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WP3 : Target Station and Pion Extraction

Eric Baussan (Coordinator) & Tamer Tolba (Co-coordinator)

ESSnuSB+
2nd Annual Meeting
Hamburg (23-27/09/2024)

WP3 : Target Station and Pion Extraction

Eric Baussan (Coordinator) & Tamer Tolba (Co-coordinator)

1. Overview of the Target Station Facility
2. Deliverables & Milestones
3. WP3 Activities
4. Answer to comments by the international advisory panel after 1st Annual Meeting

WP3 : Target Station & Pion Extraction

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Work package number	3	Lead beneficiary:			1		
Work package title	Target Station and pion extraction						
Participant number	1	9	15	2	20		
Short name of participant	CNRS	UHH	CERN	UNISTRA	ESSB		
Person/months per participant:	46	52	14	12	7		
Start month:	1		End month:		48		

Task List

- 3.1: Coordination of the Target Station WP (CNRS)
- 3.2: Adapt the ESSvSB target station to the pion production requirements (CNRS, UHH, UNISTRA)
- 3.3: Investigate pion Extraction and Initial Focusing System (UHH, CNRS, CERN, UNISTRA)
- 3.4: Target Station Facility (CNRS, ESSB, UHH, UNISTRA)

Deliverables

- D3.1: Optimize the ESSvSB+ horn design and its pulse generator, month 18.
- D3.2: Design of the pion Extraction and Initial Focusing Systems, month 24.
- D3.3: Design of the Target Station, month 46.

WP3 : Global Overview

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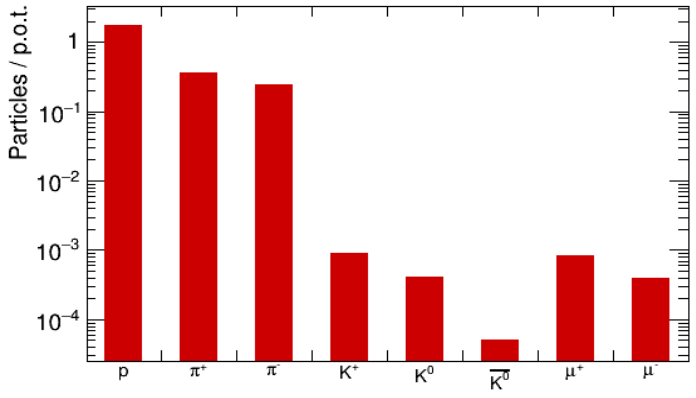

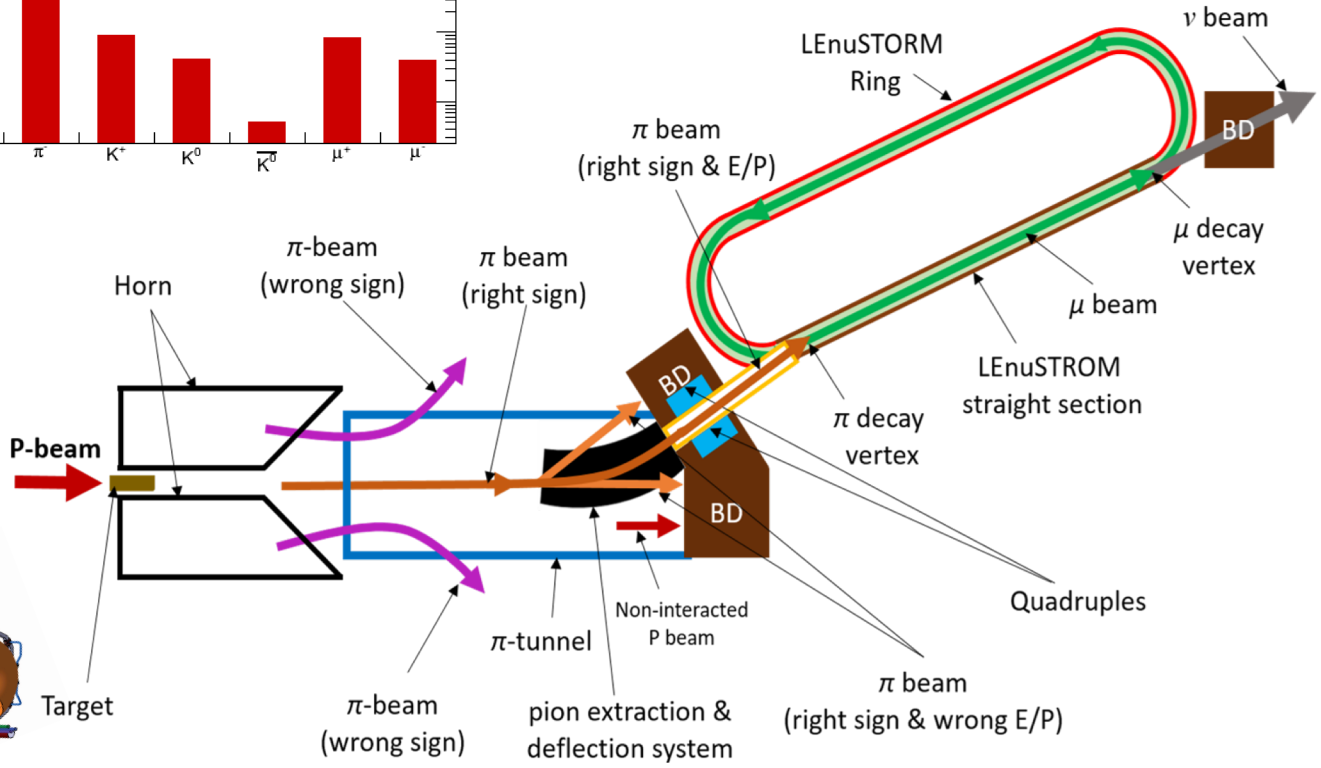

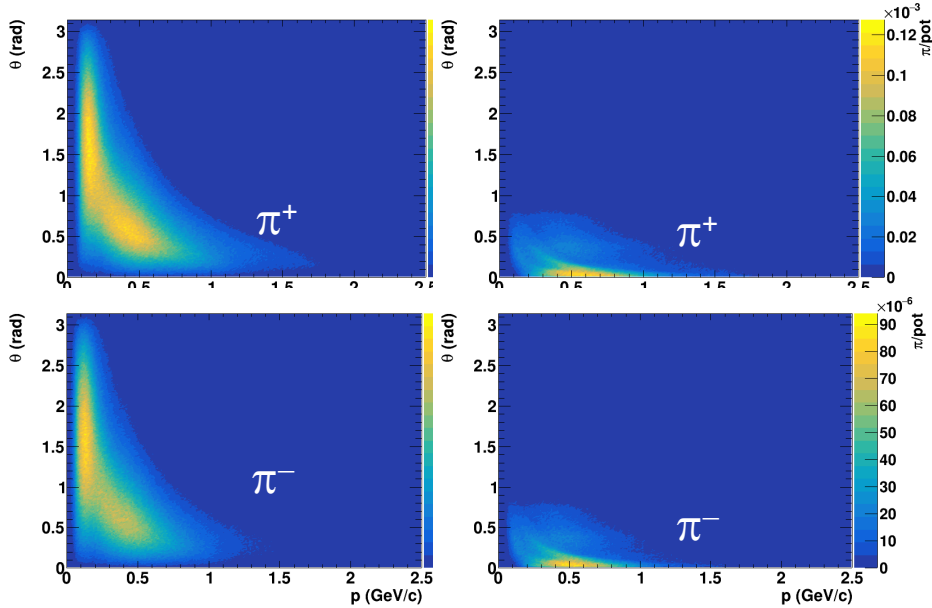

One horn-target system

Adaptation of the ESSnuSB horn to the ESSnuSB+ physics goals

WP3 : Target Station & Pion Extraction

Use of Resources (extracted from Periodic Report)

Period M1-M12 (Men/ Month)	CNRS	UHH	CERN	UNISTRA	ESSB	Total
Planned for 2023-2026	46	52	14	12	7	131
Actual	4.49	7.1	0.35	6.06	1.75	19.75
Fraction (%)	9,76	13,65	2,5	50,5	25	15,07

Status of the postdoc:

- CERN : Fellow started January 1st, 2024, expected to work 50% in WP4.
- CNRS : recruitment still going. (The position opened and advertised on 11 Oct. 2023.)

Deliverables & Milestones

DELIVERABLES MILESTONES	DEADLINE	YEAR	DESCRIPTION OF THE TASK	PARTNER RESPONSABILITY	STATUS
D 3.1	M18	2024	Optimize the ESSnuSB+ horn design and its pulse generator.	CNRS	Delivered
D 3.2	M24	2024	Design of the pion extraction and focussing systems.	UHH	
D 3.3	M46	2026	Design of the Target Station.	CNRS	
MS 3.1	M12	2023	First design of the hadron collector.	CNRS	Delivered
MS 3.2	M24	2024	Preliminary design of the pion extraction and focusing system	CNRS	
MS 3.3	M36	2025	Final estimation of the pion beam	CNRS	
MS 3.4	M42	2026	Evaluation of the baseline design of the target station	CNRS	

WP3 Activities

Meetings:

During the last annual year, 13 meetings were organized in total. After the 1st Annual Meeting :

- 5th WP3+ Meeting 07 November 2023
- 6th WP3+ Meeting 13 December 2023
- 7th WP3+ Meeting 06 April 2024
- 8th WP3+ Meeting 05 March 2023
- 9th WP3+ Meeting 29 June 2023
- 10th WP3+ Meeting 07 May 2024
- 11th WP3+ Meeting 04 June 2024
- 12th WP3+ Meeting 2 Juillet 2024
- 13th WP3+ Meeting 3 September 2024

Mid Term Meeting between WP's 23th April 2024

=> Impact of the **« ESSnuSB+ Design Guidelines »** by Management Team (DocDB#1719)

Conferences:

- Neutrino 2024, "The ESSnuSB+ Target Station" has been presented as a poster for the Neutrino 2024.
- ICHEP 2024, "The ESSnuSB+ Target Station Design Study" has been presented as a poster.
- NBI2024, "Neutrino Beam Instrumentation" Workshop will happen in Japan from 7th of 10th of October 2024.

WP3 Impact on Civil Engineering

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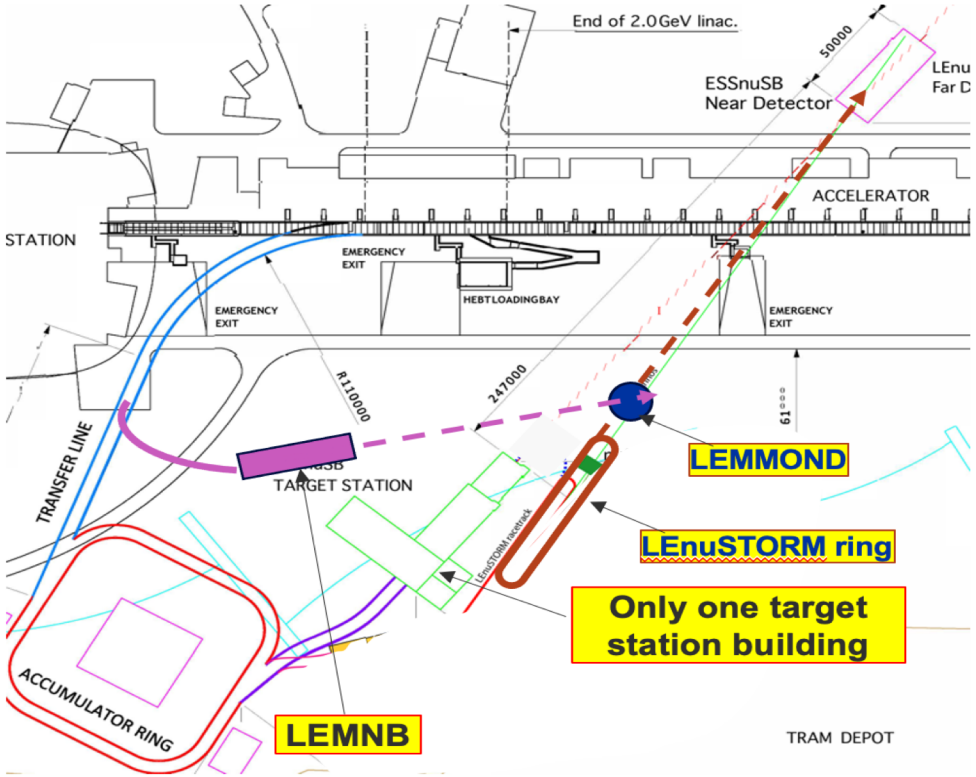
ESSnuSB+ Layout

Phase 1 – LEMNB



- **Use the same extraction point from the LINAC**
- **Design a transfer tunnel that branches off at some point towards a low-energy target station (300kW) in-between the accumulator ring and the LINAC**
- **Stay near the surface and point to LEMMOND only at ~100m distance from the target**
- **Pros:**
  - Initial phase construction is limited to what is required
  - The target station is a low-intensity kW class which needs only conventional magnets and ventilation/cooling systems
  - Decoupled from the heavy civil engineering for the second phase
  - Eventually could be decommissioned and removed!

WP3 Impact on Civil Engineering

ESS Linac Power

I. ESSnuSB+ Low Energy Monitored Neutrino Beam (Low Power!)

< 1 MW

- Accumulator not requested
- Specific Target Station with instrumented decay tunnel
- Rough integration to the the design at the moment

II. ESSnuSB+ Low Energy nuSTORM (1.25 MW)

1.25 MW

- Accumulator requested
- No Beam Switchyard
- Hadronic collector based on one Horn
- Room for Power Supply Units
- Morgue and Hot cell

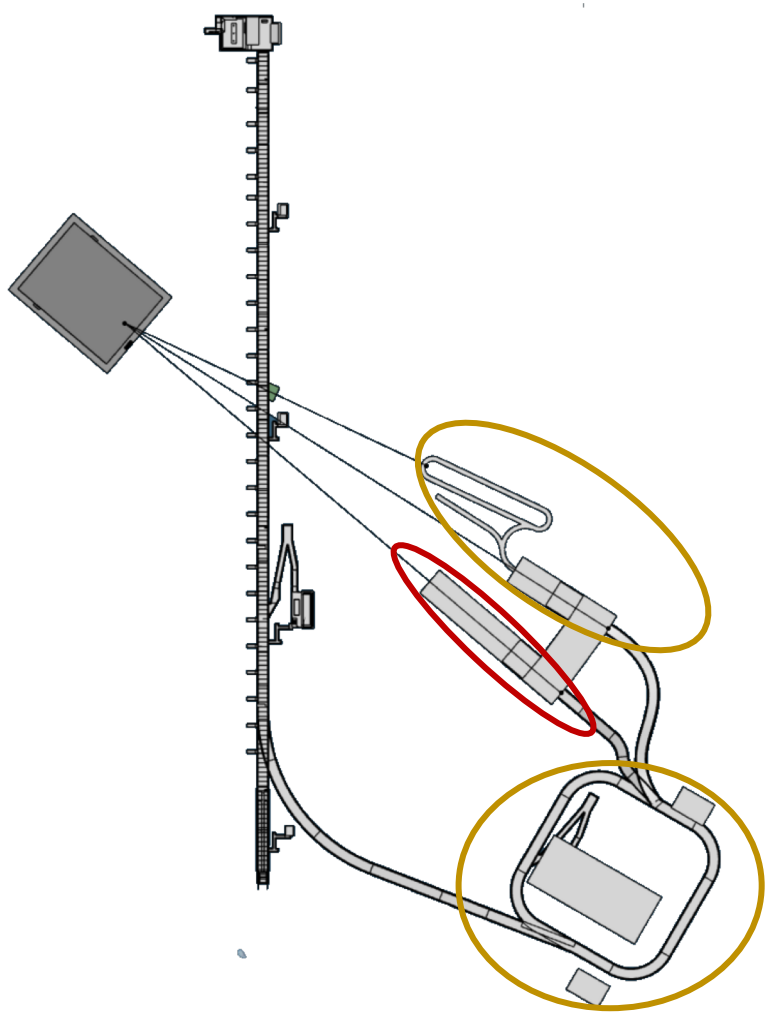
\+ Extraction System + Racetrack Ring

\+ Decay Tunnel 50m long

III. ESSnuSB Target Station (5 MW)

5 MW

- Accumulator requested
- Beam Switchyard requested
- Hadronic collector based on Four Horn
- Room for Power Supply Units
- Morgue and Hot cell



v4.0 of the CAD model

WP3 : Target Station and Pion Extraction

Eric Baussan (Coordinator) & Tamer Tolba (Co-coordinator)

Answers to comments by the international advisory panel after 1st Annual Meeting

Answers to comments by the IAP

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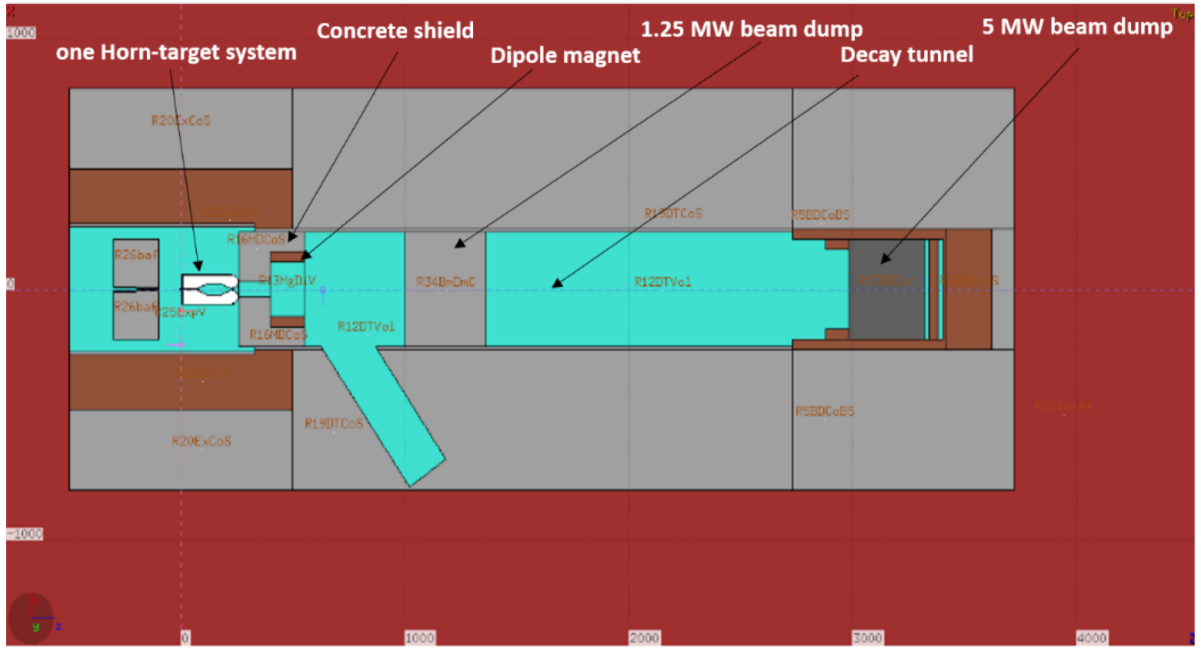
Recommendations - Target Station

We recommend making design concepts based on a single target station to accommodate both the LEMNB and LEnuSTORM experiments. This could be achieved by developing a modular target-horn assemblies design such that it can be handled remotely. As these two experiments will be performed sequentially, it is important to first develop a LEMNB target station with prepared pion beam extraction towards the muon decay ring, which can be decommissioned and replaced with civil structures for the LEnuSTORM experiments. While developing a single target station, **we recommend to reserve space for future super beam target station upgrades, in case the first target station cannot accommodate the 4-horn based targets and longer decay cave.**

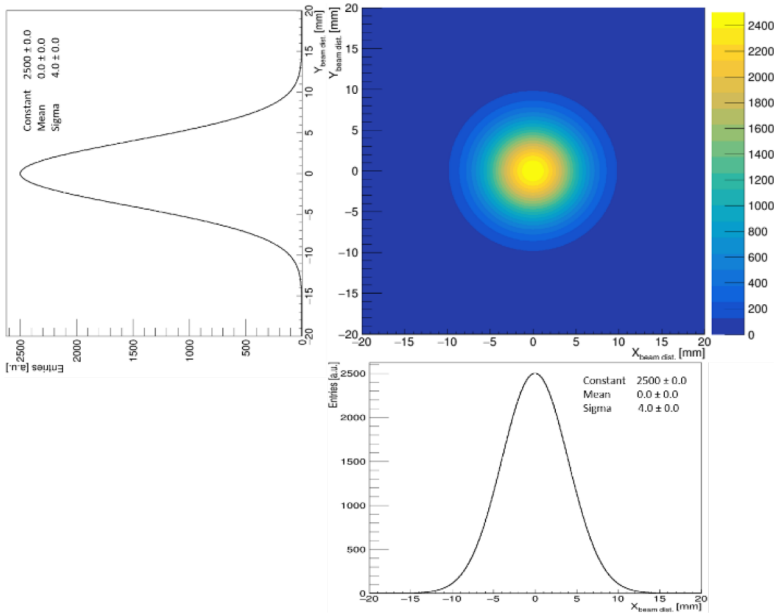
- The MW-class target station is detached from the MegaWatt target station.
- One facility building composed of two parts:
  - The Horn Gallery is common to phase 2 and 3
  - The downstream parts can be separated
- Pion Deviation System will be located as close as possible of the horn
- Intermediate Beam Dump for phase 2 an will be removed after decommissioning.

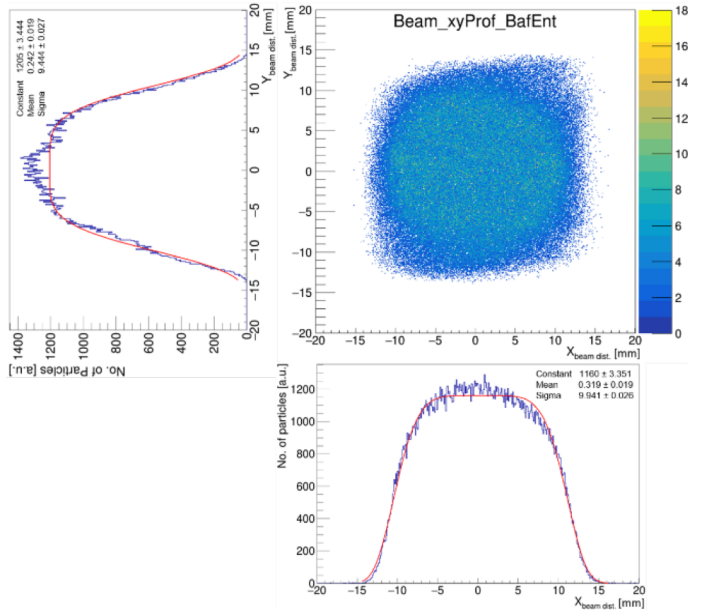


Answers to comments by the IAP

Recommendations – Target

As Sievers' granular target design is based on different beam parameters. **We recommend the WP3 team to elaborate further on the physics of the LEnuSTORM target to identify the effects of beam size, target radius, target length, and target material on the downstream neutrino yield. In this regard, we recommend to include the beam size effects on the neutrino yield study for the LEMNB target as well.**





The main purpose of the ESSnuSB+ target station is to optimize the charged pion beam, which will then be fed to the LEnuSTORM ring to produce the neutrino beam from the decay of the muons, in contrast to the ESSnuSB target station, which is designed to directly produce the neutrino beam from the decay of the pions. We have examined two options for the proton beam size:

1) a gaussian beam with beam size (FWHM) = 1 cm
2) a super-saturated beam, which resulted from the proton beam studies of the accumulator group using TraceWin software.

Answers to comments by the IAP

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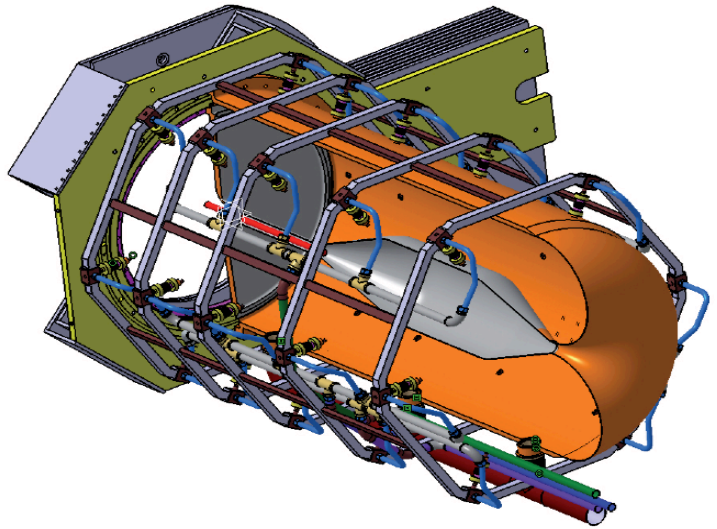
Recommendations - Horn and Power Supply

With low beam energy, the particle flux downstream the target has a larger solid angle than higher energy beam. As a result, there will be higher nuclear heating from the bombardments of primary and secondary particles on the horn compared to existing horn designs at other facilities where incident proton beam energy is at least an order of magnitude higher. **We recommend the WP3 team to analyze the energy deposition and heat effects in the horn on its thermal and mechanical behavior.** Likewise, high hadron fluxes on the horn induce higher radiation damage, which could limit the lifetime. To assess radiation damage induced lifetime criteria for the horn system, we recommend the WP3 team to **analyze the displacement damage, helium production and solid transmutations in the horn using particle transport codes**. Also to be considered is the fact that **the corrosion and erosion of the horn material** accelerates in the target environment in case the horn is cooled by water.

We share the concerns of the IAP member on these points. However, during the ESSnuSB design study program, detailed energy deposition, radiation safety and thermodynamic simulations were performed on the horn. As the ESSnuSB+ horn baseline design is in principle very close to the ESSnuSB horn, these, ESSnuSB, studies will be used as a starting point for the modified ESSnuSB+ horn design.



Answers to comments by the IAP c

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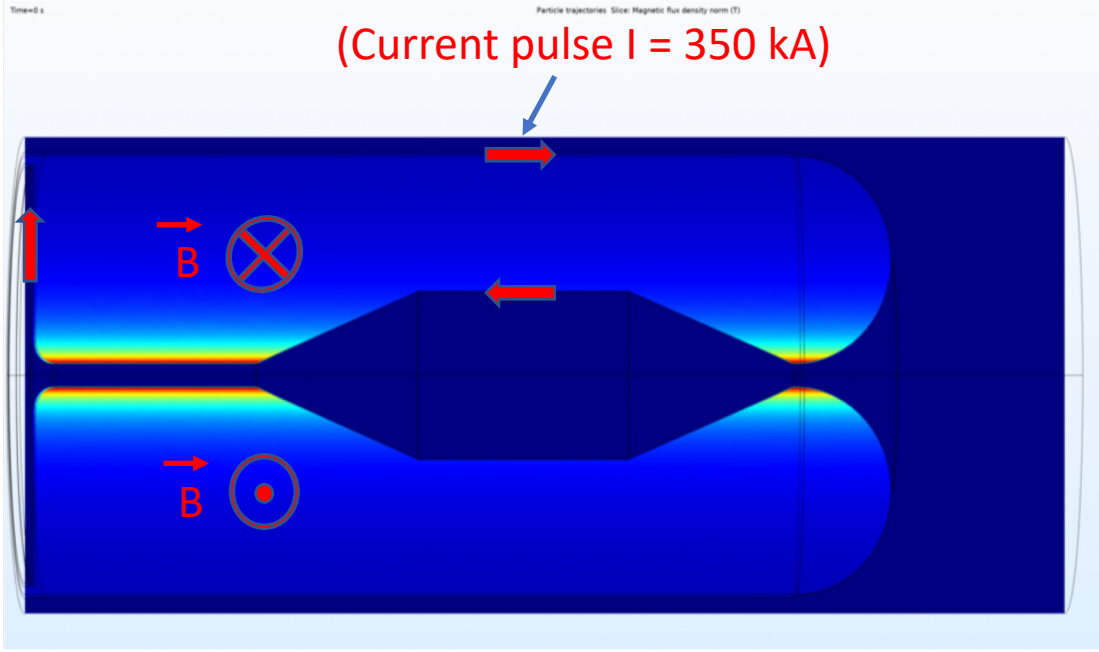
Recommendations - Horn and Power Supply

There are challenges with **short electric pulses with a high transient current to power the horn**. We recommend the WP3 team carefully analyze the **highly dynamic transient electromagnetic phenomena in the power supply system**, which include dynamic transient structural loads from pulse induced thermal expansion, high current induced Lorentz force and dielectric strength of the medium across the high voltage.

The power supply unit (PSU) will be based on a modular approach to reduce the electrical constraints on the components. In ESSnuSB+, a total of 8 modules are needed to deliver a total of 350 kA in the horn at 14 Hz compared to ESSnuSB project which the PSU is based on four horn system supplied by 16 modules due to a more complex proton pulse scheme.

The electrical constraints in each module will be updated with respect to ESSnuSB+ horn requirements. In addition, the strip lines will be used to transfer the electrical pulses from the modules to the horns.

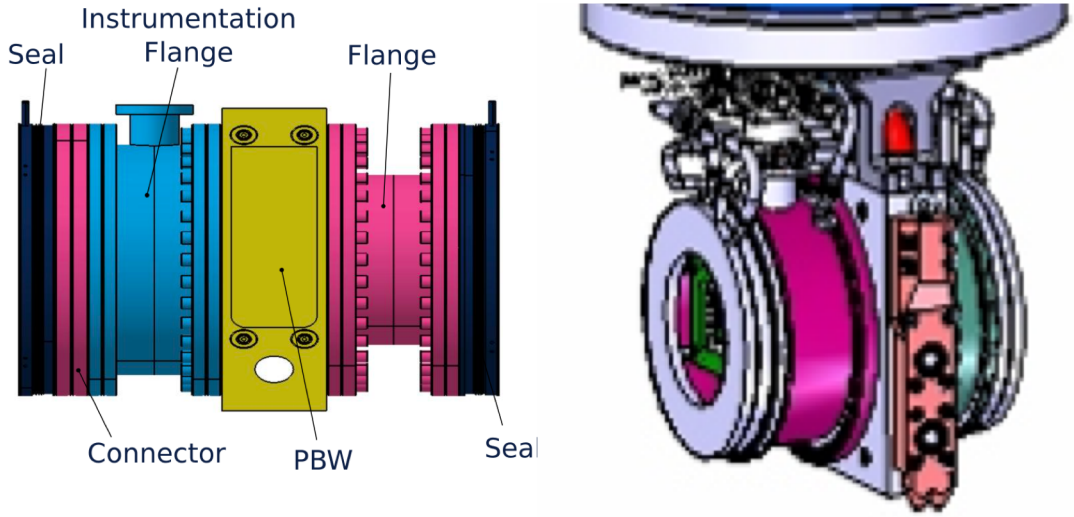


Answers to comments by the IAP

Recommendations - PBW

The beam spot size (3 cm in diameter) is smaller than the ESS PBW (30 cm2 beam footprint) which is made of Al6061-T6. **We recommend the WP3 team to calculate the maximum temperature in the PBW proposed**. To avoid the overaging of the precipitation hardened aluminum alloy, the maximum temperature in the PBW shall not exceed 130 C. With a steady temperature above 130 C, **the Al6061-T6 loses precipitation hardened condition, losing its intended mechanical strength**.

For practical reasons, the proton beam window (PBW) system for ESSnuSB was **inspired by the 5 MW ESS technology with its complete cooling system**. However, this design is not considered as a standard technology for neutrino superbeam experiments, in particular **beryllium material is the baseline option**. Very preliminary studies on the energy deposition and therefore the maximum temperature in the PBW were performed during the previous design study program. A new detailed design study will be performed in the framework of ESSnuSB+.



ESS Proton Beam Windows (5MW/14Hz)

R. Vivanco et al 2018 J. Phys.: Conf. Ser. 1021 012065

Answers to comments by the IAP

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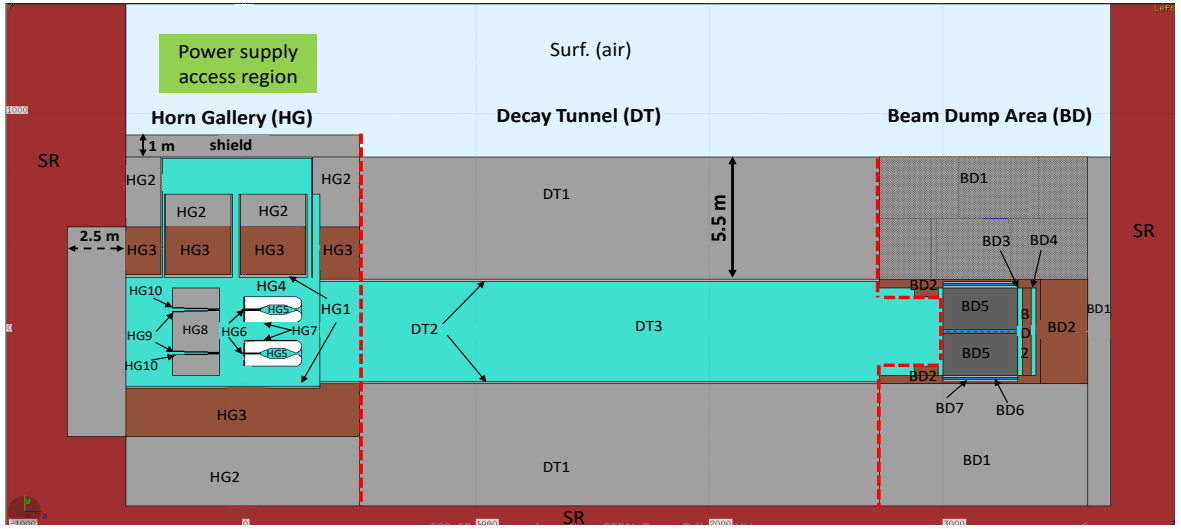
Recommendations - Dipole Magnet LEnuSTORM

Primary and secondary particles downstream of the target have a large solid angle distribution causing a high ionizing dose in the electrical insulating materials in the dipole magnet. As a high ionizing dose in the magnet significantly degrades the functionality of the insulating polymers, **we recommend the WP3 team to define dose limit criteria at least at a preliminary level, to determine required shielding size of the target station. Shielding is a big cost factor**. We also recommend calculating the equivalent dose from target-horn assembly, which Is important in determining remote handling. It is also important to elaborate on remote handling strategy and concepts for target handling and upgrade from LEMNB to LEnuSTORM.

The MW-class target station is detached from the design of the shielding for the 5 MegaWatt target station is a good starting point for ESSnuSB+ for safety studies

As for the shielding of the dipole magnet components, we are planning to conduct a preliminary radiation studies to define a dose limit. However, it also depends on the insulation materials that are expected to be used in the dipole structure.



WP3 Sessions

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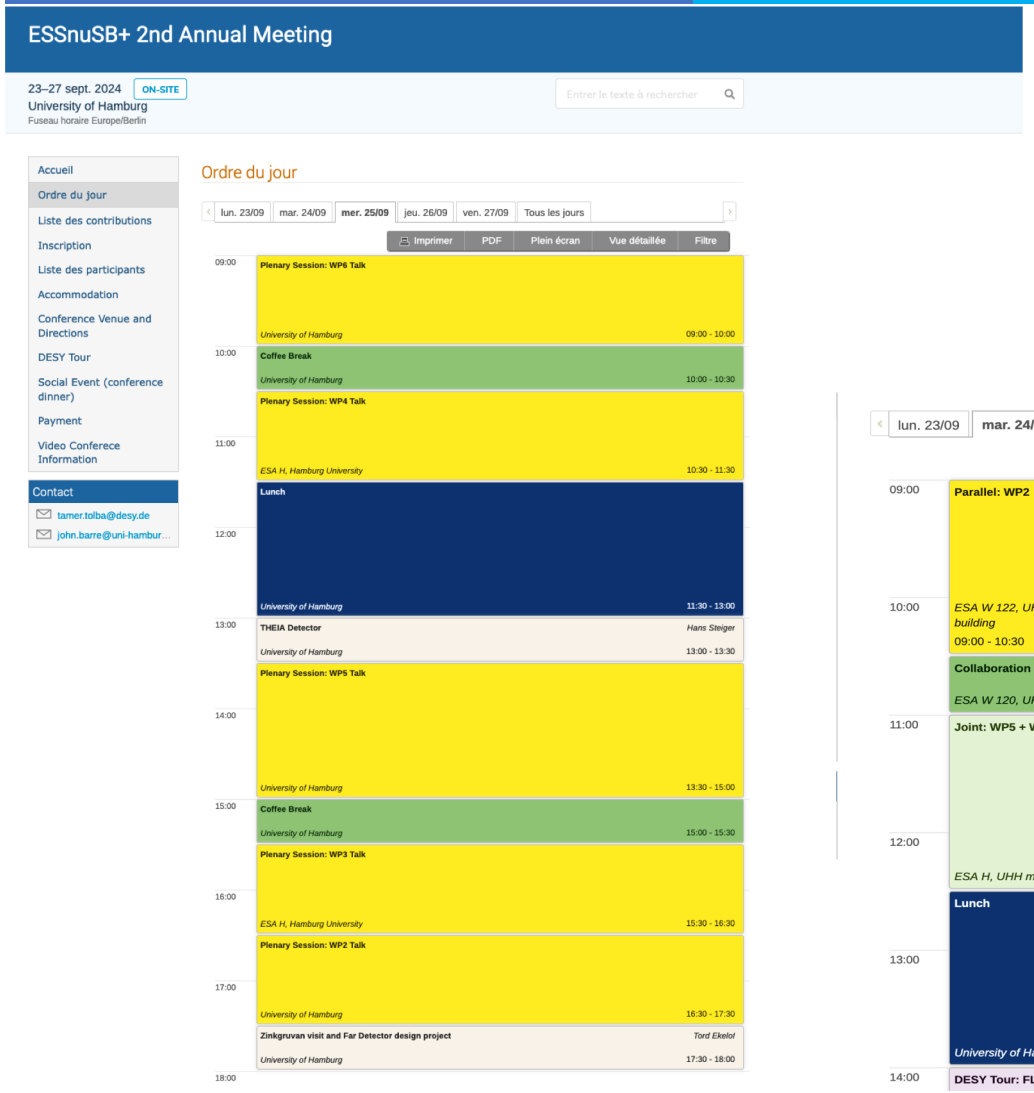
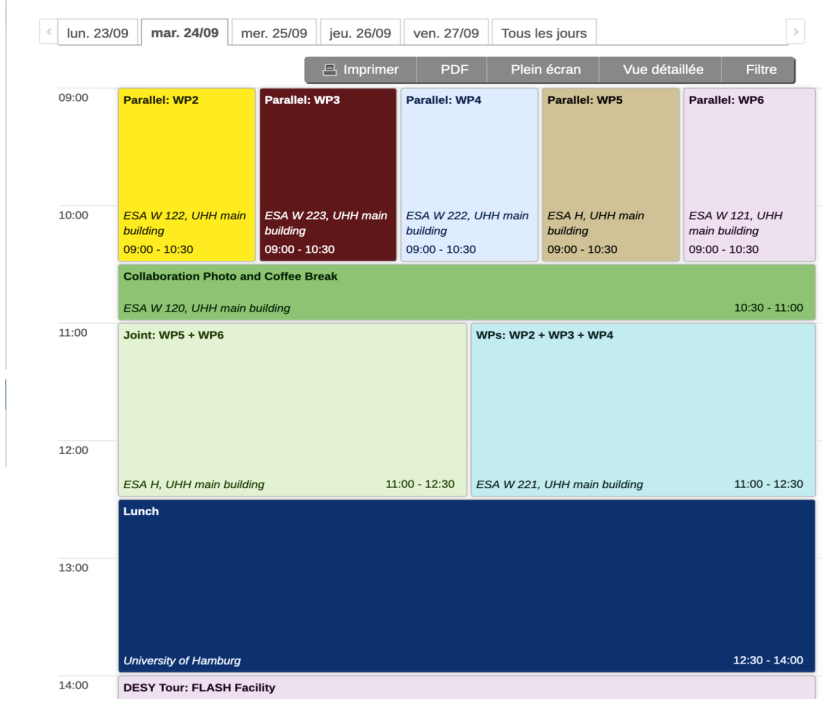
Agenda of the WP3 session

- Target Station Facility
- Extraction System
- Target System
- Costing Discussion (Parallel)





Summary

- The Implementation of the different Target Station on the ESS site has been clarified.
- The first deliverable D3.1 has been produced and lead to the optimisation of the horn geometry.
- In term of human resources, the job recruitment at IPHC is still on going.
- Next step is to design of the downstream part of the Target station in particular the magnetic device to feed the LEnuSTORM ring.
- Work on specific point related to the horn is on going.
- Safety and costing.