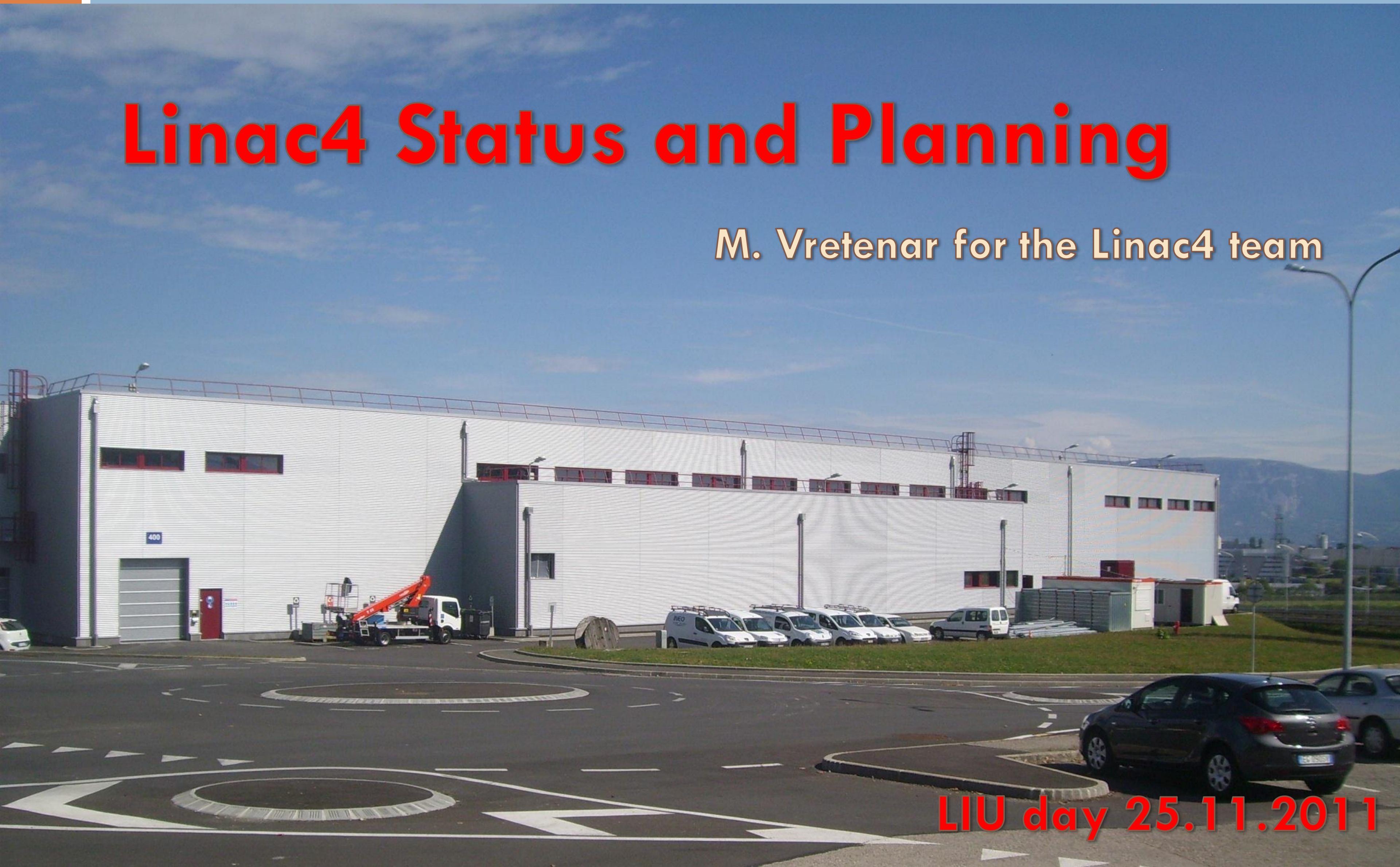
Linac4 Status and Planning

M. Vretenar for the Linac4 team



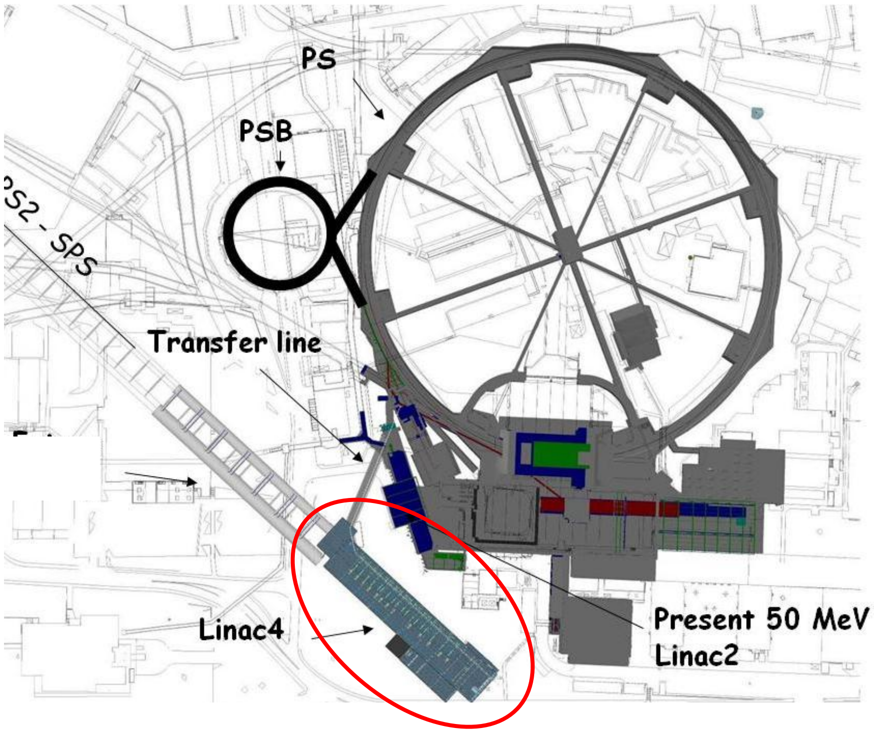
LIU day 25.11.2011

Linac4 layout and motivations

a quick reminder of what everyone should know…

New 160 MeV H- linear accelerator to replace Linac2 as injector to the PS Booster. First step of the upgrade of the injectors for the LHC Luminosity Upgrade.

approved in June 2007, started January 1st, 2008.

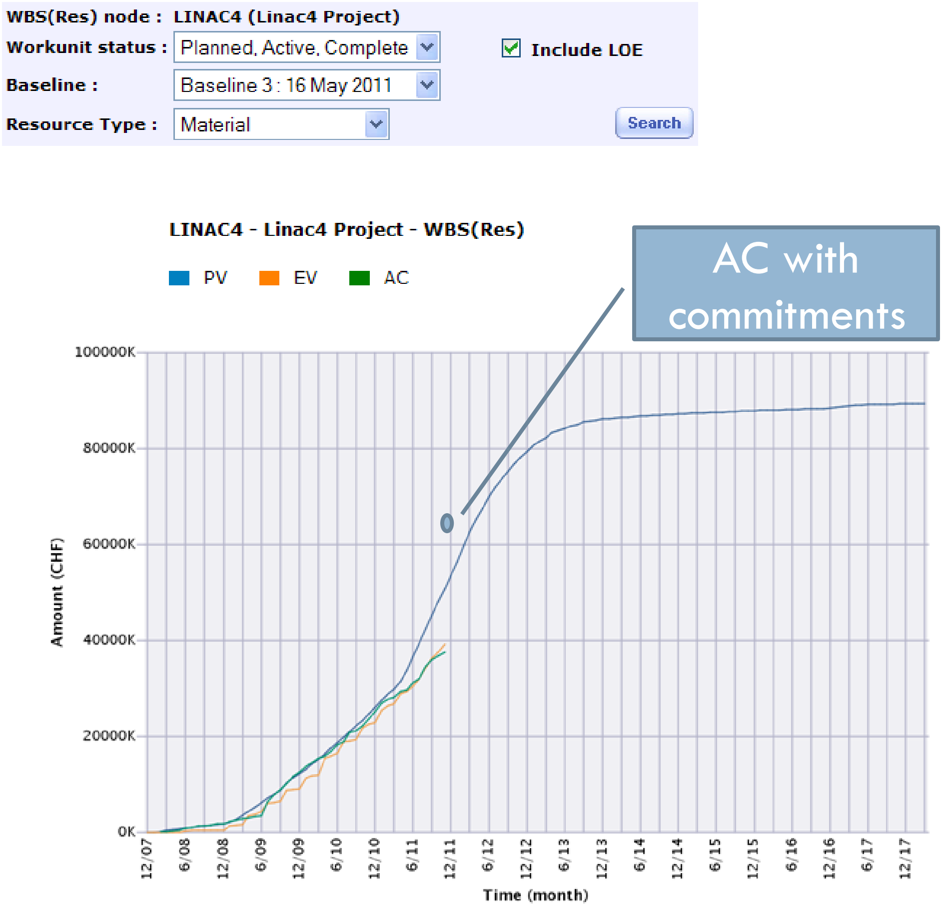


Bunch Frequency	352.2	MHz
Max. Rep. Frequency	2	Hz
Max. Beam Pulse Length	0.4	ms
Max. Beam Duty Cycle	0.08	%
Chopper Beam-on Factor	65	%
Chopping scheme:	222 transmitted /133 empty buckets	
Source current	80	mA
RFQ output current	70	mA
Linac pulse current	40	mA
Tr. emittance (source)	0.25	π mm mrad
Tr. emittance (linac exit)	0.4	π mm mrad
Max. repetition frequency for accelerating structures 50 Hz		

MOTIVATIONS:

1. Make possible an upgrade of the LHC luminosity beyond nominal, by reducing space charge at PSB injection (factor 2 in $\beta\gamma^2$ and brightness going from 50 to 160 MeV).
2. More modern and sustainable than Linac2 (worries for long-term operation of Linac2).
3. Flexible operation and reduced loss with new technologies (chopping, H- injection).
4. Higher intensity for non-LHC users.
5. Prepare for a possible high-intensity upgrade (neutrino facility).

Where do we stand now (11.11)?



EVM extraction, 22.11.11

40MCHF earned value (=actual cost)
90MCHF total value.
☞ 45% of the project value achieved

Committed 23 MCHF
☞70% of the project value achieved or committed.

Good correspondence actual cost/earned value, few months delay

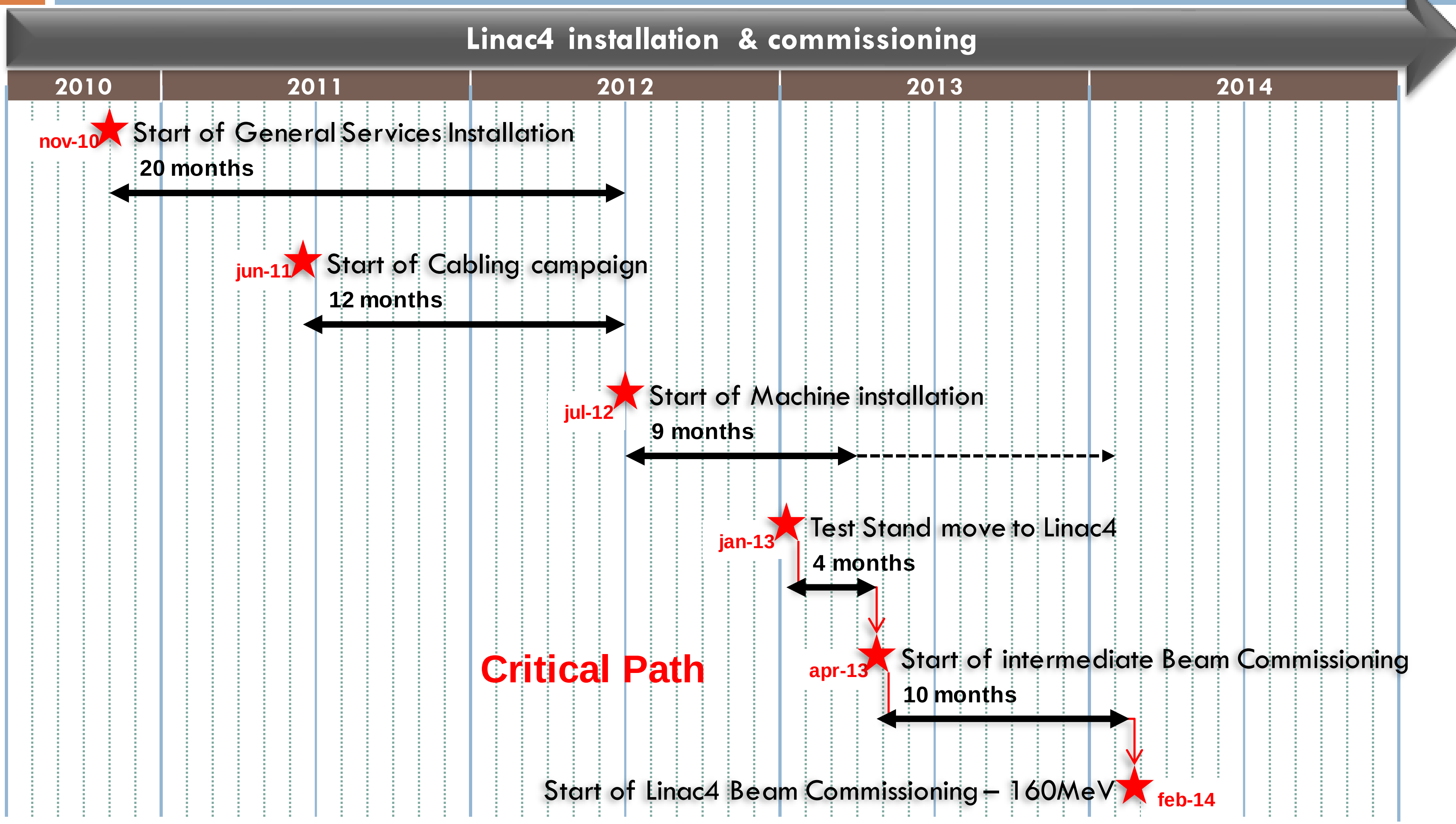
Progress with Infrastructure

Installation of infrastructure is progressing in building and tunnel

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

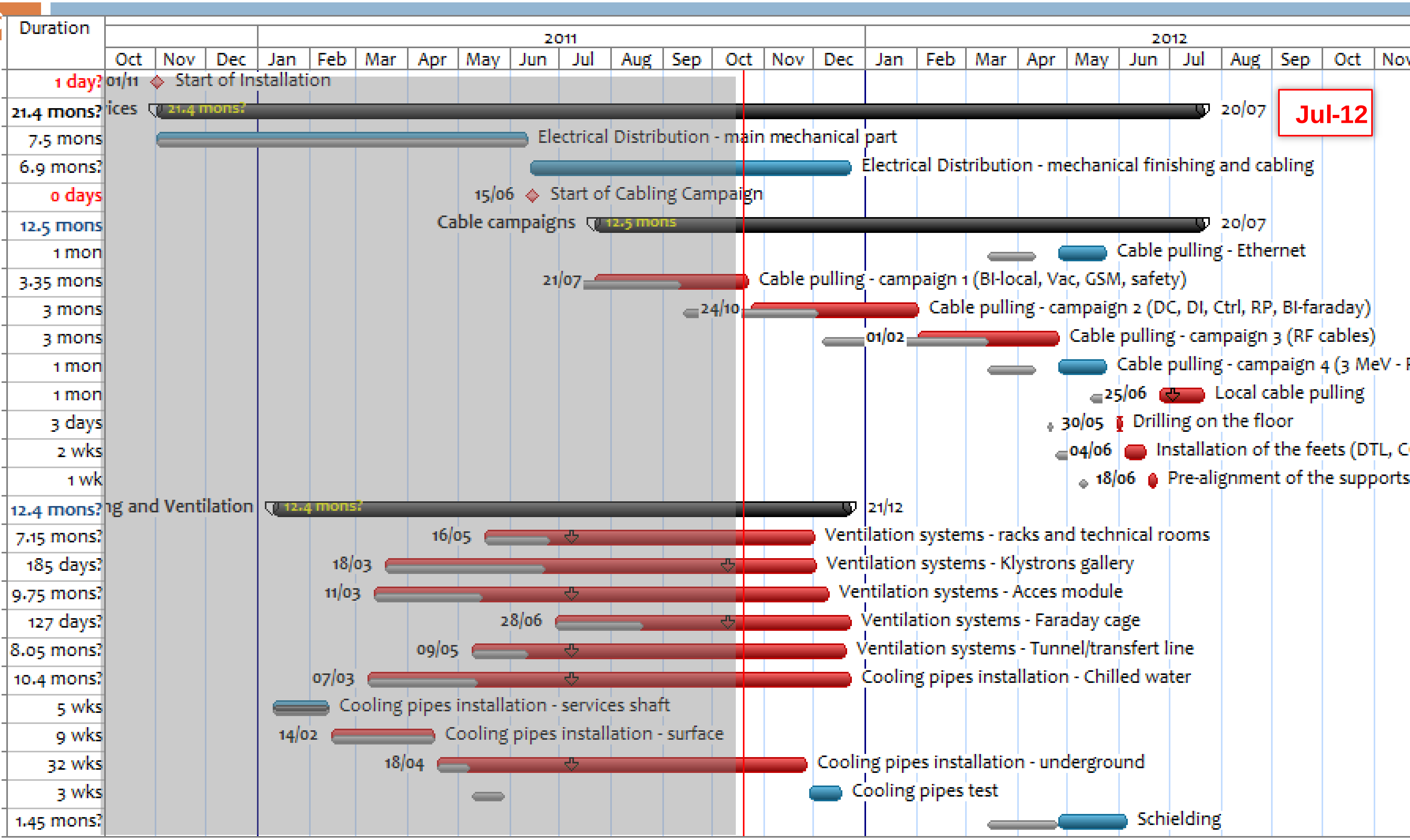
Next steps:
Cabling campaigns
Infrastructure completed by June 2012

Milestones of baseline 3

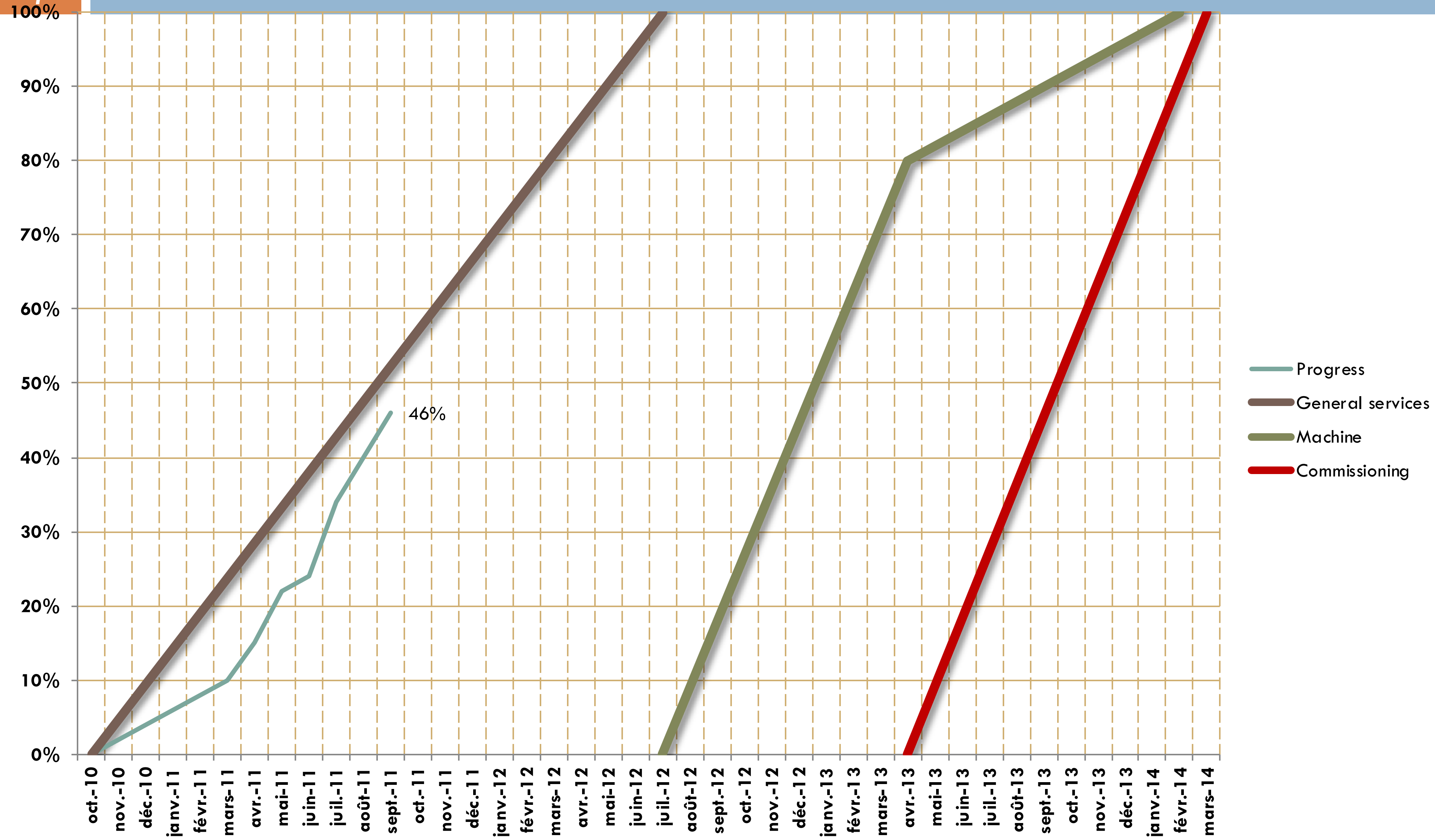


J.Coupard 20/10/2011

General Services



Planned and achieved installation progress



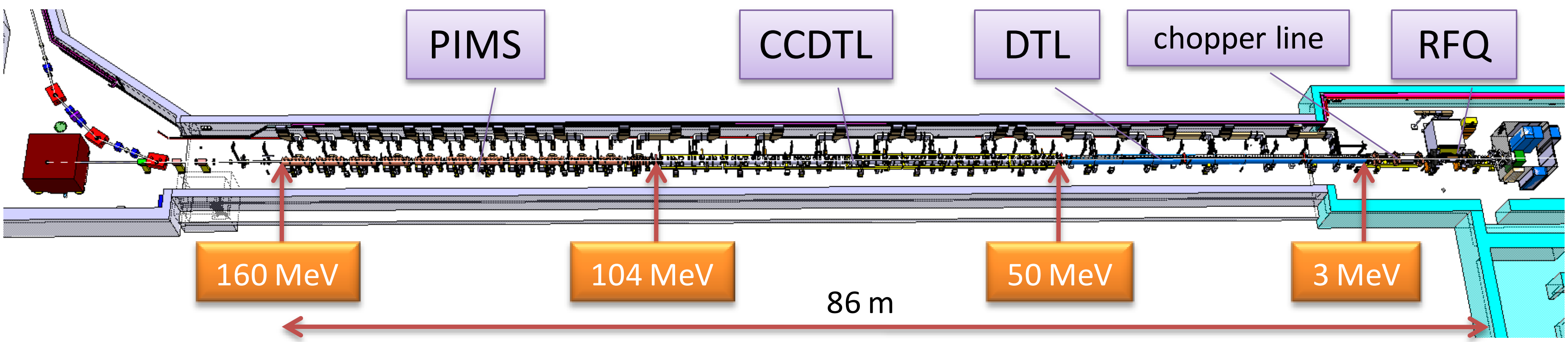
Linac4 layout

Normal-conducting linear accelerator, made of:

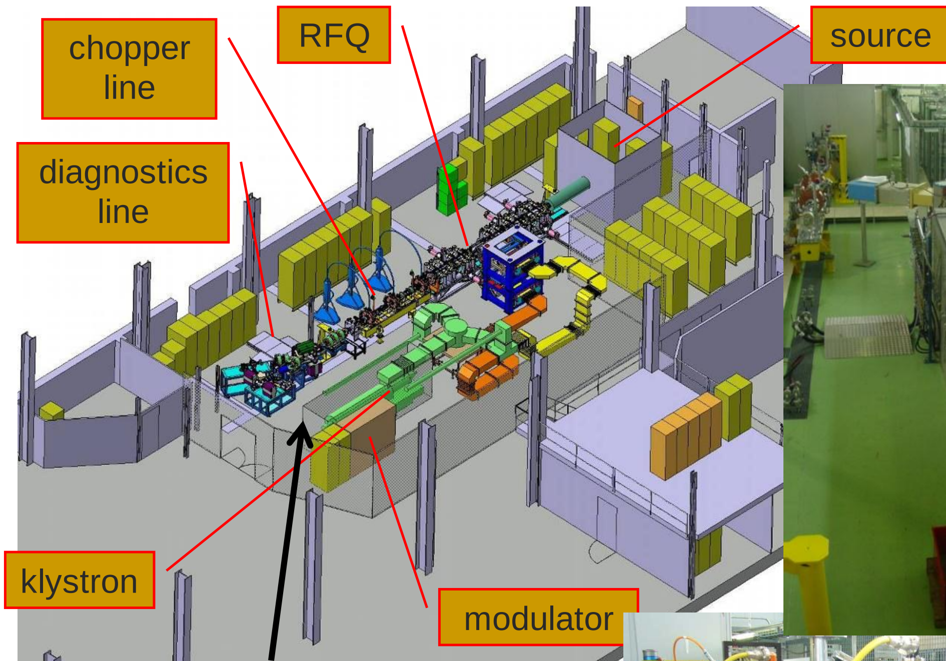
1. Pre-injector (source, magnetic LEBT, 3 MeV RFQ, chopper line)
2. Three types of accelerating structures, all at 352 MHz (standardization of components).
3. Beam dump at linac end, switching magnet towards transfer line to PSB.

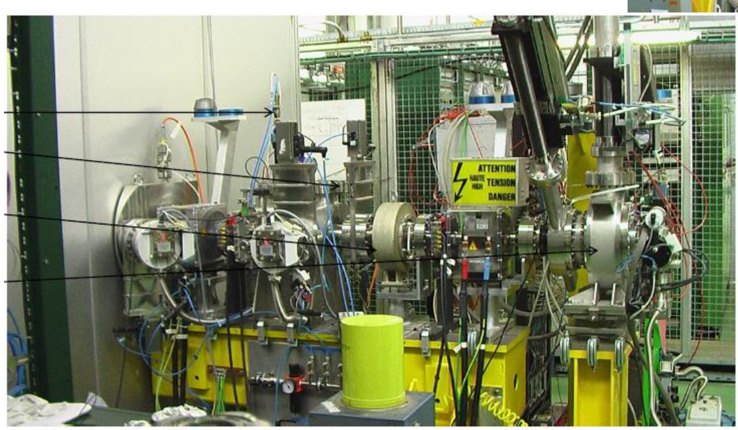
- No superconductivity (not economically justified in this range of β and duty cycles);
- Single RF frequency 352 MHz (no sections at 704 MHz, standardised RF allows considerable cost savings) ;
- High efficiency, high reliability, flexible operation → 3 types of accelerating structures, combination of PMQ and EMQ focusing.

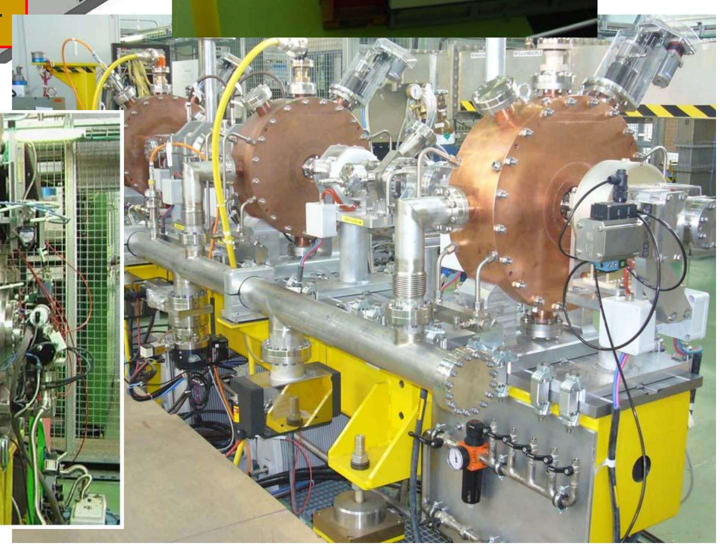
	Energy [MeV]	Length [m]	RF Power [MW]	Focusing
RFQ	0.045 - 3	3	0.6	RF
DTL	3 - 50	19	5	112 PMQs
CCDTL	50 - 102	25	7	14 PMQs, 7 EMQs
PIMS	102 - 160	22	6	12 EMQs



Linac4 – Low energy test stand





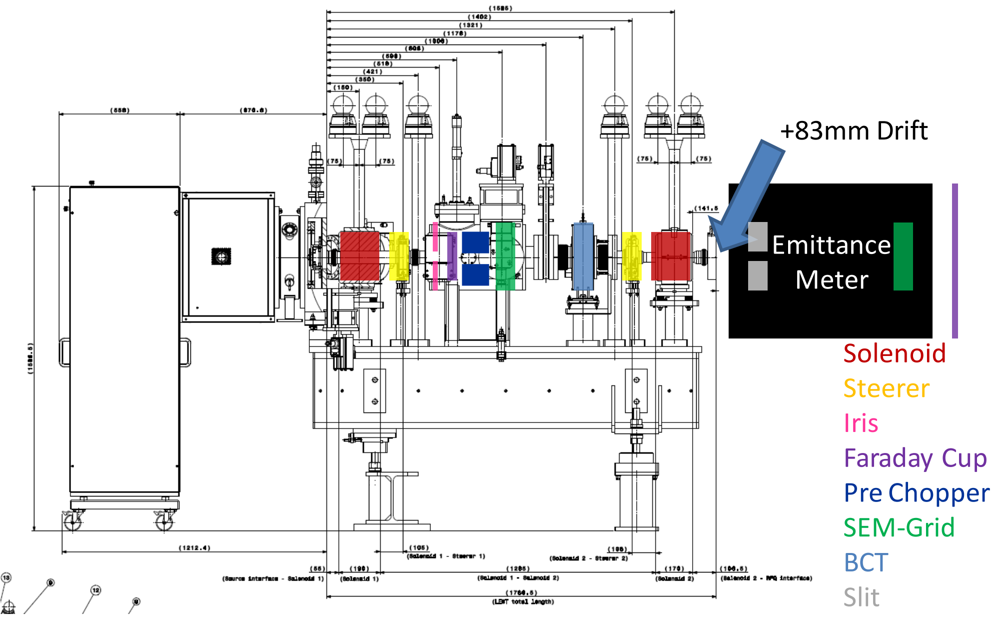


3 MeV TEST STAND for early characterization of low-energy section; will be moved to Linac4 in 2013

- ☞ 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.

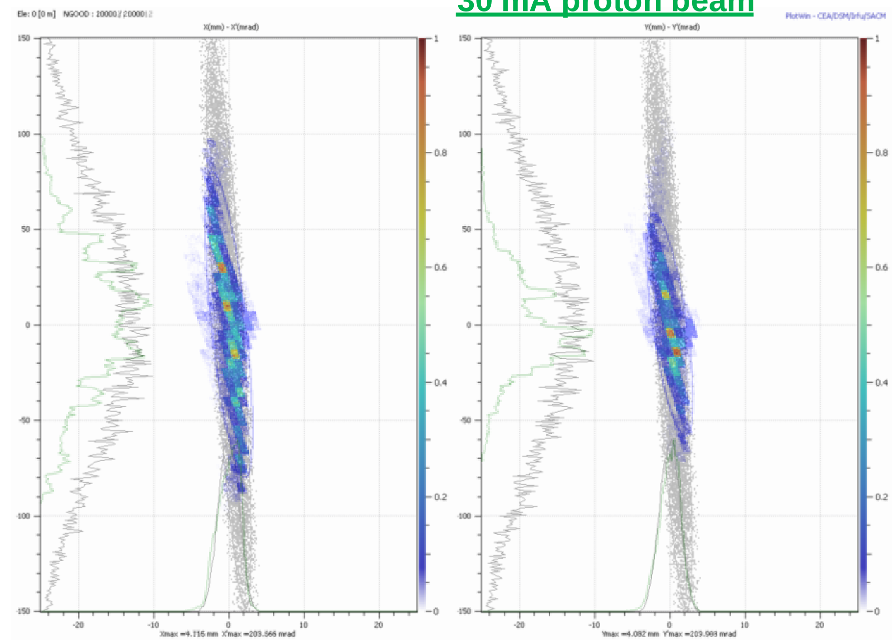
Beam tests with RFQ from beginning 2012

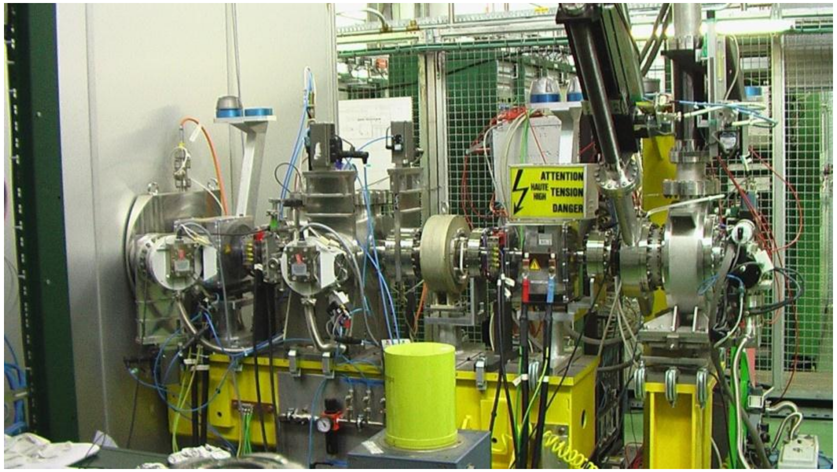
First beam measurements



Phase Space x-x' and y-y'

background RFQ acceptance
Colour Measured emittance
30 mA proton beam





First measurement campaign completed (A. Lombardi and her team):

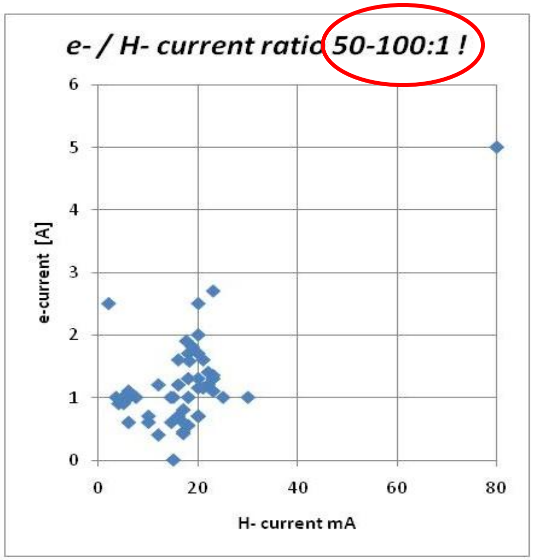
- Characterization of beam out of the source
- Understanding the behavior of the LEBT
- Matching the beam to the RFQ input

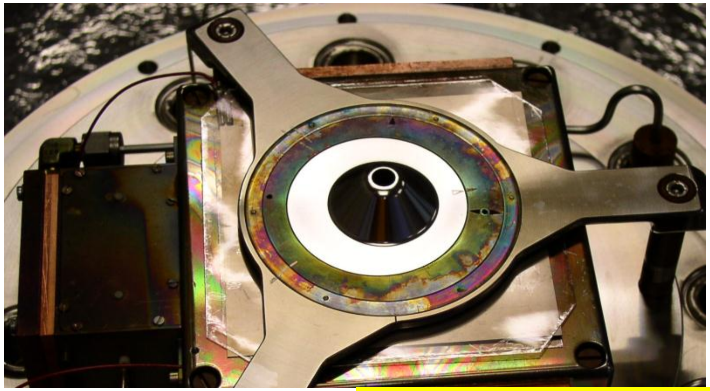
Problems with the H- source

- 2005: decision to build an RF Volume source based on the DESY design:
  - no resources for an internal development;
  - DESY source had high reliability (external antenna, Cesium-free);
  - higher extraction voltage + improvements to RF generator and matching to achieve higher current: 45 kV, 100 kW for 80 mA (DESY: 35 kV, 30 kW, 30 mA).
- June 2009: source started in the "3 MeV test stand". Extensive measurements at 35 kV.
- From May 2010: increase extraction to 45 kV but severe sparking forbids operation.

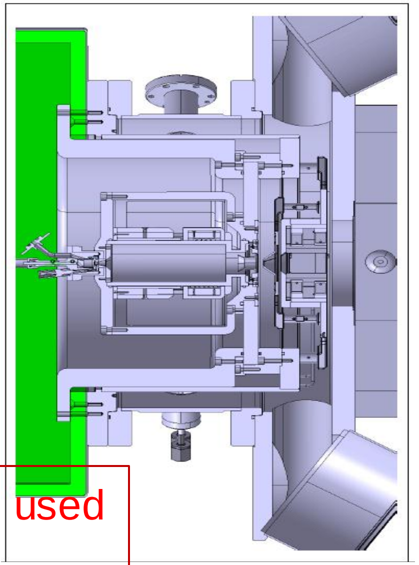
Reason: intense electron beam co-extracted with the H- melts the e^- dump (up to >200 kW instantaneous power in e- beam!). Vaporization (and destruction) of the dump induces sparking.

DESY had less electrons (with less voltage) and more H-. A "chemical" reason?





extraction electrode



DESY source now converted to protons and used for commissioning of the 3 MeV test stand

New source program

WPIS H^- Ion source: staged approach, 2 units each + *spare*

	#1 Volume source	#2 Surface source	#3 Magnetron
Operational experience H^- current	DESY 30 mA →	SNS 50 mA →	BNL 80 mA ?
Plasma Heating process	2 MHz RF Ext. antenna	2 MHz RF Int. & Ext. antenna	Arc discharge
Cesiation		Cs-chromate Single deposition:	Cs metal Constant flow
Cs-Oven test stand		Nov. 2011	Nov. 2011
Electron / H^- ratio	10-100	10	0.5 - 1
357 Plasma test stand (operational)	→ Sept. 2012	2013	2014-2015
3MeV test stand (until Dec-2012) (operational, Bldg. 152)	Jul. 2012- Dec-2012		
IS test stand (Bldg. 357)		2013	2014
Linac4, building 400	Jan 2012	Oct 2013	2015

2 test stands,

B.357: ion source (+LEBT, diagnostics)

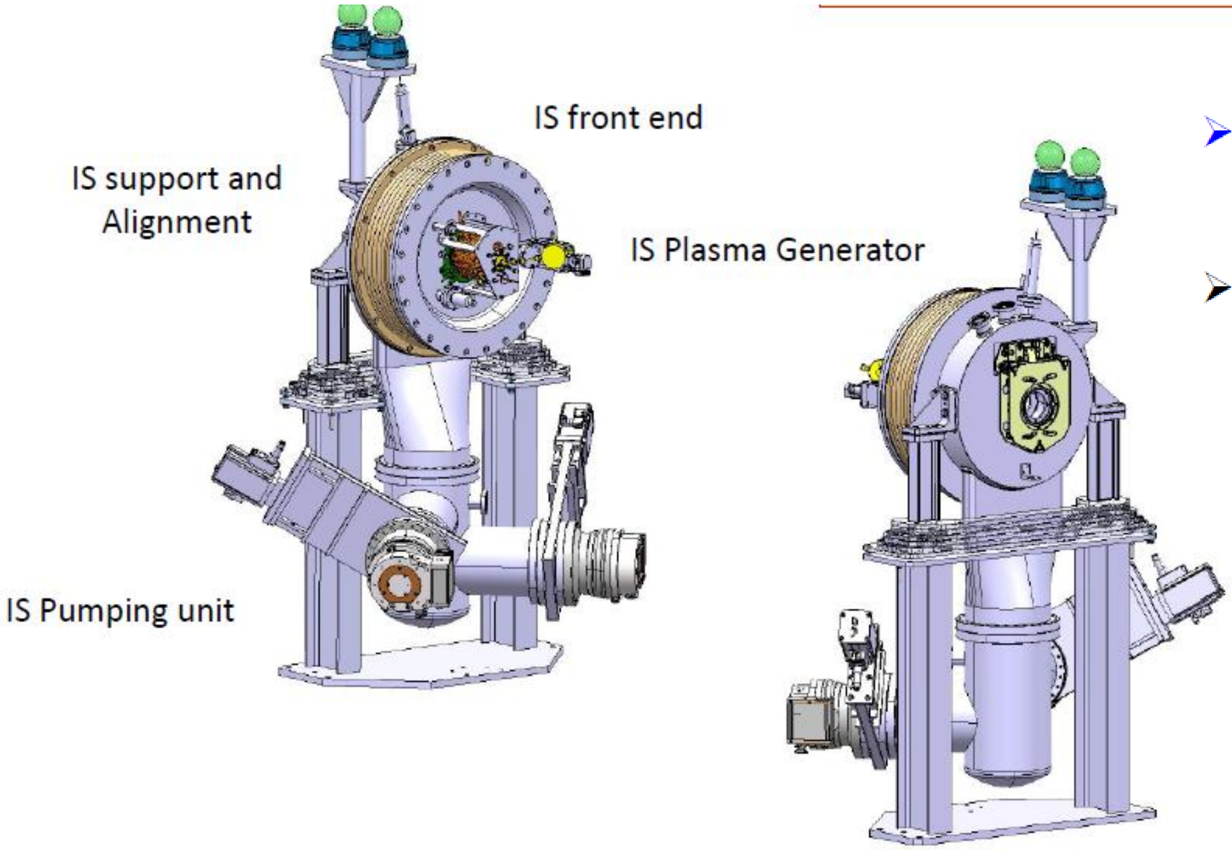
B.152: RFQ and chopper testing

1. Extend and improve the source test stand in Bld. 352 (ex-SPL source test stand).
2. Build quickly an improved RF volume source for 3 MeV and L4 commissioning.
3. Build and optimize a Cesiated RF source for L4 2nd part of commissioning and operation.
4. Study (and build) a magnetron-type source to go to high currents – if needed.

Status of the new ion source

New RF volume source for 3 MeV test stand and initial Linac4 commissioning (no Cesium, improved design and electron extraction to avoid melting of the dump)

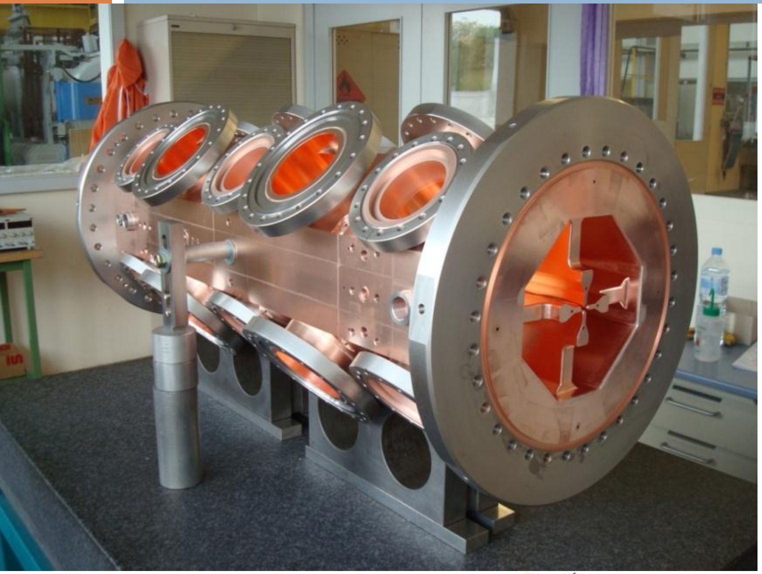
design completed, construction started



- June-August 2012: Installation at the 3MeV test stand of a volume source (sub nominal H- current)
- Commissioning and test of the 2nd Ion Source (spare+R&D) on the IS-test stand (357)

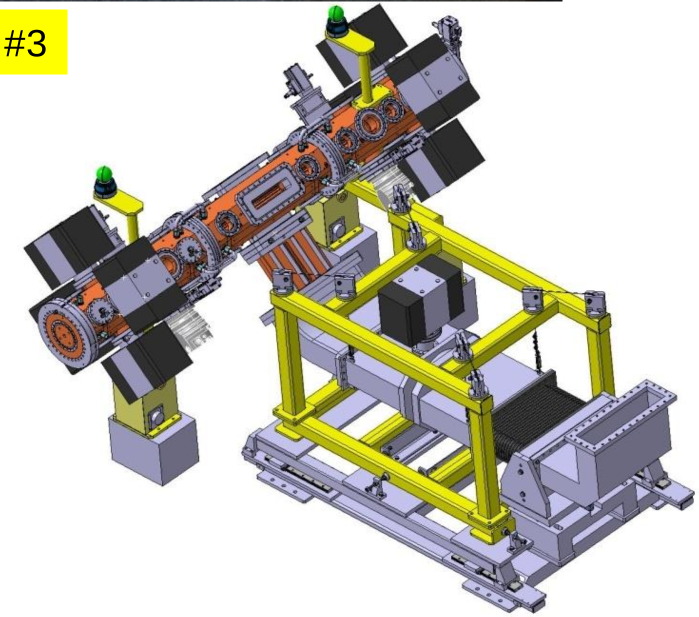
Courtesy of J. Lettry and his team

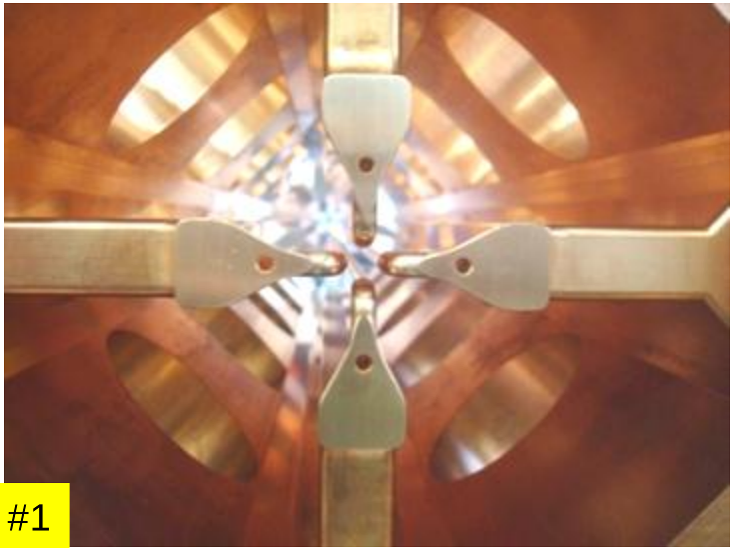
The Linac4 RFQ



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 failed the 2nd and last brazing, **being redone next week**.
Programme: RF tests and conditioning beginning 2012, beam tests with protons March/June 2012.

module #3





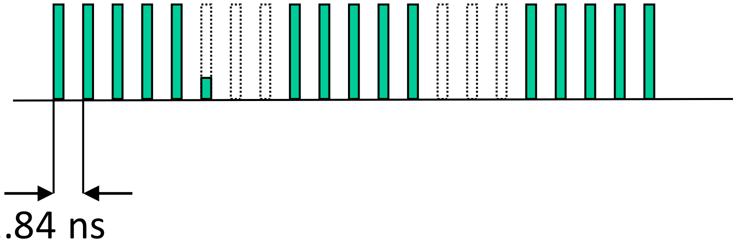
module #1

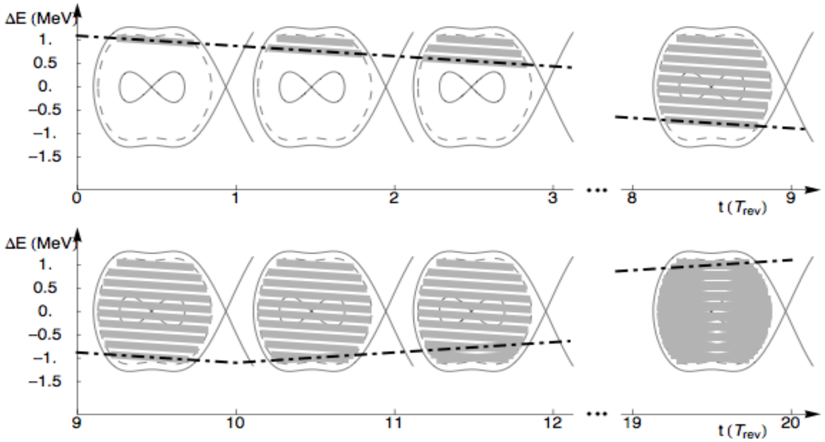
Chopper line

Length 3.6 m

Already completed, installed in the test stand and tested without beam.

Chopper: 2 meander-line structures on ceramic substrate.





PSB injection scheme (with energy ramping)

3 MeV Test stand programme

Official schedule

	April	May	June	July	August	Septemb.	October	November	December
RFQ beam commissioning (protons)									
Installation of new ion source									
LEBT beam commissioning (H-)									
RFQ beam commissioning (H-)									
Chopper line beam commissioning									

Emergency backup schedule (in case of delays with the ion source):

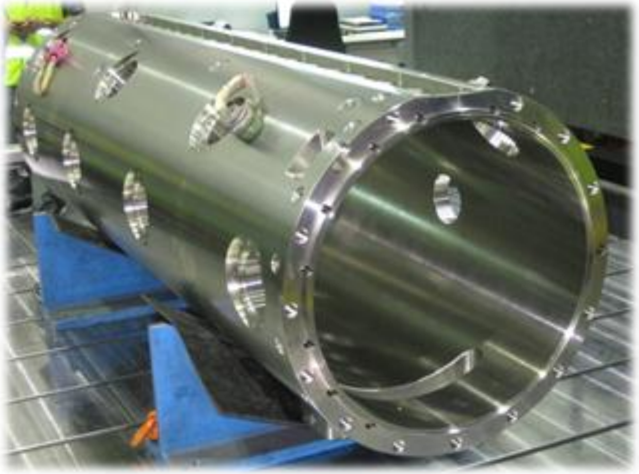
	April	May	June	July	August	Septemb.	October	November	December
RFQ beam commissioning (protons)									
Chopper line commissioning (proton)									
Installation of new ion source									
LEBT beam commissioning (H-)									
RFQ beam commissioning (H-)									
Chopper line commissioning (H-)									

Would delay the start of H- tests aimed at addressing potential risks with the new particles

C. Rossi responsible
for 3 MeV Test Stand

Linac4 DTL

- Pre-series tank and girder segments supplied by industry.
- Tank Segment T1S1 final machined with high quality from CADINOX
- Girder Segments T1S1 and T1S2 pre-machined from two companies
- Girder T1S1 final machining at CERN
- High quality drift tube parts from DMP
- Assembly of drift tubes at CERN:
  - E-beam Welding
  - Re-machining
  - Metrology
  - Testing
- Pre-series of 9 drift tubes complete

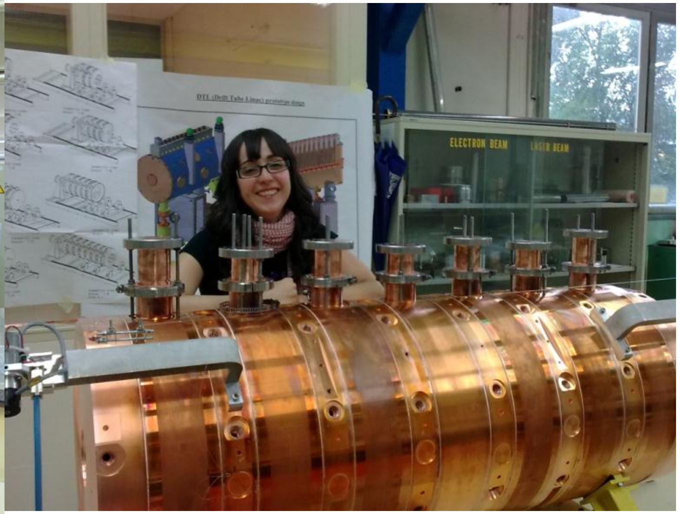


Linac4 CCDTL

- Construction at VNIITF (Snezhinsk) and BINP (Novosibirsk) in Russia,
- 3 out of 7 modules are produced,
- Module 2 has been qualified by CERN team in Novosibirsk (5-11 Nov 2011).

Linac4 – Pi-Mode Structure

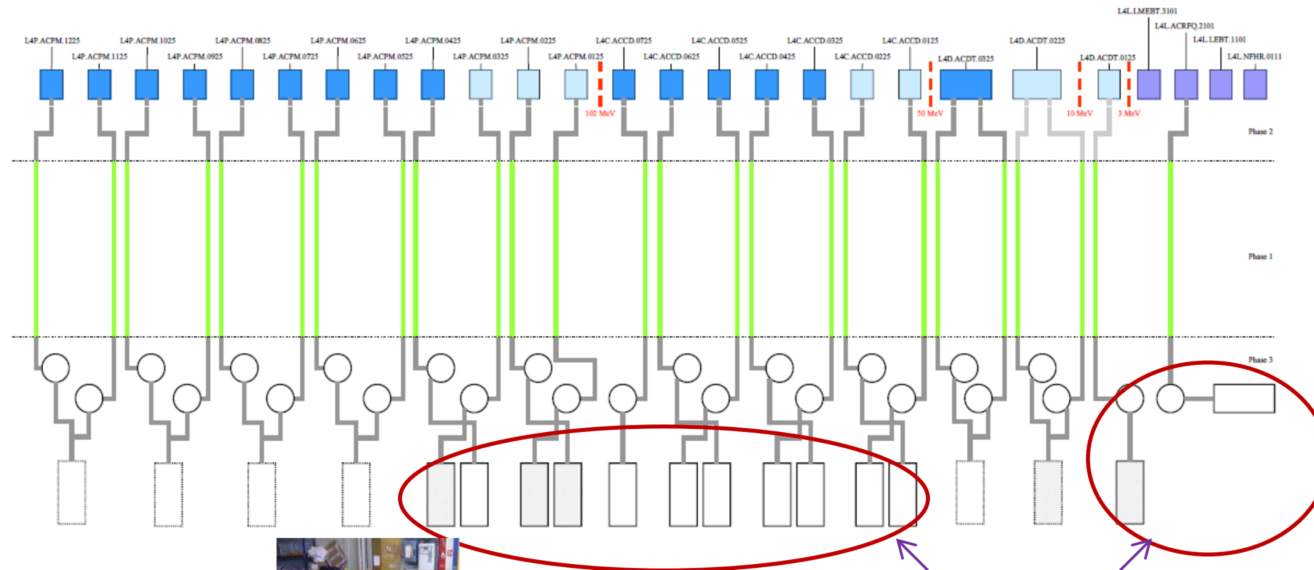
- Tank #1 (pre-series) completed and RF conditioned to 1.25 times the design voltage.
- Construction in collaboration with Soltan Institute (Warsaw) and FZ Julich.
- EB welding at Julich qualified, actual production started. Visit to Poland in December.



Structure used for the first time in a proton accelerator !

RF system

- Complex RF system
- Combination of LEP klystrons (1.1-1.3 MW) and new pulsed klystrons (2.8 MW) with splitting to 2 cavities.
- 8 new klystrons ordered (4 from Thales and 4 from CPI)



old LEP klystrons
to be replaced with new klystrons after some years of operation

- Klystron test stands ready
- Prototype klystrons to be delivered for tests beginning of 2011
- Testing of LEP klystrons in pulsed mode in progress – some problems in going >1.1 MW, to be checked.

Plaques de blindage supérieures

Berceau et blindage à Vélizy (Sept 11)

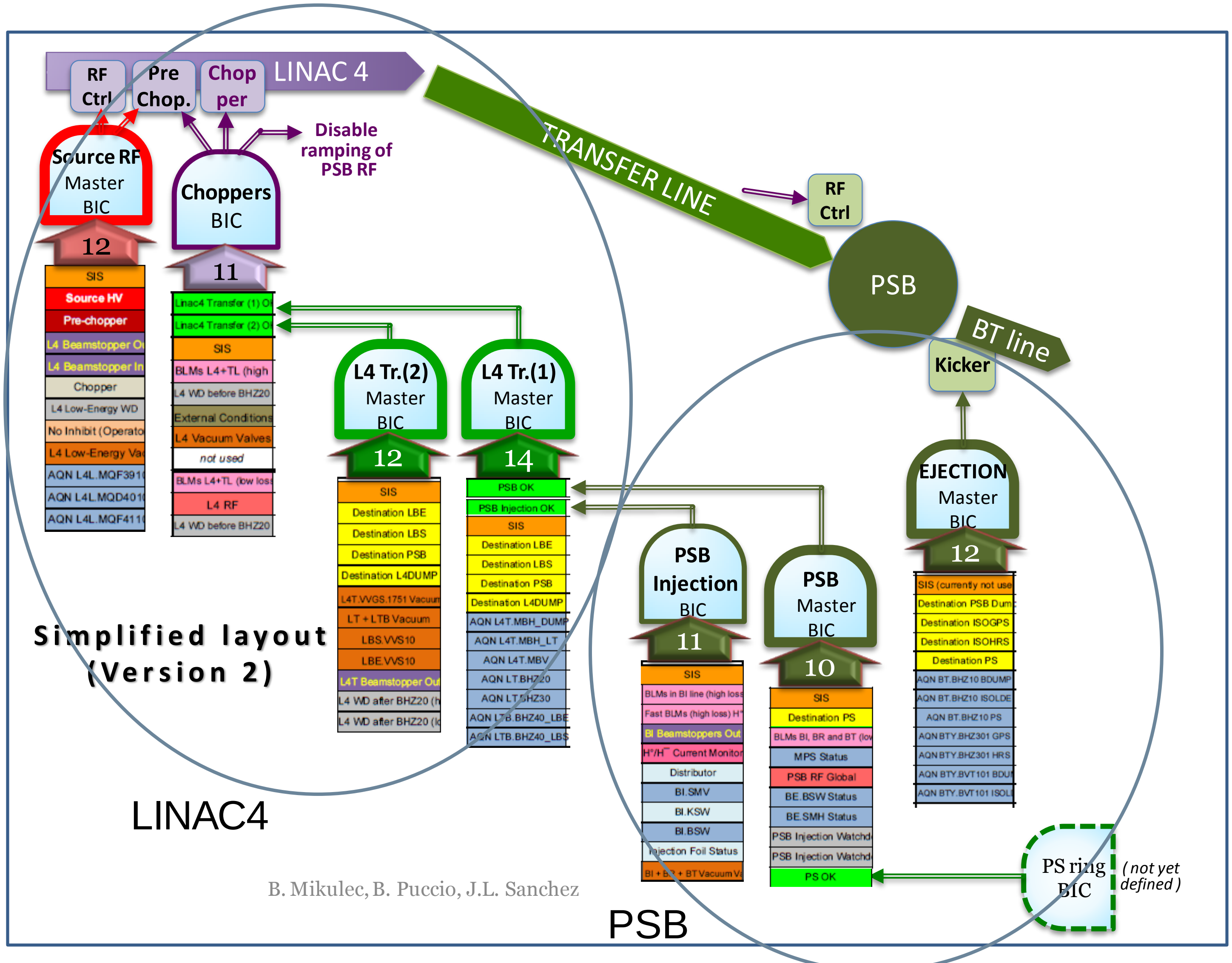
Première ébauche a ne pas considérer

1st Thales Klystron

Focalisateur intégré Vélizy (Sept 11)

Collecteur (Aout 2011)

Beam Interlock System



A low-energy beam (160 MeV) presents some dangers, because an accidental beam loss in a critical position can make a hole in the vacuum chamber

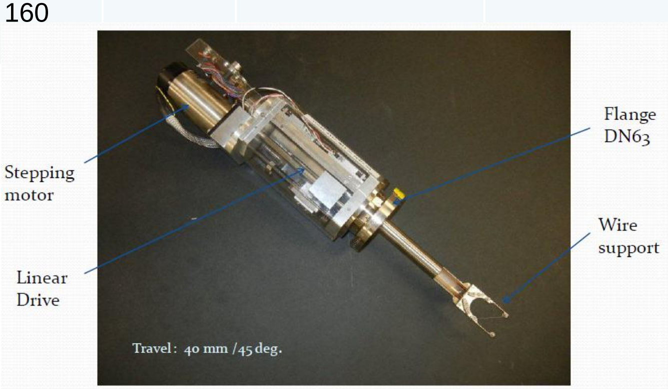
⇩

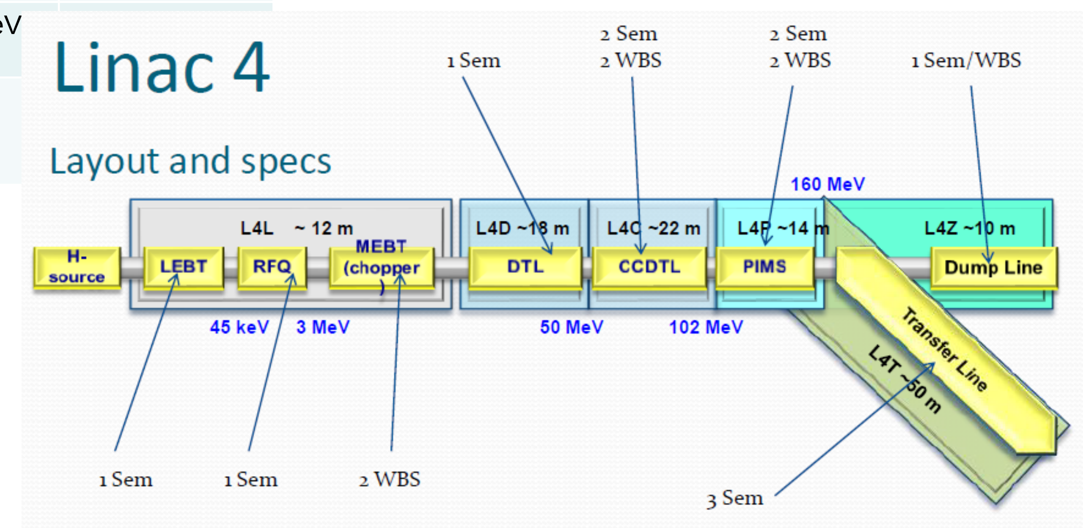
Machine protection requires a sophisticated Beam Interlock System, integrating Linac and PSB

Beam instrumentation

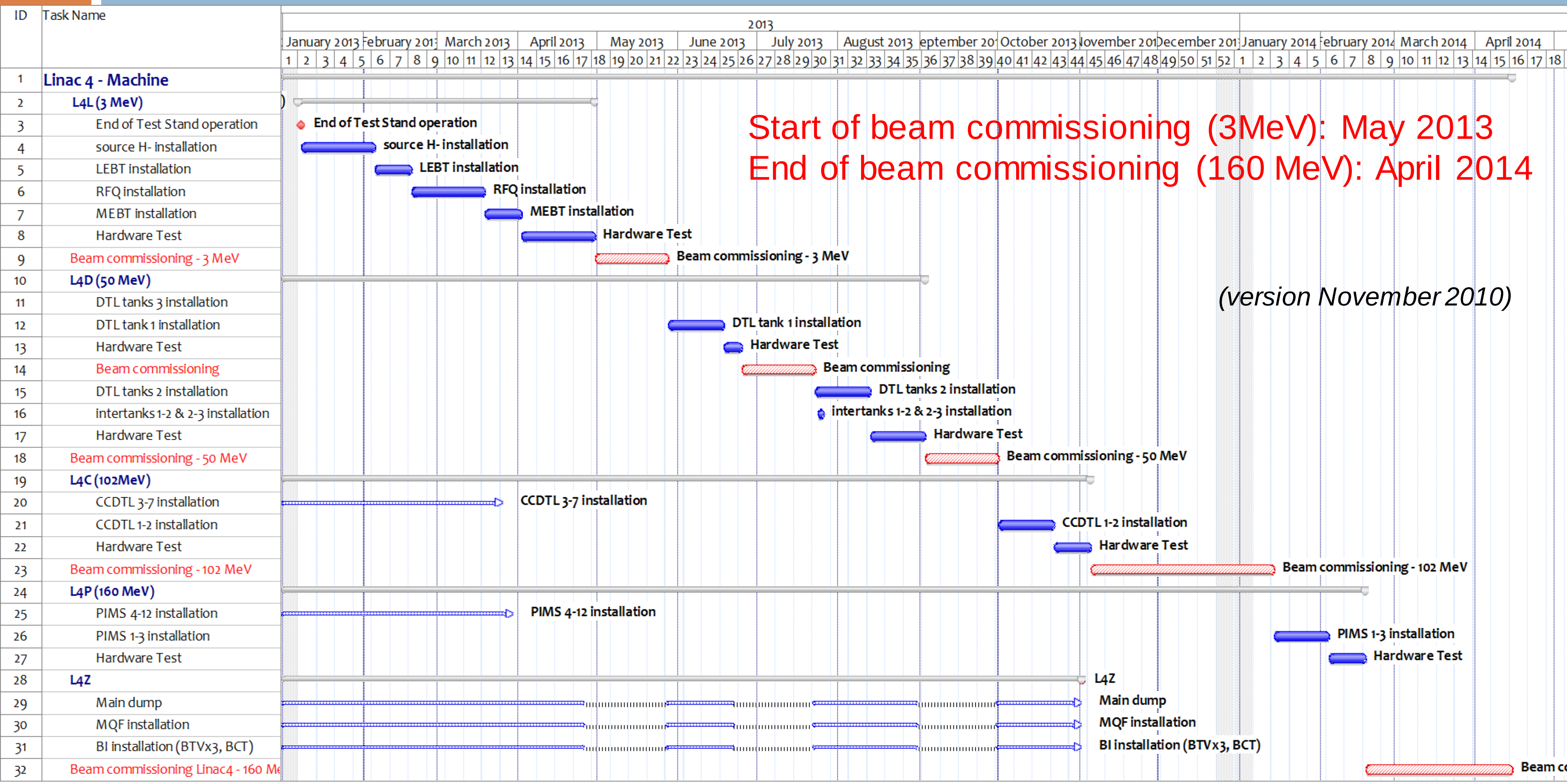
Instrument	number	location	energy	details
Faraday Cup	2	LEBT	45 KeV	only scope
Emittance meter	1 1/2	LEBT, MEBT	45 KeV 3 MeV – 12 MeV	
BPMs	31	MEBT - Booster	3 MeV – 160 MeV L2-Booster transfer	Pos, intensity Phase
SEMGrids	18	LEBT – Booster	45 KeV – 160 MeV	
Transformers	16	LEBT - Booster	45 KeV – 160 MeV	
BSM	1	MEBT - PIMS	3 MeV – 160 MeV	Russian coll
Halo Monitor	1	MEBT	3 MeV	M. Hori (finished)
Wire Scanners	6	MEBT, CCDTL, PIMS	3 MeV – 160 MeV	
BLMs	26	MEBT - Booster	3 MeV – 160 MeV	Positions to be confirmed
Laser Wire tests	1	MEBT - Booster	3 MeV – 160 MeV	
Emittance meter at 160 MeV	2	L4Z, LBE	160 MeV	

- impressive list of equipment !
- some new designs, to fit in the short available space
- International review on 18-19.11
- doubts on the use of SEMgrids for H- (stripped e- from adjacent wires) >10 MeV





Linac4 commissioning schedule



5 commissioning stages:
(on intermediate dumps)

3 MeV 10 MeV 50 MeV 100 MeV 160 MeV

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

Linac4 Plans 2013/2014

2013												2014												2015		
1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3
				Linac4 beam commissioning																						
																Reliability run										

Linac4 ready for connection to PSB (H- 160 MeV or protons 50 MeV)

Linac4 Ready for connection means:

1. Transfer line up to Linac2 wall installed;
2. Equipment for connection to LT.BHZ20 ready

Connection options

End of Linac4 commissioning + some reliability run (2014)

Option1

Connect to the PSB during an intermediate length shut-down (2015/16 or 2016/17) → **READY IN 2015**

a 4-5 month shutdown for upgrading the pixel detector has been asked by CMS for 15/16 or 16/17. We need 7 months for the connection, and if we start during the end-of-year ion run the time should be sufficient.

Option2

In case of problems with Linac2 connect Linac4 to produce 50 MeV protons → **READY AT END 2014**

degraded PSB performance because of lower peak current, no need to modify LBE/LBS or the LT/LTB lines, minimum additional shielding in Linac2 area. Need to prepare Linac4 transfer line and proton source or stripping.

Option3

Connect to the PSB during LS2 (2018 or 2019?)

→ after reliability run, keep the machine ready for connection from end 2015.

Option4

Depending on the physics results, there is still a (minor) possibility that LS1 will move (by one year?). In this case, one could connect eg. in 2015.

Present baseline

From minutes of LMC 112, 26.10.11:
Steve Myers answered that there would be a decision on this point (possible connection of Linac4 to the booster) **at Chamonix 2012, but that at present the work should continue according to the baseline schedule.**

Present baseline schedule:
- Commissioning of Linac4 in 2014;
- Ready to send 50 MeV protons in emergency from 2nd half 2014;
- Ready to connect to PSB in 2015.

Main actions for PSB connection, from the Linac4 side:

a) install new LBE/LBS measurement lines
b) improve shielding in Linac2 area
c) install new connection magnet (BHZ20)

Thank you for your attention