Level-0 / Level-1 Trigger Architecture

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<u>This talk</u>

- Physics motivation
- Baseline for Phase-II
- Constraints from Detectors
- Rates from Phase-I System
- Phase-II Architecture
- Rate Estimates
- Comments/Conclusions

Physics Motivation

★ Design of Phase 2 upgrade of TDAQ needs to be motivated by **physics goals** of experiment

★ Needs to be based on the gain going from

300 fb^{-1} to 3000 fb^{-1}

- Phase-2 will represent 90 % of all ATLAS data
- We hope for new physics…
- At this stage trigger needs **flexibility**
- Strong desire to trigger on leptons at EW scale

Goals:

★ Maintain trigger efficiency for
- EM 20: ~20 GeV electrons
- MU 20: ~20 GeV muons

★ + Sufficient bandwidth for taus, photons, jets, missing ET, …

★ + Build in flexibility (or don't build it out)

Current Baseline

- ★ **Split Level-0/Level-1 hardware trigger**
  - **Total rate: 200 kHz**
  - **Total latency: 20 μs**
  - **Synchronous**

- ★ **Level-0**
  - **Same functionality as Phase-I Level-1**
  - **Total rate: at least 500 kHz**
  - **Total latency: 6 μs**

- ★ **Level-1**
  - **Additional latency of 14 μs**
  - **RoI-based track trigger**
  - **L1Calo using full calorimeter granularity**
  - **MDT based muon trigger**

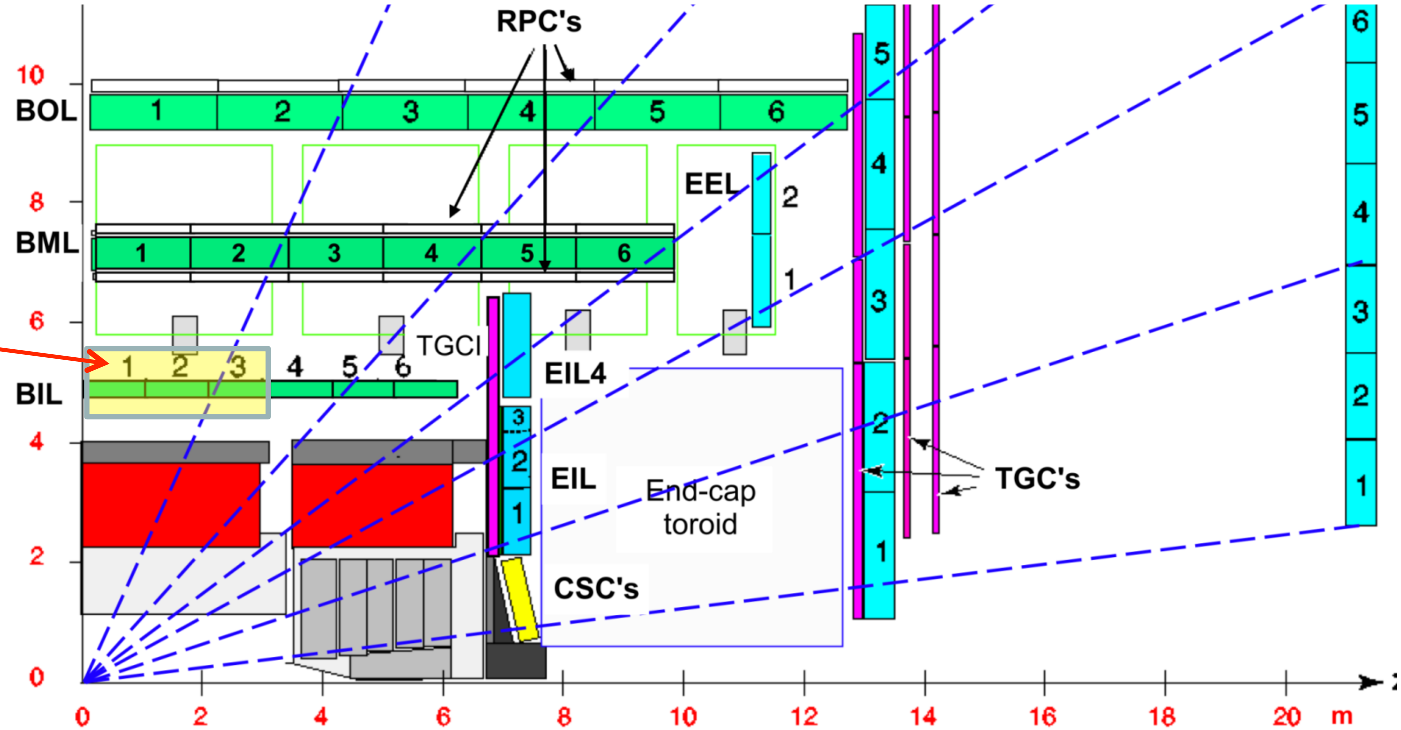
- ★ **Level-2: 5-10 kHz, more offline-like algs**

- ★ **Will try and motivate this choice in following slides**

Constraints from Detectors

- ★ Most detector system can replace electronics
  - can significantly extend pipelines…
  - latency/rates mostly limited by cost
- ★ One (?) exception MDT
  - Inaccessible – no opportunity to replace FEE

Not possible to change FEE



Constraints from MDT

- ★ MDT imposes major constraint
  - ~30 % of electronics in Barrel Inner Layer (BI) of spectrometer are inaccessible
- ★ Impact
  - Progress with understanding cavern background
  - Tube rate ~ 100 kHz at 7E34
  - Barrel Inner layer MDTs FEE limited to:
    - ~200 kHz L1 accept
    - latency ~20 μs

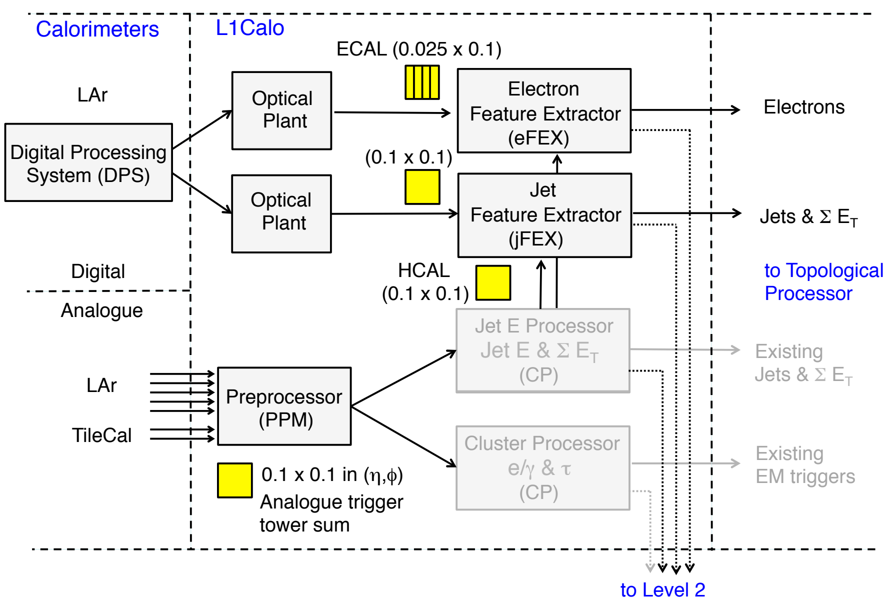
Constraints

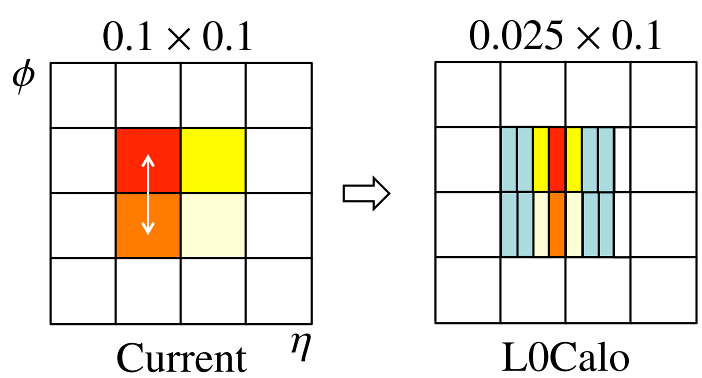
★ Current understanding of limitations across systems

	Max Rate	Max Latency
MDT	~200 kHz	~20 μs
LAr	any	any
Tile	>300 kHz	any
ITK	>200 kHz	< 500 μs

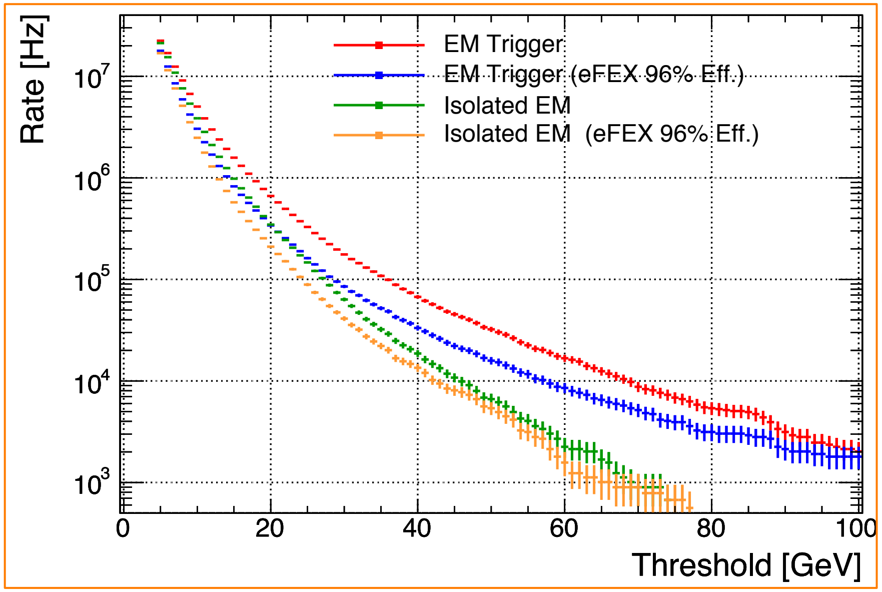
★ Suggests Level 1 operating point:
- 200 kHz
- 20 μs

- **Evaluate rates at : $(5 – 7) \times 34\ cm^2s^{-1}$**
- **Note: still significant uncertainties in rates**
  - **Phase 1 upgrades only partially simulated/cavern background**
  - **Rates dominated by L1Calo (EM, jets,…)**
  - **Recent studies with eFEX folded in**





EM and Tau rates

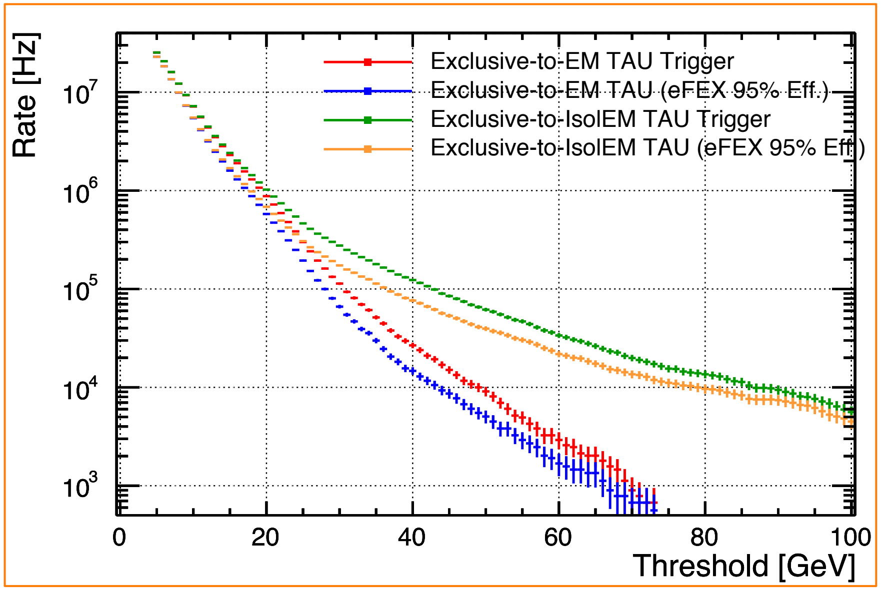


★ **EM Triggers (5E34)**

- eFEX brings factor 2-3
- Non-isolated rates
  - EM25 rate ~200 kHz
  - EM20 rate ~500 kHz
- With hadronic isolation
  - EM20 rate ~200 kHz

★ **Tau triggers (5E34)**

- Rate exclusive to EM25
- eFEX helps (< factor 2)
- Relative to EM ISOL
  - TAU40 rate ~100 kHz
- Relative to non-ISO EM
  - TAU40 rate ~20 kHz



Muon/Jet/MET Triggers

Muons:

- ★ L1_MU_20: estimated rate at 7E34: > 40 kHz
  includes NSW

EM triggers (electrons/taus) are more problematic than muons

Jets/MET:

- ★ not studied in depth, but
  thresholds will be high…

Rate Estimates

★ *Estimate* of overall picture (based on phase 1 system)

Object	Estimated Rate
EM 20 – EM 25	200 - 100 kHz
MU 20	>40 kHz
Di-Lepton 10 GeV	~100 kHz
TAU 40	100 kHz
JETs + MET*	~100 kHz
Total	~500 kHz

★ Tentative "conclusions":

- To keep single lepton triggers at ~20 GeV and di-lepton triggers at ~10 GeV : L0 rate **~500 kHz**
- No safety factors !
- Not compatible with likely 200 kHz detector limit

*somewhat arbitrary number – essentially whatever the headroom

Options

- ★ Live with high L1 rate
  - Let L2 do the work
  - high ~500 kHz (inc. safety factor)

→ Simple
But probably excluded from detector side

- ★ Rely on full calo granularity
  - L1 via RODs

→ Requires split L0/L1
  - Gains not known
  - May not be sufficient

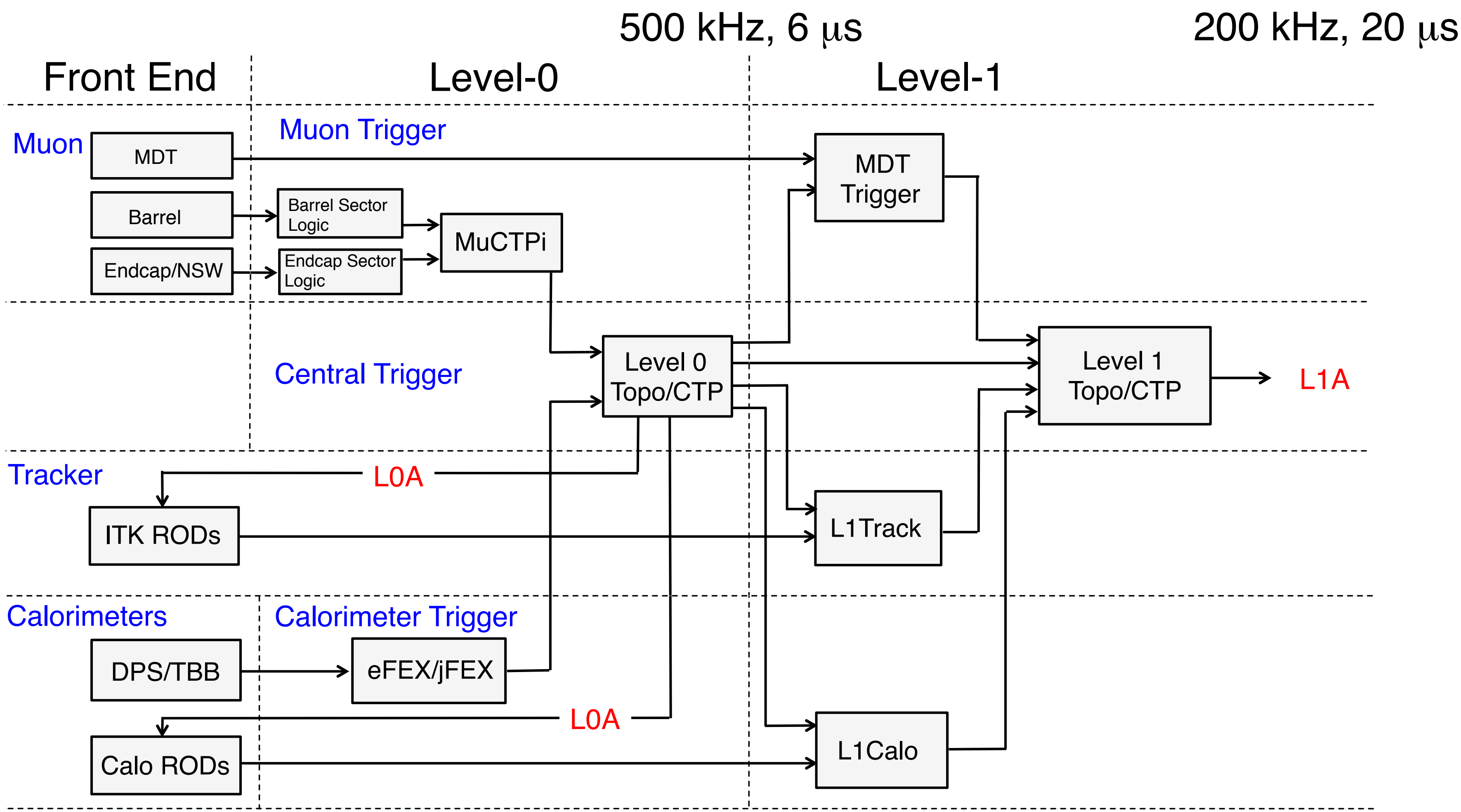
- ★ Implement Track Trigger

→ Single Level 1
  - Self-seeded

→ Split L0/L1 trigger
  - RoI-based

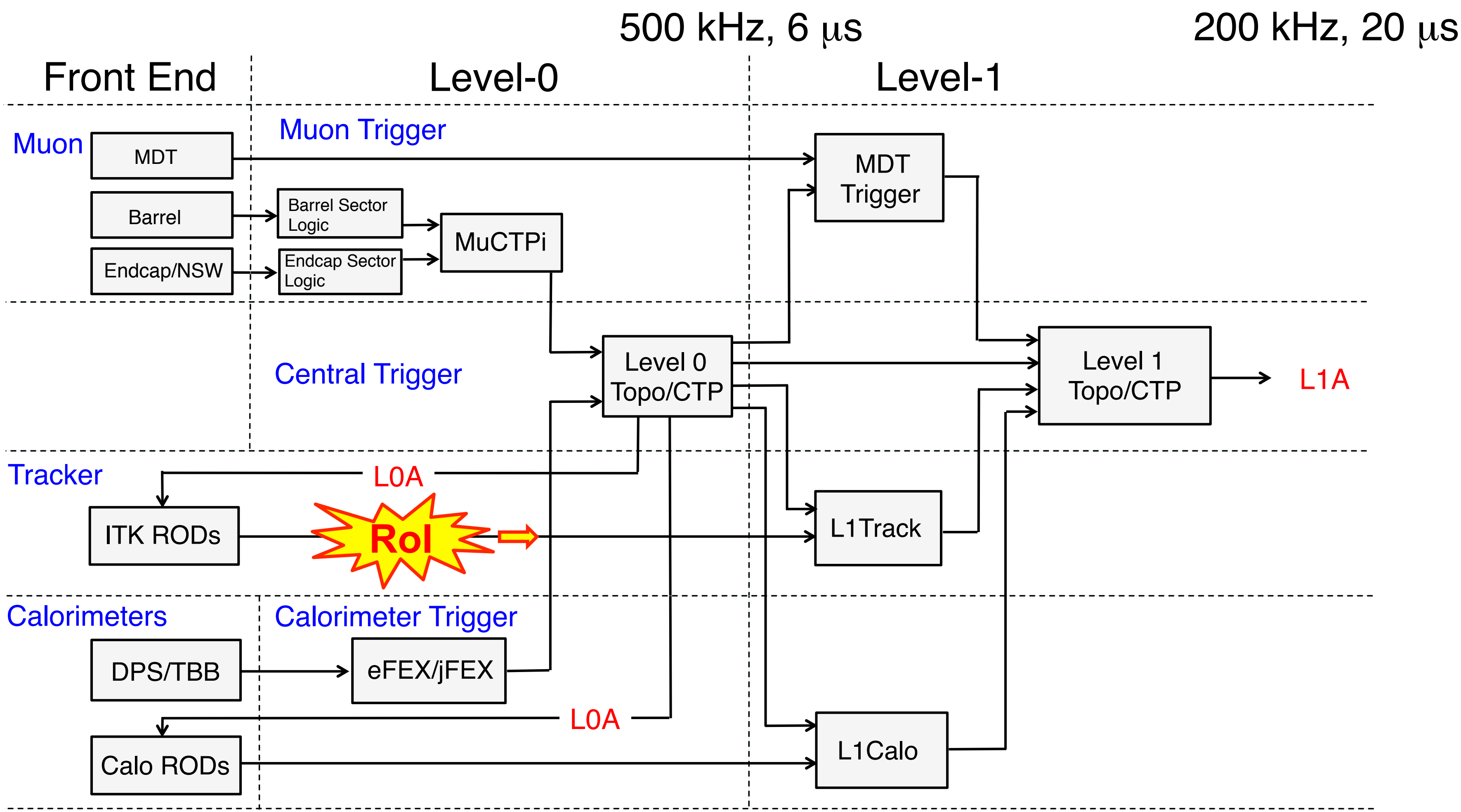
- ★ Points to split Level-0/Level-1 system

Level-0/Level-1 Architecture



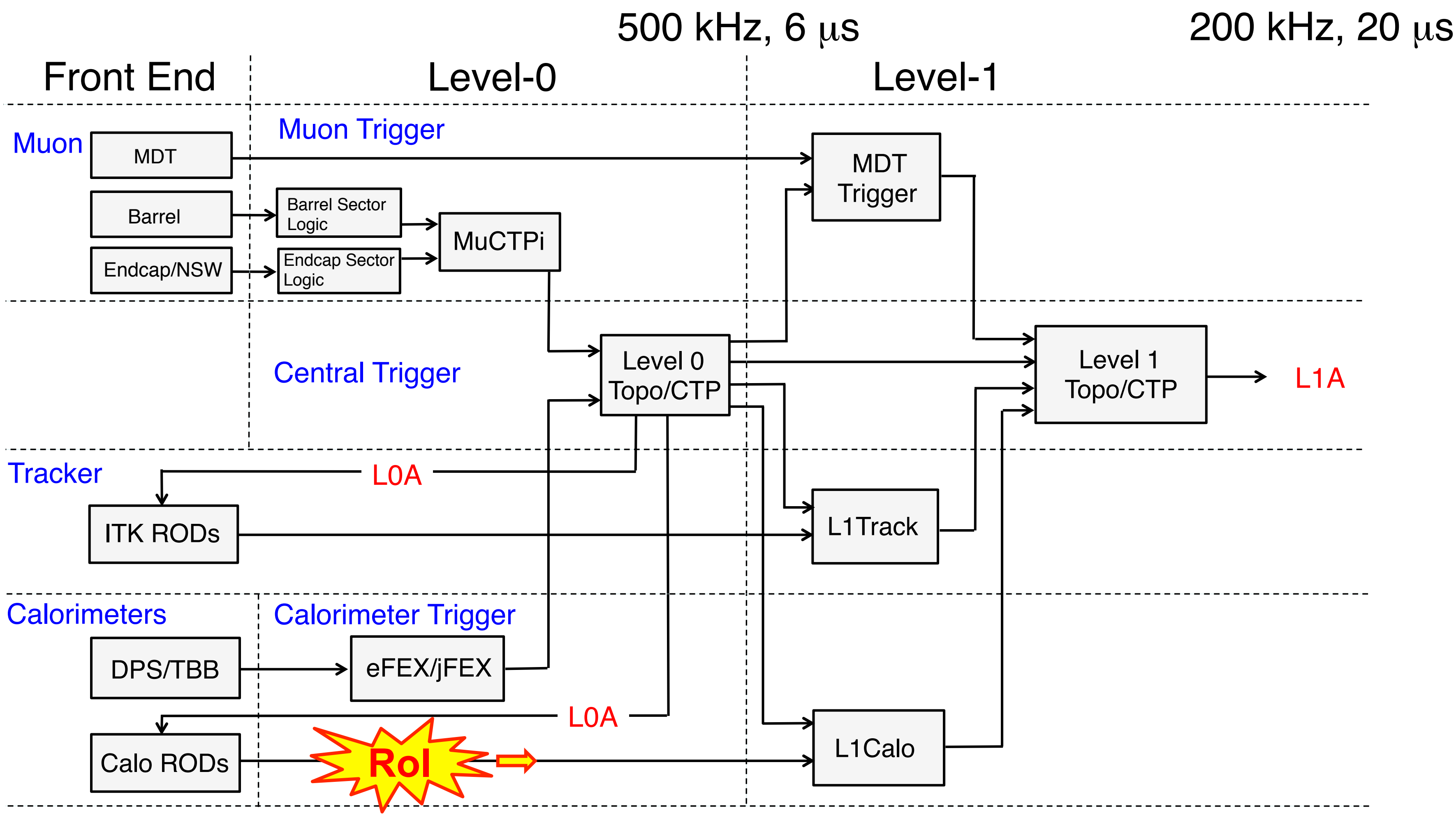
★ **Baseline is FTK-style RoI-based track-trigger**

Level-0/Level-1 Architecture



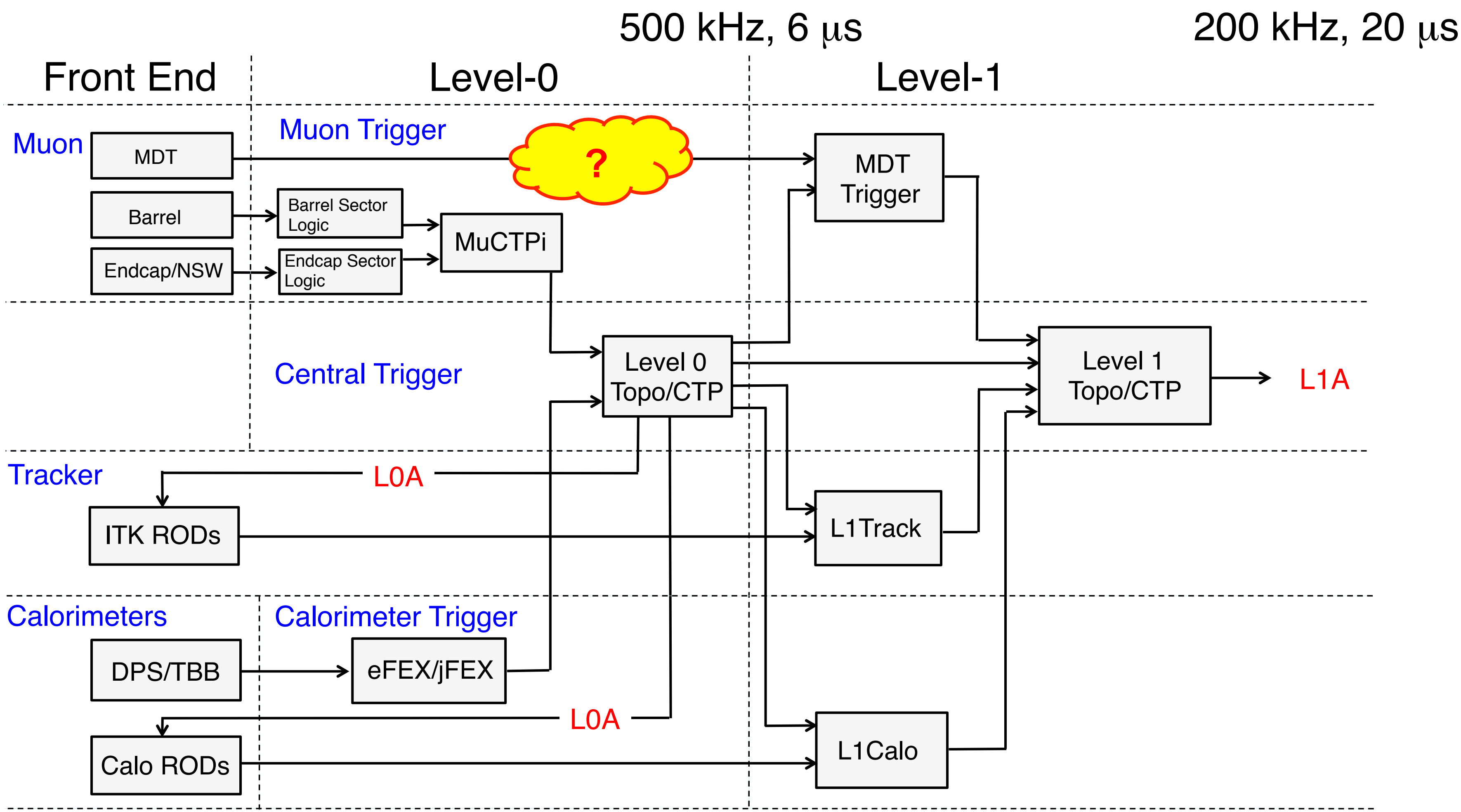
★ **ITK readout into L1 only from EM and MUON RoIs**

Level-0/Level-1 Architecture



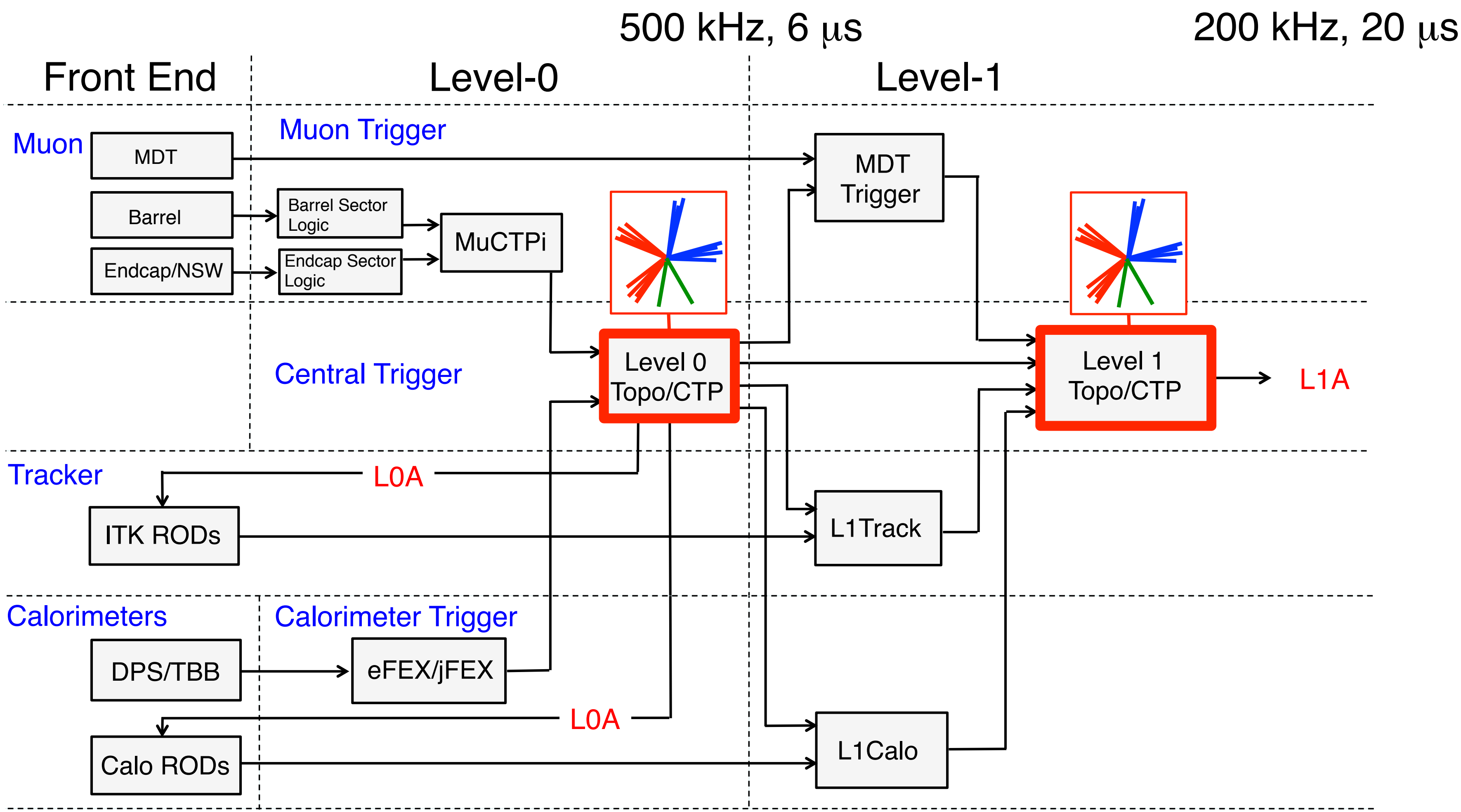
★ **Possibility of full calorimeter granularity at L1Calo via RODs for (at least) RoIs**

Level-0/Level-1 Architecture



★ **Potential to use additional latency to generate MDT trigger – sharpen up turn-on curve, need to quantify gain**

Level-0/Level-1 Architecture



- ★ **Topological processing at L0 and L1**
  - **division between Topo and CTP ?**

Comments: Track Trigger

★ Track trigger *would* represent the single major change to ATLAS L1 trigger system - for details see tomorrow

Two options

❶

★ Self-seeded
- generate fast (<5 μs) on detector L1 accept

Pros:
- fits in with normal Level 1 architecture

Cons:
- technically challenging – higher risk
- potentially large impact on Tracker design

❷

★ RoI-based
- "FTK-style" solution seeded by L0A RoIs
- Generate L1 accept on timescale of 20 μs

Pros:
- reduces impact on tracker

Cons:
- only works in more involved L0/L1 split trigger

Estimated rates

*these are educated estimates – not full simulation

		No L1Track	With L1TT
Object	Trigger	Rate	Rate/kHz
e	EM25	125 kHz	25 kHz
γ	EM40	20 kHz	10 kHz
μ	MU20	>40 kHz	10 kHz
τ	TAU50	50 kHz	20 kHz
ee , γγ	2EM10	30 kHz	5 kHz
eτ , μτ	TAU20+	25 kHz	2 kHz
μμ , eμ , ττ	Various	~30 kHz	~5 kHz
Others	JET+MET	~100 kHz	~100 kHz
Total		>400 kHz	~175 kHz

Assumes factor 2 from L1Calo

Tentative conclusion: 200 kHz L1Calo looks viable with track trigger

Comments: L1Track

★ Question asked early "Track trigger drives split L0/L1 +..., is there an *alternative* ?"

- EM25 (with isolation) alone will eat current rate limit of < 100 kHz
- ⇒ Have to increase rate, Status Quo not an option
- To control rates at level of ~200 kHz, need to use additional information *e.g.* L1Calo with full ECAL granularity
- Will require additional latency (~ extra few μs)
- Forced to higher rate/longer latency, regardless of L1Track [unless accept 500 kHz L1A]
- L1Track only dictates total latency

+ L1Track brings additional flexibility

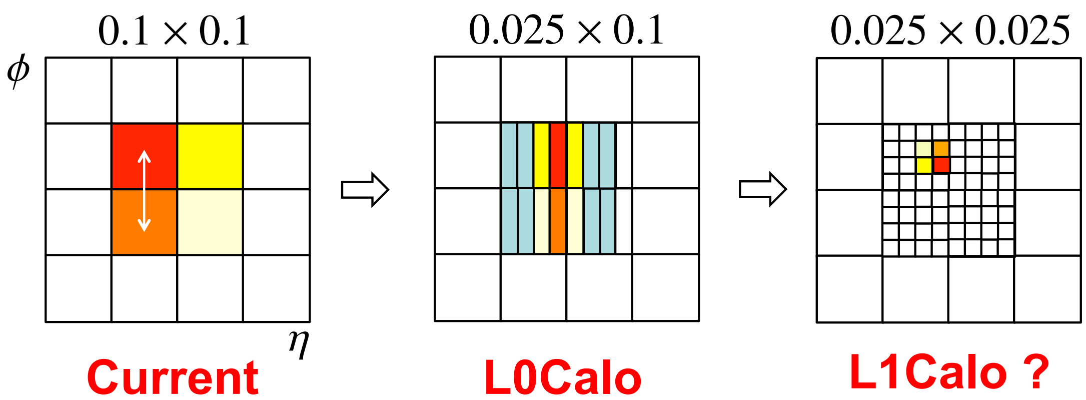
What next ?

★ **Studies/estimates are still preliminary**
- Best we have but…
- Now need to firm up numbers, **simulation, simulation, simulation, …**

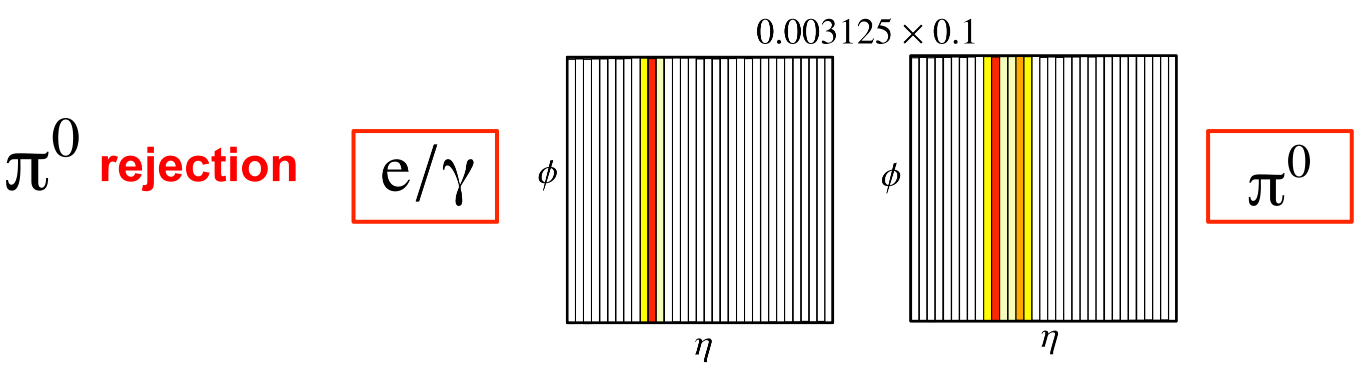
e.g. what does L1Calo bring

★ **Possible benefits of L1Calo** (again needs quantitative studies)

i) fine-grained EM shower identification



What is the gain in Phase-II environment?



ii) what can be done to improve MET, MET significance reconstruction ?

Summary

★ Current baseline for Phase-II trigger architecture
- Split L0/L1 trigger
- Level 0 Accept at: 500 kHz
- Level 1 Accept at: 200 kHz
- Total L0/L1 latency: 20 μs
- RoI-based L1Track track trigger
- Level 2: 5 – 10 kHz

★ Believe this to be a viable option for Phase-II
- Needs to be studied with full simulation