The CMS Beam Conditions and Radiation Monitoring System (BRM)

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Outline:

1. Description of BRM
2. Beam Scintillation Counters (BSC)
3. Beam Conditions Monitor (BCM)
4. Fast Beam Condition Monitor (BCM1F)
5. BRM feedback to CMS control room and LHC operation
6. Summary

1- Description of BRM

The BRM system of the Compact Muon Solenoid detector in LHC is used to:

- Measure the radiation level close to or inside all sub-detectors.
- Monitor the beam halo conditions with different time resolution.
- Support beam tuning .
- Protect CMS in case of adverse beam conditions by firing a beam abort signal.

It is composed by several subsystems:

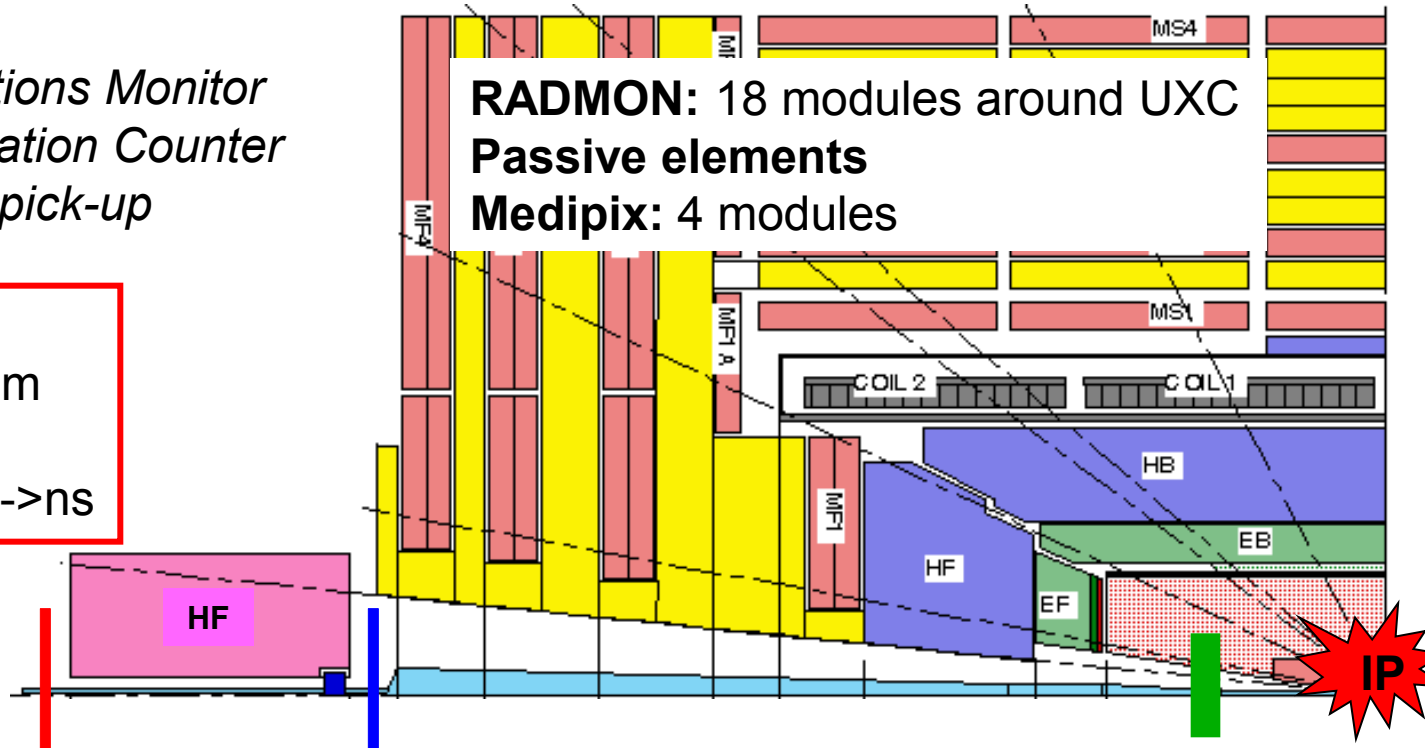
- *BCM: diamond based current monitor (Beam Abort & BKGD3).*
- *BSC: Beam Scintillator Counters (triggers, rates & time info of background and collision products).*
- *BPTX: beam pick-up (triggers).*
- *BCM1F: diamond detector for monitoring beam halo and collision products*

BRM subsystems in CMS

CMS half cross section and location of BRM detectors

BCM: Beam Conditions Monitor
BSC: Beam Scintillation Counter
BPTX : Fast beam pick-up

RADMON: 18 modules around UXC
Passive elements
Medipix: 4 modules



BCM2 & BSC2
Position: z = ±14.4 m
Time resolution:
BCM2->40μs, BSC->ns

BPTX
Position: z = ±175 m
Time resolution: 200ps

BSC1
Position: z = ±10.9 m
Time resolution: ns

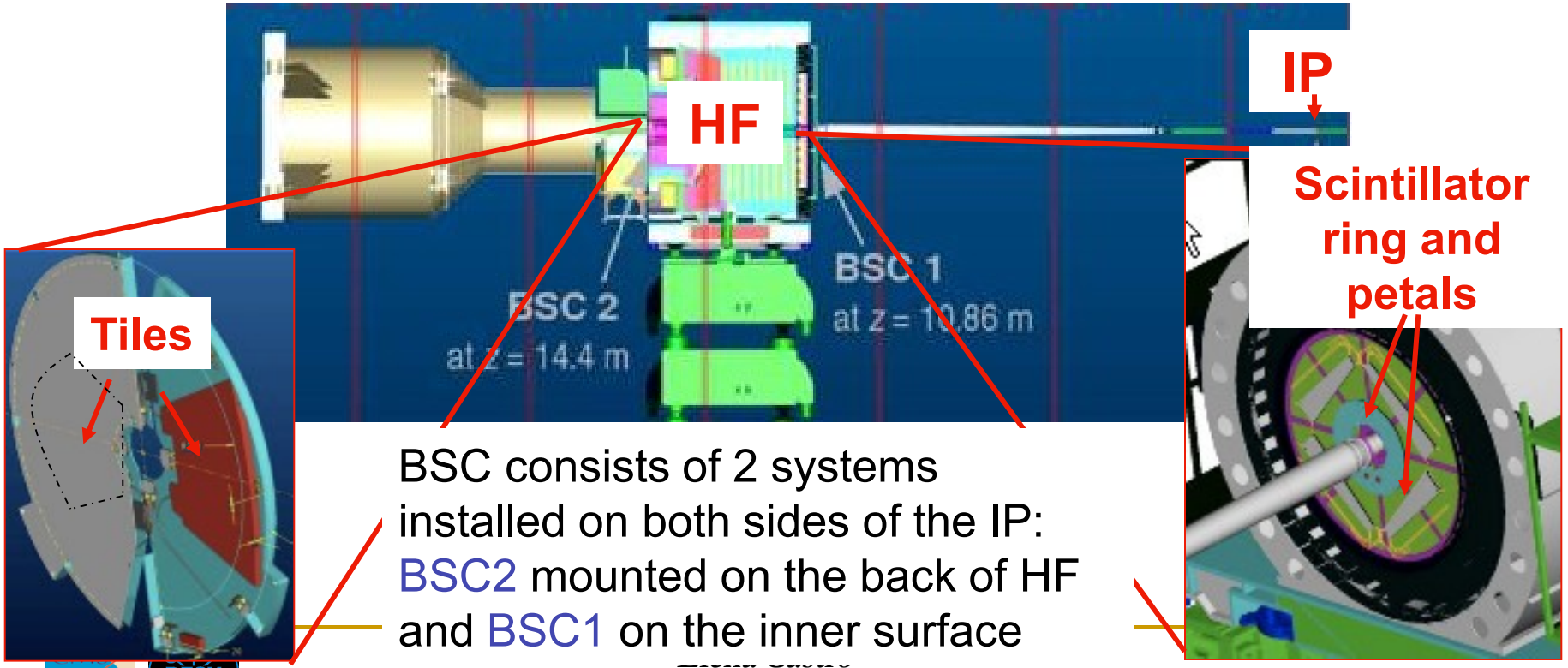
BCM1F, BCM1L and PLT
Position: z = ±1.8 m
Time resolution: BCM1F->ns

2- Beam Scintillation Counters (BSC)

BSC is a particle counter with nanoseconds time resolution.

- **It was used to provide triggers, hit rates and time information of beam halo (BKG2) and collision products before entering into saturation with the increase of luminosity in 2011 (saturation observed at ~50μb-1, cured with reduction of HV).**

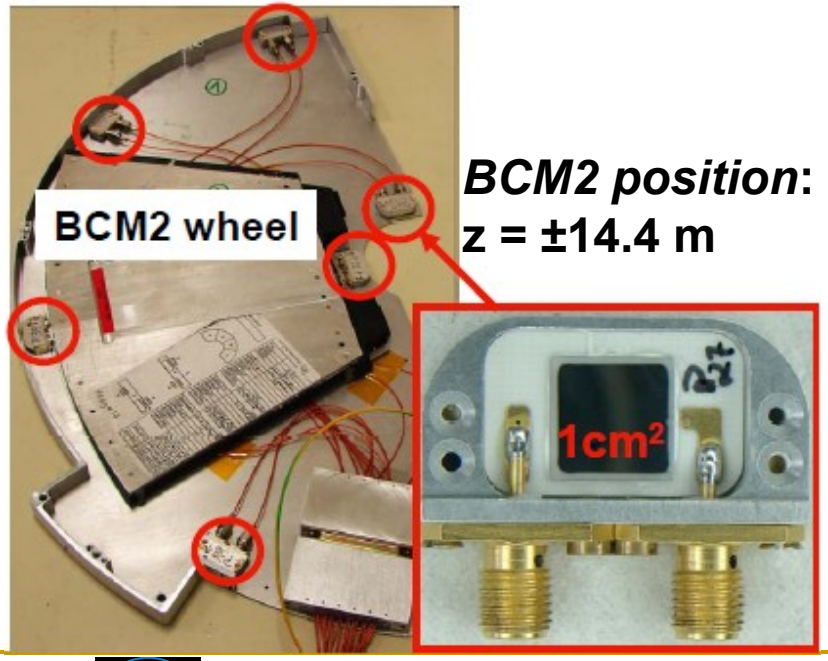
- **Currently it monitors the beam before collisions.**



BSC consists of 2 systems installed on both sides of the IP: BSC2 mounted on the back of HF and BSC1 on the inner surface

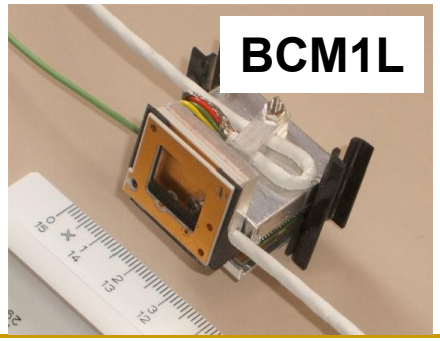
3- Beam Conditions Monitor (BCM)

- BCM measures sensor current in diamonds.
- It is composed by 2 subsystems: BCM2 and BCM1L
- BCM2 can dump the beam in case the *abort thresholds* (set to protect Pixel and Tracker from too high particle fluxes) are reached. So far, no abort signal was asserted.



***BCM2 position*:**
z = ±14.4 m

Detector	**18 pCVD diamonds**
Size	**10×10×0.4 mm³**
Metallization	**9×9 mmTungsten Titanium**
Bias voltage	**200V**



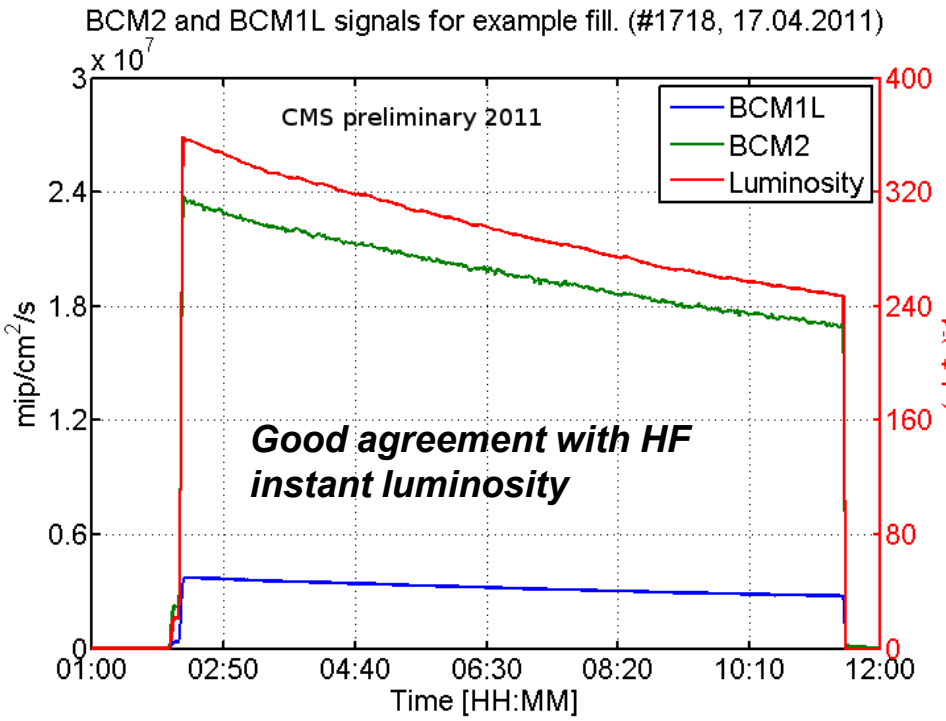
***BCM1L position*:**
z = ±1.8 m

BCM measurements with beam

BCM has been integrated in the LHC beam abort since the first running of LHC.

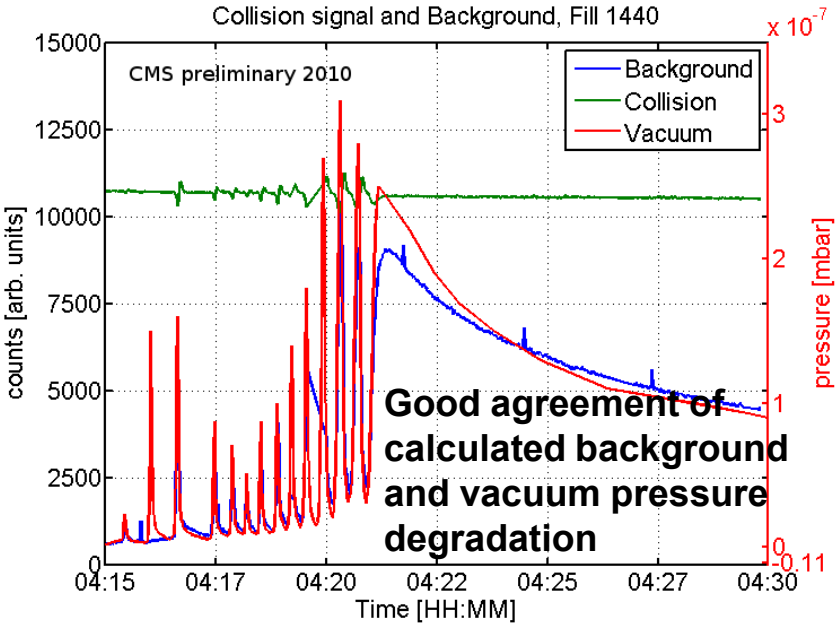
It delivers information about the beam condition to CMS and LHC and can be used for the monitoring of long and short time scale events

Typical signals during a proton fill



Background discrimination

Calculated background and collision signal for the vacuum event



Plots courtesy of Moritz Guthoff (CERN)

4- BCM1F: Beam Condition Monitor (Fast)

Particle detector with nanosecond time resolution measuring the beam halo particles and collision products

Tasks:

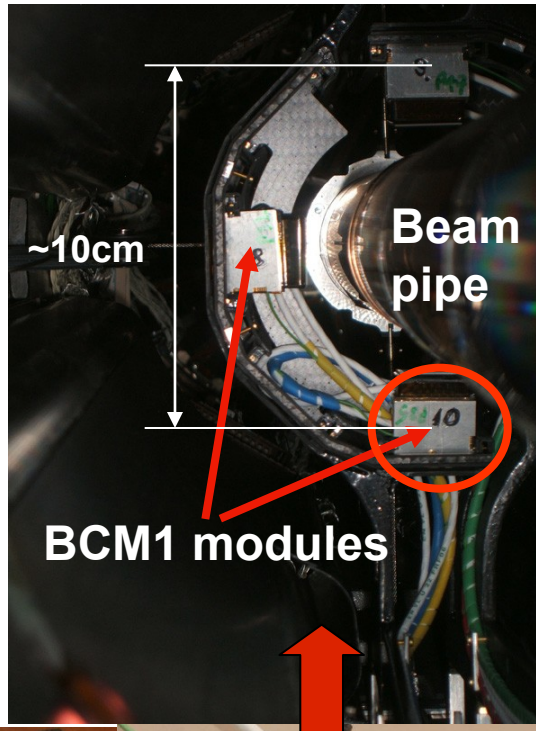
- Monitoring and protection
- BKGD1 (flux in the inner detector region) to LHC

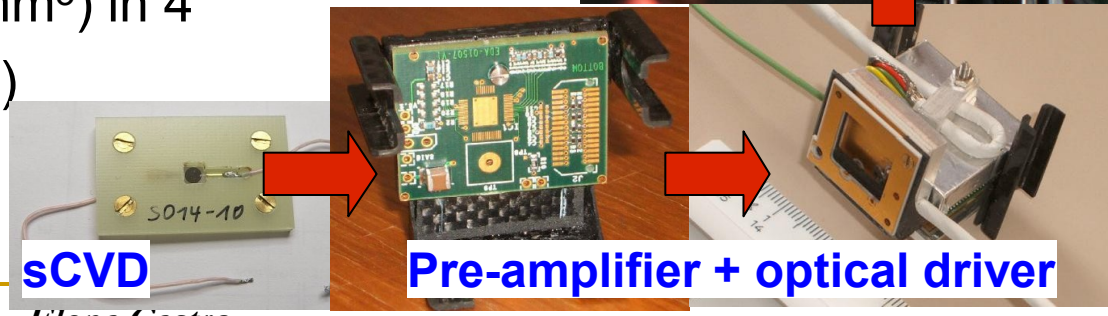
Requirements:

- Detection of MIPs
- Low power and radiation hardness

Design:

4 Single Crystal Chemical Vapor Deposition (*sCVD*) Diamond sensors (5 *x* 5 *x* 0.5 mm^3) in 4 modules at Z= ± 1.8m (~6.25ns) on both sides of the CMS IP, r < 5 cm

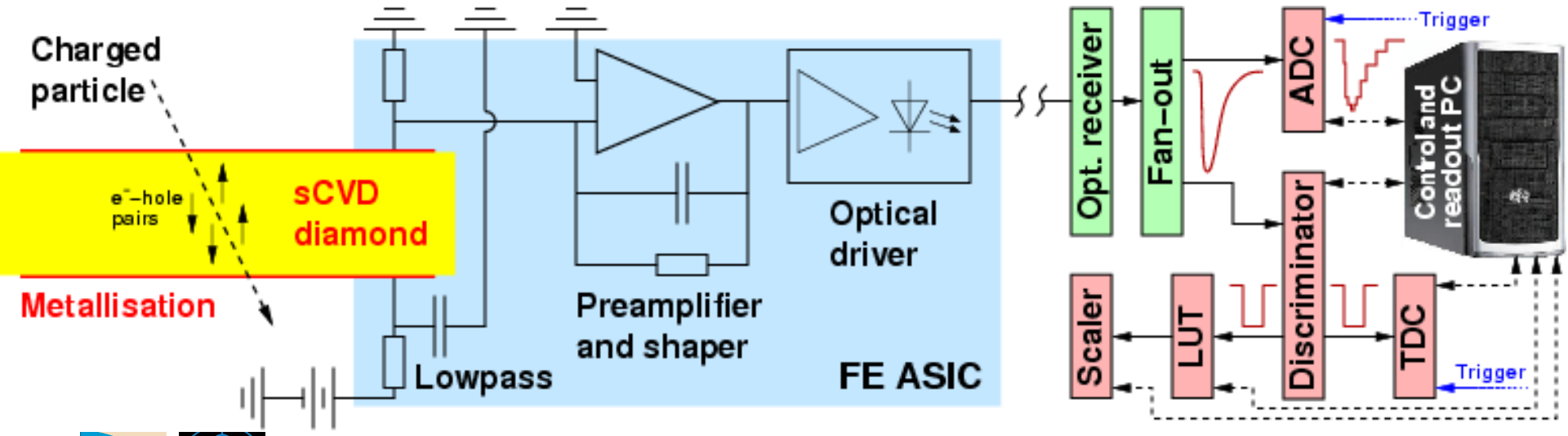




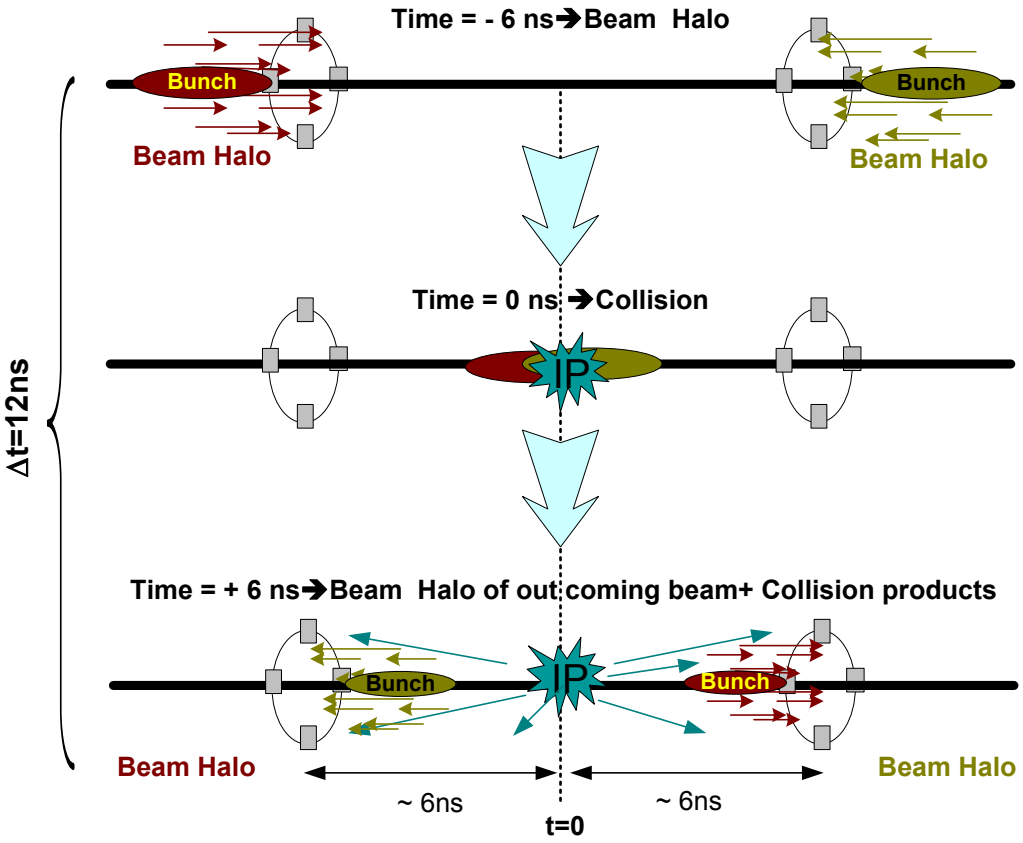
BCM1F components

Front-end:
The sensors are metallized on both sides and operated as solid state ionization chambers. A charge sensitive pre-amplifier collects the induced charges and shapes a proportional signal that is transmitted to the counting room as analog optical signal.

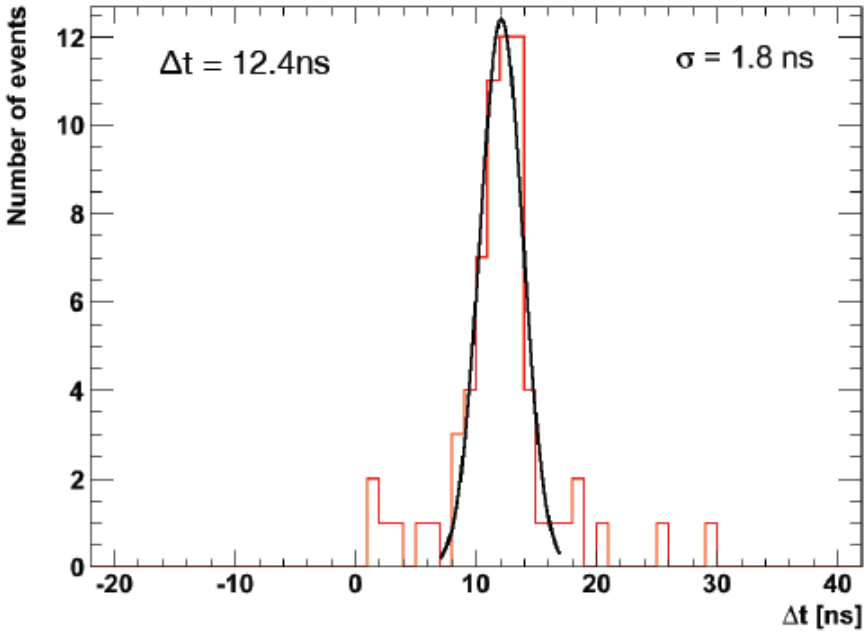
Back-end: the optical signal is converted into electrical signal and is processed and stored independently of the CMS framework.
The main data-acquisition devices are: scalers, ADCs and TDCs



What BCM1F should see...



ToF measured from ADC data of beam halo (2008 first data with beam)



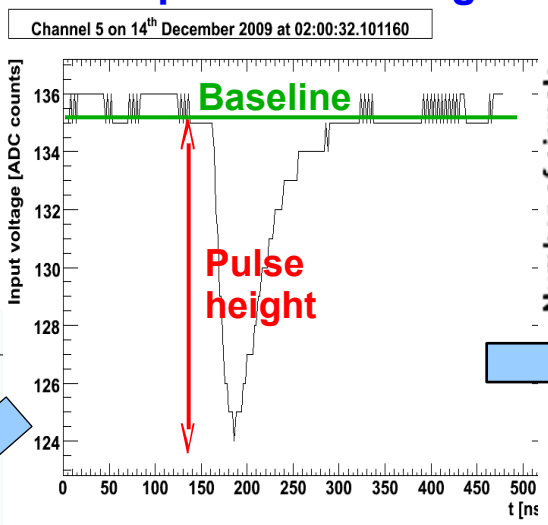
NIM A614,433 (2010)

Signal sampling with the ADC

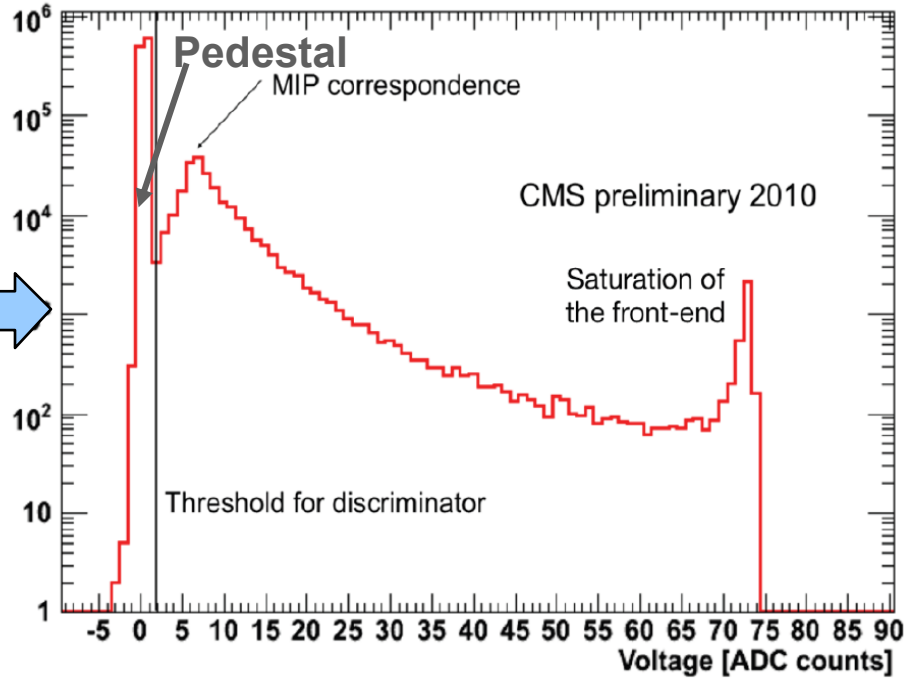
The sensor signals are digitized in a VME CAEN v1721 flash ADC.

Data are used for characterization and maintenance: baseline monitoring, test pulse readout, signal spectra (for SNR estimation or signal-noise separation), performance studies.

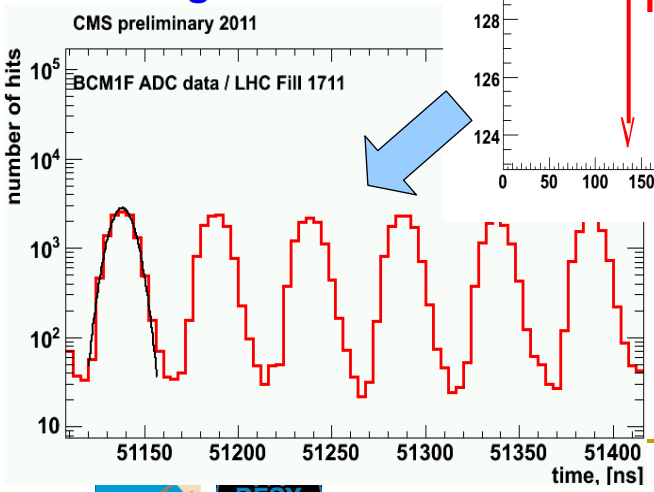
Sampled BCM1F signal



Amplitude spectrum



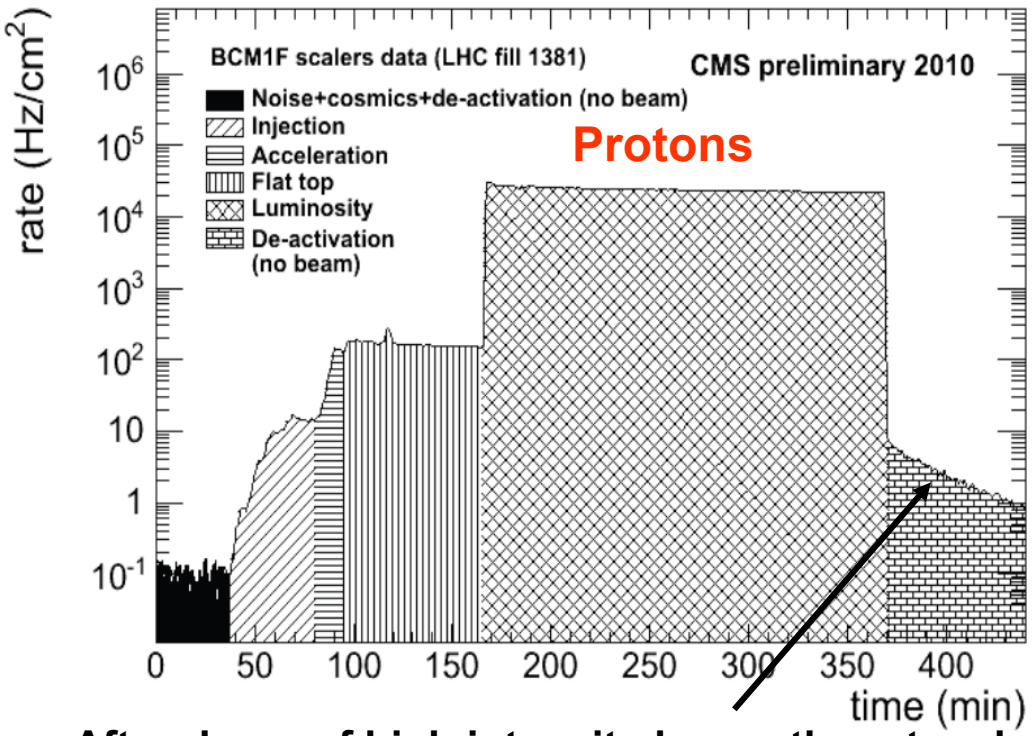
With of arrival time distribution (6ns) obtained from 50ns colliding bunches

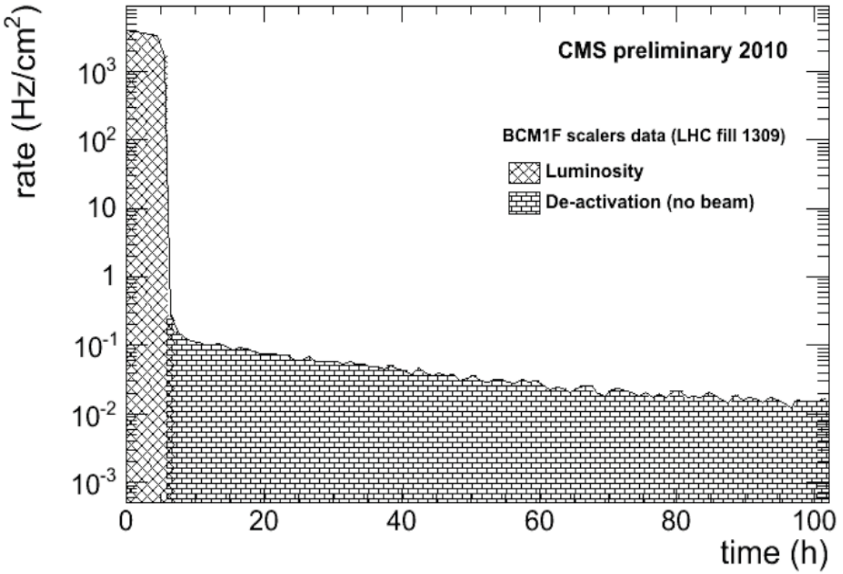


Particle rates

Discriminated sensor signals are counted in a CAEN v560B scaler and forwarded to LHC as BCKD1 (flux in inner detector region).

The rates reflect the different stages of a beam fill





A longer deactivation tail of ~40 h is also present.

After dump of high intensity beam, the rates drop exponentially for ~34 min due to de-activation of material around BCM1F

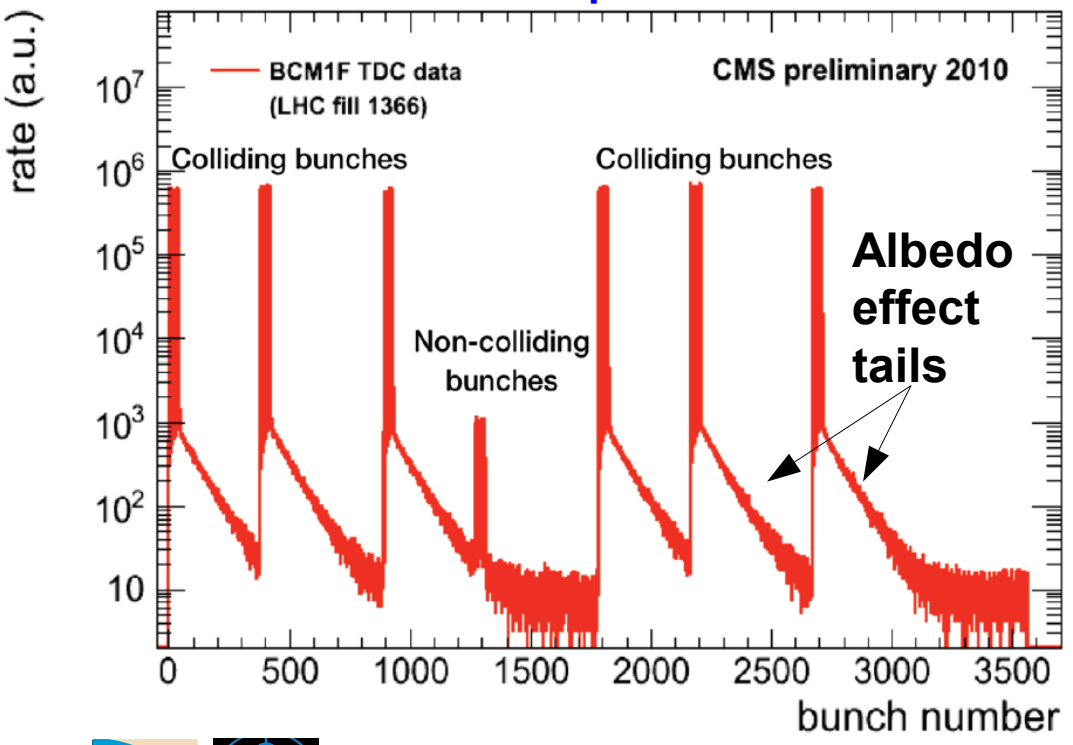
Timing information

Discriminated sensor signals are time digitized by a multi-hit VME TDC CAEN v767 board with 0.8 ns resolution using the LHC orbit as trigger.

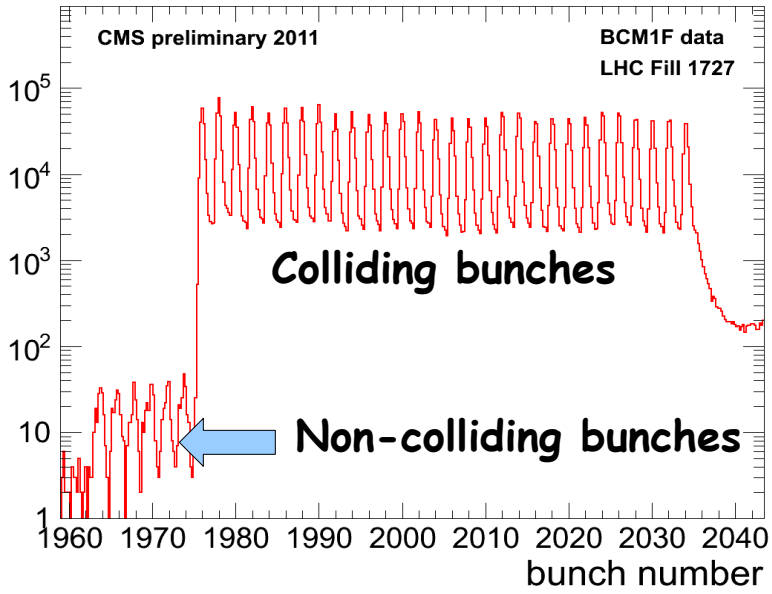
Using the arrival time distribution of the hits, the bunch number identification is done and published to the CMS control room.

$$BN = \frac{t_{TDC} - 6290}{24.95} + 1$$

Bunch ID plot



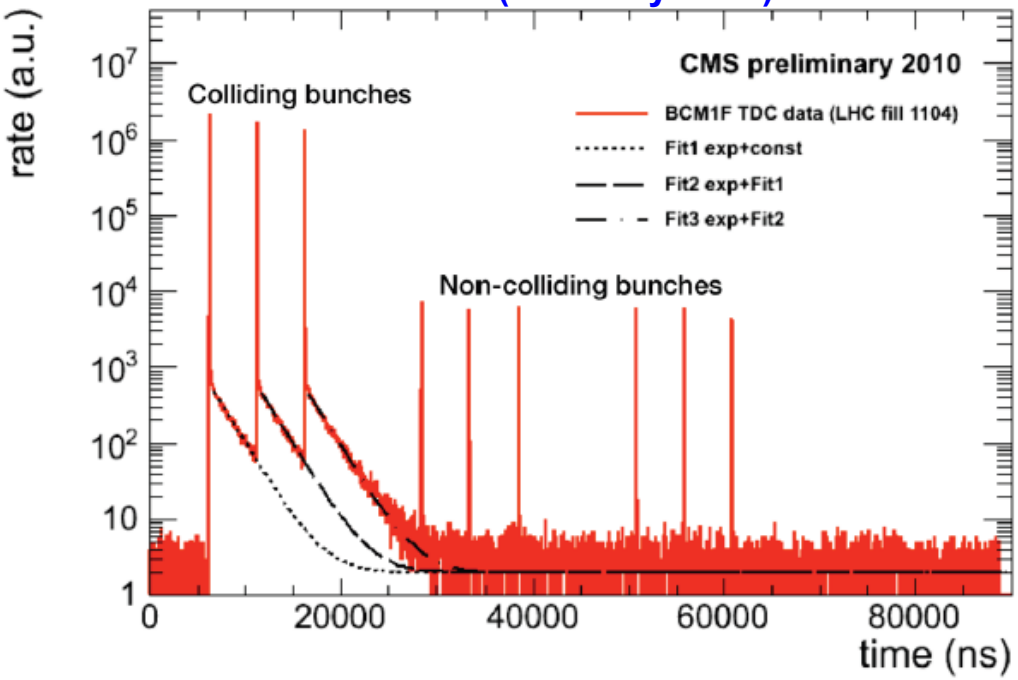
Zoom in 50ns bunches



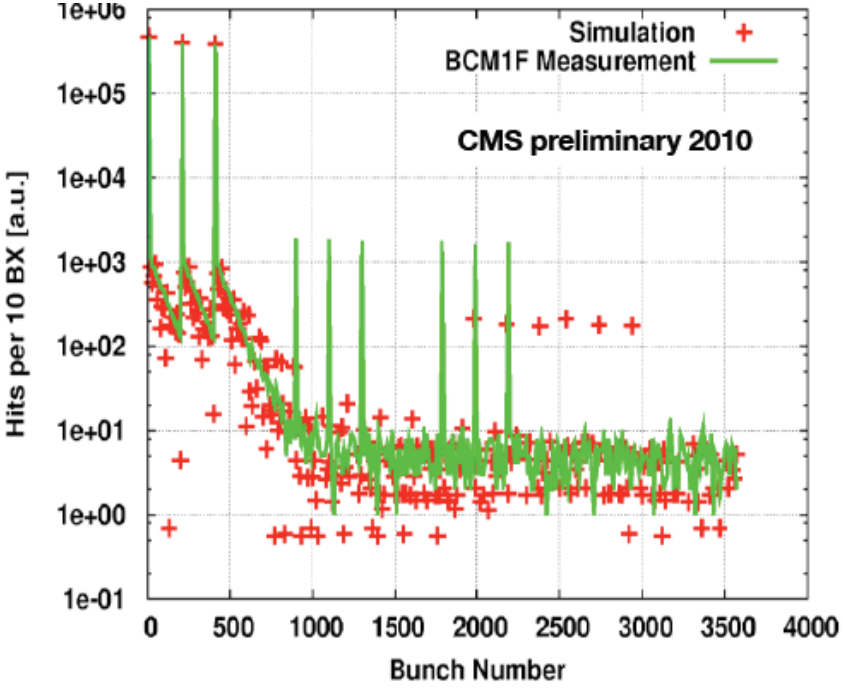
The Albedo effect

- **p-p collisions** produce long tails, of exponential and constant shapes with a 'lifetime' of (2.12 ± 0.02) μs.
- Simulations with FLUKA show good agreement with the data. Tails are mostly populated by electrons and positrons (up to 400 bunch crossing) and by neutrons and photons.

Real data (15th May 2010)



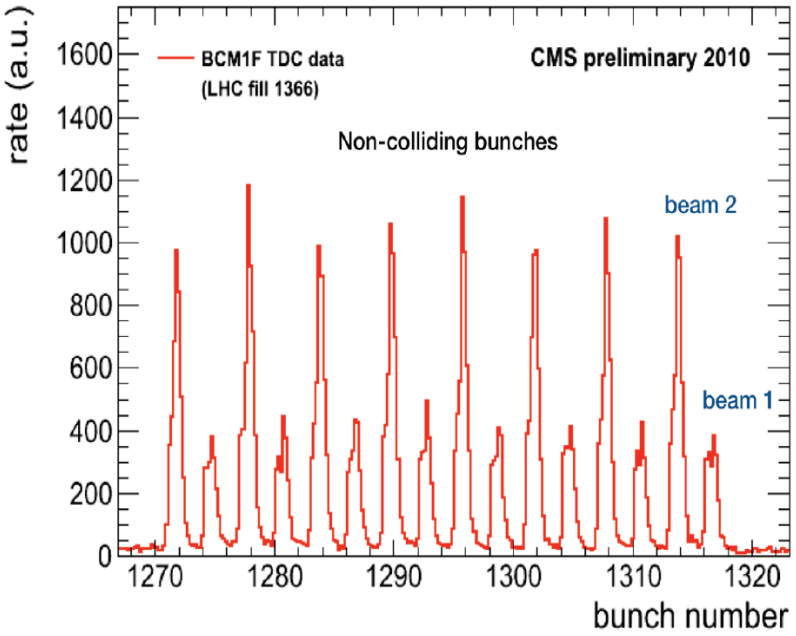
FLUKA simulation of bunch crossings at 7 TeV pp interactions (Steffen Mueller, KIT)

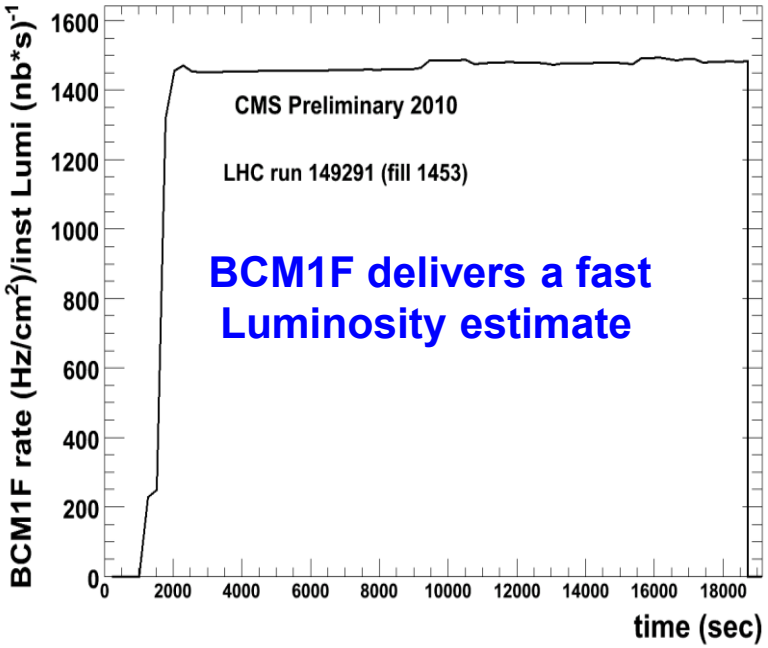


Sensitivity of BCM1F to beam conditions

BCM1F showed to be very sensitive to beam conditions inside CMS such as vacuum quality and also to collimator and "*van der Meer*" scans.

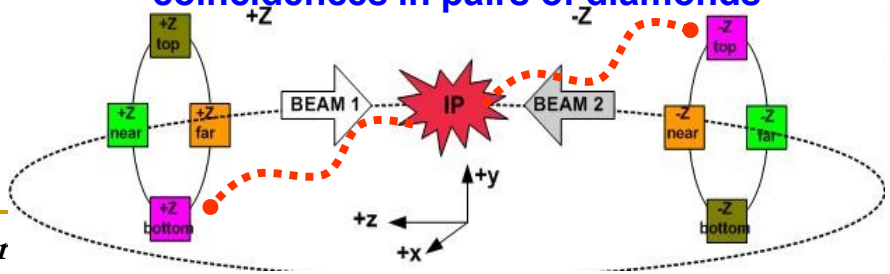
BCM1F reflects vacuum degradation In higher rates (beam-gas) interaction for Beam 2 entering in CMS





BCM1F delivers a fast Luminosity estimate

Possible inst lumi monitor based on back to back coincidences in pairs of diamonds



BMC1F modules for a LHC Beam Loss Monitor

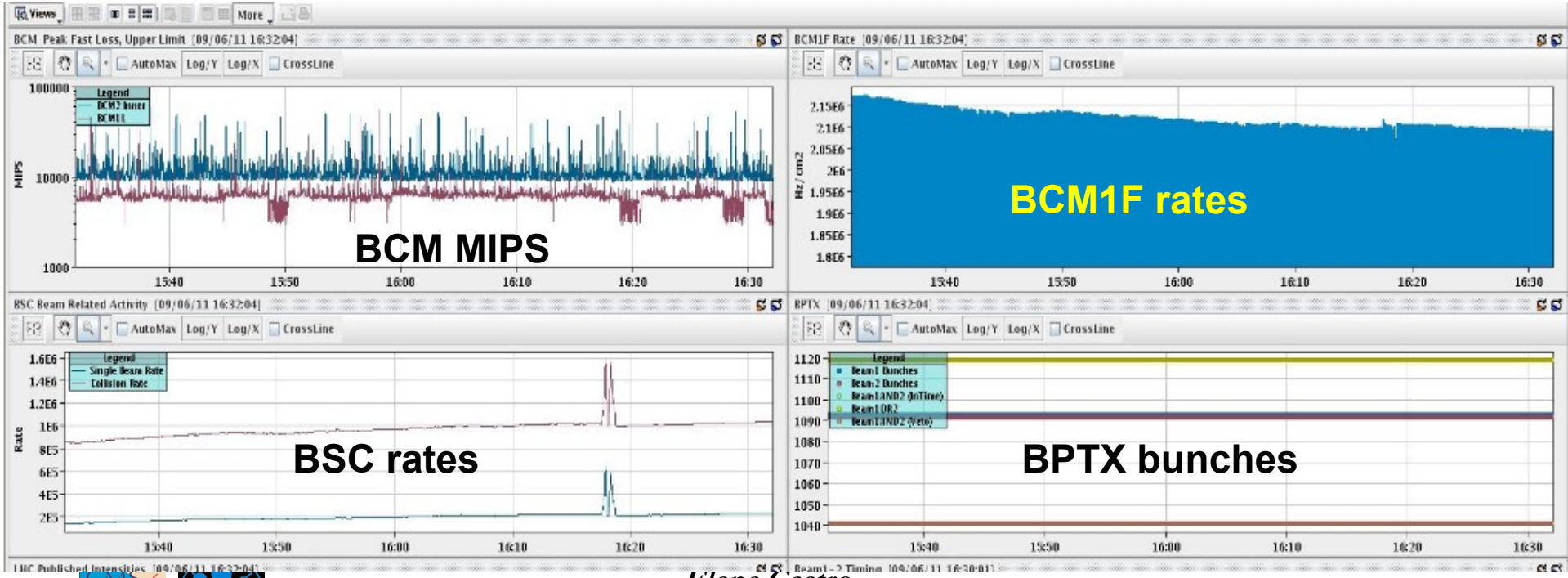
- BCM1F is considered by the LHC Beam Instrumentation group as being useful as a beam loss monitor for LHC at several positions around the orbit

- One module (FEE and diamond) is already installed in Point 2 of LHC (LHCb location) and 7 additional will be delivered along 2011.

5-BRM feedback to CMS control room and LHC operation

Several BRM monitors are available in CMS control room to:

- **Monitor beam conditions**
- **Supply Background values**
- **Cross-check injection bunch scheme**



BRM feedback to LHC

OP Vistars

http://op-webtools.web.cern.ch/op-webtools/Vistar/vistars.php?usr=LHC3

09-Jun-2011 13:51:46 Fill #: 1862 Energy: 3500 GeV I(B1): 1.23e+14 I(B2): 1.23e+14

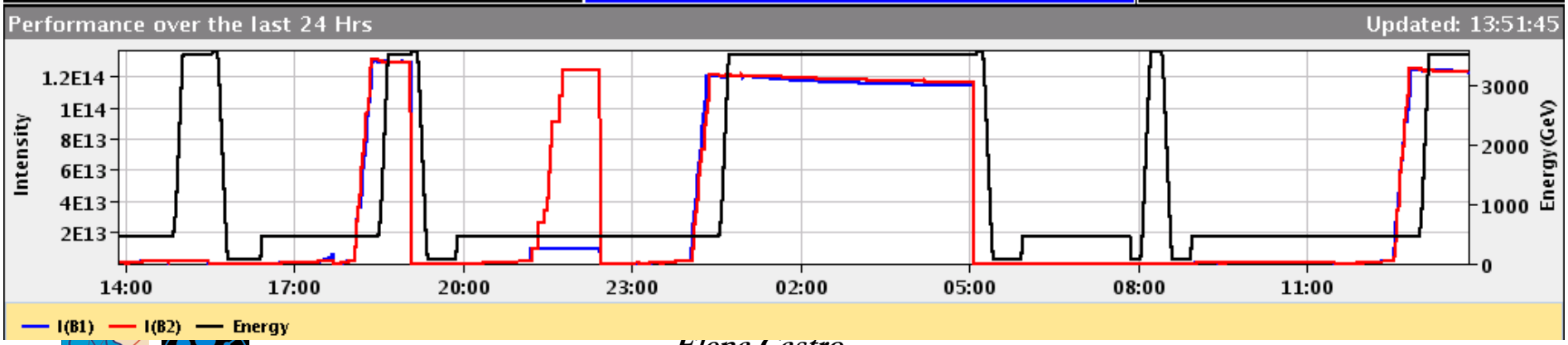
	ATLAS	ALICE	CMS	LHCb
Experiment Status	PHYSICS	PHYSICS	PHYSICS	PHYSICS
Instantaneous Lumi (ub.s)^-1	77.368	0.667	1062.028	266.769
BRAN Luminosity (ub.s)^-1	1135.874	1.023	1165.313	74.515
Fill Luminosity (nb)^-1	0.0	0.4	748.3	91.9
BKGD 1	0.000	0.392	0.001	0.798
BKGD 2	20.643	1.093	0.002	0.436
BKGD 3	8.762	1.976	3.366	0.982

BCM1F

BSC

BCM

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



6- Summary

- The BRM system is a valuable tool in the daily safe operation of the CMS detector.
- It has been working in a reliable mode since LHC start in 2008, with BSC giving the first indication of collisions in CMS.
- BCM can dump the beam in case of dangerous conditions but so far, no beam dump was induced.
- The BCM1F, has been used as a beam conditions monitoring tool since the LHC restart in autumn 2009. It became a key tool in the BRM system by giving valuable beam information and it shows, in the day-by-day operation, that new monitoring capabilities are still to be exploited.

Thank you!