The Linac4 Project at CERN

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Upgrading LHC Luminosity

	Luminosity ($cm^{-2}s^{-1}$)	Beam intensity @ injection (*)
Present (2011)	~2 $\times 10^{33}$	
Nominal (2015 ?)	1 $\times 10^{34}$	1.1 $\times 10^{11}$
Upgraded (2021 ?)	~5 $\times 10^{34}$	~2.4 $\times 10^{11}$

(*) protons per bunch, in 3 μm emittance

planned

requires upgrade of both LHC and injectors, to be completed in the 3rd long LHC Shut-down (~2021/22)

+ luminosity leveling for higher integrated luminosity

At the moment, the injectors can provide only the intensity required for the nominal luminosity

Need of an upgrade program of the injectors for higher brightness and intensity.

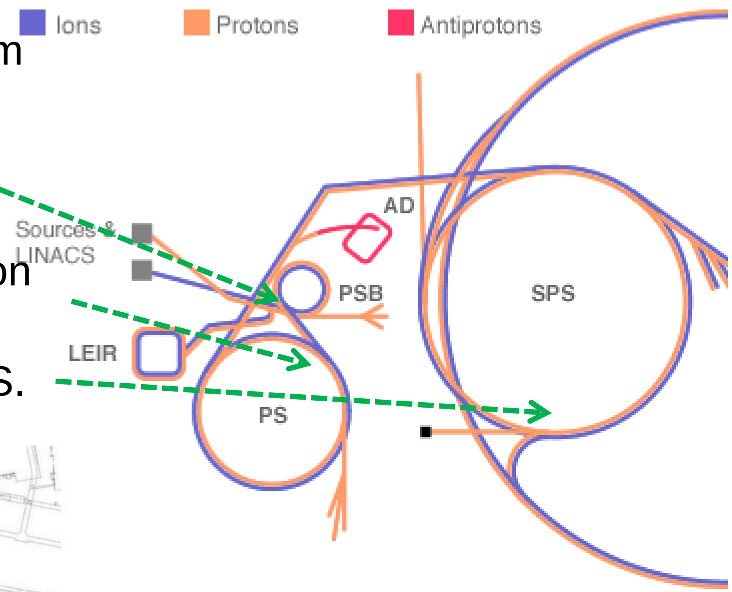
LIU (=LHC Injectors Upgrade) Project, *poster WEPS017*.

LHC Injectors Upgrade

Limitations to injector intensity

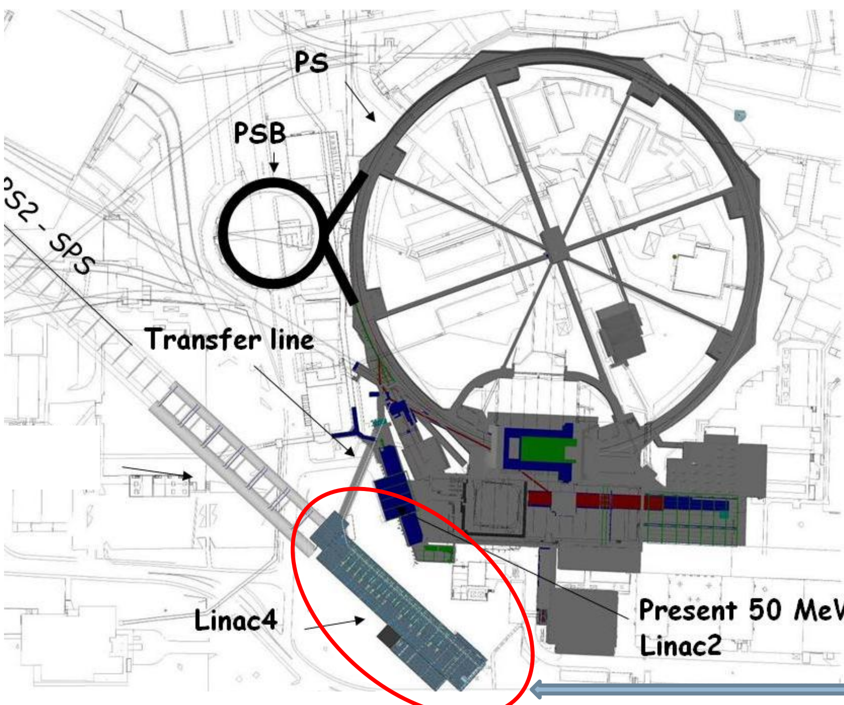
Three bottlenecks for higher intensity from the LHC injectors:

1. Space charge tune shift at PSB injection (50 MeV).
2. Space charge tune shift at PS injection (1.4 GeV).
3. Electron cloud and instabilities in SPS.



Present LHC injection chain:

Linac2 (50 MeV)
↓
PS Booster (1.4 GeV)
↓
PS (25 GeV)
↓
SPS (450 GeV)
↓
LHC

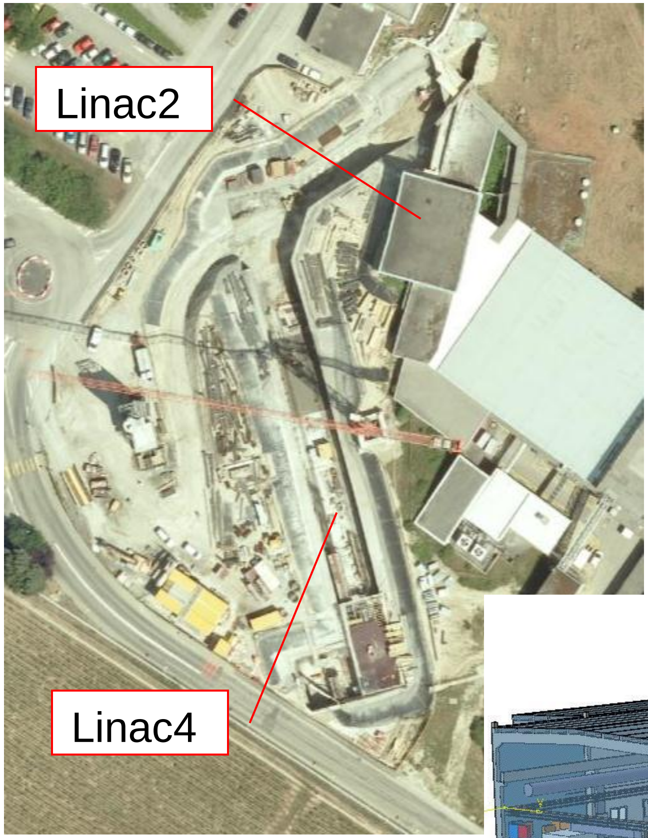


Low injection energy into the PSB is the first and most important limitation →

Decision (CERN Council, June 2007) to build a new linac (Linac4) to increase PSB injection energy from 50 to 160 MeV (factor 2 in $\beta\gamma^2$ and brightness) and go from proton to H^- injection.

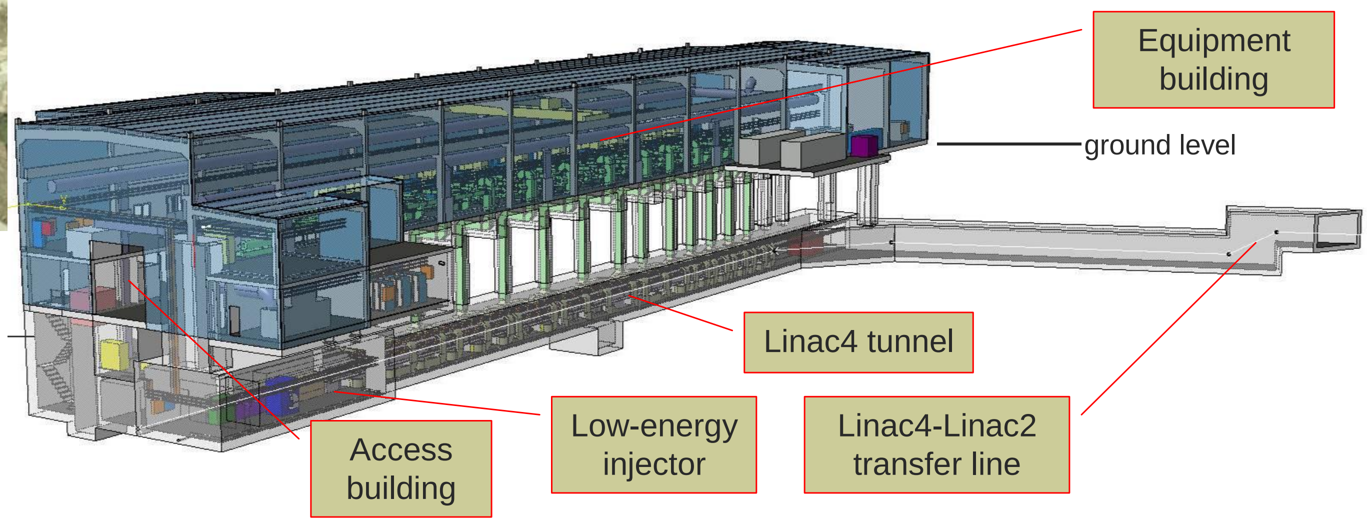
Factor 2 in PSB beam intensity for LHC beams and for other PSB users + modern injector

Linac4 on the CERN site



Linac4 excavation works, May 2009 (aerial photo)

- ☞ About 100m in length, built on one of the last "free" areas on the CERN Meyrin site, providing easy connection to the PSB and the option of a future extension to higher energy and intensity (SPL, 4 GeV) for a ν physics programme.
- ☞ Linac tunnel 12 m underground, surface building for RF and other equipment, access module at low energy.
- ☞ Construction works started in October 2008, completed in October 2010 (2 years).
  3.25 years from project approval to delivery of the building!



Building construction – 2008/10

Surface building, August 2010

Under the PSB

Linac4 Infrastructure

Installation of infrastructure is progressing in building and tunnel

- Electrical distribution, cable trays, piping
- Waveguides
- Faraday cage for electronics
- False floor

Next steps:
Cabling campaigns
Infrastructure completed by June 2012

Linac4 Beam Parameters

Ion species	H^-	
Output Energy	160	MeV
Bunch Frequency	352.2	MHz
Max. Rep. Frequency	2	Hz
Max. Beam Pulse Length	0.4	ms
Max. Beam Duty Cycle	0.08	%
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
Tr. emittance (source)	0.25	π mm mrad
Tr. emittance (linac exit)	0.4	π mm mrad

Max. repetition frequency for accelerating structures 50 Hz

H^- for the first time at CERN!

Factor 2 in $\beta\gamma^2$ w.r.t. Linac2

Frequency of LEP (ideal for a linac), some klystrons and RF equipment still available

1.1 Hz maximum required by PSB

Chopping at low energy to reduce beam loss at PSB.

Current and pulse length to provide >twice present intensity in PSB.

- Accelerating structures and klystrons designed for 50 Hz.
- Cooling, power supplies and electronics only for 2 Hz.

Linac4 layout

Normal-conducting linear accelerator, made of:

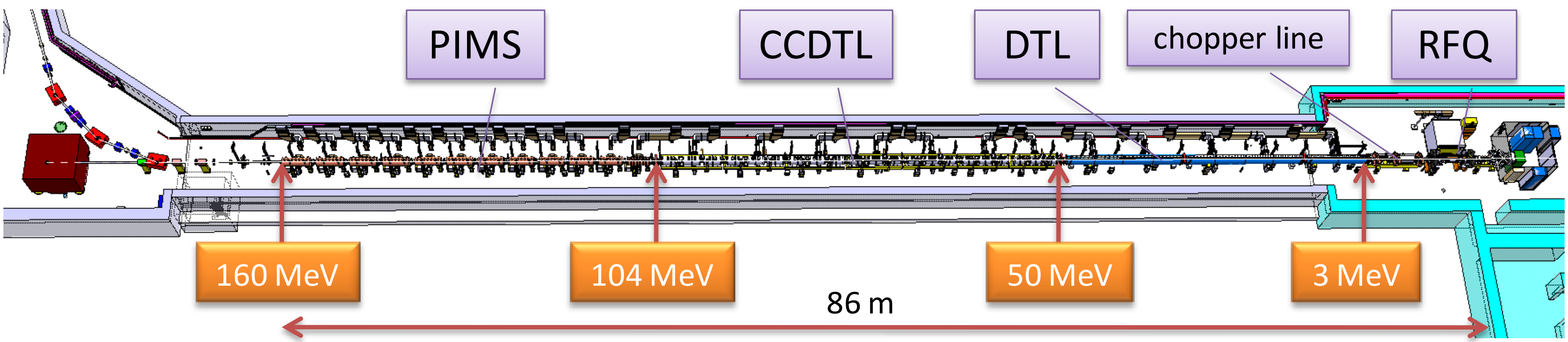
1. Pre-injector (source, magnetic LEBT, 3 MeV RFQ, chopper line)
2. Three types of accelerating structures, all at 352 MHz (standardization of components).
3. Beam dump at linac end, switching magnet towards transfer line to PSB.

☞ No superconductivity (not economically justified in this range of β and duty cycles);

☞ Single RF frequency 352 MHz (no sections at 704 MHz, standardised RF allows considerable cost savings) ;

☞ High efficiency, high reliability, flexible operation → 3 types of accelerating structures, combination of PMQ and EMQ focusing.

	Energy [MeV]	Length [m]	RF Power [MW]	Focusing
RFQ	0.045 - 3	3	0.6	RF
DTL	3 - 50	19	5	112 PMQs
CCDTL	50 - 102	25	7	14 PMQs, 7 EMQs
PIMS	102 - 160	22	6	12 EMQs



Linac4 – The challenges

- **Low-energy section: ion source, RFQ, chopping**

  generation of low-emittance intense H- beams, transport and emittance preservation through LEBT and RFQ, efficient transport and chopping

- **Accelerating structures**

  design prototyping and construction of reliable high efficiency RF structures

- **Linac beam dynamics**

  emittance preservation, low loss design for possible high-duty operation

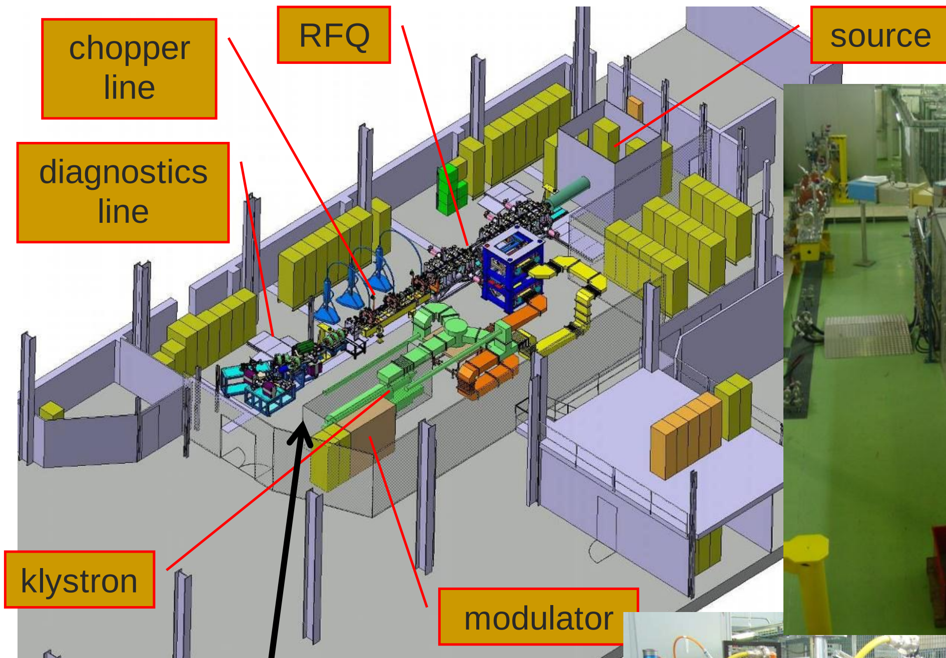
- **PSB injection**

  4-ring stripping, beam optics

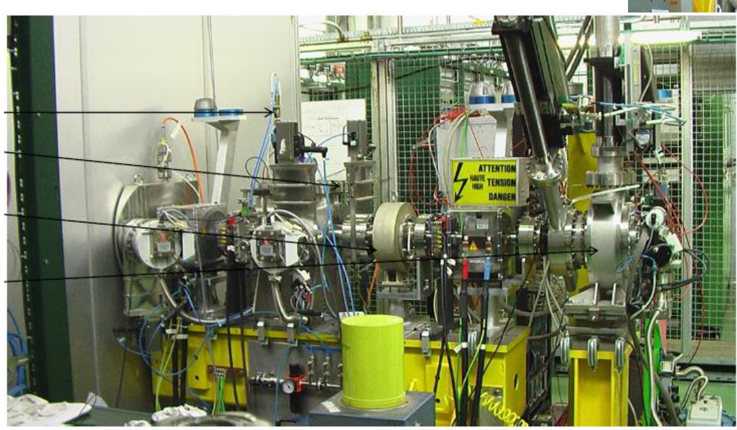
- **Reliability**

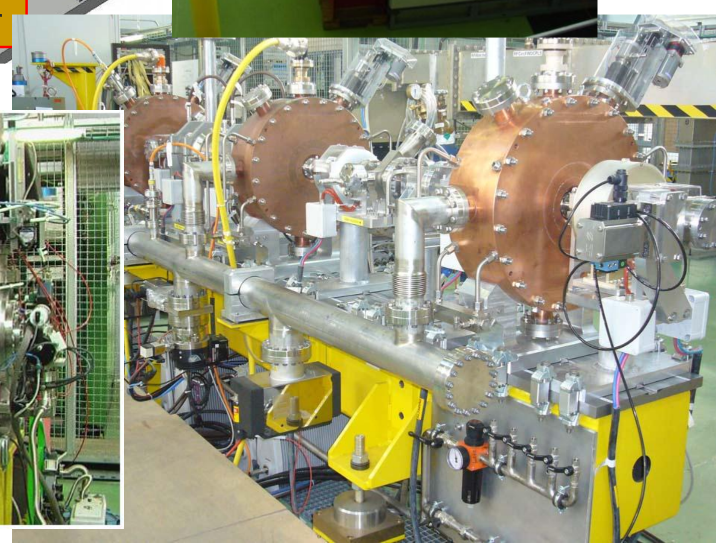
  benchmark: present availability of Linac2 is 98.5%!

Linac4 – Low energy test stand



3 MeV TEST STAND for early characterization of low-energy section; will be moved to Linac4 in 2013

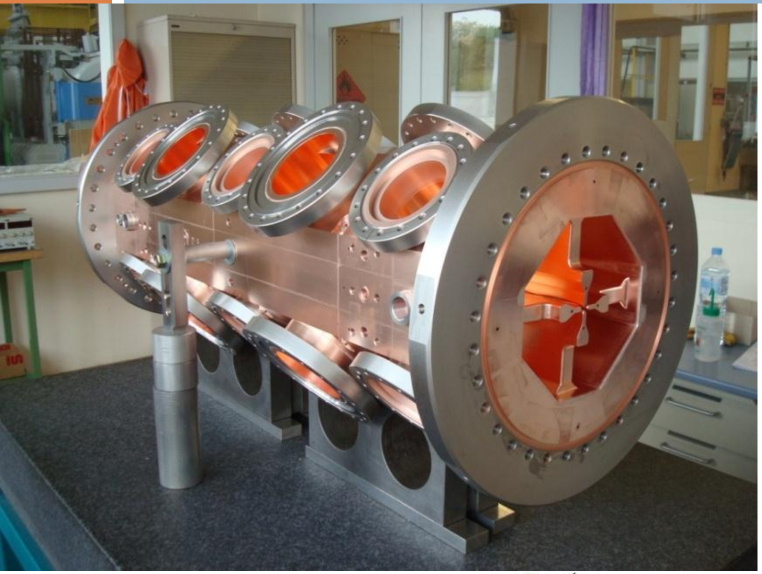




- ☞ Ion source and LEBT completed and under test;
- ☞ RFQ in construction;
- ☞ Chopping line completed, tested without beam;
- ☞ LEP klystron and modulator installed and tested.
- ☞ Complete beam diagnostics line being assembled.

Beam tests with RFQ from beginning 2012

The Linac4 RFQ



Energy **3 MeV,** length **3m**, 3 section of 1 m each.

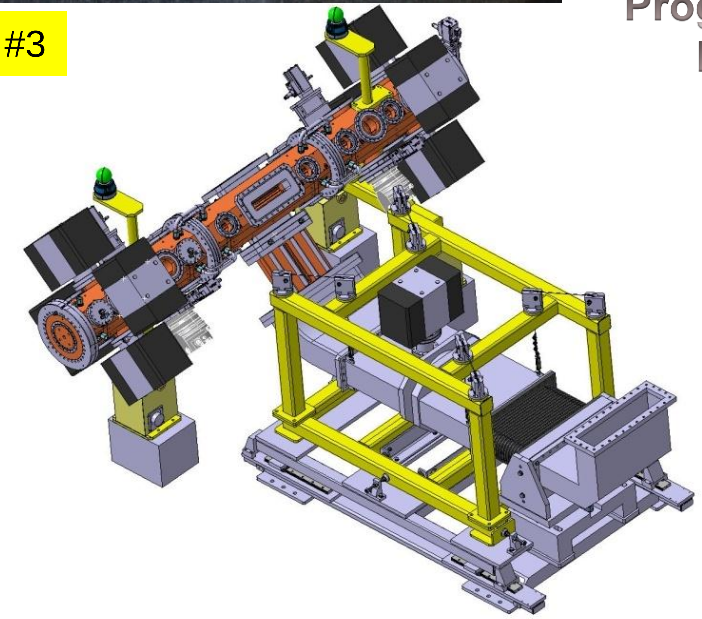
Brazed 4-vane design with simplified shape and cooling, for max. duty cycle 10%.

Construction entirely done at CERN: machining, metrology, brazing (horizontal). CEA (F) contribution for RF design and measurements.

Status: Modules #1 and #2 completed, Module #3 ready for 2nd and last brazing.

Programme: RF tests October 2011, conditioning November/December 2011, first beam end 2011.

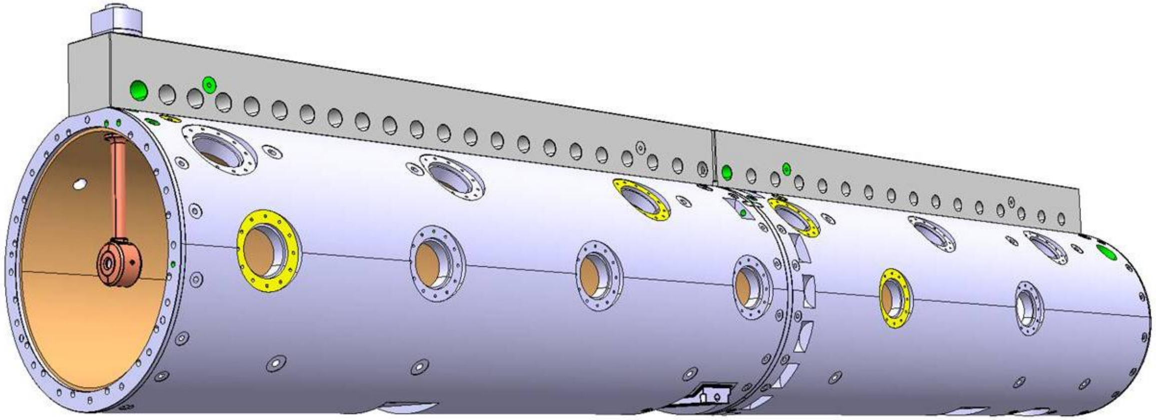
module #3

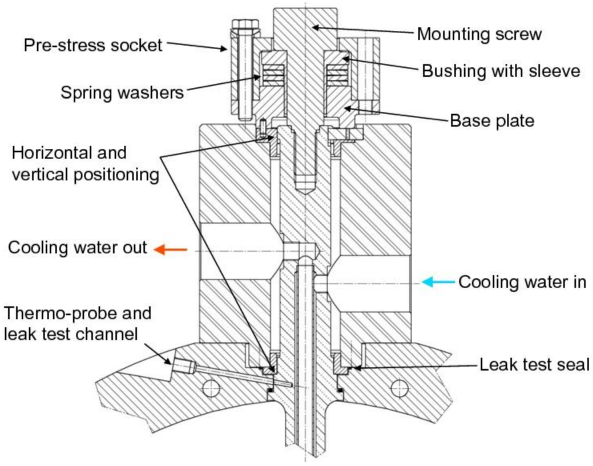


module #1

Linac4 – Drift Tube Linac

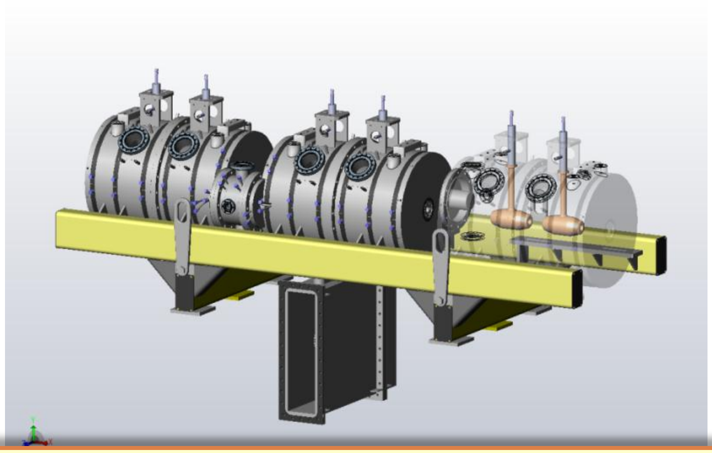
- 3-50 MeV, 3 tanks.
- New CERN design, tested on a prototype (1m, 12 drift tubes) at full RF power (10% duty cycle).
- Main features: drift tubes rigidly mounted on a girder, with special mounting mechanism, only metallic joints and no adjustment. Tank in Cu-plated stainless steel. Permanent Magnet Quadrupoles in vacuum.
- Construction started (DTs with ESS-Bilbao).
- Tank1 ready for tests at beginning 2012.





Linac4 – Cell-coupled DTL

- 50-100 MeV, 7 modules of 3 tanks each.
- New design, tested on a prototype (2 tanks, 4 drift tubes) at full RF power (10% duty cycle).
- Main features: Focusing by PMQs (2/3) and EMQs (1/3) external to drift tubes. Short tanks with 2 drift tubes connected by coupling cells.
- Construction started at VNIITF (Snezinsk) and BINP (Novosibirsk) in January 2010.
- Module#1 and #2 completed, under low-power tests at BINP. To be delivered to CERN for testing end 2011.

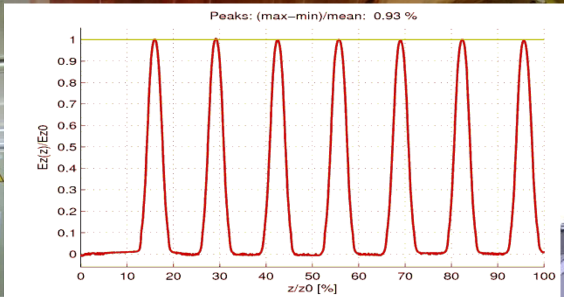


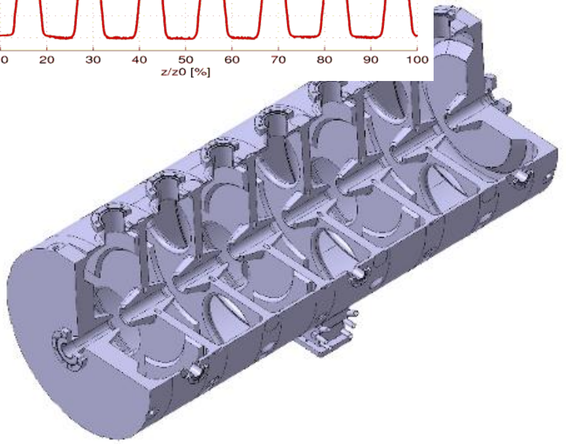
Structure used for the first time in a particle accelerator !

Linac4 – Pi-Mode Structure

Posters TUPS100 - MOPC055

- 100-160 MeV, 12 tanks of 7 cells each.
- Tank #1 (pre-series) completed and RF conditioned to 1.25 times the design voltage.
- Main features: Focusing by external EMQs, tanks of 7 cells in pi-mode. Full-Cu elements, EB-welded.
- Construction started (2011) in collaboration with Soltan Institute (Warsaw) and FZ Julich.

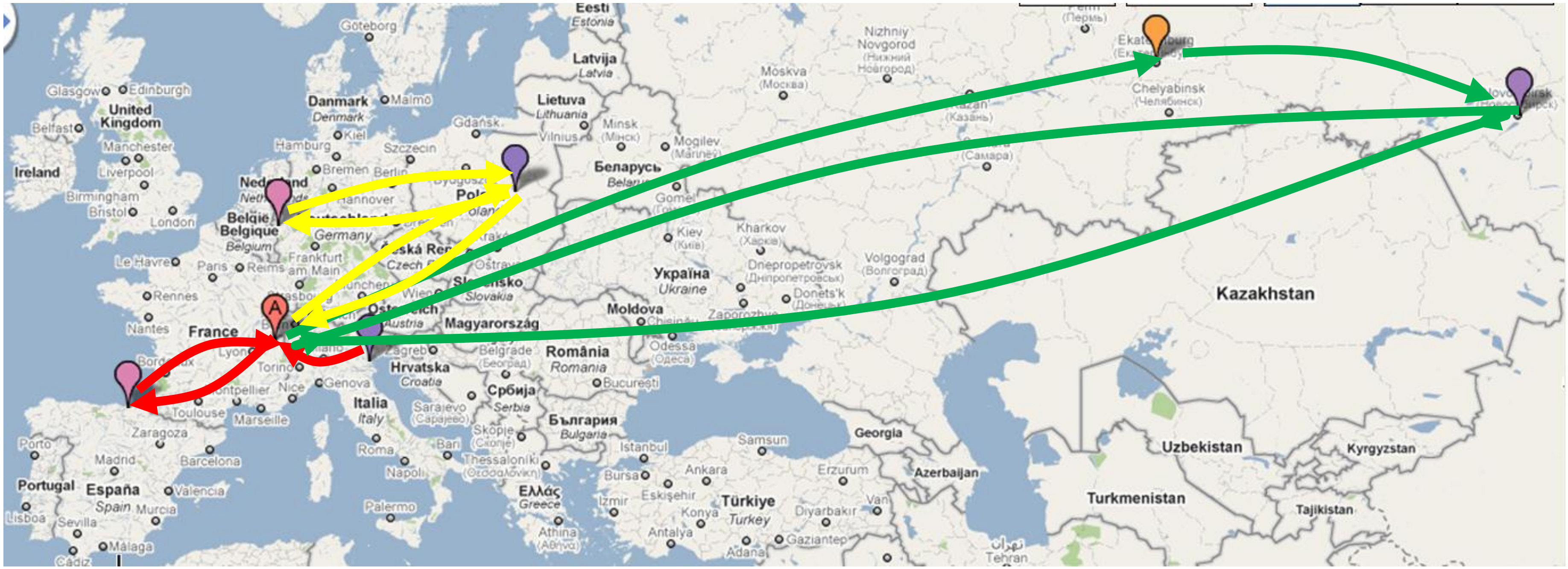




Structure used for the first time in a proton accelerator !

Accelerating structures construction

Construction of the Linac4 accelerating structure – an European enterprise (and beyond…)



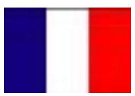
Drift Tube Linac (DTL):
prototype from INFN/LNL (Italy), drift tubes from ESS-Bilbao (Spain), tanks and assembly at CERN

Cell-Coupled DTL:
tanks from VNIIEF (Snezinsk), drift tubes and assembling from BINP (Novosibirsk)

PI-Mode Structure (PIMS): tanks from Soltan Institute (Poland), EB welding from FZ Juelich (Germany), assembly and final EB welding at CERN.

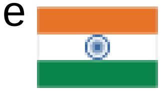
Linac4 – External Contributions

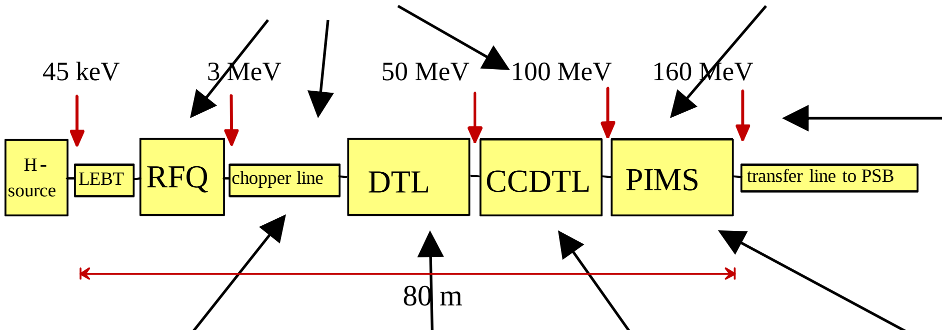
Network of agreements to support Linac4 construction. Relatively small fraction of the overall budget, but access to specialized manpower and share of information with other teams. Integration at the component level.



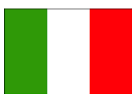
RFQ RF design, RF amplifiers, modulator construction (French Special Contribution), *started.*

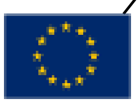
Prototype modulator, waveguide couplers, alignment jacks from India, *started*





Movable tuners from Italy, *started*





Chopper line built in a EU Joint Research Activity *completed*

Participation of ESS-Bilbao in DTL construction, *started*

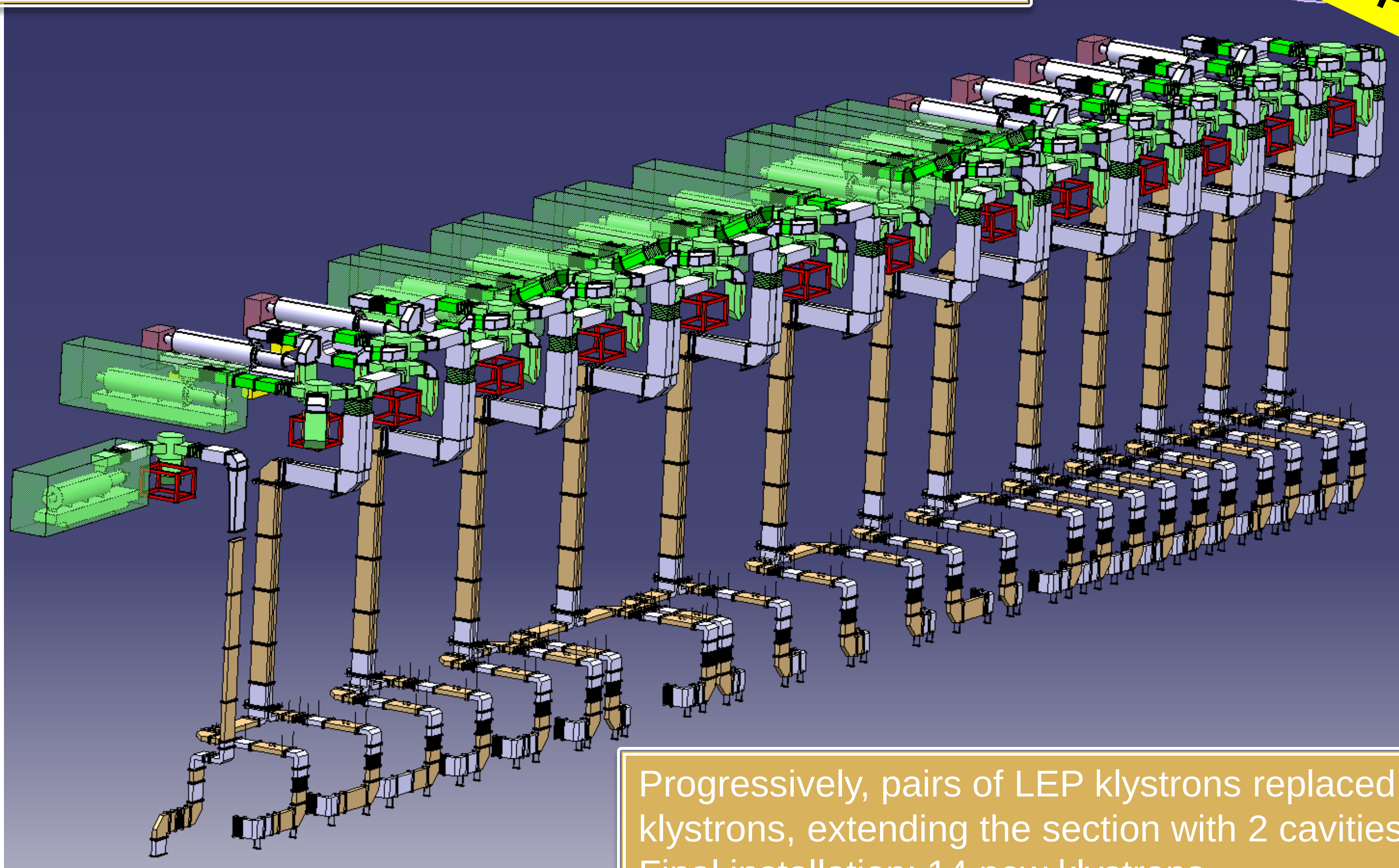
Construction of CCDTL in Russia, via an ISTC Project *started*

Collaboration agreement with Soltan Institute (Poland) for PIMS construction, *started*

The RF System – overall view

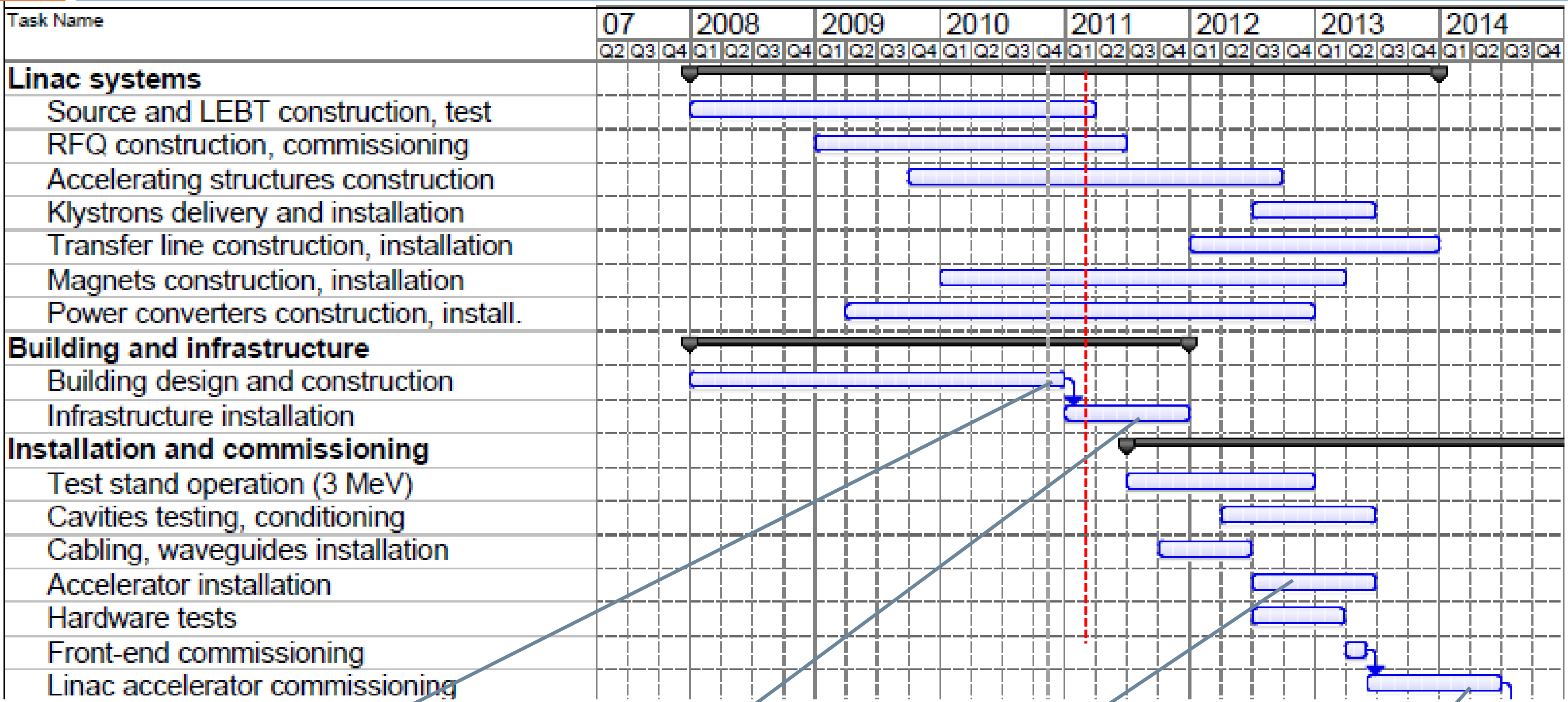
Initial installation: 13 LEP klystrons (1.3 MW) + 6 new klystrons (2.8 MW) → 2 cavities/klystron only in the PIMS section;

Poster **MOPC138**



Progressively, pairs of LEP klystrons replaced by new klystrons, extending the section with 2 cavities/klystron.
Final installation: 14 new klystrons

Linac4 – schedule



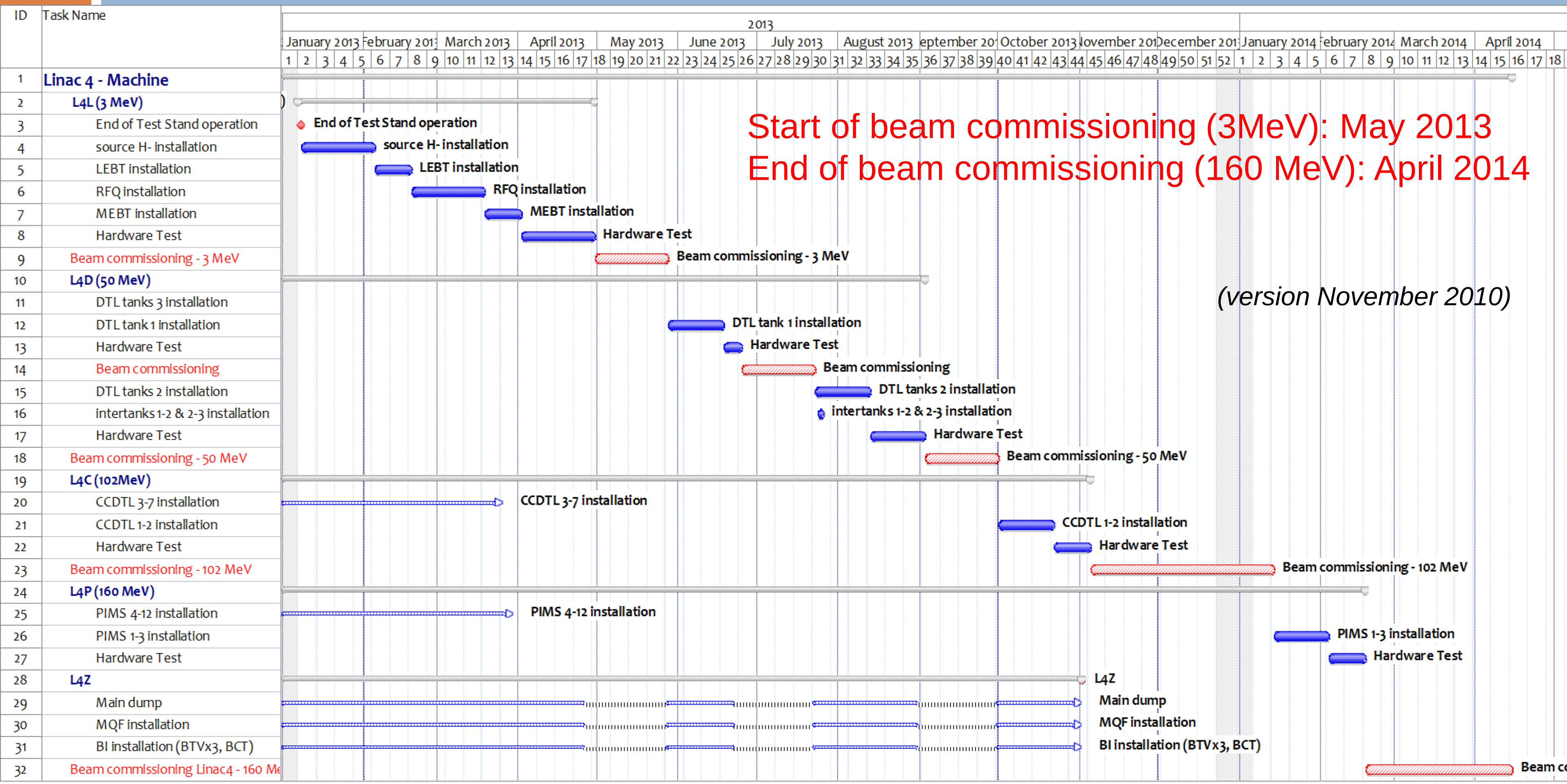
Building delivery

2011: Infrastructure installation

2012/13: Accelerator installation

2013/14: Commissioning

Linac4 commissioning schedule



Start of beam commissioning (3MeV): May 2013
End of beam commissioning (160 MeV): April 2014

(version November 2010)

5 commissioning stages: 3 MeV | 10 MeV | 50 MeV | 100 MeV | 160 MeV

(on intermediate dumps)

Connection to the PSB during a long (min. 7 months) LHC shut down after 2014.

Thank you for your attention