LHC Injectors Upgrade

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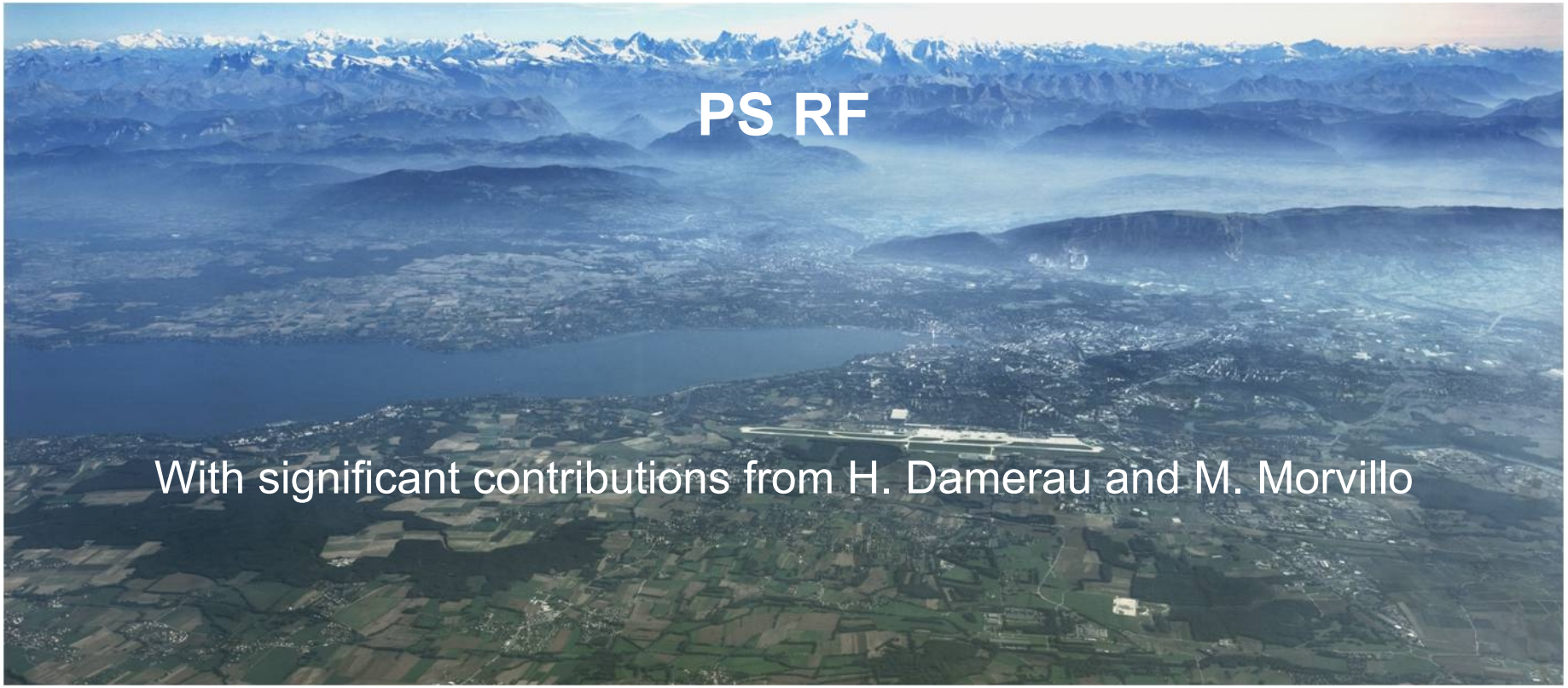


PS RF

With significant contributions from H. Damerau and M. Morvillo

PS RF - Overview

① The PS high level RF system

② Issues in the PS longitudinal phase space

③ Implications for the hardware

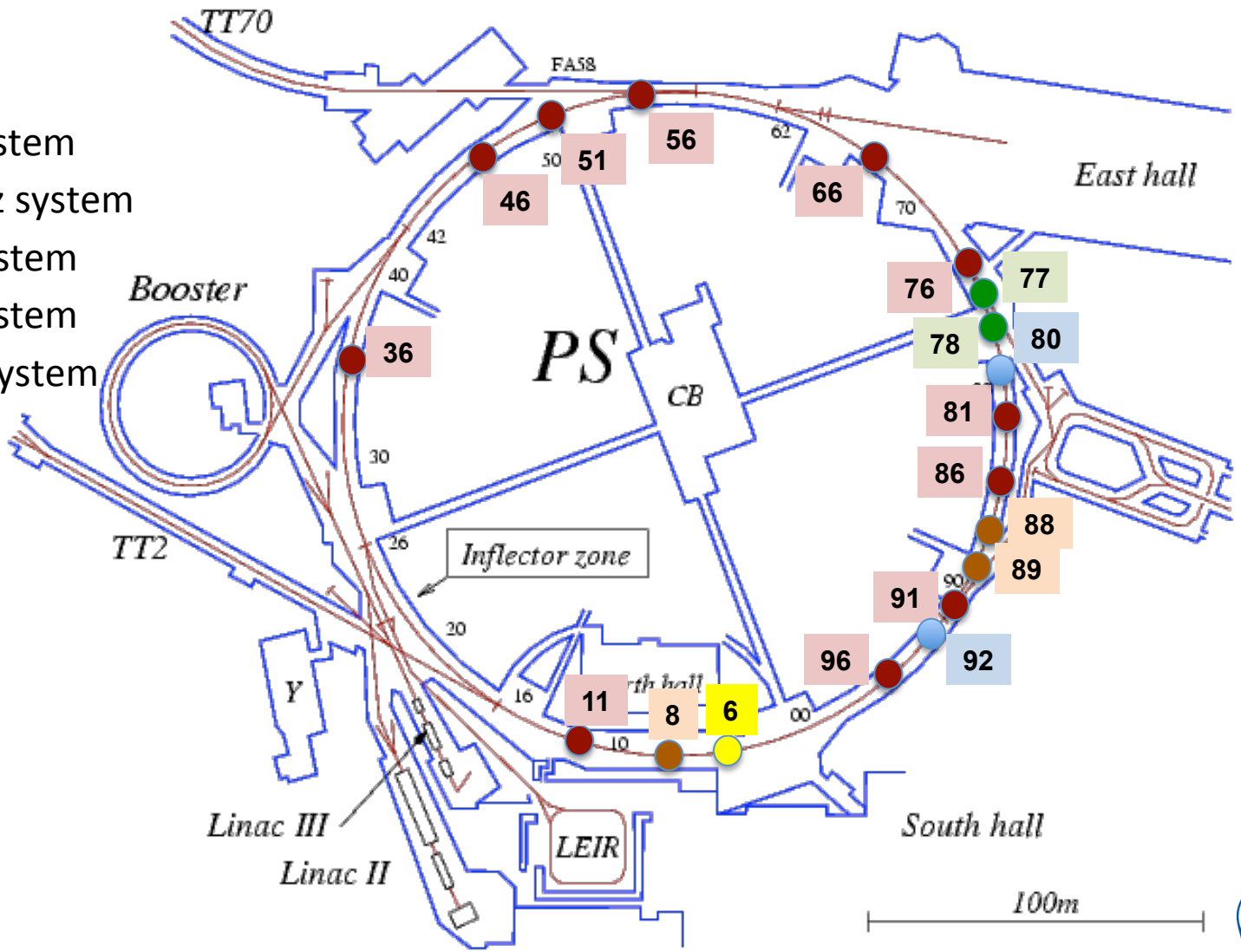
④ The high level RF upgrade program (possible options)

⑤ What is already in the pipeline

⑥ Concluding remarks

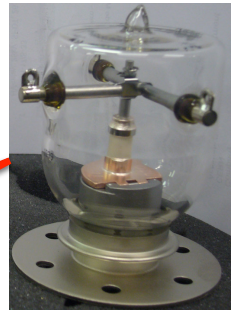
PS high level RF systems - overview

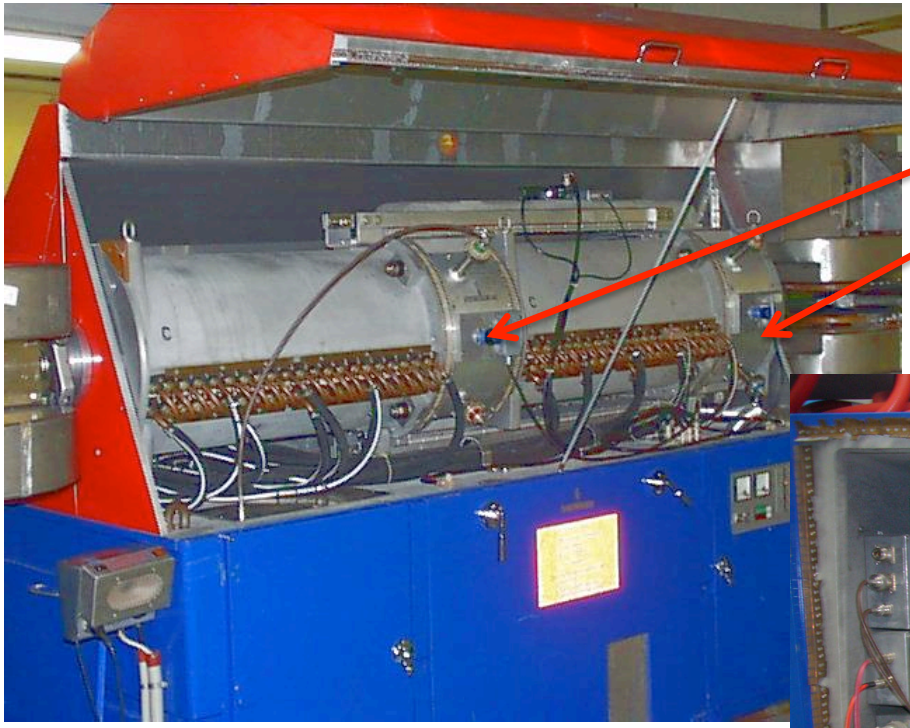
- 10 MHz system
- 13/20 MHz system
- 40 MHz system
- 80 MHz system
- 200 MHz system



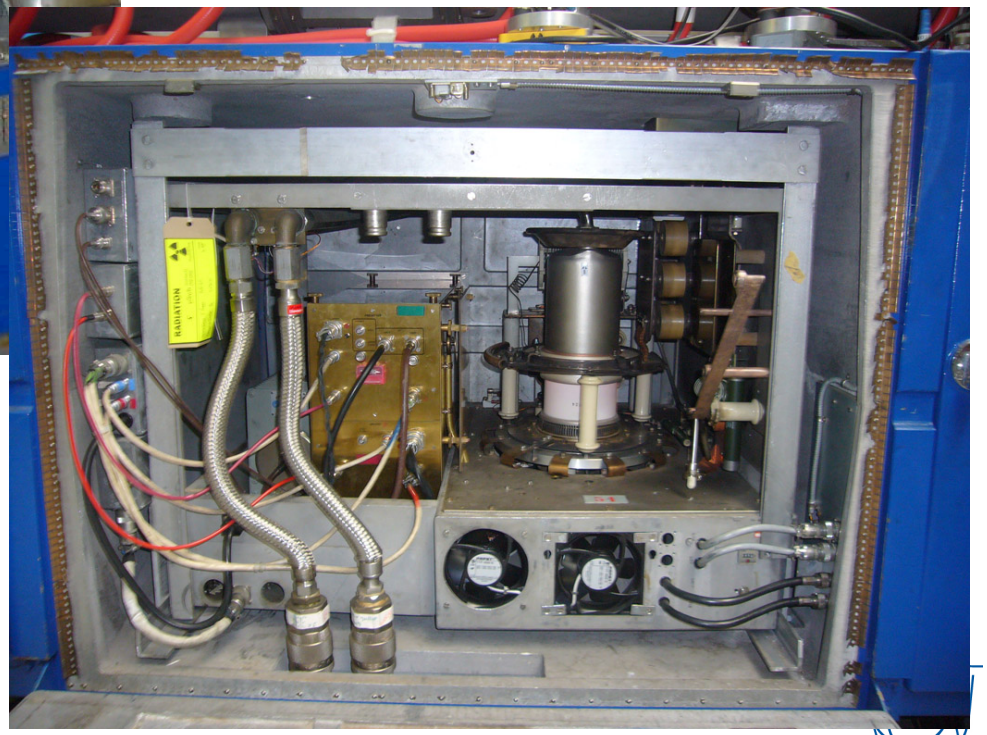
The 10 MHz system

Gap relay





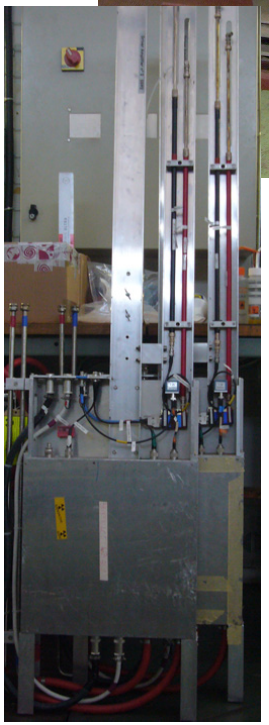
Ferrite loaded cavity
Freq range 2.8 – 10 MHz
2 RF gaps / cavity
20 kV / cavity
Built in 1975, upgraded in 1988



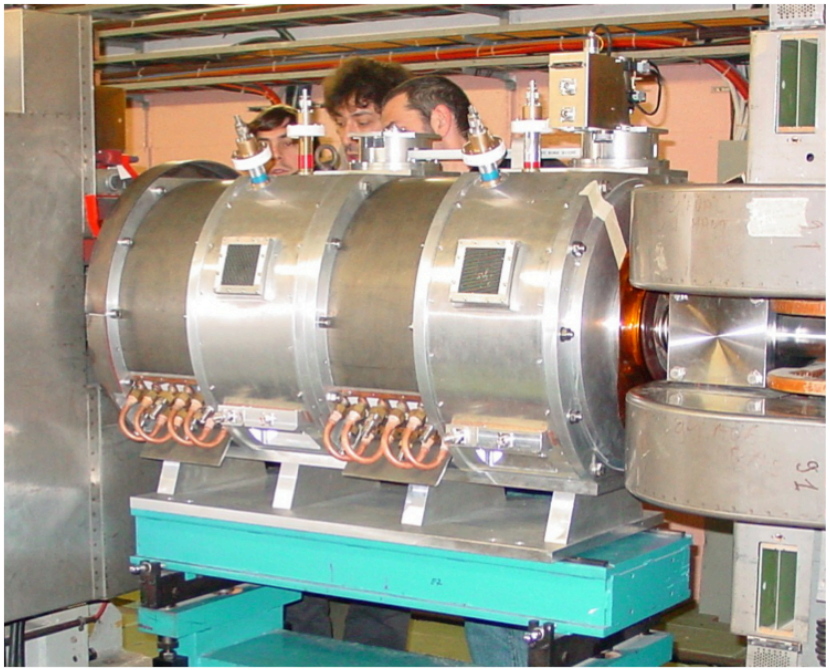
RF amplifier adopting:
3 x YL1056 tubes in the feedback stage;
1 x RS1084 in the final stage.
Housed in the cavity base.

The 13/20 MHz system

Ferrite loaded cavity
Frequencies 13 or 20 MHz
2 RF gaps / cavity
20 kV / cavity peak
Built in 2002

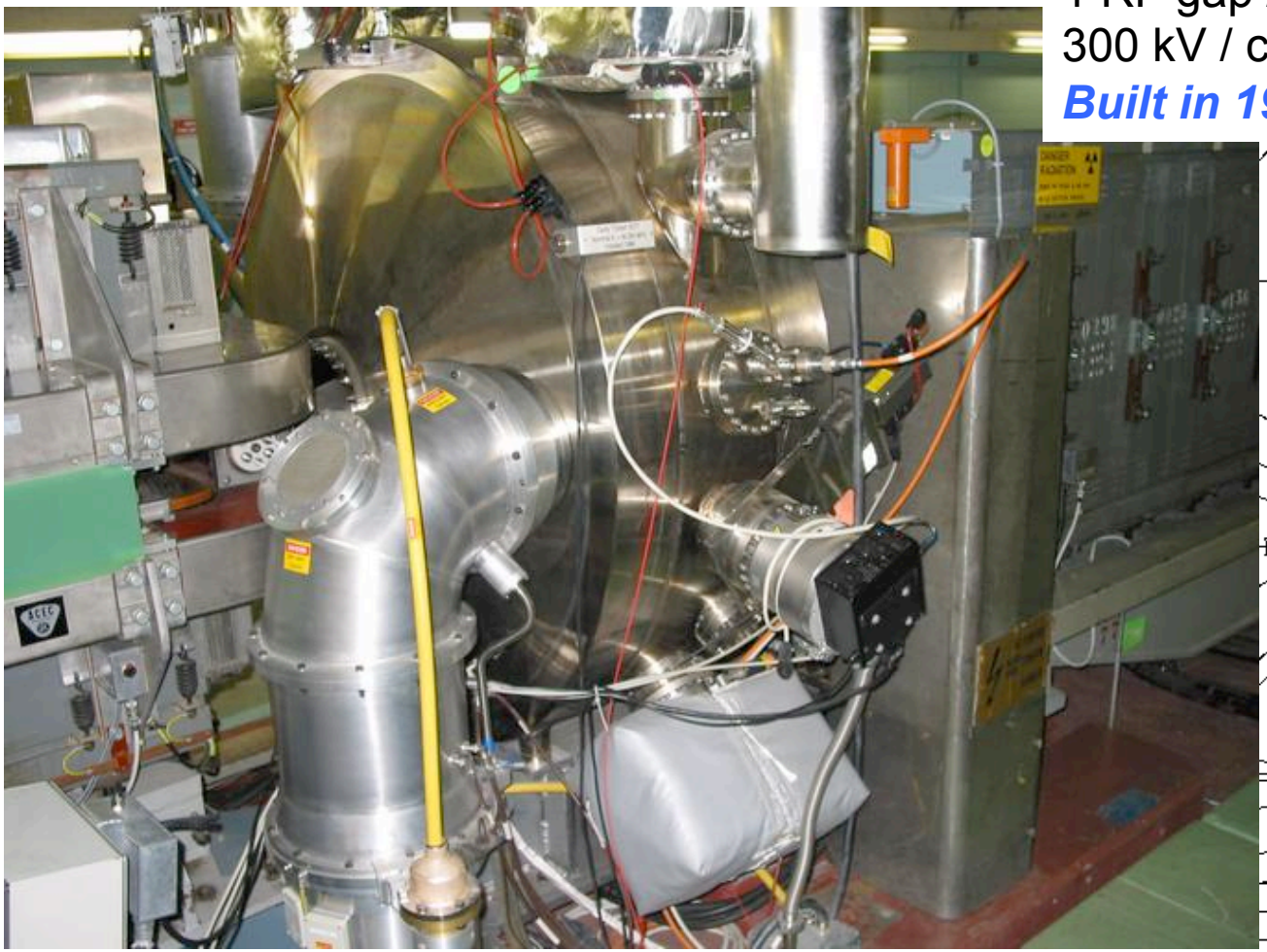


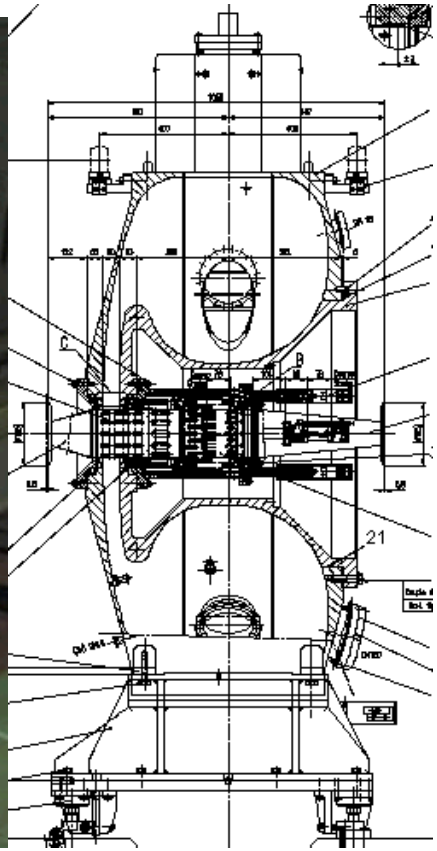
Driver amplifier
Especially designed to slide in the gallery



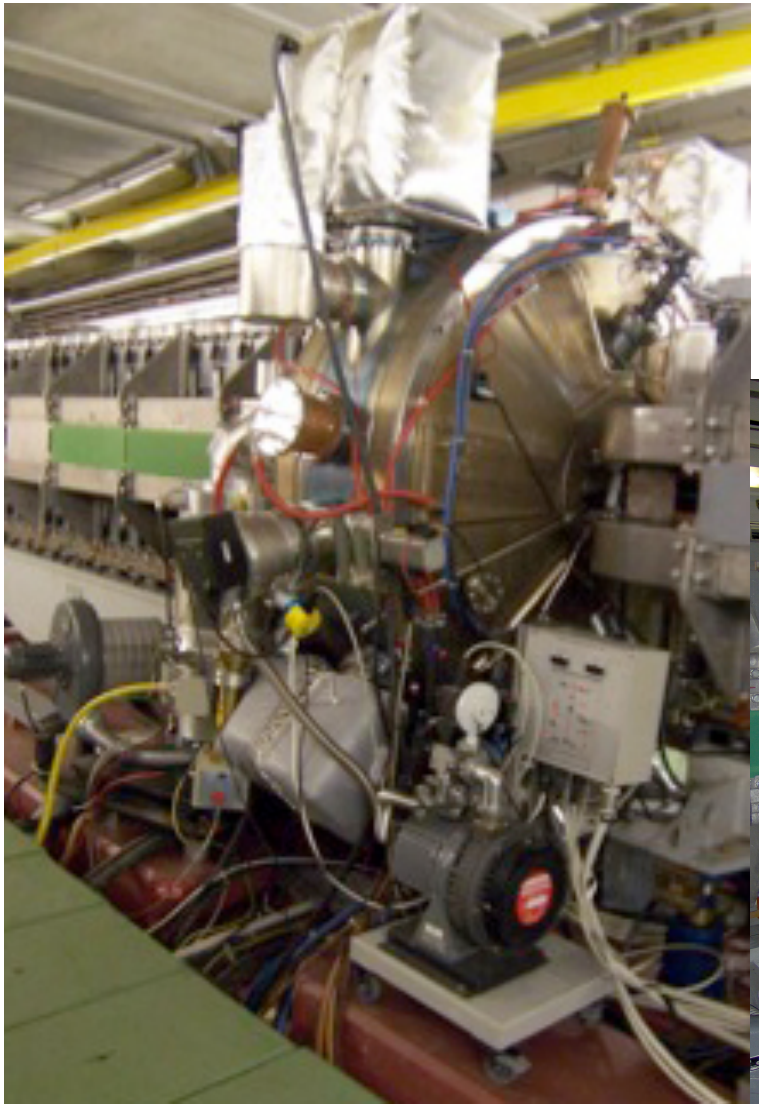
The 40 MHz system

Vacuum reentrant cavity
Frequency 40 MHz
1 RF gap / cavity
300 kV / cavity
Built in 1996

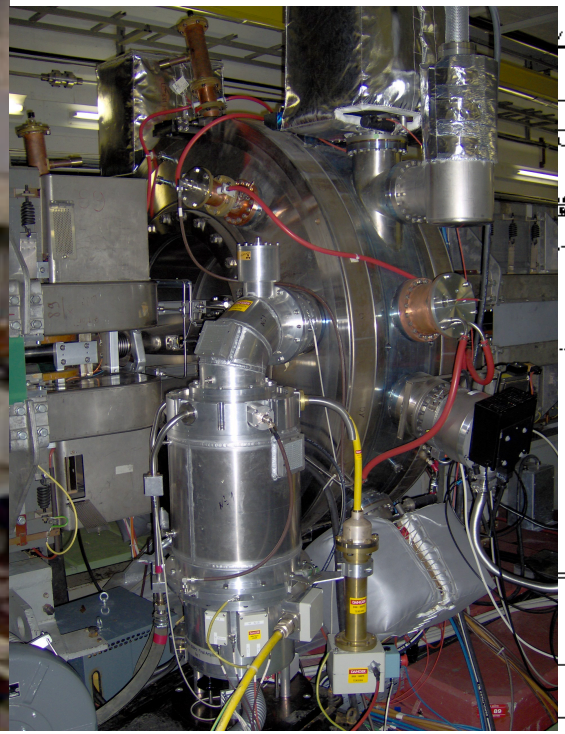


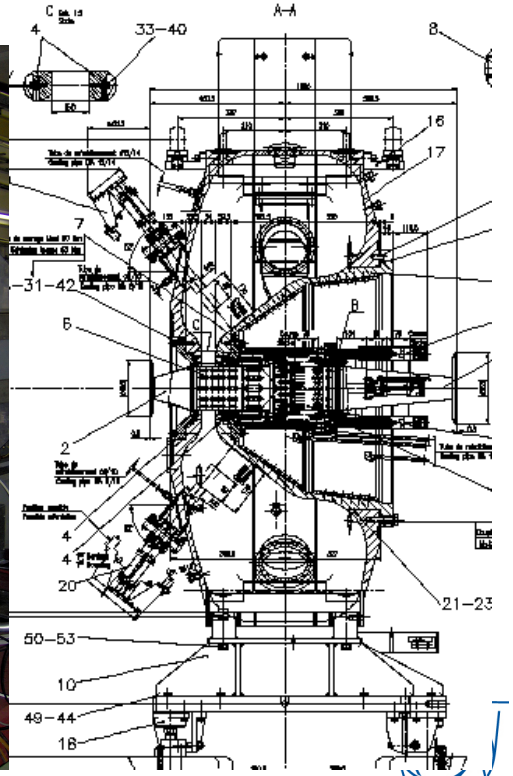


The 80 MHz system

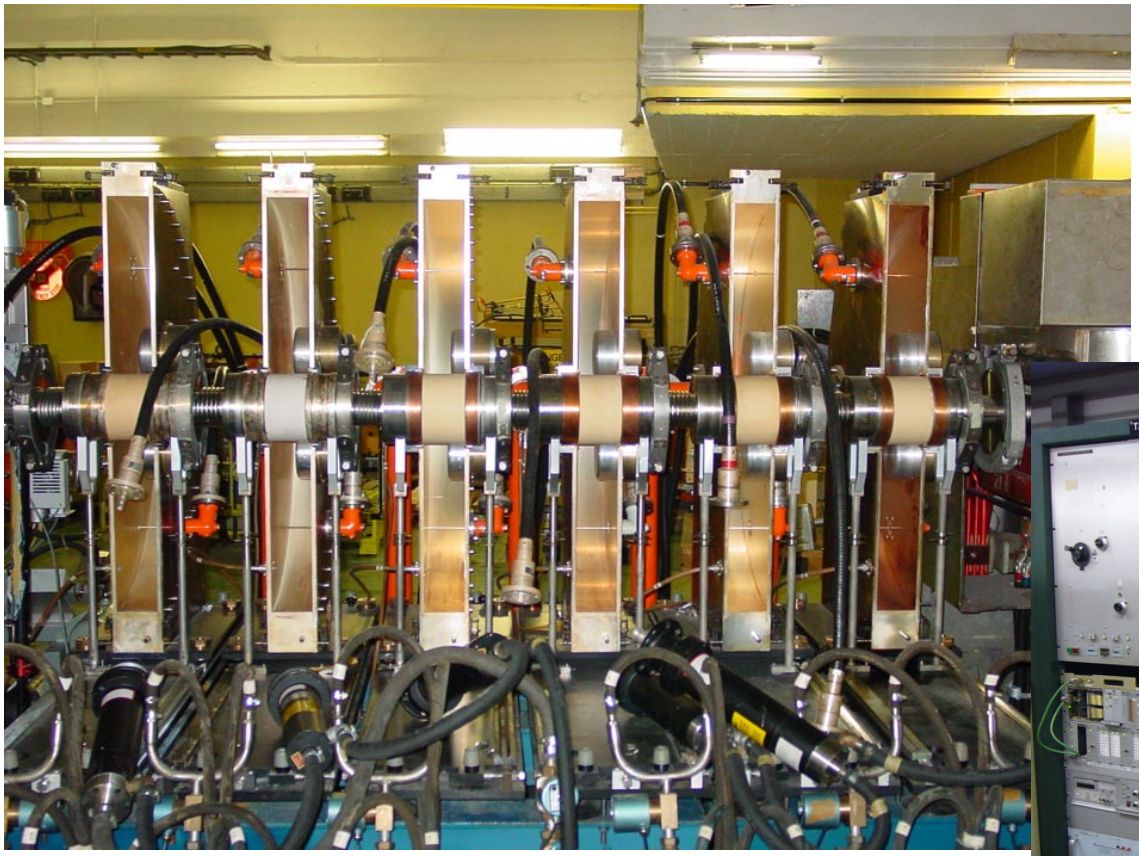


Vacuum reentrant cavity
Frequency 80 MHz
1 RF gap / cavity
300 kV / cavity
Built in 1997





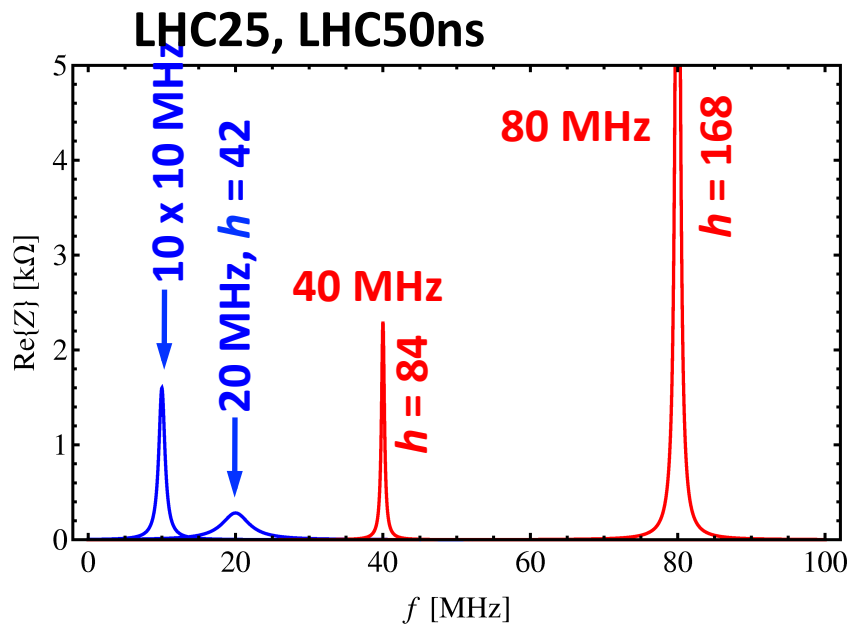
The 200 MHz system

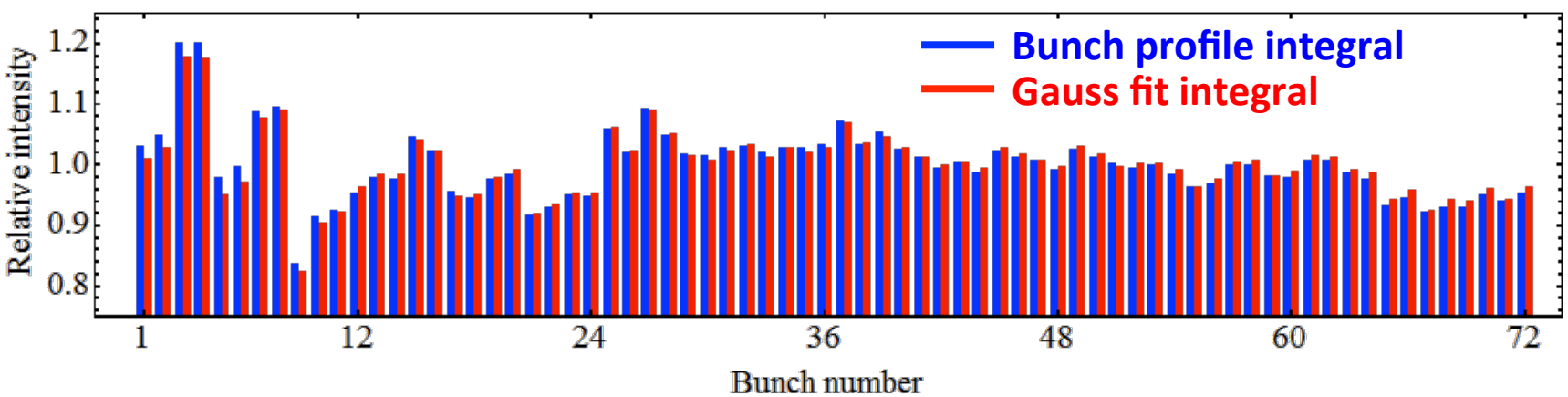


Pill-box cavity
Frequency 200 MHz
1 RF gap / cavity
6 cavities
50 kV / cavity
Built in 1979

Amplifiers and HV power supplies partially renovated in 2005

The PS Longitudinal phase space – CBI & TBL





For more details see S. Hancock's presentation, this LIU Event.

Possible remedies to PS longitudinal limitations

Main longitudinal limitations:

1. **Coupled-bunch instabilities during acceleration and on flat-top**
   - → **New coupled-bunch feedback: based on 1-turn delay electronics**
   - → **Longitudinal kickers: 10 MHz RF cavities or dedicated wide-band cavity?**
   - → **Impedance reduction of all cavities, especially 2.8 – 10 MHz**

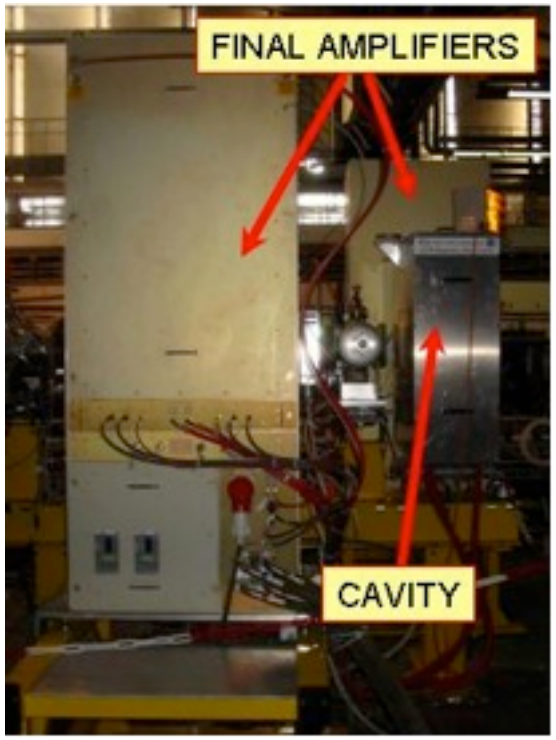
2. **Transient beam loading during bunch splitting manipulations**
   - → **Distributed issue: all RF systems for bunch splittings concerned**
   - → **10 MHz: new 1-turn delay feedback, new feedback amplifier or completely new amplifier?**
   - → **20 MHz: 1-turn delay feedback**
   - → **40 MHz: 1-turn delay feedback, new feedback amplifier?**
   - → **80 MHz: 1-turn delay feedback, new feedback amplifier, fast ferrite tuner?**

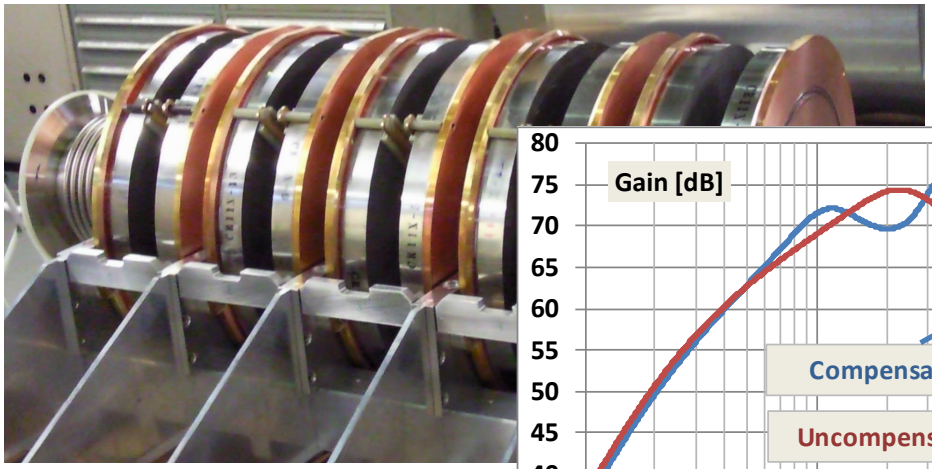
H. Damerau's presentation, LIU Event 2010.

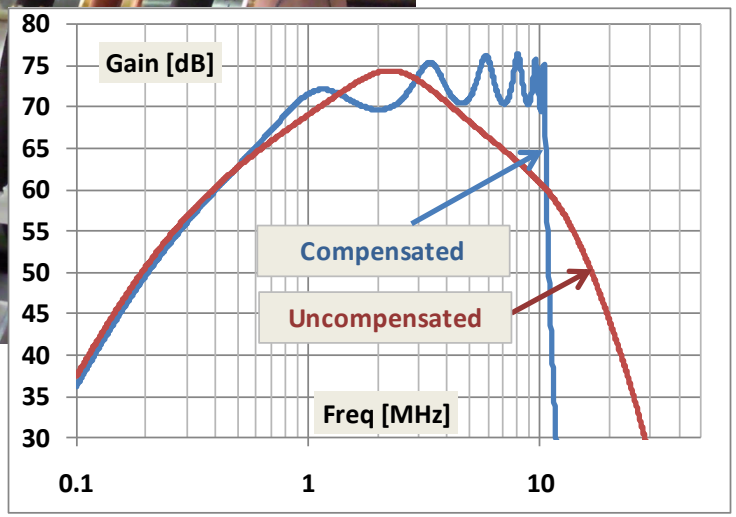
Some ideas for hardware developments

New 1-turn delay feedback around all systems would be beneficial for both CBI and TBL.

A dedicated wide band RF system using magnetic alloy rings in the resonator may result very effective in fighting CBI.







Prototype for PSBC04 RF cavity.

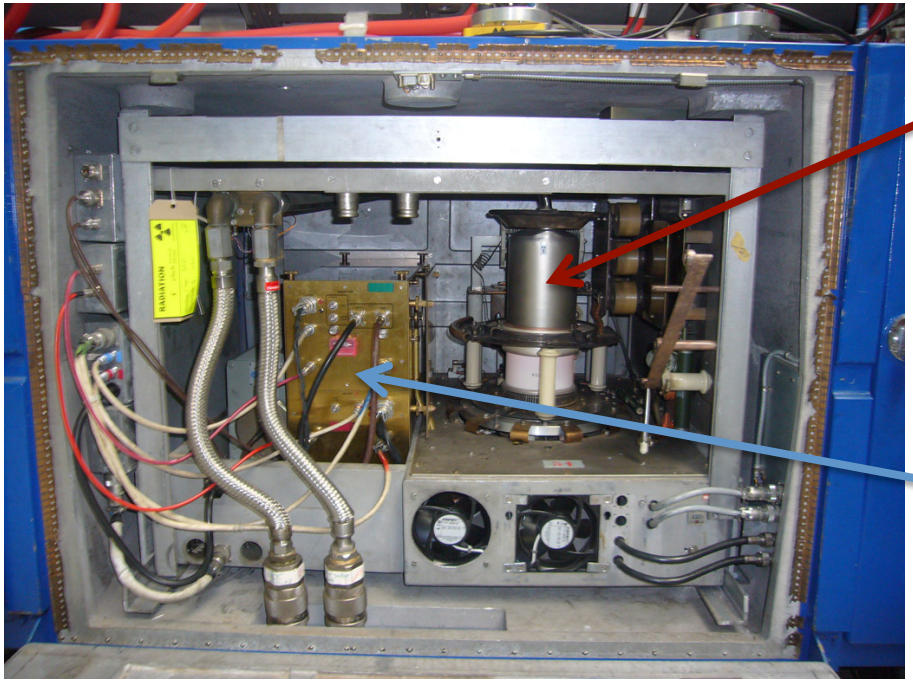
See M. Paoluzzi's presentation, this LIU Event.

LEIR RF system operational since 2004, built in collaboration with KEK.

10 MHz developments

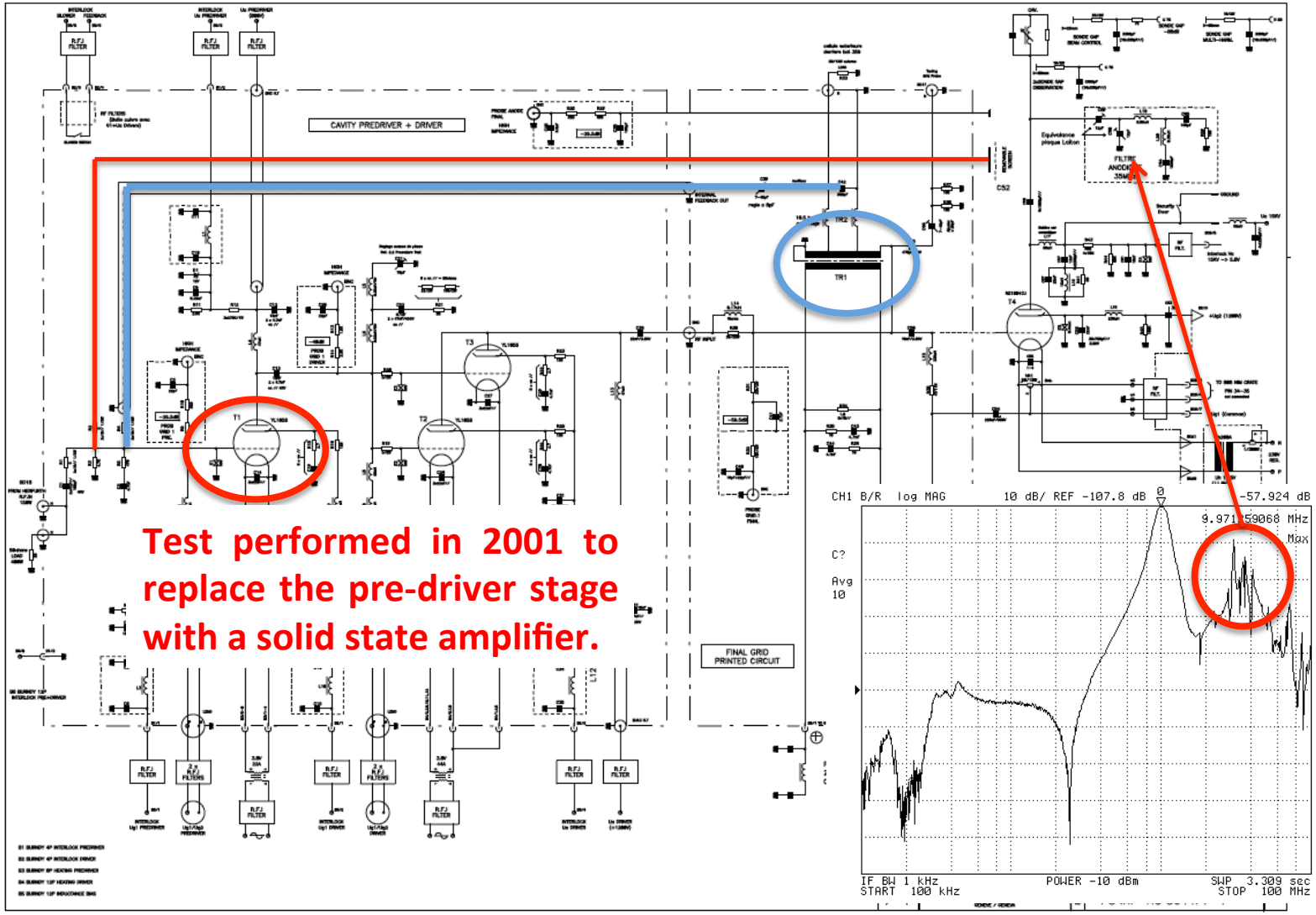
A new 1-turn delay feedback around the 10 MHz system is already in the pipeline.

If possible, an increase of the amplifier fast feedback beyond the present 26 dB could significantly reduce further the cavity impedance seen by the circulating beam.



10 MHz developments – feedback increase

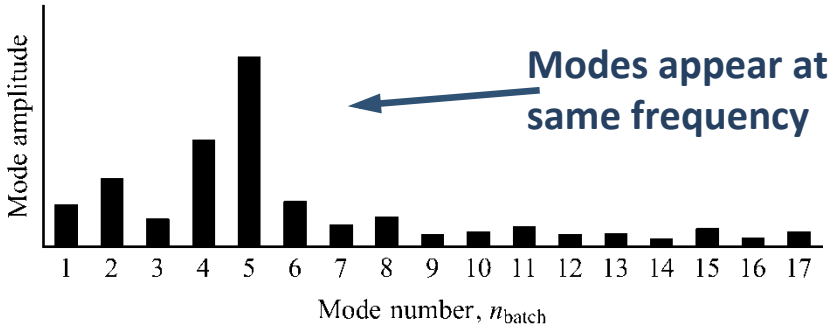
limitations from the present architecture



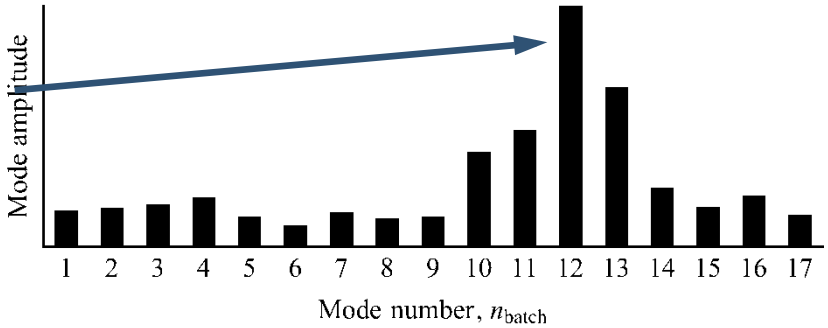
Test performed in 2001 to replace the pre-driver stage with a solid state amplifier.

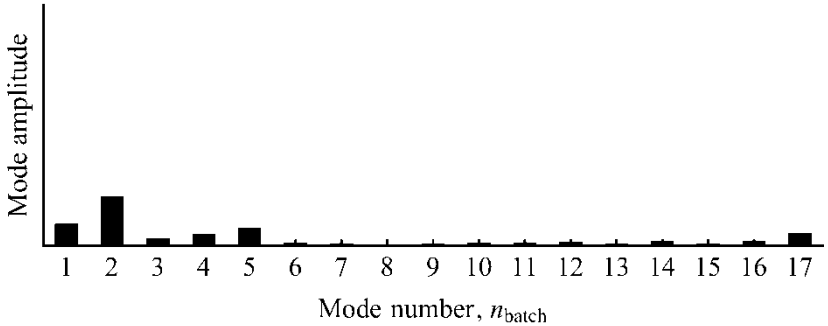
10 MHz developments – second gap relay
installed in 2011

Both gap relays close | **Only one relay closes**



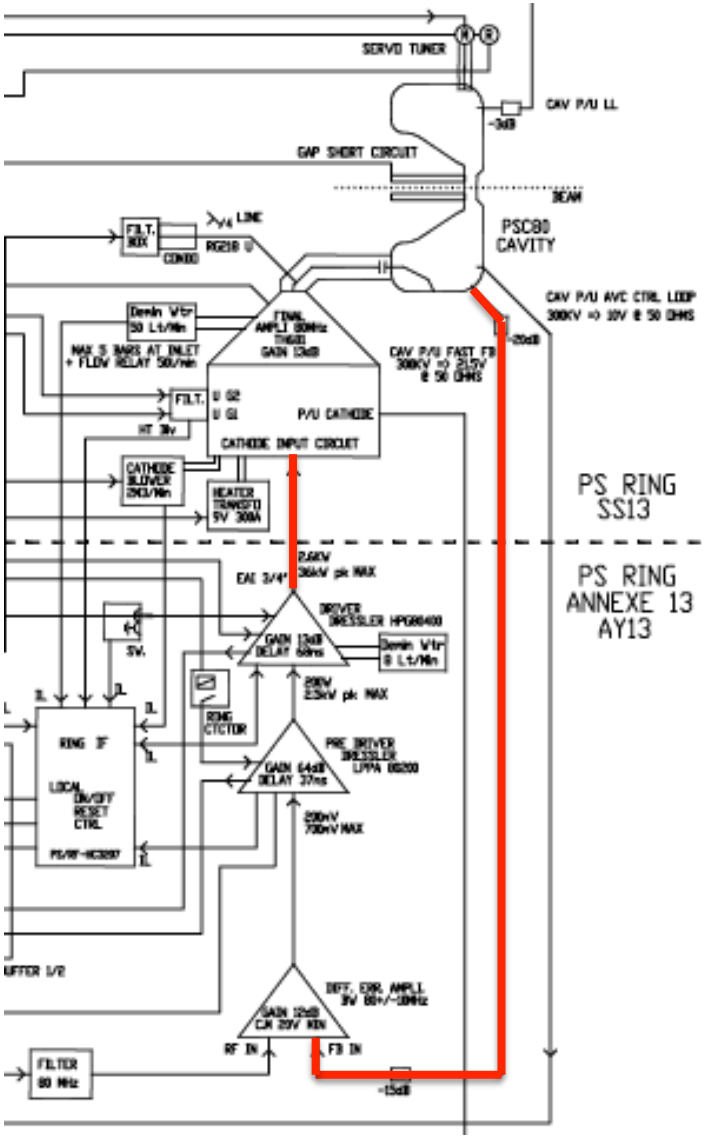
Modes appear at same frequency





With one gap relay closed and 8/10 cavities parked at h=6.5 the result is much more impressive.

40/80 MHz developments – feedback increase

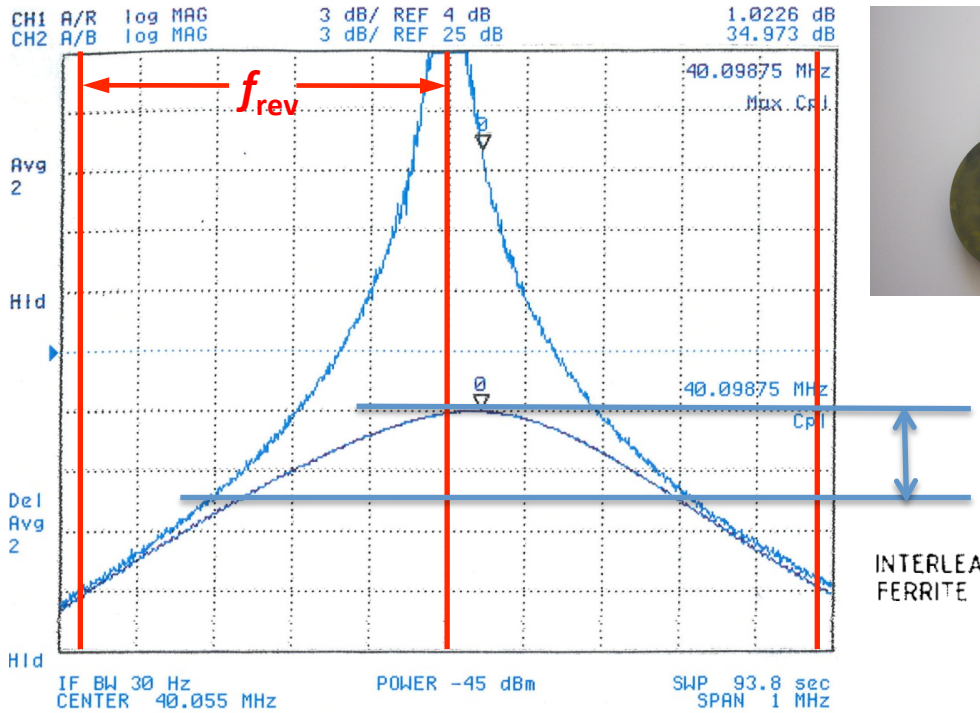


Long cable length from the cavity to the feedback amplifier and back to the final amplifier (120 ns) is a limit to push the feedback beyond the present performance (43 dB) .

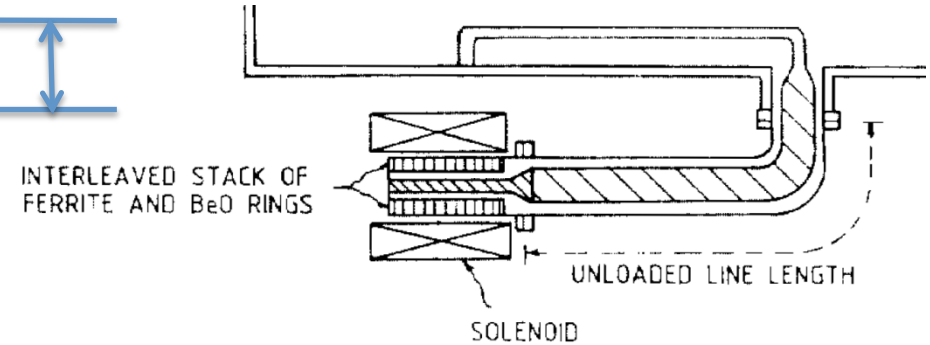
A second limitation comes from the HV power supplies, already limiting the present performance of the system in the presence of high beam loading or cavity detuning.

40/80 MHz developments – cavity detuning

Mechanical gap relay cannot be used in a pulse to pulse operation to reduce the cavity impedance seen by the beam (pneumatic actuator).



Use perpendicularly biased ferrites to build a fast tuner.



By parking the cavities at an intermediate frequency (250 kHz off resonance) 2 to 4 dB could be gained in impedance reduction.

Some planning and what is already in the pipeline

Activity	Schedule	Status
LLRF studies	05/2011 – 06/2012	active
1-Turn delay feedback	01/2012 – 12/2014	active
Coupled bunch feedback	06/2014 – 06/2016	planned
HLRF studies	05/2011 – 12/2012	active
10 MHz system renovation	01/2013 – 06/2018	planned
Longitudinal kicker in the PS	01/2014 – 12/2017	planned
40/80 MHz feedback renovation	06/2012 – 06/2017	planned
Fast tuner for the 80 MHz system	01/2012 – 12/2015	active

Concluding remarks

- The final choice among the possible optional developments will depend on experimental results from MD studies and operational decisions;
- A prioritized list of interventions will be decided soon, depending on impact, available resources and possibility of success;
- Aspects related to the maintenance of equipment and to the application of the ALARA principle will be a relevant factor in the decision process;
- The R&D program will be anyway strongly dependent on available resources and on manpower, in particular.

LHC Injectors Upgrade

THANK YOU FOR YOUR ATTENTION!