X-ray Scanners*
for ATLAS Barrel TRT Modules

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** On the behalf of ATLAS TRT Collaboration

Abstract

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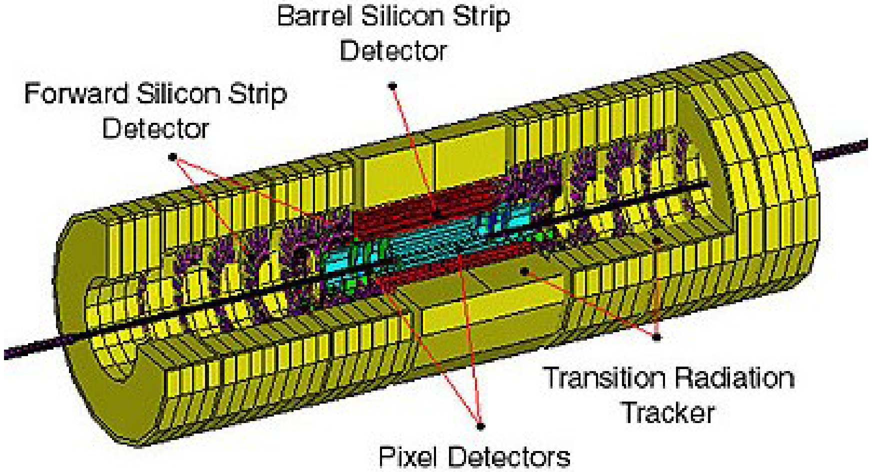
- X-ray scanners for gain mapping of ATLAS Barrel TRT modules were developed at Hampton University and are running successfully for quality assurance purposes at Hampton and CERN.
- Variation in gas gain can be caused by varying wire offset from the center of the straw, contamination on the wire, wire diameter variation, etc., (Excessive wire offset can lead to HV breakdown).
- Results were used to decide whether wires were removed or re-strung, and to evaluate overall module quality.

ATLAS TRT Barrel Detector



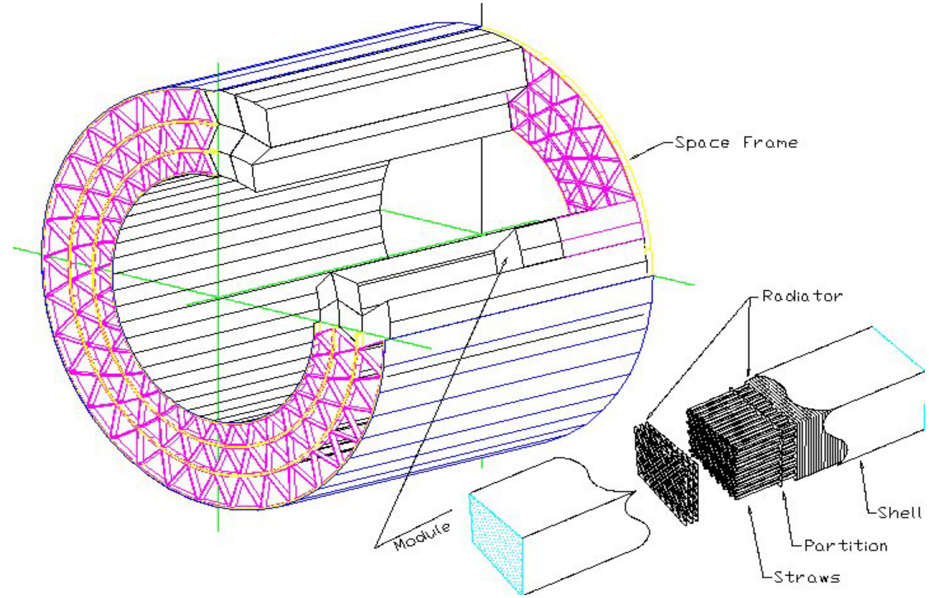
- **Straw based tracking chamber with transition radiation (TR) capability for electron identification.**
- **Straws are parallel to beam line.**

- **Active gas is Xe/CO_2/O_2 (70/27/3) operated at ~$2x10^4$ gas gain**
- **Counting rate ~ 6-18 MHz at LHC design luminosity 10^{34} $cm^{-2}s^{-1}$**

Modular Design of Barrel TRT

Design is modular for:

- reduced risk
- distributed production to multiple sites

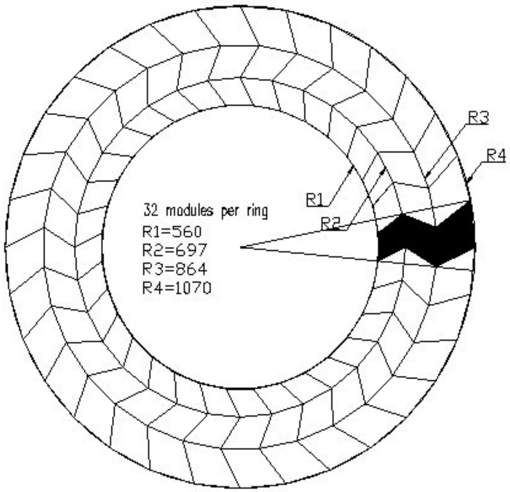


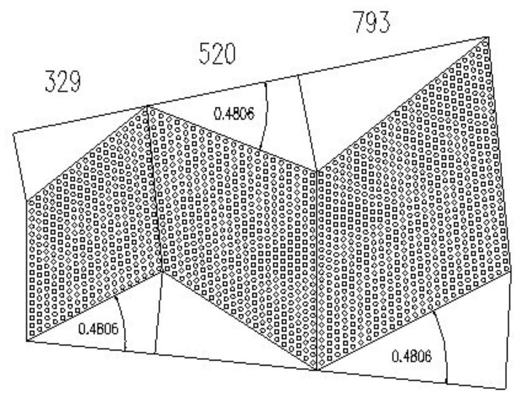
Module Length	1.5 m
Sense Wire Length	2 x 0.75 m
Straw Diameter	4 mm
Wire Diameter	30 um
Distance between straws	6.8 mm
High Voltage Grouping	8 straws

- **Basic Design of the Module:**

  Straws are embedded in radiators and supported by dividers and endplates which are connected across the module by a carbon-fiber shell

TRT Barrel Module Types



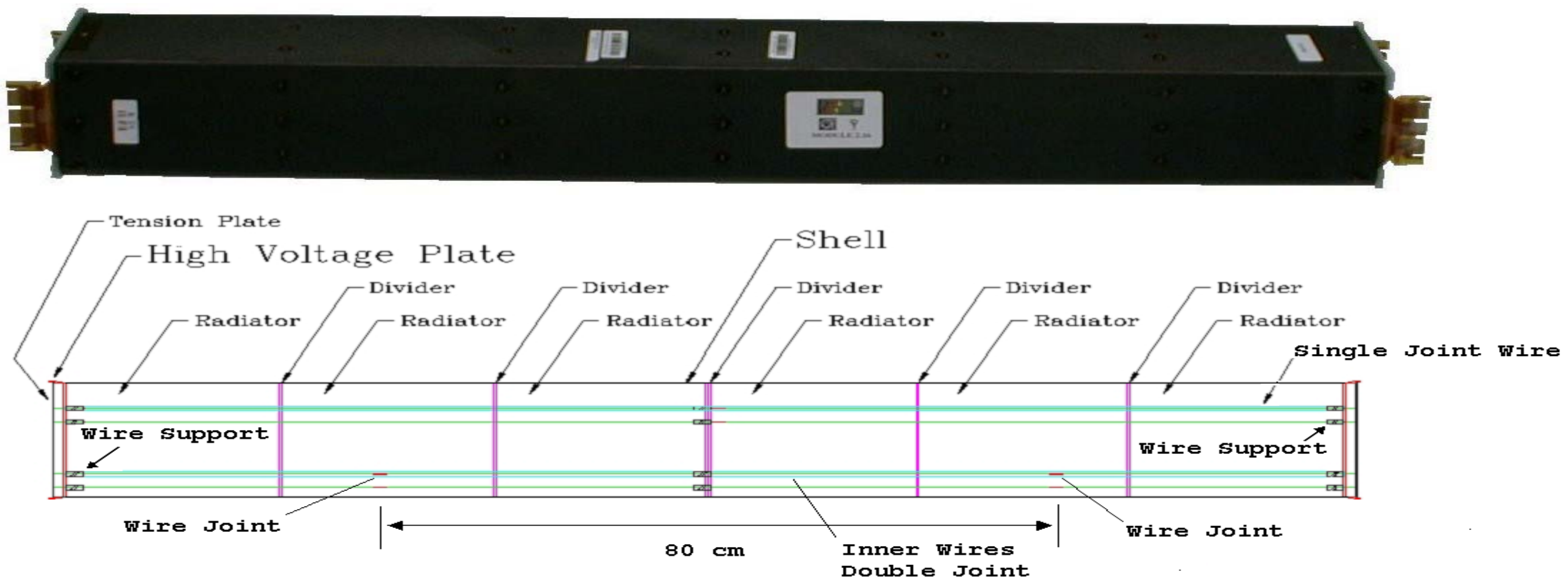


	Type 1	Type 2	Type 3
Number of Modules	32	32	32
Straws per Module	329	520	793
Straw Layer Number	19	24	30
Inner Radius (mm)	560	697	864
Outer Radius (mm)	697	864	1070

- Entire barrel is divided into 3 rings of 32 modules.
- Straws are distributed for a continuous tracking geometry
- 52,544 straws,

  105,088 readout channels
- Average number of straws crossed by a track = 36, out of 73 layers
- Average number of TR-hits for 20GeV Pt electron = 7

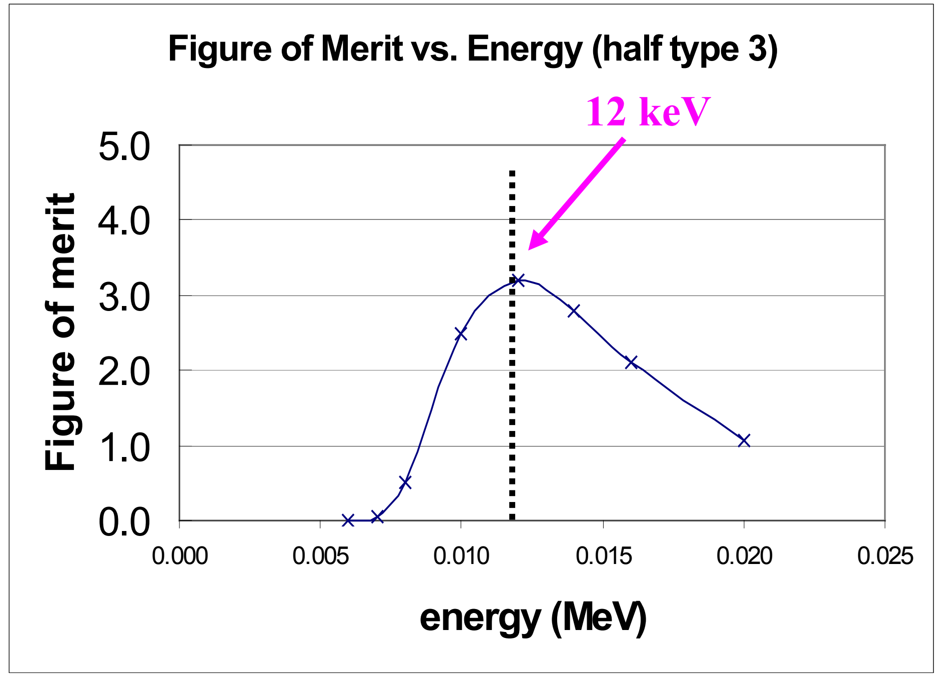
TRT Barrel Module



- Sense wires are split in half to reduce counting rate.
- This is not enough for the 11 inner most layers of wires!
- ±40cm from the center of these wires are deadened by using 2 wire joints.
- All straws are the same, but there are 2 different kinds of wires: "Single joint" & "Double Joint"

Choice of Energy for X-ray Scanner

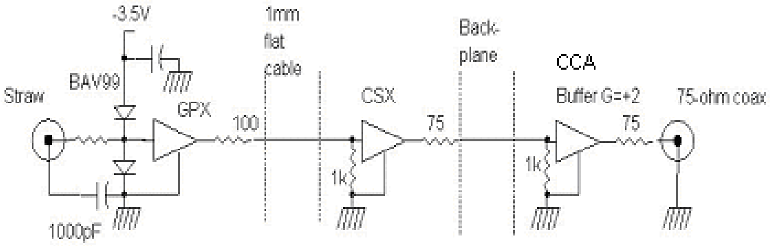
- To measure gas gain, it is useful to have a fixed energy deposit in the gas. In our case that was achieved by using nearly monoenergetic 12 keV x-rays from x-ray fluorescence (XRF) from bromine. This energy was chosen to optimize the time to obtain the required gain resolution



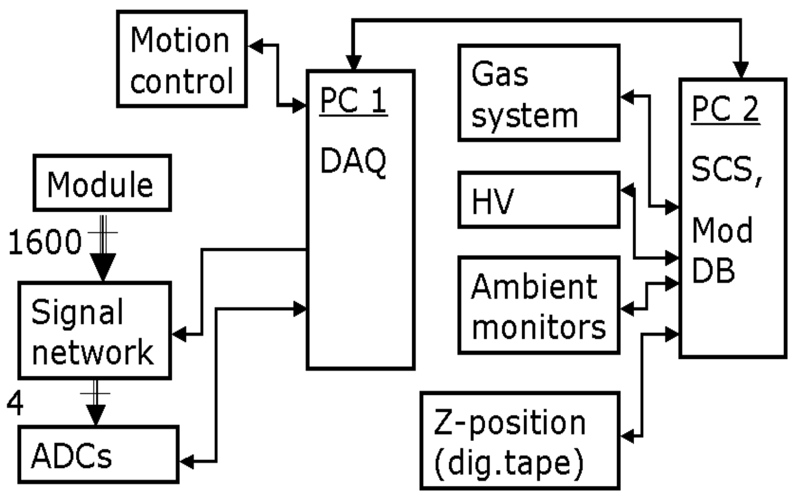
- FOM = (Attenuation in 1.16 g/cm^2 Carbon) * (Attn. Length of argon, cm^2/g) * (Ratio of 2 mm/Max(2mm, CSDA range))

Electronics for X-ray Scanner

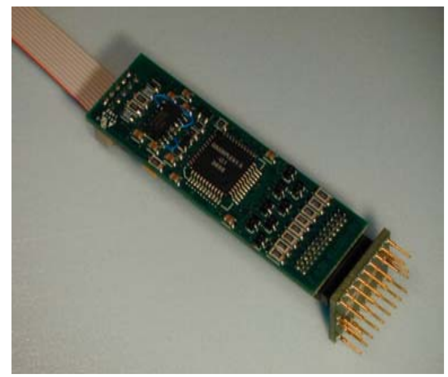
- **Basic Chain of Electronics**

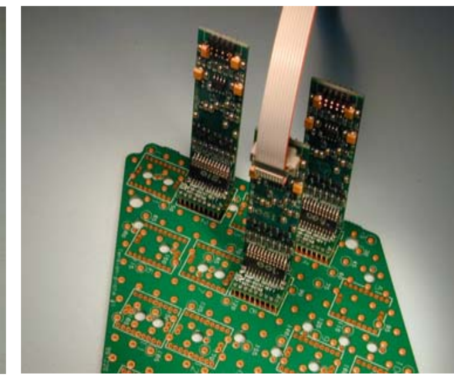


- **DAQ Physical Layout**



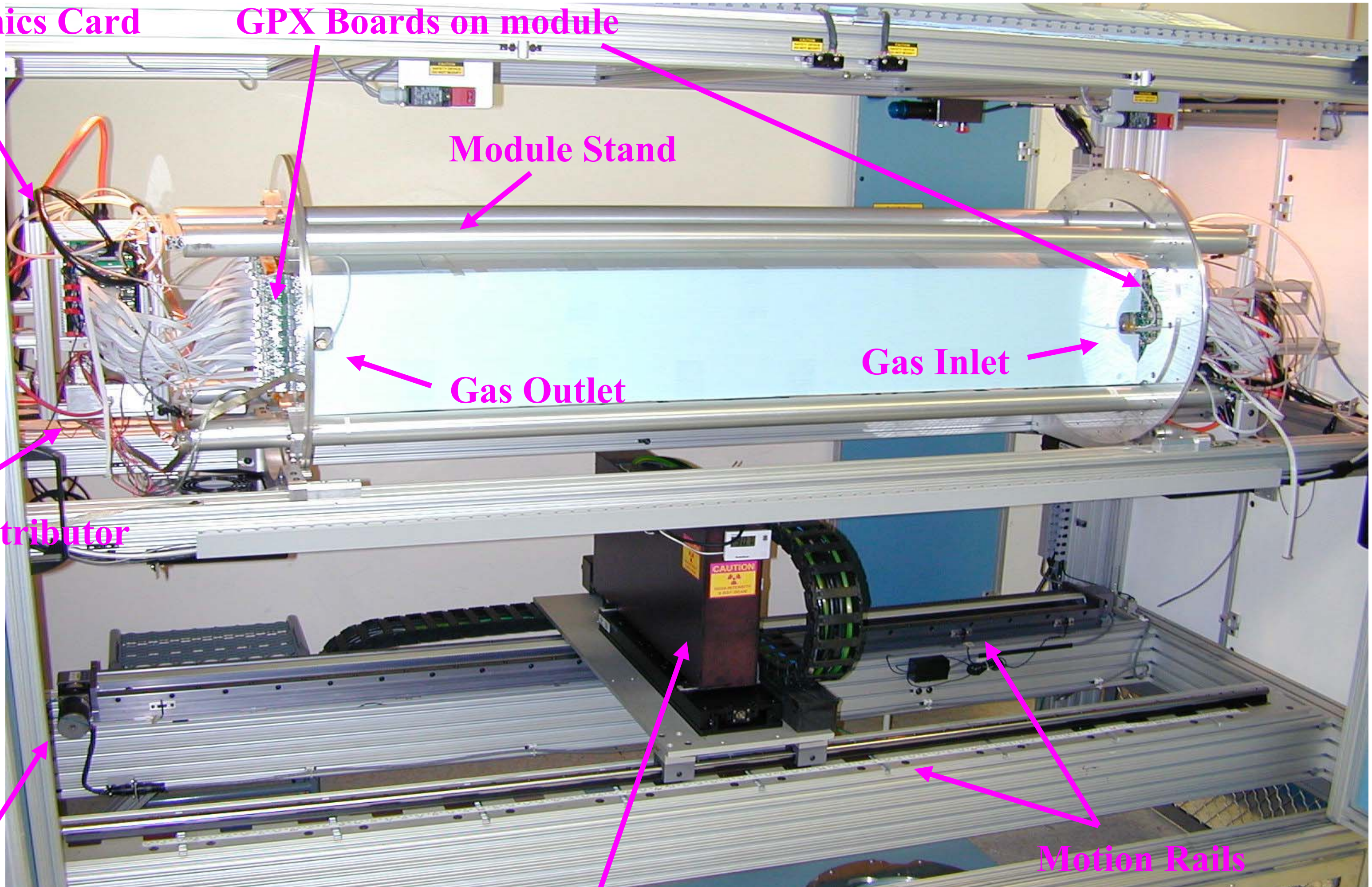
- **Front-end (GPX) boards**





- Input protection circuits, a single Gassiplex1.5 ASIC and support circuits
- Takes signals from the sense wires, amplifies and shapes them and allows selection of single channels to be passed on the ADCs

X-ray Scanner in Hampton University



X-ray Scanner in CERN

Operating Condition of X-ray Scanner

- Ar/CO_2 (70/30) gas with flow rate of 1 vol/hr
- HV set at 1255 V (< nominal gain)
- Bromine XRF
- ^{55}Fe as a reference signal
- Air or Ar/CO_2 gas in the shell volume
- Module flushed and trained to low current on HV before scanning
- Ambient temperature of ~23 ^{o}C
- Measure gains for 50 positions for each straw

Data Reduction

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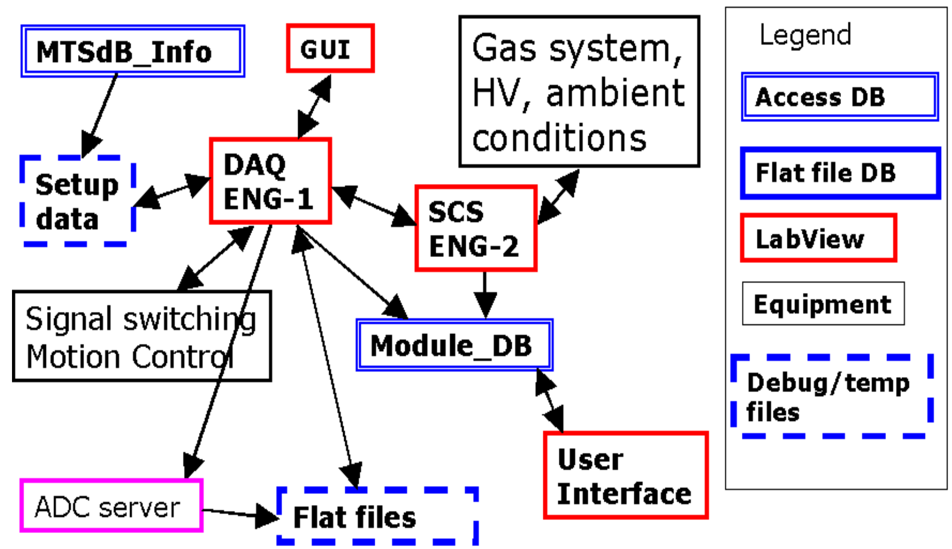
- Data Recording : the raw spectra and fitted means (g_p) and widths (σ_p) of the peaks, as well as straw number, run number, z position, normalized gains, time, and SCS parameters.



- The peak in each spectrum is fitted with a gaussian, finding the mean (g_p), standard deviation (σ_p), and goodness of fit
- The ratio of the straw mean to the monitor mean is multiplied by 500 (i.e., the ^{55}Fe mean is arbitrarily scaled to 500 ADC counts) to give the 'normalized gain, g_n.'
- The gain variation, G, is defined as: $G=(g_{n,max} - g_{n,min})/g_{n,min}$

Pulse Height Spectra and Gain Variations

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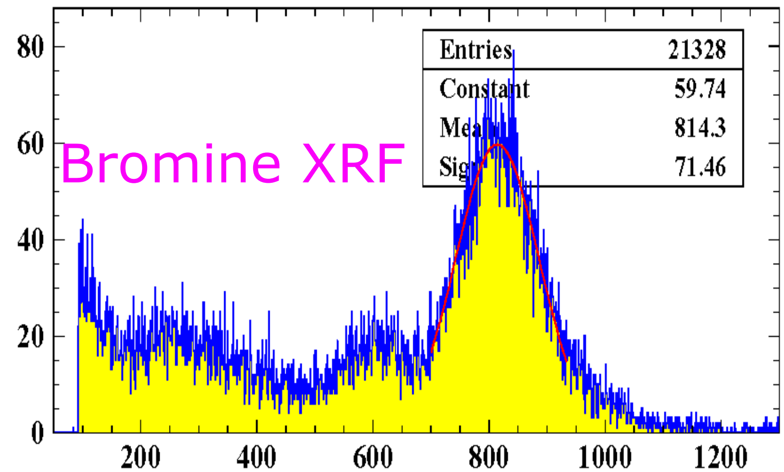

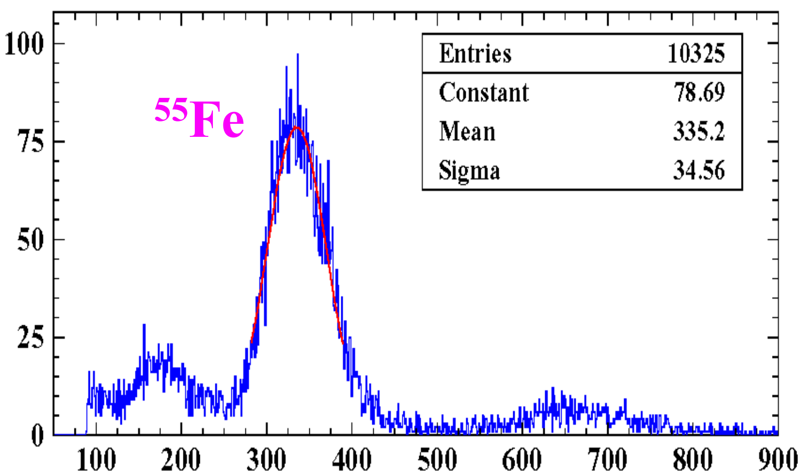

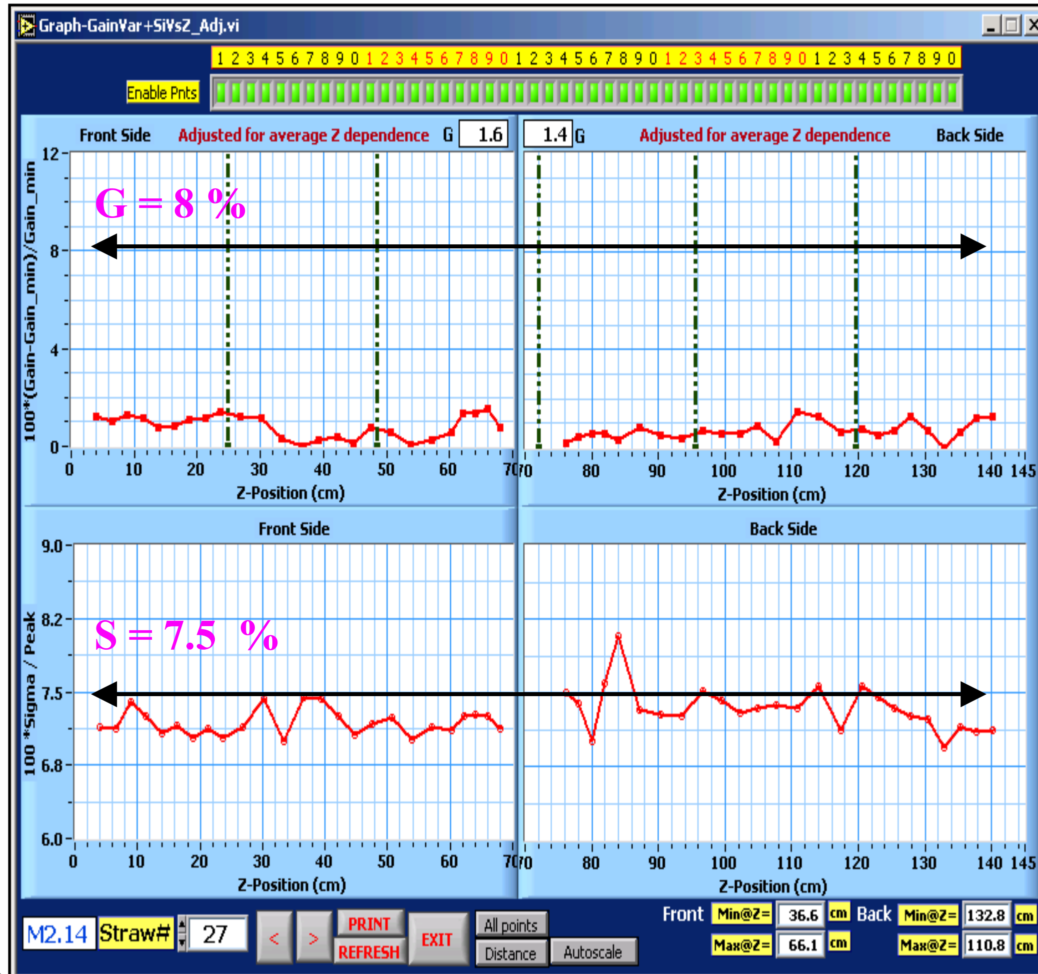

Gain Maps

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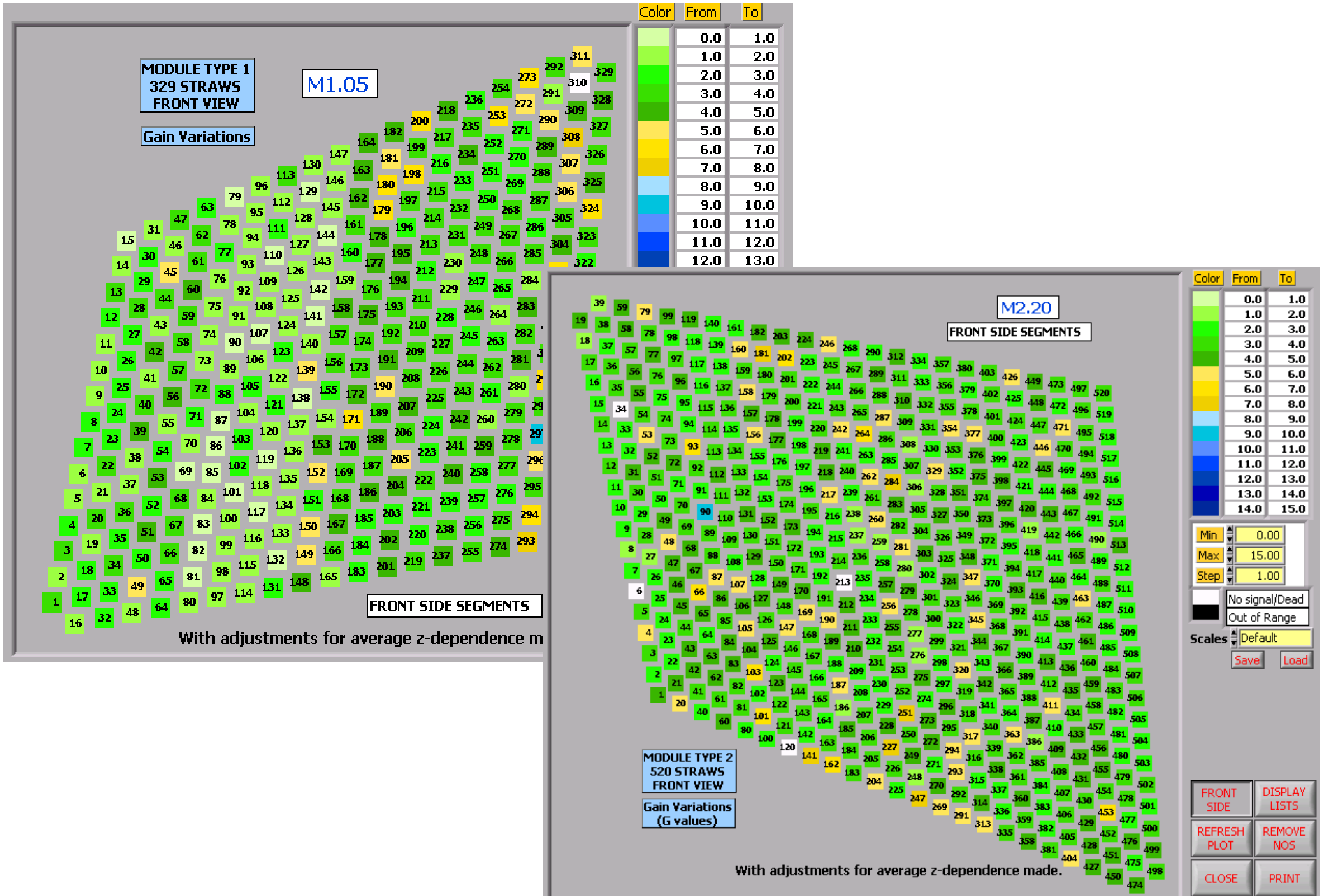

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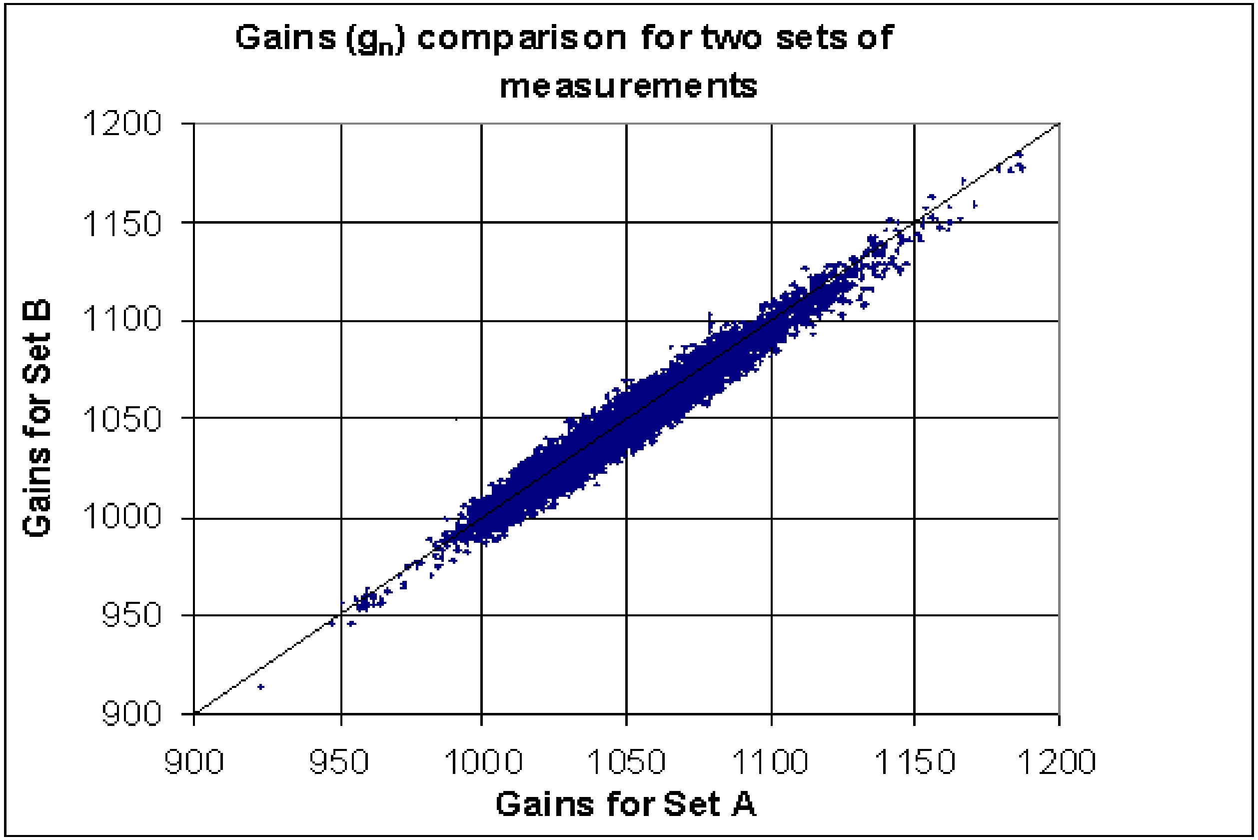
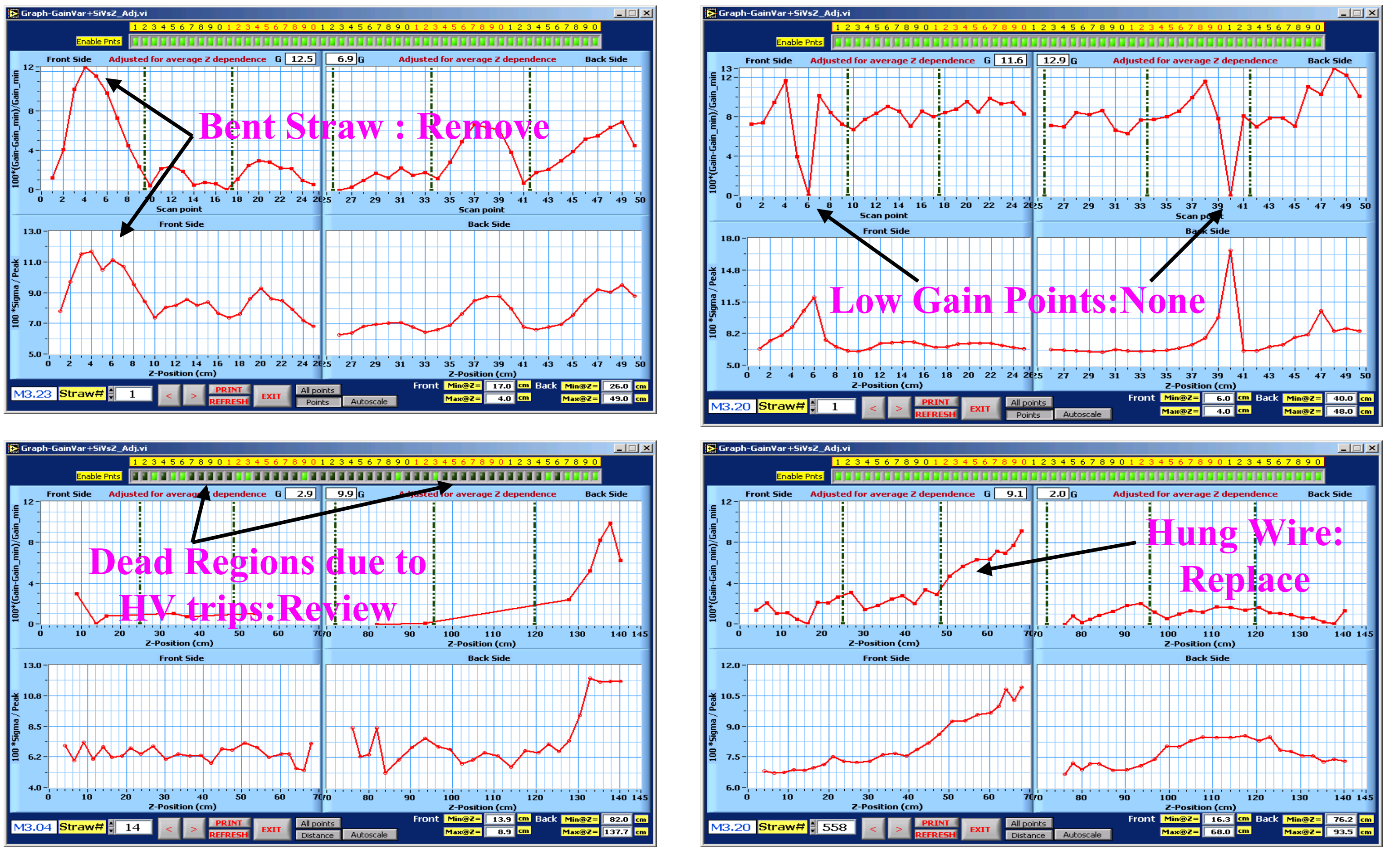
Reproducibility of X-ray Scanners



- **Comparison of the normalized gain (g_n) from two sets measured on the same module.**

Gain Variation Examples

- *G* > 8% & *S* > 7.5 % wires require action



Summary

- X-ray scanners for the purpose of quality control of the ATLAS TRT Barrel detector modules were developed at Hampton University(HU) and are operating at HU and CERN.
- The scanners map the gain using 12 keV photons, at 50 points along each straw. Results were used to decide whether wires were removed or re-strung, and to evaluate overall module quality.