KIRCHHOFF-
INSTITUTE
FOR PHYSICS

Using the BPTX for relative bunch population measurements
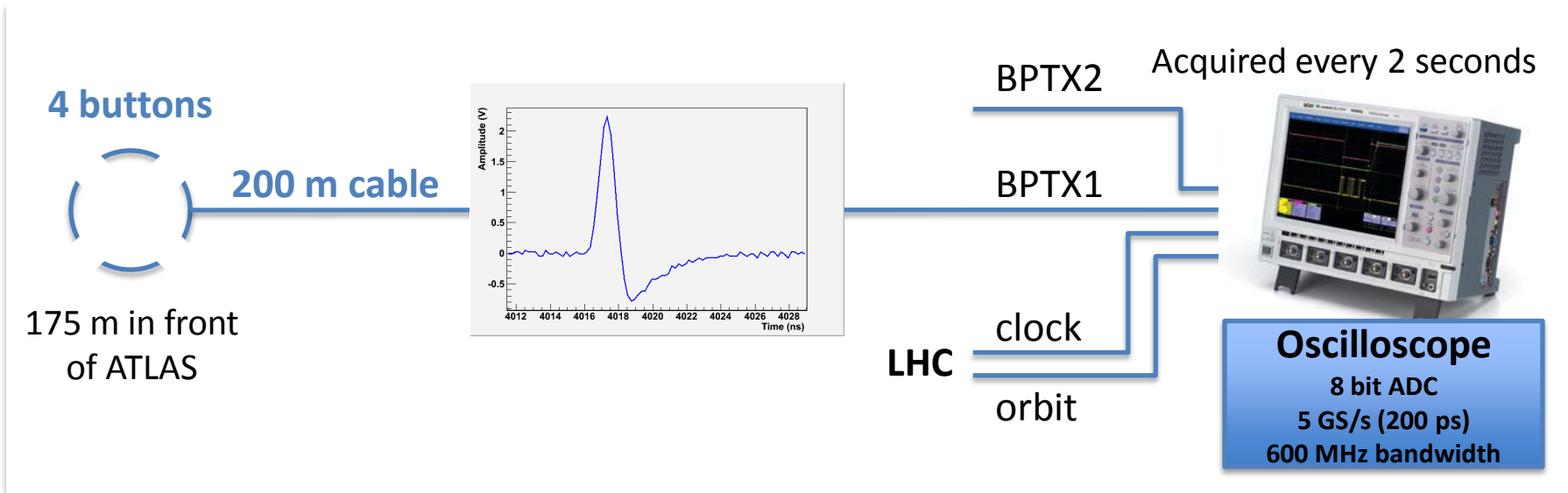
Gabriel Anders

(CERN / KIP Heidelberg)

LHC Luminosity Days 2012

ATLAS Beam Timing system (BPTX)

4 buttons

200 m cable

175 m in front
of ATLAS

BPTX2

BPTX1

clock

LHC

orbit

Acquired every 2 seconds

Oscilloscope
8 bit ADC
5 GS/s (200 ps)
600 MHz bandwidth

- One BPTX station per beam, provided by BE-BI
- Mainly used for measurements of the bunch timing
  - Phase with respect to the LHC clock
  - Time difference between bunch pairs
- By-products of the timing measurements
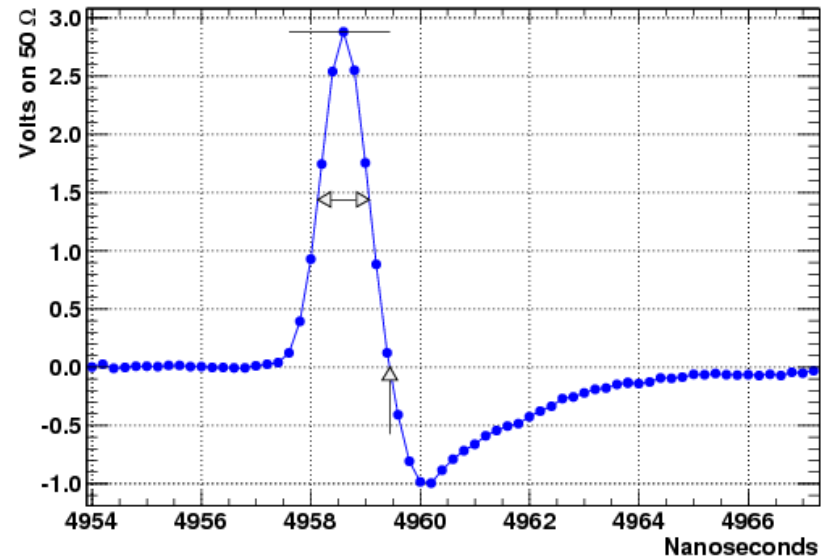 - Relative bunch intensity and bunch length

BPTX signals
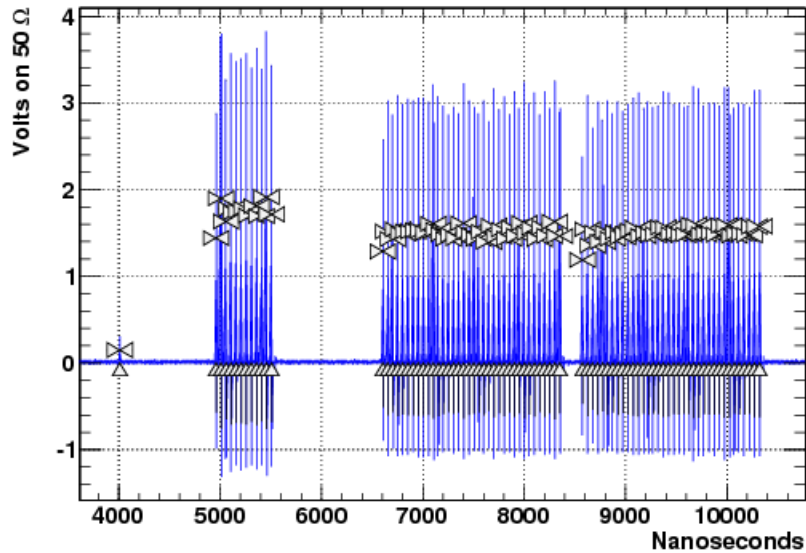
- Waveform snapshot taken by the oscilloscope

- Zoom on a single bunch signal

BPTX software

- To ensure that the BPTX software is reliable and fast, a simple reconstruction algorithm is applied to the signals

- Every 2 seconds measurement of:
  - Phase (t) = Time(bunch) - Time(LHC clock edge)
  - Intensity (I)
  - Length (L)

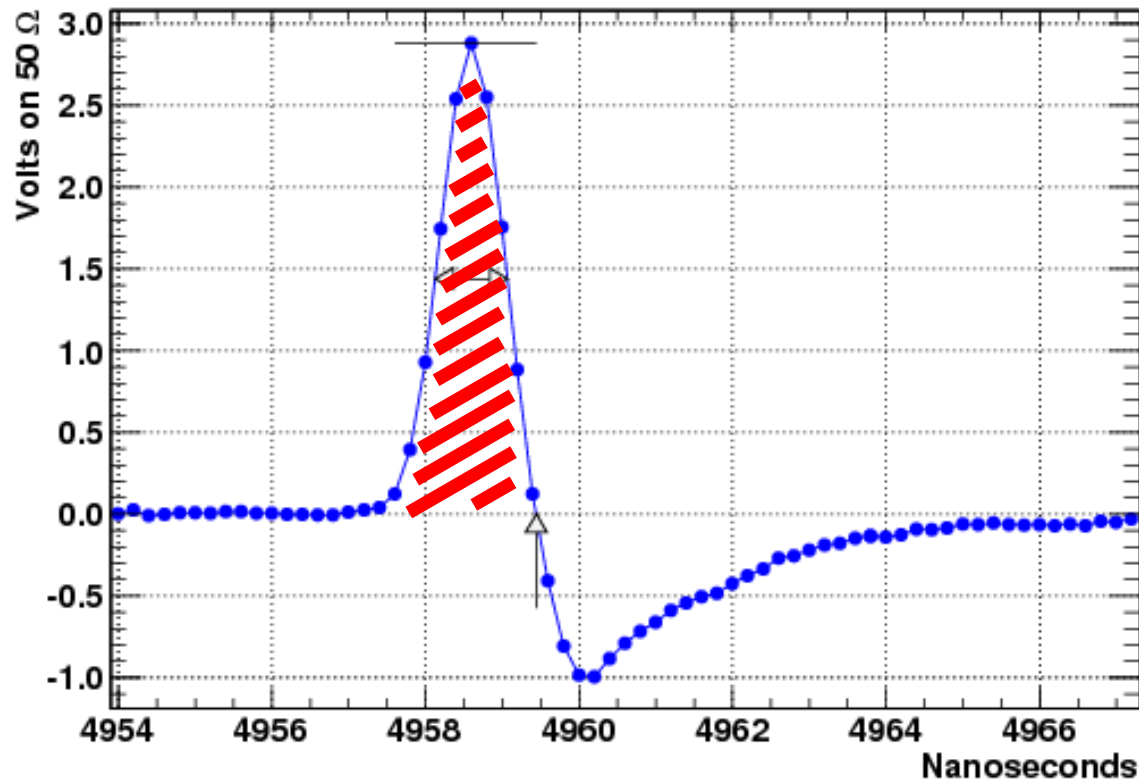- Additionally every minute a waveform snapshot is stored for future references

Online reconstruction algorithm

- **Timing:** The zero-crossing of the bunch signal
- **Intensity:** The positive part integral of the bunch signal
- **Length:** The FWHM of the bunch signal
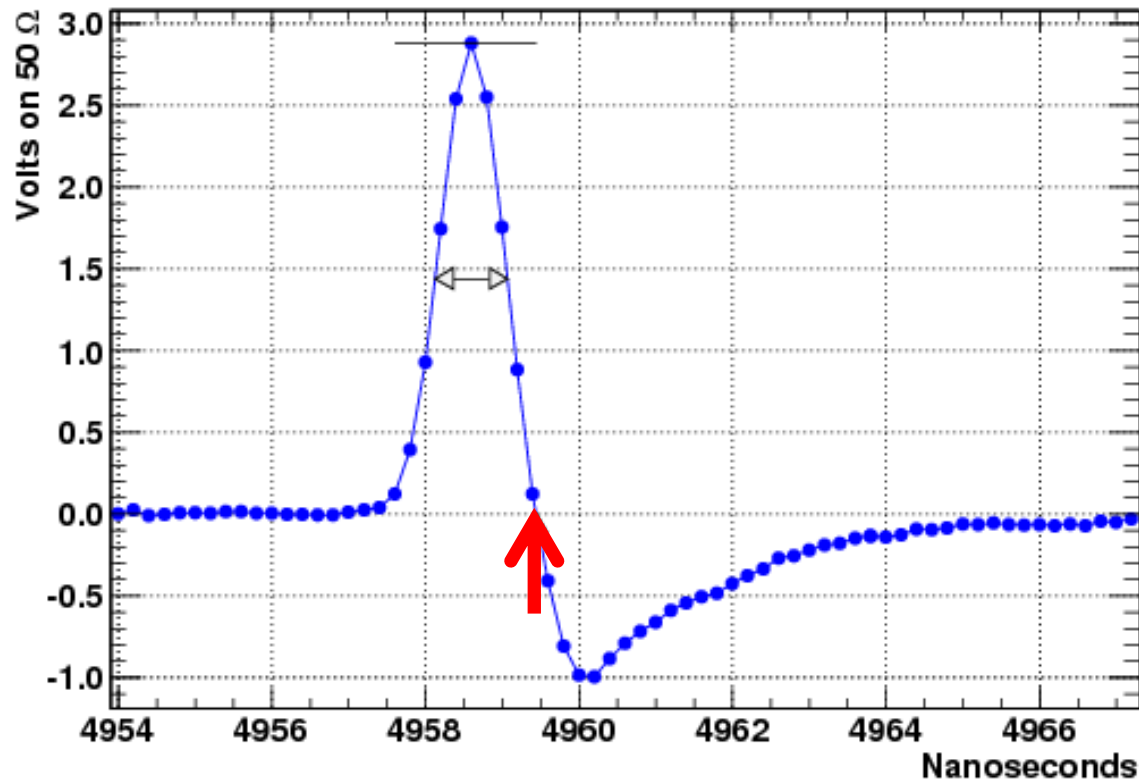
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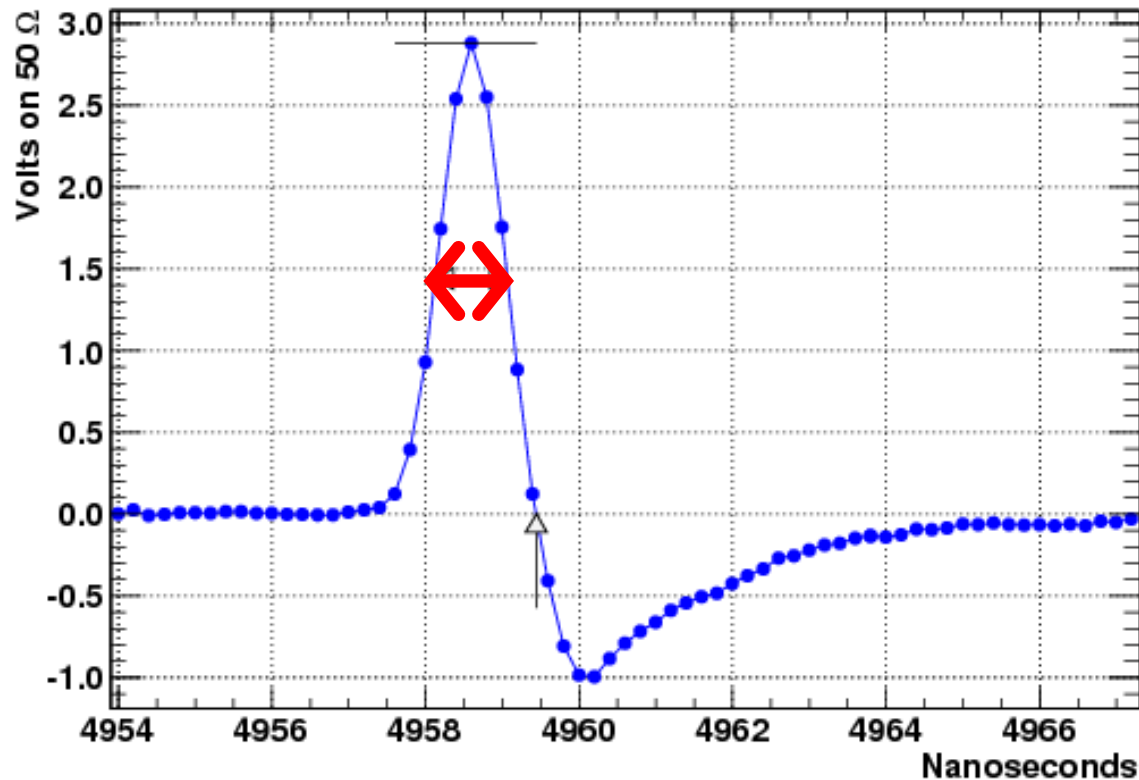
Bunch length dependency

- **But** the online bunch parameters are not the true parameters!
- Bunch intensity measurements affected by bunch length
  - Effects from long cable, combiner and limited scope bandwidth
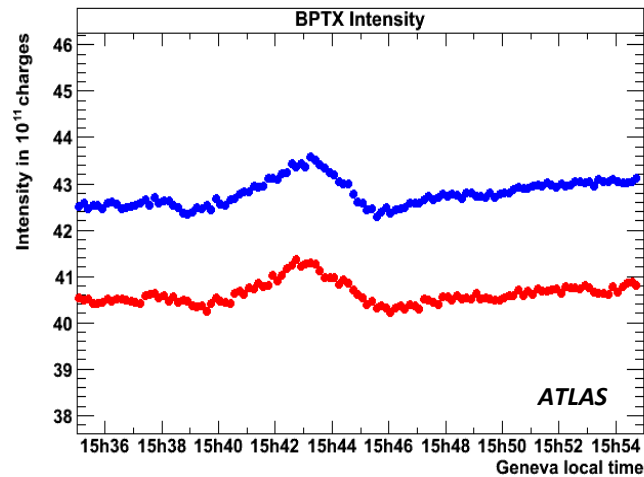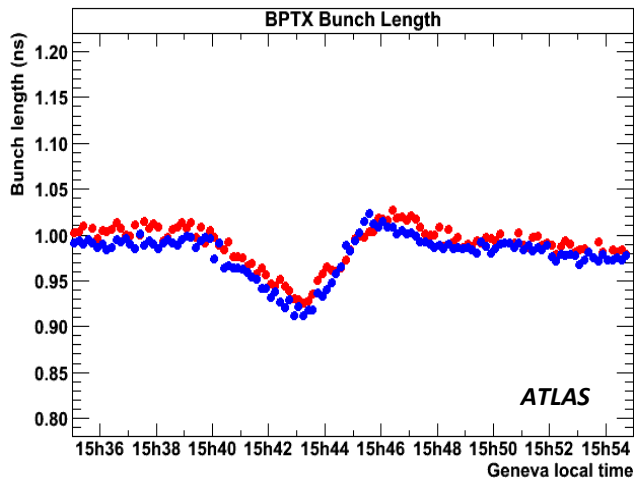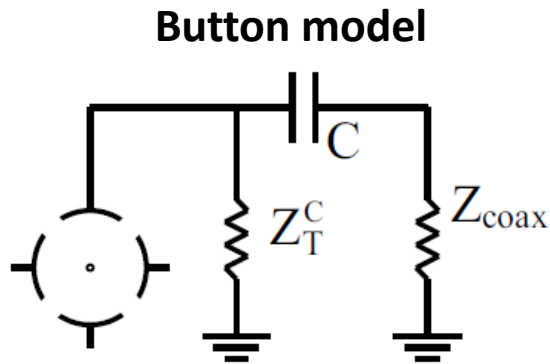

24 August 2010:
13.35h – 13.55h (UTC)

- Is it possible to correct for the bunch length dependency?
- Yes, with a parametrisation of the true intensity **N** :

$$N_{true} = \mathcal{P}(N_{online}, \sigma_{z,online})$$
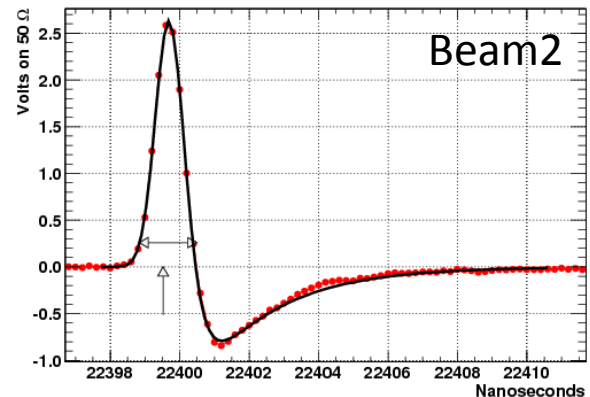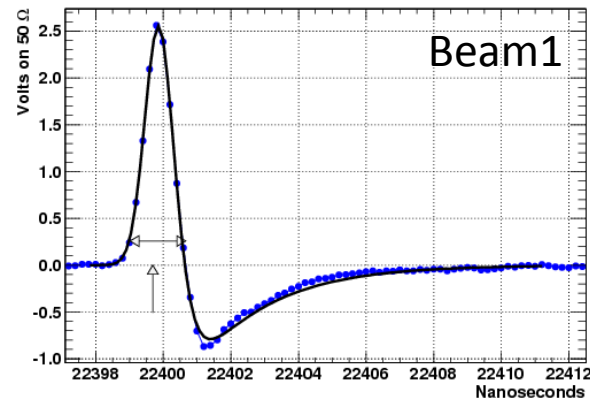
Simulation of the BPTX

- The BPTX system can be described by a simple model

Button model

$$C$$
$$Z_T^C \qquad Z_{coax}$$

+

Effective capacitance and effective low-pass filter

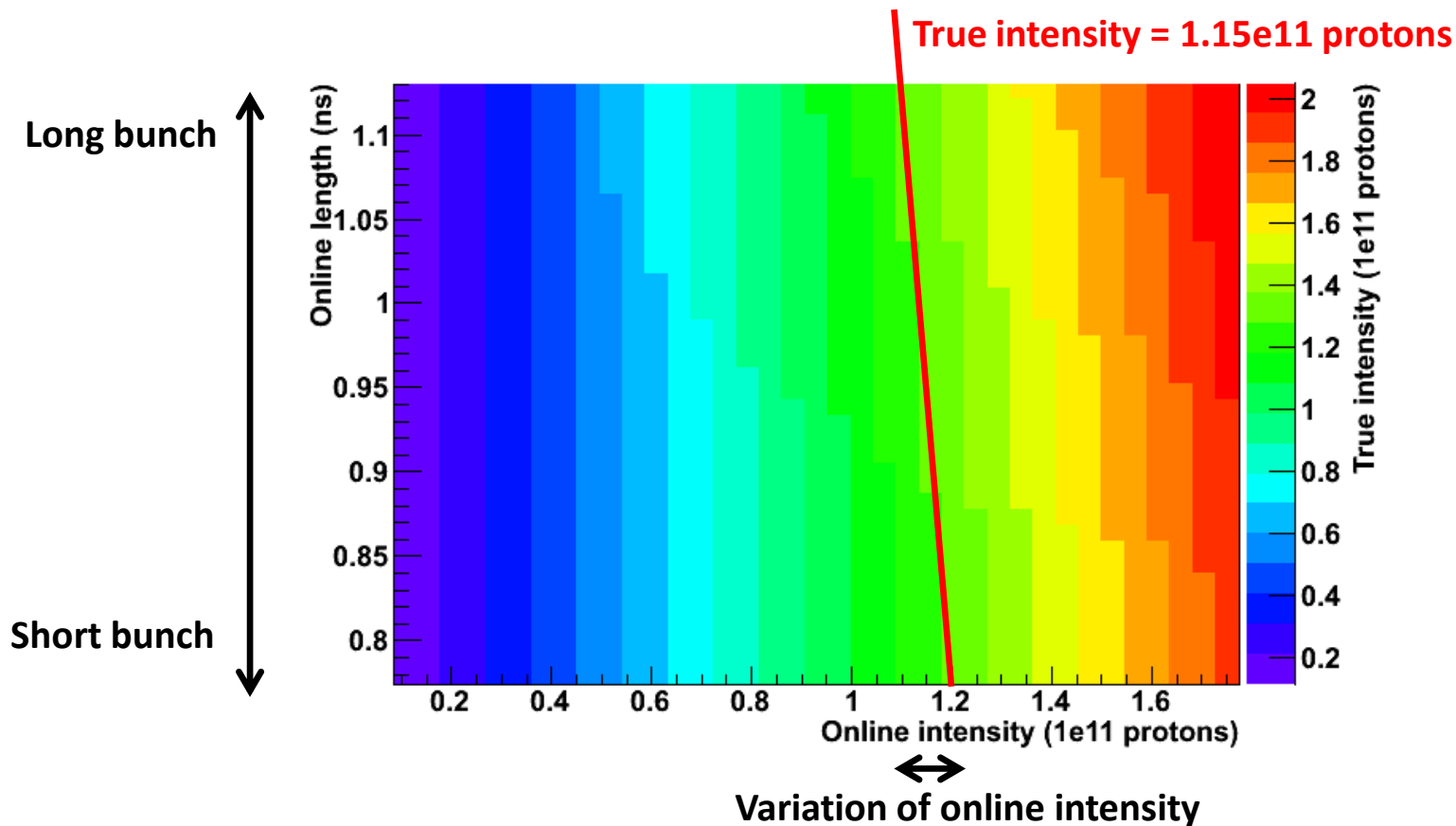Real signals allow to fix the model parameters

Fit real signals

Beam1

Beam2

Assumption: Longitudinal bunch charge density follows a Gaussian distribution

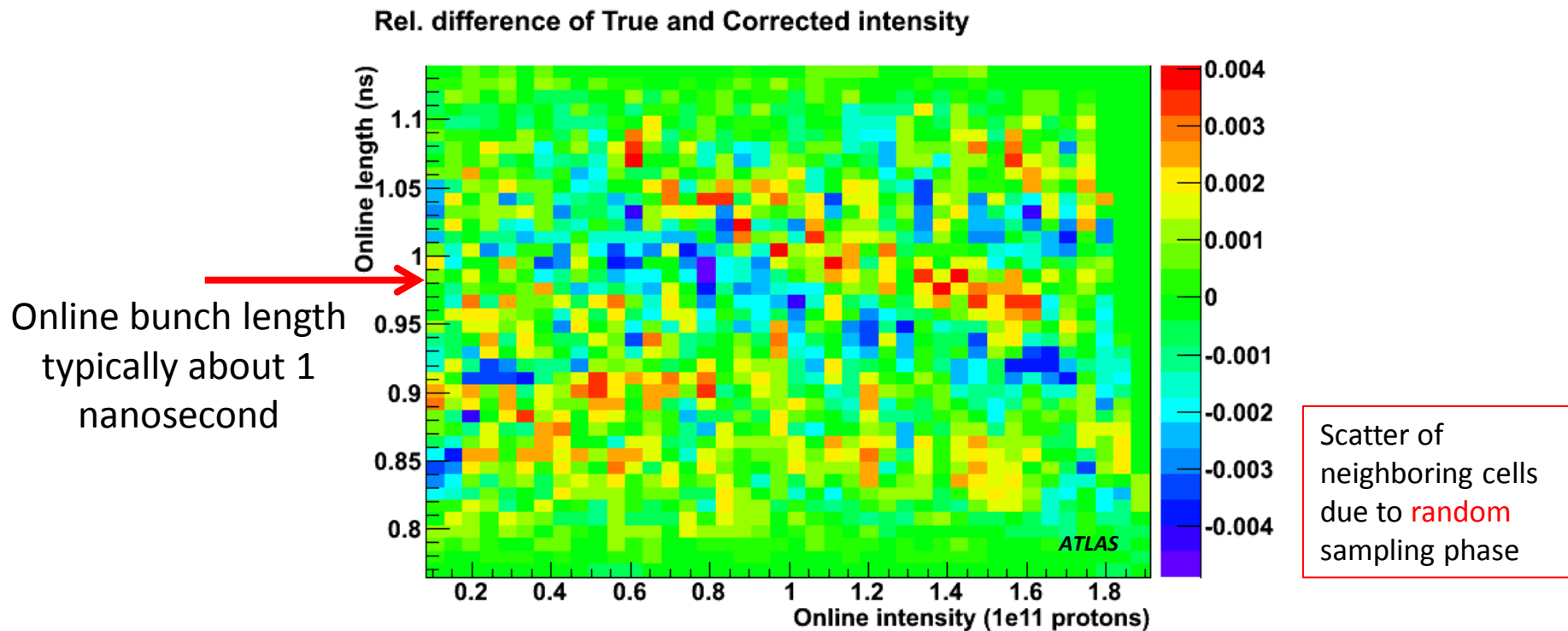- Shapes of real signals are appropriately described by model

Intensity correction based on simulation

- **Reminder:**   Find $N_{true} = \mathcal{P}(N_{online}, \sigma_{z,online})$

- **Correlation** of true and online intensity from simulation:

True intensity = 1.15e11 protons

Long bunch

Short bunch

Variation of online intensity

Accuracy of intensity correction

- ## How precise is the obtained correction?

Rel. difference of True and Corrected intensity

Online bunch length typically about 1 nanosecond

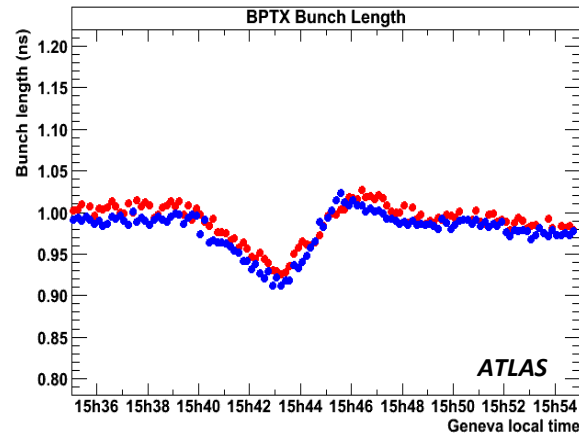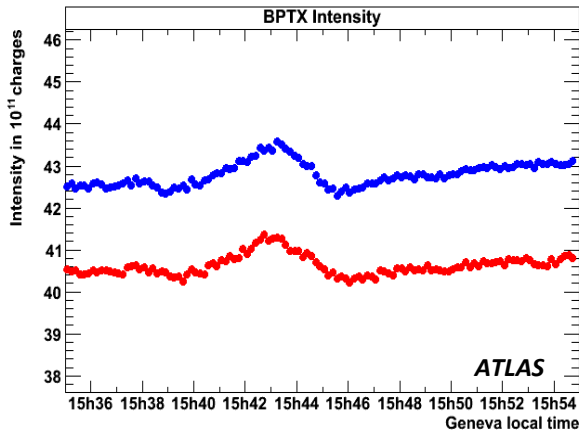Scatter of neighboring cells due to random sampling phase

- ## Accuracy **better than 5 per mill** over a wide range of intensity and bunch length

Application of intensity correction to real signals

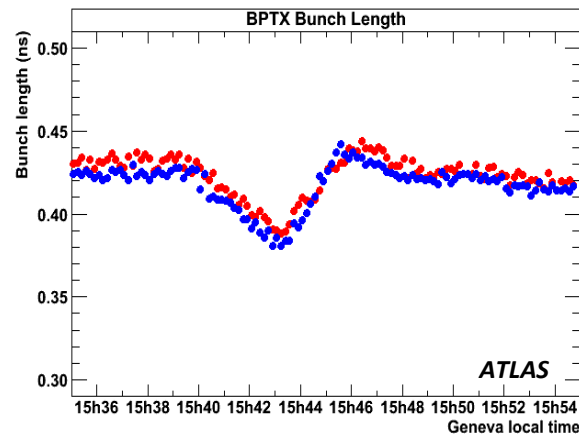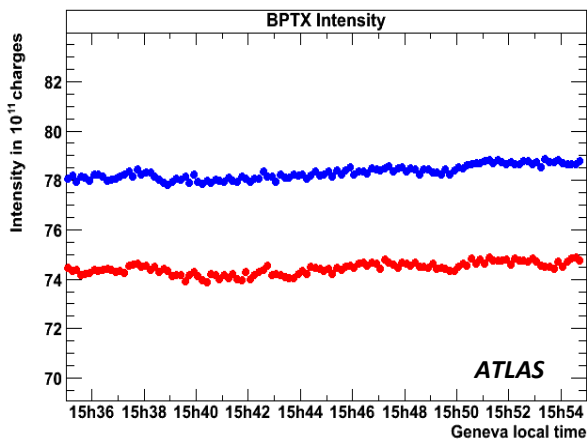**Intensity and length with online reconstruction algorithm:**

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Correction

Intensity and length after correction:

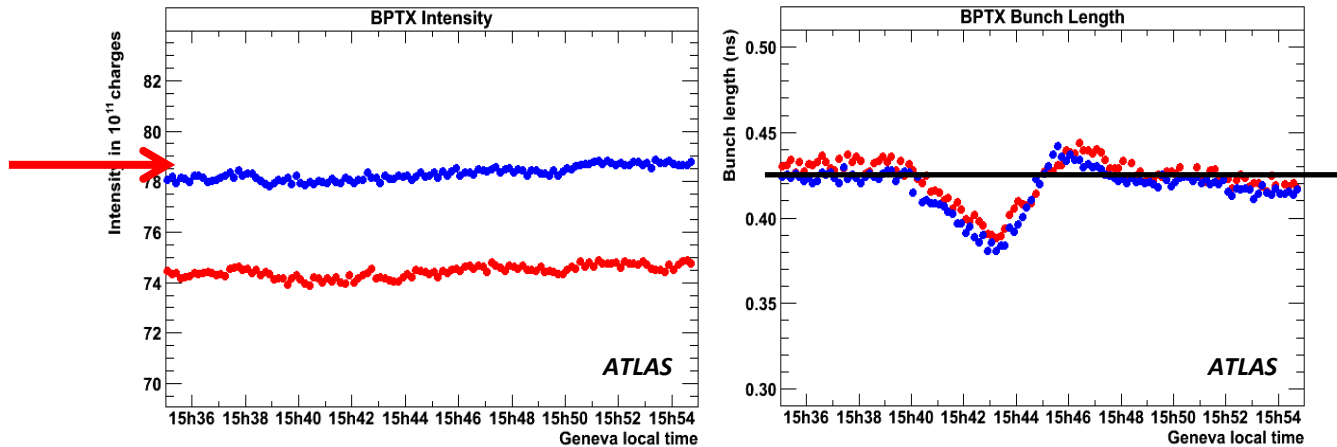
The corrected intensities are independent on the bunch length

Further error sources

What causes the slight increase of intensity with time ?


- Possible error sources
  - Measurements not independent on **transverse position of beam**
    - Effect on **relative** bunch population expected to be small
  - **Longitudinal bunch charge density** does not follow a Gaussian distribution
  - Accuracy of **bunch intensity correction** is limited (5 per mill)

Performance – BPTX vs FBCT

- **Agreement** of BPTX and FBCT relative bunch intensities
  - typically a few per mill
  - larger for small intensity bunches

See previous talk by Massimiliano Ferro-Luzzi:
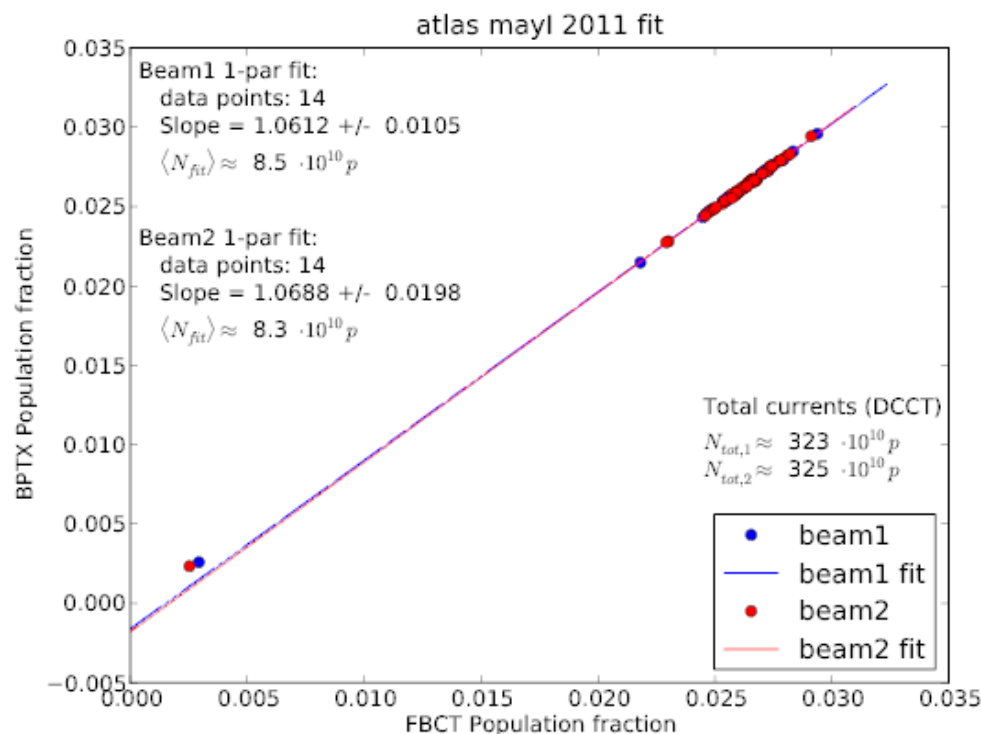
Summary

- The BPTX is the ATLAS bunch timing reference
- By-product of timing measurements:
  - Bunch **intensity** and length
- Simulation of BPTX helps to improve the intensity measurements
  - Good agreement with FBCT readings
- BPTX bunch by bunch intensity measurements soon available in LHC Logging Database for wider usage
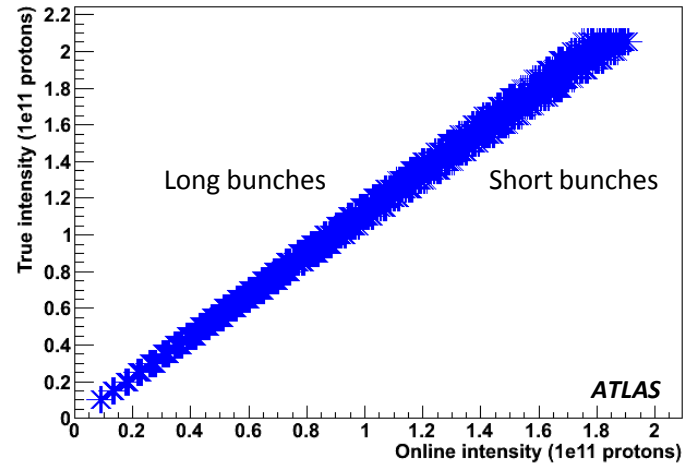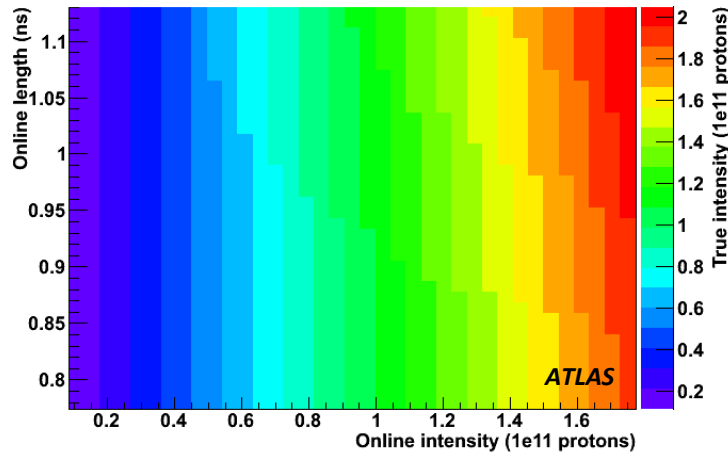 - **Corrected** for bunch length dependency
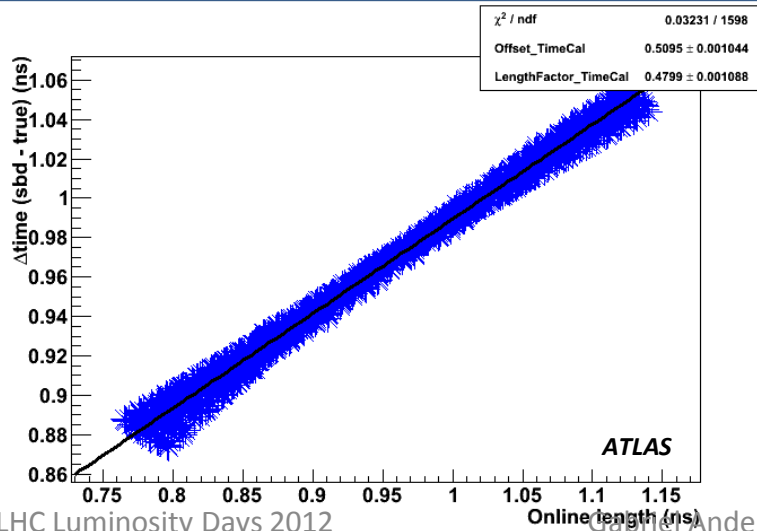 - **Averaged** over 1 minute

Backup
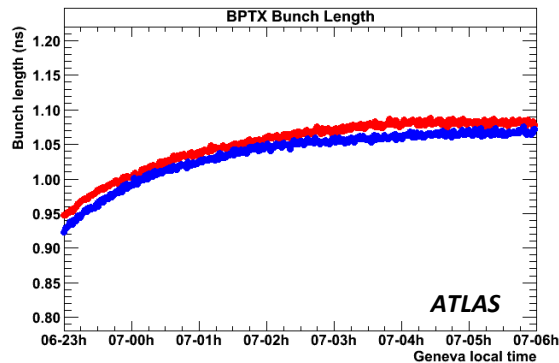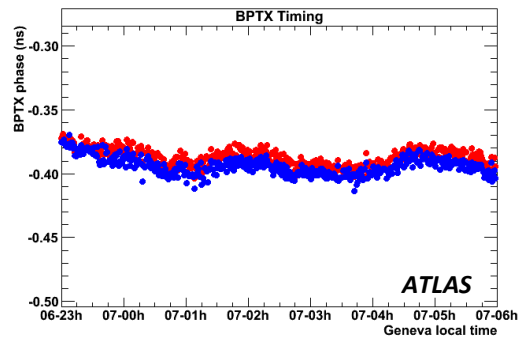
Correction plots
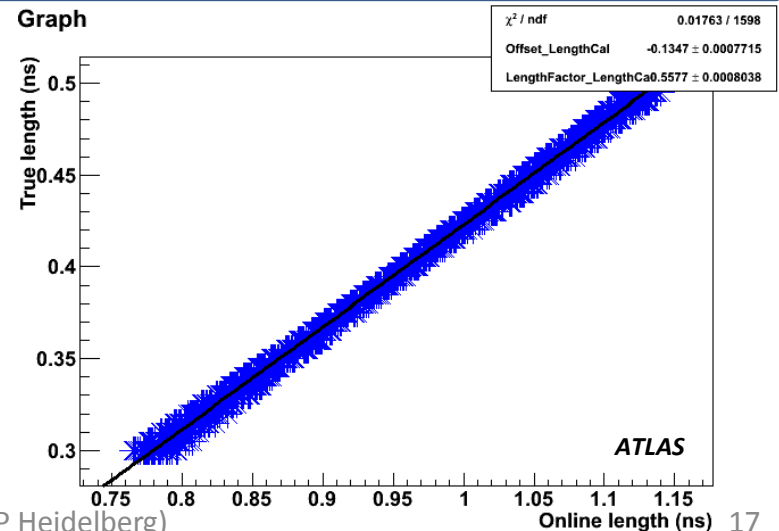
Application of phase correction to real signals

- During a fill the longitutinal bunch size increases and therefore the measured phase between BPTX and LHC clock
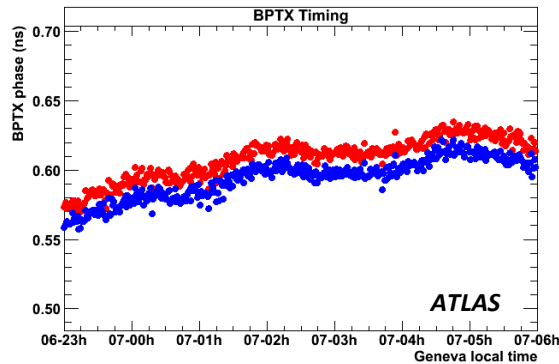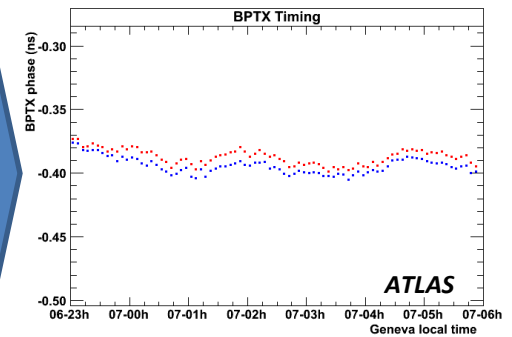
06 September 2010:
23.00h – 06.00h (local time)

Correction

Averaging over 5 minutes

- Phase more stable after applying correction
- Averaging suppresses noise
- Phase can be measured with a precision of ±20 ps