The Global Feature Extractor (gFEX)

an ATLAS L1 Calorimeter Trigger Phase-I upgrade

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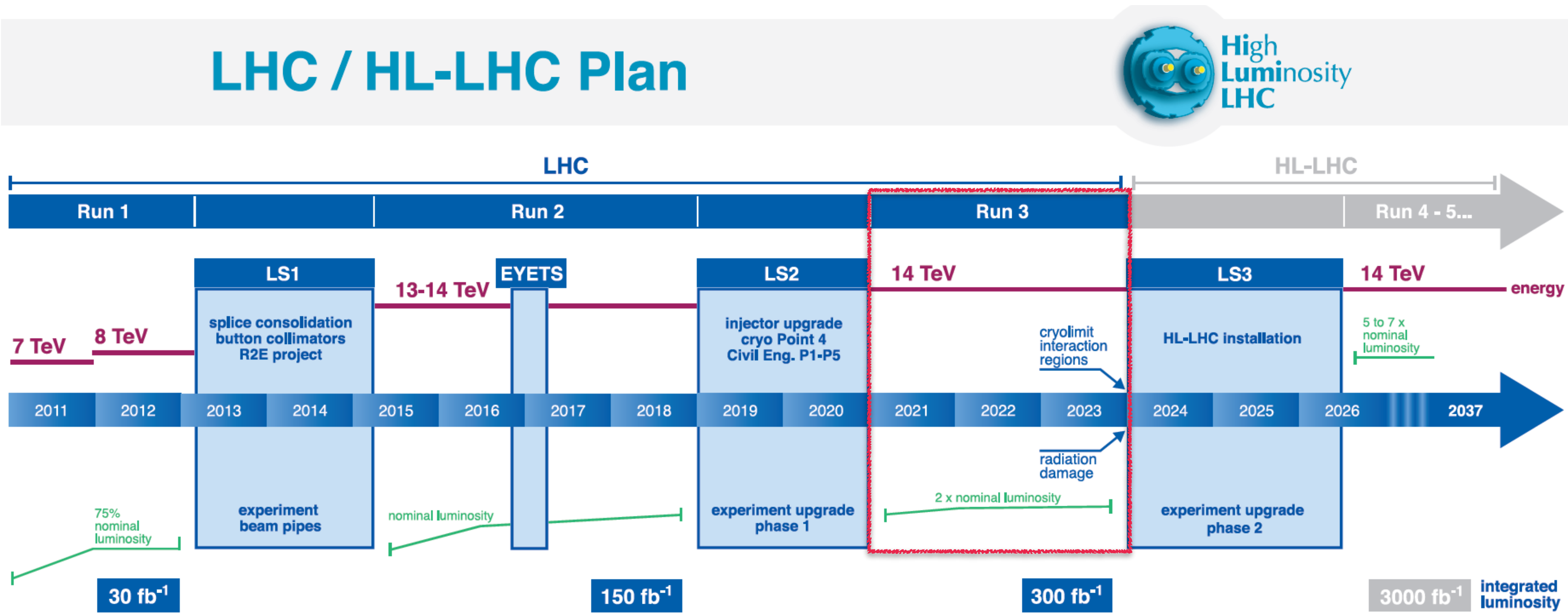
LHC Roadmap

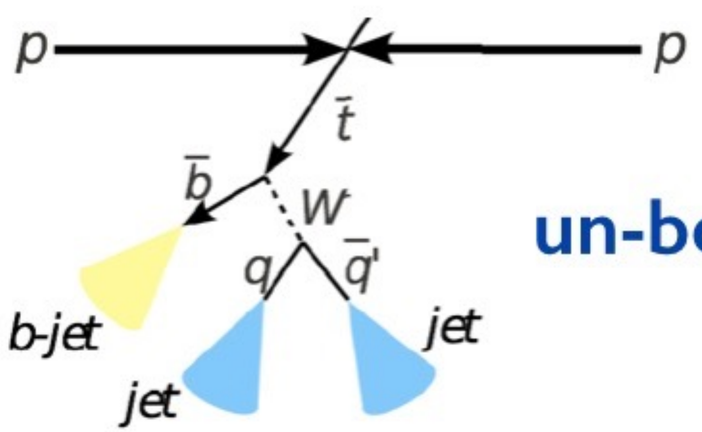


LHC / HL-LHC Plan
High Luminosity LHC
LHC
HL-LHC
Run 1
Run 2
Run 3
Run 4 - 5...
LS1
EYETS
LS2
LS3
7 TeV
8 TeV
13-14 TeV
14 TeV
14 TeV
energy
splice consolidation
button collimators
R2E project
injector upgrade
cryo Point 4
Civil Eng. P1-P5
cryolimit
interaction
regions
HL-LHC installation
5 to 7 x
nominal
luminosity
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2037
radiation
damage
2 x nominal luminosity
75%
nominal
luminosity
experiment
beam pipes
nominal luminosity
experiment upgrade
phase 1
experiment upgrade
phase 2
30 fb-1
150 fb-1
300 fb-1
3000 fb-1
integrated
luminosity

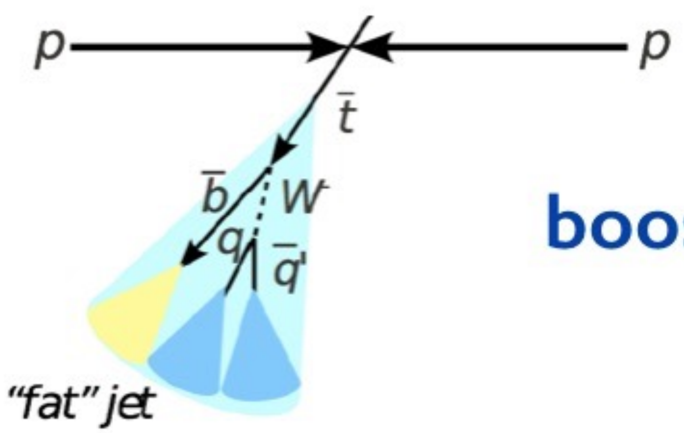
Motivation

- W, Z and H bosons, top quarks produced by pp collisions
- Used in precision measurements and beyond the SM searches
  - non-isolated leptons
  - overlapping jets that contain substructure from the decay of SM particles
  - Bottom quarks that merge with nearby jets

} *boosted topologies*



un-boosted



boosted

The higher the energy the more the boost!

Challenges at High Luminosity

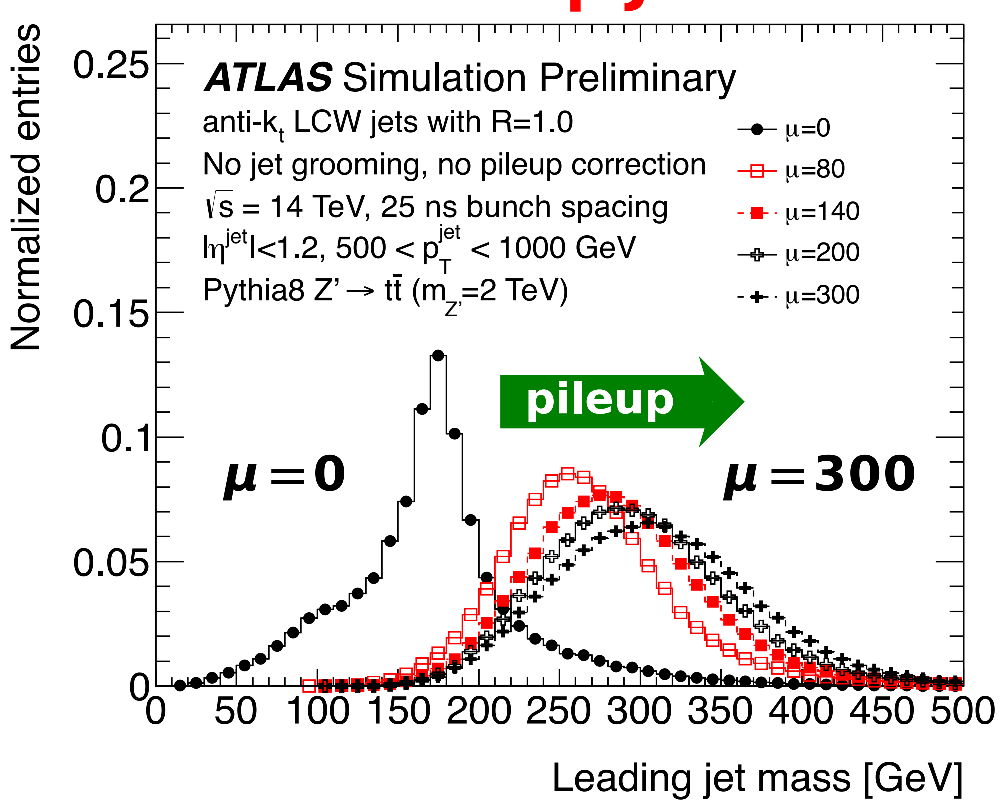
- Pileup is major challenge
  - ☑ extra energy
  - ☑ degraded jet and E_T^{miss} resolution due to event-by-event and local fluctuations
  - ☑ additional jets

$$\langle\mu\rangle = \frac{L \times \sigma_{\text{inel.}}}{N_{\text{bunch}} \times f_{\text{LHC}}},$$

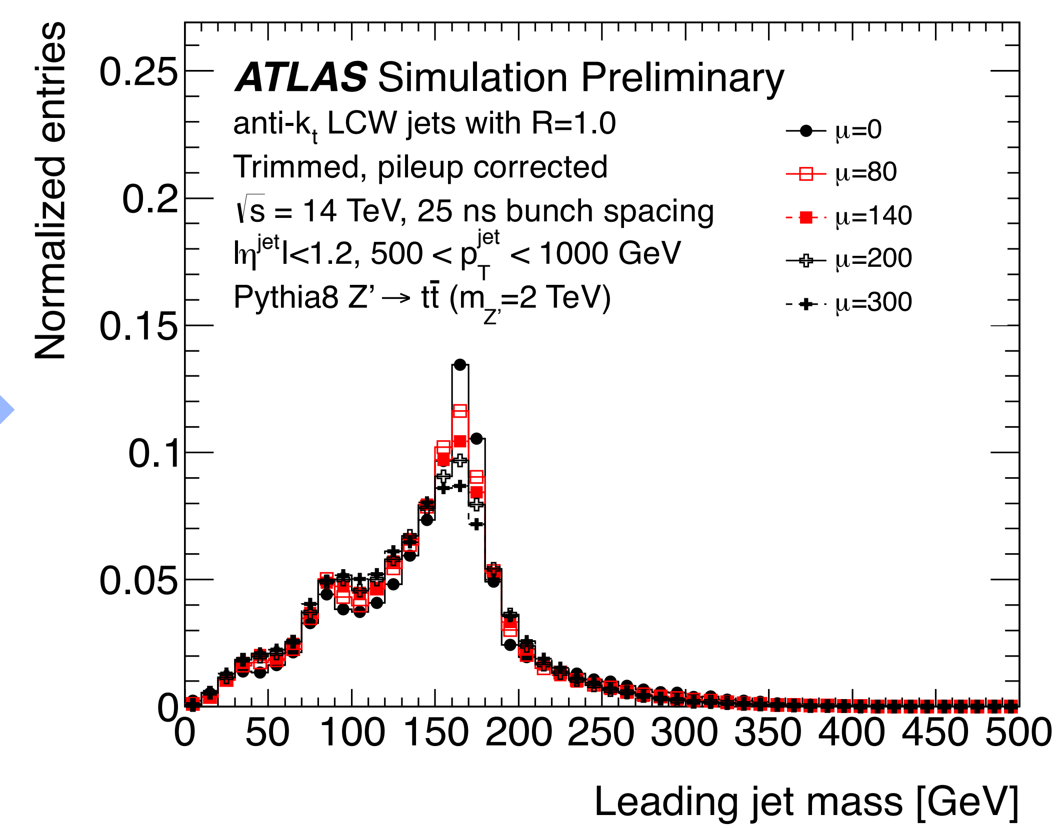
mean number of inelastic *pp* interactions per bunch crossings

σ= total inelastic pp xsec
f: average frequency of bunch crossings

Boosted Top Jet Mass

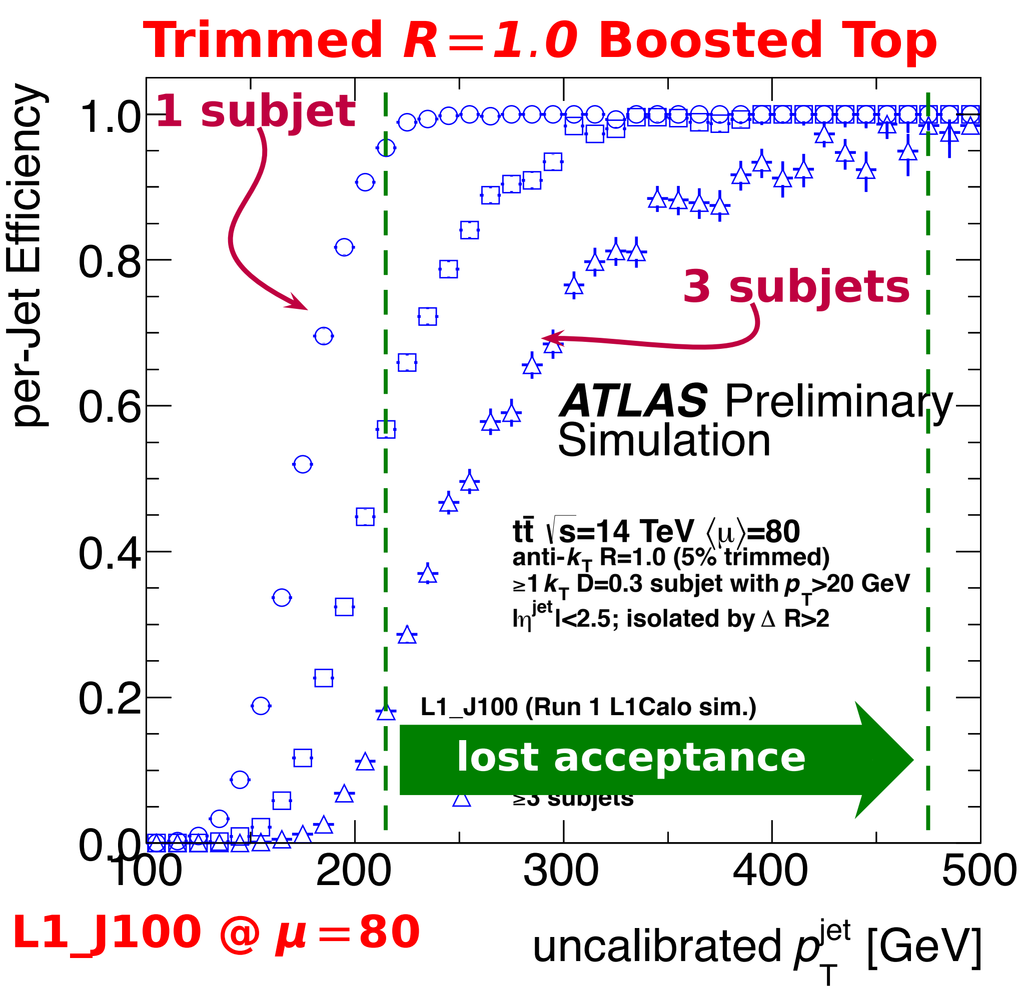


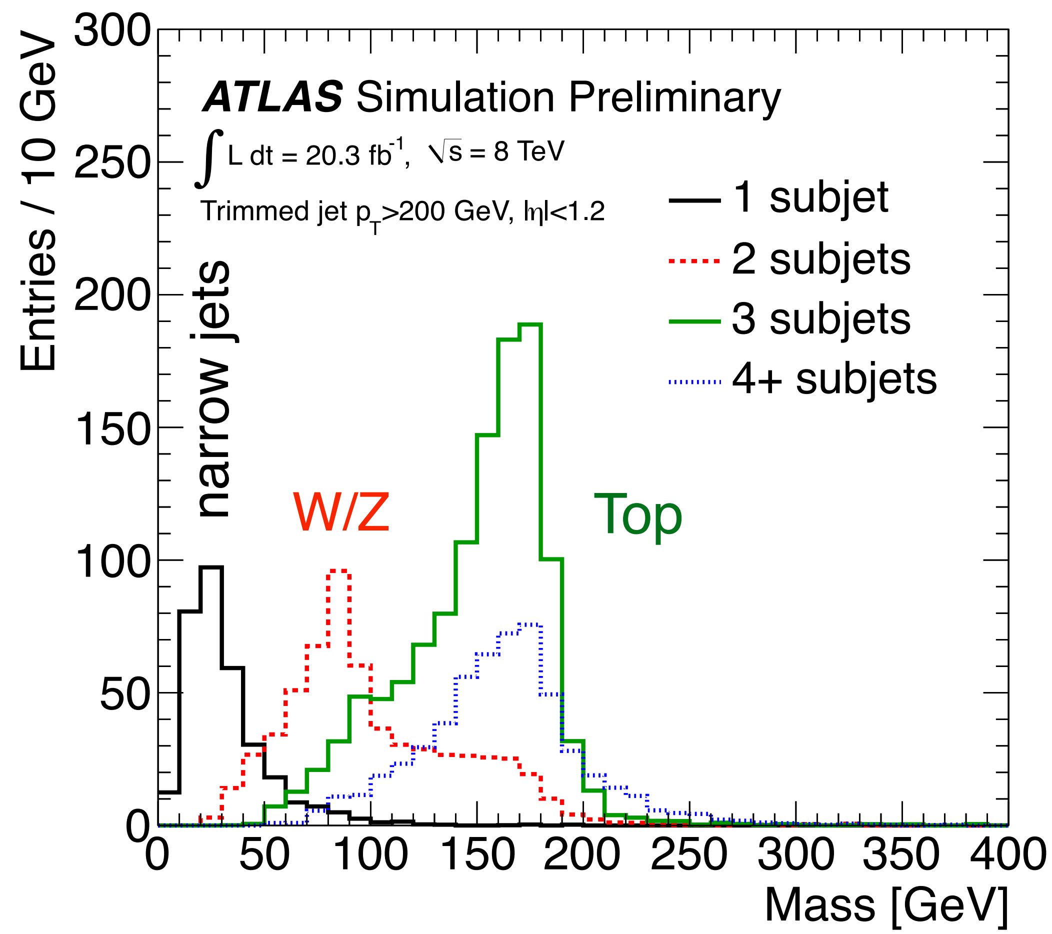
trimming pileup subt.



Challenges at High Luminosity

- Identification of events with jet substructure
  - current trigger insufficient for jets with significant substructure!
  - large-R jet acceptance in HLT restricted due to L1 requirements
  - L1 trigger designed for narrow jets in Runs 1 and 2





Motivation: L1Jet Trigger Acceptance

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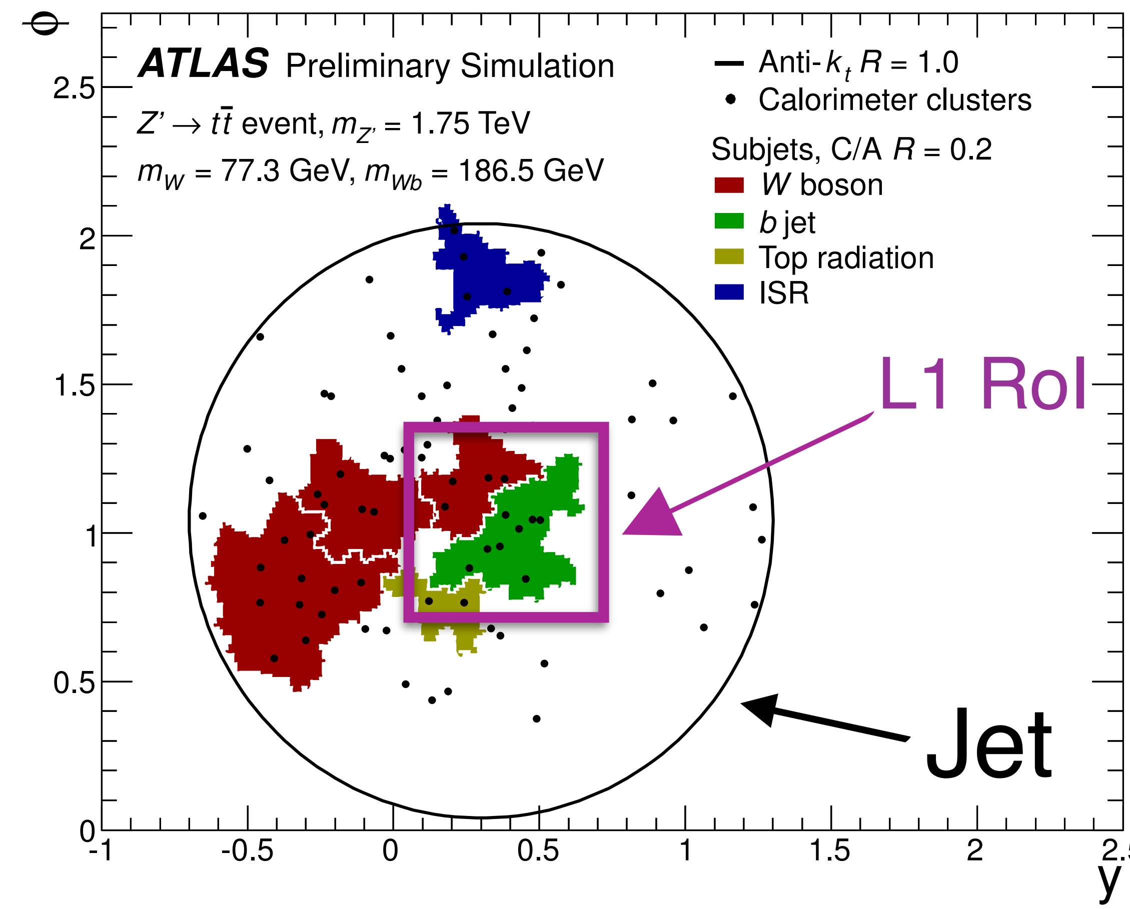
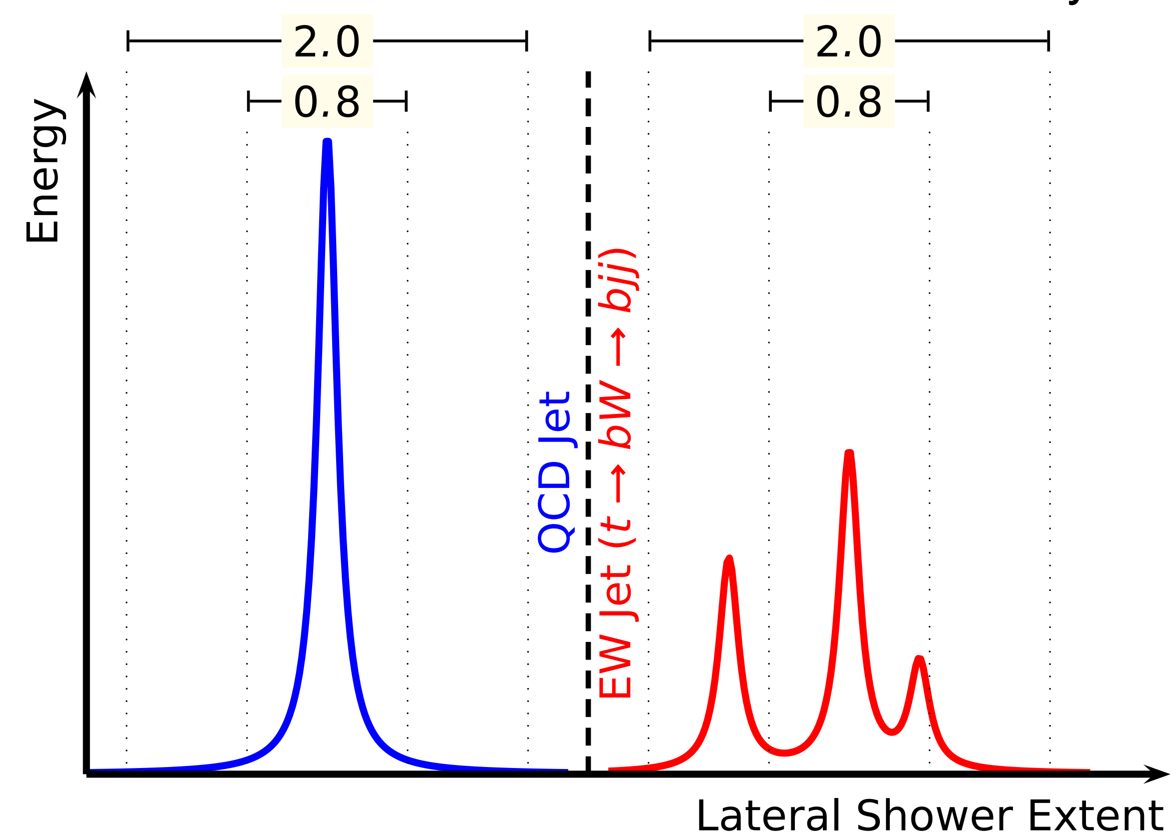
- ATLAS L1 Jet Trigger designed for narrow jets, with limited acceptance for large objects
  - ΔηxΔϕ: 0.8x0.8 in Runs 1 and 2
- Need significantly larger RoI to avoid biasing against boosted objects

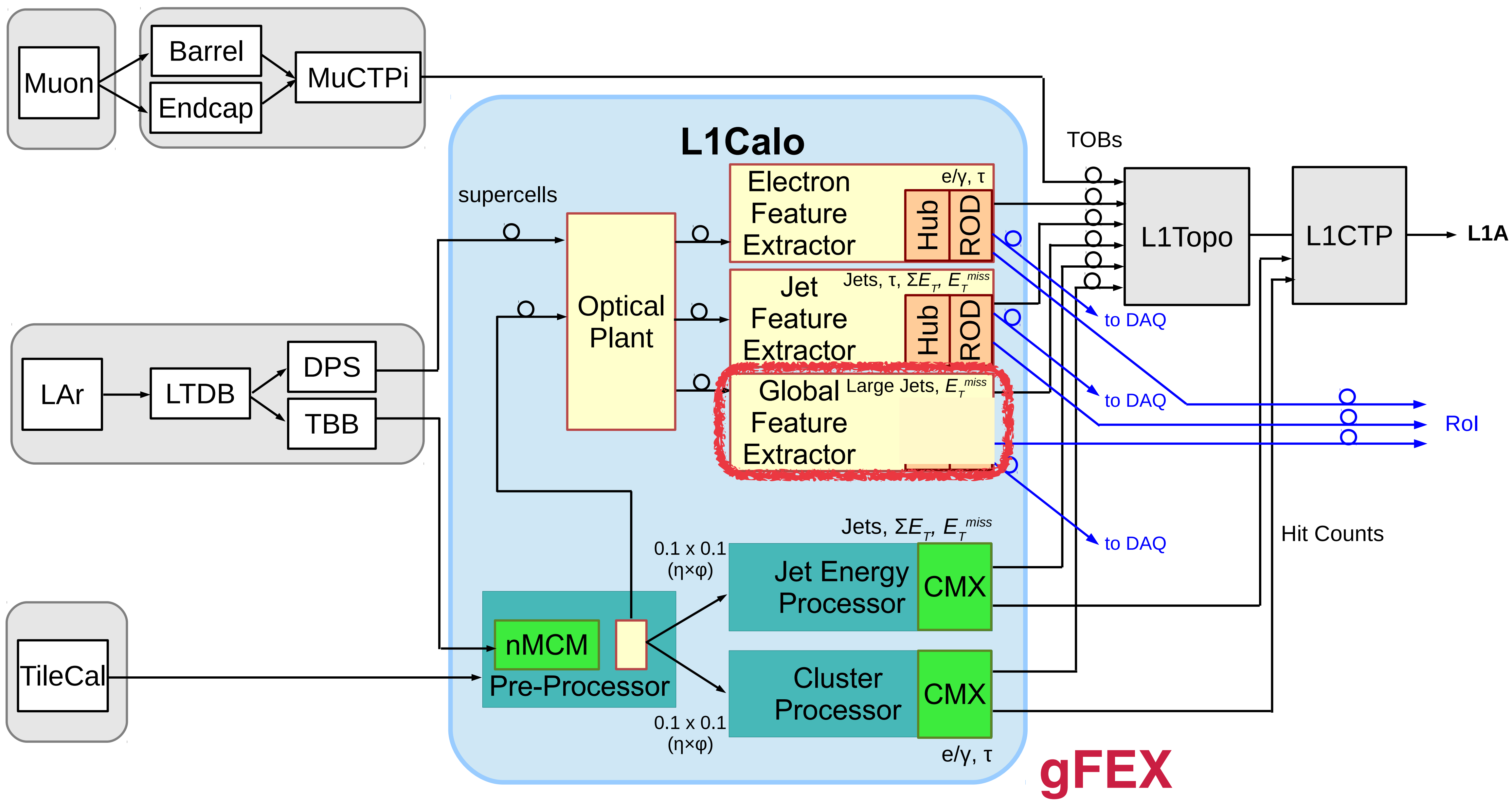


Consider 2 jets with equal pT
- a 0.8x0.8 RoI contains
  - most of QCD jet
  - fraction of EW jet
- a 2.0x2.0 RoI would have comparable efficiency for both!
  - with much higher trigger rate



Phase I L1 Calorimeter Upgrade

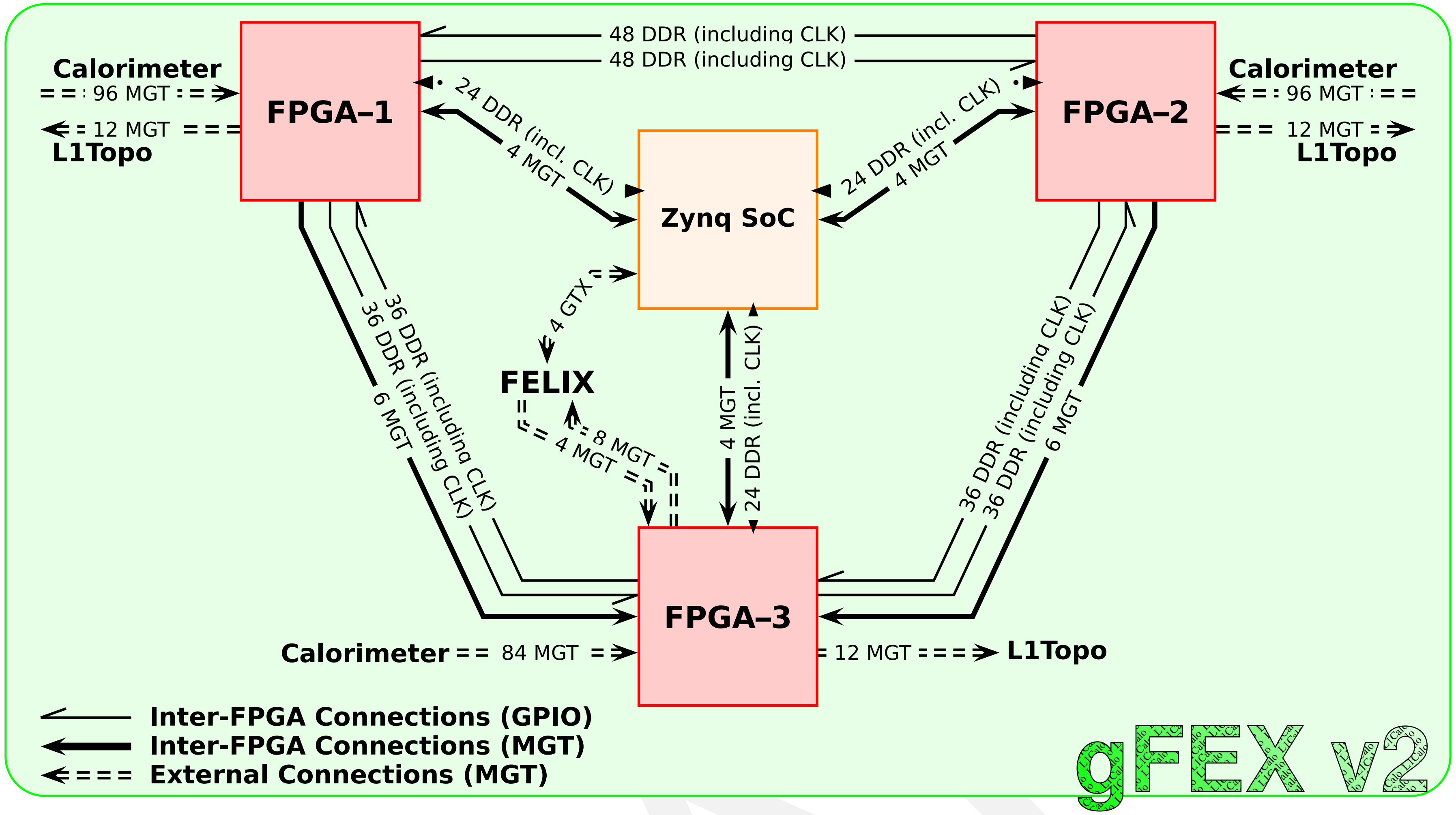
- L1 Calorimeter during Run 3
  - new LAr calorimeter trigger electronics
  - new Feature Extractors for electrons/taus, jets and **large (boosted)** objects



global Feature Extractor (gFEX)

- Entire calorimeter on a single module!
  - receives ΔηxΔφ=0.2x0.2 calorimeter towers
- Identifies events with large-radius jets
  - improves acceptance for boosted objects
  - jet-level pile-up subtraction
  - can reject QCD jets compared to EW jets
  - subjet multiplicity
  - substructure variables
- Calculates global event variables
  - E_T^{miss}, centrality..
  - jets-without-jets observables

  http://arxiv.org/abs/1310.7584



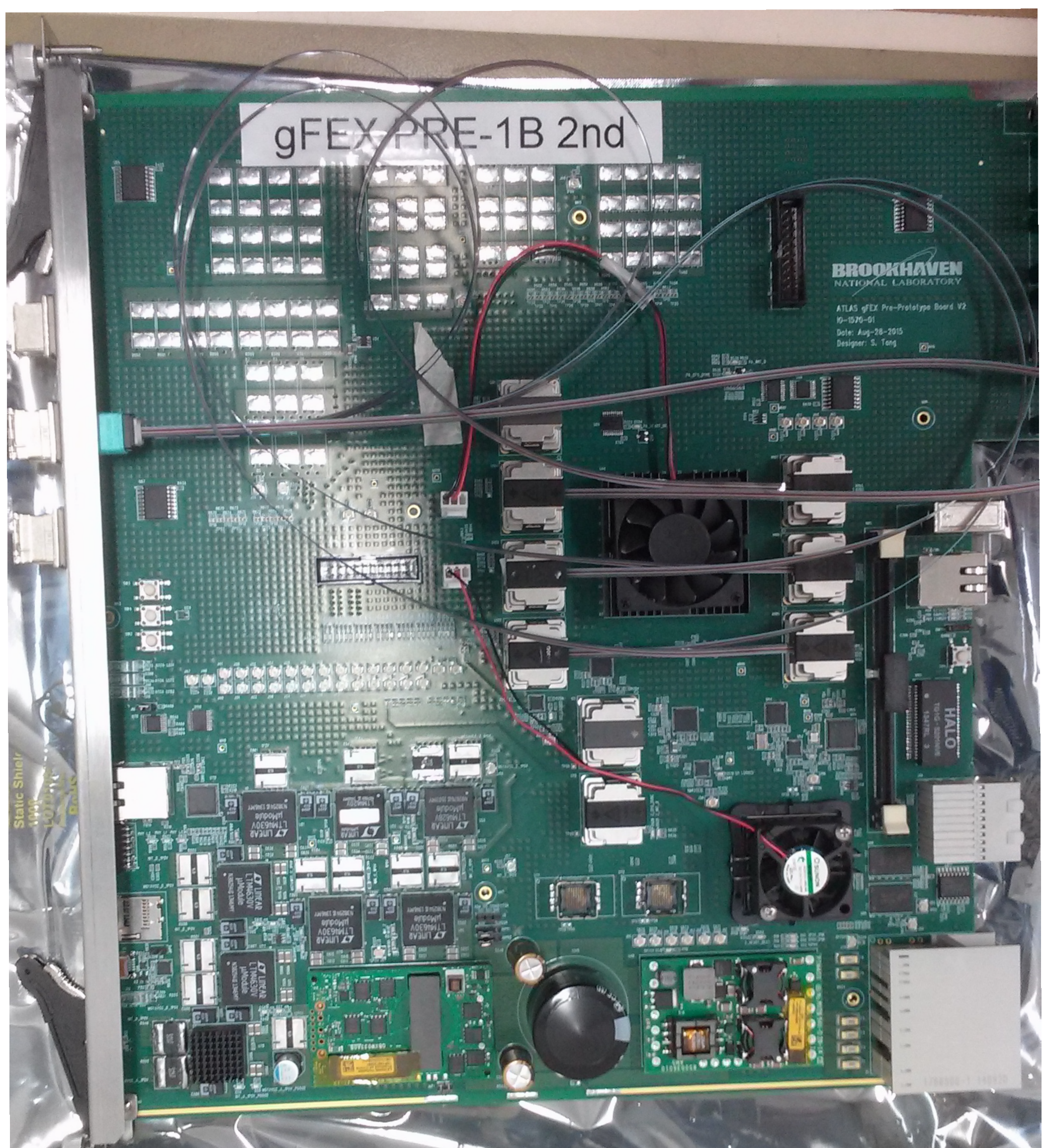
gFEX prototypes

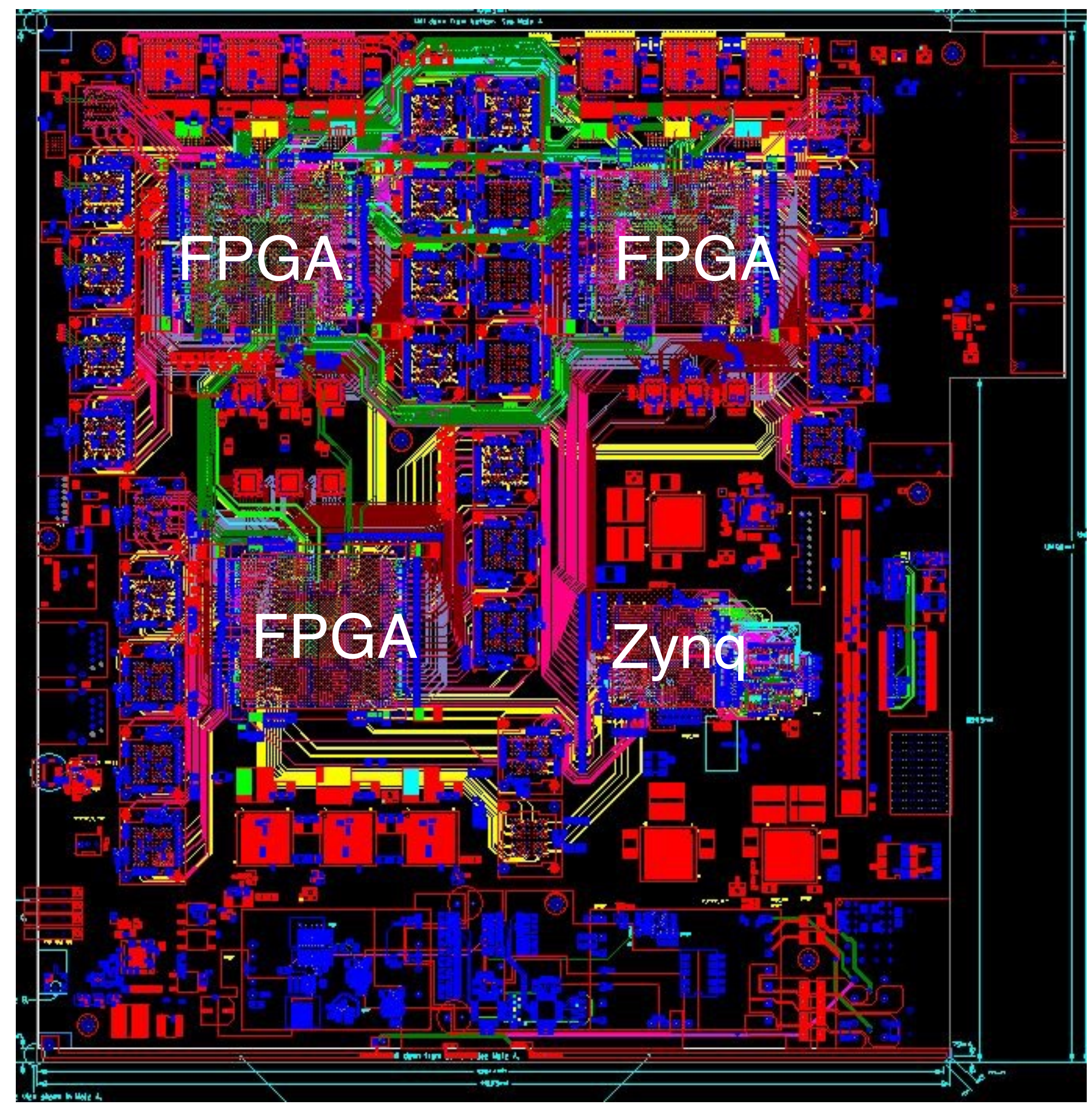
Prototype v1.b

- 1 Virtex-7 FPGA
- Zynq SoC
- board infrastructure
- test components, interfaces, routing

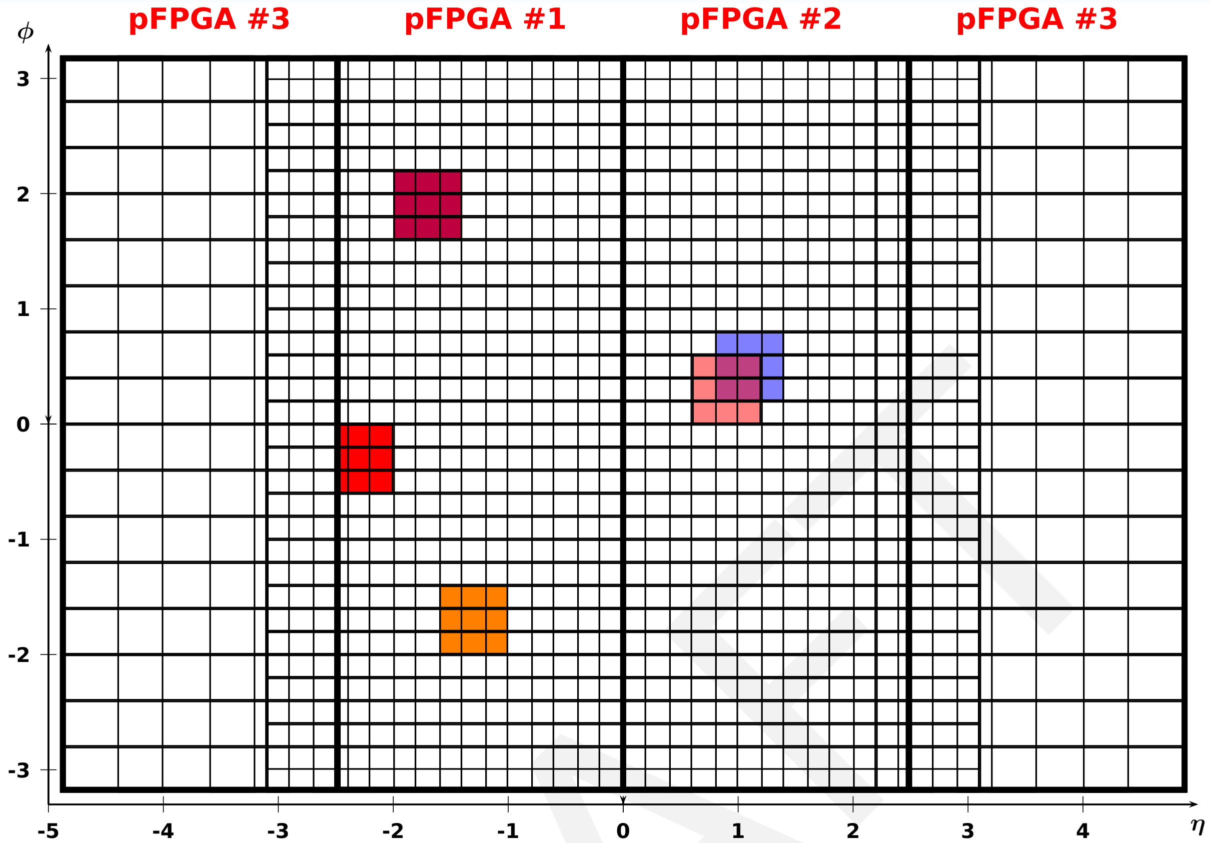
Prototype v2

- 3 Virtex-Ultrascale FPGA
- Zynq SoC
- board layout 100% ready
- submitted for manufacture



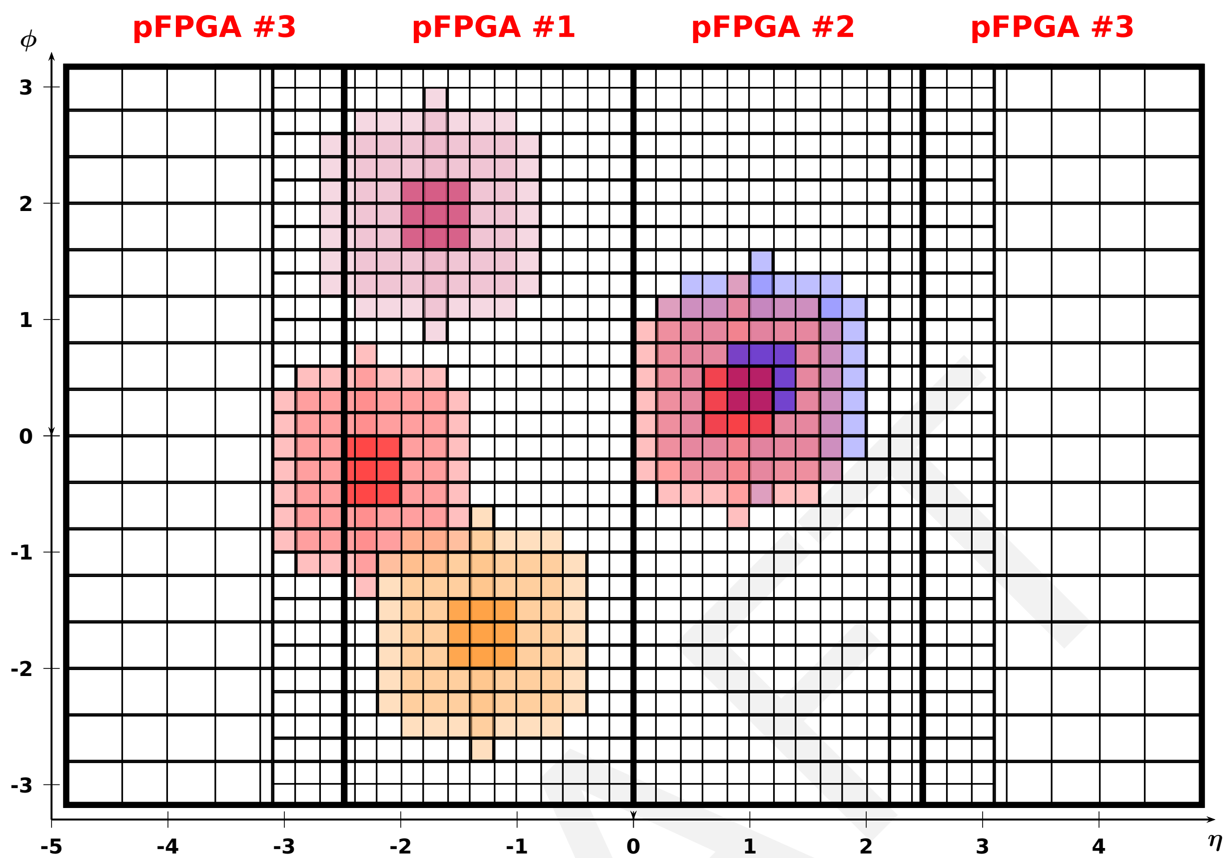


Finding Large Radius Jets



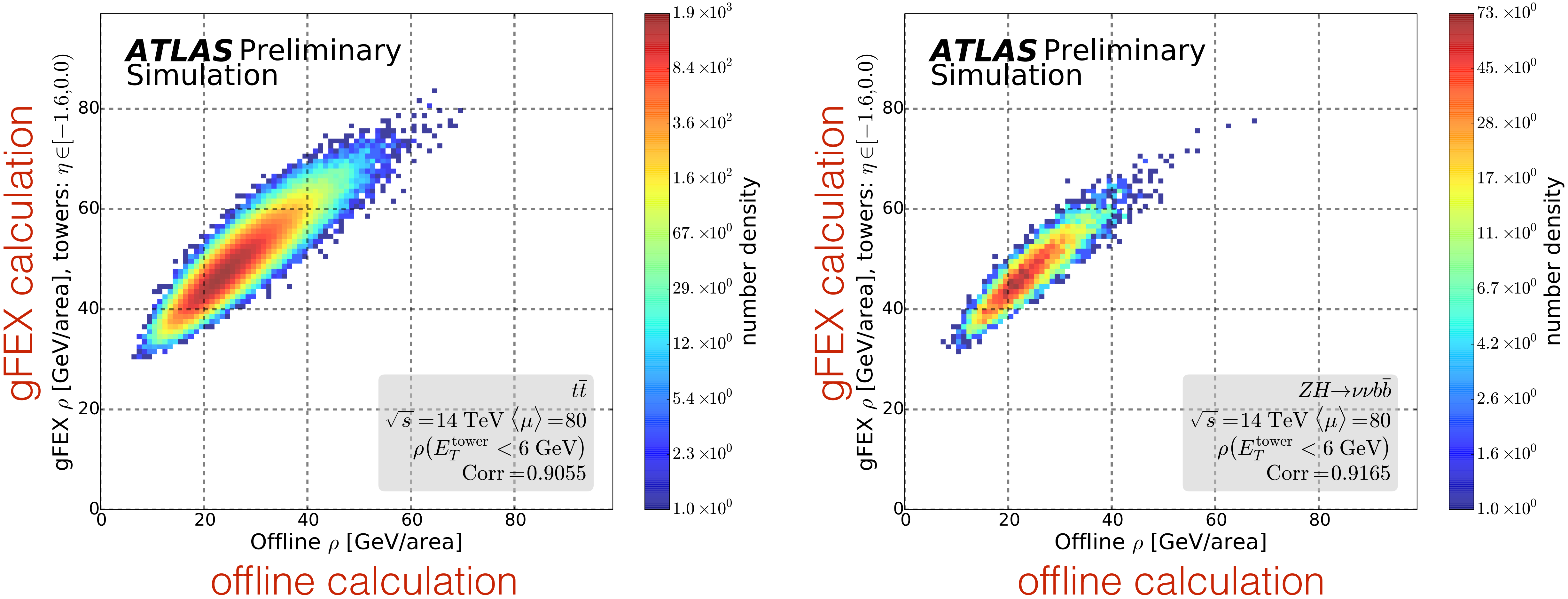
Step 1: Find seeds. Seeds are towers with energy above a set E_T threshold.

Step 2: Sum energy from neighboring towers. Estimate pile-up energy. Jets allowed to overlap to maximize efficiency.



Step 3: Subtract pile-up energy per jet and join results to provide large R-jet. The final result is stored on the processing FPGAs.

Area based pile up subtraction



- ρ calculated on gFEX highly correlated with the offline value
- Similar pileup suppression technology can be applied as in standard offline

median pT density ρ

ρ ~ to pileup activity

$$\rho = \mathrm{median}\left\{\frac{p_{T,i}^{\mathrm{jet}}}{A_i^{\mathrm{jet}}}\right\},$$

A: jet area four momentum

Expected performance in Run3

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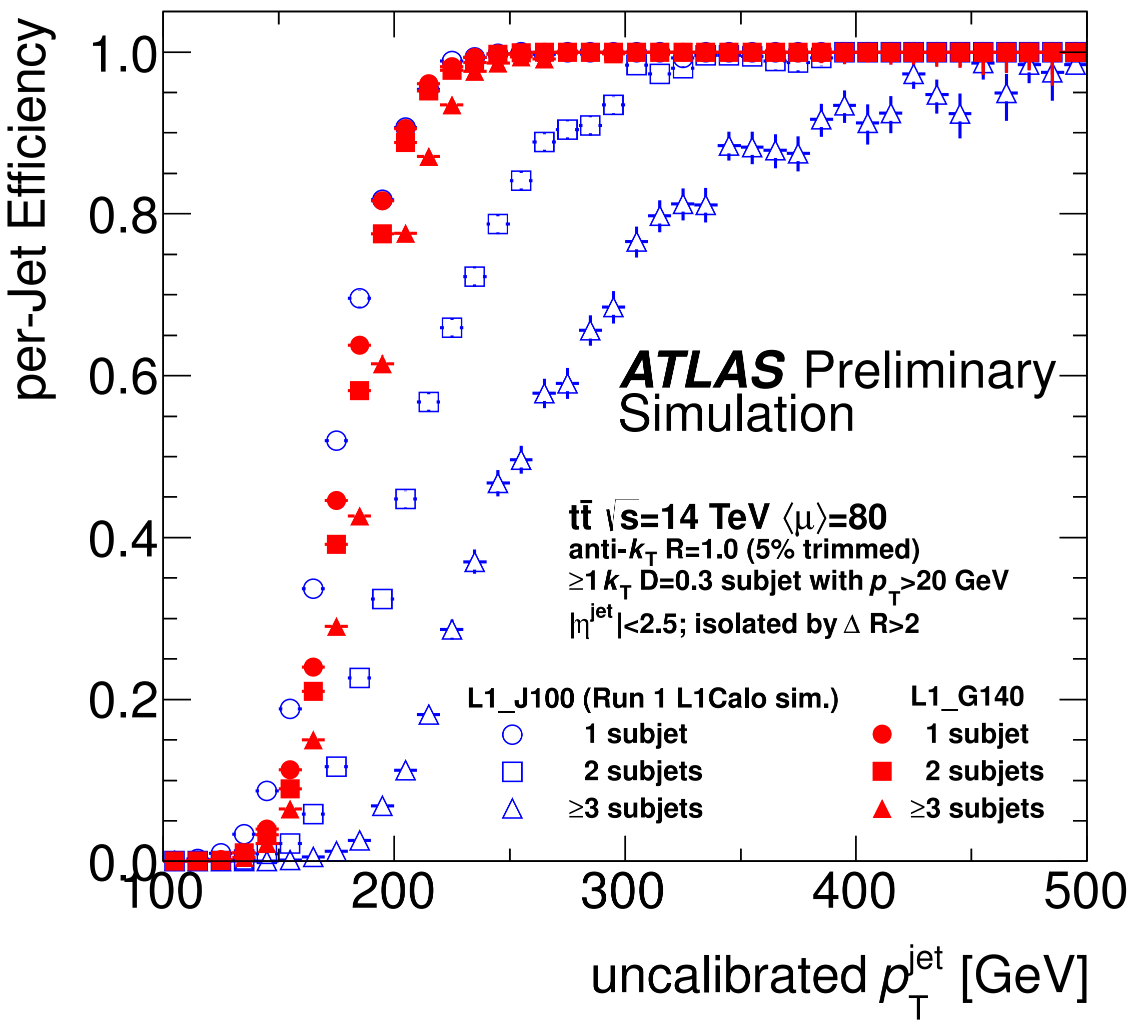
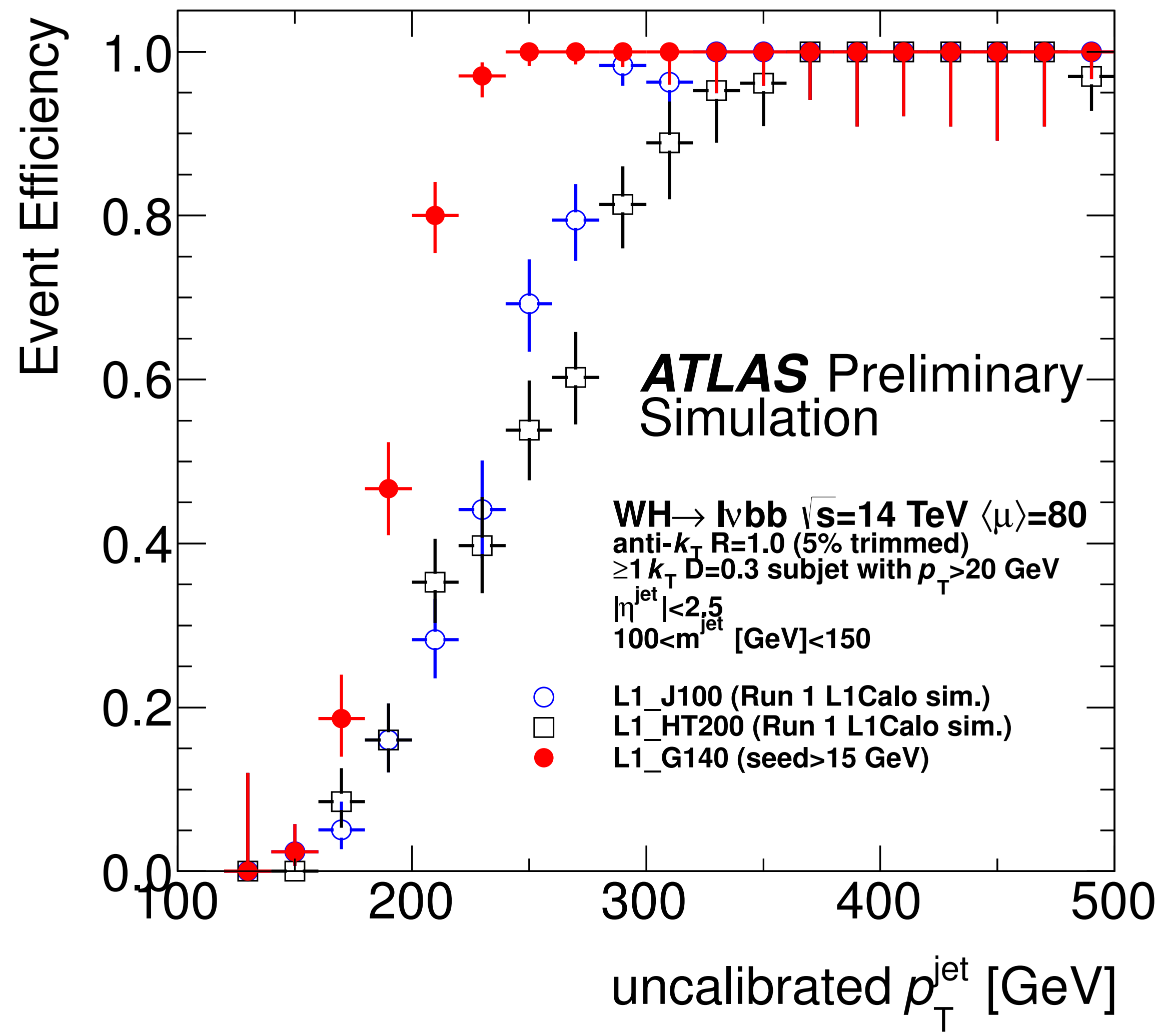
Increase trigger efficiency for *Fat-jets* or boosted objects in ATLAS





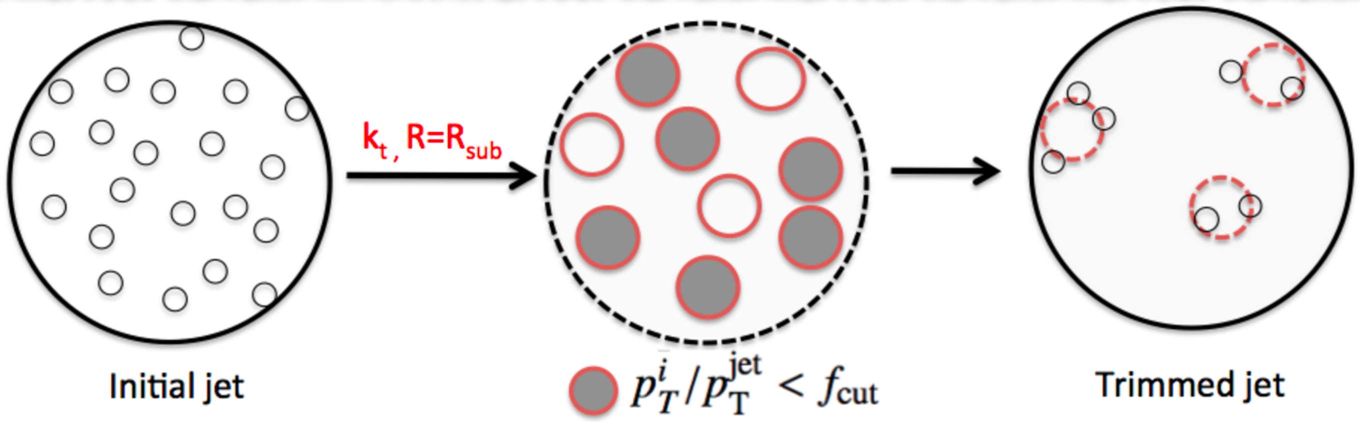
Conclusions

- The study of hadronic decays of high-pT bosons and fermions is a critical and vital part of the ATLAS physics program
- The high luminosity expected from the LHC necessitates increased trigger rejection to preserve acceptance
- The gFEX adds capability and flexibility to the ATLAS L1 Trigger
  - efficient large-*R* jet finding
  - pileup suppression
  - "jets-without-jets" and other event shapes
  - centrality-dependent Heavy-Ion triggers
  - many possibilities for improved rejection using jet substructure
- First link speed tests between L1 and Calorimeter systems have been finished, allowing us to continue smoothly to the next steps

back up slides

Jet Trimming

Trimming



Compares pT(constituients) with pT(jet) – removes soft components which are primarily from UI & PU

http://arxiv.org/abs/1306.4945

gFEX Interfaces and processing chain

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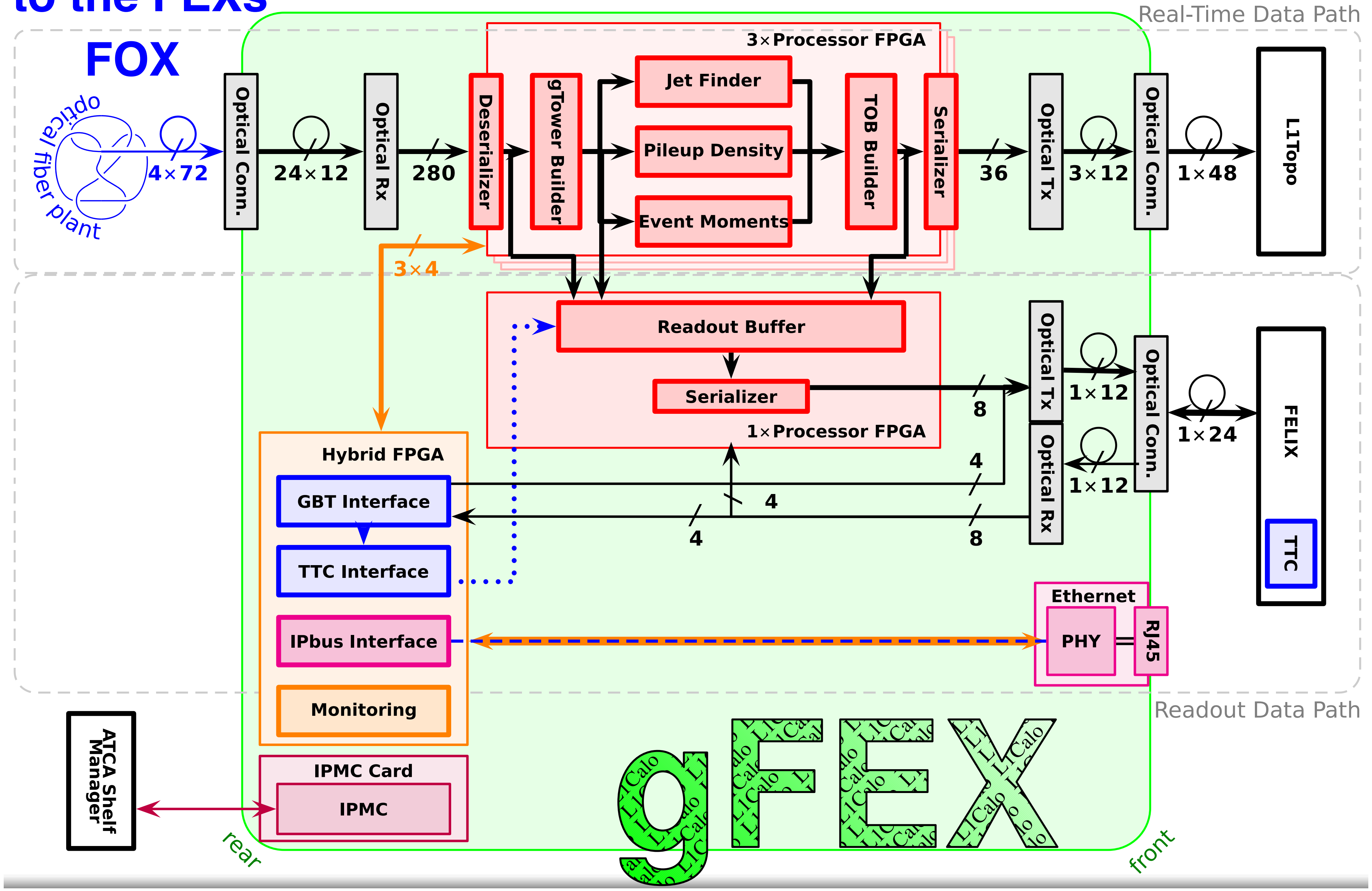
Digitized signals transmitted optically to the FEXs

Data processing: algorithms run on FPGAs



L1Topo

Data and clock transmitted via FELIX

Zynq provides configuration, slow control, monitoring and playback for gFEX