Trigger Commissioning and Menus

Ricardo Gonçalo – Royal Holloway

ATLAS UK Meeting – Cambridge, 6-8 January 2010

Introduction

- This talk will try to give an overview of the 2009 LHC run period from 20th November to 16th December from the trigger perspective

- Will only give an outline: more details in following talks

Trigger (14:45 - >16:45)	**Chairperson:** Alan Watson (*University of Birmingham*) , John Baines (*RAL*) , John Baines (*Particle Physics-Rutherford Appleton Laboratory-STFC - Science &*)
14:45	**Trigger Commissioning & Menus** (20') — Ricardo Jose Morais Silva Goncalo (*Royal Holloway*)
15:10	**Level-1 Calorimeter Trigger Commissioning** (15') — Juraj Bracinik (*University of Birmingham, UK*)
15:30	**Minimum Bias Trigger** (15') — Emily Nurse
15:50	Tea (15')
16:05	**electron/photon trigger** (15') — Rudi Apolle (*University of Oxford-Unknown-Unknown*)
16:25	**Inner Detector Trigger Commissioning** (15') — Jiri Masik (*University of Manchester*)

Note: will report on the work of many people; names mentioned occasionally, when author is clear. But ultimately the credits go to the **whole ATLAS Collaboration**!

LHC Milestones

Date	Day	Achieved
Nov 20	1	Each beam circulating. Key beam instrumentation working.
Nov 23	4	First collisions at 450 GeV. First ramp (reached 560 GeV).
Nov 26	7	Magnetic cycling established (reproducibility).
Nov 27	8	Energy matching.
Nov 29	10	Ramp to 1.18 TeV.
Nov 30	11	Experiment solenoids on.
Dec 04	15	Aperture measurement campaign finished. LHCb and ALICE dipoles on.
Dec 05	16	Machine protection (Injection, Beam dump, Collimators ts.
Dec 06	17	First collisions with STABLE BEAMS, 4 on 4 pilots at 450 GeV, rates around 1Hz.
Dec 08	19	Ramp colliding bunches to 1.18 TeV
Dec 11	22	Collisions with STABLE BEAMS, 4 on 4 at 450 GeV, > 10^{10} per bunch, rates around 10Hz.
Dec 13	24	Ramp 2 bunches per beam to 1.18 TeV. Collisions for 90mins.
Dec 14	25	Collisions with STABLE BEAMS 16 on 16 at 450 GeV, > 10^{10} per bunch, rates around 50Hz.
Dec 16	27	Ramp 4 on 4 to 1.18 TeV. Squeeze to 7 m.

Friday night: splashes

Monday: first LHC collisions!

Much work, little sleep…

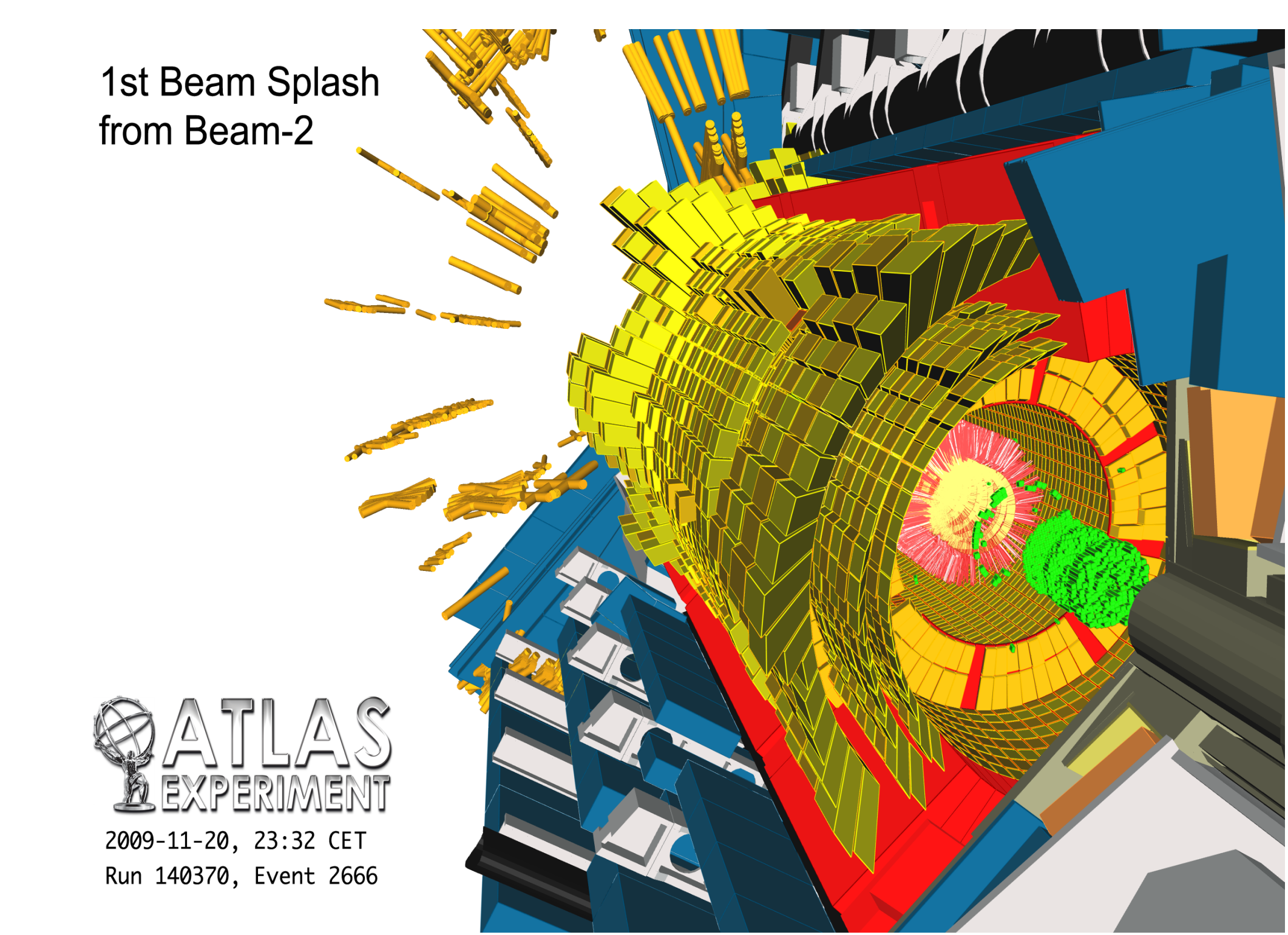
LHC breaks energy record!

Other news big and small

High-energy collisions!

In the ATLAS Control Room…

1st Beam Splash from Beam-2



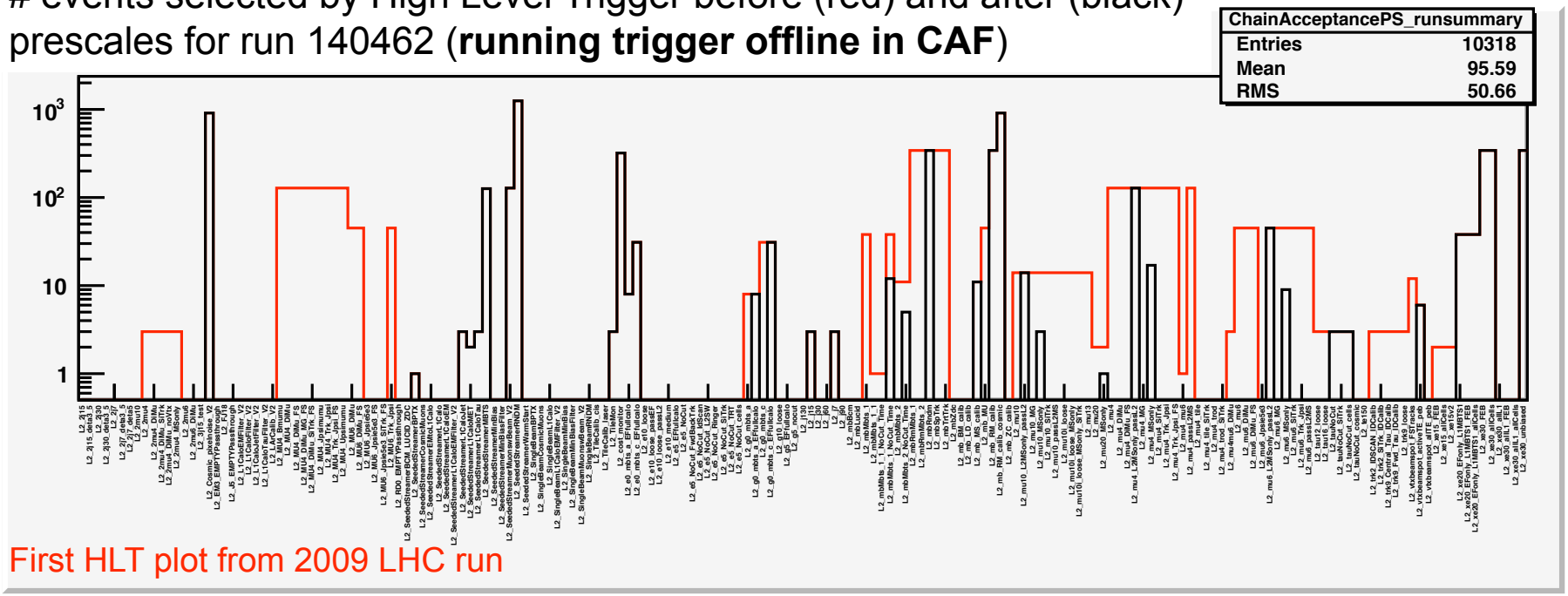
ATLAS EXPERIMENT

2009-11-20, 23:32 CET

Run 140370, Event 2666

- Only Level 1 items active during the splashes:
  - **MBTS** (Min. Bias Trigger Scintillator)
  - **EM14** – set to fire on central barrel energy deposits
- Used splash events to time-align **BPTX** (Beam pickups)
- High Level trigger ran offline in **CAF** on collected events – ready **a few hours** after each run was taken

events selected by High Level Trigger before (red) and after (black) prescales for run 140462 (**running trigger offline in CAF**)

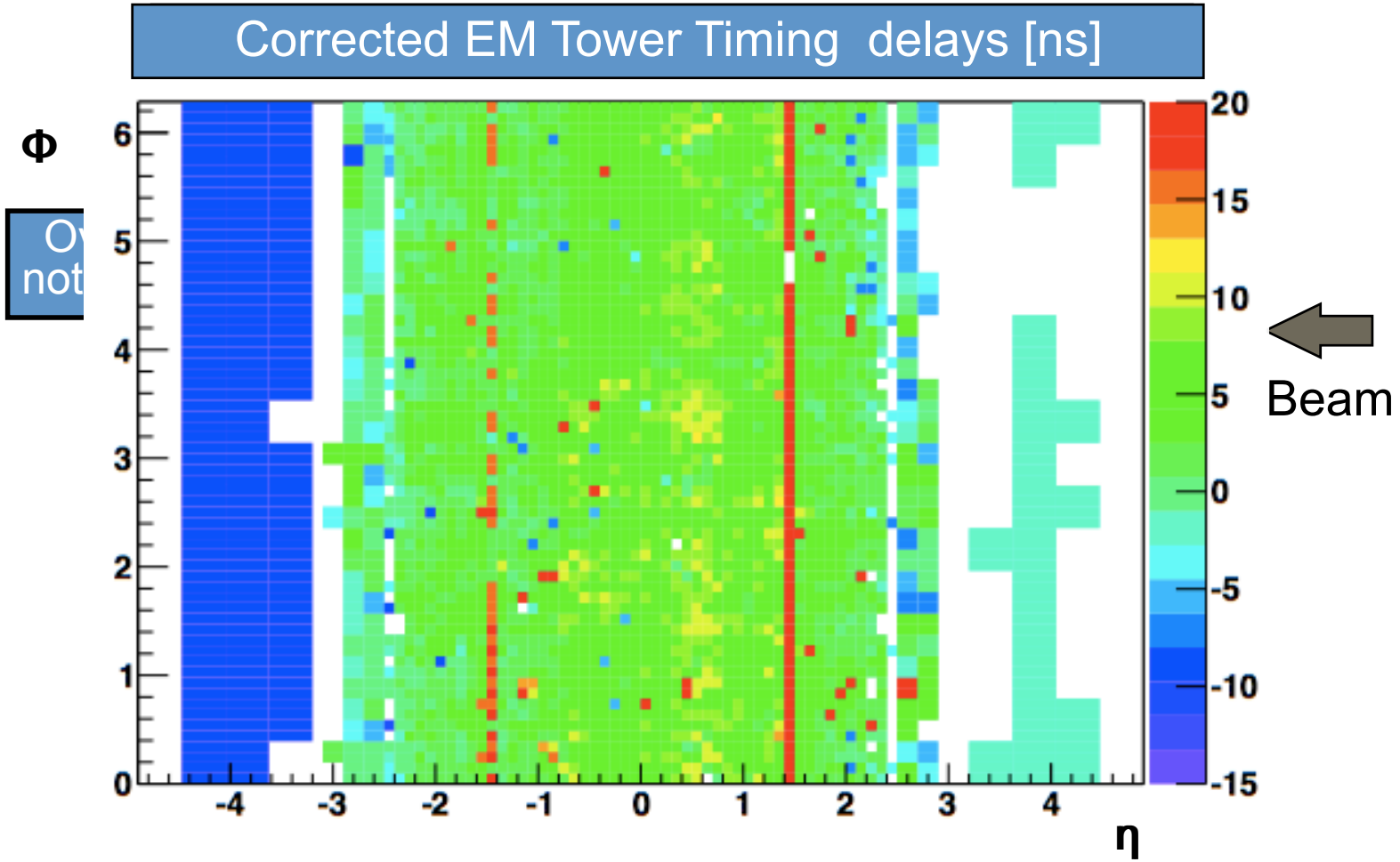


First HLT plot from 2009 LHC run

Nov Dec

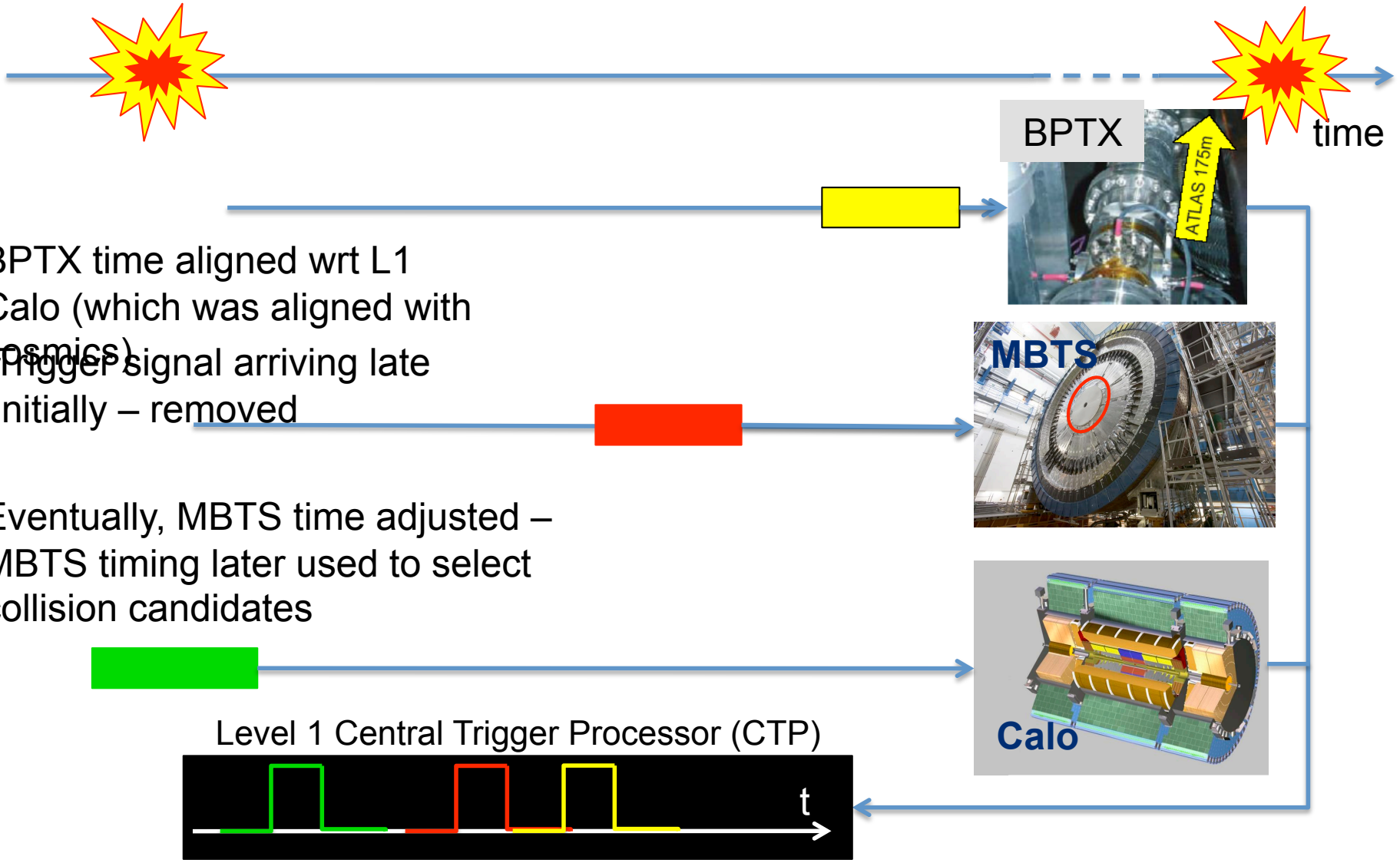
20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

L1 Calo Time



- L1Calo timing distribution of first high-ET splash event
- L1CaloEM timing accuracy mostly already at the ±10 ns level (notice scale change)
- Observed time differences between up/downstream towers are mainly due to time of flight

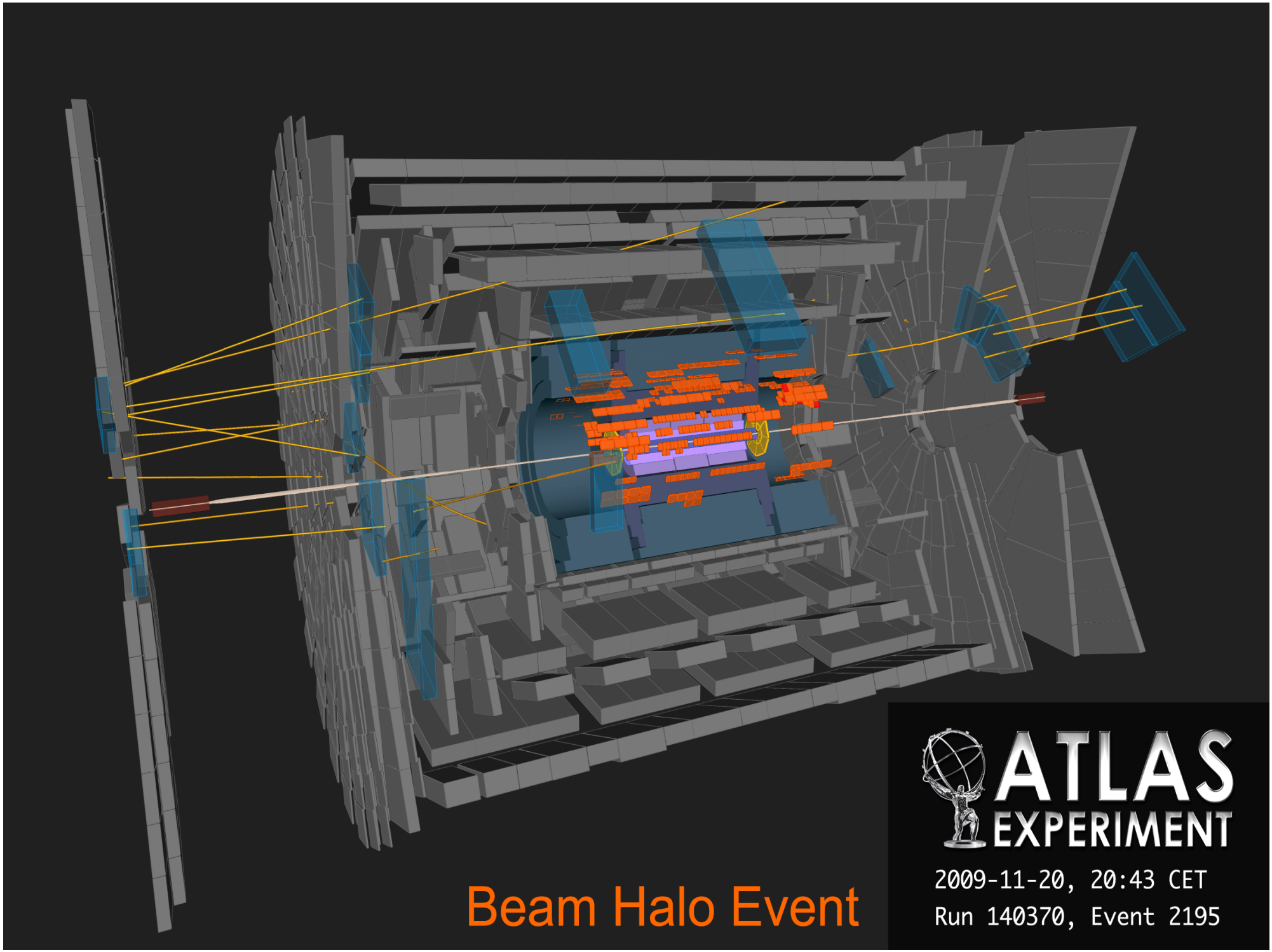
Time Alignment With 1st Splashes



BPTX time aligned wrt L1 Calo (which was aligned with cosmics)

Trigger signal arriving late initially – removed

Eventually, MBTS time adjusted – MBTS timing later used to select collision candidates

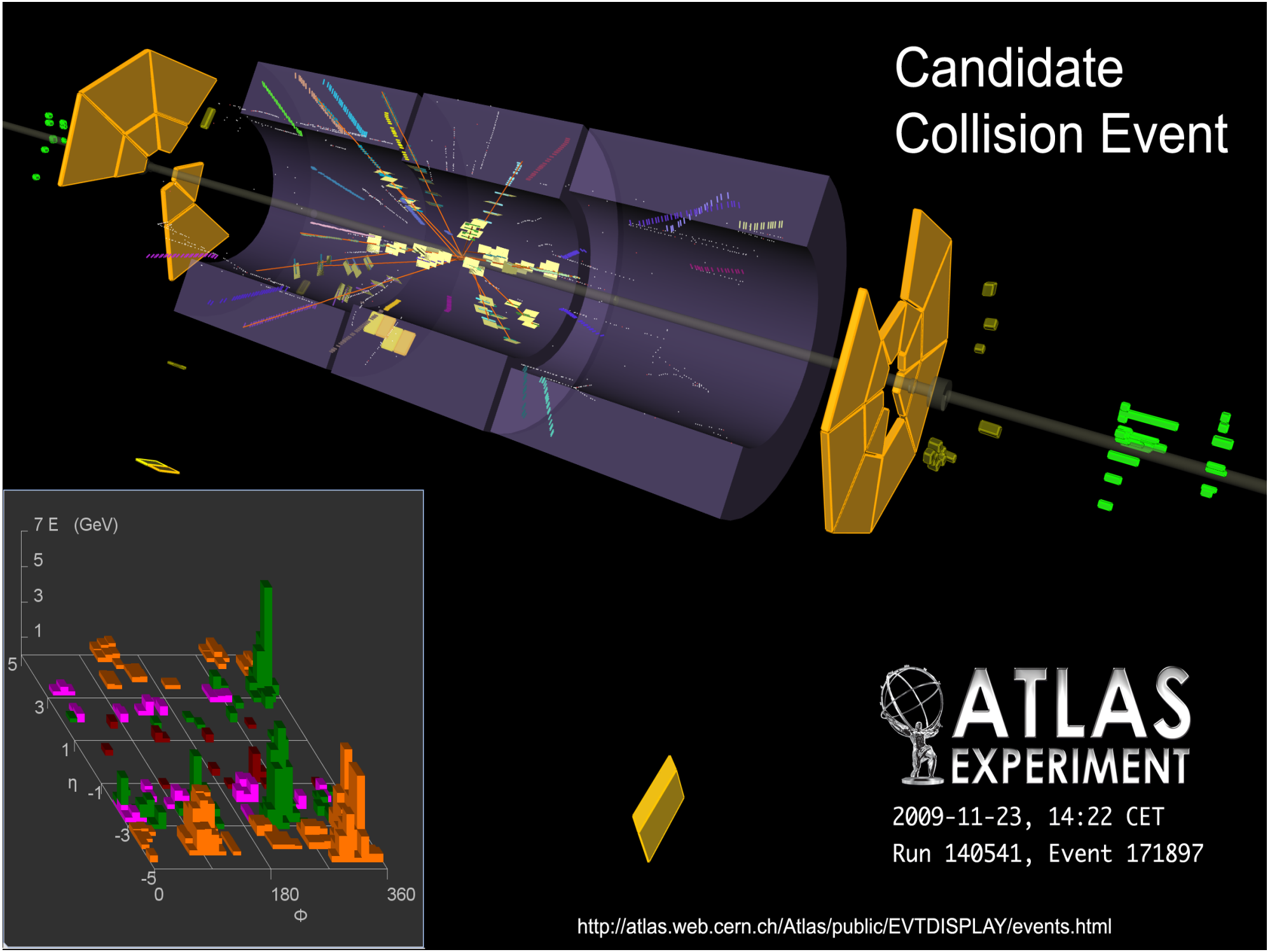

ATLAS
EXPERIMENT
2009-11-20, 20:43 CET
Run 140370, Event 2195
Beam Halo Event

Beam-gas and Halo Events

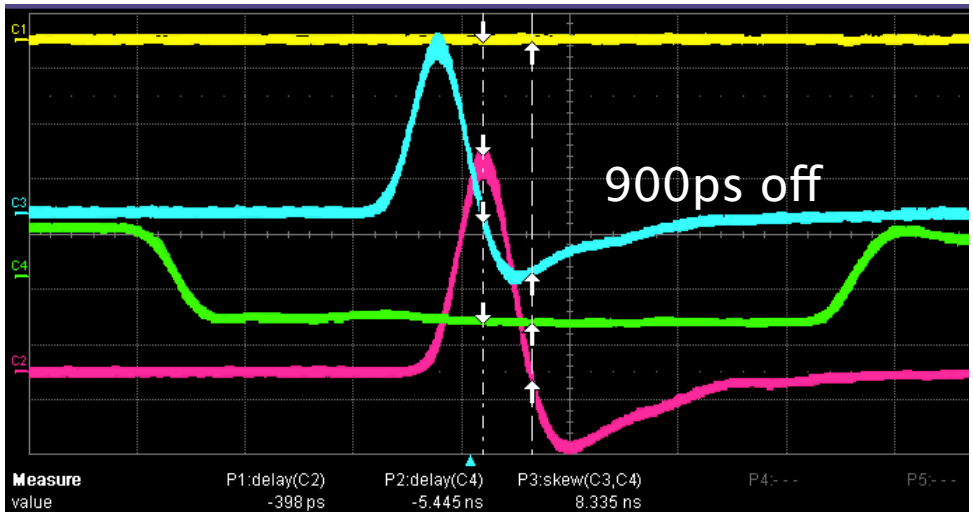
- After **BPTX** timed in, used it in coincidence (AND) with other trigger items
  - To **suppress cosmics** and enhance **beam-related** events
- Used this scheme in single-beams and collisions
  - Caveat: **BPTX** efficient only for large enough currents (> 1.5×10^9 proton in bunch)

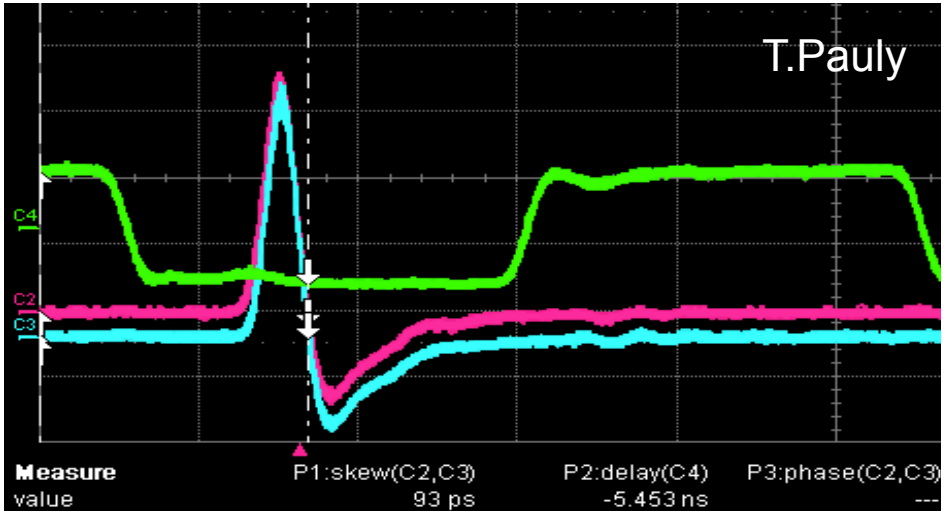
- To avoid loosing events when current was too low, used the **bunch-group** mechanism:
  - A bunch group is a set of Bunch-Crossing IDs (BCID). E.g.:
    - beam1=2554 on November 20th
    - beam2=1358 before Sunday 22nd
    - beam2=2554 afterwards – i.e. bunches cross in ATLAS at the right time
- Several changes were made to the menu, to respond to problems

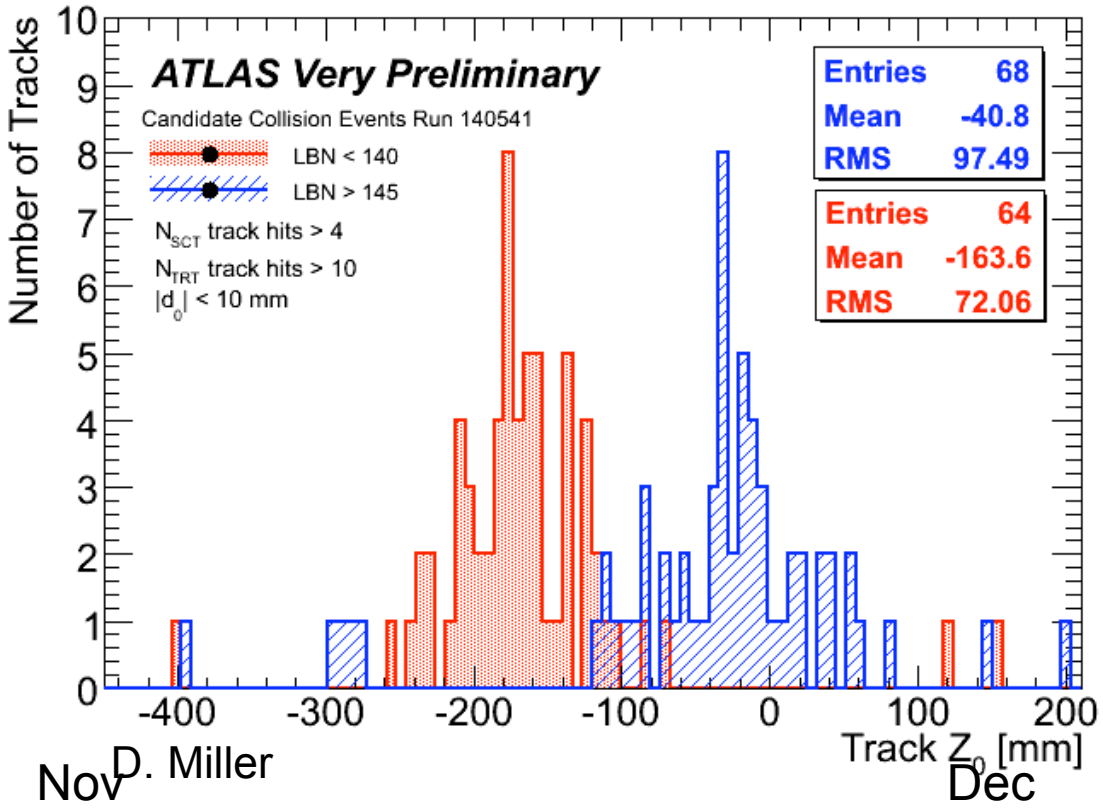
- **First tracks** from beam were registered!


Candidate
Collision Event
7 E (GeV)
5
3
1
5
3
1
η
-1
-3
-5
0
180
360
Φ
ATLAS
EXPERIMENT
2009-11-23, 14:22 CET
Run 140541, Event 171897
http://atlas.web.cern.ch/Atlas/public/EVTDISPLAY/events.html

- At this point the question was how to be sure these events were collisions and not beam-gas or beam halo
- Proof came within hours with frantic email exchanges and bright ideas flying around
- Detailed analysis of LAr signal times: selected events coming from the centre of ATLAS
- Later, got more confident when vertex Z distribution was seen to move after LHC phase adjustment ("RF cogging") of 900ps
- Some days later, **MBTS** timing coincidence on sides A and C of ATLAS was used to have a **collision trigger**







900 ps corresponds to a vertex shift of 13.5 cm

SCT track Z position before and after adjustment: Mean moved 12.3 cm towards zero!

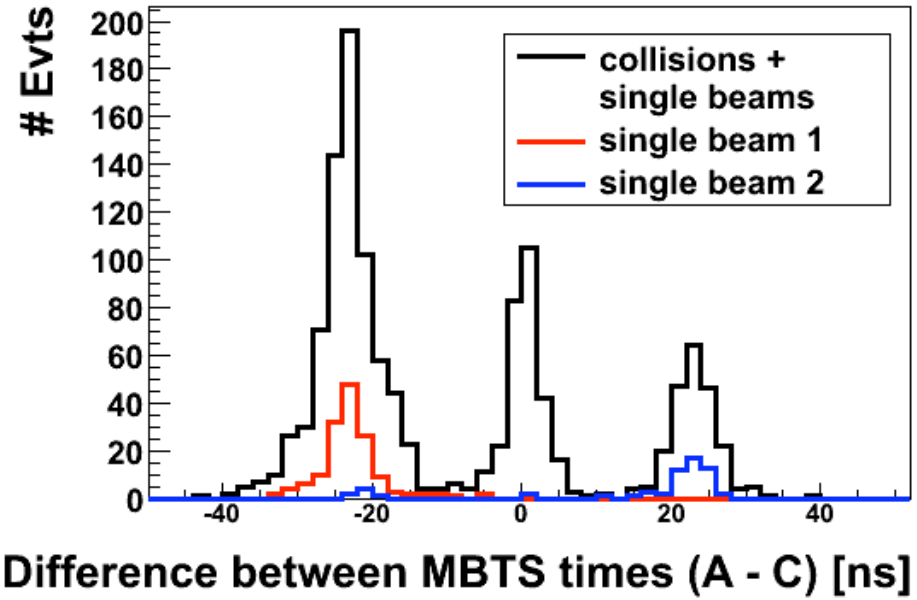
#SCT > 4; #TRT > 10; d_0 < 10mm

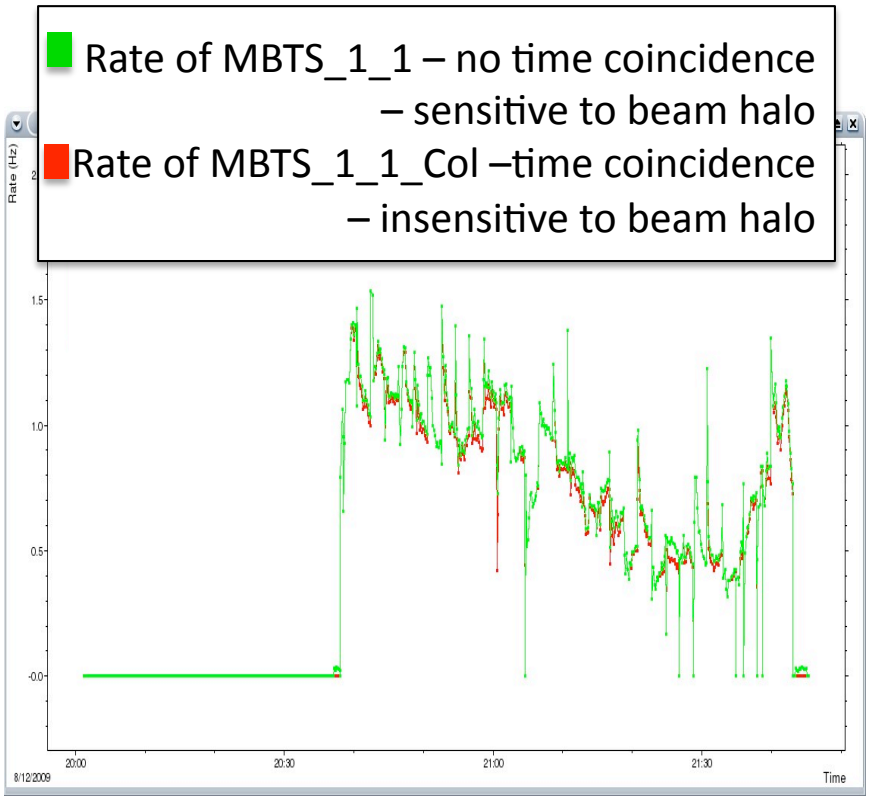
D. Miller

Nov Dec

20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16

- **MBTS** time coincidence in sides A and C provides a Level 1 trigger for collision events
  - **MBTS_1_1_Col** has a strict coincidence requirement; **MBTS_1_1** doesn't
- Could see beam conditions are very clean: no difference between two rates => not much beam gas/beam halo
  - Ramp starts shortly after 21:30 and one clearly sees the collision rate increase as the energy increases.



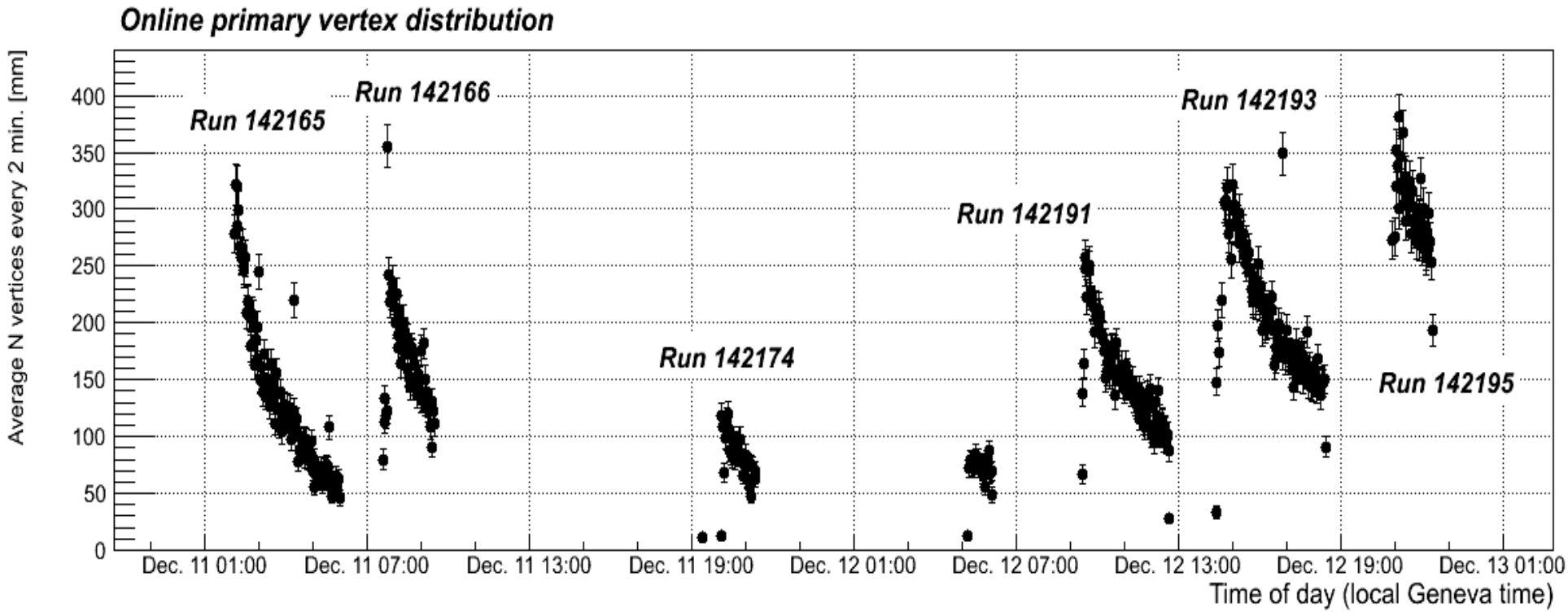


- So far, **High Level Trigger** was running offline on all interesting runs in **CAF/Tier0**
  - Analyzed debug streams to classify errors
  - Processed bytestream files and produced ESD/ntuple **with high level trigger information** for commissioning analysis
  - Major step forward was to run jobs automatically
  - In general, High Level Trigger ran successfully with little or no errors and no crashes – gave us enough confidence to run it online

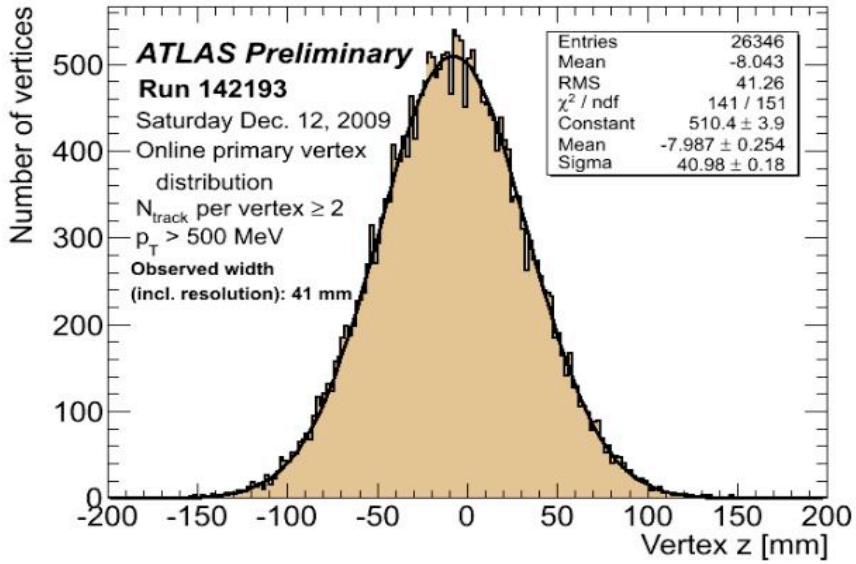
- On December 6th, **full High Level Trigger** running **online** – run 141811, lumi bl.142
  - **Full menu** running, and all calibration streams active
  - **No event rejection** – special chains to accept all events regardless of high level trigger decision

- Primary vertex position measured **in real time** in Level 2 trigger!

- On December 11th (2am) High Level Trigger algorithms used to perform **active event rejection**
  - On **one stream only** (physics_BPTX)
  - Fed by Level 1 BPTX
  - Level 2 minimum bias chains used inner detector algorithms to reject events
  - Other streams still accepting all events



- Vertex position determined online from fit to impact parameter of Level 2 trigger tracks versus ϕ
- Z vertex distribution width ~40mm (including resolution)
- Number of vertices can be seen to decay with decreasing luminosity in fill



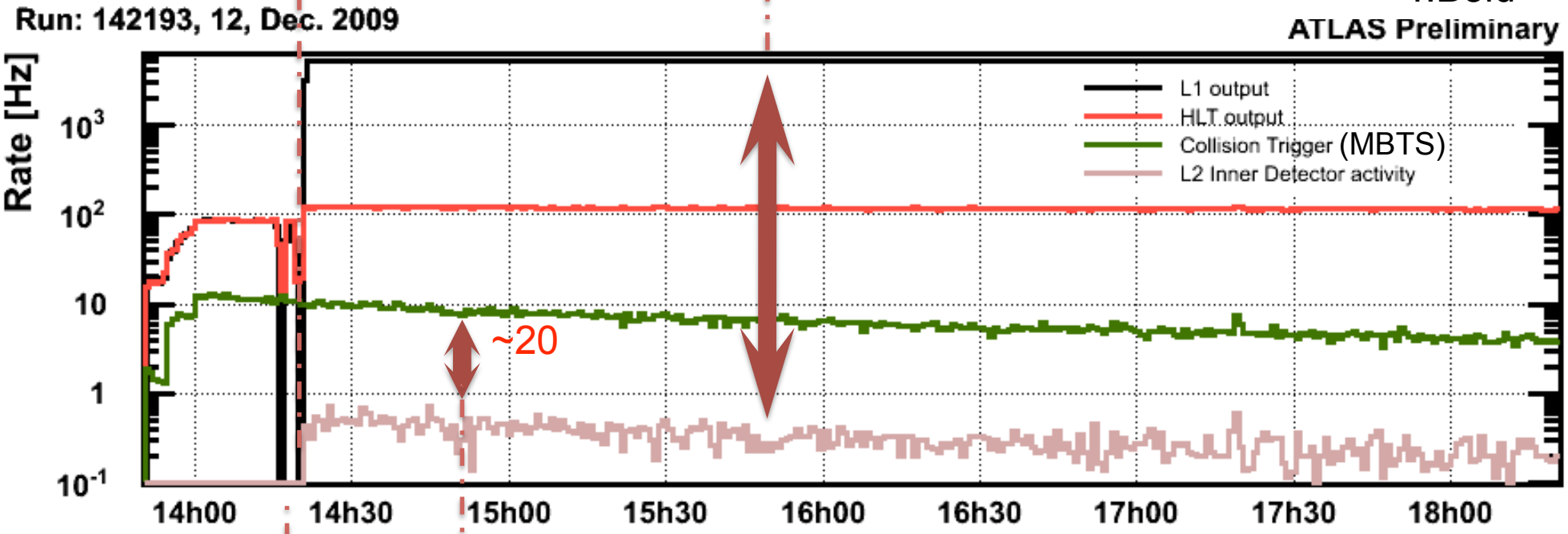
Typical “Stable Beams” run

Beam injection, record collision events.
HLT algos off.

L1 BPTX prescale lowered => L1 rate increases
HLT active after LHC declares stable beam

Rejection factor of ~10^4 looking for space points in the Inner Detector at Level 2 trigger – **active event rejection**

T.Bold

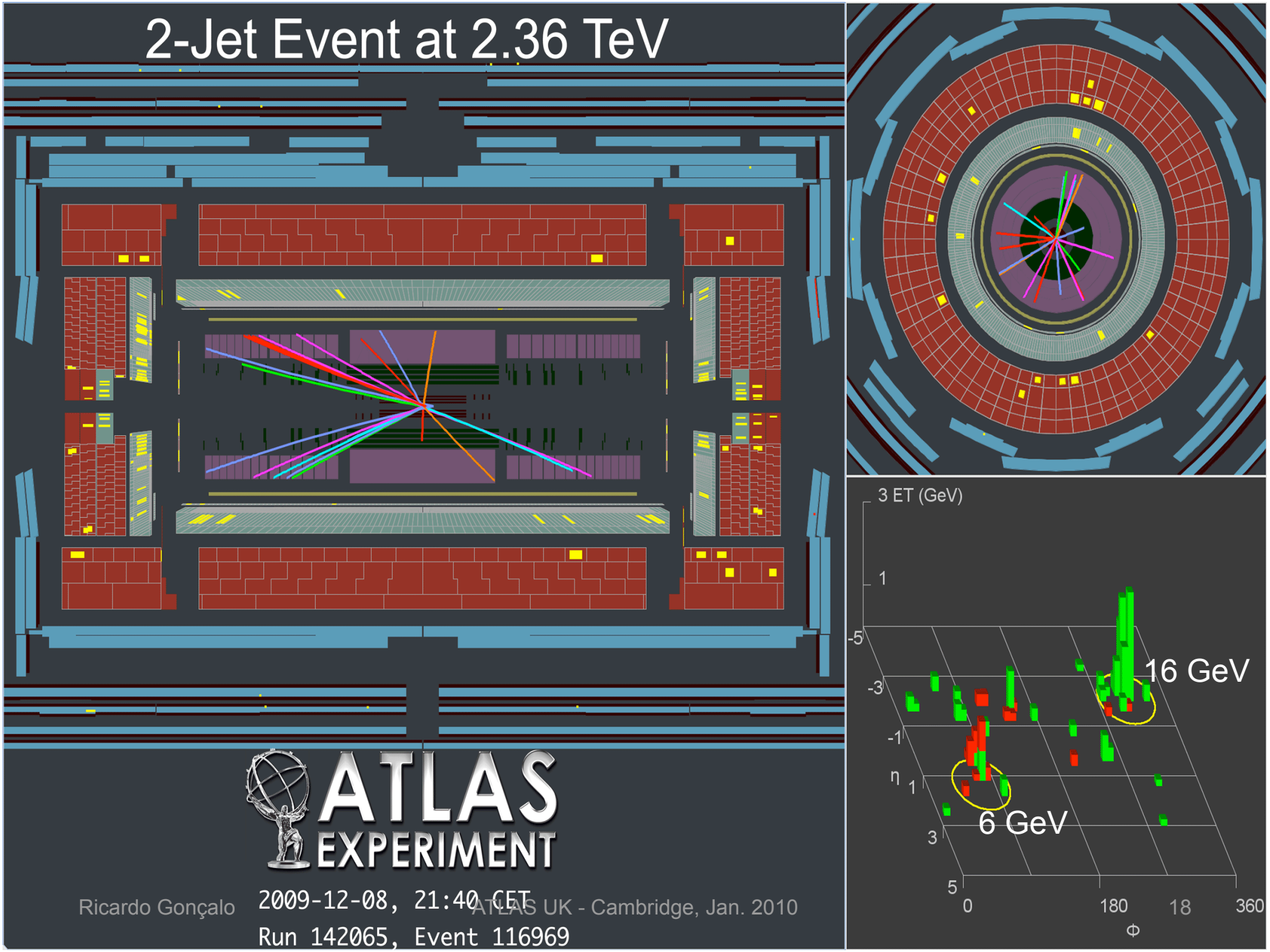


Holding trigger as stable beams declared

BPTX prescaled by x20 at input to L2

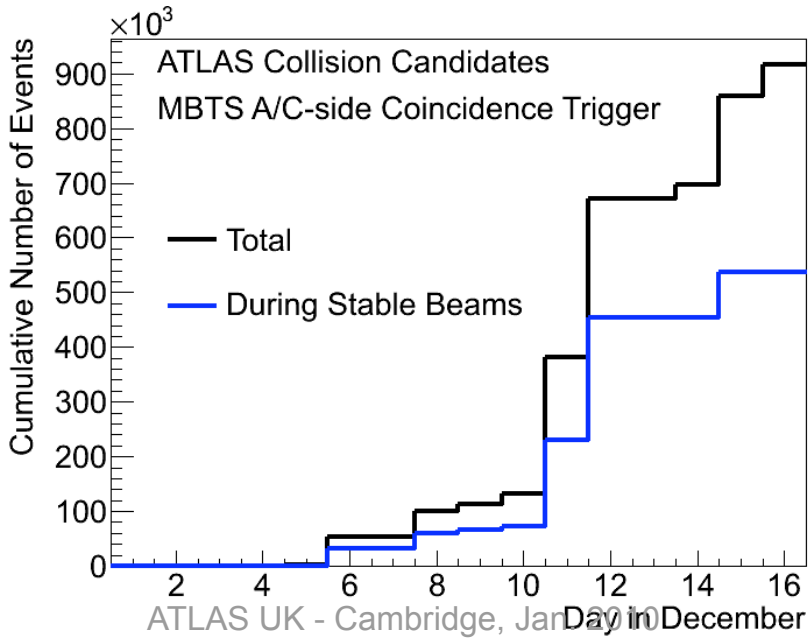
Nov Dec

20 21 22 23 24 25 26 27 28 29 30 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16


2-Jet Event at 2.36 TeV
ATLAS
EXPERIMENT
2009-12-08, 21:40 CET
Run 142065, Event 116969
3 ET (GeV)
1
-5
-3
-1
η
1
3
5
16 GeV
6 GeV
0
180
18
360
Φ

Conclusions

- It was an incredibly exciting end of a busy year!
  - The Level 1 trigger behaved very well and successfully selected single-beam and collision events
  - The High Level trigger was carefully exercised offline, and later used online – first parasitically and then to reject events
- All of this was possible due to an enormous amount of work done in the last few years (both "online" and "offline")
  - Much of this work was done by the UK institutes involved in the trigger

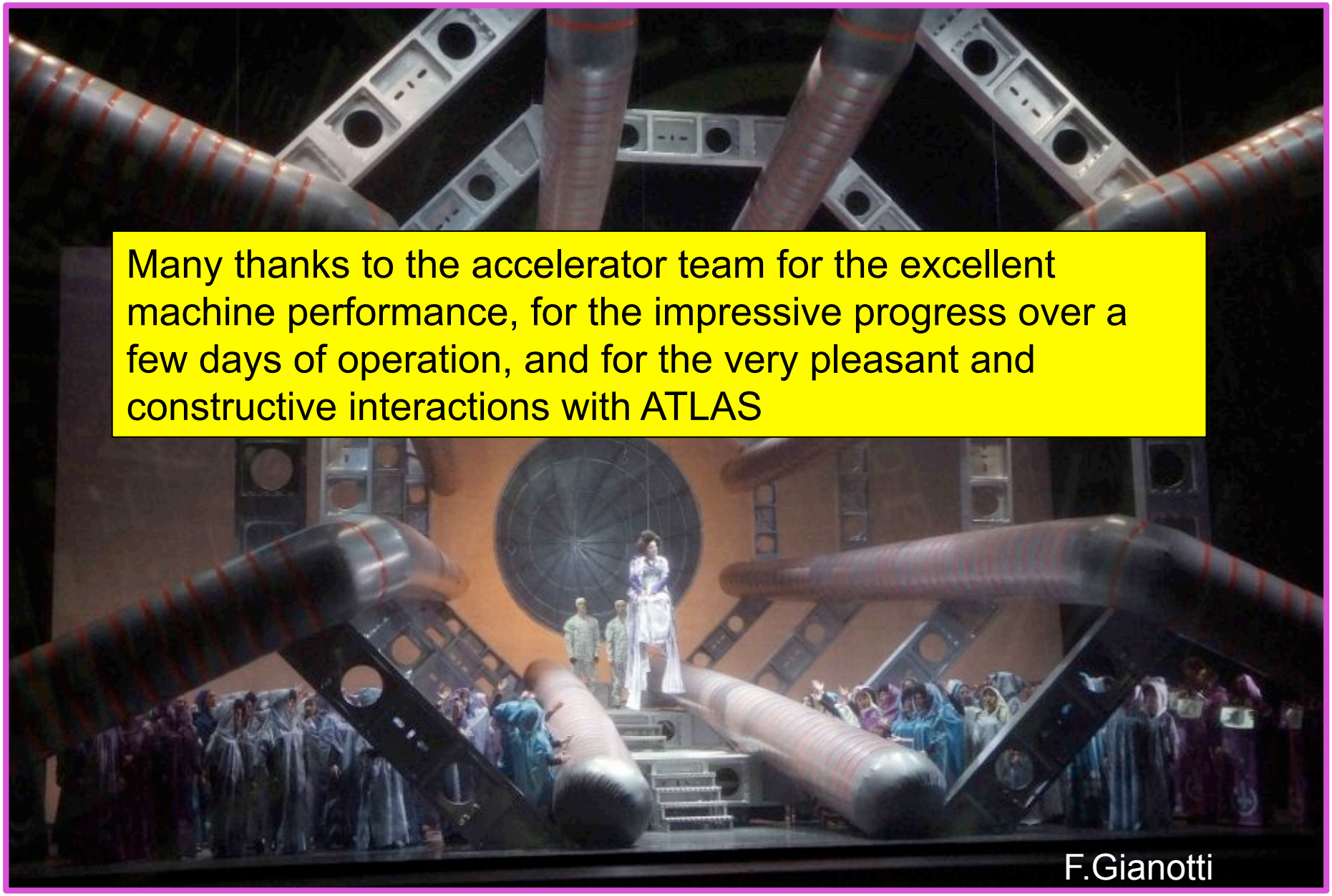


The Future…

- There are **very exciting times ahead**!
- The next step is to turn our trigger into a well-tuned tool to select physics events with good efficiency – after the commissioning, focus on physics performance
- An excellent trigger performance is fundamental to doing physics with ATLAS
- Now it's time to **exploit the ATLAS potential**, and (with a bit of luck) to **change the physics textbooks**!

Backup slides…

Hector Berlioz, “Les Troyens”, opera in five acts
Valencia, Palau de les Arts Reina Sofia, 31 October -12 November 2009



Friday, 20 November:

~ 20h: beam-1 threading → 6 beam splashes to ATLAS

~ 22h: beam-1 RF capture

~ 23h: beam-2 threading → 7 beam splashes to ATLAS

~ 24h: beam-2 RF capture

Saturday, 21 November:

~ 1h: beam-2 splashes dedicated to ATLAS → 27 events (side C)

~ 4h: beam-1 splashes dedicated to ATLAS → 26 events (side A)

RF consolidated → estimated beam lifetime up to ~ 10 hours

Sunday, 22 November:

~6h: 15 splash events to test beam abort by BCM→ successful

Then single beams …

Monday 23 November:

~ 6:30: last series of splashes to ATLAS → 25 events (side C)

~13:30: two beams injected, one bunch per beam ~ 4×10^9 p, both in bucket 1 for collisions at IP1 and IP5

~ 14:22: first collision event observed in ATLAS (first experiment !)

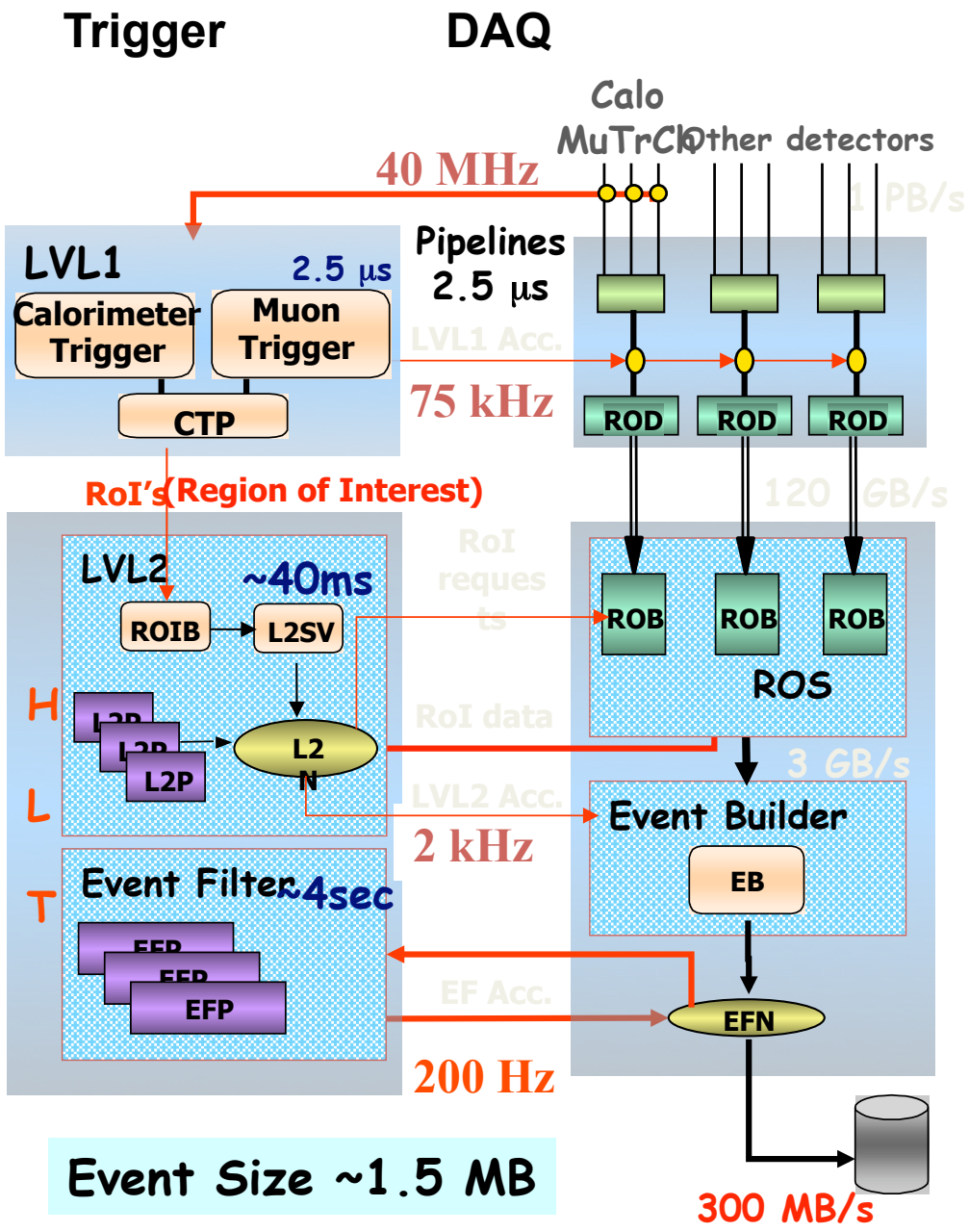
~ 16:00: beams set up for collisions at IP2 and IP8

~ 19:00: beams again in bucket 1 for collisions at IP1 and IP5

~ 20:30 CERN Press release out → our event can go public

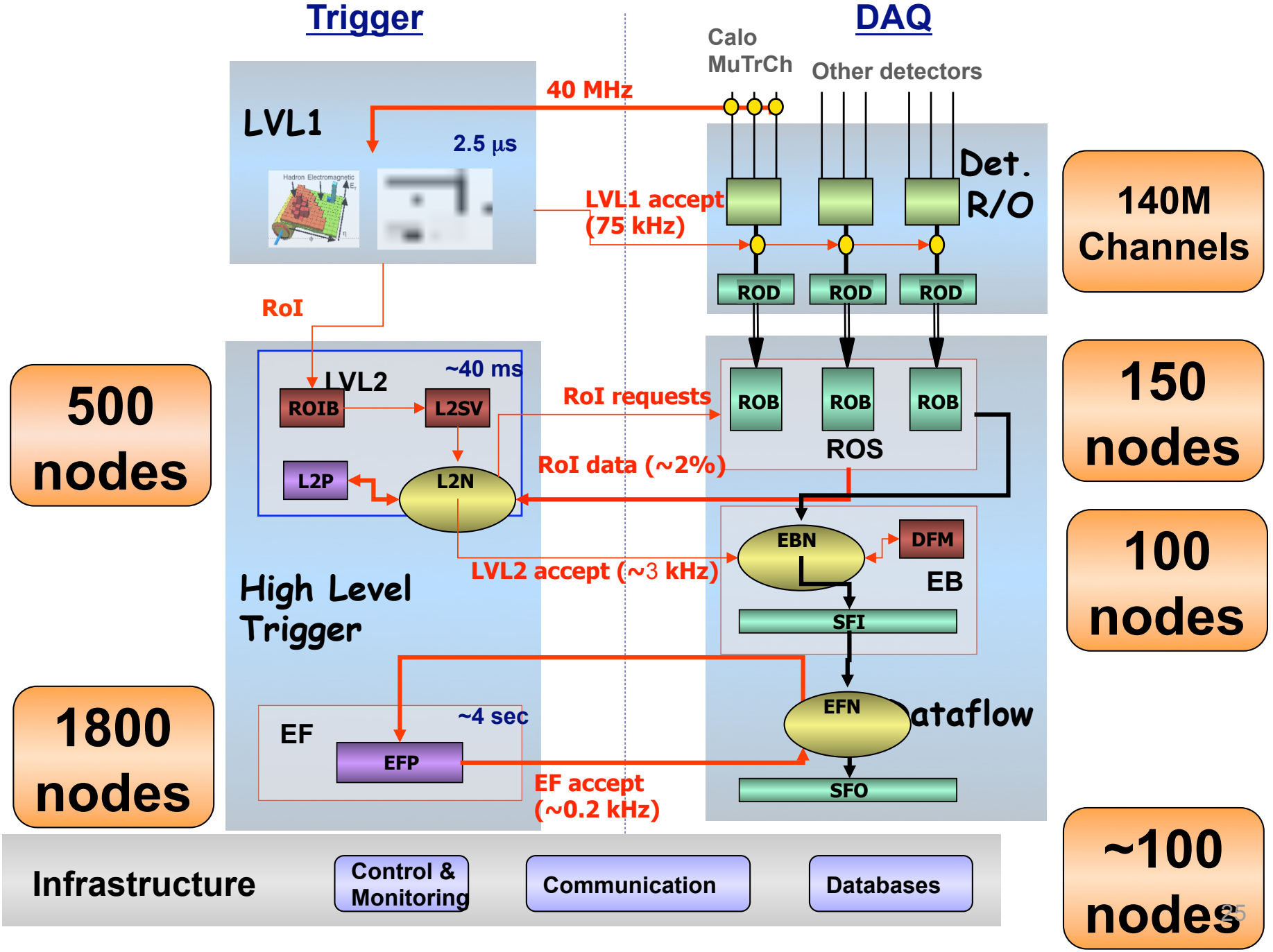
~ 24: beam 1 ramped up to 540 GeV

- Three trigger levels:
- Level 1:
  - Hardware based
  - Calorimeter and muons only
  - Latency 2.5 μs
  - Output rate ~75 kHz
- Level 2: ~500 farm nodes(*)
  - Only detector **"Regions of Interest" (RoI) processed - Seeded by level 1**
  - Fast reconstruction
  - Average execution time ~40 ms(*)
  - Output rate up to ~2 kHz
- Event Builder: ~100 farm nodes(*)
- Event Filter (EF):~1600 farm nodes(*)
  - Seeded by level 2
  - Potential full event access
  - Offline algorithms
  - Average execution time ~4 s(*)
  - Output rate up to ~200 Hz



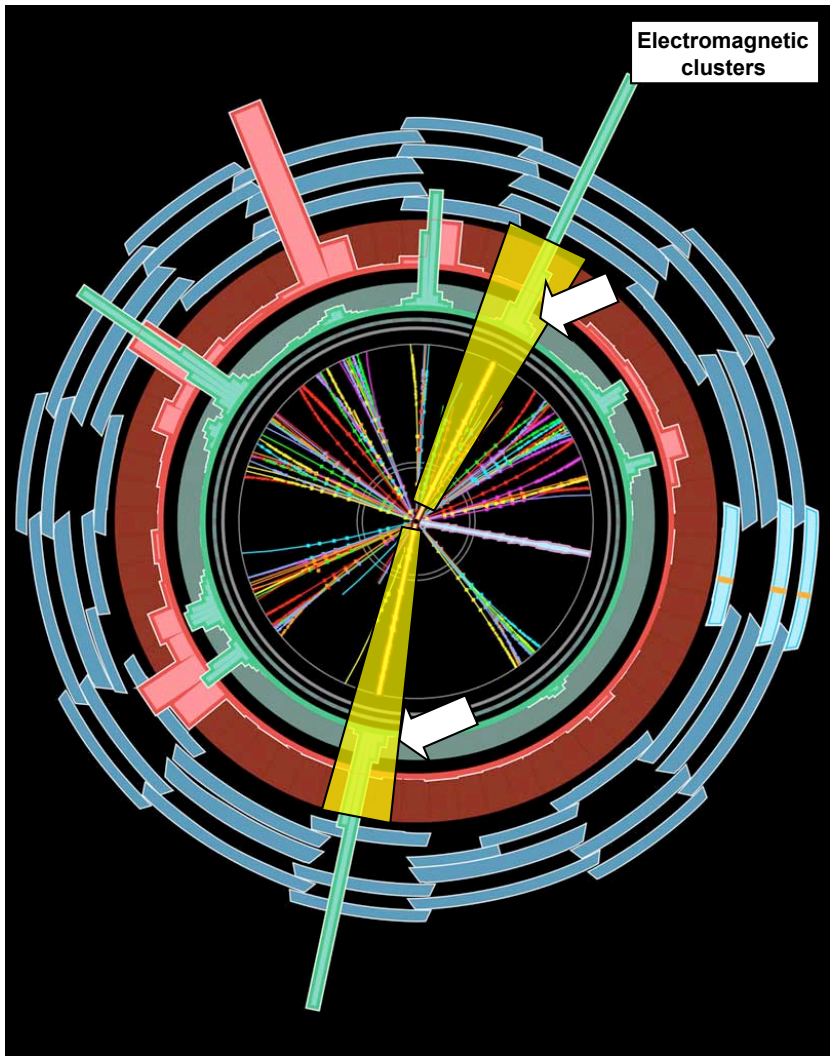
(*) 8CPU (four-core dual-socket farm nodes at ~2GHz

Architecture



Selection method

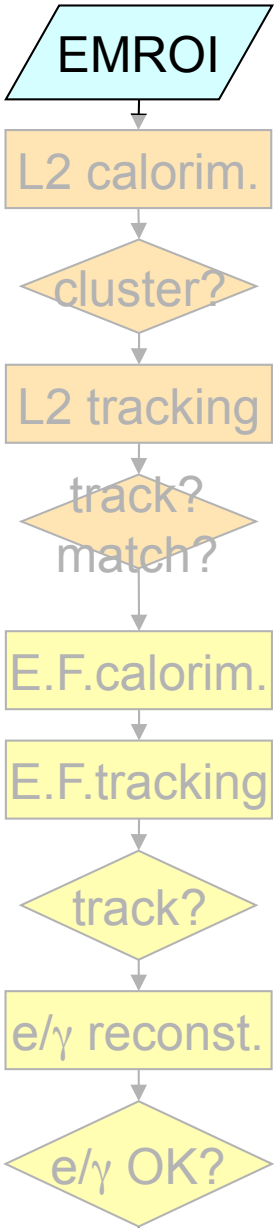
Event rejection possible at each step



Level1 **Region of Interest** is found and position in EM calorimeter is passed to Level 2

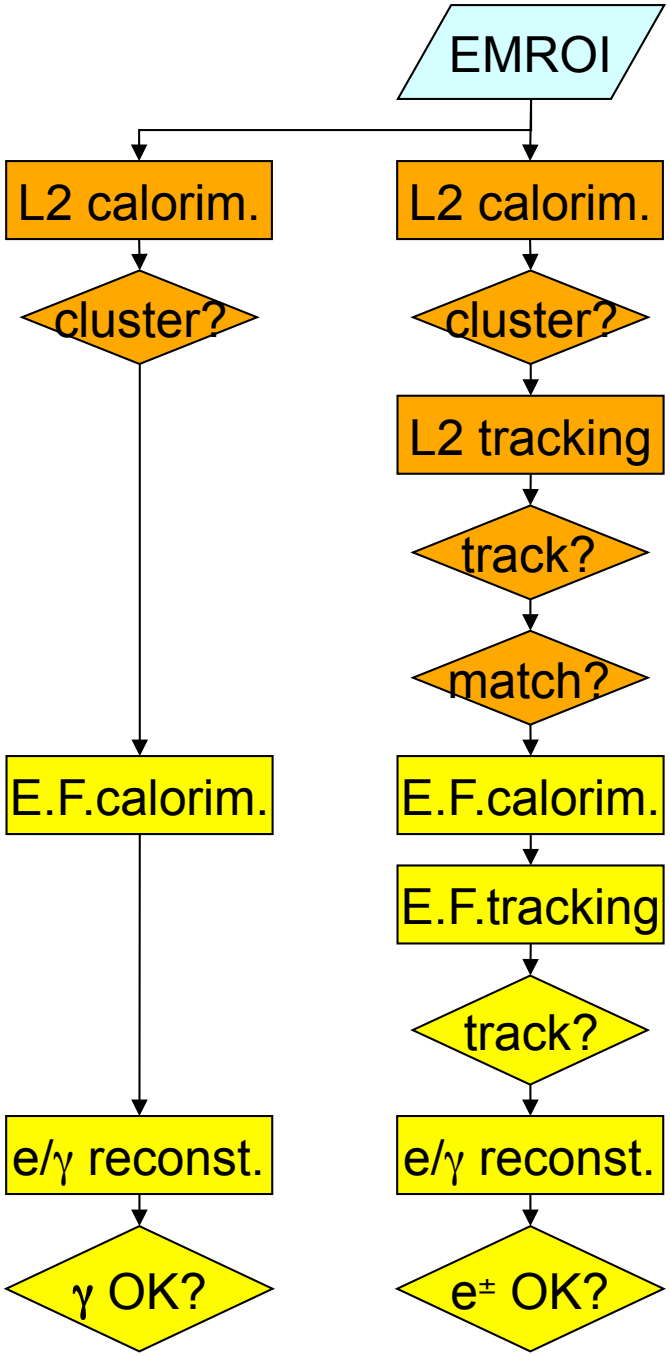
Level 2 seeded by Level 1
Fast reconstruction algorithms
Reconstruction within RoI

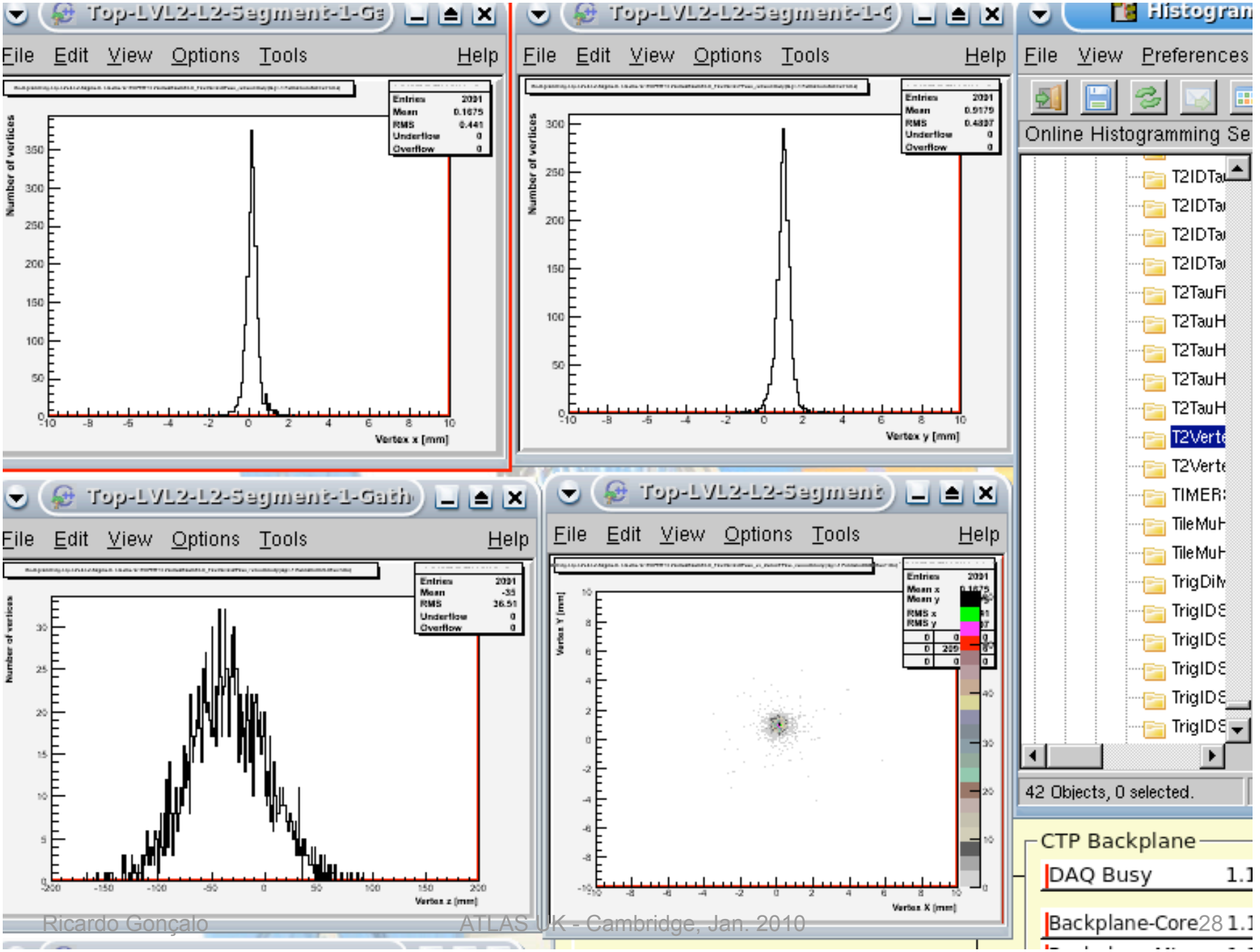
Ev.Filter seeded by Level 2
Offline reconstruction algorithms
Refined alignment and calibration

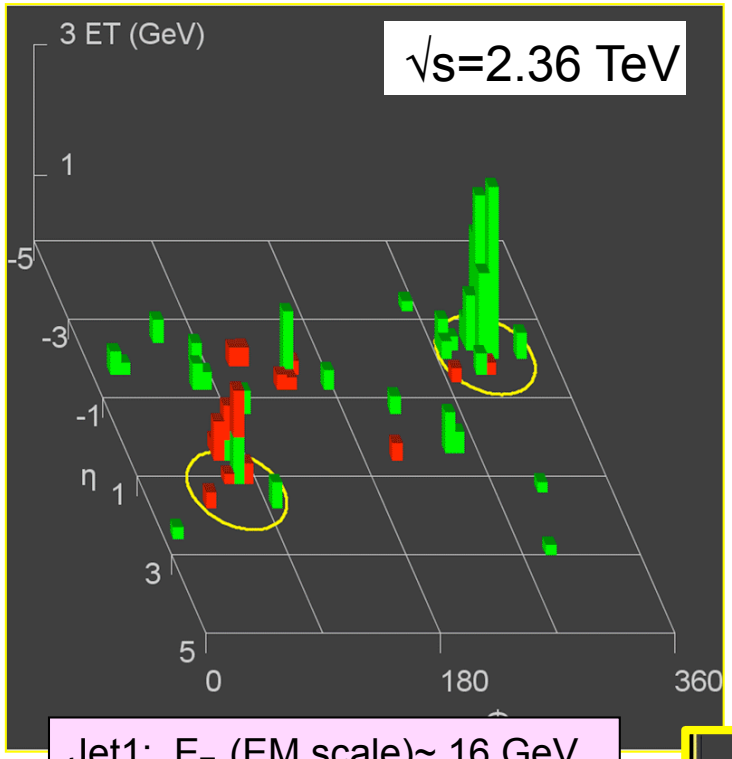


Steering

- Algorithm execution managed by Steering
  - Based on static trigger configuration
  - And dynamic event data (RoIs, thresholds)
- Step-wise processing and early rejection
  - Chains stopped as soon as a step fails
  - Reconstruction step done only if earlier step successful
  - Event passes if at least one chain is successful
- Prescale (1 in N successful events allowed to pass) applied at end of each level
- Specialized algorithm classes for all situations
  - Topological: e.g. 2 μ with $m_{\mu\mu} \sim m_Z$
  - Multi-objects: e.g. 4-jet trigger, etc…

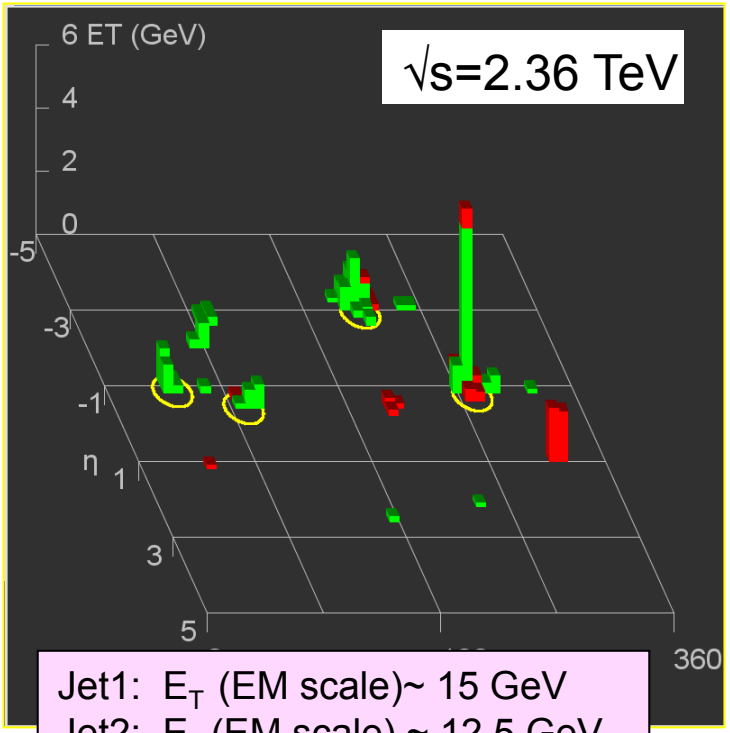



Top-LVL2-L2-Segment-1-Gs
File Edit View Options Tools Help
Entries 2091
Mean 0.1675
RMS 0.441
Underflow 0
Overflow 0
Number of vertices
Vertex x [mm]
Top-LVL2-L2-Segment-1-G
File Edit View Options Tools Help
Entries 2091
Mean 0.9179
RMS 0.4837
Underflow 0
Overflow 0
Number of vertices
Vertex y [mm]
Histogram
File View Preferences
Online Histogramming Se
T2IDTa
T2IDTa
T2IDTa
T2IDTa
T2TauFi
T2TauH
T2TauH
T2TauH
T2TauH
T2Verte
T2Verte
TIMER
TileMuH
TileMuH
TrigDiM
TrigIDS
TrigIDS
TrigIDS
TrigIDS
TrigIDS
42 Objects, 0 selected.
Top-LVL2-L2-Segment-1-Gath
File Edit View Options Tools Help
Entries 2091
Mean -35
RMS 36.51
Underflow 0
Overflow 0
Number of vertices
Vertex z [mm]
Top-LVL2-L2-Segment
File Edit View Options Tools Help
Entries 2091
Mean x 0.1675
Mean y
RMS x
RMS y
Vertex Y [mm]
Vertex X [mm]
CTP Backplane
DAQ Busy 1.1
Backplane-Core28 1.1

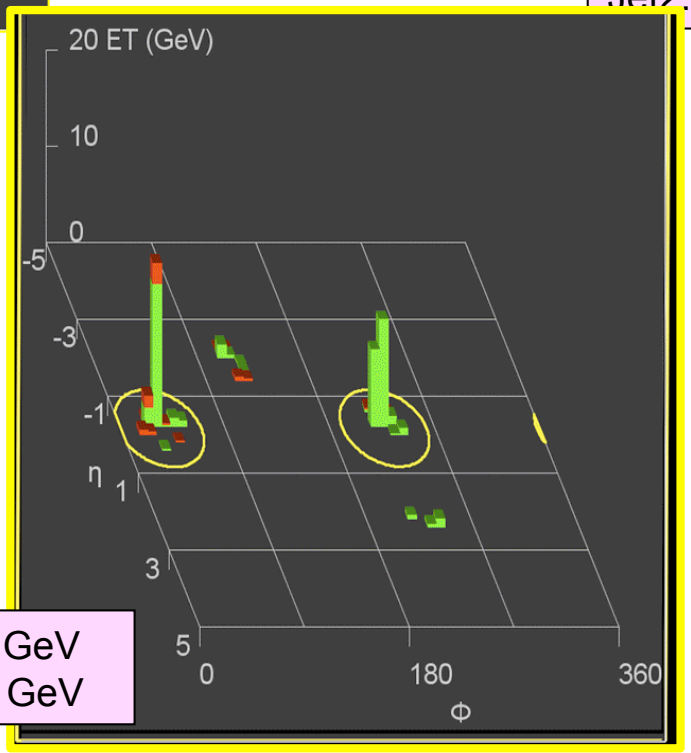


Jet1: E_T (EM scale)~ 16 GeV
Jet2: E_T (EM scale) ~ 6 GeV

Jets



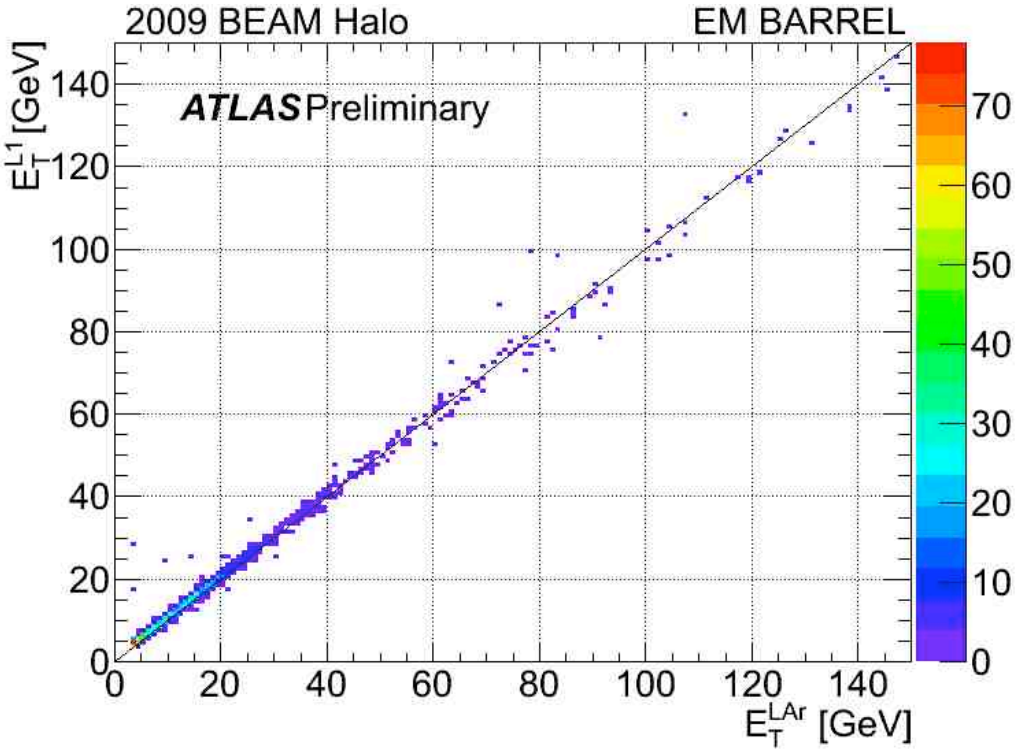
Jet1: E_T (EM scale)~ 15 GeV
Jet2: E_T (EM scale) ~ 12.5 GeV



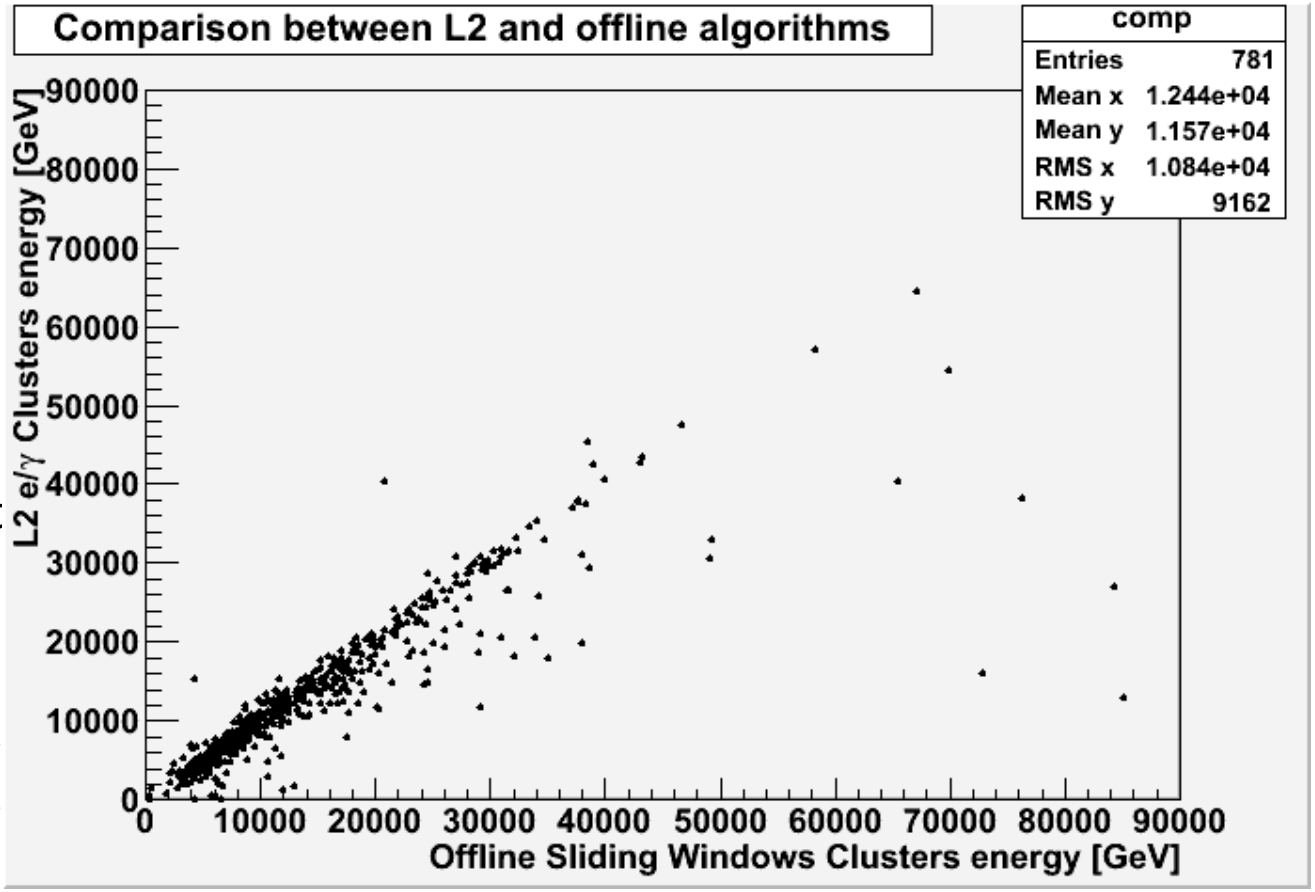
Jet1: E_T (EM scale)~ 37 GeV
Jet2: E_T (EM scale) ~ 37 GeV

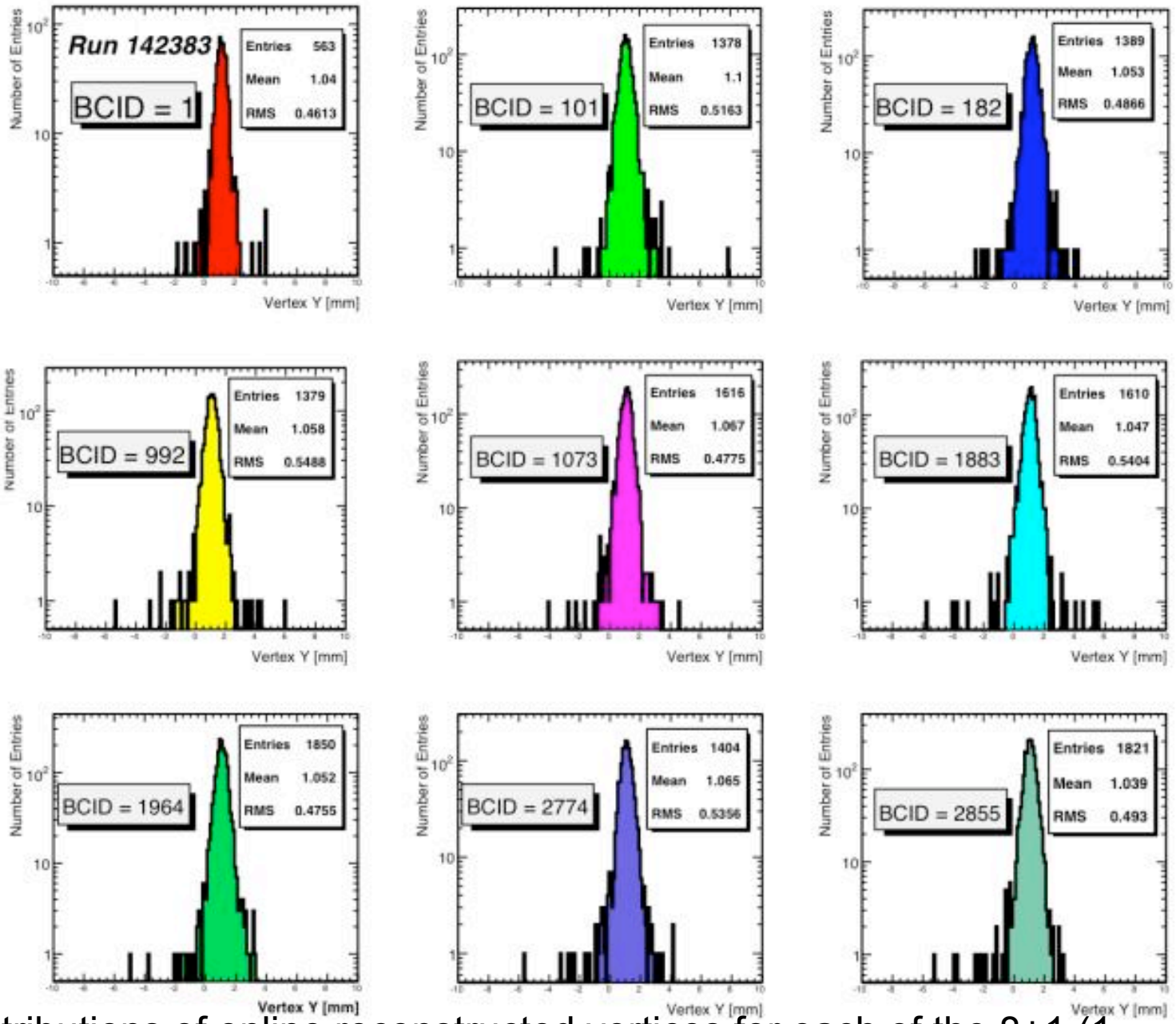
F.Gianotti

LVL1 CALO plots The entry in LVL1 Calo Et correlation to Offline plot is on Trigger Tower (0.1*0.1 in eta-phi range) bases, L1Et is calculated from the L1Calo ADC readout using (MaxADC-Pedestal)/4., which MaxADC is fitted by a parabola around the peak. And pedestal is calculated from recent run 136379 random events. LArgEt is the summation of energy from the cells connected to the corresponding trigger tower, convert to transverse energy. Trigger Towers with both L1Et and LArgEt greater than 3 GeV are kept. The resolution of LVL1 Calo Et with respect to LArgEt is divieded into LArgEt bin [3,5],[5,9],[9,17],[17,33], [33,65]GeV, and in each bin, the resolution fitted by a Gaussion. These plots are produced from data09_1beam physics_L1Calo.



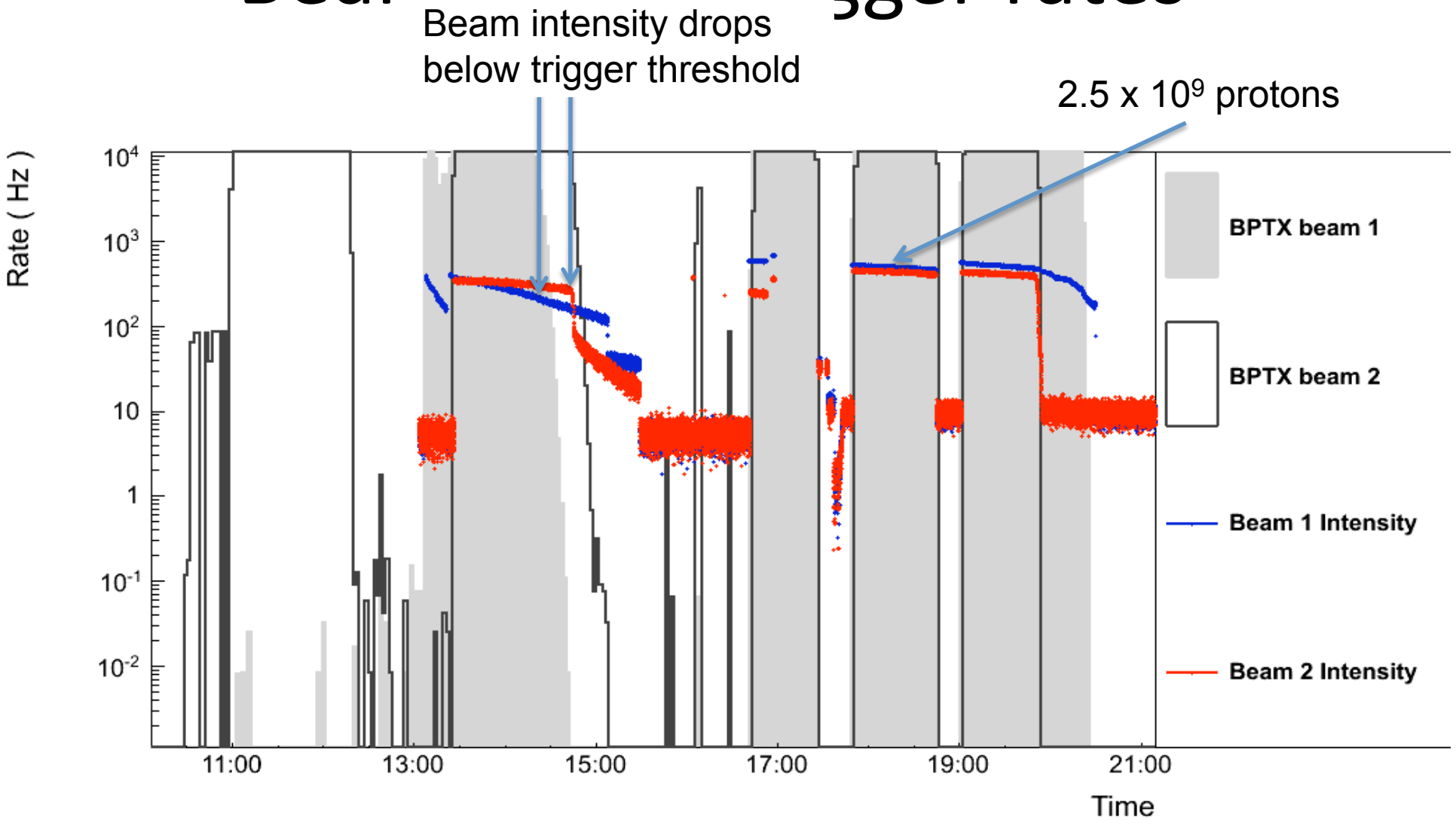
- Offline to L2 egamma comparison of the clusters energy.
- Differences understoo to come from offline over-correction for clusters with higher energy in the back of t cluster.
- Accumulation of runs 142144, 142149, 1421 142171, 142191, 1421 142195, 142383



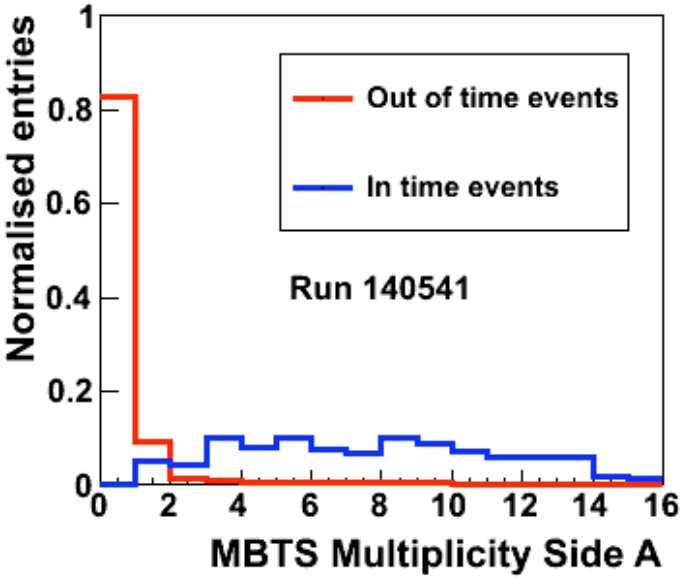


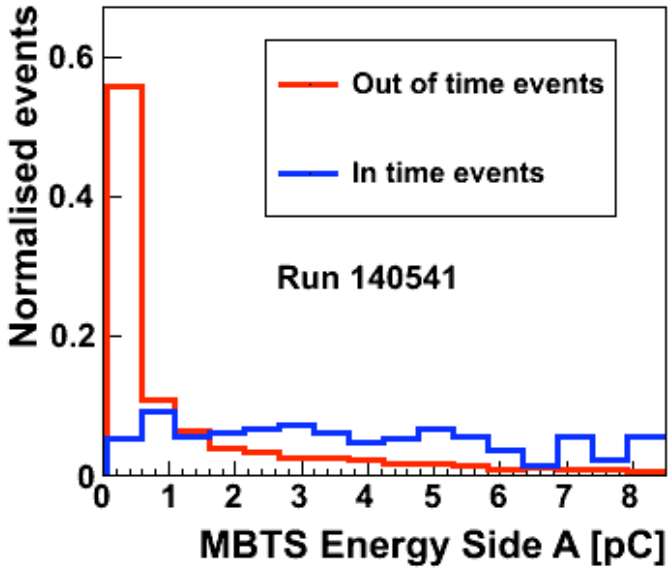
Y distributions of online reconstructed vertices for each of the 8+1 (1 pilot bunch) pairs of colliding bunches separately. No evidence for shifts beyond the few x10 um level.

Beam pickup trigger rates

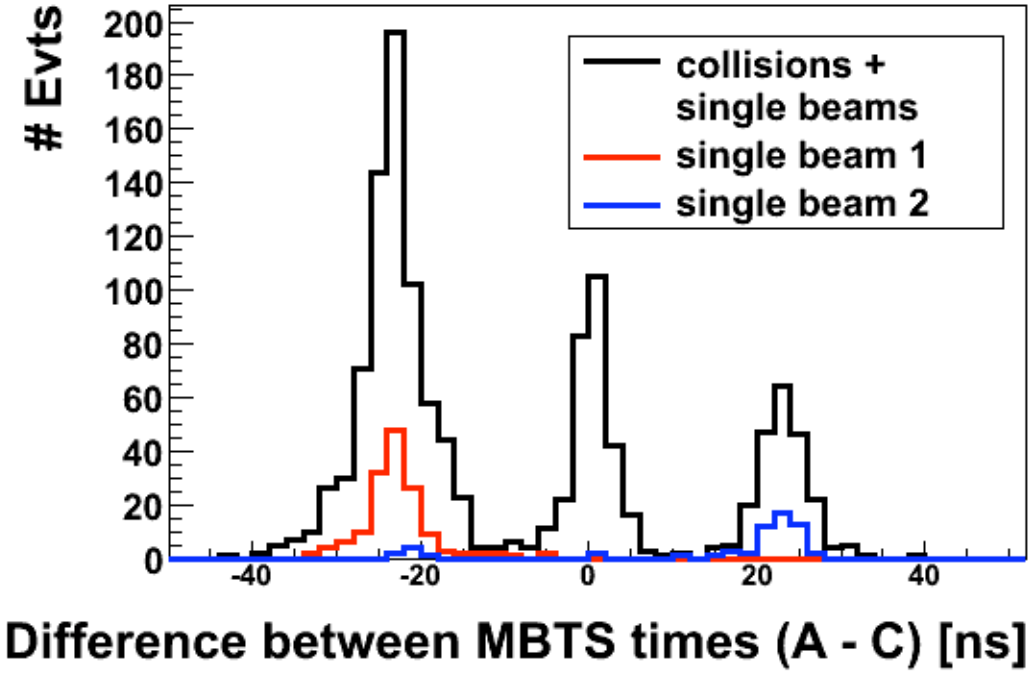


Beam related MBTS data





Readout timing information



In time: +- 10 ns
Out of time: the rest