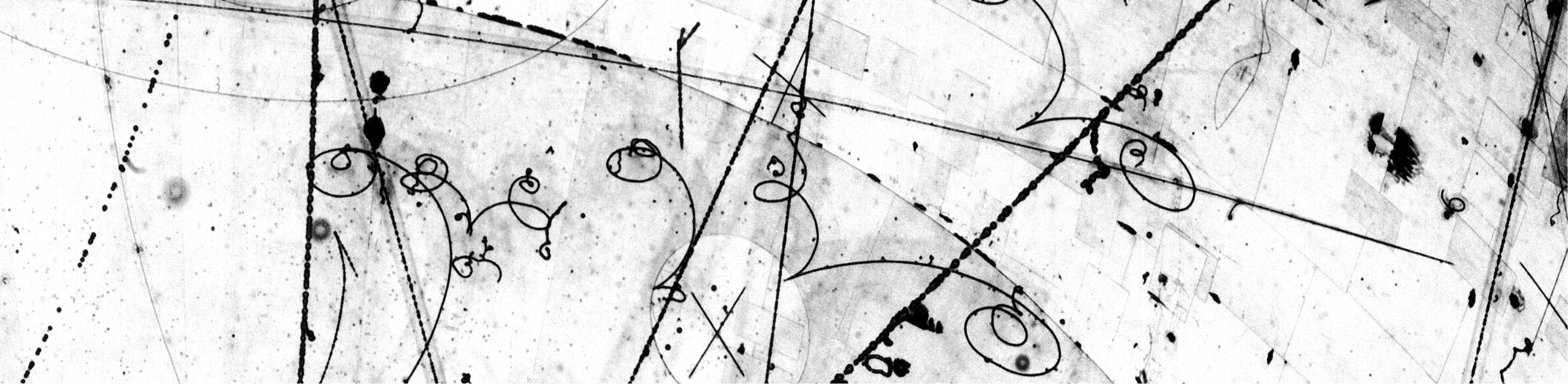
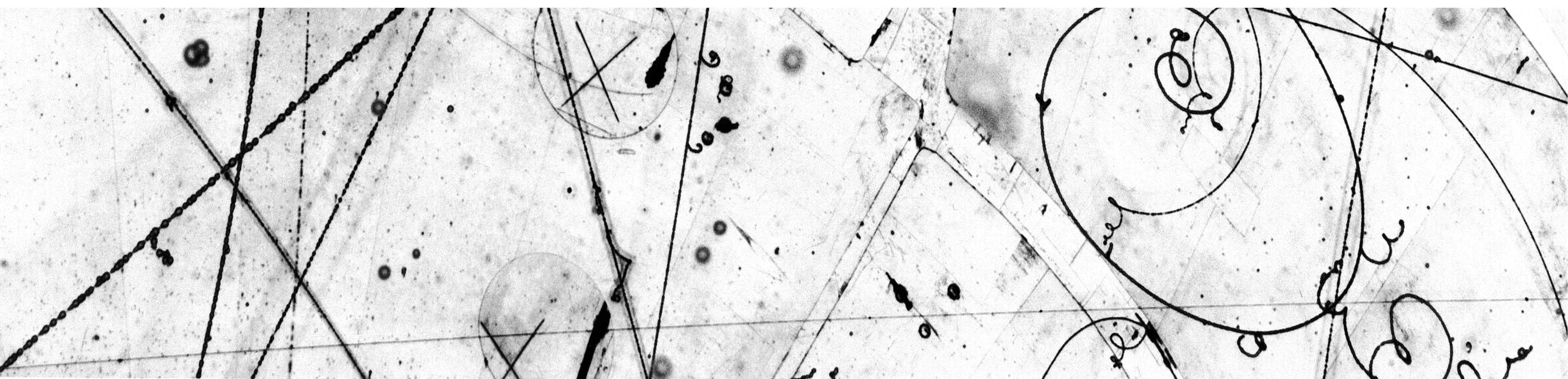
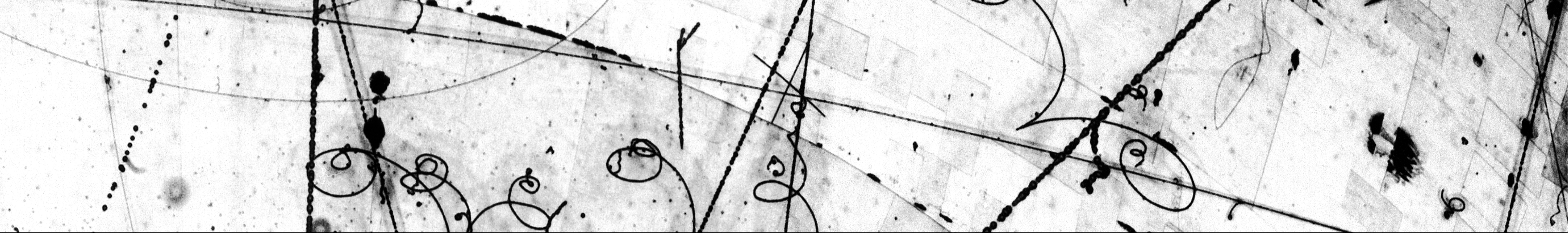


Trigger and Data Acquisition (II)

Brigitte Vachon (McGill)

HCPSS 2010



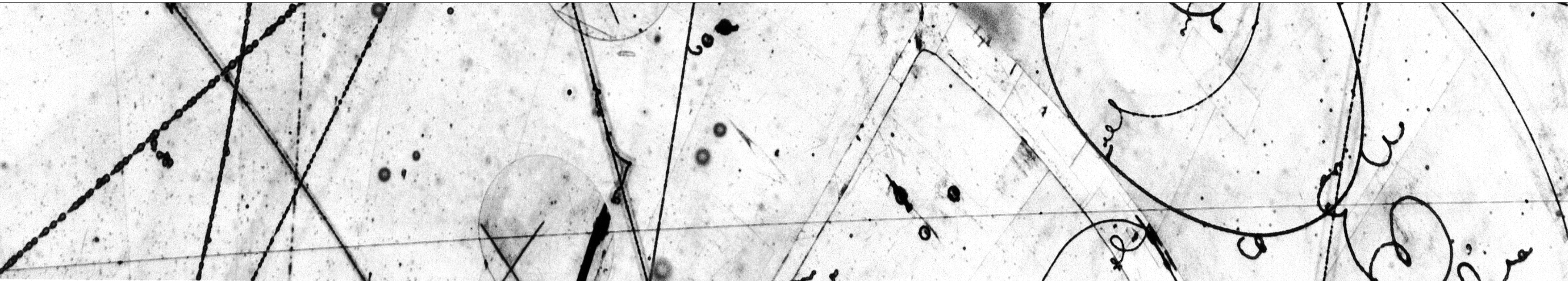


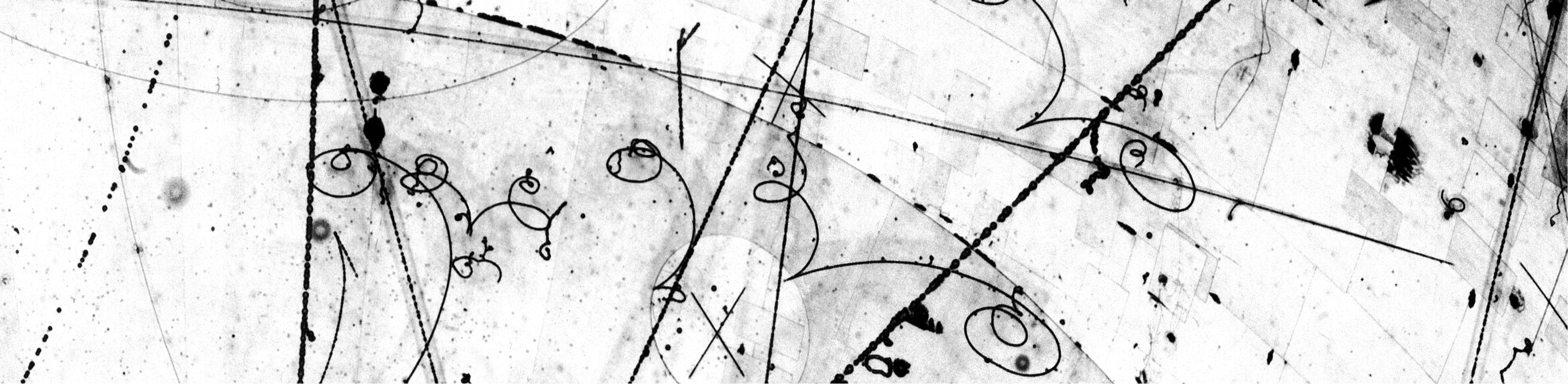
Part-I

- Introduction
- Trigger and Data Acquisition Basics

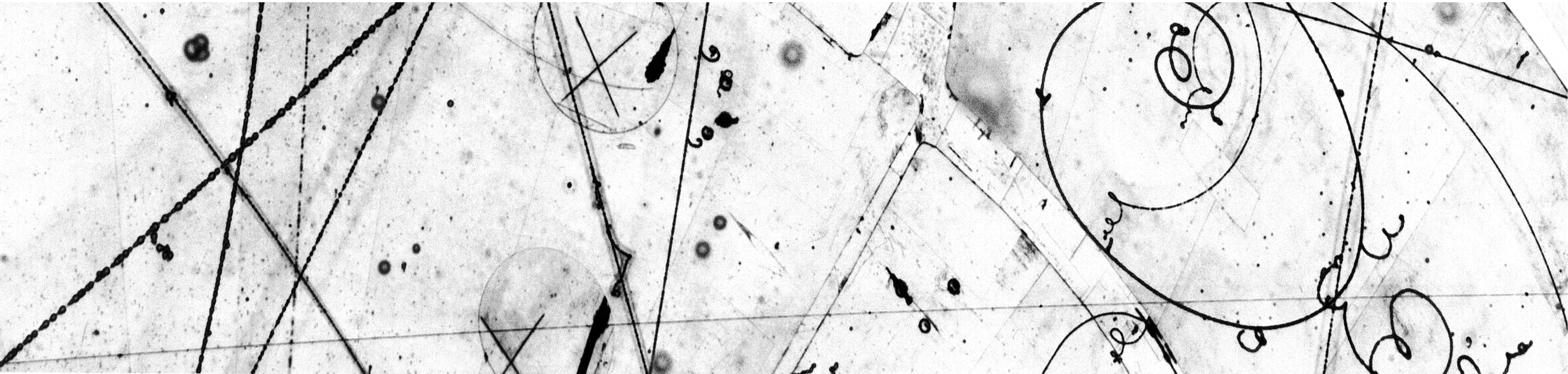
Part-II

- System Commissioning
- Trigger Selection
  - Electron and Jets
  - Muons
  - Secondary vertex
- Trigger Menu Design





Trigger/DAQ Commissioning



Trigger/DAQ Commissioning

The trigger and DAQ system is the “nervous system” of an experiment. It is very complex and relatively fragile.

Any problems with the system will have a big impact on the experiment as a whole.

The trigger system is also a system where subdetectors can have a large impact on each other.

First line of defence where big problems are usually spotted (ex. hot cells in the calorimeter leading to unacceptable high trigger rate)

However, it is typically very hard to detect problems at the < 1% level

Trigger/DAQ Commissioning

Start by testing/commissioning individual components of the system, then work on integration of all the different parts.

Use teststand/testbeam

- Useful to a certain extent, but setup does not represent exactly the real complete system

Inject test patterns at different points in the trigger/DAQ dataflow

- Can only test for a limited set of patterns or patterns you can think of..
- Tests only part of the system

Read out "noise"

- Events are either very small or very large (with no zero suppression)

Record cosmics data

- Detectors designed to record events that happen at specific times and particles originating from the Interaction region.
- Special trigger-DAQ configuration not exactly that of the designed system

Use single beam running and first collisions

- Useful for system timing and overall system integration
- Sometimes limited statistics

Trigger Simulation

- Verify trigger decision (in firmware and software)

Experience from the field...

Can't fully debug trigger and readout stage until downstream system can take the full rate

Never under-estimate the hardware's ability to do “interesting” thing!

- designer usually cannot thing of all possible conditions a system may have to face
- interactions with other systems can lead to unforeseen conditions
- forgotten debugging information or small changes for specific tests

Experts move on to other jobs. Corollary: There's rarely too many experts on a system.

Never have too many diagnostic/debugging tools

T/DAQ Diagnostic Tools

You never have too many diagnostic tools!

(diagnostic tools ≠ monitoring tools)

Need to be able to examine data at any interface

- for example, look at hex dumps

Need the ability to dump status registers of any type of hardware

Need to be able to inject test patterns at different points in T/DAQ chain

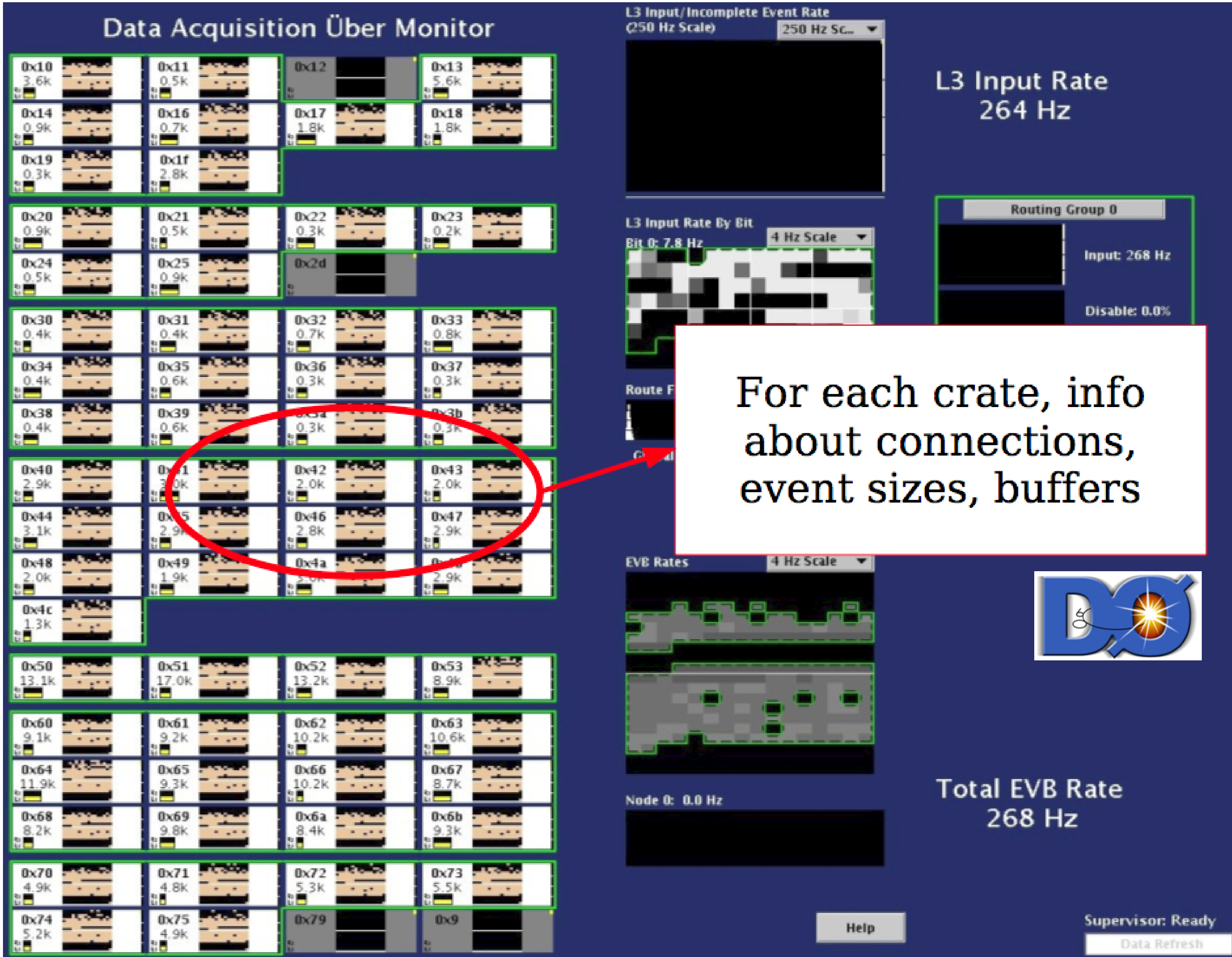
All firmware/software code need to be clear and well-documented

Dataflow GUI are very useful (if well designed...)

- see where the data is stuck
- see instantaneous and averaged buffer occupancy
- etc.

Dataflow GUI (DØ)

Slide from G. Brooijmans



For each crate, info about connections, event sizes, buffers

Timing-In Trigger and Detector

Slide from A. Hoecker

Cannot reconstruct useful data before timing-in of all detector systems

Adjust timing and delays to ensure that all data shipped with an event belong to same bunch-crossing (BC) ID and L1-accept (L1A) ID

Timing-in requires 4 adjustments (all systems)

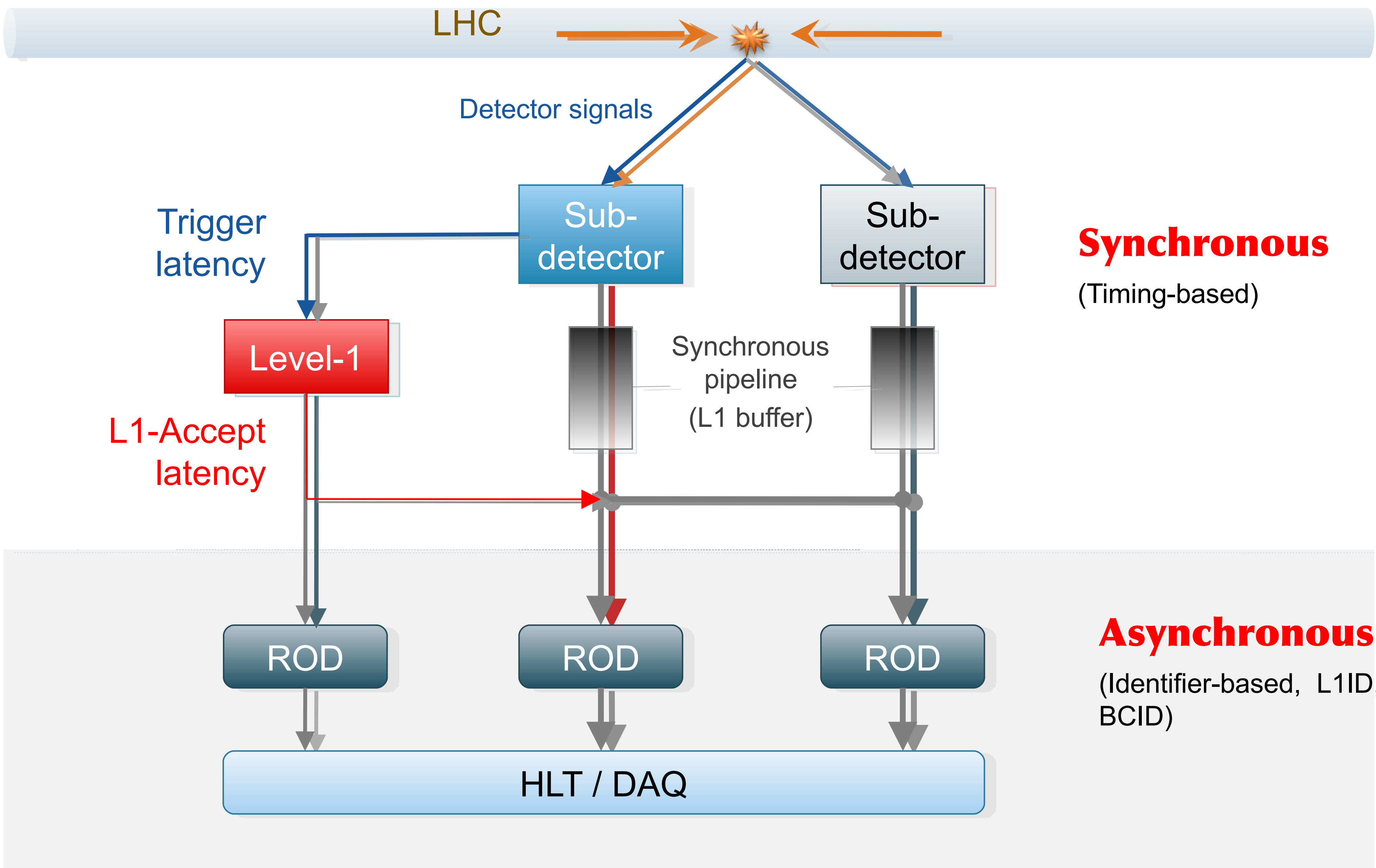
1. Data forming: clock phase between bunch crossing and detector signals
2. Data alignment: in steps of 25 ns
3. BCID identification: individually adjust BC reset delay
4. Readout alignment: individually adjust L1Accept delay in steps of 25 ns

[Steps 2–4 partially known from cosmics commissioning, delay calculations/measurements, test pulses]

Timing depends on run configuration (cosmics, single beam, collisions)

Detector and Trigger Timing

Slide from A. Hoecker



Synchronous

(Timing-based)

Asynchronous

(Identifier-based, L1ID, BCID)

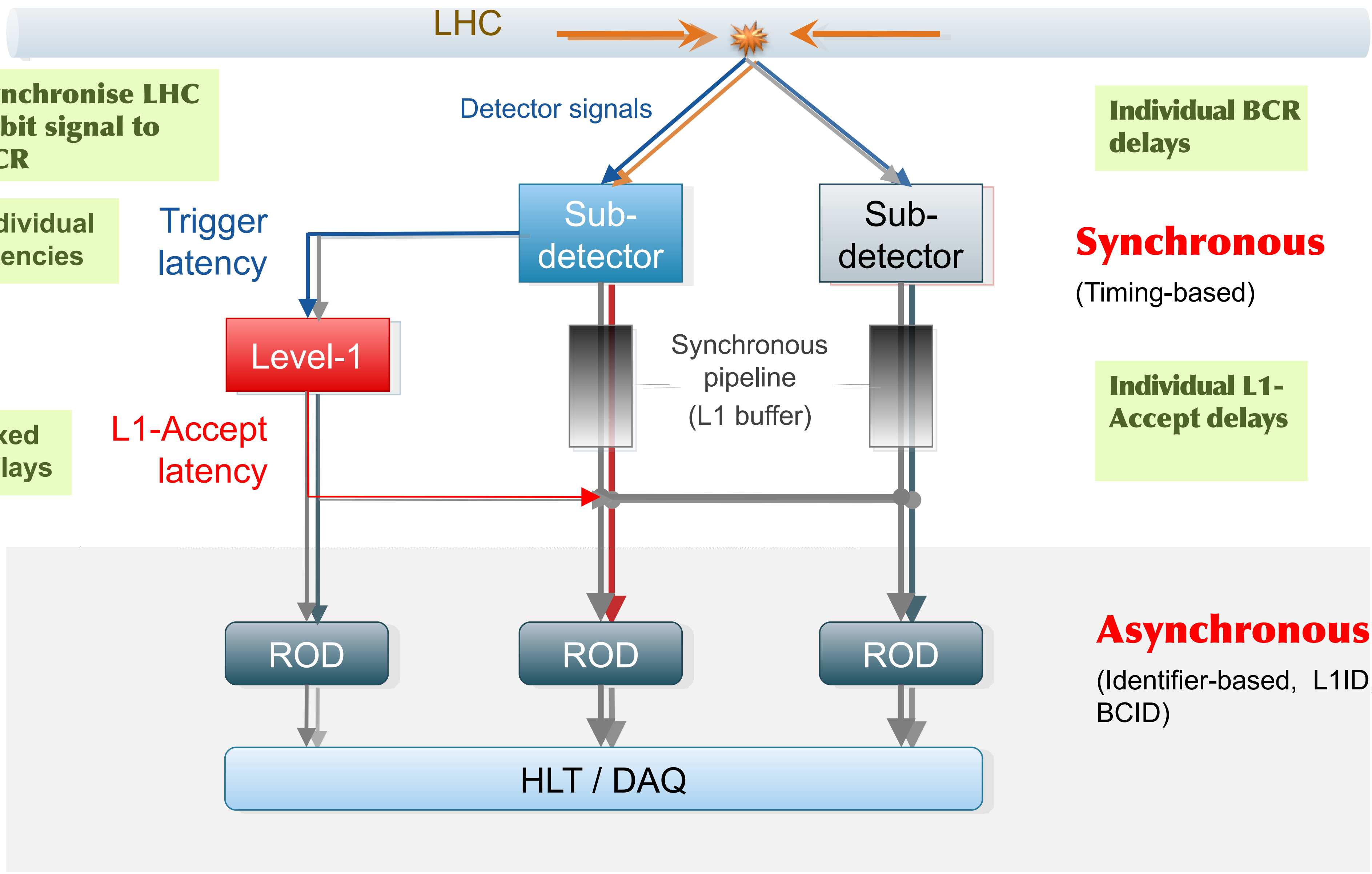
Detector and Trigger Timing

Slide from A. Hoecker

Synchronise LHC orbit signal to BCR

Individual latencies

Fixed delays



Individual BCR delays

Synchronous

(Timing-based)

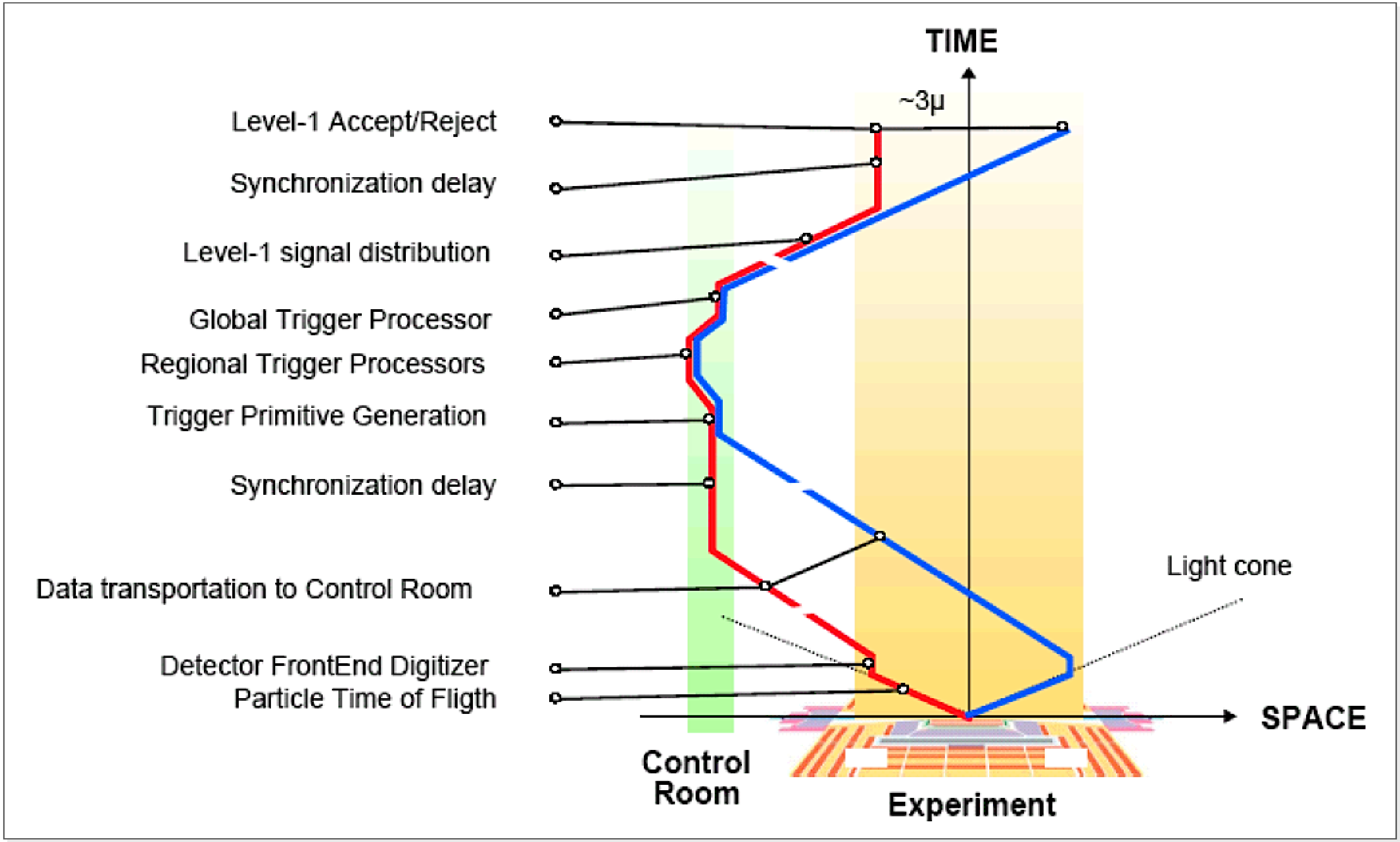
Individual L1-Accept delays

Asynchronous

(Identifier-based, L1ID, BCID)

Trigger Communication Loop (CMS)

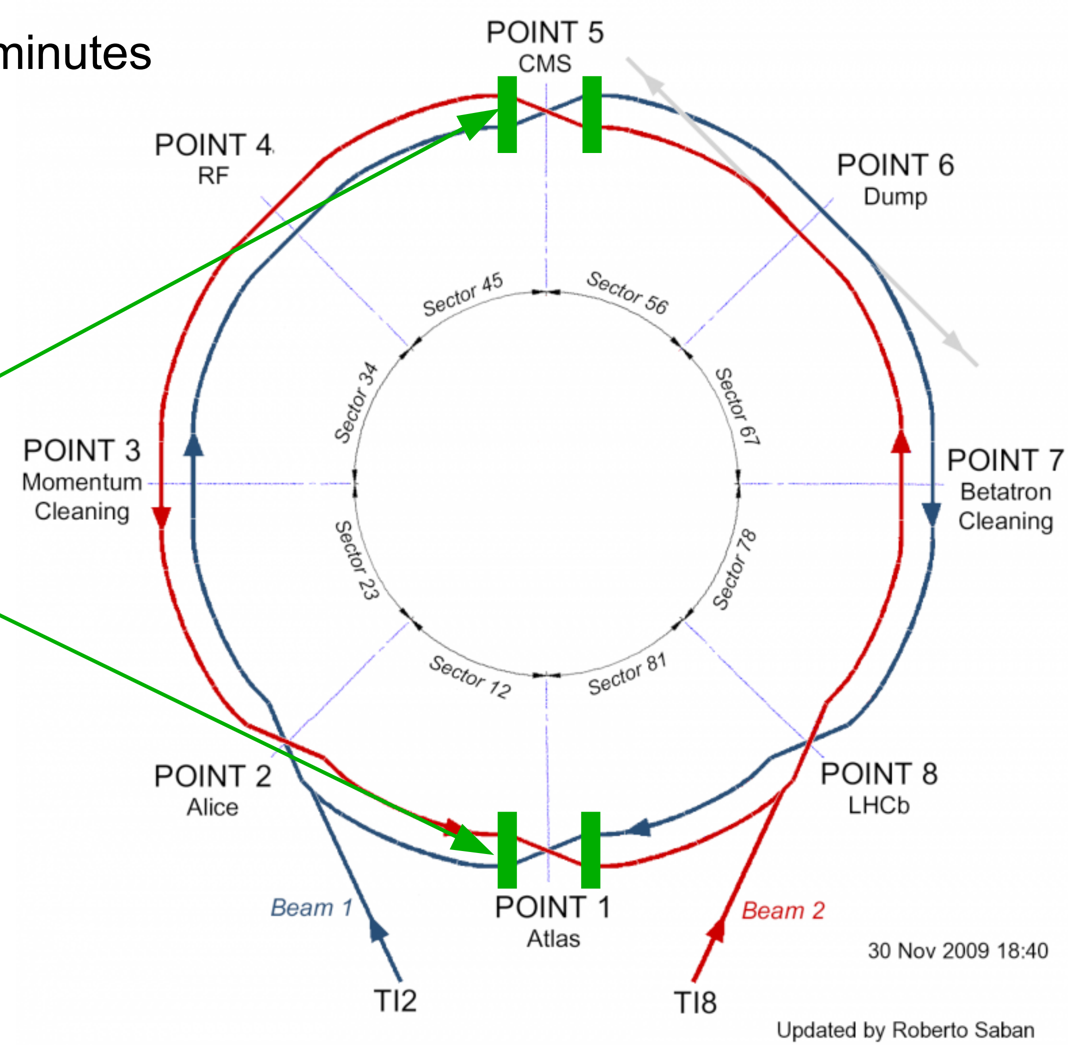
Slide from A. Hoecker



Ex: LHC commissioning with beam

10 September 2008, first beam in the LHC
No collisions (just single beam), no acceleration (injection energy)
Both beam directions, 1 bunch at a time, 450 GeV
Beam on collimators – “beam splash” events
Beam circulating for a few turns up to tens of minutes
Radio-frequency (RF) capture of bunch

Beam collimators at
± 140m of ATLAS and CMS

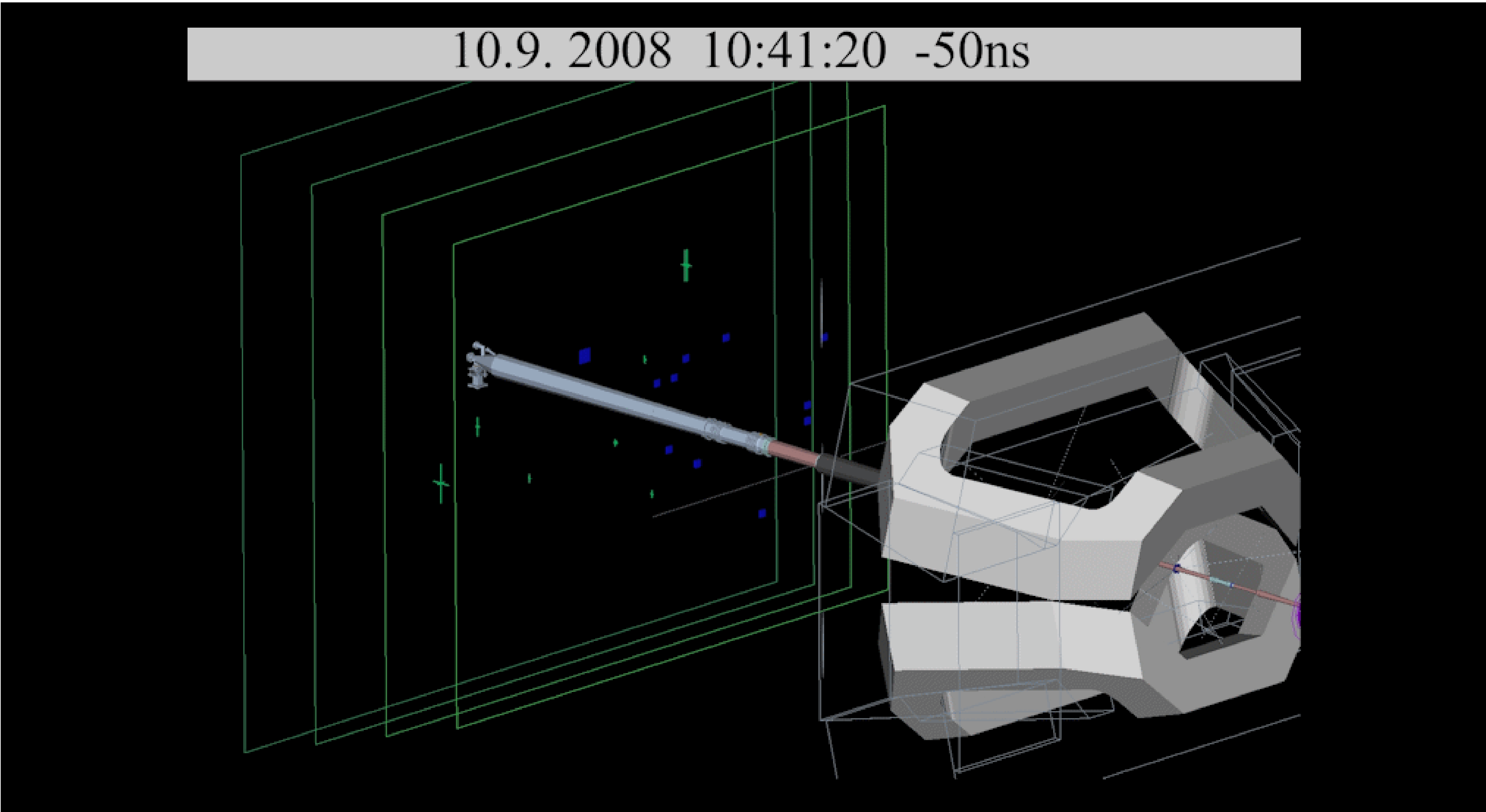


LHCb Event Display

Slide from A. Hoecker

Beam also stopped in front of, and passed by **LHCb** – here, only beam-1 is useful !

Collimator “splash” event read out with calorimeter and muon chambers



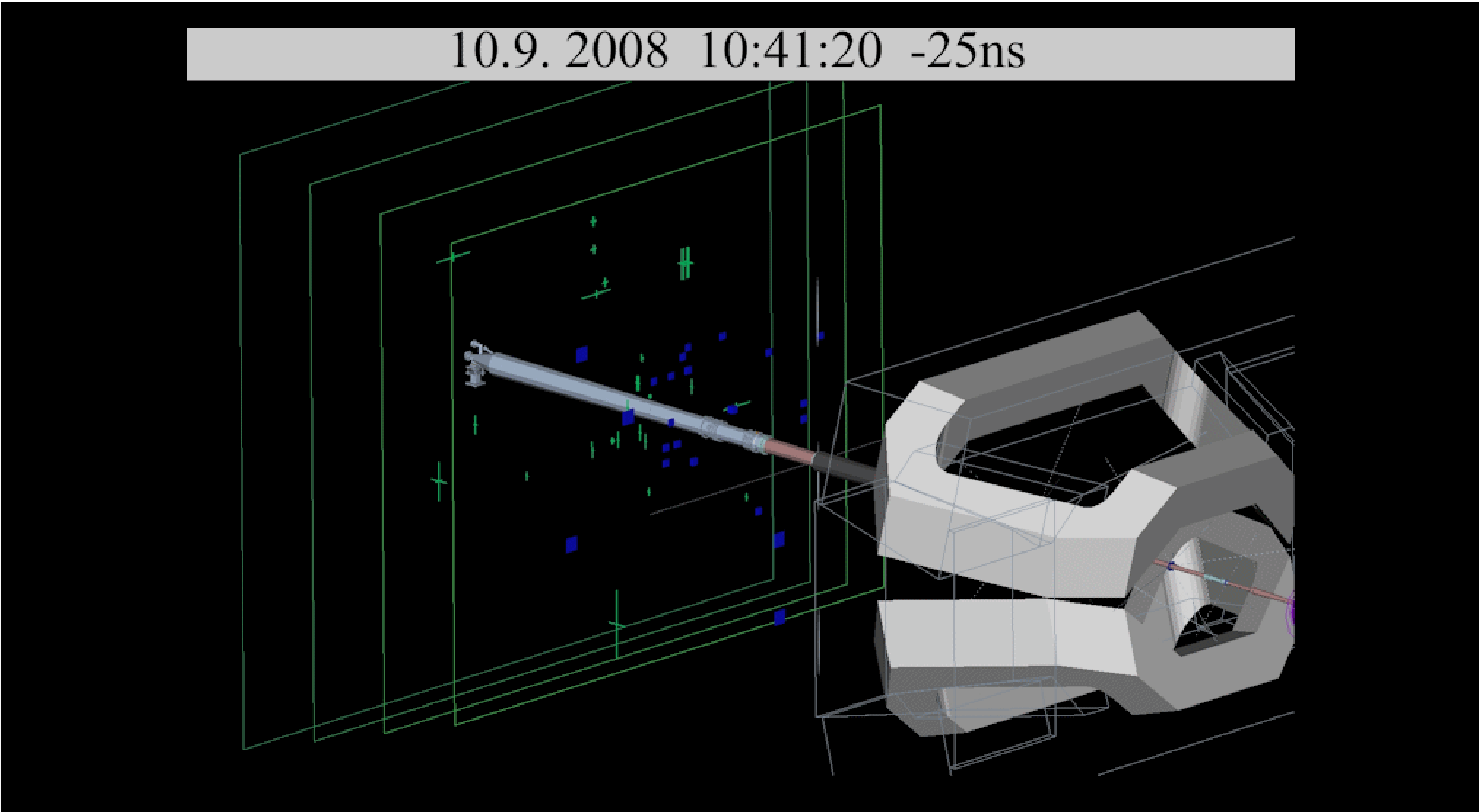
LHCb is capable of triggering and reading out up to 16 consecutive bunch crossings (every 25 ns)

LHCb Event Display

Slide from A. Hoecker

Beam also stopped in front of, and passed by **LHCb** – here, only beam-1 is useful !

Collimator “splash” event read out with calorimeter and muon chambers



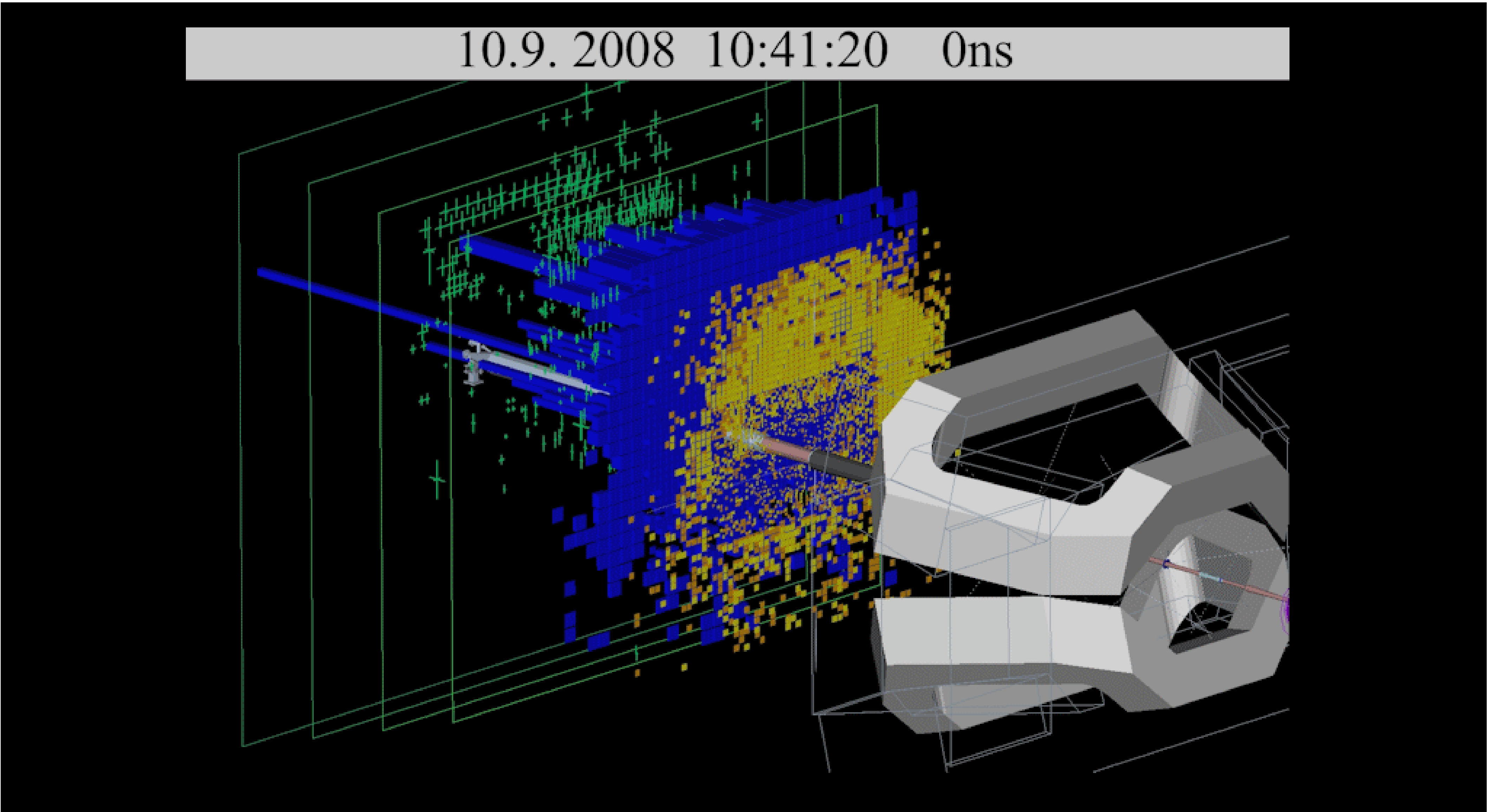
LHCb is capable of triggering and reading out up to 16 consecutive bunch crossings (every 25 ns)

LHCb Event Display

Slide from A. Hoecker

Beam also stopped in front of, and passed by **LHCb** – here, only beam-1 is useful !

Collimator “splash” event read out with calorimeter and muon chambers



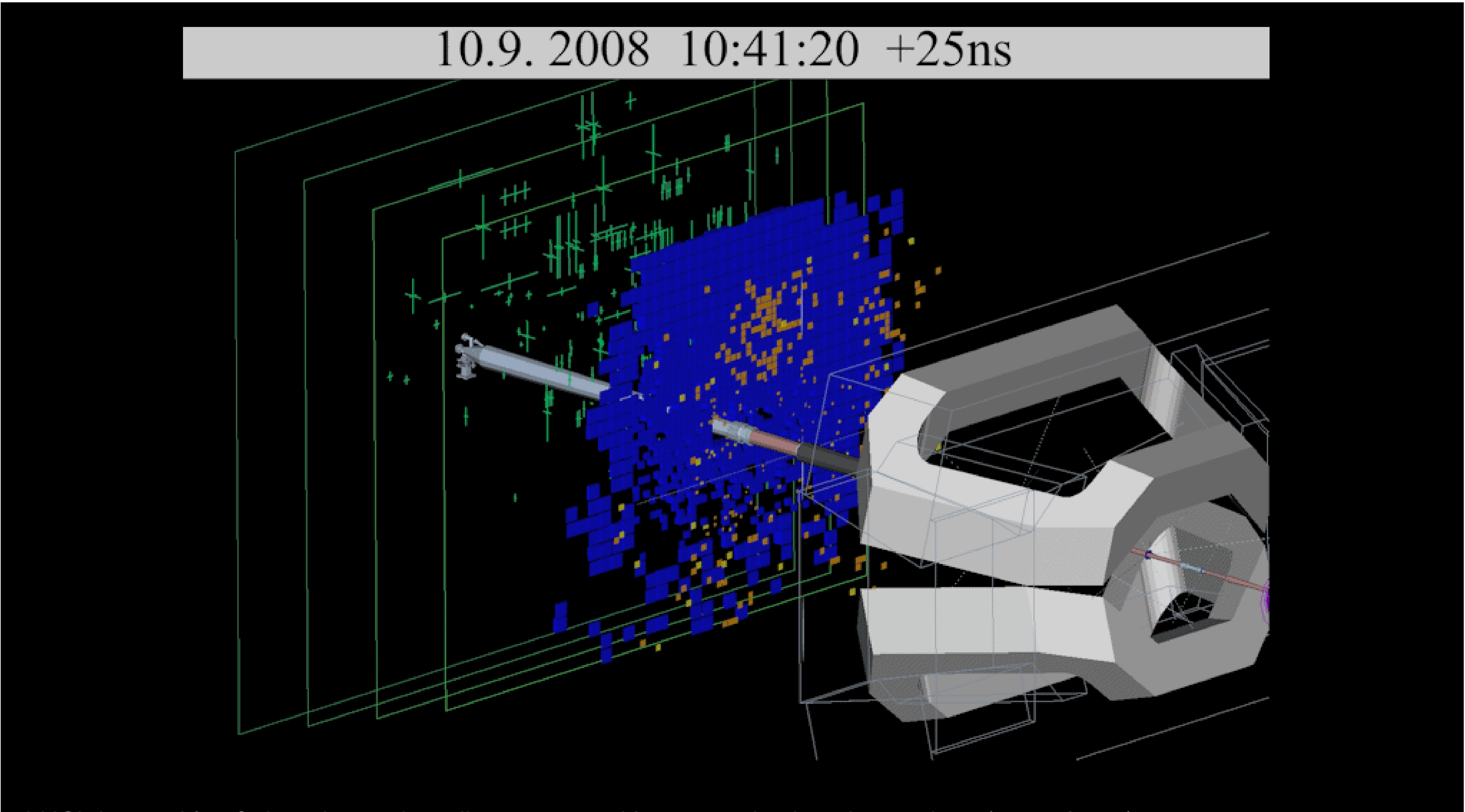
LHCb is capable of triggering and reading out up to 16 consecutive bunch crossings (every 25 ns)

LHCb Event Display

Slide from A. Hoecker

Beam also stopped in front of, and passed by **LHCb** – here, only beam-1 is useful !

Collimator "splash" event read out with calorimeter and muon chambers



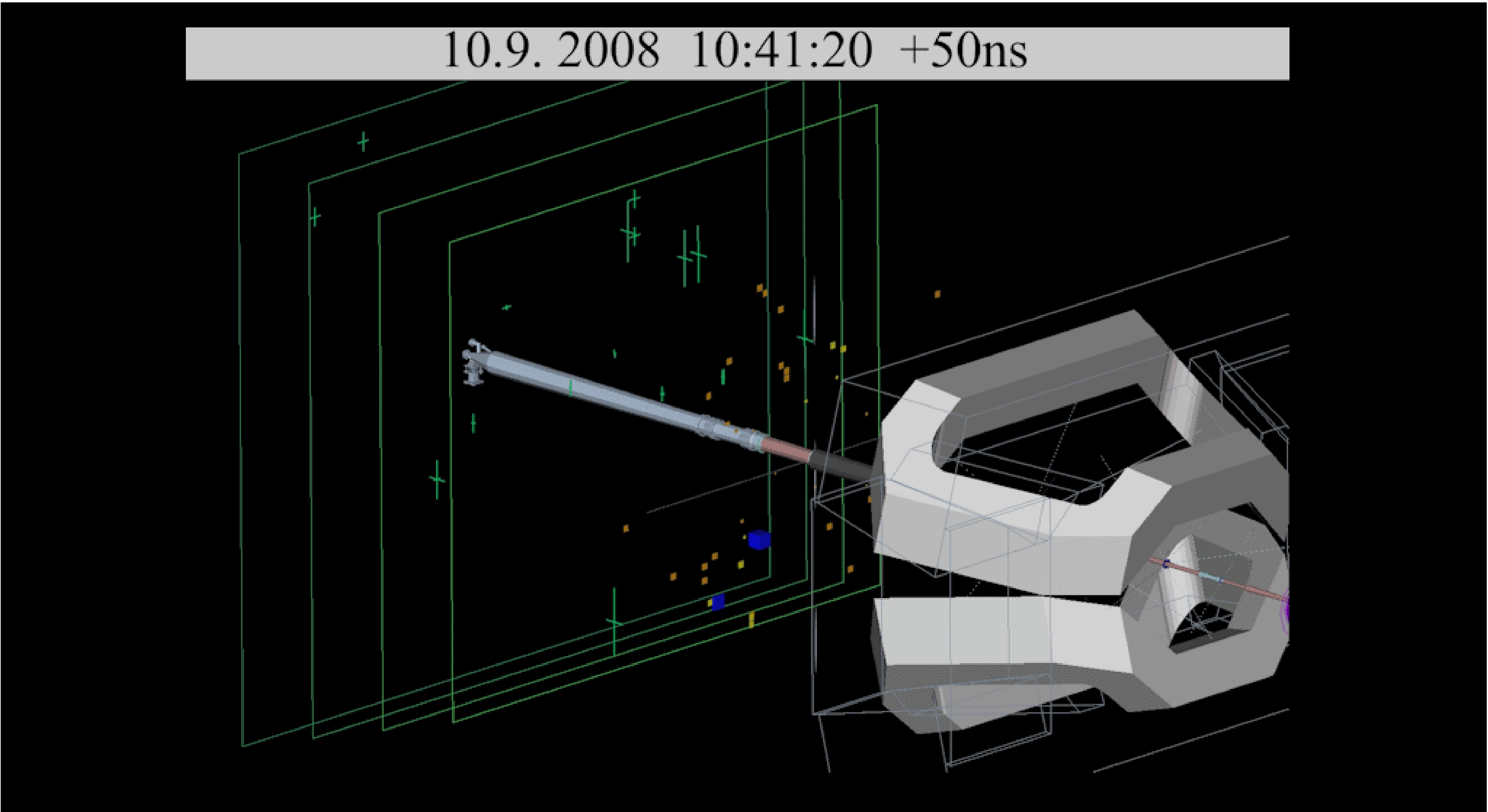
LHCb is capable of triggering and reading out up to 16 consecutive bunch crossings (every 25 ns)

LHCb Event Display

Slide from A. Hoecker

Beam also stopped in front of, and passed by **LHCb** – here, only beam-1 is useful !

Collimator "splash" event read out with calorimeter and muon chambers



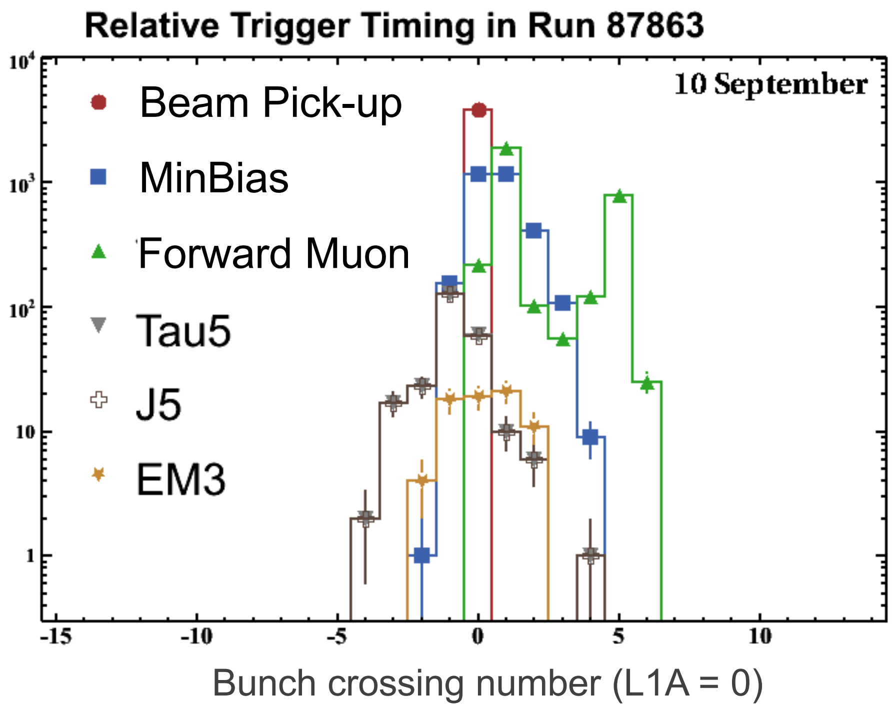
LHCb is capable of triggering and reading out up to 16 consecutive bunch crossings (every 25 ns)

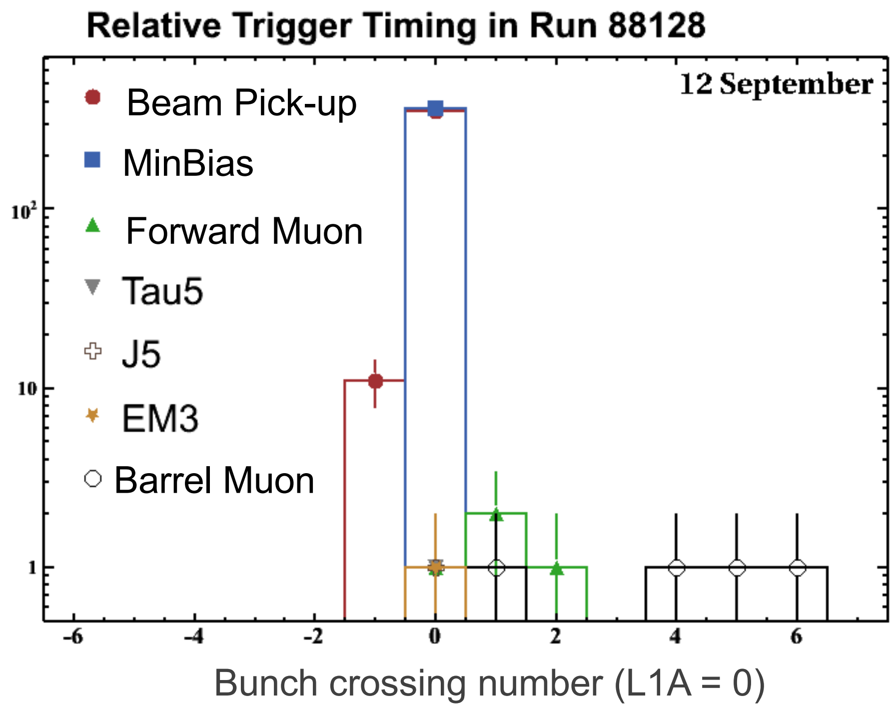
ATLAS Trigger Timing

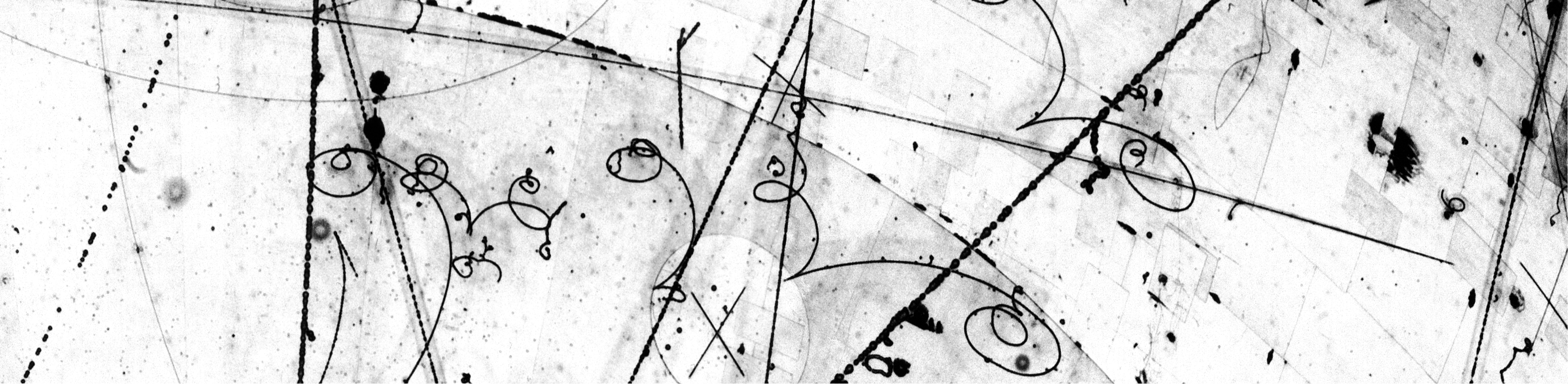
Progress in trigger timing alignment between 10 and 12 September 2008

Relative time of arrival of different inputs to the trigger with respect to Level-1 accept signal.

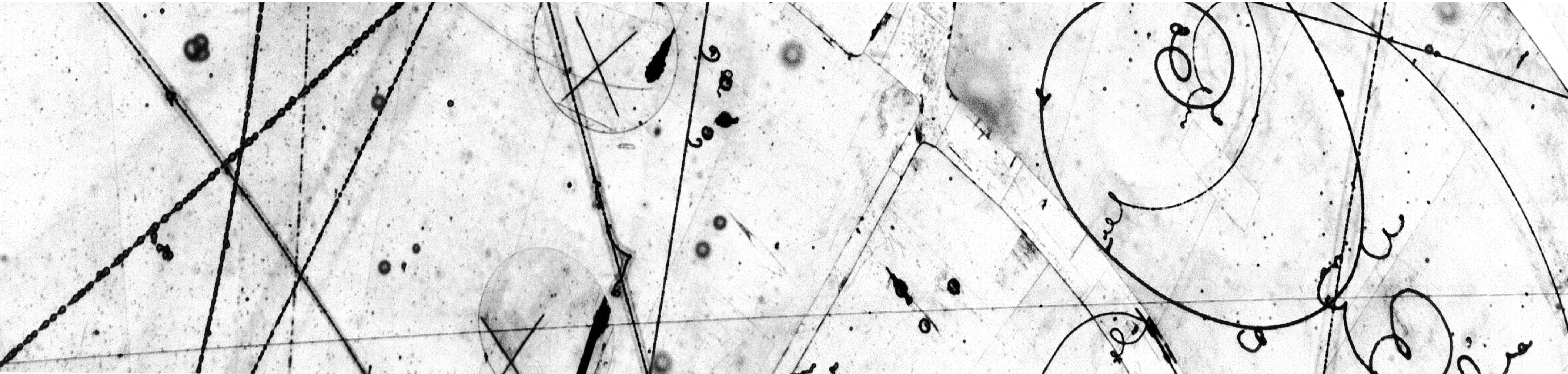
Improvements from ToF corrections and adjustements of relative timing of triggers from different parts of the detector or from different detector channels.







Trigger selection



LHC Physics Program

Mass

Search for the Higgs boson

Electroweak unification

Precision measurements (M_W, m_{top}) and tests of the Standard Model

Hierarchy in the TeV domain

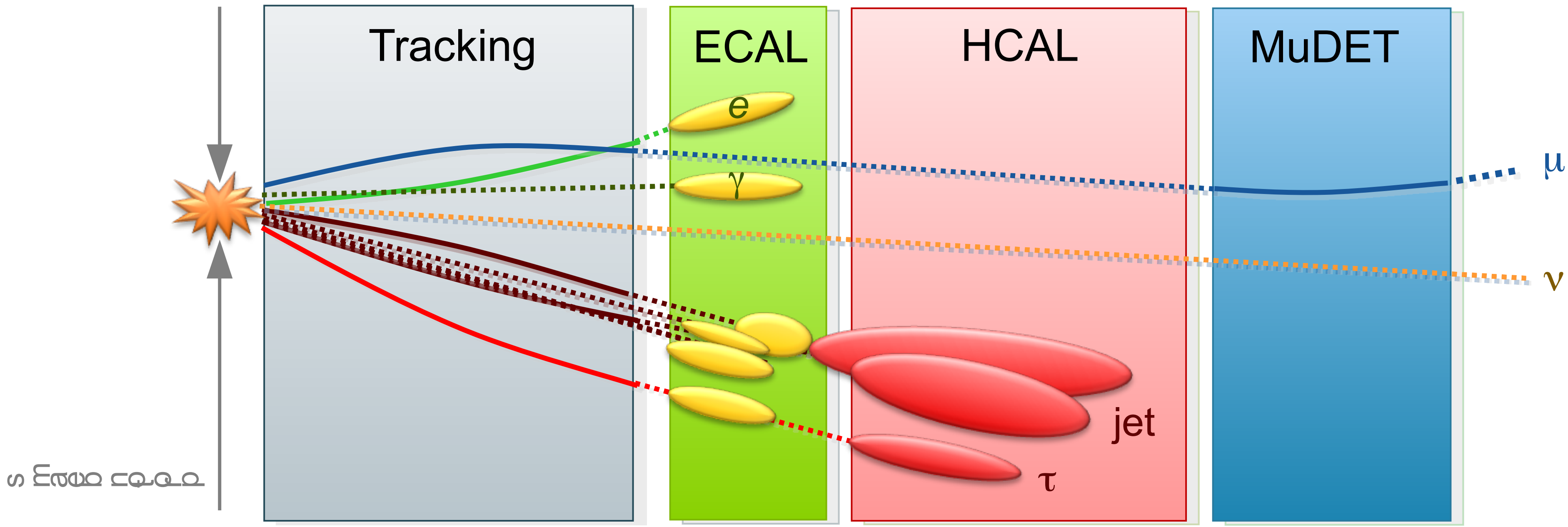
Search for Supersymmetry, Extra dimensions, Higgs composites, …

Flavour

B mixing, rare decays and *CP* violation as tests of the Standard Model

Trigger systems in the general-purpose proton–proton experiments, ATLAS and CMS, have to retain as many as possible of the events of interest for the diverse physics programs of these experiments.

Particle Identification



Features distinguishing new physics from the bulk of the SM cross-section

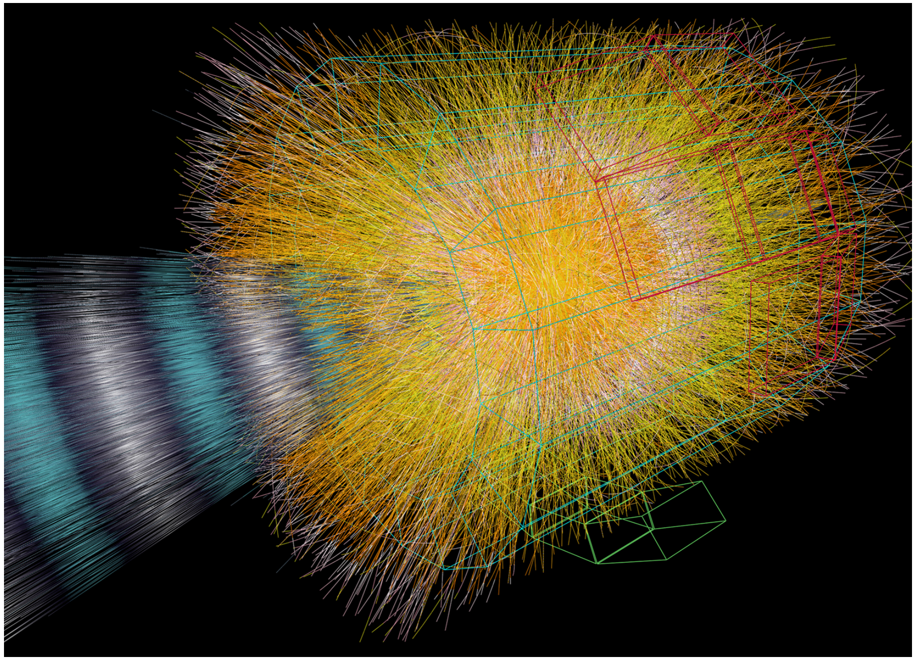
- Presence of (isolated) high-p_T objects from decays of heavy particles (min. bias $\langle p_T \rangle \sim 0.6$ GeV)
- The presence of known heavy particles (W, Z)
- Missing transverse energy (either from high-p_T neutrinos, or from new invisible particles)
- [displaced vertices]

Which Detectors Are Used in Trigger

Muon detectors and calorimeters typically encounter low occupancy and pattern recognition is "straightforward"

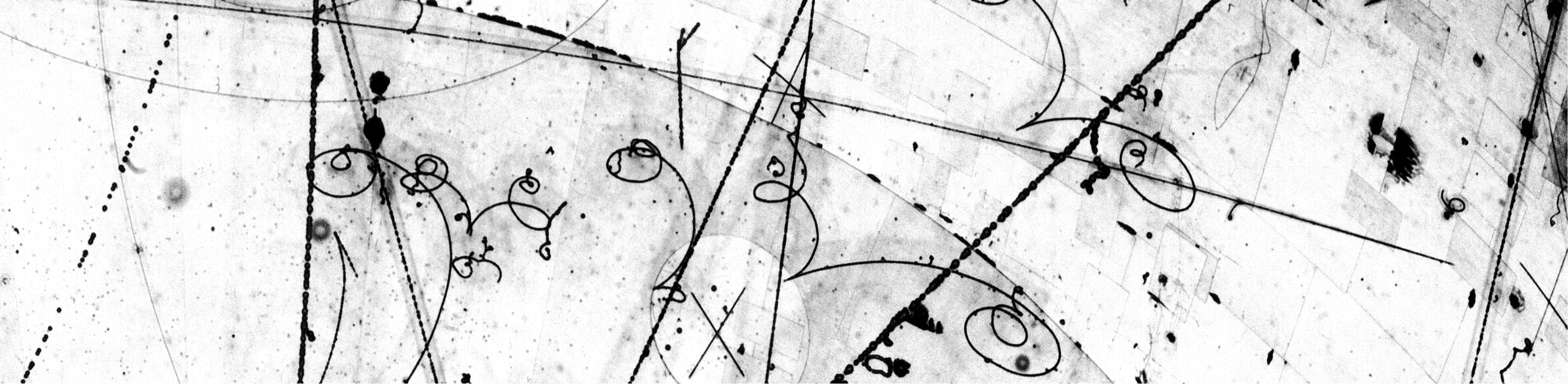
- Simple reconstruction algorithms → fast
- Small amount of data
- Can take "regional" decisions

ALICE simulated Pb-Pb collision



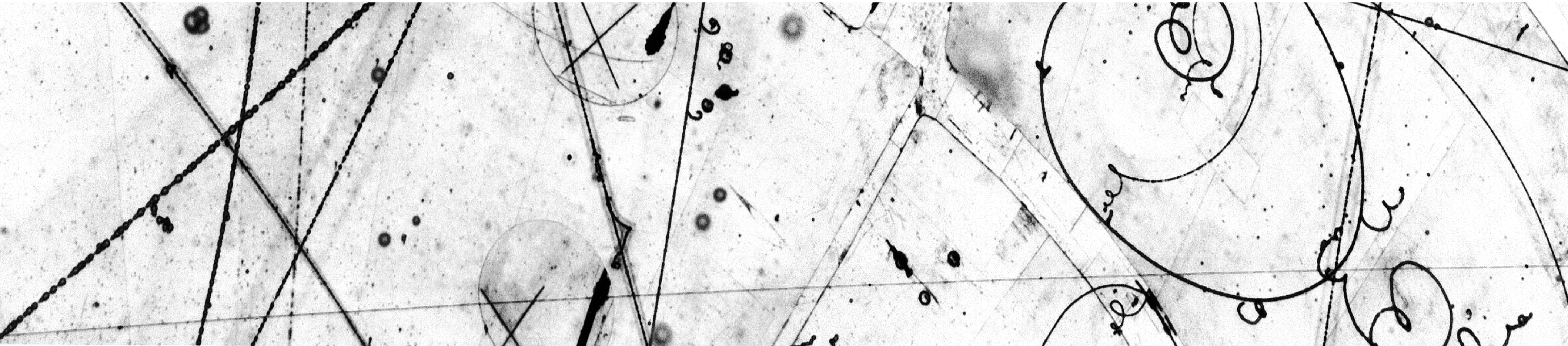
Tracking detectors have to deal with high occupancy

- Complicated events
- Complex reconstruction algorithms → slow
- Huge amount of data
- Need to link to other detectors for additional information

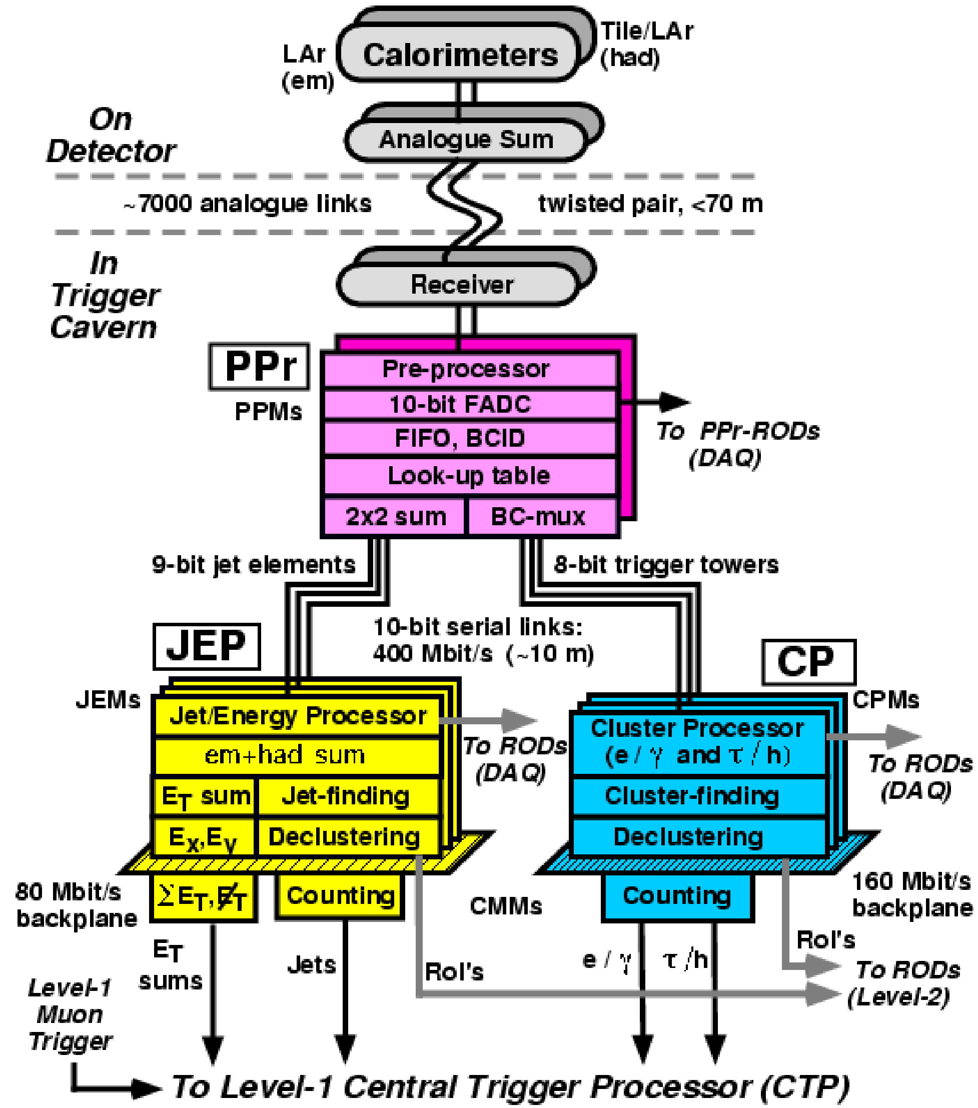


Trigger selection

- Electrons and Jets (ATLAS)
- Muon (CMS)
- Vertex finder (LHCb)



L1 Calorimeter Trigger (ATLAS)



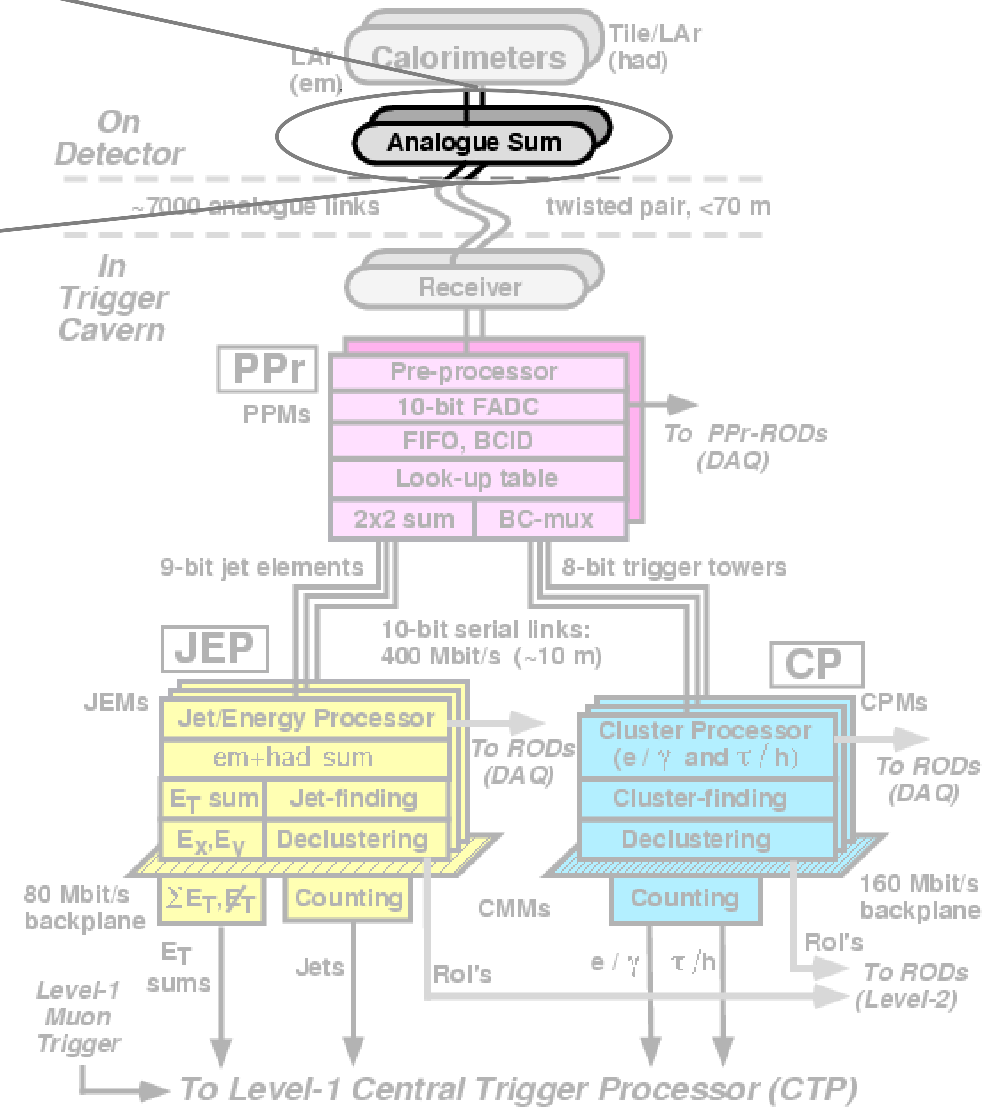
L1 Calorimeter Trigger (ATLAS)

Level-1 Calorimeter Pre-processor crate

Analogue trigger cables received in electronics cavern

L1 Calorimeter Trigger (ATLAS)

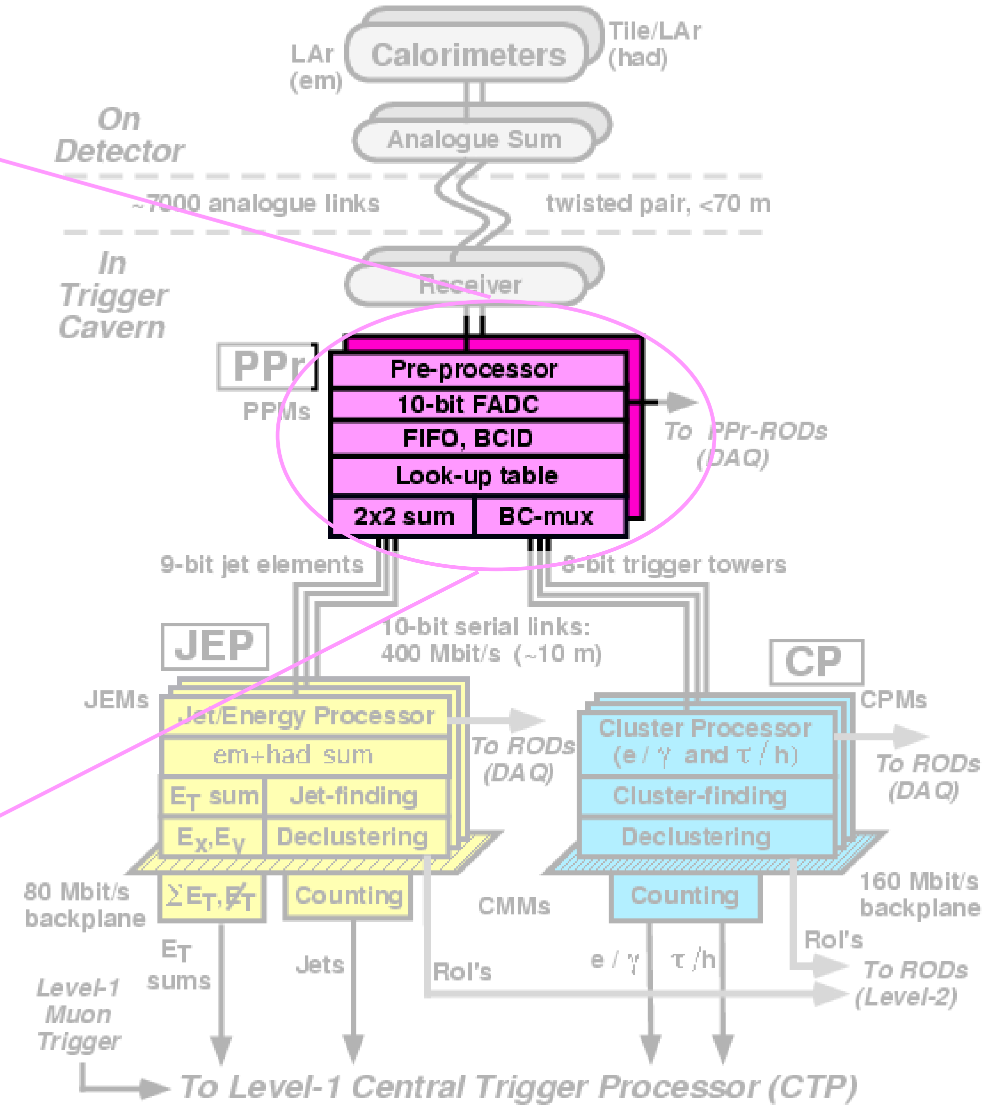
Analogue electronics on detector sums signals from individual calorimeter cells to form trigger towers



L1 Calorimeter Trigger (ATLAS)

Pre-processor

- Signals received, digitised and Synchronised
- Digital data processed to determine E_T per tower (calibration)
- Performs BC identification
- Prepares digital signals for serial transmission

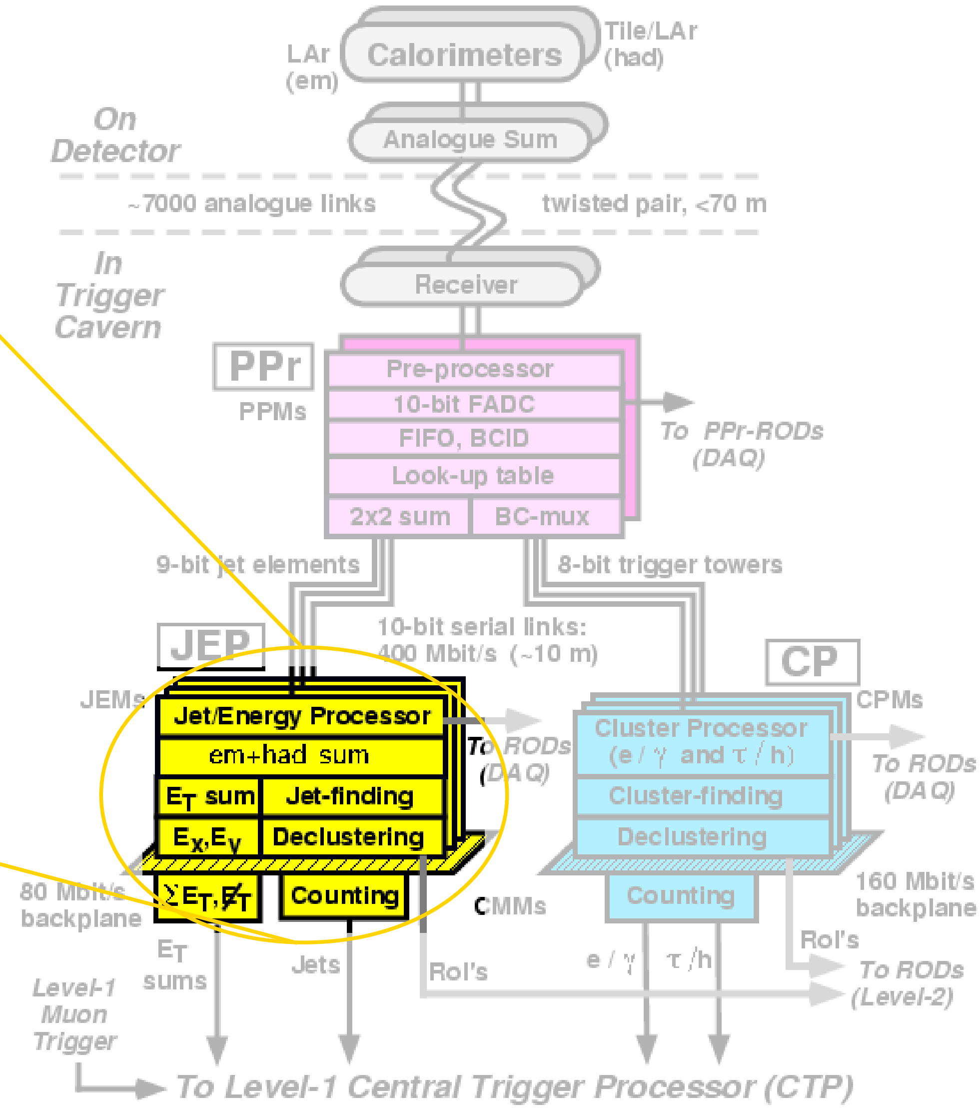


L1 Calorimeter Trigger (ATLAS)

Jet/Energy Processor

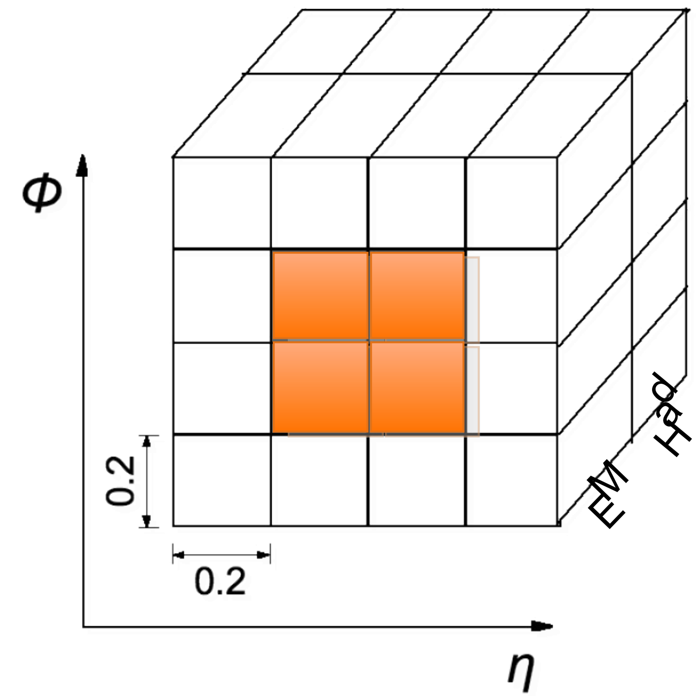
Receives EM and hadronic towers with coarse granularity ($\Delta\eta \times \Delta\varphi = 0.2 \times 0.2$) from Pre-processor

Looks for extended "jet-like" objects and for sum of missing transverse energy



L1 Jet Trigger (ATLAS)

Jet trigger is based on 4×4 *overlapping, sliding windows* of "jet elements"
($\Delta\eta \times \Delta\varphi = 0.2 \times 0.2$ summed over EM+Had)



Jet object is required to have:

- Local E_T maximum in a $\Delta\eta \times \Delta\varphi = 0.4 \times 0.4$ cluster
- Transverse (EM+Had) energy within window above given (adjustable) threshold

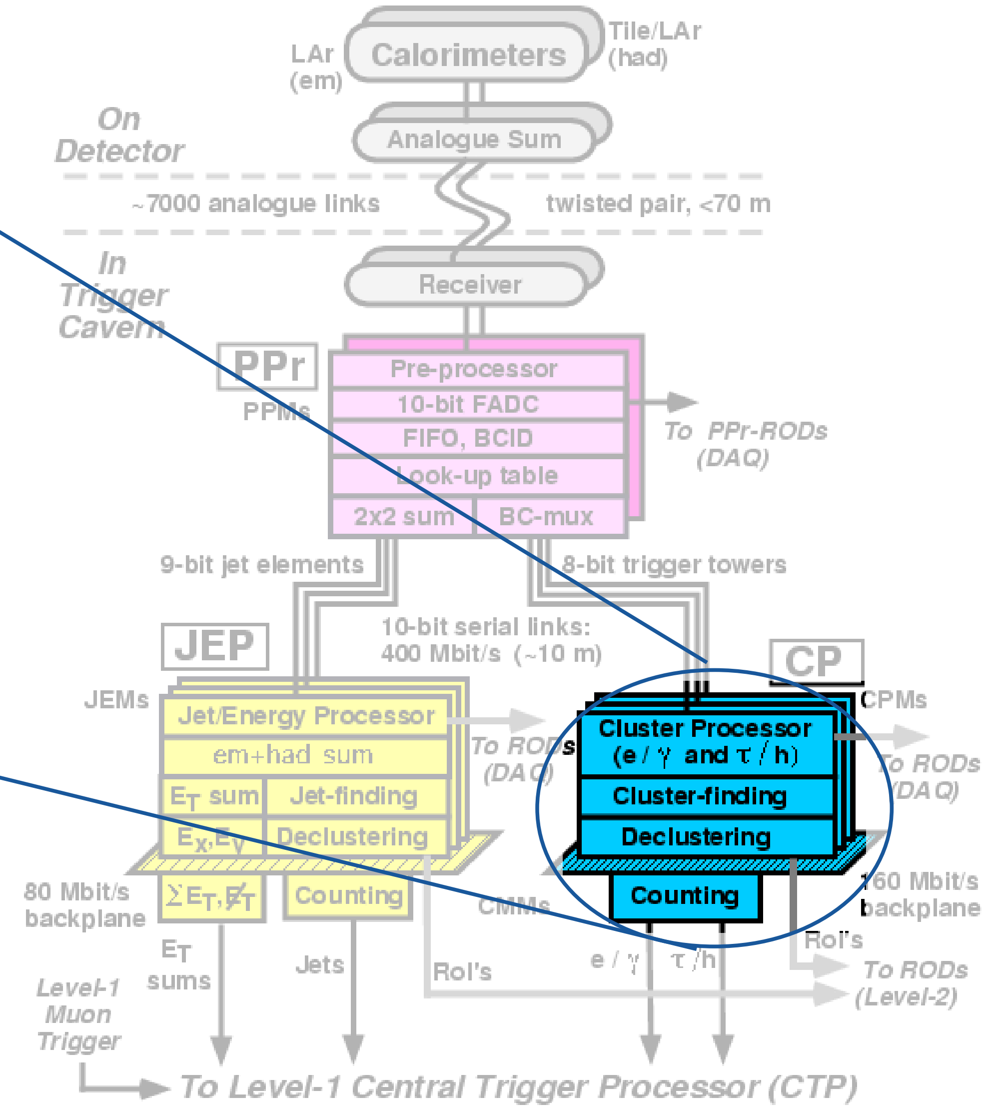
Note: ATLAS calorimeter is non-compensating:
response to EM showers ≠ hadronic showers (→ calibration)

L1 Calorimeter Trigger (ATLAS)

Cluster Processor

Receives EM and hadronic towers ($\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$) from Pre-processor

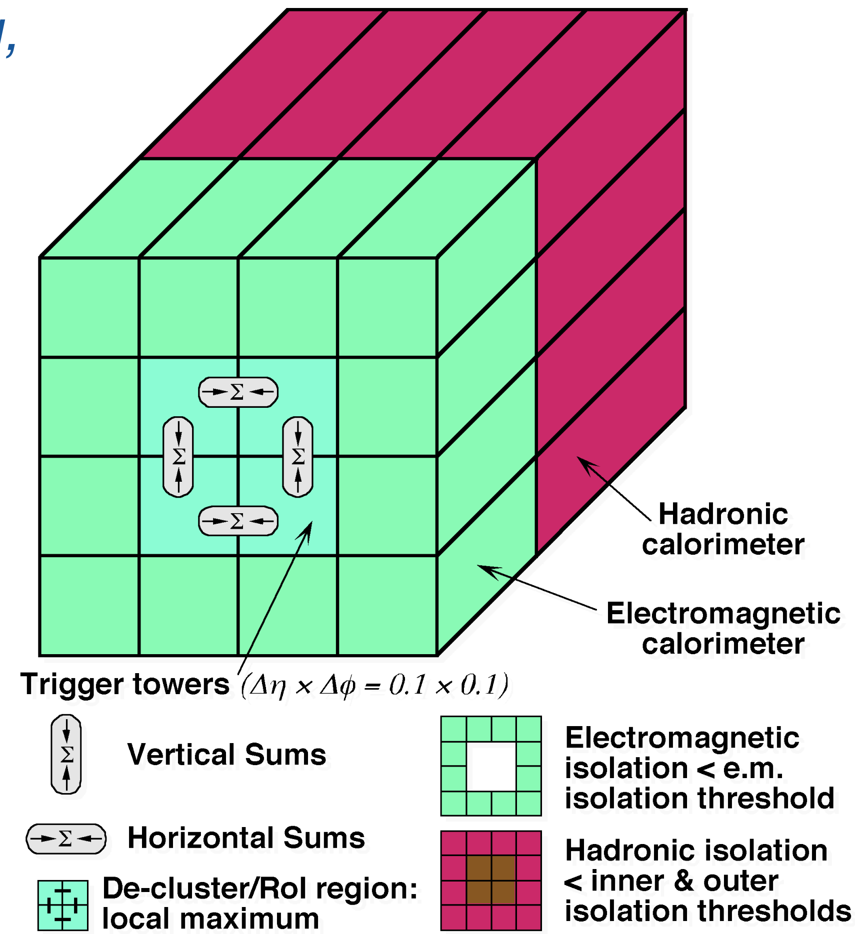
Identifies objects, whose energy-deposits are contained in narrow calorimeter regions (e, γ, τ, h)



L1 electron trigger (ATLAS)

Electron trigger is based on 4×4 *overlapping, sliding windows* of trigger towers

- Each trigger tower is $\Delta\eta \times \Delta\varphi = 0.1 \times 0.1$
- ~3500 such towers in each of the EM and hadronic calorimeters



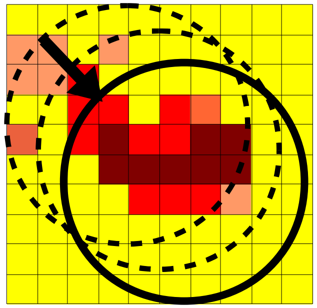
"De-clustering": cluster must have more E_T than 8 surrounding 2×2 ones → avoids double counting

Electron object is required to have:

- Sum of two EM towers E_T above a predefined threshold
- Total E_T in EM isolation ring must be less than or equal to predefined threshold
- Total E_T in Hadronic isolation ring must be less than or equal to predefined threshold
- Total E_T in Hadronic core isolation region must be less than or equal to predefined threshold
- Local E_T (EM+Had) maximum in a $\Delta\eta \times \Delta\varphi = 0.2 \times 0.2$ cluster

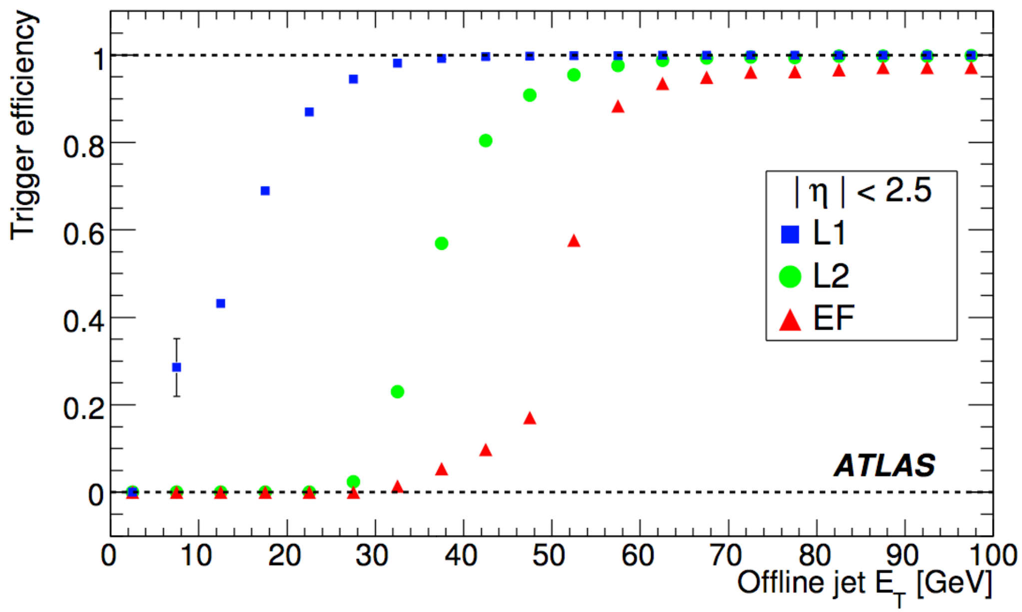
HLT Jet Trigger (ATLAS)

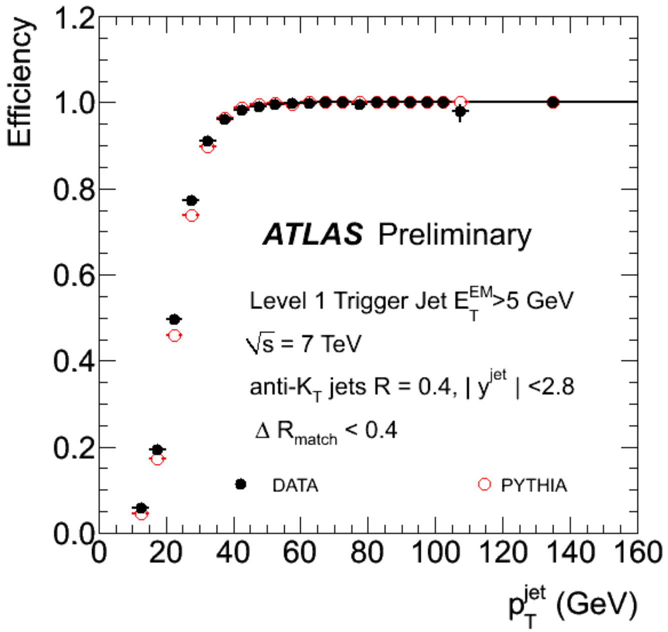
L2: - Apply a simple cone-like algorithm within a predefined window size around the RoI position
- Use cell granularity
- Simple dedicated calibration applied to obtain jet energy at hadronic scale



EF: - Run full offline jet reconstruction within a predefined window size around L2 jet position
- Use offline jet calibration

Note: ATLAS calorimeter is non-compensating: response to EM showers ≠ hadronic showers





HLT Electron Trigger (ATLAS)

L1 electron trigger already very selective

- Need to use complex algorithms and full-granularity detector data in HLT

Calorimeter selection

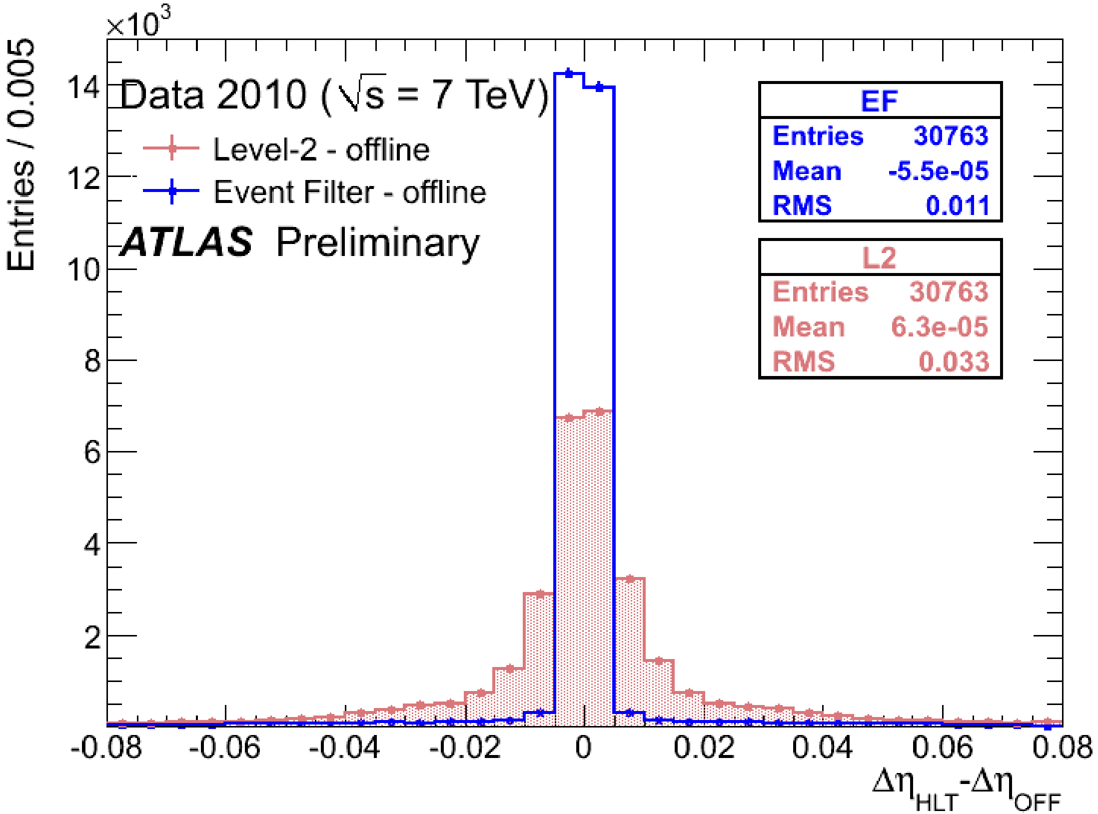
- Sharpen E_T cut
- Use shower-shape variables to improve jet rejection

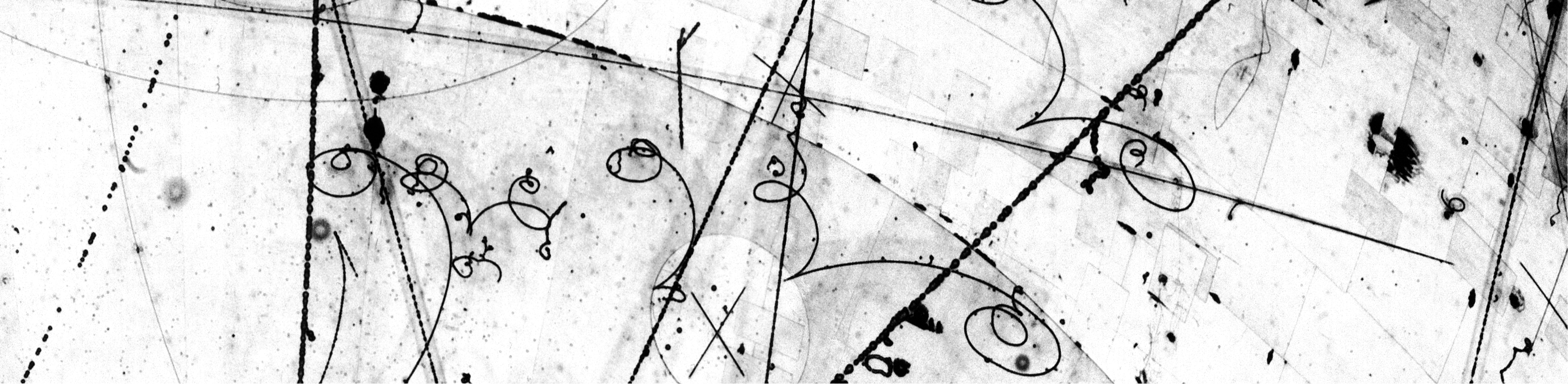
Associate track in inner detector

- Matching calorimeter cluster
- Compute E/p

Optimise signal efficiency and background rejection

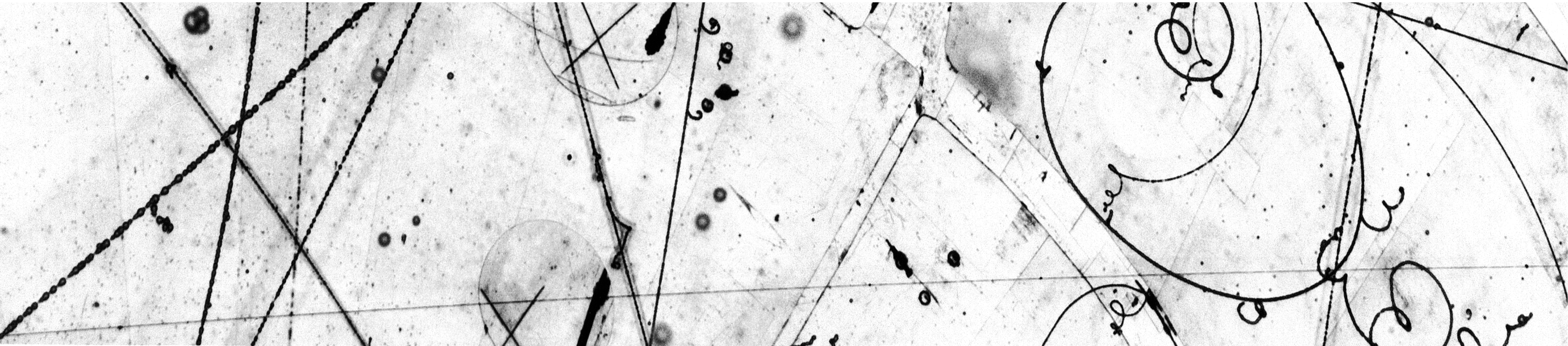
- May use multivariate techniques already in trigger !





Trigger selection

- Electrons and Jets (ATLAS)
- Muon (CMS)
- Vertex finder (LHCb)



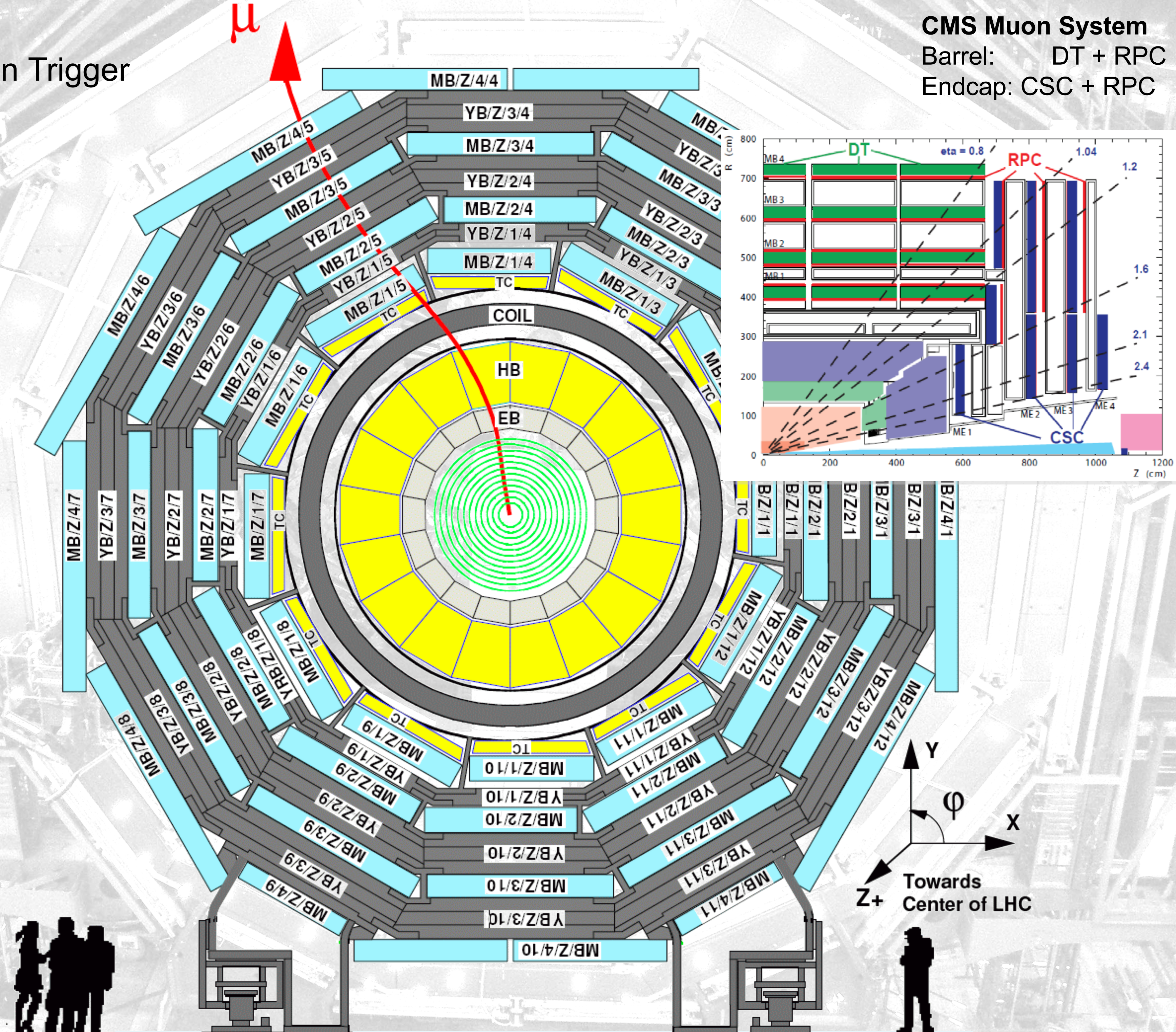
CMS

Level-1 Muon Trigger

CMS Muon System

Barrel: DT + RPC

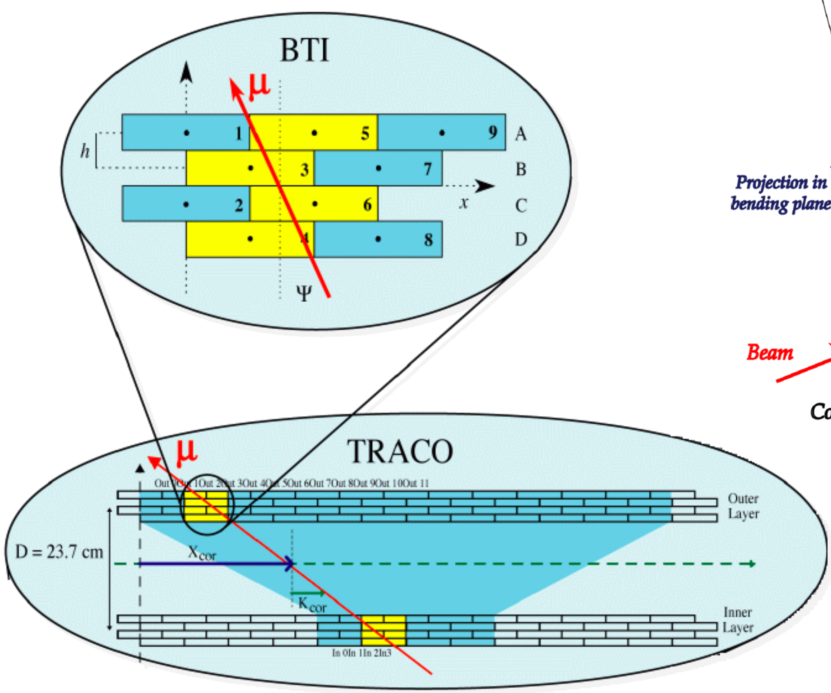
Endcap: CSC + RPC

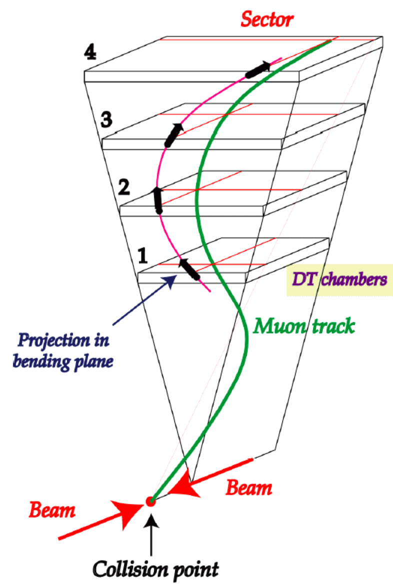


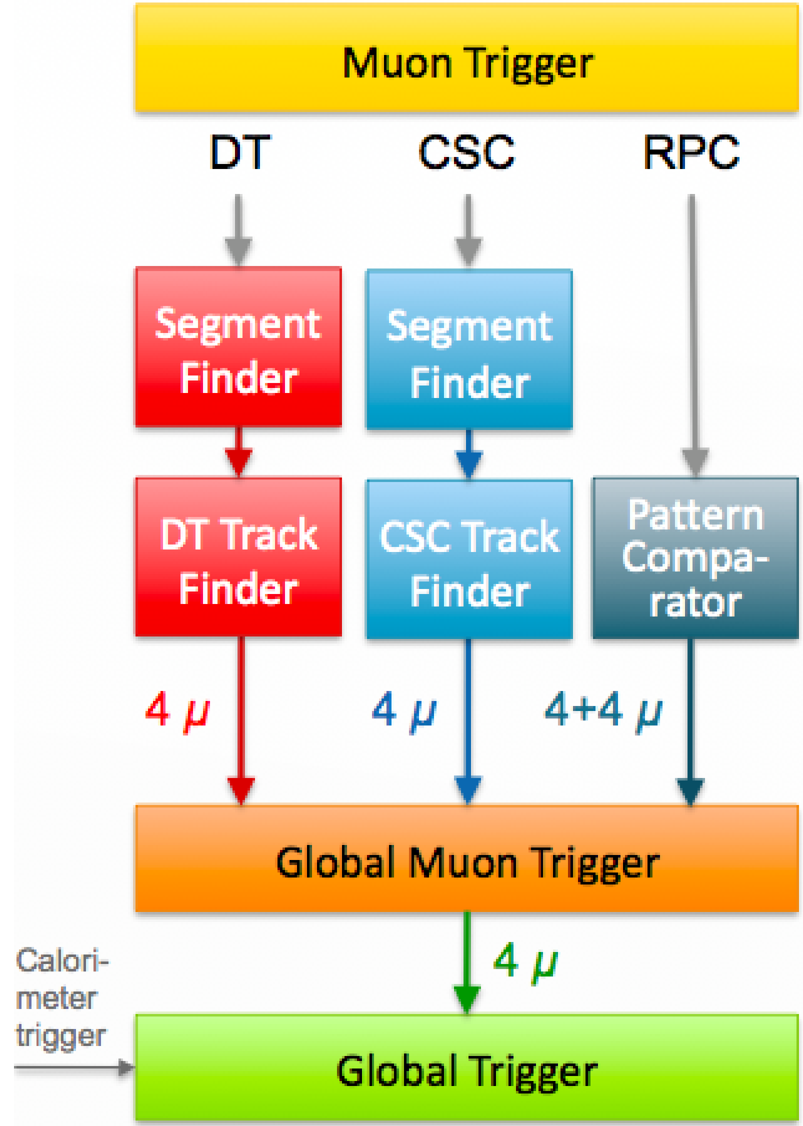
Level-1 Muon Trigger (CMS)

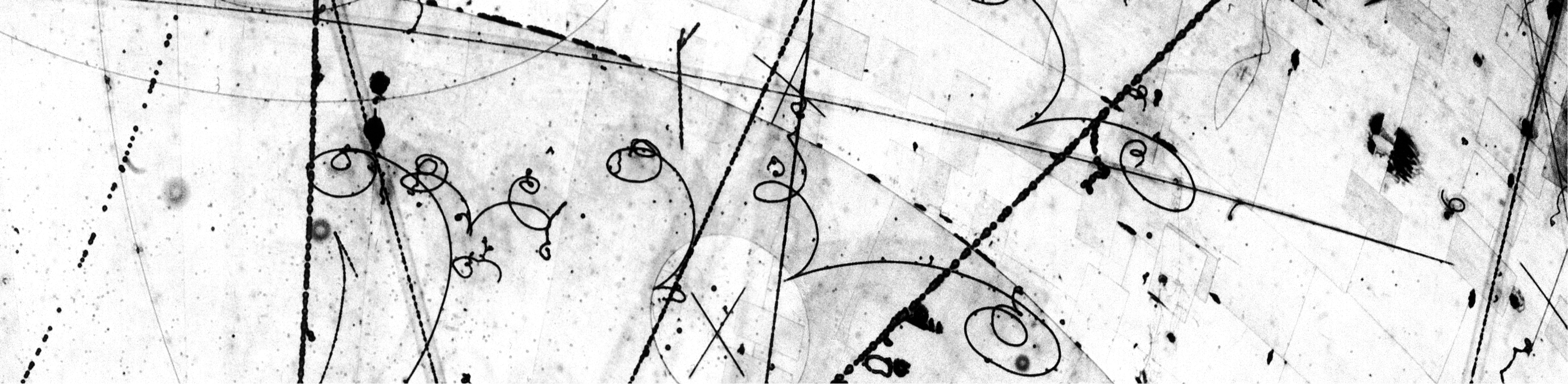
Example: trigger with drift tubes in barrel:

- Reconstruct local segments on chambers using ASICs
- Segment position, p_T and quality sent to Track Finder
- TF combines segments to form μ track using FPGAs (LUT)
- Typical p_T resolution 20%



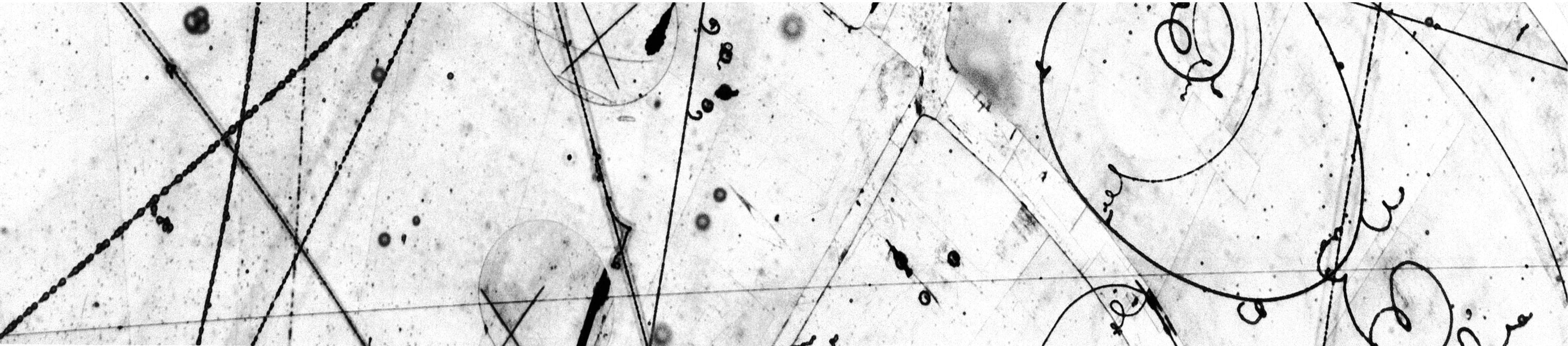






Trigger selection

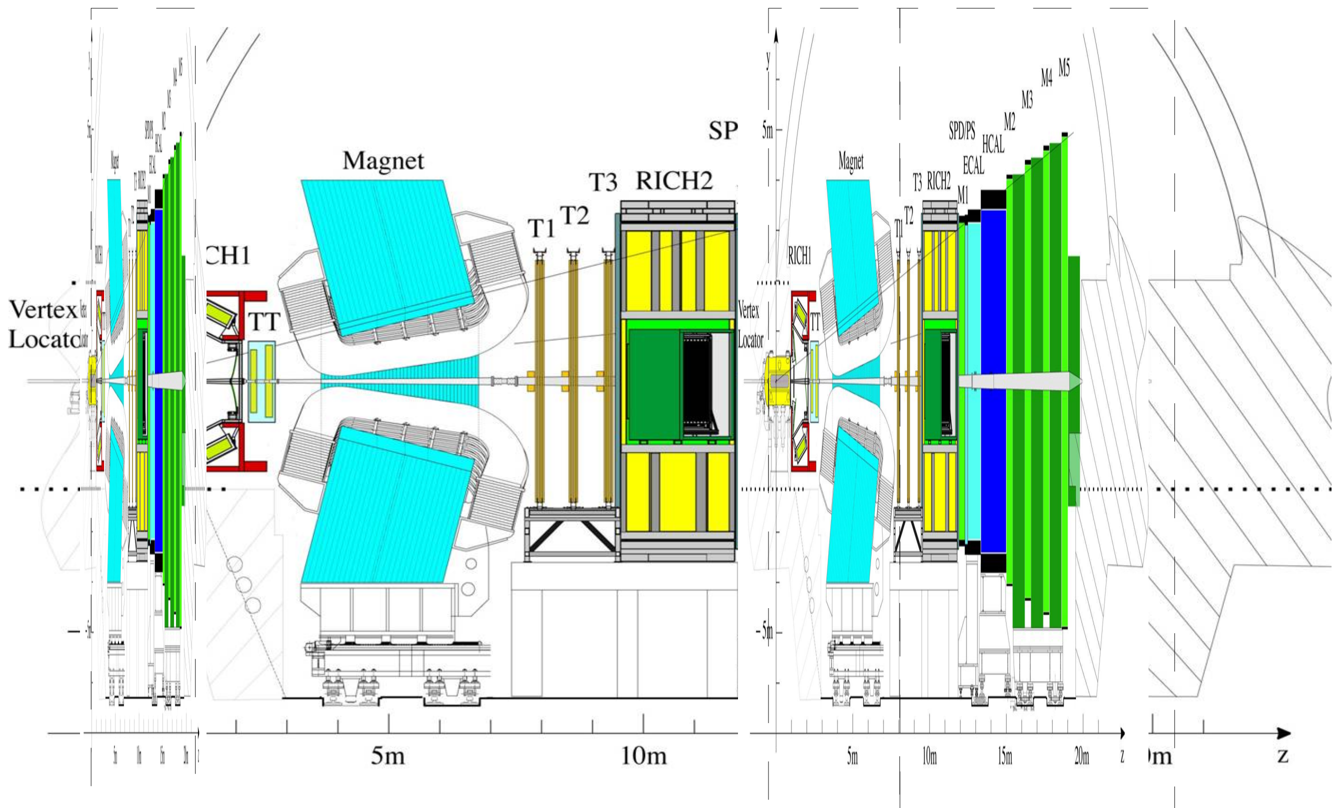
- Electrons and Jets (ATLAS)
- Muon (CMS)
- Vertex finder (LHCb)



LHCb Level-0 Trigger

Luminosity: 2x10^{32} cm^{-2} s^{-1}
[Prefer single *pp* collisions to identify *B* vertices]

Level-0 output rate: 1 MHz



Pile-up system

Calorimeter trigger

Muon trigger

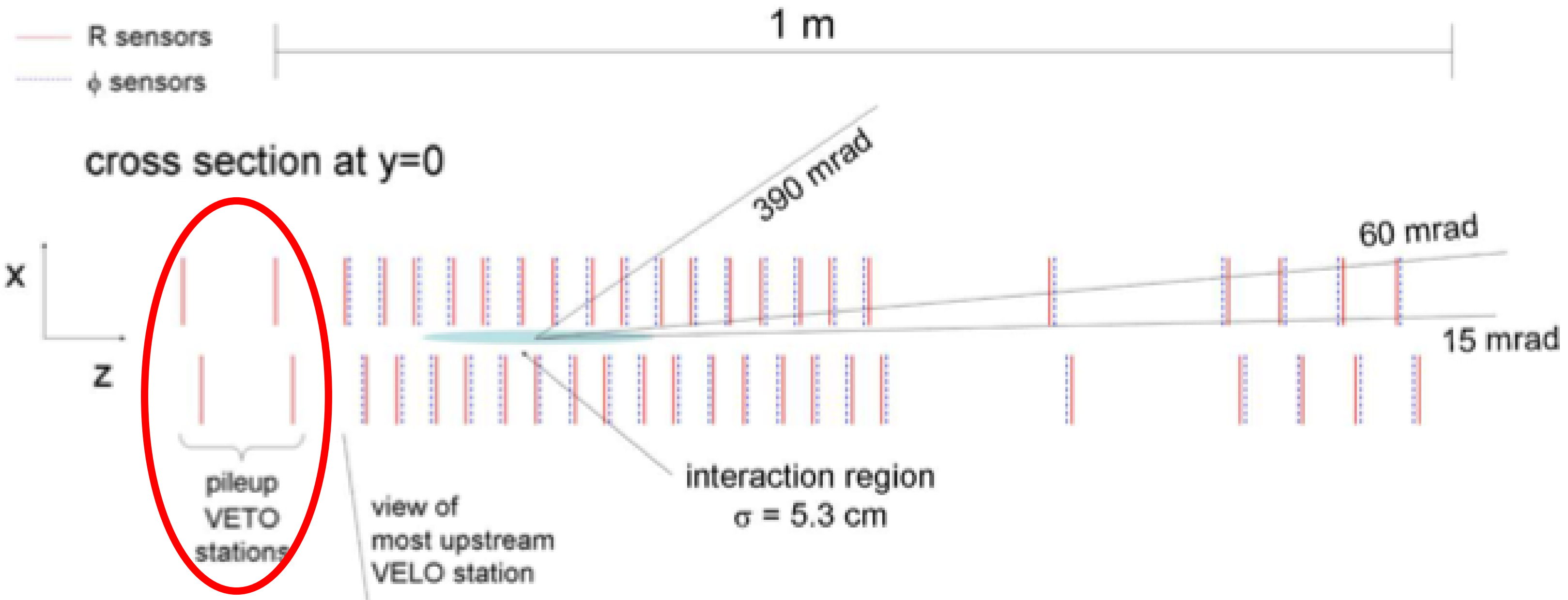
Level-0 Decision unit

LHCb (Level-0) Pile-up System

The pile-up system aims at distinguishing between crossings with single and multiple visible interactions.

It provides the position of the primary vertices candidates along the beam-line and a measure of the total backward charged track multiplicity.

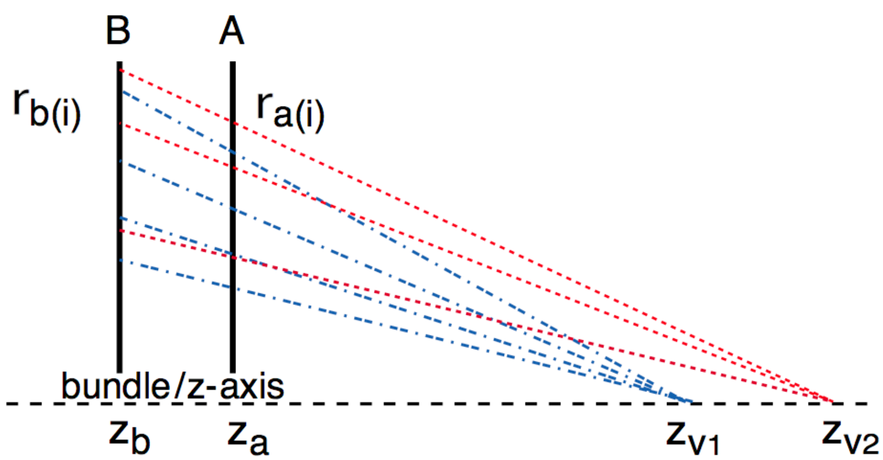
Pile-up system consists in two planes of silicon sensors perpendicular to the beam-line



LHCb (Level-0) Pile-up System

For track originating from the beam line, the vertex position can be calculated using

$$z_v = \frac{kz_a - z_b}{k-1} \quad \text{where} \quad k = r_b/r_a$$

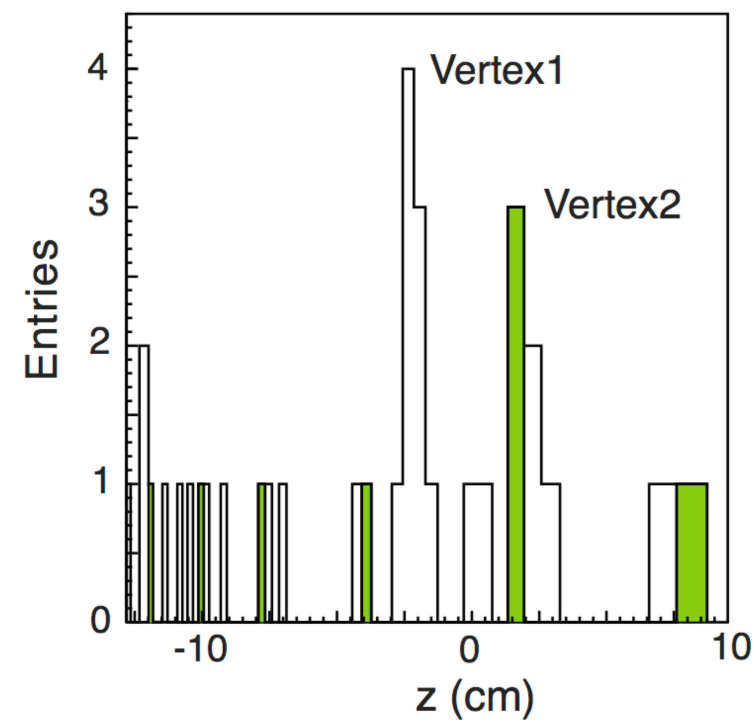


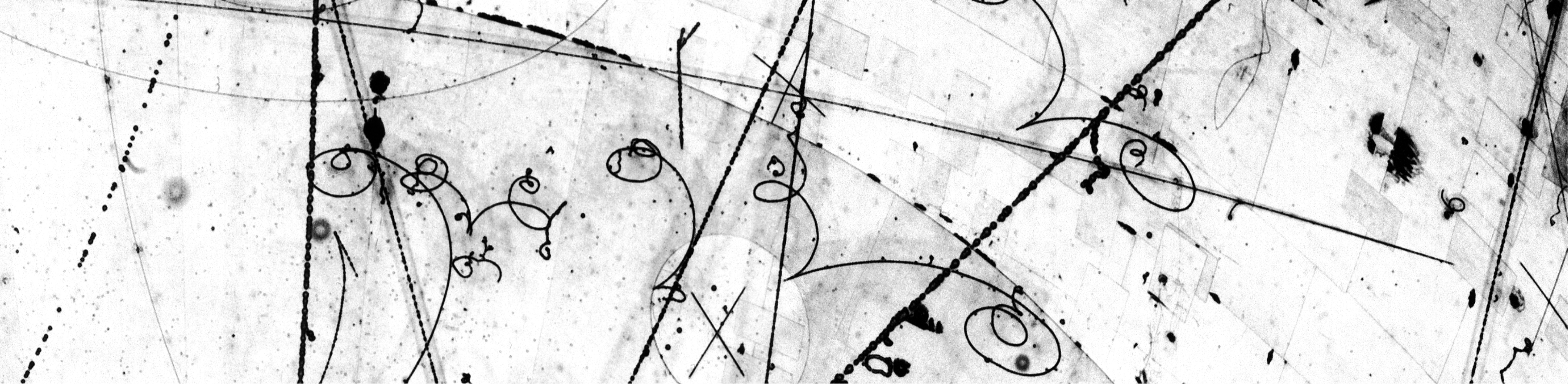
1 – Measure the radii of track hits r_a and r_b.

2 – Combine all hits in teh same octant of both planes according to equation. Make a histogram of all values of z_v and search for a peak.

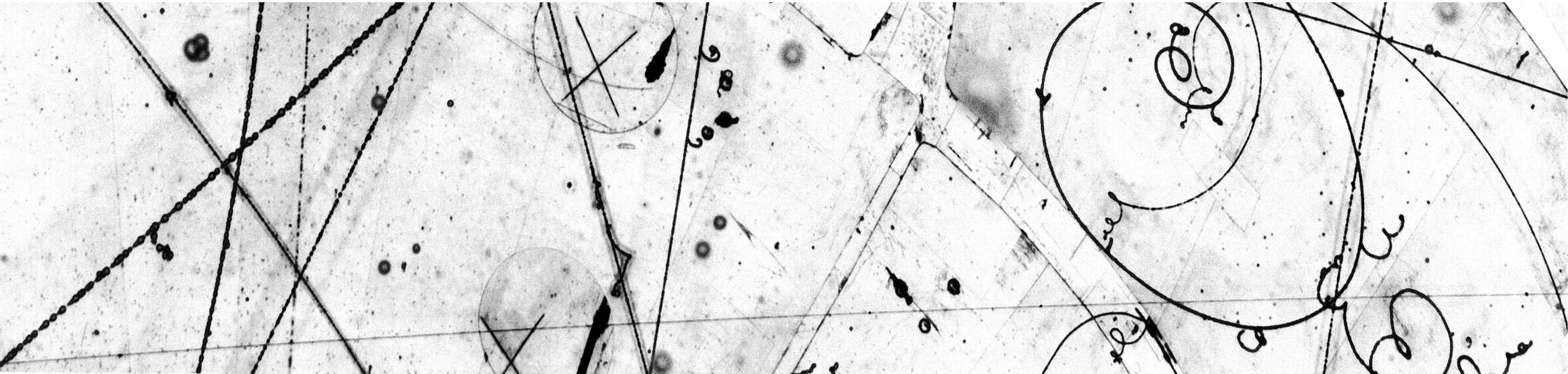
3 – All hits contributing to the highest peak in the histogram are masked, after which a second peak is searched for. The height of this second peak is a measure of the number of tracks coming from a second vertex.

4 – Apply cut on the heigh of the second peak to detect multiple interactions.





Trigger Menu Design



Trigger Selection Goal

Select "interesting" events (while minimizing deadtime of the experiment)

"*Interesting*" is a relative concept....

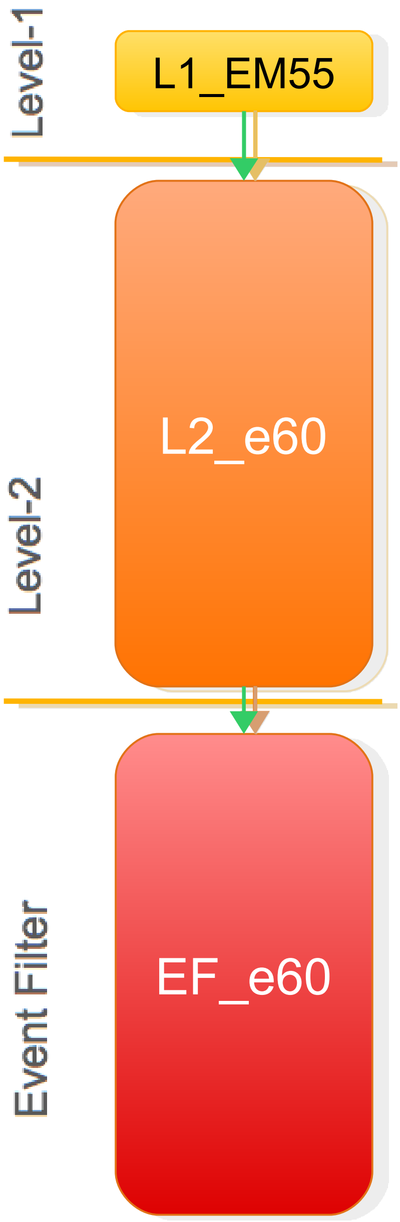
- depends on physics priorities
  - need for compromise in multi-purpose experiments
- events are interesting only if they satisfy offline analysis selection cuts!
- includes events needed to validate analysis
  - determination of efficiencies, background, systematics, calibration, etc.
- Includes event topologies not even thought of!

Trigger Lines

A trigger line (or trigger path or trigger chain)...

...consists in a unique set of L1, L2, L3.. trigger criteria

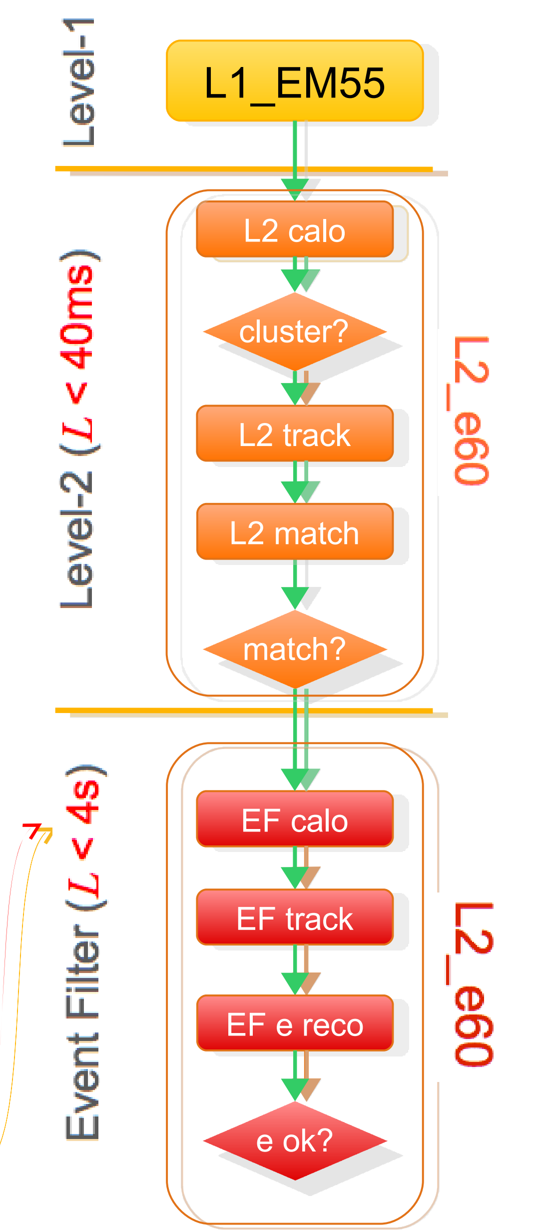
...defines a particular topology for events to be recorded.



Trigger Lines (ATLAS)

ATLAS distinguishes “*feature extraction*” and “*hypothesis*” algorithms:

- *Feature extraction* retrieves detector data from readout buffers and reconstructs physics quantities/objects. Smart caching makes sure that objects already reconstructed by one algorithm can be reused by all others.
- *Hypothesis algorithms* apply the actual trigger cuts, and may stop a trigger line



The early reject algorithm benefits from separating HLT algorithms into steps

- As soon as one steps is unsuccessful, the execution of the rest of the trigger line is stopped.

Compare to full event reconstruction *O*(10s) per event

Trigger Menu

A trigger menu (or trigger list or trigger table)...

... consists in an ensemble of trigger lines

... corresponds to the list of trigger criteria that defines all the possible characteristics of events we want to record.

Illustrative example of a trigger menu

signature	Level-1	Level-2	Level-3
e20	L1_e15	L2_e20	EF_e20
2e15	L1_2e10	L2_2e15	EF_2e15
mu20	L1_mu20	L2_mu20	EF_mu20
2mu15	L1_2mu10	L2_mu15	EF_mu15
j100	L1_j50	L2_j80	EF_j100
2j50	L1_2j30	L2_2j40	EF_2j50
3j30	L1_3j20	L2_3j25	EF_3j30
j30_met50	L1_j20_met40	L2_j25_met50	EF_j25_met50
....	...	...	...

Trigger Line

An event is selected by the trigger if it satisfies at least one trigger line contained in the Menu. A typical menu for a multi-purpose experiment at a hadron collider contains hundreds individual trigger lines.

Trigger Menu Content

A realistic menu contains many different kind of trigger lines:

- primary physics triggers
  used to record signal events used in physics analysis
- supporting triggers
  for physics background and systematic studies
- “orthogonal” triggers
  to study trigger reconstruction and efficiencies
- “pass-through” triggers
  for trigger monitoring and validation
- calibration triggers
  to select events specifically used for detector calibration
- backup triggers
  in case unusual data taking conditions require the removal of a primary physics trigger (ex.Unforeseen increase in rate due to change in beam quality, subdetector problems, etc.)

A trigger line generally fits into more than one category, that is, one “orthogonal” trigger is also another primary physics trigger.

Prescales

It is sometimes not necessary to record all the events that satisfy the criteria specified in a trigger line → prescale the trigger line

A *prescale* factor define the fraction of events satisfying a trigger line that should be recorded.

Ex. Prescale = 10 ← record only 1 out of 10 events
Prescale = 1 ← record all the events

Trigger Menu Evolution

Trigger menus need to be modified/changed periodically (more often earlier on in the life of an experiment) to adapt to

- changing accelerator performance (ex. Increase in instantaneous luminosity)
- trigger system improvements (ex. hardware/software changes, algorithm improvements)
- feedback from physics analysis and detector needs
- evolution in physics priorities of an experiment
- new physics ideas

But aim for ***stability*** and ***simplicity***!

Trigger Menu Design

<u>Challenge</u>:

- Optimize trigger efficiency within a certain rate budget
  - Implies being able to estimate rates (for current and foreseen instantaneous luminosities.)
- Many signatures, particularly in multi-purpose experiments
  - Need to make compromises
- Enormous flexibility, especially at higher trigger levels

Trigger Menu Design

Methodology:

(1) estimate efficiency of one (or more) trigger line for events of interest

- Use trigger simulated objects in MC simulation
  - MC typically does a fair job at reproducing p_T distributions, but is often not so good for variables depending on detector occupancy (isolation,hadronic veto, met,..)
- *A posteriori* efficiency measurements (for physics analysis) performed using data
  - ➡ See Rick Van Kooten's lectures

(2) estimate rate of individual trigger lines

(3) estimate total rate of menu and overlap between different trigger lines

Trigger Rate Estimates

Simulation-based:

- Run trigger simulation on MC events expected to be dominant background(s)

  Ex. Use MC di-jet events at hadron collider

- Main method prior to the beginning of data taking
- Rate estimates only approximate

  MC simulation does not fully reproduce all contributing physics processes and real data taking environment

Data-driven:

- Ideally would like tens of seconds of unbiased collision data

  - Not practical: At LHC 40 MHz x 10s / 200 Hz = 2 x 10^6 s ≈ 1-2 months of exclusive data taking.

- Instead, record "enhanced bias" data: Use lowest thresholds for each Level-1 objects and apply prescales at HLT.

  - still need a lot of bandwidth
  - no need to reconstruct data, only need trigger objects for offline analysis

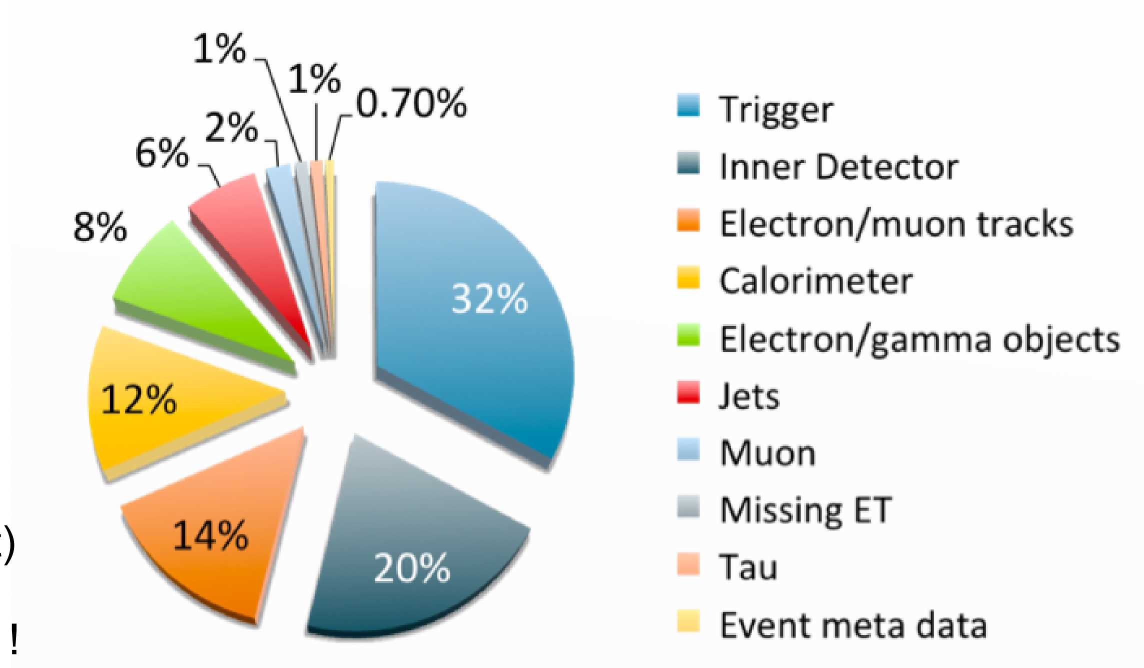
Tools for Trigger Menu Design

Trigger simulation

- Need fully validated trigger simulation (including firmware)
- Need ability to run any "online" menu and modify it

Write trigger objects in data

- Mandatory for the offline study of trigger reconstruction, decision, determination of trigger efficiency, etc.



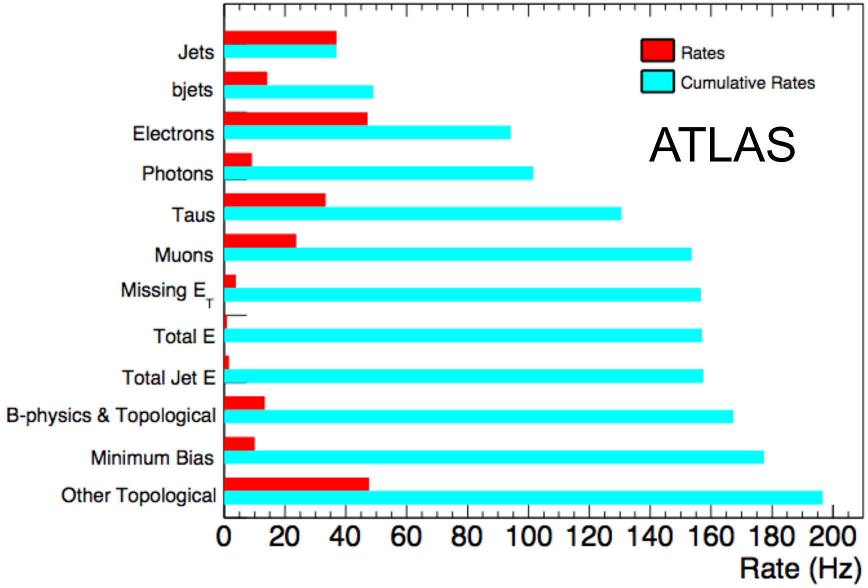
Content of ATLAS physics analysis data format for simulated top events (167 kB/event)

Biggest contribution (32%) by trigger features !

Tools for Trigger Menu Design

Package to calculate total rate, unique rate, overlap fraction, etc.

- for individual trigger lines
- for groups of triggers

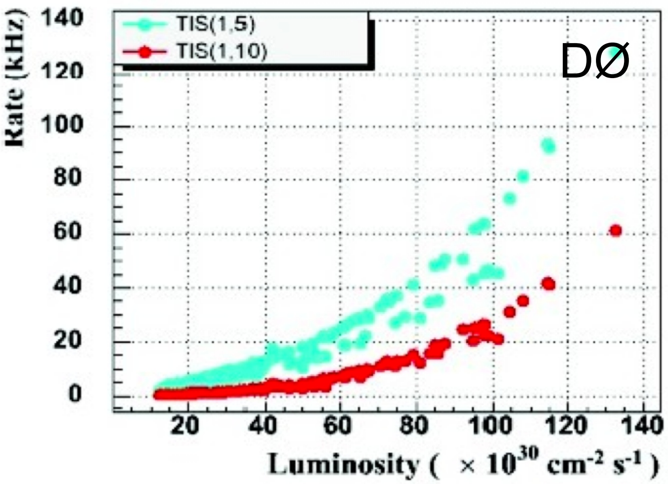


Trigger Name DØ	# of events	bandwidth fraction	rate to tape (Hz)	unique fraction	unique rate to tape (Hz)	largest overlap with trigger	largest overlap
E1_T14LH2SH17	4331	0.002	0.301	0.006	0.002	E2_T14LH2SH17	0.908
E1_SHT15_JHA80	27598	0.015	1.921	0.003	0.006	E1_SHT25	0.859
E1_SHT15_2J_J25	44320	0.024	3.084	0.012	0.038	E1_SHT25	0.824
E1_T13L15HT100V	7951	0.004	0.553	0.219	0.121	E2_T13L15HT100V	0.505
E1_2L15SH15_L20	15004	0.008	1.044	0.038	0.040	E2_2L15SH15_L20	0.743
E1_2L20_L25	11622	0.006	0.809	0.113	0.092	DE1_2L20_L25	0.711
E1_2SH10_SH15	5247	0.003	0.365	0.040	0.015	E2_2SH10_SH15	0.821

Trigger Rate Extrapolation

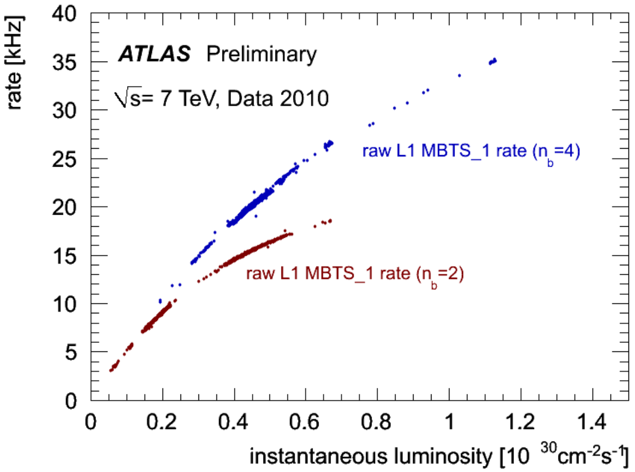
"Enhanced bias" data used to estimate trigger rates typically recorded at lower luminosity than that for which you are designing a new trigger menu.

➡ Need to extrapolate measured rates



Many trigger objects have non-linear rates as function of luminosity due to increased occupancy.

- Fit the rate vs luminosity curve
  - Extrapolation with large uncertainty
- Re-weigh events as a function of the number of primary vertices
  - Implies running reconstruction



Trigger Menu Design Strategy

One possible approach is to group triggers by final states:

- Single muon/electron/photon
- di-muon/electron/photon
- lepton/photon + jet(s)
- Jet + MET
- Multijet
- ...

In each group there are two categories of trigger lines:

- "unprescalable": Need to record every event
  Ex. Searches for and studies of rare processes

- "prescalable": Physics case does not need to record all events
  Ex. High rate physics processes (jets at low p_T), some B-physics topics, monitoring triggers

Trigger Menu Design Strategy

To put it all together, start with "unprescalable" trigger lines and cap their total rate to a fixed fraction of the total bandwidth

- Typically ~ 70-80%
- Usually need to tweak thresholds and/or quality criteria to fit within allocated bandwidth

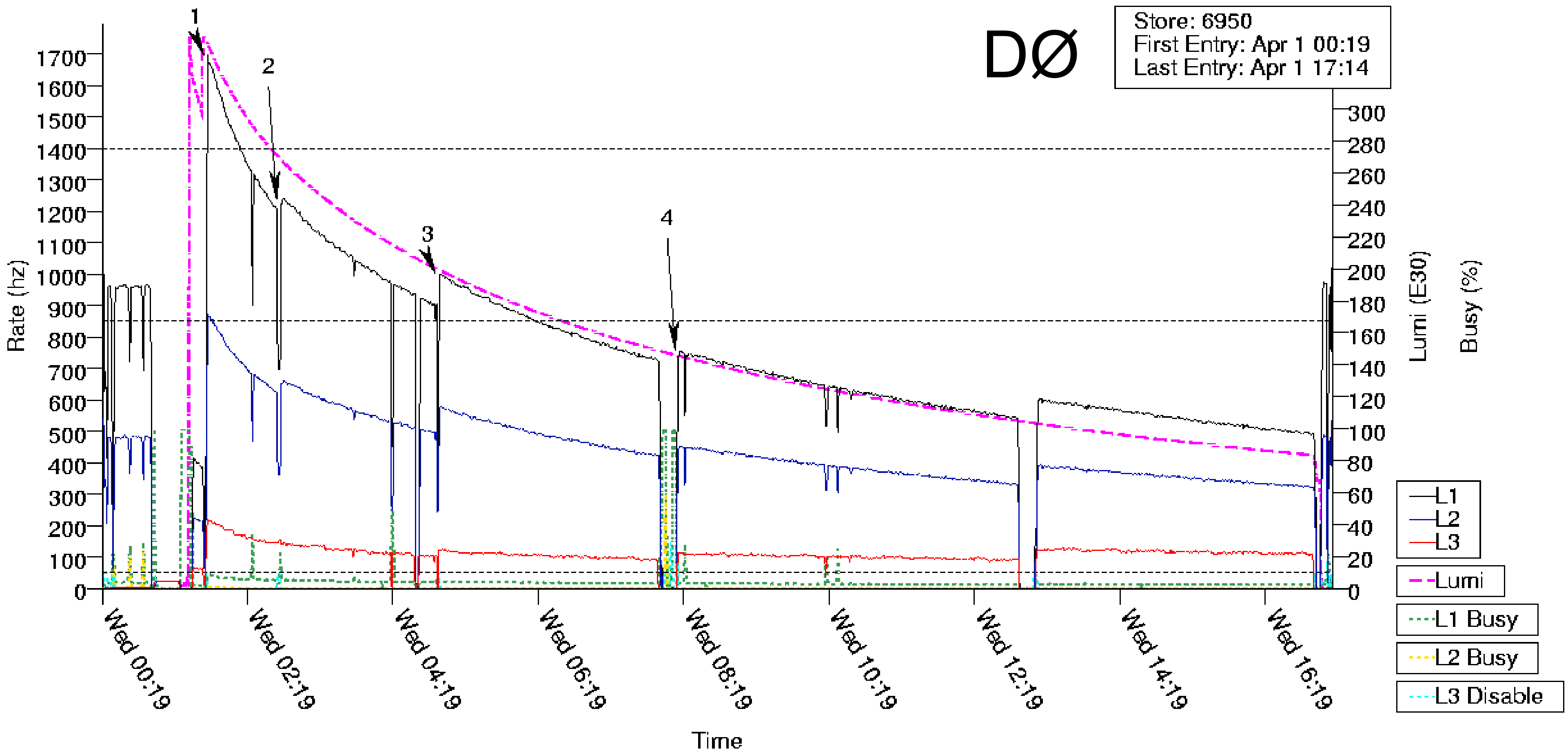
Then, add "prescalable" trigger lines.

- Need to choose different prescale factors as function of luminosity

In addition (or alternatively), can also consider approximate targets for total rate per trigger signature groups (which include both unprescalable and prescalable trigger lines)

- Ex. x% for electron, y% for muon, z% for jets, etc.

Luminosity Evolution



	Run	Duration	inL	Live	scl/hr	pause	<Tape Rate>	Prescale_File
1	250808	0.99 h	347.1	-1	-1.0	-1.00 h	-1.0 hz	310-340E30
2	250809	2.18 h	275.2	-1	-0.5	-1.00 h	-1.0 hz	260-310E30
3	250810	3.11 h	202.1	-1	-0.3	-1.00 h	-1.0 hz	150-200E30
4	250815	4.92 h	147.2	-1	-0.2	-1.00 h	-1.0 hz	100-150E30

Trigger Menu Design Strategy

How to fit everything within the finite bandwidth?
Need to make compromises!

Some physics in the category of "presalable" trigger lines easier at Low luminosity

Ex. Exclusive B decays, diffractive physics

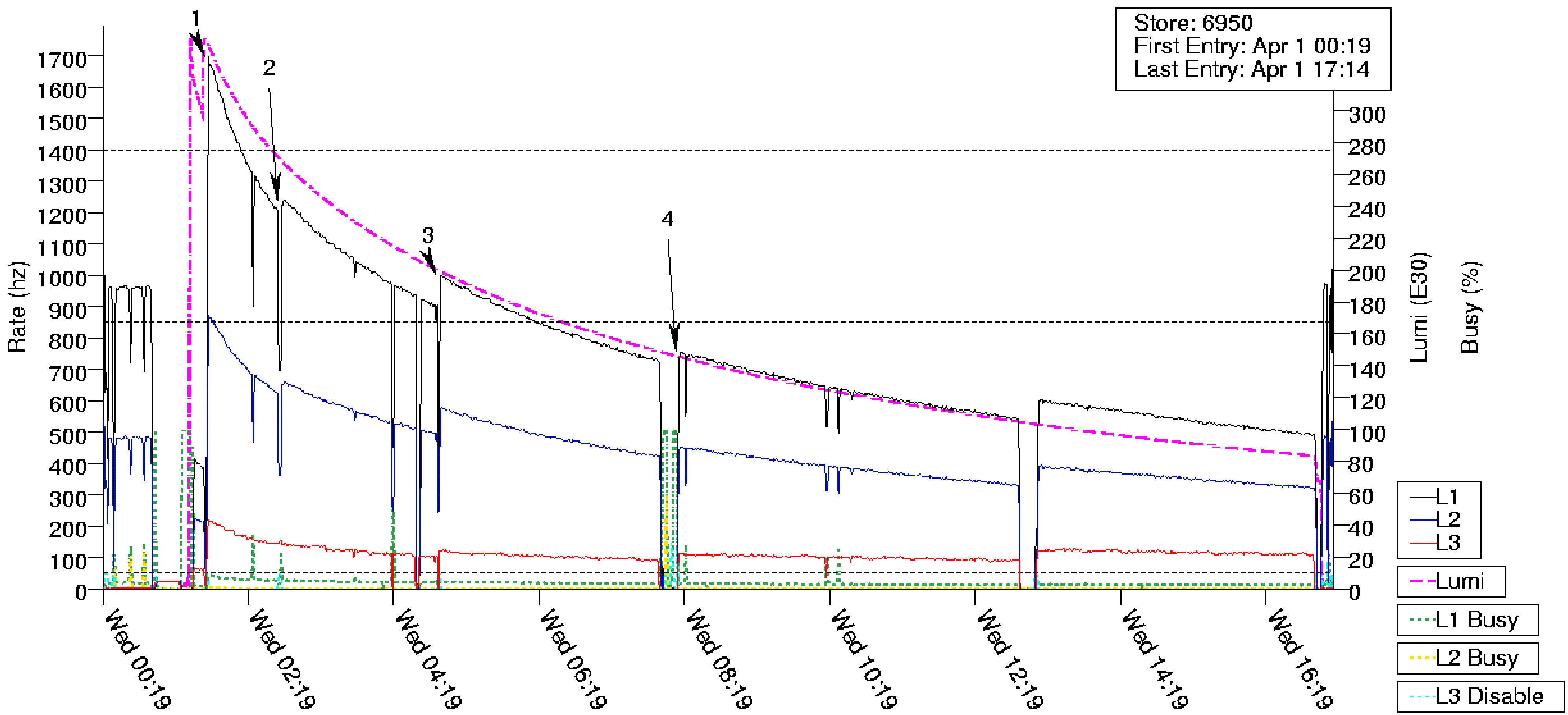
Trade bandwidth: Less bandwidth at high luminosity for analyses that prefer clean events, more bandwidth at lower luminosity.

Rate-to-tape can be different as function of luminosity

Changing Prescales

Manually (DØ):

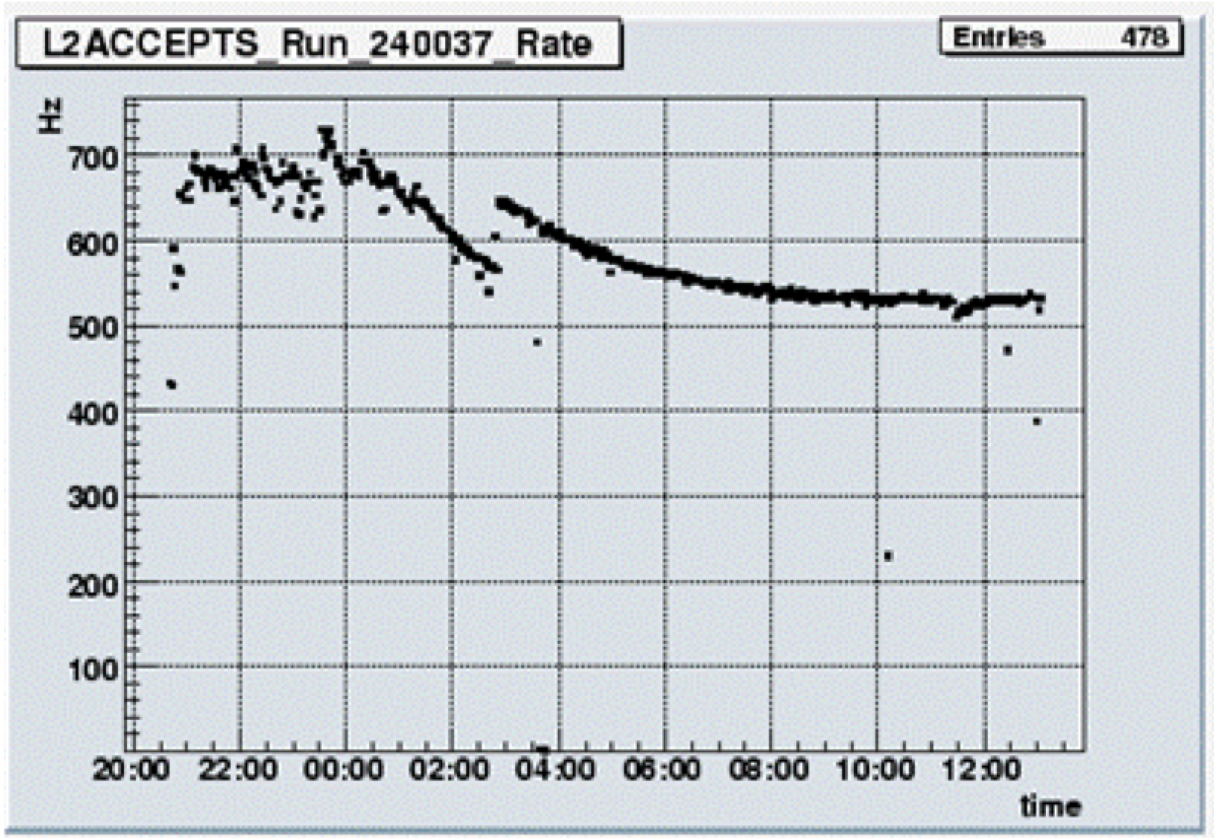
After ~ 4 hours start a new run with a different prescale set.



Changing Prescales

Dynamically (CDF):

Use feedback system based on total rate and individual trigger line rates to automatically change prescale factors at L1 and L2, thereby maximizing bandwidth utilization as function of luminosity.

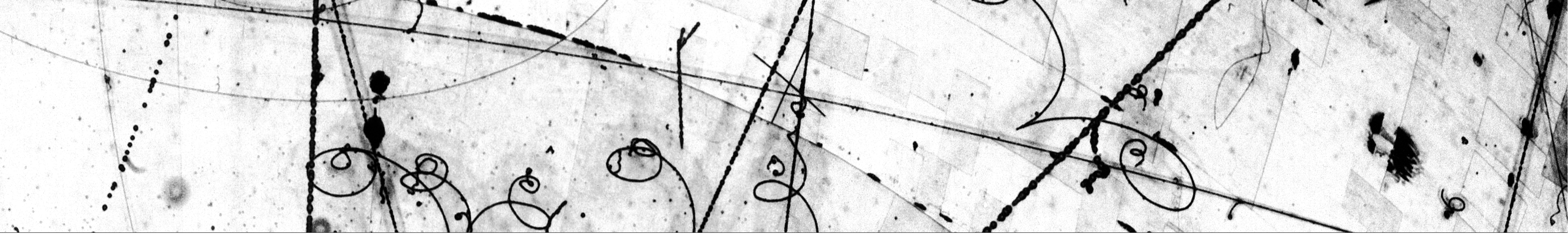


Putting It All Together

Example of a trigger menu for selecting events with electron(s) and photon(s). (ATLAS)

	Level-1			HLT			
Signature	**Item**	**Pre-scale**	**Rate [kHz]**	**Sel-ection**	**Pre-scale**	**Rate [Hz]**	**Motivation**
e5	EM3	60	0.7	medium	1	4.8 ± 0.2	$J/\Psi \to ee$, $\Upsilon \to ee$, Drell-Yan
2e5	2EM3	1	6.5	medium	1	6	$J/\psi \to ee$, $\Upsilon \to ee$, Drell-Yan
Jpsiee	2EM3	1	6.5	medium	1	1	$J/\psi \to ee$, $\Upsilon \to ee$
e10	EM7	1	5.0	medium	1	21	$e^{\pm}$ from b,c decays, E/p studies
γ10	EM7	1	5.0	medium	100	0.6 ± 0.1	$e^{\pm}$ direct photon cross-section, e-no-track trigger
e10_xe30	EM7_ XE30	1	0.2	medium	1	0.3 ± 0.3	access low p_T-range for $W \to e\nu$
2γ10	2EM7	1	0.5	loose	1	< 0.1	di-photon cross-section
2e10	2EM7	1	0.5	loose	1	0.4 ± 0.2	$Z \to e^+e^-$
Zee	2EM7	1	0.5	loose	1	< 0.1	$Z \to e^+e^-$
2e12i_L33	2EM7	1	0.5	tight	1	< 0.1	trigger for L$\sim 10^{33}$ cm^{-2} s^{-1}
γ15	EM13	1	0.7	medium	10	1.3 ± 0.1	$e^{\pm}$ direct photon cross-section
e15_xe20	EM13_ XE20	1	0.2	loose	1	1.0 ± 0.4	access low p_T-range for $W \to e\nu$
2g17i_L33	2EM13I	1	0.1	tight	1	< 0.1	trigger for L$\sim 10^{33}$ cm^{-2} s^{-1}
γ20	EM18	1	0.3	loose	1	5.4 ± 0.2	direct photons, jet calibration using γ-jet events, high-p_T physics,check tracking eff.
e20_ passL2	EM18	1	0.3	loose	200	< 0.1	check L2EF performance
e20 passEF	EM18	1	0.3		125	0.1	check L2EF performance
em20_ passEF	EM18	1	0.3		750	0.5 ± 0.1	check HLT performance
em20i_ passEF	EM18I	1	0.1		300	0.5 ± 0.1	check L1 isolation
e22i_L33	EM18I	1	0.1	tight	1	1.2 ± 0.1	trigger for L$\sim 10^{33}$ cm^{-2} s^{-1}
γ55_L33	EM18	1	0.3	tight	1	1.2 ± 0.1	trigger for L$\sim 10^{33}$ cm^{-2} s^{-1}
em105_ passHLT	EM100	1	1		1	1.0 ± 0.1	New physics, check for possible problems
γ150_ passHLT	EM100	1	1		1	< 0.1	check for possible problems in express stream

Table 5: Summary of triggers for the first physics run assuming a luminosity of L$\sim 10^{31}$ cm^{-2} s^{-1}. For each signature rates and the motivation for this trigger are given.

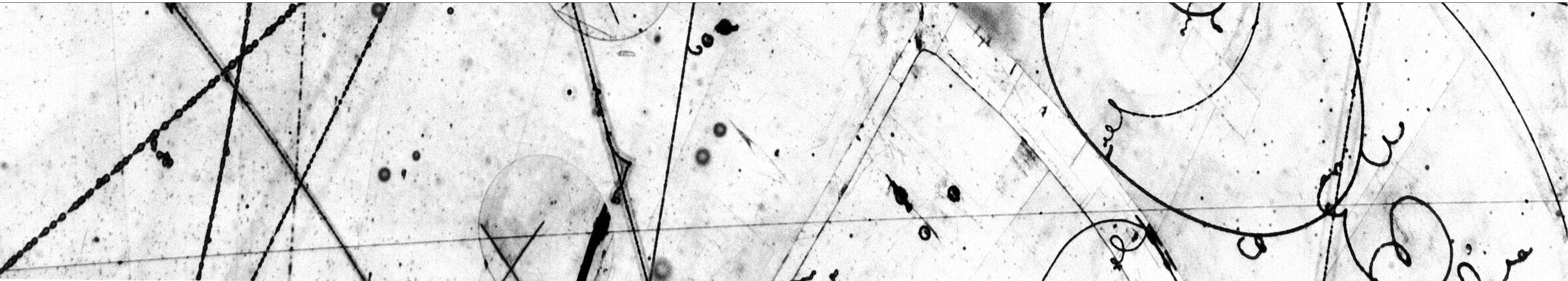


Part-I

- Introduction
- Trigger and Data Acquisition Basics

Part-II

- System Commissioning
- Trigger Selection
  - Electron and Jets
  - Muons
  - Secondary vertex
- Trigger Menu Design



Discussion Session

Topic for the discussion session this afternoon:

Pick your favourite physics analysis and discuss all the different trigger lines that are necessary to carry out this analysis (primary physics trigger(s), supporting trigger(s), "orthogonal" trigger(s), backup trigger(s), etc.)