Linac4 Construction Status and Plans

M. Vretenar for the Linac4 team

LIU day 12.04.2013

Outline

- Introduction: layout, progress
- Schedule and plans
- Status of different subsystems
- Main open points
- Conclusions

Friday, April 12, 2013

08:30 - 09:20 General

08:30 **Welcome** *5'*
Speaker: Steve Myers (CERN)

08:35 **Welcome & LIU project news 8'+7'** *15'*
Speaker: Roland Garoby (CERN)

08:50 **Linac4 construction status and plans 20'+10'** *30'*
Speaker: Maurizio Vretenar (CERN)

09:20 - 10:20 Beam Studies

09:20 **Progress in the PSB (Low emittance, space charge...) 10'+10'** *20'*
Speaker: Elena Benedetto (CERN)

09:40 **Progress in the PS (Xverse damper, resonance compensation, impedance...) 10'+10'** *20'*
Speaker: Guido Sterbini (CERN)

10:00 **Progress in the SPS (transfer efficiency, beam instabilities, ...) 10'+10'** *20'*
Speaker: Theodoros Argyropoulos (National Technical Univ. of Athens (GR))

10:20 - 10:40 Coffee Break

10:40 - 12:30 Highlights 2012-2013

10:40 **Latest results in the 3 MeV test place (RFQ, ion source, chopper...) 10'+10'** *20'*
Speaker: Giulia Bellodi (CERN)

11:00 **H-injection system in the PSB 10'+10'** *20'*
Speaker: Wim Weterings (CERN)

11:20 **Finemet cavities: status and plan for PSB RF and PS damper during LS1 10'+10'** *20'*
Speaker: Mauro Paoluzzi (CERN)

11:40 **Digital LLRF 10'+10'** *20'*
Speaker: Maria Elena Angoletta (CERN)

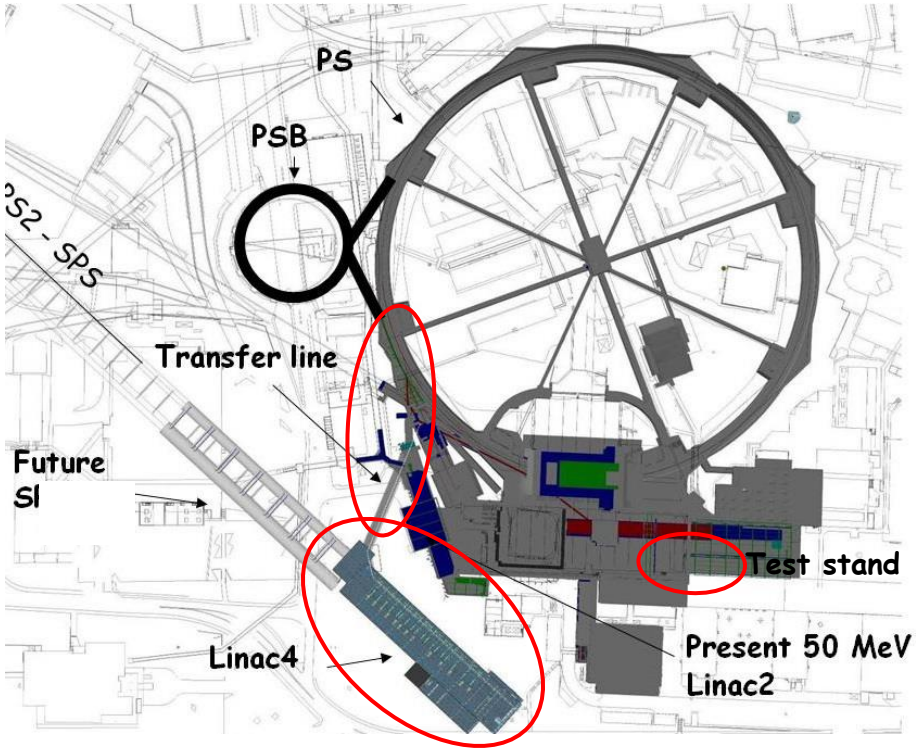
But today this is the most important presentation !!

Layout, parameters, motivations

a quick reminder of what everyone should know…

New 160 MeV H- linear accelerator, will replace Linac2 as injector to the PS Booster. First step of the LIU upgrades.
Project approved June 2007, started January 2008.

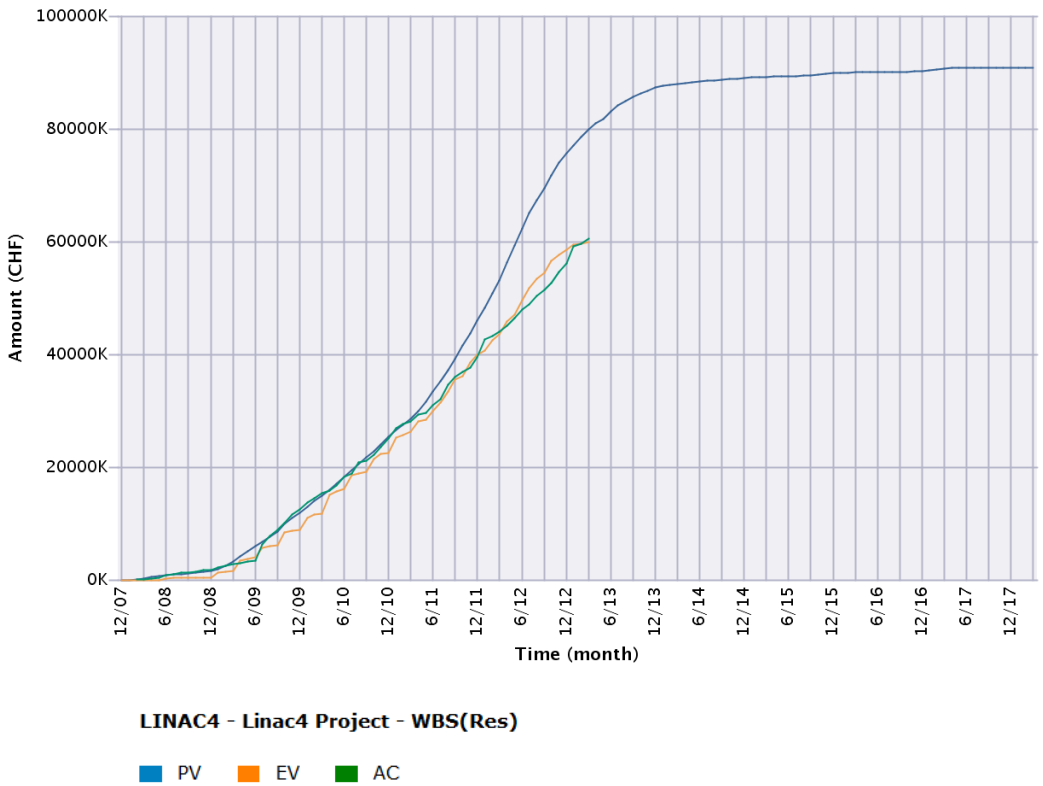
Bunch Frequency	352.2	MHz
Max. Rep. Frequency	2	Hz
Max. Beam Pulse Length	0.4	ms
Max. Beam Duty Cycle	0.08	%
Chopper Beam-on Factor	65	%
Chopping scheme:	222 transmitted /133 empty buckets	
Source current	80	mA
RFQ output current	70	mA
Linac pulse current	40	mA
Tr. emittance (source)	0.25	π mm mrad
Tr.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



1. Preparation of the injectors for an upgrade of the LHC luminosity: increase PSB injection energy to reduce space charge (factor 2 in $\beta\gamma^2$ and brightness).
2. Modern design, providing long term reliability (concerns for Linac2 vacuum).
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? EVM…

a first macroscopic point of view…



EVM extraction, March 2013

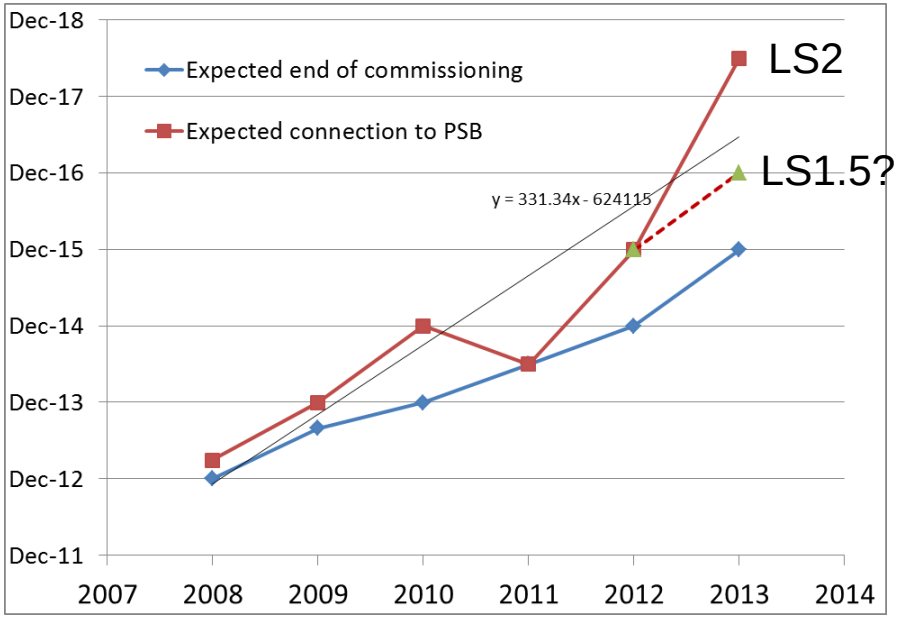
66 % of the project value achieved

Including commitments, 79% of the project value achieved or committed.

Good correspondence actual cost/earned value, delay due to baseline not up-to-date

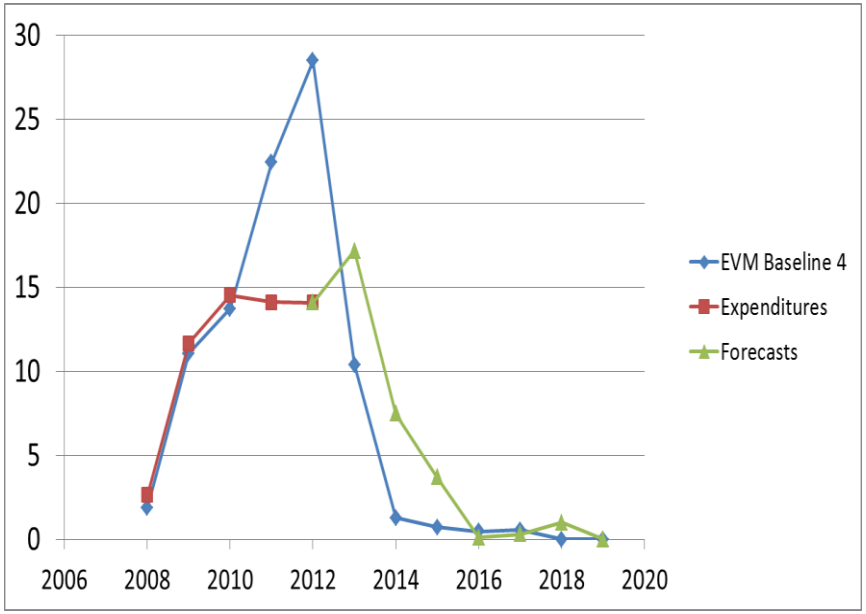
When are we going to finish Linac4?

EVOLUTION OF PROJECT END DATES from project start to now



With the foreseen connection date advancing by 331 days/year, a simple extrapolation shows that we will connect in September 2060.

PROJECT EXPENDITURES actual and initial/present forecast

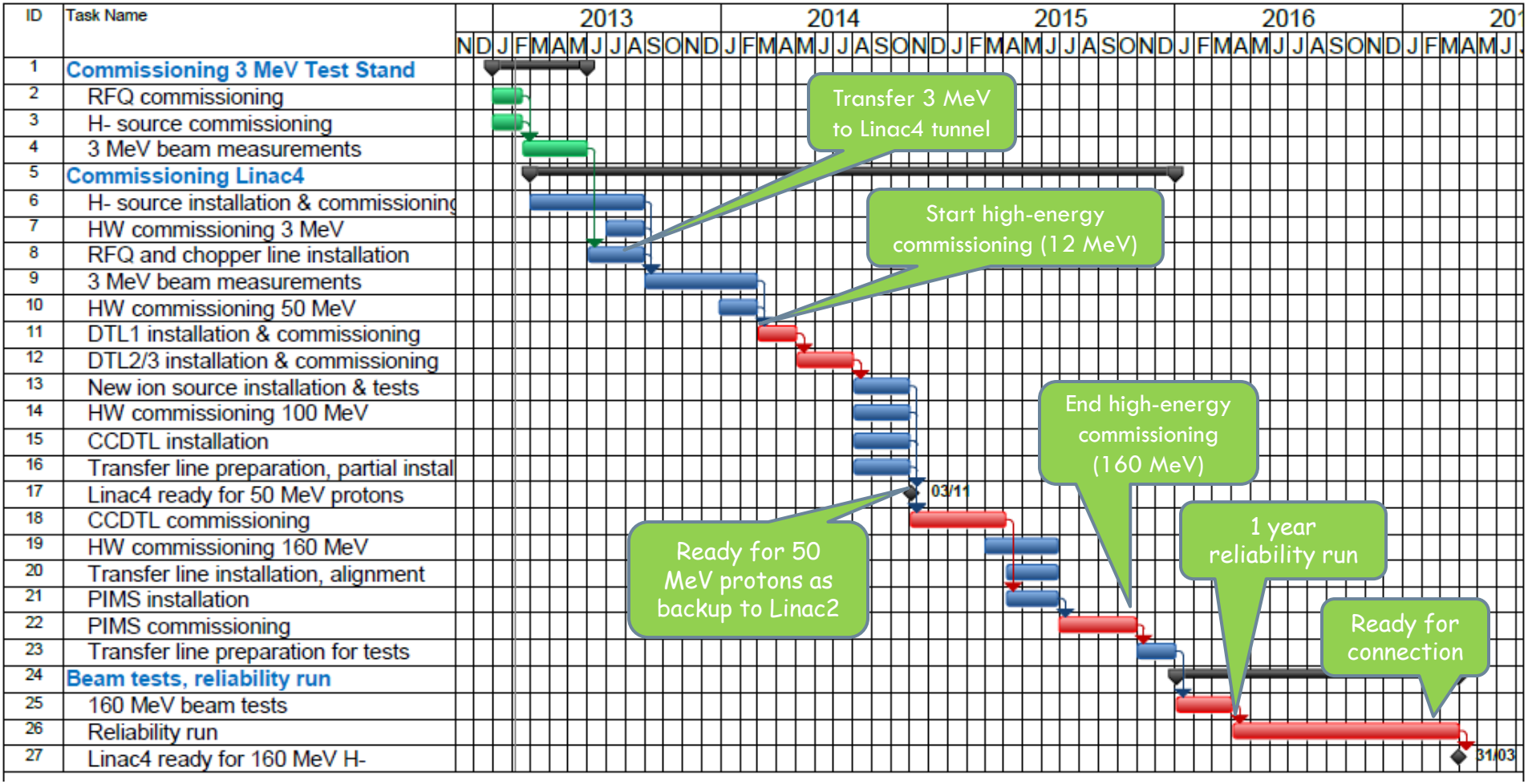


Saturation at 14 MCHF/year of project expenditures (CET) mainly due to limitations in available manpower: 2013 should be the last saturated year!

the project is well advanced by now and we are getting out of saturation → we can seriously plan for the future and engage for a connection date.

Linac4 – New Masterplan

2013/16 Masterplan, adapted to limited availability of resources during Long Shutdown 1 (2013/14)



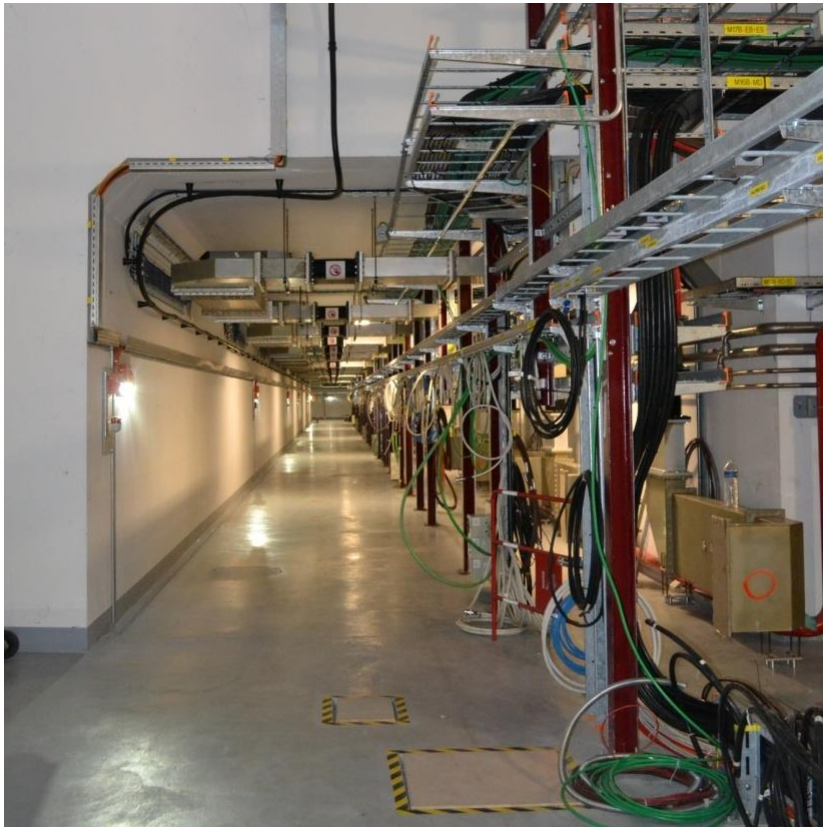
Options for connection to the PS Booster:

a) Long Shutdown 2 (2018?) or b) intermediate length shut-down after end 2016

Progress with Infrastructure

Impressive amount of work in 2011/12

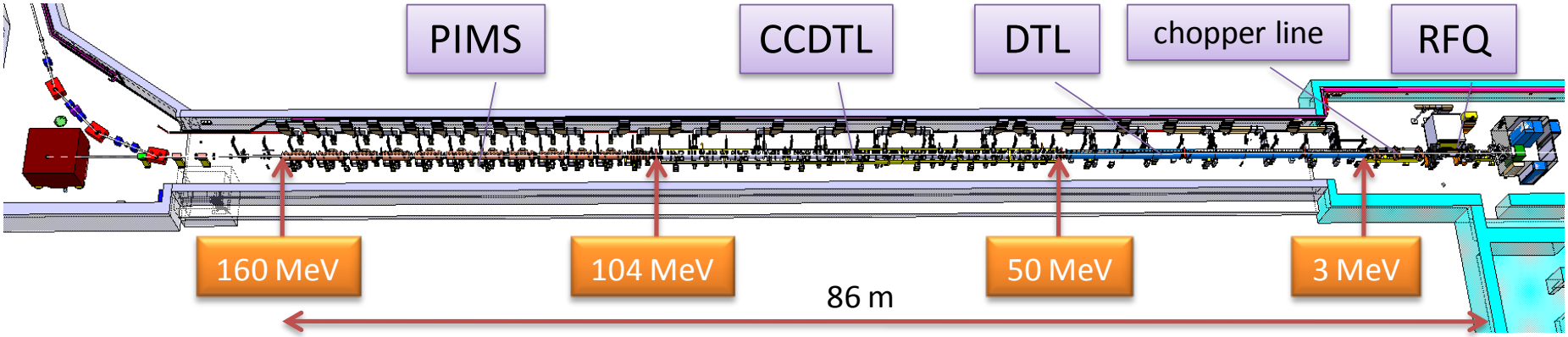
- Electrical distribution and CV infrastructure completed
- Cabling completed: all cables ready to be connected
- Waveguides and circulators installed
- Installation of klystrons progressing (50% achieved)
- Installation of modulators starting soon



Reminder - Linac4 layout

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

	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



The ion source saga

- 2005: decision to copy the DESY RF volume source (reliable, no Caesium)
- 2009: DESY-type source completed, equipped with CERN power supplies and RF generator.
- May 2010: tests show that it can not operate at 45 kV nominal voltage because of excessive electron current coextracted with the H- that destroyed the electron dump.
- End 2010: launched crash programme to build an improved source of CERN design operating in volume mode but upgradable to surface (Cs-based) production.
- December 2012: new source ready, but the plasma generator could not produce a useful H- beam.
- February 2013: installed DESY plasma generator on CERN extraction: 17 mA of H- obtained, with an emittance of 0.55 π mm mrad (twice nominal). Started RFQ and chopper line commissioning.
- Next steps: installation of a new version of the source in Linac4, for 3 MeV commissioning there from 09/13.
- The Cs version of the source, to be installed in August 2014 will be very similar to the SNS source and should be capable of producting higher H- currents (>40 mA ?).

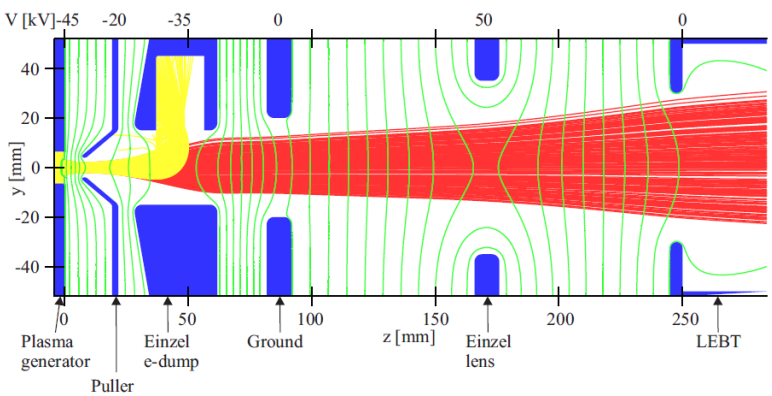
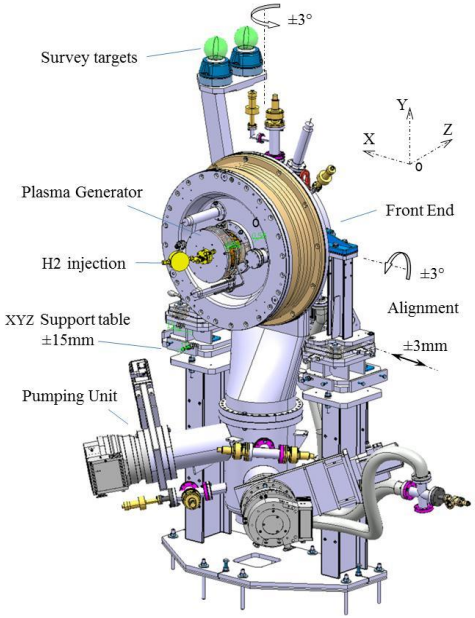
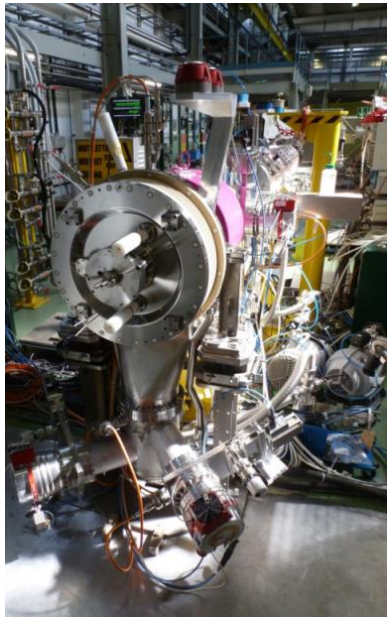


FIGURE 1. Simulation of the extraction system of the Linac4 ion source. The electron beam in yellow (light grey) is deviated and dumped in the magnetized Einzel lens. The H^- beam in red (dark grey) is focused by two Einzel lenses and transported to the entry of the LEBT.





Conclusions on the ion source

1. It looks like contamination (with low work-function metals: Cs, K, Na, Li,…) is essential for H- production.
2. It seems unlikely that we will reach the nominal 80 mA (*) with this type of source; the options are:

   a) reduce the requirements: 40 mA out of source are sufficient for all present beams + twice present LHC intensity in 40 turns/ring (160 μs). If and when ISOLDE wants more, should be possible either to increase the number of PSB turns (600 μs linac pulses are now possible instead of nominal 400 μs) or to reduce the chopping factor from the present very conservative 35%.

   b) build a magnetron-type source, in principle capable of higher currents, at an additional cost of 900 kCHF (only initial studies and general design included in Linac4 project)
3. Development work on the ion source will have to continue in parallel with Linac4 commissioning: present 3 MeV Test Stand will be used for source tests.
4. So far, stability and reliability of the source are excellent: the design is solid.

(*) : Nominal Linac4 currents are
80 mA out of source
67 mA out of RFQ
43 mA after chopping
40 mA to PSB

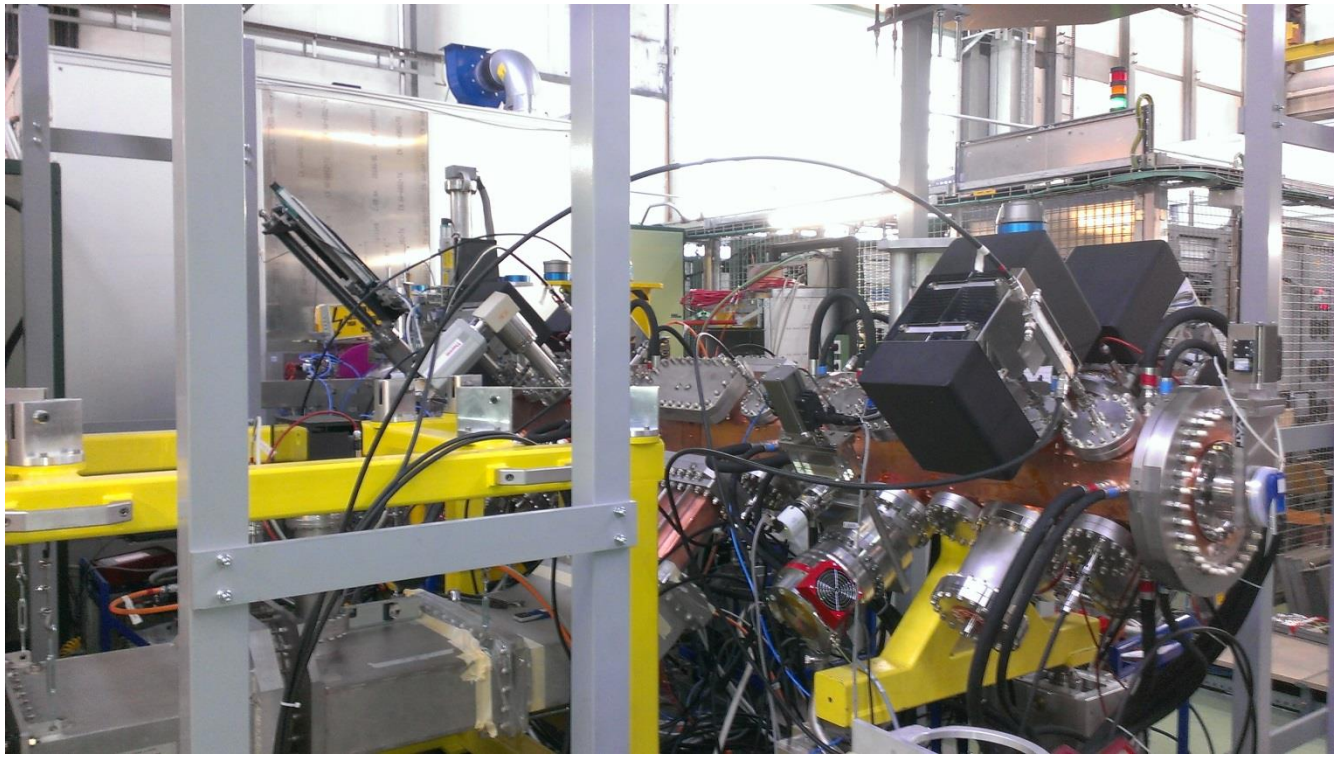
The RFQ is alive and well !

Original schedule: end of construction September 2009.

Actual completion: September 2012 (delays in machining, brazing problems, etc.).

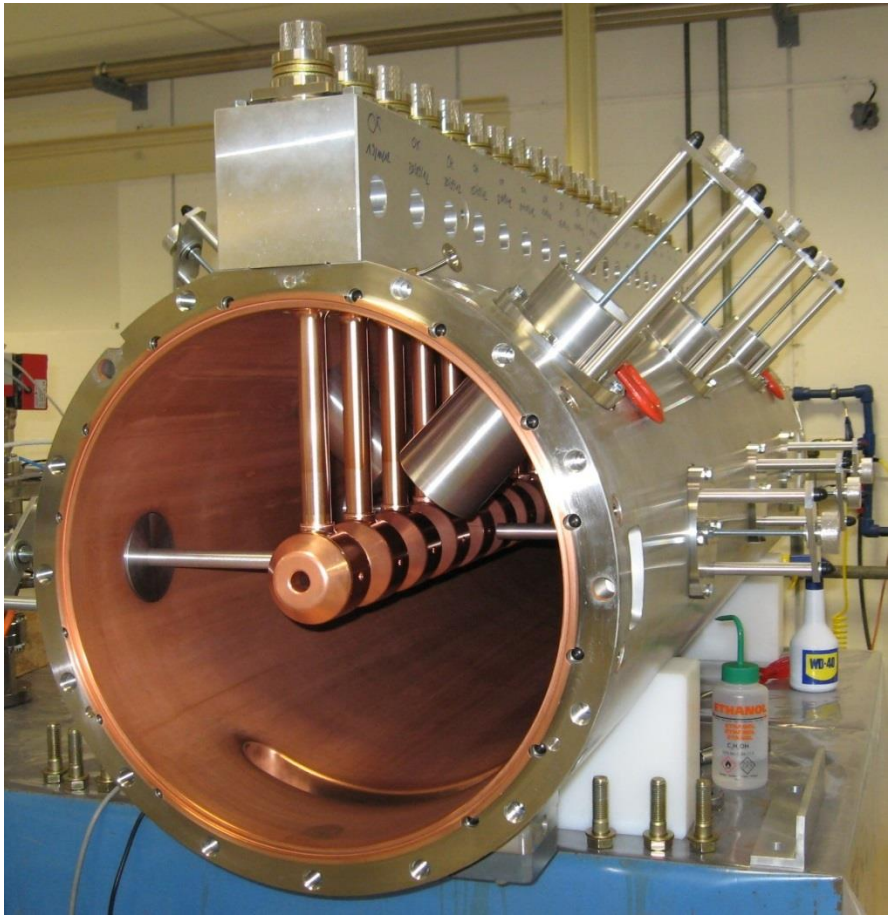
Commissioning with beam started on 13.3.2013 (and completed on 28.3!).

Late, but commissioned before the 2 RFQs (IPHI and TRASCO) started well before us and whose construction experience was used for the design of our RFQ.

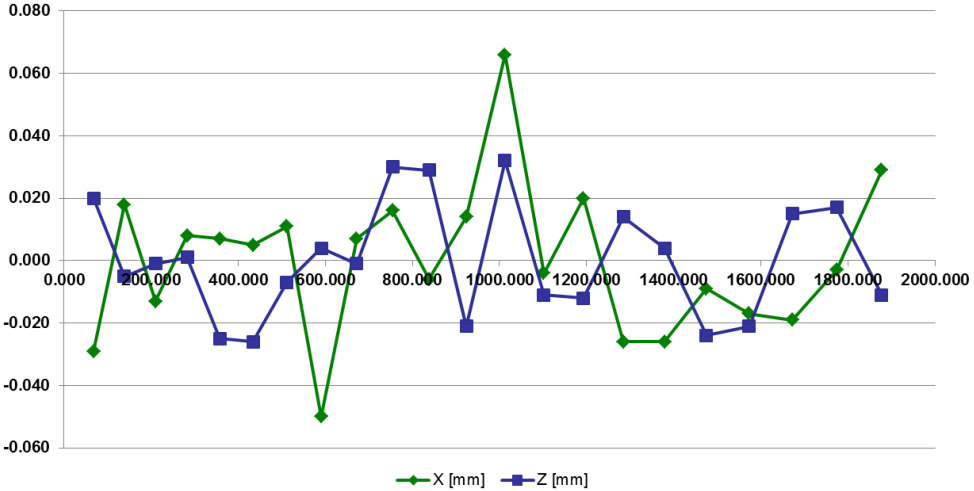


The RFQ not only focuses and accelerates the beam as required, but so far it does it in a stable, reliable and reproducible way!

DTL assembly



- 1st segment of Tank 1 (out of 2) assembled with girder and drift tubes.
- DT alignment tested, vacuum tested, RF tested.



Next steps:

- T3S1 delivered, at copper plating
- T1S2 & T3S3 delivered, under repair at CERN, will then go to copper plating.
- Delivery of all other segments by June 2013.
- Drift tubes of T1 and T3S1 completed. Rest to be completed by June 2013.
- Assembly, tuning and power test of complete T1 in 2013

Information from S. Ramberger

CCDTL assembly

A team from BINP/Novosibirsk is working at SM18 for the assembly and tuning of the 7 CCDTL modules:

- module 2,3,4,5 assembled, leak tight
- module 3 assembled with intertank elements, currently being conditioned.
- module 2 conditioned to nominal peak power (but not yet nominal pulse length) end of 2012.

- A new type of vacuum joints has been successfully tested in March!

- delivery of module 1,6,7 in May
- assembly of module 1,6,7 in June 2013
- high-power conditioning of all modules finished before the end of 2013
- installation of first modules in the Linac4 tunnel before summer 2013

Information from F. Gerigk

PIMS construction

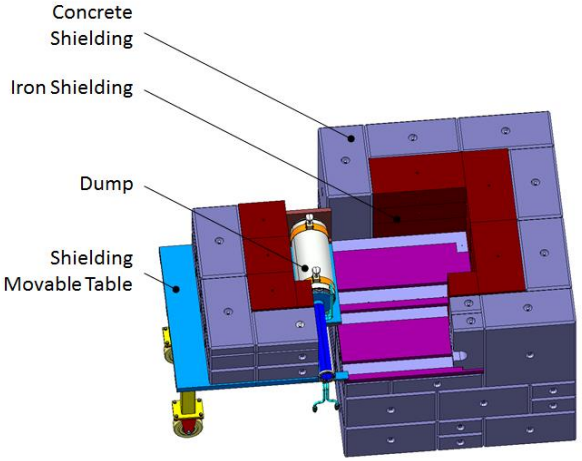
Information from R. Wegner

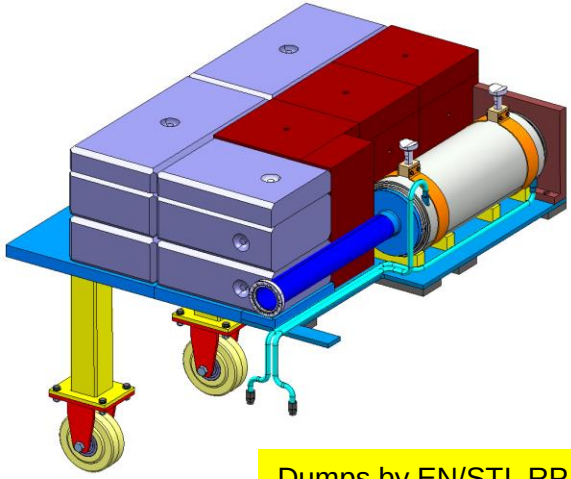
Module 1 built at CERN (hot prototype, promoted module 1 after testing)

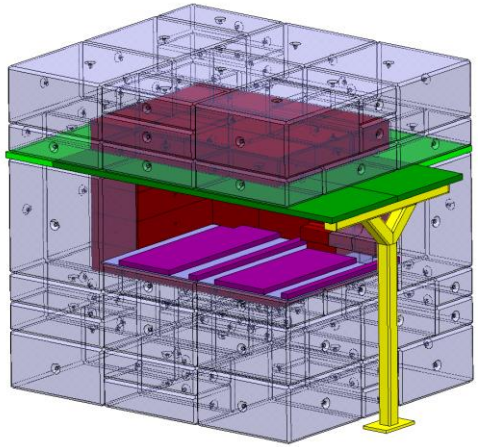
Remaining 11 modules + debuncher to be built at NCBJ (Poland).

- After 2 years of transfer of technology and machining procedures, the tight specifications are nearly reached for most parts
- Qualification could be given for all rough machining steps and green light was given to complete the first 2 cavities
- A 2-cell short module was analysed at CERN (dimensions and surface quality, assembling, low power RF tests) with good results
- Remaining concerns on nose cone surface quality and stresses introduced by milling => high power test of first cavity needed.
- Production status: all 96 discs rough machined, 8 finished; 60 out of 84 rings rough machined, 1 ring finished
- New milling machine purchased by NCBJ to speed production, to become operational in summer 2013; new staff hired for a 2nd shift.
- first complete cavity foreseen in June 2013 (port welds done by FZ Juelich, brazing of waveguide ring).
- 3 cavities expected at CERN in 2013, 4th completed before end 2013
- remaining 8 cavities and auxiliary parts to be delivered to CERN before October 2014 (assembly and EB welding to be done at CERN afterwards).

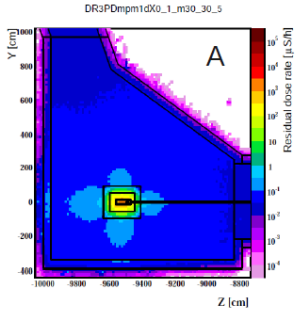
Dump design and integration



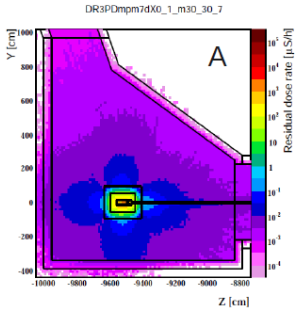




1 day cooling time



1 week cooling time

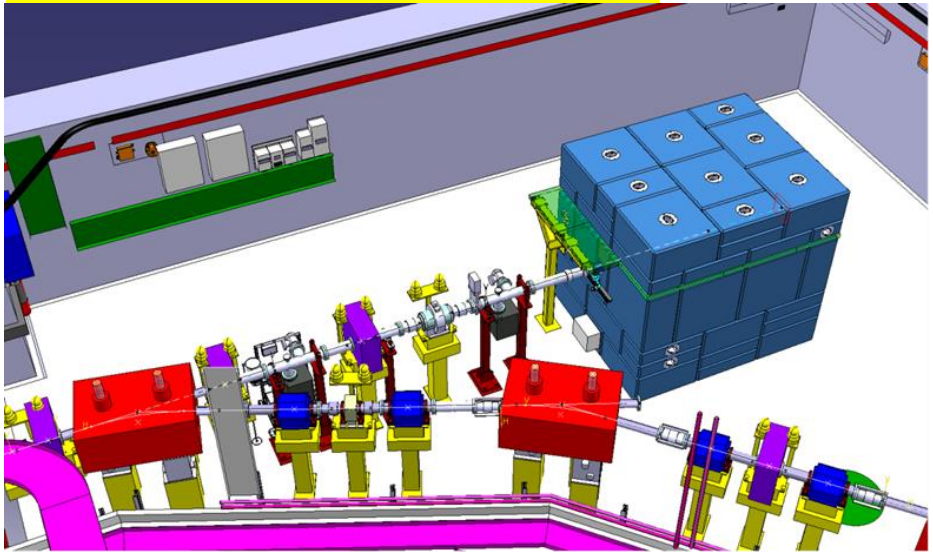


Dump core: graphite
Shield: steel+borated concrete

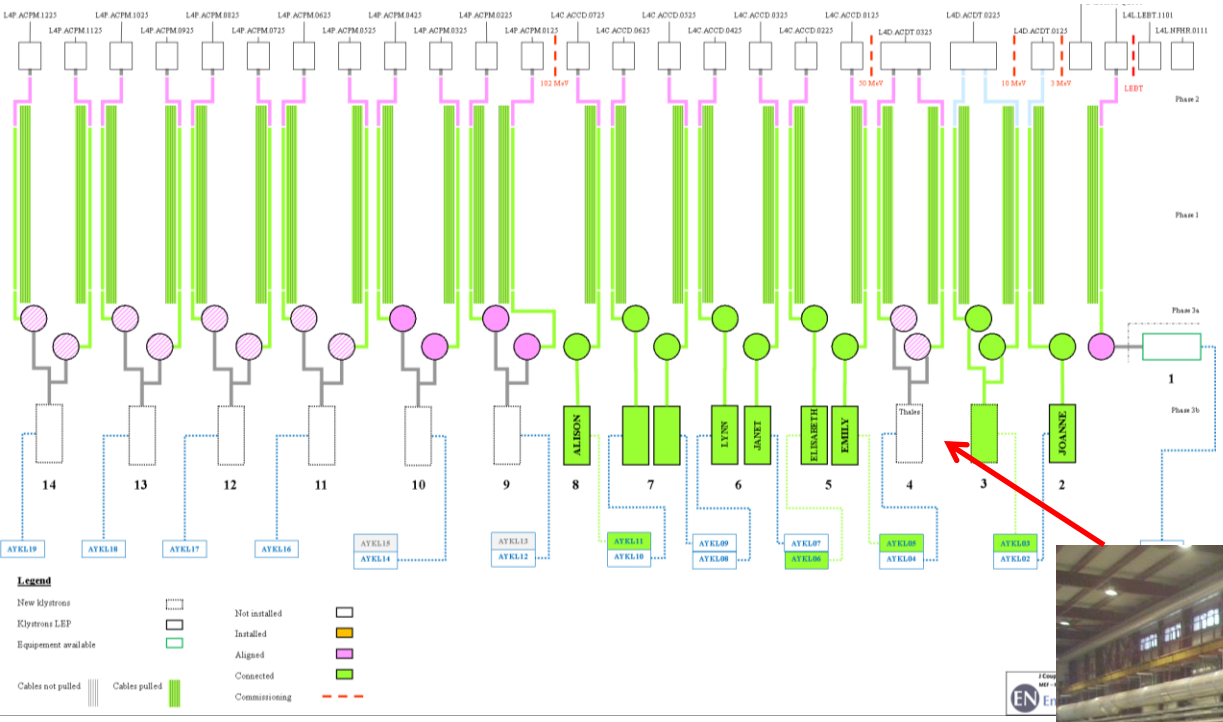
Dose rate <1μSV/h (contact, 1 day cooling time)

Fully dismountable for repair / decommissioning

Dumps by EN/STI, RP calculations by DGS/RP (C. Maglioni – J. Blaha)



Progress in RF system installation



The new Thales 2.8 MW pulsed klystron

10/17 klystrons installed (8 LEP, 2 new)

LINAC4 Modulators

Operation on CERN teststand

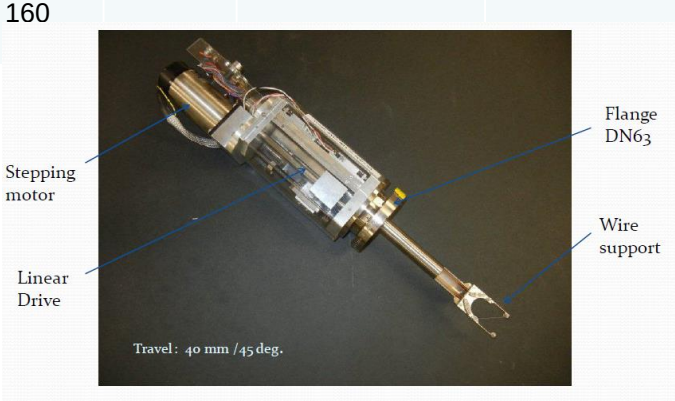
- HV reception tests ongoing
- First unit to be installed May 2013

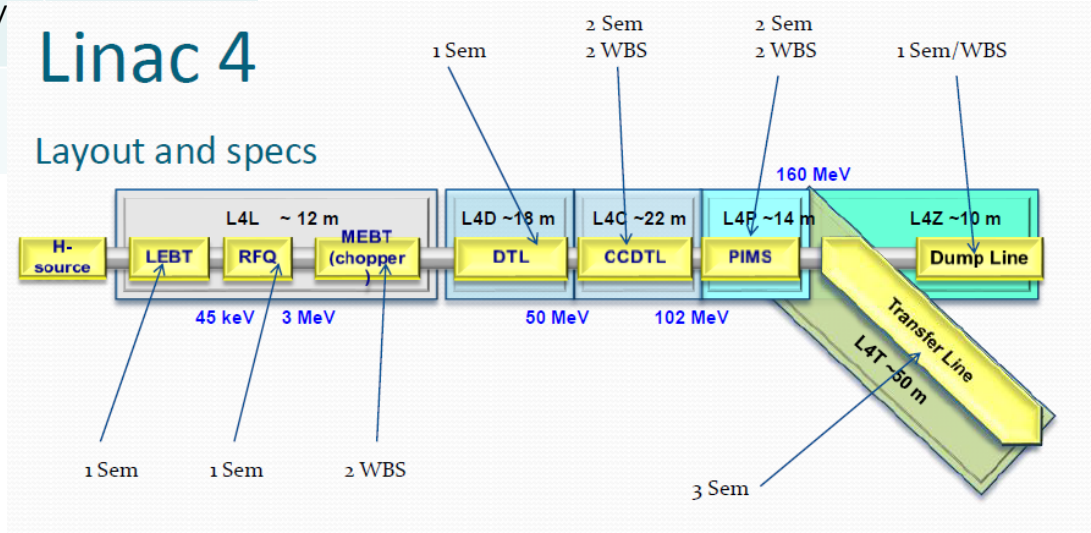
Slides provided by D. Nisbet

Beam instrumentation

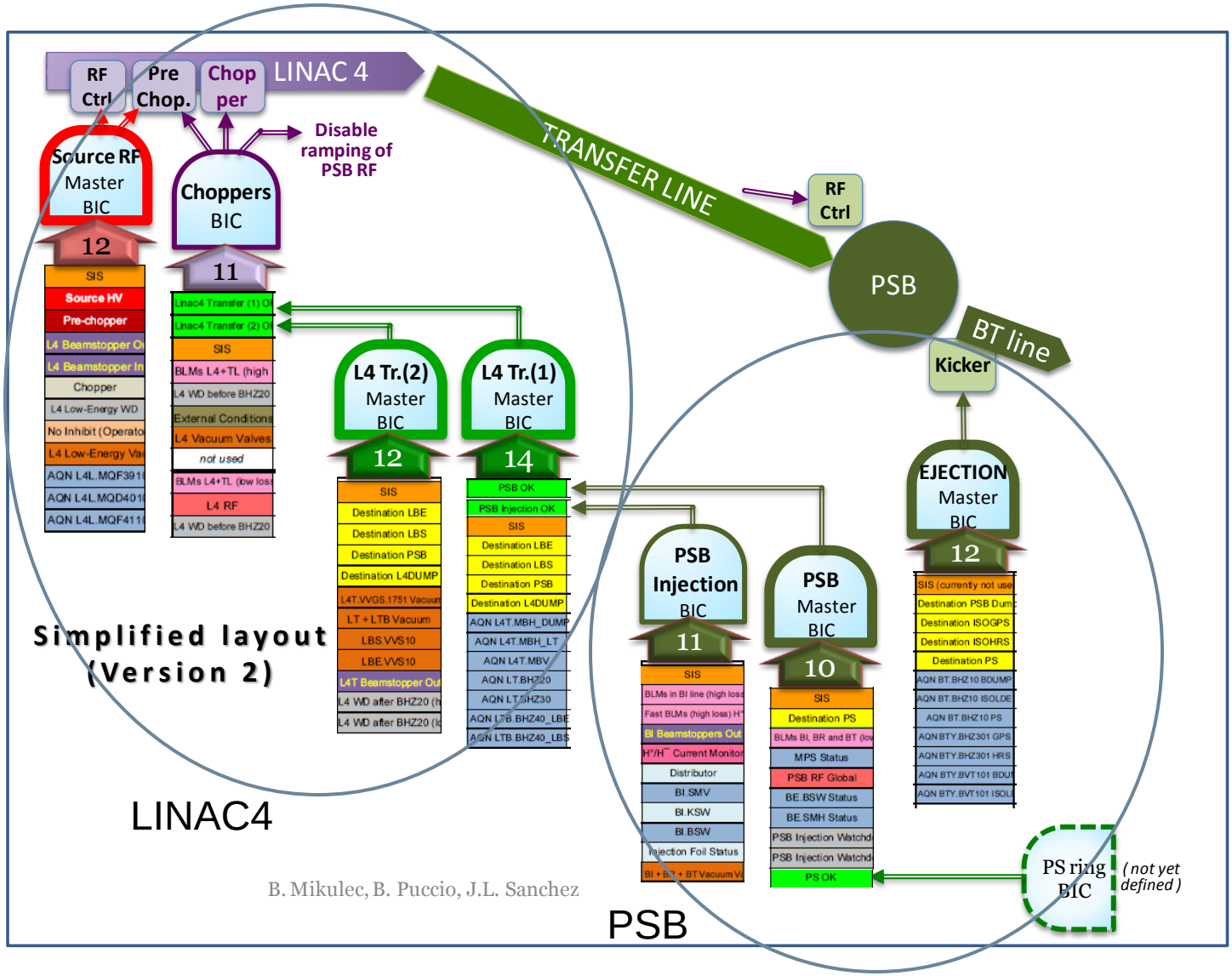
Instrument	number	location	energy	details
Faraday Cup	2	LEBT	45 KeV	only scope
Emittance meter	1 1/2	LEBT, MEBT	45 KeV 3 MeV – 12 MeV	
BPMs	31	MEBT - Booster	3 MeV – 160 MeV L2-Booster transfer	Pos, intensity Phase
SEMGrids	18	LEBT – Booster	45 KeV – 160 MeV	
Transformers	16	LEBT - Booster	45 KeV – 160 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
- progressive commissioning of equipment going on at the test stand.





Beam Interlock System



B. Mikulec, B. Puccio, J.L. Sanchez

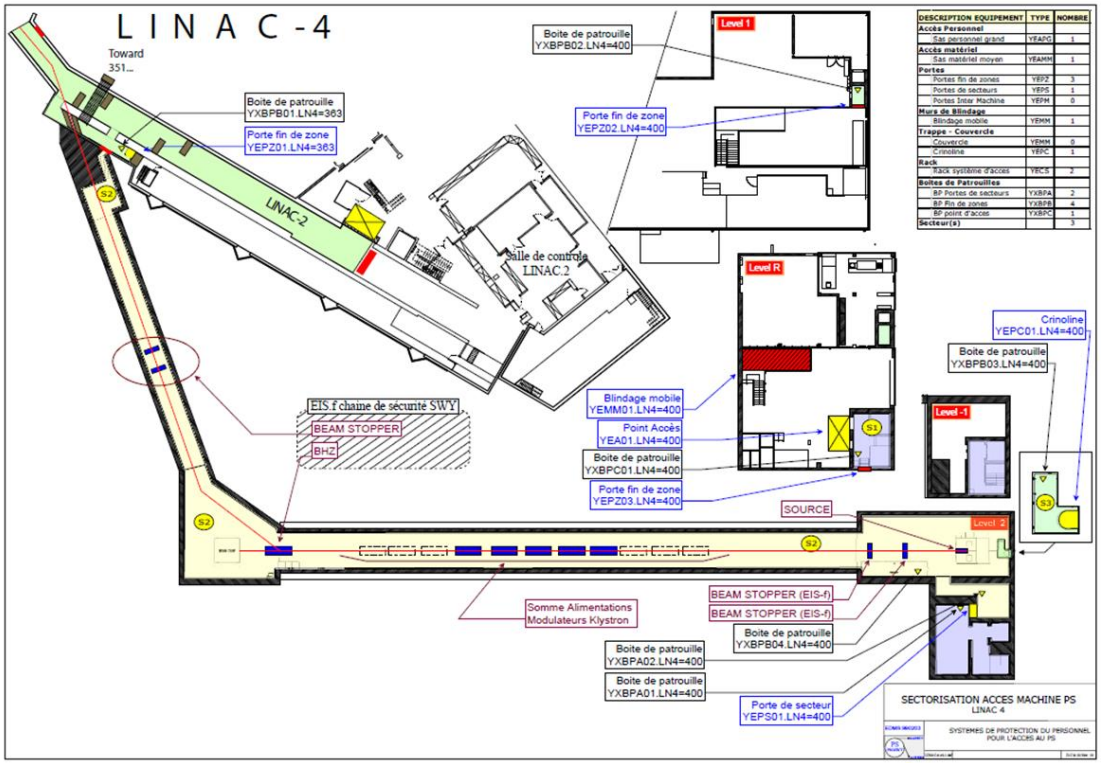
A low-energy beam (160 MeV) presents some dangers, because an accidental beam loss in a critical position can make a hole in the vacuum chamber

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

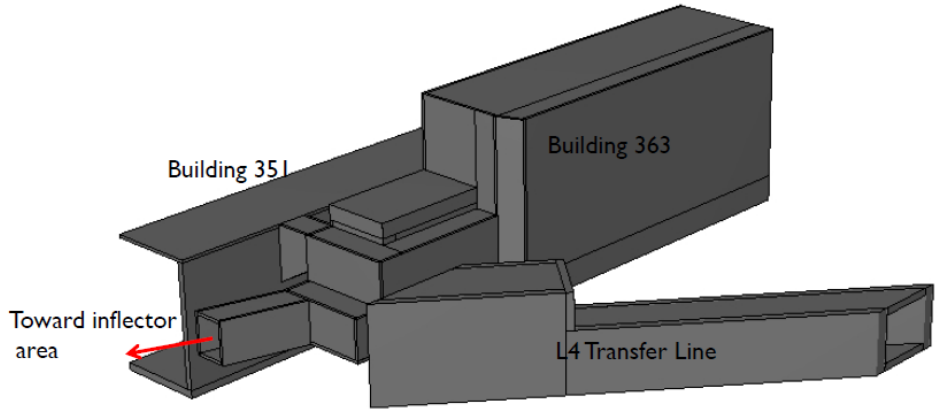
Work in progress

Precise definition of the modifications to the Linac2 area and lines at the moment of the connection to PSB:

- Layout of racks and cablings for B.363 (L2 equipment hall)
- Precise definition of additional shielding in the Linac2 area
- Precise new layout of measurement lines LBE, LBS (inflector zone, before PSB wall) and way to access them for installation (PS or PSB?).



Interface Linac4 – Linac2

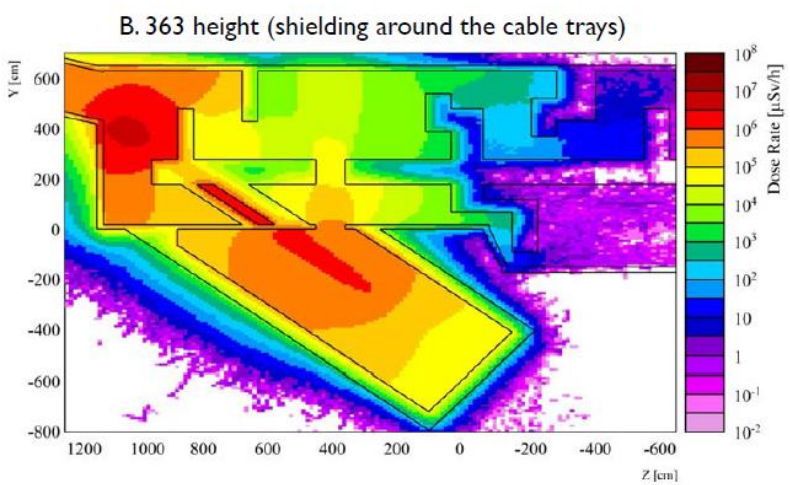


Complex building geometry (entered in FLUKA)
Calculations done with the 1 W/m criterion (very conservative for PSB operation)

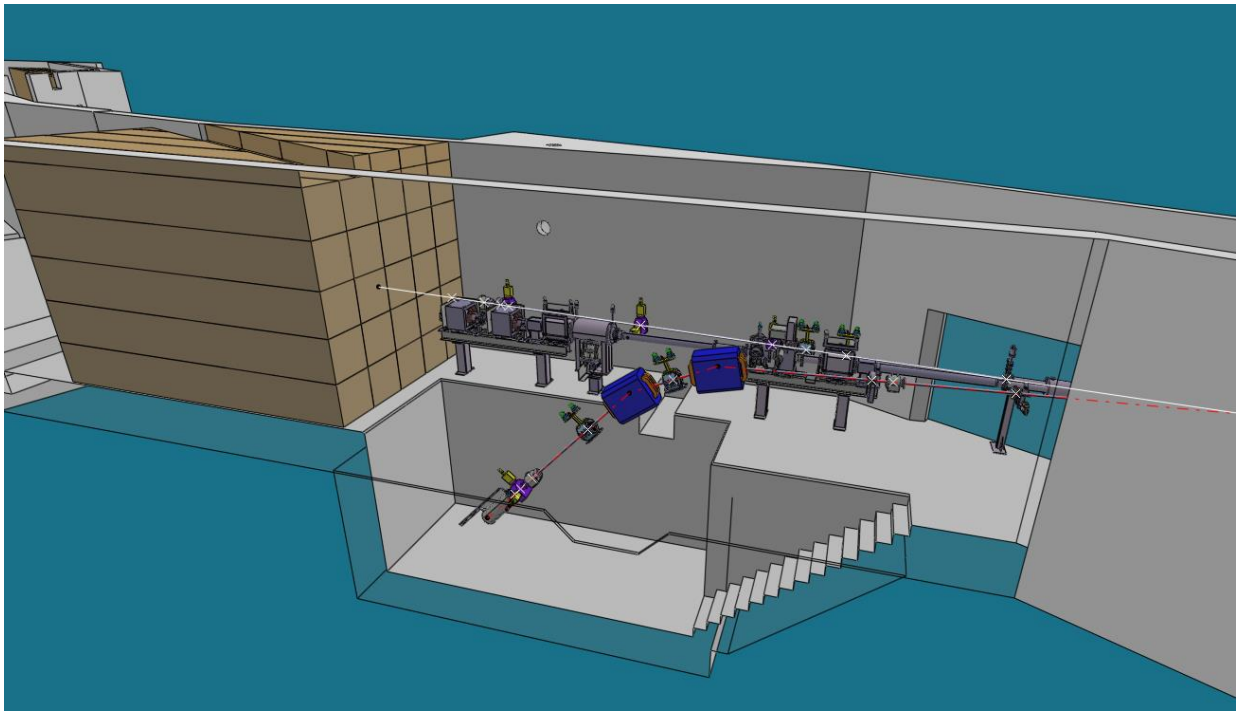
Shielding criterion 2.5 μSv/h (non-permanent work place)

Radiation dose from distributed loss + loss in bendings → ok in Linac2 buildings, apart from 2m directly in front of existing cable tray → reduction of cable tray size and specific shielding

Distributed Loss + Loss in Bend (12 + 5 W)



Upgrade of measurement lines



Upgrade of the beam measurement lines at the entrance of PS Booster:

- Upgrade for 160 MeV energy (new magnetic elements and new measurement technique);
- Introduction of appropriate beam dumps to be used during measurements

IN CONCLUSION:

Many thanks to all those who have actively contributed to the impressive achievements of these last months!

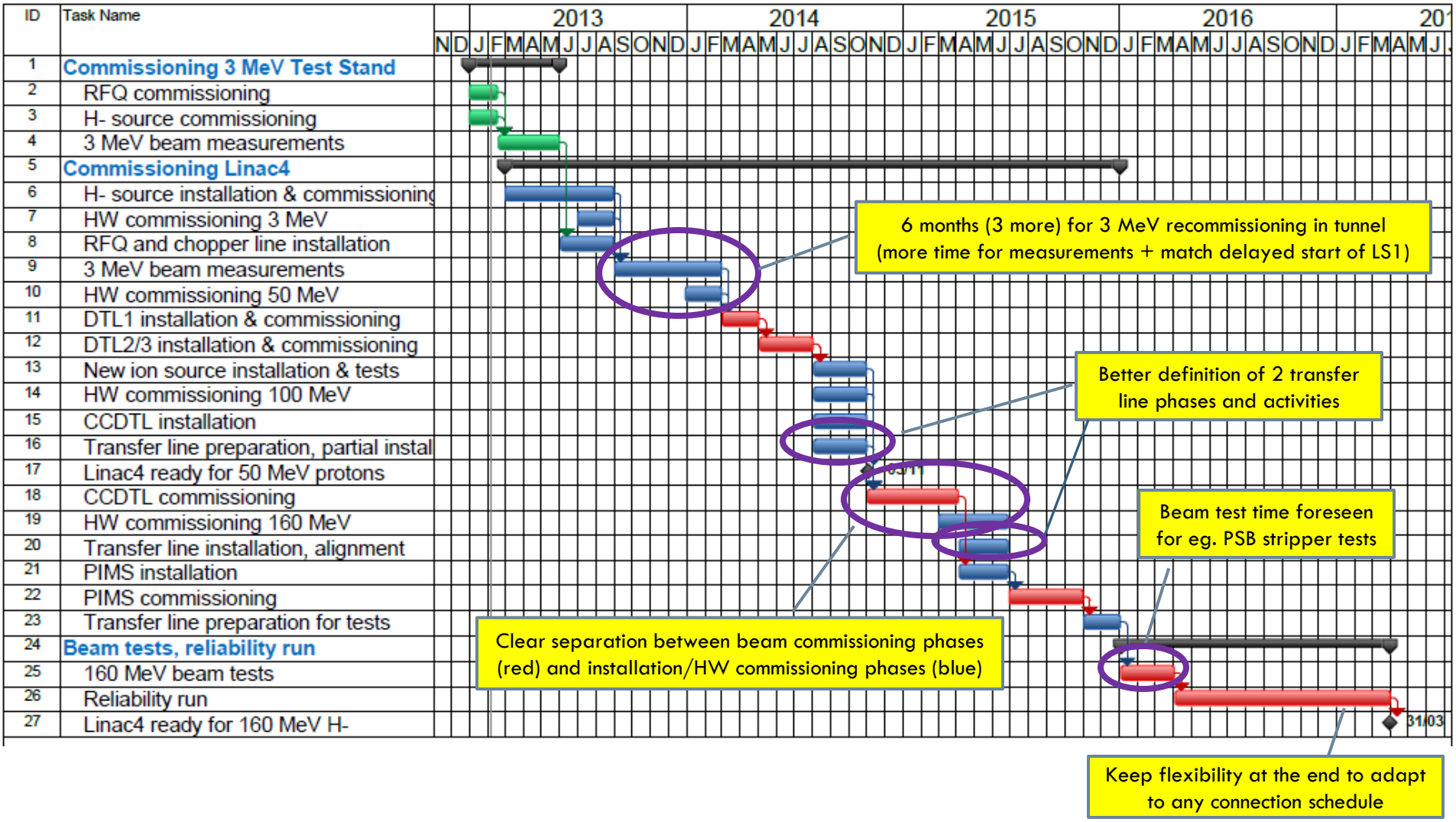
In particular:

- The teams in charge of the building: infrastructure, cabling and supervision.
- The ion source team
- The different RF teams (6 sections out of 8!)
- The survey
- The vacuum team
- The engineering support
- The beam instrumentation team
- The beam optics and beam commissioning team

Spare slides

Masterplan – What is new

New with respect to the Masterplan of June 2012, adapted to LS1



The Linac4 Safety File(s)

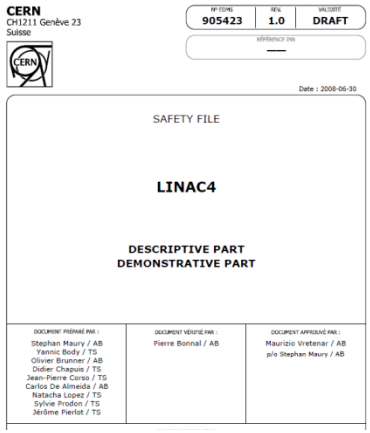
the project phases

2004 — 2008 — 2014/2016 — 2046?

STUDY → PROJECT EXECUTION → OPERATION → DISMANTLING

UPGRADE ?

Linac4 Safety File (EDMS 905423)
June 2008, 91 pages
All safety aspects of project, more emphases on civil engineering and machine equipment


CERN
CH1211 Genève 23
Suisse

N° EDMS	REV.	VALIDITÉ
905423	1.0	DRAFT

Date : 2008-06-30

SAFETY FILE

LINAC4

DESCRIPTIVE PART
DEMONSTRATIVE PART

DOCUMENT PRÉPARÉ PAR :	DOCUMENT VÉRIFIÉ PAR :	DOCUMENT APPROUVÉ PAR :
Stephan Maury / AB Yannic Body / TS Olivier Brunner / AB Didier Chapuis / TS Jean-Pierre Corso / TS Carlos De Almeida / AB Natacha Lopez / TS Sylvie Prodon / TS Jérôme Pierlot / TS	Pierre Bonnal / AB	Maurizio Vretenar / AB p/o Stephan Maury / AB

Approval for tendering of building and execution phase

New Linac4 Safety Folder
In preparation by Anne Funken
All safety aspects of project, more emphasis on operation. Update of existing Safety File, document following recent CERN safety documentation standard
(EDMS1177755, 15.6.2012).

Approval for operation above 3 MeV energy (2014)

Linac4 Decommissioning Report
In preparation (deadline end 2012)
Calculation of activation at end of life
Estimate of material quantities for disposal
Estimate of the costs (for financial reports)

Requirements for Linac4 current

MAIN LINAC4 USERS	PSB out (ppp)	PSB in (ppp)	Linac4 current in 400μs (mA)	Linac4 current in 160μs (mA)	Linac4 current in 80μs (mA)
LHC present	0.7×10^{13}	0.9×10^{13}	(3.6)	9	**18**
ISOLDE present	3.5×10^{13}	4.5×10^{13}	**18**	-	-
LHC final	1.4×10^{13}	1.8×10^{13}	(7.2)	**18**	**36**
ISOLDE final	7.0×10^{13}	9.0×10^{13}	**36**	-	-
		with 20% margin for beam loss		40 turns / PSB ring	20 turns / PSB ring

1. *Linac4 design 400 μs pulse and 40 mA current correspond to 10^{14} ppp (twice present ISOLDE with some additional margin).*
2. *After connection of Linac4 to the PSB, Linac4+PSB is required to provide the present nominal beams. It is expected to reach the goal for LHC 1-2 years after connection; there are no clear commitments to ISOLDE.*
3. *In order to gain some more margin, the maximum Linac4 pulse has been recently extended to 600 μs.*

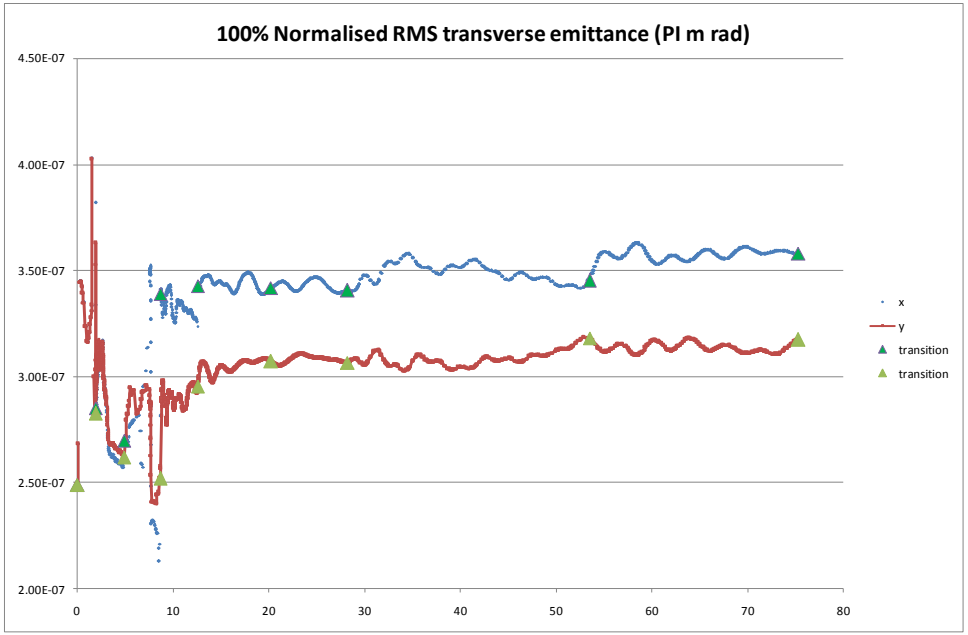
- With linac current **20 mA** → present beams in PSB + full intensity LHC beam with 40 turns injection.
- With linac current **40 mA** → maximum ISOLDE beam + full intensity LHC beam with 20 turns injection.

Requirements for Linac4 emittance

- Design transverse emittance from ion source 0.25 π mm mrad (rms)

- Design transverse emittance at PSB input 0.4 π mm mrad (rms)

We risk to need compromising between current and emittance…



Maximum acceptances (no errors, zero current)

RFQ : 0.55 π mm mrad
Chopper : 0.4 π mm mrad
DTL : 0.8 π mm mrad
(comparable for other accelerating structures, larger for the transfer line)
The PSB can accept a somehow larger emittance