GEM Detectors for SuperBigbite

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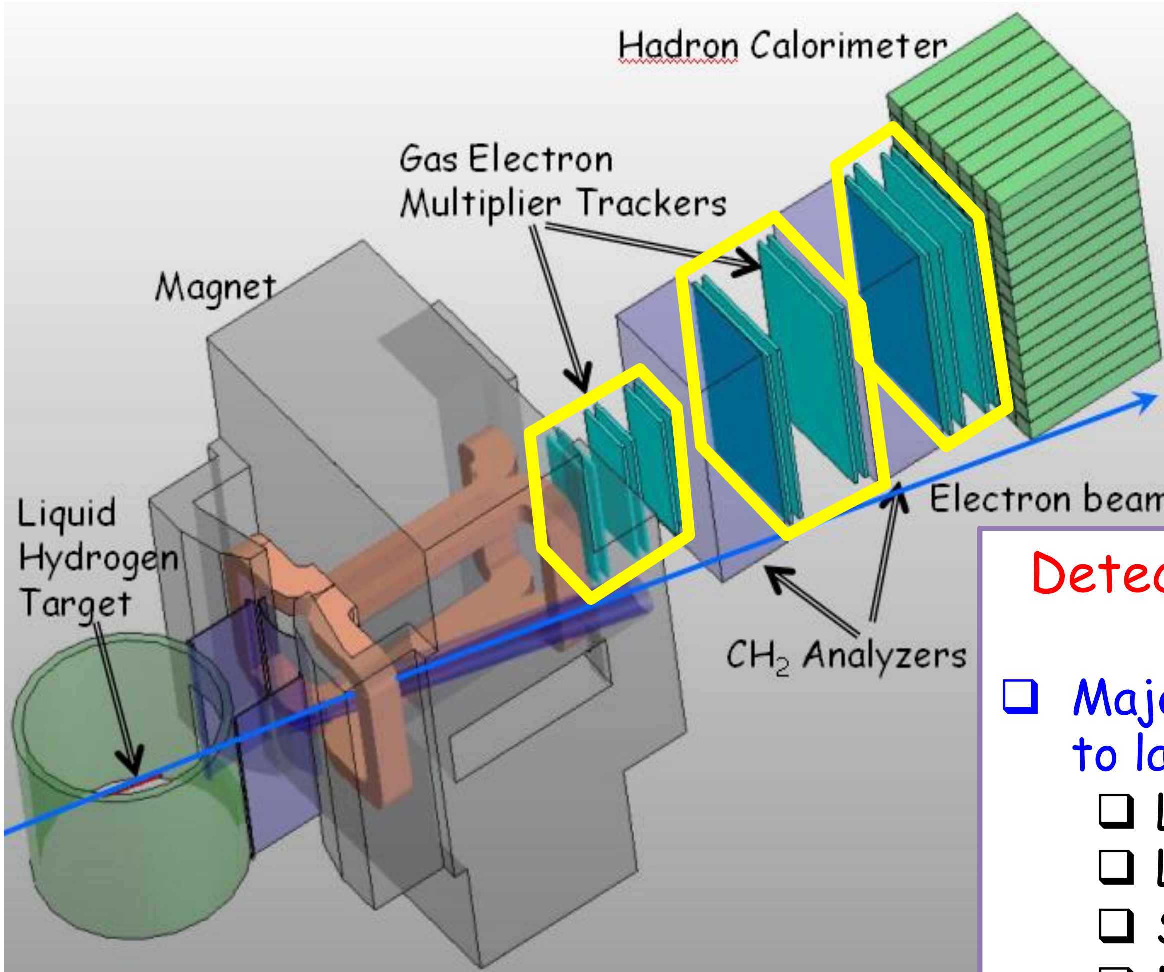
Outline

- SBS tracking concept
- SBS GEM tracker overview
- SBS GEM R&D
- GEM construction plans under WBS 2 and WBS 3
- ESH&Q Integration
- Conclusion

SBS Concept



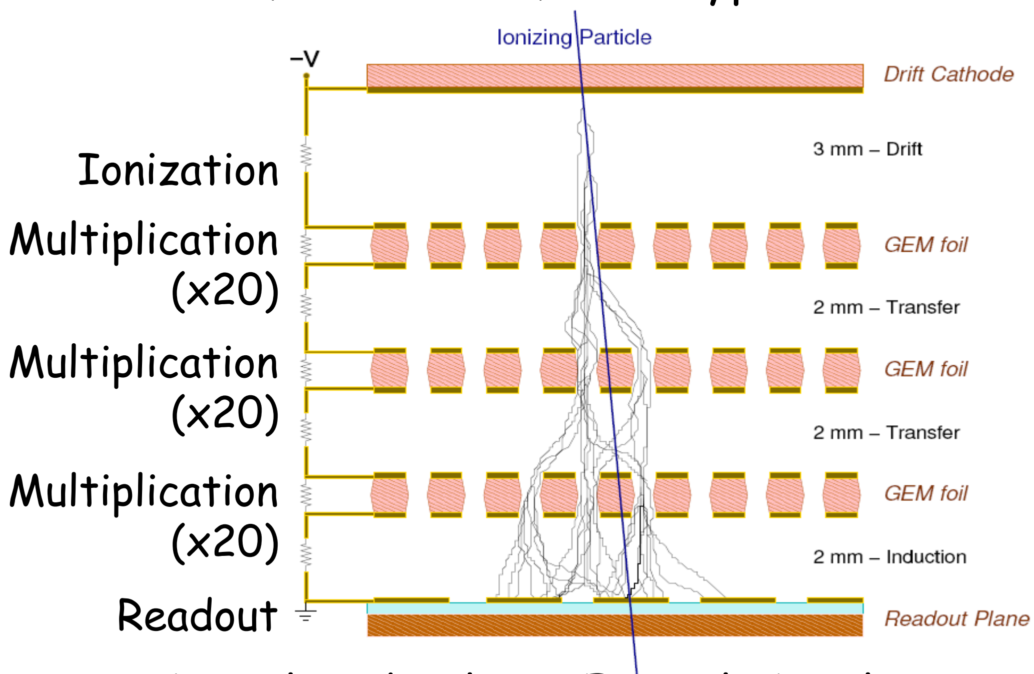
Detectors behind a large dipole magnet:

- Major advantages which pave way to large FOM:
  - Large solid angle
  - Large momentum bite
  - Straight line track analysis.
  - Detectors shielded from charged particle background.
- Consequences:
  - High rates at detectors.
  - Need good coordinate resolution.

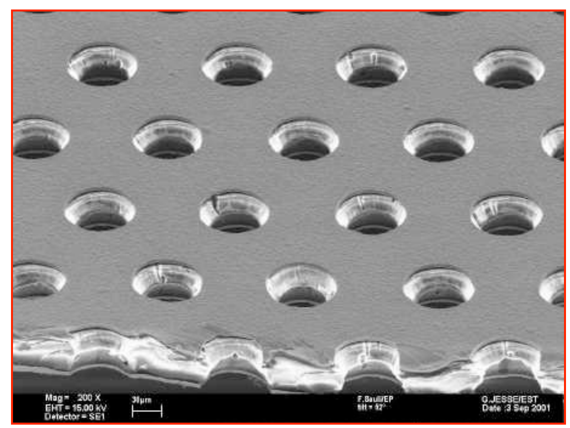
Why GEMs ?

- Super Bigbite Spectrometer concept leads to high rate in trackers: up to 500 kHz per cm^2 in the front detector, 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, KLOE, TOTEM, STAR FGT, Prototypes for CMS upgrade etc.



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

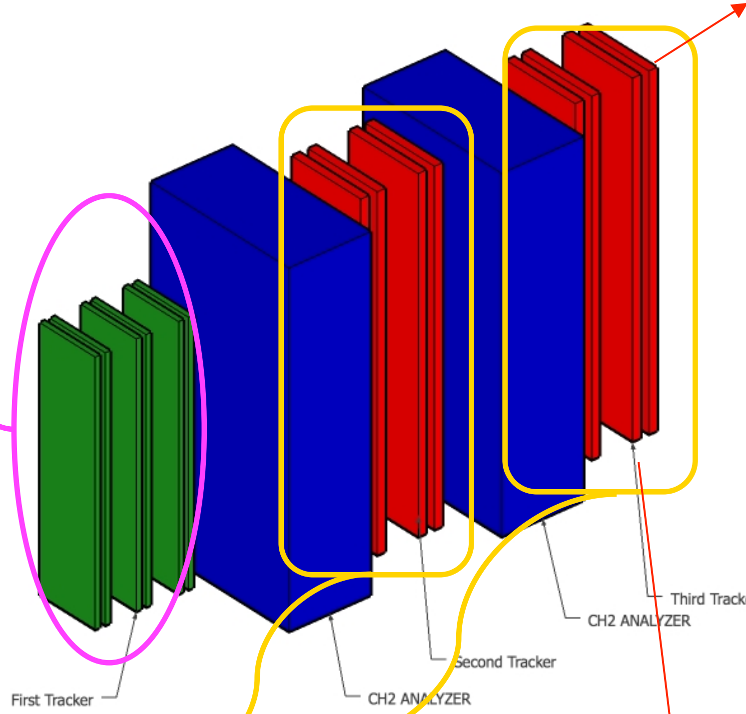


Novel technology: F. Sauli, Nucl. Instrum. Methods A386(1997)531

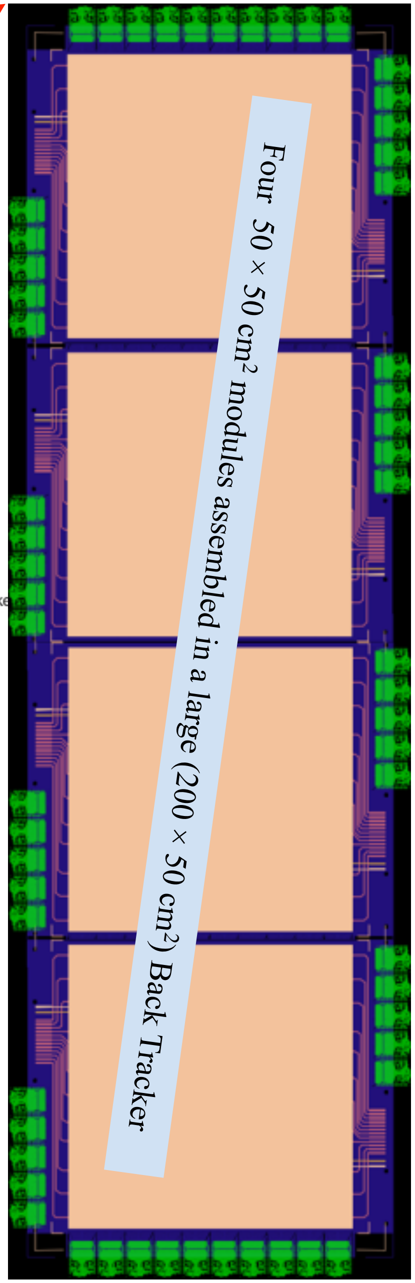
SBS GEM Trackers

Front Tracker

- 50 cm x 40 cm Modules
- Six 40 cm x 150 cm GEM layers
- 60 k readout channels
- INFN Funding: being built in Italy – (E. Cisbani's talk)



SBS Back Tracker Chamber



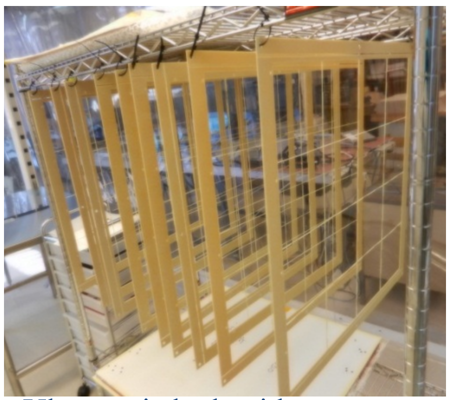
Polarimeter trackers

- 50 cm x 50 cm modules
- Ten 50 cm x 200 cm GEM layers: 40 modules
- 64 k readout channels
- SBS project: built in Virginia (this talk)

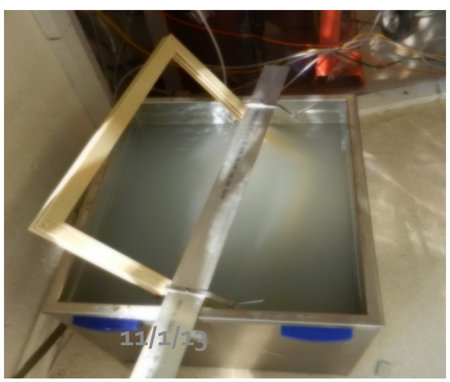
SBS GEM pre R&D at UVa: August 2011-July 2013

- Funding: Jlab SBS pre-R&D funding, and also UVa internal funds
- UVa GEM team: Liyanage (PI), Two Research scientists and Three graduate students; search for a full time technical post-doc currently underway.
- Close collaboration with Jlab (Wojtsekhowski, Camsonne) and INFN (Cisbani, Musico).
- Nicely coupled with the EIC detector R&D effort: UVa project – construction of a ~ 1 m long GEM detector with 2D readout.

Storage of the frames



Ultra sonic bath with demineralized Water



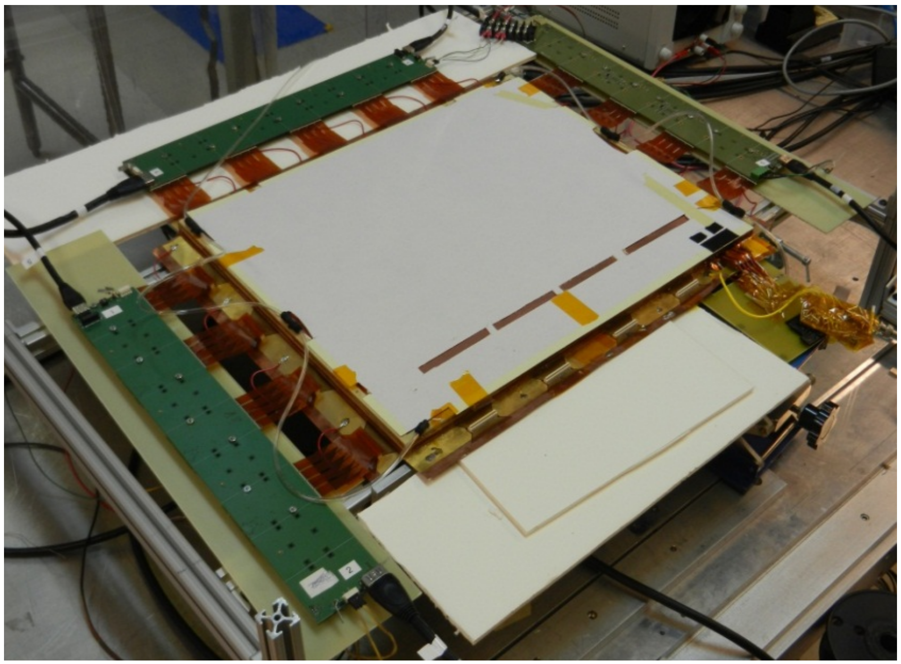
Large area (3 × 7 m^2) class 1000 Clean Room

Glue dispenser

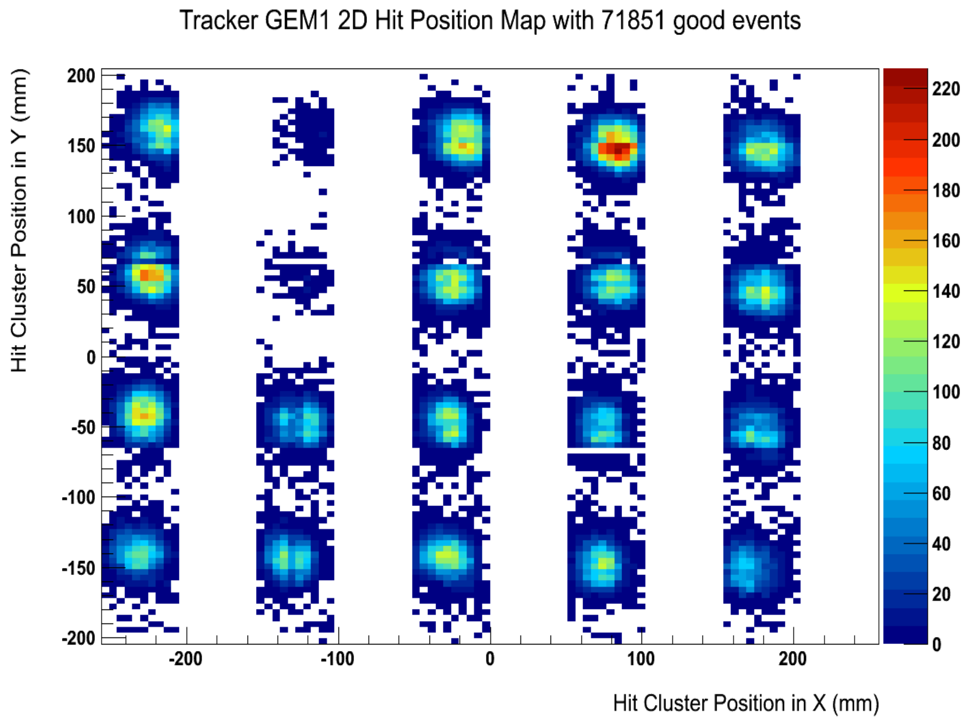
Tacky roller ➔ dust removal

SBS GEM pre R&D

- 2011-2012: constructed two 40 x 50 cm^2 SBS prototype modules
  - SBS GEM prototype I: operational, with 4 out of 20 sectors disabled.
  - SBS GEM prototype II: operational, with 1 out of 20 sectors disabled.
  - conclusion: basic design works, but needs design improvements to facilitate fabrication and operation.

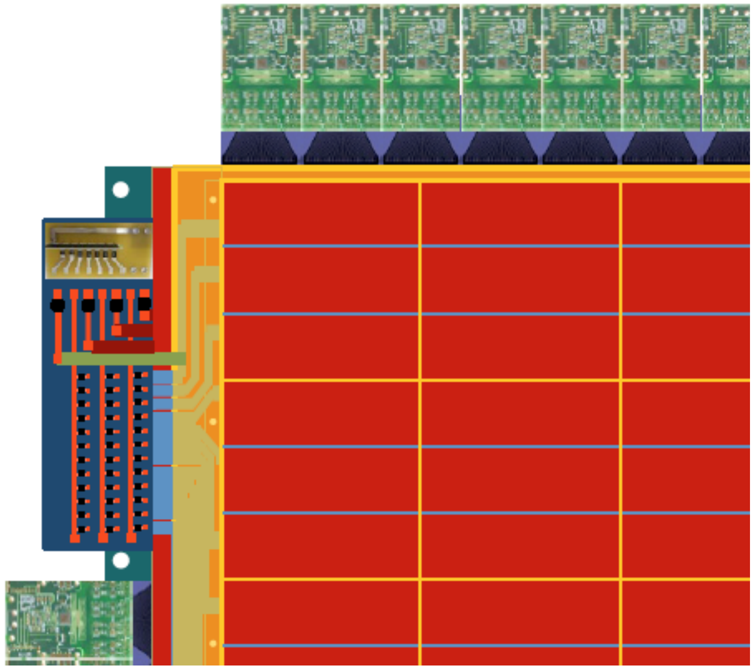


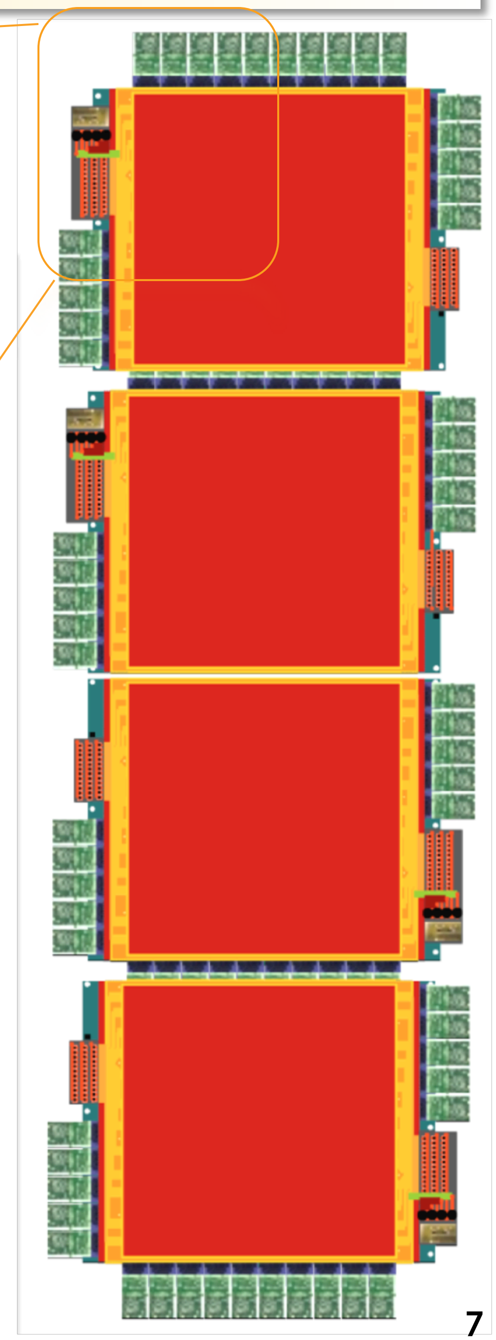
SBS prototype I: in bench tests with cosmics



Data from the SBS prototype II – a powerful ^{90}Sr source was used for this test. One sector (out of 20 sectors) shows lower efficiency

SBS GEM pre R&D

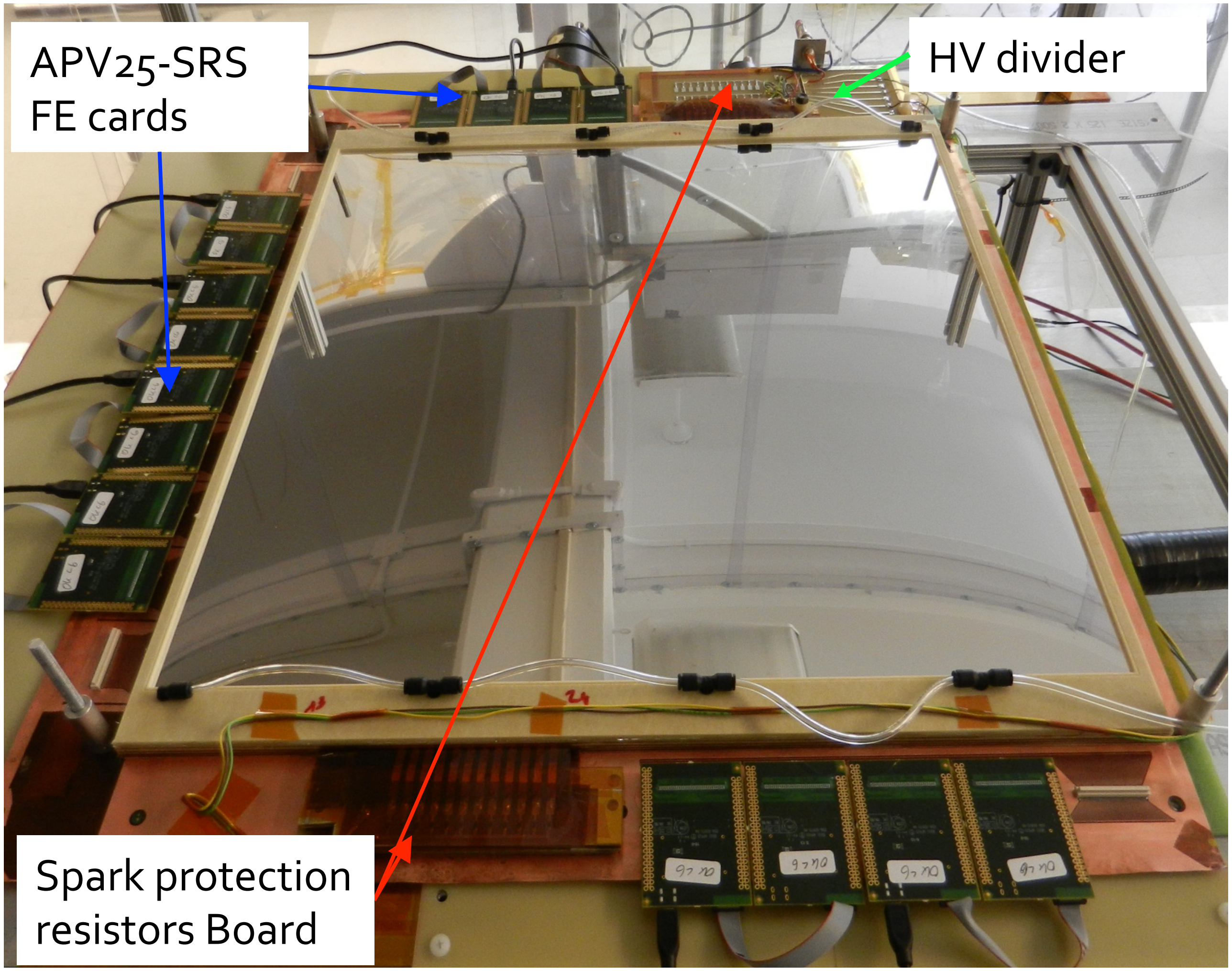




- New SBS Polarimeter GEM module design – Fall 2012
  - Protection resistors moved to be outside the chamber: reliable, easy access.
  - Large alignment pins, away from the active area
  - Wider frames on the two sides not in active area: better mechanical rigidity and more room for gas inlets, HV traces etc.
  - Electronics rearranged to minimize the material within active area.

SBS GEM pre R&D

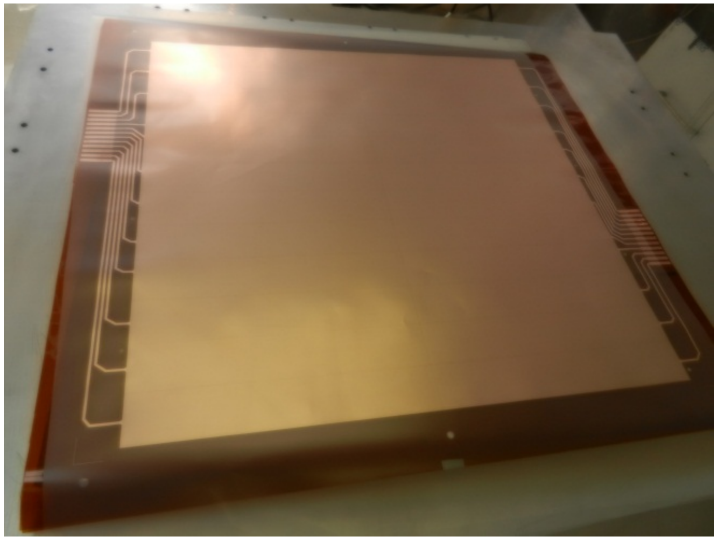
- 2013: – Constructed two SBS prototype modules based on the new design
  - fabrication considerably improved with the new design.
  - All sectors operational with results meeting SBS design criteria.
  - SBS GEM module design and fabrication methods established.
  - Beam test just concluded at Fermilab: test the SBS modules in beam conditions.



SBS Back Tracker Prototype III: fully operational

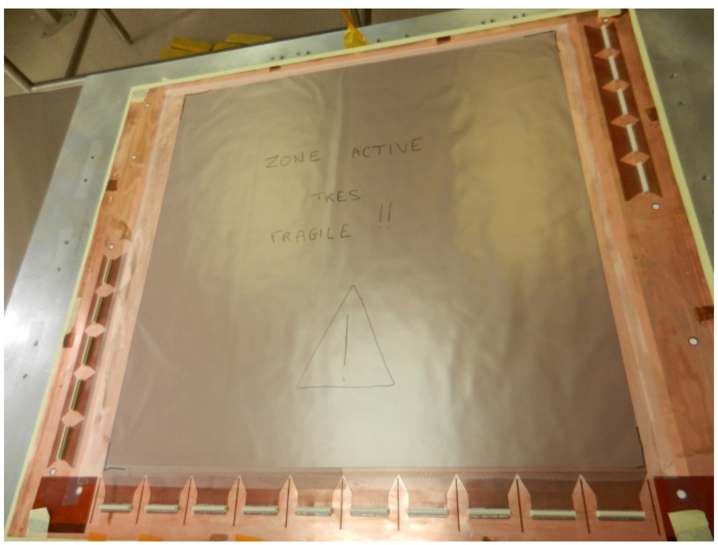
Polarimeter GEM module: components

GEM foil (CERN PCB workshop)

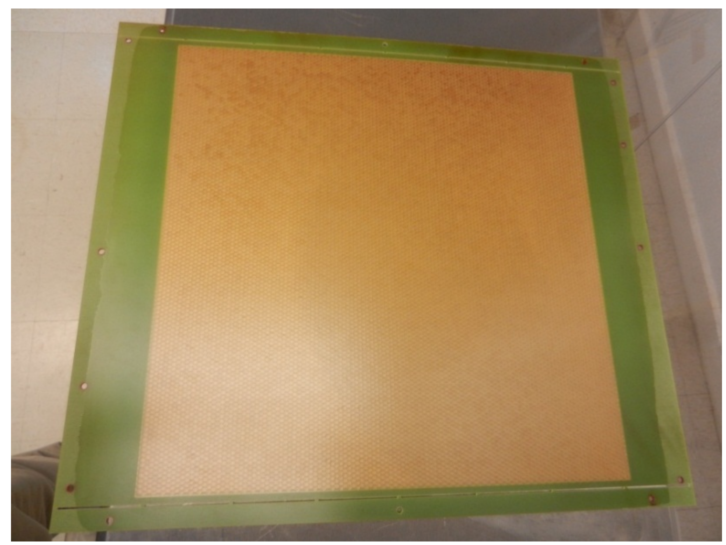


Support frame with spacers (RESARM Belgium)

Flexible 2D readout board (CERN PCB workshop)

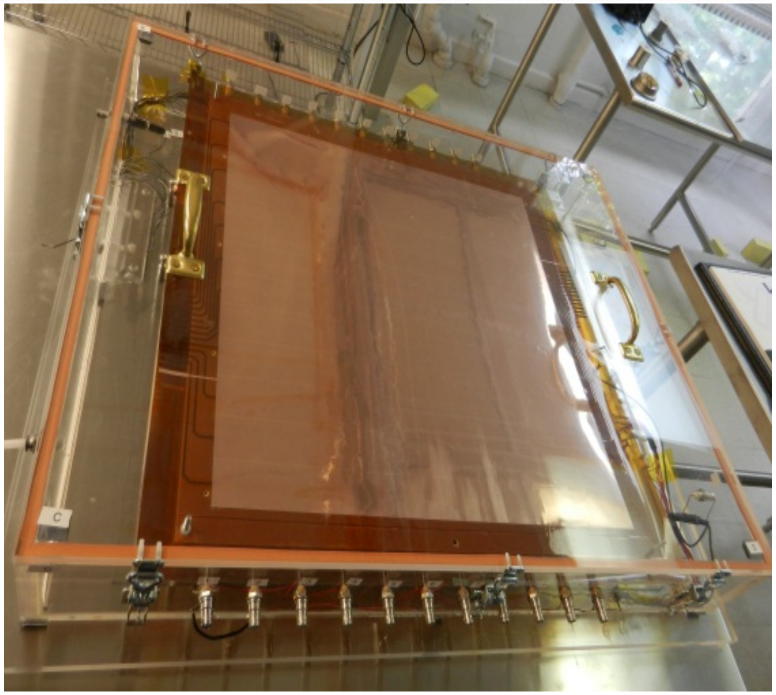


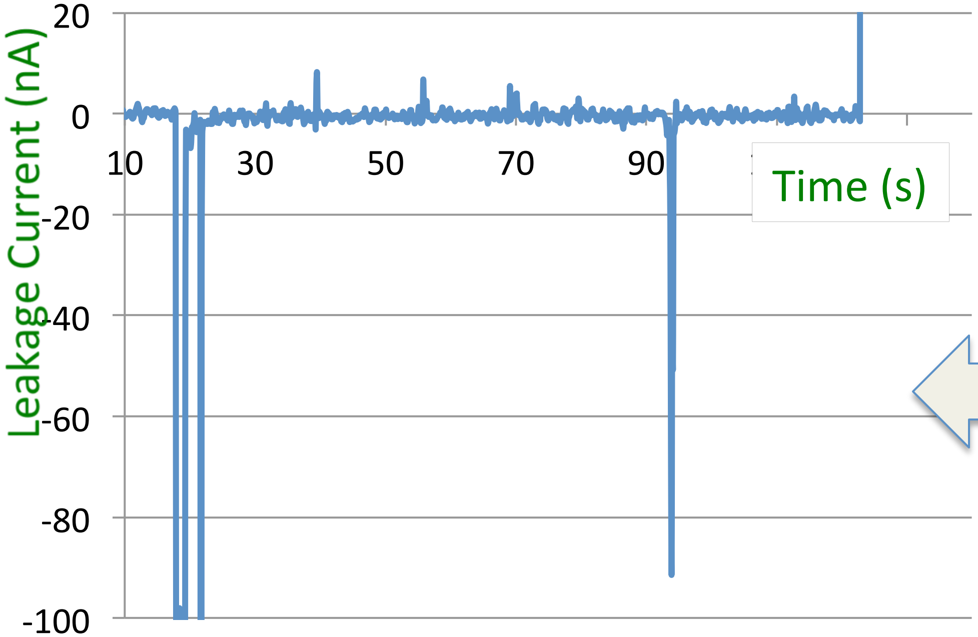
Honeycomb support board (CERN PCB workshop)



Foil testing and Leakage Current Measurement

- Proposed by Rui De Oliveira at CERN
- Rapid HV ramp-up to 550 V –causes quick burn-up of dust without polymerization or damage to foil.
- At 550 V: the initial current is a few of μA (re: capacitance of the sector).
- Then quickly drops and stabilizes to less ~ 1 nA leakage current: far better than the 5 nA requirement.
- Initially a few μA level sparks; spark rate slows down to quickly after that.



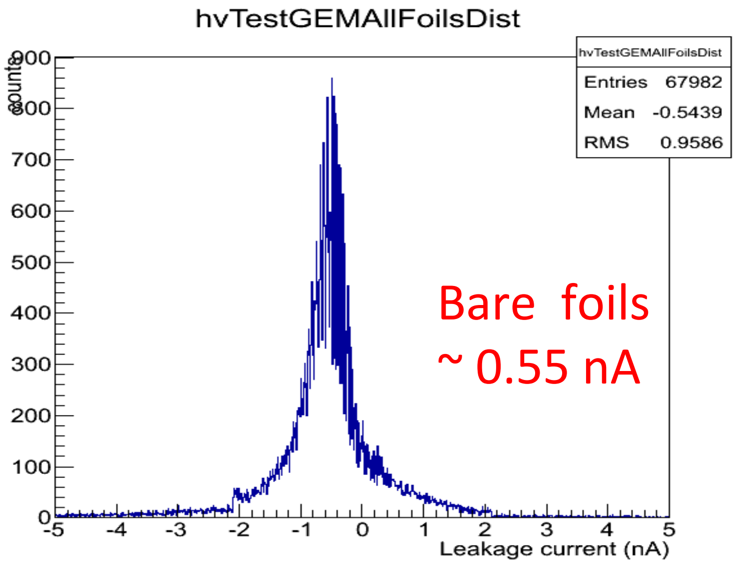


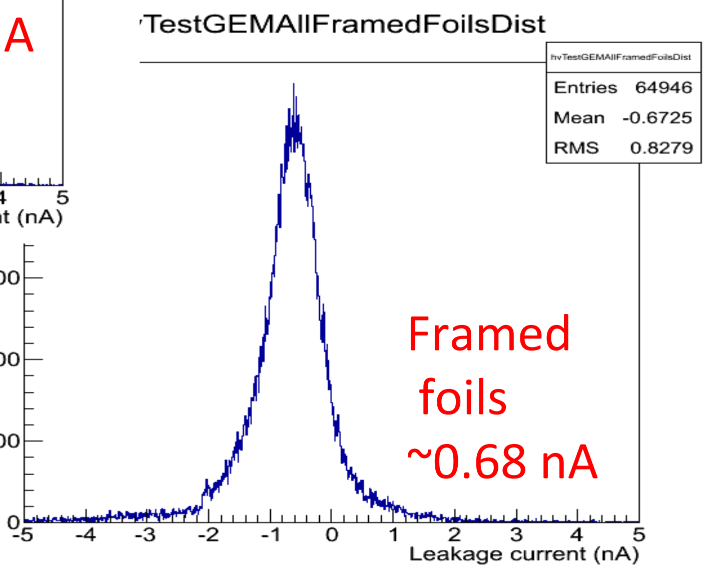
If the test indicates that a foil is bad: send back to CERN

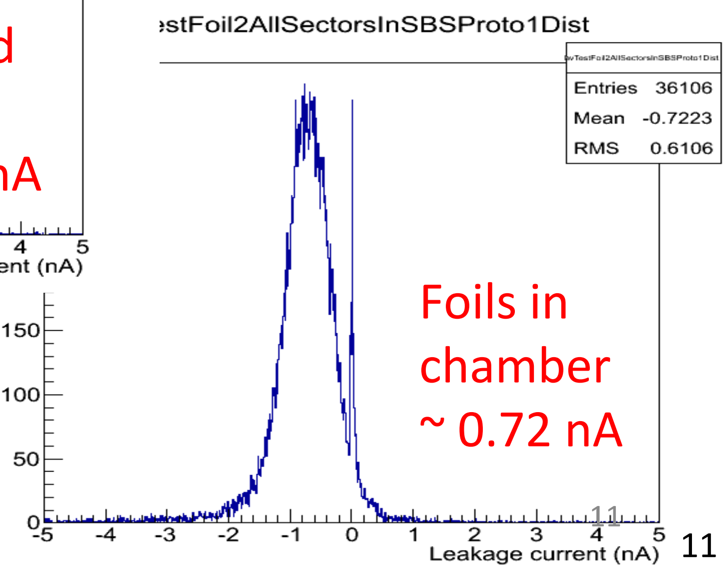
- The current drawn by the GEM foil measured using a picoammeter (through a Labview interface and saved into a text file.)
- the ~ 100 nA spike associated with someone moving near the HV test box.

Foil testing and Leakage Current Results

- Distribution of leakage current for all 72 sectors of a GEM chamber (24 sectors per foil x 3 foils)
- Current for 550 V in N_2 for bare, framed foils and in chamber
- Each sector tested for 120 s.
- PMP key performance parameter for accepting a foil: Leakage current < 5 nA

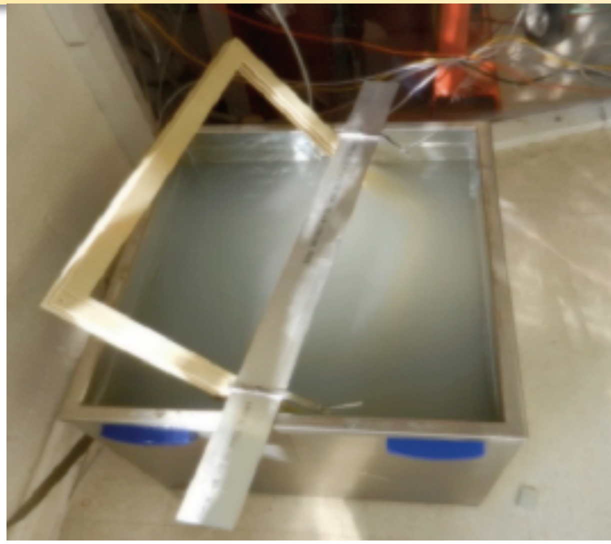




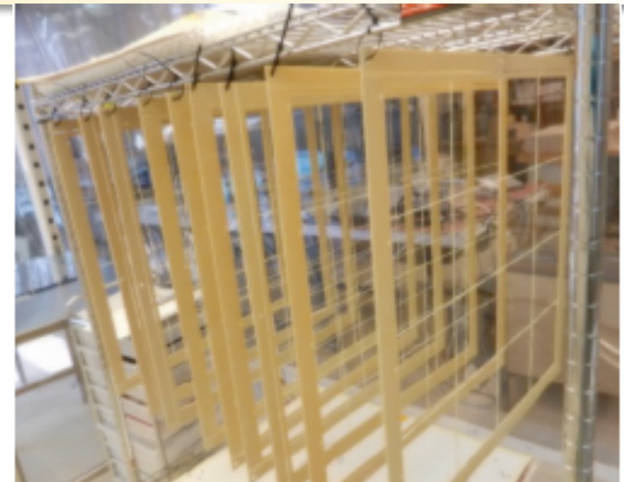


PMP key performance parameter met for all foils arriving from CERN.

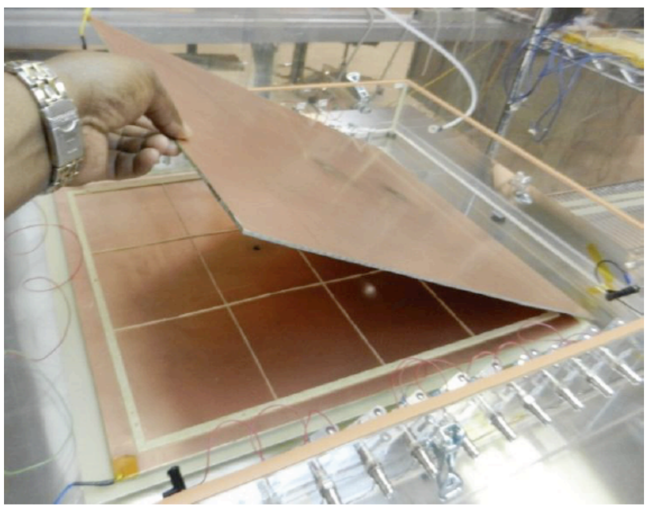
Preparation of the frames



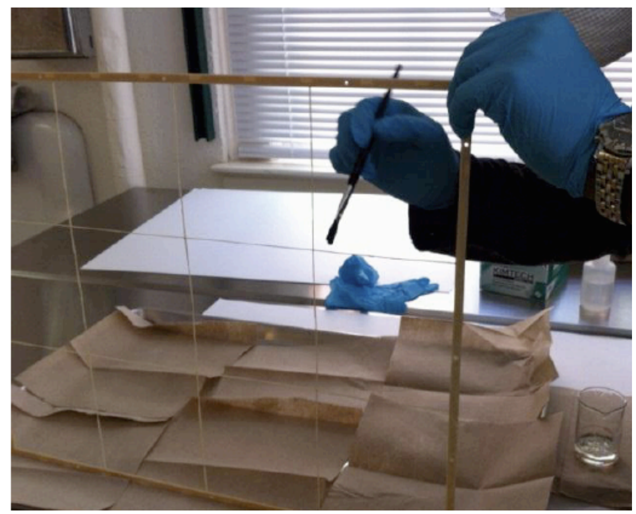
Spacers sanded, then frames cleaned in Ultra-sonic bath with demineralized Water



Dried for 4 days under a filter hood .

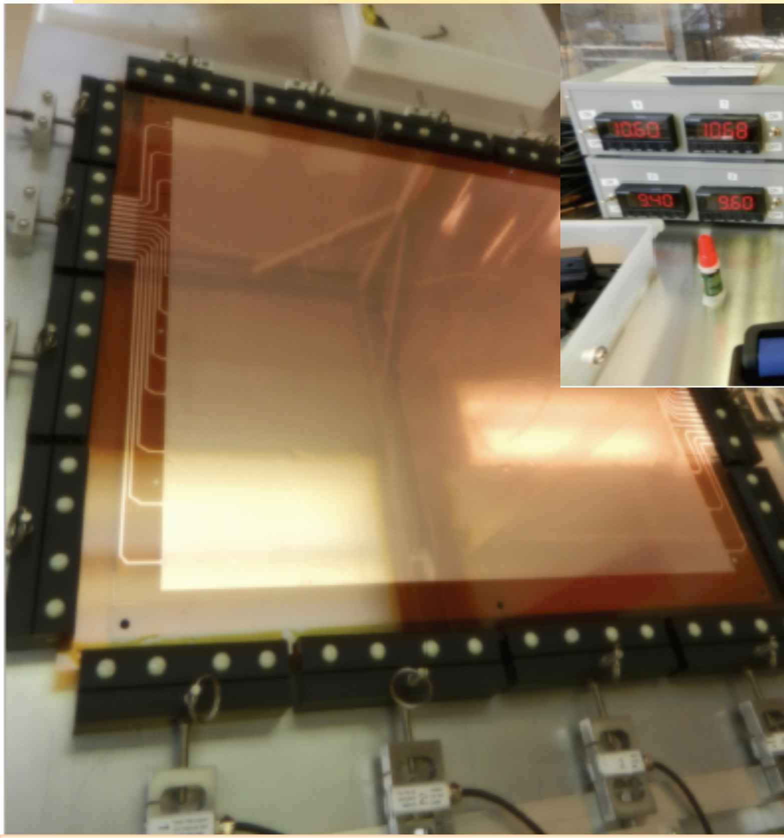


Loading the frame into the dry N2 box for testing at 4000 V



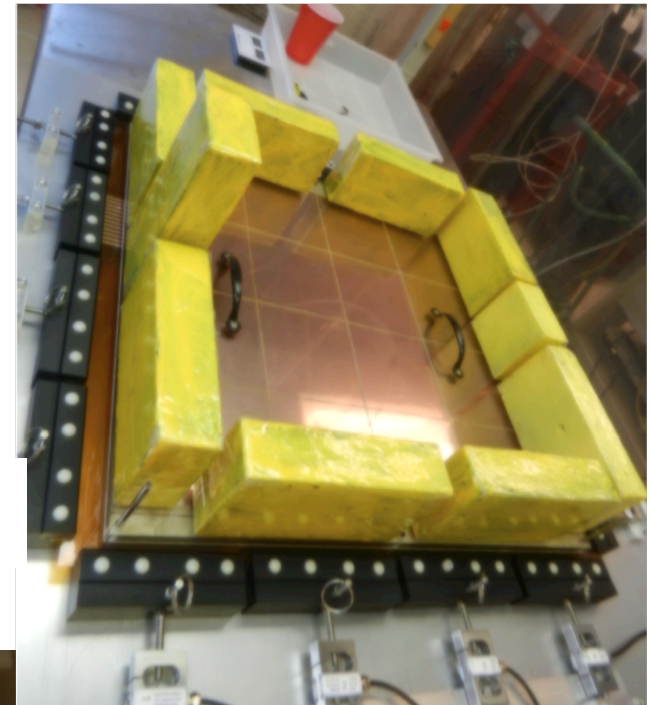
Machined surfaces sealed with a layer of polyurethane (Nuvovern LW) to prevent surface irregularities, residual fibers or sharp edges in the active area of the chamber

Foil Stretching and Glueing

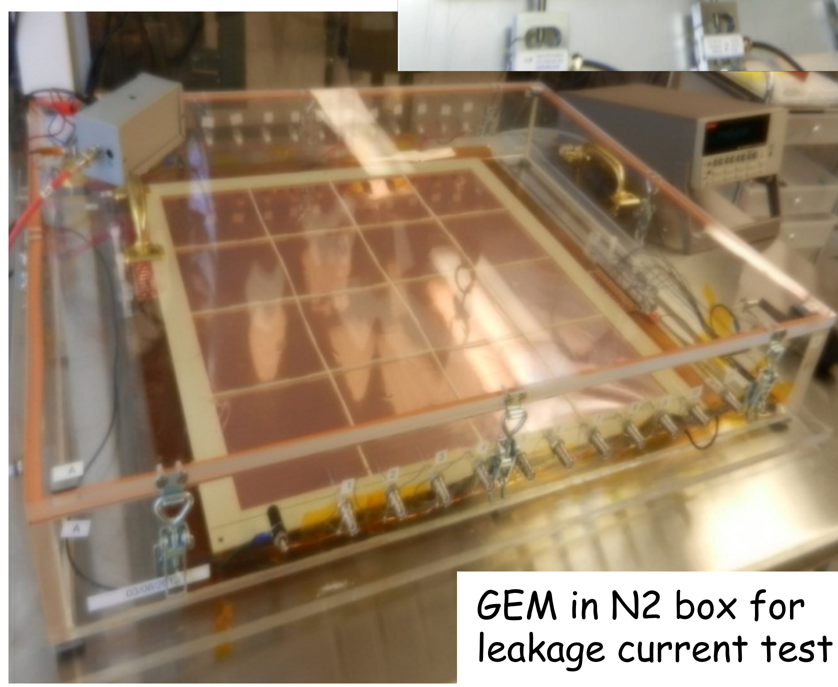


50 cm x 50 cm GEM stretcher at Uva

- Stretcher concept from LNF / Bencivenni et al. and INFN.
- Stretching time ~ 1 hours
- Foil Tension: T ~ 0.3 kg/cm

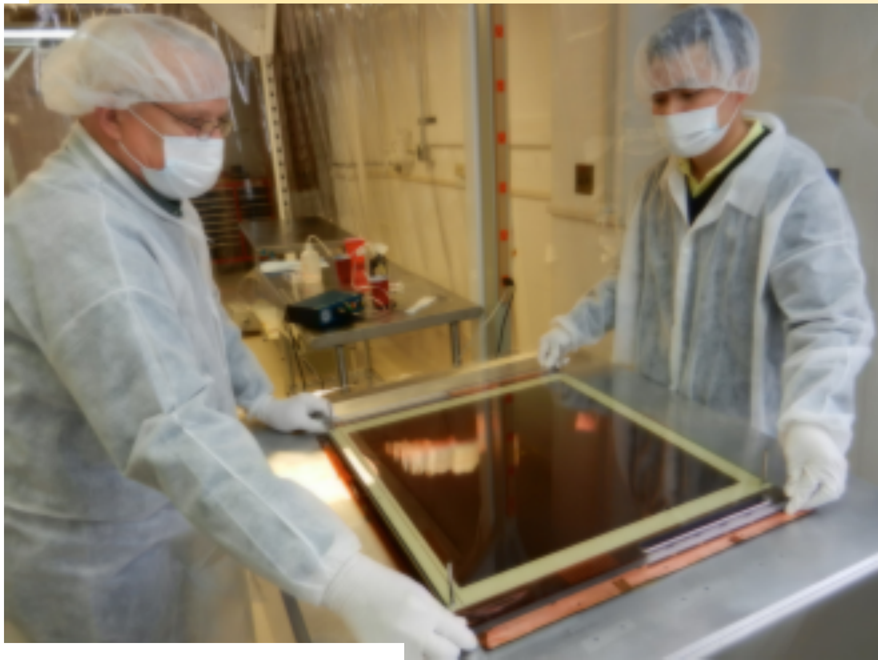


Frame glued on.
Overnight drying.

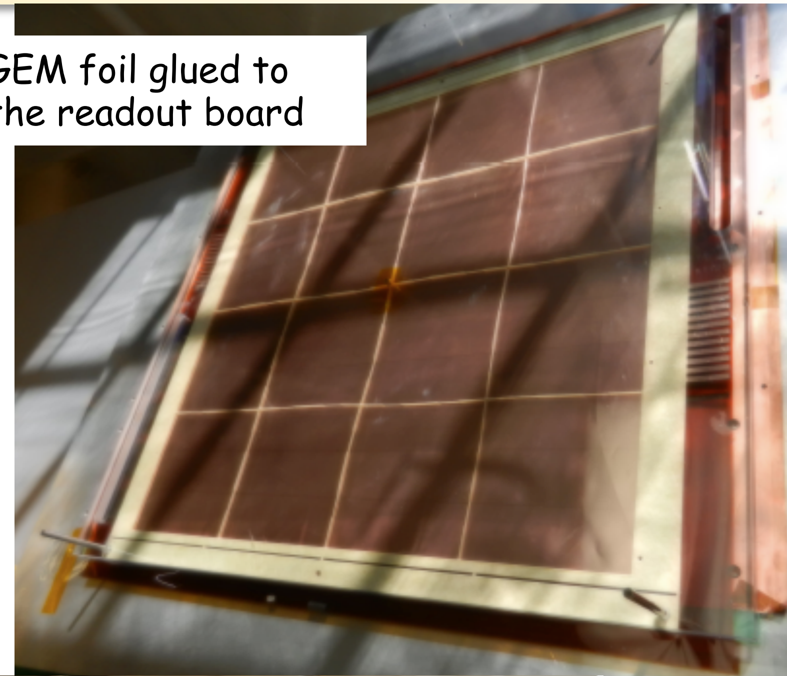


GEM in N2 box for leakage current test

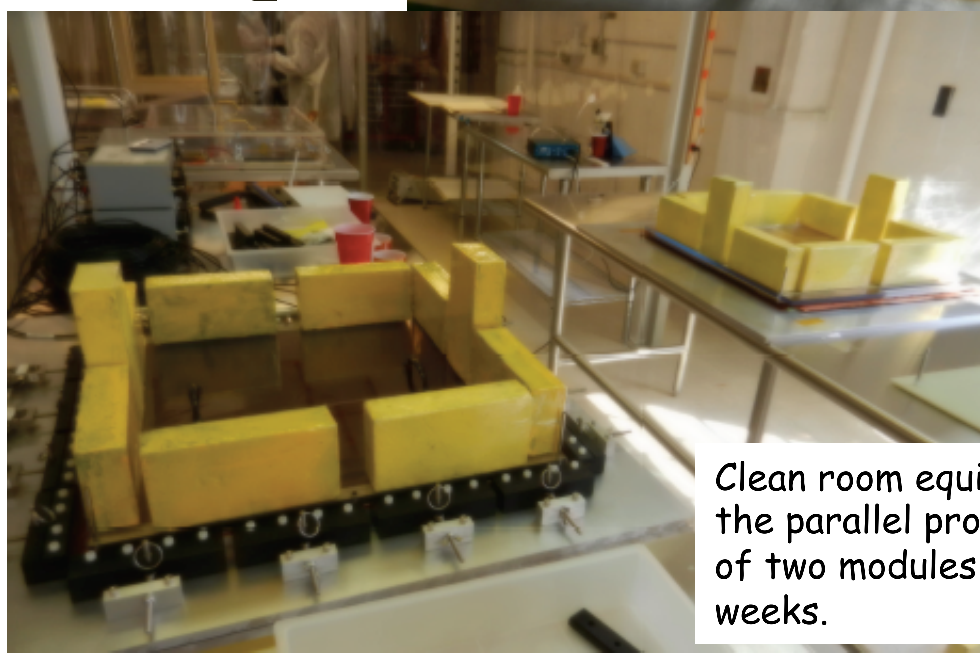
Final Assembly



Four large dowel pins at the corners used to align the frames to within 100 μm



GEM foil glued to the readout board

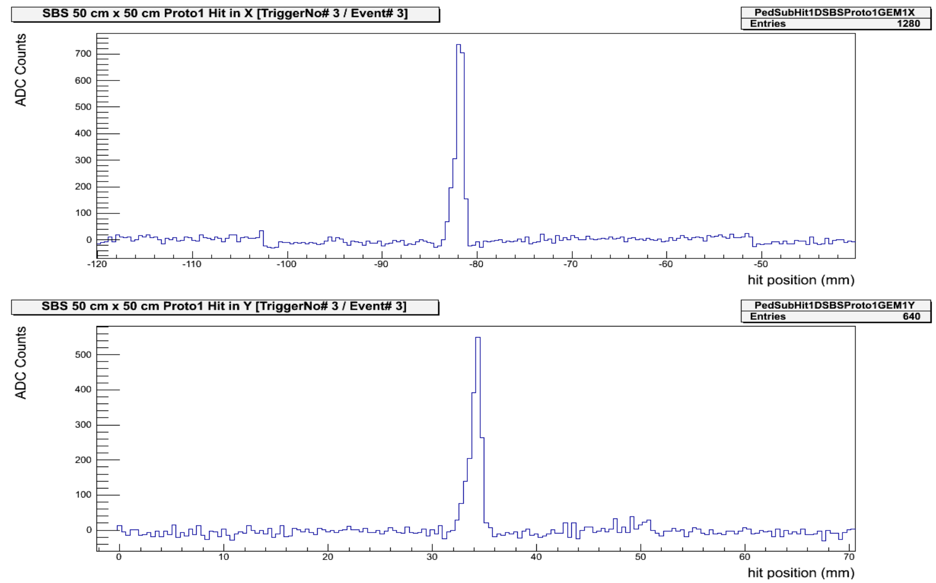


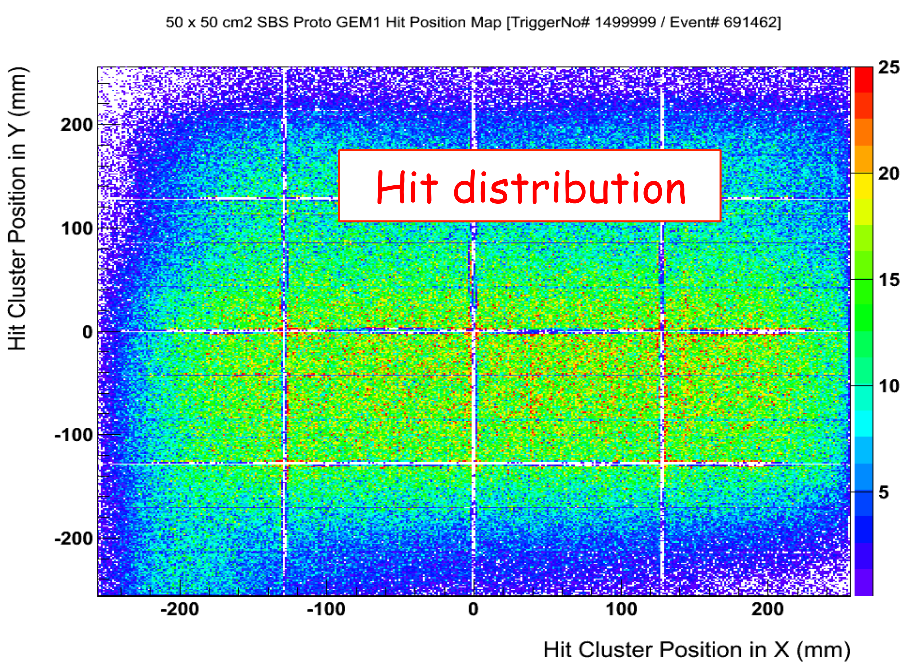
Clean room equipped for the parallel production of two modules in 3 weeks.

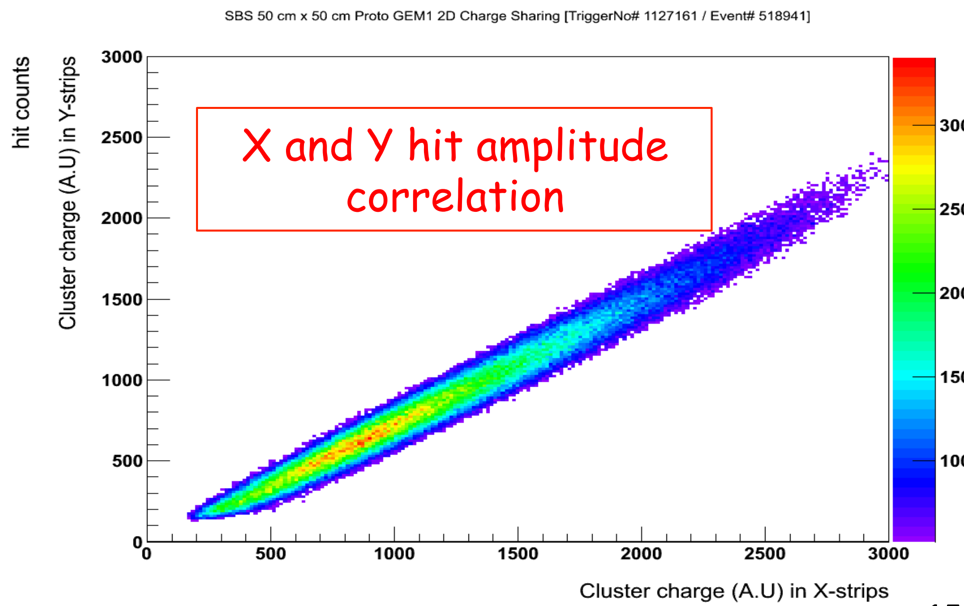
SBS GEM module full-size prototype results

- Bench test with cosmics: acceptance limited by trigger scintillators
- Gas: Argon/CO2 – 70:30, HV: 4300 V (a gain of ~8000)
- S/N ratio is ~ 25:1 on average
- Clean X-Y ADC correlation: critical for multi-hit tracking

2D X/Y strips hits event on prototype I







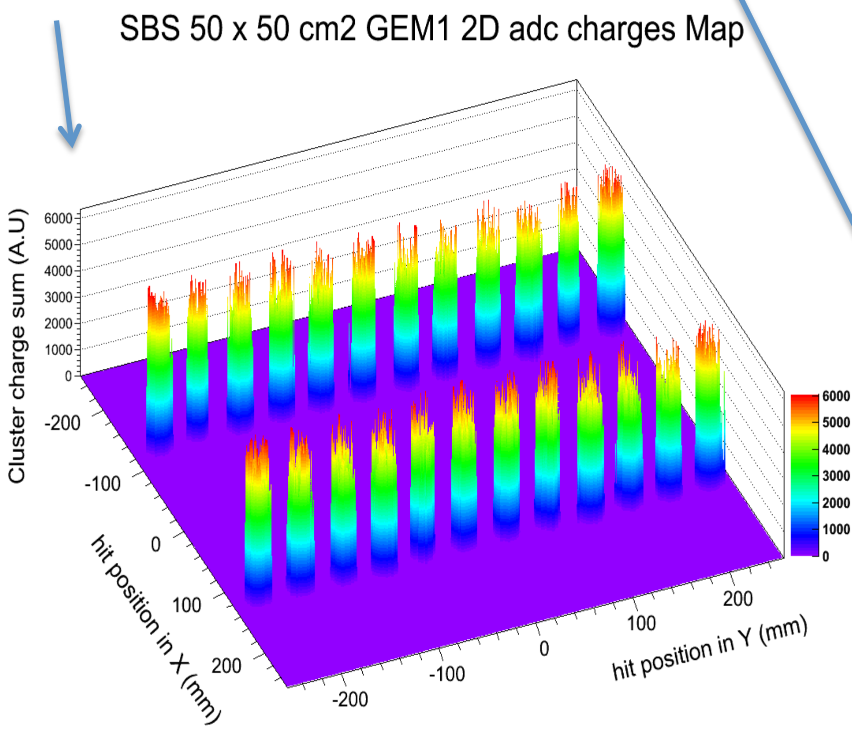
SBS Prototype I with Cosmic: Gain uniformity

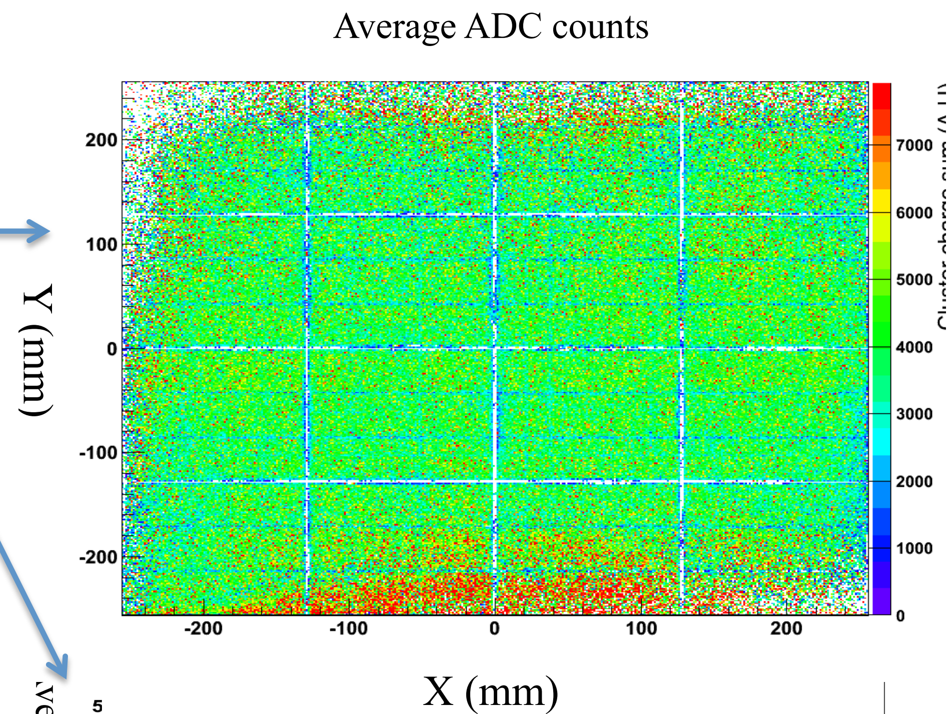
Average ADC count per bin over a large number of events

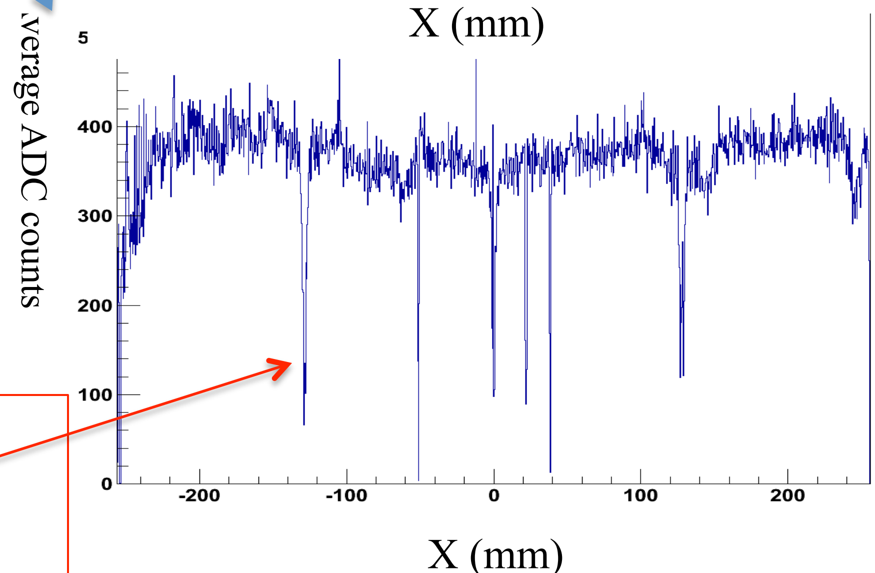
=

Σ_N (ADC counts) / N_{hits}

- Cosmics data – right plots
- ^{90}Sr data below.

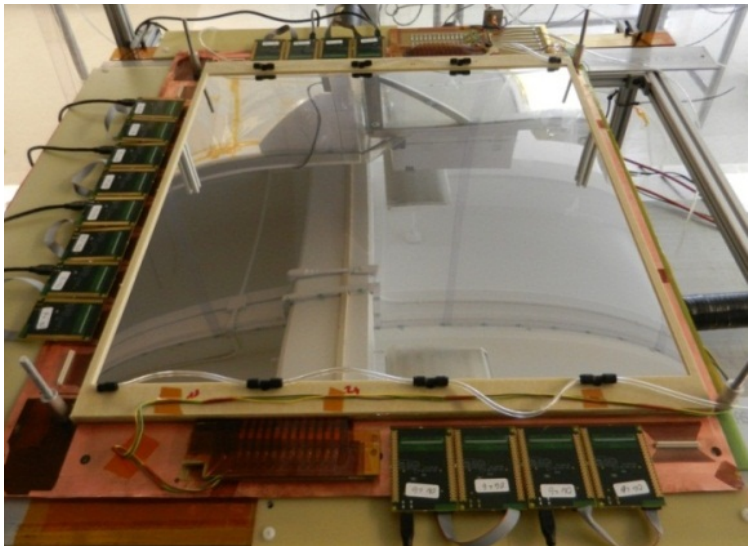




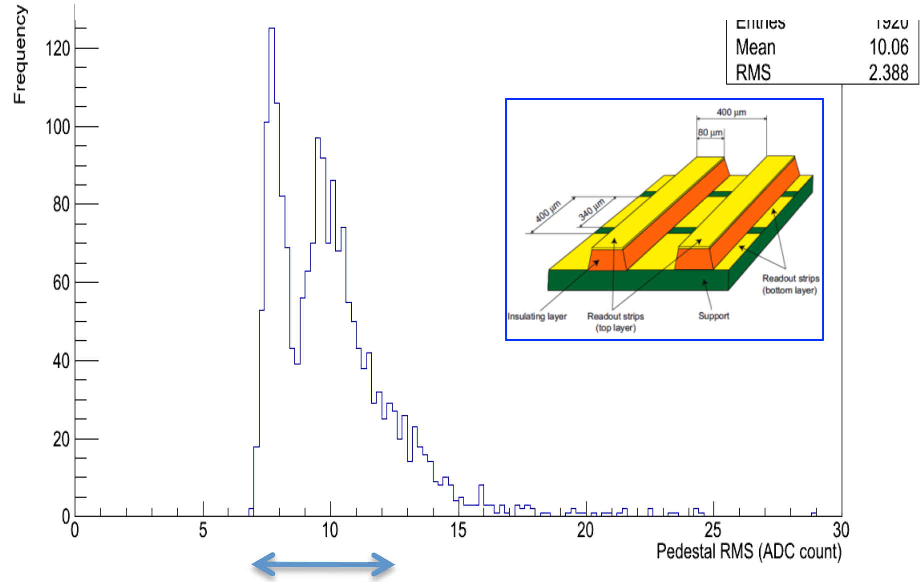


- ❑ Efficiency drops at the spacers: causes about 2.5% drop in overall efficiency.
- ❑ R&D underway now to reduce the number of spacers by a factor of 3.

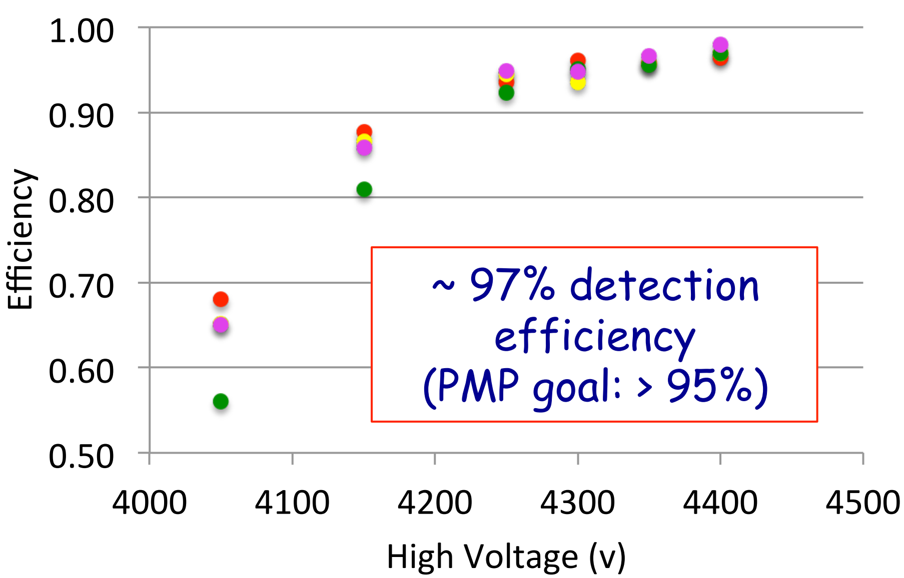
SBS GEM module full-size prototype results



APV25-SRS Pedestal noise



~ 1600 e- to 2750 e-
(PMP goal: < 3500 e-)
With a gain of 8000 the average signal per strip will be ~ 50,000 e-

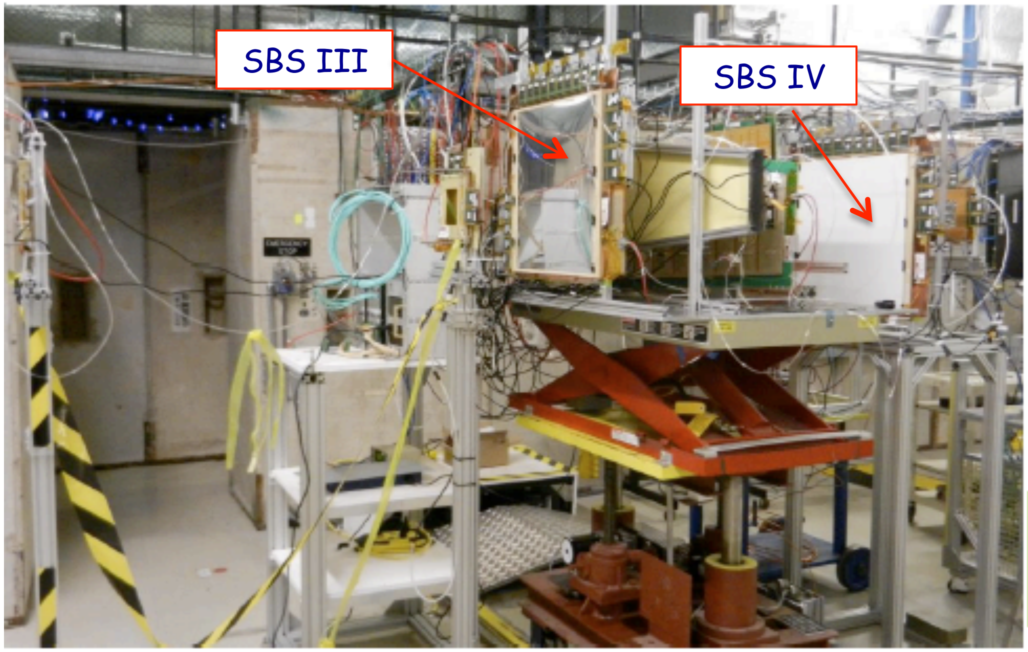


~ 97% detection efficiency
(PMP goal: > 95%)

Prototype meets SBS design requirements stated in the MP

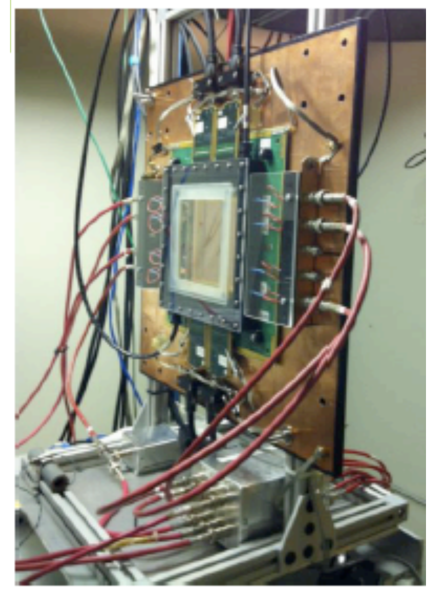
Test Beam T-1037 @ Fermilab: R&D on GEM for EIC Tracking and PID detectors

UVa & Florida tech: Large Size GEM for forward tracking

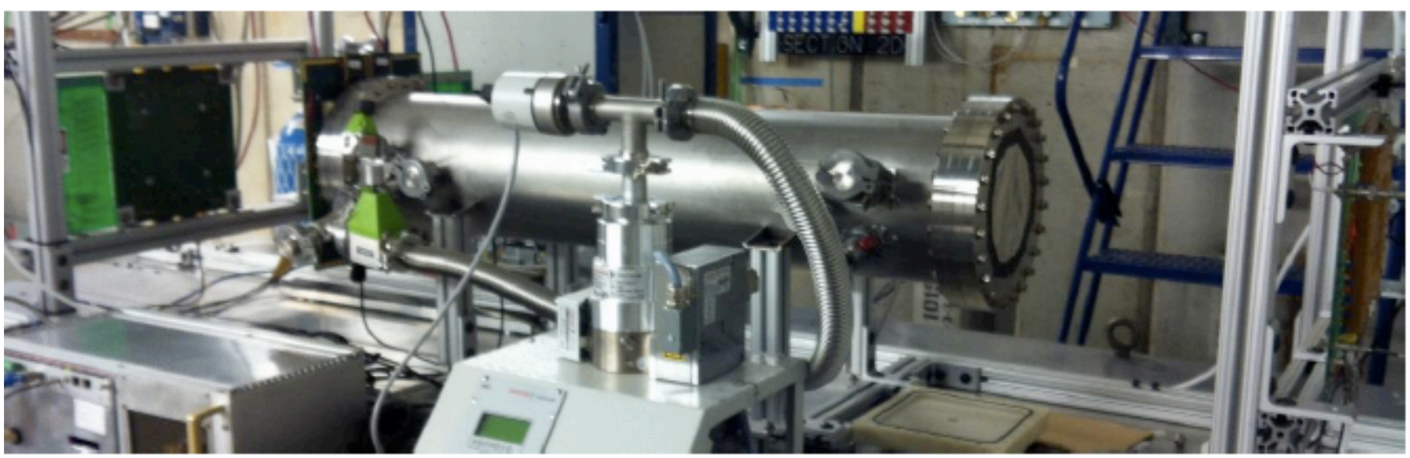


Yale Univ: 3D-Coordinate GEM setup

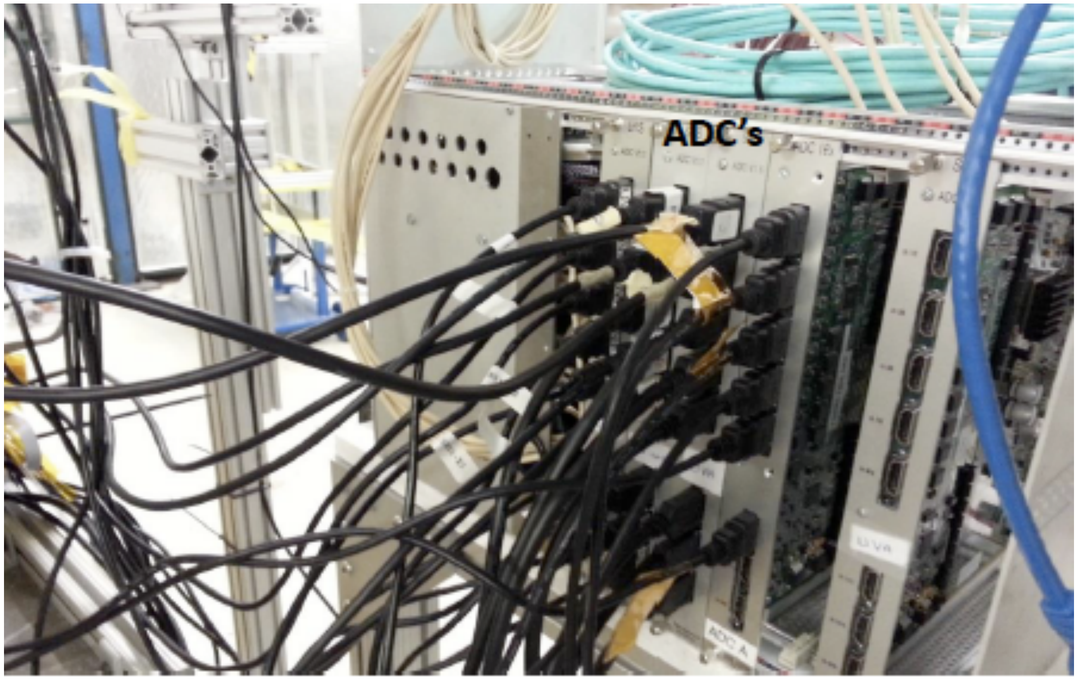
BNL: Mini drift GEM

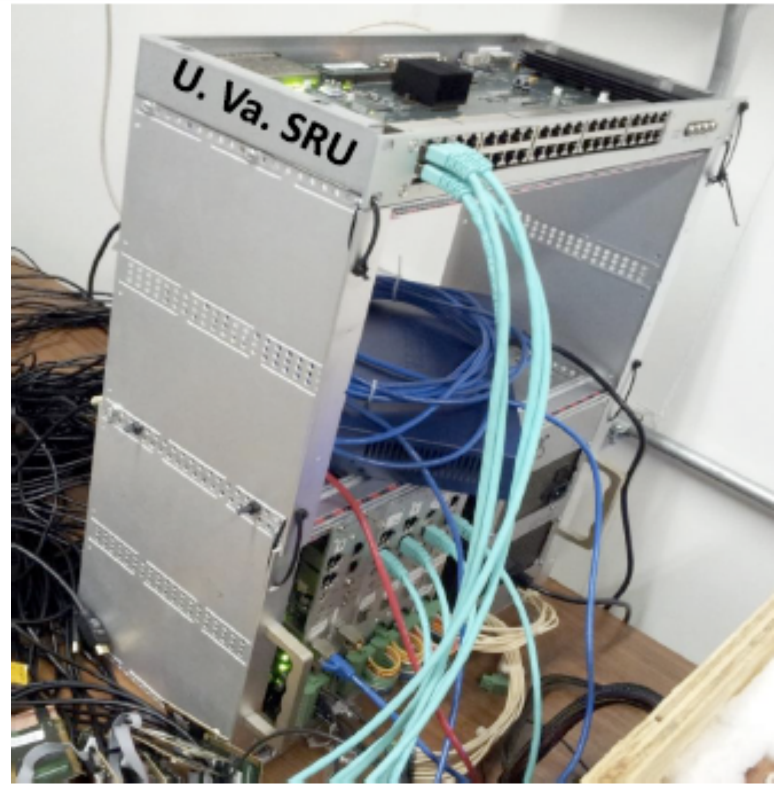


Stony Brook Univ: GEM-RICH setup



The 8000 chan. SRS APV system test at Fermilab.

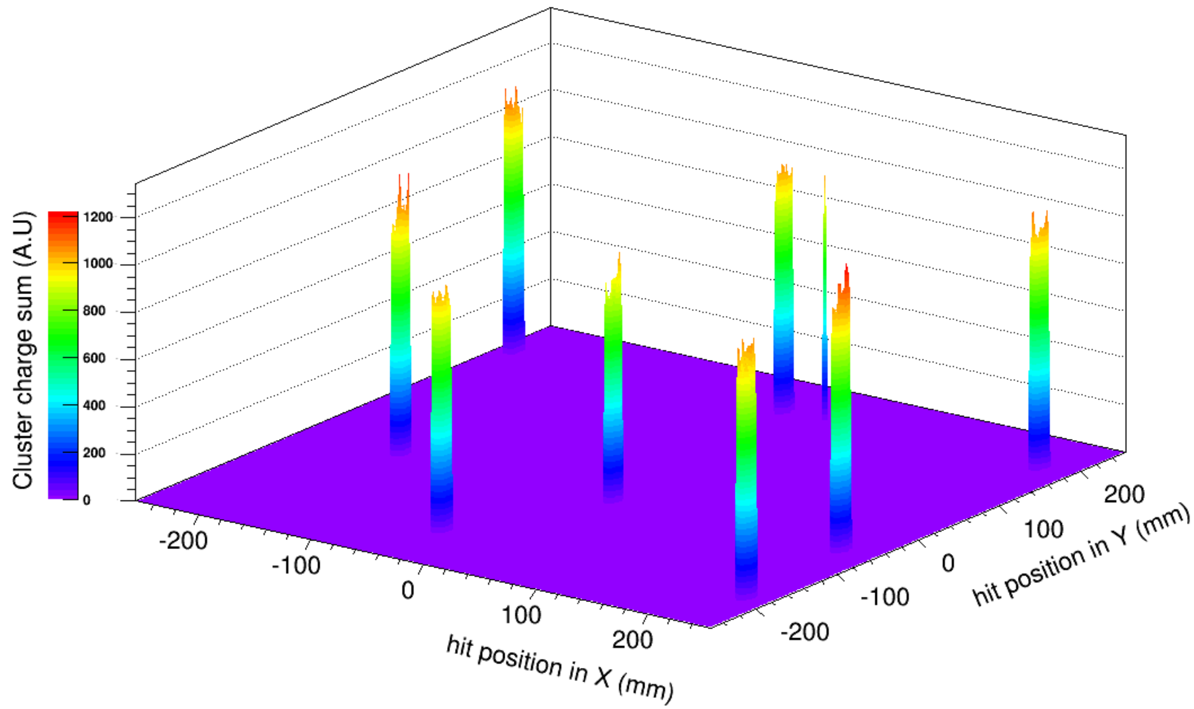




- The 8000 channel APV25 readout system successfully tested in beam conditions at Fermilab.
- Noise level comparable to observed in bench tests.
- More on electronics in Evaristo Cisbani's talk.

Fermilab Beam test results

Average ADC distribution for data taken with beam hitting several different locations of the GEM module. (average particle rate ~ 10 kHz/cm^2)



Data analysis currently going on to obtain

- ❑ Efficiency
- ❑ Resolution
- ❑ 2D hit distributions
- ❑ Pedestal noise

SBS GEM pre R&D Outcome

- GEM pre R&D completed in July 2013:
  - Full size prototypes meeting design goals
  - finalized the design for polarimeter GEM modules.
  - GEM module fabrication methods established.
  - A team of personnel trained.
  - GEM lab at UVa fully equipped to SBS GEM module production.
  - Two APV-25 based readout systems (13,000 channels total) assembled and tested.
  - Pre R&D report submitted to Jefferson lab..

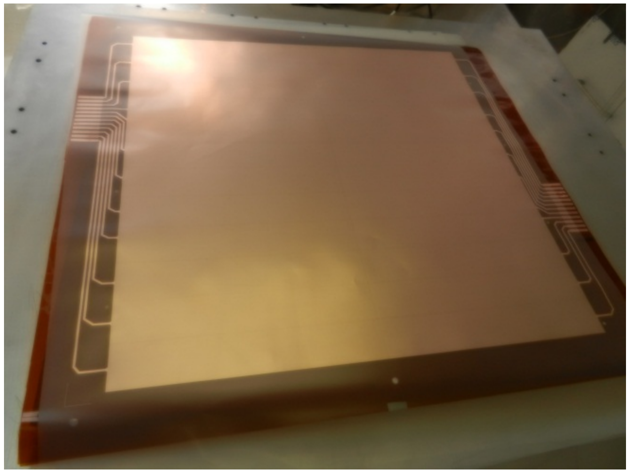
UVa is ready for the construction of the polarimeter GEM tracker

2011 Review Comments

- The required size of GEM foils of about 40 x 50 cm^2 is such that double-mask and single mask production procedures at the CERN could be used. It is strongly suggested to compare the procurement of CERN produced foils to foils manufactured in industry by Tech-Etch Inc. using glass masks rather than mylar foil masks. The optical uniformity of large foils as produced by Tech-Etch Inc. is superior compared to those produced at CERN. Another critical performance characteristic is the leakage current behavior, in particular the long-term performance regarding charge build-up. It is strongly suggested to purchase prototype foils at CERN and Tech-Etch Inc. and characterize those foils in terms of uniformity and leakage current. The delivery schedule for CERN-produced foils is a concern.

Response

- Tech-Etch has not acquired the single mask GEM production technology yet: single mask technology is better for large GEM foil production.
- The recent experience in the community: the quality of Tech-Etch produced foils has not been consistent
- The quality of CERN produced foils has been very high- 100% success rate in our stringent tests for the 16 large area CERN GEM foils so far.



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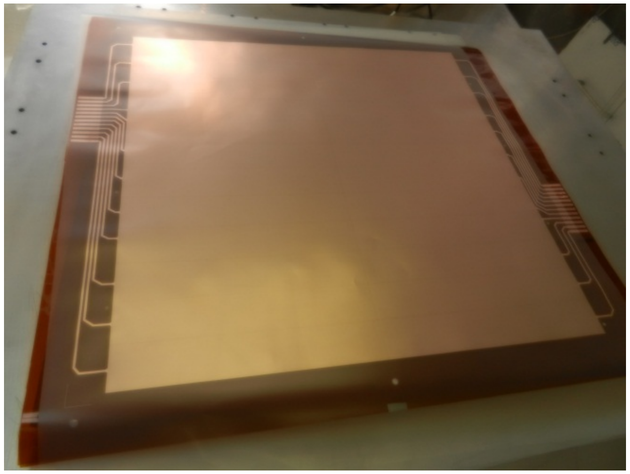
Response

- The quality of CERN produced foils has been very high: 100% success rate in our stringent tests for the 16 large area CERN GEM foils so far.
- We have a contract with CERN to deliver the components for the first 32 modules by January 2015.



2011 Review Comments

- The length of the readout strips of ~50 cm is such that care should be taken regarding the input capacitance for each APV25 chip. A careful evaluation of signal to noise

Response

- This was evaluated using calculations and real data: not an issue, the signal to noise ratio is still very high (> 25:1) for 50 cm strips.
- Noise calculation agrees well with observation

- Each Front-End electronics (FEE) module is mounted onto a carrier board at the edges of each triple GEM detector. The overall orientation of the FEE modules is appropriate. Appropriate care should be taken in inserting and extracting FEE modules. It is understood that some FEE modules are mounted at 90º requiring bending of the 2D readout board foil. Care must be taken to avoid breakage of readout strips.

Response

- This was checked with the actual detector and not a problem: 1 cm bending radius, ~ x 100 larger compared to the foil thickness.

2011 Review Comments

- The high voltage (HV) distribution from a HV board should be designed in such a way that one can disable one sector individually in case it develops a large leakage current.
  Response: New design feature according to this recommendation: described in the presentation.

- Once a vendor is selected a clear list of specifications in terms of uniformity and leakage current performance should be formulated and agreed upon, followed by a small-scale procurement for the purpose of confirming each agreed upon specification. Those specifications should include explicitly the need for clean handling in particular in the case of Tech-Etch Inc. produced foils. It is strongly suggested to assemble several full scale prototype modules and test their performance to practice all assembly steps in the local UVA clean room environment
  Response: Four full size prototypes successfully built at Uva.

- The The production of spacer grid frames could turn into a rather labor intensive effort. The collaboration should consider water jet cutting which provides a rather cost effective solution
  Response: This has not been an issue. Resarm Inc. from Belgium provides machining of the frames at a reasonable cost.

GEM production Plans: WBS 2

- Goal: build 29 GEM modules by 03/2015
- Funding: $ 541 k

Date	Milestone	Notes
08/15/2013	WBS 2 GEM contract in place	Done as of 09/30/2013
09/30/2013	Orders for GEM chamber components placed	Done
02/01/2014	First Batch of GEM foils arrived	
05/30/2014	Complete the production of 5 modules, test and deliver to Jlab	
09/30/2014	Complete the production of another 10 modules	
03/01/2014	Complete the production of the remaining 14 modules	

- Assumes production of ~ 2 modules per month: feasible with established procedures.
- Related Goals: Design and fabricate two holding frame, assemble and test with a full complement of electronics.

GEM production Plans: WBS 3

- PMP Plan: 35 GEM modules (assume GEMs for coordinate detector)
  - Fabricate 35 GEM modules.
  - Assemble eight 50 cm x 200 cm GEM detector layers for polarimeter.
  - Assemble two 80 cm x 300 cm GEM detector layers for coordinate detector.
  - Equip all GEM modules with electronics and test.
    - Time required: 24 months starting March 2015.

- If PMT-based coordinate detector approved: 11 GEM modules
  - Fabricate 11 GEM modules.
  - Assemble eight 50 cm x 200 cm GEM detector layers for polarimeter.
  - Equip all GEM modules with electronics and test.
    - Time required: 12 months starting March 2015.

ESH&Q Integration for SBS GEM trackers

- Safety features:
  - No flammable gasses used: operate with $Ar+CO_2$ mixture.
  - High-Voltage power supplies with 1 mA current limits and fast trip feature.
  - The light weight of chambers: each module ~ 5 kg including electronics and cables.
- ESH&Q plan:
  - Proper coordination between INFN, UVa and Jefferson lab.
  - Once the design for module holding frames are complete, perform a design and safety review.
  - Freeze the holding frame design after this review to prevent surprises for installation and running.

Conclusion

- Pre R&D for SBS Polarimeter GEM tracker modules at UVa highly successful:
  - New design with improvements.
  - GEM module production procedures established.
  - Lab setup for production.
  - Full size prototypes built and working meeting design goals as stated in PMP
  - Ready for final production
- SBS WBS2 production contract is now in place
  - Build 29 Modules by March 2015
- Evaluation of Electronics being finalized now
  - Report by December
  - Setup contract by January