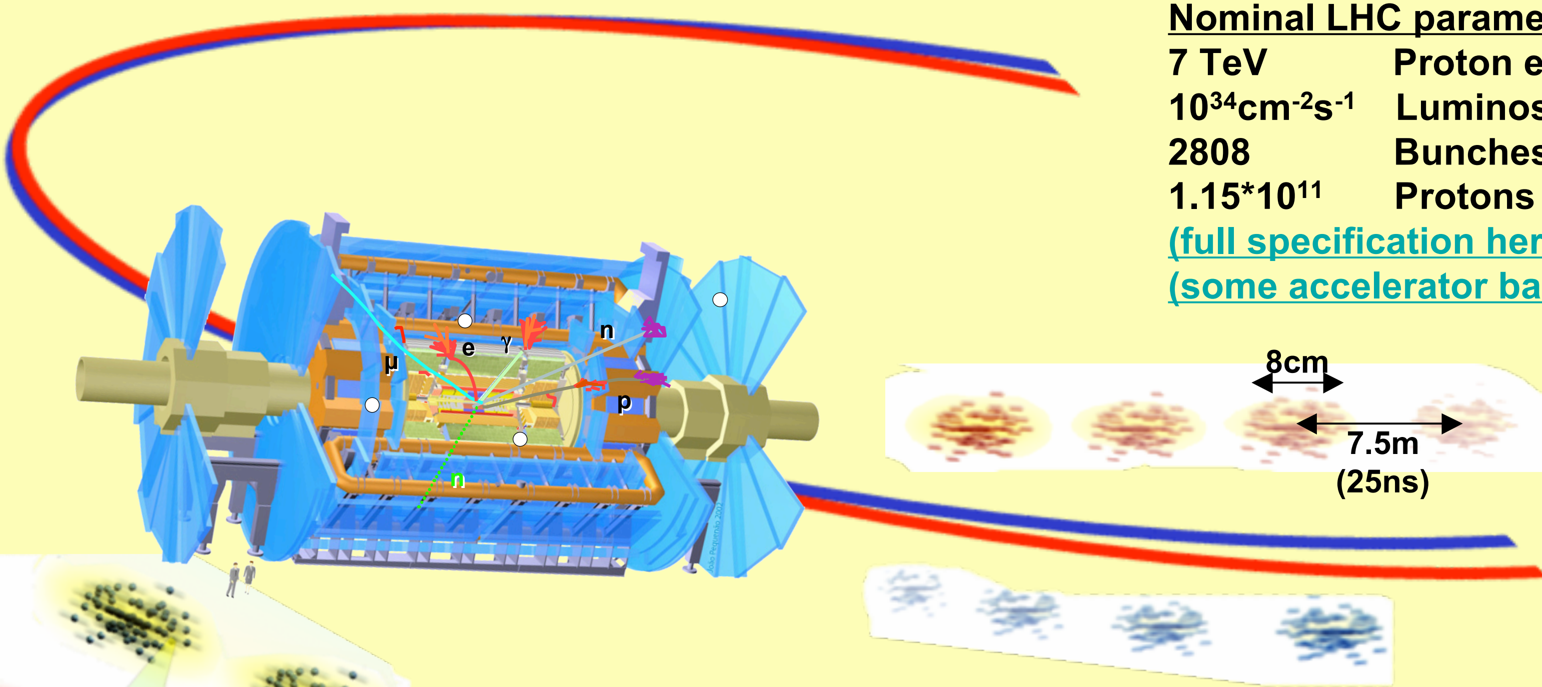
ATLAS Data Flow

LHC, ATLAS, Trigger+DAQ
to Offline processing centres

Hans von der Schmitt

Proton-Proton collisions at LHC



Nominal LHC parameters:

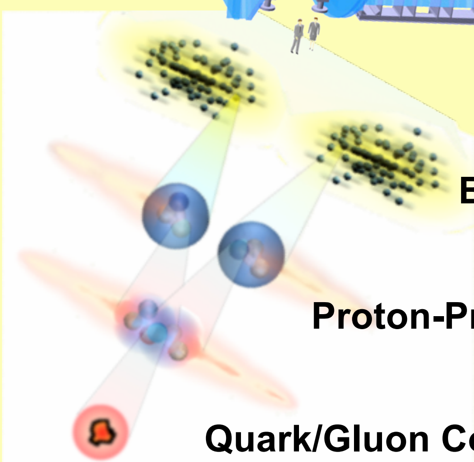
7 TeV	Proton energie
$10^{34}cm^{-2}s^{-1}$	Luminosity
2808	Bunches per beam
$1.15*10^{11}$	Protons per bunch

(full specification here)

(some accelerator basics here)

0.58 A per beam

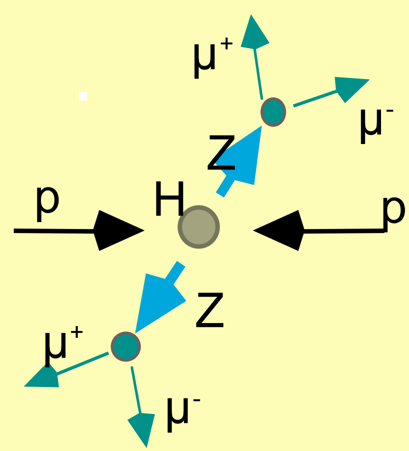
362 MJoule per beam



Bunch Crossings $4x10^7$ Hz

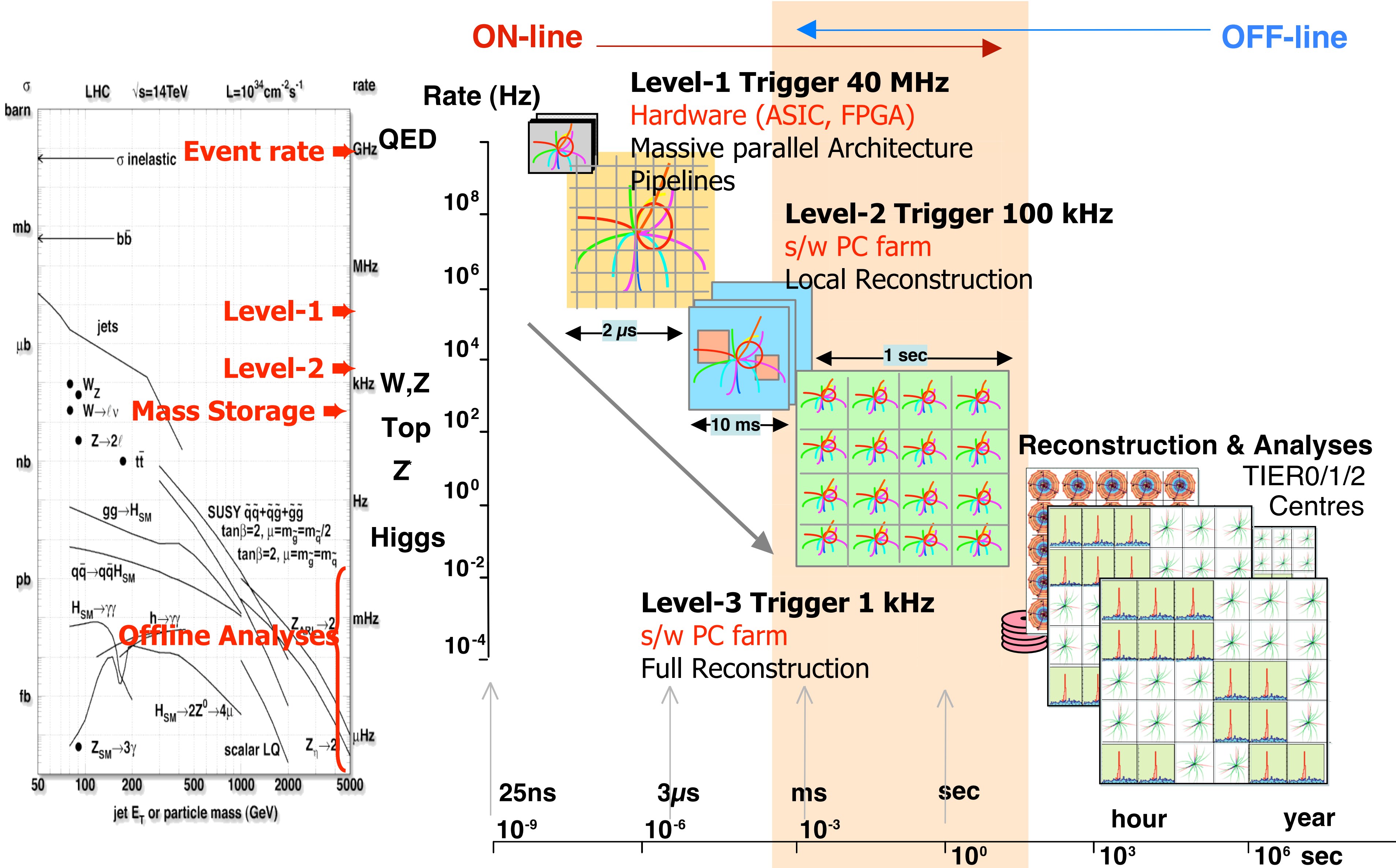
Proton-Proton Collisions 10^9 Hz

Quark/Gluon Collisions

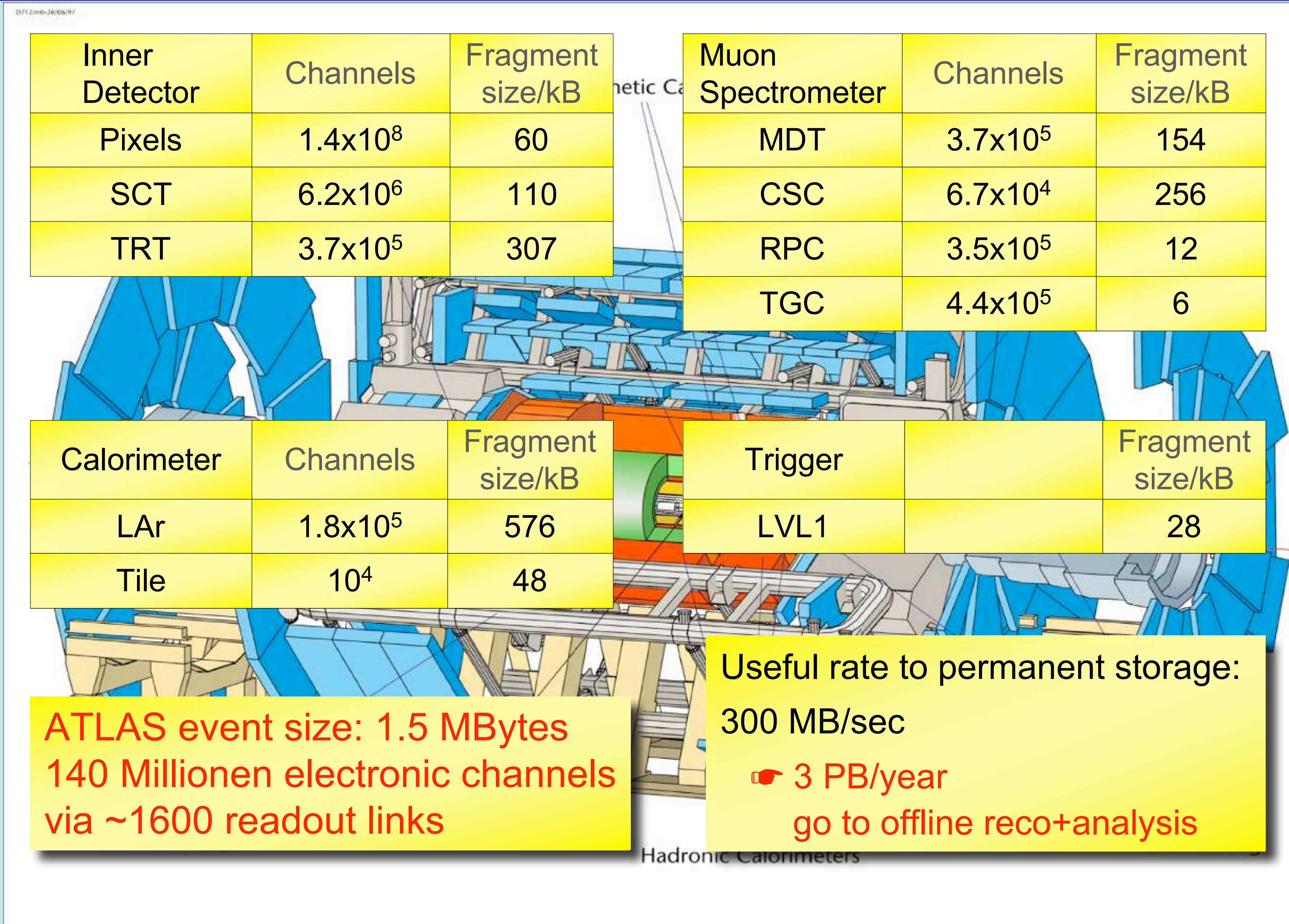


Production of heavy particles $10^{+3...-7}$ Hz
(W, Z, t, Higgs, SUSY,…)

From bunchcrossings to physics analyses



ATLAS and data volumes



Inner Detector	Channels	Fragment size/kB
Pixels	1.4×10^{8}	60
SCT	6.2×10^{6}	110
TRT	3.7×10^{5}	307

Muon Spectrometer	Channels	Fragment size/kB
MDT	3.7×10^{5}	154
CSC	6.7×10^{4}	256
RPC	3.5×10^{5}	12
TGC	4.4×10^{5}	6

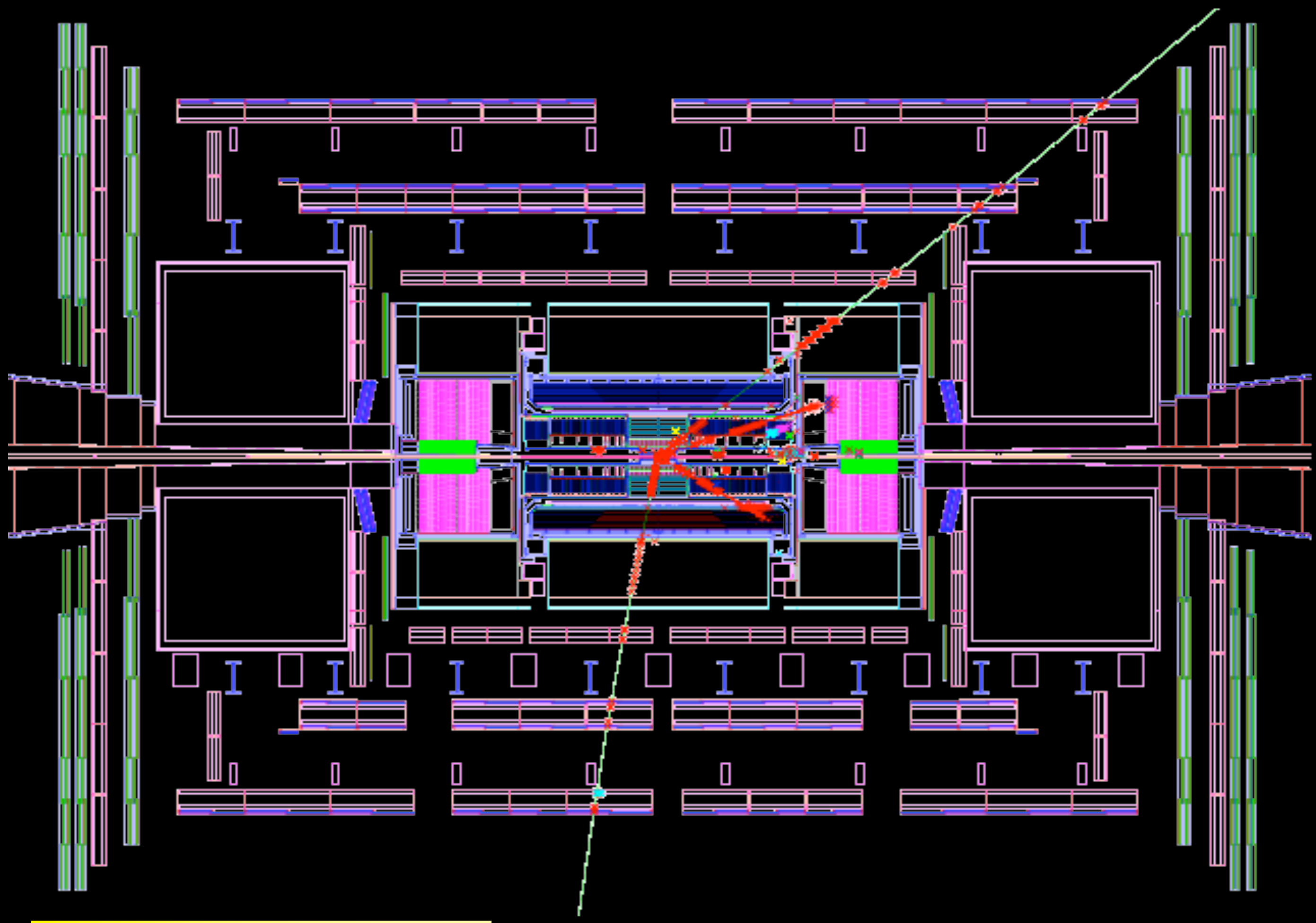
Calorimeter	Channels	Fragment size/kB
LAr	1.8×10^{5}	576
Tile	10^{4}	48

Trigger		Fragment size/kB
LVL1		28

ATLAS event size: 1.5 MBytes
140 Millionen electronic channels
via ~1600 readout links

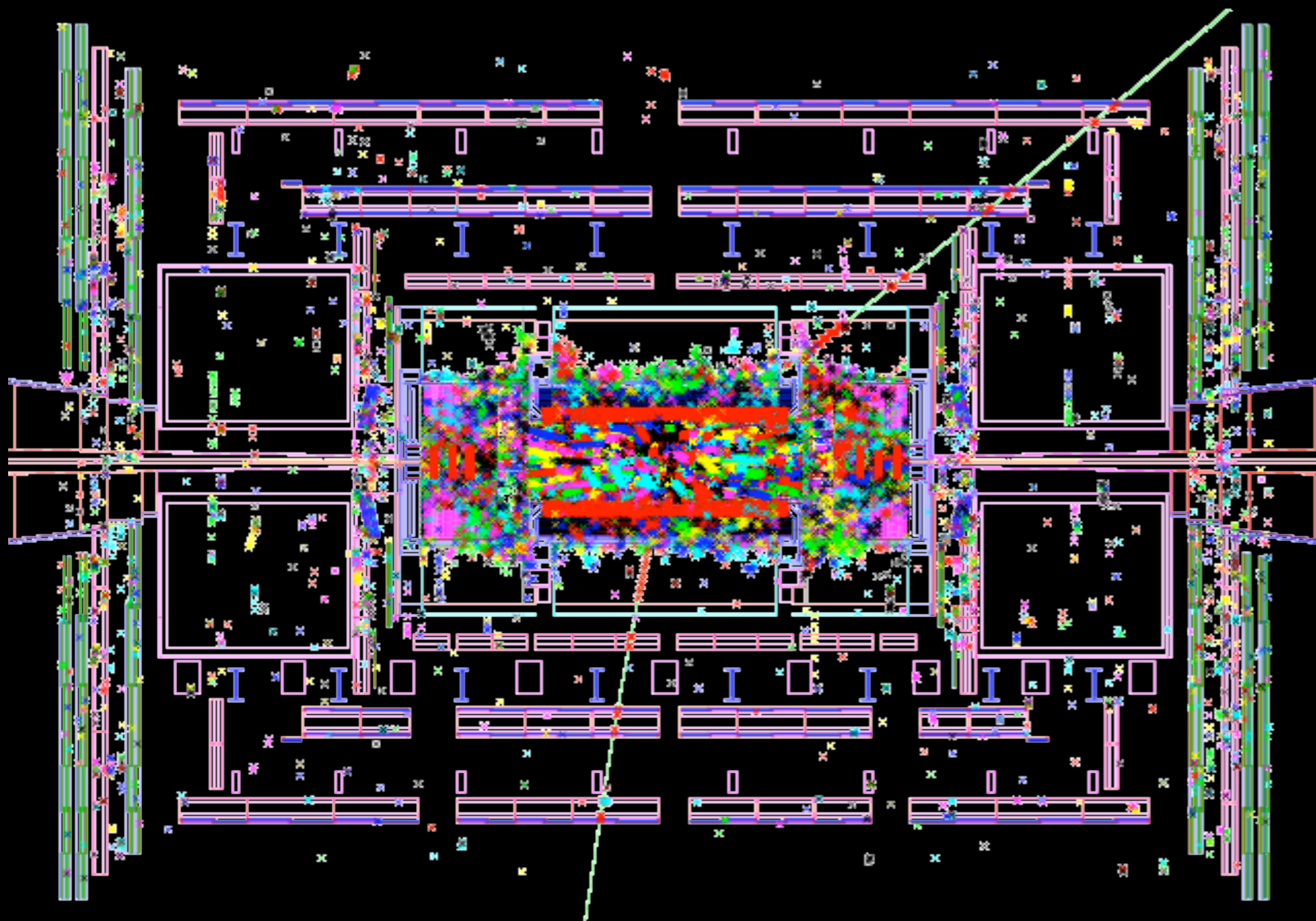
Useful rate to permanent storage:
300 MB/sec
☛ 3 PB/year
go to offline reco+analysis

Finding interesting events



Higgs → ZZ → 2e+2μ

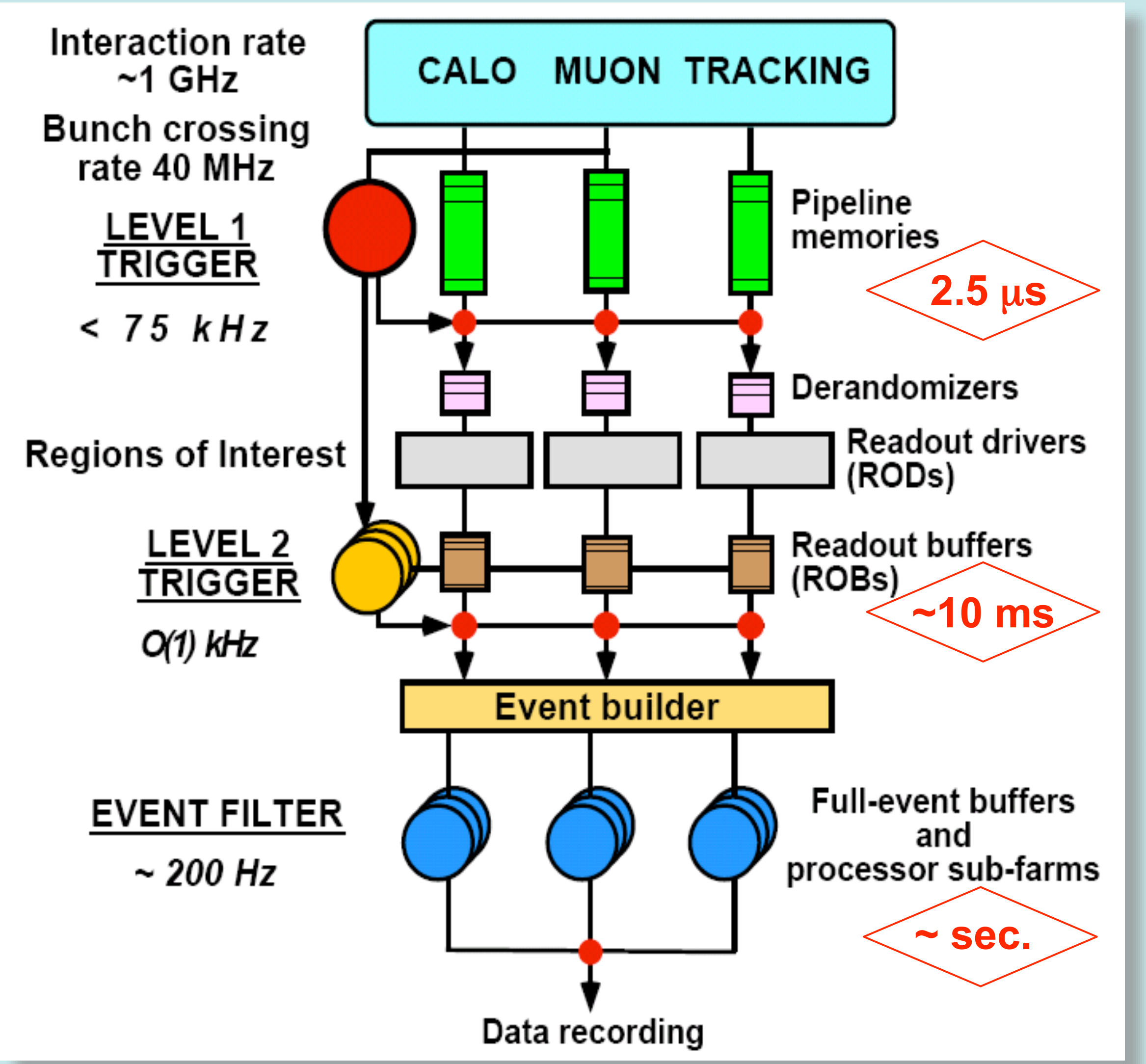
Finding interesting events



Higgs → ZZ → 2e+2μ

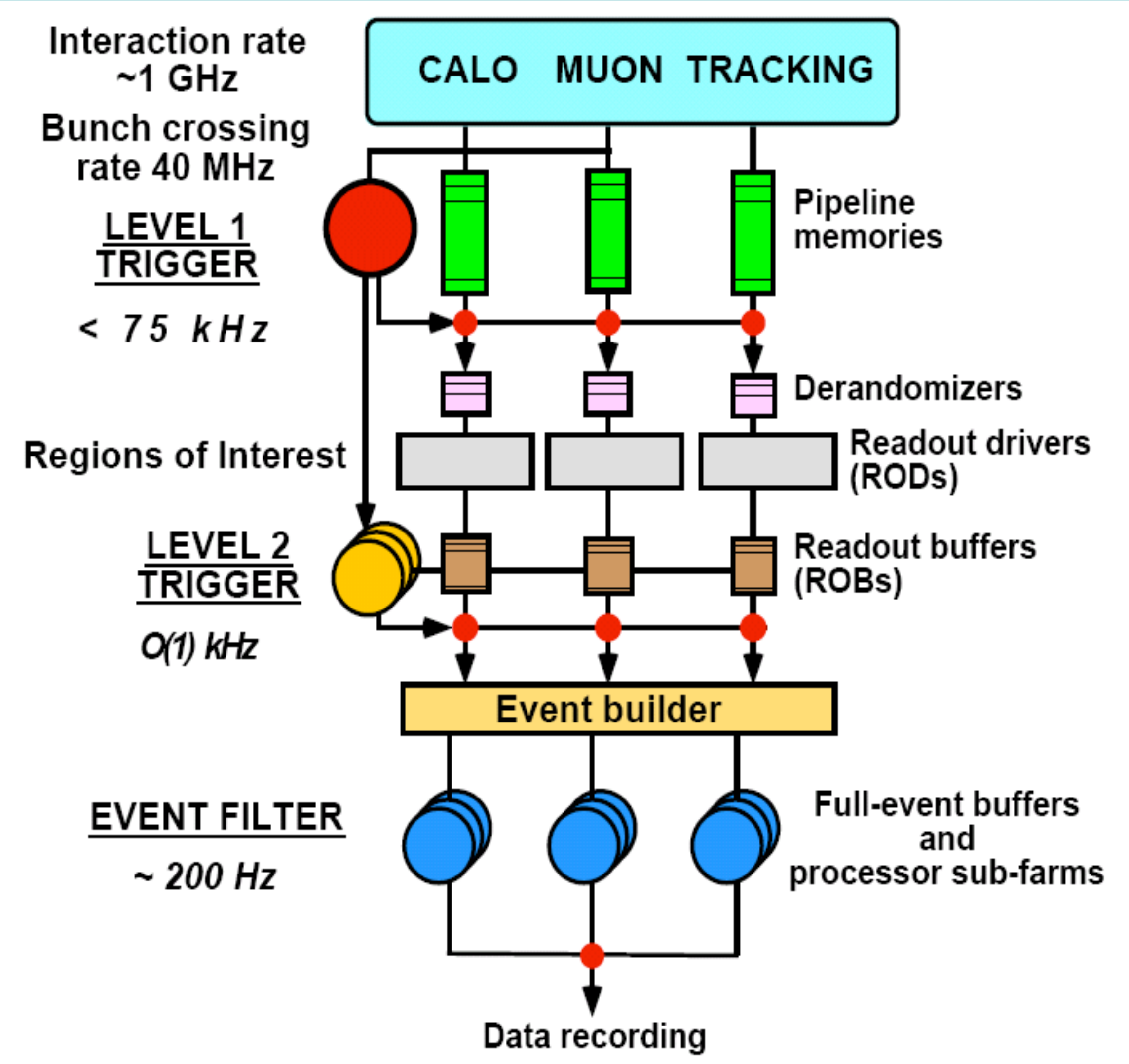
Plus 23 min bias events

ATLAS: three-stage event selection (trigger)



- LVL1-selection in hardware using Calorimeter data with coarse granularity and Myon triggerchamber data.
  - Buffering at the detector
- LVL2 takes Region of Interest Data (ca. 2%) with full granularity and combines information from detectors; early rejection.
  - Buffering in ROBs
- Event Filter refines the selection: Event reconstruktion with full granularity, use of recent alignment- and calibration data.
  - Buffering in EB & EF

ATLAS: three-stage event selection (trigger)



Configuration:

LVL1 HW

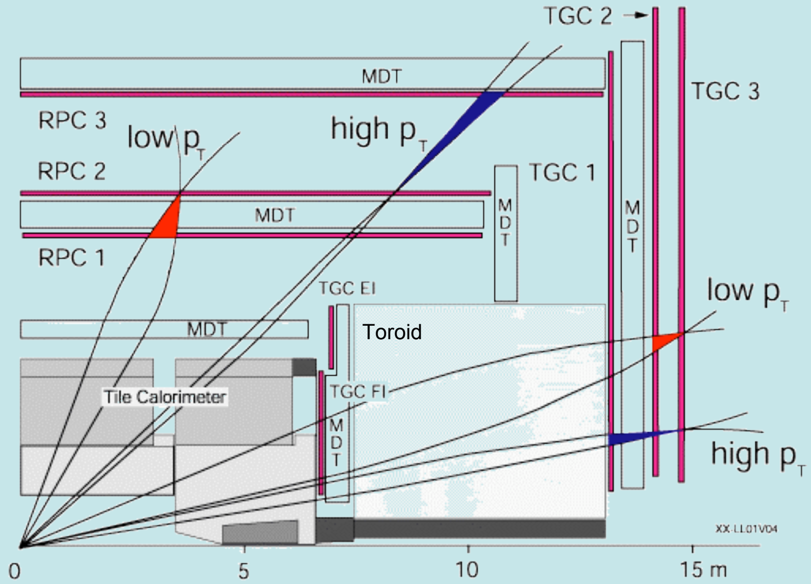
VME modules of

- L1Muon (RPC+TGC)
- L1 Calo
- Central Trigger

~ 3000 HLT computers (Linux OS, framework and algorithms in C++ from offline)

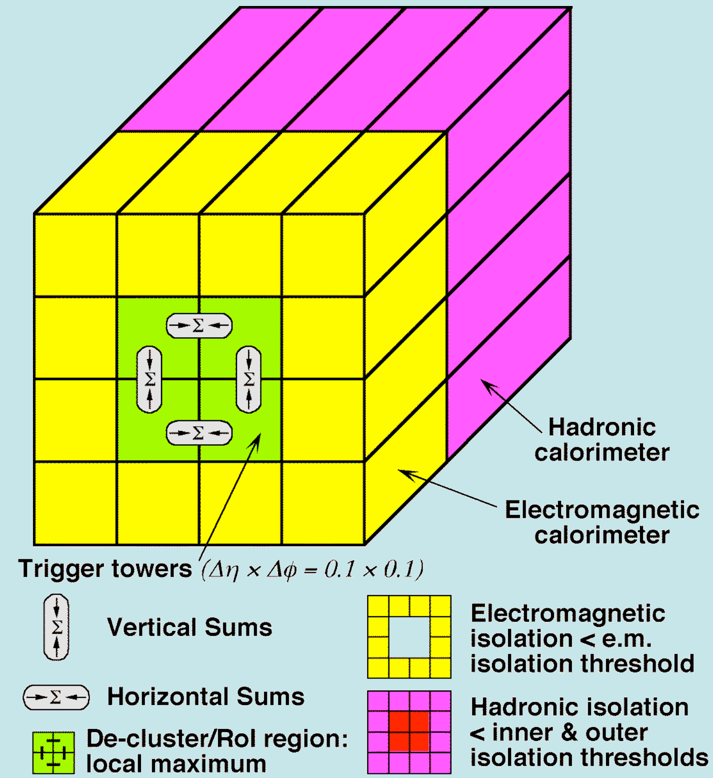
Lvl2 and EF

ATLAS Trigger Level 1 (LVL1) - Myons and Calorimeters



Myon trigger selects coincidences in Myon trigger chambers
2 of 3 (low-p_T; >6 GeV) and
3 of 3 (high-p_T; > 20 GeV)

Trigger efficiency 99% (low-p_T) and 98% (high-p_T)



Calorimeter trigger selects e/γ/τ + Jets

- **Combinations of cluster sums and isolation criteria**
- **$\Sigma E_T^{em,had}$, E_T^{miss}**

Region of Interest (RoI) mechanism

LVL1 trigger for high pT objects

- Calorimeter cells + Myon chambers find e/γ/τ-jet-μ candidates above threshold

LVL2 uses Regions of Interest as identified by Level-1

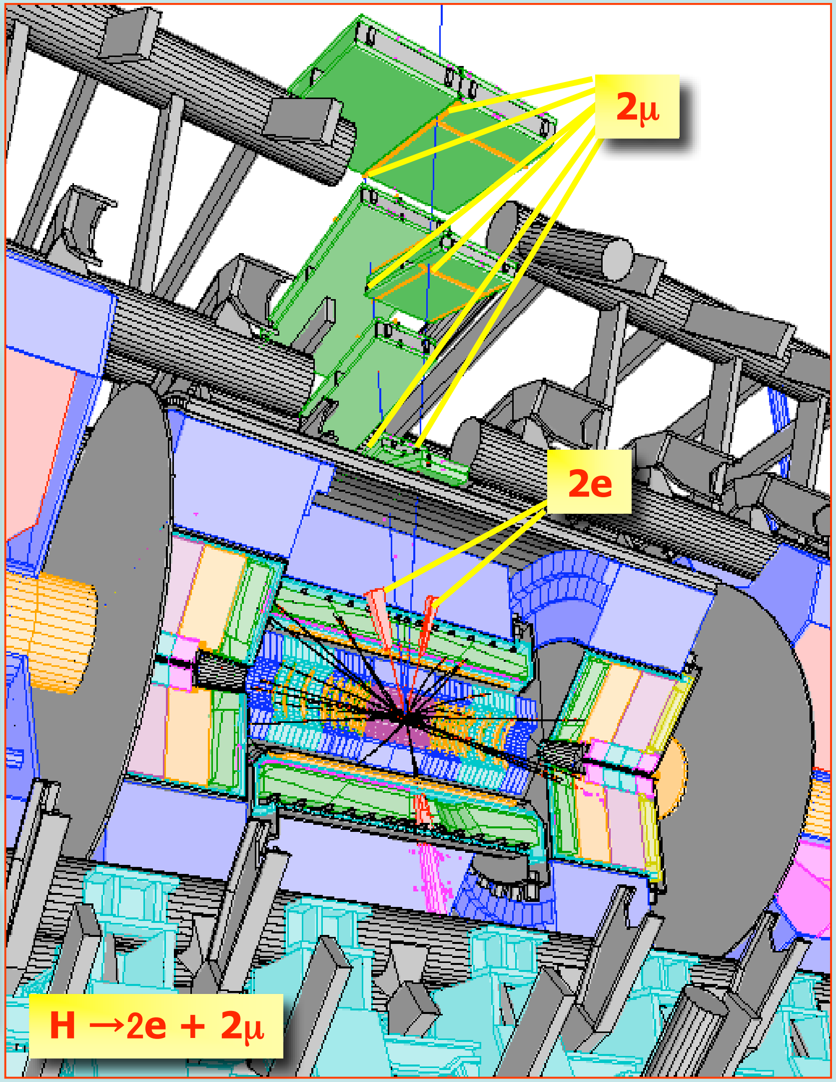
- Local data reconstruction, analysis, and matching of subdetector RoIs

RoI data volume ist small

- ~2% of throughput, but needs to be extracted with 75 kHz

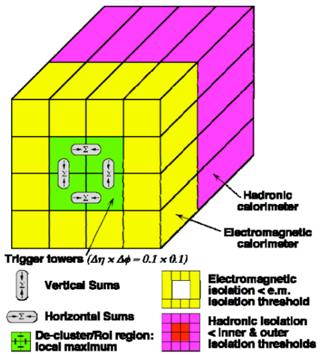
EF uses entire event

- as well as LVL2 results



Online event selection - ingredients

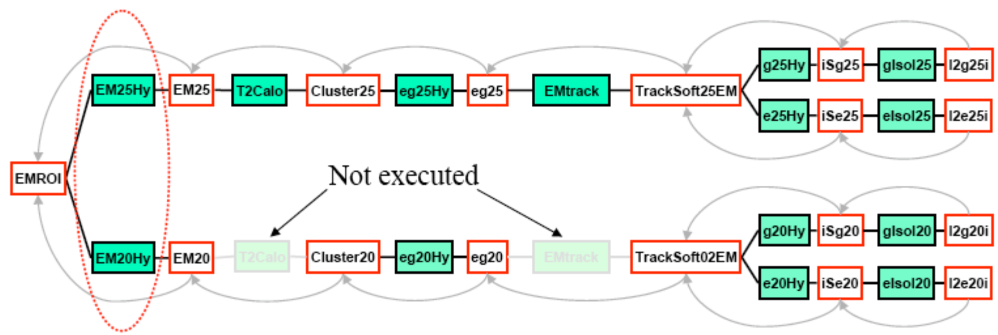
LVL1



L1Calo: RoIs

CTP: decision

HLT



algorithms (refinement of Trigger-elements/ RoI)

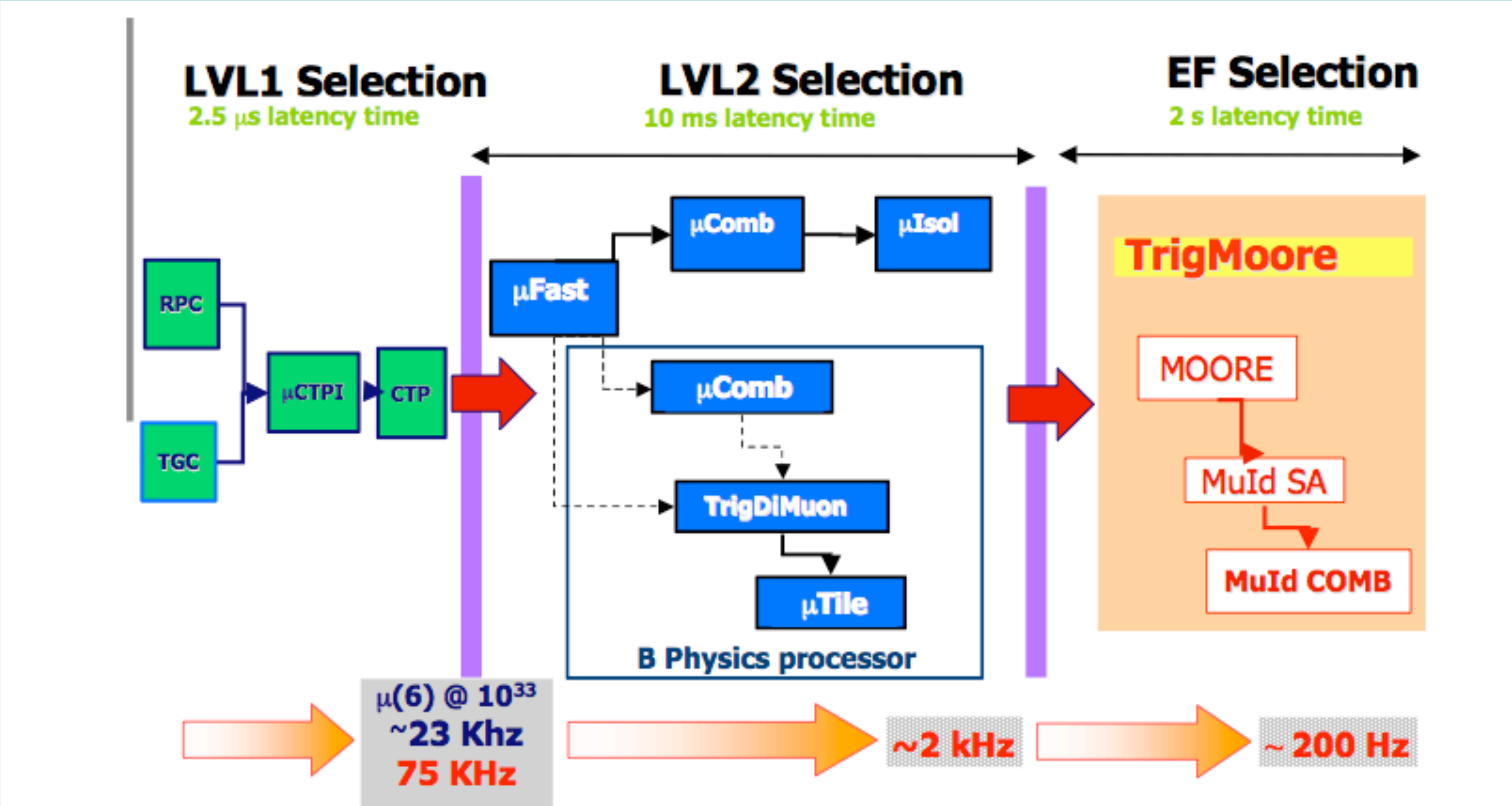
Steering (stepwise calling of algorithms, stepwise decisions, early reject)

Configuration:

LVL1 menu	HLT JobOptions	HLT menu
to be configured:		
L1 subsystems + CTP	algorithms	Steering

Trigger "slices" - selection of the various physics signatures

- Egamma slice
- Muon slice
- Jet and EtMiss slice
- Tau slice
- Btagging & Bphysics slice

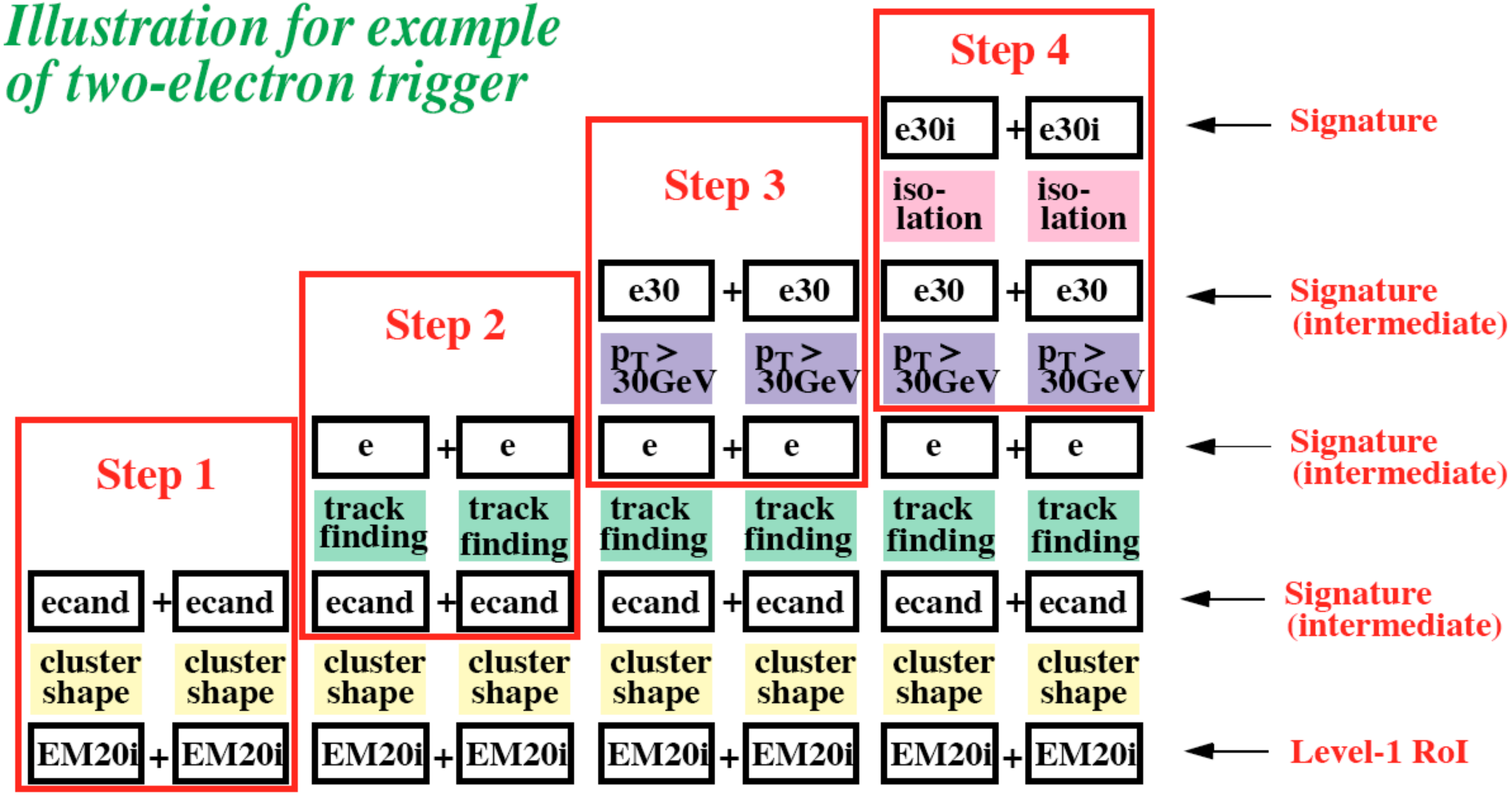


Trigger "steps" - sequence of trigger processing

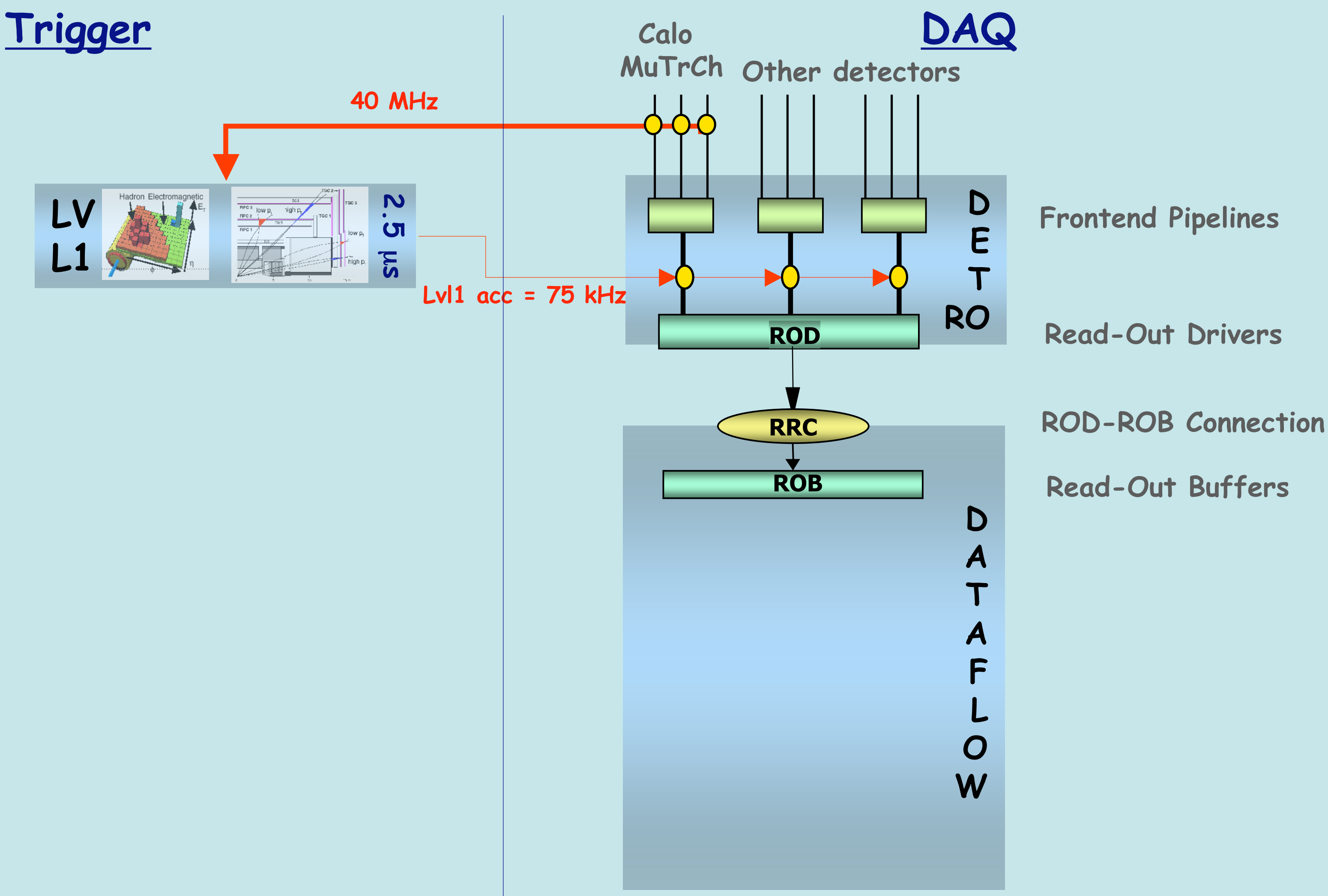
→ Minimizing latency and data transfer:

- Process in steps (early rejection), start with Level-1 Region-of-Interest (**RoI**)
- **Trigger element** = (refined) candidate objects
- **Trigger signature** = combination of trigger elements
- At each step: compare to list of required trigger signatures

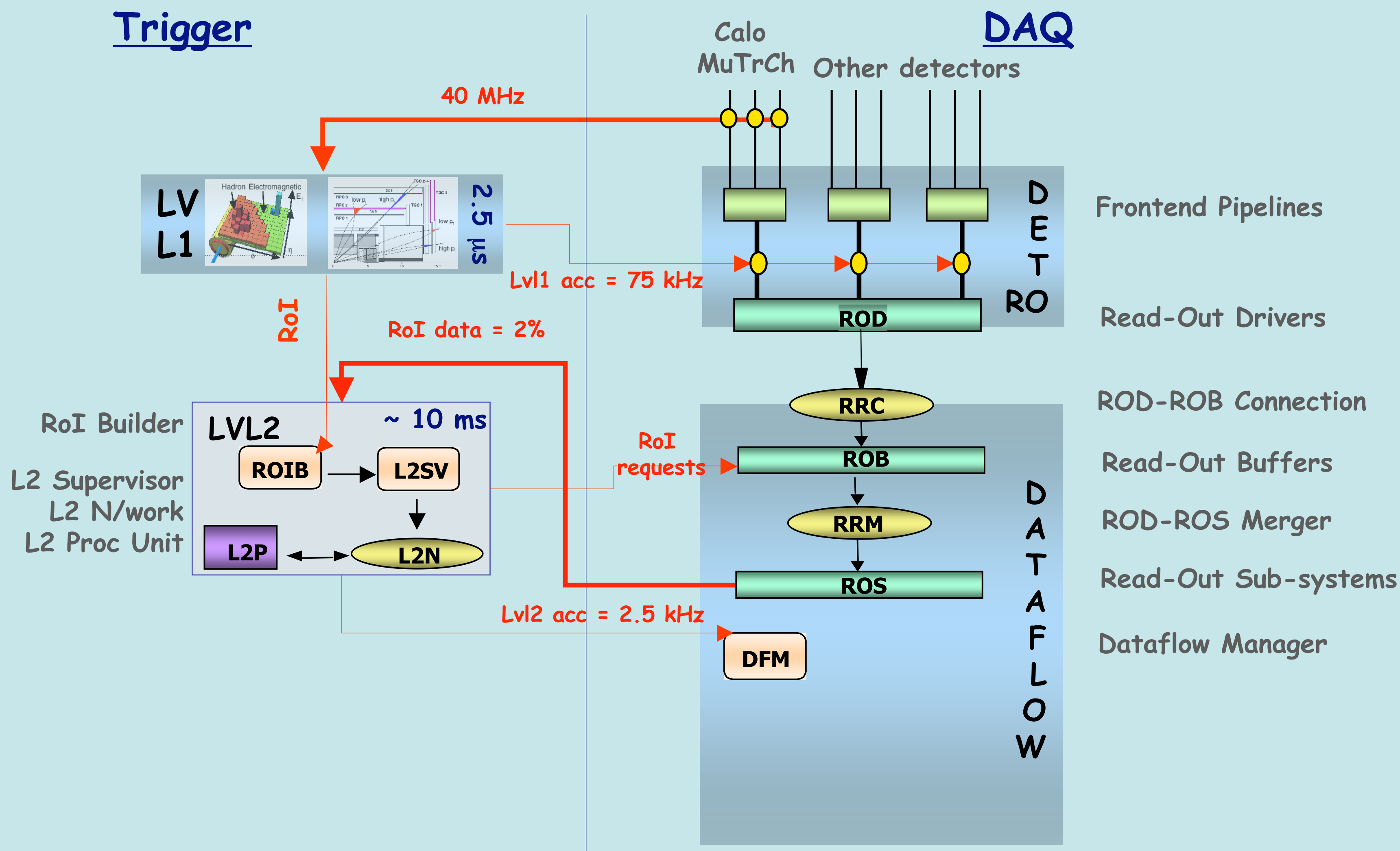
Illustration for example of two-electron trigger



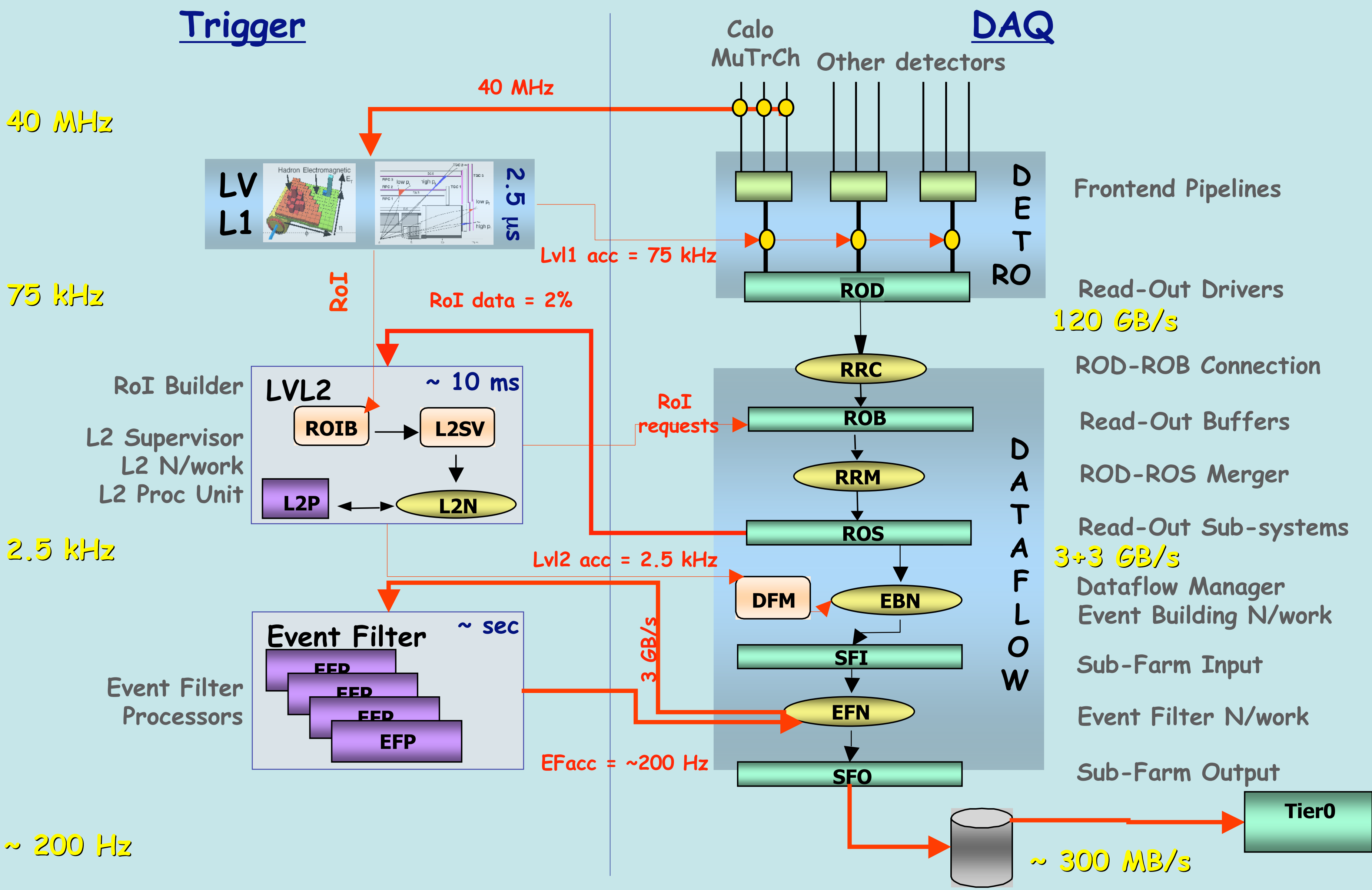
Trigger + data acquisition (TDAQ) - more detail, upto LVL1



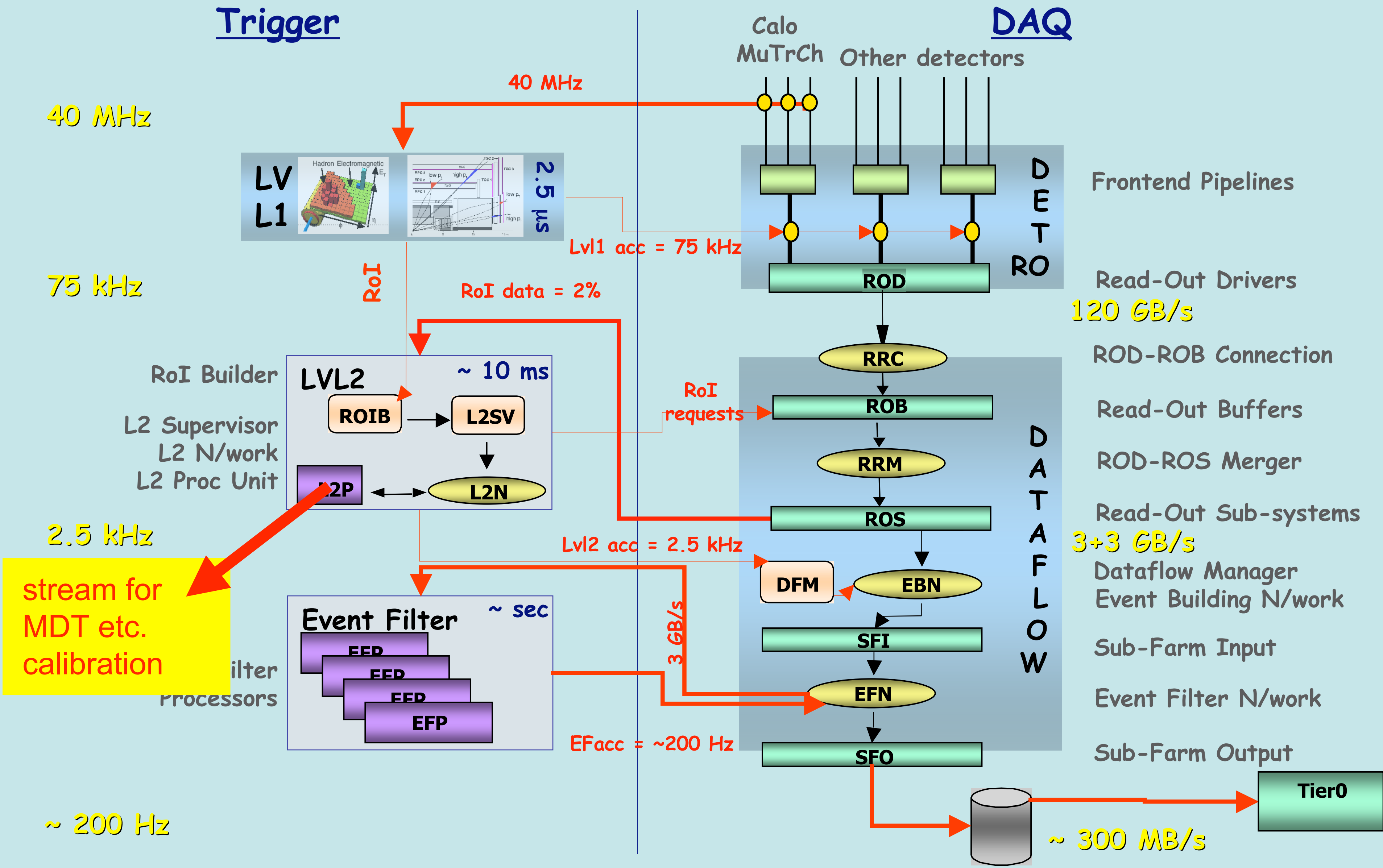
Trigger + data acquisition - upto LVL2



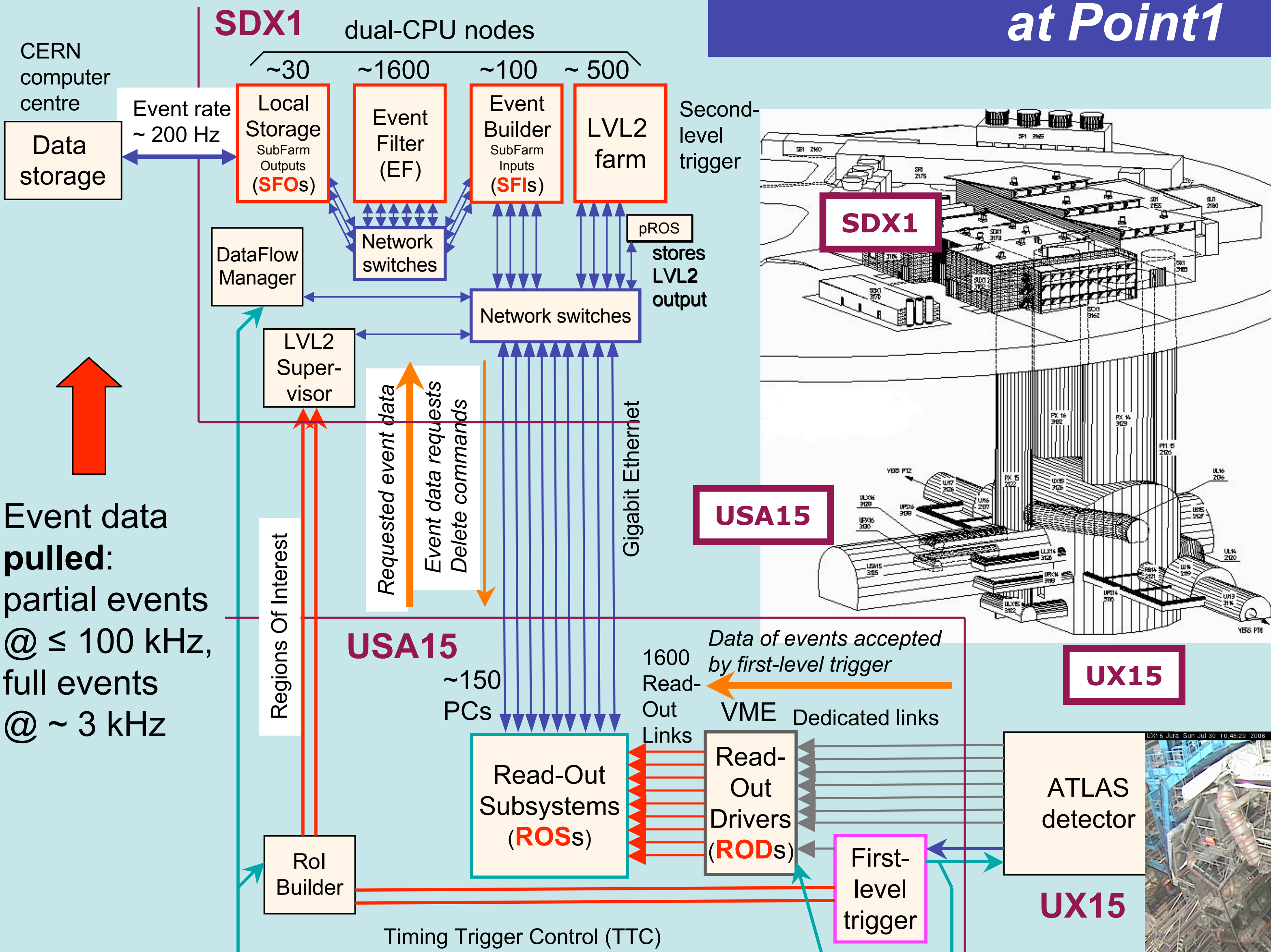
Trigger + data acquisition - upto EF and Tier0

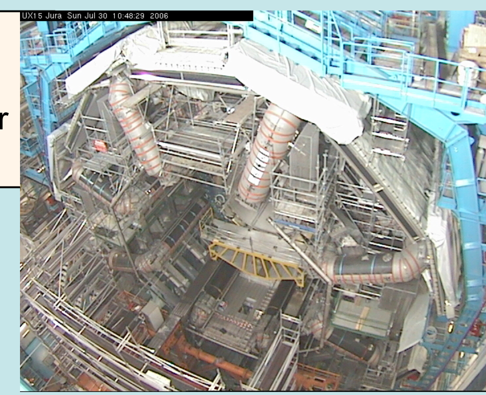


Trigger + data acquisition - Muon RoI calibration stream



ATLAS Trigger/DAQ data flow at Point1



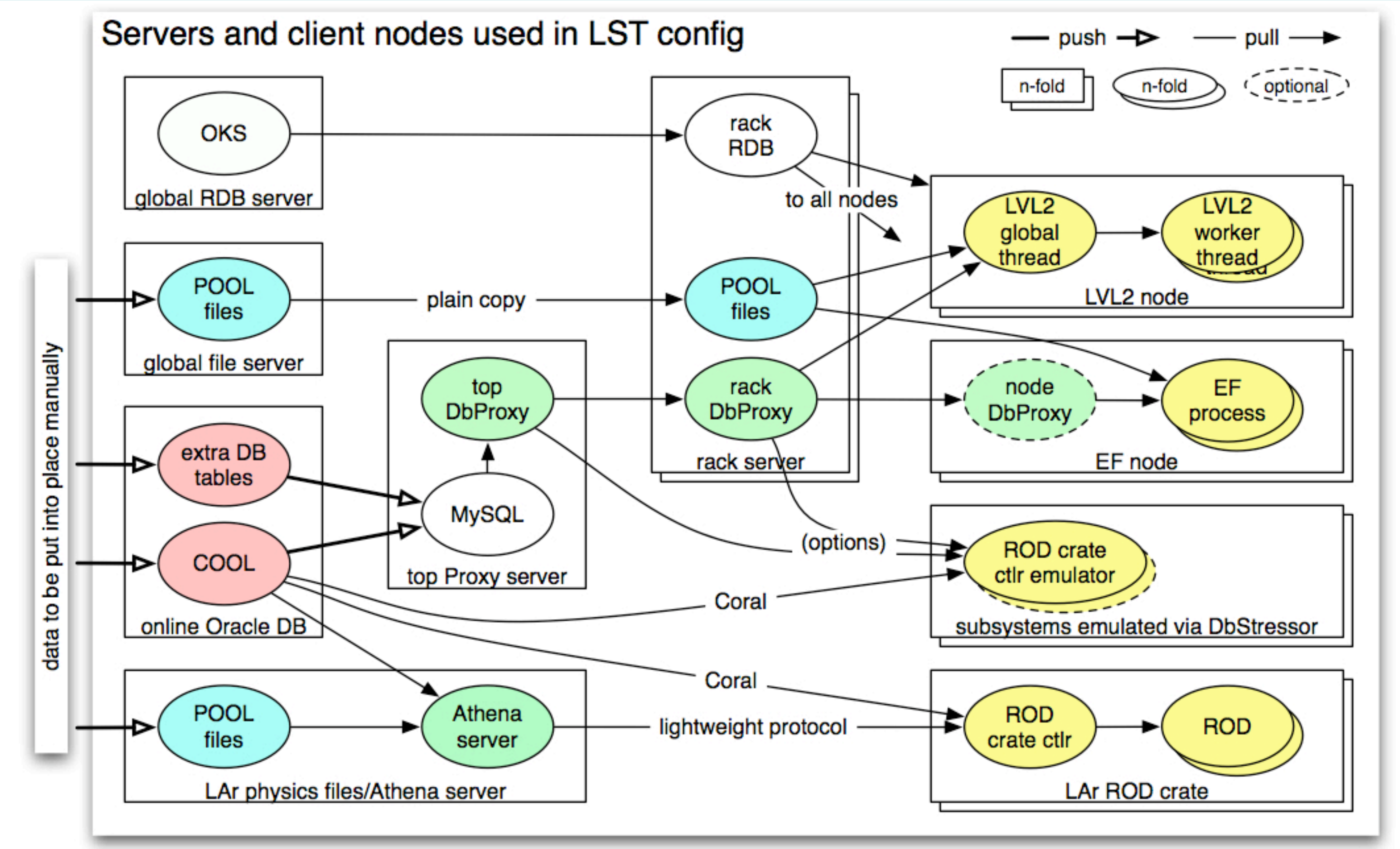


Event data **pulled**:
partial events @ ≤ 100 kHz,
full events @ ~ 3 kHz

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

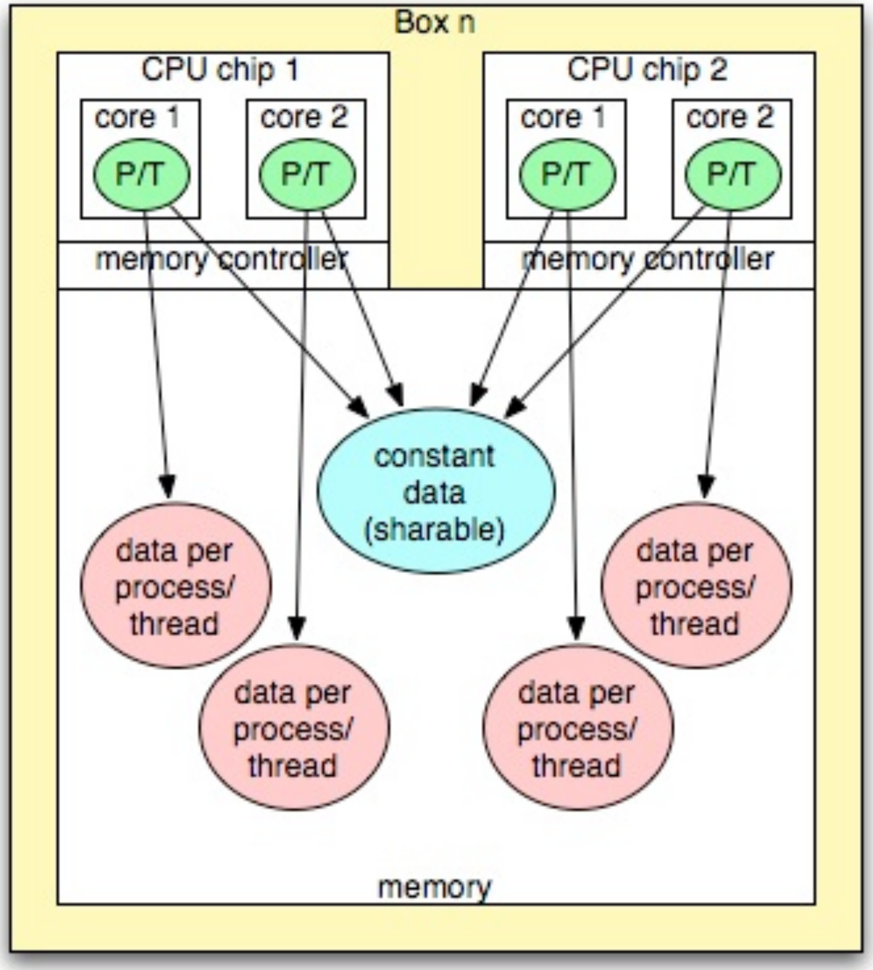
HLT setup is being exercised at present (Large Scale Tests)

- "Large Scale Tests" being done with hardware provided by CERN IT
- Using the TDAQ framework for run control etc., with up to 1200 dual-processor nodes for Level 2 and Event Filter (~ half of full setup 2008 ff)
- Tests last until 7 Dec - now using a few 100 nodes



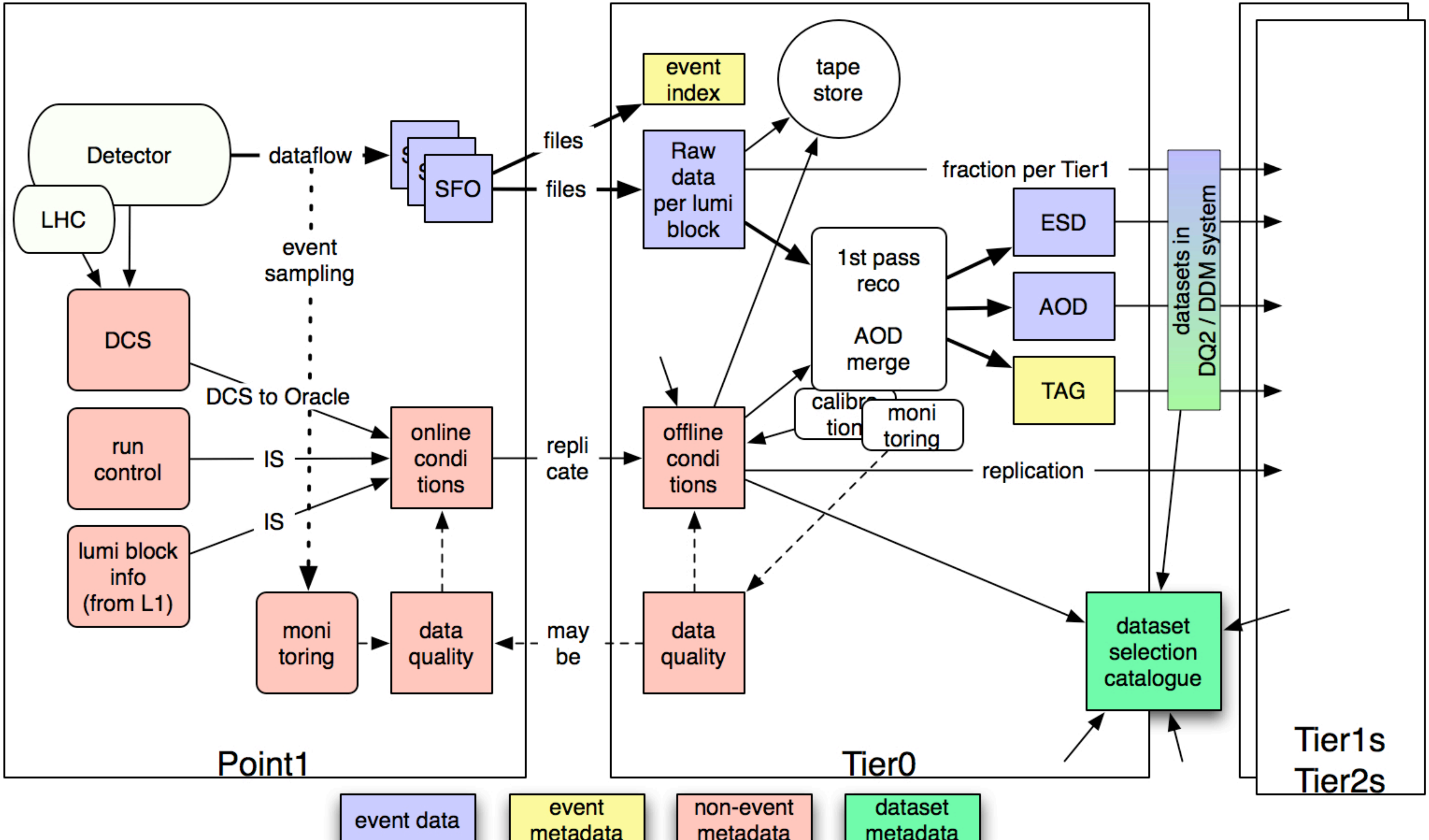
Tricks needed in HLT processor farms

- Now: 4 CPU cores per box: 2 chips * 2 cores => 8 cores per box
- Typically one Athena process (LVL2: one thread) per core
- Multihreading: naturally assign sharable data to global thread, i.e. have only one copy for all threads
- Geometry, field maps, conditions data... and data which are constant throughout process
- Use also for single-threaded environment (event filter, offline)
- Advantages:
  - Save DB accesses (volume, #connections)
  - Save physical memory
- Athena not there yet...

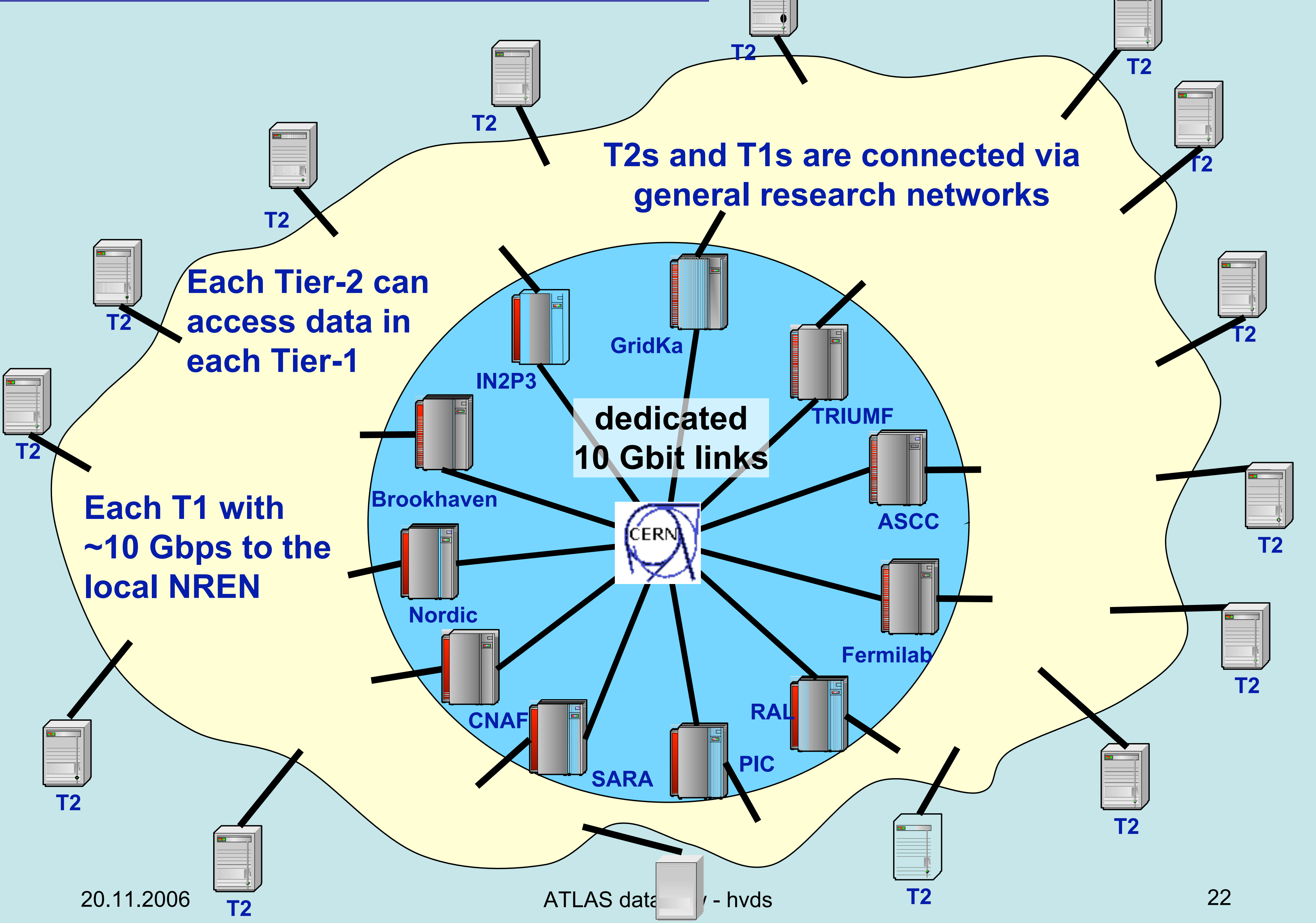


Flow of Data and Metadata Point1 - CERN Tier0 - Tiers1/2

- Metadata exist per: Event - Luminosity-Block - Dataset - Run
- Detector and LHC Status, Run control, Lumiblock, Monitoring (quality) => non event related metadata
- Dataset related Metadata are derived from these
- Metadata may be refined/enhanced later - after data analyses, possibly with manual input
- Event related Metadate (TAG): can contain a small fraction of quality data



Processing centres Tier0,1,2



Extra slides (details on trigger menus)

Plan for first LHC commissioning with beam - 2*450 GeV

(Helmut Burkhardt, 18.11.2006)

	Phase	Beam time [days]
1	First turn	4
2	Establish circulating beam	3
3	450 GeV – initial	3
4a	450 GeV - consolidation	1-2
4b	450 GeV – system commissioning	2-3
5a	2 beam operations	1
5b	Collisions	1-2
		16 days

Given an operational efficiency of 60%, this gives an elapsed time of about 26 days.

Took about a month in LEP and 1y for RHIC

Trigger menus for early running with beam

- Recently discussed on the Trigger & Physics week (30 Oct - 3 Nov 2006)
- Details in Nick Ellis' summary - including 900 GeV running in 2007
  http://indico.cern.ch/materialDisplay.py?contribId=84&sessionId=5&materialId=slides&confId=6824
- Hardware boundary conditions:

- LVL1
  - Ultimate 100 kHz
    - Limited by detector FE electronics and HLT/DAQ capacity
      - Increased dead-time for rates > 75 kHz
  - Nominal 75 kHz
  - In 2008 run hope to have HLT/DAQ that can cope with ~ 45 kHz
    - This depends on funding that is not yet secure!
- LVL2
  - Nominal ~2000 Hz
  - In 2008 run hope to have EF that can cope with ~1000 Hz
    - This depends on available processing power in the EF (money) and also the algorithm execution time per event
      - Depends on offline as well as TDAQ software
- EF
  - Nominal ~200 Hz
    - Depends on capacity of offline computing (Tier-0, etc)
    - Can go to ~300 Hz for short periods as long as daily average is within nominal limits for standard duty cycle

Early 14 TeV running at low luminosity (10^{31})
see Nick's slides for 900 GeV running (43 bunches, 10^{29})

- Which signatures (muon, electron / photon, …)?
- What thresholds (LVL1, HLT – not yet separated LVL2 and EF)?
- Other settings (isolation, use of calo/muon/ID in HLT, etc)
- Use of forced-accepts or HLT "pass-through", etc
- Rates (must be kept within limits of TDAQ and offline systems)
- Coverage for different purposes
  - For physics studies
    - Signal samples
    - Control samples
    - "Insurance policies" for most important physics studies
      - E.g. Ensure that priority physics is covered with loose LVL1 selection (e.g. no isolation) and, initially, with HLT pass-through
    - Complemented with much lower thresholds for other physics, relying on the HLT to get the rate down
    - Also including pre-scaled LVL1 triggers, including minimum bias
  - For detector studies
    - Samples for calibration, alignment and technical studies (e.g. study backgrounds)
  - For trigger studies
    - Samples for measuring rates and efficiencies
      - Needed to optimize trigger for future running
- Recognize that menu will evolve with time
  - Start of with simple, safe selections
    - Add complexity (more rejection for same efficiency) as we gain confidence

Muons and B-physics

Item	LVL1 Rate (Hz)	Comment	HLT Rate (Hz)
MU4	~1000		
MU6	~240		
MU15	~50	HLT pass-through	~50
MU6 pre-scaled (could use MU4 or combination of both)		HLT pass-through with LVL1 pre-scale factor	~10
MU4 with further HLT muon selection (validation, p_T cut)		mu6 full HLT (rate can be tuned with LVL2 p_T cut value)	~60
MU4 + full scan		B-physics (full scan)	~50
2MU4		2mu4 LVL1 only	?

Electrons and Photons

Item	LVL1 Rate (Hz)	Comment	HLT Rate (Hz)
EM10	5400	Pre-scaled in HLT (factors vary with LVL1 threshold passed)	10
EM15	1500	"	
EM20	470	"	
EM25	240	"	
EM30	130	"	
EM25I	65	HLT pass-through	65
		Standard HLT e15?i? selection	10
		Standard HLT γ20?i? selection	10
2EM10	570	Pre-scaled in HLT	10
2EM20	80	HLT pass-through	80
2EM20I	3	HLT pass-through	3
		2e10?i?	?
		2γ15?i?	?
2EM7		J/ψ ee?	?

Jets

Item	LVL1 Rate (Hz)	Comment	HLT Rate (Hz)
J20	1750	Pre-scale in HLT / Require rapidity-gap	3.5+
J40	400	Pre-scale in HLT	2.7
J60	100	Pre-scale in HLT	3.3
J80	40	Pre-scale in HLT	4
J100	15	Pre-scale in HLT	3
J120	8	HLT pass-through	8
2J90	7	HLT pass-through	7
3J30	44	Pre-scale in HLT / Tag b-jets	?
3J40	16	HLT pass-through	16
4J20	20	Pre-scale in HLT / Tag b-jets	?
4J30	12	HLT pass-through	12

Tau and ETmiss

Item	LVL1 Rate (Hz)	Comment	HLT Rate (Hz)
XE?	?	HLT pass-through	~10
XE30	~500	Pre-scale in HLT / Refine selection in HLT	?
SUMET300	~1000	Pre-scale in HLT / Refine selection in HLT	~10
TAU10i	~7000	Pre-scale and refine selection in HLT	~10
TAU15i	~2300	Pre-scale and refine selection in HLT	~10
TAU35i	~190	Refine selection in HLT	~4
TAU?i	?	HLT pass-through	?
J60+XE60	~2	HLT pass-through	~2
TAU25I+XE30	?	Pre-scale in HLT / Refine selection in HLT	?
EM25+XE20	~90	Pre-scale in HLT / Refine selection in HLT	?

Minimum bias, also beam-gas and beam halo

- Objectives
  - Key ingredient in “timing in” the experiment
  - Samples for commissioning of detectors, trigger and offline
  - Studies of minimum-bias physics per se
  - Studies of minimum-bias as backgrounds to other physics
  - Samples for evaluation of efficiencies of LVL1, LVL2, EF and offline reconstruction
- Techniques
  - Bunch-crossing LVL1 trigger + selection at LVL2 and/or EF
    - Bias-free at LVL1
    - Discussion in Standard Model group on how to select non-empty BCs (offline)
      - Implementation at LVL2/EF to be addressed
    - Detectors
      - Minimum-Bias Trigger Scintillators (MBTS) using precision readout
      - Inner detector (pixels sensitive to low p_T)
      - LUCID and other forward detectors?
      - Calorimeters?
  - MBTS trigger at LVL1 (followed by further selection in HLT)
    - Some bias at LVL1 (η range; efficiency for minimum-ionizing particles; multiplicity requirements; etc.)
    - Needed at very low luminosity where interactions per BC << 1