Neutrino Plans in Europe

ν-activities in Europe (accelerator based)

- Operational ν-beam : **CNGS**

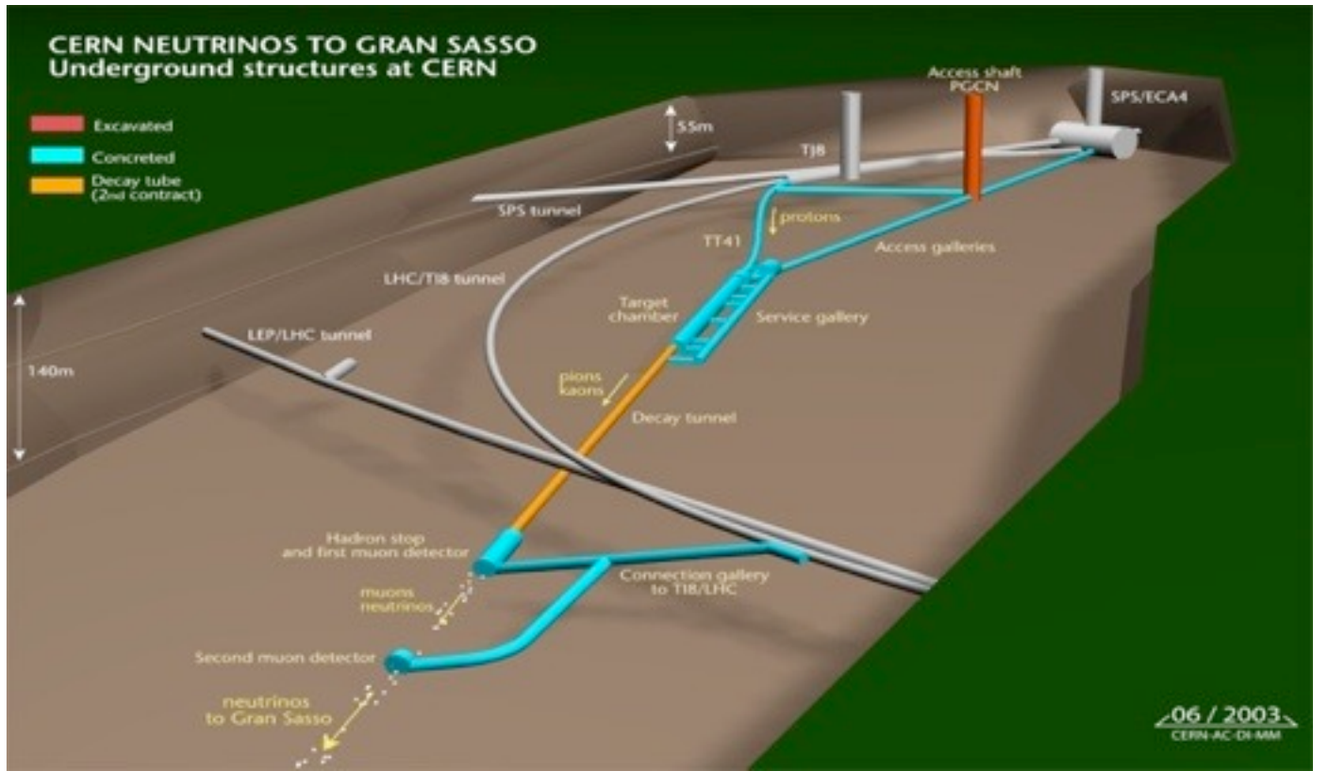
- Design Studies
  - **EUROν**/FP7 (2008-2012) : SuperBeams - BetaBeams - NeutrinoFactory (IDS-NF)
    - R&D projects & experiments [MICE, EMMA, targetry (protons/ions), ….]
  - **LAGUNA**/FP7 (2008-2011) : Far detector for astroparticle and beam physics
  - **LAGUNA_LBNO**/FP7 (20011-2014) : LAGUNA + Beam from CERN
    - Incremental Approach towards a ~2MW ν-beam facility
    - R&D on detectors
  - R&D activities for HP-SPL

- Strong European participation in T2K and MINOS ν-experiments

- ν-experiment proposals
  - **Short-baseline** neutrino Beam at CERN/PS(or SPS) - sterile neutrinos

CERN Neutrinos to Grand Sasso - CNGS LBL beam

- Long-baseline ν beam designed for ν oscillation studies via ν_τ appearance
  - two optimized detectors at LNGS : **OPERA** (1.2kt) - **ICARUS** (0.6kt)



Approved program:

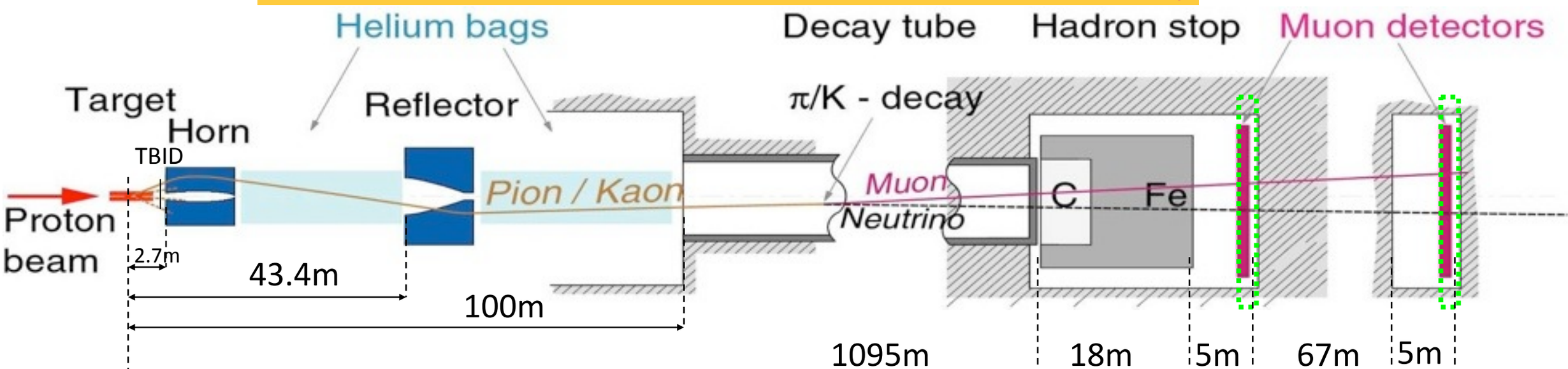
- **4.5×10^{19} protons/year** – 5 year program
- ~3.5×10^{11} ν_μ/year at Grand Sasso
- ~3000 CC ν_μ interactions/kt/year at the experiment
- **~2÷3 ν_τ interactions detected/year** (OPERA)

- Construction completed in **2006**, physics since **2008**

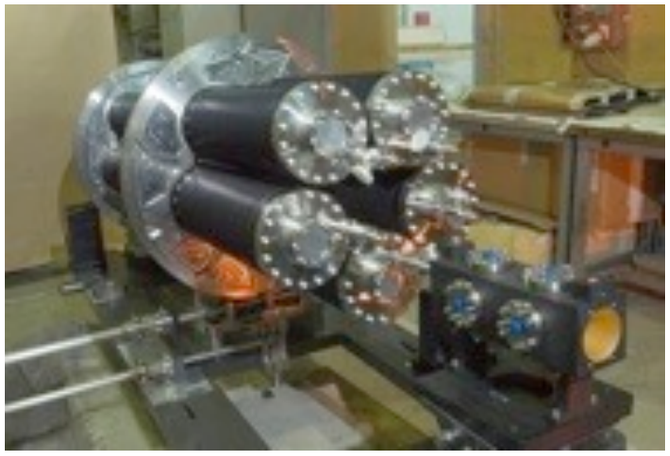
Beam parameters	Nominal beam
Nominal energy [GeV]	400
Normalized emittance [μm]	H: 12 V: 7
Emittance [μm]	H: 0.028 V: 0.016
Momentum spread Δp/p	0.07% ± 20%
# extractions per cycle	2 separated by 50 ms
Batch length [μs]	10.5
Cycel length [s]	6
# of bunches per pulse	2100
Intensity per extraction	**$2.4\ 10^{13}$**
Beam power [100%df]	**510 kW**
Bunch length [ns] (4σ)	2
Bunch spacing [ns]	5
Beta at focus [m]	H: 10 V: 20
Beam sizes at 400 GeV [mm]	0.5 mm
Beam divergence [mrad]	H: 0.05 V: 0.03

CNGS : Conventional long-baseline ν beam

$p + C \rightarrow (\text{interactions}) \rightarrow \pi^+, K^+ \rightarrow (\text{decay}) \rightarrow \mu^+ + \nu_\mu$



Target Unit



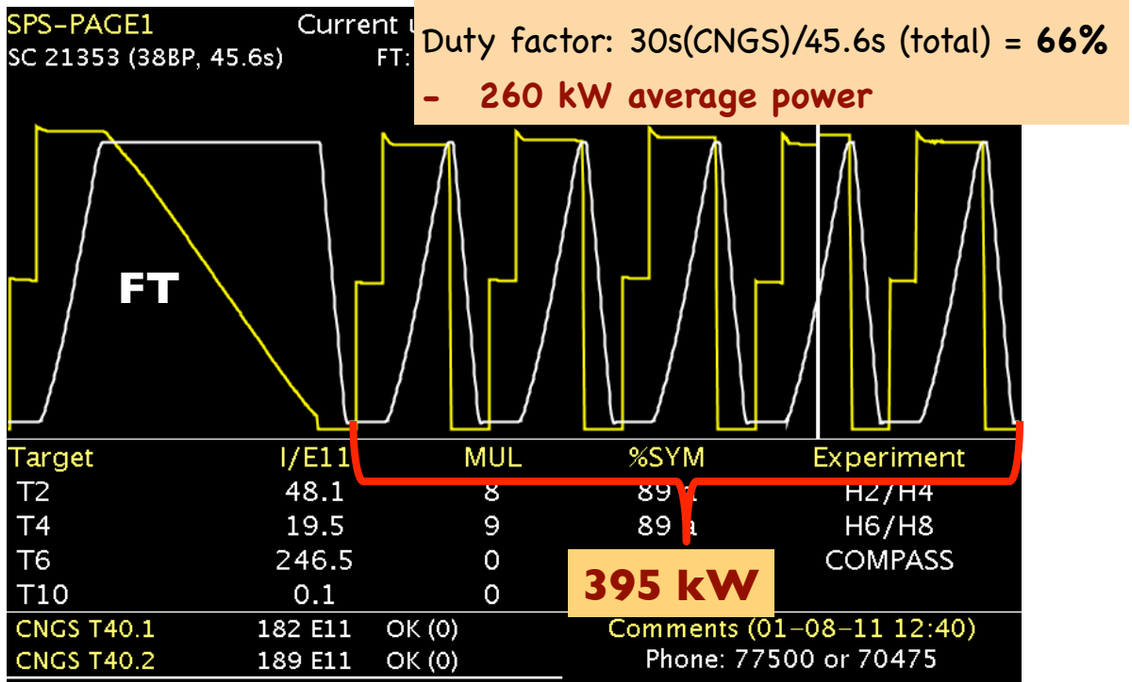
- C rods
- 5(4) mm Ø
- 5 in-situ spares

Muon detectors

- 2 × 41 fixed monitors
- 2 × 1 motorized monitor

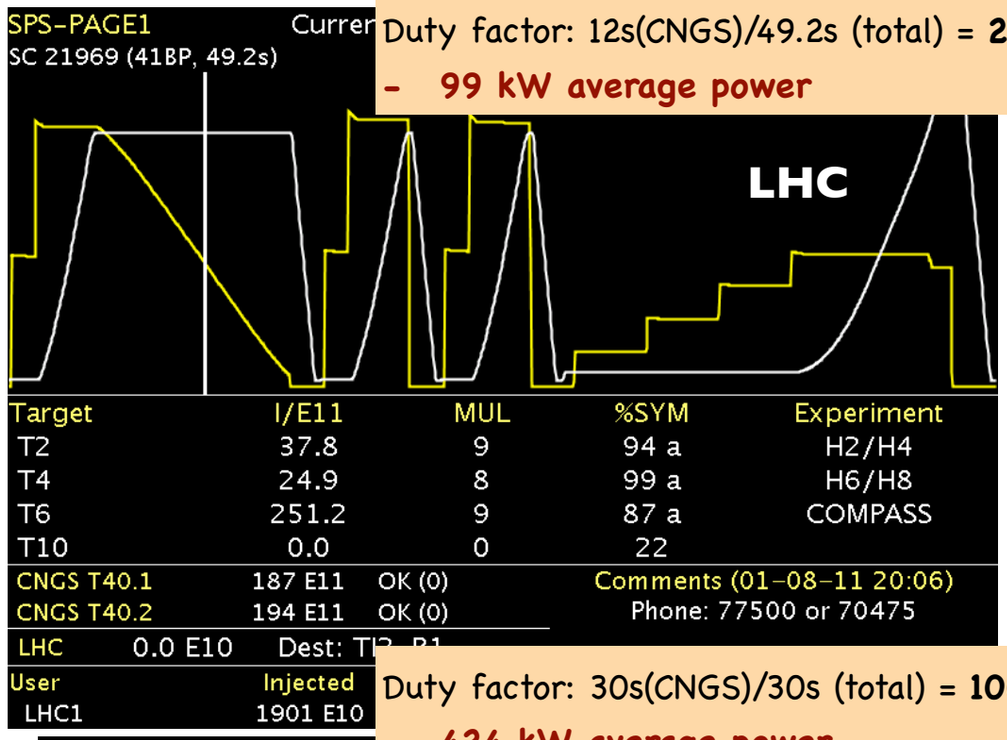
Magnetic Horns

CNGS : Operation



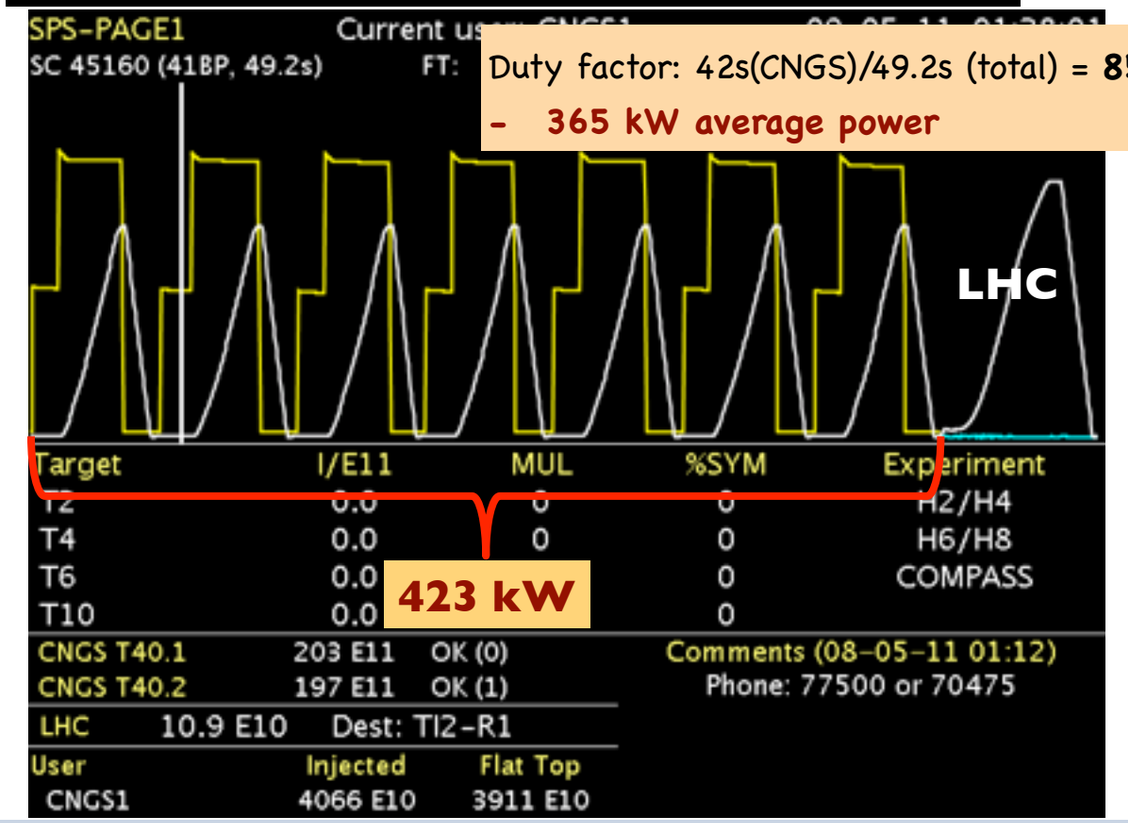
Duty factor: 30s(CNGS)/45.6s (total) = **66%**

- **260 kW average power**



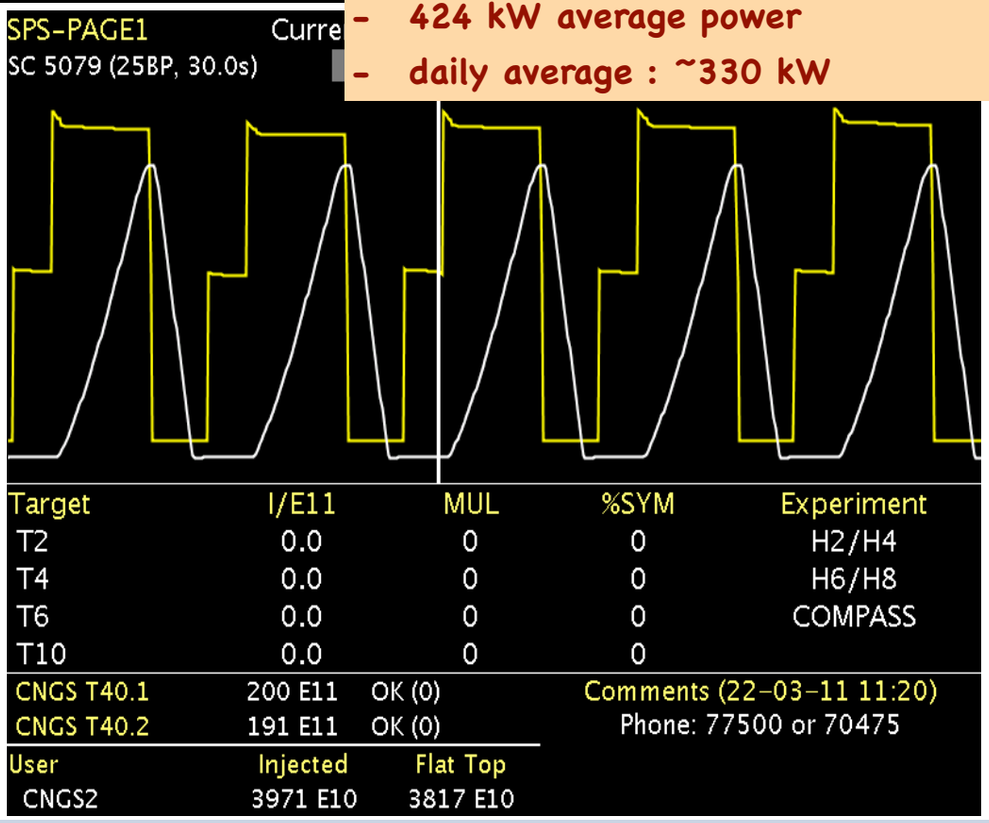
Duty factor: 12s(CNGS)/49.2s (total) = **24%**

- **99 kW average power**



Duty factor: 42s(CNGS)/49.2s (total) = **85%**

- **365 kW average power**



Duty factor: 30s(CNGS)/30s (total) = **100%**

- **424 kW average power**
- **daily average : ~330 kW**

CNGS : Operation history

- physics run MTE tests, bunched beam
- physics run MTE tests
- physics run MTE tests
- physics run
- beam commissioning with high intensity
- beam commissioning
- construction

2001 | 2005 | 2006 | 2007 | 2008 | 2009 | 2010 | 2011

- leak in the reflector cooling circuit : repair and improvements
- broken stripline cable : repair and improvements

- radiation effects in proximity electronics
  - additional shielding, reconfiguration

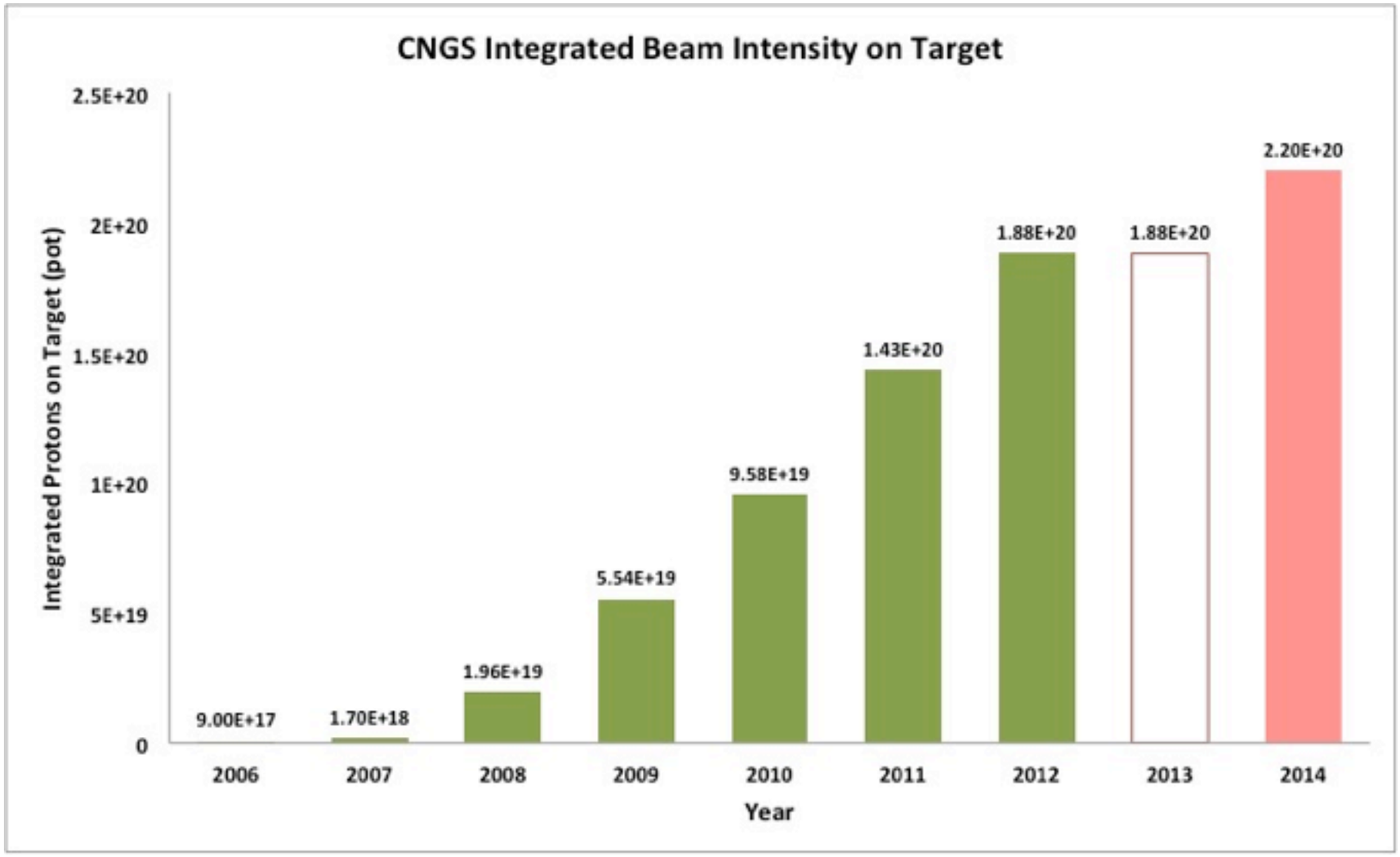
- damaged target rotation mechanism : inspection

- tritium issue : civil engineering works, new configuration of the drain water circuit

- tritium issue : reconfiguration of ventilation system

CNGS : Status & Plans

- At the end of 2012 CNGS should reach **1.88 × 10^{20} pot**
  - to complete the presently approved program **(5y × 4.5 10^{19} pot/y = 2.2 10^{20} pot)** running in 2014 will be required
- decision to continue beyond Long-shutdown#1$_{(2013)}$ still pending
  - would depend on the results obtained in 2012 (**ν-velocity**)

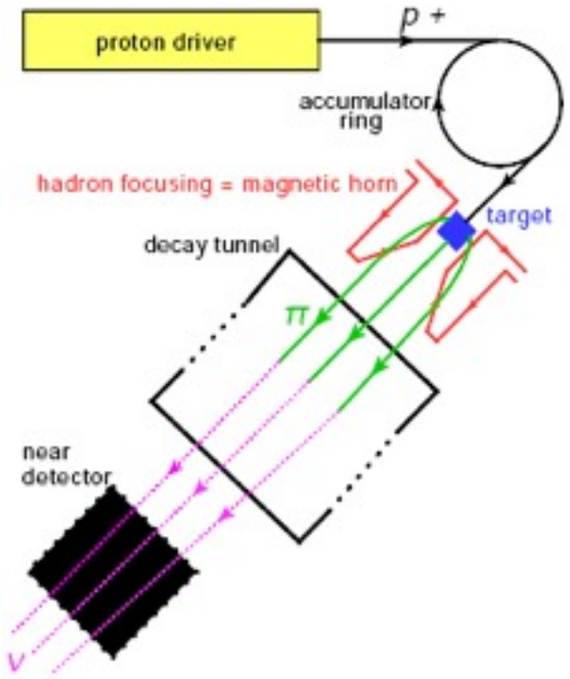


EUROnu / FP7 - Design Study (2008-2012)

- Three neutrino beam facilities under study

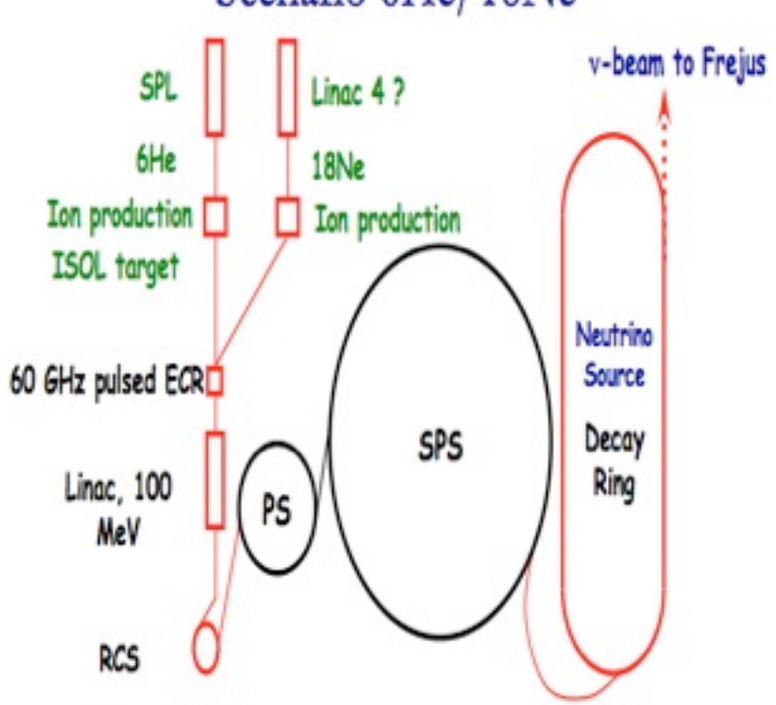
- Super beam : CERN ⇒ Frejus(FR)

- **4MW** proton beam from CERN HP-SPL @ 5 GeV
- **130 km** baseline
- **440 kT** fm detector



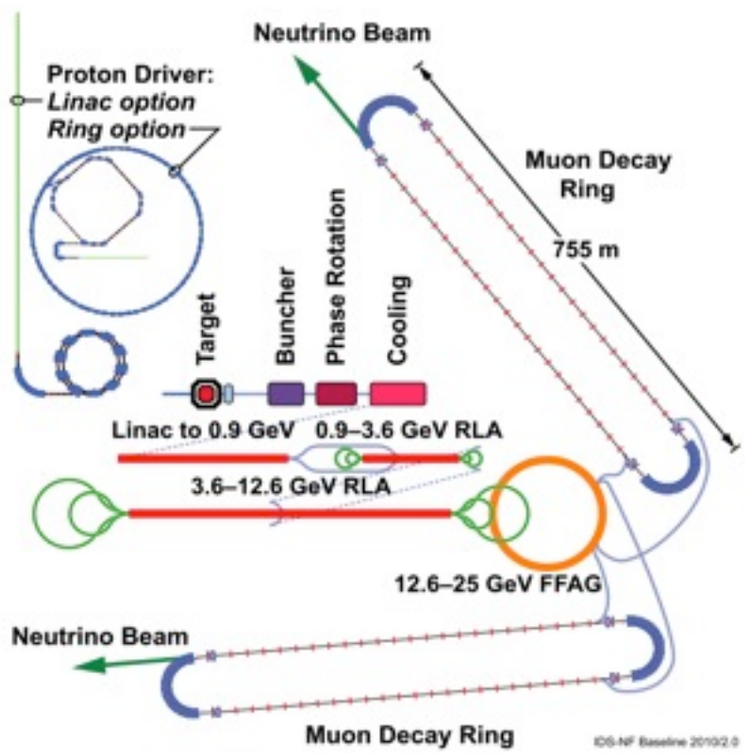
- β-beam : CERN ⇒ Frejus(FR)

- ion production options:
  - **He^6/Ne^{18}** - Li^8/B^8
- γ=100



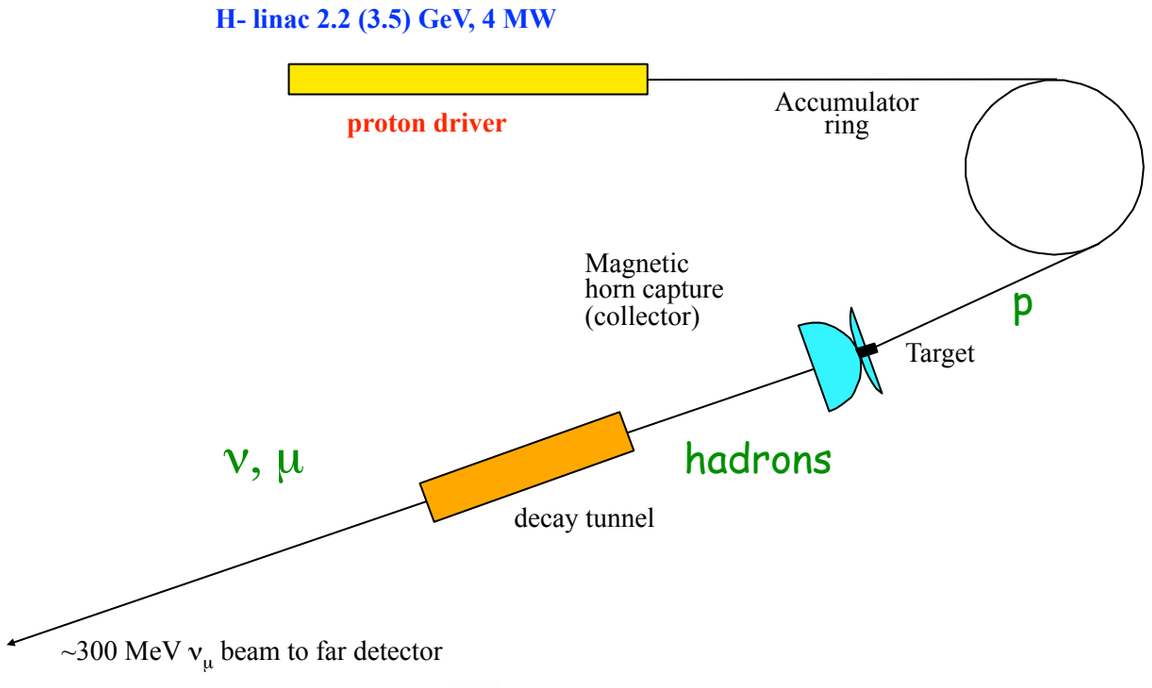
- Neutrino Factory - IDS/NF

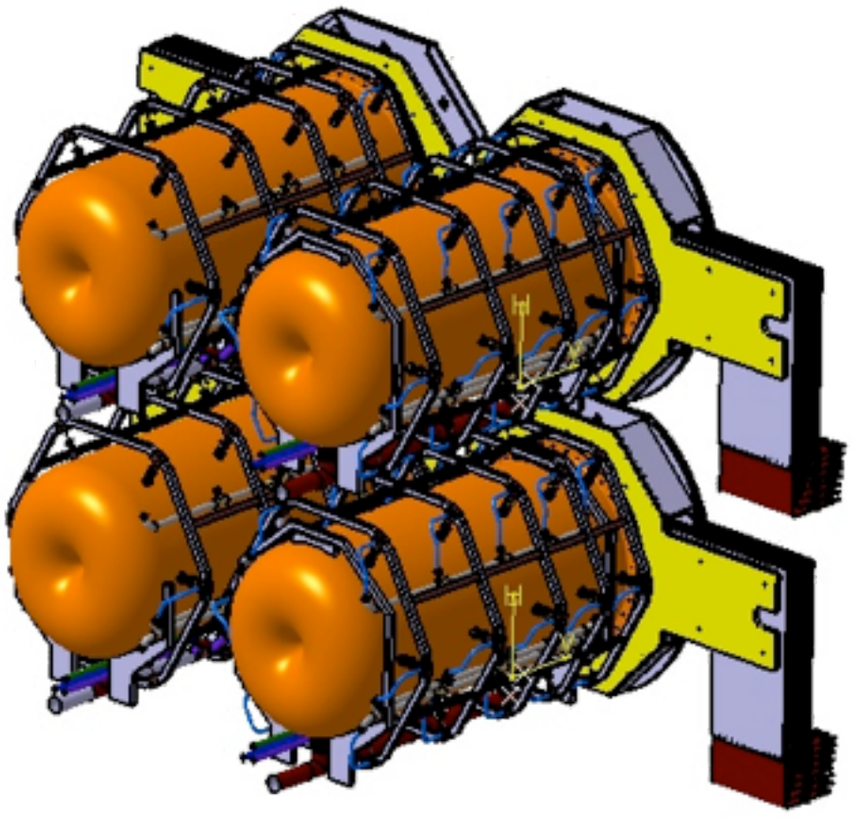
- **4MW** proton driver
- **target station** and **cooling** channel
- muon acceleration to 25 GeV or
- **low-energy NF** based on θ_{13} value



- Deliverable : comparison evaluation based on **cost**, **physics reach**
  - use CERN as example site for localization dependent costs

EUROnu : CERN Super-beam to Frejus





Technical Challenges

- Target design
  - impact of the 4 MW beam
  - 50 Hz operation
- Horn design
  - high-current, mechanical constraints due to physics requirements, radiation, heating (Joule effect + radiation), pulsing

Solution

- 4 × 1 MW = 4 MW !!
- four target/horn assemblies mounted on a common mechanical structure
- 12.5 Hz operation, beam delivery ???

EUROnu : CERN Super-beam to Frejus

Courtesy : Chris Densham - EUROnu

- **Target baseline :** packed bet with Ti spheres

Science & Technology Facilities Council

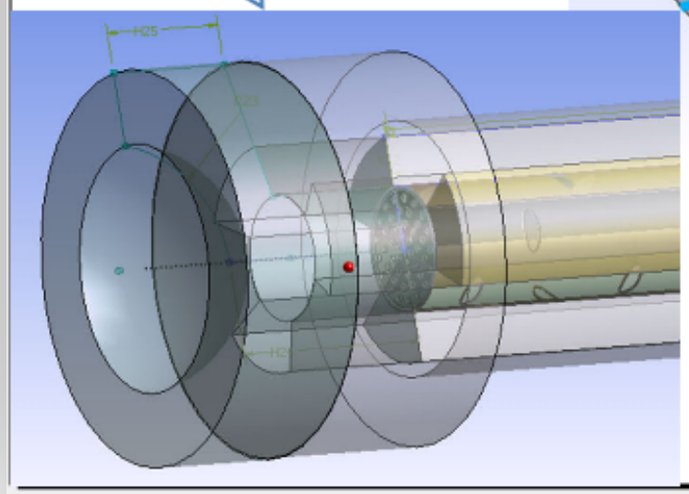
Packed Bed Target Concept for Euronu (or other high power beams)

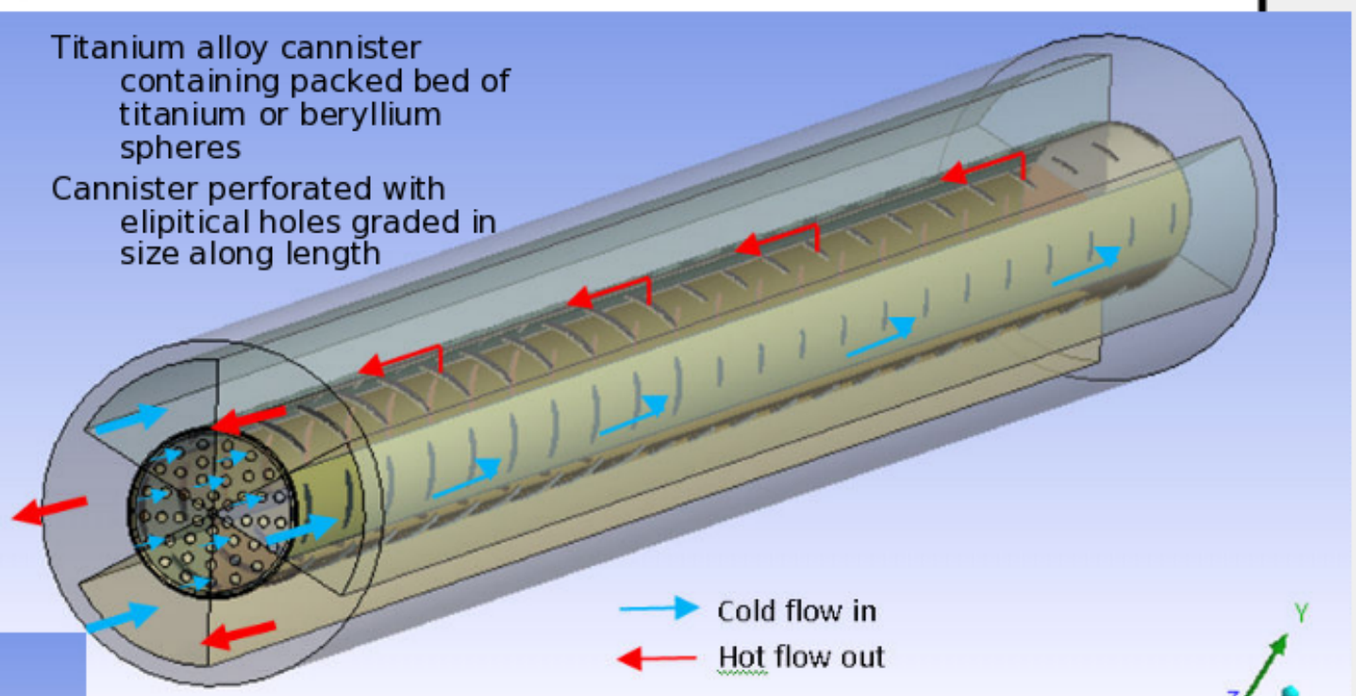
Titanium alloy cannister containing packed bed of titanium or beryllium spheres

Cannister perforated with elipitical holes graded in size along length

Packed bed cannister in parallel flow configuration

Packed bed target front end





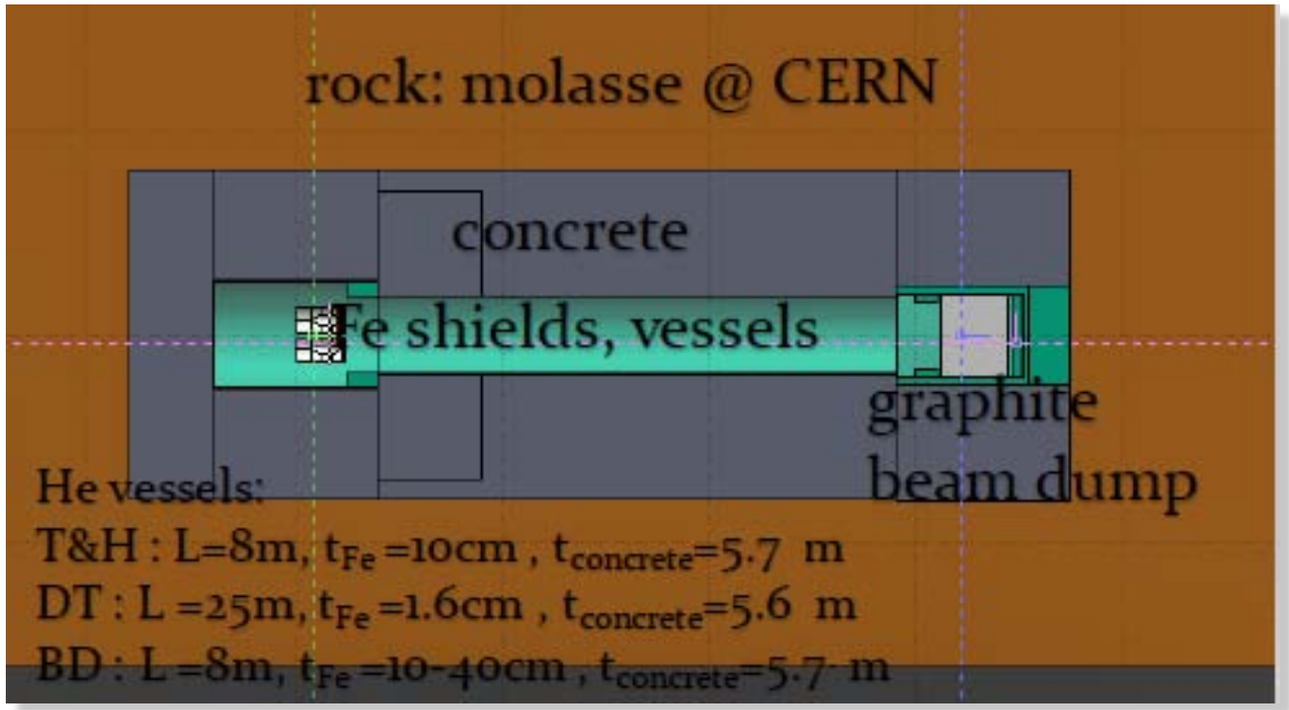
Model Parameters

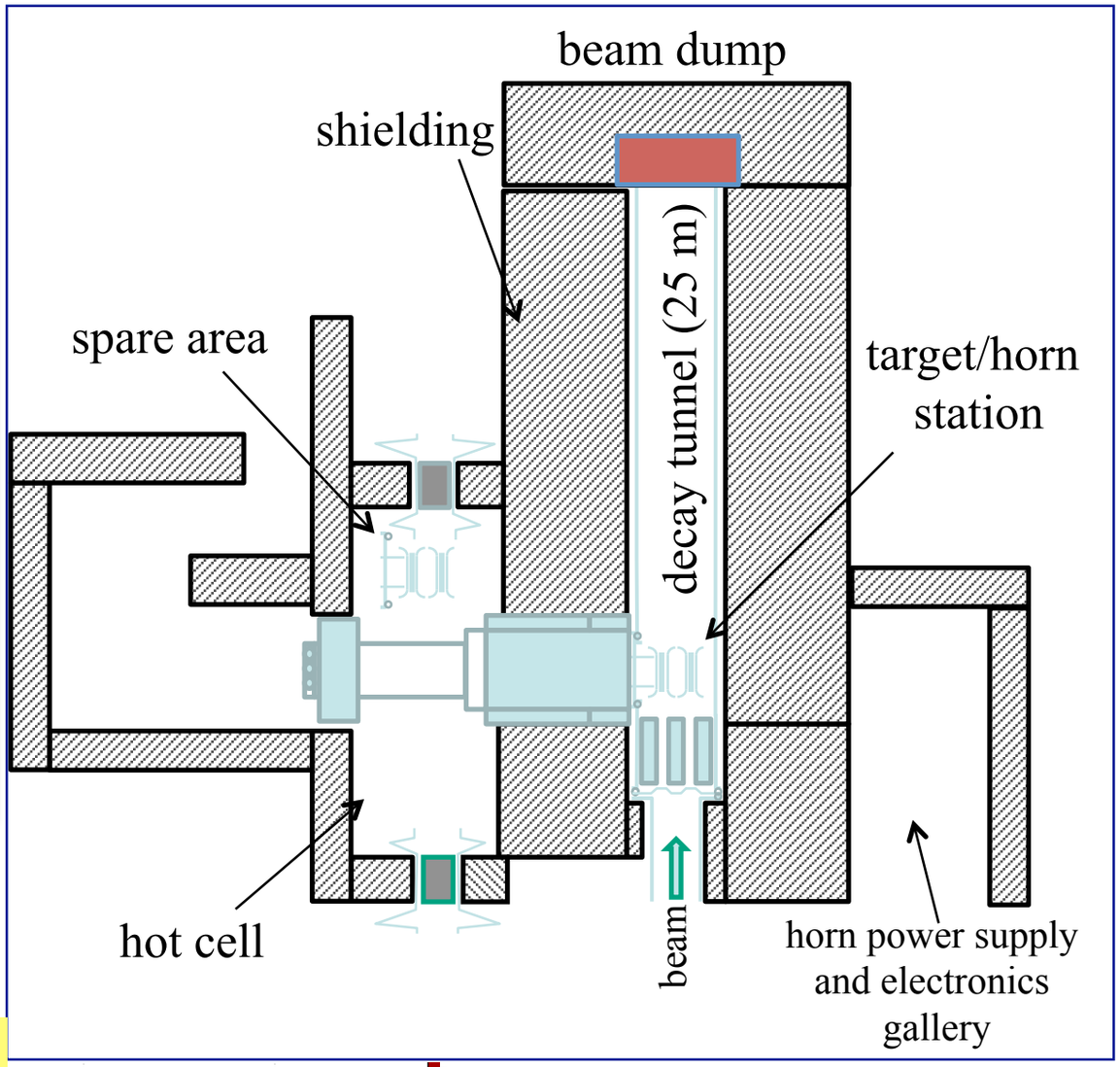
Proton Beam Energy = 4.5GeV
Beam sigma = 4mm
Packed Bed radius = 12mm
Packed Bed Length = 780mm
Packed Bed sphere diameter = 3mm
Packed Bed sphere material : Beryllium or Titanium
Coolant = Helium at 10 bar pressure

- test with beam in the new **HiRadMat@SPS** facility at CERN in 2012 under consideration

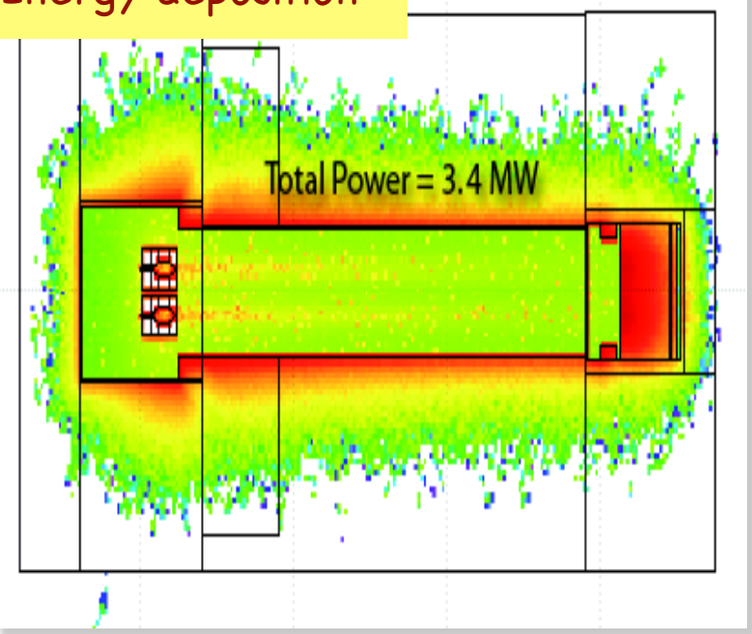
EUROnu : CERN Super-beam to Frejus

Layout and RP studies

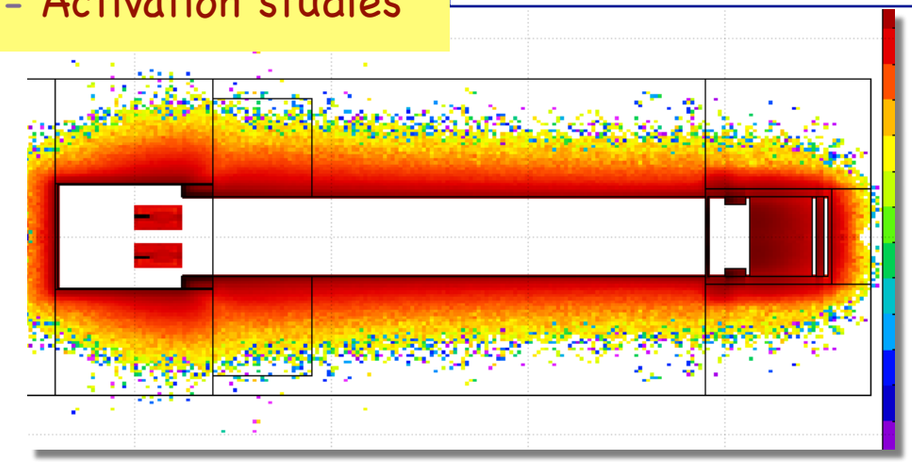




- Energy deposition



- Activation studies



- A **6m thick concrete wall** surrounding all the layout is sufficient to limit the production of radionucleides in the molasse.

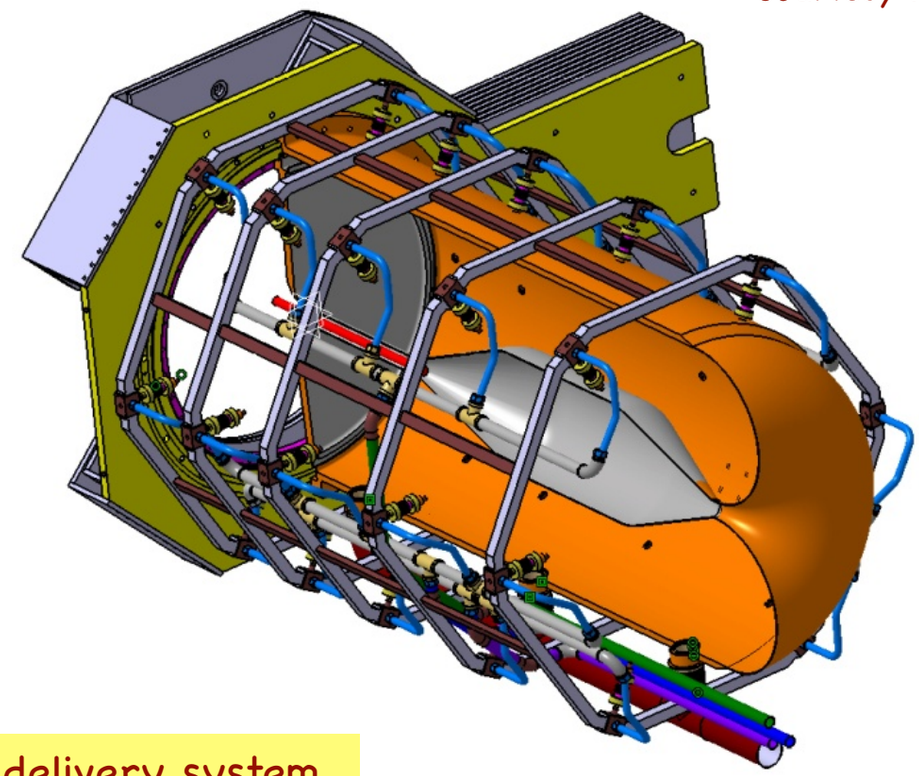
Courtesy : M. Dracos - EUROnu

EUROnu : CERN Super-beam to Frejus

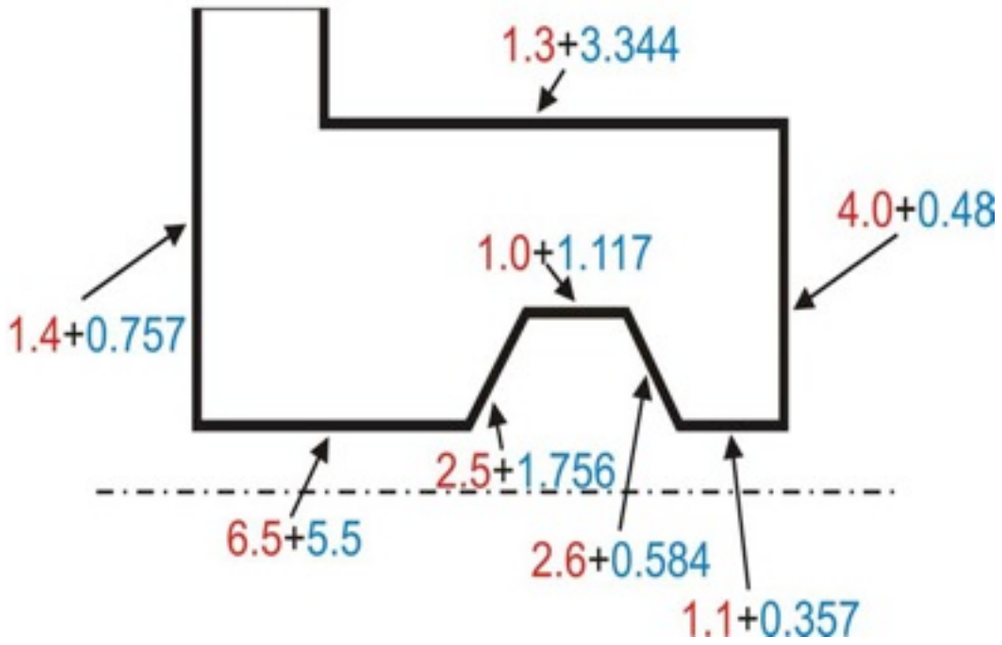
Horn

- mini-BOOvE inspired horn design
- 300 kA current
- 12.5 kHz pulsing

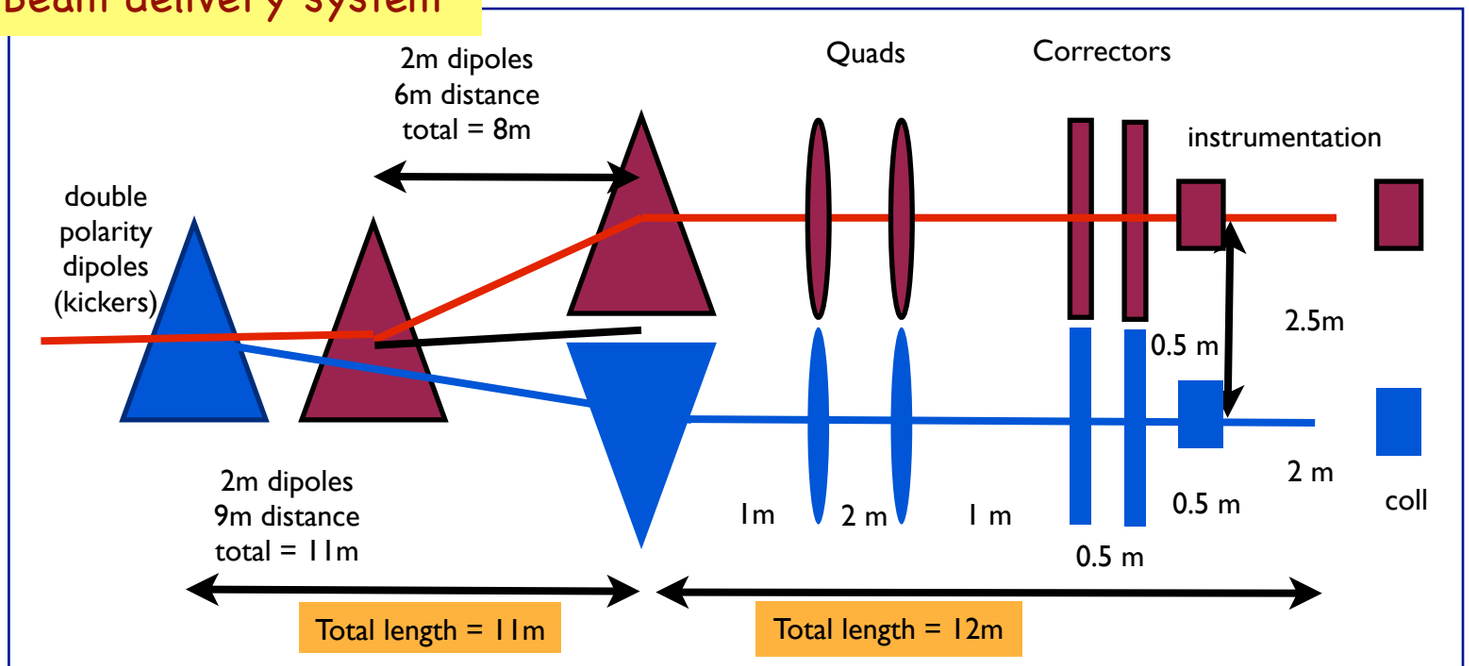
Courtesy : M. Dracos - EUROnu



Thermal loads [kW]
current + particles

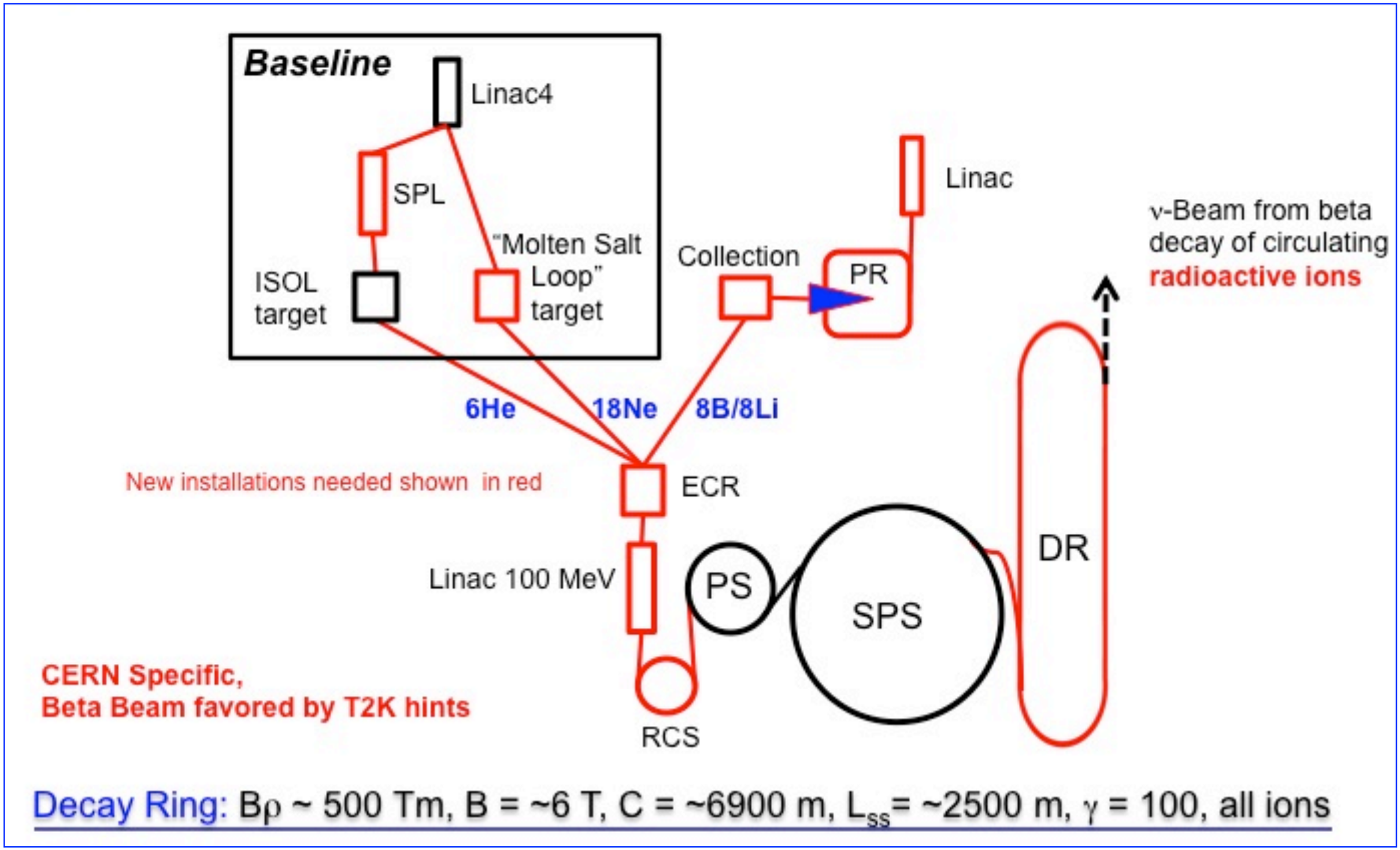


- Beam delivery system



EUROnu : CERN Beta-beam to Frejus

Courtesy : E. Wildner - EUROnu



EUROnu : CERN Beta-beam to Frejus

Courtesy : E. Wildner - EUROnu

Aim: 2.0 10^{13} for low-Q **Targets below MWatt is a considerable advantage!**

Type	Accelerator	Beam	I_{beam} mA	E_{beam} MeV	P_{beam} kW	Target	Isotope	Flux s^{-1}	
ISOL & n-converter	SPL	p	0.07	2 10^3	135	W/BeO	6He	5 10^{13}	
ISOL & n-converter	Saraf/GANIL	d	17	40	680	C/BeO	6He	5 10^{13}	
ISOL	Linac 4	p	6	160	960	23Na 19F Molten NaF loop	18Ne	1 10^{13}	
ISOL	Cyclo/Linac	p	15	60	900	23Na 19F Molten NaF loop	18Ne	1 10^{13}	
ISOL	LinacX1	3He	85	21	1800	MgO 80 cm disk	18Ne	1 10^{13}	
P-Ring	LinacX2	d	0.160	25	4	7Li	8Li	3 10^{13}	
P-Ring	LinacX2	3He	0.160	25	4	6Li	8B	8 10^{11}	

Planned experiments ISOLDE CERN

Experimentally OK

On paper OK, exp. 2011

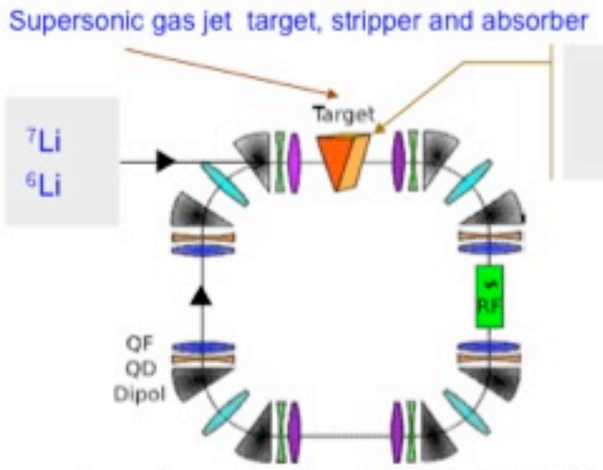
Not OK yet

EUROnu : CERN Beta-beam to Frejus

Courtesy : E. Wildner - EUROnu

EUROnu : CERN Beta-beam to Frejus

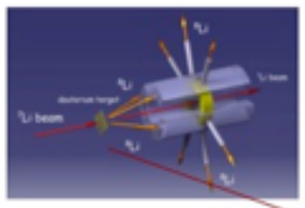
Courtesy : E. Wildner - EUROnu



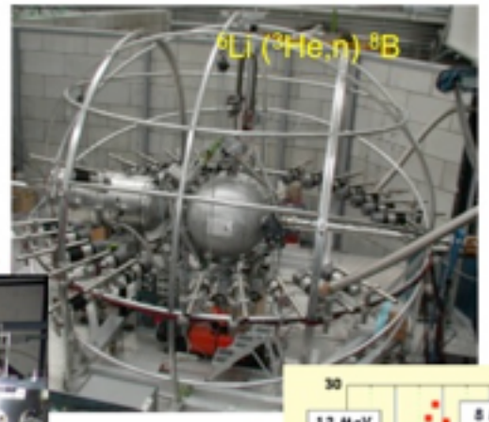
Aachen Univ., GSI, CERN

Production of 8B and 8Li
C. Rubbia, EUROnu proposal

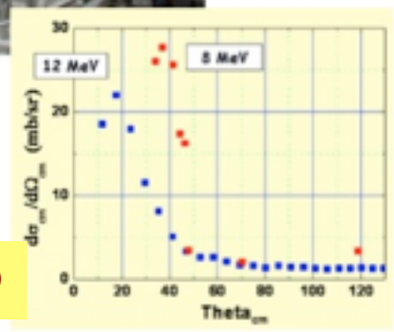
- Gas Jet target proposed in EUROnu:
  - too high density would be needed
  - vacuum problems
- Direct Production with liquid film targets
  - Collaboration ANL



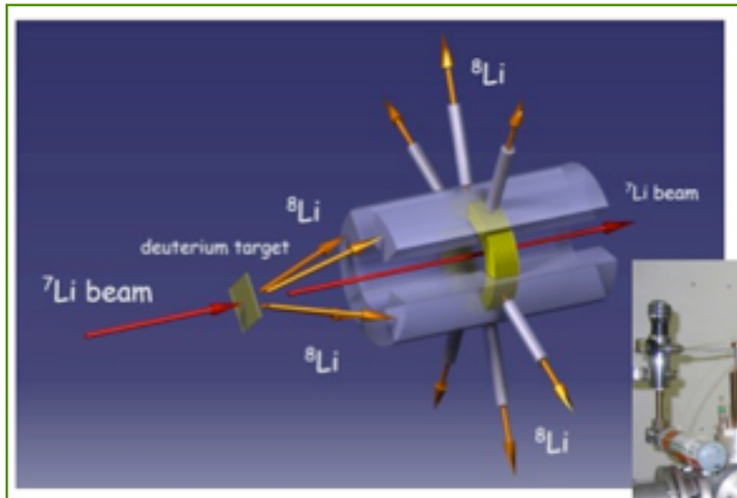
^{7}Li (d,p) ^{8}Li ^{6}Li (^{3}He,n) ^{8}B



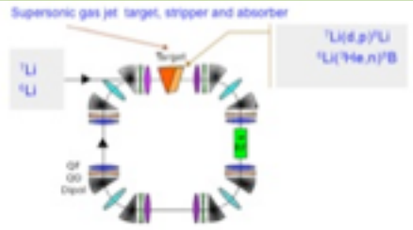
INFN, Legnaro

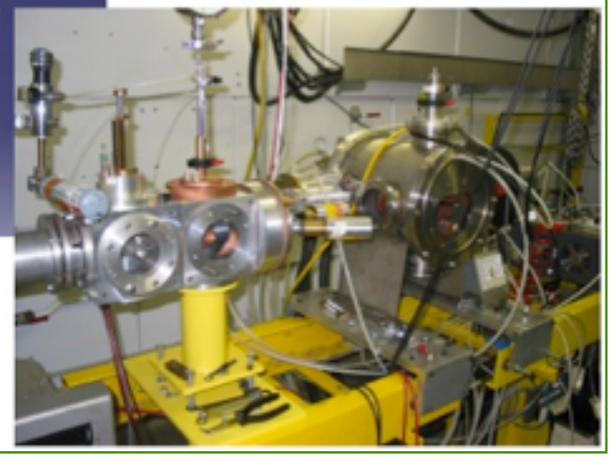


- ^{8}B and ^{8}Li production X-section R&D



UCL, Louvain la Neuve





- Ion production target R&D

EUROnu / IDS-NF : Neutrino Factory

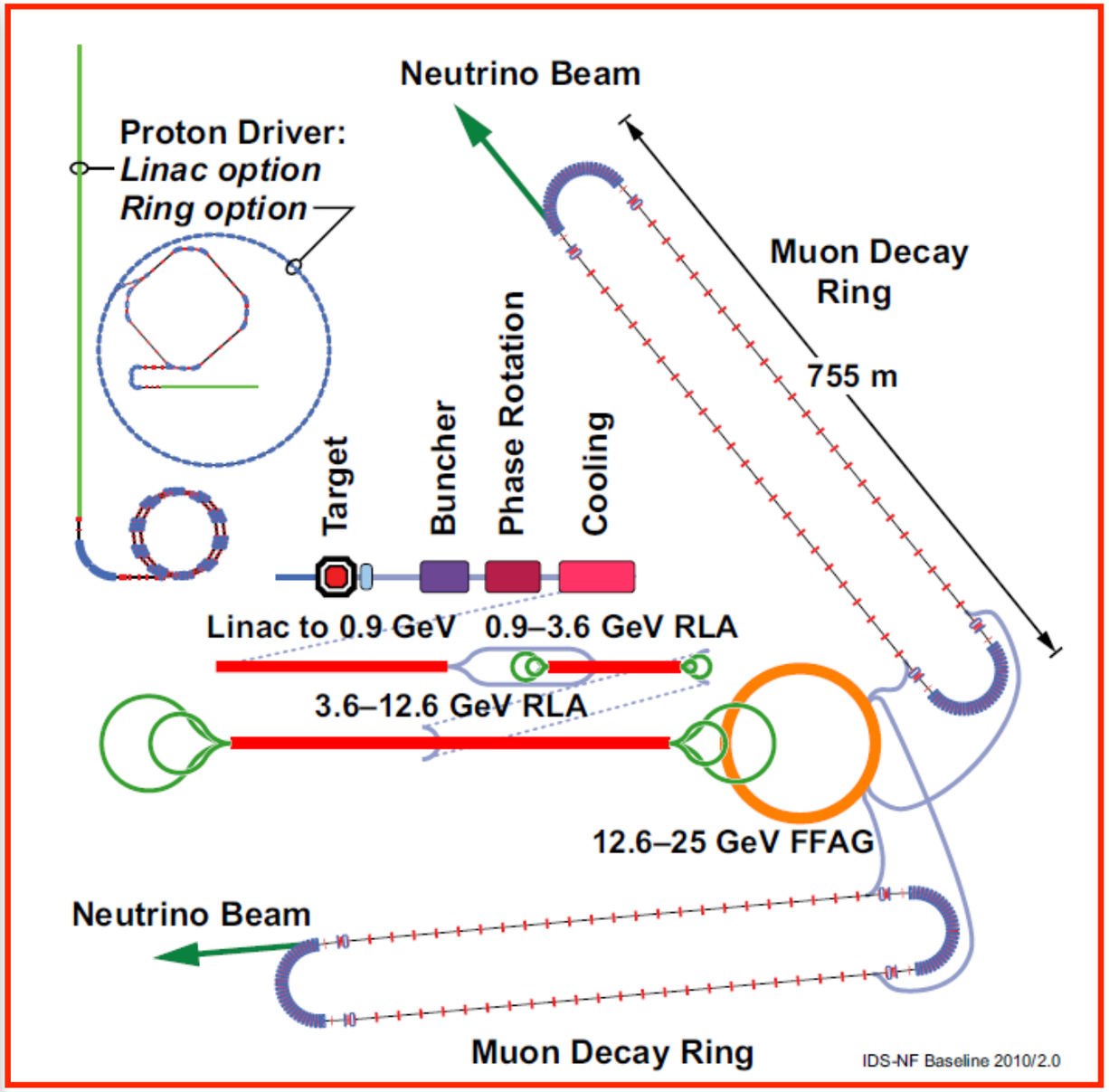
International Design Study for the
Neutrino Factory

IDS-NF-020

Interim Design Report

The IDS-NF collaboration

March 19, 2011

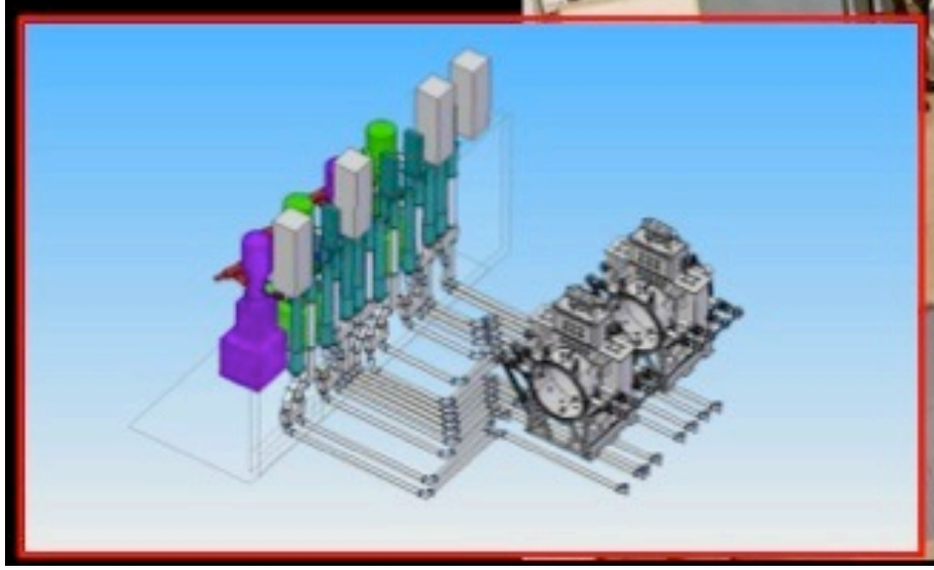


Parameter	Value
Muon total energy	25 GeV
Production straight muon decays in 10^7 s	10^{21}
Maximum RMS angular divergence of muons in production straight	$0.1/\gamma$
Distance to intermediate baseline detector	2 500–5 000 km
Distance to long baseline detector	7 000–8 000 km

Courtesy : K. Long - EUROnu/IDS-NF

EUROnu / IDS-NF : Neutrino Factory

- MICE Experiment

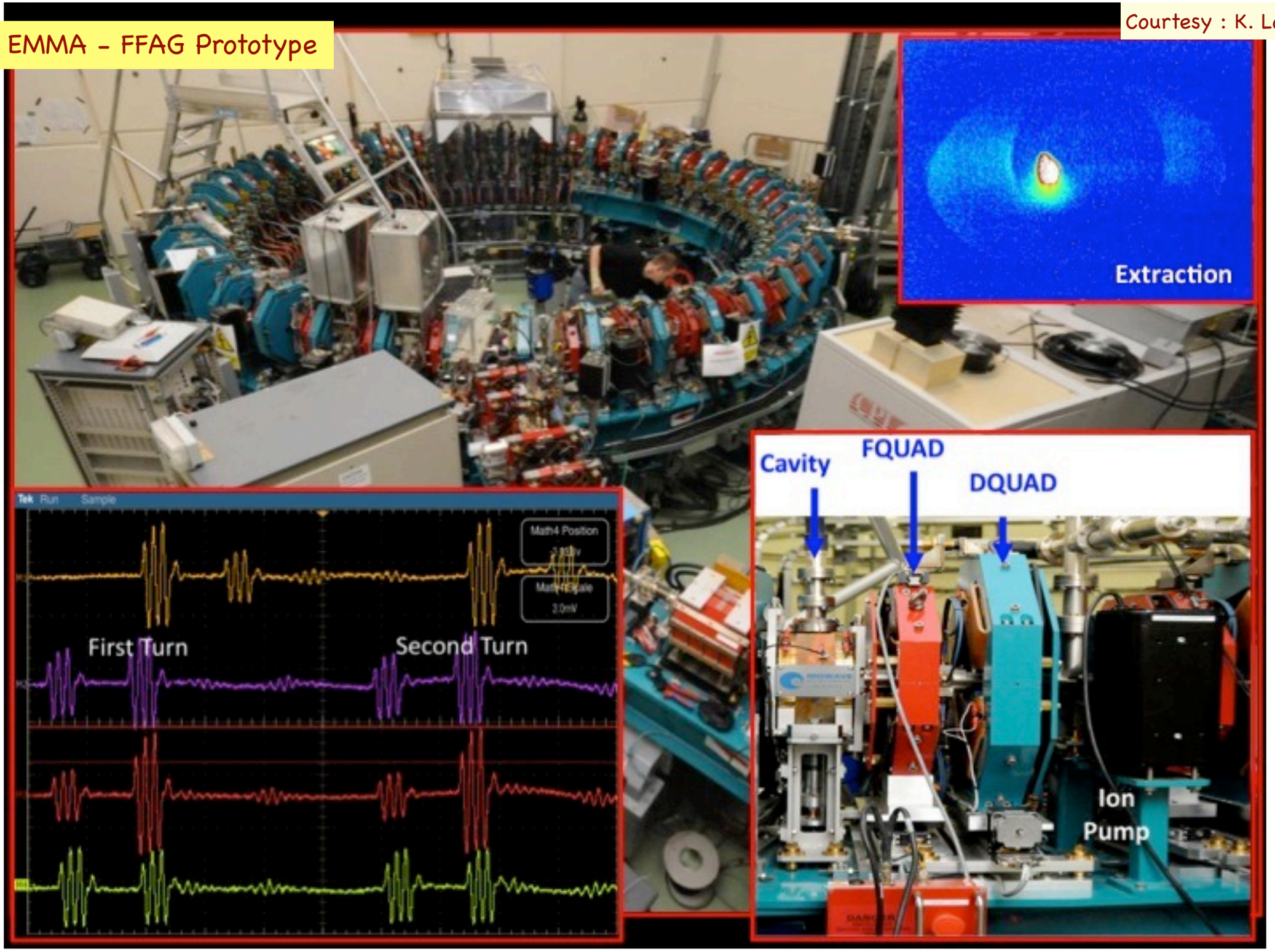


Courtesy : K. Long - EUROnu/IDS-NF

EUROnu / IDS-NF : Neutrino Factory

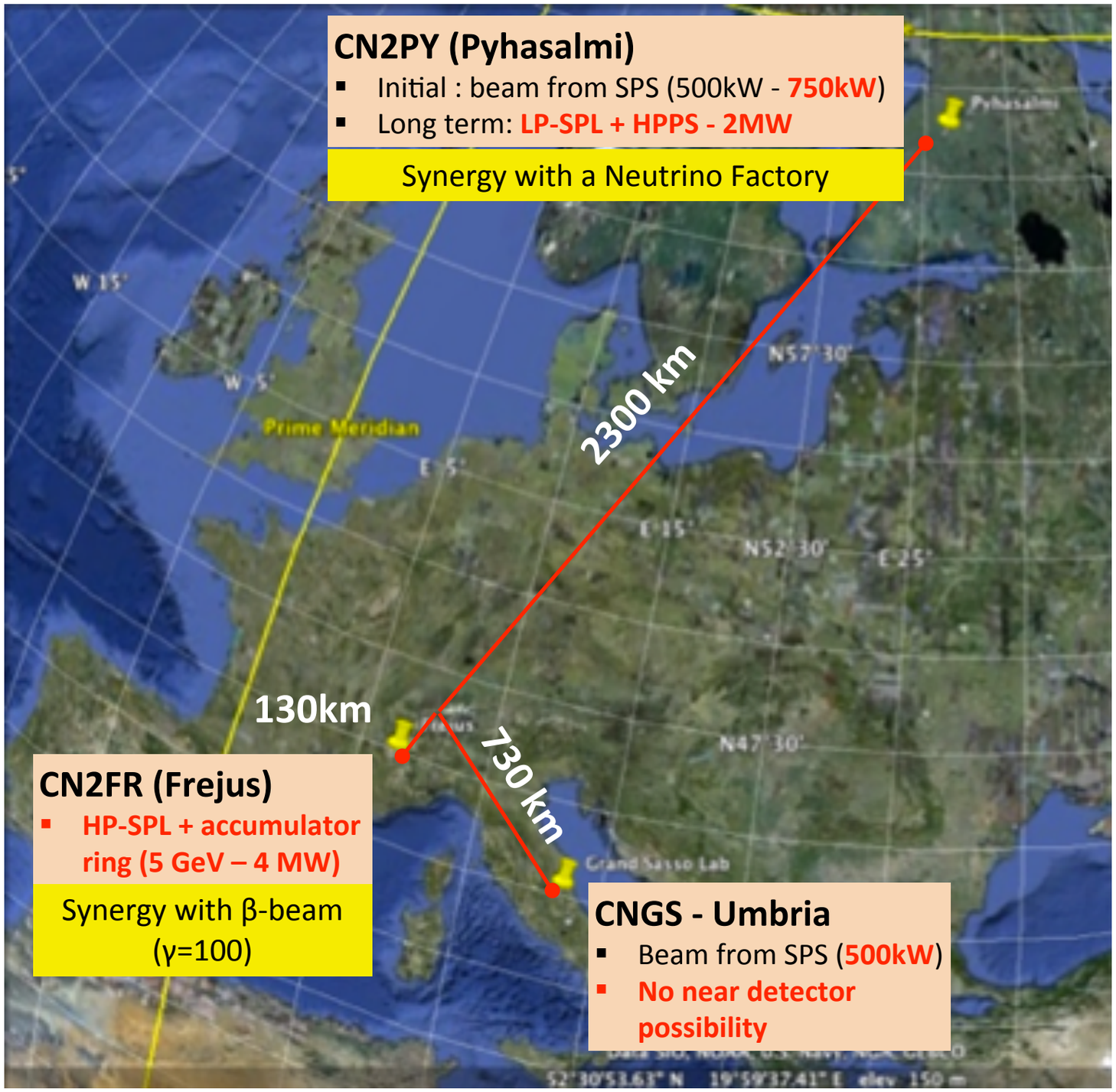
- EMMA - FFAG Prototype

Courtesy : K. Long - EUROnu/IDS-NF



LAGUNA_LBNO / FP7 Design Study (2011-2014)

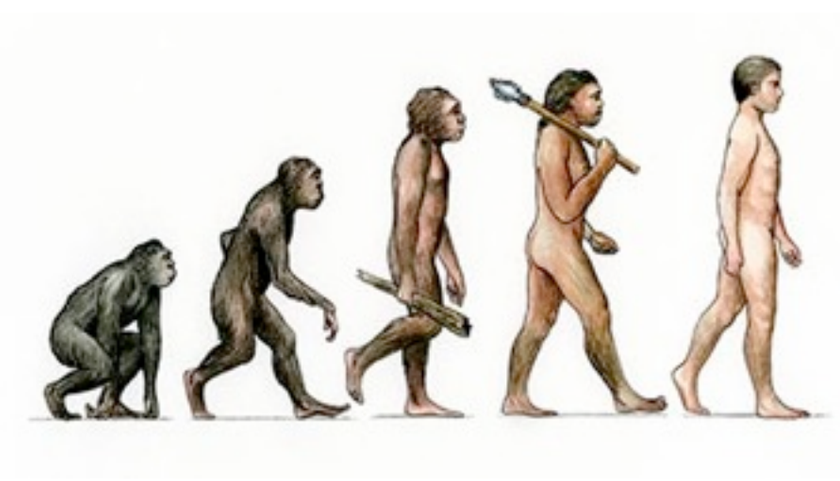
- New design study, extending that of LAGUNA, **including the neutrino beams from CERN**
- Beam options for **unique physics** opportunities in Europe
- Profit from **experience** gained with the CNGS operation
- **Incremental** approach with competitive physics goals at each stage
- **Synergy** with other ν-beam options
  - CN2FR : β-beam
  - CN2PY : Neutrino Factory
- Collaboration in a **global** scale, profit from know-how in other ν-beam facilities in US and Japan



LAGUNA-LBNO - FP7 DS - Beam studies

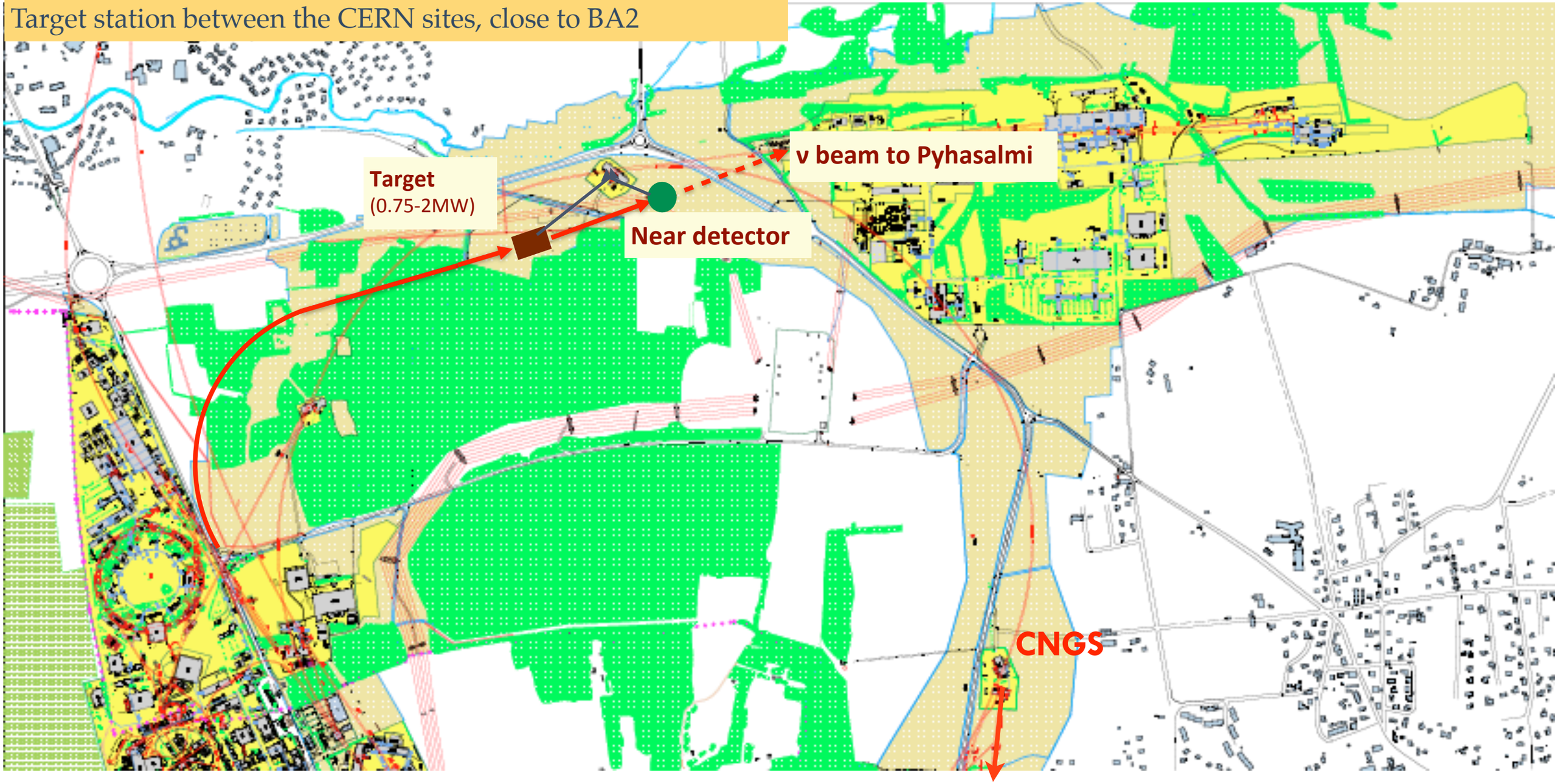
Objectives (1)

- Develop schemes for construction of **new neutrino beams at CERN** for the LAGUNA-LBNO programme - **INCREMENTAL APPROACH**
  - Study of designs to profit from an **increased SPS beam power to ~700kW** including layout, and engineering of a **new conventional long-baseline neutrino beam** line based on the CNGS technology, directed towards a **LAGUNA site** including a near detector
  - Study a new **high power proton accelerator (HP-PS)** using the **LP-SPL** followed by a synchrotron and delivering ~**2MW of beam power at 30-50 GeV**, that could be used as second-phase injector for the same long-baseline beam



CERN ν-beam to Pyhasalmi - CN2PY

Option A:
Target station between the CERN sites, close to BA2



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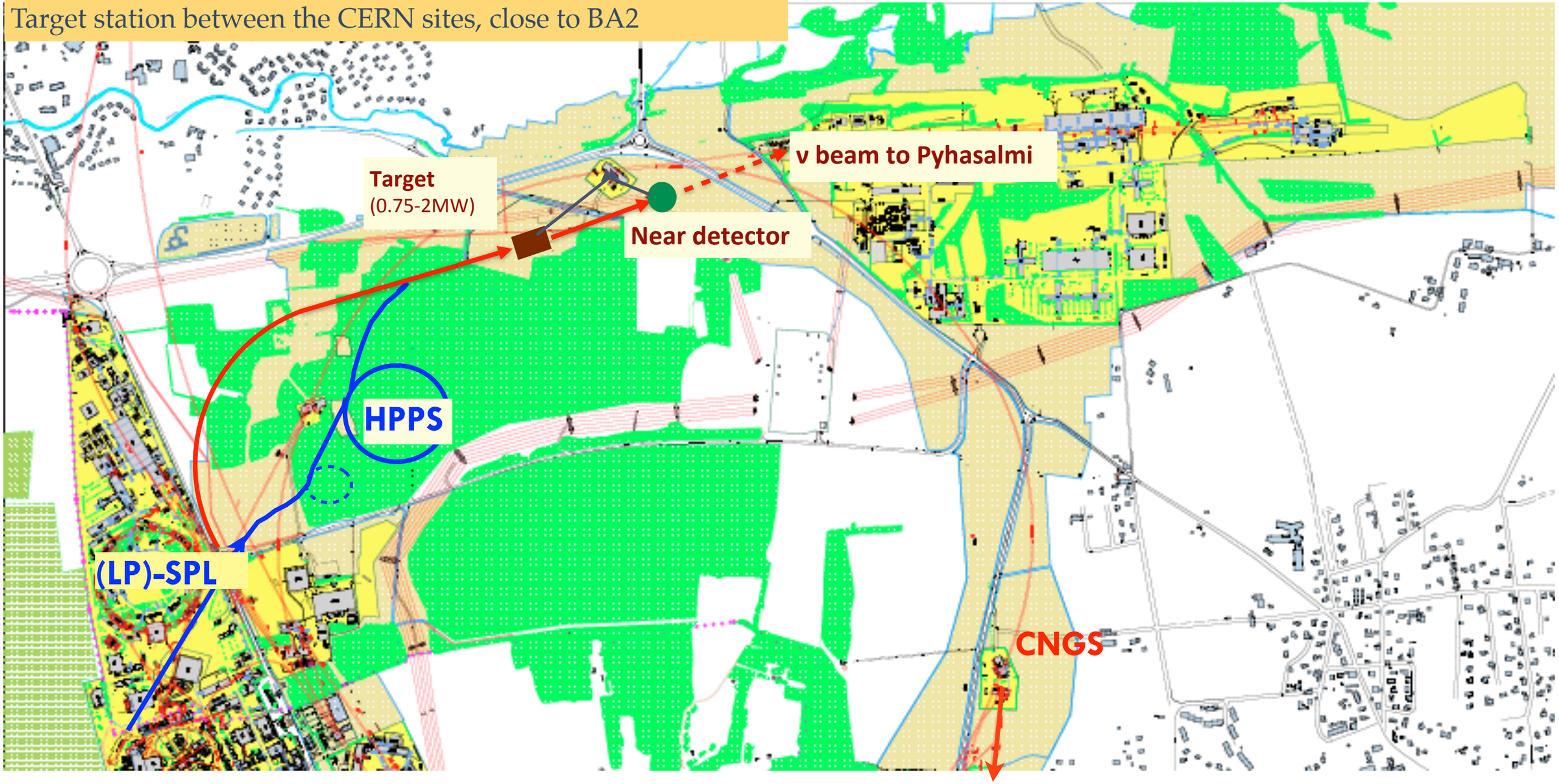
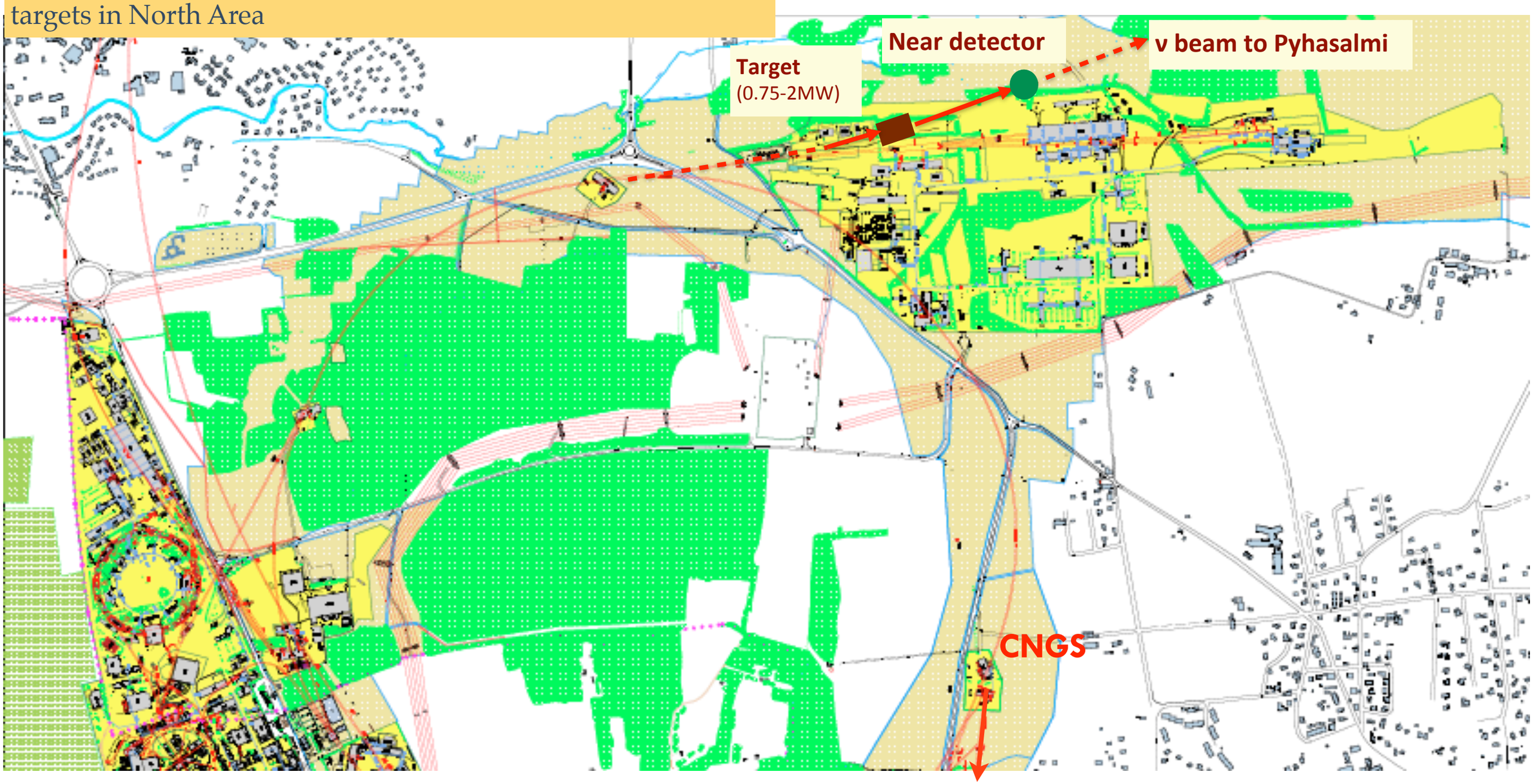


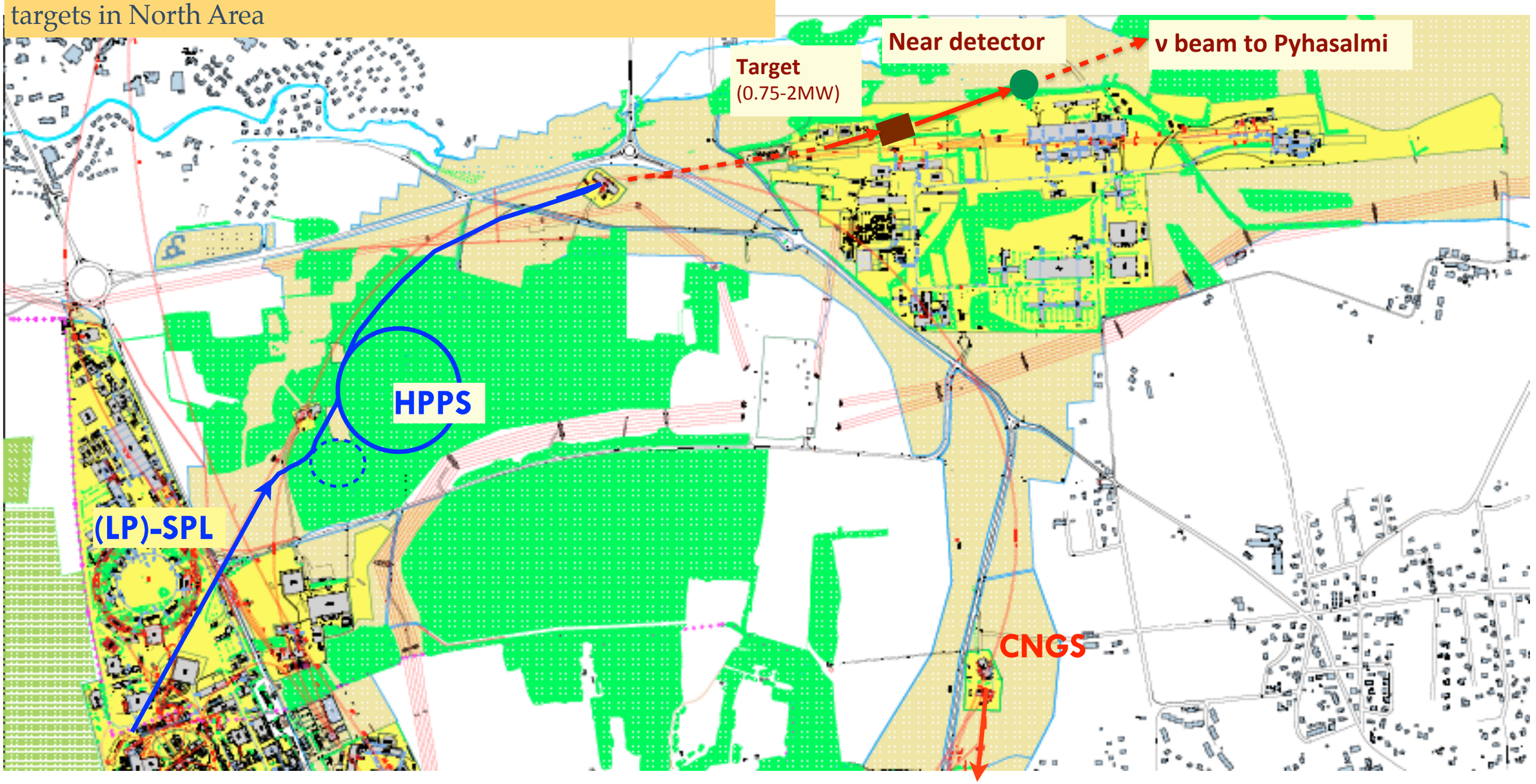
CERN ν-beam to Pyhasalmi - CN2PY

Option B:
Use TT20 for the first stage, target station close to existing targets in North Area

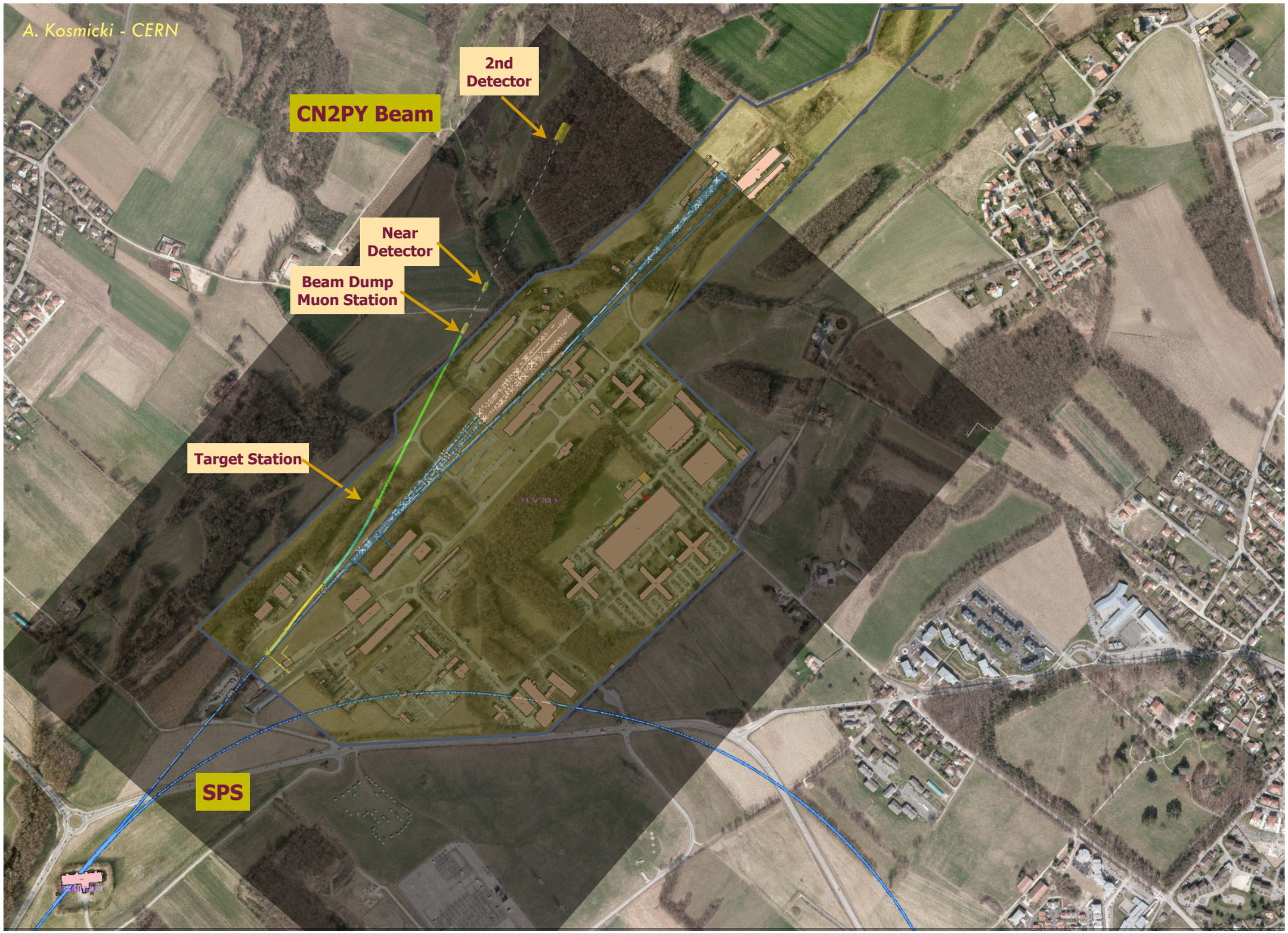


CERN ν-beam to Pyhasalmi - CN2PY

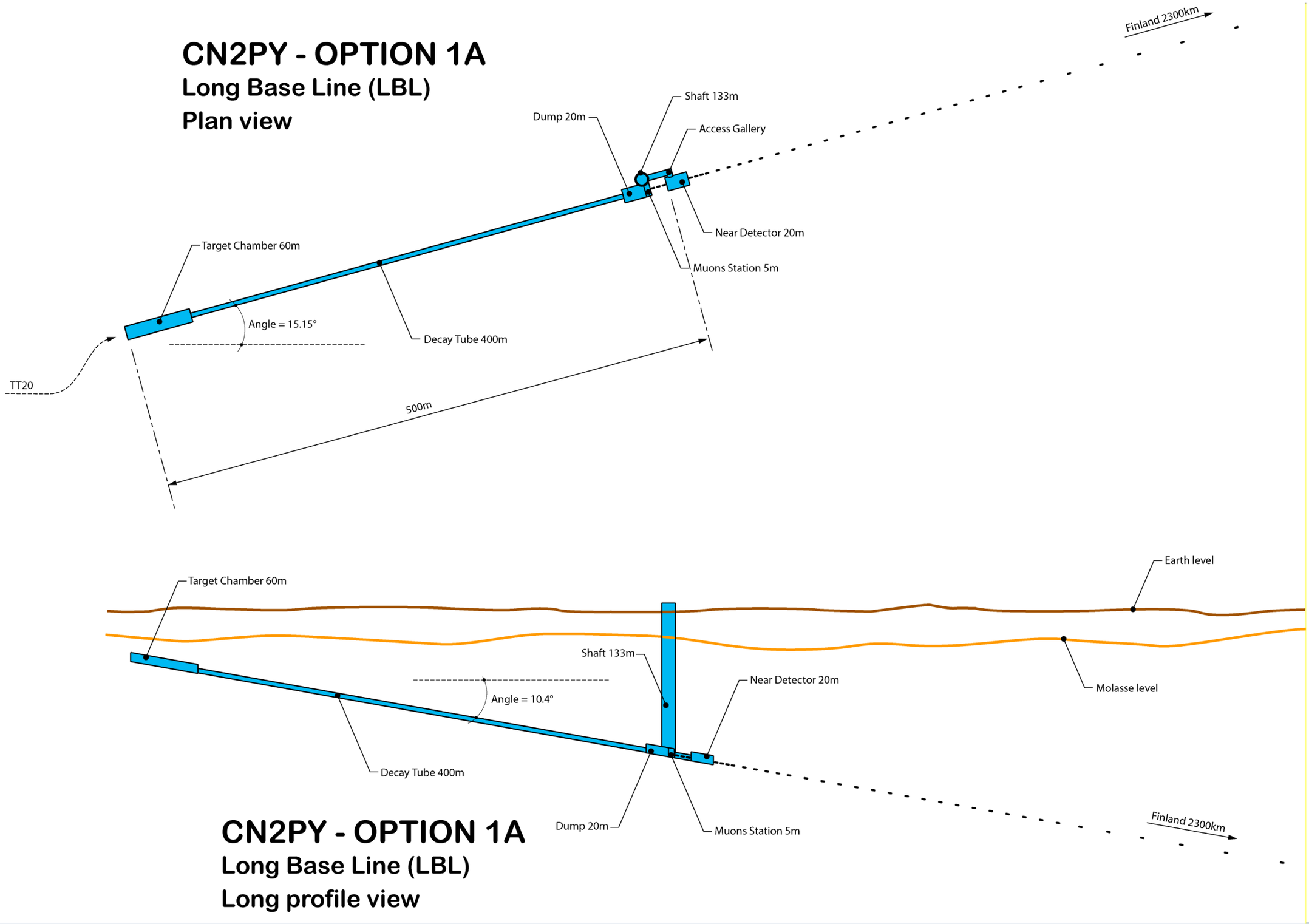
Option B:
Use TT20 for the first stage, target station close to existing targets in North Area



CN2PY Implementation – SPS North Area



CN2PY Option-B Layout study

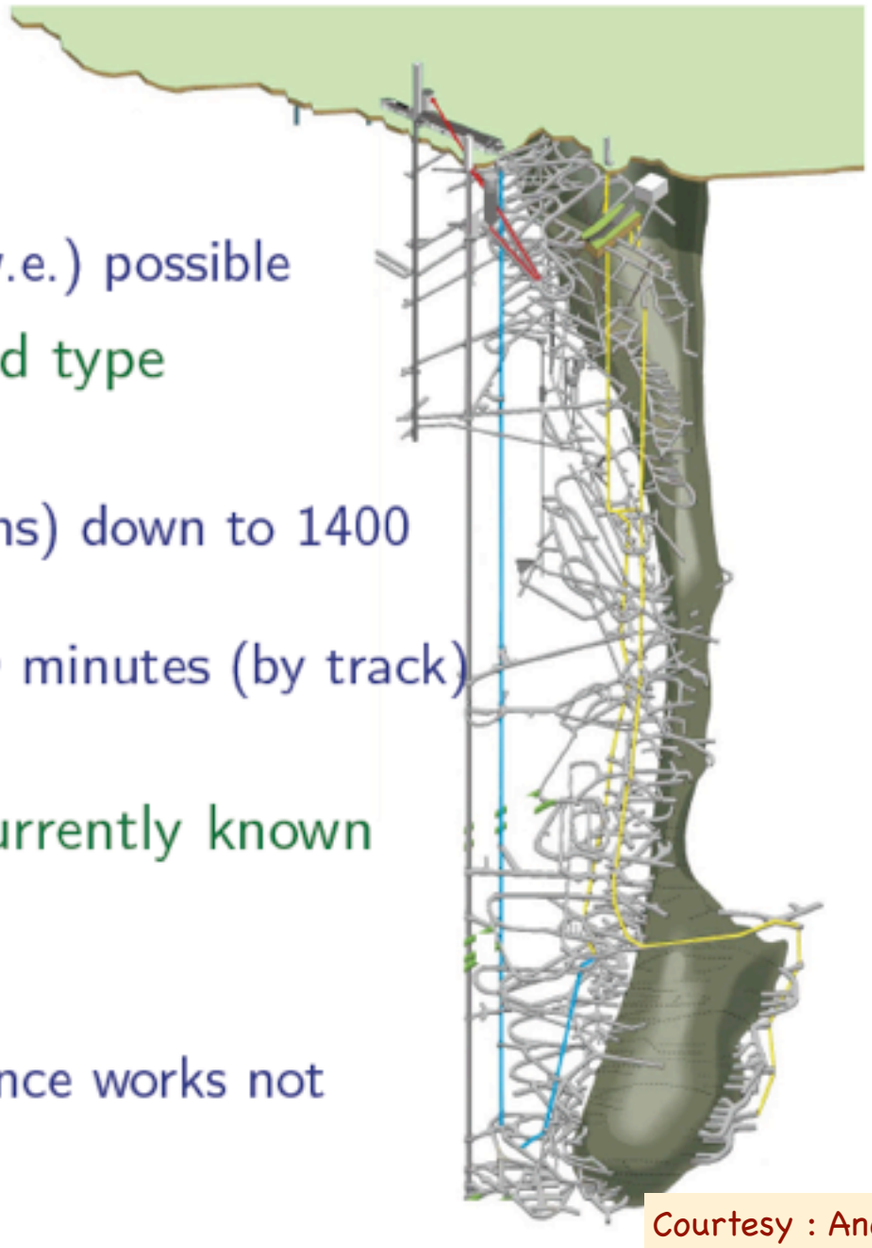


The Pyhasalmi site

Present state of location

Present: The Pyhäsalmi mine (Inmet Mining Ltd., Canada)

- Procudes Cu, Zn, and FeS_2
- The deepest mine in Europe
  - Depths down to 1400 m (4000 m.w.e.) possible
- The most efficient mine of its size and type
- Very modern infrastructure
  - lift (of 21.5 tons of ore or 20 persons) down to 1400 metres takes ∼3 minutes
  - via 11-km long decline it takes ∼40 minutes (by track)
  - good communication systems
- Operation time still 7–8 years with currently known ore reserves
- Compact mine, small 'foot print'
  - water pumping and other maintenance works not major issues

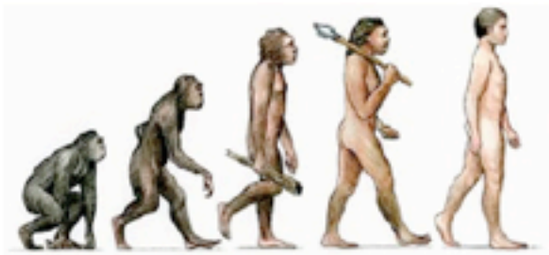


Courtesy : Andre Rubbia - LAGUNA

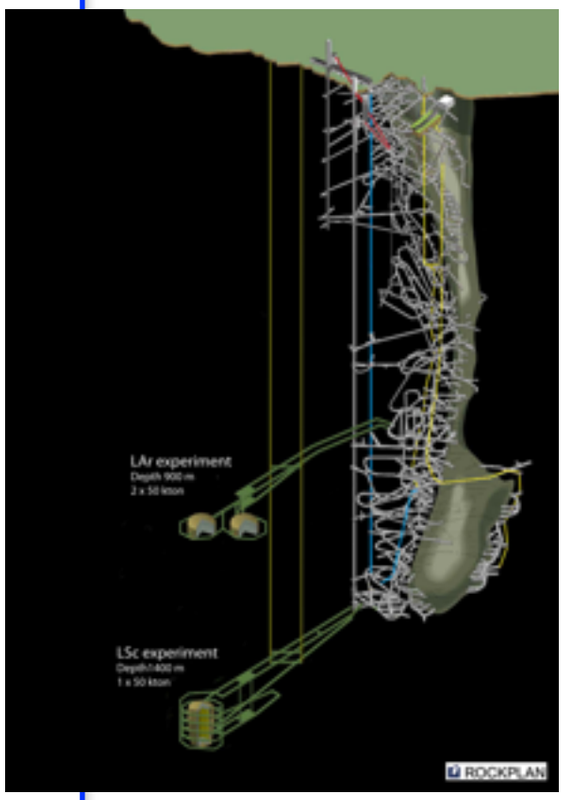
A. Rubbia Fundamental physics at the intensity frontier, Nov-Dec 2011 8

Incremental Approach for Far Detector

Incremental far detector



- **It is very likely that the far detector will be realized *incrementally*:**
  - Phase 0 : excavation (caverns @900m+1400m) and preparation of underground space
  - Phase 1: LAr 20kt @ 900m + LSc 25kt @ 1400m + Fe detector
  - Phase 2: add LAr 50kt @ 900m + add 2nd LSc 25kt + add Fe
  - Phase 3: replace LAr 20kt by LAr 50kt + add Fe



- **Advantages of an incremental approach:**

Produce significant physics results at each phase
Reduce overall risks
Alleviate some funding challenges w/ acceptable total cost
Leave possibility to alter the direction after each phase

A. Rubbia — Fundamental physics at the intensity frontier, Nov-Dec 2011

Courtesy : Andre Rubbia - LAGUNA

CNGS Technology @ 700 kW

- **Limitations:**
  - key elements of the secondary beam line: **target**, **horns**, **beam windows**
  - **layout** and **RP** considerations, SPS RF and beam extraction system
- **SPS upgrade:**
  - limitations : RF power and beam extraction system
  - Possibilities will be studied within the LHC Injector Upgrade project (**LIU**)
  - **750kW** may be reachable, if not understand bottlenecks and mitigation options

Int. per PS batch	# PS batches	Int. per SPS cycle	200 days, 100% efficiency, no sharing	200 days, 55% efficiency, no sharing	200 days, 55% efficiency, 60% CNGS sharing
		[prot./6s cycle]	[pot/year]	[pot/year]	[pot/year]
2.4×10^{13} - Nominal CNGS	2	4.8×10^{13}	**1.38×10^{20}**	**7.6×10^{19}**	**4.56×10^{19}**
3.5×10^{13} - Ultimate CNGS	2	**7.0×10^{13}**	2.02×10^{20}	1.11×10^{20}	6.65×10^{19}

M.Meddahi, E.Schaposnicova - CERN-AB-2007-013 PAF

750kW design limit for the target

working hypothesis for RP calculations

Incremental exposure

We define **exposure** ≈ Npot@50GeV * mass(kt)

	SPS now	SPS+LIU	SPS++	LP-SPL+HP-PS
Proton energy (GeV)	400	400	400	50
ppp	4.00E+13	6.00E+13	7.00E+13	2.50E+14
Tc (s)	6	6	6	1.2
Beam power (MW)	0.43	0.64	0.75	1.67
Global eff	0.85	0.85	0.85	0.85
Beam sharing	0.85	0.85	0.85	1
Running (d/year)	200	200	200	200
Npot/year	8.32E+19	1.25E+20	1.46E+20	3.00E+21
Npot equiv at 50 GeV	7.00E+20	1.00E+21	1.20E+21	3.00E+21

}4xPS2

Phase 1 + SPS+LIU: 5+5 years running : 200e21 pot*kt

Phase 2 + SPS++: 5+5 years running : 840e21 pot*kt

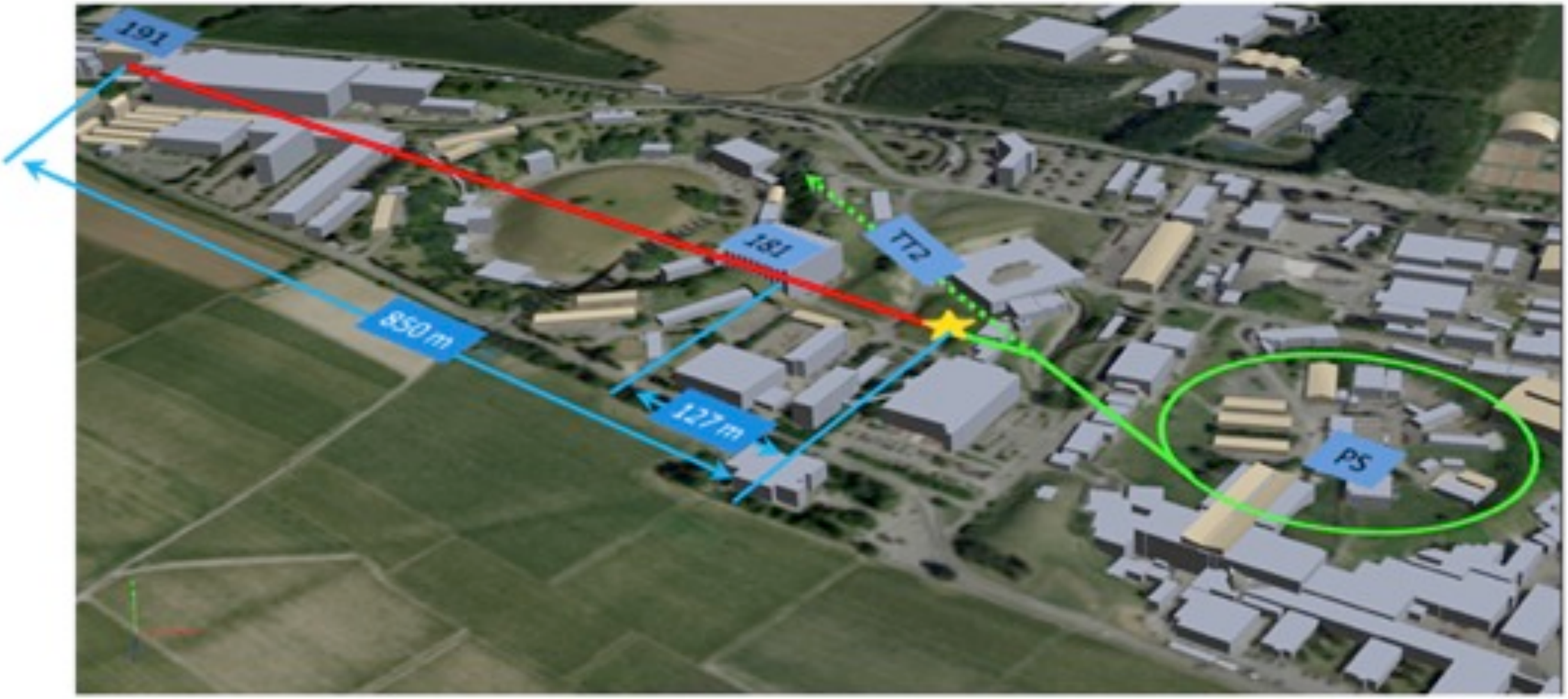
Phase 3 + HP-PS: 5+5 years running : 3000e21 pot*kt

A. Rubbia Fundamental physics at the intensity frontier, Nov-Dec 2011

Courtesy : Andre Rubbia - LAGUNA

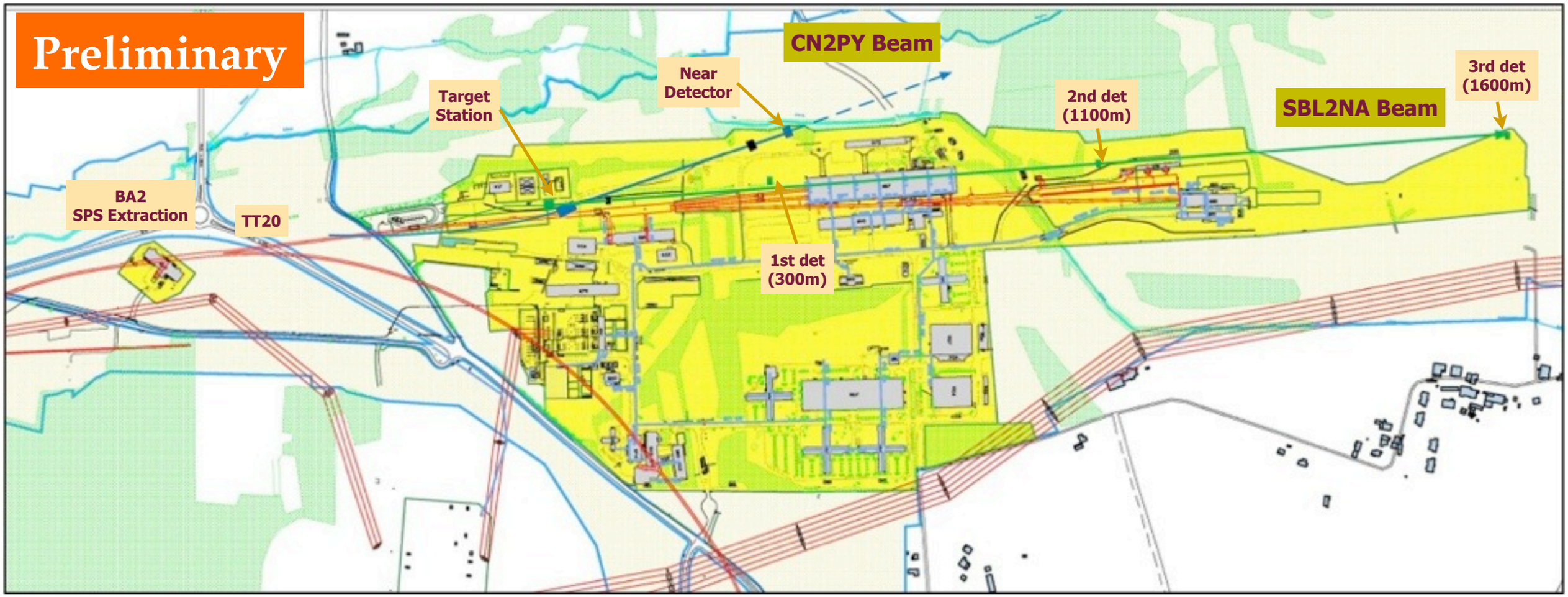
PS Short Baseline ν-beam

- Short baseline to search for anomalous ν oscillations – sterile ν's ??



- Beam line originally operated in early 80's for PS169, PS181, PS180(BEBC)
- Near (**150t**) + Far(**600t**) detector with **ICARUS LArgon technology**
- Expect : **6.13 10^{19} ÷ 2.1 10^{20} pot/y @ 20 GeV**, depending on beam sharing
- reviving an old facility not trivial - studies on technical issues and cost to be made

NA Long & Short Baseline ν beams



- **CN2PY Beam layout parameters**
  - 10.4 deg downwards slope to point to Finland
  - 15.1 deg angle wrt North Area beams
  - target station at ~34m underground
    - 20 m deeper than the existing TCC2 targets
    - ~6m of concrete shielding around to allow 2MW operation
  - decay pipe ~300-400m long
  - near detector at ~500m, 116m underground, within the CERN area

- **Short-Baseline beam**
  - horizontal (or slightly upwards) beam line
  - short decay pipe (~50m) followed by the beam dump
  - target station at ~10m underground, adjacent to existing TCC2 target station
  - possibilities for detectors at 300, 1100, or 1600m
    - profit from existing infrastructure, including cryogenics
  - detector position and on/off axis location depending on physics
  - requires fast-extracted beam at ~100 GeV/c

From design studies to projects – European Strategy

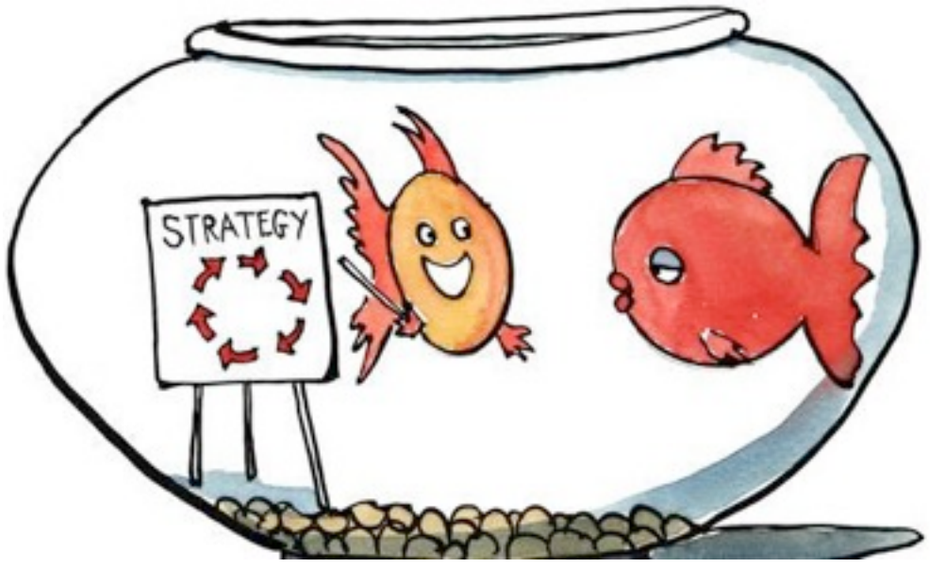
The European strategy for particle physics 2006

4. In order to be in the position to push the energy and luminosity frontier even further it is vital to strengthen the advanced accelerator R&D programme; *a coordinated programme should be intensified, to develop the CLIC technology and high performance magnets for future accelerators, and to play a significant role in the study and development of a high-intensity neutrino facility.*

6. Studies of the scientific case for future neutrino facilities and the R&D into associated technologies are required to be in a position to define the optimal neutrino programme based on the information available in around 2012; *Council will play an active role in promoting a coordinated European participation in a global neutrino programme.*

European Strategy - The Challenge

- The interest for ν-physics as high as ever. The latest results changed the landscape and will help to better define a future ν-program among the all possible options currently under study
  - **T2K :** θ_{13} non-zero and **large**
  - **NuMI/MINOS :** θ_{13} , ν ↔ anti-ν results
  - **CNGS:** # ν_τ events, ν-velocity
  - **Reactor experiments :** θ_{12}, θ_{13} measurement/new limits



- Propose a European based ν-physics program,
  - with strong, interesting, unique, physics case,
  - that completes and possibly extends similar programs elsewhere,
  - that can be realized in // to LHC and its upgrades,
  - builds upon the experience gained with today's facilities (CNGS, T2K, MINOS),
  - has an incremental approach balancing short and long term prospects to face budget and technical challenges, with clear physics goals at each stage.

Neutrino Physics in Europe - Roadmap proposal

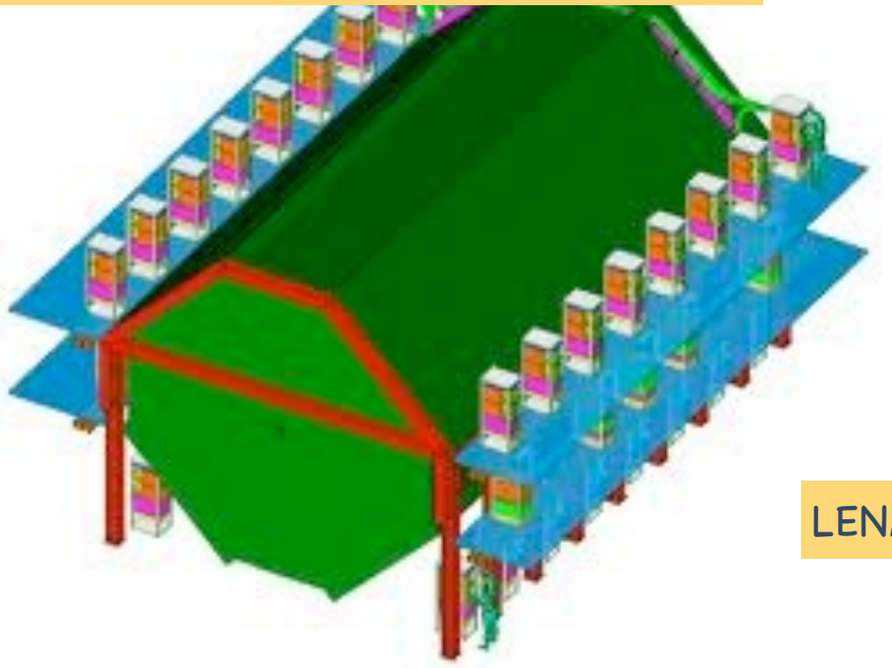
- The far detectors and underground cavern options will determine the way to go
  - possibility for single or mixed detector technology
  - collaboration strength to design, build and operate the detectors
  - budget and administrative effort to setup the physics lab at the mine
  - The Pyhäsalmi site, presently under study in LAGUNA-LBNO, is such an option

ν-source:

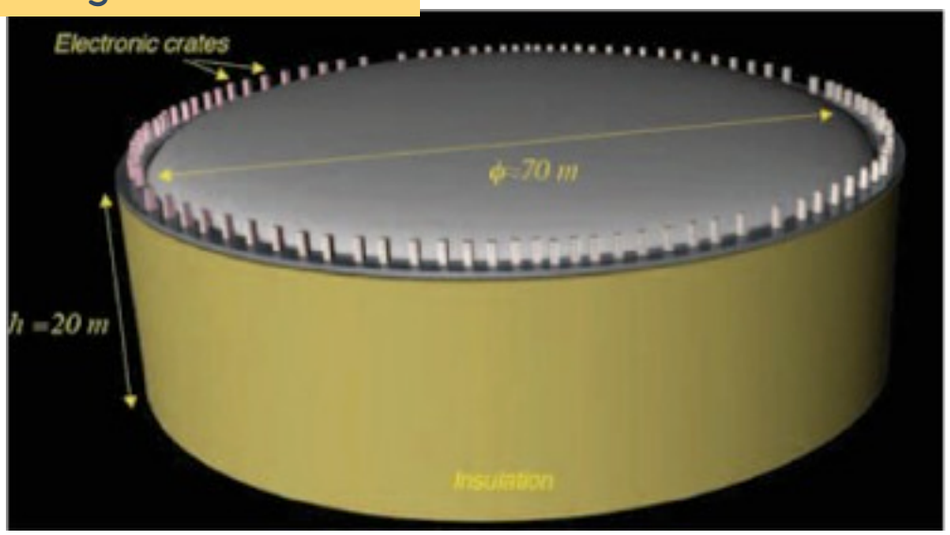
- CN2PY LBL beam : SPS+upgrades (700kW), HP-PS (2MW)
  - a third generation conventional LBL beam for CPV, MH studies
- Setup an R&D program as continuation of the present DS, for the ultimate facilities
  - MICE, targetry (RIB,...), fast acceleration, ...
  - Collaboration at a GLOBAL scale
  - fully cover the ν-physics questions: precision, physcis beyond SνM,...

Neutrino Physics Detectors

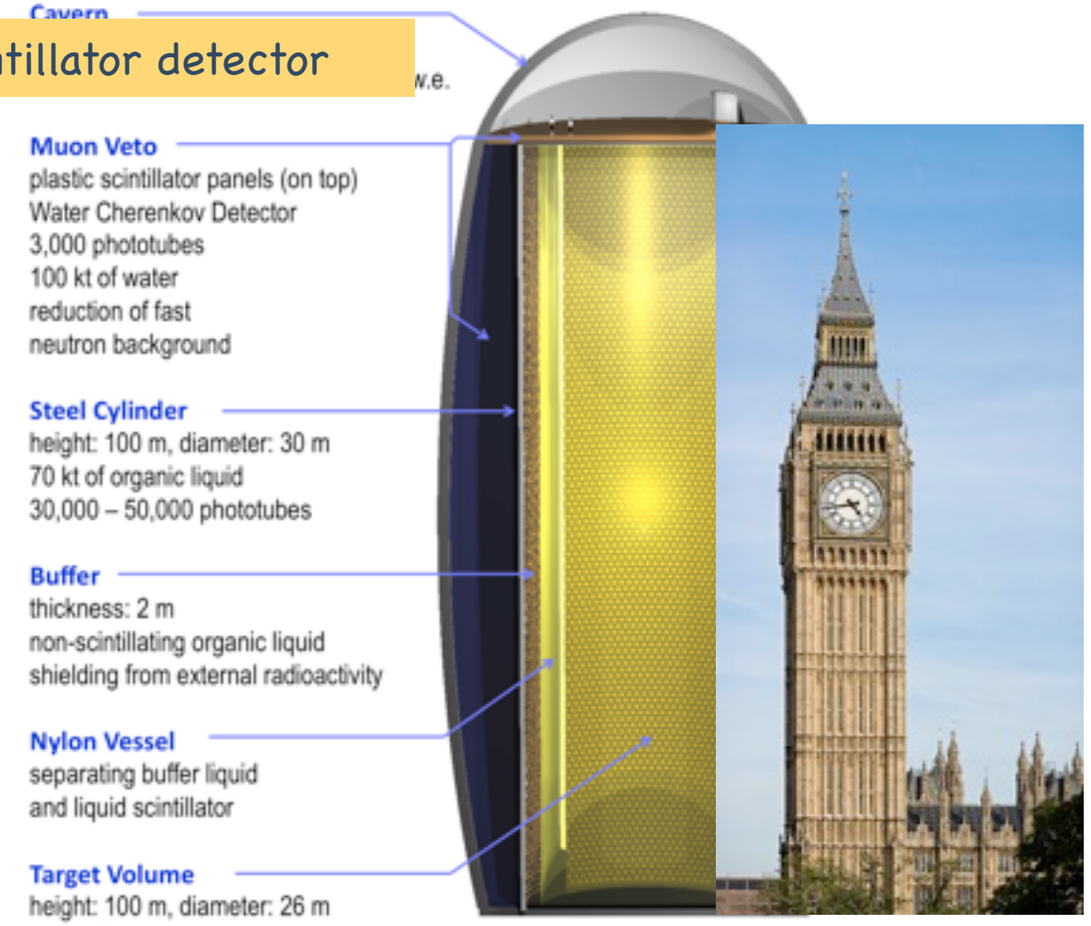
MIND (MINOS) - Fe/Scint. detector



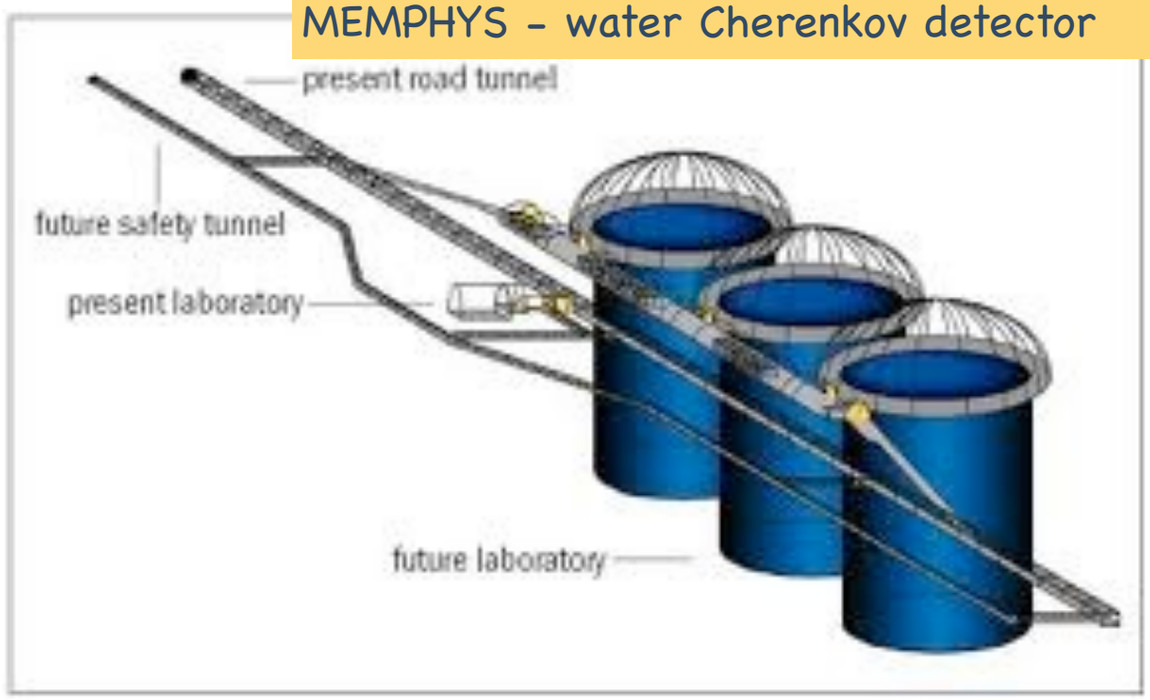
GLACIER - LArgon detector



LENA - liquid scintillator detector



MEMPHYS - water Cherenkov detector



European Strategy - The process (Strategy Group)

- Call for proposals by the **Strategy Secretariat** send out on February 1, 2012
  - Bottom-up approach
  - Individuals or groups to submit proposals (<15 pages) directly to the Secretariat

- **Timeline:**
  - **September 10-12, 2012 : Cracow Symposium September**
    - Physics of Neutrinos is a separate session
    - deadline for proposals to the session conveners : **July 31st, 2012**
  - **January 21-26, 2013 : Strategy group closed session**
    - discuss outcome of Cracow symposium + late proposals until **October 15, 2012**
    - produce the **Briefing Book** and **Executive Summary** to the CERN council
  - **March 2013** : special CERN Council meeting to finalize strategy proposal
  - **June 2013** : special CERN Council meeting + EU ministers to endorse proposals

European Strategy - The process (Neutrinos)

Neutrino Timeline

- **May 14-16, 2012 - Neutrino "Town-Meeting" at CERN**
  - status of various projects, DS, ideas ==> invitation end of this week
  - discuss and possibly propose a coherent roadmap document for the next 5-years
  - program committee setup (23 people) to prepare the roadmap document

- **April 2-3, 2012 - Program Committee meeting**
  - prepare first draft of roadmap document as input to the town meeting

- **End June/July 2012 - Wrap-up meeting of Program Committee**
  - finalize roadmap document - submission

Your presence- input -feedback is important !!