CERN Neutrino beams
CERN Neutrino platform

23th June, 2014

APPEC, International Meeting for Large Neutrino Infrastructures (IMLNI)

M.Nessi

… CERN and Europe long history of Neutrino Physics : last on the long series of neutrino facilities the CNGS

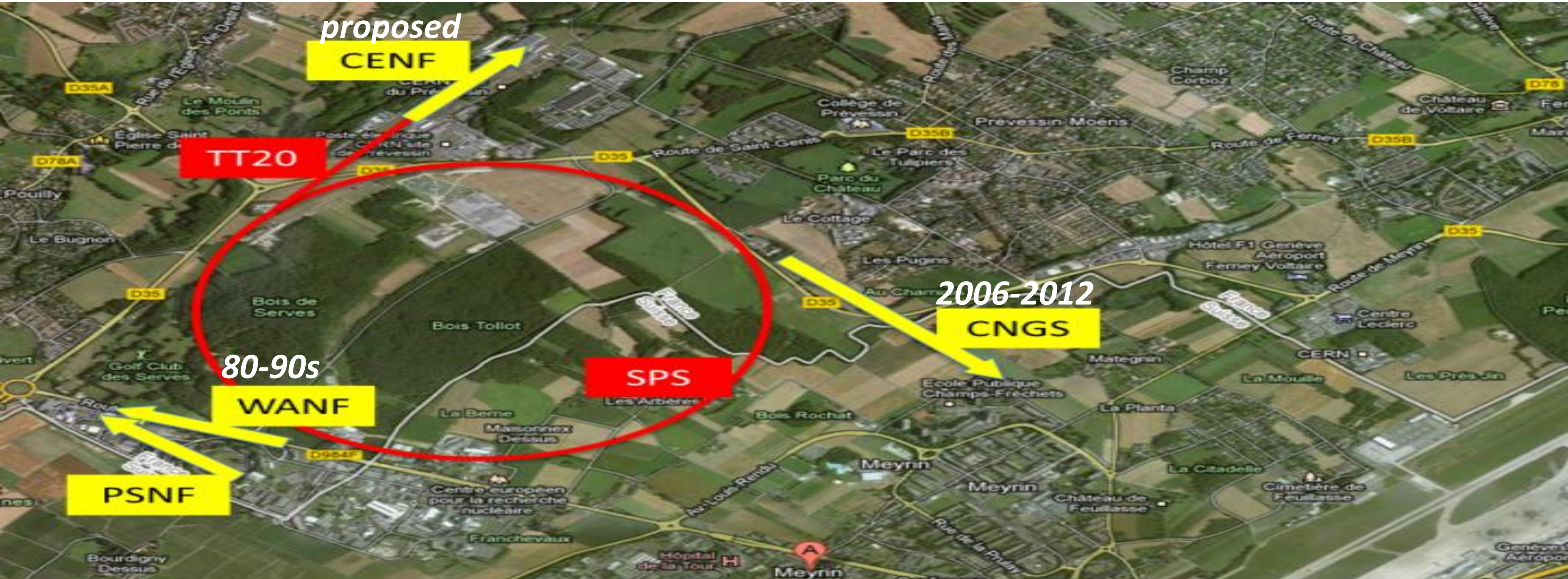
- **Short Baseline Neutrino physics and infrastructure**
- **Long Baseline Neutrino physics and infrastructure**
- **Generic R&D on future Neutrino technologies (detectors, beams, ..)**

… the agreed 2013 European Strategy : *"Rapid progress in neutrino oscillation physics, with significant European involvement, has established a strong scientific case for a long-baseline neutrino programme exploring CP violation and the mass hierarchy in the neutrino sector. CERN should develop a neutrino program to* ***pave the way*** *for a substantial European role in future long-baseline experiments. Europe should explore the possibility of major participation in leading long-baseline neutrino projects in the US and Japan."*

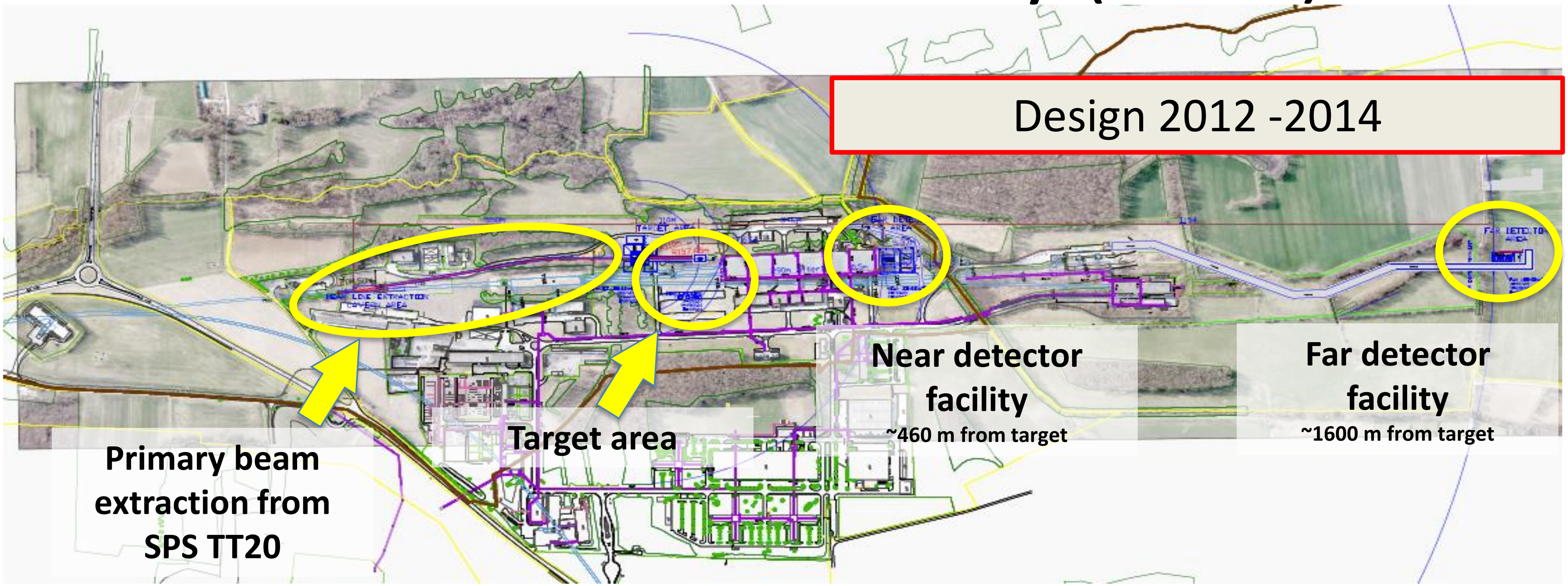
Short Baseline

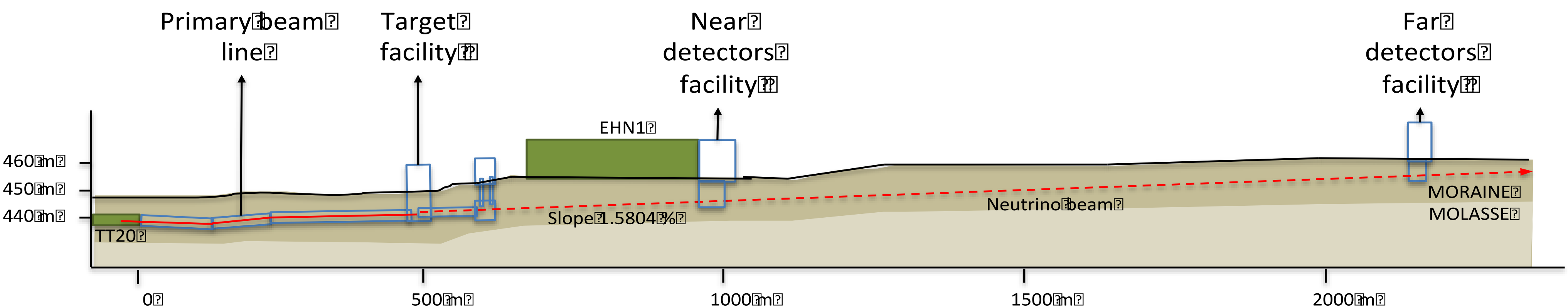
Triggered by:

- Sterile neutrino searches (ICARUS and NESSiE proposal)
- Test facility for new technologies (2 phases LAr TPC LAGUNA proposal, MIND detector, ….)



CERN Neutrino Facility (CENF)

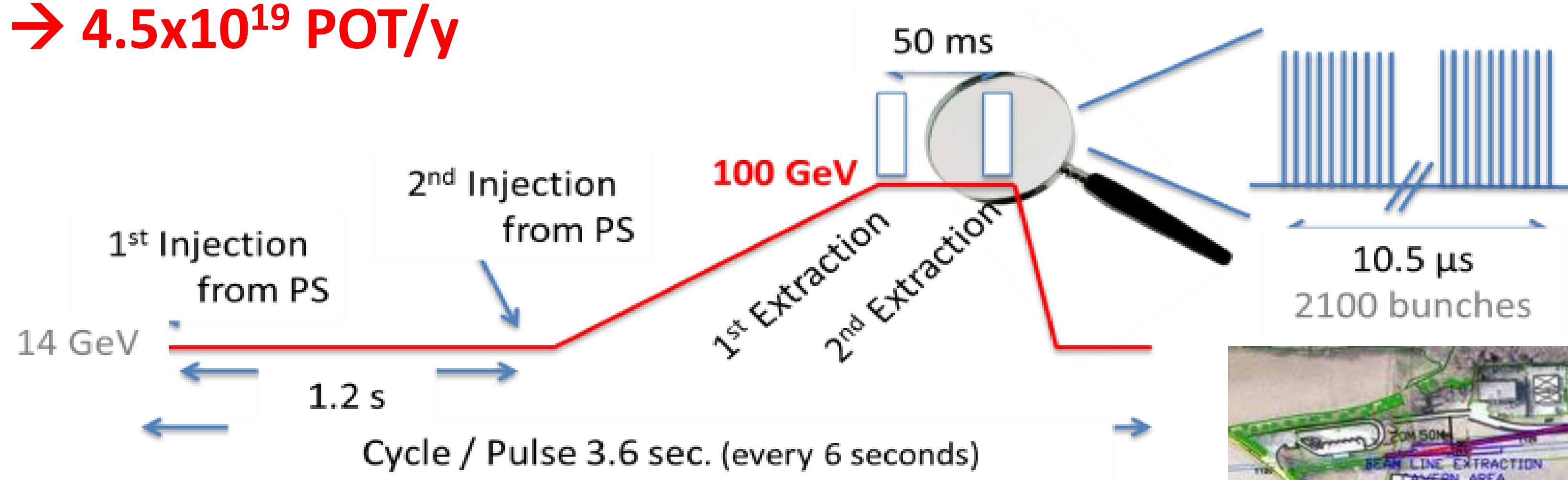




CENF : Primary p-beam characteristics

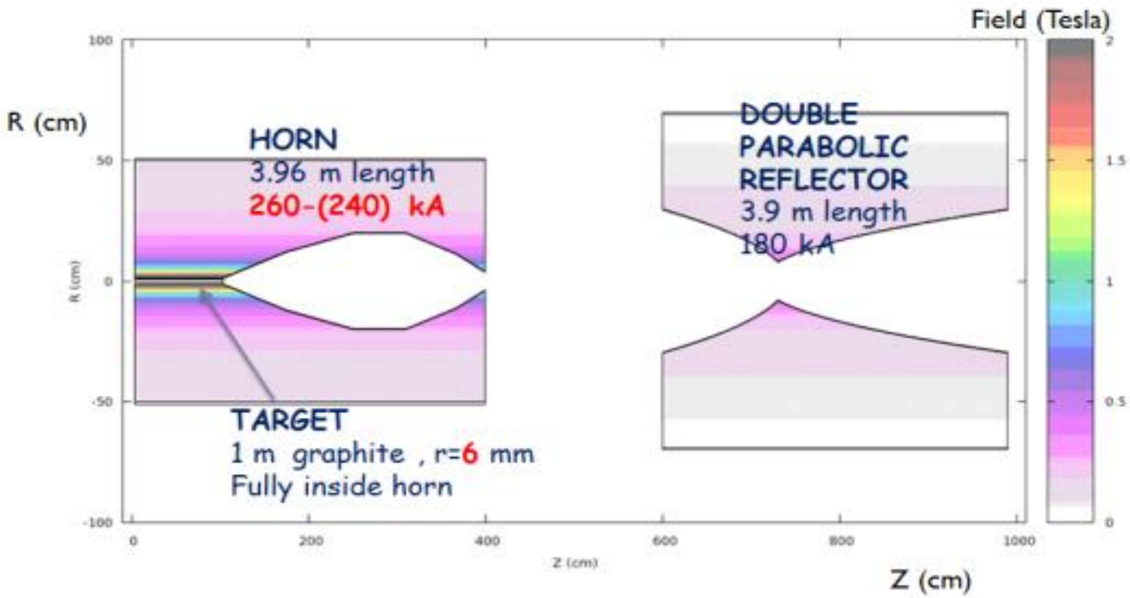
- Beam time structure similar to CNGS
- Primary beam momentum **100 GeV/c**
- Fast extraction: beam excitation via injection kicker in LSS1 and extraction in LSS2
- Novel solution tested for low intensities during recent beam tests
- ~720 kJ/pulse → ~200 kW on target

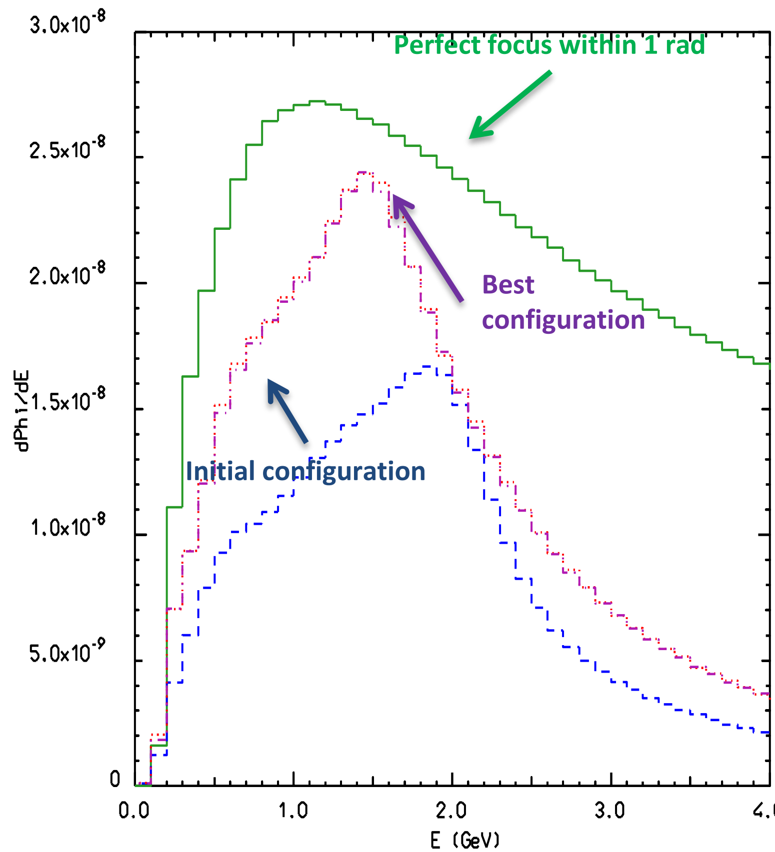
→ 4.5×10^{19} POT/y



CENF: Neutrino beam optimisation

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





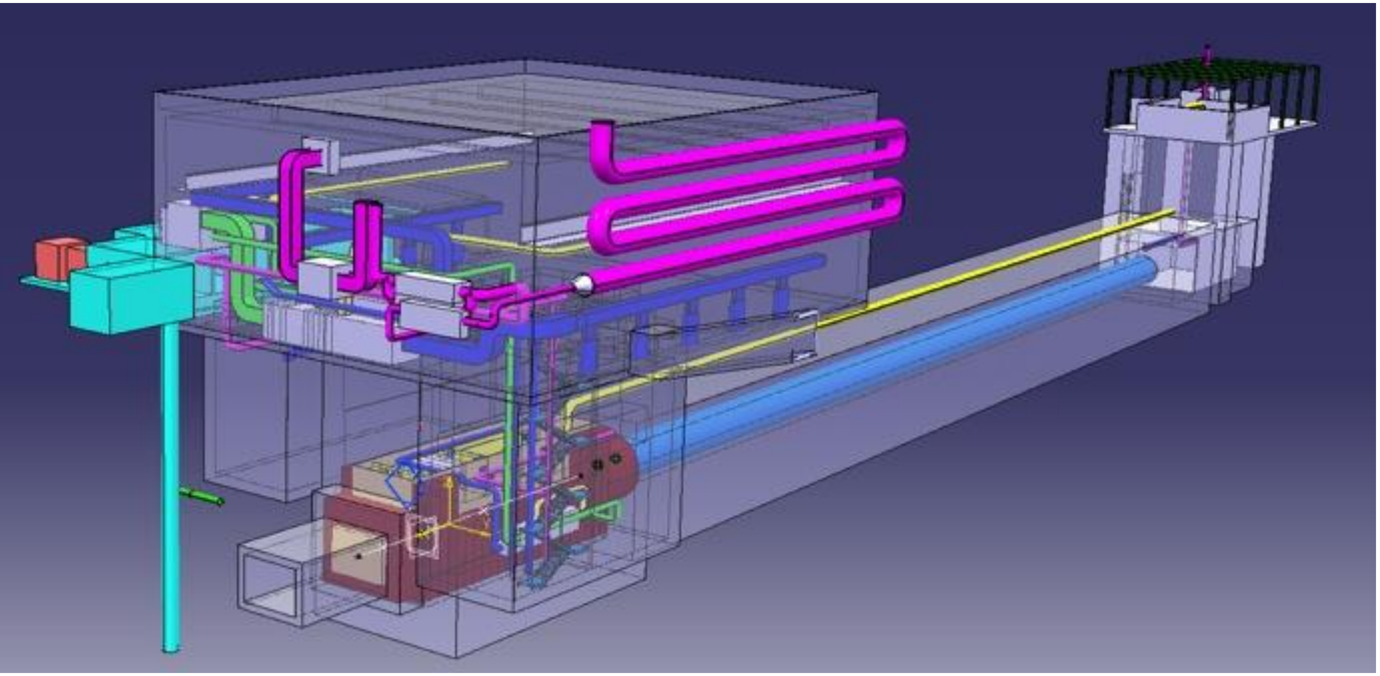
- Far detector: ~1M ν_μ /y

Rates for 1-year (4.5 10^{19} pot), 1kt, E<5 GeV

	neutrino mode		antineutrino mode	
	Far detector (1600m)	Near det (500m)	Far detector (1600m)	Near det (500m)
ν_μ CC	2.0×10^6	2.3×10^7	1.9×10^5	2.1×10^6
$\bar{\nu}_\mu$ CC	5.5×10^4	5.9×10^5	5.6×10^5	6.1×10^6
ν_e CC	1.2×10^4	1.4×10^5	3.0×10^3	3.4×10^4
$\bar{\nu}_e$ CC	8.9×10^2	1.0×10^4	3.4×10^3	3.8×10^4

Large event statistics at both positions will allow a systematic study of ν_μ **and** ν_e topologies, both in neutrino and antineutrino mode !!

CENF : Neutrino Beam



Secondary beam (target, decay pipe,…) engineering design very advance and will be finalised by the end of 2014, ready for a future eventual implementation if requested!

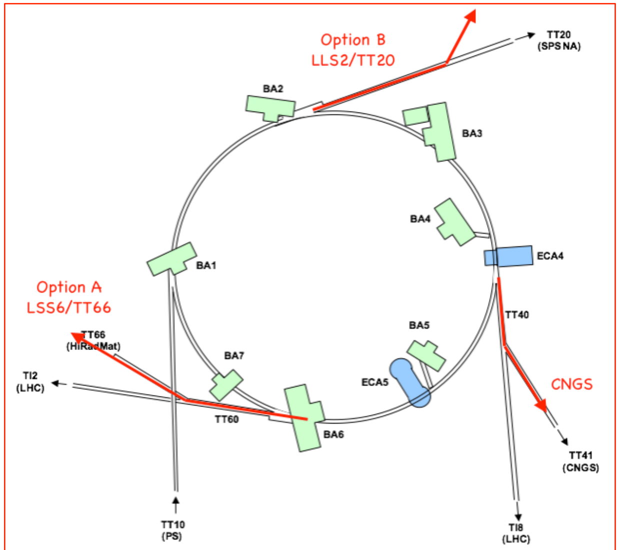
1) An LOI for a CENF short baseline was presented in March 2013 to the CERN directorate
2) Cost of the Facility estimated to ~70 MEuro
3) This generated a lot of discussion inside the community and inside CERN

4) Decision taken **not** to implement it now as a Short Baseline Neutrino facility at CERN
5) But decision to bring all implementation studies to maturity, ready for an eventual implementation
6) Interest for short baseline moved to the US- FNAL neutrino facilities
7) **Implement the near detector facility as an R&D platform with charged beams possibilities**

LBNO Long Baseline

Triggered by:

- the LBNO EU FP7 design study for a ν beam pointing to Finland



CERN Neutrinos 2 PYhasalmi beam

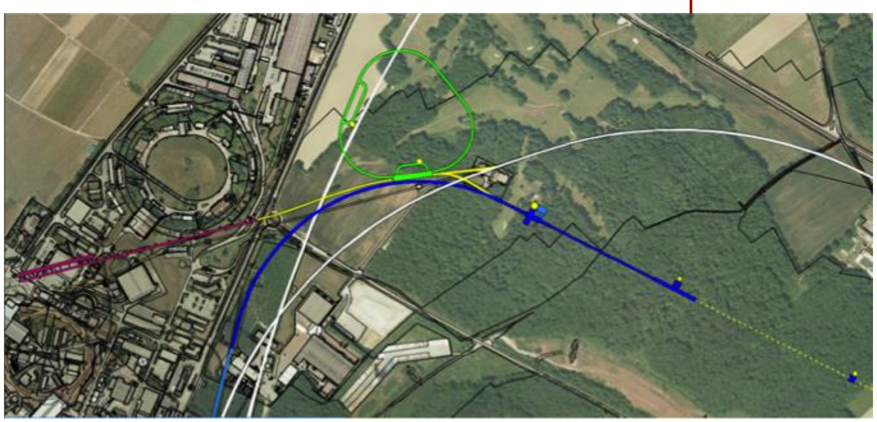
- Phase 1 : proton beam extracted beam from SPS
  - -400 GeV, max 7.0 10^{13} protons every 6 sec, ~750 kW nominal beam power, 10 μs pulse
- Phase 2 : use the proton beam from a new HP-PS
  - -50(75) GeV, 1 Hz, 2.5 10^{14} ppp, 2 MW nominal beam power, 4 μs pulse
  - -alternative option: upgraded SPS

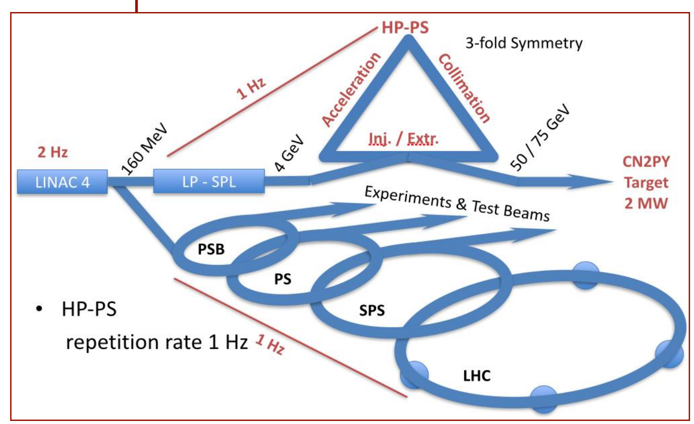
SPS Extraction

The CN2PY ν-beam

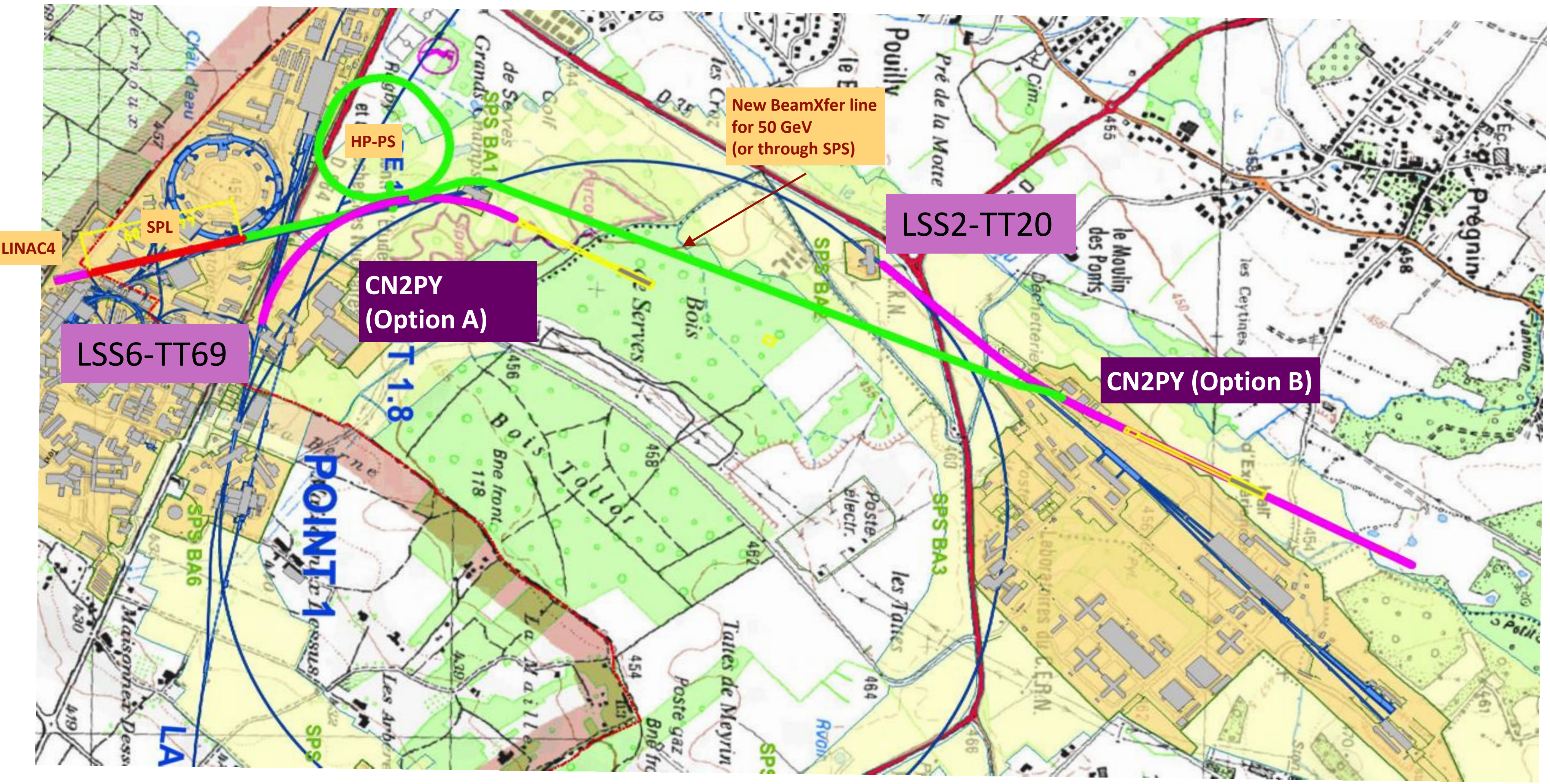
ν-beam

HP-PS

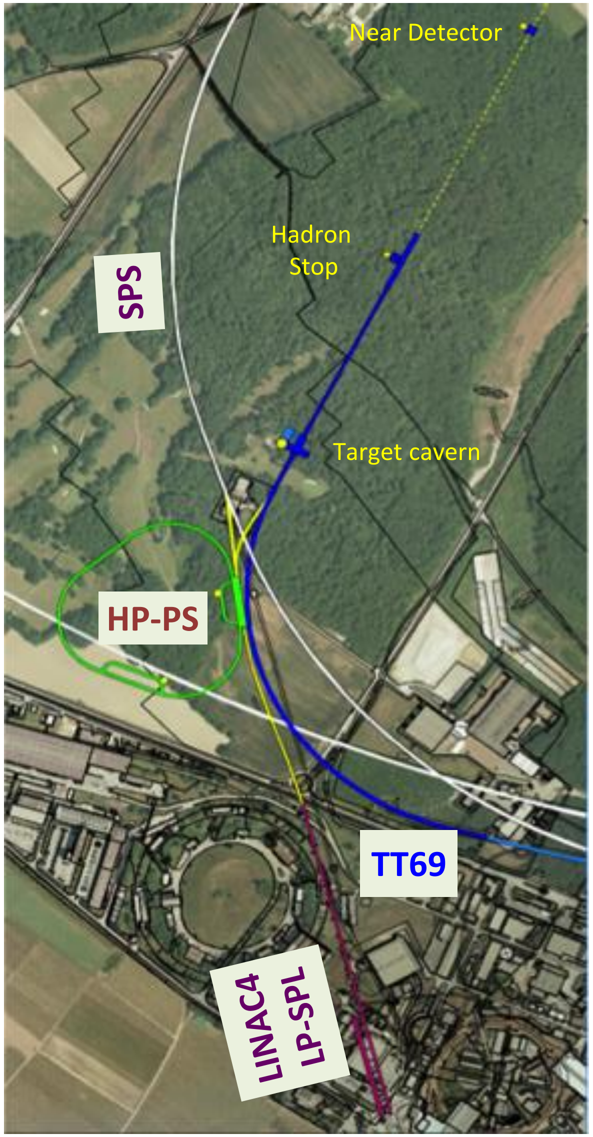




LBNO - CN2PY Layout Options (two)

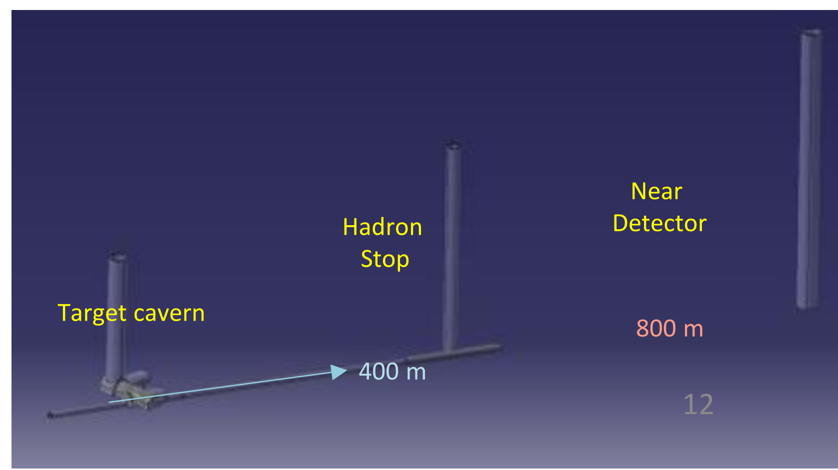


LBNO - CN2PY Layout Option A

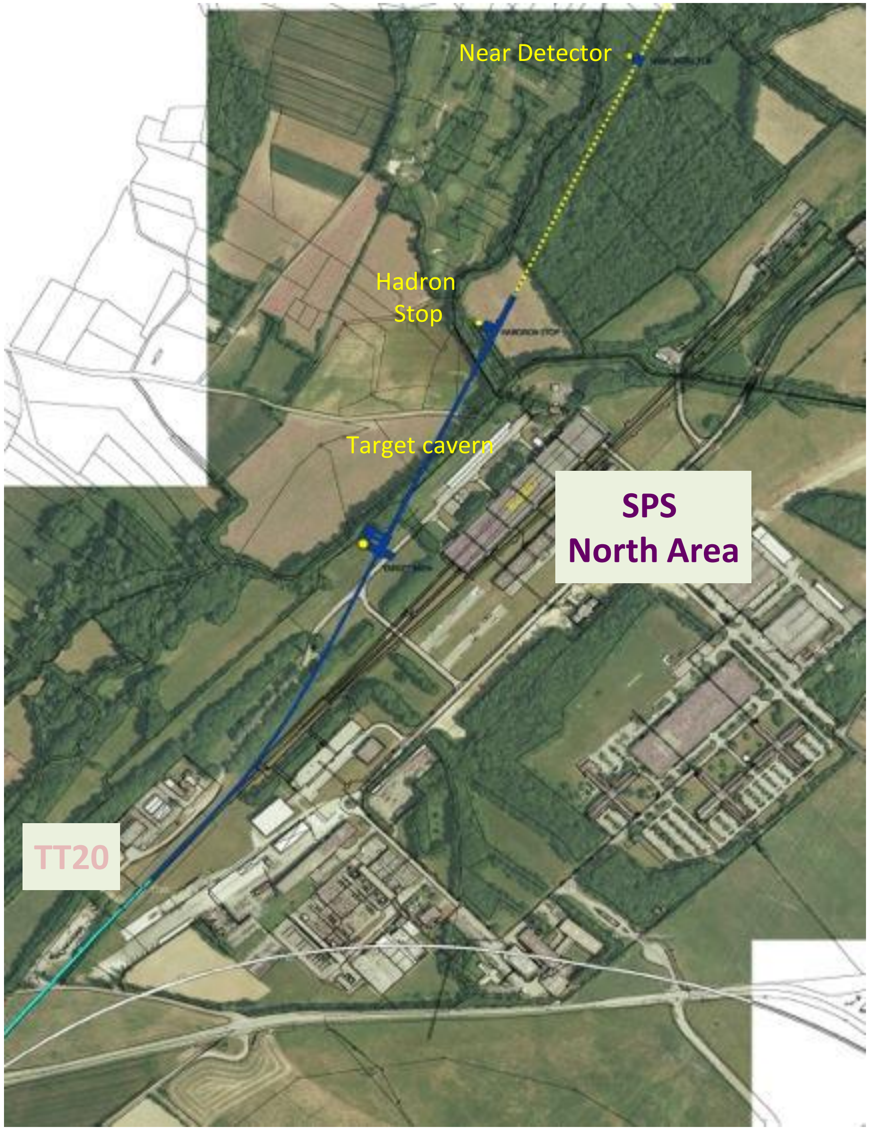


- **New TT69 beam line**
  - continued from existing TT66 beamline (HiRadMat)
    - will eventually require a switch between TT66 and TT69, with a lateral displacement of TT66 for HiRadMat
  - FODO arc with 35 m half-cell length, 6 dipoles per half-cell
- Superconducting dipoles assumed for the TT69 arc
  - 4.0 m long magnetic, 4.6 T field
  - 13.85 mrad bend angle per dipole, 6.9 mm sagitta
  - H/V aperture of ~40 mm (good field region)

CN2PY	Depth
Target Cavern	-117 m
Hadron Stop	-189 m
Near Detector	-262 m

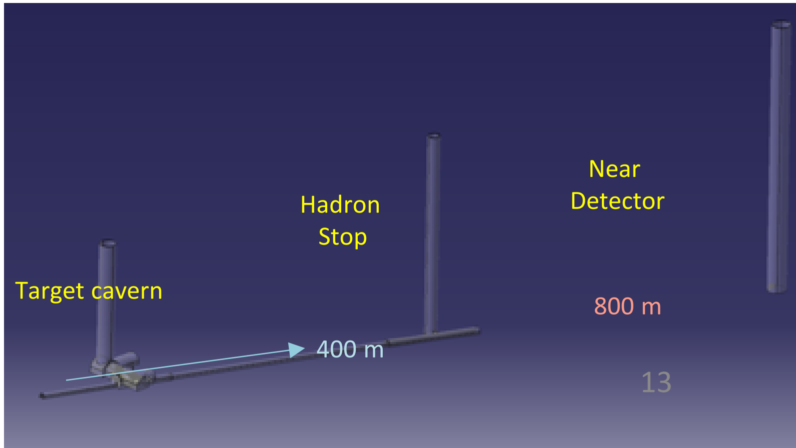


LBNO - CN2PY Layout Option B



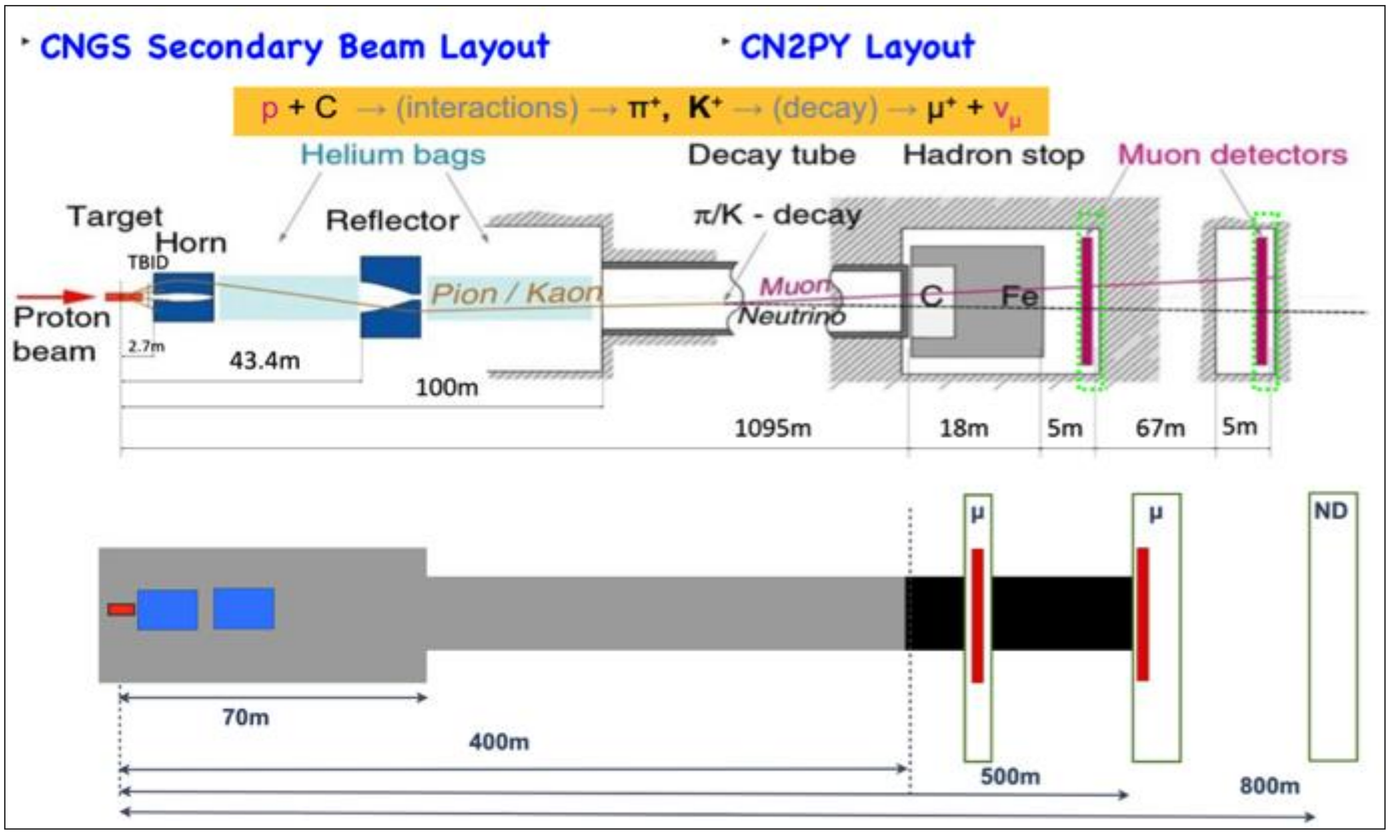
- **SPS Operation @ 400 GeV**
  - **New extraction switch upstream the NA targets**
    - continued from existing TT20 beamline
    - NC dipoles similar to CNGS
- **HP-PS Operation @ 50 MeV**
  - HP-PS remains close to Meyrin site
    - Remain closer to LP-SPL with the possibility to inject into SPS
  - New transfer line or passage through SPS to bring the beam to NA
- ν-beam layout same in both cases

CN2PY	Depth
Target Cavern	-117 m
Hadron Stop	-189 m
Near Detector	-262 m

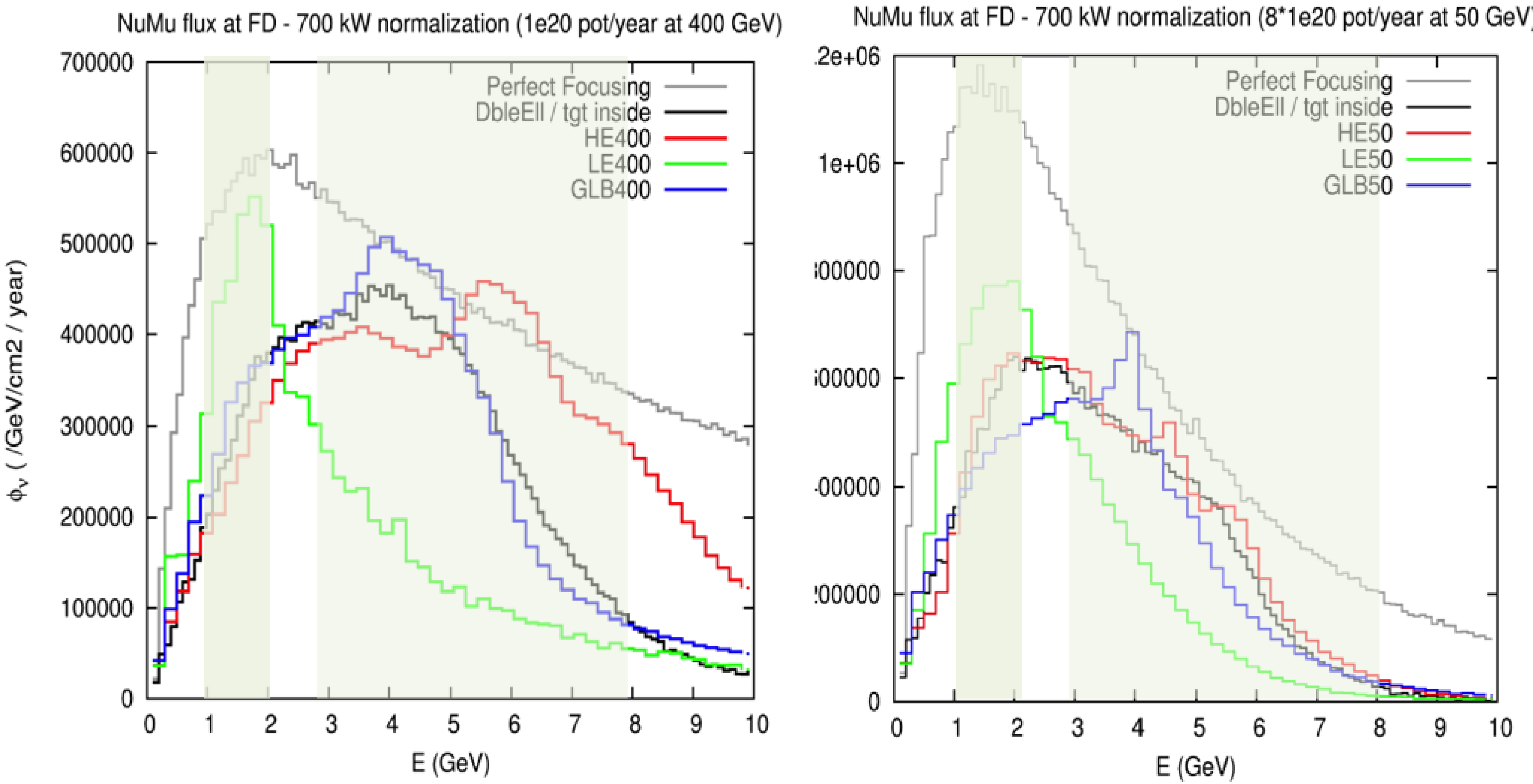


LBNO - CN2PY ν-beam design

- Conventional neutrino beam
- Constraints/challenges:
  - have the same layout for 400 & 50 GeV beams
  - control or radiation environment (2 MW beam power !)
  - ν-flux optimisation for both oscillation prob. maxima
  - **steep slope of 18%**
- Additional considerations
  - The length of the hadron stop and near detector location determined by the μ flux limit requirement for the 400 GeV case (< 9 μ/m²/spill)
  - Additional μ flux monitoring stations must be foreseen for the 50 GeV operation



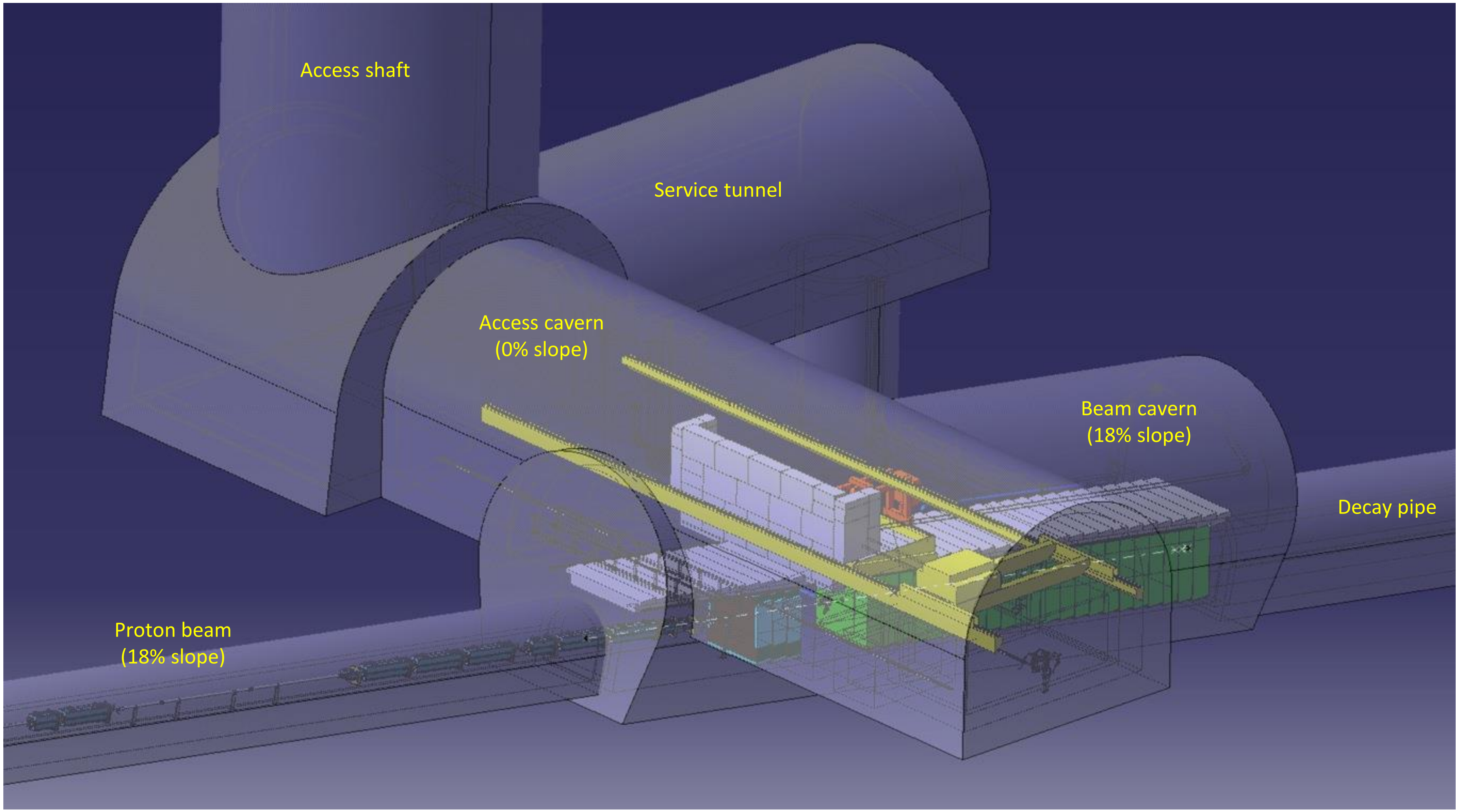
LBNO - CN2PY ν-beam optimisation



Optimisation regions: [1-2], [3-8] GeV regions corresponding to 1st and 2nd maximum of oscillaiton probability

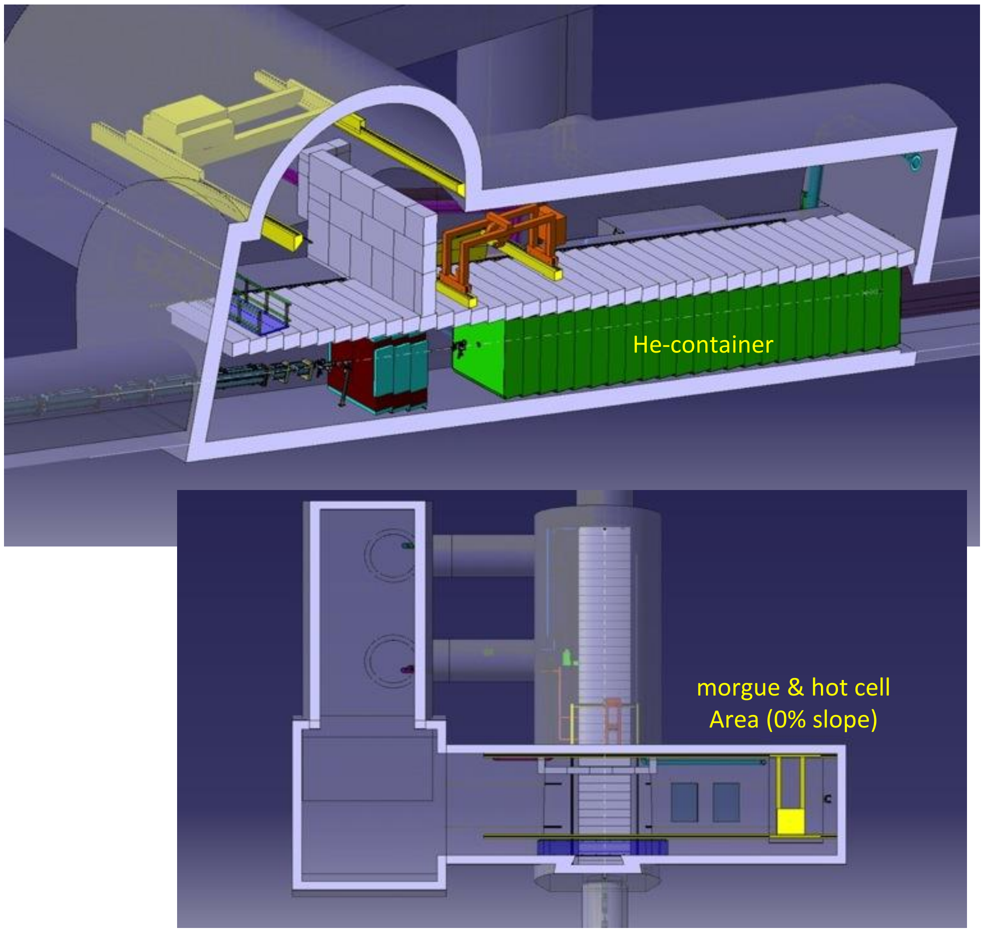
LBNO - CN2PY ν-beam design

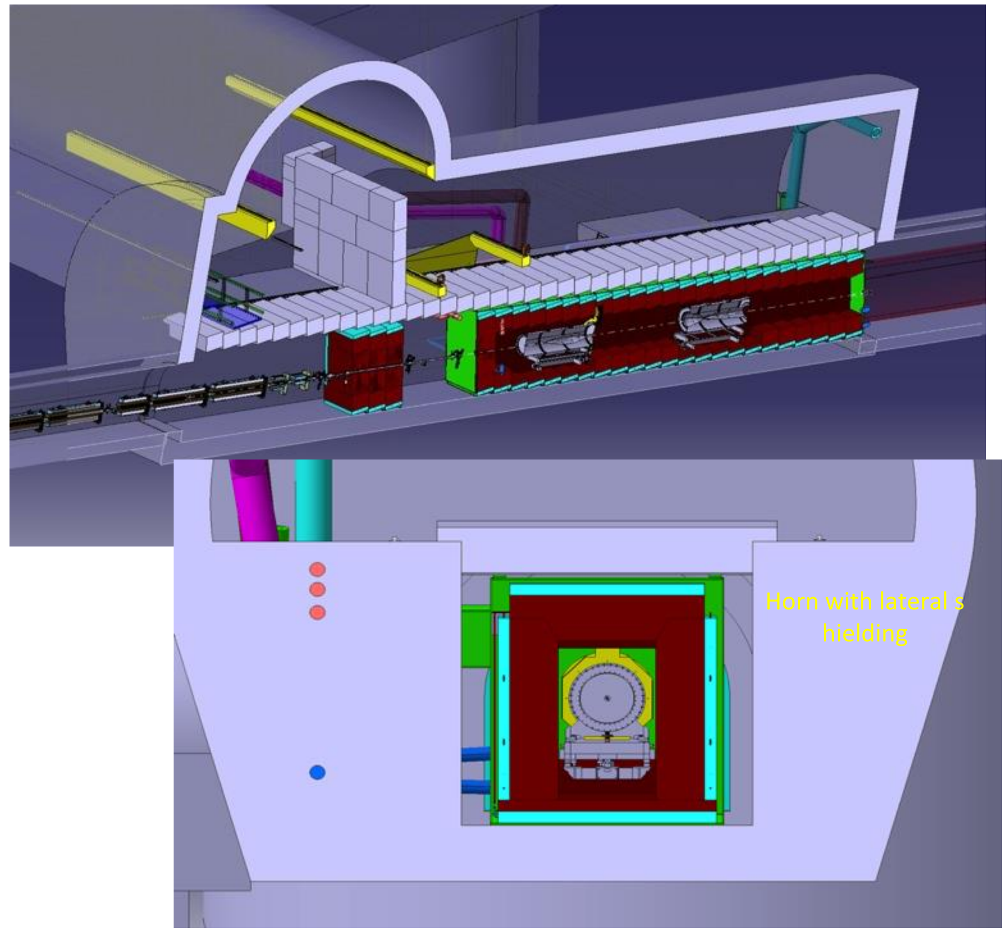
- Key challenge : manage the slope, whilst maintaining reasonable tunnel sizes for optimized cost and operation at high-power.



LBNO - CN2PY ν-beam design

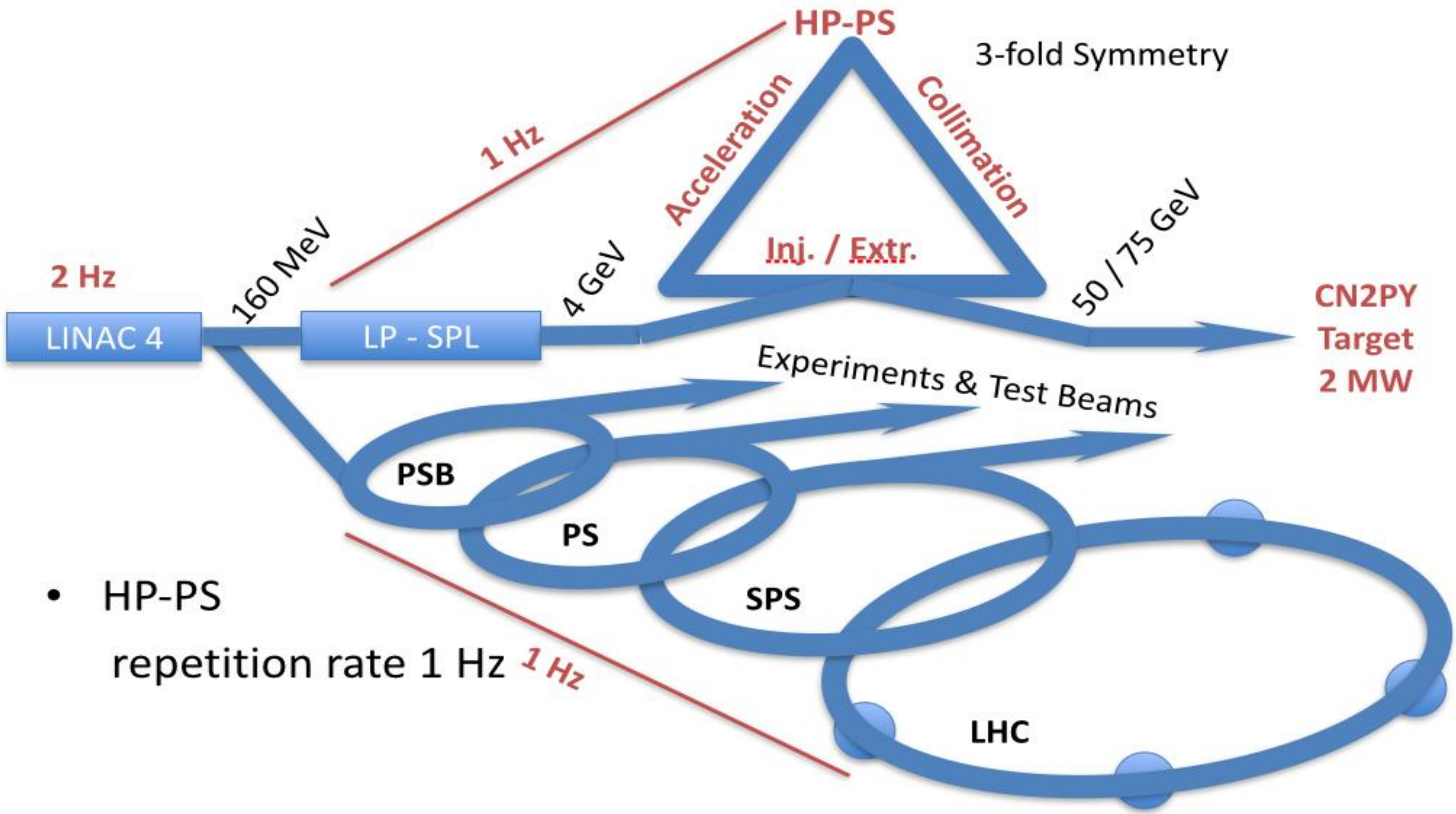
- ν-beam elements in He container to minimize the production of radioactive elements and limit corrosion effects
- Water cooled shielding blocks, remote handling of all equipment





CN2PY Phase 2: HP-PS Design

- Possible accelerator landscape including the new HP-PS

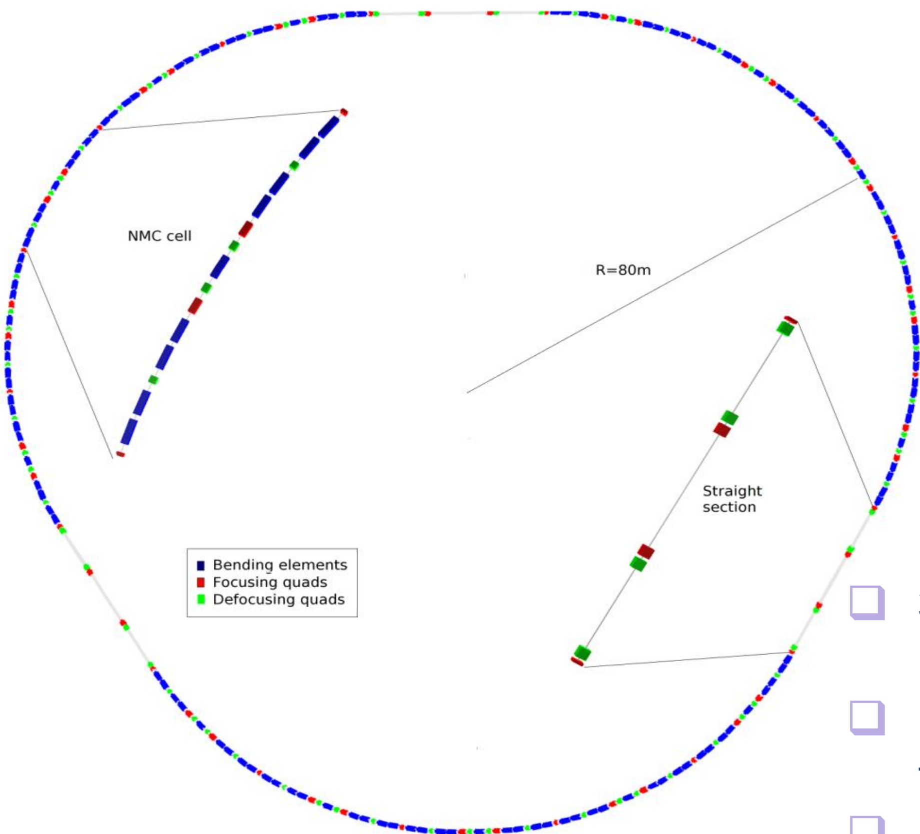


- HP-PS

  repetition rate 1 Hz

LAGUNA-LBNO: HP-PS main characteristics

Based on PS2 design



Parameter	PS2 (ref.)	HP-PS
Circumference [m]	1346.4	1174
Symmetry	2-fold	3-fold
Beam Power [MW]	0.37	2
Repetion Rate [Hz]	0.42	1
Kinetic Energy @ ext. [GeV]	50	50/75
Protons/pulse [10^{14}]	1.1	2.5/1.7

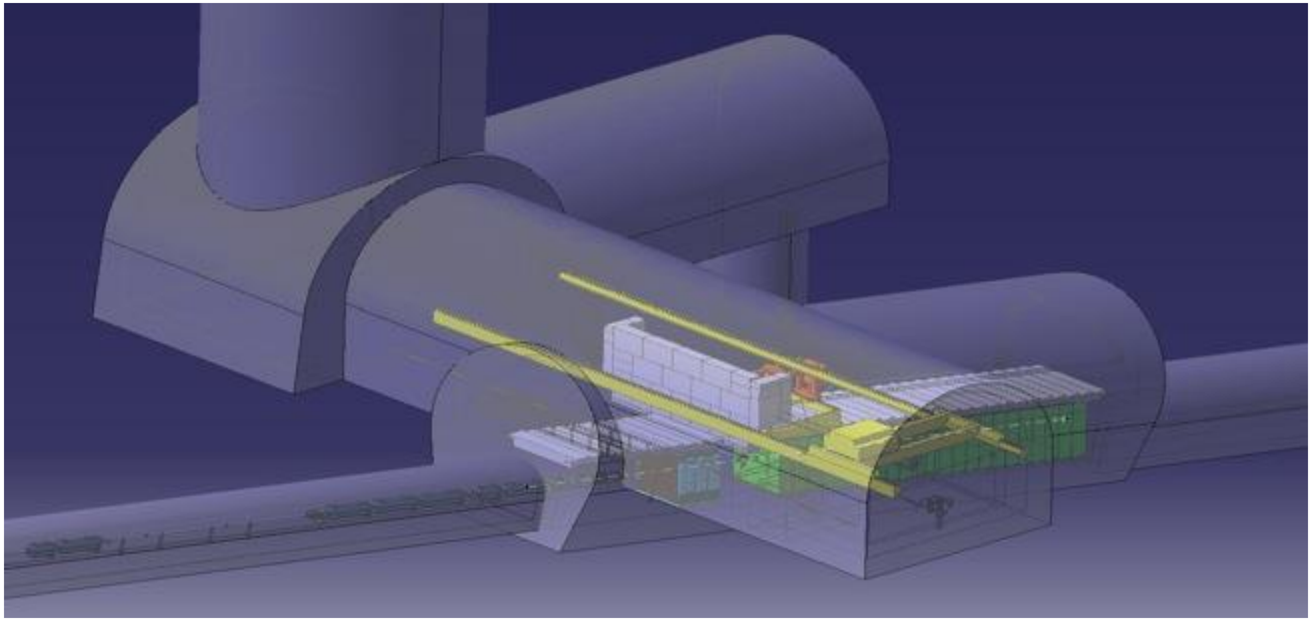
- **3-fold symmetric** ring with transfer, collimation and RF in separate long straight sections
- **Negative Momentum Compaction (NMC) arc cell** to avoid transition
- **Doublet Long Straight Section (LSS)** giving space for BT equipment, collimation and RF

See R.Garoby @ICFA neutrino https://indico.in2p3.fr/conferenceOtherViews.py?view=standard&confId=8974

HP-PS Parameters

HP-PS Parameter	50 GeV	75 GeV	Units
Inj. / Extr. Kinetic Energy	4 / 50	4 / 75	[GeV]
Beam power	2		[MW]
Repetition rate	1		[Hz]
f_{rev} / f_{RF} @ inj.	0.234 / 39.31		[MHz]
RF harmonic	168		-
f_{rev} / f_{RF} @ extr.	0.238 / 40.08	0.238 / 40.08	[MHz]
Bunch spacing @ extr.	25		[ns]
Total beam intensity	**2.5 E14**	1.7 E14	-
Number of bunches	157		-
Intensity per bunch	1.6 E12	1.1 E12	-
Main dipole field inj. / extr.	0.19 / 2.1	0.19 / **3.13**	[T]
Ramp time	500	500	[ms]
Dipole field rate dB/dt (acc. ramp)	3.5	**5.5**	[T/s]

CN2PY : Neutrino Beam



1) All studies presented here are part of the LAGUNA-LBNO FP7 design study EU project with CERN participation in the beam work package (final report due in summer 2014)
2) Cost of the beam Facility not yet estimated, as well as the infrastructure cost of the near detector facility (@ -262 m)

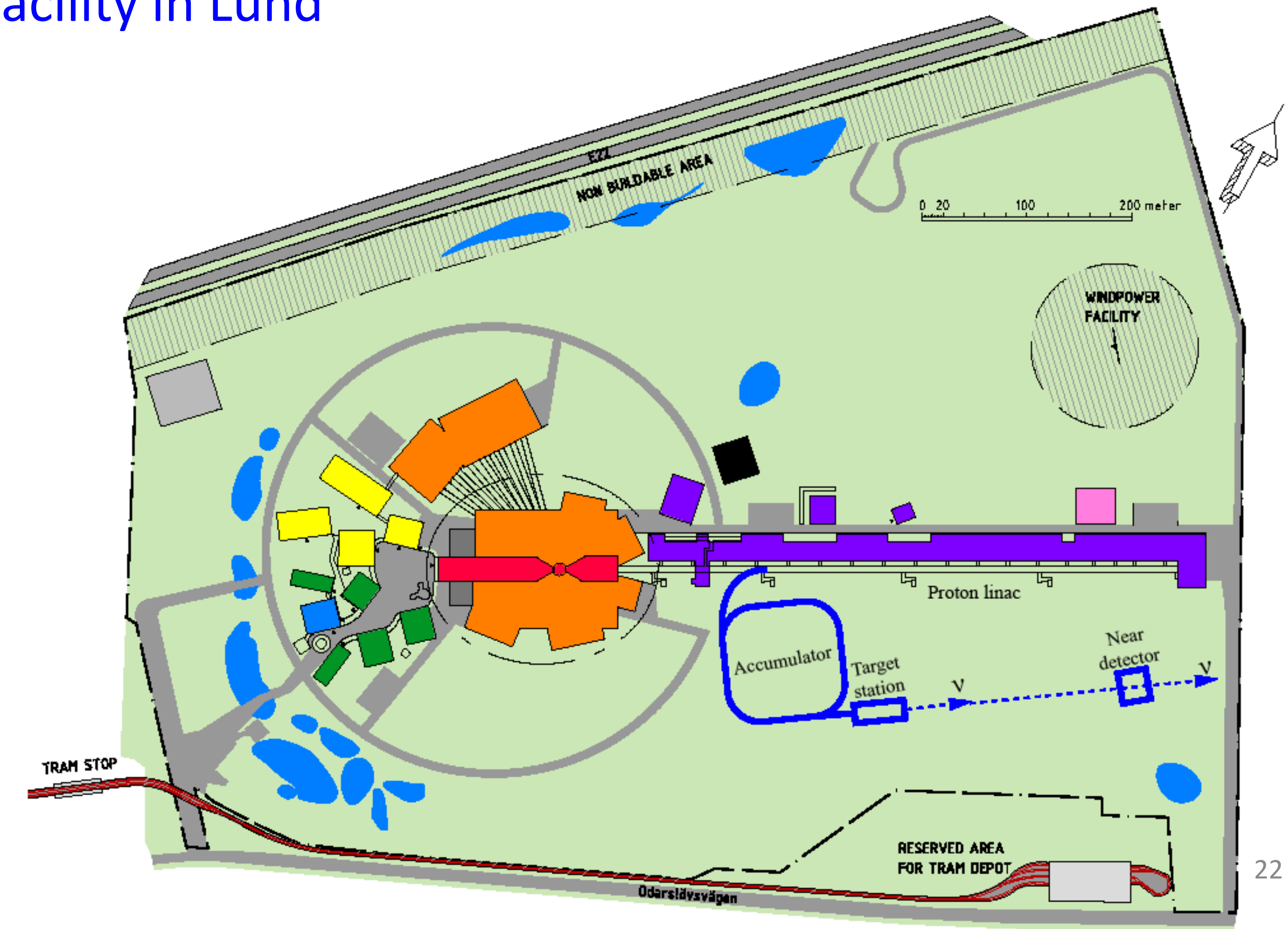
3) This beam and its infrastructure is for the moment not part of the medium term plan of CERN

ESS Long Baseline

Triggered by:

- recent idea (design study group just forming) for a superbeam at the ESS new facility in Lund

Doubling pulse frequency → 10 MW of which 5 MW for neutrino beam



ESS Long Baseline

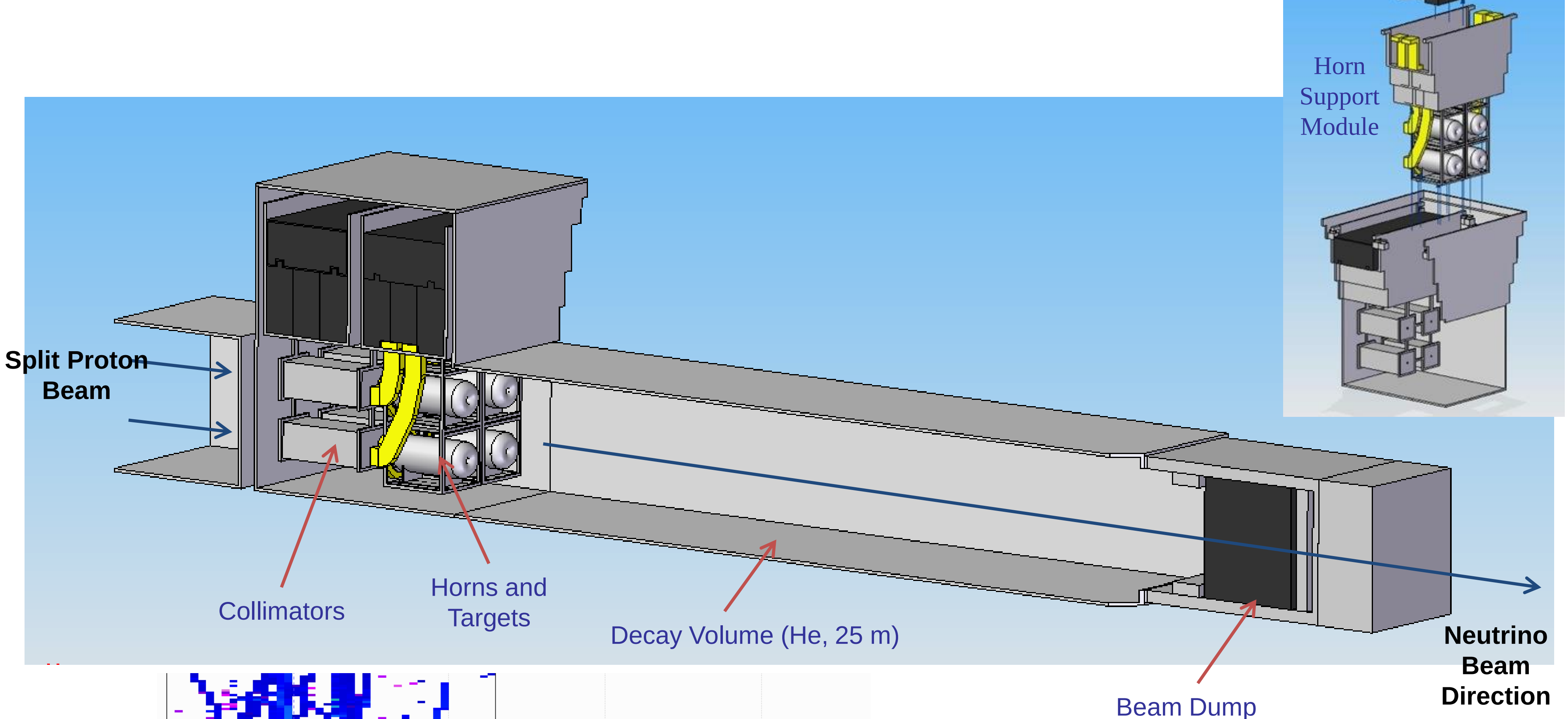
Triggered by:

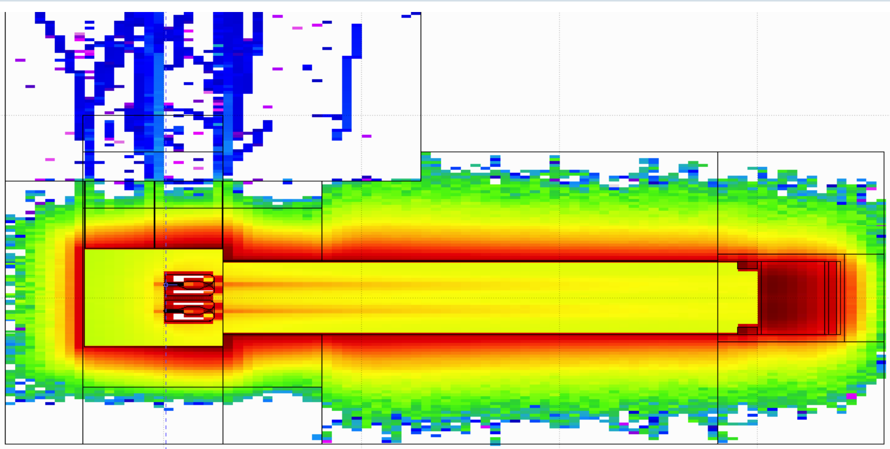
- recent idea (design study group just forming) for a superbeam at the ESS new facility in Lund

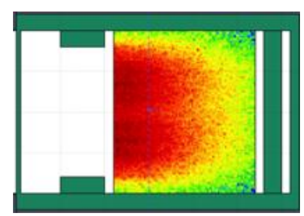
- The ESS will be a copious source of spallation neutrons
- 5 MW average beam power in the linac
- 125 MW peak power
- 14 Hz repetition rate (2.86 ms pulse duration, 10^{15} protons) → **28 Hz**
- 4% duty cycle
- 2.0 GeV protons (up to 3.5 GeV with linac upgrades) → **ν ~ 300 MeV**
- **>2.7x10^{23} p.o.t/year**

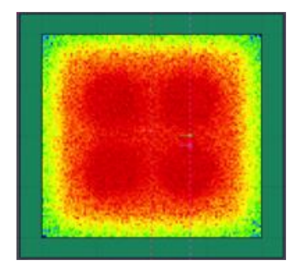
(http://lanl.arxiv.org/abs/1212.5048)

ESS ν production target









Given the still vague/evolving road map on long baseline ν activities in Europe, Japan and US

⇩

CERN adopted (pragmatical) position is to support, on the short term, generic R&D on ν detectors & beams and to support physics related to a ν short baseline (steriles, cross-sections, calibration, event reconstruction, ….). The goal is to assist and foster collaboration in Europe among the various ν institutions, independently where a Long and/or Short ν baseline(s) will be implemented

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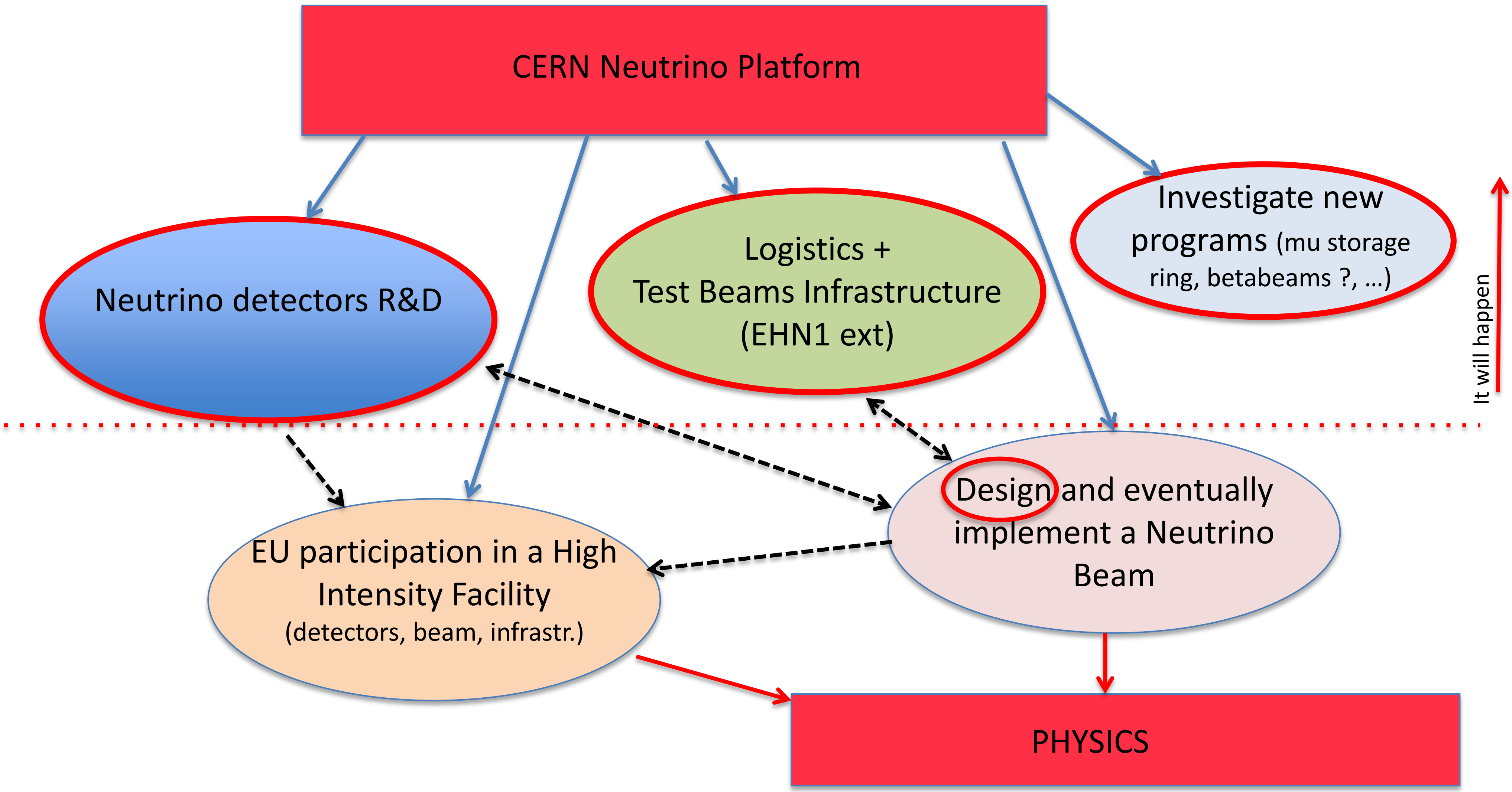
CERN Neutrino Platform

CERN Neutrino Platform

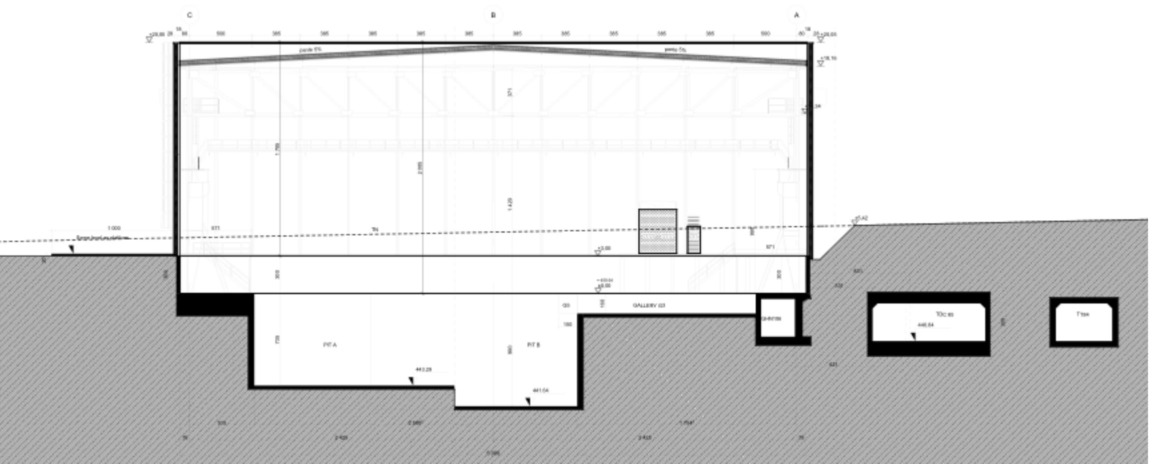


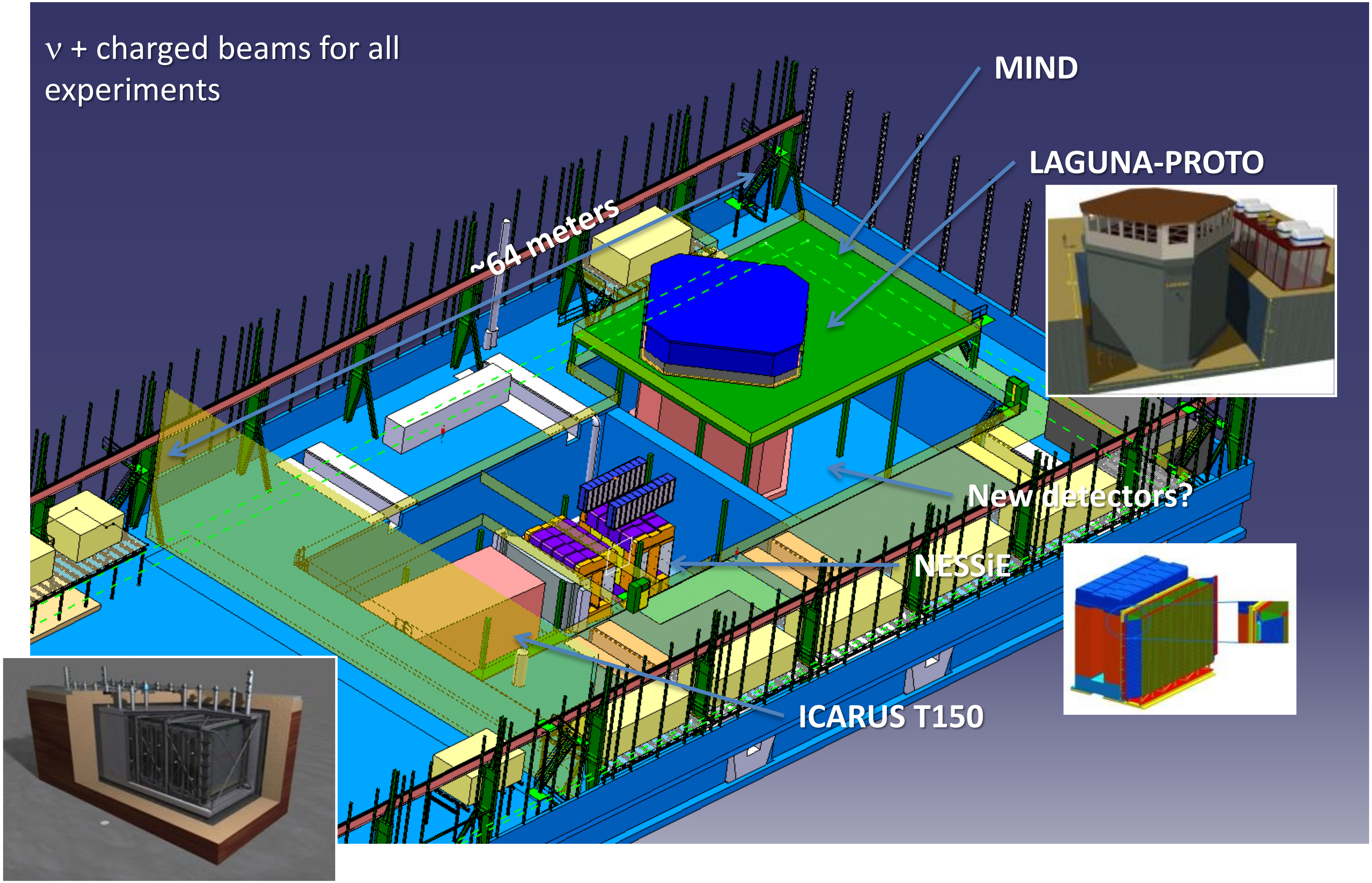
CERN council last week has decided to implement the proposed Medium Term Plan (MTP) which for the first time (since years) contains an important allocation of resources in the next 5 years dedicated to the Neutrino CERN Platform

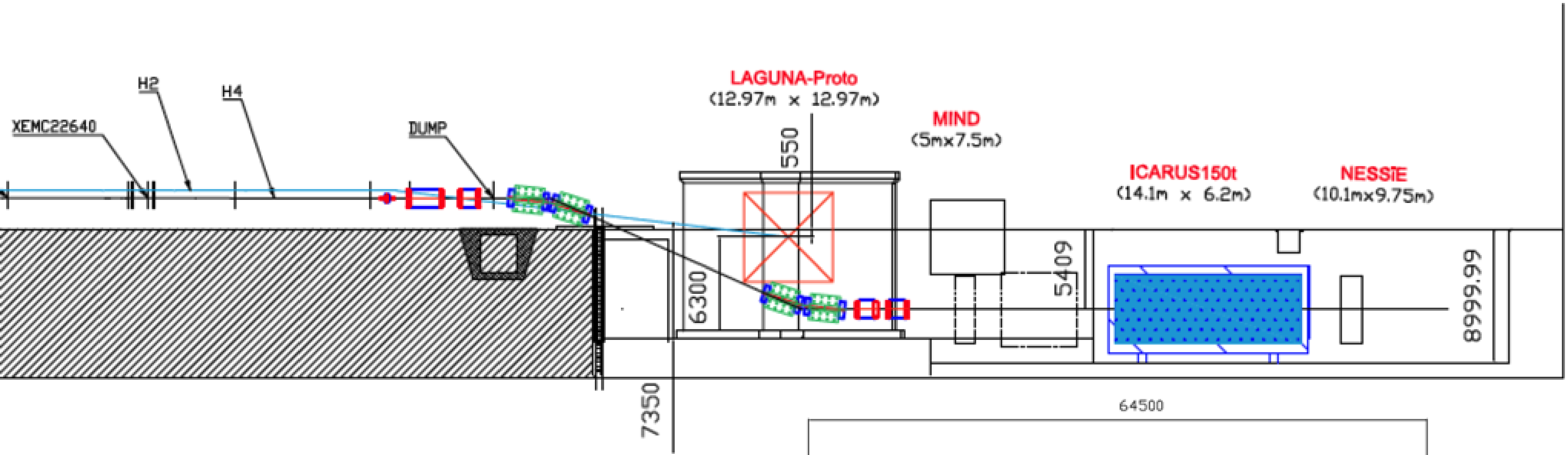
This will cover:

- Generic ν detector R&D including large prototypes
- Design and generic R&D on ν beams
- The construction of a new experimental hall dedicated to neutrinos (Nord Area extension : EHN1) with charged test beams capabilities
- The reinforcement of various Technical/Scientific groups at CERN (cryogenics, physics, ….) which will support the activities of the platform
- The support with detectors and components of the Short Baseline at FNAL
- Support to various design/feasibility studies on this field (nustorm, ESS beam, …..)

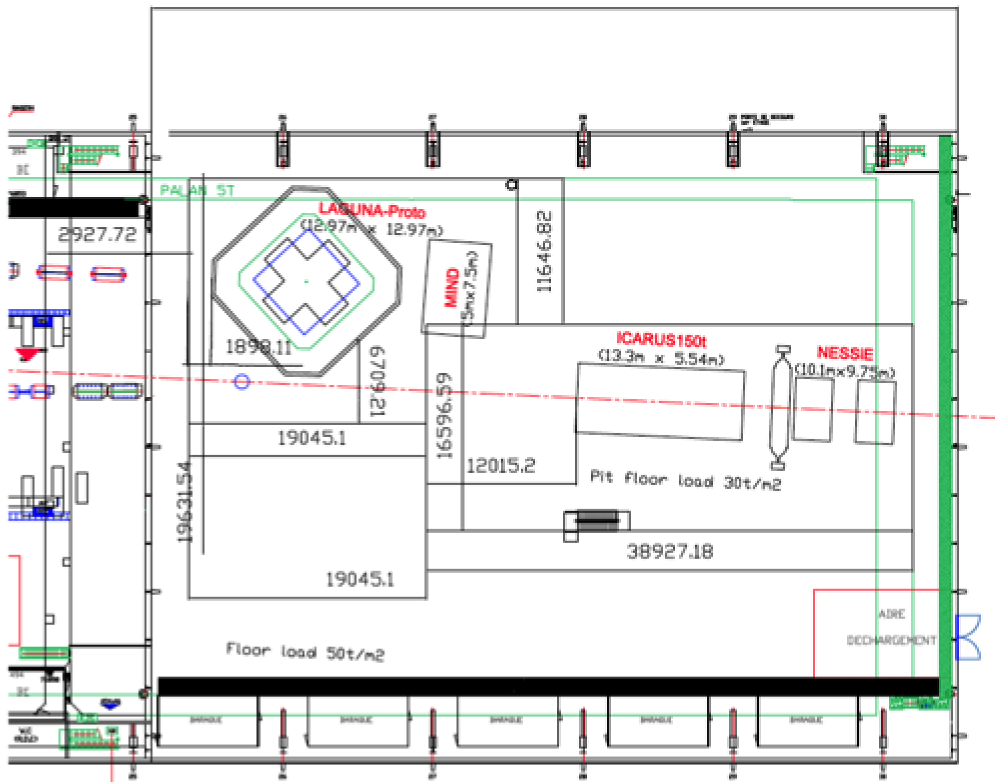
Nord Area EHN1 extension




ν + charged beams for all experiments
MIND
LAGUNA-PROTO
~64 meters
New detectors?
NESSiE
ICARUS T150



charged beams layout
(~0.5 – 20. GeV)



CERN Neutrino Platform

Neutrino detectors R&D

2014 -2018

Preparation of 5 MOUs addenda in progress

WA104: rebuild ICARUS T600 in bldg 185 and make it ready for a FNAL beam

WA104: R&D on an AIR core muon detector (NESSiE) or eventually integrate a solenoid in the main TPC

WA105: R&D on 2 phases large LAr TPC prototypes

MIND : R&D on muon tracking detectors

LBNF : Test of a LBNE module inside the WA105 cryostat

In the pipeline : Argoncube-TPC, Hyper-Kamiokande EU prototypes, new 200t TPC, ...

CERN Neutrino Platform

2014 -2018

Neutrino detectors R&D

MOUs preparation in progress

CERN direct contribution under evaluation:

- all logistics aspects (incl. various assembly buildings at CERN !85,182,..)
- cryostats (membrane and new ICARUS type)
- cryogenics
- cleanrooms, civil engineering
- services and utilities (CV, EL, Power Suppl., Cooling unit, gas, …)
- controls & DAQ
- magnets and B-fields
- integration and assembly
- host for visiting collaborators (PJAS, fellows, students, scientific associates,..)
- special studies (feasibilities, particular techniques, …)

MOU frame

Memorandum of Understanding

for providing a framework for developing a Neutrino Program at CERN

between

The EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH, an Intergovernmental Organization having its seat at Geneva, Switzerland, ('CERN,'), as the Host Laboratory,

on the one hand,

and

The FUNDING AGENCIES/INSTITUTIONS PARTICIPATING IN THE NEUTRINO PHYSICS RESEARCH PROJECTS AT CERN ('the Neutrino Institutions'),

on the other hand,

(collectively "the Parties")

Preamble

(a) As endorsed by the CERN Research Board at its meeting of August 28th, 2013 and detailed in Annex 1, CERN has decided to develop a Neutrino Program at CERN ('the Neutrino Program') to pave the way for a substantial European role in future Long-Baseline Experiments and explore the possibility of major participation of Europe in leading Long-baseline Neutrino Projects in the United States and Japan;

(b) The Neutrino Institutions, including possibly CERN, wish to collaborate in the research and development (R&D) and construction of prototypes, equipment and related infrastructure for the Neutrino Program and have obtained the support of their Funding Agencies to enable them to participate in the Neutrino Program;

How to get in?

- Present to the CERN SPSC a LOI or an expression of interest
- When approved we prepare together an MOU (addendum) which defines all responsibilities and resources needed
- Then a CERN experiment is created (WA104, WA105, …), with all priviledges and requirements

https://edms.cern.ch/document/1353815

5 MOUs are being prepared for signature

Addendum No. 01

to the
Memorandum of Understanding
for Collaboration in the Neutrino Program

WA104

Overhauling of the ICARUS T600 and R&D on Liquid Argon Time Projection Chamber (LAr TPC)

ANNEXES

Annex 1: List of the Sub-units (systems) and/or deliverables provided by participating institutes

Annex 2: Organization and Management structure of the Collaboration and persons currently holding management positions

Annex 3: List of Institutes, Funding Agencies and Representatives

Annex 4: Value of deliverables, grouped by Funding Agency and/or sub-units (systems) and payment profile

Annex 5: Project Milestones

The European Organization for Nuclear Research (CERN)

and

The INFN, on behalf of the WA104 Collaboration

declare that they agree on the Present Addendum to the Memorandum of Understanding for the overhauling of ICARUS T600 and R&D on Liquid Argon Time Projection Chamber (LAr TPC)

Done in Geneva

....

for CERN

Sergio Bertolucci
Director of Research and
Scientific Computing ....

For the participating institutes

Institute / Funding Agency	Signatory
....	....
Place and Date	Signature
....	....

CERN Neutrino Platform

Summary:

- ✓ CERN offers a platform for Neutrino detectors R&D. This platform is now part of the CERN MTP. We will support this platform in an active way and will help WA104, WA105 and others proposals in this initial phase
- ✓ CERN will construct a large neutrino test area (EHN1 extension) with charged beams capabilities, available in 2016
- ✓ CERN will assist the EU neutrino community in their long term common plans. For the moment CERN is not committing to any neutrino beam at CERN, in view of an agreed road map between all partners