The 19th International Workshop on Neutrinos from Accelerators
NUFACT2017

The ESSνSB Switchyard, Target Station and Facility Performances

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ESSνSB Collaboration

IPHC-IN2P3/CNRS Strasbourg

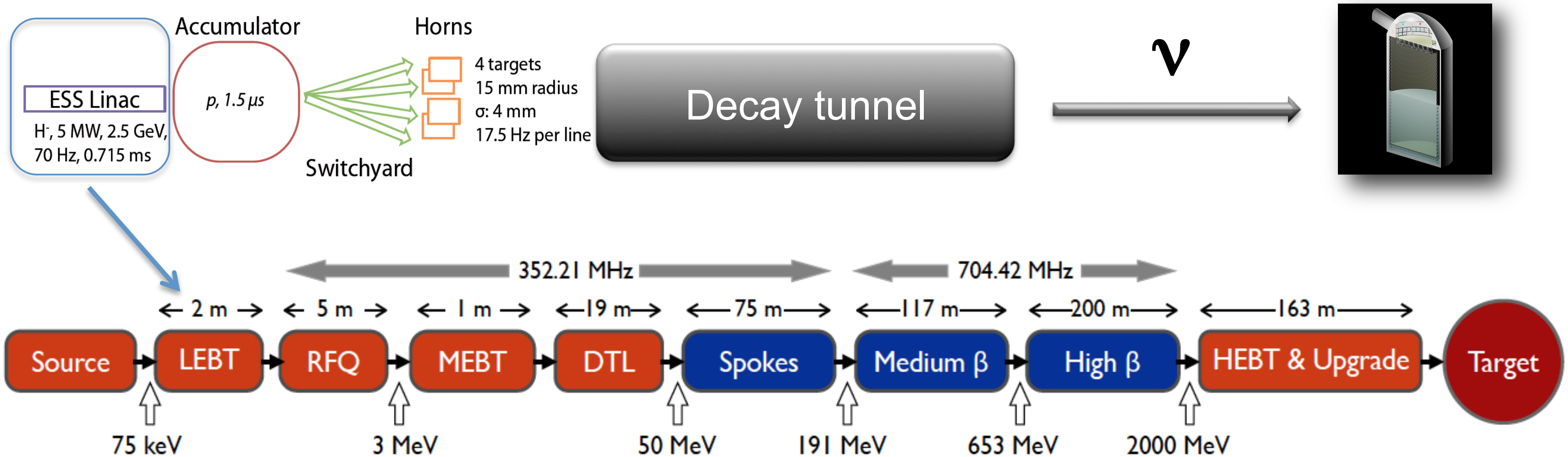
Precision era in neutrino physics

- Next generation of neutrino accelerator based experiments will address the fundamental questions on CP violation and Mass Hierarchy.
- Common efforts are needed to realize the future facilities:
  - Accelerator challenges to develop a proton driver at MW scale.
  - R&D program for Mt scale detectors with conventional or novel technology with improved sensitivity.
  - An international program based on an incremental approach has been established (LBNF/DUNE, T2K,…) taking benefits from previous studies…

Super Beam Facility : Target Station

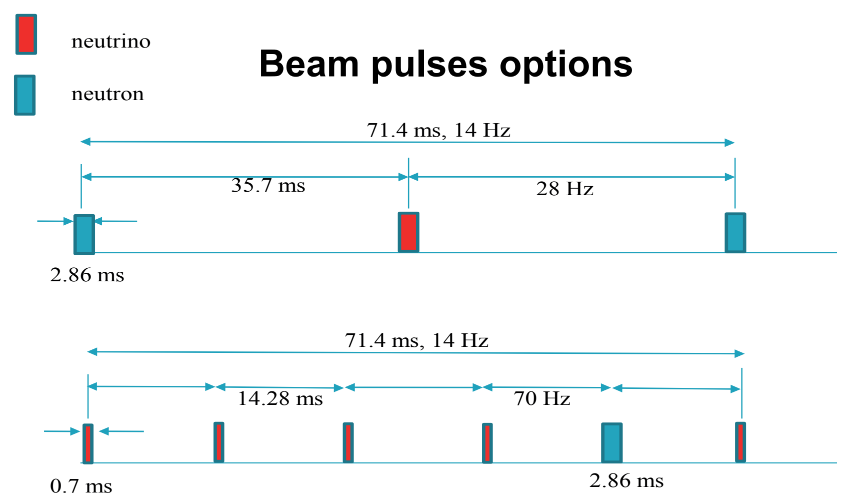
- **Design:**
  - Producing a high intensity neutrino beam from MW proton beam is a technical challenge and requires R&D:
    - Target able to support Multi Mega Watt proton beam
    - Focusing system with minimum failures during run time
    - Remote handling system for maintenance
  - Minimize risk of failures during beam operations
  - Safety for workers
  - Respect environmental conditions
  - Reduce production and running costs
  - …

ESS Proton Beam LINAC

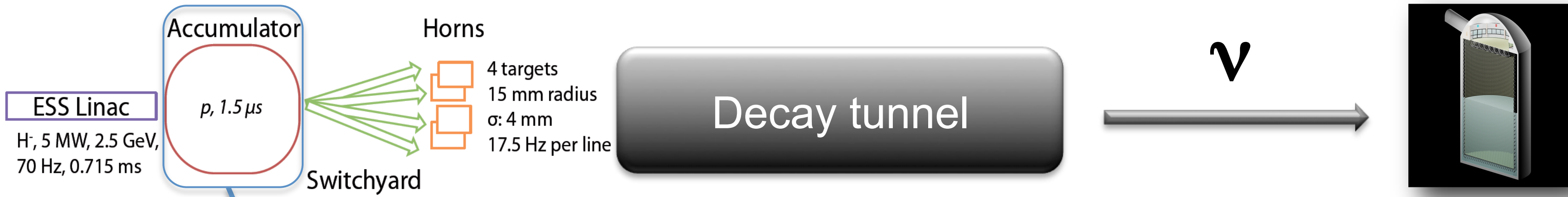


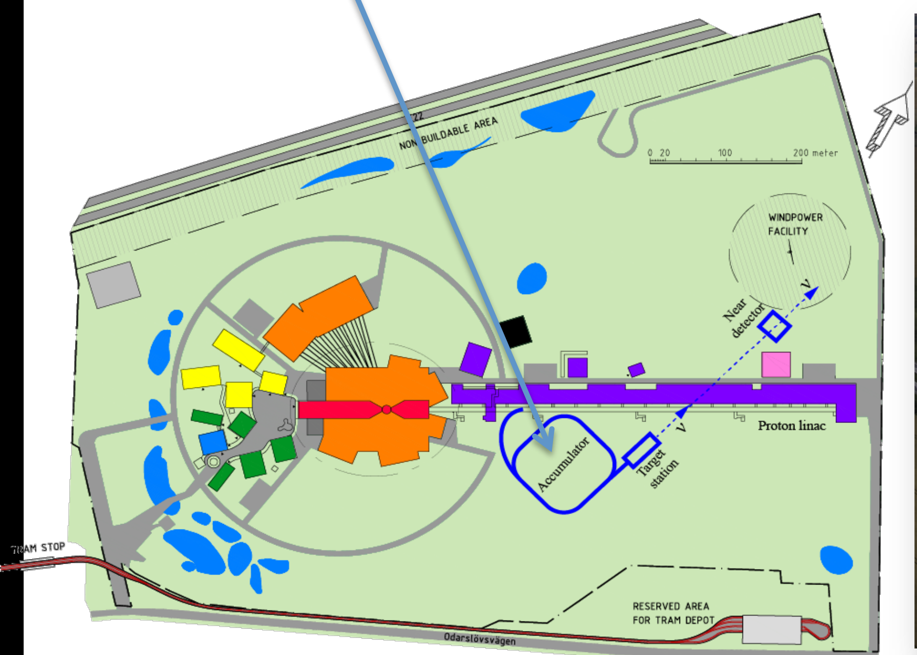
ESS LINAC requirements for a super beam

- Increase beam power : 5 MW to 10 MW
- Extra RF power capacity
- Accumulator ring to shorten the pulses to micro second order for the horn
- Extra H^- source for additional pulses
- Several beam pulse profiles are under investigations



Accumulator





Accumulator implementation on ESS site

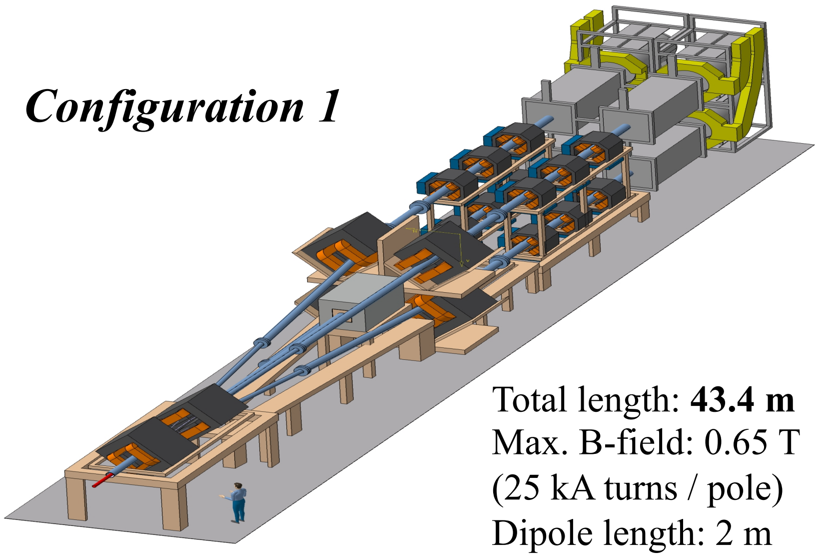
ESS construction site

IPAC'15 Proceedings: E. Wildner et al., "*The Accumulator of the ESSnuSB for Neutrino Production*", THPF100

Switchyard Driver

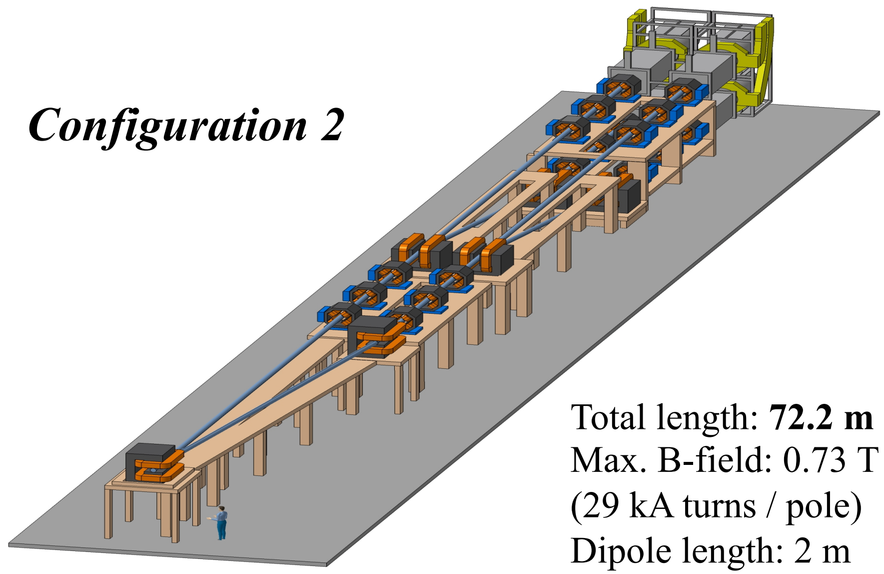
- Update of the switchyard preliminarily designed for EUROν with ESS beam parameters (Config.1)
- Other possible layouts currently being studied (Config.2)
- Selection criteria: number of magnetic elements needed + type of operation (i.e. simple or bi-polar) + prospective of beam dump requirements.

Configuration 1



Total length: **43.4 m**
Max. B-field: 0.65 T
(25 kA turns / pole)
Dipole length: 2 m

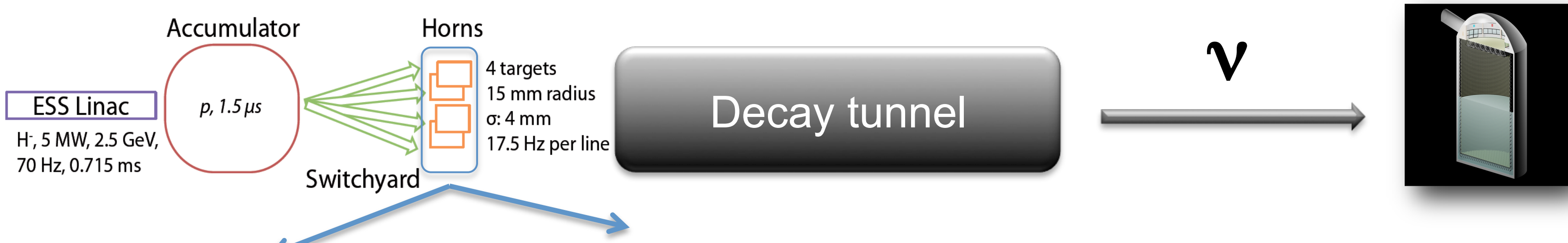
Configuration 2



Total length: **72.2 m**
Max. B-field: 0.73 T
(29 kA turns / pole)
Dipole length: 2 m

IPAC'15 Proceedings: E. Bouquerel, "*Design Status of the ESSnuSB Switchyard*", MOPWA017

Focusing System



Target concept:

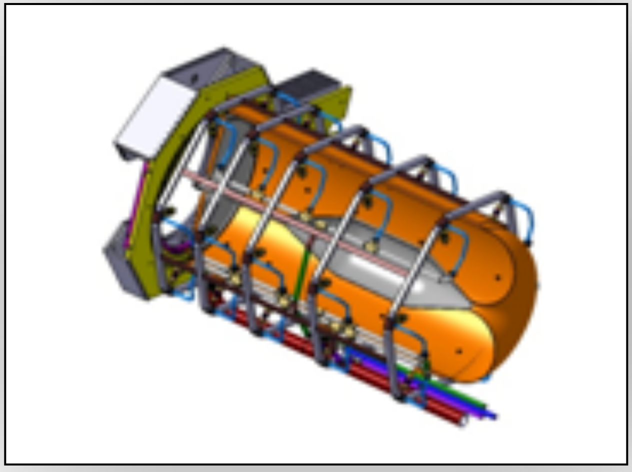
- Power 1.25 – 1.6 MW
- Potential heat removal rates at the hundreds of kW level
- Helium cooling
- Separated from the horn

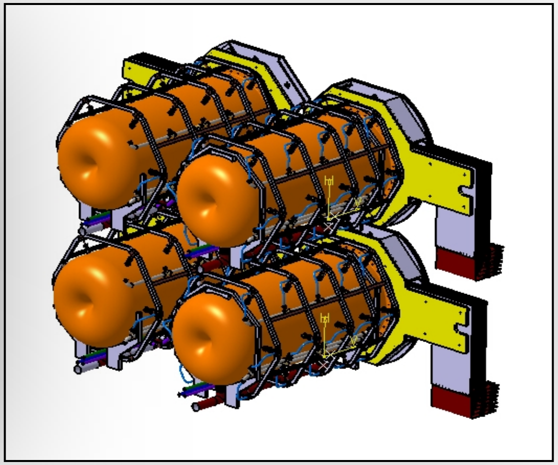
Packed Bed/Segmented Target

(EUROnu WP2 Options)

Focusing system:

- 4-horn/target system to accommodate the MW power scale
- Solid target integrated into the inner conductor : very good physics results but high energy deposition and stresses on the conductors
- Best compromise between physics and reliability



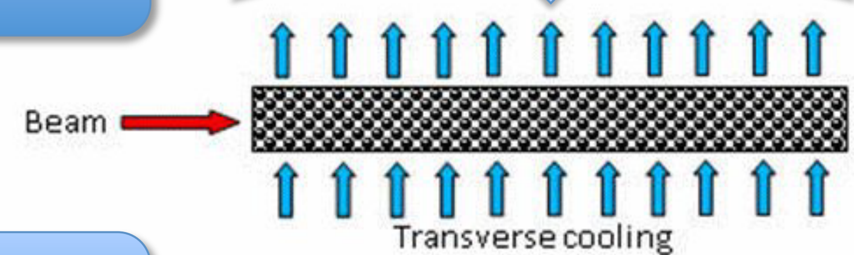


Target Concept

Heat removal

Mechanical stresses

Radiation Damages



Packed Bed Target

Geometrical Constraints

Remote Handling

Safe Operations

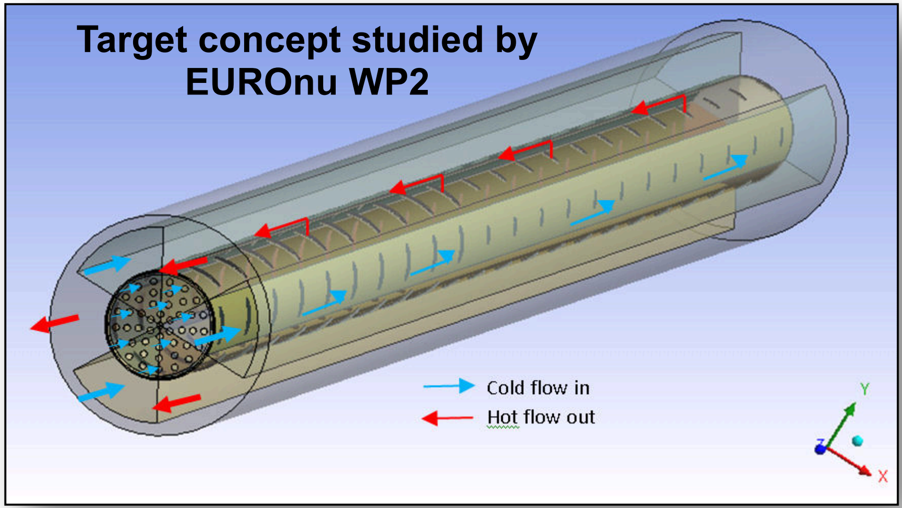
Improved Lifetime

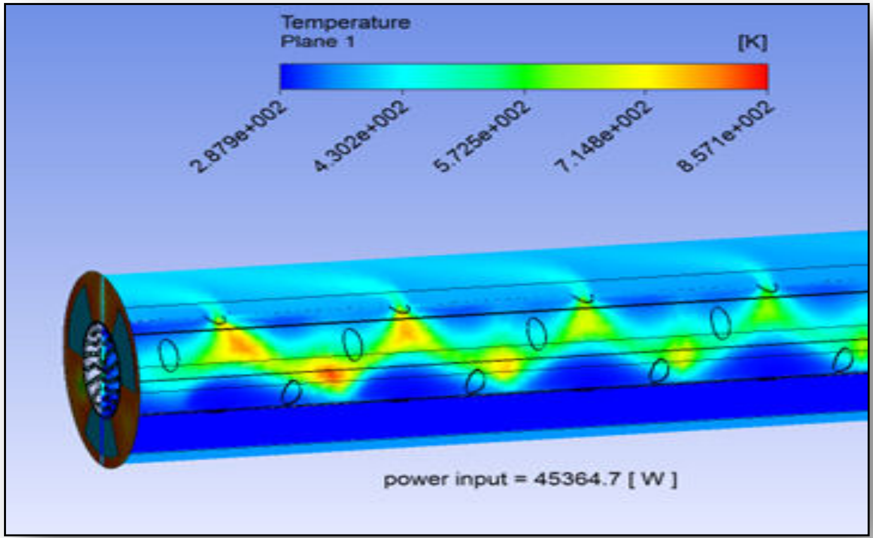
Packed Bed Target

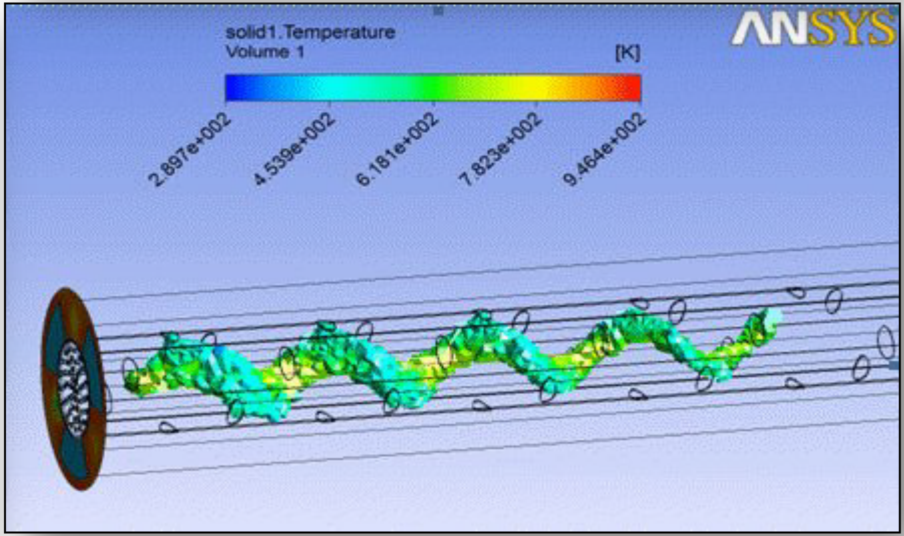
Target : 3 mm diameter titanium spheres
Proton Beam : 4.5 GeV, 1MW (SPL - Parameters)
Beam width : 4 mm
Target geometry radius/Length : 12 mm / 780 mm
Coolant : Helium at 10 bar pressure

Titanium temperature contours:
Temperature < 673°C (Melting temp =1668°C)

=> Concept will be upgraded for ESSνSB



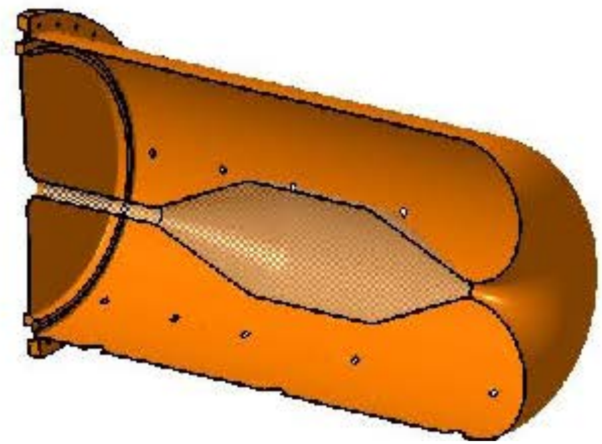


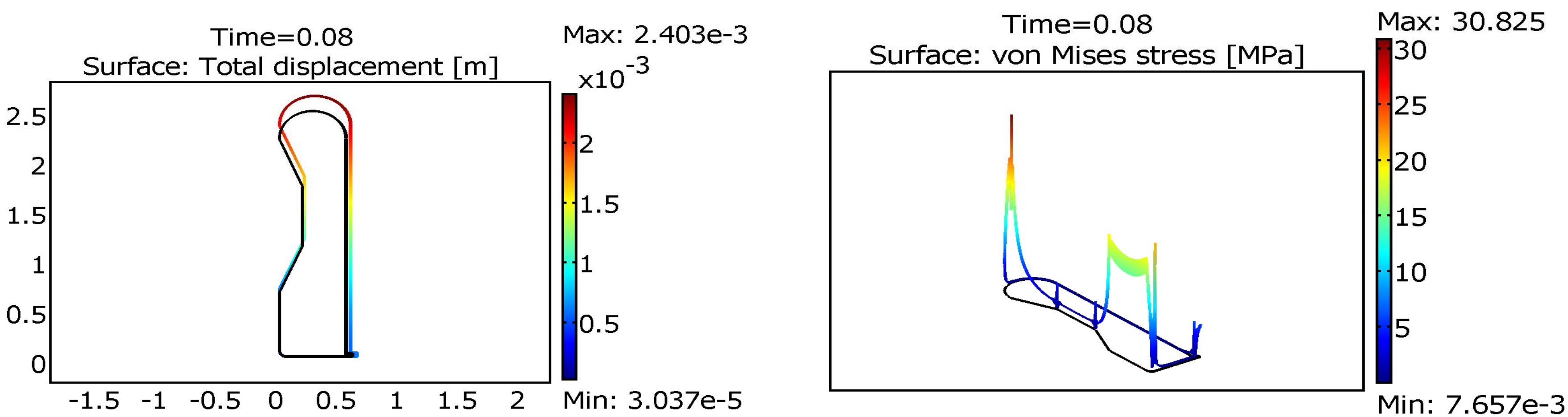


Horn

Design : MiniBooNe-Like Horn
Material : Aluminum Al T 6061 – T6
Geometry : Length 2.4 m – Diameter 1.2 m
Inner/Outer conductor thickness : 3 mm /10 mm
Peak Current : 350 kA

=> Concept will be upgraded for ESSνSB

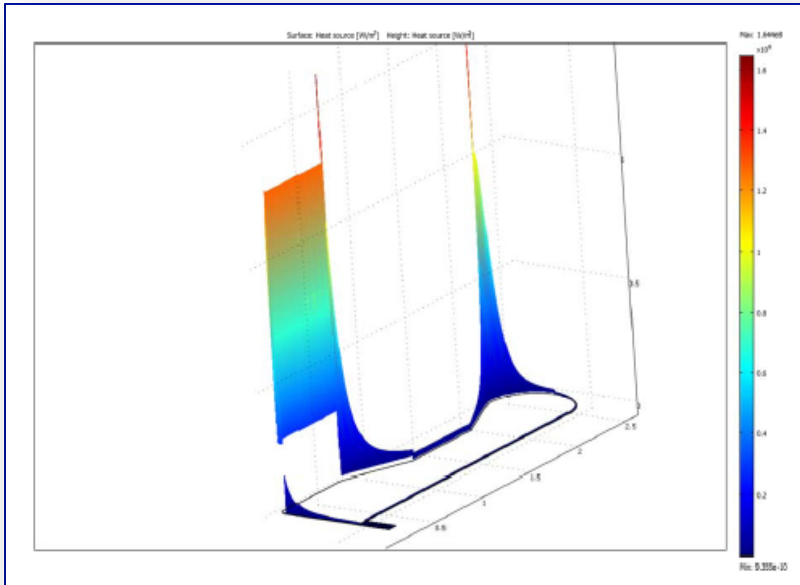


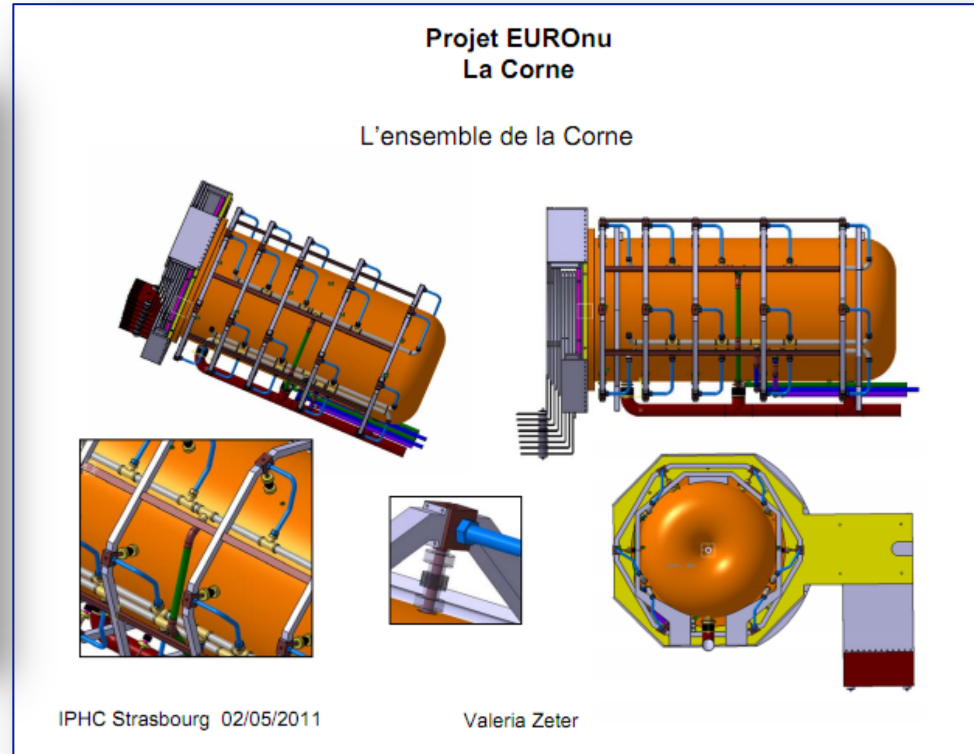


a) $u_{max} = 2.4$ mm, $t = 80$ ms   b) Von Mises stress $s_{max} = 30.$ MPa, $t = 80$ ms

Figure 16: Displacement field a) and von mises stress b) due to thermal dilatation with uniform temperature $T_{horn} = 60°C$

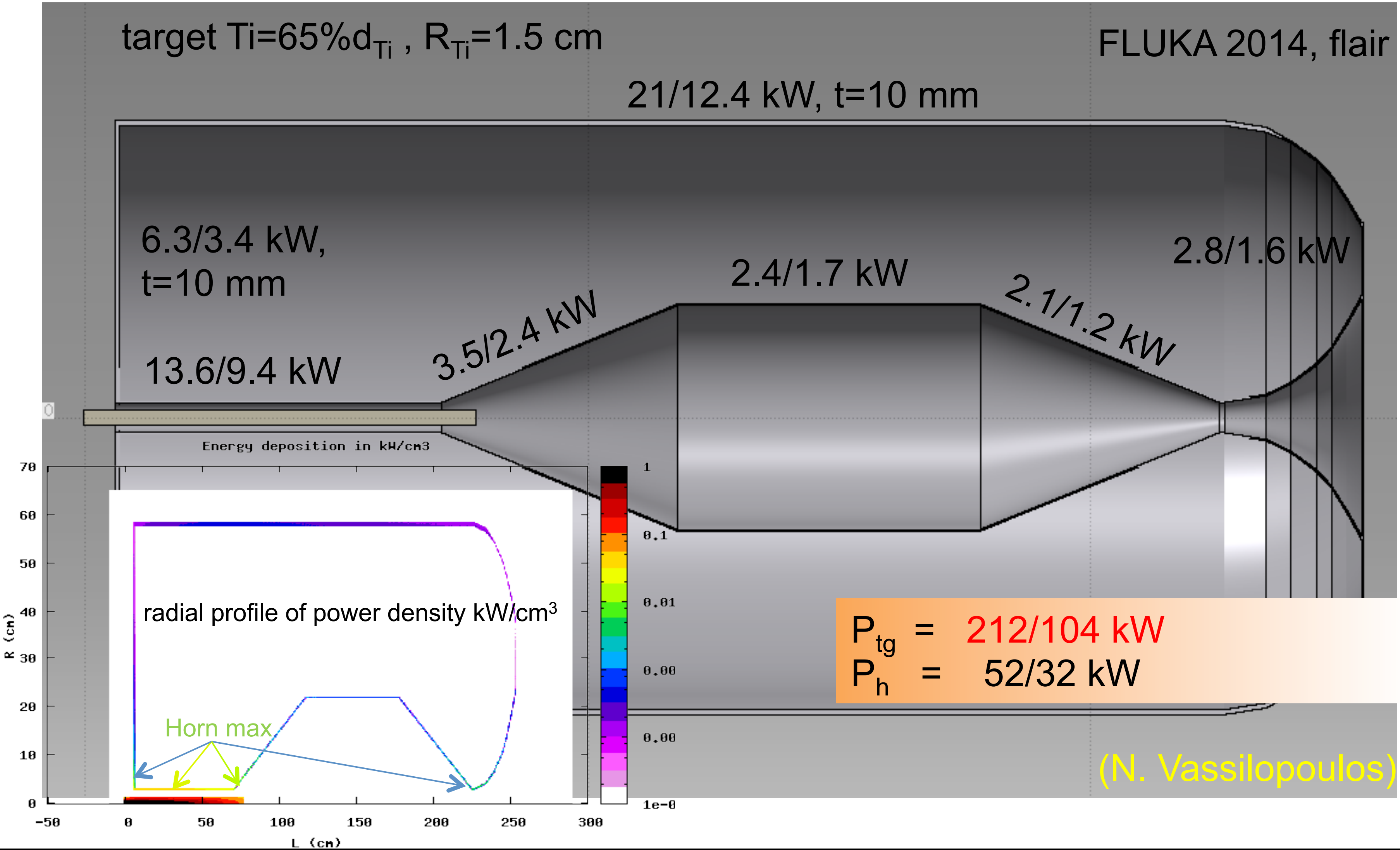
Water Cooling System





Cooling system

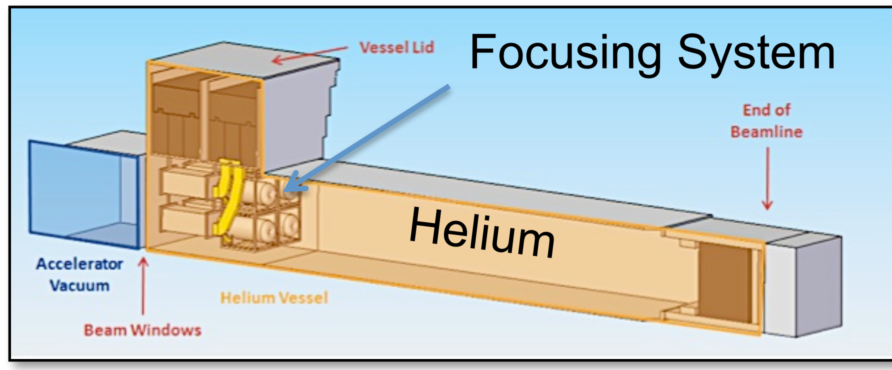
- Planar and/or elliptical water jets
- 30 jets/horn, 5 systems of 6-jets longitudinally distributed every 60^0
- Flow rate between 60-120l/min, h cooling coefficient 1-7 kW/(m^{2}K)
- Longitudinal repartition of the jets follows the energy density deposition
- $\{h_{corner}, h_{horn}, h_{inner}, h_{convex}\} = \{3.8, 1, 6.5, 0.1\}$ kW/(m^{2}K) for $T_{Al\text{-}max} = 60\ ^0C$


target Ti=65%d$_{Ti}$, R$_{Ti}$=1.5 cm
FLUKA 2014, flair
21/12.4 kW, t=10 mm
6.3/3.4 kW,
t=10 mm
2.4/1.7 kW
2.8/1.6 kW
3.5/2.4 kW
2.1/1.2 kW
13.6/9.4 kW
Energy deposition in kW/cm3
radial profile of power density kW/cm^3
Horn max
P_{tg} = 212/104 kW
P_h = 52/32 kW
(N. Vassilopoulos)
R (cm)
L (cm)

Target Station Concept

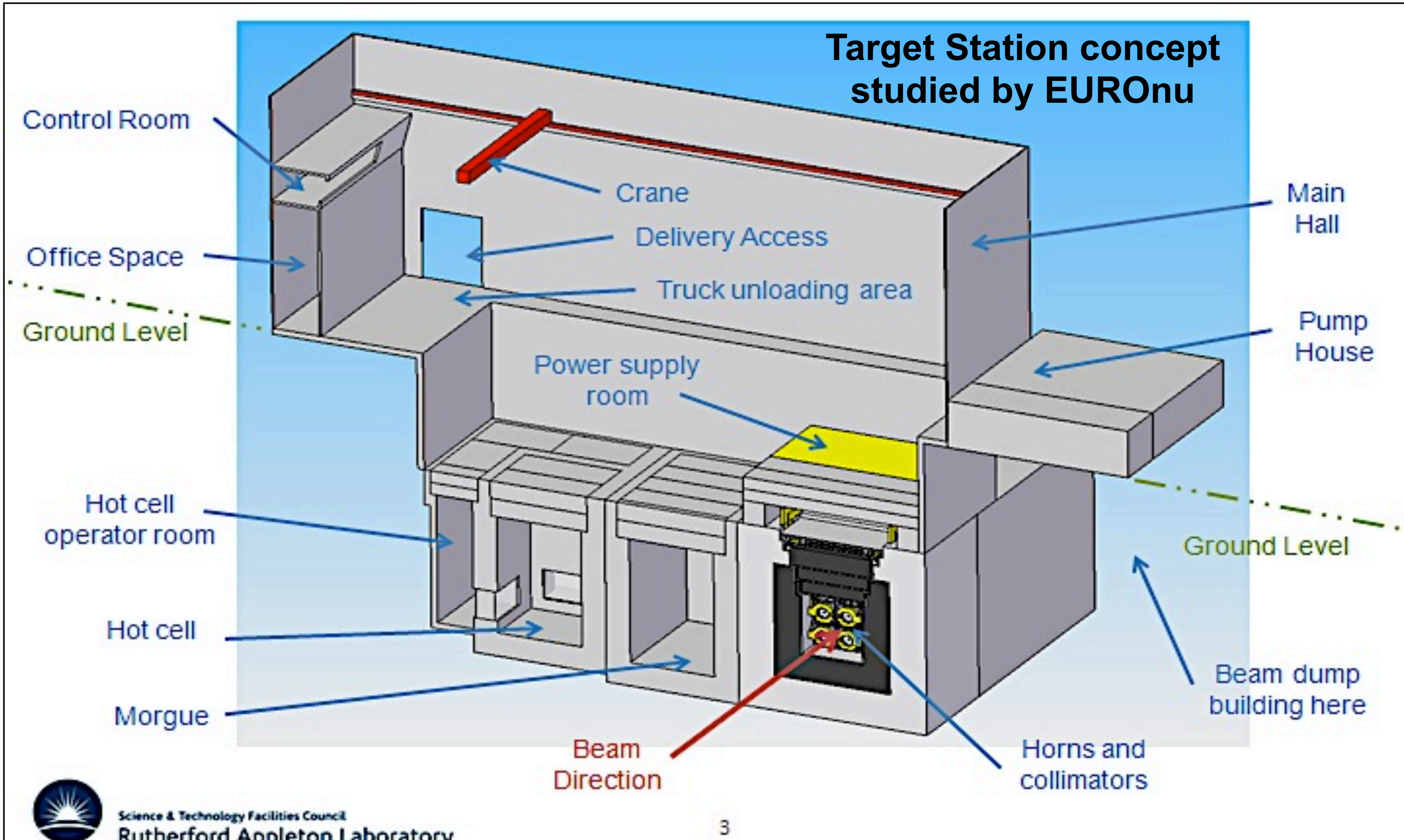
Target Station Requirements

- Focusing System
- Crane System
- Automated robot
- Supporting structure for focusing system
- Dose Rate Monitoring System
- Residual Dose Rate platform
- Operation under helium atmosphere
  - flushing with air
  - filter to measure radioactive pollution (dust, tritium …)
- Investigation of other radionuclides transport (environmental constraint)

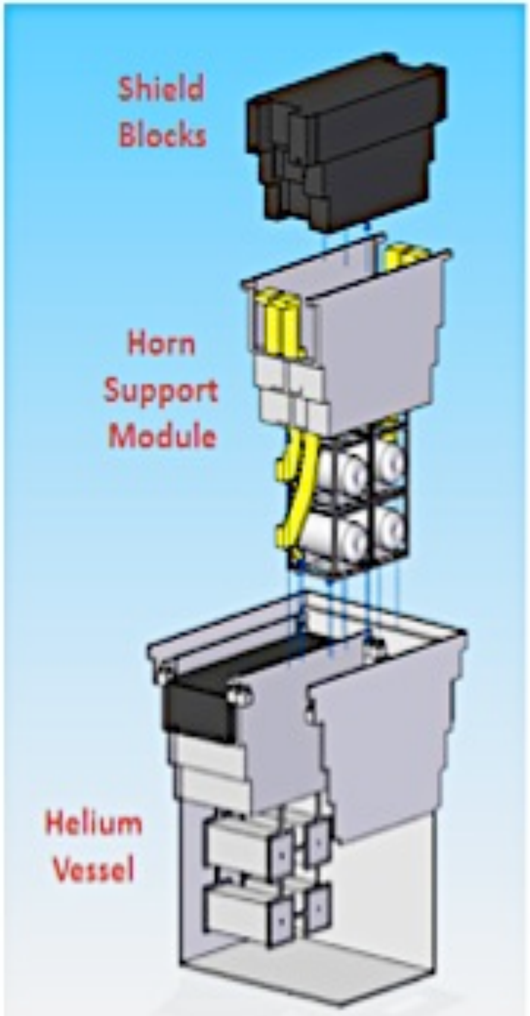


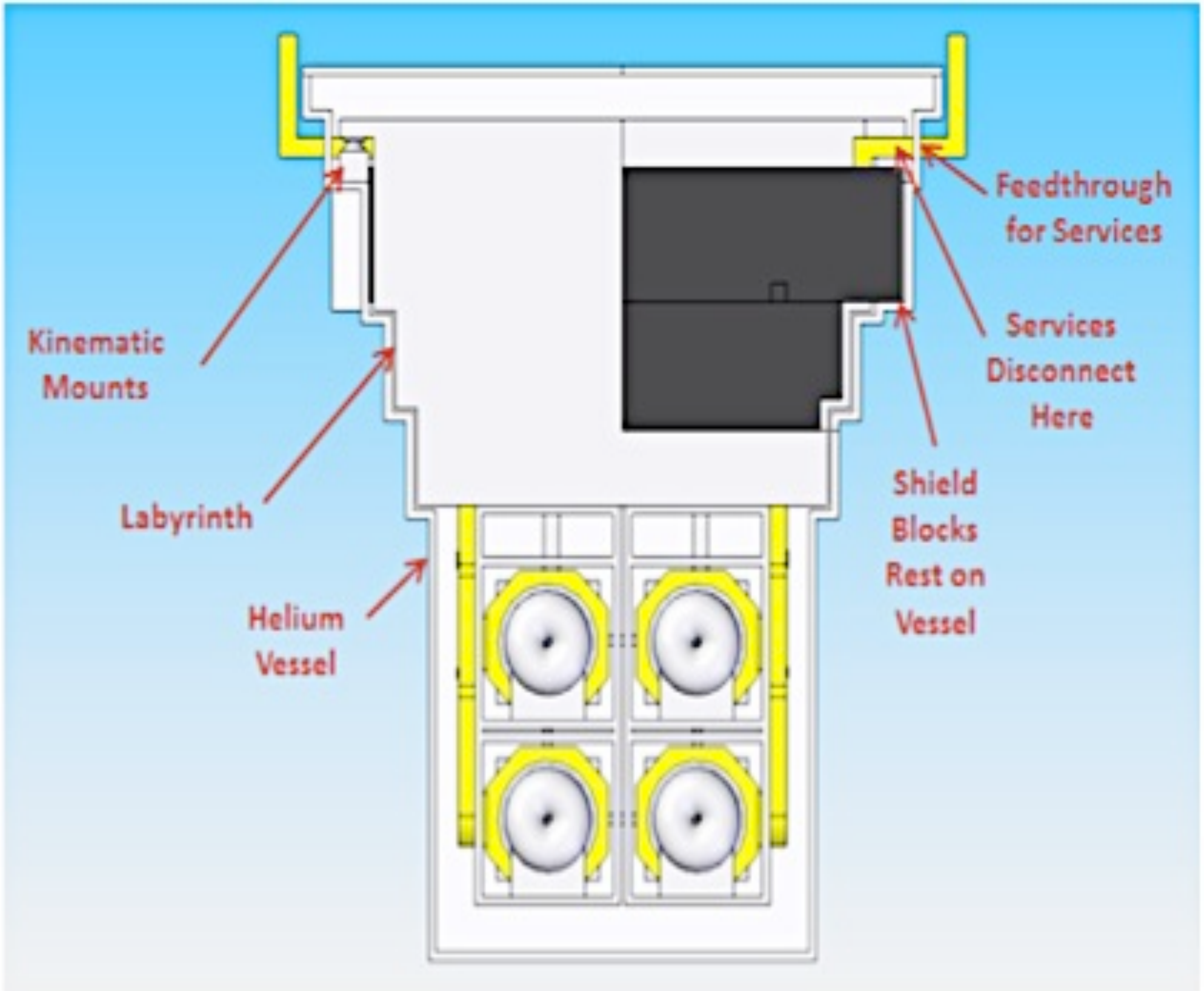
ESSνSB Target Station Concept

Target Station Concept

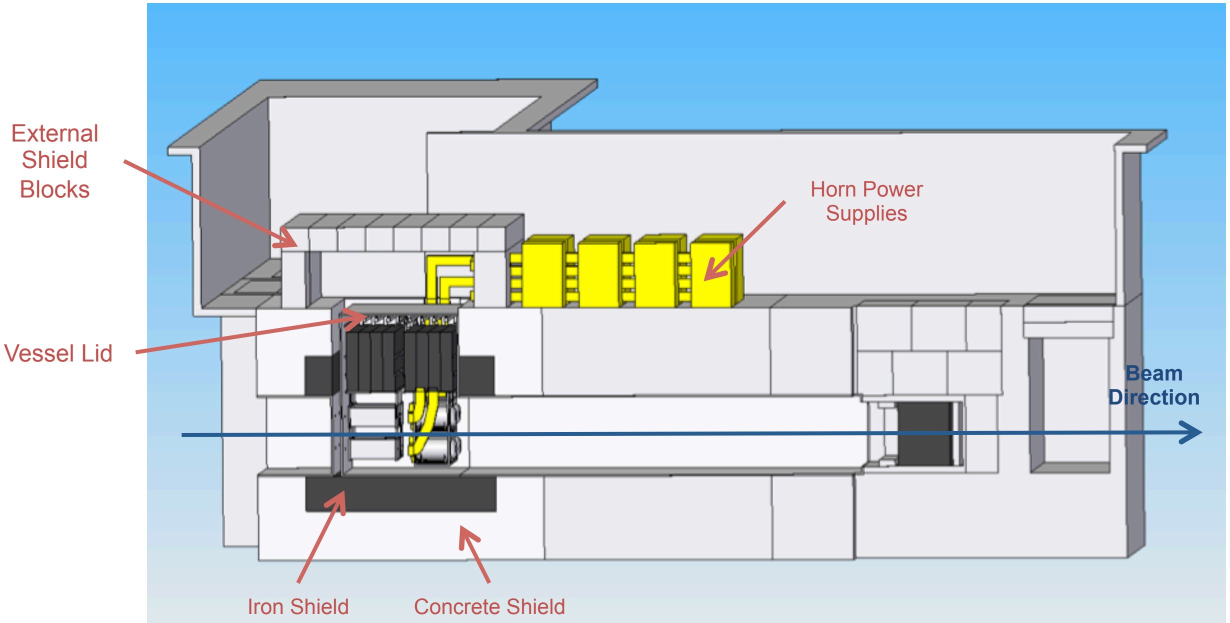


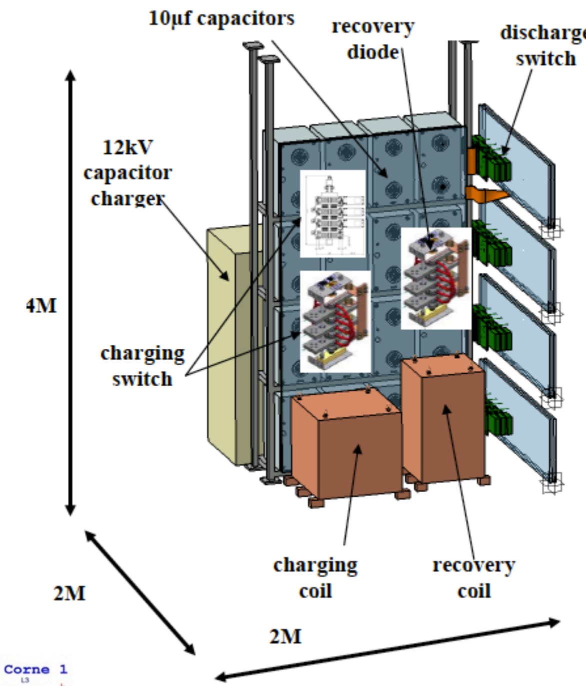
Target Station Concept

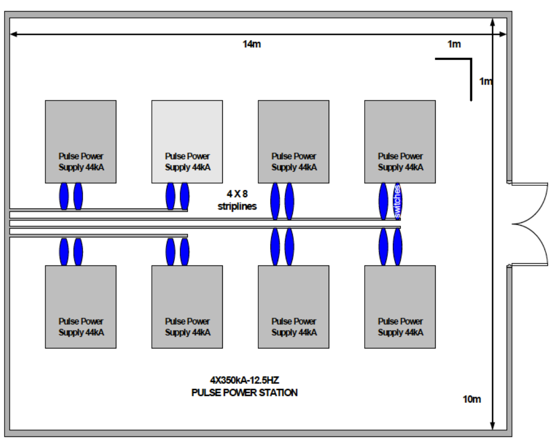


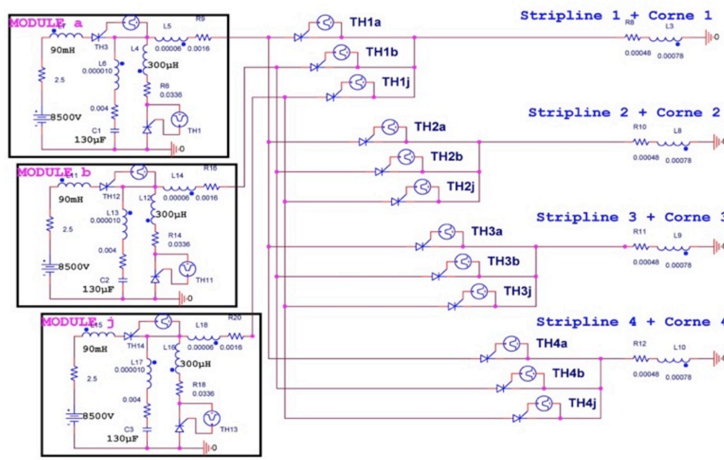


Horn Power Supply and Strip lines



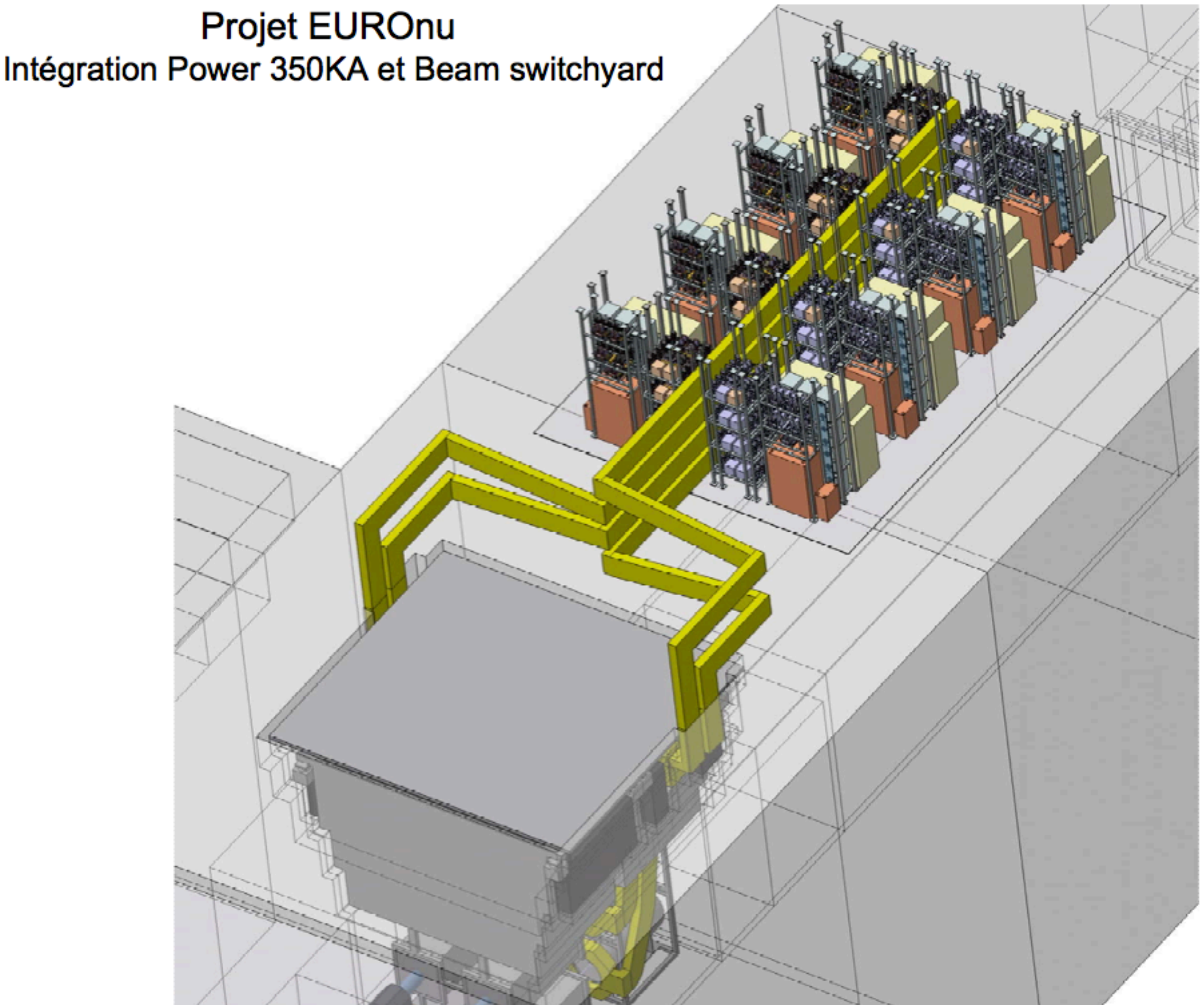






- each MODULE delivers a current of 44kA max at F=50HZ
- For each HORN : current of 350kA max at 12.5HZ
- energy recuperation (>90%) and reinjection
- lifetime > 13 Bcycles (10 years, 200 days/year)

Horn Power Supply and Strip lines

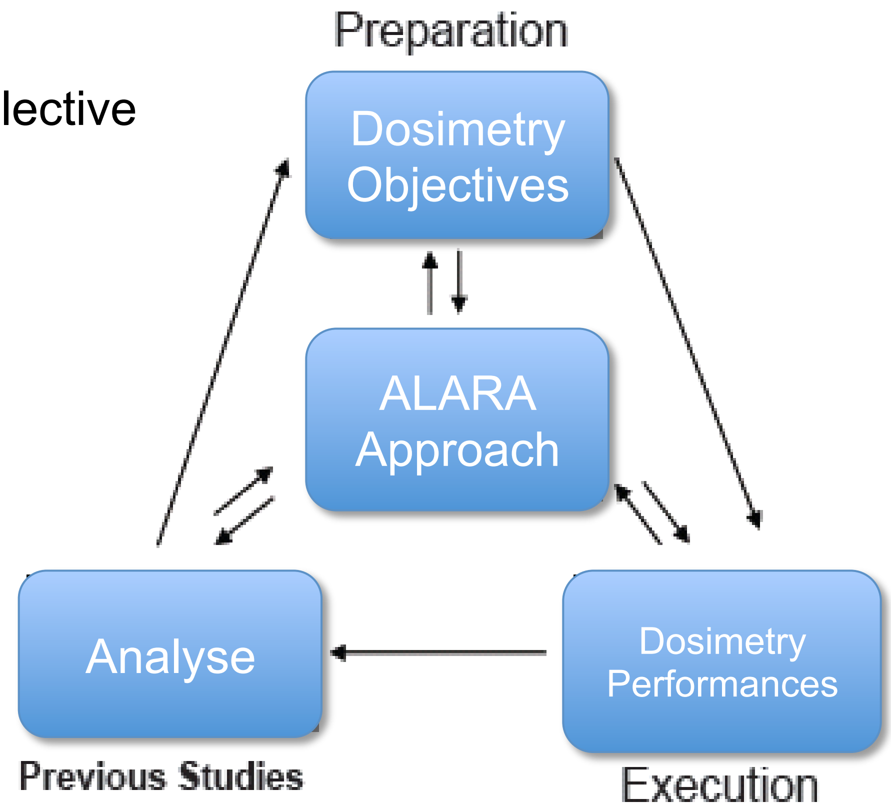


ALARA Approach:

- Anticipate and reduce individual and collective exposition to radiation

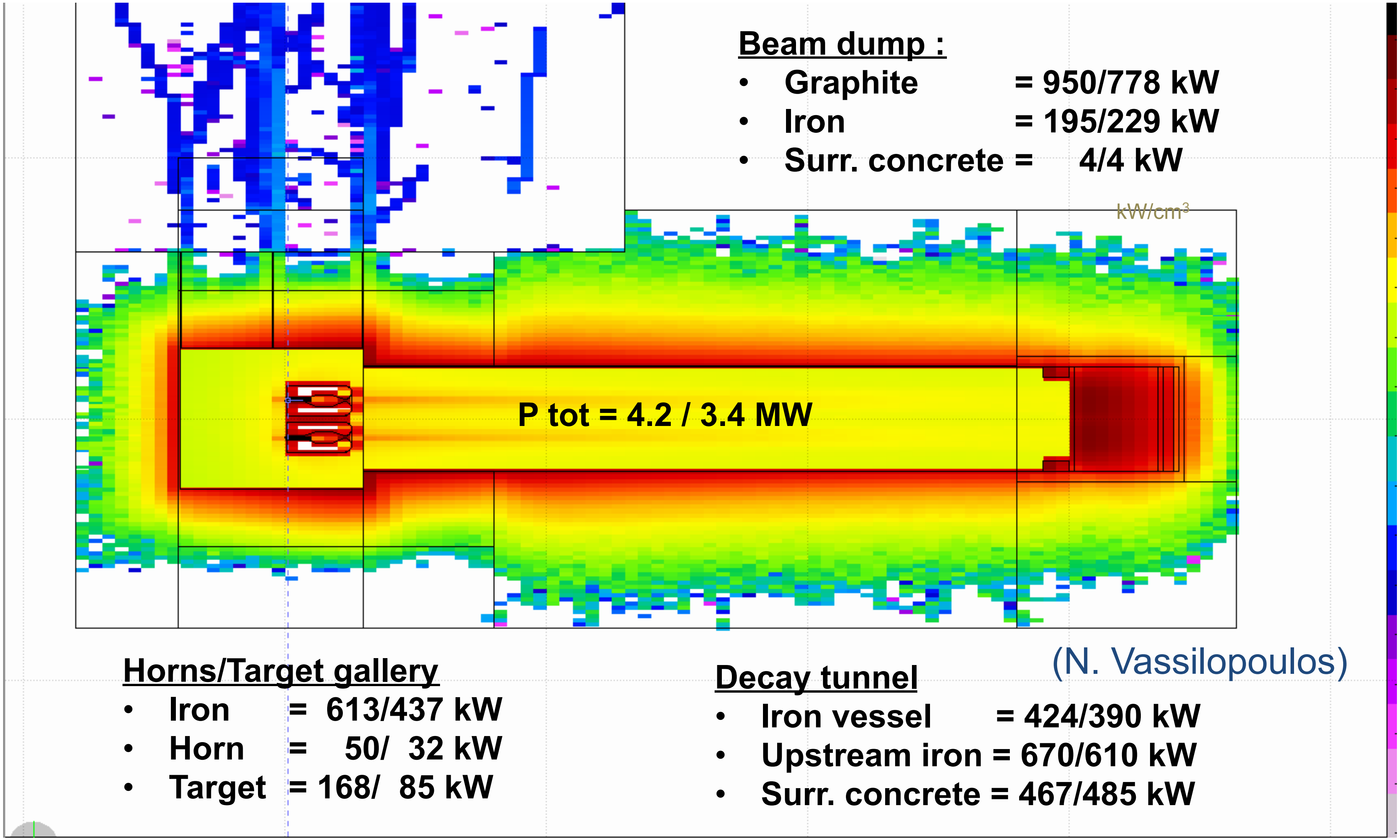
Iterative processes

- Preparation
  - Building structure list of materials
  - Dose Equivalent Rate Estimation
  - Optimize operation during maintenance and running phases
  - Evaluation residual activity of wastes
- Execution
- Feedback from previous facilities (WANF, CNGS, NuMI, j-PARC,…)



As Low As Reasonably Achievable

Target Station Energy Deposition
ESSvSB 1.6 MW / EUROnu -1.3 MW



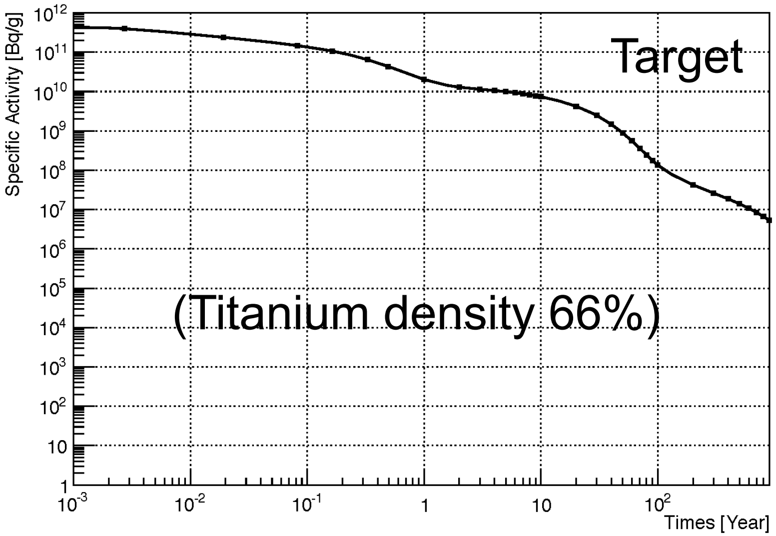
Beam dump :
- Graphite = 950/778 kW
- Iron = 195/229 kW
- Surr. concrete = 4/4 kW

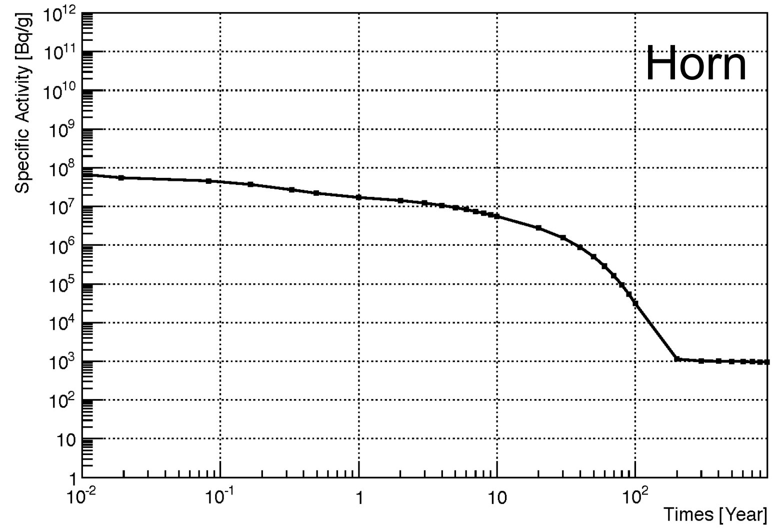
Horns/Target gallery
- Iron = 613/437 kW
- Horn = 50/ 32 kW
- Target = 168/ 85 kW

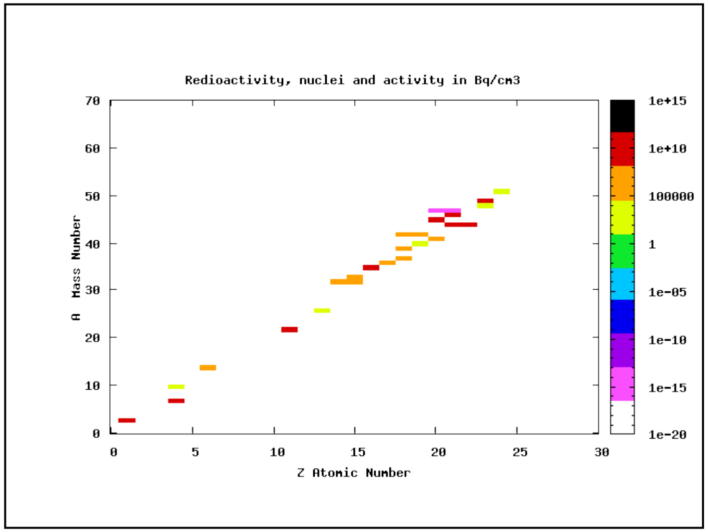
Decay tunnel
- Iron vessel = 424/390 kW
- Upstream iron = 670/610 kW
- Surr. concrete = 467/485 kW

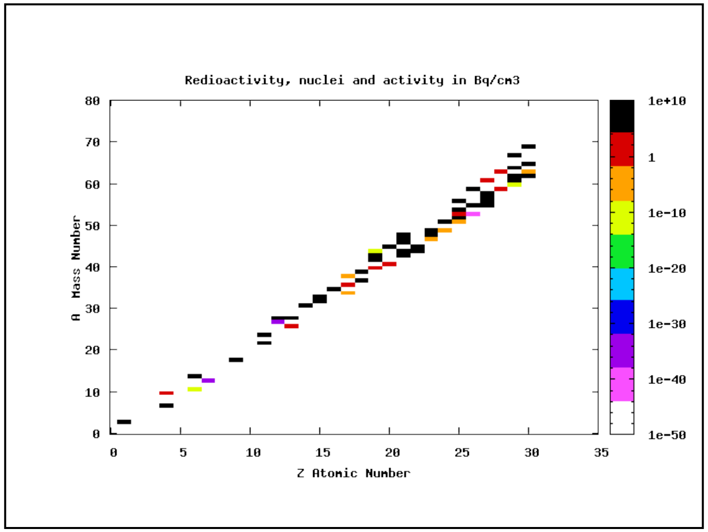
(N. Vassilopoulos)

Safety : Material Activation

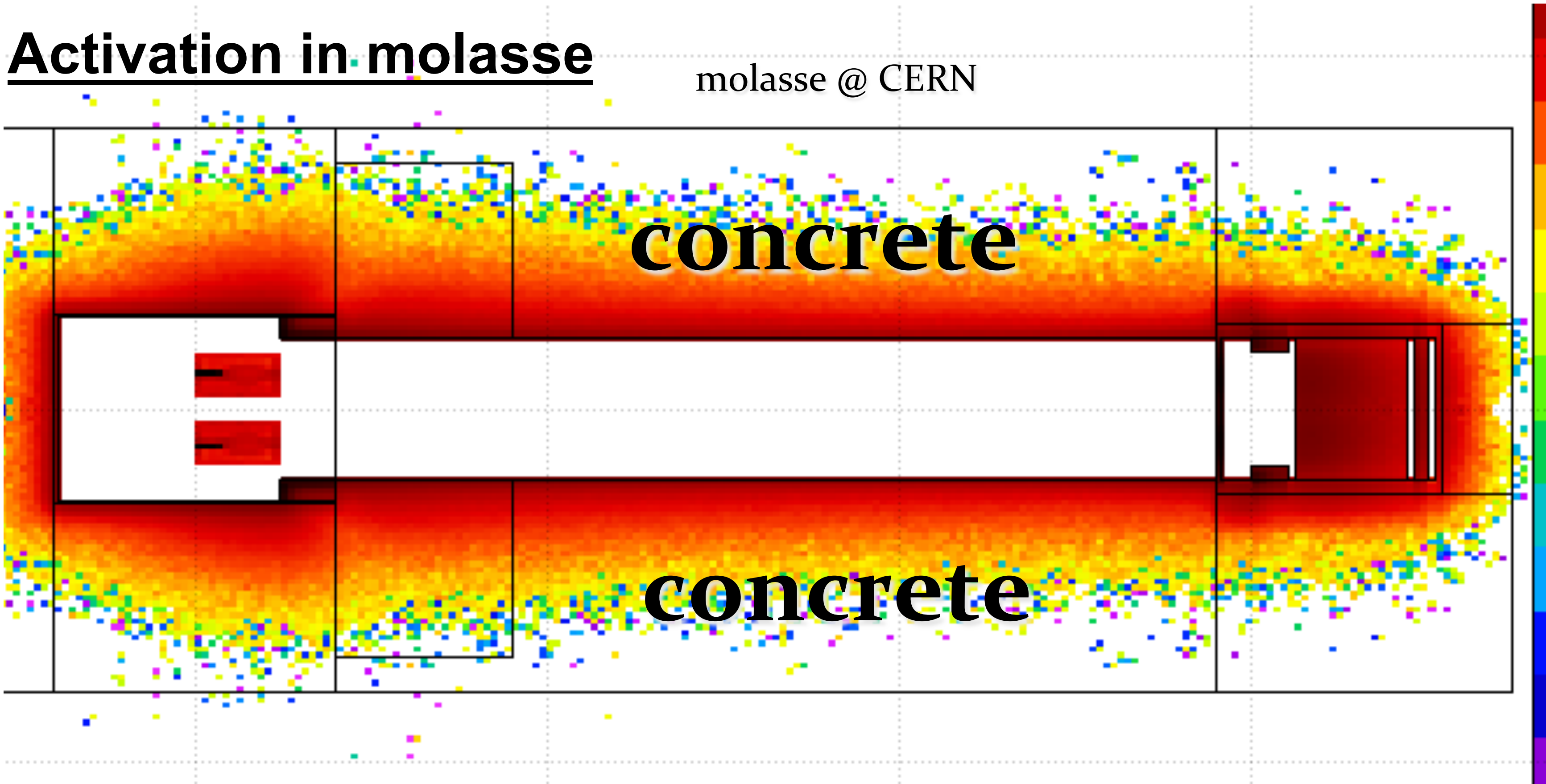








Activation in molasse

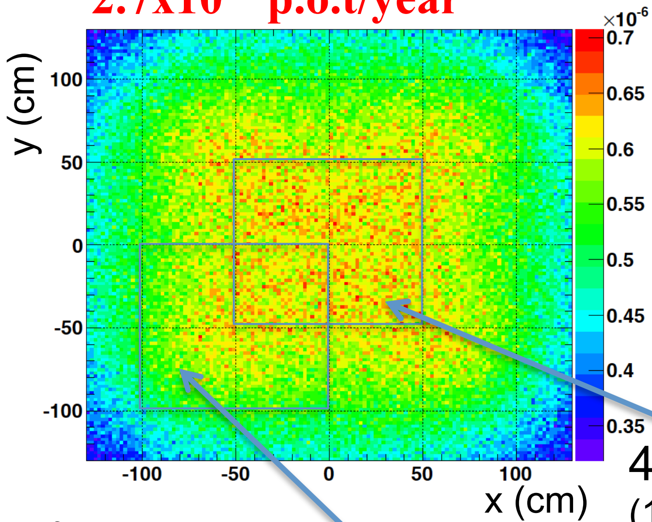


All the radionuclide's created, especially ^{22}Na and tritium, could represent a hazard by contaminating the ground water.

Other possible physics

Muons at the level of the beam dump

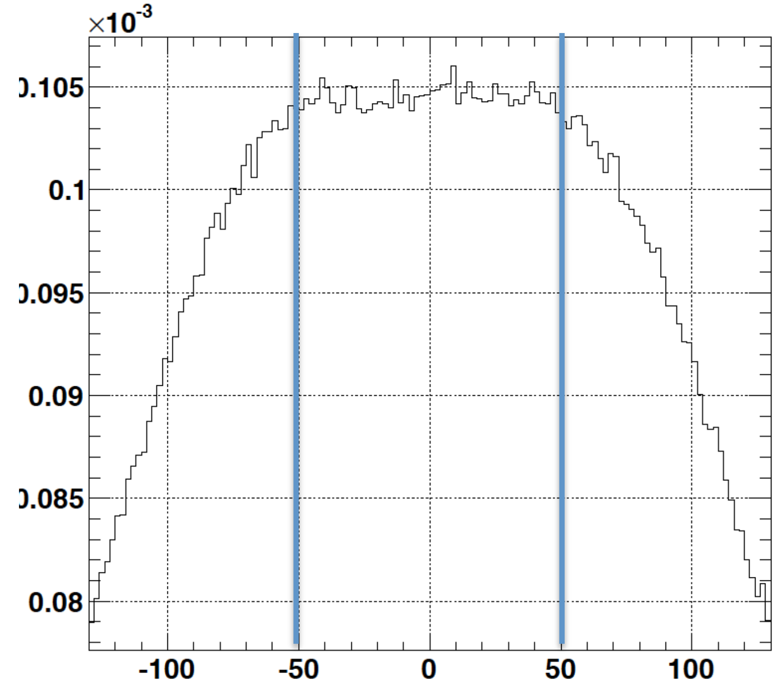
2.7×10^{23} p.o.t/year



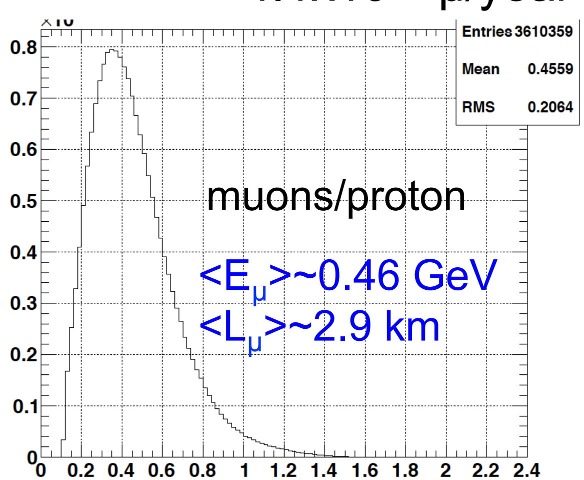
muons at the level of the beam dump (per proton)

4.2×10^{20} μ/year
(16.3×10^{20} for 4 m²)

4.1×10^{20} μ/year

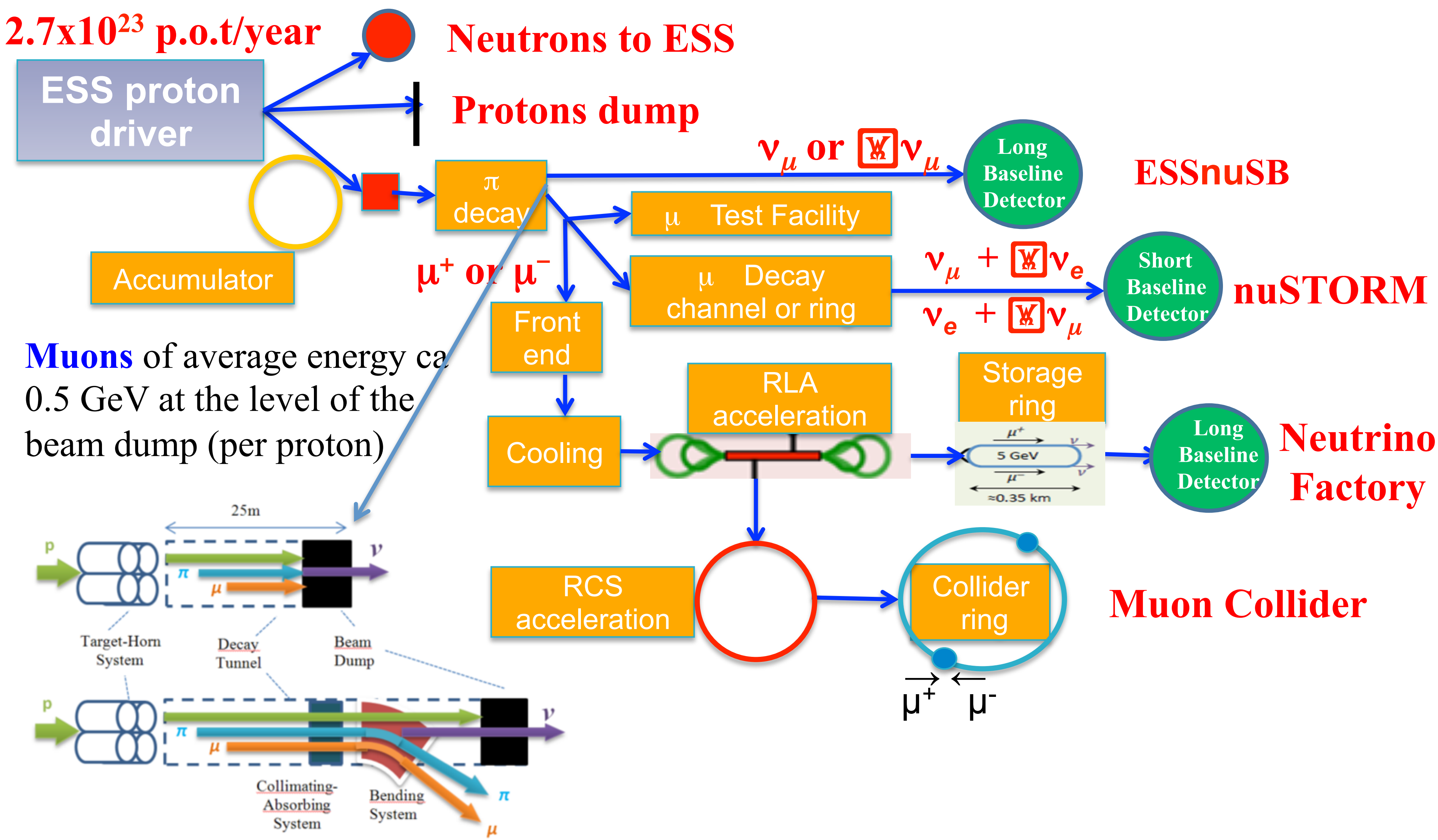


10^{-3}



- input beam for future 6D μ cooling experiments (for muon collider),
- good to measure neutrino x-sections (ν_μ, ν_e) around 200-300 MeV using a near detector,
- low energy nuSTORM,
- Neutrino Factory,
- **Muon Collider**.

Muons at the level of the beam dump



Muons of average energy ca 0.5 GeV at the level of the beam dump (per proton)

Summary:

- European Spallation Source is under construction and will provide a 5 MW beam power by 2023.
- ESSνSB Project offers a good opportunity to study CP violation in leptonic sector with an improved sensitivity thanks to the 2nd Oscillation maximum.
- Technical constraints of a Super Beam with a Multi Mega Watt proton driver have been studied in the EUROnu WP2 framework and will be upgraded for ESSνSB
- ESSνSB can also be used as a platform to develop future muon beam experiments.