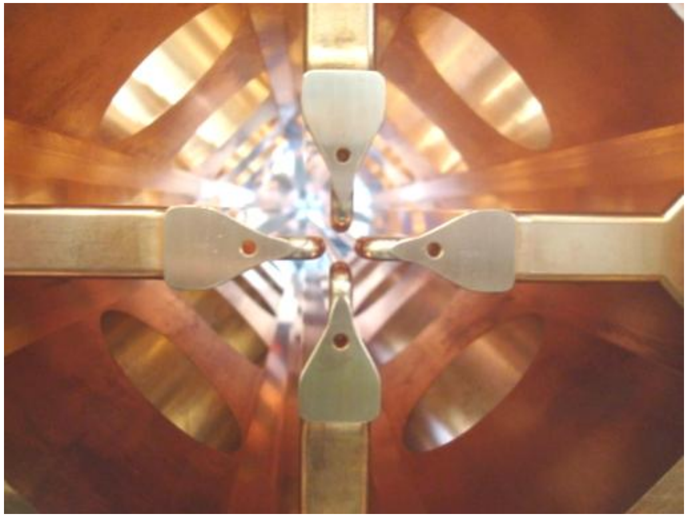
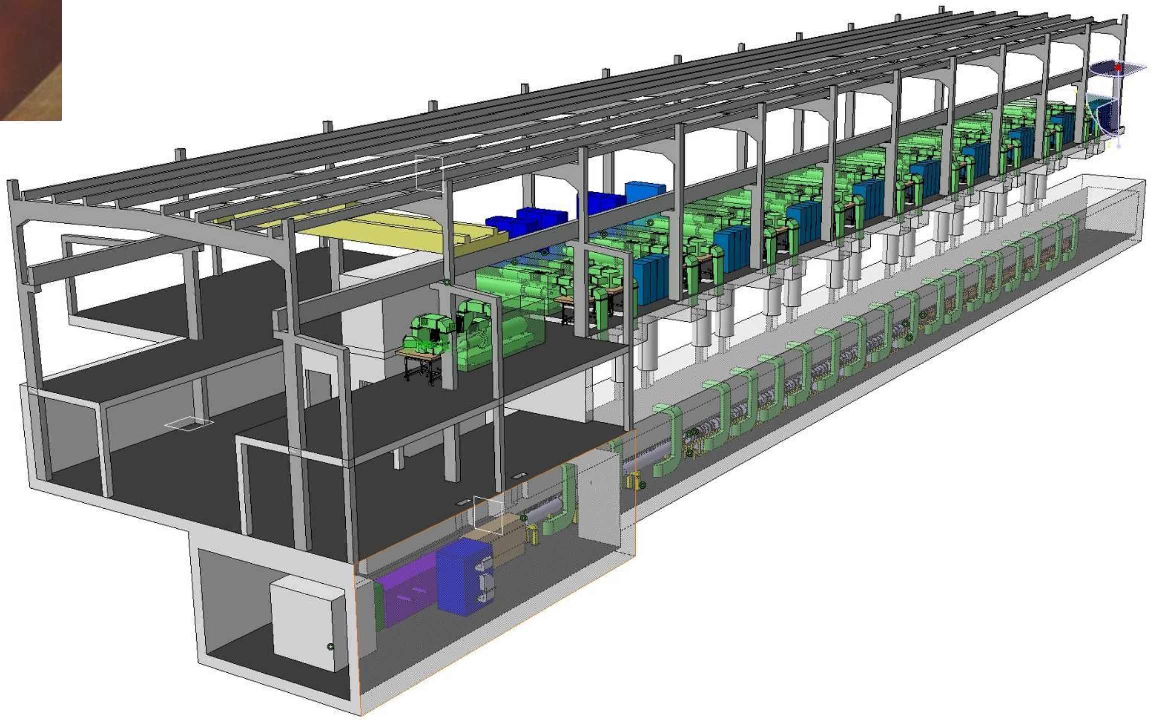


Linac4 Status



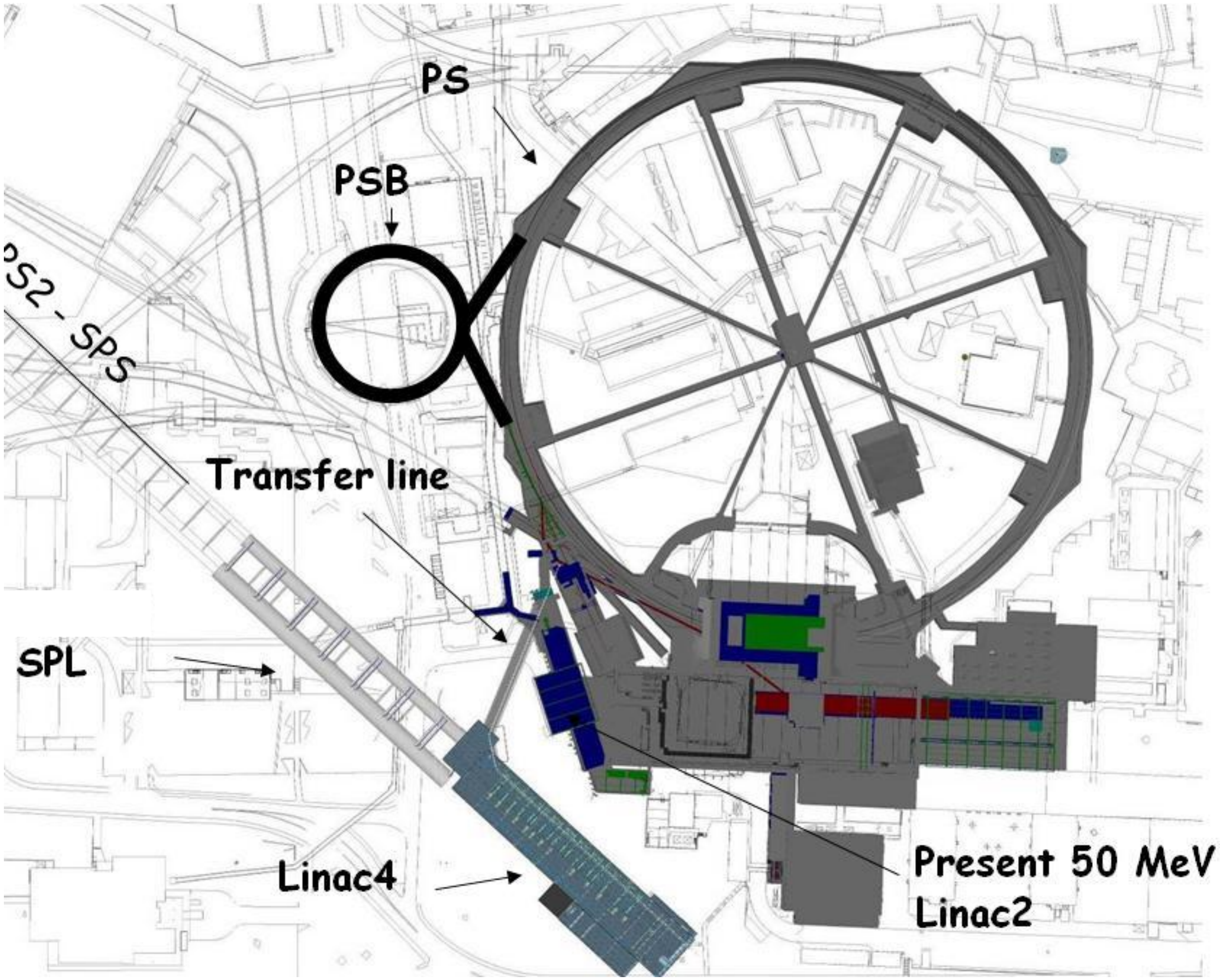
M. Vretenar
sLHC public event
23.06.2010

Linac4 - Description

Linac4 is a new **160 MeV H^-** linear accelerator, which will inject into the PS Booster (PSB) replacing Linac2. It could be later extended into the SPL.

Project started in 2008 (White Paper), completion foreseen for 2015.

Linac4 because 4th linac built at CERN.



Linac4 - Motivations

1. Linac 4 is the 1st step of a programme aiming at increasing LHC Luminosity. First limitation ("bottleneck") for increased intensity from LHC injector chain = space charge induced tune shift at 50 MeV injection in the PSB → need to increase injection energy.

2. Linac2 giving serious reliability/sustainability worries: persistent vacuum problems, obsolete RF tube design → instead of an intensive consolidation program, replace with a new linac.

3. Increase intensity for other PSB (and PS) users: ISOLDE,...

4. Implement at CERN modern technologies for improved injection and reduced losses (chopping, H- charge exchange injection).

5. Prepare for a possible evolution towards higher intensities → Linac4 is compatible with 50 Hz operation and as injector to a high-duty cycle SPL (Superconducting Proton Linac).

Linac4 – Main Parameters

- ☞ Energy of 160 MeV giving a factor 2 in $\beta\gamma^2$ with respect to Linac2 (50 MeV) → space charge tune shift (limiting accumulated intensity in PSB) $\Delta Q \sim N/\beta\gamma^2$ → with twice the energy, double N keeping the same tune shift.
- ☞ RF frequency 352 MHz, as old LEP RF system → can recuperate some klystrons and RF components from the LEP surplus.
- ☞ Repetition frequency 2 Hz: 1.1 Hz present PSB limit, margin for some upgrade.
- ☞ Beam current 40 mA in 400 μs: provide >2 present PSB maximum number of particles.

Linac4 Parameters

Ion species	H^-	
Output Energy	160	MeV
Bunch Frequency	352.2	MHz
Max. Rep. Rate	2	Hz
Max. Beam Pulse Length	1.2	ms
Max. Beam Duty Cycle	0.24	%
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
N. particles per pulse	1.0	$\times 10^{14}$
Transverse emittance	0.4	π mm mrad

Max. rep. rate for accelerating structures 50 Hz

H^- particles + higher injection energy (160/50 MeV, factor 2 in $\beta\gamma^2$) $\rightarrow$ same tune shift in PSB with twice the intensity.

Re-use 352 MHz LEP RF components: klystrons, waveguides, circulators.

Chopping at low energy to reduce beam loss at PSB.

- Structures and klystrons dimensioned for 50 Hz.
- Power supplies and electronics dimensioned for 2 Hz.
- Infrastructure (cooling, electricity) dimensioned for 2 Hz.

CERN Accelerator complex performance with Linac4

LHC INJECTORS WITH LINAC2		Nominal LHC Double Batch	Expected Maximum Double Batch
PSB out	ppr	1.62 x10^{12} *(1bunch/ring)*	1.8 x10^{12} *(1bunch/ring)*
(ε ≤ 2.5 μm)*		↓ *(6 bunches, h=7)*	↓ *(6 bunches, h=7)*
PS out, per pulse	ppp	9.72 x10^{12}	10.8 x10^{12}
PS out, per bunch	ppb	1.35 x10^{11} *(72 bunches)*	1.5 x10^{11} *(72 bunches)*
(ε ≤ 3 μm)*		↓ *15% loss*	↓ *15% loss*
SPS out	ppb	1.15 x10^{11}	*1.27 x10^{11}*

Comparison Linac2 – Linac4 injecting into the PSB (25 ns bunch spacing)

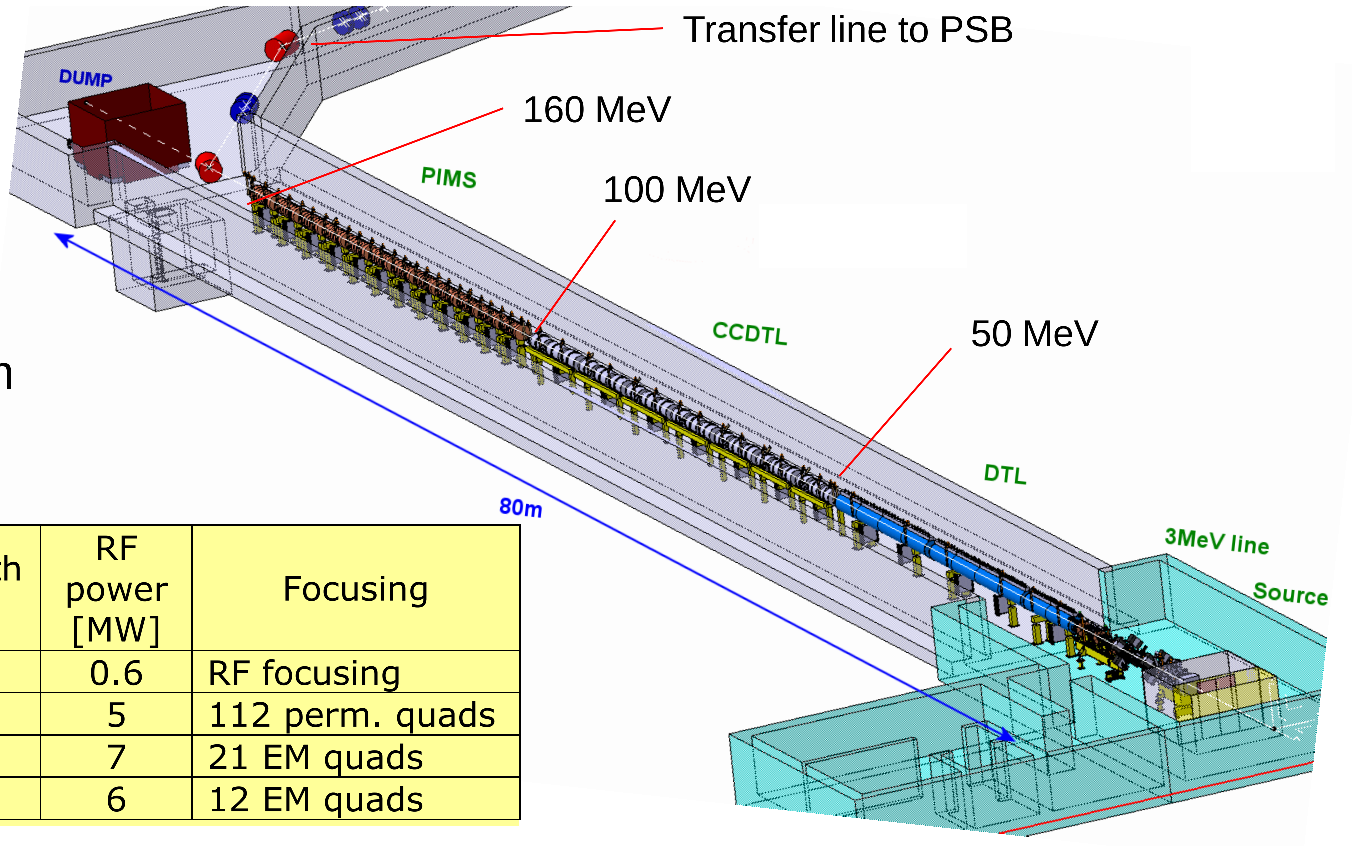
Limitations highlighted in yellow. values to be demonstrated are in italic.

LHC INJECTORS WITH LINAC4		Nominal LHC Single batch	Maximum Single batch	Maximum Double batch	PSB @ 2 GeV Double batch
PSB out	ppr	3.25 x10^{12} *(2bunch/ring)*	3.6 x10^{12} *(2bunch/ring)*	2.05 x10^{12} *(1bunch/ring)*	*3.2 x10^{12} (1bunch/ring)*
(ε ≤ 2.5 μm)*		↓ *(6 bunches, h=7)*	↓ *(6 bunches, h=7)*	↓ *(6 bunches, h=7)*	↓ *(6 bunches, h=7)*
PS out, per pulse	ppp	9.72 x10^{12}	*10.8 x10^{12}*	*12.3 x10^{12} (PS limit scaled for 206ns bunches)*	*19.2 x10^{12} (PS limit scaled to 2 GeV)*
PS out, per bunch	ppb	1.35 x10^{11} *(72 bunches)*	*1.5 x10^{11} (72 bunches)*	*1.7 x10^{11} (72 bunches)*	*2.7 x10^{11} (72 bunches)*
(ε ≤ 3 μm)*		↓ *15% loss*	↓ *<15% loss*	↓ *20% loss*	↓ *??% loss*
SPS out	ppb	1.15 x10^{11}	*>1.3 x10^{11}*	*1.37 x10^{11}*	
Goal:		Nominal intensity in single batch: shorter filling time, lower losses and emittance growth.		Potential for ultimate intensity out of PS in double batch (33% increase w.r.t. Linac2).	Potential for > ultimate out of PS with PSB @ 2 GeV (factor 1.8 increase w.r.t. Linac2).

Linac4 layout

• Standard (normal-conducting) linac layout, based on:

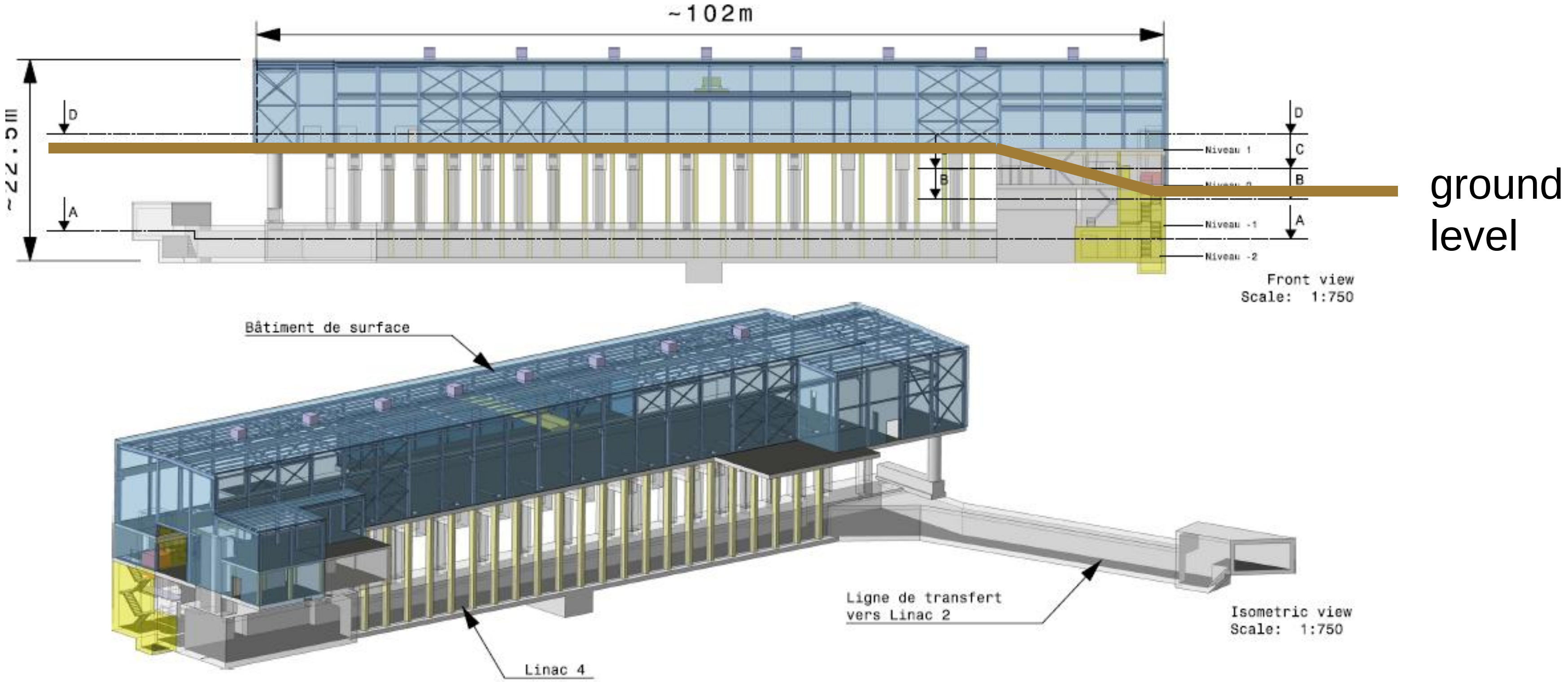
1. pre-injector (source, magnetic LEBT, 3 MeV RFQ, chopper line)
2. Three different types of accelerating structures, matched to the specific energy range (max. shunt impedance, easy access and maintenance, minimum construction cost).
3. Beam dump at linac end, switching magnet towards transfer line – PSB.
4. Beam measurements at linac end and at PSB entrance.



Linac length ~ 80 m

	Energy [MeV]	Length [m]	RF power [MW]	Focusing
RFQ	0.045 – 3	3	0.6	RF focusing
DTL	3 – 50	19	5	112 perm. quads
CCDTL	50 – 102	25	7	21 EM quads
PIMS	102 – 160	22	6	12 EM quads

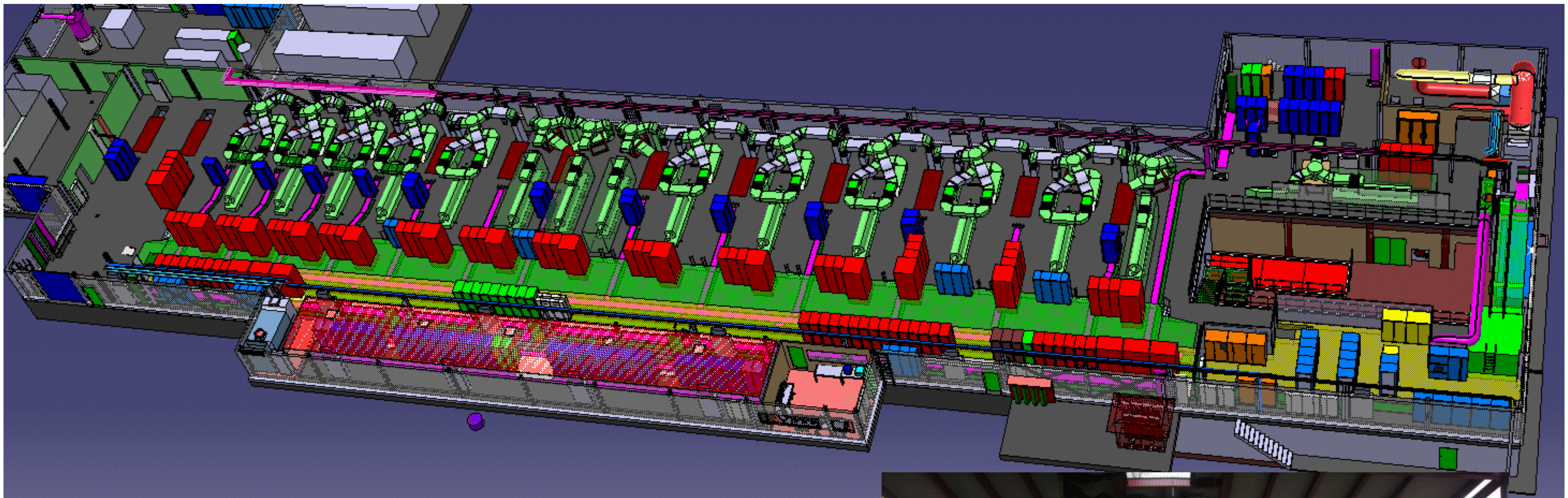
Linac4 building



- Overall floor surface of Linac4 installations = 3’305 m2 (over 4 levels);
- Overall floor surface of Linac2 installations = 1’181 m2 (over 5 levels).

Accurate integration of equipment and optimization of the available space:
Linac4 makes >3 times the energy and keeps the option of high-duty cycle operation using only 2.8 times the surface of Linac2 !

Linac4 – equipment hall



Radio Frequency:

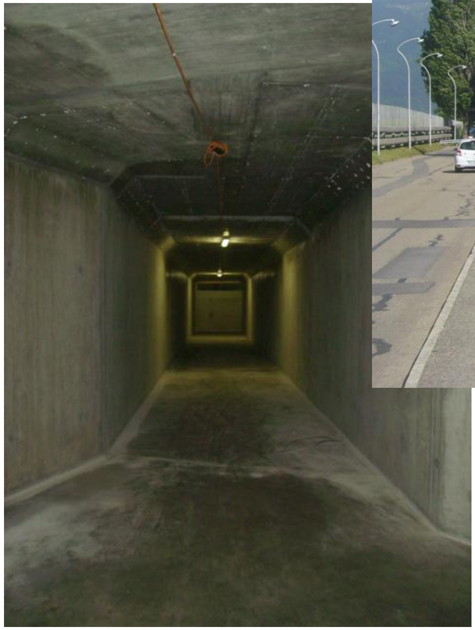
13 klystrons from LEP (1.25 MW) + 6 new klystrons (2.8 MW, pulsed) feeding 23 cavities.

In the long term, pairs of LEP klystrons will be replaced by new klystrons (at end of life).

Linac4 construction

Civil engineering basically on schedule.

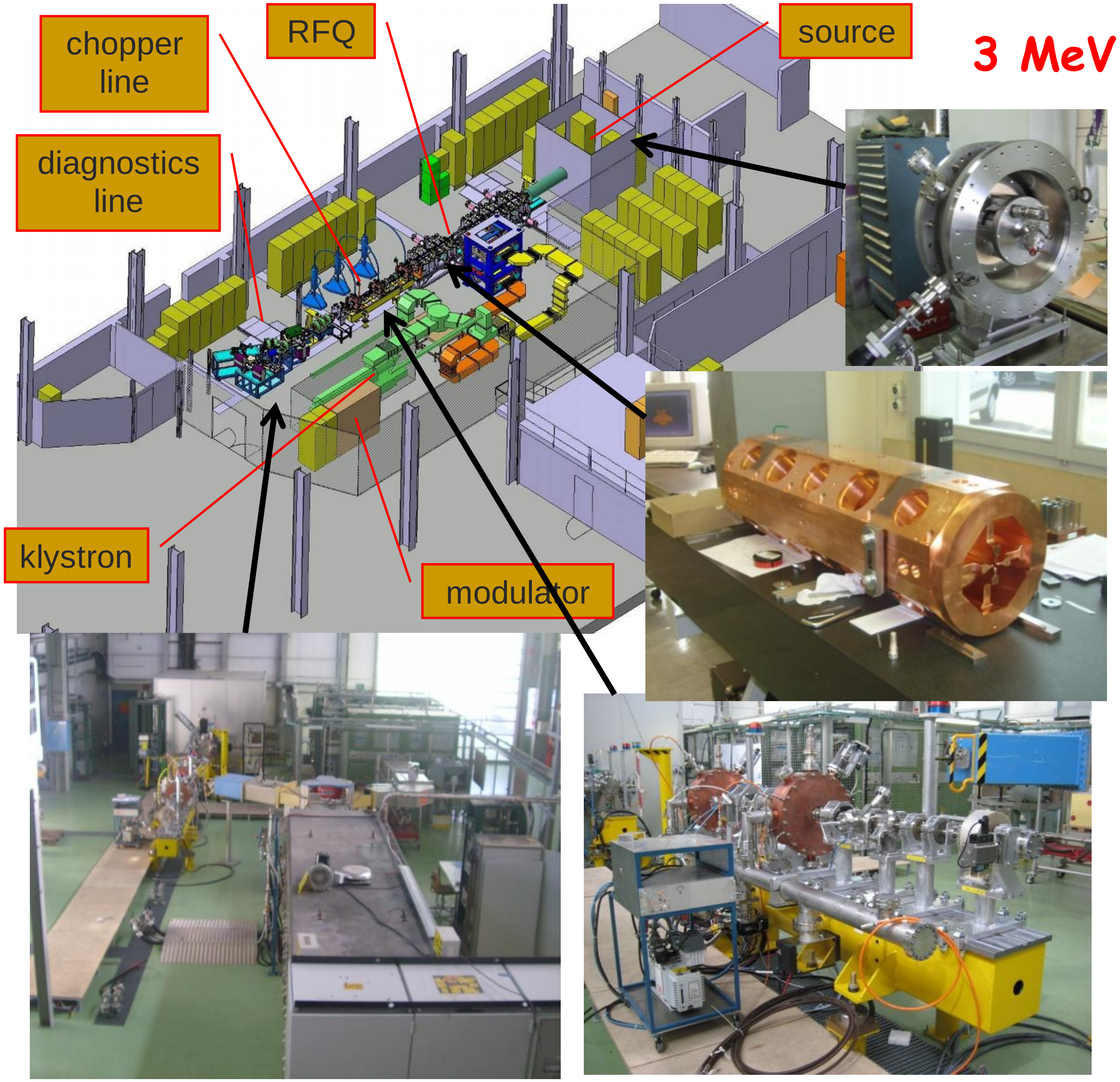
Finishing during summer, delivery foreseen for mid October.



Linac4 – Main technical challenges

- Low-energy section: ion source, RFQ, chopping
- Accelerating structures
- PSB injection and beam optics
- Linac beam dynamics
- Reliability

Linac4 – Low energy

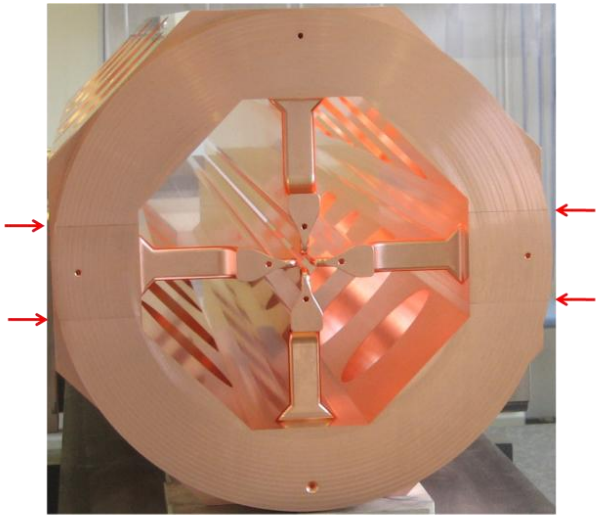


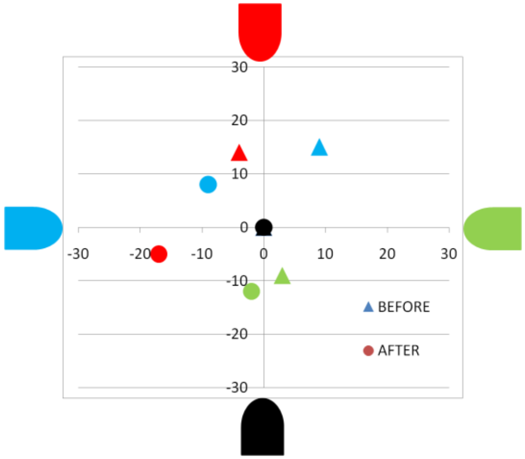
3 MeV TEST STAND in the PS Hall:

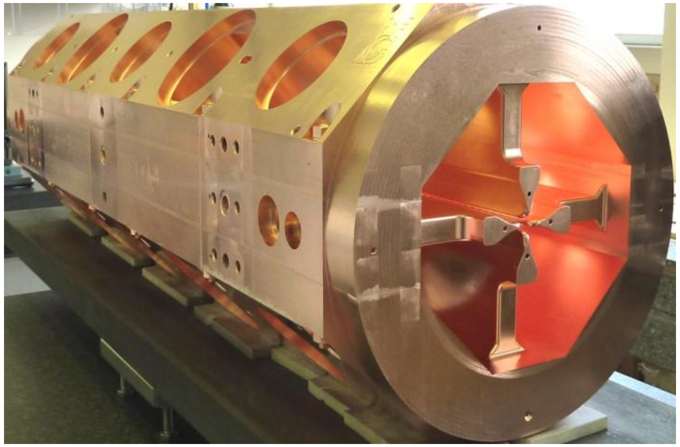
- ☞ Ion source completed, first beam in July 2009, presently improving current.
- ☞ Magnetic Low Energy Beam Transport in construction.
- ☞ Radio Frequency Quadrupole being built at CERN, to be delivered in early 2011.
- ☞ Chopping line built and tested (w/o beam).
- ☞ LEP klystron (+ modulator) installed and tested in pulsed mode.

Early characterization of the low energy beam is essential for a linac project!

Brazing of the 1st RFQ Module

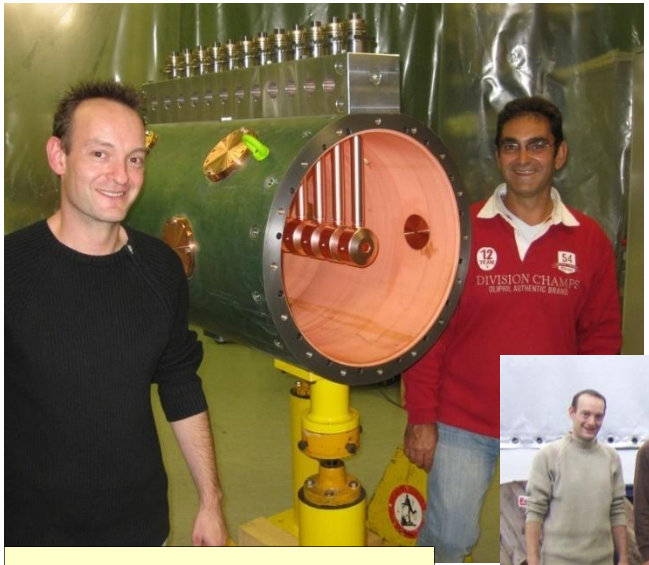






On May 3rd the first (out of 3) 1-m long module of the Linac4 RFQ went successfully through the critical horizontal brazing step. Deformations <25 μm (tolerance 30 μm).

Linac4 – Accelerating structures



DTL prototype, 2009

CCDTL prototype, 2008

PIMS prototype, 2010

Three structures of new design:

DTL (Drift Tube Linac): complete revision of mechanical design w.r.t. other projects.

CCDTL (Cell-Coupled DTL): new structure, first time built for a linac.

PIMS (Pi-Mode Structure): new structure, first time built for a linac.

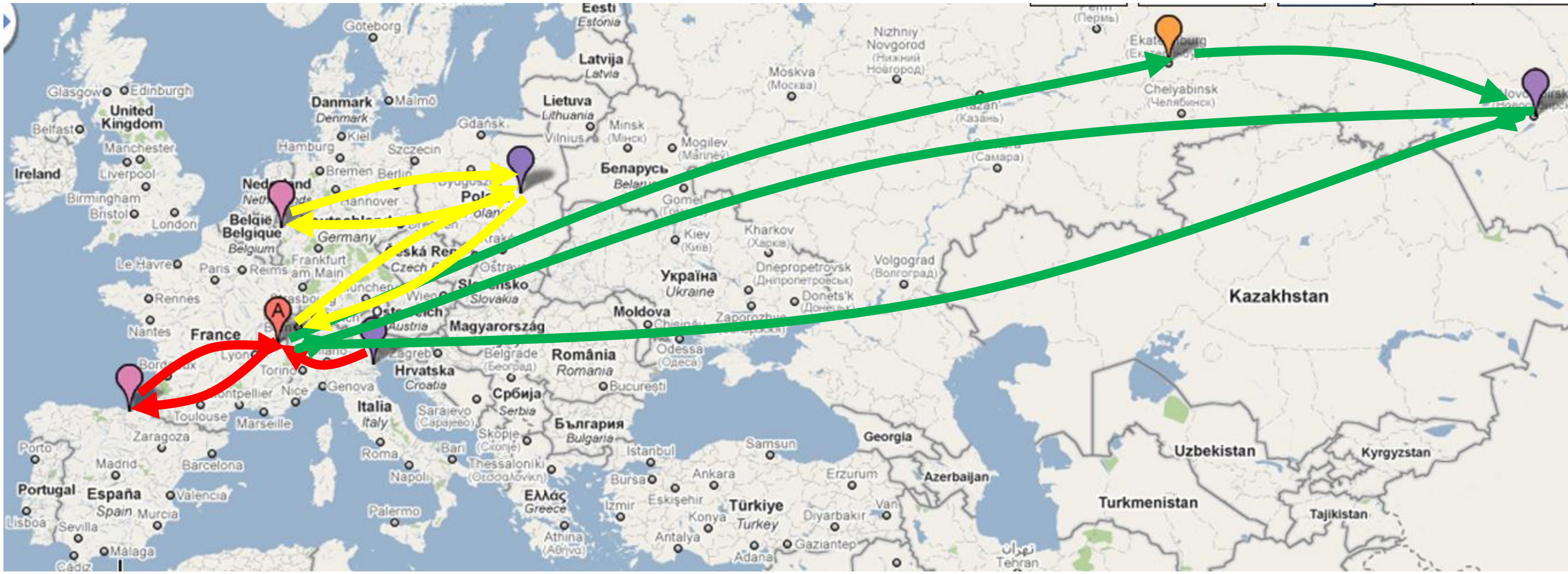
R&D since 2003.

Prototypes built (and tested at high RF power) for the three structures.

All constructions are starting in 2010.

Accelerating structures for Linac4

Construction of the Linac4 accelerating structure – an European enterprise (and beyond…)



Drift Tube Linac (DTL):
prototype from INFN/LNL (Italy), drift tubes from ESS-Bilbao (Spain), tanks and assembly at CERN

Cell-Coupled DTL:
tanks from VNIIEF (Snezinsk), drift tubes and assembling from BINP (Novosibirsk)

PI-Mode Structure (PIMS): tanks from Soltan Institute (Poland), EB welding from FZ Juelich (Germany), assembly and final EB welding at CERN.

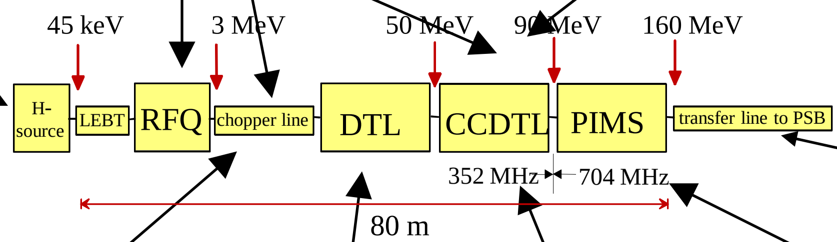
Linac4 – External Contributions

Network of agreements to support Linac4 construction – updated June 2010

RFQ RF design, RF amplifiers, modulator construction from French Special Contribution. *agreed and started.*

Prototype modulator, RF tuners, couplers, waveguides from India, *in progress*

Agreement with DESY to access drawings of H- source *completed*



Transfer line vacuum chambers and supports from Pakistan, *agreed*

Chopper line built in a EU Joint Research Activity *completed*

Participation of ESS-Bilbao in DTL construction, *agreed and started*

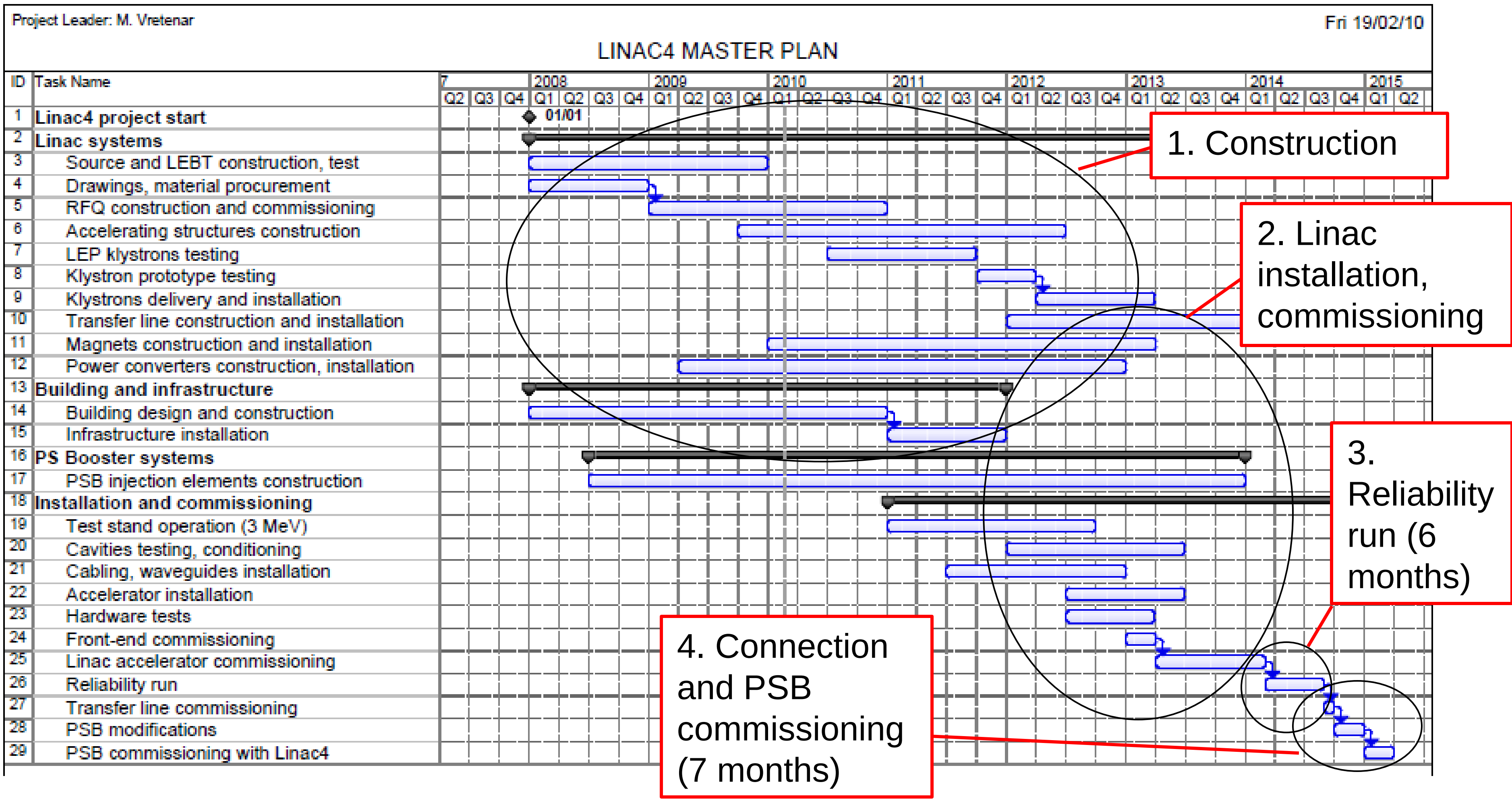
Construction of CCDTL in Russia, via an ISTC Project *agreed and started*

Collaboration agreement with Soltan Institute (Poland) and FZ Julich (D) for PIMS construction, *in preparation.*

Linac 4 – Status June 2010

- Ion source built, improving intensity.
- RFQ in construction at the CERN workshop, 1st module brazed.
- Chopper line completed, tested without beam.
- DTL prototype tested, starting construction of all 3 tanks (drift tubes in July 2010).
- CCDTL started construction in Russia. 1st module (of 7) to be delivered at end 2010.
- PIMS prototype completed. High power tests in August, construction start Jan. 2011.
- Design of dump, measurement lines and transfer line completed.
- PSB equipment in construction.
- RF layout defined, klystron contract placed, major orders in preparation.
- RF modulator prototype1 tested, prototype2 in construction, order in preparation.
- Orders for major components placed or in preparation.

Schedule – official after Chamonix 2010



GOAL: connection of Linac4 to PSB during the long shut-down 2014/15

Linac4 connection to PSB

Overall duration of LHC proton shut-down for Linac4 connection to PSB: 8 months.

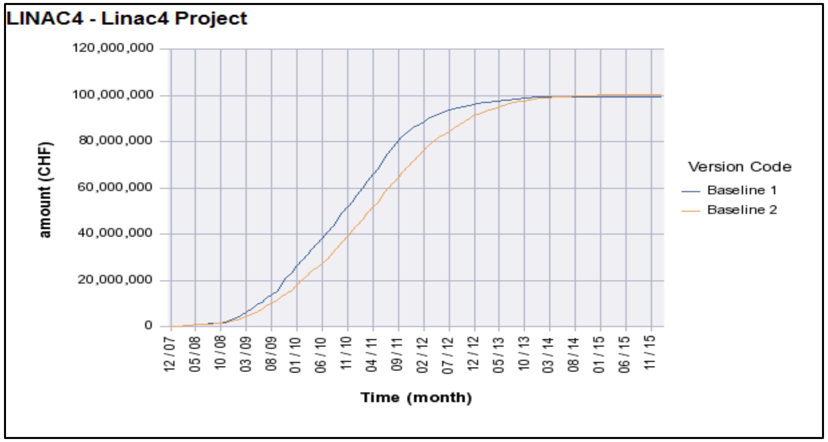
Note that we can accelerate ions in the injector complex during the Linac4 shut-down. The LHC stop can be reduced by carefully interfacing with an ion run.

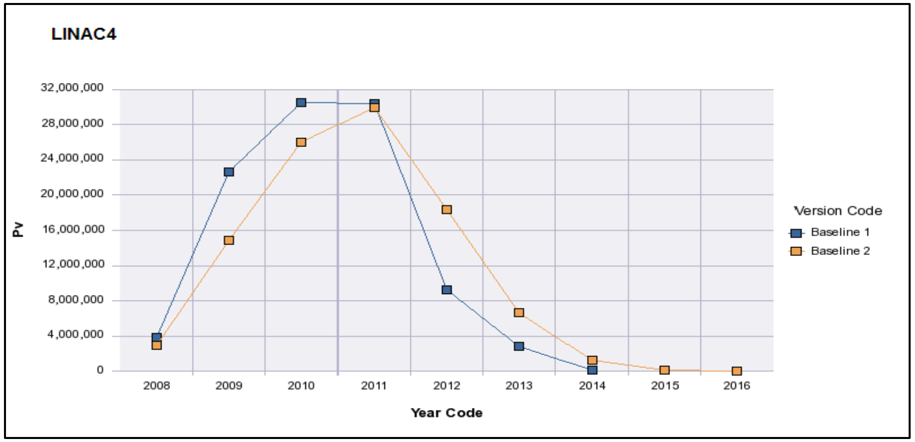
COMPOSITION LINAC4 SHUT-DOWN	1	2	3	4	5	6	7	8	month
Cool-down radiation in PSB area									
Connection transfer line (+beam tests?)									
Modification PSB hardware									
Commissioning PSB with new hardware									
Start-up PS-SPS									

Linac construction - commissioning				
Linac consolidation - improve reliability	10 months?			
LHC shut-down for Linac4 connection to PSB		8 months		
PSB to ultimate performance, in ppm			8 months	
PS to ultimate performance, in ppm	(in parallel)			
Possible time line	2013	2014	2015	2016
Shut-downs				

Budgets and progress

Linac4 budget and schedule are followed by the new CERN EVM tool (improved version of LHC EVM).
After Chamonix, a new baseline has been introduced, taking into account new schedule and new cost estimates.





June 2010 progress charts: some delay (2 months overall, 4 months linac systems), good cost performance (so far…), CPI=0.97 (earned/paid) for linac systems.