The BCM1F Detector: commissioning at LHC Run II and first results.

Olena Karacheban
on behalf of the Beam Radiation Instrumentation and Luminosity group (BRIL) of CMS

4th ADAMAS workshop, GSI
3rd December 2015, Darmstadt, Germany

Outline

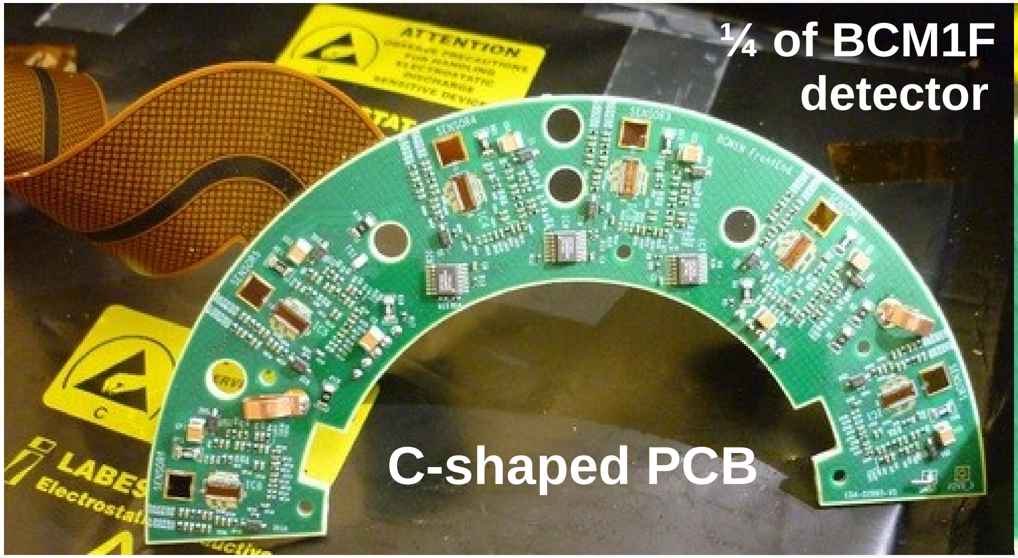
Part 1

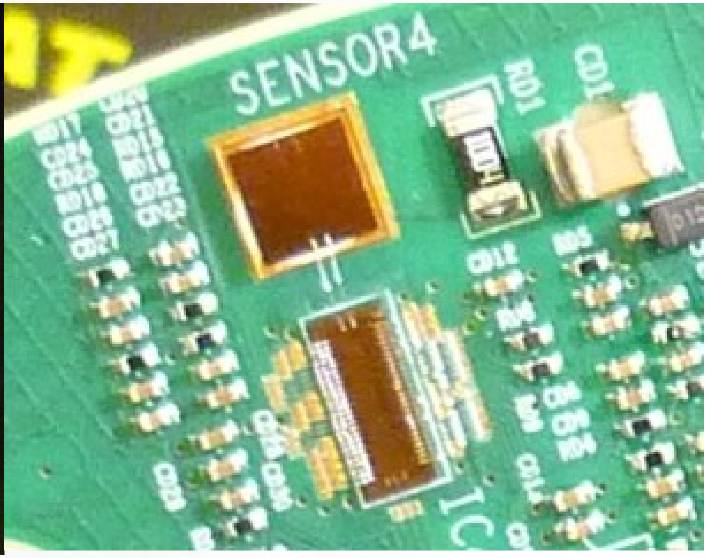
- **The BCM1F detector and back end electronics.**
- **Detector performance plots and efficiency monitoring:**
  - Radiation damage of the sensors;
  - Radiation damage of the electronics;
  - Effects in the metallization gap and non metallized edges.
- **HV instability issues.**
- **Long pulses and anomalous spikes.**

Part 2

- **BCM1F as Luminometer:**
  - Calibration and Van der Meer scan

Fast Beam Condition Monitor (BCM1F) based on diamond sensors



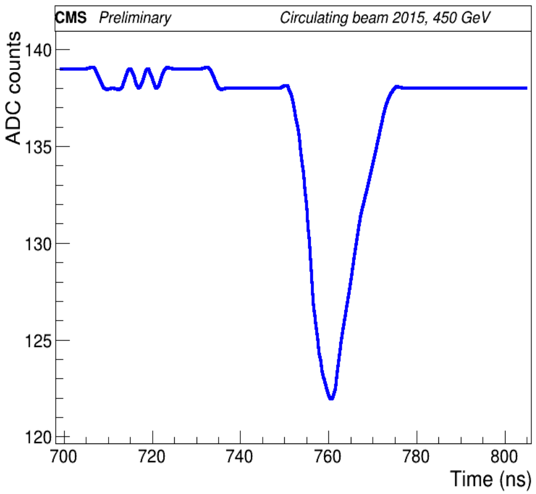


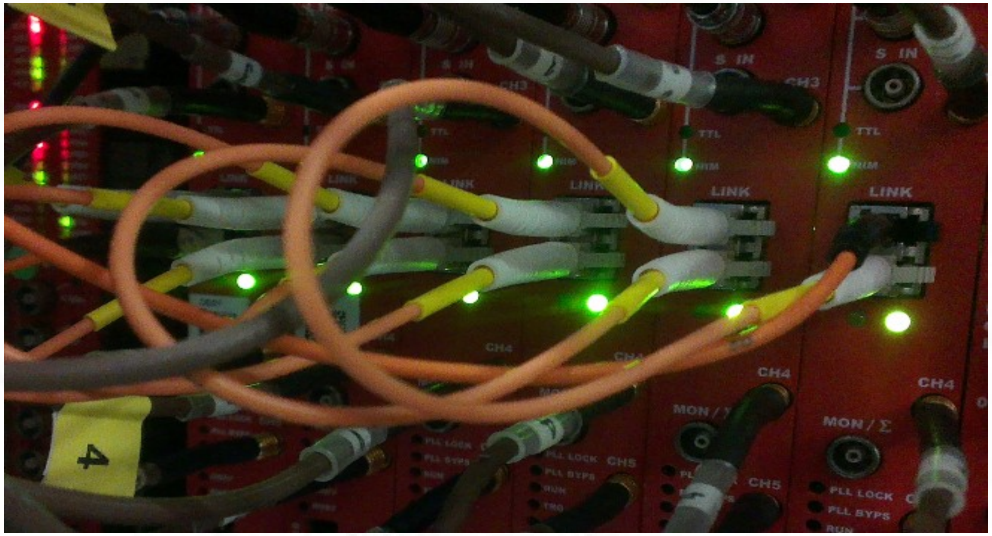
- 2 C-shaped PCB from both ends of CMS, 1.8 m from interaction point;
- 6 diamond sensors with 2 pad metallization per C-shape — 12 channels;
- Signals are preamplified with radiation hard ASIC 130nm technology;
- The electrical signal is converted into an optical signal which is then transmitted to the backend electronics in counting room (USC55).
- From optical receivers data is provided to 3 recording systems: Real-time Histogramming Unit (RHU), uTCA ADCs and VME ADCs.

More information about the BCM1F detector in M.Hempel talk.

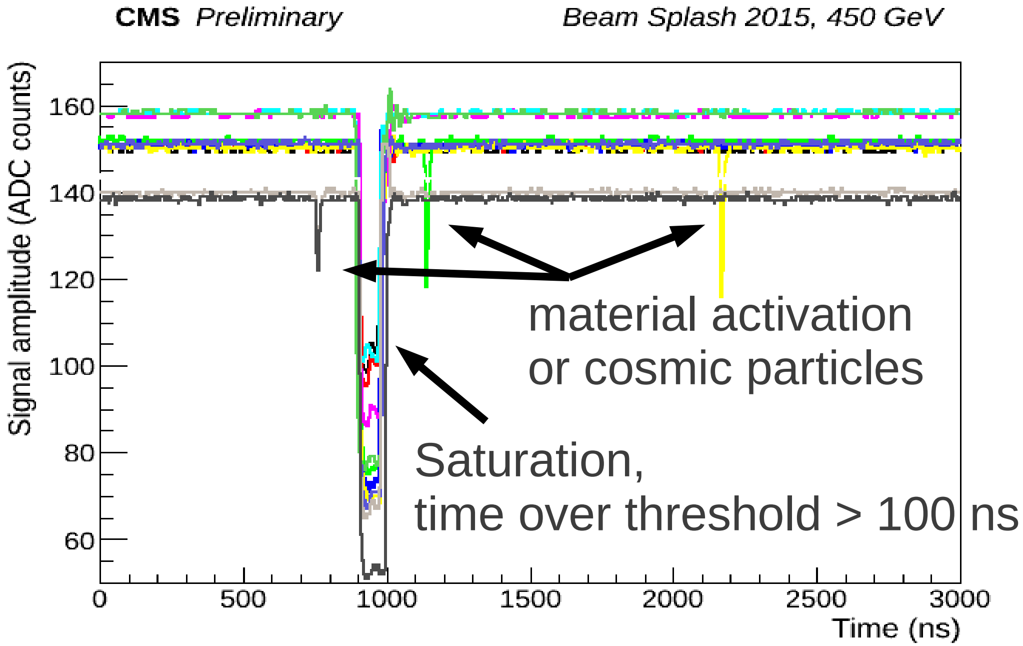
Back end: VME ADCs

- 48 channels of BCM1F are served by CAEN v1721 ADCs:
  - 8 channels 8 bit 500 MS/s Digitizer (2 ns sampling time);
- 6 ADC boards are daisy chained and read out via optical link with transfer rate up to 80MB/s.
- Whole LHC orbit (89 μs) is buffered for each channel:
  - Clock: internal;
  - Trigger for readout: external - LHC orbit clock.
- Sampled data is recorded on the server and processed offline.





Easter present: beam splashes at LHC!



- Splash event: a single bunch is dumped in a collimator just upstream of the experiment.
- Since many particles cross the sensor simultaneously the signal amplitude saturates.
- First data recorded by the VME ADCs: the response of diamond sensors in splash events.

Peak finding algorithm

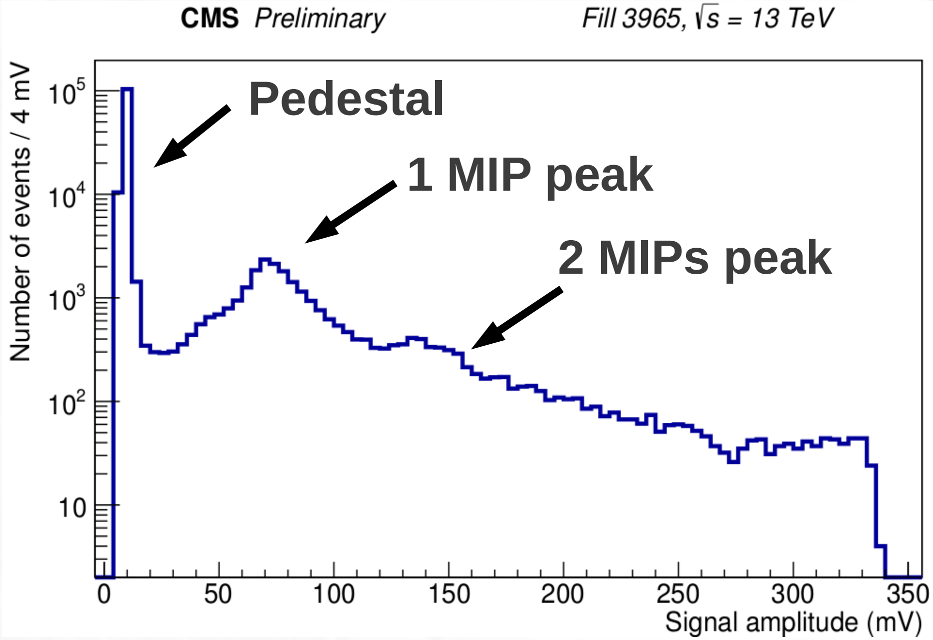
- ADC data is used to monitor:

  - baseline stability;

  - signal amplitude and length;

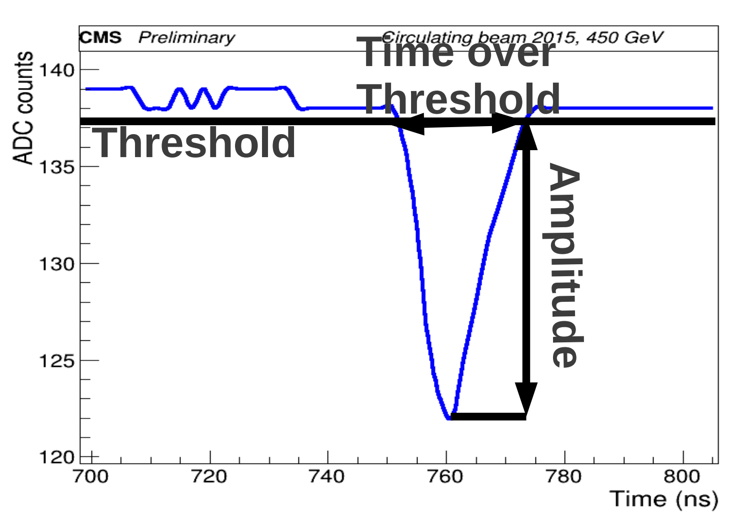
  - stability of MIP peak position;

  - Test pulse (TP) amplitude.



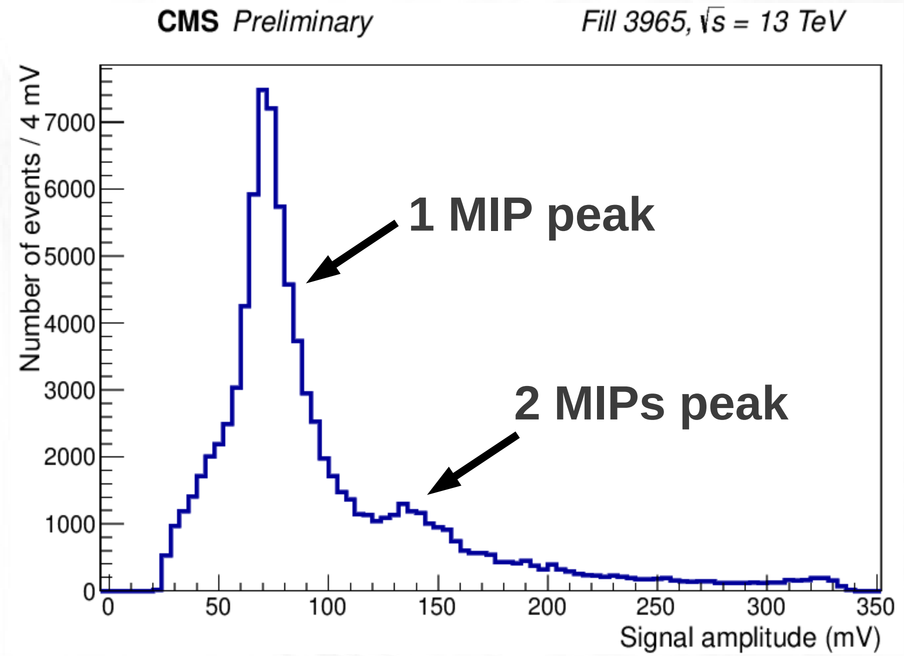
- Required parameters in the offline data processing:

  - threshold and minimum time over threshold.



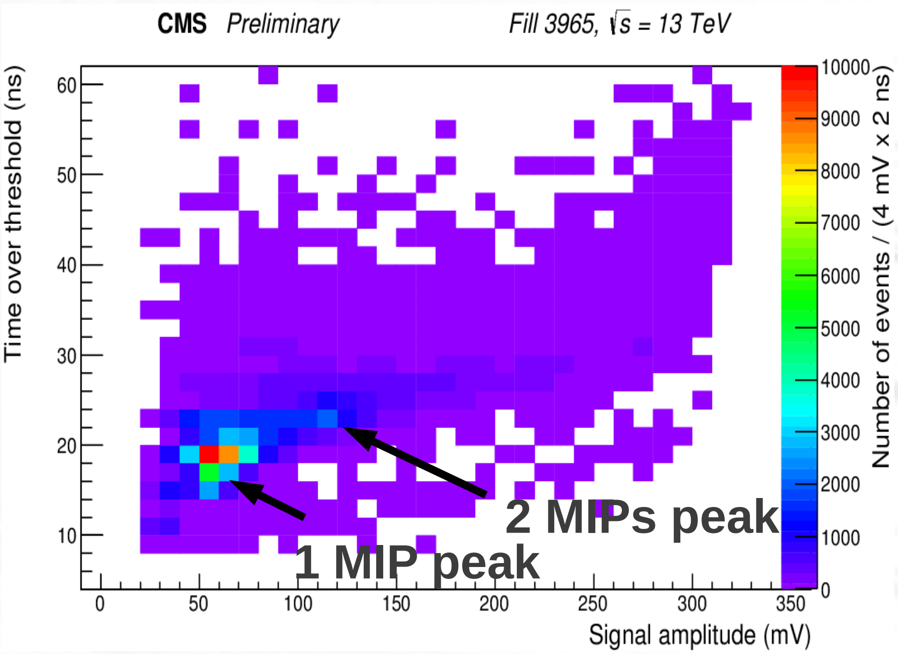
Performance plots

BCM1F amplitude spectrum.



- HV: 200 V (CCE 100%).
- Signal amplitude cut: A > 20 mV.

Time over threshold vs. signal amplitude.



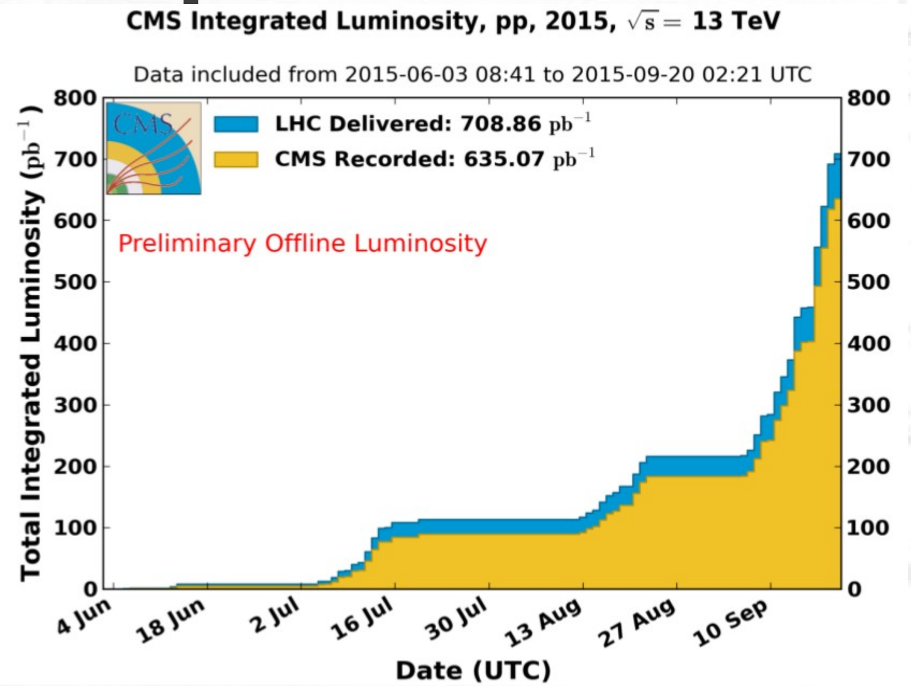
- The fraction of pulses with time over threshold > 25 ns (LHC bunch spacing) is in the range 10-25%, for this particular channel 22%.

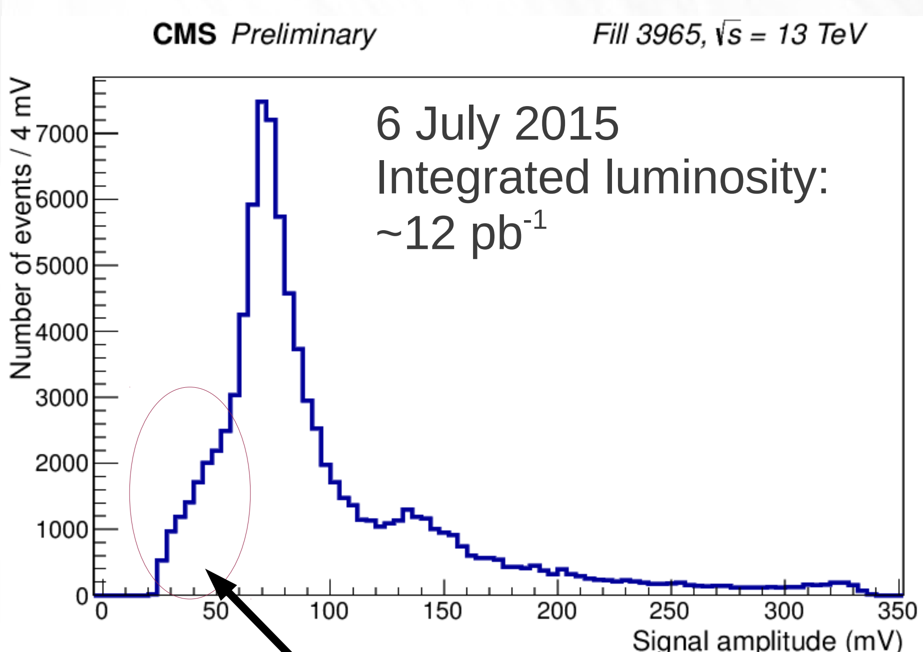
MIP amplitude spectrum

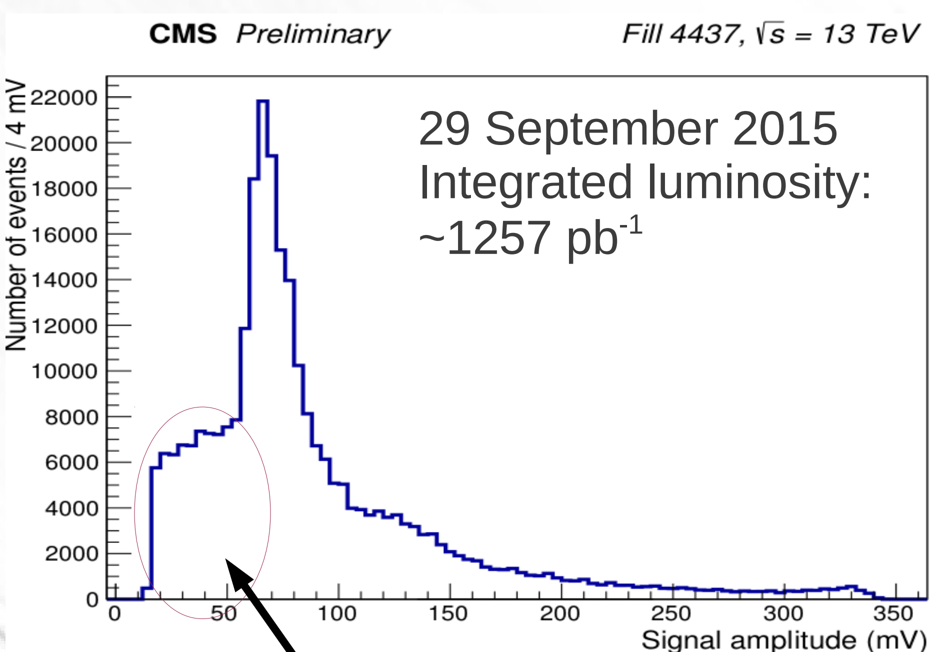
- Radiation damage of the sensor cause:

  (*) slight decrease of MIP peak position;

  (**) increased number of signals with lower amplitude (confirmed in Test beam data analysis).



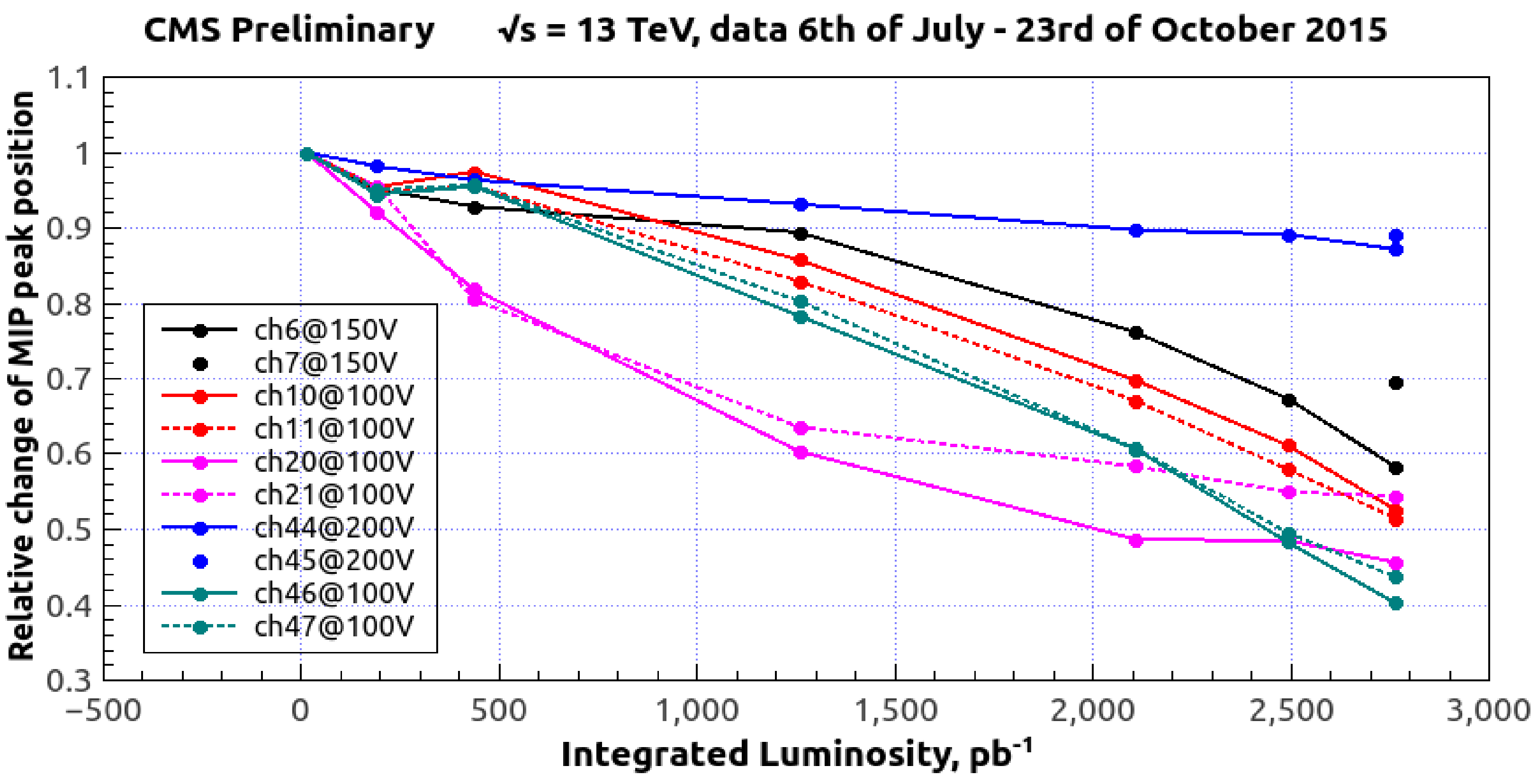




For the better understanding of the spectrum, Test beam data analysis required.

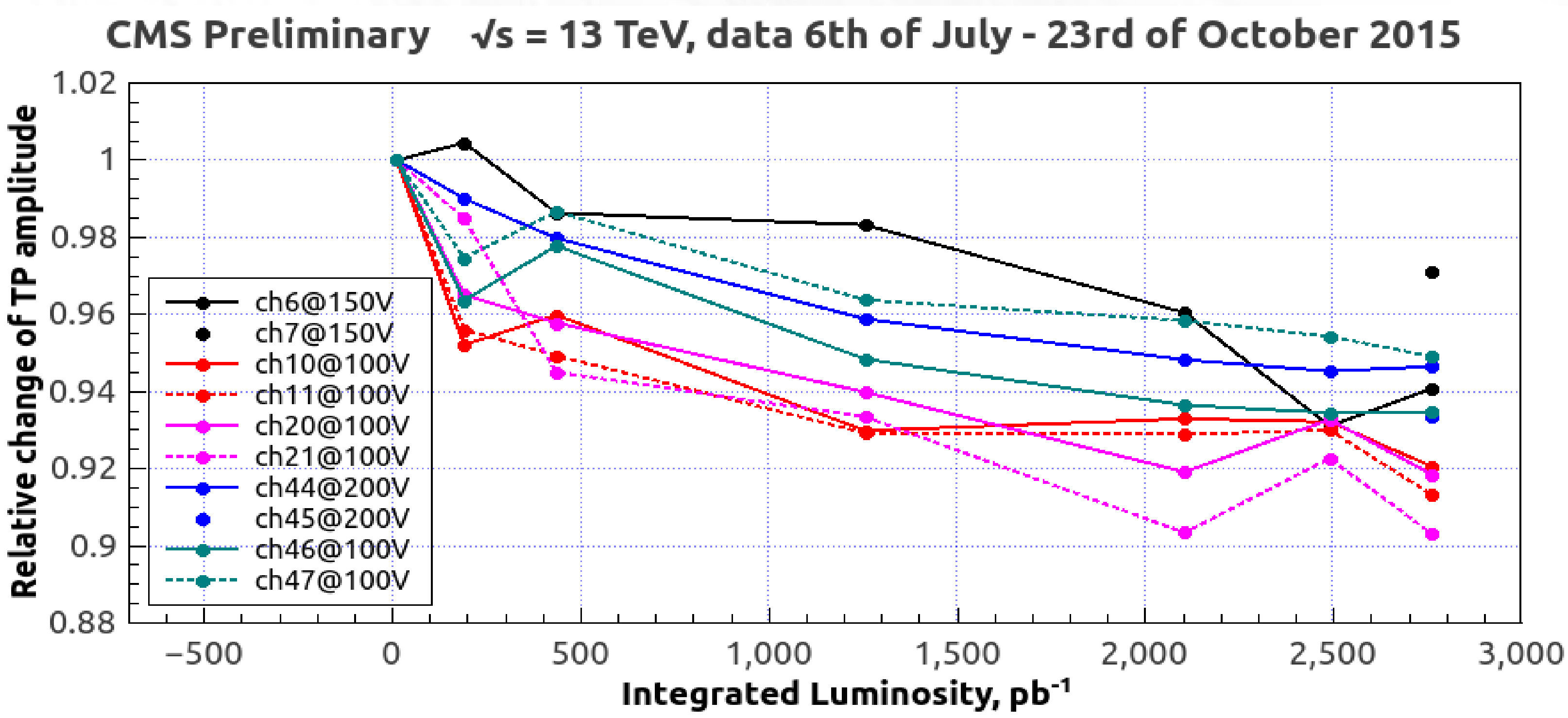
Decrease of MIP peak position (*)

- The signal amplitude spectrum of detected particles is built using a peak finding algorithm. Landau fit is used to define most probable value (MPV) of the spectrum.
- **Relative drop of MIP peak position from the beginning of operation in Run II is up to 60 % in investigated channels.** (ch44-45 are reference channels with ~10% relative drop).
- Observed drop: sensors damage + electronics damage (defined from TP).



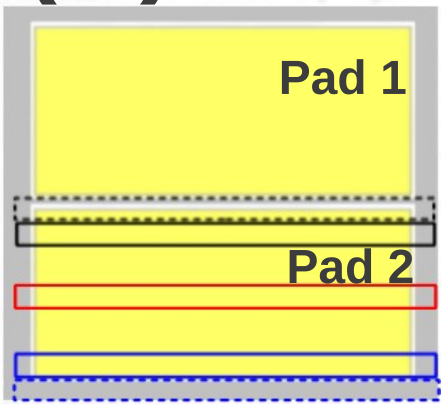
Electronics chain stability monitoring (*)

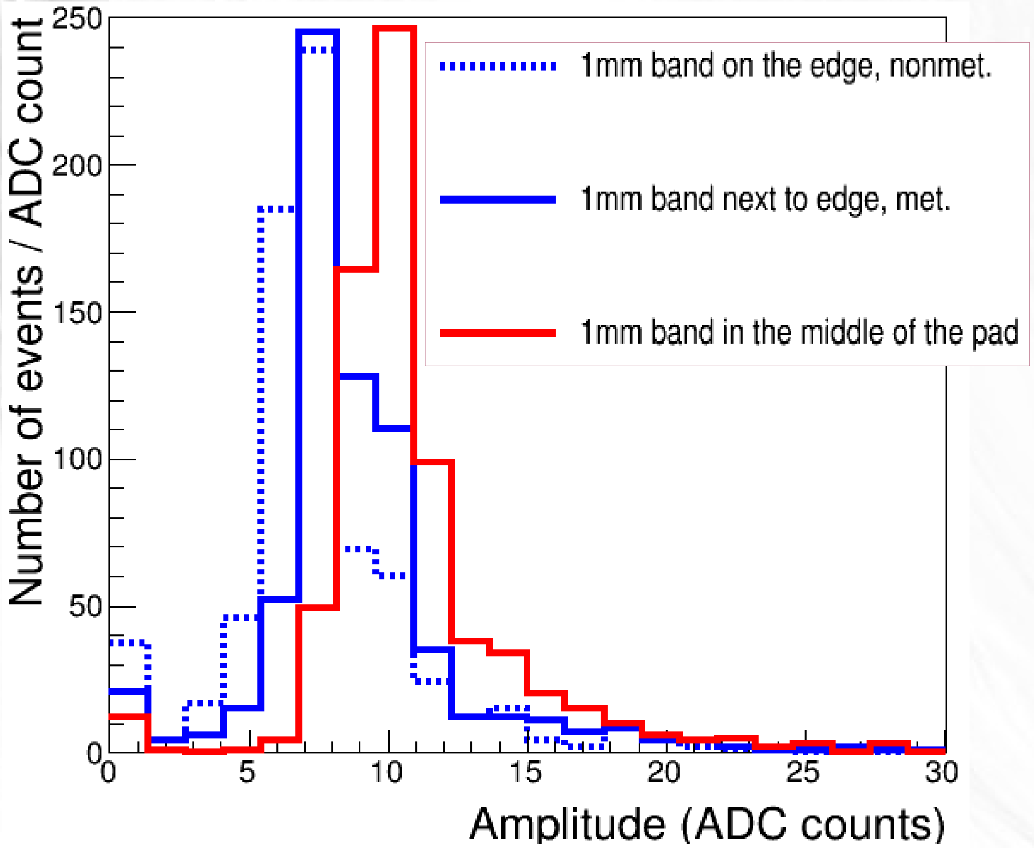
- Test pulse of known amplitude is generated in the ASIC in the abort gap of the LHC. It is used for monitoring of performance of the electronics chain.
- The signal amplitude spectrum for TP is built using a peak finding algorithm, the same as for the MIP spectrum. Gaussian fit is used to define mean value of the spectrum.
- **Relative drop of TP amplitude from the beginning of operation in Run II is <10% for investigated channels.**
- **The typical loss of signal due to the sensor is up to 50% and due to the electronics is up to 10%.**

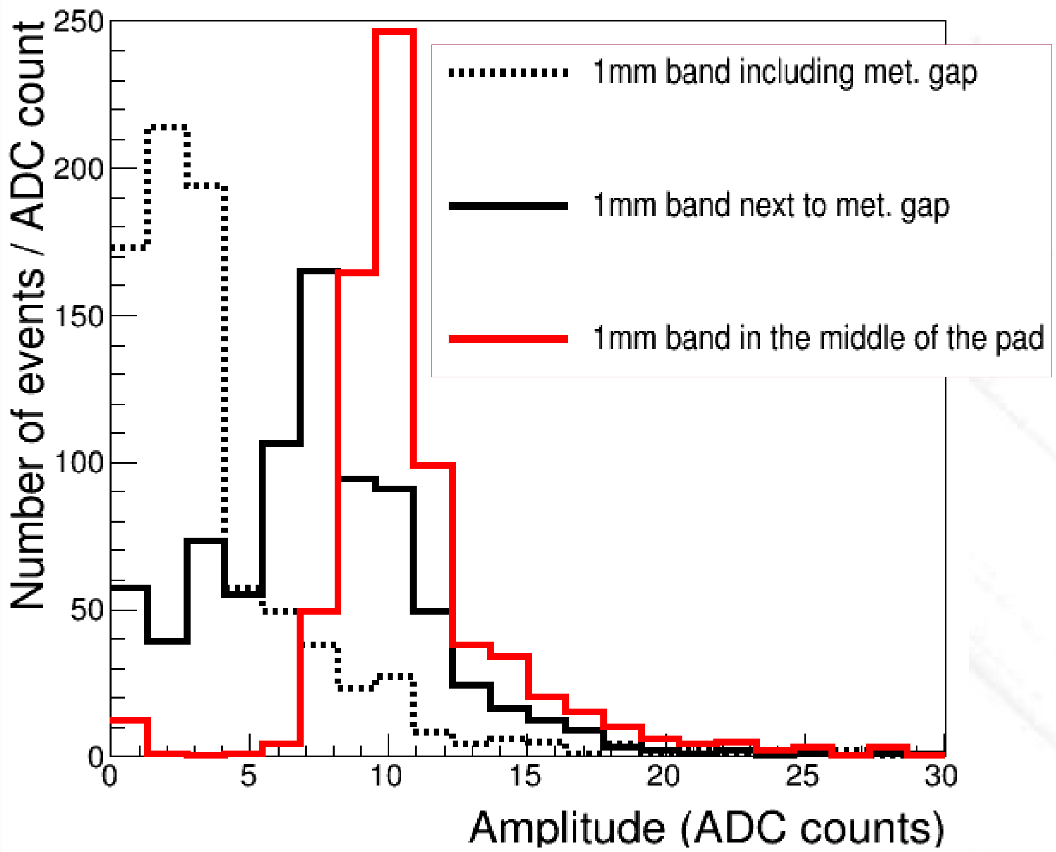


Test Beam data analysis (**)

- Hits from narrow 1 mm bands on the edge of the diamond sensor and containing the metallization gap were selected using EUDET Telescope track pointing information.
- The amplitude spectrums from non metallized area has peak at smaller values. This effect is even more pronounced in the metallization gap.

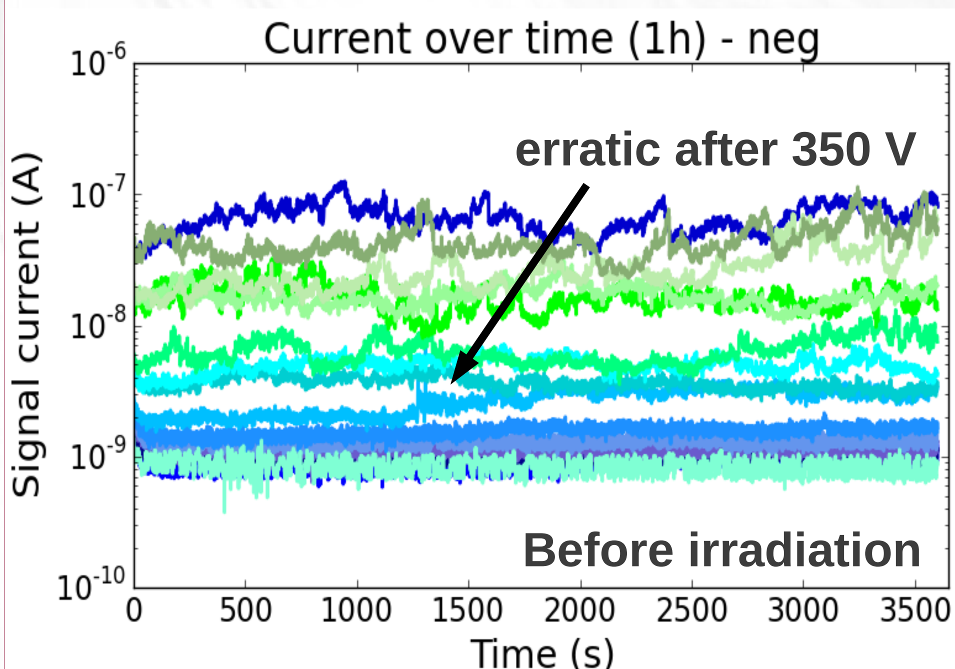


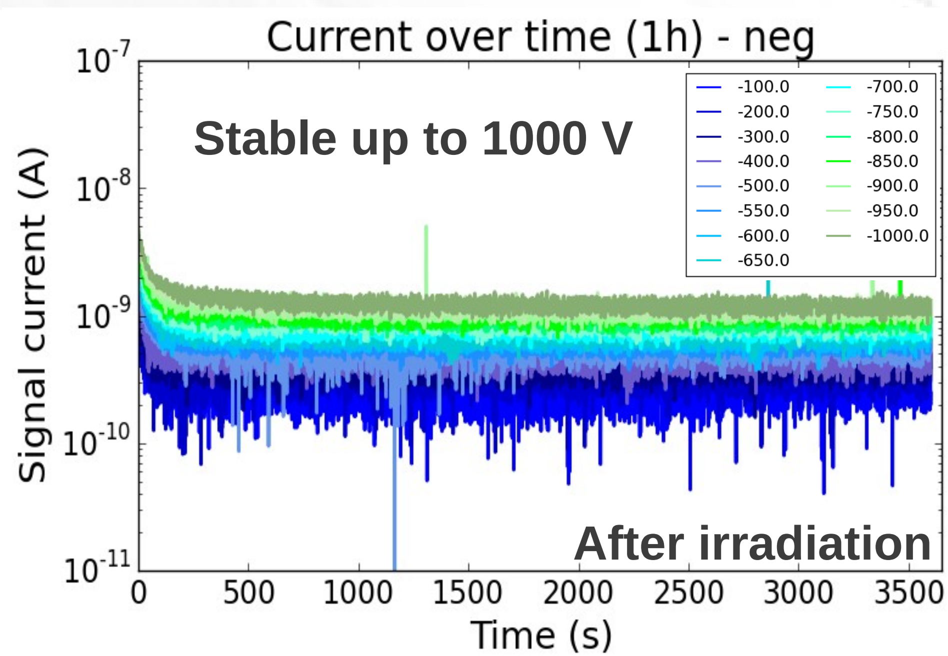




HV instability

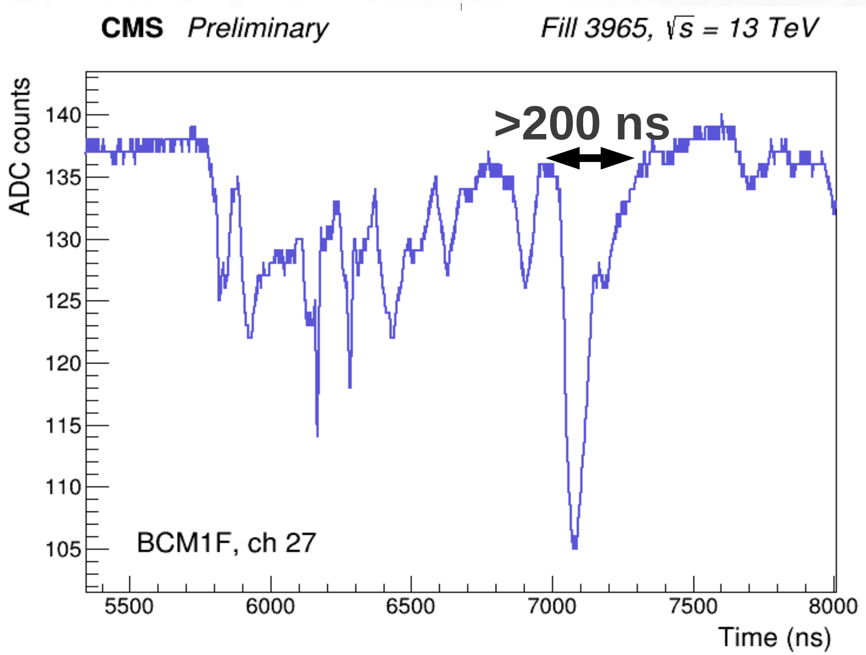
- To compensate for radiation damage, HV should be increased.
- For some of the BCM1F channels **HV trips happen**: it was not a case at the beginning of operation. These channels were stable at the same HV. Trip threshold 3 uA.
- Also magnetic field influence HV, which sensors can hold. With **Magnetic field off** HV should be lowered for 50-100V.
- Studies of sCVD diamonds behavior after irradiation at KIT show increase of the stability with irradiation for the majority of sensors.

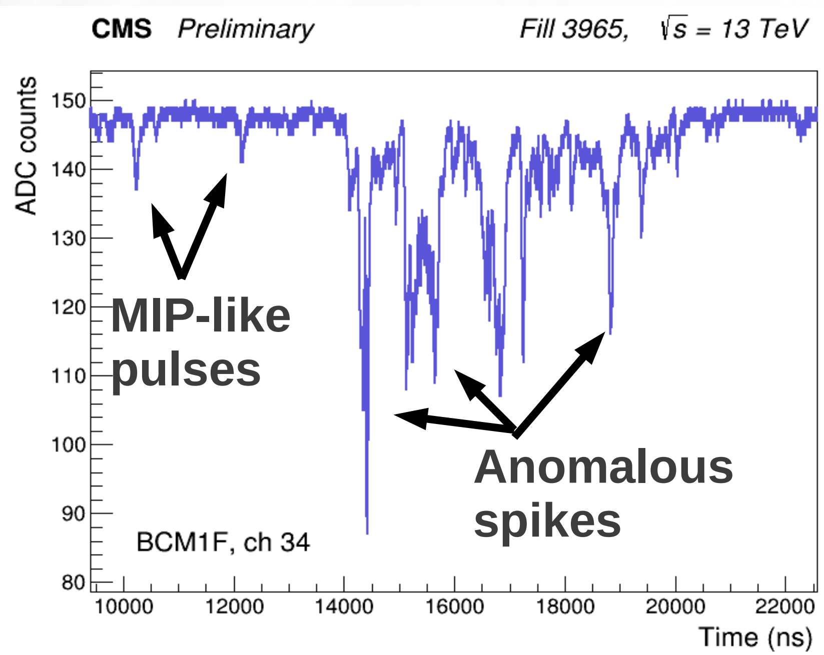




Plots: F. Kassel, Irradiation campaign 2015 at KIT.

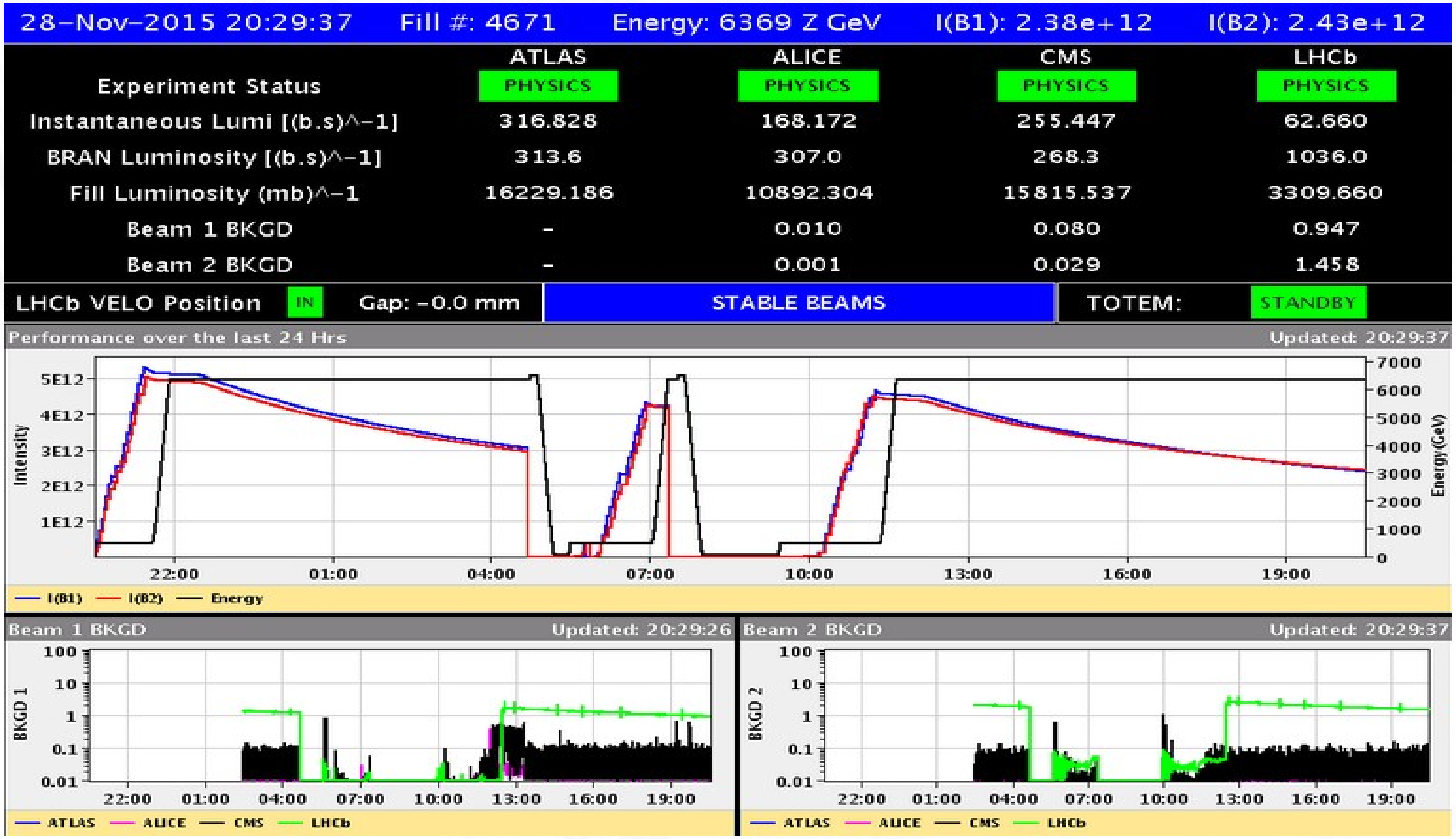
Long pulses and anomalous spikes





- Data corresponds to the low luminosity beam in the LHC, no saturation of the electronics or particle hits one after another are expected.
- Full width at half maximum (FWHM) of the pulse generated by Minimum ionising particle (MIP) is expected to be ~10ns.
- Currently orbits, containing such long events are excluded from analysis. Fraction of excluded orbits in Fill 3965 is <1%.

Part 2: ONLINE Luminosity and Background measurements



28-Nov-2015 20:29:37 Fill #: 4671 Energy: 6369 Z GeV I(B1): 2.38e+12 I(B2): 2.43e+12

	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	PHYSICS	PHYSICS	PHYSICS
Instantaneous Lumi [(b.s)^-1]	316.828	168.172	255.447	62.660
BRAN Luminosity [(b.s)^-1]	313.6	307.0	268.3	1036.0
Fill Luminosity (mb)^-1	16229.186	10892.304	15815.537	3309.660
Beam 1 BKGD	-	0.010	0.080	0.947
Beam 2 BKGD	-	0.001	0.029	1.458

LHCb VELO Position IN Gap: -0.0 mm STABLE BEAMS TOTEM: STANDBY

Some measurements of Machine Induced background in M.Hempel talk.

BCM1F as Luminometer

- **Luminosity (*L*)** is a key quantity of the collider, which allows to determine absolute cross section (the cross section,σ) from the observed rate in the detector (the rate,R):

$$R = \sigma L$$

- Fast diamond sensor response allowed to use BCM1F as a luminometer even with 25 ns bunch spacing in the LHC Run II.
- Rates are measured with fast backend electronics - Realtime Histogramming Unit (RHU) developed in DESY Zeuthen:

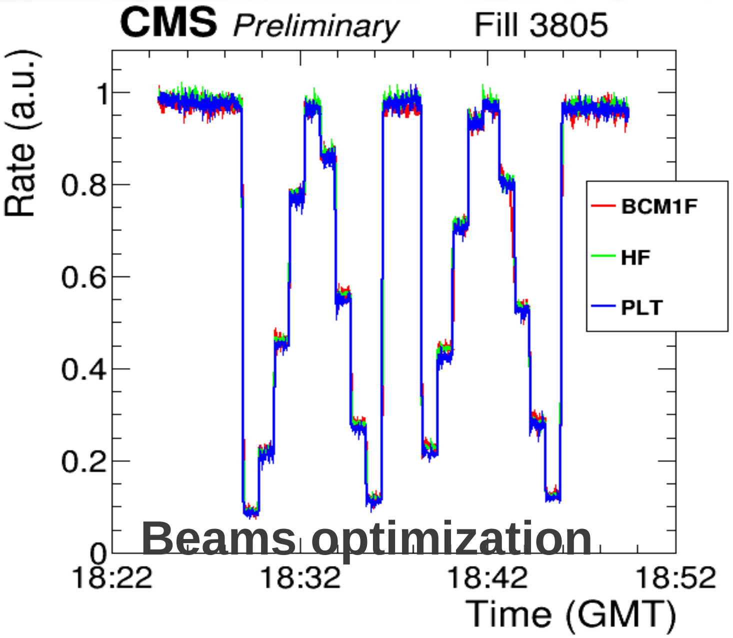
  - 6.25 binning → 25 ns are saved in 4 bins

- From first days of operation CMS Luminometers are in a good agreement:

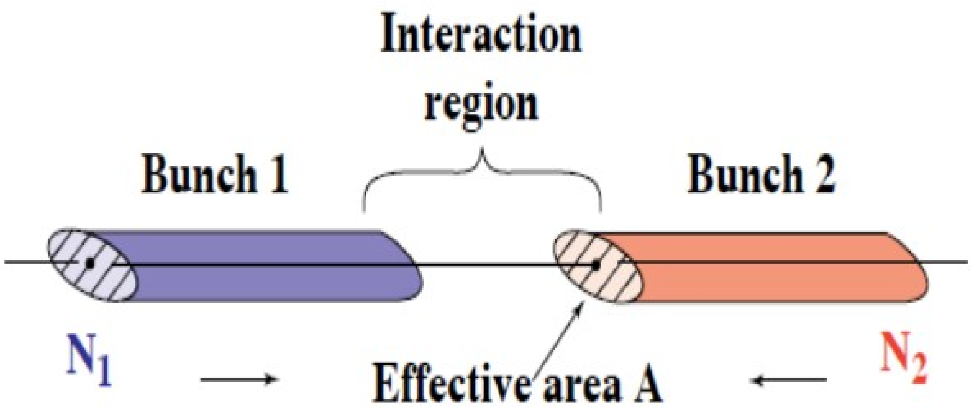
  - Fast Beam Conditions Monitor (BCM1F)

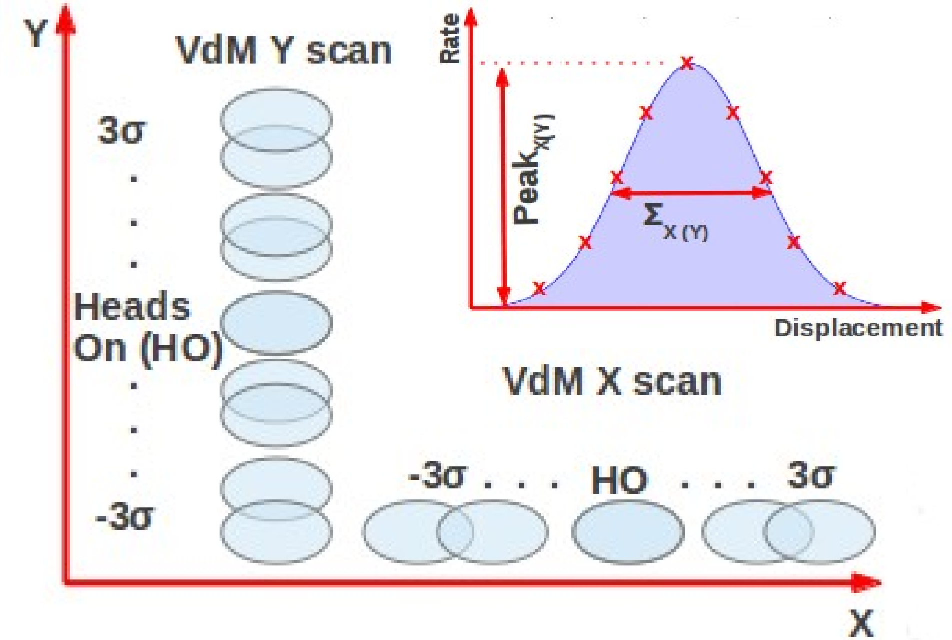
  - Forward calorimeter (HF)

  - Pixel Luminosity Telescope (PLT)



Calibration of BCM1F as luminometer



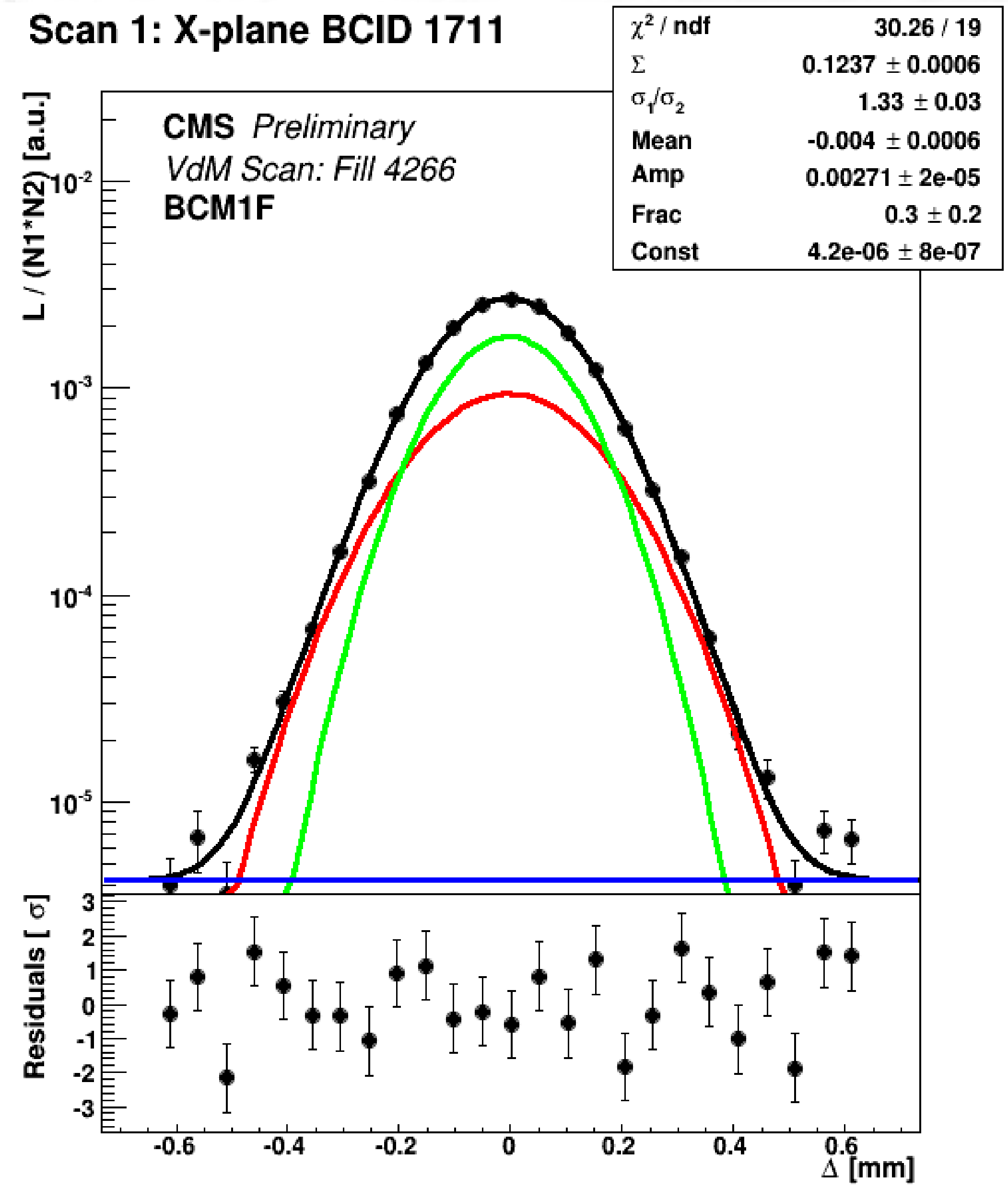


$$L = N_1 N_2 f \, n_b / A_{eff} \, ,$$

where $\boldsymbol{N_1}$, $\boldsymbol{N_2}$ - number of protons in beams 1 and 2, ***f*** - LHC orbit frequency, $\boldsymbol{n_b}$ - number of colliding bunches, $\boldsymbol{A_{eff}}$ - effective area.

- ***Van der Meer scan method*** proposed by Simon van der Meer: determine $\boldsymbol{A_{eff}}$ by measuring rates as a function of the beams displacement. Scans obtained in X and Y planes separately.
- Assuming Gaussian beams: convolution of two Gaussians is itself Gaussian. From VdM scans determine sigma («CapSigma» Σ_X and Σ_Y) and amplitudes ($Peak_X$ and $Peak_Y$).

Visible cross section measurement



- Analysis framework is used to fit beam overlap and calculate visible cross section - the effective cross-section seen by the lumi-nometer:

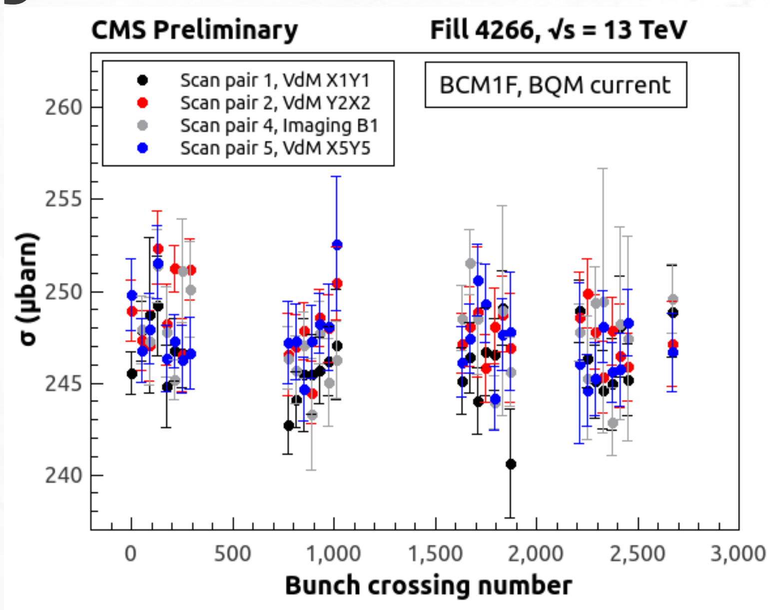
$$A_{eff} = 2\pi \Sigma_1 \Sigma_2,$$

$$\boxed{\sigma_{vis} = \frac{2\pi \Sigma_X \Sigma_Y}{N_1 N_2 f\, n_b} \left(\frac{Peak_X + Peak_Y}{2} \right).}$$

- The distribution is fitted with a Double Gaussian + Constant fit (fit functions are shown in green, red and blue and resulting function in black).
- The errors shown are statistical only.

Summary

- Upgraded Fast Beam Conditions monitor based on 24 diamond sensors is sucessfully installed in the end of 2014.
- From first days of LHC operation in 2015 BCM1F provides online bunch by bunch machine induced background and luminosity measurements.



- **The BCM1F is official CMS luminometer for physics for 50 ns data taking period (June-July 2015).**

- Due to radiation damage MIP peak position lost between 10% and 60% from initial position. Increasing of HV would compensete these losses.
- HV instability and long pulses are issues to solve.

Acknowledgements

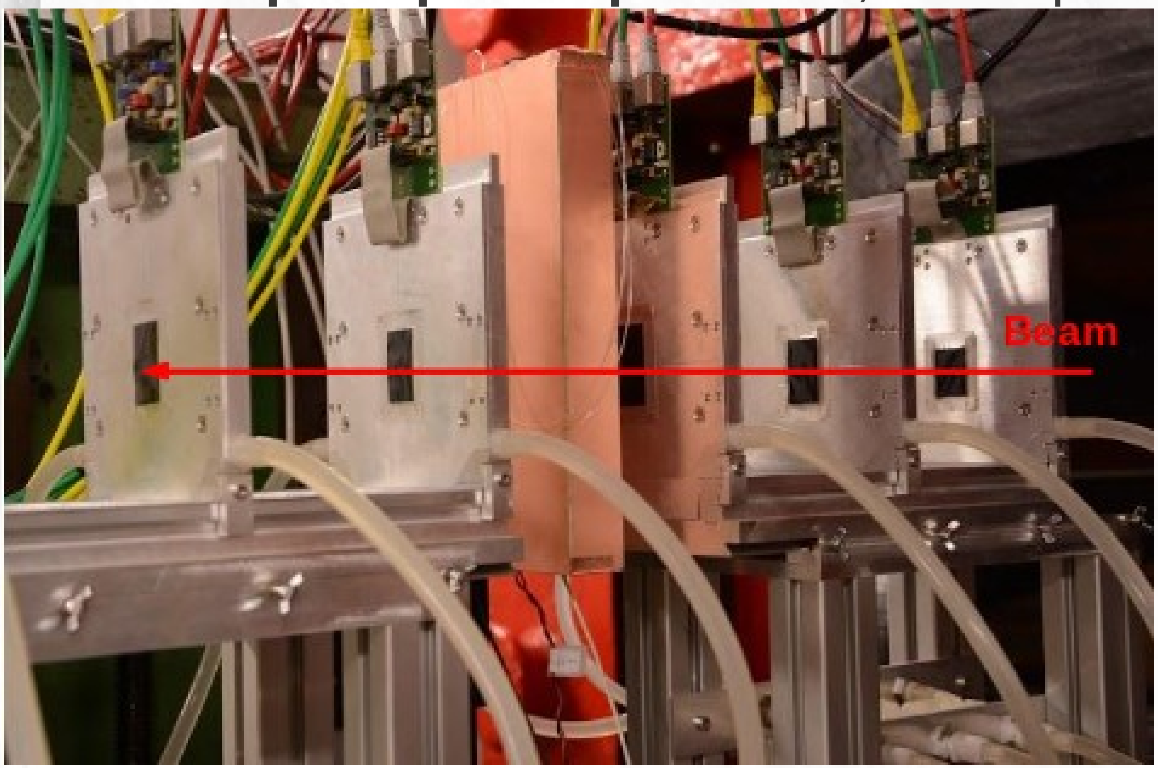
- Great thanks to the German-Israel Foundation (GIF), the Brandenburg University of Technology (BTU) and DESY-Zeuthen for support!
- Also to Prof. Wolfgang Lohmann and whole CMS BRIL group for interesting ideas, enthusiasm and motivation!

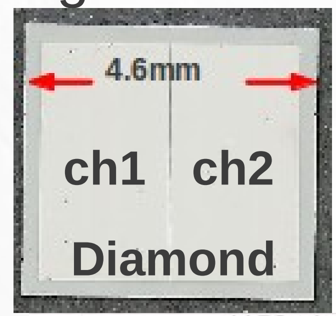
Thank you for attention!

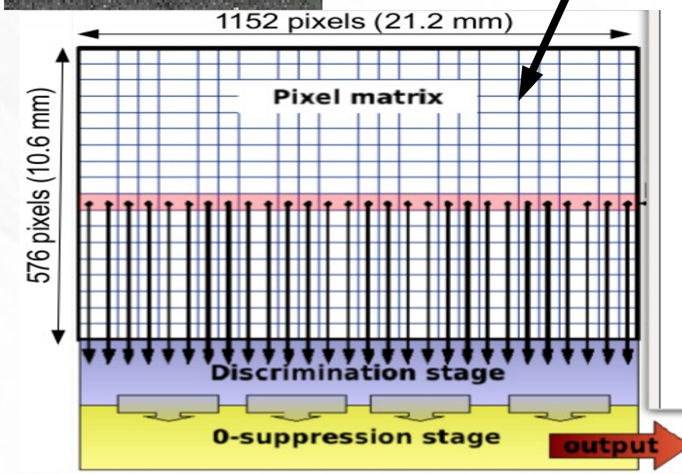
Testbeam and sensors

EUDET Telescope - tracking device designed for detector prototype characterisation at the test beam:

- Active area of the telescope - **6 Mimosa26 pixel sensors**.
- **6 space points per track**, Track pointing resolution <10 μm.







DESY II, TB area 22, 5 GeV electrons, 100 Hz rate.