Putting jFEX & gFEX to the test – Measuring L1Calo trigger efficiencies

ATLAS-Heidelberg Meeting @ Trifels 2024 – Felix Fleischle – 18.7.24

Motivation – the Phase-I upgrade

Run-2 $\langle\mu\rangle \approx 30$
- 2015 - 2018

→ Phase-I upgrade →

Run-3 $\langle\mu\rangle \approx 50$
- 2022 - 2025

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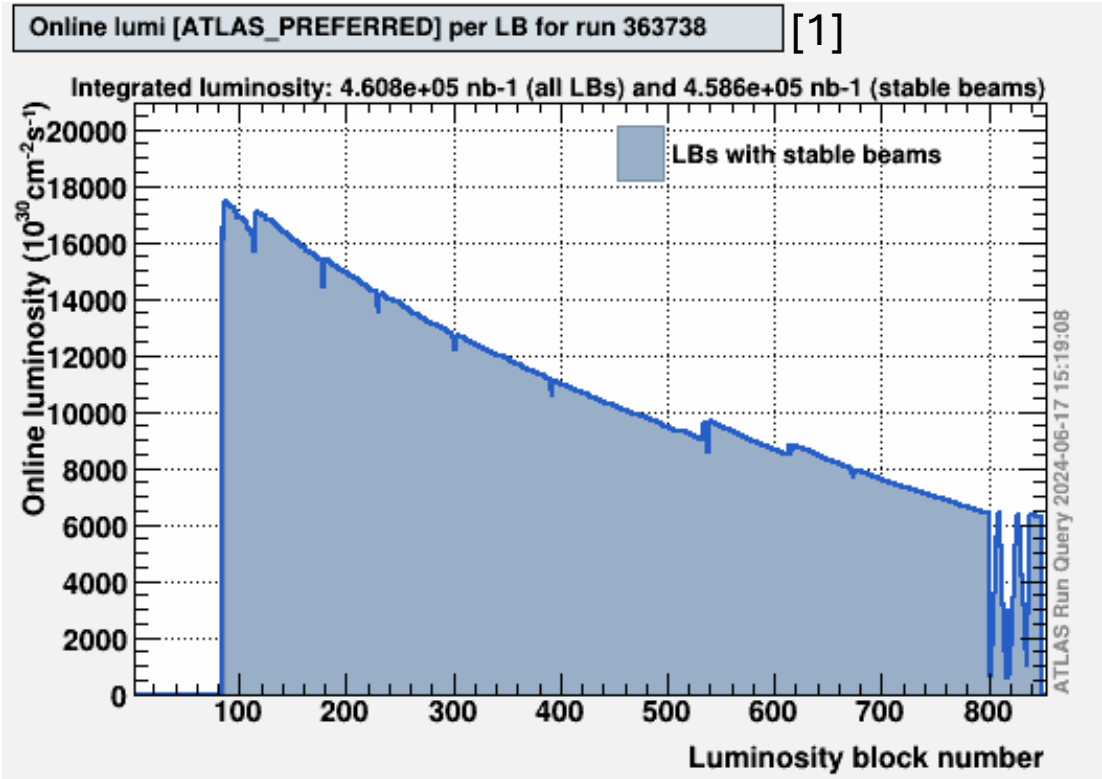
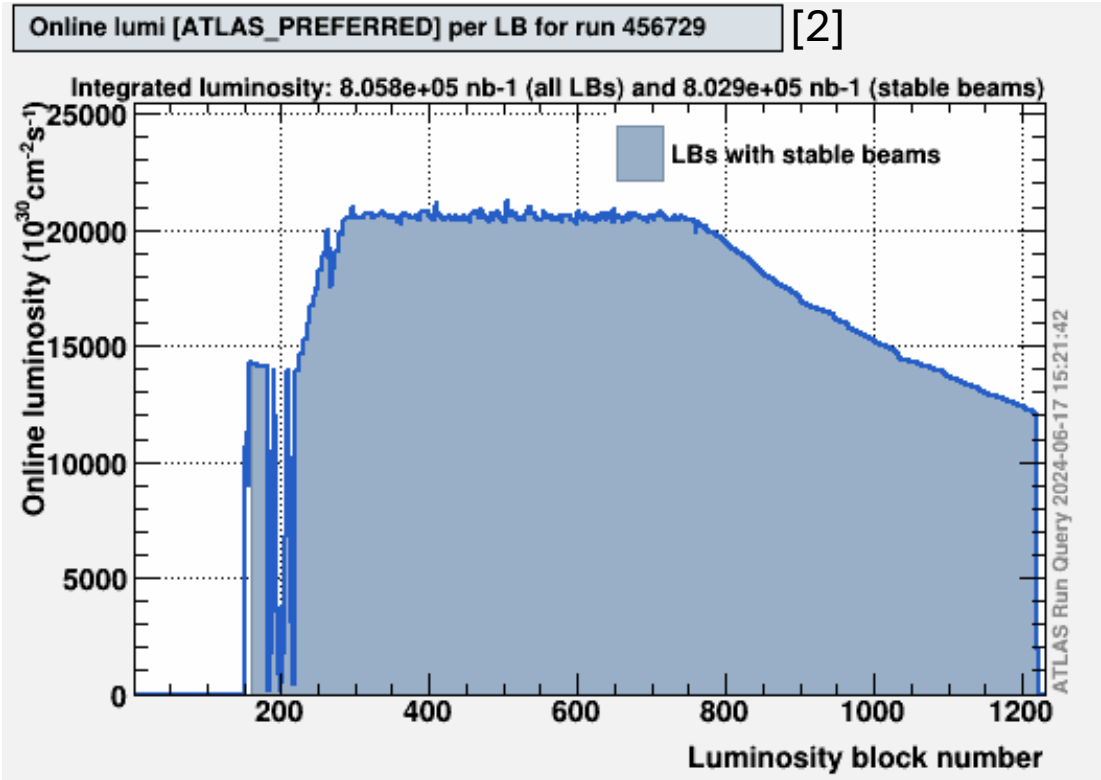


[1]



[2]

Motivation – the Phase-I upgrade

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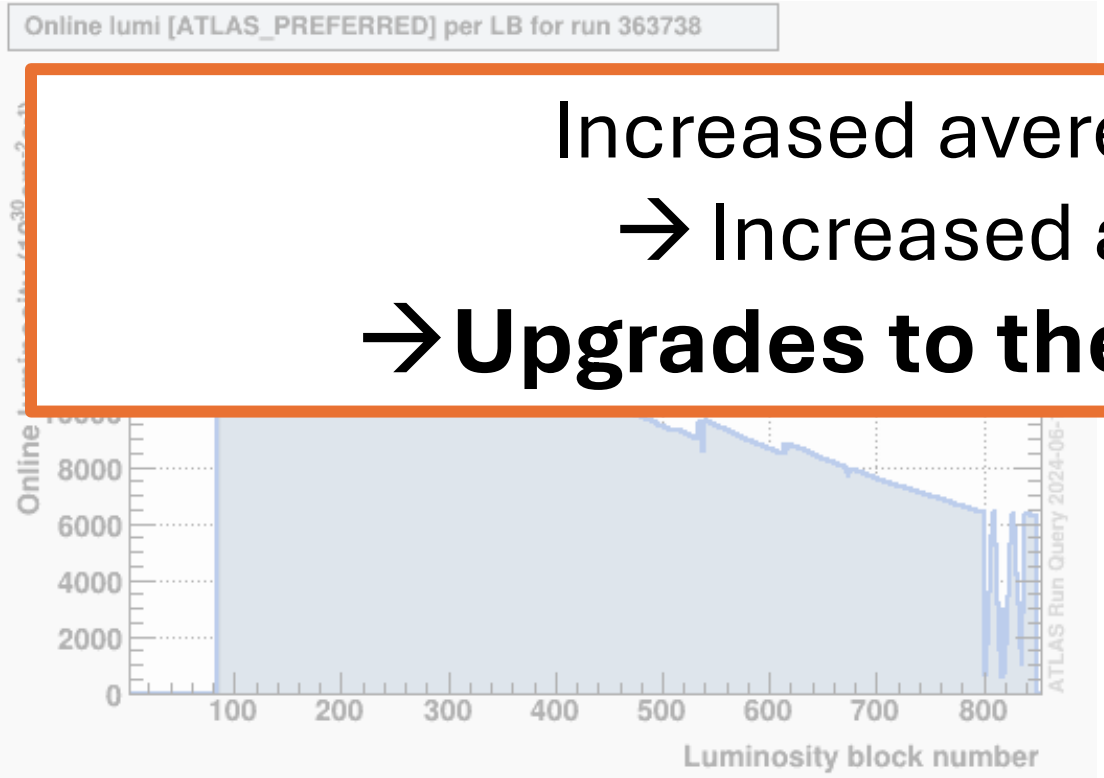
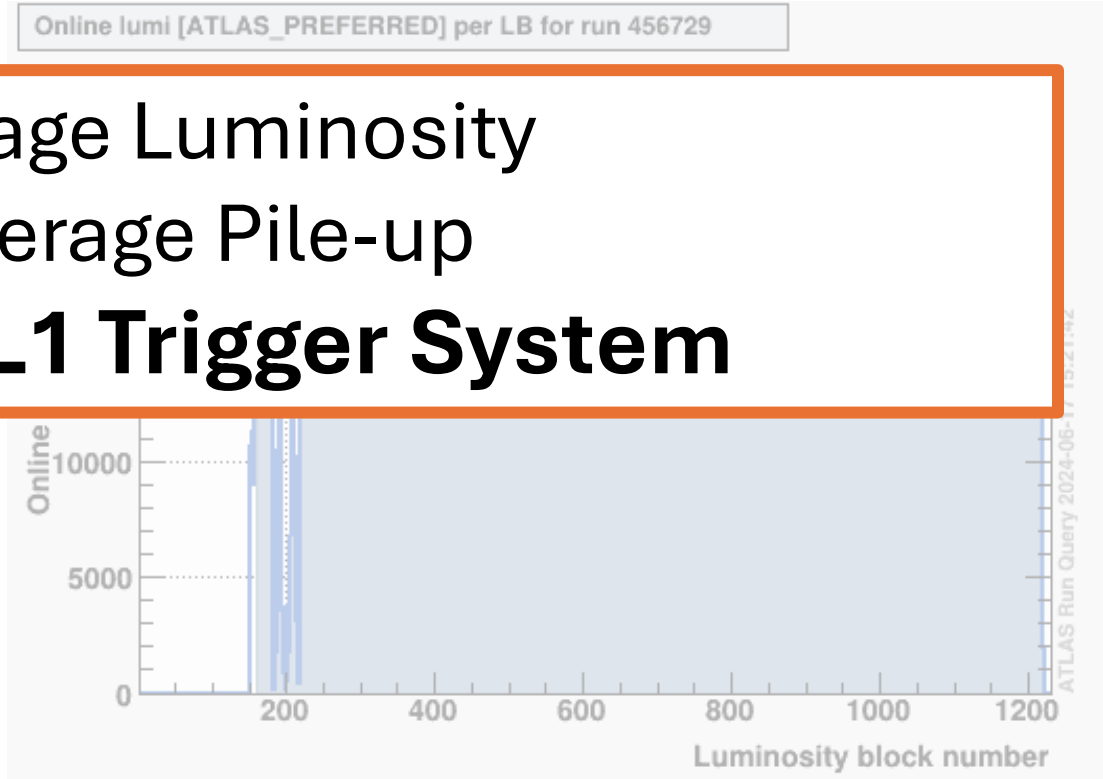
Phase-I upgrade

Run-3 $\langle\mu\rangle \approx 50$
- 2022 - 2025



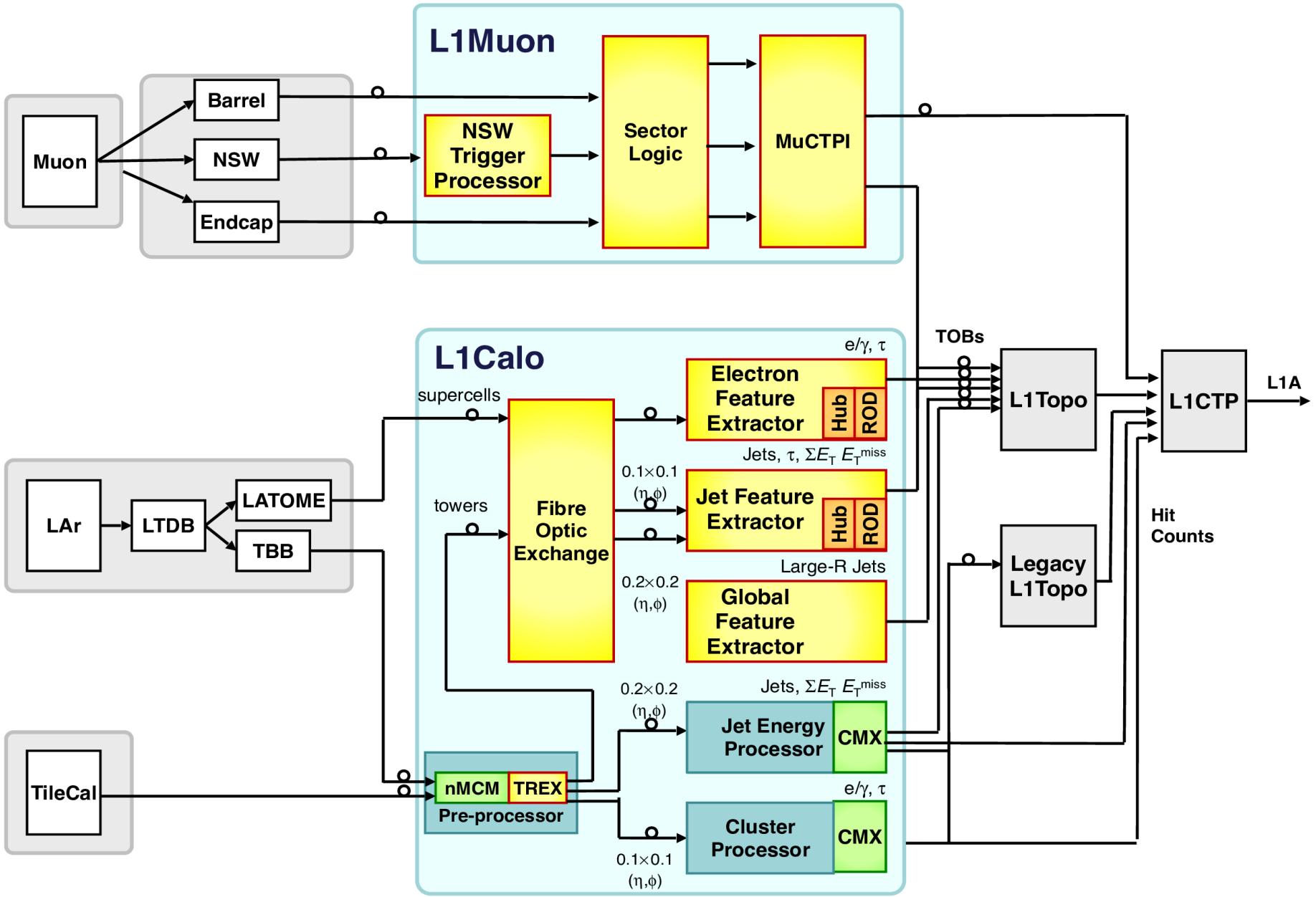


Increased avererage Luminosity

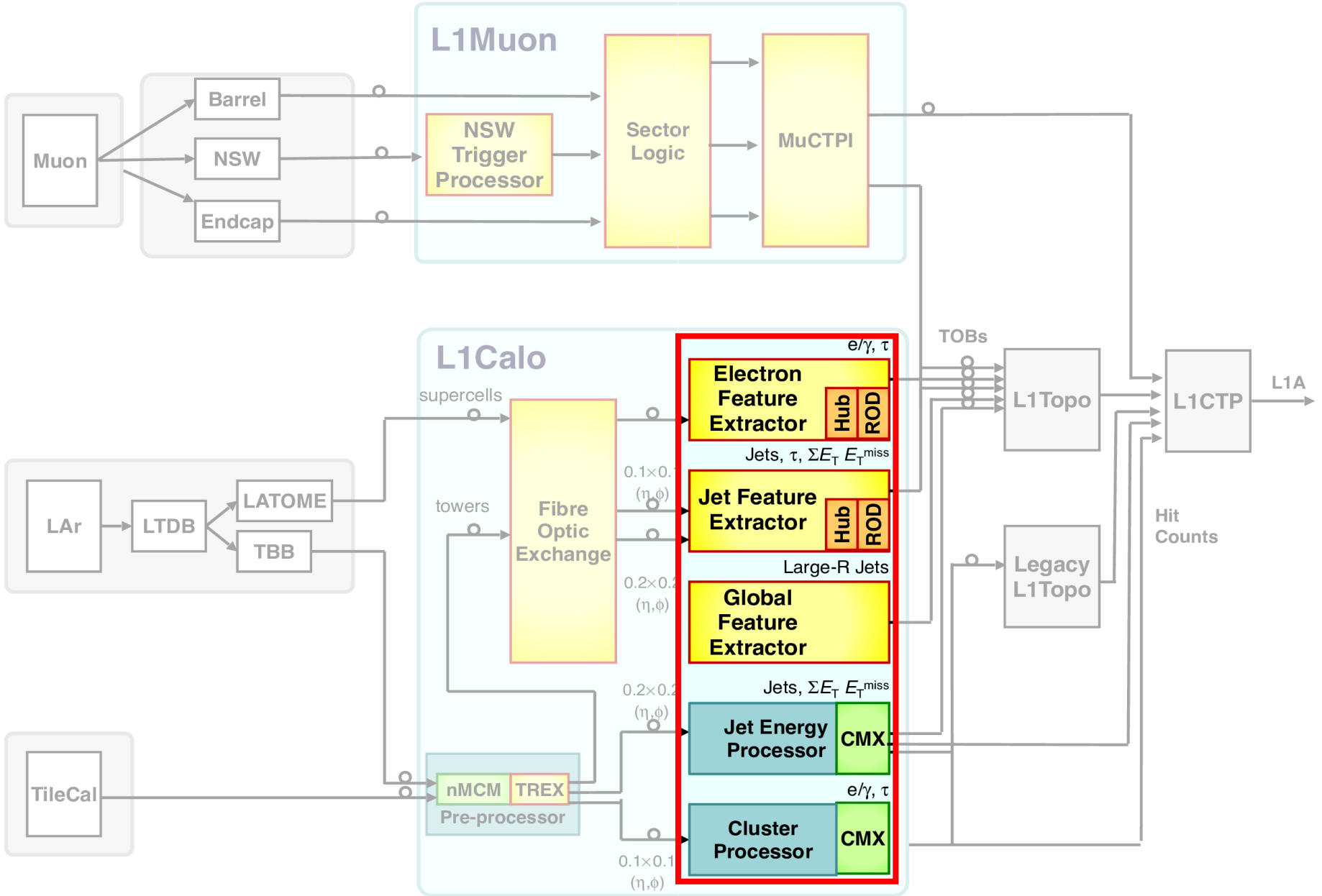
→ Increased average Pile-up

→ **Upgrades to the L1 Trigger System**

The L1 trigger system



The L1Calo trigger system



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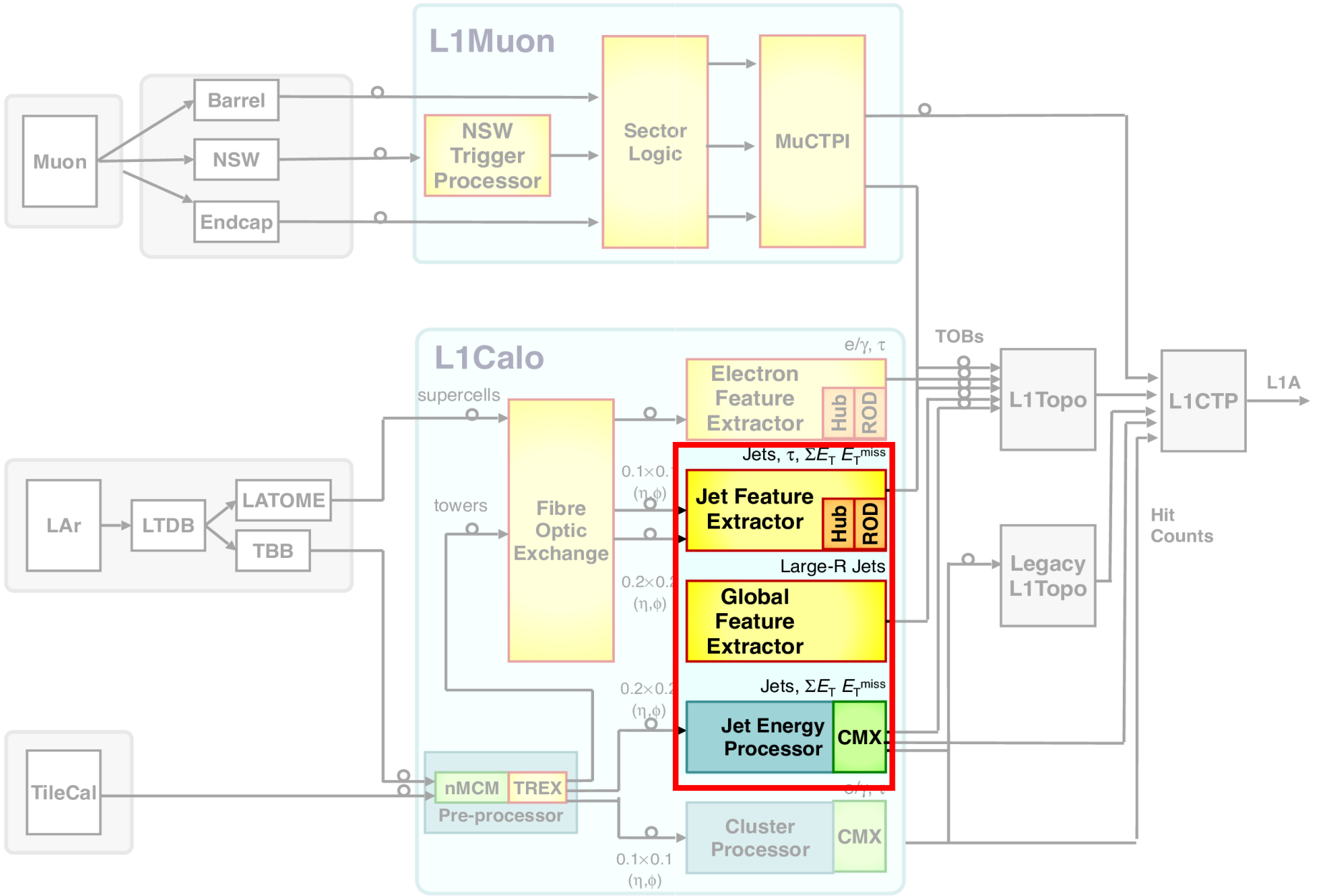
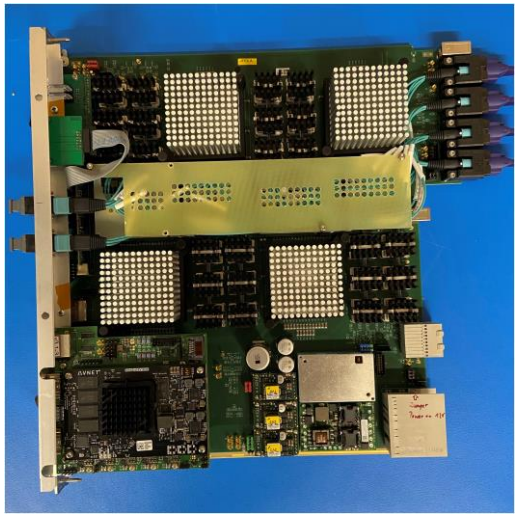


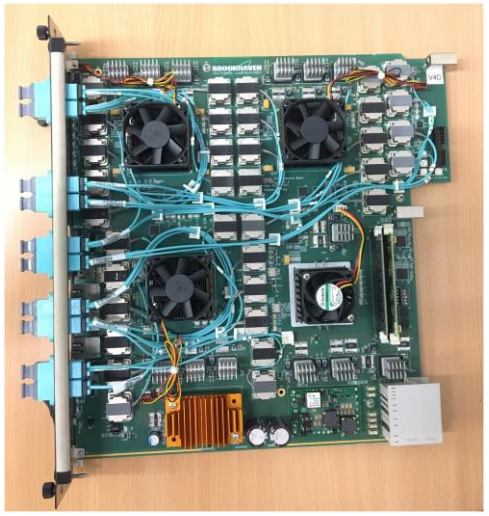
Jet Feature Extractor (jFEX)

- Jets, $\sum E_T$, E_T^{miss}, τ
- 6 modules
  - 4 in the barrel region $|\eta| \leq 1.6$
  - 2 endcap/forward $1.6 < |\eta| \leq 4.9$



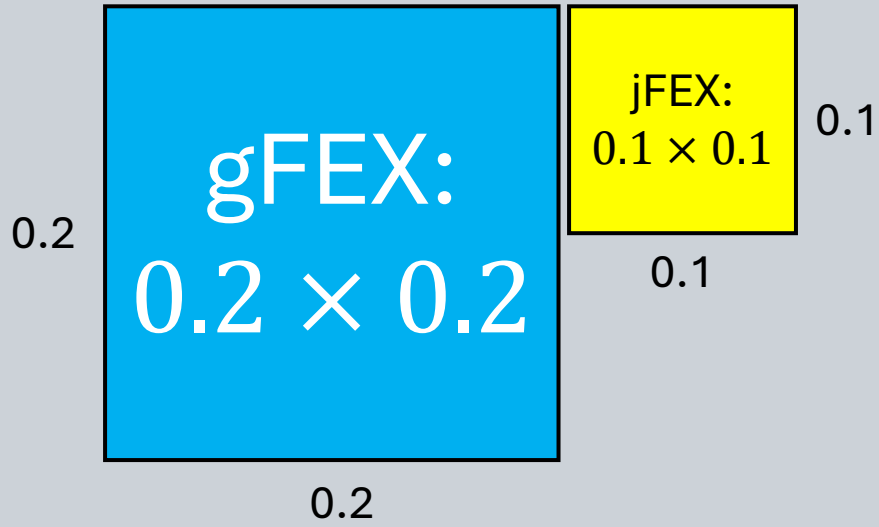
Global Feature Extractor (gFEX)

- Large-R jets, E_T^{miss}, $\sum E_T$
- 1 module covering the entire detector
- 3 FPGAs
  - 2 central region $|\eta| \leq 2.5$
  - 1 forward



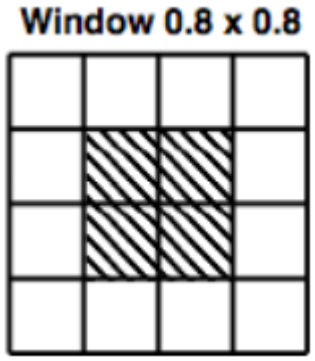
Legacy vs. Phase-I

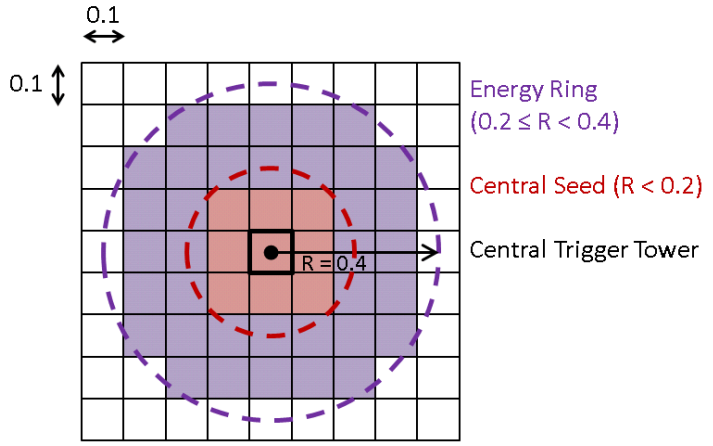
Legacy	Phase-I
Input granularity ($\eta \times \phi$):	Input granularity ($\eta \times \phi$):



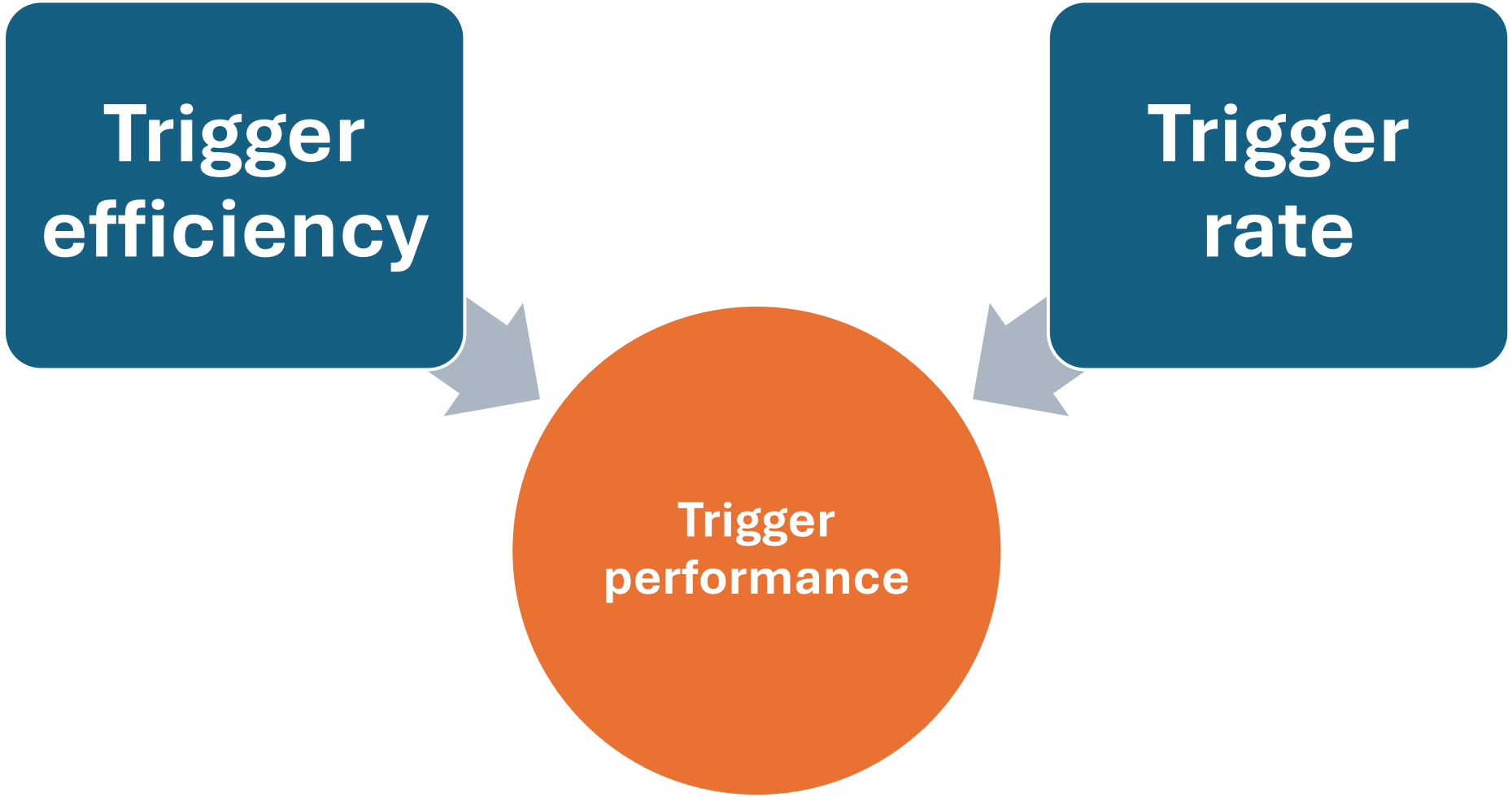
Legacy vs. Phase-I

Legacy	Phase-I
calibration on event-level	calibration on jet-level in jFEX
Legacy jet algorithm • 0.8×0.8 jet elements	Phase-I jet algorithms • jFEX: Round $R < 0.4$ jets • gFEX: 0.6×0.6 gTowers





Jet trigger performance



Efficiencies – Strategy

Tag-and-probe method

- Select a tag object which has triggered the event
- Use the remaining probe objects for a clean efficiency calculation

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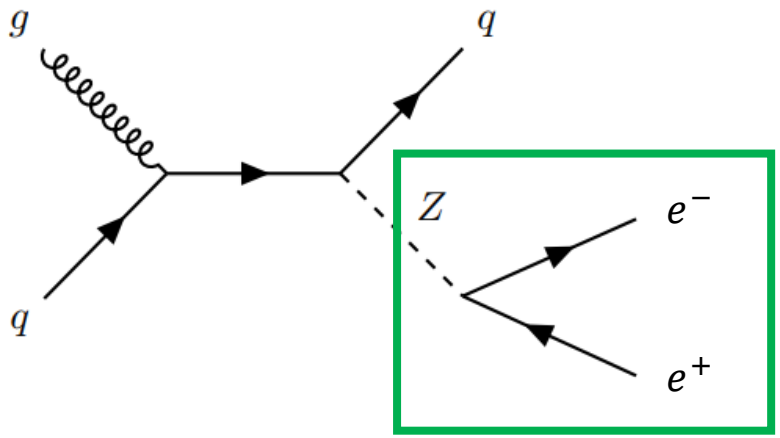
Tag:
Z boson / 2 leading e^+/e^-

Obtained using Z event selection



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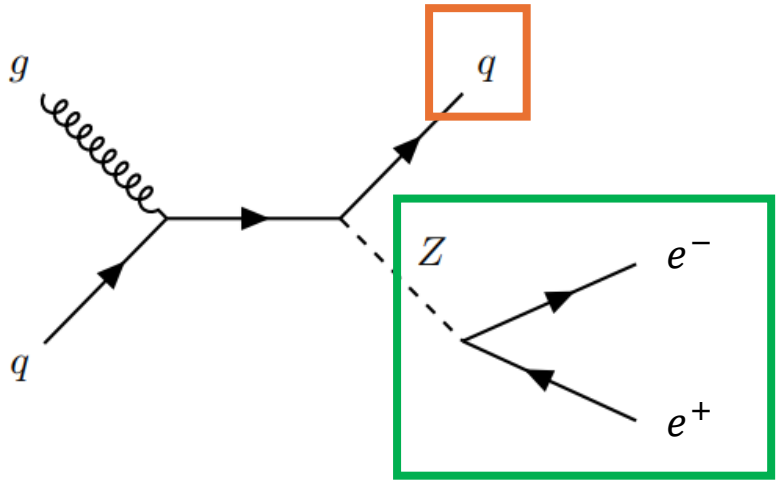


Probe:
Jets from higher order processes

Probe jets after event selection

TOB / offline jet matching

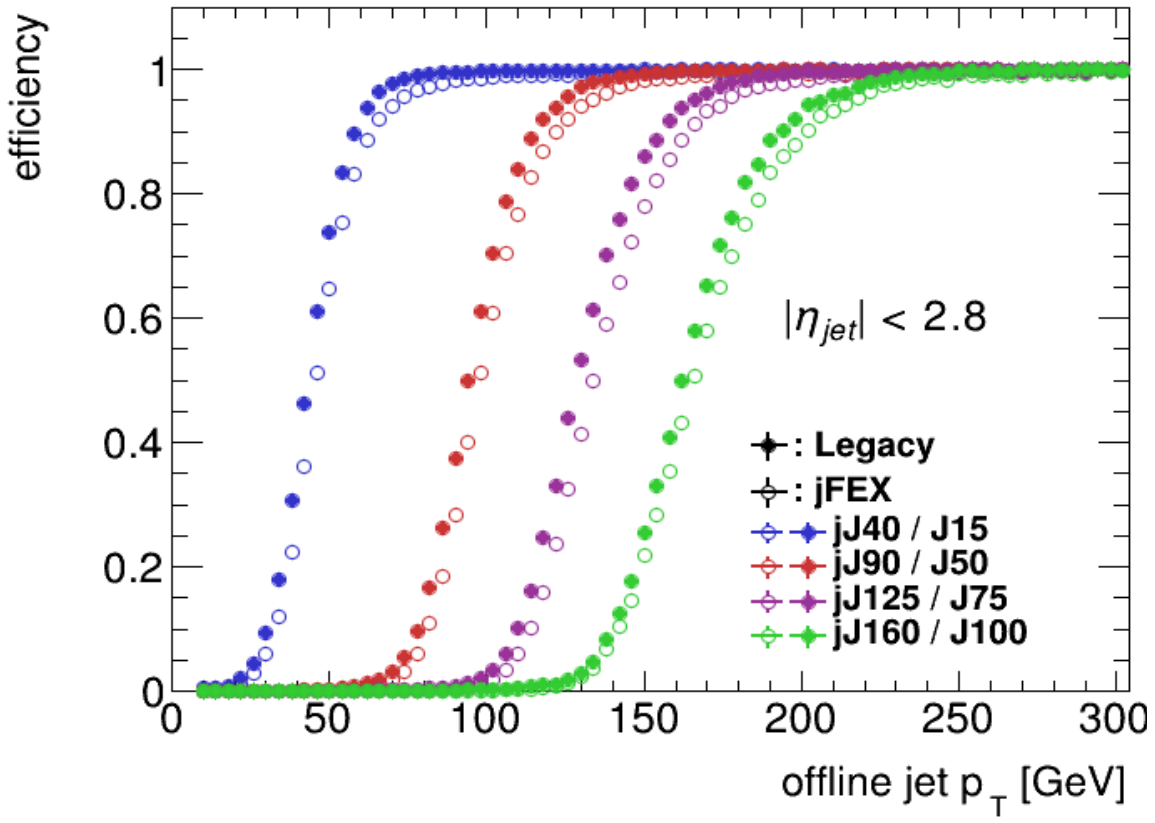
Matched TOBs

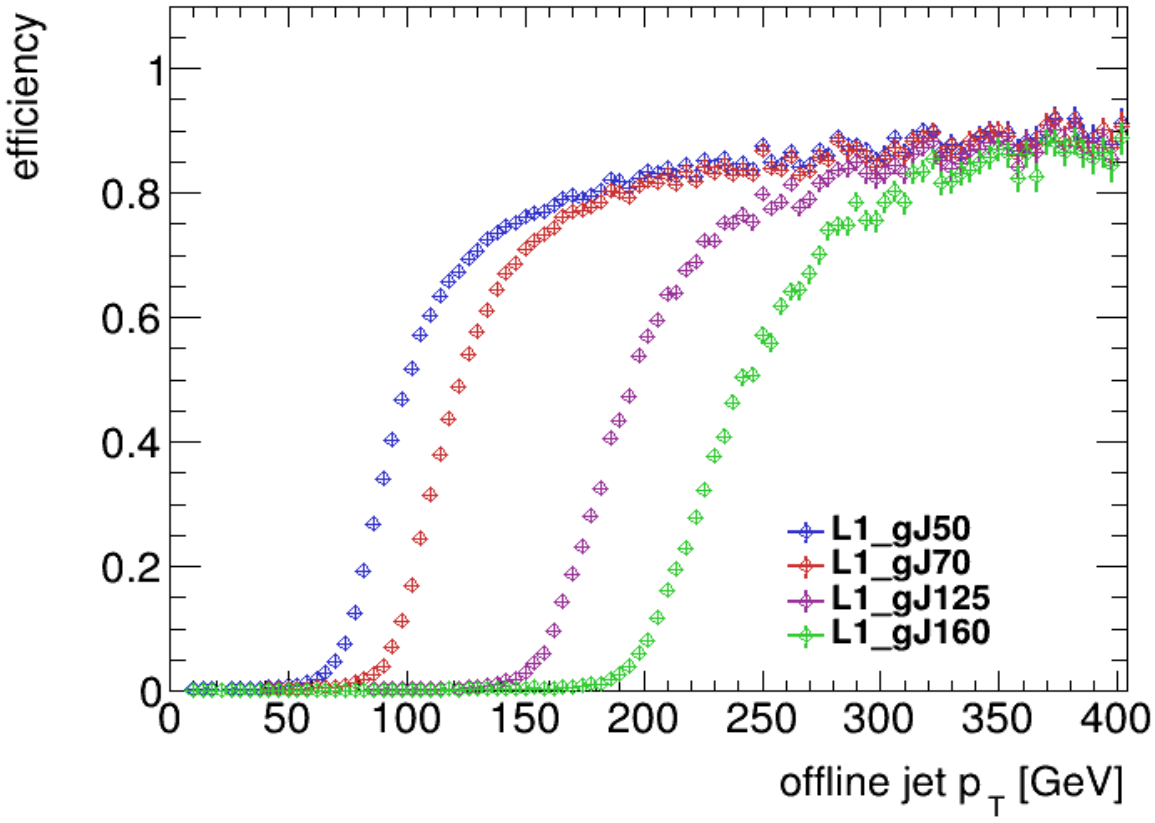
Efficiency calculation
Comparing TOBs and offline jets

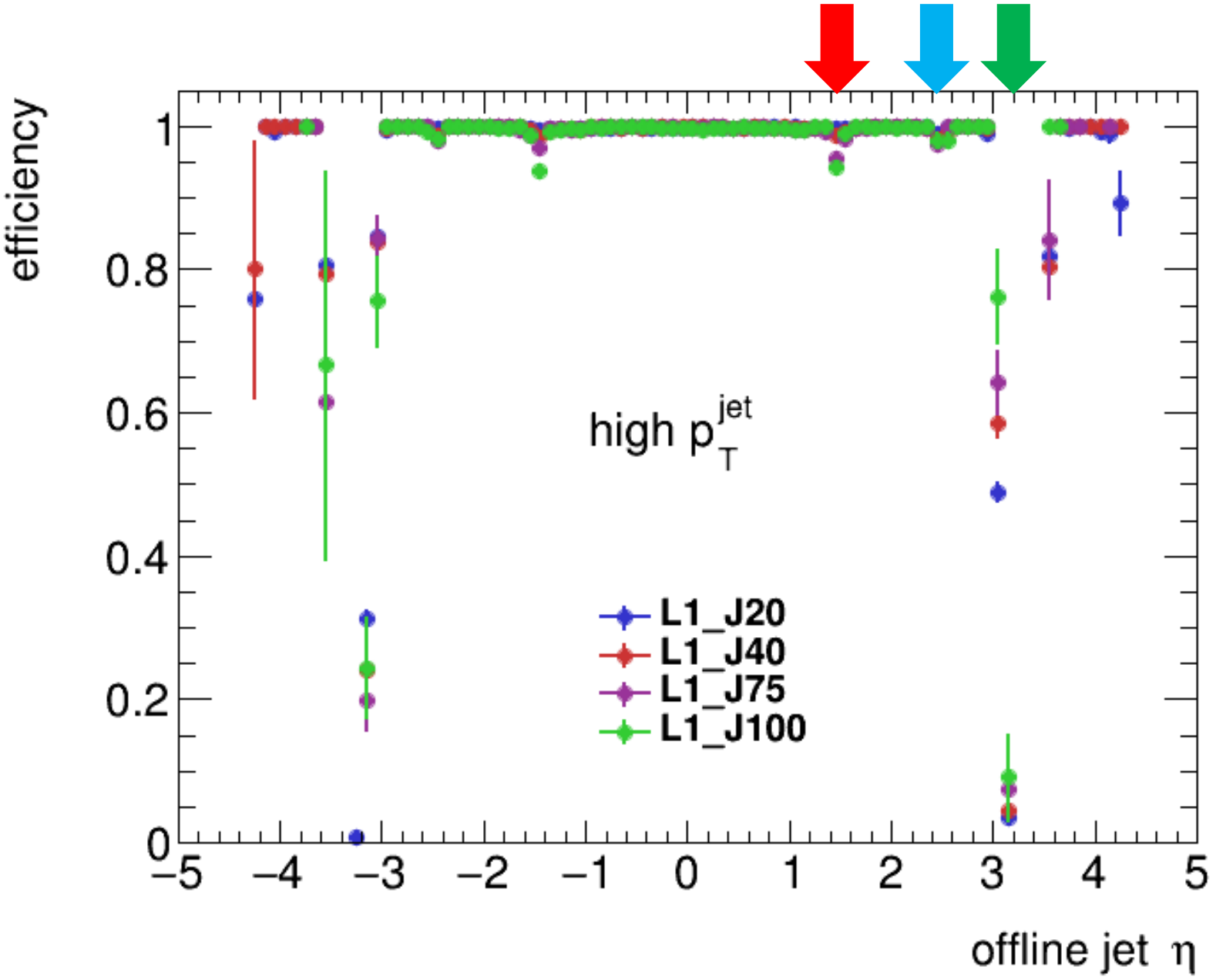
Efficiencies – TOB / offline jet matching

- For each offline jet:
  - Select TOB closest to offline jet in $\Delta R = \sqrt{\Delta\eta^2 + \Delta\phi^2}$
  - If $\Delta R < 0.4$, TOB and offline jet are **matched**

$$\varepsilon = \frac{\text{Number of matched TOBs with } E > E_{th}}{\text{Number of offline jets}}$$





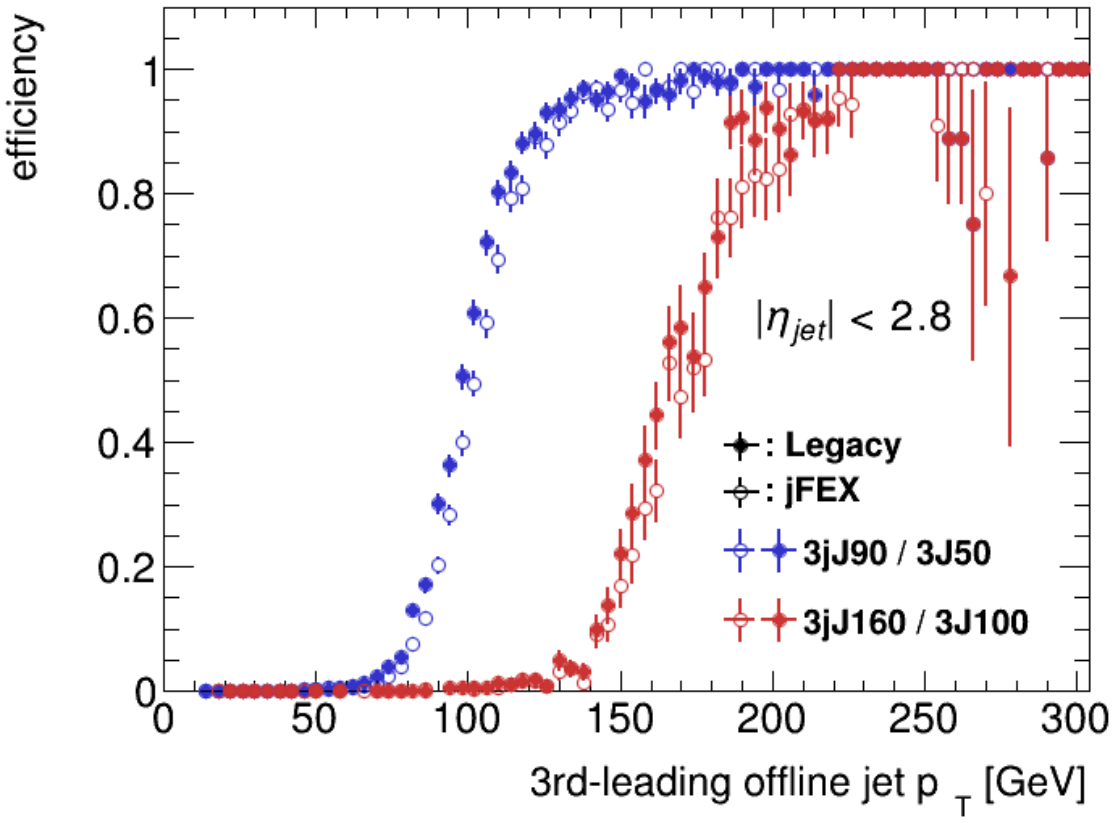


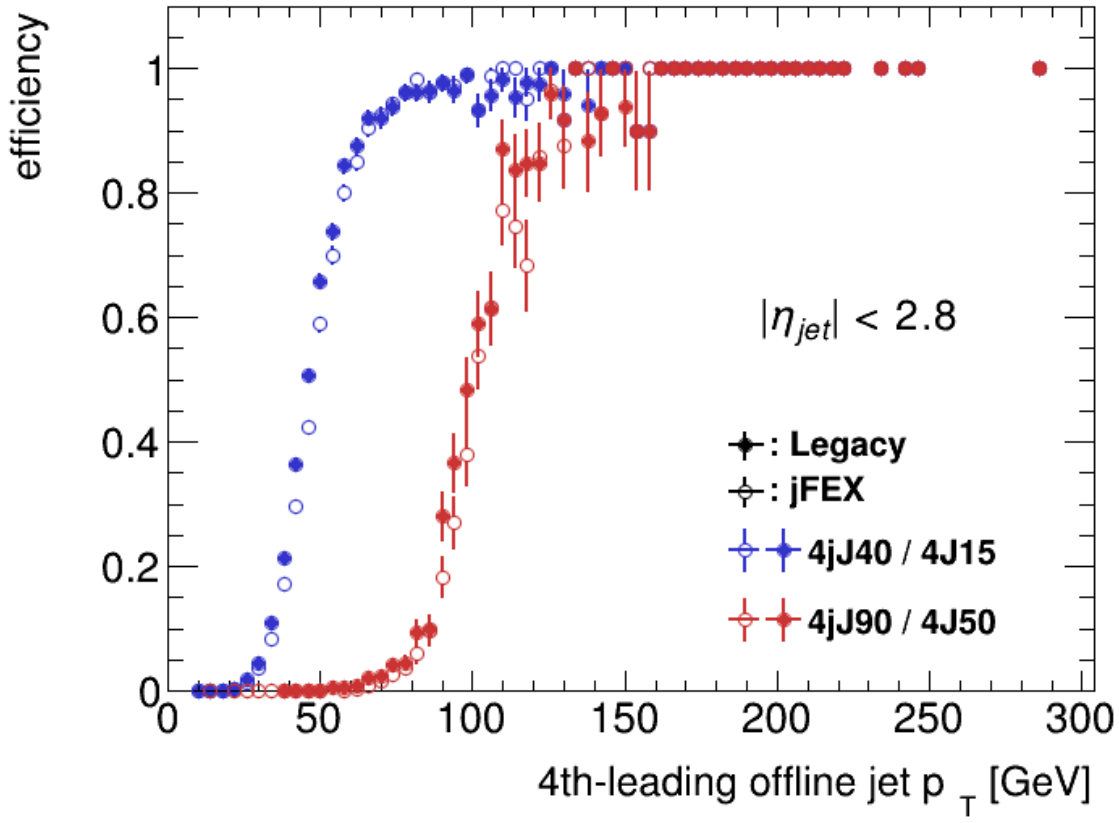
$|\eta| = 1.7$
crack region

$|\eta| = 2.5$
Coarser granularity: Input Trigger Towers, EMEC and HEC cells

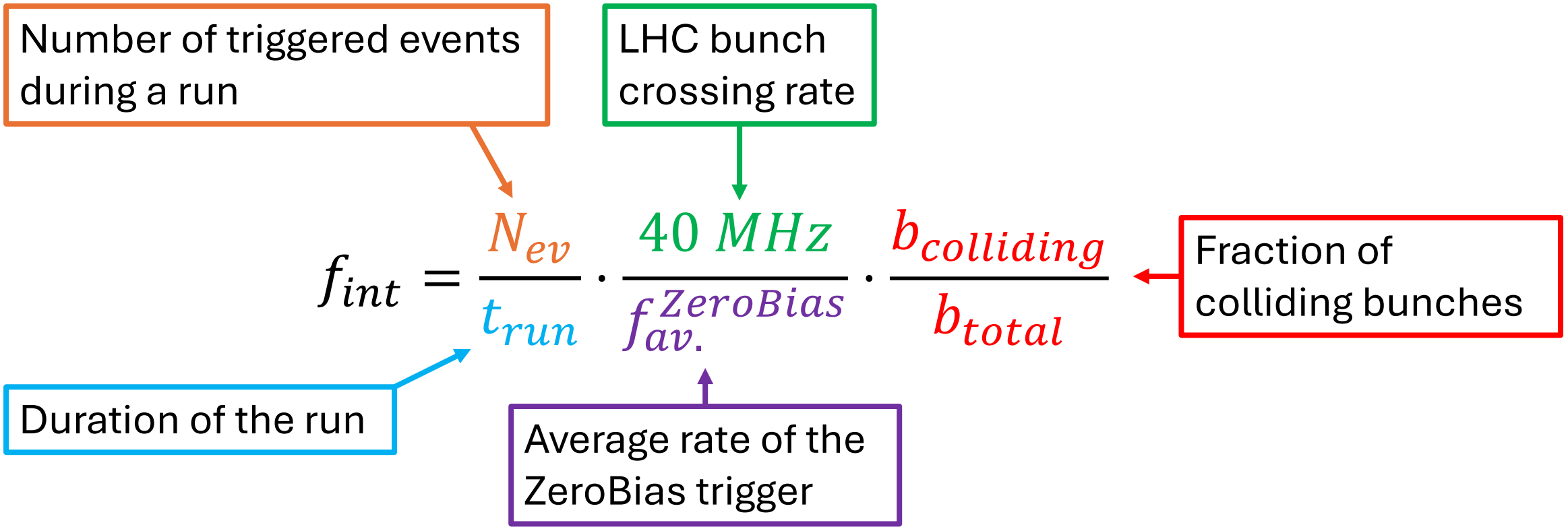
$|\eta| = 3.2$
Start of the FCal

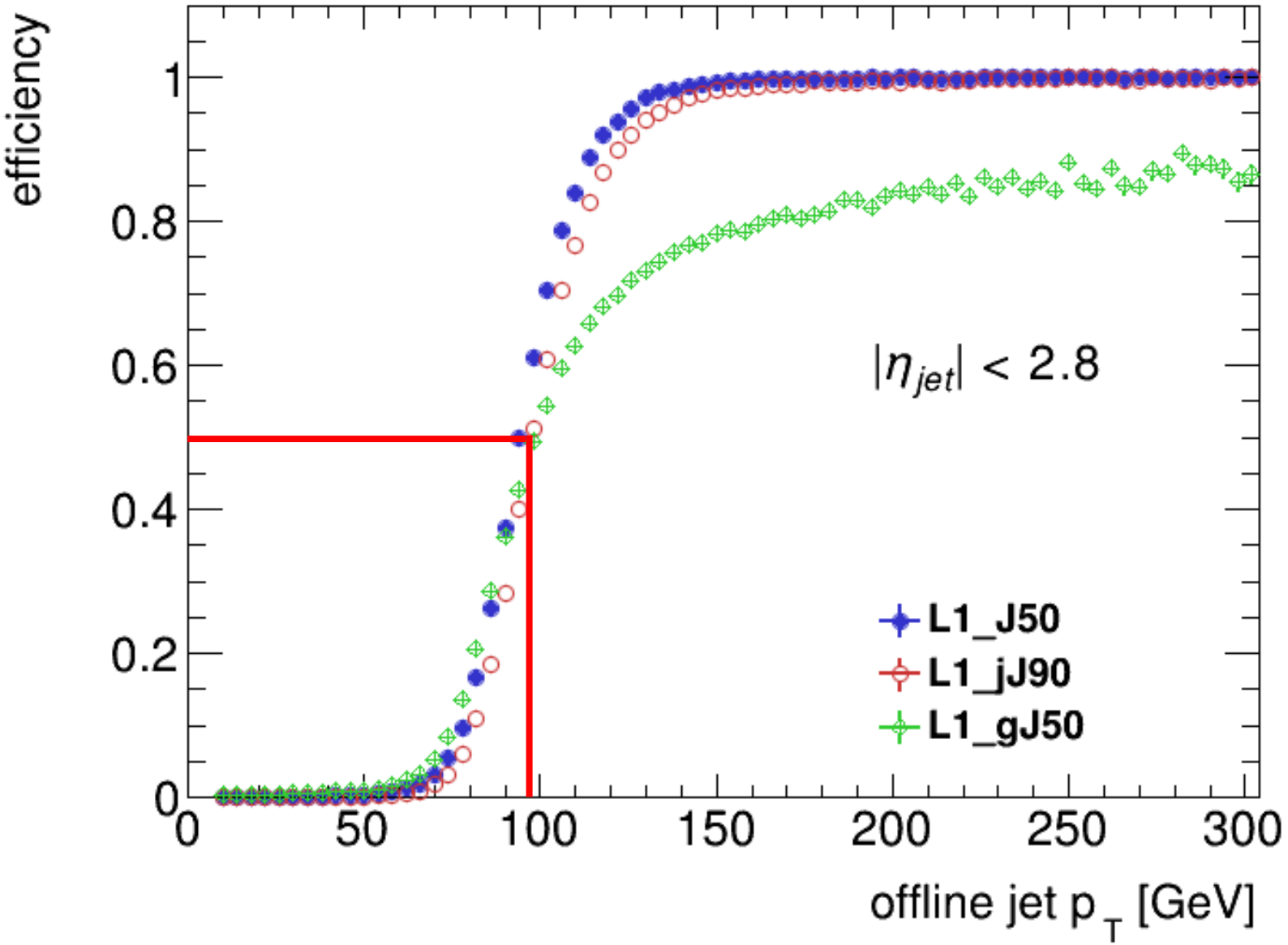
$$\varepsilon = \frac{\text{Number of events with } \mathbf{n} \text{ matched TOBs with } E > E_{th}}{\text{Number of events with at least } \mathbf{n} \text{ offline jets}}$$

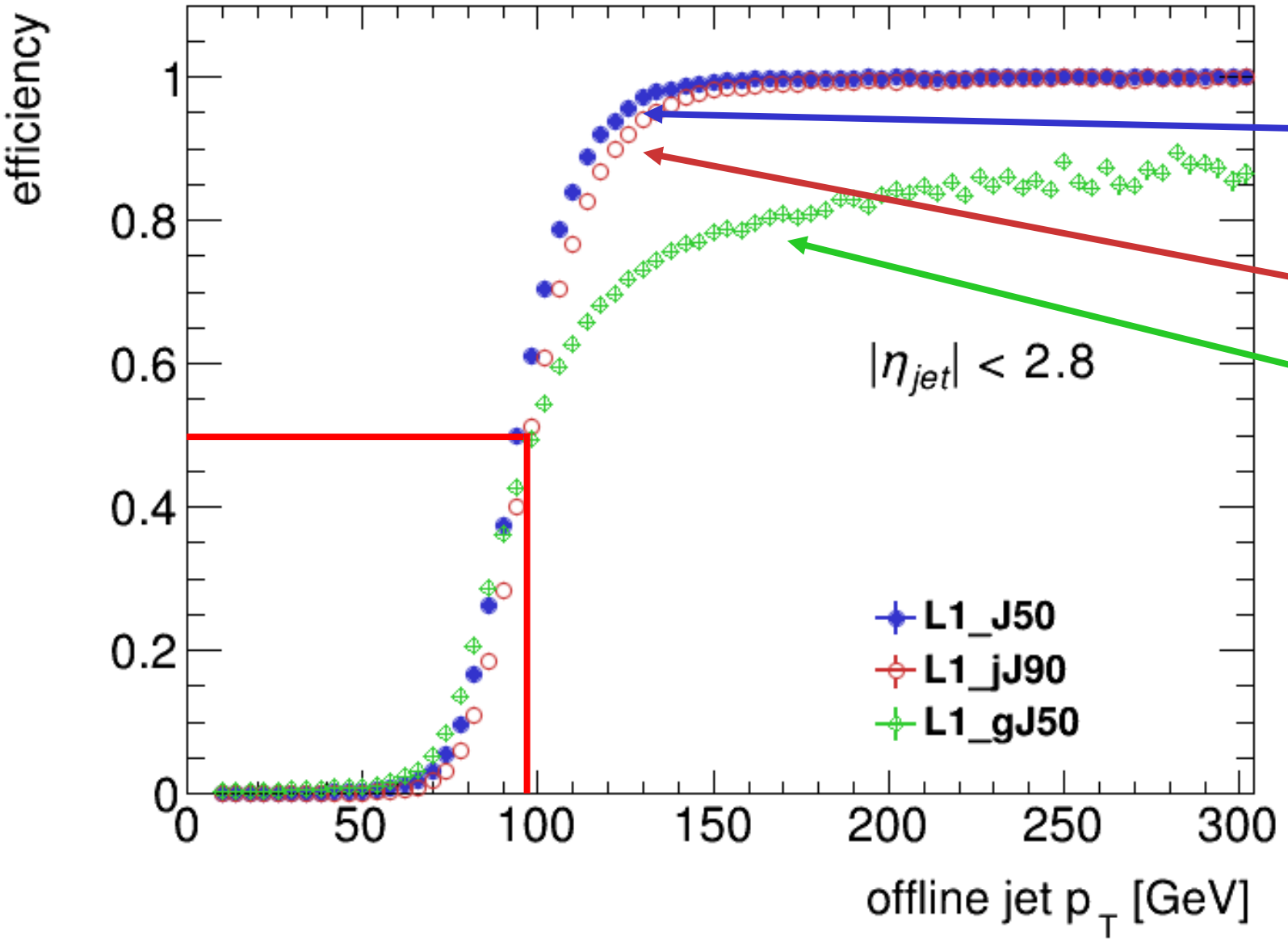




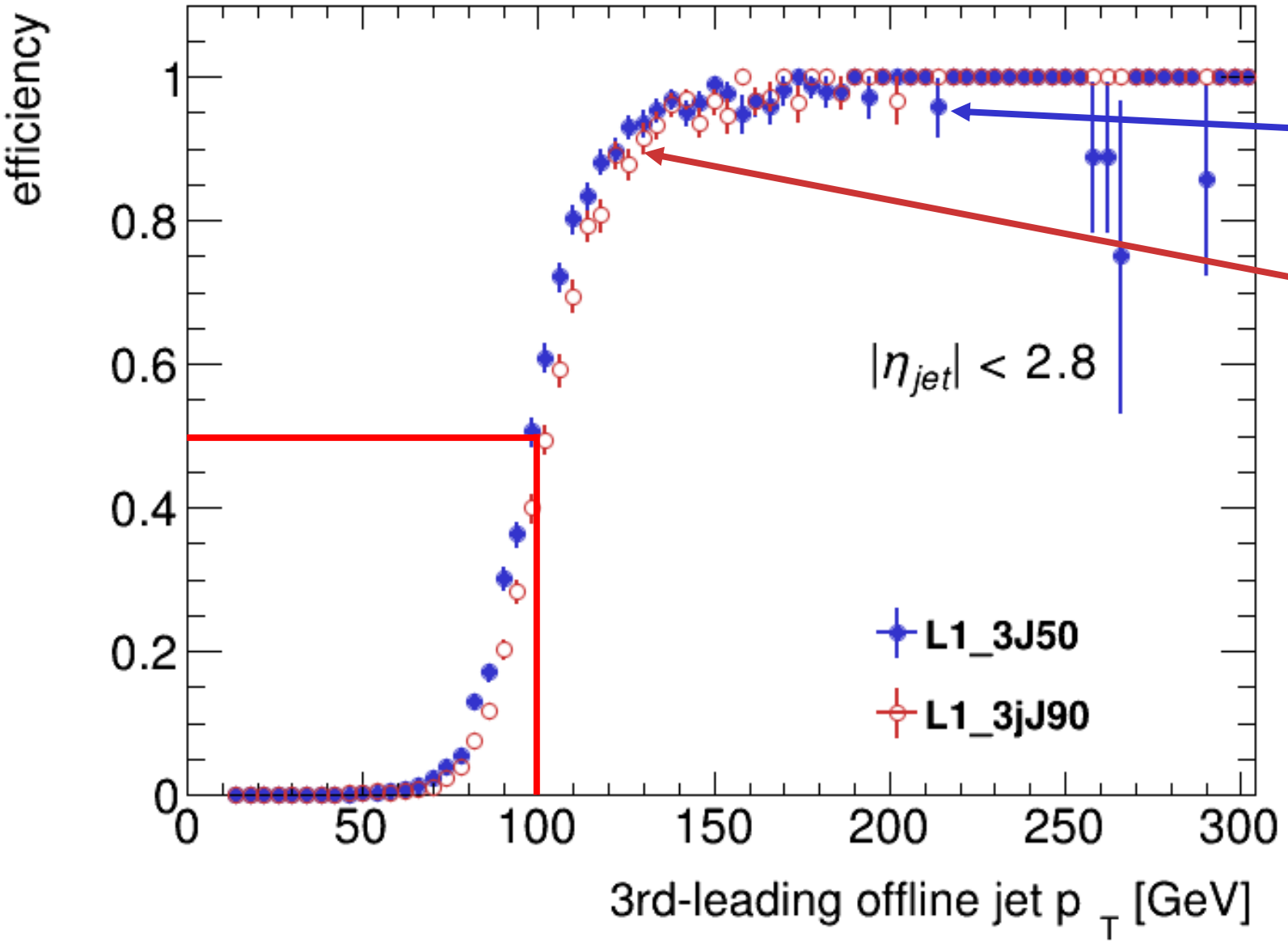
Integrated rate calculation




efficiency
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
offline jet p_T [GeV]
|η_jet| < 2.8
L1_J50
L1_jJ90
L1_gJ50



Trigger	Integrated Rate f_{int} [kHz]
Legacy: L1_J50	38.2 ± 1.5
jFEX: L1_jJ90	31.8 ± 1.4
gFEX: L1_gJ50	37.6 ± 1.5



Trigger	Integrated Rate f_{int} [kHz]
Legacy: L1_3J50	0.63 ± 0.20
jFEX: L1_3jJ90	0.69 ± 0.21

Conclusion

- **Phase-I is well equipped to deal with increased average luminosity and pile-up in Run-3**
  - jFEX improved performance compared to legacy
  - gFEX worse performance for small-R jets (which it was not ultimately designed for)
- Phase-I introduces many promising changes while not only maintaining a jet performance similar to the Legacy system, but improving the trigger rate

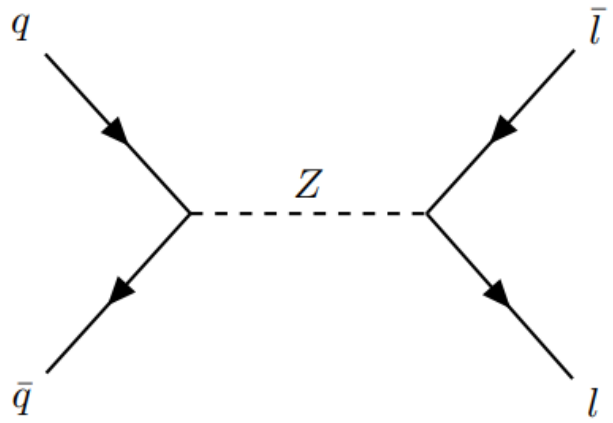
Image Sources

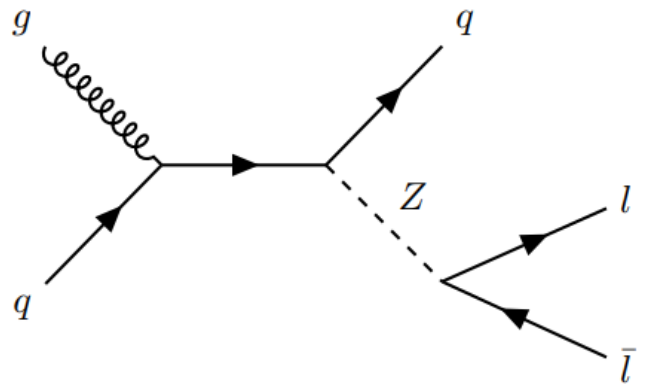
[1] https://atlas-runquery.cern.ch/data/arq_240617/arq_240617131852momc/popupContent_olclumi_363738.html

[2] https://atlas-runquery.cern.ch/data/arq_240617/arq_240617132134pjba/popupContent_olclumi_456729.html

The remaining images are taken from my Bachelors Thesis

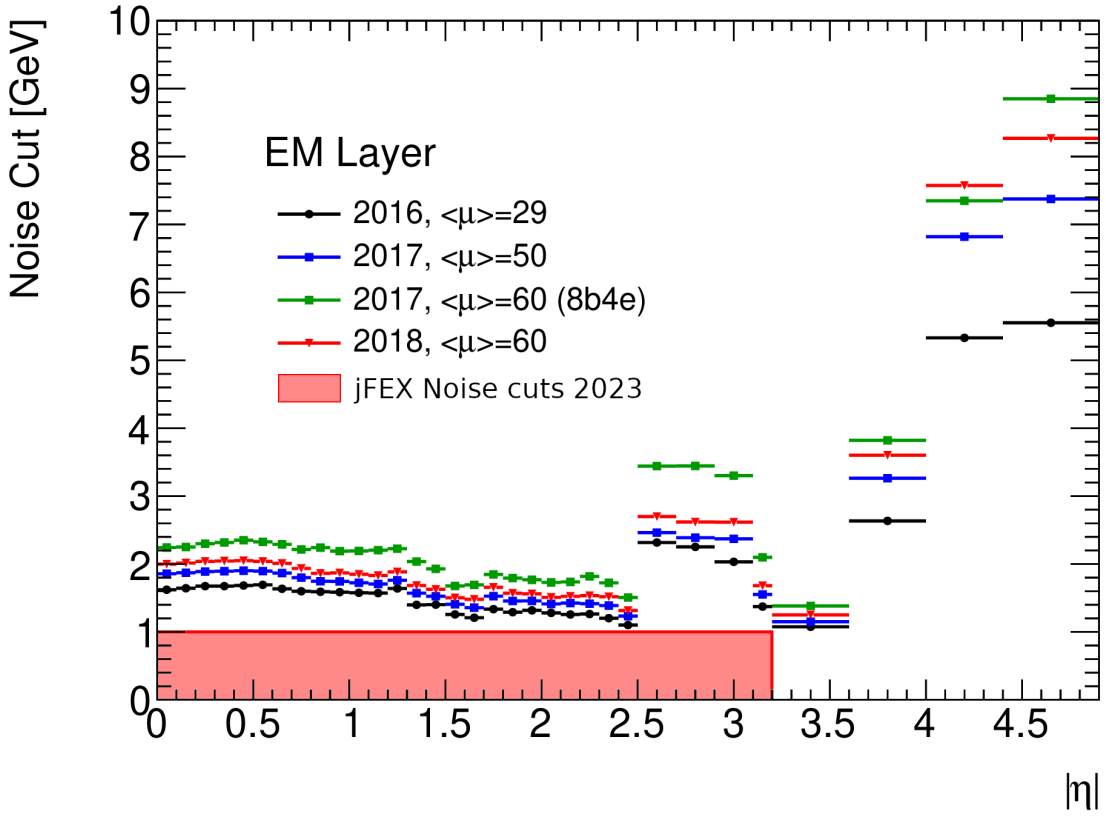
Backup Slides

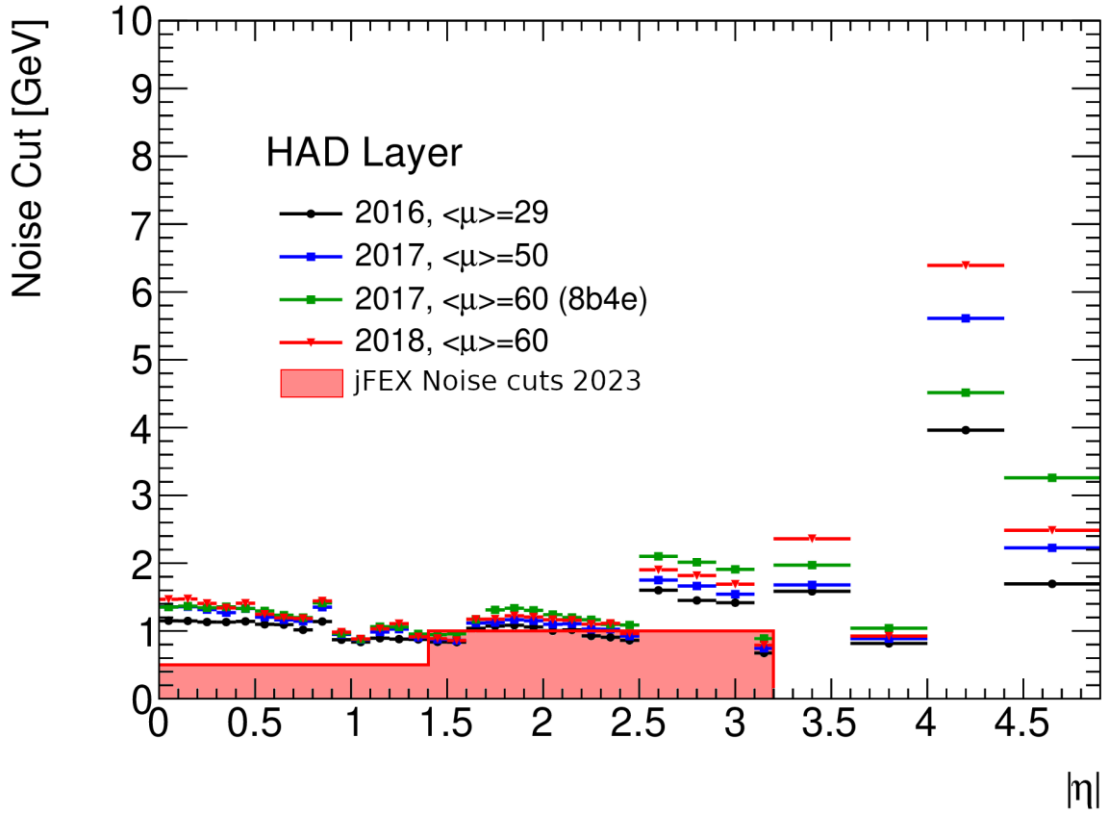

q
$\bar{l}$
Z
$\bar{q}$
l


g
q
Z
l
q
$\bar{l}$

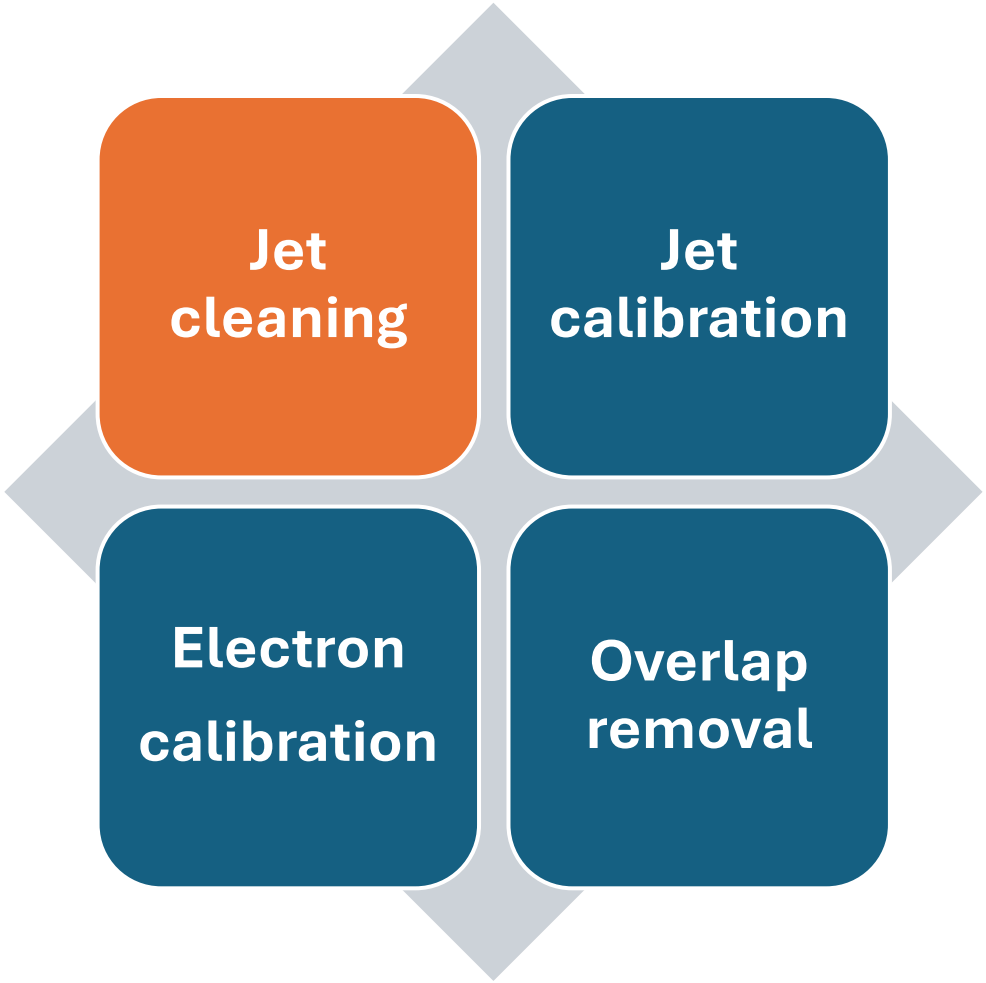
Legacy vs. Phase-I

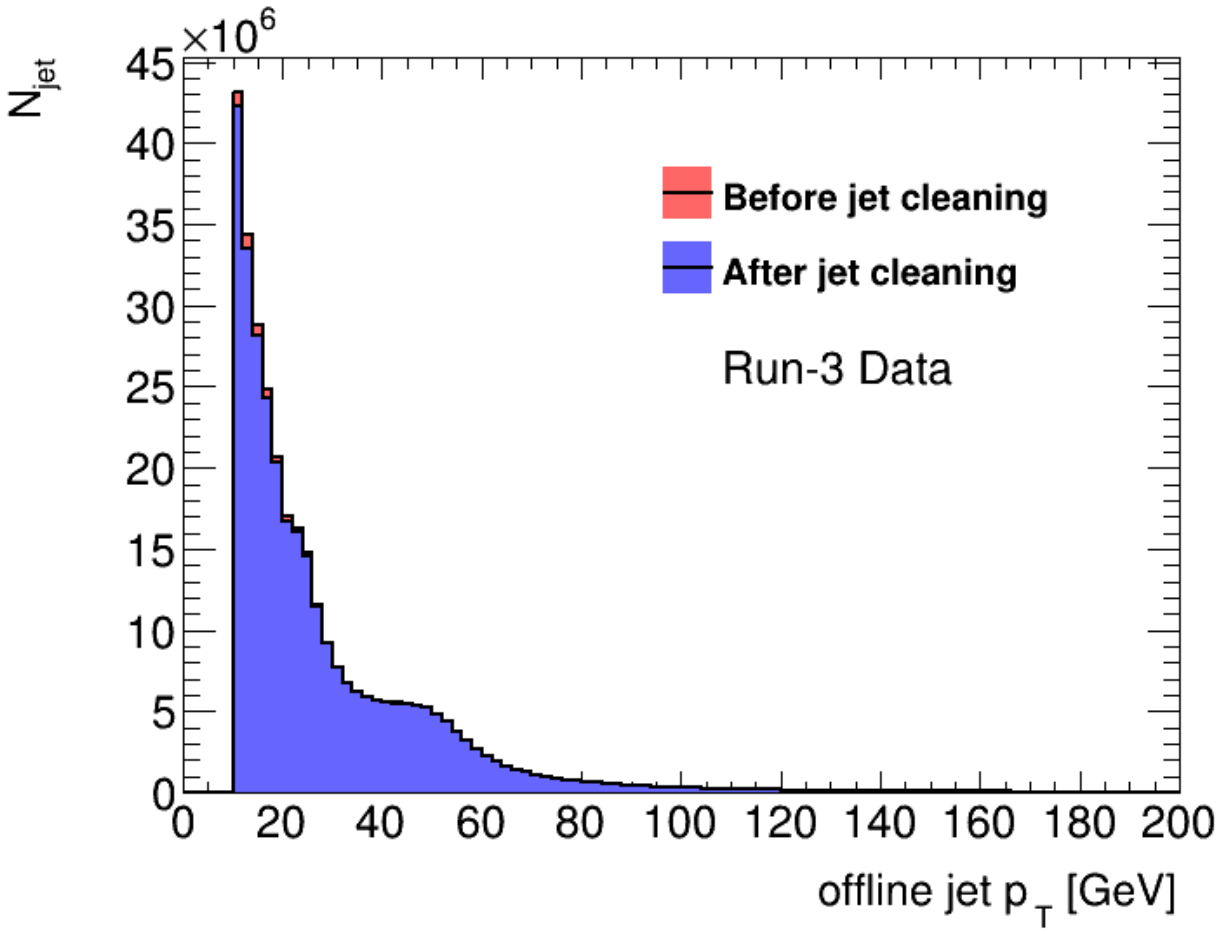
Legacy and Phase-I noise cuts:





Efficiency Framework





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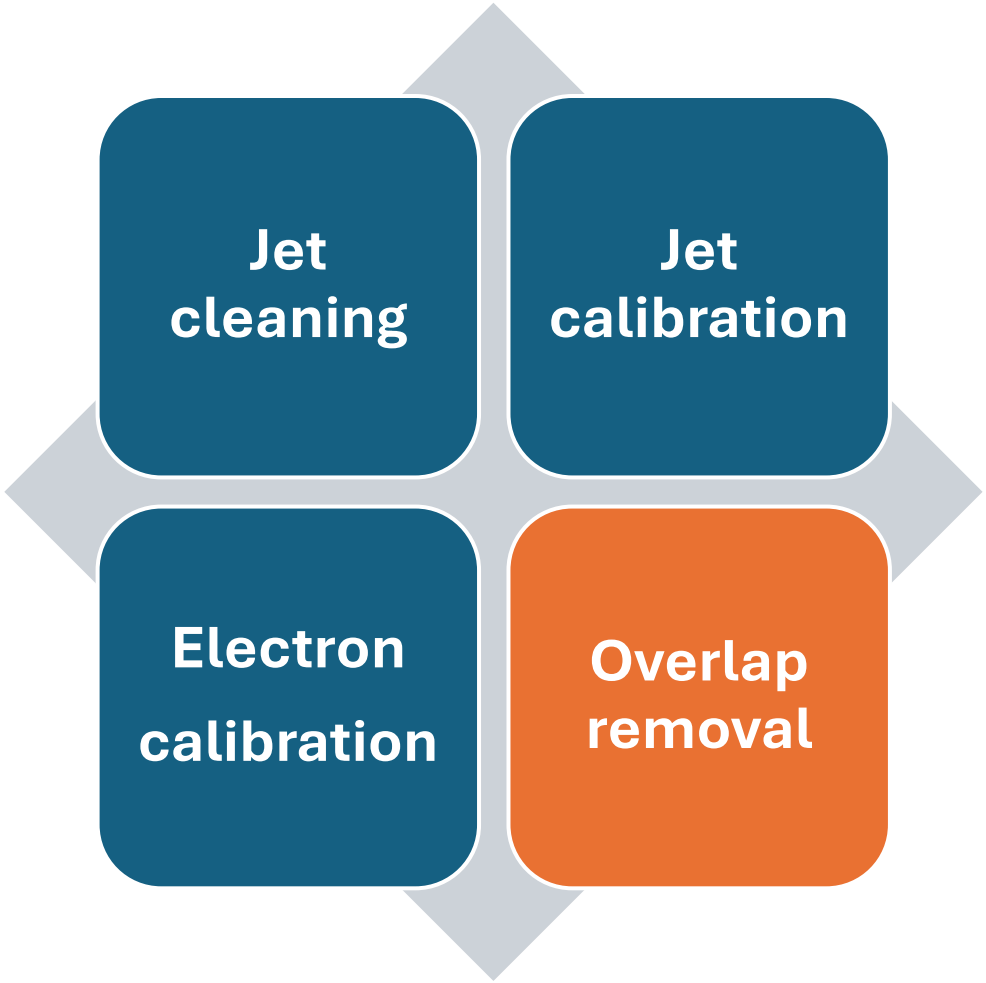

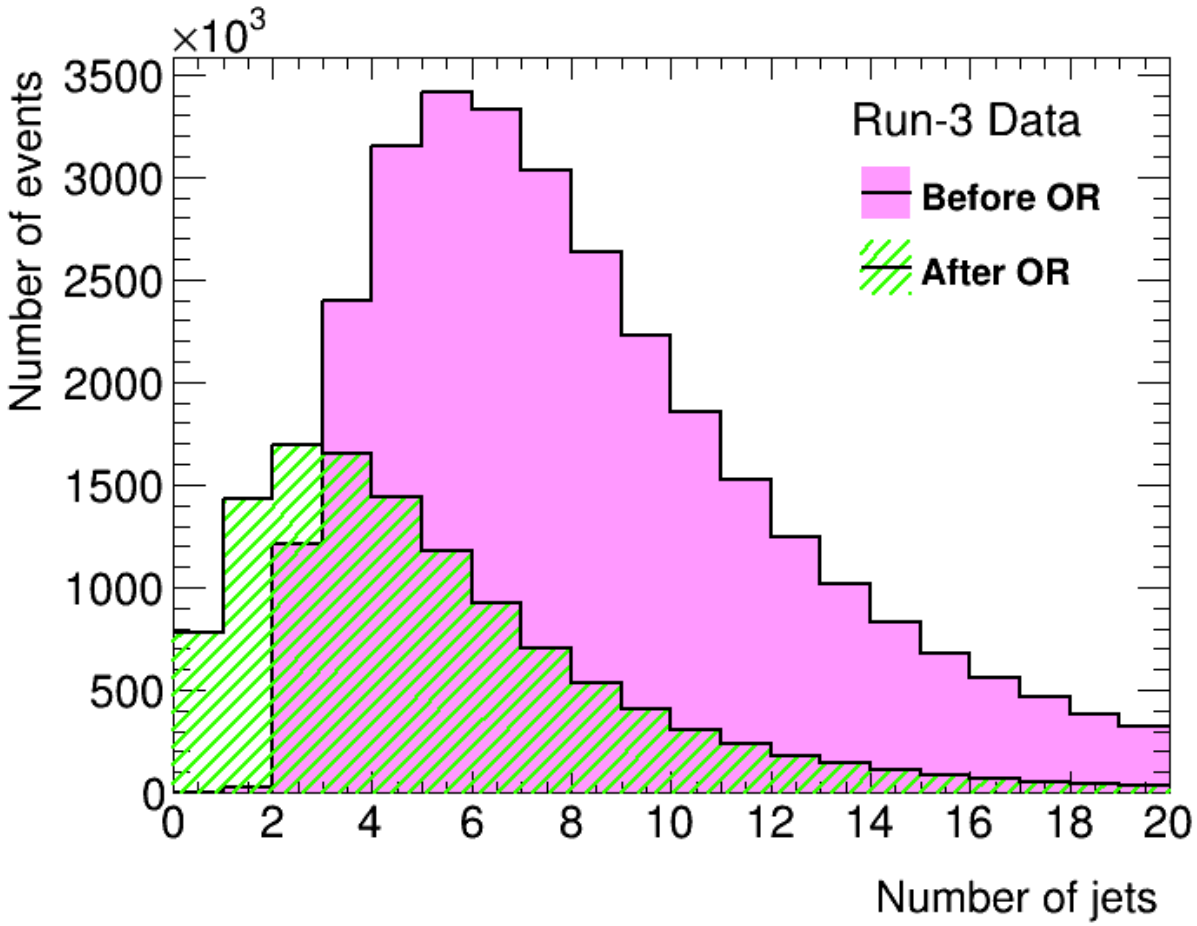

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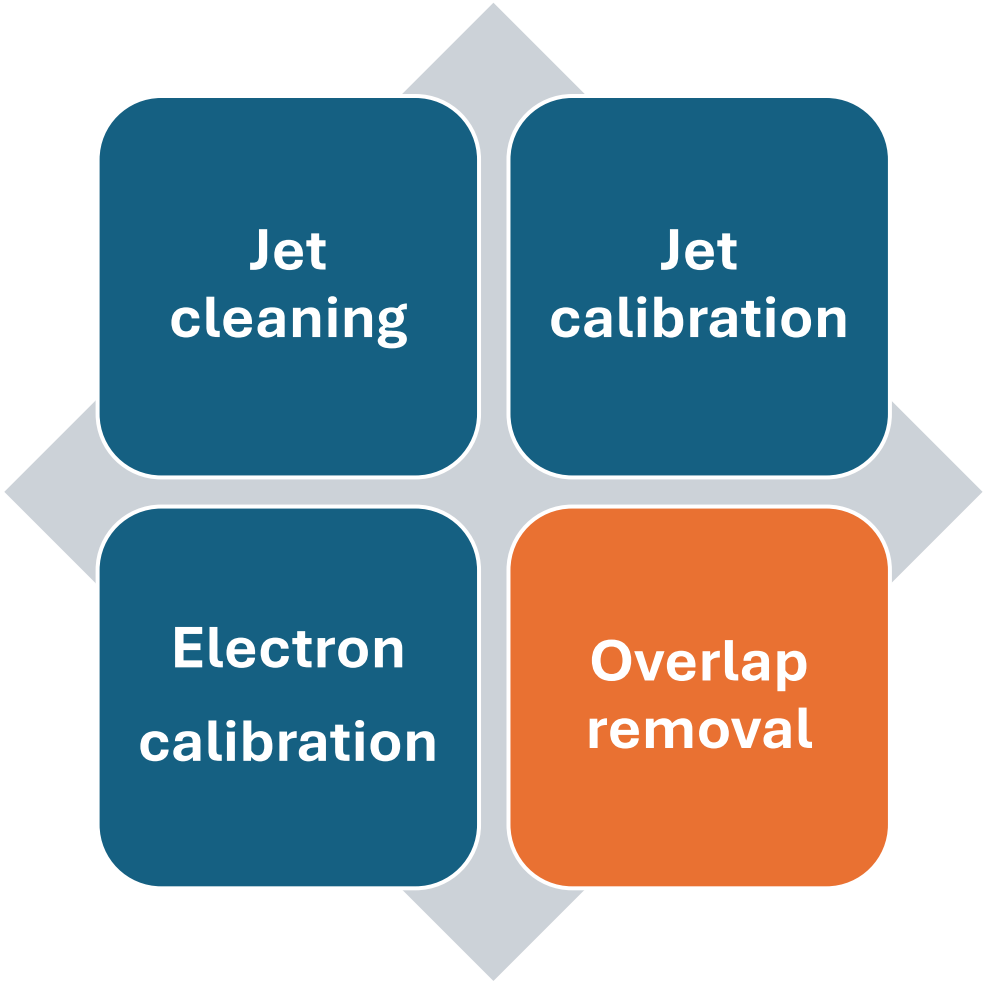

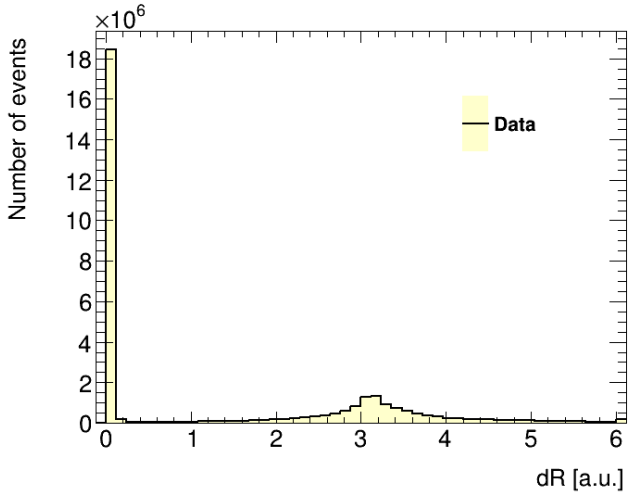

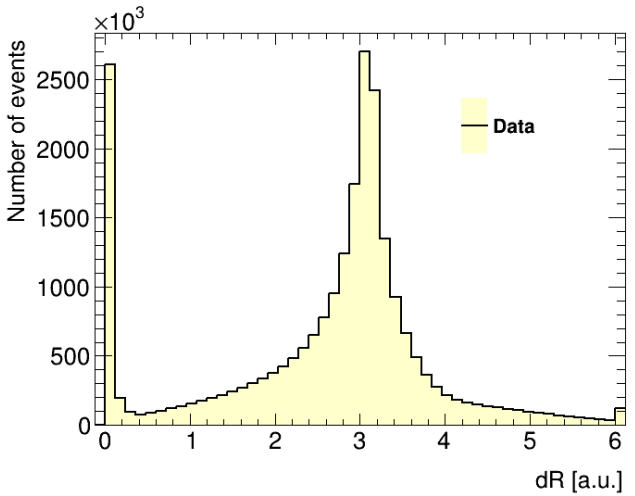

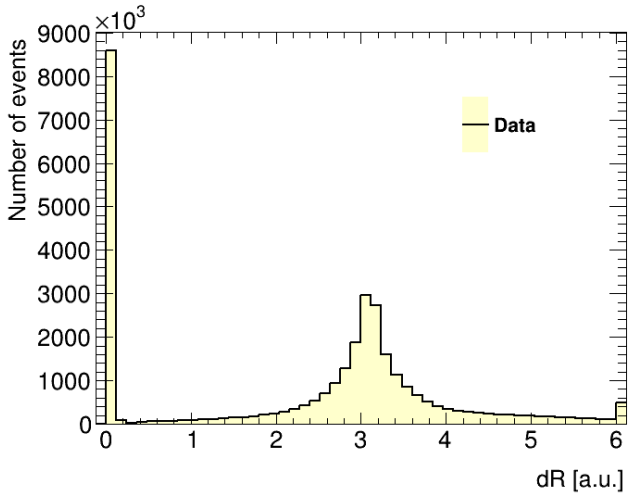

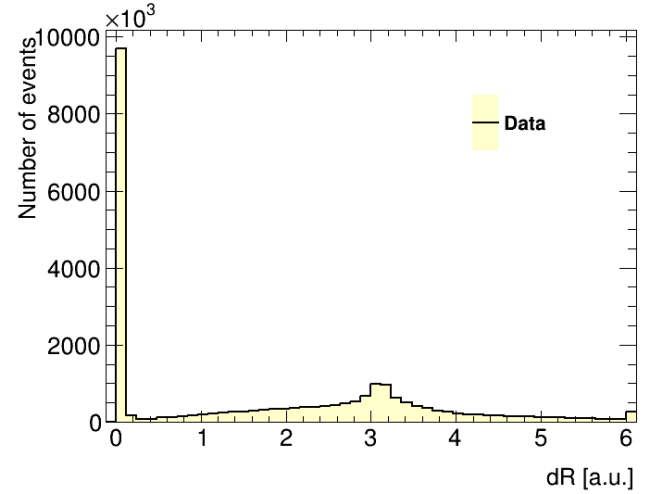

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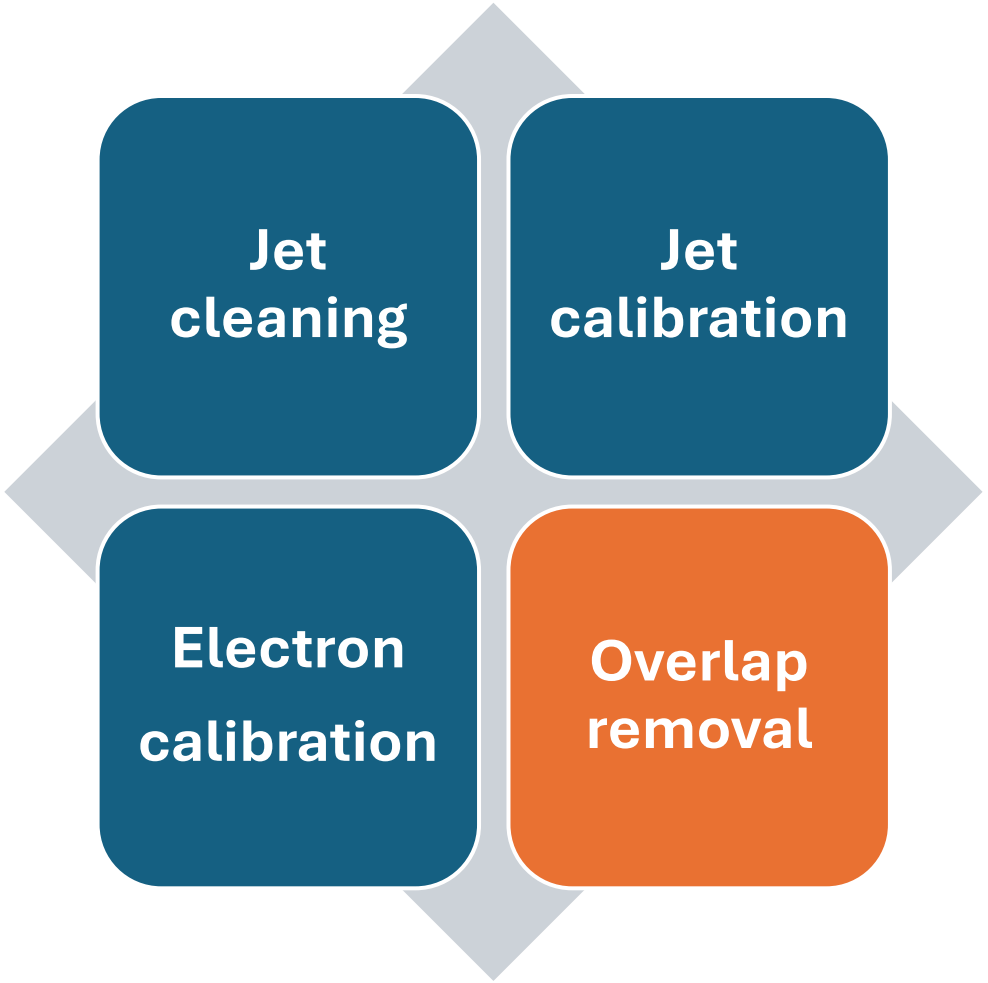

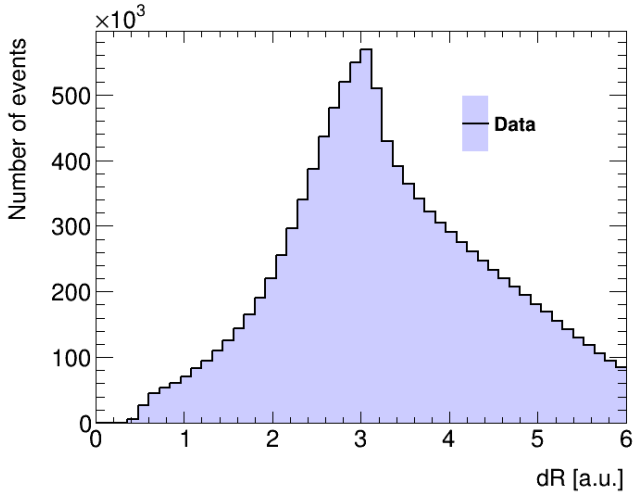

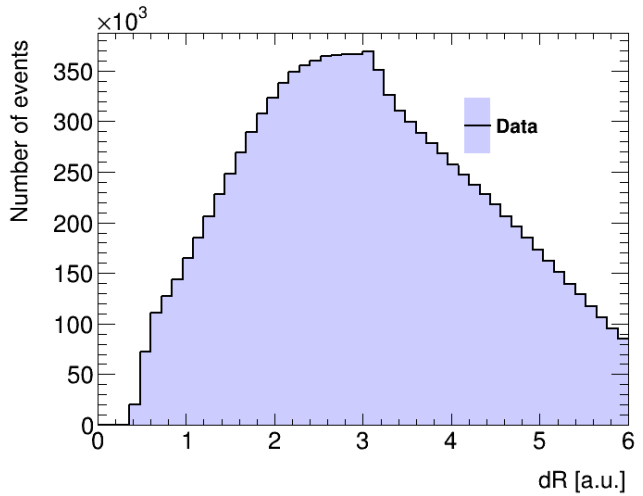

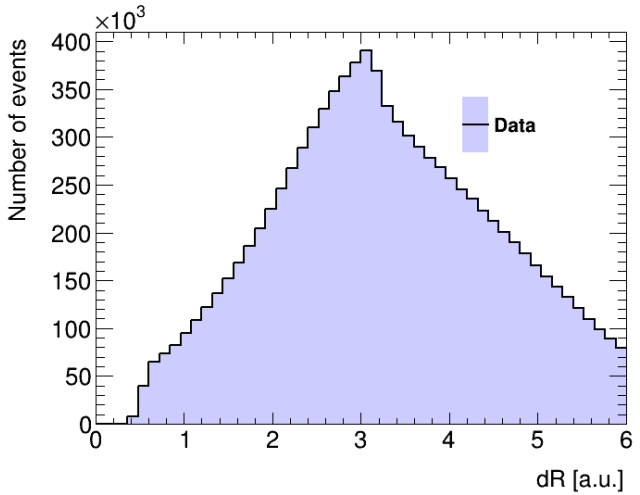

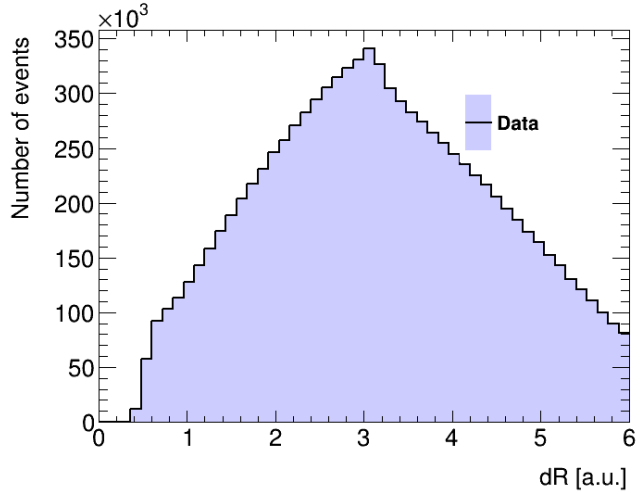

Efficiencies – Event Selection

Beam-induced-background (BiB) from muons → fake jets	BiB flags
Bias from events triggered by jet triggers	Electron trigger cut
Properties of electrons from Z decay	Electron object-level cuts
Well known Z mass	Z mass cut: 76.2 GeV < M < 106.2 GeV
Opposite charge of final state electrons	Z charge

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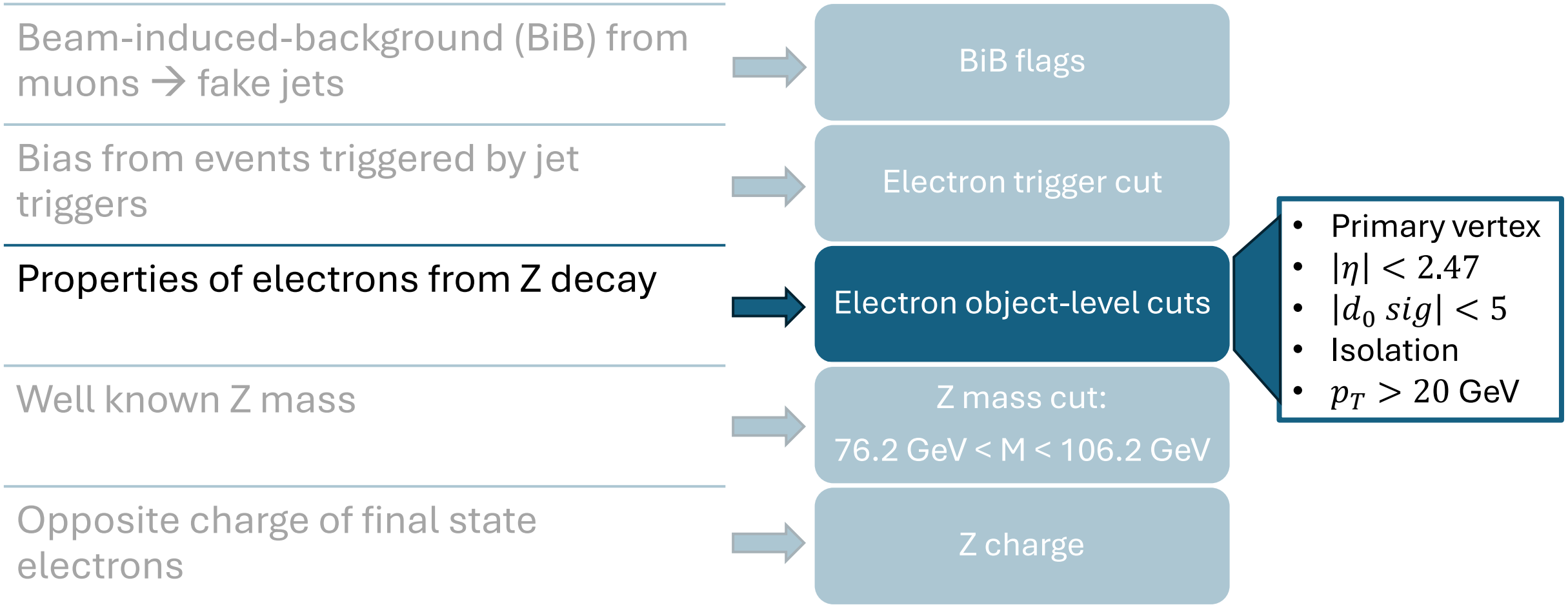

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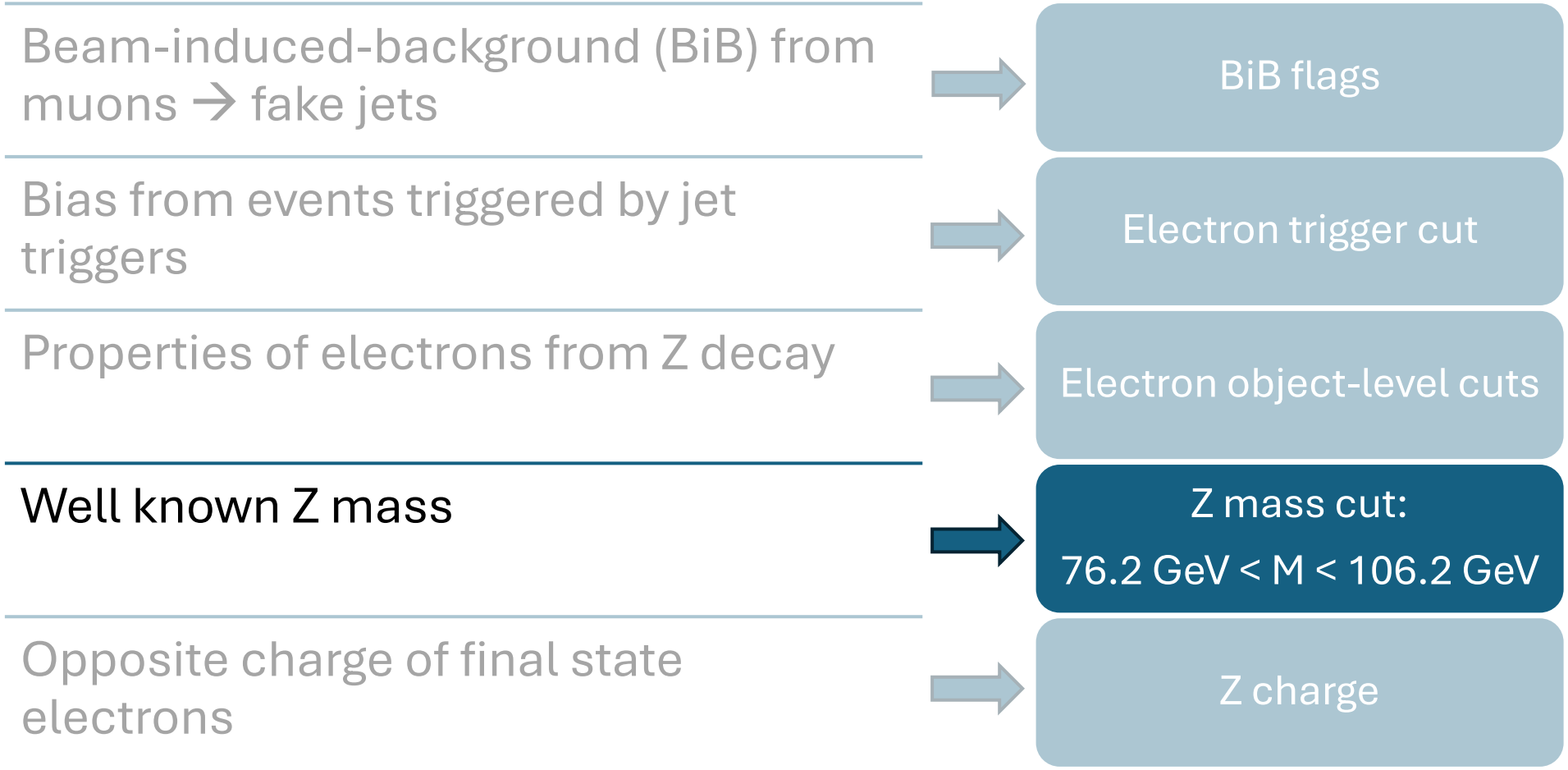

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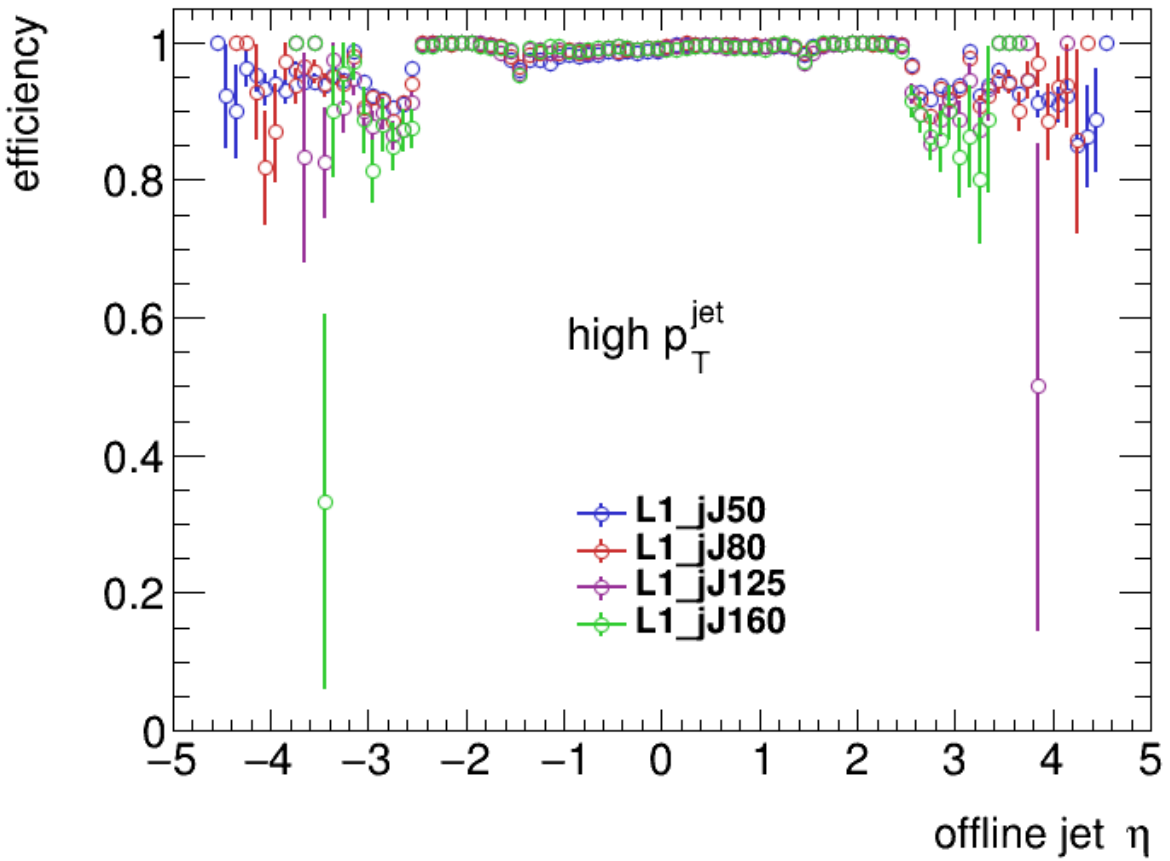
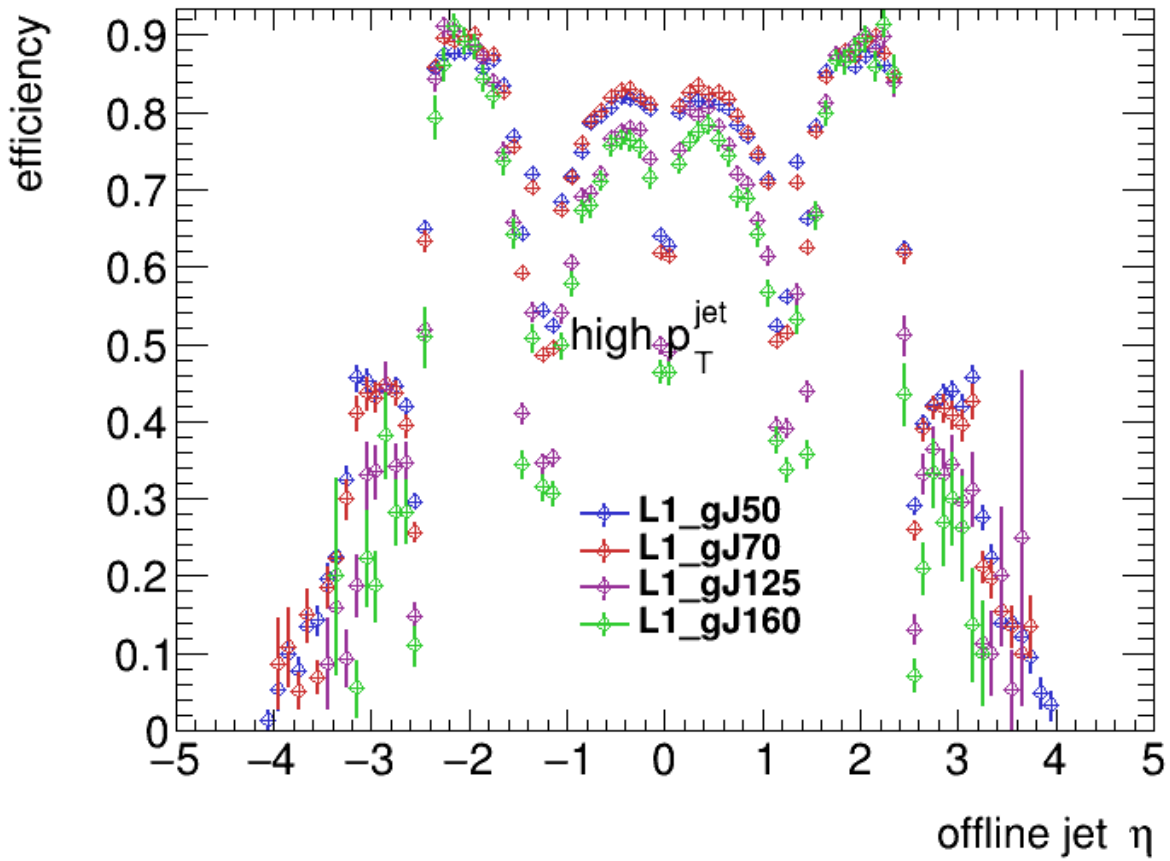
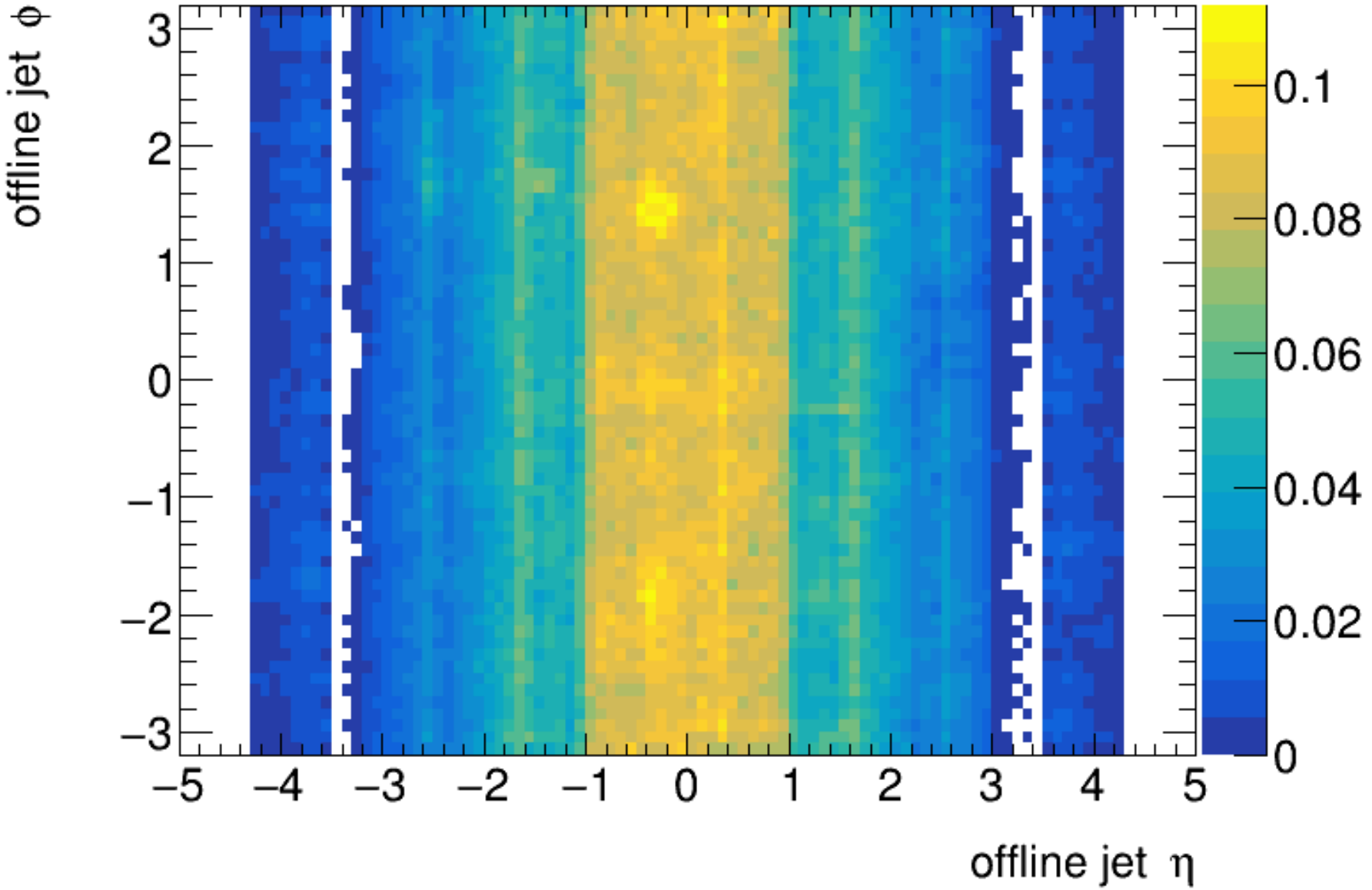
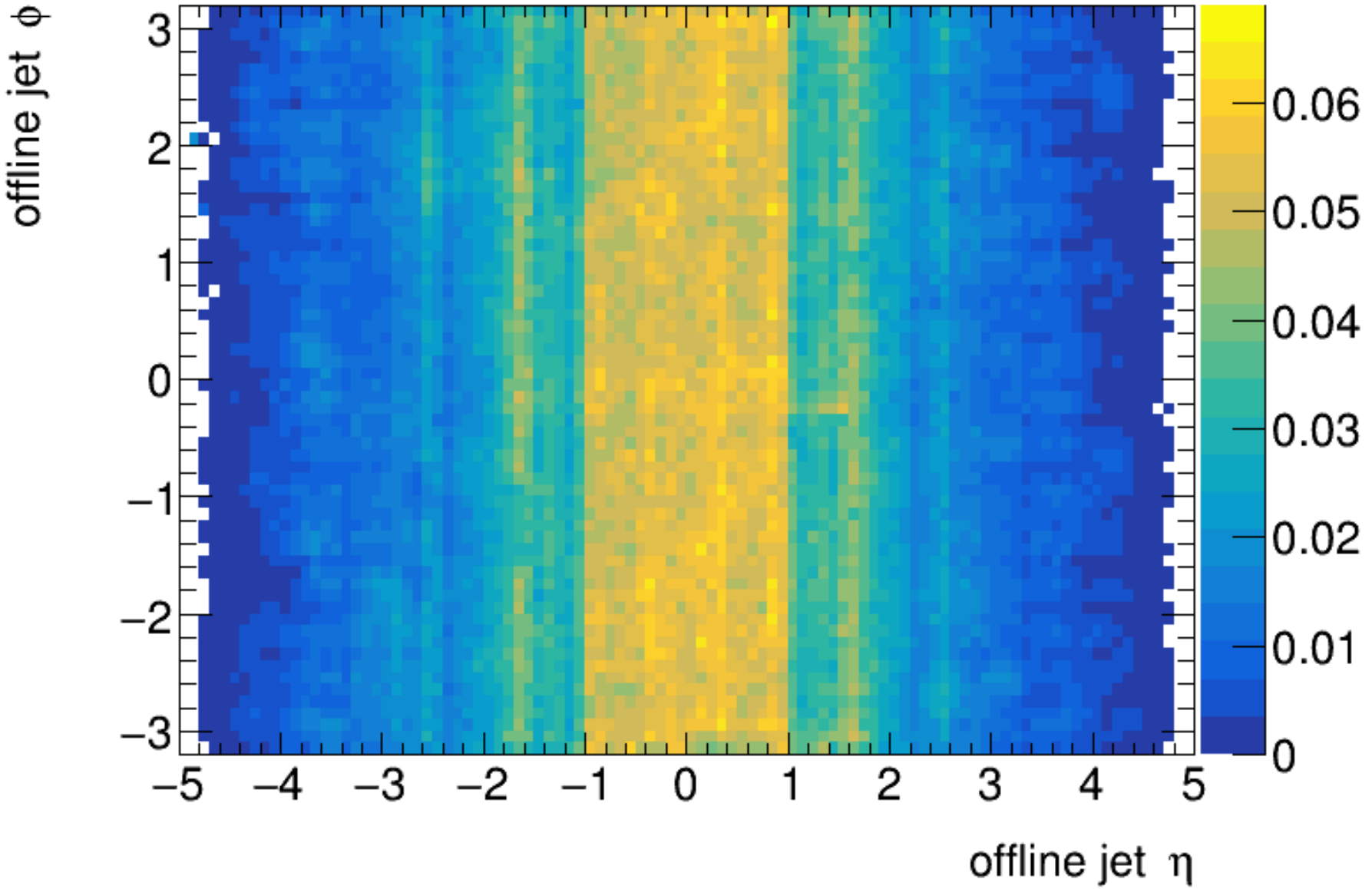
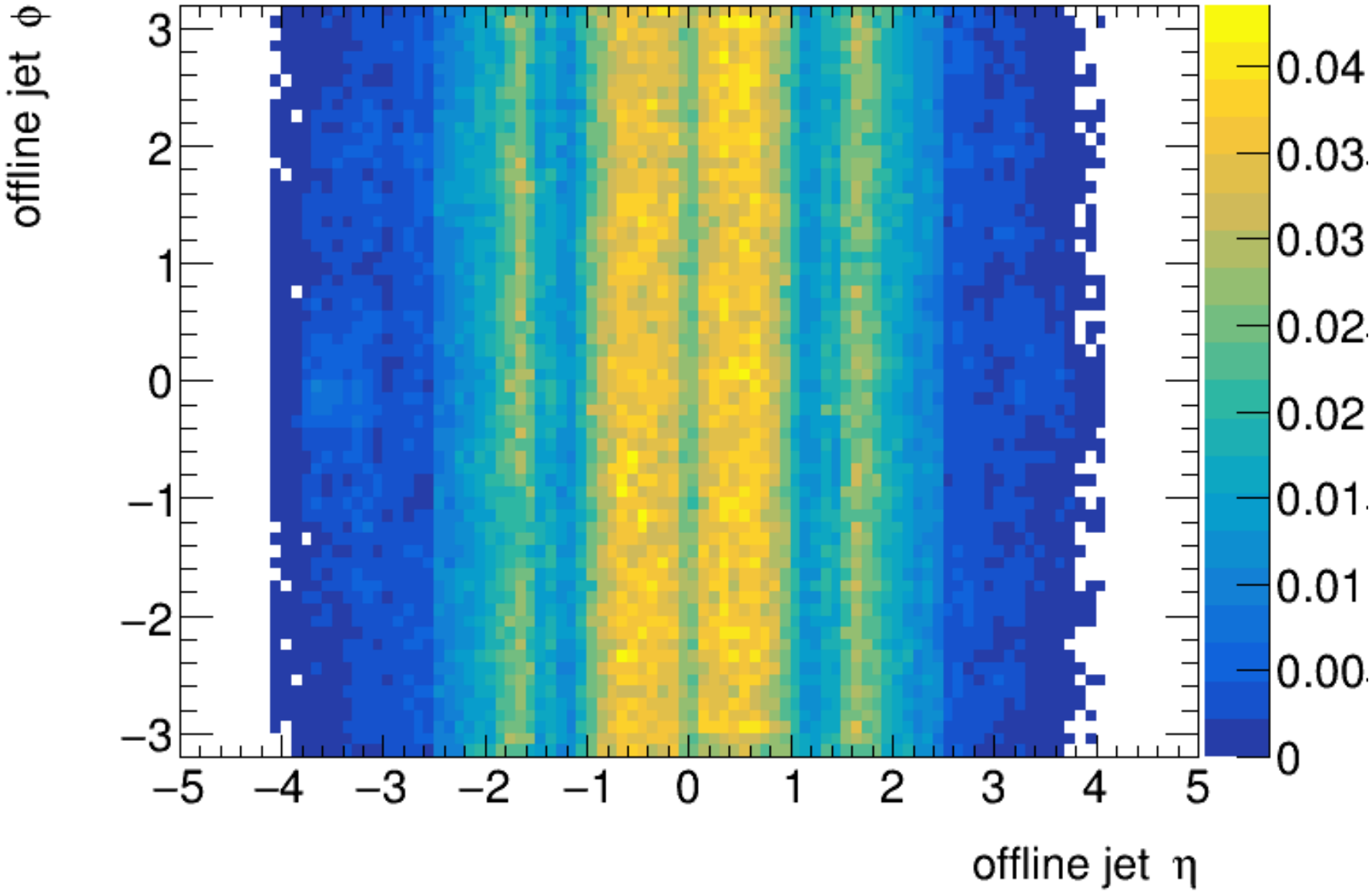
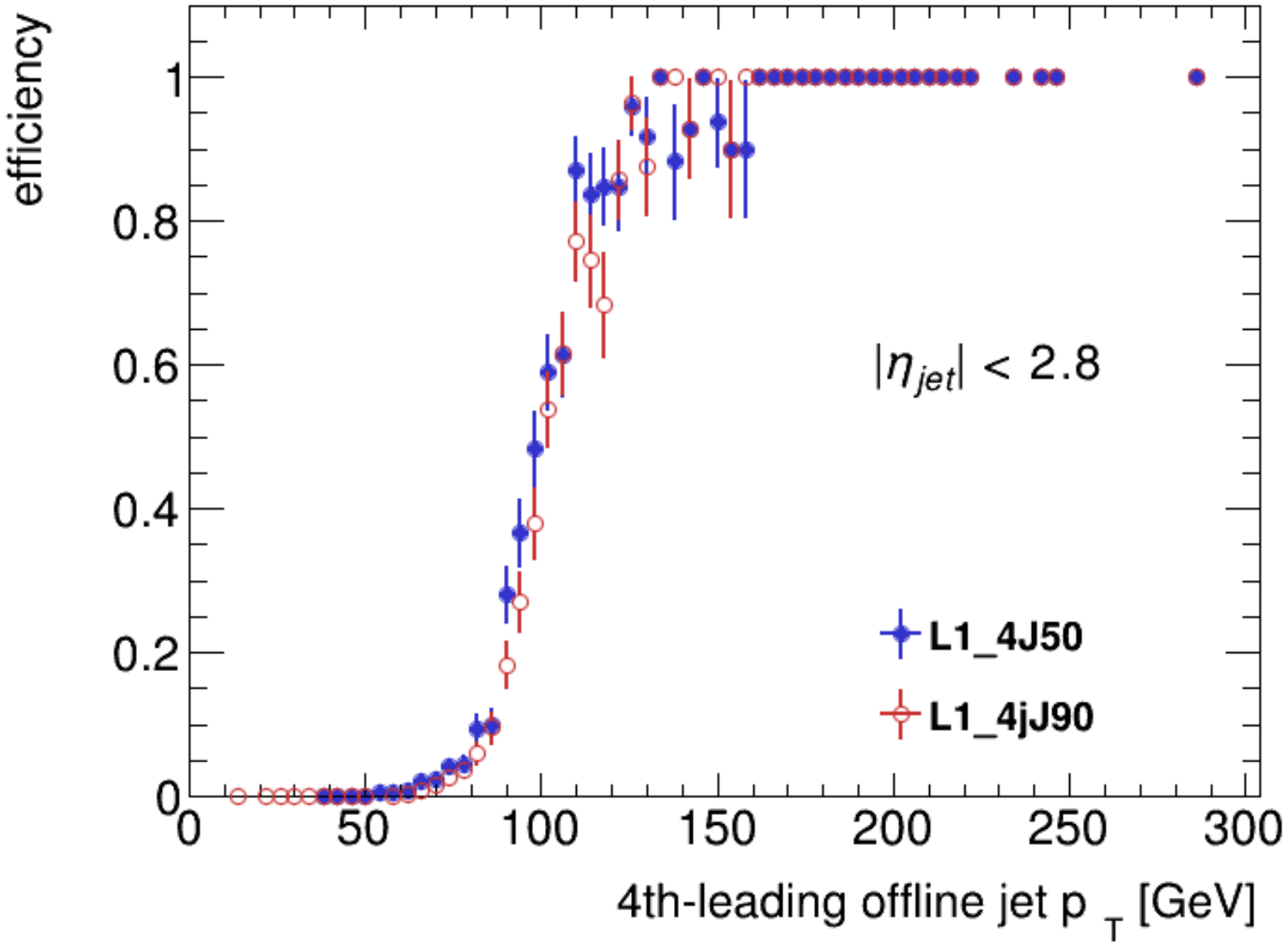

efficiency
high p_T^{jet}
L1_jJ50
L1_jJ80
L1_jJ125
L1_jJ160
offline jet η

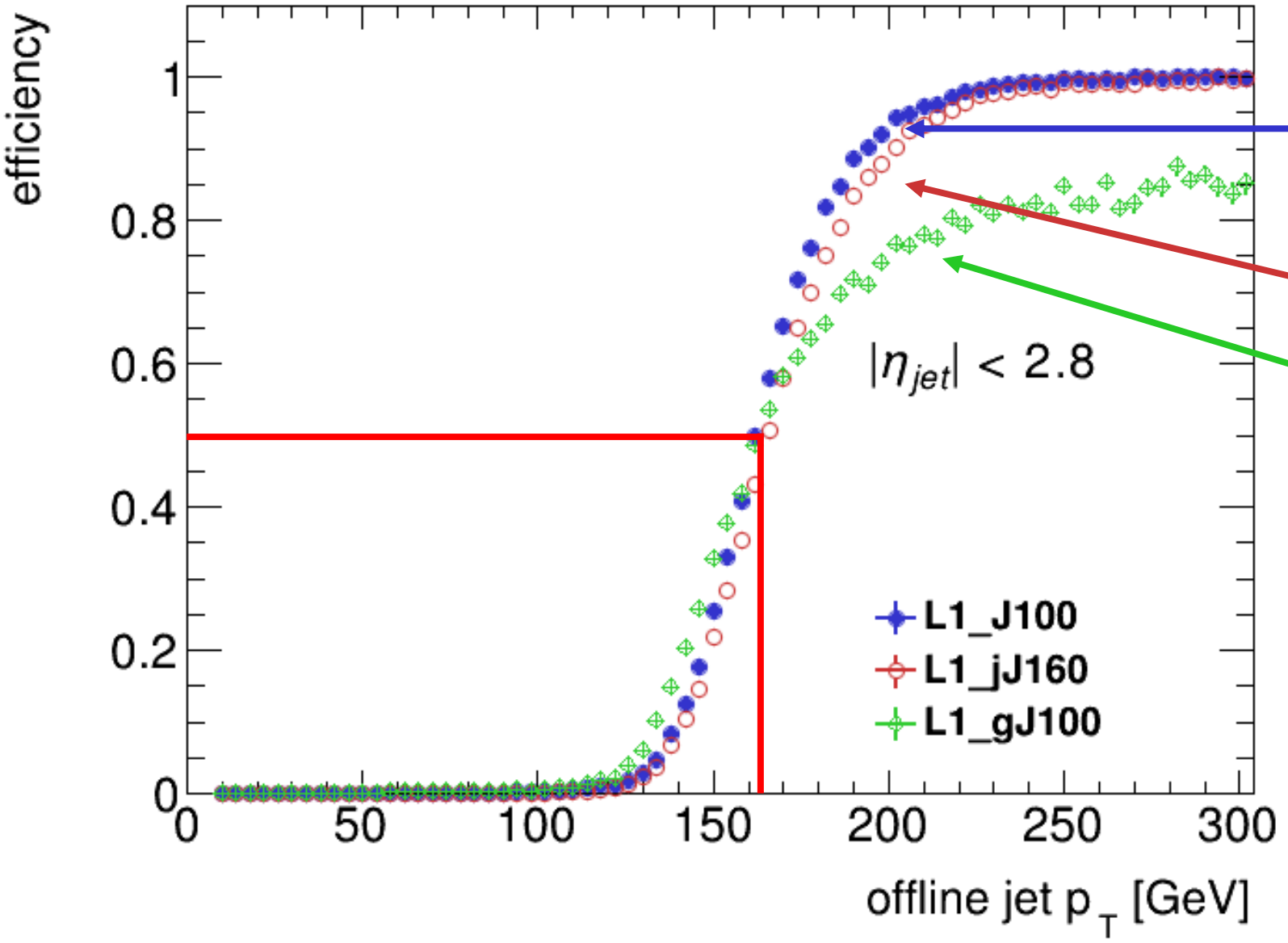

efficiency
high p_T^{jet}
L1_gJ50
L1_gJ70
L1_gJ125
L1_gJ160
offline jet η


offline jet ϕ
3
2
1
0
−1
−2
−3
−5
−4
−3
−2
−1
0
1
2
3
4
5
offline jet η
0.1
0.08
0.06
0.04
0.02
0


offline jet ϕ
3
2
1
0
−1
−2
−3
−5
−4
−3
−2
−1
0
1
2
3
4
5
offline jet η
0.06
0.05
0.04
0.03
0.02
0.01
0


offline jet ϕ
3
2
1
0
−1
−2
−3
−5
−4
−3
−2
−1
0
1
2
3
4
5
offline jet η
0.04
0.03
0.03
0.02
0.02
0.01
0.01
0.00
0


efficiency
1
0.8
0.6
0.4
0.2
0
0
50
100
150
200
250
300
$|\eta_{jet}| < 2.8$
L1_4J50
L1_4jJ90
4th-leading offline jet p T [GeV]



Trigger	Integrated Rate f_{int} [kHz]
Legacy: L1_J100	2.9 ± 0.4
jFEX: L1_jJ160	2.5 ± 0.4
gFEX: L1_gJ100	2.9 ± 0.4

Performance evaluation

Single-jet triggers

Trigger	Integrated Rate f_{int} [kHz]
L1_J50	38.2 ± 1.5
L1_jJ90	31.8 ± 1.4
L1_gJ50	37.6 ± 1.5
L1_J100	2.9 ± 0.4
L1_jJ160	2.5 ± 0.4
L1_gJ100	2.9 ± 0.4

Multi-jet triggers

Trigger	Integrated Rate f_{int} [kHz]
L1_3J50	0.63 ± 0.20
L1_3jJ90	0.69 ± 0.21
L1_4J50	0.06 ± 0.06
L1_4jJ90	0.13 ± 0.09