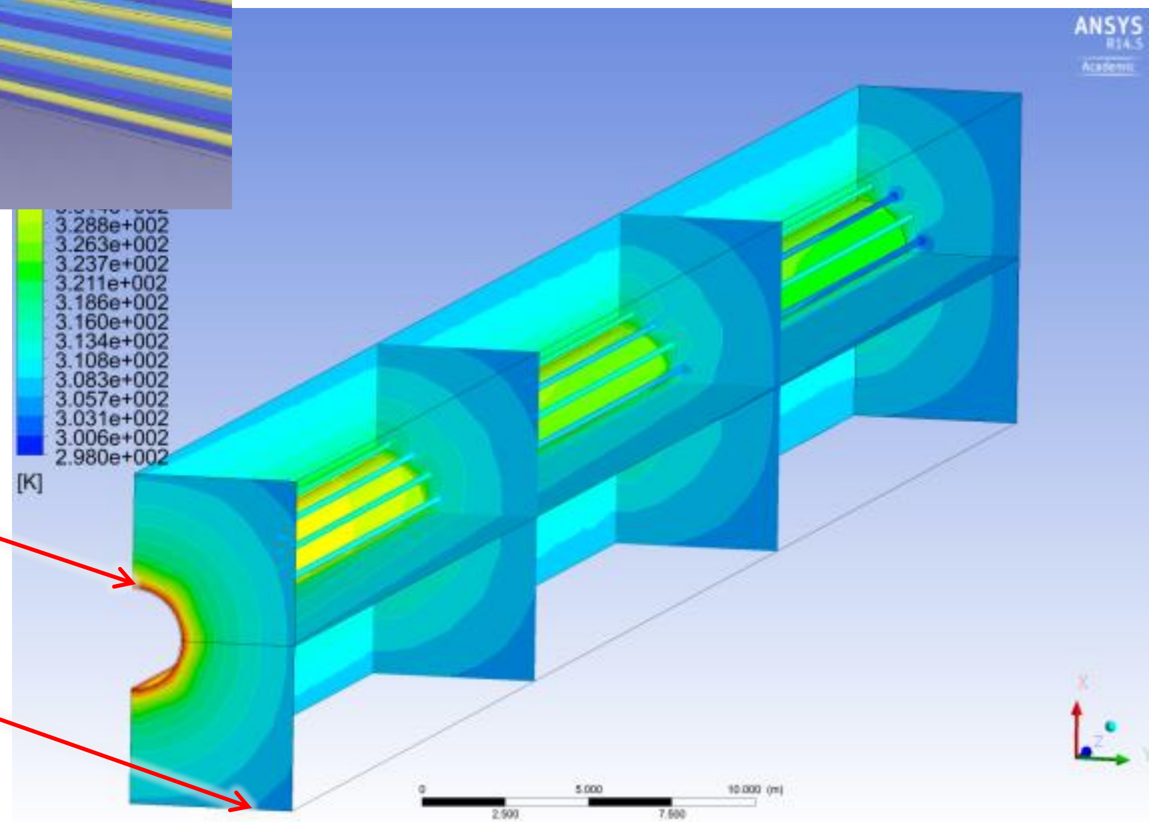
- Water cooled shielding steel blocks:
  - 5 pipes, in contact with lateral shielding (0.5 m/s at 25 °C)
  - Bottom layer cooled by conduction with lateral steel blocks
    - Max shielding temperature <40 °C



Decay pipe cooling

- **DP steel/concrete is air (or He) cooled (~80 kW)**
- 8 pipes (x2), Ø=20 cm
- Total air flow 8000 m^3/h (x2 for He)



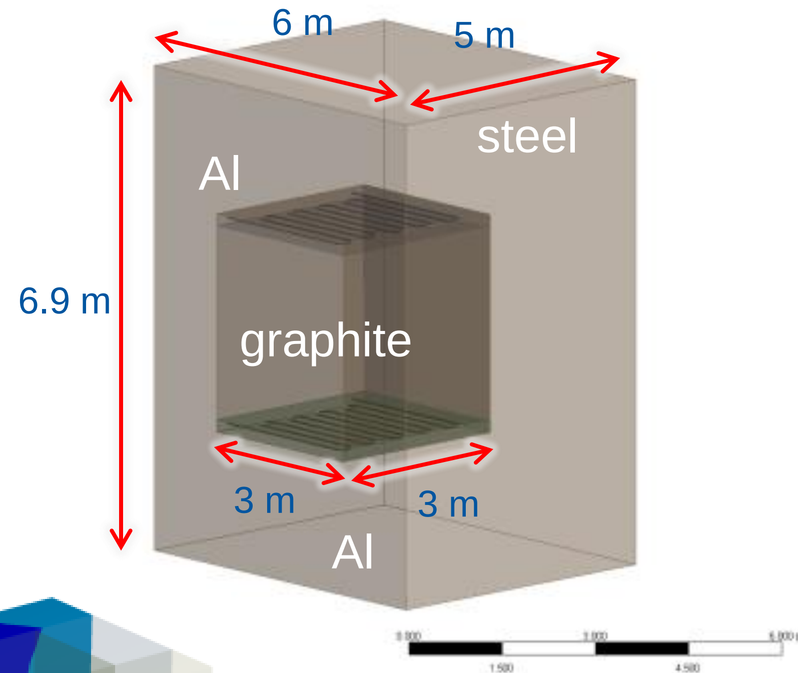


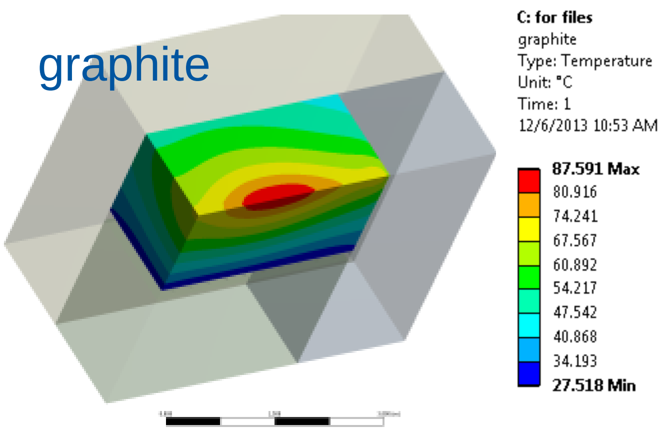
- ΔT ~15 °C
- Max velocity 11 m/s (16 m/s for He)
- ΔP ~690 Pa (320 Pa for He)

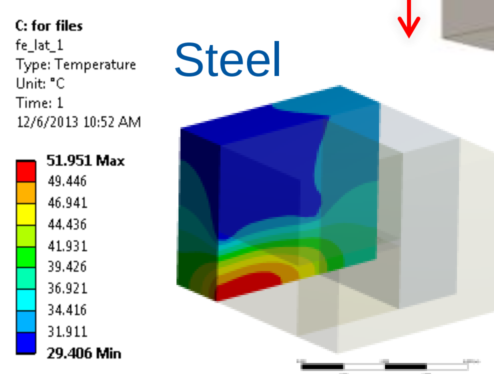
- Max temperature **~75 °C** on steel wall
- Concrete external temperature (@3.5 m) **~32 °C**

Hadron absorber cooling

- Basic design is a CNGS-like dump (total power ~75 kW)
- Graphite (Al) core, cooled by two water-cooled Al sinks
- Steel shielding (for muon and RP)

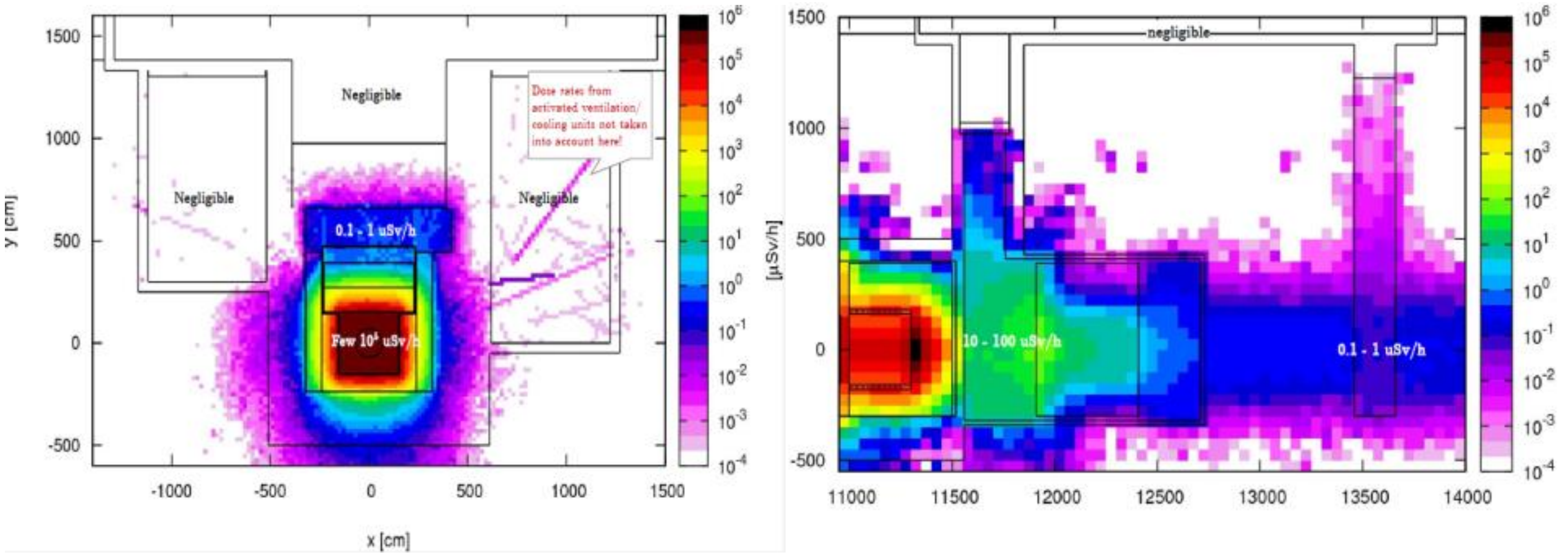






Radioprotection

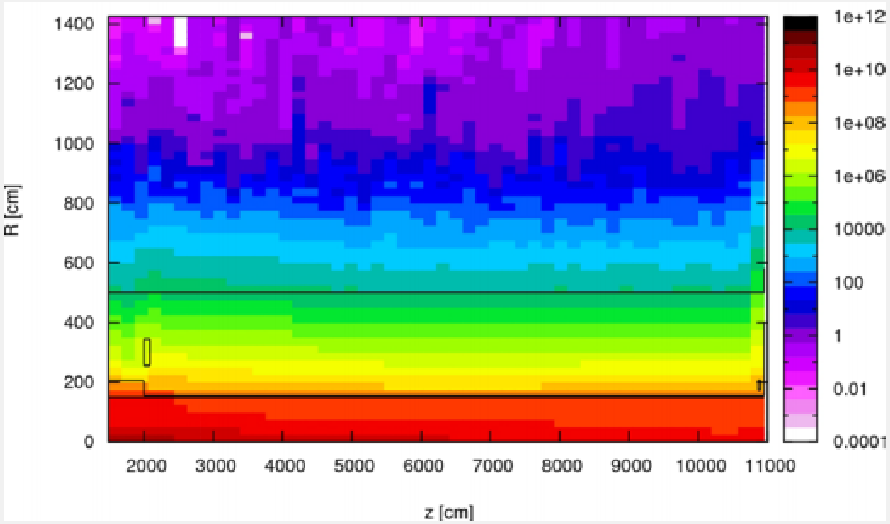
- **Radioprotection pivotal aspect for the design of (any) installation**
- Additional complexity due to the proximity to CERN fence (~70 meters)
- Analysis performed:
  1. **Air activation** → *max annual releases <10 TBq/y*
  2. **High energy hadrons** and **cumulated dose**
  3. **Waste zoning**
  4. **Prompt dose** and **soil activation**
  5. **Residual dose rates**



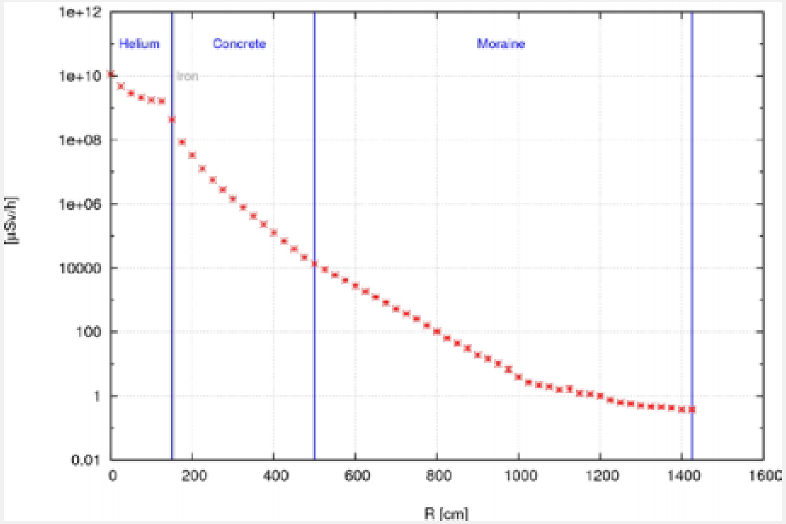
- Prompt dose in accessible areas during operation **<15 μSv/h**
- Residual dose rate in service pit (above He-vessel), **0.1 – 1 μSv/h**
- Yearly ambient dose rate at CERN fence is **≤5 μSv/y**

Prompt ambient dose rates above decay pipe – Results based on new geometry v21c

H*(10) at beam dump / muon pit area
Side view (uSv/h)



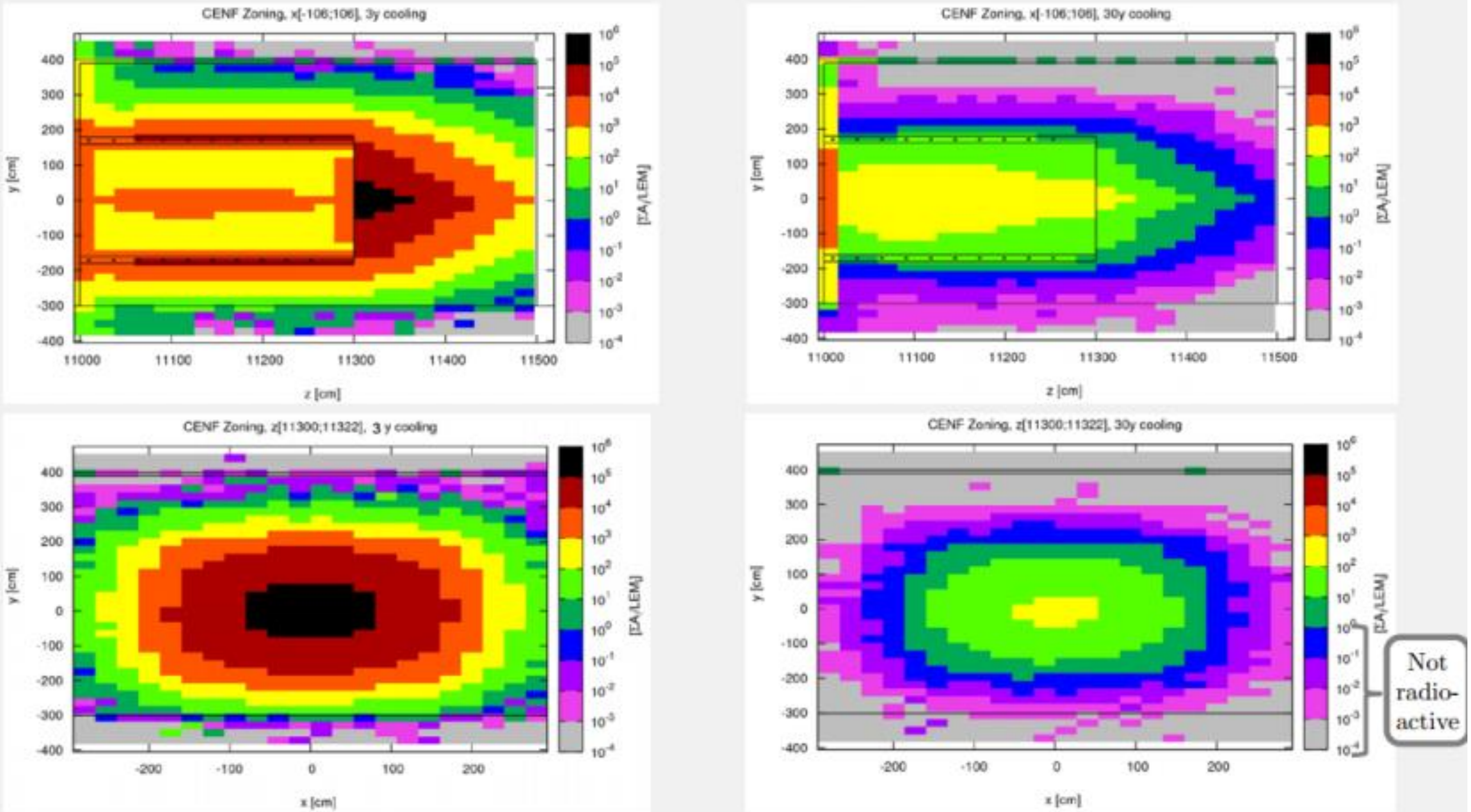
H*(10) around B757
Top view (uSv/h)



- *~1uSv/h at ground level*

- *Results reach dose limits for non-designated areas, wherefore the ground should be fenced (no special access system only simple lock needed)*

Radioactive waste zoning shows that a layer structure separating radioactive from standard waste regions would be favourable



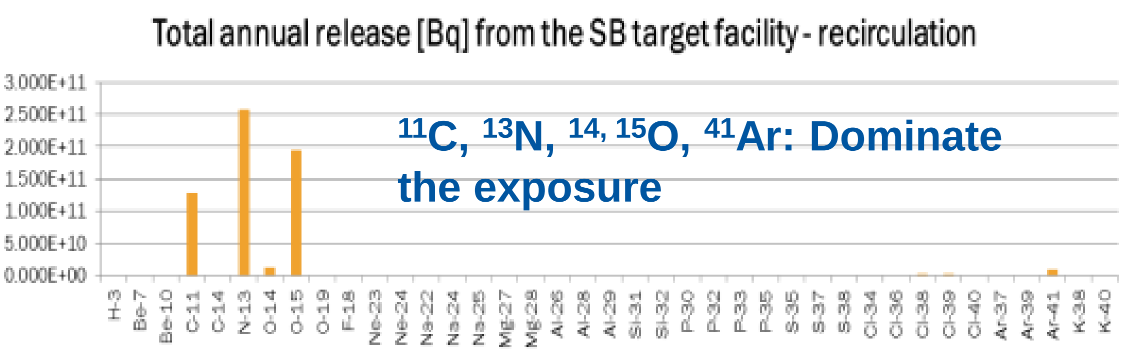
Assumed scenario: 5 years each of 87 days of operation and 278 days of shutdown , average beam power of 96 kW, i.e. 0.6 x 10^{13} protons/s ≙ 4.5 x 10^{19} pot/year

LEM : limits for waste characterization based on design limits representing the minimum of the recommended exemption limits

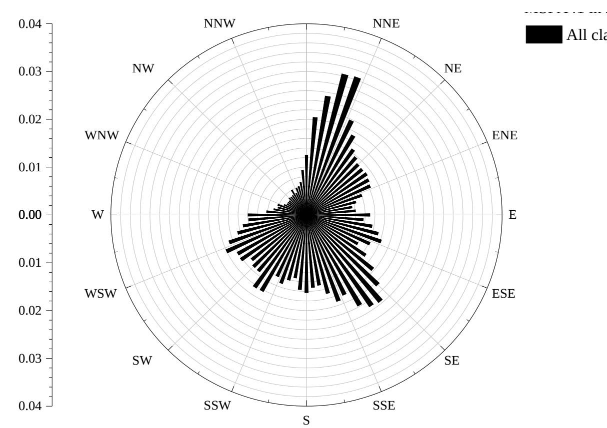
Environmental releases

- A complex model has been developed at CERN for this project in order to estimate the annual releases from the various subsystems
- Key aspect is the <u>ventilation system design</u>

Facility / mode (4.50E+19 POT/y)	TBq/y
Target Facility - recirculation	0.60
Target Facilty - once-through	3.20
Traget Facility - once-through and decay duct	1.41
Muon Pits	0.04



^{11}C, ^{13}N, ^{14,15}O, ^{41}Ar: Dominate the exposure



- Expected maximum dosimetric impact **<0.05 μSv/y**

Environmental releases

1. With the designed ventilation system, the radioactive emissions from the target facility are not a show-stopper
   - Recirculation in the service pit is preferred (removal of ^{7}Be and P)
2. In case of an air-filled target chamber production of radionuclides would be at least 10x larger
3. Limited – contributions from the water evaporator system (^{3}H)
   - Collection of humidity from underground areas and potentially contaminated drains

Preliminary risk analysis

- As a part of the project, a safety study has been launched
  - Identification of **hazard and risks reduction** for the CENF target facility
  - Analyse in detail **possible accident scenarios** related to every hazard
  - Evaluate the **role in the risk reduction** of every protection barriers
  - Document the **Safety Qualification Requirements** for the **safety system implementation** (part of the design study)

Summary

1. A **sound technical design** for a new CERN neutrino beam line is being developed
2. Facility designed for a beam power of **200 kW** (with margins), but the design is scalable for <u>higher power</u>
3. A design study report will be released during the course of 2014
4. **The design choices could be applicable also for other target facilities proposed at CERN using SPS beam @NA**