Experiences with (BI) MPS related systems and foreseen improvements for LS1

LHC MPP workshop

11-13 March 2013

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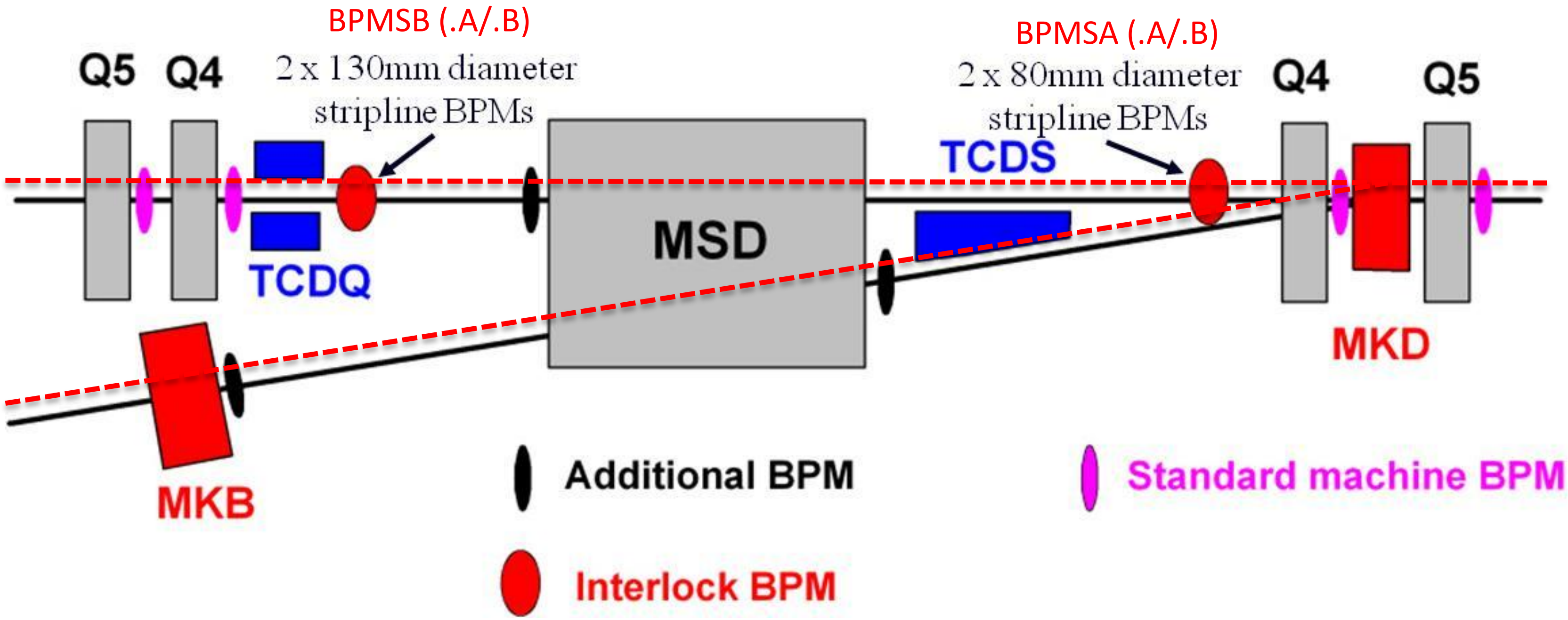
Outline

- Interlocked BPMs
  - Status
  - Plans
- dI/dt
  - Status
  - Plans
- Abort gap monitor
  - Status
  - Plans

Interlocked BPMs

- Strip line pick-ups installed in IR6 just after Q4 (BPMSA) and just before the TCDQ (BPMSB)
- Each monitor is doubled for redundancy (systems A and B)
- Acquisition is based on the LHC BPM design, but has a custom firmware adding the interlocking features
- For the warm parts of the machine the BPM system uses long cables
- There are two operational ranges available (high and low sensitivity modes)

Dump Channel



The main aim of these BPMs is to avoid large orbit offsets leading to high losses on the septum protection during a dump

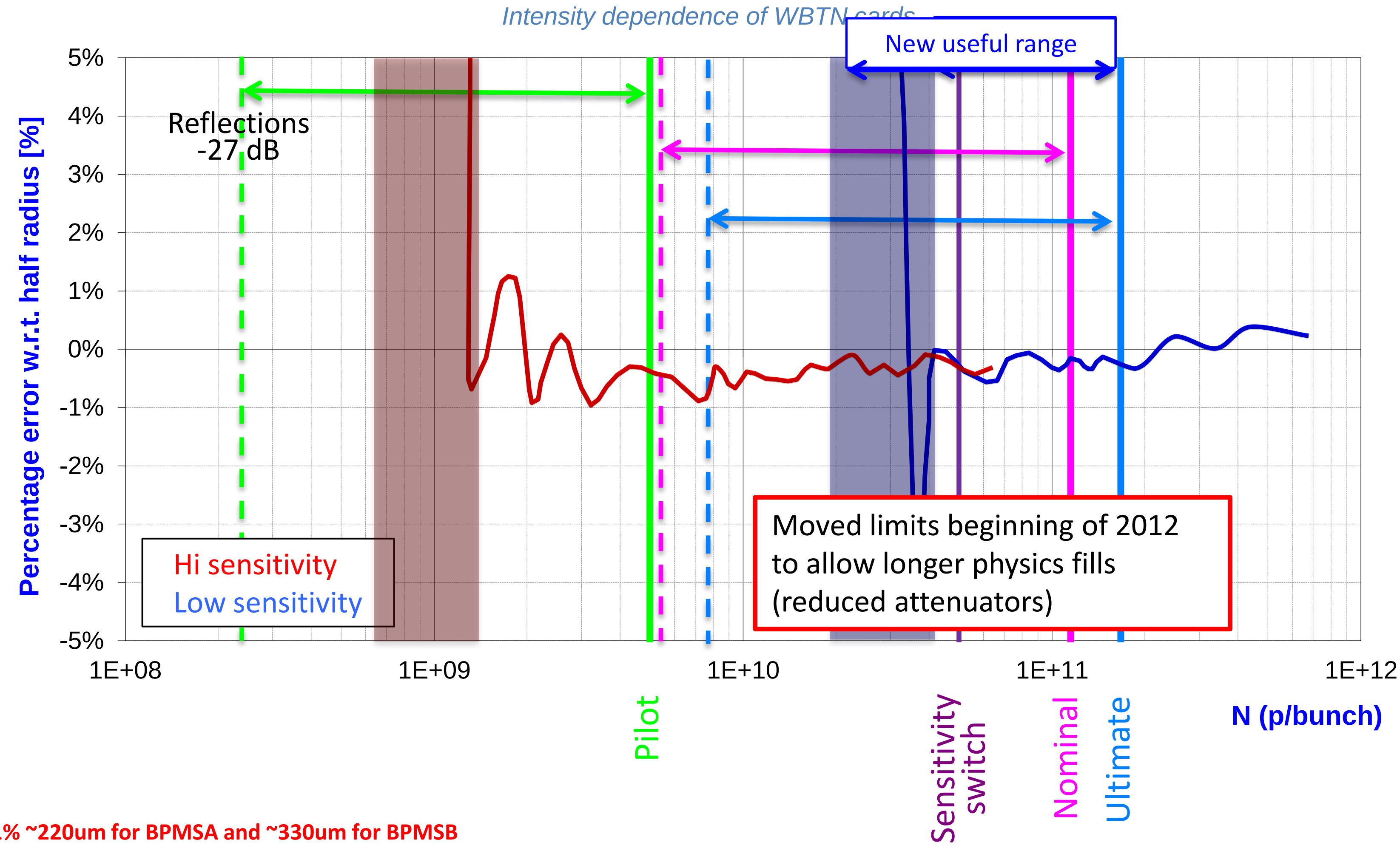
Interlock Mechanism

- Two separate trigger logics
  - 70 reading in the last 100 turns out of limits (a single bunch can trigger the dump)
  - 250 reading in the last 10 turns out of limits (response to fast orbit changes)
- Limits set to ~±3mm (see Brennan's talk)
- The whole chain from readout to beam dump trigger is in hardware (and firmware)
- Interlock signal connected to a maskable channel of the BIS

Issues

- The interlock fires when the intensity of the weakest bunch goes near the detection threshold
- The reflections of the bunch signals can trigger the beam dump
- Insufficient / ”expert only” diagnostics for the analysis of the beam dumps triggered by the BPMs
- Need lengthy scraping tests after every change of attenuators
- 158 dumps in 2012/13 run
  - 1 setup, 120 injection, 3 flat top, 2 ramp, 3 adjust, 29 stable beams (of which 22 are in 2013)
- Note: the system always triggers when needed!

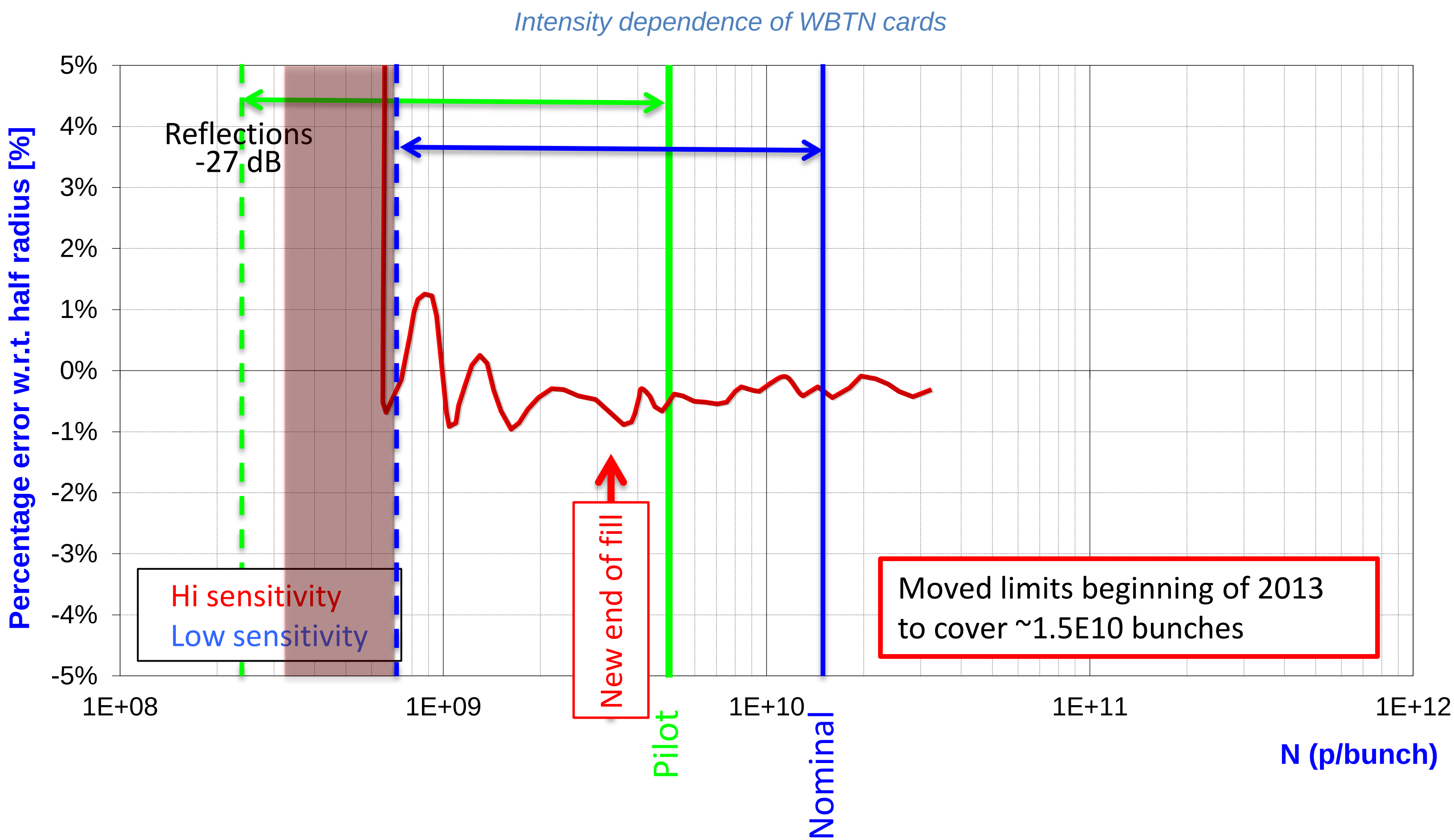
BPMs Signals (Protons)



Note: 1% ~220um for BPMSA and ~330um for BPMSB

BPMs Signals (Ions)

- With p-Pb only use Hi Sensitivity mode (only 1.5 10^{10} charges / bunch)
- P-Pb MD showed that the satellites of the nominal beam triggered the interlock



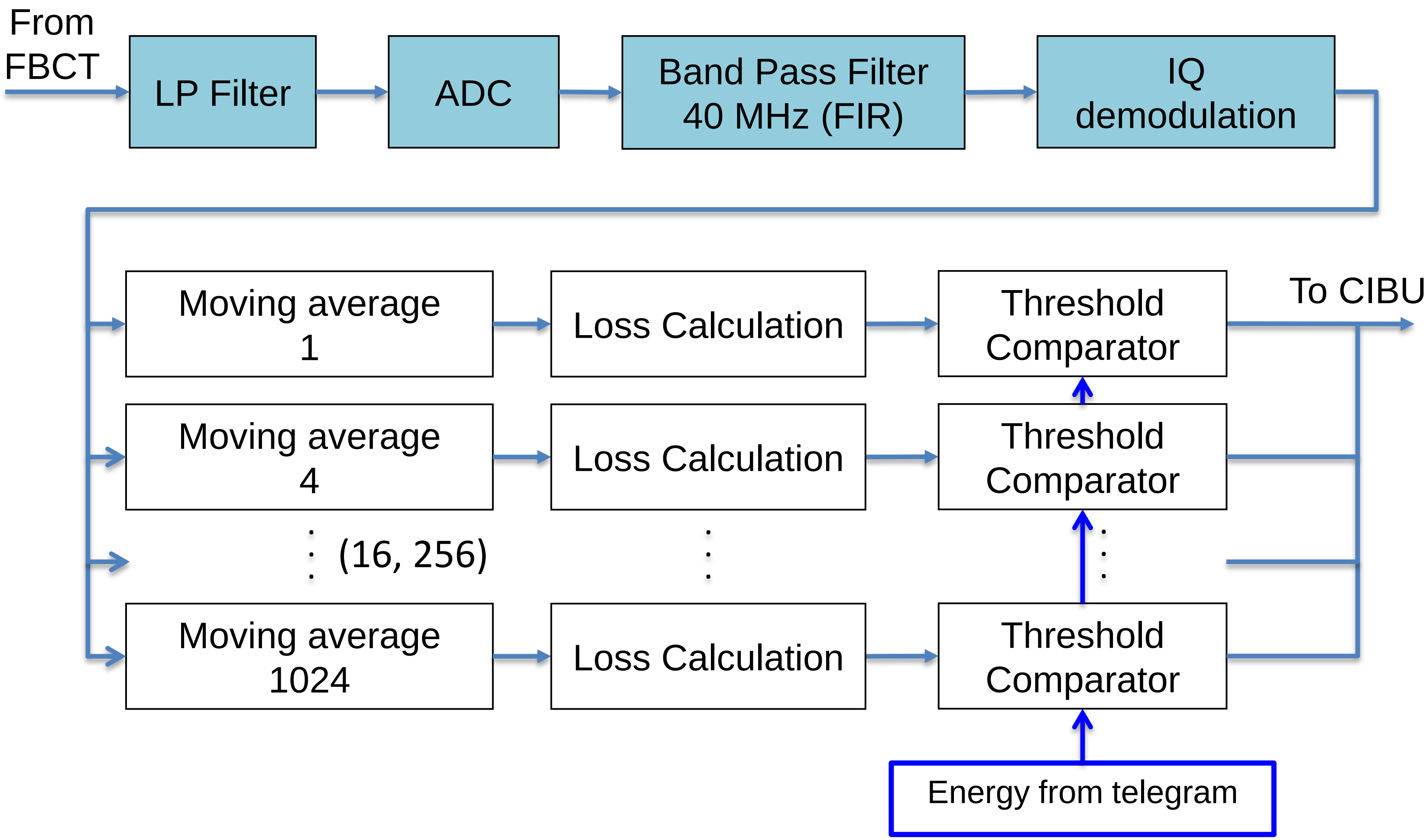
Plans for LS1

- Install filters near the BPMs to reduce the reflections (symmetric Gaussian filters)
  - This will extend the usable range of the High Sensitivity mode (to be quantified, theoretically 1E9 to 3E11 possible)
- Replace the two (fixed) threshold levels with a programmable DAC
  - Similar effect as changing the attenuators, but can be done remotely
- Investigate improvements of the normalizer card
  - Reduce the error in the “gray” zone
- Improve the diagnostic / post mortem analysis
  - A bit more complicated than just firmware changes
  - Hopefully this will not be important anymore after LS1 ☺

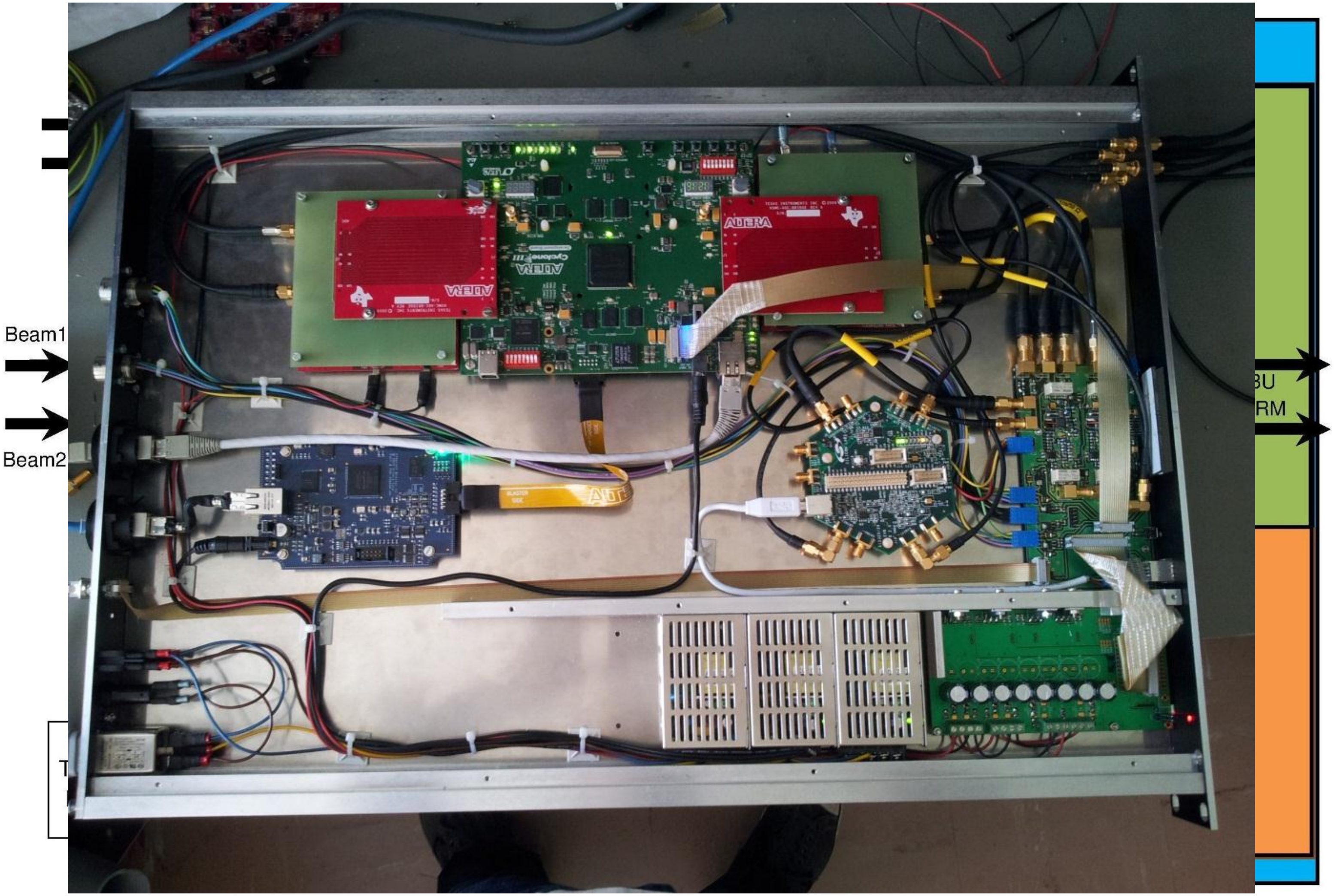
dI/dt

- Interlock system based on the reading of the fast beam current transformers
- Detects rapid changes of beam currents (i.e. losses or debunching)
- Six different integration windows have been implemented

dI/dt Signal Processing



Detail of Implementation



dI/dt Status

- Two systems running in parallel in 2012
  - Same hardware
  - Different firmware (one by CERN and the other by DESY)
- Both systems were connected to the same beam
  - Algorithms could be compared
- The results are a bit different, but the overall performance is comparable
- Data of CERN version is logged in TIMBER and a dedicated expert GUI exists
  - Data can be looked and analyzed online
- Second system data acquisition and storage is based on a local PC
  - Analysis possible only offline

Performance (CERN Version)

- "Noise floor" at about 0.3% for the full machine
  - i.e. few 10^{11} particles
- This limit is not due to the dI/dt electronics, but to the FBCT performance (beam position dependence) and environmental noise
- Small cross-talk between beams in the order of -30 / -40 dB observed
- Noise from the digital part is the main source for the overall electronics noise of the system

Plans for LS1

- The electronics design of the system will be reshuffled by eliminating the various development boards and replacing them with a unique custom-made board
  - This will improve the electronic noise by properly screening the analog part
  - Each acquisition box will process a single channel to eliminate/reduce the crosstalk observed
- Production of 6 complete units
  - 2 per beam plus 2 spares
  - Each beam should have 2 redundant DIDT operational by the end of LS1
- Improvement of the FBCT device in order to minimize the beam position and bunch length dependency
  - This is a major limitation to the present DIDT implementation
  - Three different devices are being investigated. Once ready they will be compared and the one giving the best results will be deployed (ICT Bergoz, ICT CERN, Inductive pickup)
- Software development for the control and acquisition

Abort Gap Monitor

- Monitors the particles population inside the 3μs abort gap (needed by the dump kickers)
- The abort gap monitor is not linked to an interlock, neither hardware nor software
  - Alarm warning sent to the announcer, operators have to take the proper actions
- The AGM is based on the detection of synchrotron light by a gated photomultiplier and is integrated in the BSRT telescope
  - There are compatibility issues

AGM Performance

- A-gap population published and logged at 1Hz
- Sensitivity and accuracy depends on the energy and the particle type
  - The higher the emission the more precise the measurement
- For protons the sensitivity is better than 10% of quench level (fulfilling the specs) for all Energies
- For Pb ions the AGM only fulfills the specs above 1.5 TeV
  - Would need a new undulator to solve this
- The error on the measurement is of the order of 50%

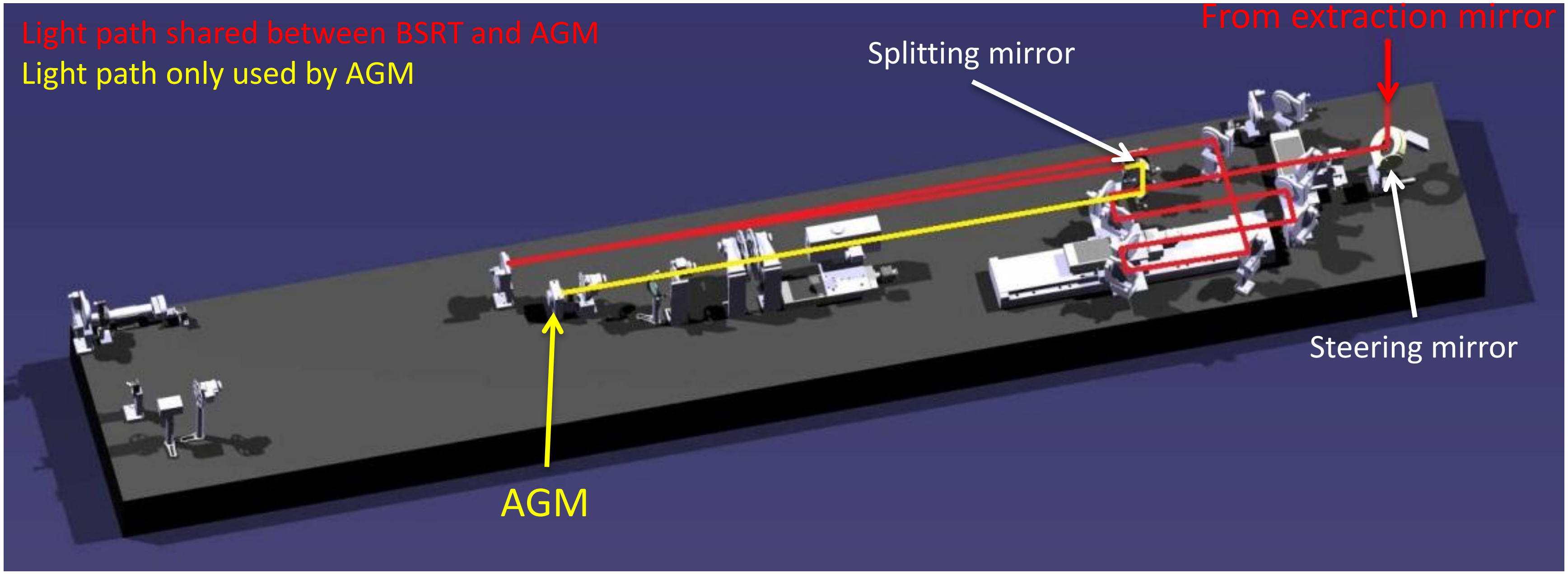
AGM Error Sources

- Alignment and steering
  - Light collection efficiency very sensitive to these
- Attenuation of light in optical components
  - Can change due to dust, radiation etc.
- PMT gain vs. voltage stability and HV control
- Photocathode ageing
- Electromagnetic noise in the signal

Reliability Issues

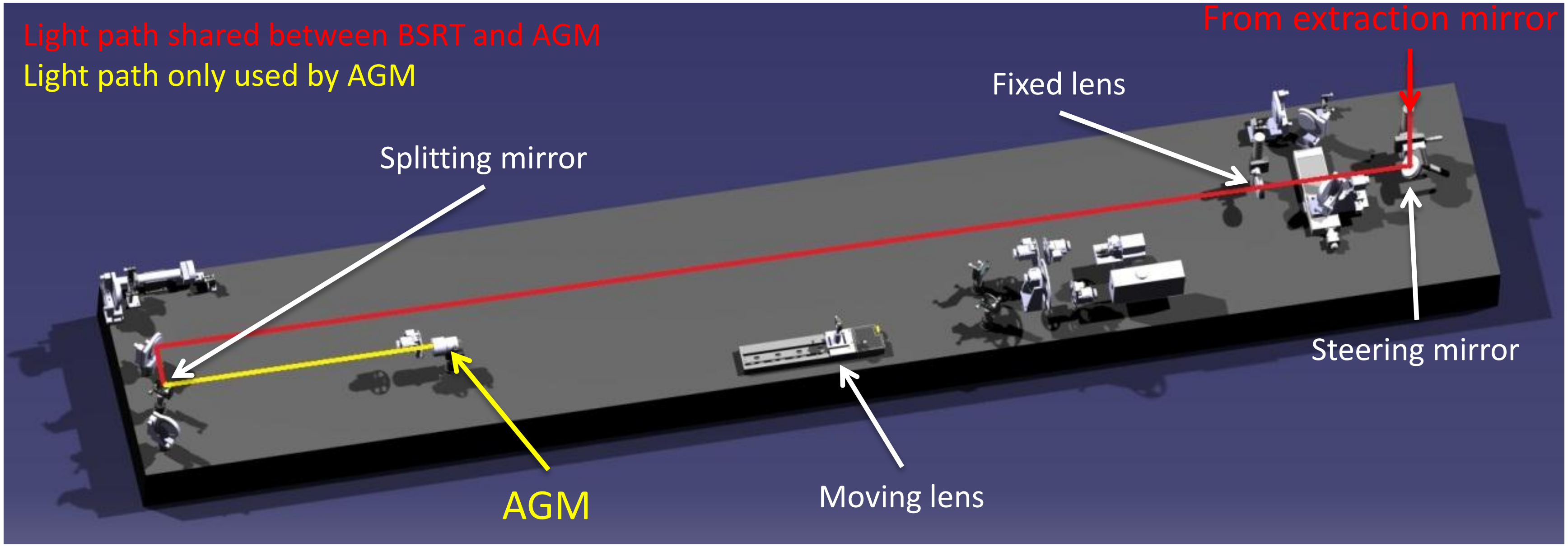
- The BSRT consists of a rather complex optics system in order to measure the beam spot size precisely
  - Complexity means reduction of reliability
  - The system has been simplified during 2012 based on the experience gained so far with clear improvements in reliability
  - Calibration of the AGM remains however complex (by nature)
- Beam induced heating on the light extraction mirror is currently the main issue
- Software issues (both on the BSRT and on the AGM) caused frequent unavailability of the system requiring the intervention of an expert
- Timing distribution problems also affected the AGM in 2012

Original BSRT Telescope Layout



- Telescope was based on spherical mirrors (hoping to use IR for ions at inj.)
- In order to cope with the different synchrotron light sources an optical delay line ("trombone") was used. This meant that the light had to go through many mirrors making alignment difficult
- Errors in the alignment resulted in large variation of light collection efficiency

New BSRT Layout



- Spherical mirrors replaced by lenses
- Since we can move the lenses, there is no need for the optical delay line anymore ("trombone")
- No moving parts before the AGM
- Alignment much simpler and light collection less influenced

Plans for LS1

- Address the extraction mirror heating problem
  – May require a considerable change in the layout
- Consolidate the telescope hardware
  – New systems installed during technical stops
- Consolidate the software
  – Automatic steering of the BSRT
  – Introduce internal checks, "self" calibration, robust saturation recovery and watch dogs in the AGM
  – A document describing the AGM software modifications is being finalized and will be circulated for approval

AGM after LS1

- No change in term of sensitivity
- No major hardware modifications to the AGM part
- Improved system stability
  - No more loss of beam spot on the BSRT
  - Less frequent calibration needs
- Introduction of several internal checks so that problems can be spotted automatically and alarms triggered

Conclusions

- The interlocked BPMs should not be a performance limit after LS1
  - Discussion and agreement between BI, OP and MPP needed
- A full set of dI/dt monitors will be available
  - Prototype gave encouraging results, probably some debugging fine tuning will be required going to the final systems
- Reliability of AGM will be improved
  - No changes in performances
  - System should become much more reliable and in particular self-diagnosing

Thanks!

The End