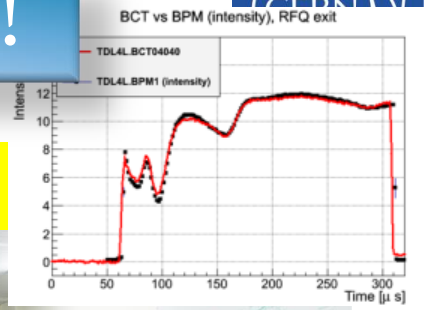
Status of Linac4

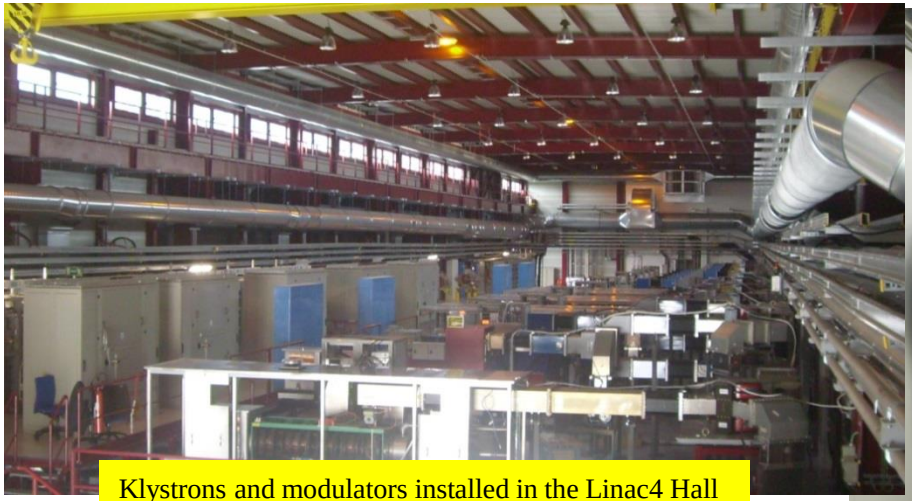
Ion Source Review, 14 November 2013

M. Vretenar, CERN

2013 : a memorable year !



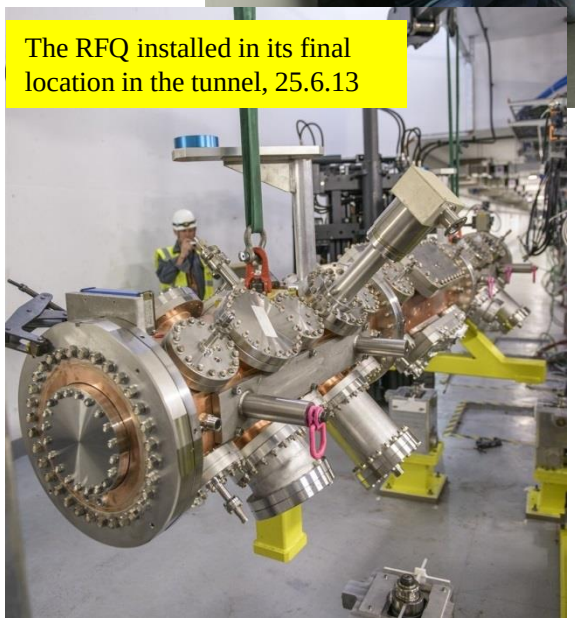
A cheering crowd celebrating the first beam accelerated by the RFQ, 13.3.2013



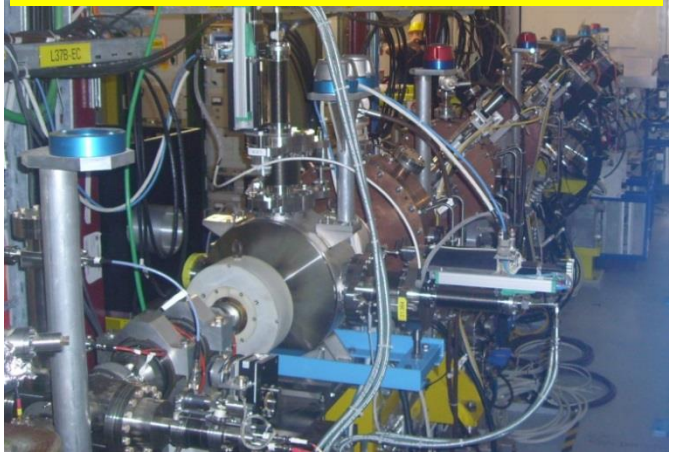
Klystrons and modulators installed in the Linac4 Hall

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!

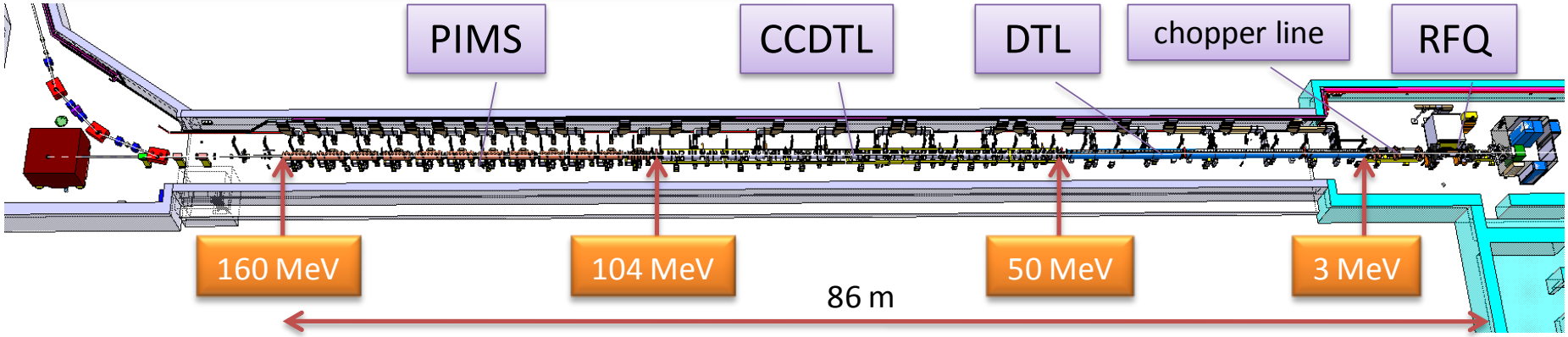


Linac4 layout

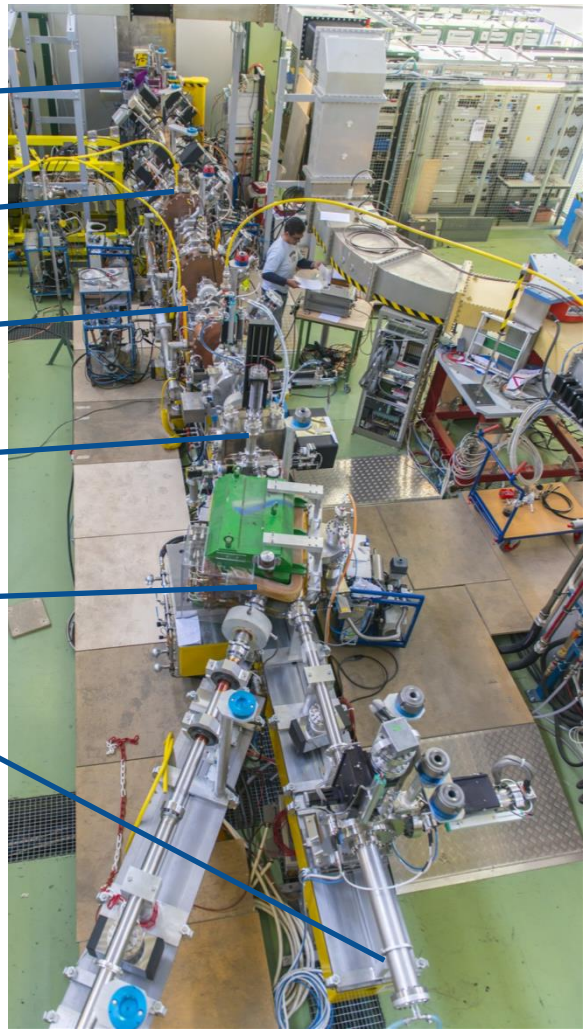
1. Pre-injector (source, magnetic LEBT, 3 MeV RFQ, chopper line)
2. Three types of accelerating structures, all at 352 MHz (standardization of components).
3. Beam dump at linac end, switching magnet towards transfer line to PSB.

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



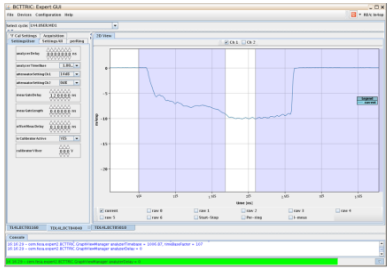
Commissioning 3 MeV



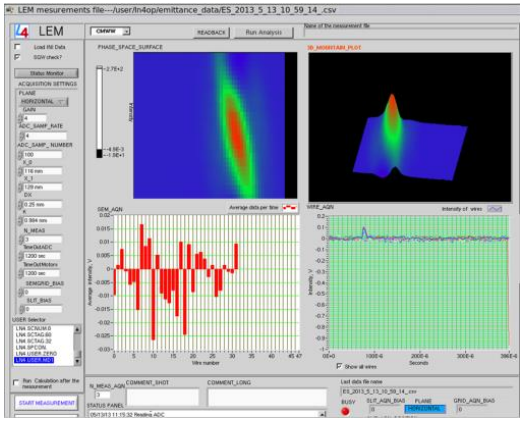
Hard time to get there, but commissioning completed in just 3 months!

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

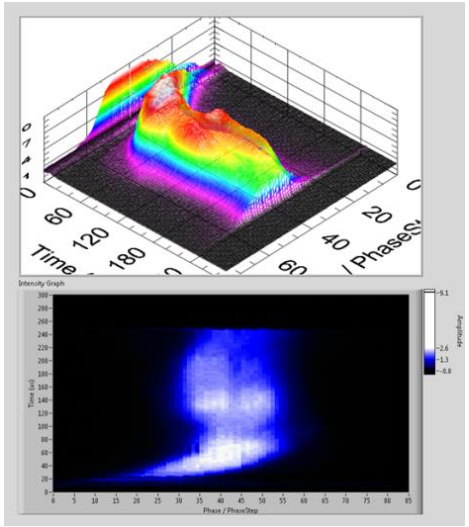
19.2.2013	First usable H- beam (45 keV)
13.3.2013	Beam through RFQ
16.4.2013	Beam through chopper line
21.5.2013	Switch to protons (for higher intensity)
31.5.2013	End of the beam tests, start transfer to tunnel



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



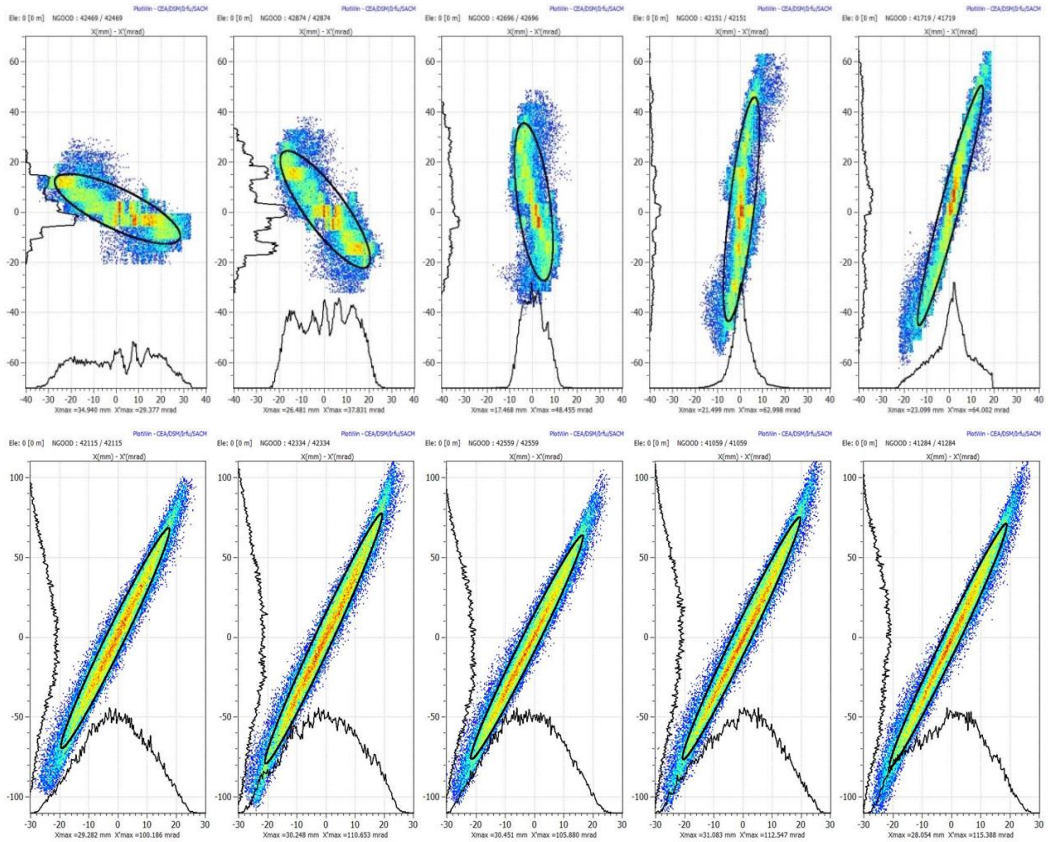
Emittance scan



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

Emittance from the source

Source | Sol | ε measurement | Sol



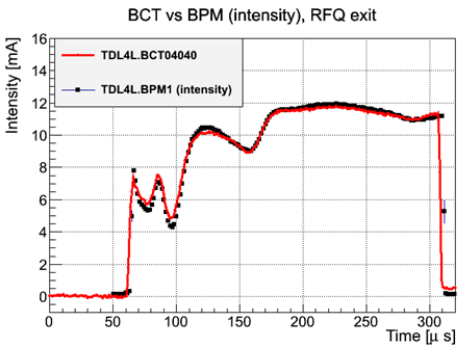
Transverse emittance measured for different solenoid settings.

Beam reconstructed at source output and effective space charge estimate.

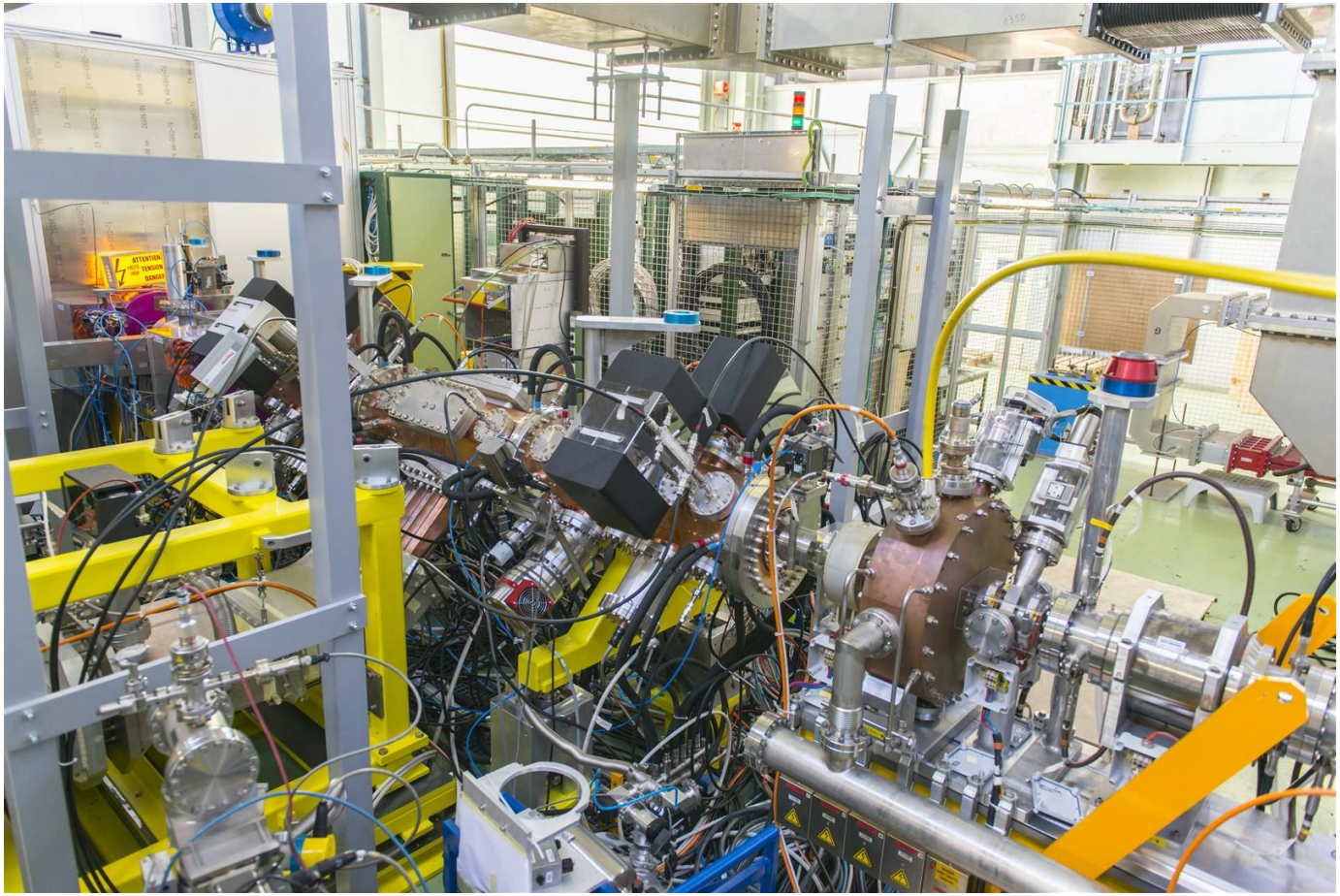
16-20 mA current
0.7-0.8 mm.mrad

The Linac4 RFQ

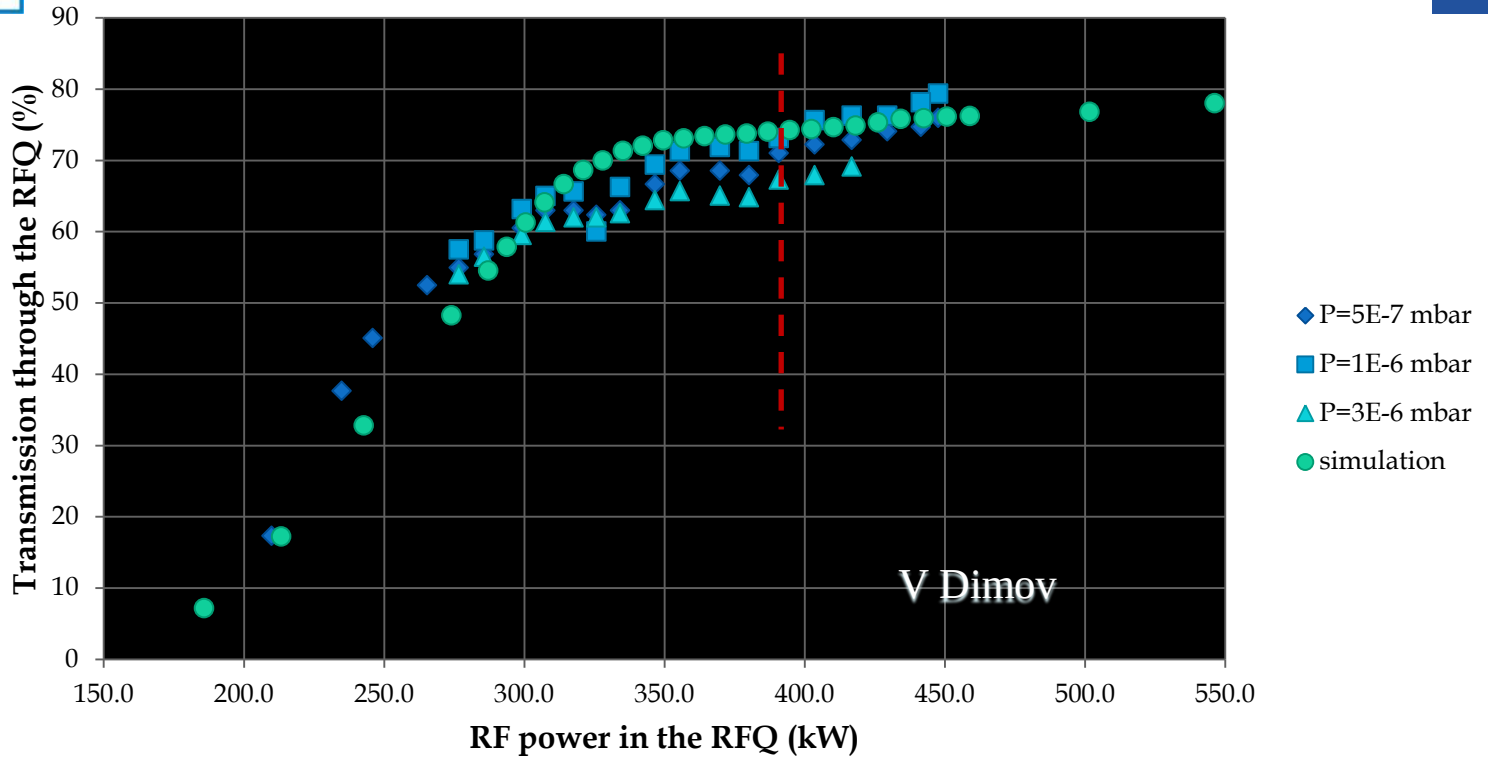
Completed in September 2012 (some delays in design, machining, brazing).
RF conditioning in less than a week, commissioning with beam started on 13.3.2013 and completed on 28.3.
Compact and solid design, aiming at high reliability.



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!



RFQ transmission vs RFQ RF power measurements and simulation



- 70-75% RFQ transmission achieved at nominal settings (<94% design value, but as expected and confirmed by simulations because of the bigger input beam emittance)
- LEBT H2 gas pressure was changed to study experimentally the effect of neutralisation

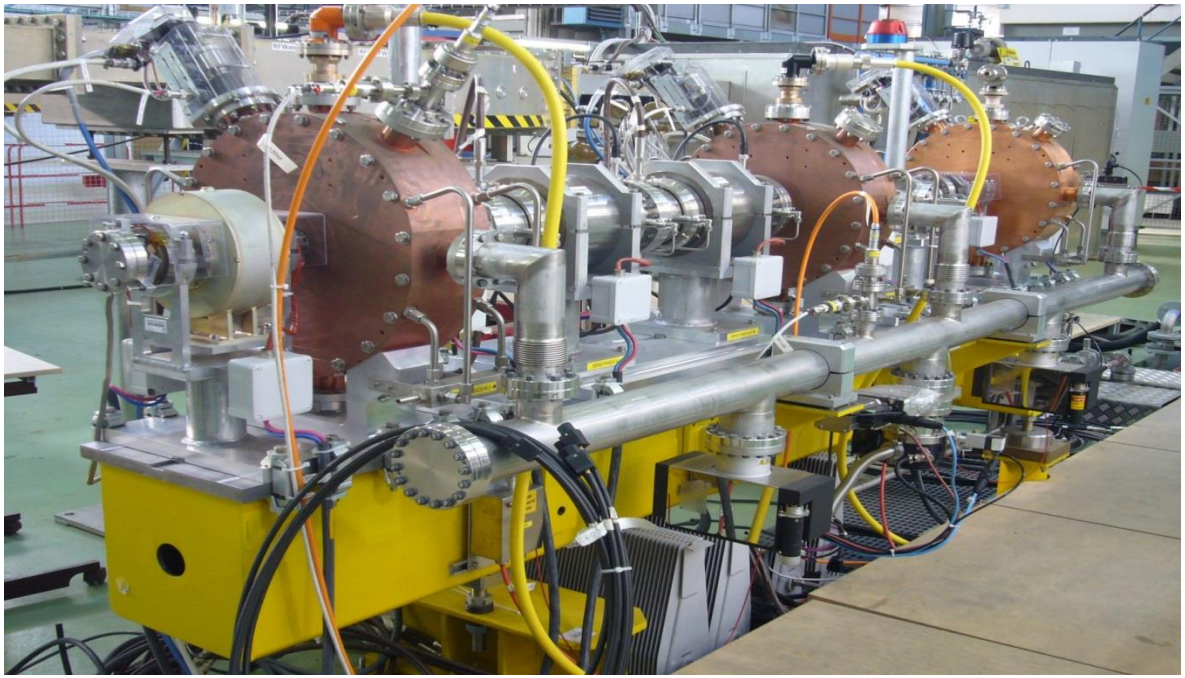
Chopper and MEBT

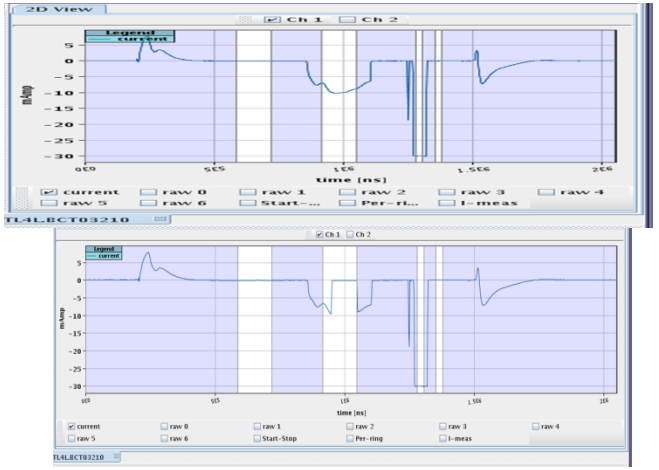
Chopper line (MEBT), 3.6 m:

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

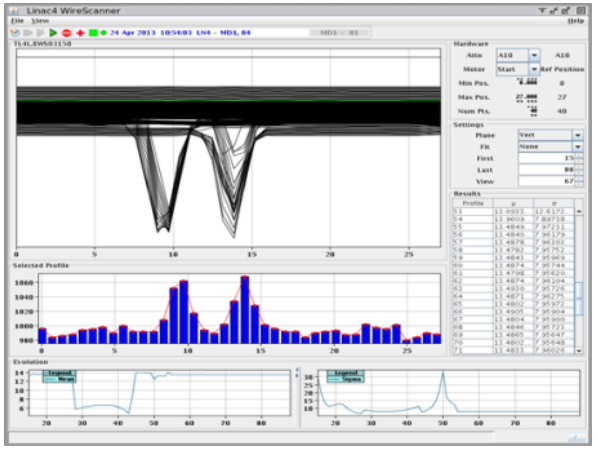
Quadrupoles used to increase separation chopped/unchopped beam reducing the required chopper voltage (600 V).

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



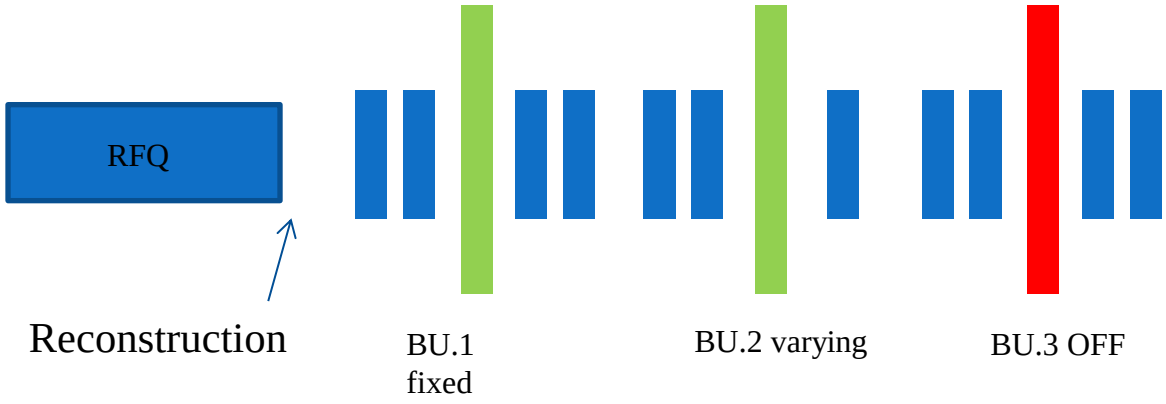


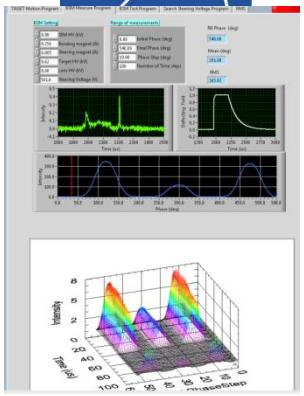
"hole" in the beam pulse produced by the chopper

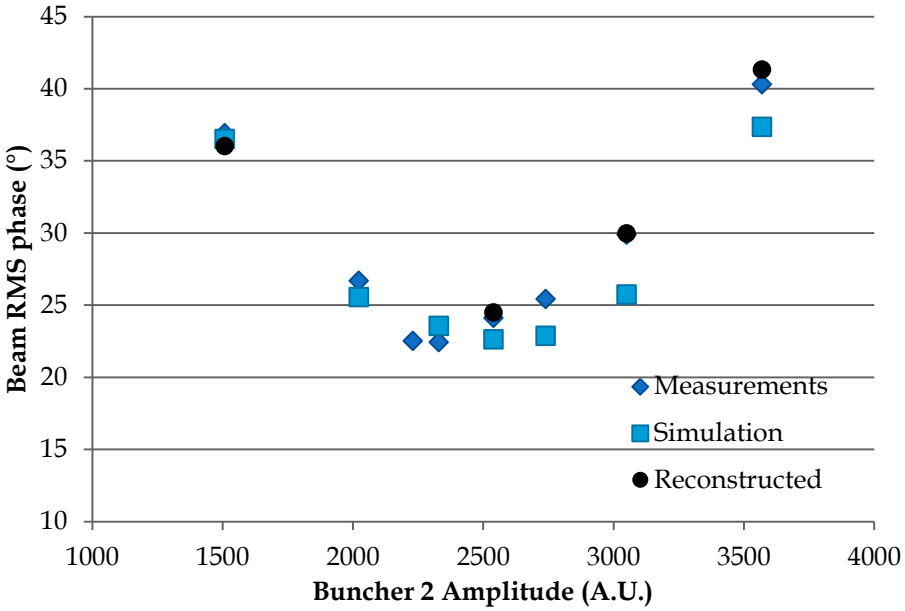


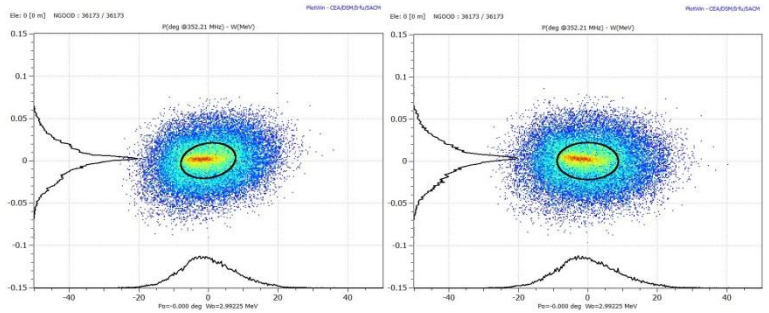
Separation of chopped and unchopped beam measured by the Wire Scanner

Longitudinal emittance reconstruction







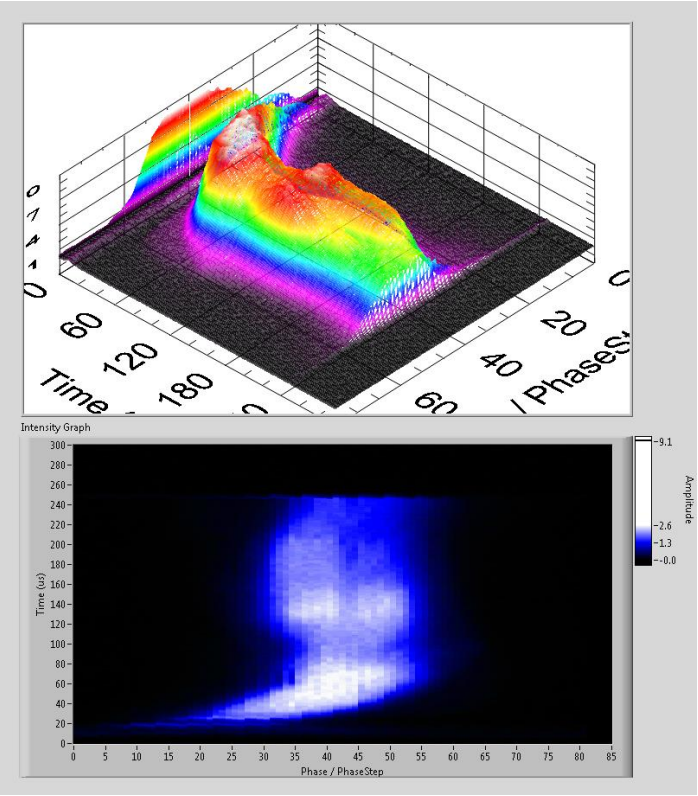


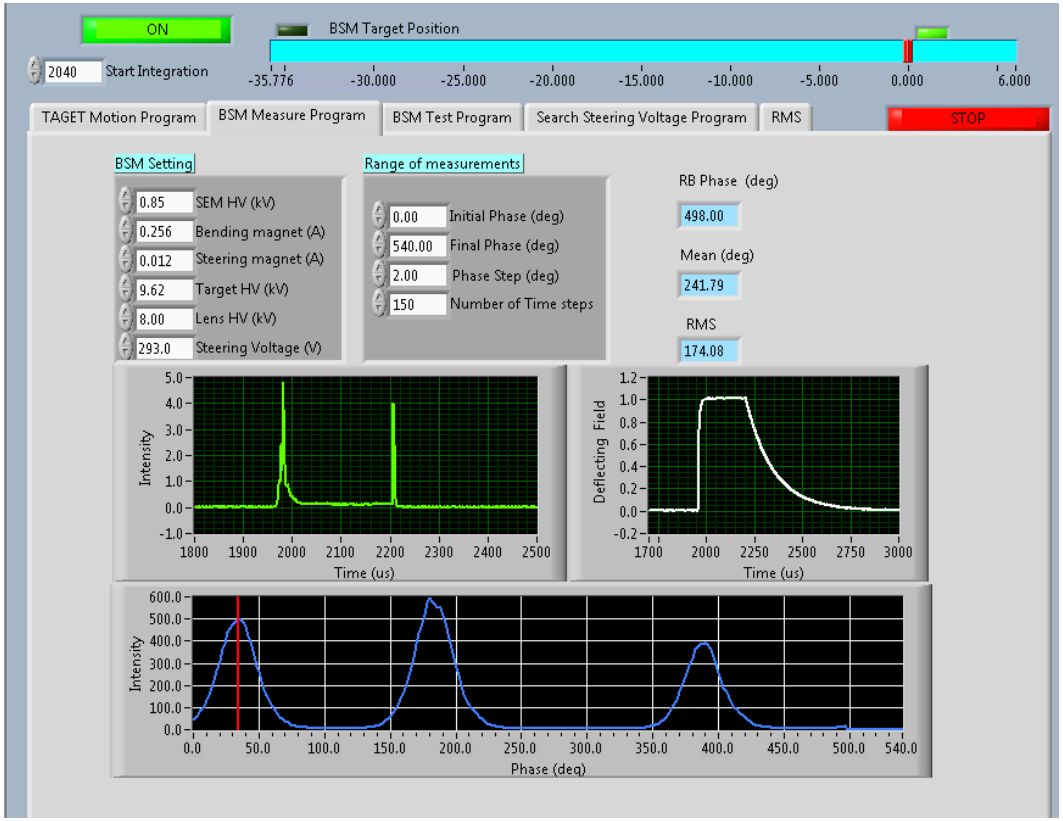
	Expected	Recons.
ΔE (keV)	21	22
Δφ (°)	7.8	8.8

BSM / Feschenko monitor

First commissioning completed by INR team

BSM measurements



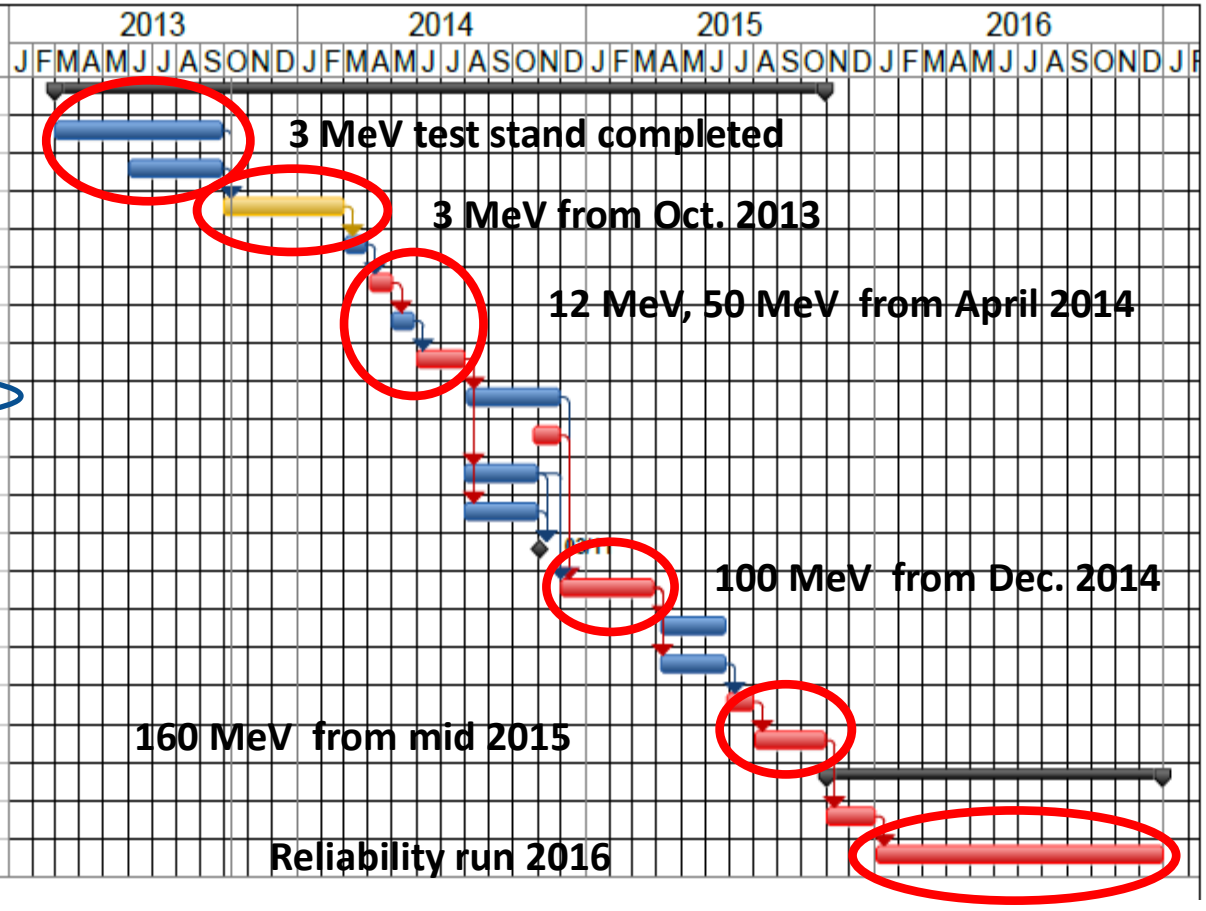


Installation in B.400

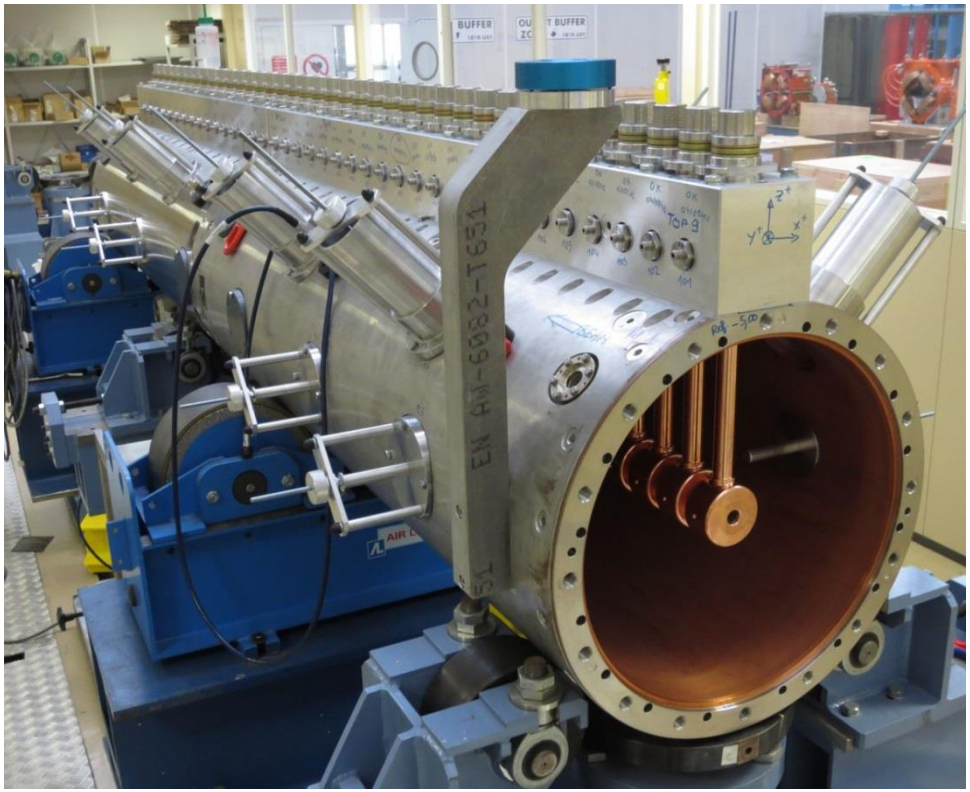
- Infrastructure (Electrical, cooling, ventilation, all cabling) completed
- Waveguides and circulators installed
- 12 klystrons /17 installed
- 6 modulators /14 installed
- Ion source, RFQ, MEBT line installed, HW tests completed
- All safety clearances passed on 8.11.13, beam tests starting…

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 installation
6	DTL1 commissioning
7	DTL2/3 installation
8	DTL2/3 commissioning
9	H- source2 installation & commissioning
10	HW commissioning 100 MeV
11	CCDTL installation
12	Transfer line installation 1
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 commissioning
19	Beam tests, reliability run
20	160 MeV beam tests
21	Reliability run



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.

The future ?

When are we going to connect Linac4

to the booster and with what particle?

- Linac4 will be completed at end 2016.
- Converting to H- the PS Booster injection takes 9.2 months (incl. 2 months cool-down and renewed cabling).
- LHC will restart in 2015 and run for 3-4 years: it is very difficult to obtain an intermediate stop for Linac4 connection (although physics has plans for a 4.5 months interruption at end 2016).
- Options:

a. (favored): connect with H- at end 2016 (intermediate shut-down for physics) or at end 2017 (early Long Shut-down).

b. (back-up): use Linac4 as 50 MeV proton injector *replacing or in parallel with* Linac2 between end 2016 (intermediate physics shutdown) and end 2018 (maximum for long Shutdown start), increasing (proton) current to 80 mA (half current and half emittance than Linac2).