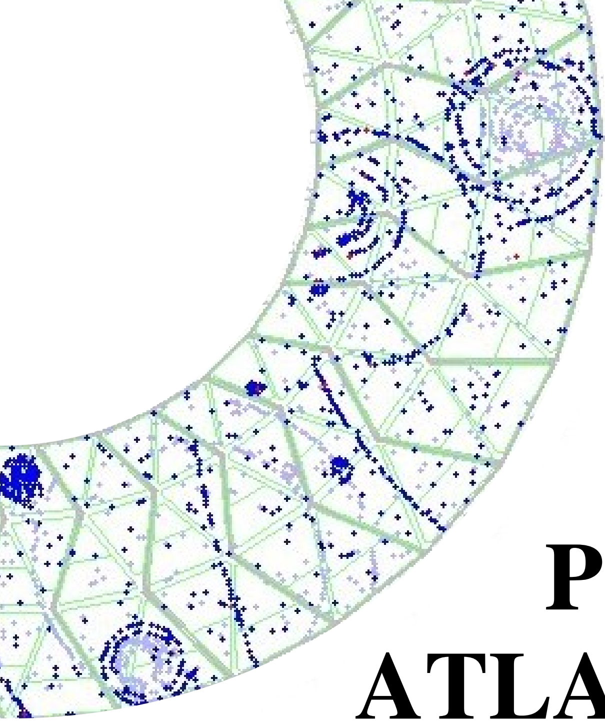
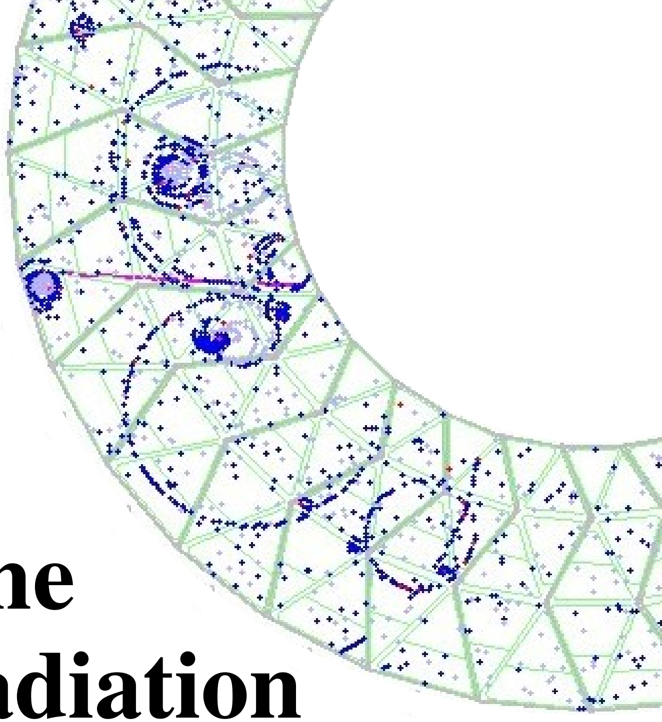




Performance of the ATLAS Transition Radiation Tracker Readout with High Energy Collisions at the LHC

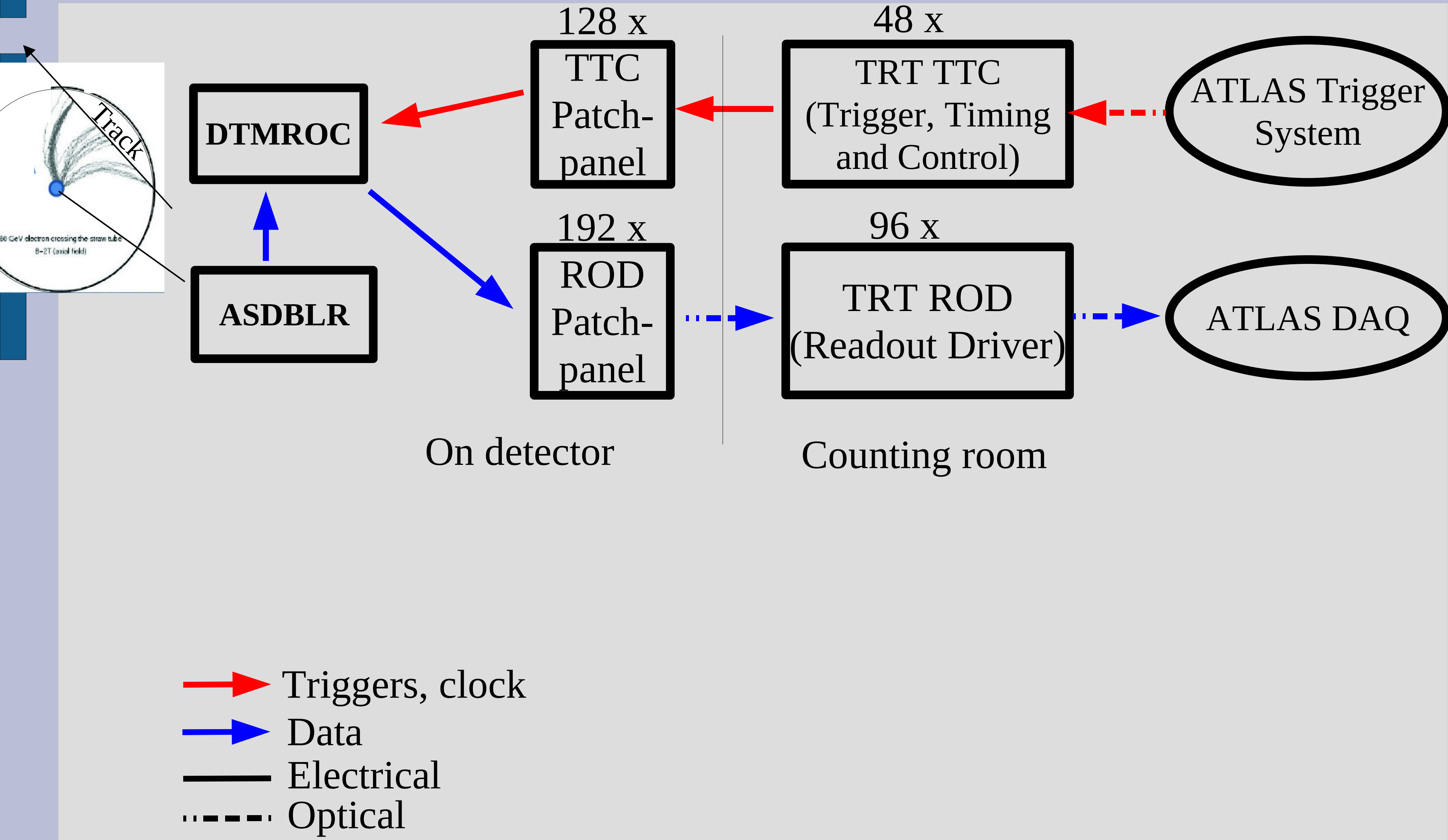
Peter Wagner
University of Pennsylvania

for the TRT Community

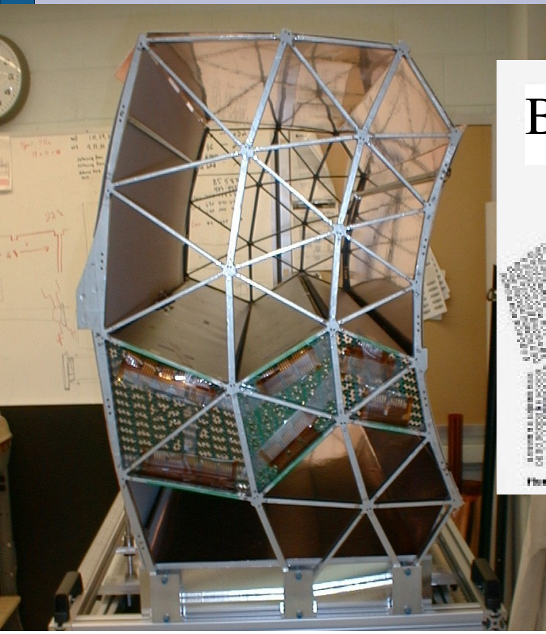
Outline

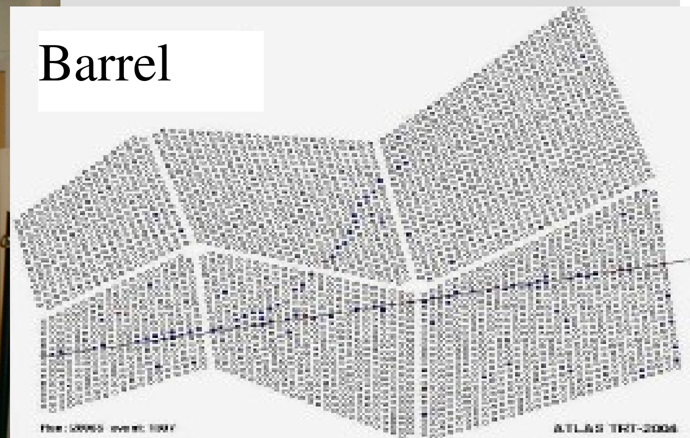
- ATLAS Inner Detector and Transition Radiation Tracker (TRT) – will skip this one (see Jahred's talk)
- TRT DAQ and Electronics – Overview
- From straw to recorded signal
- Front End Functionality and Calibrations
- TRT Fast-OR Trigger
- Resynchronization
- Data Compression
- Conclusion

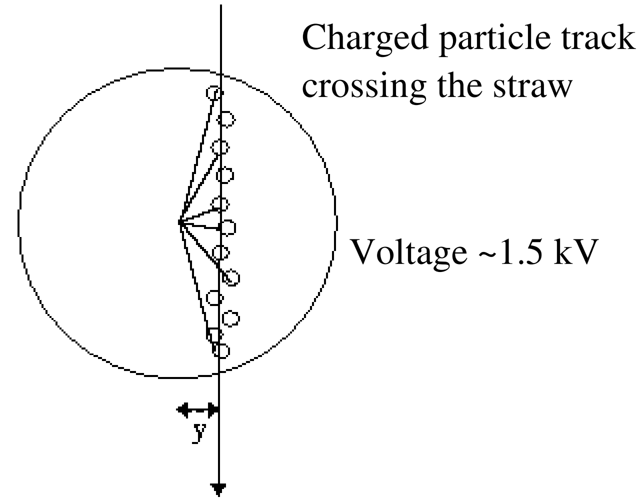
TRT Electronics – Overview

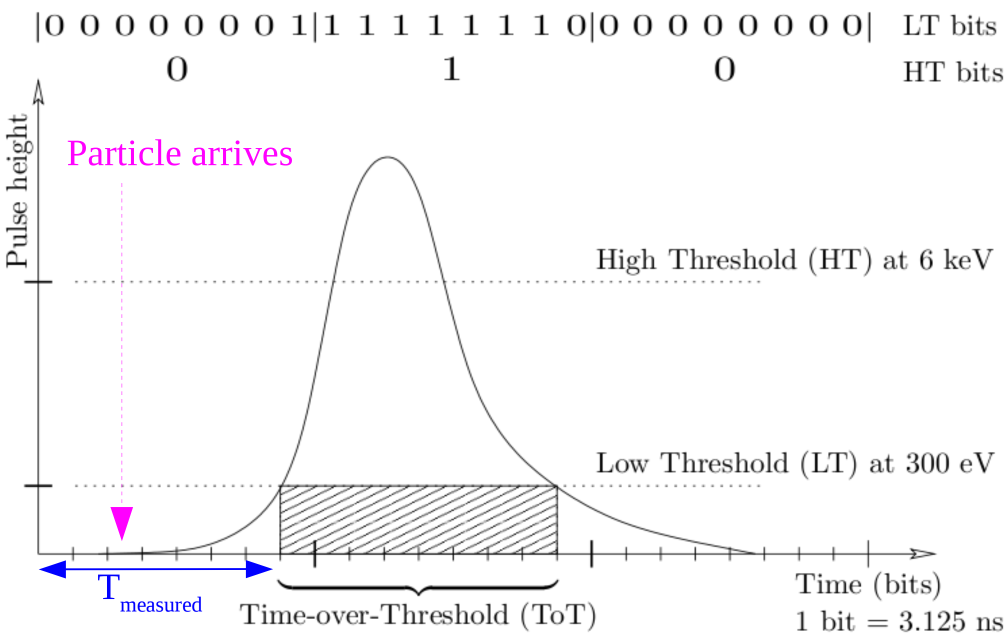


Straw Signal → Recorded Signal



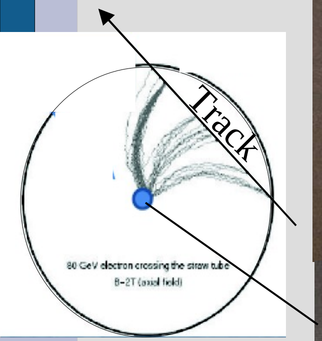




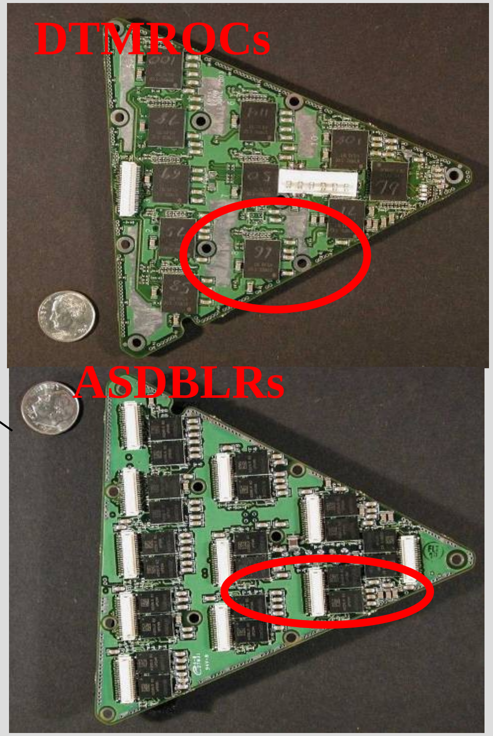


- Avalanche electrons drift to wire, create signal of ~ 2 keV (MIP) with max. drift time ~50ns =>
  - Apply tracking threshold (~ 300 eV) to discriminate from noise
  - Noise rate ~ 300 kHz
  - Readout window per trigger: 3 x LHC bunch crossings (25ns)
- Measurement of straw signal: 3.12ns time bins => 120um hit precision achievable
- Separate threshold for transition radiation at ~6 keV (=> dual readout scheme → later!)
- Store 1 TR bit per bunch crossing

TRT Electronics – Front End



8 straw channels per ASDBLR



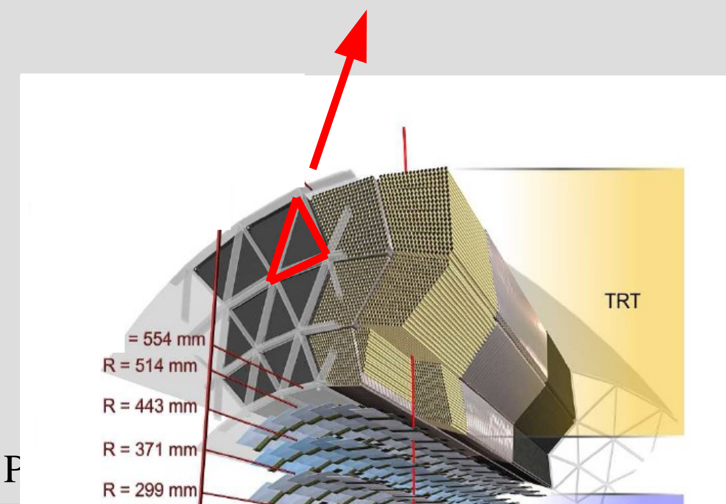
“DTMROC”: “Drift Time Measurement Readout Chip”

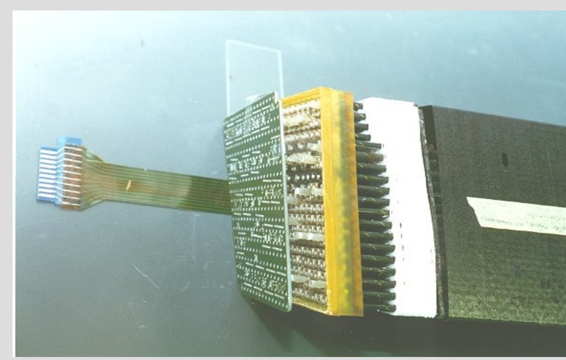
Digital

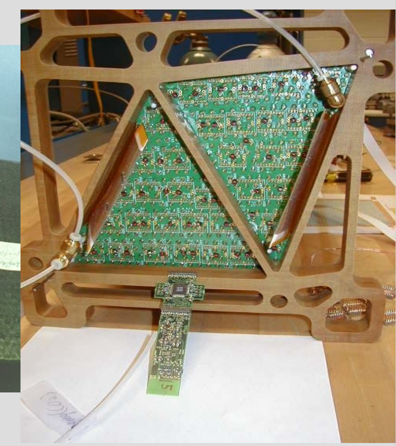
Consists of two parts mounted back to back

Analog

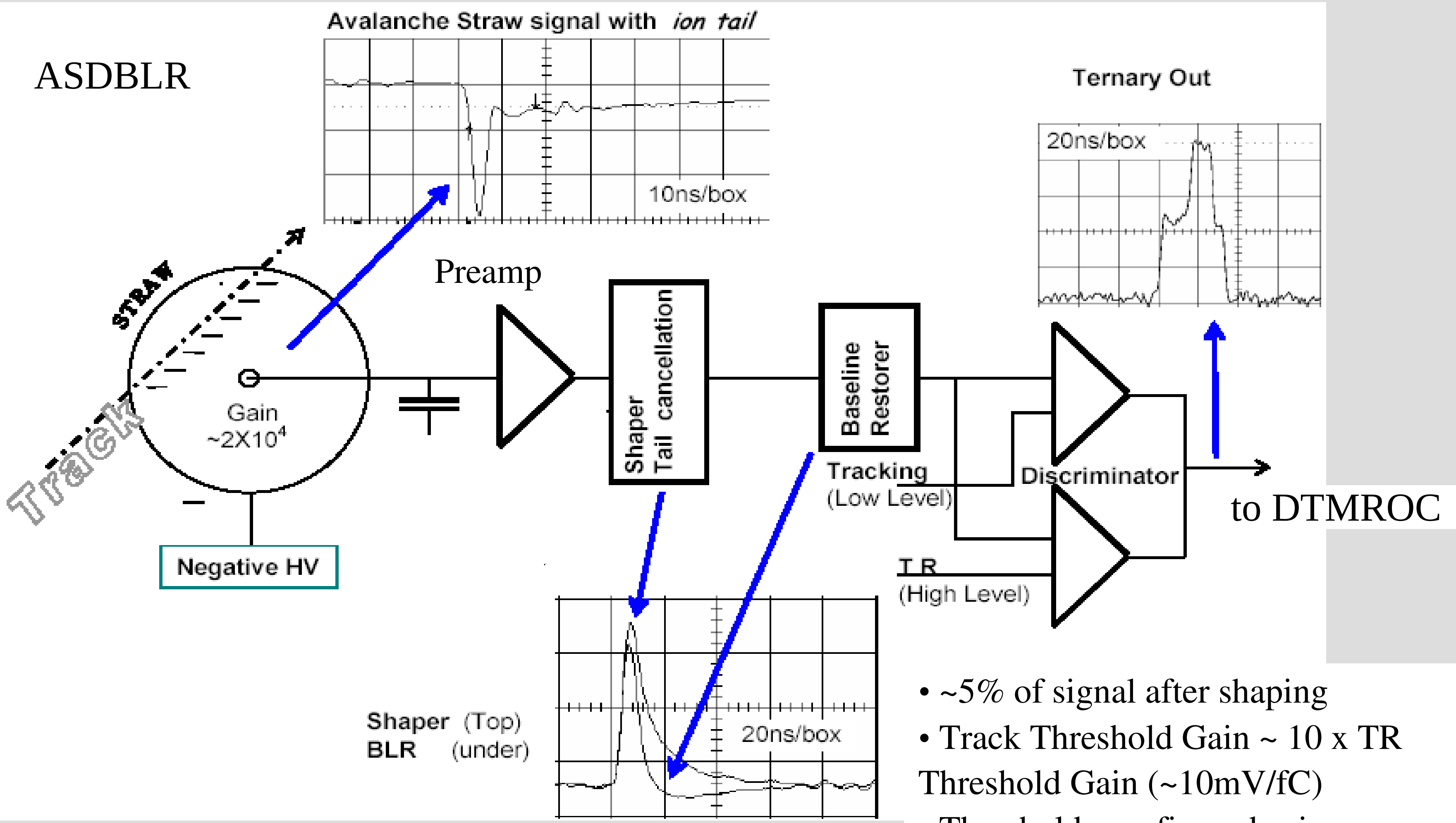
“ASDBLR”:
“Amplifier Shaper Discriminator Baseline Restorer”





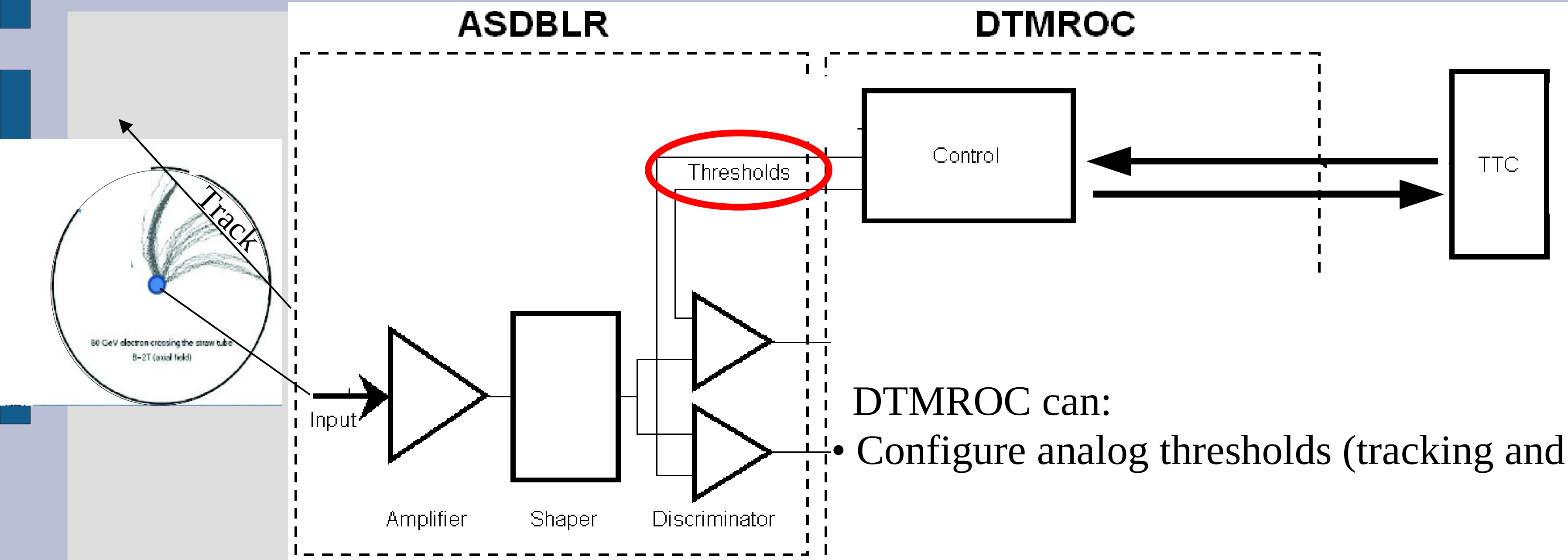


TRT Front End – Signal shaping



- ~5% of signal after shaping
- Track Threshold Gain ~ 10 x TR Threshold Gain (~10mV/fC)
- Thresholds configured using Digital-Analog Converters on DTMROC, ~30mV stepping

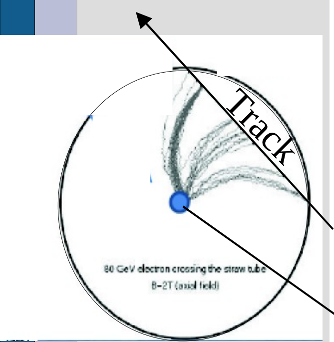
TRT Electronics – Functionality

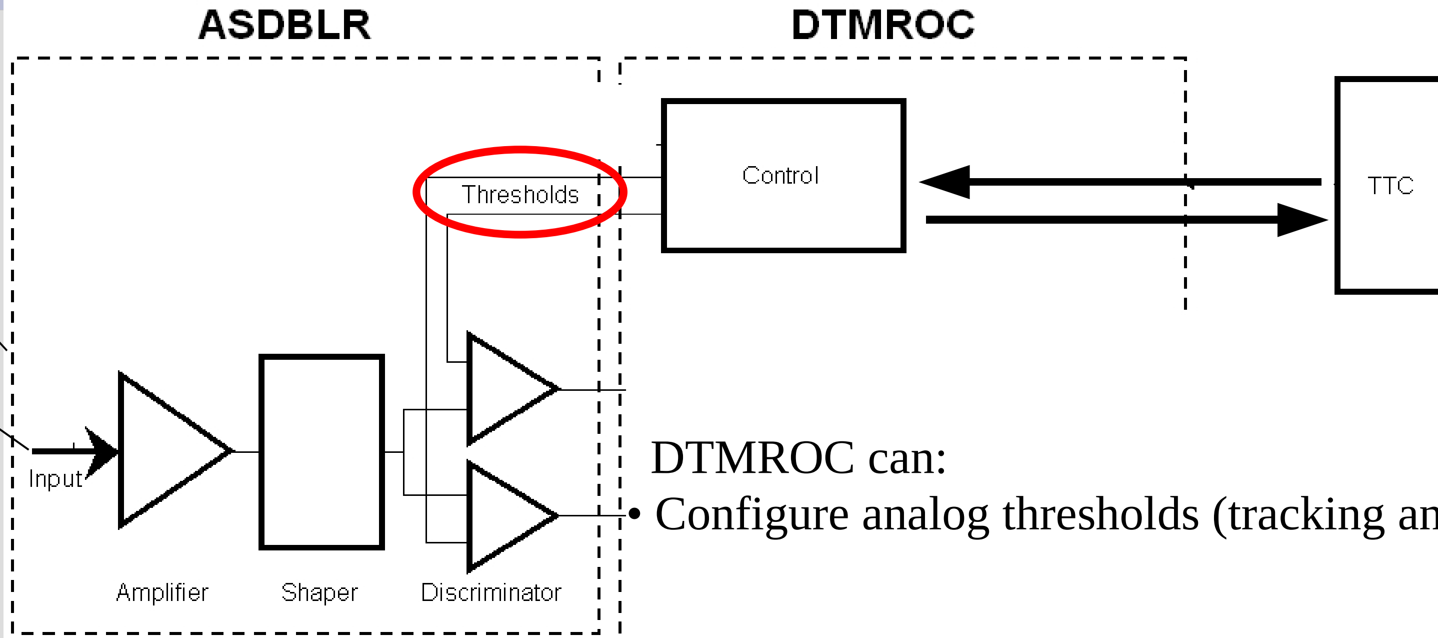


DTMROC can:

- Configure analog thresholds (tracking and TR)

TRT Electronics – Functionality





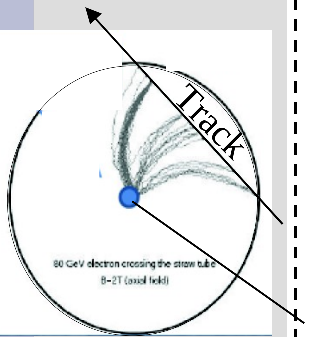
DTMROC can:

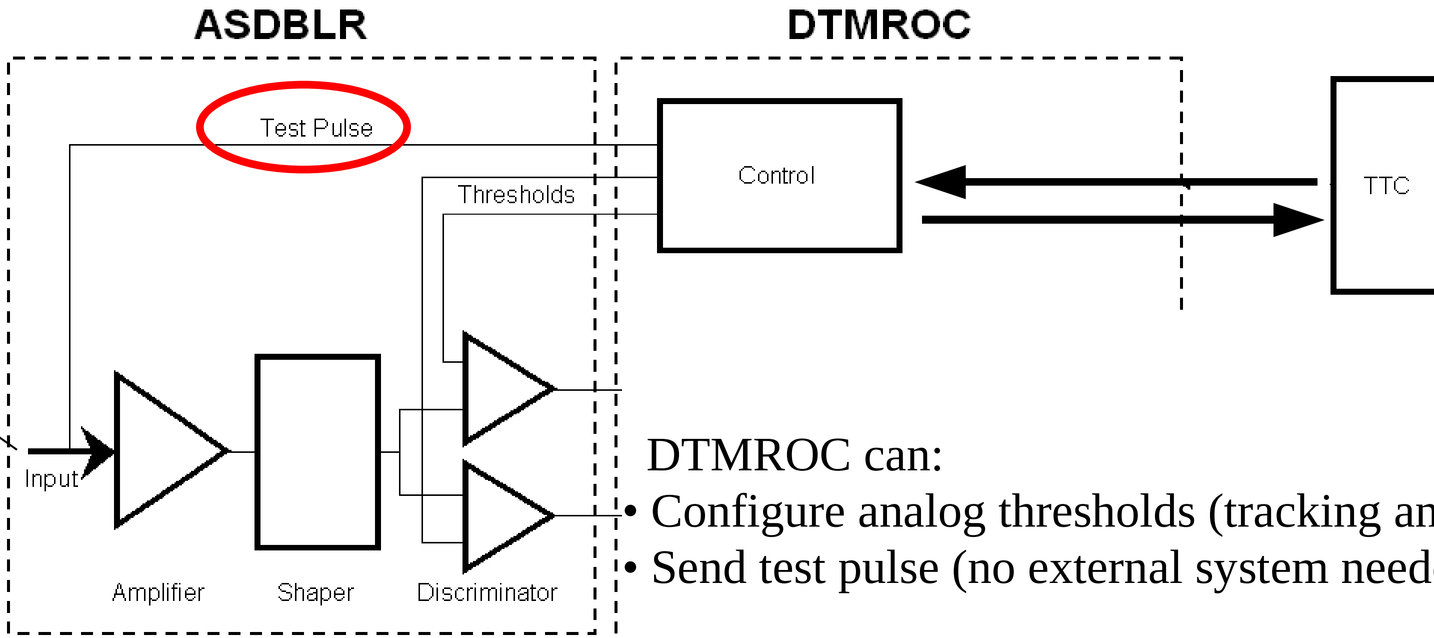
- Configure analog thresholds (tracking and TR)

In practice:

- Ensure uniform tracking hit efficiency by calibrating tracking thresholds to constant noise occupancy (300 kHz)
- Method:
  - Take noise data, measure occupancy
  - Correct deviations from 300kHz using fits to occupancy vs. threshold curves
  - Iterate...
- Duration ~ 10 minutes. Done after any system intervention as final check.

TRT Electronics – Functionality

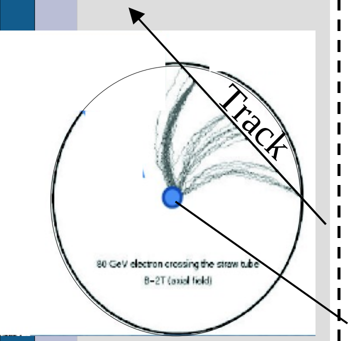


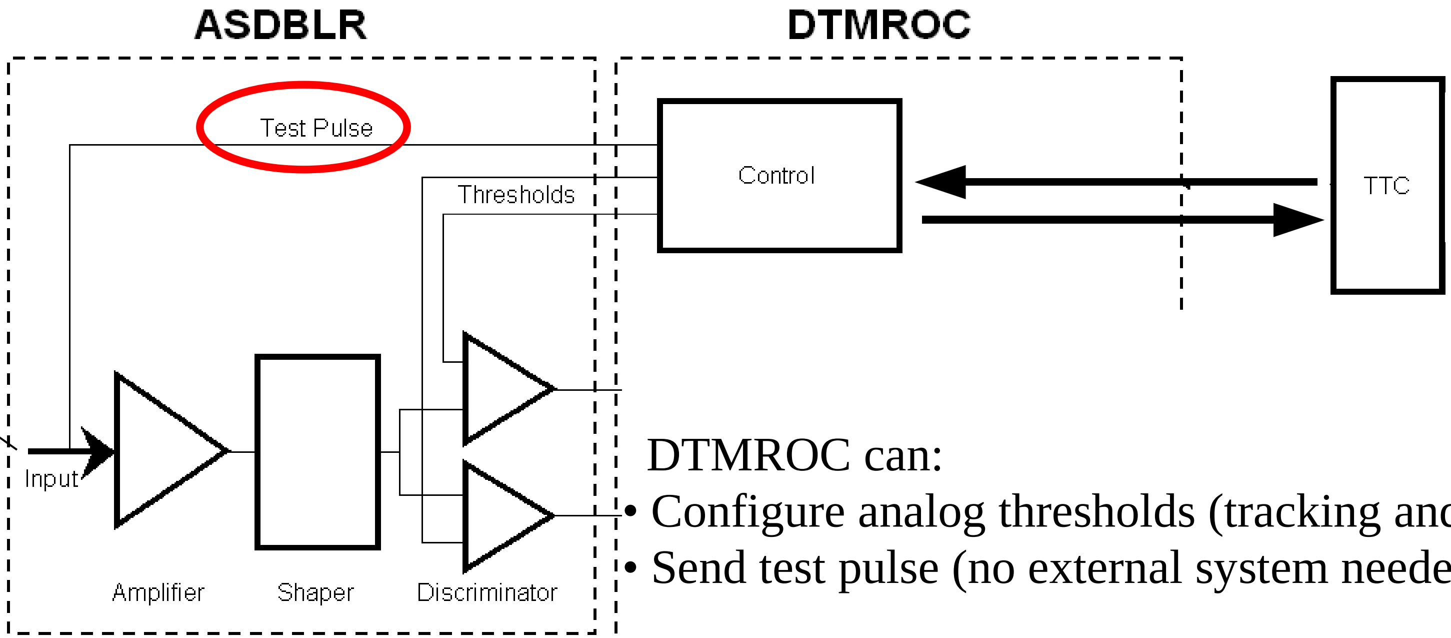


DTMROC can:

- Configure analog thresholds (tracking and TR)
- Send test pulse (no external system needed!)

TRT Electronics – Functionality





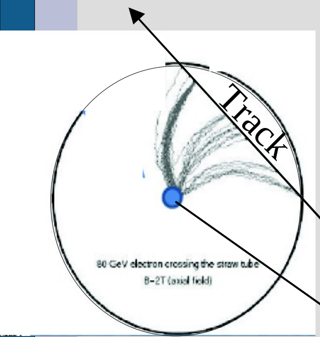
DTMROC can:

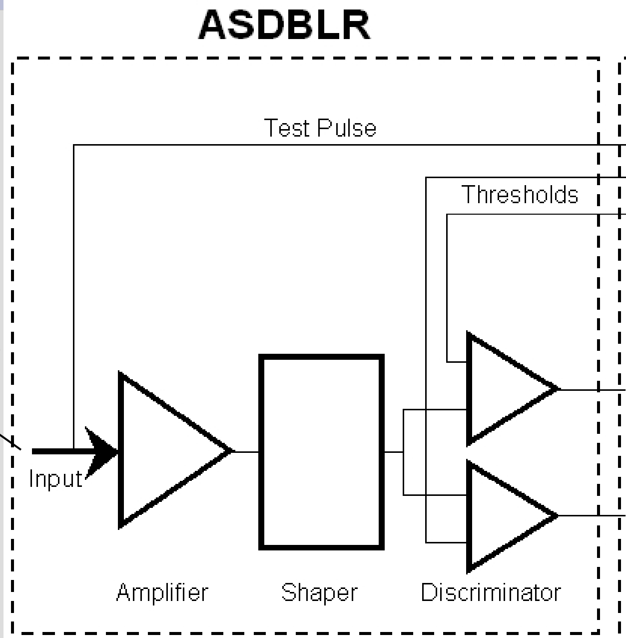
- Configure analog thresholds (tracking and TR)
- Send test pulse (no external system needed!)

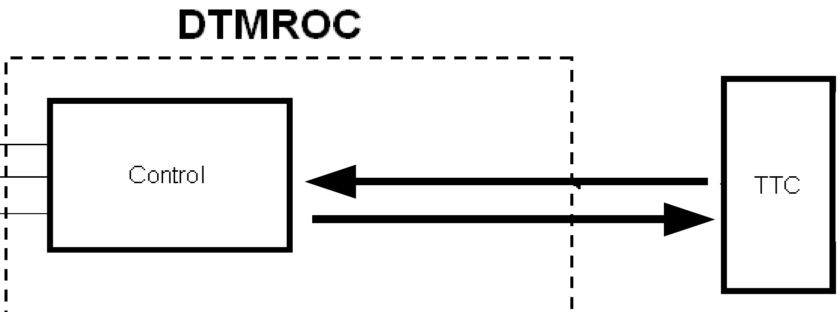
In practice:

- Radiation damage affects gain of ASDBLR
- Use test pulse with known amplitude to measure amount of radiation damage over time

TRT Electronics – Functionality







DTMROC can:

- Configure analog thresholds (tracking and TR)
- Send test pulse (no external system needed!)
- Transmit data to TTC during data taking

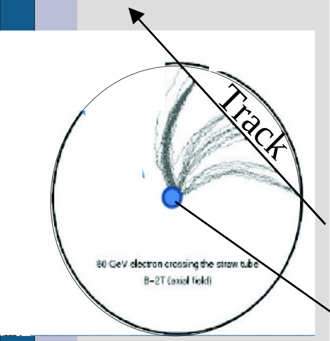
Minimize impact from radiation damage ("Single Event Upsets"):

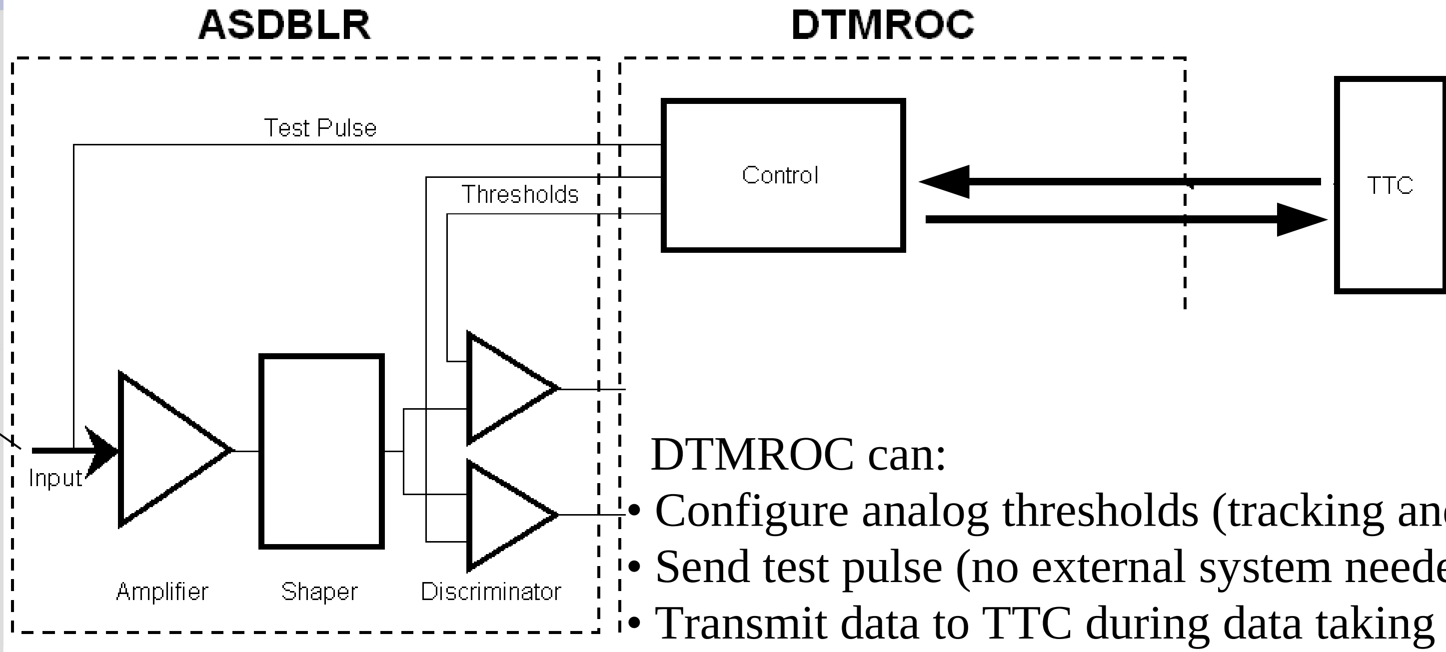
- Expected SEU rate in full system ~Hz at design luminosity
- Key DTMROC registers triplicated

→ During data taking:

- All registers monitored during and rewritten in case of change
- stored in database for further evaluation

TRT Electronics – Functionality





DTMROC can:
- Configure analog thresholds (tracking and TR)
- Send test pulse (no external system needed!)
- Transmit data to TTC during data taking
- Measure chip supply voltages

- Analog and digital boards powered separately
- Grounded differently

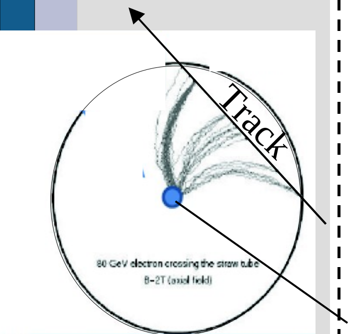
=> Tracking and TR thresholds sensitive to low voltage setting!

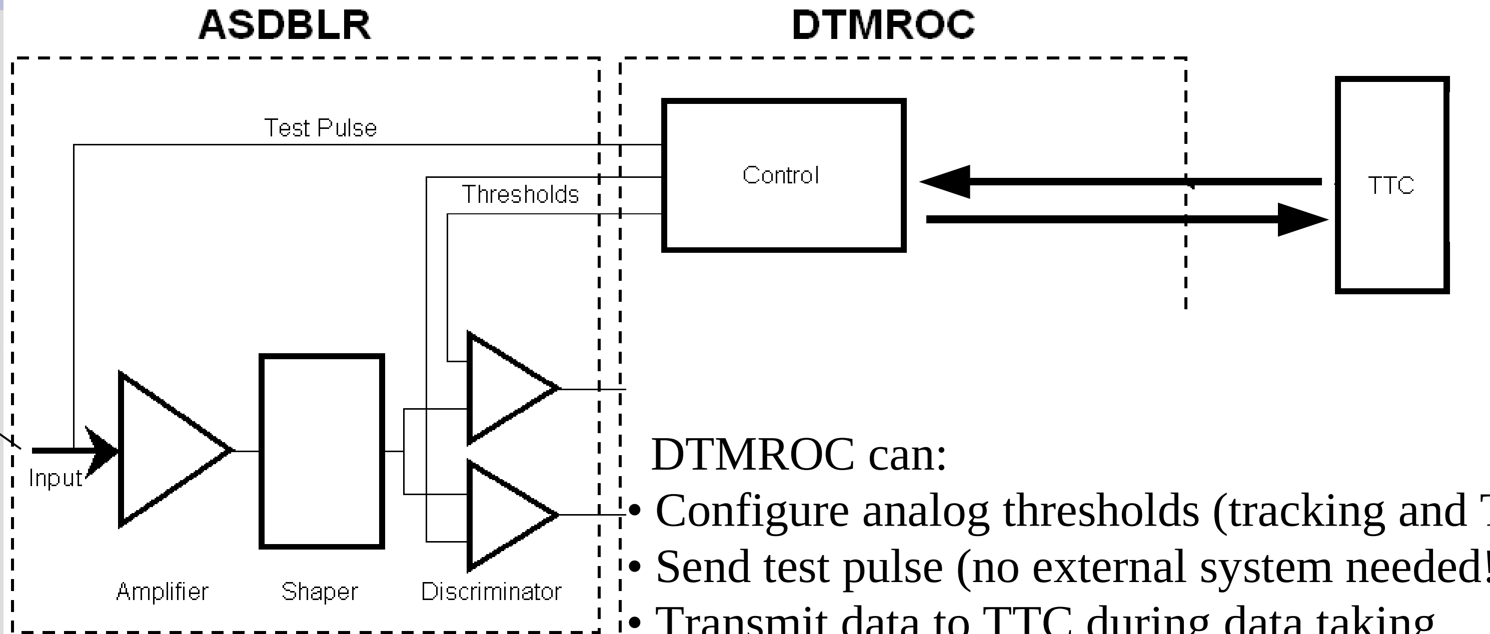
→ Voltages continuously monitored

→ Developed tools to investigate possible problems

→ can easily modify voltage settings if necessary

TRT Electronics – Functionality





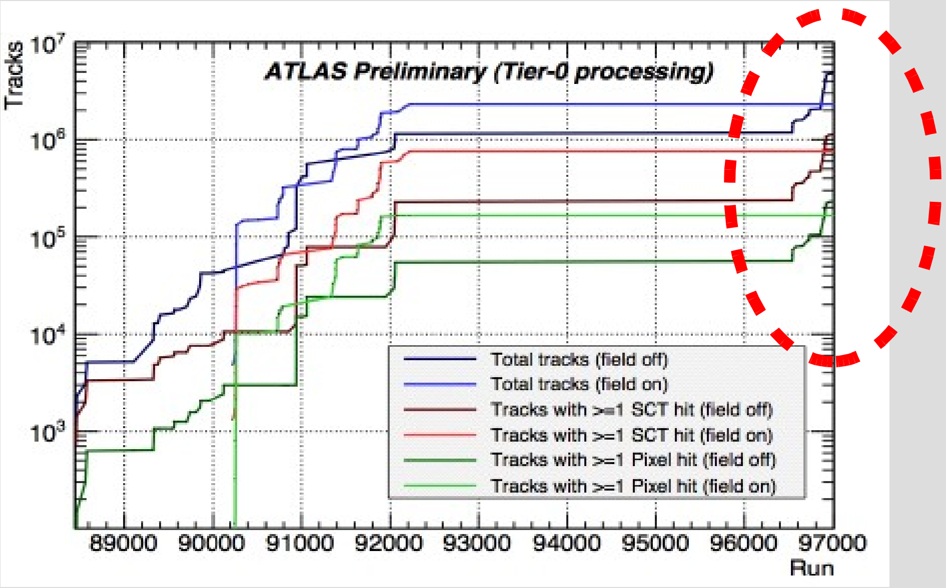
DTMROC can:

- Configure analog thresholds (tracking and TR)
- Send test pulse (no external system needed!)
- Transmit data to TTC during data taking
- Measure chip supply voltages
- Send trigger signal (“Fast-OR”) to TTC

  → next slide!

The TRT Fast-OR Cosmics Trigger

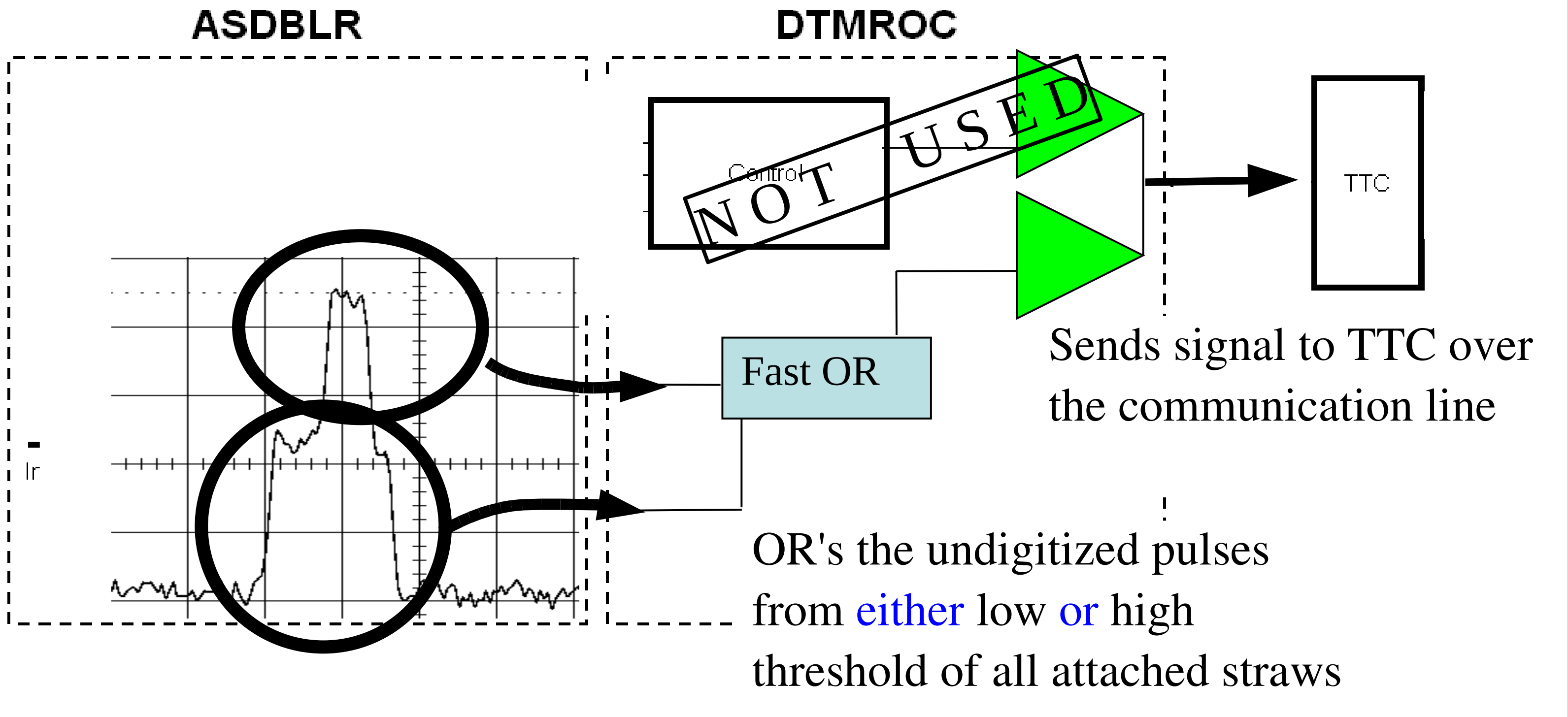
- After Sept. 2008 LHC incident → decision to finalize the trigger for cosmics data
- Motivation:
  - High good-track rate
  - High track rate in the end-cap region
  - Independence from other subsystems



Statistics doubled within a week!

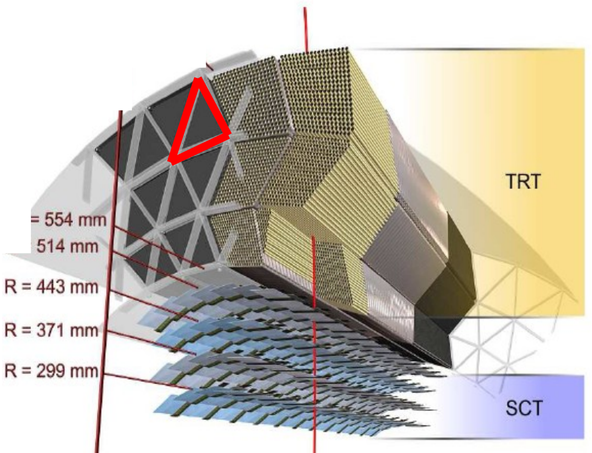
- Implementation was quick:
  First tracks Oct 29th 2008
  Timing-in completed May 2009

TRT Electronics – Fast-OR Trigger



Pulse at TTC board: "OR" of ~240 attached straws

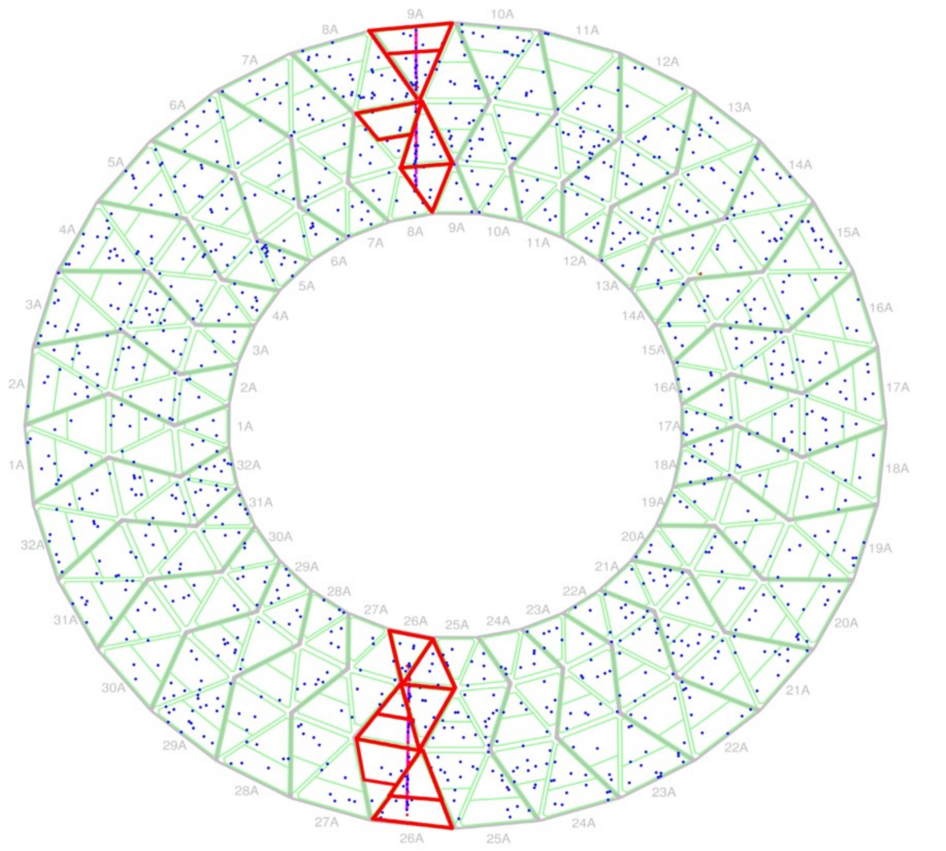
→ OK for cosmics but too coarse for collisions
→ see J. Penwell's talk



Fast-OR Trigger – Implementation

Implementation: Use DTMROC high thresholds lowered to ~MIP levels in TRT barrel

- ~a third of all straws that the track crosses have hits
- Advantage: very low noise
- Minor disadvantages:
  - makes high threshold calibration difficult due to thresholds at MIP level
  - no configuration data transmission from front end possible (no SEU monitoring)

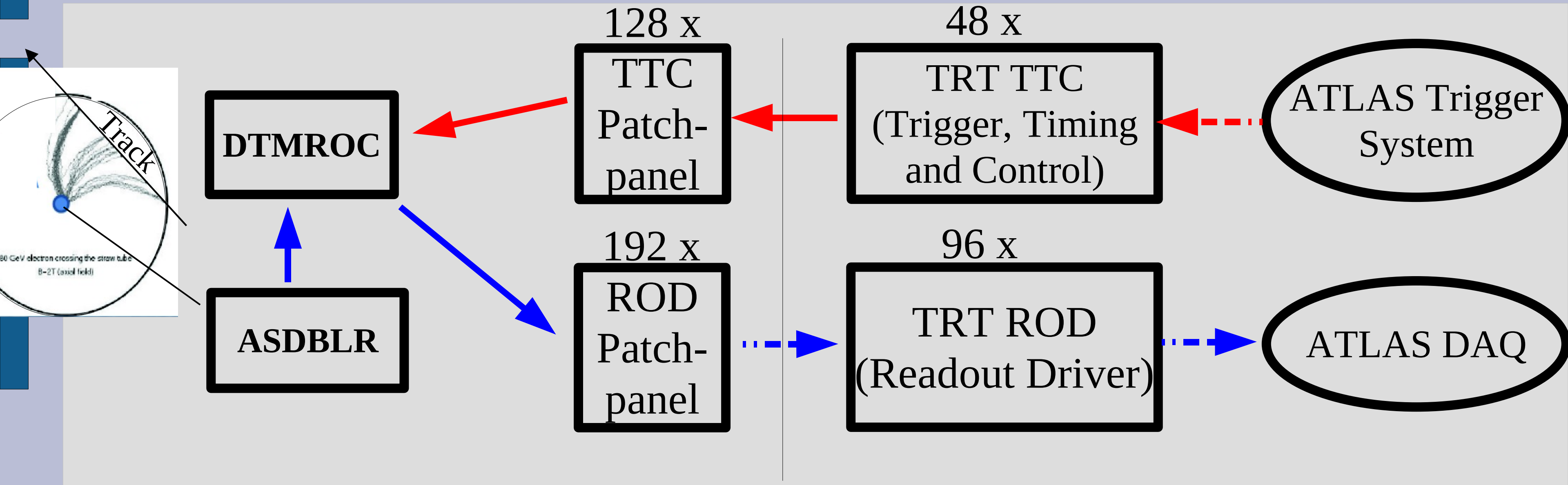


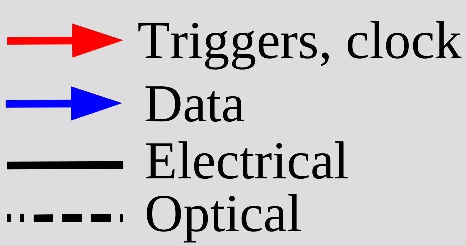
Fast-OR Trigger – Results

- Very good trigger timing jitter of > 90% of triggers within 1 clock cycle
- Trigger rate ~10Hz with a high purity of ~98% events with tracks

- A major player in ATLAS commissioning!
  - Reference trigger for timing-in of other ATLAS triggers
  - Helped improve RPC timing jitter
  - Helped SCT and Pixel readout timing
  - Used for TRT first pass TR threshold calibration

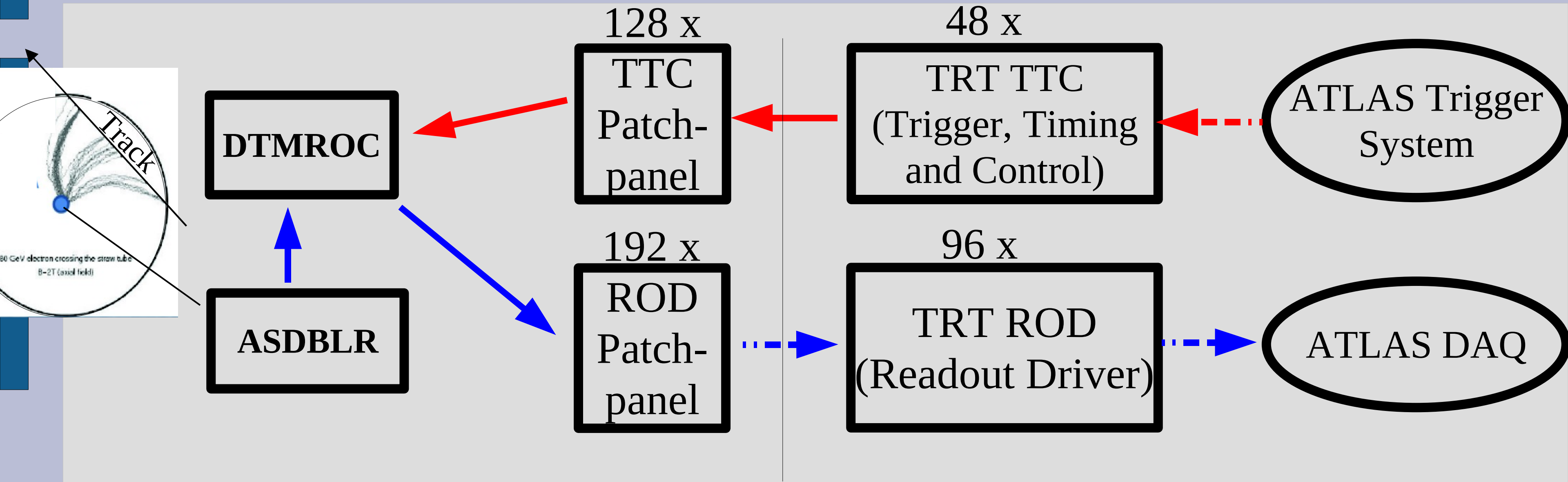
TRT Electronics – Resynchronization



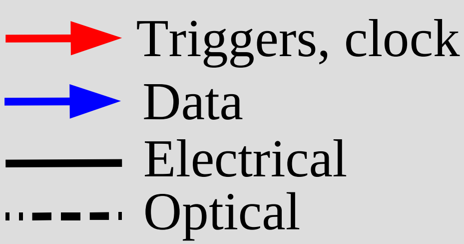


- Lots of "QPLL"s (Quartz PLLs – clock stabilizer) in the system
  => sensitive to changes in the LHC clock, e.g. during injection ramping
- If any unlocked then data loss
  => implemented QPLL monitoring and automatic resynchronization (= force QPLL re-lock) during data-taking
- Time needed: ~10 sec (during the injection ramp)

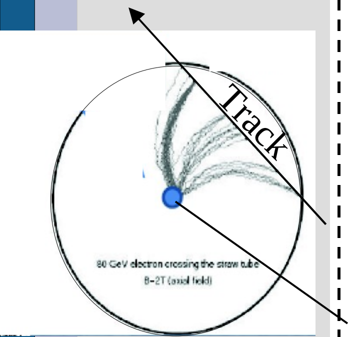
TRT Electronics – Resynchronization

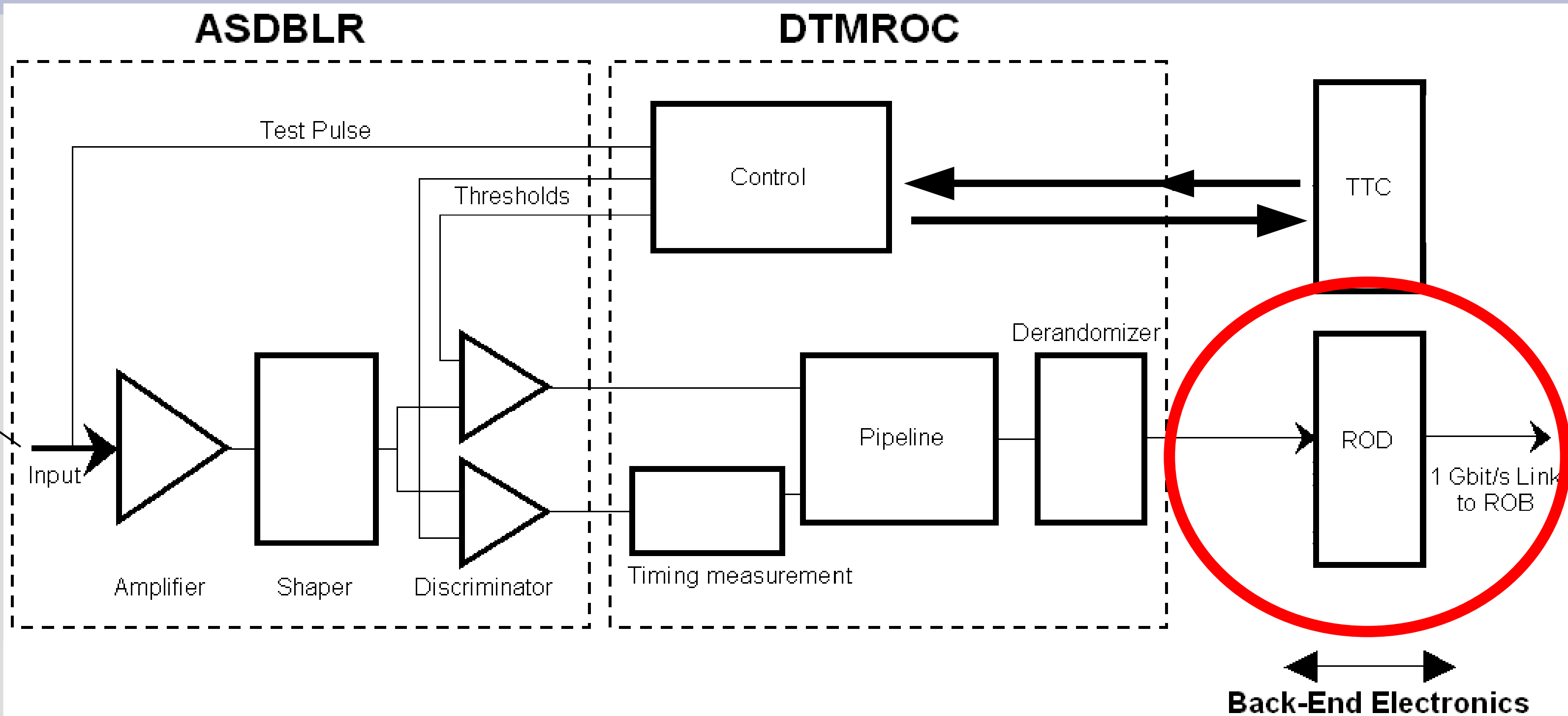


- Further: Use same software framework to monitor for hardware failures and synchronization with rest of ATLAS during regular data-taking
  - Offending electronics part (TTC/ROD/...) is disabled without stopping data-taking run
  - Failures corrected "on the fly" by reconfiguring offending part
  - Total turnaround time ~10-30s
- Maximizes data taking efficiency
- Used **very** rarely



TRT Electronics – Data Compression





- Nominal TRT event size too big for ROD (at trigger rates > 20 kHz)
- Use Huffman encoding algorithm on ROD for lossless data compression
    - Basically: convert the most frequent bit patterns in straw data (simplest example: series of 0s) to short patterns using a lookup table
    - Compression factor ~ 10 (very approximate)
- Can deal with high occupancy events as we had in heavy ion running

Conclusion

- Very successful commissioning phase
- Fast-OR trigger played major role in ATLAS commissioning
- Automated procedures to maximize data taking efficiency
- Good quality data for 100% of LHC stable beam periods 2009-2011: highest in ATLAS

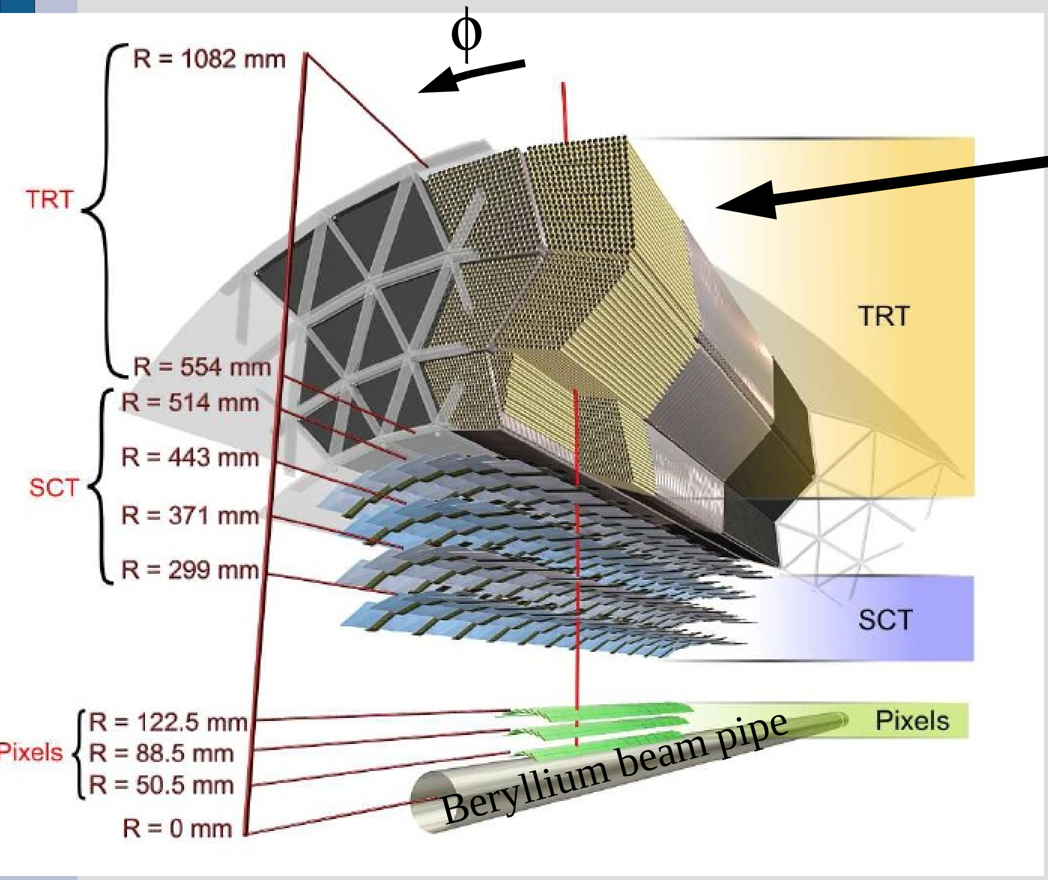
Inner Tracking Detectors			Calorimeters				Muon Detectors			
Pixel	SCT	TRT	LAr EM	LAr HAD	LAr FWD	Tile	MDT	RPC	TGC	CSC
97.7	96.4	100	94.4	98.7	99.3	99.2	98.5	98.3	98.6	98.3

Luminosity weighted relative detector uptime and good quality data delivery during 2010 stable beams at √s=7 TeV between March 30th and August 14th (in %)

Thanks to all the TRT community for their hard work!!

Backup

The ATLAS Transition Radiation Tracker



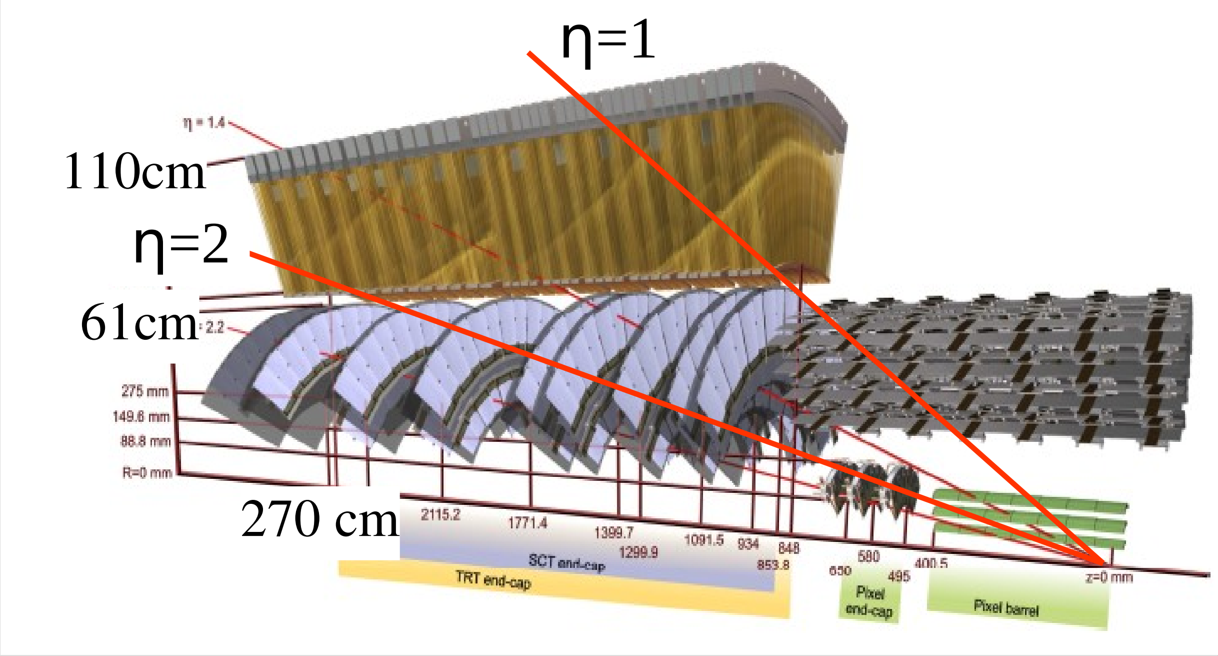
TRT barrel

- 3 * 32 modules
- 1.44 m straws parallel to beam axis
- wires electrically split in the middle to reduce occupancy (~1.5cm dead region)
- each end read out separately
- 105088 readout channels total
- 2 triangular front end boards per module

The ATLAS Transition Radiation Tracker

2 TRT end-caps, each with

- 20 “wheels” with 8 layers of straws each
- 39cm long radial straws
- 122880 readout channels



Occupancy and Rate

- Optimal tracking threshold configuration at ~2% noise occupancy
- Track occupancy per straw: ~3% at instant. pp luminosity 10^{31} $cm^{-2}s^{-1}$
- Expect occupancy of ~30-40% at LHC pp design lumi 10^{34} $cm^{-2}s^{-1}$
- (Max. track rate per straw: ~20MHz – due to ~50ns drift time)

- TRT performed well in occupancies of up to ~90% at moderate trigger rate (~few 100 Hz) during heavy ion running due to lossless data compression