ATLAS BCM/BLM abort logic

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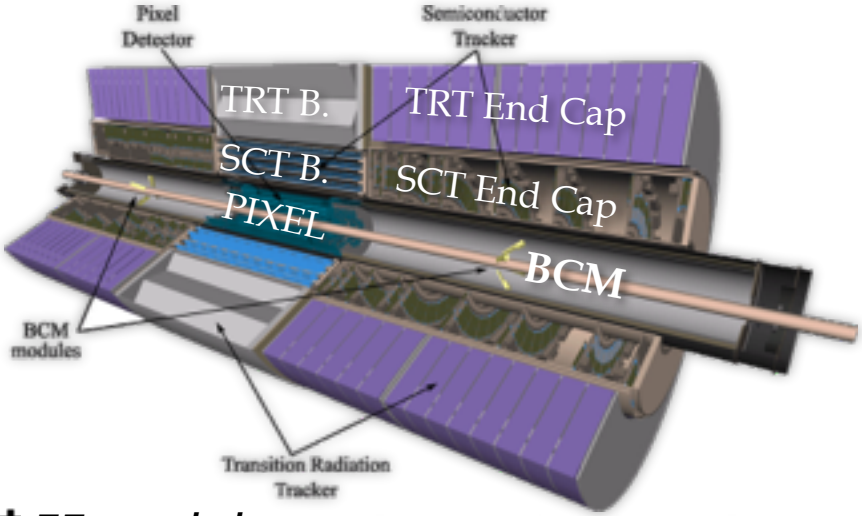
35th BLM Thresholds WG Meeting

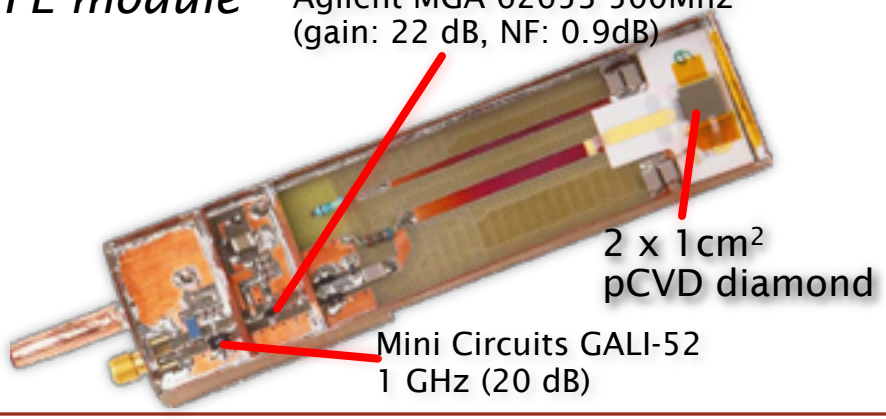
CERN, 10/05/2016

ATLAS BCM – Intro

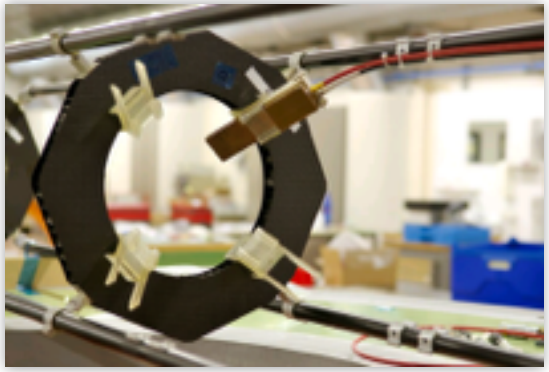
- 4 BCM detectors installed inside PIXEL volume on each side
- z=±1.84 m, r=55 mm, @ 45°



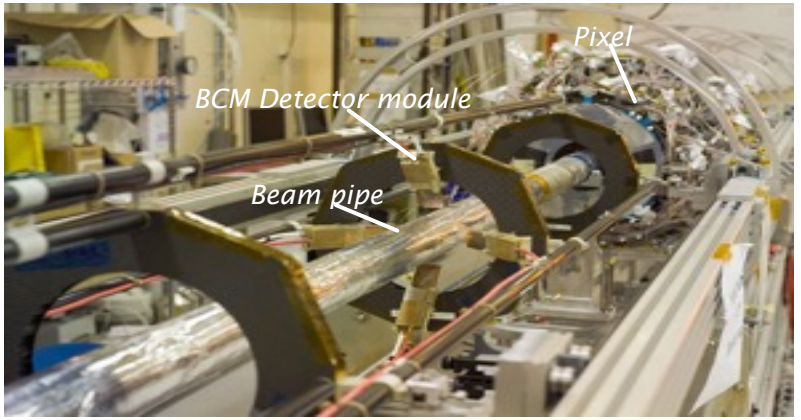
- *FE module*



- Installation on PIXEL structure



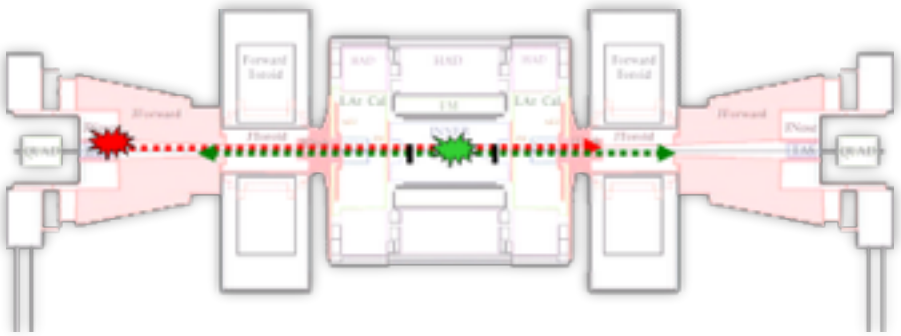
- Together with PIXEL detector



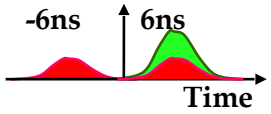
ATLAS BCM – Intro 2

Protection of ATLAS

- In case of anomalous beam behaviour and large losses
- Distinguish between interactions and background (scraping of collimators, beam gas,...)
- Fast signal and baseline restoration (<10ns)



- 2 detector stations, symmetric in z
- TAS (collimator) event: Δt=2z/c=12.5ns
- Interaction: Δt = 0, 25, … ns



In addition

- Collision rate/background rate monitoring (with single MIP sensitivity)
- Bunch-by-bunch Luminosity measurement
  - counting charged particles

$$N_A = N_{BX} N_{pp} (L) r_{tr} P_A \qquad N = N_A + N_C \qquad N_A \approx N_C$$

BC rate

number of pp in single BC (function of luminosity)

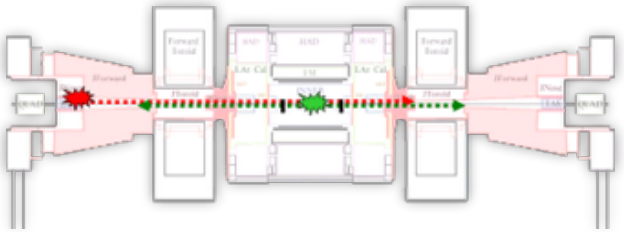
number of tracks per pp

probability of track going to side A

- Triggering:
  - BCM provides 6 different inputs to ATLAS Central Trigger Processor (CTP)
  - In time coincidences, out of time coincidences, high multiplicity,…

ATLAS BCM time (ABT)

- We count time in bins of .39 ns grouped in buckets of 25ns
- Collision happen ~6ns before the collision product reach BCM sensors
- Non-collision events (collimators, UFOs, parasitic collisions, beam-gas,…) reach "out-of-time" side ~1/2BC (12ns) earlier than "in-time" side



2 detector stations
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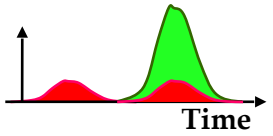
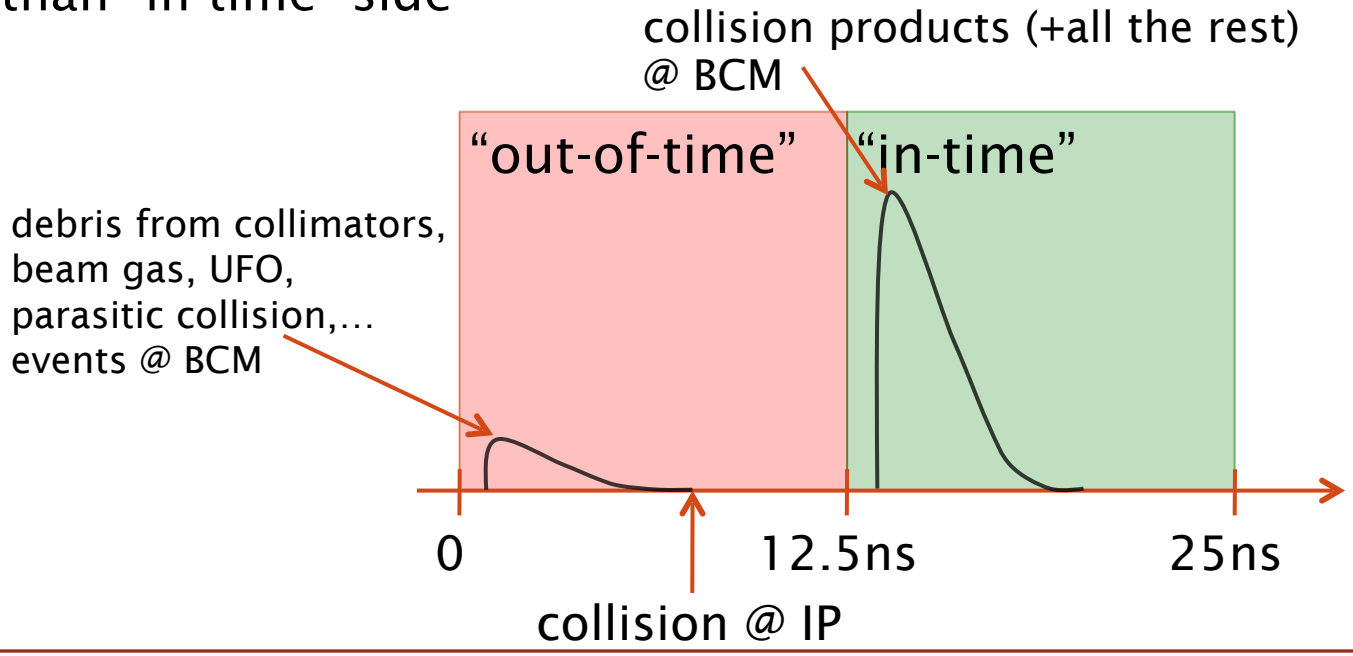
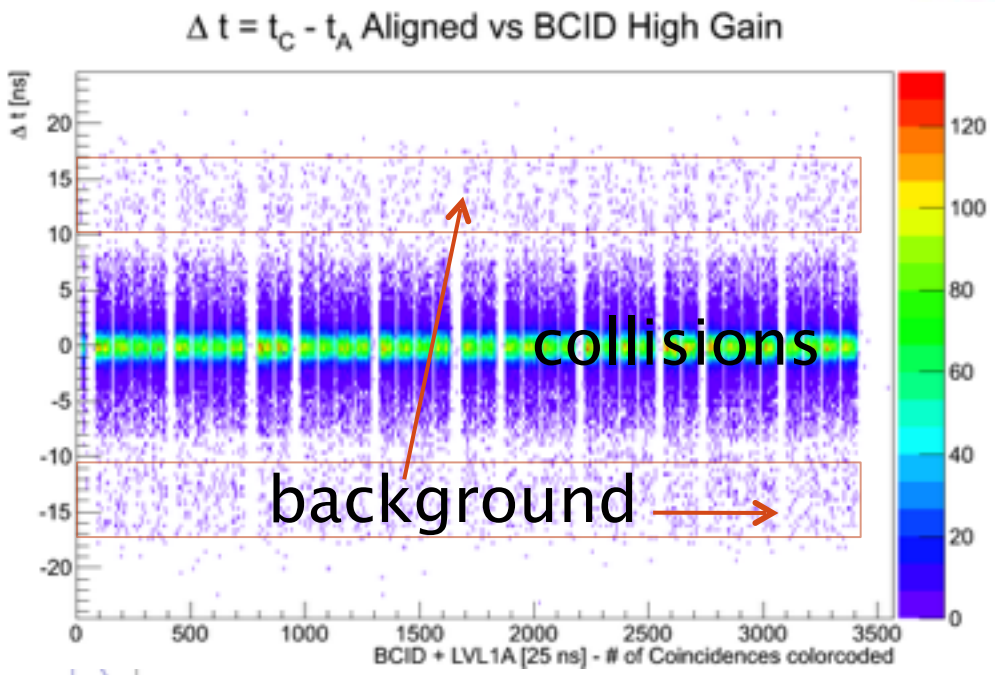


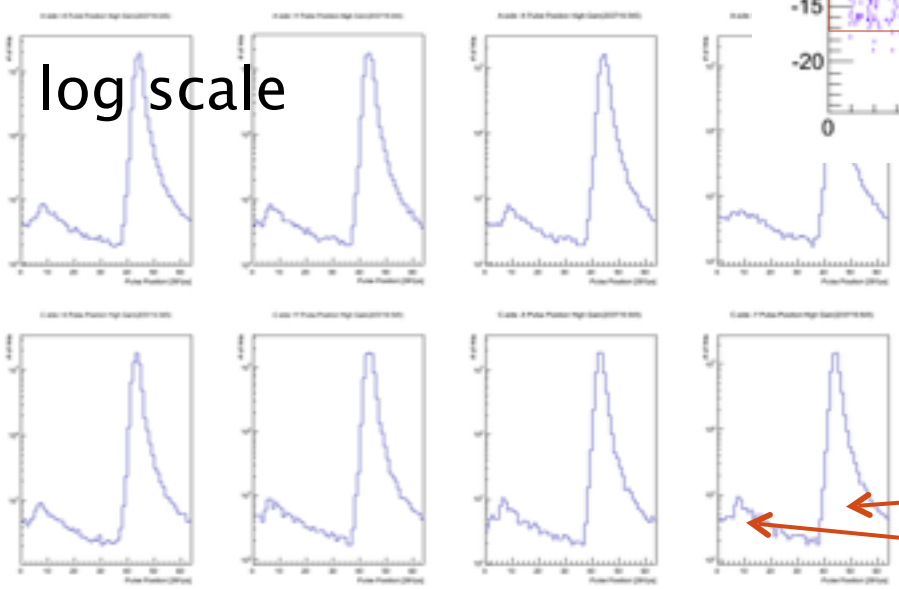


BCM online monitoring plots

- delta ABT (C – A side) vs. BCID



- absolute ABT for individual channel



BCM – Beam abort condition

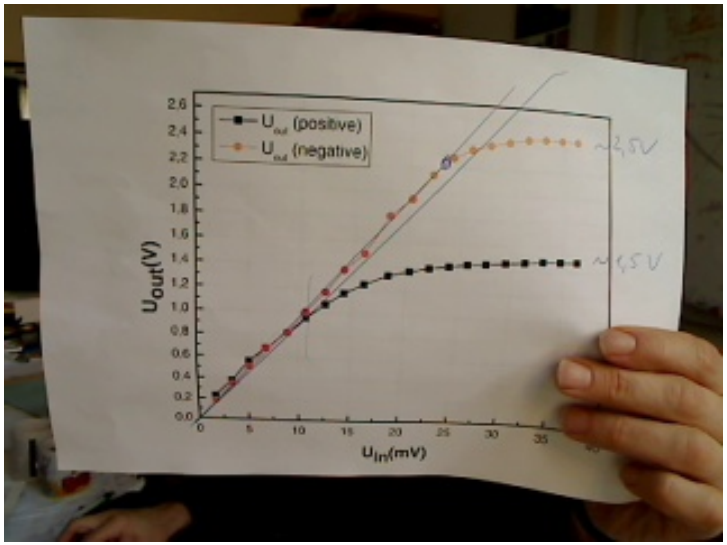
- 3 or 4 “out-of-time” signals on A (or C) side coincident with 3 or 4 “in-time” signals on the opposite side (on high threshold “abort” channels)
- → Trigger only on background events (IP collision events have only “in-time” signature)
- In addition X/Y — required that this happens twice in 1 orbit + 1 BC
- Much improved input stage – much better signal integrity
- No indication of noise pickup
- Very stable operation
- List of BCM “dumps” (nonr during STABLE BEAMs):
  - 2015/07/03 MD/Ramp
  - 2015/07/22 MD
  - 2015/09/24 Injection
  - 2015/10/05 FlatTop
  - 2016/17/04 MD

BCM threshold

- Threshold cited below are for single high thr. channel.

- Nominal conditions: HV=1000V
  - High thr. vs. low thr. signal splitting currently ~1:150.
  - saturation at FE output ~1V
    ~ 250 MIP
    ~(0.5 kMIP/cm2) at
    nominal cond.

- Single channel threshold set to
  ~250 MIP/cm2 within 25 ns
  (factor 2 not to exceed FE range)



Example: Operation experience — BCM

- New RODs fully functional since August 2012
- Counters accumulated in 55 days
- "In-time" events with 3 coincident hits on A/C – 40
- Assuming Poisson distribution
  - 39 M events with 1 "out-of-time" hit
  - 30 events with 2 coincident "out-of-time" hits
  → estimated frequency of 3 coincident "out-of-time" hits is ~10^{-5} 55 days shown

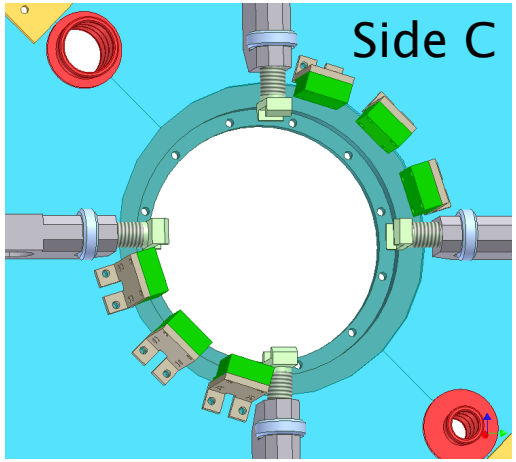
BCM Counters

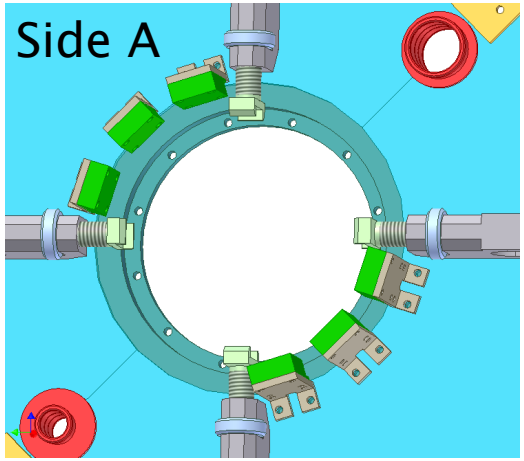
Beam Monitor		In-time Multiplicity (combined)		Out-of-time Multiplicity (combined)		Multiplicity (per side)	
Late Coincidence	1009851	Mult.1	804397702	Mult.1	39099921	Intime 2A+	241227
Early Coincidence	13	Mult.2	1861220	Mult.2	30	Intime 2C+	610574
Background Beam1	78	Mult.3	236	Mult.3	0	Intime 3A+	7
Background Beam2	231	Mult.4	0	Mult.4	0	Intime 3C+	33
		Mult.5	0	Mult.5	0	Outoftime 2A+	6
		Mult.6	0	Mult.6	0	Outoftime 2C+	11
		Mult.7	0	Mult.7	0	Outoftime 3A+	0
		Mult.8	0	Mult.8	0	Outoftime 3C+	0

- Nevertheless we are after potentially dangerous events that are a result of malfunction and will not occur at a here-predicted rate

ATLAS BLM – Intro

- 6 BLM modules installed on Inner Detector End Plate on each side
- Z-position of the inner skin of the End Plate is 3457mm for both sides
- Read out with LHC BLMCFC and BLMTC
- Only one BLMTC and two BLMCFC crates (one for A and one for C side)
- Slight modification of HW (B field) and FW (ATLAS specific)
- Much simpler than BCM





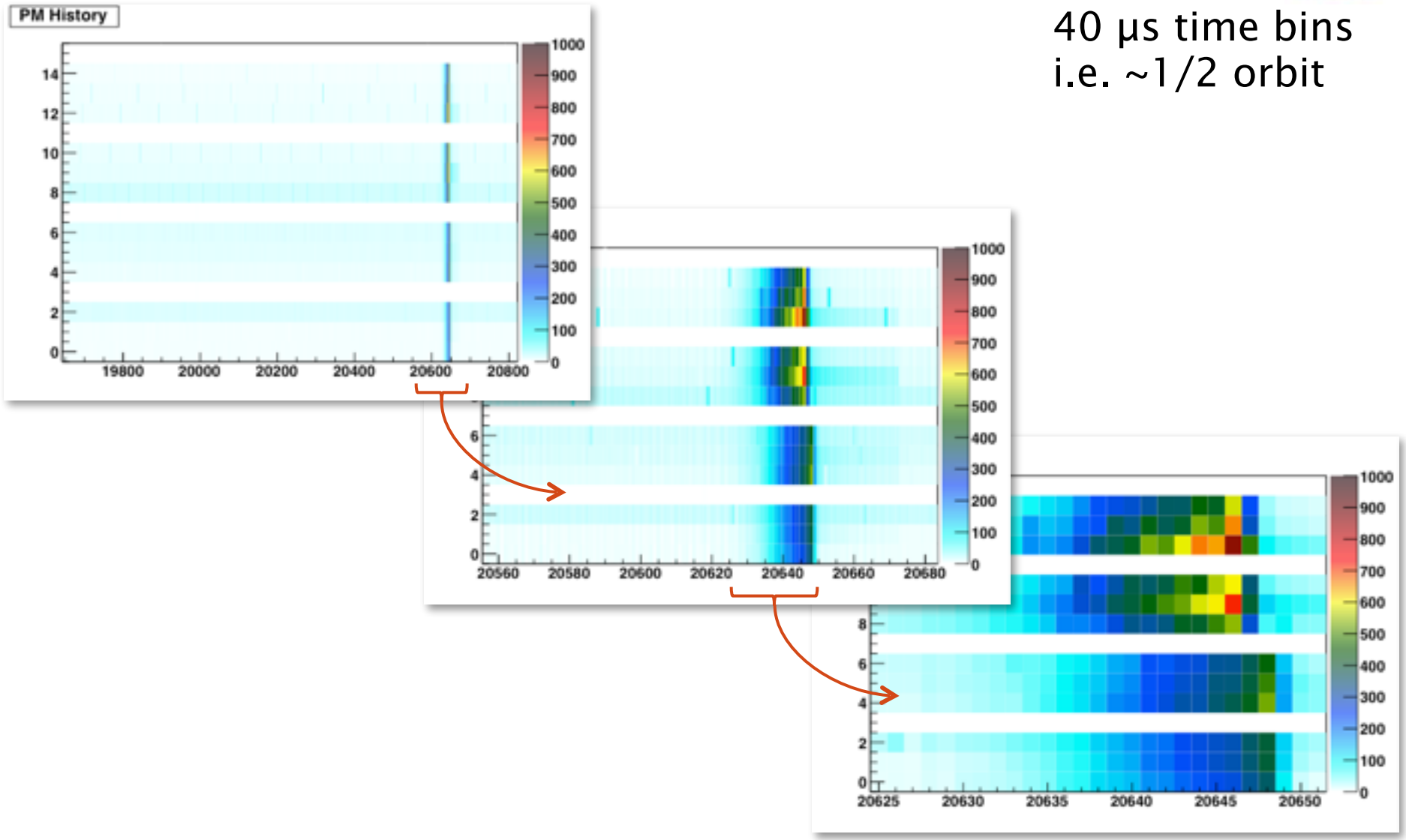
BLM threshold

- For loosing IP — require that 2/6 channels exceed threshold within 40 μs on A or on C side (ATLAS FW!). BP is lost when A and C side lower IP simultaneously
- 1 MIP in BLM diamond sensor (~1fC charge) in 40 μs causes equivalent current of ~25 pA.
- BLM thresholds set to:
  - ~750 nA (= 350 bits) in 40 μs integration channels.
  - In addition requiring 2 out of 6 channels to meet this condition within 40 μs either on A or on C side to drop **IP**
  - And in addition requiring this on both (A and C) sides simultaneously to drop **BP**
  - Compatible with ATLAS Inner Detector "danger level" (in the most unlikely event of all particles coming along Si strips)

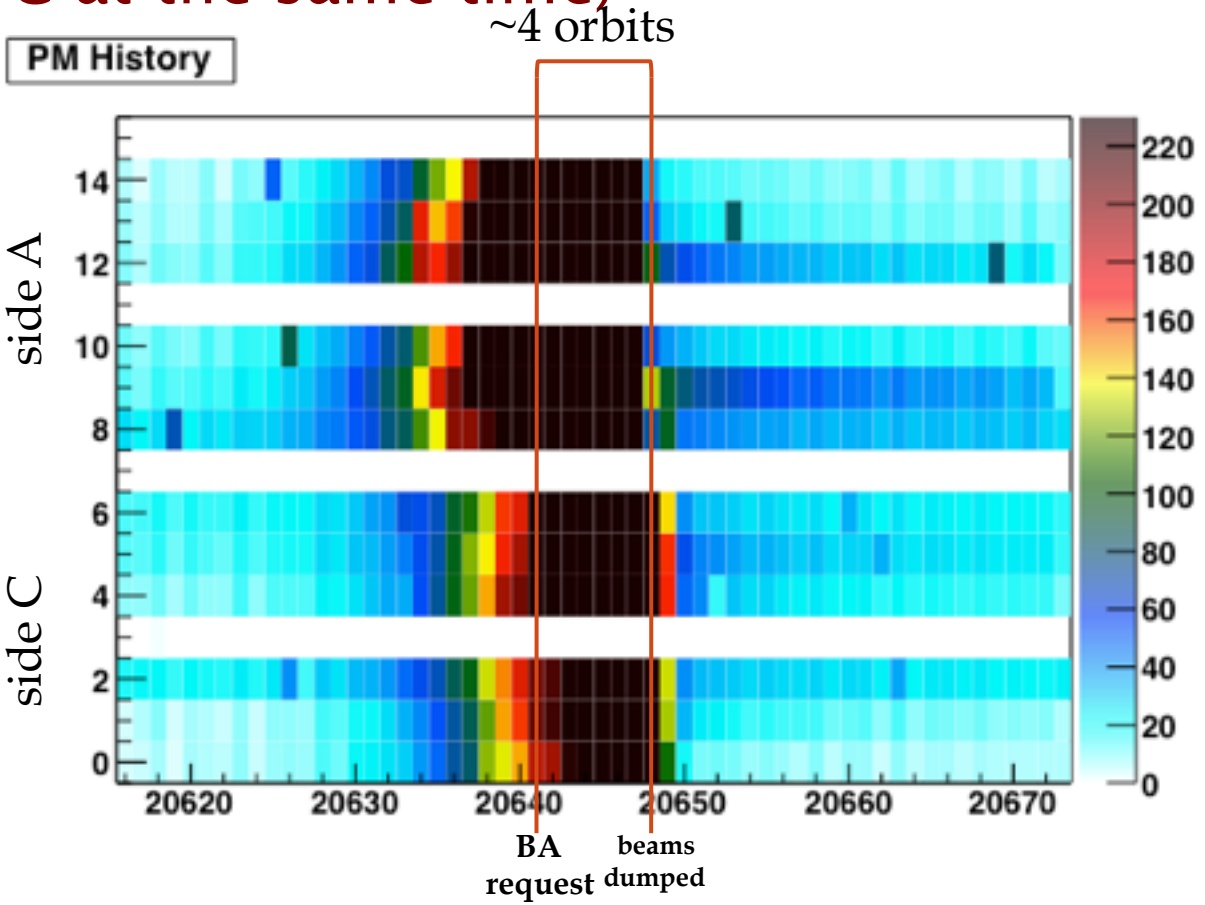
Case study: 2011 ATLAS-BLM beam dumps

- 31/07/2011 @6:47 C→A (beam 2)
- 17/08/2011 @9:48 A→C (beam 1)
- BLM reached abort threshold of 230 in RS0 (40us) in 2A and 2C channels simultaneously
- both exhibit a "UFO" like time behavior
- beams were extracted in ~4 orbits after ATLAS BLM thresholds were reached
- BCM signal was still increasing in high threshold channels ("ABORT" channels) – far from saturation
- @ BLM BA request BCM ABORT channels did not see any substantial signal
- clearly visible from BCM PM buffers that there was a lot C→A background (31/07) and A→C background (17/08)

31/07/2011 @ 6:47 – BLM PM buffer

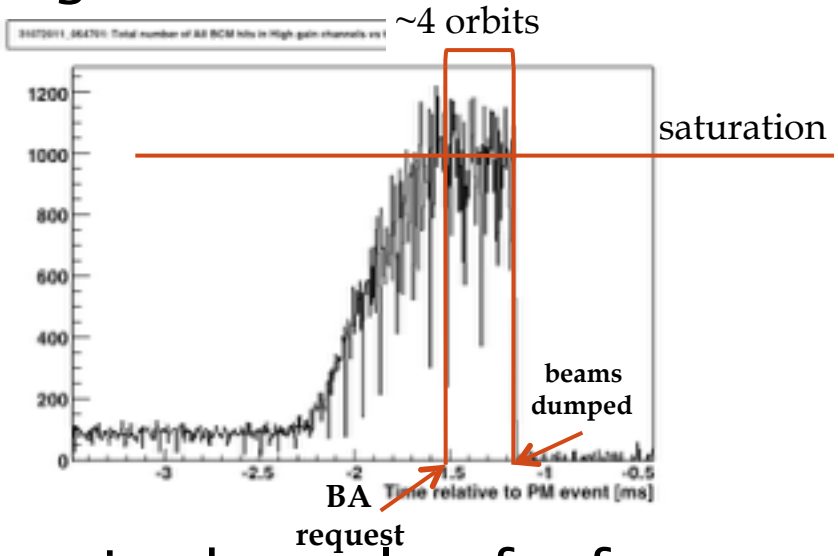


- Abort condition: 2+2 abort condition on both sides simultaneously (230 [now 350] hits in two channels on side A and C at the same time)

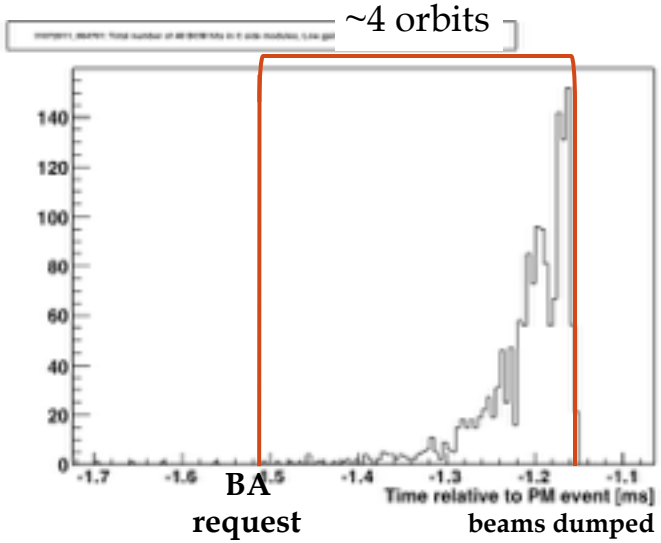


31/07/2011 @ 6:47 – BCM PM buffer

- High gain channels – saturate at ~1k in 5μs bin



- Low gain channels – far from saturation but substantial signal which looks to be exponentially increasing before beams were extracted (~14% of saturated signal). Note: when BLM fired – there was almost no signal in HT BCM channels



Summary

- BCM with fully commissioned new firmware operational from August 2012
- BCM back in CIBU since December 2012
- BLM activated in April 2010 (when BCM got disabled for consolidation and improvements)
- No indication of any operational problem observed
- ATLAS BCM and BLM are redundant safety systems for protection of ATLAS Inner Detector

- BLM thresholds set to be compatible to ATLAS ID danger levels; BCM “raw” threshold at maximum, BCM threshold set with algorithms (3+3 + X/Y)