Experience with medium-size SRS for muon tomography

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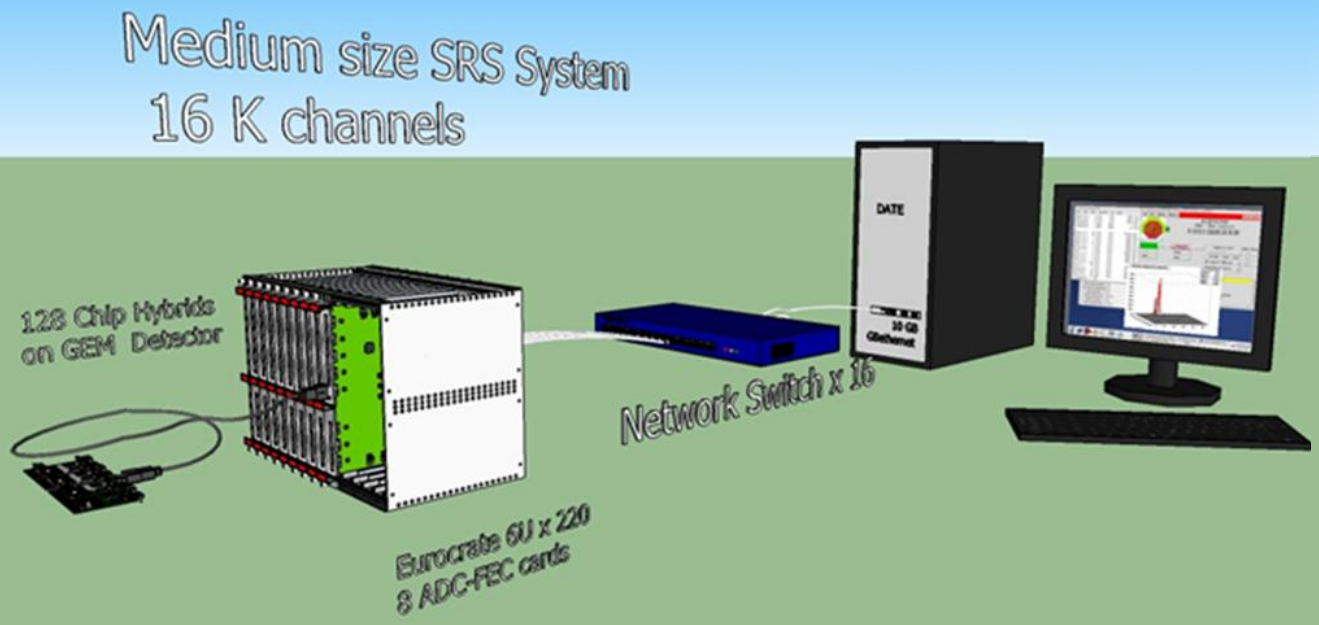
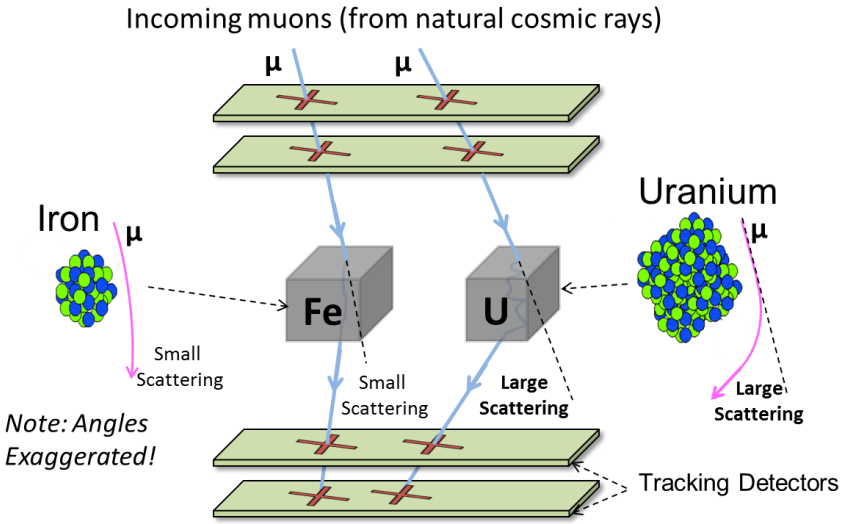
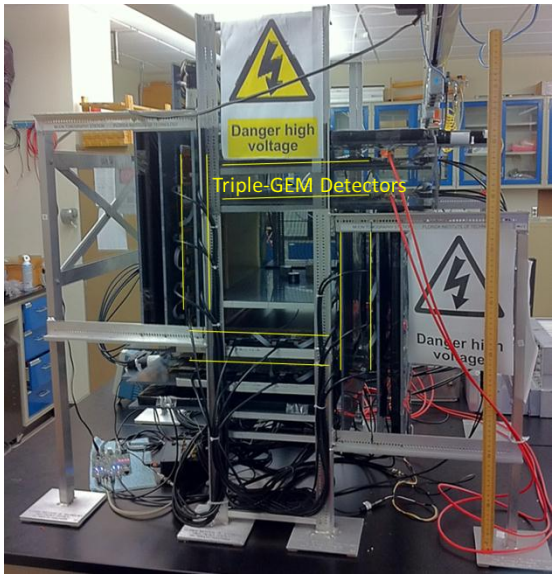


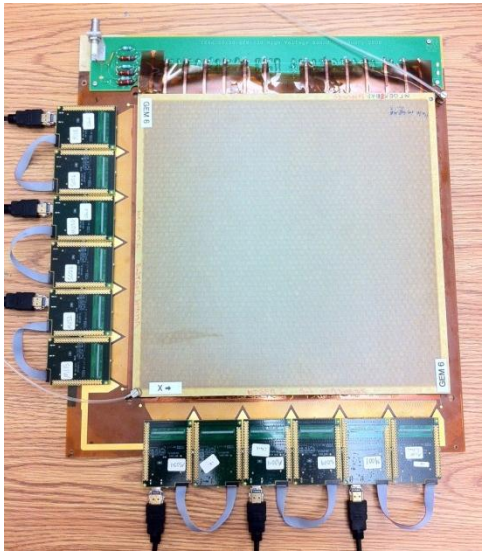
Muon Tomography at Florida Tech

Muon Tomography Concept



Eight 30 cm x 30 cm triple-GEM detectors enclosing an active area of ~ 1 ft^3



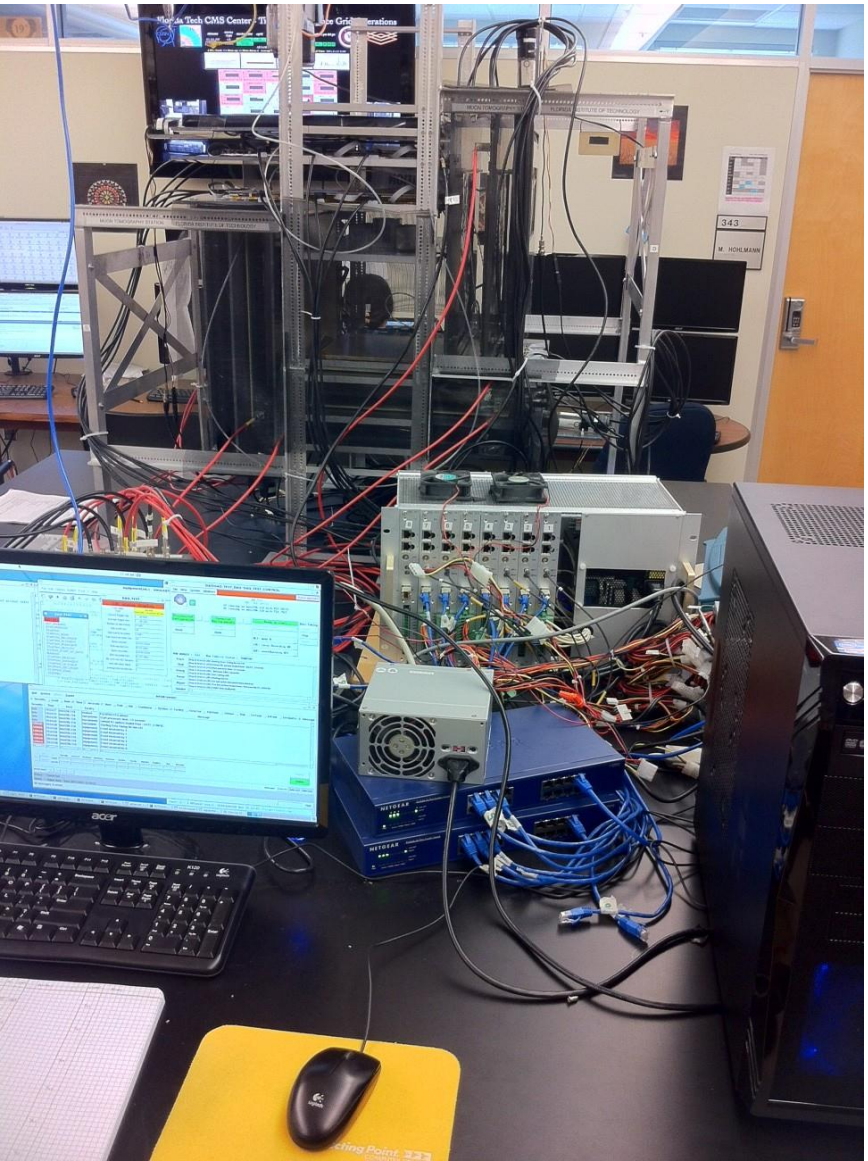


Main idea: Multiple scattering is proportional to Z and the density of the material, allowing detection of nuclear contraband by measuring scattering of cosmic ray muons.

Detector design similar to COMPASS GEMs:

- 3/2/2/2 mm gap configuration
- Cartesian XY readout strips with 400 μm pitch
- 1,536 readout channels per detector

SRS for Muon Tomography



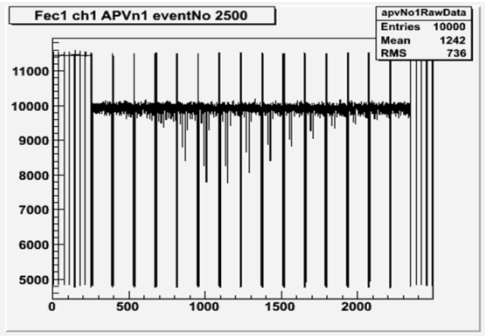
Current station configuration with 8 detectors:

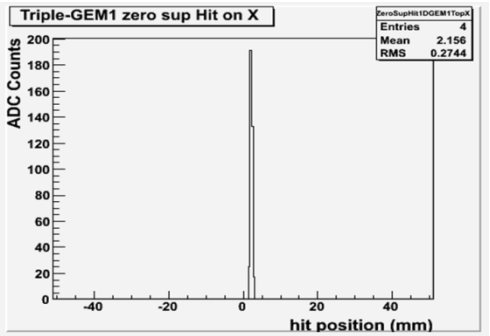
- 96 APV Hybrid (48 M/S pairs)
- 6 ADC/FEC cards
- 2 Gigabit network switches

Six 25 ns frames of data recorded for each APV per trigger yields event size of ~200kb @ 30 Hz.

DATE for data acquisition.

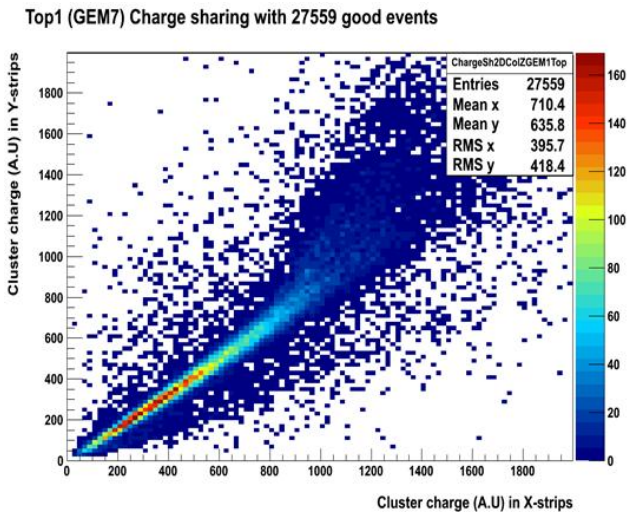
AMORE for data decoding, event monitoring and data analysis.

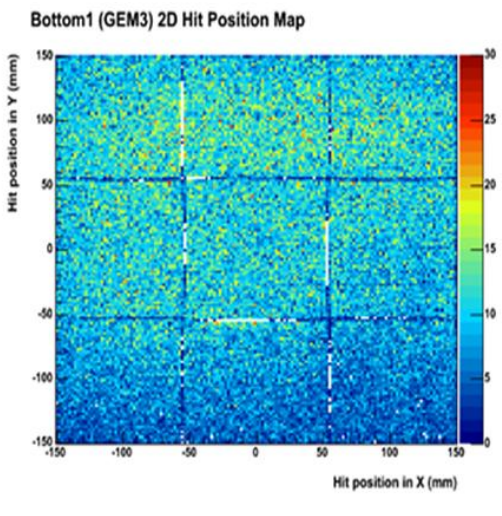


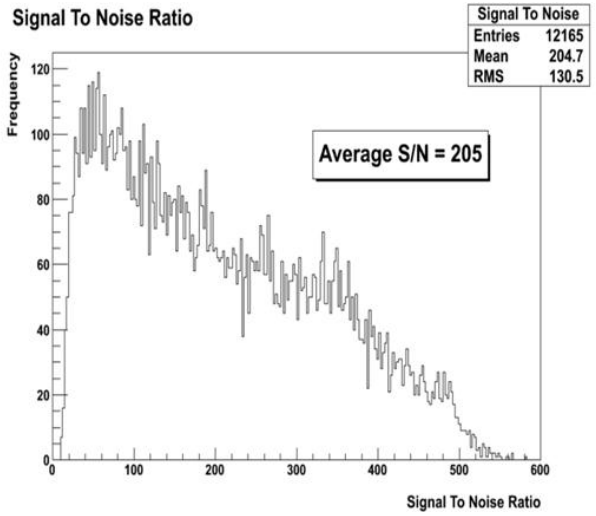


Muon Tomography at Florida Tech

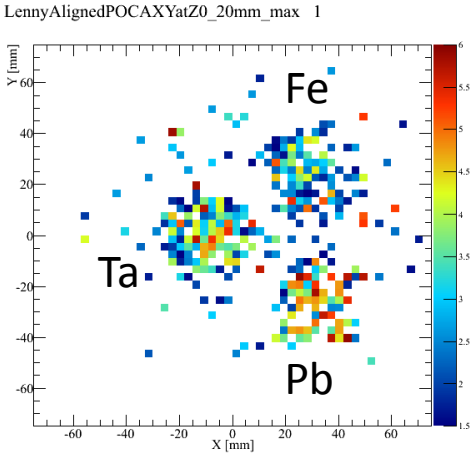
Detector Characterization

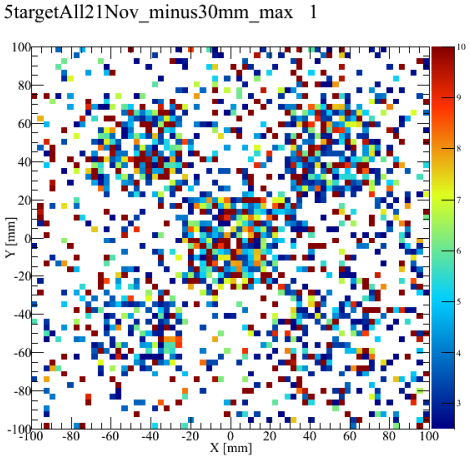






Point of Closest Approach (POCA) Reconstruction





Note: Preliminary detector alignment

Some Minor Problems

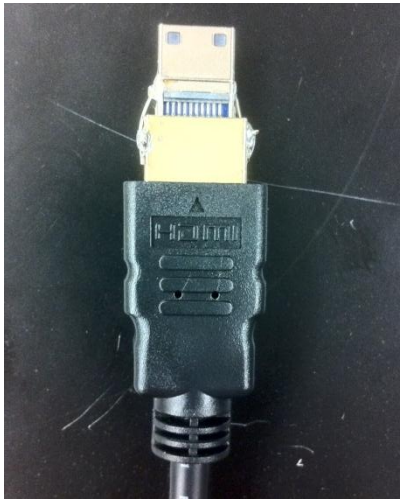
Networking

- Low-cost network switches are unable to support many FECs.
- 2 x Netgear JGS516 16-port switches currently used and can support a maximum of 4 FECs each.
- Issue not well understood.

Info	15:34:59	host206-118	readout	EQUIPMENT/s armed
Info	15:35:01	host206-118	runControlH	Start processes time : 9 seconds
Info	15:35:01	host206-118	runControlH	Current RC options loaded from : DATE_CONFIG
Info	15:35:03	host206-118	runControl	Starting Data Taking for run 522
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 8 instead 1 ... run continues
ERROR	15:35:06	host206-118	equipmentL	Event received by 2
ERROR	15:35:06	host206-118	equipmentL	Event received by 3
ERROR	15:35:06	host206-118	equipmentL	Event received by 5
ERROR	15:35:06	host206-118	equipmentL	Event received by 1
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 0 instead 2 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 1 instead 3 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 2 instead 4 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 3 instead 5 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 4 instead 6 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 5 instead 7 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 6 instead 8 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 7 instead 9 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 8 instead 10 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 9 instead 11 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 10 instead 12 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 11 instead 13 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 12 instead 14 ... run continues
ERROR	15:35:06	host206-118	equipmentL	PACKET ORDER MISMATCH (eqId 4) @ EV 0 received 13 instead 15 ... run continues

HDMI Cables

- Problem with HDMI channel mapping on APV hybrid identified.
- All HDMI cables are not the same!
- Inexpensive cables can be used, but it is important to test if they work with the system.



Some Minor Problems

Missing Triggers?

- Several data sets show some inconsistencies in the quality of the data.
- These data sets show anomalous station acceptance, and improper tracking information.
- The corruption of data can start randomly in the middle of a data set.
- This could be caused by one of the FECs missing a trigger.
- Several checks have been implemented in the firmware, but they are not perfect.
- Desychronization of FEC clocks makes it difficult to detect this problem reliably.
- For now we limit each run to 100k events to minimize the effect of bad data.

Summary and Outlook

We have successfully used the SRS to record data from eight 30 cm x 30 cm GEMs and processed this data to produce tomographic images of several high-Z scenarios.

SRS operation is stable for ~12k channel system, with a few caveats:

- Missing triggers (or packets) occasionally corrupt data
- Networking issue needs to be better understood

Zero suppression at the hardware level becomes very important for medium/large scale systems. We are very interested in testing zero suppression on the FPGA.

Clock/trigger fan-out unit may help with problem of corrupted data.