Trigger Level Analysis data preparation through co-processors

CERN openlab Summer Student Programme Lightning talks

Emilly Raiane Rodrigues

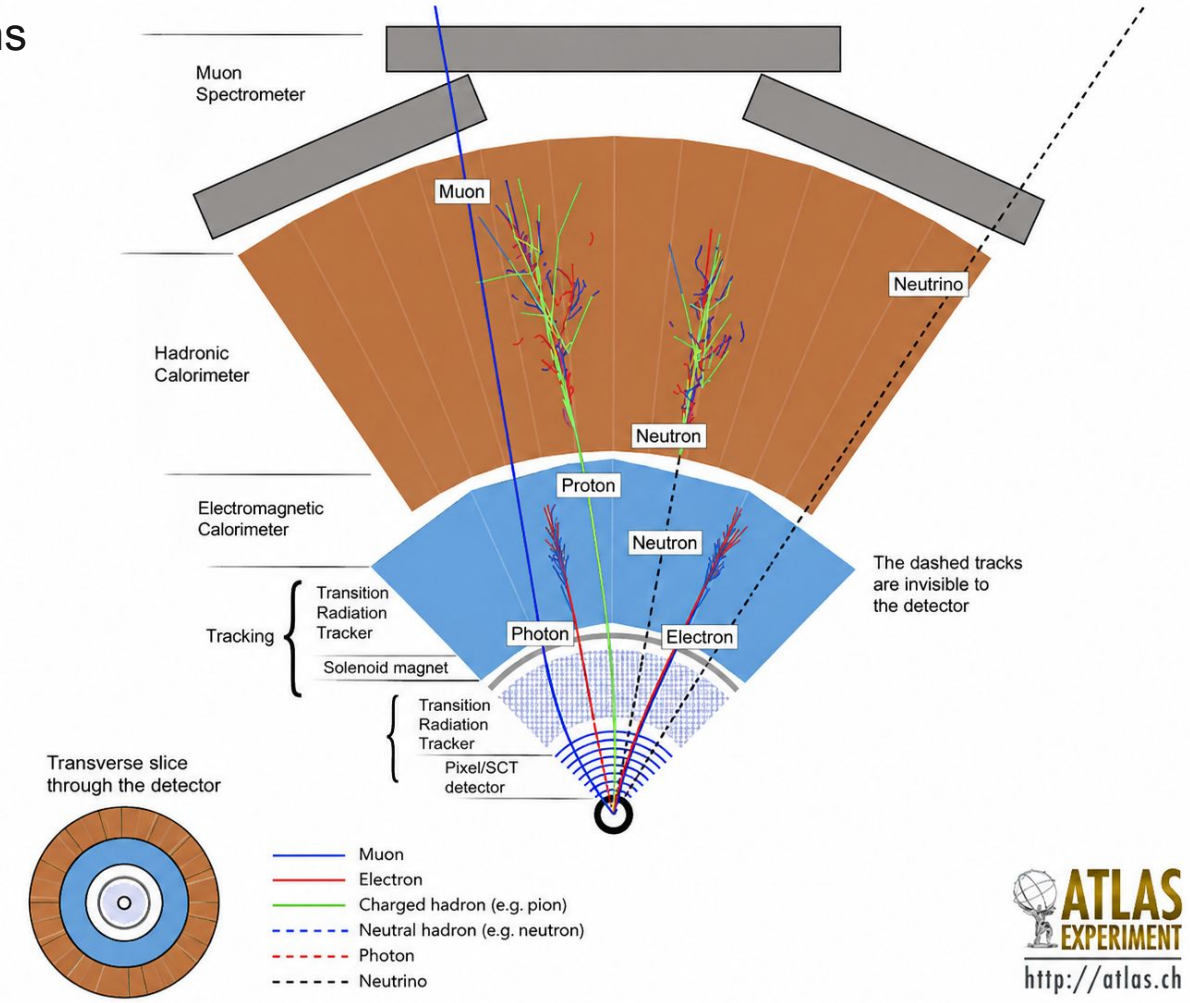
Ioannis Xiotidis
Noah Clarke Hall

Jet Reconstruction

- Many jets of particles are produced during collisions
- Jets leave energy patterns in the calorimeter
- From this pattern, we reconstruct the jets

Why?

- Better understand the physics of the collision



Jet Reconstruction at Trigger Level

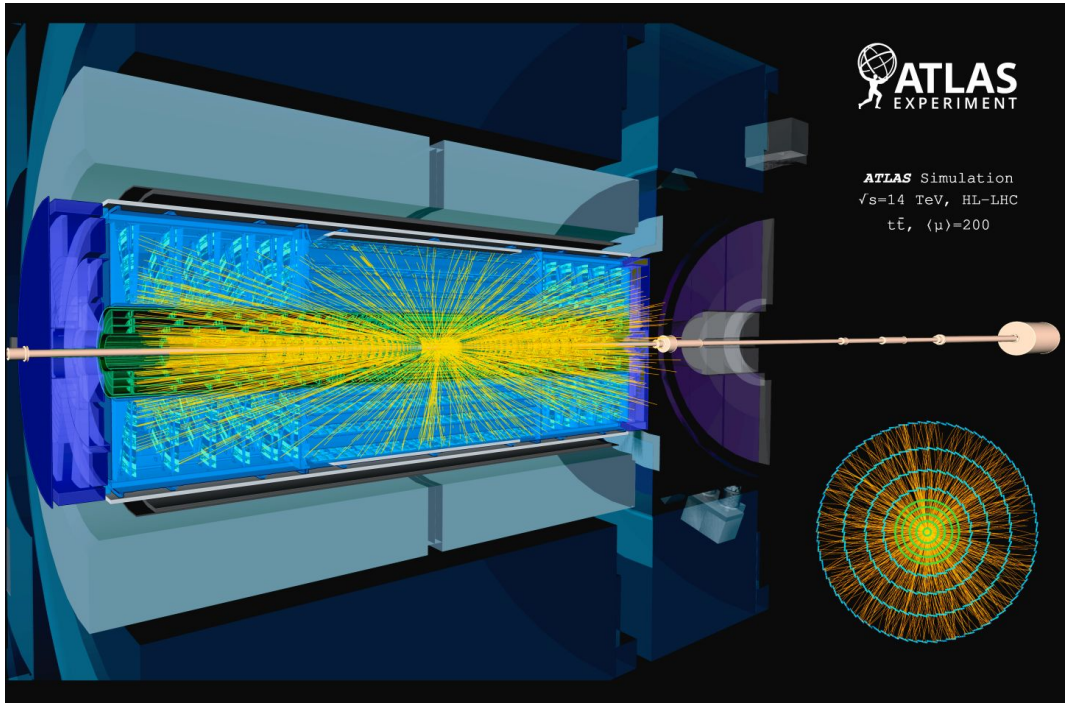
Jet reconstruction become even more important at trigger lever

Why?

- High-Luminosity LHC bring a new challenge
- Large number of collisions at the same time
- Trigger will receive a huge amount of data at **40 MHz**
- **10 µs** to decide if the event should be kept

We need to extract the important information as quickly as possible

Why not find the jets directly instead of getting all the calorimeter energies?



The project

ML model to compress calorimeter data into jet list

Input

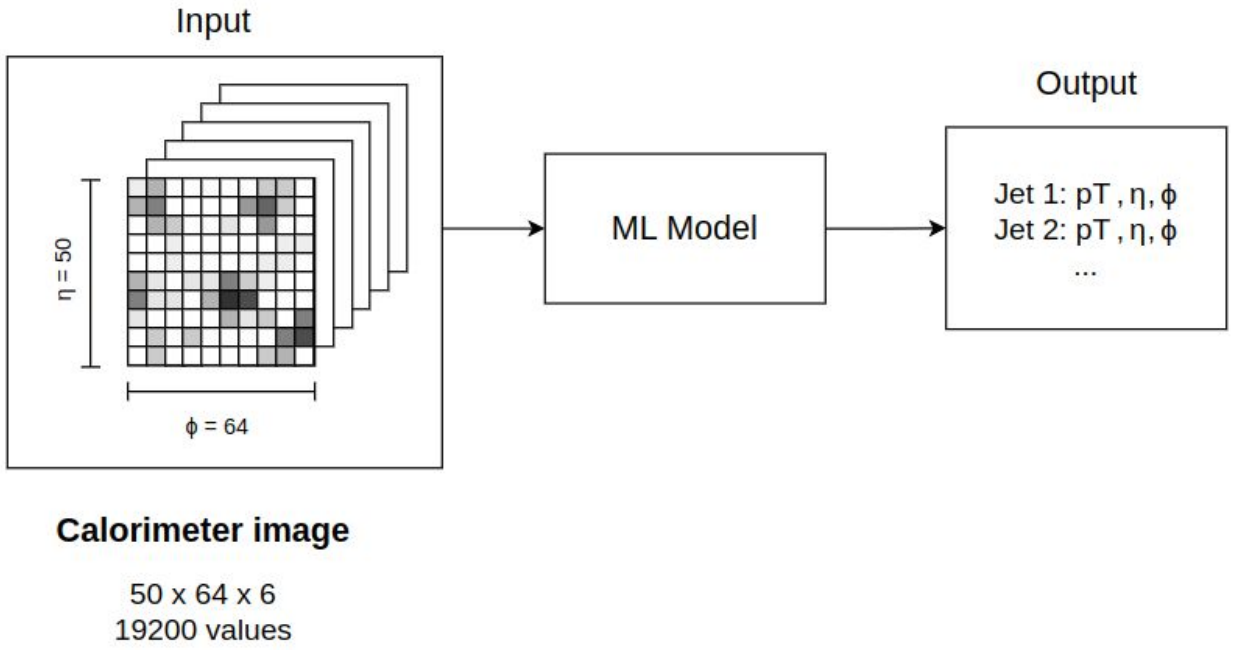
- Calorimeter image
- Each cell represents the energy deposited

The model

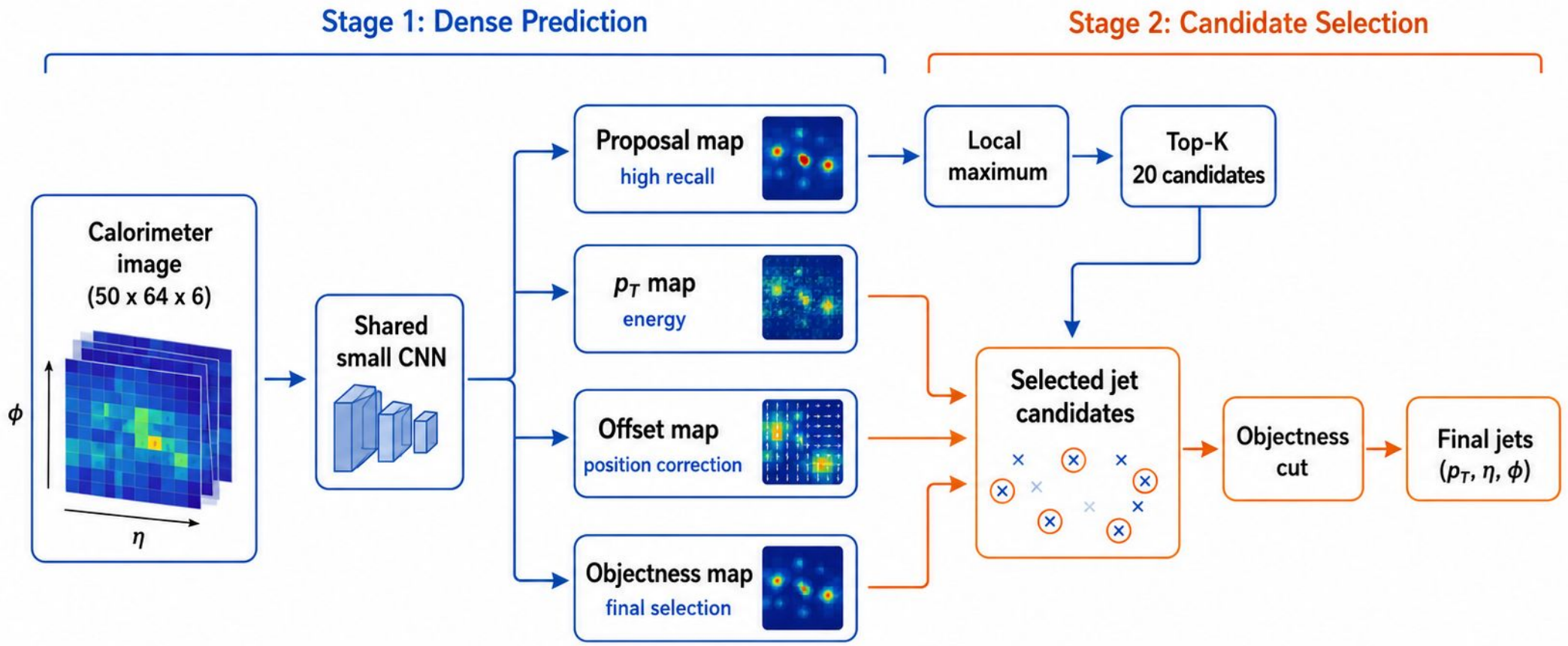
- Learns energy patterns across the layers
- Finds the jet signatures
- Compresses the calorimeter information

Output

- A list of reconstructed jets

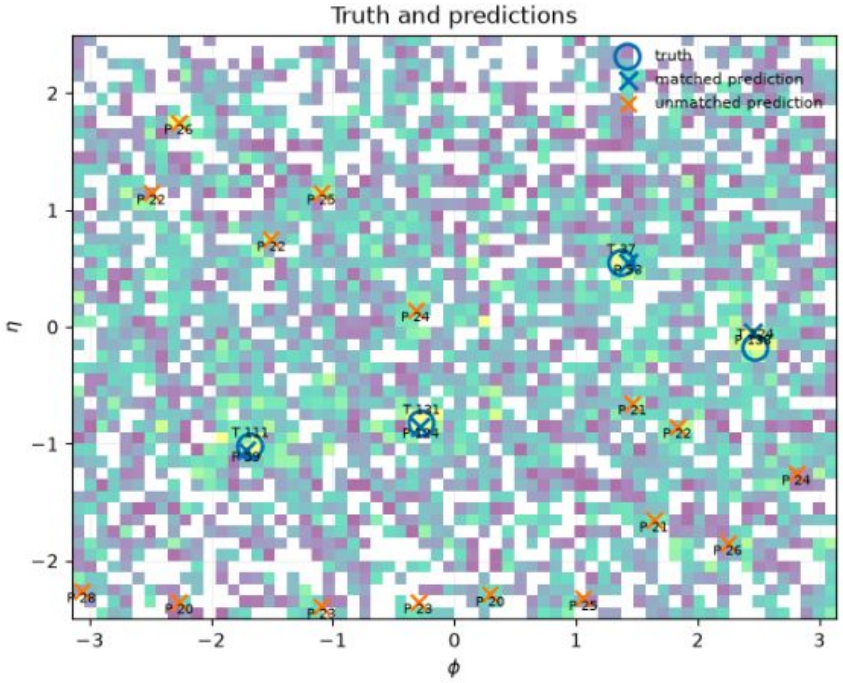


The Model


Stage 1: Dense Prediction
Stage 2: Candidate Selection
Calorimeter image (50 x 64 x 6)
ϕ
η
Shared small CNN
Proposal map
high recall
p_T map
energy
Offset map
position correction
Objectness map
final selection
Local maximum
Top-K 20 candidates
Selected jet candidates
Objectness cut
Final jets (p_T, η, ϕ)

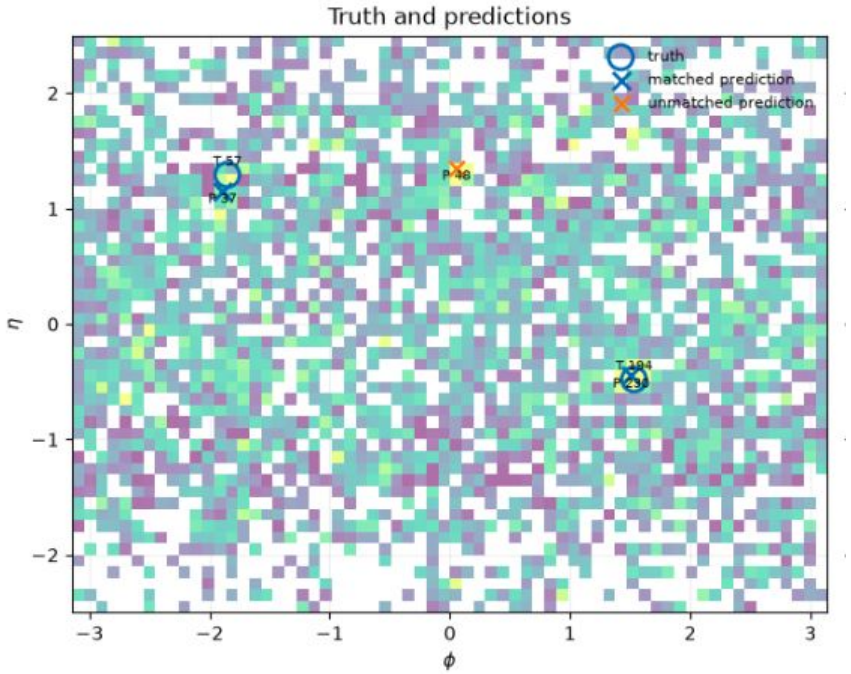
Current Results

Without objectness selection



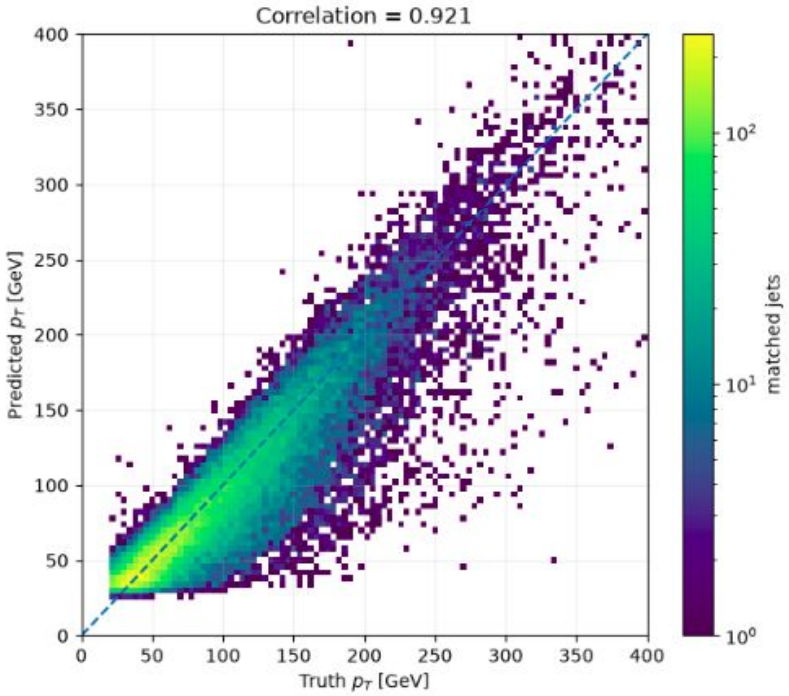
Found ~95% of truth jets
Cost: ~4× more jets per event
High efficiency, but many fake jets

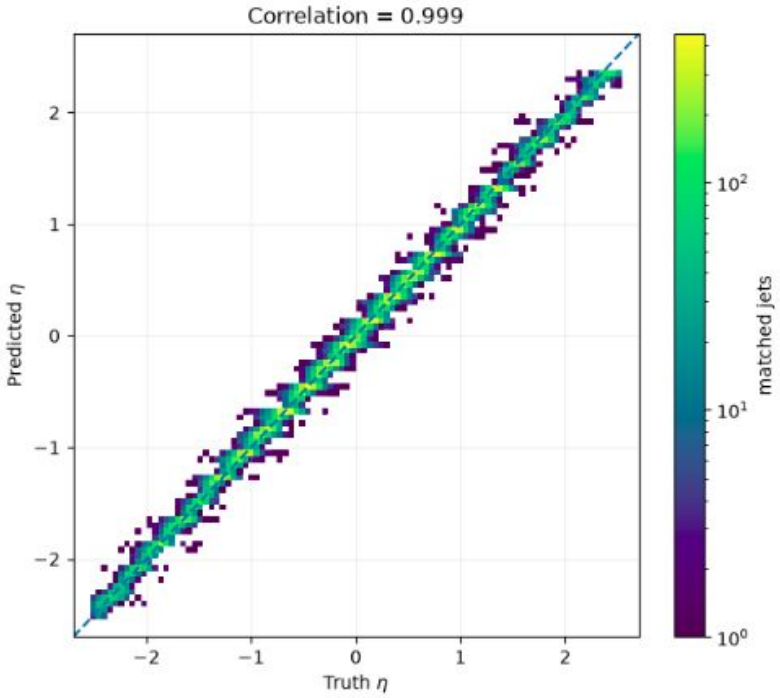
With objectness selection

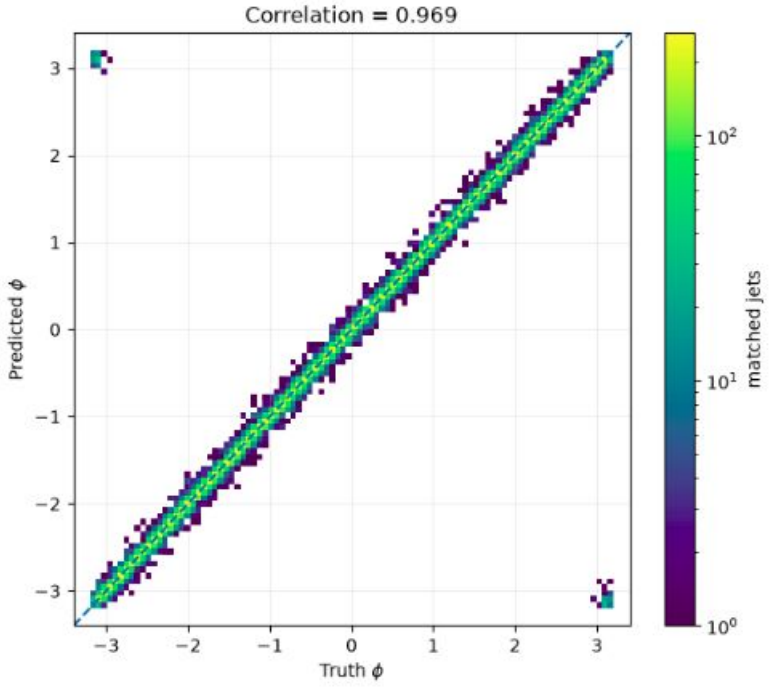


Found ~78% of truth jets found
~1.2× more jets per event
Fewer fake jets, but some truth jets are lost

Quality of Reconstruction

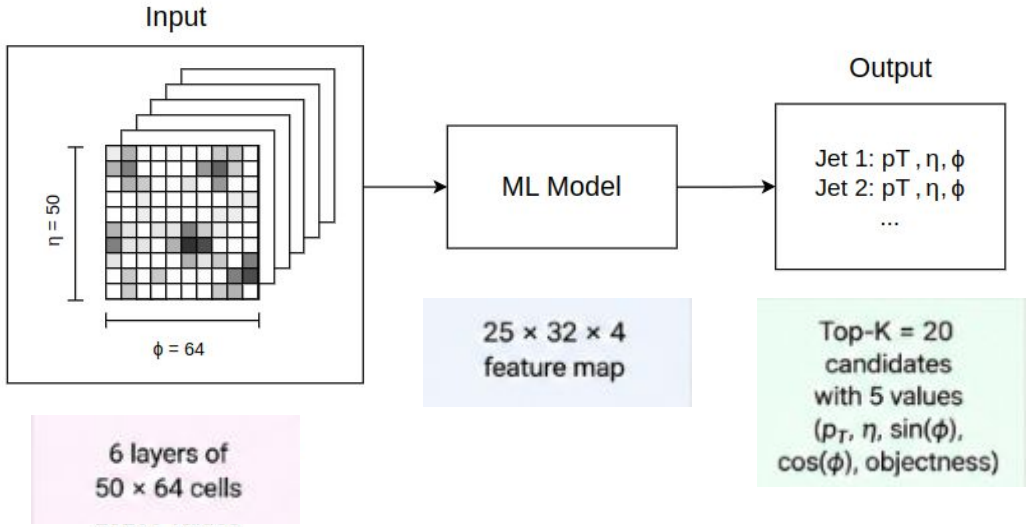






Data Reduction Factor

Stage	Values per event	Total throughput at 40 MHz	Throughput per board (49)	Reduction factor
50x64x6	19200	24.576 Tbps	502 Gb/s	1x (reference)
25x32x4	3200	4.096 Tbps	83.6 Gb/s	6x
20x5	100	128 Gbps	2.6 Gb/s	192x
Required			20 Gb/s	25x



- Extracting all calorimeter image: 502 Gb/s
- Worst case (20 predictions per event) : 2.6 Gb/s
- Almost 200x reduction

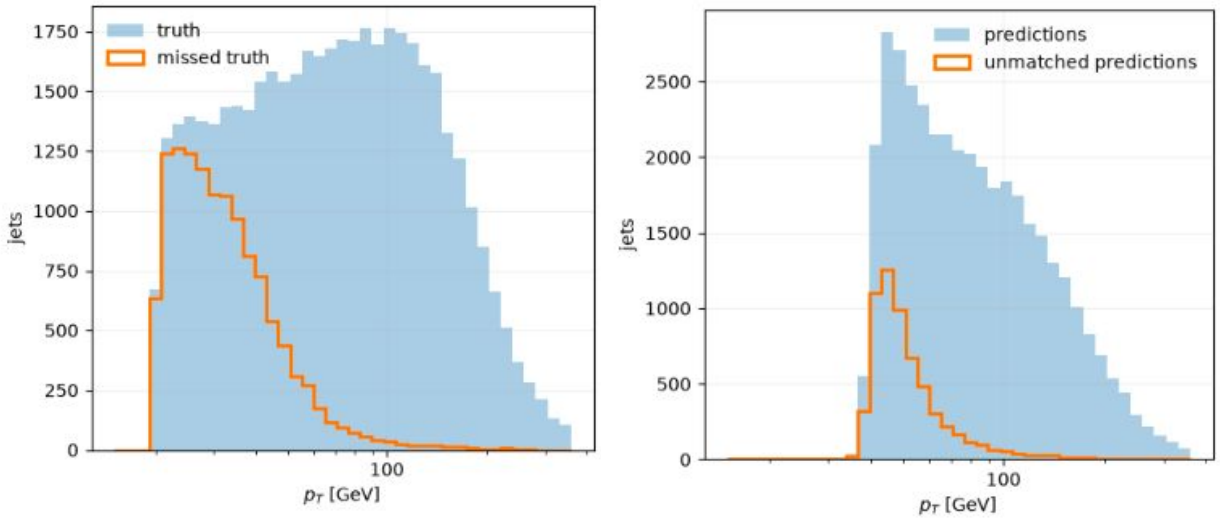
Next step

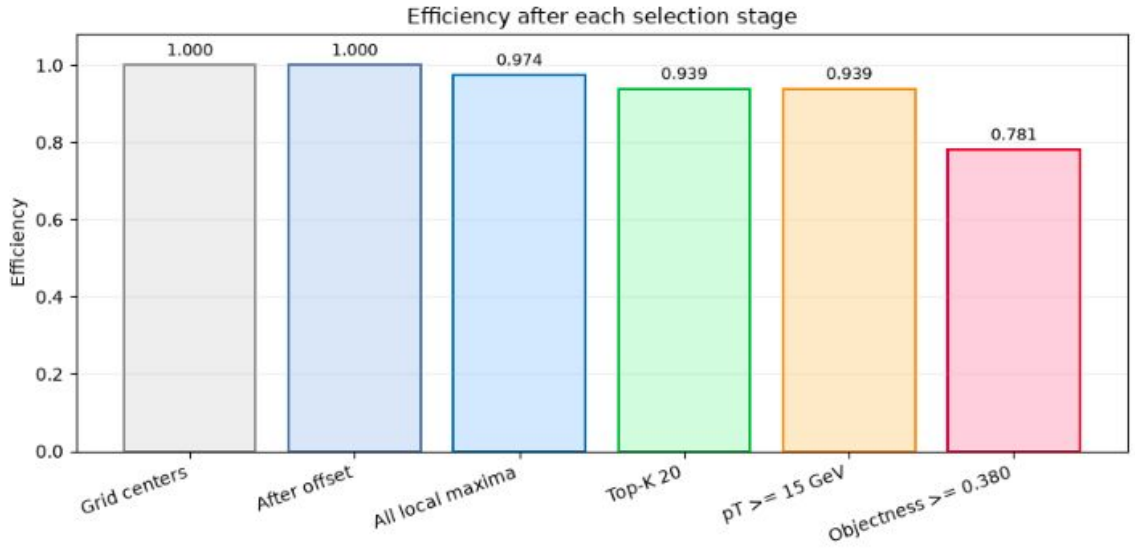
Current challenge

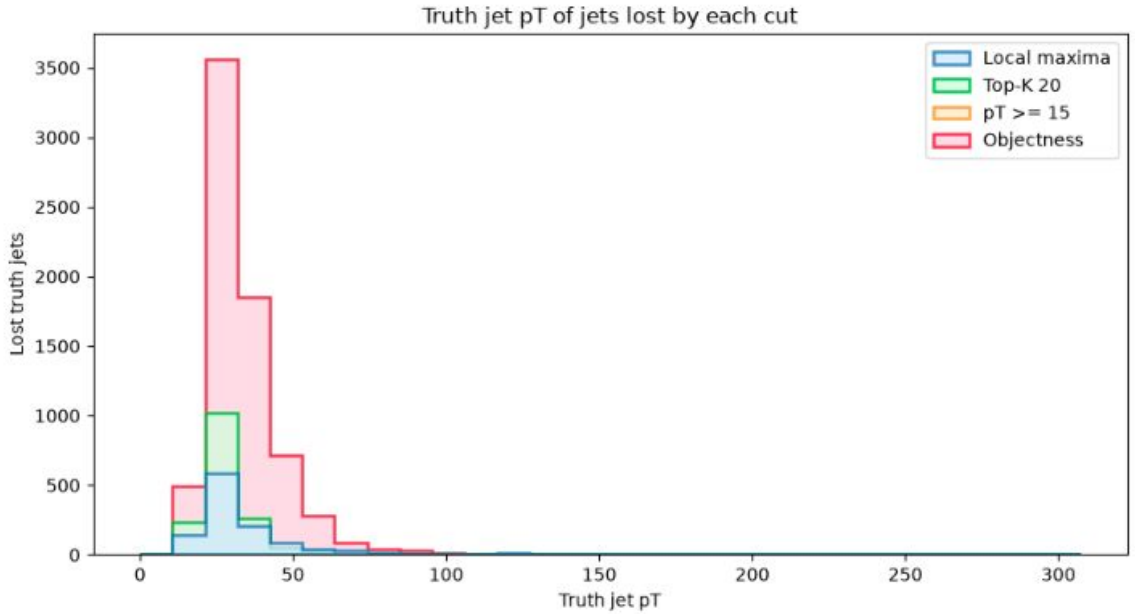
- Model struggles with low energy true jets
- Rely on jet energy instead of jet features
- Use energy as an easy shortcut

Current challenge

- Find a feature that better separate fake and truth

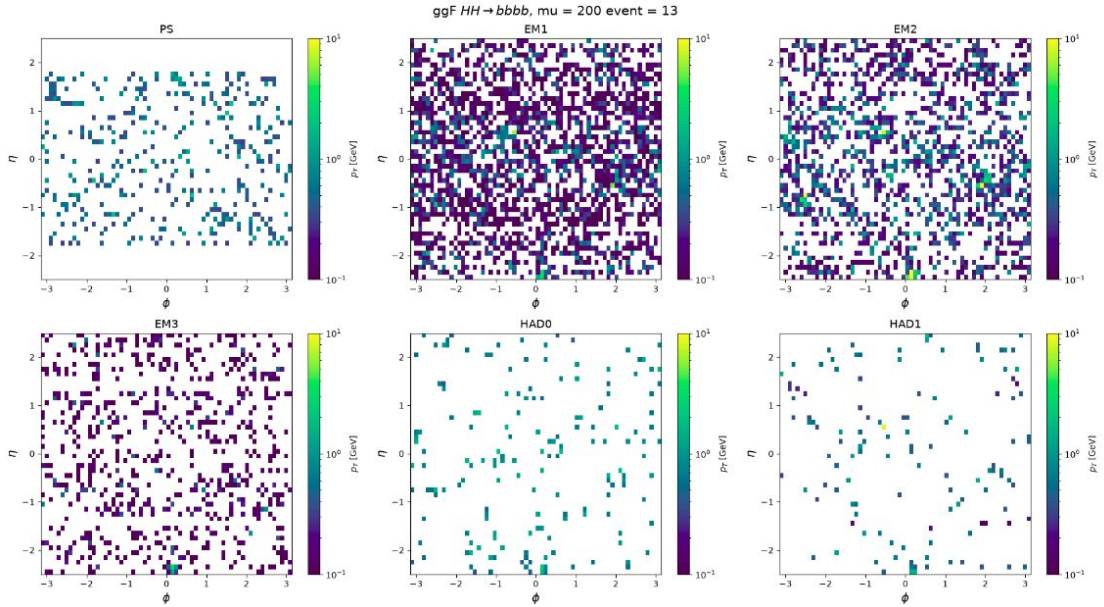






Thank you!

Why Compression Matters



50 × 64 × 6 = 19,200 values/event

32 bits/value at 40 MHz

19,200 × 32 bits × 40 MHz = 24.576 Tbps

24.576 Tbps/49 boards = **~502 Gbps/board**

Hardware context

49 boards

Global Trigger processing nodes

~100 Gb/s

available per board

Available bandwidth

~20 Gb/s

per board for jet reconstruction

Required throughput without compression

~502 Gb/s

per board

25x

more than the available