

# Review of SPL sc RF parameters

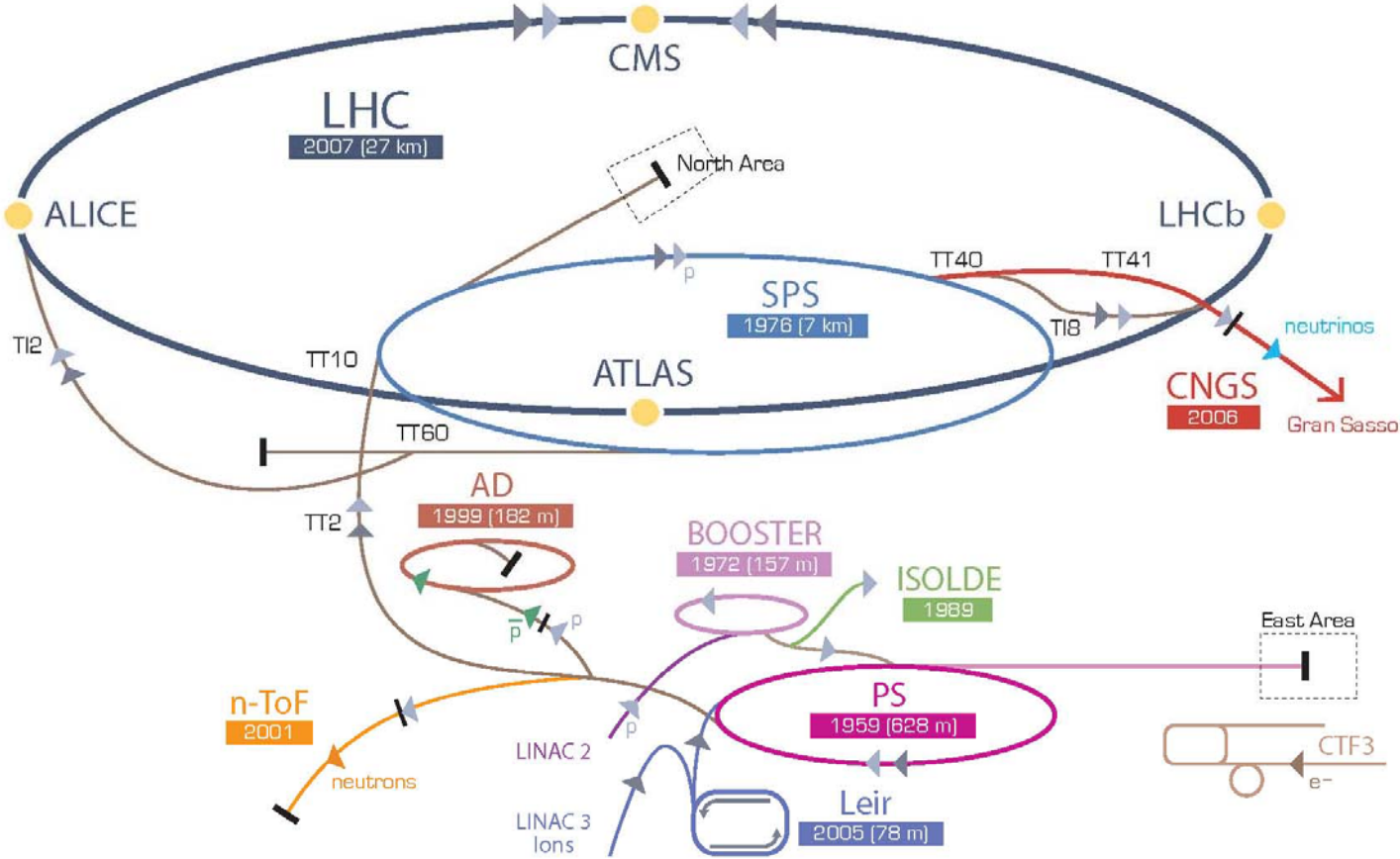
## OUTLINE

- ✓ Introduction
- ✓ The new linacs
  - Implementation stages
  - Specific constraints
- ✓ Meeting goals

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# INTRODUCTION

# CERN accelerator complex



▶ p [proton]   ▶ ion   ▶ neutrons   ▶  $\bar{p}$  [antiproton]    $\leftrightarrow$  proton/antiproton conversion   ▶ neutrinos   ▶ electron

LHC Large Hadron Collider   SPS Super Proton Synchrotron   PS Proton Synchrotron

AD Antiproton Decelerator   CTF3 Clic Test Facility   CNGS Cern Neutrinos to Gran Sasso   ISOLDE Isotope Separator OnLine DEvice  
 LEIR Low Energy Ion Ring   LINAC LINear ACcelerator   n-ToF Neutrons Time Of Flight

# Upgrade procedure

## 1. Lack of reliability:

Ageing accelerators (PS is 48 years old !) operating far beyond initial parameters

⇒ need for new accelerators designed for the needs of SLHC

## 2. Main performance limitation:

Excessive incoherent space charge tune spreads  $\Delta Q_{SC}$  at injection in the PSB (50 MeV) and PS (1.4 GeV) because of the high required beam brightness  $N/\varepsilon^*$ .

$$\Delta Q_{SC} \propto \frac{N_b}{\varepsilon_{X,Y}} \cdot \frac{R}{\beta\gamma^2}$$

with  $N_b$  : number of protons/bunch

$\varepsilon_{X,Y}$  : normalized transverse emittances

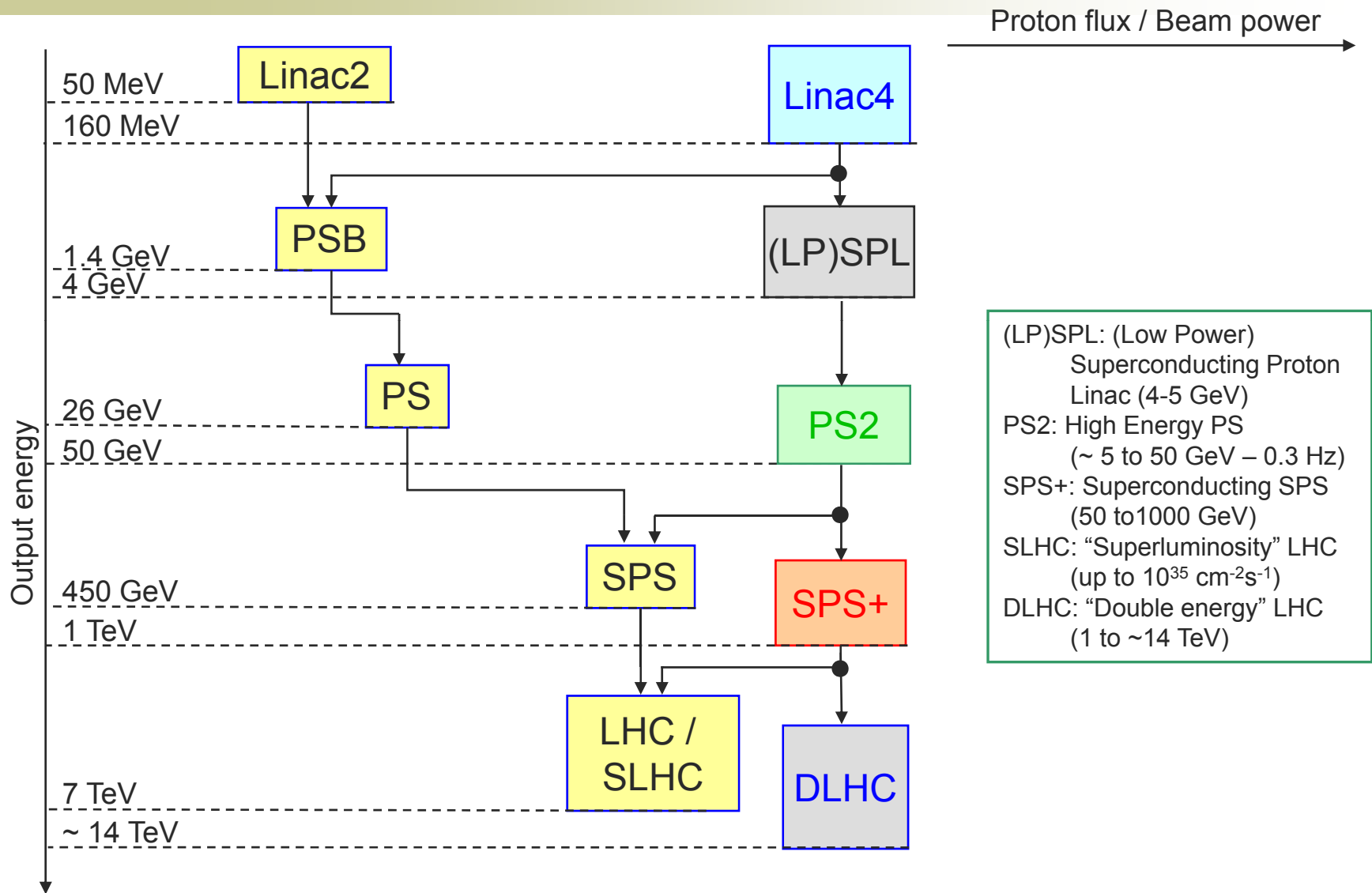
$R$  : mean radius of the accelerator

$\beta\gamma$  : classical relativistic parameters

⇒ need to increase the injection energy in the synchrotrons

- Increase injection energy in the PSB from 50 to 160 MeV kinetic
- Increase injection energy in the PSB from 25 to 50 GeV kinetic
- Design the PS successor (PS2) with an acceptable space charge effect for the maximum beam envisaged for SLHC: => injection energy of 4 GeV

# Present and future injectors

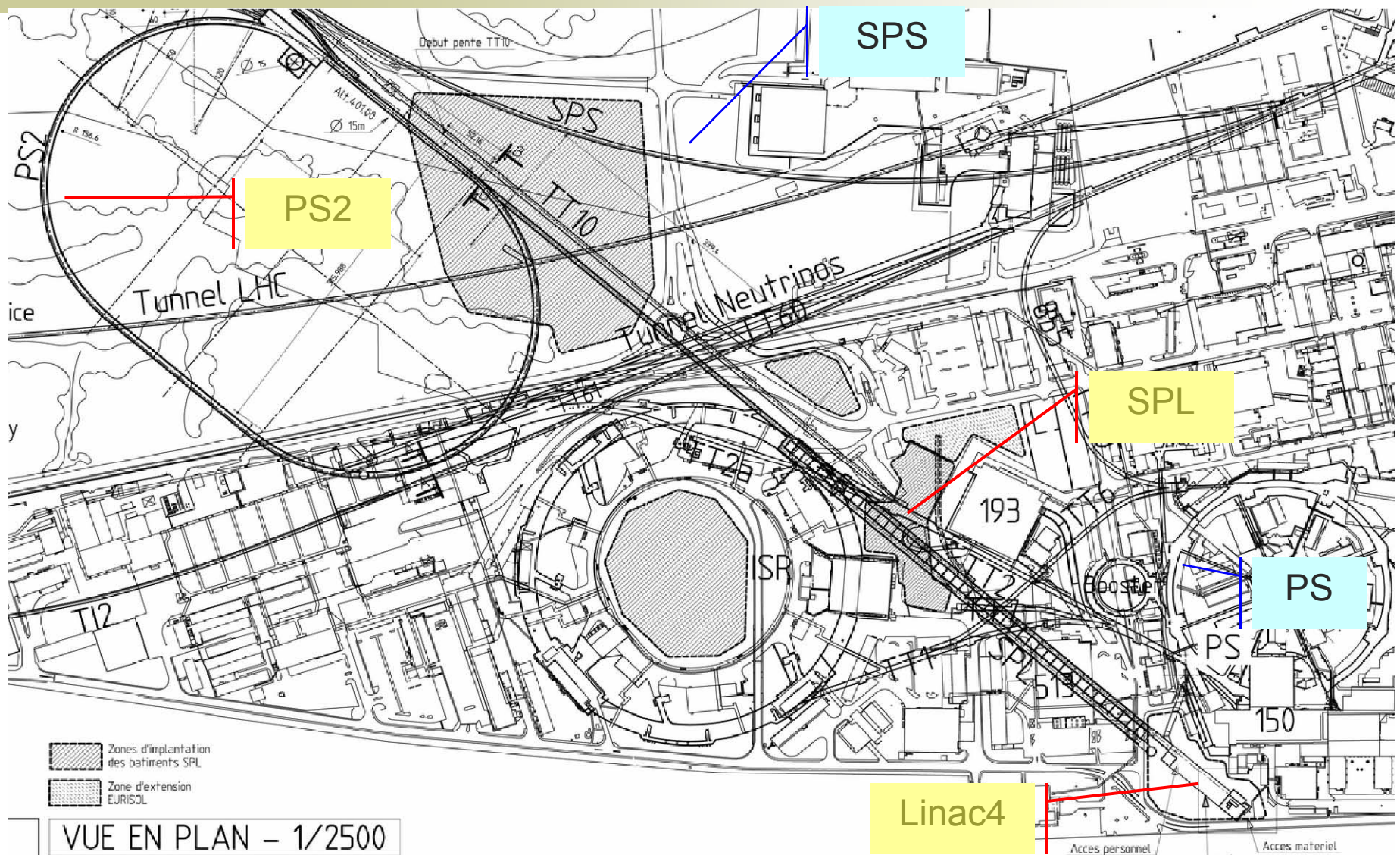


20 July 2007

30 April 2008



# Layout of the new injectors (1/2)

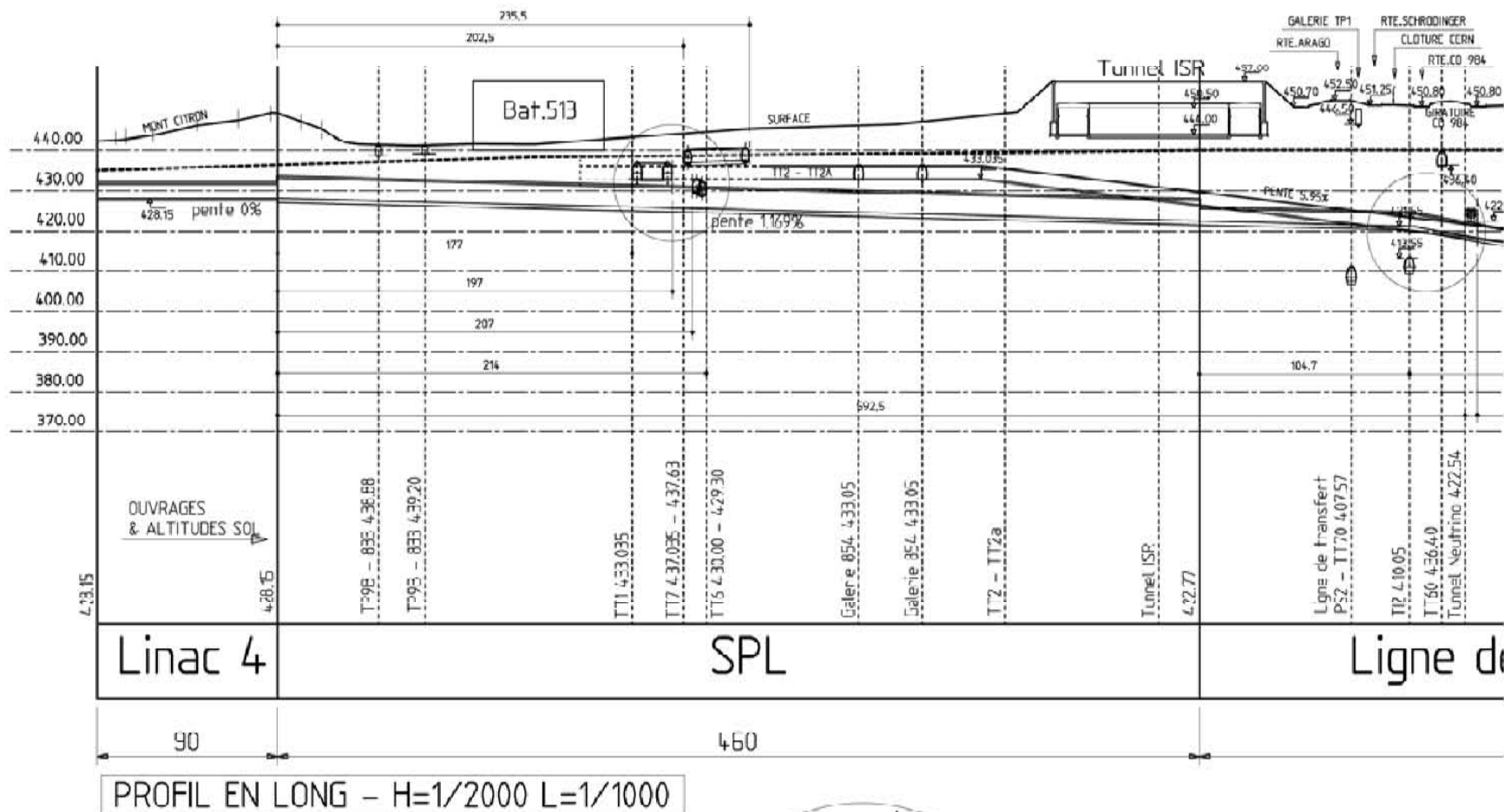


VUE EN PLAN - 1/2500

Note: Retrouvez les references des batiments SPL sur le plan intitule "SPL PROJECT"

Linac 4  
30 April 2008

# Layout of the new injectors (2/2)

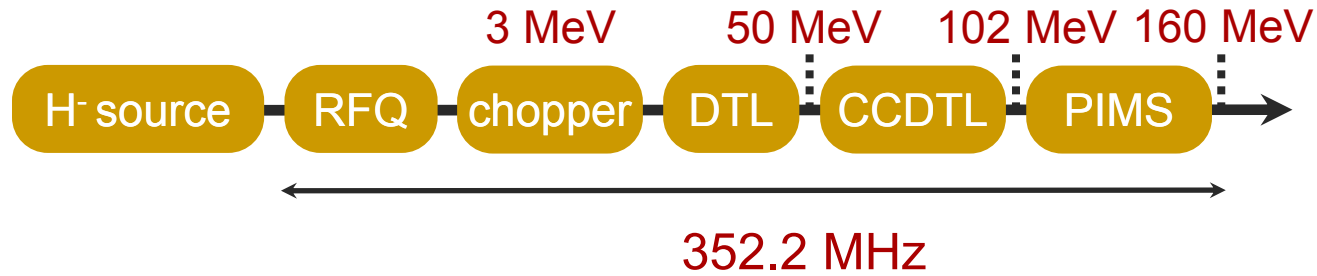


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# THE NEW LINACS



# Stage 1: Linac4 (1/2)

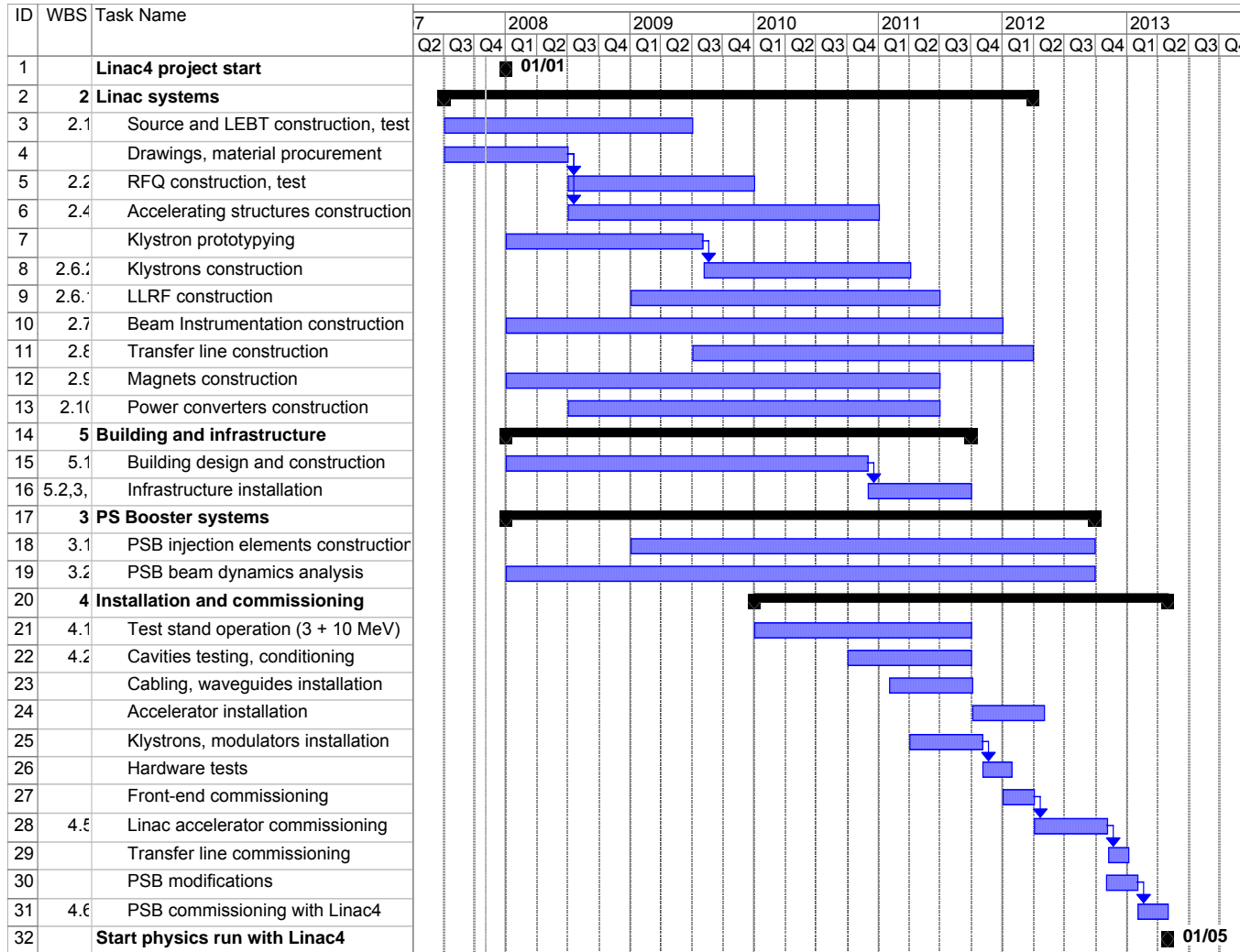


Linac4 beam characteristics

Ion species	H <sup>-</sup>
Output energy	160 MeV
Bunch frequency	352.2 MHz
Max. repetition rate	1.1 (2) Hz
Beam pulse duration	0.4 (1.2) ms
Chopping factor (beam on)	62%
Source current	80 mA
RFQ output current	70 mA
Linac current	64 mA
Average current during beam pulse	40 mA
Beam power	5.1 kW
Particles p. pulse	$1.0 \cdot 10^{14}$
Transverse emittance (source)	0.2 mm mrad
Transverse emittance (linac)	0.4 mm mrad

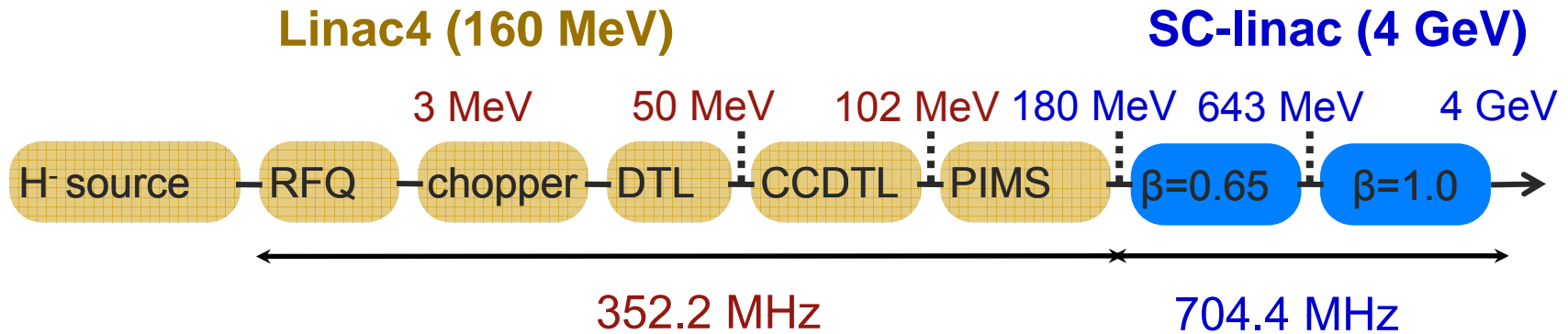


# Stage 1: Linac4 (2/2)



- ### Milestones
- End CE works: December 2010
  - Installation: 2011
  - Linac commissioning: 2012
  - Modifications PSB: shut-down 2012/13 (6 months)
  - Beam from PSB: 1st of May 2013

# Stage 2: LPSPL (1/2)

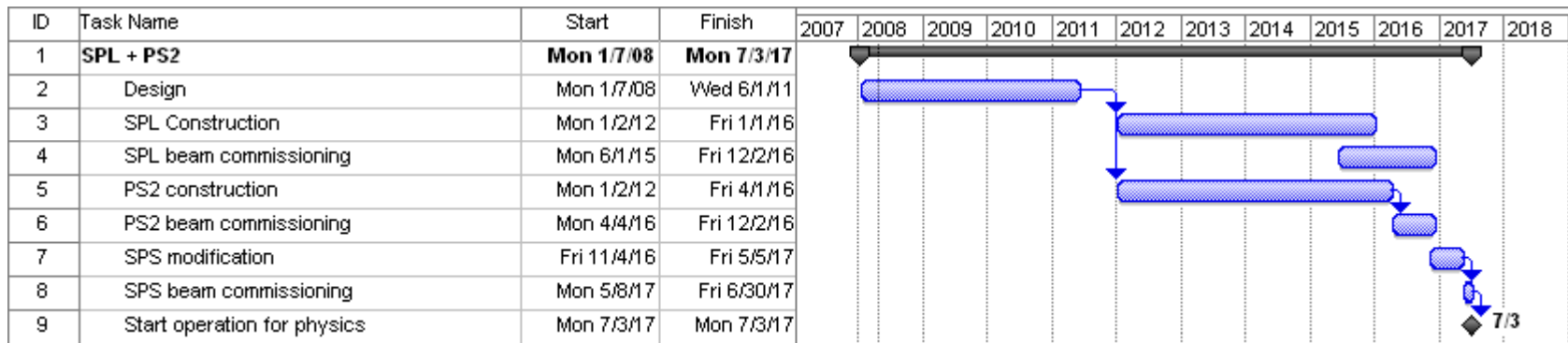


LPSPL beam characteristics

Energy (GeV)	4
Beam power (MW)	0.19
Rep. frequency (Hz)	2
Protons/pulse ( $\times 10^{14}$ )	1.5
Av. Pulse current (mA)	20
Pulse duration (ms)	1.2
Bunch frequency (MHz)	352.2
Physical length (m)	~460

# Stage 2: LPSPL (2/2)

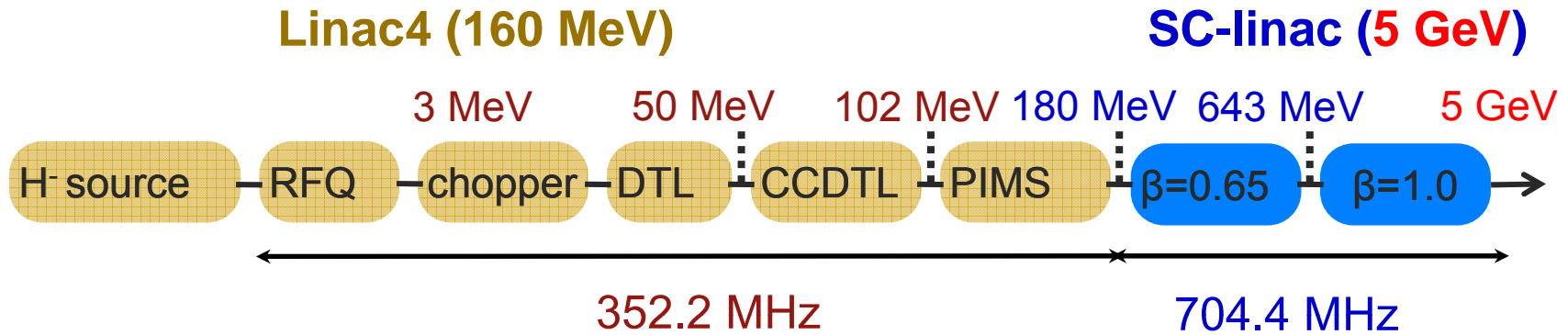
Construction of LPSPL and PS2 will not interfere with the regular operation of Linac4 + PSB for physics. Similarly, beam commissioning of LPSPL and PS2 will take place without interference with physics.



## Milestones

- Project proposal: June 2011
- Project start: January 2012
- LPSPL commissioning: mid-2015
- PS2 commissioning: mid-2016
- SPS commissioning: May 2017
- Beam for physics: July 2017

# Stage 3: SPL (1/2)



SPL beam characteristics

Energy (GeV)	5
Beam power (MW)	4 – 8
Rep. frequency (Hz)	50
Protons/pulse (x 10 <sup>14</sup> )	1 (3)
Av. Pulse current (mA)	40
Pulse duration (ms)	0.4 (1.2)
Bunch frequency (MHz)	352.2
Physical length (m)	~535

## Stage 3: SPL (2/2)

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- ✓ The upgrade from LPSPL to SPL will depend upon the approval of major new physics programmes for Radioactive Ion beams (EURISOL-type facility) and/or for neutrinos (Neutrino factory).
- ✓ Staged hardware upgrade during shutdowns
- ✓ Earliest year of operation: 2020



# Specific constraints

- Beam parameters:
  - Bunching frequency: LEP legacy => 352.2 MHz
  - Potential for high flux:
    - Low loss => careful design + safety margins
    - Radiation => adequate shielding
    - High duty factor => proper dimensioning of cooling capabilities of costly equipment (accelerating structures, magnets...) and empty space for additional equipment
- Layout:
  - Compatibility with existing accelerators + CERN site with easy extension
  - Slope ~ 1.5 %
- Physics:
  - Minimum interference with the physics programme:
    - => Minimum duration of additional shutdown and setting-up (Construction + commissioning in parallel with operation)
    - => Maximum reliability in operation
  - Capability to cover the needs of the known and of the major new programmes envisaged :
    - => flexibility
- Economics...
  - => Minimize construction and exploitation cost
  - => Minimize material and human resources for exploitation
  - => Search for synergies with other projects

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# MEETING GOALS

- 
- To summarize all the available information
  - To collect feedback from a broader audience

in view of

- Checking validity of statements
- Looking for missing arguments
- If possible, concluding...
- Or at least listing the next actions and the way to proceed for arriving at a properly motivated decision in the Summer of 2008

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# References

# “New Initiatives 2008-2011” (1/2)

- Formal request of the CERN direction to the Council in June 2007:

“ **Scientific Activities of CERN and Budget Estimates for the years 2008-2011 and provisional projections until 2016**” – CERN/2728/Rev.

- 3 high priority themes (the study of SPL and PS2 are parts of the 2<sup>nd</sup> theme together with the construction of Linac4)

White Paper  
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## B) Second Theme:

As a high priority, the renovation of the entire old injector complex should be started in order to eliminate the concern about reliability of LHC operation in the longer term and the technical bottlenecks in the present injection line. The proposed strategy is firstly to replace the present Linac 2 with a new PS Booster (PSB) injector, Linac 4, and later to replace the PS by a new one (PS2), with a similar cycling rate but capable of 50 GeV. PS2 will probably be fed by a new high beam-current superconducting proton linac (SPL) capable of about 5 GeV. SPL could also be appropriate for a neutrino production facility.

In the period up to 2011, this strategy should thus be implemented by two actions:

- The first is to build Linac 4, capable of 160 MeV instead of 50 MeV and with a better emittance. These features will enhance the ability to operate the LHC reliably at high

# “New Initiatives 2008-2011” (2/2)

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- The second, to be executed in parallel to the first, is to push forward the design of PS2 and SPL. The requested effort represents the CERN contribution to attract international partners, typically in the context of FP7 proposals. Despite the comment of the SPC panel, the requested effort for SPL is not felt to be excessive in order to prepare such a large project (see also comment on Linac 4 construction above).

**Estimated P requirement = 30 FTEs for PS2 and 40 FTEs for the SPL.**

- A lower priority theme to be financed with 10 MCHF/year in 2010 and after

White Paper  
page 24

**D) Fourth Theme:**

This Theme includes activities that are of high scientific interest, but which rely only partially on CERN contributions and will require an agreement with outside partners for an amount that is currently unknown. The components of this Theme are:

- 1) A facility to be (re)built at CERN, profiting from earlier investments (LEP), including additional equipment and a facility for testing superconducting cavities. Projects that would need such a facility include: International Linear Collider, Superconducting Proton Linac; high intensity Neutrino Facility; High Intensity and Energy ISOLDE. This facility would include clean rooms, an electro-polishing facility, cryogenic cooling infrastructure at 4.2 and 1.8 K, RF testing equipment, etc.). The contribution of CERN may be in the range of:

**M + P = 10 MCHF + ~ 20 FTEs.**





## Prospects for scientific activities over the period 2012-2016



Results available from LHC operation during the period 2008-2011 and from the activities proposed above should allow the CERN Council in 2010-2011 to decide on the future of CERN for more than one decade.

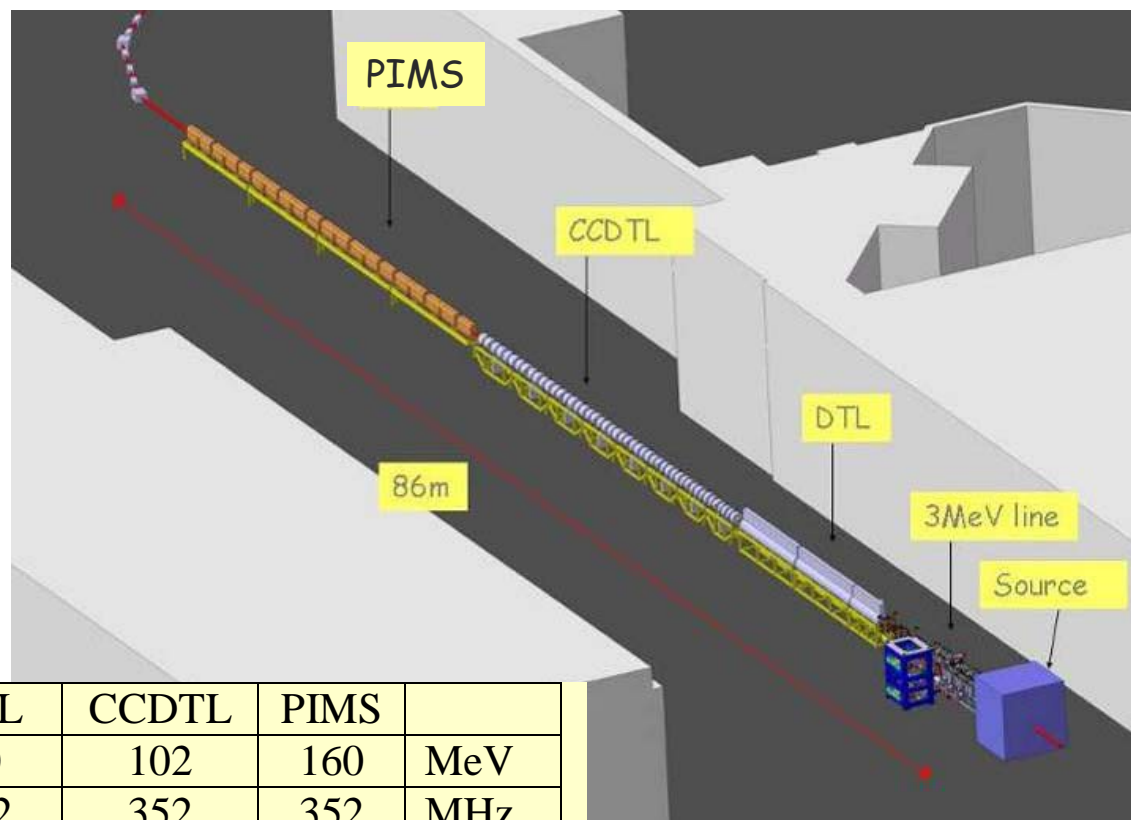
- If results from the LHC, as is highly likely, suggest the need for an increase in luminosity allowing a more extensive exploration of the new territory opened by the LHC, **a decision on the luminosity increase** (new RF system, new magnets for IR, increased cooling, new tracking in detectors, etc.) **will entail a simultaneous decision to build a new injector (SPL and PS) since higher LHC performance cannot be achieved reliably enough without a new injection line.**

The total cost of the investment, which is assumed to be realized in 6 years (2011-2016), is within the range 1'000-1'200 MCHF and will require a staff of 200-300 per year, thus a total budget of about 200-250 MCHF per year.

# Linac4 accelerating structures

Linac4 accelerates H<sup>-</sup> ions up to 160 MeV energy:

- ❑ in about 80 m length
- ❑ using 4 different accelerating structures, all at 352 MHz
- ❑ the Radio-Frequency power is produced by 19 klystrons
- ❑ focusing of the beam is provided by 111 Permanent Magnet Quadrupoles and 33 Electromagnetic Quadrupoles

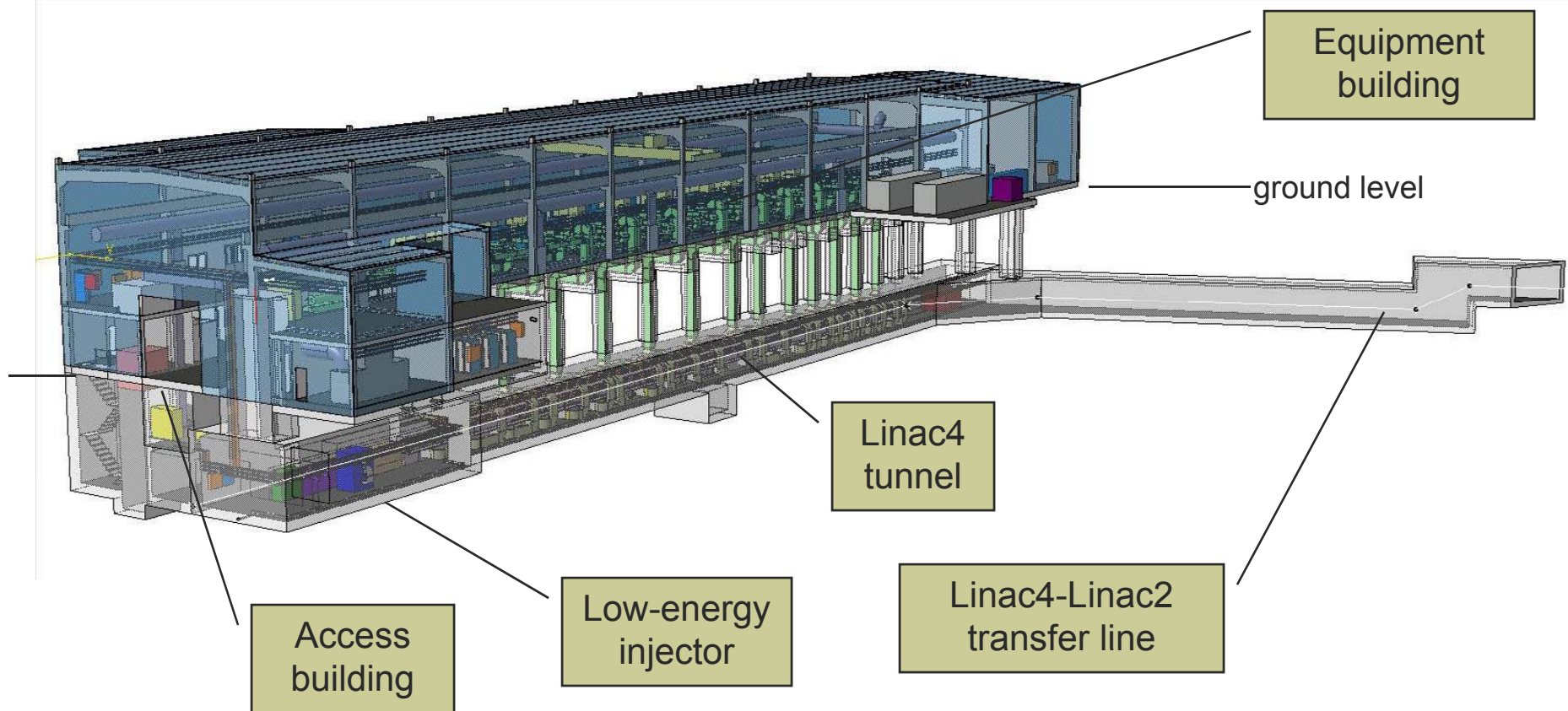


	RFQ	DTL	CCDTL	PIMS	
Output energy	3	50	102	160	MeV
Frequency	352	352	352	352	MHz
No. of resonators	1	3	7	12	
Gradient $E_0$	-	3.2	2.8-3.9	4.0	MV/m
Max. field	1.95	1.6	1.7	1.8	Kilp.
RF power	0.5	4.7	6.4	11.9	MW
No. of klystrons	1	1+2	7	4+4	
Length	6	18.7	25.2	21.5	m

A 70 m long transfer line connects to the existing line Linac2 - PS Booster



# Linac4 civil engineering



Pre-integration May – October 2007: definition of building dimensions and characteristics  
Tendering drawings preparation November 2007 – April 2008  
Integration continuing, for small modifications before start of works.

30 April 2008