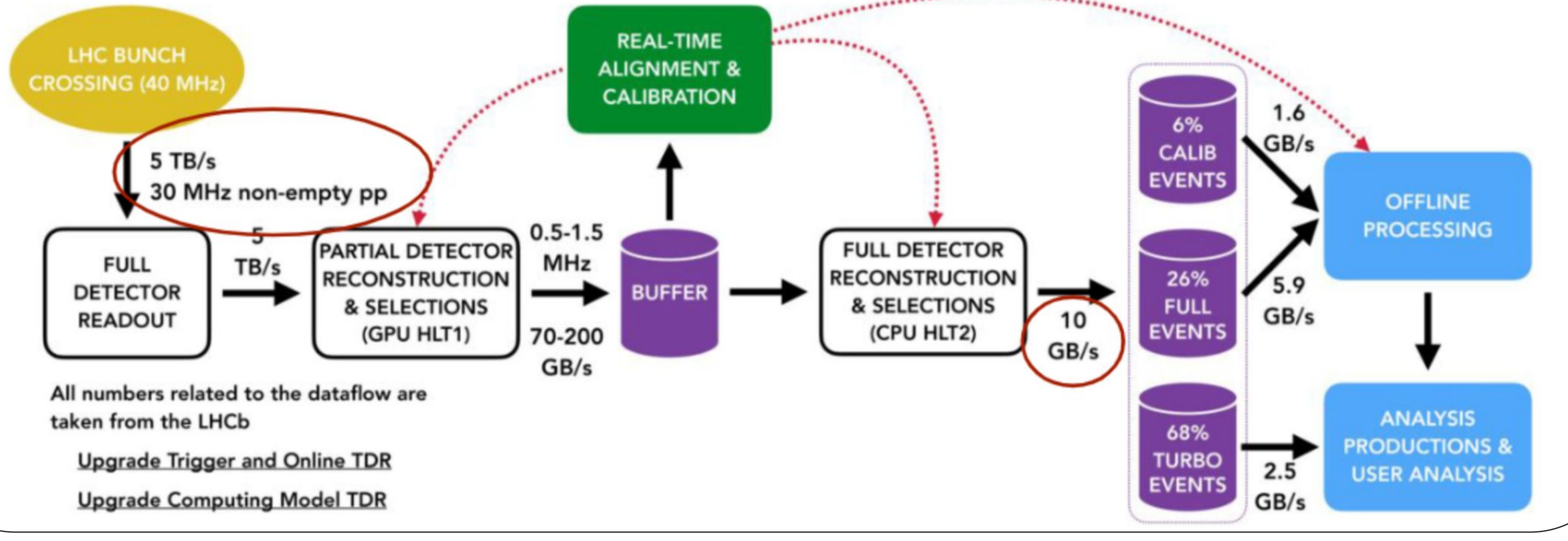
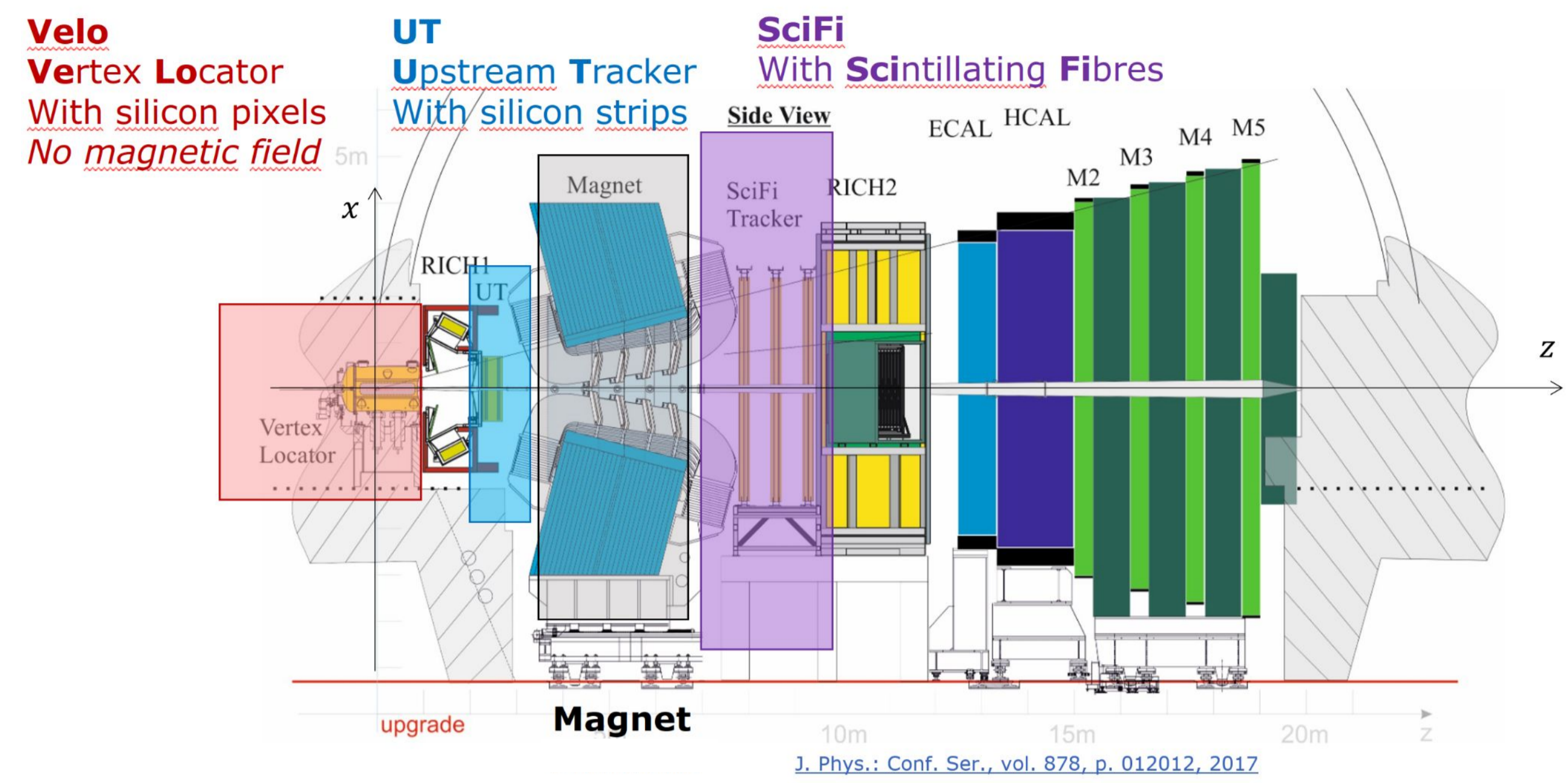


LHCb Detector and Dataflow

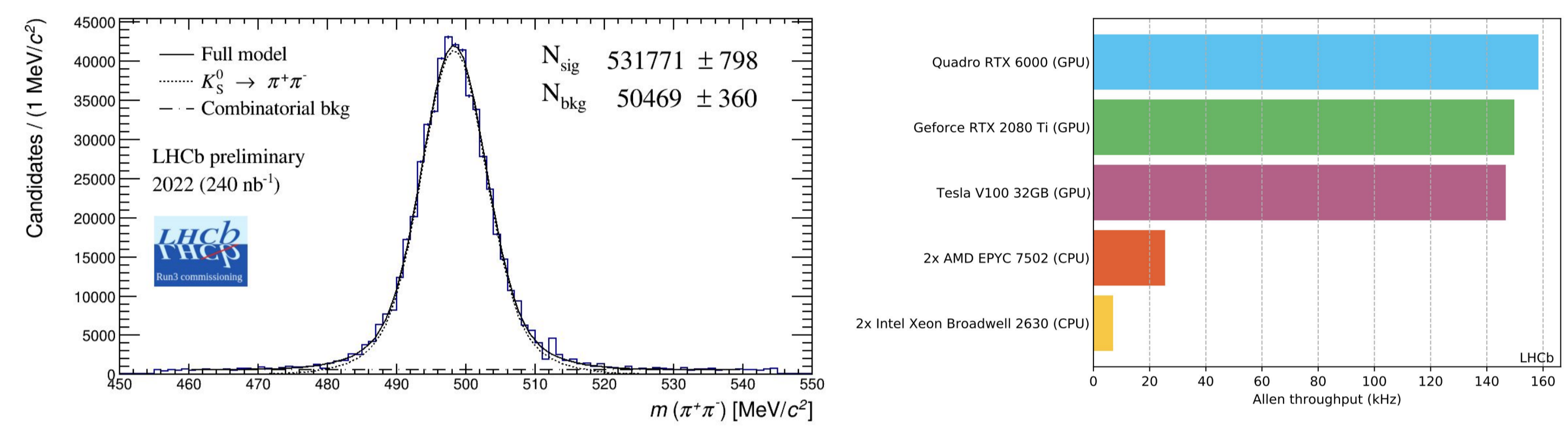


First Level Trigger (HLT1)

LHCb moved the **first level trigger from CPU to GPU**. This is the first time in high-energy physics that GPU processors have been used for a first-level trigger system.

Compared to the CPU baseline the GPU trigger allowed numerous additional physics functionality to be implemented: calorimeter reconstruction, low-momentum tracking, as well as finding tracks produced outside the LHCb vertex detector.

Implementing this trigger on **340 GPU processors** also resulted in **very substantial cost savings** with respect to the CPU baseline system.



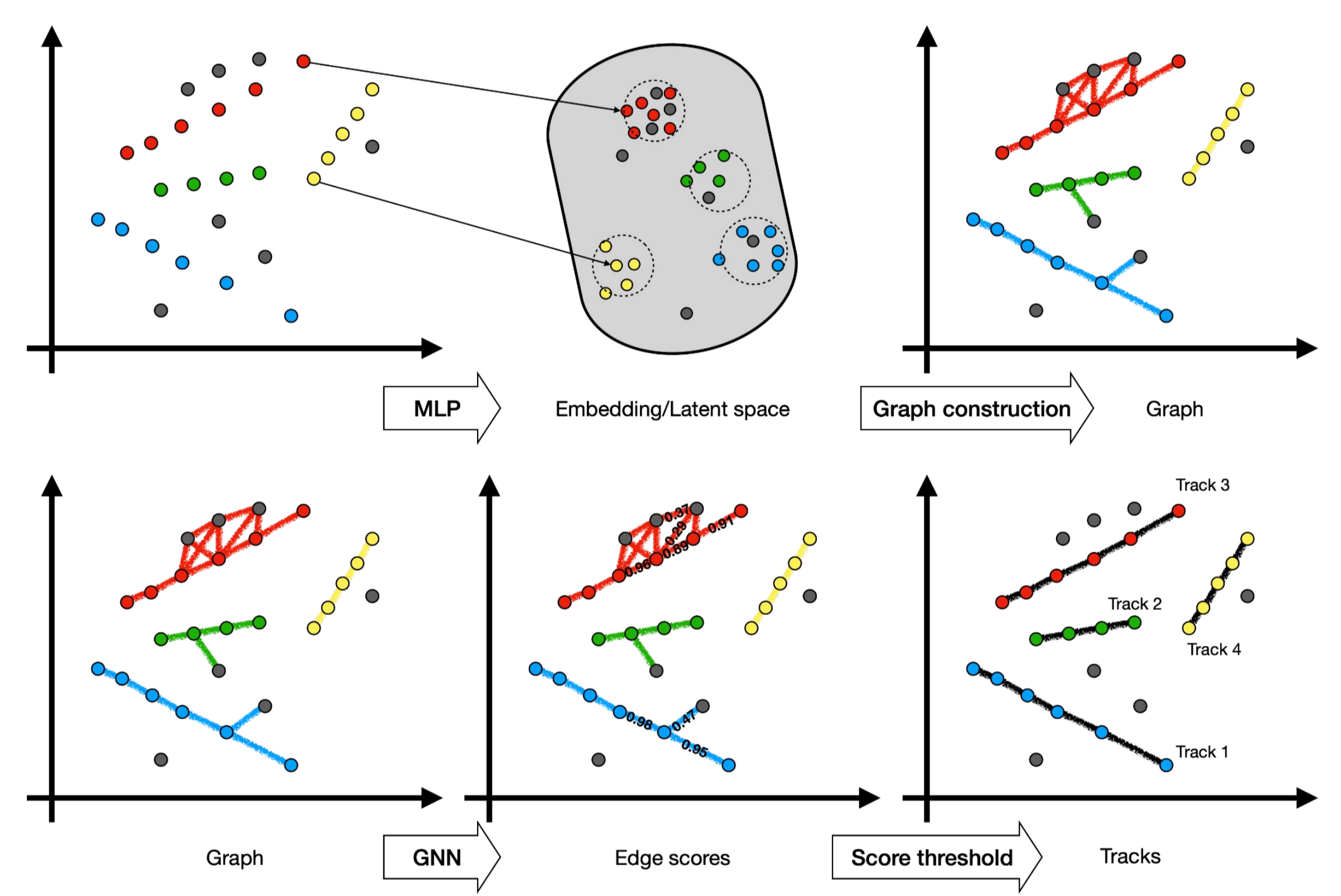
ETX4VELO: Graph Neural Network-Based Pipeline for Track Finding in the Velo at LHCb

The focus is to evaluate deep-learning algorithms performance for **EFFICIENCY** and **THROUGHPUT**, and estimate how these models scale up with the increase of data rate.

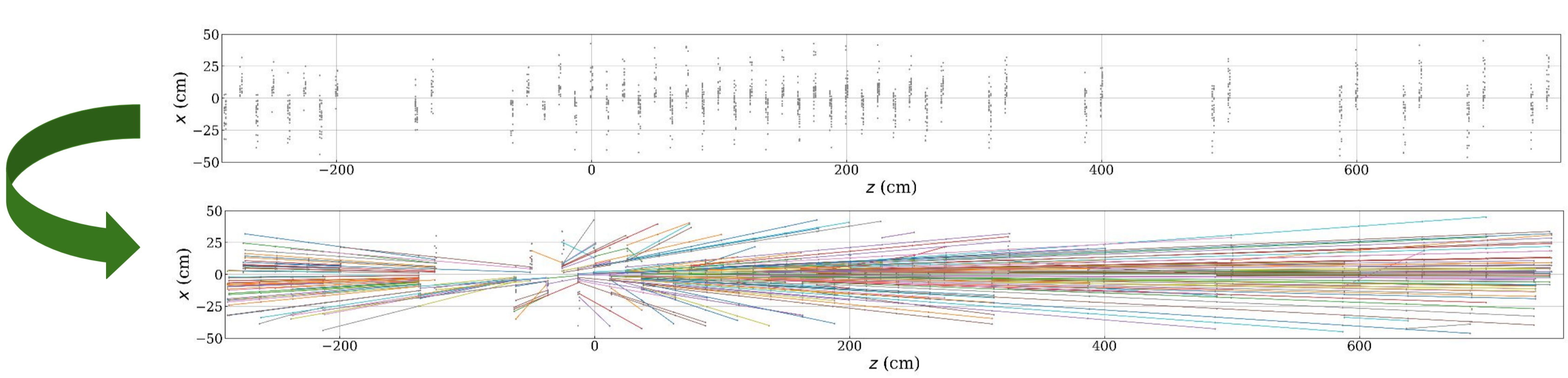
For this purpose we developed the **ETX4VELO** pipeline which focuses on developing Graph Neural Networks (GNNs) algorithms for track reconstruction.

- Steps of the pipeline:
- Embedding
 - Graph Construction
 - GNN
 - Triplets (not shown in the diagram)
 - Score cut

The efficiency reached at this level is higher than Allen. The **ETX4VELO** pipeline is based on **edge and triplet GNN** model that can reconstruct harsh cases of shared hits between tracks.



Category	Metric	Allen	ETX4VELO smaller graph	ETX4VELO Larger graph
Long, no electrons ✓ In acceptance ✓ Reconstructible in the velo ✓ Reconstructible in the SciFi ✓ Not an electron	Efficiency	99.26%	99.28%	99.51%
	Clone rate	2.54%	0.96%	0.89%
	Hit efficiency	96.46%	98.73%	98.90%
	Hit Purity	99.78%	99.94%	99.94%
	Ghost rate	2.18%	0.76%	0.81%
Long electrons ✓ In acceptance ✓ Reconstructible in the velo ✓ Reconstructible in the SciFi ✓ Electron	Efficiency	97.11%	98.80%	99.22%
	Clone rate	4.25%	7.42%	7.31%
	Hit efficiency	95.24%	96.54%	96.79%
	Hit purity	97.11%	98.46%	98.46%
	Ghost rate	2.18%	0.76%	0.81%
Long, from strange ✓ In acceptance ✓ Reconstructible in the velo ✓ Decays from a strange Good proxy for displaced tracks	Efficiency	97.69%	97.50%	98.06%
	Clone rate	2.50%	0.92%	0.81%
	Hit efficiency	97.69%	98.22%	98.77%
	Hit purity	99.34%	99.68%	99.68%
	Ghost rate	2.18%	0.76%	0.81%
X	Ghost rate	2.18%	0.76%	0.81%



Inference of the ETX4VELO Models on GPUs and FPGAs

Then we focused on running these algorithms on architectures with more potential for performance.

- Integration inside the LHCb's first-level GPU trigger (HLT1)
- Inference of the MLP and GNN on GPU
- Inference of the MLP on FPGA

