Beamlines for future projects

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A.Kosmicki, A.Caldwell, I.Efthymiopoulos, M.Meddahi, C.Bracco, K.Cornelis, R.Assmann, C.Hessler, C.Carli, M.Calviani, R.Steerenberg, P.Sala, J.Osborne, V.Mertens
and many others

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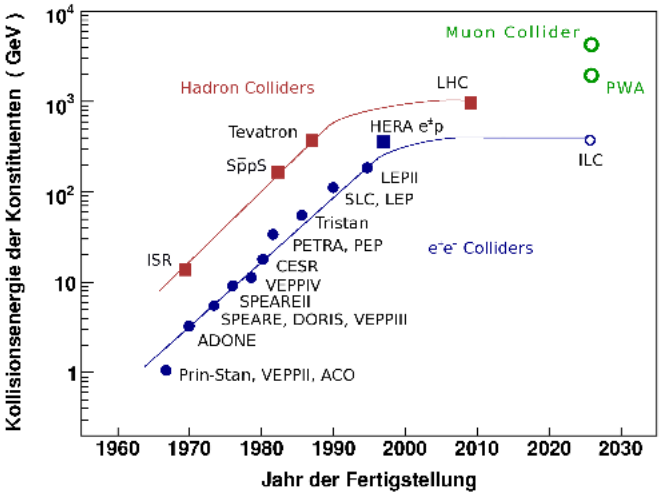
- Proton Driven Plasma Wakefield Acceleration beamline from SPS
- Options for new short-baseline neutrino beamlines in PS or SPS
- Neutrino beamlines under study for LAGUNA-LBNO
- Radiobiology at LEIR
- Status/plans
- Conclusion

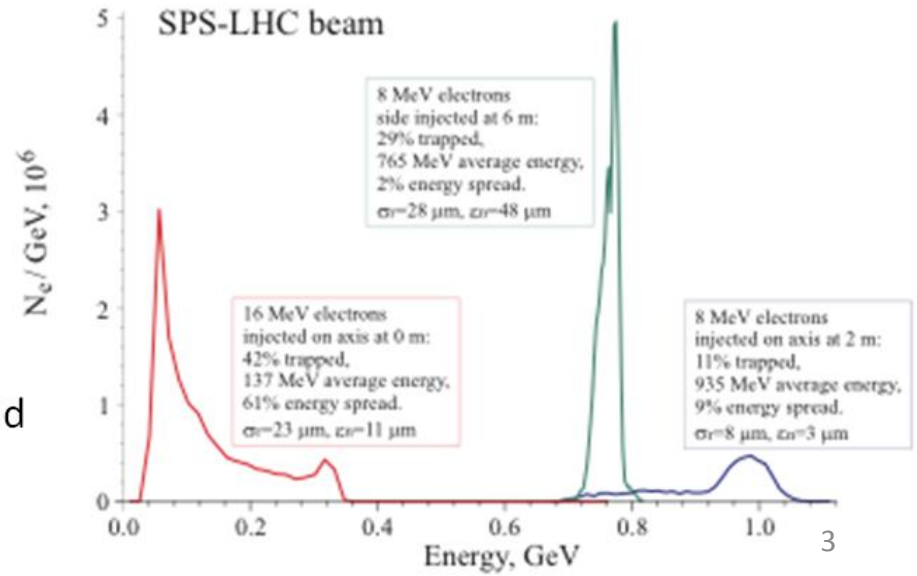
PDPWA Motivation



$$E_{z,\max} \approx 2\ \mathrm{GeV/m} \cdot \left(\frac{N_b}{10^{10}}\right) \cdot \left(\frac{100\ \mu\mathrm{m}}{\sigma_z}\right)^2$$

- Investigation of 'next generation' accelerating method
- Aim to reach 1 GeV in 10 m plasma (proof of principle)

Particle-in-cell simulations predict acceleration of injected electrons to beyond 1 GeV.



Courtesy A.Caldwell

What is needed for PDPWA

1. **Beam production:** Done in the SPS. Exists.
2. **Beam extraction and transport to plasma:** Extraction regions and tunnels exist. Beam line elements to be reused or installed (existing old magnets or new).
3. **Bunch compressor:** Not evident. Must be integrated in SPS and/or beam transport line. **Not for first phase of experiment**.
4. **Plasma cell:** To be contributed from collaborators.
5. **Imaging beam line:** Generates image point π downstream of the proton-plasma interaction point. To be installed in existing tunnel.
6. **Spectrometer:** Crucial for energy diagnostics. Must be integrated with imaging beam line.
7. **Diagnostics section:** Measure energy gain and loss, etc.
8. **Beam dump:** Safely dump the beam.

Adapted from R. Assmann, PPA09

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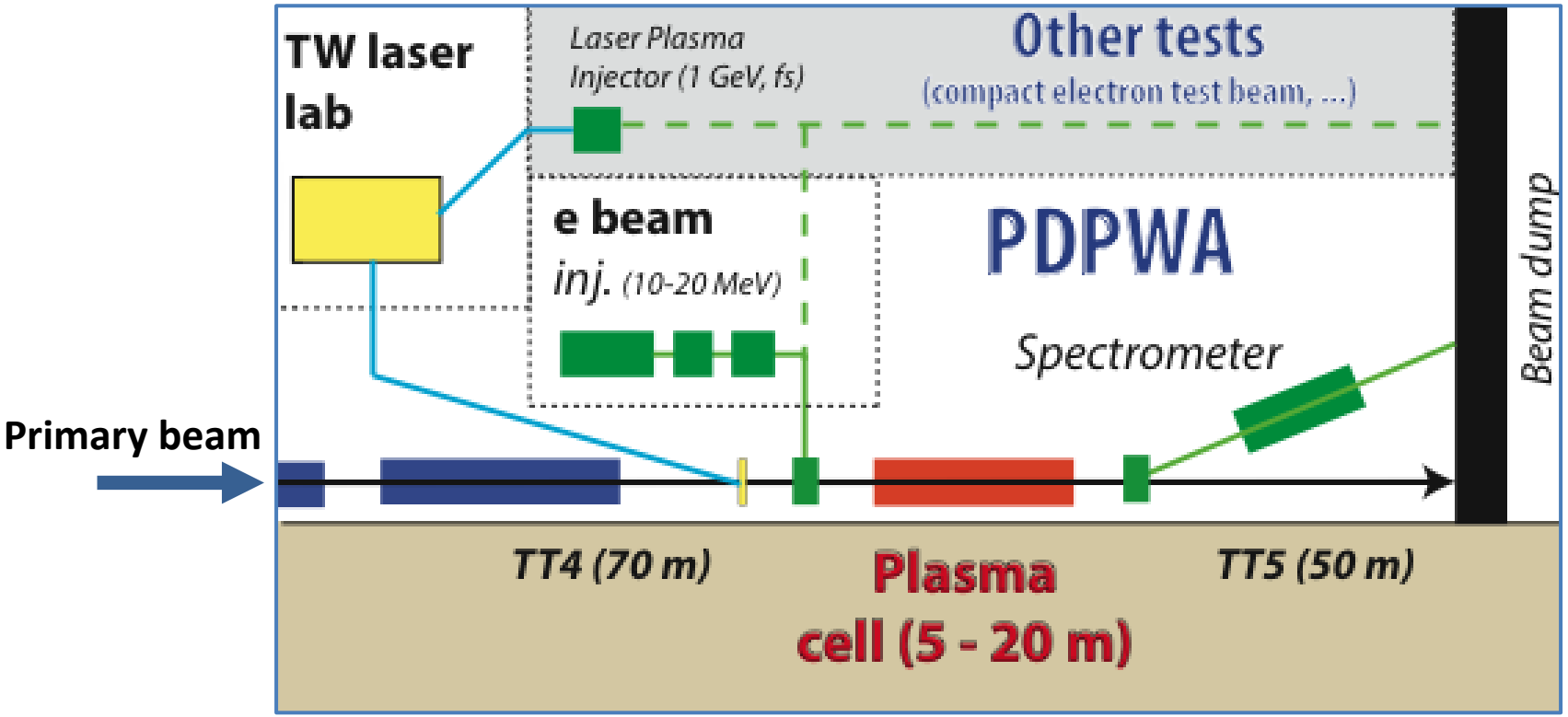
What is needed for PDPWA

2. **Beam extraction and transport to plasma:** Extraction regions and tunnels exist. Beam line elements to be reused or installed (existing old magnets or new).

Fast extraction of single short LHC-type bunch
1 -3e11 p+, small transverse emittance , 450 GeV/c

Parameter	SPS-LHC	SPS-Opt
E_P (GeV)	450	450
N_P (10^{10})	11.5	30
σ_P (MeV)	135	135
σ_z (cm)	12	12
σ_r (μm)	200	200
ε_{norm} (μm)	3.5	3.5
β (m)	5	5

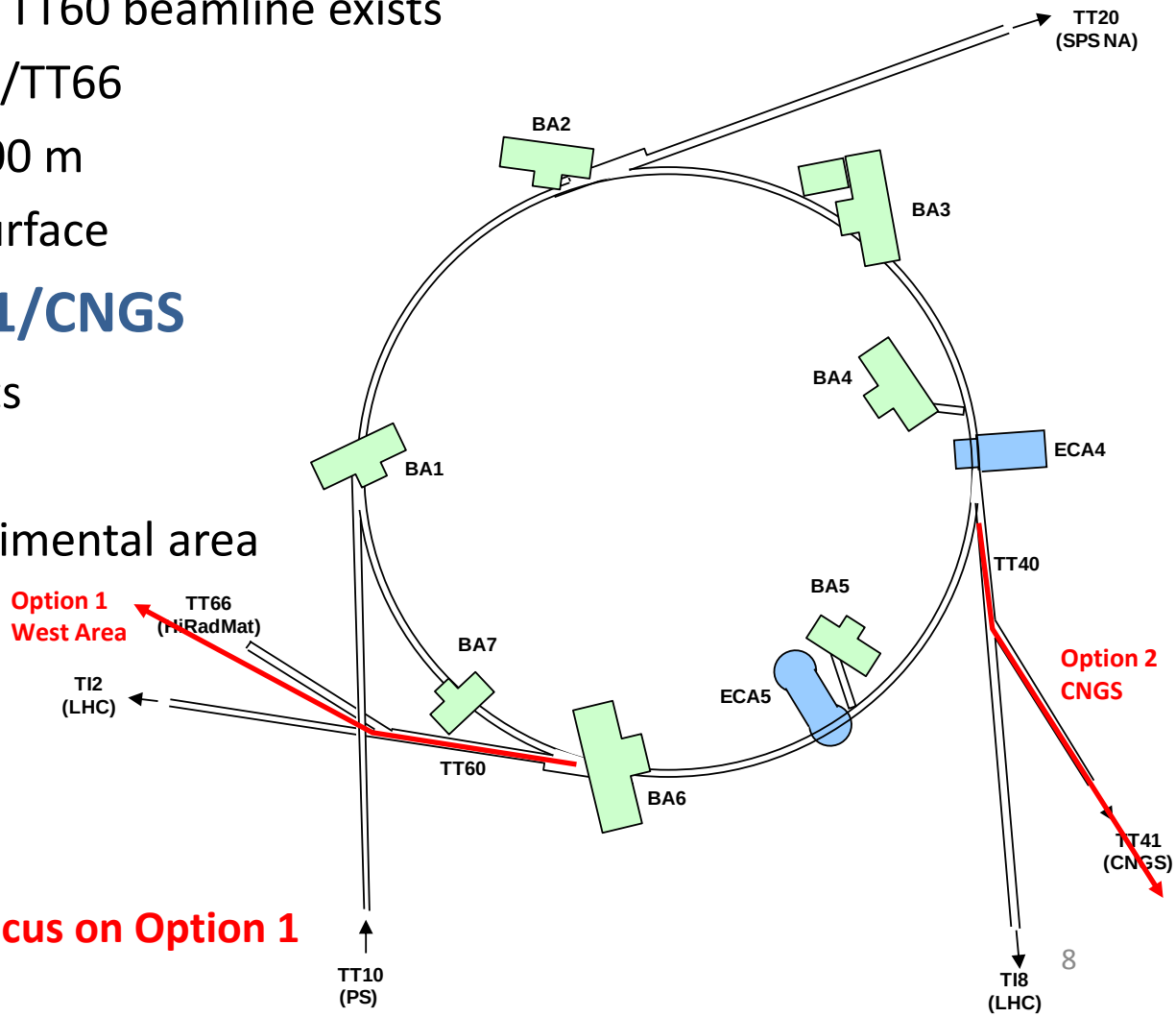
Experimental area needs for PDPWA



- Requires about **135 – 150m** for experimental area (width?)
- Needs **access** to laser lab, electron injector and control rooms

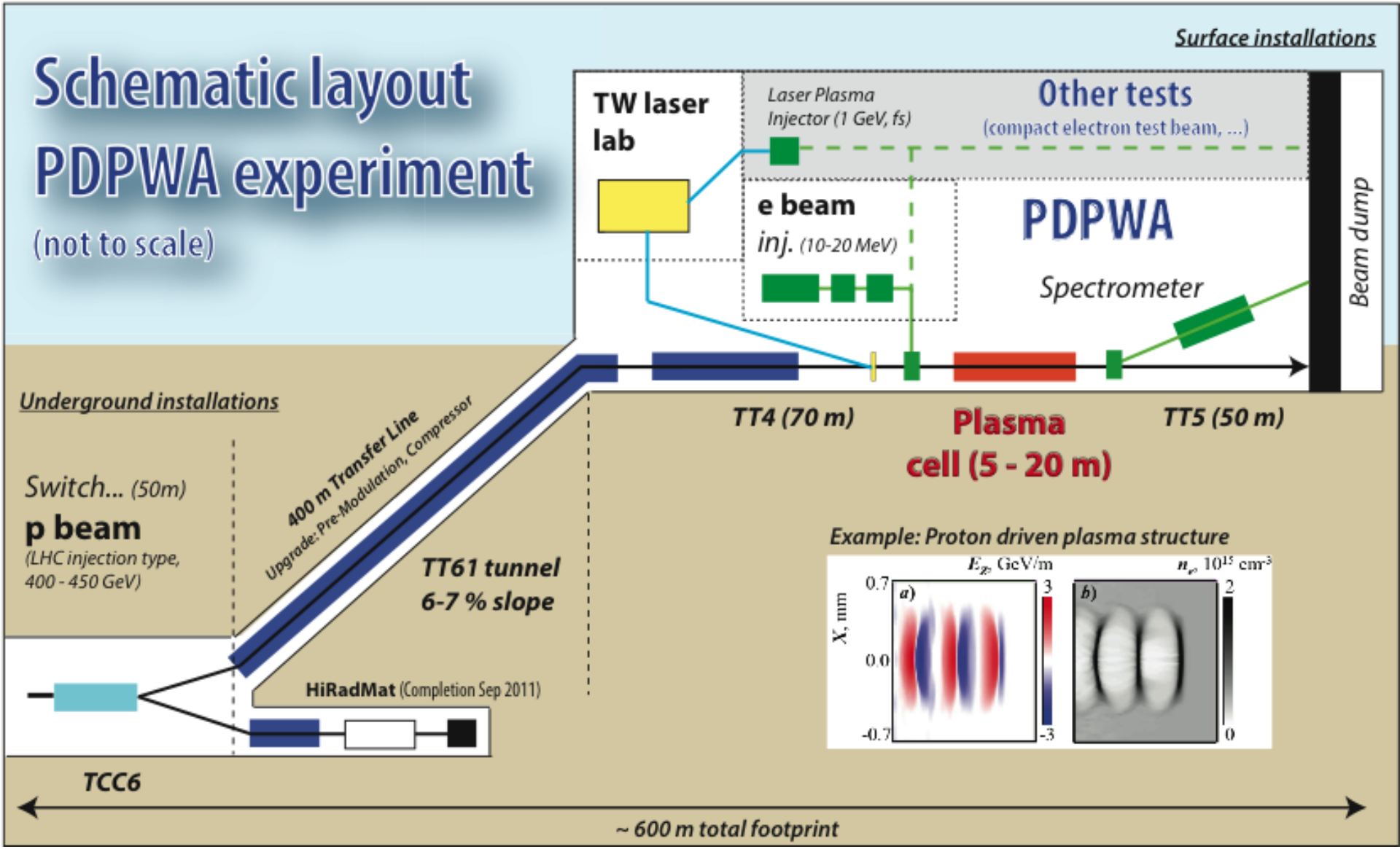
Options at SPS for PDPWA

- **Option 1: LSS6 – TT61/West Area**
  - LSS6 fast extraction and TT60 beamline exists
  - New switch region TT61/TT66
  - New TT61 beamline ~400 m
  - Experimental area on surface
- **Option 2: LSS4 – TT41/CNGS**
  - LSS4 fast extraction exists
  - TT41 beamline exists
  - New underground experimental area

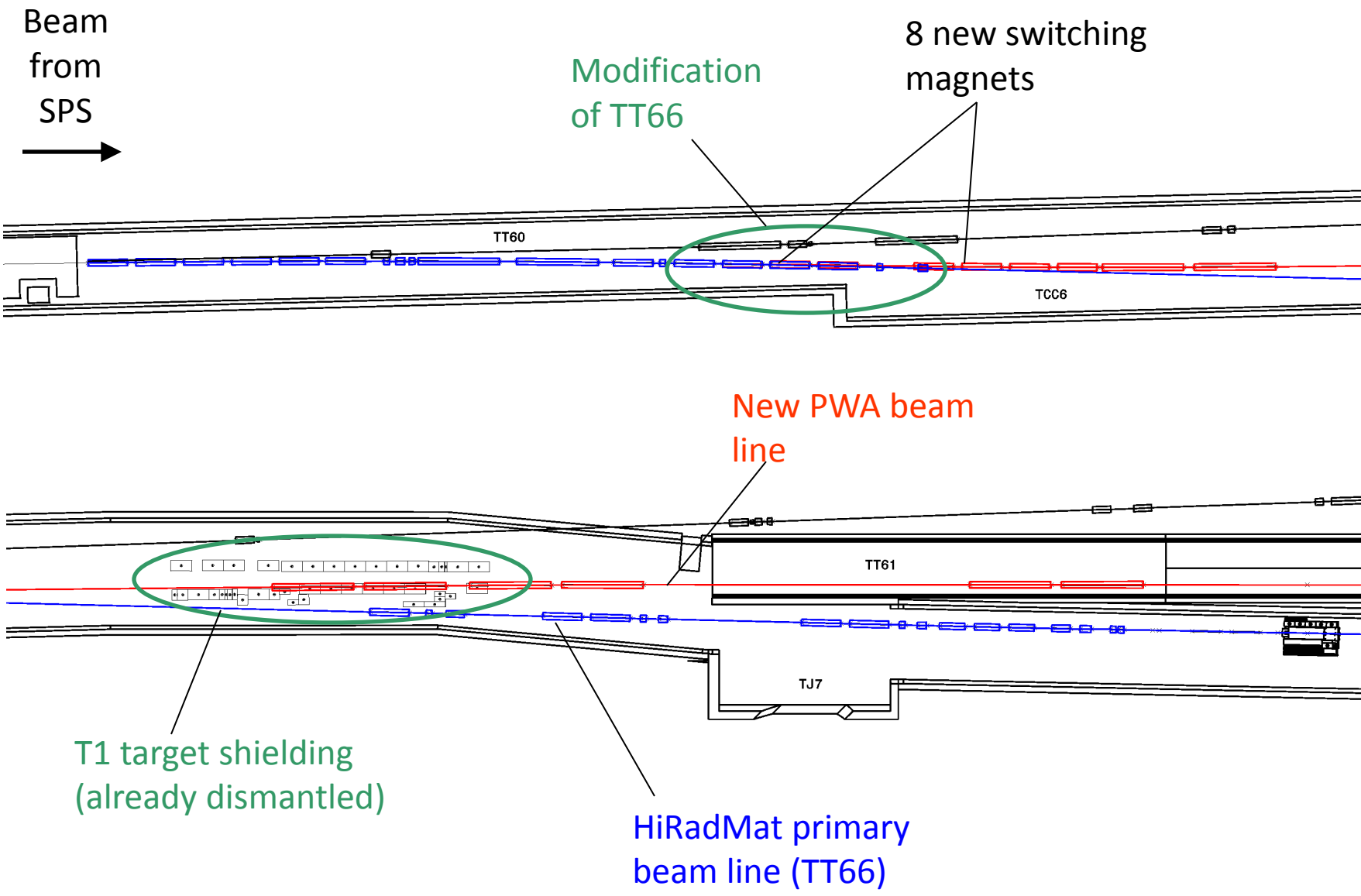


Both to be evaluated – here focus on Option 1

PDPWA in West Area, from SPS LSS6



PDPWA2WA: TT60/TT66 Compatibility



Adapted from C.Hessler, PPA 09

PDPWA: Beamline considerations

- **For LSS4 option**, fully operational 450 GeV beamline exists.
  - Only beamline work for final part of line (rebuilding Experimental Area, final focus, ...).
  - Obvious difficulties associated with decommissioning and civil engineering
- **For LSS6 option to West Area**, needs a new beamline
- New series of MBSW type switch magnets (8+spares)
- New optics and layout to make for ~400 m beamline
  - Previous H3 line worked at 250 GeV
  - At 450 GeV large vertical bends should be possible with rotated MBBs (need 4-5 per bend to reach 40 mrad).
  - Would keep SPS FODO cell length of ~64 m .
  - Appears relatively straightforward – maybe somewhat tricky to match to zero dispersion at plasma cell
- Parameters and reuse of existing magnets to be investigated – but generally costly to refurbish

PDPWA operational considerations

- No new HW in SPS ring
- Single bunches at low frequency (every ~30 s)
- Would be dedicated short 7.2 s LHC cycle
- Beam parameters seem within reach, assuming no complicated bunch rotation schemes
- Impact on machine and other users minimal
- Very low average intensity, so few radiation/activation concerns for machine

SBLν: Motivation

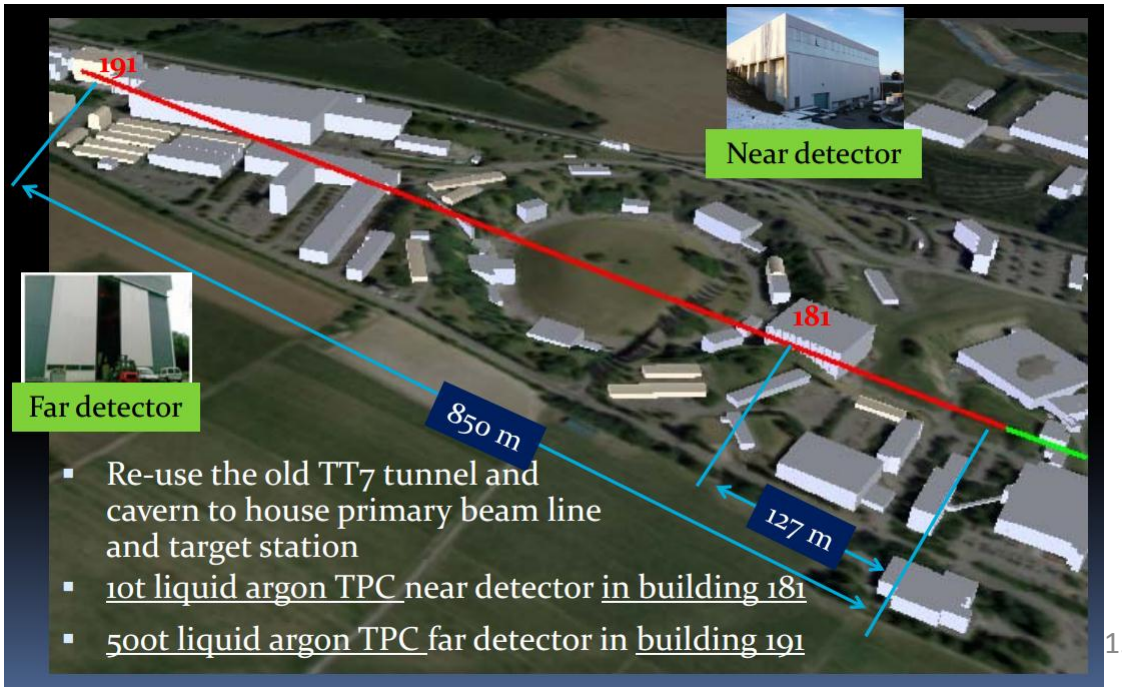
- Investigating sterile neutrinos through $\nu_\mu \rightarrow \nu_e$ oscillations
  - Implications for new physics beyond Standard Model, Dark Matter, leptonic CPT volation
- Short baseline (few hundred m) with two near detectors
- Reuse of ICARUS (presently installed at LNGS)
  - Reuse existing 600 t LAr-TPC detector, plus 100 t identical 'nearer' detector
  - Hunting anomalous oscillations both in neutrino and antineutrino channels, changing sign of beam focussing.
- Optimal distance for oscillations in region of $\Delta m^2 \geq 1\ eV^2$
  - Requires a low energy (1-3 GeV) beam at few hundred meters from detector
- Has to be fast extraction –1-2 ms fast-resonant spill is too long

Options for SBLν at PS and SPS

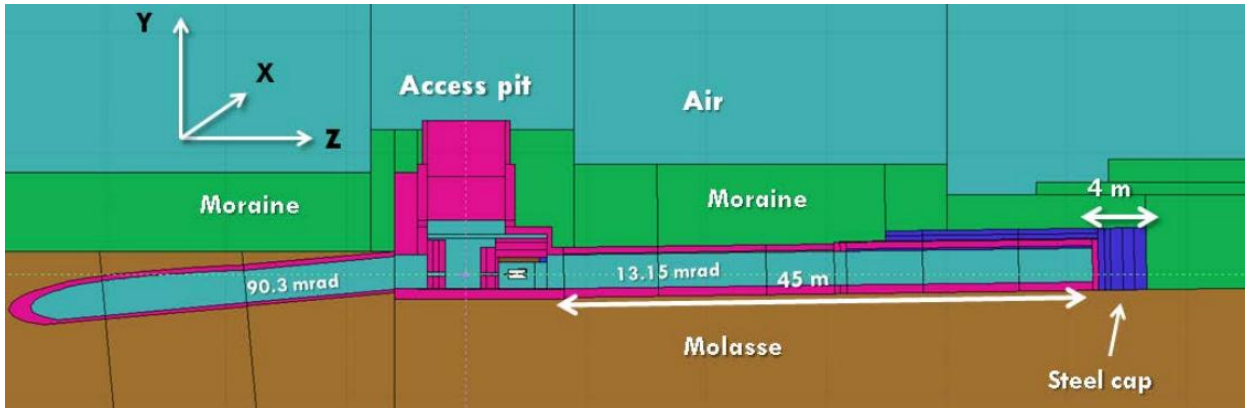
- **Option 1: 20 GeV p+ from PS, TT7**
  - PS fast extraction exists
  - Refurbishement of TT7 beamline
  - New target
- **Option 2: 100 GeV p+ from SPS LSS2, TT20**
  - Needs new fast extraction sytem in LSS2
  - TT20 beamline exists
  - New switching area and beamline section to target
  - Target area near existing TCC2 cavern

Option 1: 20 GeV p+ beam from PS

"PSNF"

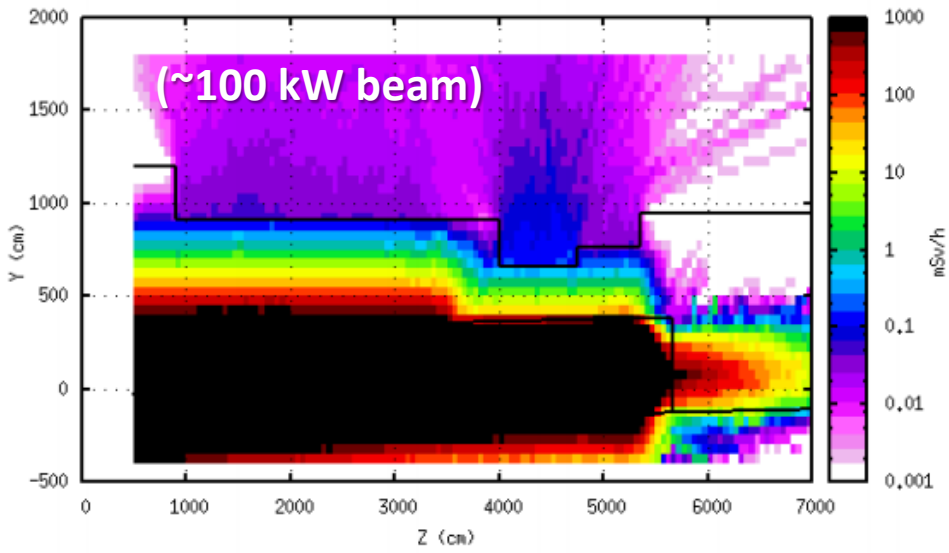


PSNF secondary beam line: FLUKA studies



- Full FLUKA implementation of the area is available together with a preliminary target/horn assembly

- Analysis of energy deposition in most critical elements performed
- First assessment of the areas requiring interventions has been produced with realistic solutions
- Details to be addressed in a TDR

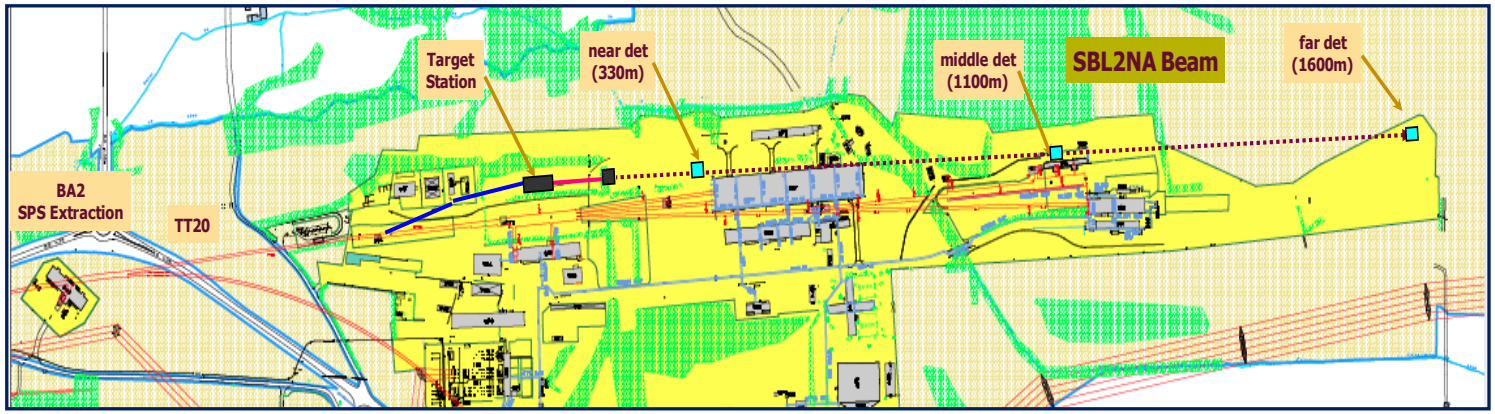


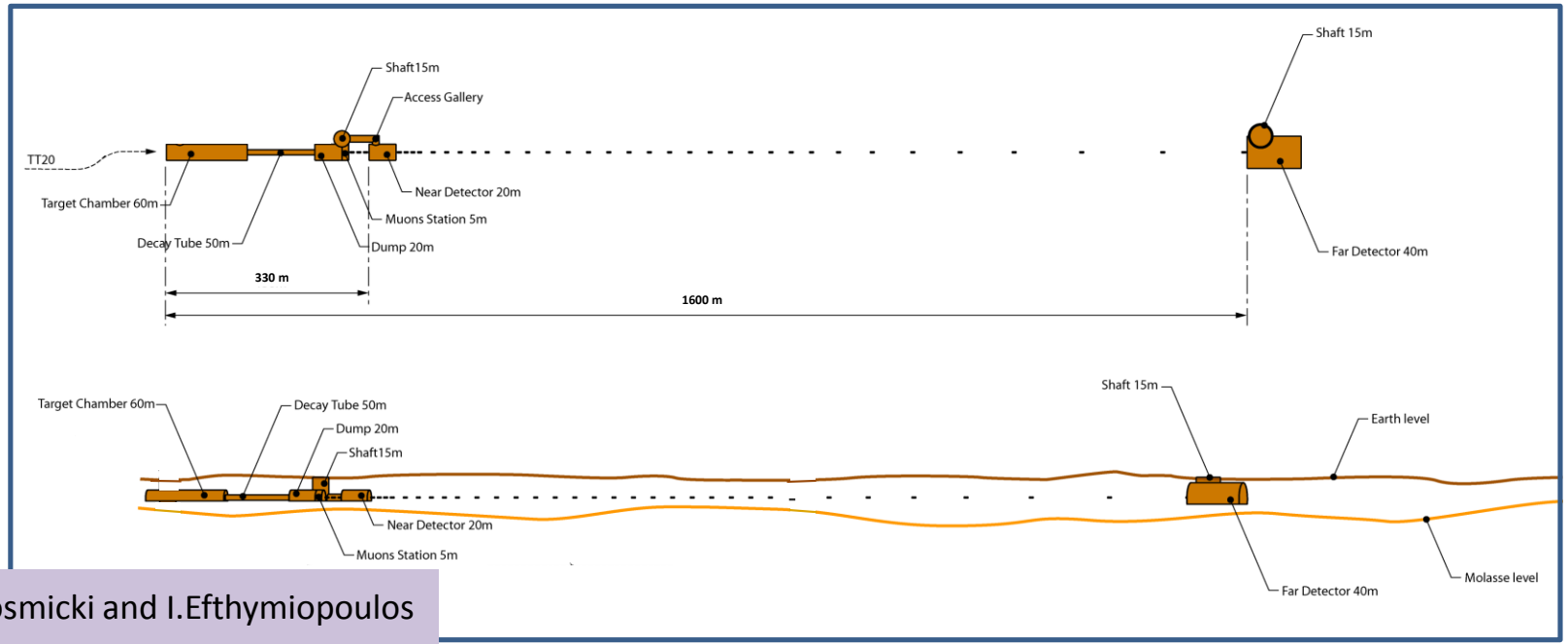
ATS-Note-2011-088 TECH

Option 2: 100 GeV p+ beam from SPS

- Reuse TT20 to bring beam near to surface in North Area
- Near detector ~330 m from target, far detector ~1600 m

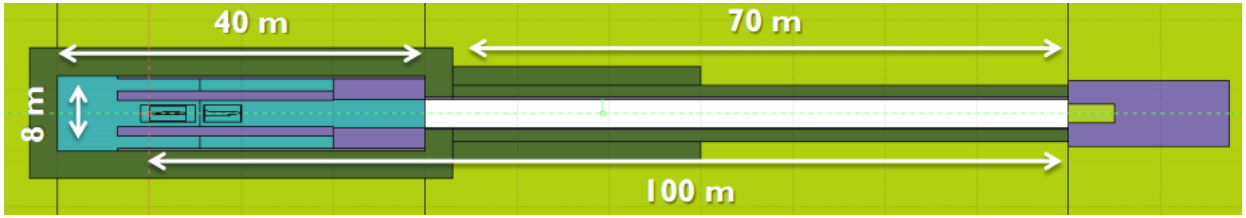
"SBL2NA"





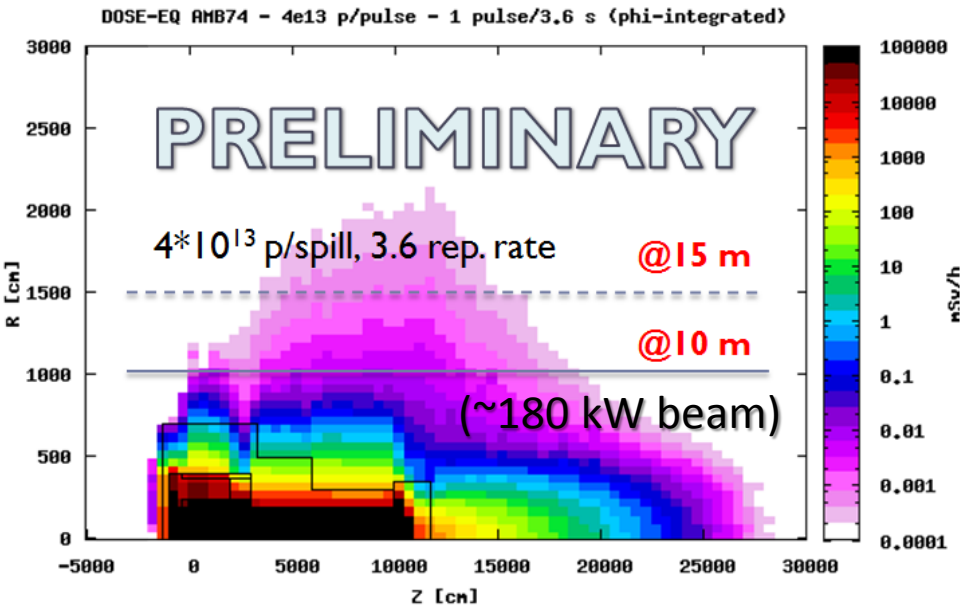
Adapted from A.Kosmicki and I.Efthymiopoulos

SBL2NA: preliminary FLUKA studies



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

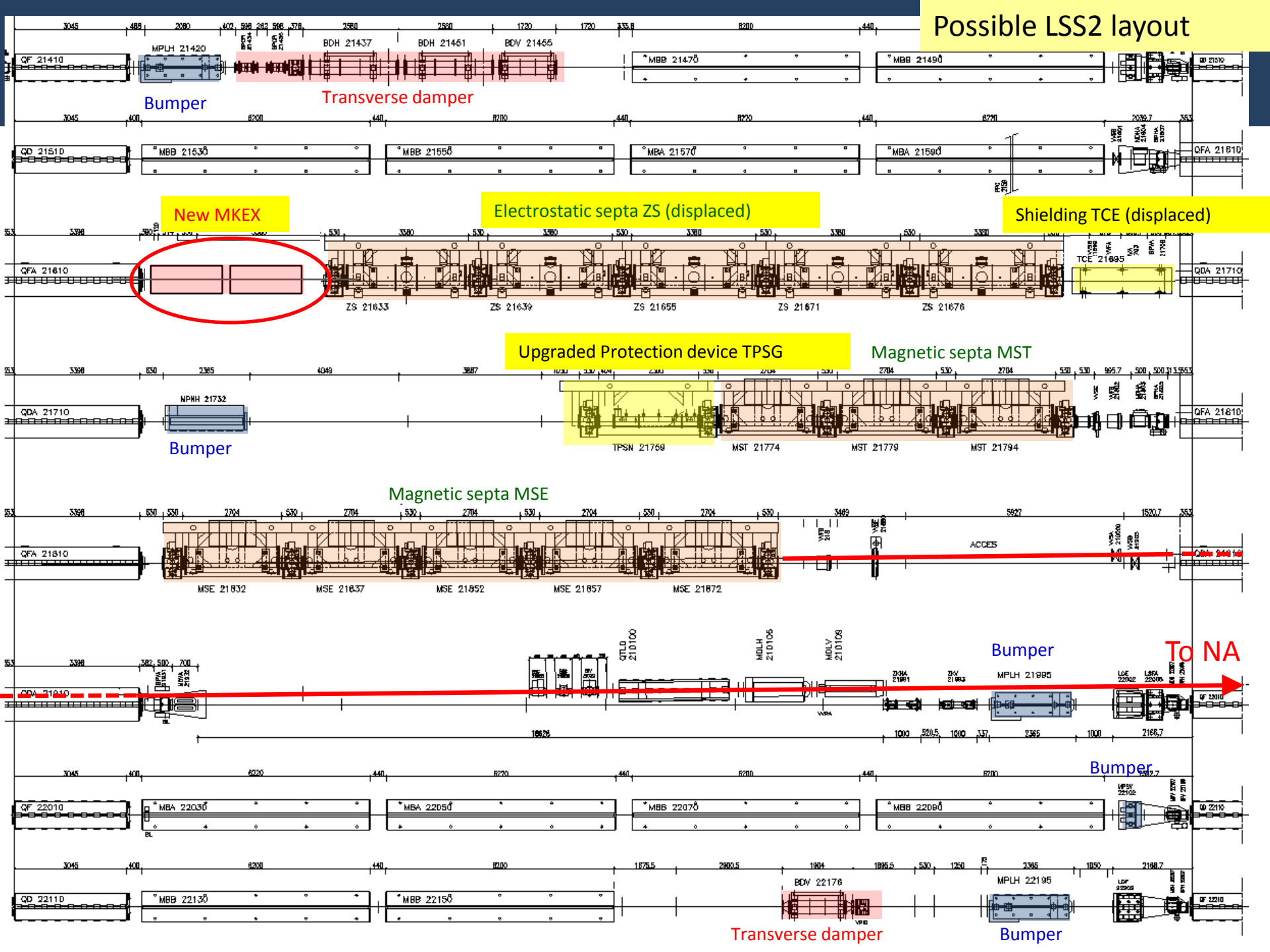
- First generic implementation to study the sensitive points – not fixed design, room for optimization
- Massive shielding required due to location close to surface
- Muons not a problem for near detector is placed at 330 m from target (< 1 μ/spill/detector)
- Soil activation could be a problem (^{3}H and ^{22}Na) – mitigation possible
- Further studies are needed!



SBL2NA: New fast extraction in SPS LSS2?

- First preliminary feasibility study made
- Need to keep slow extracted beam capability to North Area
  - Hybrid extraction needed for slow and fast extracted beams
- Preliminary solution found with displacement of ZS girder and TCE downstream by 3m
- Two new MKEX kickers – larger H aperture than MKE
- Extraction energy limited to 100 GeV with 1 us kicker rise time
  - 400 GeV would imply much slower kicker rise time (3.5 – 4.0 us)
  - Cannot mix 100 and 400 GeV extraction (unless 100 GeV extraction accepts 3.5 – 4.0 us rise (and fall) time, and 10 us pulse length)
- Emittance limited to about 8 π.um in H, and 5 π.um in V

Possible LSS2 layout



SBL2NA: Operational considerations

- Beam energy should be around 100 GeV
  - Experimental requirements, extraction system aperture, cycle time, dump
- Maximising POT: 3.6 s cycles, high intensity beam (~CNGS)
  - Beamlosses, activation, RP are major design issues
- Some effect on NA.FT and LHC beams
  - MST opening, losses, 25 % more MKE impedance, ZS HT performance
- No parallel operation with slow extraction
  - Some hours to switch with ZS and MST girders moved
- Installation should be same time as recabling of LSS2
- Switching between 100 GeV, 1 us and 400 GeV, 4 us extraction means significant upgrade of extraction kicker systems
  - Would need a long (old fashioned standard) shutdown
  - Could be future step once Sterile neutrino program is completed

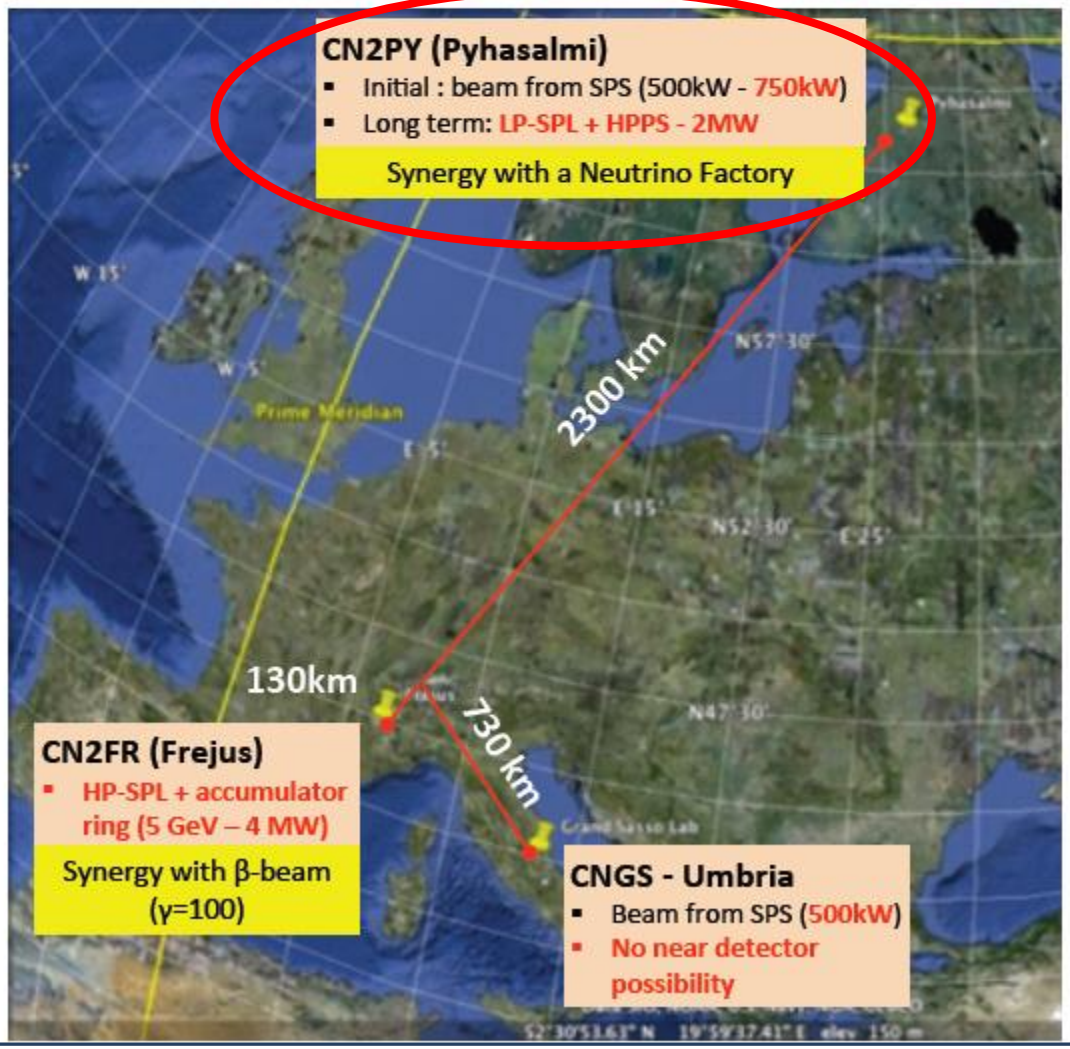
LAGUNA Motivation

- Proton decay – implications for Grand Unification, requires megaton detector
- Neutrino astronomy – supernovae, solar, atmospheric and geologial neutrinos
- Artifical (accelerator driven) neutrino beams – flavour oscillations, leptonic CPT voilation

Large
Apparatus studying
Grand
Unification
Neutrino
Astrophysics
... and
Long
Baseline
Neutrino
Oscillations

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



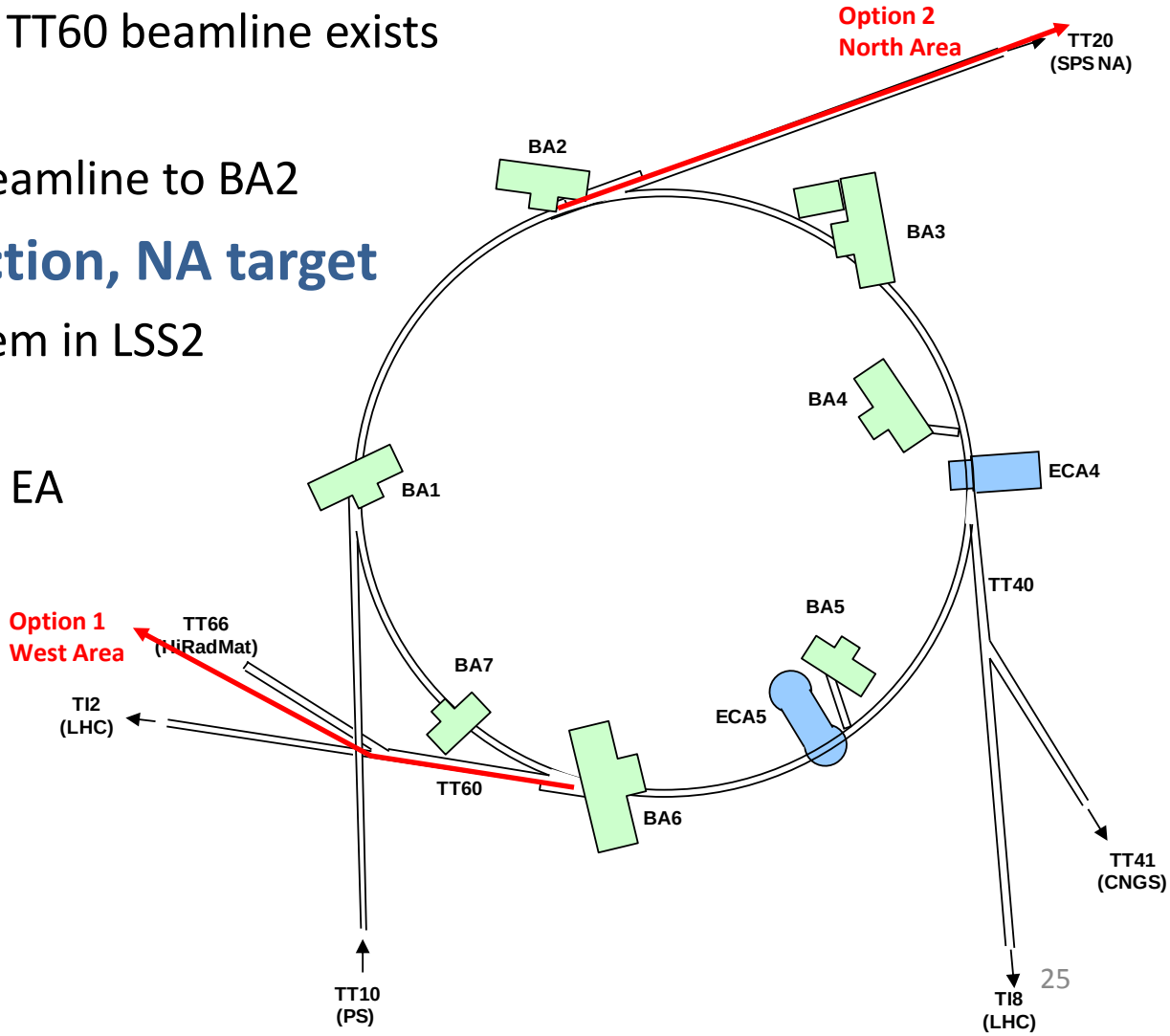
LAGUNA-LBNO: Staged to 2 MW

1. Present SPS with CNGS-type beam (400-500 kW)
2. SPS to 750 kW (7e13 ppp at 400 GeV every 6 s)
3. New 2.0 MW proton driver (e.g. LP-SPL, new 50 GeV "HPPS")

- Ideally common target and secondary beam infrastucture for all LAGUNA-LBNO phases
- Implies designing beamline layout from SPS with future proton driver already in mind
- 2nd integer extraction maybe OK for experiment, but not for SPS (2-3% beamloss expected) → fast extraction needed

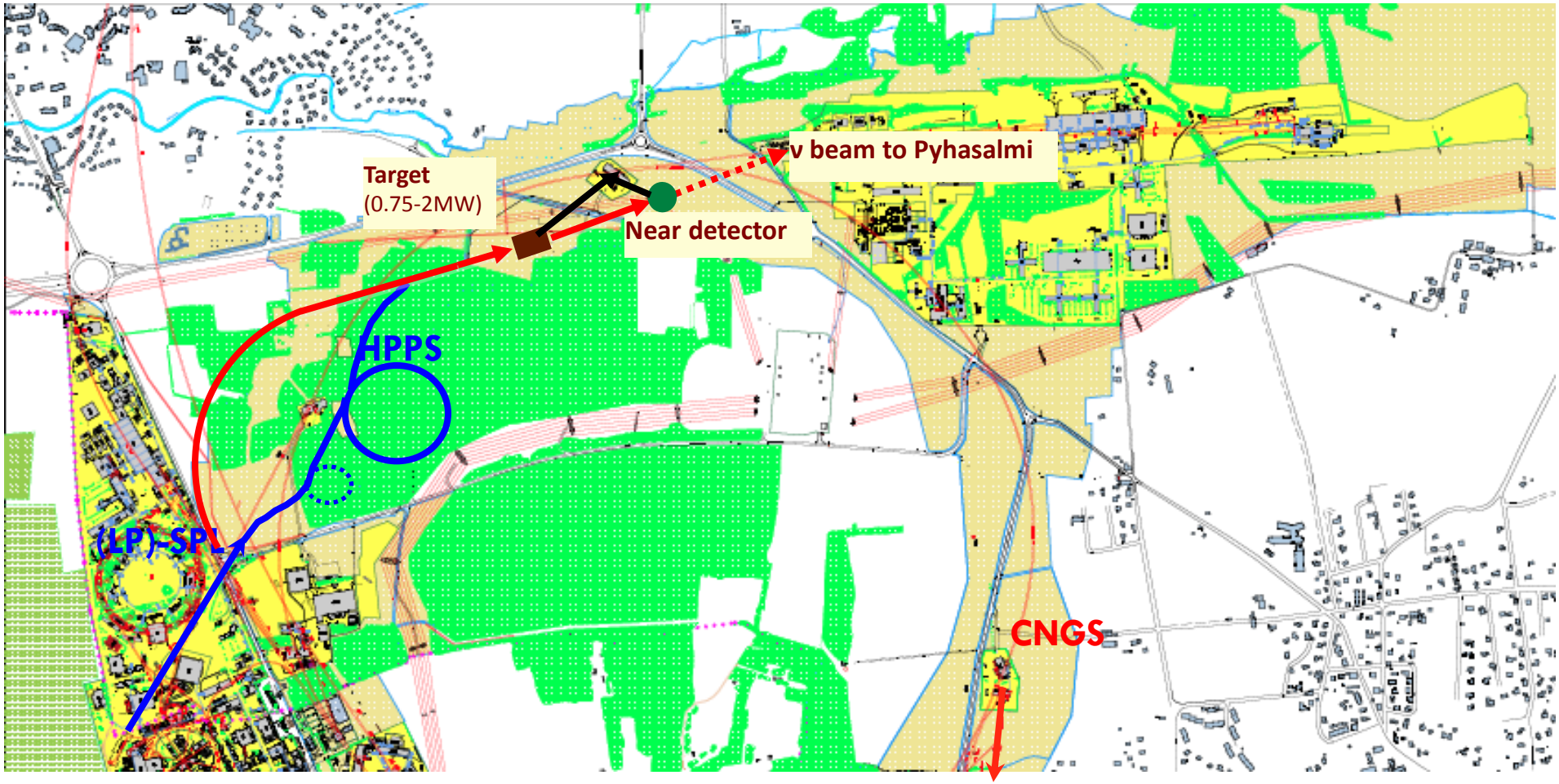
Options at SPS for LAGUNA-LBNO

- **Option 1: LSS6 extraction, target near BA2**
  - LSS6 fast extraction and TT60 beamline exists
  - New switch region
  - New 2 km tunnel and beamline to BA2
- **Option 2: LSS2 extraction, NA target**
  - New fast extraction system in LSS2
  - TT20 beamline exists
  - Target area near existing EA



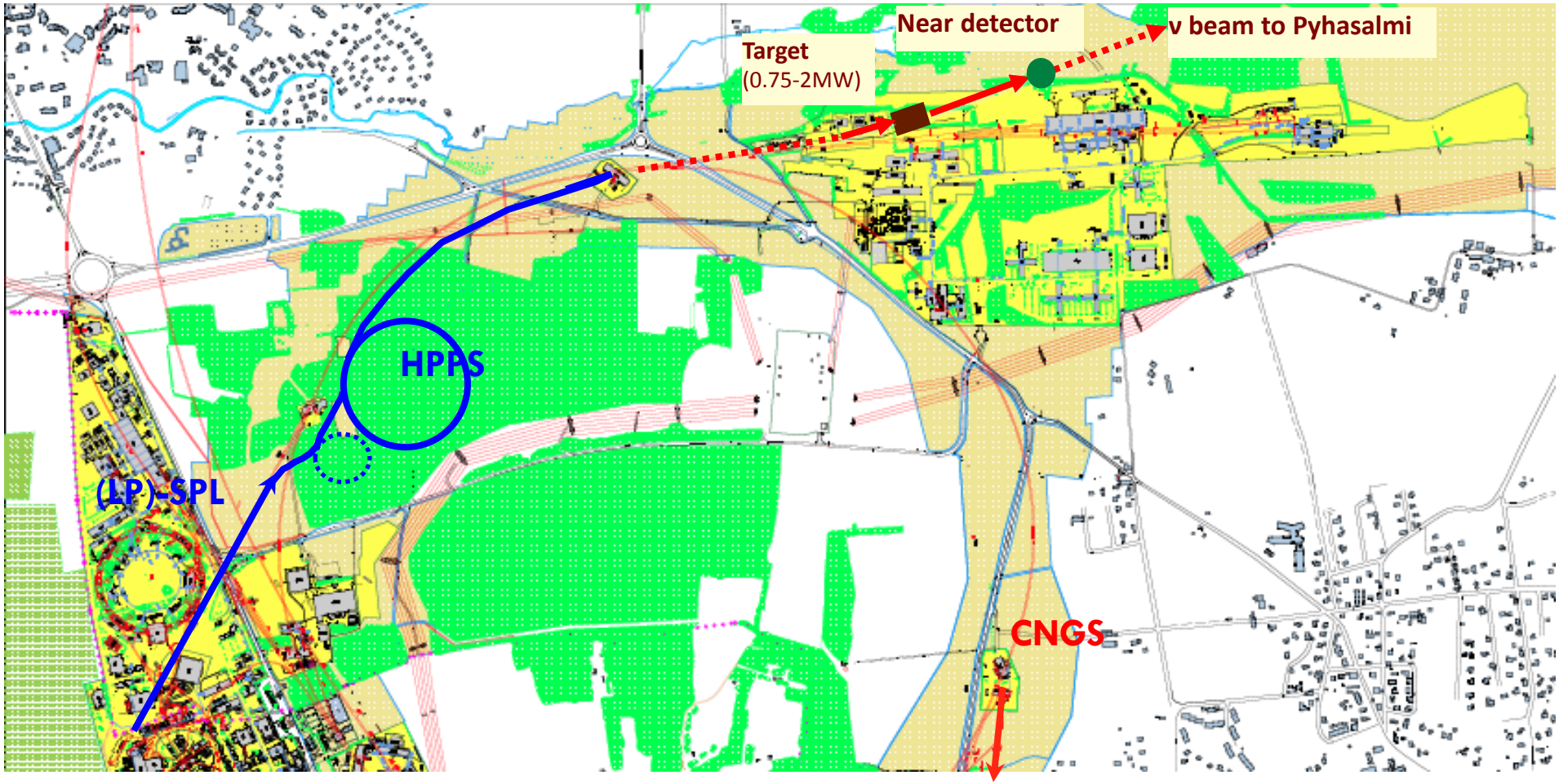
LAGUNA-LBNO: Options from SPS

- Option 1; extraction from LSS6, target near BA2

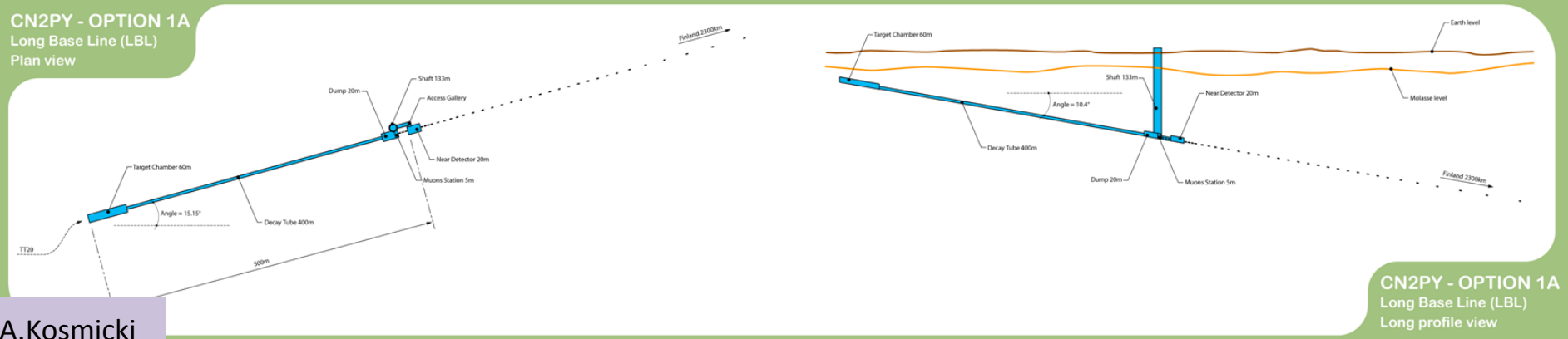


LAGUNA-LBNO: Options from SPS

- Option 2; extraction from LSS2, target in North Area



Option 2 - NA



A.Kosmicki

LAGUNA-LBNO: Beamline considerations

- **For LSS6 (option 1)**
  - Fully operational fast extraction channel exists;
  - (Another) new switch needed from TT60;
  - Junction caverns and ~1 km of new tunnel plus beamline to build for phase 1;
  - Same again for the 2 MW option;
  - Target and experimental areas further underground
  - Need to add 2 more MKE kickers to extract CNGS type beam (presently have ~6 us rise time, and 3 MKE kickers in series, short circuit mode)
- **For LSS2 option (option 2)**
  - No fast extraction exists in LSS2 – seems possible to have a “solution” with 4 us rise time for 400 GeV beam
  - 2 new MKE kickers added – same issues of impedance, layout changes
  - Tunnel and operating beamline exist to surface
  - Junction/target cavern, plus secondary beamline needed for phase 1
  - Needs maybe 1.5 km of new tunnel and beamline for 2 MW upgrade

LAGUNA-LBNO: Operational considerations

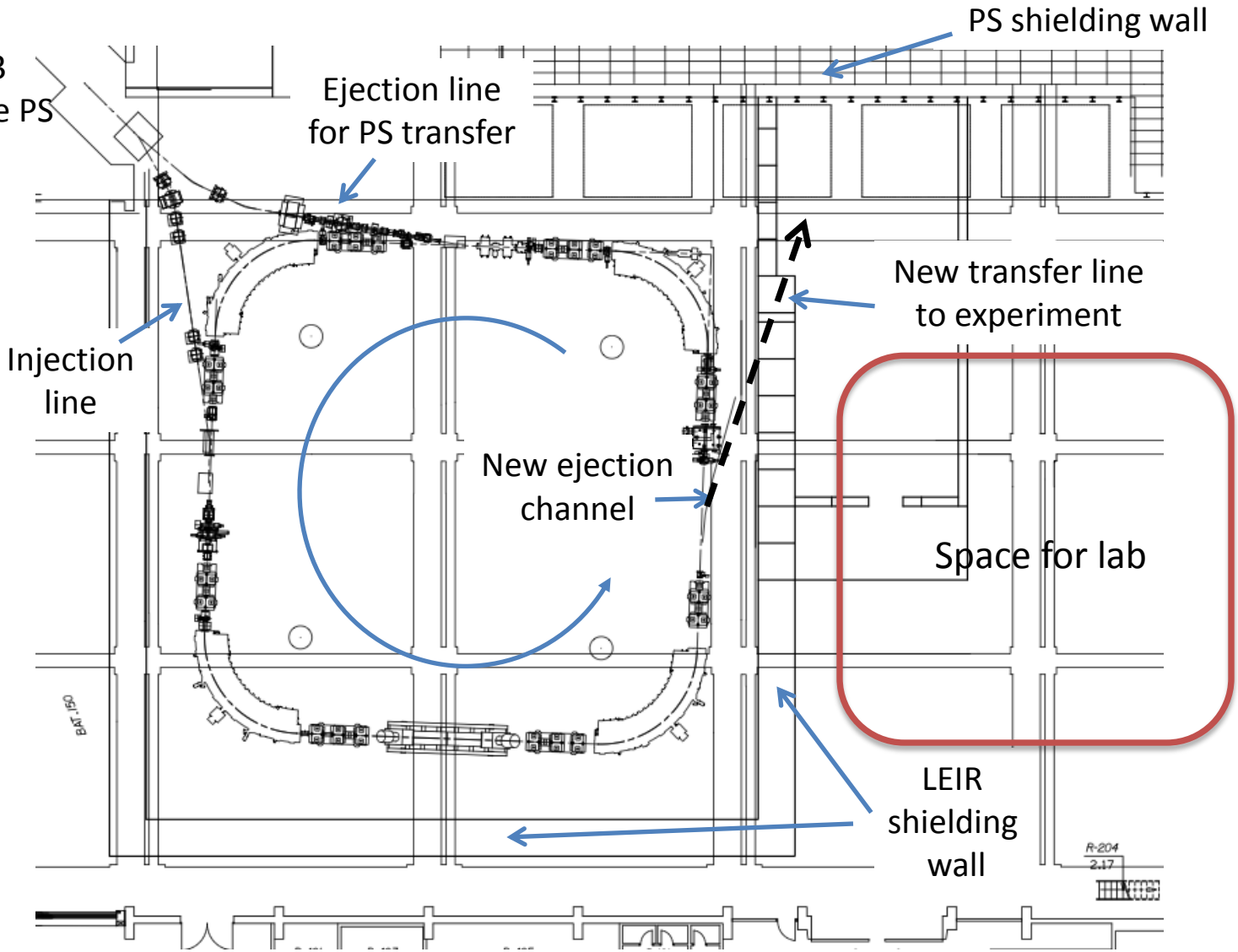
- Requires 400 GeV, maximum POT: 6 s 'CNGS' type cycle
- 2 new MKE kickers in the ring in both versions
  - LSS6 would give 1 us rise time, LSS2 only 4 us
- Specific losses from fast extraction should be similar to CNGS
  - Maybe somewhat worse in LSS2 with limited kicker strength

LEIR: Facility for Radiobiology Studies

- Discussed at “Physics for Health in Europe Workshop” at CERN in Feb. 2010
  - Provide beams for experiments in support of treatment centers (Radiobiology, investigations with different ion species (up to O), Fragmentation studies, dosimetry, radiation effects during space travel)
- Energy reach of LEIR appropriate for such experiments
  - Up to 430 MeV/n possible (with upgrade to main power convertor)
- Studies and changes needed:
  - New ejection channel for slow extraction and a (short vertical?) beam line
  - Infrastructure (Radiobiology lab …)
  - Possibly an additional ion source, RFQ …
  - Limitations from radio-protection (higher energy with higher Z/A for light ions)
- Impact on PS complex operation limited to LEIR
  - Could provide beams during LHC p+ running, or LHC ion “coasts”
  - No other machines (PS) required… minimum impact on other CERN programs

Adapted from C.Carli

Radiobiology Studies: Sketch of LEIR



Status and plans

- PDPWA
  - Letter of Intent reviewed positively by SPSC October 2011
  - Study for TDR endorsed by Research Board
  - Now setting up Work Packages: aiming at Design Report for end 2012
- SBLnu
  - Under evaluation in scientific committees
  - Common (experiment) TDR to present to SPSC April 2012, considering SPS-NA beam option
- LAGUNA-LBNO
  - FP7 design study started in September 2011
  - Experiment and machine study Work Packages defined
  - Aiming at Conceptual Design report on “conventional beams” September 2014
- LEIR radiobiology
  - Feasibilities studies starting (re-implemention of slow ejection, new extraction channel design and transfer line to experiment, RP issues)

Summary

- Many options for different facilities being considered, several at SPS;
- Overlap and 'competing' requests for space, beamlines, etc. should be moderated, avoiding mutually exclusive baselines, e.g. PDPWA and LAGUNA-LBNO from LSS6 (note projects are not all at the same timescales);
- Reuse of CNGS facility should be considered, from point of view of minimising study/work/SPS impedance (existing extraction, beamlines, tunnels)
- At this stage synergy seems minimal between different projects, possibly excepting upgrade path of 100 GeV SBL2NA extraction to 400 GeV for LAGUNA;
- Concerning SPS beamlines, no showstoppers identified, at this early stage in studies;
- Resources for these studies are an important issue – involves many groups, particularly civil engineering;
- Important to narrow each down to a baseline option, coherent across projects

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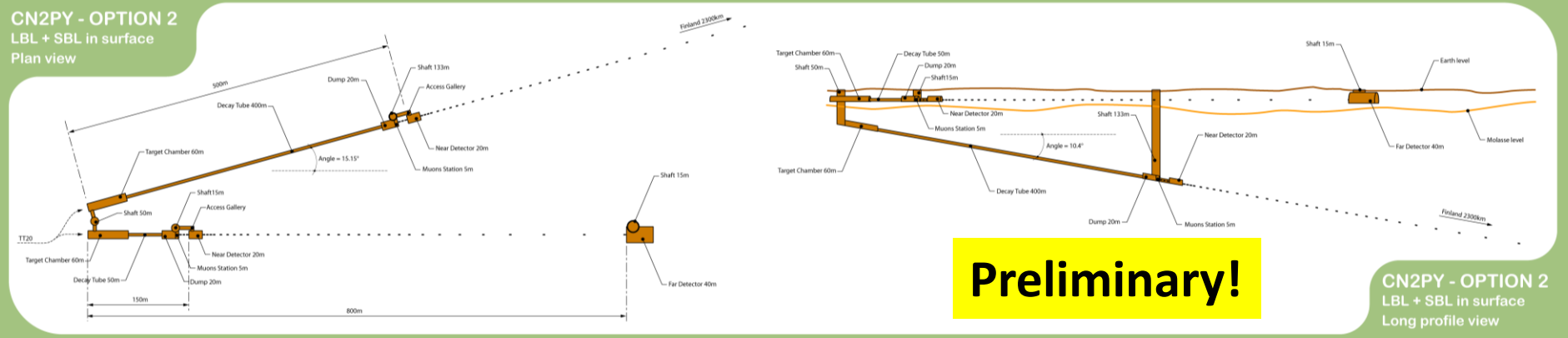
Synergy between S/LBL neutrino beams?



LAGUNA CN2PY - CERN to PYHASALMI - A.Kosmicki - 20.01.2012 - EDMS# 1179683