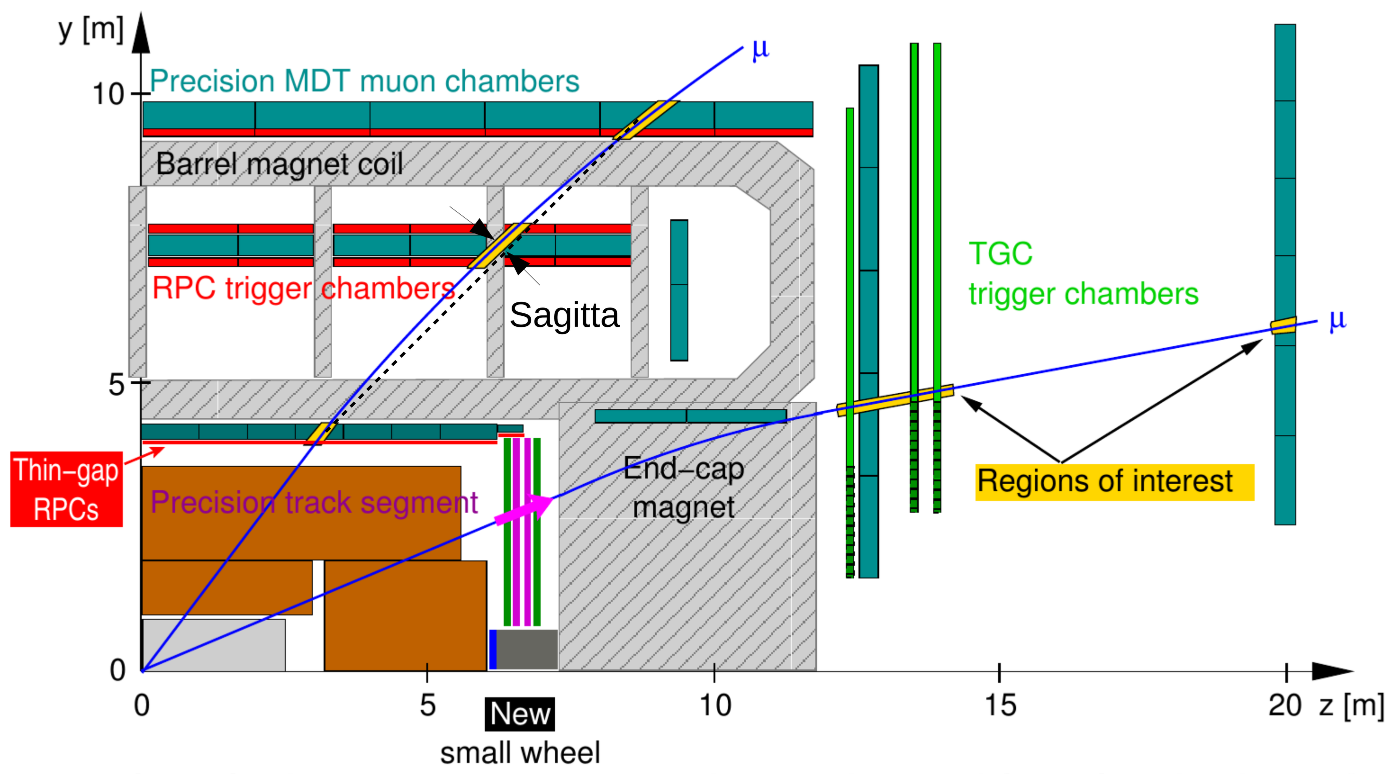
Development of a Highly Selective Muon Trigger Exploiting the High Spatial Resolution of Monitored Drift-Tube Chambers for the ATLAS Experiment at the HL-LHC

Oliver Kortner on behalf of the ATLAS Collaboration
Max-Planck Institute for Physics, Munich, Germany

Motivation

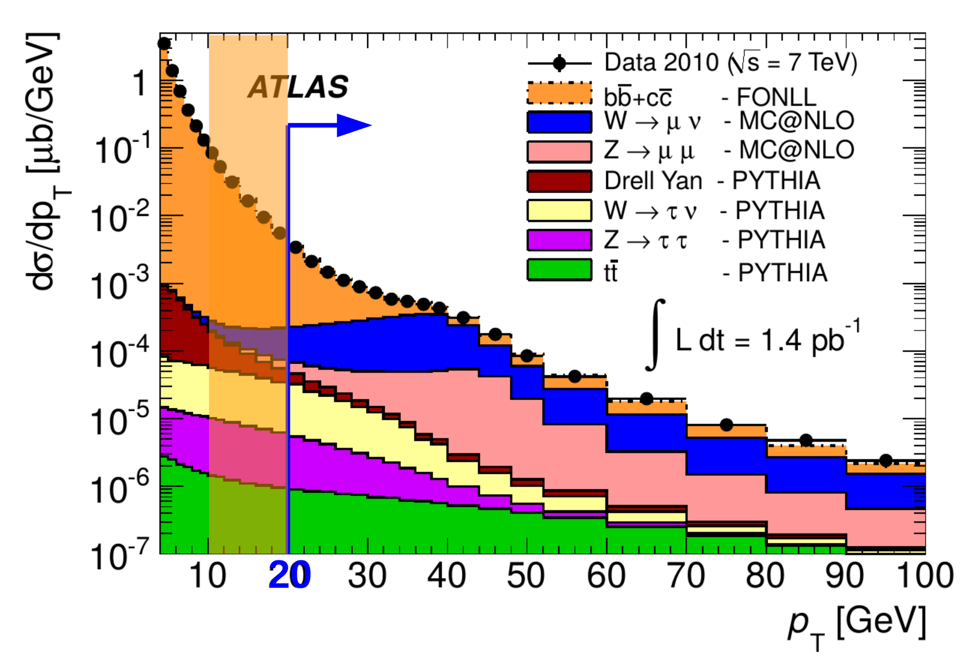
Muon trigger at the HL-LHC



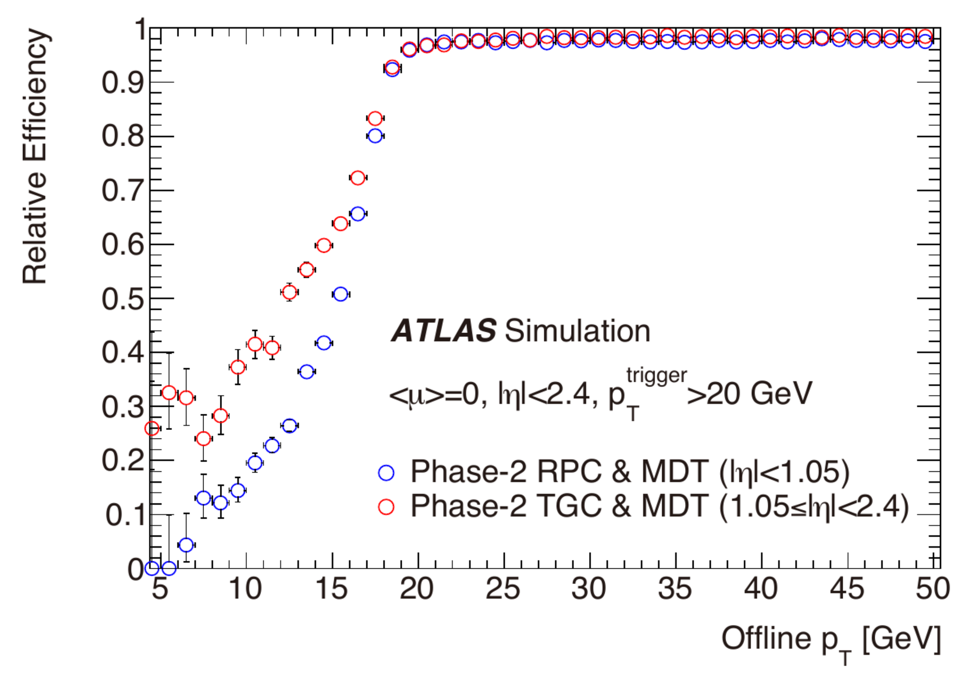
- 2-level trigger system: Hardware based level 0 (L0), software based high-level trigger (HLT).
- L0 muon trigger:
  - Pretrigger: Coincidence of RPC or TGC hits.
    → pp collision time (BCID) + η and φ position of the muon (spatial region of interest (RoI)).
    p_T measurement with low resolution.
  - Final trigger: Use of precision hits of monitored drift-tube (MDT) chambers for precise p_T measurement.

L0 muon trigger efficiency and trigger rate

Inclusive muon spectrum



Trigger turn-on curve with respect to pretriggers



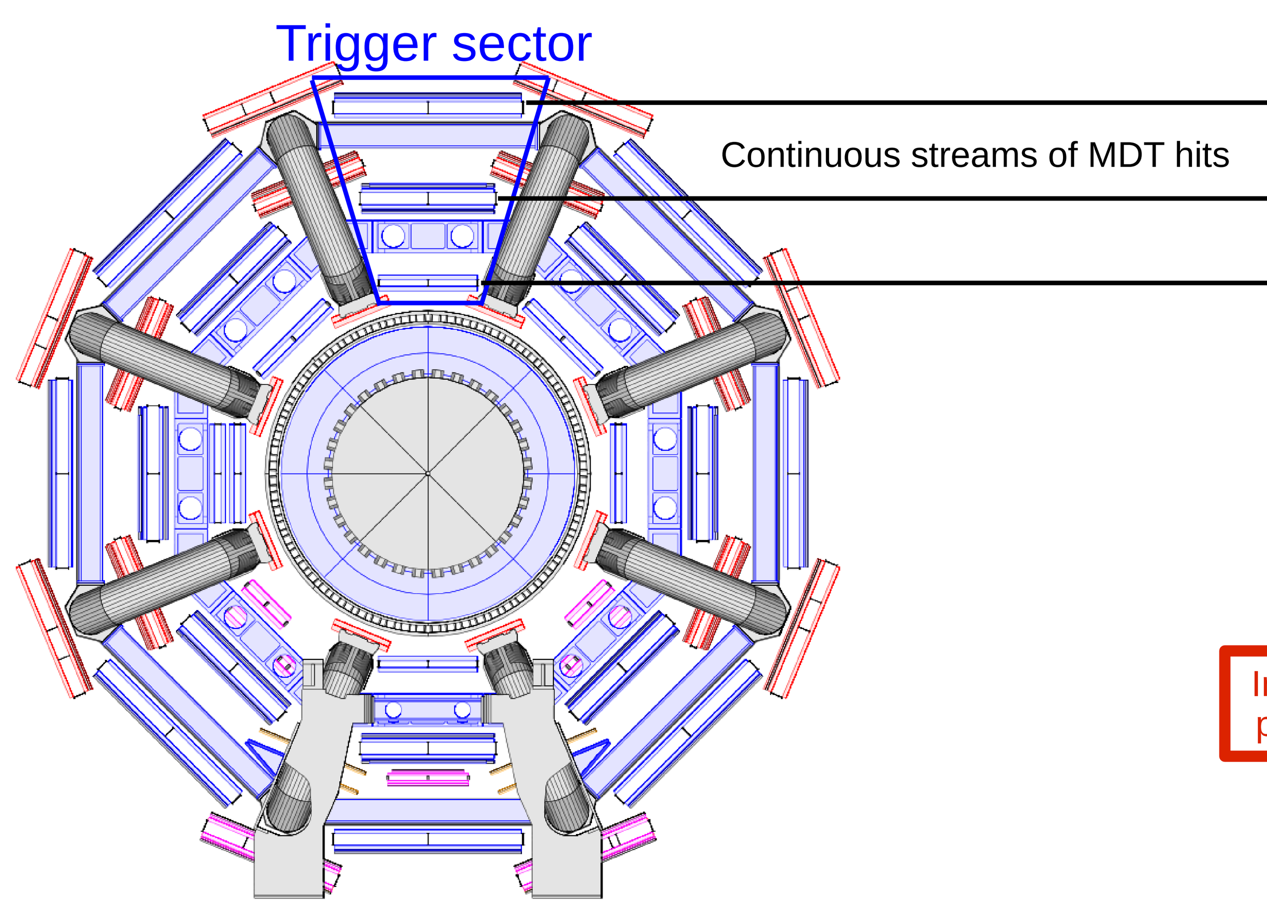
- The interesting electroweak physics is mainly at p_T>20 GeV.
- The inclusive muon cross section is very steeply rising with decreasing p_T.
- Muon pretrigger without MDT data accepts a lot of muons with 10 GeV<p_T<20 GeV.

→ Reduction of the trigger rate due to sharpening of the turn-on curve and the rejection of accidental pretriggers:

	Rate without MDTs	Rate with MDTs
Barrel (|η|<1.05)	45-85 kHz	~15 kHz
End caps (1.05<|η|<2.4)	15-20 kHz	~10 kHz

MDT trigger data flow

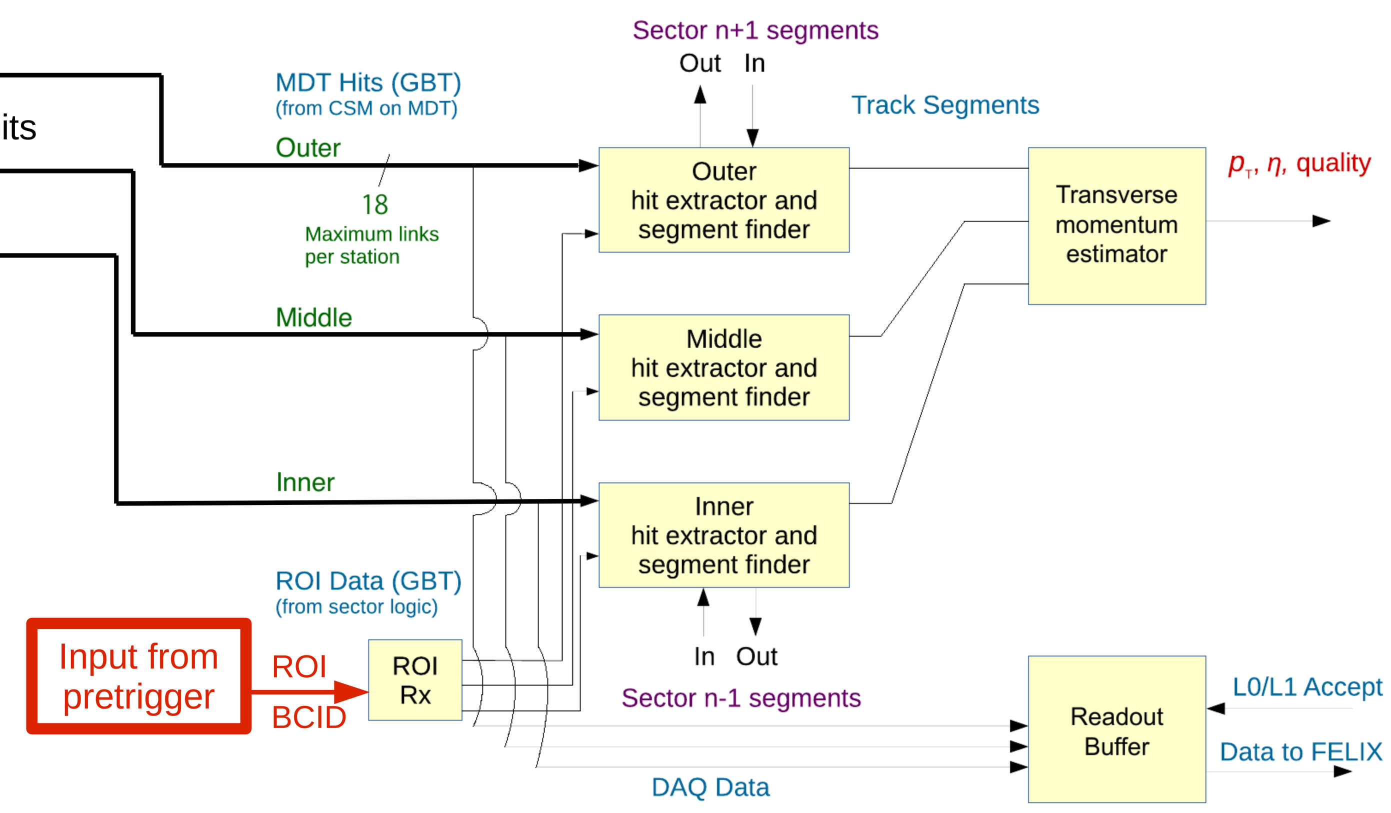
Segmentation of the MDT trigger



- MDT data of one trigger sector processed on one ATCA blade.
- Number of trigger sectors: 32 (barrel) + 32 (end caps) = 64.

→ 64 MDT trigger processor blades.

Data flow



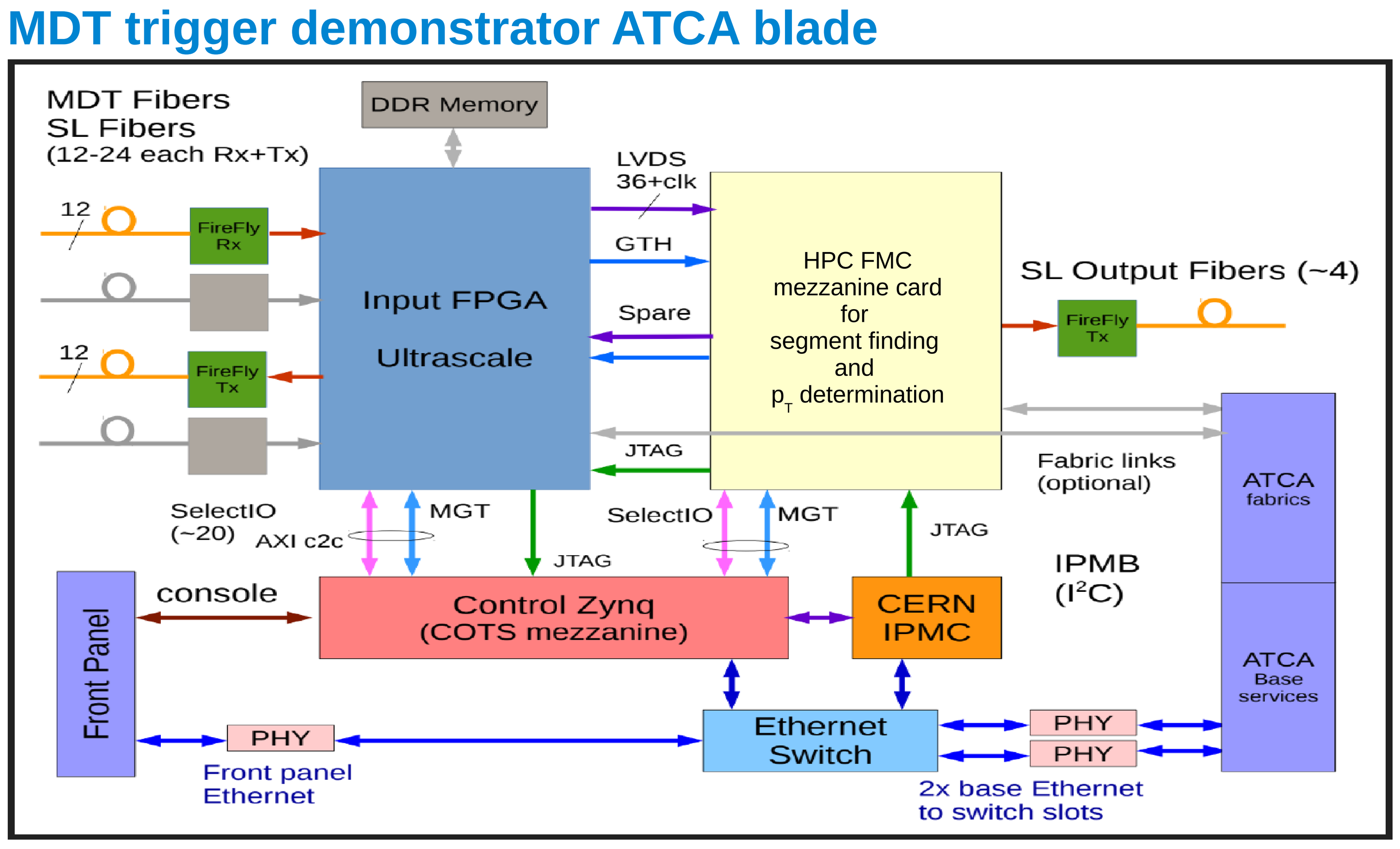
Processing steps on the MDT trigger blade

- Buffering of MDT hits.
- Selection of hits in the ROI which are compatible with the BCID.
- Conversion of hit times into drift radii.
- Track segment reconstruction in each chamber.
- Computation of sagitta from segment positions.
- Conversion of the sagitta into p_T.
- Sending of p_T to muon sector logic.

L0 muon trigger latency: <4.2 μs

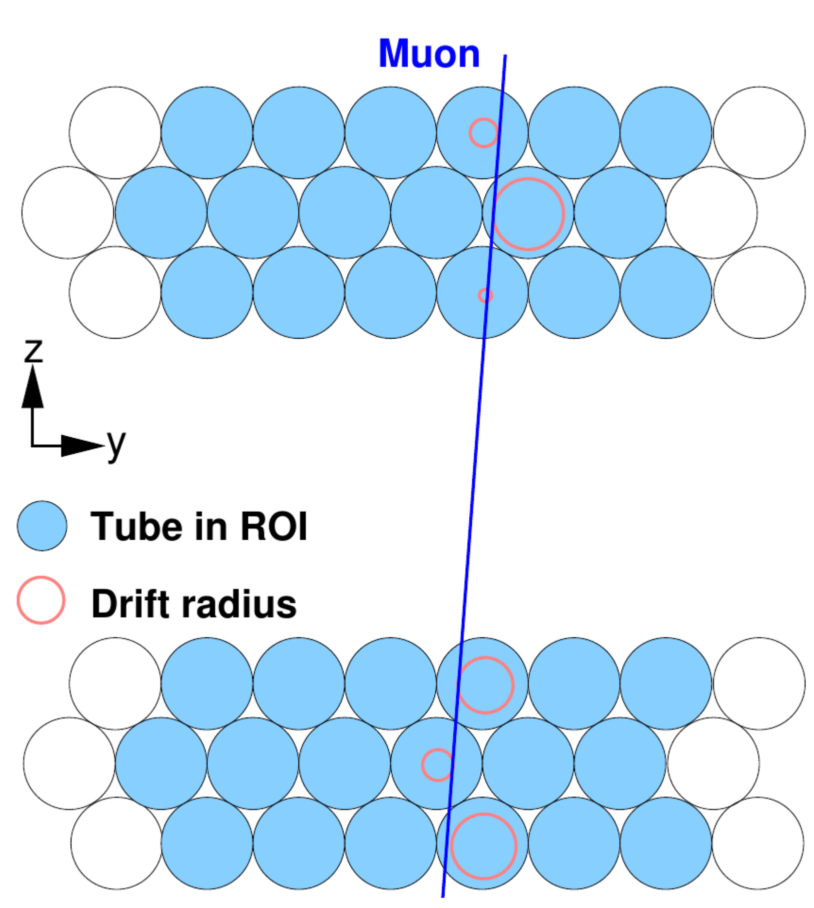
MDT trigger demonstrator blade

MDT trigger demonstrator ATCA blade



- MDT trigger demonstrator blade in preparation for end of 2018.
- Segment finding and p_T determination on a mezzanine card to study two different segment finding approaches:
  - Pattern recognition and segment fitting on an FPGA;
  - Pattern recogntion on a associative memory chip, segment fitting on an FPGA.
- Use an FPGA with an embedded microprocessor to profit from its floating point precision for the pT determination.

Segment finding strategies for the FPGA option



- Track segments are straight within a muon chamber:

$$y = a \cdot z + b$$

→ Two unknowns: slope a, intercept b.

- r: Drift radius. (y_w, z_w): Wire position.

$$r = \frac{|y_w - a\cdot z_w - b|}{\sqrt{1+a^2}} \Rightarrow b = \pm r\sqrt{1+a^2} - (a * z_w - y_w)$$

- Option 1: 1-D approach (conceptual description)
  - Use seed value for a provided by trigger chambers.
  - Compute b for all hits and histogram them.
  - Find the maximum of this histogram and refit the hits in the maximum to get precise values for a and b and a goodness-of-fit estimator.
- Option 2: 2-D approach (conceptual description)
  - Compute b for all hits and several values of a around the seed value from the trigger chambers and histogram b separately for the chosen values of a.
  - Find the maximum of this 2-D histogram to get values for a and b. Optionally refit the hits in the maximum to get a goodness-of-fit estimator.

- Main advantage of the 1-D approach: Lightweight,FPGA resource saving.
- Main advantages of the 2-D approach: Faster than the 1-D approach if one drops the goodness-of-fit estimation, but high FPGA resource consumption.