LHC slow timing
requirements for machine operation.

LHC timing working group

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LHC slow timing

What does slow timing provide in case of LEP, SPS, CPS:

- Inter-equipment synchronization
- Deterministic message broadcast
- Message sequencing
- Calendar time distribution
- Machine state distribution

Whether this functionality is provided by a “yet to be defined LHC-MTG” or to a certain extend by certain equipment, belongs to the domain of solutions.

It should not stop us from reflection on the requirements.

LHC machine

The LHC machine is best compared with LEP

The states are

- Idle and preparation
- Filling
- Ramp
- Physics preparation
- Stable beam
- Dump and post mortem analysis

A lot what we learned from LEP slow timing (both what was provided and of what was missing) is worth to review here.

LHC filling

Short period (12 minutes):

- unknown number of pilot cycles to make sure that the machine is ok and to eventually adjust machine parameters.
- One tight sequence of filling cycles to fill the machine

While filling the LHC is slave of the SPS (which is a slave of CPS...

- LHC is de-facto running some kind of super cycle.

Timing requirements:

- Scheduled timing events to control equipment:
  - Kickers
  - RF, Dampers
  - Power Converters (e.g. injection bumps ?, preprogrammed beam compensating trims - Q).
  - Acquisition and corrections

A short latency, allows a better coupling to beam availability in the SPS.

LHC Ramp (about 20 minutes)

- Ramp triggered by successful injection sequence. (short latency)
- Coordinated start of all function driven equipment. (PC, RF, FB-Loops, Collimators? Cryo?
- Keep synchronization within 1 ms (beam parameter requirement)
- Trigger preprogrammed actions during the ramp
  - RF (switch from one system to the next)
  - BI acquisitions
  - Collimator movements
  - Other preprogrammed actions ?

  <u>Could we use modified function generators for this?</u>
- Emergency stop (scheduled stops should be pre-programmed in the equipment)

A ramp is more elaborate than a simple start signal. This has important consequences for ramp abort and emergency stops.

LHC Preparing physics

Short period at the end of a ramp

- Beam parameter measurements and adjustments
- Collide sequence
  - By Power Converter trims
  - May also include RF gymnastics / trim
- Beam parameter measurements and adjustments
- Actions on other equipment? (Collimators, scrappers)

Timing requirements

- sequenced actions
- (see also requirements of ramp and filling and physics adjustment)

LHC Physics stable beams

Physics adjustments

- asynchronous trims. A set of hardware is armed for one give physics parameter adjustment and if all is ok, then the action is committed by a trim commit message.
- real time beam parameter knob. Same as above, but the hardware is committed in steps up or down. (Note: non linearity dependence of equipment parameters on a beam parameter may require predefined functions).
- Beam parameter measurements linked to beam parameter variations.

Timing requirements:

- Concurrent usage of asynchronous trims and real time parameter knobs requires distinct commit messages. (LEP was limited to one message)
  - Asynchronous trims, up to 2 commit messages / second * 5 trims
  - real time physics parameter knobs: 10 commits/second * 5 knobs
- Message sequencing (activation of a physics parameter knob/trim combined with triggering of acquisitions)

LHC etc.

Timing requirements

- Beam dump message inform all equipment to freeze their buffers for post mortem analysis.
- Machine state distribution (this is not an operational requirement)
- Time of the day distribution
- No global distribution of measured beam parameter information (e.g. B-train, magnetic regidity)

- Others
  - Robust
  - Reliable
  - User friendly
  - Good diagnostics.

LHC conclusions

- Slow timing provides three functions
- time distribution
- deterministic commit actions
- message sequencing

See also next slides:

- conclusions of the presentation "**SPS LEP (slow) timing systems**" presented to this workgroup on 12-may-1999 by M.Jonker. (2 slides)
- A repeat of the provocative observation (from the same meeting) on the PC real time system, inviting the audience to reflect whether this system could fulfill all the timing requirements.
- A summary of the characteristics of the current MTG

LHC timing, conclusion

Note: Conclusions from the presentation on May 14

The LHC slow timing system should:

- provide a mechanism to apply synchronized commits to parameter modification requests. This mechanism should be available for all equipment. (Power converters, RF, feedback controls, measurement, injection kickers, SPS, PS, etc.
- provide mechanisms for synchronized and sequenced measurement and control procedures.
- provide a central hart beat for equipment synchronization (e.g. 1-ms clock)
- distribute calendar events.
- handle emergency dump requests ?
- distribute machine state ? (exists in LEP but not used)

Note: Whatever mechanism is used by the power converters to synchronize **and control** their equipment should be available to all LHC equipment.

LHC timing, conclusion

Note: Conclusions from the presentation on May 14

- The cycling related requirements of LHC will be very minor:
  - Filling can be easily implemented with the LHC local timing as being driven from the SPS/PS complex.
  - If needed, it could be driven directly by the SPS local timing.
- Simple rendez-vous mechanism:
  - The LHC request beam, and then waits for n pilot-pulses and m filling-pulses from the SPS. When it requests, there need to be some kind of guaranteed response from PS/SPS.

Not only is the LHC machine loosely coupled to the PS/SPS, also the LHC local timing system should be loosely coupled to the PS/SPS complex.

Local synchronization and coordination aspects of LHC equipment are much more important.

LHC timing, observations

Note: Copied from the presentation on May 14

- PC control fulfills already a lot of the timing requirements (local synchronization)
- PC control will implement a powerful coordinated trim commit system. (Hopefully with independent and concurrent control channels?)
- Are they already doing part of the timing job?
  If so, can we forget about the slow timing all together?
  - Can the power converter controls also be used to control other equipment

    All equipment that needs a parameter control during the ramp or coast, including measurement equipment and feedback control, could use the power converter function generator equipment.
  - Can the power converter control also implement measurement programs like preprogrammed stepping through a function and triggering measurements?

MTG timing characteristics

- 2^{32} different messages
- 5 messages per ms
- Programmed event sequences with up to 5 events per ms
- Asynchronous events
- Simultaneous execution of asynchronous events and several event sequences (20 - 100 ms latency for start up)
- no latency in distribution 0
- event sequence abort/modification possible. Latency 5 ms (in case of hardware signal), <100 ms (software controlled)
- one way system, no knowledge required who its clients are
  - When the clients are armed they can check if timing reception is ok or not and use this information in their reply