450 GeV Initial Commissioning with Pilot Beam

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Beam Instrumentation

LHCCWG

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Instrumentation – the essentials

From Chamonix 2006

- Sector test & first turn
  - → Screens, BPMs, fast BCT, BLMs
- Circulating beams at 450 GeV
  - → BPMs, DC BCT & lifetime (fast BCT) , BLMs
  - → Tune, chromaticity & coupling
  - → Emittance: wire scanners.
- Snapback and Ramp
  - → Continuous Tune, Chromaticity & Coupling
  - → Orbit (+ feedback)
  - → BLMs to beam interlock controller etc.
  - → Continuous emittance monitoring: synchrotron light

BPM System at 450GeV

- Already commissioned (injection & first 200 turns)
  - → acquisition chain
  - → asynchronous mode
  - → most polarity errors found during threading & first turn measurements

- Steps after RF capture
  - → "time-in" the BPM system for bunch tagging
    - Set phase with respect to bunch for each monitor
    - Set turn clock with respect to end of dump gap for each monitor
      - is the pilot always in slot 1?
    - Requires BST
  - → start orbit acquisition at 10Hz
    - Verify coherence of orbit, multi-turn and post mortem data
  - → Estimate ~4hrs if all goes well!

BPM System at 450GeV

- Next Steps

→ calibrate the BPM system

- All monitors & orbit correctors - a la TI8
  - ~30secs per COD (530 CODs per plane)
  - ~9hrs for all
- Accuracy will depend on accuracy of optics model!
- Pre-requisite for orbit feedback
- Finer calibration for interlock BPMs in LSS6 & BPMs at injection Pts.
  - Required to accurately set TCDQ etc.

→ First attempt at orbit feedback?

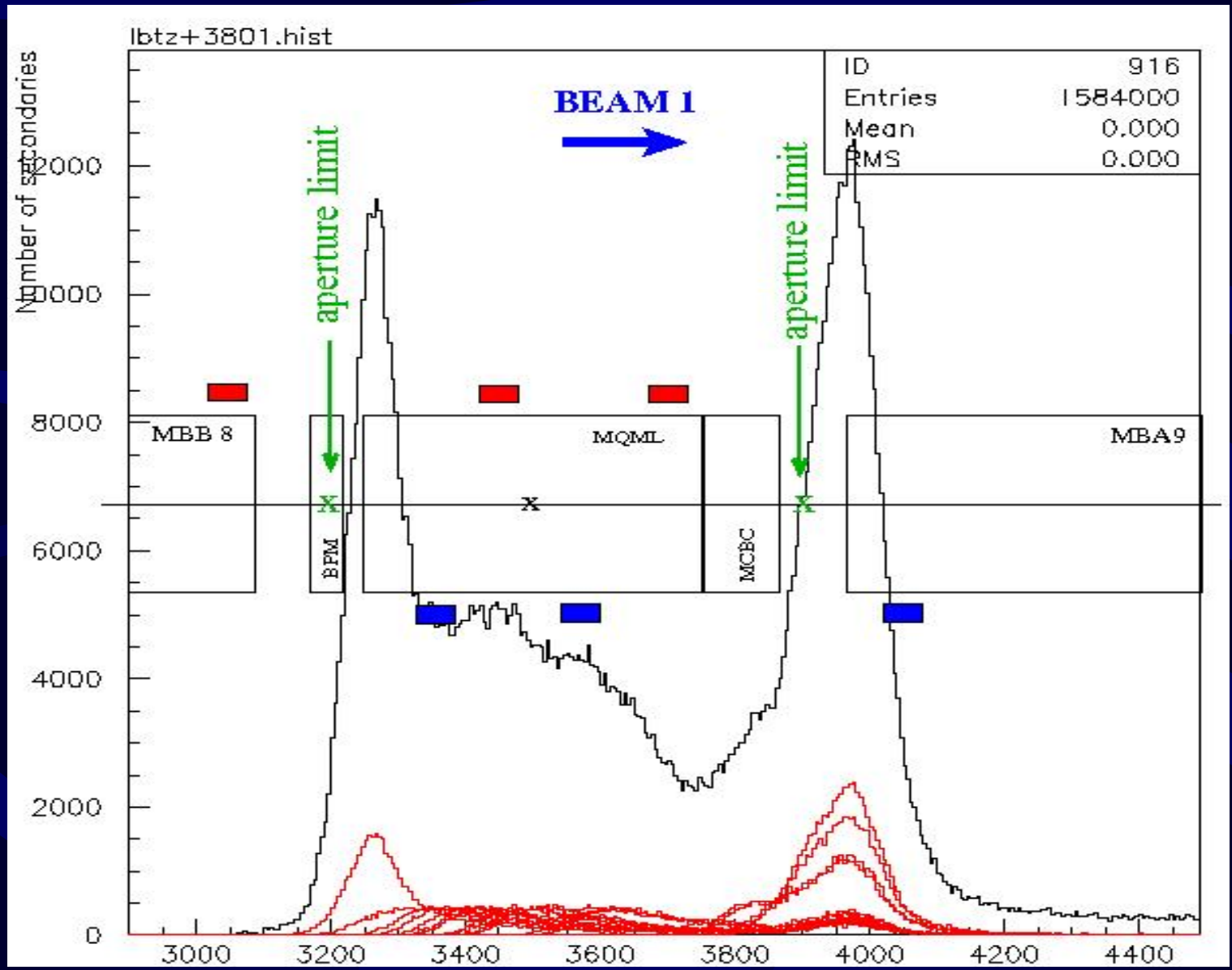
- Required before we start to use collimators?
- Controller tested without beam
- Optimise closed loop gain (~1hr beam time)

BLM System at 450GeV

- Already Commissioned
  - → Hardware functionality & detector availability

- First Adjustment of Thresholds
  - → Initially set as factor 3 below estimated quench level at 450GeV
    - Based on
      - simulations
      - lab heating test measurements (SM18)
      - possible sector test data
    - Thresholds adjusted either on a
      - Quench & learn basis if too high
      - Dump & learn basis if too low
    - Threshold change procedure under discussion in MPWG
  - → At 450GeV fast loss damage level is factor 1000 above quench level
    - No risk of damaging components

BLM Threshold Level Estimation



BCT System Commissioning

- Already commissioned
  - → BCTFR (fast BCT) response to single pass (injection) and circulating non-captured beam
- Circulating beam at 450GeV
  - → First check of DCCT response
  - → Cross calibration between the 2 DCCTs & 2 BCTFRs
- Beam presence flag and beam safe flag for early running
  - → Beam presence detected using simple comparator on BCTFR
  - → Safe Beam flag derived 1Hz intensity measurements of BCTDC (software)
  - → Commissioned at this stage
- Fast Beam Loss Rate Monitoring
  - → MPWG require measurement of loss of 3-6.10^{11} protons within a ms
  - → BCTFR response will depend on % of bunch intensity lost
    - Loss of 3.10^{11} for 43 nominal bunches ⇒ 7% change in bunch intensity (OK)
    - Loss of 3.10^{11} for 2808 nominal bunches ⇒ 0.1% change (below noise limit)
  - → NOT commissioned at this stage

Early LHC BCT System Performance

Measurement Mode	Beam type	Accuracy/ Resolution	Fast BCT (BCTFR)	DC BCT (BCTDC)
Injection	Pilot bunch	±20% / ±20%	$\pm 10^9$ (OK)	N/A
	Nominal bunch	±3% / ±1%	$\pm 3 \cdot 10^9$ / $\pm 10^9$ (OK)	N/A
Circulating Beam (>200 turns)	Pilot bunch	±10% / ±10%	$\pm 0.5 \cdot 10^9$ (OK)	1μA (on 10μA) (resolution ~2-10μA)
	Nominal bunch	±1% / ±1%	$\pm 10^9$ (OK)	2μA (on 180μA) (limit for short int time)
	43 pilot bunches	±1% / ±1%	$\pm 10^9$ (OK)	2μA (on 390μA) (limit for short int time)
Lifetime	Pilot bunch	10% (10hrs/1min)	(OK)	N/A
	Nominal bunch	10% (30hrs/10sec)	(OK)	N/A

Tune, Chromaticity & Coupling

- Day 1 with kicked beams and classical motion analysis

→ Commission MKQ

- Base Band Tune (BBQ) system for tune & coupling
  - Optimisation of gains & time constants
- Head-tail system for chromaticity
  - Verification of chromaticity with dp/p variation

→ Commission chirp excitation using the transverse damper

- Allows faster rep rate if required

→ BBQ system + chirp generation

- will replace BOSC as Standard Tune measurement for SPS in 2006
- All hardware & analysis software should therefore be operational in the LHC as soon as we have beam

Tune, Chromaticity & Coupling

- PLL tune tracking (US-LARP)
  - → Also based on BBQ acquisition
    - Separate system from standard kicked tune system
  - → Set-up in parallel to single kick
    - Requires dedicated kicker BQK (if installed) or Damper

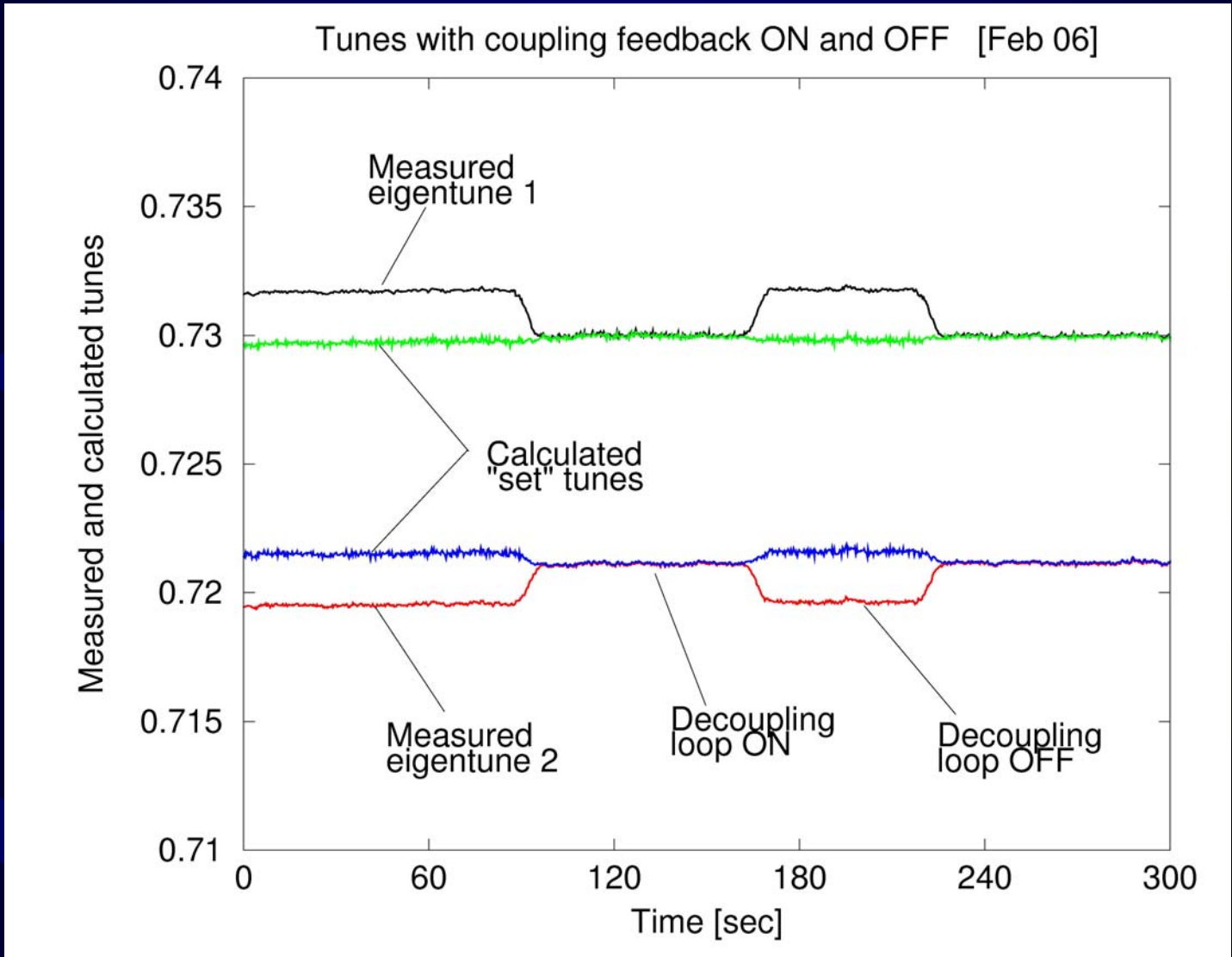
Question: Do we go all out for tune and coupling feedbacks?

If so, then this is the time to commission them

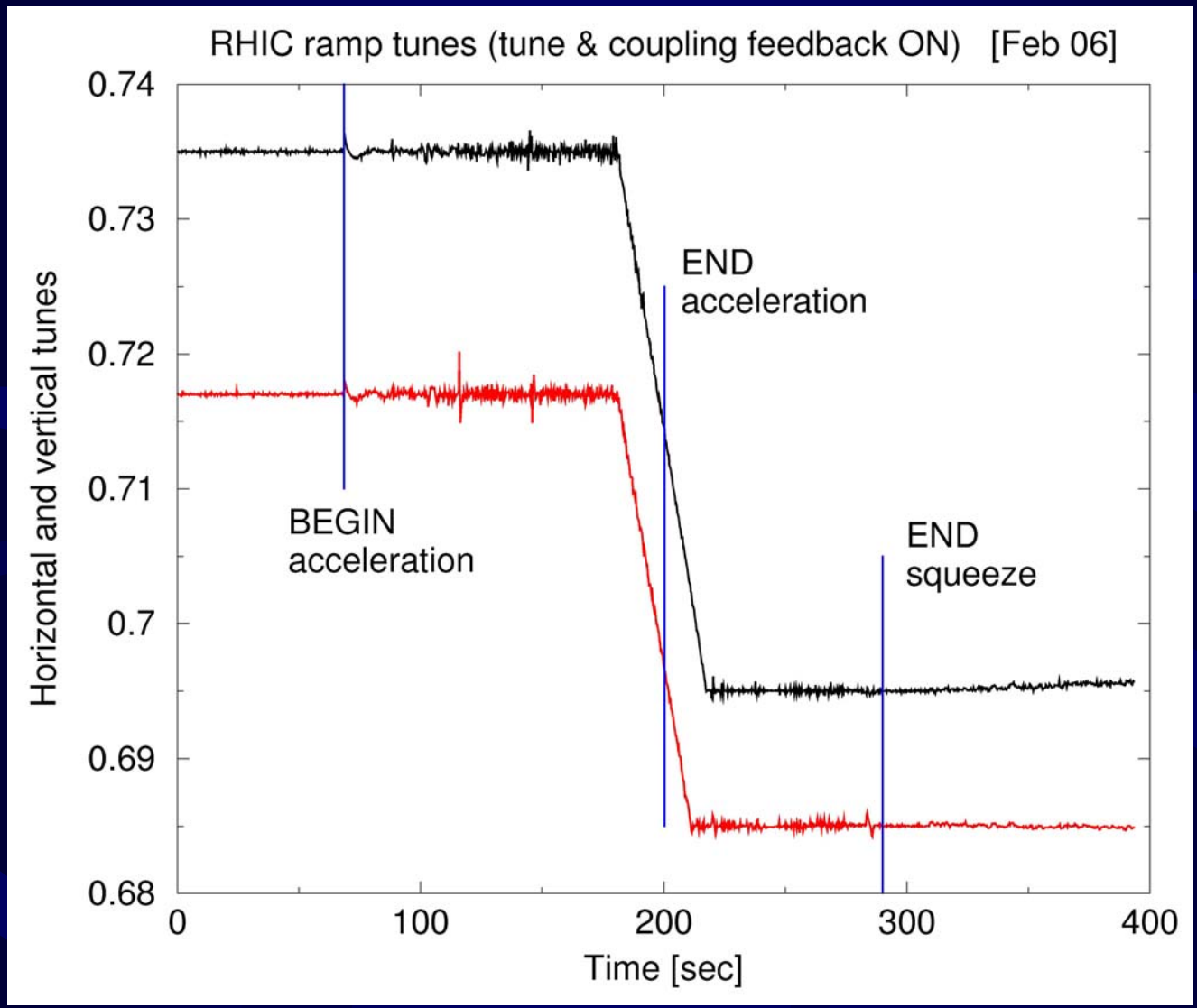
Coupling control is critical for orbit & tune feedbacks

Spending some time here to commission these systems early on may significantly reduce the time required for ramp development

Coupling Feedback at RHIC (2006)



Tune & Coupling Feedback at RHIC (2006)



Feedback using the PLL tune system

- Tune feedback requirements
  - → Stable PLL tune measurement system
  - → Knowledge of correction quad transfer functions
    - already known from initial tune corrections
  - → Implementation of feedback controller
- Coupling feedback requirements
  - → Stable PLL tune measurement system
  - → Knowledge of skew quad transfer functions
  - → Implementation of feedback controller
- Chromaticity feedback requirements
  - → Stable PLL tune measurement system
  - → RF frequency modulation

All of these will require dedicated beam time for testing the control loop response and the final closing of the loop.

Measuring Beam Size at 450GeV

- Wire Scanners (BWS)
  - → Operational
- Synchrotron light monitor (BSRT)
  - → Requires undulator to be ON
  - → Cross calibration with wirescanner
    - Requires “stable” beams
- Ionisation profile monitor (BGI)
  - → Verification of bump closure of BGI compensators
    - Should be negligible even at 450GeV
  - → Requires pressure bump for pilot bunches if nominal vacuum
  - → Cross calibration with wirescanner
    - Requires “stable” beams

Abort Gap Monitor (BSRA)

- Requirement – detect at 10% of quench level
  - At 450GeV : detection of 4×10^9 charges/100ns within 100 ms
  - At 7TeV : detection of 6×10^6 charges/100ns within 100 ms
- Protons

→ Gated photomultiplier will look at synchrotron light using same light source as synchrotron light monitor
  - Either gated over entire 3μs abort gap or in 30, 100ns time slots

→ Single pilot bunch will allow verification and calibration of photon production to proton number
  - Estimate ~300 photons / 100ns / turn at 450Gev

→ May require tunnel intervention to change light splitting ratio between BSRT and BSRA

→ Should be commissioned before we increase intensity
  - Check of threshold
  - Check of timing
  - Check of interlock (BIC?)