

# Linac4 Topics

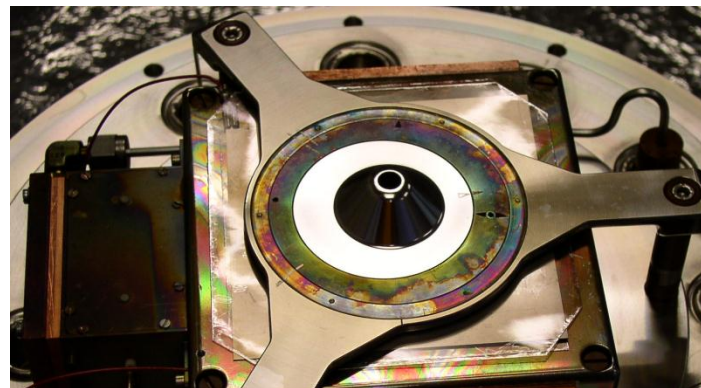
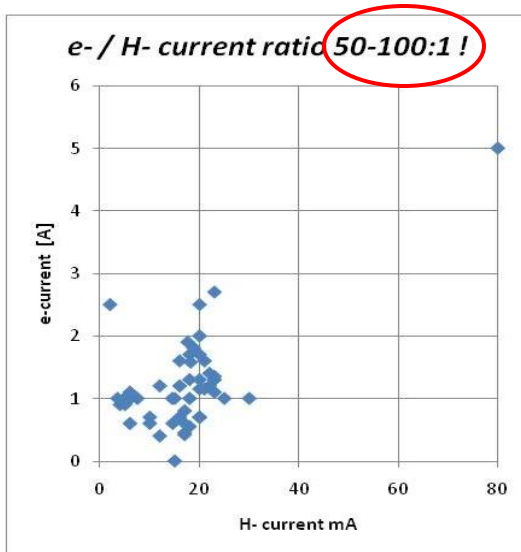
M. Vretenar for the CERN MAC 22.08.2011

- 1. Summary of H- source review**
- 2. Options for connection to the PS Booster**

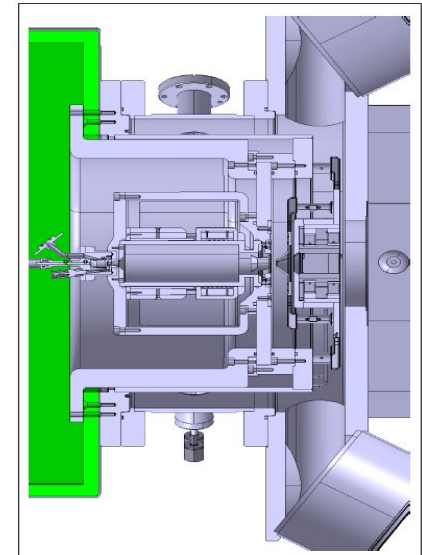
- 2005: decision to build an RF Volume source based on the DESY design:
  - no resources for an internal development;
  - DESY source had high reliability (external antenna, Cesium-free);
  - higher extraction voltage + improvements to RF generator and matching to achieve higher current: 45 kV, 100 kW 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<sup>-</sup> dump (up to >200 kW instantaneous power in e<sup>-</sup> beam!). Vaporization (and destruction) of the dump induces sparking.

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

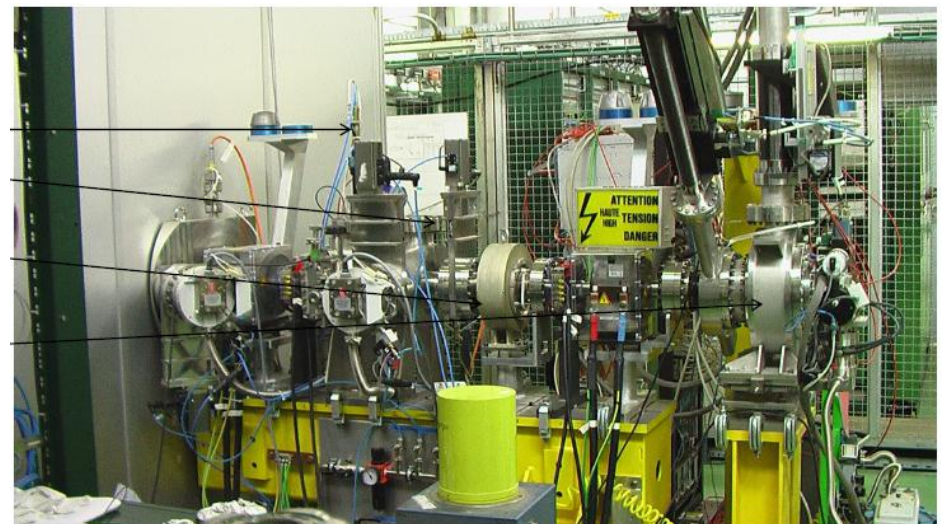


extraction electrode





- From July 2010 it was clear that there was **no hope** to get the Linac4 beam from the original H- source.
- Decision: convert the present source to **protons** and use it to commission diagnostics and LEBT (in 2011), then RFQ and chopper (in 2012). In parallel, start the **construction of a new H- source**.
- **Strengthen the source team** (J. Lettry, E. Mahner) and find additional funds.
- Select an appropriate **source type** and define a construction **roadmap** compatible with Linac4 schedule.
- Confront the choice and the roadmap with the community → organize an **ion source review** with external experts.



Present measurement set-up after ion source and LEBT (protons)



## Linac4 Ion Source Review

from Tuesday 07 June 2011 at 09:00 to Wednesday 08 June 2011 at 14:00 (Europe/Zurich)  
at CERN ( 6-R-012 )

**Description** The Ion Source Review will present to a committee of external reviewers and to the CERN experts, an overview of the recently revised and strengthened H- source programme for Linac4. On the second day, the reviewers will present their comments and recommendations to the CERN Management.

Members of the review committee: M.P. Stockly (SNS, chair) D. Faircloth (RAL) O. Tarvainen (Jyvaskyla) J. Alessi (BNL)

[Go to day](#)

**June 7 – 8, 2011**

Review Committee: M. Stockly (SNS,chair)  
D. Faircloth (RAL)  
J. Alessi (BNL)  
O. Tarvainen (Jyvaskyla Univ.)

Representing the laboratories with more experience in building and operating H- sources.

- 14 presentations covering all aspects of Linac4 source programme
- 6 hours for committee discussions
- 30' presentation and discussion from the reviewers
- Report (still to be delivered...)

<https://indico.cern.ch/conferenceDisplay.py?confId=129870>



# The program to be reviewed



5

WPIS H<sup>-</sup> Ion source: staged approach, 2 units each + spare

	#1 Volume source	#2 Surface source	#3 Magnetron
Operational experience	DESY	SNS	BNL
H <sup>-</sup> current	30 mA	50 mA	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 <sup>-</sup> 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

(slide from J. Lettry presentation)

2 test stands,

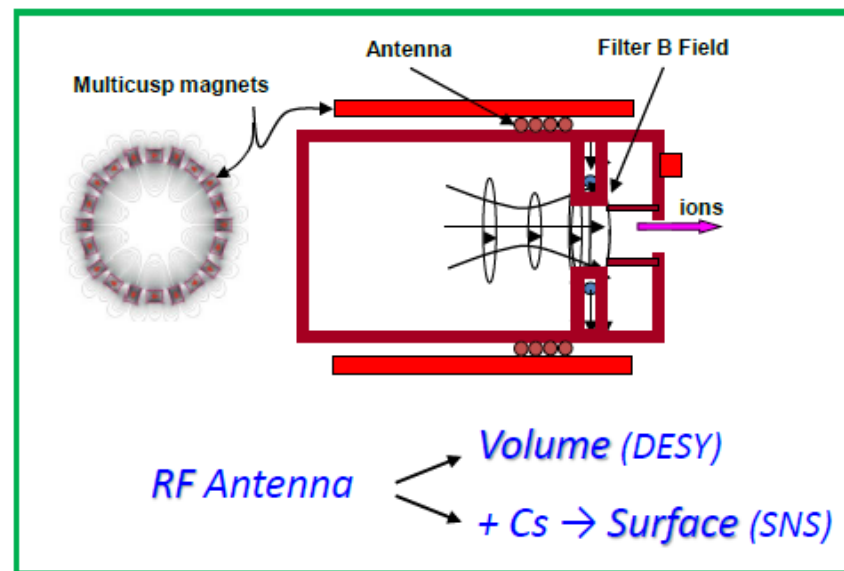
B.357: ion source (+LEBT, diagnostics)

B.152: RFQ and chopper testing

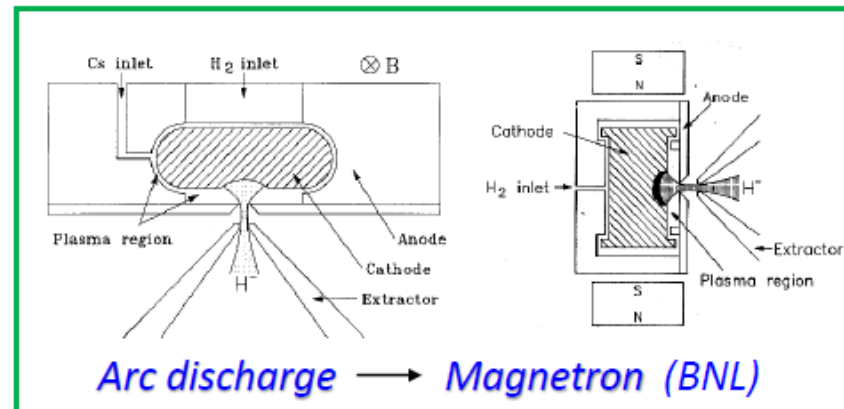
1. Extend and improve the source test stand in Bld. 352 (ex-SPL source test stand).
2. Build quickly an improved version of the DESY RF source for L4 commissioning.
3. Build and optimize a Cesiated RF source for L4 2<sup>nd</sup> part of commissioning and operation.
4. Study (and build) a magnetron-type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

- Builds on the SLHC-PP EU program (2 years of work on plasma generator at 50 Hz, plasma test stand).
- Old SPL test stand transformed in a full source test stand (with HV extraction, LEBT, diagnostics, Cs lab).
- Choice of RF surface source builds on existing work and investment on RF volume source and profits of the SNS experience.
- New sources are of modular design, 2 units/source, with new and improved power supplies.
- Redesign Faraday cage for pulsed power supplies and easier access for maintenance.
- Magnetron source as high-current backup (BNL, simple and reliable, but large emittance).

*Linac4 baseline:*



*Linac4 high current option:*





## General comments

We agree with the basic technical choices.

Highest short-term risk: not achieving operational 45 kV extraction and dealing with co-extracted electrons.

The proposed schedule is ambitious but possible

Very important: agreement on the technical choices!

i.e. to have again the problem that we had with the DESY source. Extensive 3D simulations give us enough confidence.

Important statement !

Resources are adequate but additional effort directly in H- production is highly desirable.

~ 99.5 % ion source availability is likely. However, lower availability must be expected for the first few years.

i.e. try to get as quickly as possible the H- on the test stand

High source availability is possible – but not the first years...

All the aspects required for the ion source development are adequately covered.



## Recommendations

- Focus on 40 mA, which likely can be reached for LINAC commissioning by 2013
- Expedite the build up of test stands to extend testing time and development of the sources.
- As soon as possible install a simple extraction system and FC on the plasma test stand to correlate plasma studies with H- production and extraction.
- To mitigate risk consider investing less time with proton tests and more with H- on the 3 MeV test stand at 45 kV.

Note that Linac4 design current of 40 mA needs 80 mA from ion source (40% chopped, 10% loss).

But all present operational beams + some improved LHC beam can be provided with half the current: 20 mA for the linac and 40 mA for the source.





- an H- source can be **reliable** (goal of 99.5% availability) and maintenance can be organized within the standard CERN schedule (short technical stops and longer yearly shut-downs).
- using **Cesium** presents some safety concerns, but is feasible and done routinely in all other laboratories.

# Options for the connection between Linac4 and PS Booster



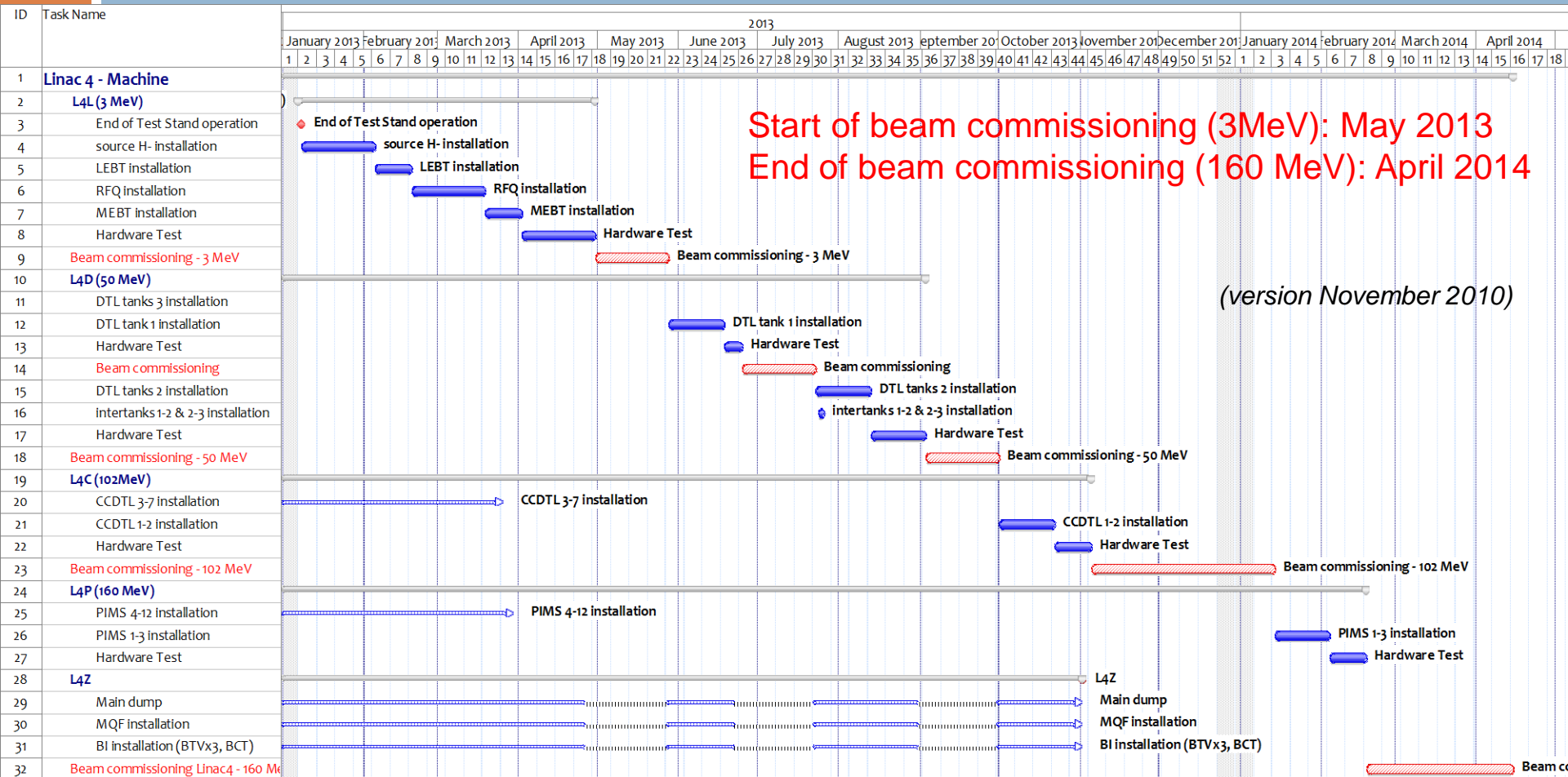
1. Linac4 Commissioning Schedule
2. Timeline for connection to PSB
3. Conclusions and options



# Linac4 commissioning schedule



11



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

*(version November 2010)*

**5 commissioning stages:**  
(on intermediate dumps)



**Linac4 ready : April 2014**





# Comparison with SNS and JPARC



12

Question: is the Linac4 commissioning schedule realistic ?

Compare with SNS and JPARC

	SNS (2003/04)	JPARC (2006/07)	LINAC4
Front-end run	2.5 months	?	1 month
DTL1 run	2.5 months	? (done at KEK)	1 month
DTL 50 MeV run	3 months	?	1 month
50-160 MeV run	3 months	2 months	4.5 months
From DTL1 start to end of commissioning to ~160MeV	<b>14 months</b>	<b>10 months</b>	<b>10 months</b>
Comments	Mixed installation and commissioning	Installation followed by commissioning	Most of installation done before commissioning

- Linac4 schedule in line with JPARC and 30% shorter than SNS.
- JPARC has done more installation before (shorter commissioning).
- SNS commissioned at 5 Hz (then 60 Hz), JPARC at 25 Hz → more time than for 1 Hz.

**(my) conclusion:**

The Linac4 schedule looks realistic, but there is no margin for compression.



COMPOSITION LINAC4 SHUT-DOWN	1	2	3	4	5	6	7	8	month
Cool-down radiation in PSB area									
Connection transfer line (+beam tests?)									
Modification PSB hardware									
Commissioning PSB with new hardware									
Start-up PS-SPS									



**7 months**

from the “green light” to start dismantling the PSB proton injection to beam at LHC entrance

3 months hardware modifications

3 months PSB recommissioning

1 month PS and SPS start-up

Note 1: the goal at start-up is to reproduce the same beams as with Linac2

Note 2: Linac4 connection is a non-reversible operation (requires civil engineering work in Linac2 area for shielding and extensive installation/recabling in PSB).

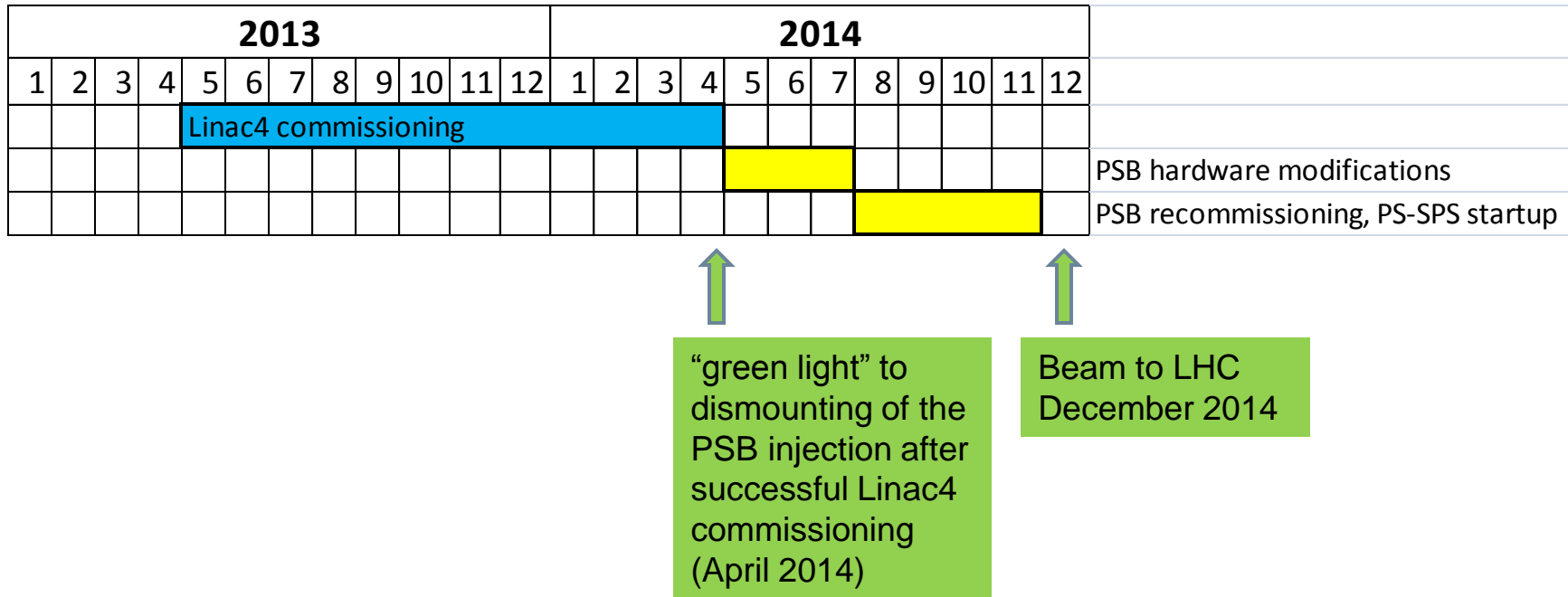


# LHC-independent connection scenario



14

Putting together the two schedules (Linac4 commissioning & Linac4 connection):



Important point: what will be the reliability of Linac4 after commissioning?

- : it is a new machine...
- + : for production of the normal beams the top performance is not required  
(50% of current is sufficient).





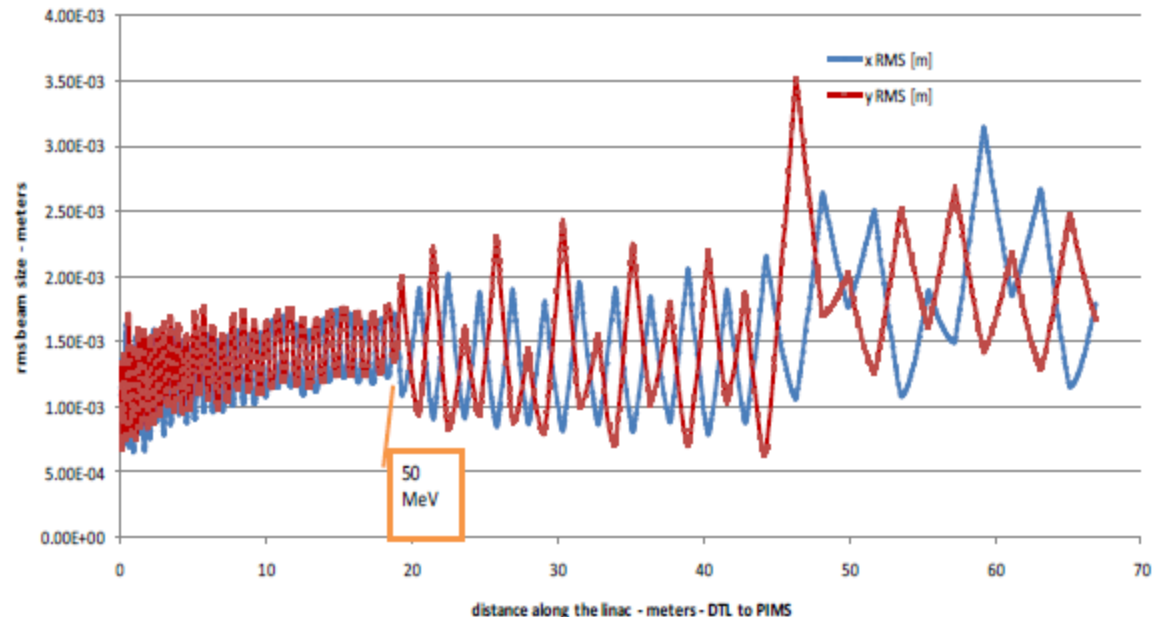
## Present baseline scenario (in my understanding):

1. Keep the Linac4 **commissioning schedule (April 2014)** → optimum use of resources;
2. Schedule **connection to the PSB only in Long Shutdown 2** → time to improve offline reliability and performance and to optimize the connection process → minimum risk, but need to operate in parallel **Linac2 and Linac4** for some years;
3. In case of problems with Linac2, be ready from 2015 to an **“emergency” connection** of Linac4, with 2 possible options:
  - a) with **H-** and full performance after a **7-month** shutdown;
  - b) with **protons at 50 MeV** after a **few days** shutdown but with reduced PSB performance.



## Preliminary study (mainly A. Lombardi and C. Carli):

- The **ion source** could be rapidly exchanged with a proton source (duoplasmatron Linac2 type, 60 mA – 100  $\mu$ s);
- **Acceleration of protons** in Linac4 to 50 MeV is not straightforward. The fixed-polarity PMQ focusing channel in the DTL requires careful rematching using the EMQs in the chopper line, but it can be done.
- 50 MeV is exactly the **output energy of the DTL** → all other RF structures need to be off and detuned (with one CCDTL acting as debuncher).

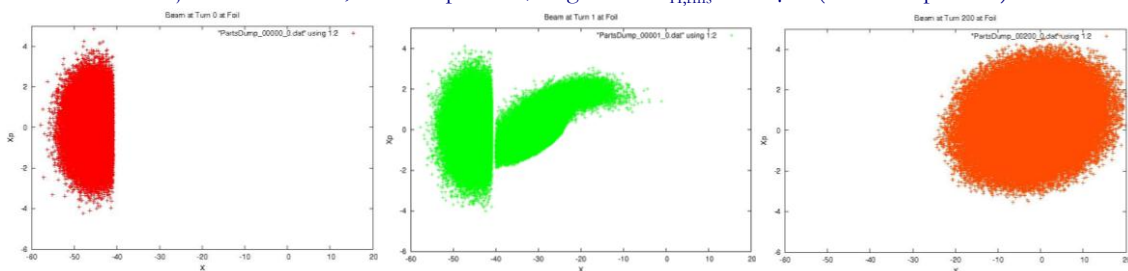


- **Physical connection**: segment of beam pipe to install, magnet BHZ20 to be turned, some additional shielding (bricks?).
- But: beam **current is limited to 40 mA** by the Linac4 RF, vs. 160 mA from Linac2; however emittance from Linac4 is about 3 times smaller. Pulse length is limited by the proton distributor to about 100  $\mu\text{s}$  (Linac4 can make 400  $\mu\text{s}$ ) → PSB performance will be **limited** by the lower current.

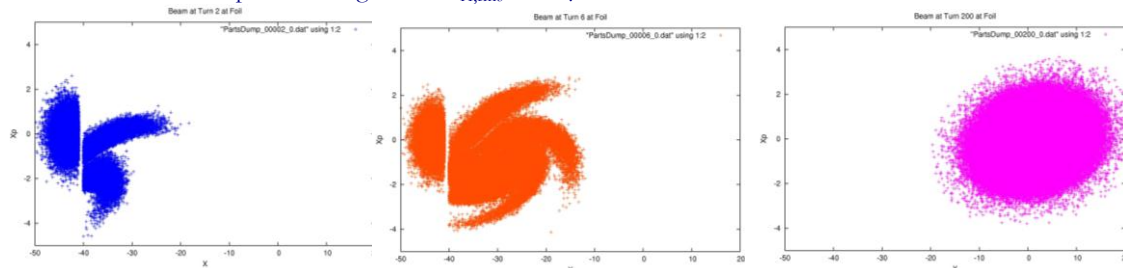
➤ Recent simulations (V. Raginel, 11.8) compare Linac2 and Linac4 proton injection. With 7 turns injection instead of 2 and longer injection bump fall time looks like we can produce the **LHC beam** in the PSB with **about ~37% reduction** in intensity (preliminary results, need more understanding).

➤ Lower efficiency to be expected for the high-intensity beams, unless the PSB distributor is changed allowing for longer pulses (Linac4 H-distributor?).

- With Linac2 parameters (reference case close to present parameters)
  - \* Injection of 2 turns, 220  $10^{12}$  protons/ring within  $\epsilon_{H,rms}^* = 2.23 \mu\text{m}$  (similar to practice)



- With Linac4 parameters and optimisation of injection and injection bump durations
  - \* Injection of 7 turns, injection bump fall time increased from 50  $\mu\text{s}$  to 70  $\mu\text{s}$
  - \* 160  $10^{12}$  protons/ring within  $\epsilon_{H,rms}^* = 2.57 \mu\text{m}$



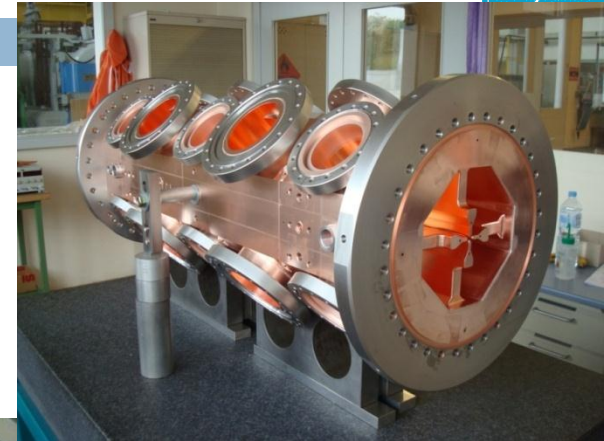




# Back-up slides



- **RFQ**: 2/3 segments completed, 3<sup>rd</sup> being brazed. Commissioning expected for end 2011.
- All 3 prototypes of accelerating structures completed and tested at full RF power.
- **DTL**: Drift tubes and tanks in production, Tank1 expected to be assembled beginning 2012.
- **CCDTL**: in construction in Russia, modules 1 and 2 (/7) ready at end 2011.
- **PIMS**: production started in Poland.
- **Klystrons**: prototypes (Thales and CPI) expected at end 2011. LEP klystrons under test.
- **Modulators**: prototype tested, contract for series construction being placed.
- **Quadrupoles**: PMQs for DTL1 received and tested, for DTL2 and 3 ordered; call for tenders out for EMQs.
- Building completed, **installation of infrastructure** (electricity, cooling, cabling, waveguides) in progress, to be completed by June 2012.



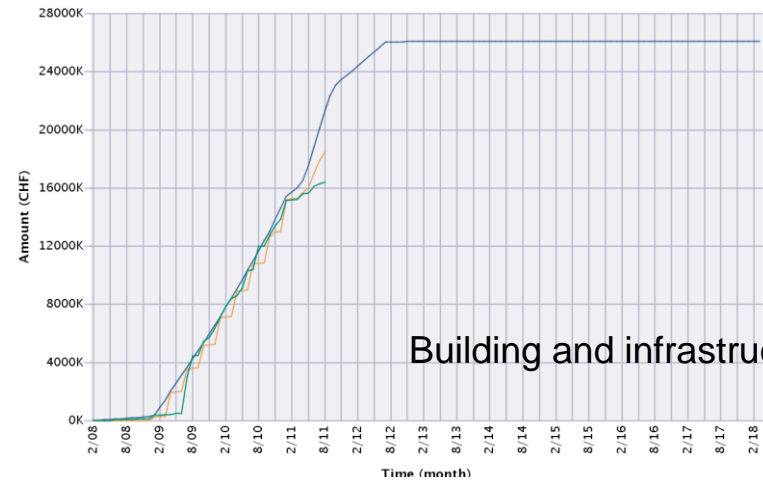
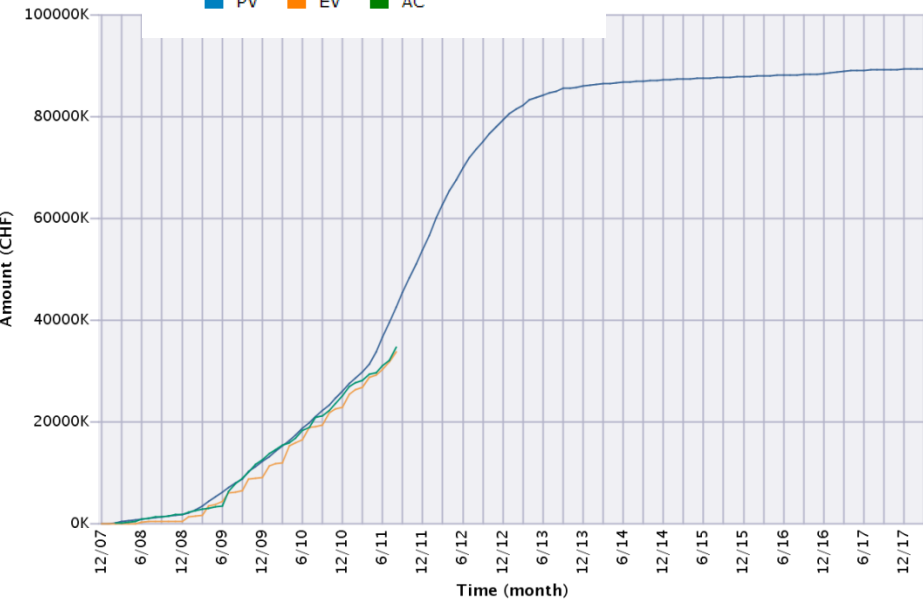


# Linac4 status from EVM – Aug 11

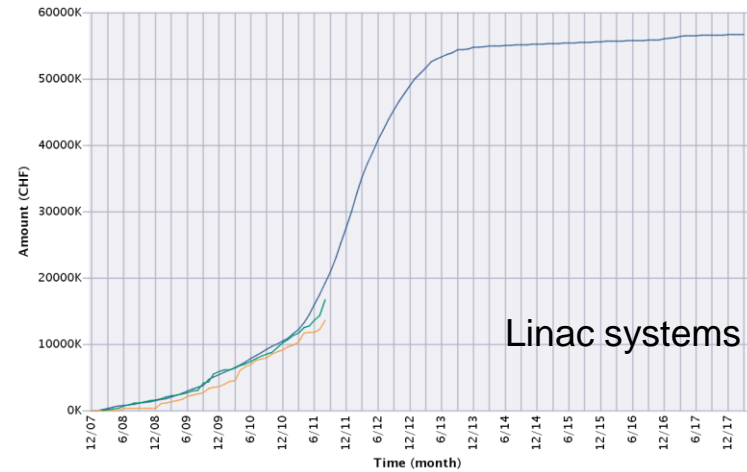


LINAC4 - Linac4 Project - WBS(Res)

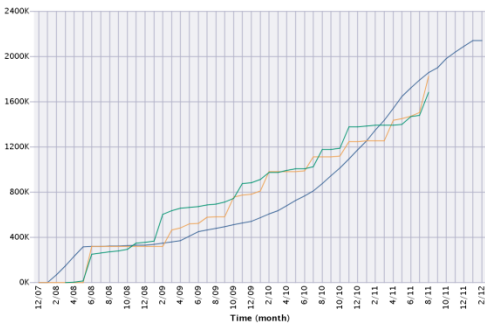
PV EV AC



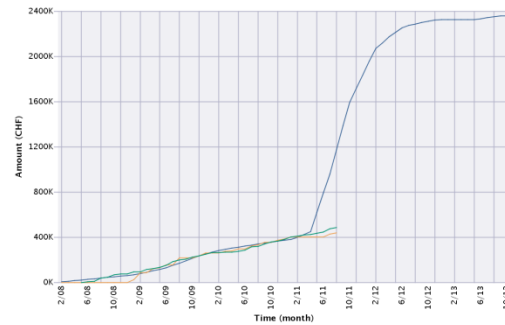
Building and infrastructure



Linac systems



RFQ



DTL