Test beam studies of the TRD prototype filled with different gas mixtures based on Xe, Kr, and Ar

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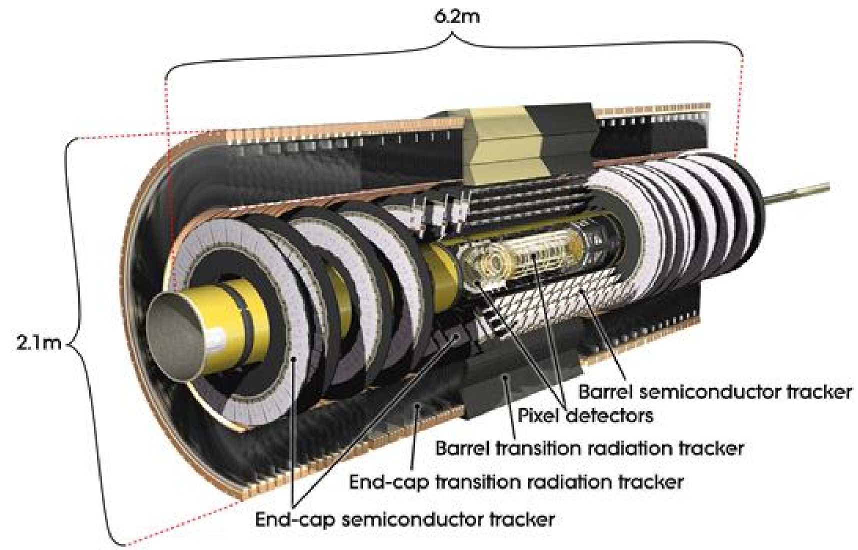
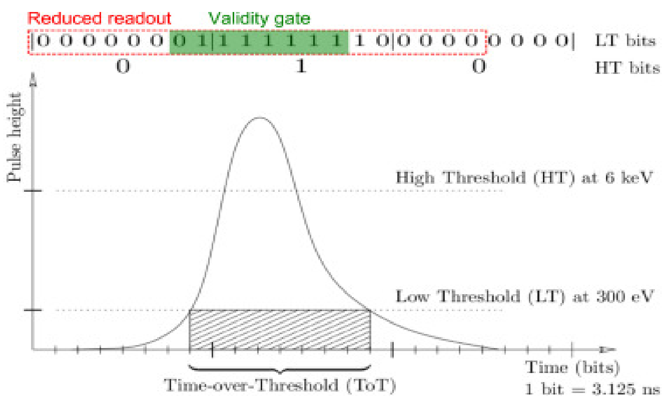
Outline

- Transition Radiation Tracker (TRT)
- Transition Radiation and Highlevel Hit probability
- Gas Leak Issue
- TRT Test Beam 2015 Setup
- Analysis of the Test Beam Data
- Conclusion

Transition Radiation Tracker(TRT)

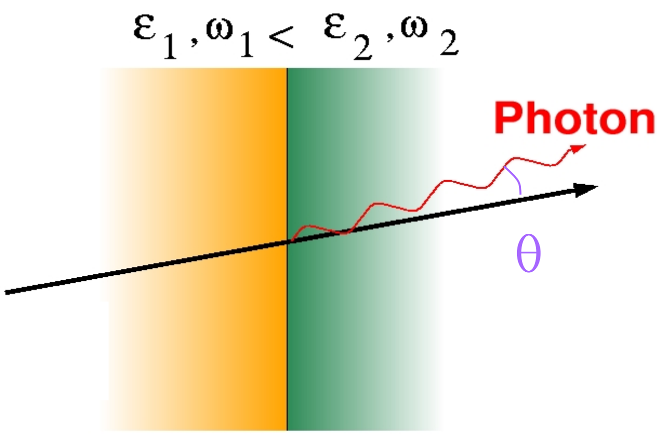
- TRT is the outermost part of the Inner detector. It is a gaseous ionization detector consists of ~300000 small diameter proportional counters called straws.
- TRT has ~130 μm drift radius resolution but it doesn't provide position measurement along each the drift tube.
- Most often a charged particle track would have about 30 TRT hits.
- Along with the tracking ability ,TRT helps particle identification by measuring transition radiation(TR).
- TR measurement done by comparing the input signal with a high threshold (HT) value.





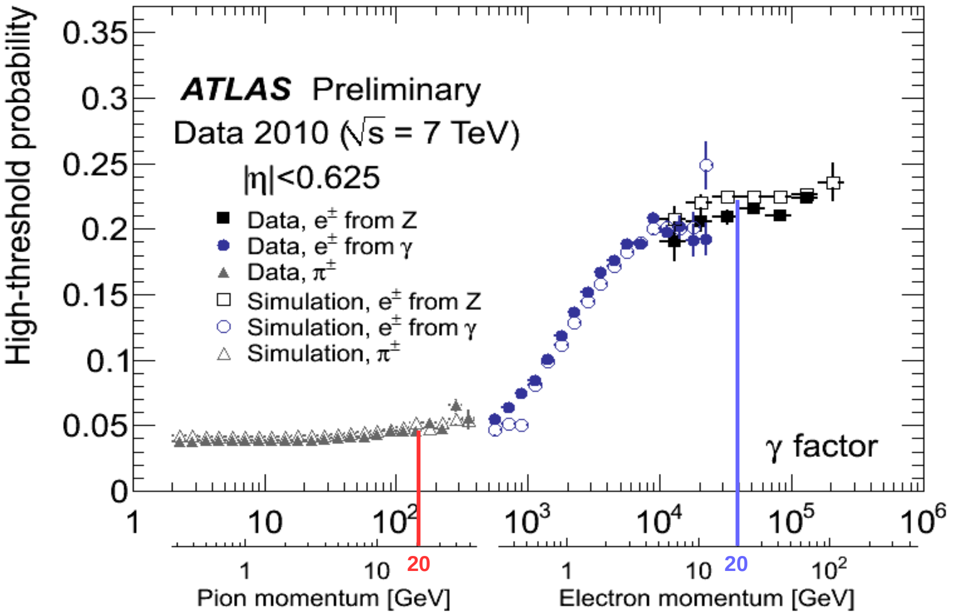
Transition Radiation

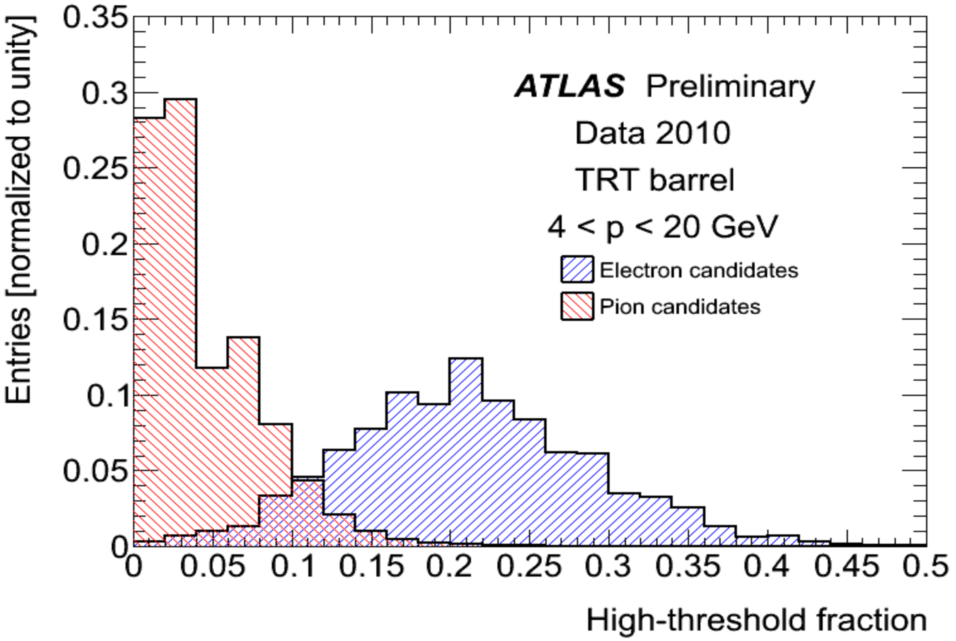
- When a charged particle passes through the boundary between two materials with different dielectric constants transition radiation(TR) can occur
- At highly relativistic speeds this can emerge as soft X-ray photons.
- The TR spectrum hardens with the increasing Lorentz factor and the angle θ is proportional to inverse of the Lorentz factor.
- To increase probability of Transition radiation, structures with many transition surfaces like many layered foils,foams,fibers can be used.



High Level Hit probability

- As shown in the the high level hit probability changes with the Lorentz factor of the particle as show in the upper figure on the right.
- The HT probability can help to distinguish pions and electrons in the momentum range 1-200 GeV.
- A particle track will have ~30 TRT measurements. Therefore the HL to LL ratio on track will correlate with HL probability.

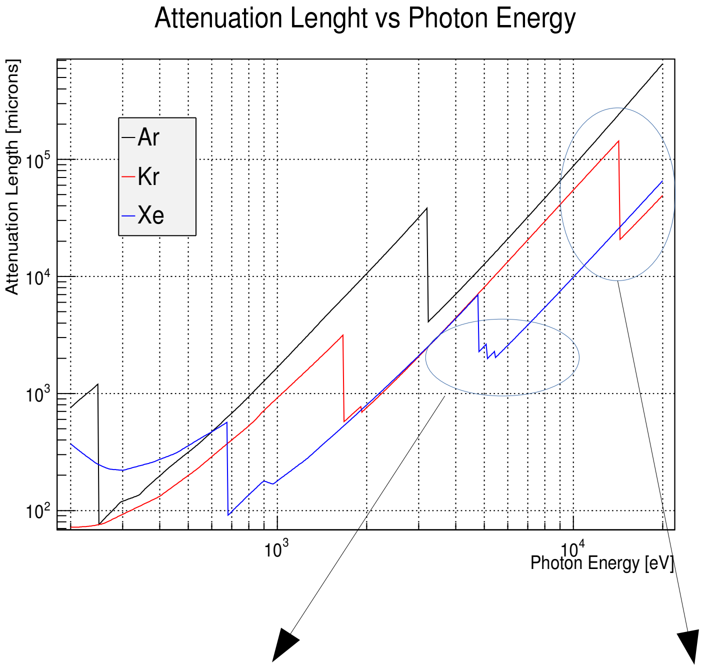




Gas Leak Issue

- TRT used a Xenon based (Xe/CO2/O2 : 70/27/3) gas mixture in LHC Run 1. Due to some unforeseeable effects cracks developed in the gas pipes and some of the damage was impossible to repair.
- This leads to a big Xe losses which is very expensive gas. Alternative gas mixtures are considered to be used if they can preserve particle identification properties of the TRT.
- In LHC Run 2, gas mixture changed to Argon based one in critically effected parts.
- This affected the HL probability since Argon TR capture efficiency is significantly lower.

Motivation for Krypton based Gas Mixture

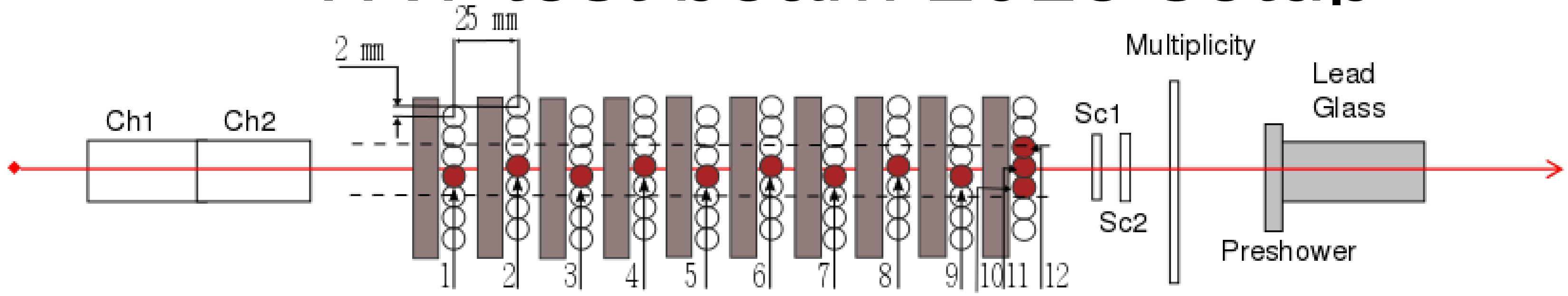


Xenon L shell edge

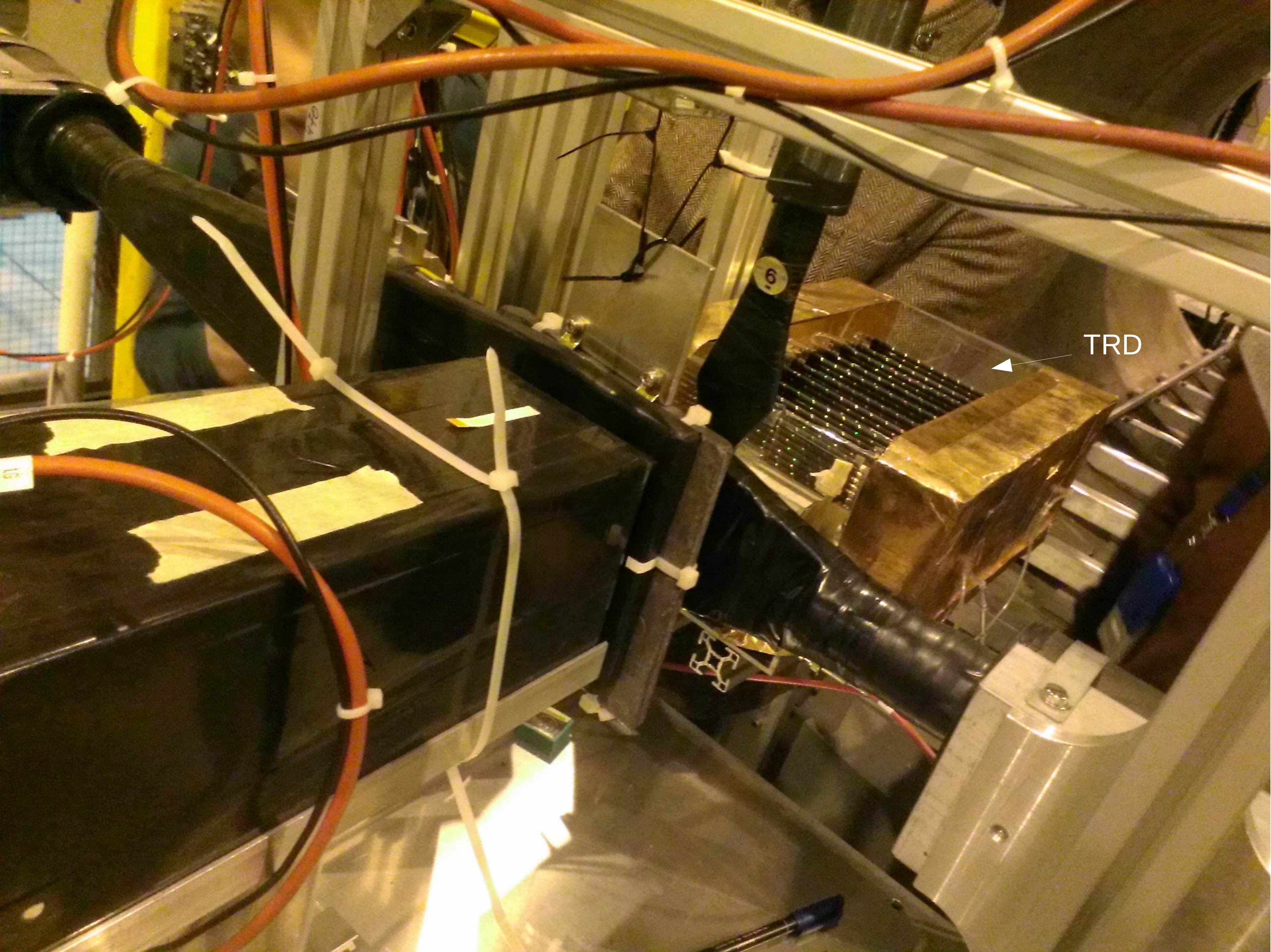
Krypton K shell edge (~14 keV)

- TR spectrum is roughly 4 keV to 20 keV.
- Photons more likely to interact with the gas atoms if the absorption length for the gas is short.
- The comparison of absorption lengths for Xenon, Argon and Krypton are given in the figure.
- It is seen that around 5 keV for Xenon, absorption length is smaller than others and the Krypton is in between Xenon and Argon.
- Around 14 keV Krypton photon absorption cross section is higher than Xenon.
- For a ~14 keV photon upon interaction with the Krypton atom there is a %65 probability that atom will emit a escape photon with 12 keV energy.
- Yet there is ~ 2 keV energy left in the straw and with the dE/dx energy combined they can have contribution to energy range where TR expected.
- As a result the Krypton mixture (after threshold optimization) might be a good candidate for Particle Identification purposes

TRT test beam 2015 setup



- TRT test beam 2015 that was held at CERN (SPS north area H8) during 26 th May-1 st June.
- The aim of this effort was to understand the TR photon capture performance of the Krypton based gas mixture.
- To this extend we used a transition radiation detector (TRD) made out of TRT straws and we used radiators like the ones used in TRT.
- In the figure circles represents straws and the rectangles represents radiator placement.
- Sc1 and Sc2 used for triggering in the data taking. Their coincidence was used as trigger condition. Their size was roughly the size of the beam.

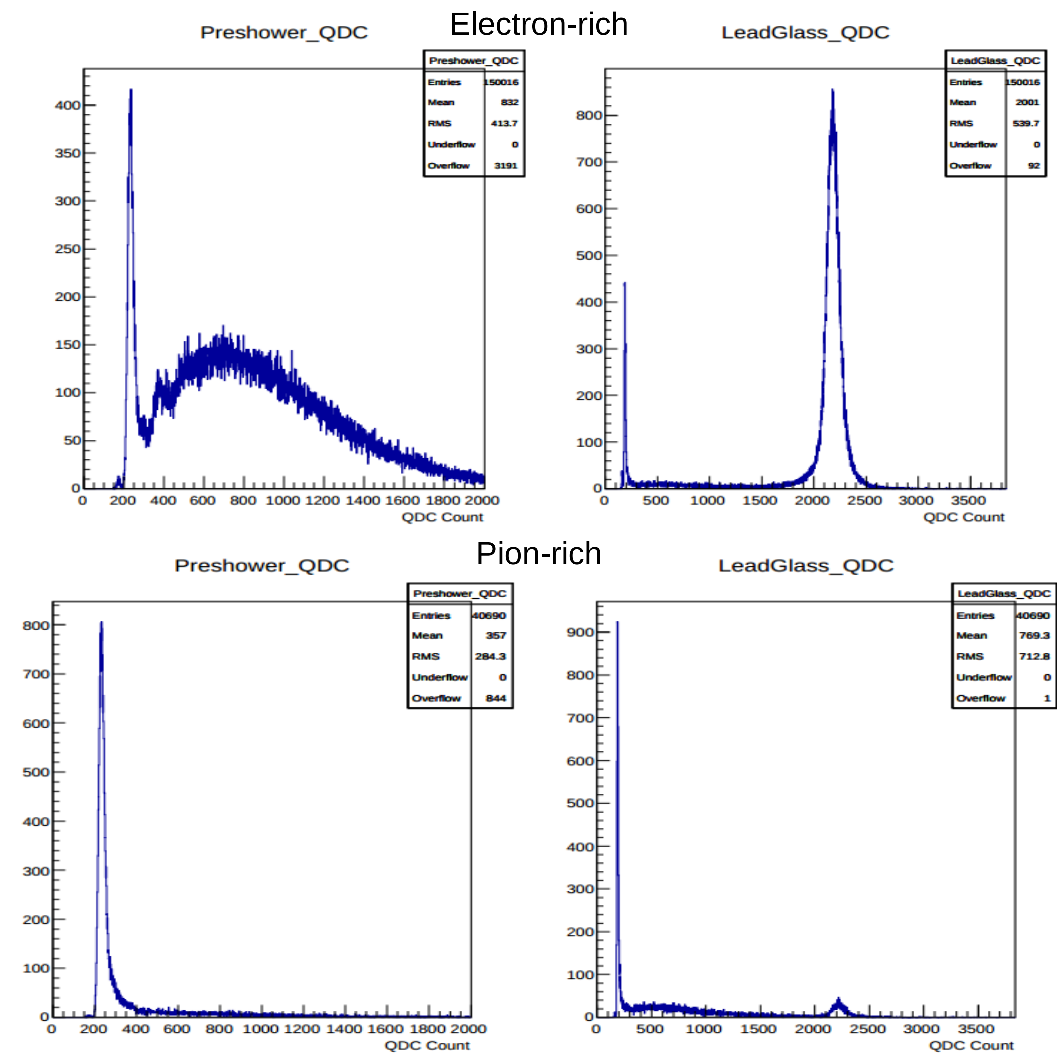

TRD

TRT test beam 2015 setup

- Mixed Electon/pion beam was used during the tests.
- We had two type of beams;
  - 20 Gev Electron-rich run with small amount of pions.
  - 20 Gev Pion-rich run with small amount of electrons.
- Measurement with Xenon Argon and Krypton gases performed.
- Regular Fe55 calibration of each straws was done.
- Gas gain was controlled with accuracy about 2%.
- Multiple radiators and arrangements used with TRD.
- In this study we used fibre and foil(Polypropylene) radiators along with no radiator case.

Particle Identification

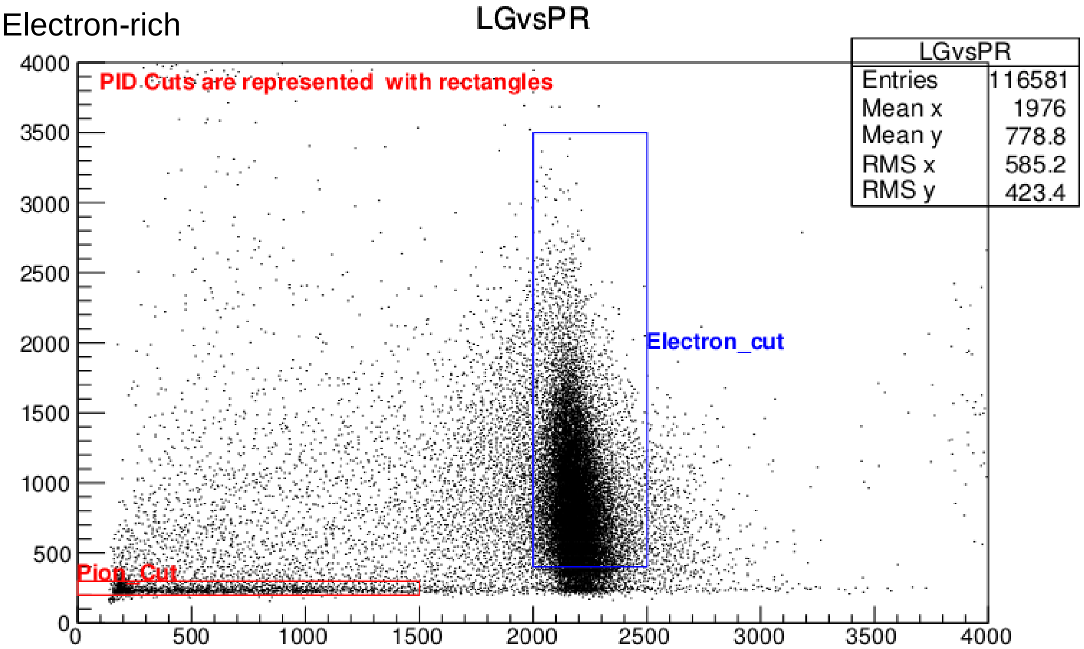
- The beam compositions was mixture of electrons and pions.
- Most of the data taken with electron-rich run. But we had few pion-rich runs.
- The lack of different-composition runs beyond the two types mentioned above overrules the possibility of a quantitative study of the beam composition in an attempt to determine the amount of possible contamination from other particles, such as protons and kaons.
- If these contaminations were of a significant level, we would expect to see the tail of a decaying function underneath the sharp electron peaks in the leadglass calorimeter QDC count histograms



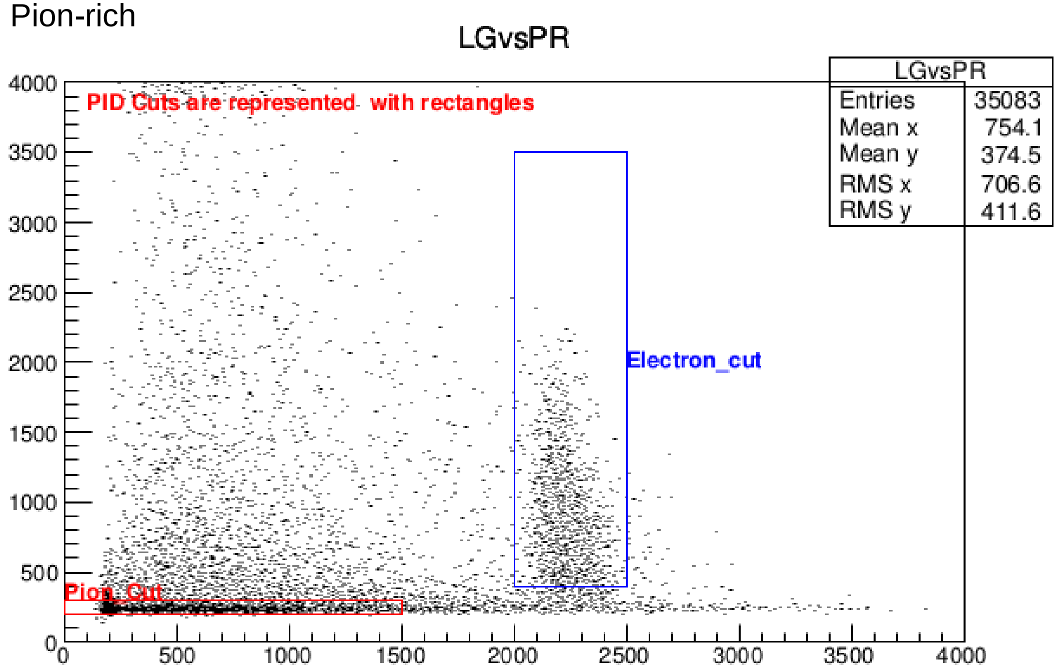
Electron and Pion selection

- Particles with the leadglass QDC values between 2000-2500 and preshower QDC values between 400- 3500 are taken as electrons
- Particles with the leadglass QDC values between 0-1500 and preshower QDC values between 200-300 are taken as pions.
- Furthermore straw hits with energy value smaller than 0.055 keV are rejected throughout the study
- The electron cut is shown with the blue rectangle, whereas the pion cut is in red.
- Particle selection purity is around 10^{-3}.

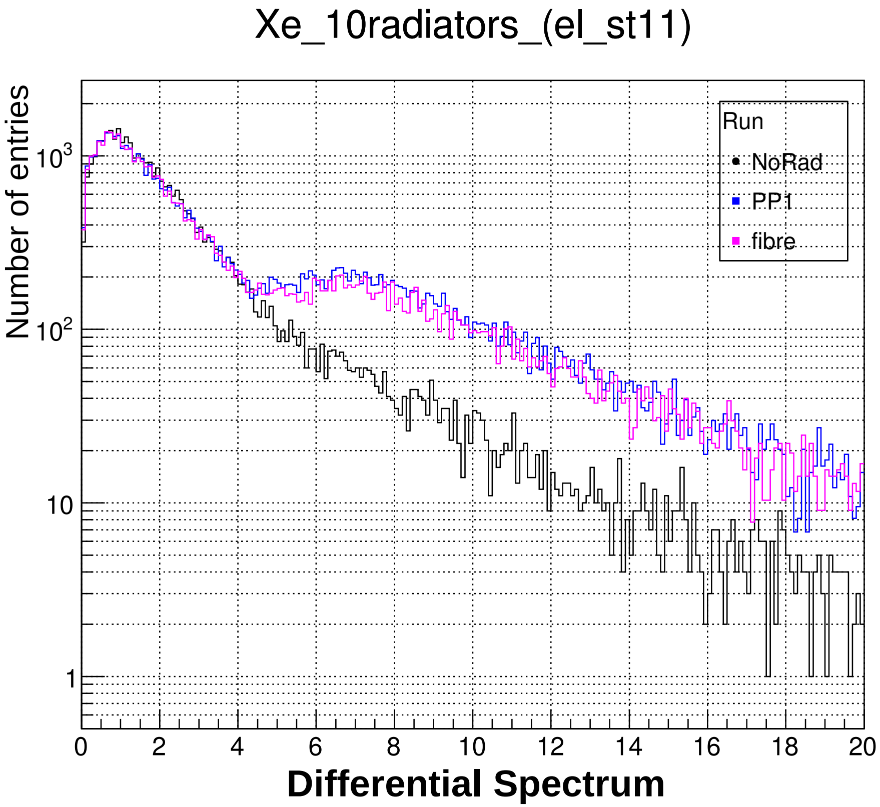
Electron-rich

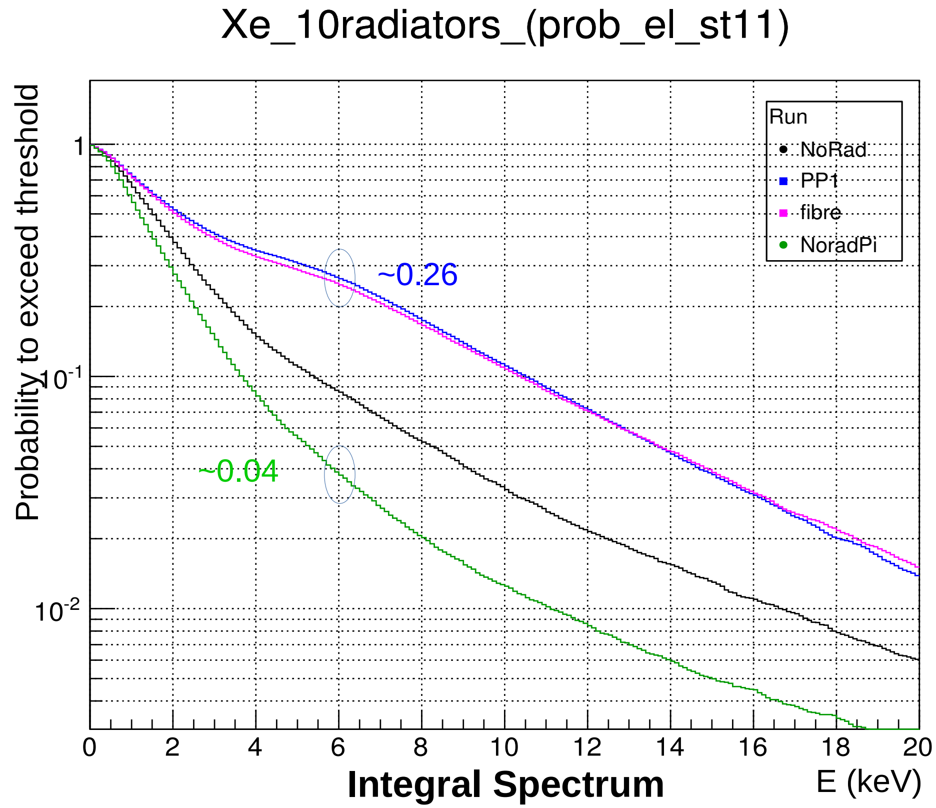


Pion-rich



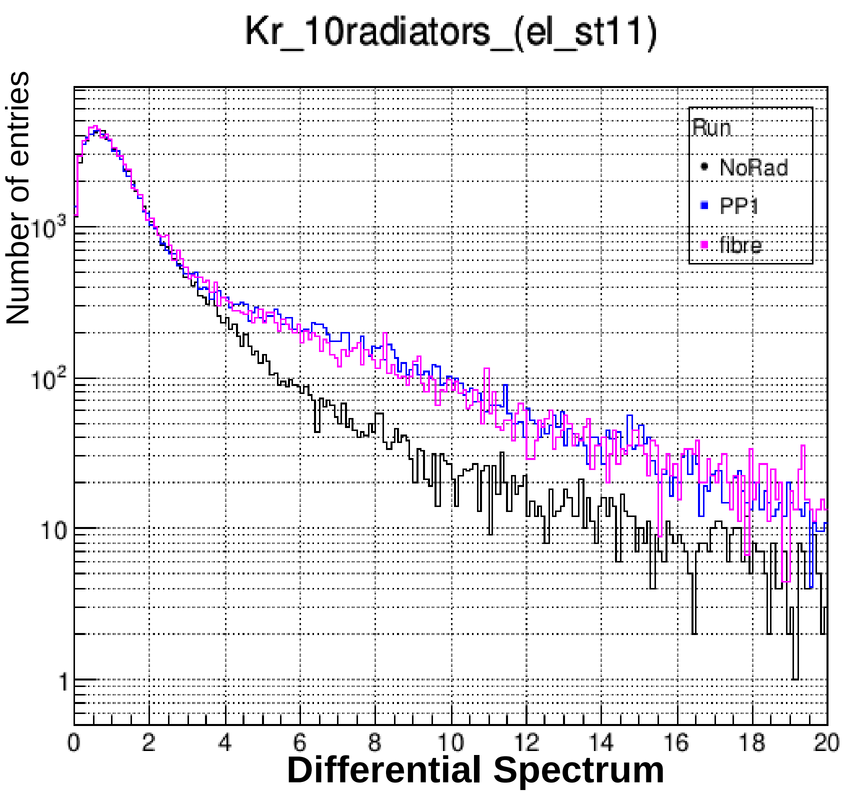
High Level Threshold Probability

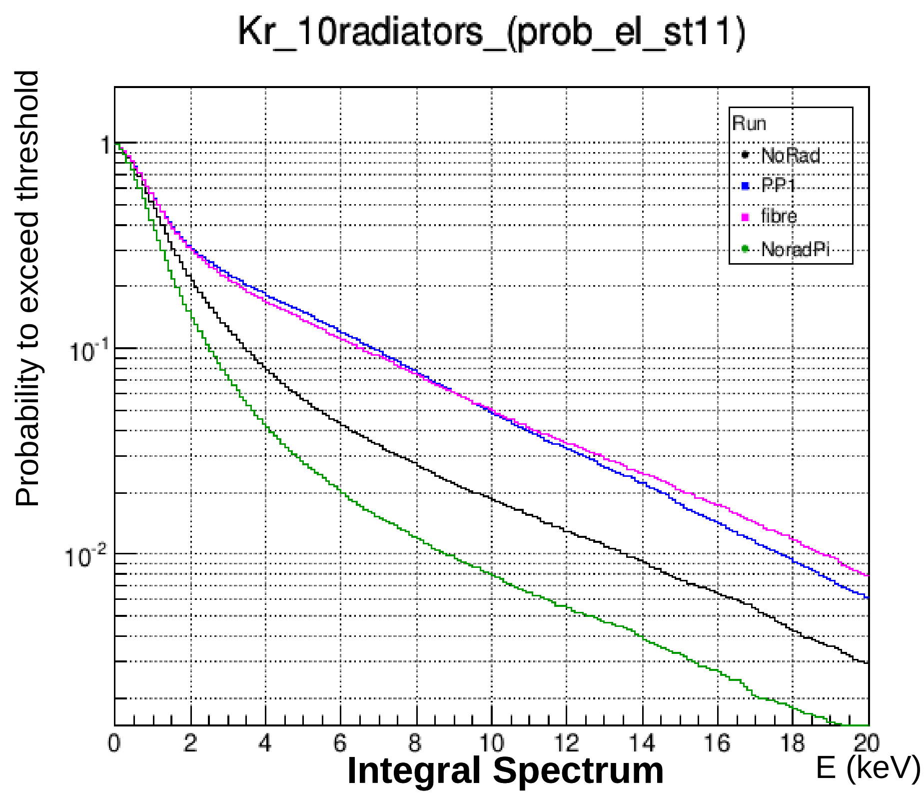




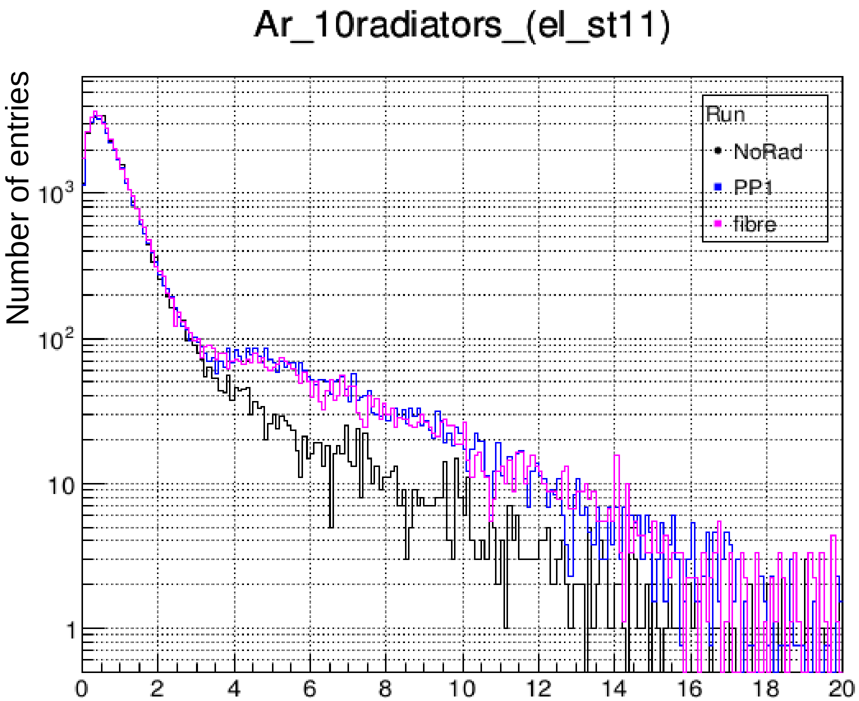
- To investigate different thresholds one can produce integral spectrum which is the plot of the integral of the differential spectrum for values greater than that threshold normalized by the whole spectrum integral. In short y axis corresponds to probability to exceed threshold and x axis corresponds to different threshold values.

Krypton Spectra

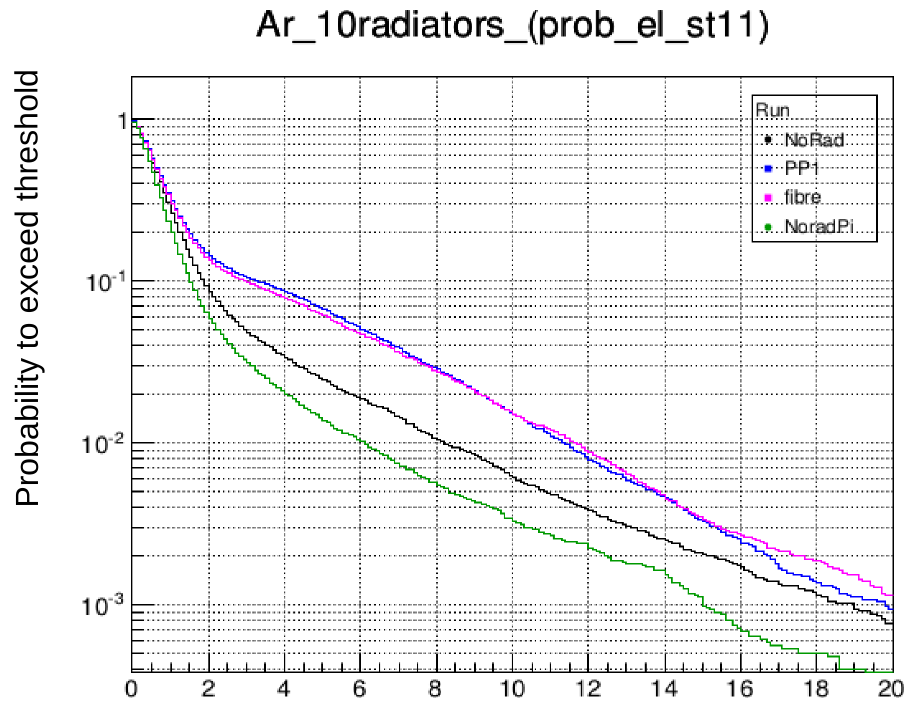




Argon Spectra



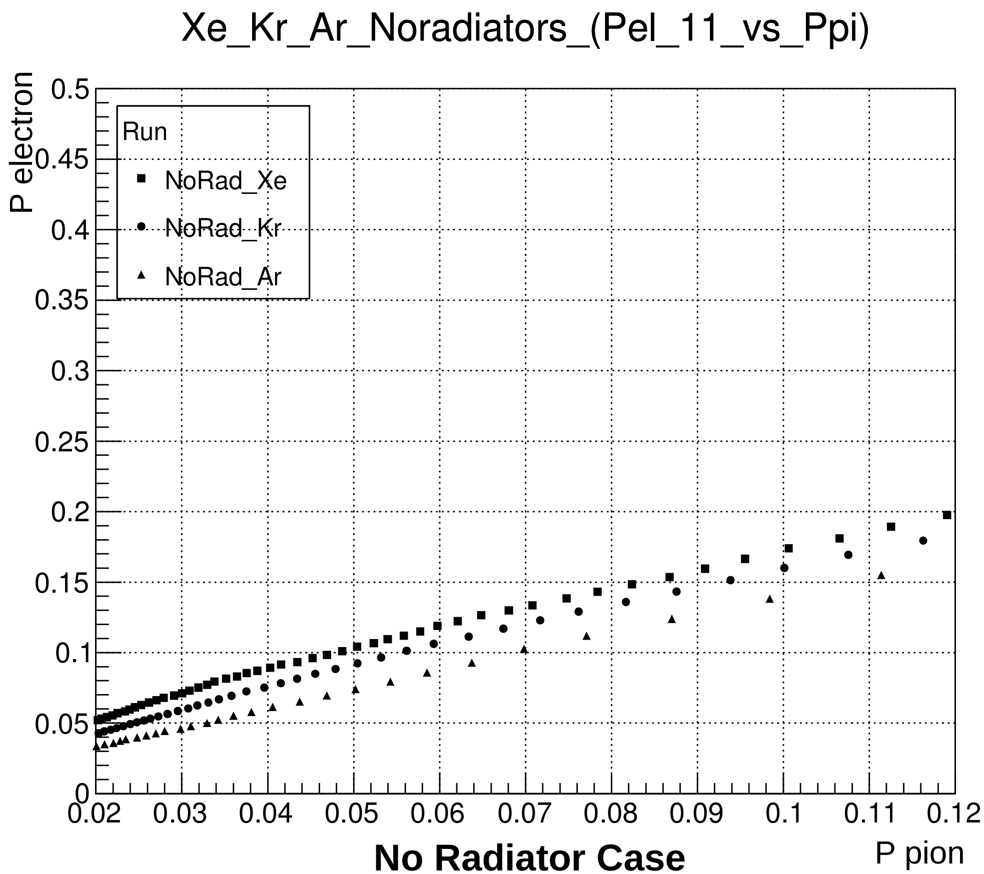
Differential Spectrum

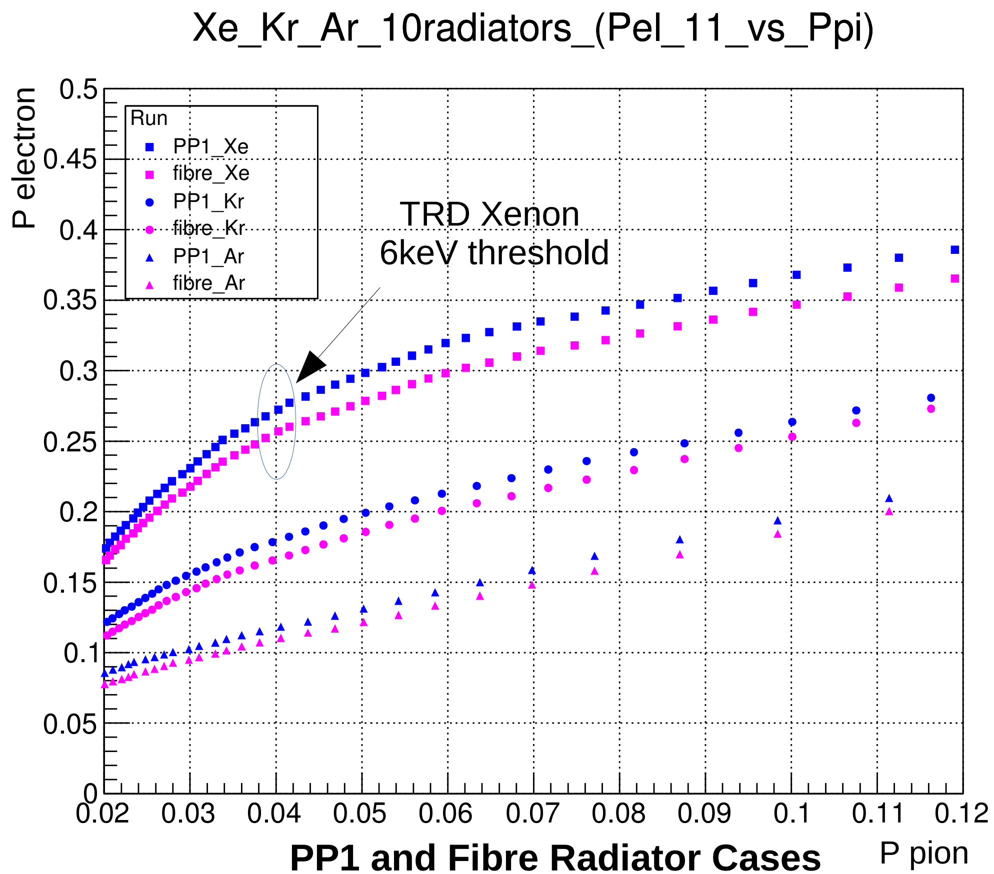


Integral Spectrum

E (keV)

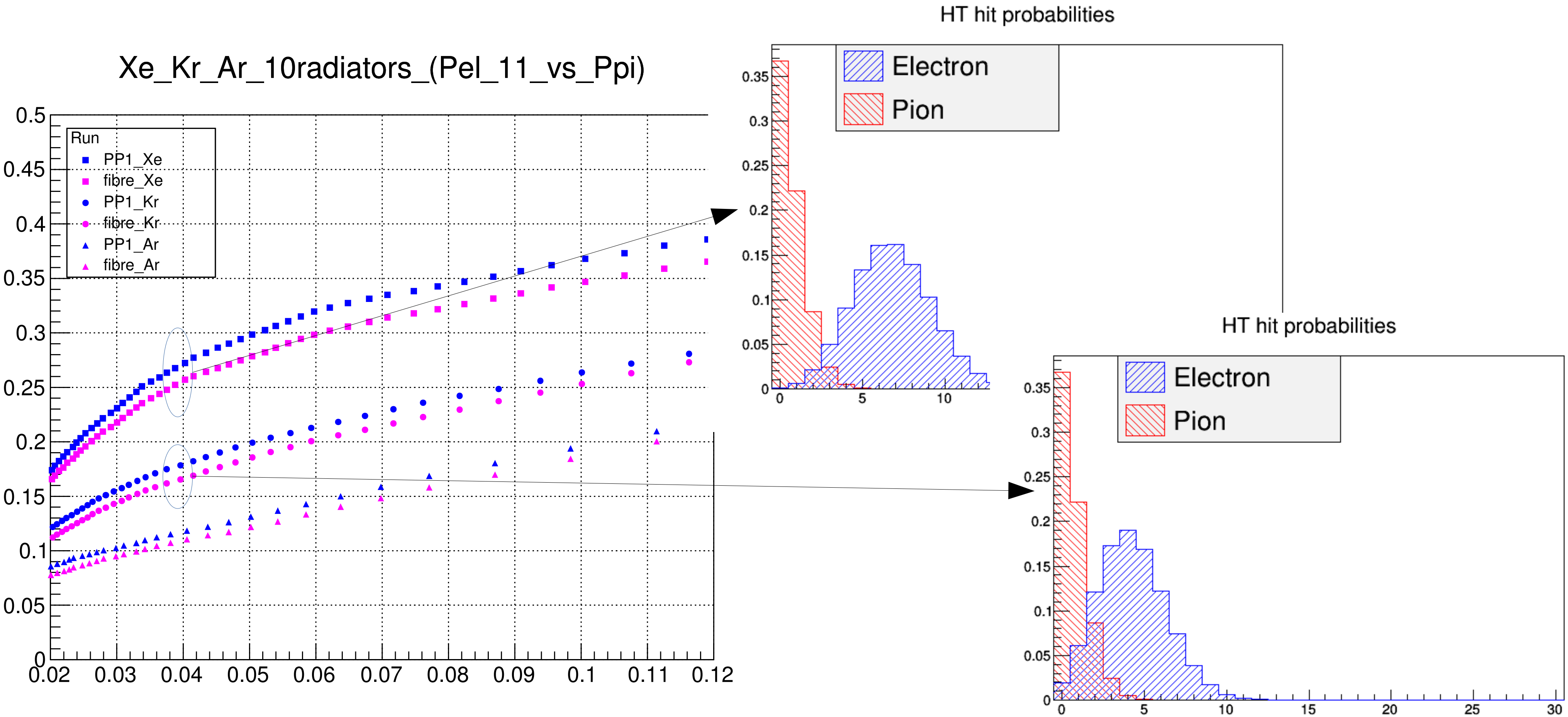
Results





- The probability to exceed threshold for electron vs pion plots were produced for different gas and radiator combinations.
- One note here ; The probability to exceed threshold for pions taken from no radiator run cases.
- Clearly this plot verifies that Krypton performs better than Argon but worse than Xenon.

Particle Identification Performance

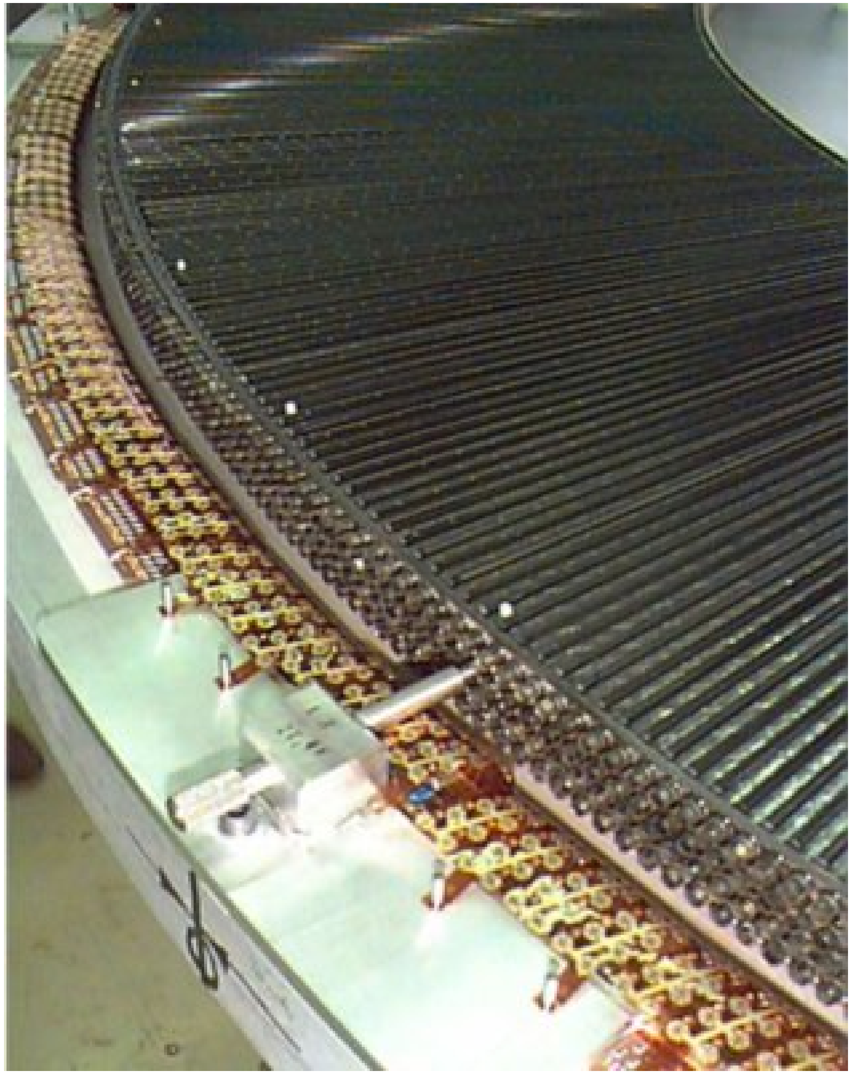


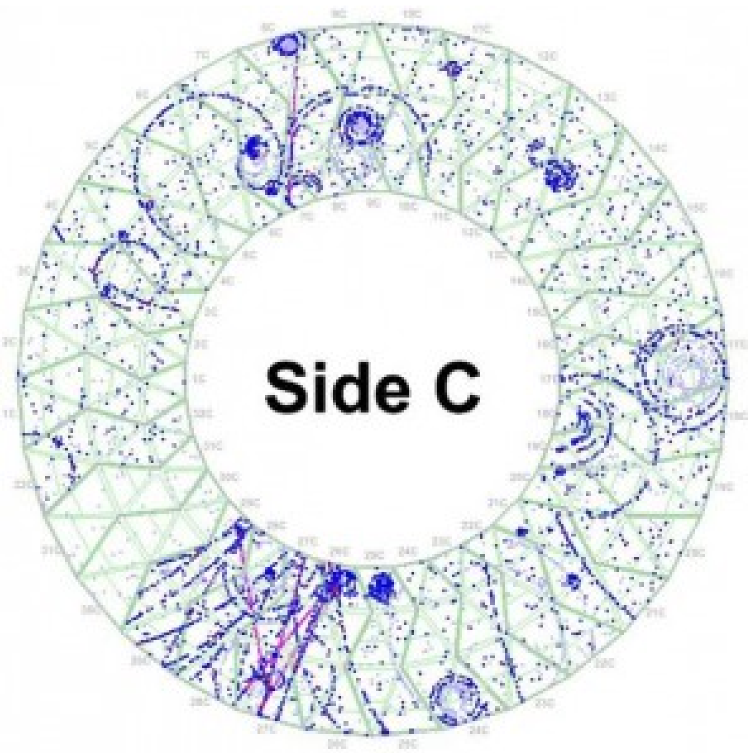
- The plot (left) allows to obtain a good estimate of the particle separation of the detectors with the design used in the tests beam.
- For instance if we have 30 straw layer TRD detector the distribution of number of straws on track with energy depositions more than 6 keV for Xe and more than 4 keV for Kr are shown no figures on the right side.

Conclusion

- The analysis performed to obtain high-threshold TR probability plots that will allow us to determine the operating point for TRT straws with alternate gas mixtures. The actual decision for choice of such operating points require a detailed Monte Carlo simulation of the TRD.
- Although the effect of larger Kr cross section for photon energies greater than 14 KeV is not strongly pronounced in the particle separation is still quite good. Optimization of the detector geometry for Kr mixture can significantly improve its PID performance.

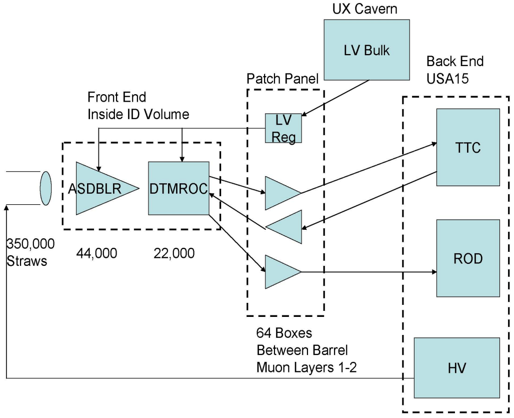
Backup

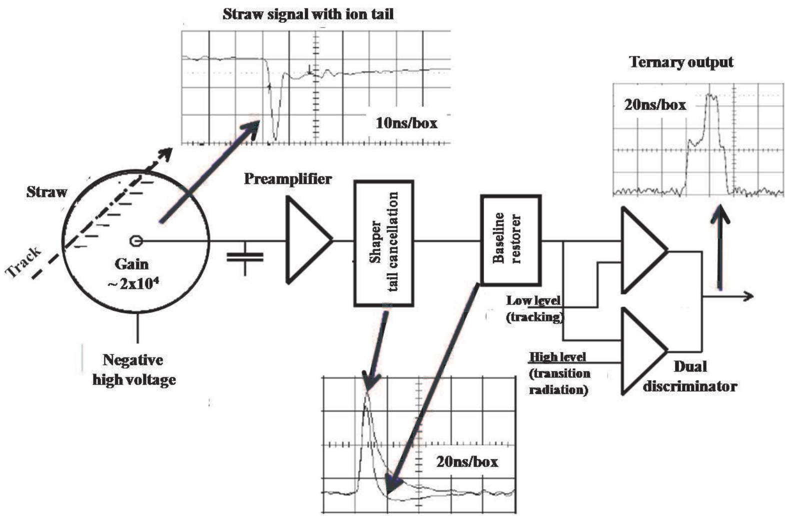


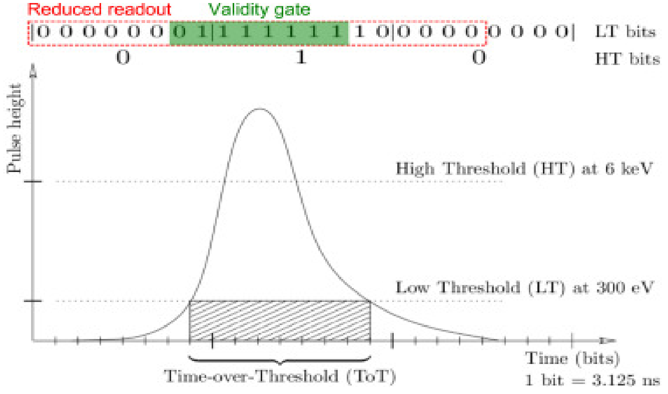


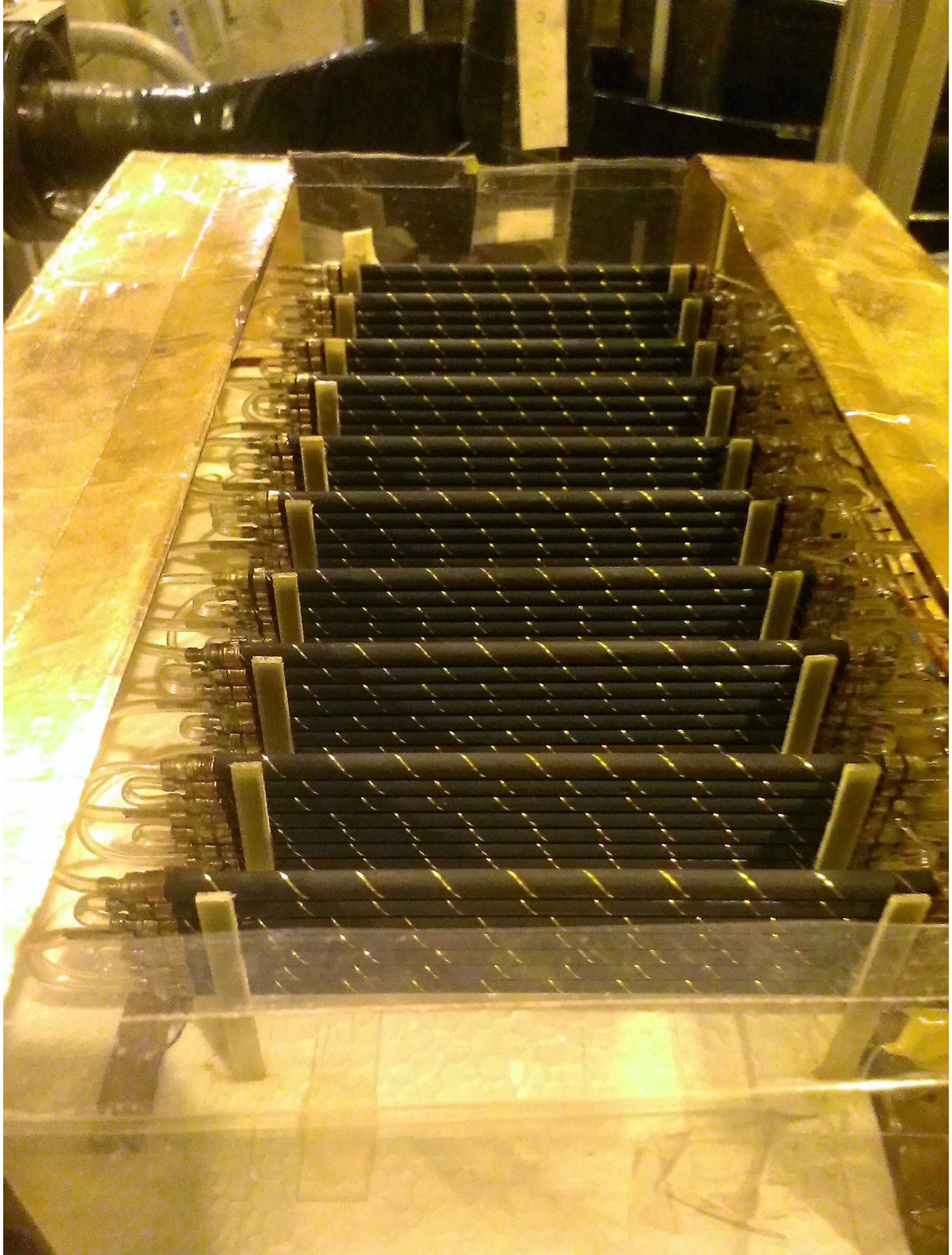
Backup
TRT Electronics

- Straw signal is prepared to digitization with Amplifier/Shaper/Discriminator with Baseline Restoration Chip (ASDBLR) the resulting three level analog signal is digitized with Drift Time Measurement Readout Chip (DTMROC).Input signal and its digitization represented in the bottom right figure.
- ASDBLR and DTMROC chips are in the front end (inside the Inner Detector volume).
- The DTMROC sends the digitized signal data to TRT readout drivers via patch panels.









Backup: Straws

- Straws made are made of 4 mm diameter tubes and a gold plated tungsten anode wire of diameter ~ 30 µm.
- To produce the tube, Kapton film is coated with aluminum and carbon-polyimide layer on one side and with a heat activated adhesive on the other side. The coated film slit into tapes and formed into tubes as shown in the figure on the right.
- To add mechanical dexterity straws are reinforced with carbon-fibre bundles.
- Resulting straws is allows soft x-rays inside the tube and they can support their wire tension as well as other structures like barrel radiators.