Status of GEM Trackers for GMn:

Response to the ERR charge

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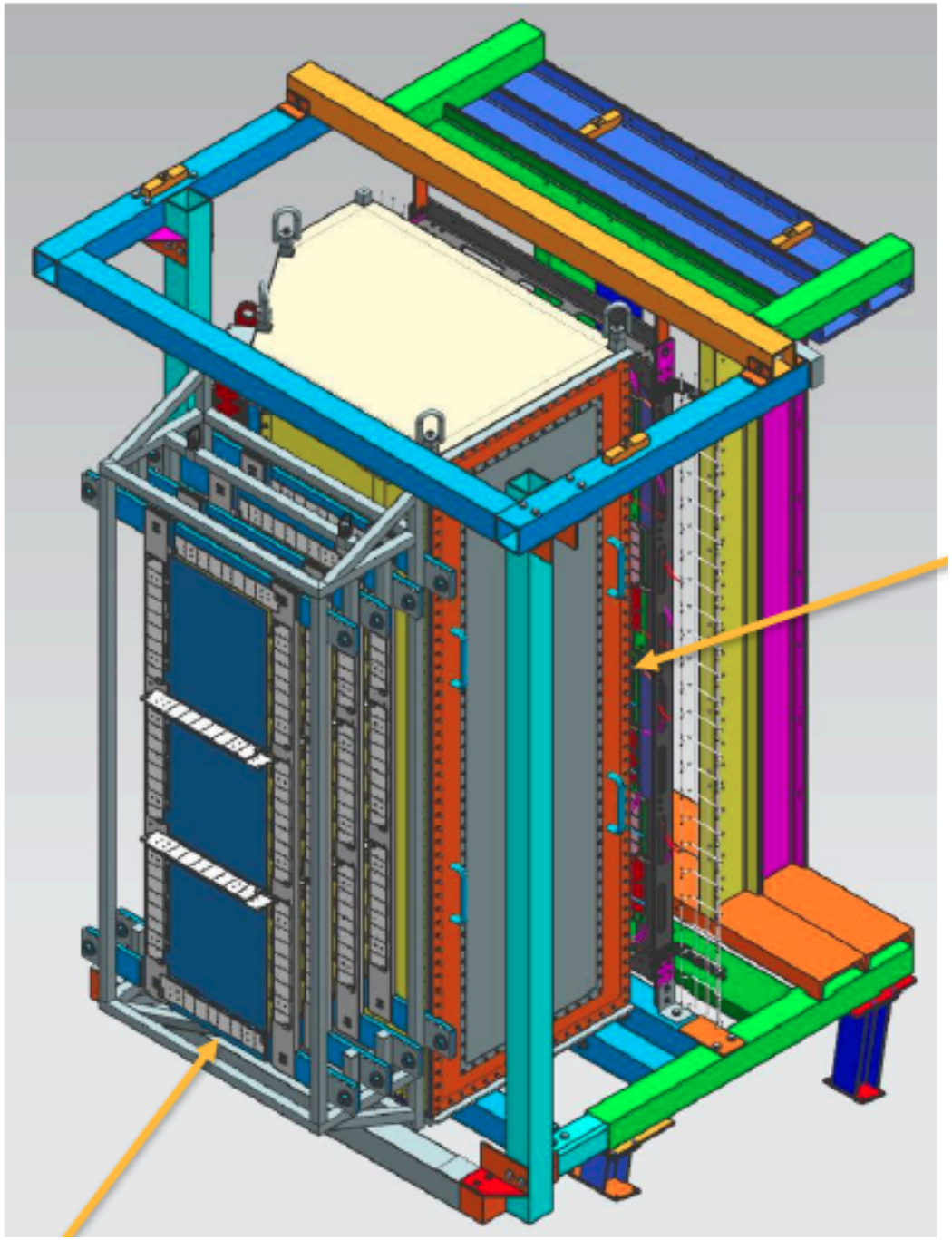
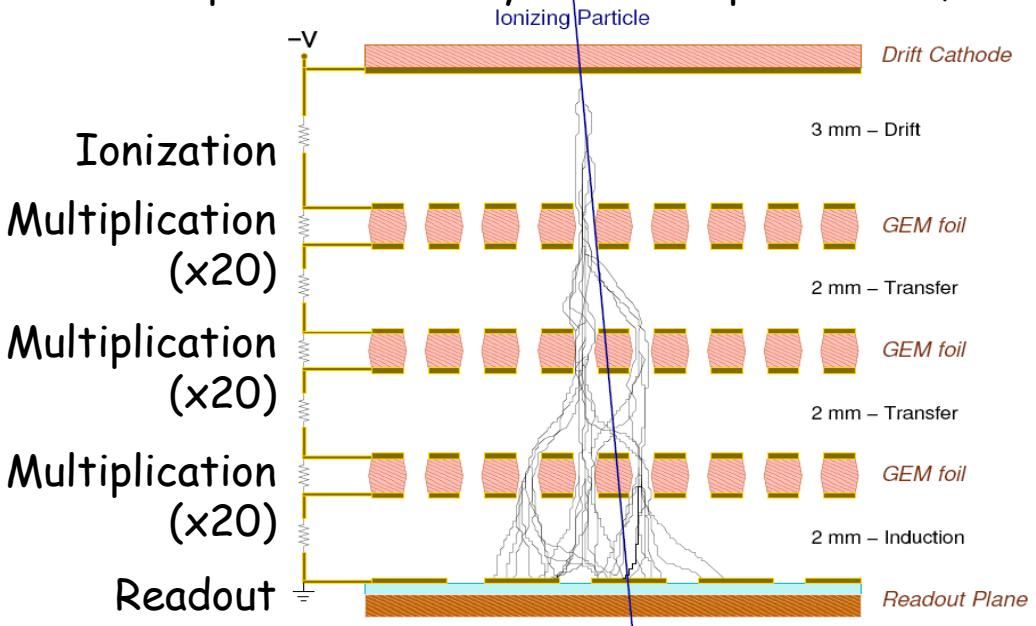
University of Virginia

Bigbite Spectrometer for the GMn experiment

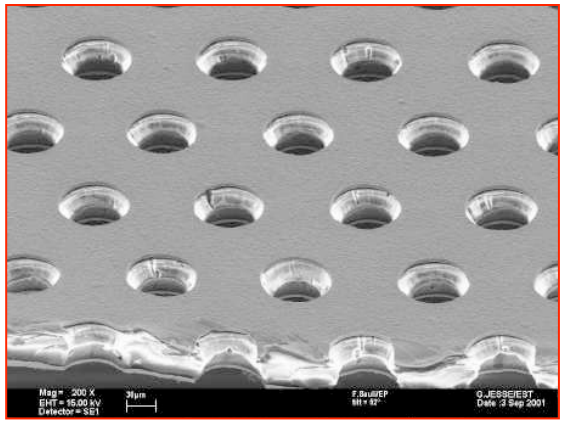


Why GEMs ?

- Bigbite and Super Bigbite Spectrometer concept leads to high rate in trackers: and requires good resolution.
- Gas Electron Multiplier (GEM) detectors provide a cost effective solution for high resolution tracking under high rates over large areas.
  - Rate capabilities higher than many MHz/cm^2
  - High position resolution (< 75 μm)
  - Ability to cover very large areas (10s – 100s of m^2) at modest cost.
  - Low thickness (~ 0.5% radiation length)
  - Already Used for many experiments around the world: COMPASS, Bonus, KLOE, TOTEM, STAR FGT, ALICE TPC, pRad etc.
  - And planed for many future experiments:, CMS upgrade, SoLID, Moller, P2 @ Mainz

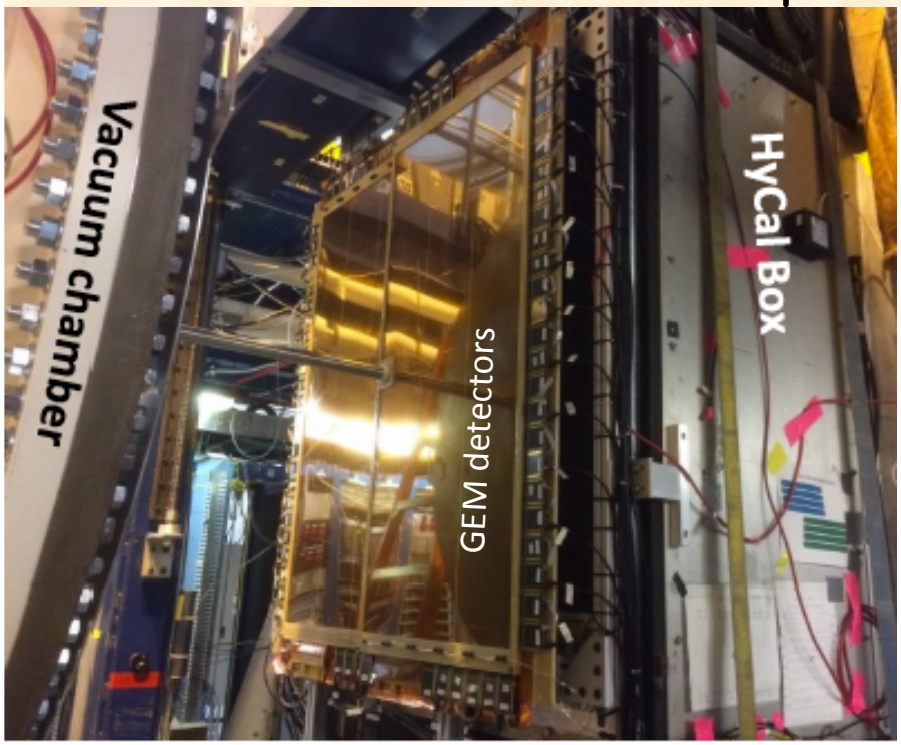


GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch

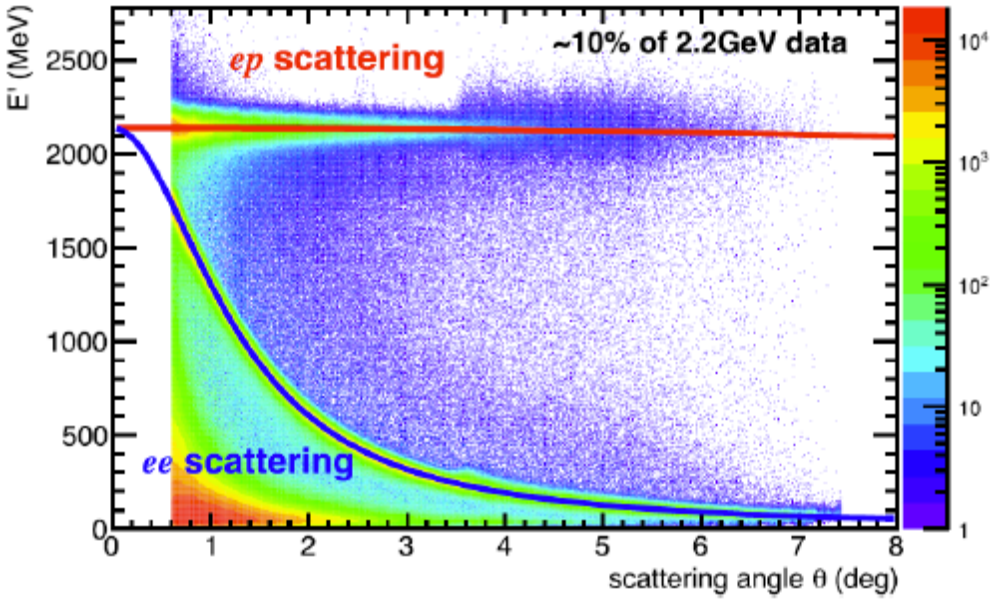


Novel technology: F. Sauli, Nucl. Instrum. Methods A386(1997)531

pRad GEMs

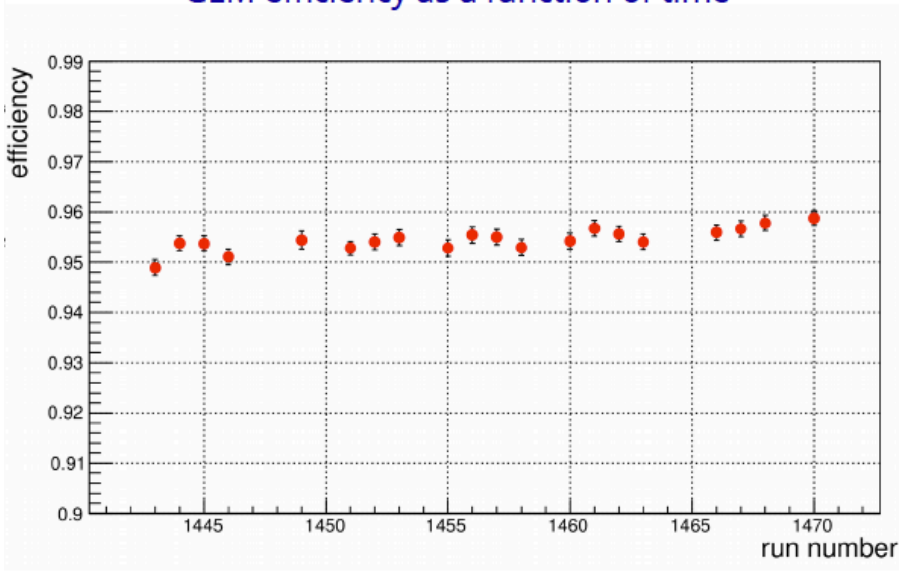


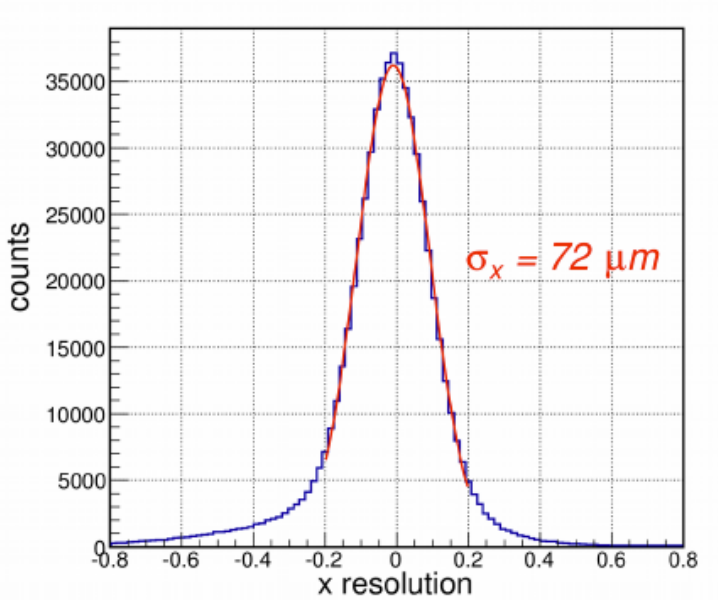
Using coordinates from GEM detectors, and energy from calorimeter.



2.2 GeV beam

GEM efficiency as a function of time





Status of the GEMs for GMn

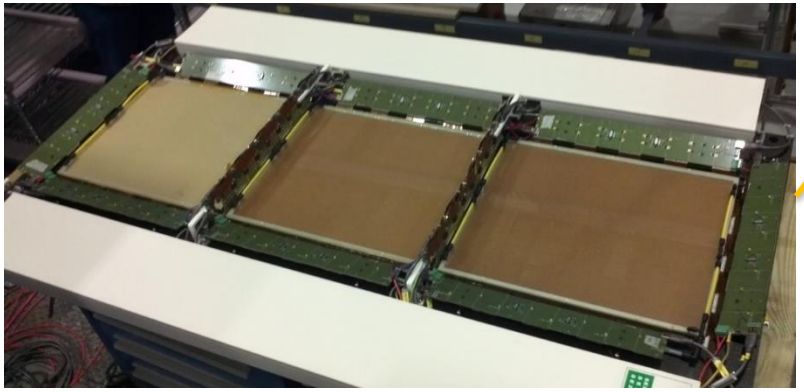
GMn GEM Tracker: 4 layers (INFN GEM modules)

- INFN groups at Roma, Catania, Genoa and Bari
- Required a total 12 modules, each layer (150 cm x 40 cm) made of 3 INFN modules.
- Italian group have already built 16 modules: 5 more will be built
- 2 chambers (modules + frames + FE electronics) already delivered @ JLab
- Other 2 remaining chambers on their way

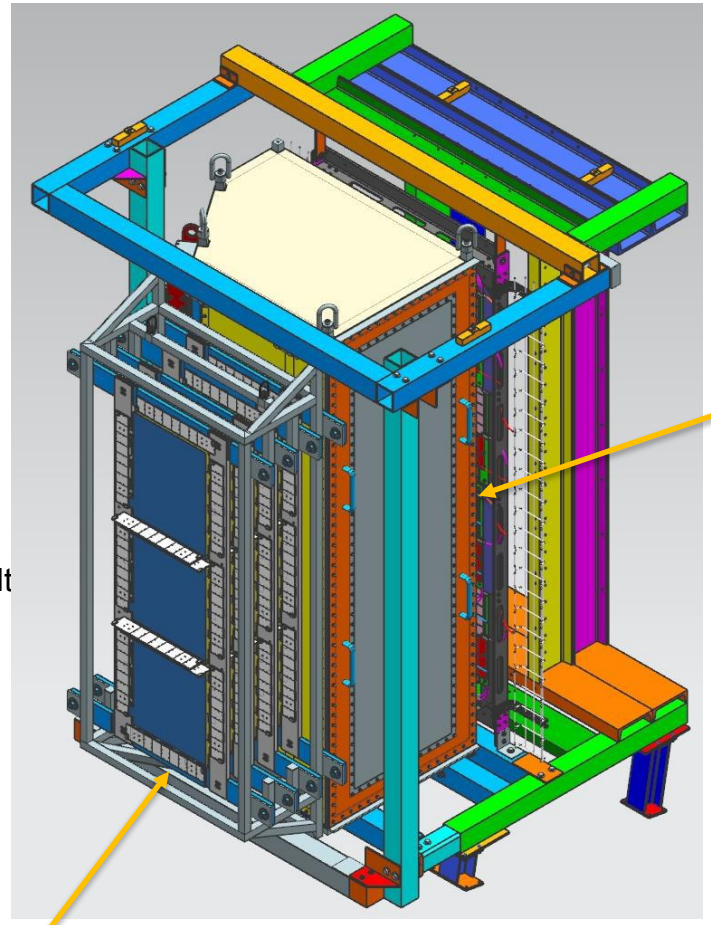
One additional layer behind the GRINCH detector:

- Back layer (200 cm x 50 cm) made of 4 UVa modules
- More than 42 UVa modules avaliable: 6 more will be built
- Module migration to JLab to start in June
- The Aluminum frame has been built and tested with modules @ UVa

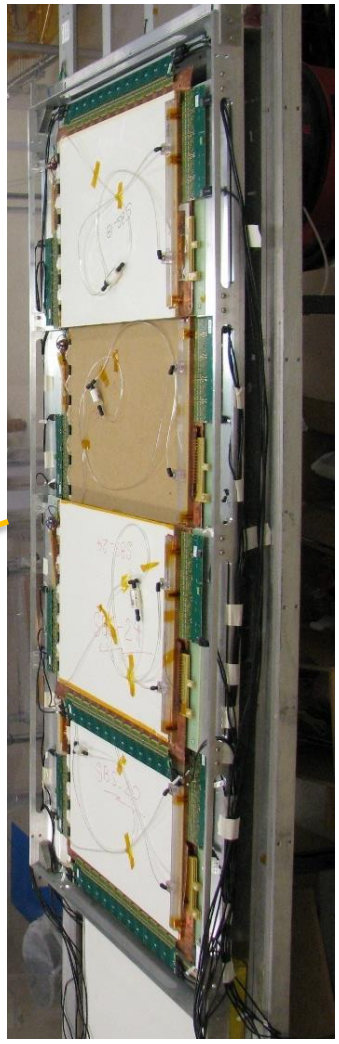
One layer of the Front Tracker GEM chamber



Bigbite Spectrometer for the GMn experiment



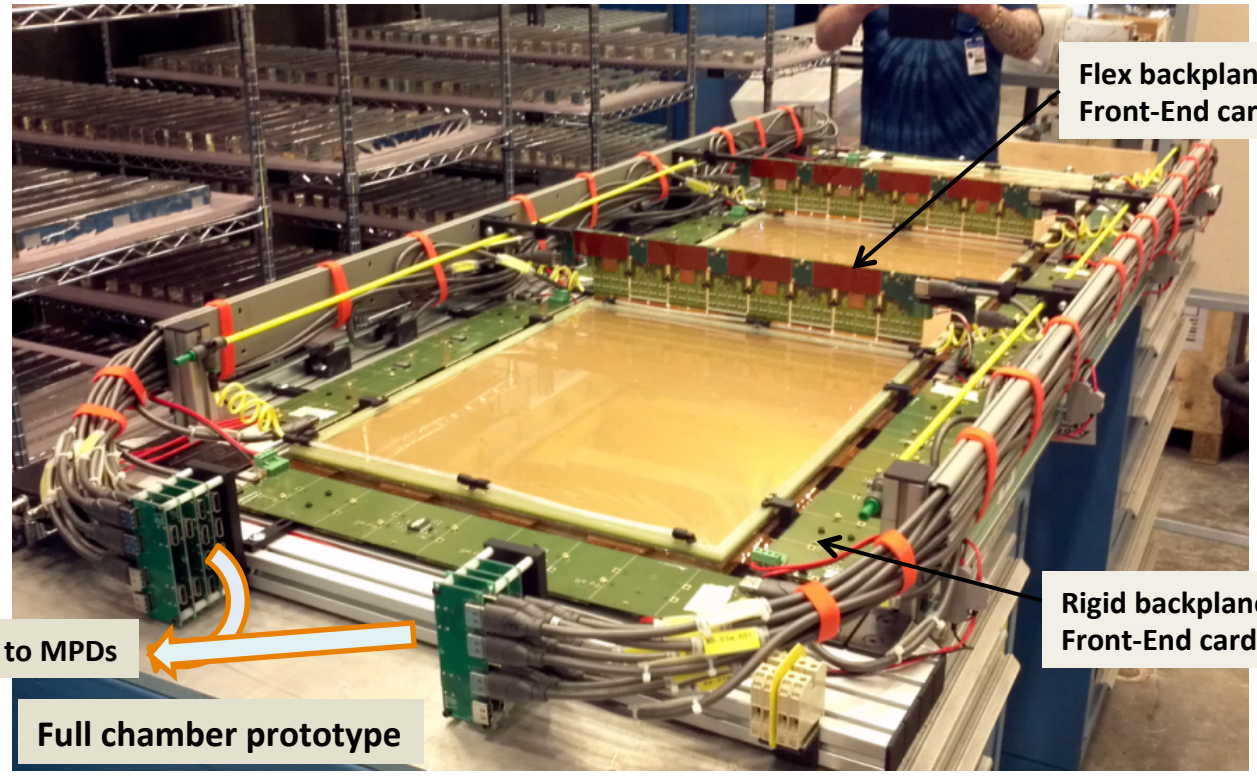
Rear GEM chamber

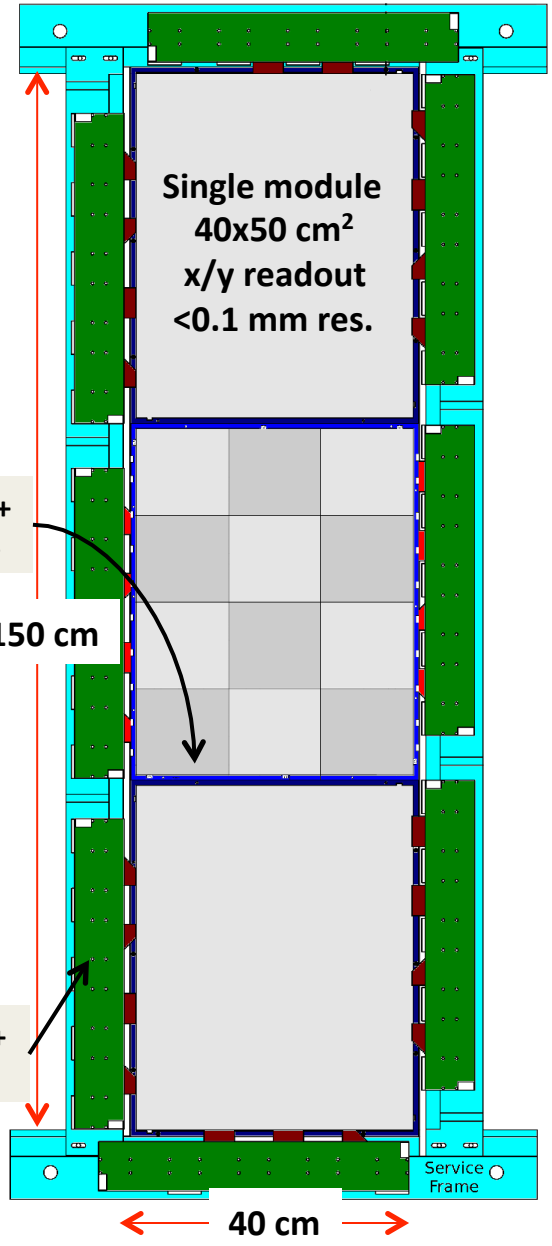


- Setting the cosmic stand for characterization and commissionning of the GMn tracker

Front Tracker – Full Chamber

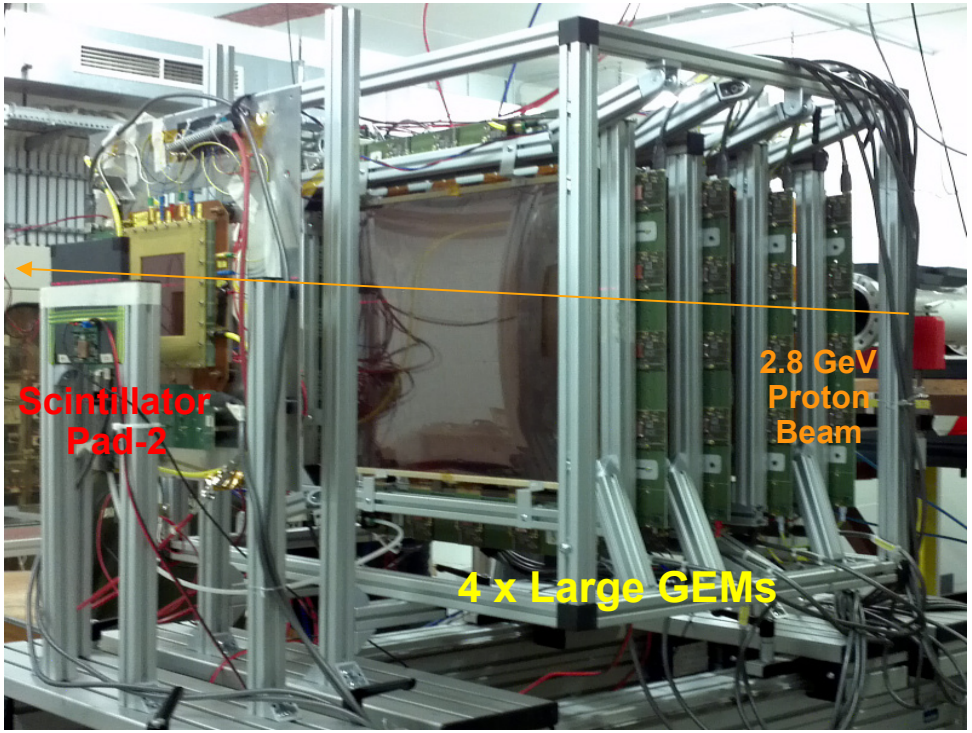
- **Spatial resolution < 0.1 mm; high radiation tolerance**
- 150x40 cm^2 chambers with small dead area (~10%)
- Each chamber consists of 3x 50x40 cm^2 lightweight 3xGEM modules with **x/y strip readout** (0.4 mm pitch)
- Readout electronics based on high channel density APV25 ASIC driven by VME64x modules (total channels 41472)

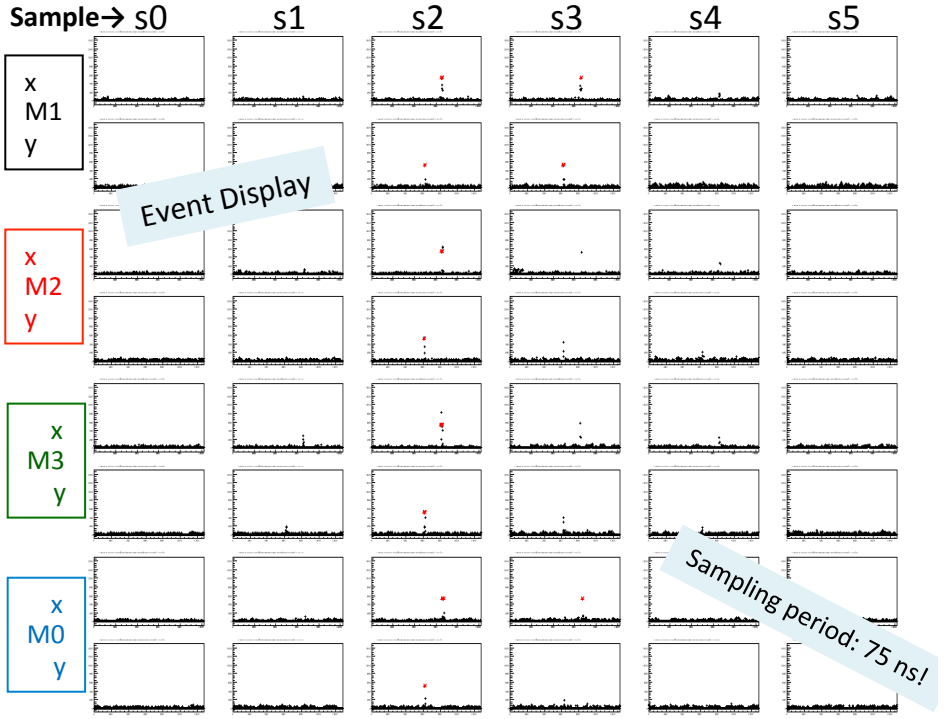




FT - High Intensity Proton Beam (Julich/COSY) Test

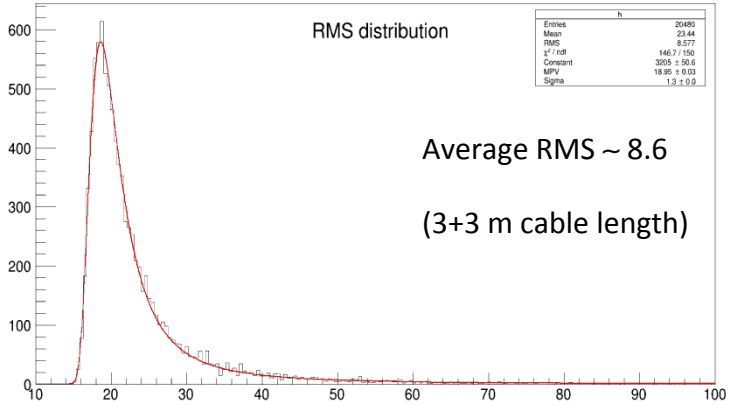
Beam Intensity: 1.4x10^9 p/bunch ~ **1 Mp/s/cm2**; beam position: module center



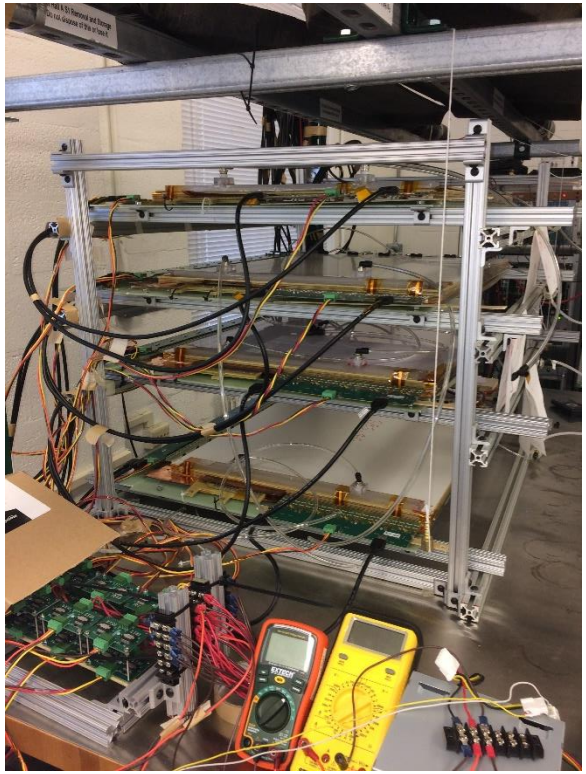


- Study GEM response in high intensity proton beam (small spot ~ few cm^2)
- Use different HV dividers on each module
- Investigate HV and gas flow

- Efficiency slightly affected by the high beam intensity
- No noticeable effects from gas flow rate



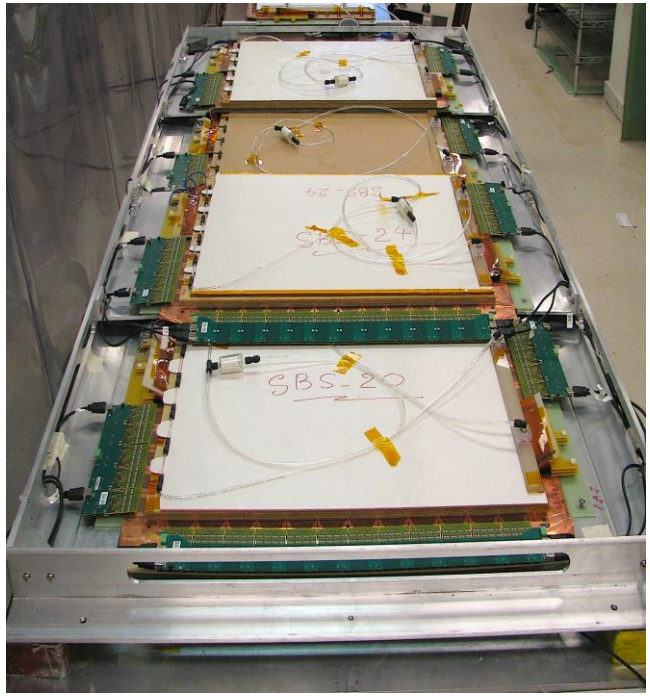
Back Tracker GEMs



Production status

- 42 modules built and tested so far
  - ⇨ 40 modules 100% operational
  - ⇨ 2 modules have one bad sector ⇨ (97% active area operational)
  - ⇨ **Six spare modules in the queue for assembly, Expected by Aug 2017**
- UVa Comic stand with full MPD electronics for 4 modules
  - ⇨ Use to test newly built modules
  - ⇨ Additional test of the modules before shipment to JLab to define working HV
- Prototype of mounting frame for BT GEM layers assembled and tested

H. Nguyen's Talk @ MPGD2017: https://indico.cern.ch/event/581417/contributions/2556718/attachments/1464747/2263931/HuongNguyen_MPGD2017.pdf



Migration of UVa modules to JLab

- 5 modules currently at JLab since 2016
  - ⇨ Danning's high rate tests in Hall A
  - ⇨ Probably for another high rate test team this fall in Hall C for
- Planning to move 4 more modules in June 2017
  - ⇨ Test the chamber on the cosmic stand in June-July
- Migration of all modules to JLab will start August 2017
  - ⇨ Modules will stored at in the GEM clean room space

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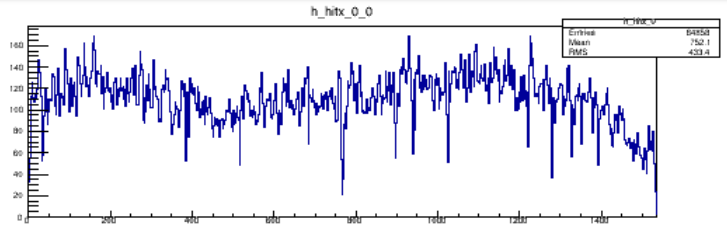
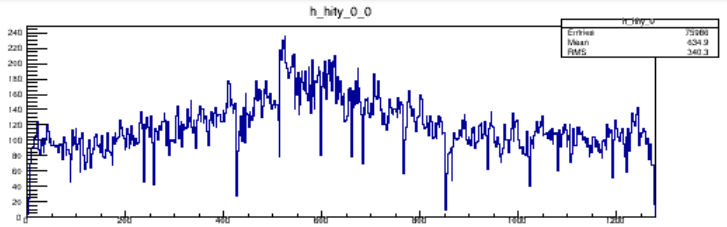
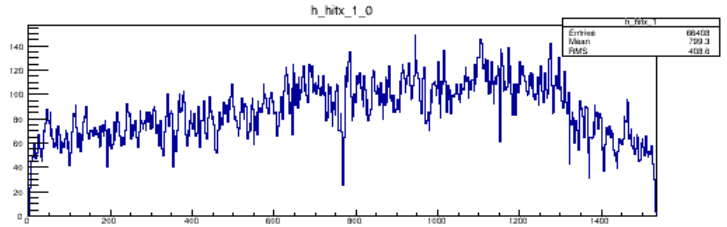
Beam Test in Hall A

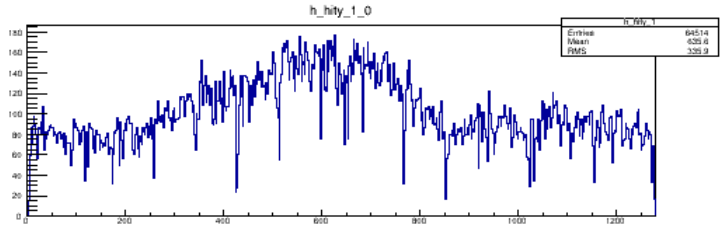
- Fall 2016
- Five modules separated by 10 cm each: very similar to a SBS tracker.
- Triggered by a lead-glass matrix at center
- Goals: Identify good tracks in a high rate background, study effectiveness of timing and charge correlation cuts to suppress background
- Placed at 70°, occupancy is ~ 1%, similar range as expected for GMn

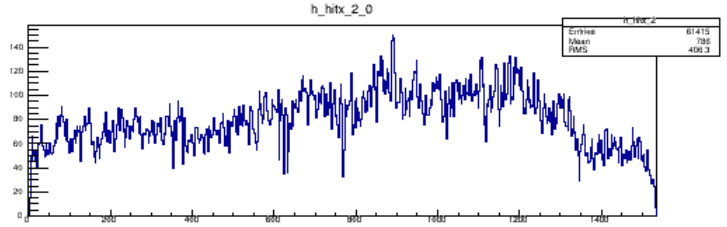
Beam Test in Hall A

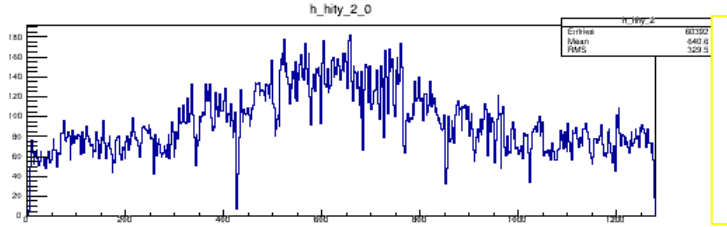


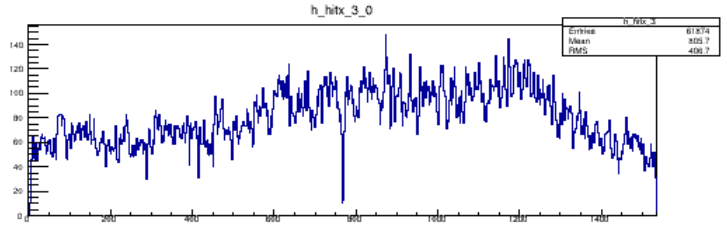


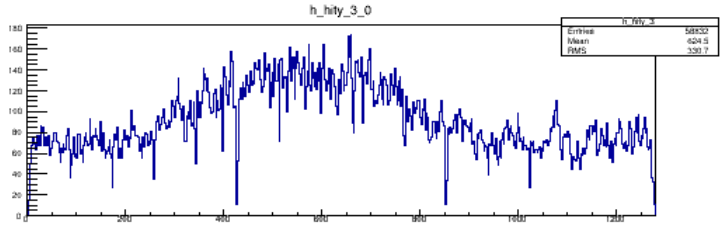


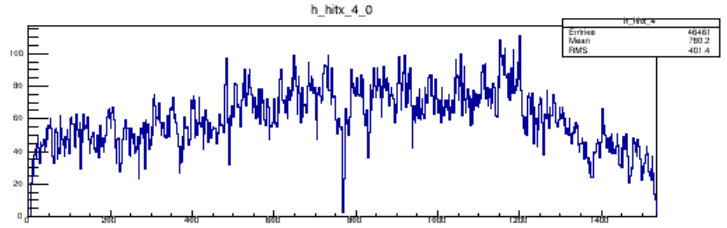


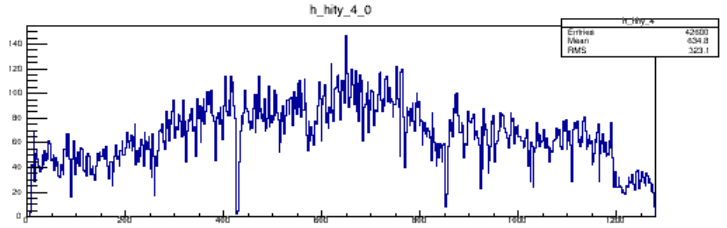






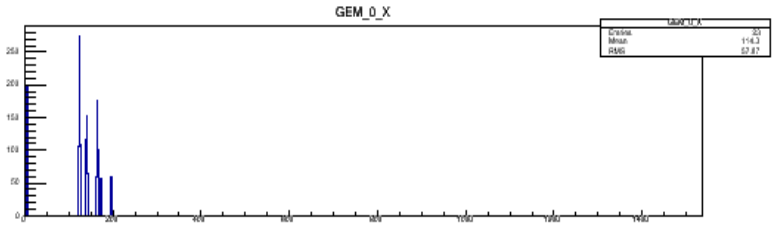


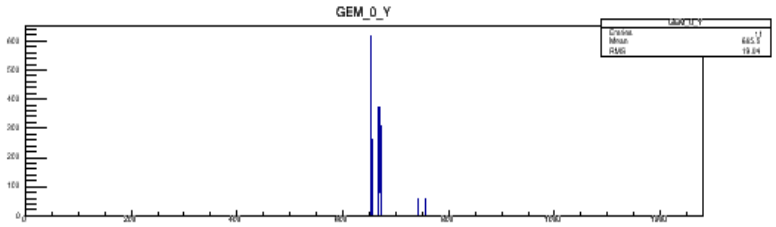


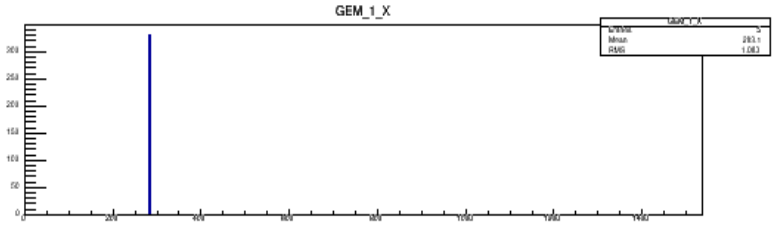


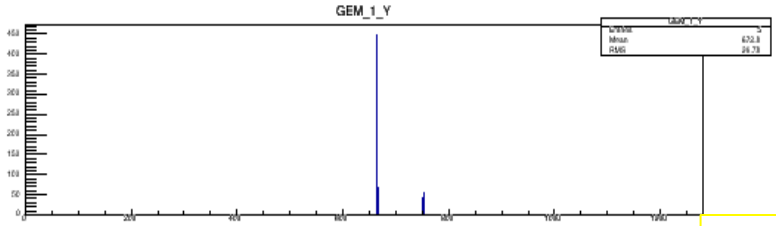
1 D hit distributions

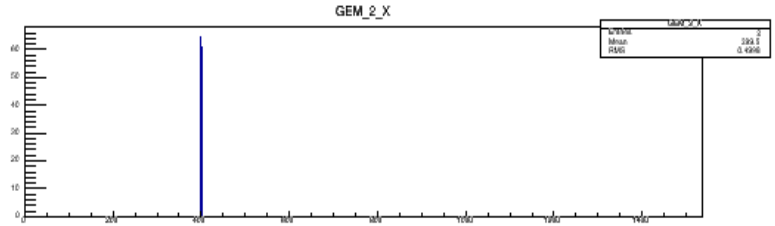
Beam Test in Hall A

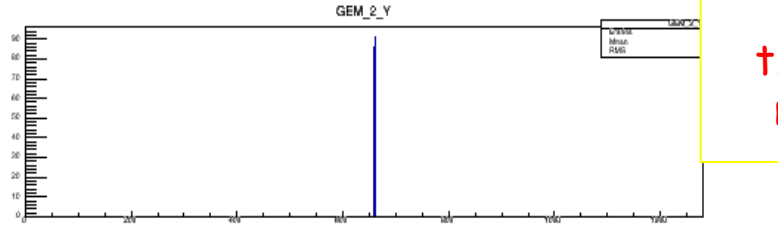


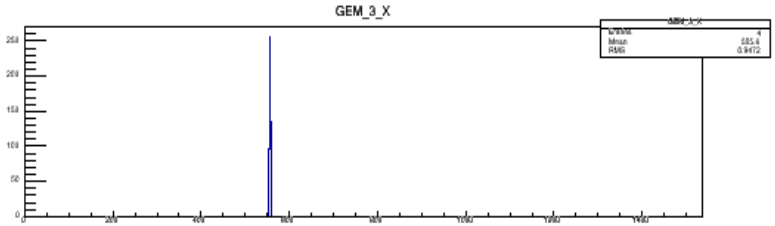


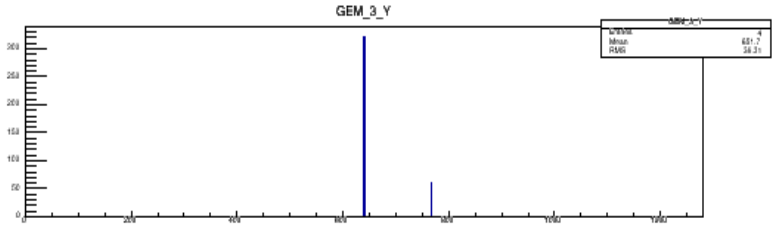


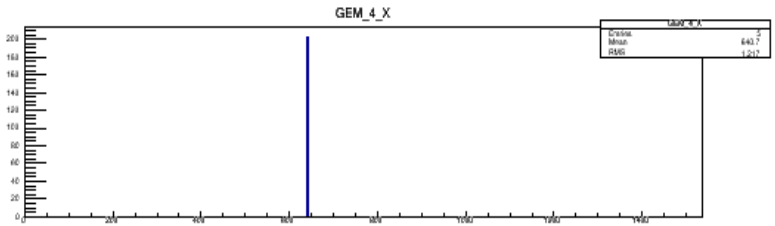


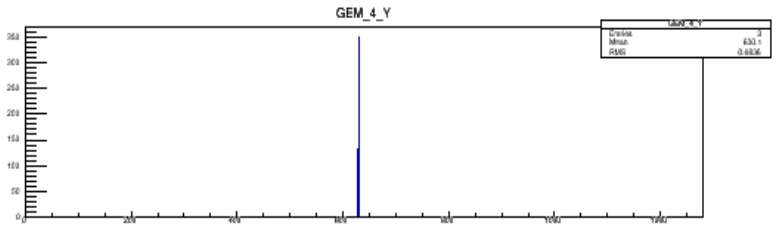




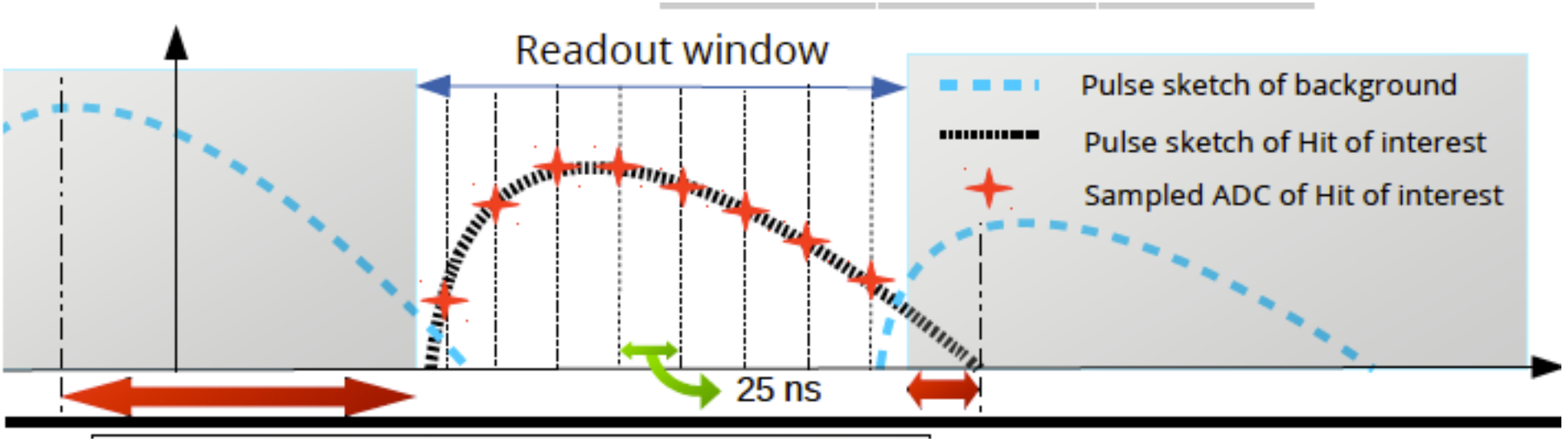




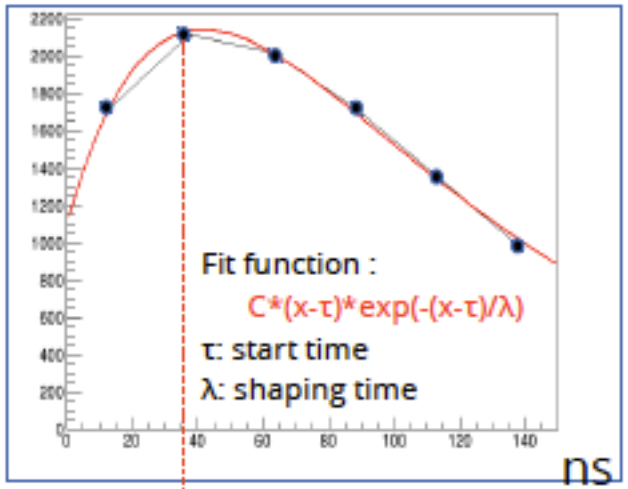




A track through 5 modules

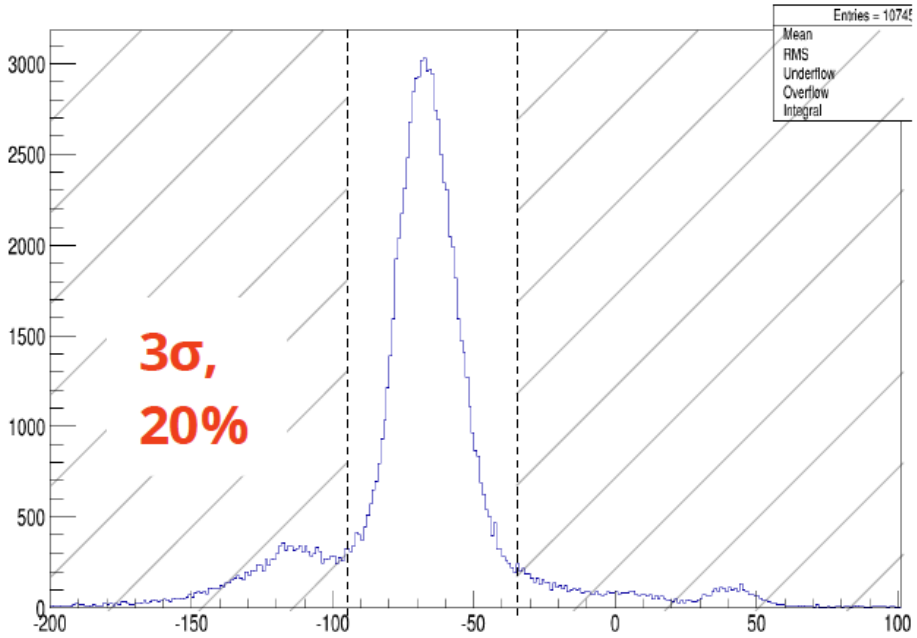


Pulse shape fit on 6 sample data

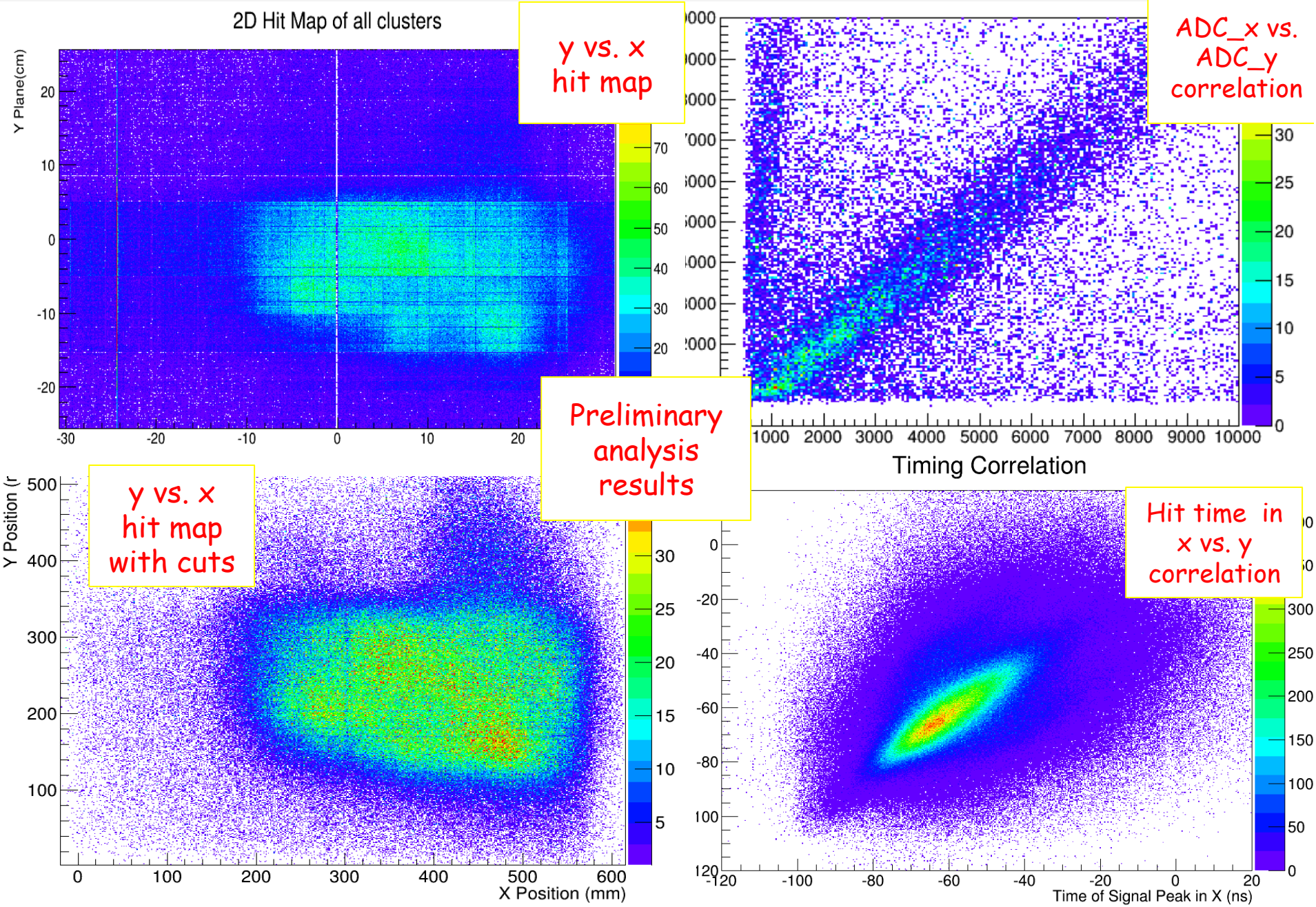


Pulse peak time

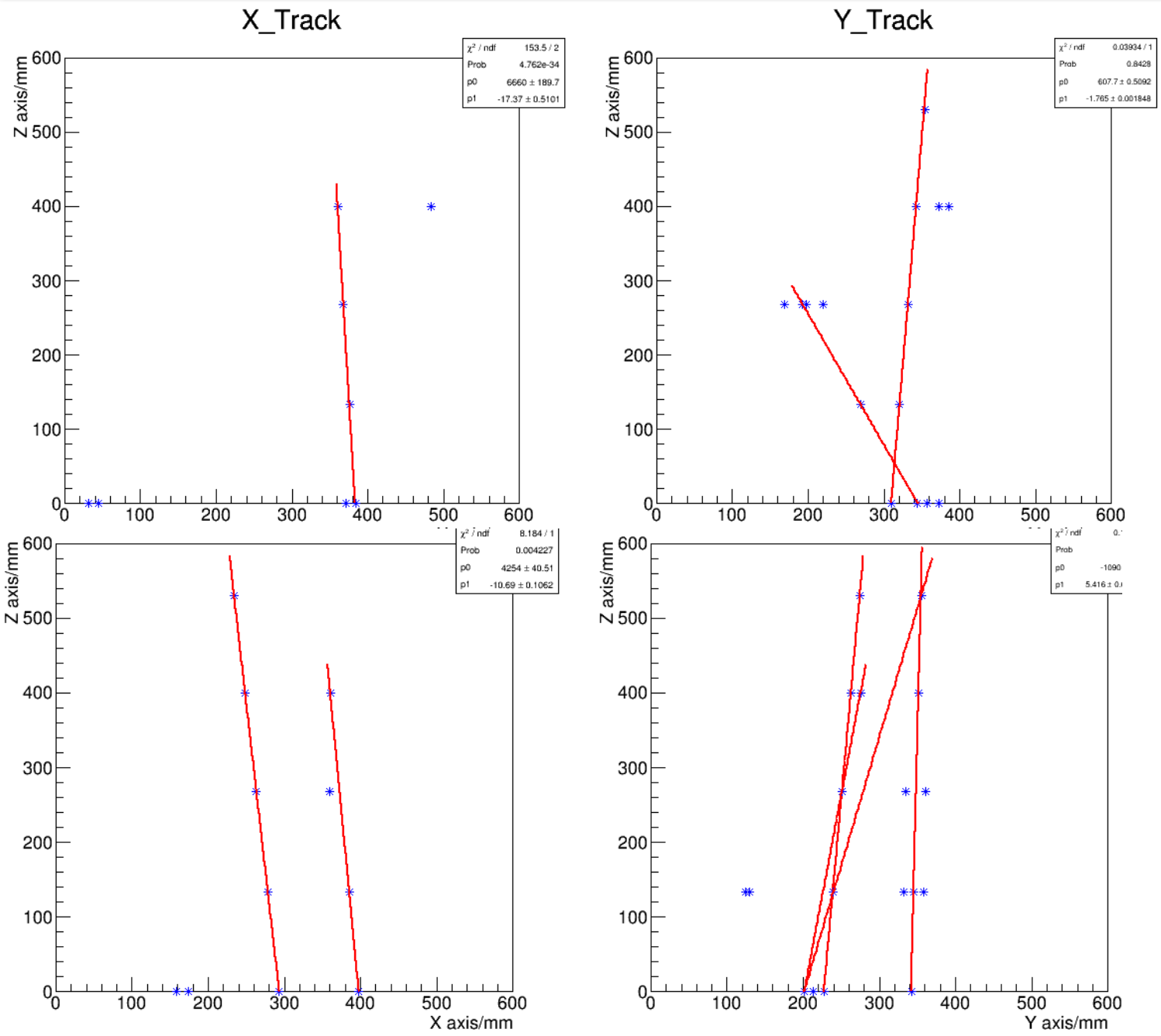
1% occupancy peak time distribution



Beam Test in Hall A



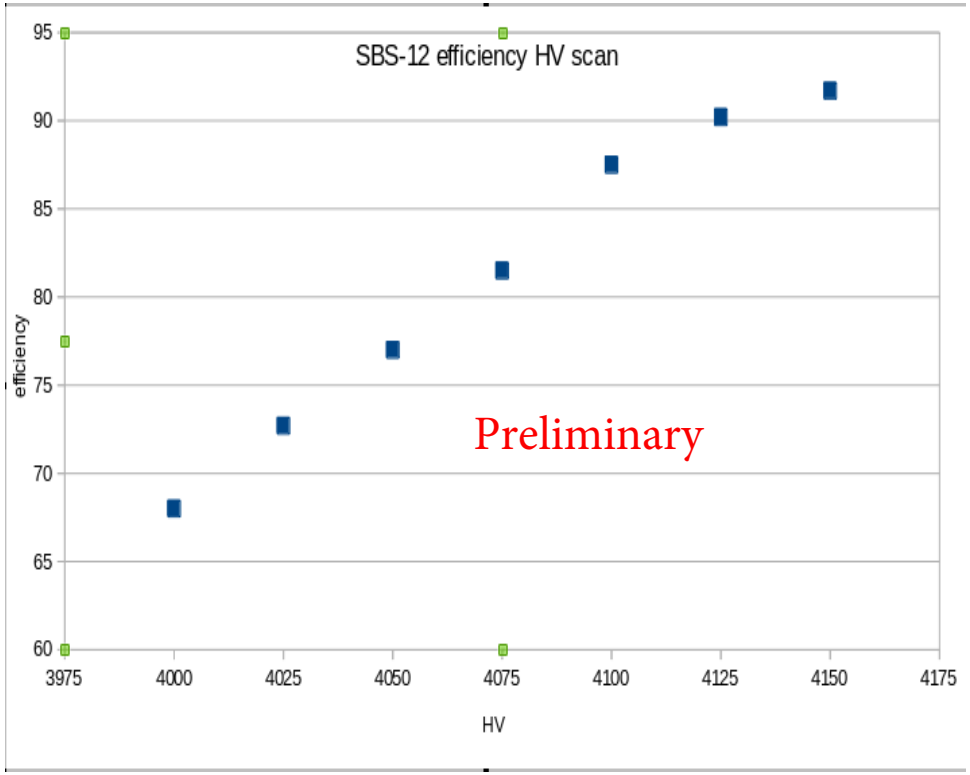
Beam Test in Hall A



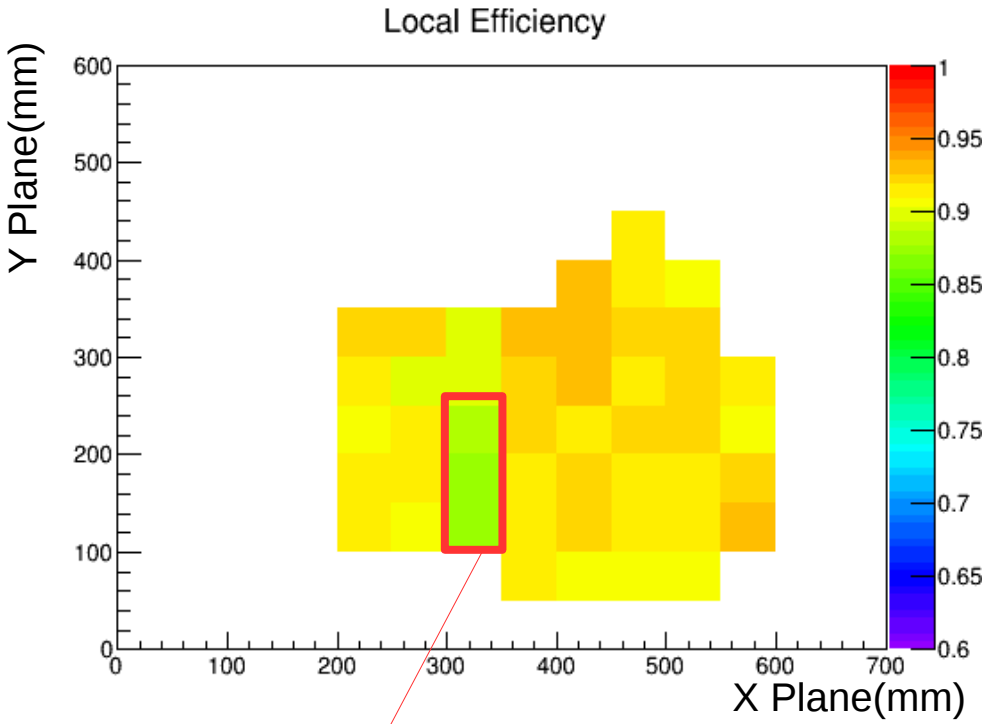
Preliminary analysis results

Efficiency

Overall efficiency HV scan



HV from 4000 V to 4150 V with step of 25 V

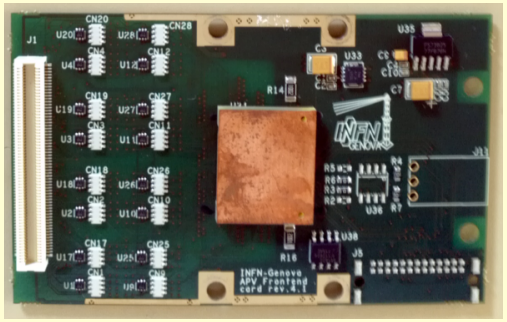


HV: 4100V

Efficiency drop due to spacer

GEM Readout Electronics

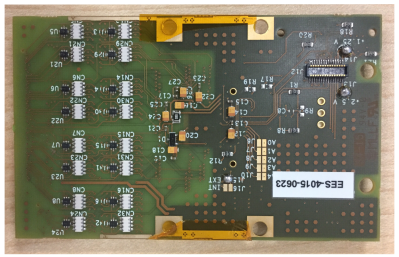
GEM – APV-MPD based Readout Electronics



- 128 analog ch / APV25 ASIC
- 3.4 μs trigger latency (analog pipeline)
- Capable of sampling signal at 40 MHz
- Multiplexed analog output (100 kHz readout rate)

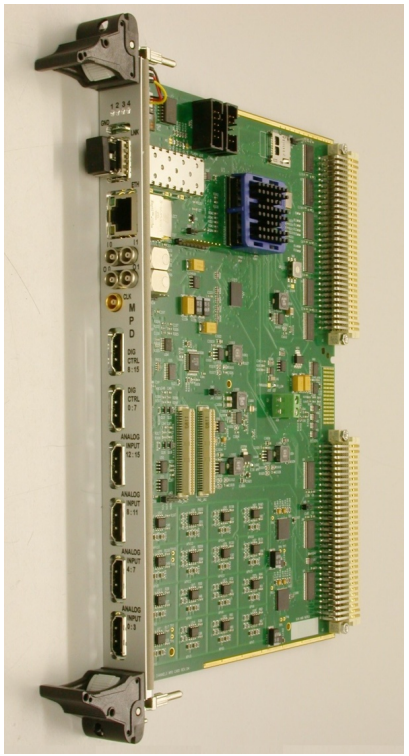
- **Up to 16 APV25 cards (2048 chs) on a single MPD (parallel readout)**
- Altera Arriga GX FPGA / RAM: DDR2 (128 MB)
- **Optical Fiber Link interface (Aurora ~2 Gb/s peak)**
- 100 MHz system clock and Front panel coax clock
- Used HDMI-A for analog and digital signals
- **VME/32, VME64, VME64-VXS compliant (up to 200 MB/s peak)**
- 4 high speed line on the VXS available for data transfer
- Firmware v. 4.0 (74% resources):
  - Finite-Impulse-Response Filter (16 parameters)
  - Zero Suppression (sparse readout)
  - Common mode and pedestal subtraction
  - Remore reconfiguration
  - ~2 ns trigger time resolution
  - VME / Optical Fiber simultaneous implementation

Data acquisition

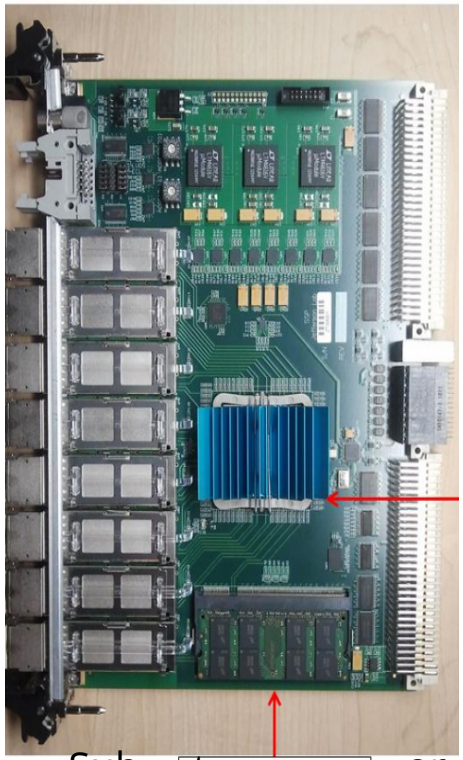


APV-25 FEC

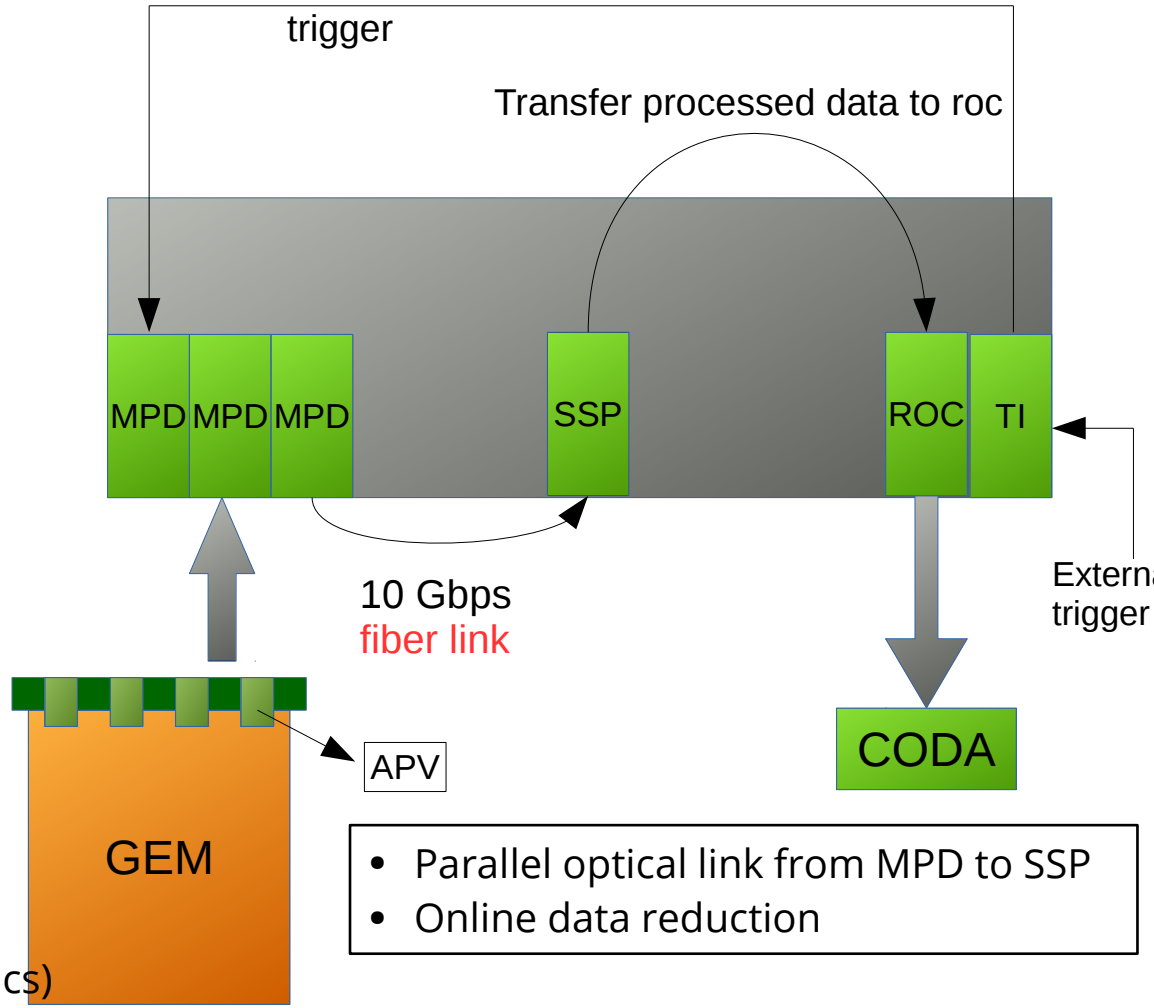
SBS requirements: 2-4kHz
Data injecting rate on each SSP at 2 kHz: 1000 MB/s



FPGA based digitizer



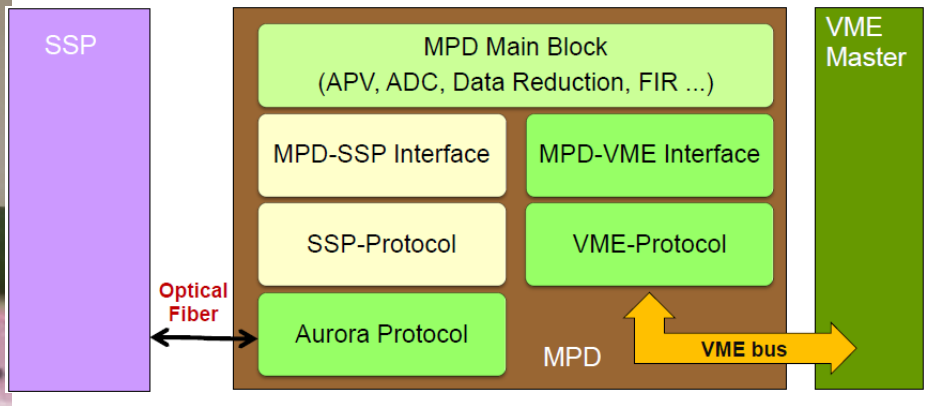
Subsystem processor
(JLab customized electronics)

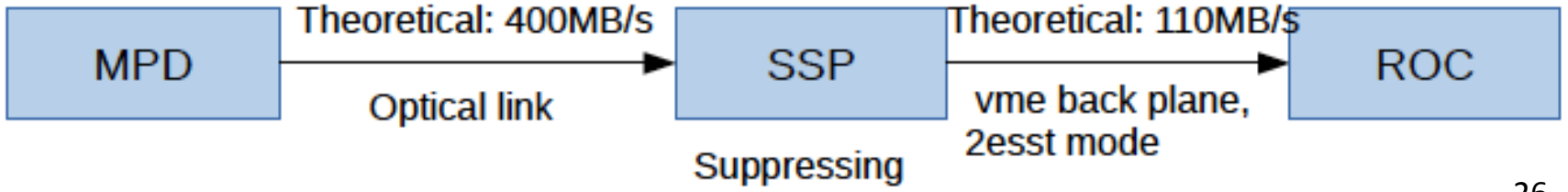


- Parallel optical link from MPD to SSP
- Online data reduction

MPD Firmware latest status

- Version 4.0 – 74 % FPGA resources used
- New (optimized and better organized) memory map tested succesfully
- All VME cycles tested; minor issue to be fixed
- Optical Link to SSP under deep testing (thanks to the CODA setup with SSP and Intel CPU recently installed in Italy)

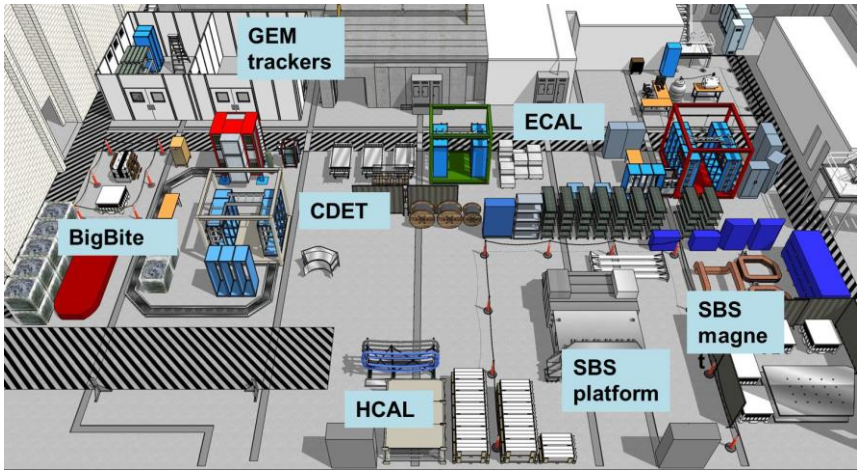




Commissioning of GEM Trackers

Status of the construction of Clean Room space

- Space allocated in the test lab for the storage of the GEMs modules and the cosmic stand
- Clean room **now ready**



Setting of the cosmic stand for GEM trackers

- Full characterisation of the GEM modules with cosmics
  - ⇨ Evaluate the dead area (disabled HV sector), study efficiency,
  - ⇨ Define the optimal working HV and gas flow for each module
  - ⇨ Full readout perfromance DAQ
- Setup of the stand (**06/15 – 07/15/2017)**
  - ⇨ Setup of trigger with 1.6 m long scintillators / PMTs
  - ⇨ UVa GEM layer (4 modules) will be used for testing the setup
- Have 4 FT GEM layers on the cosmic stand (**07/15 -07/31/2017)**
  - ⇨ Expect all modules and frames for the 4 layer at JLab
  - ⇨ Assembly and connection to HV, gas, electronics
  - ⇨ We should start cosmic data taking by **08/01/2017**
- One VME crate for the readout will be used

GEM Readout Electronics & DAQ

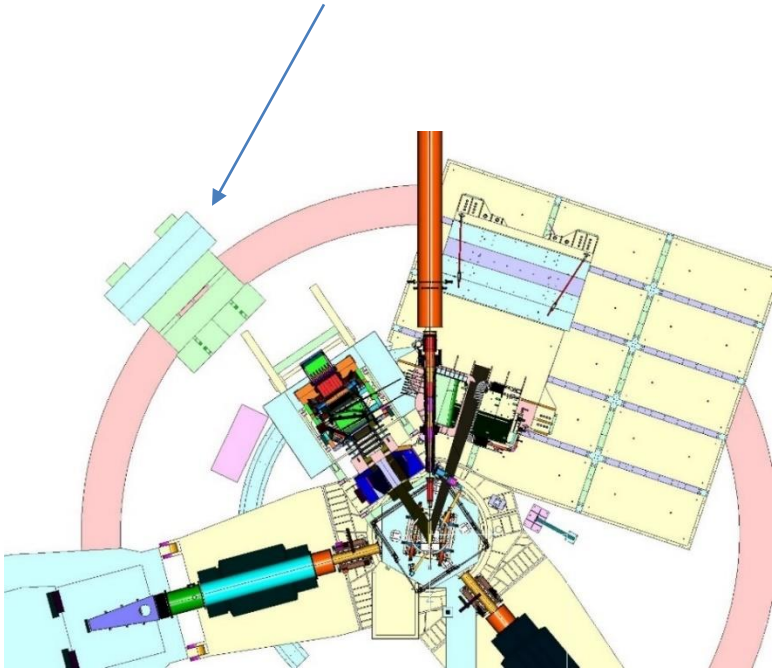
2 VME crates for all 4 + 1 GEM layers

Front Tracker crate	**Back Tracker crate**
16 MPDs (v4.0)	7 MPDs (v.40)
1 SSP	1 SSP
1 Trigger Supervisor	1 Trigger Supervisor
1 VME CPU or Controller	1 VME CPU or Controller
2 slots for HV PS	1 slots for HV PS (or not)

Electronics Hut & Shielding for GMn/Gen GEM electronics

Shielding and dose simulations study done

http://hallaweb.jlab.org/12GeV/SuperBigBite/SBS-minutes/2017/obrecht_GMn_hut.pdf



Progress on the DAQ and rate capability

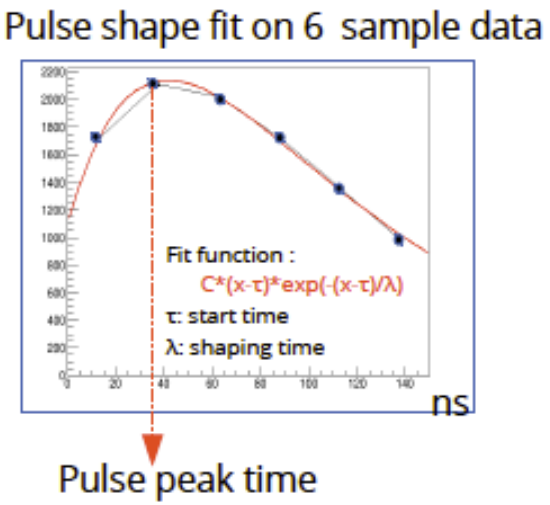
- MPD4.0 with the implementation of the SSP module and optical link
- The system is under test (Danning, Alex, Paolo and the DAQ group).
- Ongoing debuging of the data transfer with optical link

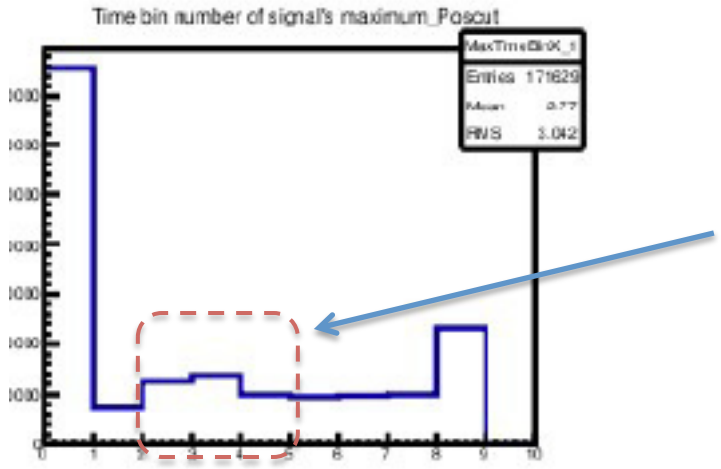
High background level challenges

- GEM and readout hardware aspects under control.
- One area where we have to work hard is to overcome challenges associated with high background rates.
- Rate in GEMs ~ 100 kHz/cm^2
- Trigger rates ~ 2-4 kHz
- Effective readout window ~ 250 ns:
- Leads to raw occupancy rates around 15% - 20%
- This could lead to data volumes too large for band width and disk R/O

As a result, need hardware level zero suppression, signal time deconvolution, time based background rejection etc. to reduce data volumes to acceptable levels.

- Plan to work with Jlab DAQ group to achieve this at the SSP.
- Possible to get the occupancies down to < 5% level.





Good data will have max ADC peak in these time bins only

Manpower and Resources for the GEM tracker

Commissioning of GEM trackers on the cosmic stand

- UVa team this summer (Kondo, Siyu, Danning)
- Evaristo's team will provide support during the setting of the cosmic test and commissioning phase
- We will have one undergrad student from HU this summer

GEM readout electronics and DAQ

- Danning, Alex and DAQ group (Ben Raydo, ..)
- Support from Evaristo and Paolo
- Full scale test on cosmic stand (Kondo, Siyu)