LHC Low Level RF

Technical Review

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and the support of EST/DEM

Reported by P. Baudrenghien

The calendar so far

- LLRF Project started in Sept 02
- Brainstorming sessions. Detailed study of the LLRF of RHIC (BNL), SNS (Los Alamos), PEP2 (SLAC) and our local expertise (AD, PSB, PS, SPS and LEP).
- Functional specifications and proposed implementation Jan 03
- Choice of platform (customized VME) Feb 03
- Design of modules March 03 ……

Still in the prototyping phase…

The four sub-systems

- Cavity controller. One per cavity. UX 45.
- RF synchronization. One. SR4.
- Beam Control. One per ring. SR4.
- Longitudinal Damper. One per ring. SR4.

Note: The installation of the 200 MHz damping system (ACN) is staged. However a limited amount of damping can be achieved using the ACS cavities.

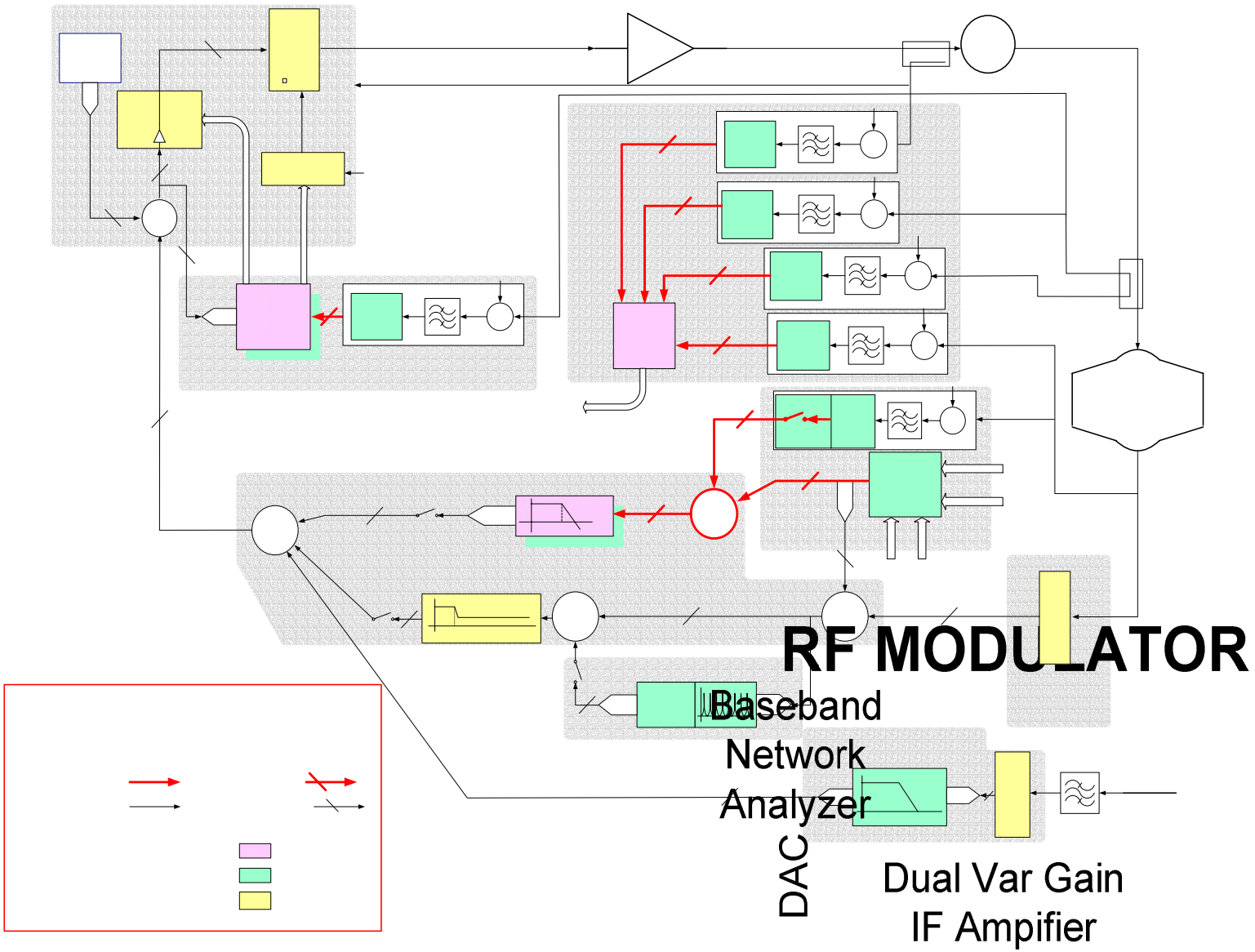
Cavity Controller. Functions.

- Control phase and amplitude of cavity voltage.
- Keep demanded klystron power reasonable (300 kW max).

Cavity Controller. Implementation.

- Klystron Polar Loop: Compensates for the klystron gain/phase changes.
- RF Feedback Loop: Reduces the cavity impedance by 10 at the exact RF.
- 1-T Feedback: Adds factor 10 reduction on the revolution frequency side-bands.
- Tuner Loop: Minimizes klystron current.
- Set Point: Customizes the voltage for each bunch.

Cavity Controller. Block Diagram.

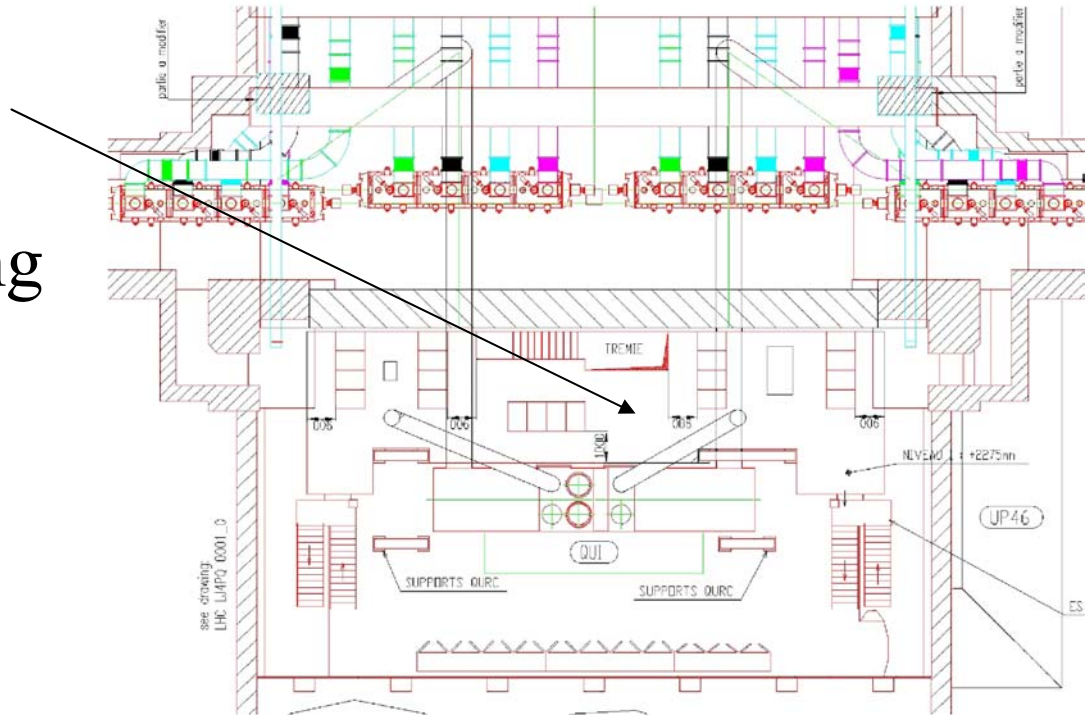


Cavity Controller. Status (1)

- Technical specifications complete.
- Technical solution found/chosen : I/Q as in PEP2 and SNS, Hybrid feedback (Analog/Digital).
- Platform chosen: VME.
- Test in SM18 in April 04: 7 RF modules needed containing 9 cards…work started on all cards but time is running fast …
- Final system: 31 cards in 22 modules to be developed by end 05.

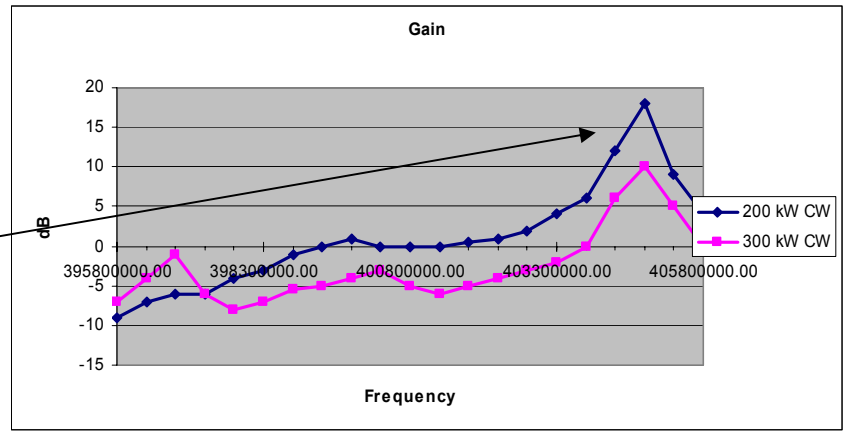
Cavity Controller. Status (2)

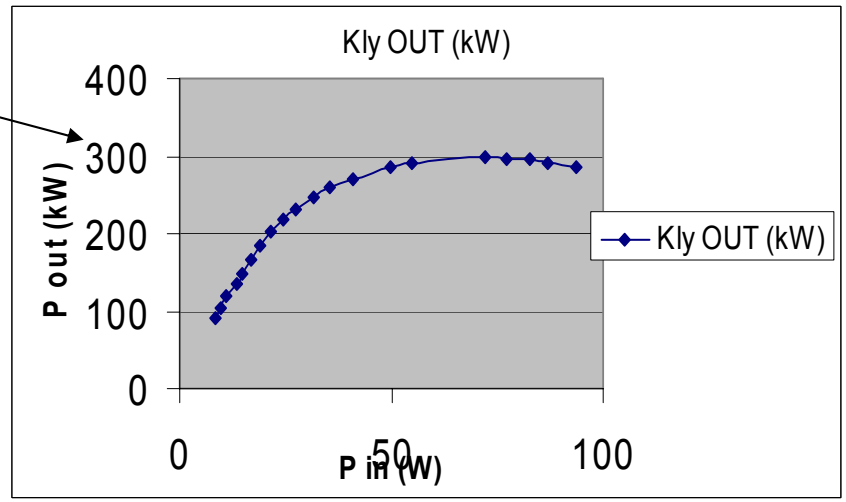
- Integration: 1 rack per cavity on a platform in UX45.
- Cable list and routing done.



Potential technical problems (1)

- Behavior of the RF feedback with
  - Spurious klystron resonance around 404 MHz
  - Non linearity of klystron (similar to PEP2)





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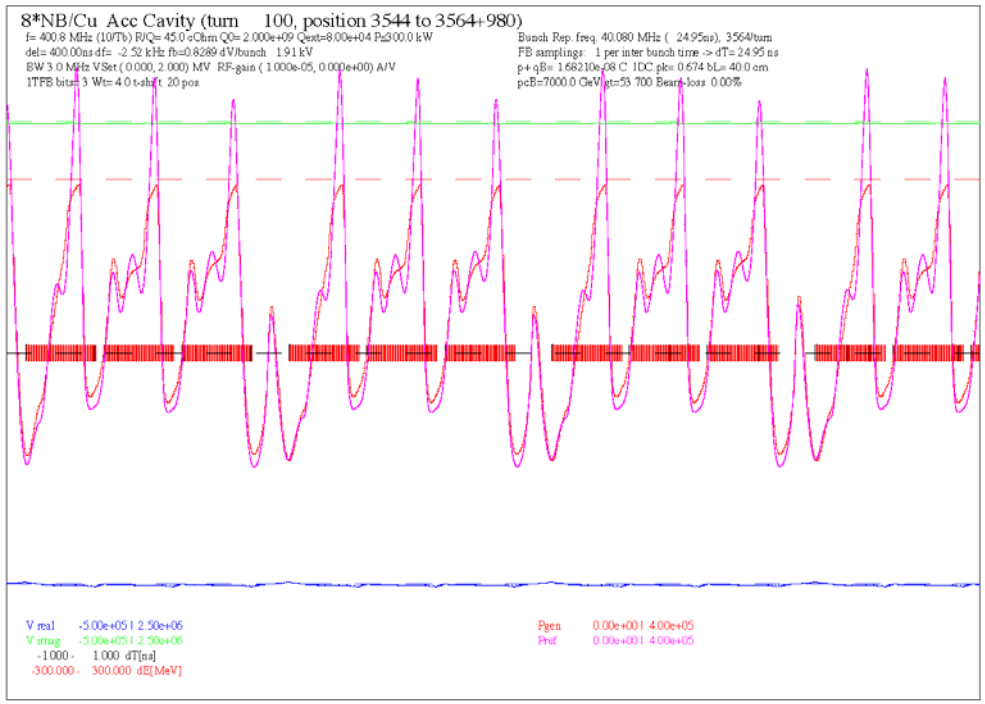
Potential technical problem (2)

- Dealing with klystron drive transients.
- Caution: at nominal intensity, 1 klystron trip -> loss of beam.



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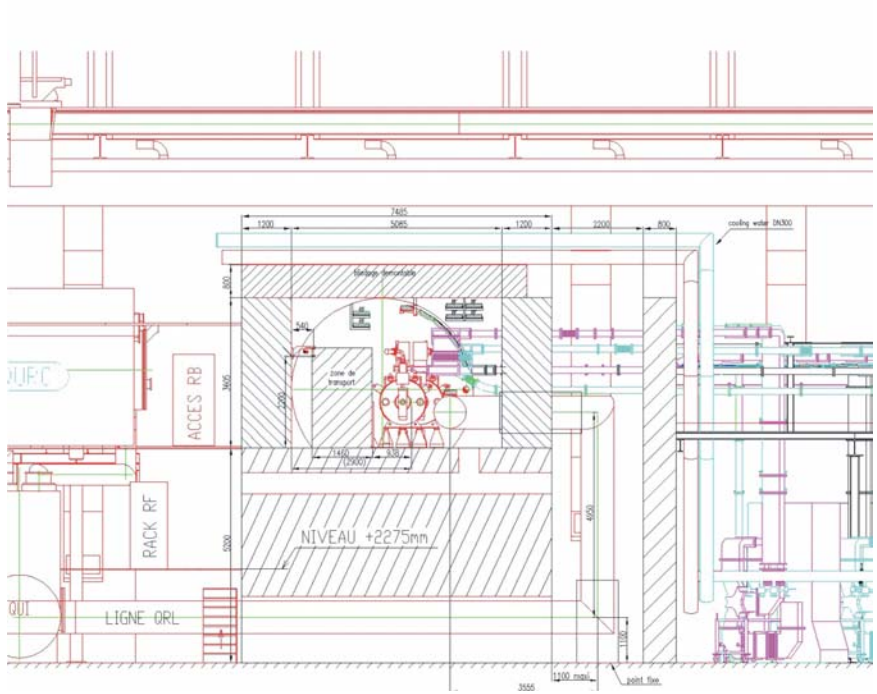
Potential technical problems (3)

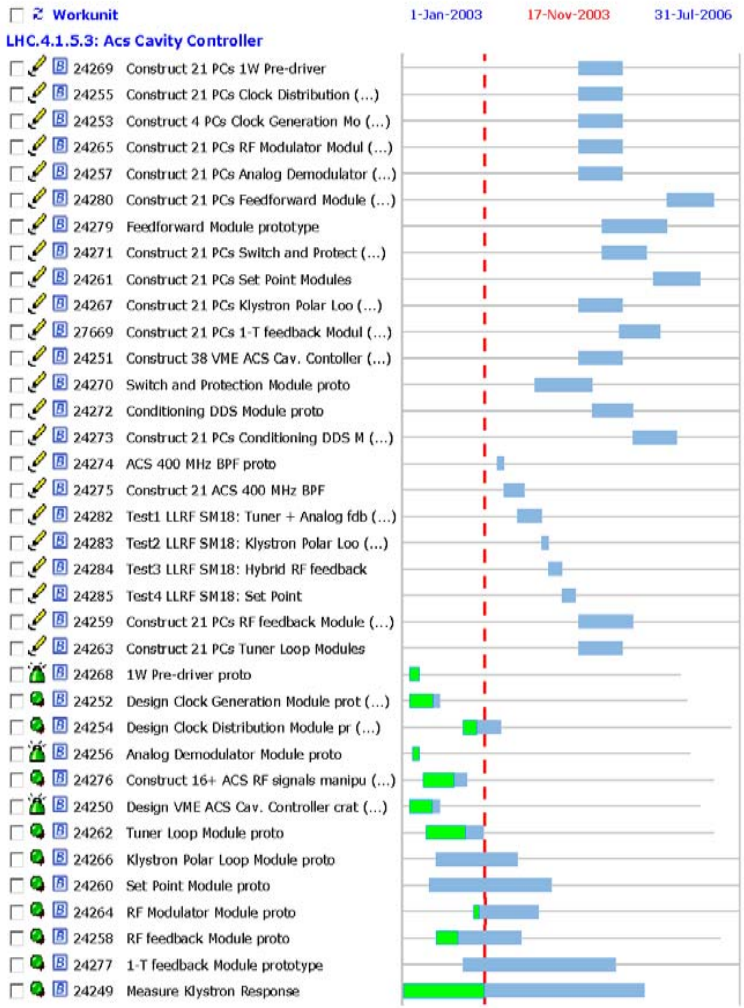
- Radiation levels in the LLRF racks

- FLUKA simulations predict Single
- Level of SEUs acceptable (~3 per
- Linear with vacuum → could be a
- Beam-gas in RF wideband pickups

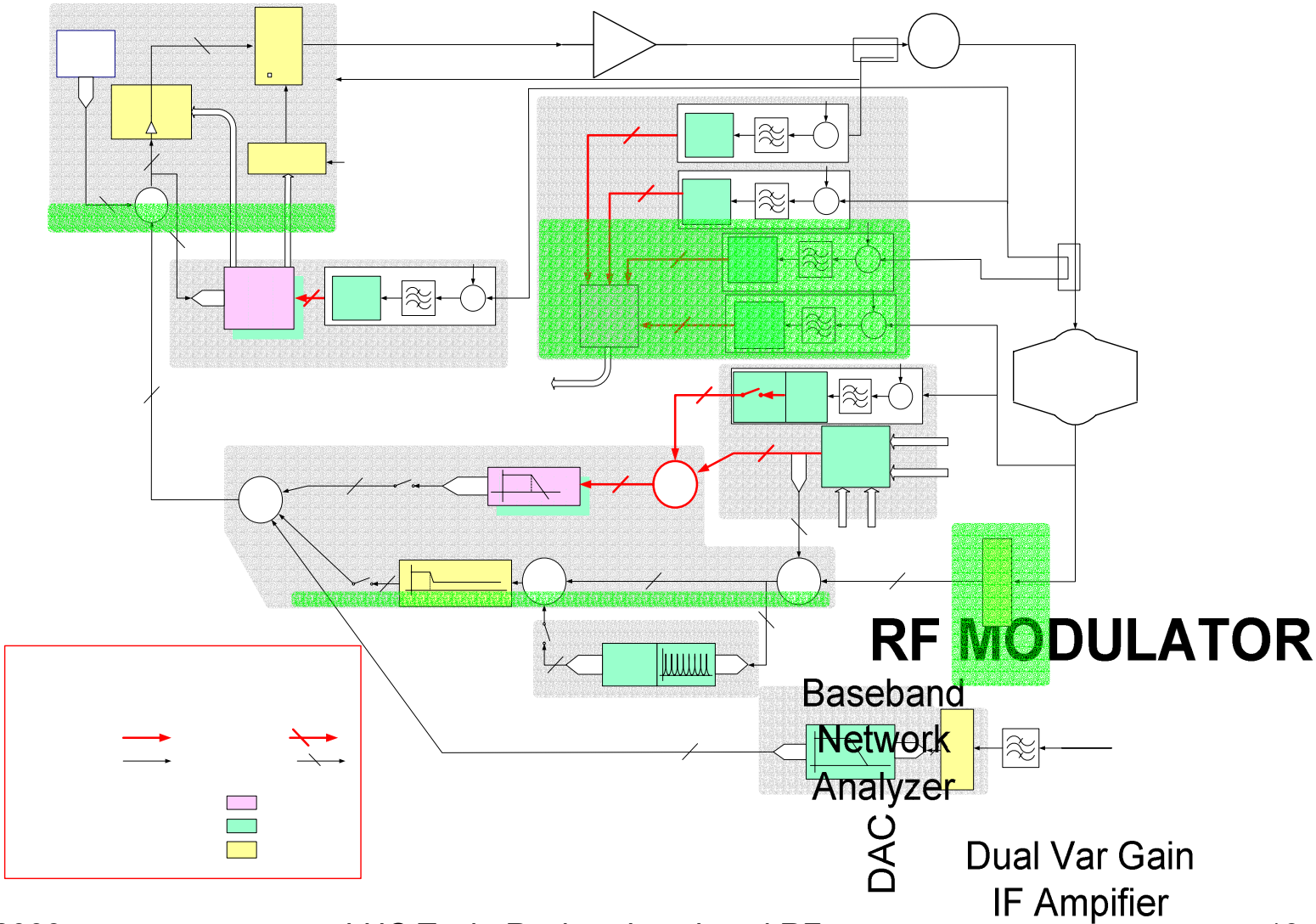


Potential non-technical problem

- After 14 months we are ~4 months late …
  - Developments not started before final decision on implementation (VME, VXI, PCI, NIM, …)
  - Period needed for learning new technology (bigger FPGA: Virtex II, DSP board) and new tools (Cadence and Visual Elite HDL). Initial investment will pay …
  - Manpower foreseen in EVM has not been available
    - Budgeted EVM: 120 M.WK.
    - Available: 84 M.WK.

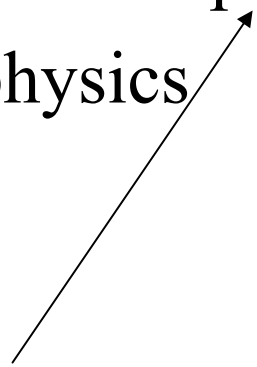


Cavity Controller. Modules developed



RF Synchronization. Functions.

- Synchronization of bunch into bucket transfer SPS – LHC.
- Generation of beam synchronous signals (40 MHz bunch frequency, revolution frequency, kicker pulses)
- Fine rephasing of the two rings before physics



Needed for sector test!

RF Synchro. Status (1)

- Block diagram completed
- Located in a Faraday Cage in SR4
- Cable/Fiber list done
- Agreement reached on signal exchange with AB/CO (40 MHz and revolution frequency) and AB/BT (revolution frequency for beam dump and the kicker pulses)

RF Synchro. Status (2)

- No hardware developed yet. In agreement with planning.
- 11 modules with 15 cards to be developed by Dec 05

CAUTION: A partial system must be operational in April 06 for sector test!

Beam Control and Long. Feedback. Function

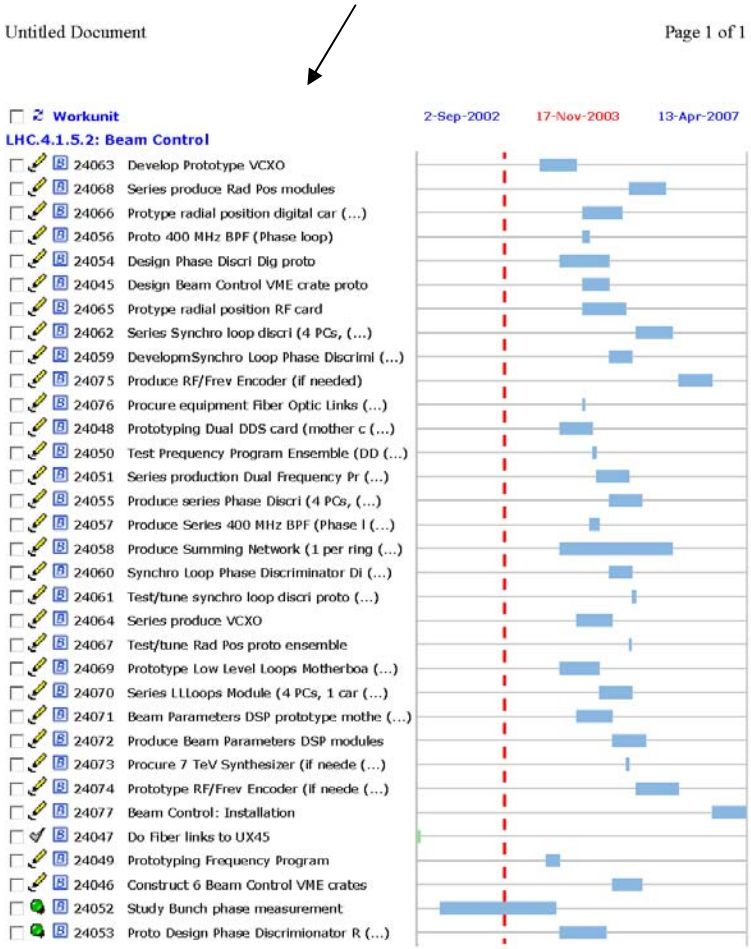
- Generate the beam centered RF reference for each ring
- Minimize noise effects (phase noise) to optimize lifetime in physics

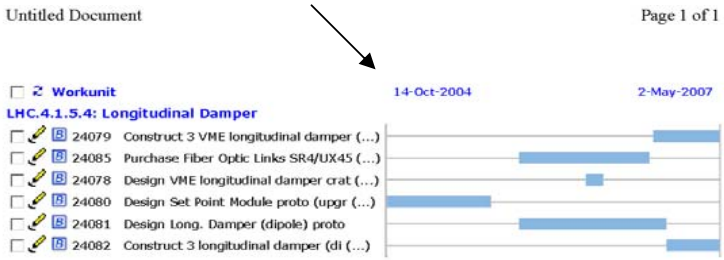
- Reduce blow-up due to filamentation caused by phase and energy errors at injection
- Dipole mode only
- Acting on the ACS cavities.

Beam Control and Long. Feedback. Status (1)

- Block diagram finalized
- Located in a Faraday Cage in SR4
- Cable/Fiber list done
- No hardware developed yet. In agreement with planning.

Beam Contrl and Long. Fdbk. Stat (2)





1 module with 2 cards to be developed by Dec 06

7 modules with 11 cards to be developed by Dec 05

http://pptevm.cern.ch/lhc/ui/workunits/wu_ganntchart.jsp 11/17/2003

Controls issues

- Equipment controls integration:
  - Aim: integrate all equipment into standard AB/CO controls infrastructure (AB/CO standard CPUs + Front End Software Architecture)
  - Front-end SW and drivers being developed in collaboration with AB/CO
  - Aim to integrate external and internal analog diagnostics into OASIS
- Application software:
  - AB/RF is developing specialist SW for RF experts
  - AB/RF will provide the interfaces necessary to integrate RF systems into the LHC operations software

Instrumentation

- Longitudinal:
  - 2 Wide-band PU/beam (APWL1, APWL2)
  - Wall current monitor type
  - Adapted from SPS model
  - Used for Bunch Phase Measurement (Beam Control)
  - Signal routed to rack in UX45 with Digitizing Scope for Longitudinal Profile Measurement. Application for OP is not responsibility of RF
- Transverse:
  - 2 Wide-band PU/beam (APWTH, APWTV)
  - 1 BPM/beam Used by Beam Control (Radial loop)
  - Responsibility of AB/BDI

Cavity Controller. Planning (1).

- Without 1-T fdbk, feedfwd and bunch set-point:
  - Test SM18 from April 04 to Nov. 04
  - Series production Nov. 04 – June 05
- 1-T fdbk, feedfwd and set-point
  - Test SM18 until Oct 05
  - Series production ended April 06
- Assembly of crates before installation May –June 06
  - 40 VME crates containing 280 VME modules (240 home designed, 22 different types)
  - 16 RF Predriver
  - 150 passive RF devices: splitter, coupler, var. attenuator (home designed)
- Installation UX45 July 06 – Sept 06
  - 20 racks
- Test in situ Sept 06 – March 07 (ACS cavity cooldown Oct 06)

Underground UX45

Fully tested in SM18 before installation. Reliability!

Cavity Controller. Planning (2).

- Requirements:
  - SM18 must be available until mid 06 minimum
  - Transport of crates (20 racks of equipment) to UX45 platform July-Sept 06
  - Services available on the UX45 platform July 06
  - Control facilities including timing and functions generators operational on the UX45 platform Sept 06

SR4 equipment planning (1).

- Prototyping phase June 04 – Dec 05
  - 19 VME modules containing 28 cards
- Series production until June 06
  - 80 VME modules (65 home designed)
- Partial installation (sector test) Jan-March 06
  - RF Synchronization (partial)
  - 6 racks in Faraday Cage SR4
  - 3 VME crates
  - fiber optic links to SPS and AB/BT.
- Final installation and test Oct 06-March 07
  - Complete RF Synchro plus Beam Control and Longitudinal Damper
  - 10 racks in Faraday Cage SR4
  - 9 VME crates

Surface building 4

SR4 equipment planning (2).

- Requirements:
  - Manpower! In 2004 – 2005 we have to design proto AND complete tests in SM18 !
  - Faraday Cage finished (with 50 racks/outgoing cables) Dec 05
  - Services in SR4 Dec 05
  - Controls operational in SR4 Jan 06 including timing
  - Fiber optic links to SPS and AB/BT operational Jan 06
  - Potential bottleneck in the EST/DEM office

Documentation

- All modules in edms
  - eda number if designed via EST/DEM
  - aed number if designed in the AB/RF group
  - entry of MTF data after test