The ESSνSB Workshop 8-9 of October 2019
UHH – Barendeld -DESY

ESS NEUTRINO SUPER BEAM

Funded by the Horizon 2020 Framework Programme of the European Union

The ESSνSB Target Station

E. Baussan on behalf of ESSnuSB WP4
IPHC-IN2P3/CNRS Strasbourg

ESSnuSB Baseline

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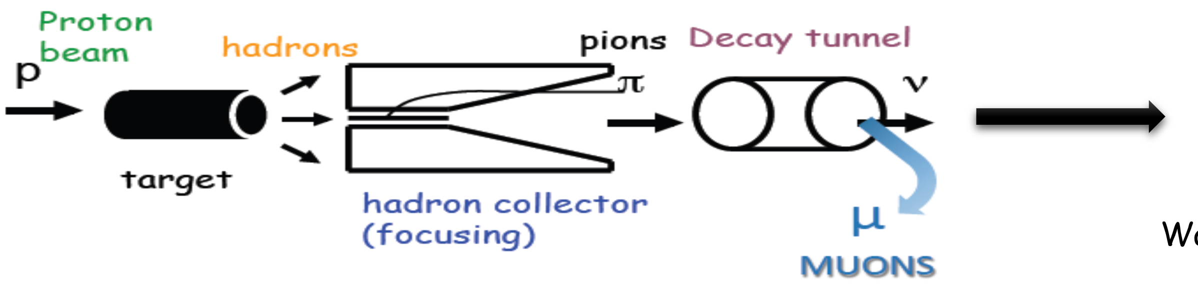
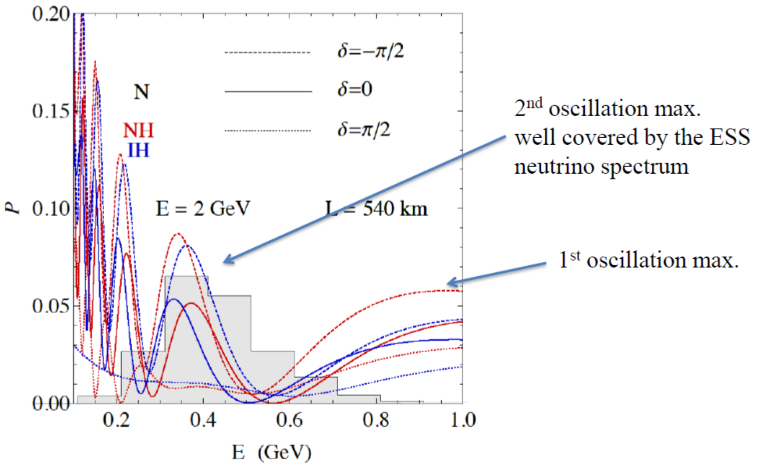


Water Cherenkov Detector

Given sufficient statistics, as obtainable with the **ESS 5MW LINAC** the sensitivity to CP violation is higher at the second oscillation maximum, as compared to the first

Neutrino Asymmetry:

$$\mathcal{A} = \frac{P_{\nu_\mu \to \nu_e} - P_{\bar{\nu}_\mu \to \bar{\nu}_e}}{P_{\nu_\mu \to \nu_e} + P_{\bar{\nu}_\mu \to \bar{\nu}_e}}$$



1st oscillation max. : **A=0.3 sin δ_{CP}**

2nd oscillation max. : **A=0.75 sin δ_{CP}**

More sensitivity on 2nd Osc. Max

(see arXiv:1310.5992 and arXiv:0710.0554)

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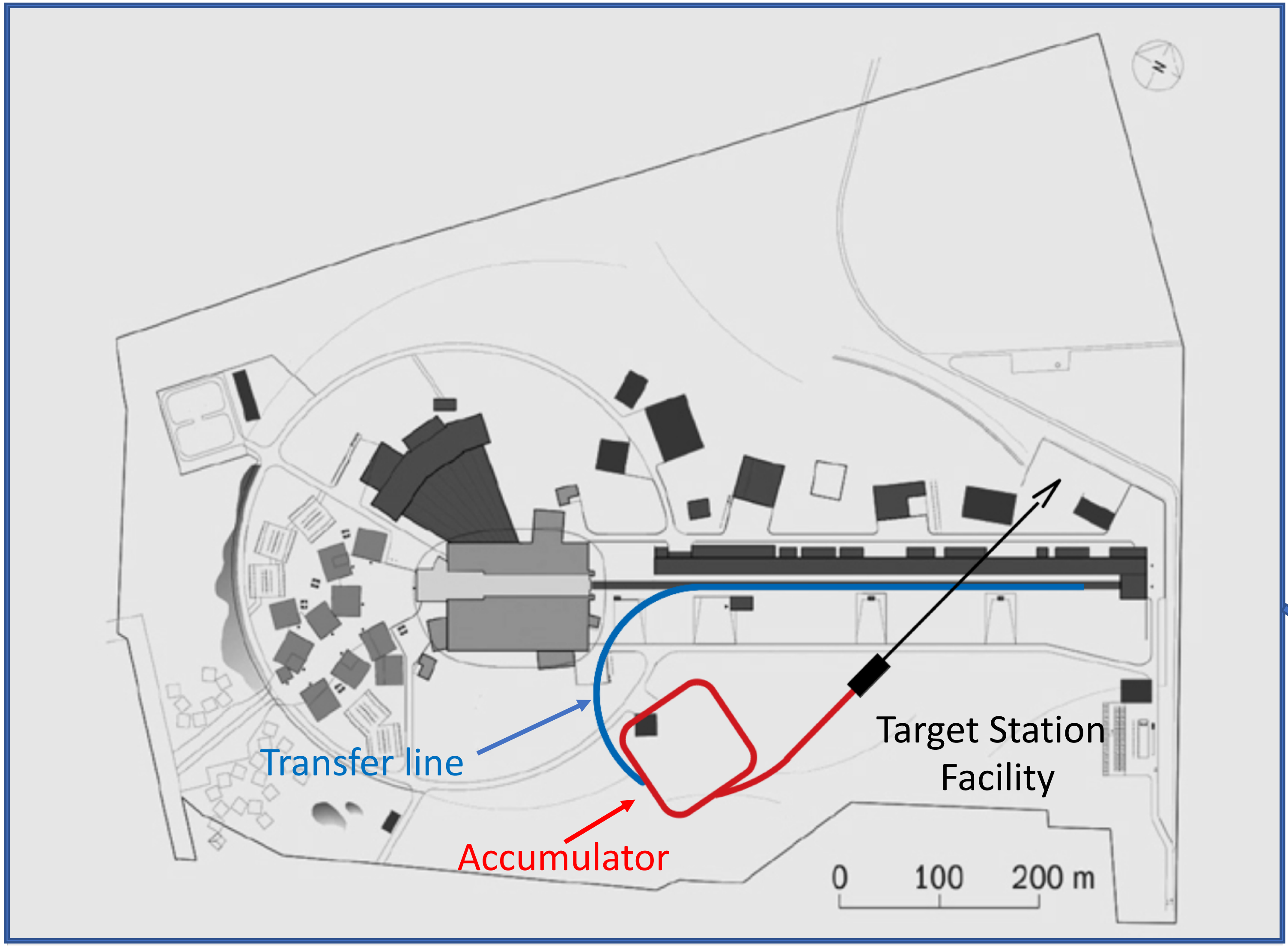

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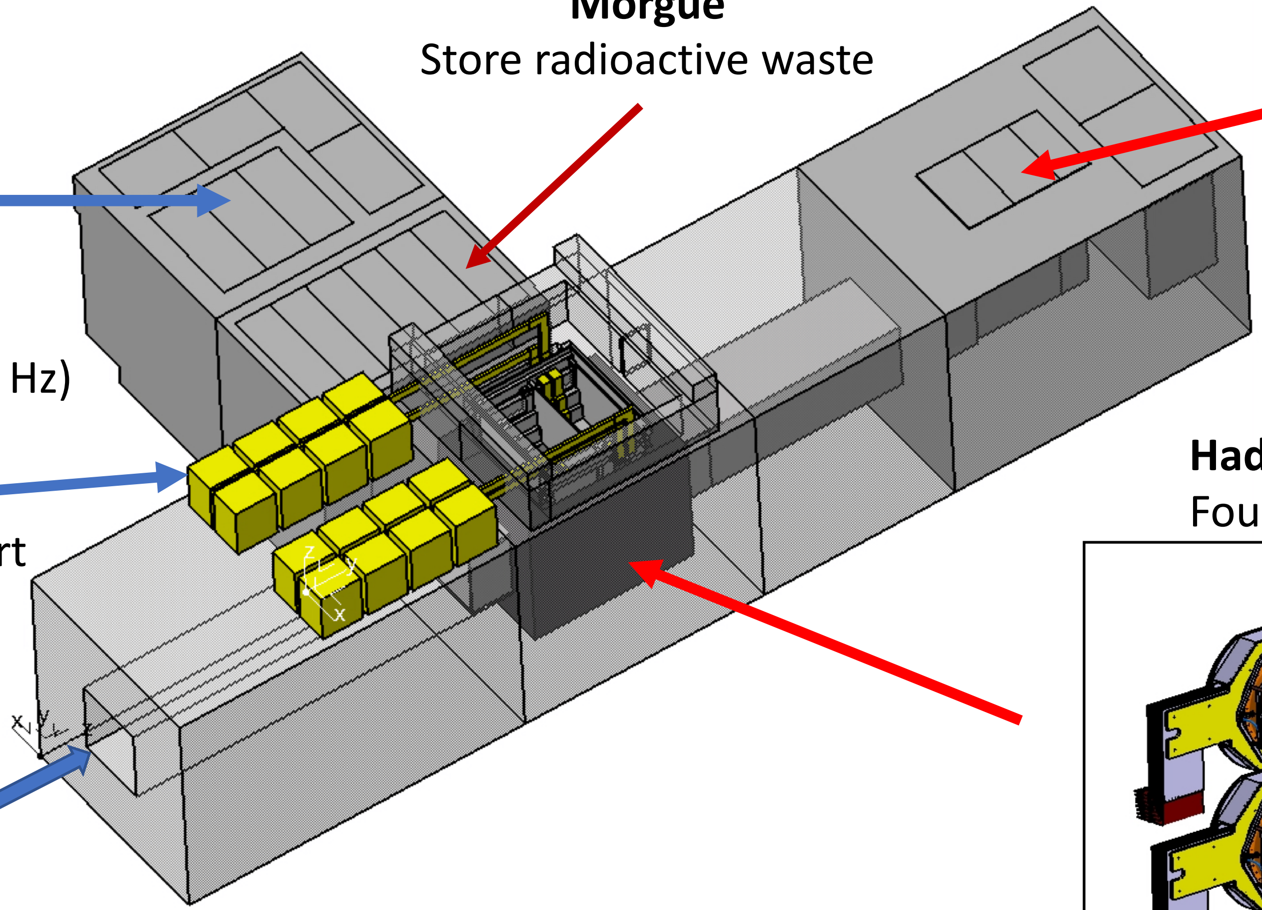
Hot Cell
- Able to manipulate/repair Hadron collector.
- Work under radioactive environment.

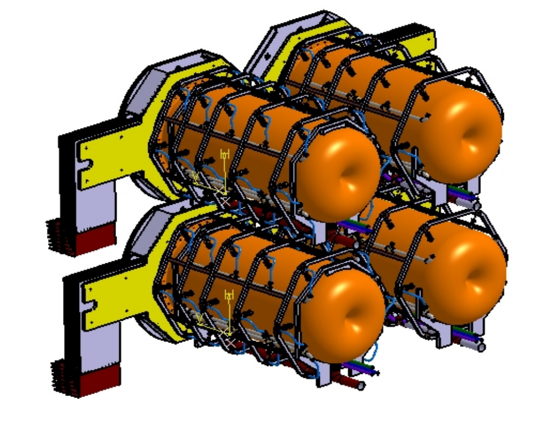
Morgue
Store radioactive waste

Beam Dump

Power Supply Unit
- 16 modules (350 kA pulse/14 Hz)
- Located above the beam switchyard
- Outside of the radioactive part of the facility
- Good position to synchronize with switchyard PSU



Hadronic Collector
Four Horn System



Proton Beam
4 x 1.25 MW

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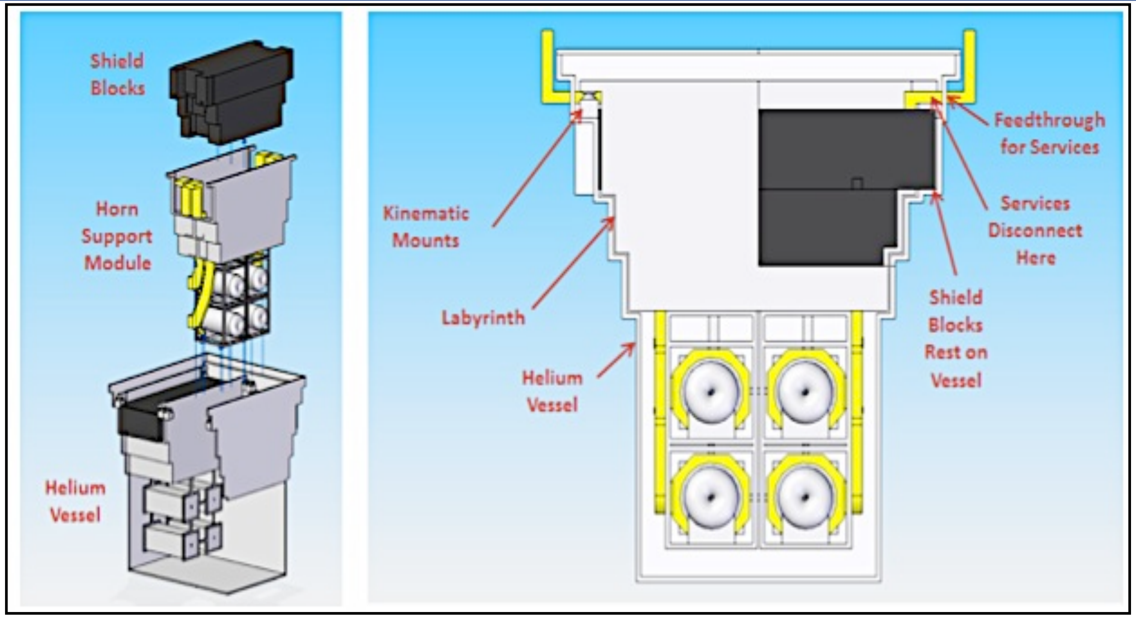
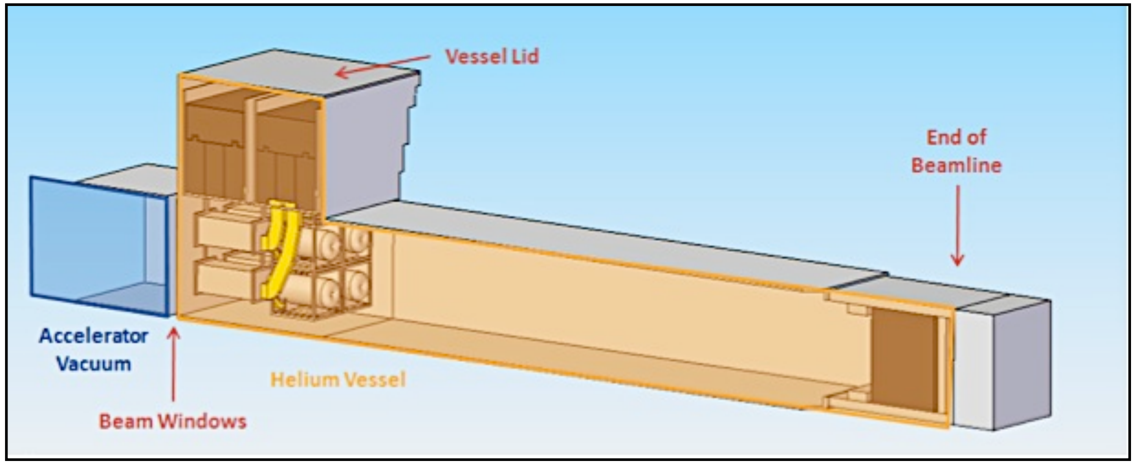
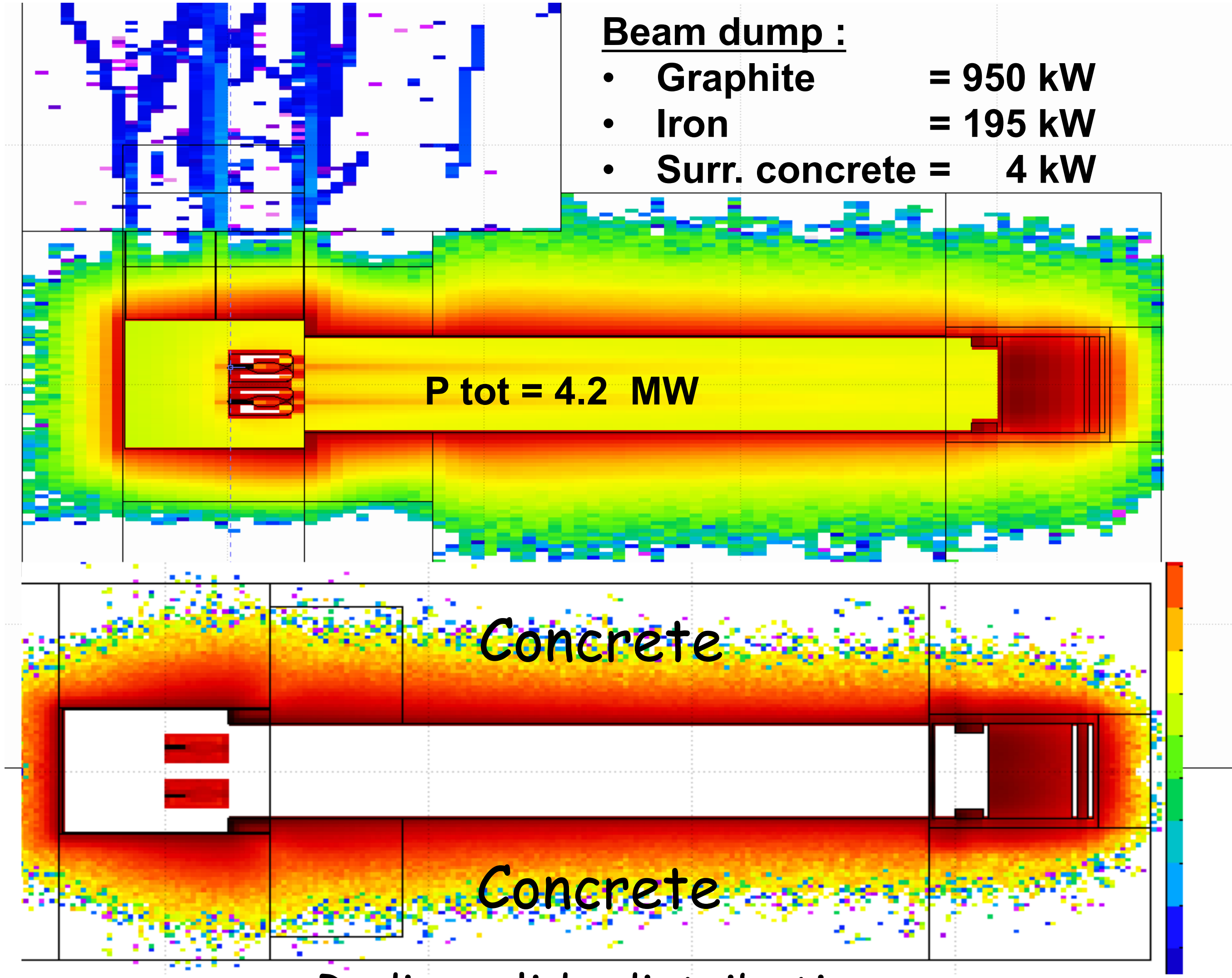




Beam dump :

- Graphite = 950 kW
- Iron = 195 kW
- Surr. concrete = 4 kW



Radionuclide distribution

ESSnuSB Hadron Collector

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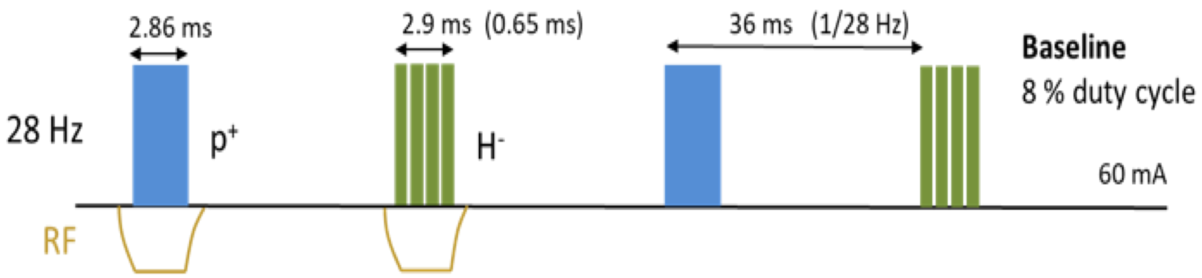
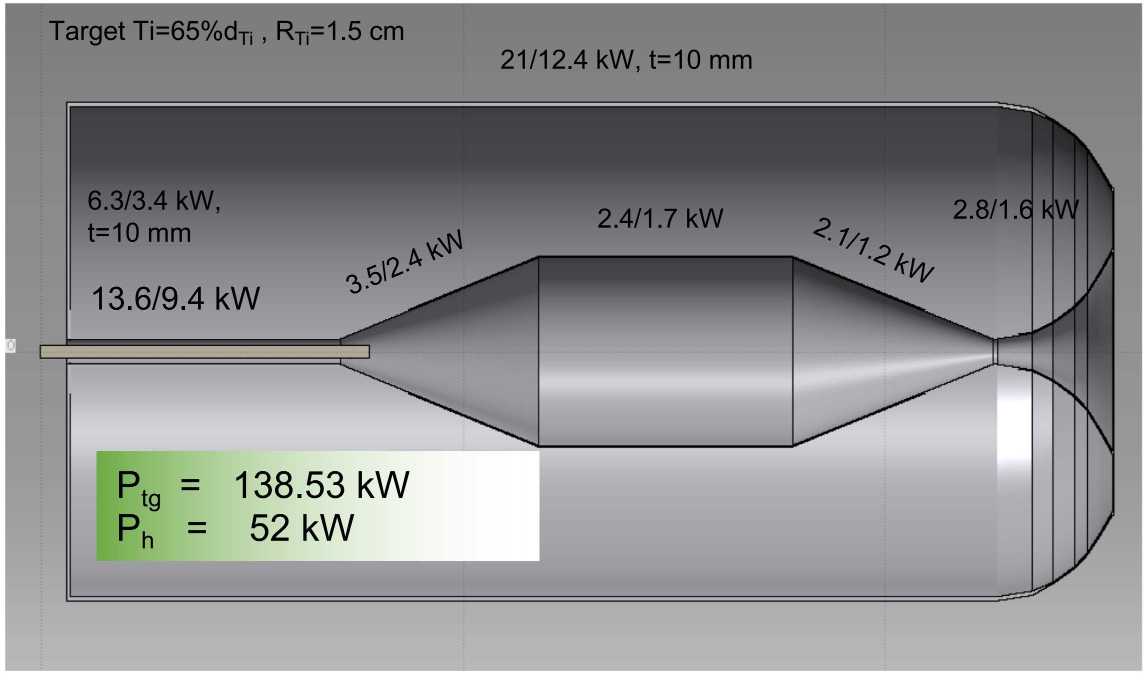
Beam pulse structure:



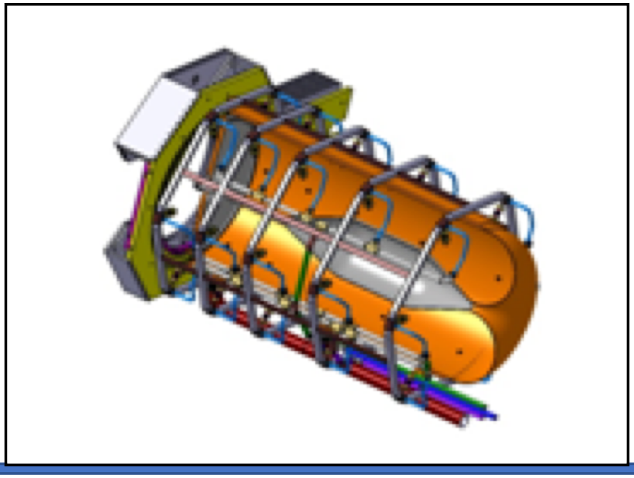


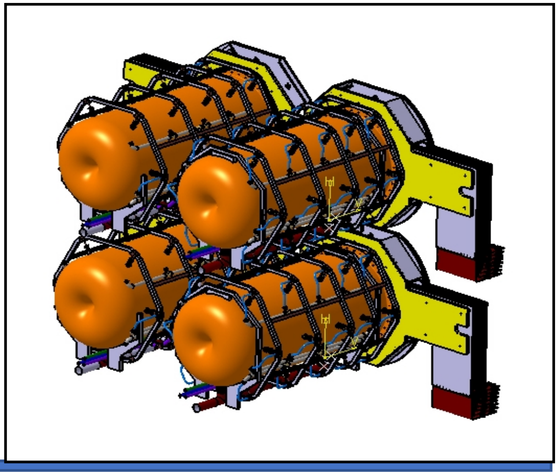
MW Target:

- Proton beam power : 1.25 MW – 1.6 MW.
- Heat removal rates at the hundreds of kW level.
- Efficient cooling.
- Separated from the horn.

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.
-





ESSnuSB Packed Bed Segmented Concept

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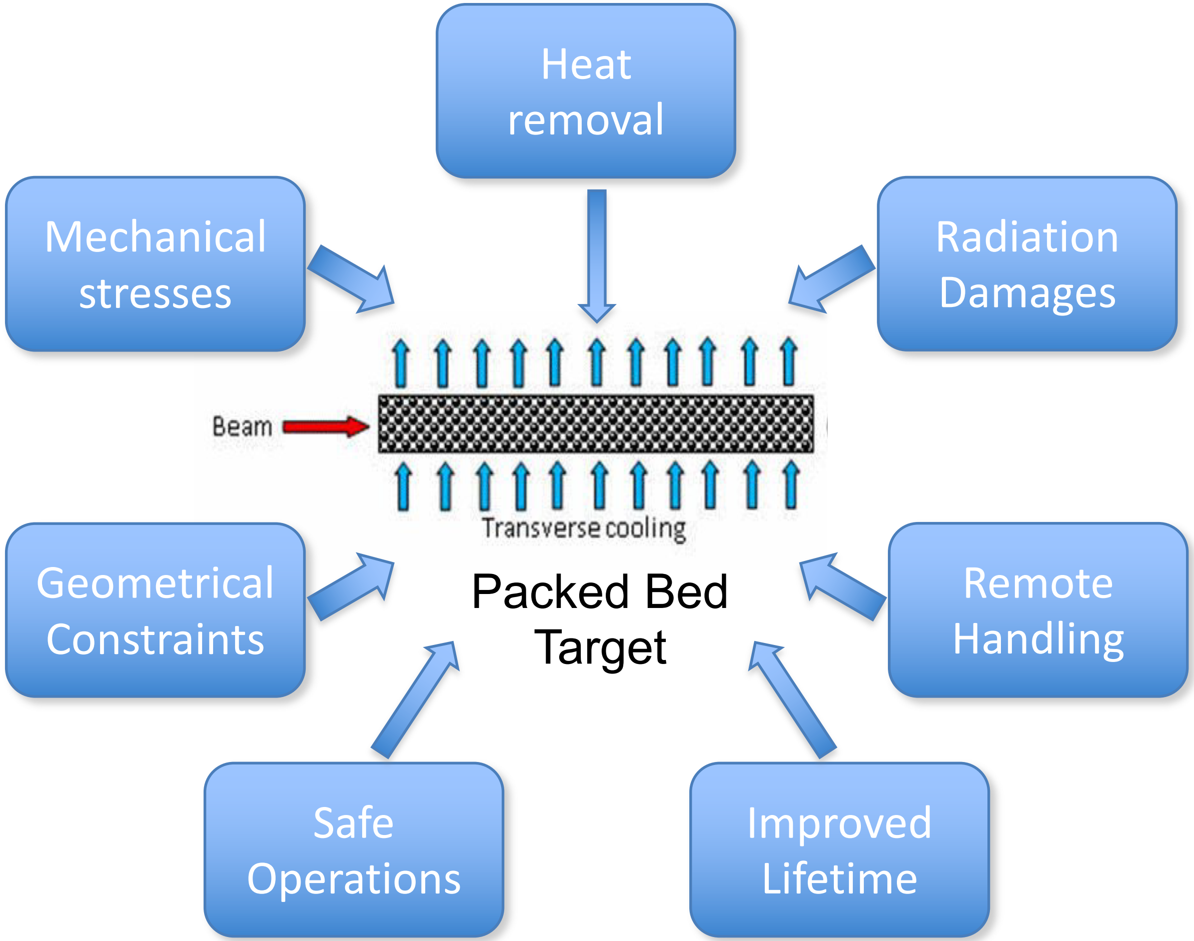


P. Sievers' proposal of a granular target at CERN (2001)

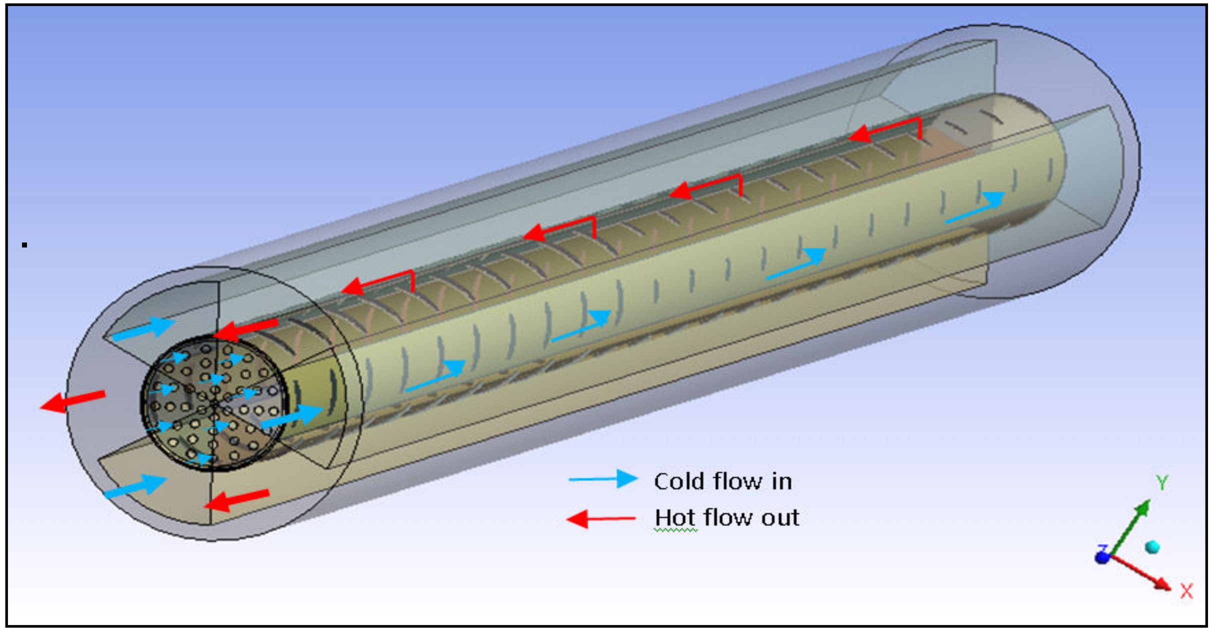
Target : 3 mm diameter titanium spheres.

Proton Beam : 2.5 GeV, 1.25 MW (from ESS LINAC)

Beam width : 4 mm.

Target geometry radius/Length : 15 mm / 780 mm.

Coolant : Helium at 10 bar pressure.



Packed-bed target, studied at RAL within the EUROnu project (arXiv: 1212.0732)

ESSnuSB Packed Bed Segmented Concept

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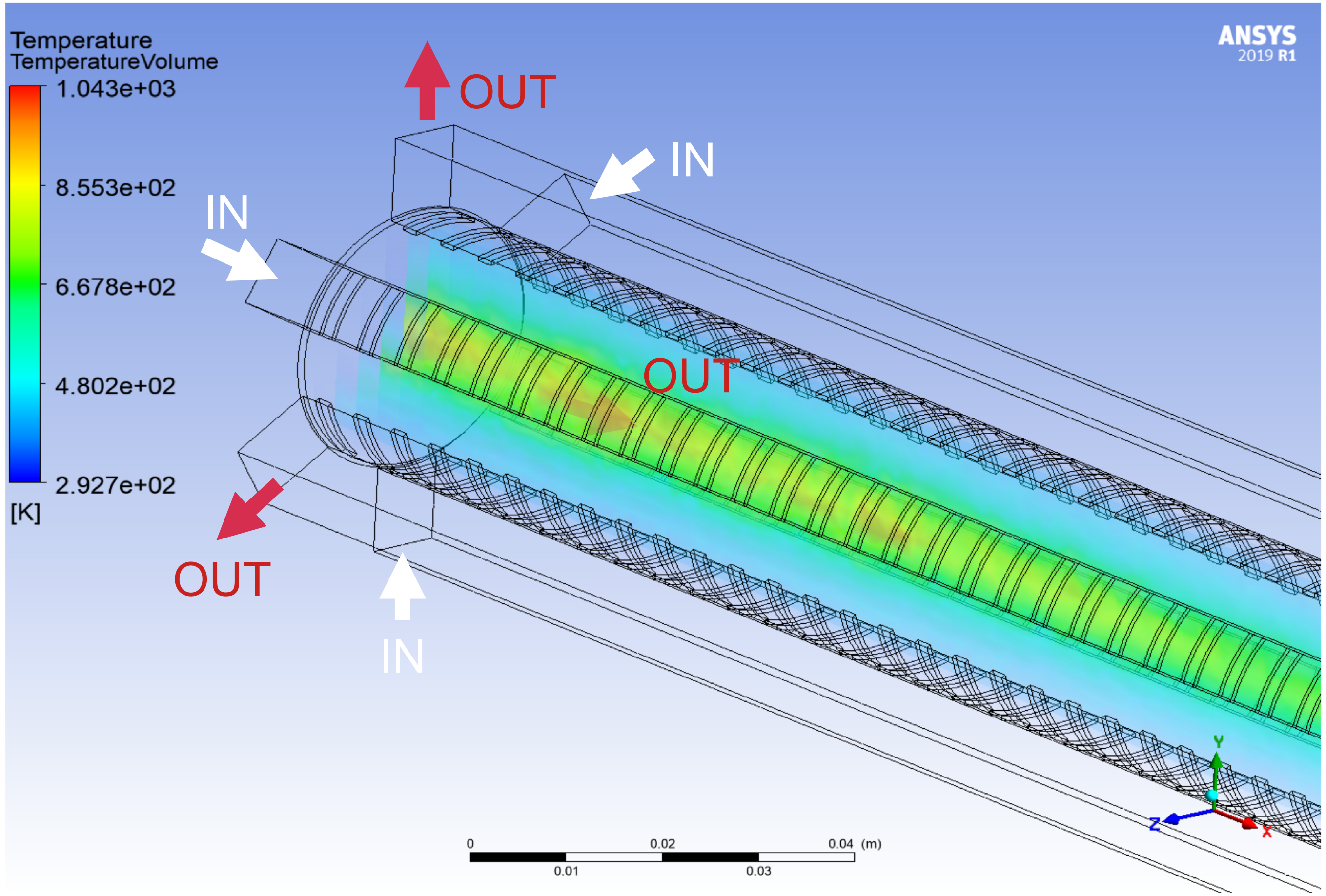
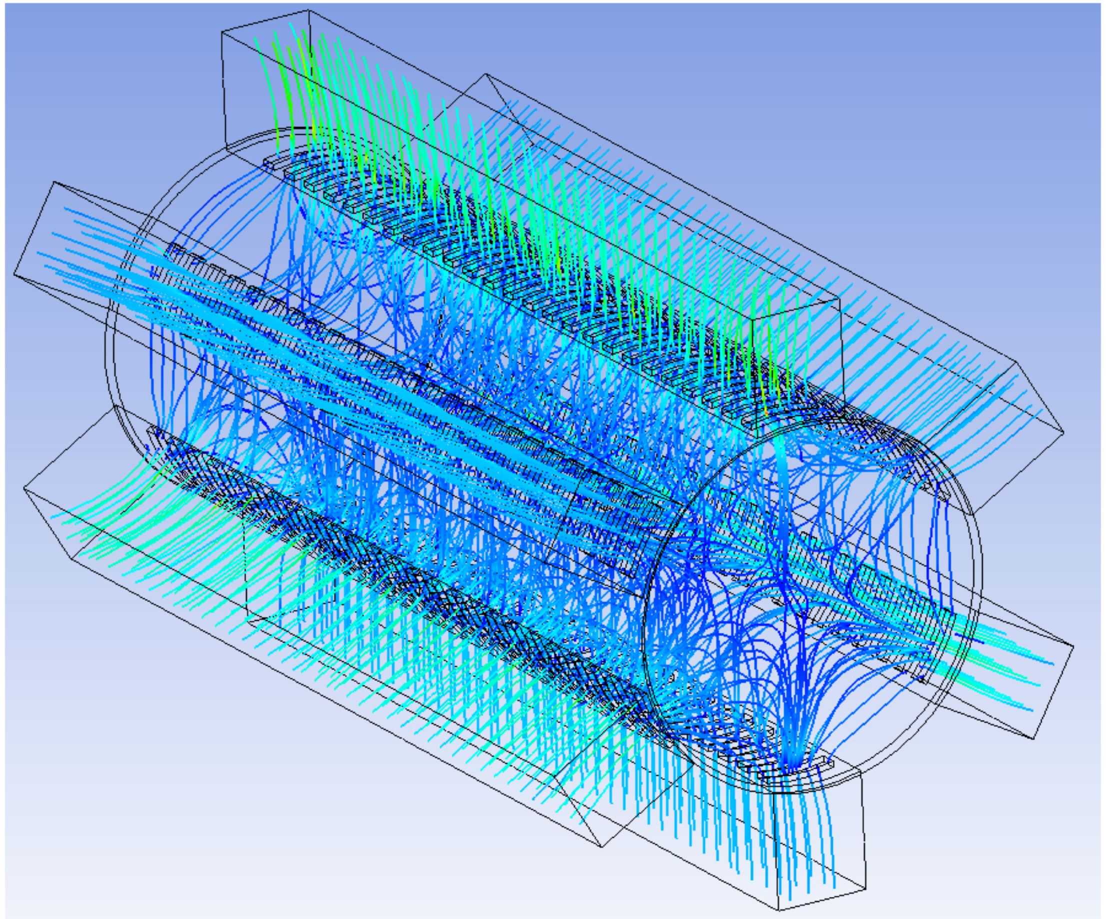
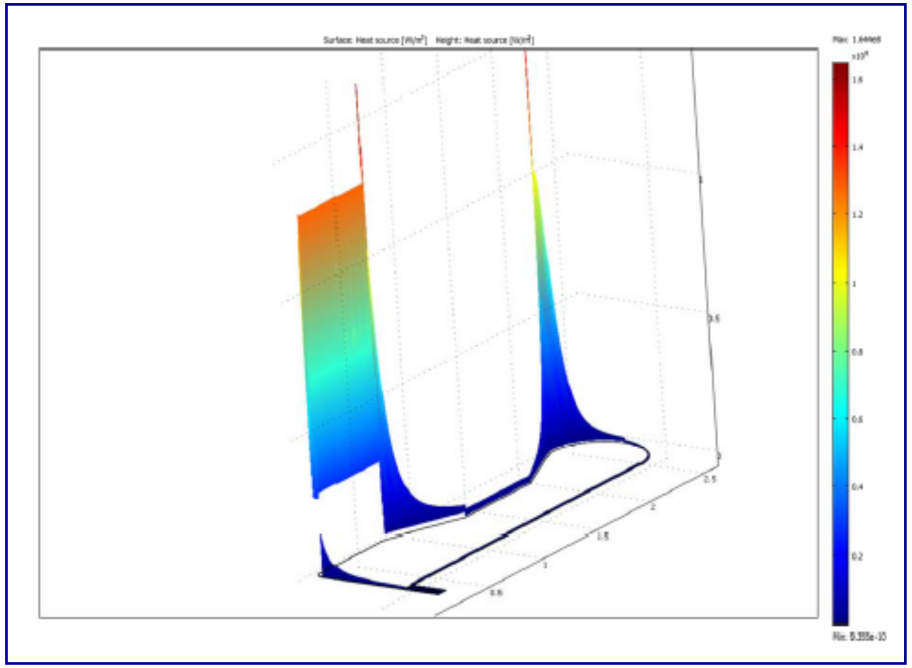
Packed Bed configuration (Titanium packing Fraction 66%)



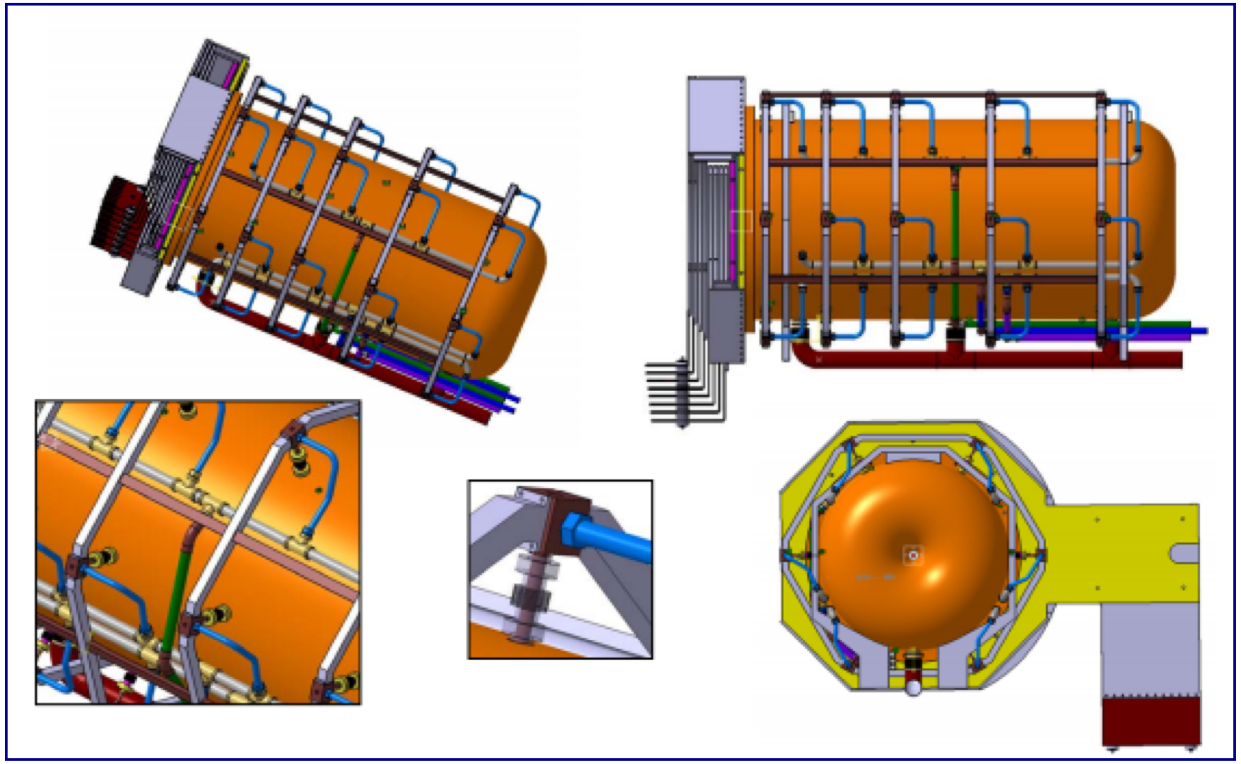


Maximum temperature 900 K (< $T_{melting}$ = 1941 K) ; Max Outlet Velocity = 40 m/s; Pressure drop = 0.6 bar.

ESSnuSB Horn Cooling



Temperature distribution



Water pipe distribution

Cooling system:

- Planar and/or elliptical water jets
- 30 jets/horn, 5 systems of 6-jets longitudinally distributed every 60^0
- Flow rate between 60-120 l/min, h cooling coefficient 1-7 kW/(m^2K)
- 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^2K) for $T_{Al\text{-}max}$ = 60 ^{0}C (assuming 1 MW per horn)

ESSnuSB Power Supply Concept

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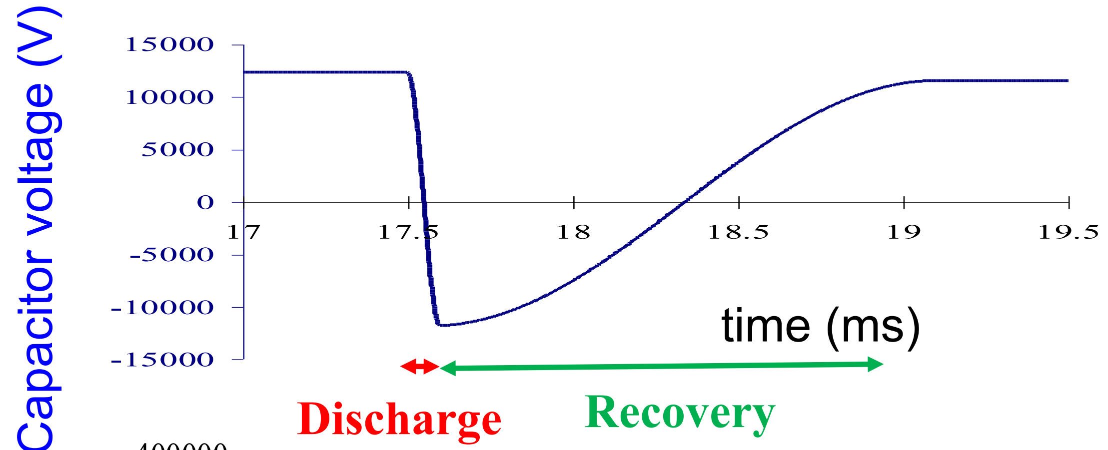
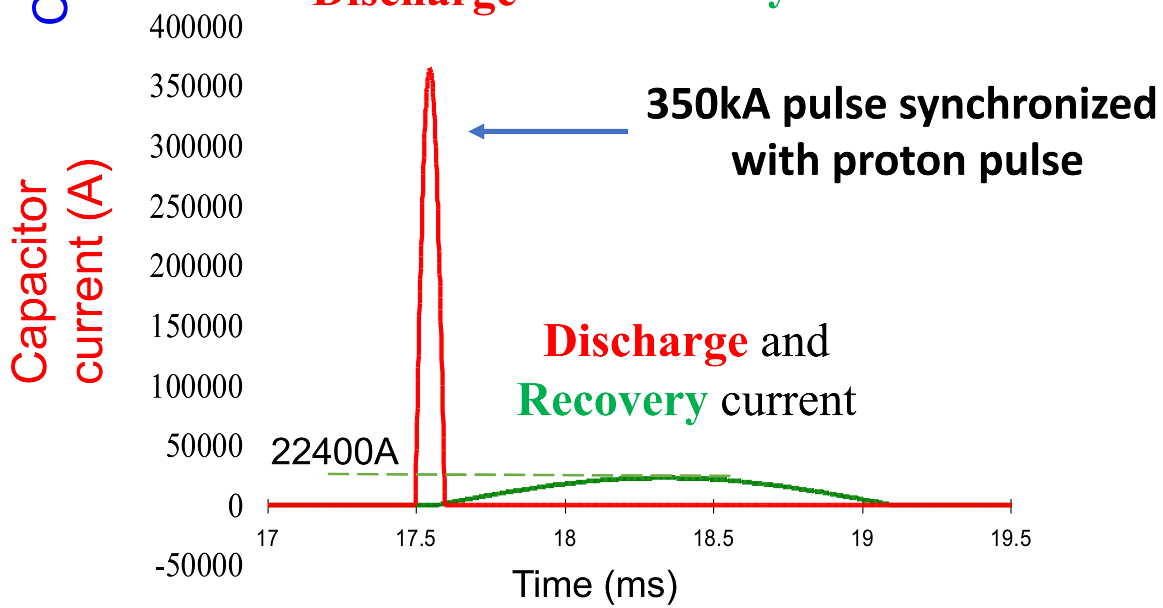
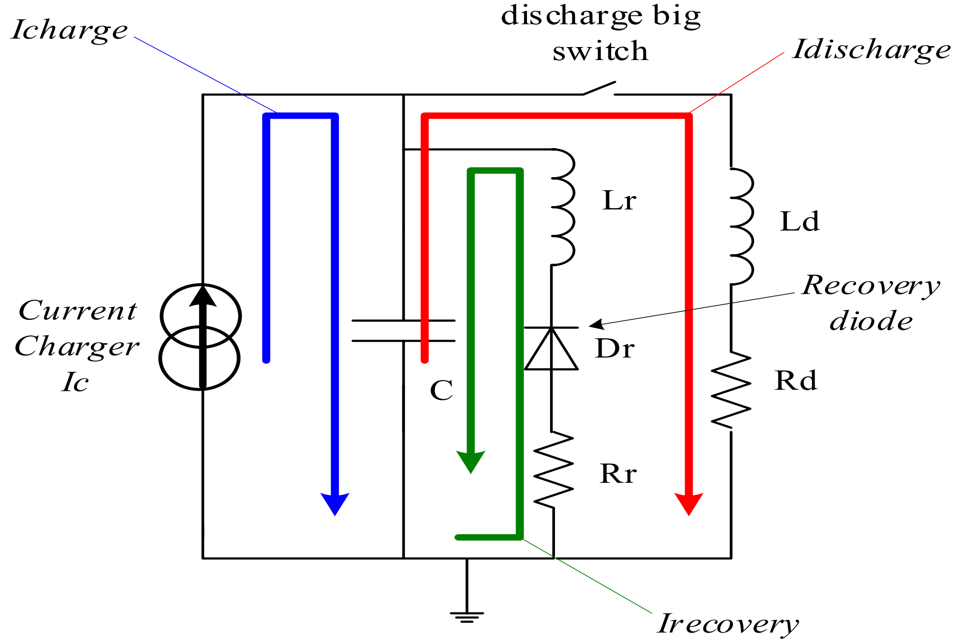
Microsecond pulse at 350 kA is required by each individual horn at 14 Hz







Caveat : Discharge switch are not able to commute **from 0 to 350 kA** at micro second level !!!
But with 44 kA should be feasible.

PSU Design : Based on modular approach
8 modules (44kA) connected in parallel
for each stripline.

P. Poussot

ESSnuSB Power Supply

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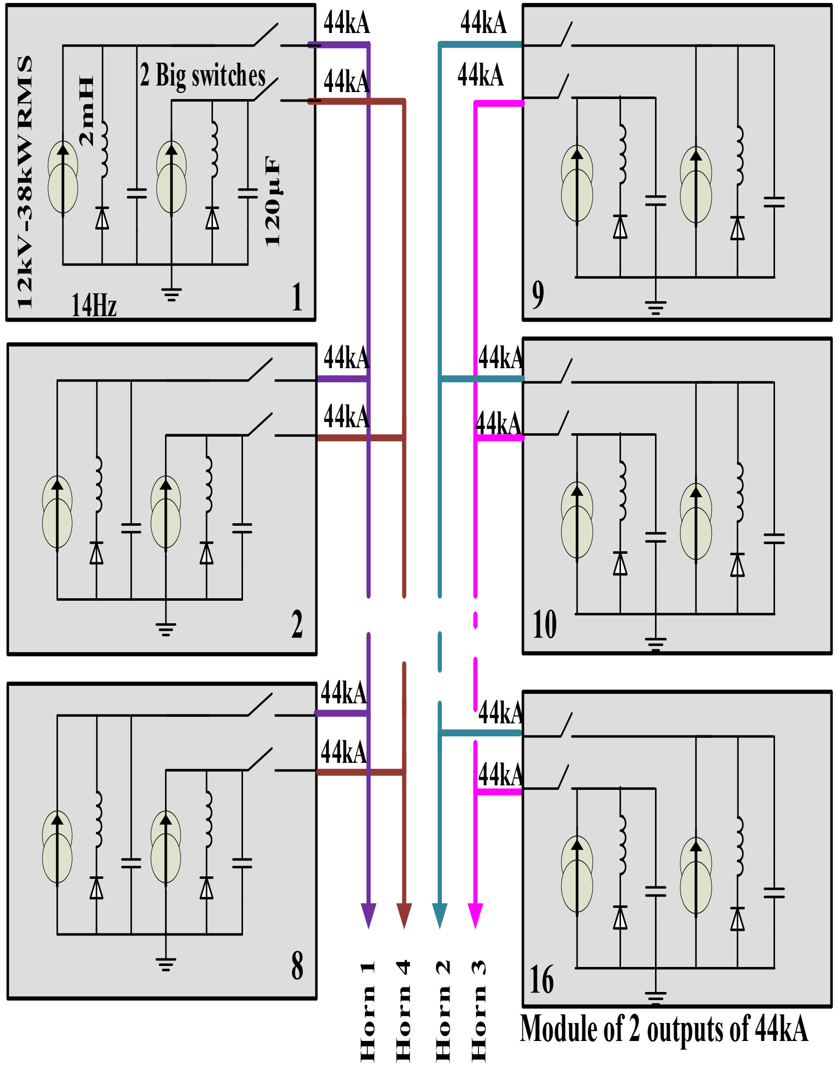

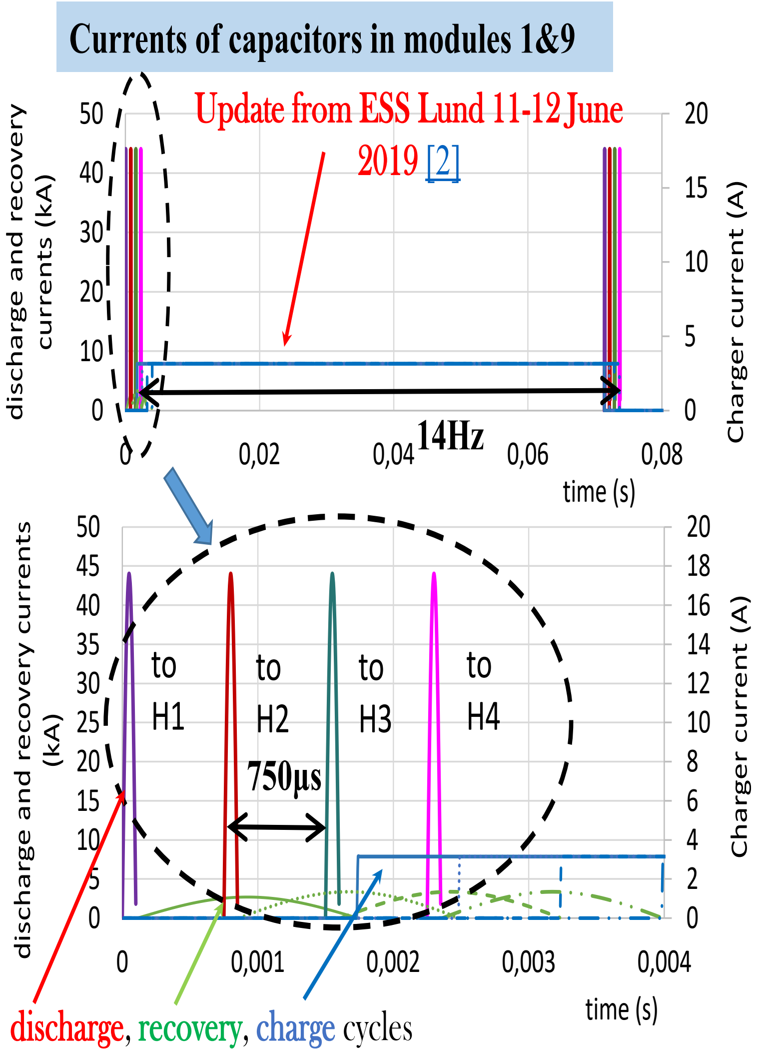

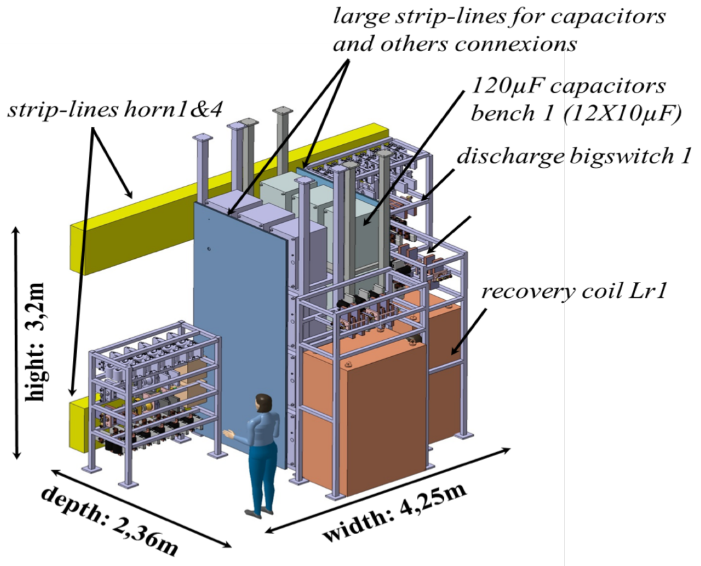

PSU Design

- For each horn : current pulse of 350kA at microsecond time width at 14 Hz.
- Good energy recuperation and reinjection system.
- Estimated lifetime > 13 Bcycles . (10 years, 200 days/year)

ESSnuSB Beam Dump

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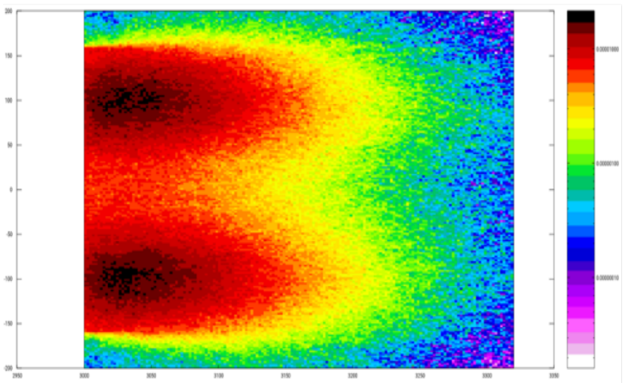
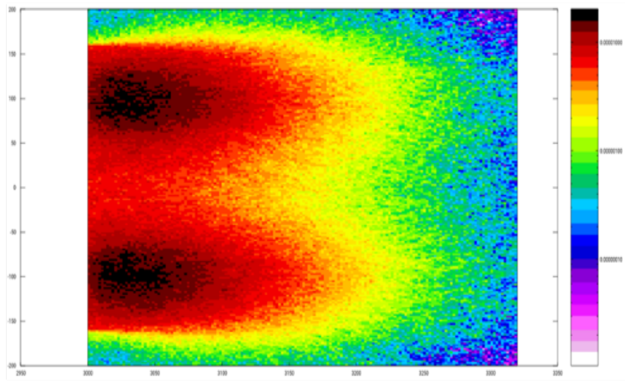
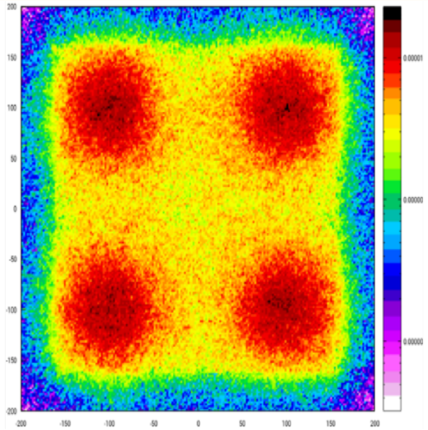
View from the radial direction (x-axis) on the side of the dump core



View from the normal to the beam axis (Y-axis) on the side of the dump core



View from the direction of the beam axis (z-axis) on the front surface of the dump core



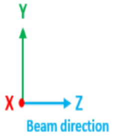
Color scale:

min. value = 3.1×10^{-8} kW/cm^3

max. value= 2.3×10^{-5} kW/cm^3

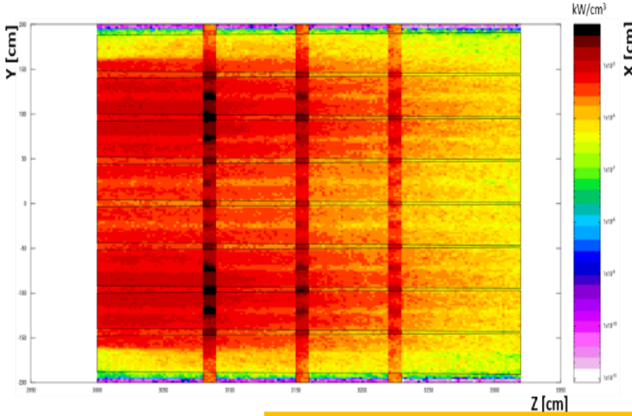
Integral (4-horns) = 826 kW

One-block graphite core & T2K core

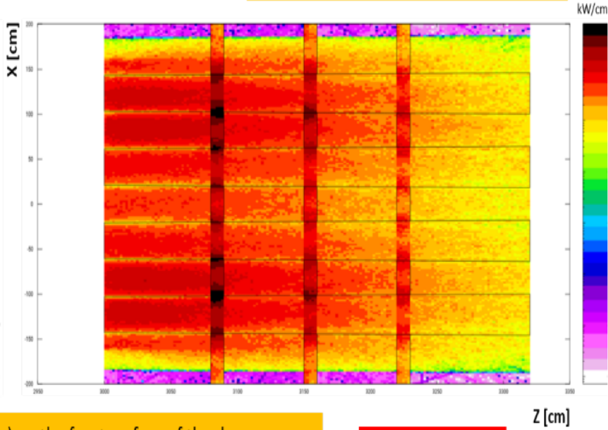


Bulk Design

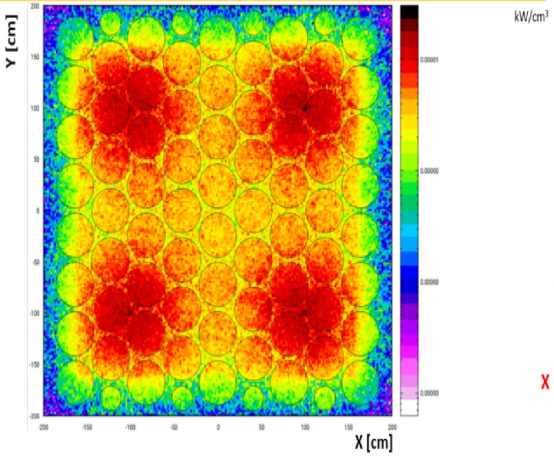
View from the radial direction (x-axis) on the side of the dump core



View from the normal to the beam axis (Y-axis) on the side of the dump core



View from the direction of the beam axis (z-axis) on the front surface of the dump core



Color scale:

min. value = 6.2×10^{-9} kW/cm^3

max. value= 3.0×10^{-5} kW/cm^3

Integral (4-horns) = 796 kW

Multi-cone graphite core

Segmented Design

T. Tolba

ESSnuSB Hadronic Collector

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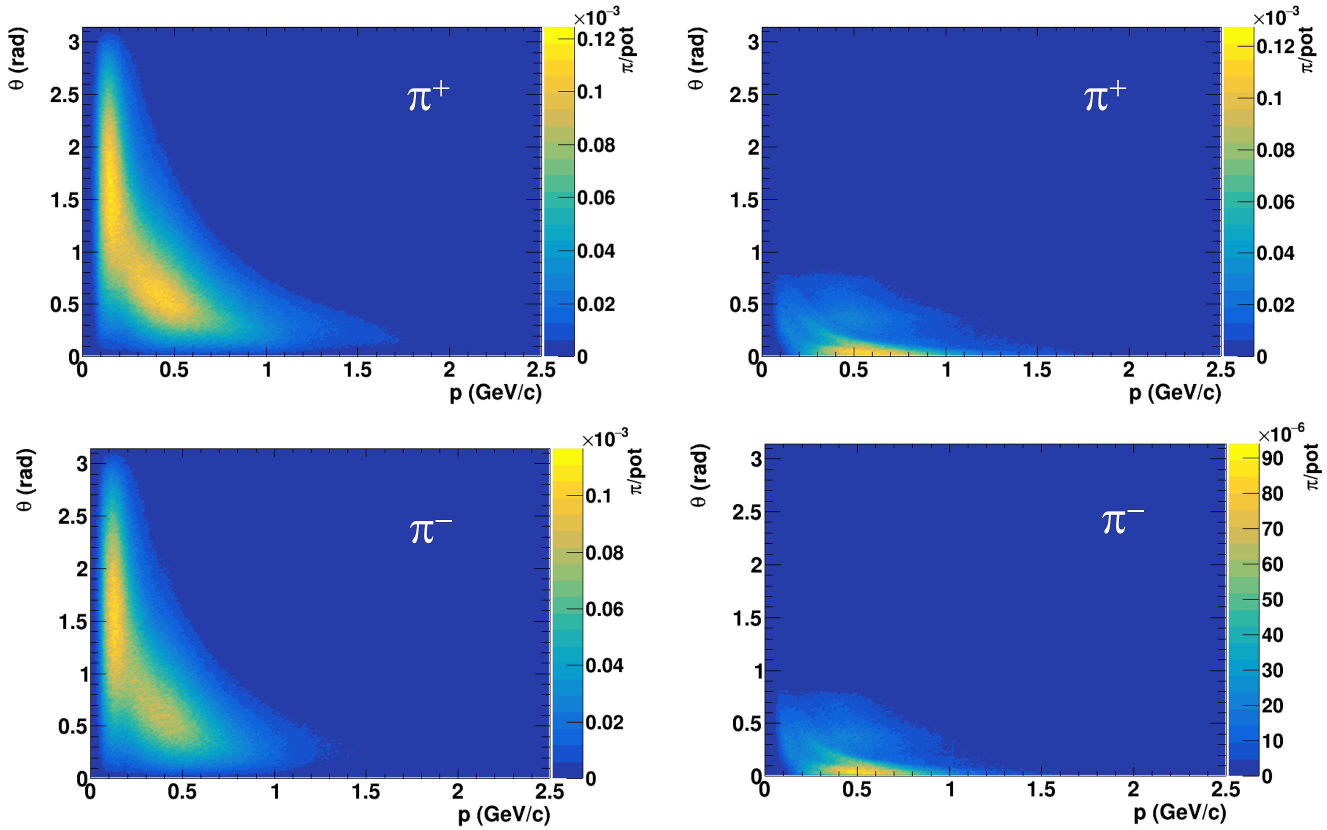
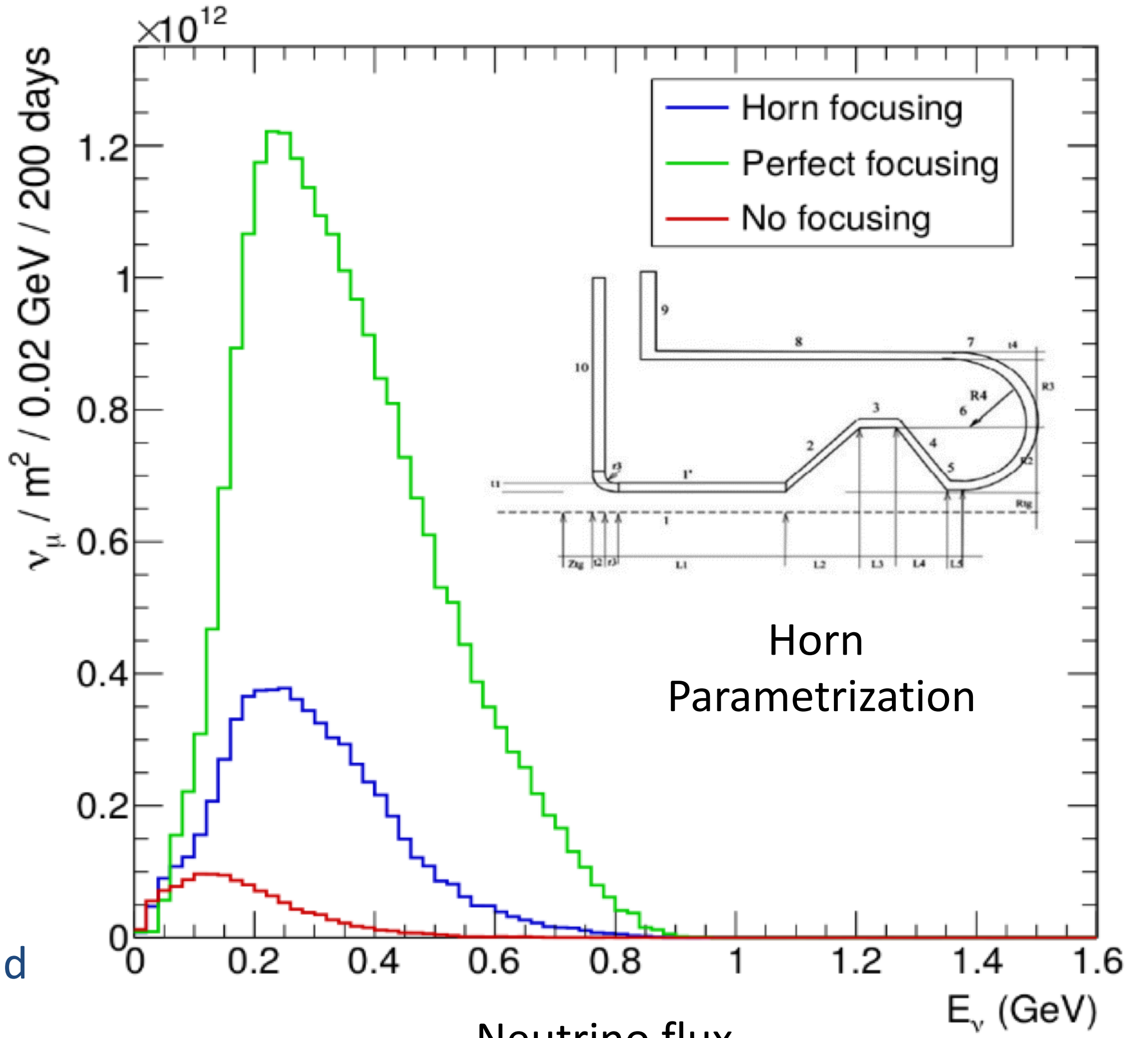
Focusing performance optimization



Momentum vs angle distribution of pions exiting the target (left) and entering the decay tunnel (right panel).



Neutrino flux

ESSnuSB Neutrino Flux

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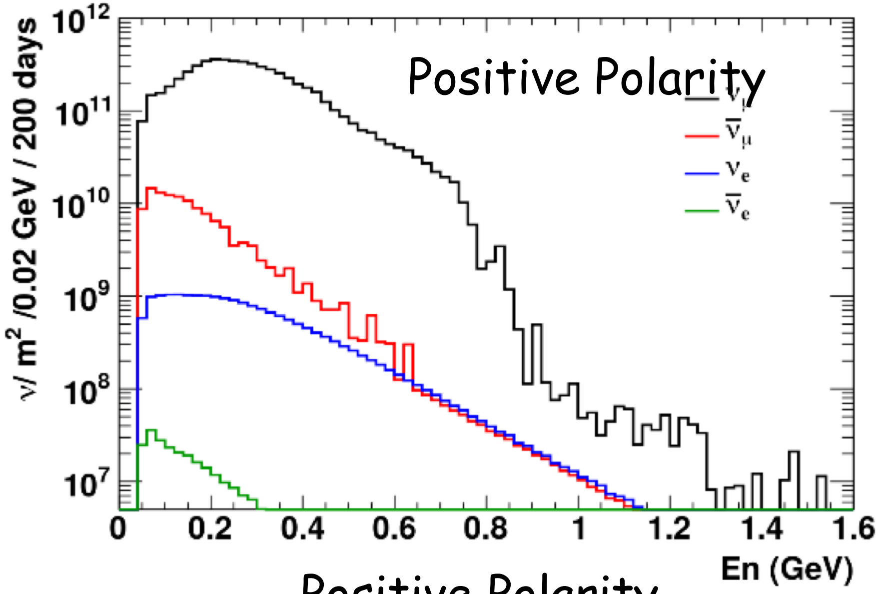
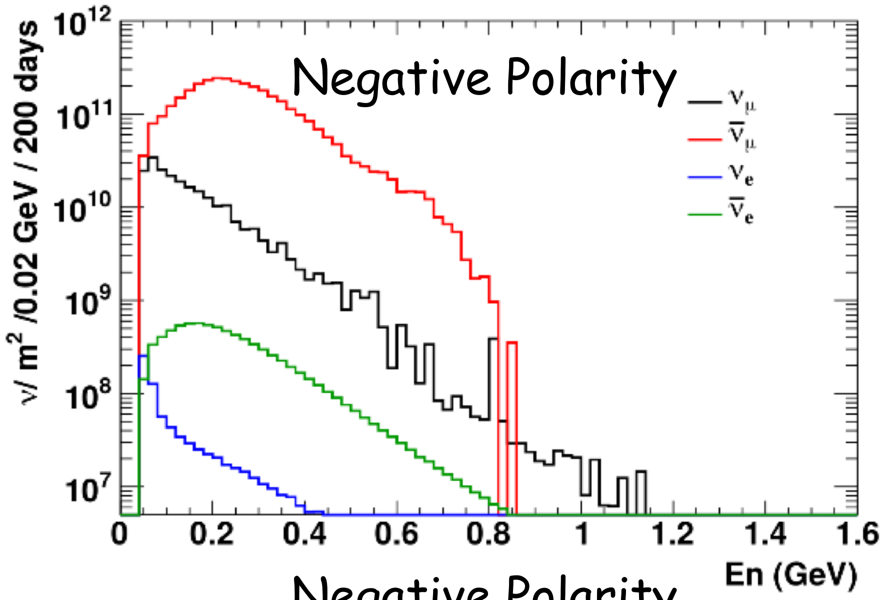


Positive Polarity



Negative Polarity

	Positive Polarity		Negative Polarity	
	$N_\nu\ (10^{10}/\mathrm{m}^2)$	%	$N_\nu\ (10^{10}/\mathrm{m}^2)$	%
ν_μ	583	98	23.9	6.55
$\bar{\nu}_\mu$	12.8	2.1	340	93.2
ν_e	1.93	0.3	0.08	0.02
$\bar{\nu}_e$	0.03	0.01	0.78	0.21

Neutrino flux composition at 100 km distance from the target station.

ESSnuSB Muons flux at Beam Dump Level

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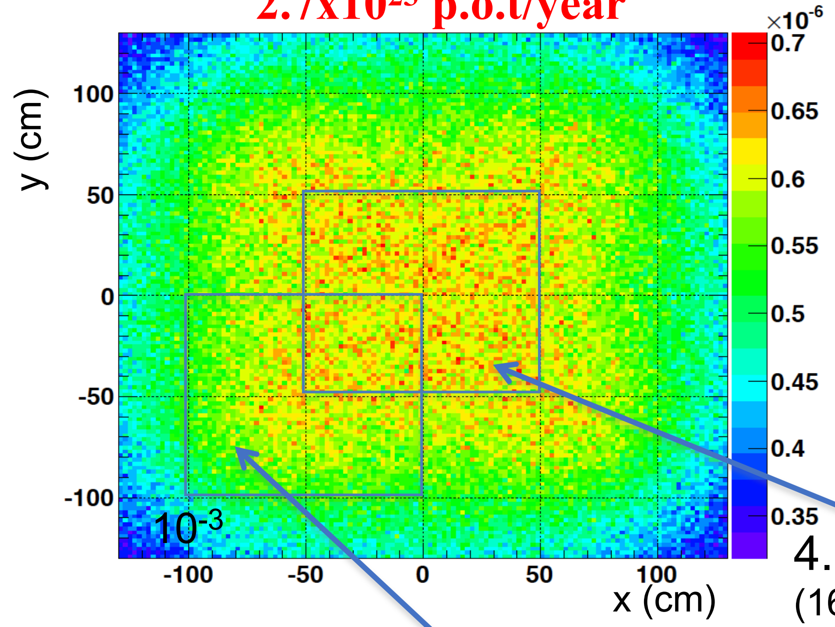
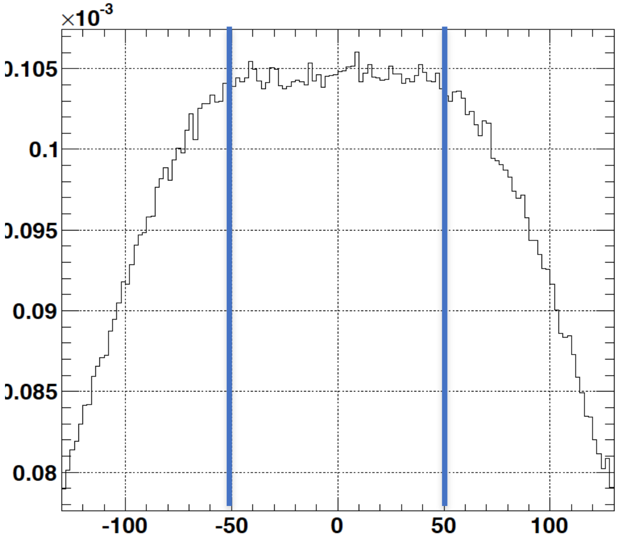
2.7x10^{23} p.o.t/year

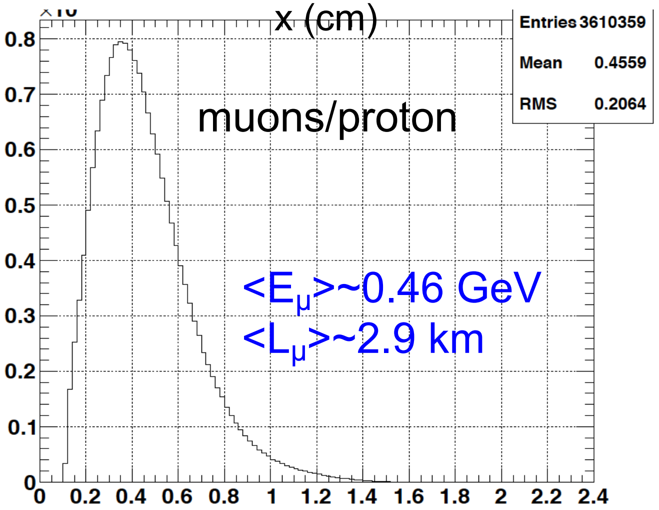


Muons at the level of the beam dump (per proton)

4.2x10^{20} μ/year
(16.3x10^{20} for 4 m^2)

4.1x10^{20} μ/year





- Input beam for future 6D m 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***.

Synergy ESSnuSB/ESSmuSB

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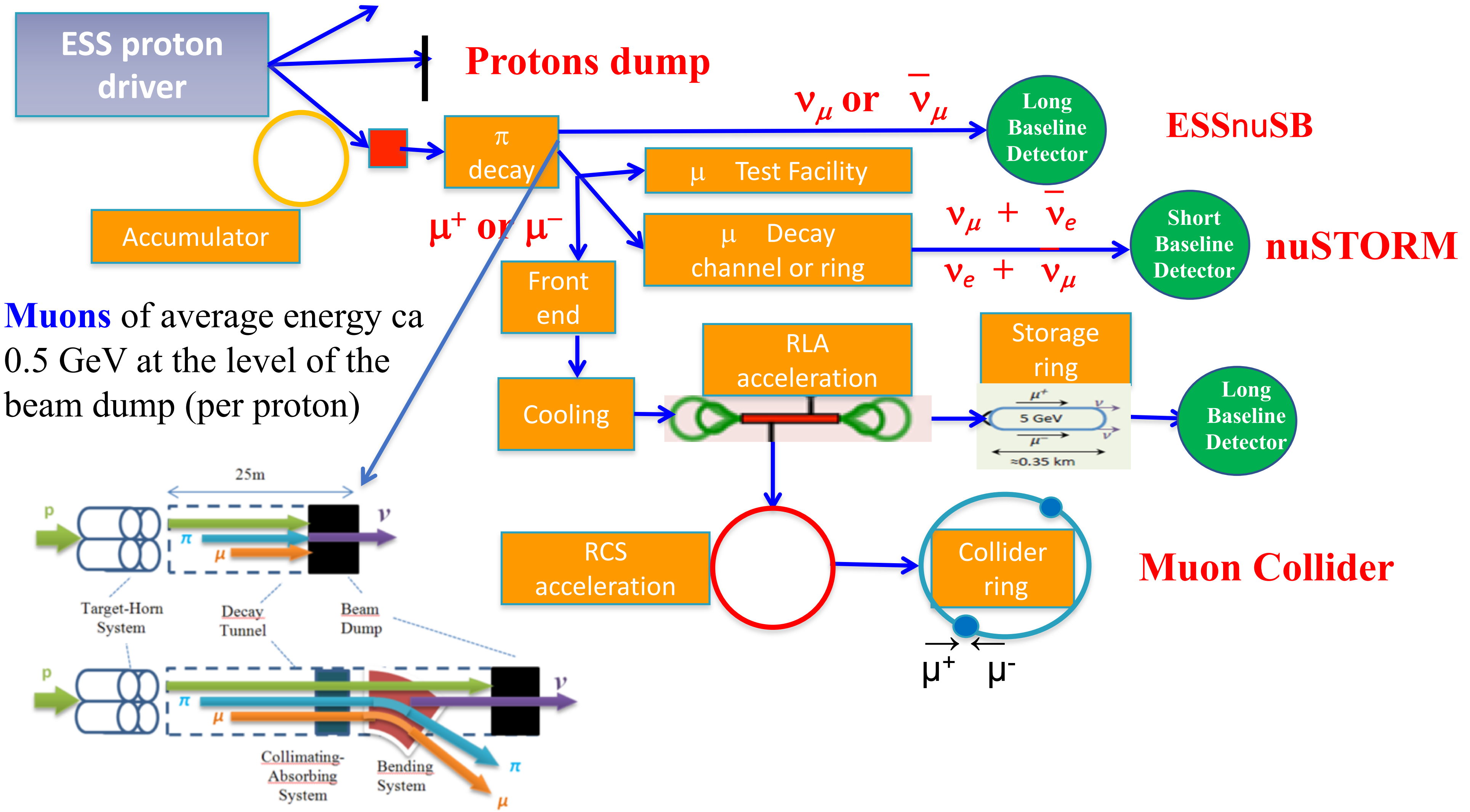

Summary

- The proposed design for the ESSnuSB Target Station should be able to work under 5 MW proton beam power at ESS.
- The packed bed target concept proposed for the target used to work MW proton beam power but simulation requires feedback prototype.
- Additional methods are under going to improve Superbeam Beam physics.
- This facility offers lots of opportunities to the community and it is an ideal platform to house R&D activities and other experiments.