



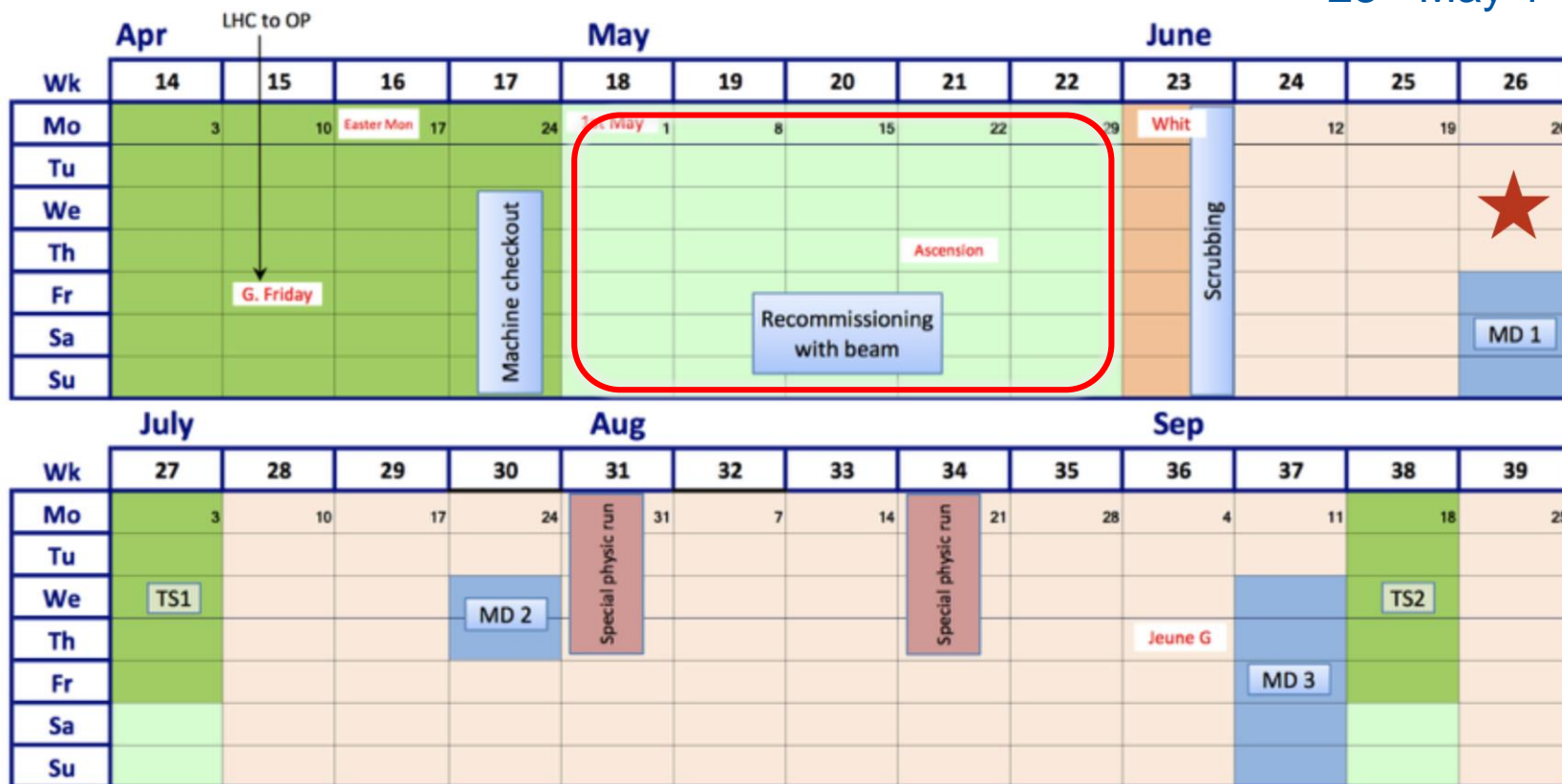
Instrumentation Performance in the LHC in 2016/17 & wishes for the future

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CERN BE/OP

With many contributions from:
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M.Pojer, S.Redaeli, F.Roncarolo, A.Sounas, C.Tambasco, G.Trad, T.Tydecks,
G.Valentino, Ch.Xu, Ch.Zamantzas

LHC Schedule 2017

23rd May 1st SB



Overview

- ❑ **Beam Loss Monitors**
- ❑ Beam Position Monitors
- ❑ Wire Scanners and BSRT
- ❑ Tune Measurement
- ❑ Chromaticity Measurement
- ❑ Other devices
- ❑ Summary and Wish List

Beam Loss Monitors

One of the **most reliable systems** of the LHC. Used for **Machine Protection** but also to assess and improve the **Performance** of the machine.

Because it covers loss measurements of the complete LHC ring and with various time scales it has an incredible potential for data to for data analysis.

- IQC/XPOC,
- UFO/ULO detection,
- Fast Beam Lifetime measurements,
- Identification of loss plane,
- Estimation of total doses in the machine,
- Halo studies, Aperture,
- Quench Limit measurement,
- Etc.



And the system and possibilities keep growing

12 integration times: 40 us to 83 sec

BLM: 100 Hz data stream

UDP packets at 100 Hz of the RS06 (10.24 ms) directed to a FESA concentrator from all channels.

Concentrator feeds several online displays and pushes data to Logging DB

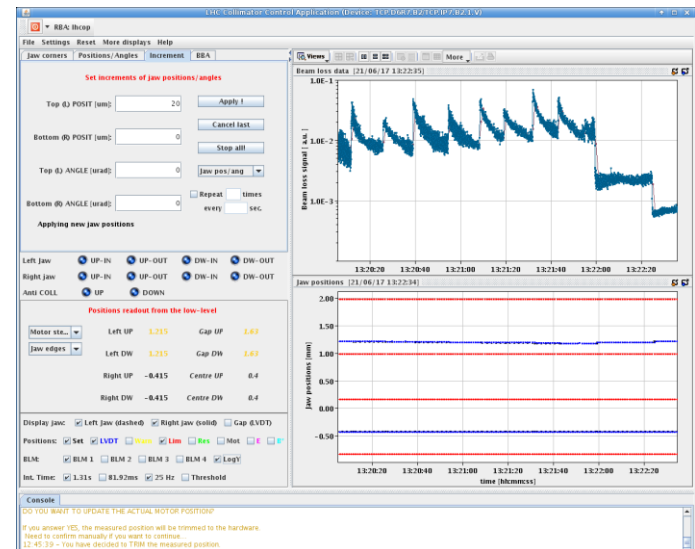
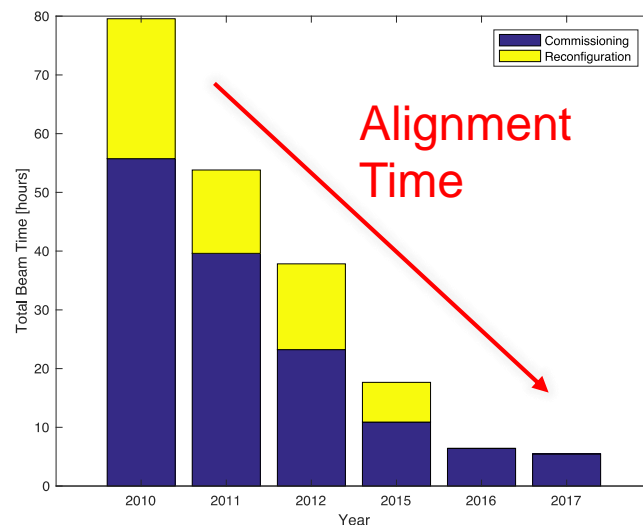
Big joint effort of BI, OP and Collimation teams to make them available.

Current main use:

Collimator semi-automatic alignment: fast spike recognition

Off-momentum loss map feedback

Detail beam tail population studies and beam diffusion measurements



BLM: diamond

Complementary devices to provide ns range time resolution data

Bunch-by-bunch information !!

Several units installed in the LHC

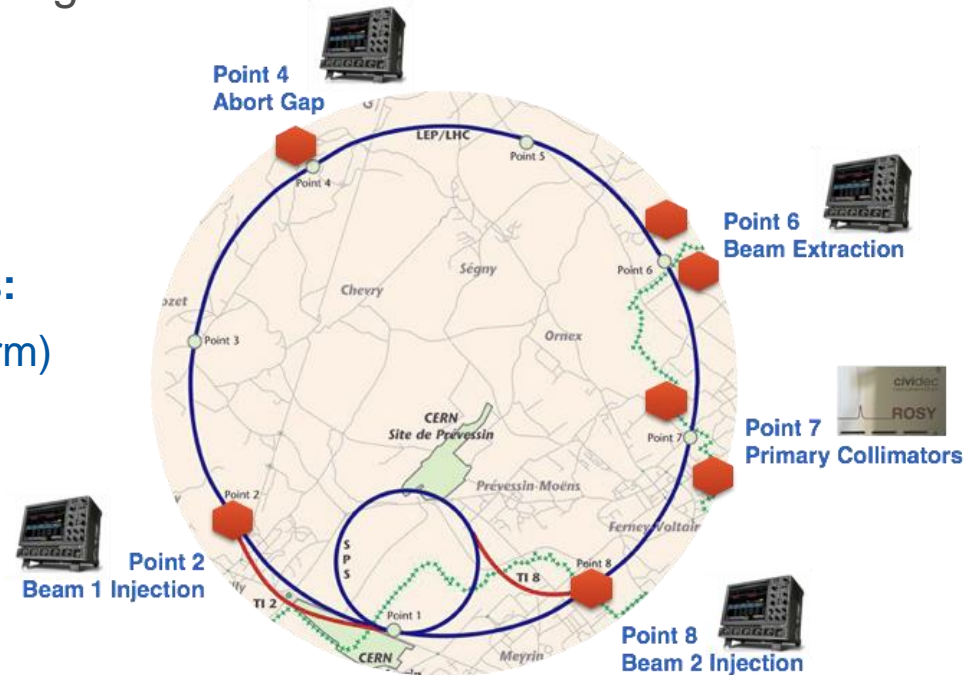
Injection/Extraction and IR7: Lecroy scope

In IR7, measuring circulating beam losses:

Beam 1 TCP/Crystal (TimeLossHist, Waveform)

Beam 2 TCP/Crystal (WaveForm)

Lecroy	Rosy Box
<ul style="list-style-type: none">○ FESA class○ Data stored in Post Mortem○ Data sent to IQC	<p>Python script for device configuring and data storing (EOS server). GUI for data offline viewing</p>



From OP there is the desired to have a more standard read-out (the same for all) but we are aware that work is on-going in this direction

Integration of dBLM in IQC

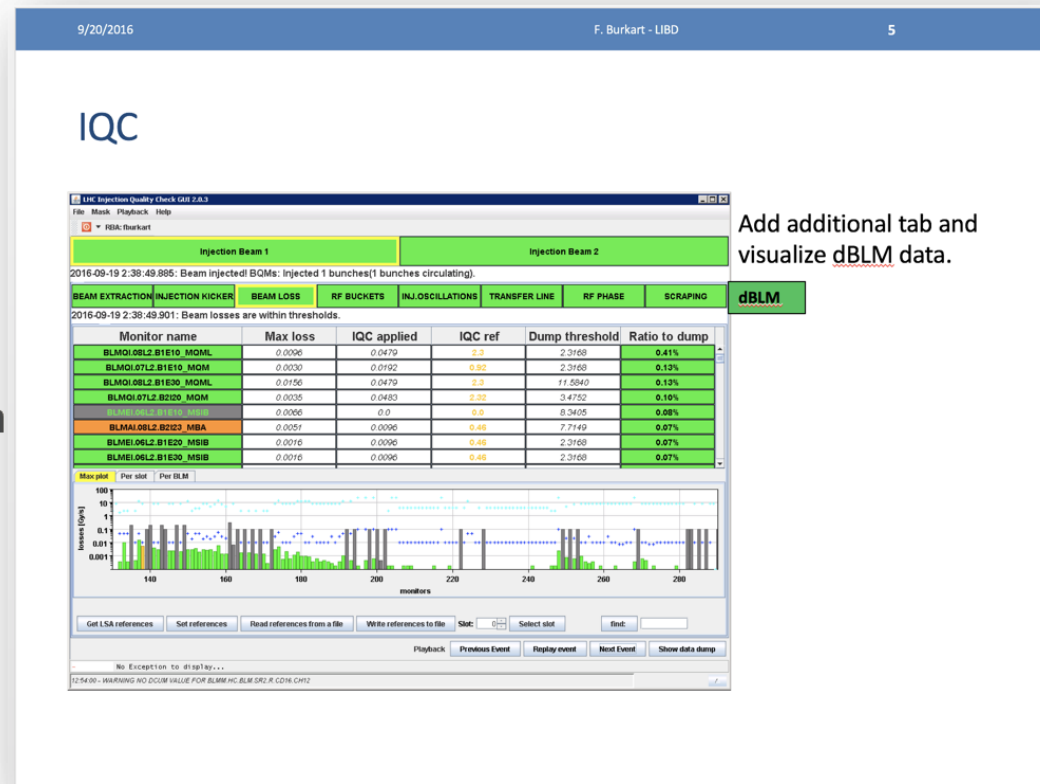
- Make diamond detector data visible in IQC.

- Identify origin of losses at injection:
 - PS ghost bunches
 - SPS recaptured beam
 - Scraping failures
 - Pilot beam over-injection on MKI rise or fall
 - Functioning of injection gap cleaning
 - Losses due to kicked circulating beam or injected beam

LIBD 20 Sep 2016 F.Burkart

<https://indico.cern.ch/event/569816/>

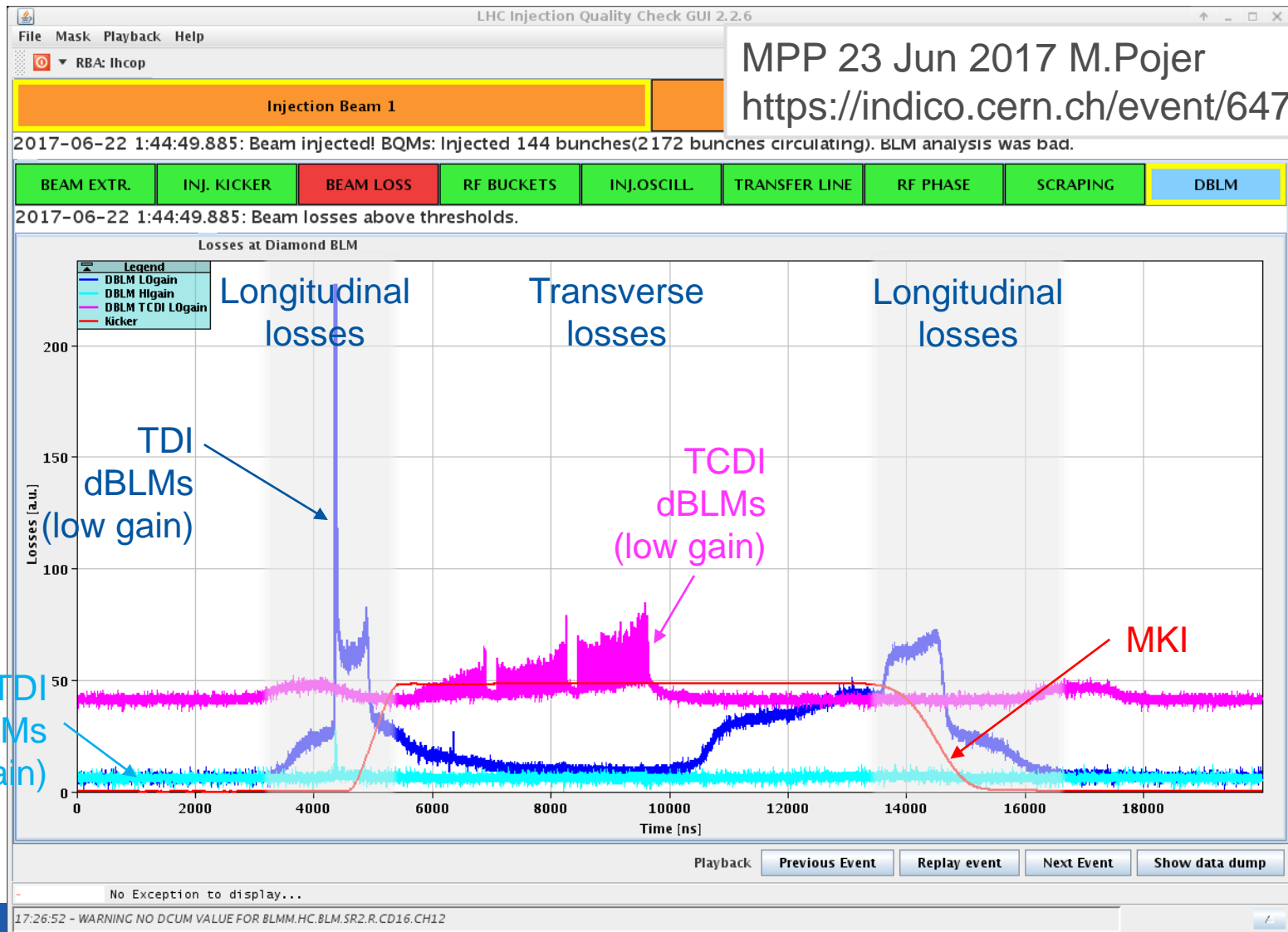
- Measure MKI rise, f.t. and fall time.



New IQC dBLM module

MPP 23 Jun 2017 M.Pojer

<https://indico.cern.ch/event/647883/>



dBLM ring losses: Histogram

Rosy Box IP7

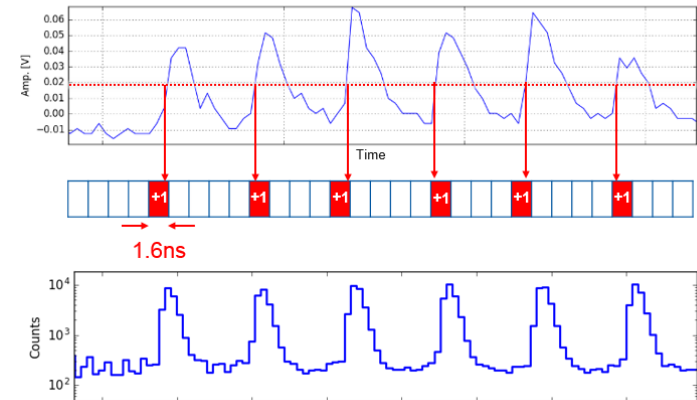
TimeLossHistogram

Precise Beam loss timing counts

Threshold of 25mV for histogram data, binning of 1.6 ns, cumulative counts over 1 second.

Cumulative counts over 1 second, the span of the LHC ring 88.9 μ s, in bins of 1.6ns

Time-Loss-Histogram: precise beam loss timing counts

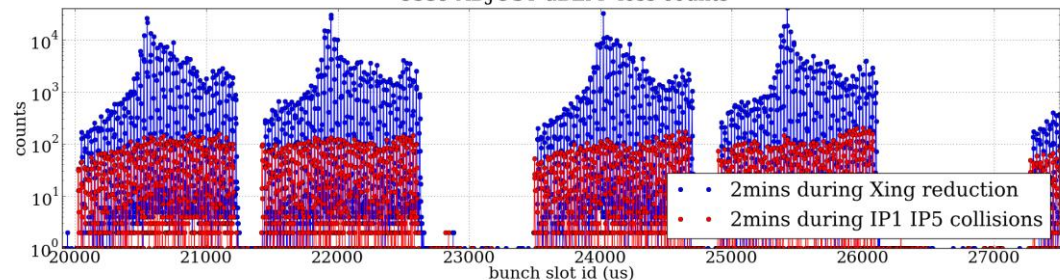


Example of usage of this data:

Losses during change of crossing angle

Bunch-by-bunch analysis, showing that central bunches were losing more/during longer times during the change of crossing angle

5339 ADJUST dBLM loss counts



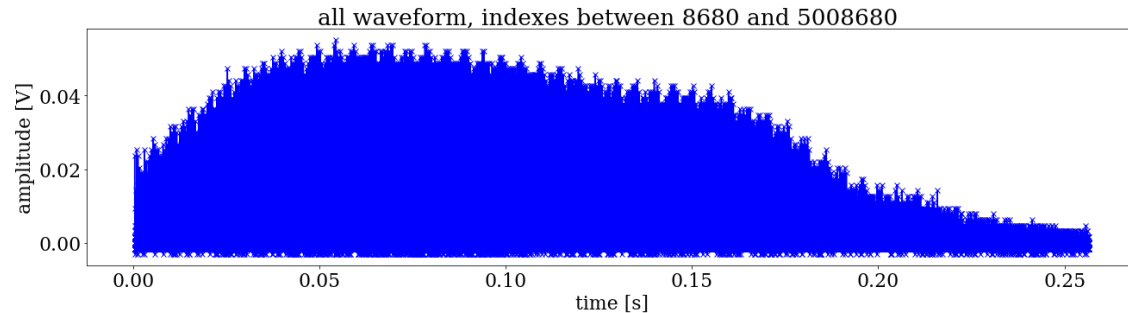
CWG 19 Jun 2017 A.Gorzawski
<https://indico.cern.ch/event/646289/>

dBLM ring losses: Waveform

Rosy Box IP7

Waveform data

Raw data containing the induced voltage, therefore scalable to the loss magnitude



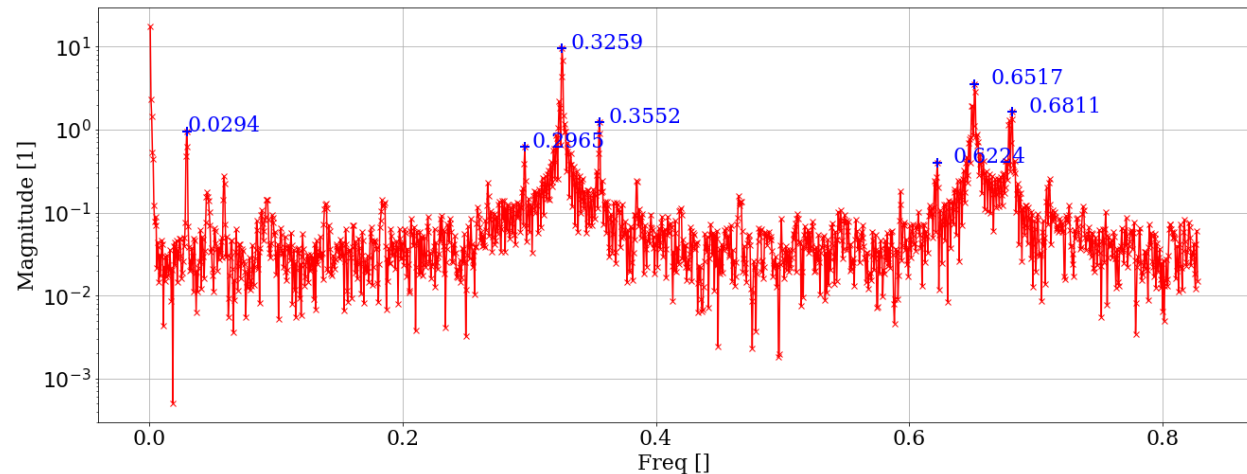
Example of usage of this data:

Losses during ~1700b fill

Bunch-by-bunch tune measurement

CWG 19 Jun 2017 A.Gorzawski
<https://indico.cern.ch/event/646289/>

Frequency analysis
reveals the tune
measurement
possibilities.
Work on-going...



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Beam Position Monitors

Evian 2016 G.Trad

<https://indico.cern.ch/event/578001/>

Three mode of operations:

Asynchronous **Orbit** acquisition mode:
average beam position over “t” sec

Used in the orbit feedback

Synchronous Orbit acquisition
*mode: average selected bunch position over
“t” sec*

Was put in operation for
operating with asymmetric
beam intensities (p/Pb)

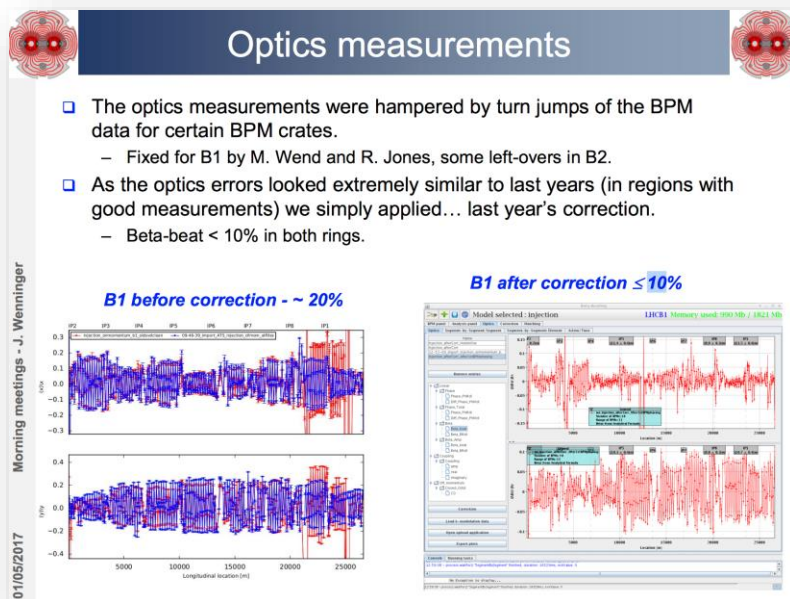
Very successful: allowed to increase proton beam intensities providing more luminosity, the limitation was moved to losses in the cold region close to the IR.

Capture acquisition mode: *bunch-by-bunch
and by turn position over “T” turns*

Used in optics measurements
And IQC

Beam Position Monitors

In general, very good performance, they were just few issues during the commissioning solved rather quickly.



Missing turn data during optics measurements, expert needs to be called, could be avoided for next year if prepared before measurements.

Interlocked BPM issues

- Interlock BPMs not dumping for vertical plane comes from a bad configuration in the firmware.
- LHC.BPMSX.A4L6.B1V not publishing (ADC=0) is a HW issue since this channel is not publishing from normal BPMs either or even with calibration. Experts onsite to identify it.
- The extra 0.5 mm of LHC.BPMSX.A4R6B2H for dumping, is believed to come from the calibration factors. (thresholds are calculated only once when set and not with every new set of calibration factors)

Morning meeting 20 May 2017

4

A review of the system could be envisaged.

DOROS for IR steering

Evian 2016
J.Wenninger

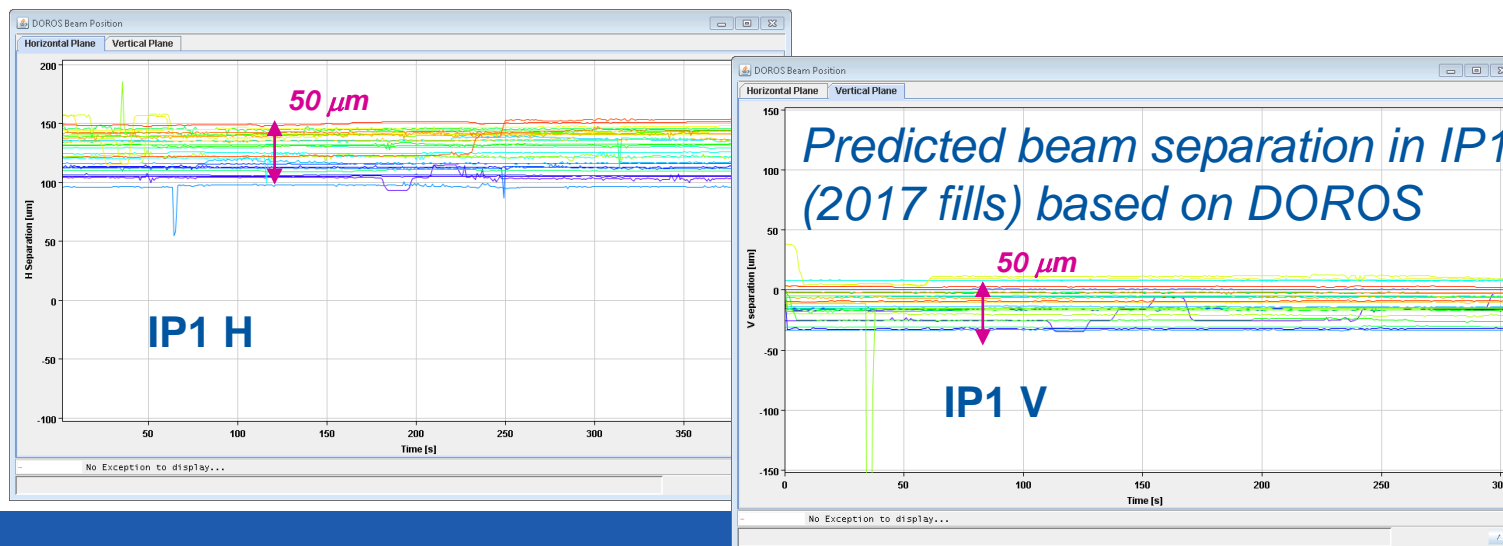
The next challenge of LHC operation will be β^* levelling in Run 3 and for HL-LHC (test in Run 2, later in 2017?).

Need precise RELATIVE beam offset measurements at IP with accuracy of $\sim 1 \mu\text{m}$ on beam separation over 5-10 minutes.

- Seems to be \sim OK from DOROS – need high reliability as it would be used on every fill.
- Needs to be integrated into the Orbit Feedback, might be challenging

Steering beams into collision: the best performance is still obtained from the orbit FB with the average orbit of standard BPMs: $\sim 5\text{-}10 \mu\text{m}$ reproducibility.

- Fill-to-fill reproducibility of IP interpolation from DOROS $\sim 20\text{-}50 \mu\text{m}$.



DOROS in SIS (1)

Interlock on the Beam Position excursion at the Collimators with BPMs.

→ SIS limit 1 sigma in 1&5, i.e. 500-800 um.

SIS interlock implemented but kept MASKED

Monitoring of spurious possible dumps now available:

→ see MPP 9 Jun 2017 A.Gorzawski

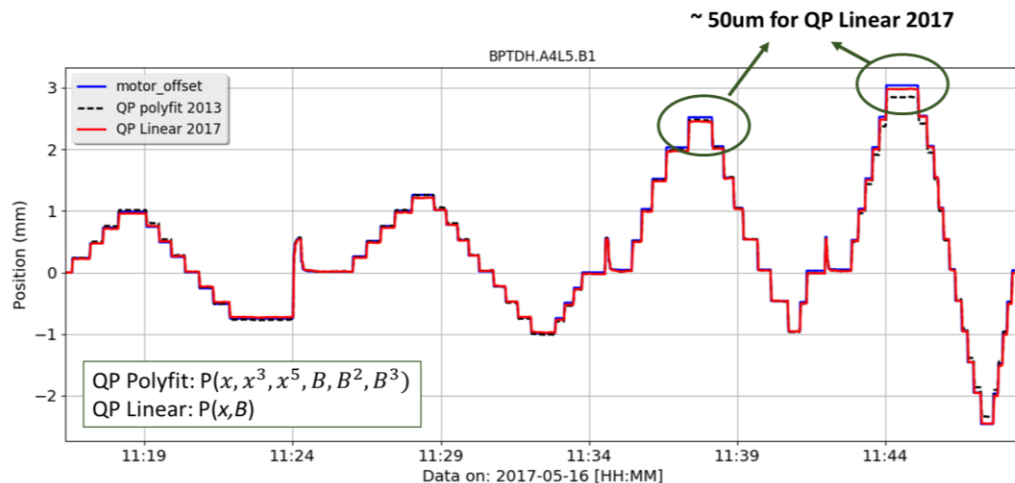
MPP 9 Jun 2017 G.Baud

<https://indico.cern.ch/event/642943/>

Preparation of SIS unmasking

- ✓ Post Mortem data: 2 min @ 25 Hz, jaw positions, raw data, etc.
- ✓ Reliable beam position:
 - Currently too complex, 18 coeff. polynomial per BPM
 - Testing 2 coeff./BPM type

Quadrupolar Scans on 16/05/2017



*Jaw Gaps during scan: 14mm, 16mm, 18mm, 22mm

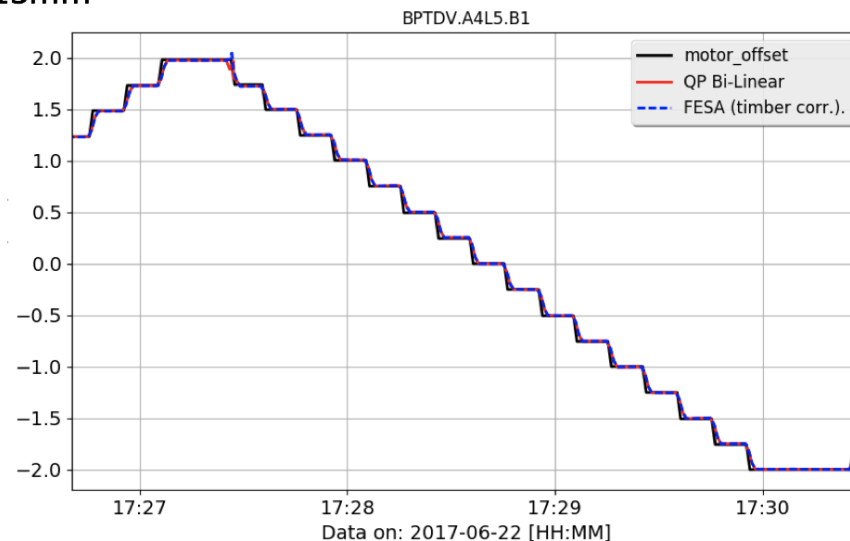
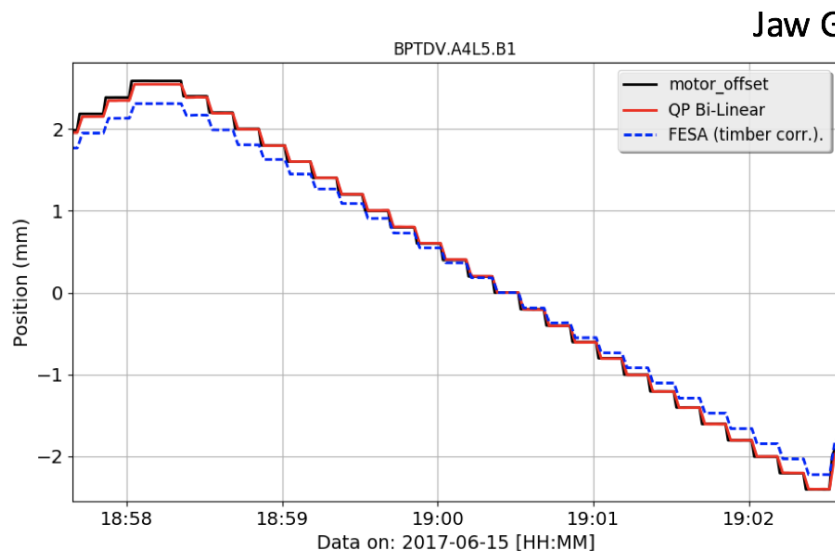
DOROS in SIS (2)

Big improvement with the BI-linear correction (already deployed).

< 50um for +-1mm offsets

<100um for +-2mm offsets

A.Sounas



FESA was updated with the same coefficients of the proposed 'QP Bi-Linear' approach

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Wire scanners (1)

Important to cross calibrate BSRT. In regular operation it is only used with the 1st train (and not always). During MD and Commissioning it is more exploited: precise beam shape measurement and study of beam tails, etc.

2017 Issues

1. VME CPU crash
2. Scan movement not completed correctly
3. Abrupt / Violent movement at the first scan after a non-completed one
4. Damage due to water leak in US45

Occurred simultaneously (but we could not trace back what caused what) on May 14th, decided to declare WS not operational since then

Put in place a laboratory test bench (exact copy of OP system, apart from long cables and multiplexers)



F.R. - LMC - 31-May 2017

4

LMC 31 May 2017 F. Roncarolo
<https://indico.cern.ch/event/643336/>

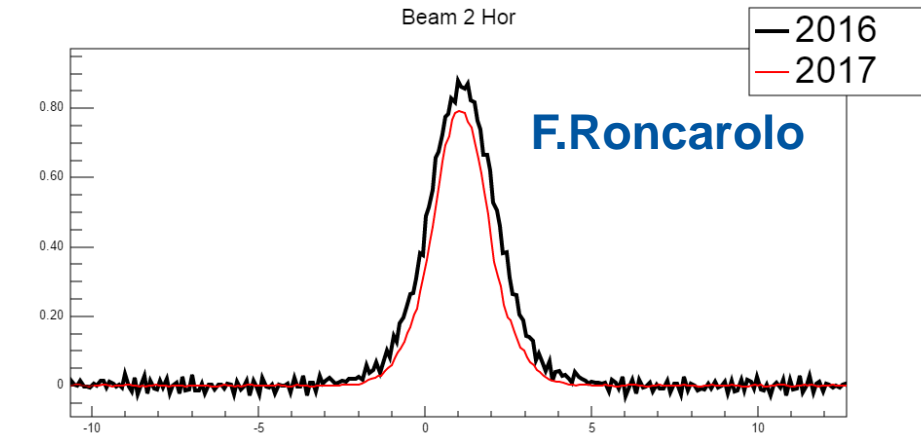
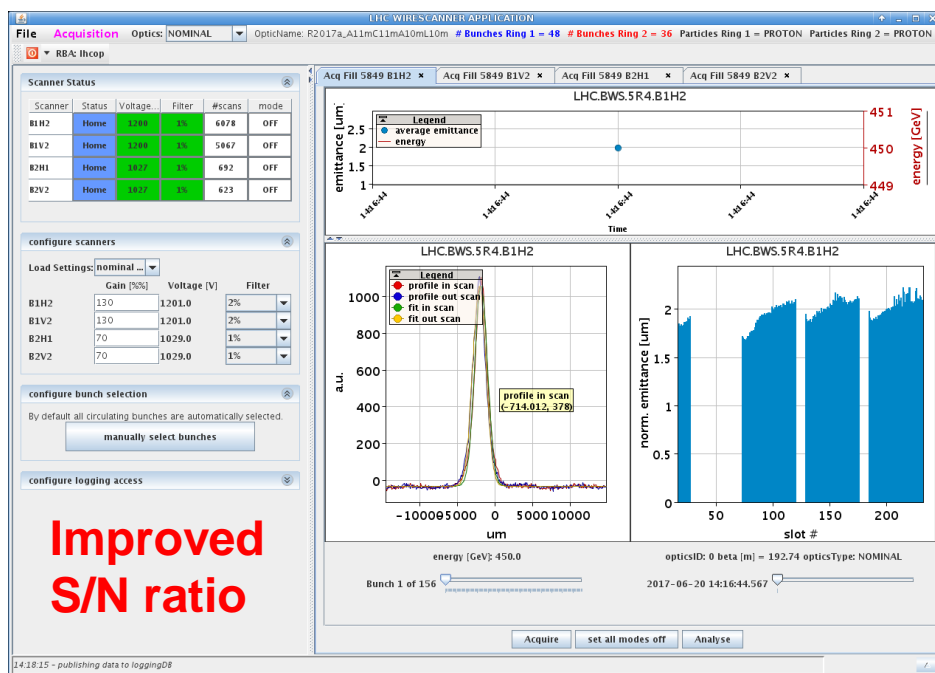
All issues solved:

- Replacement of VME B1 crate
- FESA class update

Wire scanners (2)

Now they are again operational with certain improvements:
Reduction of noise and parallel scans Beam 1 and Beam 2 available
The GUI needs to be updated to follow the change

2017 B1 – H



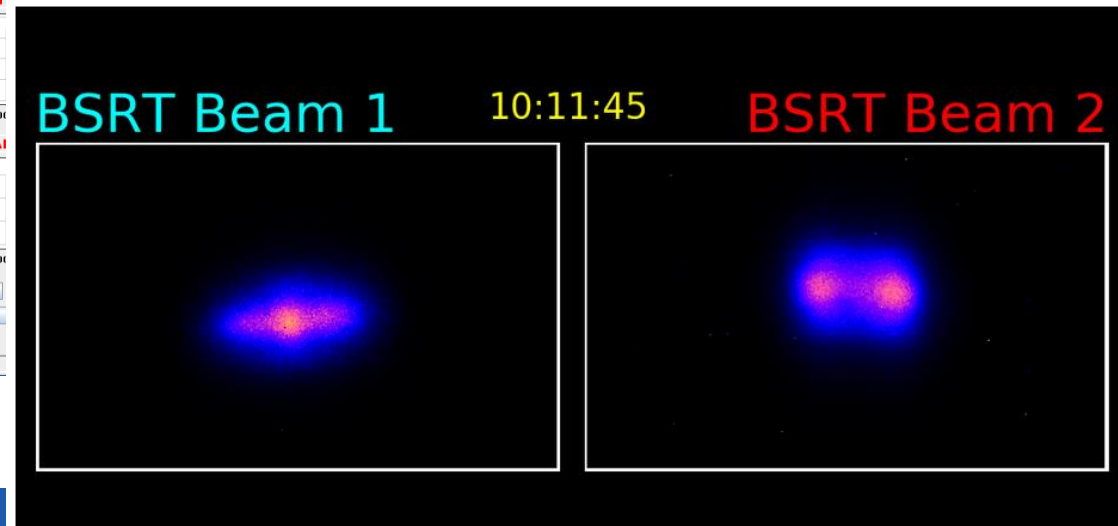
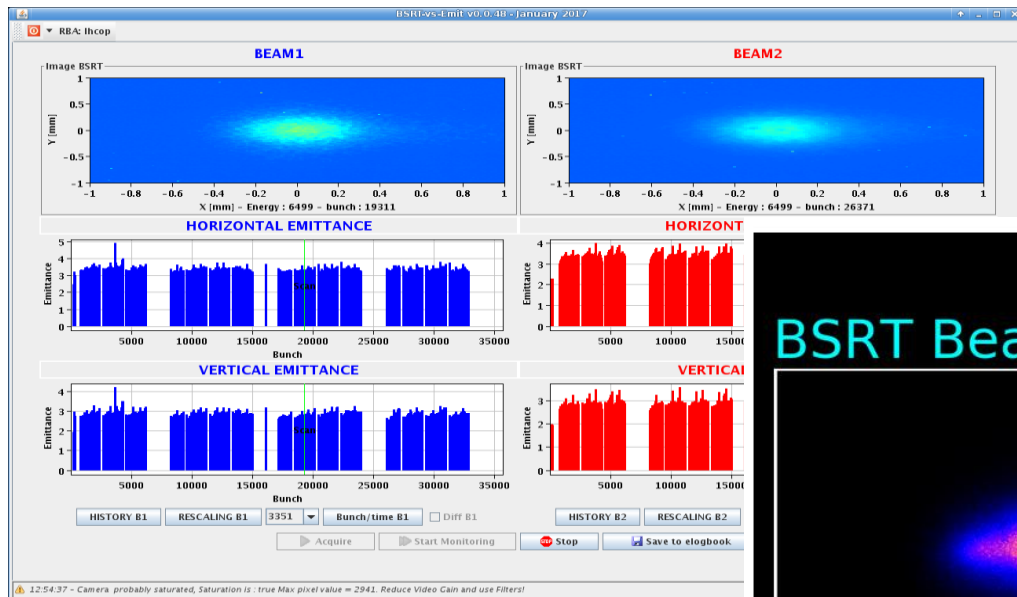
OP wish: review the intensity limit at injection. Could we measure 2 trains?

BSRT

Regularly used in OP to monitor the emittance.

Together with BCT is the bunch-by-bunch device more used during operation.

Among several improvements a Minor issue: 2017 the analog spot signal was not available. Issue solved by a digital reconstruction of the beam spot from the raw data



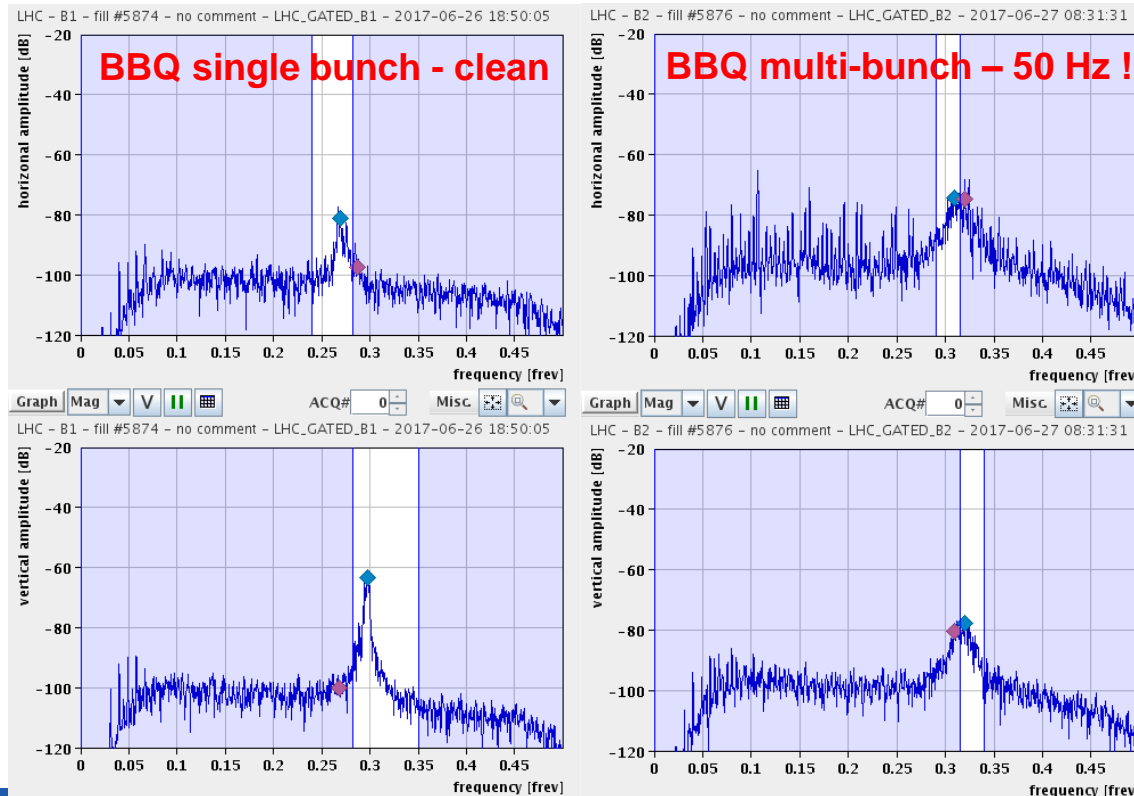
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Tune Measurement

The challenge for tunes remains the compatibility of transverse feedback (ADT) and tune measurements.

- Compromise solution of few bunches with lower ADT gain ~ok within some limits.
- Main remaining issue with BBQ are the 50 Hz lines on the horizontal spectra.
Filtering them out closer to the source (and not in the spectrum) would help.



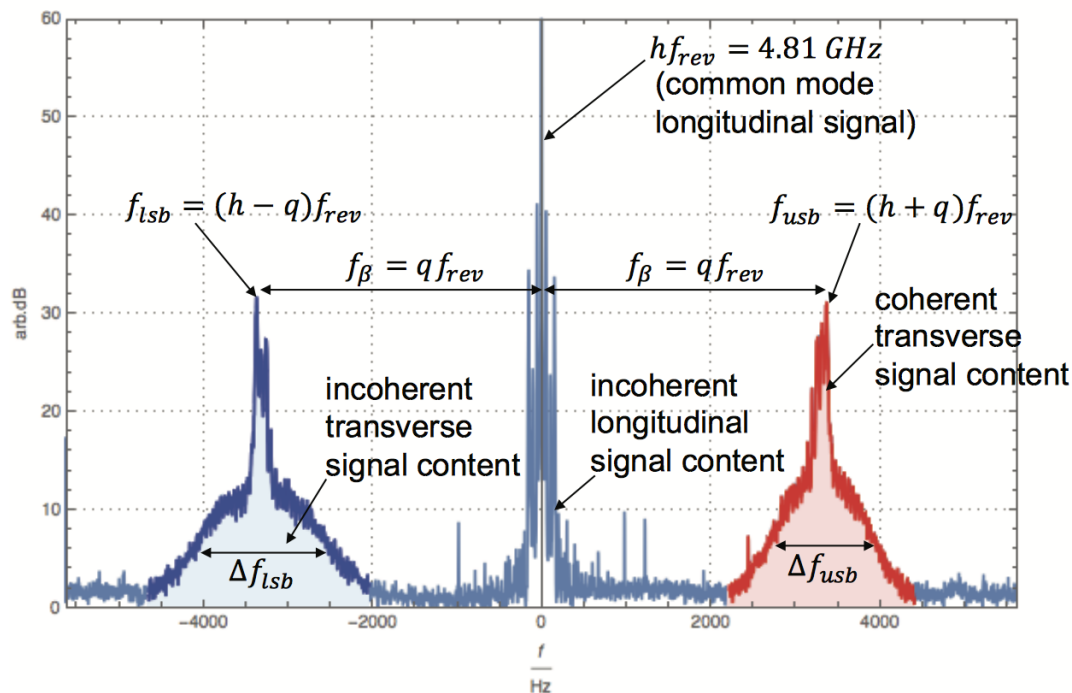
OP wish: Find other good tune sources: ADT (?), dBLMs (but need losses...)

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Schottky System

LHC **Schottky** capable of **online measurement of tune and chromaticity** in a non invasive way based on the observation of coherent and incoherent motion of each particle



Fractional Tune: peak distance
Chromaticity: width
Emittance: area

IPAC 2016 M.Betz

IBIC 2016 M.Wendt

Figure 1: Typical LHC *Schottky* spectrum.

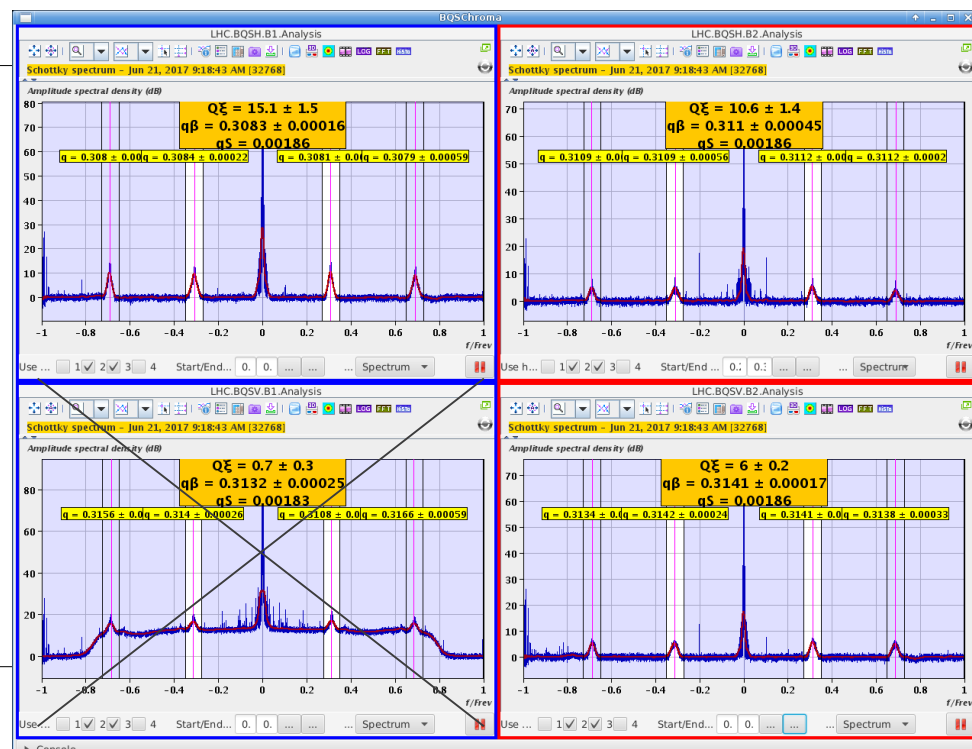
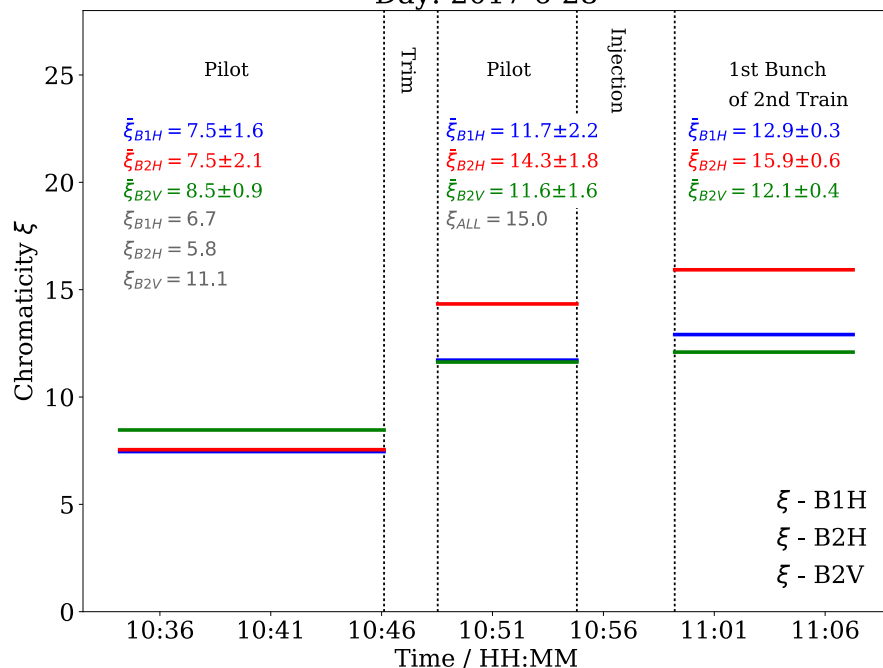
Online Chromaticity at LHC

On-going tests at the LHC to make available the online chromaticity measurements.

T.Tydecks
D. Louro Alves

Measurement is good but should be improved, error of few units.

Day: 2017-6-28



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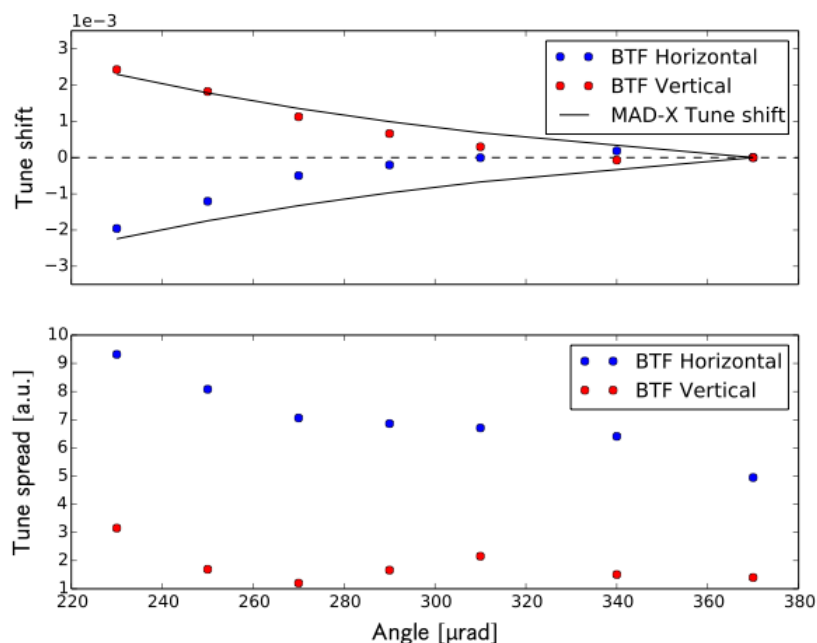
Beam Transfer Function

Extensively used last year during MD to reconstruct the stability diagram and evaluate the tune spread.

C.Tambasco
T.Pieloni
EPFL THESIS 7867

Example: BTF measurements end-squeeze with beam-beam long range interactions as a function of the crossing angle

Tune spread and tune shifts from beam-beam long range are evaluated by using the fitting method for an octupole current of 470A as during the measurements.



Thanks to the experience acquired with BTF measurements **improvements of the system are already in place for next MDs:**

- New GUI for measurement acquisitions: **more flexible and logged BTF data**
- Adjusting excitation amplitude according beam response: **improved noise to signal ratio**

BBSL: Longitudinal Density Monitor

M.Palm

Observation of satellite bunches

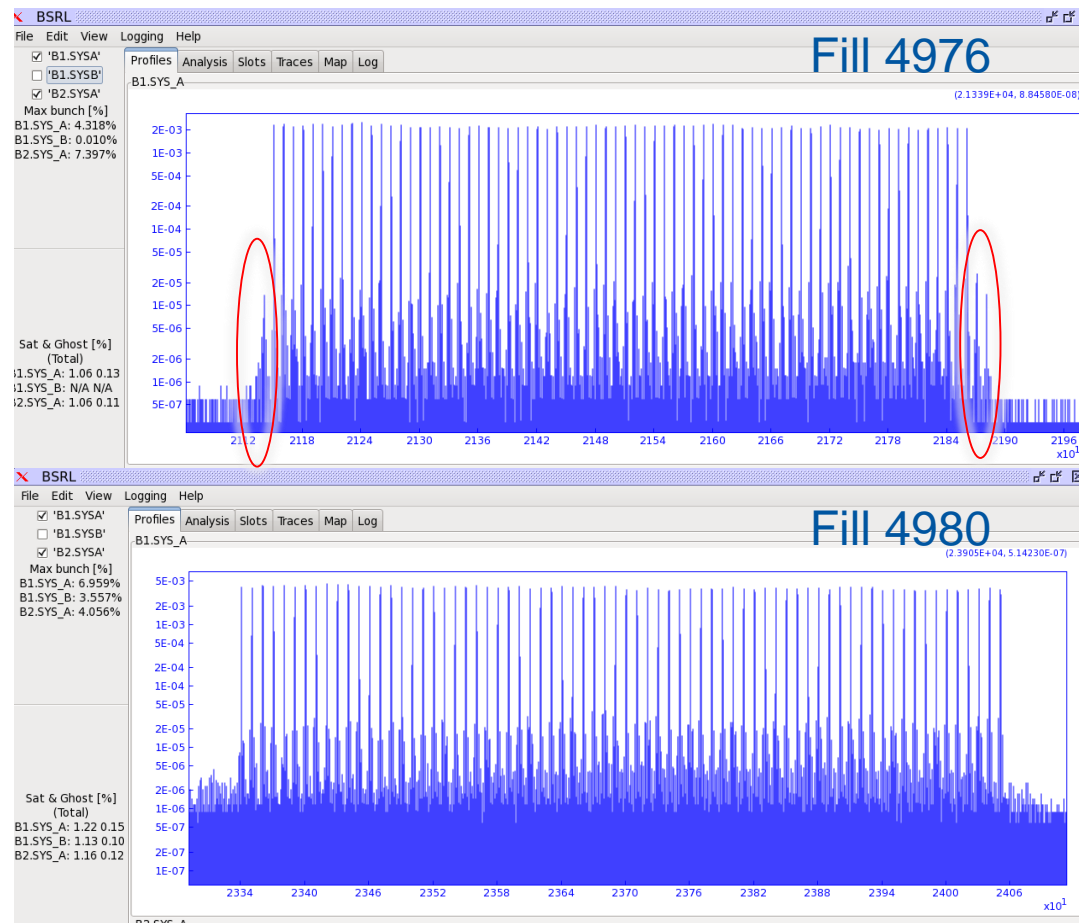
Extremely useful and used in 2016, it triggered often the request for injection optimizations.

Example:

PS optimization on the production of 25ns beam, they clean with a kicker the ghost bunches.

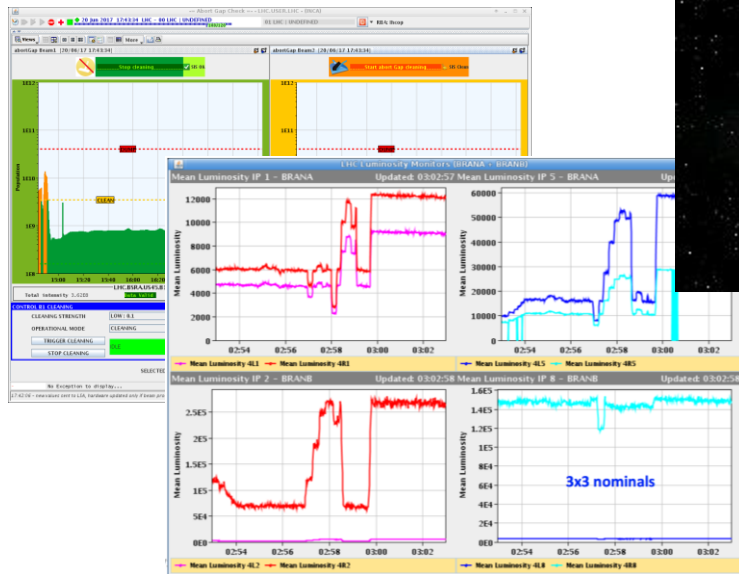
Compare fill 4976 (top) vs 4980 (bottom)

Work on going with OP in order to make a display similar to the fBCT.

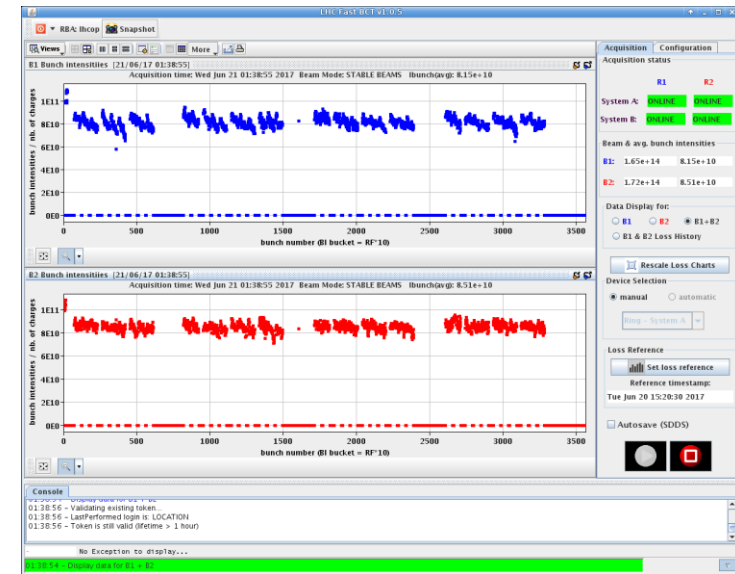
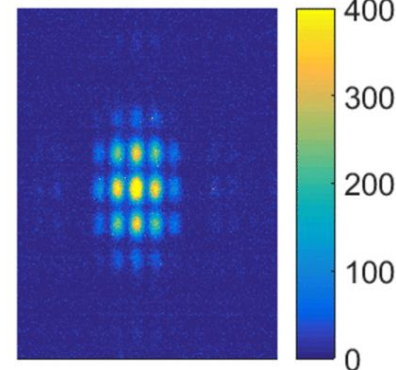


Many other devices uncovered...

- ✓ Beam Current Measurement: Improvements of gating/leakage.
- ✓ Beam Current Change Monitor BCCM
- ✓ Abort Gap Monitoring
- ✓ BRANs: stop of signal publication needs re-start from time to time.
- ✓ BGV
- ✓ Synchrotron Radiation Monitors: BSRH (coronagraph), BSRI
- ✓ BSRI (interferometer)
- ✓ MIM (multi band instability monitor)



H&V : D=3 mm



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Summary / Wish List

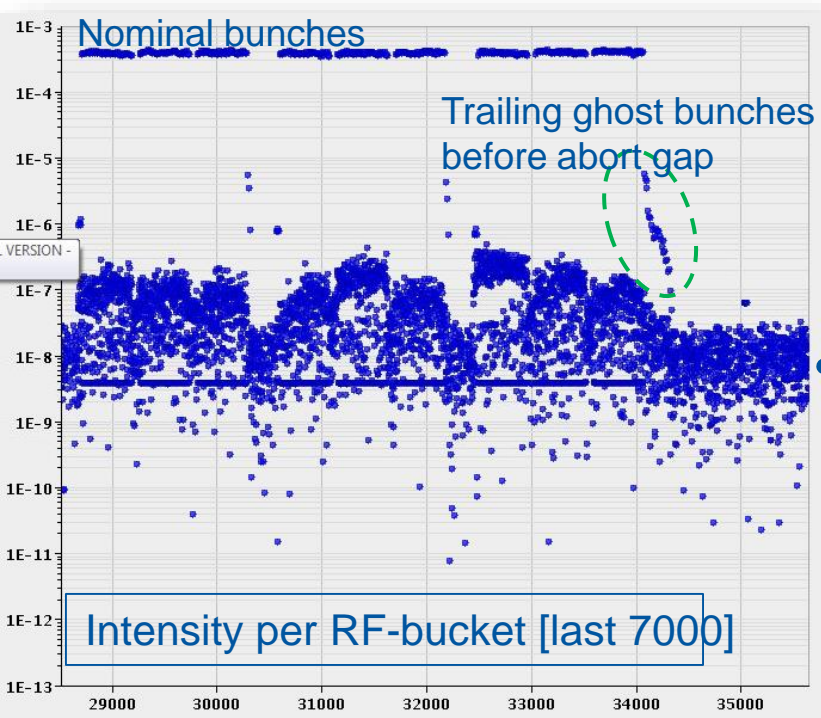
- ❑ **BLM/dBLM:** exploring the possibilities of the BbB dBLM measurement. Standardized read-out is desirable but work is on-going in this direction.
- ❑ **BPM/DOROS:** improve precision over range of amplitudes, soft IP feedback for future leveling.
- ❑ **WS/BSRT:** review/check the intensity limit, would be good to measure 1st train after 2nd injection (...)
- ❑ **Schottky:** could it be usable at injection for Q' ?
- ❑ **BBQ:** work on better quality (50Hz lines).



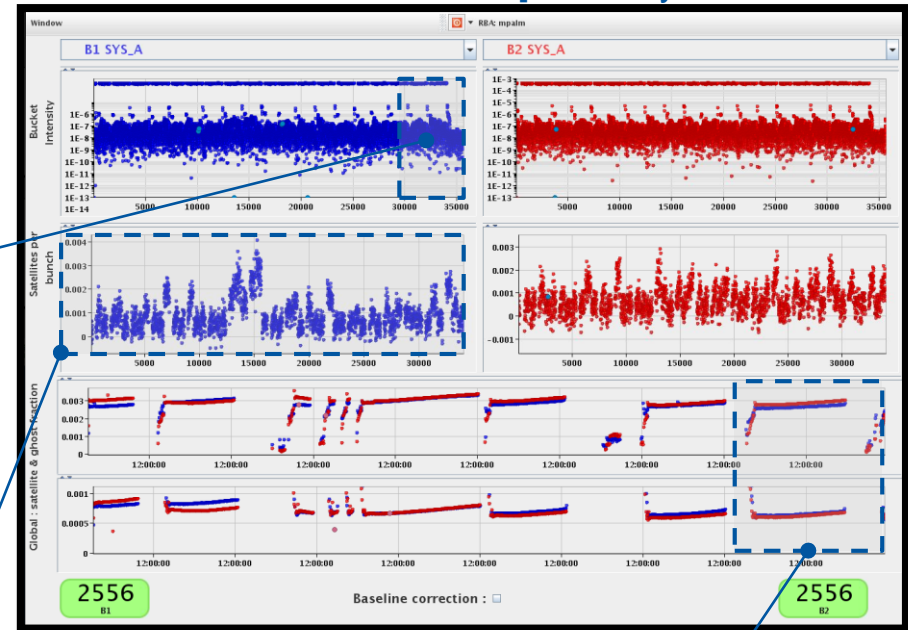
Thank you!

Summary LHC status

- ❑ LMC 28 June LHC Machine Coordinators
 - Last intensity ramp up BCMS 2556 bunches
 - Peak luminosity $1.55 \text{ e}34 \text{ cm}^{-2}/\text{s}^{-1}$
 - Integrated luminosity in 24 h above 700 pb⁻¹
 - Maximum stored energy 293 MJ (flat top)
 - Avg. bunch intensity $1.2\text{e}11 \text{ p/b}$



BSRL "Demo version" [Courtesy S. Bart Pedersen]



Snapshots from Fill 5880

