MAX-PLANCK-INSTITUT
FÜR PHYSIK

Development of a self-seeded drift-tube chamber trigger

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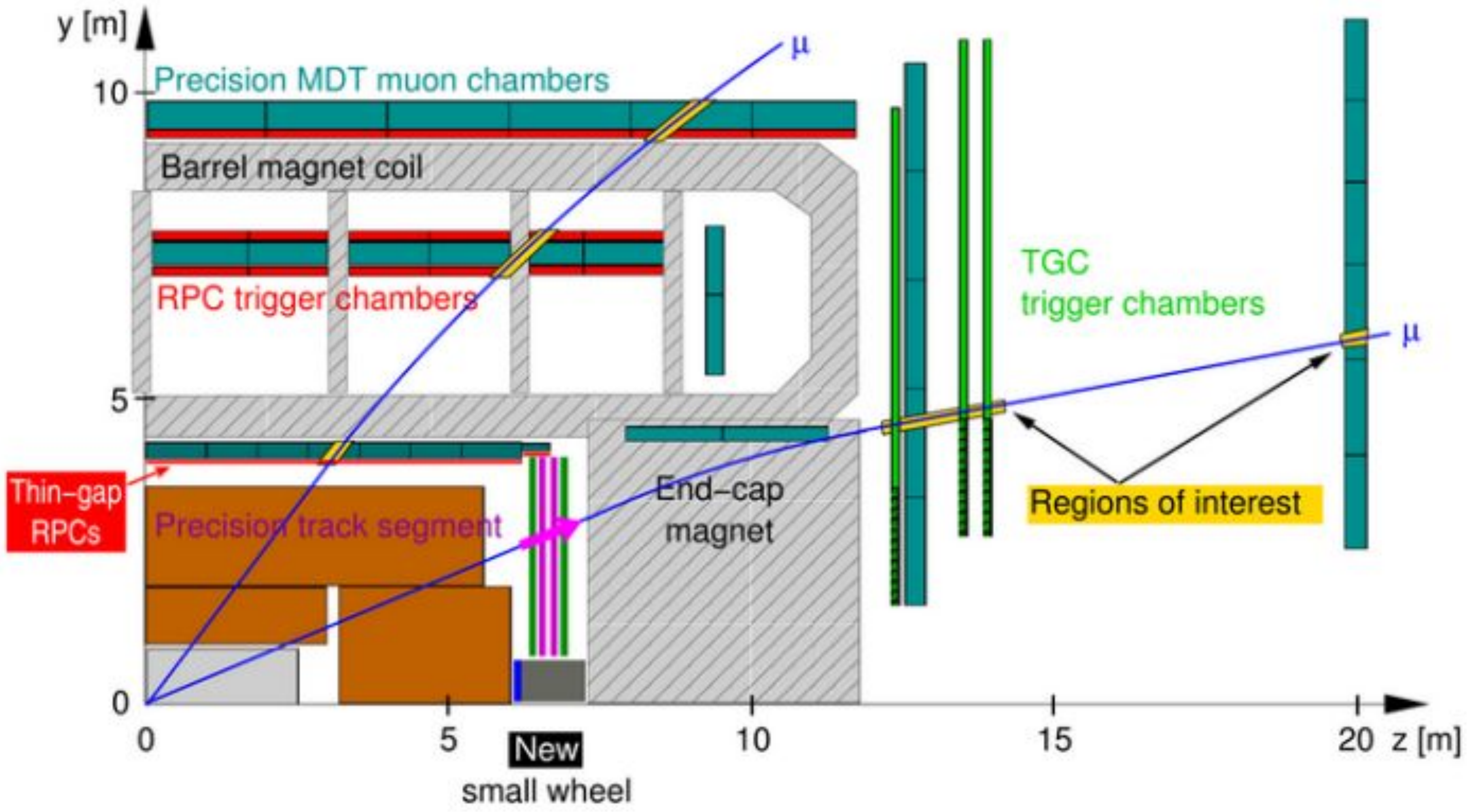
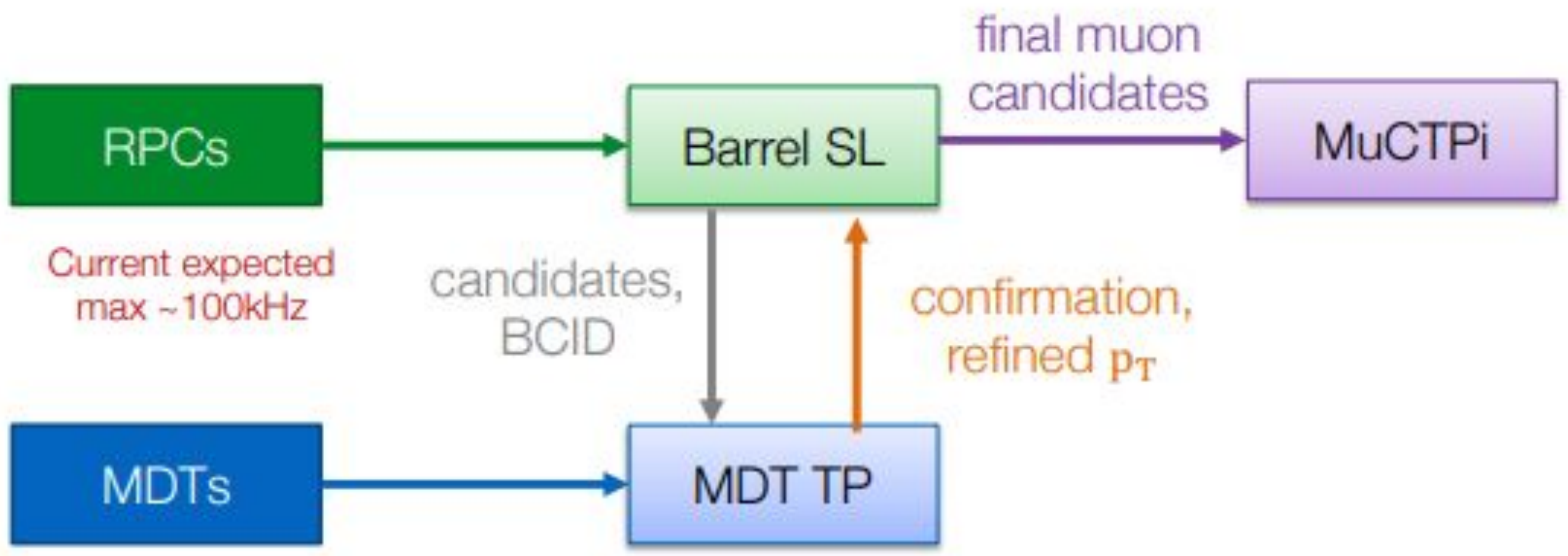
19.06.2024 - 2nd DRD1 Collaboration Meeting

Example Drift-Tube Trigger (ATLAS L0MDT)

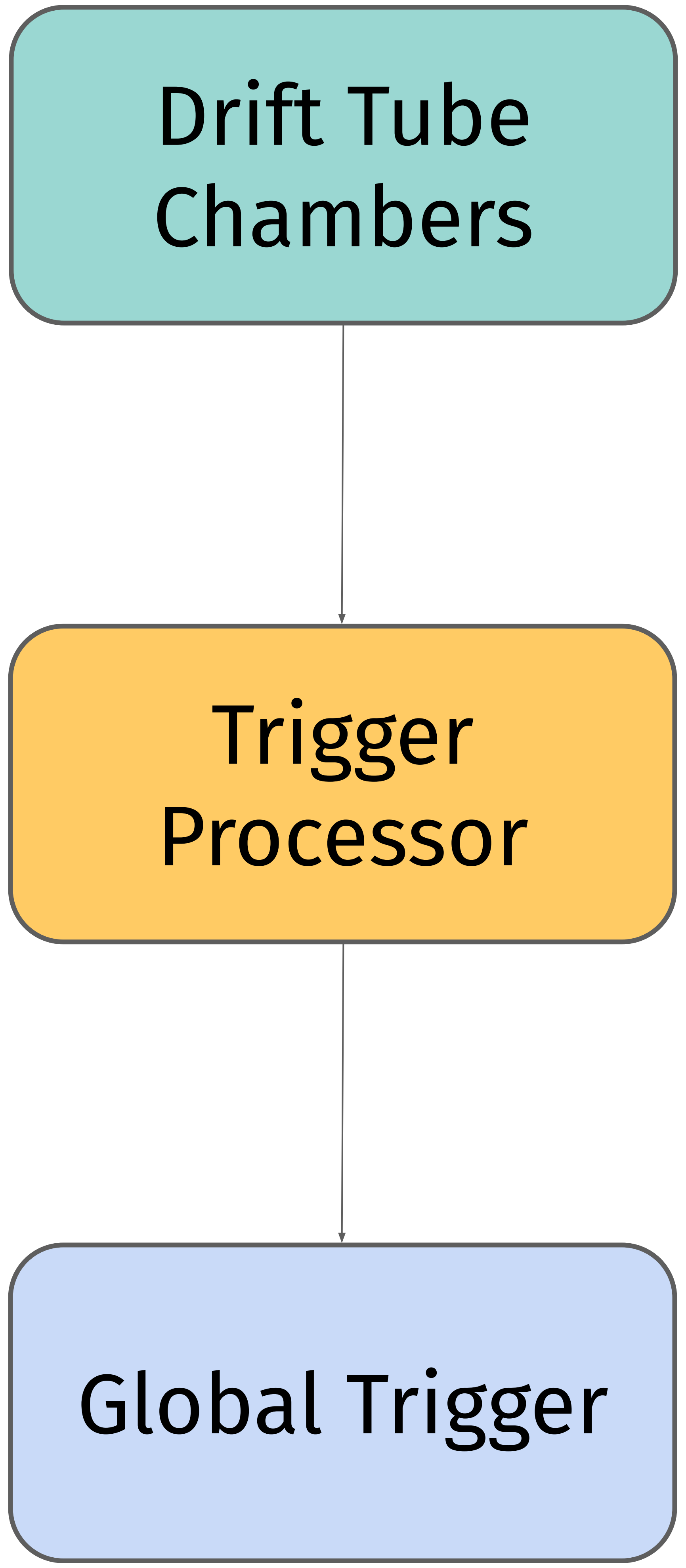




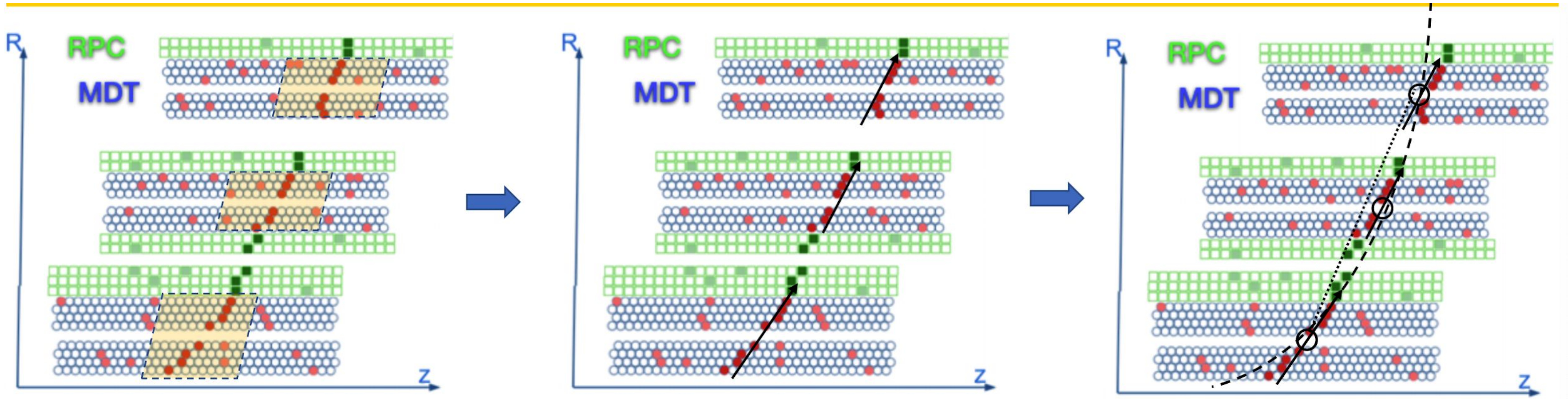
- Typical Goal: unprescaled 20 GeV single muon trigger and an unprescaled low-pT threshold dimuon trigger
- Baseline drift-tube trigger acts only on pre-triggers of the RPC and TGC trigger system
    - RPC/TGC provides Bunch Crossing reference time and region-of-interests (ROI)
    - Straight-line track segments reconstructed using precise drift-tube info
    - Use the segment parameters to compute muon transverse momentum

Going Standalone

- The higher expected rate of FCC-hh would make very difficult to use RPCs in the forward region
- A “standalone” drift-tube trigger can be designed to avoid completely dependency on RPCs
- Small drift-tubes are better suited for this purpose, thanks to their smaller maximum drift time



Baseline MDT Trigger Algorithm in ATLAS



Hit Extraction

- Reconstruct SL vectors per MDT station
- Match the MDT hits to SL input in space and time

Segment Finding

- Reconstruct segments in the different MDT stations using the matched MDT hits

pT estimation

- Calculate the muon candidate pT by estimating the deflection between the segments due to the B-field

The Challenges

1. Bunch Crossing Identification

Drift-time calculated by subtracting bunch crossing reference time from absolute hit time.
Hit time compatible with multiple BCIDs, instead than a single one with RPCs

2. Region-of-Interest

No RPC to filter drift-tube hits in space. Pattern recognition should happen in the entire drift-tube chamber.

3. Trigger Rate and Latency

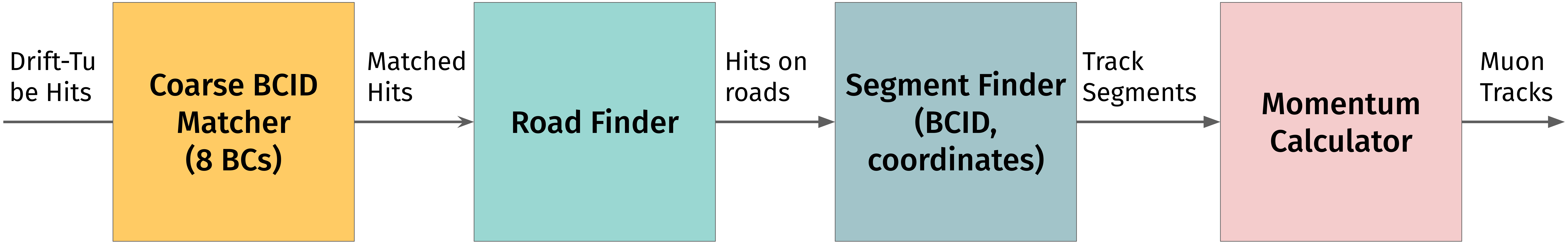
Standalone trigger should reduce trigger rate from 40 MHz to ~40 kHz, with a limited latency budget

4. Efficiency

Self-seeded drift-tube trigger should reject bad coincidences, while keeping a high efficiency around the chosen pT threshold

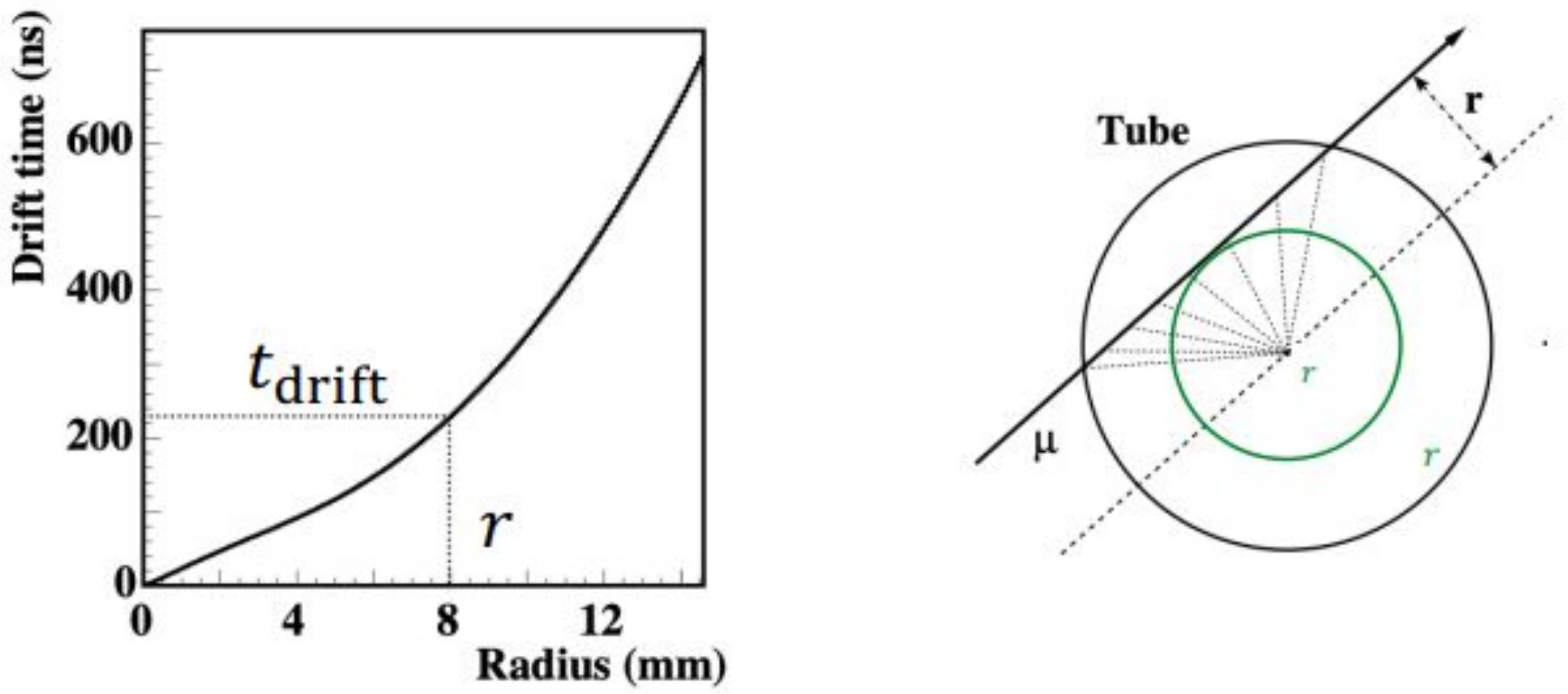
The Design

- (Very) preliminary FPGA architecture for the standalone trigger design
  - Efficiency and rate performance to be studied
  - Idea is to estimate resource usage, to see if it could fit in current system
- Concept study applied to a muon spectrometer with standard drift-tubes with radius of 15mm (max. Drift-time of 800ns)

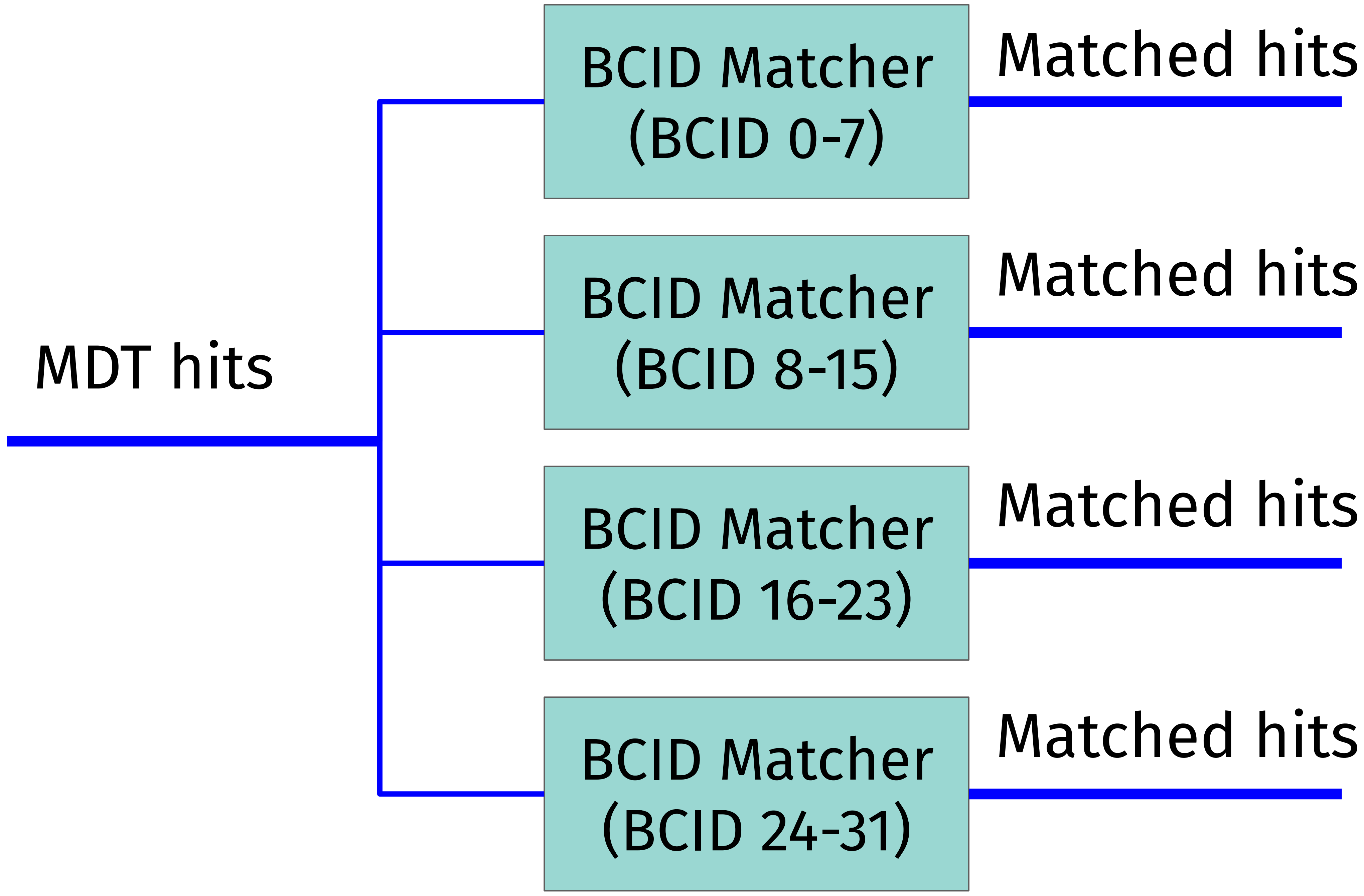


Coarse BCID Matching

$$t_{drift} = t_{hit} - t_{BC} - t_{offset}$$

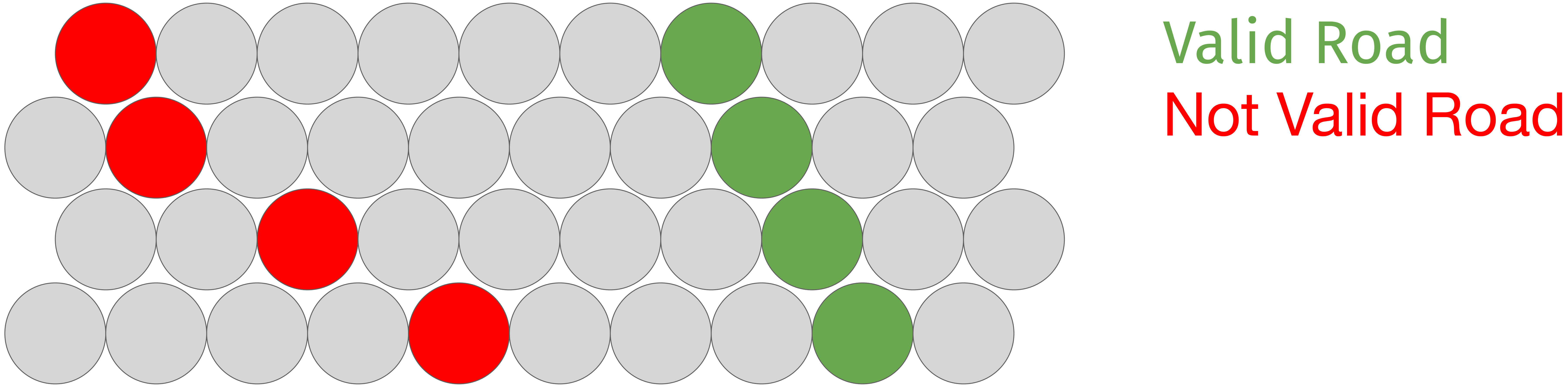


A radius-time RT relation then allows us to obtain a drift circle



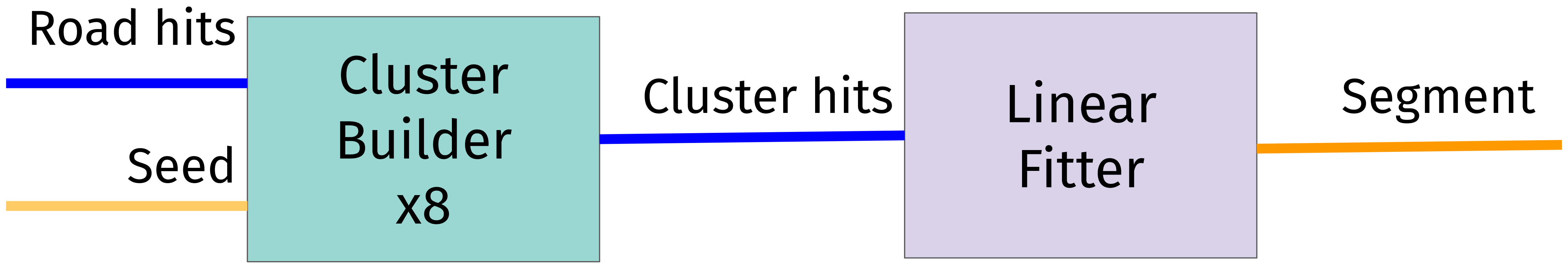
- Each drift-tube hit is compatible with 32 possible bunch crossings
  - Maximum drift time 800 ns, FCC bunch crossing period 25 ns
  - Number of BCID matcher blocks at FCC-hh will depend on BC spacing and actual tube radius
  - If 7.5mm radius tubes, only one block is required
- Hits are sent to four BCID Matching blocks, that checks compatibility with a group of eight bunch crossings

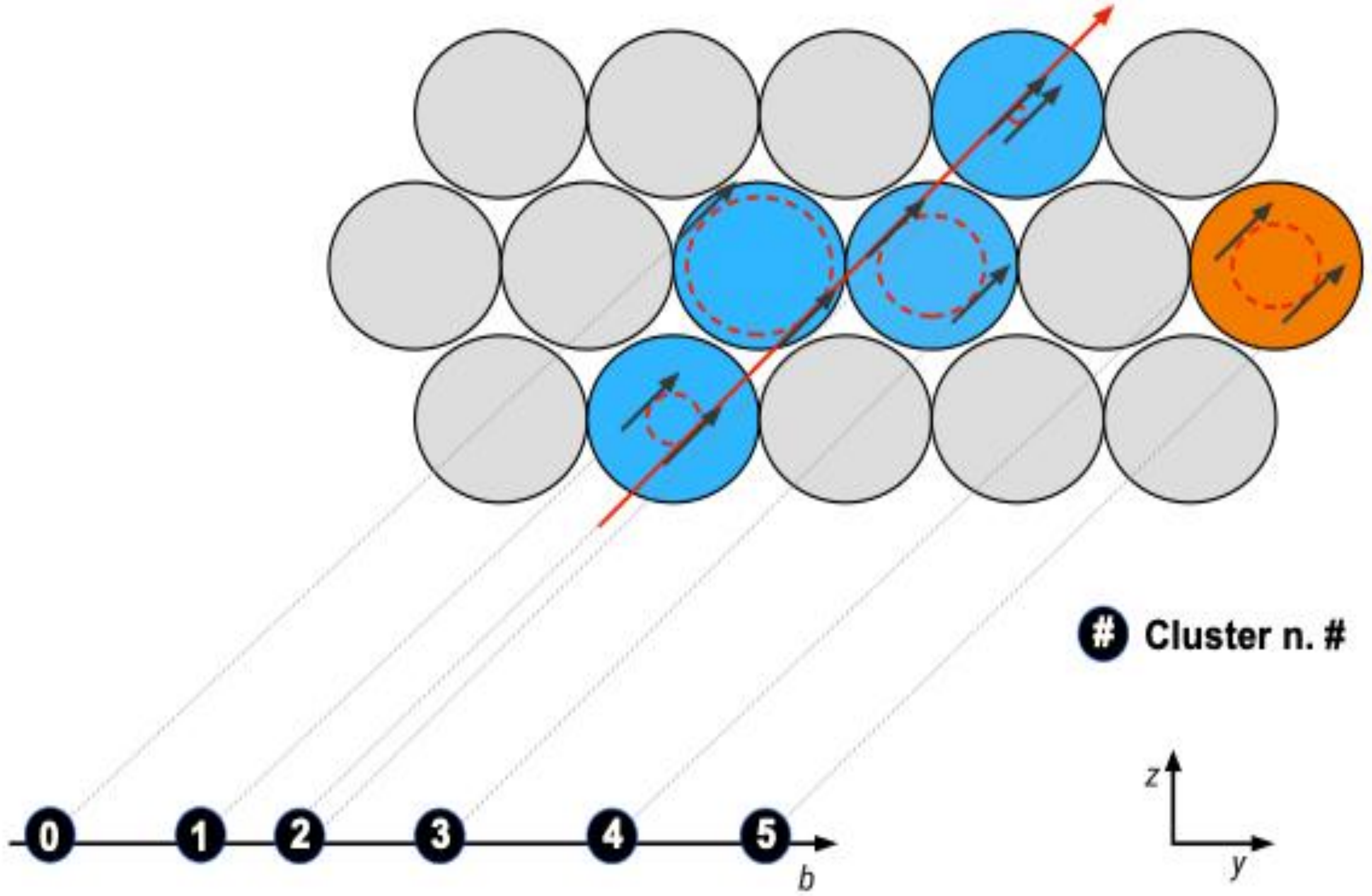
Road Finder



- Hits matched in time, used to search for valid roads inside a full chamber
- A maximum of 16 roads per chamber can be identified for the same 8 bunch crossings
- The road with the highest hit content is identified, and the tube coordinates are then fit to extract the seed parameters (angle, position)
- This process is done independently for each drift-tube chamber and layer (6x3)

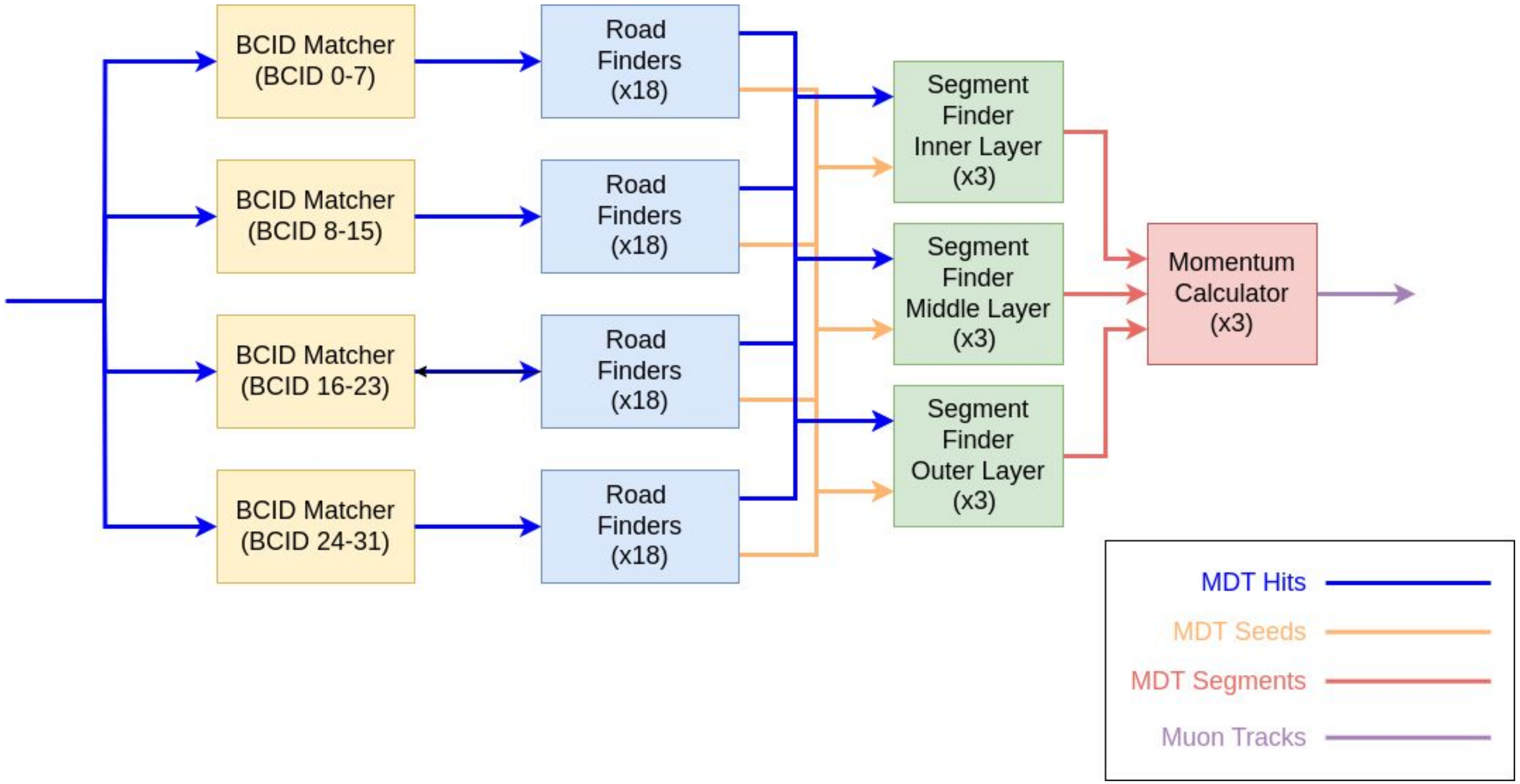
Segment Finder





- Segment Finder reconstructs track segments using hits on roads and the just calculated seed angle
- Eight possible drift radius can be calculated for each hit -> Eight different segment finders
- Segment Finder builds for hit clusters along the *y* axis, using the two possible hit positions (two-fold ambiguity)
- Cluster with the highest hit content identifies segment and bunch crossing
- Hits in cluster fitted to measure segment parameters

Firmware Implementation



- Self-seeded trigger algorithm implemented in VHDL targeting Xilinx VU13P FPGA
- No. *Road Finders* per BCID group is equal to total number of chambers in sector (18)
- No. *Segment Finders* per station and No. of *Momentum Calculators* equal to max. number of tracks that can be reconstructed per BCID group (3, arbitrary)
  - Segment Finder + Momentum Calculator requires less than 200 ns -> Same blocks for all BCID groups

FPGA Implementation

- First implementation fits well in VU13P (~37% LUTs)
  - Could be operated even with state-of-the-art technologies
- Total latency: 1.0 us

Component	#	LUTs	FFs	DSPs	BRAM	URAM
Road Finder	72	4904	717	12	0	0
Segment Finder	9	9502	7590	86	16	0
Momentum Calculator	1	1972	2796	33	59	0
DAQ	1	26942	43508	0	28.5	99
Infrastructure	1	174420	320384	0	300	0
Tot.		**641940**	**486622**	**1671**	**531.5**	**99**
Available VU13P		1728000	3456000	12288	2688	1280
Percentage		**37.15%**	**14.08%**	**13.60%**	**19.77%**	**7.73%**

Resource Usage

Block	Clocks	Latency (ns)
BCID Matcher	1	3.125
Road Finders	272	850
Segment Finder	30	93.75
Momentum Calculator	21	65.625
Total	**324**	**1012.5**

Latency

Conclusions

First study of a self-seeded drift-tube trigger. Design could be operated with available state-of-the-art technology.

Performance analysis still to be done.

Thanks for listening!
Any questions?