Beam instrumentation performance overview

session 6: system operational performance

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LHC Beam Operation Workshop

Evian 2011.12.13

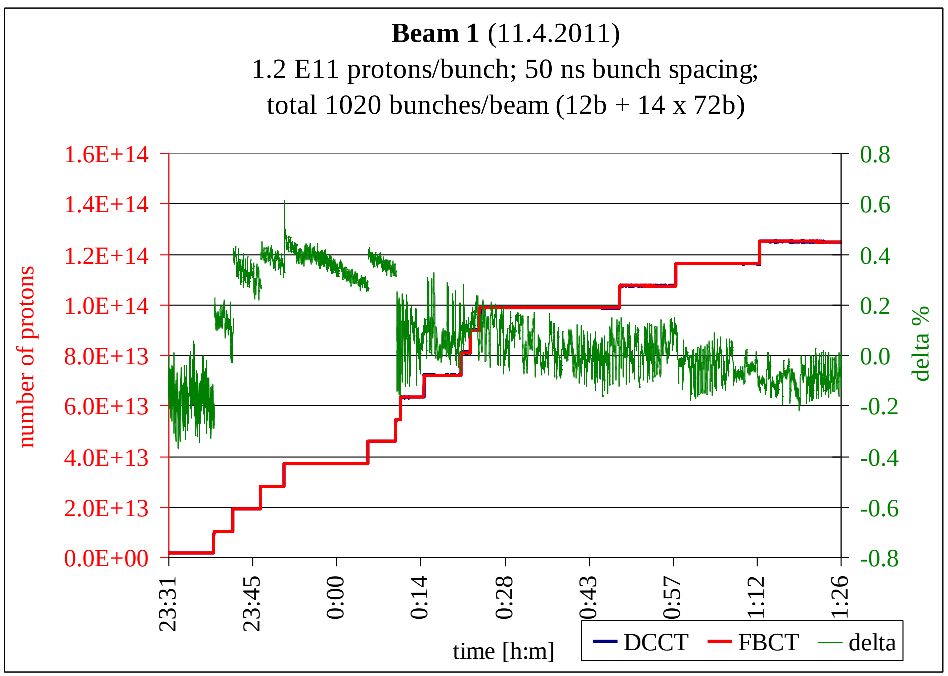
Systems covered:

- BCT
- BPM
- LDM
- Wire Scanners
- Synchrotron Light Monitors
- Beam Gas Ionization Monitors
- a word about Shottky if there is time left…

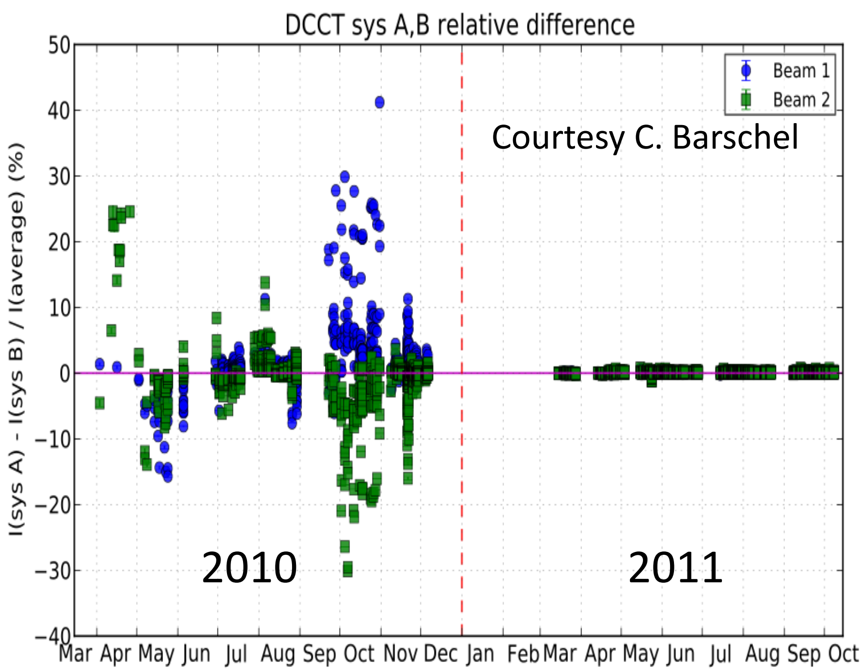
BCTs

Subject: DCCT - severe problems with filling pattern dependence & saturation (Evian 2010)

- Modifications made to DCCT itself & electronics to remedy this in 2010 Winter TS
  - No sensitivity to filling pattern observed in 2011
  - Calibrations & studies in 2011 show absolute accuracy & reproducibility at well below 1% level
- 2012 – concentrate on improving the fast BCT system



DCCT v FBCT – no fill pattern dependence observed



Agreement between A & B systems

BPM: temperature stability (1/4)

Subject:

Unphysical drift of the measured orbit due to temperature variation in the crate

Status:

- Standard BPM calibration added to sequencer mitigates part of the problem. (Evian2010: “Reset effect”)

Should be done JUST BEFORE injection (it takes < 10 min).

Sometimes injection finally occurs several hours after task has been run.

- During the fill temperature is monitored & linear correction is applied using a gradient per channel (that was itself calculated ~once per month).
- Gradients seem constant over the year.
- Student will analyse this to try to improve correction in 2012.

Long-term improvement:

- Water-cooled (thermally stabilized) racks.
- Prototype under test since a month in SUX1
- Preliminary results are encouraging.
- Replacement of all racks still planned for LS1 (as stated in Evian 2010).

BPM: Interlock BPMs (2/4)

Subject:

- Current settings dump beam if 70 bunch measurements in 100 turns are outside acceptance limits, i.e. sensitive to a single bunch
- Can happen if system is in low sensitivity & 1 bunch drops below ~3e10 charges.
  - Either stops giving readings (= no impact)
  - Gives spurious readings (= dump beam)

Possible action:

Remove 4dB attenuators from stripline BPMs

- Will decrease 3e10 threshold to ~2e10
- May give more spurious triggers at high bunch intensity (cable reflections)
- *What is the upper limit for single bunch intensity in 2012?*

BPM: orbit position resolution (3/4)

Subject: Increase of the orbit position resolution.

Description:

- New firmware deployed allowing longer integration time for asynchronous mode
- Removes sensitivity to turn by turn oscillations when bunch number >> 100
- Improves orbit resolution from ~10 µm to ~1 µm (arc BPMs during MD).

Action 2012:

- Integration time should be configured according the number of bunches in machine

  (Otherwise the large delay in response for single bunches perturbs the OFB)
- Two choices:
  1. Integrate into sequencer – need to change dynamically as bunches are injected
  2. Make it automatic in front-end (should be available for 2012 start-up)

     Count number of bunches per turn & select suitable filter setting

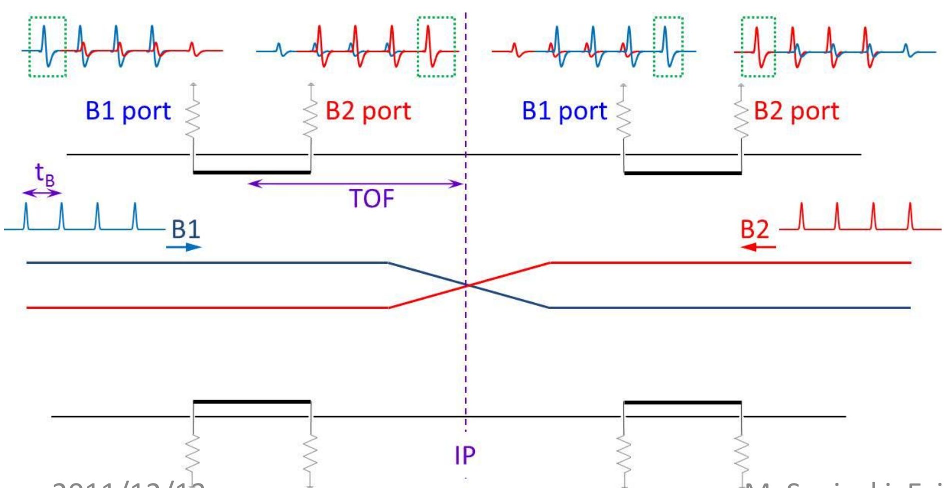
BPM: orbit in LSS (4/4)

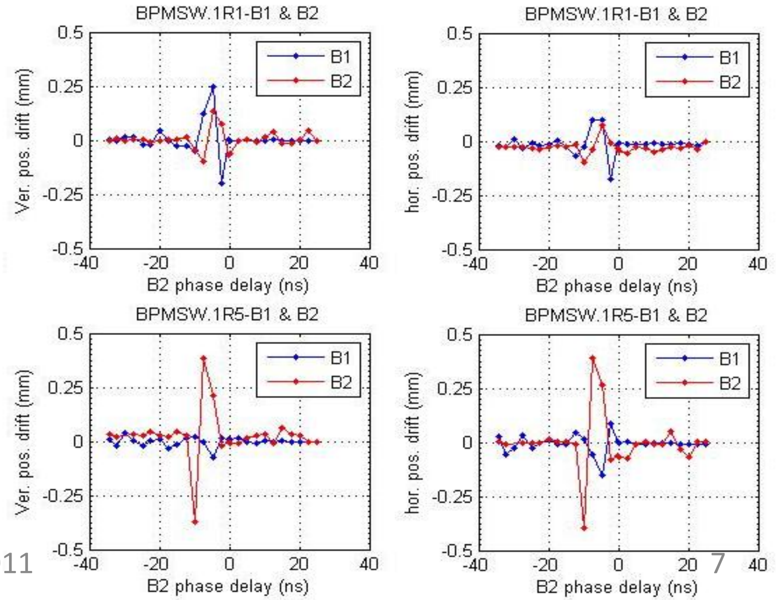
Subject: Cross-talk between both beams in insertion BPMs (stripline).

Solution: Use synchronous mode with orbit calculated from single bunch which has no long range collision close to BPM location. Firmware deployed since January 2011.

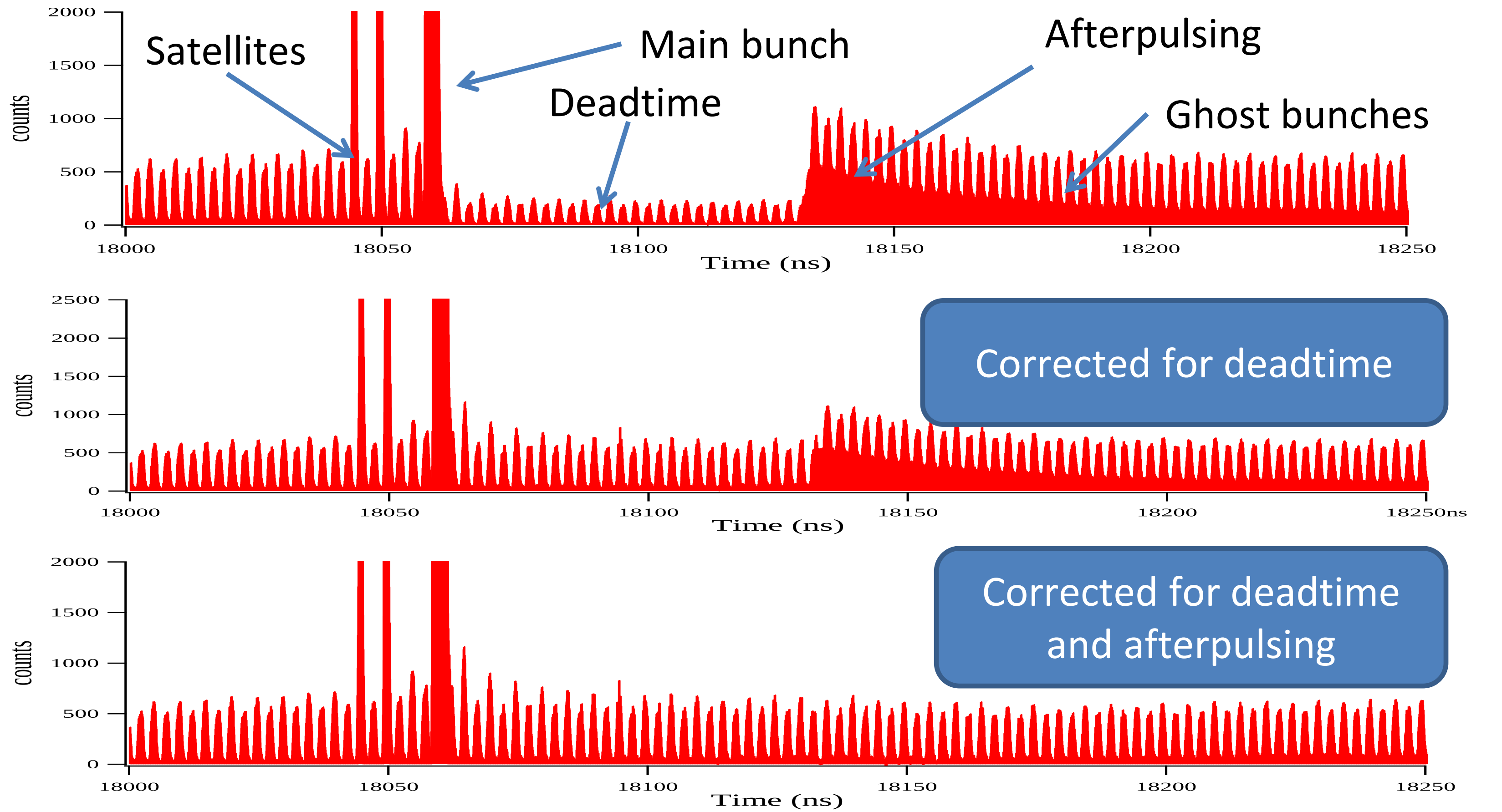
Action 2012:

- Mask needs to be configured for each BPM and dynamically as filling progresses
- There is a (OP) person working on an application to do this automatically.





Longitudinal Density Monitor



Aims:

- Profile of the whole LHC ring with 50ps resolution
- High dynamic range for ghost charge measurement

Method:

- Single photon counting with Synchrotron light
- Avalanche photodiode detector
- 50ps resolution TDC

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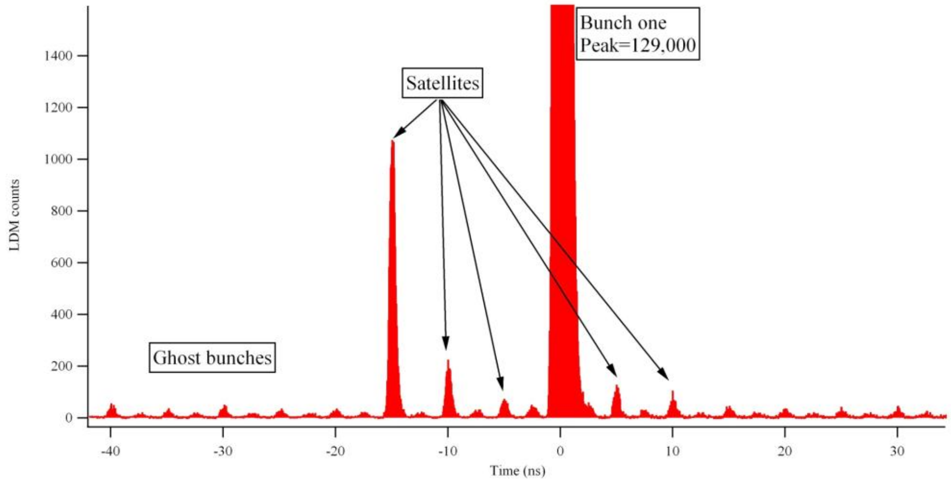
Longitudinal Density Monitor

Status:

- Operational on both beams
- Regular use for satellite / ghost measurement
- Dynamic range of 10^5 with 15 minutes integration
- Data logged in Timber & SDDS



Lead ions at 3.5 Z TeV
10 min integration

Action 2012:

- Finalize software for fully automatic running & improved display / online analysis (User-friendly GUI)
- Adapt optical system to eliminate dependence on transverse bunch size.

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Wire Scanner (1,2/5)

Subject: Measurement accuracy

- Comparison turn vs bunch mode:
  - Beam size evaluated with 2 modes within the measurement error (RMS 2%).
  - Results produced offline by retrieving the data from logging database & fitting Gaussian fits
- Bunch mode cross talk measurements:
  - Residual signal in the slot next to the bunch (25ns) is about 8% of bunch signal
  - For 50 ns spacing the remaining signal represents only 2.5%

Subject: Predicting failures

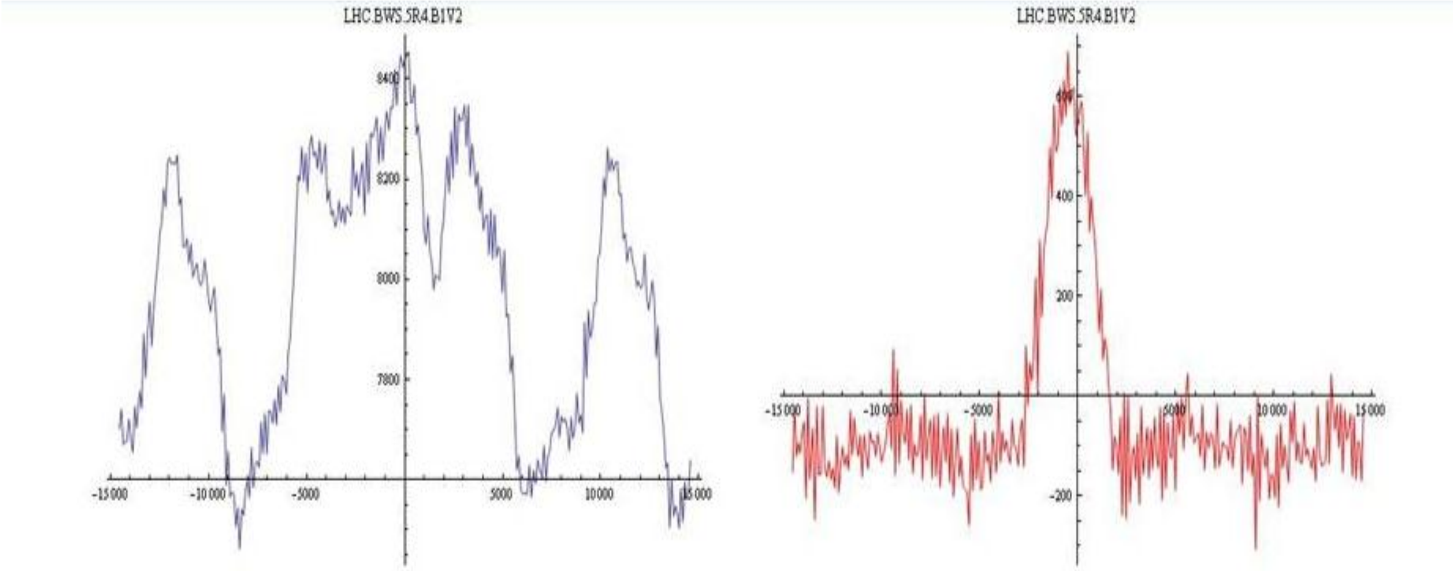
- Daily crown-job reports about WS use
  - Also proposed for injectors
  - Should allow preventive maintenance to be performed before failure occurs.

Wire Scanner (3/5)

Subject: Noise on B1 signal

Solution:

- Source investigated during several technical stops – not identified.
- Remedy was by acquiring in abort gap & subtracting the noise (MD3)



Wire Scanner (4,5/5)

Subject: Reproducibility

Description: Finding optimal gain/filter settings is not straightforward

- particularly important during ramp measurements
- During MDs 2011 system linearity (position, acquisition) has been checked

Action 2012:

- Put in place automatic PM gain & filter settings depending on beam parameters , to be always in the linear part of the system response.

Subject: Ease of use

Description:

- Automatic scans at determined intervals throughout injection, ramp & squeeze
  - When allowed by beam conditions (intensity & energy dependence)
- Easier handling of bunch-by-bunch scans

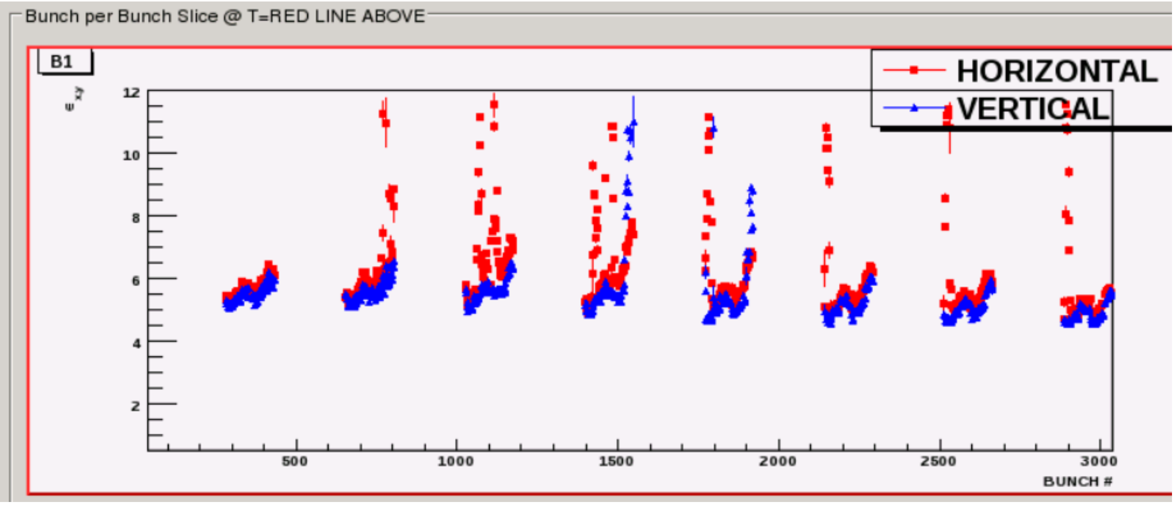
Action 2012: Better application?

BSRT (1/2)

Subject: bunch-by-bunch scan

Issues:

- bunch-by-bunch scan is slow
  - 1-3 s/bunch
- driven by expert application



Action 2012:

- New Front-End CPU
  - Aim at 10 to 25 Hz acquisition
- Scan driven by FESA server
- Need an application which allows to set basic parameters of bbb scan and to display the results
  - maybe based on Elliott McCrory's bunch by bunch correlation display?
  - OP help needed to develop this further

BSRT (2/2)

Subject: Accuracy and absolute calibration (Evian2010)

$$\sigma_{meas}^2 = (MAG \cdot \sigma_{beam})^2 + \sigma_{PSF}^2$$

Description:

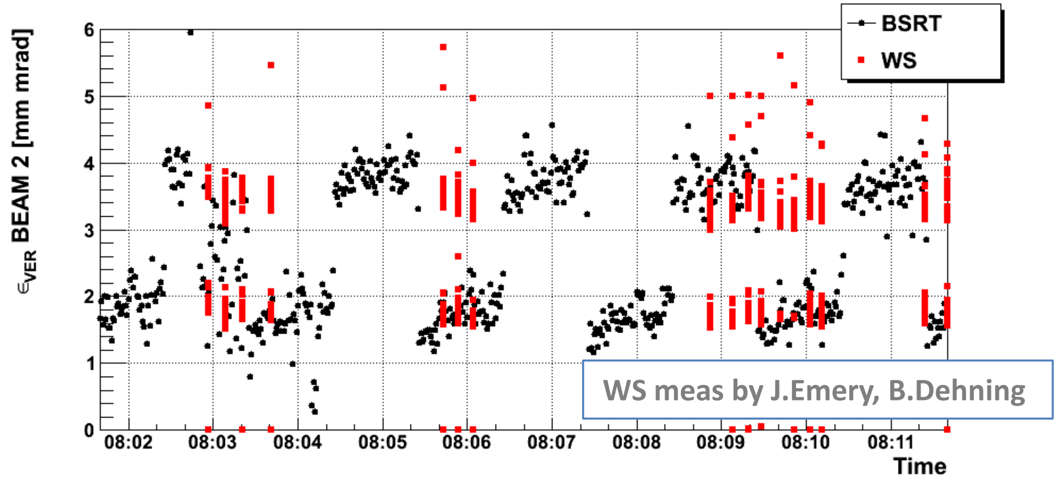
- Large correction factors required (as in many synchrotron light systems)
- For given system setting (camera position, color filter) can calculate correction factors for nominal bunches, nominal emittances.

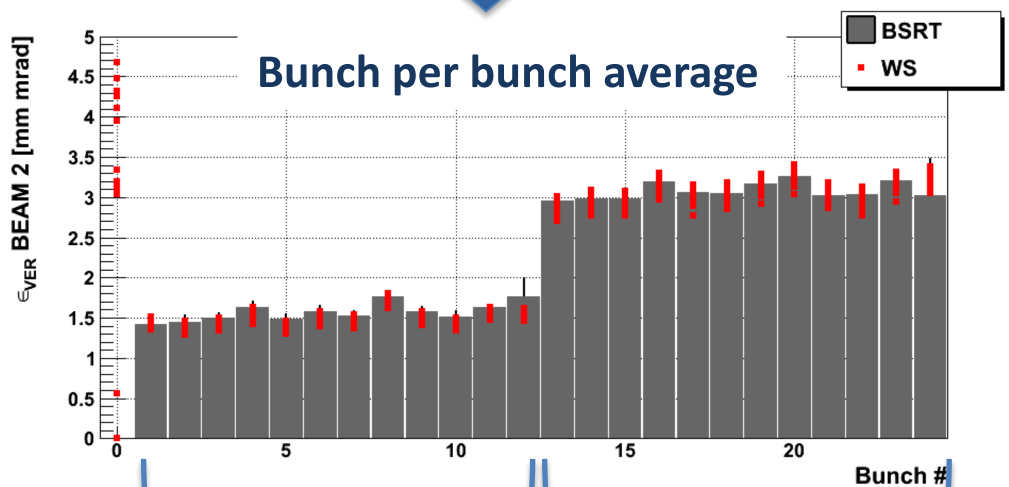
Actions 2012:

- Aim to publish corrected sigmas, with an error of about +-10%
- Understand sources of errors:
  - Analyze in detail data from last MD to determine
    - Magnification at 450 and 3500 GeV via closed orbit bumps
    - Verify that with such magnifications correction factors work for all bunch sizes
  - Still have to completely exclude any dependence on
    - Intensifier gain
    - Steering
      (lose light on mirrors, cuts, aberration increase if not in mirror centre ,etc)

Calibration (GOOD) example

Bunch per bunch meas lasted ~10 min
-17 WS meas per bunch
-15 BSRT acq. Per bunch





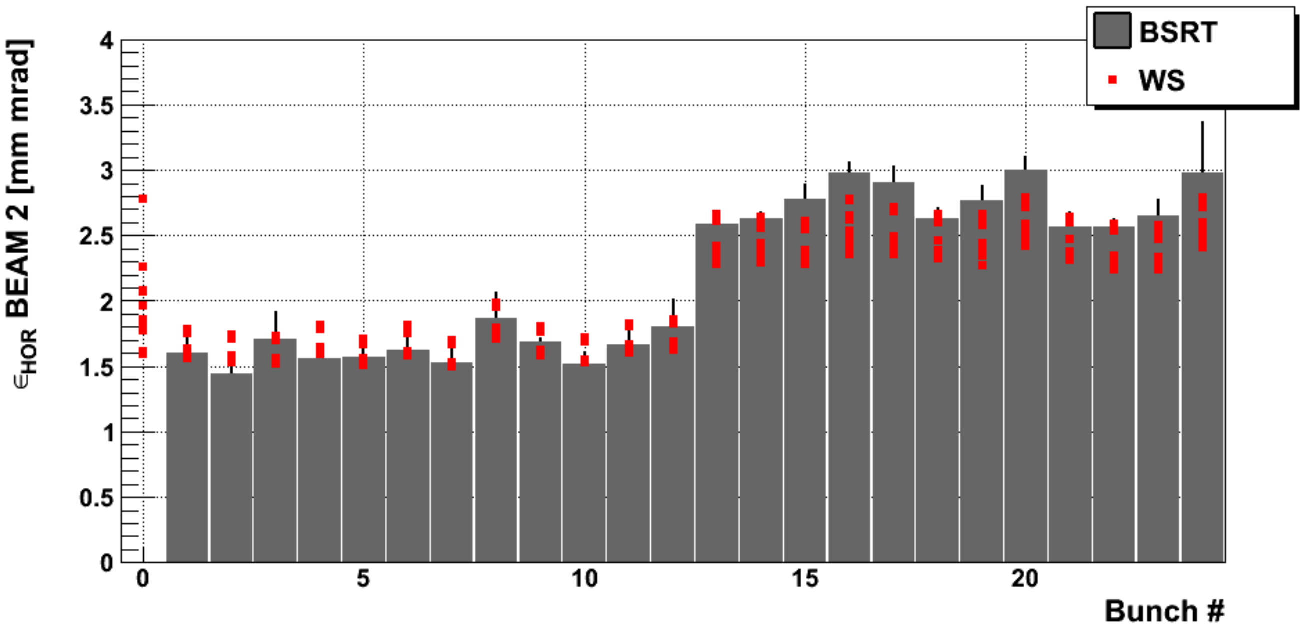
Beam 2 Vertical 450 GeV

- 12 ‘small’ emittance bunches
- 12 ‘large’ emittance bunches

CONCLUSION

- WS – BSRT b-to-b agreement ~ 1%
- Obtained during special MD period (BI experts optimization)

Calibration (not so good) example



- B2 HOR 3.5 TeV
- Single correction factor doesn't work for both small and big bunches

→ Indication of a scaling factor in addition to the correction in quadrature (confirmed by correction factors vs beta function correlation ….)

BGI (1,2/5)

Subject: camera gain/gate control (Evian2010)

Description: camera gain and gate must be controlled by server

Status: Done (Spring)

Subject: gas injection control (Evian2010)

Description: gas injection system could be controlled only by expert

Status: VAC developed application which now can be controlled by OP (Autumn)

Actions 2012: make the application even easier

BGI (4,5/5)

Subject: Signal quality

Description: The Image intensifiers MCPs deteriorate and gain become non-uniform over their surface.

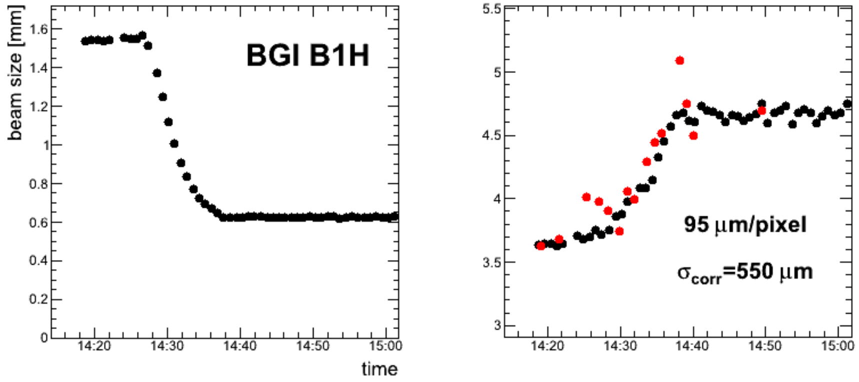
Status: A procedure to correct for this effect has been deployed in FE.

Actions 2012: Exchange all MCPs during winter TS. Better image processing.

Subject: Accuracy of emittance

Description: The obtained emittance does not agree with WS (depending on monitor)

Actions 2012: Ongoing simulations, need MD time in the beginning of 2012.



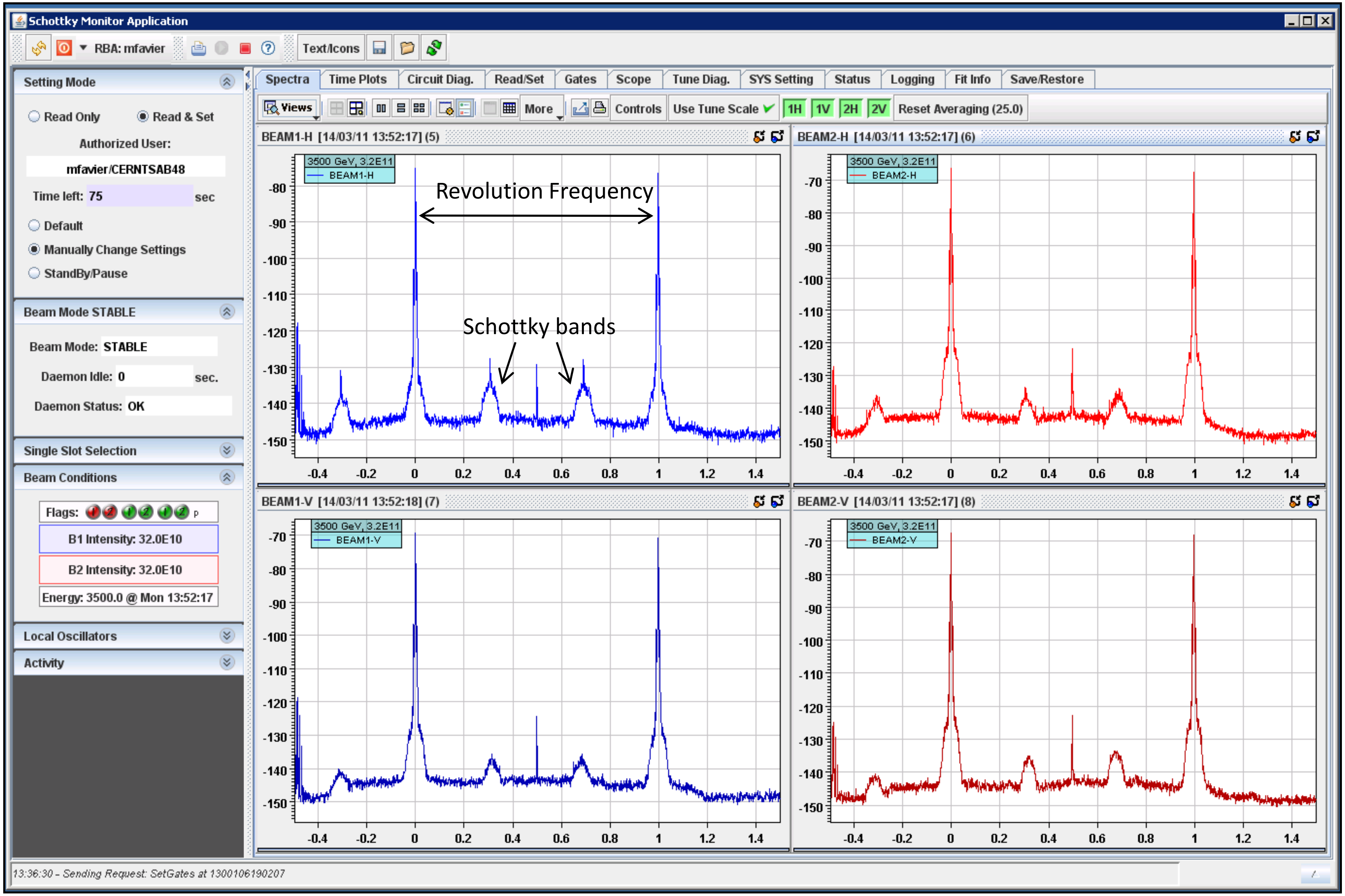
Summary: perspective for 2012

- BPM:
  - LSS BPMs should be more reliable (needs commissioning time for checks)
  - Automatic filter selection - improved orbit position resolution (1 μm)
  - Temperature dependence still there
- LDM:
  - Fully automatic & improved fixed display
- Wire scanner
  - Automatic gain/filter setting
- BSRT:
  - 20 times faster bunch-by-bunch measurement
  - better accuracy (will require further MDs in 2012 to improve this)
- BGI
  - independent continuous emittance measurement
- Shottky
  - bunch-by-bunch tune

thank your for your attention

Backup slides

Schottky Spectra from B1 & B2: Screen shot of the GUI



Mathilde Favier

Shottky (1&2/2)

Subject: Signal quality.

Description:

B1H gives the best signal. Signal quality depends on varying beam conditions. Shottkys are sensitive to coherent longitudinal and transverse oscillations (longitudinal blow).

Action 2012: Bring all signals to level equivalent to B1H. Try to make it less dependent on beam conditions.

Subject: bunch-by-bunch tune measurement independent on dumper

Action 2012:

Provide it except of period of about 30 minutes after squeeze (for protons, ions ok)

potential resolution (MD): 2e-4

Issues & Limitations

Schottky devices are really sensitive to:

Coherent longitudinal oscillations

- Longitudinal blow-up during ramp.
- No more signal right after start of Ramp
- 30 MINS BEFORE SIGNAL RE-APPEARS in COLLISIONS

Coherent transverse Signal

System has 100dB dynamic range but still sensitive to:

- Bunch position
- Bunch Intensity -> Saturation of the Electronic

B1H always nice, why?

- **investigation still ongoing**
- **Trying to improve symmetry of the signal before taking the difference.**

Expectations for 2012

Good Schottky Spectra observed with favourable conditions:

- **Especially with the ions**
- **Also for Protons once stabilized in coast**
- **Possibility to measure bunch to bunch tune with a resolution of 1e-4.**
- **Chromaticity measurement demonstrated but needs to be cross checked.**
- **Need to keep working on the fit to improve the measurements of the other parameters.**

PRIORITY: Bring all the signals to the equivalent level of B1H.

- Not many optimisation parameters
- Mainly dependent on varying beam conditions
- Working to make it less dependent & more operational

Wire scanner performance (2/3)

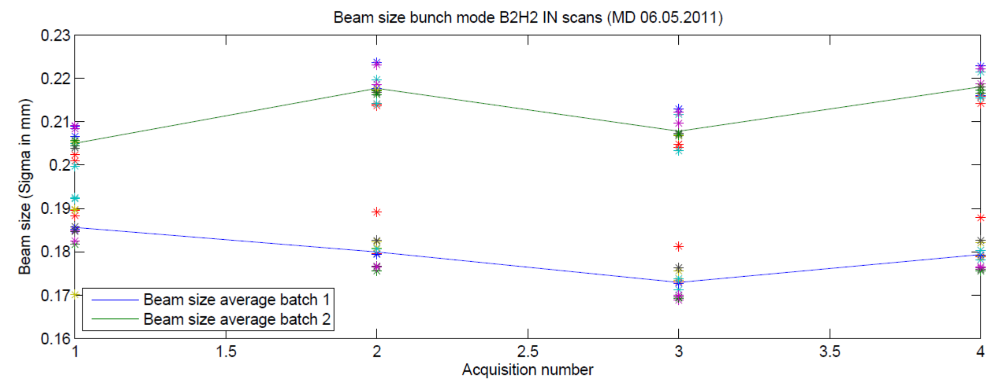
Comparison turn vs bunch mode

The beam size evaluated with the 2 modes is very close to each other, within the measurement error observed in the 2 modes (RMS 2%). The results were produced offline by retrieving the data from the logging database and fitting it with Gaussian fits (fig WS4).

Bunch mode cross talk measurements

Including any source of perturbation coming from the beam into account, the residual signal in the slot next to the bunch (25ns) is about 8% of the bunch signal, after 50 ns the remaining signal represent 2.5%.

Cronjob for quality check of the measurements and data analysis is being put in place. Further results during the next run.



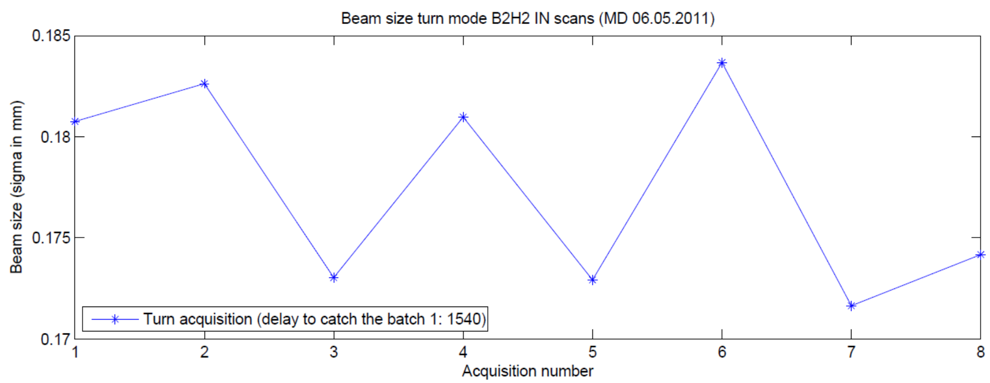


Fig WS4: Comparison between turn and bunch mode with beam 2 horizontal scanner

Reference measurements: LHC Transverse profile monitors studies (MD1 on May 6th, 2011)

Wire scanner performance (3/3):

First measurements of the same beams across the injectors and LHC during the BI MD2 (fig WS5)

During 2011 run, noise coupling was observed on Beam 1.

Software correction was applied to reduce it by subtracting noise signal from the abort gap.

Now the Sigma curve follows Intensity curve and the overall measurement spread for the corrected profiles is significantly reduced (fig WS6).

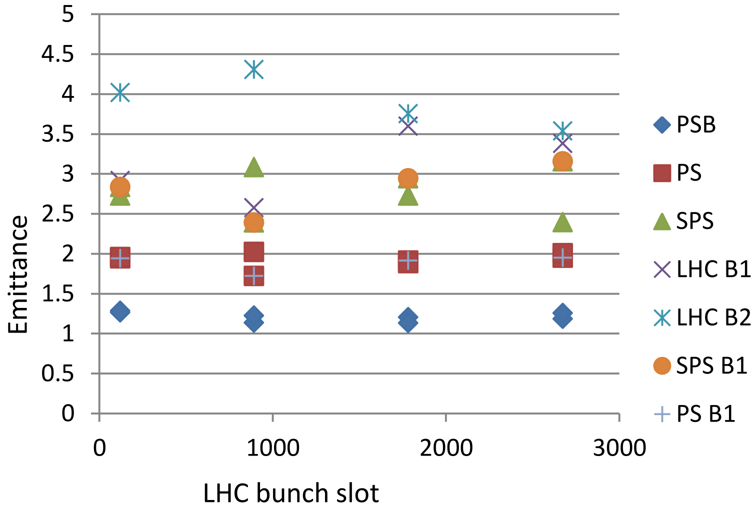


Fig WS5: Emittances across the injectors and LHC
LHC Transverse profile monitors studies (MD2 in August, 2011)

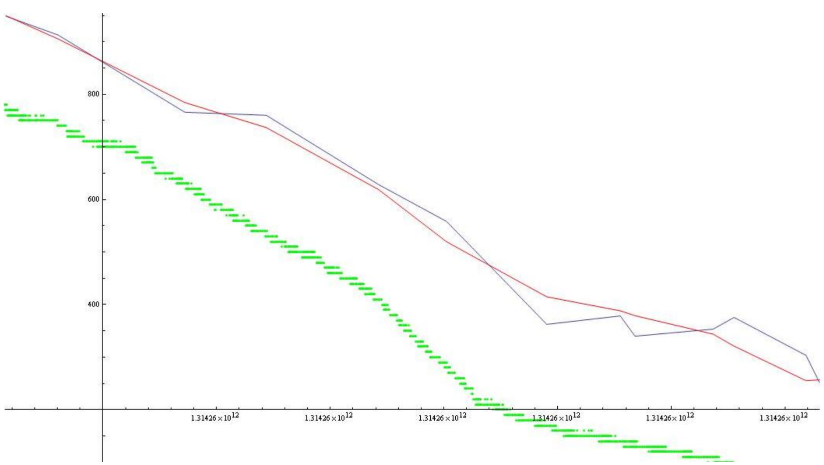


Fig WS6: Measured beam size with (red) and without (blue) correction
Reference measurements LHC Transverse profile monitors studies (MD3 on August, 2011)

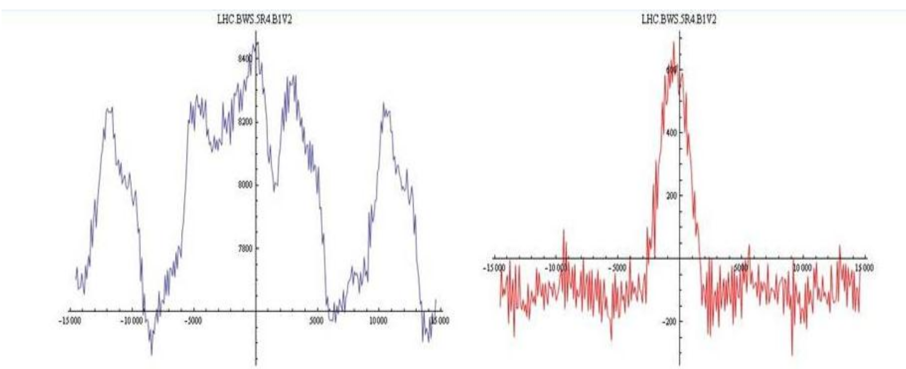


Fig WS7: beam profiles measured with (red) and without (blue) correction

BPM: channel availability (1/6)

Description: some BPM channels (2%) are masked in Orbit Feedback system because:

1. systematic non-physical offset
2. high noise
3. high error rate

Most of the masked monitors are in LSS (long cables).

To know which BPMs should be intervened during the TS and why, is not always easy.

There has been some improvements, since the OP masks are now stored in LSA with dates and “comments”. (*Please, try to make clear comments!*)

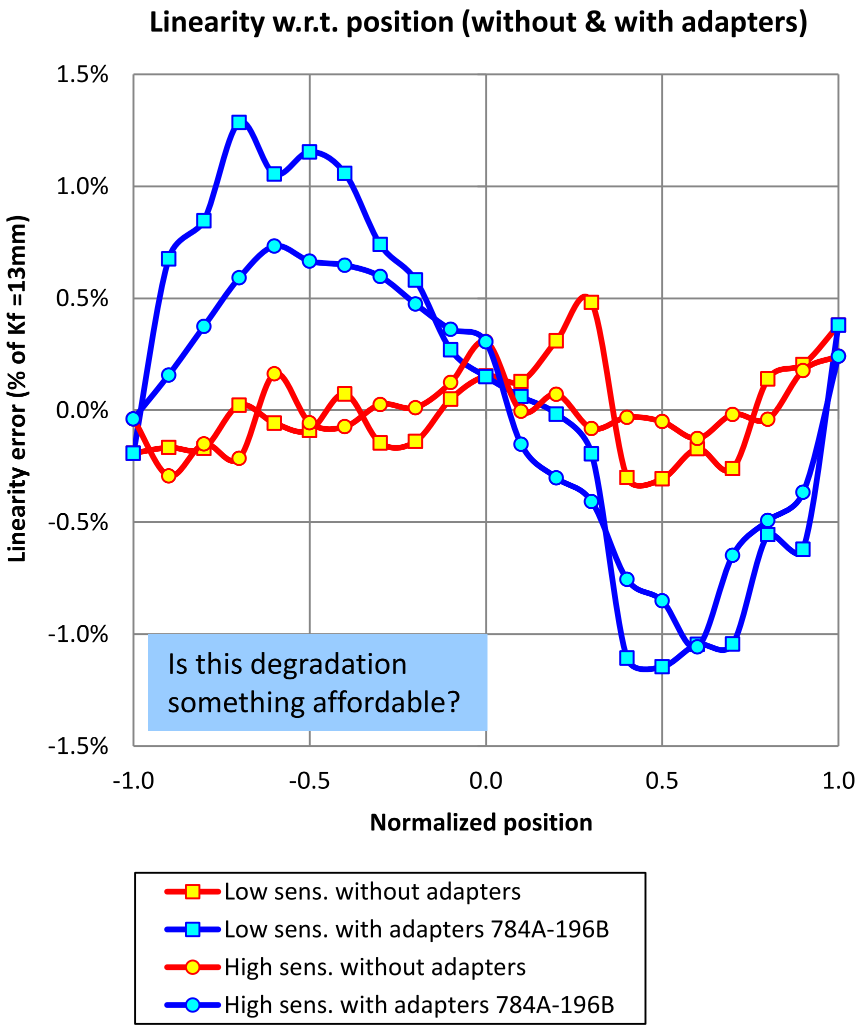
Action: Cable adapters, containing low pass filters, were proposed in Evian2010. They reduce RMS noise but affect slightly the linearity.

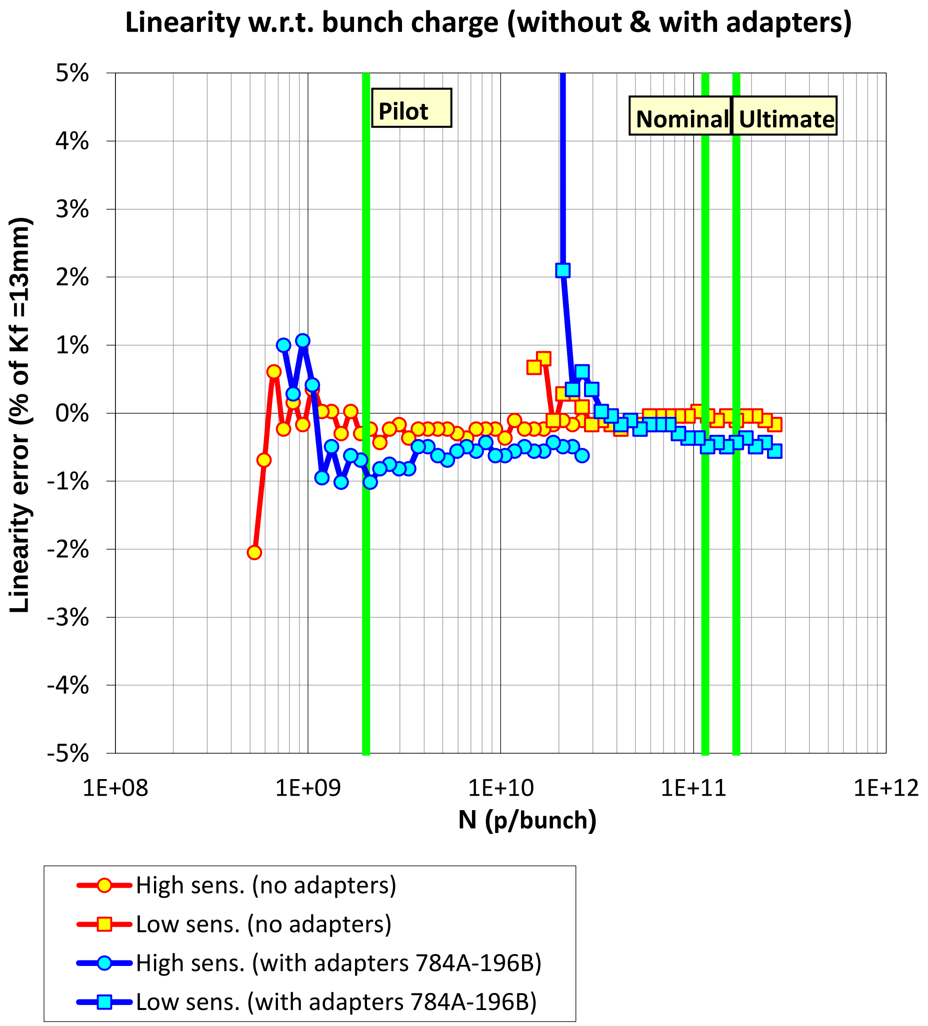
Status: about 40 adapters tested in lab and installed (IP6 and IP1)

Still need to test 500 adapters (out of ~1000) - FSU working since 3 weeks – 20 adapters/day (→ 5 BPMs/day). More will be successively installed during TS but:

beam data from the installed should be analyzed before progressing with installation.

The cable adapters compromise





The will improve the resolution by filtering noise, but they will degrade the linearity.

BPM: bunch-by-bunch (5/6)

Subject: Availability and accuracy of bunch-by-bunch data.

Description:

- Bunch-by-bunch data available in various ways.
  - Bunch orbit mode – Averages of each bunch over 225 turns (reject 50 Hz mains ripple)

In this mode, some bunches (at the beginning of the train) have systematic error (of the order of 100 microns).

What absolute bunch-by-bunch resolution/accuracy is needed?

Beam-beam interactions require resolution at the few micron level, that are beyond the possible bunch orbit resolution of the BPM system. *An upgrade of the electronics to this level means huge effort and could be done only in LS1.*

Bunch Scan

2011:

-1 sec per bunch (3 sec to reduce noise)

-scan driven by BI Expert GUI

2012:

-new FE CPU, aim at 10 to 25 Hz acquisition (w.r.t. 1 Hz 2011)

-scan driven by FESA server

FAST camera (aiming at turn-per-turn, bunch per bunch) tests: not enough light at inj., need > 10-15 turns)

Accuracy $\sigma_{meas}^2 = (MAG \cdot \sigma_{beam})^2 + \sigma_{PSF}^2$

For a given system setting (camera position, color filter) we can calculate correction factors for nominal bunches, nominal emittances)

→2012: aim at publishing corrected sigmas, with an error of about +-10%

SOURCE OF ERROR (relatively large correction factors) to be understood

•We still have to analyze in detail the last MD data to determine

- •Magnification at 450 and 3500 GeV via closed orbit bumps
- •Verify (likely need more data beginning of next year) that with such magnifications we end up with PSF correction factors that work for all bunch sizes

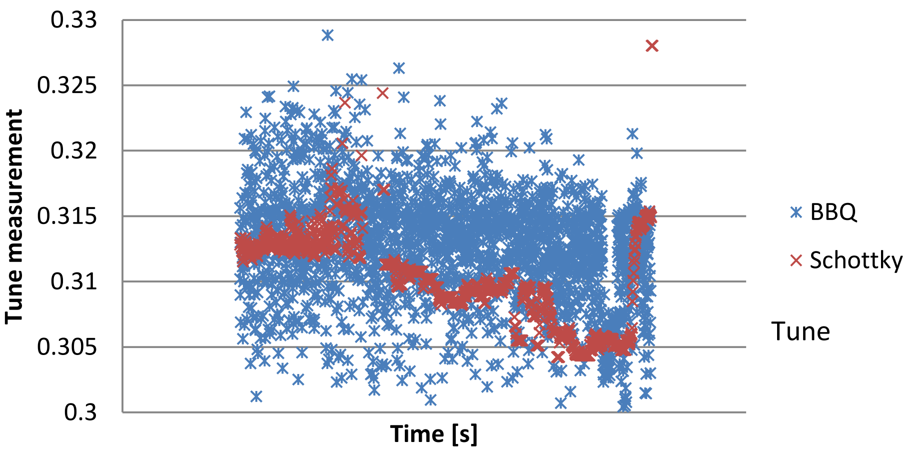
•We still have to completely exclude any dependence on

- •intensifier gain
- •Steering → loose light on mirrors, cuts, aberration increase if we don’t pass through mirrors center etc ….

Measurements & Results

- Tune Measurements

Tune measurement comparison

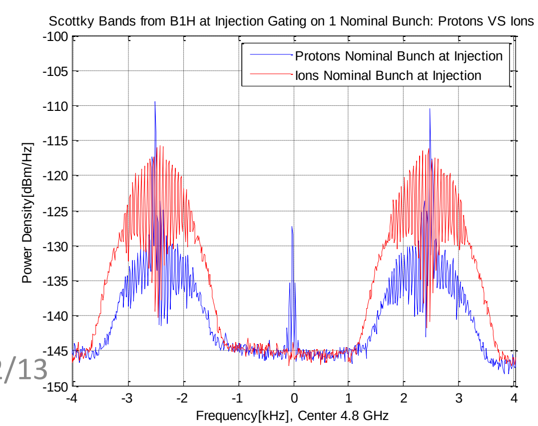


BBQ with dampers on, quite noisy, not so clear.
BBQ peaks give DeltaQ * Yokoya factor (around 1.21) so we had from BBQ 0.02 total tune shift.
Expected Schottky incoherent tune spread: 0.016.
Measured Schottky incoherent tune spread : 0.014 which is fine.

Comparison of Ion and Proton spectra

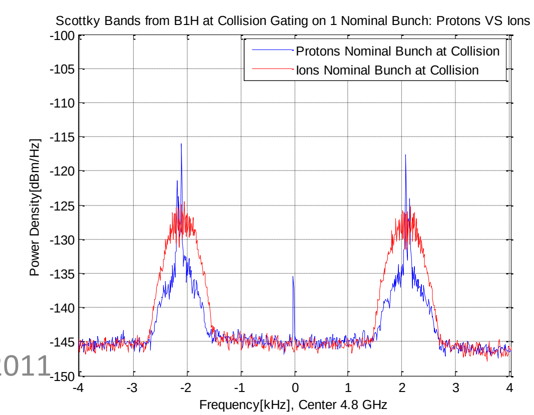
Nominal Bunch **at Injection**:

	Intensity	Bunch Length
Protons	1.26E+11	1.19ns
Ions	6.9E+09	1.9ns



Nominal Bunch **at Collision**:

	Intensity	Bunch Length
Protons	1.20E+11	1.13 ns
Ions	7.41E+09	1.7ns



BGI (3/5)

Subject: HV stability

Description: voltage instabilities observed, leading to automatic shut-down of the HV and to 2 beam dumps (one was actually thermal runaway of MCP)

Status: Stability test started in September, for ion run a stable working conditions established.

Actions 2012:

- Inspection of BGIs during technical stop.
- Likely, with gas injection BGI can operate with HV far from unstable region also for high-intensity proton beam – it must be carefully observed during intensity ramp-up.
- Additional conditions to shut down HV in case of instabilities will be implemented into server.

BGI (6,7/5)

Subject: New Fixed Display

Status: a simple FD with emittance history over the last 10 hours exists

Actions 2012: New, more flexible FD will be developed during 2012 run (betas from LSA, maybe standalone fit, to be defined)

Subject: Bunch-by-bunch

Status: Theoretically possible but missing hardware and software.

Actions 2012: Test synchronization, try to gate the camera.