ATLAS High-Level Trigger Algorithms for Run-2 Data Taking

C. Schiavi
for the ATLAS Collaboration

Summary

Short overview of infrastructural HLT changes:

- unified High-Level Trigger processing
- use of offline reconstruction tools and data structures

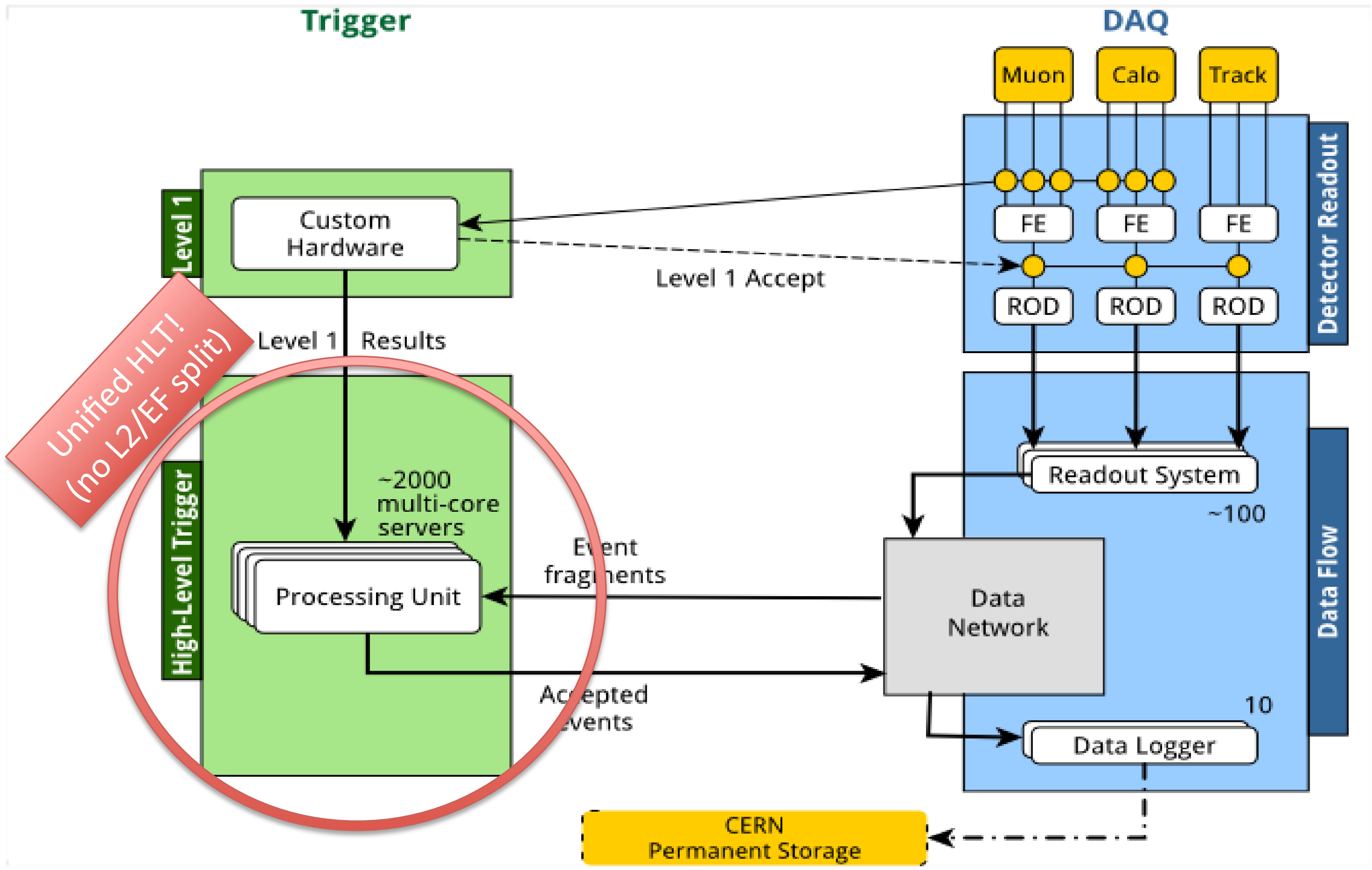
Improvements in trigger selections:

- examples of improvements in trigger detector software
- a few selected highlights from different trigger signatures

Not only HLT:

- many general improvements in the overall trigger strategy
- see talk by Yu Nakahama

High-Level Trigger Farm Merging



The Run-1 HLT selection ran in two separate farms: Level2 and Event Filter

A few of the consequences: separate rate boundaries; data transfer from L2 to EF; some processing duplication

The HLT processing is now unified into just one farm:

- reduces the complexity of the system
- provides efficient coupling between subsequent selection steps, reducing duplication of CPU usage and network transfer
- allows flexible combination of fast and detailed processing

Harmonization with Offline Reconstruction

Feedback from Run-1 analyses: important to improve the correlation between online and offline object identification

For Run-2 all trigger signatures focused on adopting offline techniques wherever possible:

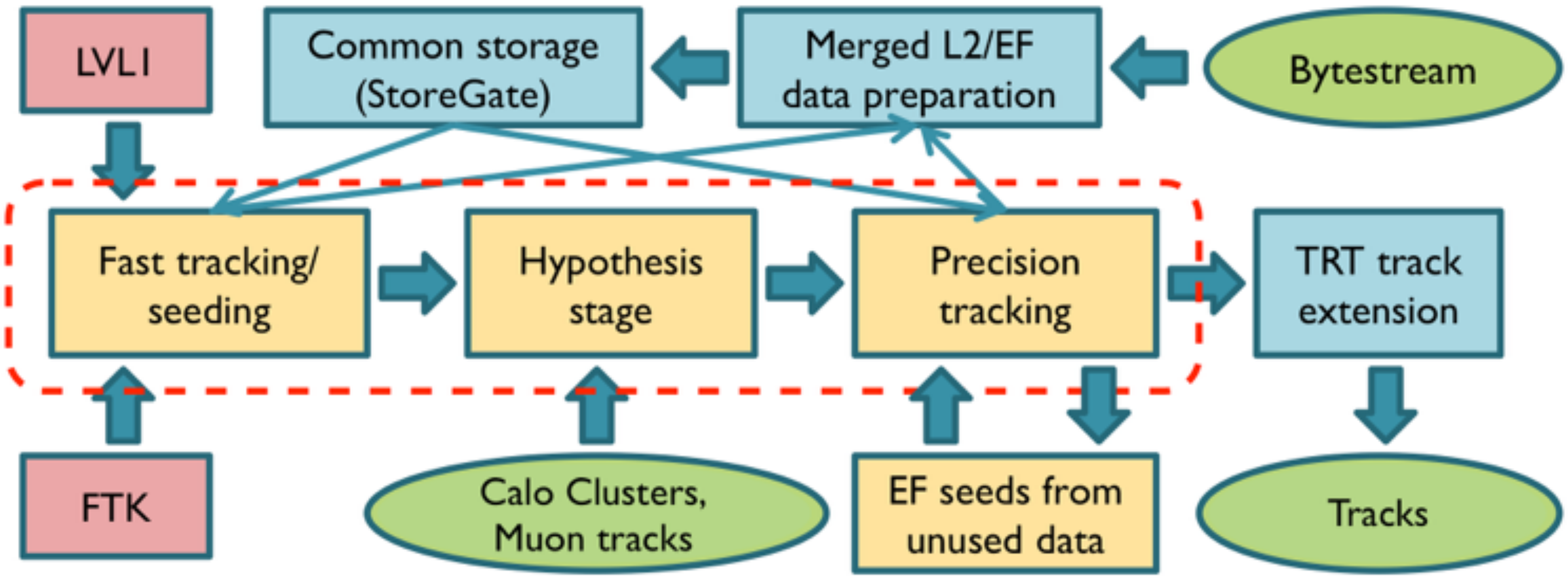
- data preparation
- detector software
- reconstruction
- selection cuts

Aim: increased acceptance after analysis cuts and higher rejection
In addition: allows specific trigger tuning for particular analyses

Technical aspects:

- adoption of xAOD data structures, mostly in common with offline: allows easier reuse of offline code
- large reduction of coding and commissioning duplications
- easier calibration of triggers along with offline selections
- pile-up corrections: possible access to average collision number

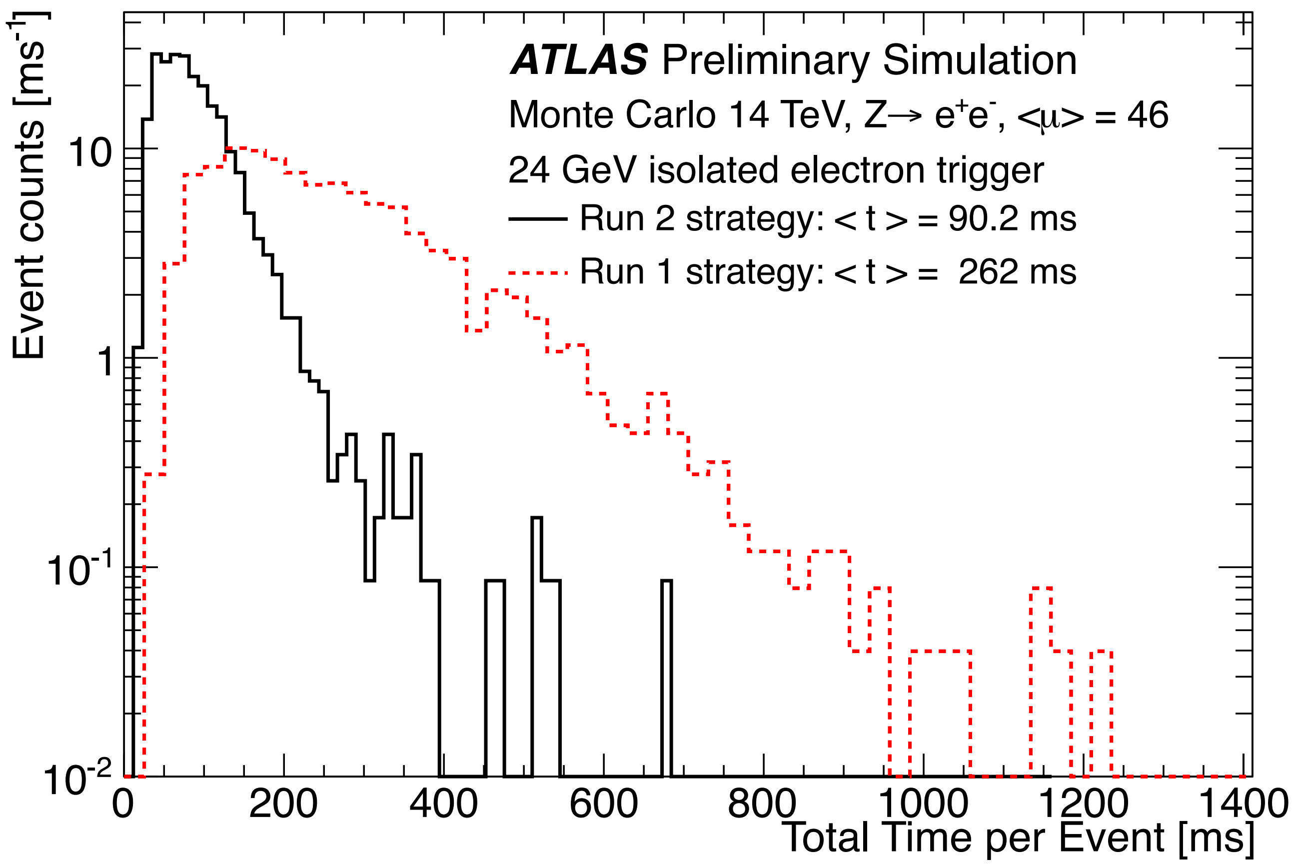
Detector Software: Inner Detector Tracking

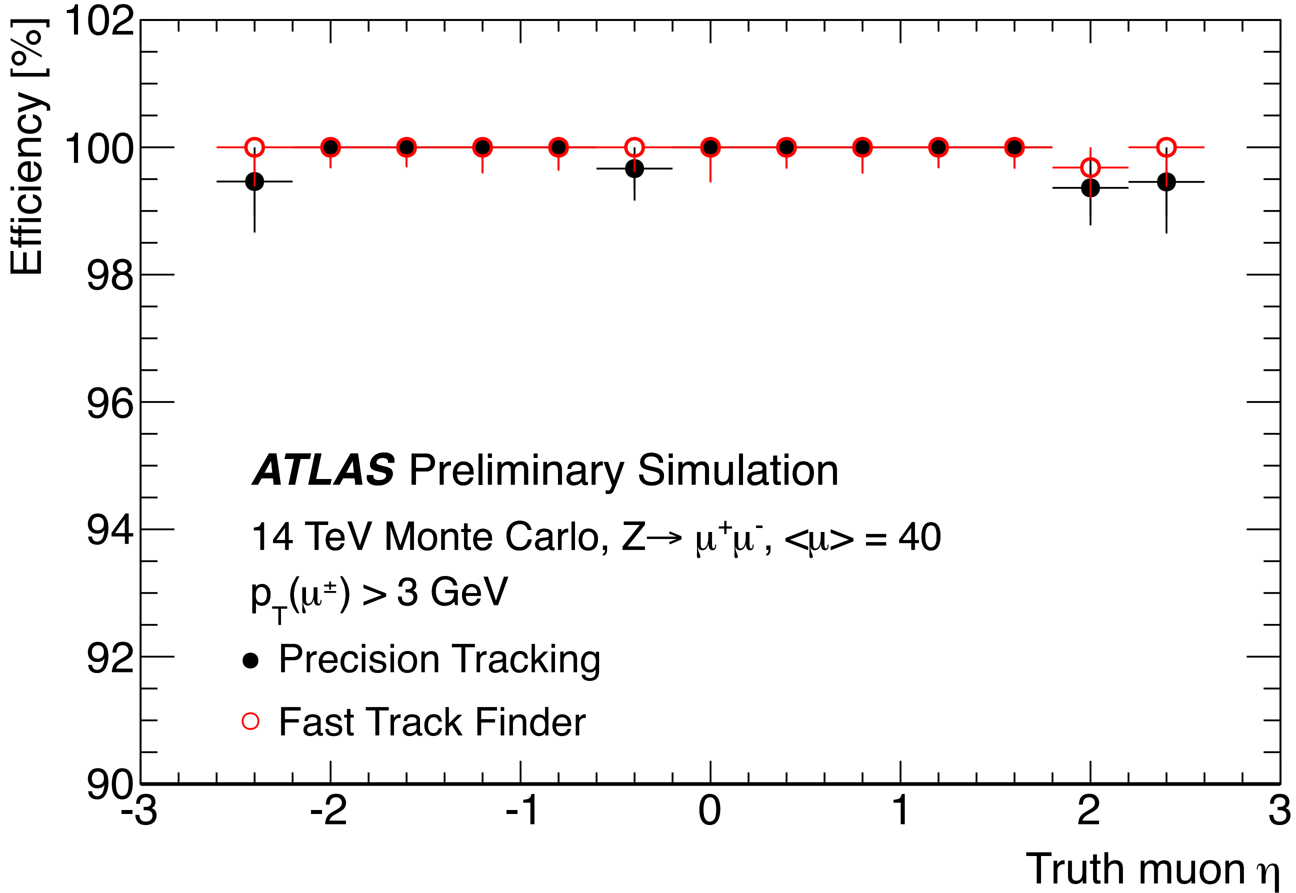


New HLT ID tracking exploits running on a single CPU node:

- common data preparation performed just once
- first Fast Track Finder step provides fast tracking info
- this is reused as a seed for Precision Tracking instead of restarting from scratch, as in the L2/EF scheme
- common data structures for both steps: easy switching
- ready to receive seeds from additional sources, as FTK
- see poster by Stewart Martin-Haugh

Detector Software: Inner Detector Tracking





The new unified HLT approach also performs much better in terms of CPU consumption, after offline and online code optimization:

- example: approximate average total electron chain execution time is now 90 ms to be compared with 260 ms for Run-1
- faster execution obtained without affecting efficiency
- similar improvements measured for the muon slice

Trigger Signatures: EGamma and Taus

Both signatures profit from L1 improvements and disambiguation

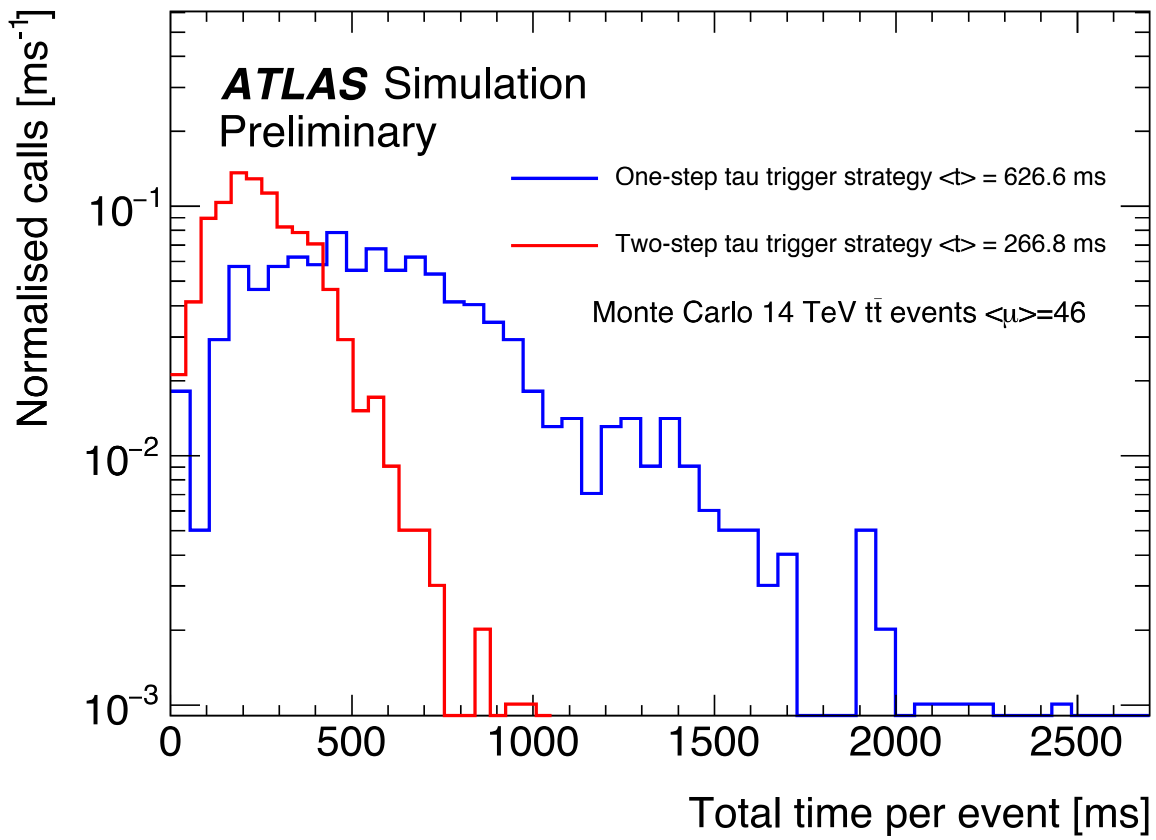
EGamma:

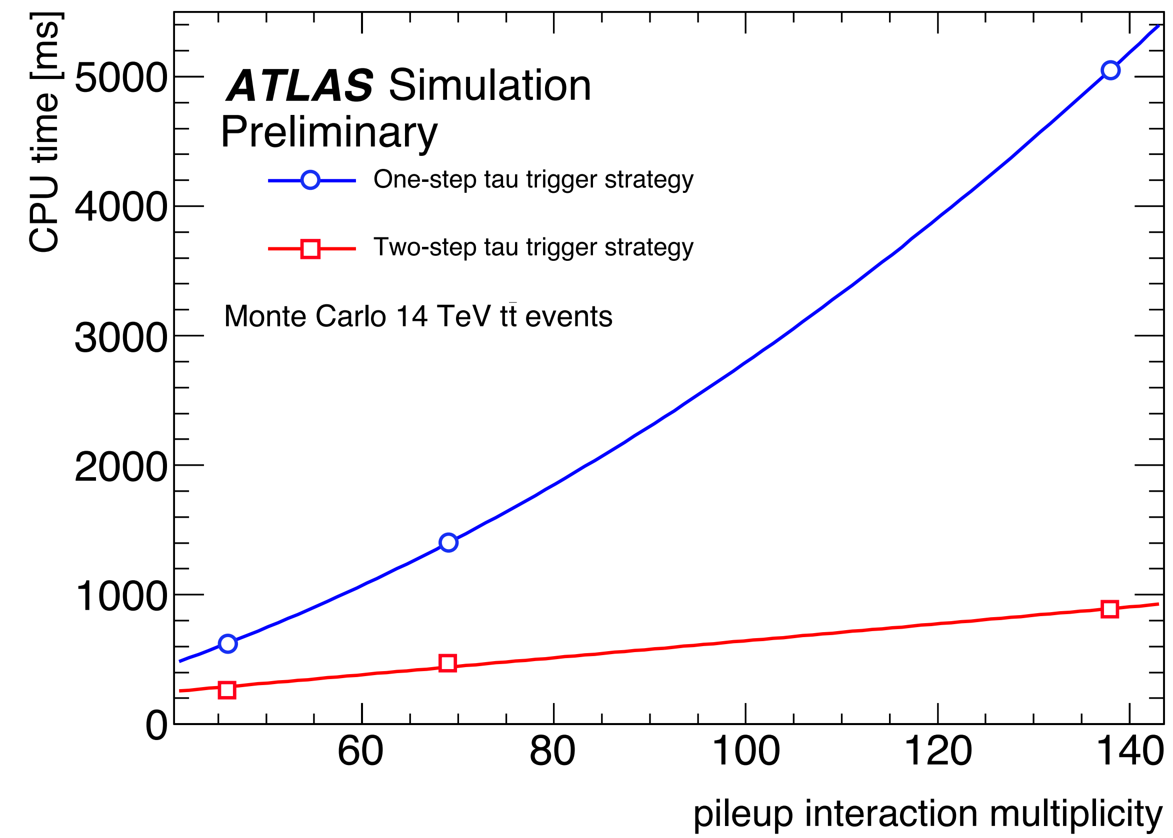
- aim to have HLT as close as possible to offline, using MVA energy calibration and conversion reconstruction
- for electrons, will commission in parallel two alternative selections, one cut-based and one likelihood-based
- exploit L1Topo for ultimate precision tag-and-probe calibrations

Taus:

- implemented two-step tracking approach, granting faster processing enhancing early rejection: process core region first, looking for signal tracks, then process isolation ring
- following offline, introduced new variables sensitive to π^0
- also pile-up corrections harmonized with offline

Trigger Signatures: EGamma and Taus





Taus:

- implemented two-step tracking approach, granting faster processing enhancing early rejection: process core region first, looking for signal tracks, then process isolation ring
- following offline, introduced new variables sensitive to π^0
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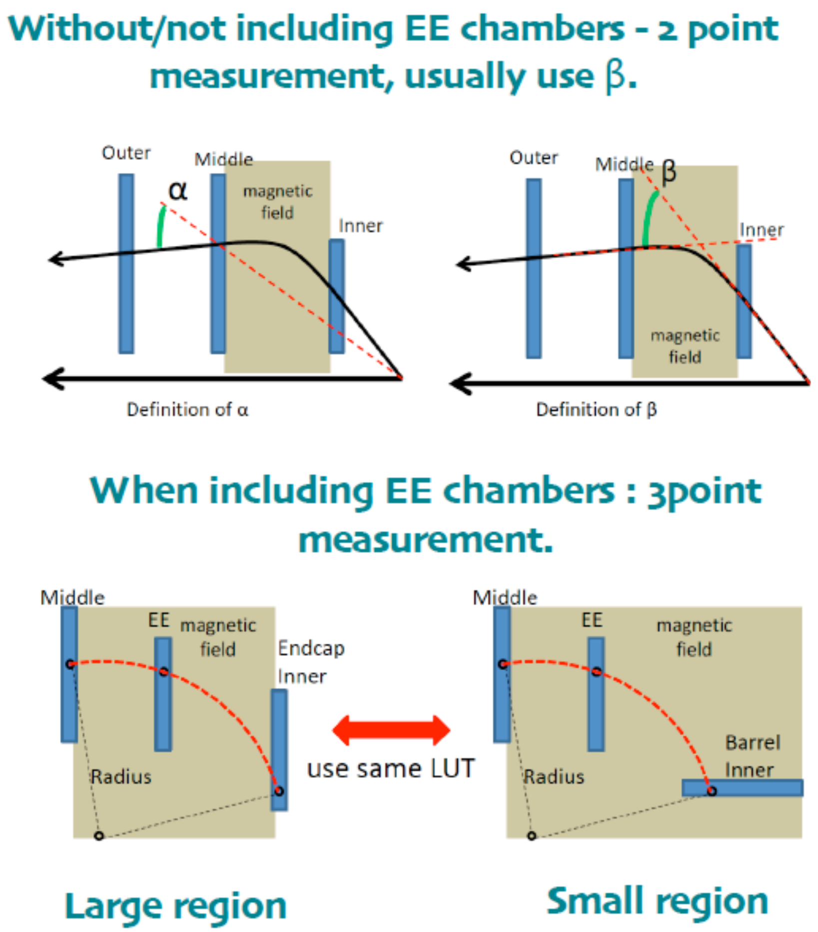
Trigger Signatures: Muons



Muon identification proceeds in two steps:

- major rewrite of the standalone reconstruction for the first selection
- news: p_T calculation enhanced using hits from new EE MDT chambers (approx. factor 2 resolution improvement)
- final selection using offline strategies for muon reconstruction

Completely redesigned muon full scan search: used to improve search for di-muon events, starting from single muon at L1

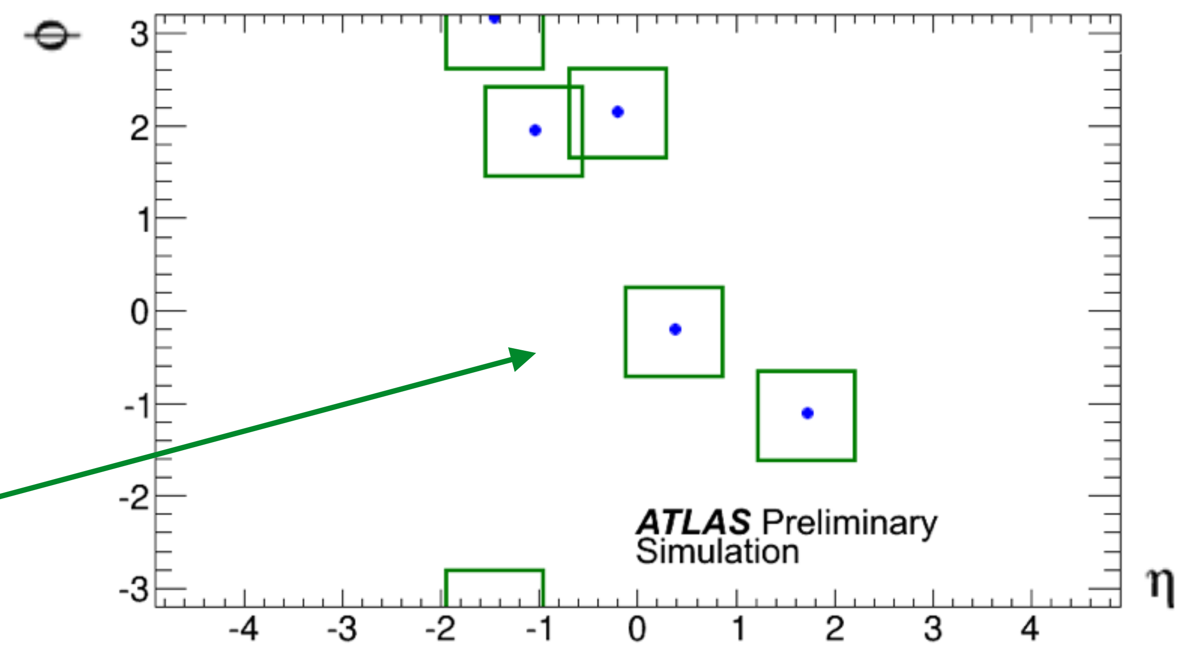
- in Run-1, full scan done in both Muon Spectrometer and ID
- now, full scan MS reconstruction is followed by ID tracking is run in small projections of each muon
- more than a factor 3 faster with no efficiency loss!

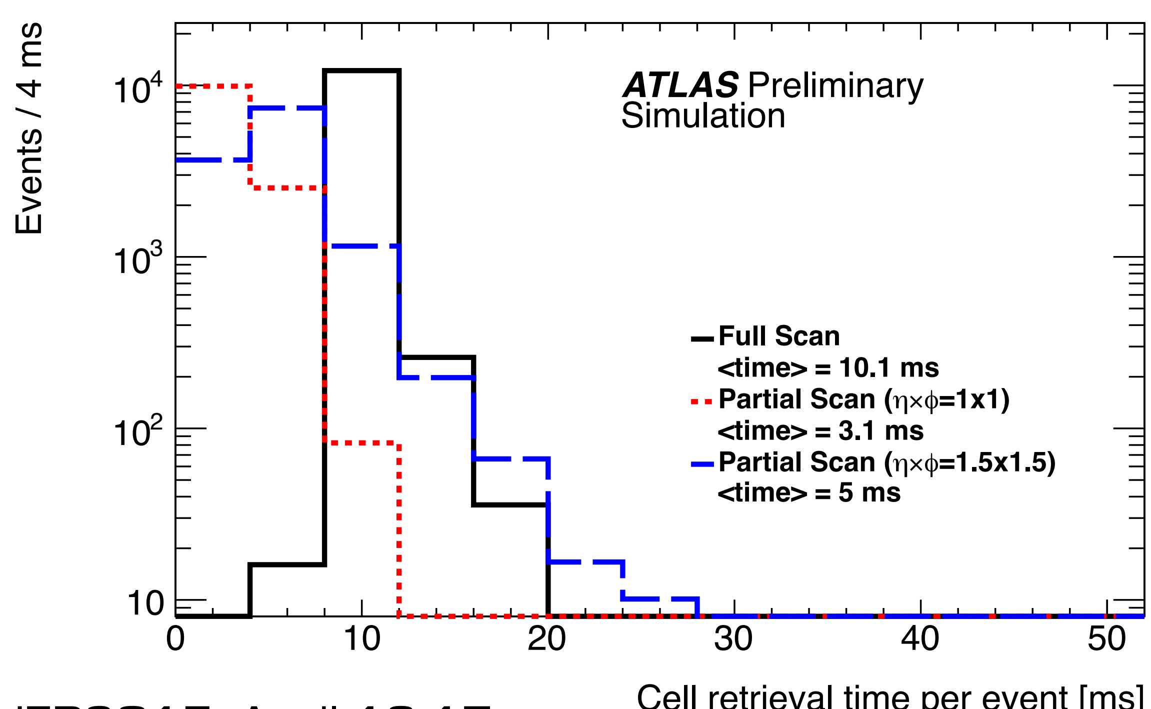
Trigger Signatures: Jets

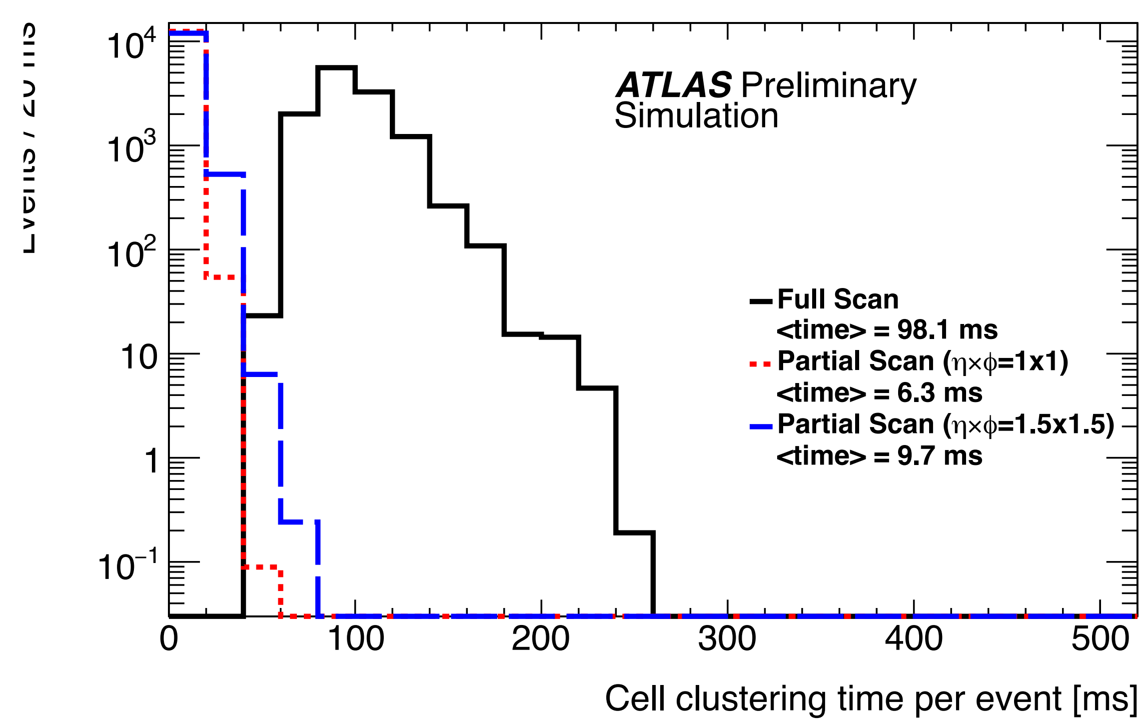
Major infrastructural rewrite allows broad use of offline tools:

- implemented jet area pileup suppression and jet energy scale
- working on further steps based on tracking result

Implemented new partial scan option for data access and reconstruction: runs a single-pass scan on calorimeter data from merged regions around L1 jets



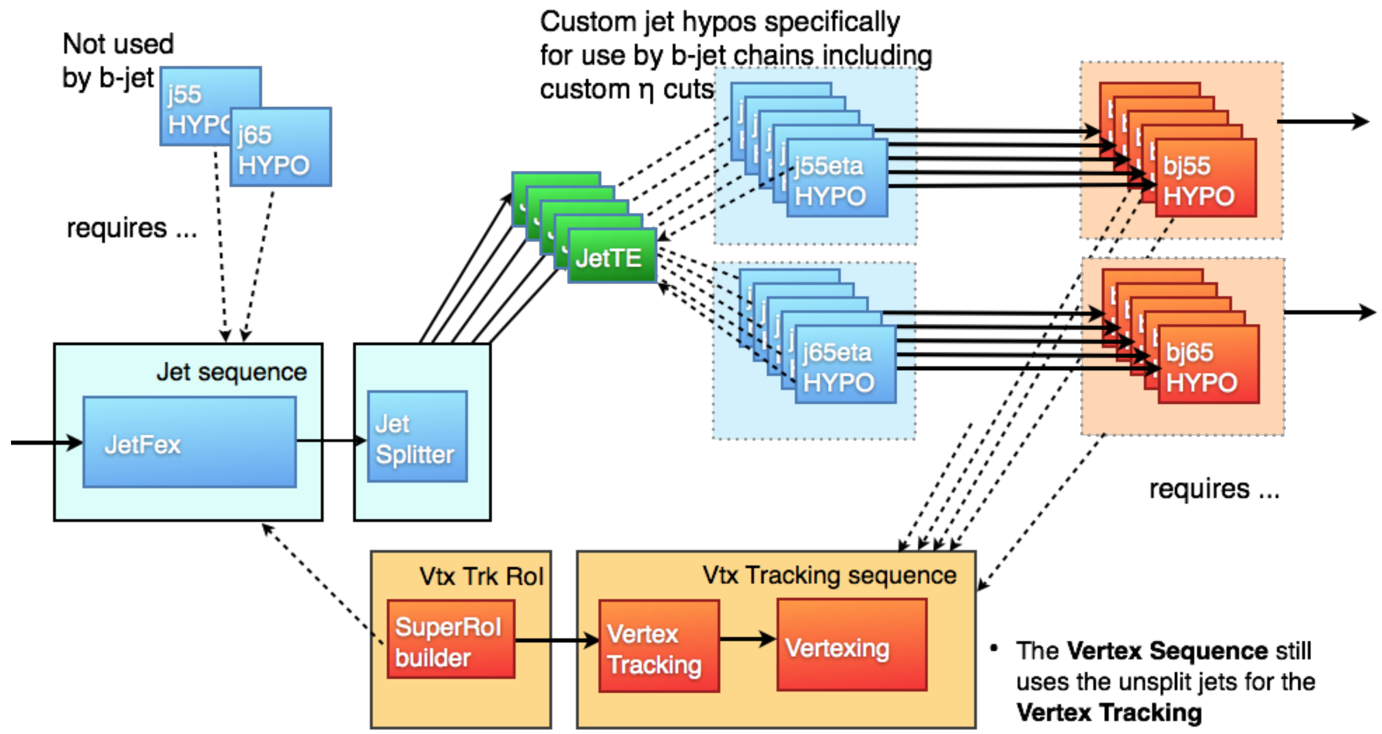




Trigger Signatures: b-Jets

Many performance improvements from infrastructural work:

- tracking / vertexing can be executed in the geometrical union of jet RoIs (SuperRoI): flexible multi-step tracking approaches
- provides significant computing speed up, even processing larger cone sizes around each jet
- big effort to reuse offline code and move to the use of advanced tools and multivariate taggers online (JetFitter, MV1, MV2, ...)
- larger rejection power allows looser working point definitions



Trigger Signatures: MET and B-physics

For both, large improvements from new L1 topological capabilities: MET using KF jet corrections, invariant mass cuts for B-physics

MET:

- use of cell-level info immediately after L1 (L2 sums in 2012)
- offline-like algorithms being examined, e.g. jets for hard activity plus topoclusters for soft activity
- pileup suppression, rejecting events where the minimum energy per object is below threshold
- additional corrections constraining MET from pileup to zero
- use of final trigger muons for MET (L2 muons in 2012)

B-physics:

- preparing HLT selections with cut on di-muon lifetime
- could be adopted for studies of rare and semileptonic decays
- requires care for onia and lifetime/angular measurements

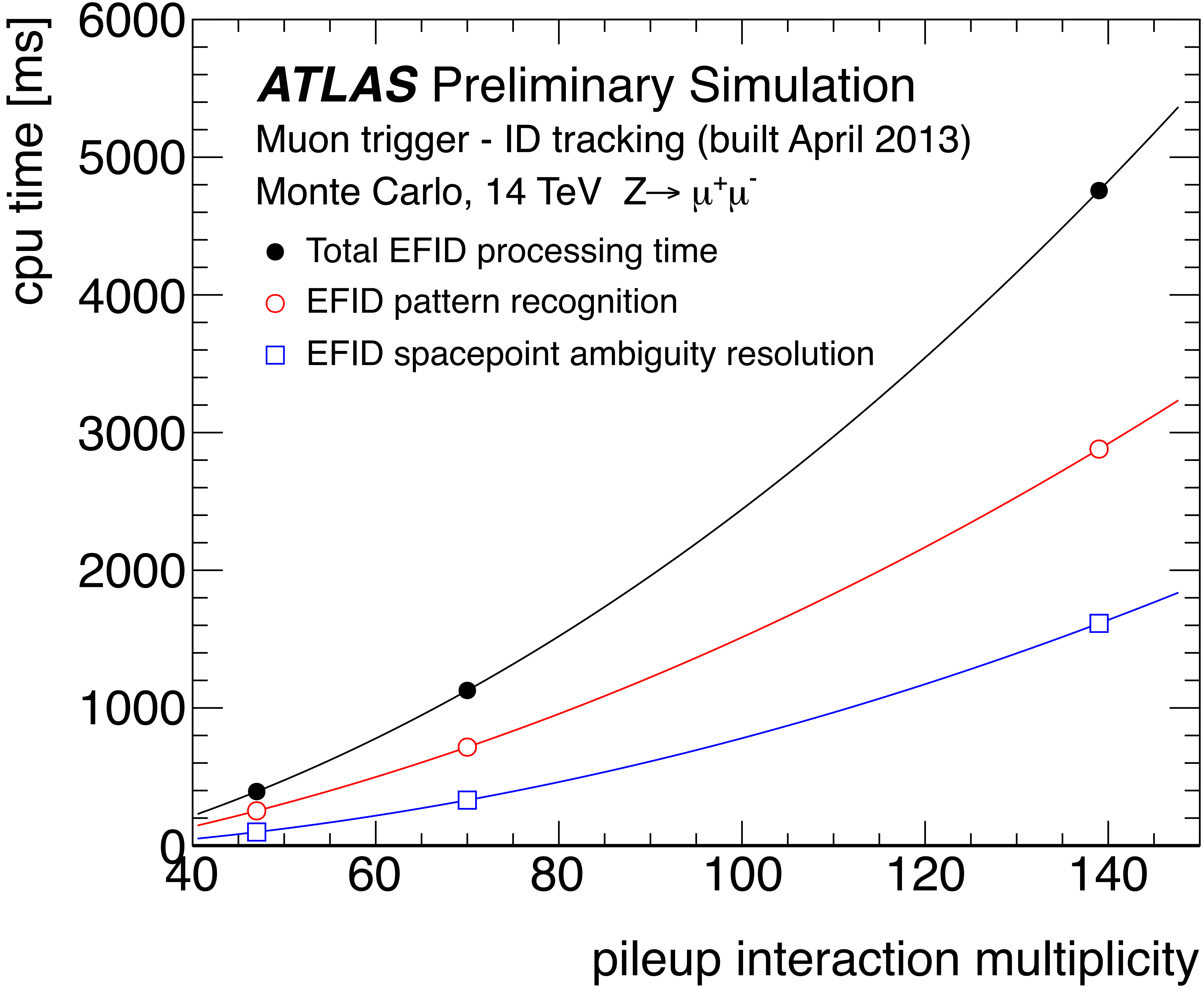
Conclusions

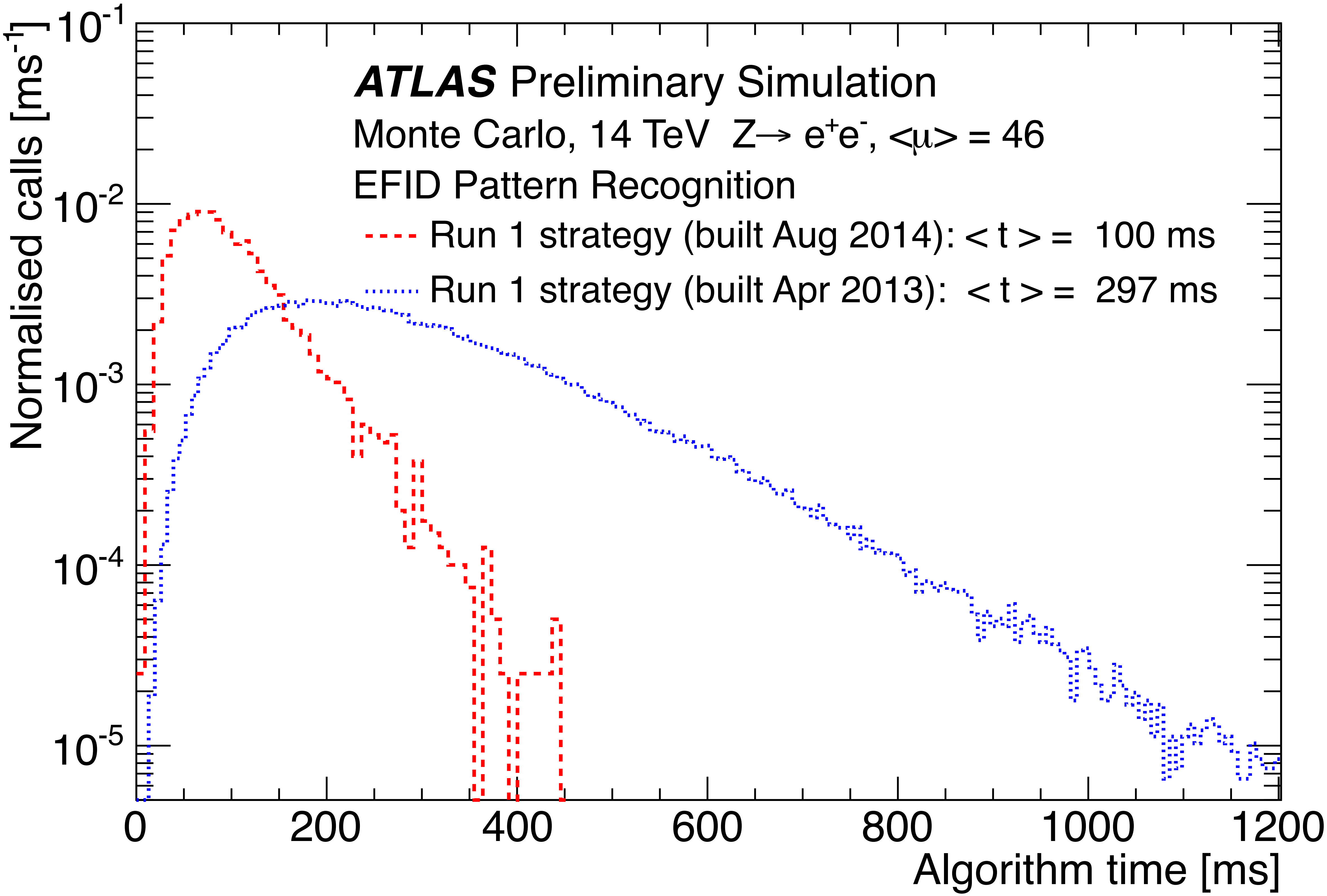
Many news since Run-1: HLT merging into a single processing node, new data structures written in collaboration with offline, in general a larger harmonization effort aiming at a better online/offline correlation and larger acceptance after analysis cuts, while enhancing rejection power against uninteresting events

A lot of good new ideas in the design of Run-2 HLT triggers, surely promising an enhanced physics reach…

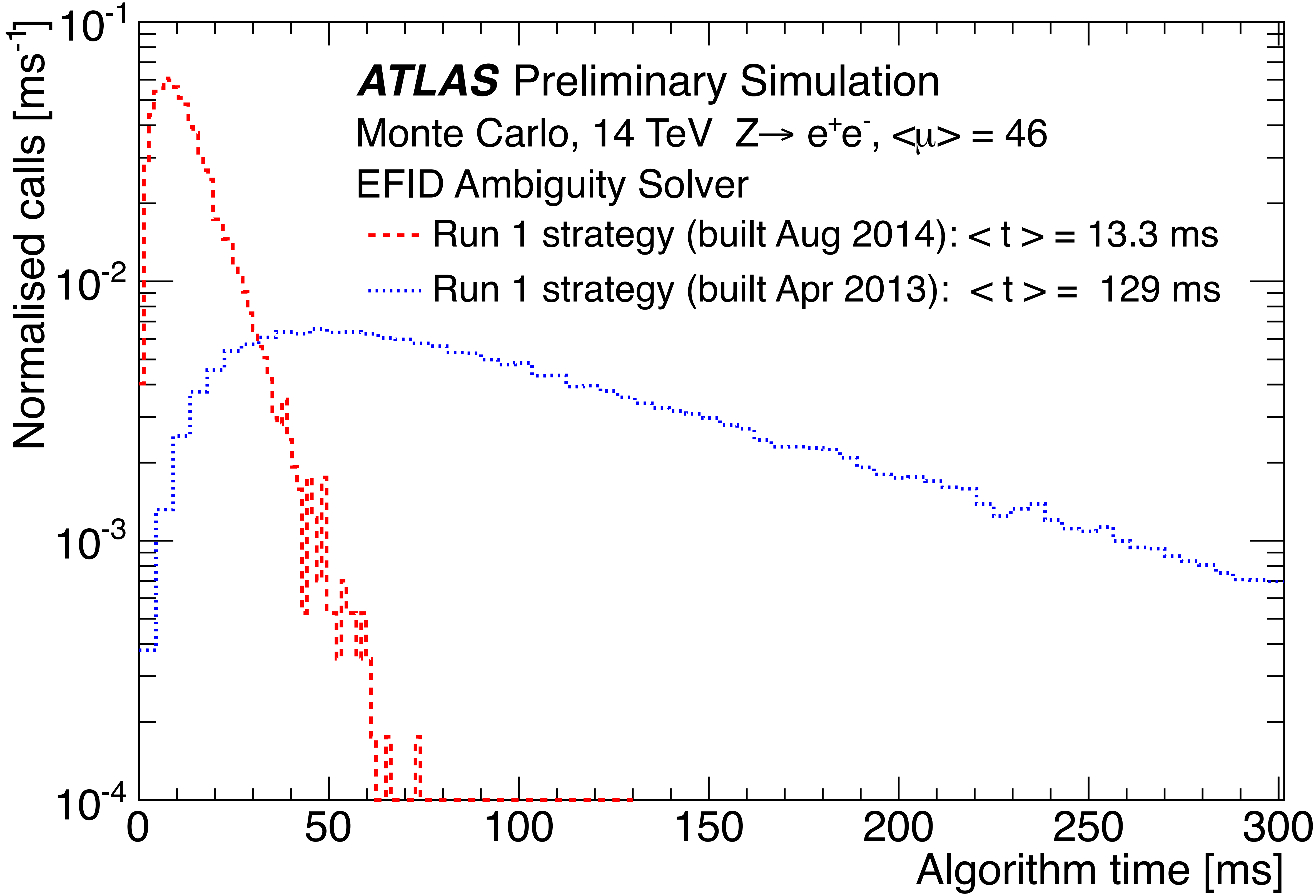
which is soon to be confirmed with fresh new collision data!

BACKUP

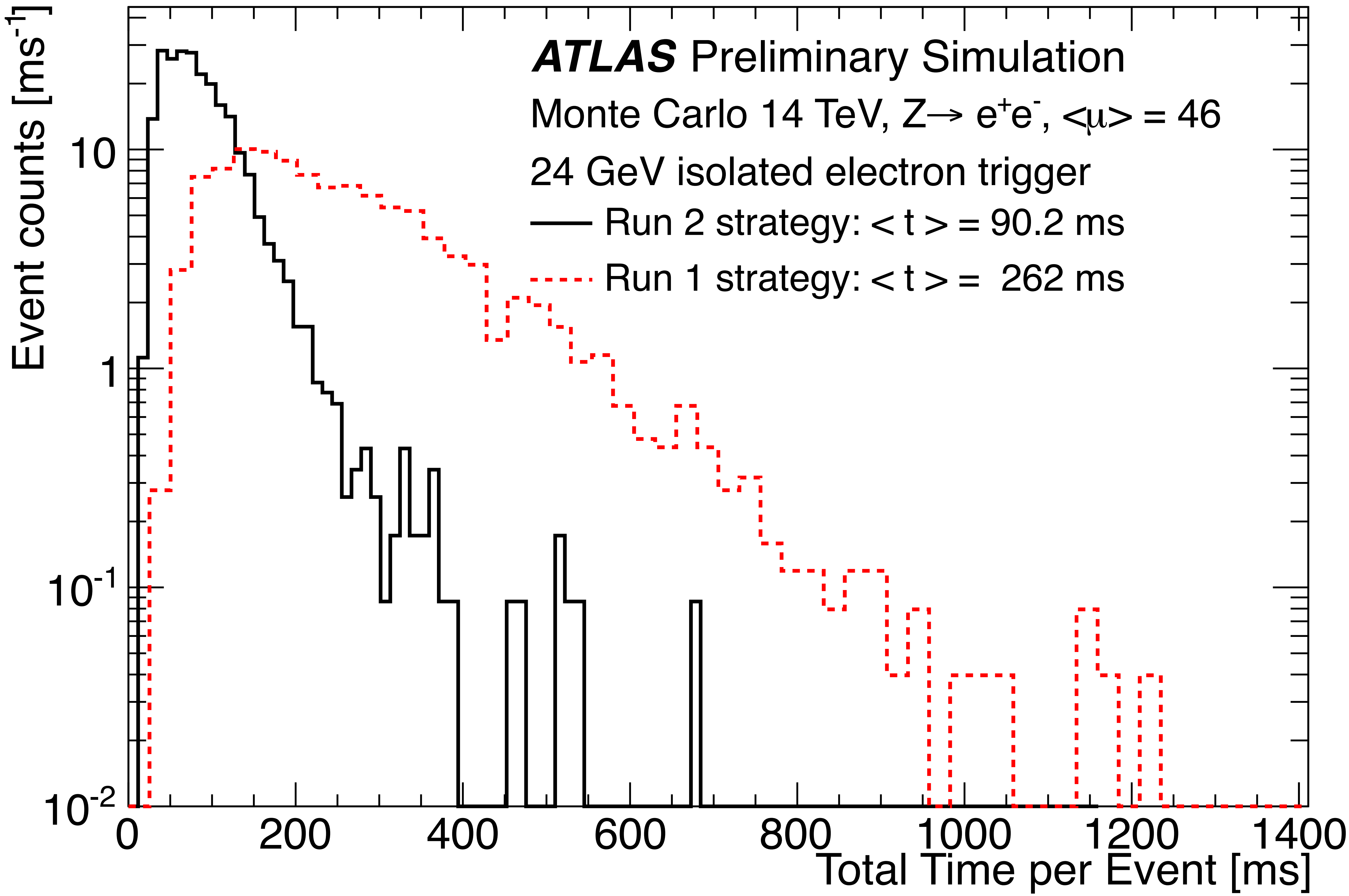

ATLAS Preliminary Simulation
Muon trigger - ID tracking (built April 2013)
Monte Carlo, 14 TeV Z→ μ+μ-
Total EFID processing time
EFID pattern recognition
EFID spacepoint ambiguity resolution
cpu time [ms]
pileup interaction multiplicity
0
1000
2000
3000
4000
5000
6000
40
60
80
100
120
140



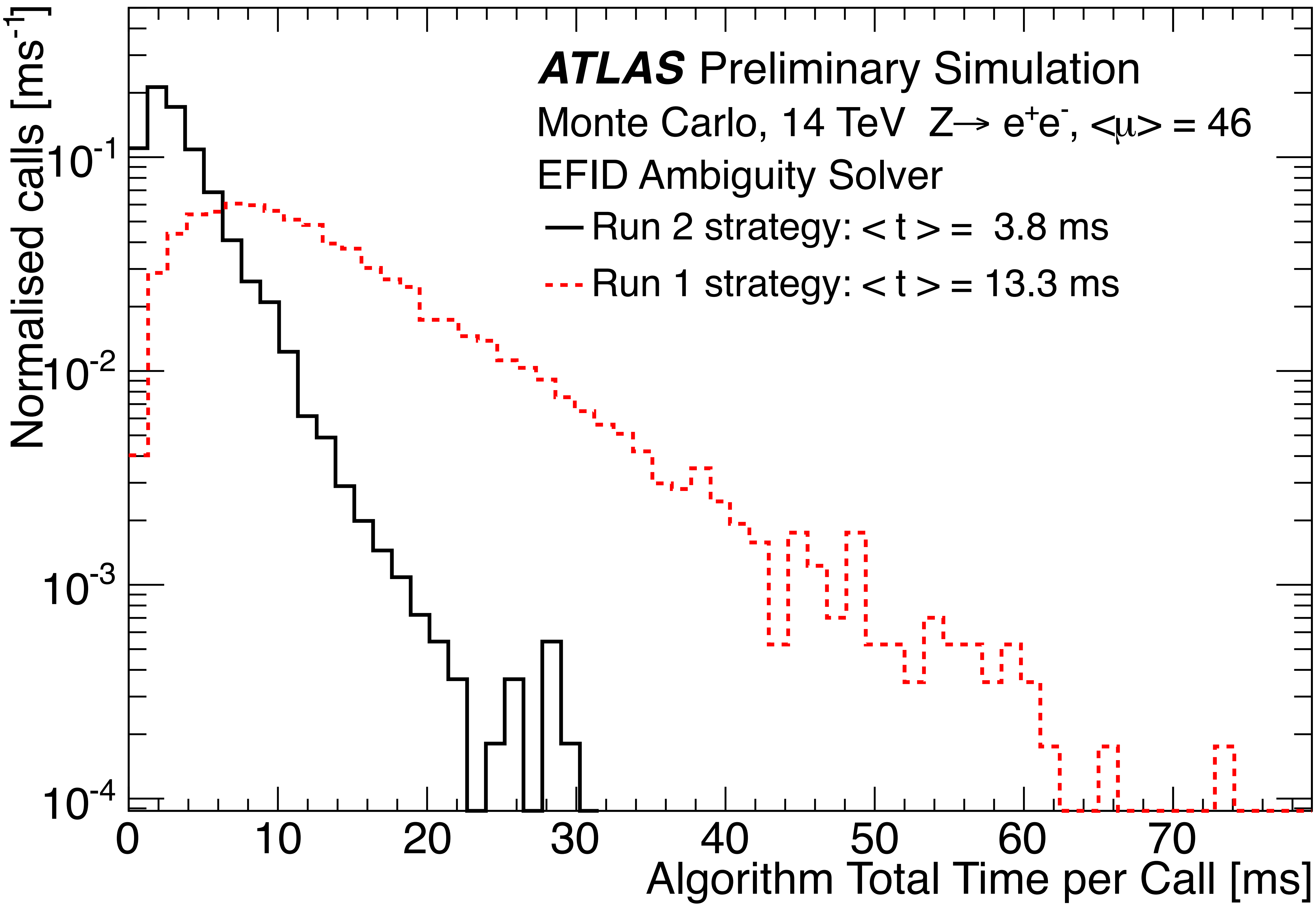
ATLAS Preliminary Simulation
Monte Carlo, 14 TeV Z→ e+e-, <μ> = 46
EFID Pattern Recognition
Run 1 strategy (built Aug 2014): < t > = 100 ms
Run 1 strategy (built Apr 2013): < t > = 297 ms
Normalised calls [ms-1]
10-1
10-2
10-3
10-4
10-5
0
200
400
600
800
1000
1200
Algorithm time [ms]



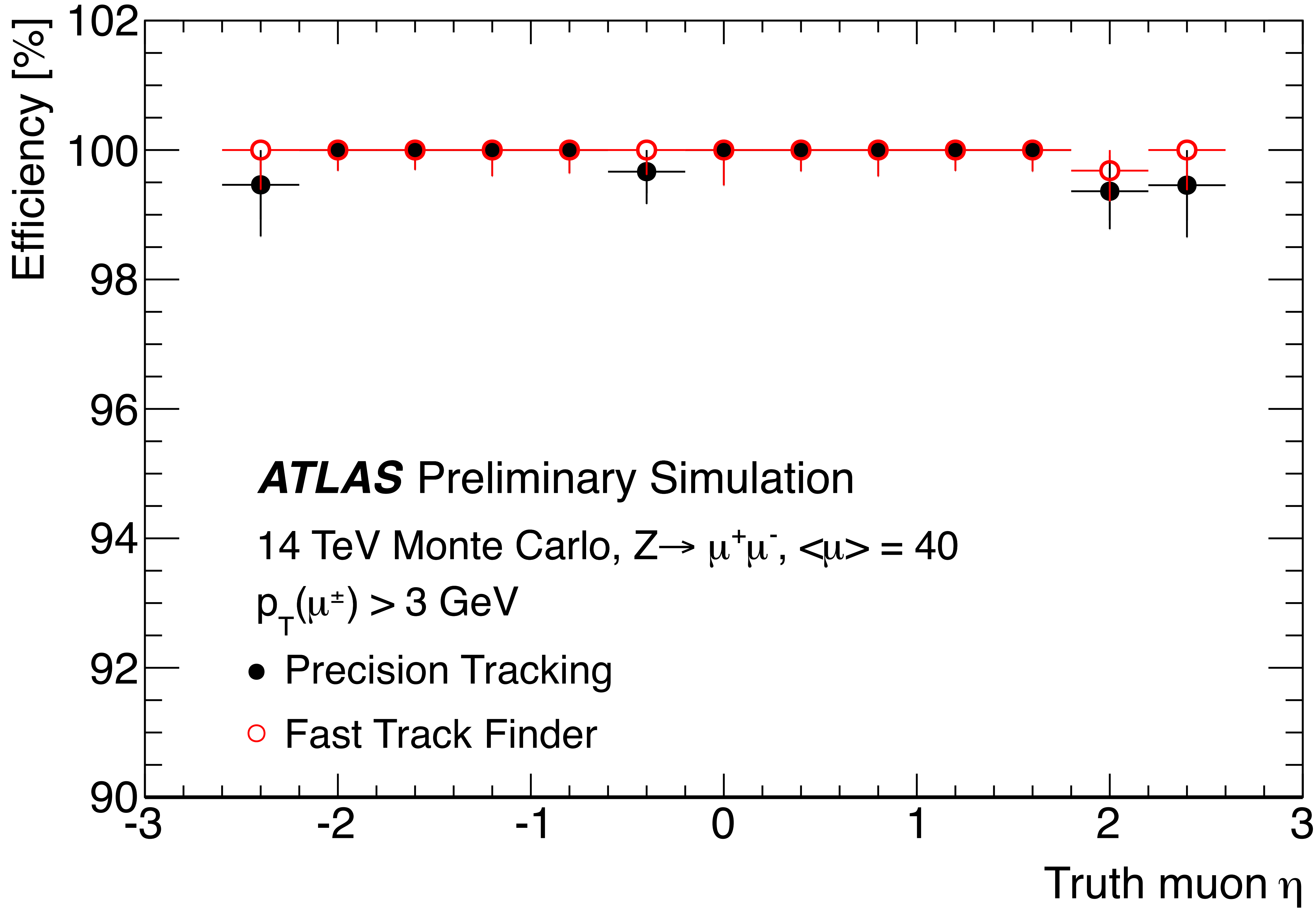
ATLAS Preliminary Simulation
Monte Carlo, 14 TeV Z→ e+e-, <μ> = 46
EFID Ambiguity Solver
Run 1 strategy (built Aug 2014): < t > = 13.3 ms
Run 1 strategy (built Apr 2013): < t > = 129 ms
Normalised calls [ms-1]
Algorithm time [ms]
10-1
10-2
10-3
10-4
0
50
100
150
200
250
300



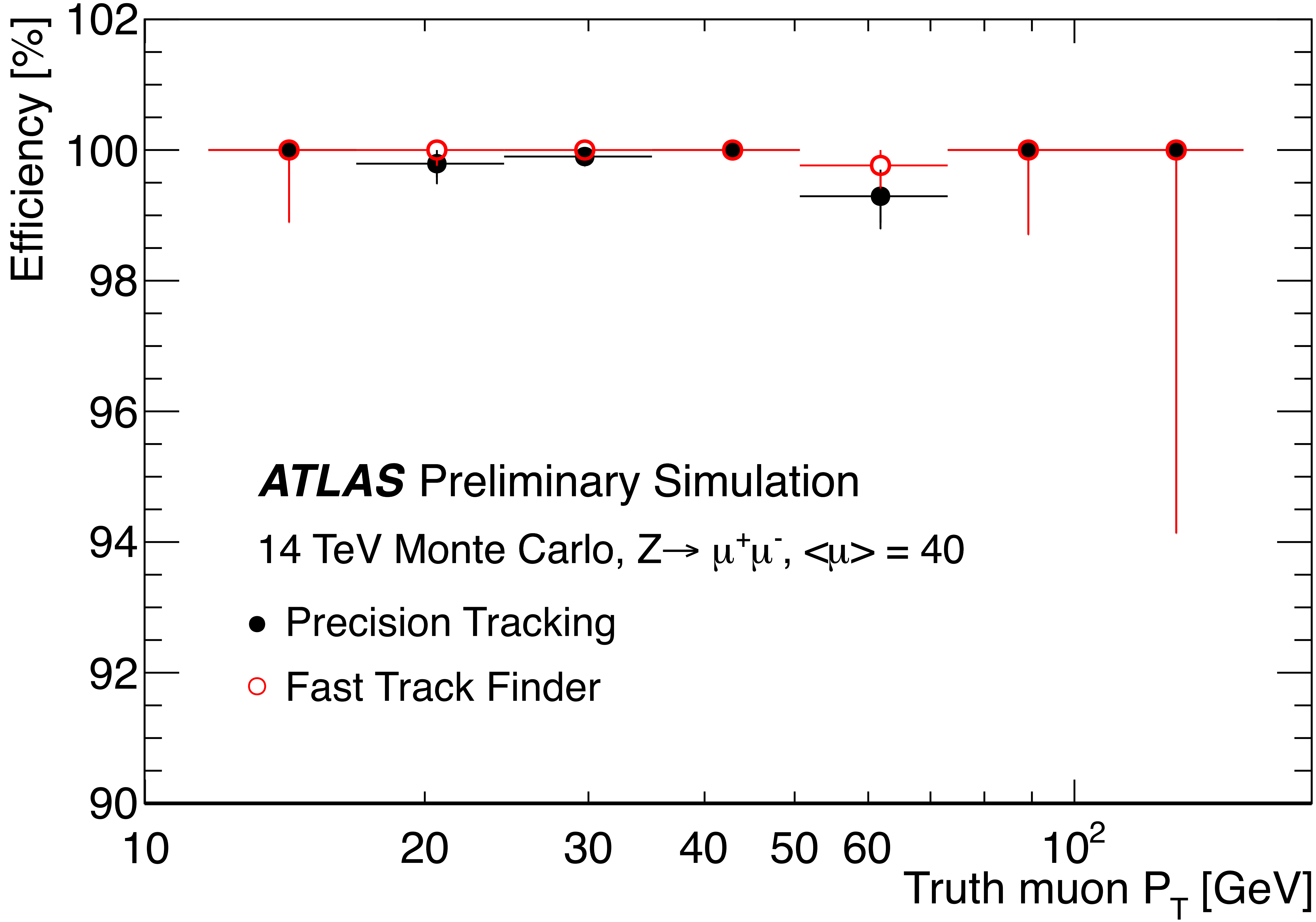
ATLAS Preliminary Simulation
Monte Carlo 14 TeV, Z→ e+e-, <μ> = 46
24 GeV isolated electron trigger
Run 2 strategy: < t > = 90.2 ms
Run 1 strategy: < t > = 262 ms
Event counts [ms-1]
Total Time per Event [ms]
10
1
10-1
10-2
0
200
400
600
800
1000
1200
1400



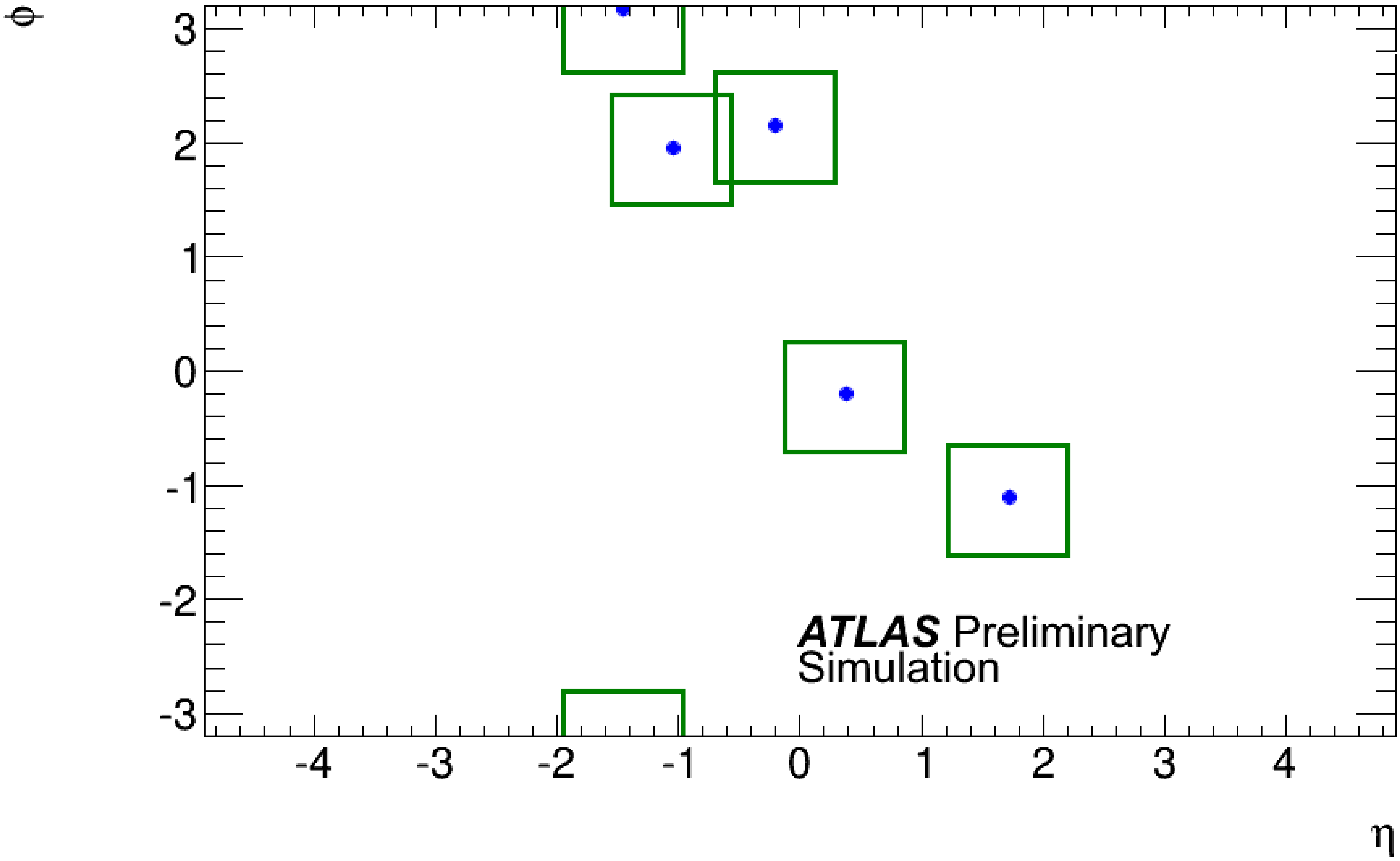
ATLAS Preliminary Simulation
Monte Carlo, 14 TeV Z→ e+e-, <μ> = 46
EFID Ambiguity Solver
Run 2 strategy: < t > = 3.8 ms
Run 1 strategy: < t > = 13.3 ms
Normalised calls [ms-1]
10-1
10-2
10-3
10-4
0
10
20
30
40
50
60
70
Algorithm Total Time per Call [ms]



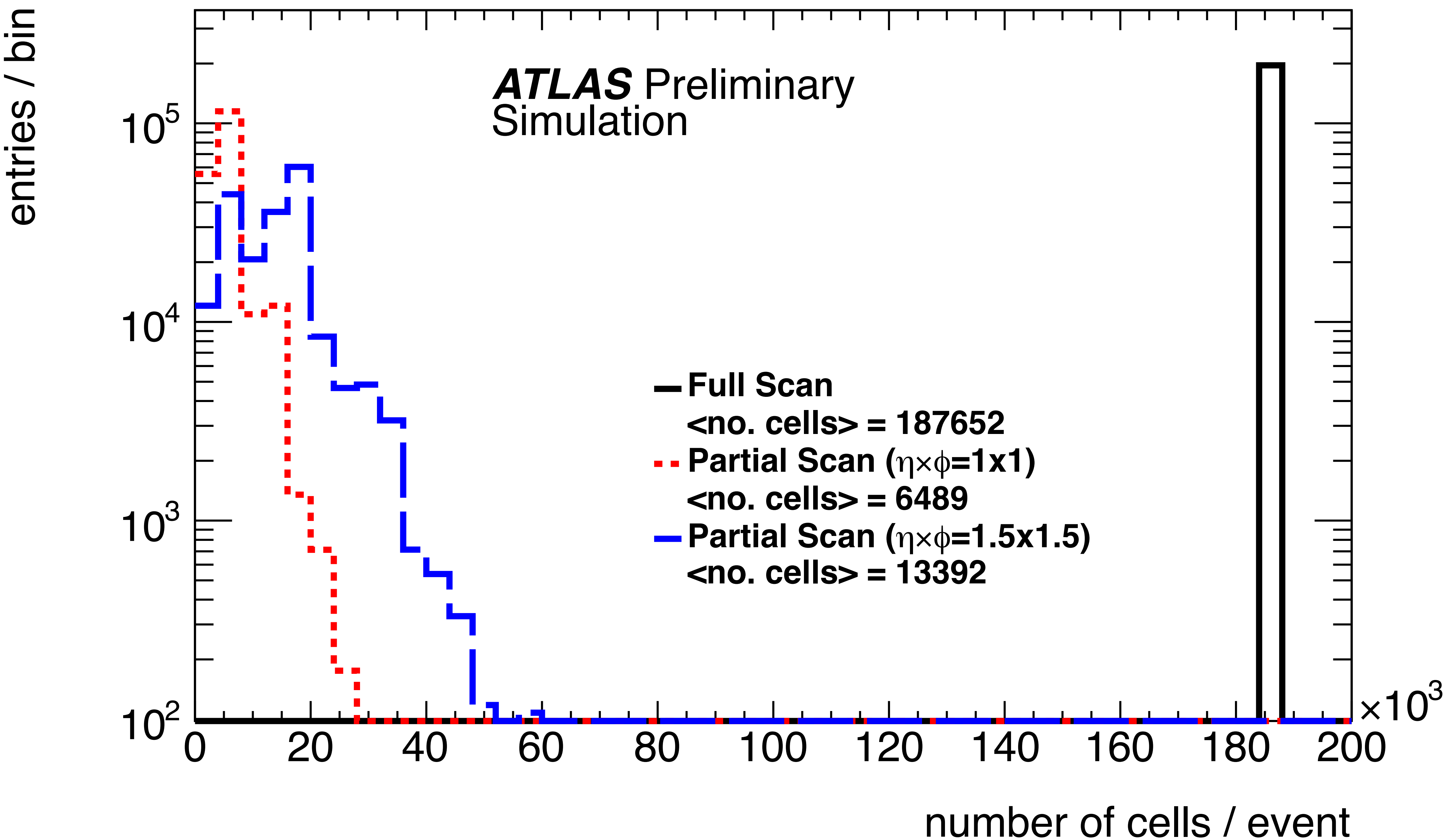
Efficiency [%]
102
100
98
96
94
92
90
-3
-2
-1
0
1
2
3
Truth muon η
ATLAS Preliminary Simulation
14 TeV Monte Carlo, Z→ μ⁺μ⁻, <μ> = 40
p_T(μ±) > 3 GeV
Precision Tracking
Fast Track Finder



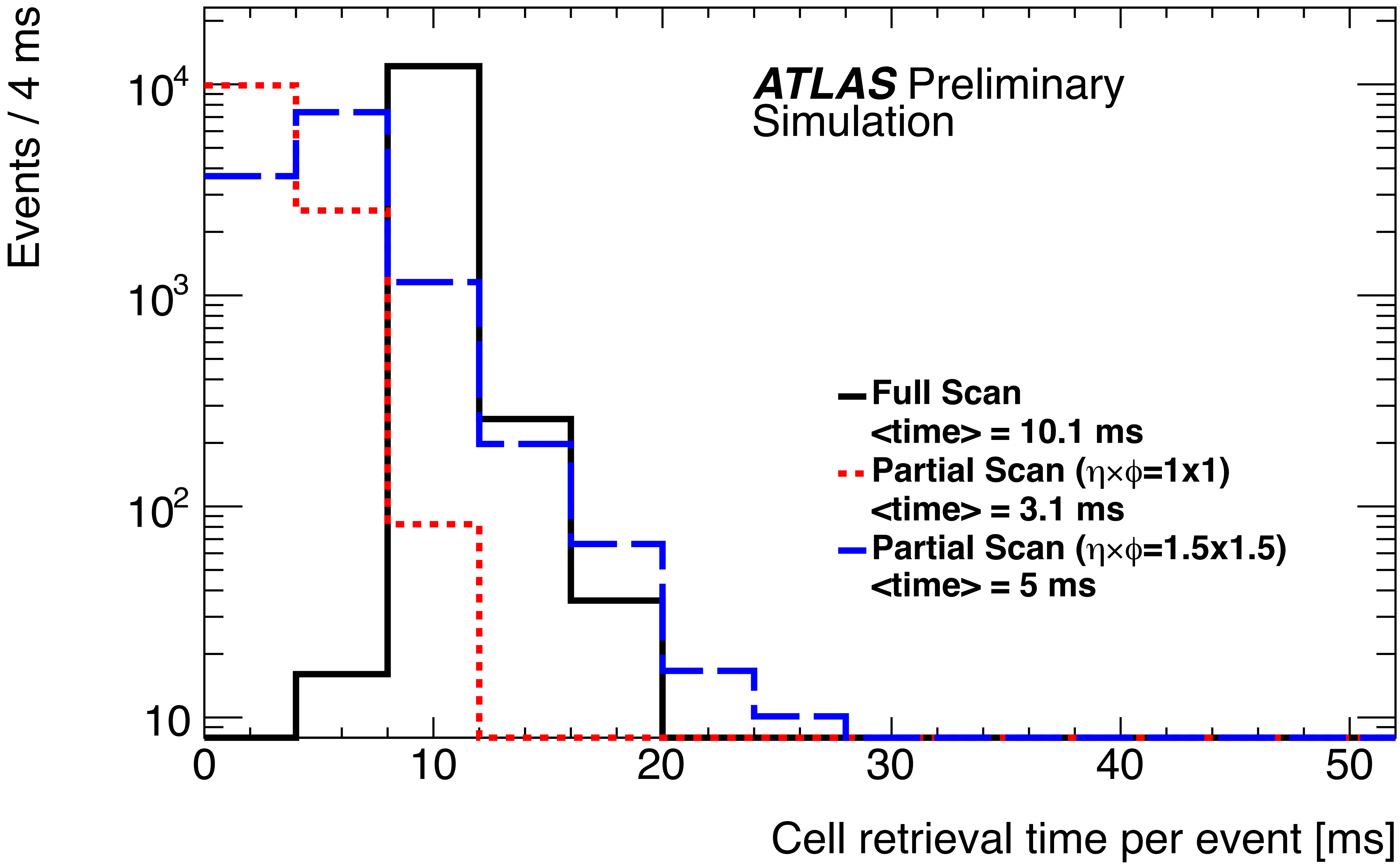
Efficiency [%]
102
100
98
96
94
92
90
10
20
30
40
50
60
10^2
Truth muon P_T [GeV]
ATLAS Preliminary Simulation
14 TeV Monte Carlo, Z→ μ+μ-, <μ> = 40
Precision Tracking
Fast Track Finder



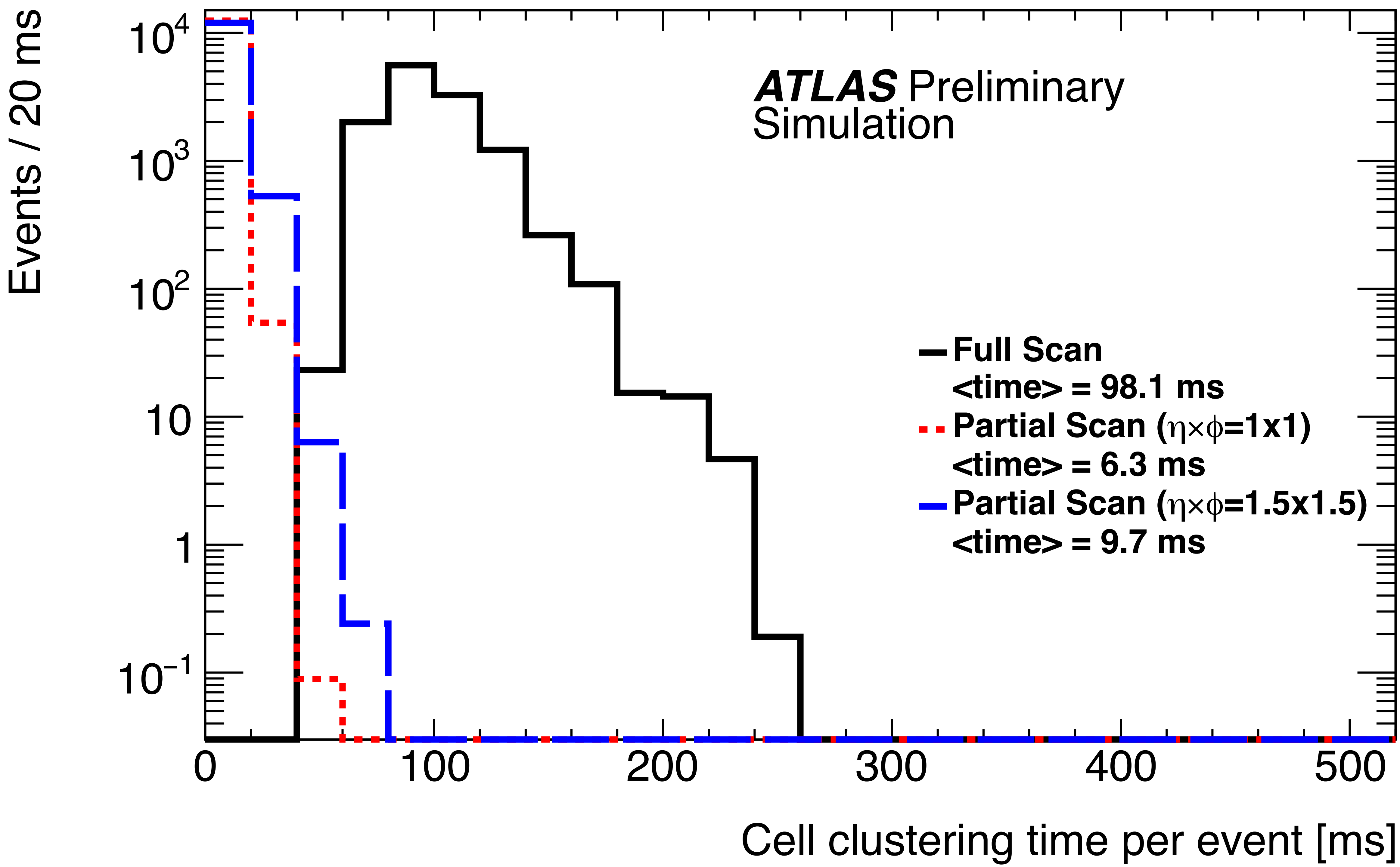
φ
3
2
1
0
-1
-2
-3
-4
-3
-2
-1
0
1
2
3
4
η
ATLAS Preliminary
Simulation

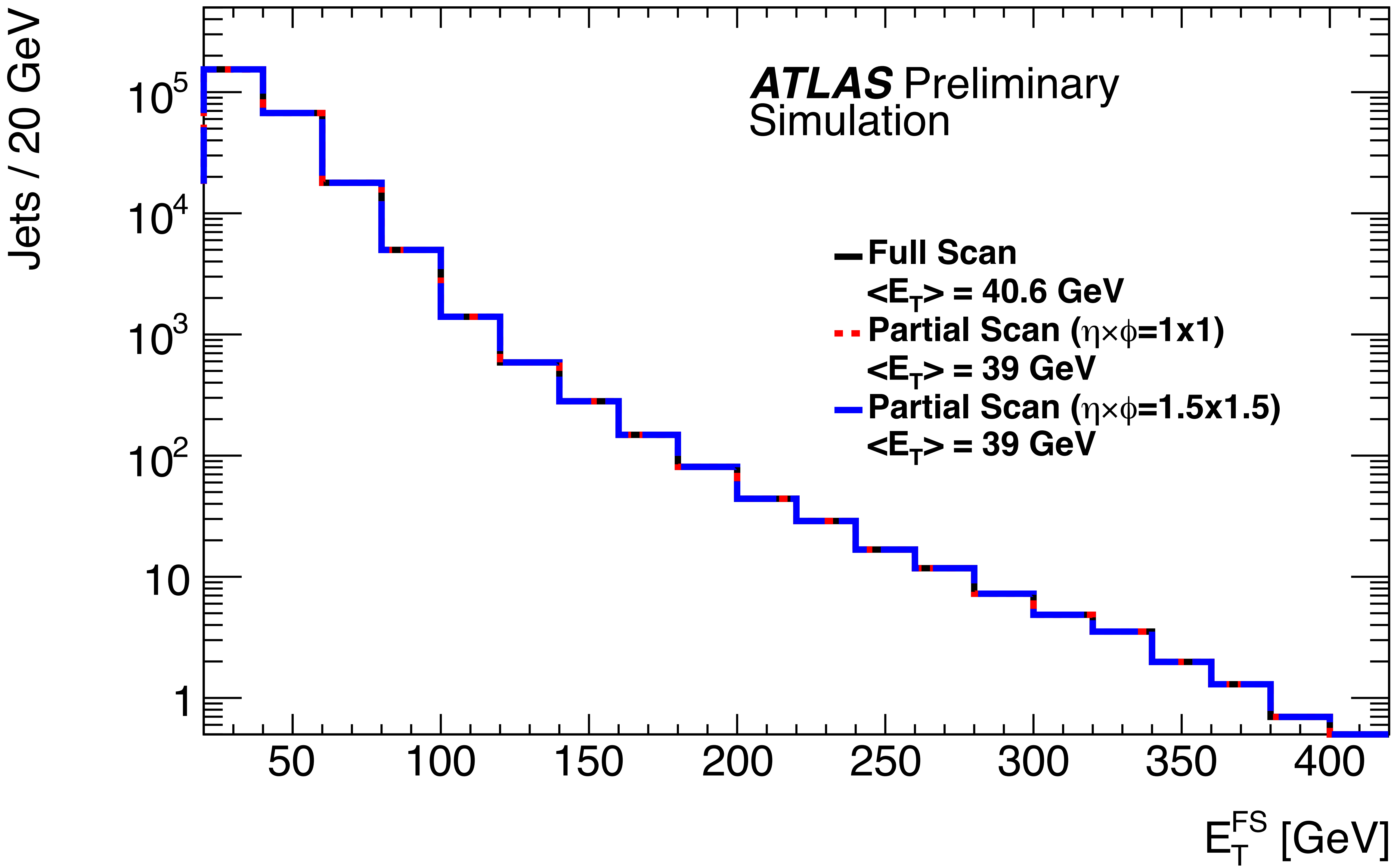


ATLAS Preliminary
Simulation
entries / bin
number of cells / event
×10^3
Full Scan
<no. cells> = 187652
Partial Scan (η×φ=1x1)
<no. cells> = 6489
Partial Scan (η×φ=1.5x1.5)
<no. cells> = 13392

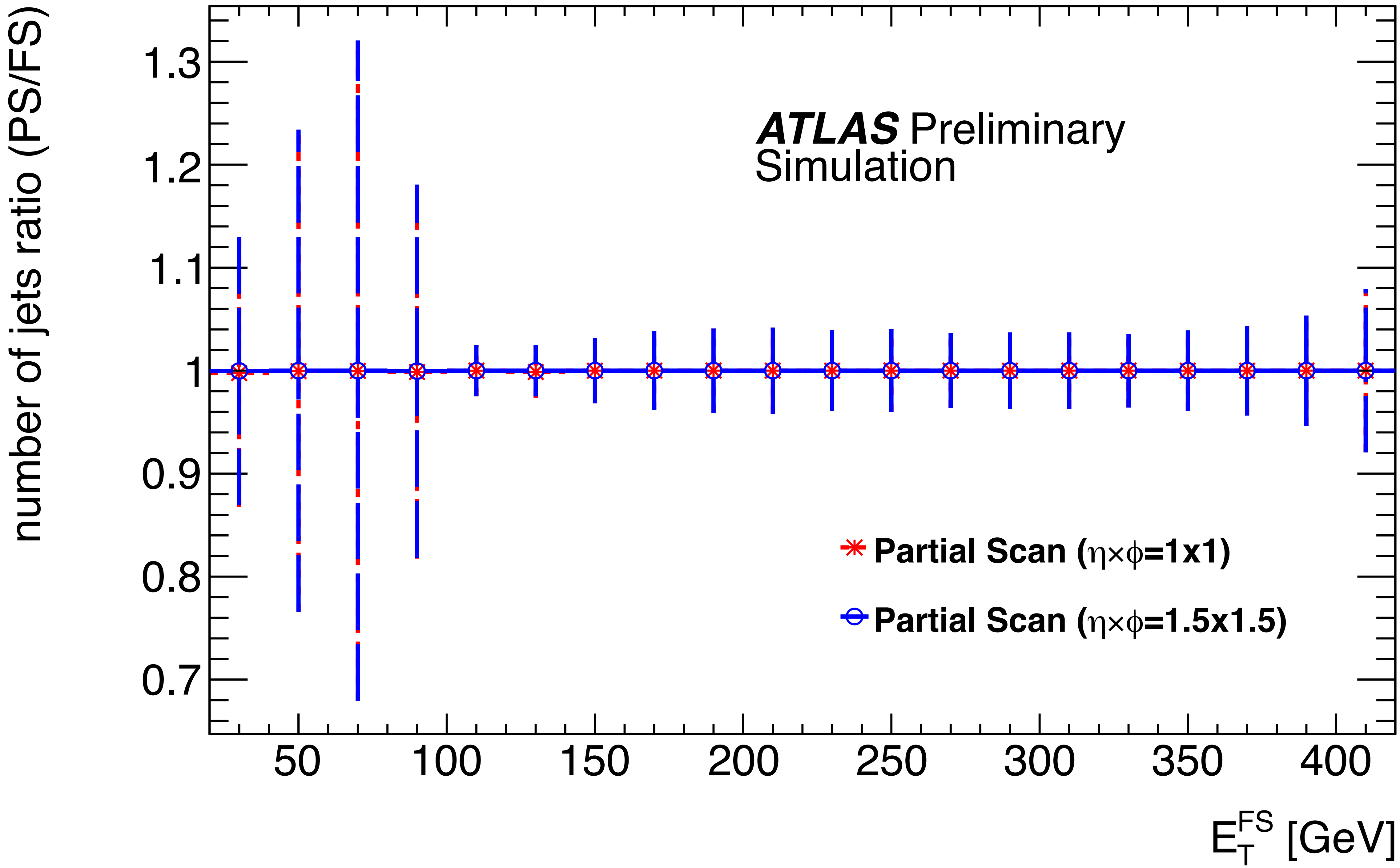


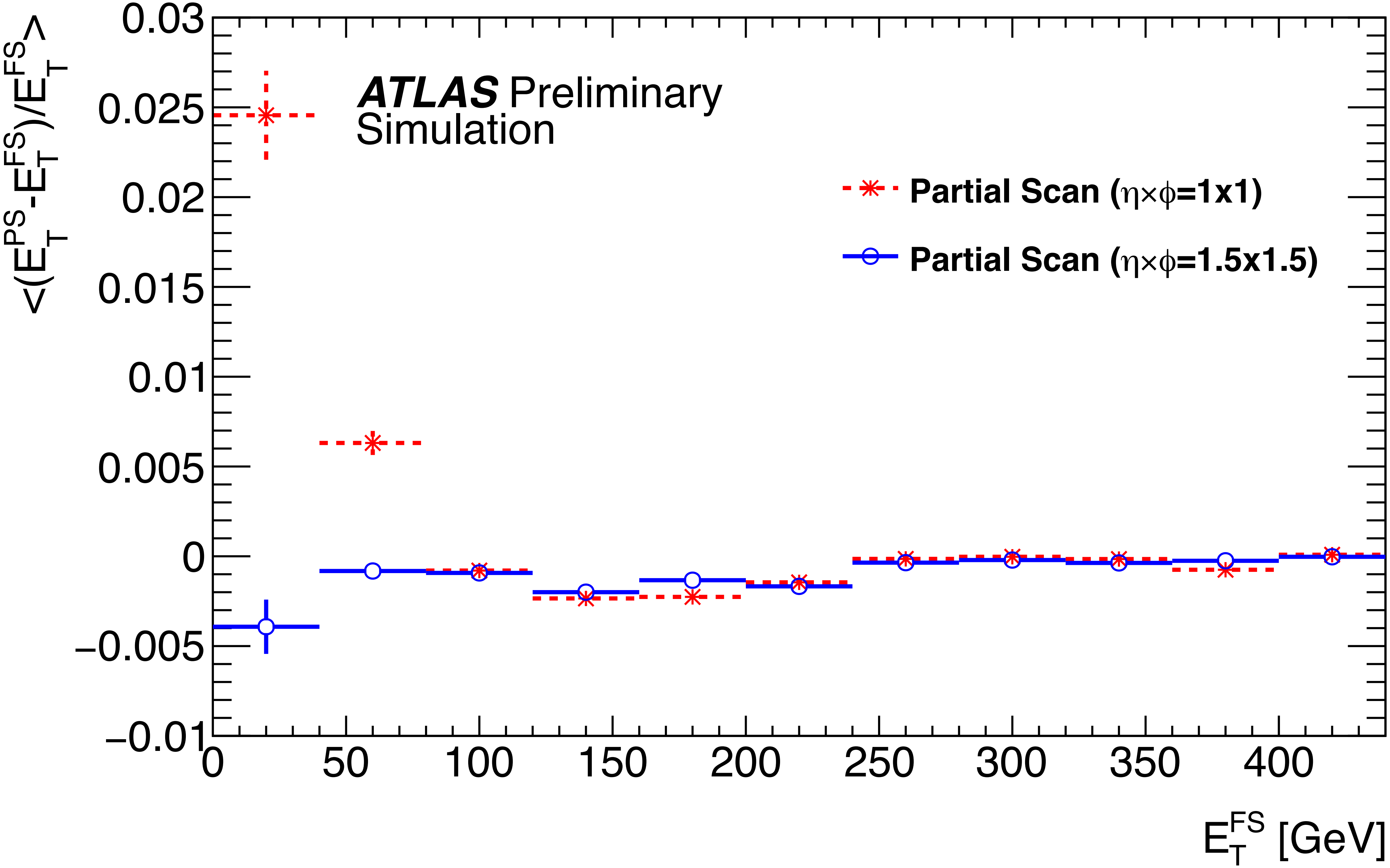
Events / 4 ms
10^4
10^3
10^2
10
0
10
20
30
40
50
Cell retrieval time per event [ms]
ATLAS Preliminary
Simulation
Full Scan
<time> = 10.1 ms
Partial Scan (η×φ=1x1)
<time> = 3.1 ms
Partial Scan (η×φ=1.5x1.5)
<time> = 5 ms


ATLAS Preliminary
Simulation
Full Scan
<time> = 98.1 ms
Partial Scan (η×φ=1x1)
<time> = 6.3 ms
Partial Scan (η×φ=1.5x1.5)
<time> = 9.7 ms
Events / 20 ms
Cell clustering time per event [ms]
0
100
200
300
400
500
10^4
10^3
10^2
10
1
10^-1



ATLAS Preliminary
Simulation
Full Scan
<E_T> = 40.6 GeV
Partial Scan (η×φ=1x1)
<E_T> = 39 GeV
Partial Scan (η×φ=1.5x1.5)
<E_T> = 39 GeV
Jets / 20 GeV
E_T^FS [GeV]


ATLAS Preliminary
Simulation
Partial Scan (η×φ=1x1)
Partial Scan (η×φ=1.5x1.5)
number of jets ratio (PS/FS)
E_T^{FS} [GeV]
0.7
0.8
0.9
1
1.1
1.2
1.3
50
100
150
200
250
300
350
400


ATLAS Preliminary
Simulation
Partial Scan (η×φ=1x1)
Partial Scan (η×φ=1.5x1.5)
<(E_T^PS-E_T^FS)/E_T^FS>
E_T^FS [GeV]
0.03
0.025
0.02
0.015
0.01
0.005
0
−0.005
−0.01
0
50
100
150
200
250
300
350
400