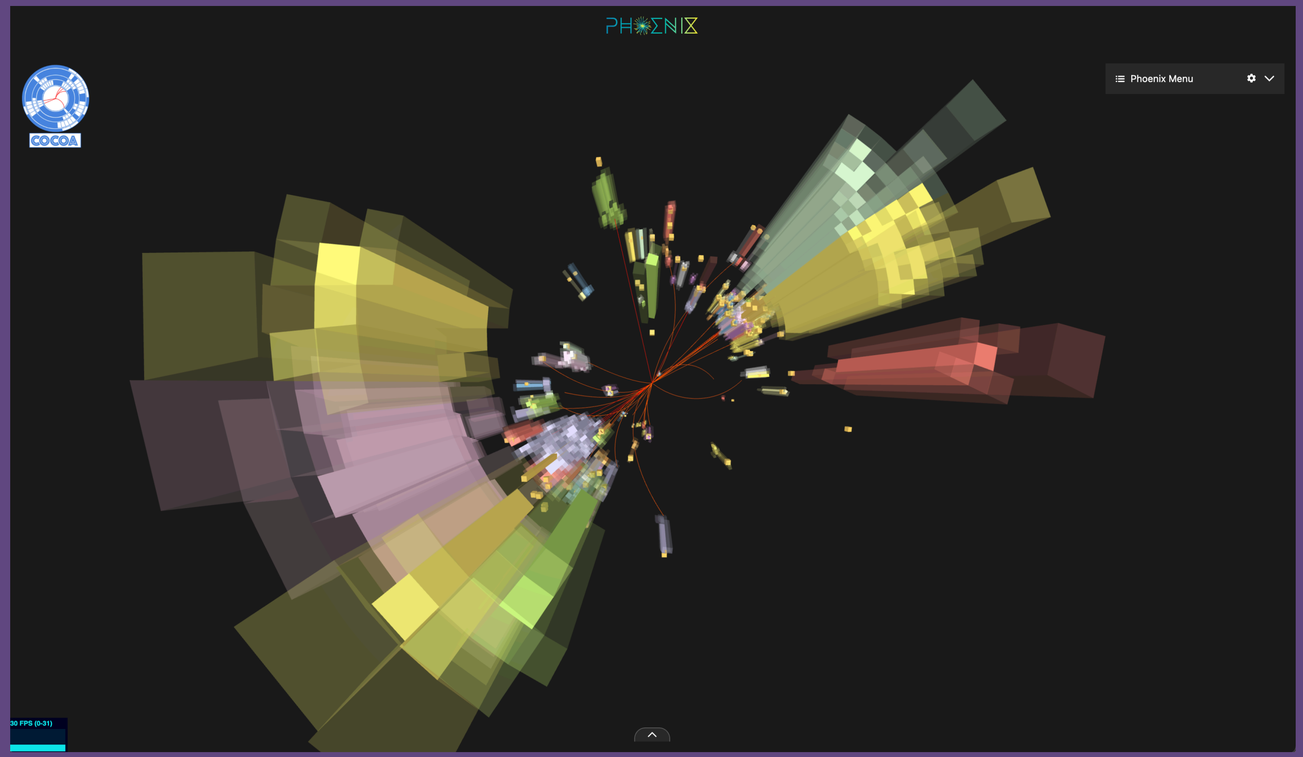
Reconstructing full pp collision events with HGPflow



ML4Jets
06 November, 2023

Nilotpal Kakati, *Etienne Dreyer, Eilam Gross, Marumi Kado*

מכון ויצמן למדע
WEIZMANN INSTITUTE OF SCIENCE

(nilotpal.kakati@cern.ch)

Event Reconstruction: 101

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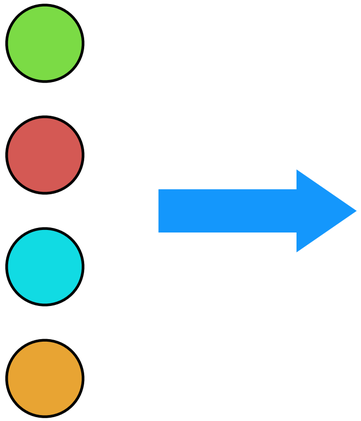
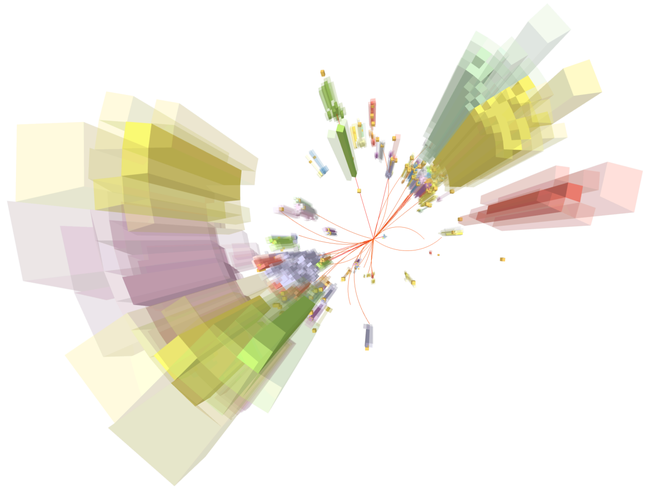
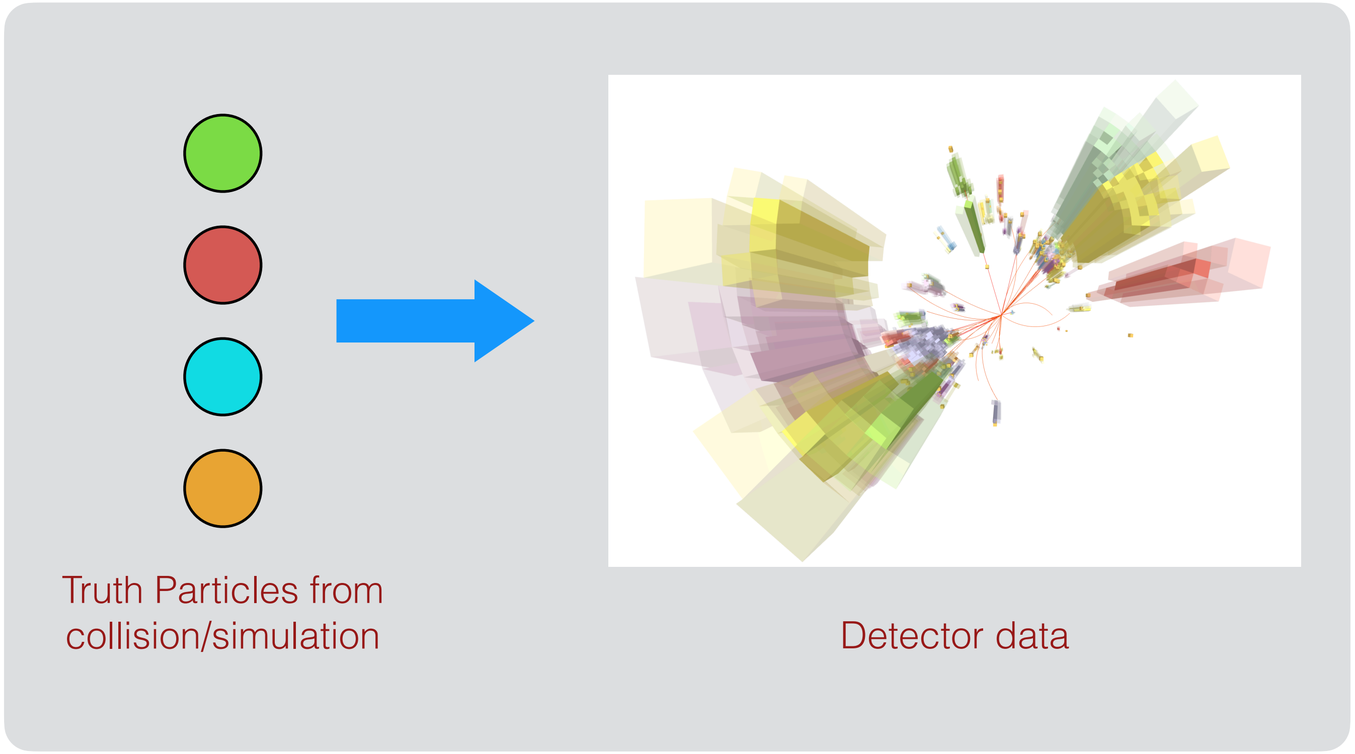


Truth Particles from collision/simulation



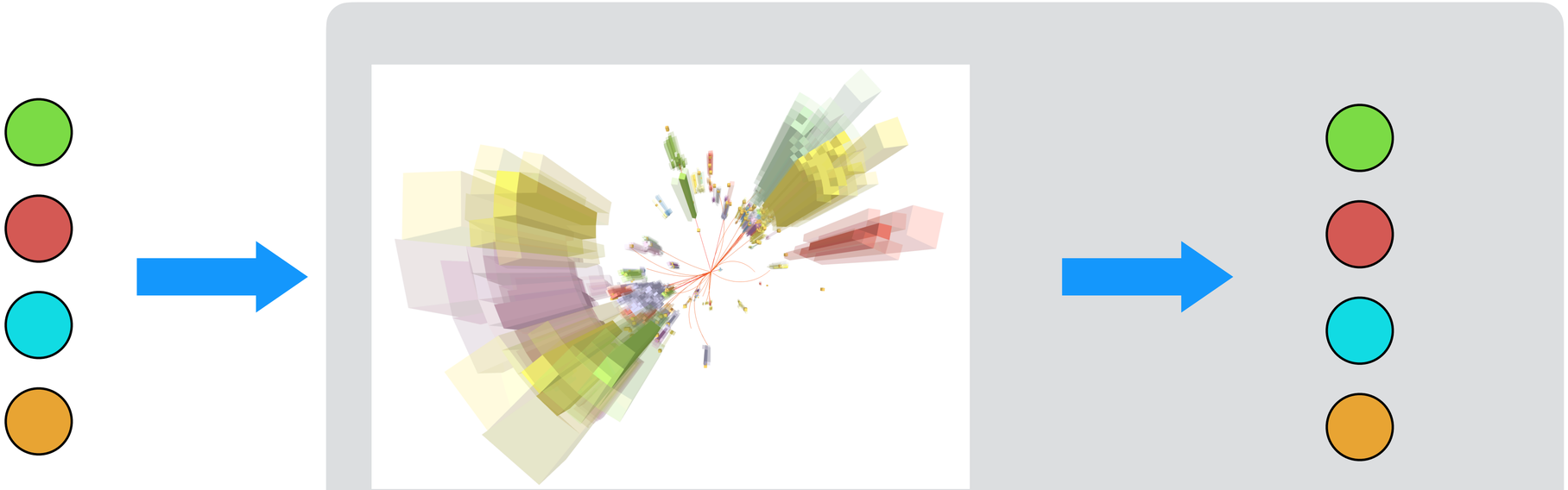
Detector data

Event Reconstruction: 101



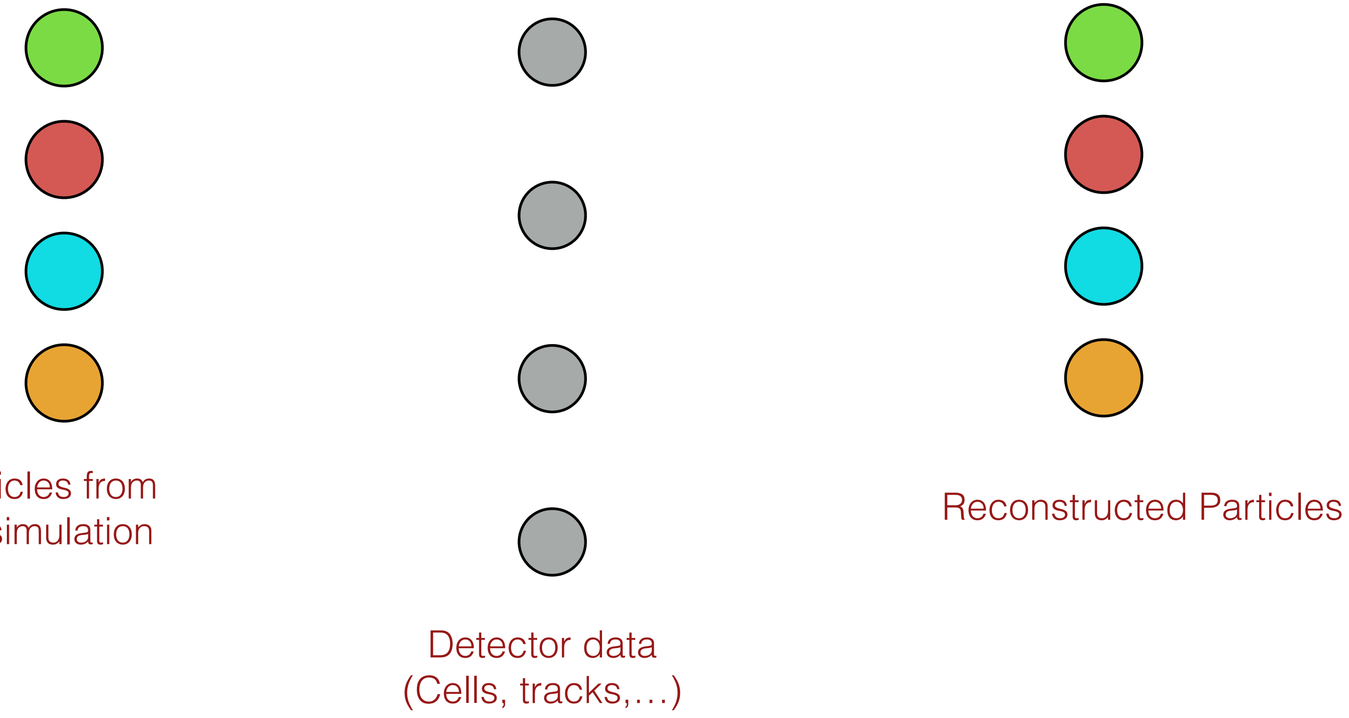
Forward problem

Event Reconstruction: 101



Inverse problem

Event Reconstruction: HGPflow

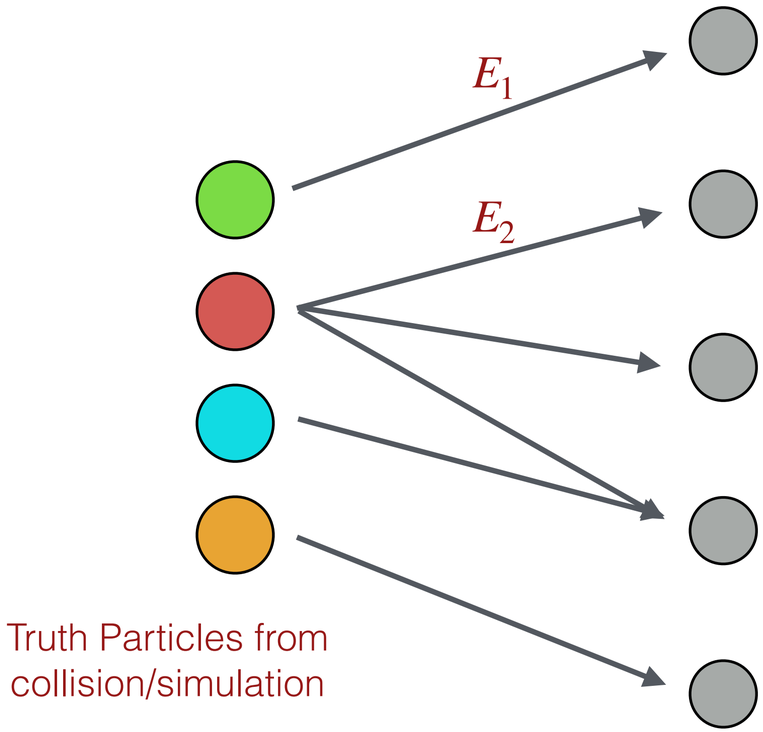


Truth Particles from collision/simulation

Detector data (Cells, tracks,…)

Reconstructed Particles

Event Reconstruction: HGPflow



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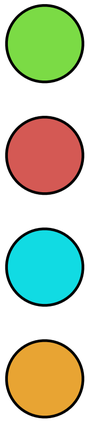

Reconstructed Particles

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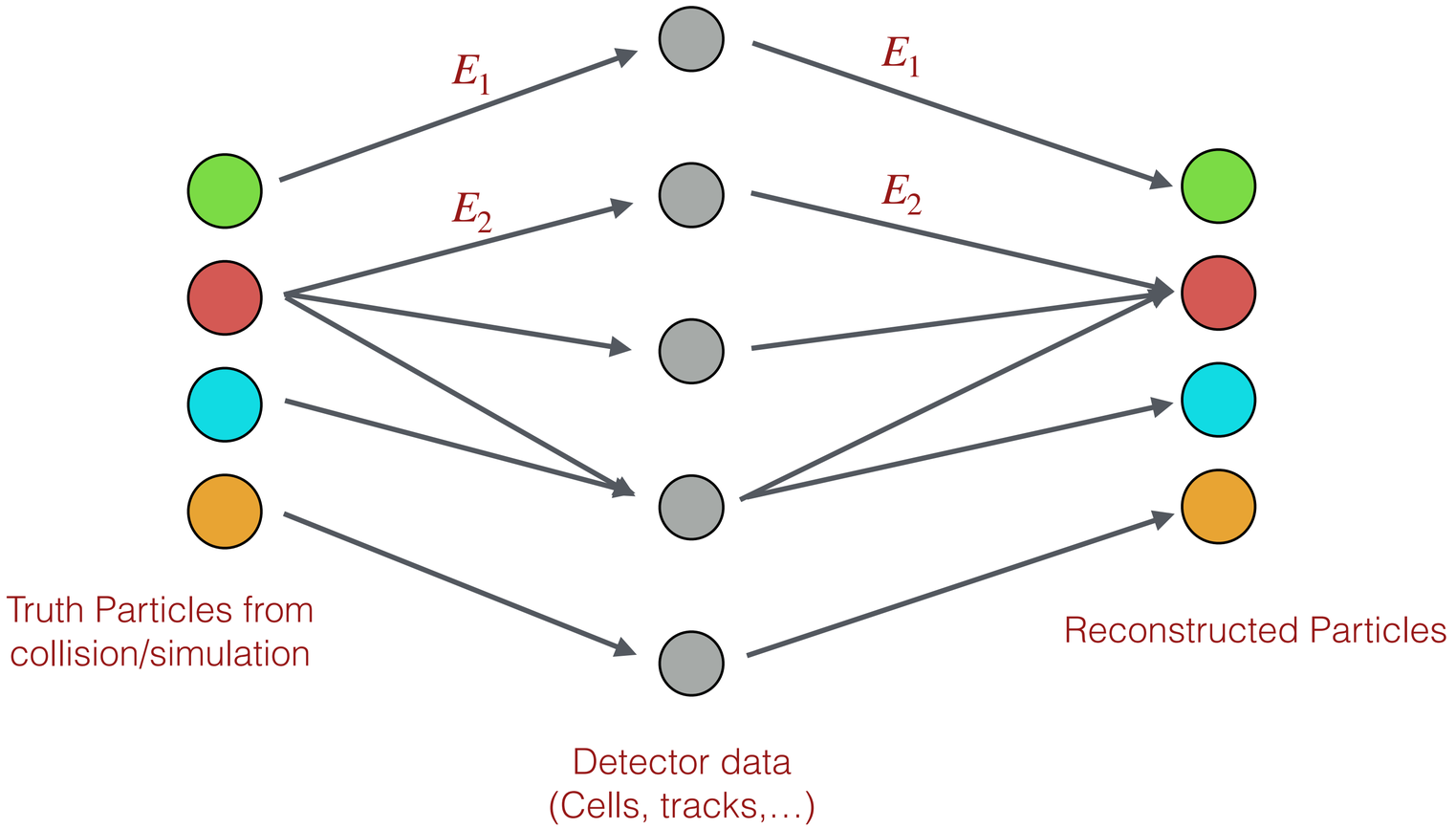

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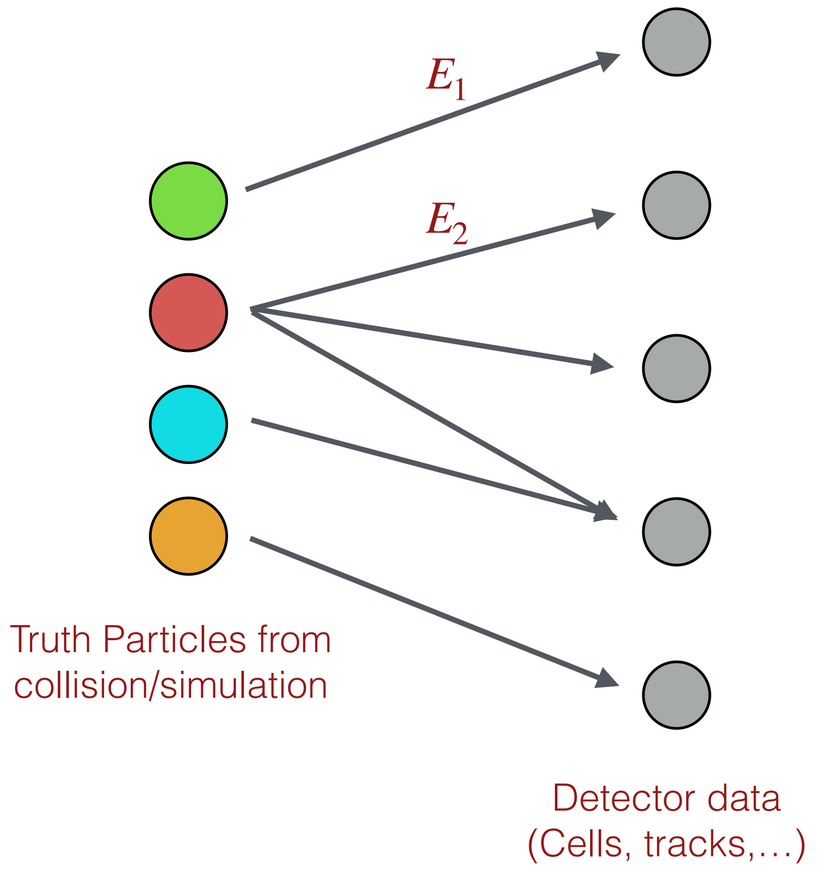

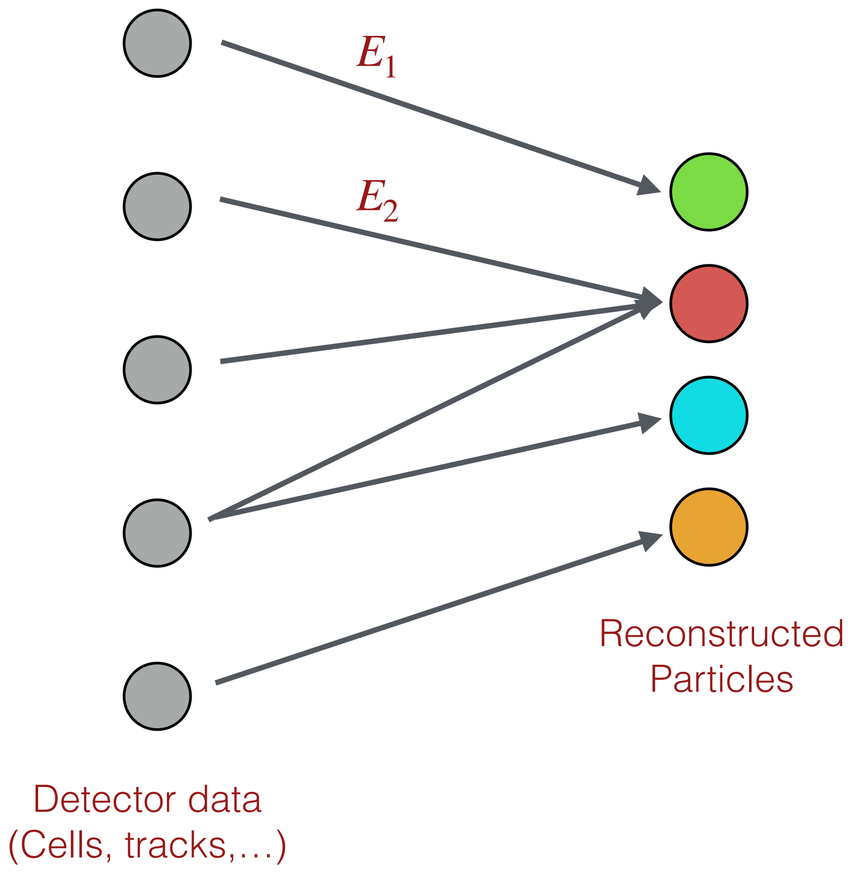

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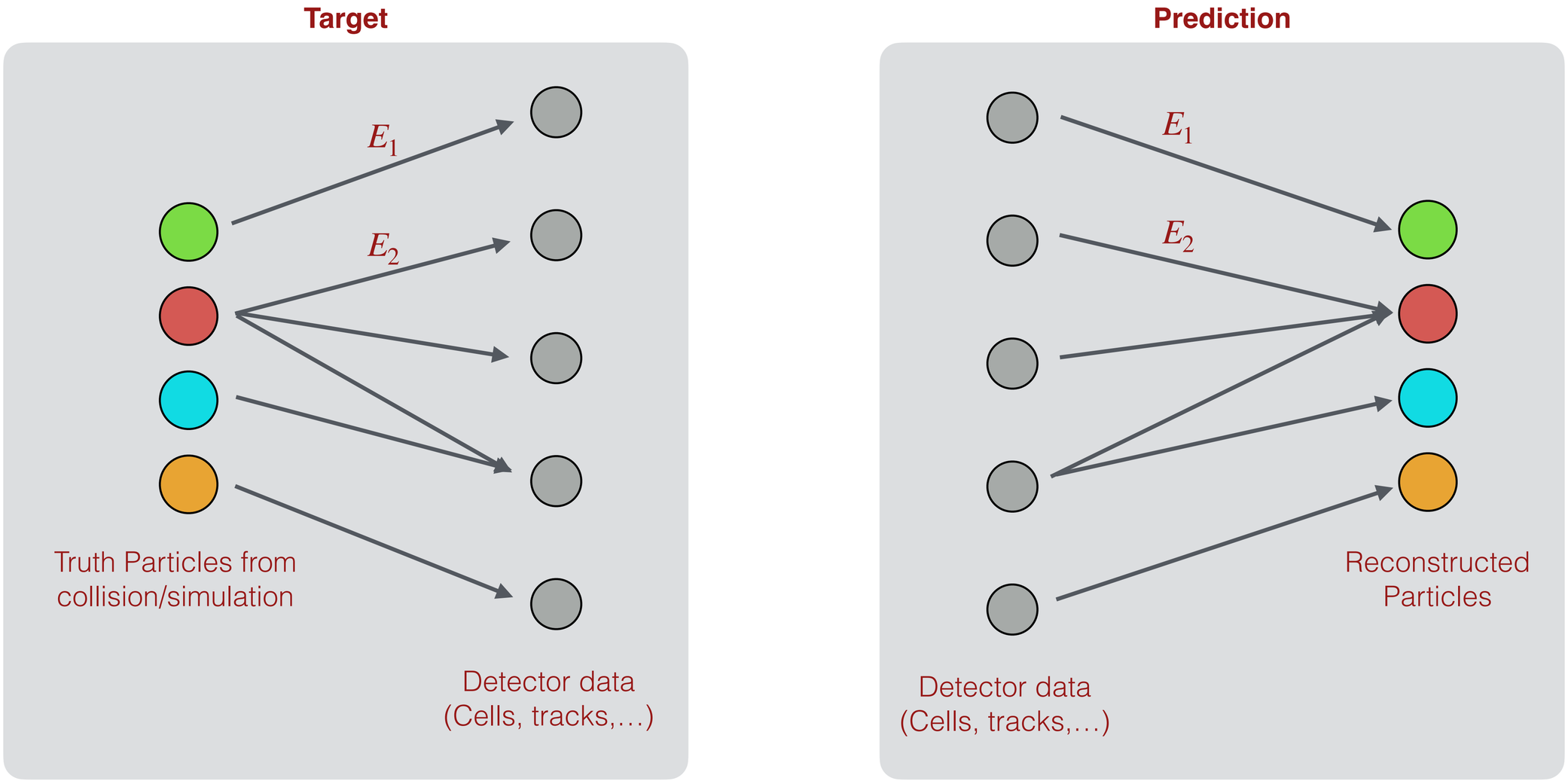

HyperGraph 101

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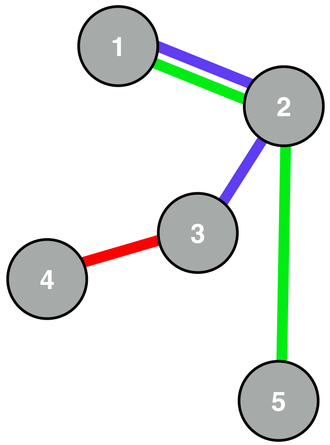
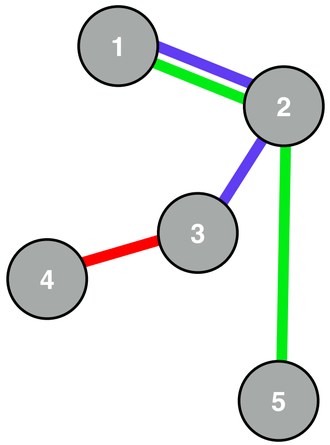
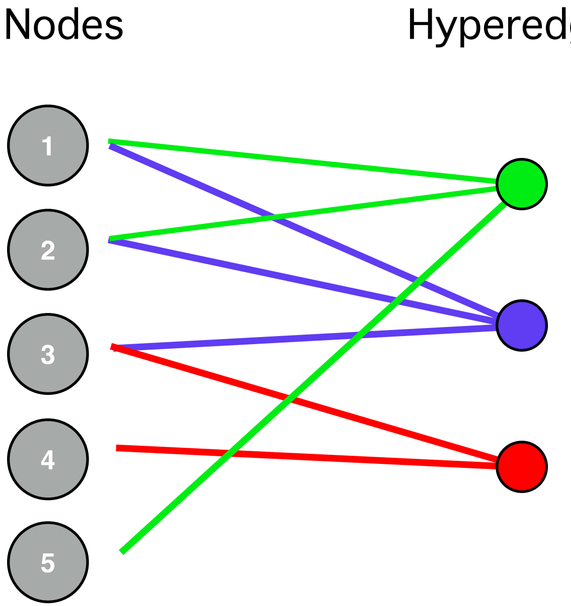


Hypergraph

HyperGraph 101

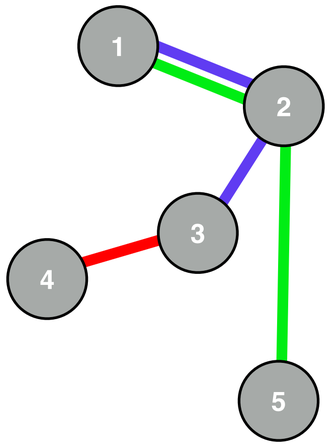


Hypergraph

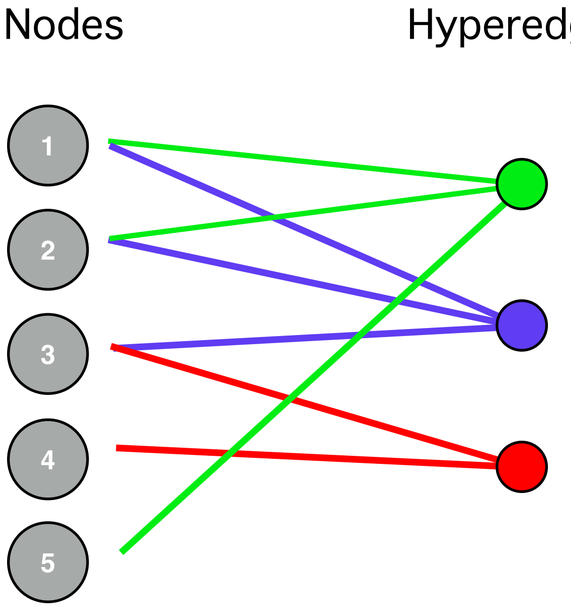


Bipartite graph

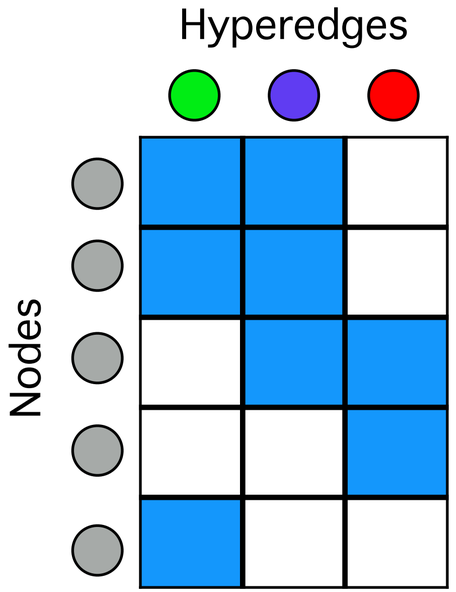
HyperGraph 101



Hypergraph

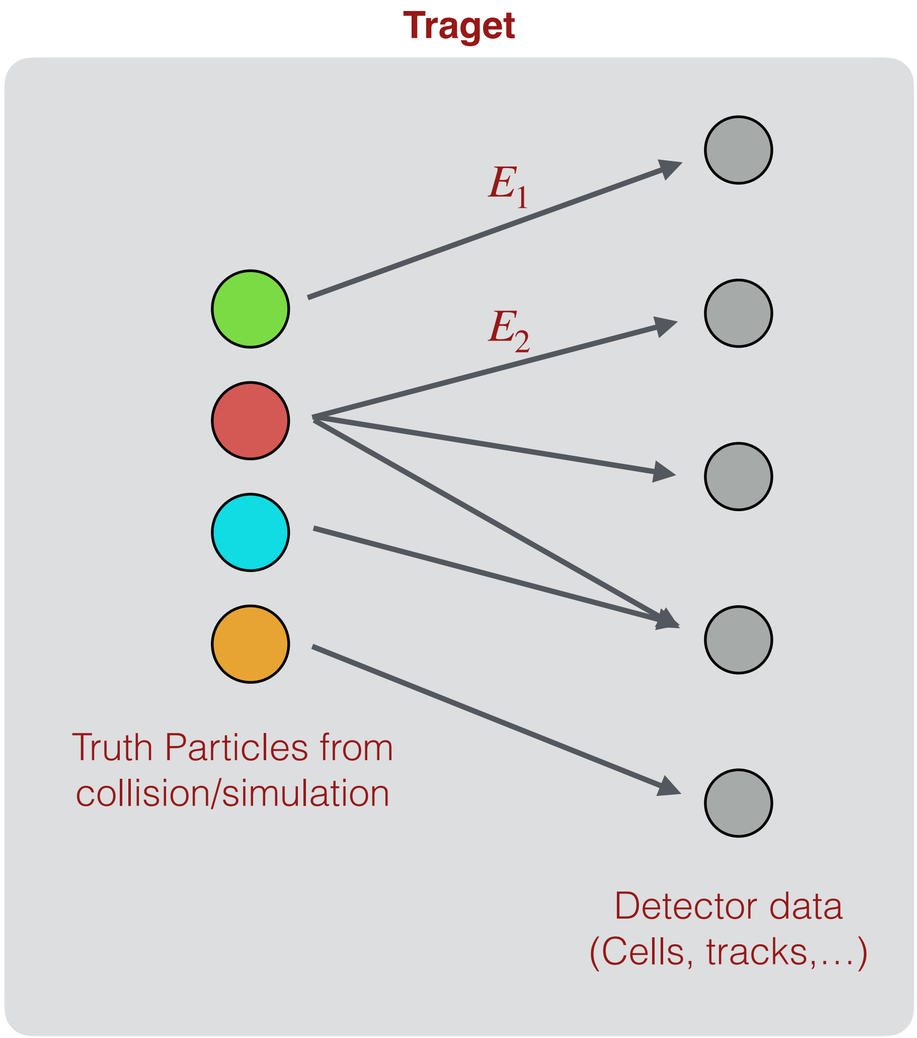


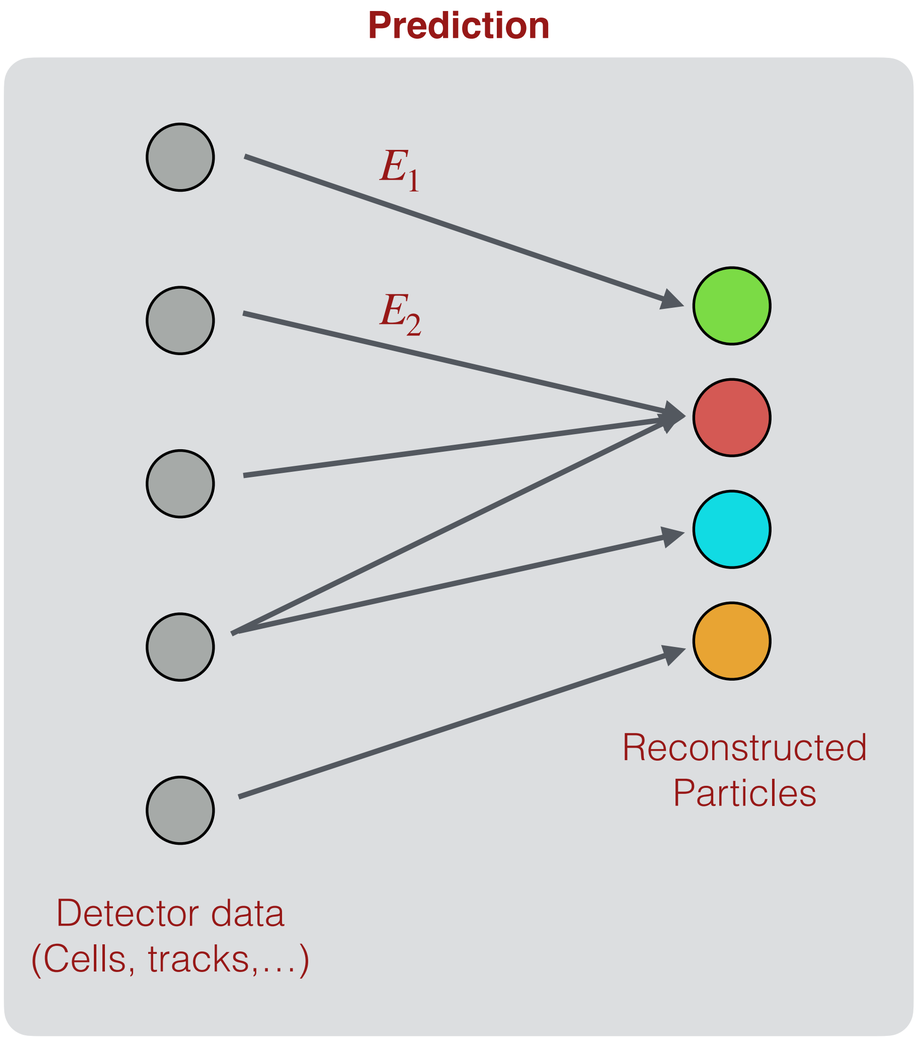
Bipartite graph



Incidence matrix

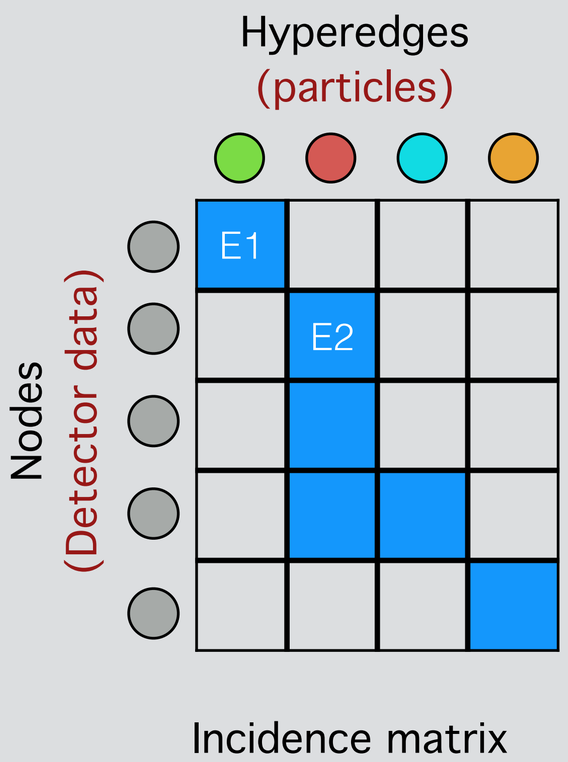
Event Reconstruction as a Hypergraph learning problem



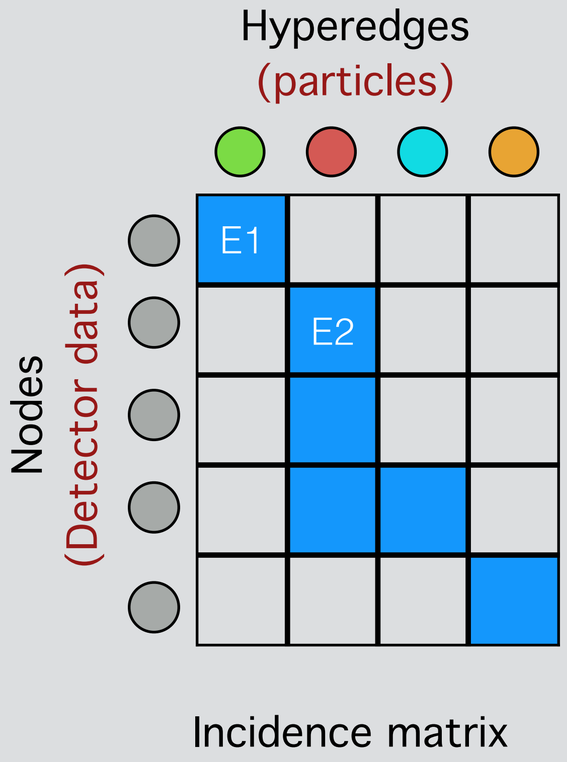


Event Reconstruction as a Hypergraph learning problem

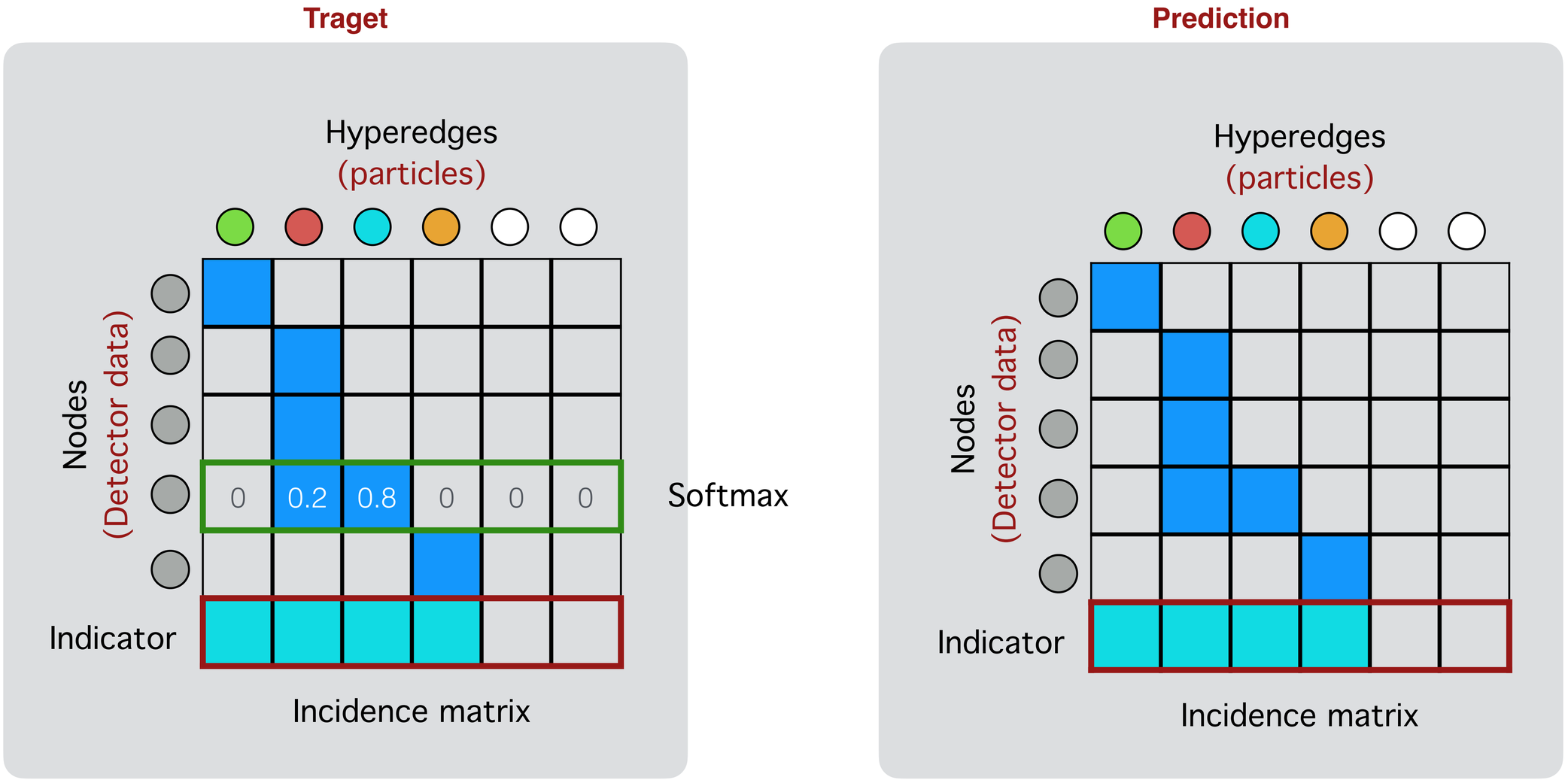
Traget



Prediction



Event Reconstruction as a Hypergraph learning problem



In theory, Incidence matrix is enough!

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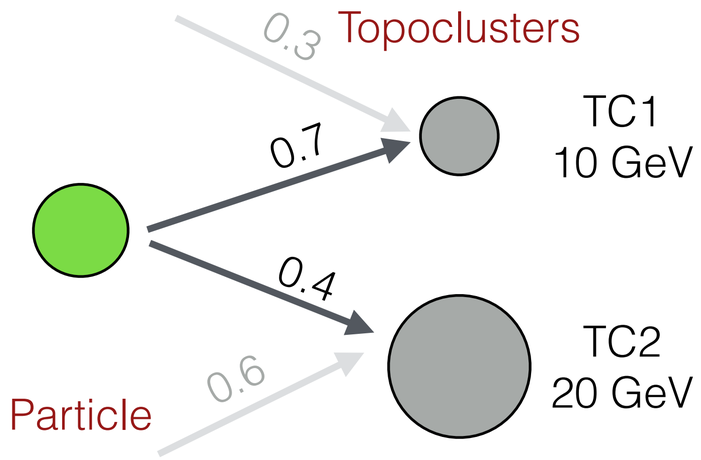

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- E = E1 + E2 = 15GeV

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- $\eta = \frac{7\eta_1 + 8\eta_2}{15}$

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Proxy properties of 

- E = E1 + E2 = 15GeV
- $p_T = \frac{E}{cosh(\eta)}$
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Putting it all together (HGPflow)

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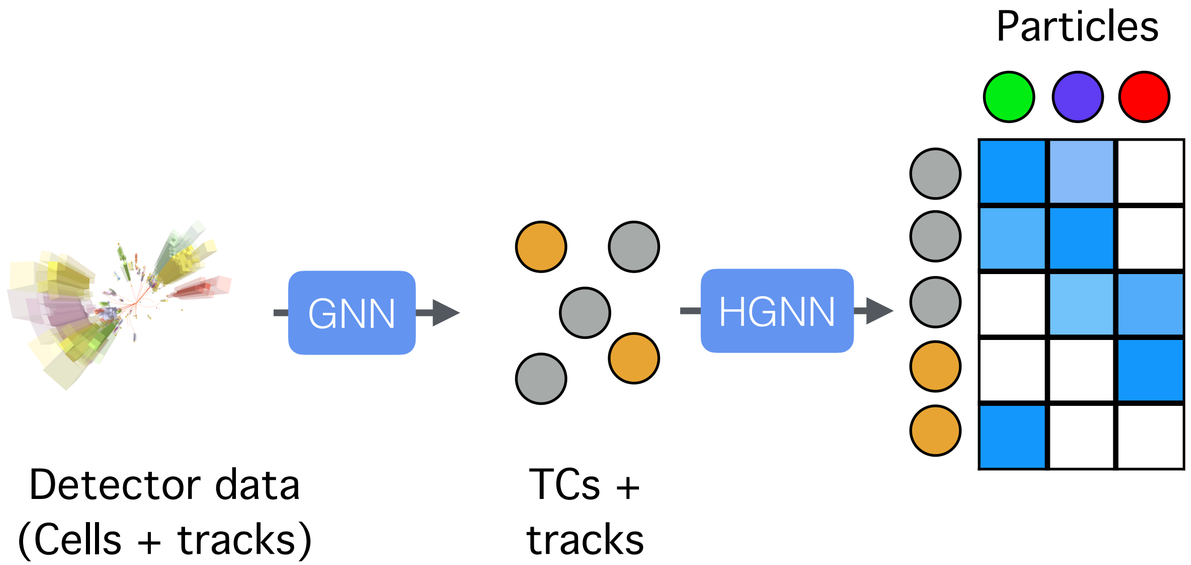
Detector data
(Cells + tracks)

TCs +
tracks

Putting it all together (HGPflow)



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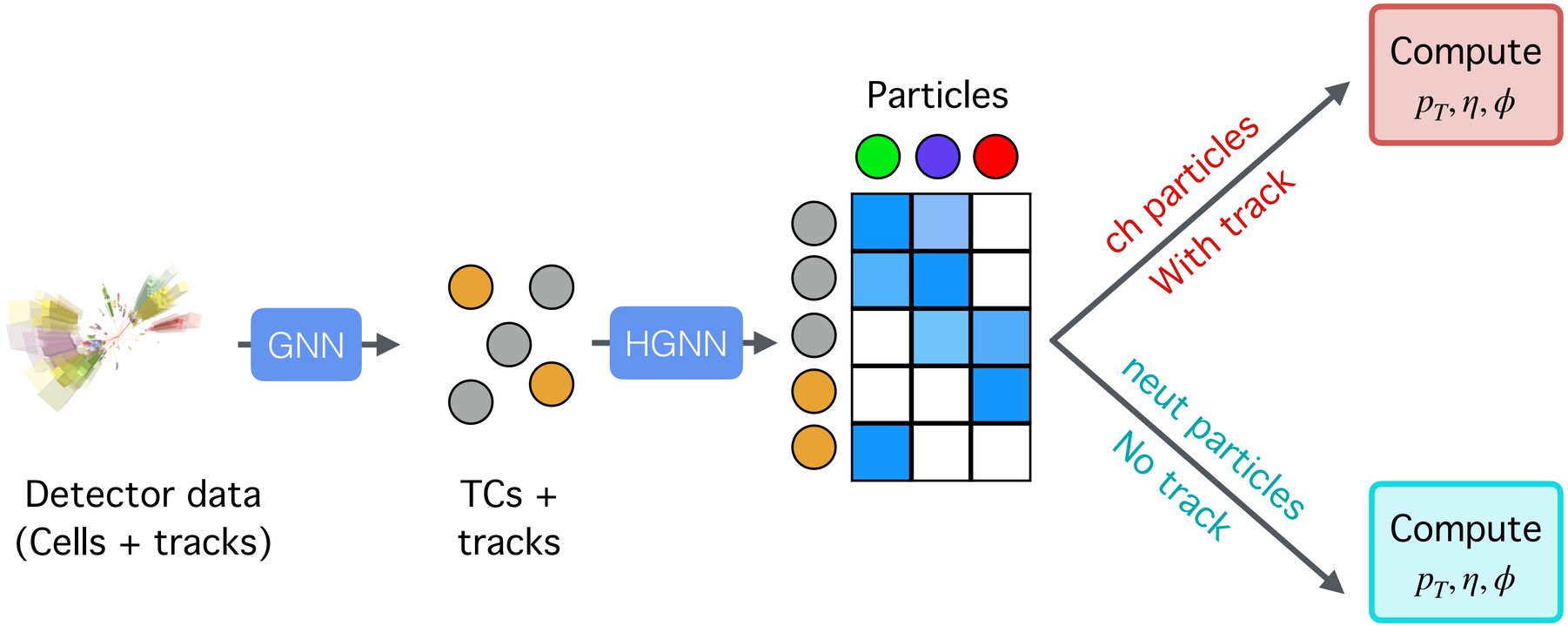

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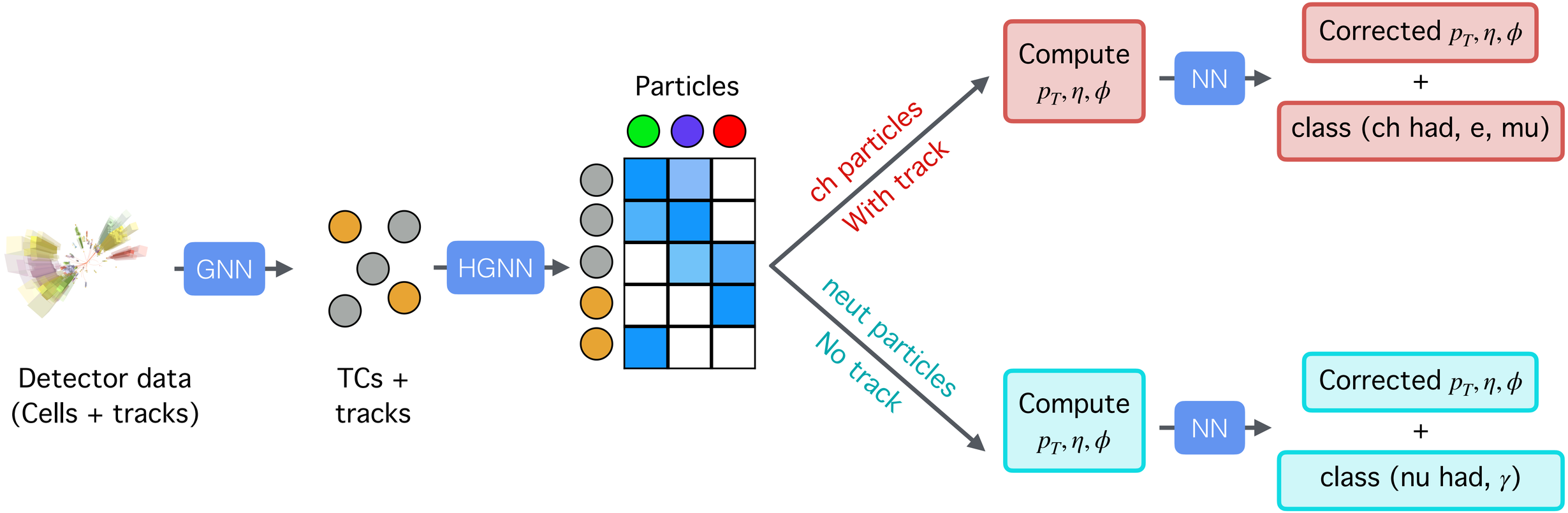

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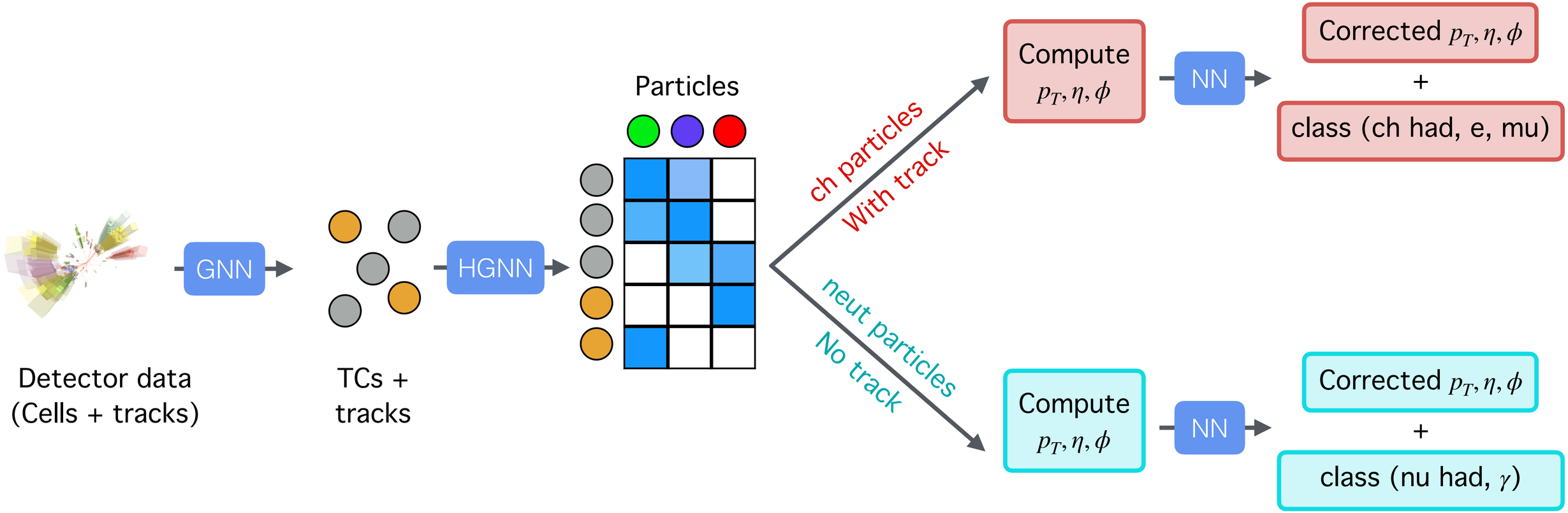

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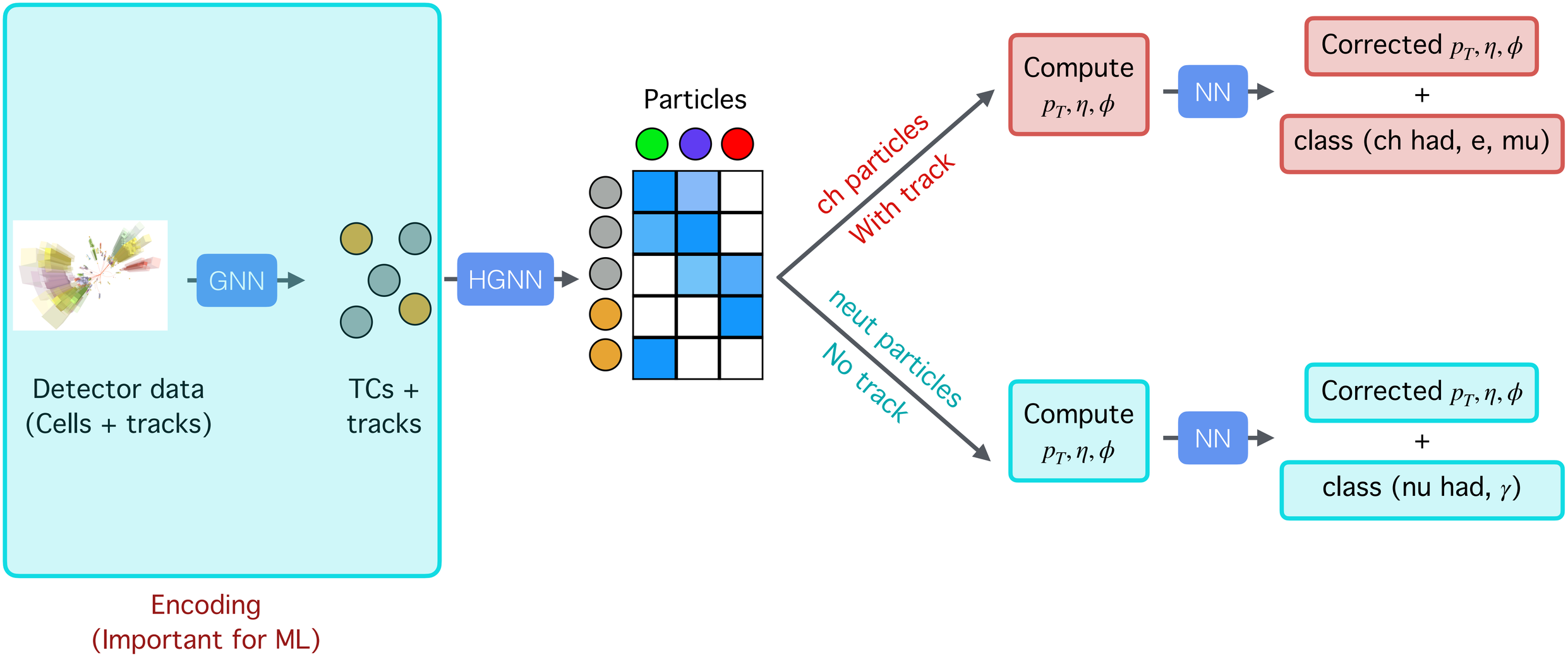

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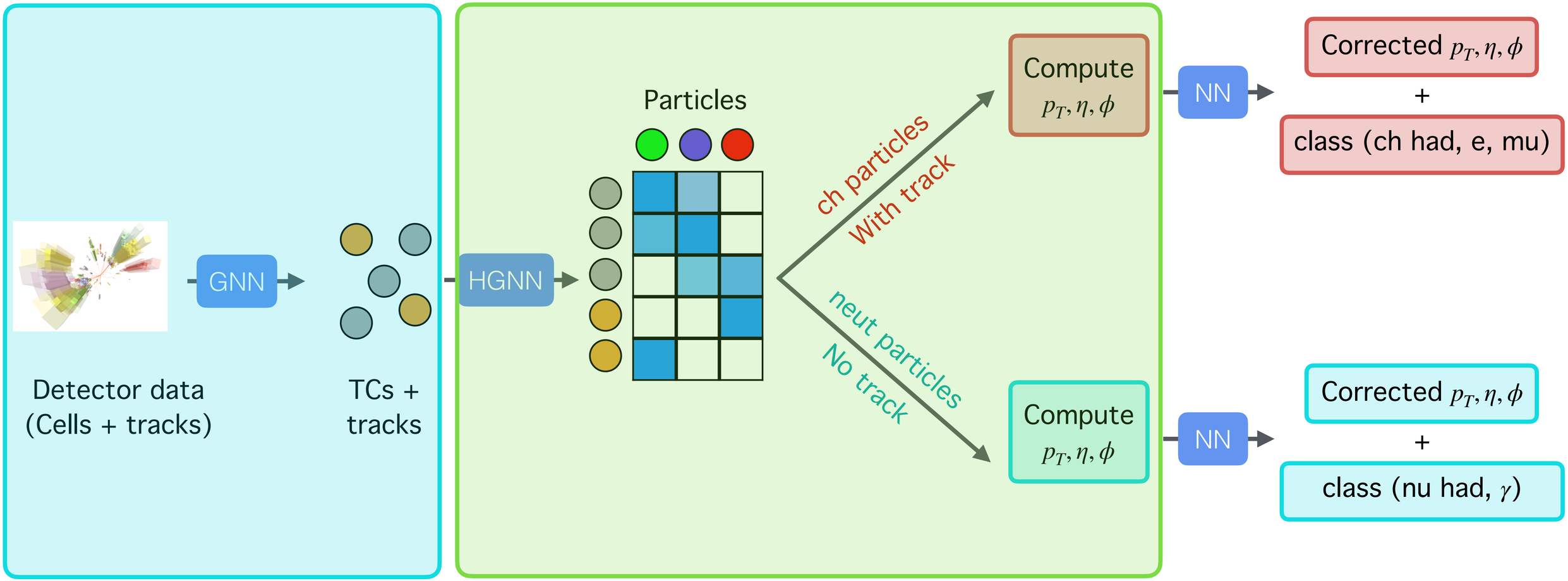

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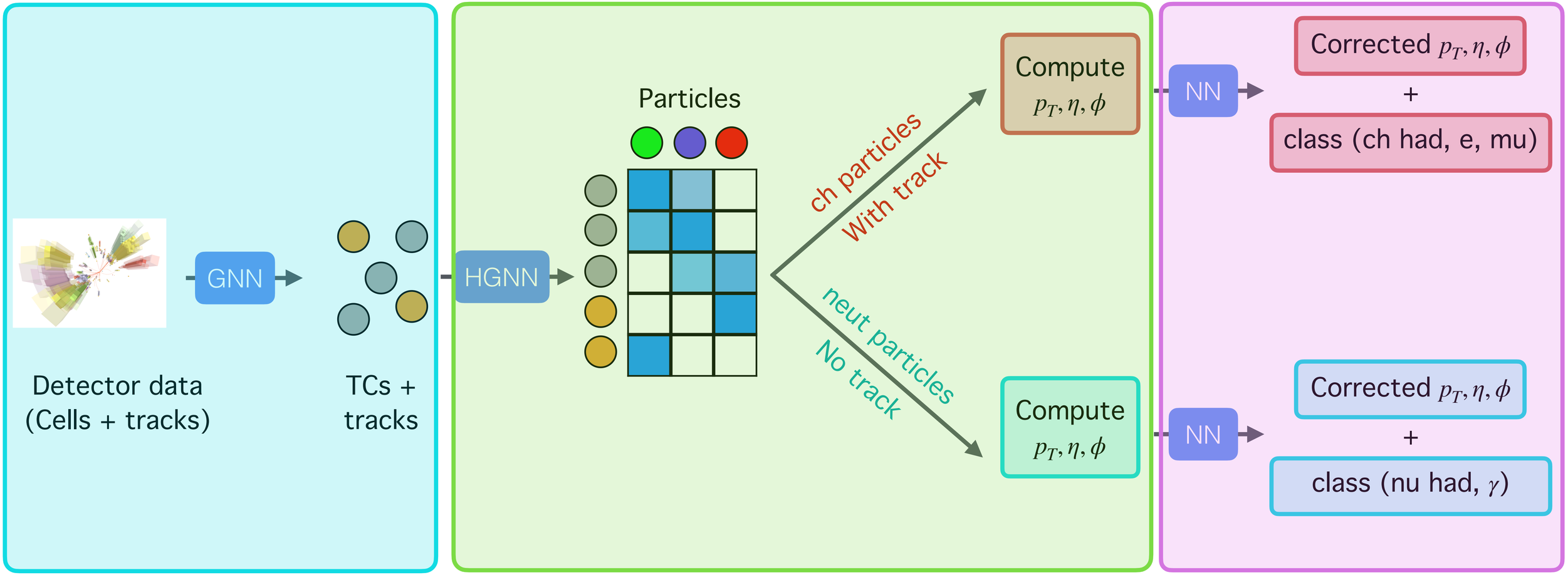


Encoding
(Important for ML)

Analogous to Classical PF

Calibration + particle identification

Previously,

Eur. Phys. J. C (2023) 83:596
https://doi.org/10.1140/epjc/s10052-023-11677-7

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Experimental Physics

https://link.springer.com/article/10.1140/epjc/s10052-023-11677-7

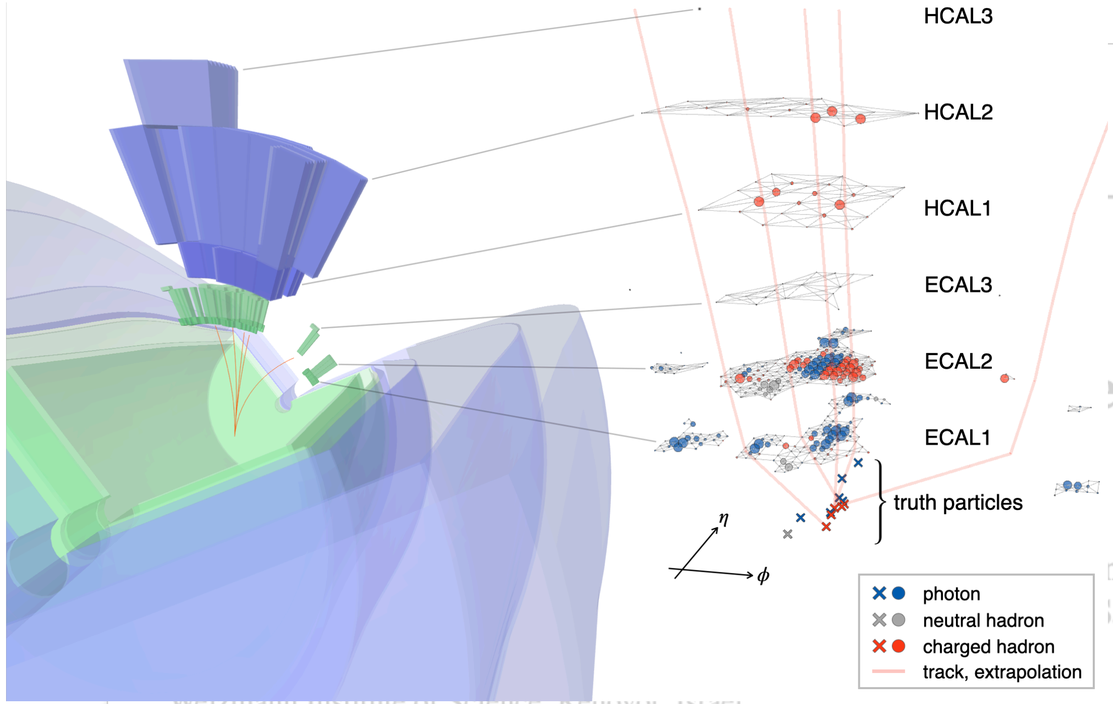
Reconstructing particles in jets using set transformer and hypergraph prediction networks

Francesco Armando Di Bello[1,a], Etienne Dreyer[2,b], Sanmay Ganguly[3], Eilam Gross[2], Lukas Heinrich[4], Anna Ivina[2], Marumi Kado[5,6], Nilotpal Kakati[2,c], Lorenzo Santi[6], Jonathan Shlomi[2], Matteo Tusoni[6]

[1] INFN and University of Genova, Genoa, Italy
[2] Weizmann Institute of Science, Rehovot, Israel
[3] ICEPP, University of Tokyo, Tokyo, Japan
[4] Technical University of Munich, Munich, Germany
[5] Max Planck Institute for Physics, Munich, Germany
[6] INFN and Sapienza University of Rome, Rome, Italy

Received: 11 December 2022 / Accepted: 4 June 2023

Previously,



THE EUROPEAN PHYSICAL JOURNAL C

Check for updates

https://link.springer.com/article/10.1140/epjc/s10052-023-11677-7

t transformer

[3] ICEPP, University of Tokyo, Tokyo, Japan
[4] Technical University of Munich, Munich, Germany
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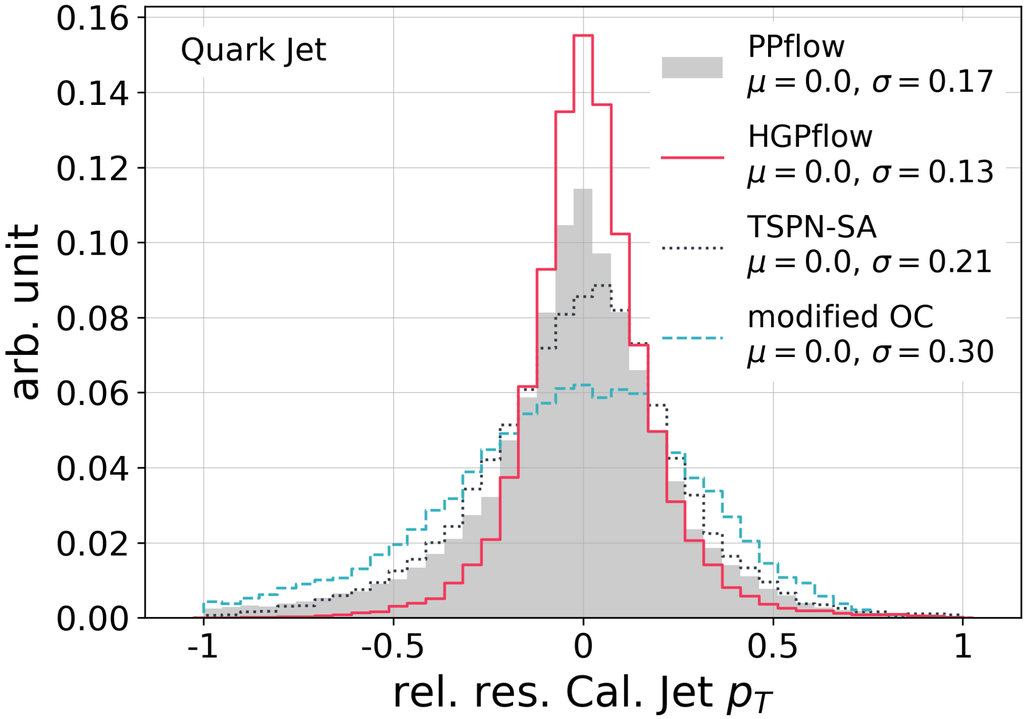
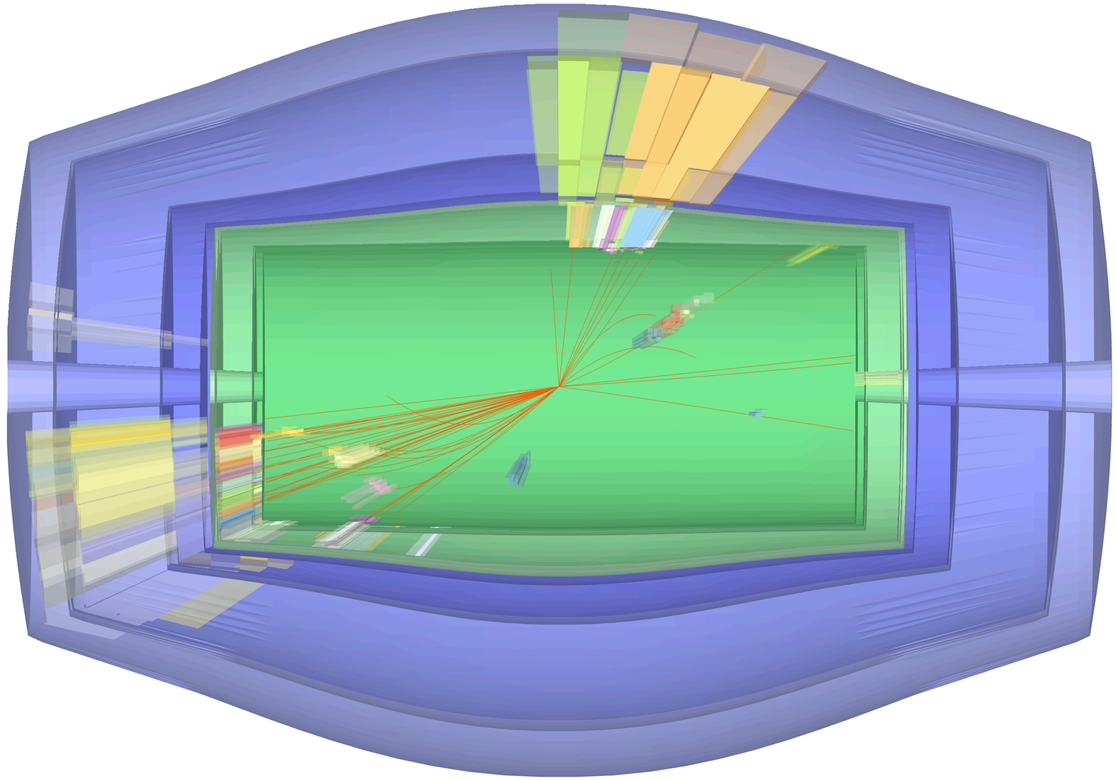


Single jet (quanta) → Full event

The obvious(?) next step…

Full event reconstruction

$Z(\nu\nu)H(b\bar{b})$



Full event reconstruction

- From a physicist's perspective
  - The two jets are correlated and we want to exploit it

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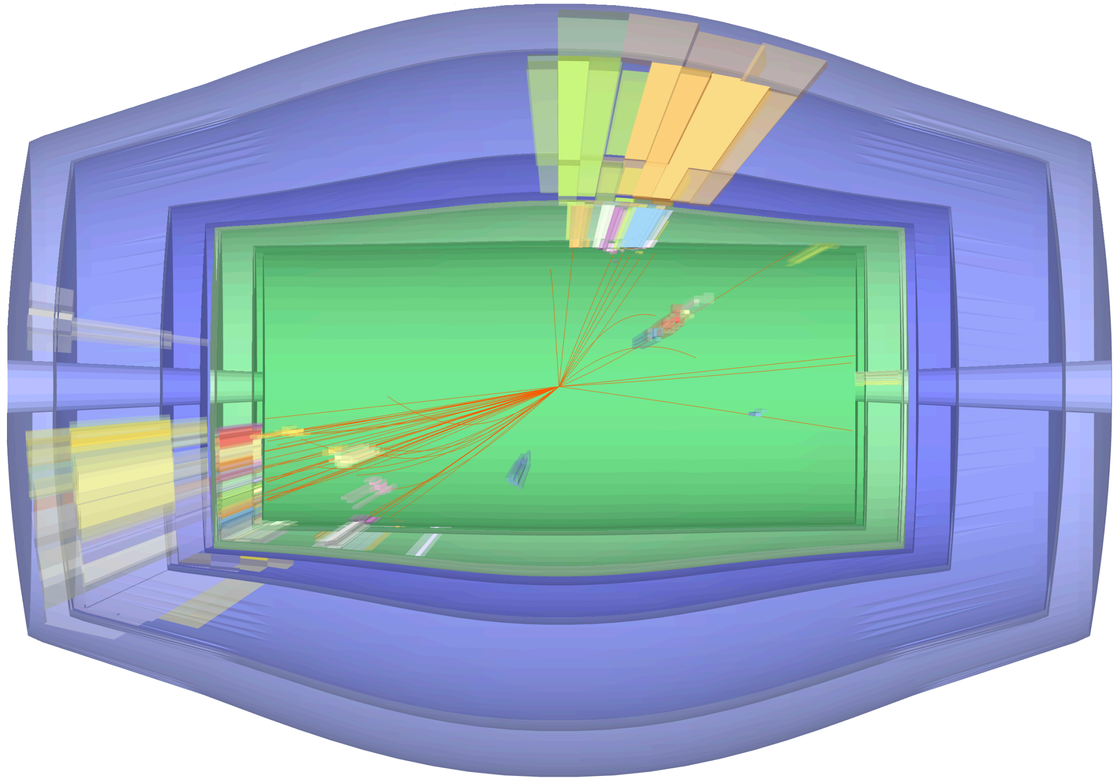

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- But from a reconstruction perspective,
  - ➡ We want to avoid this correlation

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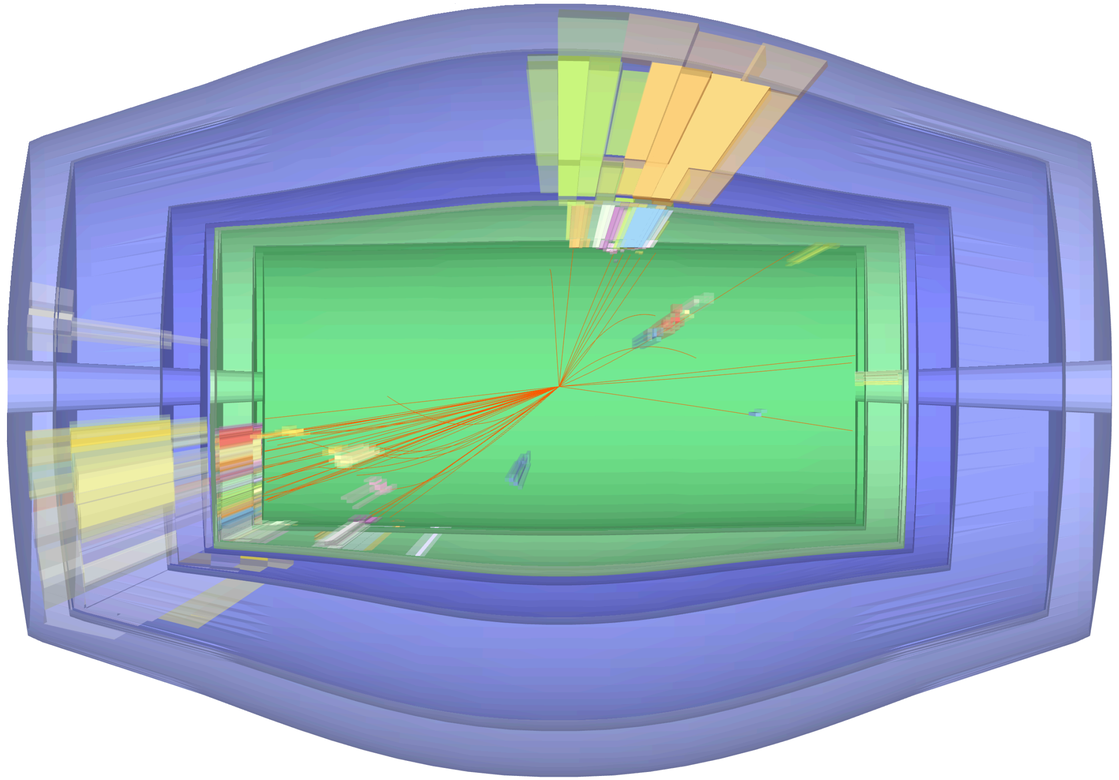

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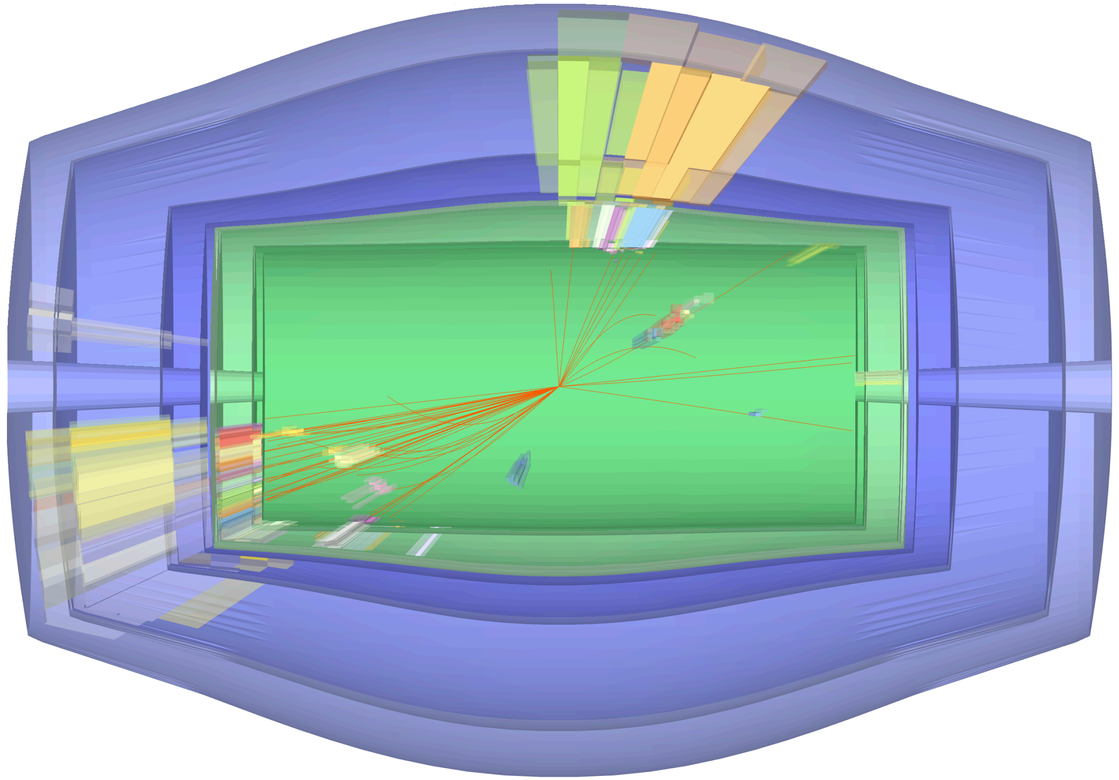

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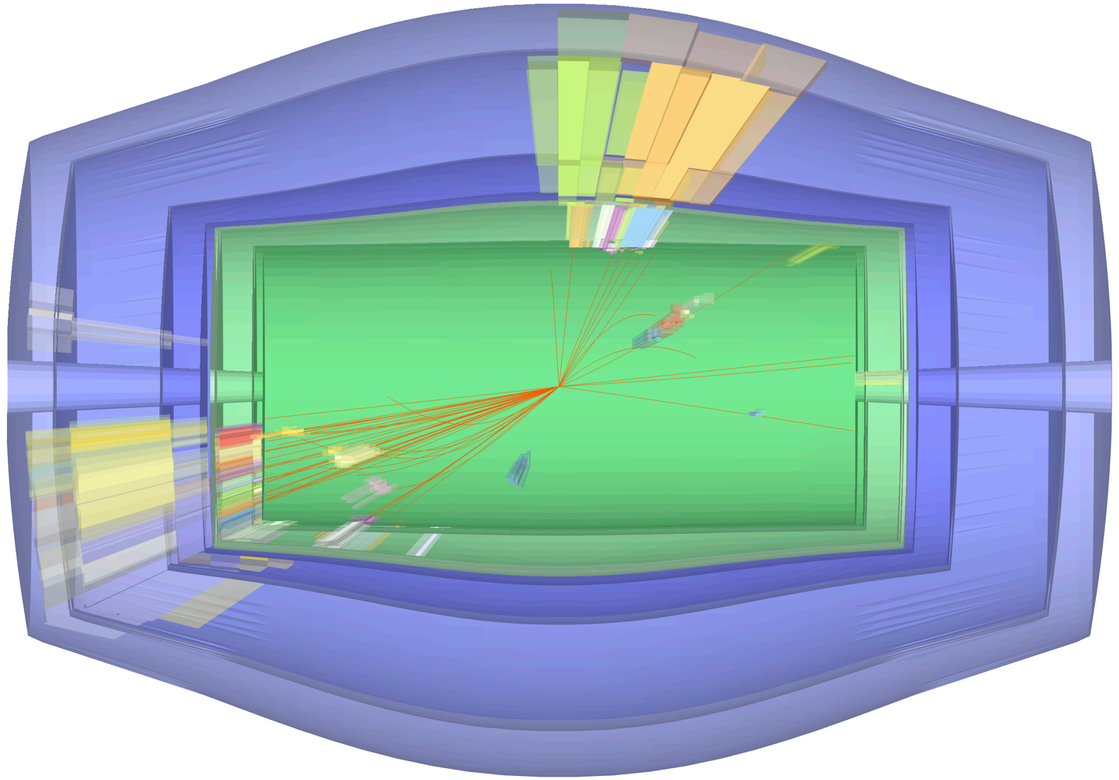
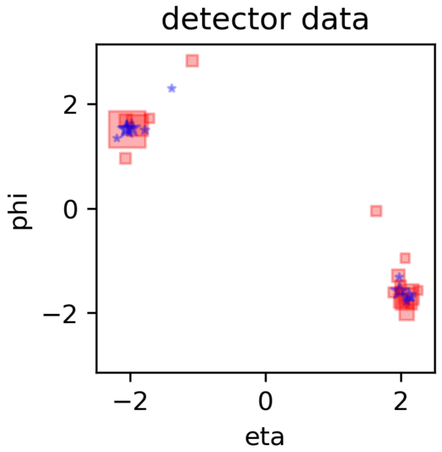


The strategy



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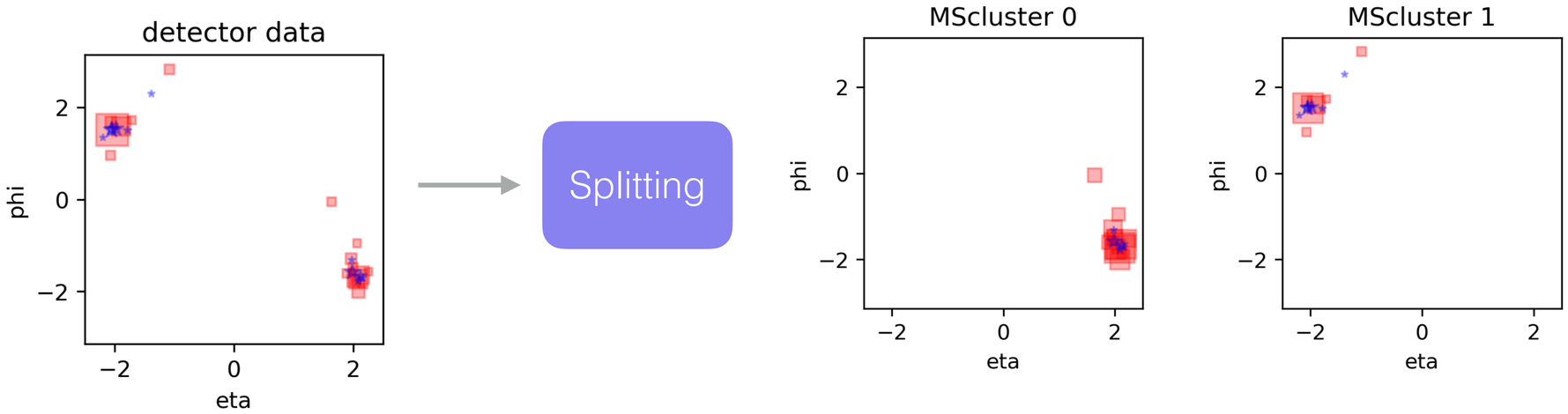

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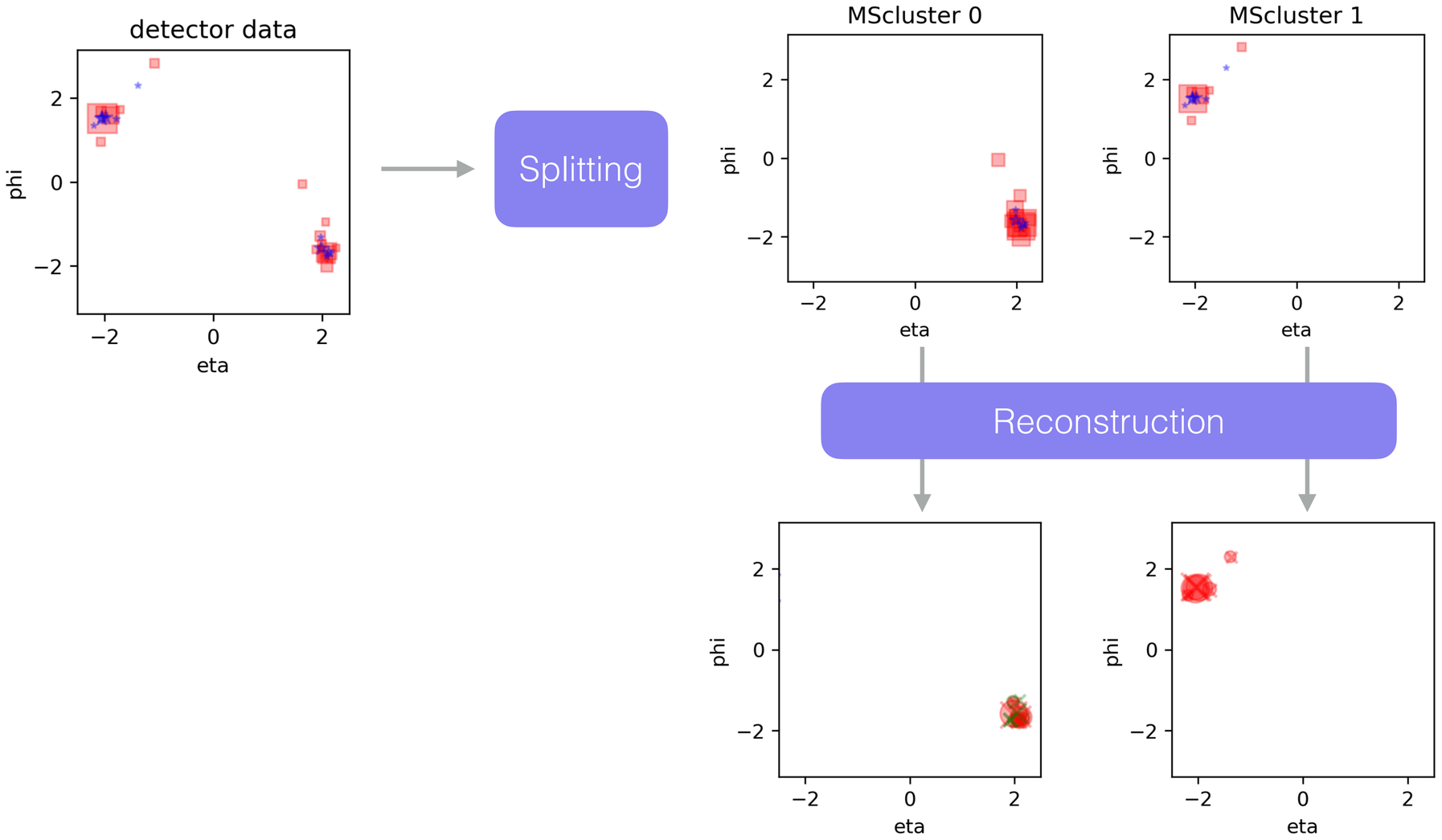

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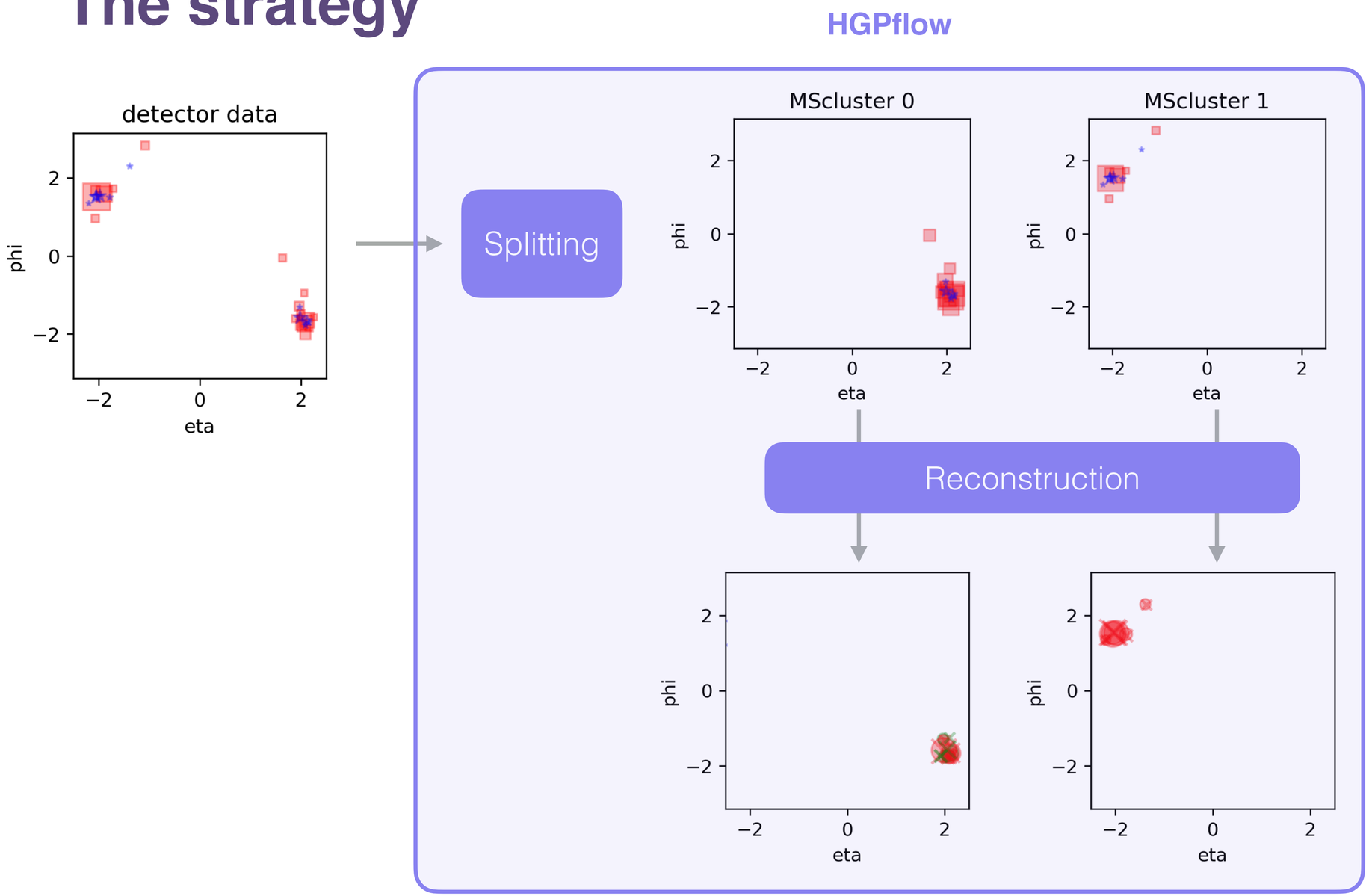

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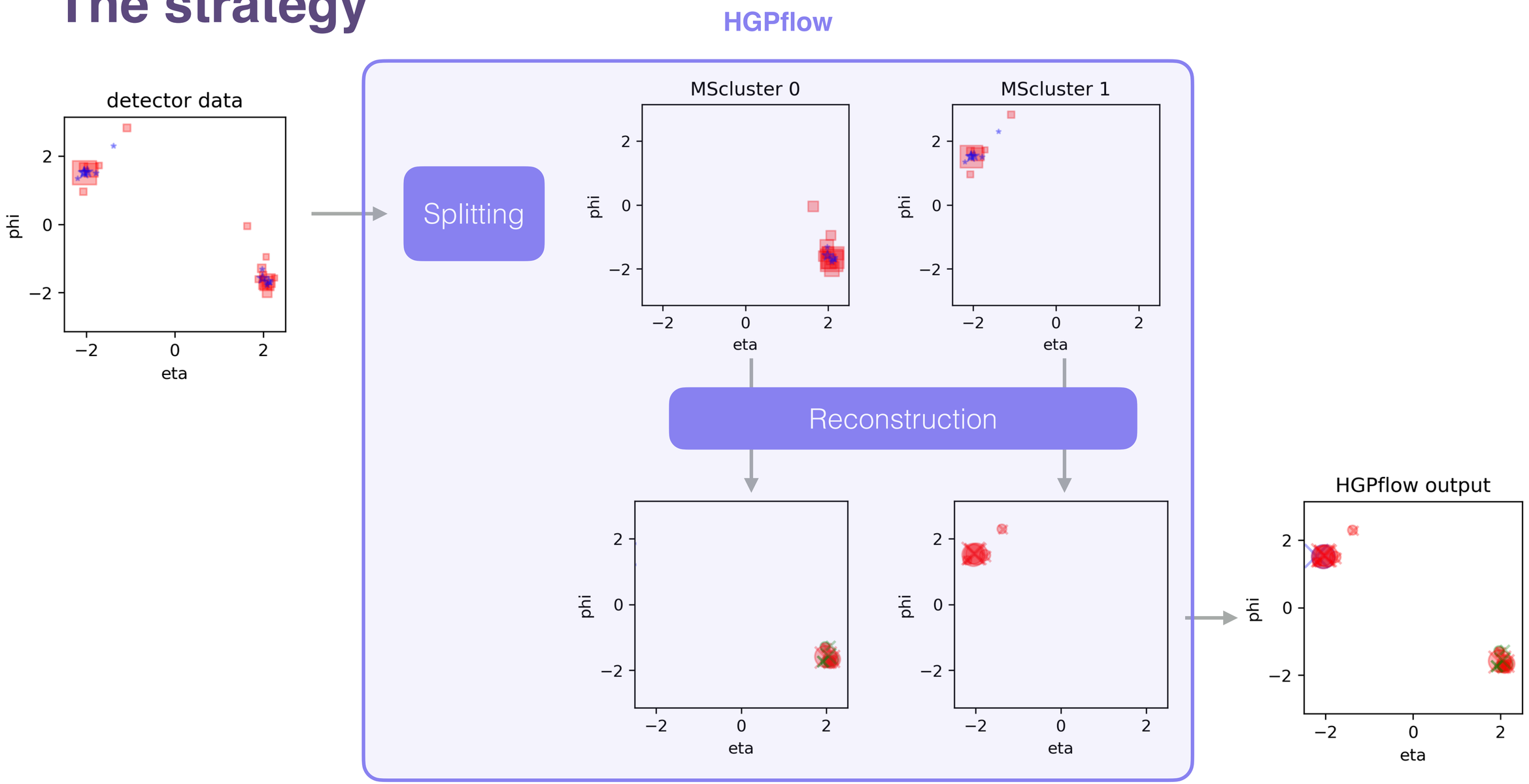

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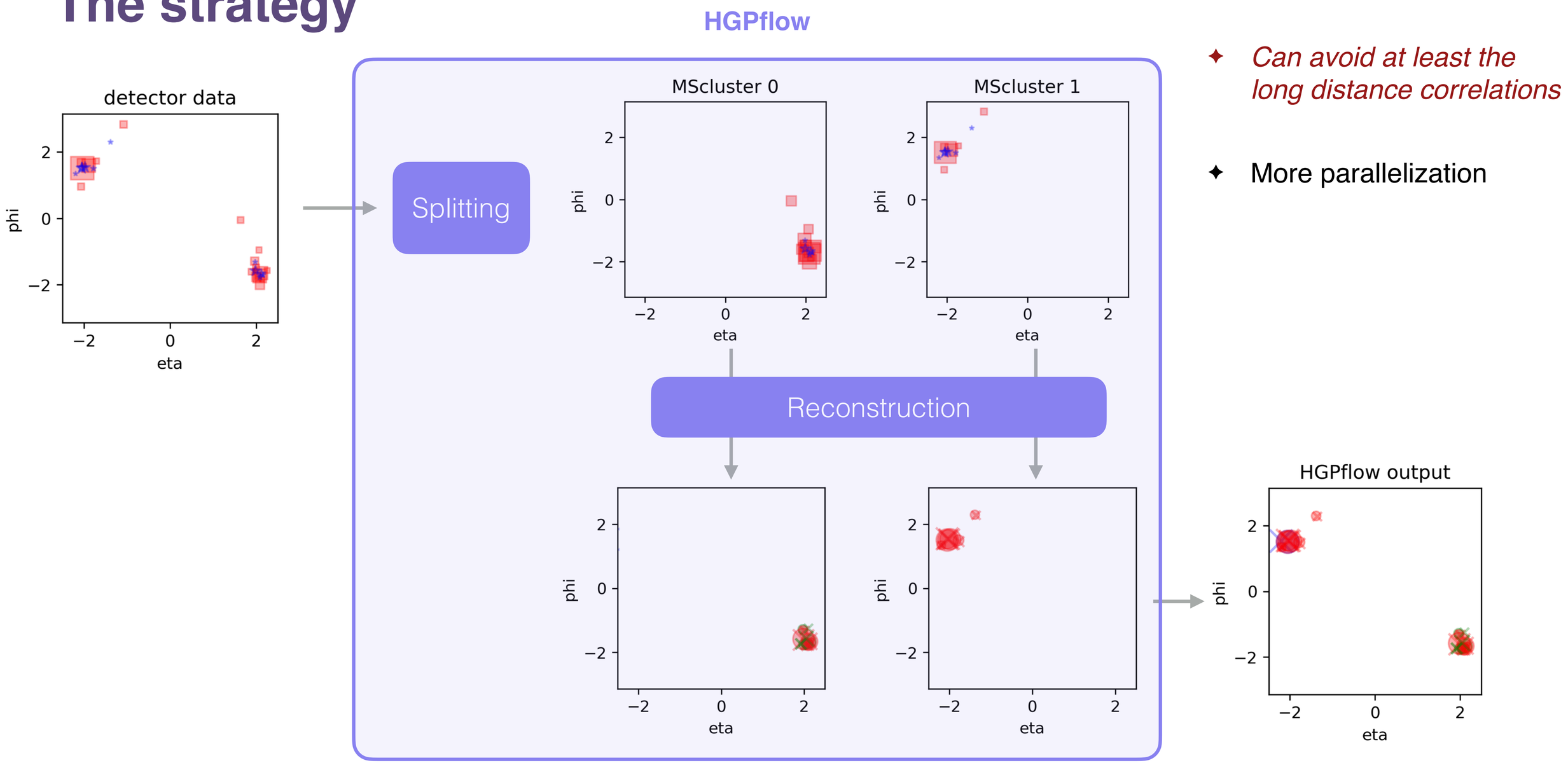
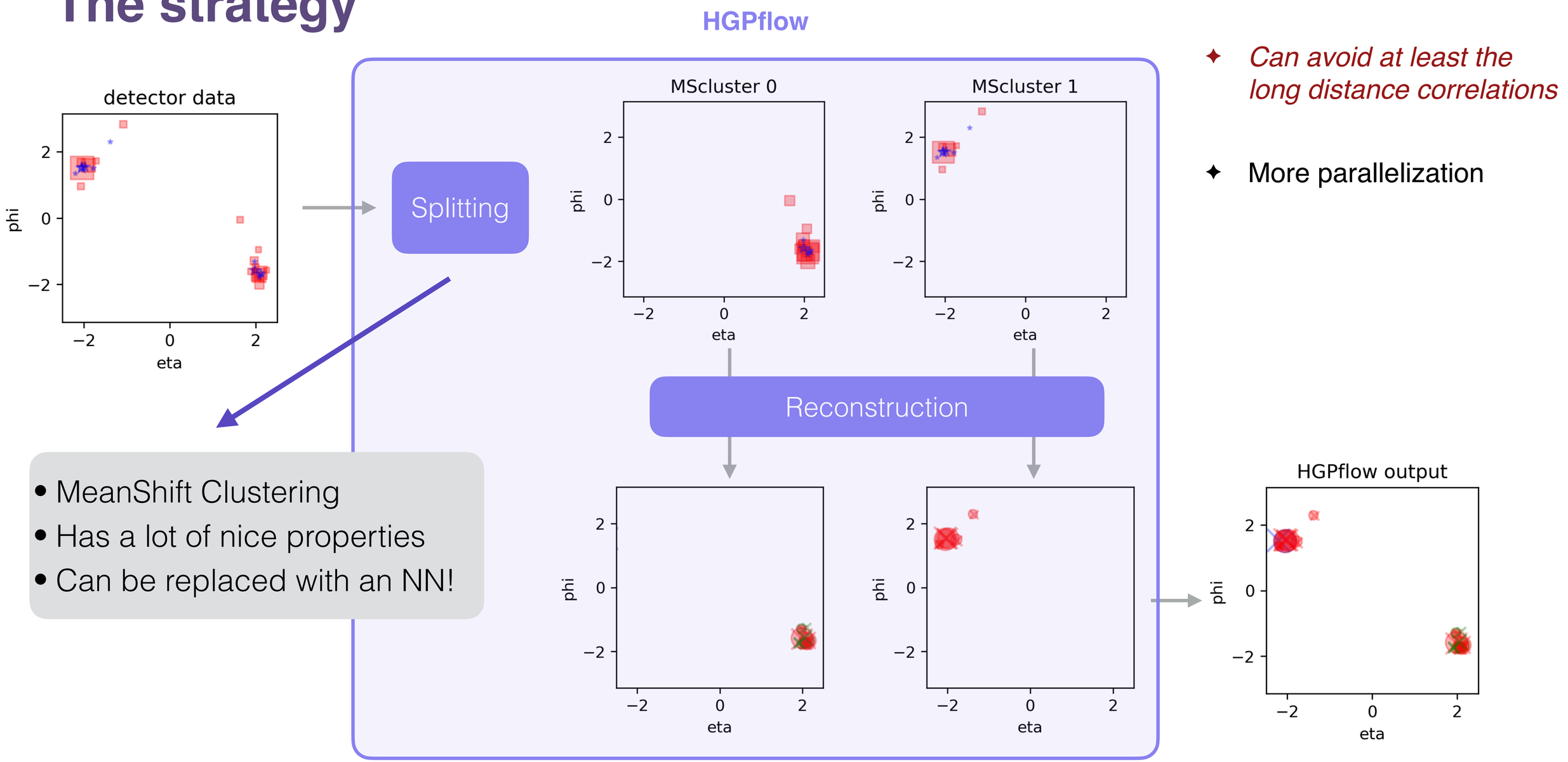


- *Can avoid at least the long distance correlations*
- More parallelization

The strategy



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Training

Training

- Dataset
  - dijet events
  - Underlying events
  - No Pileup
  - 12k events only (120k training examples)

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  - Much smaller model (1M parameters) for quick studies
  - No hyper-parameter optimization

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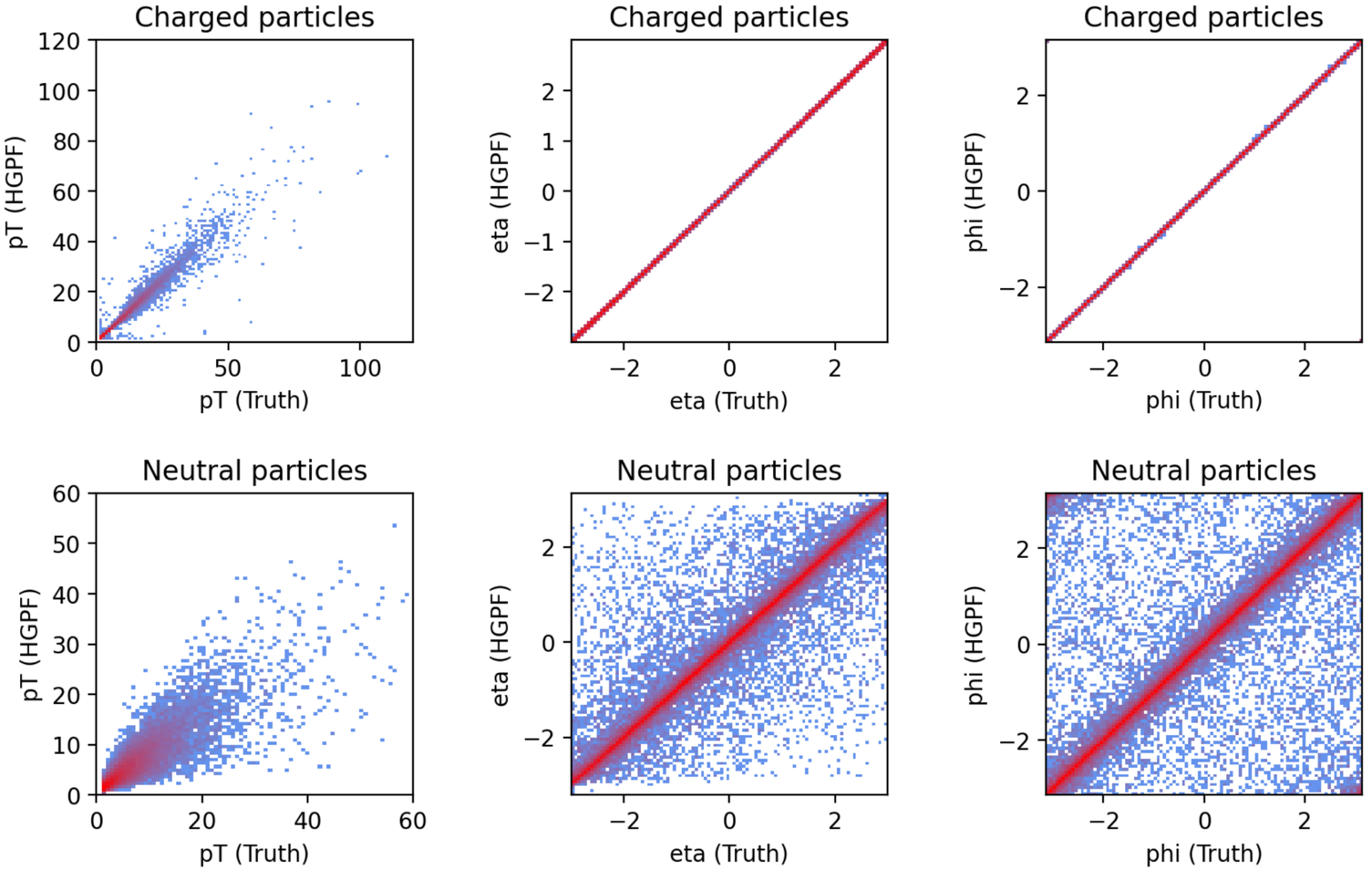
  - Underlying events
  - No Pileup
  - 12k events only (120k training examples)
- Model
  - Much smaller model (1M parameters) for quick studies
  - No hyper-parameter optimization
- Main goal: understand splitting and stitching

Particle level result (dijet test set)

Small model (1M)
+
Small dataset (12k)
+
no hyperparameter tuning



Results

Small model (1M)
+
Small dataset (12k)
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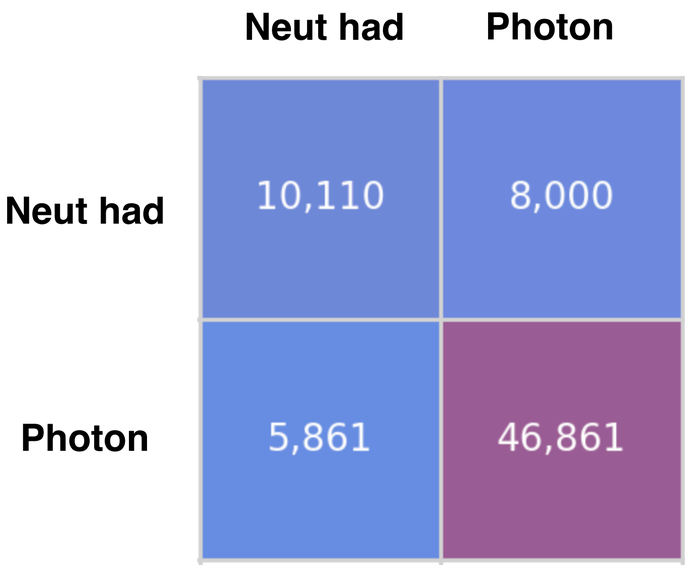


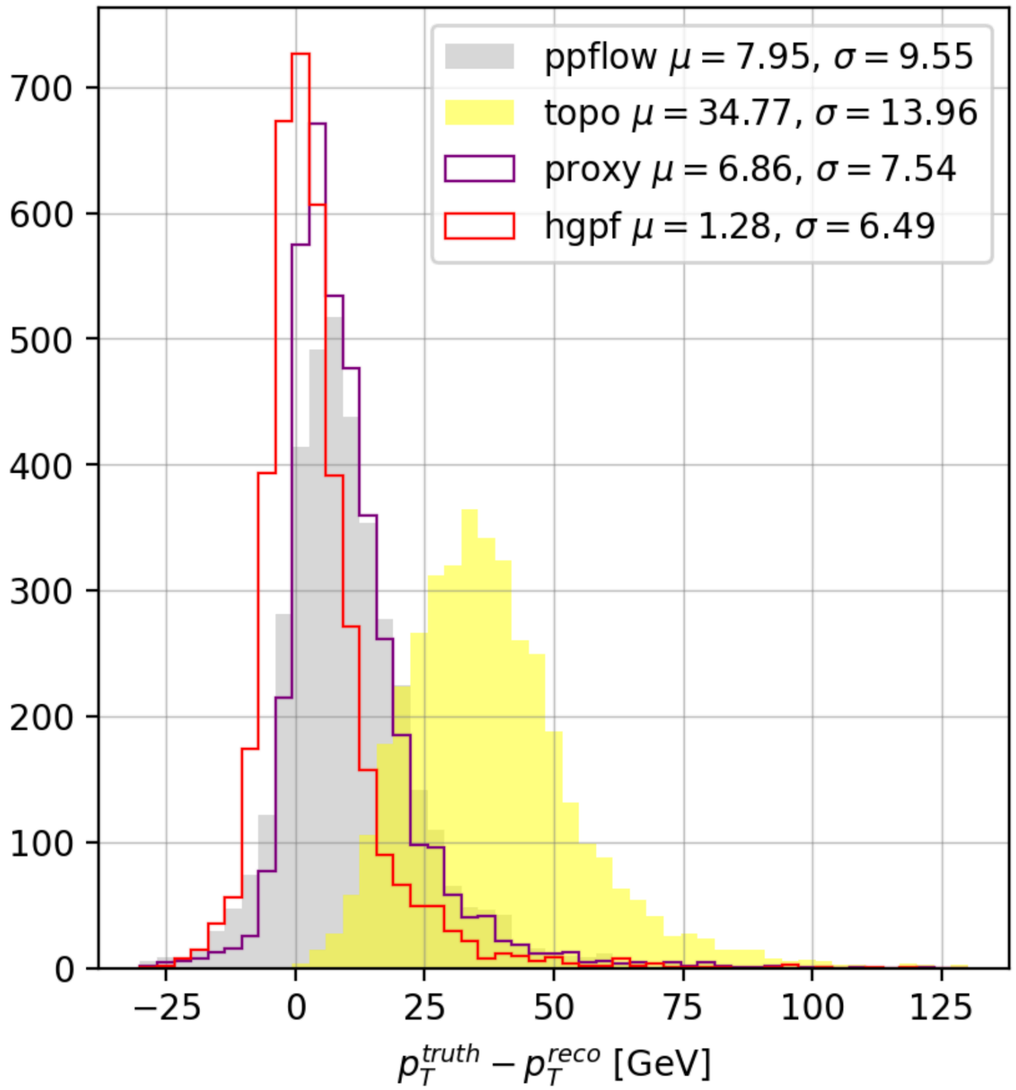
Confusion matrix (neutral only)

Results

	Neut had	Photon
Neut had	10,110	8,000
Photon	5,861	46,861

Confusion matrix (neutral only)

Leading jet resolution



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More studies (out of distribution)

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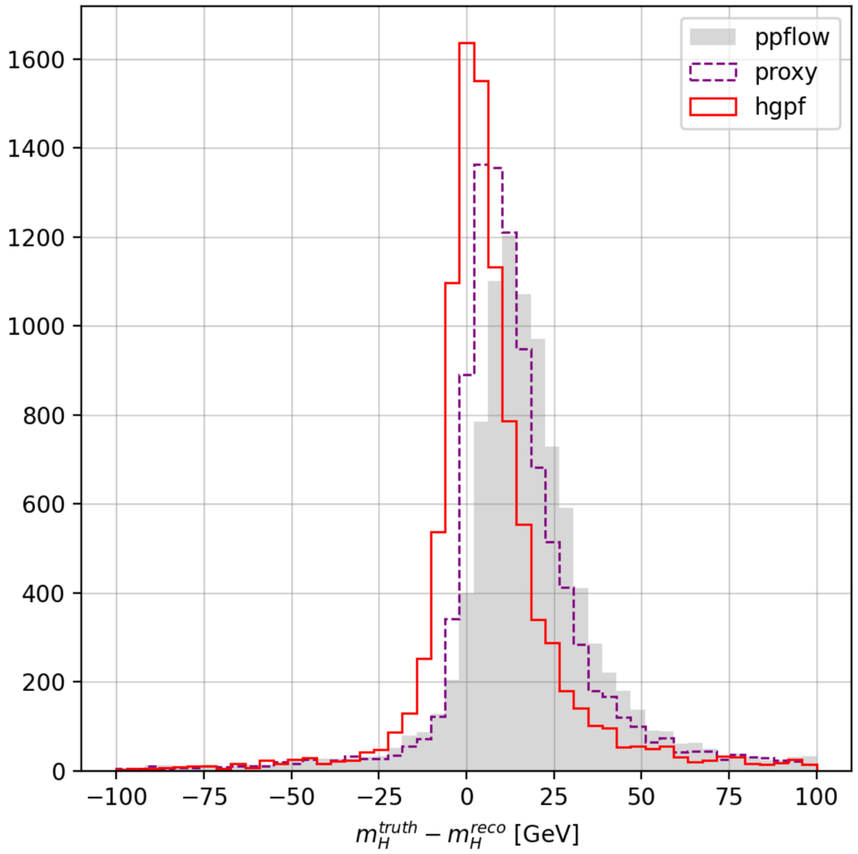
Using leading two jets (no calibration)



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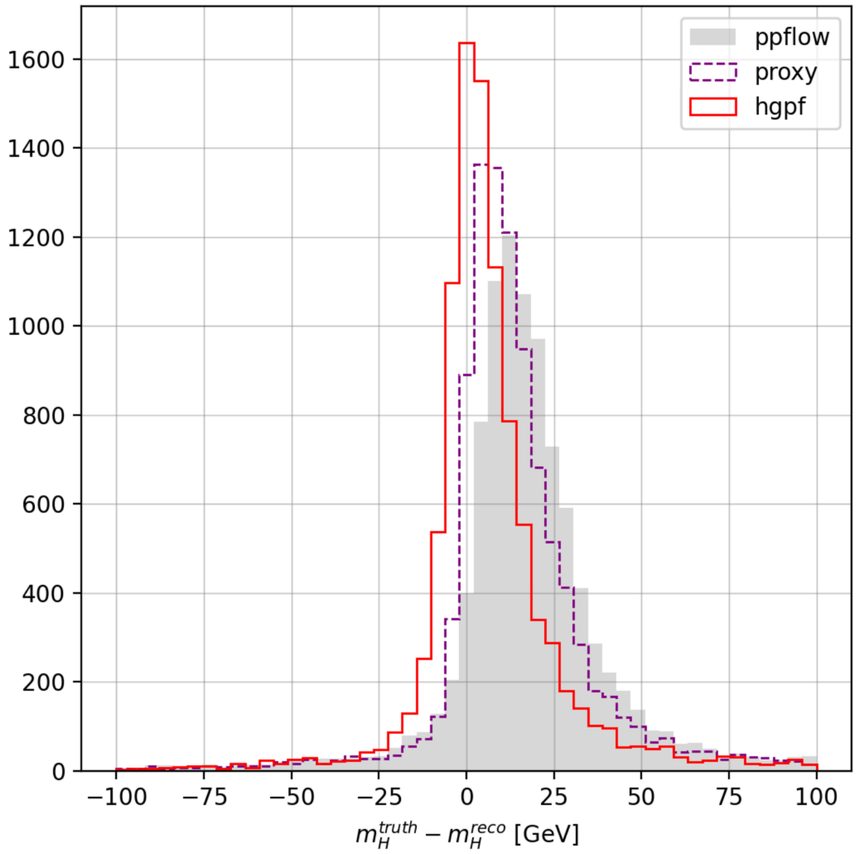
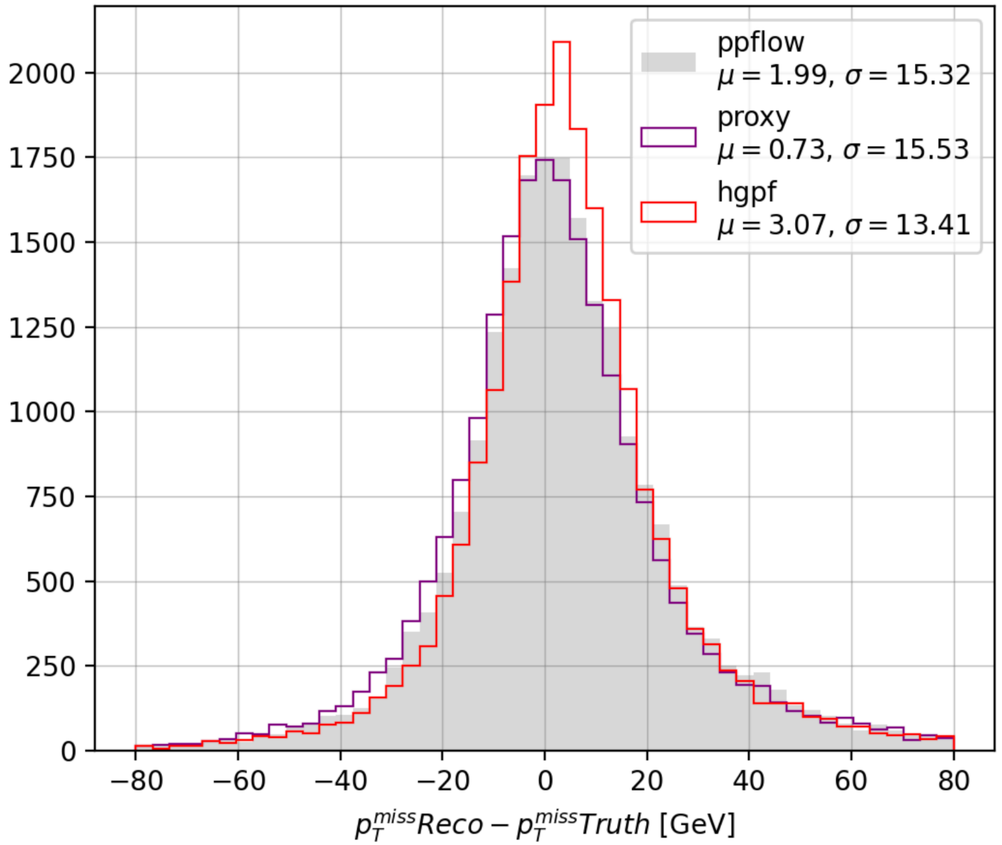


$t\bar{t}$



Conclusion

- HGPflow
  - Pros: interpretability
  - Can be scaled up to full event
  - Nice performance so far! (w/o much hyper parameter optimization)

- Splitting events
  - MSClustering seems to work well
  - Can have better ML solutions in future

- Hyperparameter optimization + larger model + larger dataset (next step)

- Talk by Javier on MLPF (more about particle flow)

Thanks!