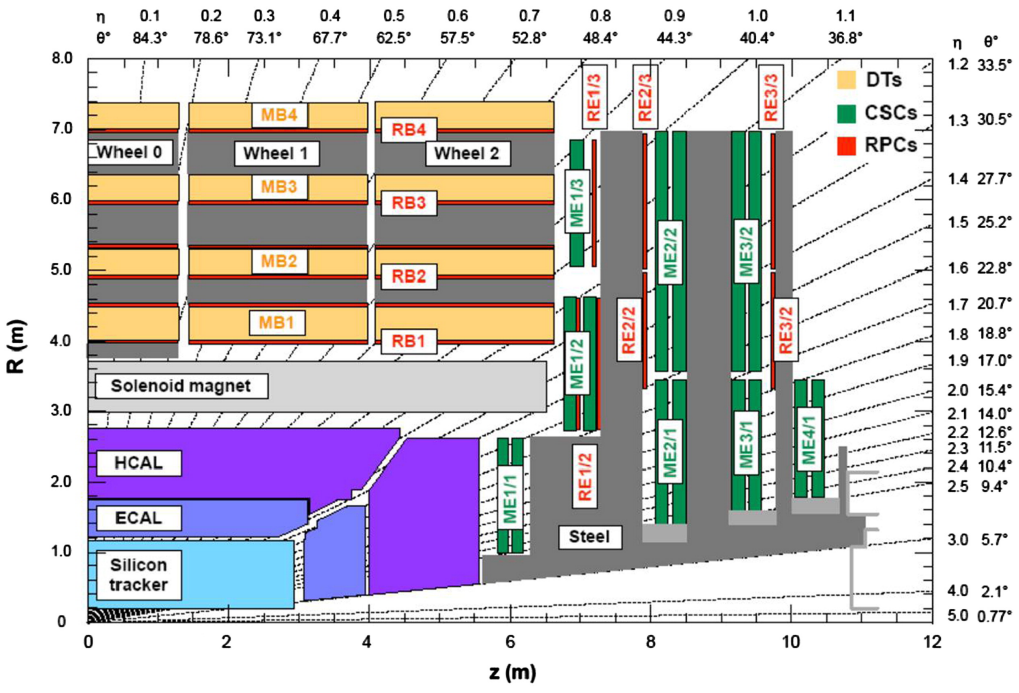
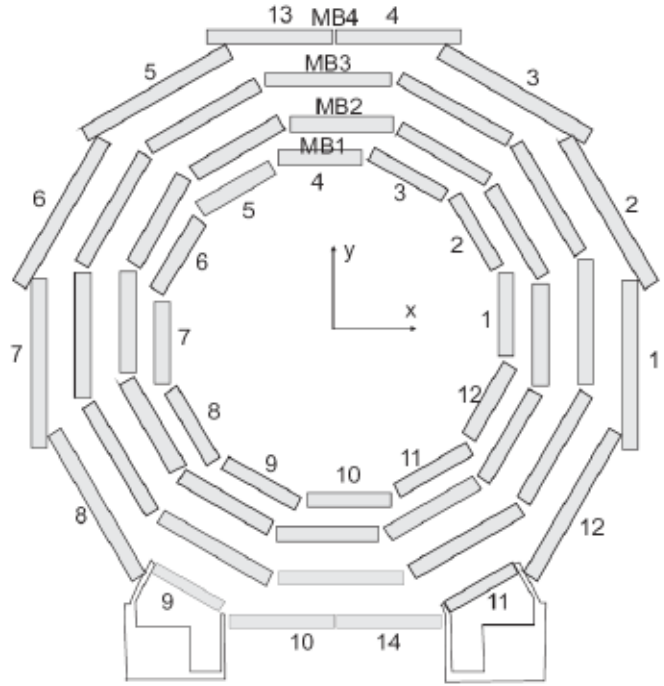
# Using the Outer Hadron Calorimeter in the TwinMux emulator for Level 1 muon trigger

# Outline

- Description of the MB and HO geometry
- Need for the HO
- The algorithm
- Algorithm performance

# The Muon Drift Tube (DT) system



# The Muon Drift Tube (DT) system

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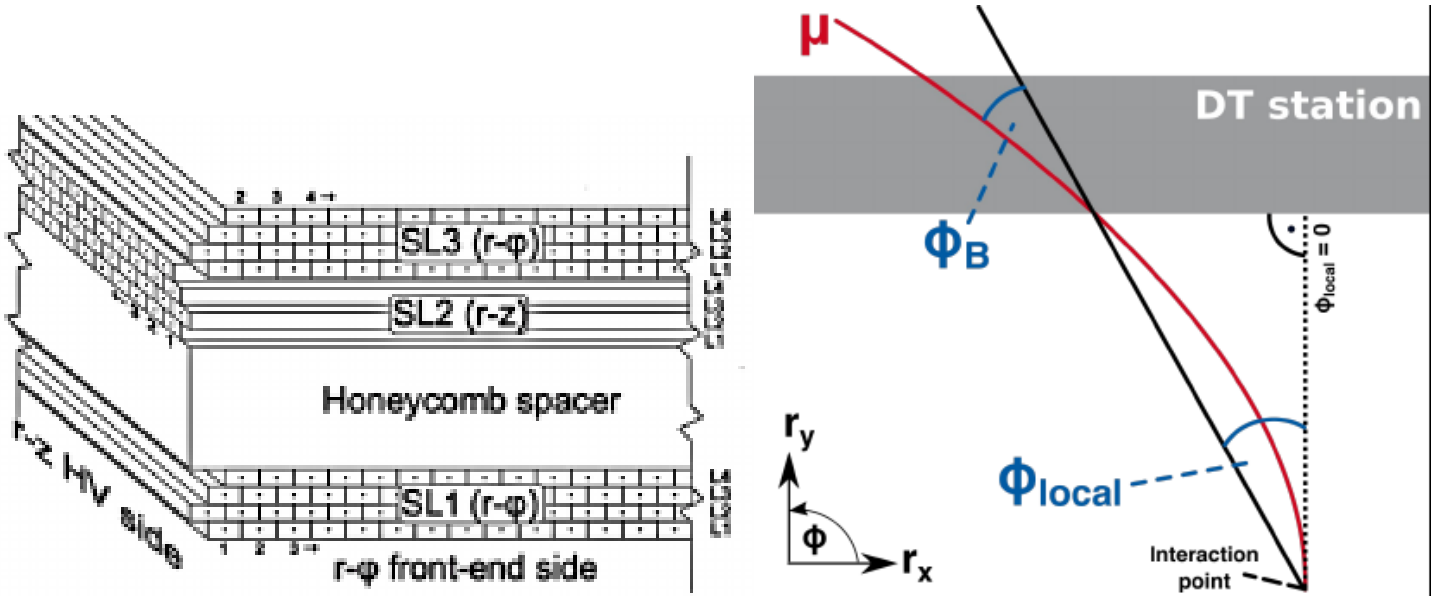


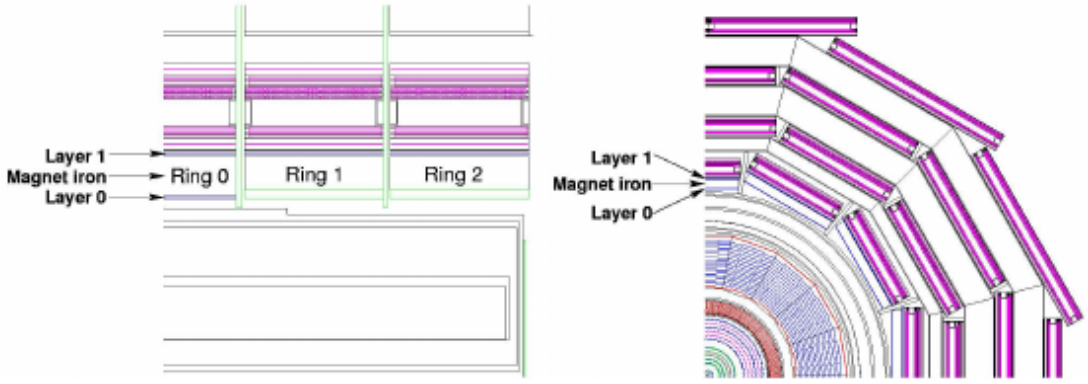

- 4 staggered layers form 1 SuperLayer (SL).
- $SL_{r\text{-}\phi}$ have wires parallel to the beamline, and measure quantities in the $r$-$\phi$ plane.
- $SL_z$ have wires perpendicular to the beamline, and measure quantities in the $r$-$z$ plane.
- In MB1/2/3, one chamber is formed by 2 $SL_{r\text{-}\phi}$ and 1 $SL_z$.

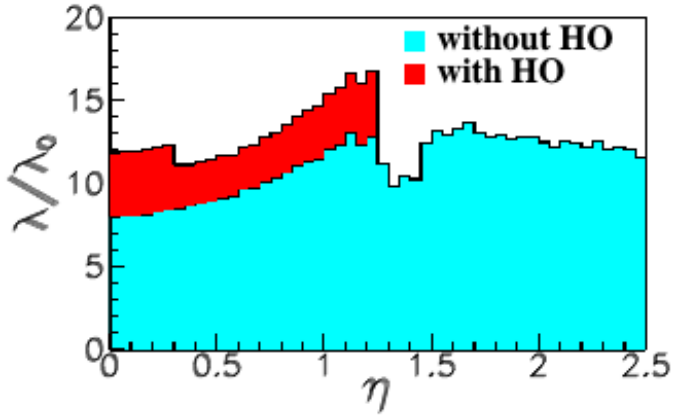
# The Muon Drift Tube (DT) system

III

- In MB4, one chamber is formed by only 1 $SL_{r\text{-}\phi}$.
- The DT chambers provide Trigger Primitives (TPs) which store information about the location of the hit, number of aligned DT-hits, the bending angle $\phi_B$ etc. It also contains a quality code which indicates the number of SL hits and the how well aligned they are.

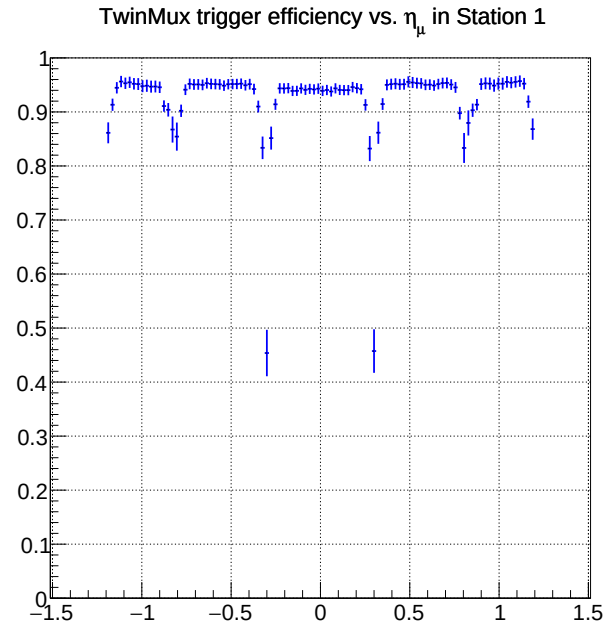
# The Outer Hadron (HO) calorimeter



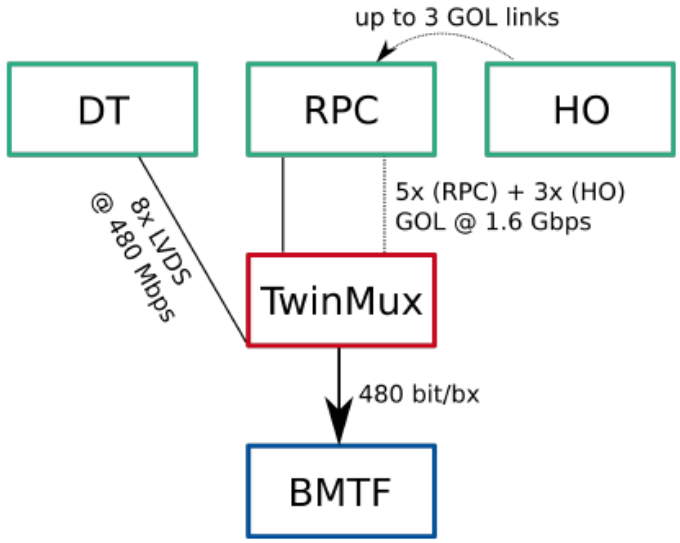

- $|\eta| < 1.4$.
- Central ring has 2 layers. The others have 1.
- Segmentation: $\Delta\eta \times \Delta\phi = 0.087 \times 0.087$.
- The HO provides Trigger Primitives (TPs) which among other things, store the $\eta$-$\phi$ location information, and also a mip-bit which stores whether the hit is mip-like (within certain thresholds) or not.

# Need for the HO



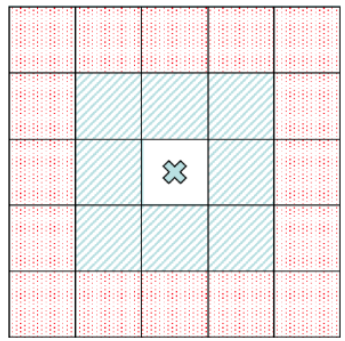

- Efficiency in muon barrel gap regions is much lower.
- Scenario where a DT station fails.
- Since the HO covers the muon barrel gap regions, it can be used to aid the muon track finder.

# The TwinMux




- The DT-TPs and HO-TPs are collected by the TwinMux (a $\mu TCA$ board), along with information from the RPC (mainly for timing), and sent to the Barrel Muon Track Finder (BMTF).
- The TwinMux emulator is a piece of code that emulates this behaviour, and can be used for stuff like testing new algorithms.
- Currently, the HO-TPs are not sent by the TwinMux to the BMTF.
- I am implementing an algorithm to decide if and when will an HO-TP be used to support the DT-TPs.

# The algorithm



Loop over all the DT-TPs in the following manner:

1. Take a DT-TP in say the first station/barrel.
2. Decide whether the DT-TP is Low Quality ($0 < LQ < 4$) or High Quality ($3 < HQ < 7$).
3. For LQ, try to find a matching HO-TP in the same wheel as the DT-TP such that $\Delta i\phi < 1$.
4. For HQ, try to find a matching HO-TP such that $\Delta i\eta \times \Delta i\phi < 1 \times 1$, i.e. within a $3 \times 3$ tile window.

# The algorithm

II

5. If a matching HO-TP is found, then the quality code of the DT-TP is modified to indicate that this DT-TP has support from the HO.
6. This modified DT-TP, say DT-TP' (primed) will be treated differently in the BMTF.

The modified DT-TPs can be used by the BMTF to:

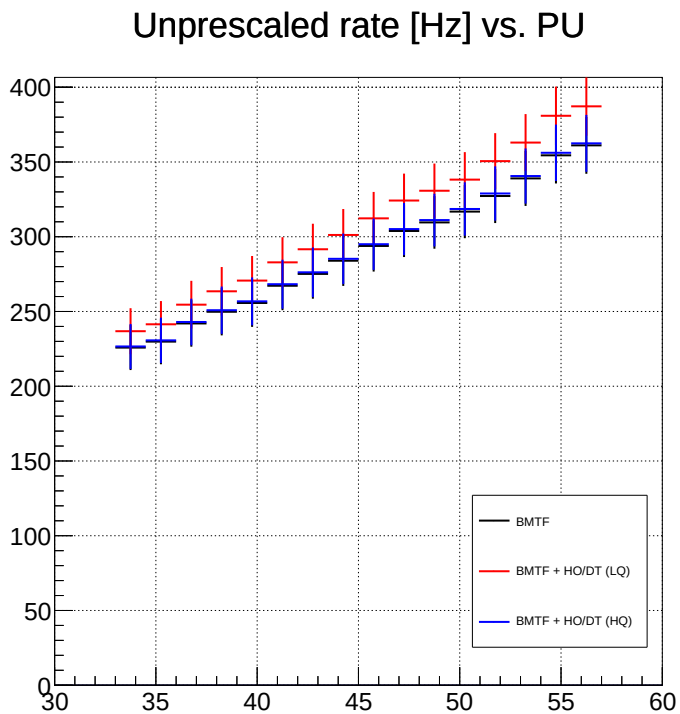
- recover muons in case of a muon barrel failure.
- recover muons in the barrel gap regions where the efficiency is low.

# Datasets

- `/ZeroBiasBunchTrains[0-5]/Run2016H-v1/RAW`

# Algorithm performance: L1 trigger rate

- Have to check that the rate increase of the L1 trigger is not too high.
- Unprescaled means $nBunch = 1$; can be scaled to any arbitrary bunch filling. The $p_T$ cut is 3 GeV.
- As can be seen, the rate increase is tolerable.

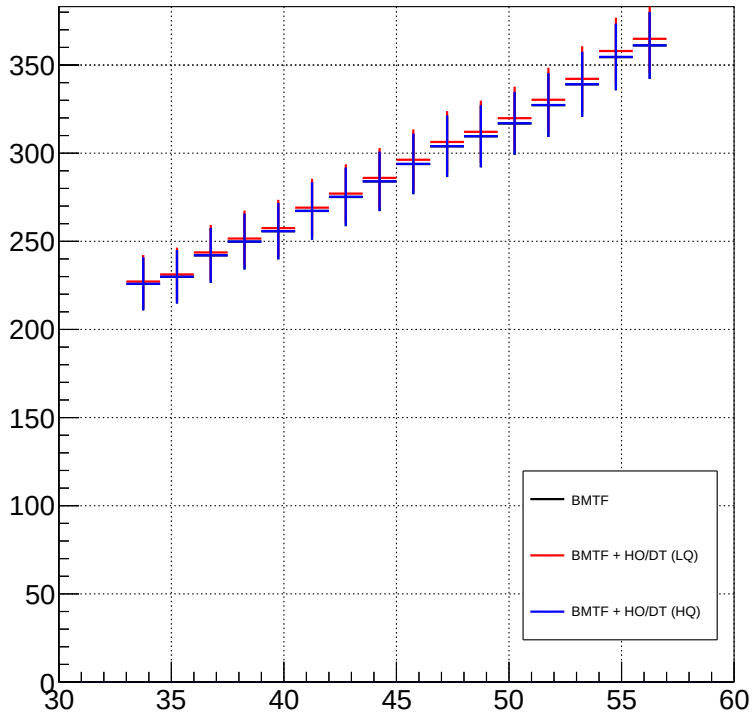


# Algorithm performance: L1 trigger rate II

- Accessing mip bit (suggested by Christopher West): `(hoTP->bits()>>hoTP->whichSampleTriggered())&0x1`
- Have been discussing with Chris, Aleko, Pooja... : what values should `hoTP->bits()` take? [0, 2, 4, 8] or [0, 1, 2, 4, 8]?
- Rate is far lower; do I need to check for the mip bit?

# Algorithm performance: L1 trigger rate

III



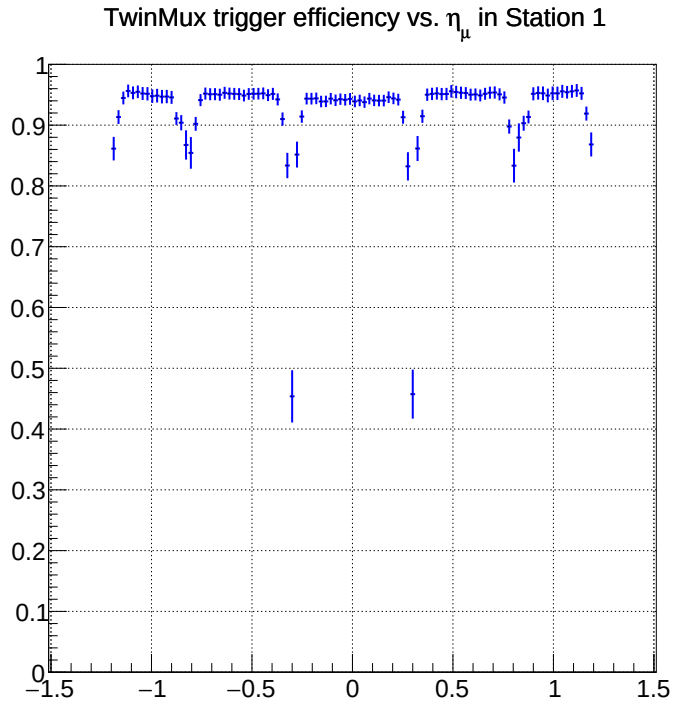
# Algorithm performance: Efficiency

- A DT track segment is reconstructed from a single DT chamber.
- In-time means that the TP must have been recorded at the correct bunch-crossing. The efficiency is defined as:

$$\text{efficiency (in a bin)} = \frac{\#\text{ of in-time Trigger Primitives matched to the denominator}}{\#\text{ of DT track segments matched to reconstructed muon tracks}}$$

# Algorithm performance: Efficiency

II




- There was an issue with the event numbers in the ntuples made by the DT group. I have corrected that, and have included the required HO-TP ntuples.
- The effciency after including HO-TPs will be produced as soon as the new ntuples are ready.