Beam instrumentation, Other instruments…

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on behalf of the BE-BI group

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Outline

- Ghosts and satellites
- Ghost busters
- Bunch length measurement
- Emittance and emittance evolution
- Beam halo measurement
- Beam stability (position)

Ghosts and satellites

- Errors in the capture process can lead to ghost bunches, i.e. wrong RF buckets being populated (400 MHz -> 2.5 ns)
- Capture/splitting errors in the injectors can lead to satellites bunches being populated
  - SPS 200 MHz -> n x 5 ns
- Particles can escape from the RF bucket due to several processes (IBS, RF noise etc.)
  - Un-captured beam is lost during acceleration but can circulate for long time while coasting

Ghost busters

- Ghosts and satellites are usually very faint (<=1% of the main bunch), but many
- They are very close to the main bunch
- Need a monitor with large dynamic range and accurate timing resolution
- Not many candidates

Ghost busters candidates

- Fast current transformers
  - Too slow and too little dynamic range
- Wall current monitor, strip line PU
  - Probably too little dynamic range and systematic effects
- Synchrotron light detection using a fast PMT
  - Not yet investigated, could be interesting
- Synchrotron light photon counting
  - Tested on beam 2 in 2010 looks quite good

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Wall current monitor

- In order to increase the dynamic range need aggressive averaging
- Need to study the systematic effects like
  - reflections
  - noise,
  - Corrections for detector and cable response
- The potential is there but need accurate study
  - Possibly upgrade/modification of the readout

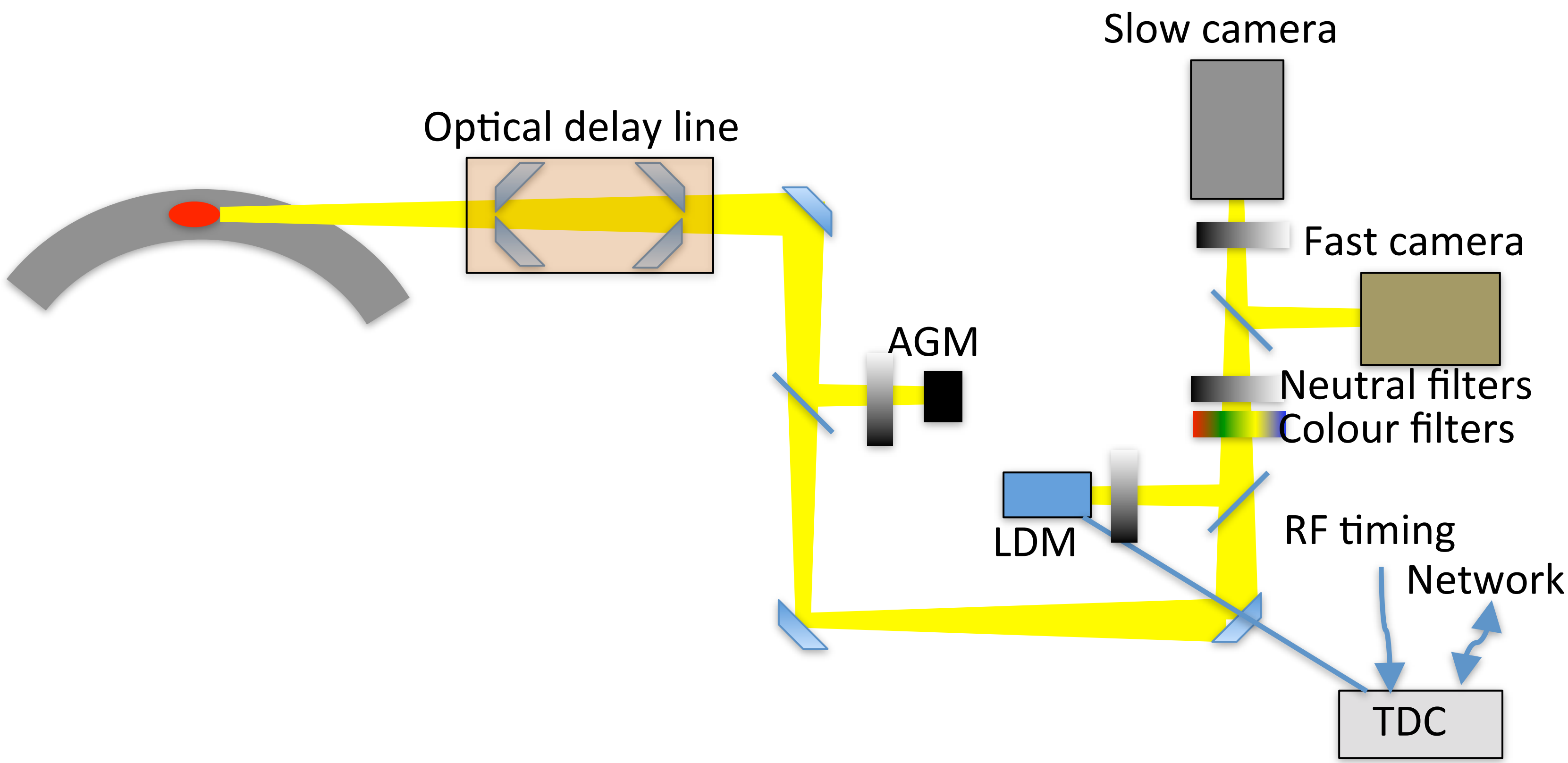
Longitudinal density monitor

- Detect arrival time of single SL photons
- Very good time resolution
  - At the moment limited by timing reference (~300 ps), 50 ps possible
- No hard dynamic range limit, main limit comes from the integration time
  - Dead time correction works well
  - Dark counts ~5 kHz are not a problem

LDM 2

- Light source in common with the BSRA and BSRT (undulator + D3 magnet)
- Light path in large part shared with BSRA/T
  – Limitations on the setting/adjustments
- Detector is an APD from id-Quantique (<50 ps)
- Precise TDC from Agilent (Aquiris) (50 ps)
- Turn clock reference from BOBR (BST)
  – Should switch to a dedicated RF signal ASAP

LDM / BSR layout



LDM example

- Fill 1525 (end of fill)
- Max count ~ 120’000
- Bin width 50 ps
- Integration time 500 s
- Corrected for dead time, after pulse and dark counts

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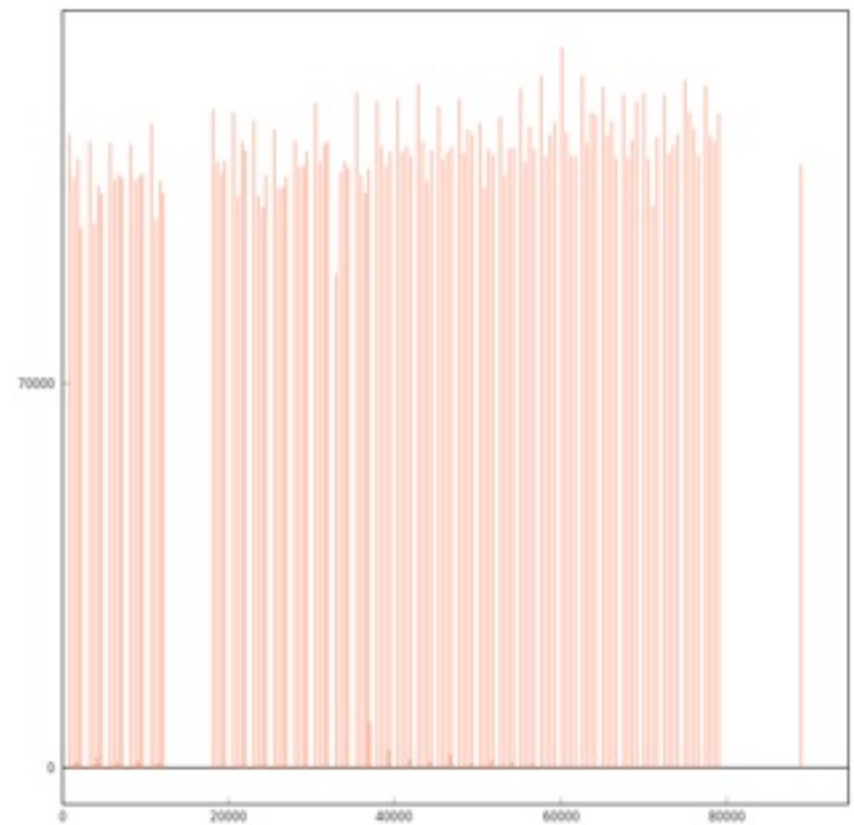

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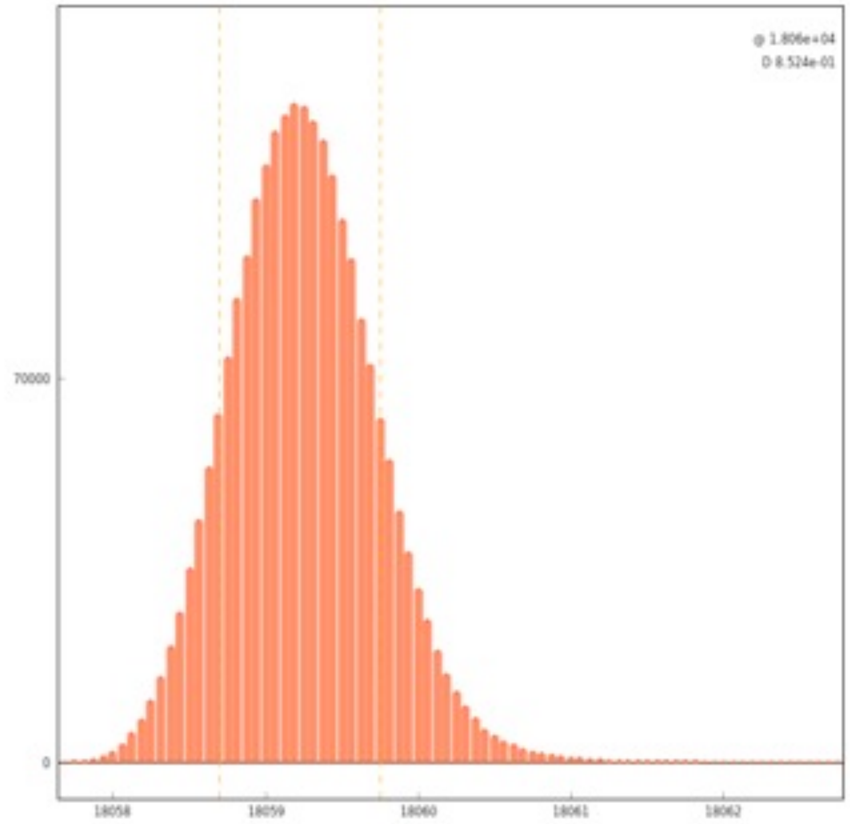

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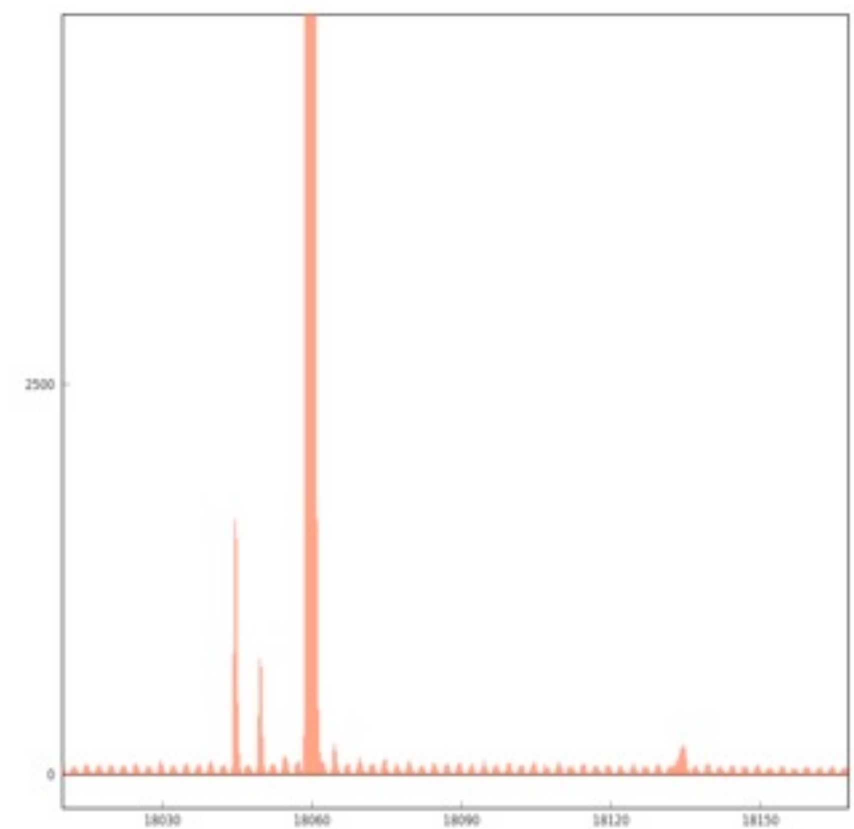

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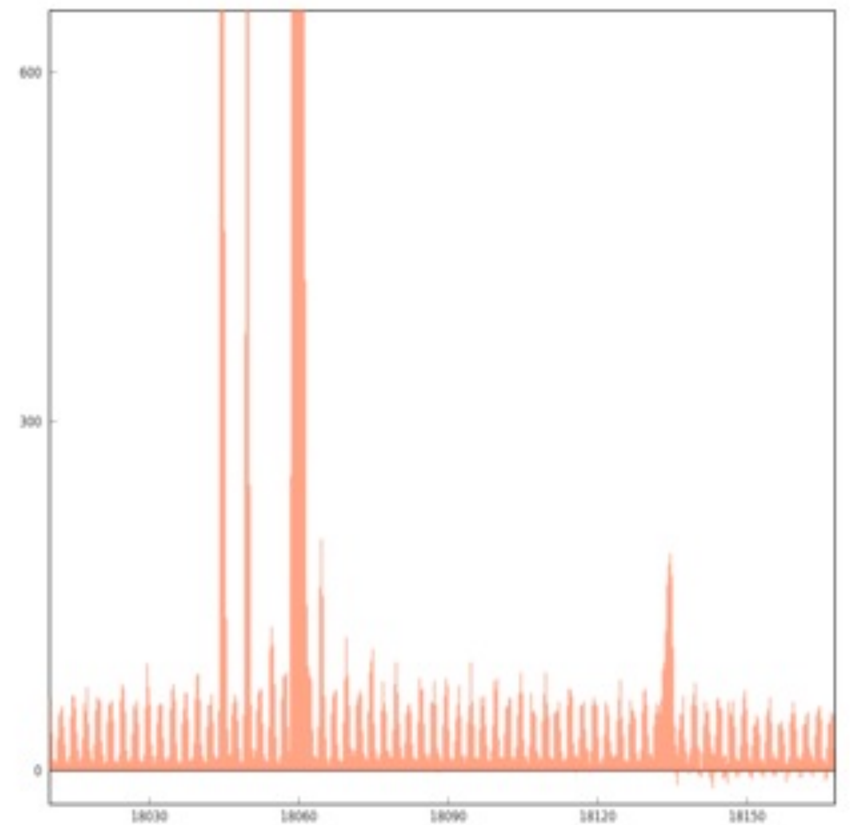

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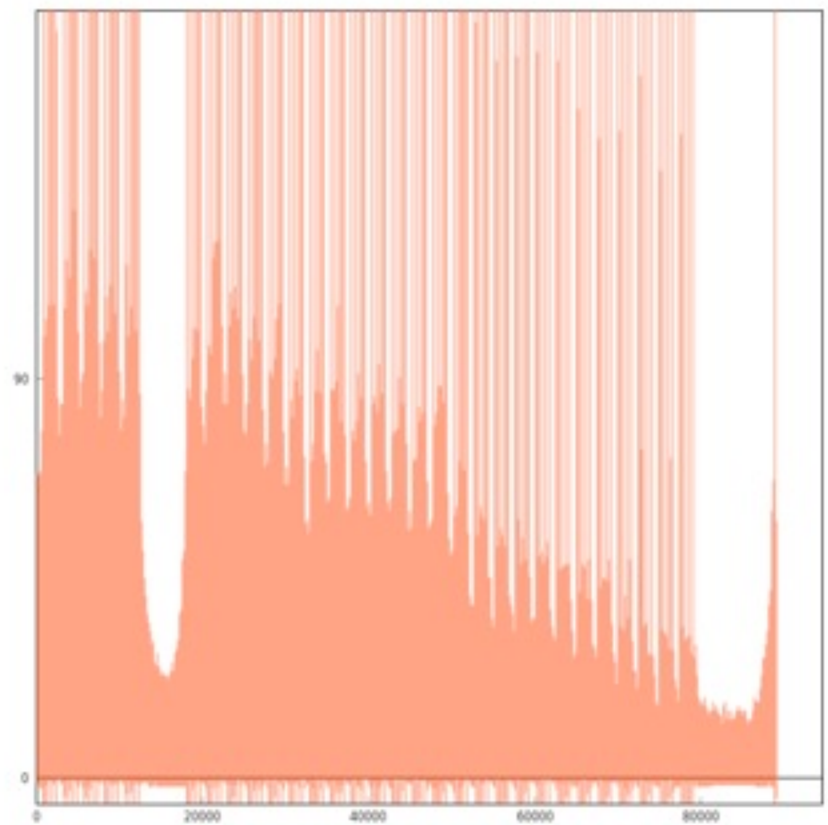

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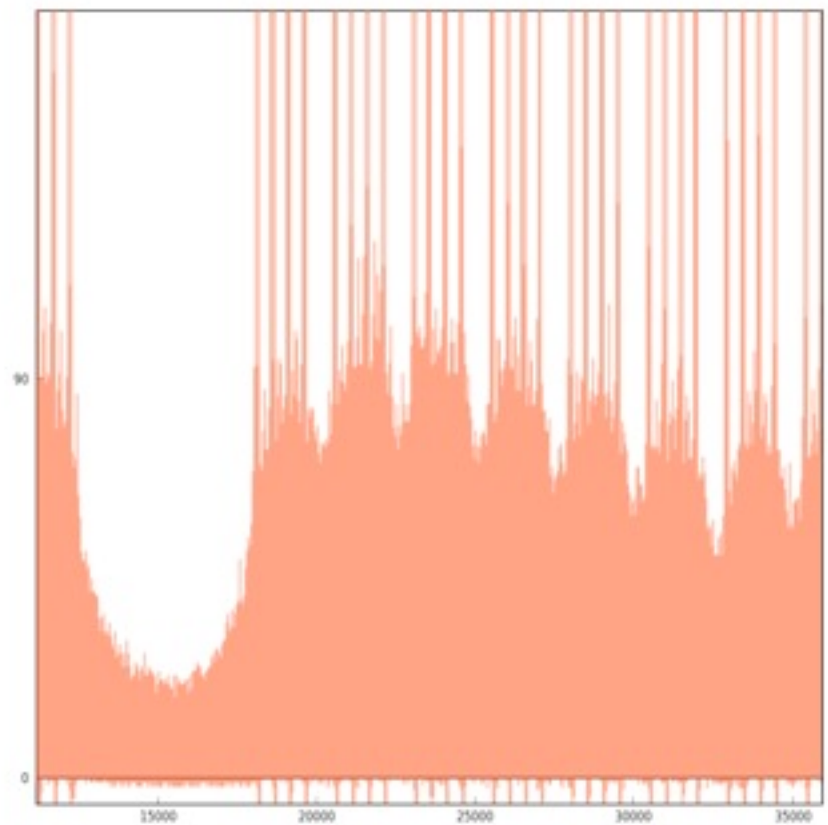

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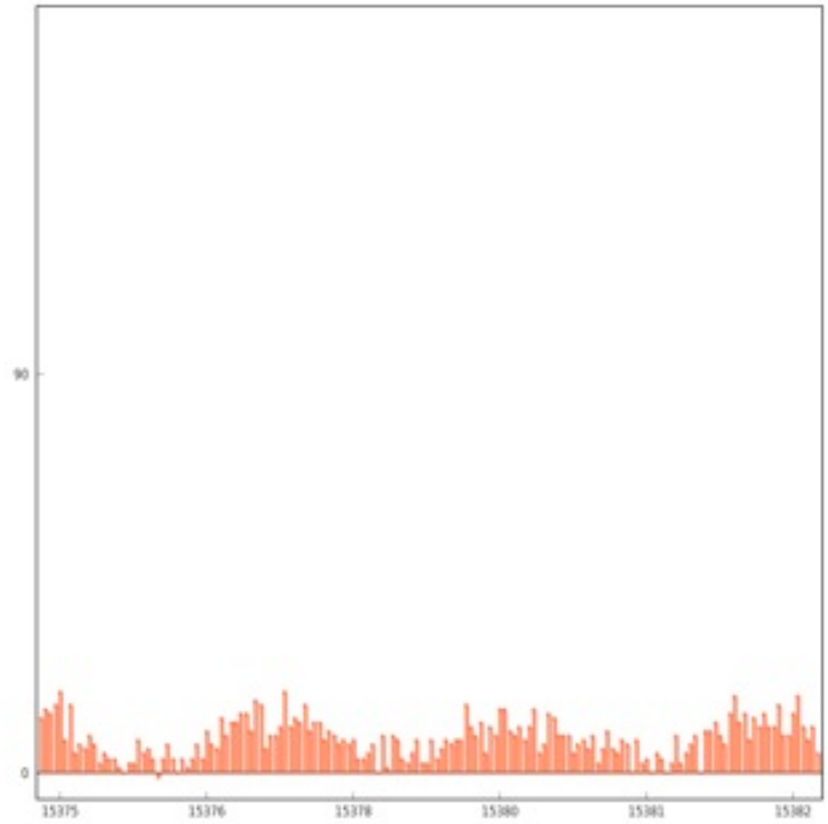
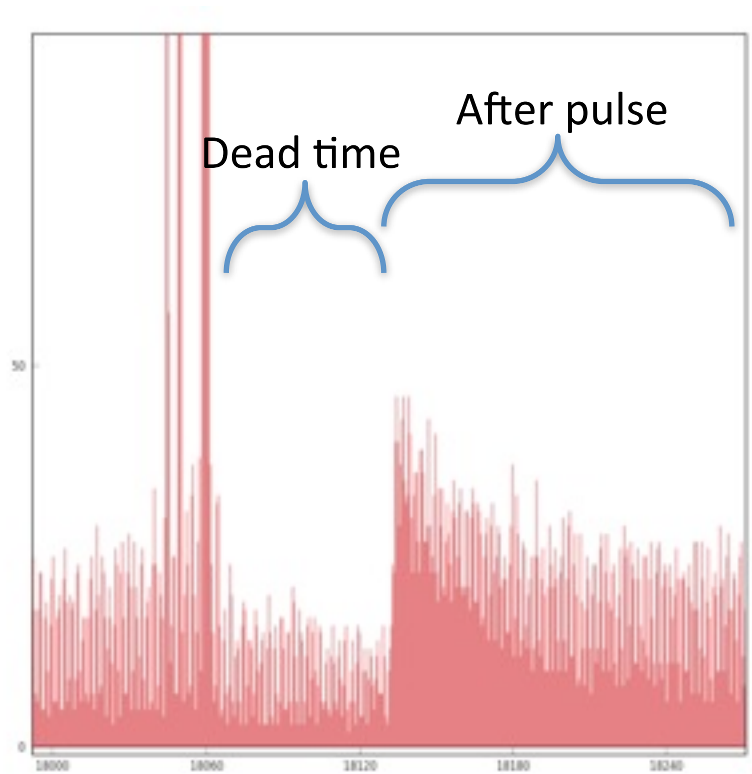
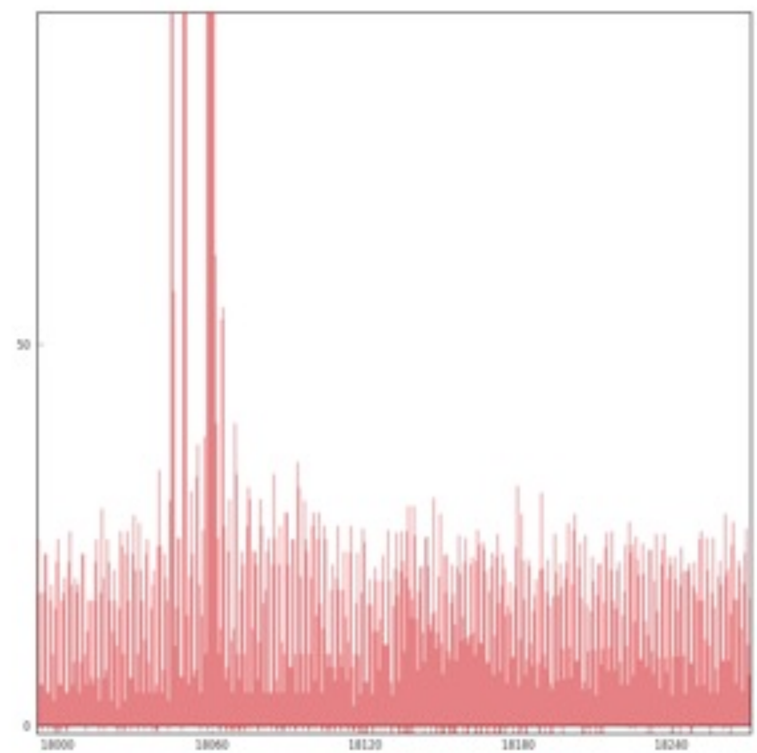


LDM corrections



Before correction



After correction

Bunch length

- Bunch lengths are typically ~0.8 ns FWHM
- Nominal LHC bunch length is σ= 250 ps
- Need a detector with high bandwidth, but no need for high dynamic range
  - Wall current monitor
  - Strip line pick-up
  - Fast PMT or photodiode with SL
  - LDM

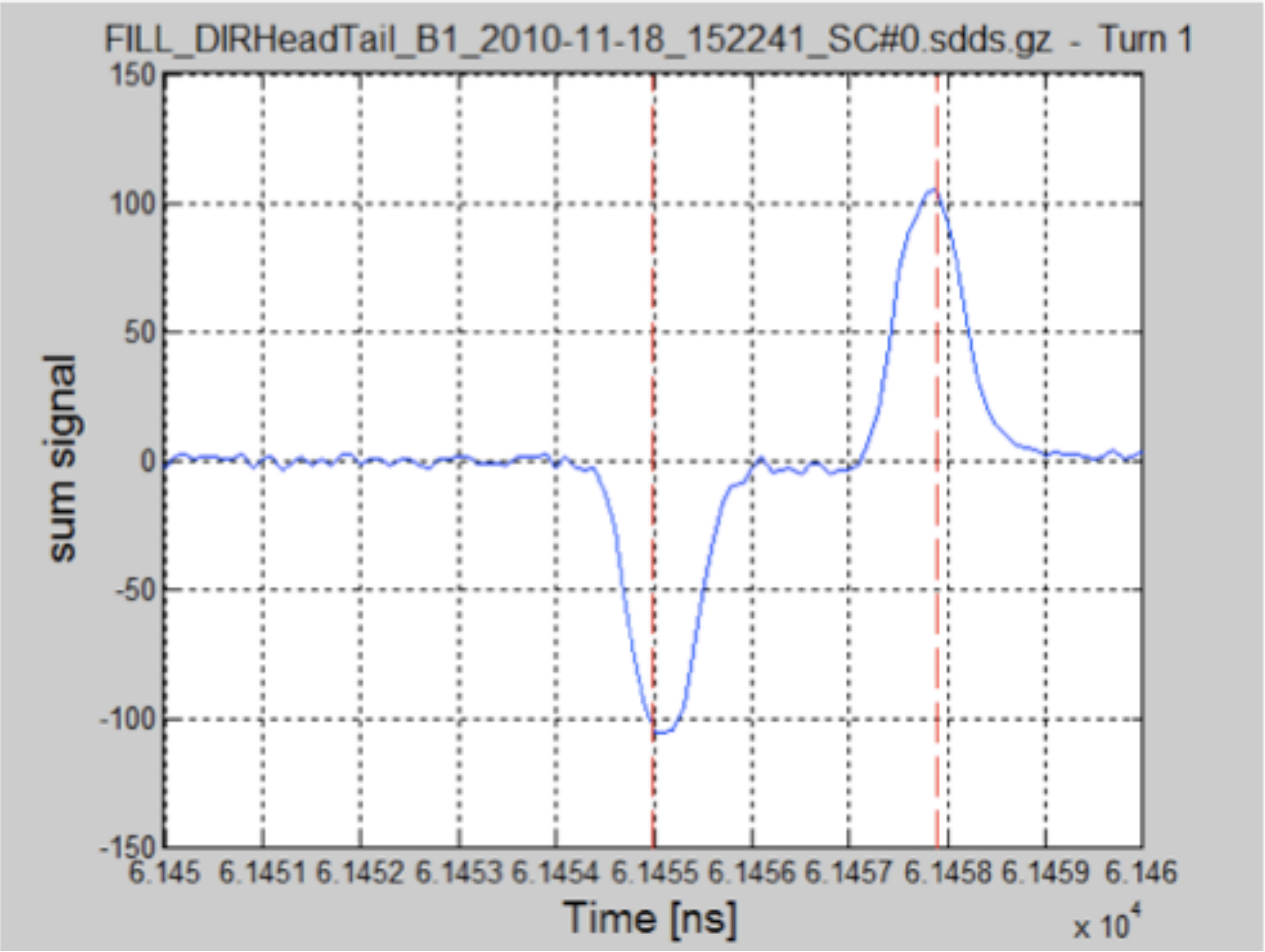
Wall current monitor

- Measures the image current on the beam pipe
- Detector bandwidth ~ 3GHz
- Sampled at 10 Gsample by a fast scope
- Non flat response function
  - Tails at the end of the bunch
- Averaging over many turns and complex frequency domain treatment used to extract more than just the bunch length

Strip line pick-up

- Main function is to measure the beam position with high temporal accuracy
  - Intra bunch oscillations (head/tail)
- Sum signal proportional to the beam current
- Bandwith ~3GHz and sampling at 10Gsample
- Measurement limited near the bunch due to the reflected peak
  - Interval defined by the length of the strip line

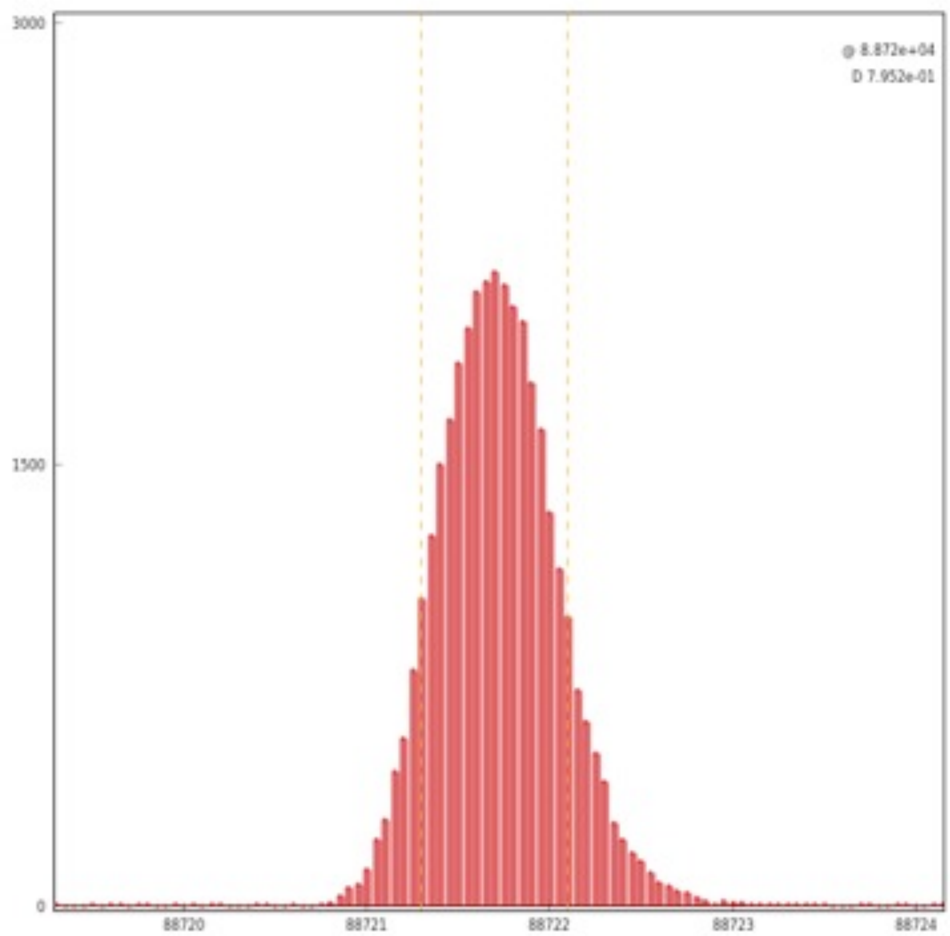
Strip line signal



LDM

- The longitudinal density monitor can measure the bunch length with high accuracy (50 ps)
- Requires a long integration time (seconds)
- Affected by timing and beam jitter
  - Should not be a problem
- Present timing jitter ~300 ps (BOBR/BST)
  - Will be improved in the future by using a dedicated RF signal (few ps jitter)

LDM signal



Fast acquisition of SL

- Not implemented yet
- It is possible to use a fast detector (PMT or photodiode) to detect the synchrotron light in analogue mode (i.e. not counting)
  - Detectors with BW ≥ 50 GHz exist (signal transport?)
- Need a fast sampler (≥10 Gsample)
  - Limited to ~ 8 bits by present technology
  - Accumulation/averaging can be used to increase resolution
  - Same problem for WCM and strip line PU

Emittance measurement

- The beam emittance is calculated using the measured beam size and the optics functions at the detectors positions
  - Errors due to uncertainty of size and optics functions (errors on measured β at the % level)
- Reference instrument is the wire scanner
- Continuous measurement using the synchrotron light and the gas profile monitor
- Schottky ? No performance analysis yet

Wire scanner

- Scan a 30 μm wire across the beam (1 m/s) and acquire the generated shower with a scintillator (some 10 m downstream)
- 2 modes
  - Average of many bunches (10 μs around trigger)
  - Bunch by bunch profiles (up to 75 profiles)
- Usage limited by the beam intensity to 2E13p
  - At 450 GeV by wire damage, at 3.5 TeV by quench

Wire scanner accuracy

- For the LHC not studied in detail yet
- For the SPS (similar device) the accuracy on the emittance was estimated to ~1% for a beam of $\sigma \approx 1$mm (by F. Roncarolo)
- Requires careful adjustment of the various parameters

BSRT

- Imaging of the synchrotron light from a dedicated undulator and/or the D3 separation magnet by a mirror based telescope
- Many sources of optical aberrations, require careful setup of the system
- Theoretical resolution not yet reached
  - The reason(s) are not yet understood

Synchrotron light source

- The intensity of the source varies over several orders of magnitude for the different beam conditions (intensity/energy)
- Need to switch from the undulator to the D3 during the ramp
  - Undulator always ON as operational constraint
- Light spectrum depends heavily on the beam energy and the light source

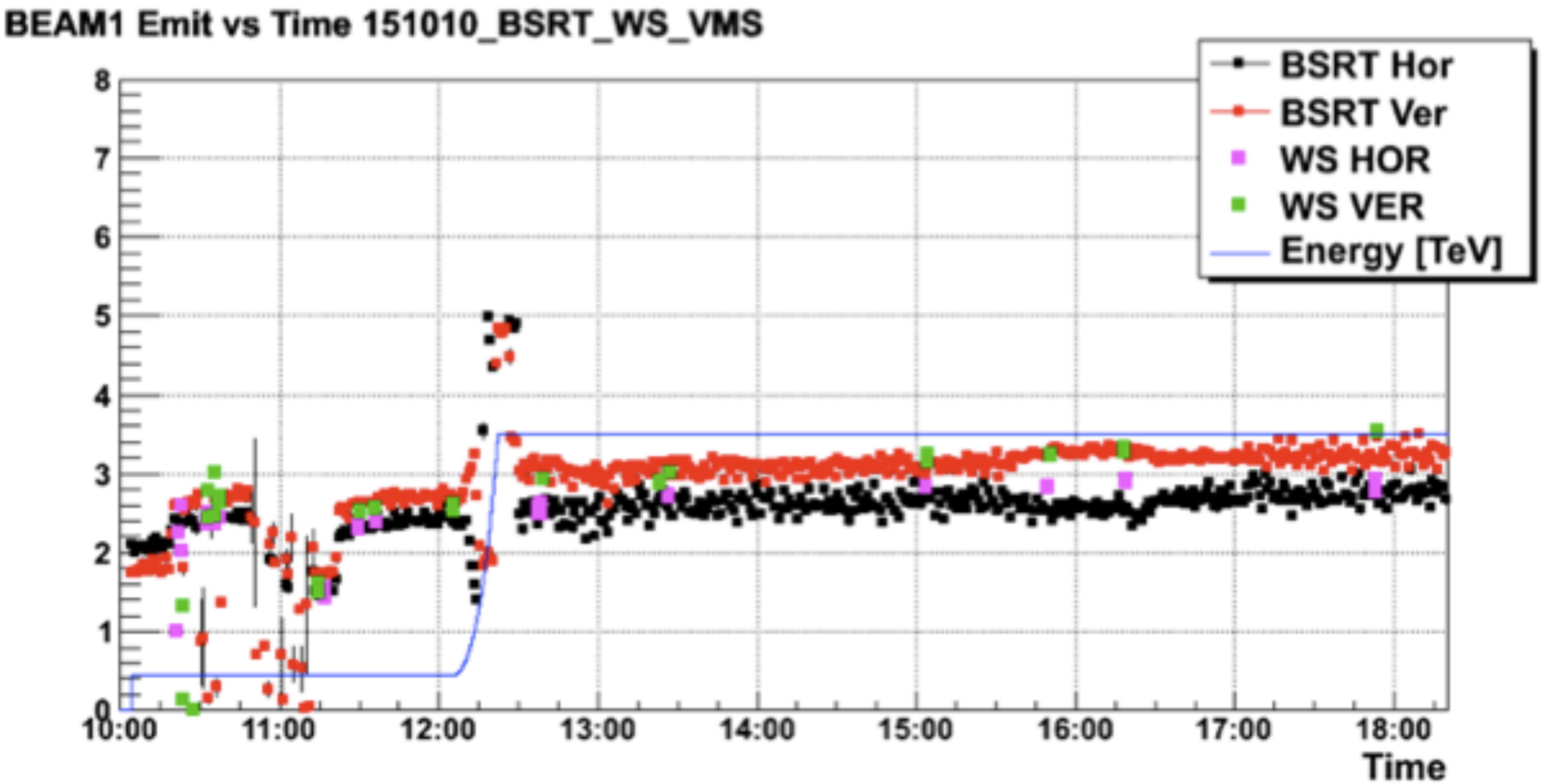
BSRT corrections

- Need to de-convolute the point-spread-function from the measured sigma

$$\sigma_{beam} = \sqrt{\sigma_{meas}^2 - PSF^2}$$

- Calculated PSF is smaller than what we observe (~500 μm at 3.5 TeV)
  - Need to revise the calculations
  - Test the optical system in the lab

BSRT vs. WS


BEAM1 Emit vs Time 151010_BSRT_WS_VMS
BSRT Hor
BSRT Ver
WS HOR
WS VER
Energy [TeV]
0
1
2
3
4
5
6
7
8
10:00
11:00
12:00
13:00
14:00
15:00
16:00
17:00
18:00
Time

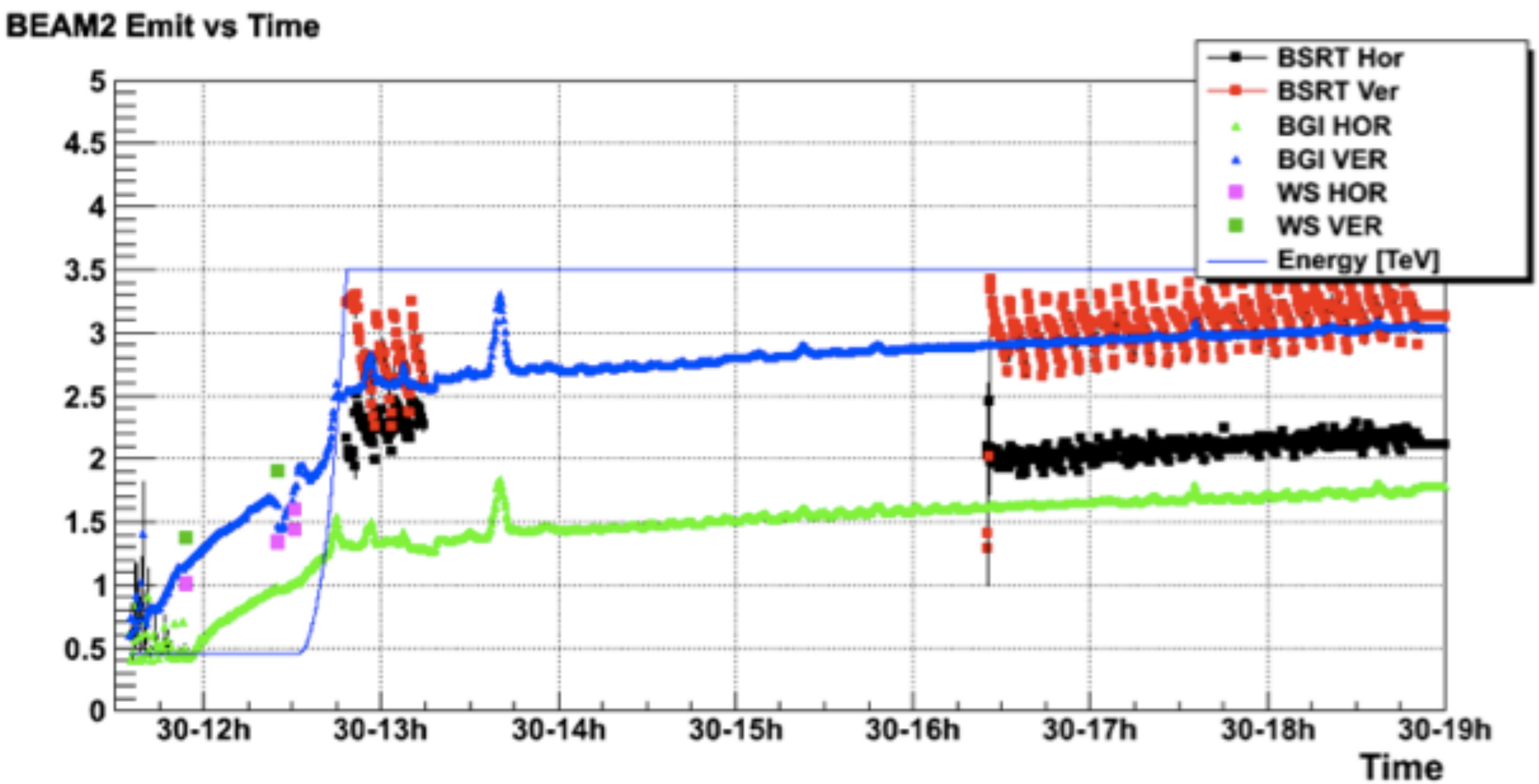
BSRT modes

- Several operation modes with 2 cameras
- Slow intensified and gated camera
  - Average over all bunches 20ms integration time
  - Single bunch (25 ns) gating
- Fast intensified and gated camera (new 2011)
  - Each bunch turn by turn (1 bunch/turn)

Gas profile monitor - BGI

- Based on the collection of rest gas ionization electrons
- Need a small pressure bump
  - This slowed the commissioning in 2010
- Still in commissioning phase
- Can only provide average beam size over all bunches

BGI, BSRT and WS



Beam halo and tails

- Functionality foreseen as part of the BSRT system
  - "Corona" type device, i.e. mask the core of the bunch
- Nothing implemented yet
- If really important could develop the functionality in relatively short time
- Dynamic range limited by scattered photons

Beam position stability at the IP

- 2 types of BPM available
  - Direction sensitive strip line
  - Button pick-up
- Both installed in front of the triplet
  - Can use ballistic model to calculate position at IP
- Buttons are more accurate (same acquisition channels for B1 and B2)
- If bunch spacing is too small buttons can not be used (< 150 ns)
- Resolution of strip-lines is ~1µm (orbit mode)

Conclusions

- LDM should provide reliable information for calculating the “colliding charge” provided the DCBCT can provide the total charge
- Several instrument provide the bunch length
- BSRT and BGI provide the emittance evolution, but the WS should be used as absolute reference
- No monitor available yet for the halo/tails