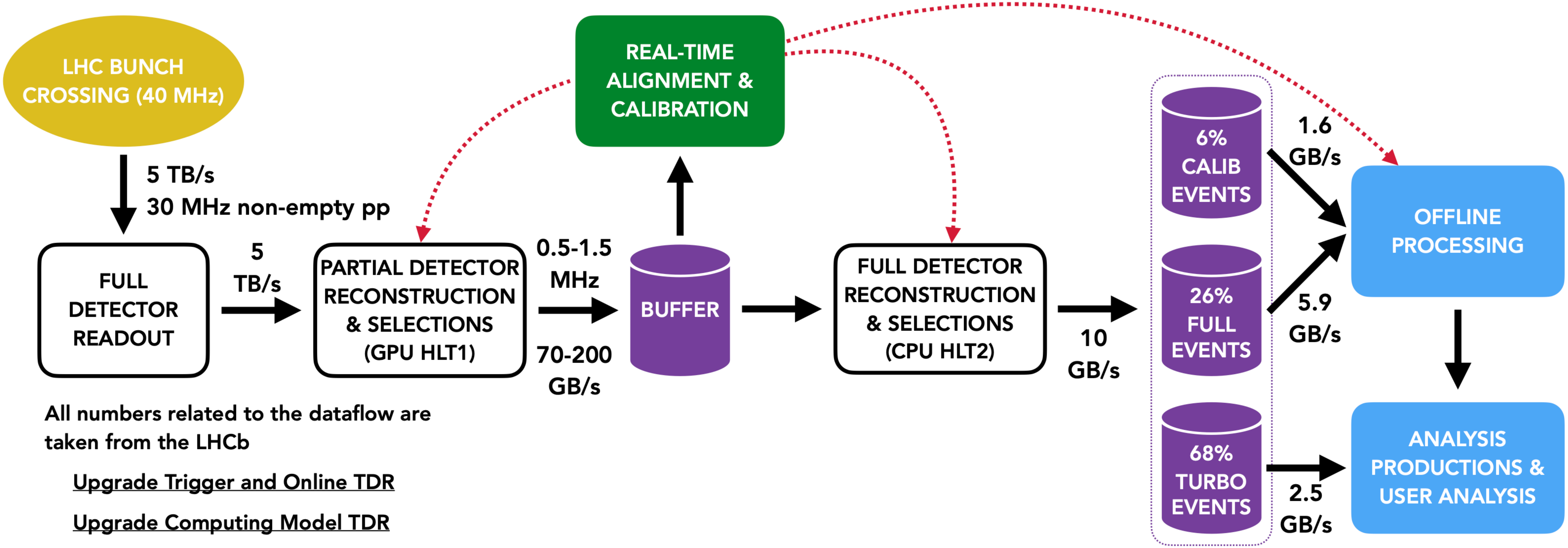
DATAFLOW IN RUN3

Renaud Amalric - LPNHE (Paris)

01/12/2022

DATAFLOW IN RUN3

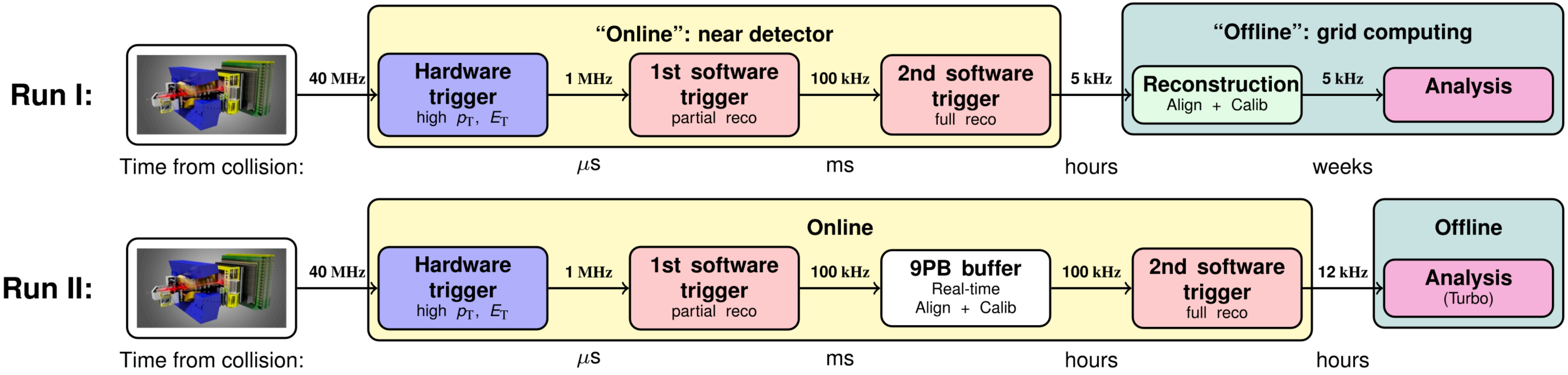


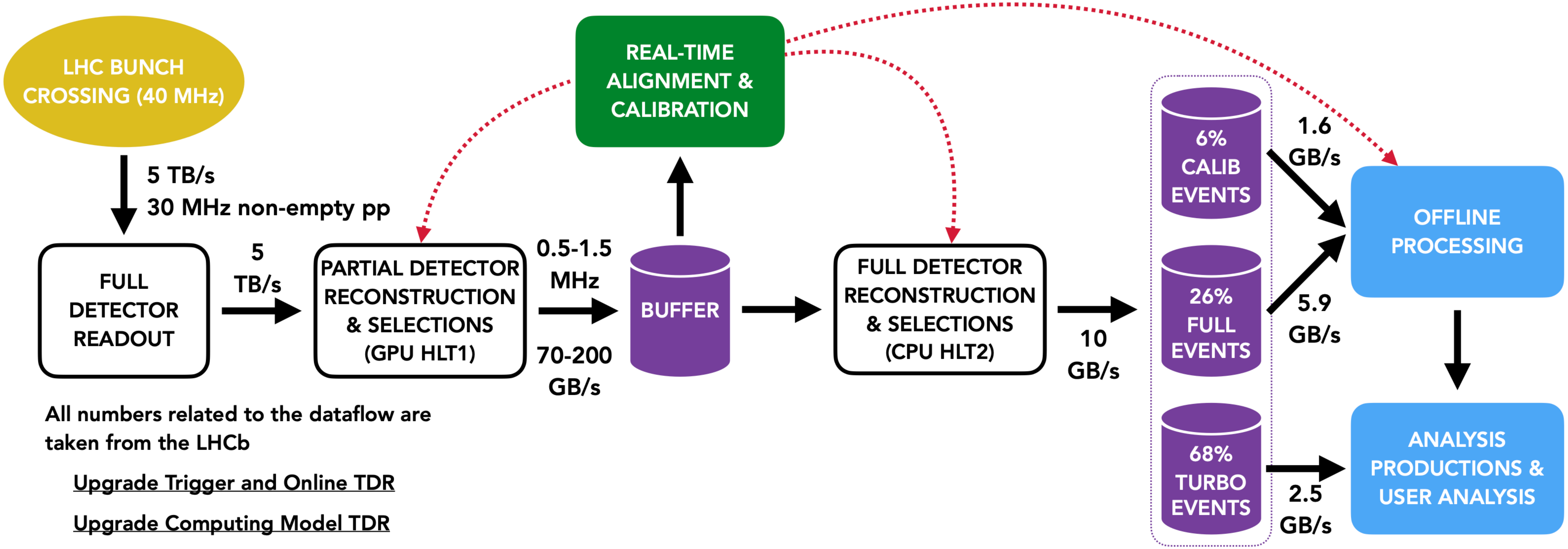
All numbers related to the dataflow are taken from the LHCb

Upgrade Trigger and Online TDR

Upgrade Computing Model TDR

WHAT CHANGED ?





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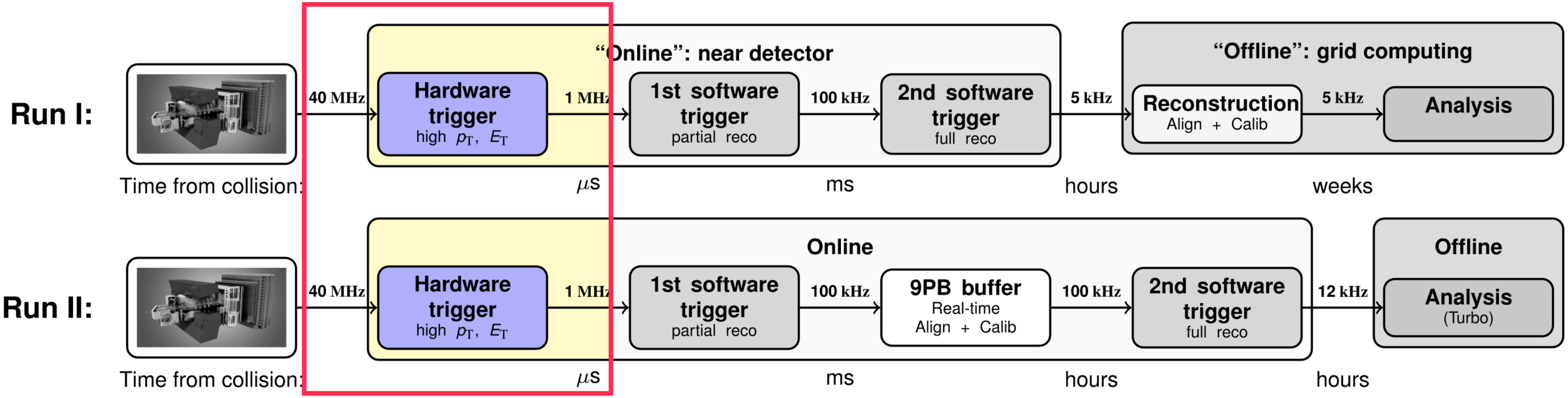
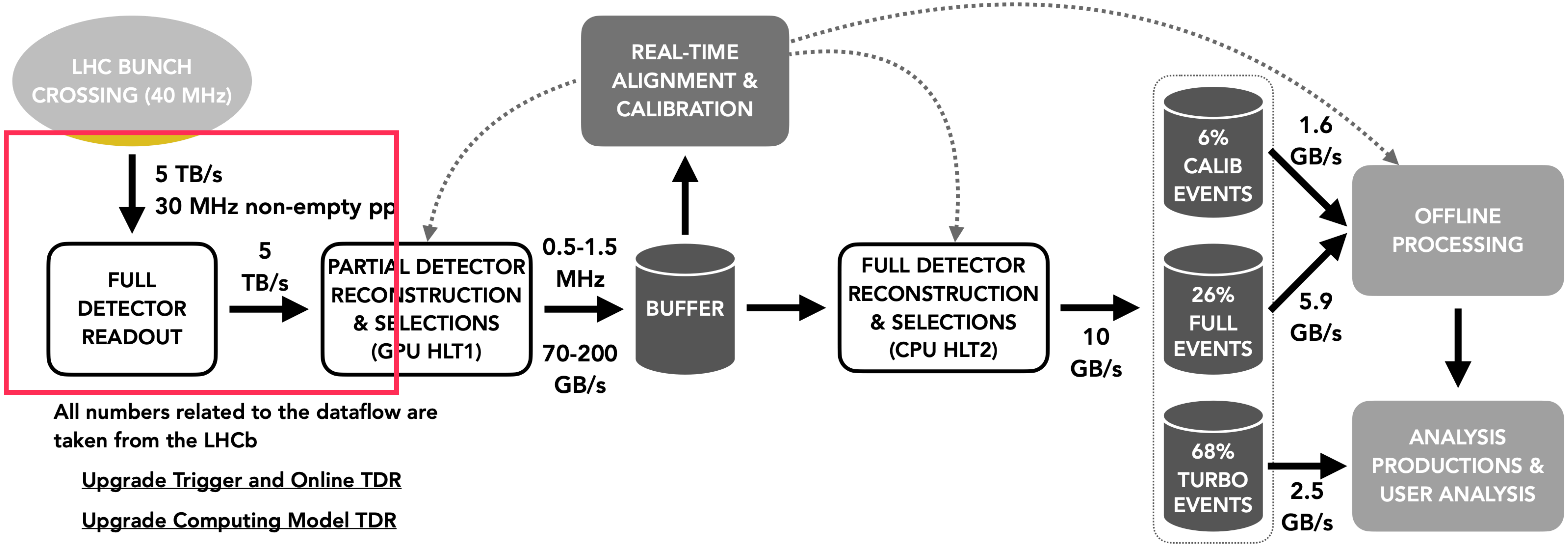
NO MORE HARDWARE TRIGGER





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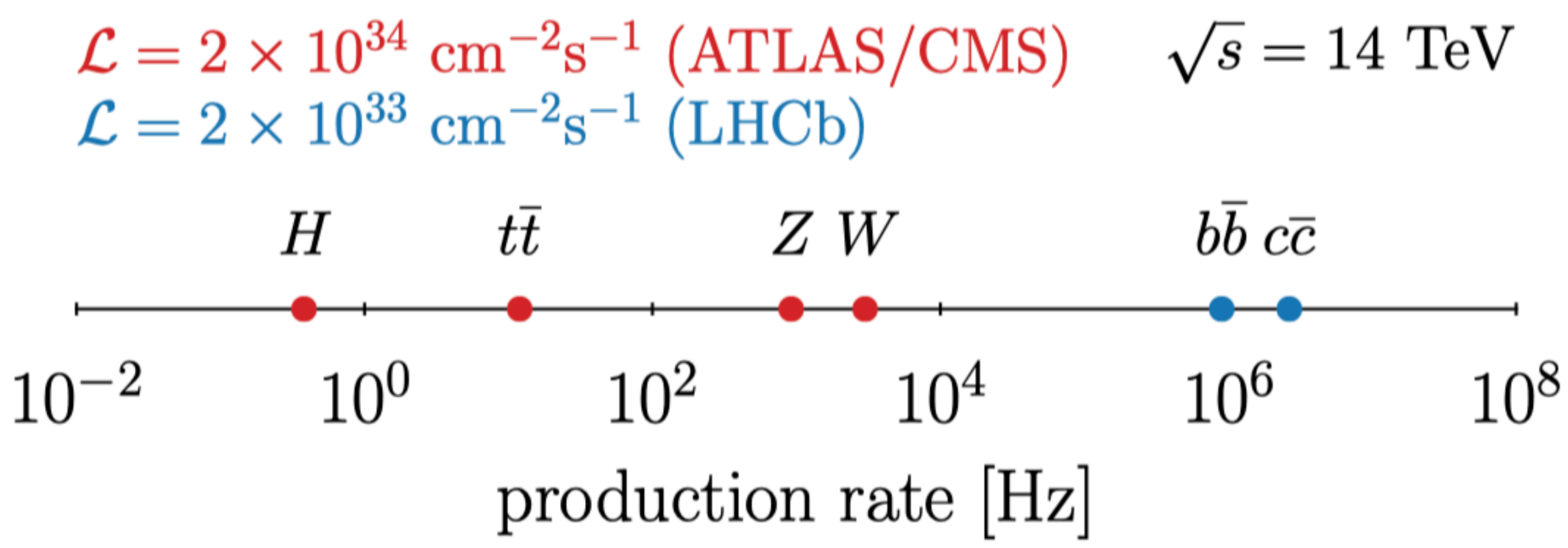
Upgrade Trigger and Online TDR

Upgrade Computing Model TDR

QUICK WORD ON TRIGGERS

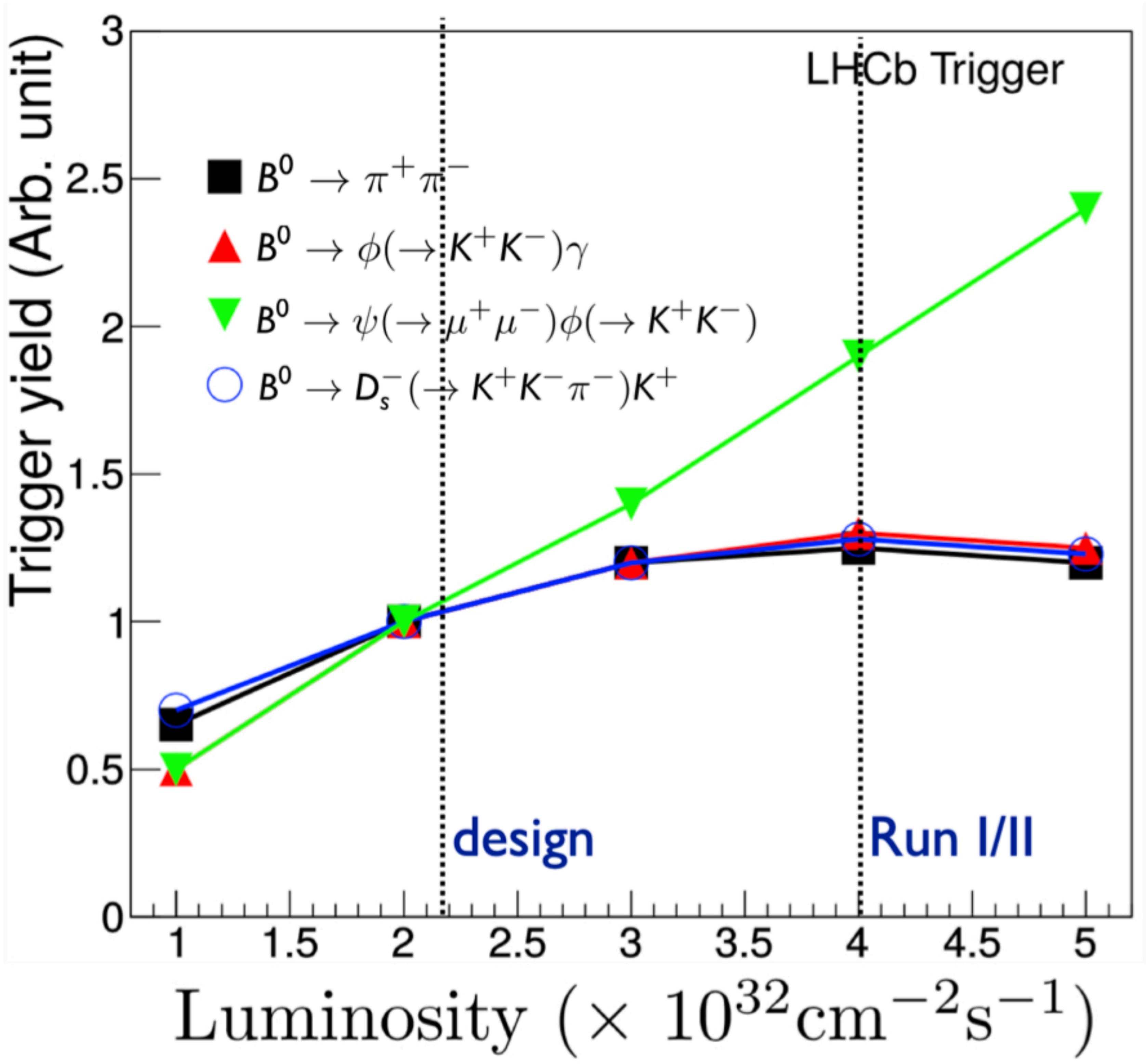
- → Gather the information from all the sub-detectors
- → Issue : we produce much more information than what we can actually store to disk to be analyse later on
- → Need triggers to select in real time what you actually want to store and do this as efficiently as possible
- → 2 possibilities
  - ➤ Hardware triggers
  - ➤ Software triggers

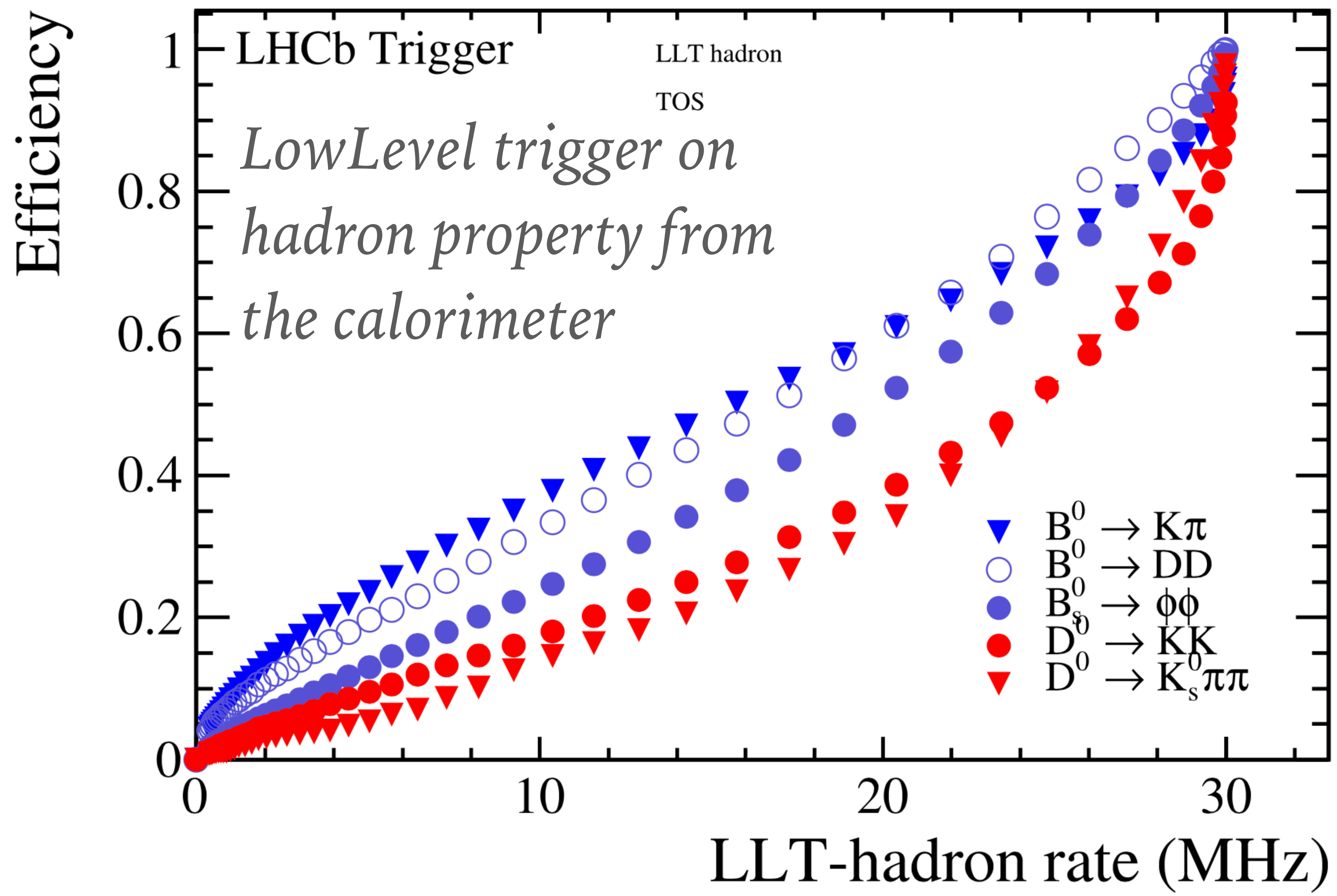


WHY NO MORE HARDWARE TRIGGERS ?

→ Trigger for many hadronic channels saturated already at Run 1–2 luminosity

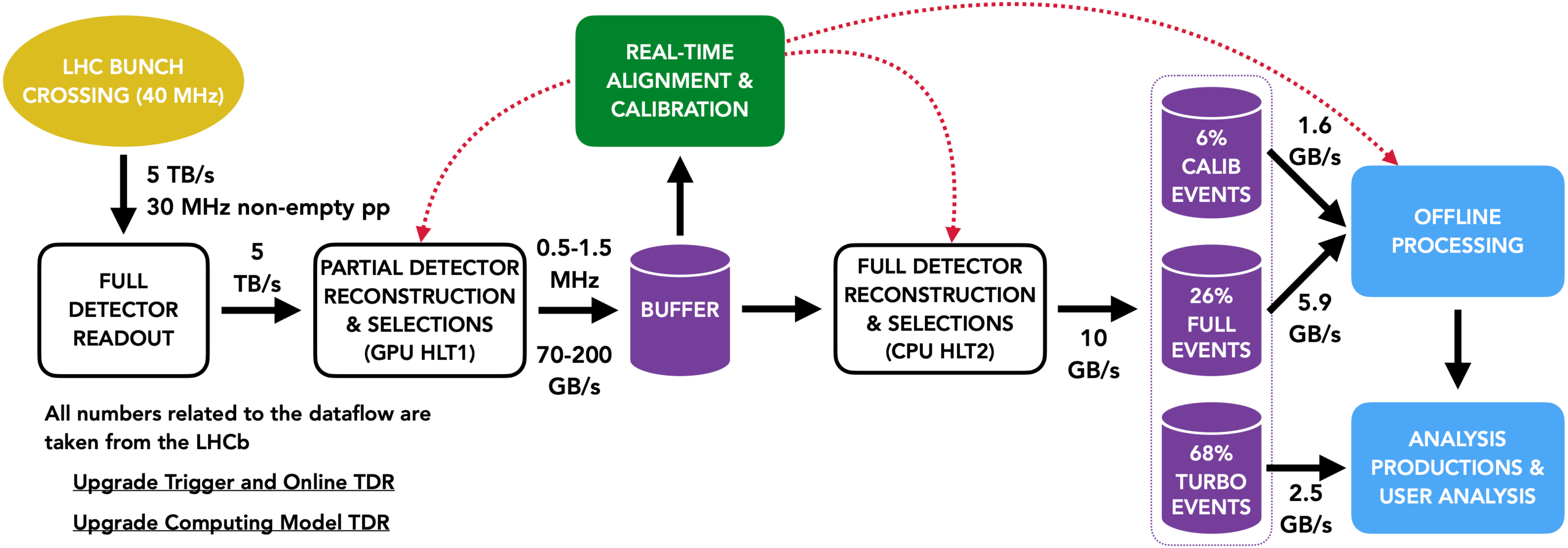
→ Cannot effectively trigger on heavy flavour using hardware signatures





⇒ **Fully software triggers**

DATAFLOW IN RUN3



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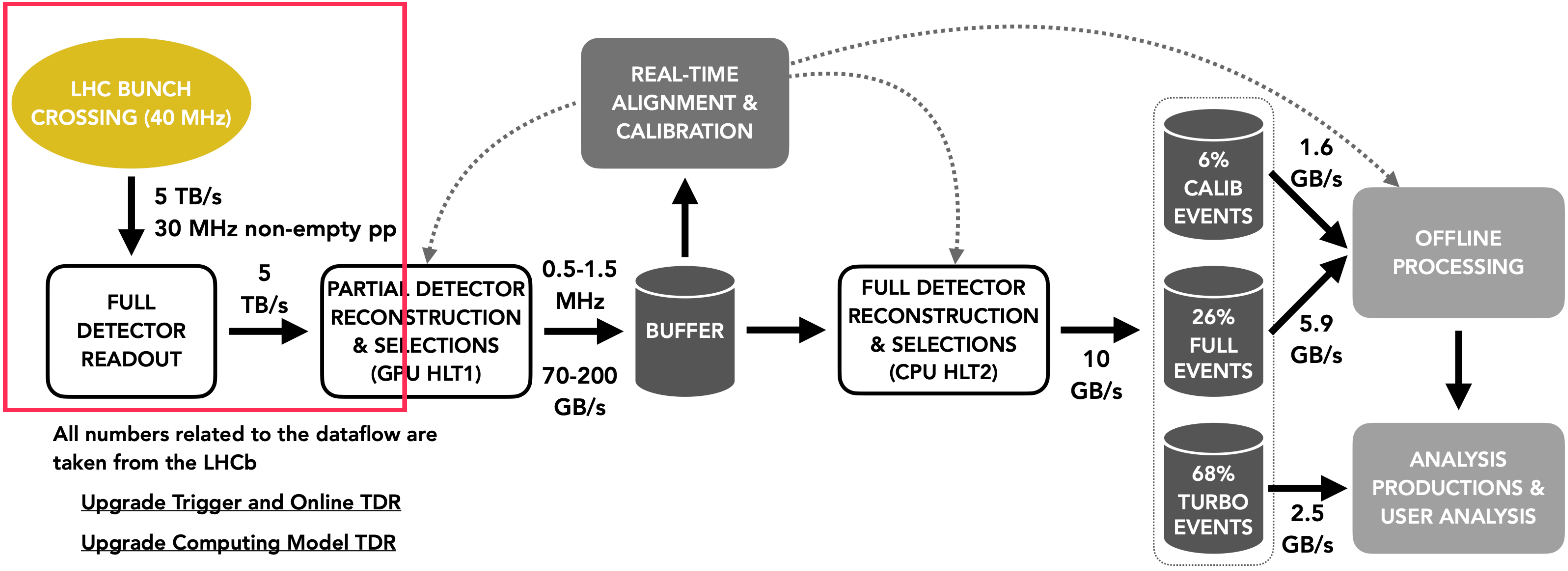
FROM THE SUB-DETECTORS TO THE COMPUTINGS FARMS



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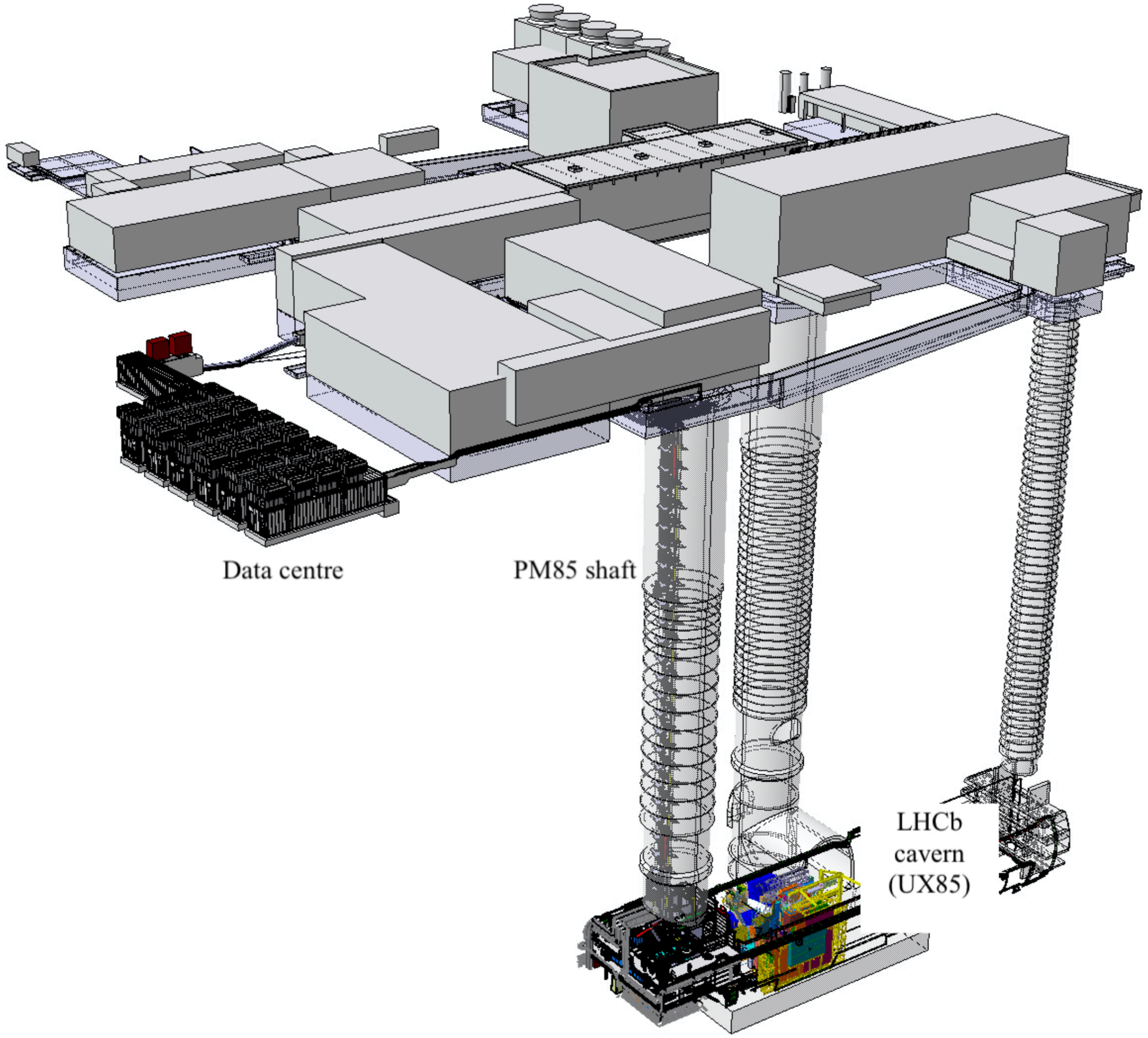
Upgrade Trigger and Online TDR

Upgrade Computing Model TDR

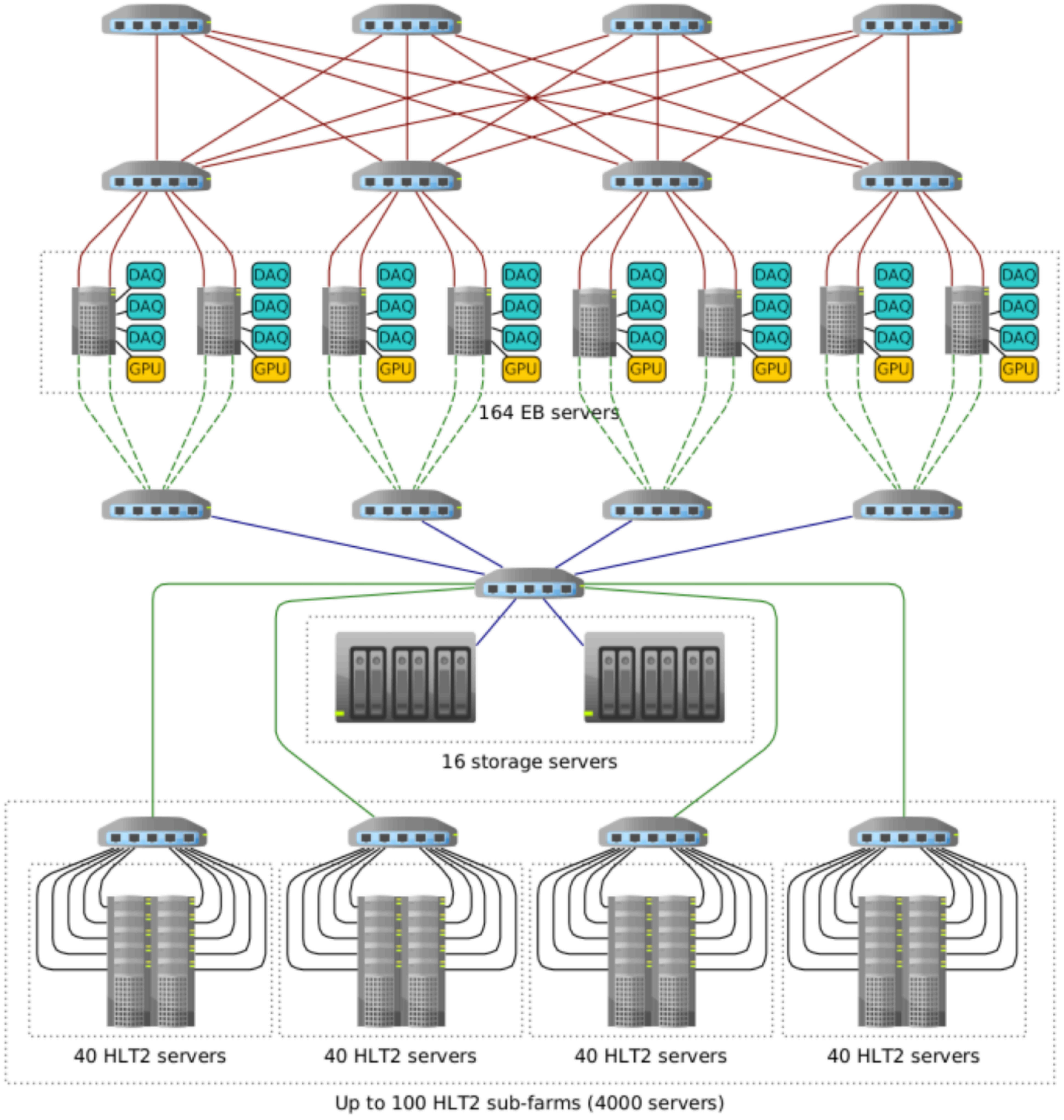
FROM THE SUB-DETECTORS TO THE COMPUTINGS FARMS

- New architecture to transmit data collected from every bunch crossing all the way to the event-building computing farms.
- The sub-detectors are connected to the data center through long-distance (~250m) optical fibres installed in the PM85 shaft.

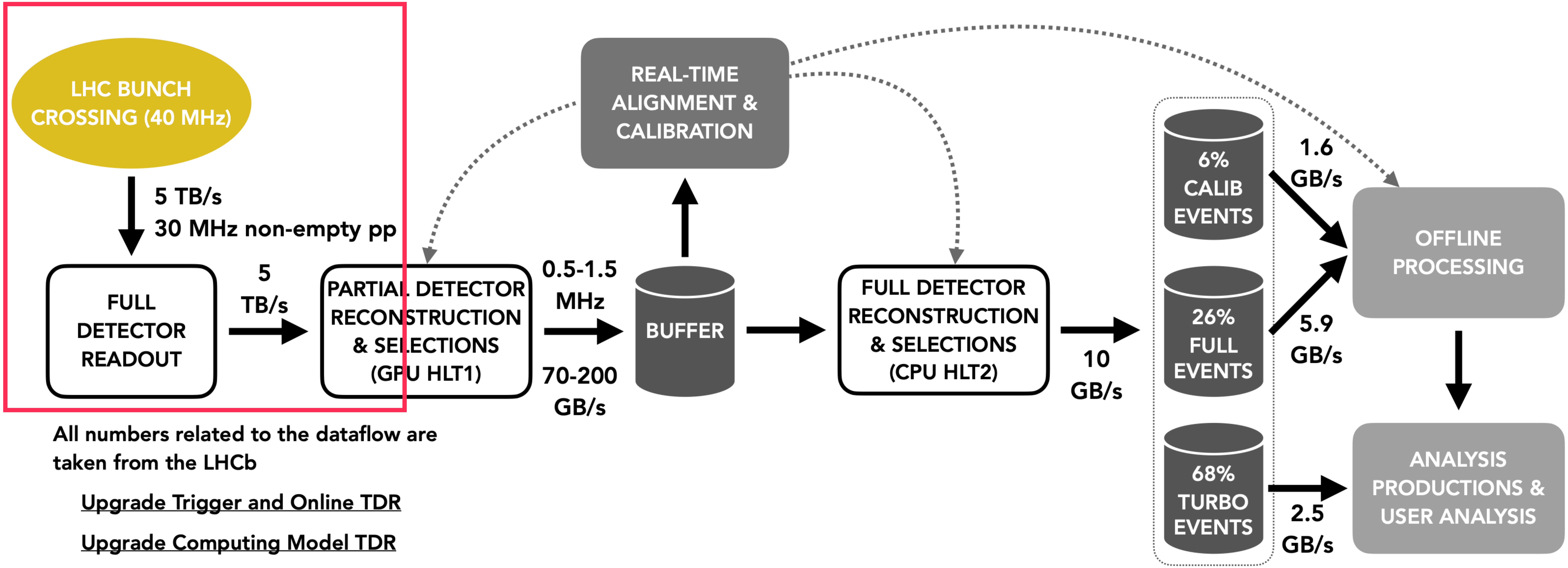


EVENT BUILDING

- To perform the selection, the full-software LHCb trigger requires the complete event information from all the sub-detectors.
- Detector's data received by ~500 FPGAs
- Regrouped to the same destination - to one server for event-building.
- Event Building : combining the raw data to form single cohesive events
- Event builder farm : ~170 servers (with 3 FPGAs each)
- Adding GPUs on those servers to apply the first step of selections → HLT1 and then send the data downstream



FROM THE SUB-DETECTORS TO THE COMPUTINGS FARMS



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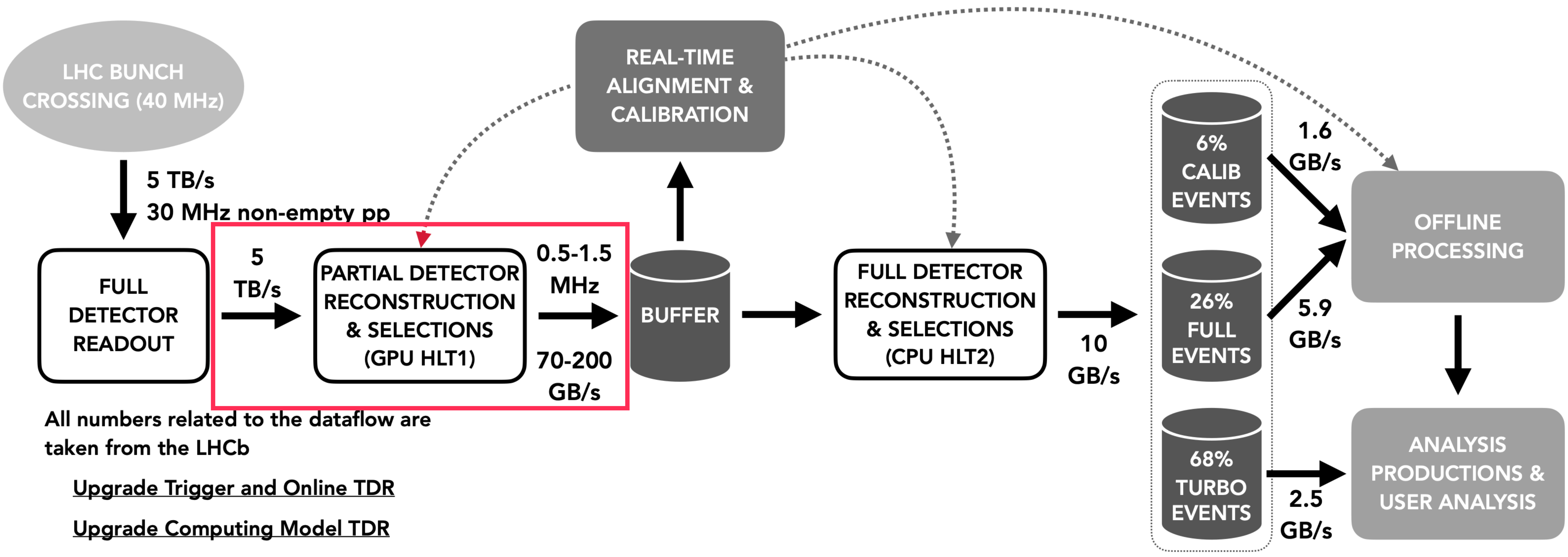
<u>Upgrade Trigger and Online TDR</u>

<u>Upgrade Computing Model TDR</u>

HIGH LEVEL TRIGGER 1



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Upgrade Trigger and Online TDR

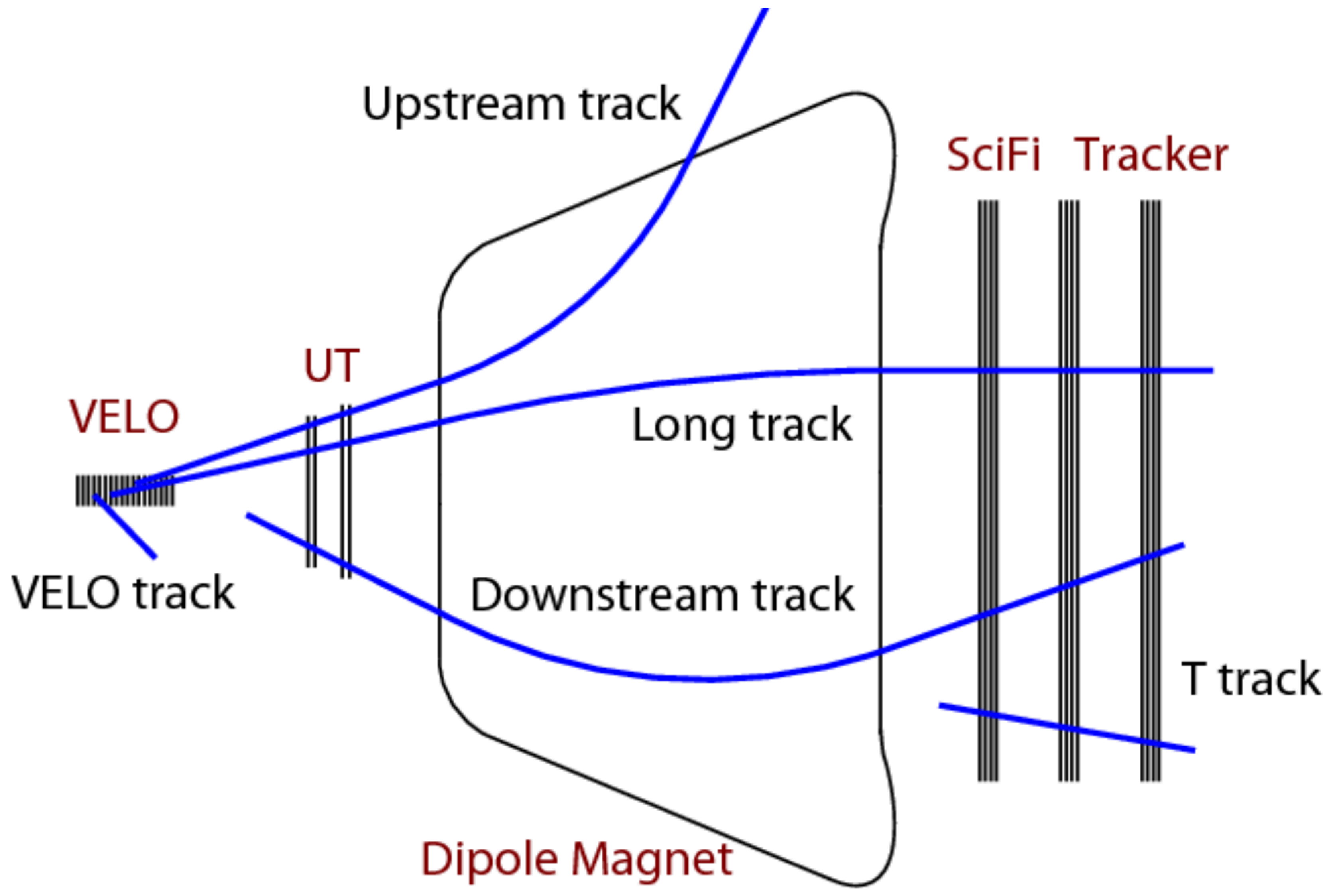
Upgrade Computing Model TDR

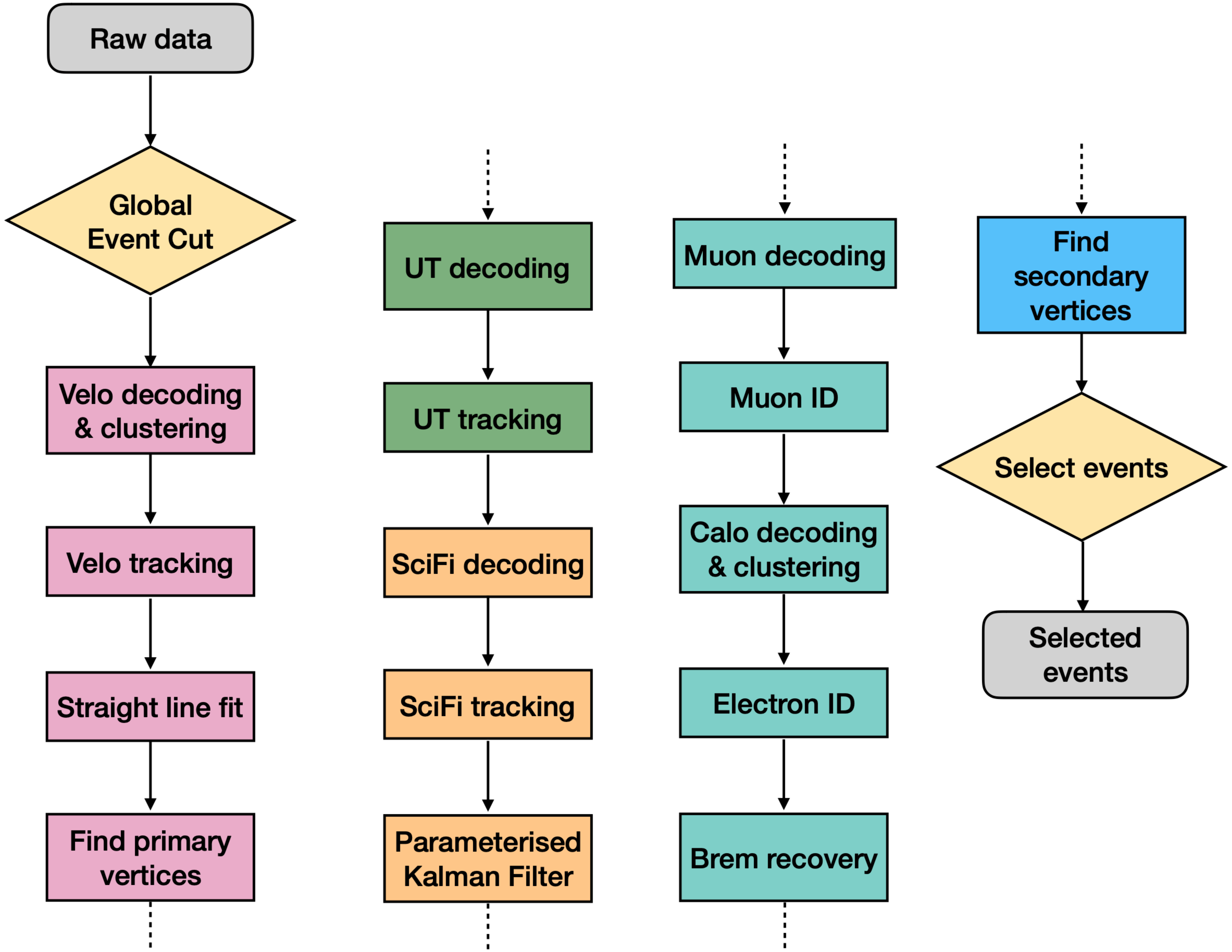
HLT1

- Fast and partial reconstruction
  - Charged particle track and vertex reconstruction
  - Electron and muon identification
- Up to ~500 GPUs (3 slots available per EB servers)
  - Manageable amount of algorithms
  - Parallel tasks
  - No detailed knowledge of magnetic field & detector required
- Software : Allen project

HLT1 SEQUENCE

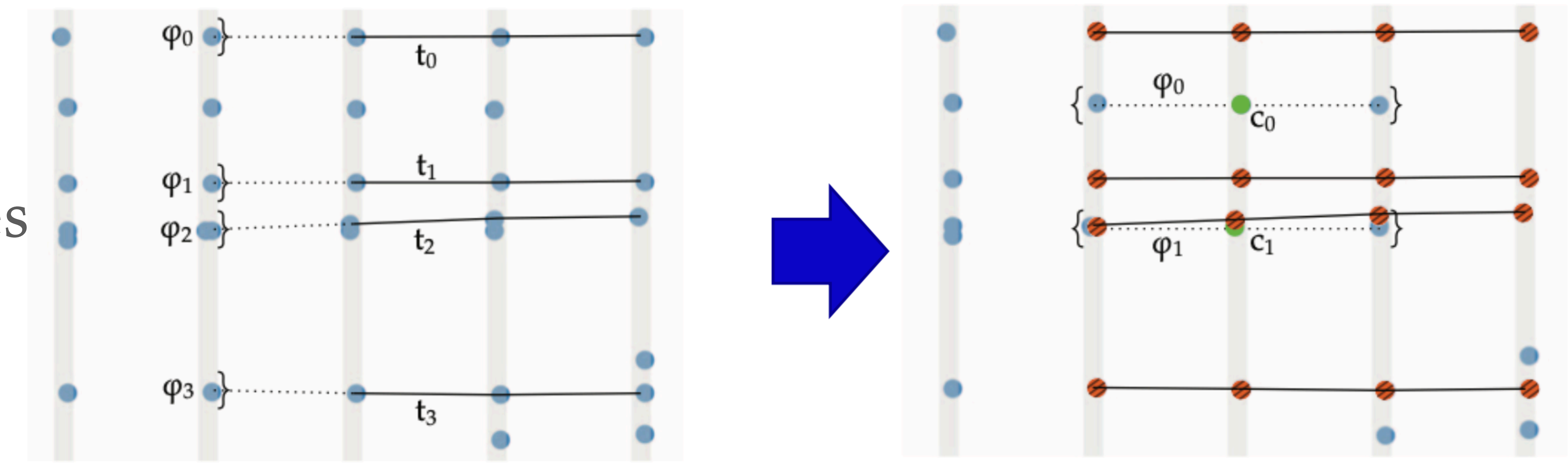
→ What do the GPUs have to do ?

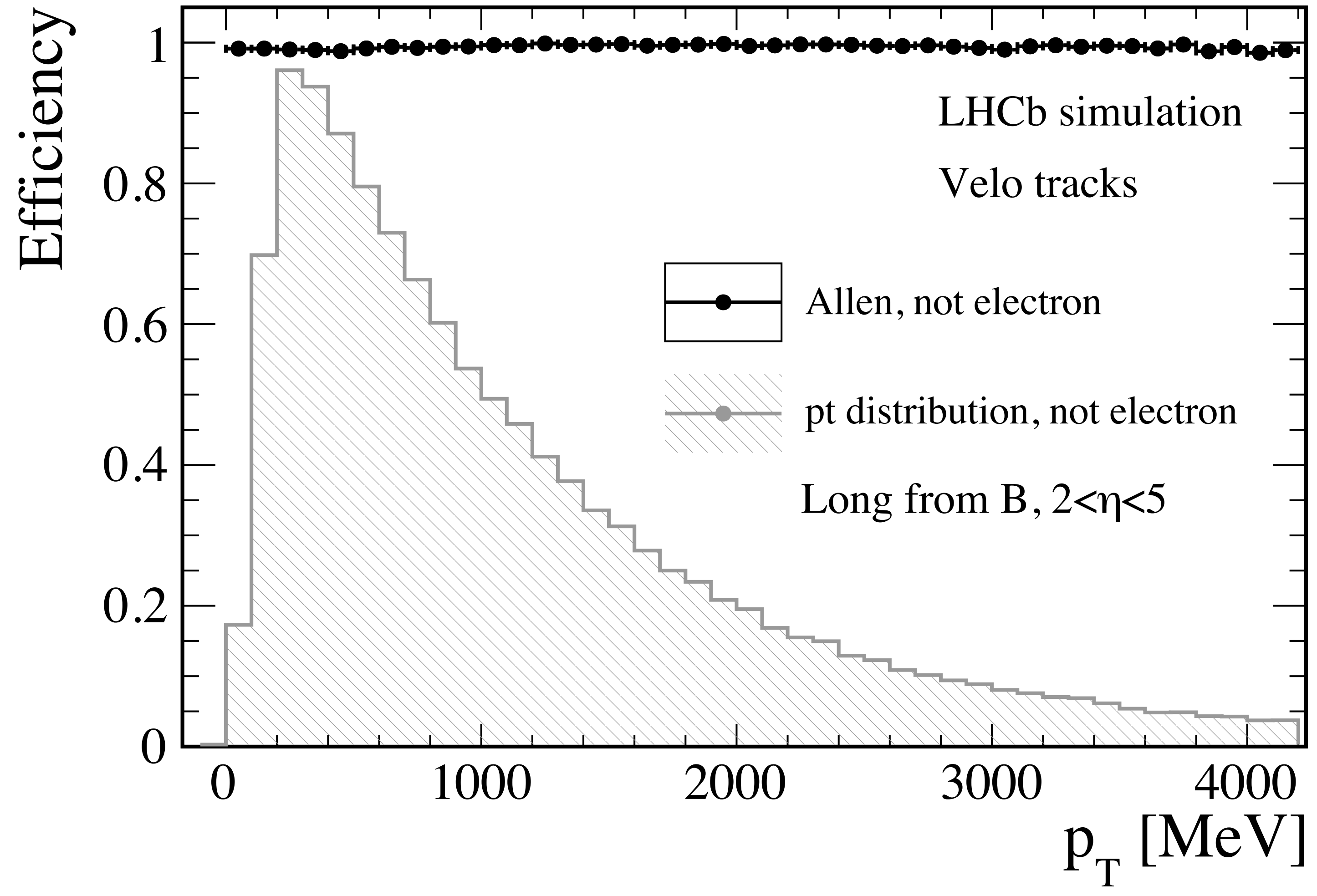


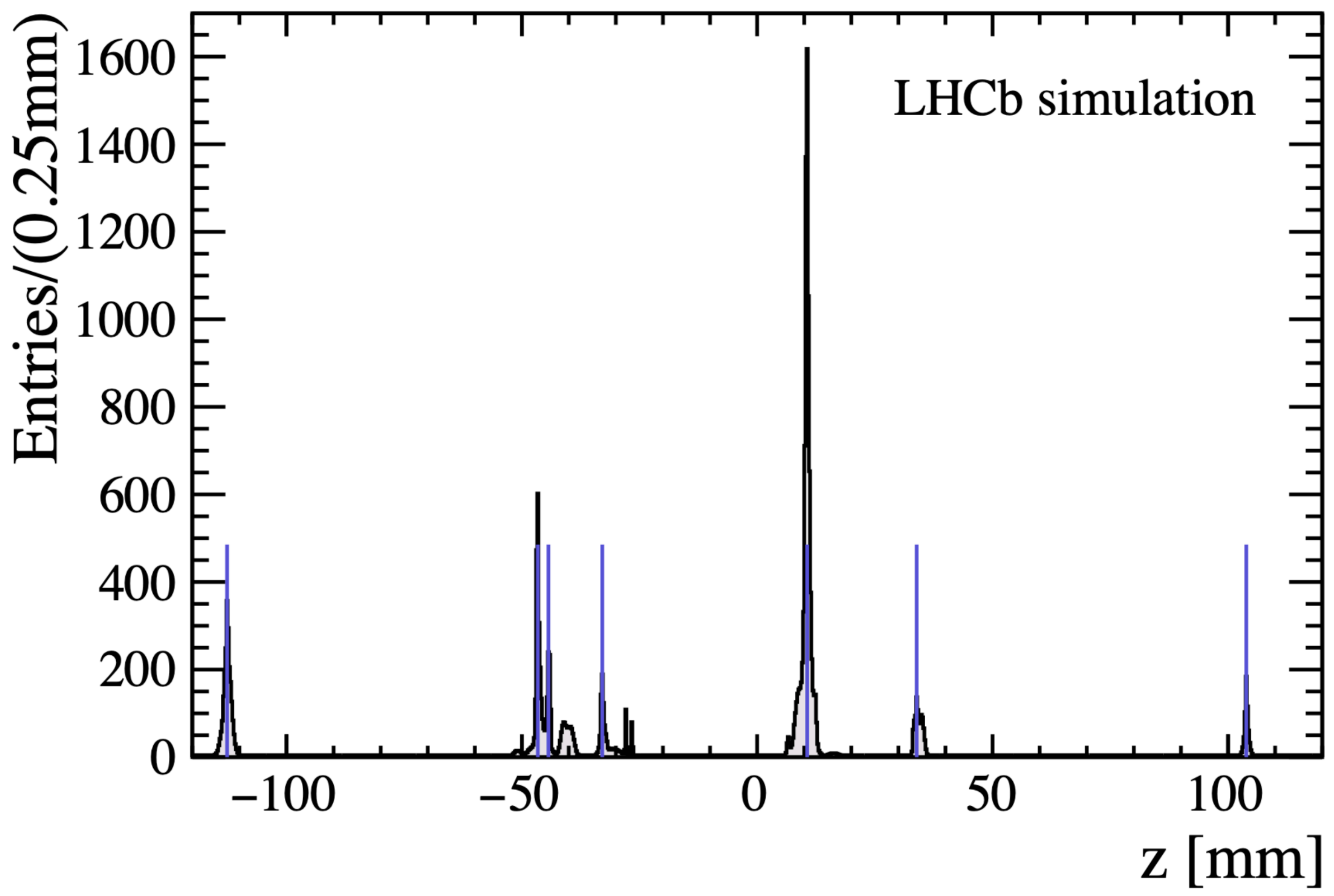


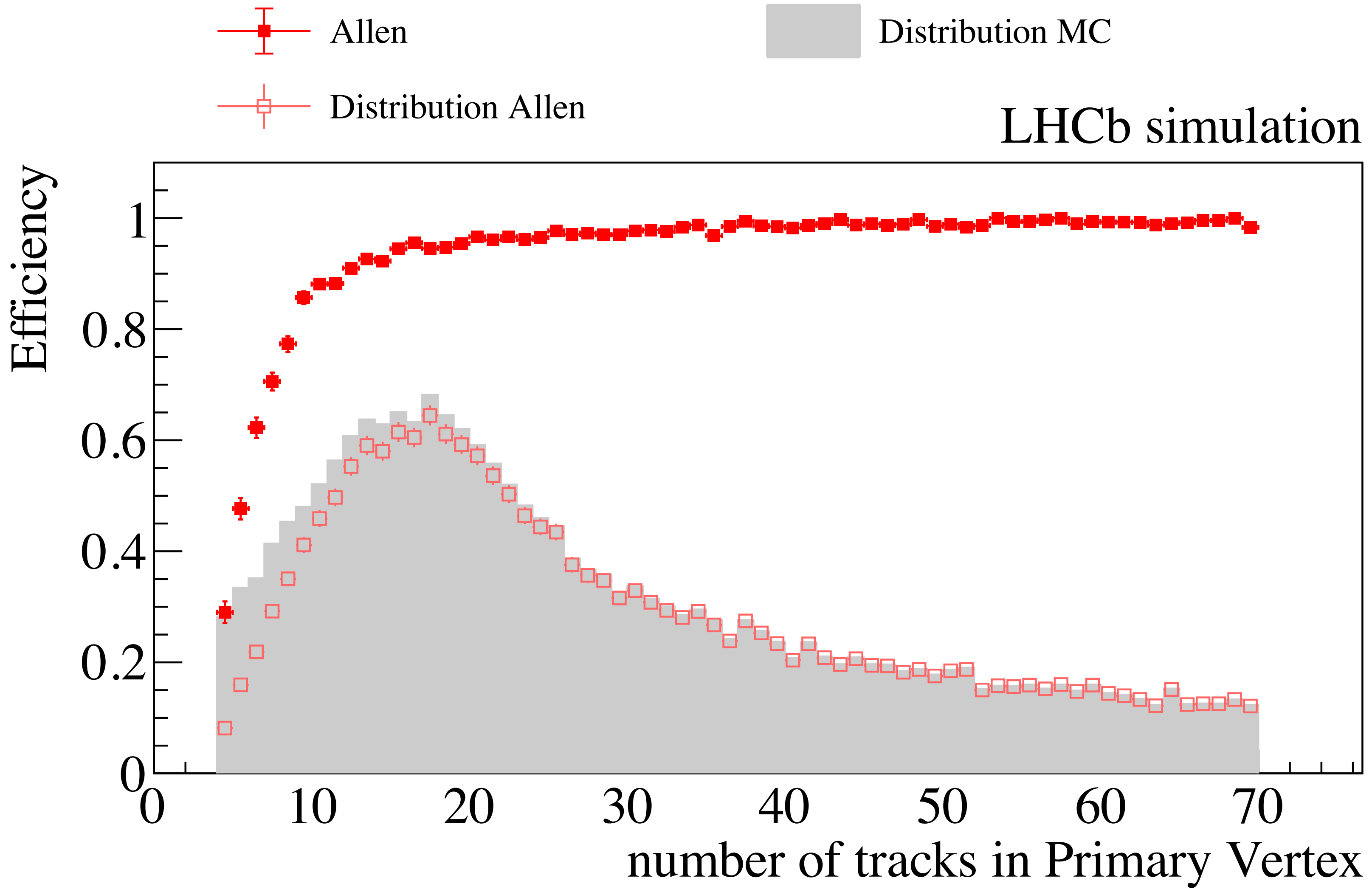
HLT1 SEQUENCE – VELO TRACKING AND PV FINDING

- Tracks in VELO expected to be straight lines.
- «Search by Triplet » algorithm:
  - Find 3 hits in neighbouring VELO modules
  - Format the triplet to other layers
  - Do this for all the triplets found
- Extrapolate the tracks to the beamline : PV's found that the intersection between the track and the beamline.



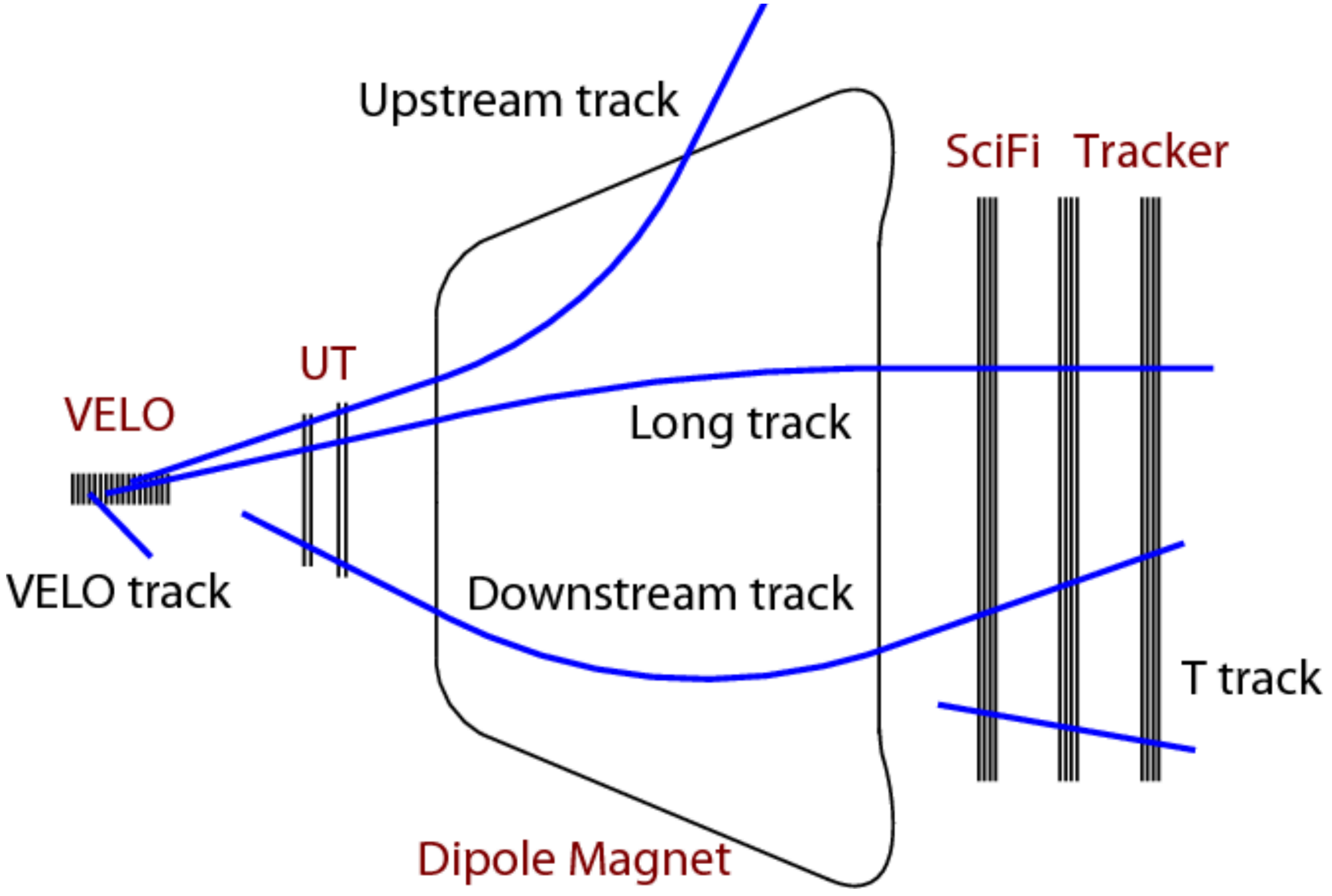


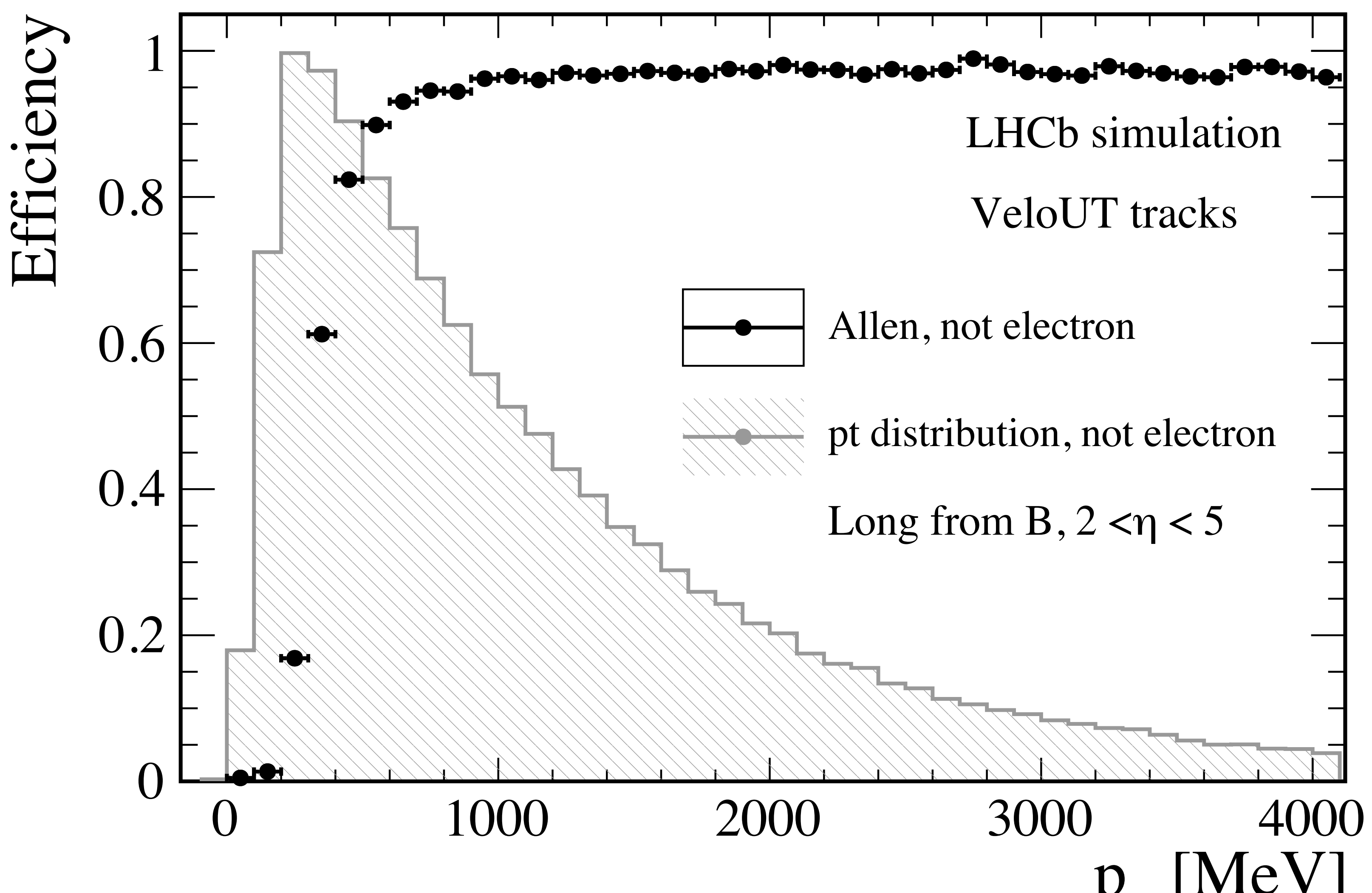




HLT1 SEQUENCE – VELO x UT

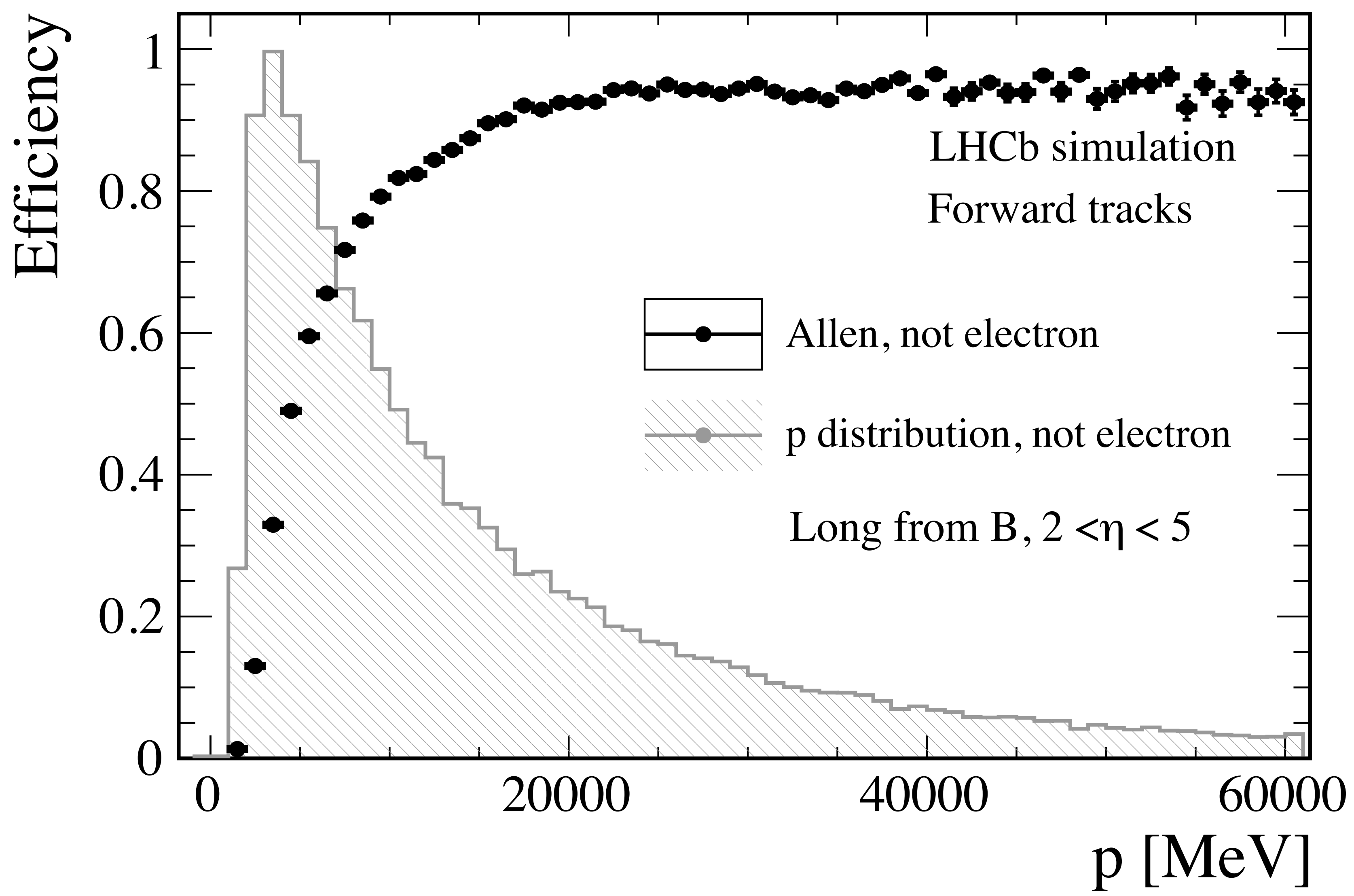
- → The UT allows to reconstruct
  - ➤ charged particles which decay after the VELO
  - ➤ low momentum tracks bending out of the magnetic field region
- → Extrapolate the VELO track to the UT silicon strips
- → Account for small magnetic field
- → Provides a first momentum estimate
- → Requires (at least) 3 hits in the UT

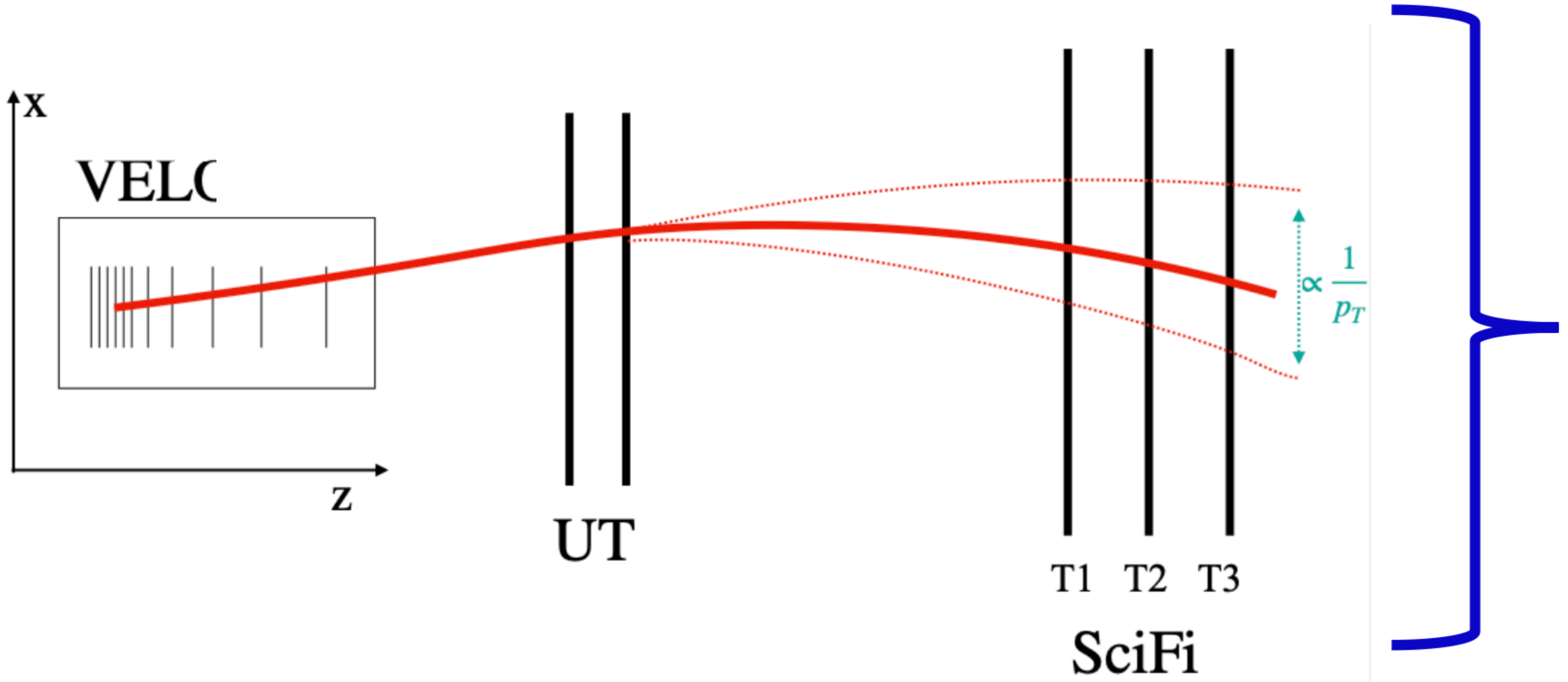


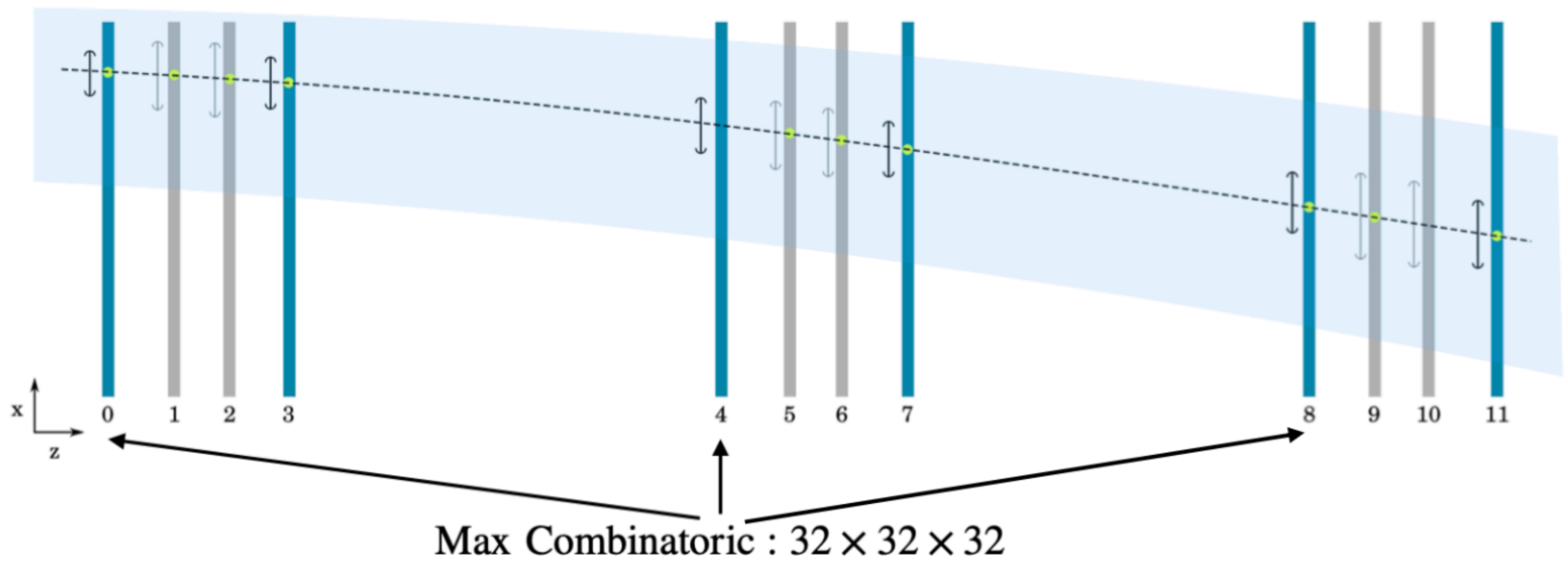


HLT1 SEQUENCE – VELO x UT x SciFi

- Forward-tracking
- Extrapolate the VEL0xUT tracks to the 12 layers of the SciFi
- Extrapolation using B field's parametrised trajectory
- Search of hits from an extrapolated tracks in windows fixed by the momentum estimation in the previous stage
- Reconstruct tracks with $p > 3$ GeV
- Momentum resolution around 1%



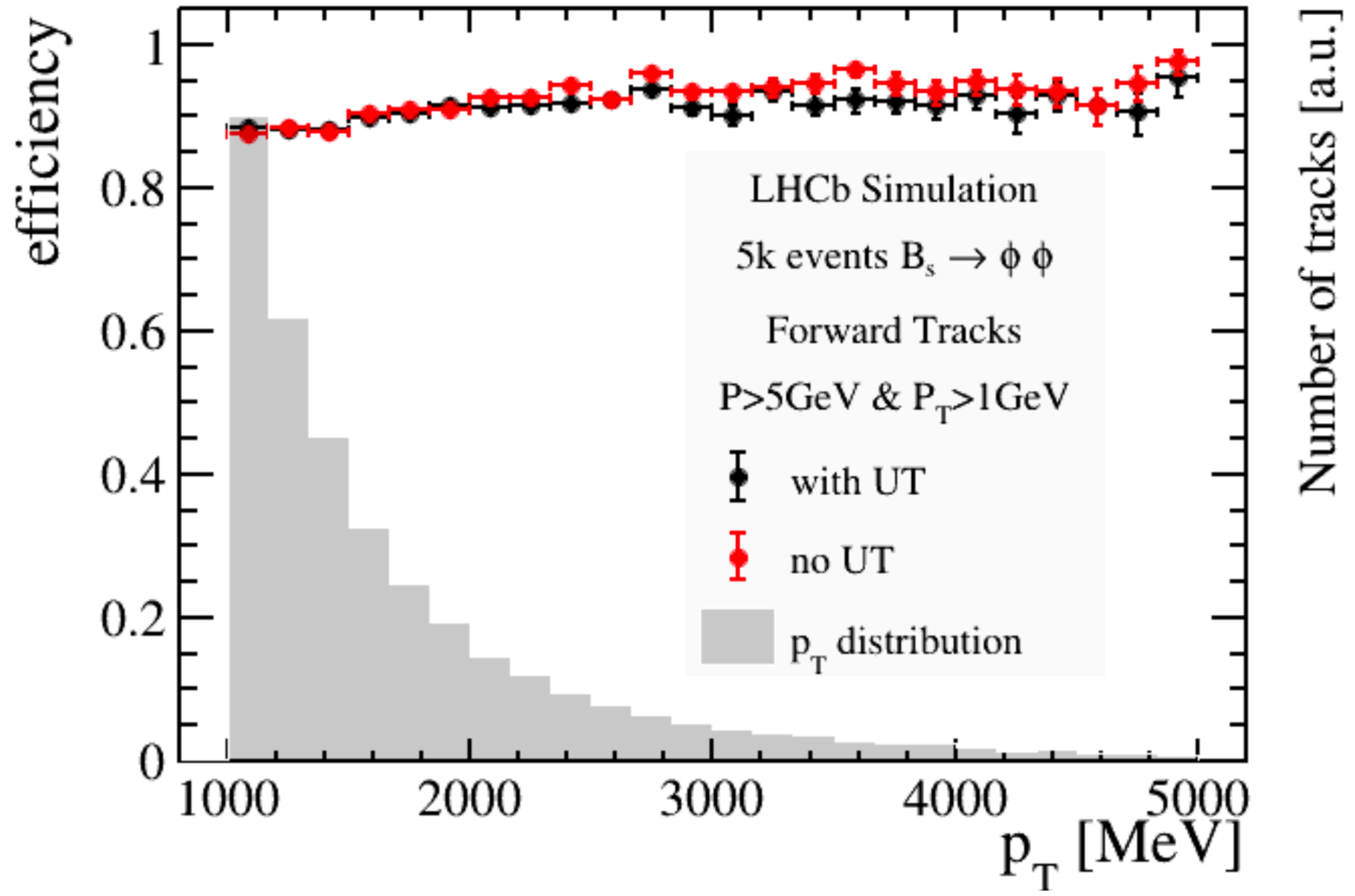


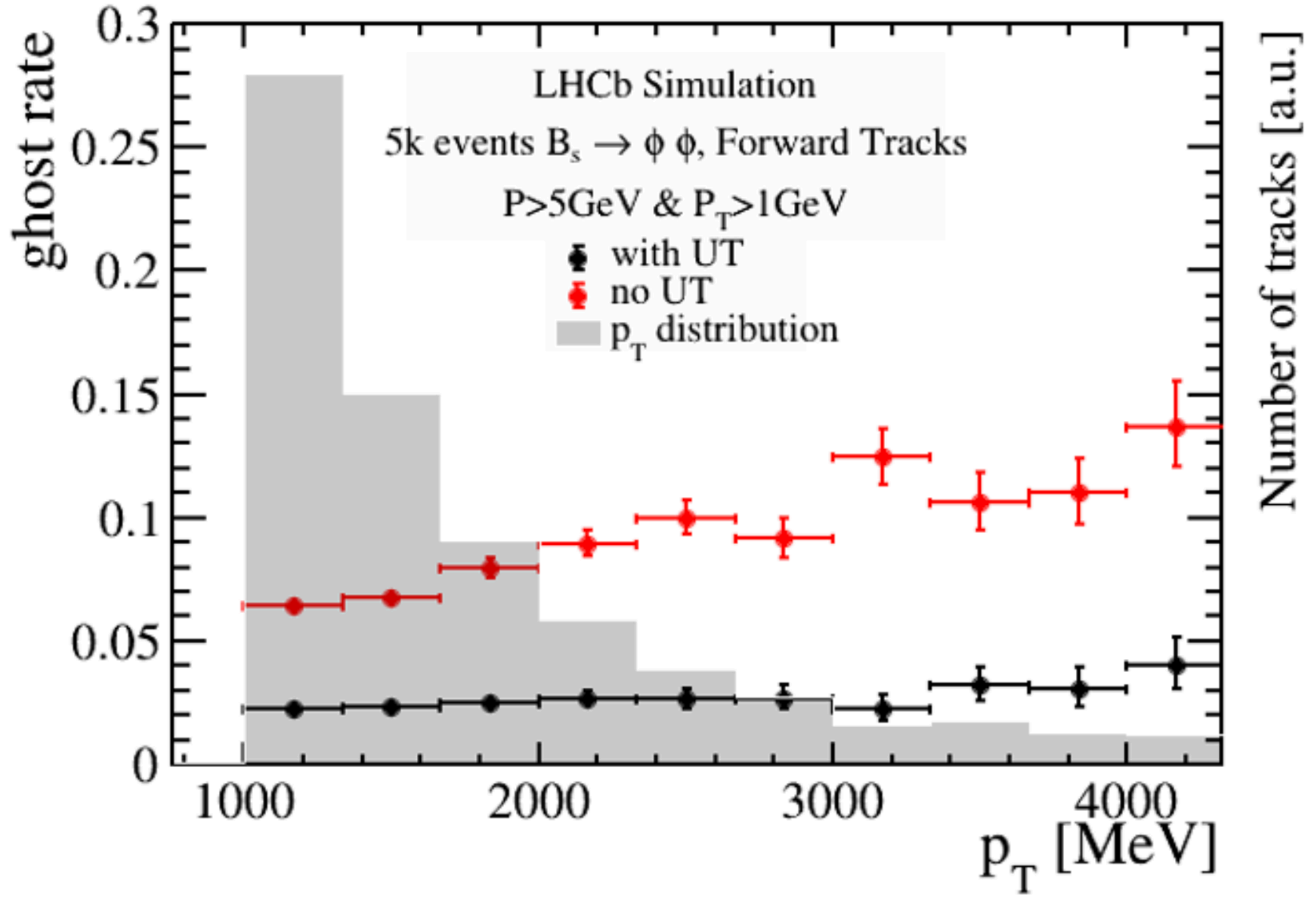


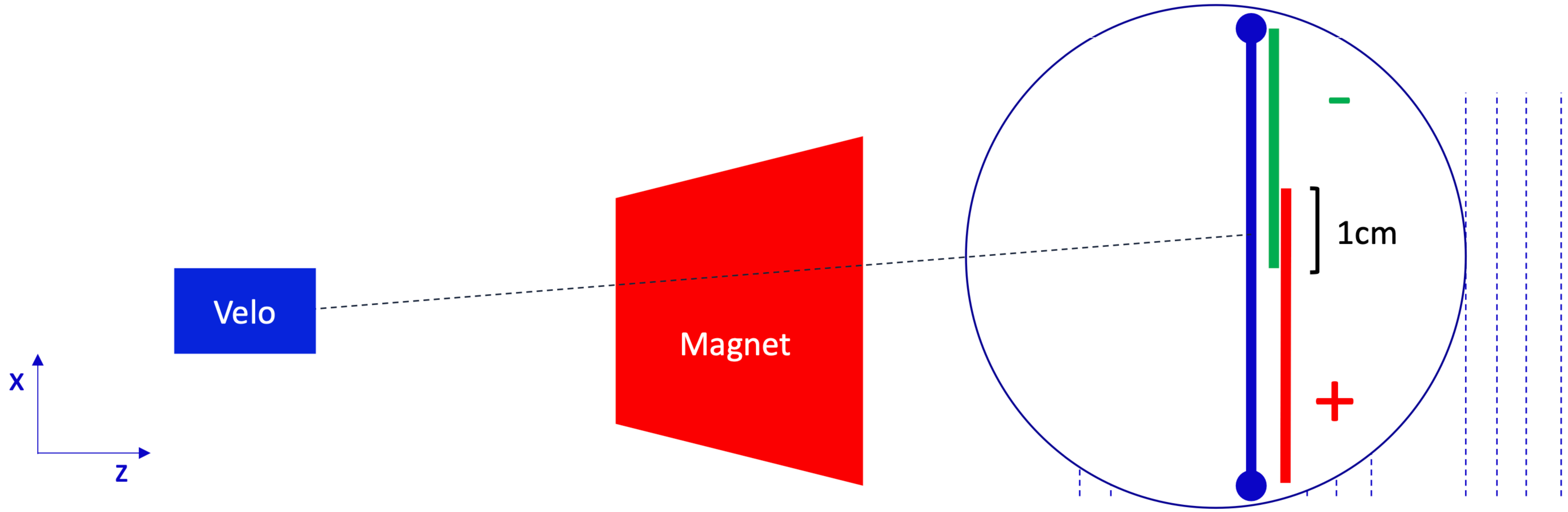
SciFi triplet finding

HLT1 SEQUENCE – VELO X NOUT X SCIFI

- Without the UT, no initial momentum estimate and no information on the charge of the particle
- Higher p and p_T requirements
- Double search windows around the VELO track extrapolation to identify the charge
- Similar reconstruction efficiency for high momentum ($p > 5$ GeV and $p_T > 1$ GeV) but with an increase in the ghost rate







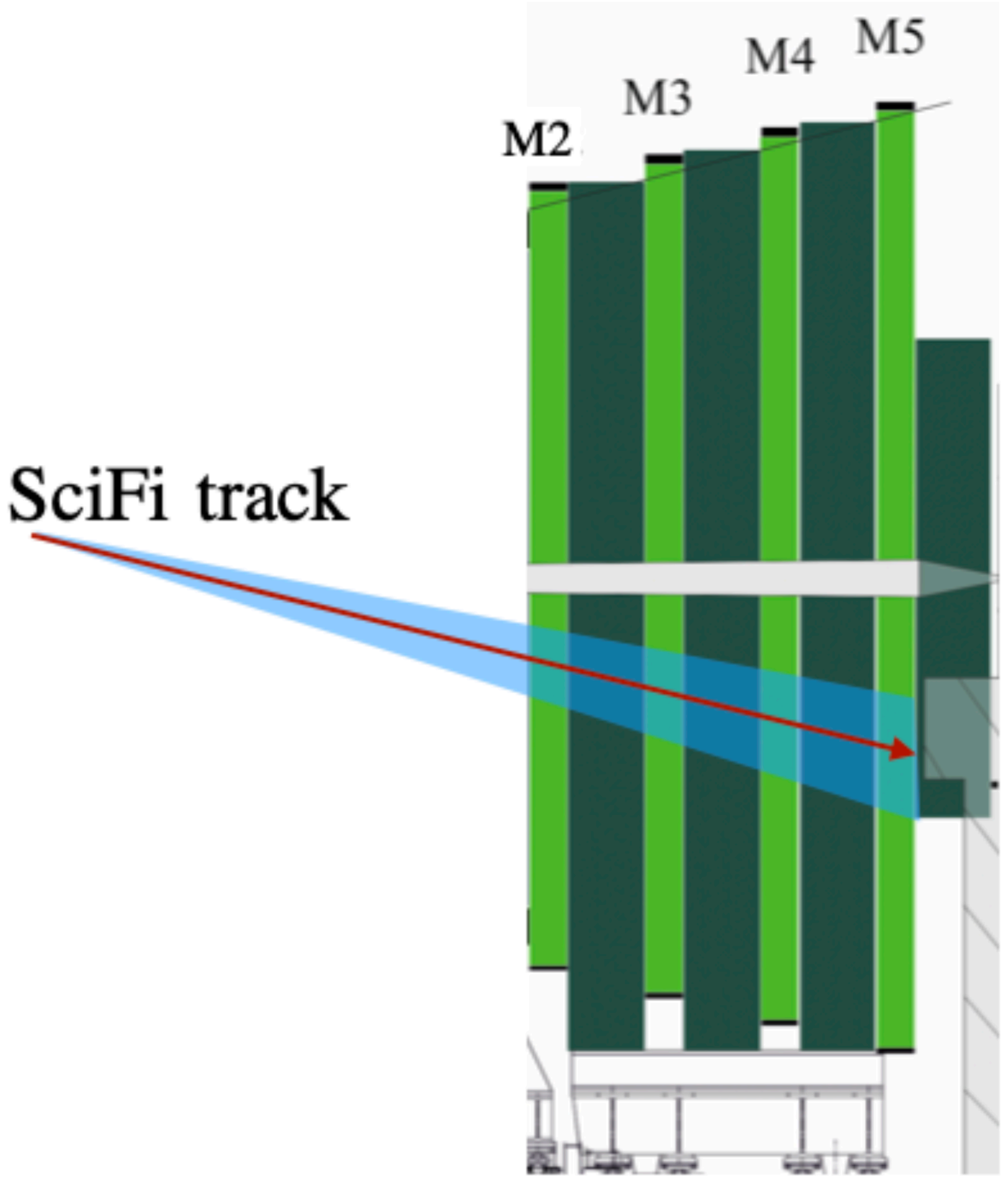
**Another solution also commissioned: Seeding+Matching*

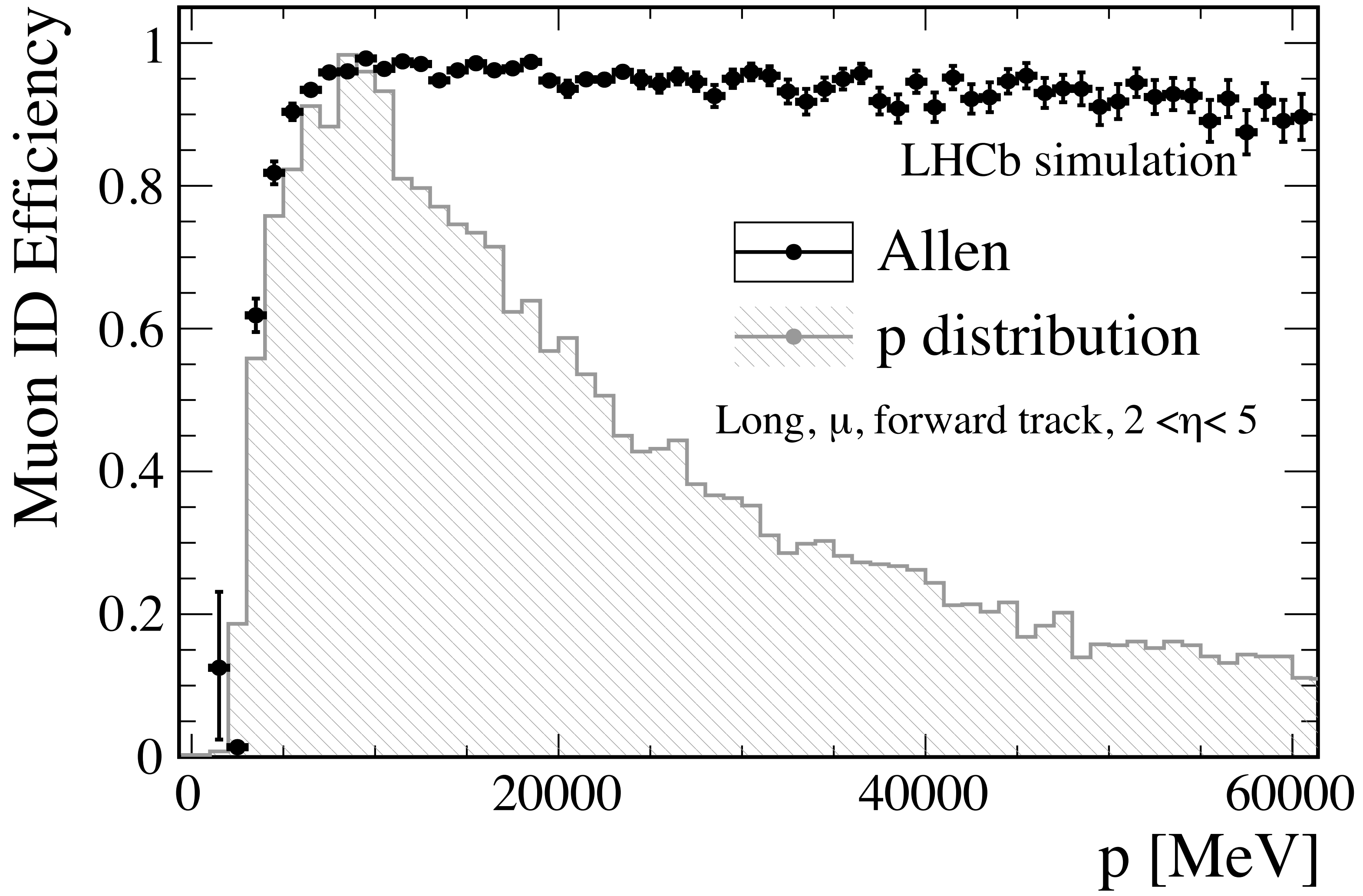
HLT1 SEQUENCE - KALMAN FILTER

- → Used to improve the estimates of the momentum and the track's impact parameter.
- → Method for track fitting, iterates over all hits on a track. For every hit, estimate the state of the track at that location (predictions + measurements).
- → Include the previous momentum estimate with the detector description to precisely estimate noise due to multiple scattering and energy loss.
- → Gives the best linear estimator for track state.
- → At HLT1 level only applied using VELO-parametrisation.

HLT1 SEQUENCE - MUON IDENTIFICATION

- Forward tracks matched with hits on Muon stations
- Important for the selection of decays with muons in final state



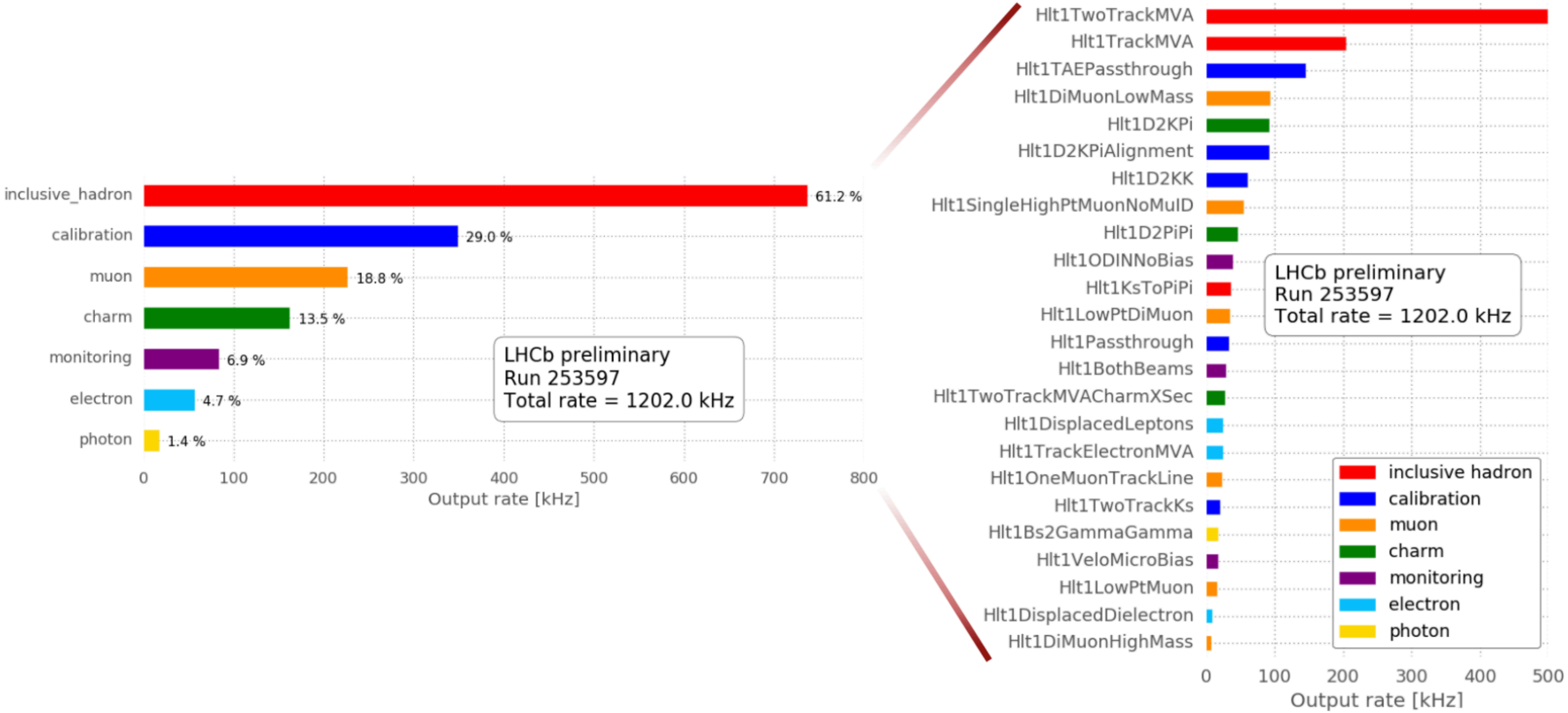


HLT1 SEQUENCE - CALORIMETER RECONSTRUCTION

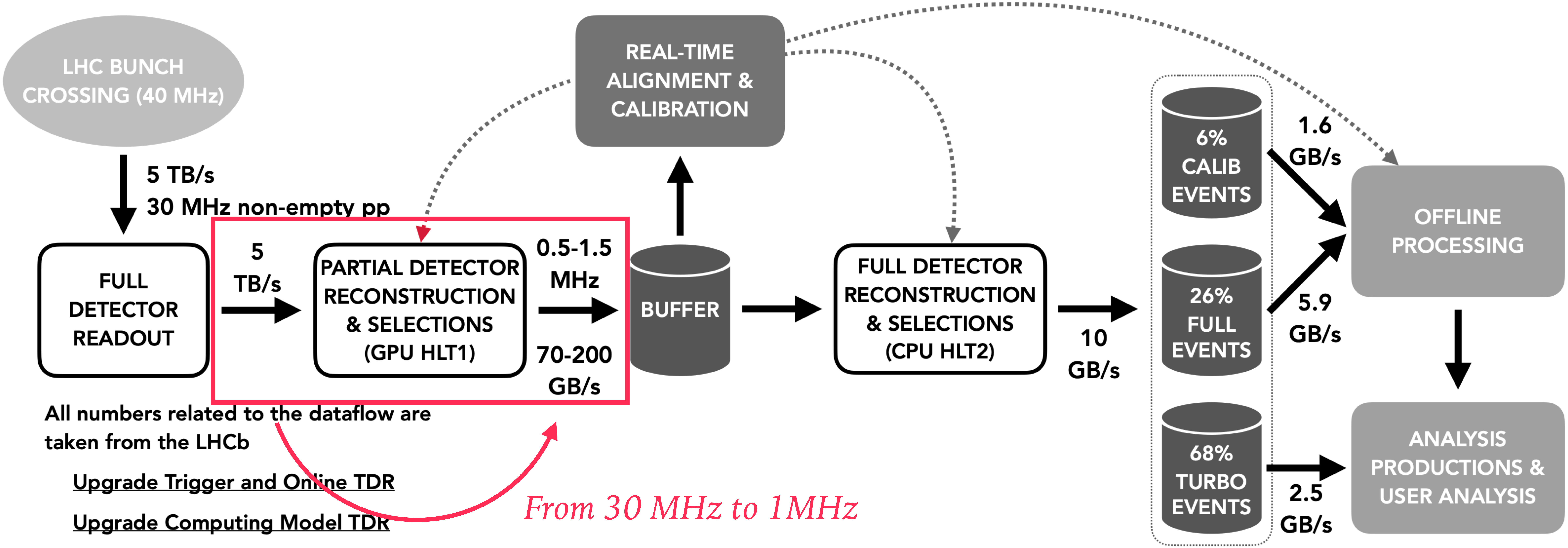
- Look for energetic clusters.
- Enable's photon and electron reconstruction at HLT1 level - for the first time.

HLT1 SEQUENCE – SELECTIONS

- Selecting events with HLT1 trigger lines for different physics purposes
- Successfully reduced the input rate to reach 1 MHz of output



HIGH LEVEL TRIGGER 1



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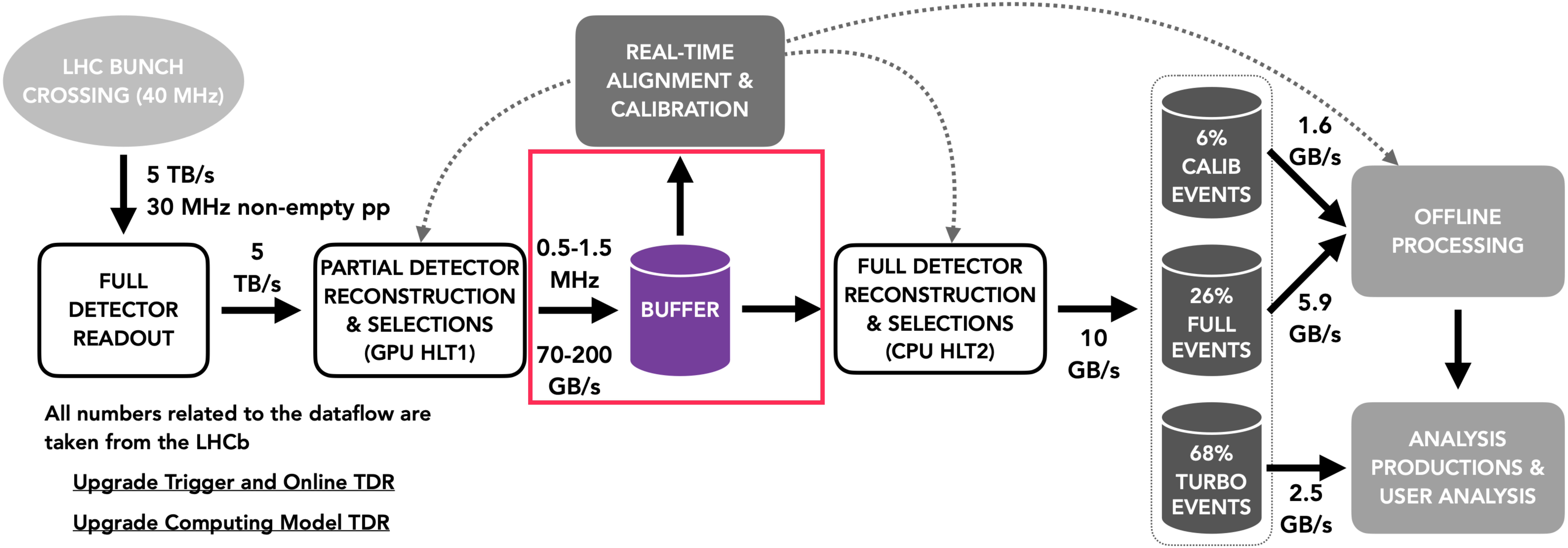
Upgrade Trigger and Online TDR

Upgrade Computing Model TDR

BUFFER



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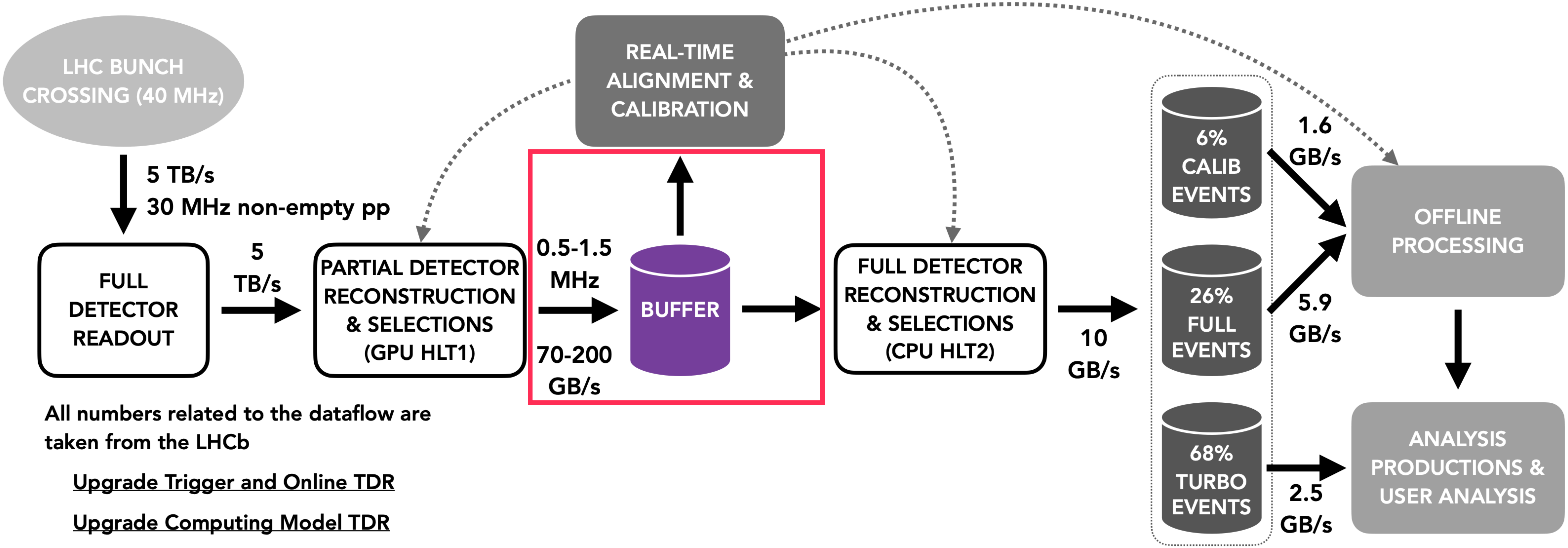
- Upgrade Trigger and Online TDR
- Upgrade Computing Model TDR

QUICK WORD ON THE BUFFER

- Serves two purposes:
  - Hold events selected by HLT1 while the Real-Time alignment and calibrations are performed
  - Allows differ processing of the HLT1 selected events in between LHC fills
- Optimal buffer size of around 30PB, which can buffered 80 hours of LHC collisions at an HLT1 1MHz output rate

BUFFER



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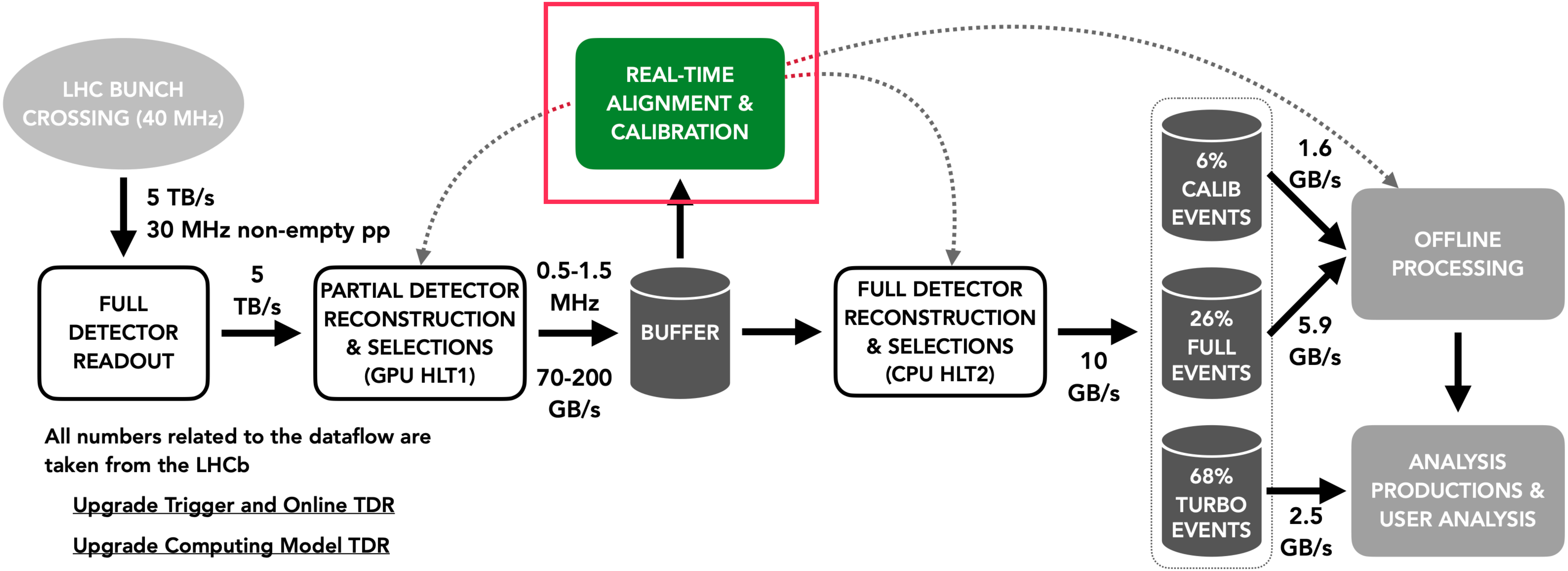
REAL-TIME ALIGNMENT AND CALIBRATION



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Upgrade Trigger and Online TDR

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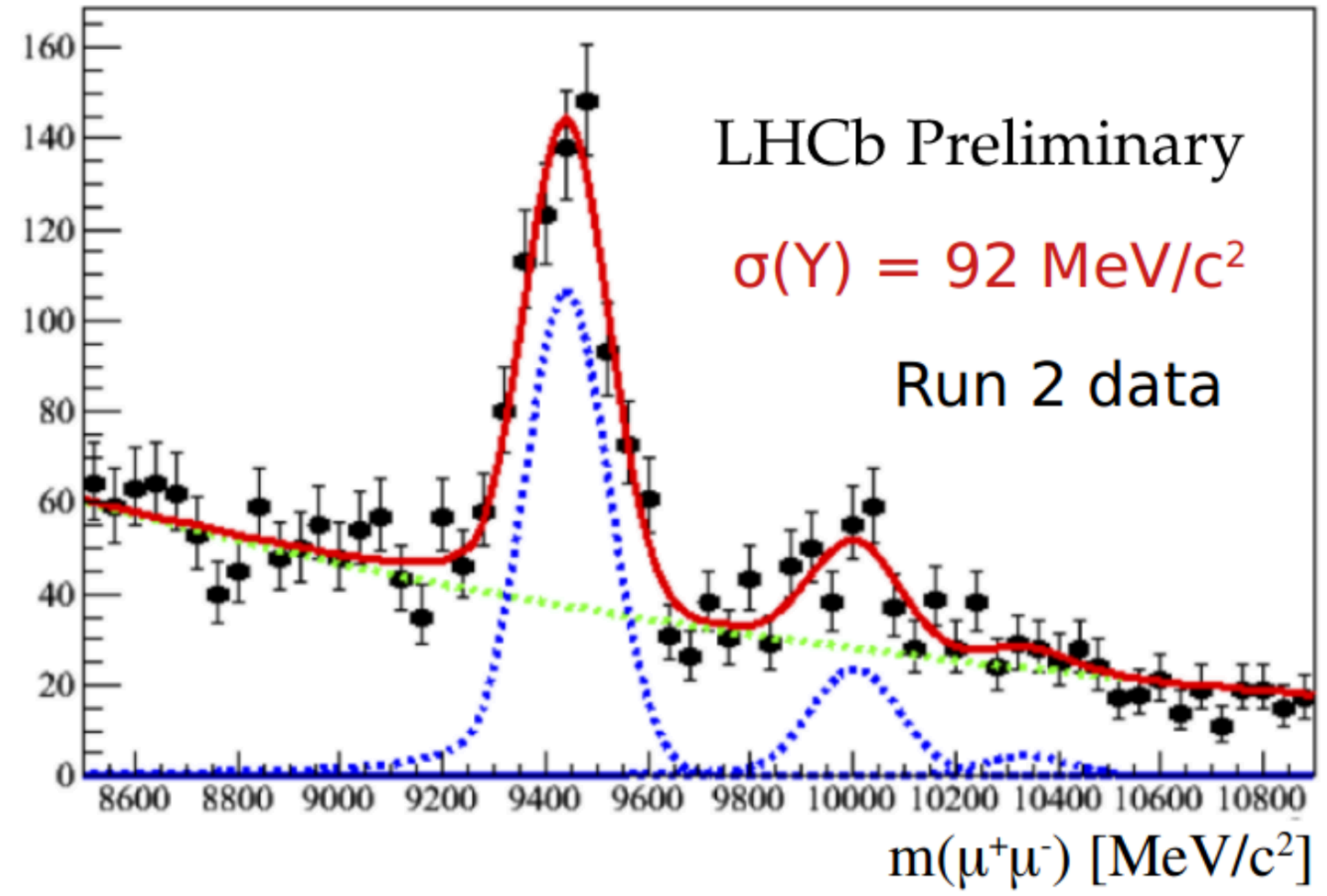
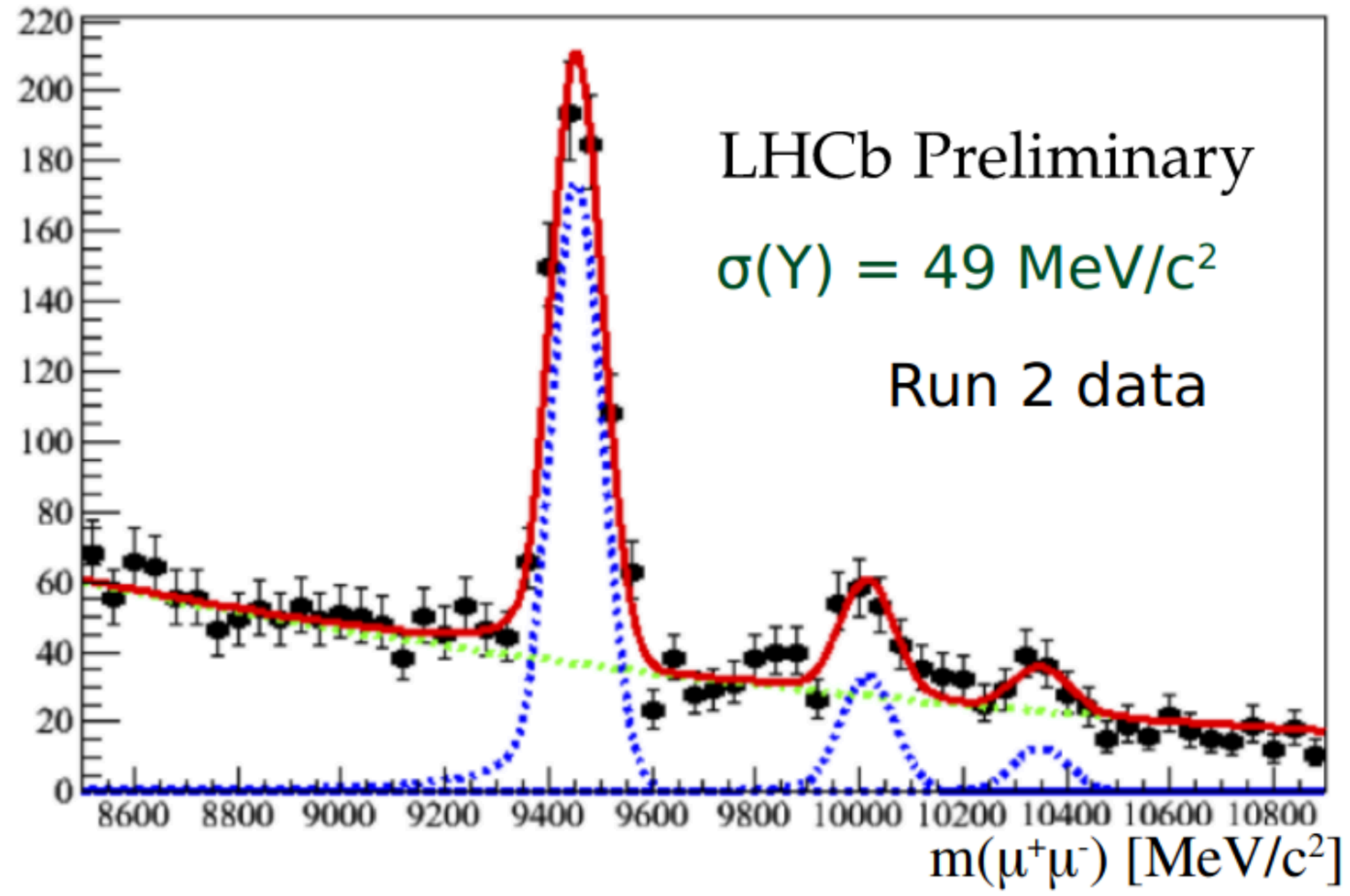
REAL-TIME ALIGNEMENT & CALIBRATION

- → Use of calibration samples selected by HLT1 stored in buffer
- → Real-time calculation of alignement and calibration contants
  - ➤ Constants that are used for the reconstruction and selections
  - ➤ Ensures measurements of physics parameters to the best resolution possible
- → Used to reach offline-quality reconstruct at the HLT2 level
- → Alignement for Tracking system and for the RICH mirrors
- → Calibration for RICH and CALO

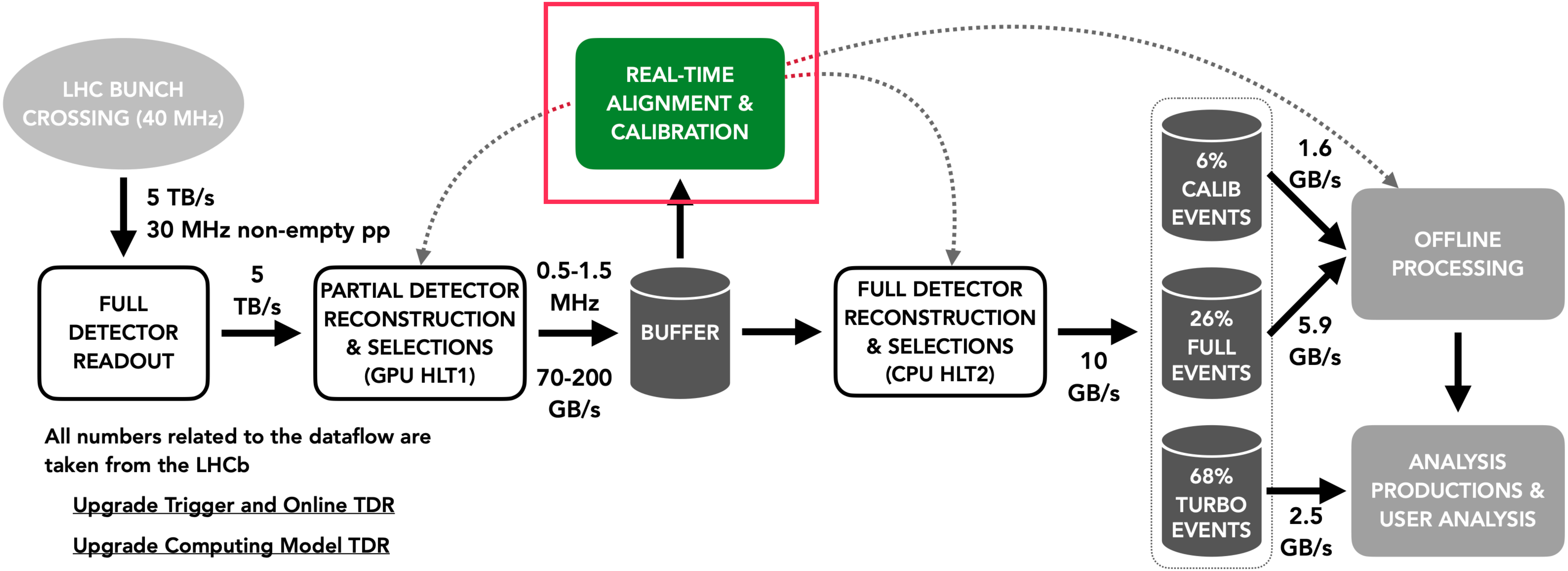
Before alignment



After alignment



REAL-TIME ALIGNMENT AND CALIBRATION



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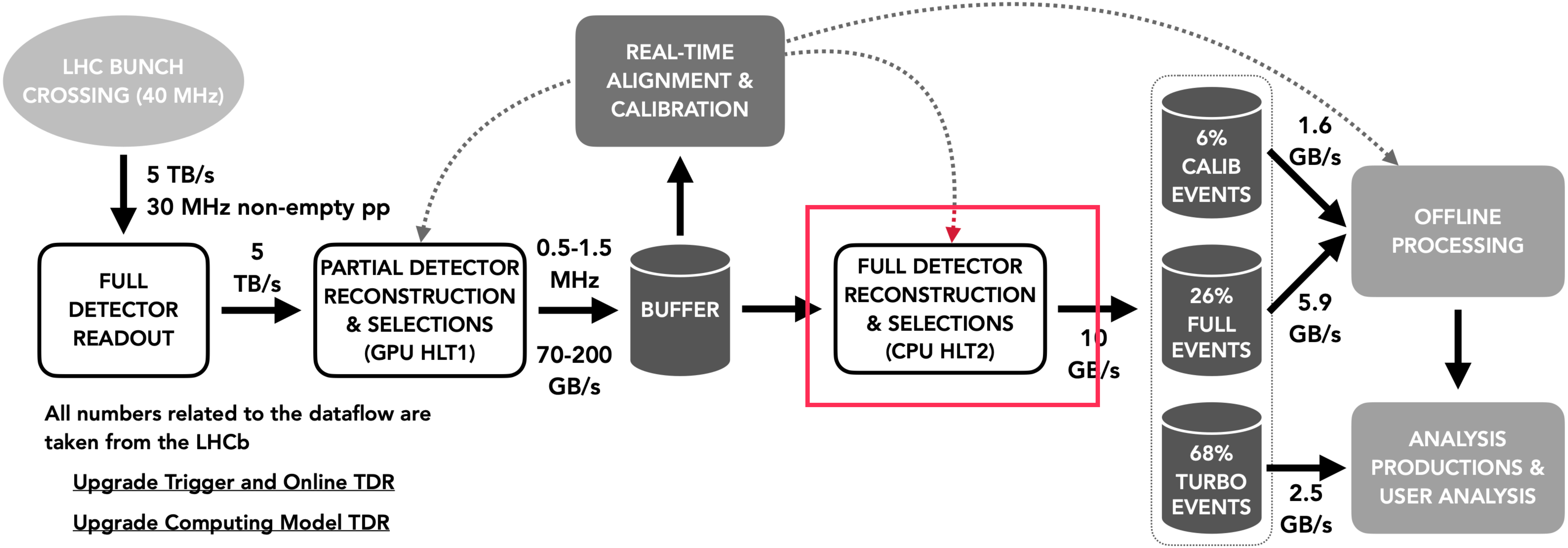
HIGH LEVEL TRIGGER 2



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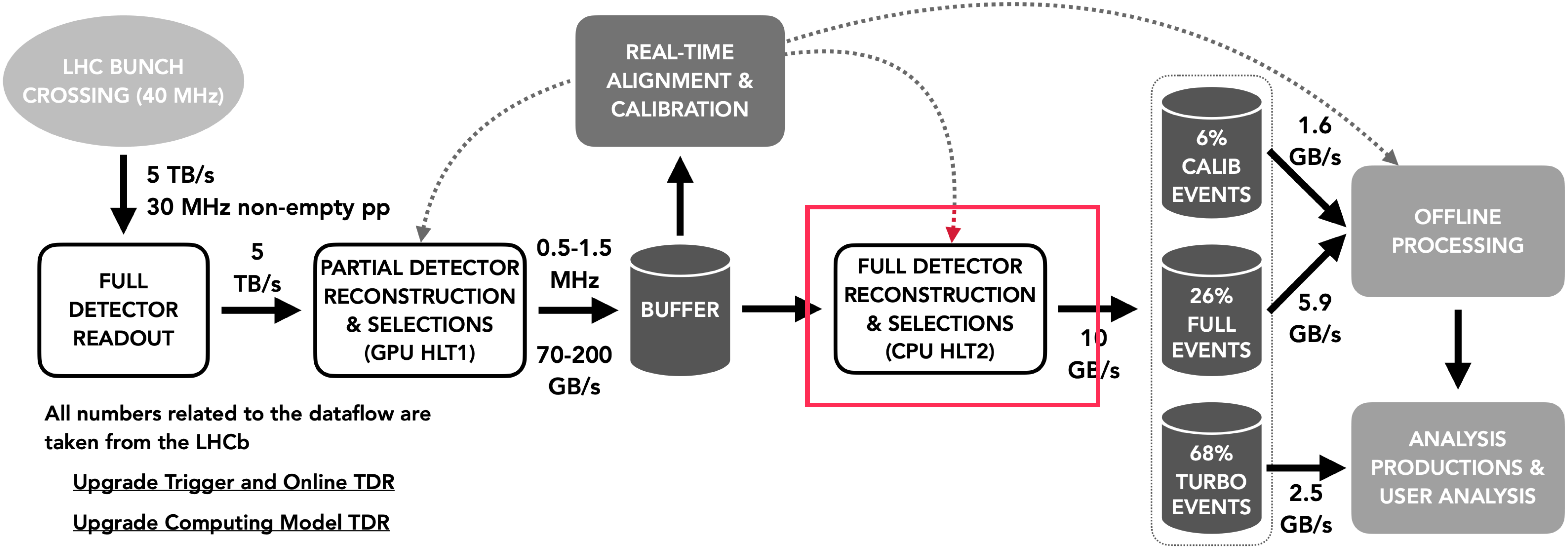
HLT2

- → Full reconstruction → offline-quality reconstruction
  - ➤ Aligned and calibrated detector (see previous step)
  - ➤ Full particle identification with RICH reconstruction
  - ➤ Full track fit, with detailed magnetic field and detector description
- → Around ~1000 selections algorithms
  - ➤ Run2 Stripping (offline) moved to the HLT2 level for Run3 (online)
- → The selections are tuned to different signal topology and physics analysis
- → Runs on CPUs
- → Implemented on Moore

More on Moore for Run3 with Jonathan

HIGH LEVEL TRIGGER 2



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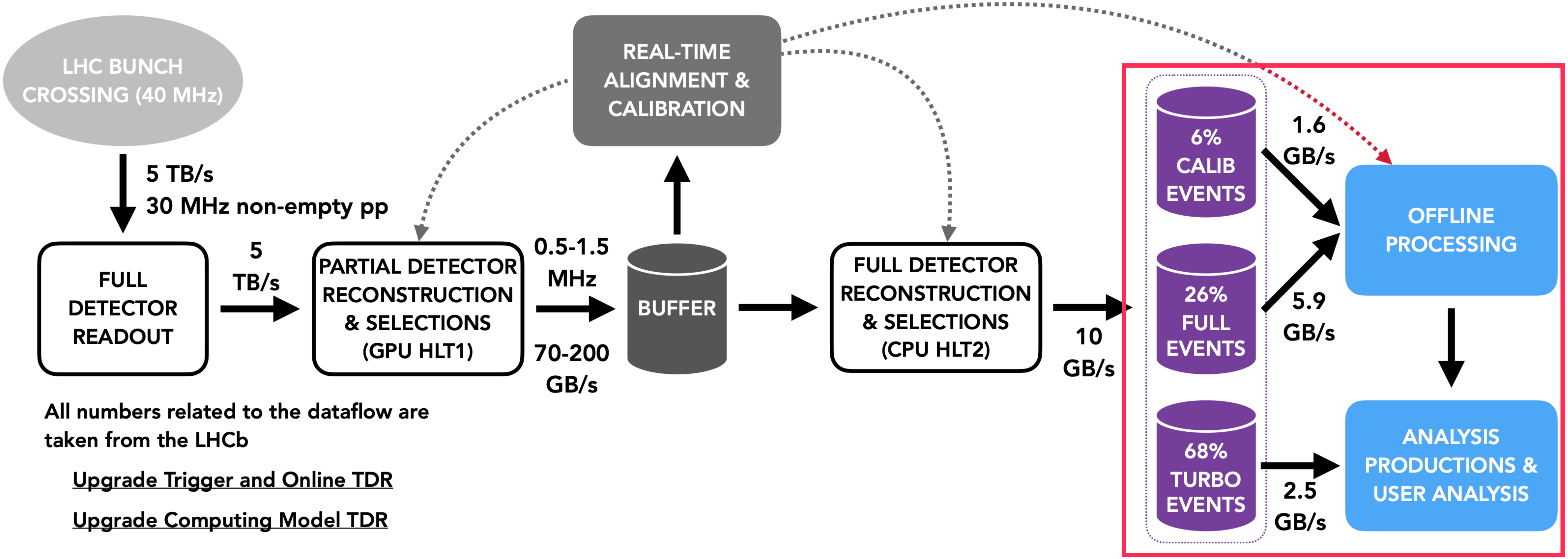
MOVING TO OFFLINE



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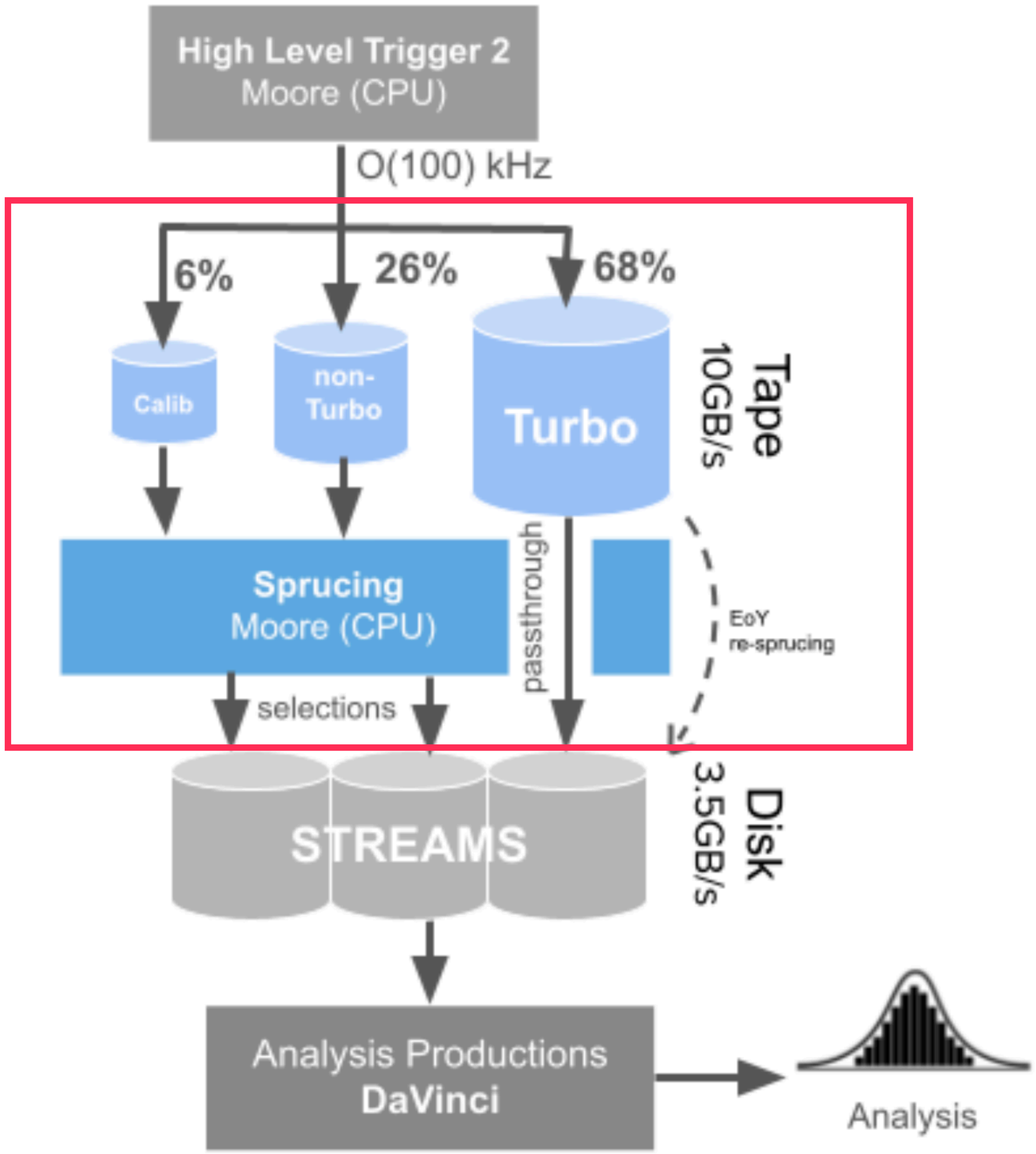
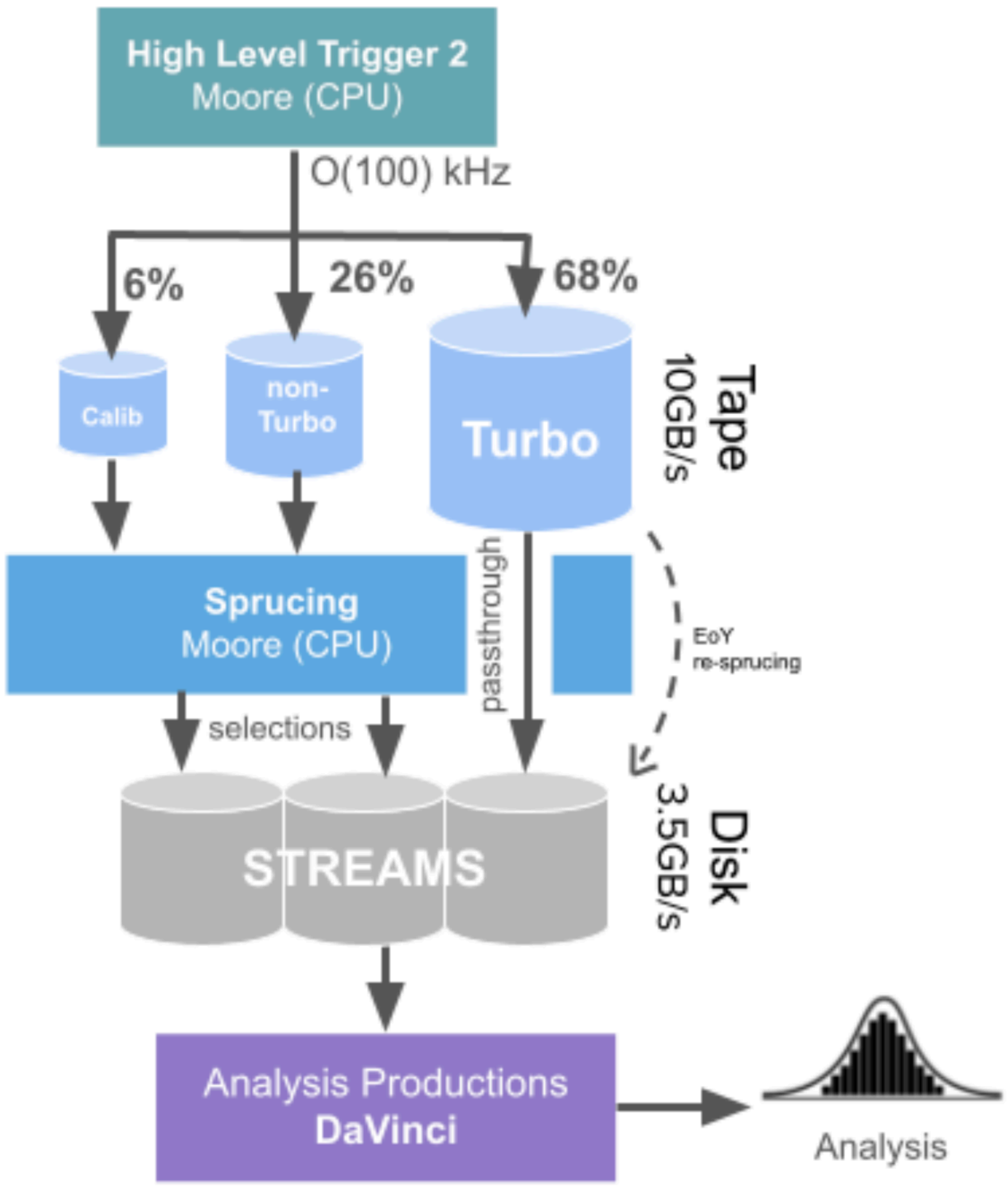
OFFLINE STREAMS



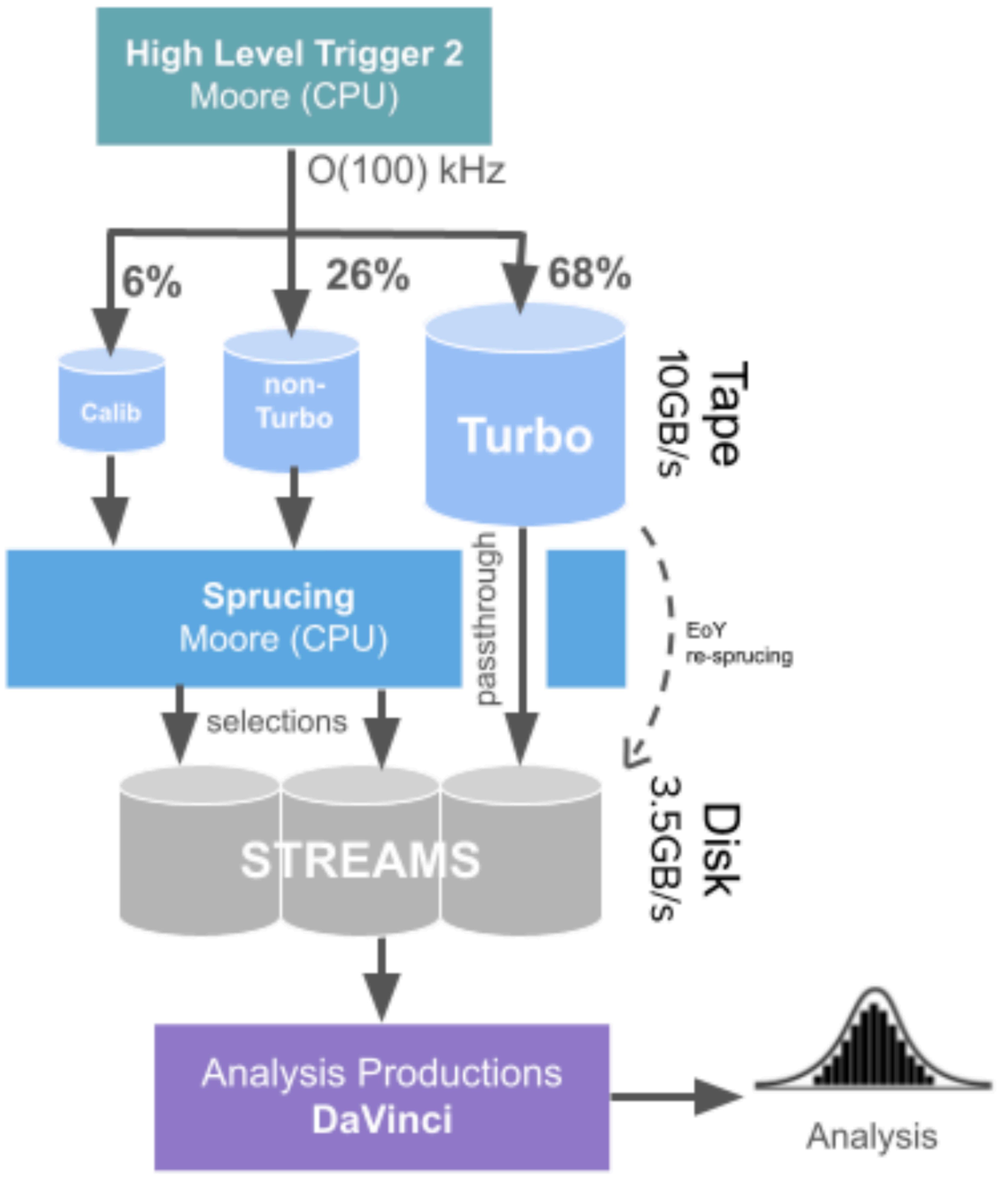
SPRUCING

- → Used for physics selections that can not go straight to disk
- → Intermediate step between the tape storage and the disk storage to reduce the data
- → Also based on the Moore project
- → No offline reconstruction - the reconstruction comes from HLT2
- → Typical case that need sprucing are inclusive HLT2 lines or to data selection/processing algorithms that are too intensive to be run online.



TURBO

- In Run 2:
  - ➤ 70% of the events passed to offline processing
  - ➤ 30% to Turbo
- In Run 3:
  - ➤ 68% passed to Turbo (Baseline in Run3)
  - ➤ 32% to offline processing
- Turbo → bypass the offline processing steps and stripping (save in storage and computing power)
- Saves only the signal candidate



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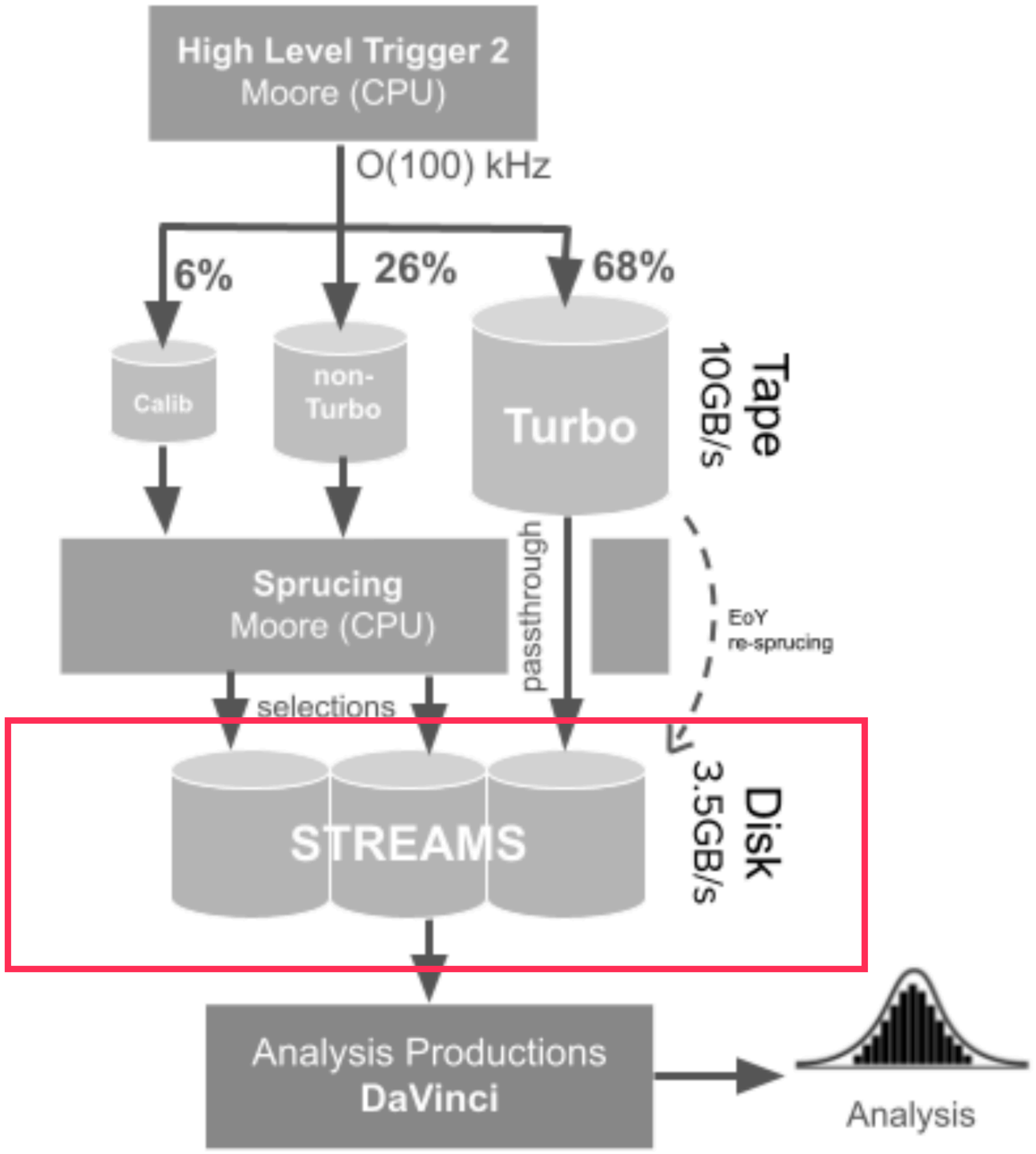

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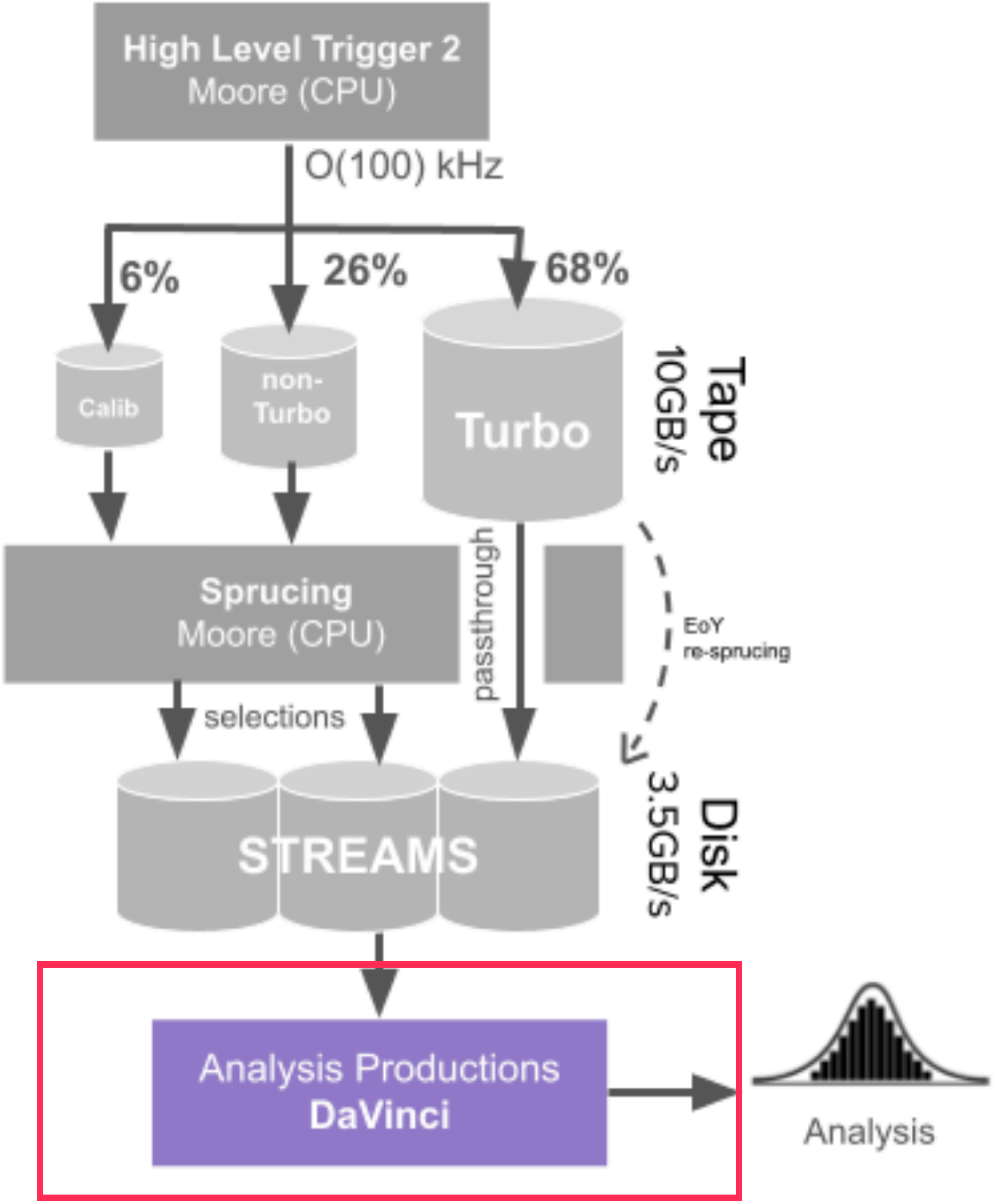


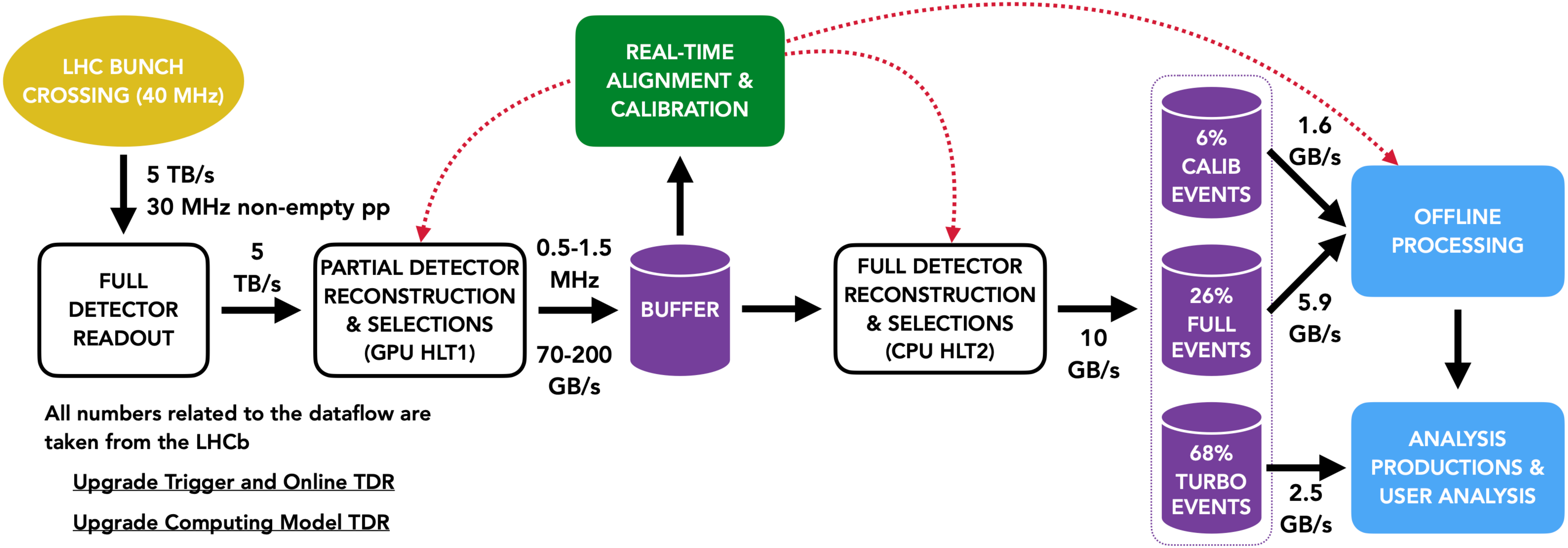
NTUPLE MAKING

- Software : DaVinci
- Used in the previous runs but majors changes
  - From LoKi to ThOr functors
  - From TupleTools to FunTuples
- FunTuples:
  - More flexibility on the choice of variables
  - Reduces the number of unused variables
  - Reduces storage and computing use

More on DaVinci for Run3 with Jonathan

ANALYSIS PRODUCTION

- Move to central analysis production from the user specific jobs
- To central production managed by DIRAC
- Analysis Productions:
  - Automatic testing
  - Automatic preservation of config details
  - Automatic error interpretation
  - Web interface



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THANK YOU FOR LISTENING !