# Updating Trigger information on ATLAS brochure(s)

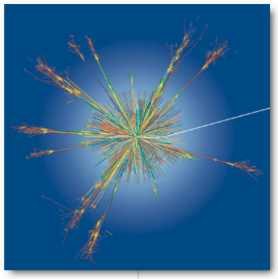
Fixing the 2009 Fact sheet (pages 2-4)

AVC smartboard slide (page 5)

Looking for ideas: summer student lectures (p 6 to end)

# Fixing the 2009 ATLAS Fact Sheet





## Event Rates

- At a beam luminosity of $10^{34}$ $cm^{-2}$ $s^{-1}$, there will be about 20 collisions per bunch crossing.
- 40 million bunch crossings per second.
- Yields about 1 billion collisions per second.
- Level 1 trigger filters that down to about 75 000 events per second.
- Level 2 trigger reduces it to about 2 000 events per second.
- The Event Filter then selects for permanent storage about 200 "interesting" events per second.

Frequency of producing a Higgs boson that has decayed to two Z bosons each of which has decayed to an electron-positron pair is extremely rare: once in $10^{13}$ = 10 000 000 000 000 interactions or one every 3 hours (a similar rate occurs when the Z boson decay to $\mu^+\mu^-$ pairs).

## Possible physics processes

Expected event rates at production in ATLAS at Energy = 14 TeV and Luminosity = $10^{33}$ $cm^{-2}$ $s^{-1}$

| Process | Events/s | Events for 10fb$^{-1}$ | Total statistics collected at previous machines by '07 |
|---|---|---|---|
| Inelastic proton-proton reactions | $10^8$ | $10^{15}$ | |
| W→eν | 20 | $10^8$ | $10^4$ LEP / $10^7$ Tevatron |
| Z→ee | 2 | $10^7$ | $10^7$ LEP |
| $t\bar{t}$ | 1 | $10^7$ | $10^4$ Tevatron |
| $b\bar{b}$ | $10^6$ | $10^{13}$ | $10^9$ Belle/BaBar |
| Higgs m = 120 GeV | 0.04 | $10^5$ | --- |
| Gluinos and Squarks m = 1 TeV | 0.001 | $10^4$ | --- |
| Black holes m > 3 TeV ($M_D$=3 TeV, n=4) | 0.0001 | $10^3$ | --- |



## Trigger and Data Acquisition (TDAQ)

The trigger system selects 100 interesting events per second out of 1000 million total.
The data acquisition system channels the data from the detectors to storage.

Bunches of protons cross 40 million times a second.
Each bunch contains $10^{11}$ protons.
Number of proton-proton collisions in the detector: 1 billion per second.
When any of the protons collide, the process is called an "event".
A given bunch crossing sometimes has particles from more than one proton-proton collision.

If all data would be recorded, this would fill 100 000 CDs per second. This would create a stack of CDs 150 m (450 ft) high every second, which could reach to the moon and back twice each year.
This data rate is also equivalent to making 50 billion telephone calls at the same time.

TDAQ has a 3 level Trigger system (reduction in three steps).
Total event reduction factor by the trigger system: 200 000.

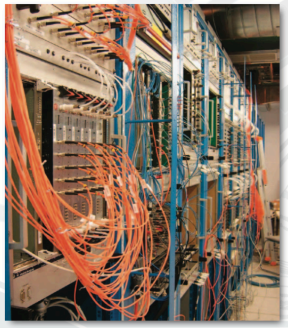
- 1st level trigger: Hardware, level 1 is done using special-purpose processors.[1]
- 2nd level trigger: Software, large computing farms with ~ 500 dual pc processors.
- 3rd level trigger: Software, large computing farms with ~ 1700 dual pc processors.

The rates and reduction factors at 14 TeV are summarized as:

| | Incoming event rate per second | Outgoing event rate per second | Reduction factor |
|---|---|---|---|
| Level 1 | 40 000 000 | 100 000 | 400 |
| Level 2 | 100 000 | 3 000 | 30 |
| Level 3 | 3 000 | 200 | 15 |

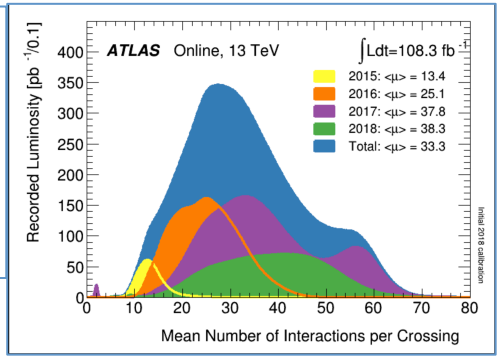
TDAQ records 320 Mbytes per second, which would fill more than 27 CDs per minute.

[1] massive parallel architecture pipeline processors (ASIC, FPGA)



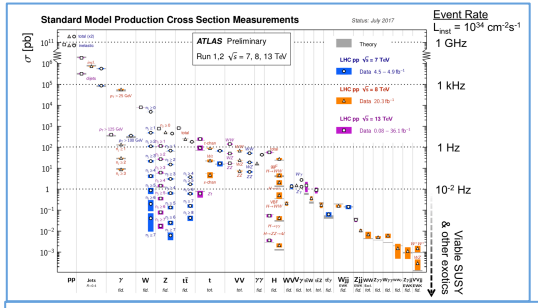
About right, but we are now running at 2 $10^{34}$. The number of collisions per beam crossing is about 40, with a maximum of ~60 .
The nice plot used to celebrate the 100 fb-1 milestone [ 29 May 2018 ] is here:

https://twiki.cern.ch/twiki/bin/view/AtlasPublic/LuminosityPublicResultsRun2#2018_pp_Collisions
https://twitter.com/ATLASexperiment/status/1001450428914196483




1 billion events per second is still the LHC number for $10^{34}$.

**The rest is obviously obsolete:**
L1 output rate ~ 100 000 events per second
L2 and EF do not exist any more
Export rate to storage ~ 1000 interesting events per second
It might be useful to mention that it corresponds to 2 GB/s




Still true, as shown on this plot taken from a talk. The official ATLAS plot misses the translation between cross section & rates
https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/SM/
https://indico.cern.ch/event/681549/contributions/2849754/attachments/1664941/2668681/LHCP2018_Upgrade_Tracking_TDAQ.pdf
(LHCP 2018, Anna Sfyrla, slide 7)

## Event Rates

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### Possible physics processes

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Still true: LHC design values, for 14 TeV and ~ 1.2 $10^{34}$ .
See the LHC "FAQ" brochure, updated in 2017 (page 30)
https://cds.cern.ch/record/2255762/files/CERN-Brochure-2017-002-Eng.pdf

**How** many collisions per second take place at the LHC?

Each beam consists of nearly 3000 bunches of particles and each bunch contains as many as 100 billion particles. The particles are so tiny that the chance of any two colliding is very small. When the bunches cross, there are up to 40 collisions between 200 billion particles. Bunches cross on average about 30 million times per second, so the LHC generates about 1 billion particle collisions per second.

????
Today's reference is blue-ray and netflix anyway
1 movie is ~ 1.5 GB
Netflix bandwidth is ~ 1 GB/hour
1 ATLAS raw event is ~ 1.5 MB

2 steps.
The online/HLT farm is now
~40-50 k processing units

L1 output rate ~ 100 000 events per second
L2 and EF do not exist any more
Export rate to storage ~ 1000 interesting events per second
TDAQ records 2 GB/s

## ATLAS Fact Sheet

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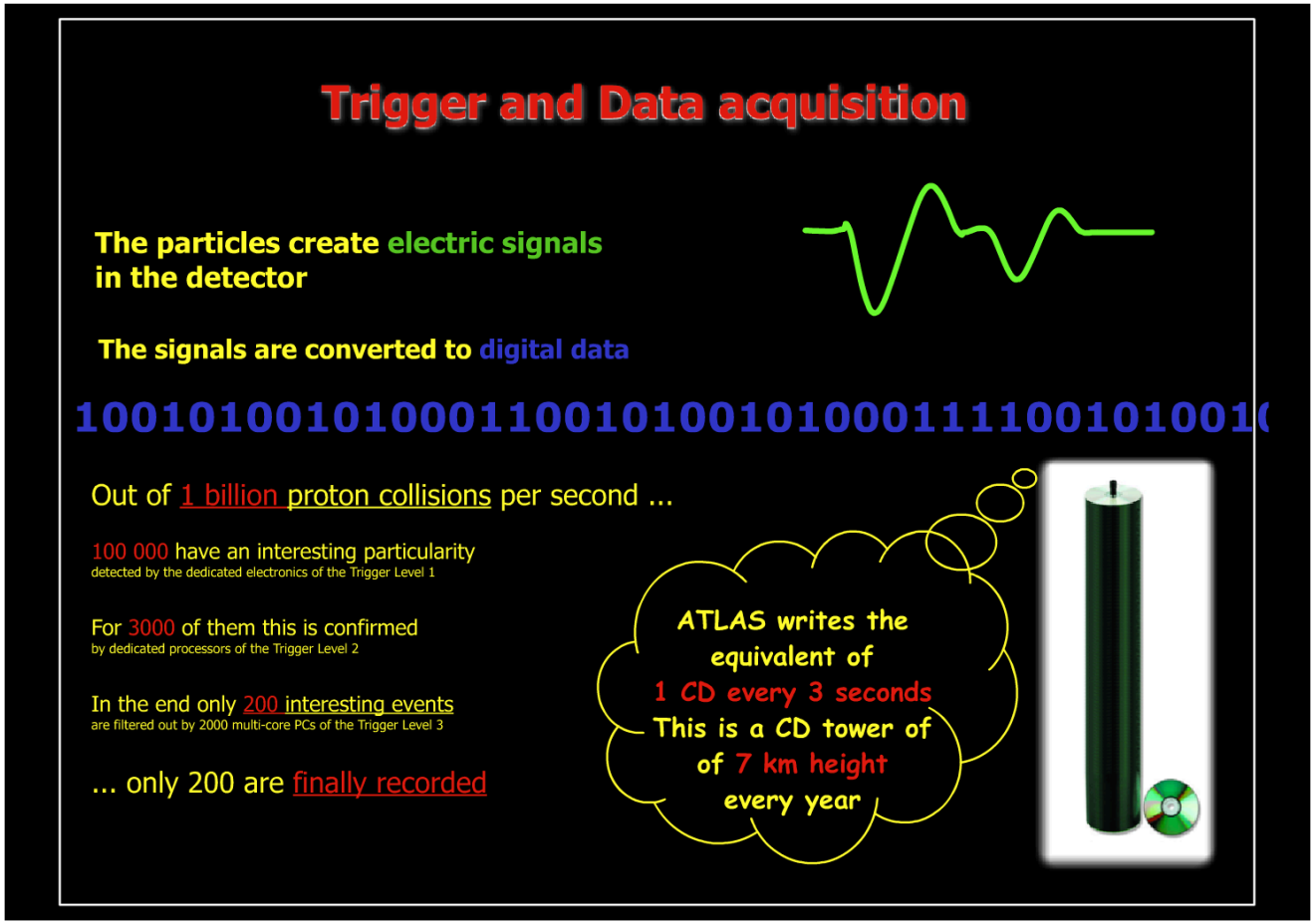
# AVC smartboard slide

Not very visible, because not included in the “short version” …



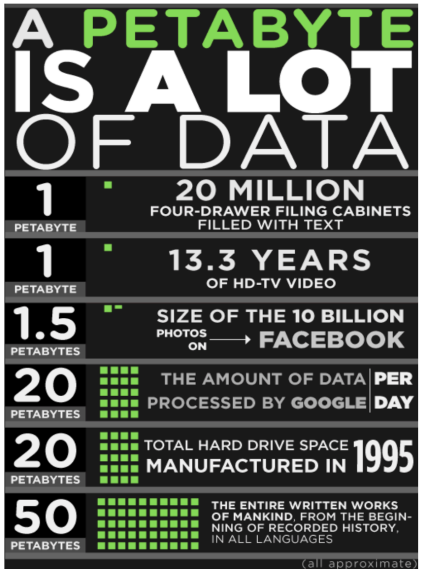
# Alternative suggestions: summer students lectures

Bryan Dahmes, 16-17 July 2013

Triggers for LHC physics
https://indico.cern.ch/event/243674/

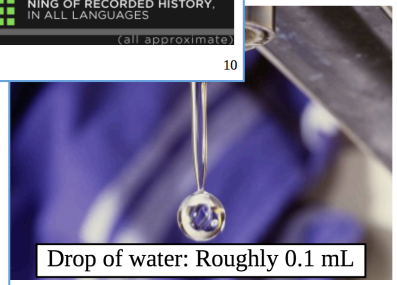
# Keeping Events

- We can't save everything!
  - Event size: about 1 MB
  - Event reconstruction time:
    - 30 sec – 1 minute
  - At a data rate of O(100 Hz)...
    - O(100) MB/sec
    - O(few) PB/year per experiment
  - Keeping every event
    - O(100000) PB/year
    - Too big to store, reconstruct, analyze




Bryan Dahmes (Minnesota) Summer Student Lecture Program: Triggers for LHC Physics (16-17 July 2013) 10

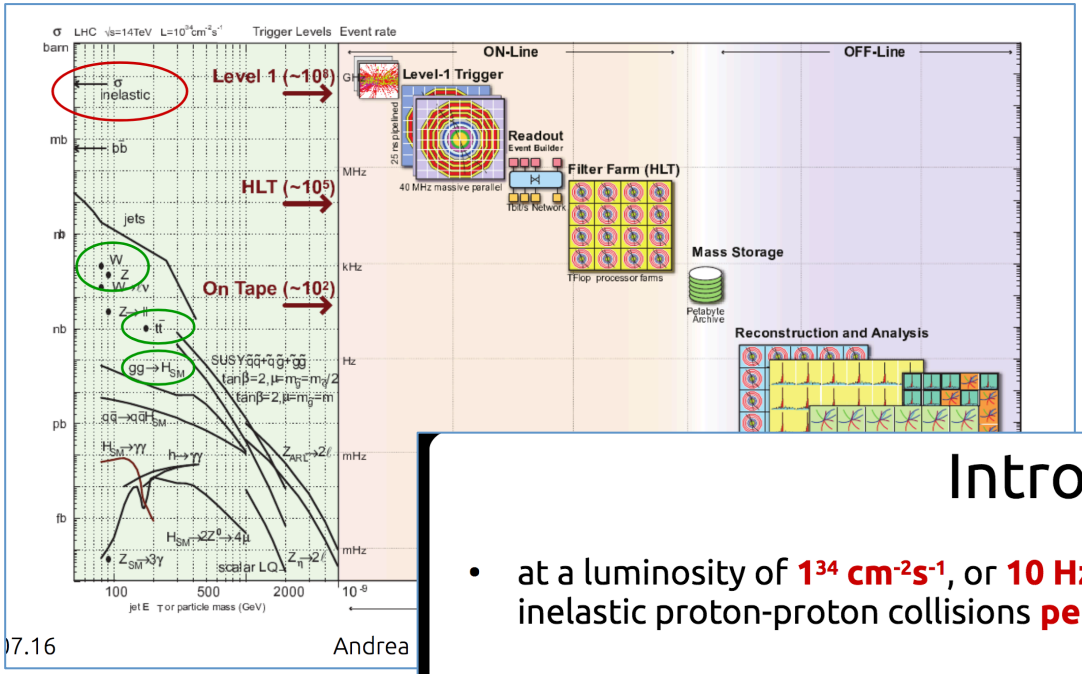
# Perspective


Drop of water: Roughly 0.1 mL

**1 in 10,000,000,000:**
Like looking for a single drop of water from the Jet d'Eau over 30 minutes


Jet d'Eau: 500 L/sec

Bryan Dahmes (Minnesota) Summer Student Lecture Program: Triggers for LHC Physics (16-17 July 2013) 8




Andrea Bocci (16.07.2015)

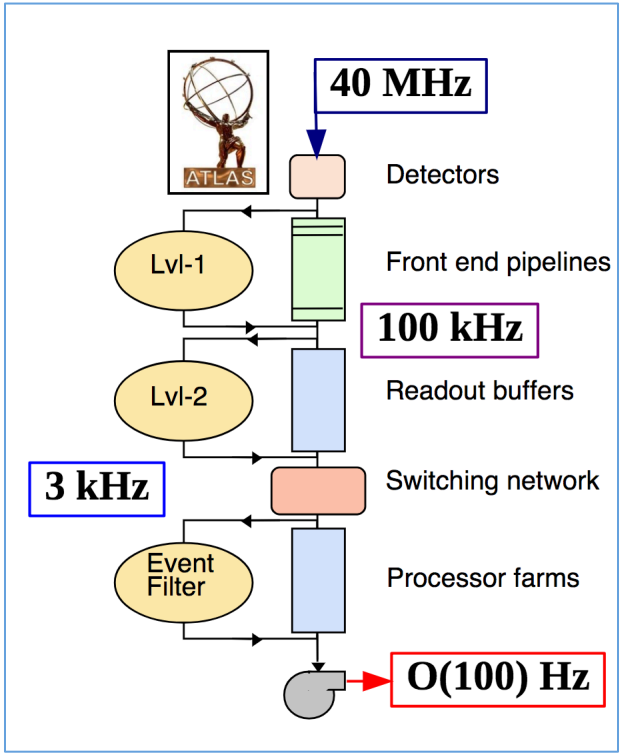
"Triggers for LHC physics"
https://indico.cern.ch/event/387992/

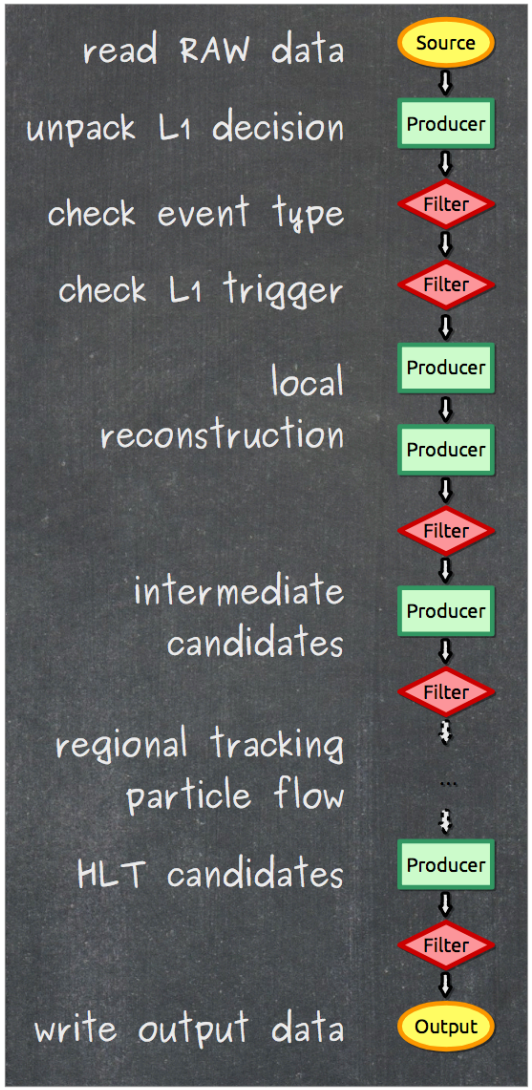
# Introduction

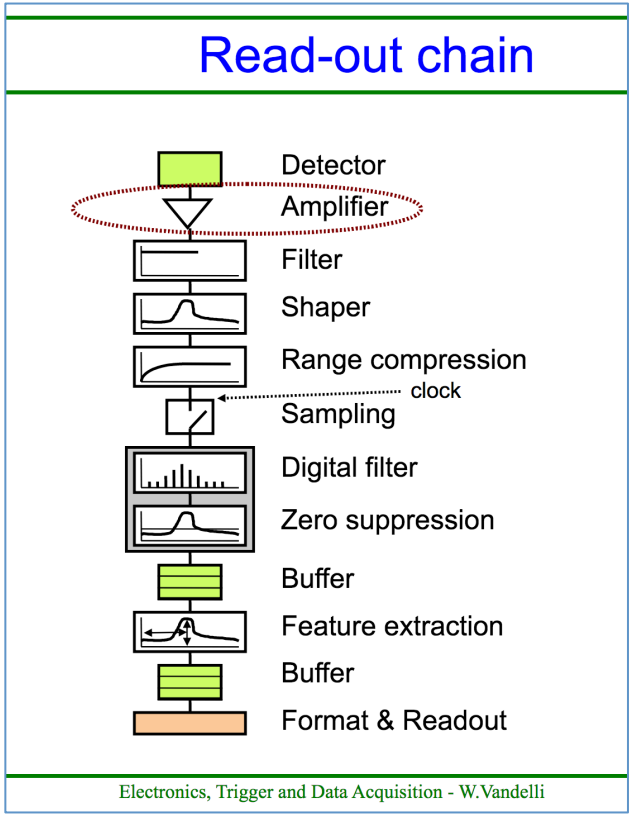
- at a luminosity of **$1^{34}$ cm$^{-2}$s$^{-1}$**, or **10 Hz/nb**, the LHC will produce **~0.8 billion** inelastic proton-proton collisions **per second**
- at the same luminosity, we expect the production of around **1000 W and Z per second**, **1 $t\bar{t}$ pair per second**, few **Higgs bosons per minute** …
- finding one Z boson is like finding a **single person** in **Stockholm** !
- finding a $t\bar{t}$ decay is like finding a **single person** in **all of Europe** !
- finding a 

is like finding a **single person** on the whole **Earth** !

| Bryan Dahmes, 16-17 July 2013<br><br>Triggers for LHC physics<br>https://indico.cern.ch/event/243674/ | Andrea Bocci (16.07.2015)<br><br>“Triggers for LHC physics”<br>https://indico.cern.ch/event/387992/ | Wainer Vandelli, 11 July 2013<br><br>Electronics / TDAQ<br>https://indico.cern.ch/event/243655/ |
|---|---|---|



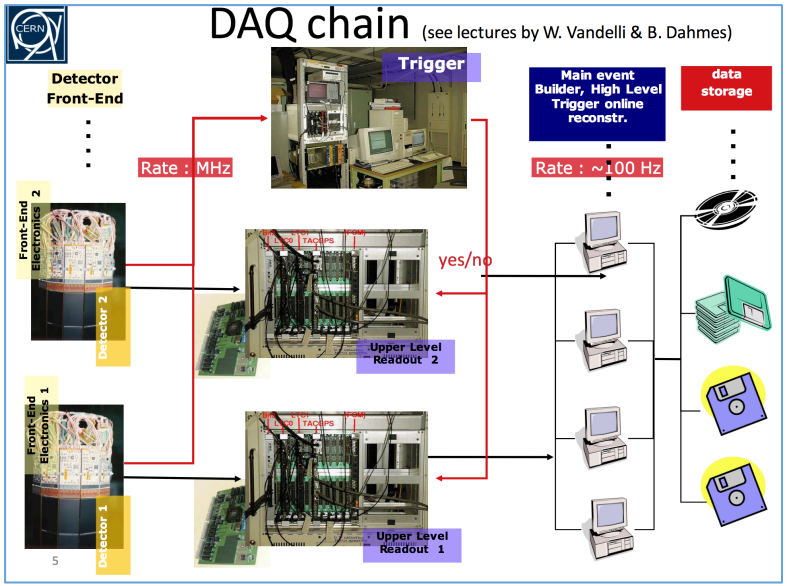



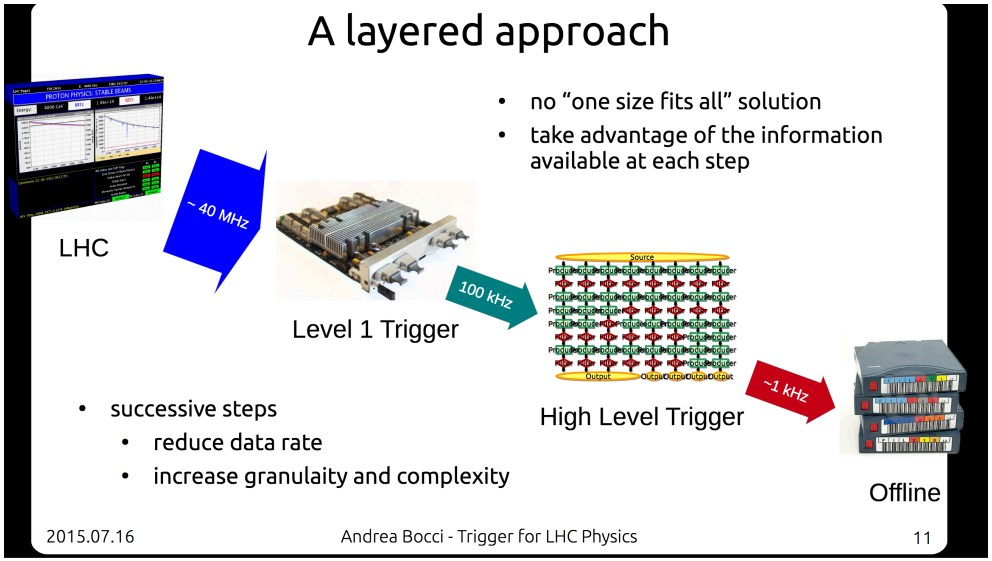
Jamie Boyd, 18-22 July 2013

From Raw data to Physics results
https://indico.cern.ch/event/243720/

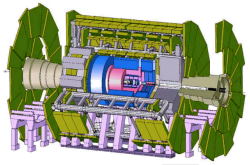
Andrea Bocci (16.07.2015)

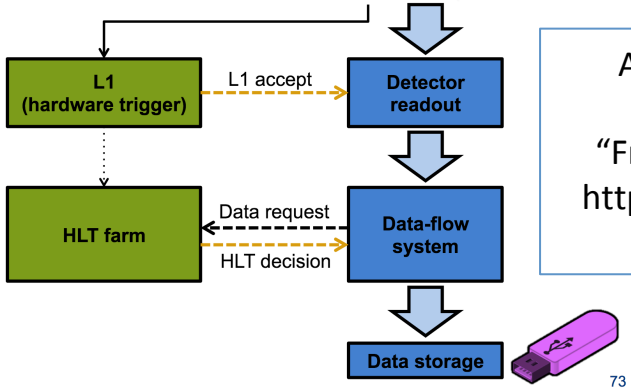
“Triggers for LHC physics”
https://indico.cern.ch/event/387992/



## THE DATA ACQUISITION



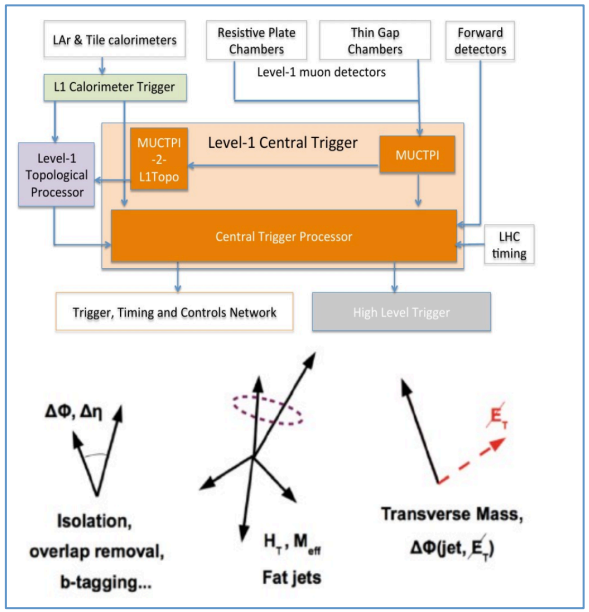



Anna Sfyrla (17.07.2015)

"From Raw data to physics"
https://indico.cern.ch/event/388222/

Andrea Bocci (16.07.2015)

"Triggers for LHC physics"
https://indico.cern.ch/event/387992/




## THE ATLAS TRIGGER SYSTEM