WP4 Report

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Objectives:

- Adapt the EUROnu designed target station to the ESSνSB requirements:
  - the target
  - hadron collector (horn)
  - power supply unit
- Investigate the possibility of using a solenoid-based hadron collector
- Optimize the facility structure
- Simulate the neutrino beam

Tasks:

Task 4.1 Coordination of the Target Station study (AGH)

Task 4.2 Adapt the EUROnu design target station to the ESSνSB requirements (AGH,CNRS,UniGe)

Task 4.3 Target integration (AGH,CNRS,CERN)

Task 4.4 Optimization of the horn-type hadron collector (CNRS, AGH, CERN)

Task 4.5 Horn current pulse generator (CNRS)

Task 4.6 Alternative hadron collector (UU, CERN)

Deliverables and milestones

Task Deliverable Milestone	Dead lines	Year	Description of task	Partner's responsibility/ Name
D4.1	M24	2019	Optimised design of the magnetic horn (M24)	AGH
D4.2	M28	2020	Evaluation of an alternative hadron collector (M28)	AGH
D4.3	M36	2020	Design of the pulse generator and of the horn cooling system (M36)	AGH
D4.4	M45	2021	Design of the target station (M45)	AGH
MS1	M12	2018	Review of the 1st year achievements, deliverables & costs (M12)	CNRS
MS5	M18	2019	Design of the hadron collection device (M18)	AGH
MS7	M24	2019	First estimation of neutrino beam intensity (M24)	AGH
MS9	M24	2019	Review on interim milestones, deliverables & costs (M24)	CNRS
MS13	M36	2020	Review of the 3rd year milestones, deliverables & costs (M36)	CNRS
MS17	M42	2021	Final design of target station (M42)	AGH
MS18	M42	2021	Cost and performance evaluation complete (M48)	CNRS

Milestone MS1 and MS5 „Design of the hadron collection design" were submitted according to schedule. The nearest deliverable (D4.1) is due at the end of the year

Realization of the objectives

Objective 1: Adapt the EUROv designed target station to the ESSvSB requirements.

A detailed overview of the results of the EUROv Design Study has been made. In many cases, the solutions that were initially studied for EUROv can be adapted to the ESSvSB conditions. This task has been realized as planned.

Objective 2: Optimize the hadron collector (horn).

Both physics and mechanical studies have been performed aimed at the optimization of the horn hadron collector. There has been some delay to this objective due to the difficulty of recruiting two postdocs. Since the postdocs were recruited, the realization of this objective proceeds well, so that the related deliverable (D4.1) planned for 31/12/2019 should be submitted on time.

Objective 3: Investigate the possibility of using a solenoid based hadron collector.

The solenoid option has been studied, but its charge selection capability appears to be considerably worse than that of a magnetic horn. An alternative design is being studied now, which makes use of the so-called "Los Alamos" device. The progress so far indicates that the deliverable for this objective (D4.2) should be submitted according to plan (30/04/2020).

Objective 4: Simulate the neutrino beam.

Detailed simulations of the neutrino beam have been performed. Milestone MS5, related to this objective, has been achieved. In recent time, coordination with WP5 activities is being emphasized, within the general simulation environment of the ESSvSB project. This objective is being realized according to plan.

Detailed tasks and progress status

T4.1			**Adapt the EUROnu design target station to the ESSνSB requirements**	**AGH/CNRS/UNIGE**	
T4.1.1			Target station concept for ESSνSB	AGH/CNRS	Done
T4.1.2			Horn electrical system	CNRS	Done
T4.1.3			Safety	CNRS	Done
T4.2			**Optimization of the horn type hadron collector**	**AGH/CNRS/CERN**	
T4.2.1			Performance	CNRS	Underway
T4.2.2			Stress levels in the horn and assessment of its lifetime	AGH	Underway
T4.1.3			Horn cooling cystem	AGH/CNRS	
T4.2.4			Horn support structure	AGH	Started
T4.2.5			Safety	CNRS	Underway
T4.3			**Horn current pulse generator**	**CNRS**	
T4.3.1			Pulse generator	CNRS	Underway
T4.3.2			Electrical power supply (Strip line connector to the horn)	CNRS	
T4.3.3			Safety	CNRS	Started

T4.4			**Alernative hadron collector**	**UU/CERN**	
T4.4.1			Performance	UU	Underway
T4.4.2			Design issues	UU	
T4.5			**Target performance and neutrino beam simulation**	**CNRS**	
T4.5.1			Simulation Geant4/FLUKA	CNRS	Underway
T4.5.2			Packed bed target (Baseline)	CNRS	Underway
T4.5.3			Graphite target (Second Option)	CNRS	Alternative
T4.6			**Target Integration**	**AGH/CNRS/CERN /UNIGE**	
T4.6.1			Definition of target integration concept	AGH/UNIGE	Underway
T4.6.2			Stress levels in the granular target	AGH	Started
T4.6.3			Target longevity	AGH	
T4.6.4			Target cooling	AGH	Underway
T4.6.5			Target material Issues	UNIGE/CERN	Started
T4.6.6			Safety	CNRS/CERN	Started
T4.6.7			Feasibility of graphite target (Second option)	AGH	Alternative
T4.7			**Target station facility**	**AGH/CNRS/CERN**	
T4.7.1			Target station layout	AGH/CNRS/CERN	Started
T4.7.2			Electrical power plant	CNRS	
T4.7.3			Cooling plant	AGH	
T4.7.4			Global safety	CNRS	Underway
T4.8			Cost evaluation	CNRS	

Recruitment of the posdocs:

The two postdocs envisaged for WP4 have been recruited, one at CNRS Strasbourg (Loris D'Alessi) and one at AGH Kraków (Łukasz Łacny). Loris began his work for the project in February 2019, Łukasz started in June 2019. Each has been employed for the duration of 24 months.

WP4 meetings are held regularly (4 WP4 video meetings held so far in 2019)
A joint WP2+WP3+WP4 held at ESS in Lund during 11-12 June 2019

Presentations during conferences and workshops specifically devoted to WP4:

- The ESSνSB Target Station (poster), *10th International Particle Accelerator Conference (IPAC2019),* Melbourne, Australia, 19-24 May 2019, E. Bouquerel
- The HiRadMat Capabilities for ESSνSB Future Target Tests, *International HiRadMat Workshop,* CERN, Geneva, Switzerland, 10-12 July 2019, P. Cupial
- ESSνSB Target Station, *21st Interational Workshop on Nutrinos from Accelerators (NUFACT2019)*, Daegu, Korea, 26-31 August 2019, L. D'Alessi
- ESSνSB Target Station Design, *11th International Workshop on Neutrino Beams and Instrumentation*, Fermilab, USA, 22-25 October 2019, E. Baussan

Technical presentations to be made during the WP4 sessions:

Loris D'Alessi „Status of the four-horn station"
Mateusz Kozioł „Mechanical studies of the magnetic horn"
Piotr Cupiał, Jacek Snamina „Analytical study of target cooling"
Łukasz Łacny „Finite element studies of a granular target"
Tamer Tolba „The beam dump"
Pascal Poussot „Status of power supply and its options"

During the joint WP2+WP3+WP4 session on Wednesday morning:
Elian Bouquerel „Status of the switchyard"
Maja Olvegard „Alternative hadron collector option"
Eric Baussan „Target station facility"

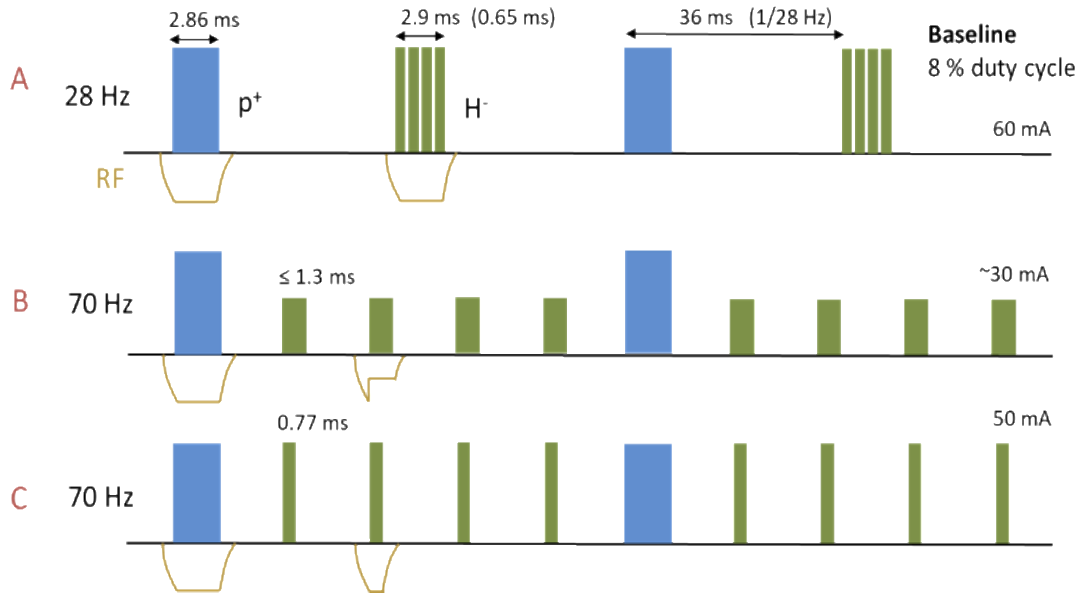
Summary of the replies to the IAP recommendations after the 1st annual meeting:

1) Clarify requirements and baseline parameters with other Work Packages. It is recommended to establish the effect of a 3 ms versus a c.1 μs bunch length on the ability to reduce backgrounds in the ND and in particular the FD. While it is clearly desirable to be able to avoid the need for an accumulator, it should be checked that this would be compatible with the required physics performance before further investigating alternatives to the magnetic horn technology which has been adopted by all conventional neutrino beams thus far.

The initial baseline parameters of the whole experiment are as provided in deliverable D1.2.
The magnetic horn hadron collector together with an accumulator ring remain the main option for ESSνSB. As far as the backgrounds are concerned, they will be more important for the ND than for the FD, due to higher exposition to cosmic rays. Since during 96% of the time the experiment will be working without a beam, the background can be precisely measured. If the alternative hadron collider option proves promising, more studies on the question of backgrounds should be done with the assistance from WP5 and WP6.

2) It is necessary to understand the consequences of the proposed accumulator bunch structure on the beam in general and in particular:

a) Horn system power supply: Since the current switched PSU baseline does not appear feasible for the current accumulator design, we would recommend that the team budget for four separate PSUs. Although this would clearly have cost implications it could nevertheless be technically easier than switching pulses between the horns.



EUROnu : 3.33 MEuros

ESSνSB Option A : 5 MEuros

ESSνSB Option (B or C) : 3.46 MEuros

b) Switchyard magnet and PSU: No comment was made about the switchyard magnet or its power supply required to switch the beam between the horns. This would be considerably more challenging than that proposed for the SPL-based Super Beam. An assessment should be made of the feasibility to switch between the horns with the required beam stability within the pulse separation envisaged for the baseline accumulator design.

The study of the switchyard is part of WP3. Since this subject is of common interest to WP3 and WP4, during the present annual meeting a presentation on the status of the switchyard will be made in a joint WP2+WP3+WP4 session.

3) We would recommend improving technical coordination both within this WP and between the other work packages so that better informed joint decisions can be made with regard to technical difficulty, cost and performance of the different technical choices and so that resources can be directed to where they would be most effective.
In order to improve technical coordination, a mid-term meeting between WP2+WP3+WP4 took place at ESS, to review the work. The possible solutions for the power supply of the four horn system were discussed during this workshop. Moreover, several presentations by the ESS people have clarified some safety issues as well as the implementation of the Target Station on the ESS site.

4) No mention was made regarding beam alignment, either with regard to the precision required for the ND or FD, and if important how it could be done e.g. whether this could be done on-line and distinguish between the 4 target & horns or whether it could only be done offline, or by mechanical alignment or optical fiducial surveys only.
The beam alignment for the target station based on a four-horn system will require specific features, to ensure the correct positioning of the proton beam with respect to the target, but also the relative position of the four horns. This alignment must also take into account the position of the far detector.
The concept of the alignment survey system is not defined at the present time. Due to high radiation levels, an optical method similar to that used in the T2K experiment could be a possible solution, and it can be considered.

5) At some point in the project and in order to inform technical choices a failure modes effects analysis should be carried out.

The definition of the failure modes requires careful study. Some failure analysis has started with respect to the horn and it is planned for the other elements of the target station. This is a continuous process, which is being studied within the framework of safety.

6) Develop a plan on tritium handling based on Swedish regulations, i.e. containment, dilution, venting etc.

The elaboration of tritium treatment requires regular civil engineering feedback, in order to comply with the Swedish regulations. The handling capacity will depend on the amount of tritium produced in the whole facility under operating conditions. This subject was discussed with ESS safety experts during the midterm meeting in Lund. The strategy to be used by ESSνSB will be based on the procedures implemented for the ESS neutron target station facility.

7) Suggest in the first instance that efforts are focused on what it is necessary to do that is different to the EUROnu study, e.g. the consequences of a lower energy, higher current beam with a different bunch structure. Try to focus on the fundamental issues before more detailed component studies are carried out.

The the target station will use 2.5 GeV proton beam energy, with a beam pulsed at 14 Hz. The ESSνSB project will use a higher proton beam power of 5 MW (4 MW for EUROnu), with a lower beam frequency 14 Hz (50 Hz for EUROnu). The magnetic horn performance for these new parameters is being checked. The target will be subjected to more severe working conditions, and its performance using the packed-bed concept has to be re-evaluated. The power supply unit needs careful reconsideration.

In addition, the IAP pointed out in finding 3 that the „ **Thermal and dynamics studies of the effects of the pulsed beam on the target granules are still rudimentary".**

Answer: The design of the target is part of the integration task, which comes later on during the project. A postdoc has been recruited within WP4, whose main task is to make target cooling calculations. New results in this direction have been obtained since the last meeting, and they will be presented during the present meeting.

Thank you