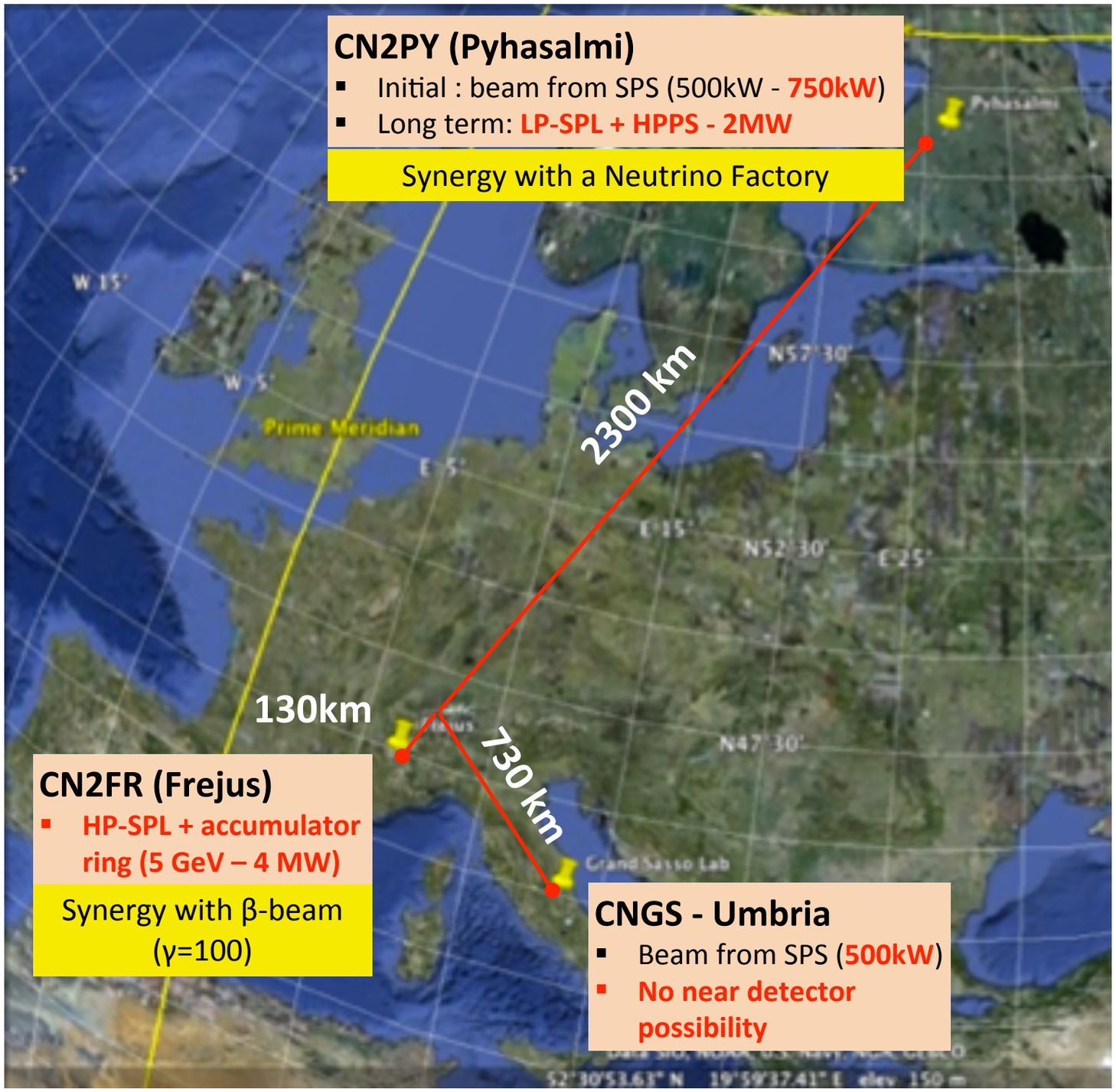
The CN2PY Beam…

…with feedback from many colleagues - **thanks!**

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



CNGS Technology - Upgrades?

Today :

- **SPS a key asset for CERN**
  - 450 kW nominal beam power today
    - 4.0 10^{13} prot @ 400 GeV, 6s cycle
    - 4.5÷4.7 10^{19} pot/y achieved

Future-I (>LS2, ~2018) :

- **SPS upgrade potential**
  - 750 kW nominal beam power
    - 7.0 10^{13} prot @ 400 GeV, 6s cycle
    - 0.8÷1.3 10^{20} pot/year

Future-II (>2025?)

- **HP-PS: a dedicated proton source**
  - provide 1.6 MW @ 30-50 GeV

Beam Intensity Upgrades - Injectors (PSB, PS, SPS)

E. Shaposhnikova, R. Garoby - LiU-LLBNO/CERN

- **Present limitations:**
  - PSB-to-PS injection, losses
    - controls
  - PS-to-SPS extraction, losses
    - MTE, bunch to bucket injection
  - SPS RF power
    - additional RF cavities
    - injection beyond transition
  - Shielding in PS
    - ongoing

Parameters	SPS record at 450 GeV		HL-LHC at 450 GeV	
	LHC	CNGS	I	II
bunch spacing [ns]	25	5	25	50
bunch intensity /10^{11}	1.3	0.13	2.2	3.6
number of bunches	288	4200	288	144
total intensity /10^{13}	3.7	**5.3**	**6.3**	5.2
long. emittance [eVs]	0.7	0.8	0.8	0.9
norm. H/V emitt. [μm]	3.0	8/5	2.5	3.0

- Studies ongoing to understand the limits and identify possible upgrade options
  - constraint : maintain the machine performance for LHC beams

- Aim to reach **~750kW** of nominal beam power (7.0E13, 6s cycle)

CNGS Beam Upgrades ? (2)

- **Limitations:**
  - key elements of the secondary beam line to increased beam power: **target**, **horns**, **beam windows**
  - **layout** and **RP** considerations (impact to environment - beam permit?), SPS RF and beam extraction system

- **Considerations** - to be further studied depending on physics program:
  - new target/horn optimization for new (lower) energy
  - near detector, optimized(?) decay pipe length, beam dump

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 head

working hypothesis for RP calculations

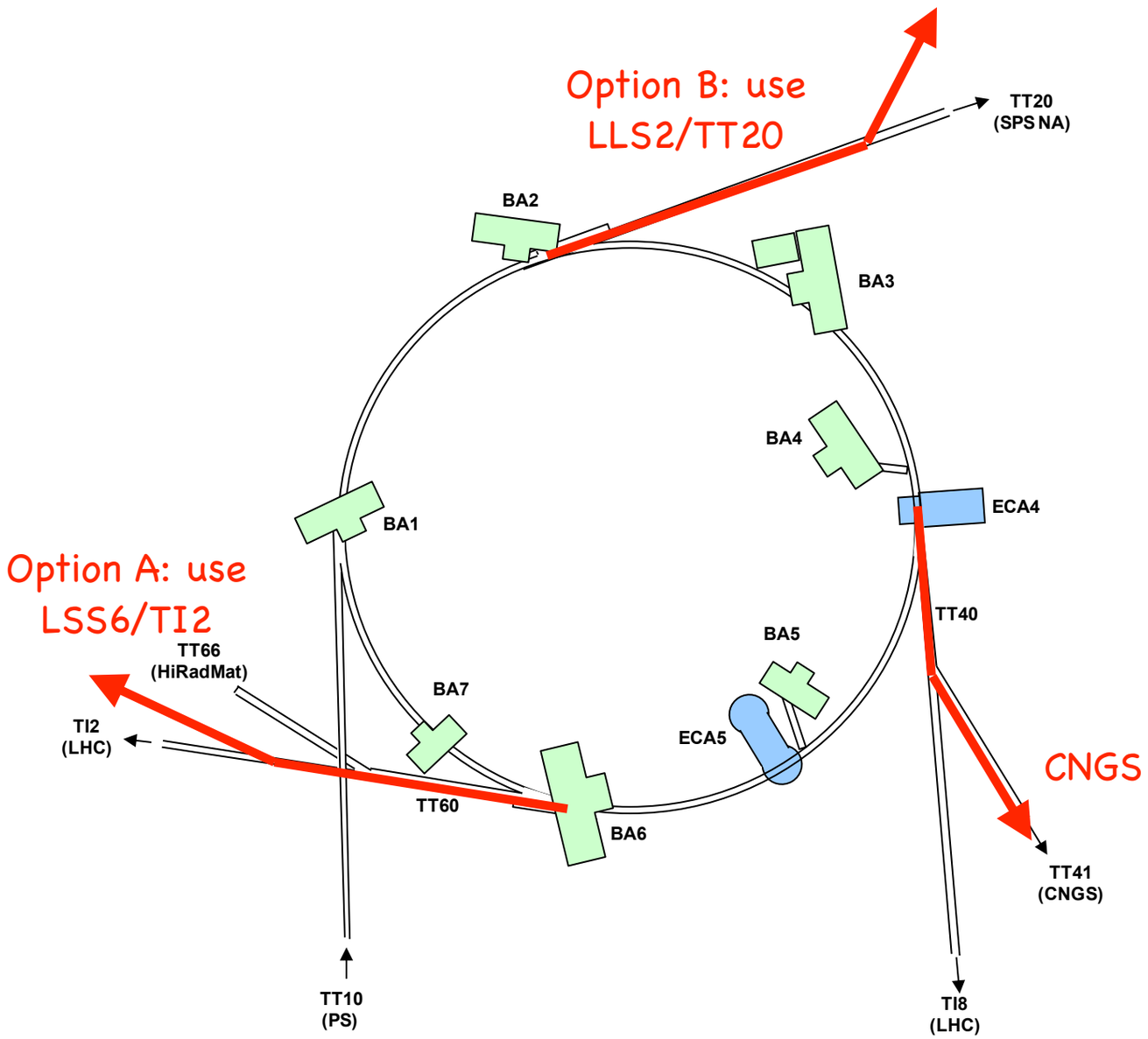
CERN ν-beam to Pyhasalmi - CN2PY

- Phase 1 layout using the 400 GeV beam from SPS

Possibilities:

- **Option A**: LSS6 extraction, target near BA2
  - LSS6 fast extraction and TT60 beam line exists
  - New switch to direct the proton beam towards North
  - Long (~1.6km) proton tunnel to bring the beam towards BA2

- **Option B** : LSS2 extraction, target near TCC2
  - new fast extraction system in LSS2
  - TT20 beam line exists
  - Target area near existing TCC2



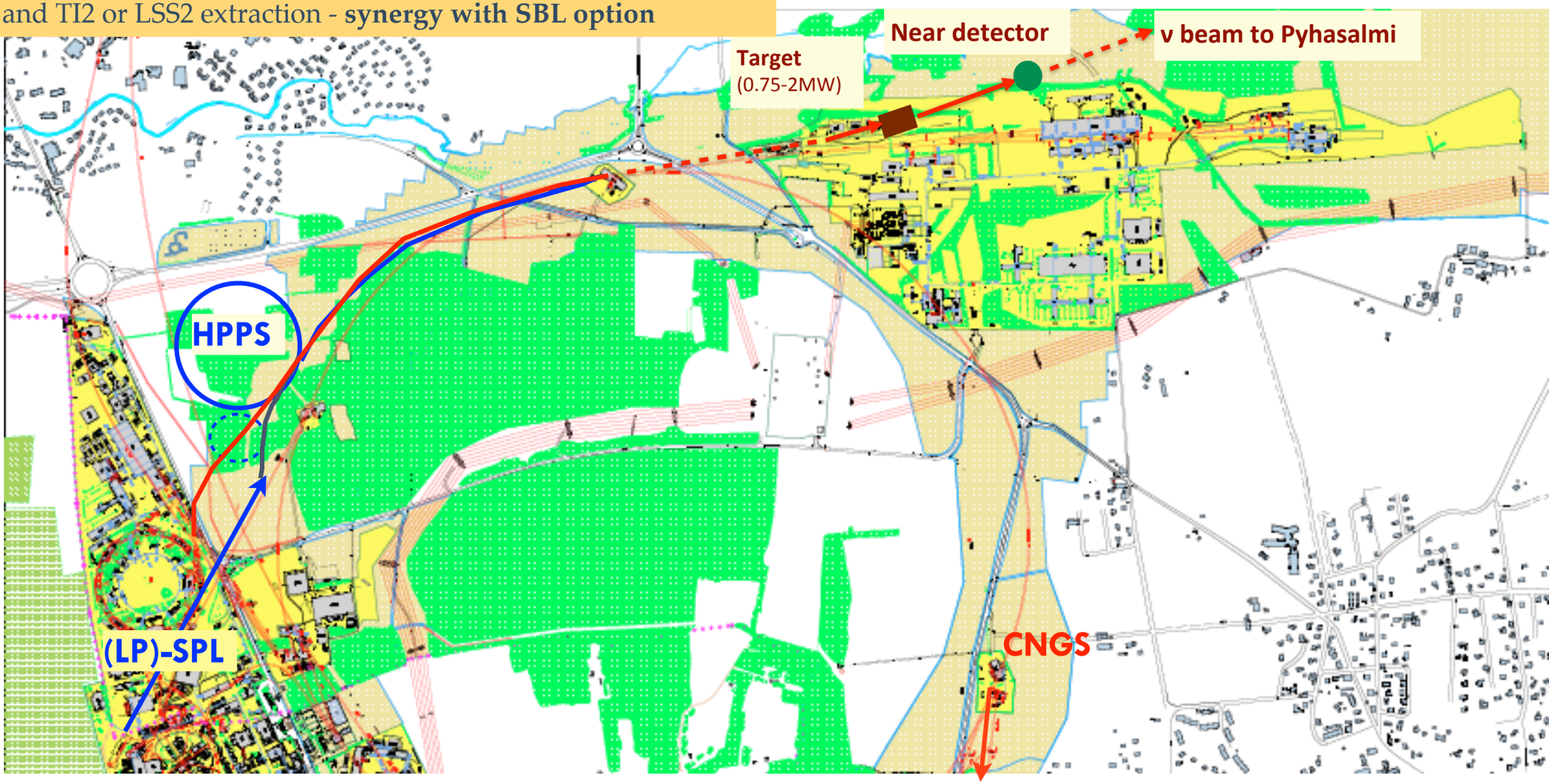
Courtesy : B. Goddard - LLBNO

CERN ν-beam to Pyhasalmi - CN2PY

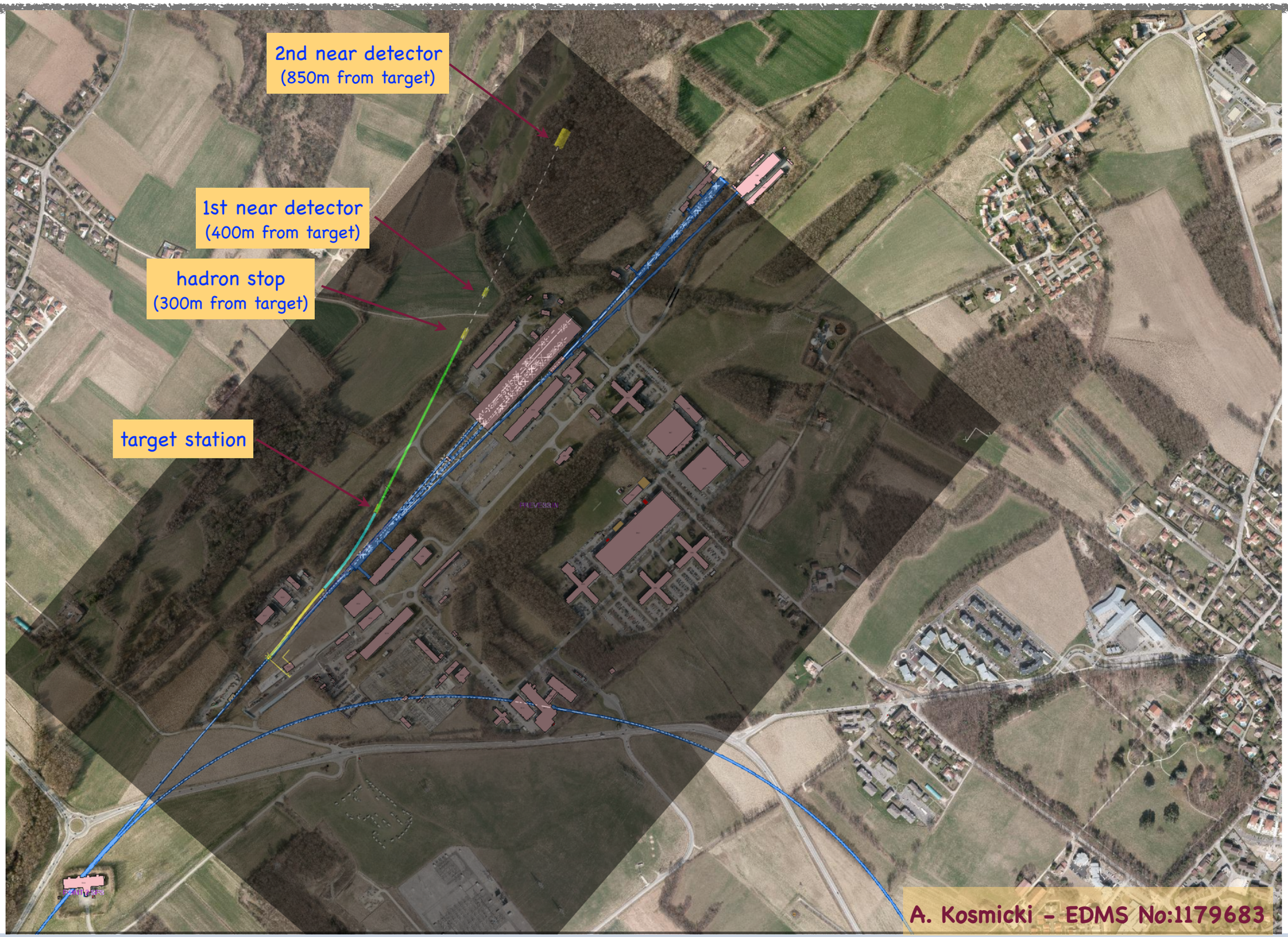
Option A:
Target station close to BA2

CERN ν-beam to Pyhasalmi - CN2PY

Option B:
Target station and ND in the North Area, use existing TT20 line and TI2 or LSS2 extraction - **synergy with SBL option**

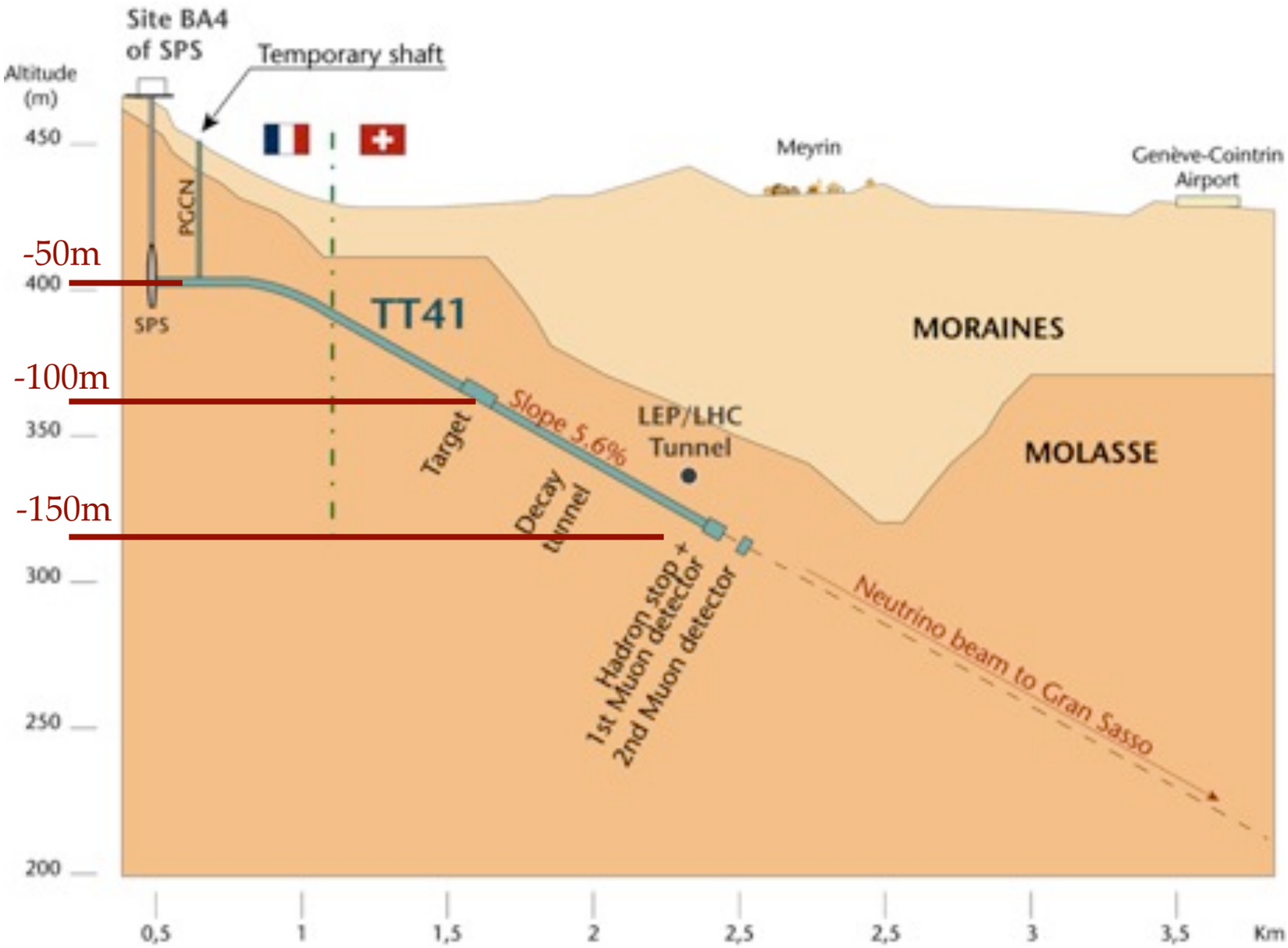


CN2PY Option-B Layout study



CN2PY - Layout considerations

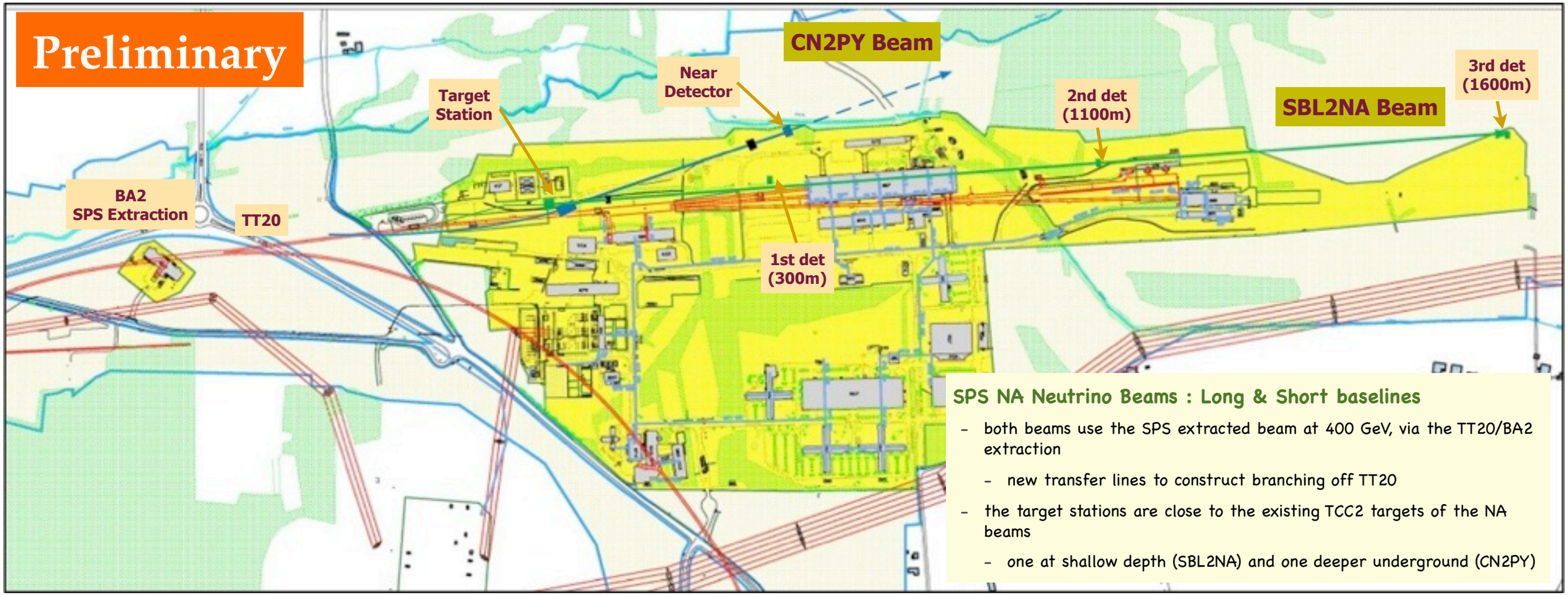
- The depth for the installations is the major concern
  - 18% slope compared to 5.6% for CNGS



CN2PY Beam - Generic Layout		
	Distance	**Depth**
Target	-	0 m
Hadron stop	300 m	-54.3 m
Muon station	330 m	-59.8 m
Near detector	400 m	-72.6 m
Middle detector	830 m	-150.6 m

- Starting the beam from the SPS level adds **~100m** to the depth of the installations
- Staying in the **molasse layer** has quite some advantages for the CE (stability) and radiation to environment (underground water activation issues) issues

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

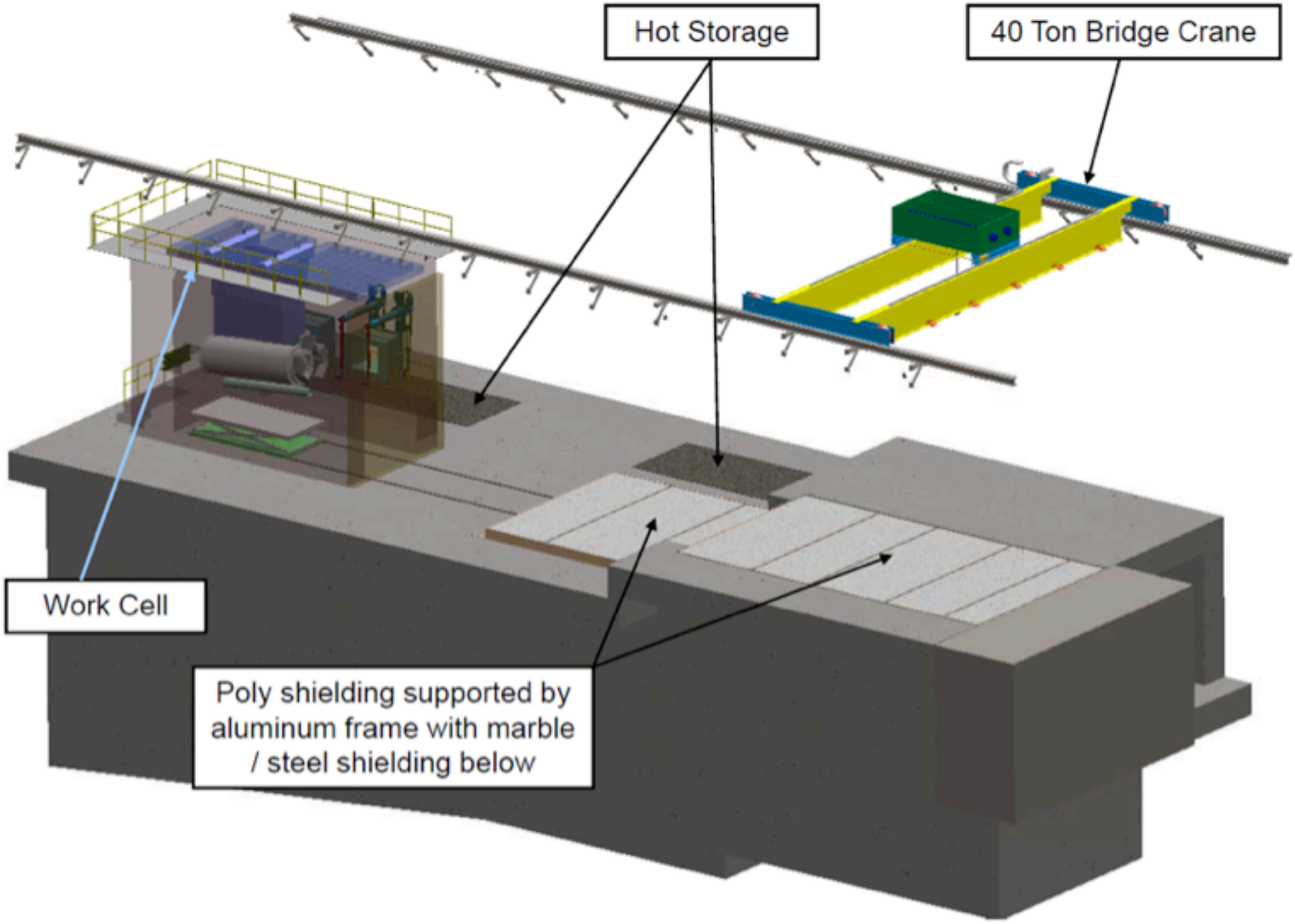
Short-Baseline beam (SBL2NA)

- 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

CN2PY/SBL2NA - A 3rd Generation ν-beams

- Profit from the existing experience from the other installations:
  - **CNGS** : radiation, tritium issues, target lifetime/operation
  - **T2K** : high-power design, He vessel for target and decay pipe, remote handling
  - **NuMI** : layout design access and repair of "hot" equipment
- .. and the design options for future projects
  - **LBNE** : target station layout options
  - **Neutrino Factory** : target station design
  - **EUROnu/SuperBeam** : target station design

LBNE – Target Chamber

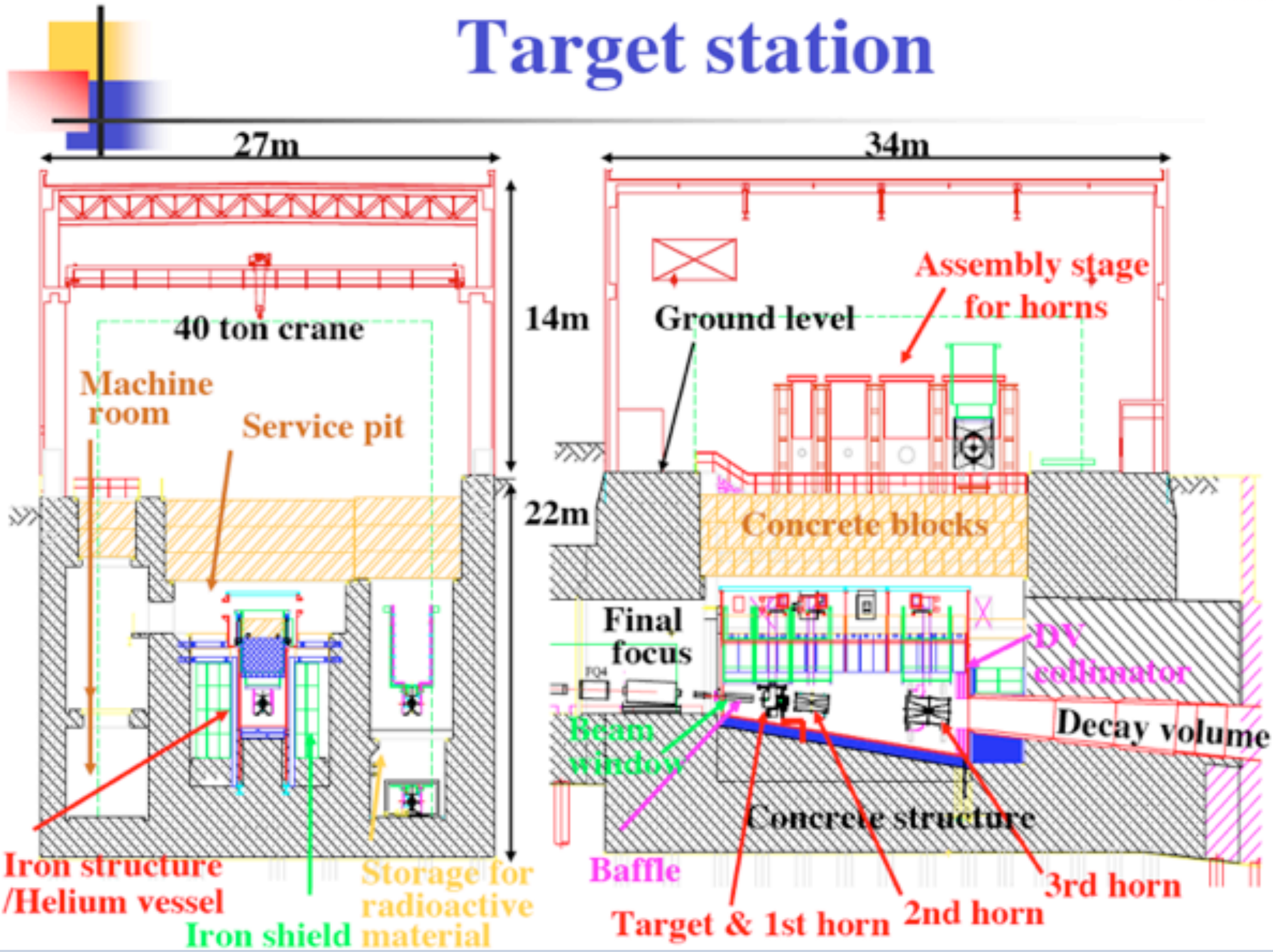


P. Hurh: LBNE Remote Handling Overview for NBI 2010

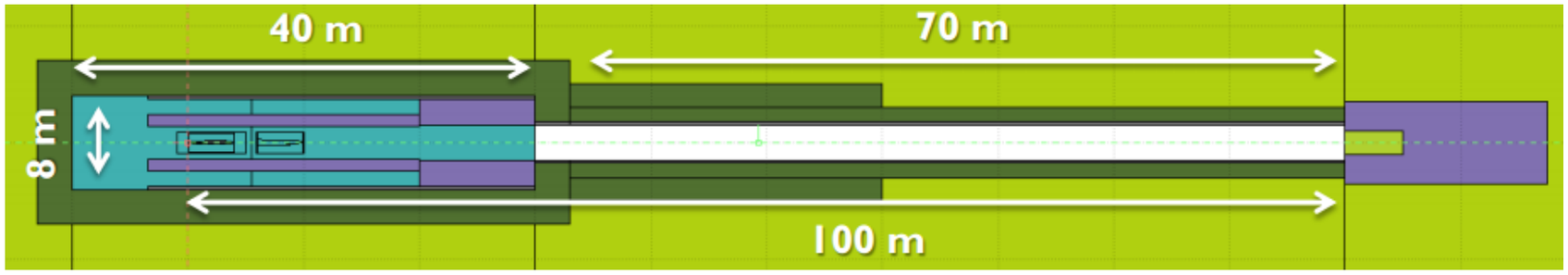
T2K Target Chamber

Y. Yamada/KEK - NBI10

Target station

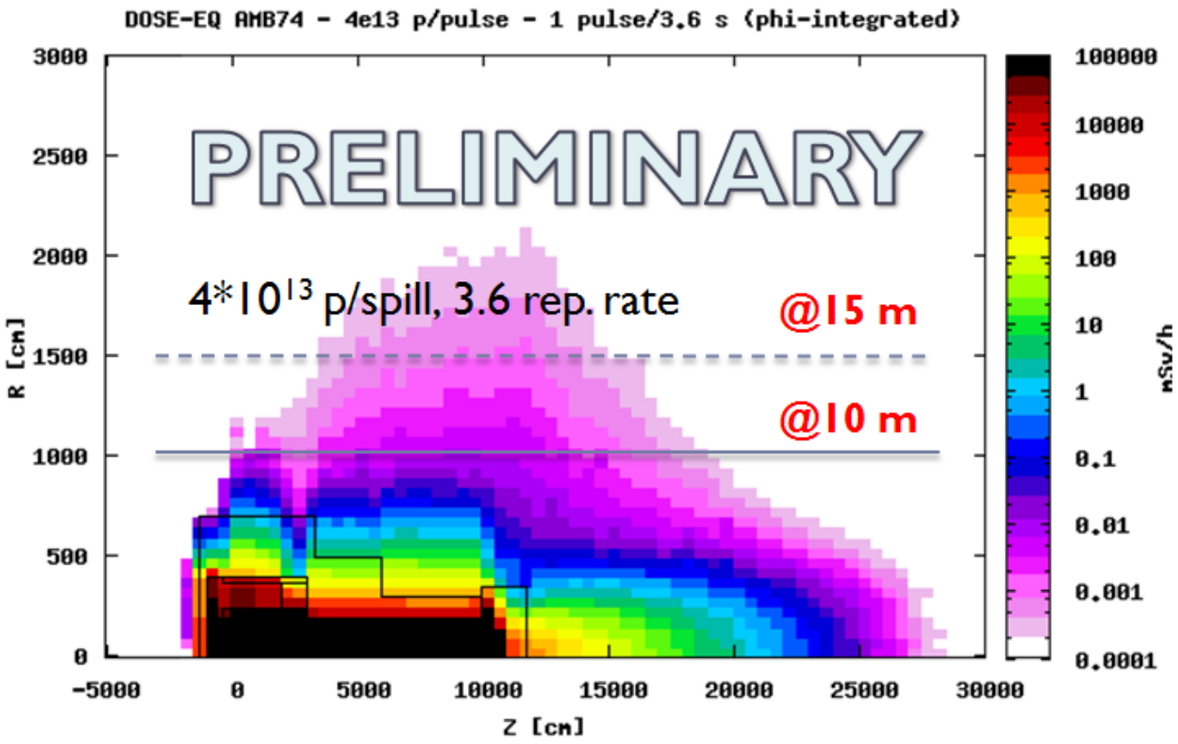


SBL2NA – RP considerations



Element	kJ/spill	kW avg.
Dump core (C)	162.29	45.08
DP inner Fe lining	139.50	38.75
Target Fe sh.	130.15	36.15
Dump (Fe)	79.01	21.95
Target Fe sh. (down)	37.87	10.52
DP upper Fe lining	10.29	2.86
DP concrete shielding	6.40	1.78
Horn inner conductor	2.39	0.66
Target	1.97	0.55
Reflector inner conductor	1.48	0.41

- In a first approximation the SBL2NA beam can receive the same beam intensity presently delivered to CNGS
  - 4÷5 10^{19} pot/year
  - further increase can come as by-product of the SPS upgrades, and a possible shorter SPS cycle (3.6s instead of 6s for CNGS) due to the lower beam energy
- Preliminary FLUKA studies
  - RP issues can be easily mitigated with appropriate shielding
  - Muons rate to near detector (330m) can be kept low: 1 μ/spill
  - Soil activation (^{3}H, ^{22}Na) and RP to environment can be under control with appropriate design



M. Calviani, A. Ferrari - CERN

New fast extraction in SPS LSS2?

B. Goddard - CERN

- Constraints : must keep slow extracted beam capability to North Area
  - Hybrid extraction needed for slow and fast extracted beams

First preliminary feasibility study

- Solution found with displacement of ZS girder and TCE downstream by 3m
  - Two new MKEX kickers - [larger H aperture version than MKE]
  - Extraction energy limited to 100 GeV with 1μs kicker rise time
    - Can be later modified to extract 400 GeV, with a rise time 3-4μs
  - Emittance limited to about 8 π.um in H, and 5 π.um in V

Beam Intensity Upgrades - HP-PS

Y. Papaphilippou, M. Benedikt, R. Steerenberg - LLBNO/CERN

Preliminary !

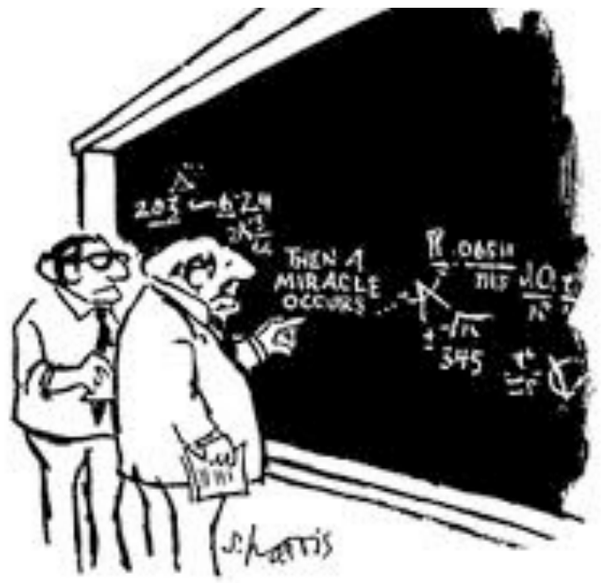
$$P = q f_r N_p E_k$$

Parameters	PS2	HP-PSa	HP-PSb	HP-PSc	HP-PSd
Circumference [m]	1346.4	**1256**	1009	763	**1256**
Symmetry	2-fold	**3 / 4-fold**			
Beam Power [MW]	0.37	**2.0**			
Repetition rate [Hz]	0.42	**2**	2	2.6	**1.3**
Kinetic Energy @ inj./ext. [GeV]	4/50	**4/50**	4/40	4/30	**4/50**
Protons/pulse [10^{14}]	1.1	**1.25**	1.6	1.6	**1.9**
Dipole ramp rate [T/s]	1.4	**6.1**	6.0	7.5	**4.0**
Bending field @ inj/ext. [T]	0.17/1.7	**0.17/1.7**	0.21/1.7	0.27/1.7	**0.17/1.7**
Fractional beam loss [10^{-4}]	35.1	**6.5**	5.0	4.0	**6.5**
Space-charge tune-shift H/V	-0.13/-0.2	**-0.2/-0.2**			
Lattice type	NMC arc, doublet LSS and DS	**Resonant NMC arc, doublet LSS**			
Norm. emit. H/V [μm]	9/6	**6.8/6.7**	8.6/8.5	11/11	**10.5/10.3**
Max. beta H/V [m]	**60/60**				
Max. dispersion [m]	3.2	**5**			

- Getting 2MW of beam power is not straight-forward
  - ramp rate, space-charge, losses, acceptance, space(circumference), **cost!**

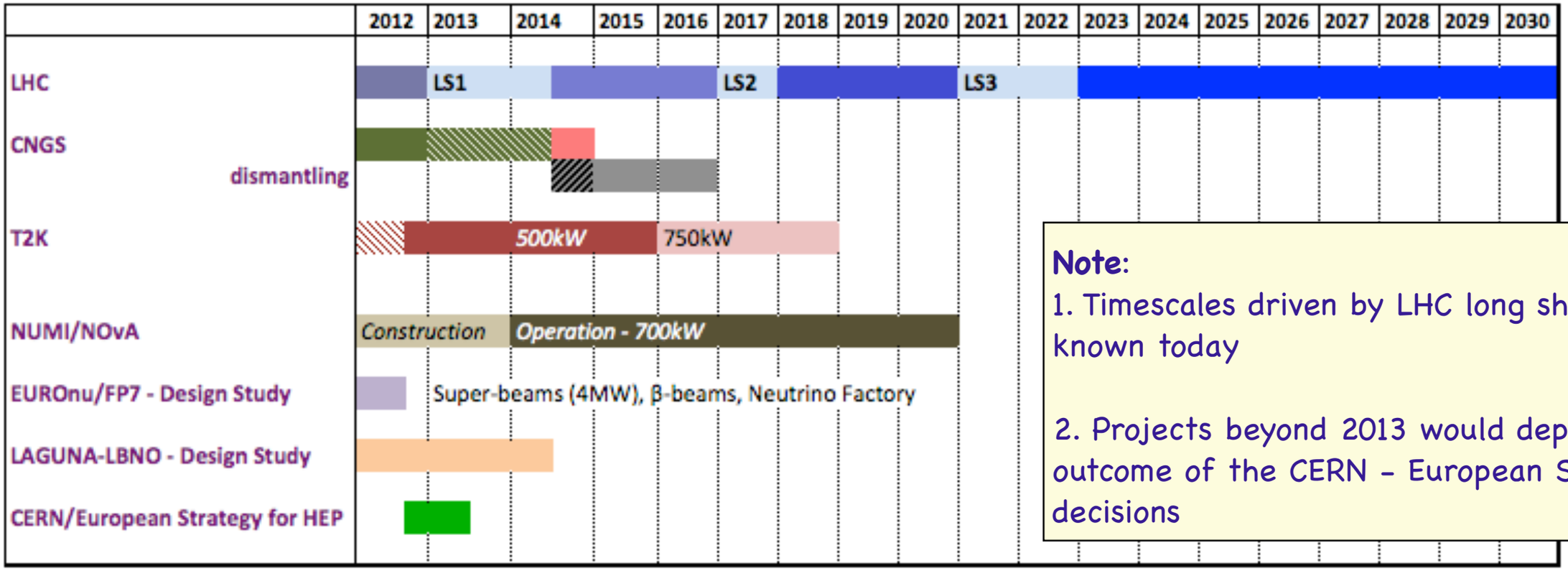
The CN2PY Beam...

including realistic timescale and cost estimate



"I think you should be more explicit here in step two."

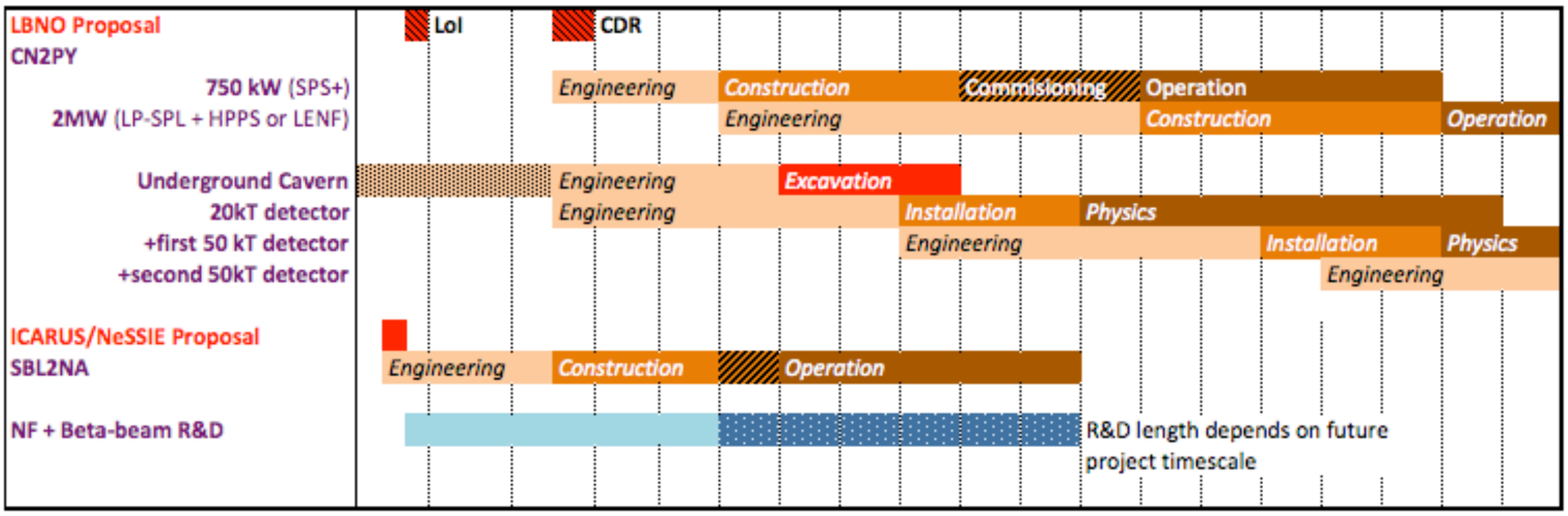
Future Neutrino Beams – possible timeline



Note:

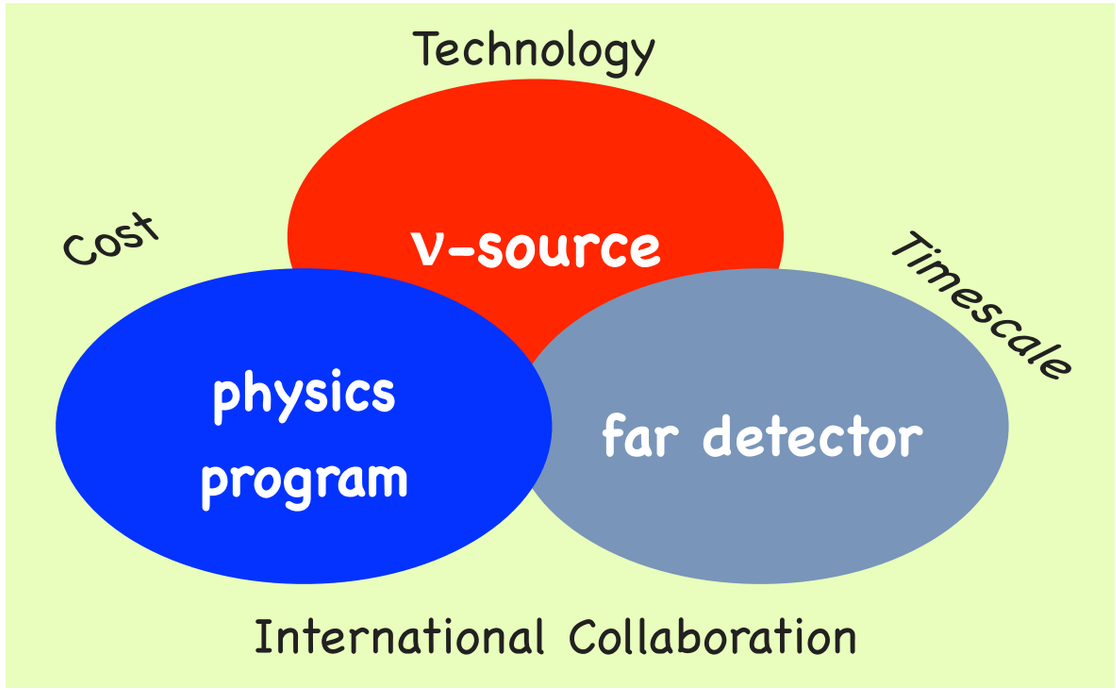
1. Timescales driven by LHC long shutdowns as known today

2. Projects beyond 2013 would depend on the outcome of the CERN – European Strategy decisions



Summary

- The new measurements enhance the interest to ν-physics and allow to better define a competitive and possibly affordable **incremental ν-physics program**



- CERN/Europe has the experience and the potential to play an important role in the new, third generation ν-experiments

- The CN2PY proposal for a future ν-experimental program
  - broad physics potential (CP-violation, mass hierarchy,..)
  - can accommodate different detector technologies, beam options, and synergy with ν-factory
  - an EoI is in preparation and will be submitted to the CERN/SPSC this month.
- The short-baseline option (SBL2NA) can be envisioned as initial step
  - for an independent physics program and detector R&D, LoI already available in SPSC