Data Analysis with the CMS Fast Beam Conditions Monitor BCM1F

Roberval Walsh
DESY

On behalf of the DESY BCM and CMS BRM groups

Outline

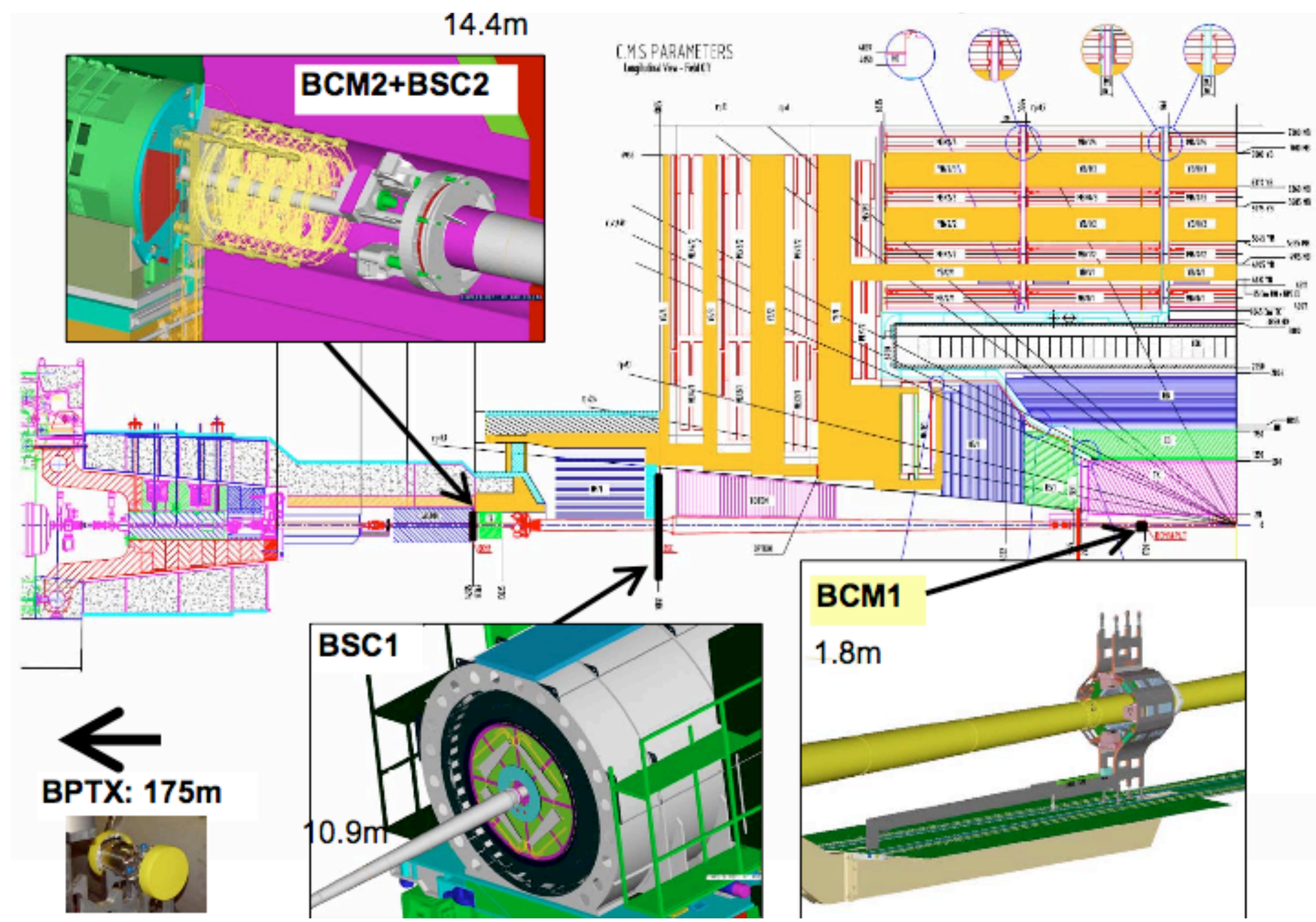
- Introduction
- Data analysis
  - Calibrations
  - Bunch structure
  - Luminosity monitoring
- BCM1F online
- Summary

Large Hadron Collider (LHC)

- Proton-proton collider
- Centre-of-mass energy 7-14 TeV
- High luminosity: 10^{34} cm^{-2} s^{-1}
- Four interaction points:
  CMS, ATLAS,
  ALICE, LHC-b
- **Beam related parameters:**
  - **Orbit time: ~88.9 μs per turn**
  - **Bunch spacing ~24.95 ns**
  - **Max 2800 bunches, to allow injection/abort gaps**

CMS Beam Radiation Monitoring

- Measurement of radiation in and around CMS.
- Subsystems for beam conditions monitoring:
  - Beam Scintillator Counters (BSC): Timing scintillators mounted at ±10.5 m and 14.4 m from IP, surrounding the beam pipe. Monitors beam conditions.
  - BCM2: Current monitor; uses poly-crystal diamond sensors (pCVD) sensors; located near the hadron forward calorimeter (HF) at ±14.4 m from IP.
  - BCM1L: Current monitor; uses pCVD; located ±1.8 m from interaction point (IP). Beam abort.
  - ***BCM1F…***

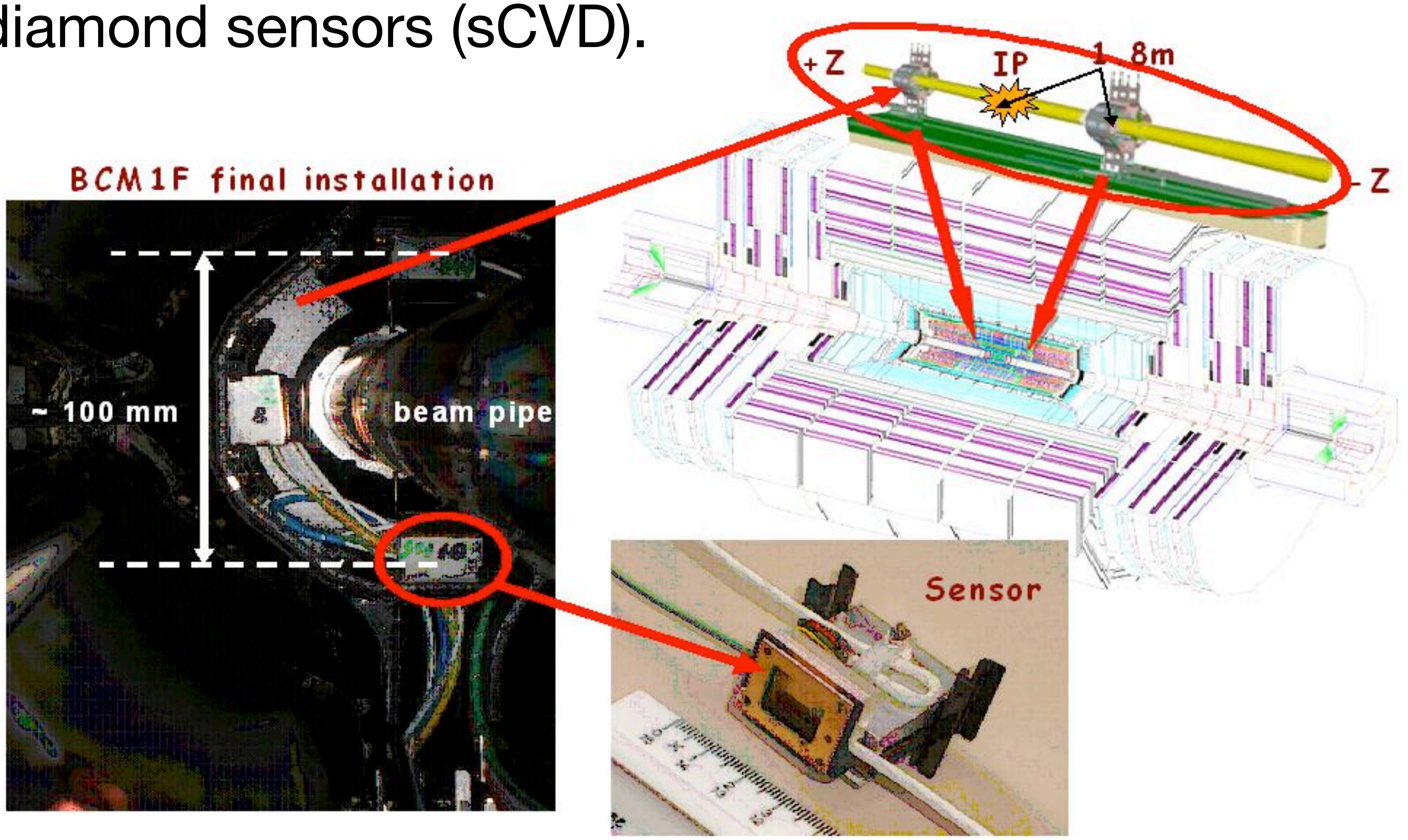


BCM1F Fast Beam Conditions Monitor

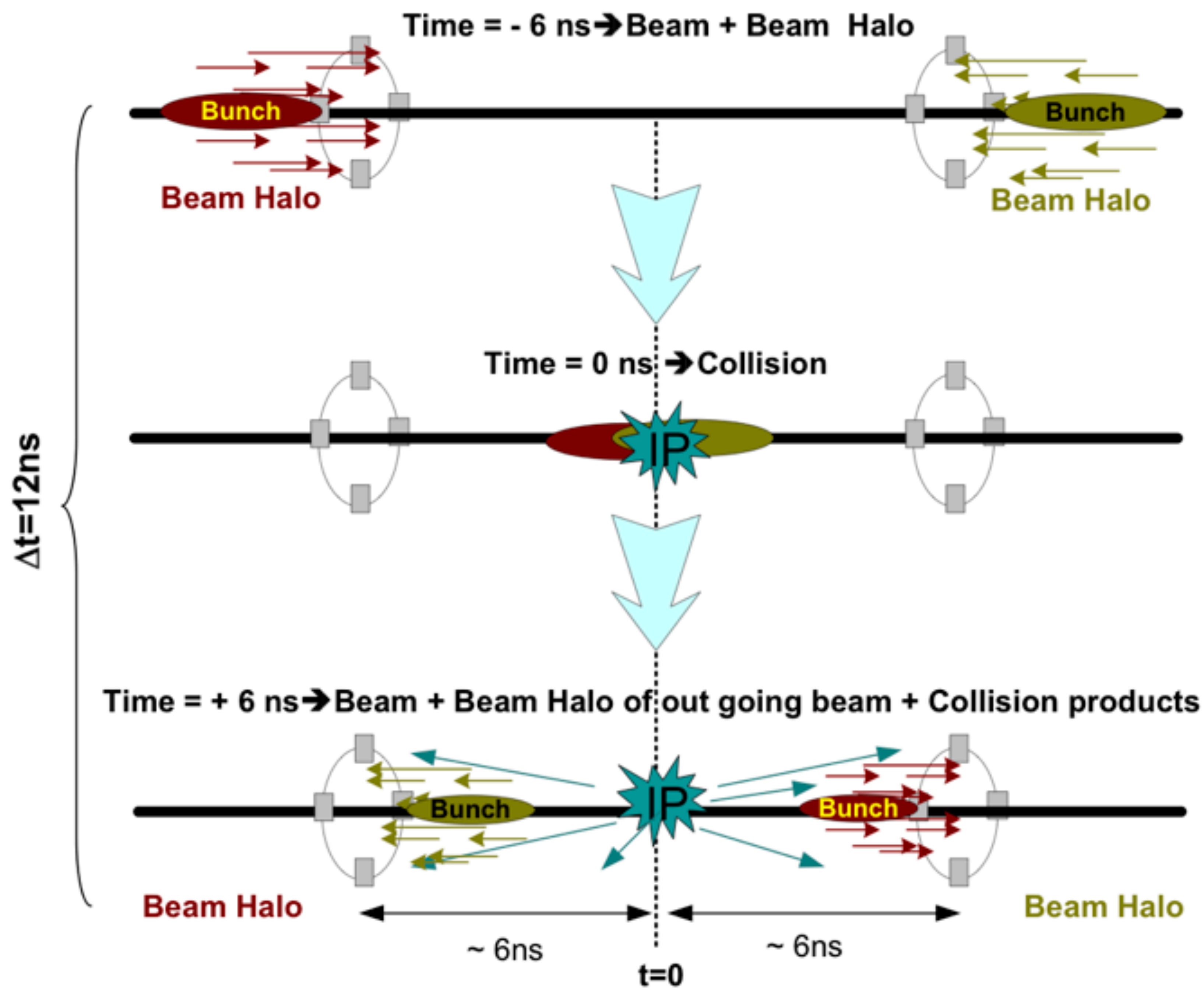
- Monitors the beam-halo flux on a bunch-by-bunch basis.

- Consists of two planes near the pixel detector located at z = ±1.8 m from interaction point. Each plane has four modules of 5x5 mm2 single crystal diamond sensors (sCVD).

- Uses radiation hard front-end electronics.

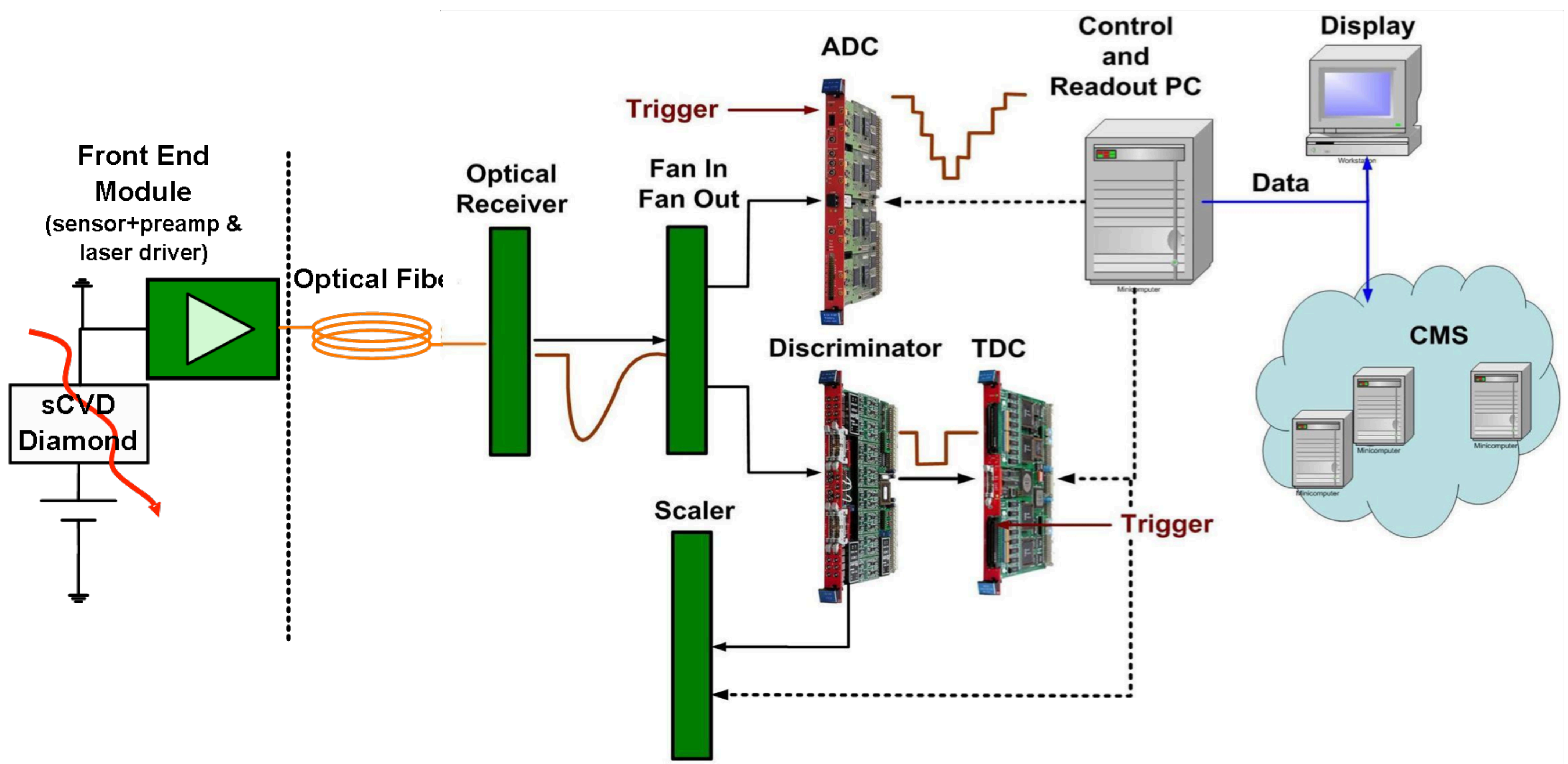


What BCM1F should see



BCM1F data acquisition

- ADC: signal sampling
- Scaler: counting rates
- TDC: time measurements

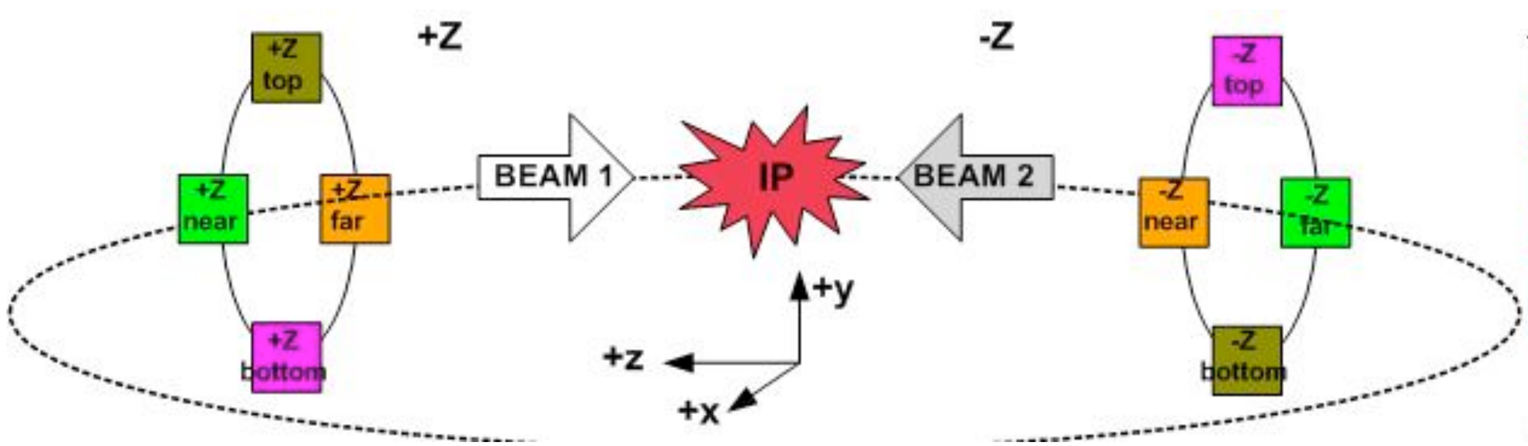


BCM1F data acquisition

New

Look-up table (LUT) – ‘sitting’ between the discriminator and the scalers

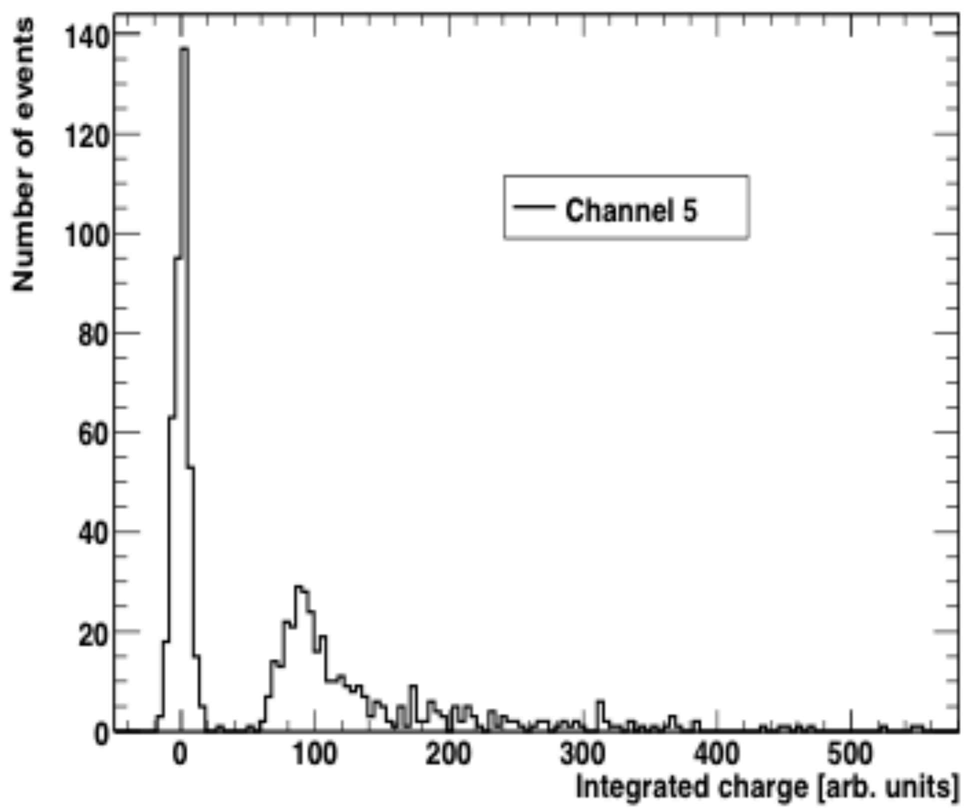
- Coincidences in channels (Luminosity estimation)
- VETO signal to TDC
- Beam Abort signal

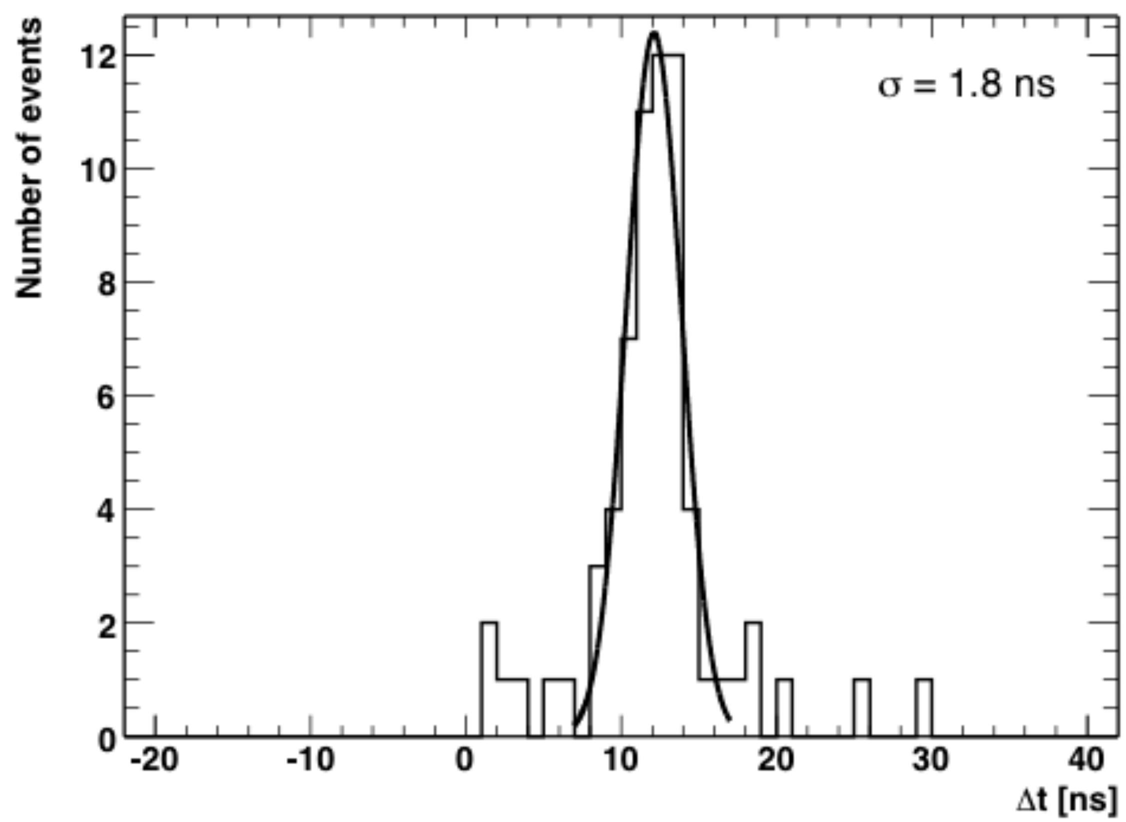


Coincidences in LUT	BCM1F channels
A	-Z top & +Z bottom
B	+Z top & -Z bottom
C	+Z near & -Z far
D	-Z near & +Z far

Analysis of the ADCs data

- First LHC beams in 2008
- Signal spectrum and time resolution measured with ADCs





Nucl. Instrum. Meth. A614:433-438,2010

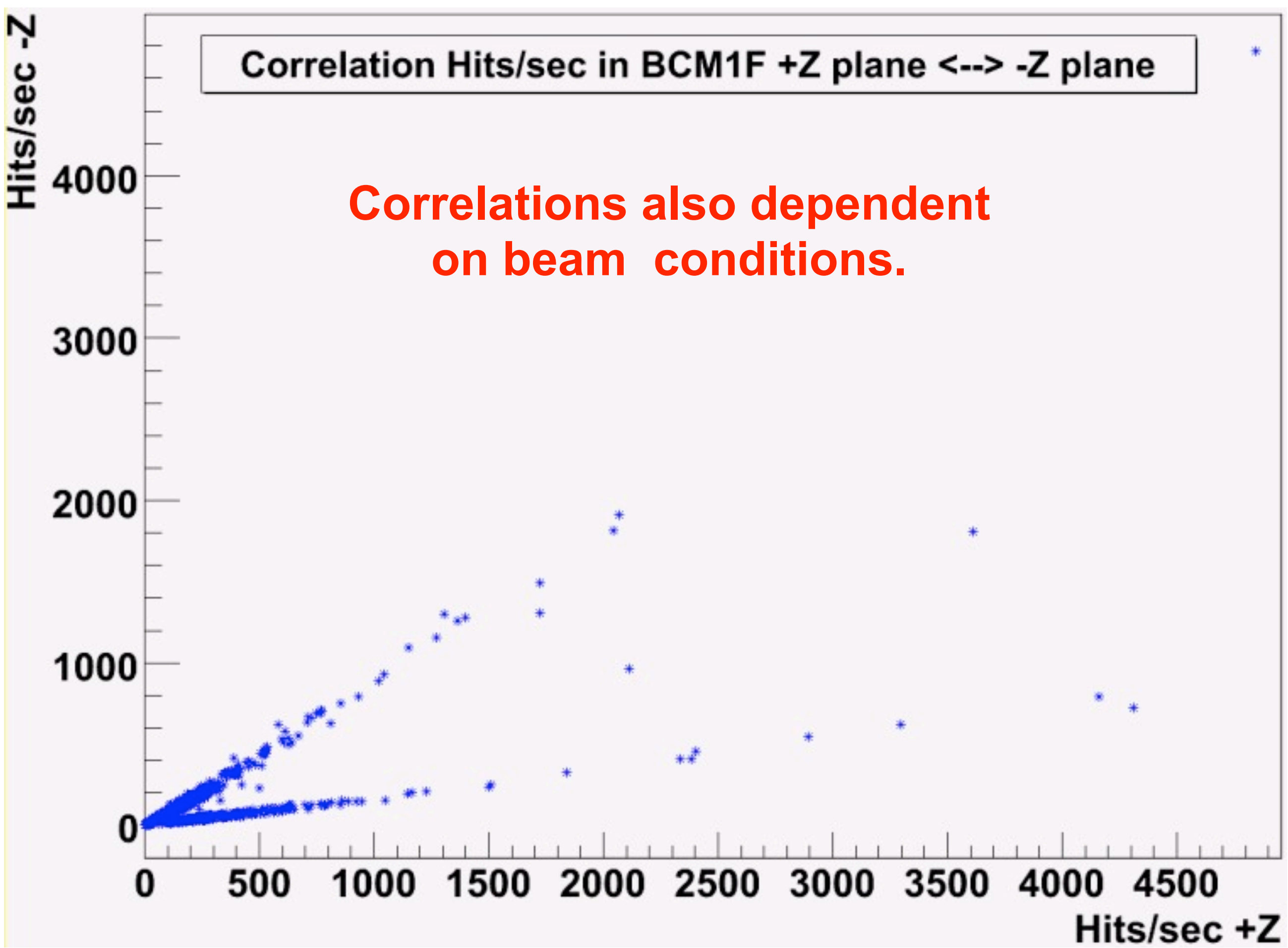
Analysis of the ADCs data

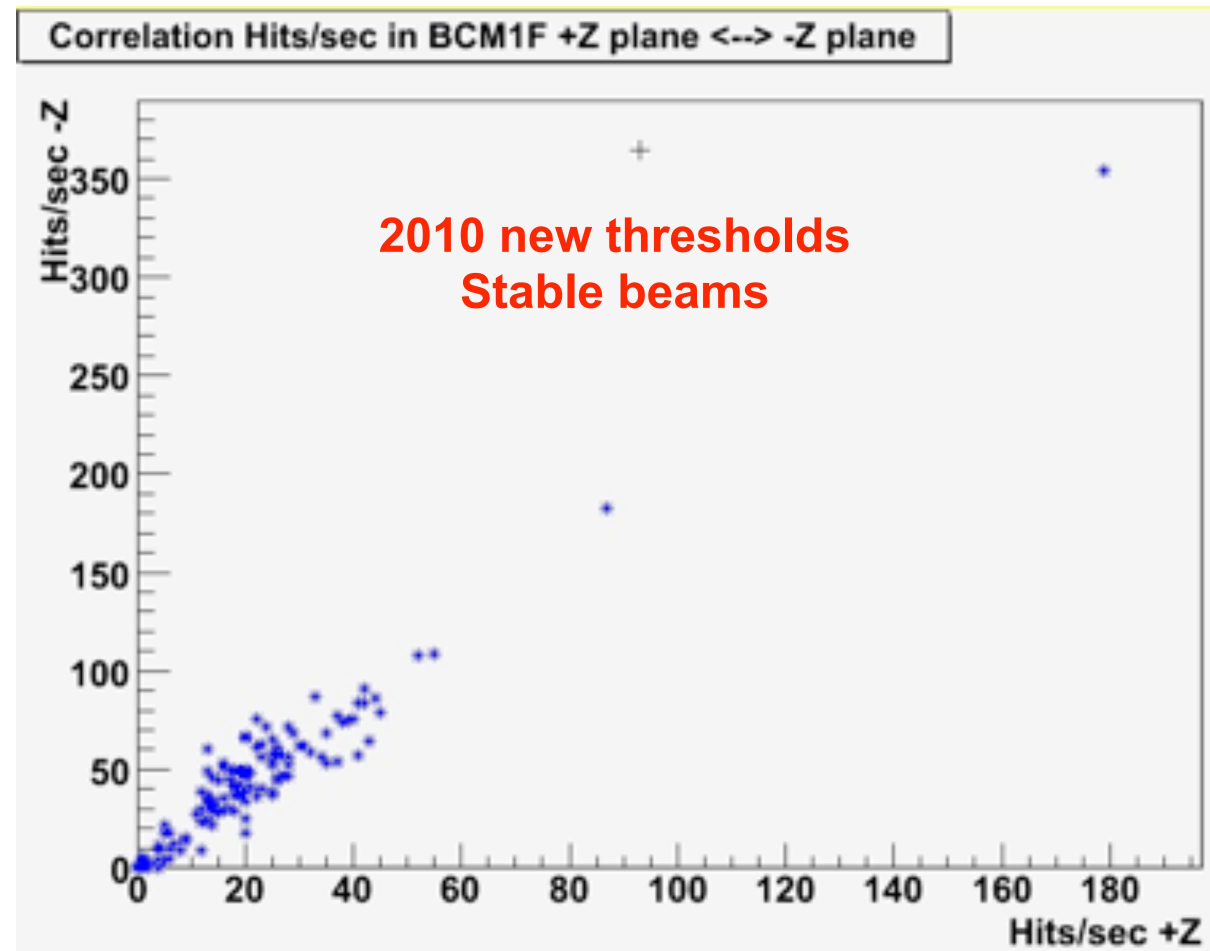
- 2009(?) running: signal spectrum used to set the thresholds of the discriminators

Signal spectrum from 2010?

Effect of the new thresholds in the count rates

- Correlation between the two planes.

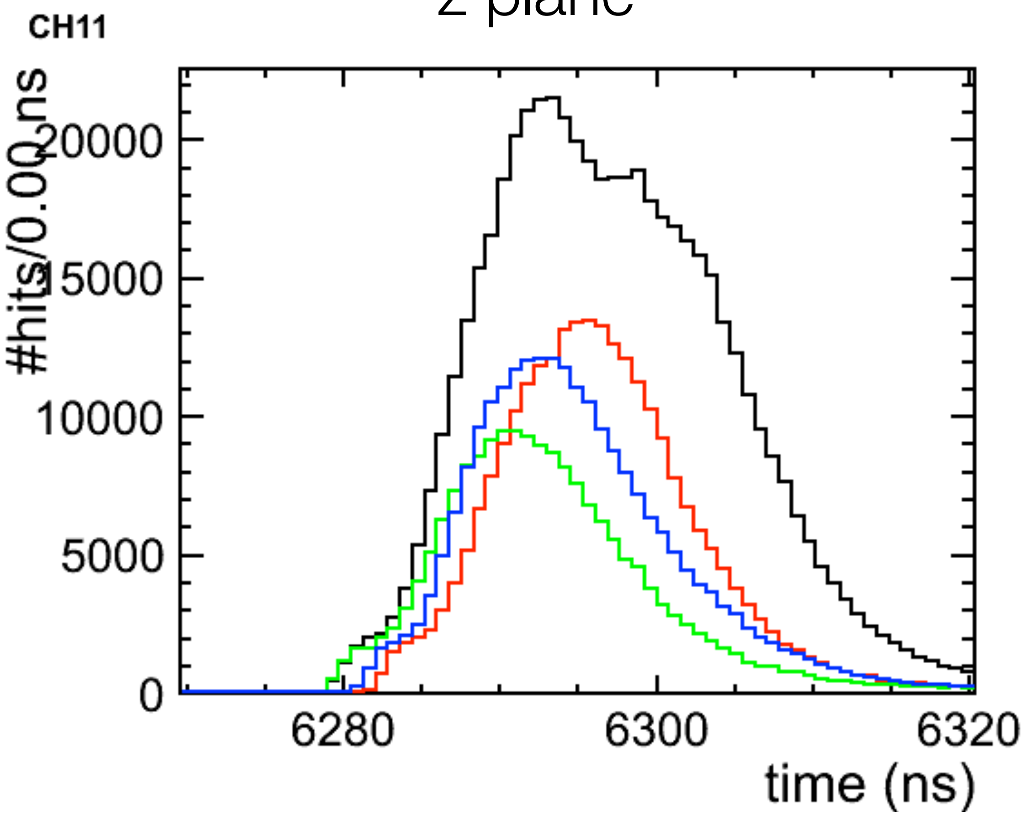




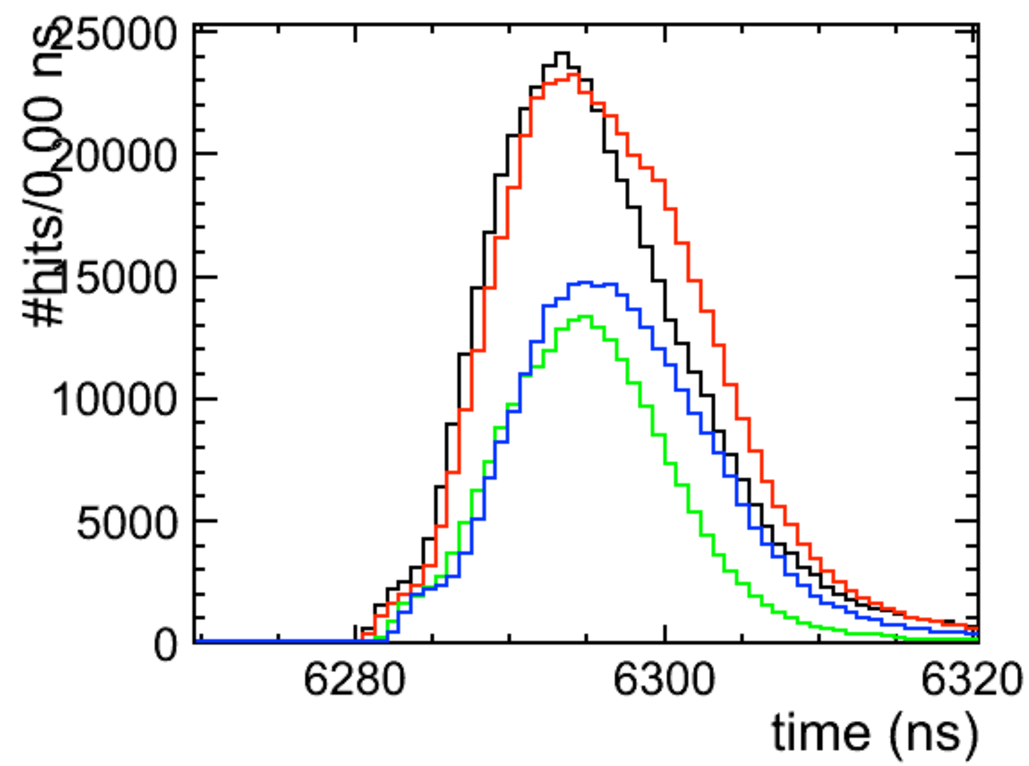
TDCs calibration

- Observed shifts of the peaks of the colliding bunches in the time distributions.

-z plane



+z plane



TDCs calibration

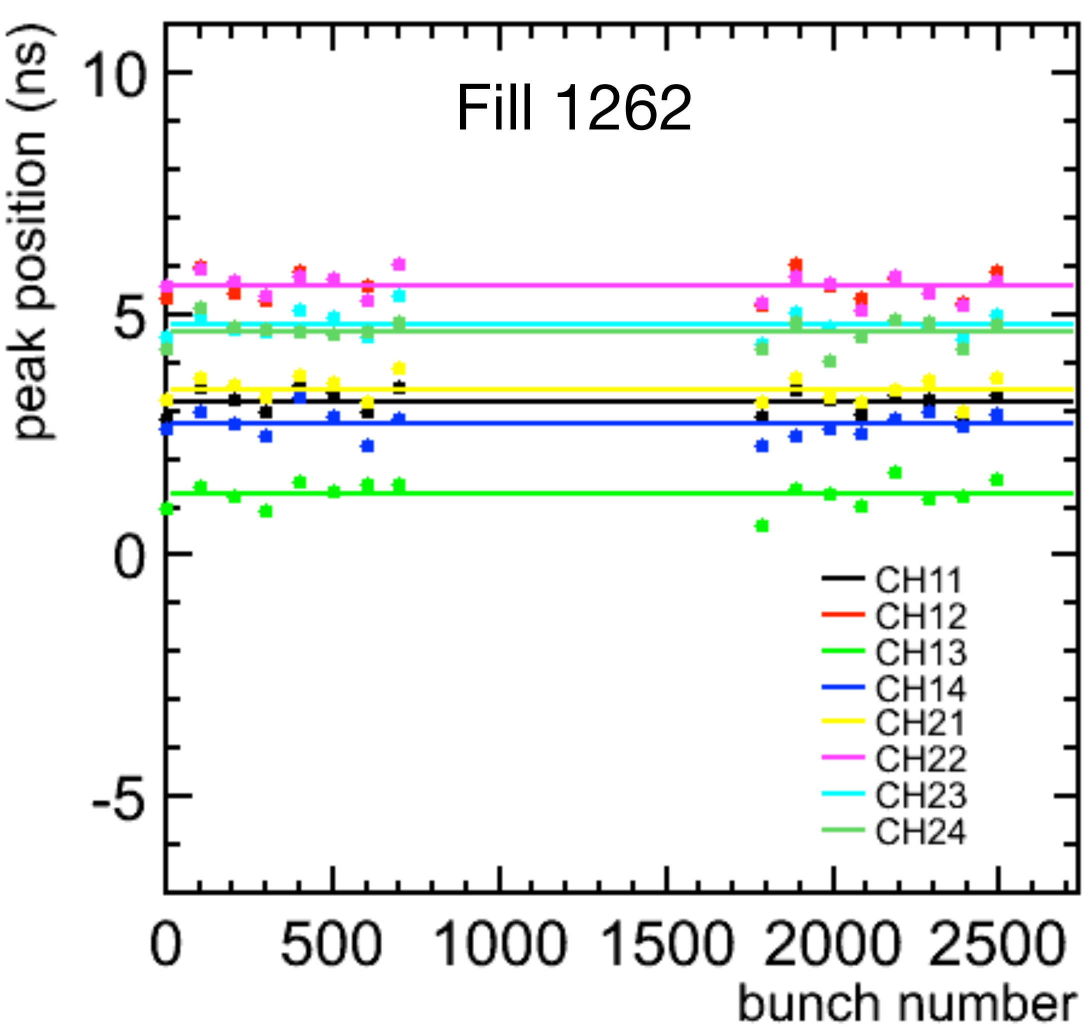
- Correct the peak position with respect to the orbit trigger.
- Fitting a gaussian around the peaks in the time distributions of the colliding bunch.
- Time distributions around each colliding bunch are shifted by a well-defined amount *t* (in ns) given the bunch number provided by the LHC.

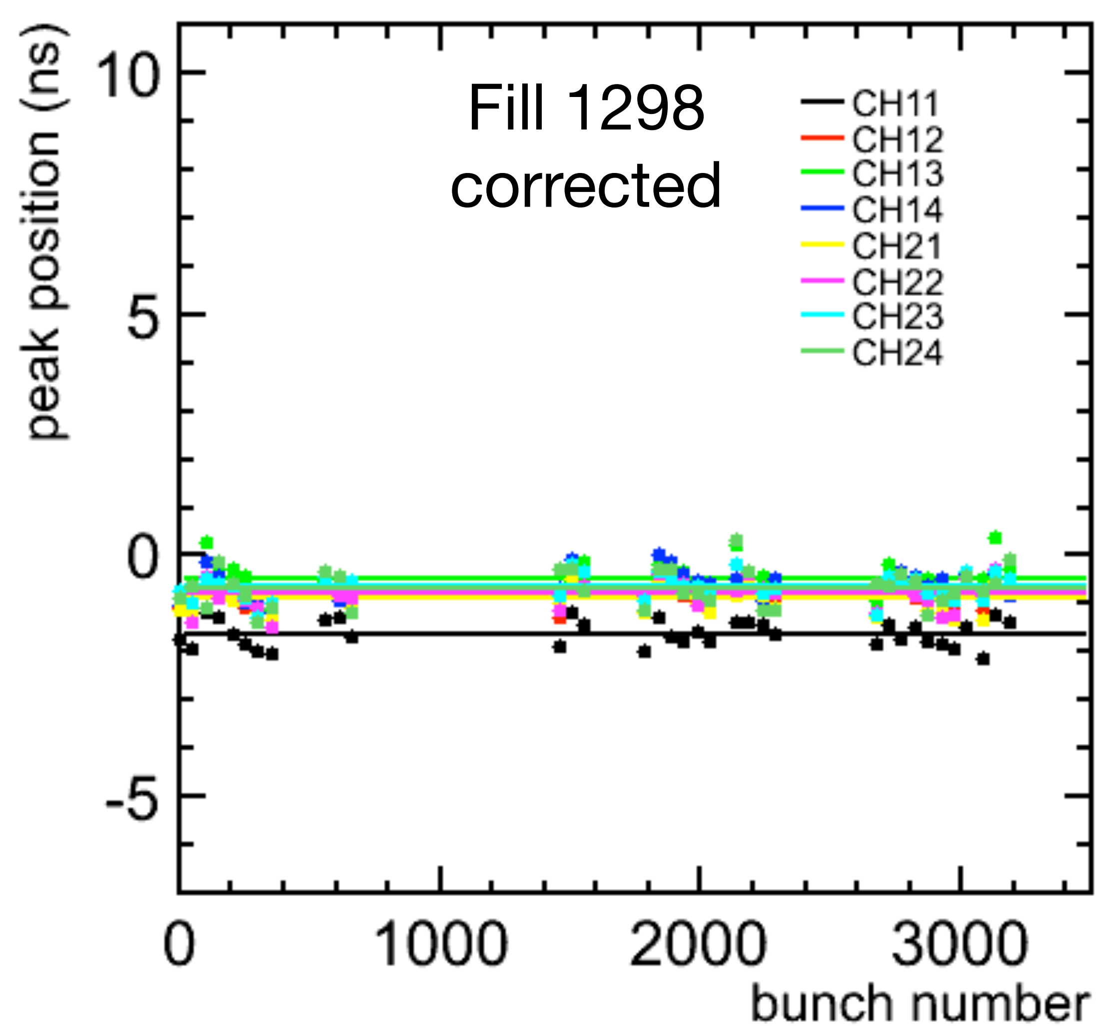
$$bn = \frac{t - 6290}{24.9505} + 1$$

- Using only orbits with size in the range (88923,88924) ns reducing jittering effects.
- Using fill 1262 (04-05.08.2010) ...
  - 16 colliding bunches:
    1, 101, 201, 301, 401, 501, 601, 701, 1786, 1886, 1986, 2086, 2186, 2286, 2386, 2486

TDCs calibration

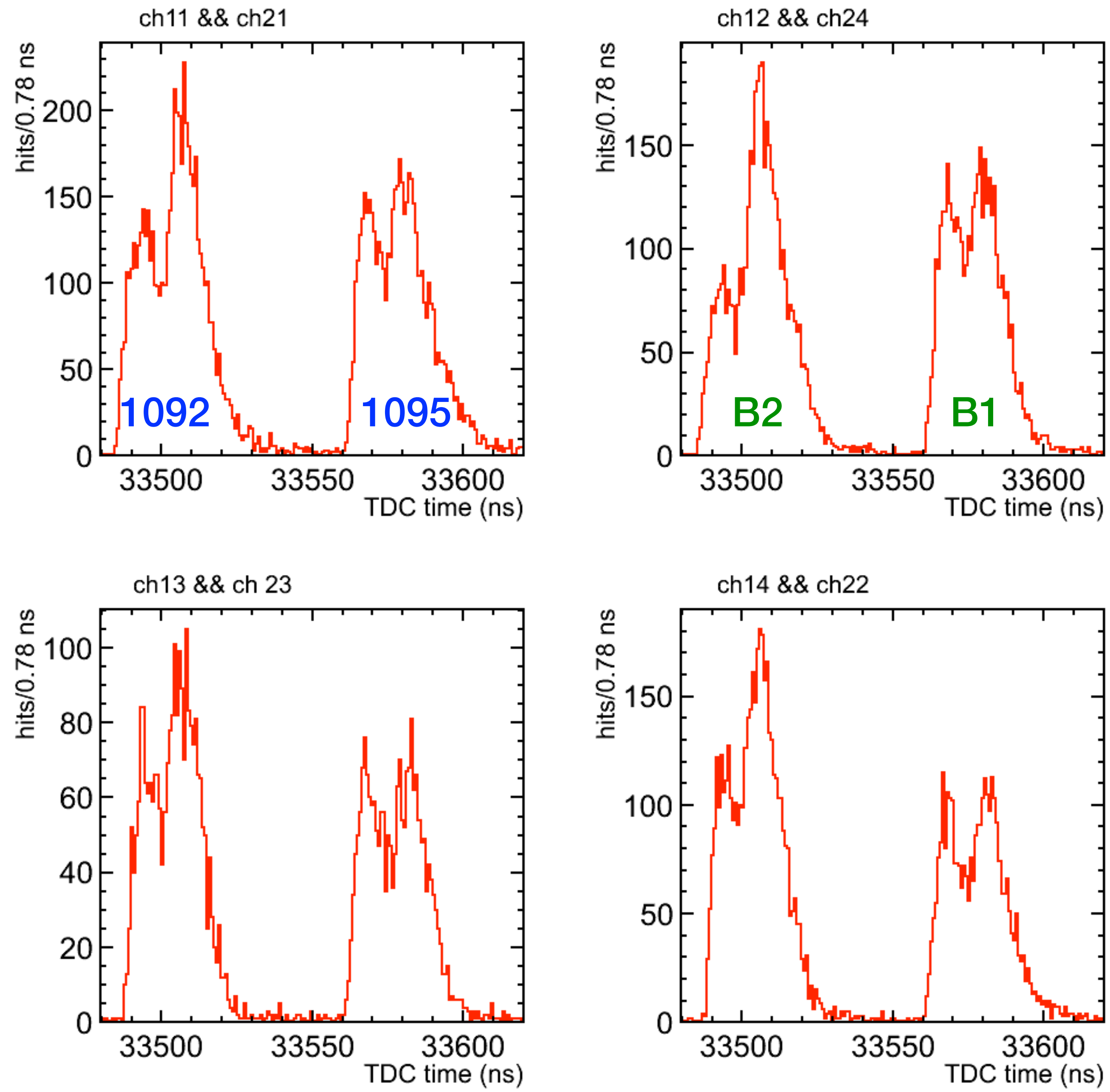
- Large spread of the time of the peaks between channels.
- Time correction factors obtained with data from fill 1262 and applied to data of the fill 1298.





Time-of-flight

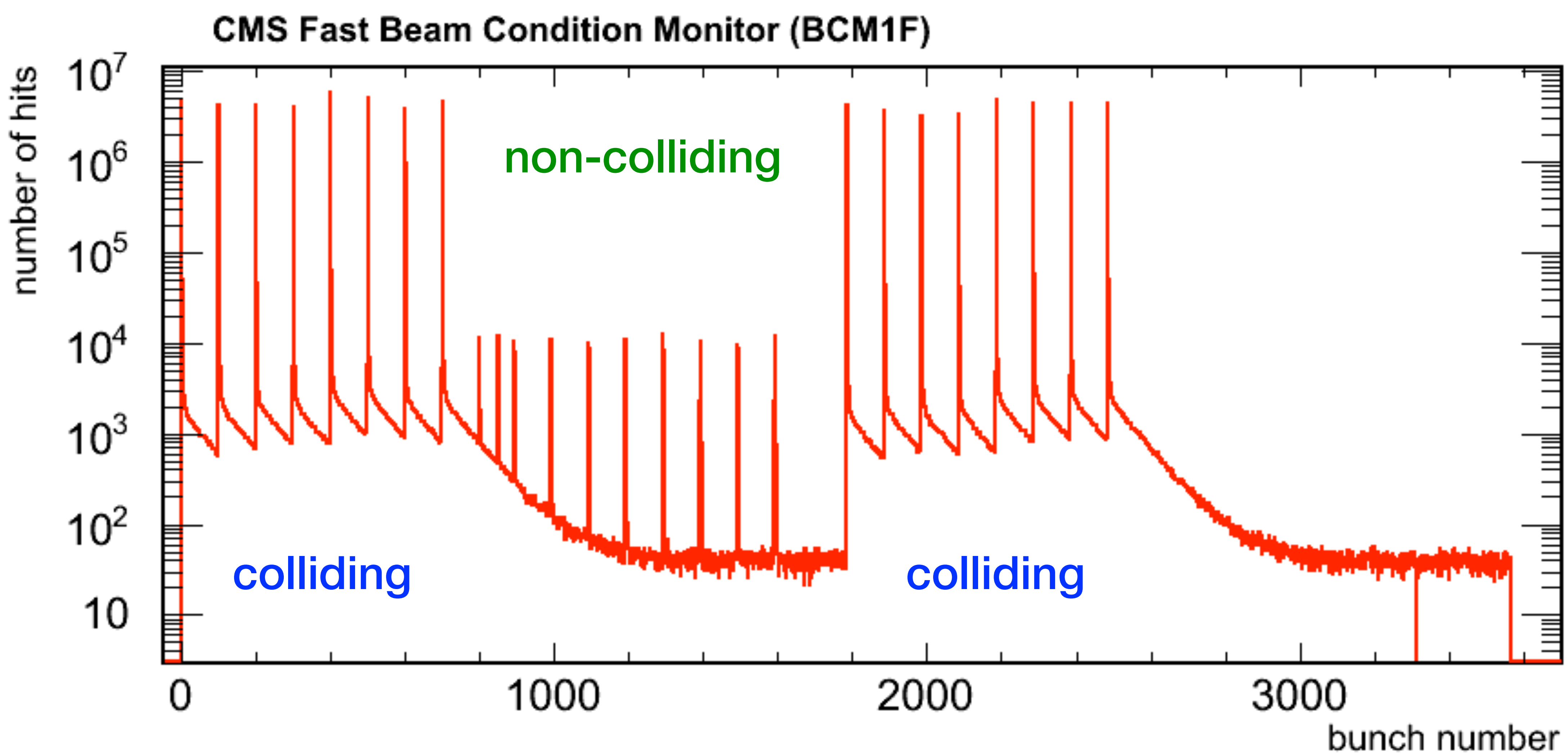
- For non-colliding bunches the time-of-flight of the beam-halo particles are resolved.
    - ‘Distance’ between peaks of the same bunch: ~12ns



Bunch structure

- Bunch structure extracted using BCM1F time information

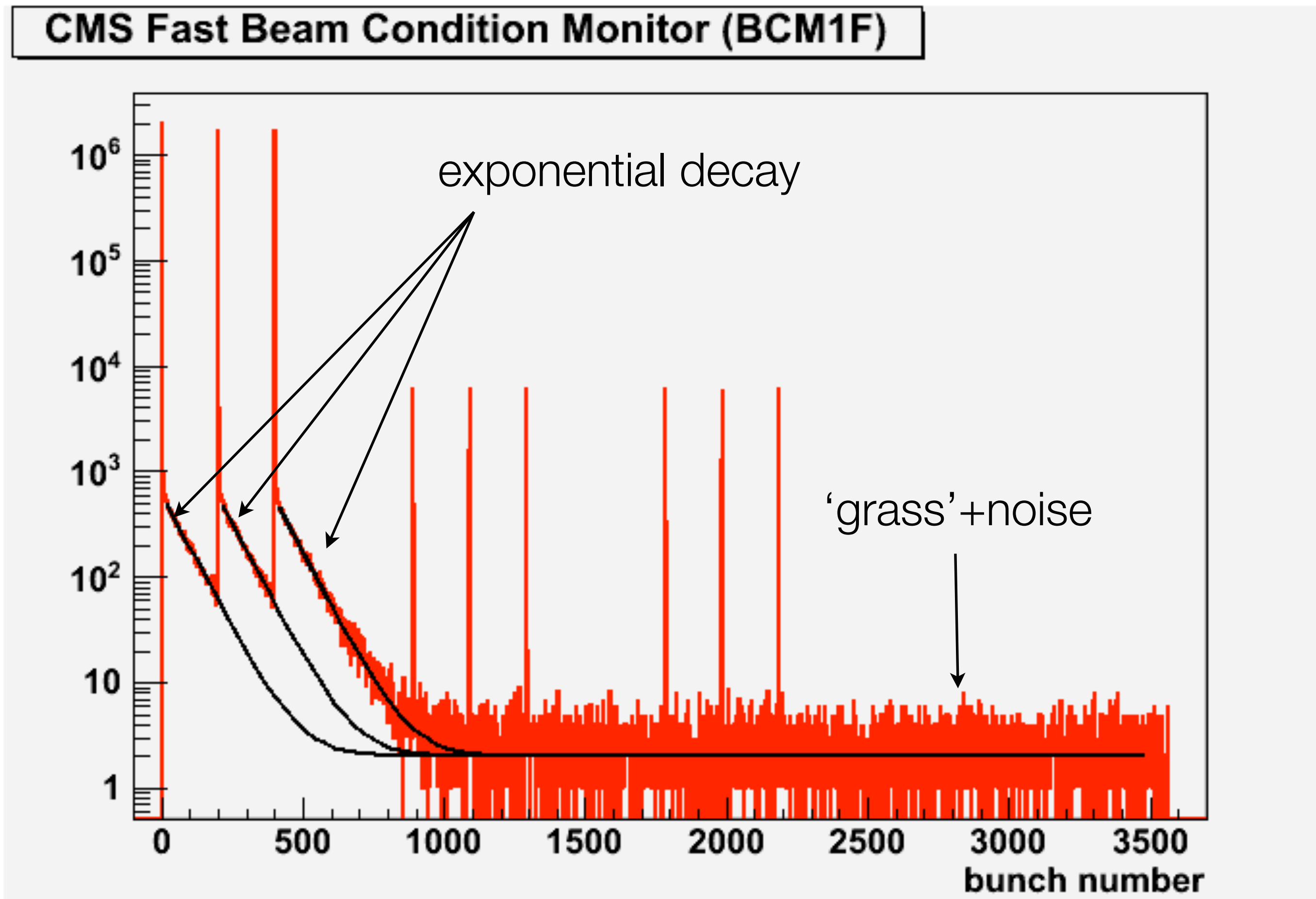
$$bn = \frac{t - 6290}{24.9505} + 1$$

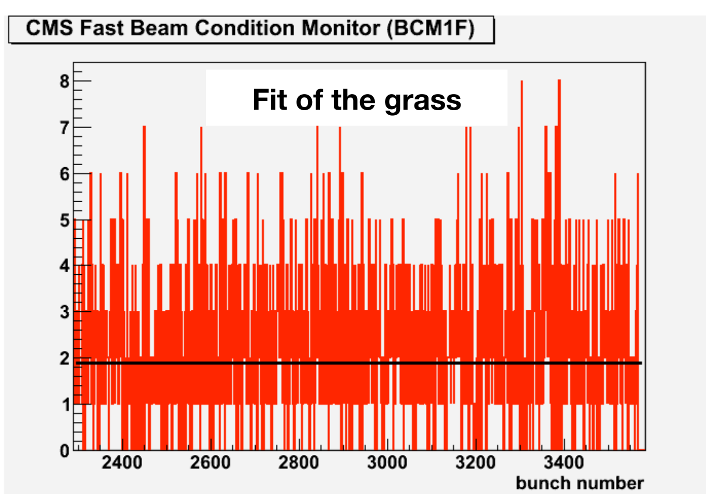


Secondary effect – After glow

- Long tails observed in the time distribution along the LHC orbit in colliding bunches associated to decay – products of collisions excite the material of the detector, that subsequently decays.

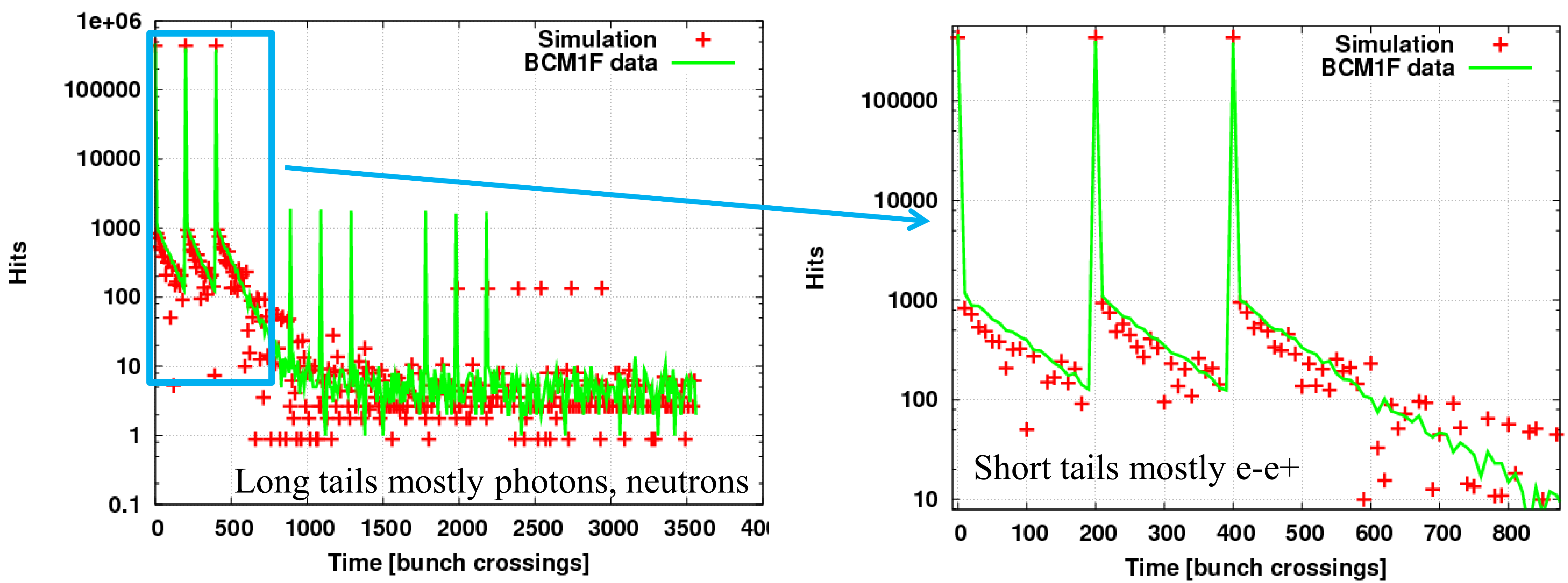
- Tails fit well an exponential giving a decay lifetime of 2.12 μs or 85 bunch numbers.





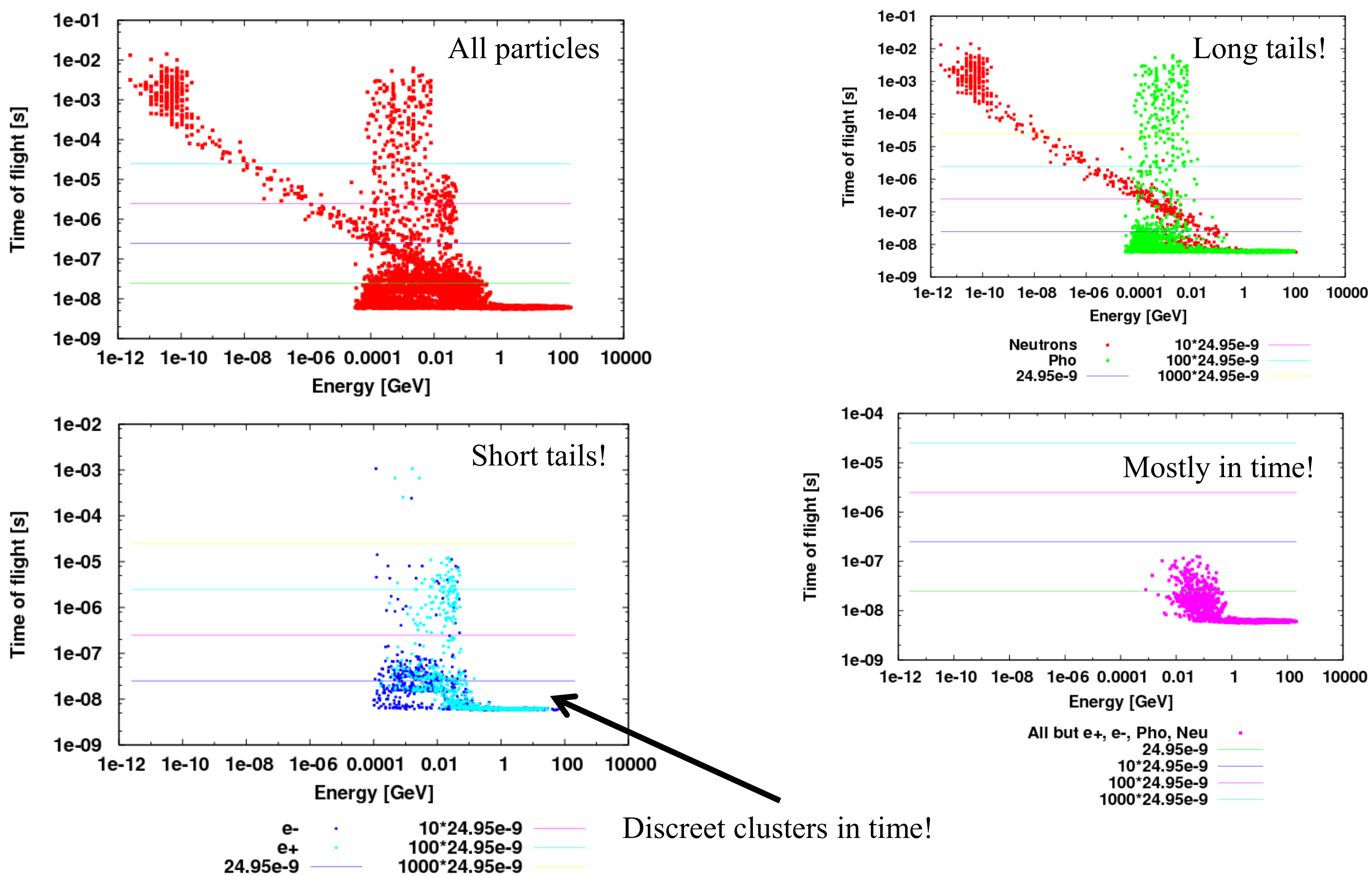
Secondary effect – After glow

- Fluka simulation by S. Mueller (KIT) in good agreement with the data



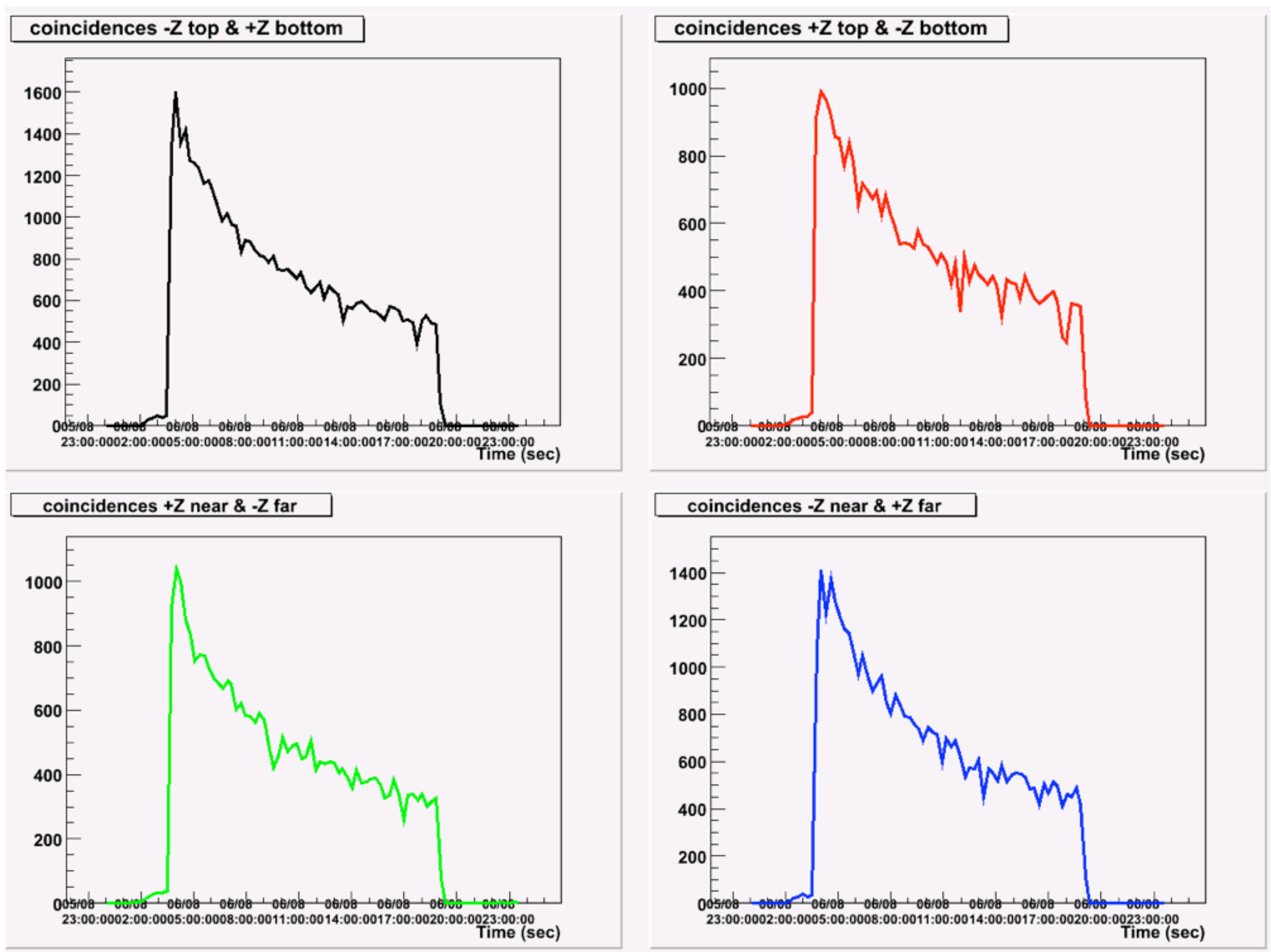
Secondary effect – After-glow

- Particle composition from simulation.



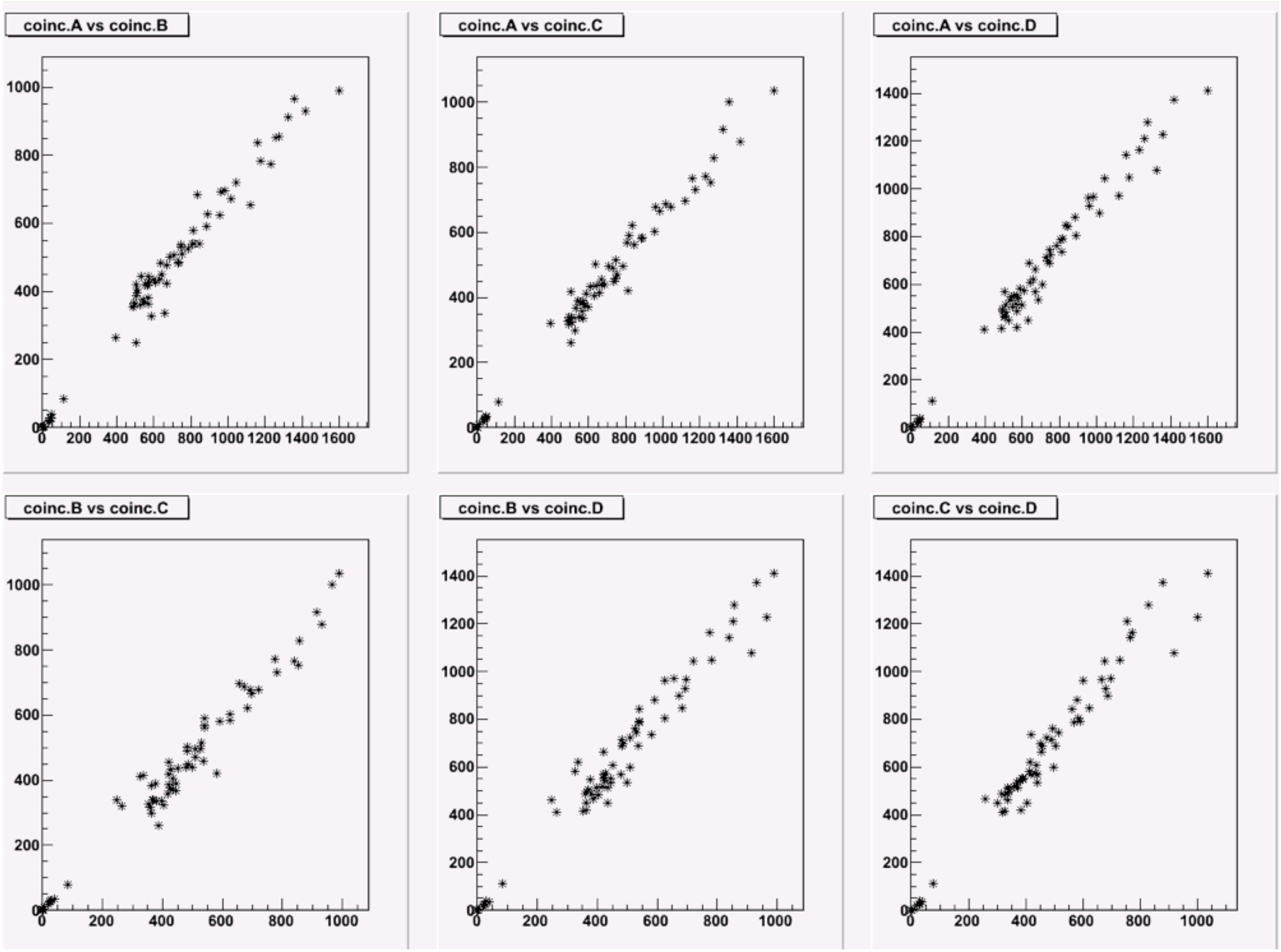
Towards luminosity monitoring

- Using the look-up table, coincident hits in back-to-back channels of BCM1F are selected.



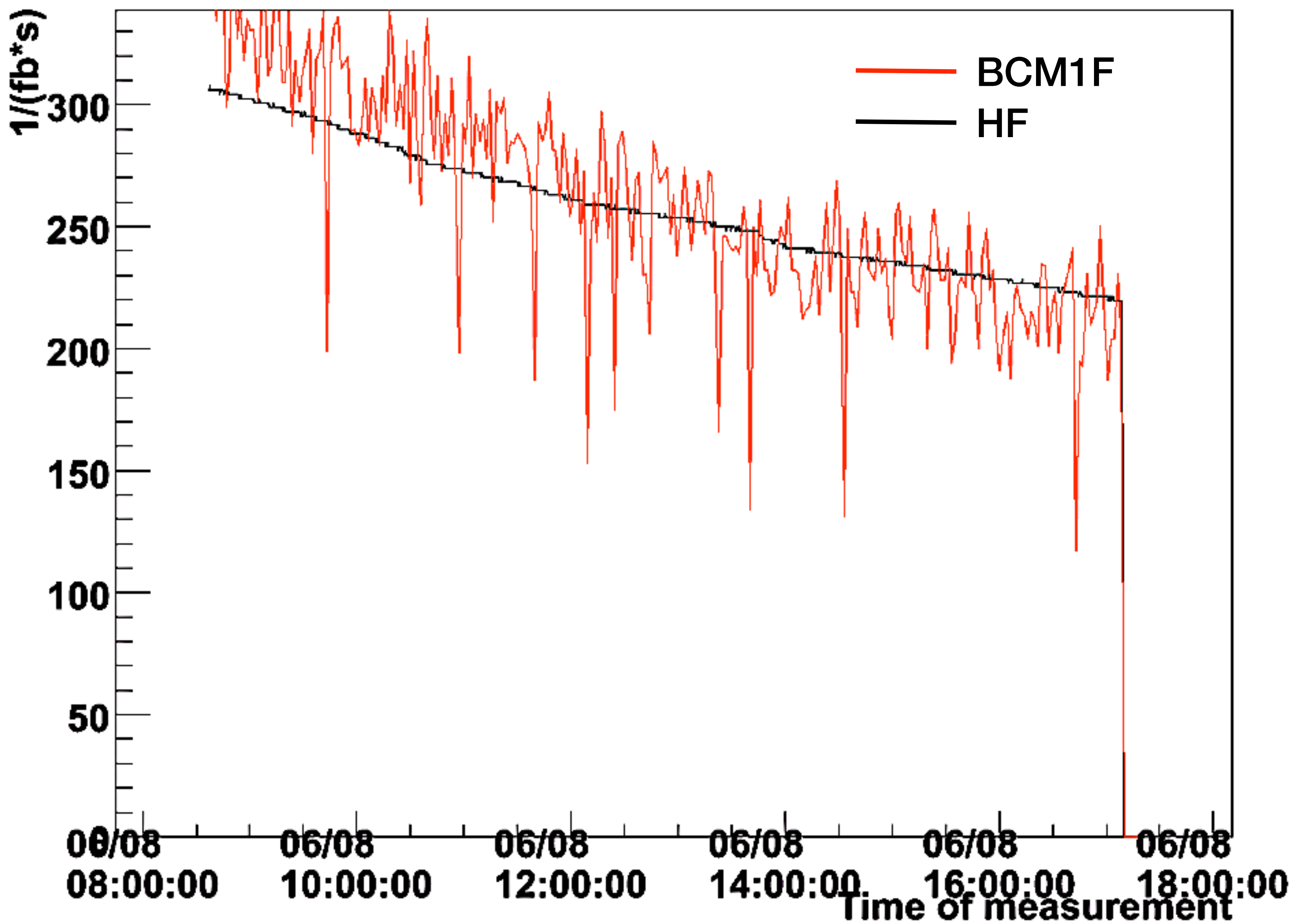
Luminosity monitoring

- Correlations



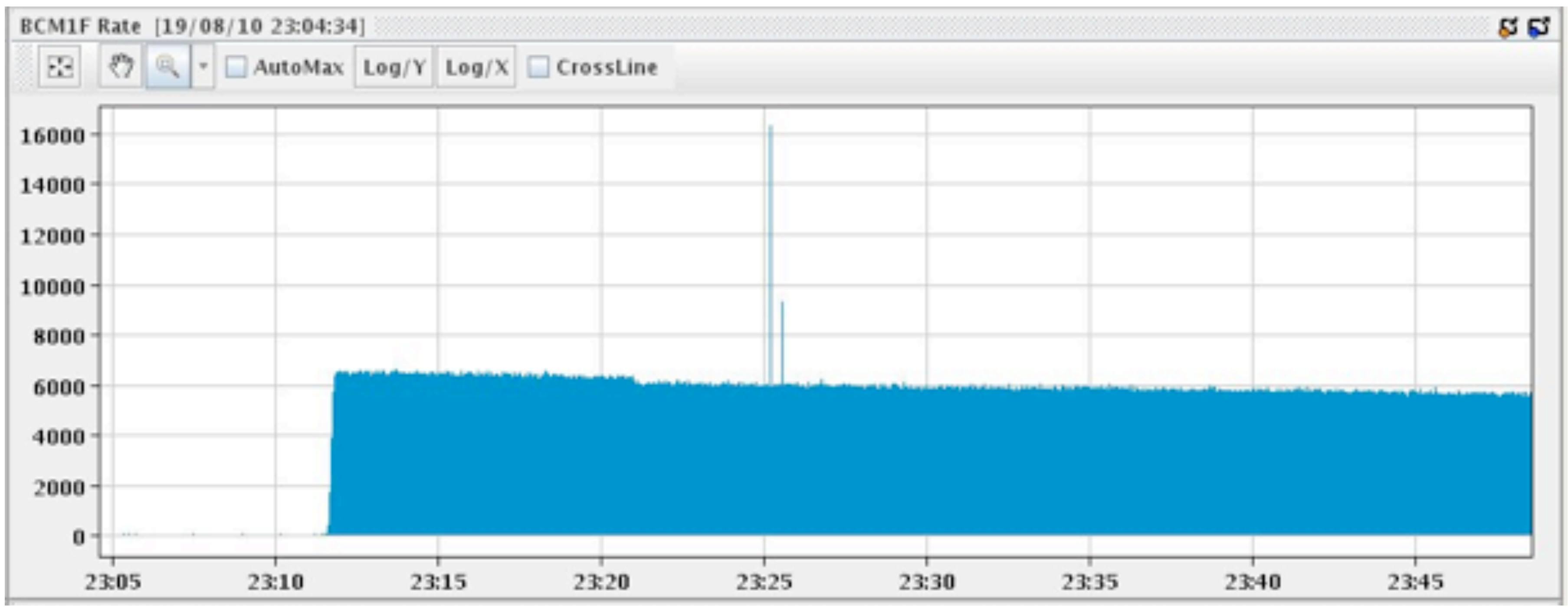
Towards luminosity monitoring

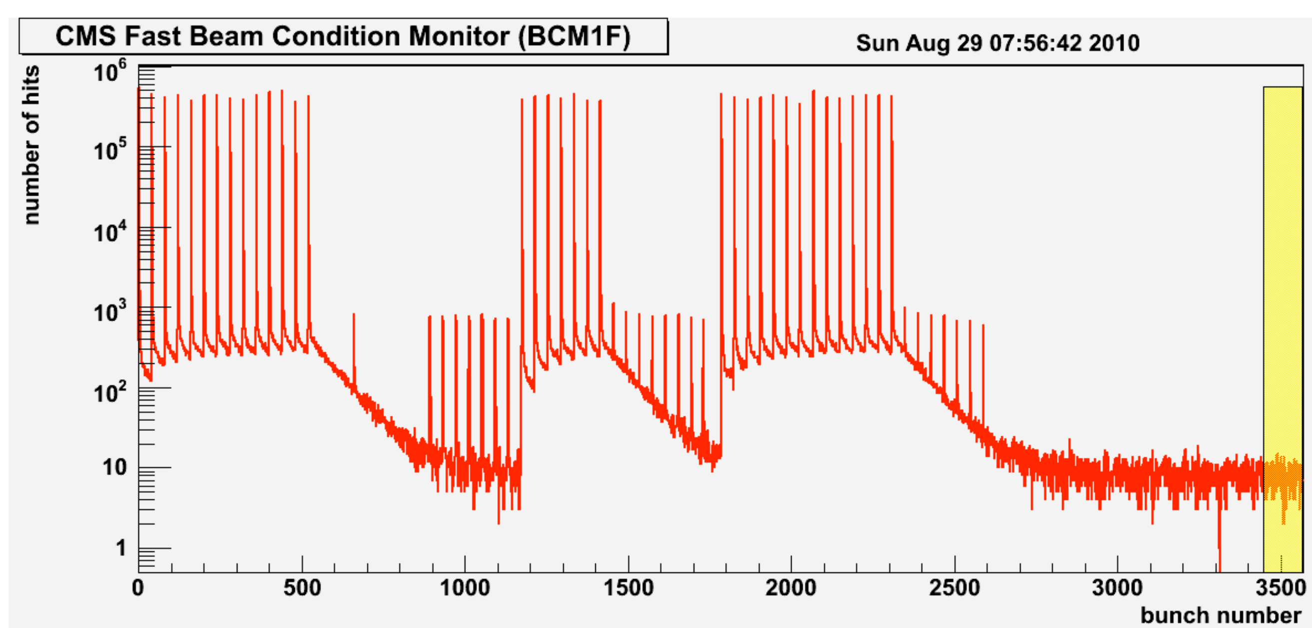
- Using the forward calorimeter HF as a reference.
  - BCM1F count rates are scaled to HF



Online information

- BCM1F information is provided online to the shift crew.





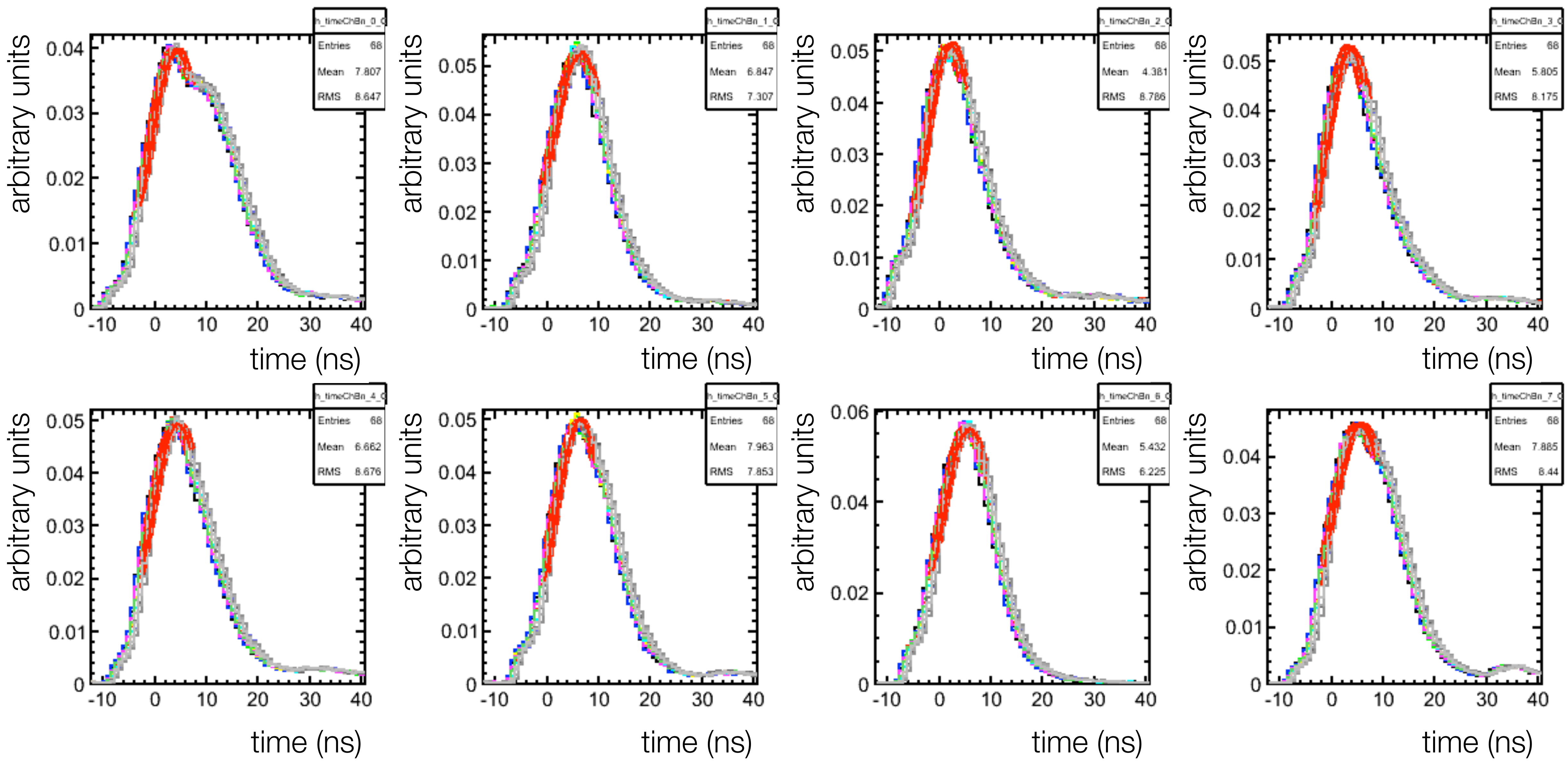
Summary

- BCM1F is running in very good shape!
- Calibrations and many other studies were already performed with the LHC data since 2008 improving our understanding of the detector and of the beam conditions.
- Various informations are provided both offline and online, in the latest case directly to the shift crew in Point 5.
    - Count rates
    - Bunch structure
    - Luminosity monitoring (soon!)
- But that’s not the end. There still are lots of work to do!

Additional slides

TDCs calibration

- Time distribution for the shifted peaks of all bunches for each channel.



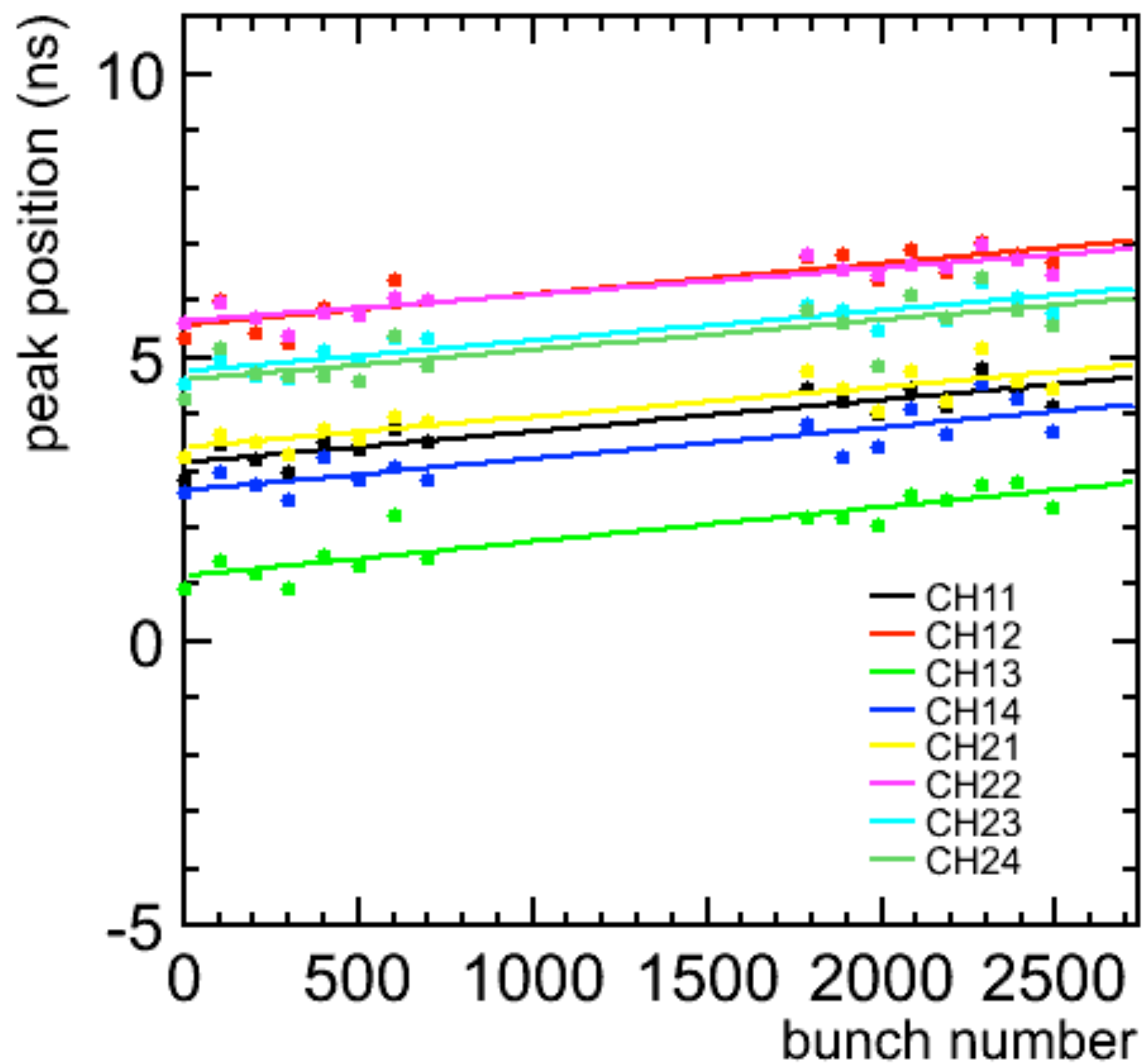
TDCs calibration

- For different bunches expected that the peak positions fluctuate around a constant value.
- But found a slope!
- The factor 24.95 ns in

$$bn = \frac{t - 6290}{24.95} + 1$$

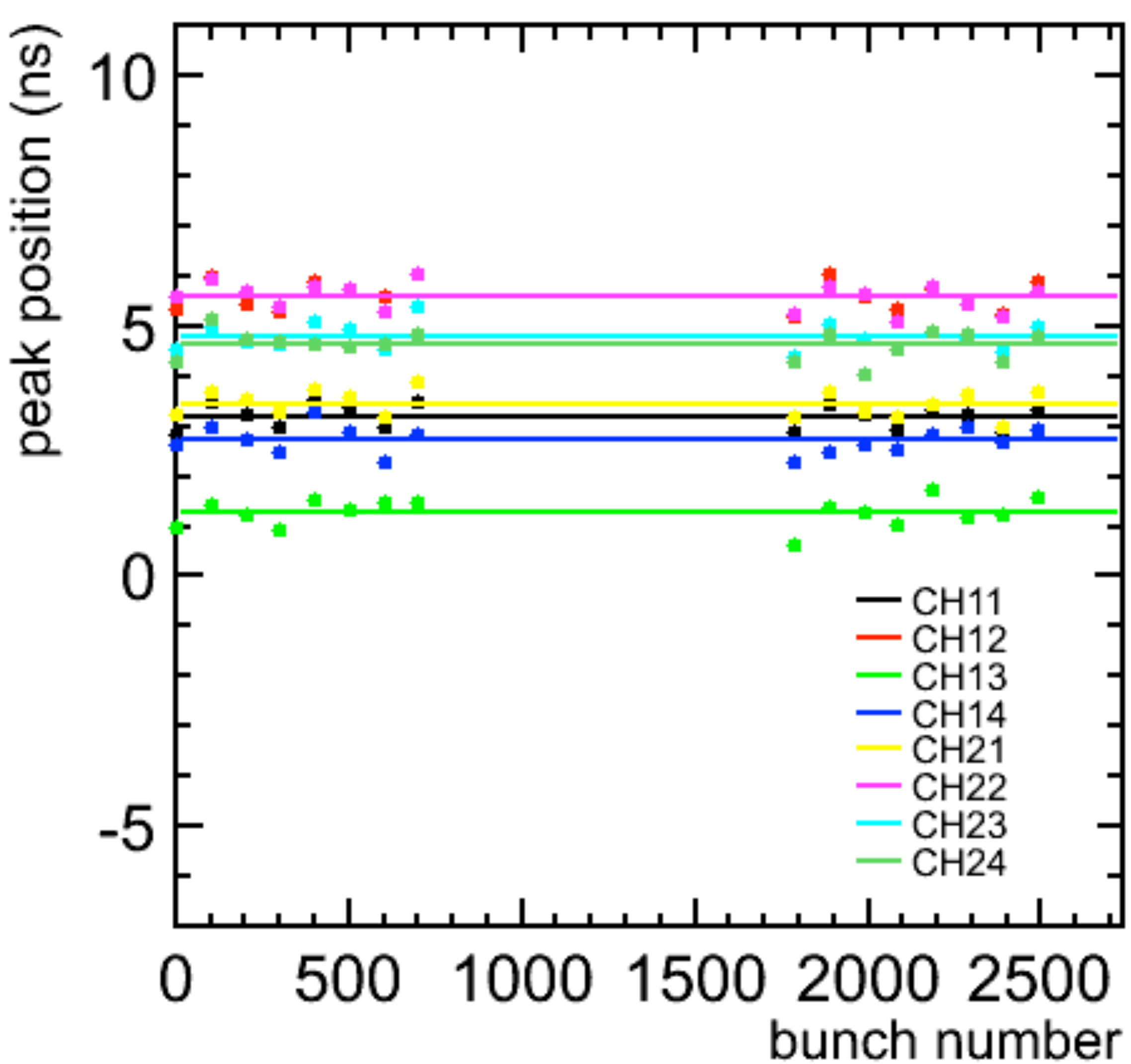
still is an approximation.

- Using 24.9505 ns instead...

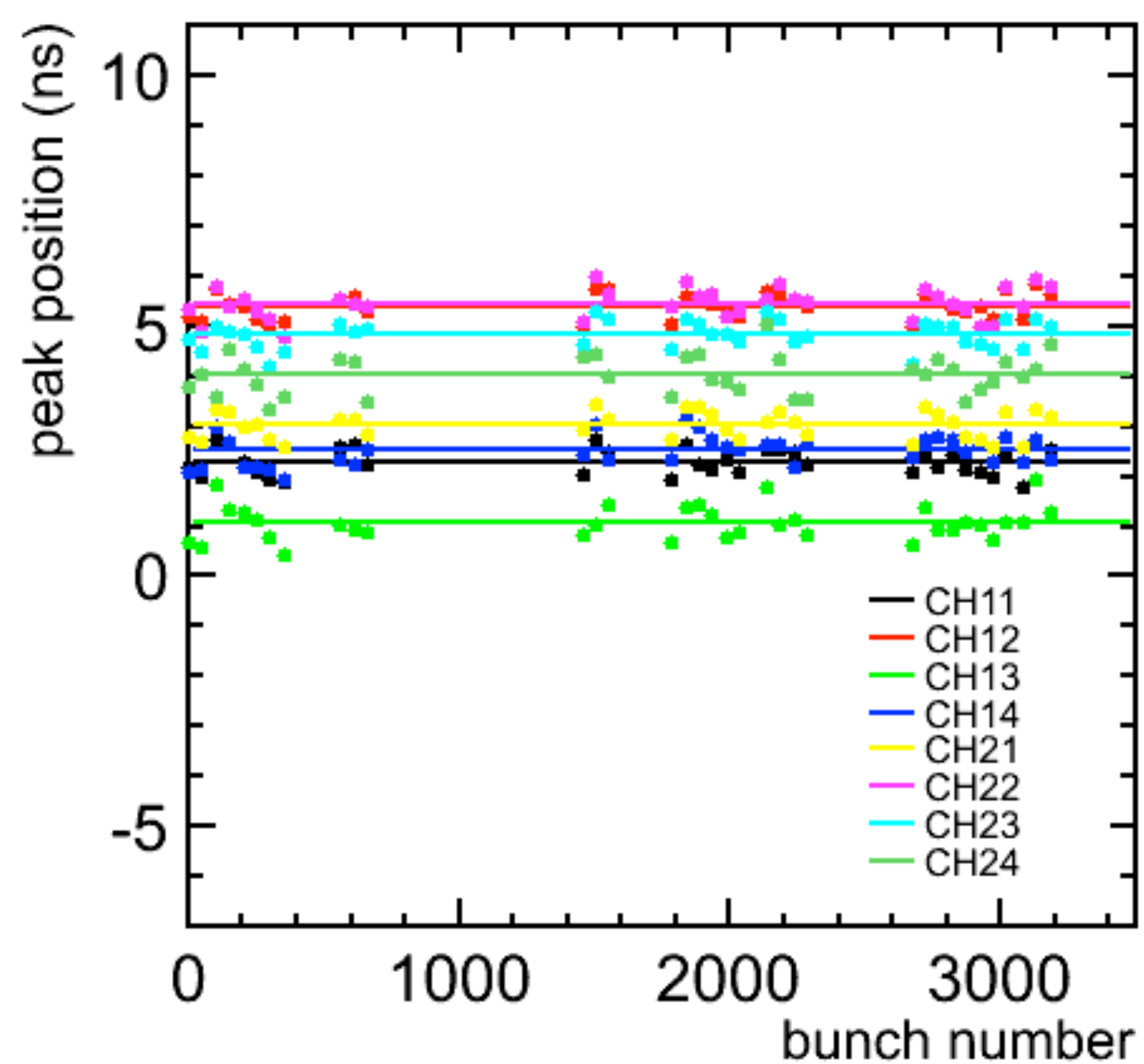


TDCs calibration

Fill 1262



Fill 1298



- Channels 11 and 24 show the larger differences. The bumps should have an effect on the fits.

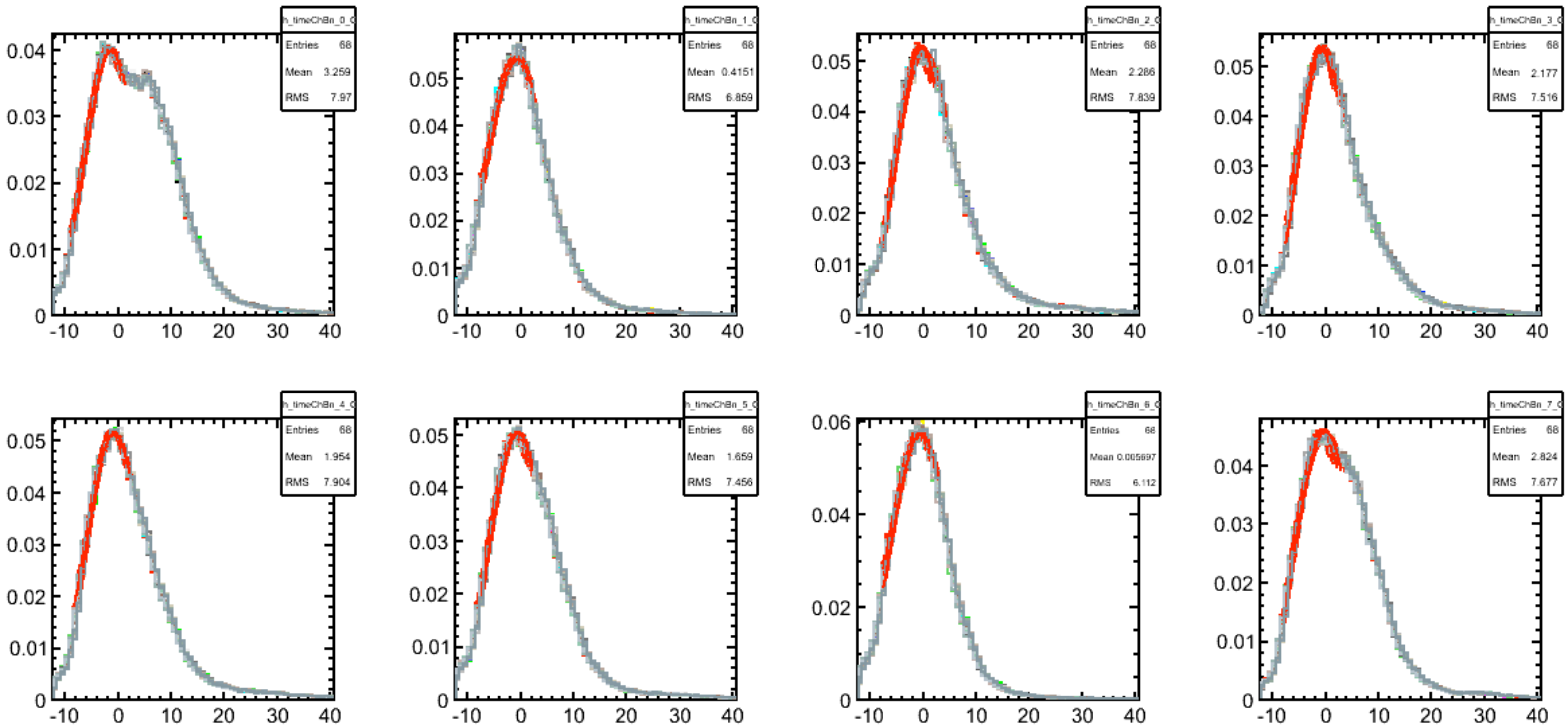
TDCs calibration

- Calibration factors – obtained using data in fill 1262.
  - The values (in ns) in the table below shold be subtracted from the hit time in each channel.

ch11	ch12	ch13	ch14	ch21	ch22	ch23	ch24
3.20	5.62	1.27	2.72	3.45	5.59	4.79	4.63

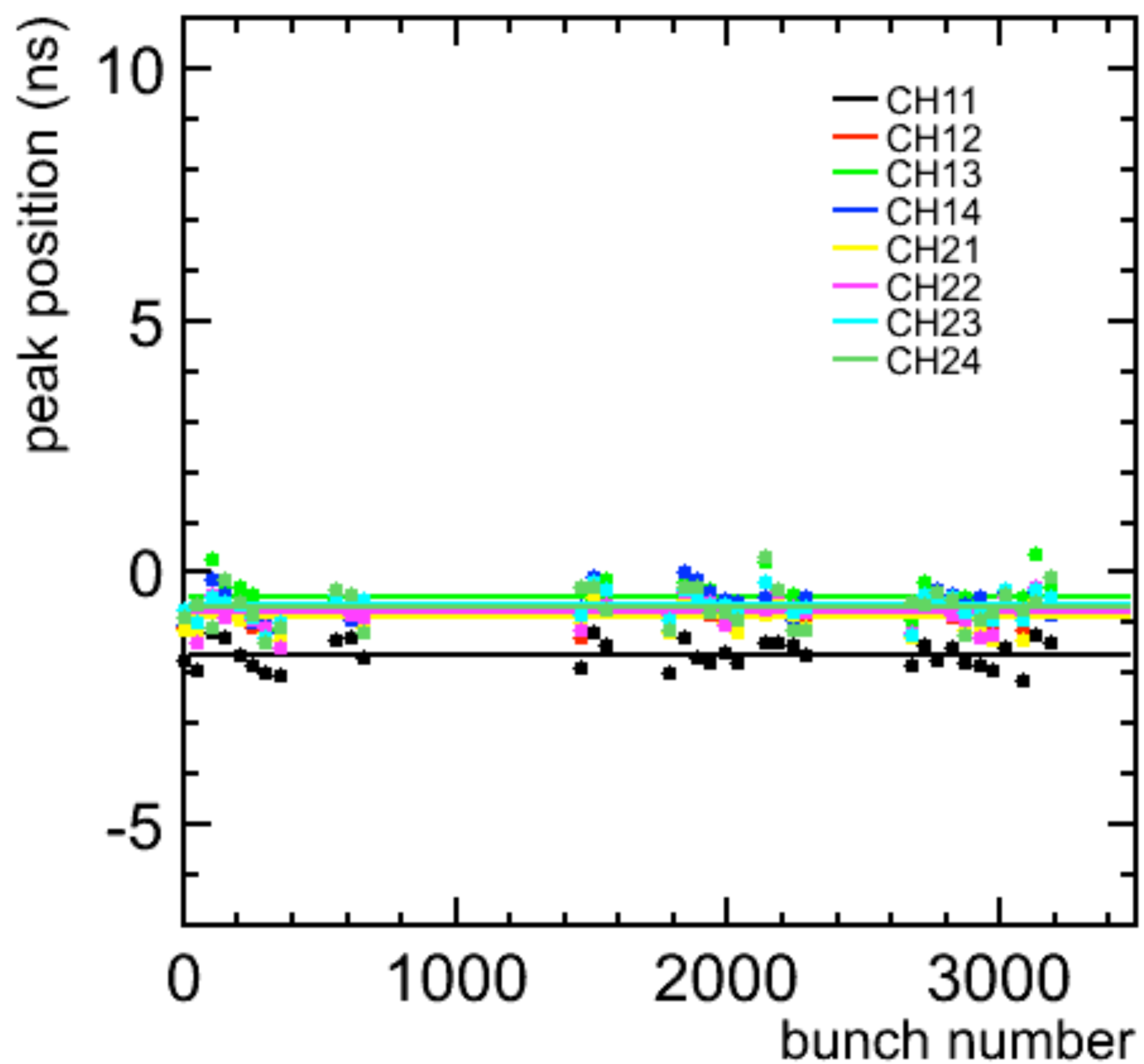
TDCs calibration

- Using the correction factors obtained from the fits using the data from fill 1262 to correct the time of the hits of the fill 1298...



The peaks are close to zero.

TDCs calibration



- Applying the correction factor obtained using the data of fill 1262 in the data of fill 1268.
- **The spread is significantly reduced!**

- Fill 1268 – 36 colliding bunches: 1, 51, 101, 151, 201, 251, 301, 351, 560, 610, 660, 1454, 1504, 1554, 1786, 1836, 1886, 1936, 1986, 2036, 2086, 2136, 2186, 2236, 2286, 2671, 2721, 2771, 2821, 2871, 2921, 2971, 3021, 3080, 3130, 3180