A Novel Highly Ionizing Particle Trigger using the ATLAS TRT

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Caveat

This talk gives an overview of a possible enhancement to the ATLAS Transition Radiation Tracker

The project is currently still in the early design stage, subject to many changes, and is not an official ATLAS project (yet)

However it does highlight an exciting possibility to improve the physics reach of ATLAS and reminds us of what unexpected benefits one can obtain from an exceptionally well designed and built TR detector ☺

What HIPs are we looking for and why are they interesting?

Highly Ionizing Particles (HIPs) are an exciting signature of new physics that could be discovered by the LHC

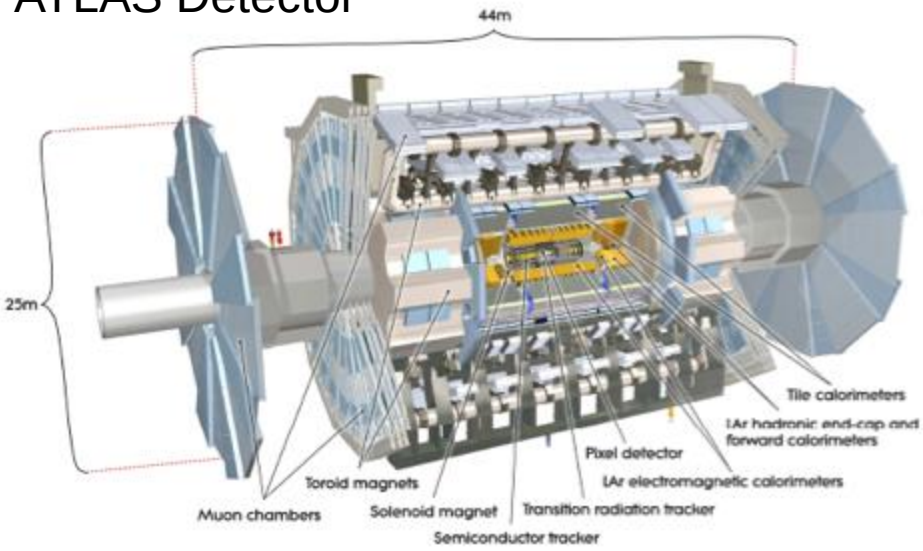
<u>Many possible HIPs to look for</u>

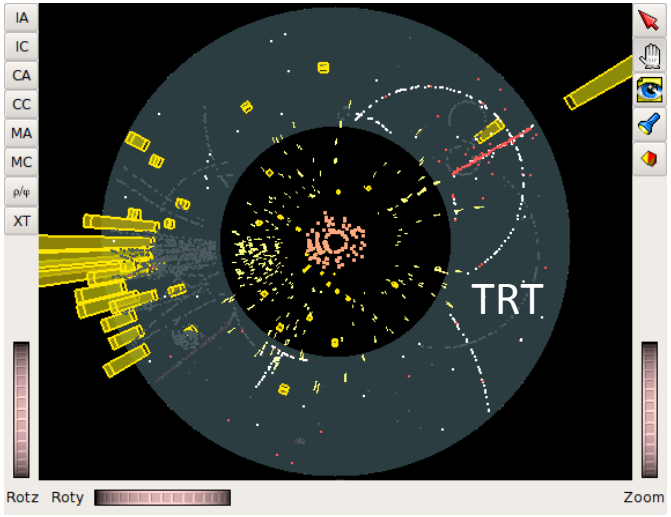
Electric charge q > 1 (Qball)
Magnetic charge g > 0 (Monopole)
Particle with both q&g > 0 (Dyon)

- A thorough search for QBalls across a large mass and charge range can provide an excellent probe of the SUSY parameter space
- The discovery of a magnetic monopole would among other things explain why electric charge is quantized

Current System and Search Method

ATLAS Detector





Simulated Inner Detector Event Display of a Drell-Yan 800 GeV Monopole

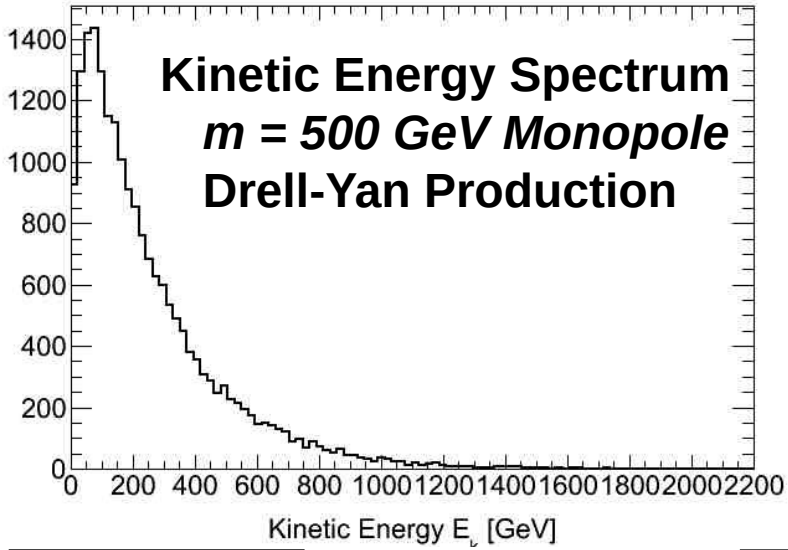
If a HIP did pass through the ATLAS Detector it would be very noticeable by eye

- The large amount of delta electron knocked off as the HIP passes through the Inner Detector create a swath of high threshold hits -> swath width can be related to the effective q

However with pp collisions nominally happening every 25ns we have to rely on the ATLAS trigger system to pick out and save these events

- At the lowest level (L1) which determines if the detector information is readout to our counting room the most useful trigger is L1EM which uses the 2nd sampling layer of LAr calorimeter

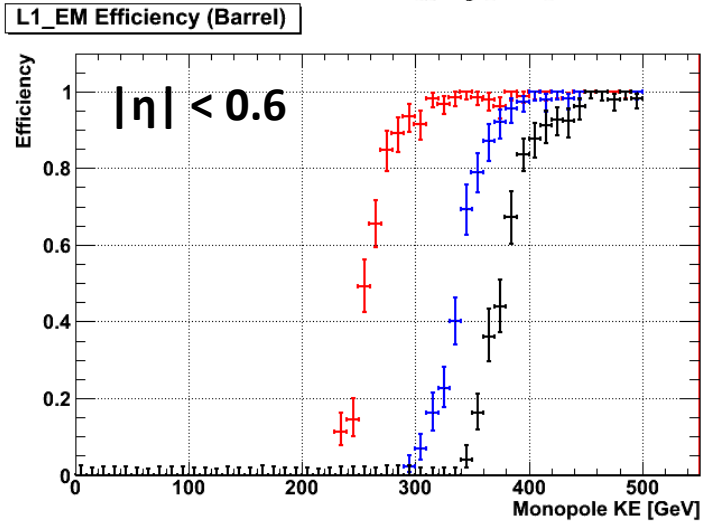
However L1EM is not optimized for HIPs

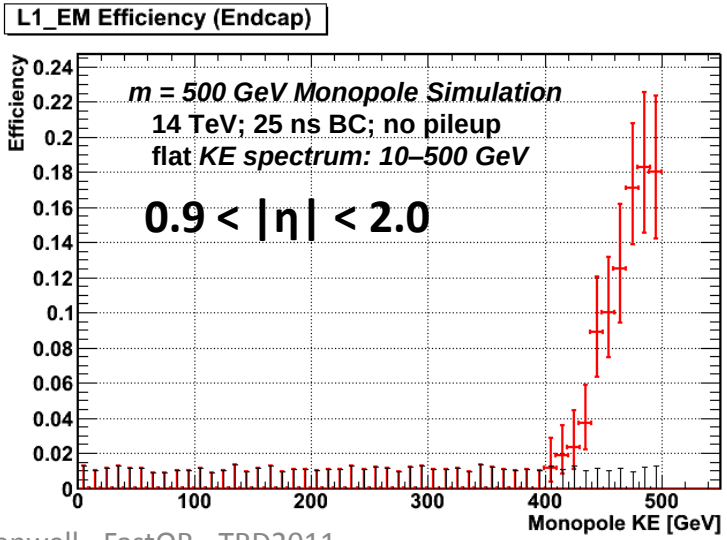


Unfortunately there is quite a bit of material between the Interaction Point and L1EM trigger towers

Inner Detector solenoid and 1st layer of LAr calo provide a lot of dense material to range out in

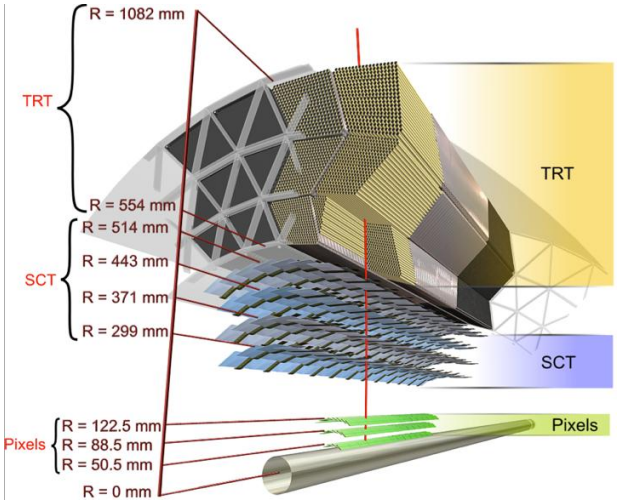
Additionally at design Lumi = 10^{34} the threshold For single L1EM trigger will have to be quite high

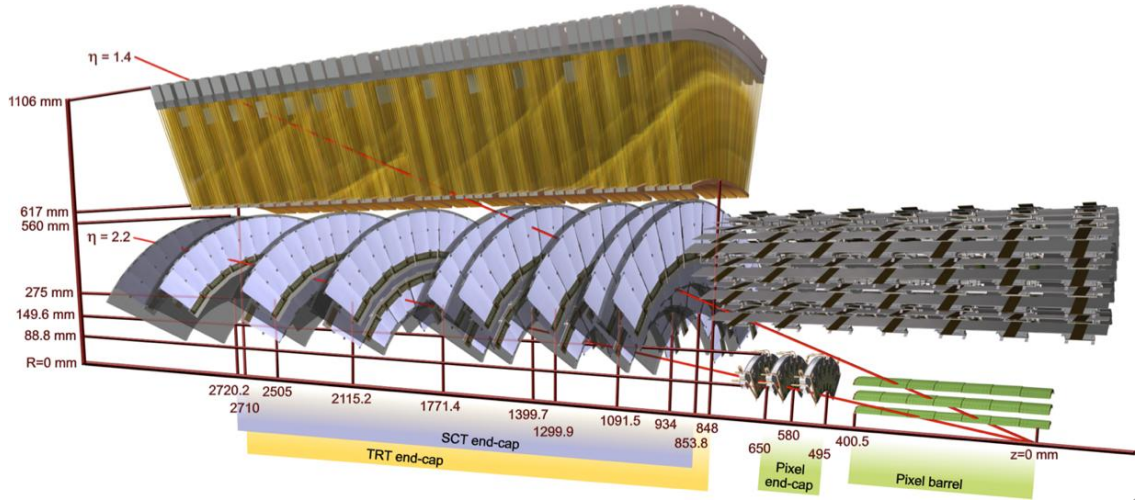




Red L1EM_20
Blue L1EM_30
Black L1EM_40

TRT to the Rescue!





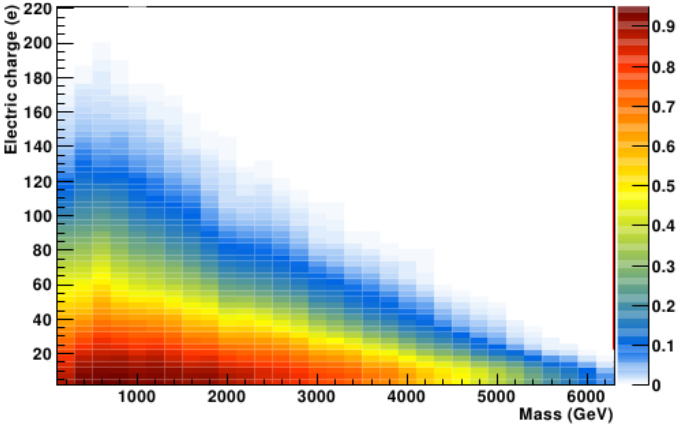
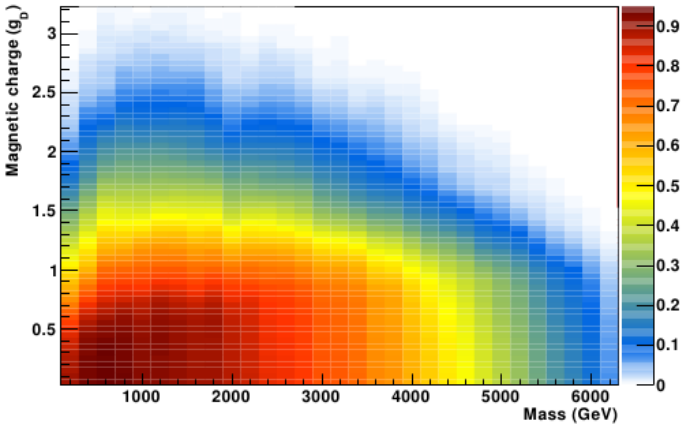
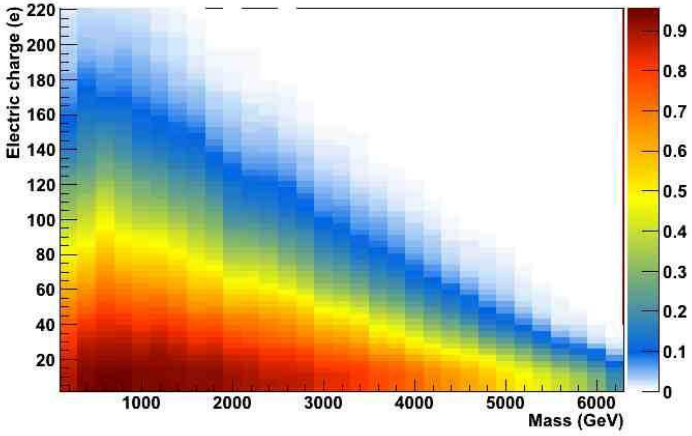
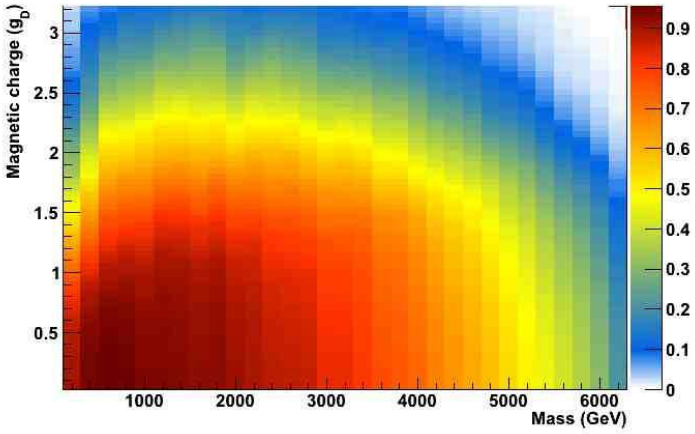
Located significantly closer to the interaction point than the L1EM trigger towers the ATLAS TRT is in a prime position to act as a new L1 trigger for HIPs

Utilizing the FastOR functionality (described in detail on slide 8) of the front end electronics to generate the trigger signal, HIPs can readily be identified from electrons and minimum ionizing particles by ~100% High Threshold hits on track and long ~100 ns time over threshold due to saturation of the pre-amp and shaper stages of the ASDBLR front end chip.

Gains in Acceptance

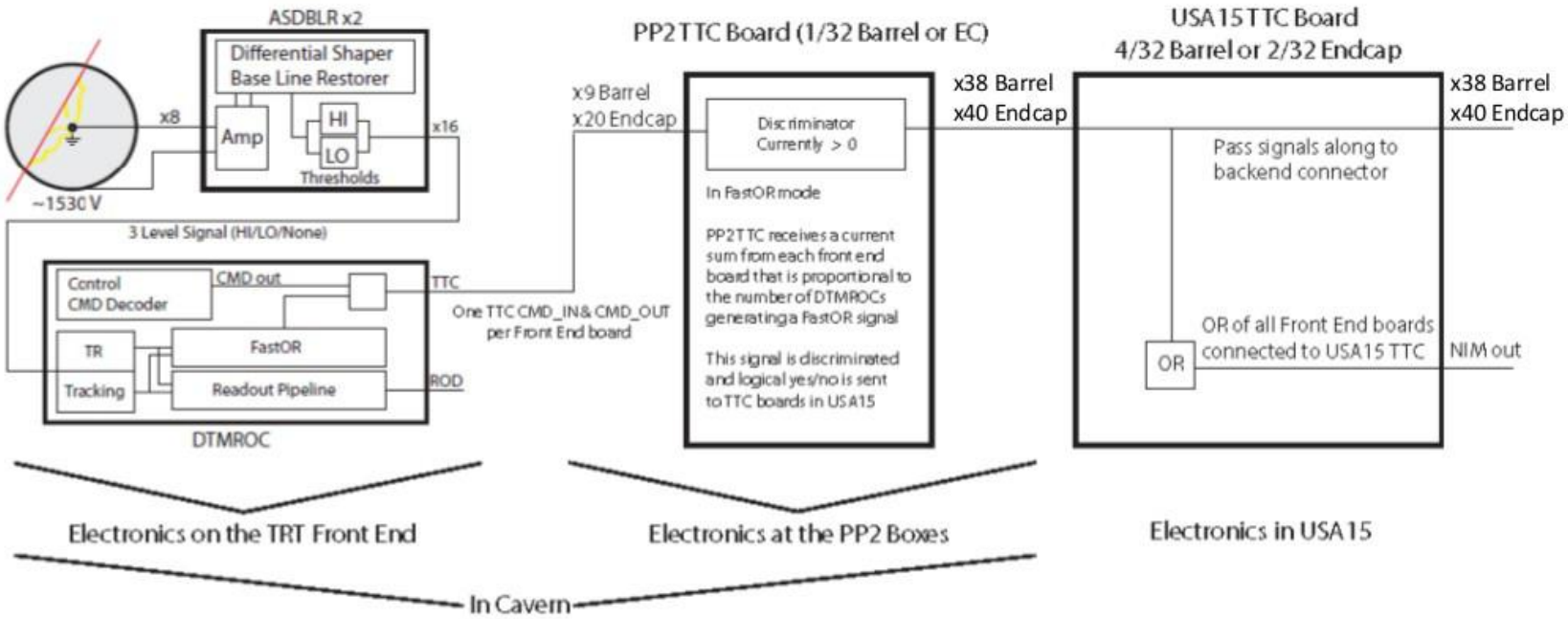
Simulated 14 TeV Drell-Yan Production

Acceptance defined as fraction of particles passing through or stopping in a given volume

	QBall	Monopole
Stopping in LAr Calo (current setup)		
Stopping in TRT (FastOR trig)		

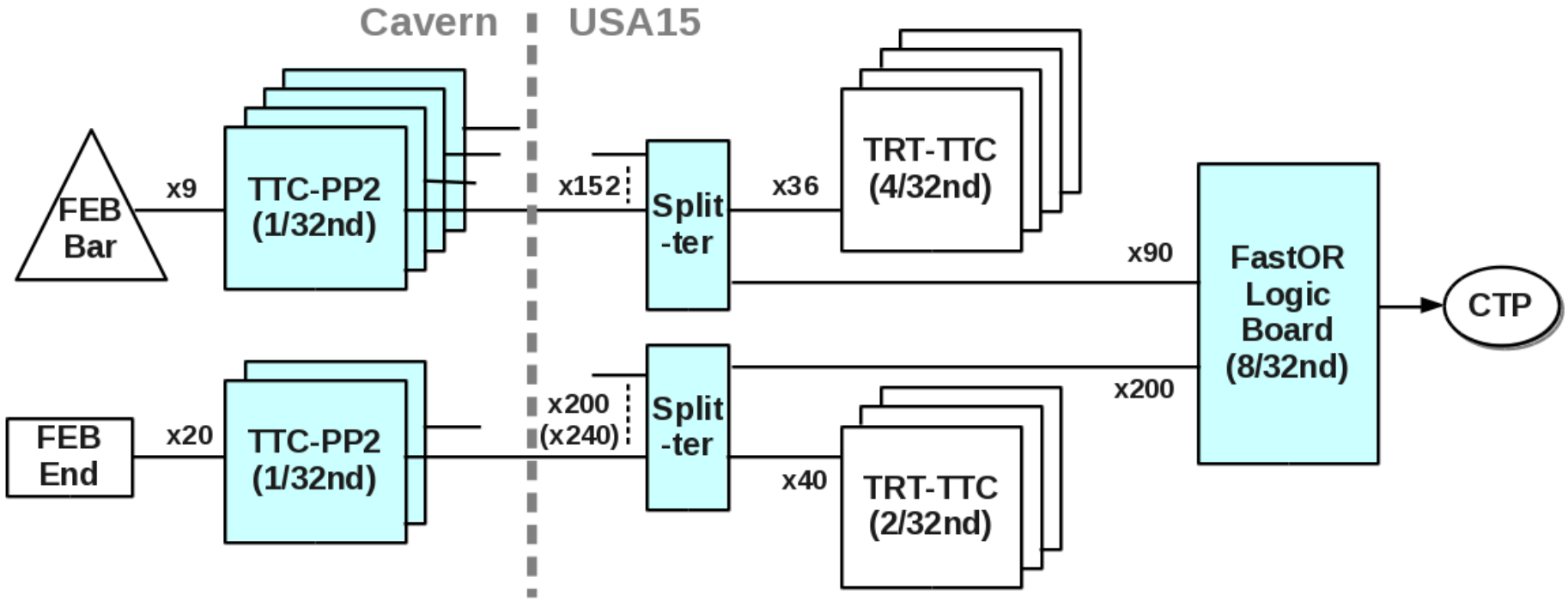
TRT FastOR

Current Electronics Setup



To date only used as a cosmics trigger during ATLAS commissioning
Cosmics trigger used NIM out on USA15 Timing Trigger Control (TTC) boards was used
Logic crate built from NIM modules generated trigger signal sent to Central Trigger Processor (CTP)
CTP received trigger ~1 μs well within 2.5 μs L1 trigger accept time

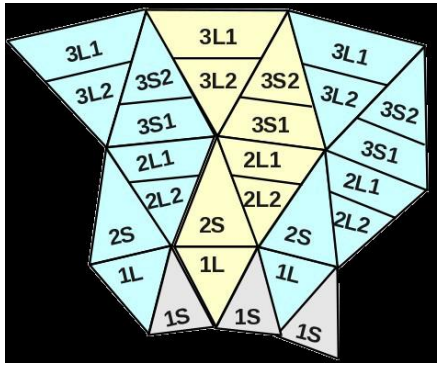
Hardware Implementation



128 PP2 Timing Trigger Control (TTC) boards located in relay electronics boxes between the barrel MDT stations need to be rebuilt to pass DTMROC multiplicity along to a logic board located in our counting room in USA15

Logic board fitting into the existing TRT VME crates in the USA15 counting room containing a set of FPGAs loaded with look up tables to make the trigger decision along with splitter boards or new cables to route signals to both USA15 TTC boards and trigger

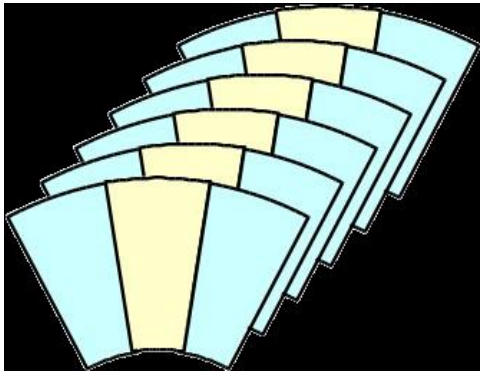
Logic Board LUTs

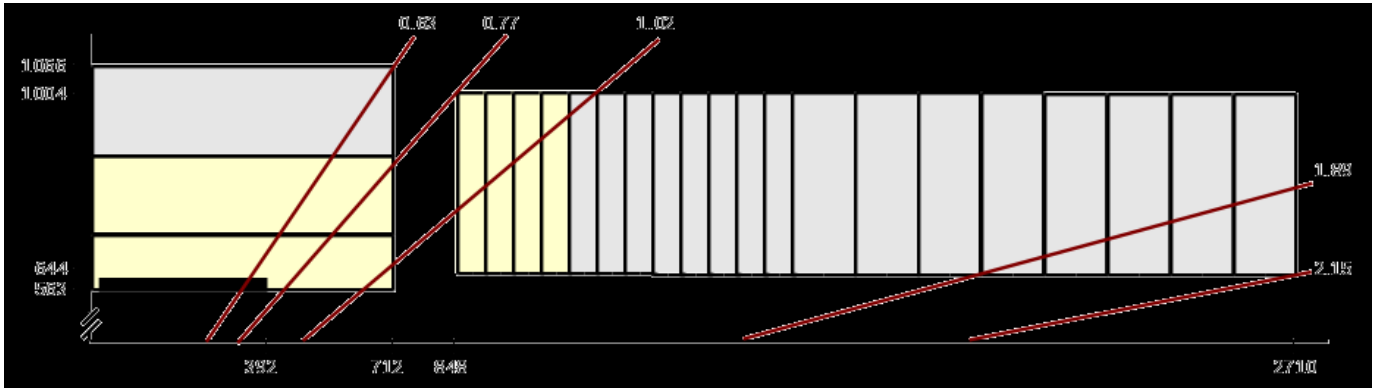


Barrel Region
(3/32 phi stacks)
$|\eta| < 0.65$
24 FastOR signals
LUT 2^{24} = 16 Mbit

Memory Requirement for Single LUT

Endcap Region
(3/32 x 6)
$1.0 < |\eta| < 2$
18 FastOR sig/grp
with 15 groups
LUT $15x2^{18}$ = 0.48Mbit

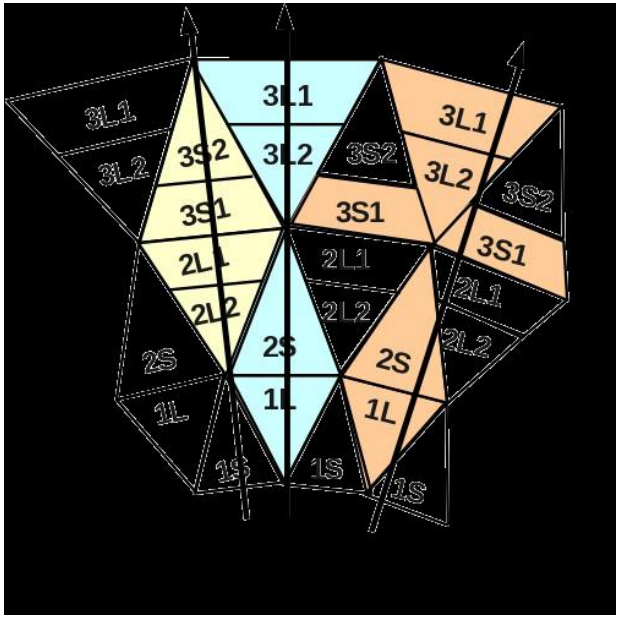




Overlap Region
(3/32)
$0.65 < |\eta| < 1.0$
Bar: layers 1,2 (12 sig)
EC: wheels 1-4 (12 sig)
LUT 2^{24} = 16 Mbit

Need x 32 (phi) x Number of trigger towers LUTs for each region
Possible to fit all LUTs for Barrel + Overlap + Endcap regions onto 256 MB of RAM

Strawman Trigger Setup



3 Trigger towers for the Barrel Region are defined

3/4: 2L2(≥2) & 2L1(≥2) & 3S1(≥2) & 3S2(≥2)
& [2L2(≥3) || 3S2(≥3)]

3/4: 1L(≥2) & 2S(≥4) & 3L2(≥4) & 3L1(≥2)

4/5: 1L(≥2) & 2S(≥2) & 3L2(≥2) & 3L1(≥2)
& [3S1L(≥2) || 3S1R(≥2)]

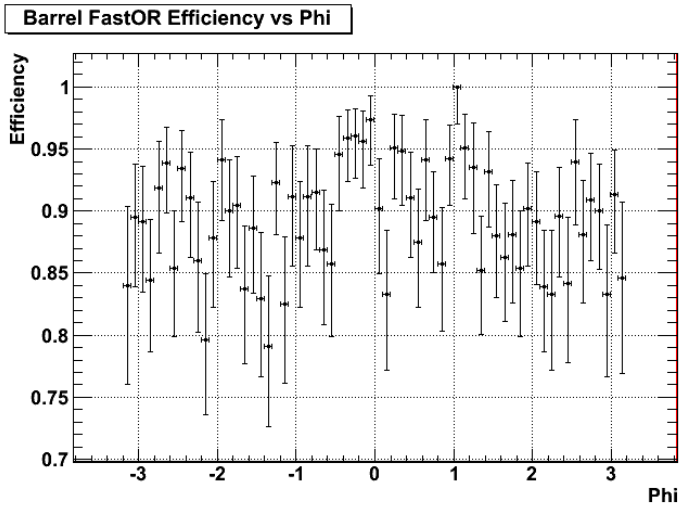
Tested very simple trigger setup for efficiency and uniformity

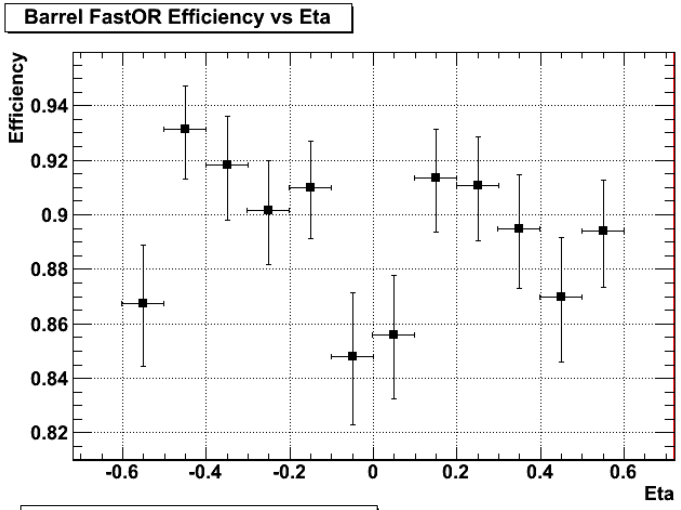
Used 500 GeV monopoles
(g = 1, q_{eff} = 68.5)
Flat KE distribution: 10-500 GeV

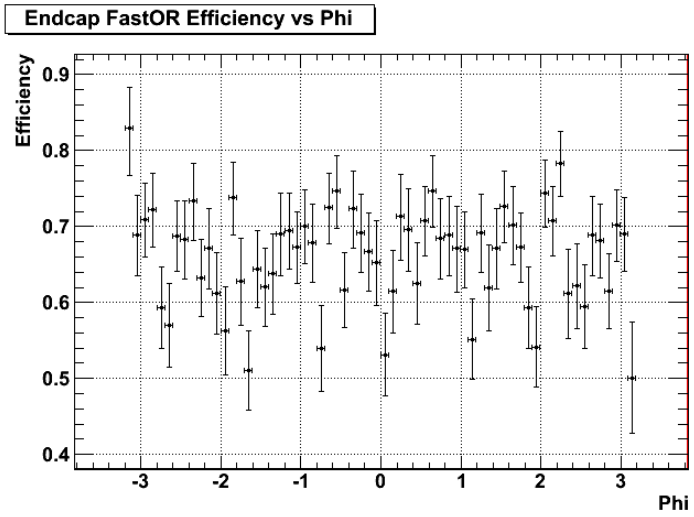
1 Trigger tower defined for EC

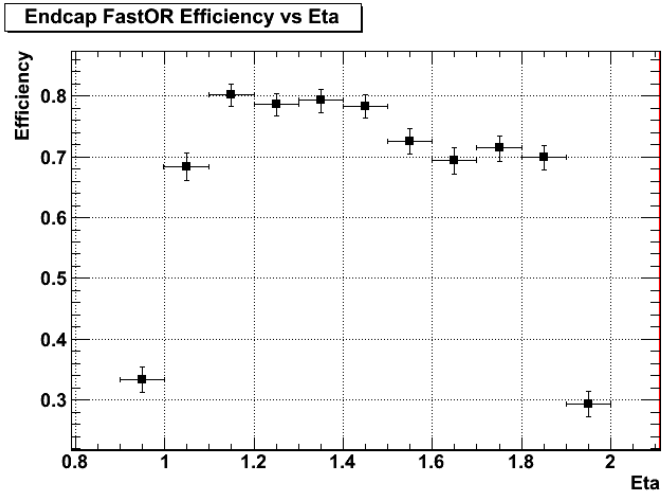
5/6 contiguous ≥ 2

Strawman FastOR Uniformity



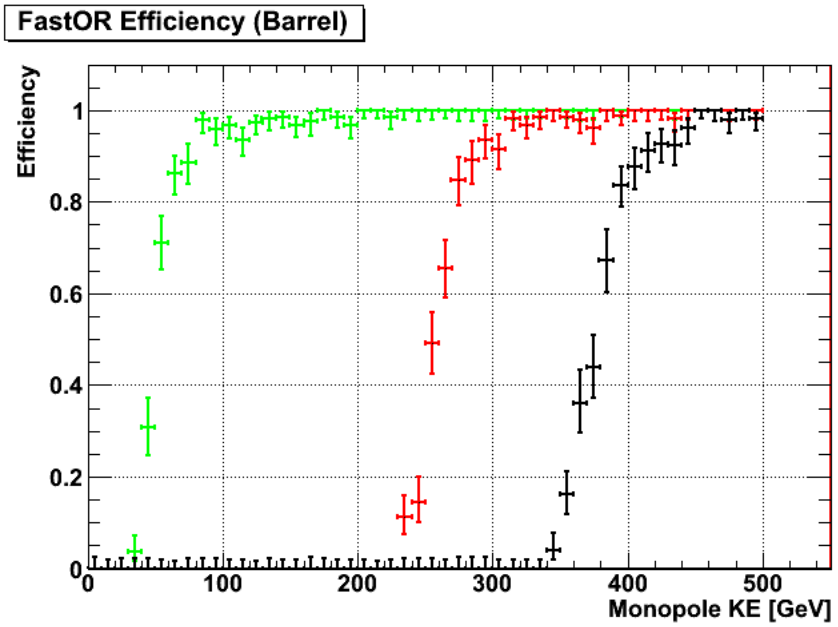


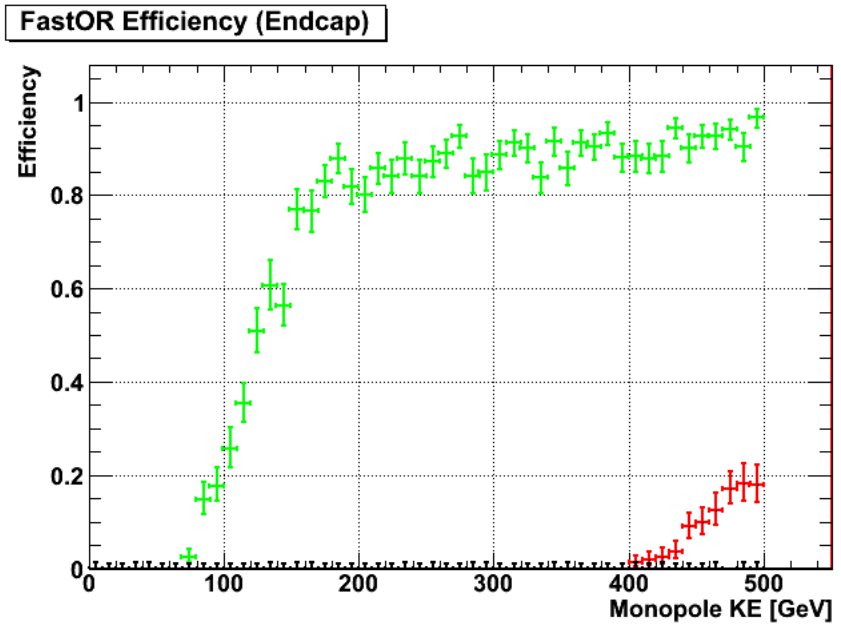


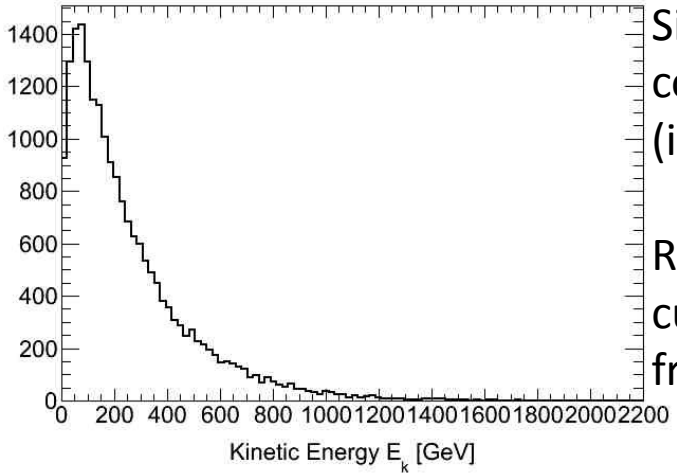


Already even with a very simple trigger setup, achieve high trigger efficiency vs both eta and phi

Strawman FastOR Efficiency







Significant sensitivity gains compared to L1EM_20 (idealized threshold for $L=10^{34}$)

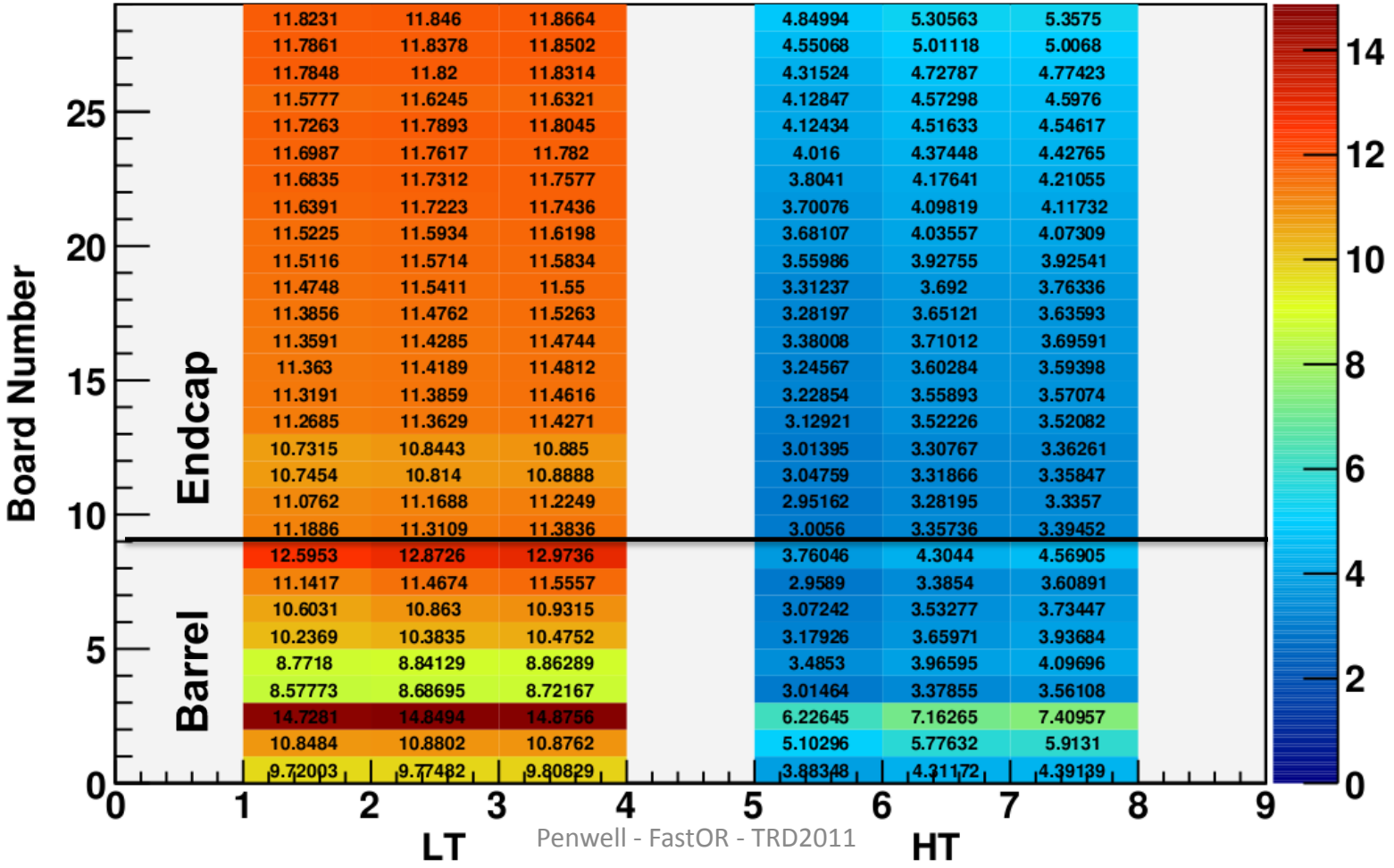
Remember Drell-Yan production curve. Exponential production rise from 300 GeV trig cutoff -> 50 GeV

Green	FastOR
Red	L1EM20
Black	L1EM40

Backgrounds

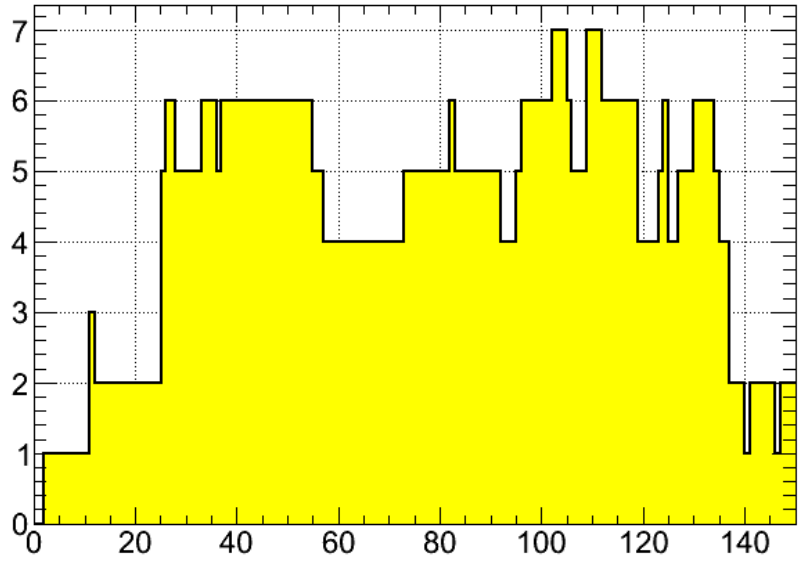
Minbias Simulation: Pythia 6 ND
Lumi 10^{34} -> 23 pileup events/BC
25 ns bunch spacing with +- 2 out of time bc

Average number of DTMROCs per front end board averaged over phi with a LT or HT signal present over the 3 25ns readout window blocks

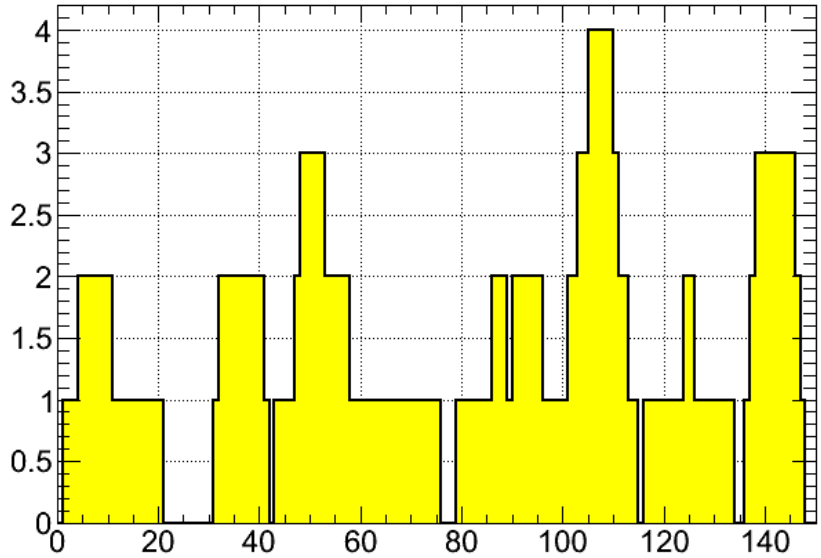


Backgrounds Part 2

HIP at 25ns



Noise only



#DTMROCs with HT hit vs Time [ns]

Simulation of HIP passing through TRT atop minbias background as stated in previous slide
Using a simple threshold of >2 DTMROCs active per frontend board over a time of 75 ns the background becomes negligible

Looking into the Future

Young and evolving project
- Still have more outstanding questions than answers
- However all initial studies have proved to be very positive and encouraging!

Also need to study the possibility of using a TRT L1 FastOR trigger to aid the L1 electron trigger during high luminosity running
- Central Trigger Processor only has a small and finite number of possible threshold settings. Need high L1EM threshold at start of run and can't pack in many dynamically prescaled lower thresholds
- To gain access to lower energy electrons as luminosity ramps down, have topological matching between L1EM and TRT FastOR

Project's current goal is to have design report by the beginning of 2012. Time schedule is tight, we would need to have the new PP2 TTC boards designed and built by 2013 to install and commission in the ATLAS cavern during the long shutdown.

The End?
No, Just the Beginning!

Many thanks to

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For their most excellent plots/pictures/diagrams that I've used in this talk