Large Area GEM for current and future experiments in Hall A @ JLab

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RD51 Coll. Meeting, July 5-6, 2013, Zaragoza, Spain

GEM R&D Team @ UVa

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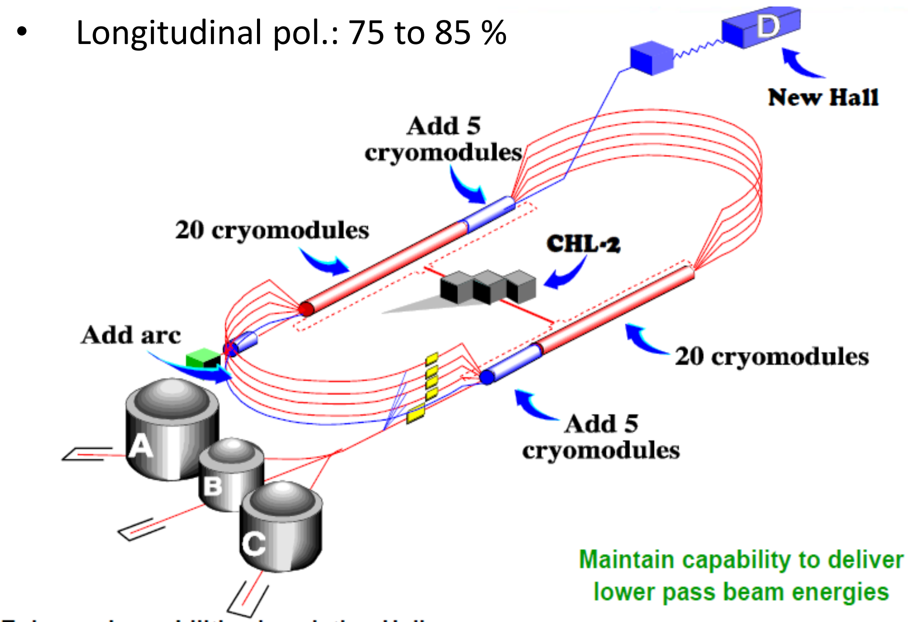
Outline

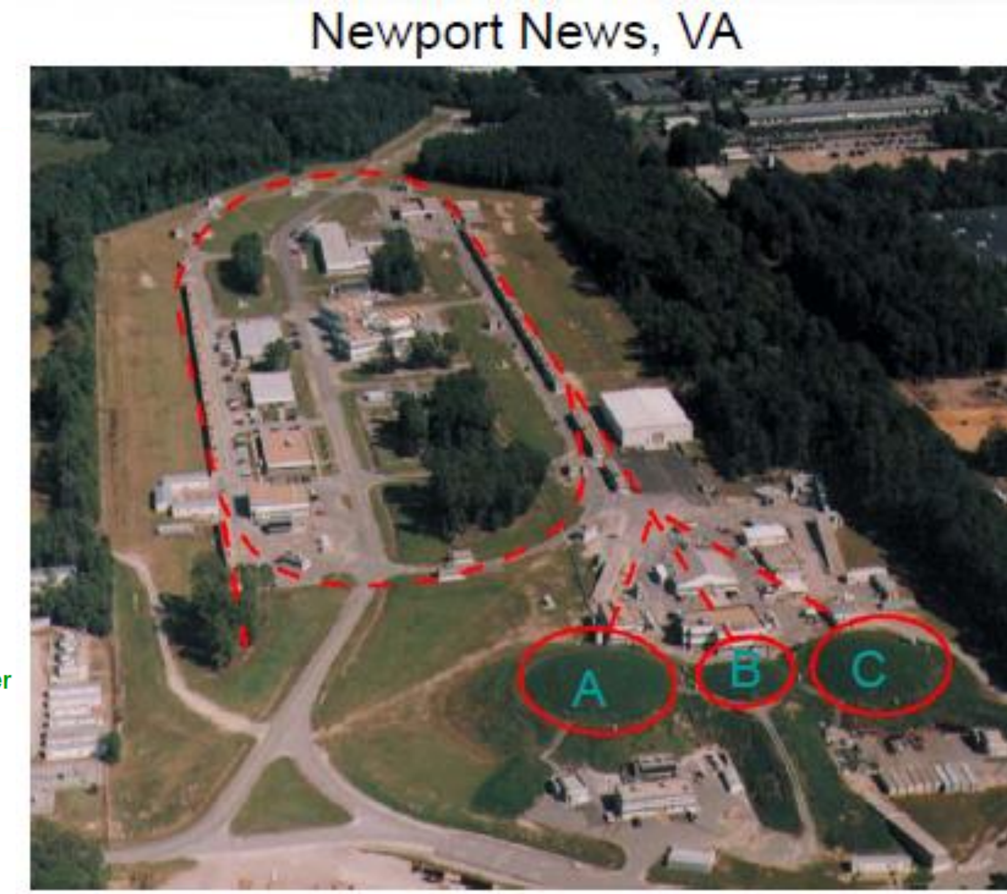
- The Super Bigbite Spectrometer in Hall A @ JLab (SBS)
  - The SBS program and GEM-based Tracking
  - Construction and preliminary tests of the SBS GEM prototypes
- Large Triple GEM R&D @ Univ. of Virginia
  - SoLID / EIC GEM Prototype
  - Design for 200 cm × 50 cm 2D triple GEM chamber
- Test beam at Fermilab in October 2013
  - Test SBS and SoLID/EIC GEM Prototypes
  - Testing large size APV25-based Electronics

12 GeV Upgrade of CEBAF @Jefferson Lab in Newport News VA, USA

CEBAF 6 GeV (before 2013)

- Max. current: 200 μA
- Max. Energy: 5.7 GeV
- Longitudinal pol.: 75 to 85 %



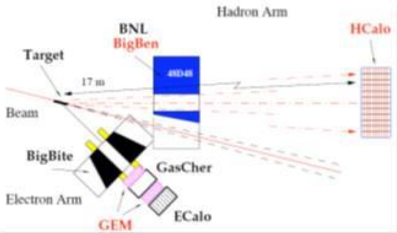
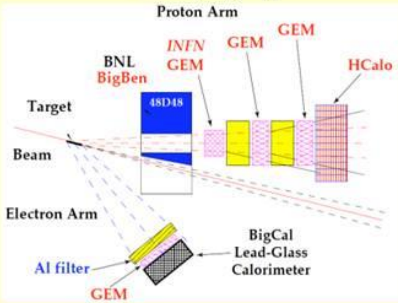
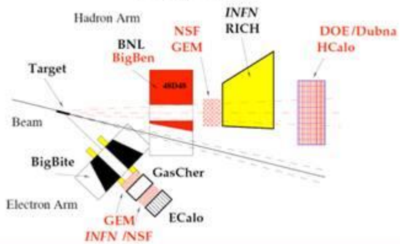


CEBAF 12 GeV (after 2014)

- Max. current: 90 μA
- Max. Energy: 11 GeV (Hall A, B, C), 12 GeV (Hall D)
- Longitudinal pol.: 75 to 85 %

The Super Bigbite Spectrometer in Hall A @ JLab (SBS)

Some challenging experiments in Hall A

Experiments	Luminosity $(s\cdot cm^2)^{-1}$	Tracking Area (cm^2)	Resolution Angular (mrad)	Resolution Vertex (mm)	Resolution Momentum (%)
GMn - GEn 	up to $7\cdot10^{37}$	40x150 and 50x200	< 1	<2	0.5%
GEp(5) 	**up to $8\cdot10^{38}$**	40x120, 50x200 and 80x300	<0.7 ~1.5	~ 1	0.5%
SIDIS 	up to $2\cdot10^{37}$	40x120, 40x150 and 50x200	~ 0.5	~1	<1%

Most demanding

High Rates | *Large Area* | *70 μm spatial resolution*

Super Bigbite Spectrometer (SBS)

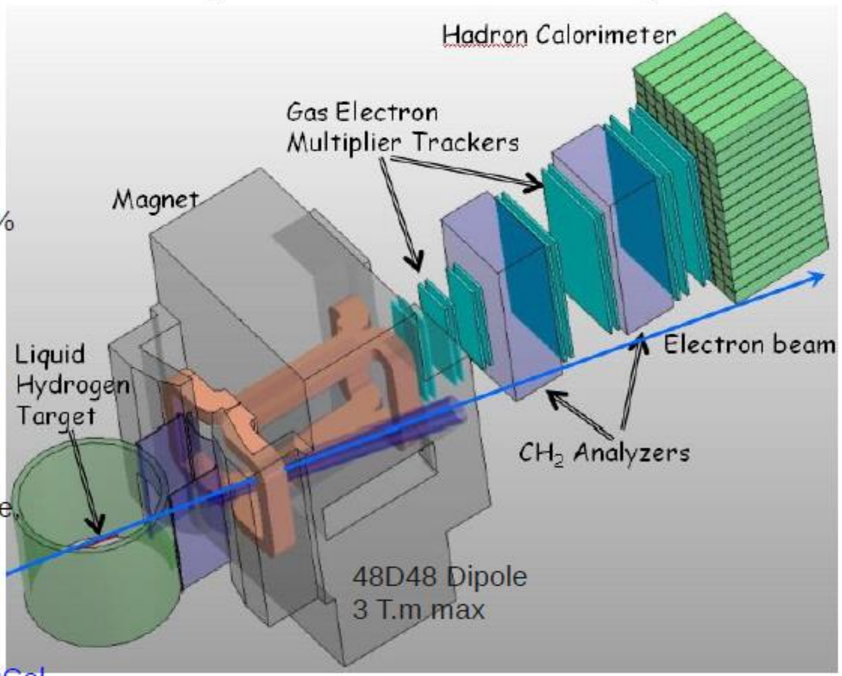
- SBS is the first apparatus built for the 12 GeV upgrade,
- Set of instrument for flexible spectrometer configuration

- Dipole Magnet
- GEM for Tracking
- Calorimeters
- CH2 Analyzer for Proton Polarimeter for GEp (5)
- Dual-radiator RICH for SIDIS Program

SBS Configured for Recoil-Proton Polarimetry

- High Luminosity: 8 x 10^{38} $cm^{-2}s^{-1}$
- Support high background: 500 kHz/cm^2 (low energy photons mainly)
- Forward angle
- Large acceptance
- Good angular (0.2 mr) and reasonable momentum (0.5% @ 4-8 GeV/c) resolution
- Flexibility: use the same detectors in different experimental setup
- 2 tracker geometries, same base module
  - 1st front, momentum, angle, vertex
  - 2nd polarimeter, asimuthal scattering
- Also GEM in BigBite and BigCal

SBS Configured for Recoil-Proton Polarimetry



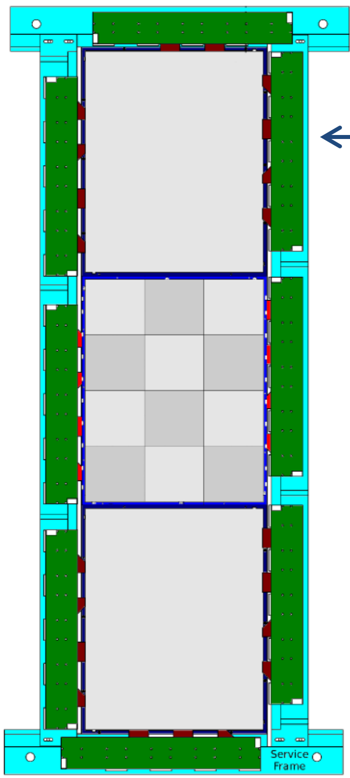
J.R.M. Annand, JointGEM Meeting, Helsinki, July 2010

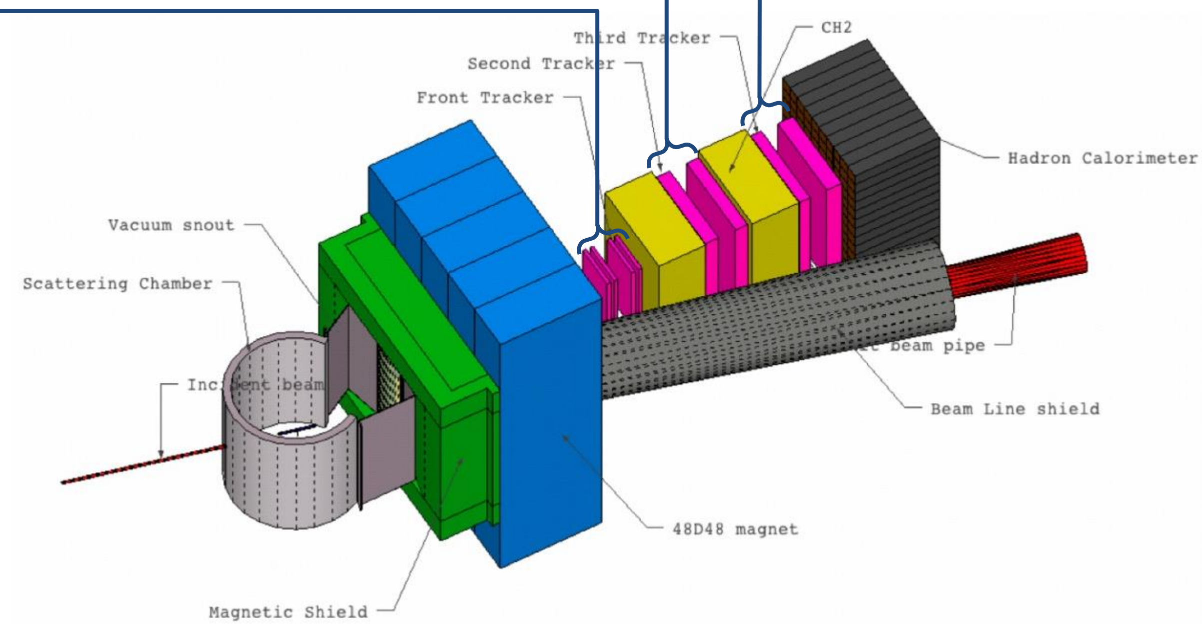
Super Bigbite Spectrometer (SBS)

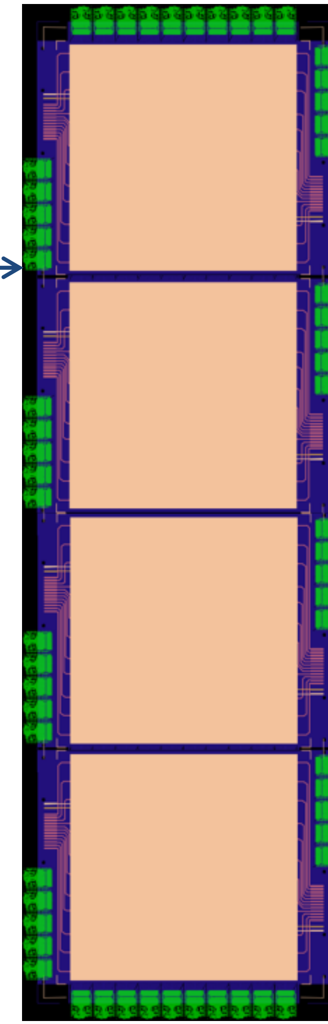
Back Tracker Proton Polarimeter:
8 GEM Layers (200 cm × 50 cm)

Proton arm layout for GEp (5) experiment

Front Tracker:
GEM Layers (150 cm × 40 cm)





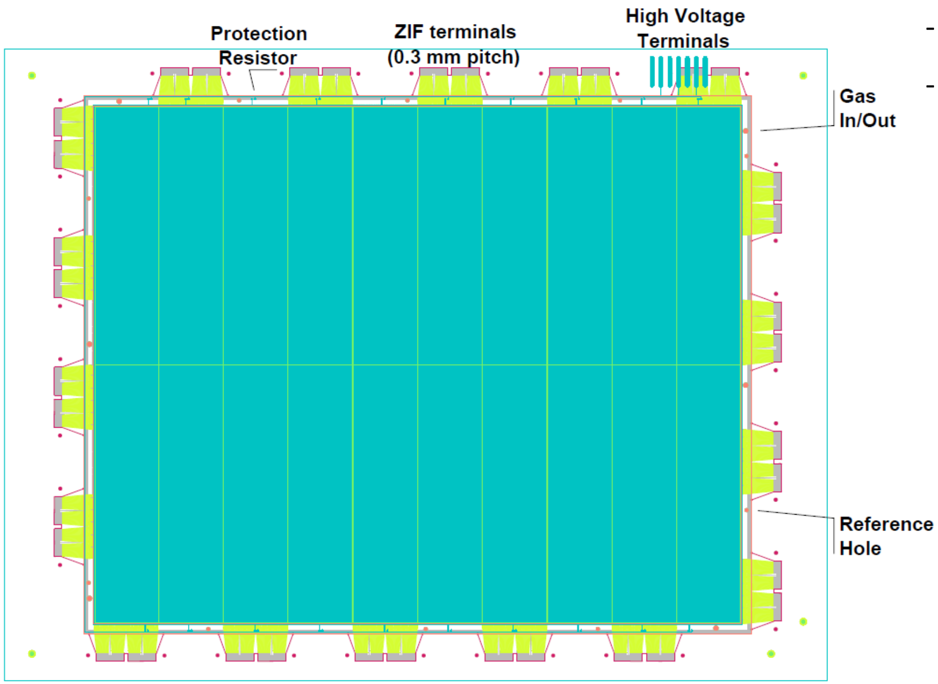


SBS Front Tracker 40 × 50 cm^2 GEM Module

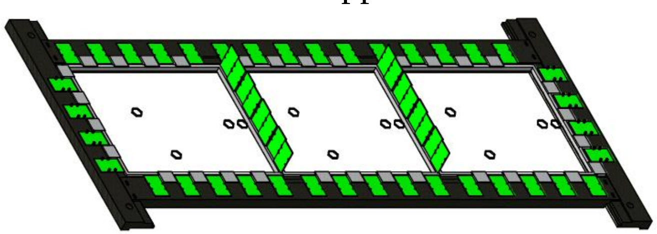
(E. Cisbani, INFN Roma, INFN Catania)

Active area 40 × 50 cm^2

- 18 modules for the 6 layers of the front tracker
- Low material budget , minimum dead area

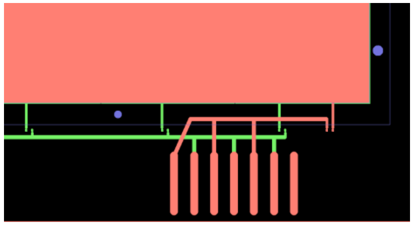


Mechanical support frame



Small revision of GEM foil:

- **Resistor pads 2 mm out of the frame.**
- **Larger HV paths**
- Pros: easy access GEM sector HV
- Cons: Resistors no longer protected by the frames

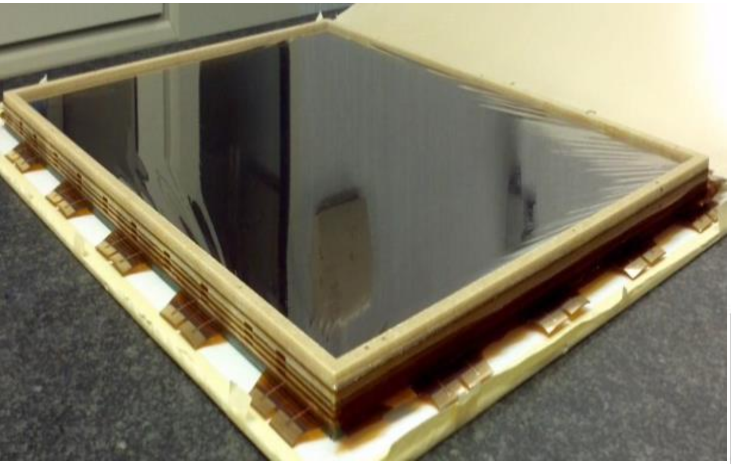


Current Status

1. Material:
   1. Procured and availabled:
      1. All PERMAGLAS frames procured and available
      2. Almost all drifts foils procured and available
      3. 10 readout foils + 3 honeycomb planes
   2. Ordered:
      1. 30 GEM foils (new design revision)
      2. Outer frame prototype (support 3 modules + electronics + gas pipes ...)
2. Electronics/Firmware ... (⇨Paolo Musico)
3. Gas system main functionalities ready
4. HV system ... Optimization to be done, spark detection (?)
5. DAQ Software ... stable versions/development
6. Analysis Tools ... slow development
7. Characterization stand ... in progress

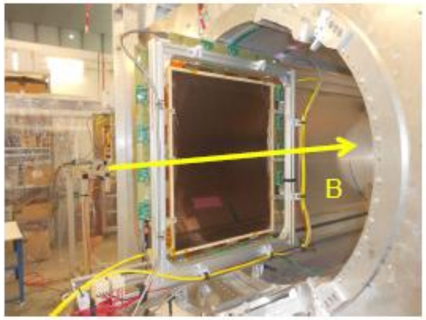
SBS Front Tracker Prototype

(E. Cisbani, INFN Roma, INFN Catania)

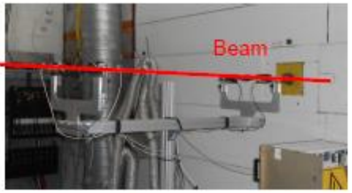


Setup at DESY test beam in April - May 2013

- 2 cm × 2 cm small scintillators as telescope for trigger
- One SBS GEM in the solenoid open space
- Either 2 small GEM chambers or 1 small and 1 SBS GEM beyond the magnet as trackers
- HV scan, beam momentum scan, magnetic field scan
- Unexpected gain drop in all chambers (reason unknown)
- 3000 runs (50K events / run), data are being analyzed



Big GEM + Solenoid

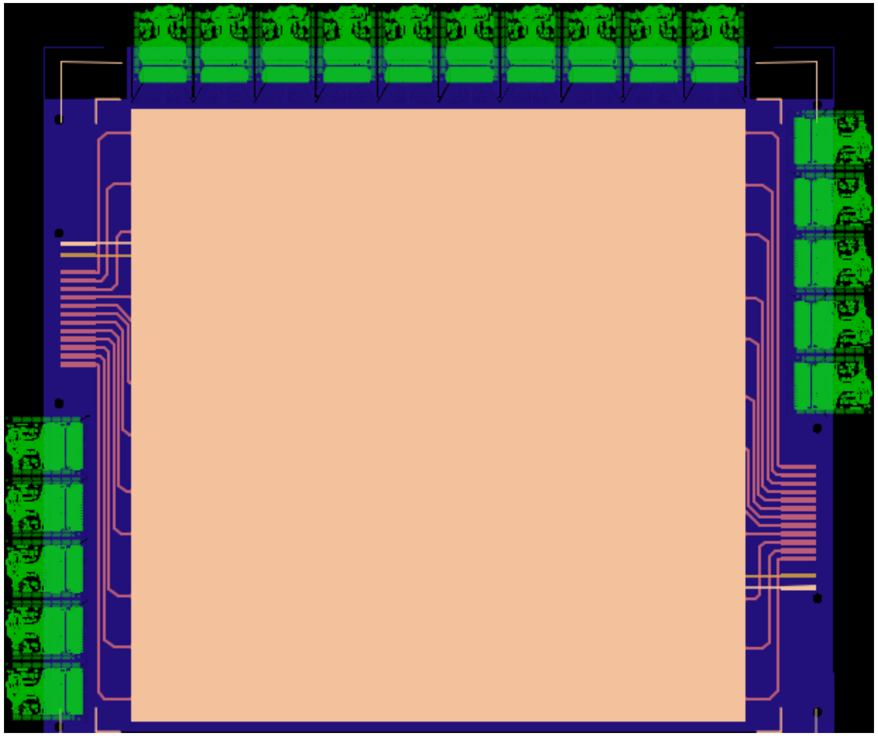


Scintillators

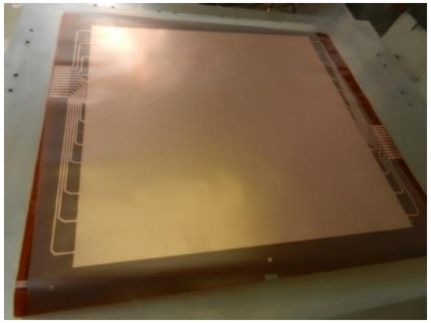
SBS Back Tracker 50 × 50 cm^2 GEM Module

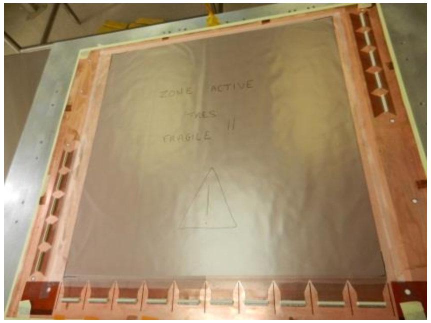
(N. Liyanage Group, Univ. Virginia USA)

- Active area 50 × 50 cm^2
  - 32 modules needed for 8 layers proton polarimeter.
- Wide GEM frames (30 mm) and readout board frames (74 mm) along x-axis
  - Better stretching, GEM HV sectors electrodes
  - alignment holes away from active area
  - Room for strips connectors
- No protective resistors on the GEM foils
  - HV sectors accessible through contacts
  - External board for protective resistances
- ZIF connectors replaced by 130-pins Panasonic connectors
  - Compatibility with SRS Electronics
  - More robust and easy to operate



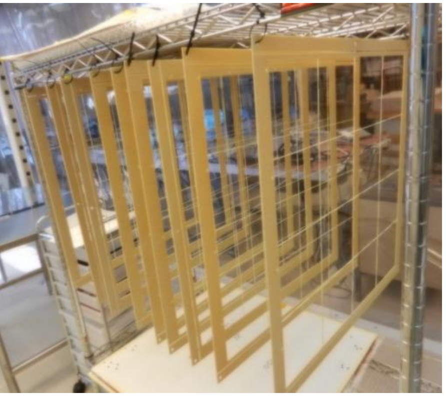
GEM and 2D readout from CERN workshop (Rui)





Clean Room & Equipment for the assembly

Storage of the frames

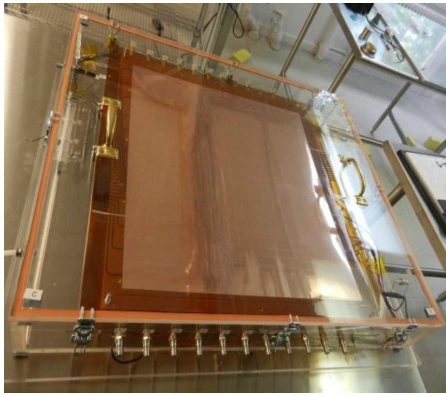


Frames holder for cleaning in USB

Ultra sonic bath (USB) with demineralized Water

Large area (3 × 7 m²) Class 1000 Clean Room

Storage of the framed foils



Glue dispenser

Tacky roller ➔ dust removal

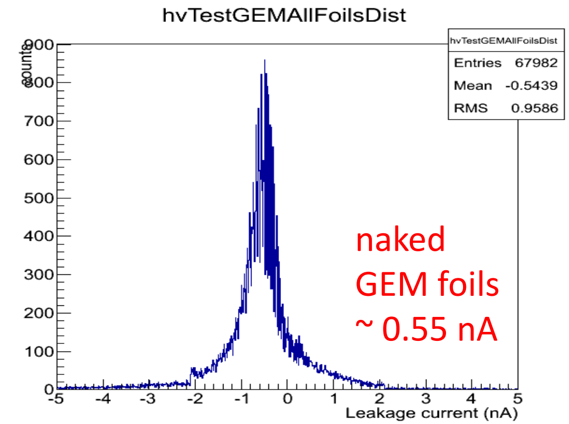
Leakage Current Measurement: HV Test in N2

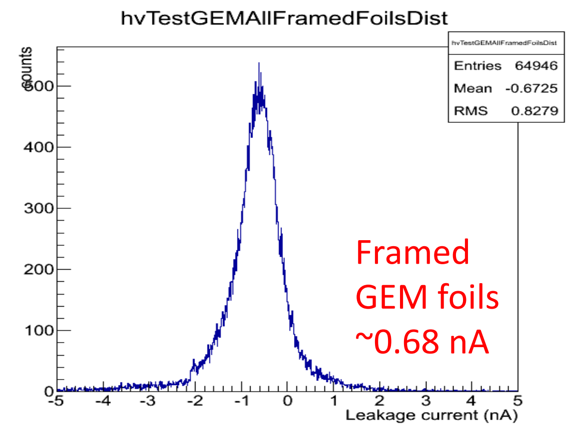
- We use an Iseg EHS 8060x_105 6 kV HV module with a Wiener MPOD high voltage crate. High voltage is controlled using a command line interface through an internet protocol.

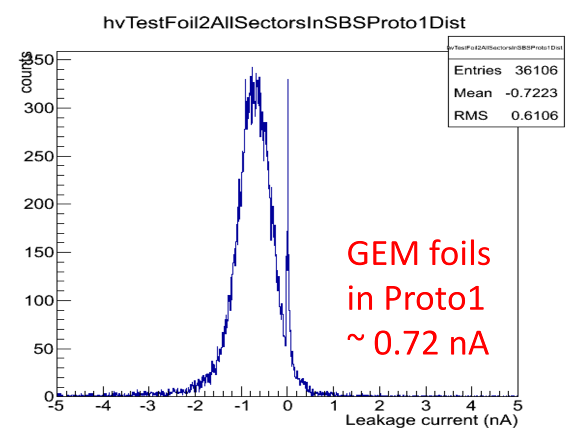
- For the test we use the fast ramp up mode of the supply with a rate of 1200 V/s. the power supply is sampling the current on a millisecond scale and the trip occurs within a few milliseconds of current over limit.

- The leakage current drawn by the GEM foil is measured using a Keithley 6487 picoammeter, at a sampling rate of 120 ms read into the computer through a Labview interface and save the readings into a text file.

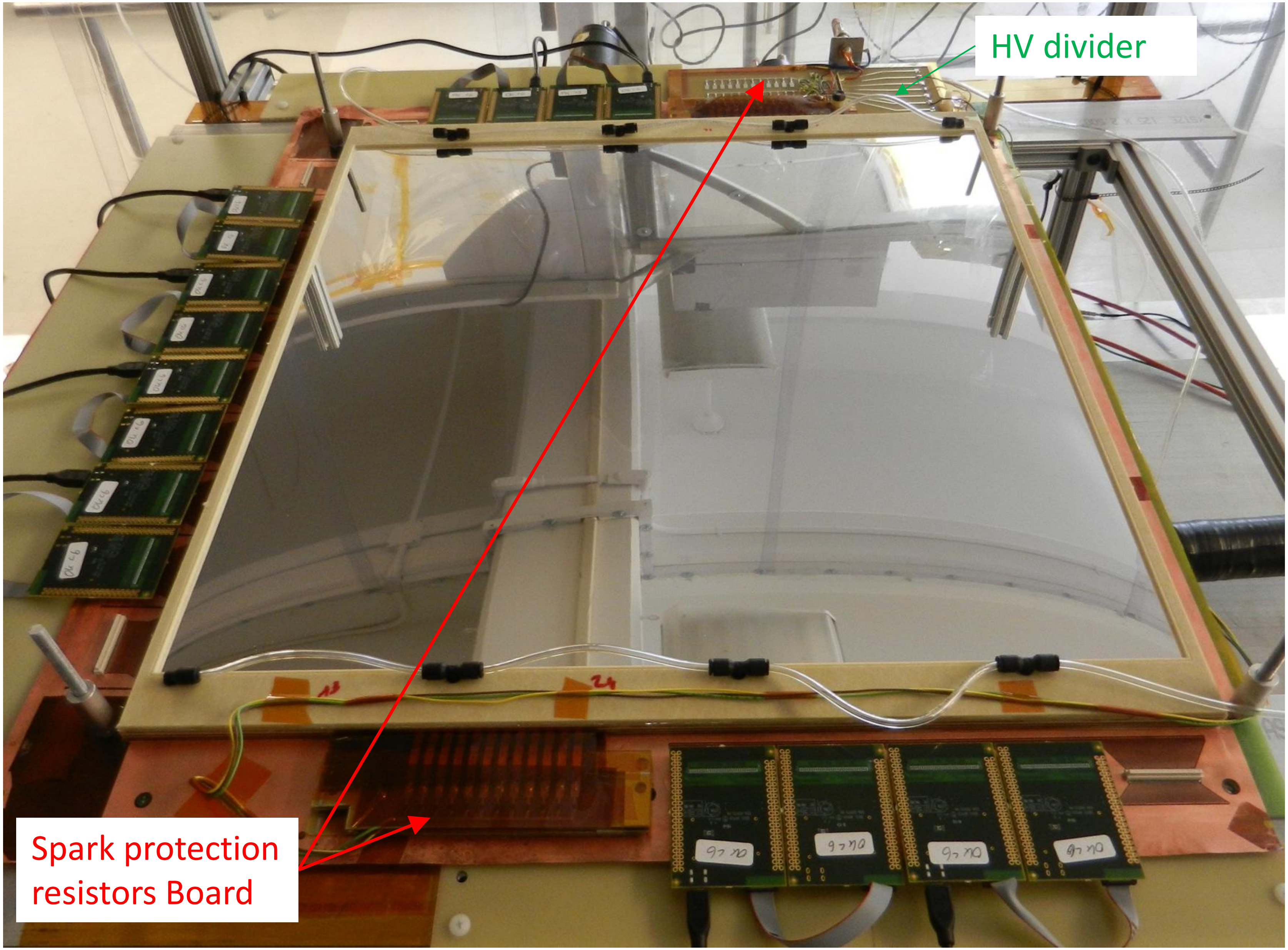
- A GEM sector has a capacitance of approximately 2 nF; and the resistance engaged in the HV module is ~ 50 MΩ, once the stable voltage is achieved this resistance is shunted automatically within the supply). As a result, when we are setting the required high voltage of 550 V, the initial current is a couple of μA, then quickly drops and stabilizes to less 1 nA leakage current far better than the 5 nA requirement.







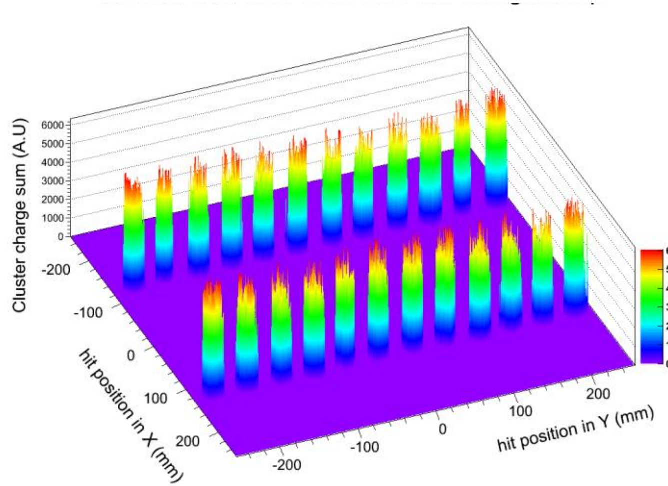
SBS Back Tracker Prototype

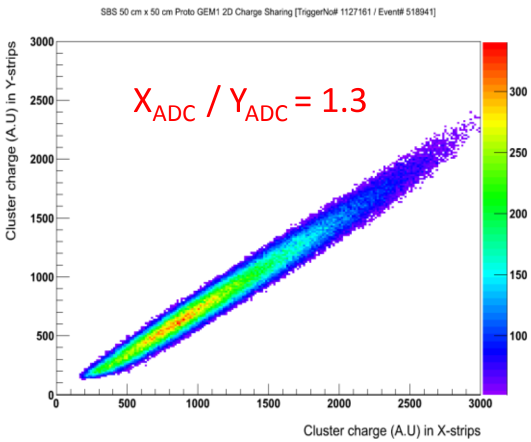


Preliminary tests of Proto I

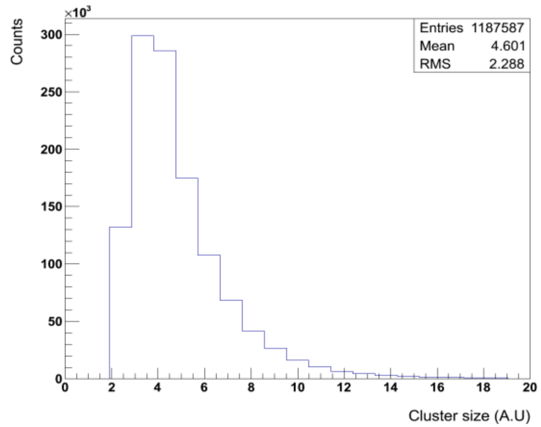
- Cosmic data: 1.5M events HV = 4.2 kV on the divider
- Cluster size = 4.6, Good charge sharing with a ratio = 1.3
- Data with the ^{90}Sr for each of the 24 HV sectors
- Average ADC count per bin = Σ_N (ADC counts) / N_{hits}, Good gain uniformity for of all sectors
- ~ 92 to 94 % efficiency for all the 24 HV sectors
- We should expect about 97% but a few % drops explained by the spacers

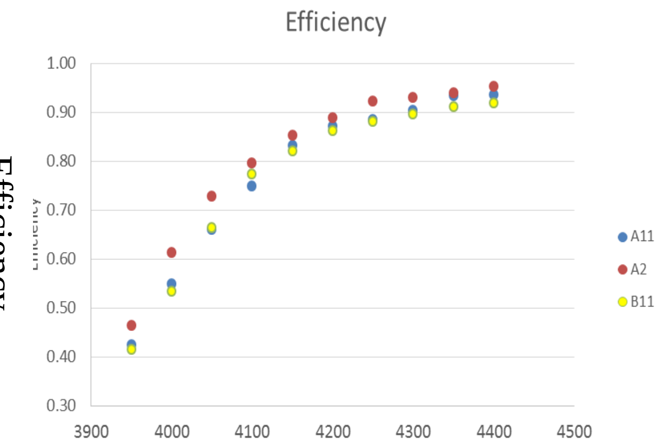
^{90}Sr: Uniformity over all sectors





Cluster size = 4.6





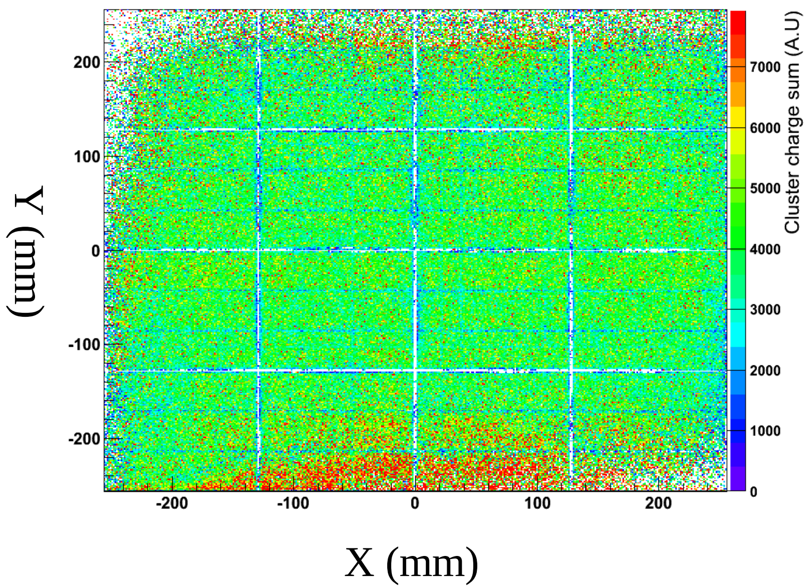
Efficiency

HV on divider (V)

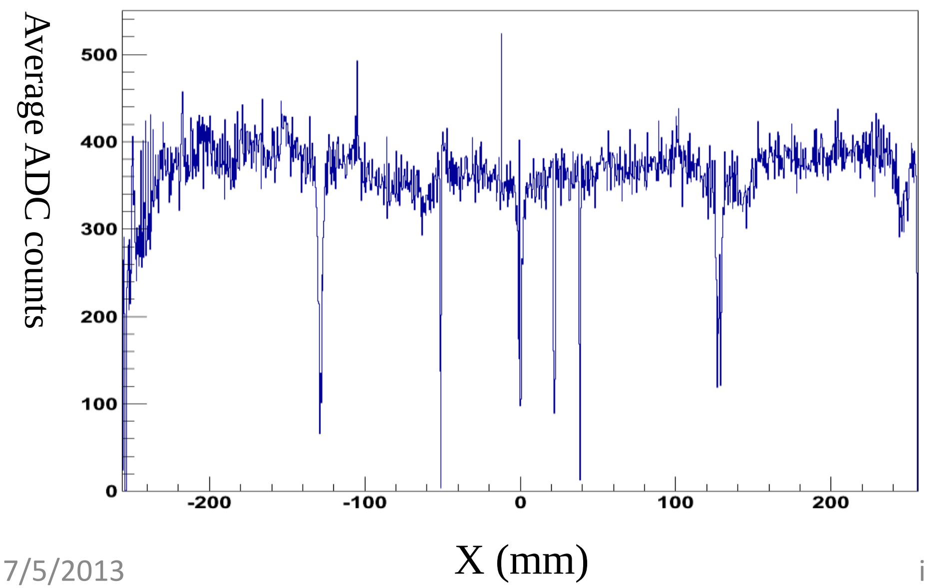
Preliminary tests of Proto I

- Big efficiency drop in the vicinity of the spacers
- Spacer width of 300 µm leads to a drop over up to 2 mm
- HV sectors boundaries also leads to efficiency drop ➔ but with lower loss and over a narrower strip
- Average ADC count per bin over a large number of events = Σ_N (ADC counts) / N_{Hits}

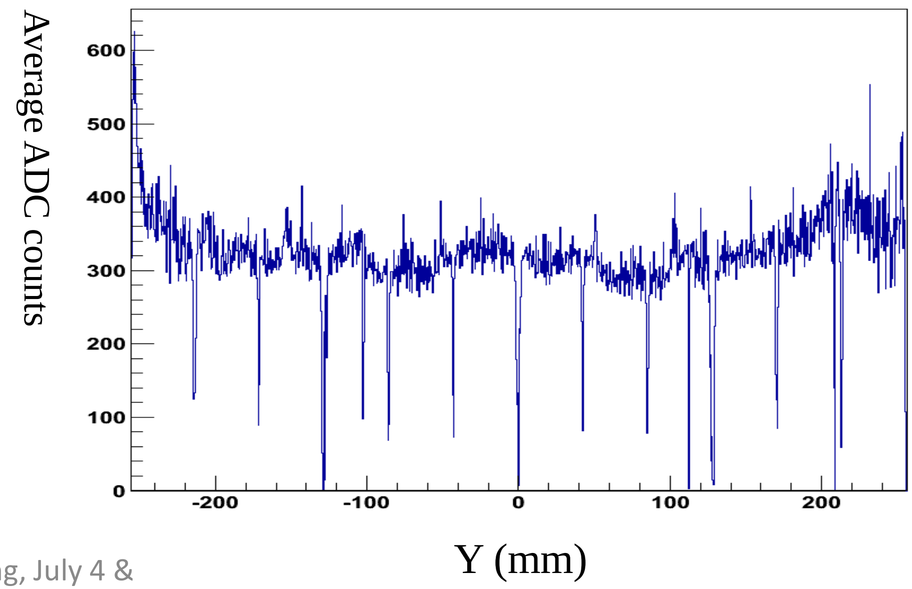
Average ADC counts



Gain uniformity along X-strips

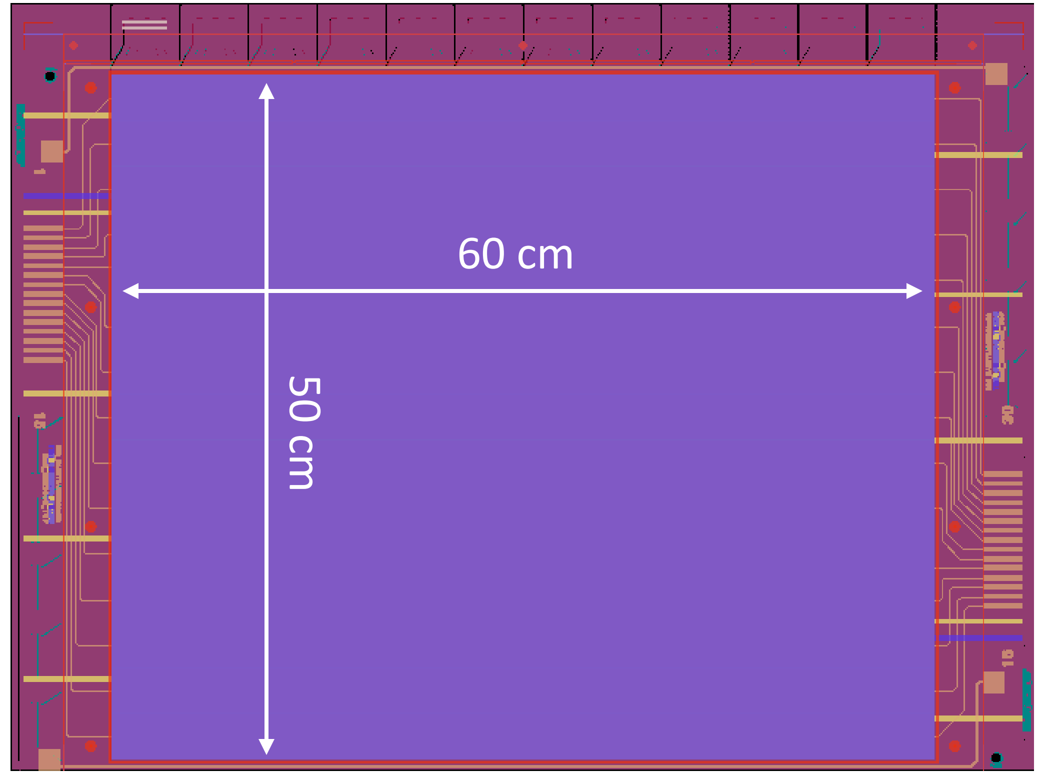


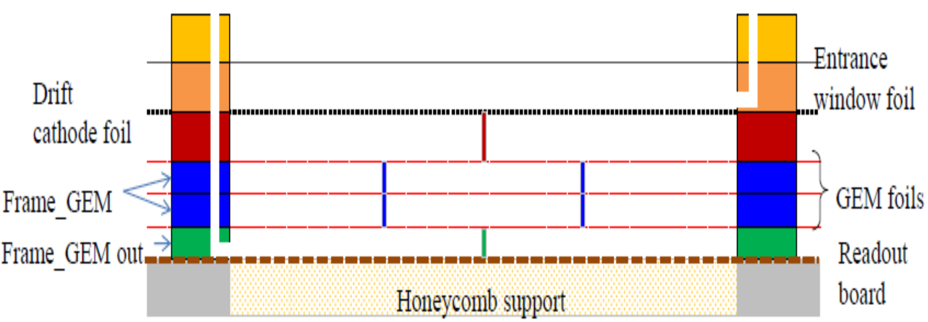
Gain uniformity along Y-strips



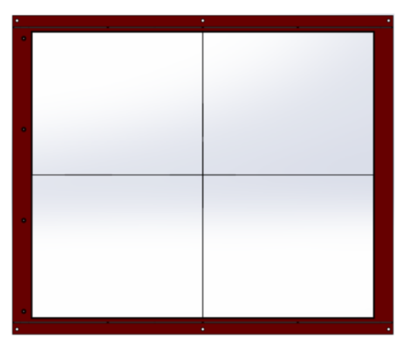
Back Tracker GEM Module: New Design

- Larger active area: 60 cm × 50 cm^2
  - Improve the F.O.V. of the proton polarimeter by 20%
- Less spacers in the frames:
  - Drift frame and 3rd GEM frame
  - duce the impact of dead area
  - Need stronger stretching tension
- Other minor adjustements
  - Vertical gas flow ➔ drift cathode is a GEM foil without copper on top
  - A few other modifications derived from experience when building the prototype

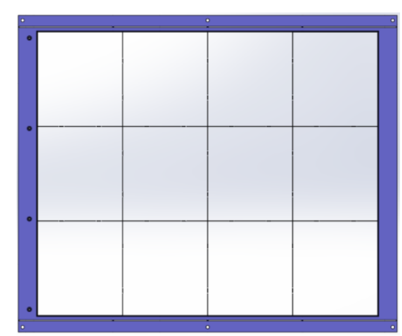




Spacers for drift and 3rd GEM frames1



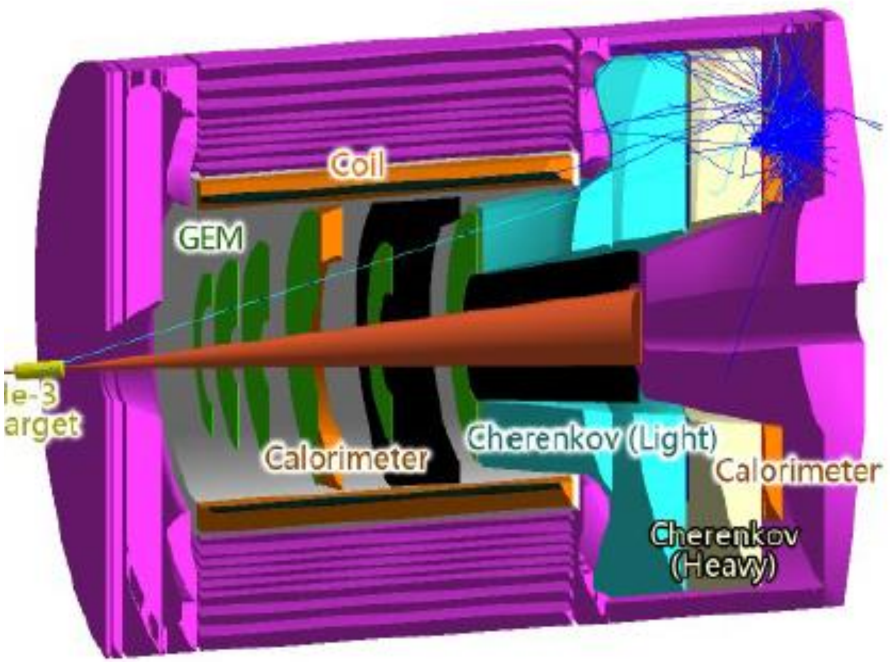
Spacers for 1st and 2nd GEM frames1



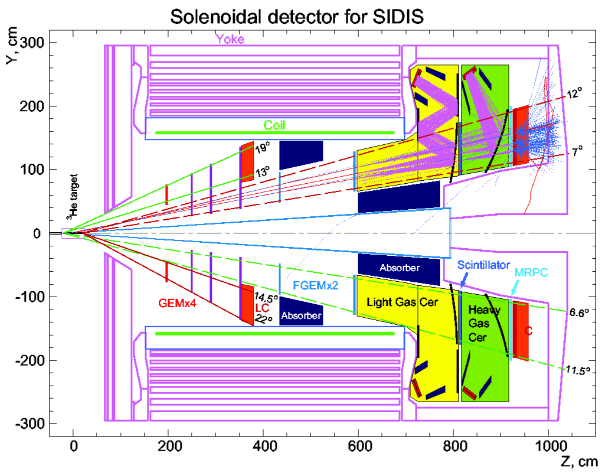
Large Area GEM R&D @ Univ. of Virginia

The Solenoid Intensity Device (SoLID) for the 12 GeV Program in Hall A @ JLab

- Beam energy = 8.8 GeV and 11 GeV
- Luminosities:
  - ^3He (neutron) : 10^{36} N/cm^2/s
  - NH_3 (proton) : 10^{35} N/cm^2/s
- Solenoid magnet
  - Full azimuthal angle coverage
  - Crucial for 4D mapping of asymmetries
  - Reduces systematics when extracting moments
- Tracking with GEMs
  - 6 GEM disks for SIDIS
  - 4 GEM Disks for PVDIS
- Electron identification:
  - EM cal. for large angle and high momentum
  - EM cal. and light gas Cerenkov for forward angle
- Pion Identification
  - Heavy Gas cerenkov andd TOF (MRPC)
- Fast pipeline electronics for DAQ

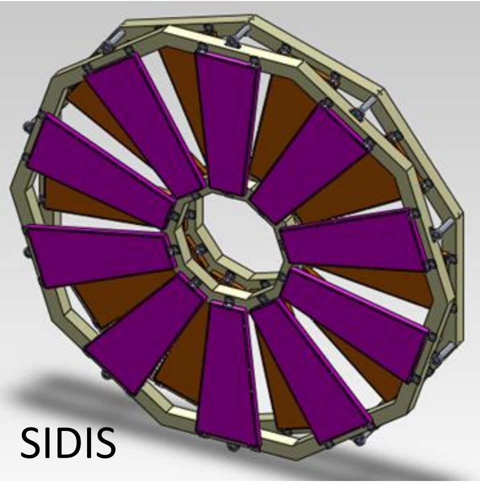


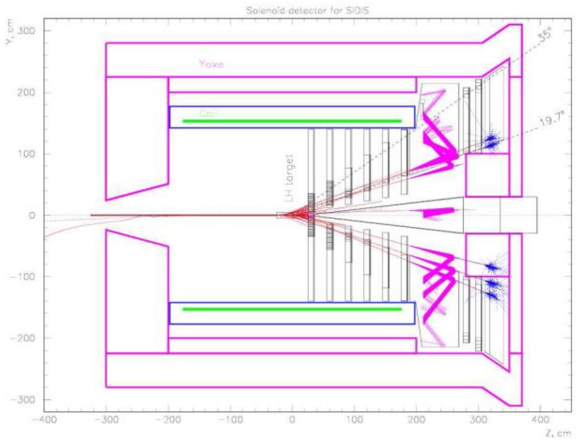
SoLID GEM Trackers



GEMs in SIDIS configuration

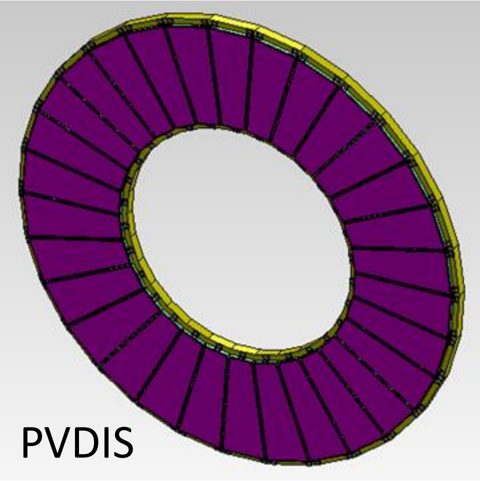
Plane	Z (cm)	R_I (cm)	R_O (cm)	Activearea	# of channels
1	197	46	76	1.1	24 k
2	250	28	93	2.5	30 k
3	290	31	107	3.3	33 k
4	352	39	135	5.2	28 k
5	435	49	95	2.1	20 k
6	592	67	127	3.7	26 k
total:				~18	~ 161 k





GEMs in PVDIS configuration

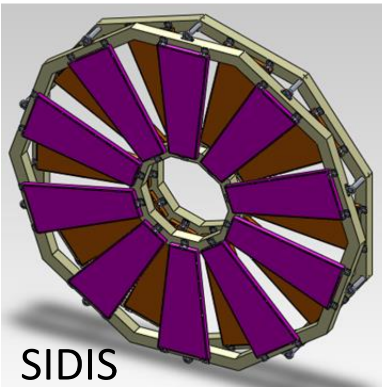
Plane	Z (cm)	R_I (cm)	R_O (cm)	# of channels
5	150	55	115	30 k
6	190	65	140	36 k
7	290	105	200	35 k
8	310	115	215	38 k
total:				140 k

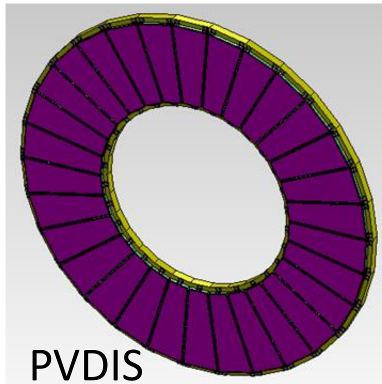


Total estimate: 100 m^2 GEM foils for SoLID

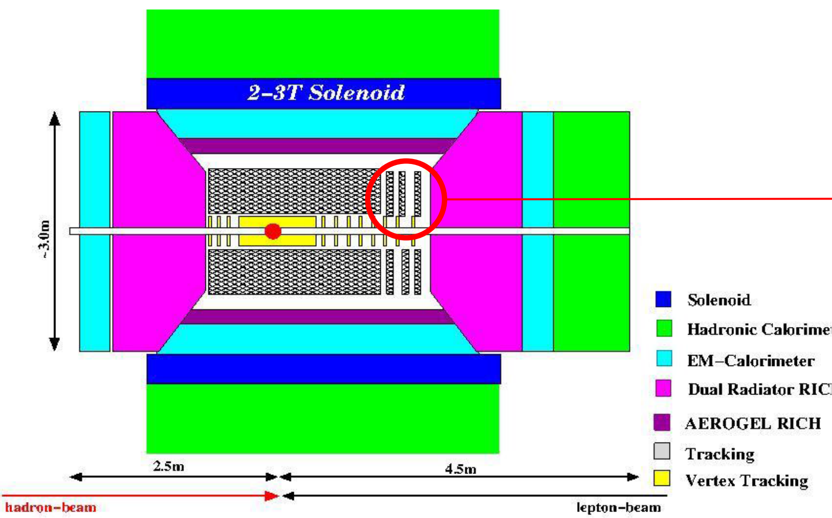
GEM R&D for SoLID and EIC

GEMs for SoLID Tracking

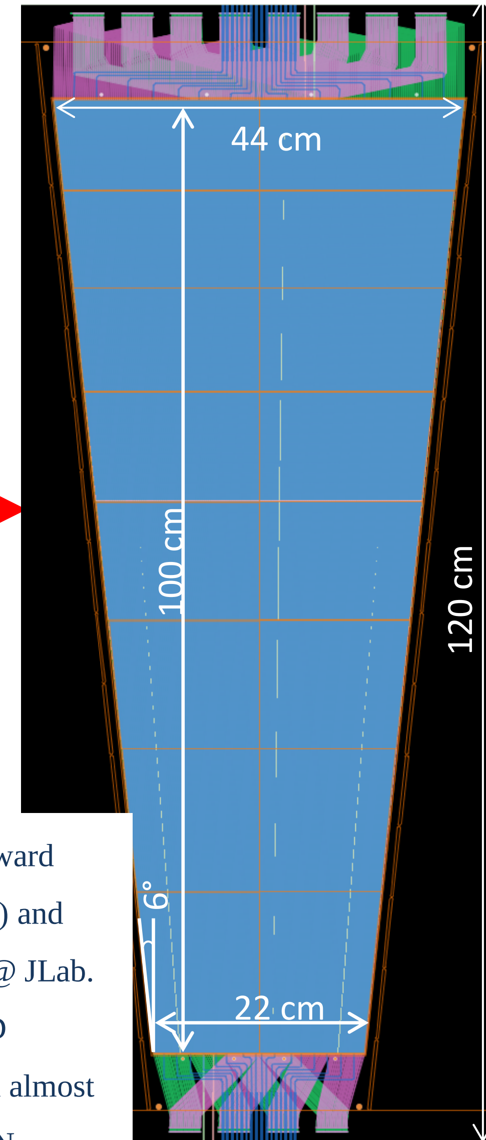




GEMs for EIC Forward Tracker



Common prototype

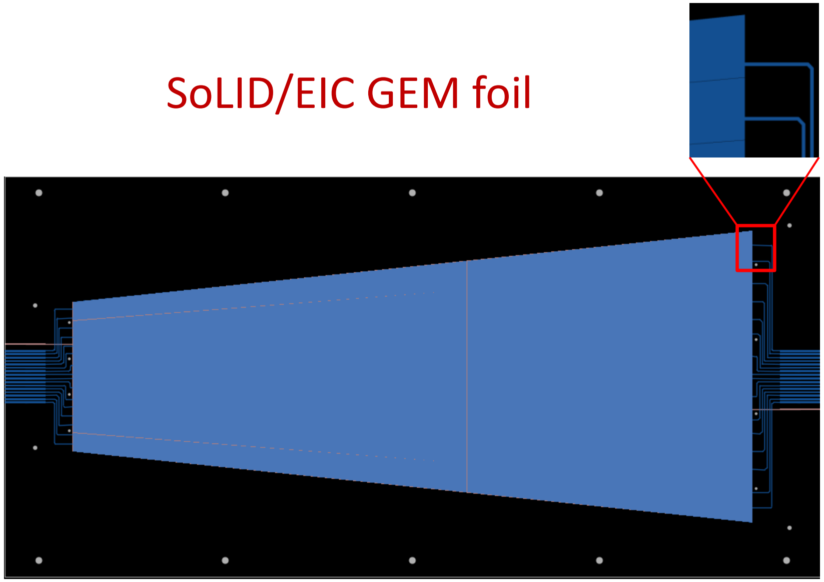


- Common R&D for triple GEM for forward tracker R&D for EIC (@ BNL or JLab) and Tracking system for SoLID in Hall A @ JLab.
- Design inspired from CMS GEM R&D
- Production of the GEM and R/O board almost completed @ Rui's workshop @ CERN

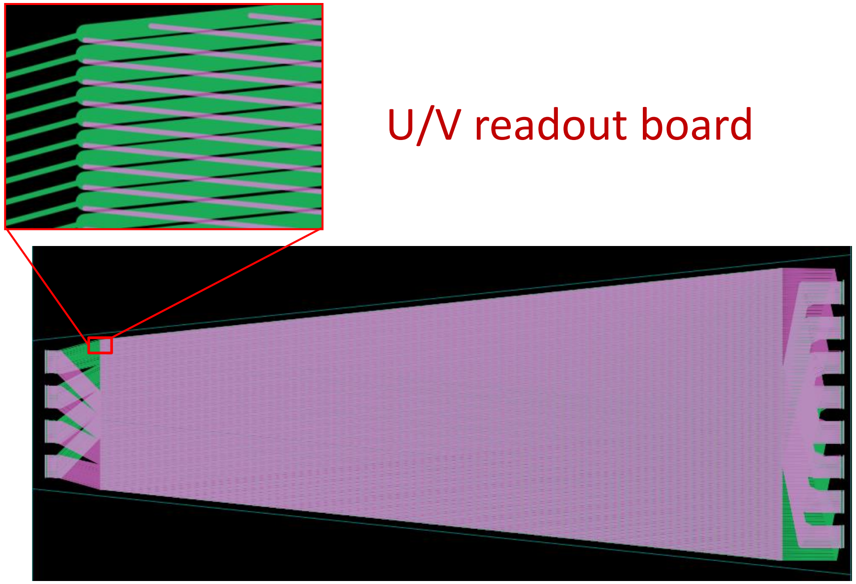
SoLID / EIC GEM Design

We should reduce as much as possible the dead area on the sides of the chambers

SoLID/EIC GEM foil



- The foil is divided into 32 HV sectors of roughly 100 cm^2
- 16 sectors from the top and 16 from the bottom



U/V readout board

- "COMPASS-like" 2D stereo angle (12°) U/V readout
- Pitch = 550 μm, top strips = 140 μm, bottom = 490 μm
- The support for the r/o based on Rohacell foam instead of honeycomb sandwiched between 100 μm fiberglass
- connectors on the top and bottom part of the r/o board

SoLID / EIC GEM 2D Current status

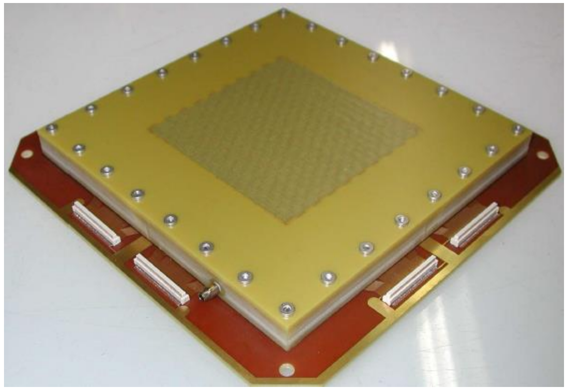
- Production of the GEM foils and readout board completed by Rui's
- Frames from RESARM (Belgium) already delivered
- We plan to build the chamber in September (2013)
- Because we would like to bring it in the Test beam at Fermilab early October (2013)

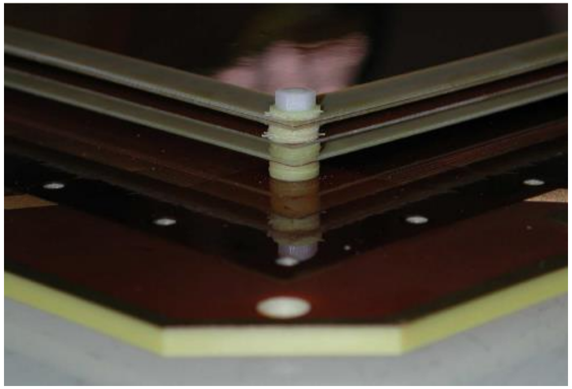
Building the Largest (2×0.5 m^2) GEM chamber

- CERN - RD51's goal for 2014: Produce a GEM foil with an 2×0.5 m^2 active area
- A large area GEM chamber would be a big breakthrough for tracking systems
  - Could be an alternative to SBS Back Tracker Chamber
  - Also could be the upgrade of the drift chamber for Hall A HRS apparatus
  - Future tracking and muon systems @ Jlab and elsewhere
- A proposal has been submitted to JLab FY14 LDRD for funding
- A lots R&D involved (see coming slides).
  - "Re-Openable" detector
  - Big challenges for 2D readout with high spatial resolution and low occupancy
  - Big challenges for the construction of such a big size detector

Idea for the assembly of the GEM chamber

From 10 cm × 10 cm "LEGO" GEM to 200 cm × 50 cm "MAXI LEGO" GEM chamber

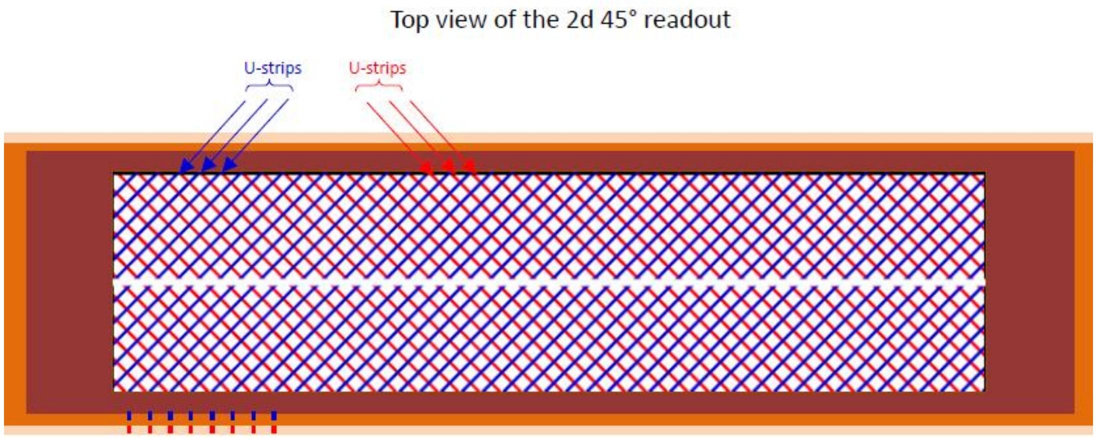


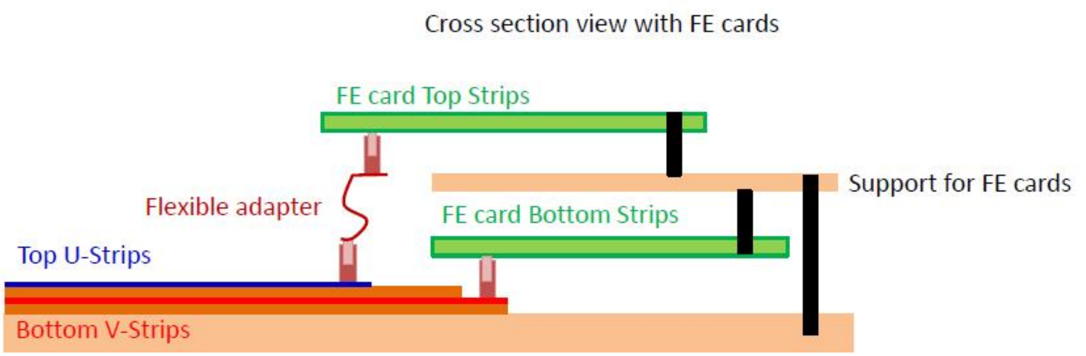


- Standard framed GEM foil (even for such large size
  - Will required very large frames (with or without spacers inside)
  - Mechanical stretching ➔ control of the stretching tension
  - Still need ~ 24 hours to frame and glue a foil (might be OK if production and assembly time is not critical issue)
- Framed GEM are not glued together in the final assembly
  - Frames are stacked just as in small 10 cm × 10 cm CERN GEM
  - Will make it simpler and faster than NS2 technique to replace bad GEM foil in the assembled chamber
- Flexibility in the design
  - We could avoid soldering the resistor directly on the GEM foil as in NS2 technique

Idea for 2D readout for 2 × 0.5 m² GEM chamber

- "COMPASS-like" 2D Cartesian readout
  - Pitch = 400 µm, top strips = 140 µm, bottom = 360 µm
- Strips 45° w.r.t the detector axis
  - Reduce the length of the strips
- Strips splits in the middle
  - Even shorter strips → reduce capacitance and strips occupancy
  - But double number of channels





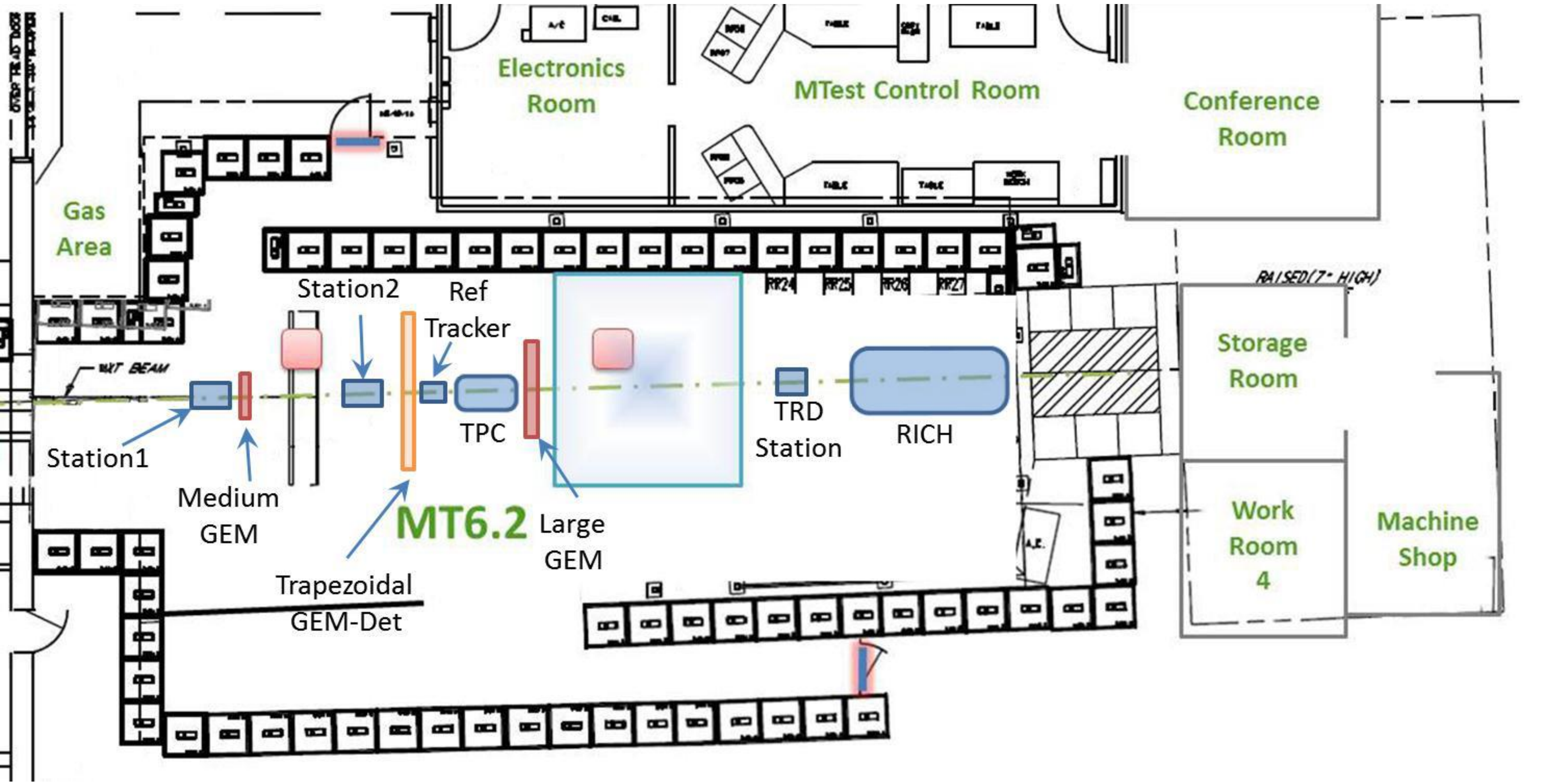
Test beam at Fermilab

Testbeam @ FermiLab FTBF (October 2013)

- FLYSUB is a consortium consisting of BNL, Florida Tech, Stony Brook University (SBU), University of Virginia (UVa), and Yale University working on the R&D for GEM-based tracking and PID detectors for the EIC
- We've been approved for 3 weeks beam access at the Fermilab Test Beam Facility (FTBT) in October 2013 ➔ the consortium will bring more than 20 GEM chambers detectors (tracking, Cerenkov, TPC …)
- UVa will be bringing:
  - SoLID / EIC large GEM prototype, one 50 × 50 cm^2 SBS GEM chambers, 3 small (10 × 10 cm^2) GEMs + 1 Micromegas for the tracking
- The main goal for us is to measure position resolution SBS and SoLID GEMs (U/V readout) and performances at high rate and in magnetic field.
- Also an opportunity to test our newly acquired UVa medium size (10K) SRS electronics

Testbeam @ FermiLab FTBF (October 2013)

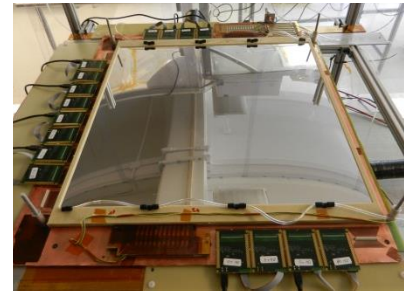
MT6.2 Layout with all detectors along the beam-line (detectors are not to scale).

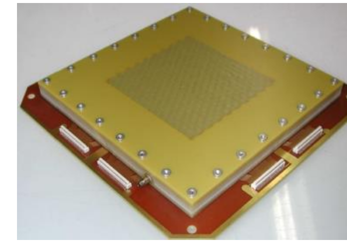


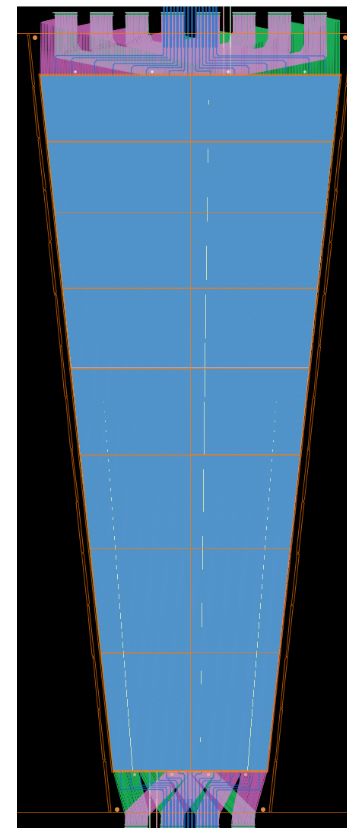
Testbeam @ FermiLab FTBF (October 2013)

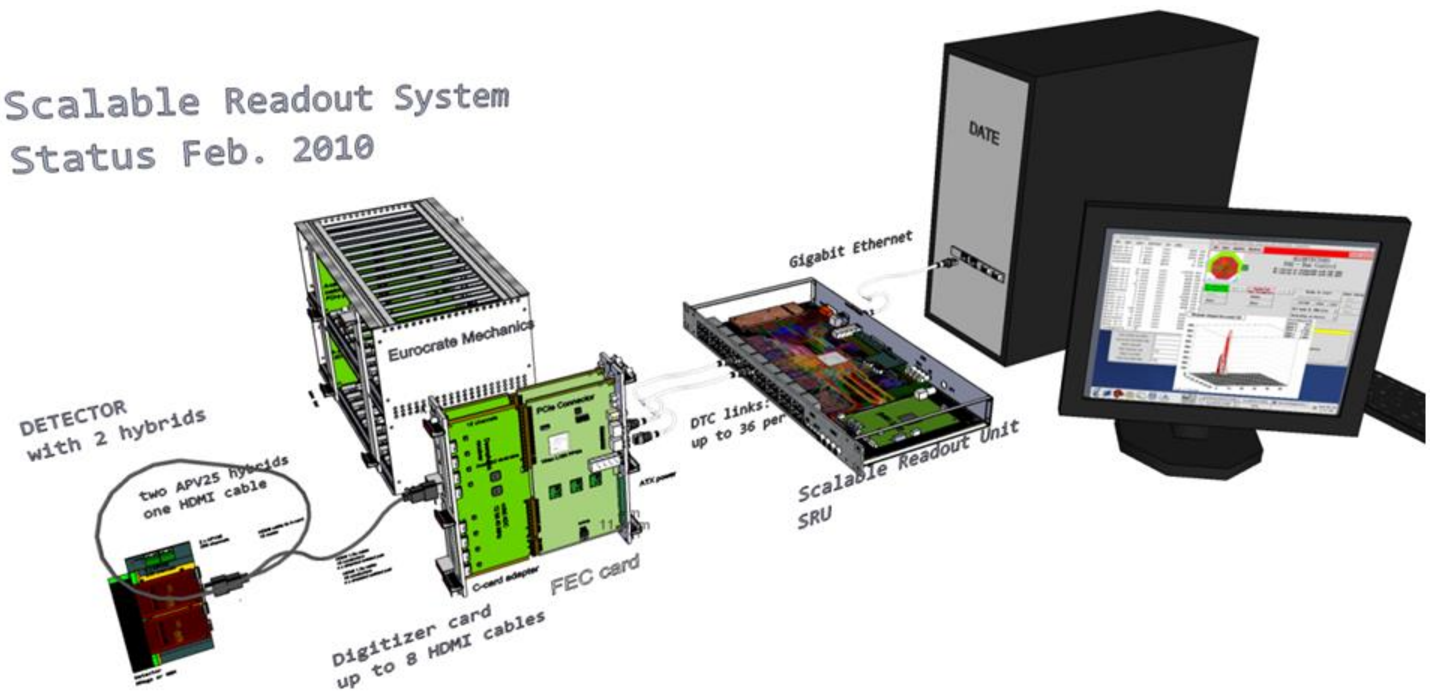
Testing the APV25-SRS system with the SRU and about 10 K channels

- 80 APV25-SRS FE cards: 10K channels
- 6 ADC boards and one SRU
- 5 FEC v6: More FPGA resources, DDR memory, dual SFP connector
- Will be used to read out all UVa GEM during the test beam
- Goal: Testing rate capability and stability of the large SRS









Testbeam @ FermiLab FTBF (October 2013)

- Electrons
  - Energy of beam: 10 GeV
  - Intensity: Single particles (if possible), Beam spot size: as small as possible
- Pions
  - Energy of beam: > 4 GeV, > 20 GeV
  - Intensity: single particles (if possible); variations 1k – 100k particles/ 4 sec spill, Beam spot size: as small as possible; about 1 cm2
- Kaons
  - Energy of beam: > 13 GeV
  - Intensity: single particles (if possible)
- Protons
  - Energy of beam: > 27 GeV
  - Intensity: single particles (if possible), Beam spot size: as small as possible

Testbeam @ FermiLab FTBF (October 2013)

http://www-ppd.fnal.gov/FTBF/schedule/MTest14.html

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Fermilab Test Beam Facility

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- Instrumentation
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- Location
- Test Experiments
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- Contact & Personnel
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- Pictures

Schedule

This is the **official** schedule for FTBF activities. Typical run periods establish beam on Wednesdays, and run through Tuesday. Scheduling meetings are held most Tuesdays at 2pm. To schedule beam time please see our Guidelines for Requesting Beam and contact the Test Beam Coordinator.

Accelerator NOvA Upgrade Shutdown **disables Test Beam from April 30, 2012 ~ July 1, 2013**

MTest FY13 | MTest FY14 | MCenter FY13 | Previous Years | Calendar

2013

	Dates	Experiment	Description	User	Area	Contact
1.	Oct 2 - Oct 8	T1037	FLYSUB-Consortium	Primary	MT6-ALL	Dehmelt
2.	Oct 9 - Oct 15	T1037	FLYSUB-Consortium	Primary	MT6-ALL	Dehmelt
3.	Oct 16 - Oct 22	T1037	FLYSUB-Consortium	Primary	MT6-ALL	Dehmelt

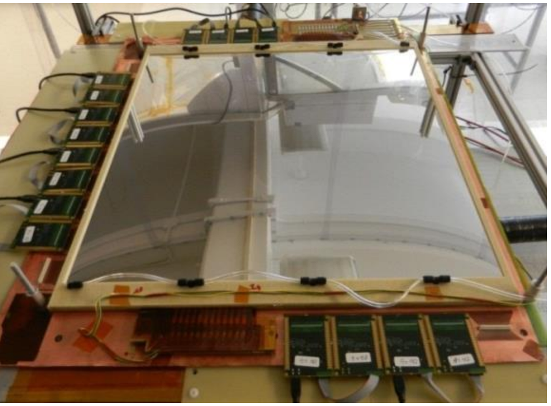
Summary

- Intense R&D activity at UVa for large area GEM for tracking systems in Hall A @ JLab
- Successful SBS Back tracker GEM prototype built and under test
- Upgraded design for SBS Back Tracker under production.
- Large trapezoidal triple-GEM prototype under construction for SoLID and EIC.
- Ongoing R&D for a 200 × 50 cm^2 Triple GEM with 2D readout
- Acquisition of a large size SRS electronics, upgrade our capability to 10K channels.
- Test beam at FermiLab in October 2013 to test SBS Back Tracker prototype and SoLID/EIC chamber as well as rate capabilities of large size APV25-SRS electronics

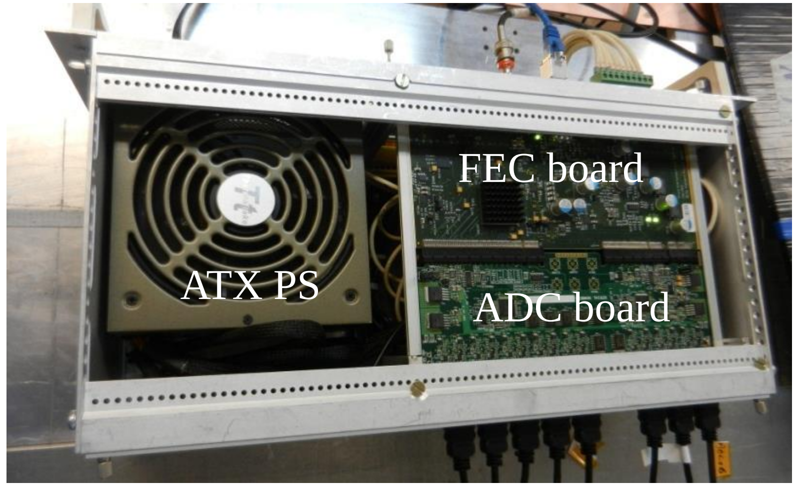
Backup

APV25-SRS Electronics @ UVa

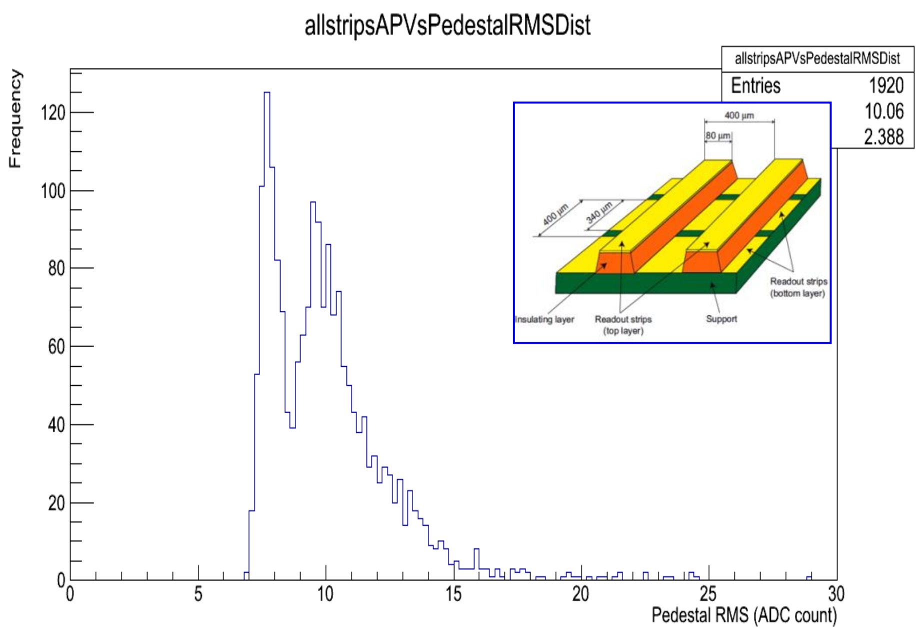
APV25-SRS FE cards on the GEM detector



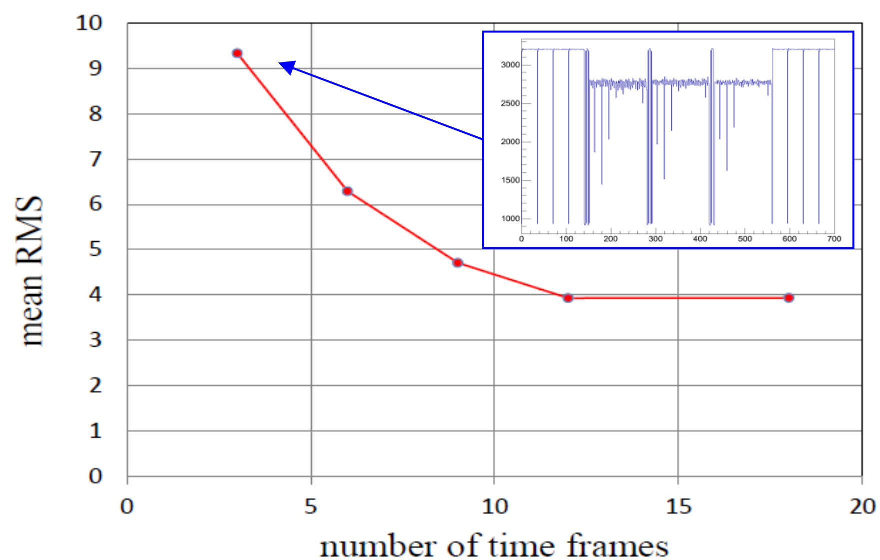
SRS small system 1 ADC/FEC combo



CERN ALICE DAQ (DATE/AMORE)



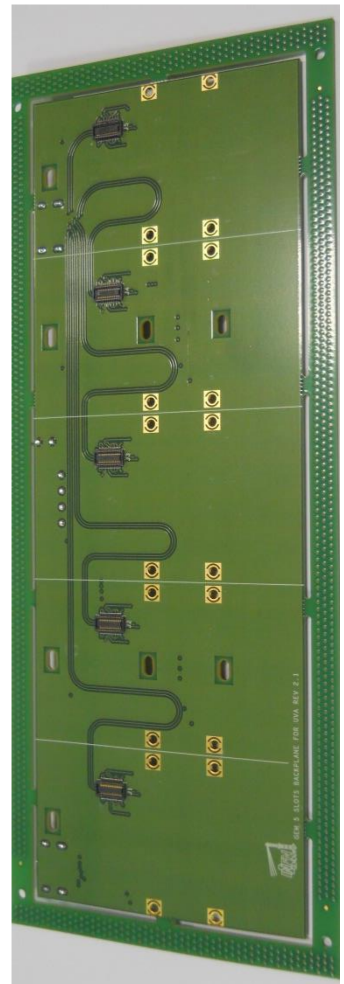
Pedestal noise vs. number of time sample

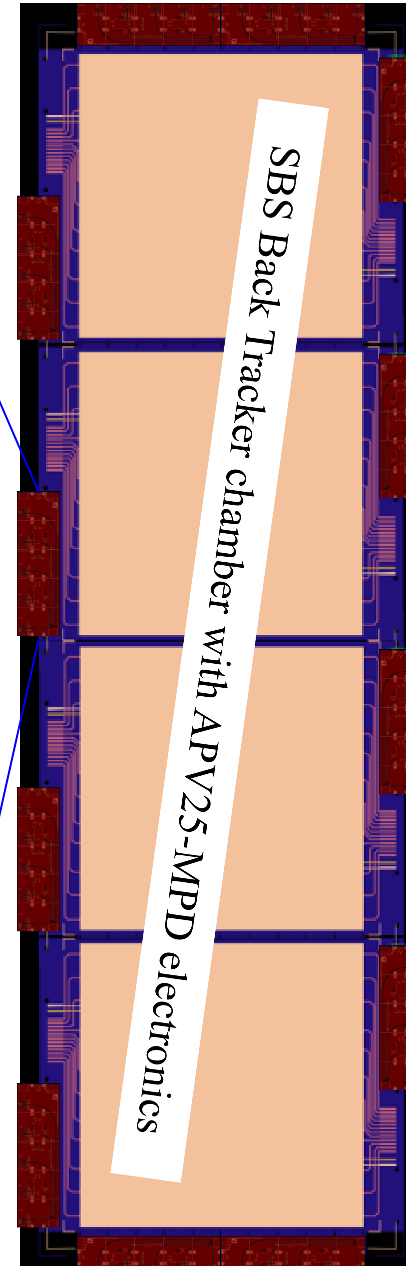


Upgrade of the APV25-MPD Electronics @ UVa

- New version of APV25-MPD cards with Panasonic connectors (P. Musico, INFN Italy)
- New Back Planes with 5 slots ➔ Compatibility with Back Tracker GEM readout (P. Musico, INFN Italy)
- We acquired the new system with 5 APV25-MPD cards, on 5-slots Back Plane and
- Latest version of the MPD VME board

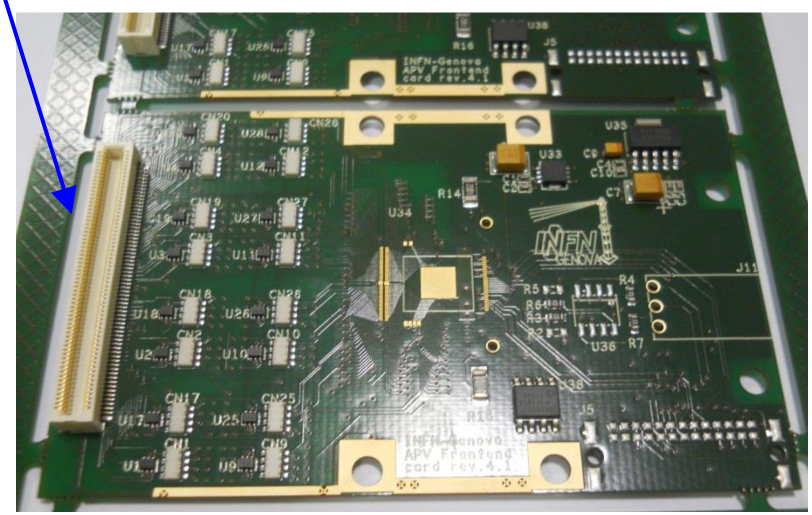
5-slots back plane





Panasonic connectors

APV25-MPD FE cards



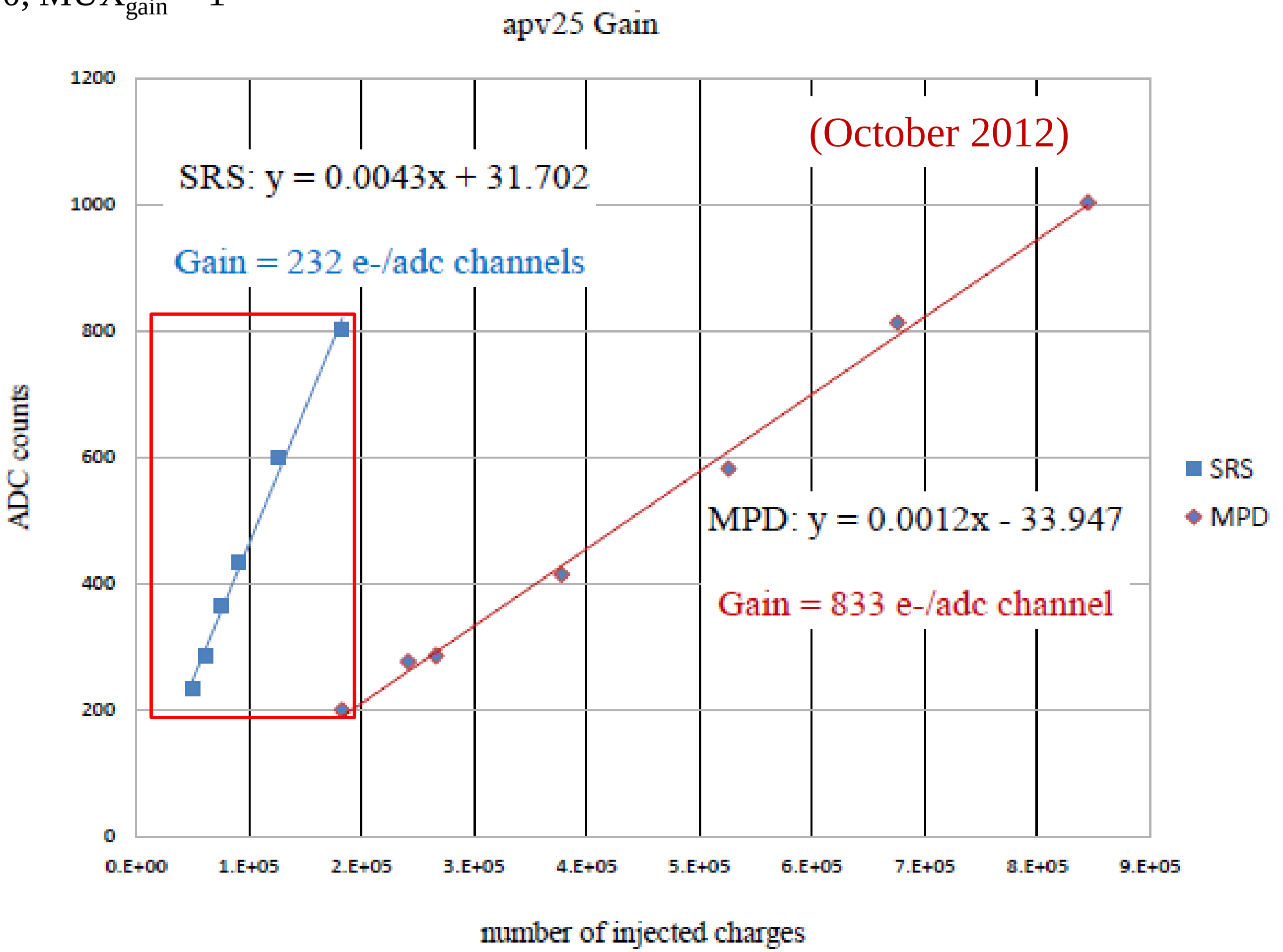
Gain study of APV25 electronics for SRS & MPD

Initialization parameters for the APV25 FE cards

$I_{pre} = 98$, $I_{pcasc} = 52$, $I_{psf} = 34$, $I_{sha} = 22$, $I_{ssf} = 34$, $I_{psp} = 55$,

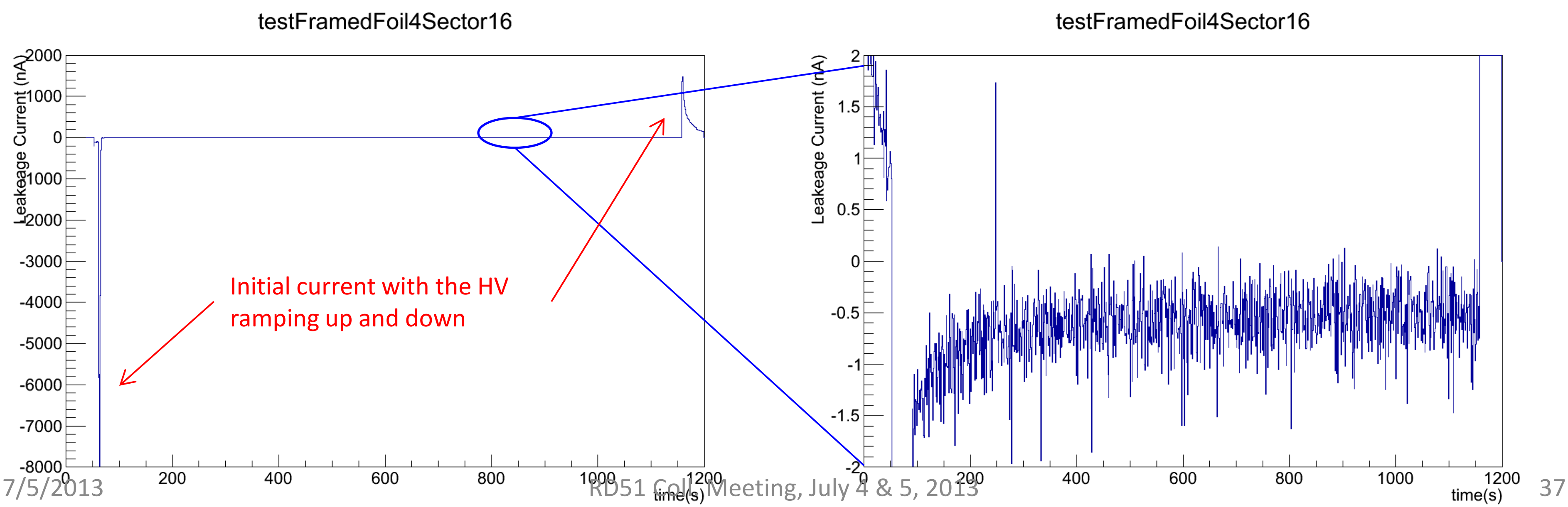
$I_{muxin} = 16$, $V_{fpr} = 30$, $V_{fs} = 60$, $V_{psp} = 40$, $MUX_{gain} = 1$

Operation of the SBS prototype: Ar/CO2 (70/30) with 4.1 to 4.2 kV on HV divider ➔ Estimated gain



HV test of the GEM sectors

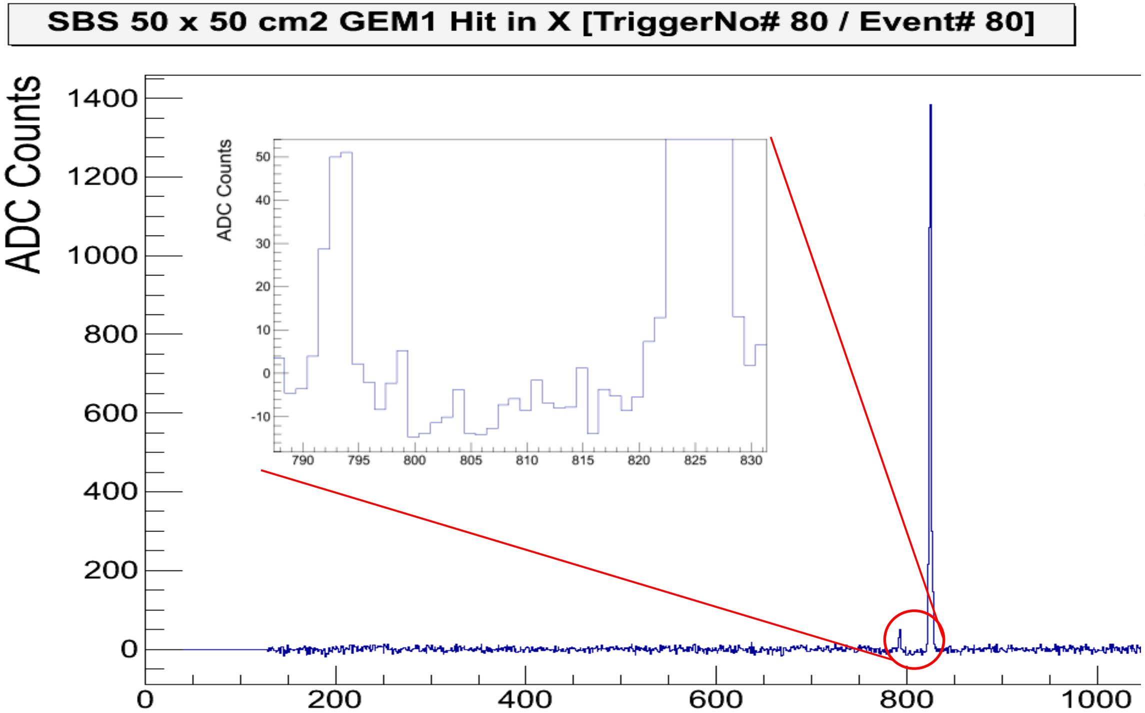
- We use an Iseg EHS 6 kV HV module in a Wiener crate, HV controlled through an internet protocol.
- Fast ramp up mode at a rate of 1200 V/s.
- The leakage current in the GEM is measured using a Keithley 6487 picoammeter, at sampling rate of 120 ms with a Labview interface and saved in txt file.
- HV GEM sector ~ 2 nF and with a resistance the HV module is ~ 50 MΩ, (once the voltage is achieved this resistance is shunted automatically within the supply).
- HV of 550 V, the initial current is a couple of μA, then quickly drops and stabilizes to less 1 nA leakage.
- We leave the HV for about 2 min and if no spark ➔ sector is good

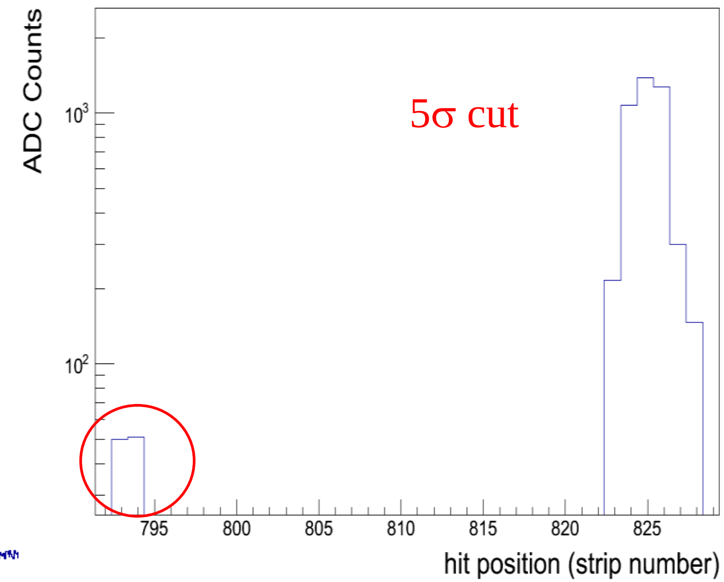


Recovering of a bad HV sector

Excess of glue leaked onto the sector during assembly ➔ sector recovered after curing on N2 or at 50 degree

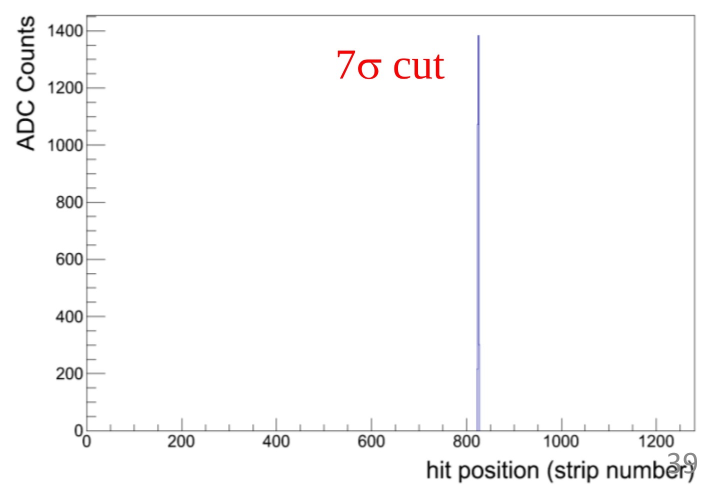
Cross Talk in APV25 Electronics





Current version of the analysis (AMORE) code:

- Only single cluster event used for 2D hit maps, X-Y charges correlation etc … and minimal cluster size = 2hits
- For high amplitude hits, cross talk cluster survives a 5σ zero suppression cut ➔ Event seen with 2 clusters and rejected
- Cross talk is suppressed at 7σ here in this example



Distribution of the relative position ($X_{cluster1} - X_{cluster2}$) of two clusters in 2-clusters events

Distribution of ADC counts ratio ($ADC_{cluster1}$ / $ADC_{cluster2}$) of two clusters in 2-clusters events