CERN LINAC UPGRADE ACTIVITIES

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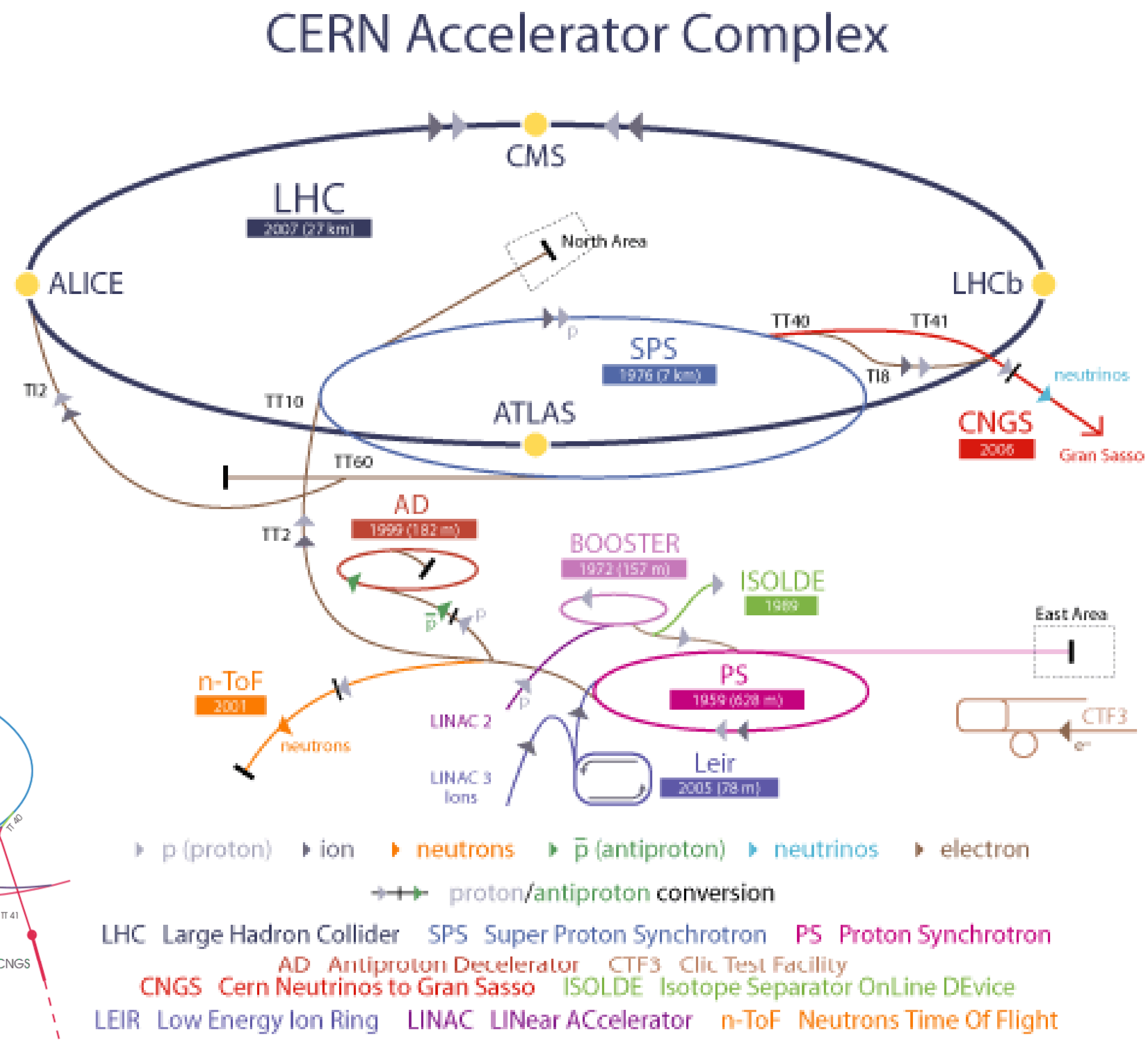
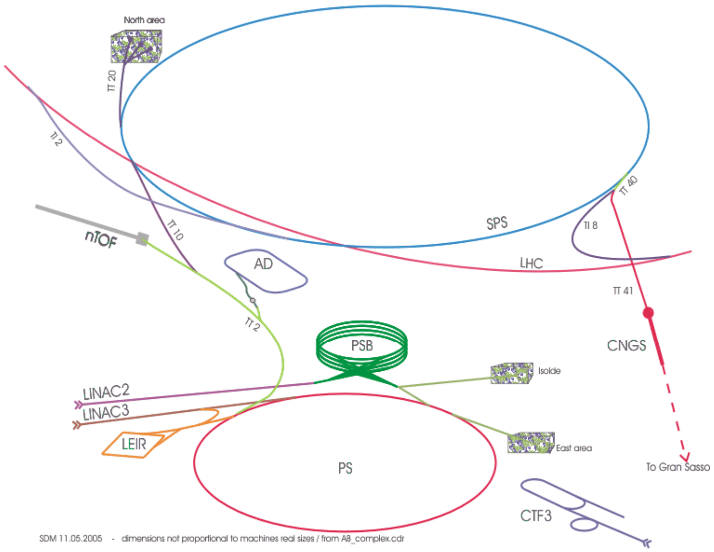
In its June 2007 session the CERN Council has approved the White Paper "Scientific Activities and Budget Estimates for 2007 and Provisional Projections for the Years 2008-2010 and Perspectives for Long-Term", which includes construction of a 160 MeV H- linear accelerator called LINAC4, and the study of a 5GeV, high beam power, superconducting proton Linac (SPL).

1. Present CERN proton LINAC
2. Staged upgrade : LINAC4 and SPL
3. CARE/HIPPI

Present


CERN Accelerator Complex
CMS
LHC
2007 (27 km)
North Area
ALICE
LHCb
TT40
TT41
SPS
1976 (7 km)
TI8
neutrinos
TI2
TT10
ATLAS
CNGS
2006
Gran Sasso
TT60
AD
1999 (182 m)
TT2
BOOSTER
1972 (157 m)
ISOLDE
1989
East Area
n-ToF
2001
PS
1959 (628 m)
CTF3
e–
LINAC 2
neutrons
LINAC 3
Ions
Leir
2005 (78 m)
p (proton)
ion
neutrons
p̄ (antiproton)
neutrinos
electron
proton/antiproton conversion
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


North area
SPS
nTOF
AD
LHC
CNGS
PSB
Isolde
LINAC2
LINAC3
LEIR
PS
East area
To Gran Sasso
CTF3

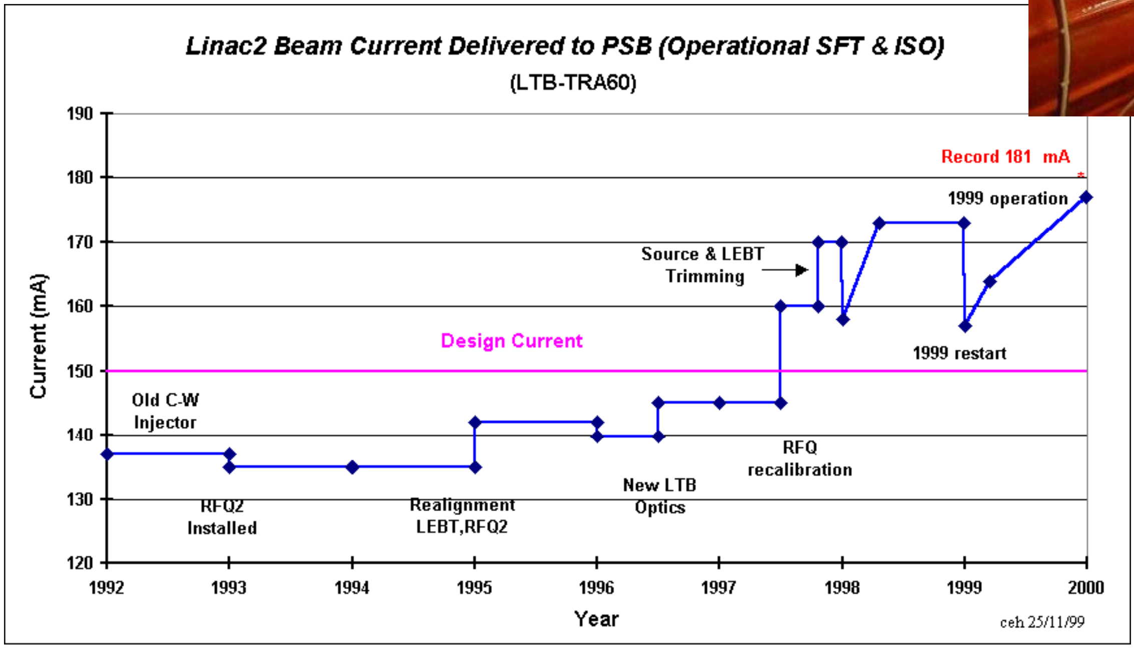
Linac2 (1978 , upgraded 1993)

- A Duoplasmaton ion source giving up to 300 mA of beam current.

- Until 1993 the pre-injector was a 750 kV Cockcroft-Walton replaced by a 4-vane RFQ (RFQ2) with an injection energy of 90 kV and an output energy of 750 keV.

- A three tank , 202.56 MHz drift tube linac with quadrupole focusing brings the beam energy to 50 MeV.

- An 80 meter beam transport carries the linac beam to the 1.4 GeV PSB .

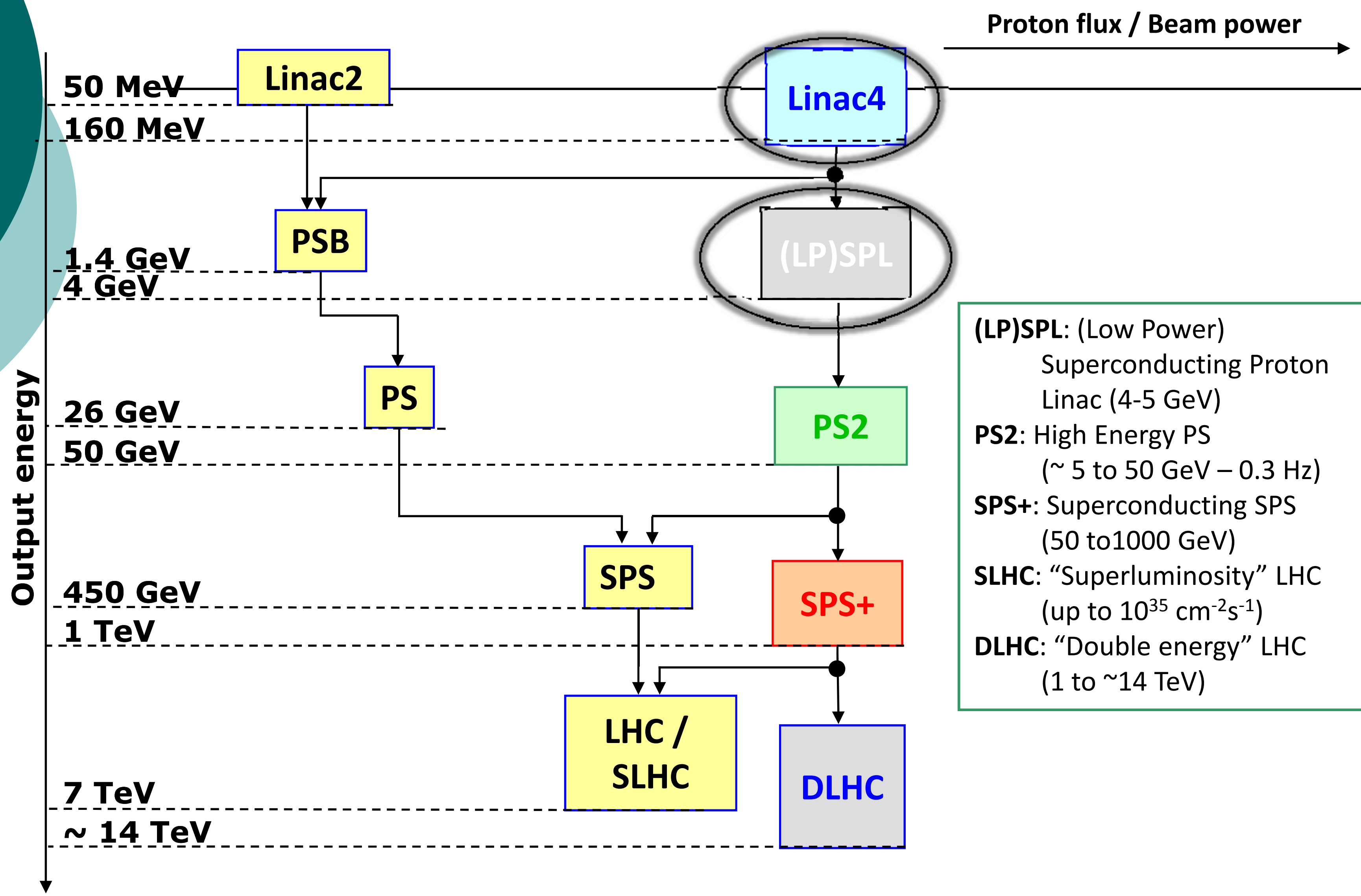


LINAC is working well above the design current.

Why upgrade the present linac

LINAC2	
protons	H- Charge exchange injection can increase brilliance in a ring.
50 MeV	Reach the limit of the space charge tune shift in the CERN PS booster.
200 MHz	RF frequency that is not widespread anymore. No components “off the shelf”.
Since 1978	Tanks, vacuum, mechanics are aging.

Upgrade with a look to the future



(LP)SPL: (Low Power) Superconducting Proton Linac (4-5 GeV)

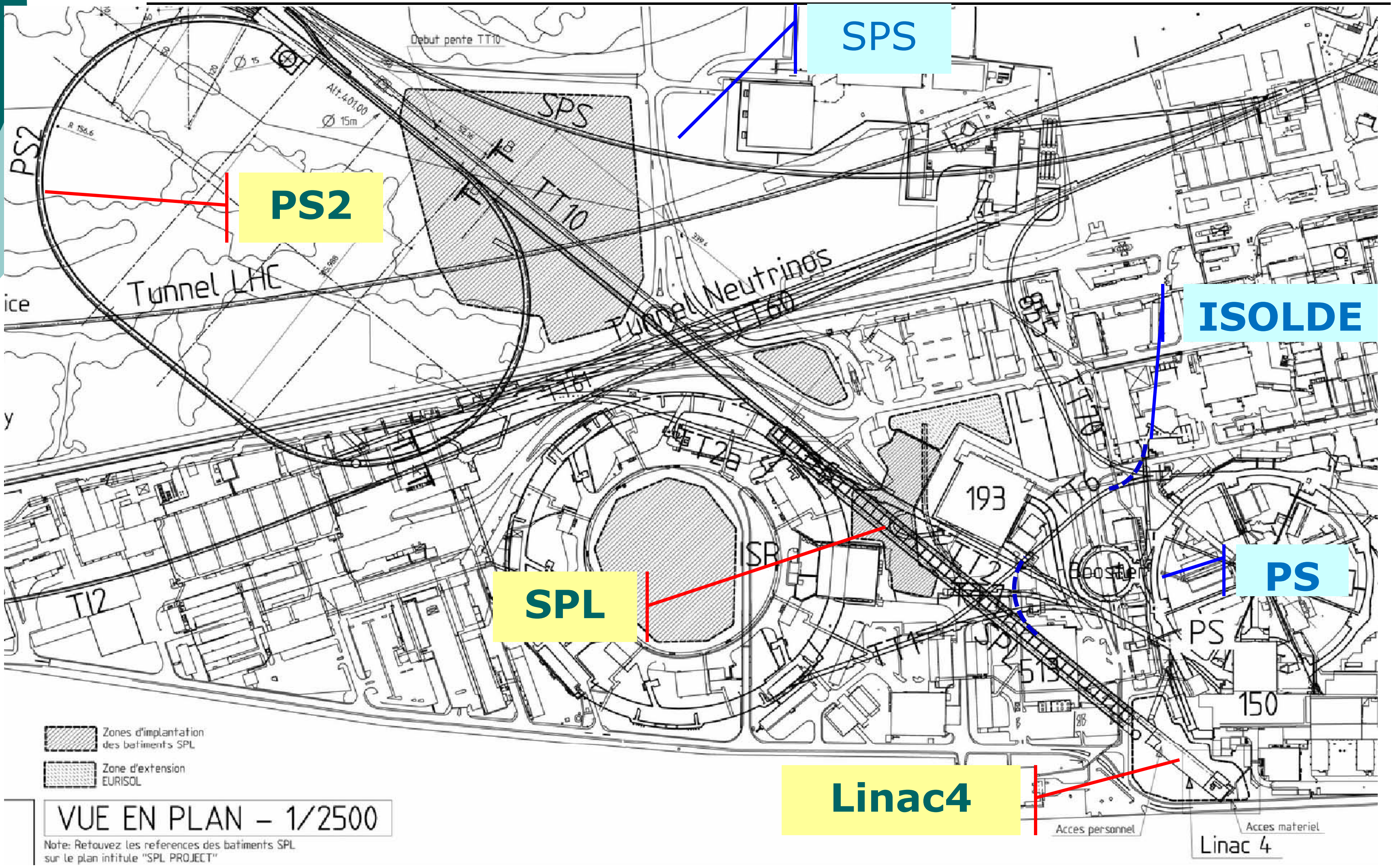
PS2: High Energy PS (~ 5 to 50 GeV – 0.3 Hz)

SPS+: Superconducting SPS (50 to1000 GeV)

SLHC: “Superluminosity” LHC (up to 10^{35} $cm^{-2}s^{-1}$)

DLHC: “Double energy” LHC (1 to ~14 TeV)

Layout of the new injectors



Expectations

LINAC4 construction is approved

- LINAC4
  - Rejuvenation of the LINAC (Linac2 dates from 1978)
  - Higher performance from the PS Booster (2 X brightness)
    - space charge tune shift decreased by 2;
    - low loss injection process ,
    - Better longitudinal injection (chopping and "energy painting")
- LP-SPL (+PS2)
  - Rejuvenation of injectors (PBS,PS date from 1972 and 1559)
  - Higher performance from SPS and more…
    - SPS could deliver 2.2X the ultimate LHC beam;
    - Potential to increase the intensity per pulse ,
    - 50% of the LP-SPL pulses are available for other physics (ISOLDE/EURISOL, LHeC…)

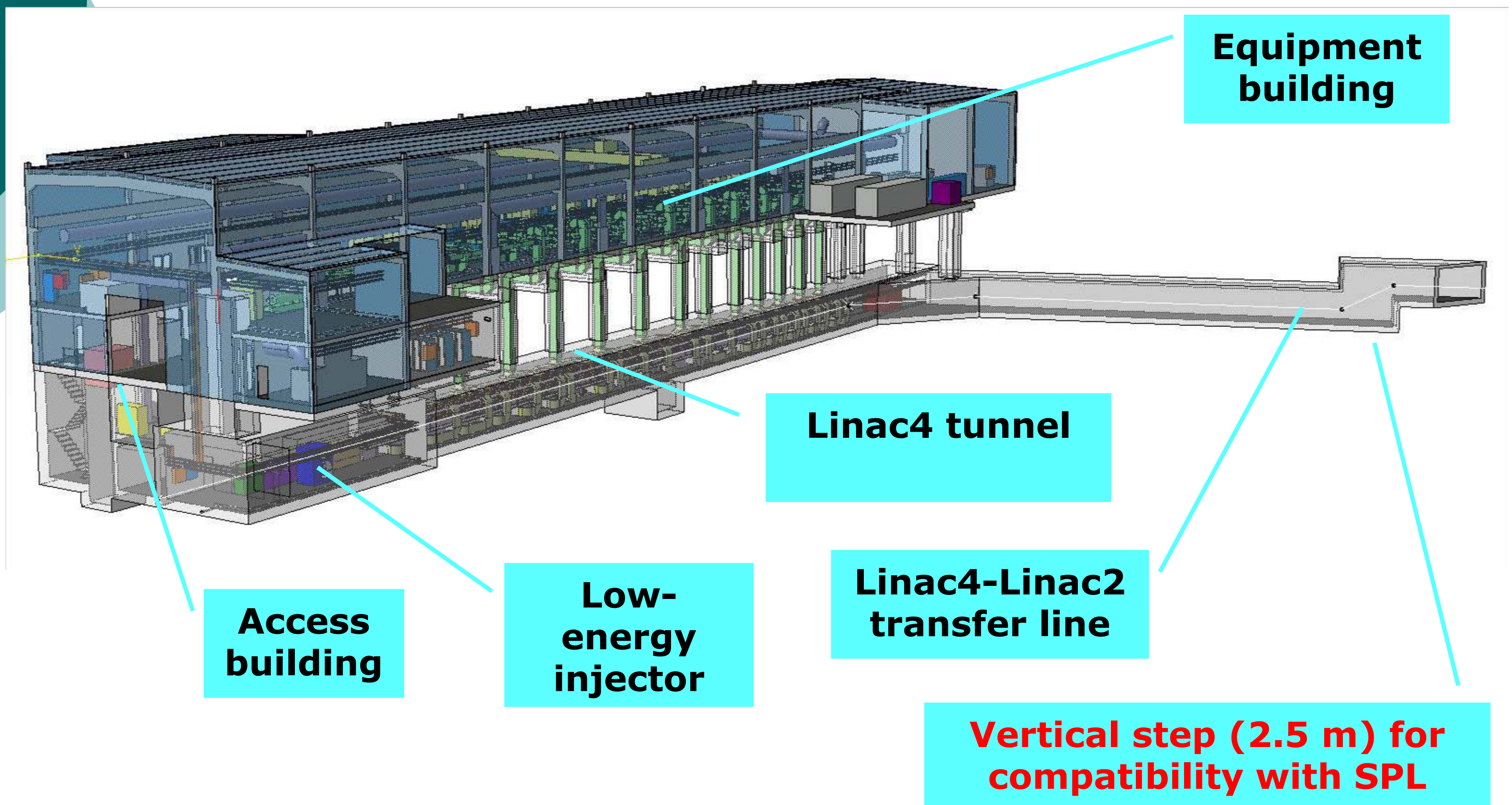
Work towards a Technical Design report for SPL and PS2

- SPL
  - High power (4MW) beam available for neutrino factory,…

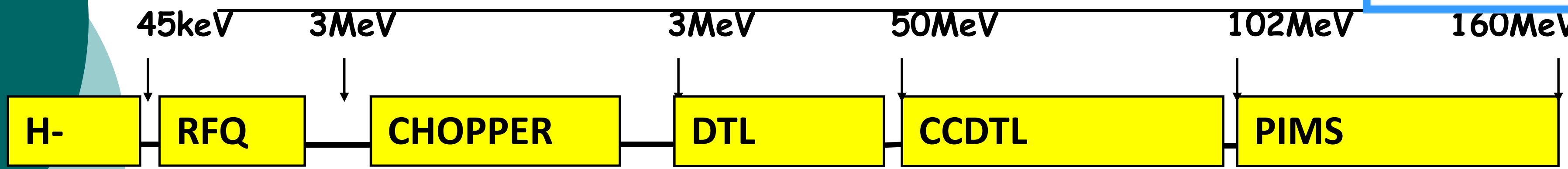
Activities Linac4 (2008-2013)
Goal : operational in 2013

LINAC4 parameters		
Ion species	H^-	Charge exchange injection
Output kinetic energy	160 MeV	Halves the space charge detuning at PSB injection
Bunch frequency	352.2 MHz	LEP klystrons
Max. repetition rate	1.1 (2) Hz	Ready for LP-SPL operation
Beam pulse duration	0.4 (1.2) ms	Ready for LP-SPL operation
Chopping factor (beam on)	65%	Limit the long. Losses at PBS injection
Source current	80 mA	
Linac current	64 mA	Losses at low energy
Average current during beam pulse	40 mA	After chopping
Beam power	2.8 kW	
Particles / pulse	$1.0\ 10^{14}$	
Transverse emittance (source)	0.25 mm mrad	
Transverse emittance (linac)	0.4 mm mrad	Half the emittance of Linac2

Linac4 Building



Linac4 Layout



RF volume source (DESY)
45 kV
1.9m
LEBT

Radio Frequency Quadrupole
352 MHz
3 m
1 Klystron
0.6 MW

Chopper

352 MHz
3.6 m
11 EMquad
3 cavities

Drift Tube Linac

352 MHz
18.7 m
3 tanks
3 klystrons
4 MW
111 PMQuad

Cell-Coupled Drift Tube Linac
352 MHz
25 m
21 tanks
7 klystrons
6.5 MW
21 EMQuads

Pi-Mode Structure

352 MHz
22 m
12 tanks
8 klystrons
~12 MW
12 EMQuads

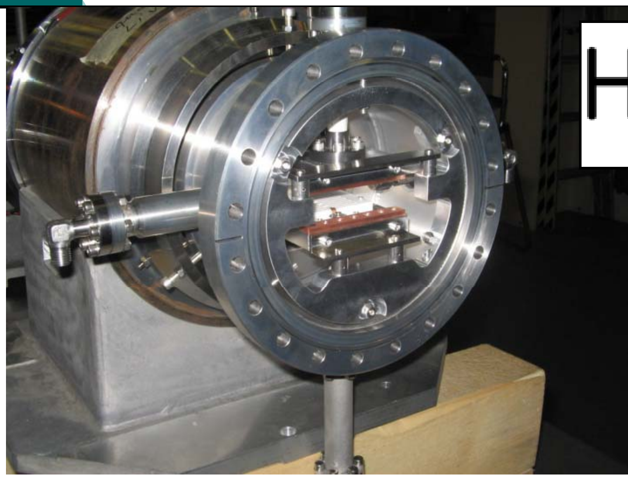
Total Linac4:
80 m,
19 klystrons

Beam Duty cycle:
0.1% phase 1 (Linac4)
3-4% phase 2 (SPL)
(design for losses : 6%)

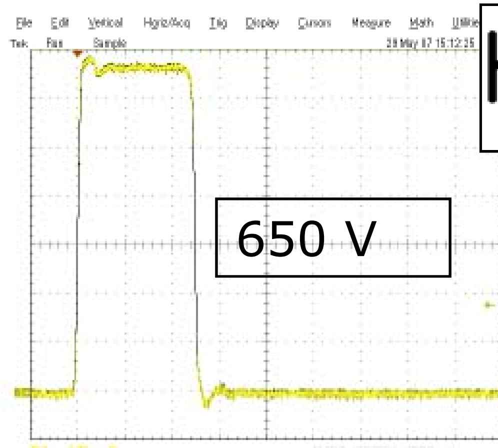
4 different structures,
(RFQ, DTL, CCDTL, PIMS)

Ion current: 40 mA (avg. in pulse), 65 mA (bunch)

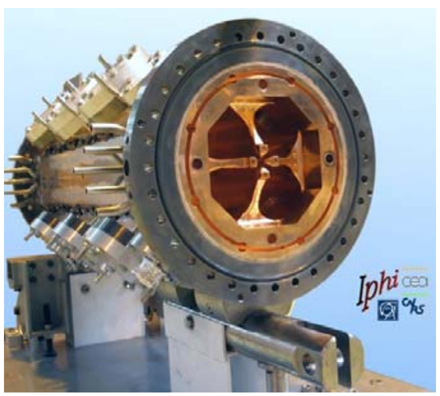
“Prototyping” activities 1/2



Chopper plates mounted inside a quadrupole

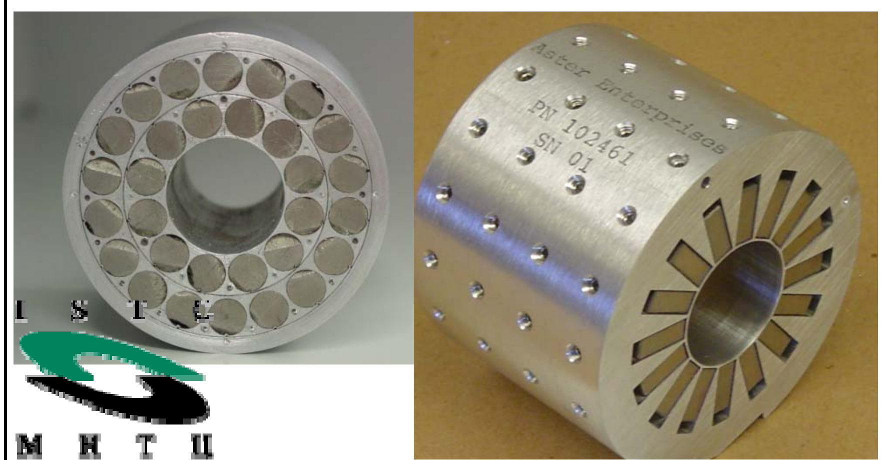


Chopper driver pulse



IPHI RFQ first module

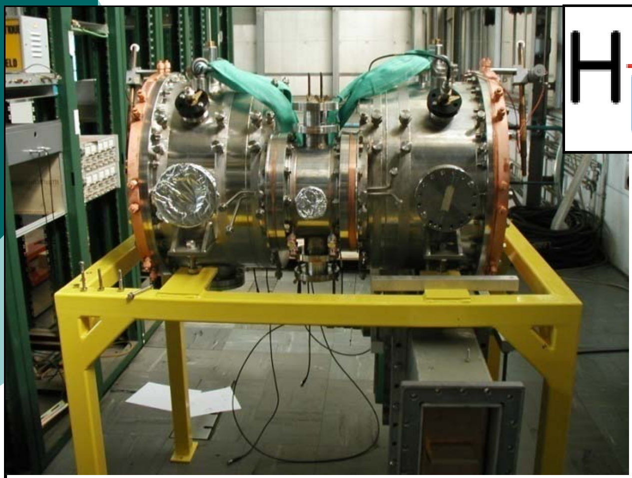
CERN DTL prototype



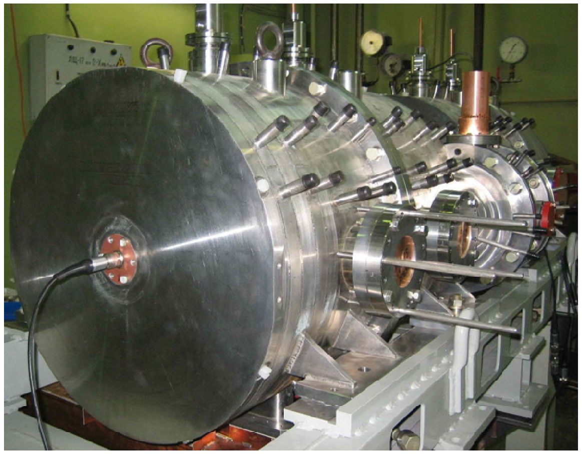
DTL Permanent Magnet Quadrupoles

“Prototyping” activities 2/2

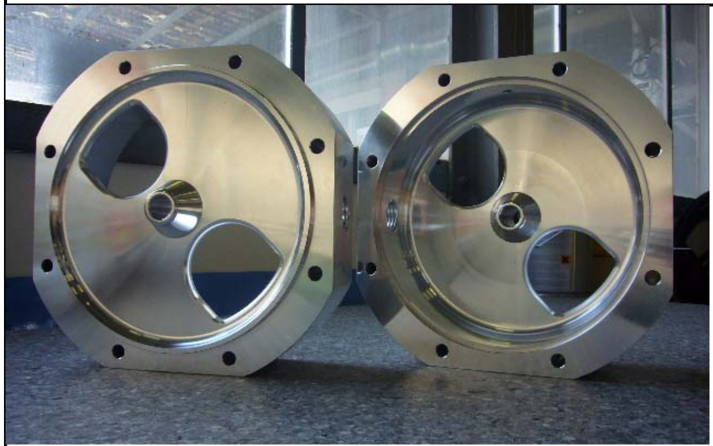
refer to papers in this conference



CCDTL CERN prototype



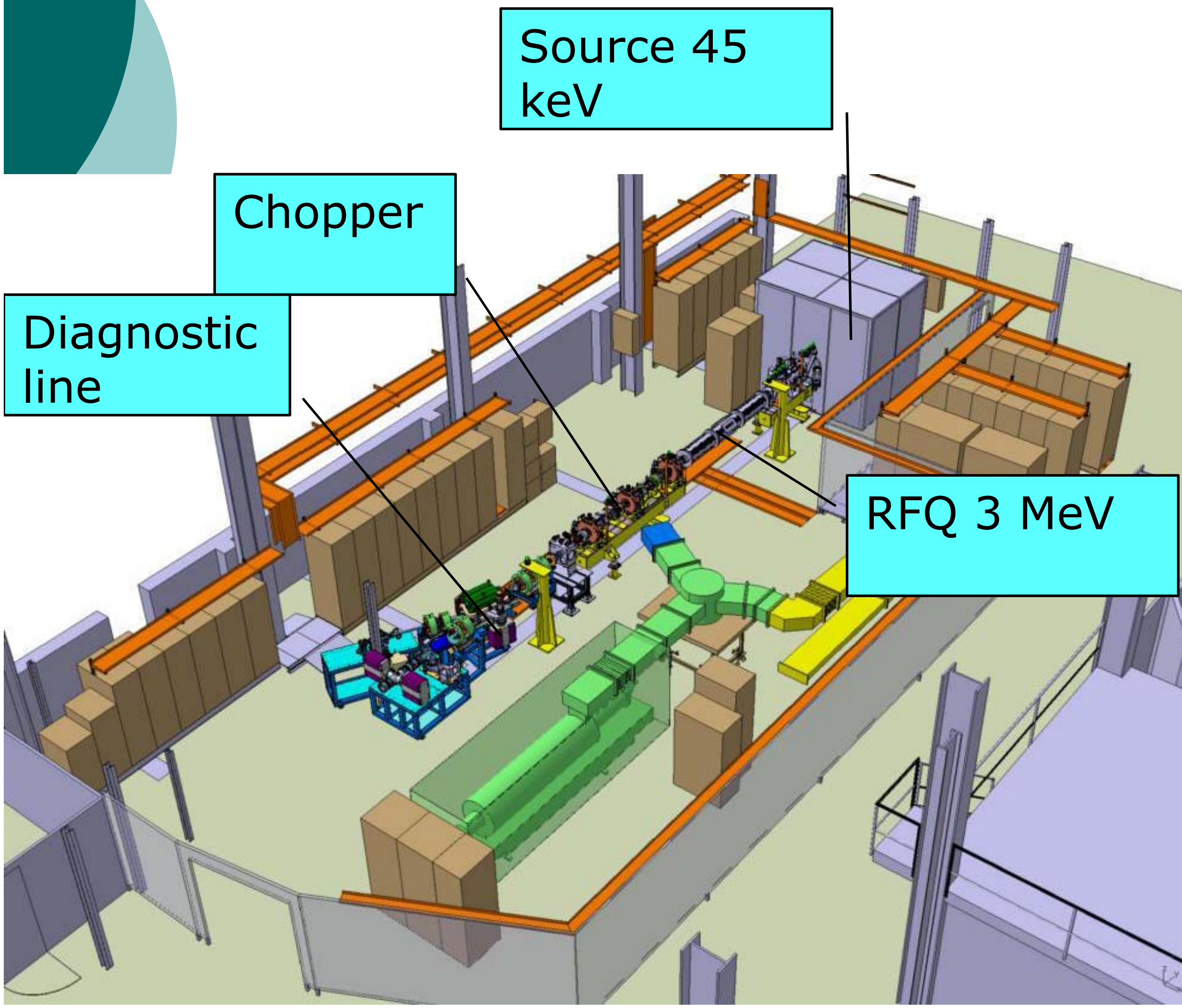
CCDTL ISTC prototype



PIMS –aluminum cold model (2 cells)

352 MHz klystron pulsed test

Testing the low energy part (0-3 MeV)



Goals :
Validate by 2010
- Source and LEBT design
- RFQ design
- Chopper

Ultimate goal is to demonstrate
70 mA H-
400 µs
1 Hz
3 MeV
0.4 mm mrad
0.15 deg KeV
Chopped and matched to the DTL

Linac4 as front end to SPL

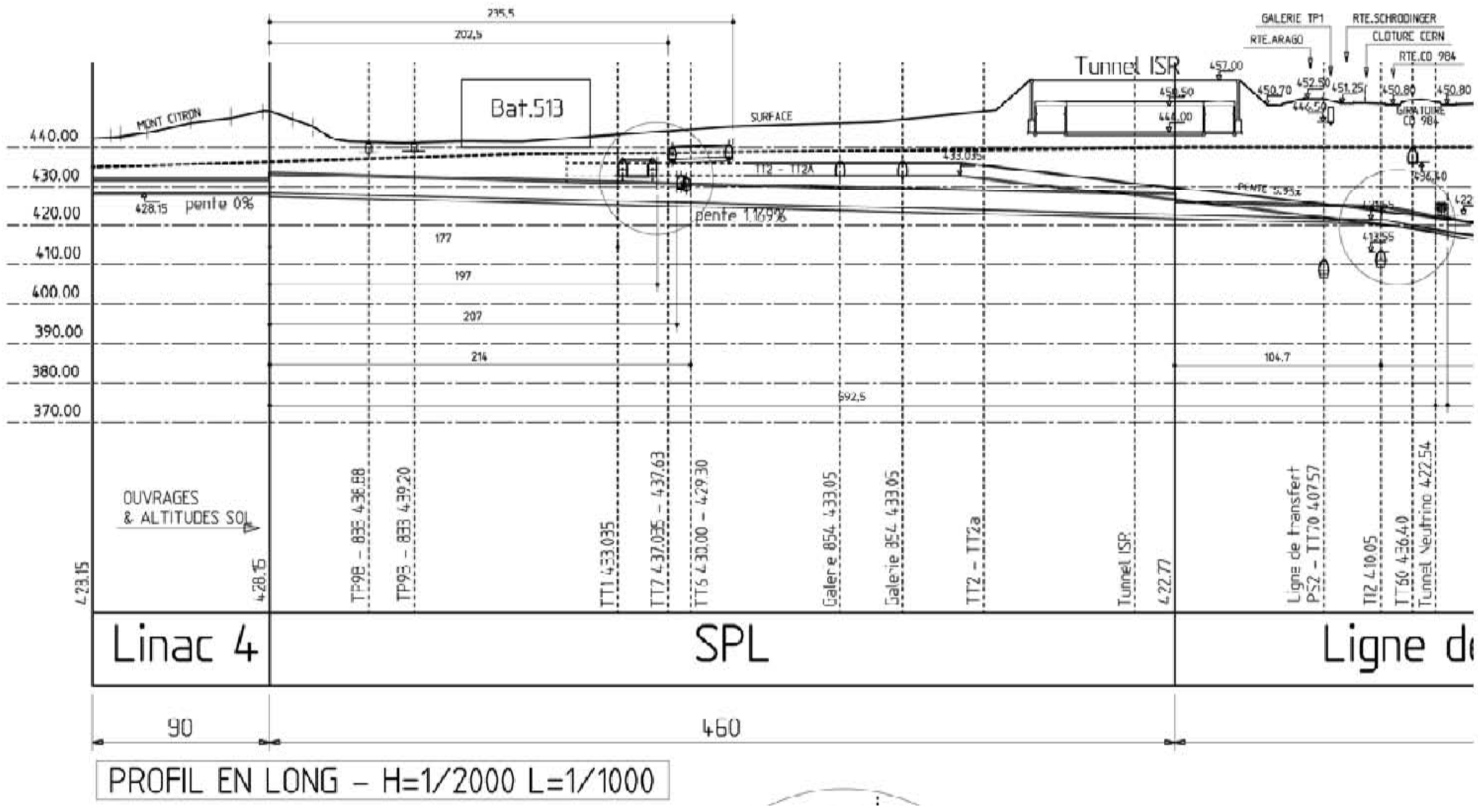
- **Linac4 will be able to operate without modifications for the low-power SPL (LP-SPL), at 0.24% duty cycle.**

- **For SPL (2-3% beam duty cycle)**
  - **A new source is needed**
  - **Electronics (power supplies, etc.) and infrastructure (cooling, electricity) are dimensioned for the low duty cycle and need to be changed.**
  - **All the accelerating structures and other hardware in the beam line are designed for a maximum duty cycle of 10% and can be reused.**
  - **The control of the losses (alignment budget and correction system) and the shielding is already implemented for HP-SPL**

Activities SPL
Goal : design study in 2011

	LP-SPL	SPL
Energy [GeV]	4	5
Beam power [MW]	0.192	>4.0
Repetition rate [Hz]	2	50
Average pulse current [mA]	20	40
Source current [mA]	40	80
Chopping ratio [%]	62	62
Beam pulse length [ms]	1.2	0.4-1.2
Beam duty cycle [%]	0.24	2.0- 6.0
Number of klystrons (704 MHz, 5 MW)	24	53
Geometric cavity beta	0.65/1.0	0.65/1.0
Number of cavities	42/160	42/200
Cavities/klystron	8 - 16	4-8
Cavities/cryostat	6/8	6/8
Length including Linac4 [m]	459	534

Definition of the layout on the CERN site

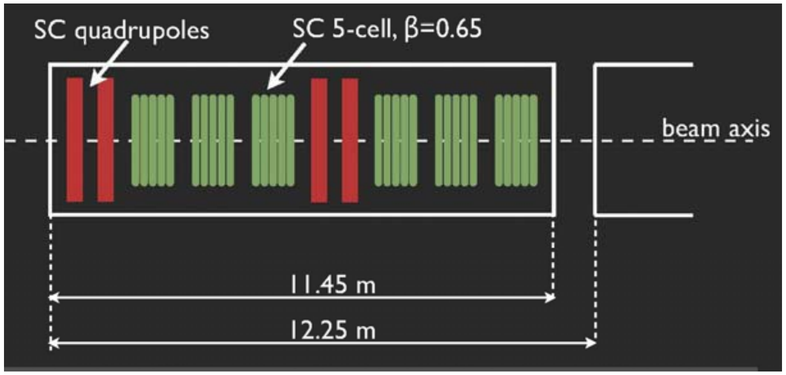
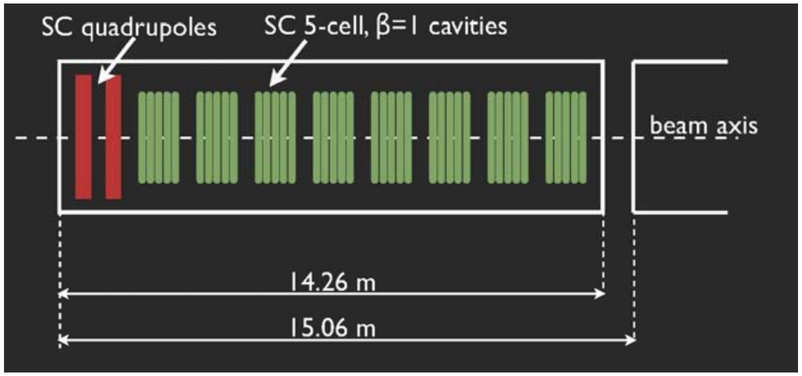


Choice of parameters

- Workshop , april 2008 "Status of analysis of SPL RF frequencies and cooling temperature"

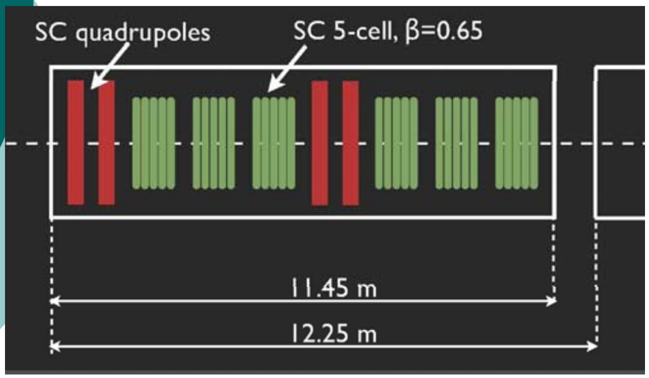
  Choice of 700 MHz and 2 K

- Building blocks of SPL :

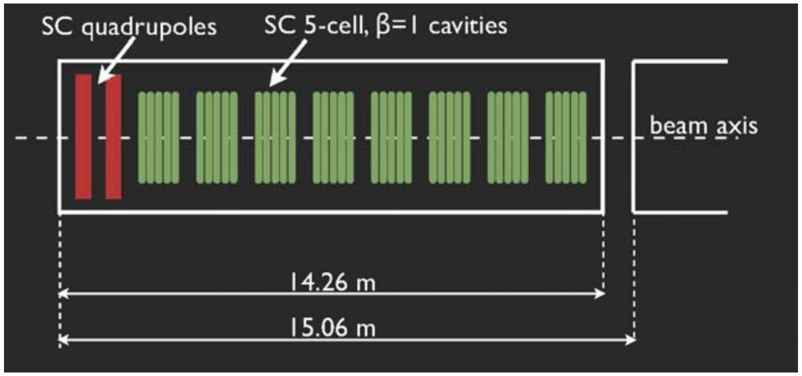
Low beta section(β=0.65)	High beta section (β=0.92)
	
5cells/cavity; 6 cavities/cryostat; 704 MHz; 19 MV/m	**5cells/cavity; 8 cavities/cryostat; 704 MHz; 25 MV/m**

SPL nominal layout and beam dynamics activities

7x



+ 24 x



160-589 MeV
87 m

589-5137MeV
361 m

- Nominal layout defined
- Beam dynamics with beam from Linac4 is verified
- RF error studies done

Prototyping SC cavities

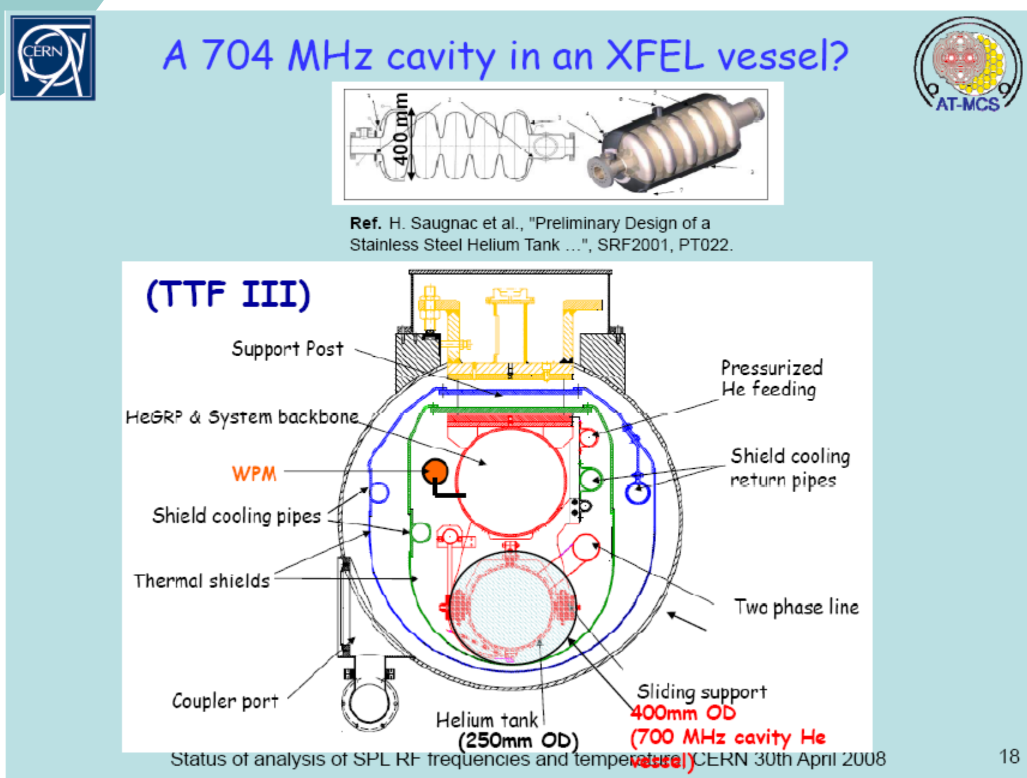
- Surface treatment techniques tests on a 700 MHz, low beta single cell from CEA, expected for 2009 (issue e-polishing at low beta).

- Prototypes β=0.65 and β=0.92 5-cell cavities, to demonstrate 19 MV/m and 25 MV/m, expected in the next years.

- Ideally a fully equipped cryostats to be tested
  - 8 cavities 5-cell Beta=0.92 for high power RF tests

Cryomodule design

Start from ILC/Tesla module and adapt to SPL, but in parallel develop an independent design



Issues are :

•the slope (1.5%)

•704 MHz cavity in a ILC type cryostats presents some engineering challenges.

HIPPI and after

Hippi (High Intensity Pulsed Proton Injector) is a Joint Research Activity in the framework of CARE, within the European FP6 (2004-2008). The activity received 3.6 M€ from the EU.

10 European laboratories participate in HIPPI and the projects supported within HIPPI are Linac4, FAIR and the ISIS upgrade.

HIPPI is organized in 4 work packages:

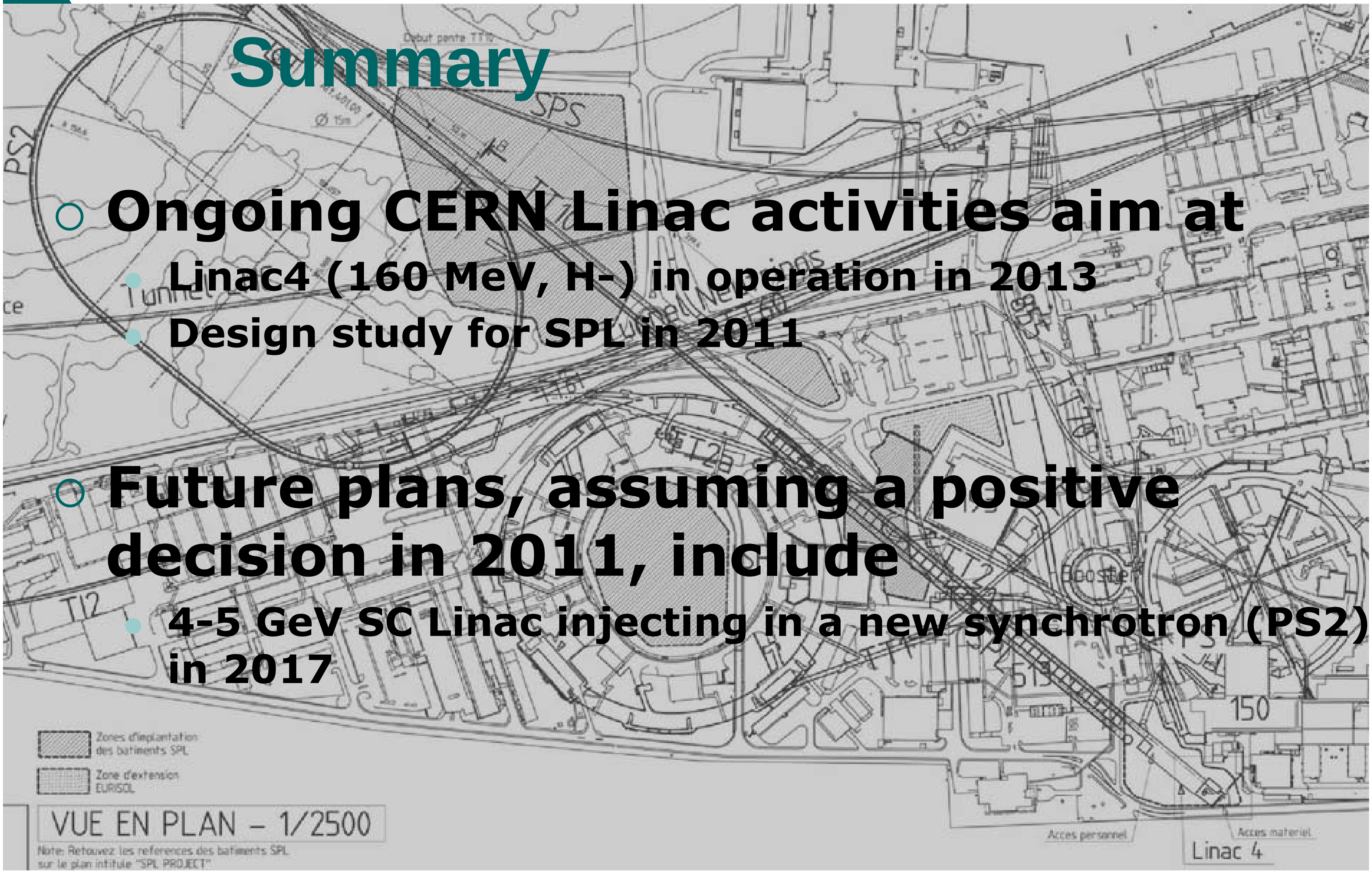
- normal conducting structure
- superconducting structures
- chopping
- beam dynamics

Lots of the prototyping work for Linac4 was covered by HIPPI

CARE , HIPPI will terminate at the end of the year. Accelerators actives will continue in FP7with EuCARD.

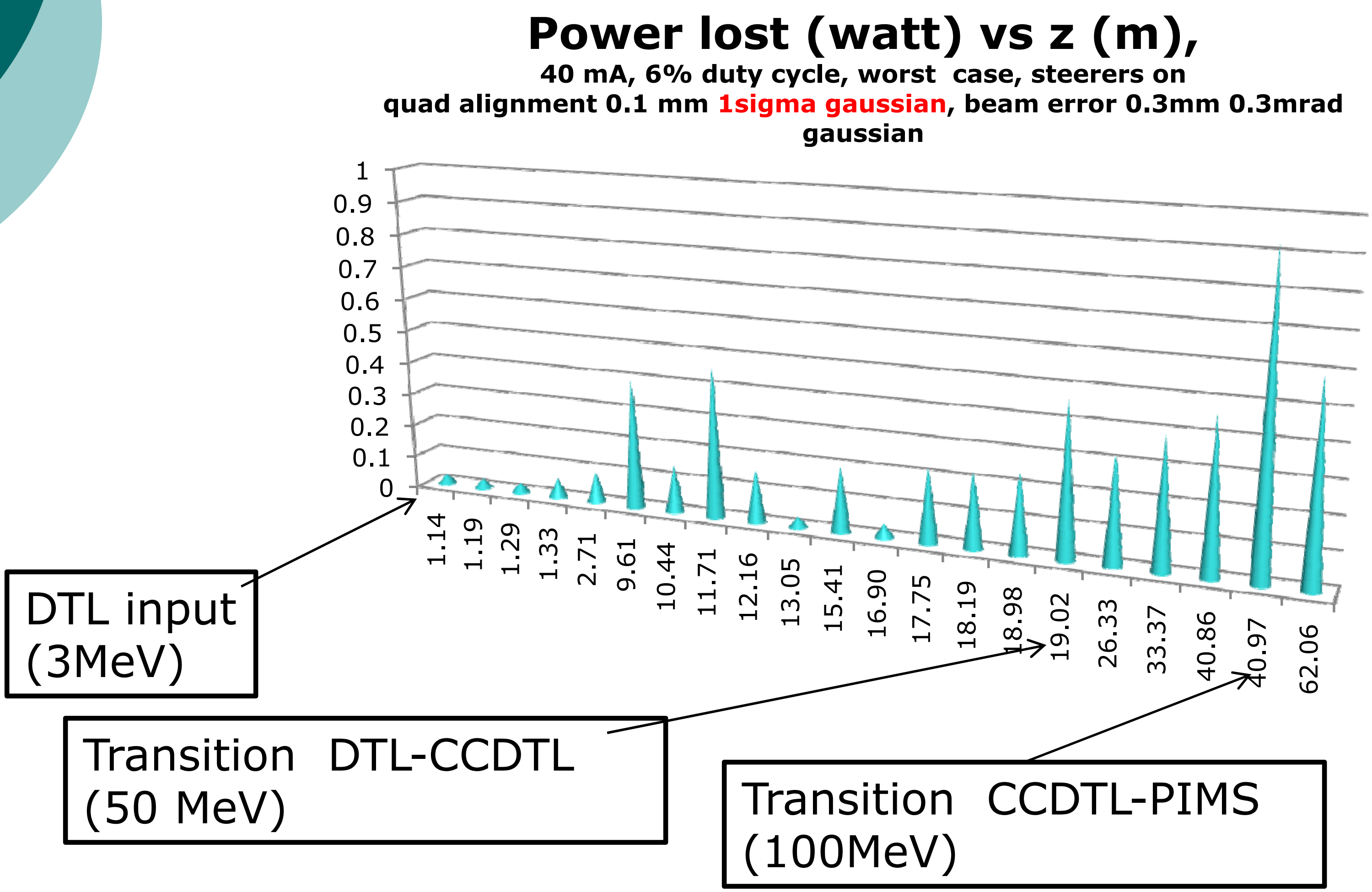
Summary

- **Ongoing CERN Linac activities aim at**
  - **Linac4 (160 MeV, H-) in operation in 2013**
  - **Design study for SPL in 2011**
- **Future plans, assuming a positive decision in 2011, include**
  - **4-5 GeV SC Linac injecting in a new synchrotron (PS2) in 2017**



RESERVE

Loss map Linac4



SPL parameter list