Trigger Introduction

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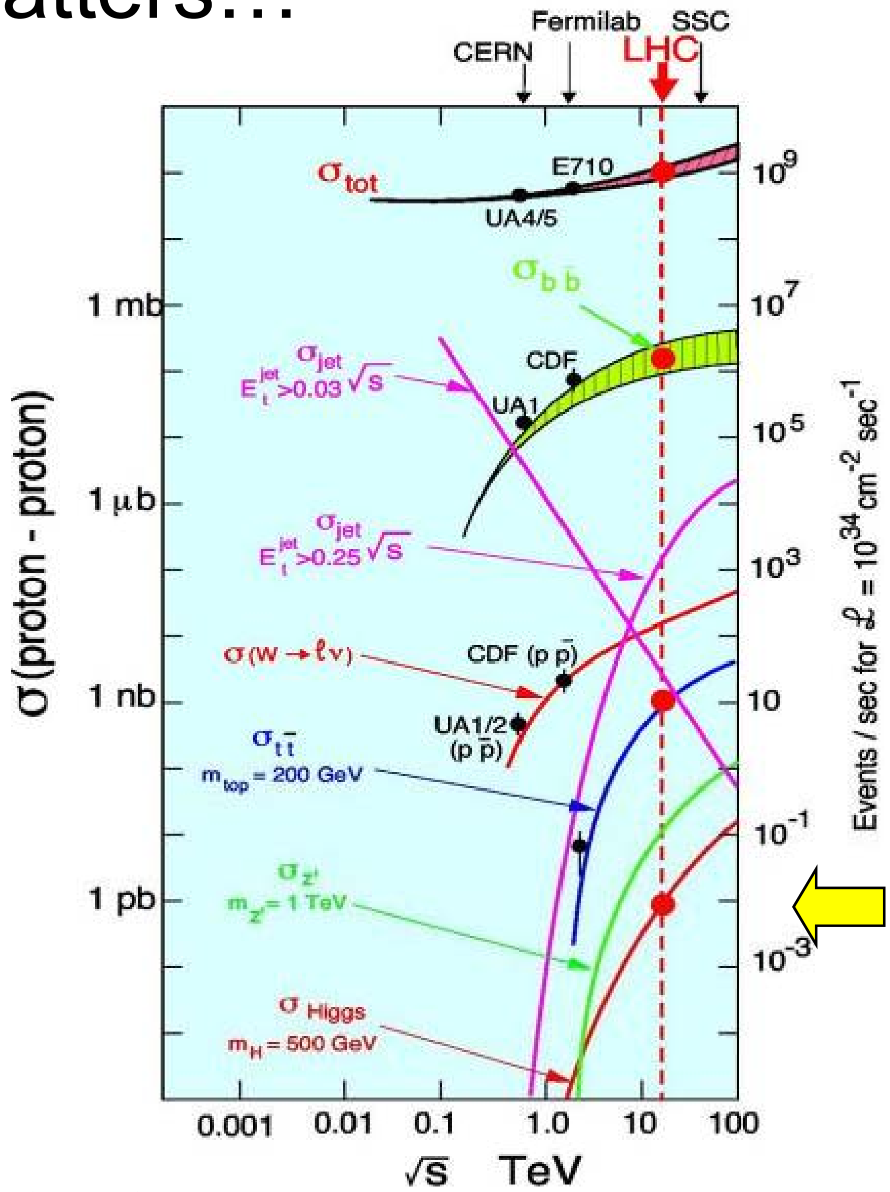
Outline:

- Why it matters
- How it works
- Trigger rates
- Trigger menus
  - TAPM meeting tomorrow

Why it matters…

- Much of ATLAS physics means cross sections at least ~10^6 times smaller than total cross section
- For the Higgs group, think ~10^6 times smaller than total cross section
- 25ns bunch crossing interval (40 MHz)
- Offline storing/processing: ~200 Hz
  - ~5 events per million crossings!
- In **one second** at design luminosity:
  - 40 000 000 bunch crossings
  - ~2000 W events
  - ~500 Z events
  - ~10 top events
  - ~0.1 Higgs events?
  - **200 events written out**



Rate

- Estimated with background: to first order, all events are background!

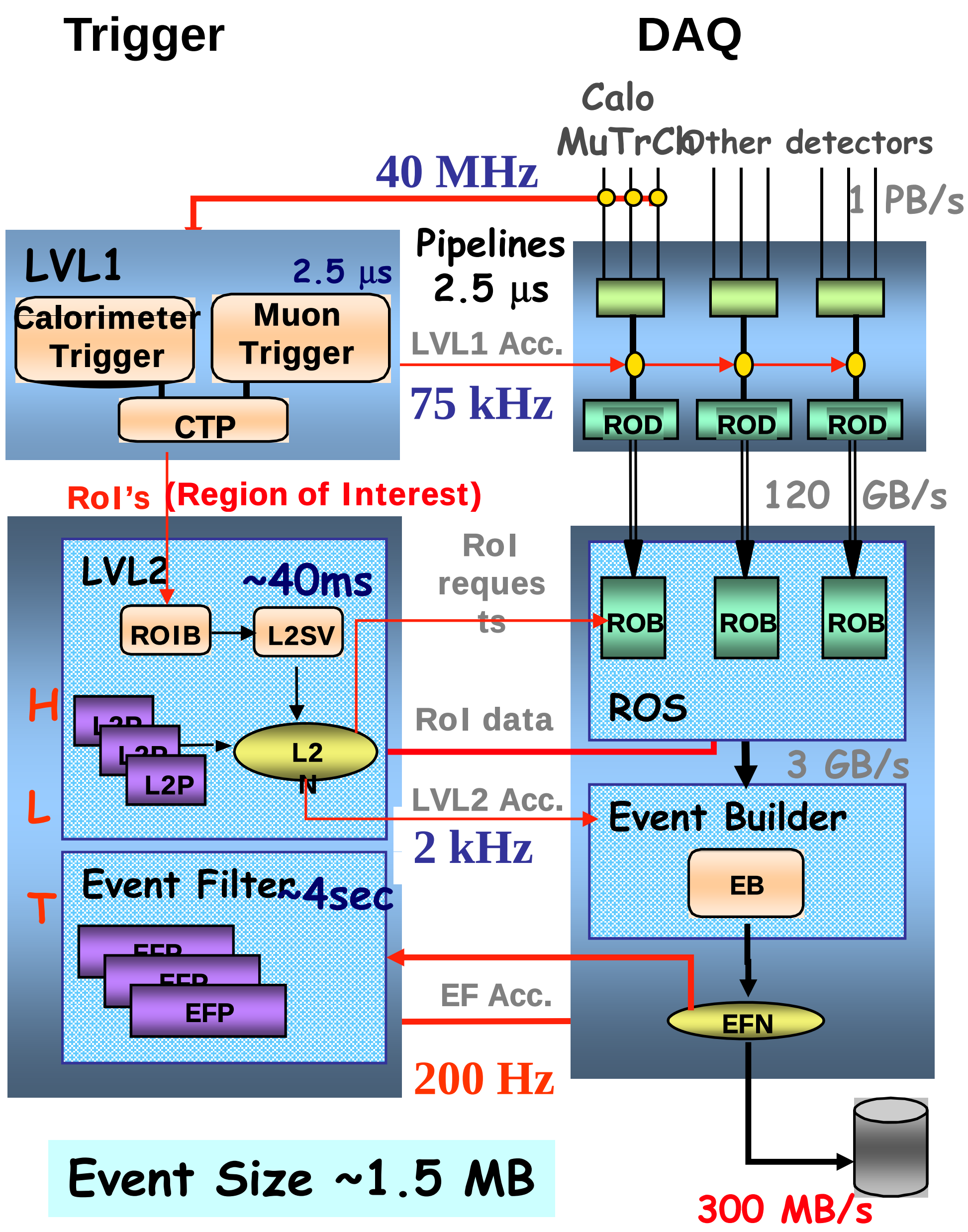
$$R[s^{-1}] = L[cm^{-2} \cdot s^{-1}] \times \sigma[cm^{2}]$$

- Overall limits:
  - **~50 kHz @ L1**
  - **~1 kHz @ L2**
  - **~200 Hz @ EF**

- Must use all available output rate to the full:
  - >200 Hz not sustainable
  - <200 Hz means wasted data

- Example: for e25i use di-jet sample with p_T>17GeV
  - No contamination from lower p_T jets expected
  - Passed events from $\pi^0 \rightarrow \gamma\gamma$, jets, e from heavy-flavour decays etc
  - Assumes rate of other processes much smaller

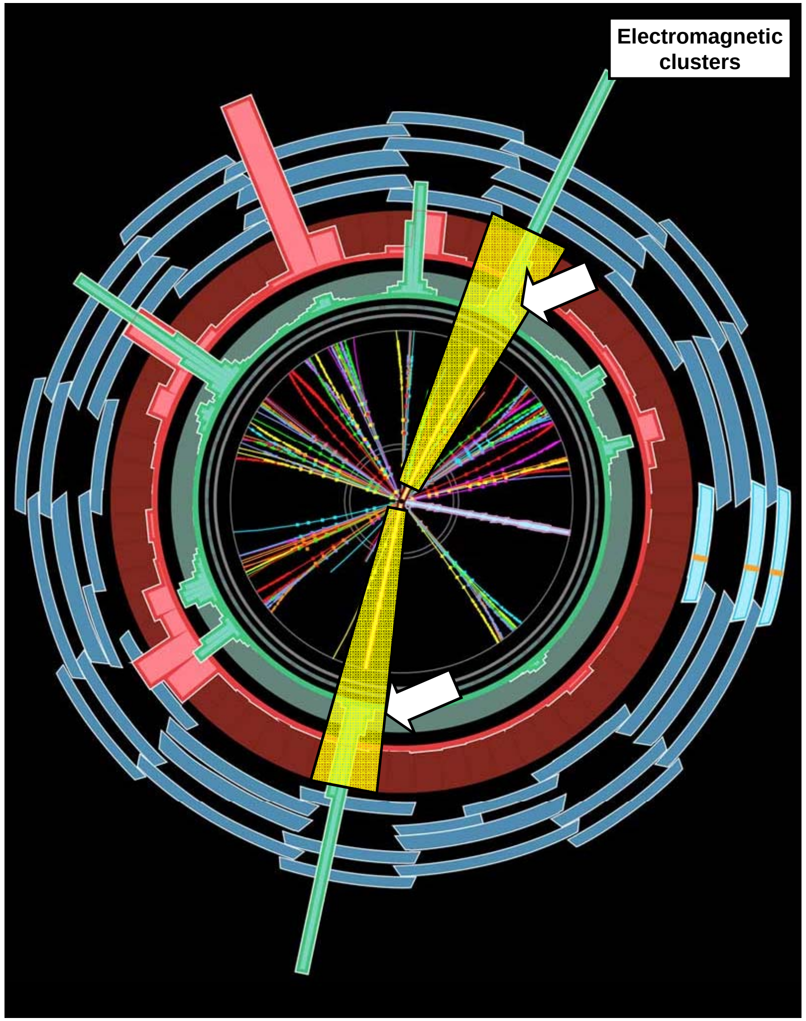
- Three trigger levels:
- Level 1:
  - Hardware based
  - Calorimeter and muons only
  - Latency 2.5 µs
  - Output rate ~75 kHz
- Level 2: ~500 farm nodes(*)
  - Only detector "Regions of Interest" (RoI) processed - Seeded by level 1
  - Fast reconstruction
  - Average execution time ~40 ms(*)
  - Output 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

Selection method

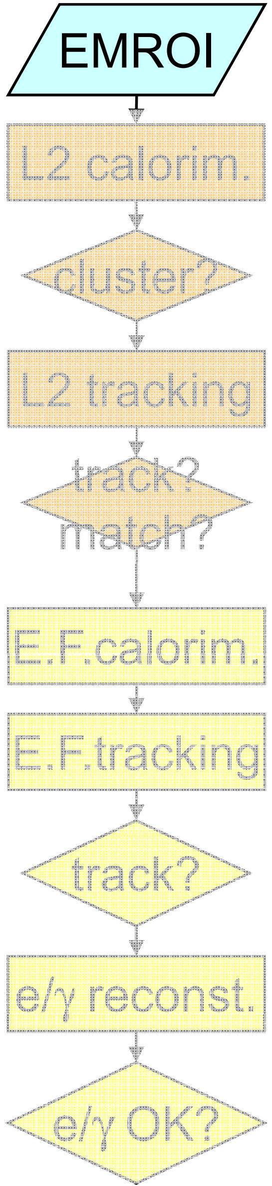
Event rejection possible at each step



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

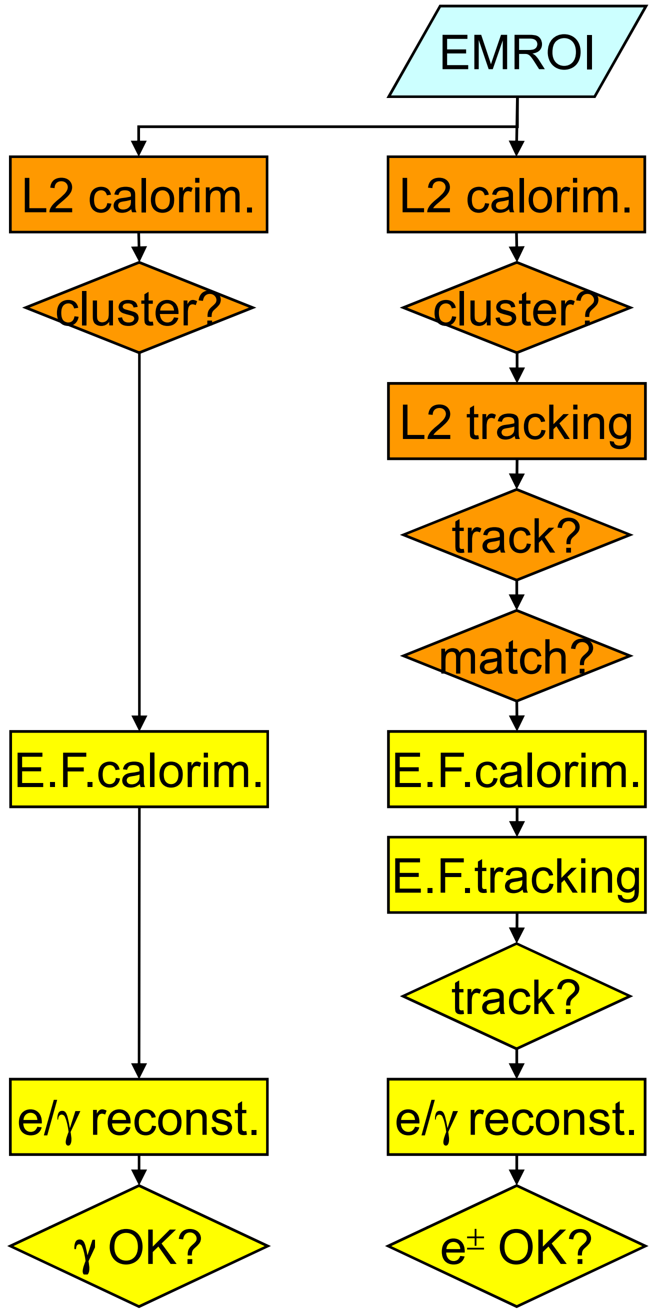
Level 2 seeded by Level 1
Fast reconstruction algorithms
Reconstruction within RoI

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



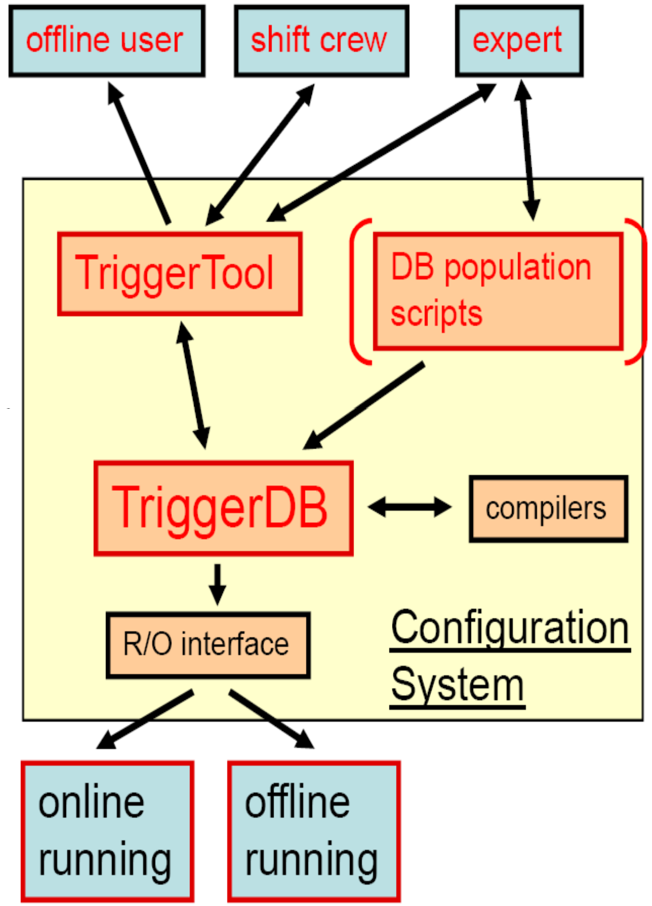
Steering

- 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…



Configuration

- Trigger configuration:
  - Active triggers
  - Their parameters
  - Prescale factors
  - Passthrough fractions
  - Consistent over three trigger levels
- Needed for:
  - Online running
  - Event simulation
  - Offline analysis
- Relational Database (TriggerDB) for online running
  - User interface (TriggerTool)
  - Browse trigger list (menu) through key
  - Read and write menu into XML format
  - Menu consistency checks
- After run, configuration becomes conditions data (Conditions Database)
  - For use in simulation & analysis



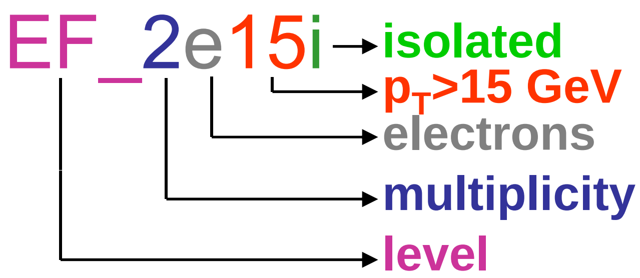
Trigger algorithms

- High-Level Trigger algorithms organised in groups (“slices”):
  - Minimum bias, e/γ, τ, μ, jets, B physics, B tagging, E_T^{miss}, cosmics, plus combined-slice algorithms
- For commissioning
  - Cosmics slice used to exercise trigger – already started!
- For initial running:
  - Crucial to have minimum bias, e/γ, τ, μ, jets
  - B physics will take advantage of initial low-lumi conditions (not bandwidth-critical)
    - Lower event rate allow low transverse momentum thresholds needed for B physics
  - E_T^{miss} and B-jet tagging will require significant understanding of the detector
- Will need to understand trigger efficiencies and rates <u>using real data</u>
  - Zero bias triggers (passthrough)
  - Minimum bias:
    - Coincidence in scintillators placed in front of calo.
    - Counting inner-detector hits
  - Prescaled loose triggers
  - “Tag-and-probe” method, etc

1. Select good offline $Z\rightarrow\mu\mu/ee$
2. Randomly select “**tag**” lepton; if triggered, use second lepton as “**probe**”
3. ε = #(triggered probes)/#(all)

Trigger Menus

- 12.0.6-7 used for CSC production;
  - Use CSC-06 configuration:
  - Stream tests use ~different menu (STR-01)
- Main physics trigger signatures:



Slice	HLT signatures	Starting from L1 items:	Comments
Electron	2e15i, e25i, e60	2EM15, 2EM25, EM60	No isolation in L1 items; e25i ~realistic
Photon	2g20i, g60	2EM15I, EM60	Start from L1 items with isolation
Muon	mu6, mu20i	MU06, MU20	No isol; mu20i ~realistic; L1 p_T ordering
Tau	tau10i, tau15i, tau20i, tau25i, tau35i	TAU10i, TAU15i, TAU20i, TAU25i, TAU35i	
Jet	j160, 2j120, 3j65, 4j50	J45, 2J45, 3J45, 4J45	L1_J45 not realistic
ETmiss	met10	TAU05	Starts from L1 tau

- In addition, technical or “expert” signatures for performance studies
  - tauNoCut, e10, jet20…
  - Needed in practice to allow trigger rerunning (must produce trigger objects)
- In 13.0.x around 90 signatures being developed aimed at an initial data taking

Trigger	p_T threshold(*)	Obs
Electron	5,10,15,	Prescale
Electron	20,25,100	No presc
Di-electron	5,10	Prescale
Di-electron	15	No presc
Photon	10,15,20	Prescale
Photon	20	No presc
Di-photon	10	Prescale
Di-photon	20	No presc
Jets	5,10,18,23,35,42,70	Prescale
Jets	100	No presc
3 Jets	10,18	B-tag
4 Jets	10, 18	B-tag
4 Jets	23	Express
τ	10, 15, 20, 35	
Di- τ	10+15,10+20,10+25	
Muon	4, 6, 10, 11, 15, 20, 40	Muon spectr.
Muon	4, 6, 10, 11, 15, 20, 40	ID+Muon
Di-muon	4, 6, 10, 15, 20	Passtthr.
ΣE_T	100, 200, 304	prescale
ΣE_T	380	No presc

Trigger	p_T threshold(*)	Obs
ΣE_T (jets)	?	?
E_T^{miss}	12, 20, 24, 32, 36, 44	Prescale
E_T^{miss}	52, 72	No presc
$J/\Psi \rightarrow ee$	Topological	B-phys
$\mu\ \mu$	4	B-phys
$J/\Psi \rightarrow \mu\ \mu$	Topological	B-phys
BsDsPhiPi	Topological	B-phys
$B\gamma X$		B-phys
e + E_T^{miss}	18+12	Prescale
μ + E_T^{miss}	15+12	No presc
Jet + E_T^{miss}	20+30	No presc
2 Jets + E_T^{miss}	42+30	No presc
Jet+ E_T^{miss} +e	42+32+15	No presc
Jet+ E_T^{miss} + μ	42+32+15	No presc
4 Jet + e	23+15	No presc
4 Jet + μ	23+15	No presc
τ + E_T^{miss}	15+32,25+32, 35+20,35+32	
τ + e	10+10	Express
τ + μ	10+6	Express
2 τ + e	10+10	Express

Backup slides

Trigger strategy for initial running

- Major effort ongoing to design a complete trigger list ("menu") for initial running
  - Commissioning of detector and trigger; early physics
  - Start with $\mathcal{L}=10^{31}$ $cm^{-2}s^{-1}$ benchmark and scale accordingly

- Many sources of uncertainty:
  - Background rate (dijet cross section uncertainty up to factor ~2)
  - Beam-related backgrounds
  - New detector: alignment, calibration, noise, Level 1 performance (calo isolation?), etc
  - Event occupancy

- Must be conservative and be prepared to face much higher rates than expected

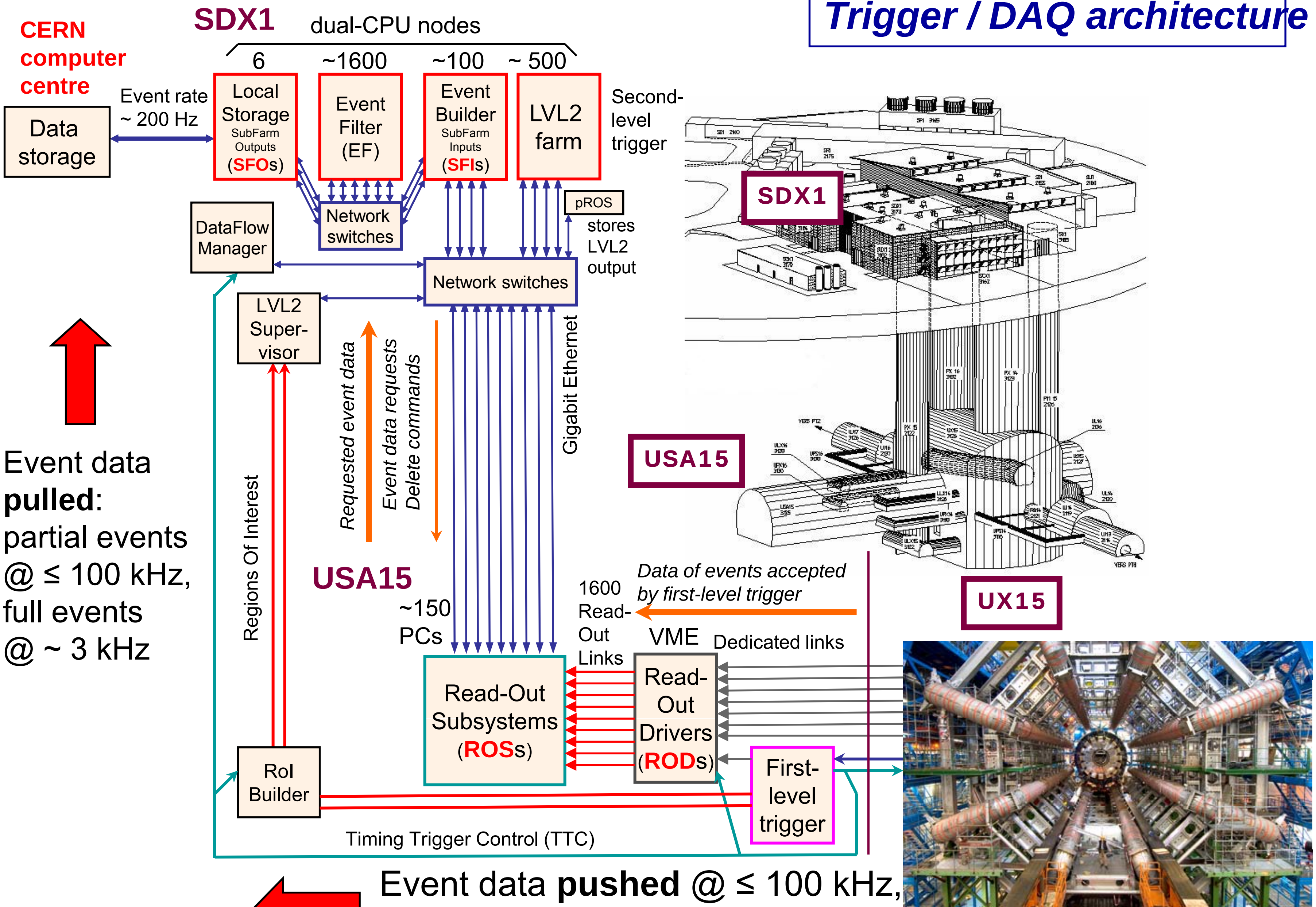
- Need many "handles" to understand the trigger:
  - Many low-threshold, prescaled triggers, several High Level triggers will run in "pass-through" mode (take the event even if trigger rejects it)
  - Monitoring framework (embedded in algorithms, flexible and with small overheads)
  - Redundant triggers
    - e.g. minimum bias selection with inner detector and with min.bias scintillators

- Expect the menu to evolve rapidly, especially once it faces real data

Prescaling

- Prescale factor of N means 1 in N passed events is accepted
  - Simply done with a counter: no bias, input events are random
- Can be applied to L1 items or HLT chains
- Affects efficiency and rate in the same way!
- Different prescales throughout run possible (desirable!):
  - Start with higher prescales and go to lower prescale set when rate is low enough
  - Try to maintain ~constant rate throughout fill to optimise use of available output rate capability

Trigger / DAQ architecture



Event data **pulled**:
partial events @ ≤ 100 kHz,
full events @ ~ 3 kHz

Event data **pushed** @ ≤ 100 kHz,
1600 fragments of ~ 1 kByte each