SPL - HOM Workshop
25-26 June 2009

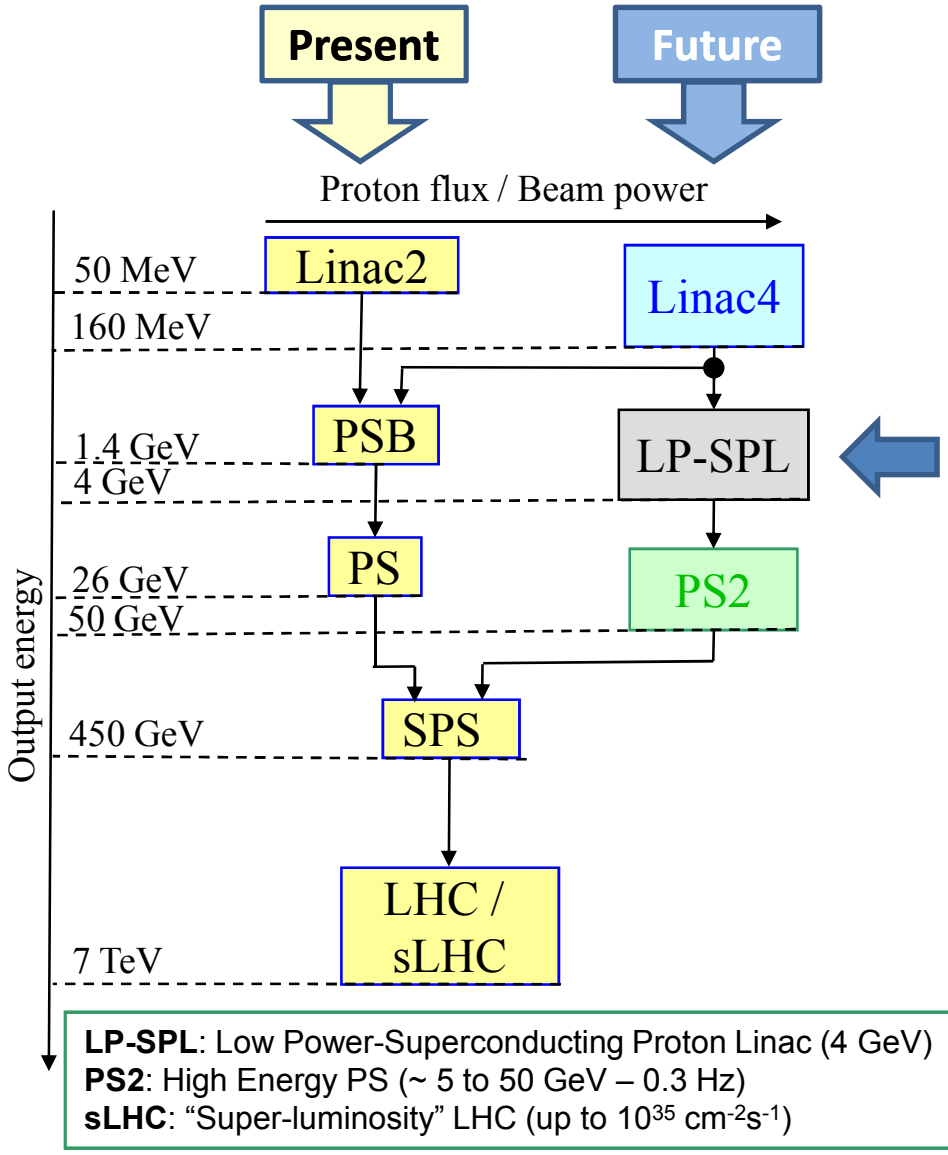
Introduction to the SPL

1. **Context**
2. **LP-SPL**
3. **SPL high power options**

R. Garoby

1. Context

Present and future accelerators



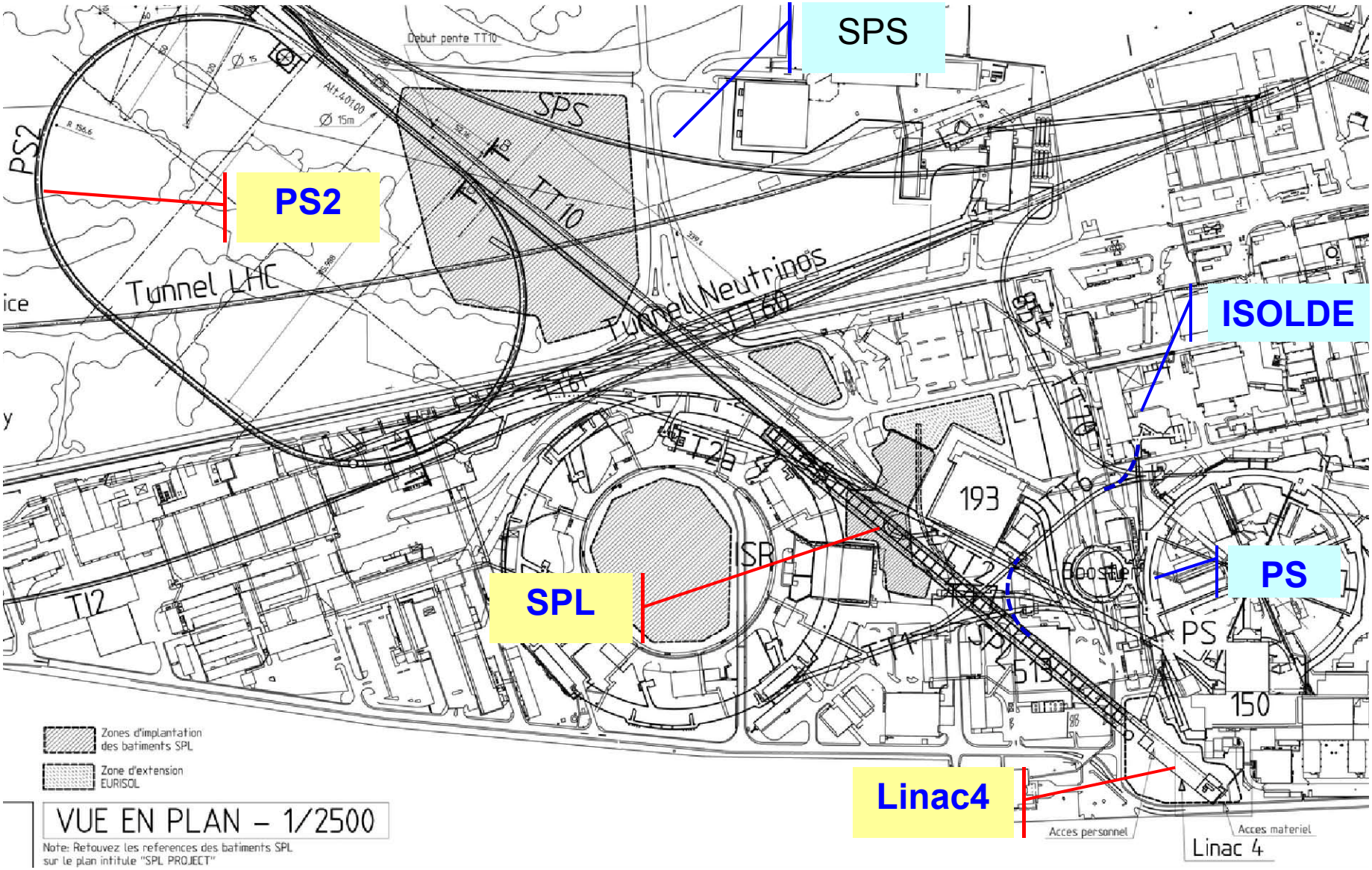
LP-SPL: Low Power-Superconducting Proton Linac (4 GeV)
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)
sLHC: "Super-luminosity" LHC (up to 10^{35} $cm^{-2}s^{-1}$)

Main requirements of PS2 on its injector:

Requirement	Parameter	Value
2.2 x ultimate brightness with nominal emittances	Injection energy	4 GeV
	Nb. of protons / cycle for LHC (180 bunches)	6.7×10^{13}
Single pulse filling of SPS for fixed target physics	Nb. of protons / cycle for SPS fixed target	1.1×10^{14}
Provide all beam time structures for LHC	Bunch spacing	25/50/ 75 ns
	Number of bunches / missing bunches	1 - 168
Flexible control of emittance and intensity per bunch	$\varepsilon_{X,Y}$ / ε_L / N_b	

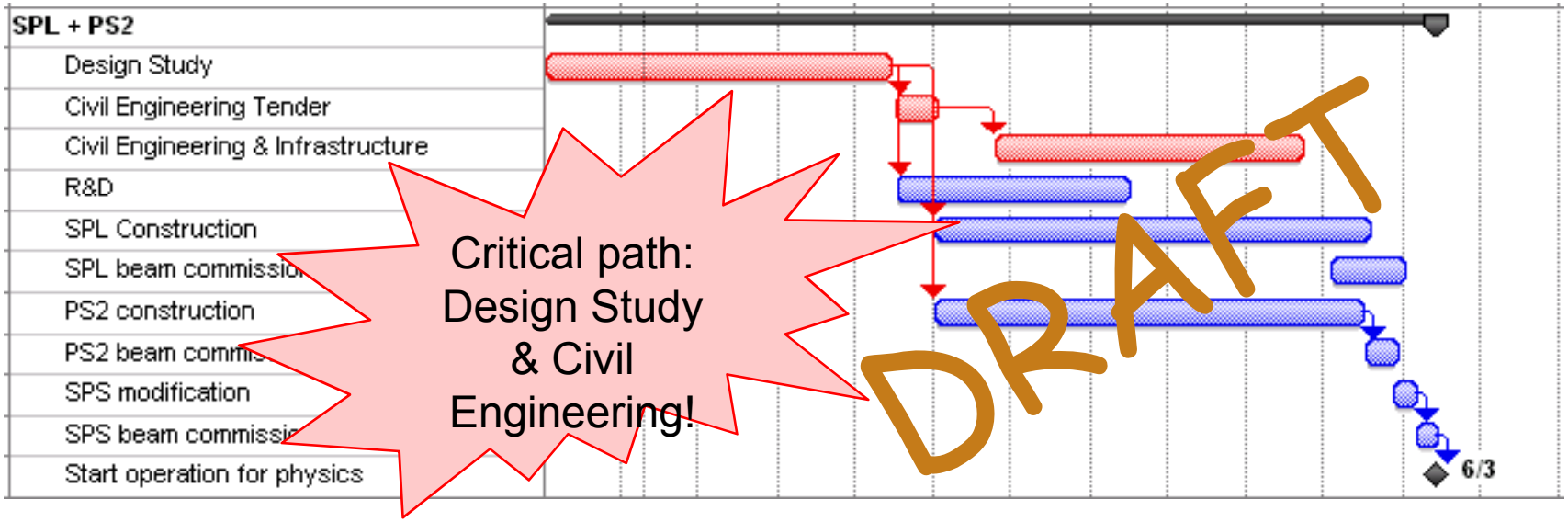
Site layout

sLHC



Implementation of the new injectors:
LP-SPL + PS2

Construction of LP-SPL and PS2 will not interfere with the regular operation of Linac4 + PSB for physics.
Similarly, beam commissioning of LP-SPL and PS2 will take place without interference with physics.



First milestones

- Project proposal: 2011- 2012
- Project start: January 2013

Goal of the SPL study (2008-2012)

from Note on 31/03/2009 (EDMS Id 993472)

The goal of the SPL study is to prepare for a start of construction of the low power SPL optimized for PS2 and LHC at the beginning of 2013.

For that purpose, a detailed Conceptual Design Report and a cost estimate will be published in May 2012. The cost of leaving the possibility of a later upgrade to 5 GeV and high beam power will also be quantified.

2. LP-SPL

Stage 1: Linac4 - Main characteristics

sLHC

Ion species	H^-	
Output Energy	160	MeV
Bunch Frequency	352.2	MHz
Max. Rep. Rate	2	Hz
Max. Beam Pulse Length	1.2	ms
Max. Beam Duty Cycle	0.24	%
Chopper Beam-on Factor	65	%
Chopping scheme:		
222 transmitted /133 empty buckets		
Source current	80	mA
RFQ output current	70	mA
Linac pulse current	40	mA
N. particles per pulse	1.0	$\times 10^{14}$
Transverse emittance	0.4	π mm mrad

Max. rep. rate for accelerating structures: 50 Hz

$H^- \Rightarrow$ charge exchange injection and painting in the synchrotron (PSB / PS2).

Higher injection energy in PSB (160/50 MeV, factor 2 in $\beta\gamma^2$) $\rightarrow$ same tune shift with twice the intensity.

Re-use of LEP RF components: klystrons, waveguides, circulators.

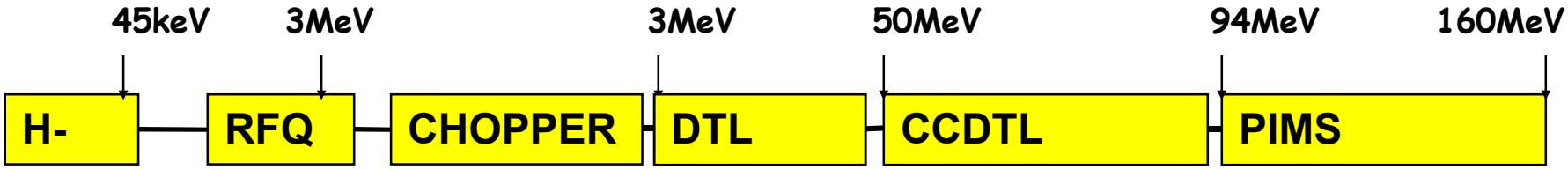
Chopping at low energy to reduce capture loss in the synchrotron (PSB / PS2).

- Structures and klystrons dimensioned for 50 Hz
- Power supplies and electronics dimensioned for 2 Hz, 1.2 ms pulse.

Stage 1: Linac4 - Block diagram

sLHC

Normal conducting RF accelerating structures: 4 types (RFQ, DTL, CCDTL, PIMS)
Frequency: 352.2 MHz
Duty cycle: 0.1% phase 1 (Linac4), 3-4% phase 2 (SPL), (design: 10%)



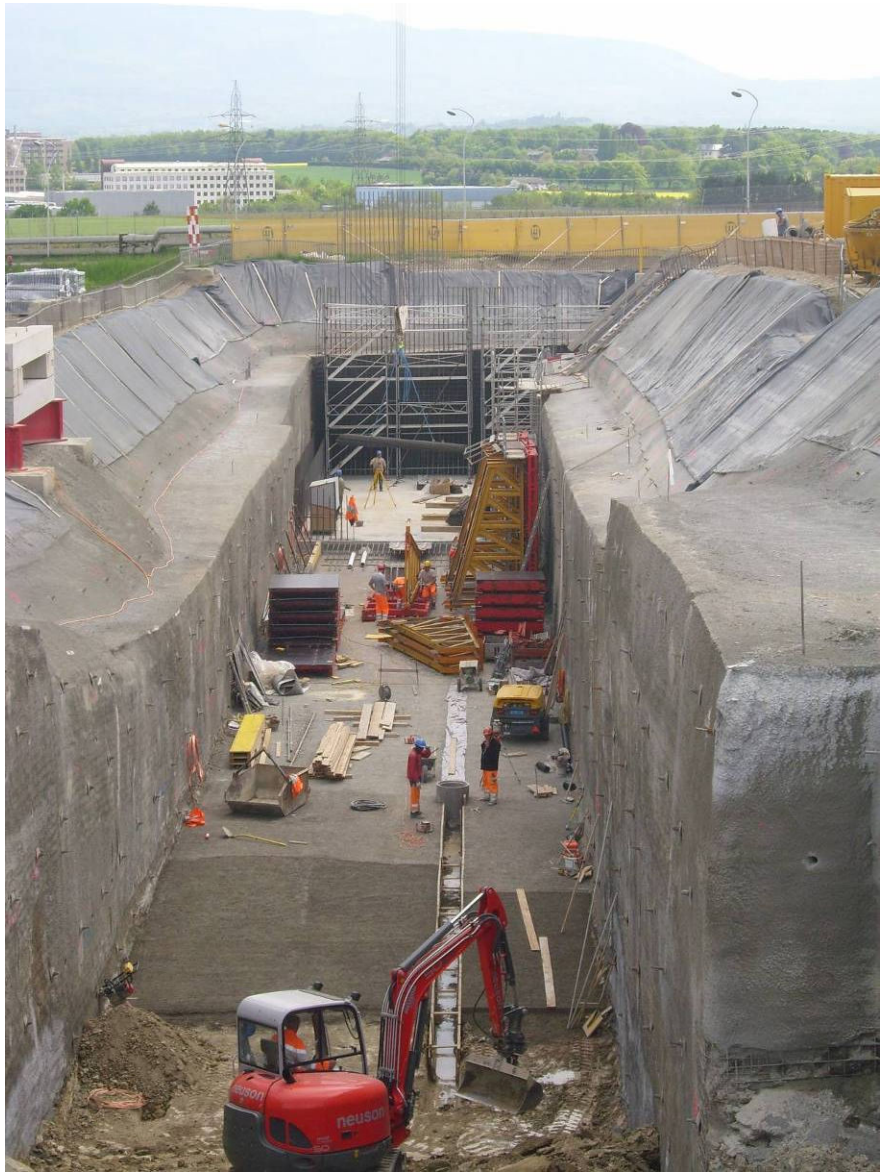
RF volume source (DESY) 45 kV Extrac.	Radio Frequency Quadrupole 3 m 1 Klystron 550 kW	Chopper & Bunchers 3.6 m 11 EMquad 3 cavities	Drift Tube Linac 18.7 m 3 tanks 3 klystrons 4.7 MW 111 PMQs	Cell-Coupled Drift Tube Linac 25 m 21 tanks 7 klystrons 7 MW 21 EMQuads	Pi-Mode Structure 22 m 12 tanks 8 klystrons ~12 MW 12 EMQuads

Ion current:
40 mA (avg.),
65 mA (peak)

Linac4: 80 m, 18 klystrons (352 MHz)

Stage 1: Linac4 - Civil engineering status

sLHC



Linac4 tunnel (“cut and cover” excavation) seen from high-energy side.

Final concrete works starting at low-energy side, excavation proceeding at high energy side.

Tunnel level -12 m, length 100 m.

Delivery of tunnel and surface equipment building end of 2010.

Stage 1: Linac4 - Civil engineering status

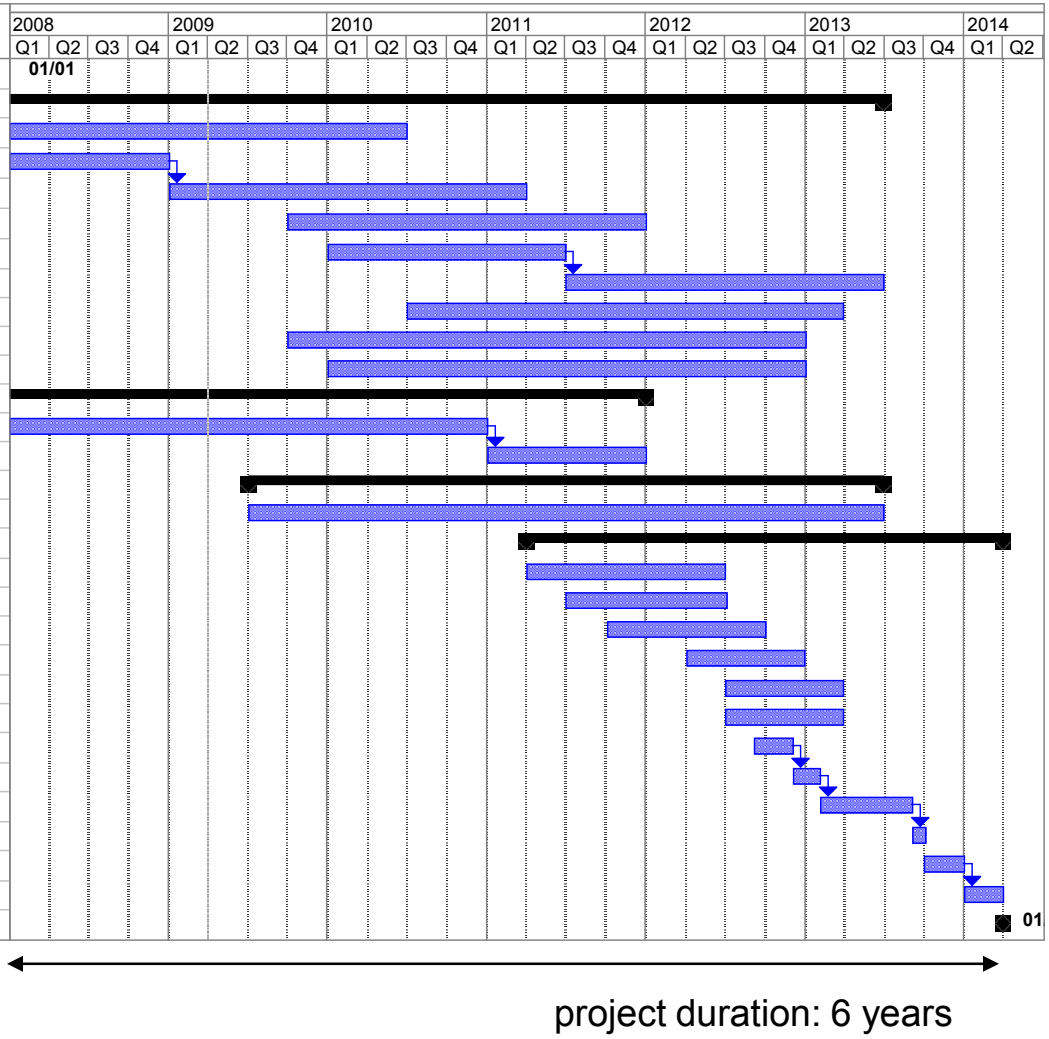
sLHC

High-energy side of Linac4 tunnel, with beam dump chamber and connecting tunnel to Linac2 line.

Stage 1 - Planning

sLHC

ID	Task Name
1	**Linac4 project start**
2	**Linac systems**
3	Source and LEBT construction, test
4	Drawings, material procurement
5	RFQ construction and commissioning
6	Accelerating structures construction
7	Klystron prototype production
8	Klystrons production
9	Transfer line construction and installation
10	Magnets construction
11	Power converters construction
12	**Building and infrastructure**
13	Building design and construction
14	Infrastructure installation
15	**PS Booster systems**
16	PSB injection elements construction
17	**Installation and commissioning**
18	Test stand operation
19	Cavities testing, conditioning
20	Cabling, waveguides installation
21	Accelerator installation
22	Klystrons, modulators installation
23	Hardware tests
24	Front-end commissioning
25	DTL1 commissioning
26	Linac accelerator commissioning
27	Transfer line commissioning
28	PSB modifications
29	PSB commissioning with Linac4
30	**PSB beam ready for PS**



project duration: 6 years

MILESTONES:

✓Building delivery: December 2010

✓ Infrastructure installation: 2011

✓ Machine and equipment installation: 2012

✓Linac commissioning: 2013

✓ PSB modifications: shut-down 2013/14.

✓Beam from PSB: April 2014.

Stage 2: LP-SPL - Main characteristics

sLHC

Ion species	H^-	
Output Energy	4	GeV
Bunch Frequency	352.2	MHz
Max. Rep. Rate	2	Hz
Max. Beam Pulse Length	0.9	ms
Max. Beam Duty Cycle	0.2	%
Nominal chopping factor (Flexible chopping scheme)	65	%
Source current	40	mA
Linac pulse current	20	mA
Number of ions per pulse	1.1	$\times 10^{14}$
Transverse emittance	0.4	π mm mrad
Max. rep. rate for accelerating structures and klystrons:	50	Hz

Required for flexibility and low loss in PS2

Required by space charge tune spread at the specified beam brightness

Re-use of LEP RF components in Front-end (Linac4)

Required for flexibility and low loss in PS2 (linac4 chopper with new driver)

- Structures and klystrons dimensioned for 50 Hz
- Power supplies and electronics dimensioned for 2 Hz, 2 ms pulse.

Stage 2: LP-SPL - Main parameters

sLHC

Frequency/temperature:

704 MHz and 2 K are confirmed,

Cavity gradient:

- 25 MV/m "on average" (= with a high yield) is very challenging and may be costly (in terms of reprocessing),
- 20 MV/m seems more achievable but will have an impact on linac length (or energy).

⇓

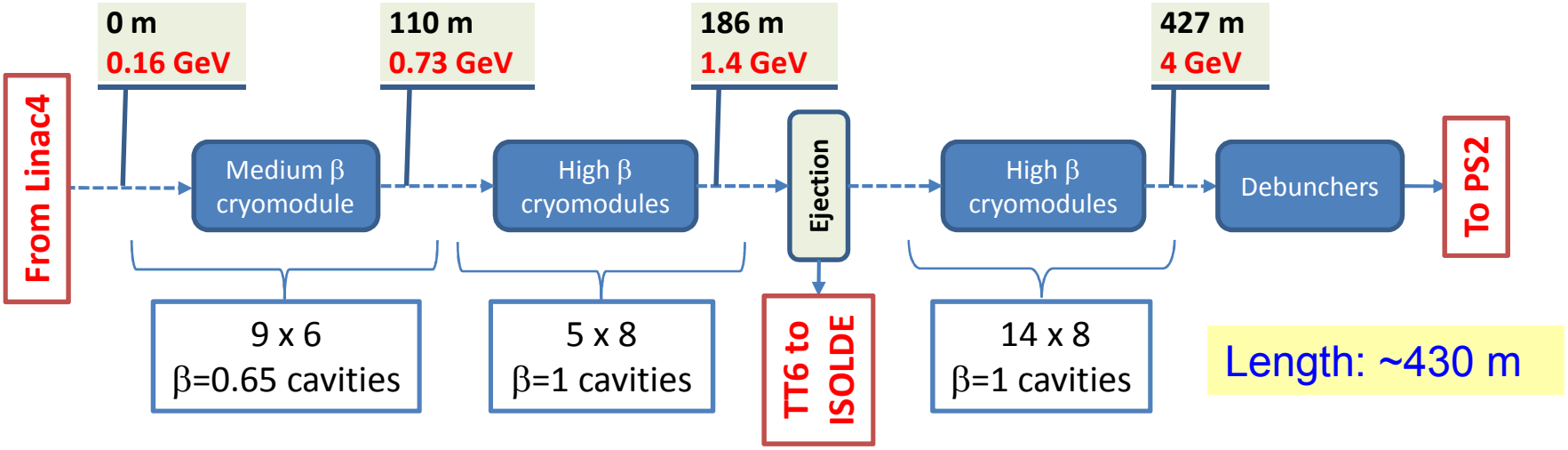
High-power RF cavity tests of fully equipped cryo-modules are mandatory for realistic SPL layout estimates!!

Ref.: Assessment of the basic Parameters of the CERN SPL, CERN-AB-2008-067-BI-RF, http://cdsweb.cern.ch/record/1136901/files/CERN-AB-2008-067.pdf

Stage 2: LP-SPL - Block diagram

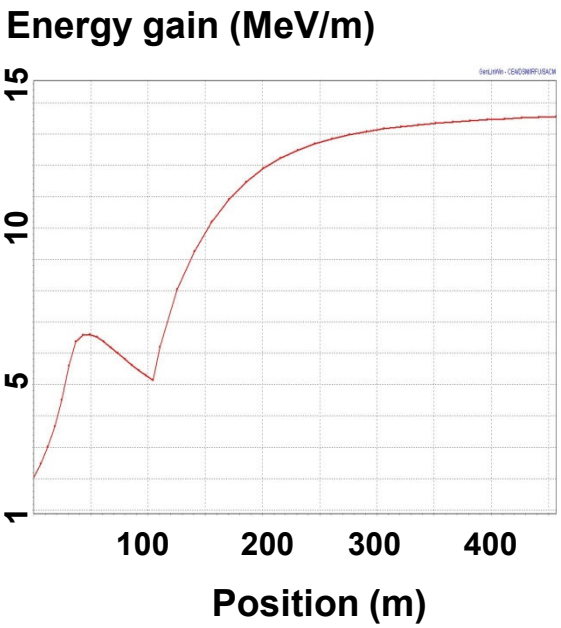
sLHC

SC-linac (160 MeV → 4 GeV) with ejection at intermediate energy



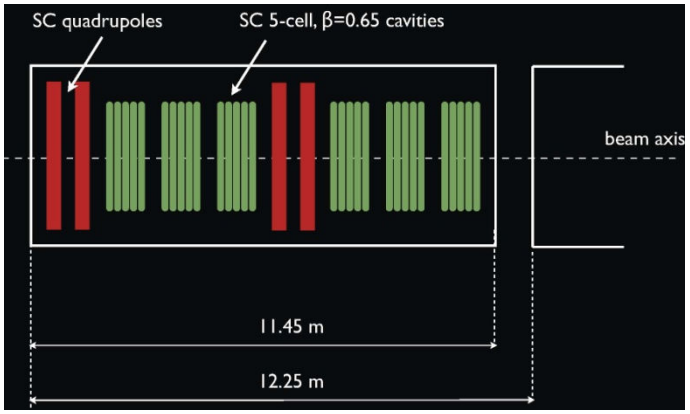
Stage 2: LP-SPL - Cryomodules

sLHC



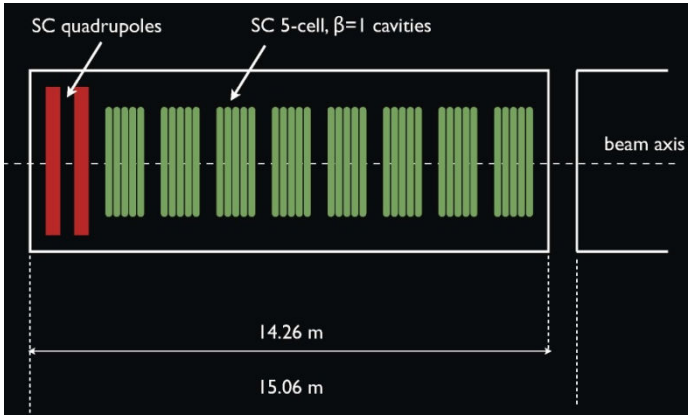
Medium β cryomodule

Energy range: 160 MeV – 732 MeV
5 cell cavities
Geometrical β: 0.65
Maximum energy gain: 19.4 MeV/m
54 cavities (9 cryomodules)
Length of medium β section: ~110.35 m



High β cryomodule

Energy range: 732 MeV – 4 GeV
5 cell cavities
Geometrical β: 1
Maximum energy gain: 25 MeV/m
152 cavities (19 cryomodules)
Length of medium β section: ~286.2 m



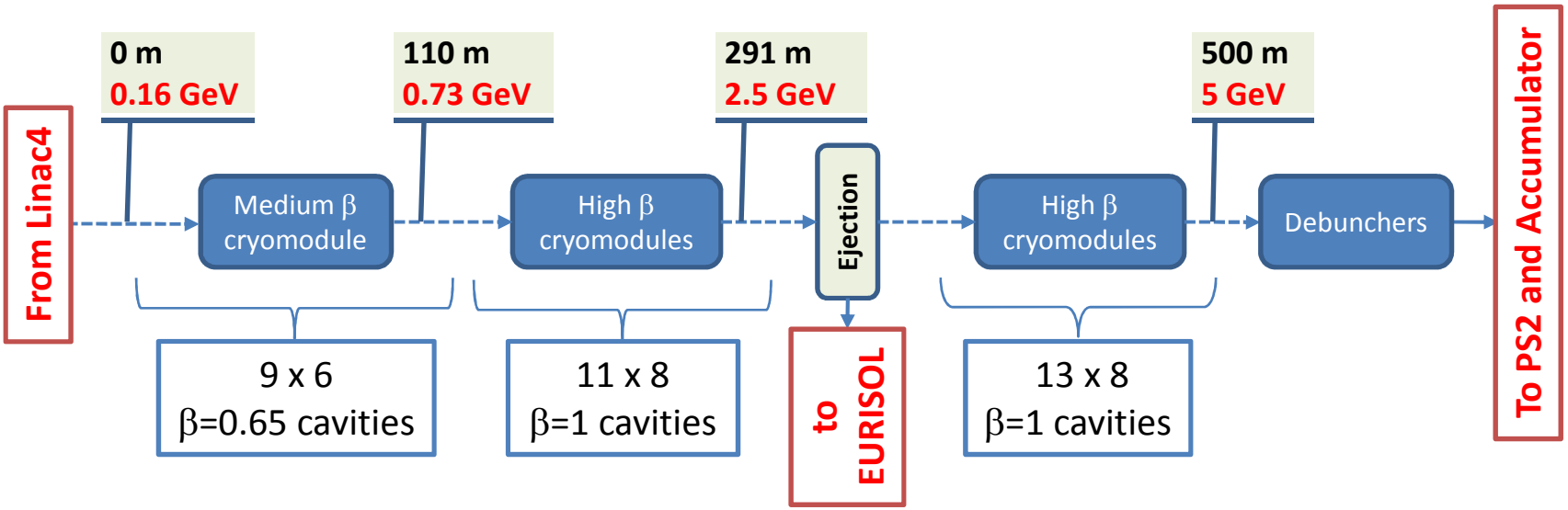
3. SPL options

High Power proton beams (HP-SPL)

sLHC

- Replacement of klystron power supplies, upgraded infrastructure (cooling & electricity, etc.)
- Addition of 5 high β cryomodules to accelerate up to 5 GeV (π production for ν Factory))

SC-linac (160 MeV → 5 GeV) with ejection at intermediate energy



Length: ~500 m

High Power proton beams (HP-SPL)

sLHC

Beam characteristics of the main options

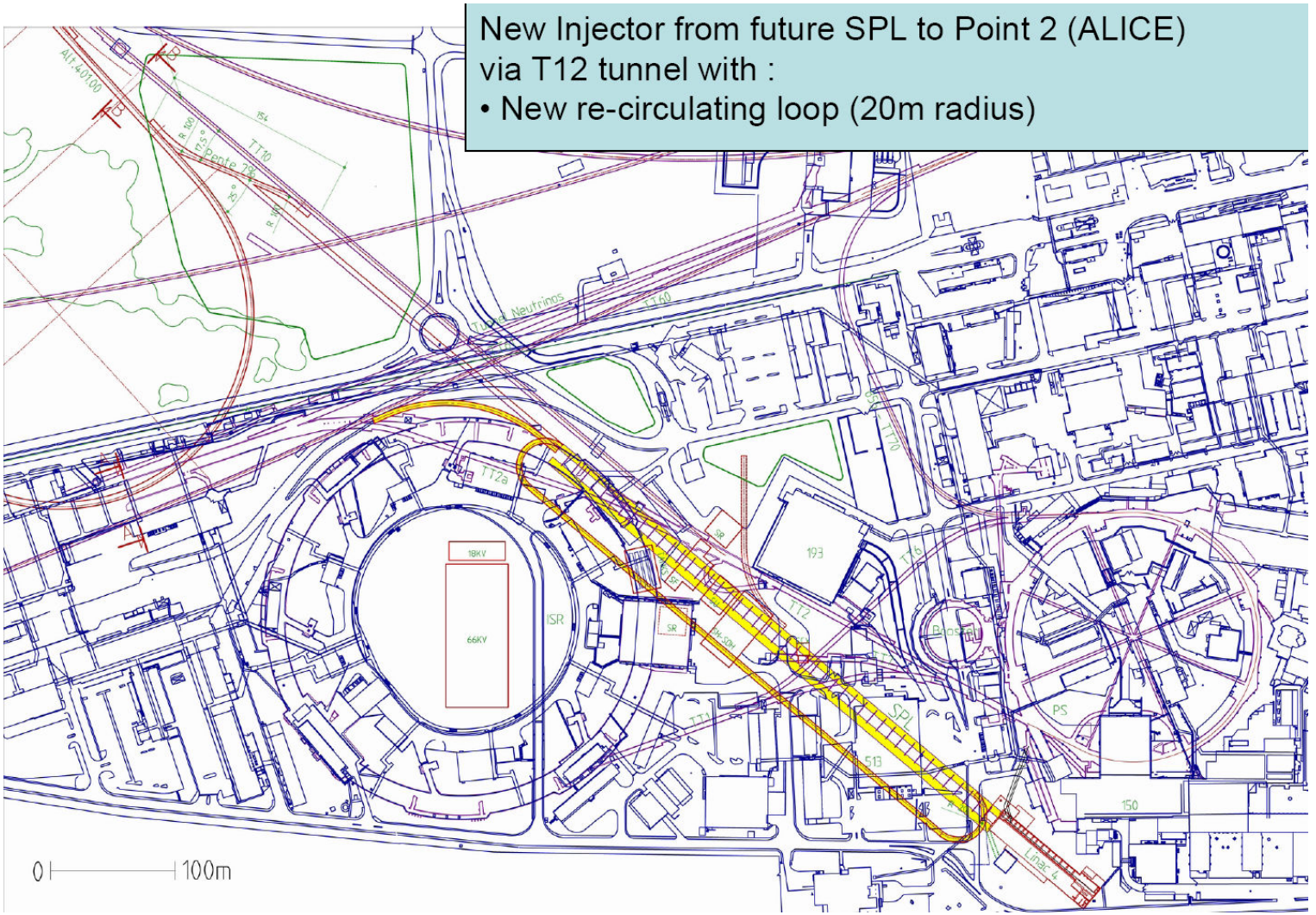
	Option 1	Option 2
Energy (GeV)	2.5 or 5	2.5 and 5
Beam power (MW)	2.25 MW (2.5 GeV) or 4.5 MW (5 GeV)	4 MW (2.5 GeV) and 4 MW (5 GeV)
Rep. frequency (Hz)	50	50
Protons/pulse (x 10^{14})	1.1	2 (2.5 GeV) + 1 (5 GeV)
Av. Pulse current (mA)	20	40
Pulse duration (ms)	0.9	0.8 (2.5 GeV) + 0.4 (5 GeV)

Faster rep. rate ⇒ new power supplies, more cooling etc.

2 × beam current ⇒ 2 × nb. of klystrons etc .

e+/e- acceleration

LHeC: 20 GeV e+/e- from the SPL (5-pass acceleration in the β=1 section) as a pre-injector for a lepton ring in the LHC tunnel (Ring/Ring option)

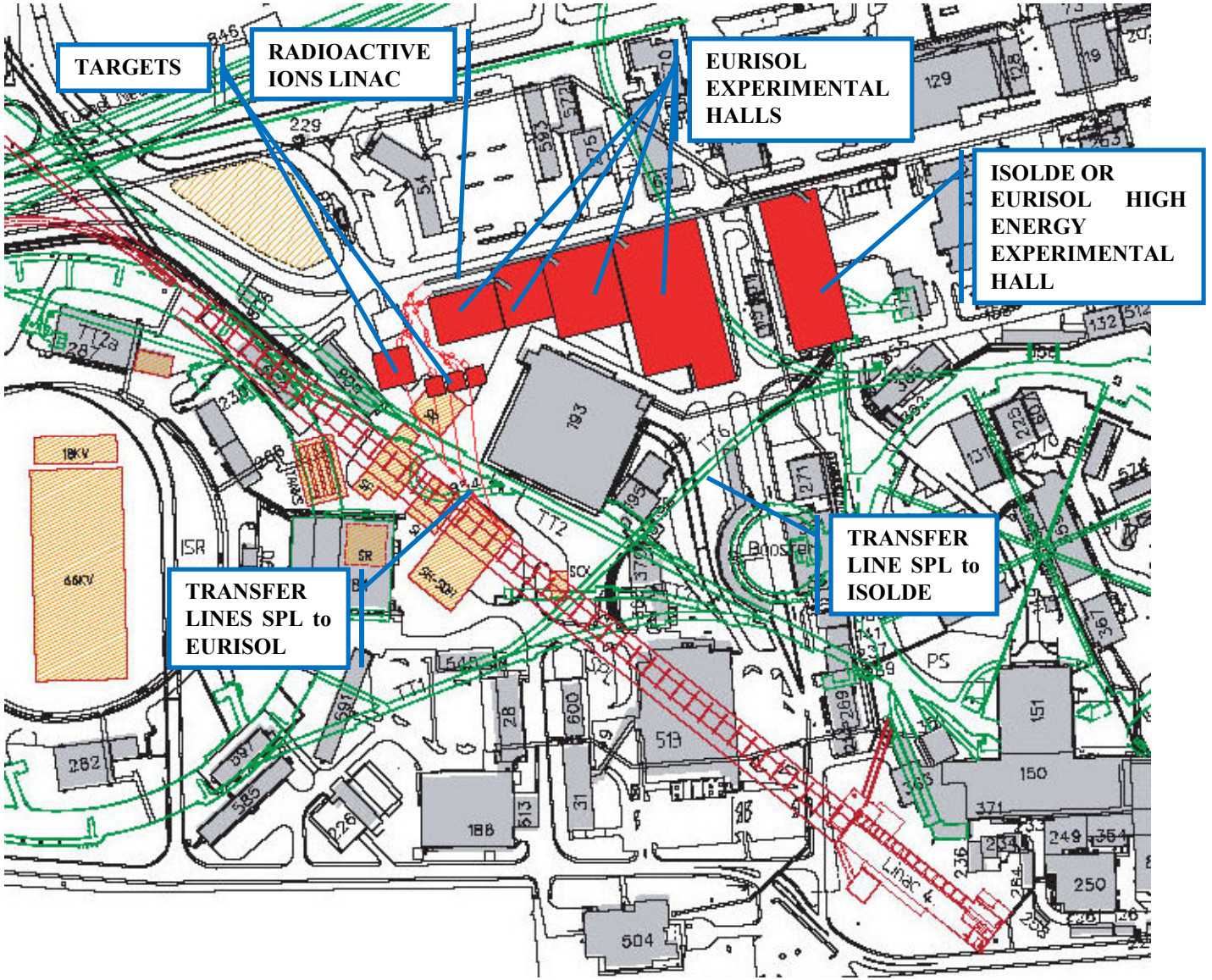


THANK YOU
FOR YOUR ATTENTION!

High power proton applications

ISOLDE & EURISOL

sLHC



Neutrino Factory