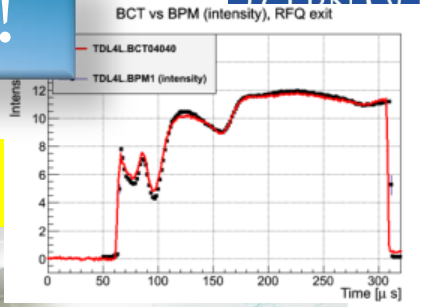
Status of Linac4

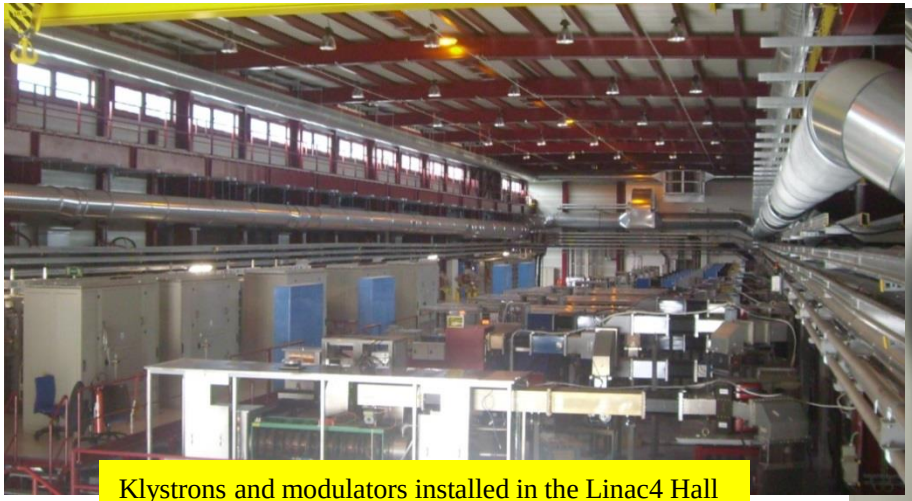
18 December 2013

M. Vretenar, CERN

2013 : a memorable year !



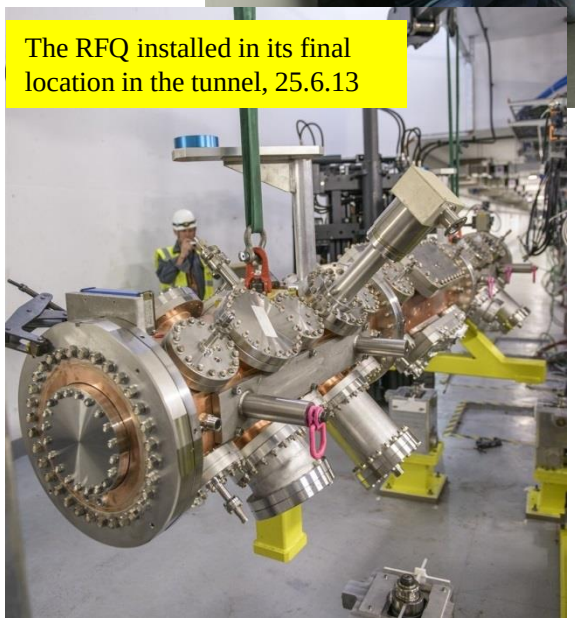
A cheering crowd celebrating the first beam accelerated by the RFQ, 13.3.2013



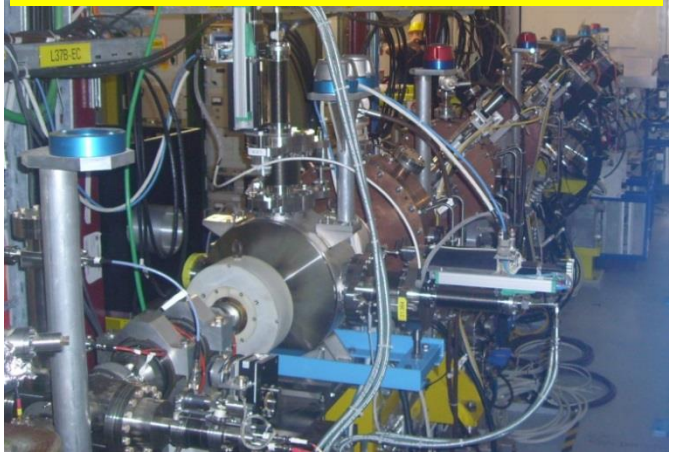
Klystrons and modulators installed in the Linac4 Hall

Open Days 2013: 2’500 visitors!

The RFQ installed in its final location in the tunnel, 25.6.13



7.11.2013: ready for 3 MeV beam tests in the tunnel!

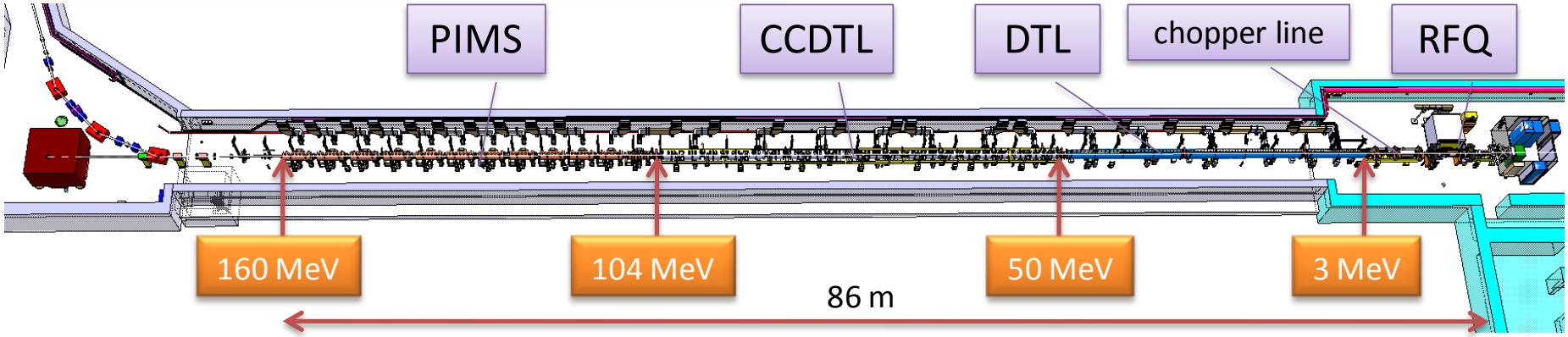


Linac4 layout

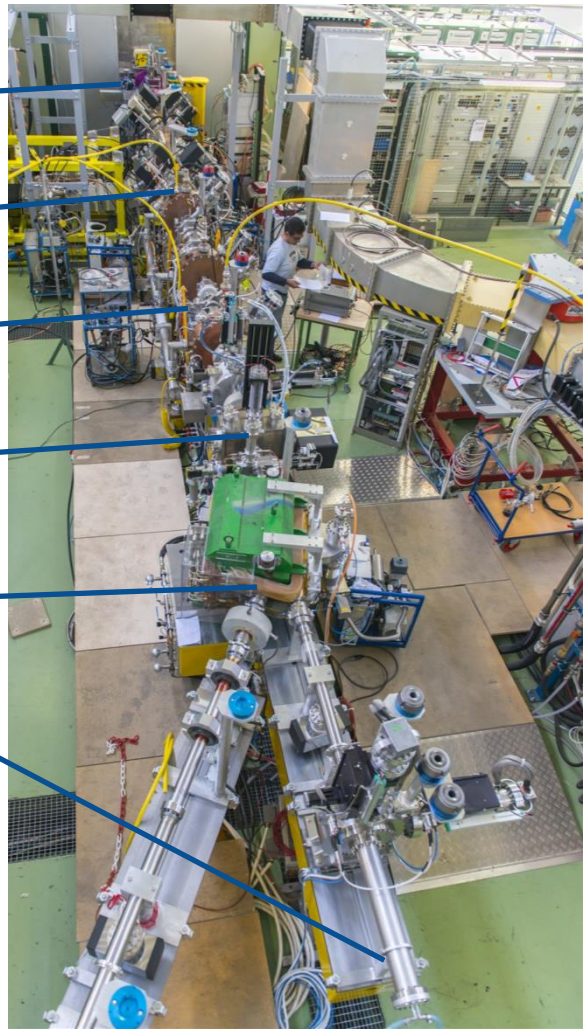
1. Pre-injector (source, magnetic LEBT, 3 MeV RFQ, chopper line)
2. Three types of accelerating structures, all at 352 MHz (standardization of components).
3. Beam dump at linac end, switching magnet towards transfer line to PSB.

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

	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 PMQ, 7 EMQs
PIMS	102 - 160	22	6	12 EMQs



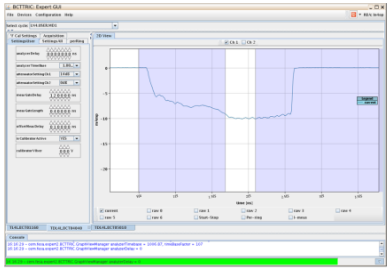
Commissioning 3 MeV



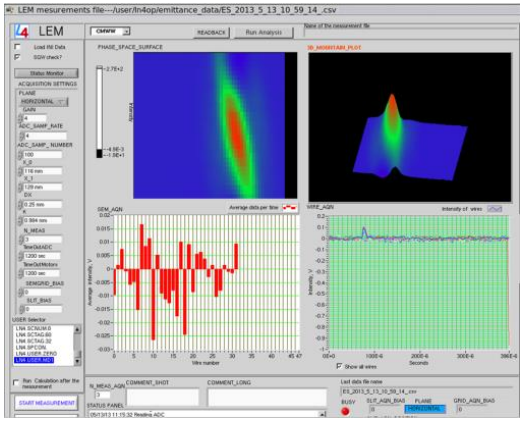
Hard time to get there, but commissioning completed in just 3 months!

The 3 MeV injector (ion source, LEBT, RFQ, chopper line) has been commissioned with beam in March-May 2013 on a test Stand

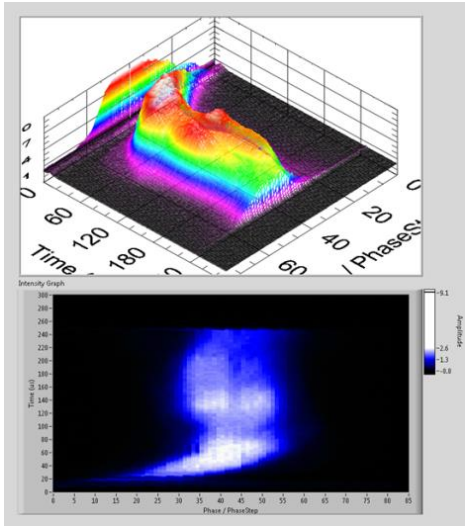
19.2.2013	First usable H- beam (45 keV)
13.3.2013	Beam through RFQ
16.4.2013	Beam through chopper line
21.5.2013	Switch to protons (for higher intensity)
31.5.2013	End of the beam tests, start transfer to tunnel



First 3 MeV beam on transformer: 10mA H- accelerated through the RFQ at first shot!



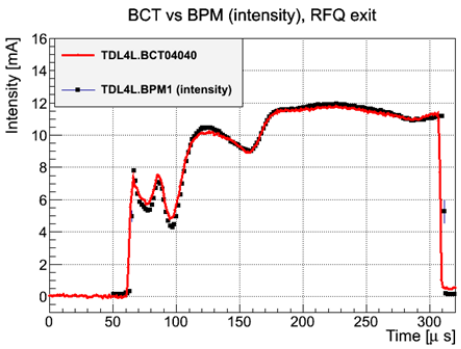
Emittance scan



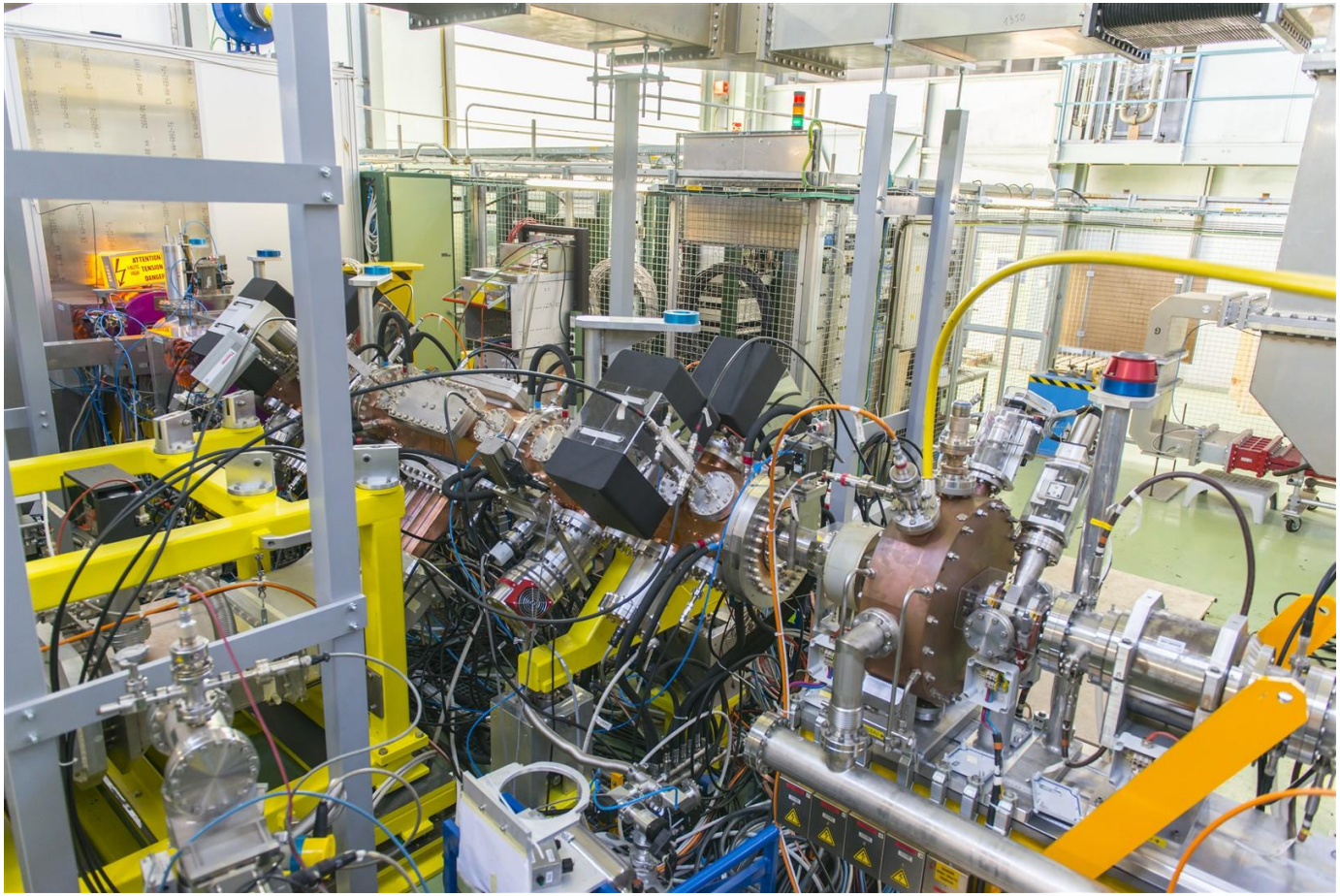
Bunch Shape Monitor: phase profile of the bunch along the pulse

The Linac4 RFQ

Completed in September 2012 (some delays in design, machining, brazing).
RF conditioning in less than a week, commissioning with beam started on 13.3.2013 and completed on 28.3.
Compact and solid design, aiming at high reliability.



The Linac4 RFQ not only focuses and accelerates the beam as required, but so far it does it in a stable, reliable and reproducible way!



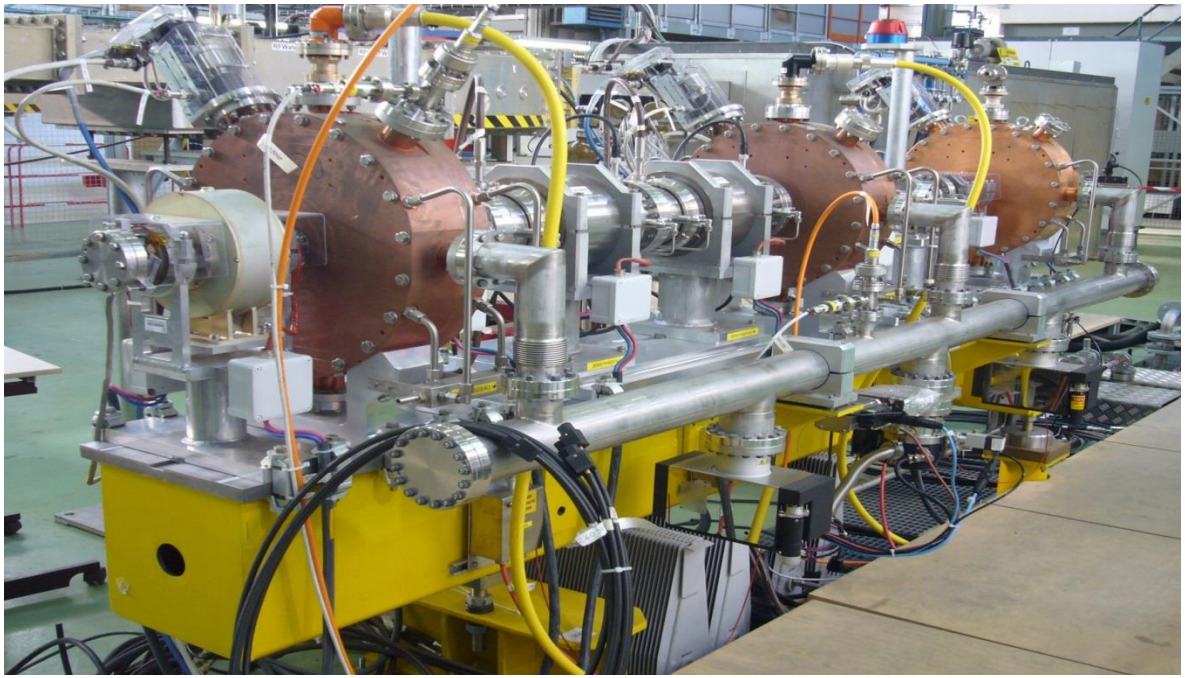
Chopper and MEBT

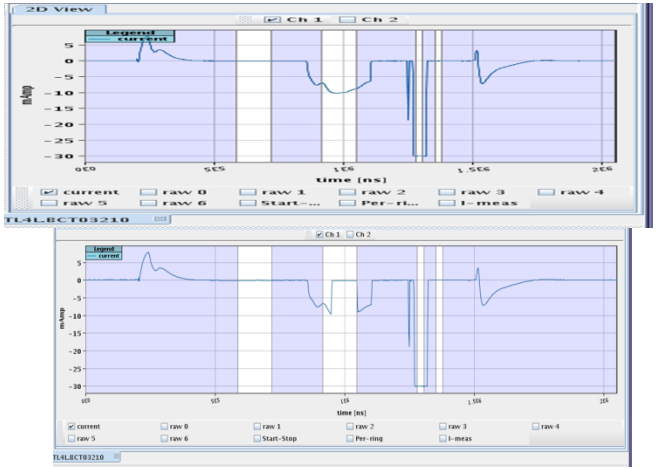
Chopper line (MEBT), 3.6 m:

- 2 choppers (double meander lines on ceramic substrate) inside quads;
- 3 bunching cavities;
- 5 quadrupoles;
- Steerers and diagnostics.
- Chopper dump (conical)

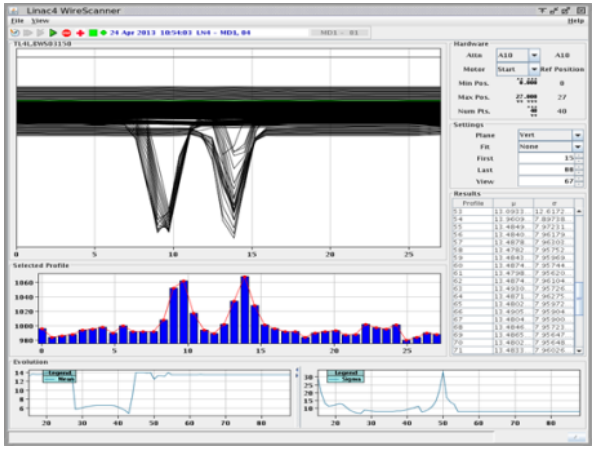
Quadrupoles used to increase separation chopped/unchopped beam reducing the required chopper voltage (600 V).

Worked perfectly, rise time (to avoid beam loss) measured by the transfos <10 ns (waiting for more accurate time resolved measurement).





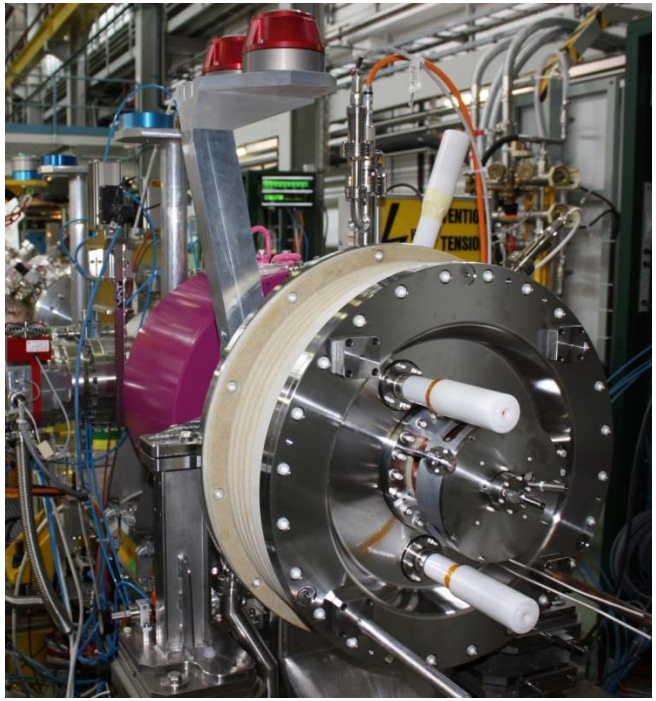
"hole" in the beam pulse produced by the chopper

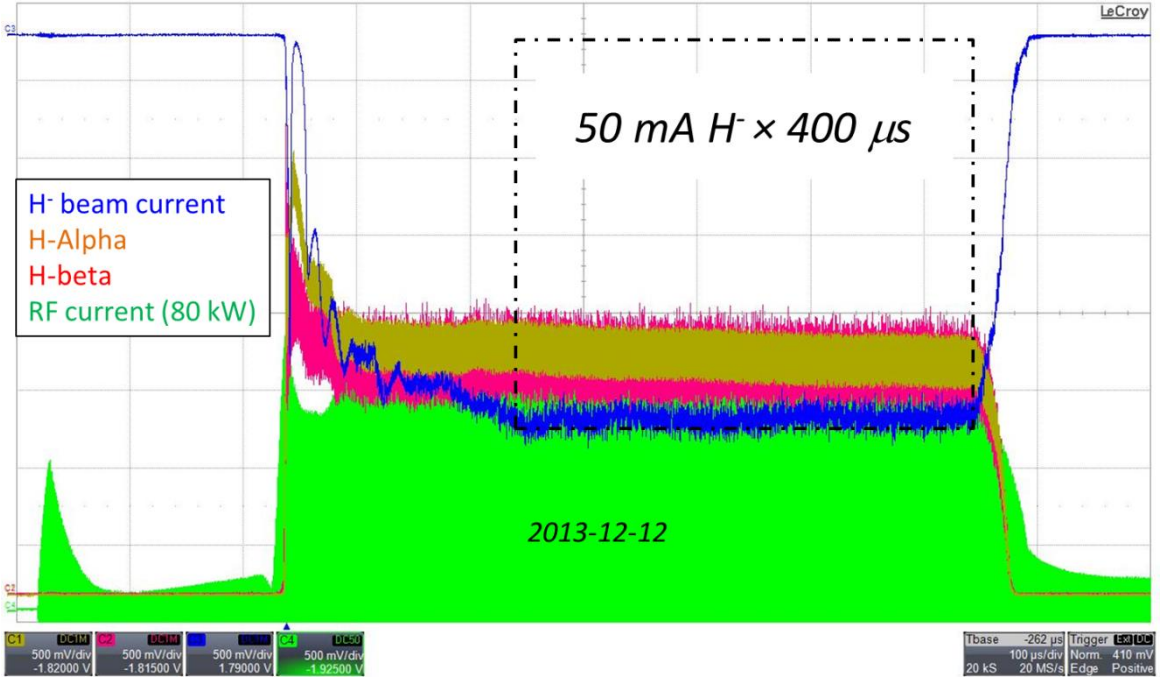


Separation of chopped and unchopped beam measured by the Wire Scanner

Cesiated Source (IS02)

- Present source (IS01, w/o Cs) delivers only 16-20 mA current with 0.7-0.8 p mm.mrad emittance (rms, norm.).
- Second version with Caesium (IS02) installed in the test stand, under commissioning.
- First H- beam produced on 12.12.13: >50 mA, still to be optimised (and emittance to be measured).

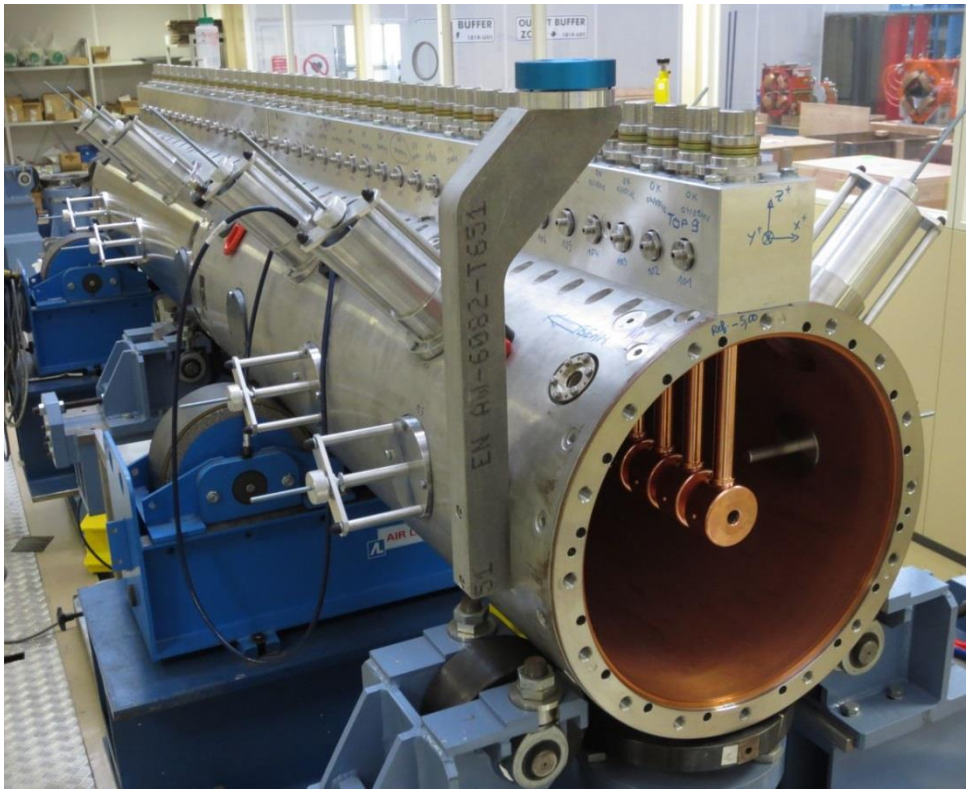




Installation in B.400

- Infrastructure (Electrical, cooling, ventilation, all cabling) completed
- Waveguides and circulators installed
- 12 klystrons /17 installed
- 8 modulators /14 installed
- Ion source, RFQ, MEBT line installed, HW tests completed
- All 3 MeV safety clearances passed on 8.11.13, beam tests started.

Next steps: DTL and CCDTL

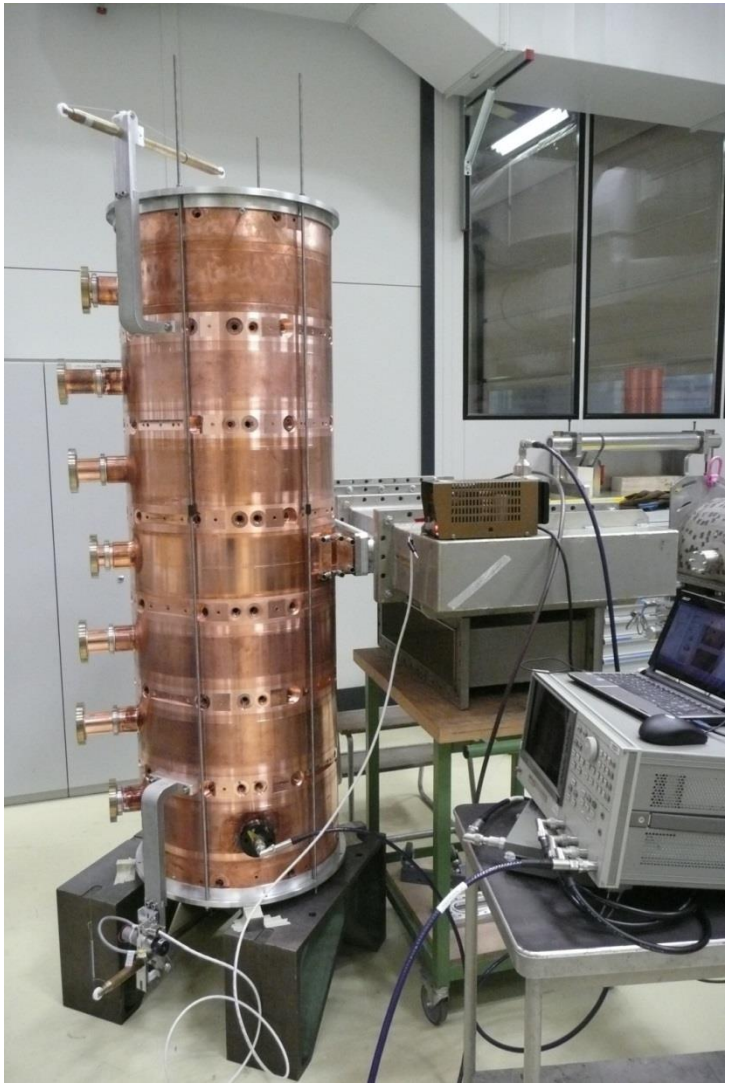


- DTL Tank 1 assembled, under RF tests.
- DTL Tanks 2 and 3 in construction and assembly.

- All 7 CCDTL modules (50-100 MeV) delivered, stored and progressively under HP tests.

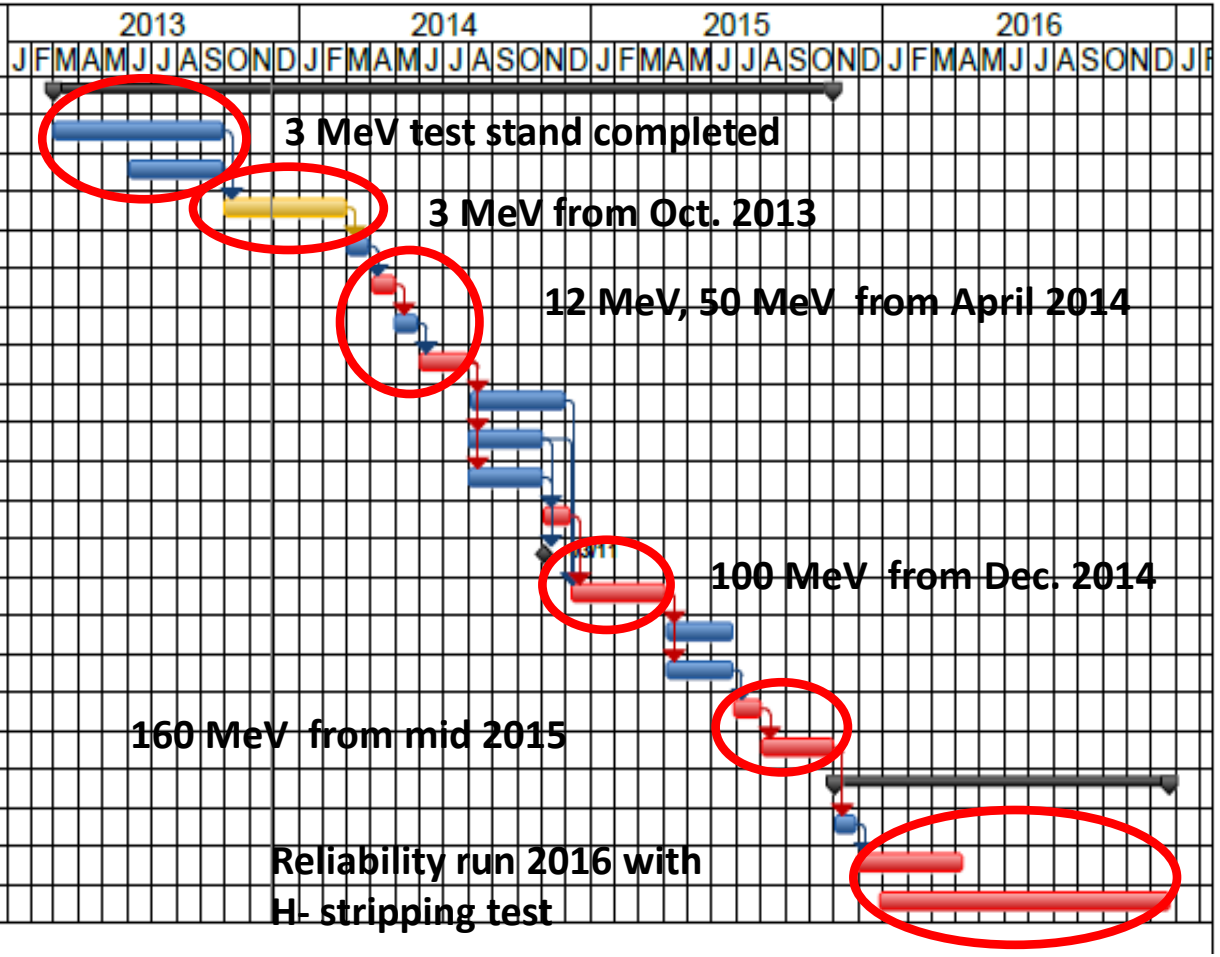
PIMS Status

- Production in Poland (with finishing at CERN) more difficult than expected: subcontractor stepped out, production insourced at NCBJ workshop, long time for qualification of all components.
- Parts for the 1st cavity (/12) delivered at CERN end November, first assembly completed 10.12.



Commissioning schedule

ID	Task Name
1	Commissioning Linac4
2	H- source installation & commissioning
3	RFQ and chopper line installation
4	3 MeV HW and beam tests
5	DTL1 + test bench installation
6	DTL1 HW + beam commissioning
7	DTL2/3 + test bench installation
8	DTL2/3 HW + beam commissioning
9	H- source2 installation & commissioning
10	CCDTL + PIMS1 + test bench installation
11	Transfer line installation 1
12	HW commissioning 100 MeV + bendings
13	Linac4 ready for 50 MeV protons
14	CCDTL beam commissioning
15	Transfer line installation 2, alignment
16	PIMS installation
17	HW commissioning 160 MeV
18	PIMS beam commissioning
19	Beam tests, reliability run
20	Half-sector installation
21	160 MeV beam tests
22	Reliability run



The future ?

- Linac4 will be completed and tested at end 2016.
- Converting to H- the PS Booster injection takes 9.2 months (incl. 2 months cool-down and renewed cabling) – *now 9.0 months…*
- LHC will restart in 2015 and run for 4 years; it was impossible to obtain an intermediate stop for Linac4 connection (although physics has plans for a 4.5 months interruption at end 2016). Connection (with H-) will take place only during the Long Shut-down 2, foreseen between June 2018 and end 2019.
- We are considering the option of an earlier connection (end 2016) producing 50 MeV protons and a switchyard magnet allowing operation of the PSB with Linac2 or Linac4. Current about 80 mA (maximum allowed by DTL RF) with ½ the emittance of Linac2. Advantages: a) save the resources required to run 2 linacs in parallel; b) have ready a solution in case of Linac2 failure; c) real-life testing of the critical sections of Linac4 with Linac2 as back-up; d) testing the injection in the PSB of a chopped beam with half emittance.