VMM “Wrapper” Implementation and Preliminary Results

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ATLAS sTGC Module-1 Characterization
Fermilab Test Beam Facility (FTBF), May 2014
James Botte – Update to BTTB Workshop, DESY
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Overview of Wrapper

- ***Motivation:***

  Want to use EUDET Telescope to perform tracking (4-7µm precision est.) through an ATLAS New Small Wheel small-strip Thin Gap Chamber (sTGC) prototype at the Fermilab Test Beam Facility.

- ***Problem:***

  Jack's Cards/VMM1 (VMM DAQ) do not have a busy signal and do not send event packet(s) if the VMM1 has no signals above threshold; however, we needed to interface them with the EUDET Telescope's Trigger Logic Unit (TLU) which requires a handshake with the DUT when it issues triggers.

- ***Solution:***

  Build a simple custom electronics board controlled by a hybrid Interface and Control System to perform the trigger/busy handshake, read out the TLU trigger number, receive VMM DAQ event packets, tag the events with the TLU trigger number, and forward the integrated VMM DAQ events so they can be positively correlated with EUDET Telescope tracks.

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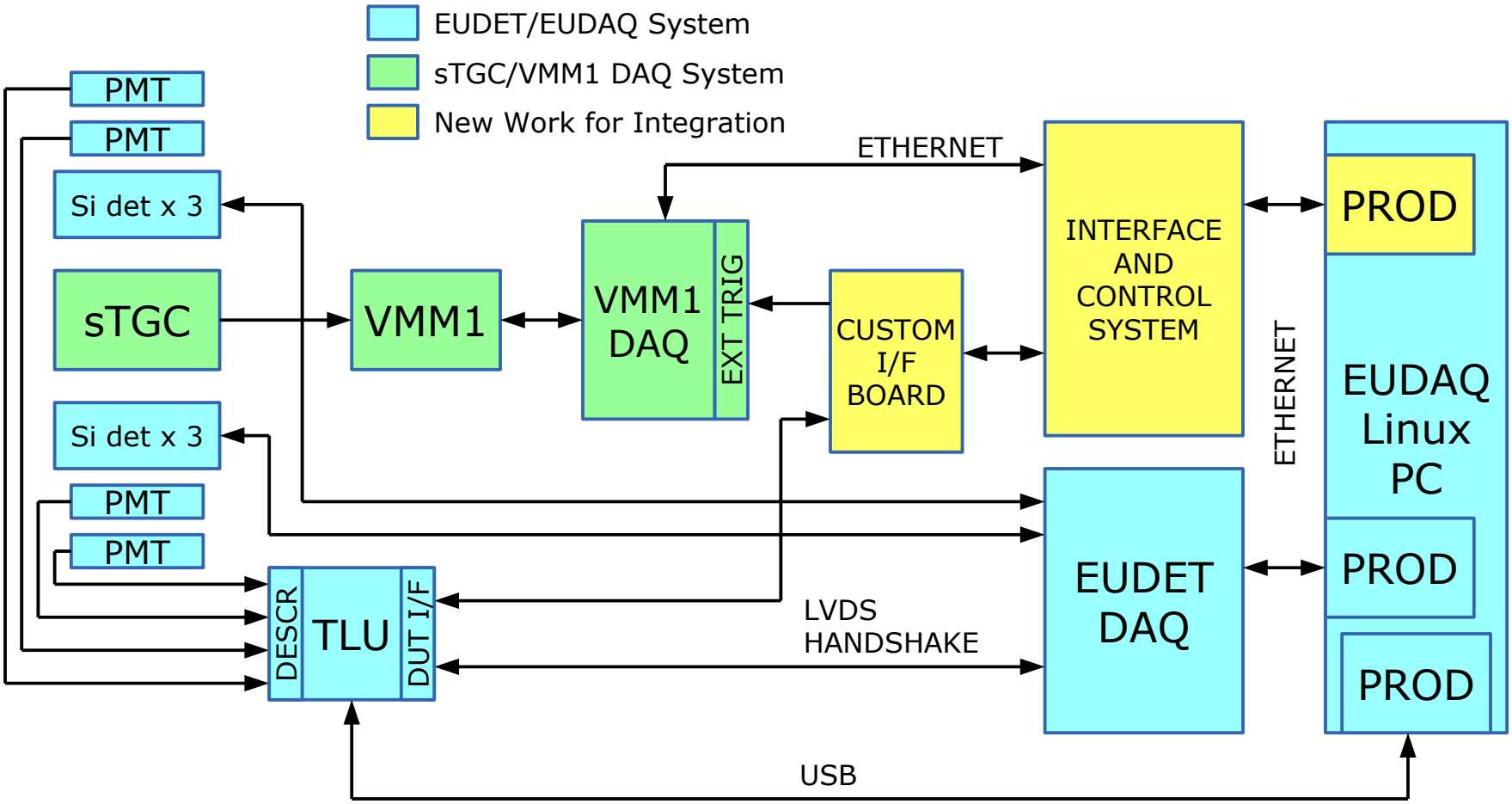
Wrapper Conceptual Diagram



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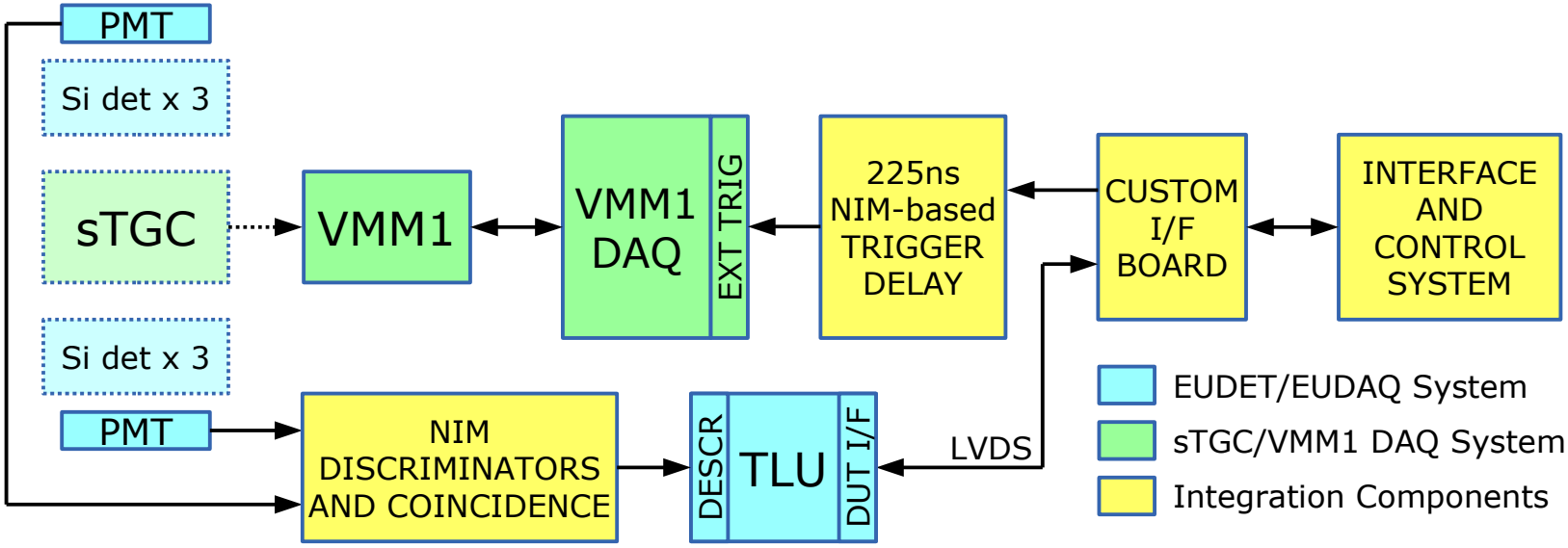
FTBF sTGC Trigger Implementation



- **Used standard NIM discriminators and two-fold coincidence to generate NIM-level trigger signal to TLU**
- **TLU generated a TRIGger signal to EUDET and the Custom I/F Board on PMT coincidence signal**
- **The TRIG signal was latched and used to immediately generate the BUSY signal back to the TLU as well as a 100-150ns TTL pulse sent to NIM electronics that cleaned up the signal pulse and delayed it 225ns to ensure enough of the beam spill had been received before the VMM1s were read out**

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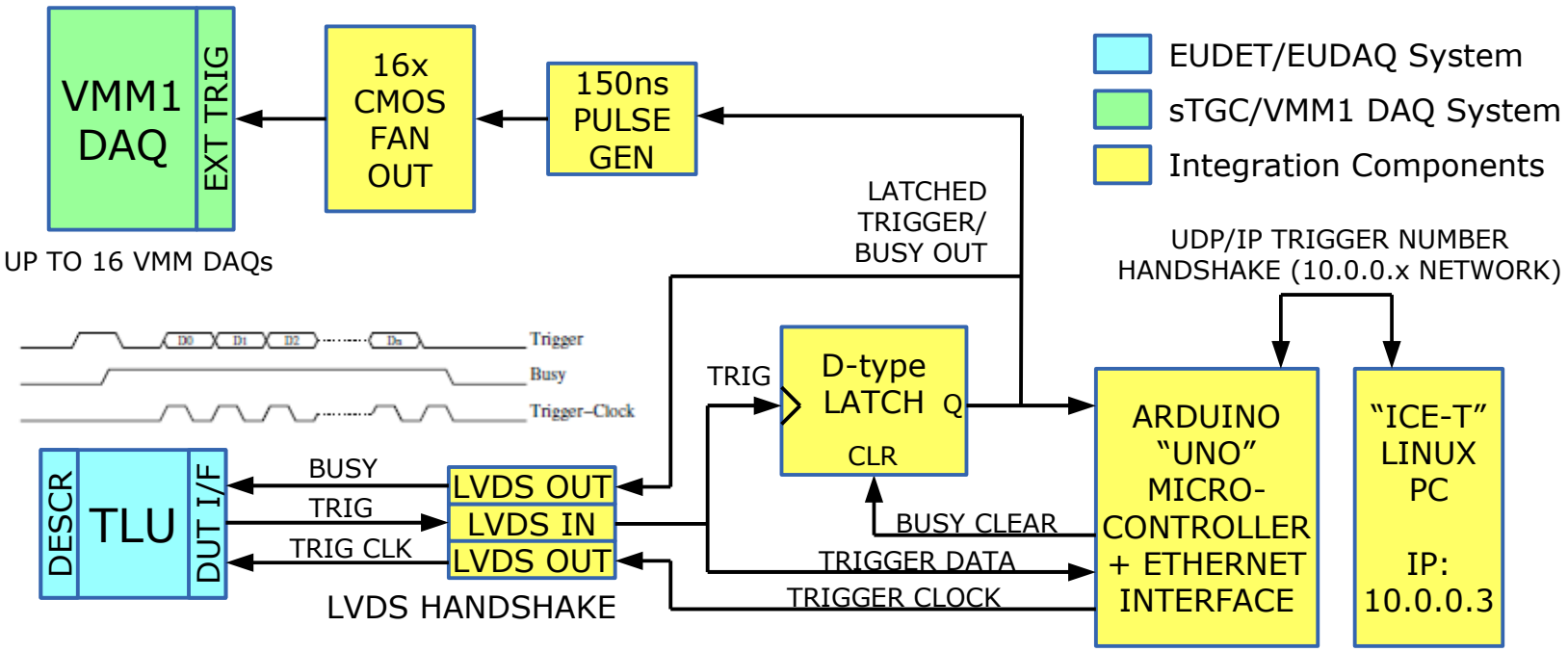
Custom VMM I/F Architecture



- **Latched Trigger/Busy signal generated immediately in hardware on receiving a Trigger signal from TLU**
- **Arduino microcontroller waited for Latched Trigger/Busy signal (from custom I/O board) in a tight loop, read out the TLU Trigger Number by toggling the Trigger Clock line to the TLU in software and reading the Trigger signal from the TLU (dual use as trigger and data line) after the clock line was toggled low**
- **Arduino waited until 300µs had gone by since the trigger and then sent a UDP packet with the TLU Trigger Count value to a Linux PC via Ethernet, waited until it received an acknowledgement UDP packet, then toggled a signal to clear the Latched Trigger/Busy signal to arm the system to accept the next trigger**

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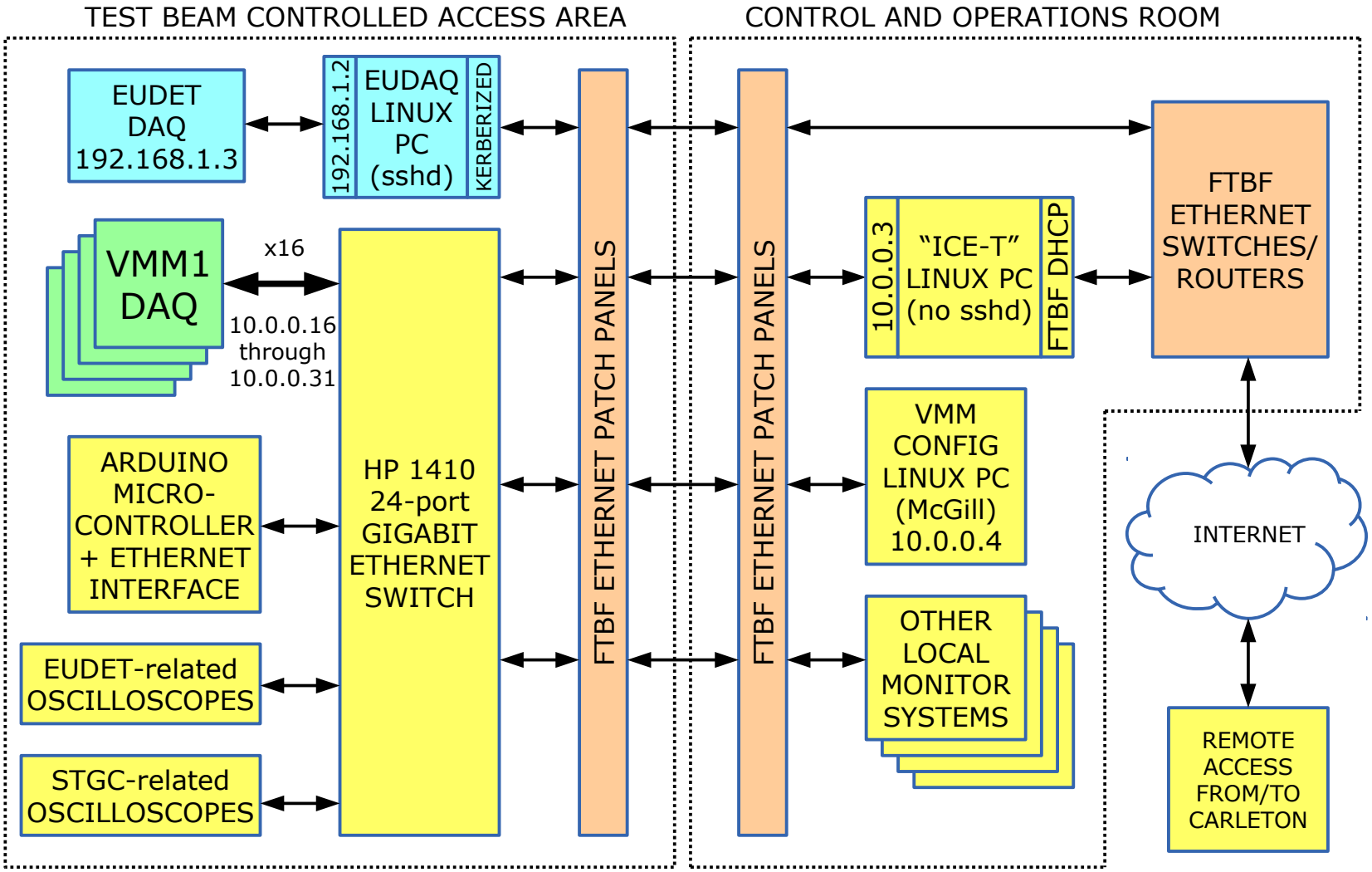
Ad Hoc FTBF Network Architecture



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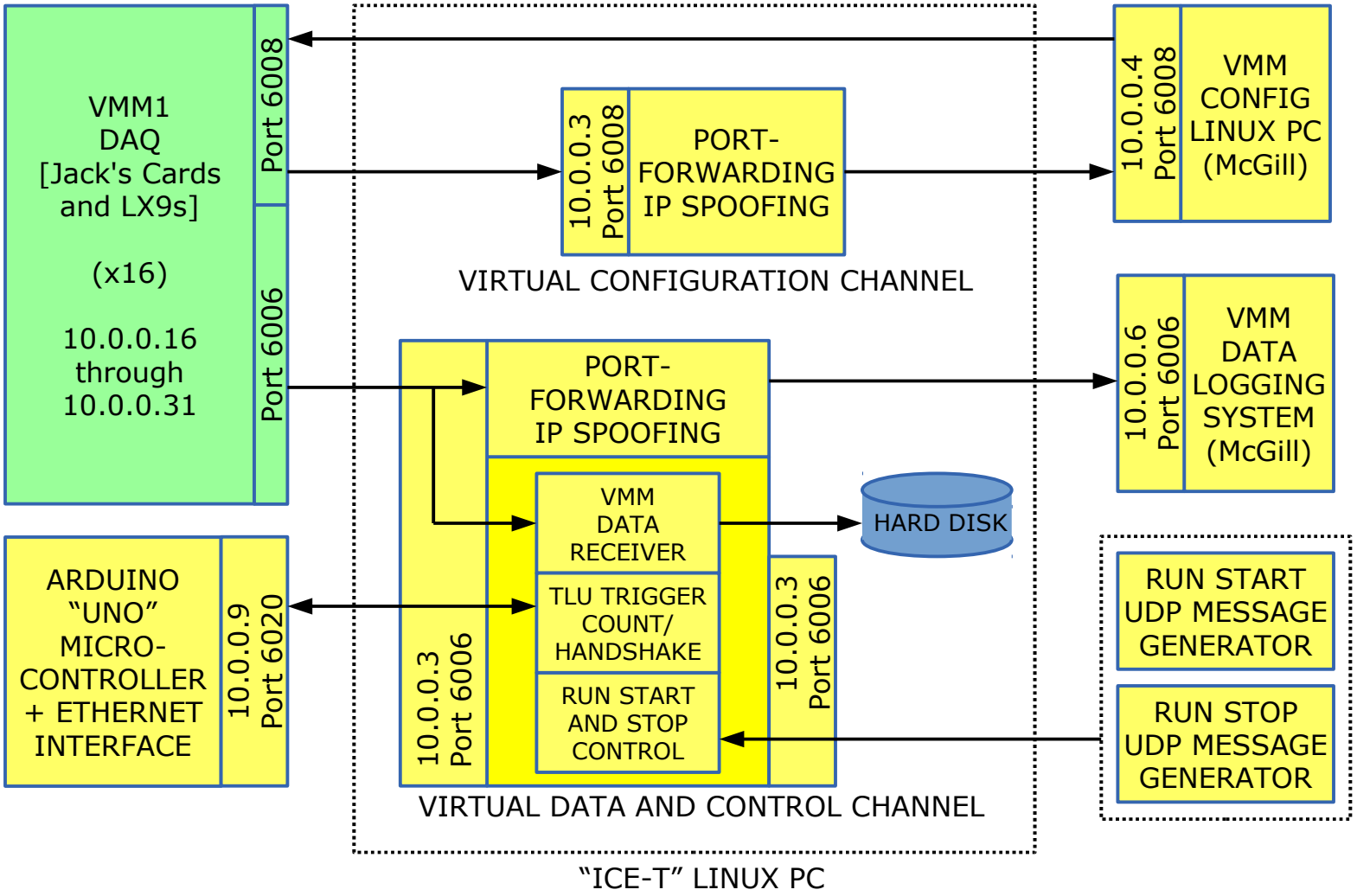
"ICE-T" System Architecture

"ICE-T": "Integrated Collection Electronics – for Testbeam" (a bad wrapper)



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"ICE-T" Packet Spoofing/Forwarding

- The Jack's Cards/LX9-based VMM1 DAQ systems could only send packets to IP address 10.0.0.3 (port 6006 for data, port 6008 for configuration acknowledgements)
- Code was developed that could receive UDP packets sent to a specified port on a host at IP address 10.0.0.3, explicitly create a spoofed UDP/IP packet with the address of the VMM1 DAQ system (10.0.0.16 through 10.0.0.31) that had sent it, then forward it to an arbitrary IP address and port number
- This allowed a computer (not 10.0.0.3) to run either the VMMDCS configurator software or the new configuration file-based configurator developed at McGill and not be able to detect that it is not talking directly to the VMM1 DAQ cards
- Note: because the configurator programs used UDP broadcast, the IP address of the configurator computer could be specified and packets received from that computer would not be forwarded back to the configurator computer (which could not handle it)
- By decoupling the configuration channel from the data channel through this packet spoofing/forwarding system, it was possible to implement the ICE-T wrapper infrastructure on the 10.0.0.3 computer and run the configurator on another one
- A second instance of the packet spoofer/forwarder was run that enabled additional features to implement the wrapper functionality, save the VMM data, and forward the VMM data packets to yet another arbitrary system (e..g runnnig VMMDCS)

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"ICE-T" VMM Data Collection

- The Virtual Data and Control Channel software was run continuously on the ICE-T Linux PC and would forward spoofed packets (so it would look like the VMM DAQs had sent them) to an arbitrary IP address/port for monitoring and test purposes
- When an integrated data taking run with the EUDET system was desired, a program was invoked that sent a specially formatted UDP packet with the manually specified run number – the ICE-T software would be primed for data taking; however, no triggers would be issued until EUDAQ was started initialized the TLU
- The ICE-T system continued to immediately forward every packet to the VMM DAQ monitoring computer (from McGill), but would also buffer all UDP packets received from the VMM DAQ cards until the Arduino (300µs after the trigger) would send the UDP packet with the TLU Trigger Count for that event, and then all the buffered VMM data was saved together as a single event – tagged with the TLU Trigger Count so the data streams could be reliably merged (the two streams were synchronized)
- The VMM data logging would continue until the ICE-T system received another special packet from another program to stop the run
- The VMM data would be stored in a file with the name "vmmNNNNN.raw" to emulate the file name of the EUDAQ raw data files, where NNNNN was the run number
- A program was written and distributed to read the VMM raw format data files

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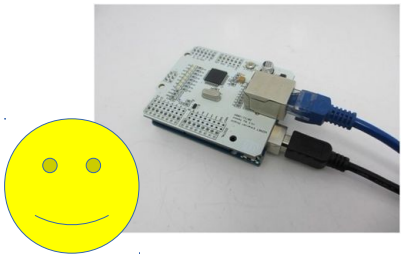
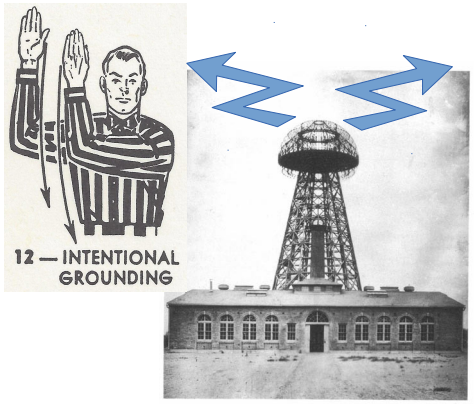
Harsh Lessons Learned at the FTBF

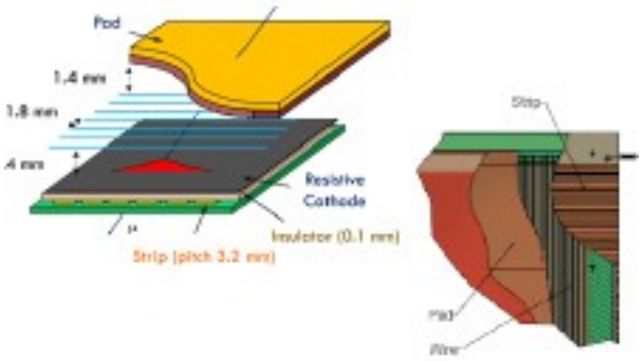




- **Replacing a $18,000 National Instruments 2.26 GHz Quad-Core Labview DAQ system with a $55 16MHz Arduino Uno (purchased and developed at the last minute from Radio Shack in desperation) allowed us to take synchronized data from both the EUDET telescope (high-precision tracking) and the sTGC (DUT). The NI system and their technical support were serious, and near disastrous, impediments to success.**
- **When interconnecting diverse systems from multiple groups, do not neglect to learn what grounding facilities are available at the test beam and coordinate between groups to ensure a unified strategy is developed ahead of time.**
- **16 cables driven by an array of high-performance and high-current single-ended LVCMOS drivers (74LVCU04A) left unconnected on one end and draped along the side of an sTGC makes for a formidable broadband radio frequency emission system that no Faraday cage can withstand.**
- **The EUDET Telescope's Trigger Logic Unit (TLU) discriminators are *not* useful, use NIM electronics instead and feed the coincidence signal into TLU discriminator input(s)**

sTGC Design

Primary Trigger Detector-sTGC

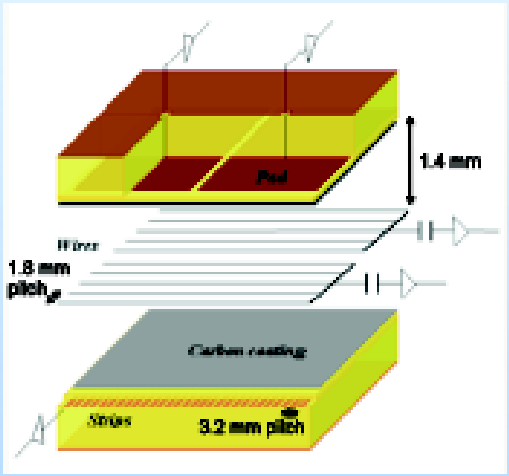


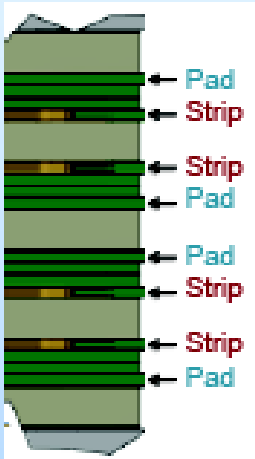
Single sTGC detector structure

sTGC basic parameters	
Cathode-anode spacing	1.4 mm
Wire spacing	1.8 mm
Cathode resistivity	100-200 kΩ/□
Strip width/ pitch	2.7/ 3.2 mm
Cathode-strip layers spacing	0.1 mm

Small-Strip Thin Gap Chambers

Each module is built with 4 gaps each containing:
Strips, wires, pads
Important to measure the angle of the muon trajectory: need high resolution on the strips





Source: Lian Guan, University of Michigan; E. Perez Codina, TRIUMF

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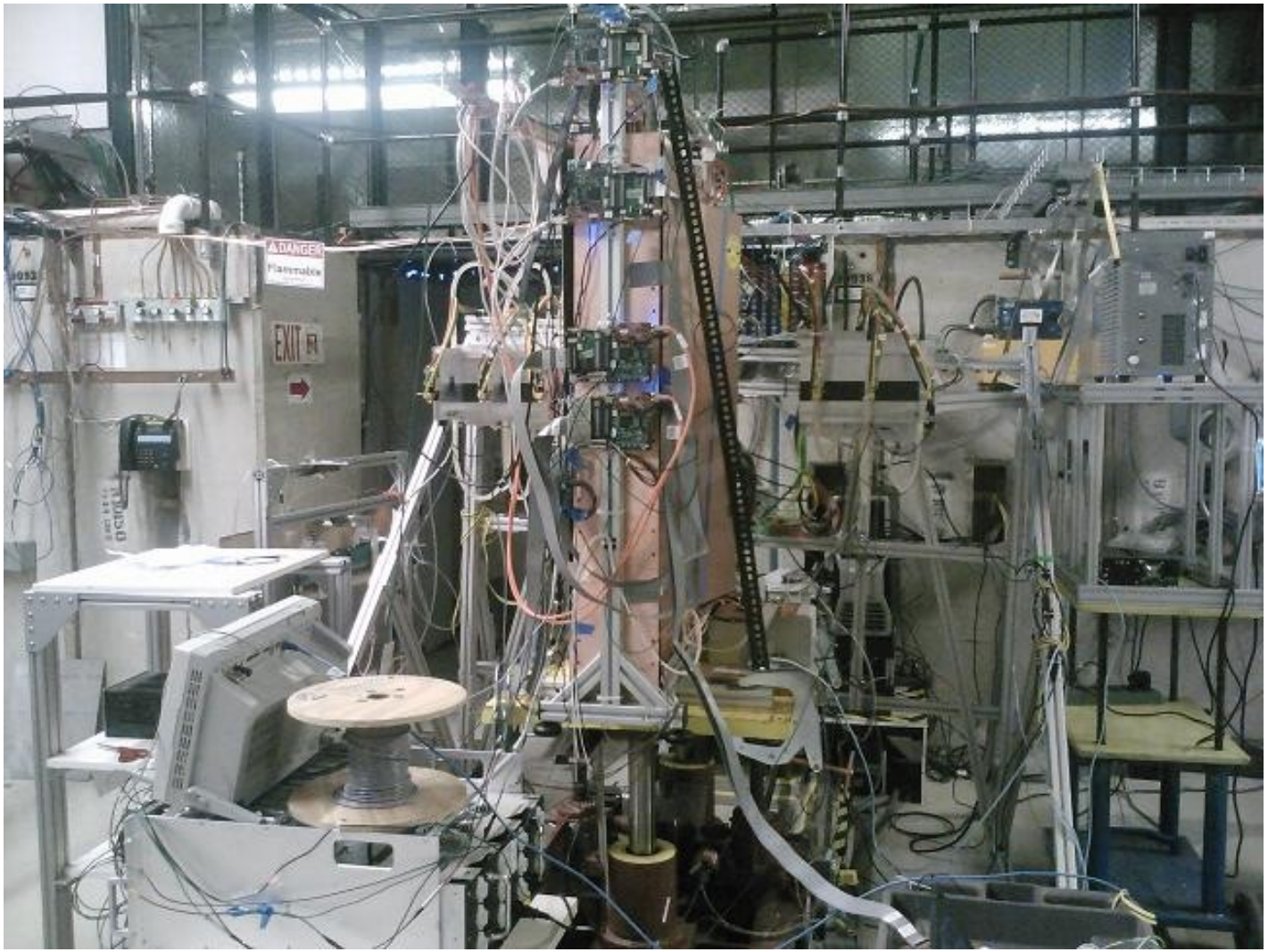
sTGC Configuration at FTBF



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Adding 40x60cm Carleton Chamber

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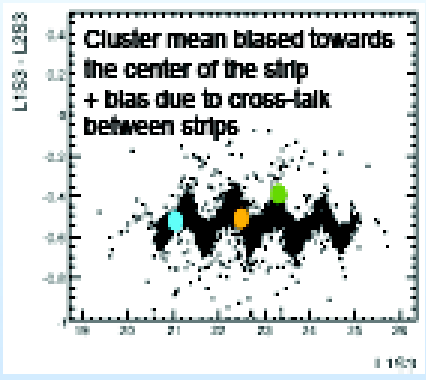
Early Results (Weeks After FTBF)

Corrections

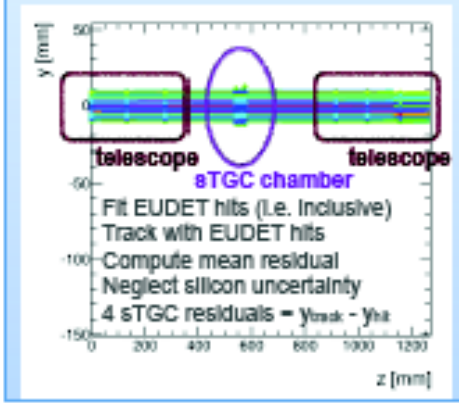


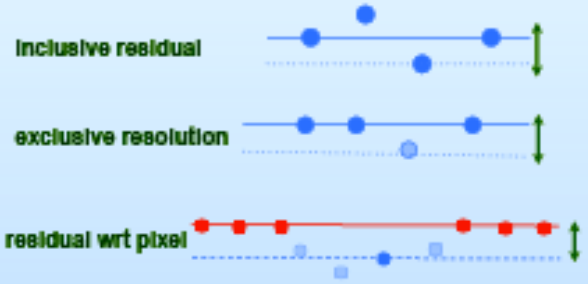
- Clean-up using timing information
- Layers shifted by half a strip
- Single cluster per layer
- Pedestals subtraction
- Cluster shape
- Correct residuals for S-shape (bias towards strip center)

Preliminary Resolution

Layer (Module -1)	1	2	3	4
inclusive residual [μm]	43 ± 1 μm	62 ± 1 μm	84 ± 1 μm	54 ± 1 μm
exclusive residual [μm]	139 ± 2 μm	88 ± 1 μm	119 ± 2 μm	175 ± 3 μm
resolution [μm]	80 ± 2 μm	70 ± 1 μm	100 ± 2 μm	100 ± 3 μm

$\sigma = \sqrt{(\sigma_{inc} \times \sigma_{exc})}$





To be able to extract the resolution from sTGC+Telescope combined data we need to take into account multiple scattering and relative misalignment

Source: E. Perez Codina, TRIUMF

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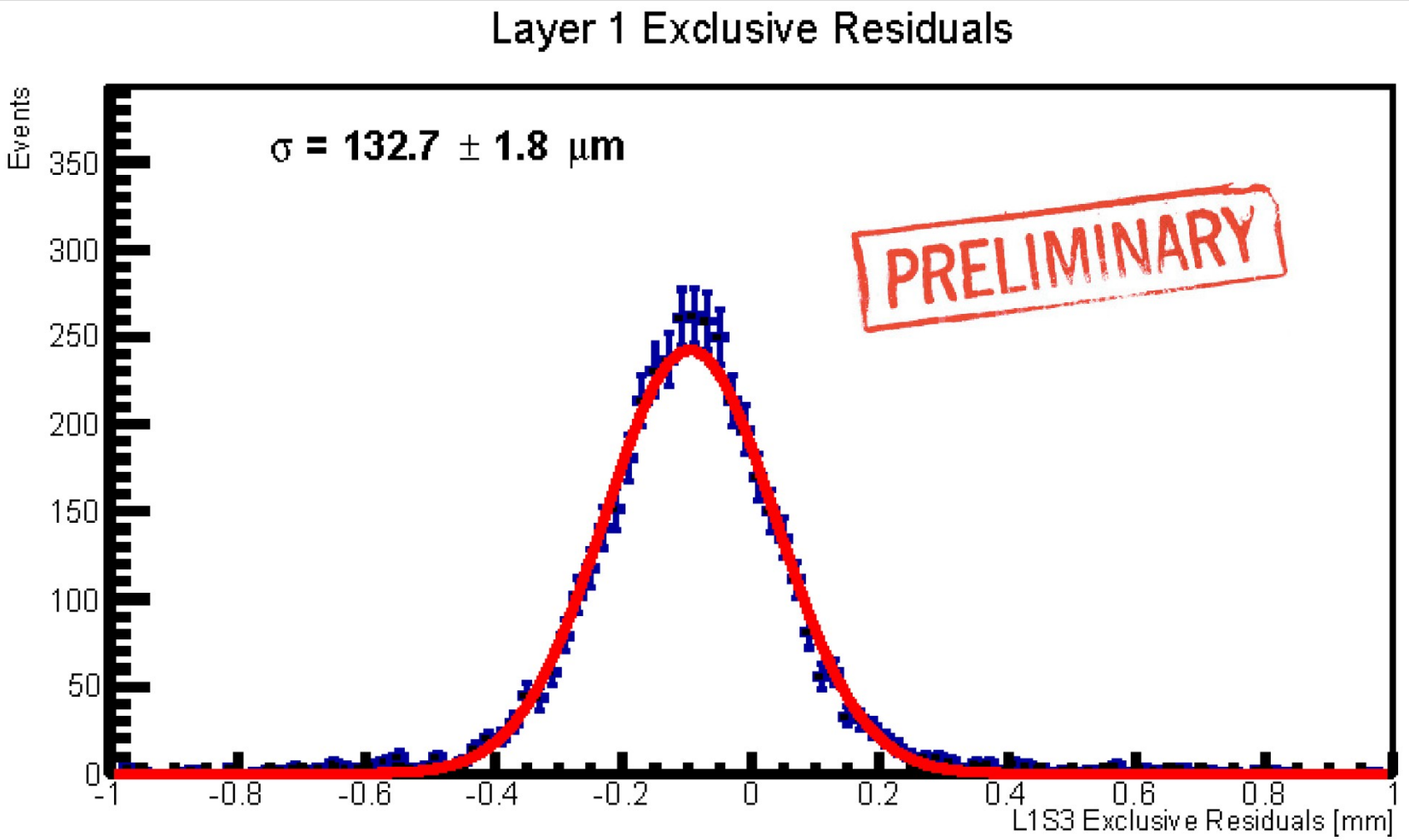
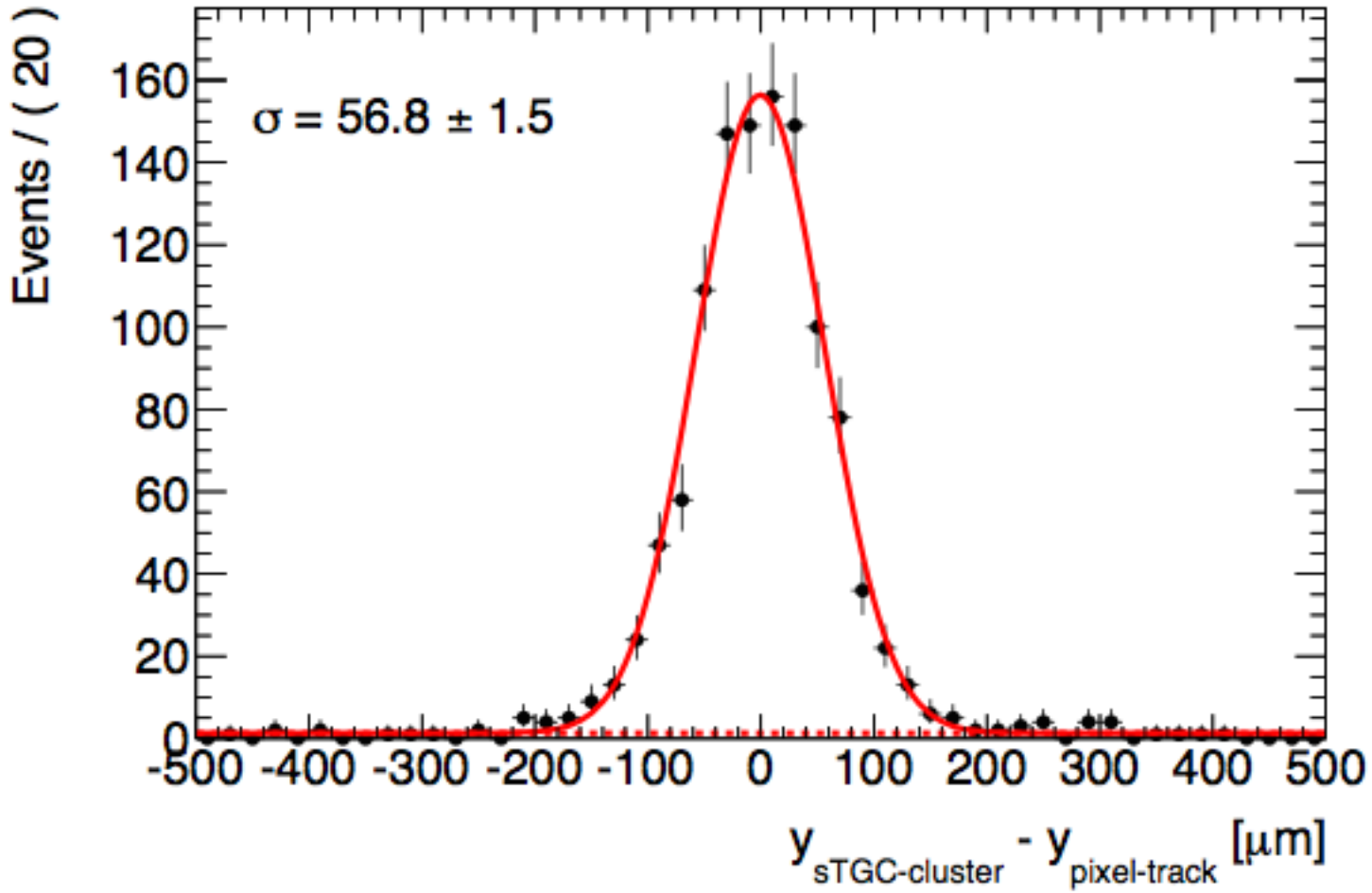
Current Public Preliminary Results



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/NSWPublicResults

Including EUDET Telescope Data



https://twiki.cern.ch/twiki/bin/view/AtlasPublic/NSWPublicResults

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Test Beam T-1049 Survivors