UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

Upgrade project and plans for the ATLAS first level trigger.

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on behalf of the ATLAS Collaboration

INFN Istituto Nazionale di Fisica Nucleare

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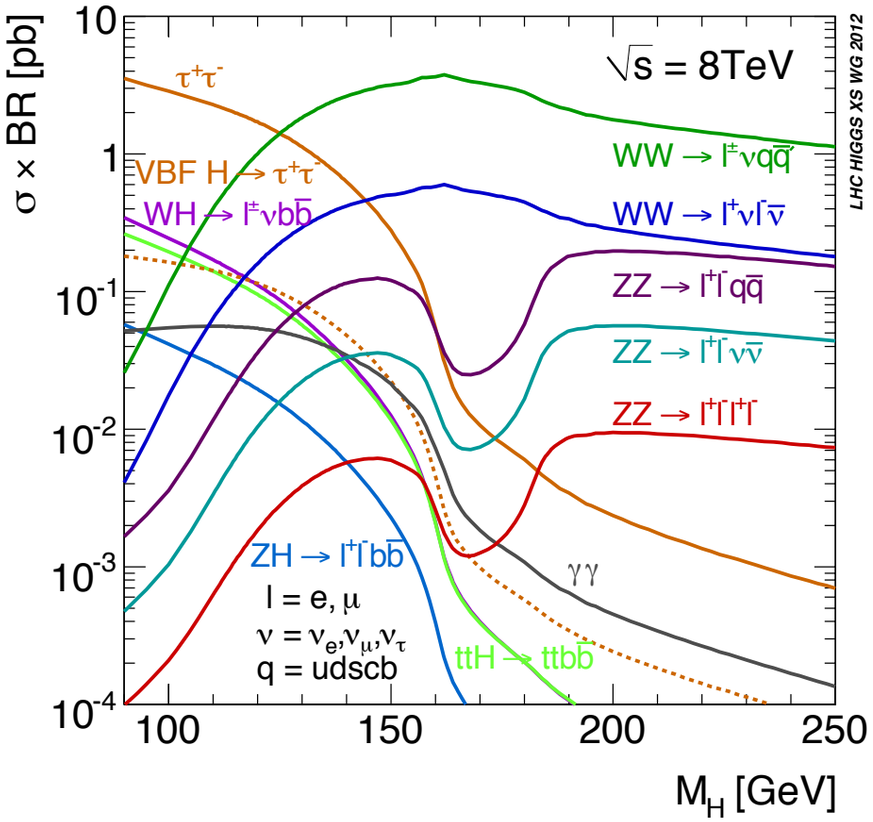
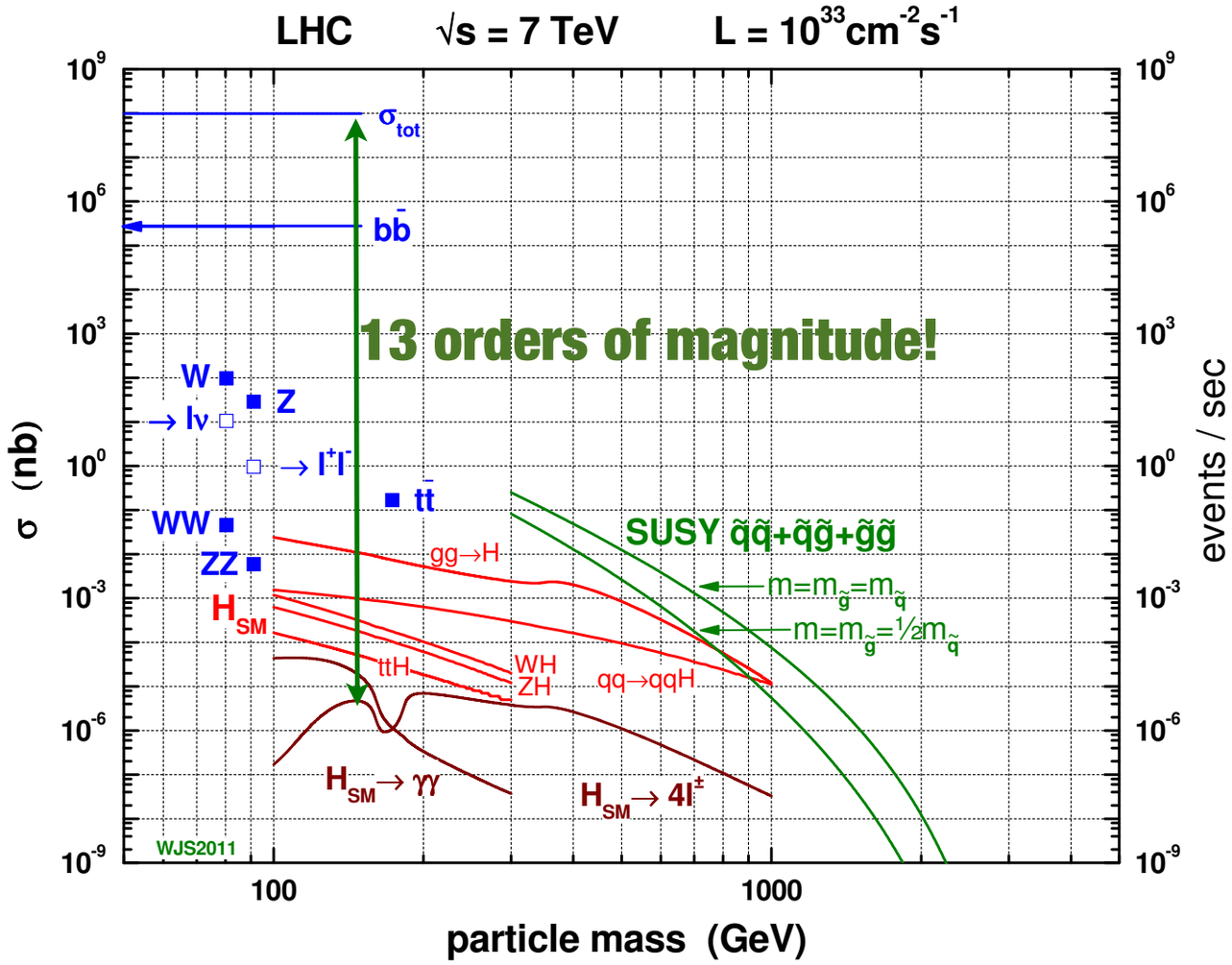
CERN

Motivation for High Luminosity LHC (HL-LHC)

- SUSY
  - Squarks and gluinos 1-1.5 TeV
  - SUSY particle properties
- 3-5 TeV W' and Z' properties?
- Gauge Boson self coupling
- Quark sub-structure
- Other phenomena





- For example if Higgs Boson is found at LHC
- Measure σ.B
- Ratio of H couplings to fermions
- Low rate Higgs couplings
- Spin (and CP)
- Self-couplings
- Dynamics of EWSB

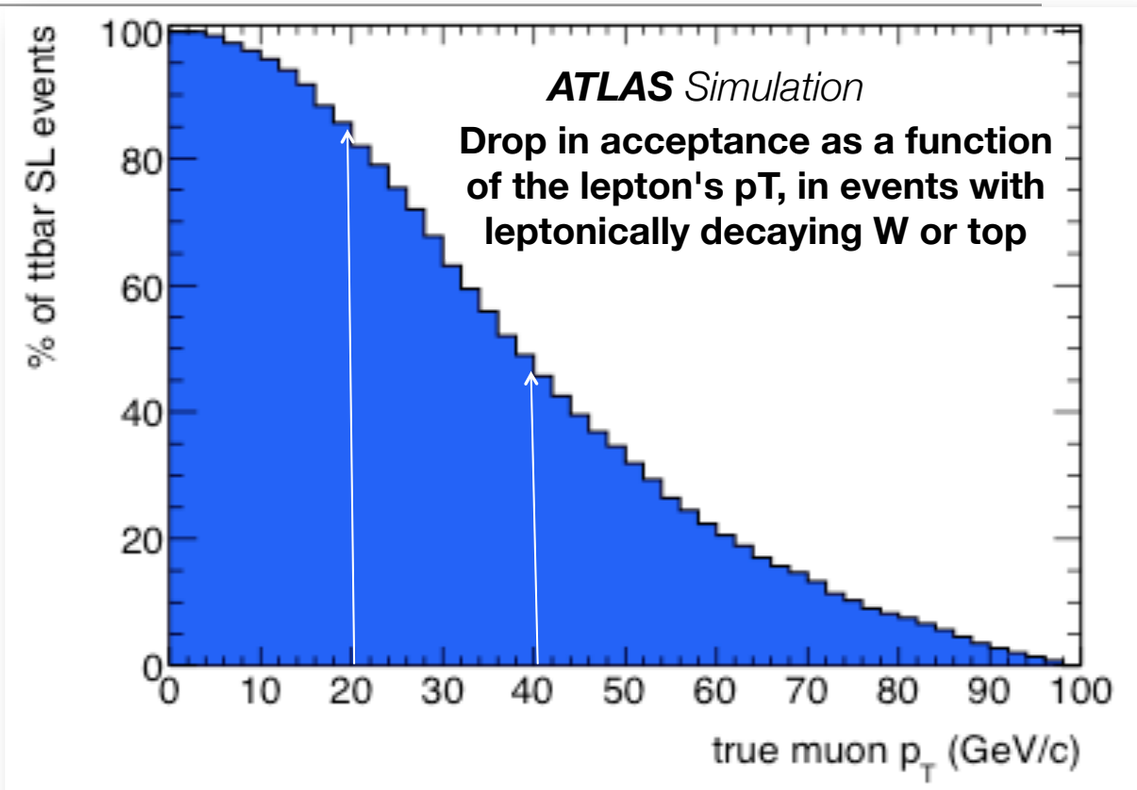
ATLAS Trigger Upgrade

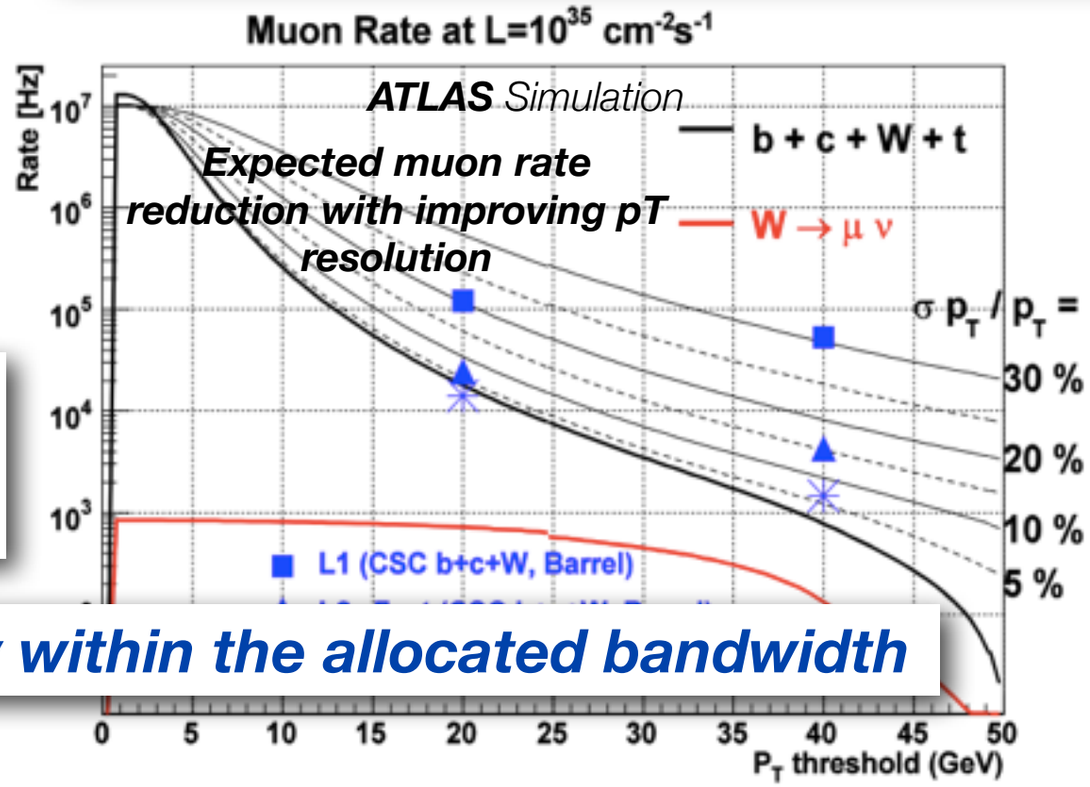
To keep the Physics reach untouched we need to:

- Maintain adequate trigger selections with:
  - Inclusive single leptons at EW scale with thresholds similar to LHC
  - (Very) high-pt objects
  - Di-lepton, exclusive / multi-object triggers

⇓

- Need for more sophisticated trigger criteria
  - Move software algorithms into electronics
  - Require better resolution
  - Add inner tracker information





Using as baseline the current sharing of bandwidth

40% taken by high pT leptons

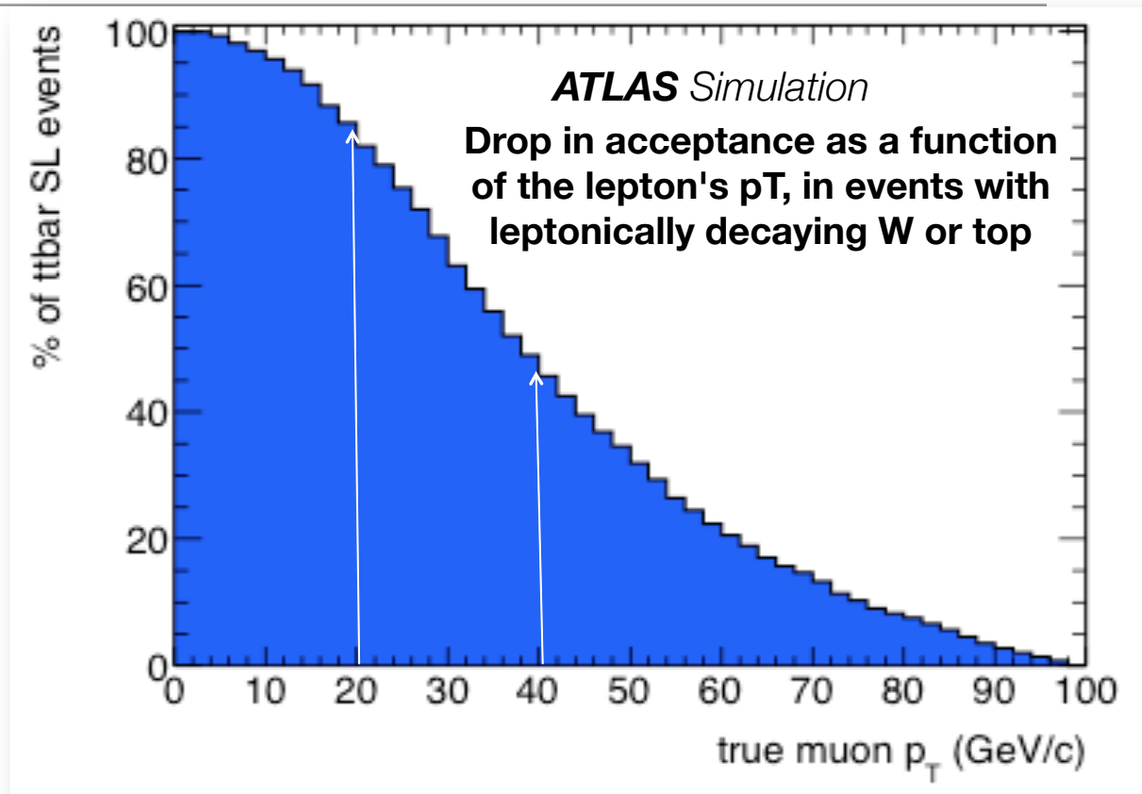
20 kHz each for L1 muons and electrons

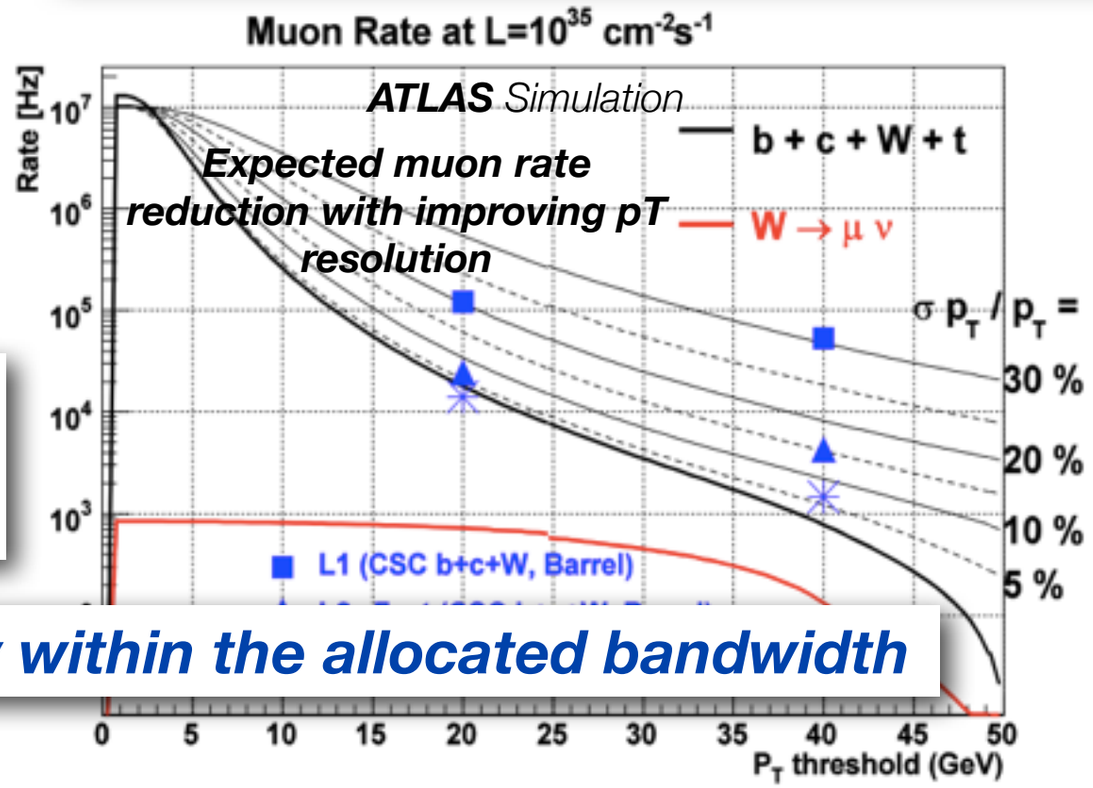
Rates scale with luminosity ⇒ Cannot stay within the allocated bandwidth

ATLAS Trigger Upgrade

To keep the Physics reach untouched we need to:

- Increase the trigger granularity where possible in order to increase the rejection power
- Add new detectors if necessary, or use detectors information that are currently not used for triggering
- Replace current Level-1 trigger electronics
  - add new algorithms,
  - add more flexibility
  - move existing software algorithms into hardware





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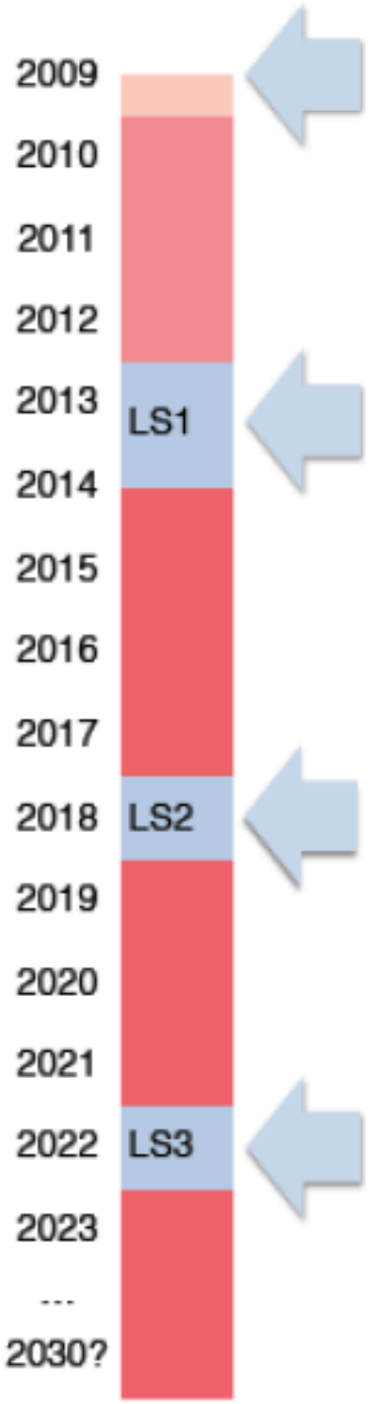
The Upgrade Timeline



✧ LHC startup, $\sqrt{s}$ = 900 GeV

$\sqrt{s}$=7~8 TeV, L=6x10^{33} cm^{-2} s^{-1}, bunch spacing 50 ns

~20-25 fb^{-1}

Topological Trigger at L1
Fast Track Trigger at L2

$\sqrt{s}$=13~14 TeV, L~1x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

Phase-0

~75-100 fb^{-1}

New Muon small wheels
Readout granularity of calorimeter increased for L1

$\sqrt{s}$=14 TeV, L~2x10^{34} cm^{-2} s^{-1}, bunch spacing 25 ns

Phase-I

~350 fb^{-1}

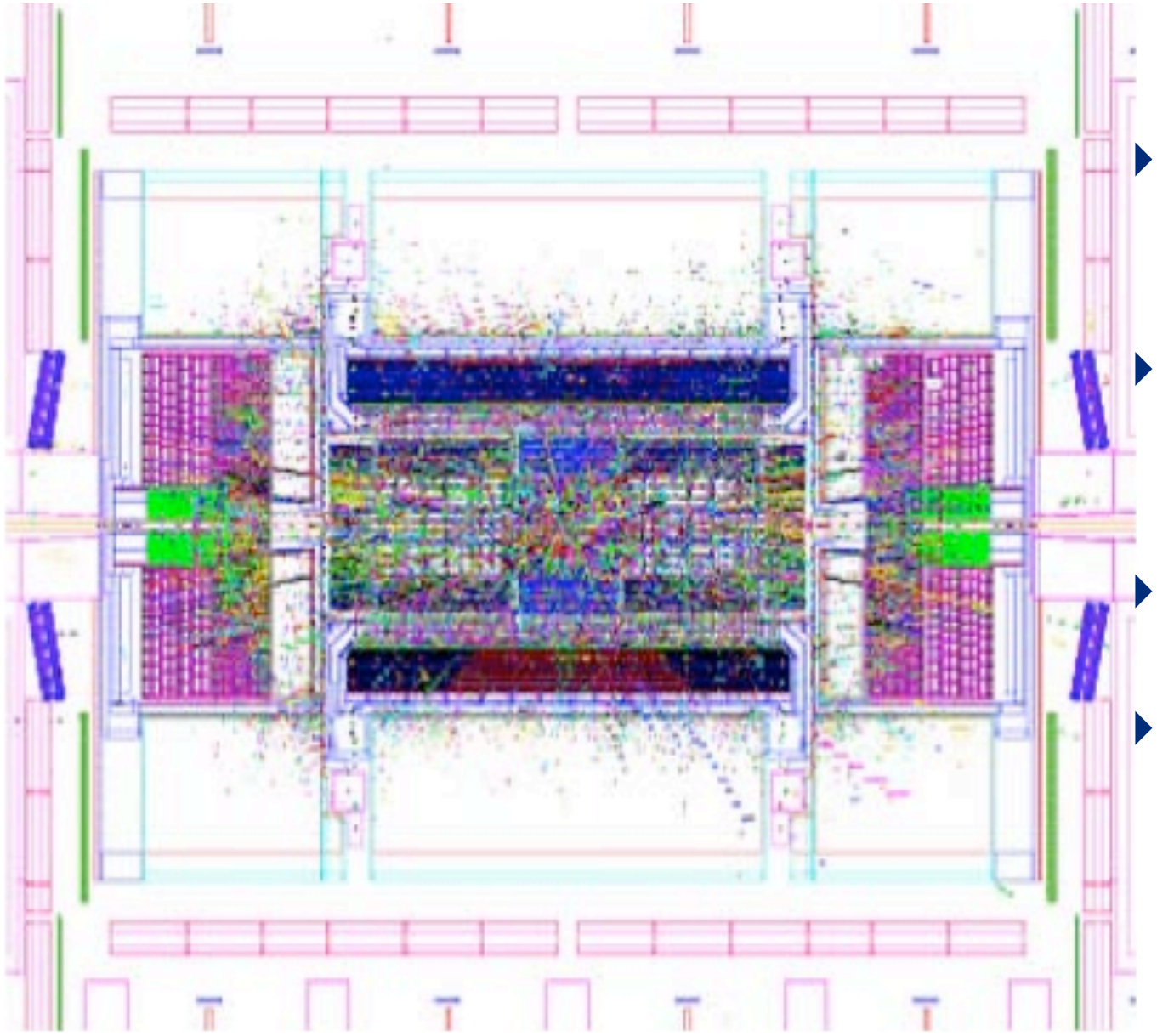
Possible use of Muon Precision chambers into the L1
Possible use of full calorimeter granularity at L1
L1 Track trigger

$\sqrt{s}$=14 TeV, L=5x10^{34} cm^{-2} s^{-1}, luminosity levelling

Phase-II

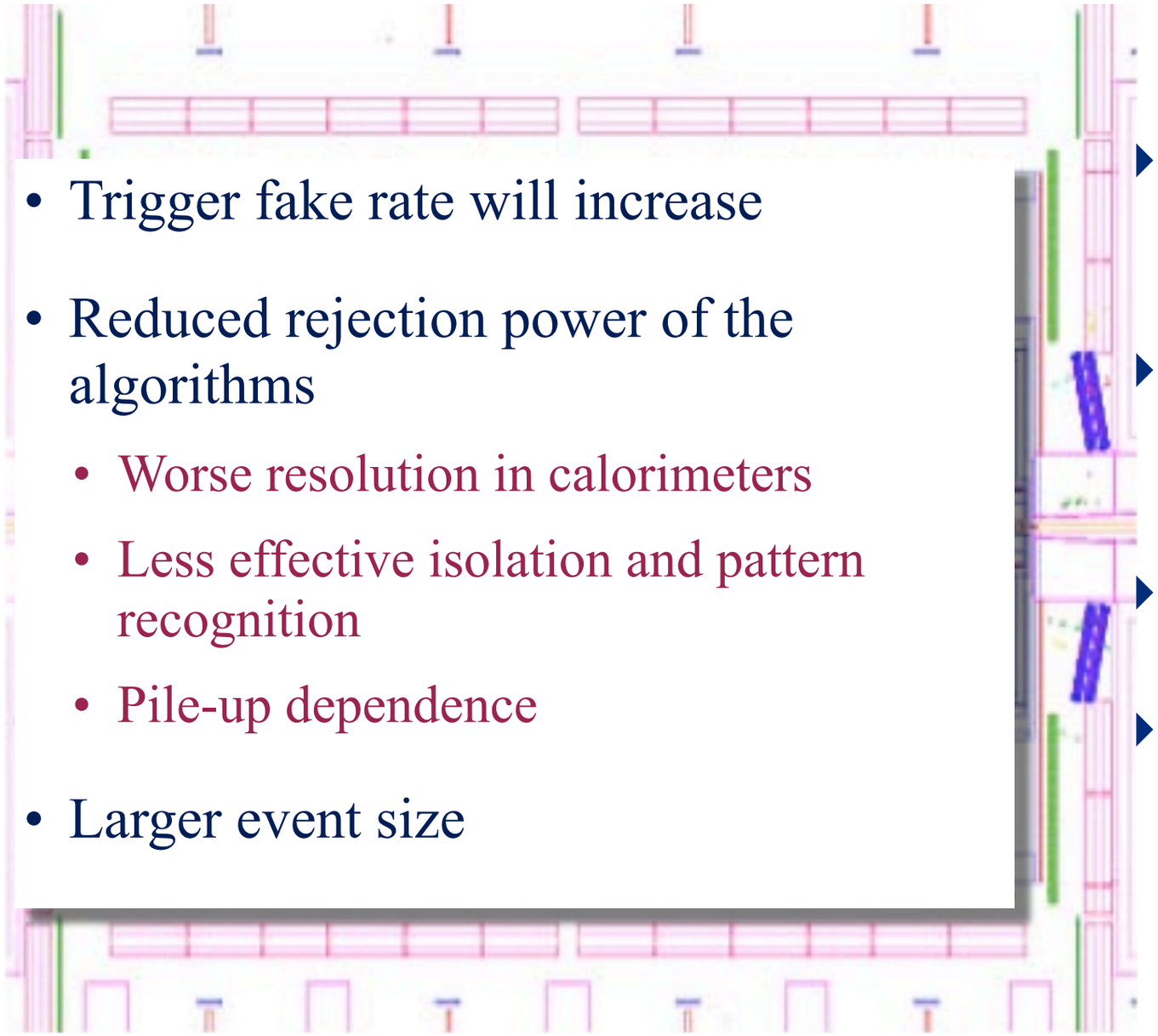
~3000 fb^{-1}

The Challenge



- HL -LHC beyond ATLAS design specification (10^{34} $cm^{-2}s^{-1}$)
- Nr. of Interaction per crossing:
  - 80 Phase-I to 200 Phase-II
- High radiation, harsh environment
- Higher occupancy in the detectors

The Challenge



- Trigger fake rate will increase
- Reduced rejection power of the algorithms
  - Worse resolution in calorimeters
  - Less effective isolation and pattern recognition
  - Pile-up dependence
- Larger event size

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  80 Phase-I to 200 Phase-II
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First-level Evolution

- L1 Muon trigger:
  - Phase-I: reduce fake rate by having a new small wheel detector
  - Phase-II: increase trigger selectivity by
    - increasing momentum resolution in the current trigger
    - add tracking information from the inner detector into the trigger
- L1 Calorimeter trigger:
  - Phase-I: use more granular information from calorimeters into L1
    - EM cluster shapes + EM/Hadron depth information:
      - improve electron purity
      - improve resolution on τ, jets and MET
  - Phase-II: possible use full granularity calorimeter into L1 for further improvement
- Central Trigger Processor and Muon processor
  - Phase-0: Increase the trigger inputs & add the topological trigger logic
  - Phase-I: New Small Wheel trigger integration & muon info to topological processor
  - Phase-II: CTP full replacement to integrate new trigger systems and new interfaces

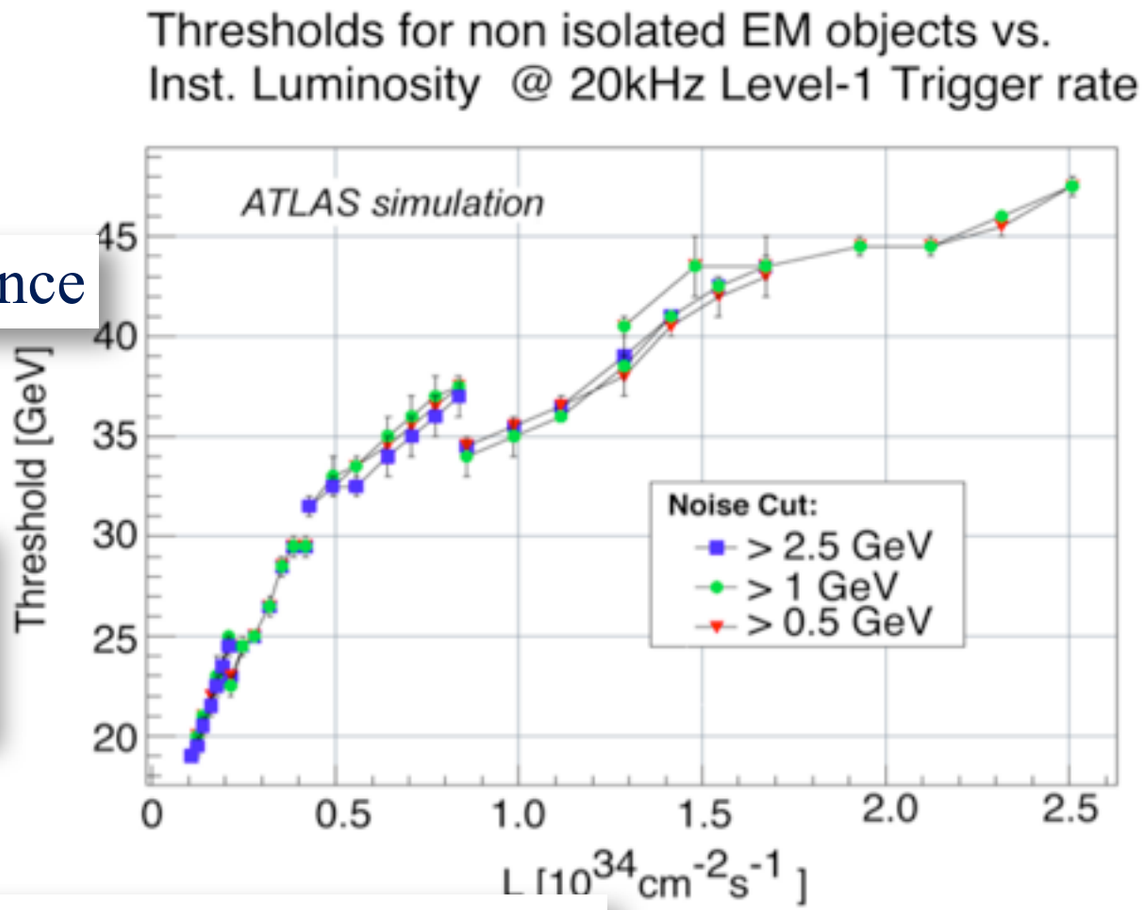
L1 Calorimeter Trigger

Rate scaling fast with luminosity ⇒ Impossible to stay within the allocated bandwidth

Try to achieve at L1 present L2 performance

- Shower shape discriminant
- Depth information

⇒ Digital Readout



- Higher processing power
- More information to the central trigger

⇒ New trigger electronics

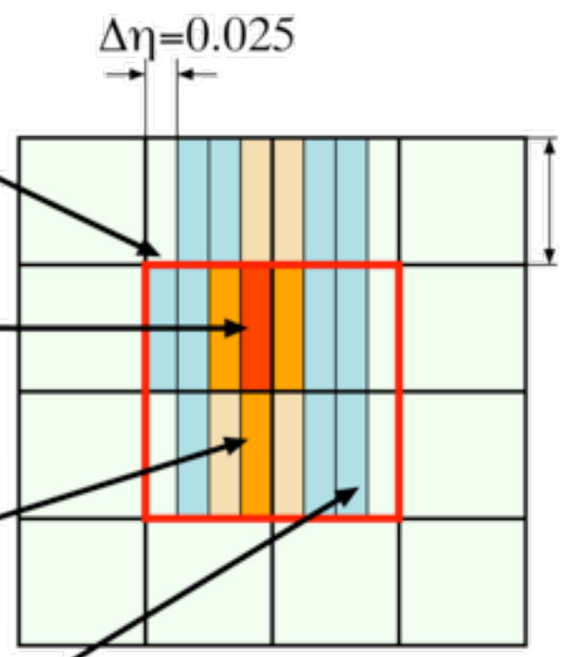
L1 Calorimeter Trigger

1. RoI location based on current Level-1 trigger system

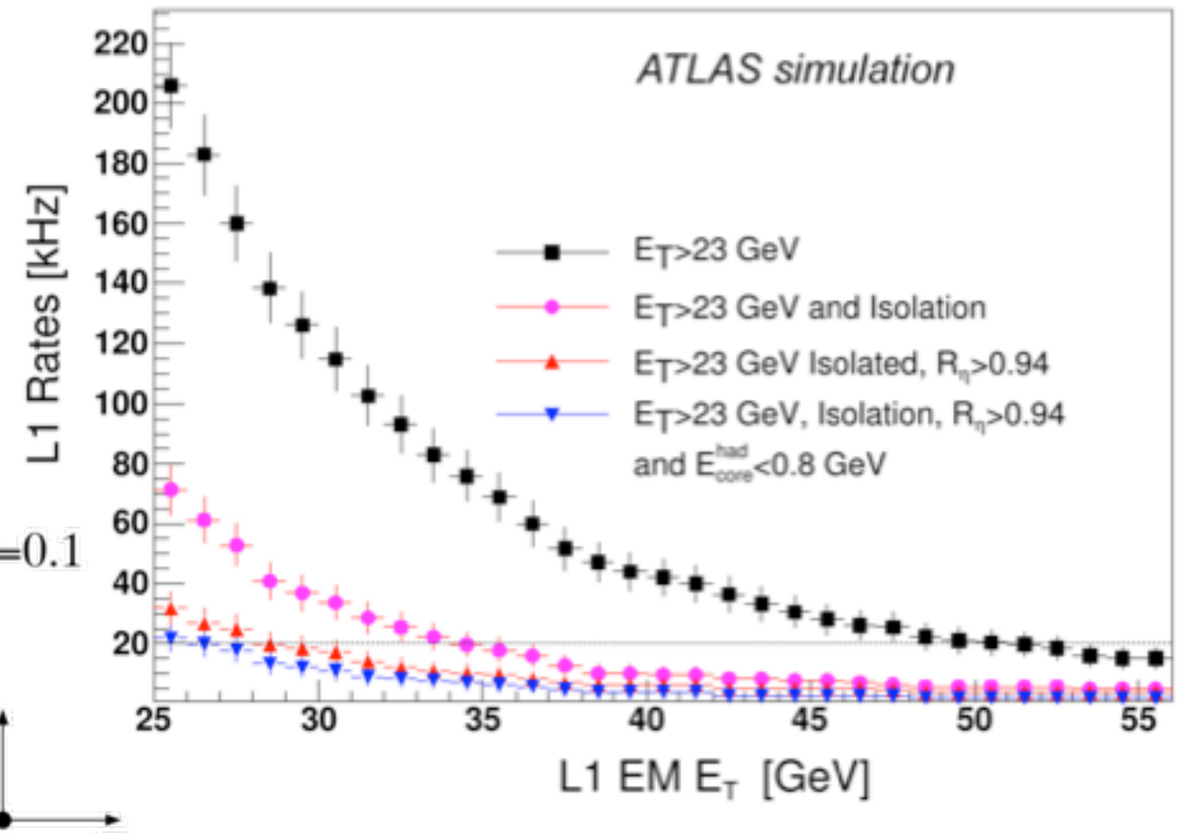
2. Algorithm seeded by most energetic $\Delta\eta \times \Delta\phi = 0.025 \times 0.1$ Super-cell

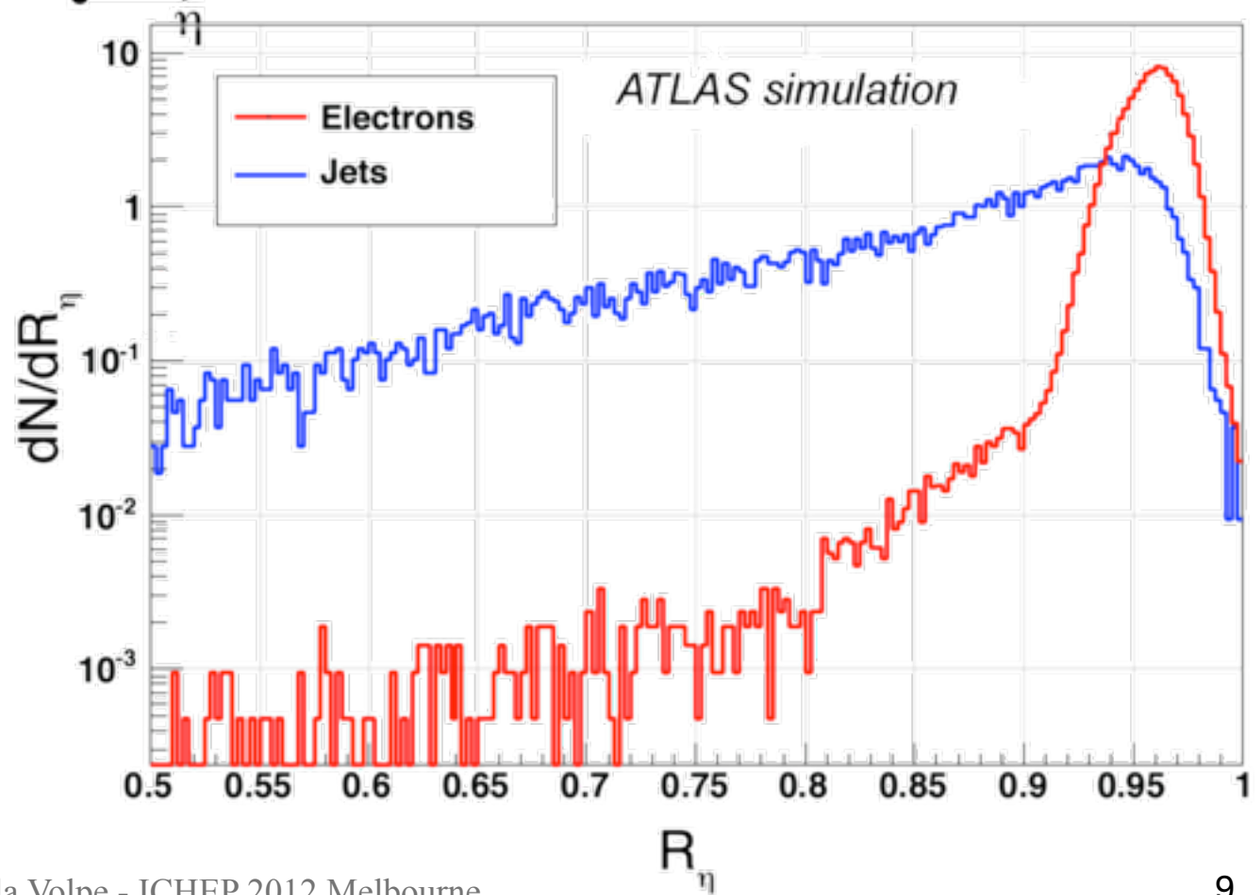
3. 2nd most energetic neighbour in ϕ (above or below) define cluster $\Delta\eta \times \Delta\phi = 0.2 \times 0.2$ core

4. Add neighbours in η,ϕ to form cluster. Wider eta environment for isolation/ rejection



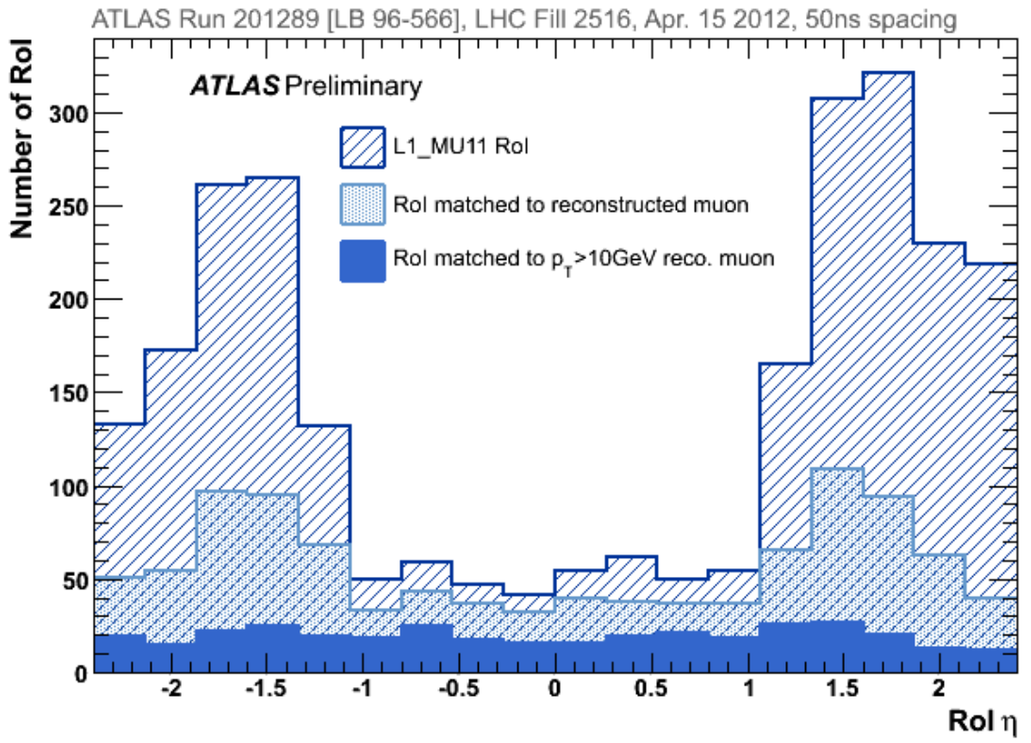
$$R_\eta = \frac{E_{3\times7}}{E_{7\times7}}$$

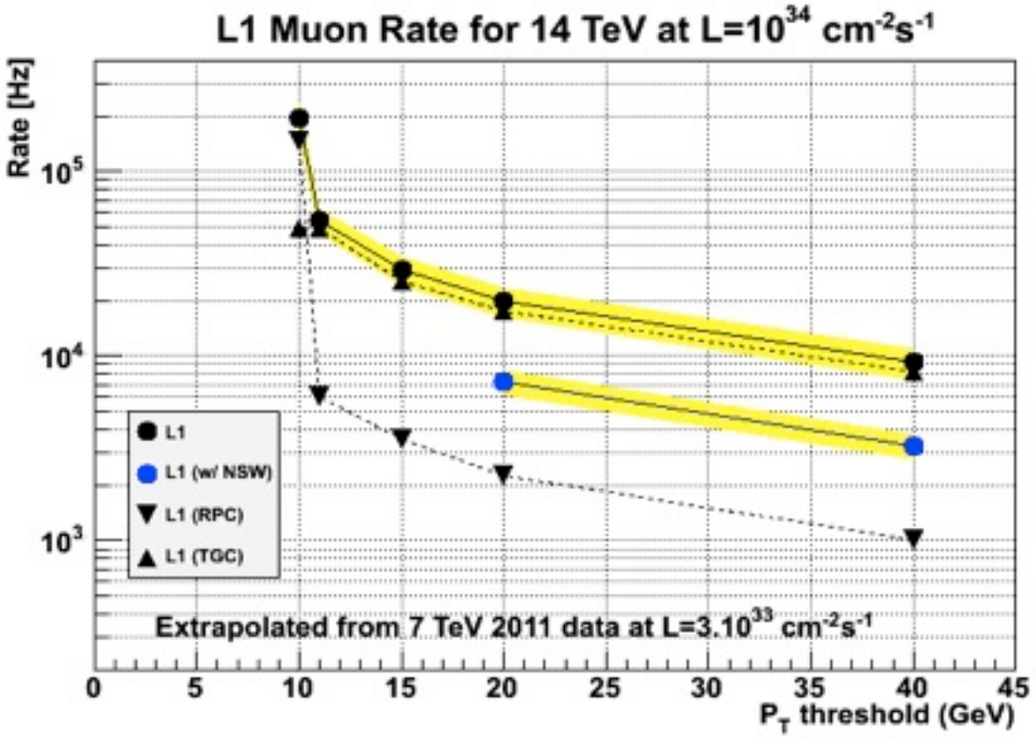


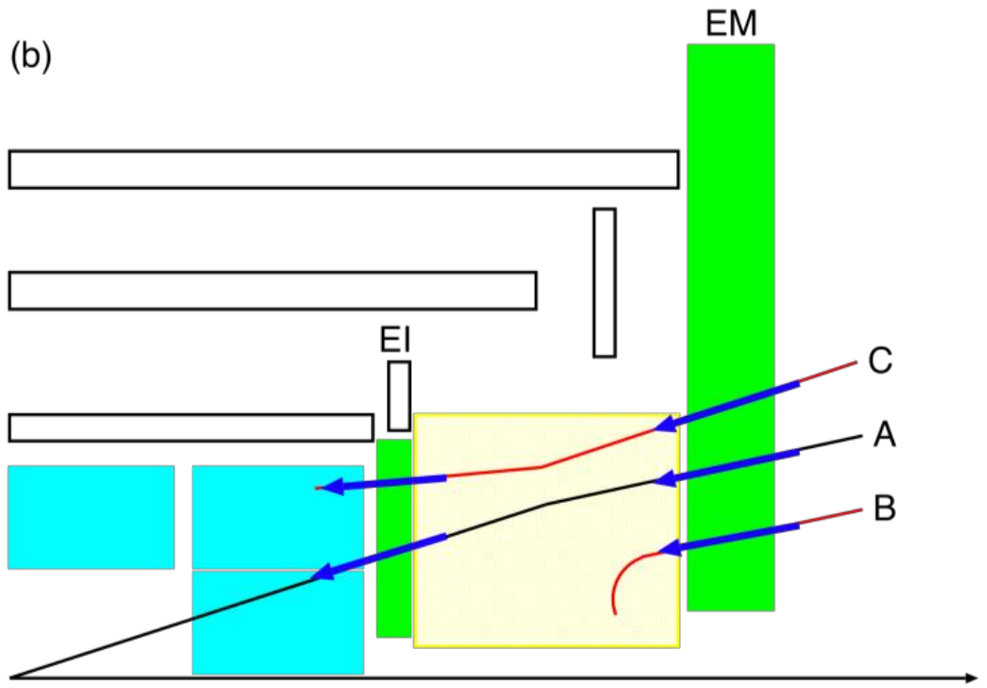


The New Muon Small Wheel

- Muon trigger rates are actually dominated by unforeseen fakes in the End-Cap region
- The Small Wheel (inner part of the End-Cap system) is currently not used for triggering
- The introduction of new trigger detectors in the Small Wheel region can significantly
  - reduce the trigger fake rate, making use of coincidence with the existing Big Wheel
  - increase the rejection power improving the p_T resolution







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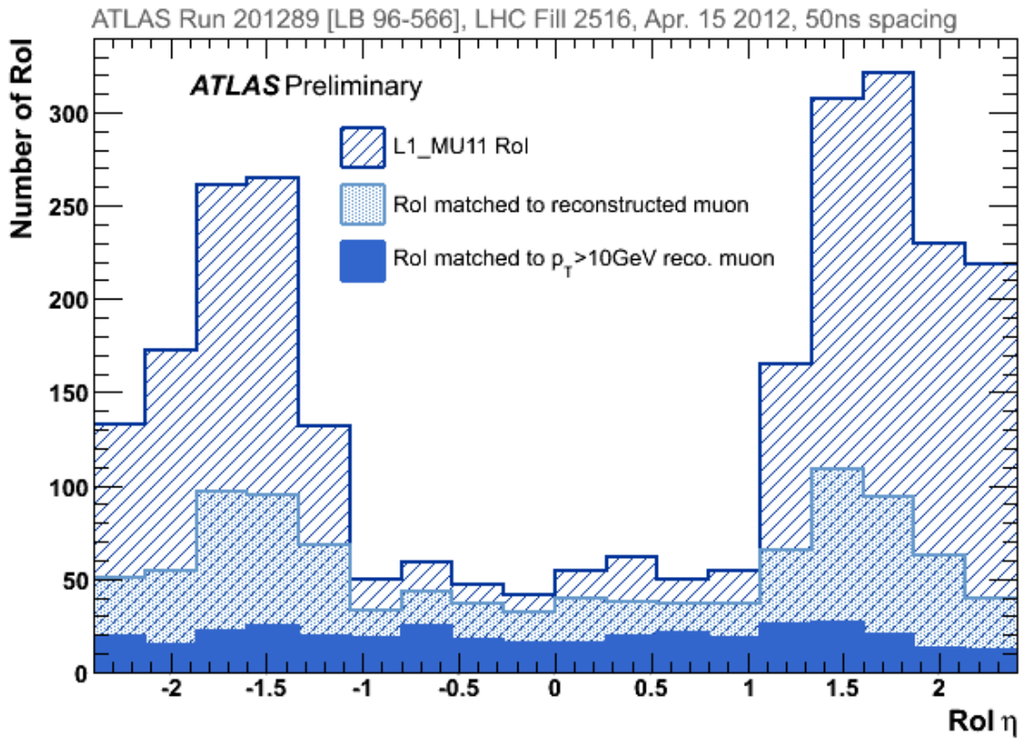

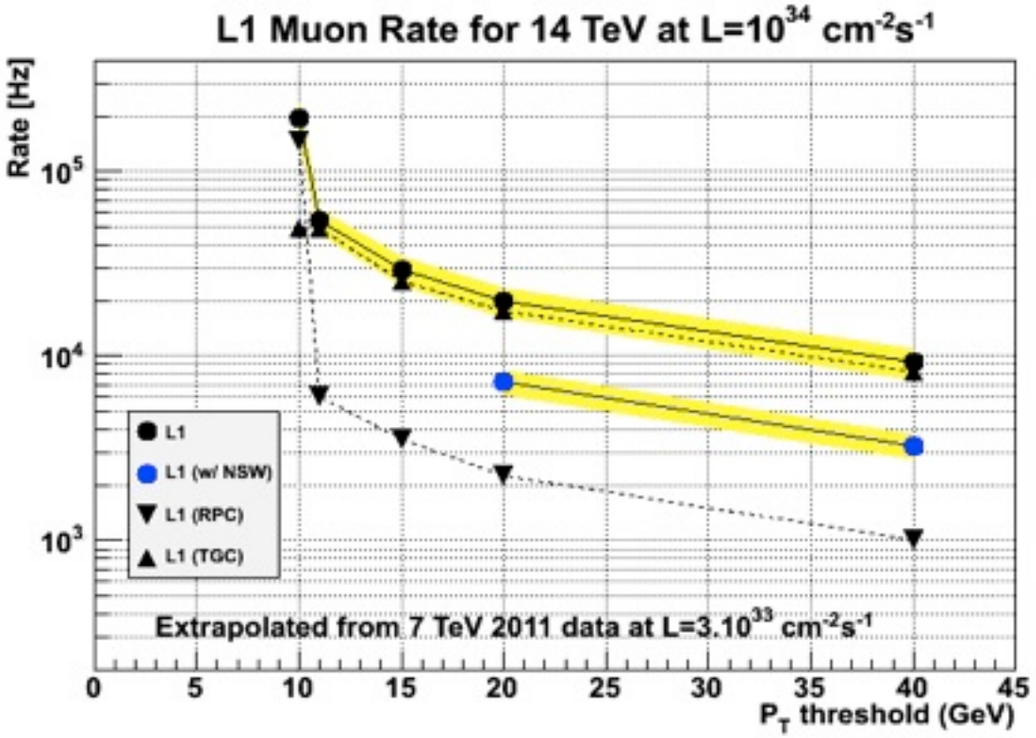

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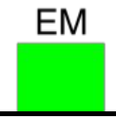
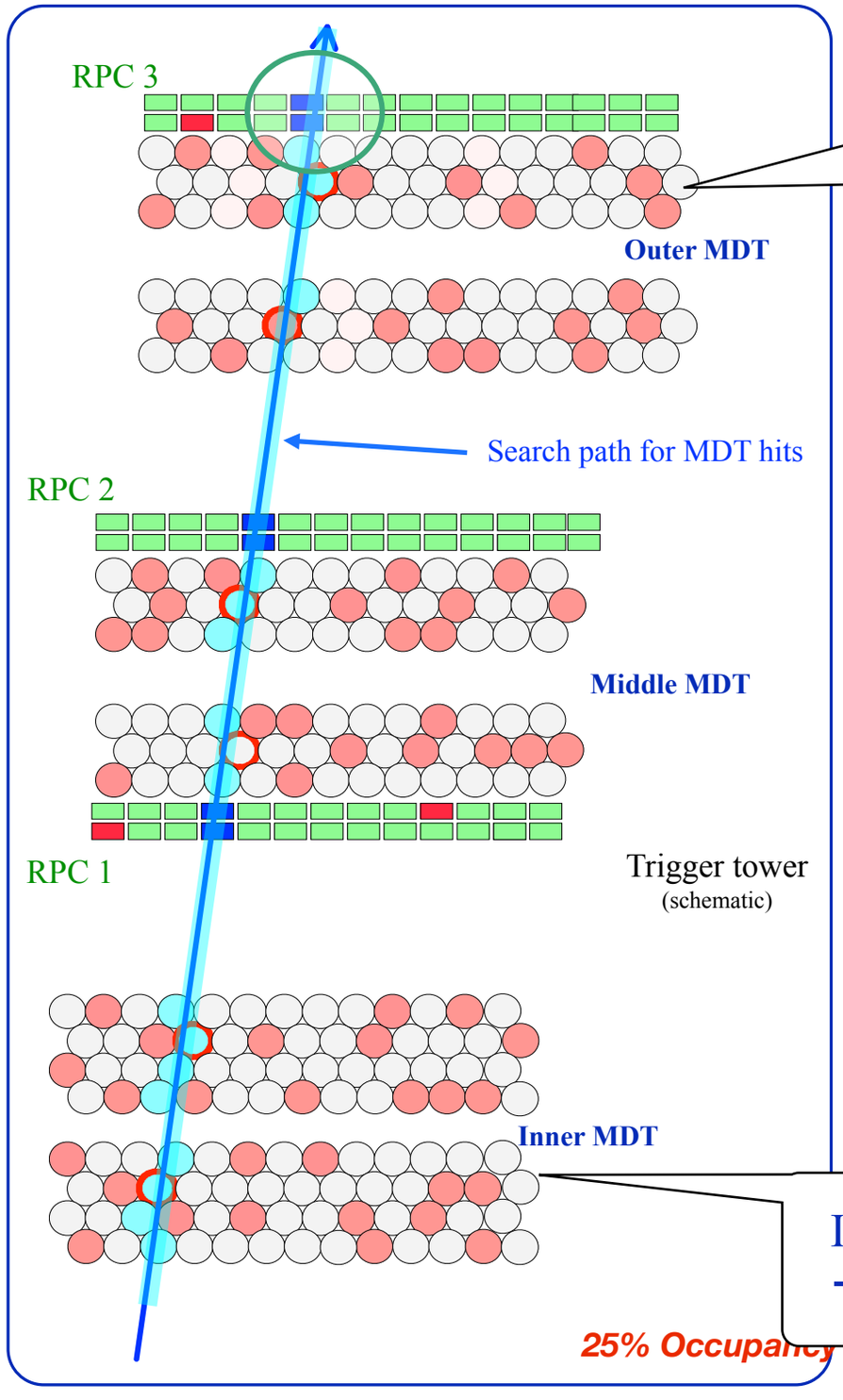
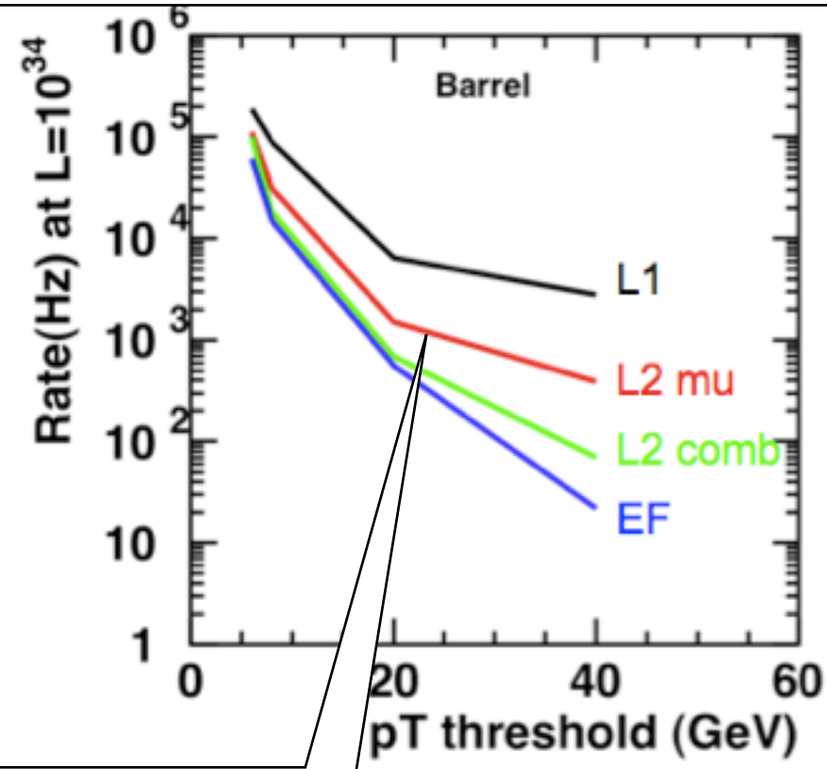


L1 rate for $L_{inst} = 3 \times 10^{34}$ cm^{-2}s^{-1}		
	without NSW	with NSW
MU20	59.6 ± 10.7 kHz	21.9 ± 3.2 kHz
MU40	28.8 ± 5.3 kHz	10.3 ± 1.6 kHz

Muon Trigger using the precision chambers



MDT provides momentum resolution 100 times better than RPC
A factor ~ 10 is enough to improve trigger selectivity!

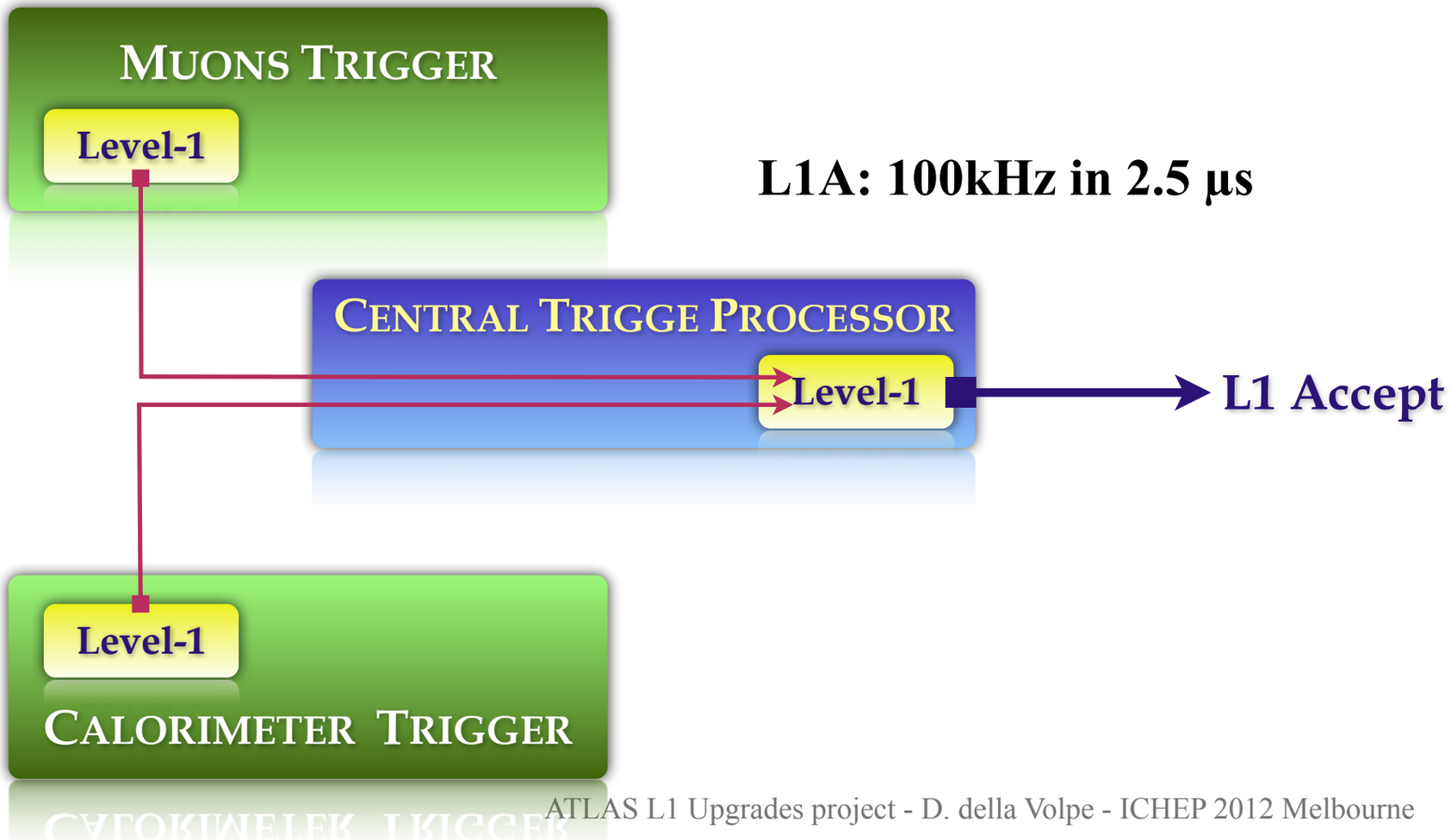


L2 performance can be achieve at L1 if precision chambers information can be used

In the present system the inner layer is not used for the L1
→ 50% of the bending power not used for the trigger!

L1 Track Trigger

- Adding tracking information in the trigger can potentially bring great benefit
  - Can reduce single lepton trigger rates combining calorimeter/muon information with tracks
  - Can improve tau identification and b-tagging
- .. but it introduces complexity and needs longer processing time
  - Increase the Level-1 latency (~ 20 μs)
  - Present single-stage L1 trigger scheme could evolve into a two-level trigger



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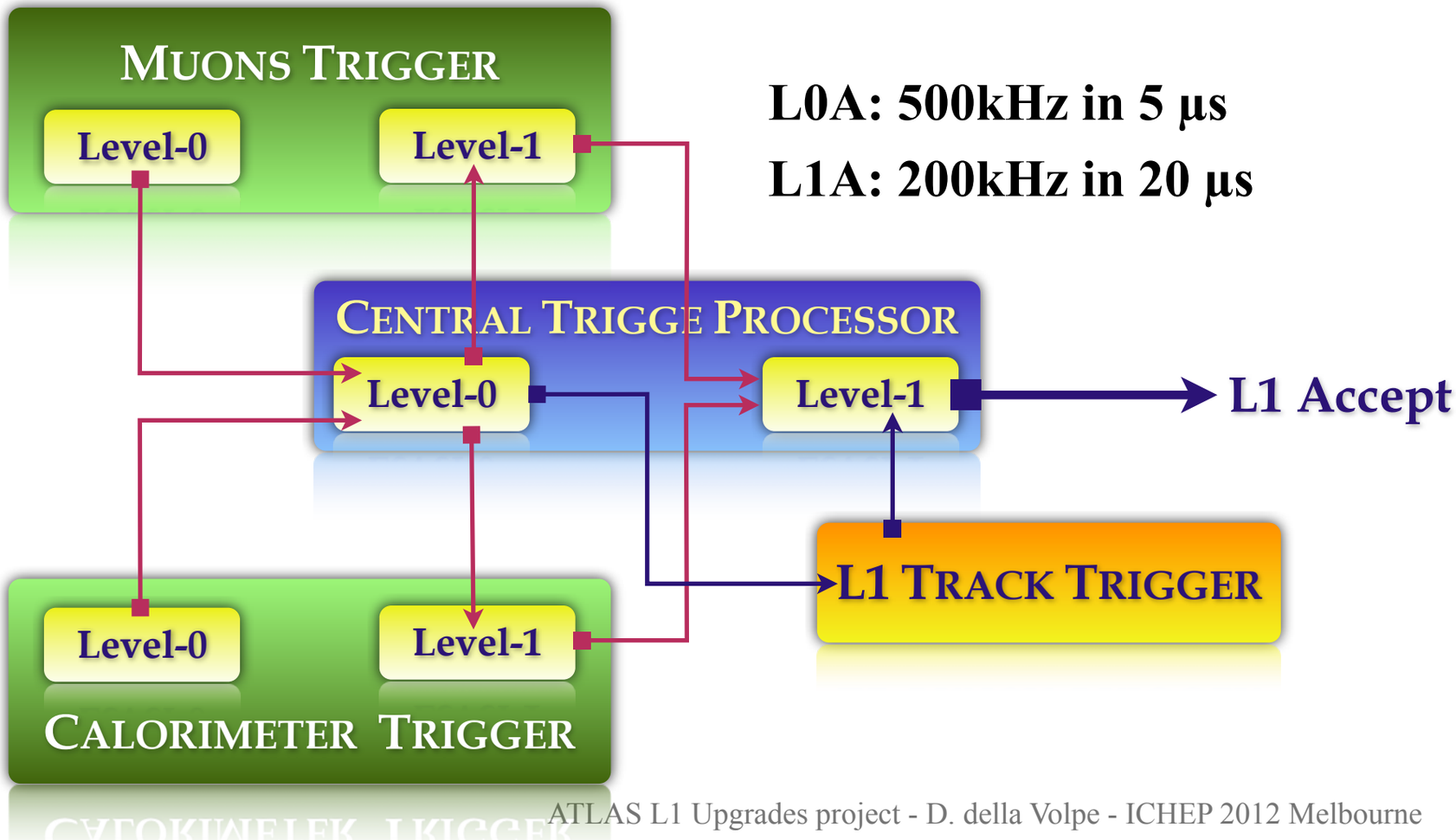

Conclusion

- The ATLAS Level-1 trigger upgrade program is rich and challenging
  - Muon
    - New Small Wheel in Phase-I
    - Include precision chamber in the trigger in Phase-II
  - Calorimeter Trigger
    - Possible use of detectors full granularity at L1 in Phase-II
  - L1 Track trigger
    - Introduce inner tracker into L1 trigger to improve selectivity
  - Central trigger processor
    - Introduce topological trigger capabilities
    - Evolve to incorporate the NewSmall Wheel and to cope with a 2 stage L1 trigger
- ATLAS Phase-1 upgrade described in their respective Letter of Intent (LoI):
  - Technical Design Reports, within the end of 2013/14, start the engineering design
- ATLAS Phase-2 upgrade studies on-going in preparation of a LoI