RF Preparation for Beam in 2009

- Status - Before and after Sept 19th 2008
- Shutdown work
- Commissioning needed before beam in 2009
- Commissioning with beam in 2009
- Risks and Spares
- Conclusions

E. Ciapala, on behalf of the AB-RF Group

RF System – Status up to Sept 19^{th}

- Klystrons, controls & LLRF electronics in UX45 cavern
  All fully commissioned

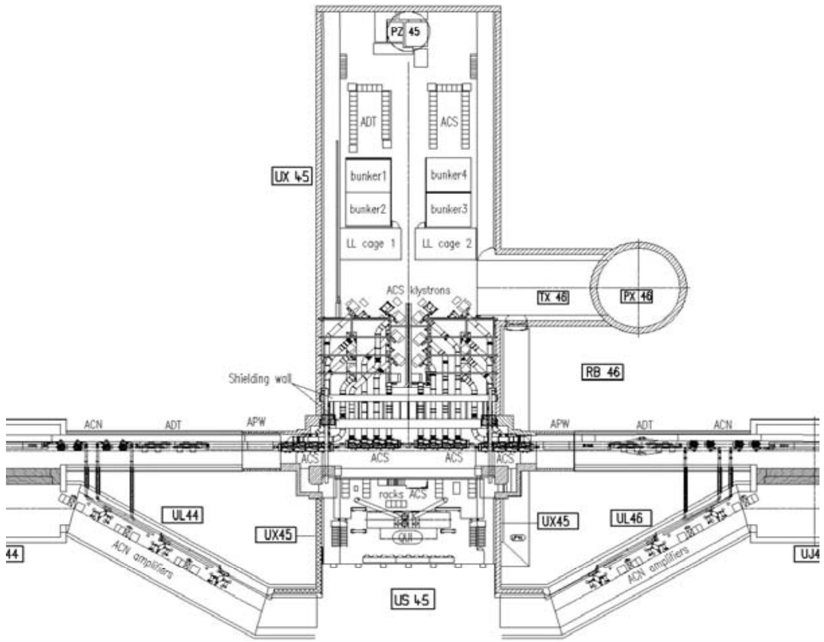
- 16 ADT Transverse Damper kickers- 4 modules left / 4 right of IP4
  Kickers & amplifiers fully power tested

- 16 SC cavities, in 4 Cryomodules (each 4 single cell cavities).
  All 16 conditioned to nominal gradient in 2008
  (Checked with beam)
  BUT Problem with tuning mechanism found..

- APW Wideband Monitors 3 left / 3 right of IP4
  Set up and used for beam measurements

- Beam controls for RF synchro, capture,
  and transverse damping tested with beam
  Beam 2 successfully captured

- Collision, acceleration, radial loop
  Nearly tested (Was planned Sept $19/20^{th}$) 2008



19th September - RF System

At the time of the incident:

- All cavities and dampers were running
- Cavities on Sector 3-4 side cut due to He pressure (D-Line)
- Cavities on 4-5 side continued to run, switched off manually ½ hour later
- Dampers continued to run on both sides, switched off manually later
- No vacuum pressure rises on cavity gauge recordings at time of the incident
- Sector valves on modules manually closed later (Had been open….)
- ADT kickers have been taken to full power since the incident, without problem

- "Contamination of the APWs, cavities or ADT kickers does not seem likely"

  Confirmed by recent opening up of LSS vacuum sectors…..(Vincent Baglin)

Actions done, (Following Incident)

- Clean up of thin layer of dust on all the RF equipment in IP4
- Removal and cleaning of ADT kicker amplifiers
  (Minor component changes also done to improve potential reliability issues identified during HWC)

Incident of 19^{th} September

Risks & Precautions for SC modules:

- Near miss - opening of both vacuum pipes. Similar event close to IP4, with sector valves open would have resulted in dust contamination in all cavities or even in mechanical damage.

- Mechanical damage will result for a full vacuum aperture opening (100mm) near the cavities, 12 bar would be reached in He tanks - See Analysis done with Cryo and SC. 50 mm would be protected by safety valves 2.1 bar

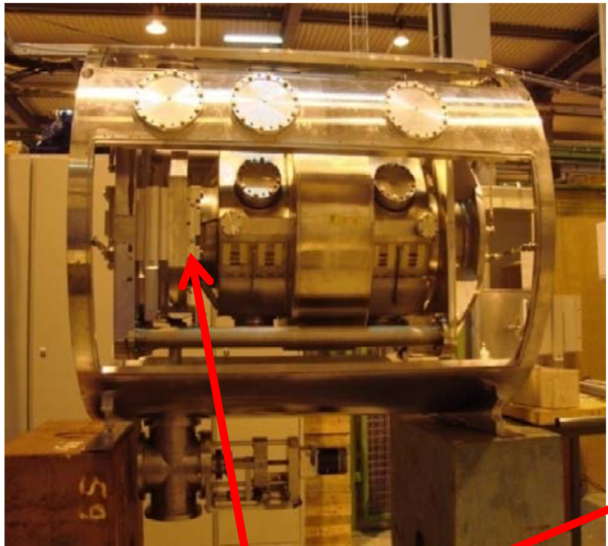
- Can regard this as highly unlikely to occur, with the precautions now in place. Sector valves must always be closed during magnet commissioning .

- Use of fast sector valves under study with Vacuum Group. Brings its own problems..

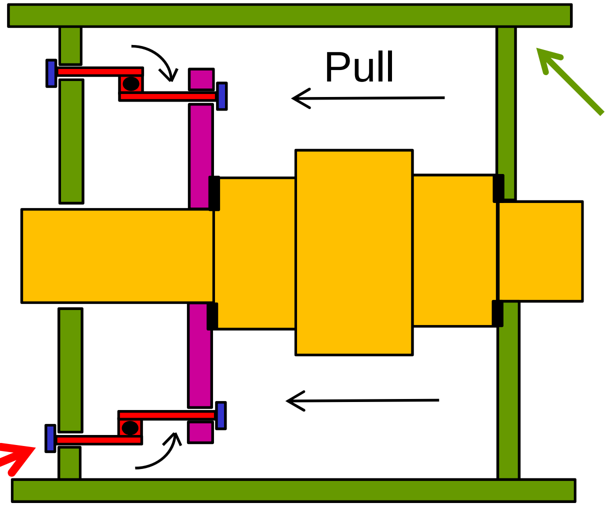
Cavity Tuning Problem

End August, Cavity 2 Beam 1 – suddenly could not be tuned (out of range)
“Bricolage” done to increase pull the mechanism back on tune..

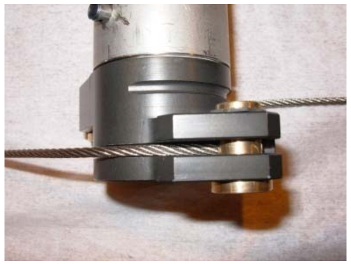
Cavity (side view)

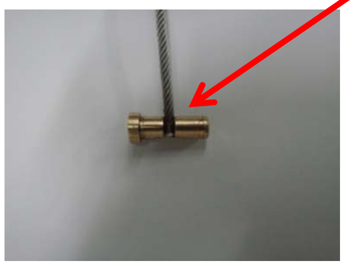


Cavity schematic top view)



Torsion bar

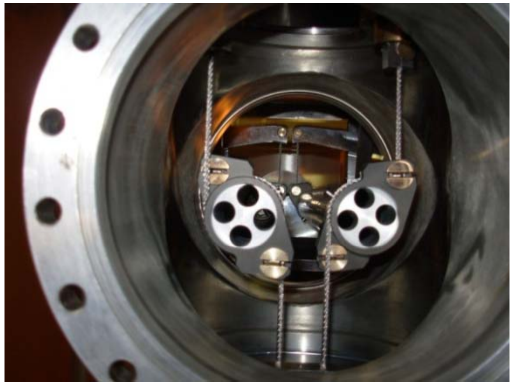




Broken cable !

Cavity Tuning - Repair

- Dowel blocking in its lever, - New cables and dowels made for all cavities

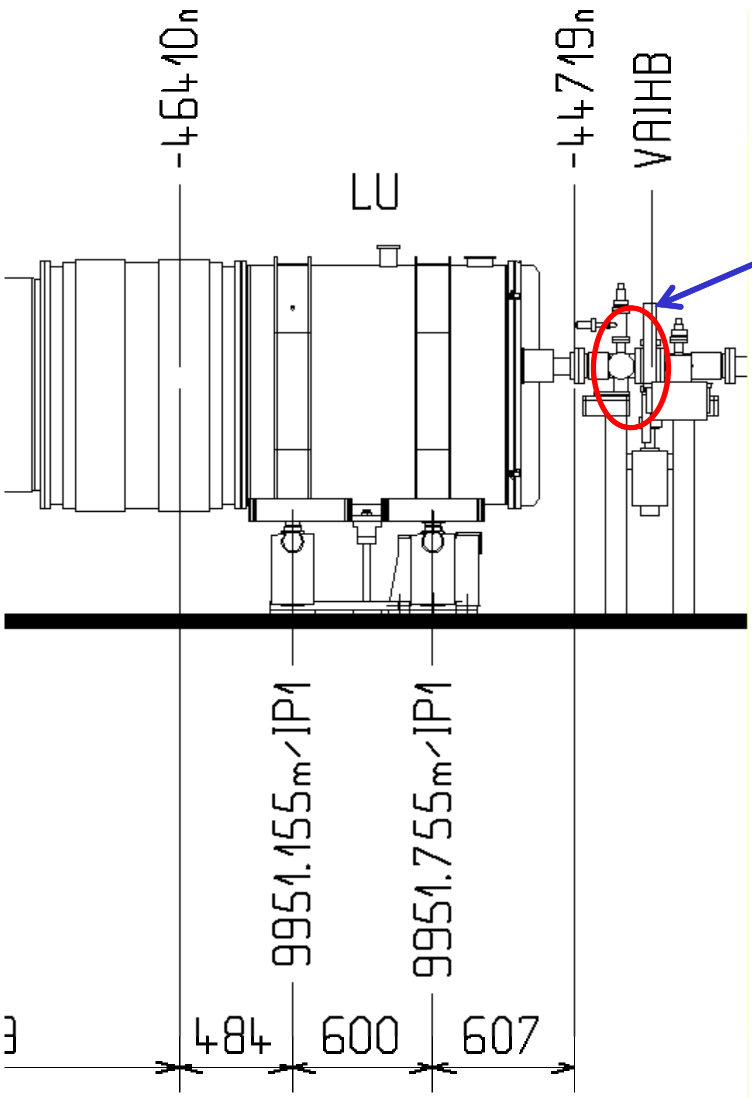


- Fortunately can be repaired in-situ, thanks to removable covers on cryostat

Nevertheless a tricky job,

But nearing completion – End of this week

Undulator Left of P4 Courtesy Vincent Baglin



If the removal of these components is enough to dismount the LU, then we probably don't need to vent the RT vacuum system

Opening of RF Sector would mean baking ADT kickers and APWs,

<u>Neither are desirable</u>

(ADT Electrodes & APW Feedthroughs)

Hardware re-commissioning before beam

ACS system:

- Power System: Full check-out all klystrons with waveguide shorts, before cool-downs.
- Roof blocks back in place by week 15 (Mid April) - Before cool down
- Cool down Sector 4-5 – close monitoring of the cool down, test of interlocks & cryo control, but no major difficulties expected
- Will not do low power tests & measurements (Avoid waveguide manipulations)
- Conditioning to 2 MV/cavity in 4-5 – should go quickly i.e. 1 to 2 weeks
- Set up cavity controllers in 4-5, RF loops 1-2 days/cavity i.e. 2 weeks
  ACCESS in UX45 NEEDED
- Keep running till beam available, for testing of software and SR4 beam control electronics (Organize for minimal access in LSS4 !)
- Sector 3-4, Cool, down, conditioning, loops - same time, or faster if all goes well.

ADT system:

- Check of powering to nominal levels, after amplifier work
- Re-checks & calibrations on SR4 beam control electronics

APW:

- Setting up of instruments in SR4, no intervention in tunnel needed

Next Stages of Beam Commissioning

Before beam

- Re-Check all hardware & software for beam controls
  (frequency ramping HW & software was tested 19th Sept)

With Beam

- Capture B1, set up phase loops
- Capture both beams, set delay for collision point (BI PUs in P2, RF PUs at P4)
- First acceleration on synchro loops, observe orbit & radial displacements
- Commission radial loops (RF PU or average orbit ?)
- Ramp
- Re-sync of B2 after acceleration for radial loop
- Switch to reference synthesizer, then collisions
- Follow the commissioning plan to high intensity….
- Test longitudinal damper on ACS cavities to damp phase error of successive batches before inclusion into phase loop average

- Note : Need regular alternate inject & dump (Reloading of settings in extraction kickers, definition of separate B1 & B2 cycles, “Dynamic Destination” in telegram)

Risks, Spares etc.

Other Risks to SC Cavities – in addition to vacuum pipe break.

- Cavity / Coupler incident with RF
  - In LHC, could lead to contamination of two modules

- Cryogenics malfunction :
  - Risk of severe mechanical damage to cavities & He tanks
  - Maximum precautions taken, adequate, & with redundancy.
    But all systems need to be pre-checked before cool down, and monitored during running.

Down time

Removal of module, dismantling, cavity rinsing, re-assembly, re-conditioning, roughly ½ year to 1 year. The time is considerably increased if we have to procure new cavities.

NOTE The cumulated final testing of all the four installed RF modules in SM18 took over three years

Spares Situation for SC cavities

- We have one spare module in SM18, still trying to complete power tests and conditioning (Limited He with 6 kW plant, inefficient cryo line to cavity bunkers) "Competition" with magnet work

- We have only one spare bare cavity (In He Tank)

- We should consider obtaining 3 or 4 more cavities, equipped with He tanks. Would make two modules available in reasonable time if we do have problems Could run with 12 MV / beam (16 MV is nominal)

Spares Situation for Other LHC RF systems

- Klystrons & power equipment – Have 3 plus 2 in test stands, one spare circulator/load, 2 in test stands.
- ADT kickers – 2 spare modules (4 kickers)
- ADT amplifiers – Putting 4 together
- APW – 2 spares from parts in Lab
- Beam control & electronics - OK but there are long term obsolescence issues for critical components

Conclusions

- 2008 was a very good year:
  Important milestones were passed in HWC and the first beam tests. (Successful test of all equipment, ACS successful capture with good lifetime, ADT preparation)
- No major problems anticipated for RF commissioning for beam, providing sufficient time allowed for “cold” tests.
- However, access restrictions in UX45 would make life difficult. Would need to implement safety measures such that access in UX45 is safe and allowed with the sectors 3-4 and 4-5 cold
- Taking precautions and extreme care need to be maintained, especially with cryo and vacuum risks for SC cavities.
- Commissioning to higher intensities, increasing bunches, will need time for RF work (ACS and ADT)
- Short review presented – Expect more on RF issues next Chamonix…

Thankyou

Spare Slides

Risks & Mitigation

Risk Analysis for SC He tanks & modules (B. Delille, S. Claudet, L. Serio)

Class/ Case	Risk Situation	Heat load	Mass flow	Pressure reached (bar)	Derogation
1a)	Static losses D line blocked, no wrl	150 W	17 g/s	1.8 with SVs *(4x2mm dia. needed)*	Tank cold - 1.8 bar max
1b-1)	D line overpressure, non-return valve failure (open) 5 magnet quench		2 Kg/s	1.8 with SVs *(4x23mm. needed*	Exceptional - 1.8 bar max.
1b-2)	D line overpressure, non-return valve failure (open) 25 magnet quench		10 Kg/s	2.1 with RDs *(4x36mm needed)*	Exceptional - 2.1 bar max.
1b-3)	D Line overpressure warm, non-return 5% leakage 25 magnet quench 20 bar		10 kg/s	2.1 with RDs *(4x34 mm needed)*	Exceptional – 2.1 bar max
1c-1)	C line blocked open (cold)		350 g/s	1.8 with SVs *(4x10mm needed)*	Tank cold – 1.8 bar max
1c-2)	C line blocked open (warm) - 2 x 1.5 bar SVs per module		80 g/s	1.5 with special SVs *(2x24mm needed)*	1.5 bar max - Safe.
1d)	Insulation vacuum break	11.4 kW	1.27 Kg/s	1.8 with SVs *(4x18mm needed)*	Exceptional - 1.8 bar max Opening of cryostat discs (P<1.5 bar)
1e)	Sustained RF quench	150 kW	2.9 Kg/s	2.1 with RDs *(4x48mm needed)*	Exceptional & worst case - 2.1 bar max.
1f)	Beam vacuum break (50 mm aperture – 350g/s air indrawn)	147 kW	2.8 Kg/s	2.1 with RDs *(4x48mm needed)*	Exceptional - 2.1 bar max.
2a)	Beam vacuum break (100 mm aperture)	480 kW *(HL limited by tank surface area)*	9.2 Kg/s	12 bar *(Pressure due to 50 mm piping)*	Exceptional & exceeds press test, even with opening of RDs. Risk of rupture He tank & opening of cryostat discs (P<1.5 bar).

Table 1: Summary of failure situations and consequences.

Risks and Consequences

- SC Cavity Experience in LEP:
    - No cavity was ever totally destroyed.
    - Vacuum incident in Pt 8, one cavity polluted, had to be removed & rinsed
    - One cavity was destroyed in the test stand when a HOM coupler melted.
    - No power coupler breaks, no cryo incidents.

Other SC Cavity Issues

- Cavity 21 can be used as spare, build 3 more. Hold 4 cavities with helium tanks.
- Coating 4 cavities: 13 weeks including equipment setup, 6 if equipment already available.
- In the case of a vacuum accident which deforms cavities or physically damages He tanks:
- Cavity + He tank: 70kCHF, ~300kCHF for 3 spare cavities if made in industry. Time to manufacture ~2 years.
- Experience in LEP, no cavity from the machine was ever thrown away. One vacuum sector was vented in Pt 8, one cavity polluted, rinsed, total time 3 months. One cavity was destroyed in the test stand when a HOM coupler melted.
- Full opening of beam pipe next to module to atmosphere will result in He vessel rupture and cavity collapse. Half aperture will be survivable with rupture discs. A He incident could be higher pressure than 1 bar, but normally colder than room temperature.
- Accel may not be able to make cavities in 5 years time. All manufacture could be done at CERN except welding.
- Fast valves: Miguel looking at possibility of installing fast valves. However dust behind shutters can cause pollution if too close to cavities.
- Running cavities at half gradient would be possible, possibly limited in voltage at capture.

Recovery of SC RF Cavities

Action	Time (w)	
Take out	0.5	
Radiation cooldown	?	
Disassemble	2	
Rinse one individual cavity, drying and pumping	0.5	
Assemble in vertical cryostat	0.5	
Test in vertical cryostat	1	
Repeat last 3 steps for 3 other cavities	3	With some overlapping
Assemble into cryomodule (clean room)	6	Assuming HOM and power coupler spares available
Pumping and leak test	1	
Installation in bunker, vacuum, cooldown, RF low power measurements	2	
High power tests & conditioning in SM18	3 x 4	Only one klystron in SM18
Warmup	2	
Transport + installation in Pt 4	2	

Repair steps to take in case of irrecoverable pollution of a module: **Total 24.5 weeks**

In case of mechanical damage – add procurement of cavities 1 year at least