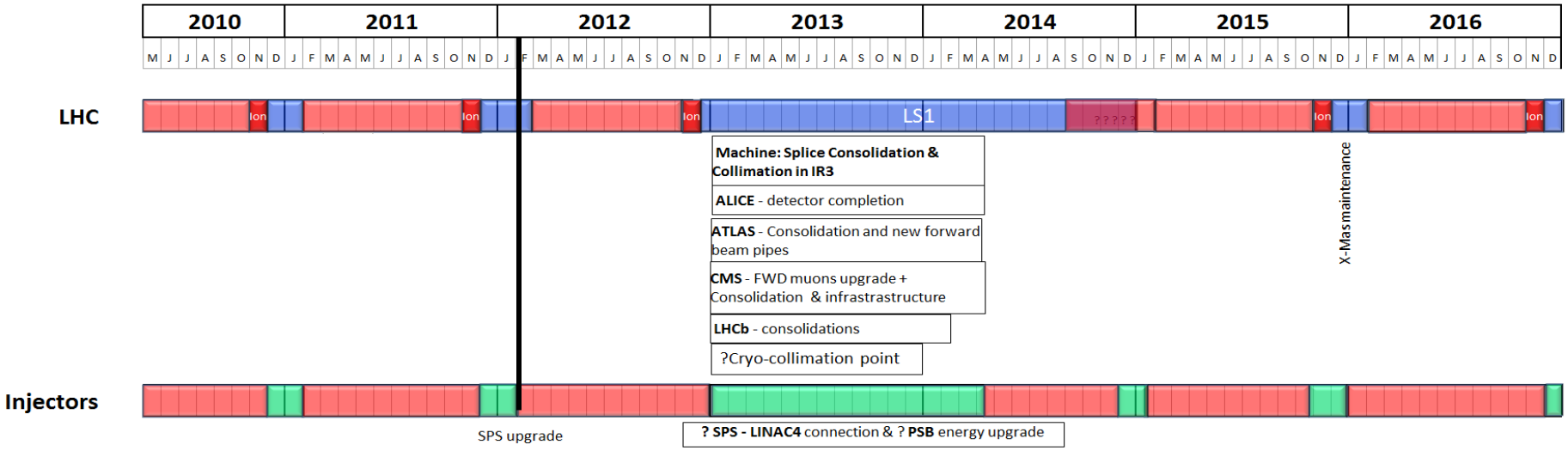
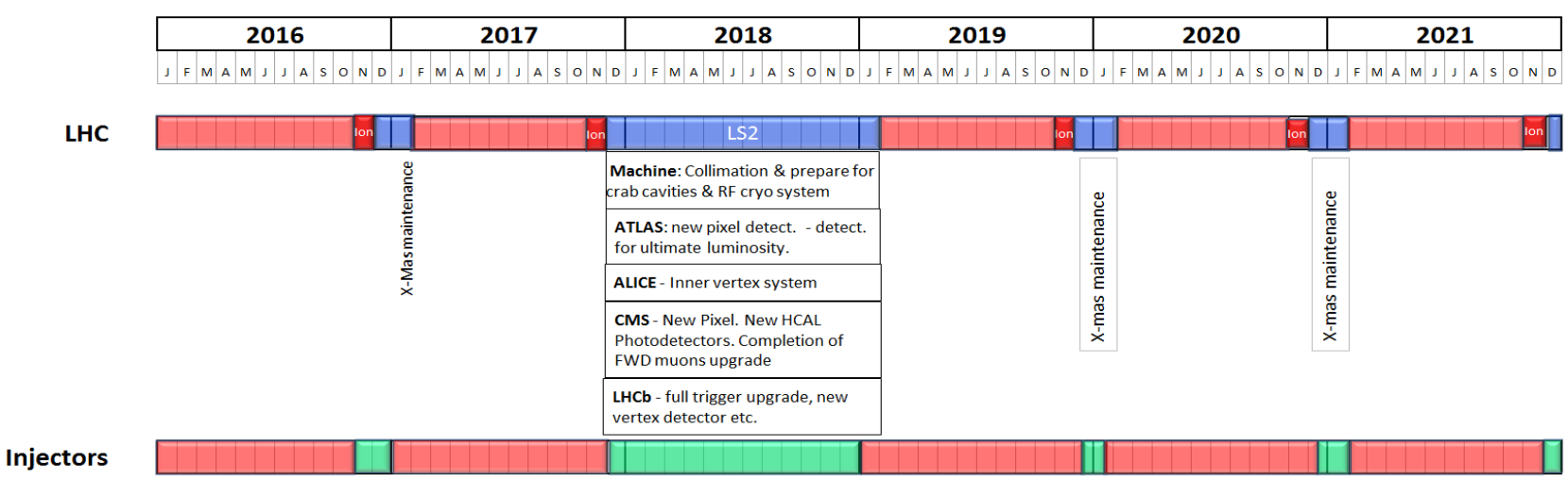
RF upgrade program in LHC injectors and LHC machine

Erk Jensen, on behalf of BE-RF

Many thanks to M. E. Angoletta, O. Brunner, R. Calaga, E. Ciapala, H. Damerau, W. Höfle, E. Montesinos, M. Paoluzzi, C. Rossi, E. Shaposhnikova, J. Tückmantel
and all those I forgot to mention

New rough draft 10 year plan





2022

LS3

Installation of HL-LHC hardware

Installation of LHeC

Preparation for HE-LHC

General

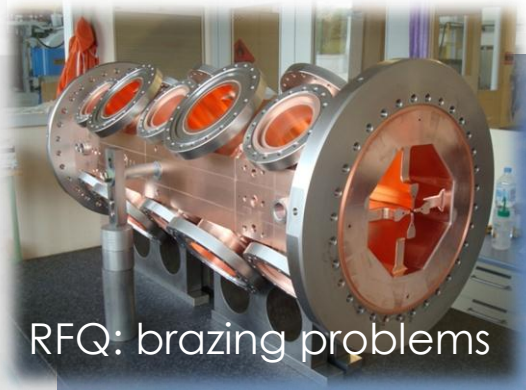
Some maintenance work could not be done during the relatively short winter shutdowns and was postponed to LS1. I quote E. Montesinos:

> "…very important maintenance program of the injector systems during LS1 due to lack of maintenance these last years. … e.g. we fixed some issues while repairing the Siemens system, **it shows we are close to the limits (5-6 near important accidents*) last year, avoided by careful survey of the team).** … we will have to do lot in order to have all our systems ready for a new 3 to 4 years run with only few technical stops".

In the following, I'll mention the major RF upgrade and consolidation activities – but the list is not exhaustive.

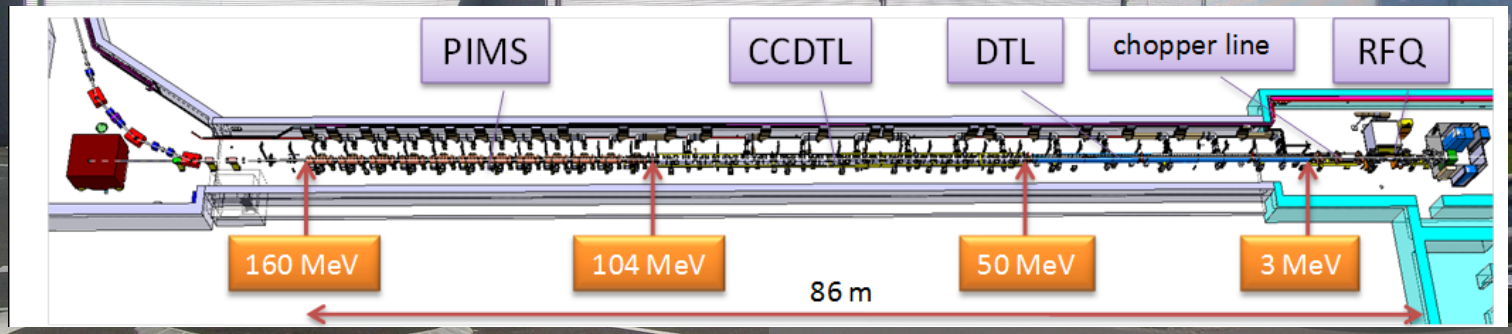
*) example: cf. spare slides

Linac 4



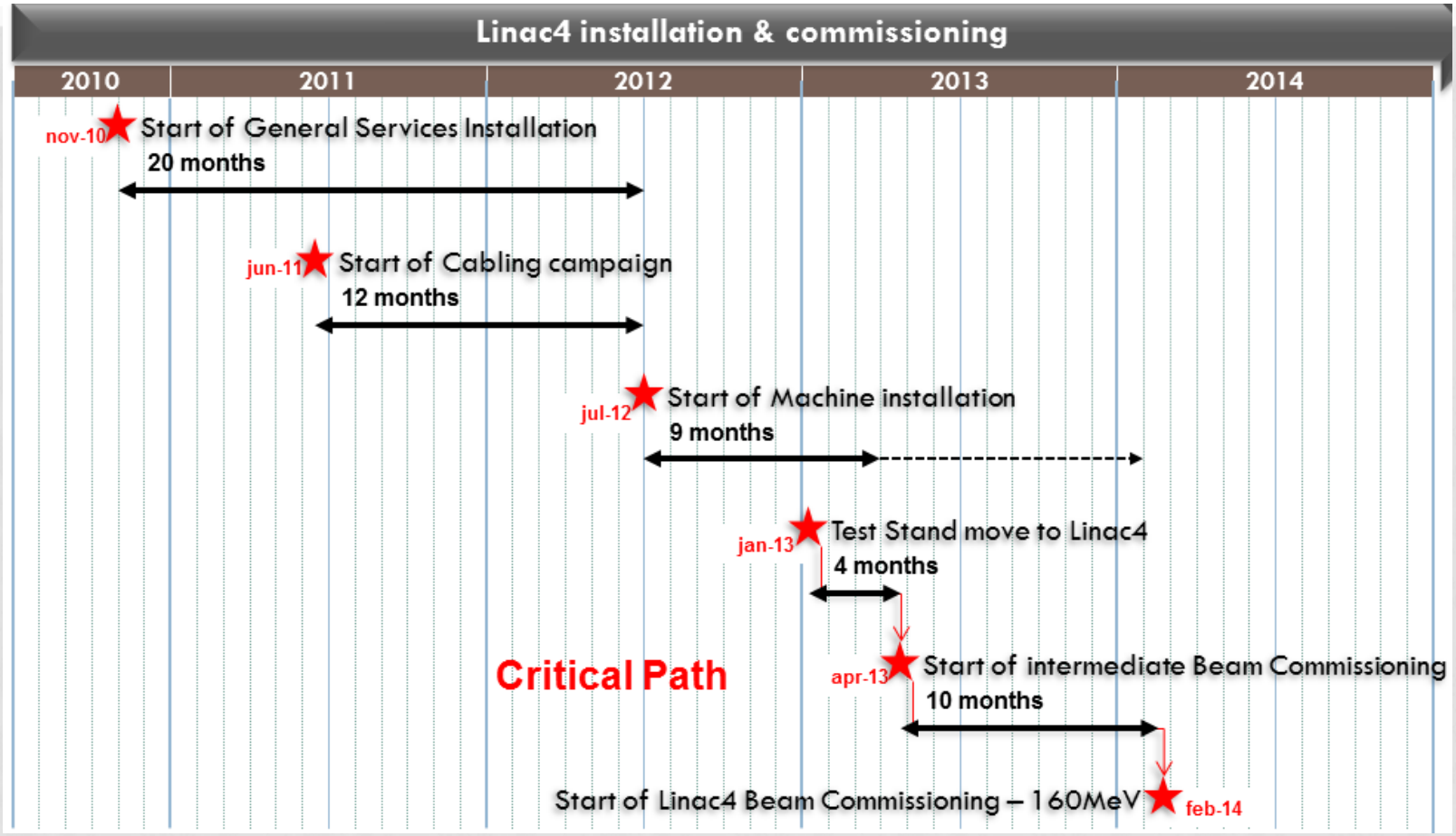
RFQ: brazing problems

CCDTL Novosibirsk (5-11 Nov 2011)



M. Vretenar, F. Gerigk, C. Rossi, …

Linac 4 timeline



M. Vretenar

PSB LLRF upgrade

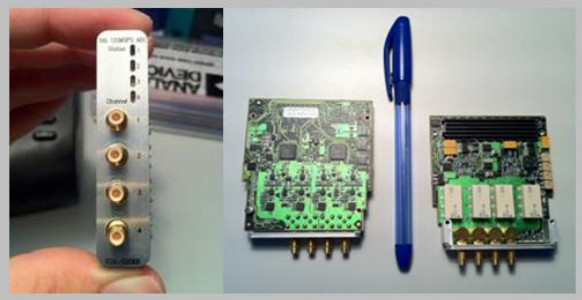
M. E. Angoletta, A. Blas, A. Findlay, J. Molendijk, …

FMC carrier: front&side views

RTM

VXS Switch: front&side views

MDDS FMC



ADC FMC: front&side views

SDDS FMC

PSB LLRF upgrade: planning

- **2011:** Beam tests with prototype hardware.
- **2012:** Beam tests: prototype + new hardware (PSB ring 4), support Finemet® prototype.
- **2013:** H/w series production for PSB
- **2014:** Full deployment of new PSB LLRF (4 rings + ring 0), support Finemet® system (full 13 cells, 8 kV)
- **2015-16:** Commissioning, prepare for injection from Linac 4

M. E. Angoletta, A. Blas, A. Findlay, J. Molendijk, …

PSB RF power upgrade: systems today

Three systems are presently installed in the machine:

C02

- Frequency range 0.6 (*1.0) – 1.8 MHz
- Gap Voltage 8 kV
- Installed in sections 7L1 and 10L1

(Built 1996 for LHC)

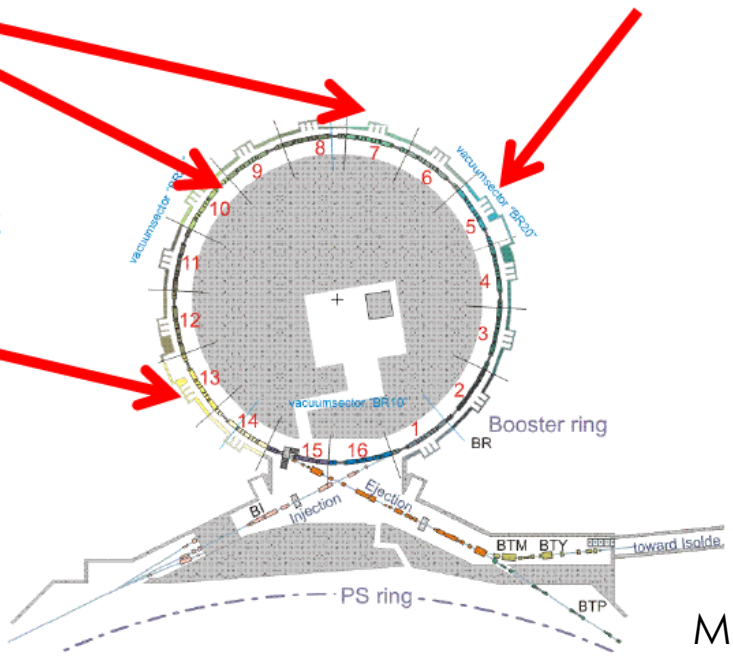
C16

- Frequency range 6.0 – 16 MHz
- Gap Voltage 6 kV
- Installed in section 5L1

C04

- Frequency range 1.2 (*2.0) – 3.8 MHz
- Gap Voltage 8 kV
- Installed in section 13L1

(ex *h*=5 system, today the system limiting intensity)



**** Frequency with injection from LINAC4***

M. Paoluzzi

PSB RF power consolidation: the plan

In the tunnel:

- Keep all cavities and C02 and C16 final amplifiers,
- Redesign C04 finals to increase available power,
- Replace all irradiated cables.

On the surface:

- Modernize interlock (PLC),
- Modernize G64 (!) controls interface,
- Move AVC & tuning loops into new digital LLRF,
- Implement new protections,
- Replace power supplies (anode and grid bias),
- Install new filament power stabilizers,
- Replace tuning supplies.

M. Paoluzzi

PSB RF power upgrade: New wideband system

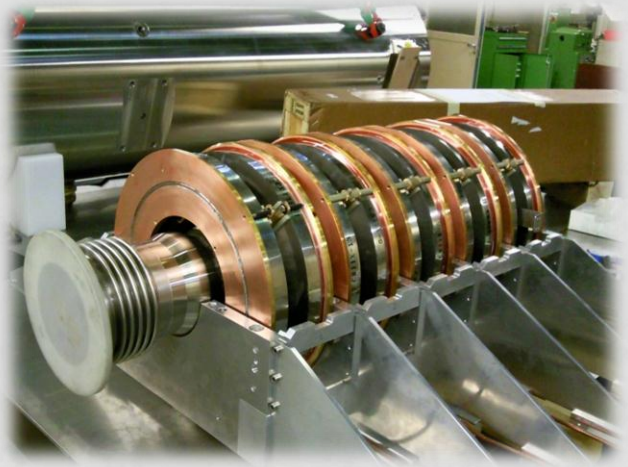
M. Paoluzzi

Advantages

- Single system to cover C02 and C04 frequency range.
- Modular system.
- Solid-state amplifier.
- Multi harmonic operation.
- No tuning.
- Substantial increase of installed RF voltage (up to 300%).
- Increased system reliability (hot back-up by on line spare cells).

Risks:

- New technology.
- New configuration
- Completely new design.
- Different beam compensation scheme.
- …?



PS consolidation/upgrade

Activity	Schedule	Status
LLRF studies	05/2011 – 06/2012	active
Digital beam control	06/2014 – 06/2018	planned
1-Turn delay feedback	01/2012 – 12/2014	active
HLRF studies	05/2011 – 12/2012	active
10 MHz system renovation	01/2013 – 06/2018	planned
Longitudinal damper in the PS	01/2012 – 12/2015	planned
Coupled bunch feedback	01/2012 – 12/2015	planned
40/80 MHz feedback renovation	06/2012 – 06/2017	planned
Fast tuner for the 80 MHz system	01/2012 – 12/2015	active
C201 C206 consolidation	01/2013 – 03/2014	planned

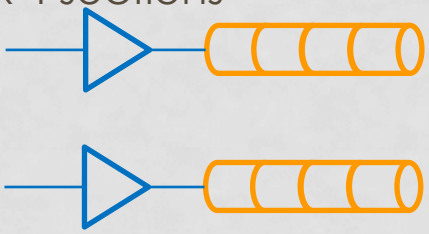
C. Rossi, H. Damerau, M. Morvillo, C. Völlinger, …

SPS 200 MHz power upgrade

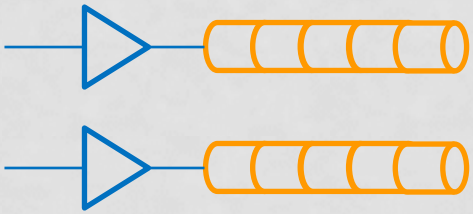
E. Montesinos

- 2011 : 4 cavities

2 x 4 sections



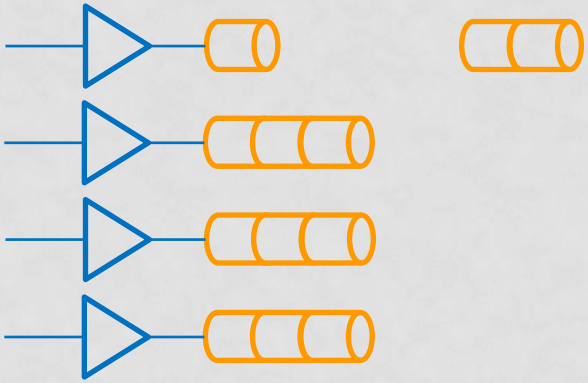
2 x 5 sections



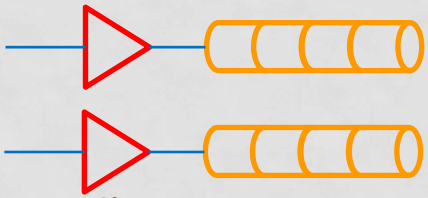
+ 3 spare sections

- 2018 : 6 cavities

4 x 3 sections



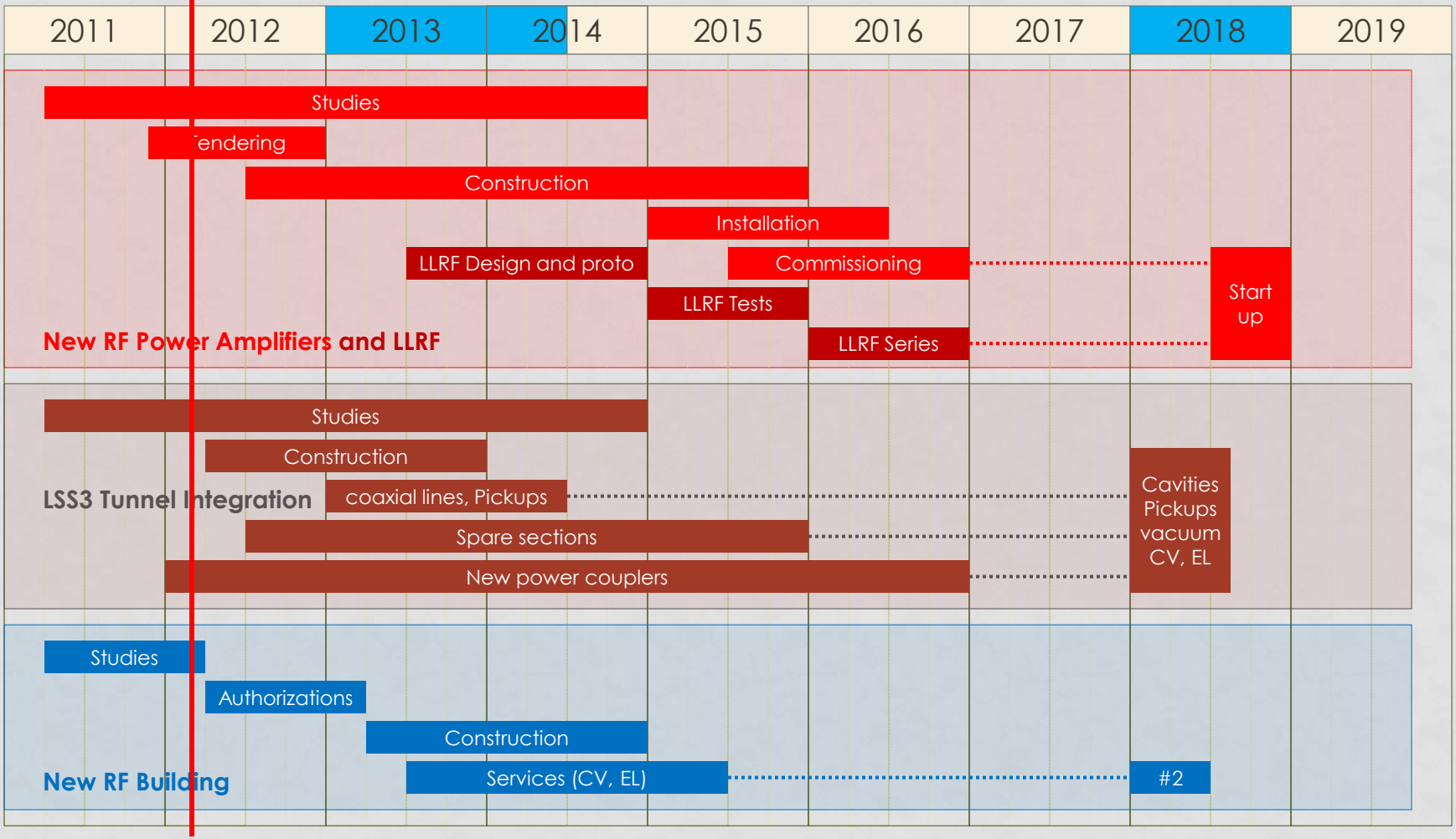
2 x 4 sections



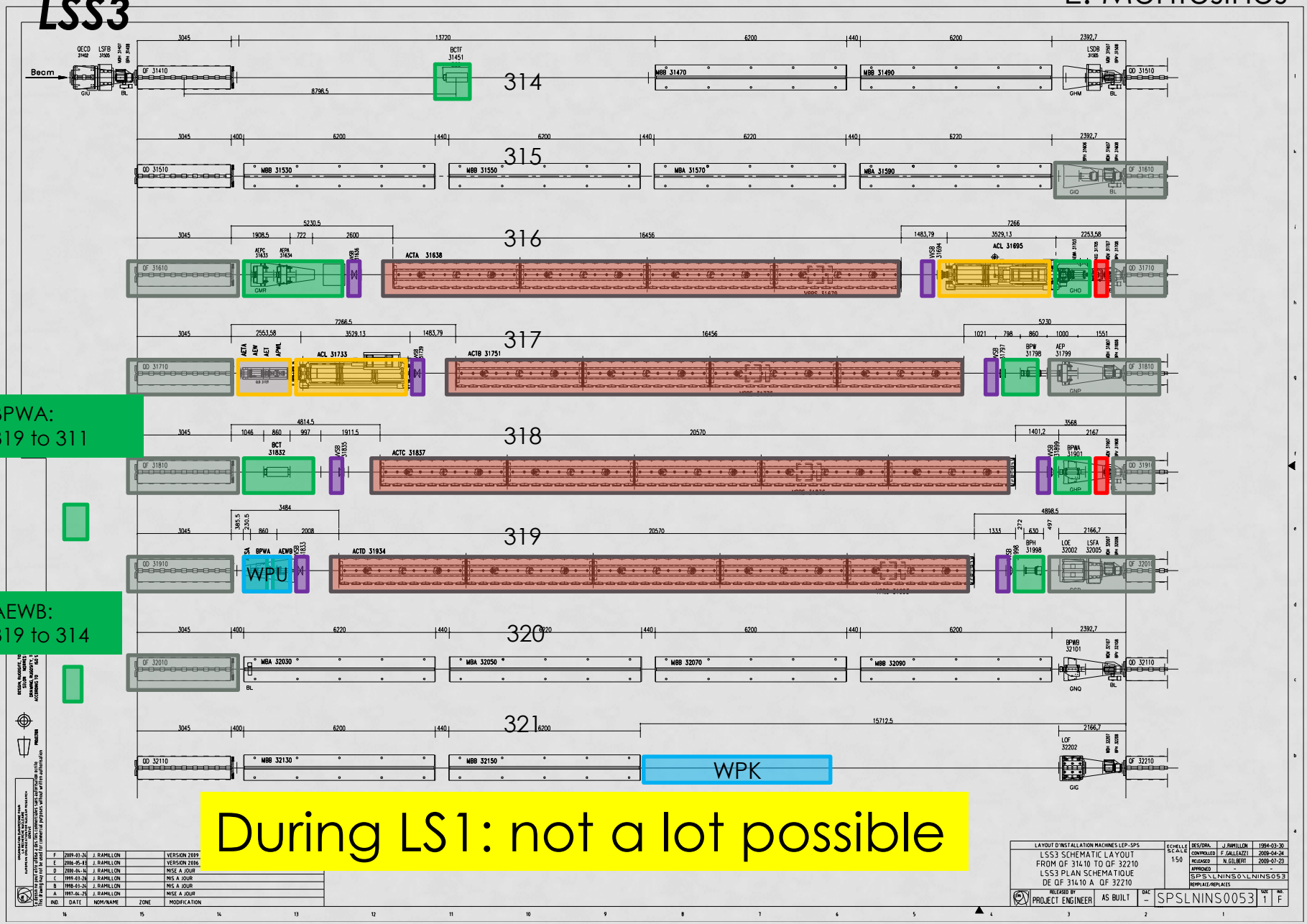
+ 1 spare section

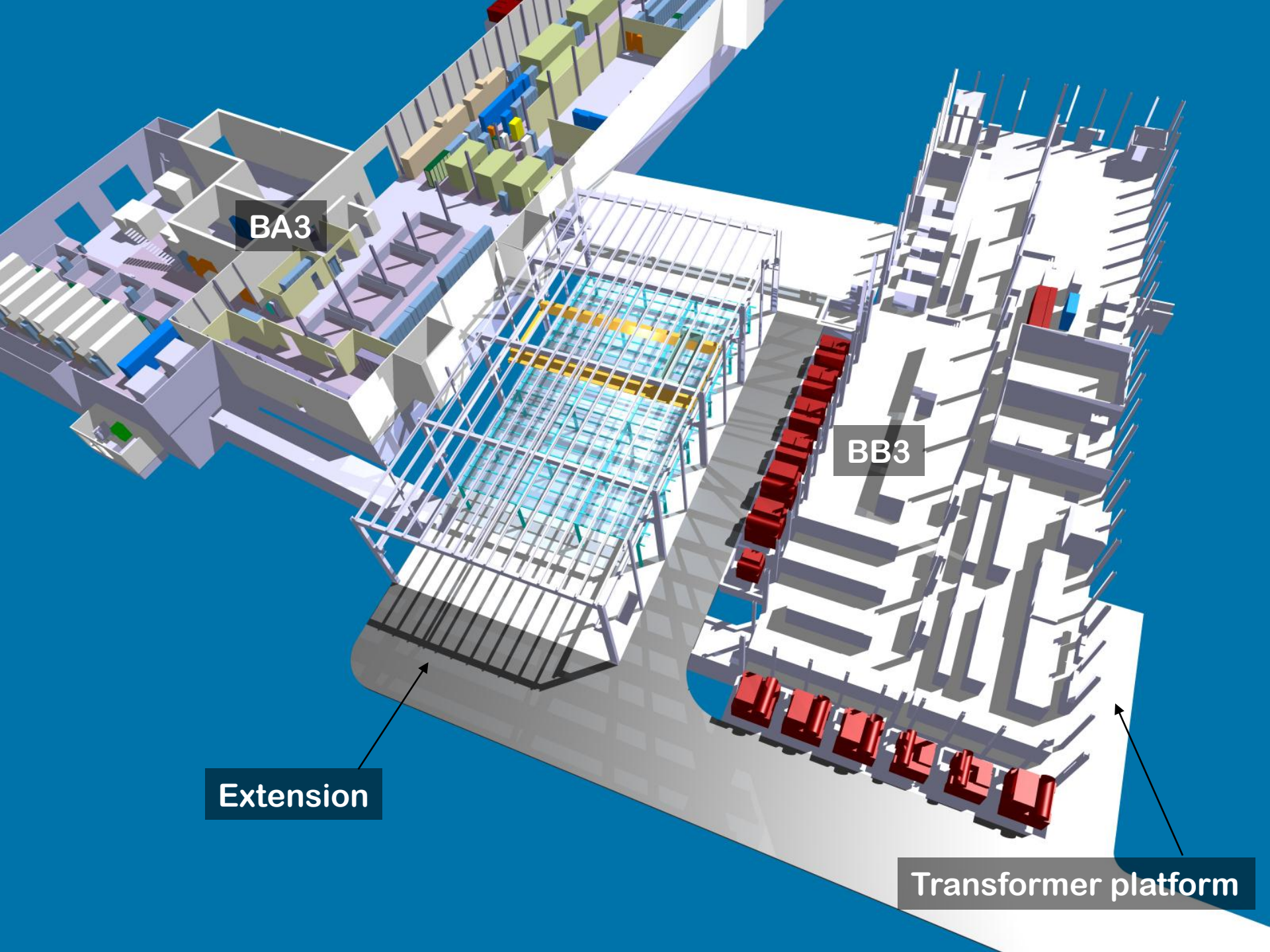
SPS 200 MHz power upgrade: Draft schedule

E. Montesinos



LSS3


Beam
314
315
316
317
318
319
320
321
QF 31410
BCTF 31451
MBB 31470
MBB 31490
QD 31510
MBB 31530
MBB 31550
MBA 31570
MBA 31590
QF 31610
ACTA 31638
ACL 31695
QD 31710
ACL 31733
ACTB 31751
QF 31810
BCT 31832
ACTC 31837
QD 31910
WPU
ACTD 31934
QF 32010
MBA 32030
MBA 32050
MBB 32070
MBB 32090
QD 32110
MBB 32130
MBB 32150
WPK
BPWA:
319 to 311
AEWB:
319 to 314
During LS1: not a lot possible
LAYOUT D'INSTALLATION MACHINES LEP-SPS
LSS3 SCHEMATIC LAYOUT
FROM QF 31410 TO QF 32210
LSS3 PLAN SCHEMATIQUE
DE QF 31410 A QF 32210
SPSLNINS0053


BA3
BB3
Extension
Transformer platform

SPS Transverse Damper, LS1

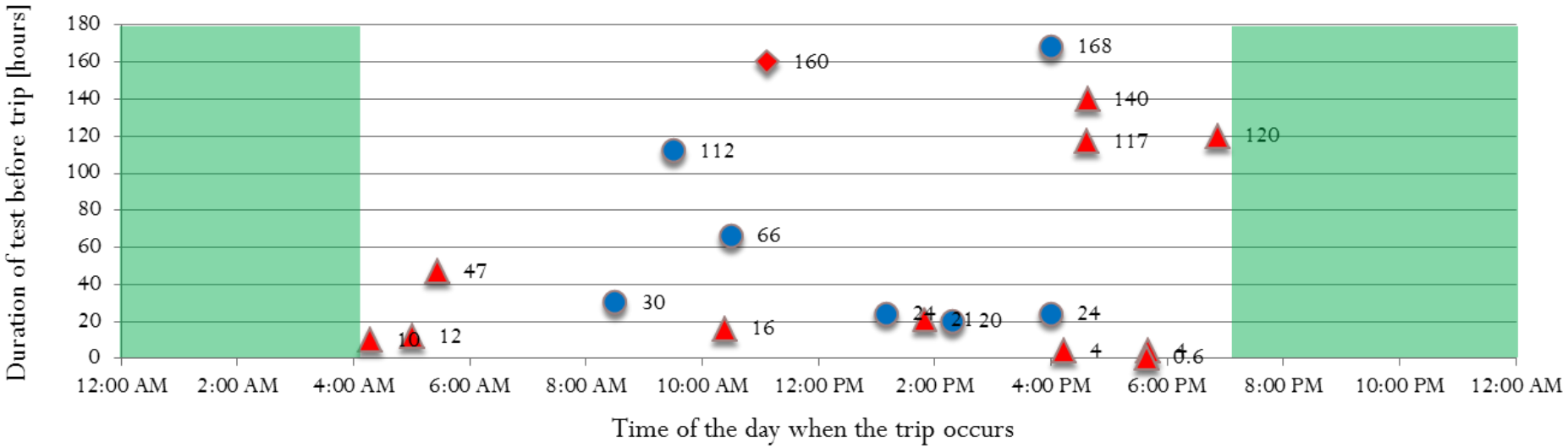
E. Montesinos, W. Höfle, US-LARP

- Re-shuffling of equipment (PUs) in SPS LSS3 to make space for new high bandwidth transverse feedback system (US-LARP collaboration) and in preparation of the increase of the number of cavities.
- Installation of new pick-ups, kickers and power amplifiers for high bandwidth transverse feedback system as they become available
- Limited upgrade/consolidation of transverse damper in BA2 of SPS; perhaps link this to clean-up of cabling in LSS2 (When exactly?)
- Installation of dedicated pick-ups for SPS transverse damper (now being discussed with BE-BI).

SPS 800 MHz upgrade

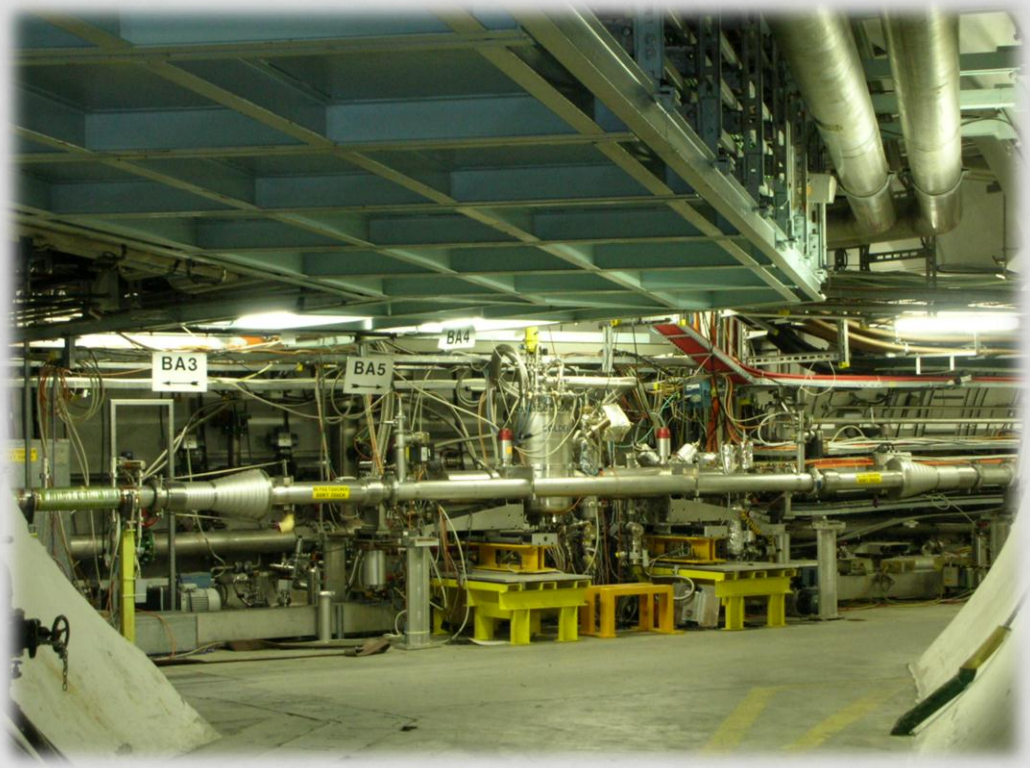
E. Montesinos, W. Höfle

- Important system to keep the beams stable, required at 1/5 nominal intensity!
- A new system, based on IOT amplifiers, will replace the old "Valvo" klystrons.
- Industry has supplied the 0-series – now under test
- Initial problems with the HVPS could be fixed.
- Now the system is under severe scrutiny for long term stability (endurance test)
- Observed: MTBF (trips) < 168 h (not good enough!);
- Probable culprit: EMC of controls – there is hope, but plan B (SS) is in preparation.
- LLRF upgrade – complete overhaul



SPS: COLDEX for Crab Cavity tests

- Crab Cavities are an important element of the LHC luminosity upgrade, HL-LHC.
- Before installing new, Compact Crab Cavities into the LHC, they have to be tested with beam in SPS.
- A suited area (with a by-pass) is Coldex (BA4); E. Metral is studying details.
- During LS1, it is planned to prepare this area for first CC beam tests in 2015 (cryogenics, general services)
- The existing cryoplant (TCF20) should be upgraded to 2 K liquefaction mode. Agreed in LHC-CC'11.
- A 1st test in LHC (P4) could be envisaged for 2017.



R. Calaga, E. Jensen, E. Metral, L. Tavian

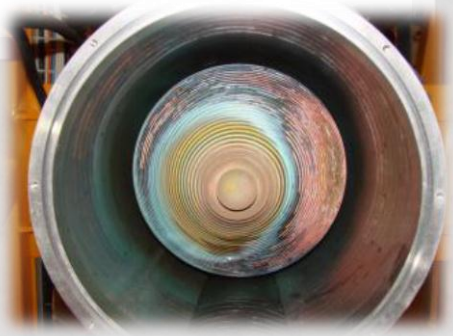
LHC Transverse Damper (ADT)

E. Montesinos, W. Höfle

- Upgrade of cabling for LHC transverse damper and measures to decrease noise level of system in preparation of 7 TeV run.
- Potentially use a number of additional pick-ups for transverse damper for noise reduction (under discussion with BE-BI, cabling required and additional bottom pick-ups if go-ahead).
- Add HV switch in the power supplies to allow automatic Off line of faulty amplifier.
- Modify water flow monitors, Eletta (ex LEP, not reliable) to rotameter, to avoid false reading.
- Modify transport system of the amplifier, induces new positioning system under the kickers, this will ease interventions.
- Need some studies to fix 40 MHz resonance (not a problem for normal intensity, but survey in view of HL-LHC)…

LHC – on-going work now and during 2012

O. Brunner



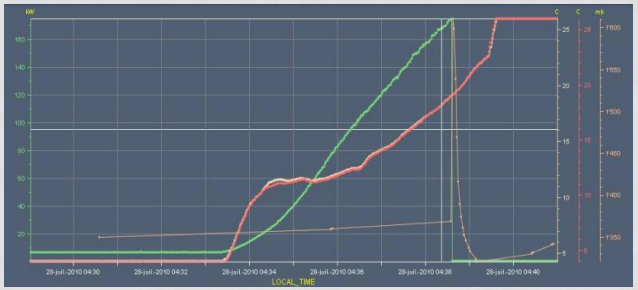
- 4 more **klystrons** were upgraded with new collector; now 8/16 can run flat out (4 for each beam), the others remain limited to 50 kV, 8 A.
- All remaining **old LEP equipment** (driver amplifiers, focus power supplies, …) were replaced by dedicated new units.
- All 4 **thyratrons** in the HV bunkers were checked and replaced or adjusted where necessary. A more modern and less delicate solution (solid state) was investigated and will be ready for test very soon.
- Approximately 100 **HV connectors** (connecting the modulators with the klystrons), some of which were problematic will be replaced when necessary during short TS's.
- The **arc detectors** were further developed and the new versions are now ready for testing – some can be scheduled during short TS's.
- The cavities were re-inspected (concern: delicate – could have been affected by cabling work!)

Account for > 50% of RF caused beam dumps 2011

LHC – planned work LS1

O. Brunner

- Finish the **klystron collector upgrade** (8 remaining) – takes about 4 weeks/klystron.
- **Thyratron** upgrade or replacement SS (in shadow).
- Replacement of **cavity module M1B2**, which contains the "sick" cavity #3:
  - First: spare module test in SM18: July/August – expected to be OK.
  - If OK, continue preparation to change module.
  - If not OK, limitation of cavity #3 (1.2 MV instead of nominal 2 MV) would remain.
  - Major intervention (2 months – RUX45 roof, vacuum, …)
- **Oil to be reconditioned** for all 4 HV bunkers – takes a few weeks/bunker (in shadow)



Virtually all cavity related trips in 2011 were in M1B2

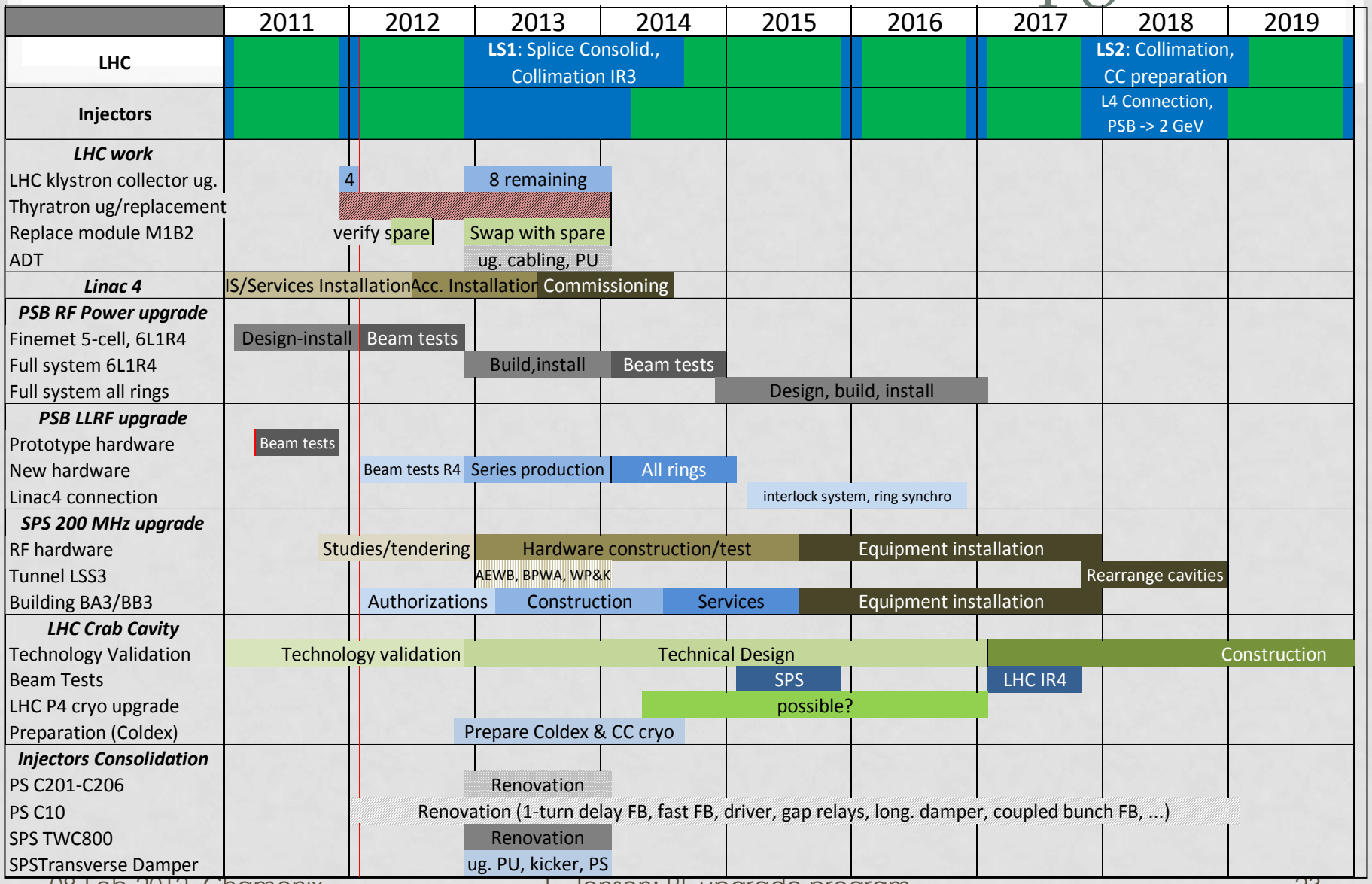
LHC Modulators: tetrode replacement

O. Brunner

- Each power converter feeds 4 klystrons; to individually control the power of each klystron, modulation anodes are used.
- The modulation anode voltage is controlled by a tetrode voltage divider (Thales TH 5186 SC).
- Old technology – Thales has announced the end of production of these tetrodes.
- A more modern solid state replacement solution is under study.

D. Valuch

Planned RF consolidation & upgrade



RF Upgrade/Consolidation: Summary

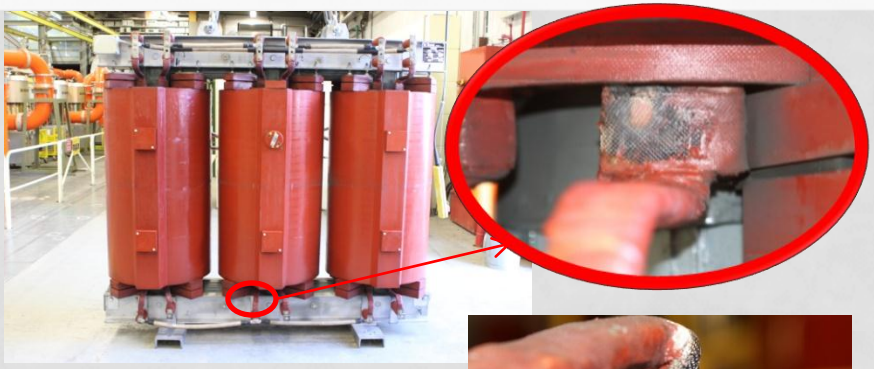
- **Whatever could be done in short TS's was done, but some maintenance work had to be delayed to LS1!**
- **Upgrade plans include:**
  - **PSB RF Power upgrade (Finemet® wide-band system)**
  - **PSB LLRF upgrade**
  - **SPS 200 MHz (cavity re-distribution, HB damper) and 800 MHz (IOT)**
  - **Prepare Coldex area (SPS) for Crab Cavity test**
- **Consolidation plans include:**
  - **PS 10 MHz Gap relays renovation**
  - **PS C201-C206 (200 MHz system)**
  - **PS C80 automatic tuning system implementation**
  - **LHC klystron boiler/collector upgrade (8 remaining)**
  - **Replace cavity module M1B2**

THANK YOU VERY MUCH!

Spare Slides

Example of near important accident SPS TX4 HV transformer

- During a daily visit, U. Wehrle identified a problem.
- Reparation at the factory (in collaboration with TE-EPC)
- No incident (fire) thanks to a good anticipation method



Reminder: in 1997 the same HVPS exploded!
→ No SPS during six months !

E. Montesinos