Large Area GEM chambers for SoLID

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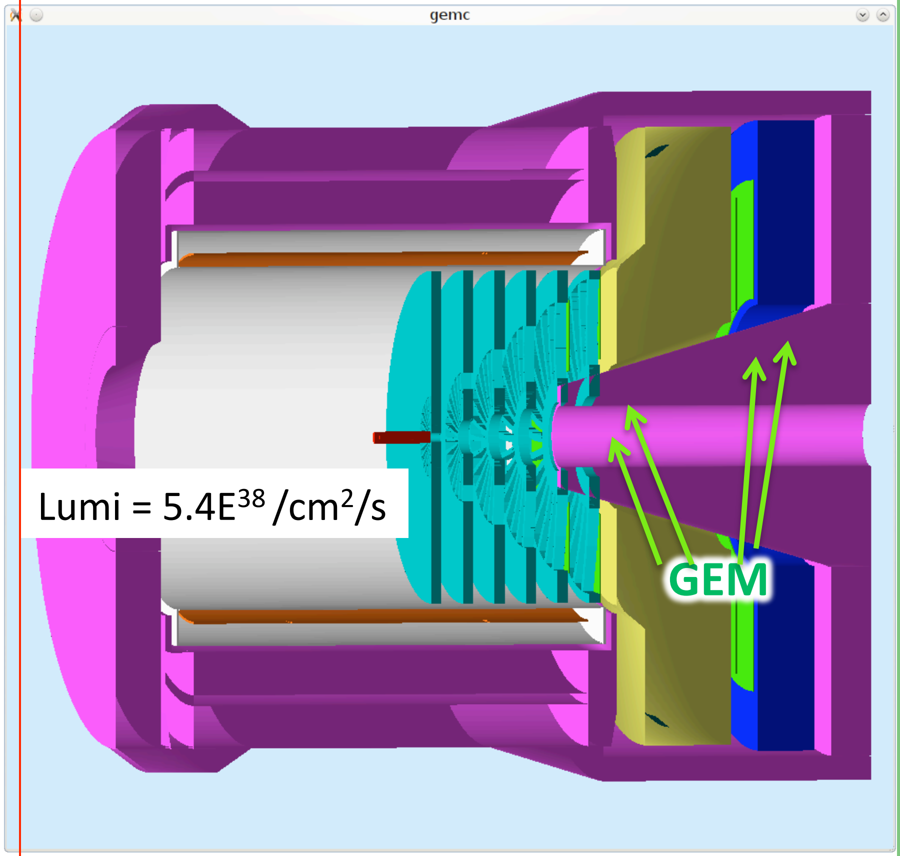
Tracking needs for SoLID (PVDIS)

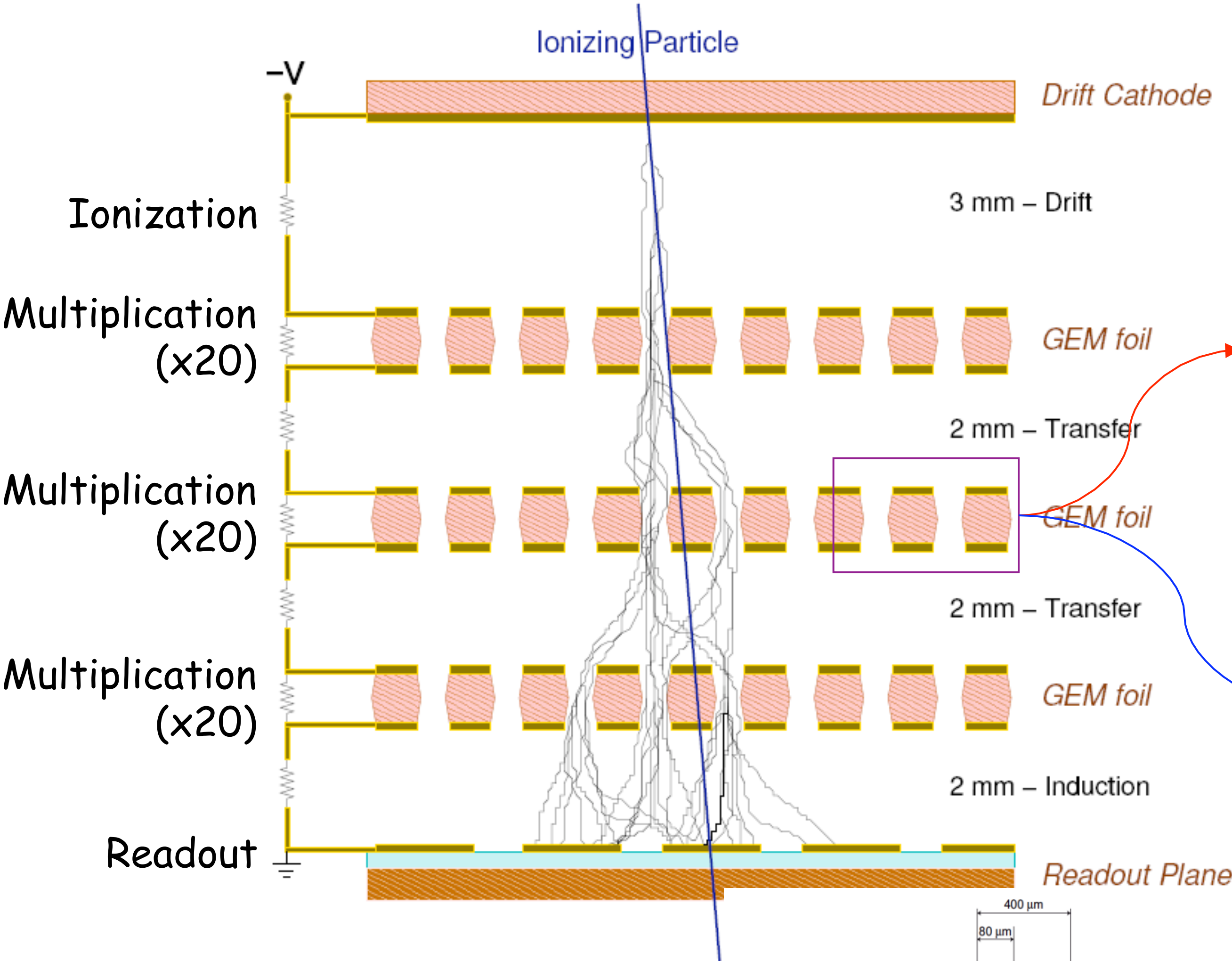
- Rate: from 100 kHz to 600 kHz (with baffles)
- Spatial Resolution: ~0.2 mm (sigma)
- Total area: ~ 33 m^2 total area (30 sectors x 4-5planes, each sector cover 10-12 degree)
- Need to be Magnetic field and radiation tolerant

Gas Electron Multiplier (GEM) provides and ideal solution

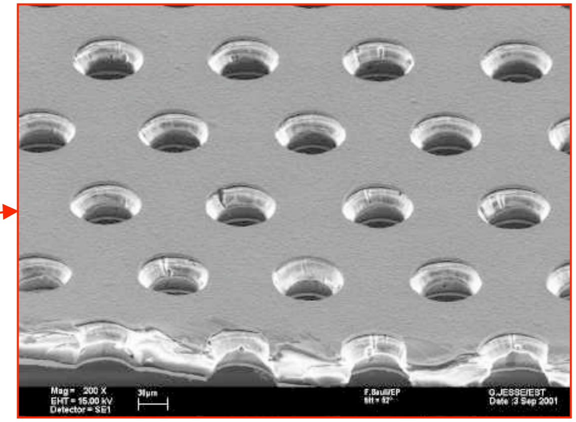
- ❑ Recent technology invented by Fabio Sauli in 1997
- ❑ High rate capability: more than 1000 higher rates than wire chambers
- ❑ Good position resolution: ~ 70 μm.
- ❑ Rad-hard
- ❑ Low cost
- ❑ Used for COMPASS experiment
- ❑ Developed for many experiments around the world

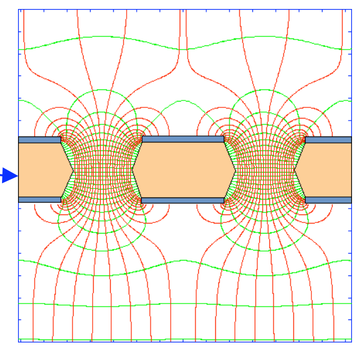


GEM working principle



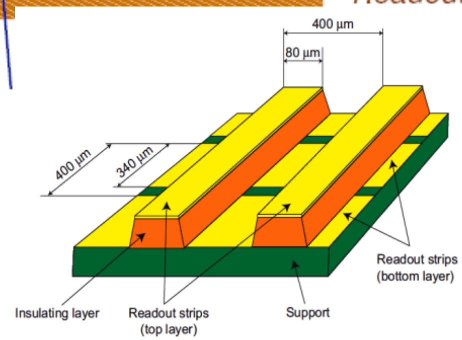
GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch





Strong electrostatic field in the GEM holes

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



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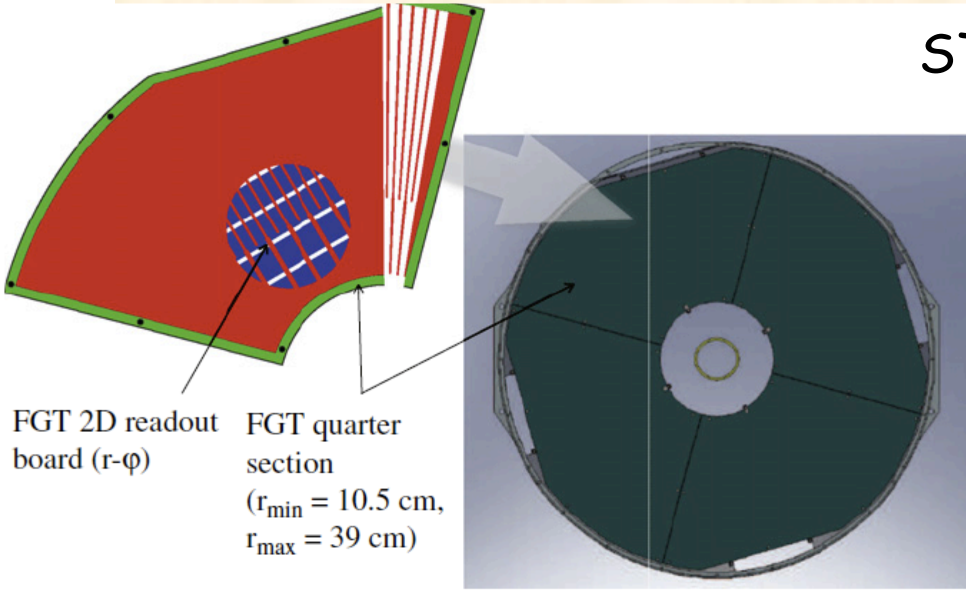
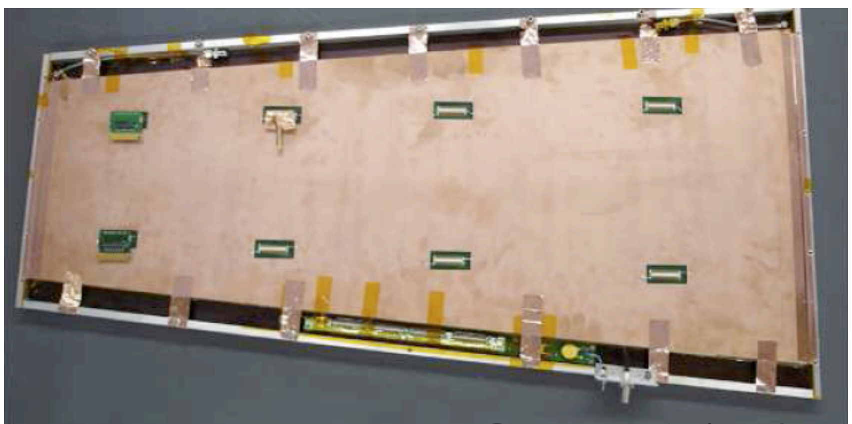
Large GEM chamber projects

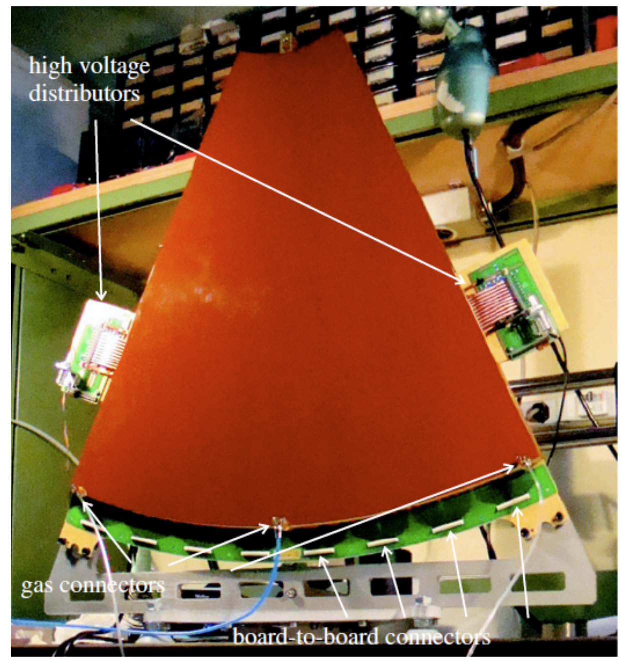
STAR Forward GEM Tracker

- 6 triple-GEM disks around beam
- IR~10.5 cm, OR~39 cm
- APV25 electronics





Large prototype GEM module for CMS: 99 cm x (22 – 45.5) cm

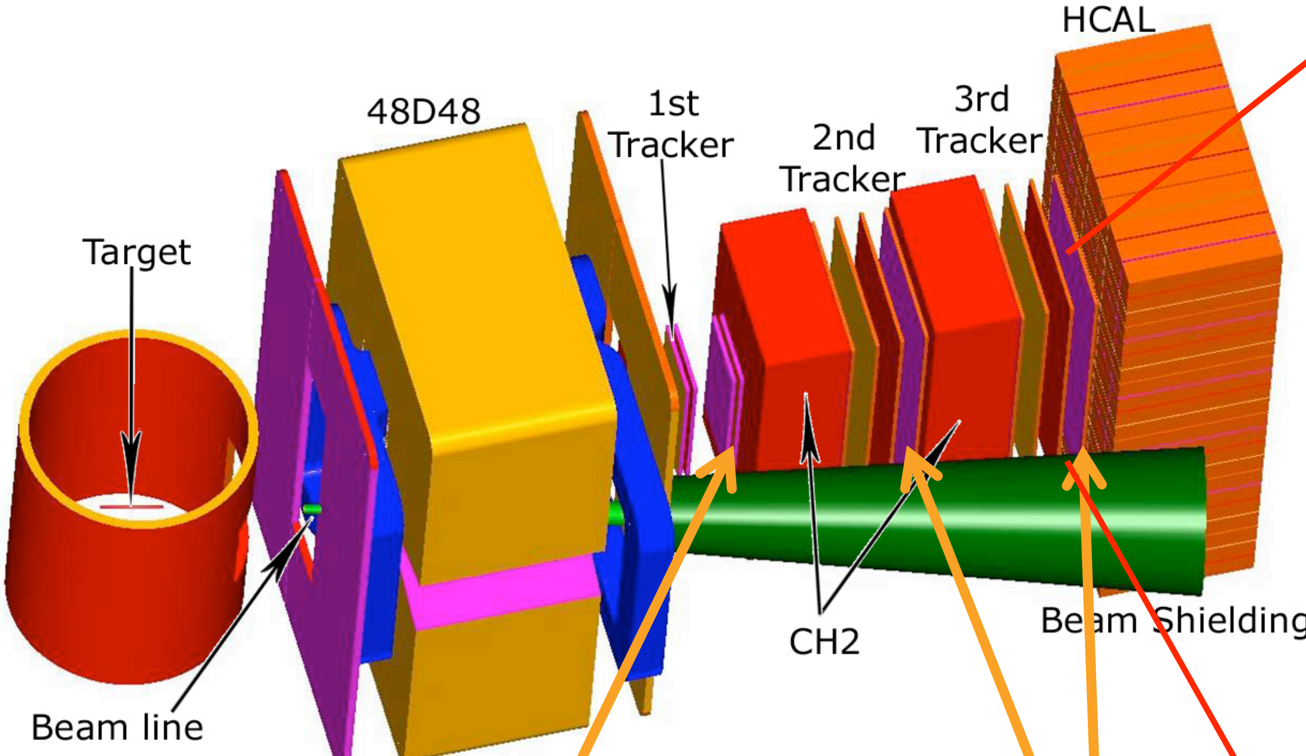


TOTEM T1 prototype made with single mask GEM foils (33 cm x 66 cm)

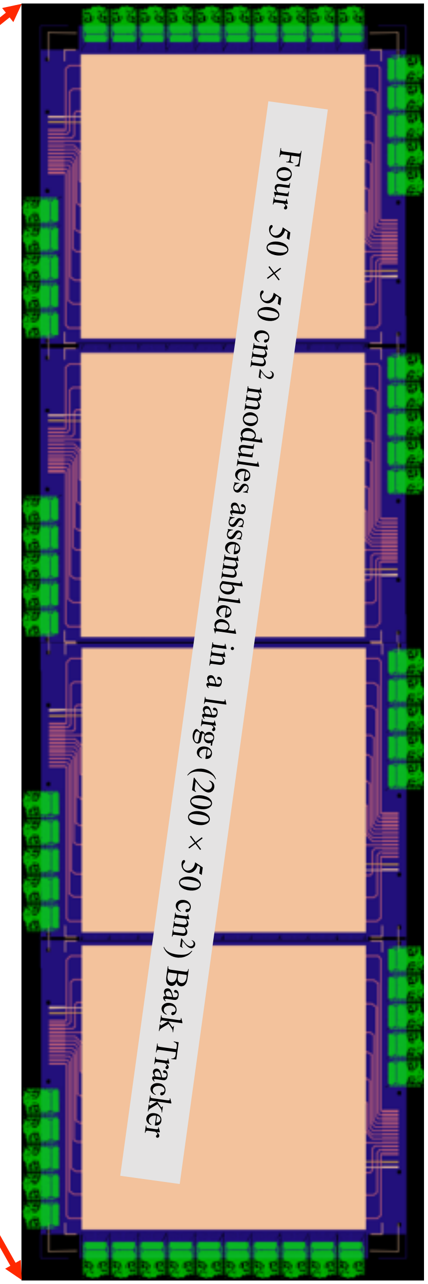
CMS prototype similar the the dimensions of largest SoLID chambers

4

Jlab Hall A SuperBigbite (SBS) GEM Tracker

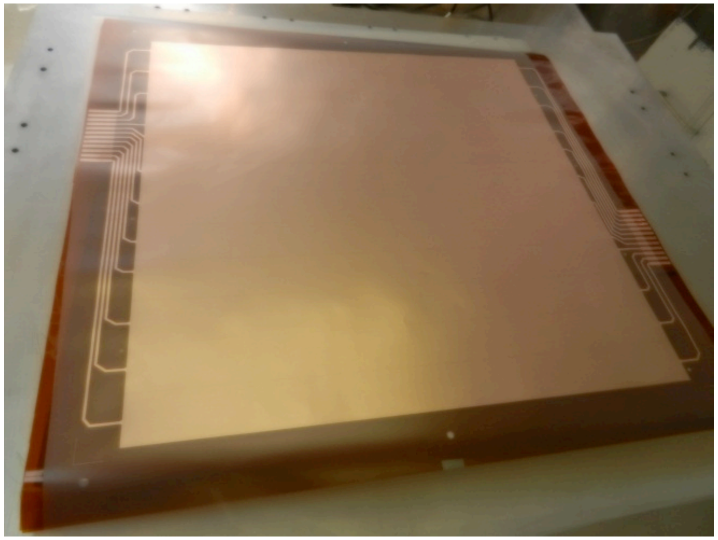


- Front tracker: Six 40 x 150 cm^2 GEM layers
  - built in Italy – INFN
- Back trackers: Eight 50cm x 200 cm GEM layers
  - Developed and Built at UVa
  - Four 50 cm x 50 cm GEM modules make a layer.
  - Lab setup for production.
  - Full size prototypes built: they meet design goals
  - Ready for final production



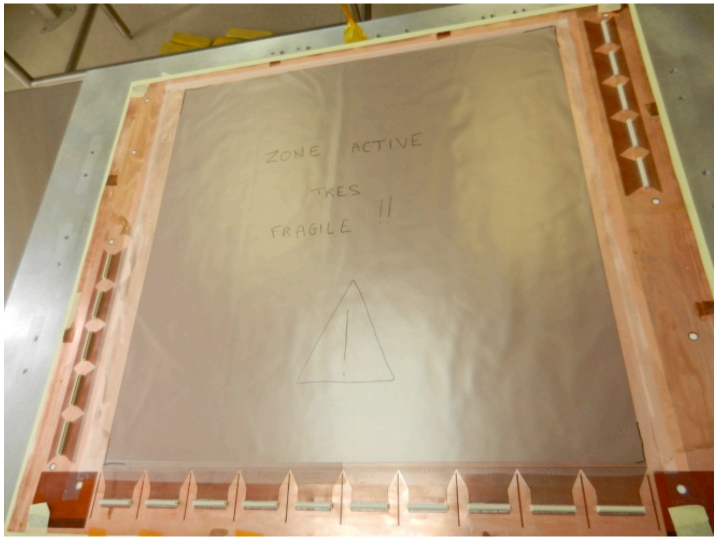
SBS Back Tracker Module Design

GEM foil (CERN PCB workshop)

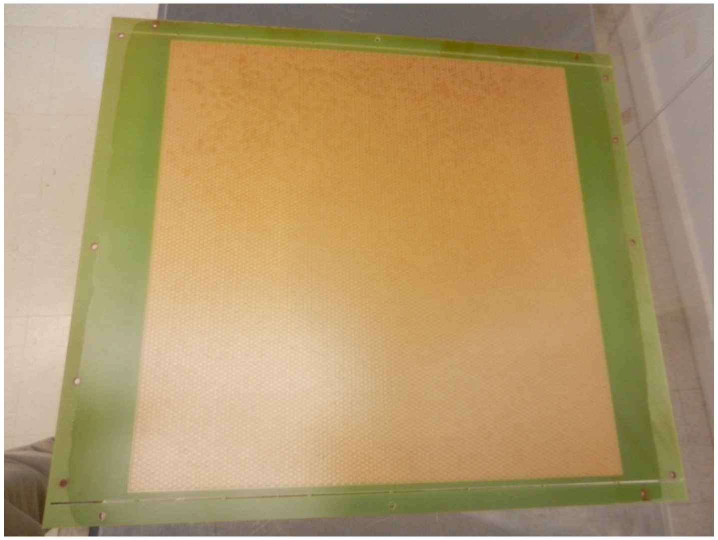


Support frame with spacers (RESARM Belgium)

Flexible 2D readout board (CERN PCB workshop)

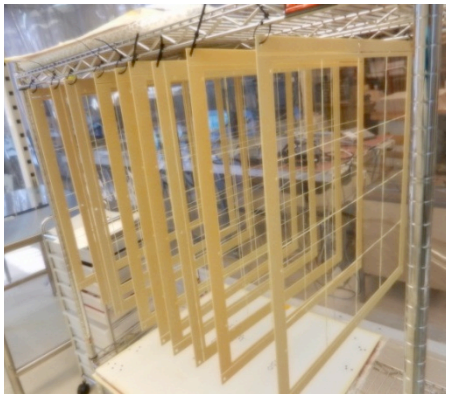


Honeycomb support board (CERN PCB workshop)



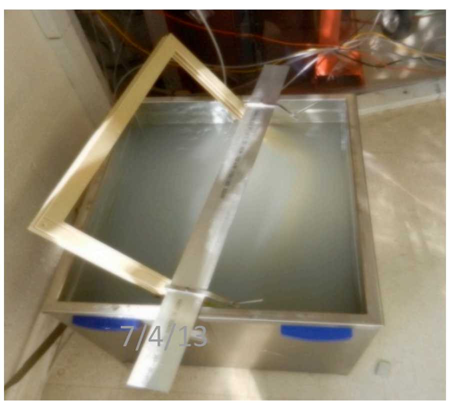
Clean Room & equipment for the assembly

Storage of the frames



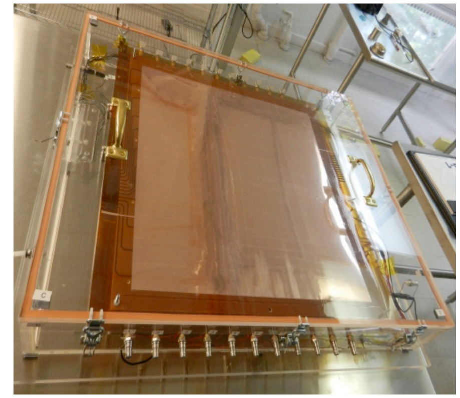
Frames holder for cleaning in USB

Ultra sonic bath (USB) with demineralized Water

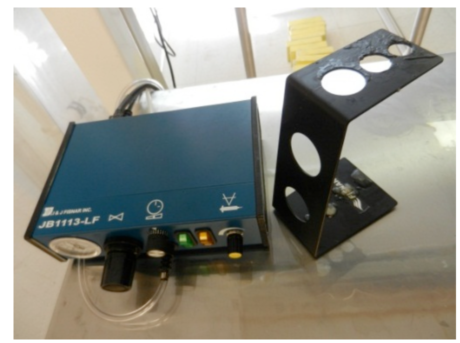


Large area (3 × 7 m^2) class 1000 Clean Room

Storage of the framed foils



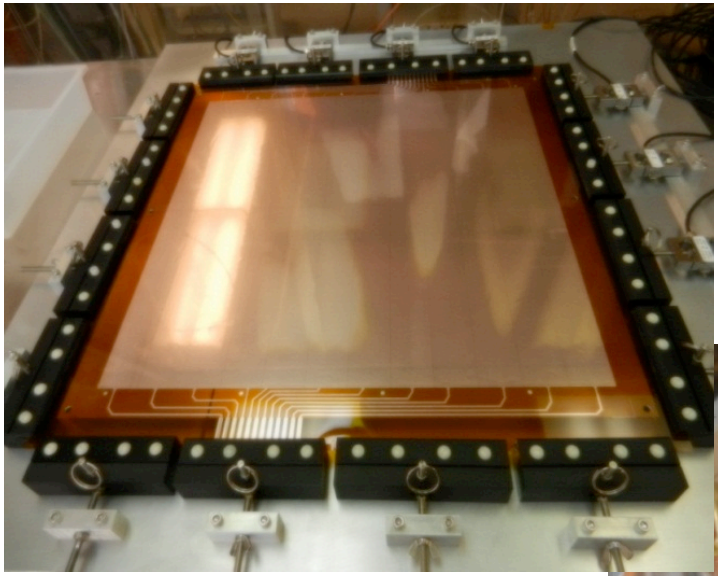
Glue dispenser



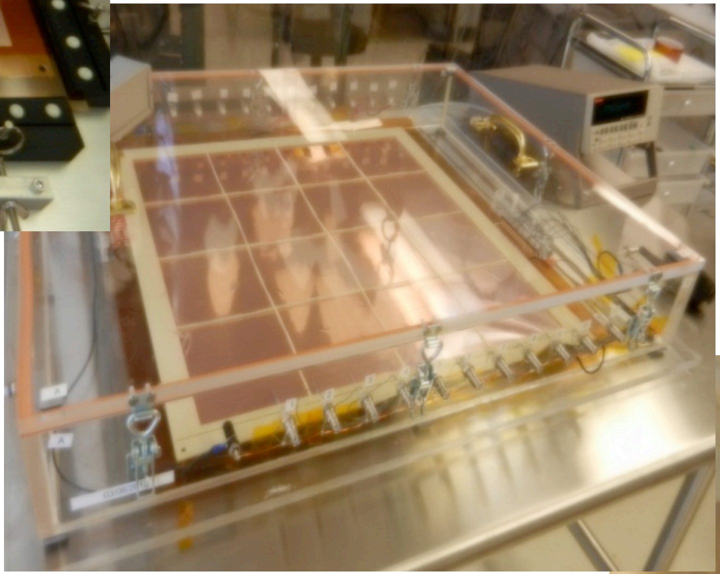
Tacky roller ➔ dust removal

Construction of the SBS GEM prototypes

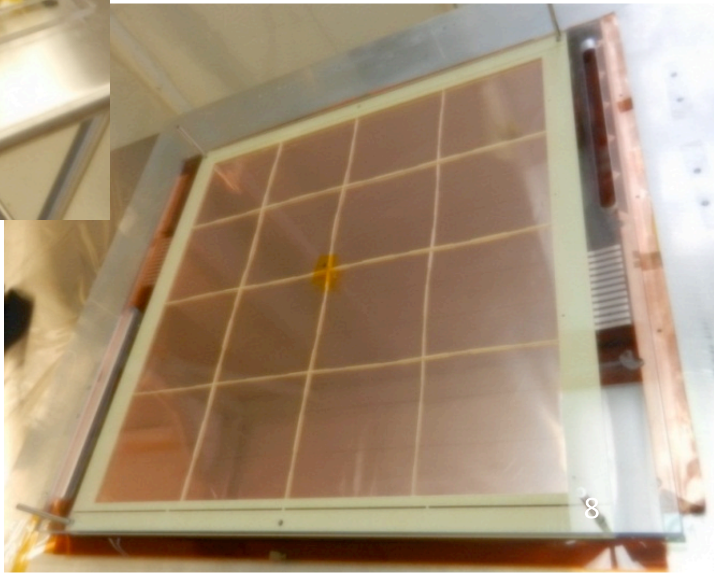
GEM foil on the mechanical stretcher



GEM in N2 box for leakage current test



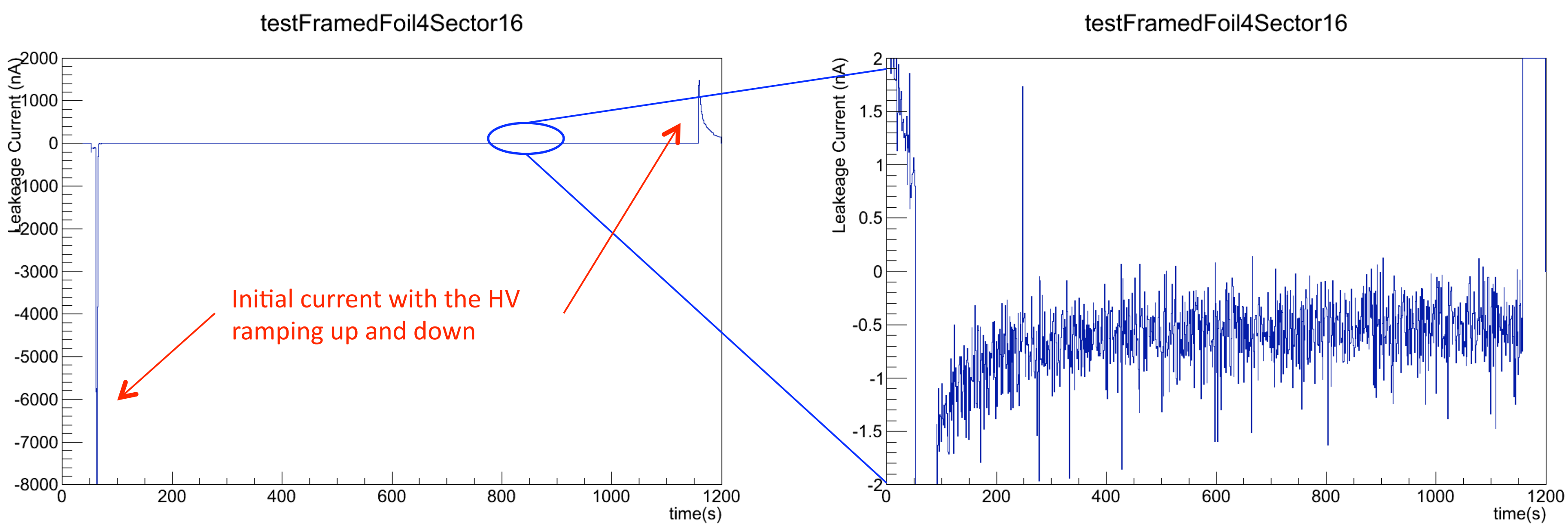
GEM foil glued to the readout board



HV test of the GEM sectors

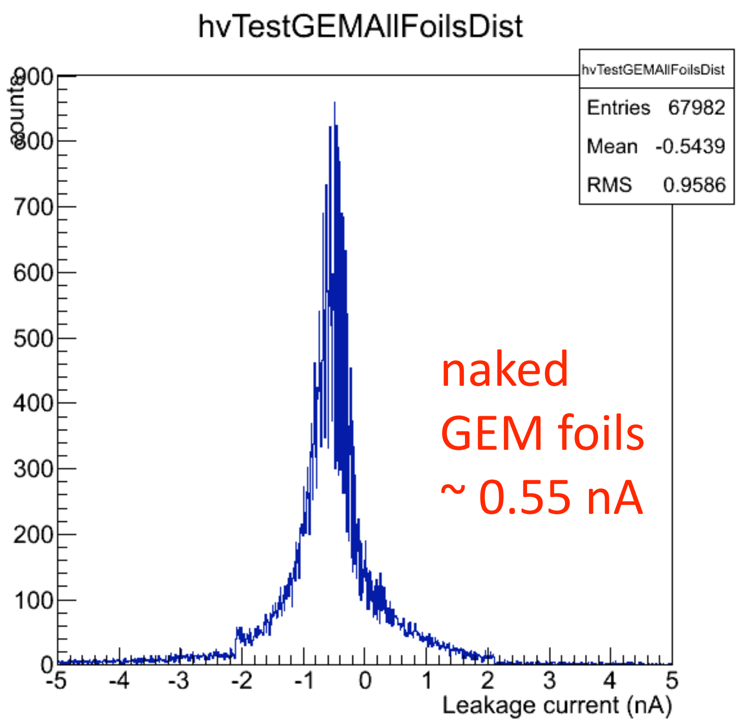
(Method suggested by Rui De Oliveira from CERN)

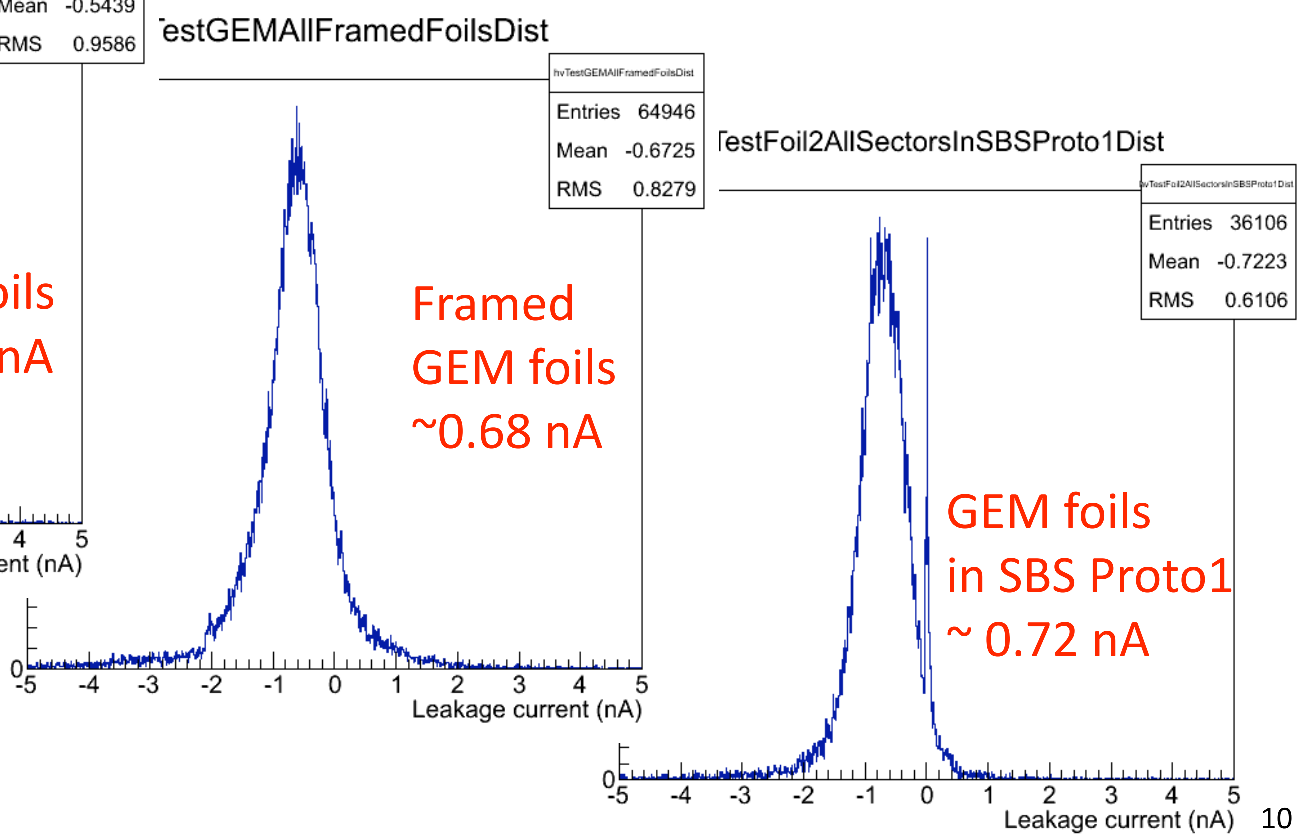
- We use an Iseg EHS 6 kV HV module in a Wiener crate, HV controlled through an internet protocol.
- Fast ramp up mode at a rate of 1200 V/s up to 550 V.
- The leakage current in the GEM is measured using a Keithley 6487 picoammeter, at sampling rate of 120 ms with a Labview interface and saved in txt 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



HV test of the GEM sectors

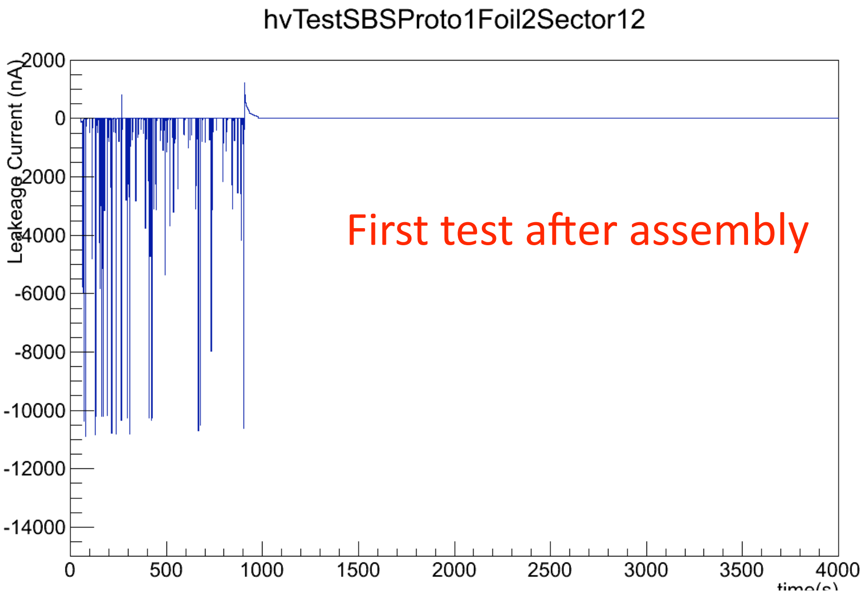
- Distribution of leakage current over all the 72 sectors (24 sectors per GEM foil and 3 foils per chamber)
- HV Test is performed at 550V in N2 for naked, framed foils and in chamber foils
- Average leakage current < 1 nA for all the tests

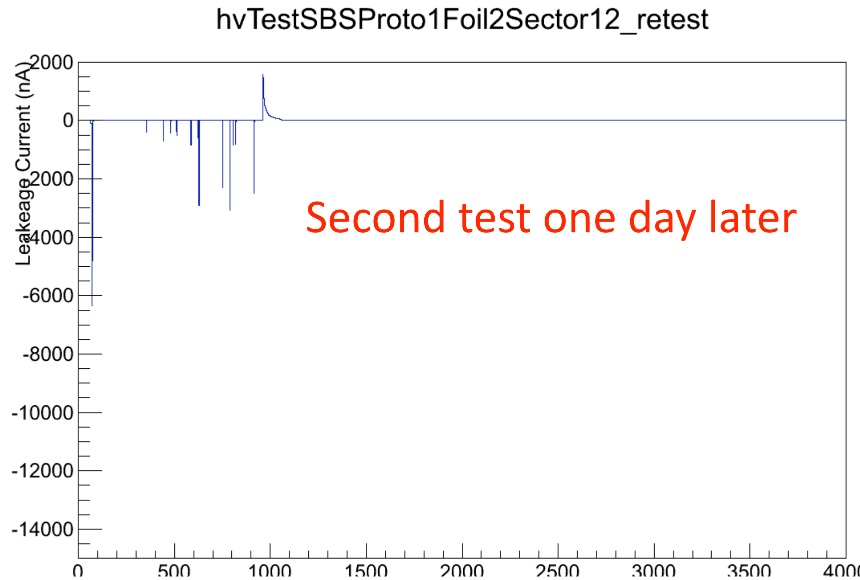


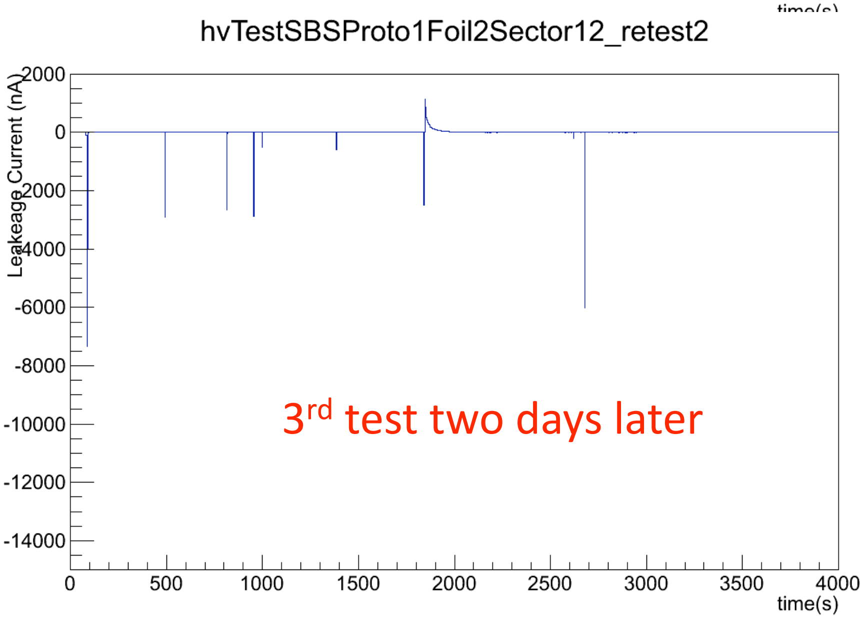


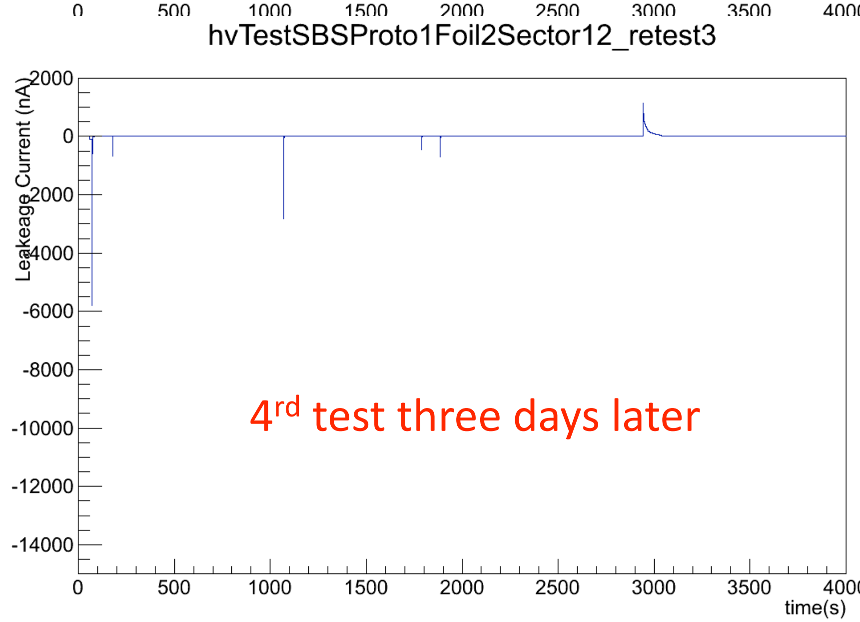
Recovering of a bad HV sector

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

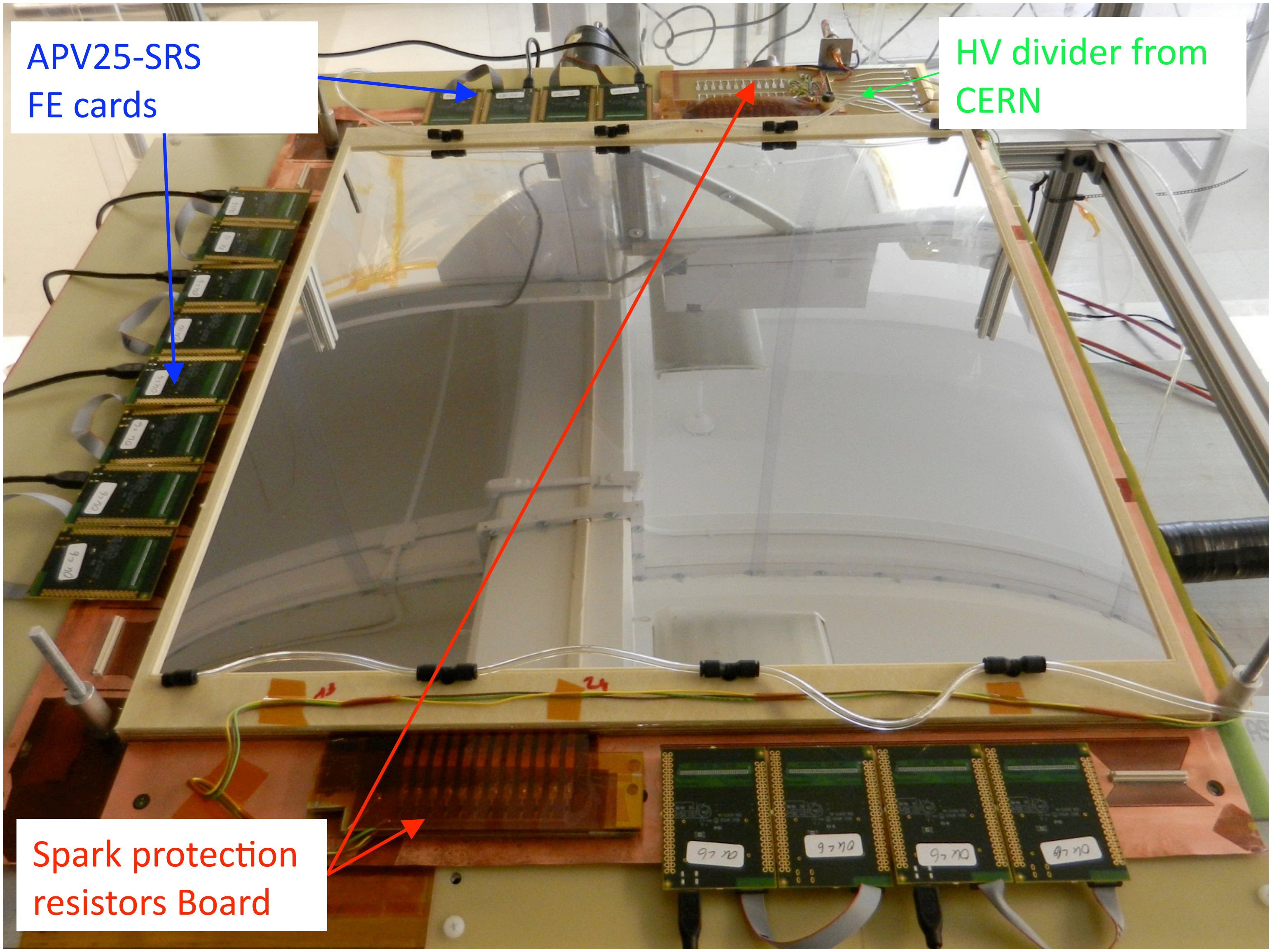




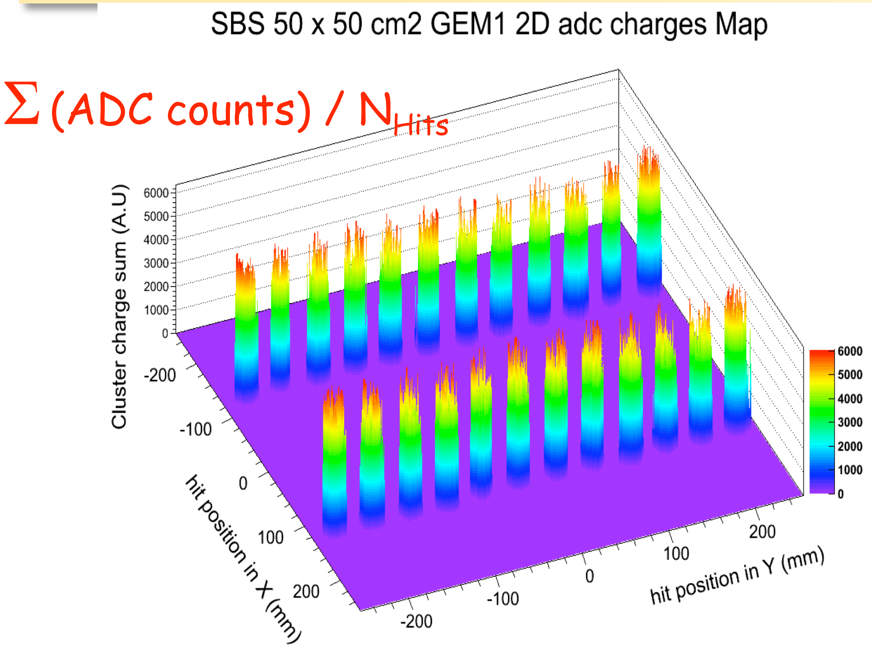


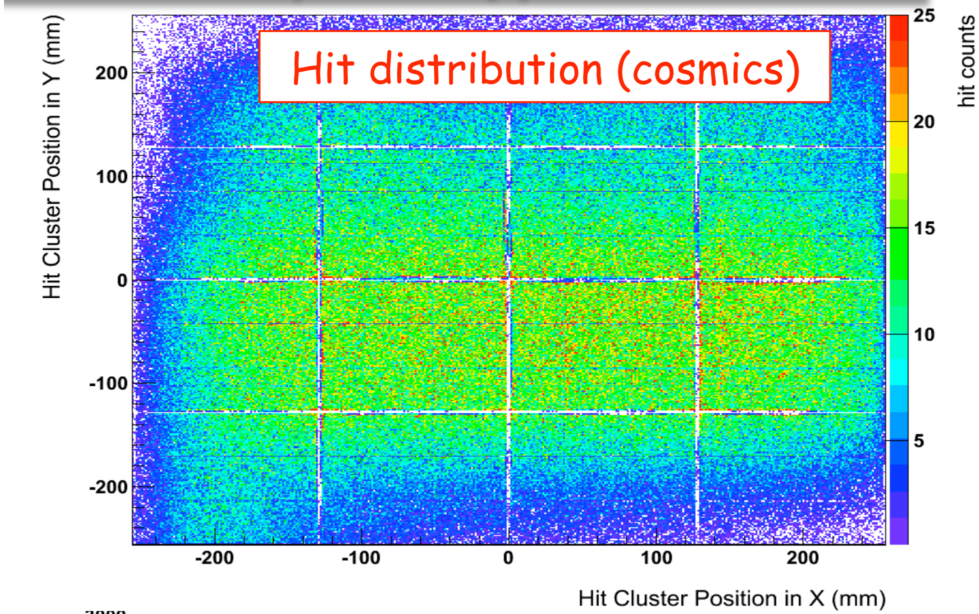


SBS Back Tracker 50 cm x 50 cm Prototype I: fully operational

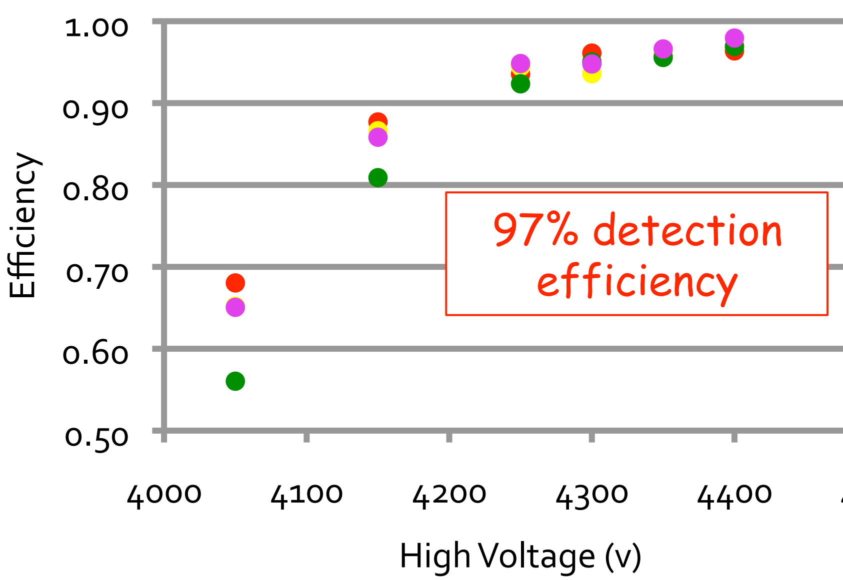


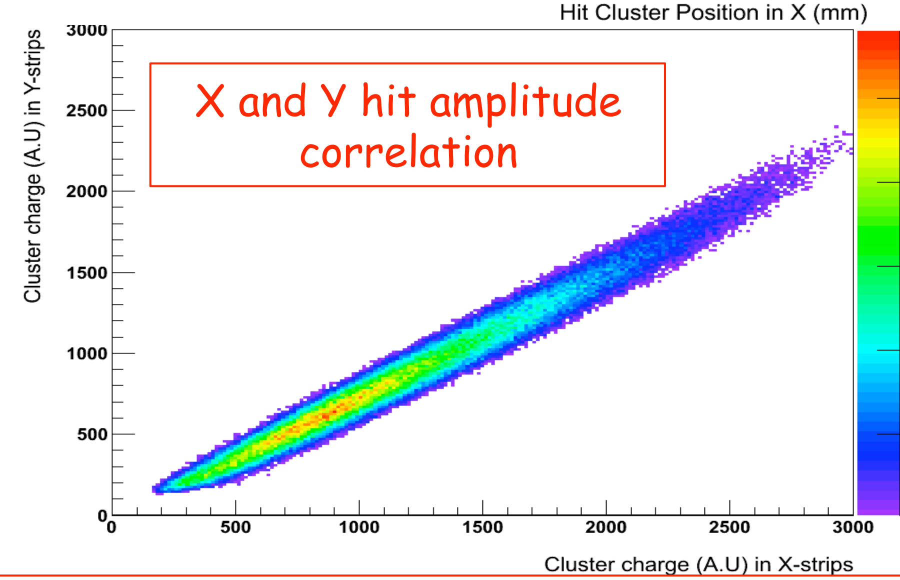
SBS GEM module full-size prototype





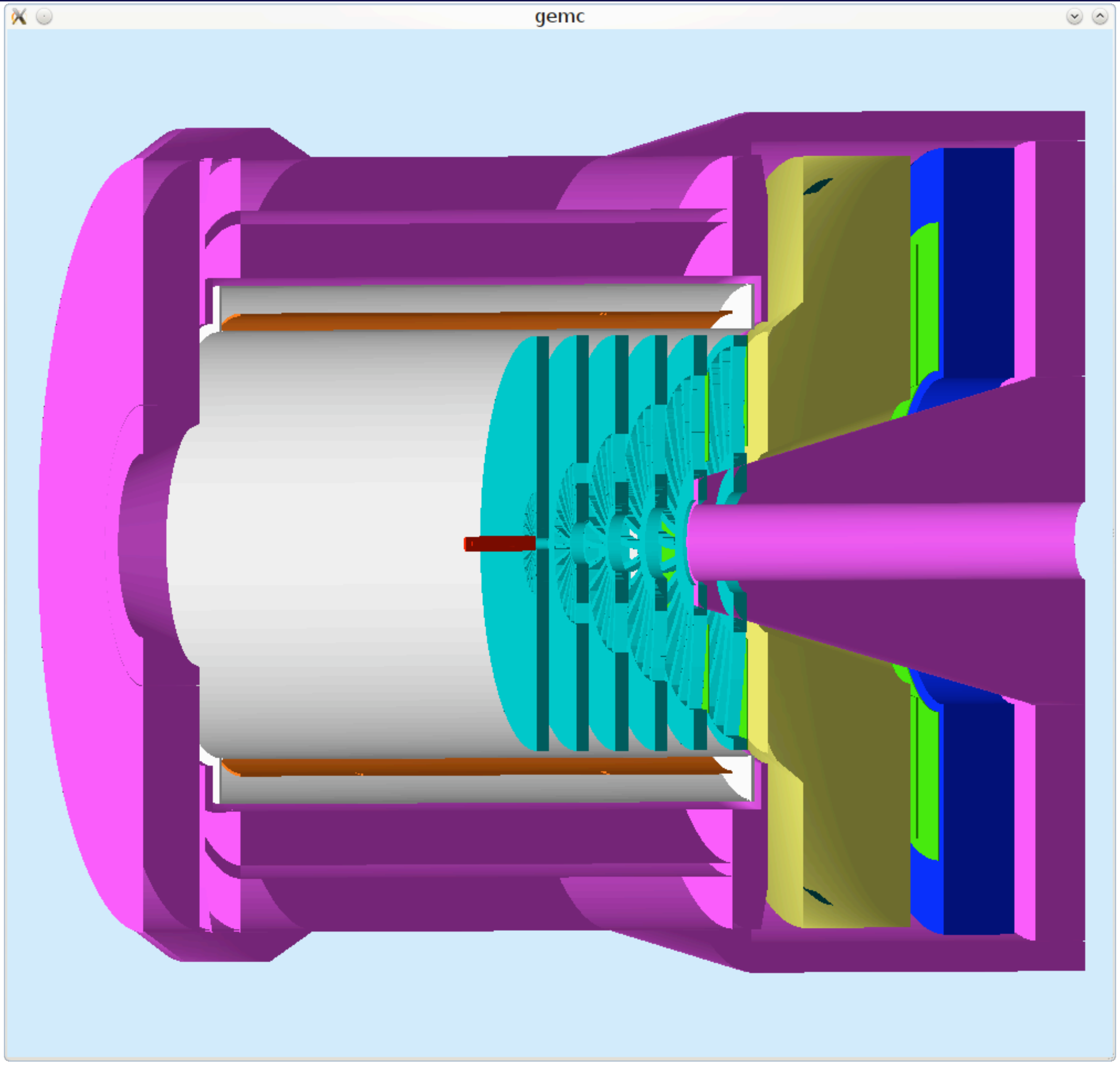
Gain Uniformity (with ^{90}Sr source)





- Prototype meets SBS design requirements
- Starting production of 40 modules in September

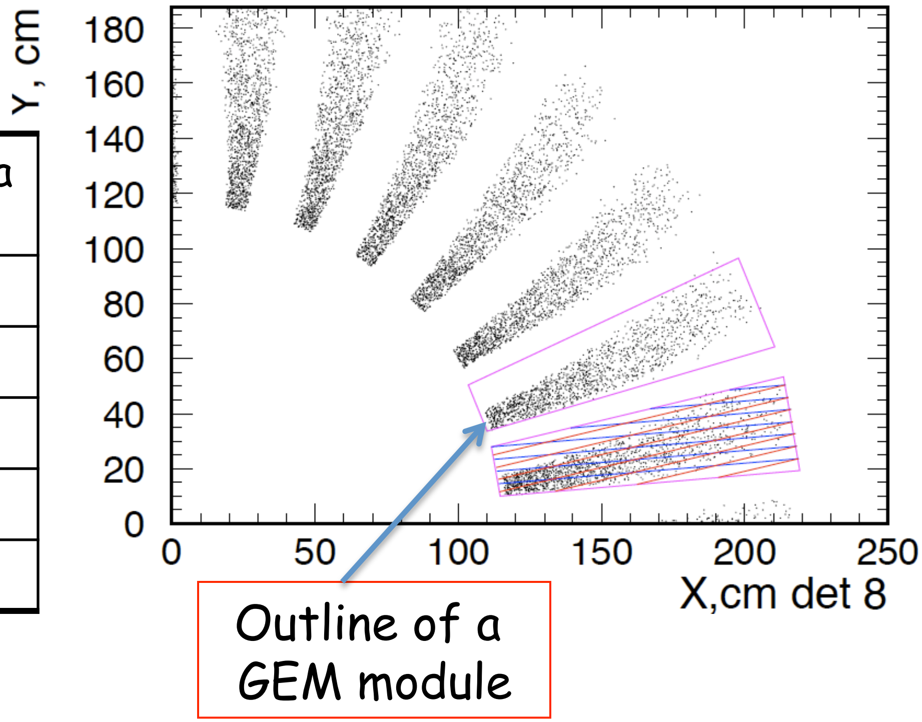
GEMs for SoLID



PVDIS GEM configuration

- Current proposal to instrument locations 5, 6, 7, and 8 with GEM: might also need at one more location
- 30 GEM modules at each location: each module with a 12-degree angular width.

Plane	Z (cm)	R_I (cm)	R_O (cm)	Active area (m^2)
5	150	55	115	2.7
6	190	65	140	4.0
7	290	105	200	7.6
8	310	115	215	8.6
total:				~ 23



Largest GEM module size required: 100 cm x (20-38) cm

PVDIS GEM configuration

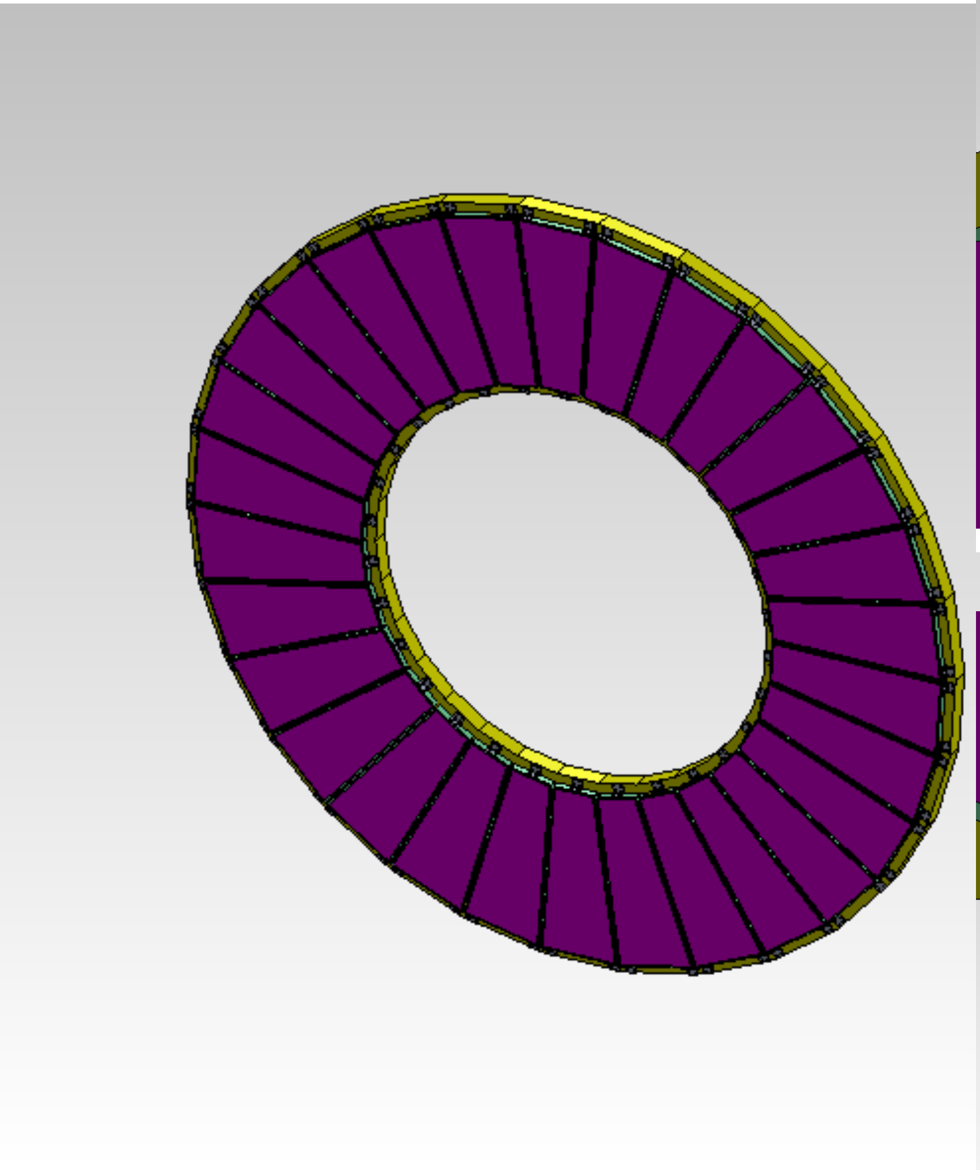
- For this readout scheme readout channel estimation

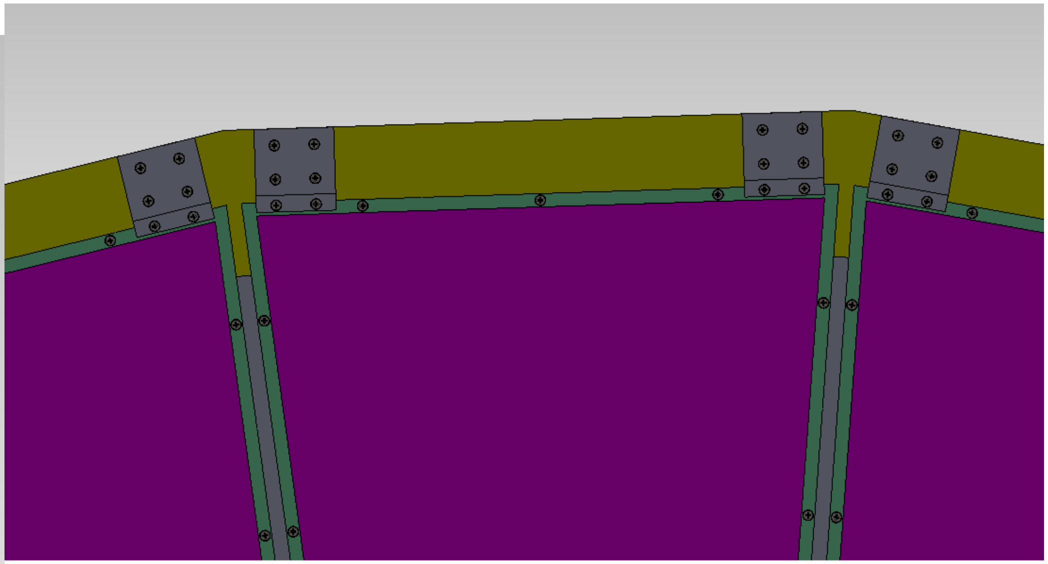
Plane	Z (cm)	R_I (cm)	R_O (cm)	# of channels
5	150	55	115	30 k
6	190	65	140	36 k
7	290	105	200	35 k
8	310	115	215	38 k
total:				140 k

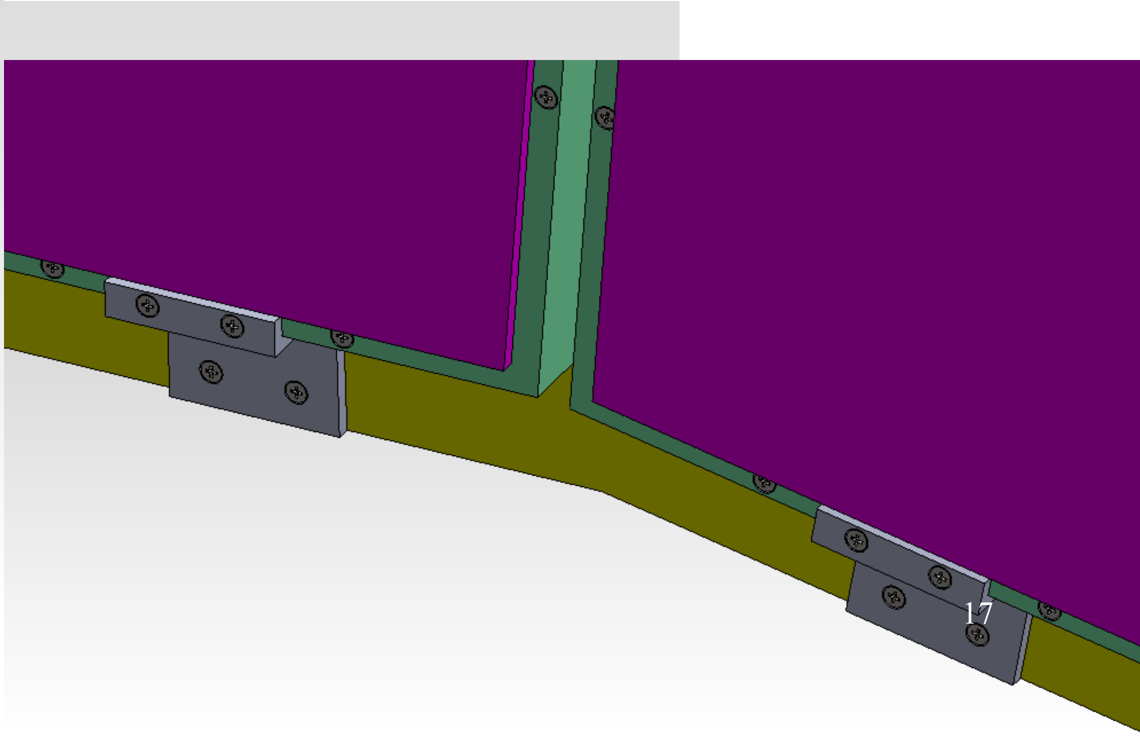
- with 20% spares, we will need about 170 k channels.
- Good news: cost of electronics going down – cost per channel for the RD51 SRS APV-25 based readout is estimated to be ~ $ 2.50 - $ 3.00 + R&D expenses to optimize electronics for SoLID needs.

The total cost of readout electronics can be less than $ 1 M

PVDIS GEM configuration



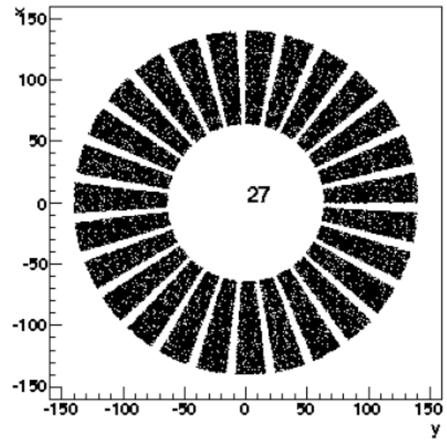




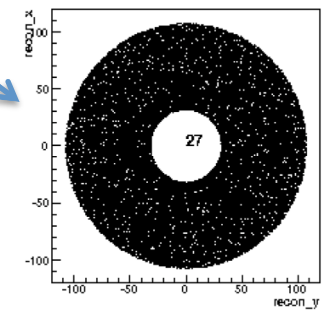
SIDIS GEM configuration

- Six locations instrumented with GEM:
- PVDIS GEM modules can be re-arranged to make all chamber layers for SIDIS. – move the PVDIS modules closer to the axis so that they are next to each other

Plane	Z (cm)	R_I (cm)	R_O (cm)	Active area	# 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



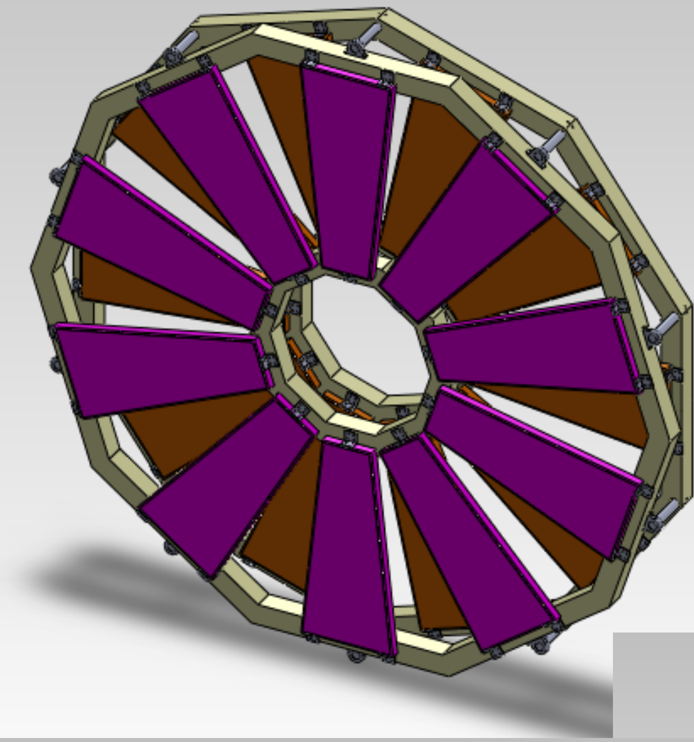
PVDIS

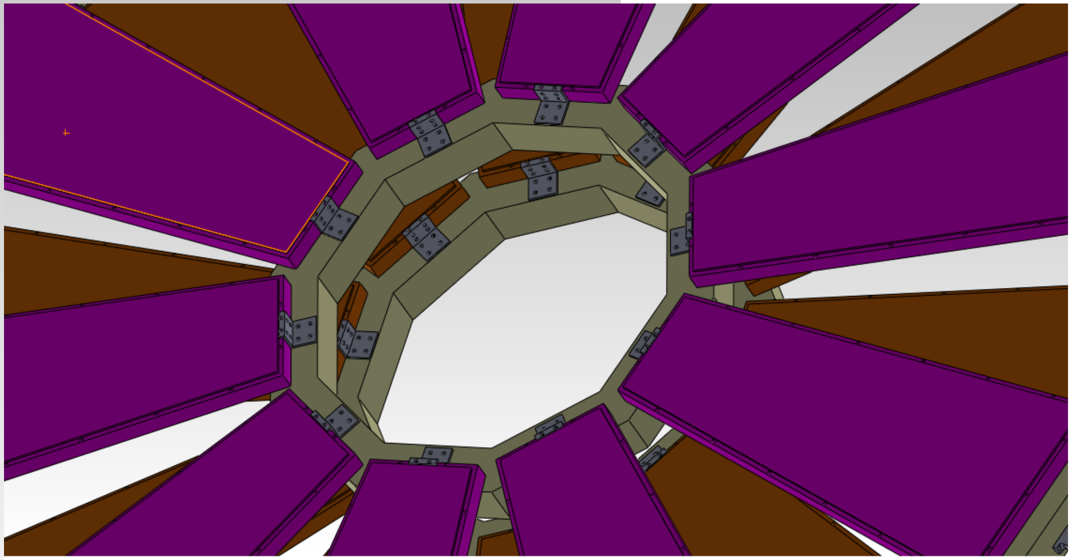


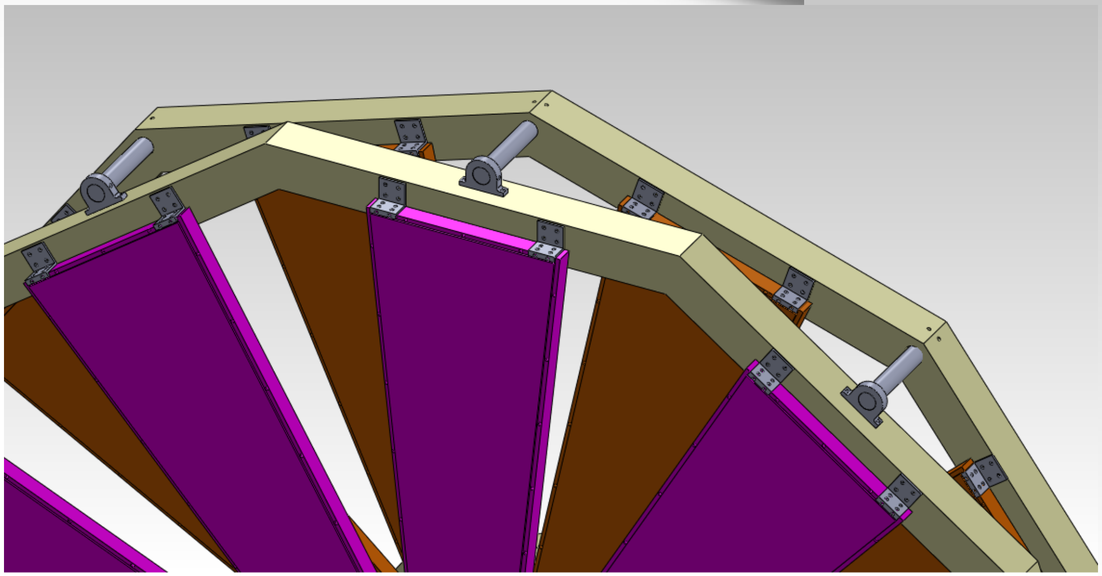
SIDIS

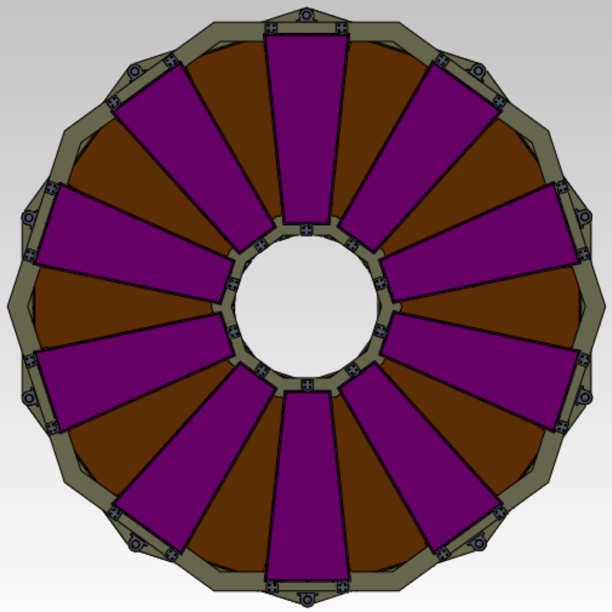
- More than enough electronic channels from PVDIS setup.
- The two configurations will work well with no need for new GEM or electronics fabrication.

SIDIS GEM configuration



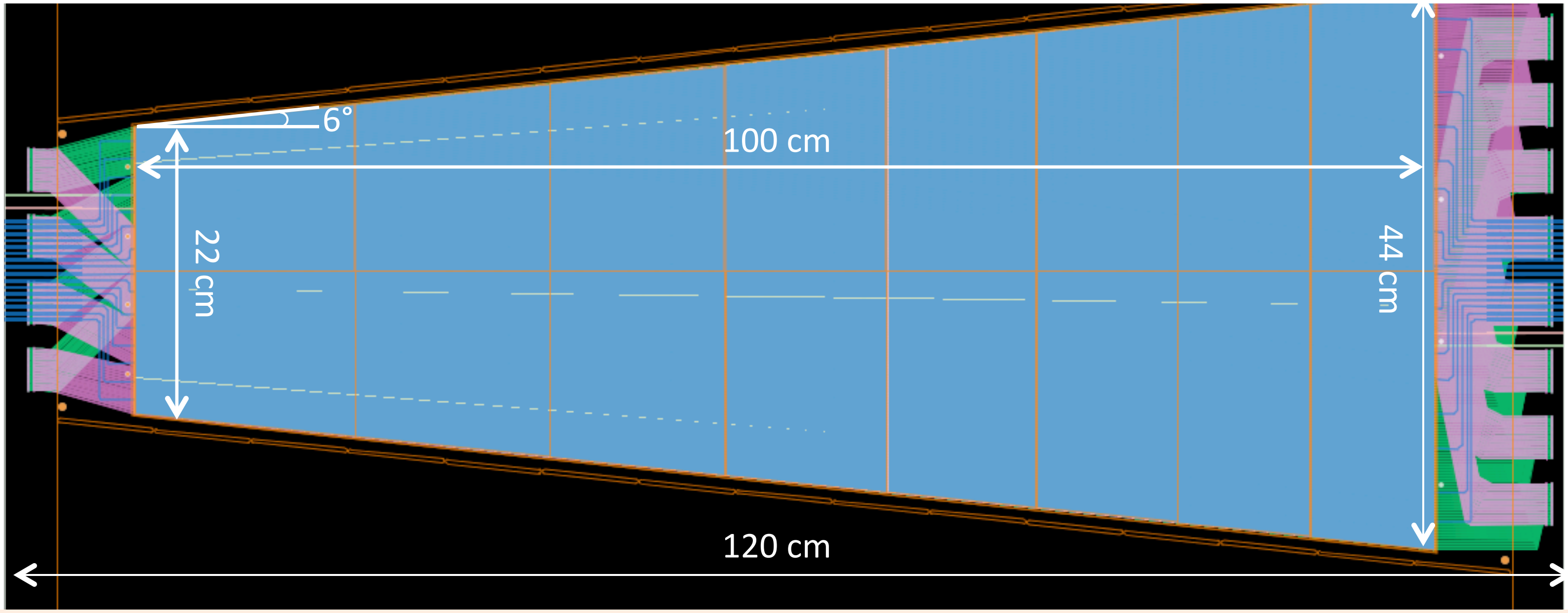






Large area GEM prototype for EIC and SoLID

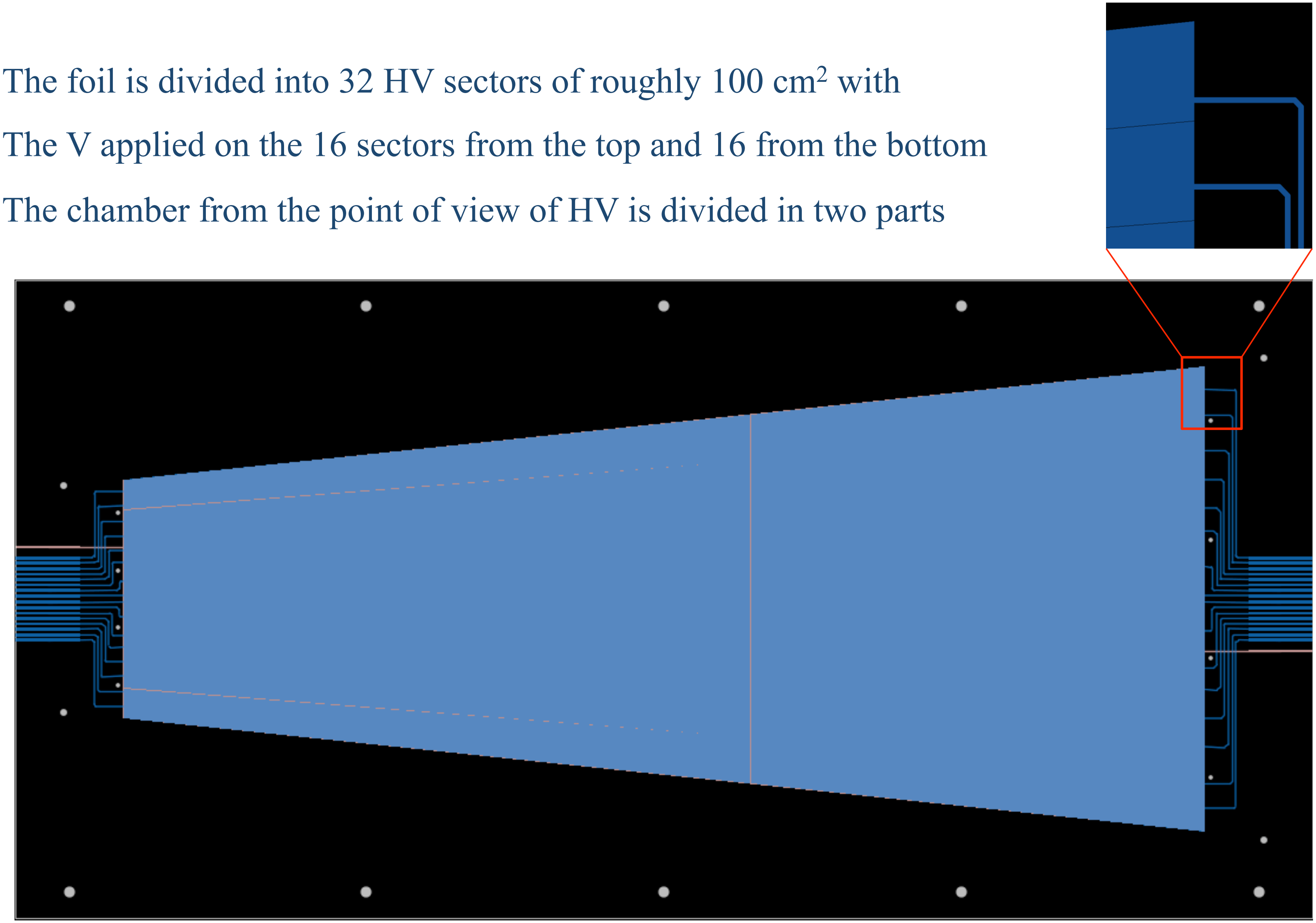
- We are building a large GEM prototype for EIC forward GEM tracker R&D
- Size similar to largest SoLID GEMs.
- Components are ready:
  - Large GEM foils and readout made at CERN: ship to UVa next week.
  - Frames already received from Resarm
- Plan to start assembly on September 1.



• Several chambers of this size have been built under the CMS upgrade program, but they are 1D readout; our chamber will be 2D readout.

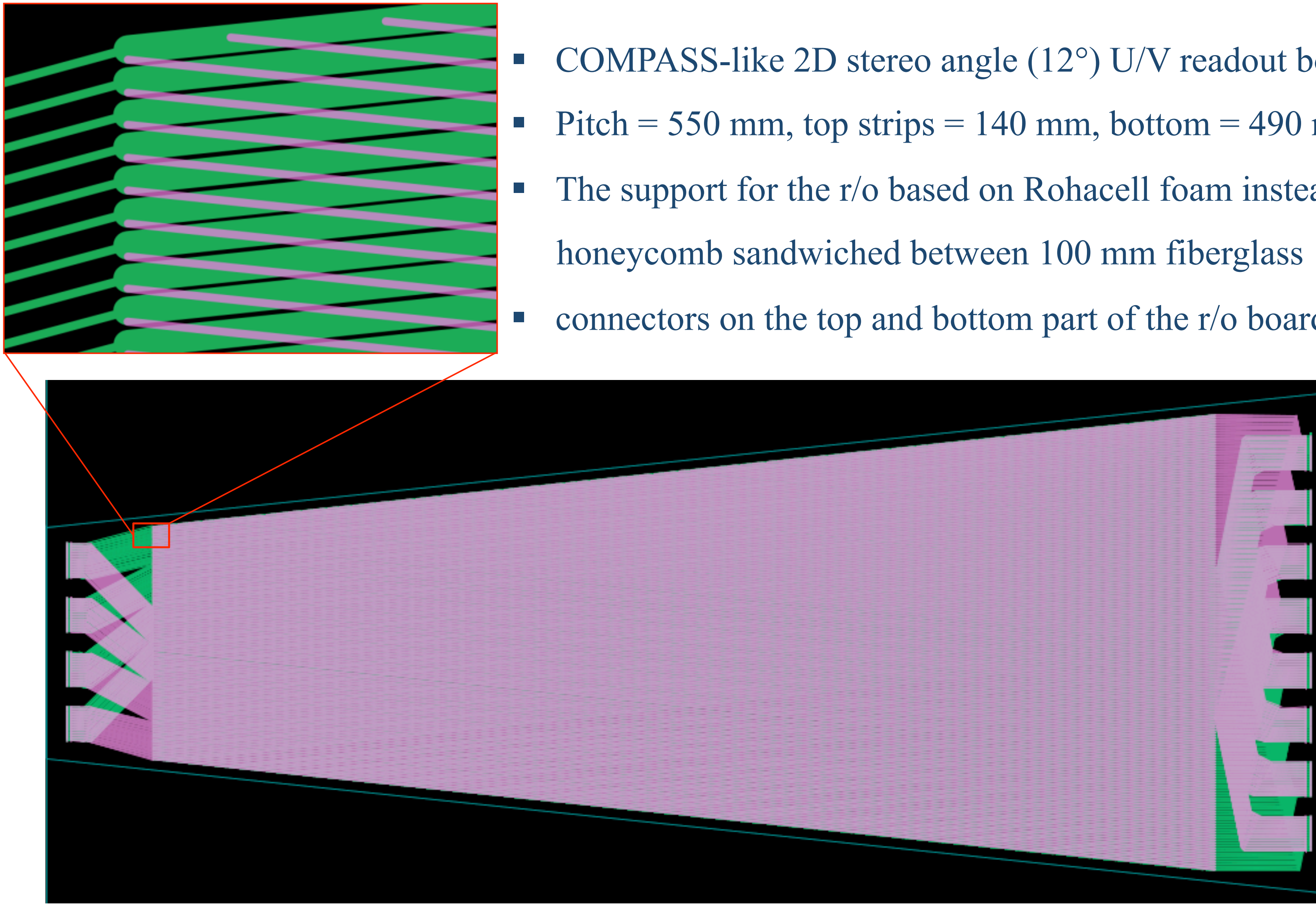
The GEM foil

- The foil is divided into 32 HV sectors of roughly 100 cm^2 with
- The V applied on the 16 sectors from the top and 16 from the bottom
- The chamber from the point of view of HV is divided in two parts



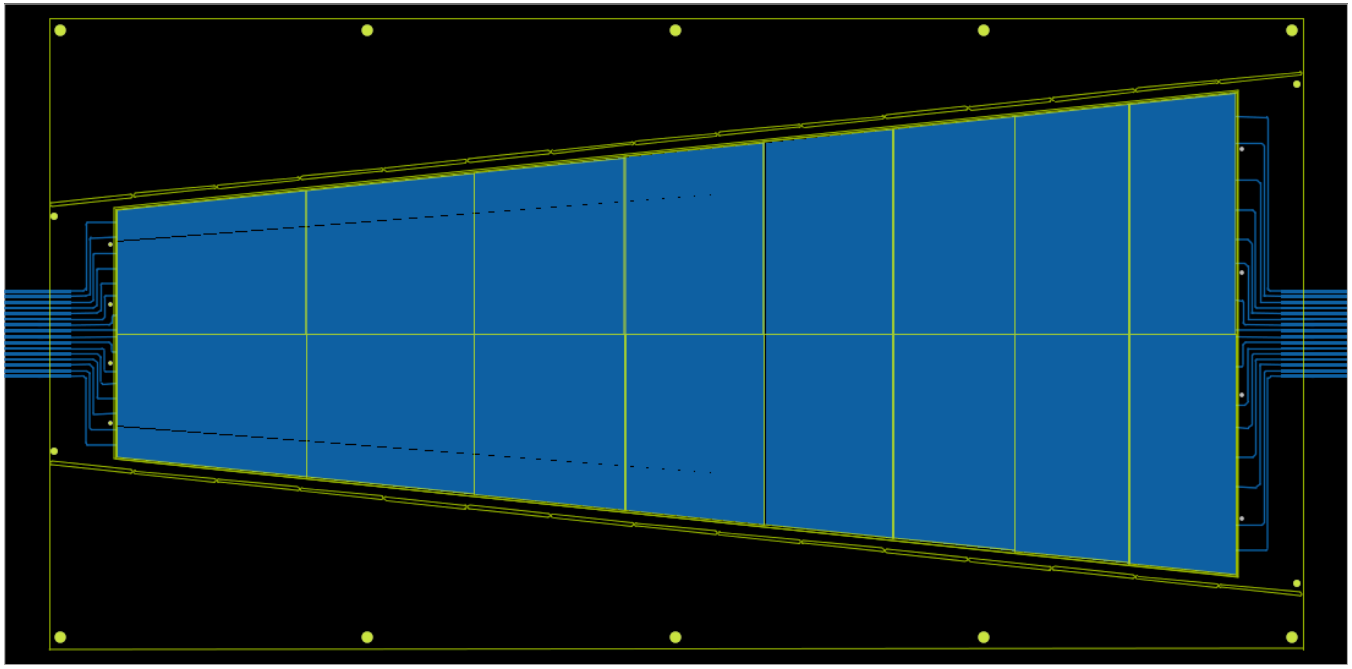
The U/V COMPASS-like readout board

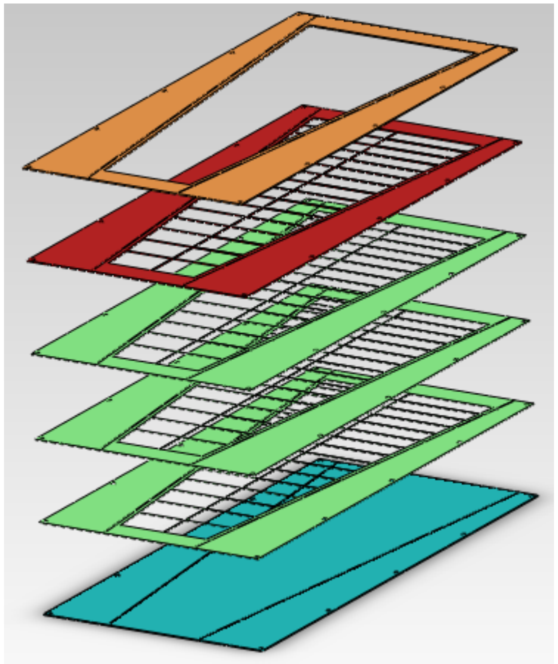
- COMPASS-like 2D stereo angle (12°) U/V readout board
- Pitch = 550 mm, top strips = 140 mm, bottom = 490 mm
- The support for the r/o based on Rohacell foam instead of honeycomb sandwiched between 100 mm fiberglass
- connectors on the top and bottom part of the r/o board



The Frames

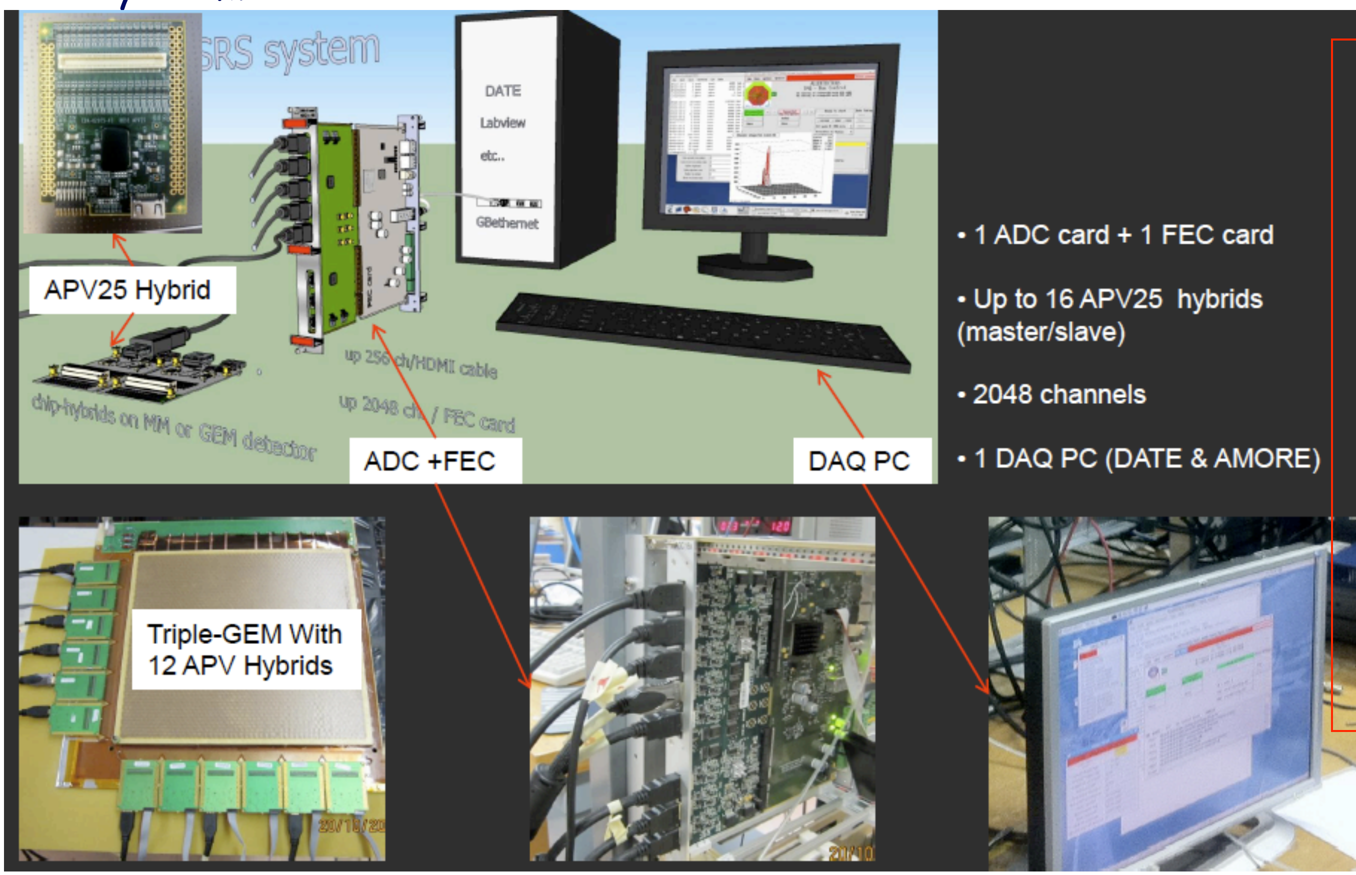
- Frames with the standard 300 μm spacers
- Extra frame material for the alignment and to hold the tension on GEM foil during assembly → cut out after
- 8 mm width on the side and 60 mm width on top and bottom
- Positioning holes on top and bottom





GEM chamber electronics

- The RD-51 Scalable Readout System provides a low-cost, common platform that can accommodate different readout chips.
- Currently tested with APV25-S1 chip
- Drawback with the APV25 chip: may not be fast enough for SoLID
- Need to work on finding a suitable chip for SoLID readout and incorporating it into SRS
- The UVa group has a 10,000 chan SRS system and a 3000 chan. INFN APV readout system.



SRS system has the benefit of the large team effort backed by RD-51

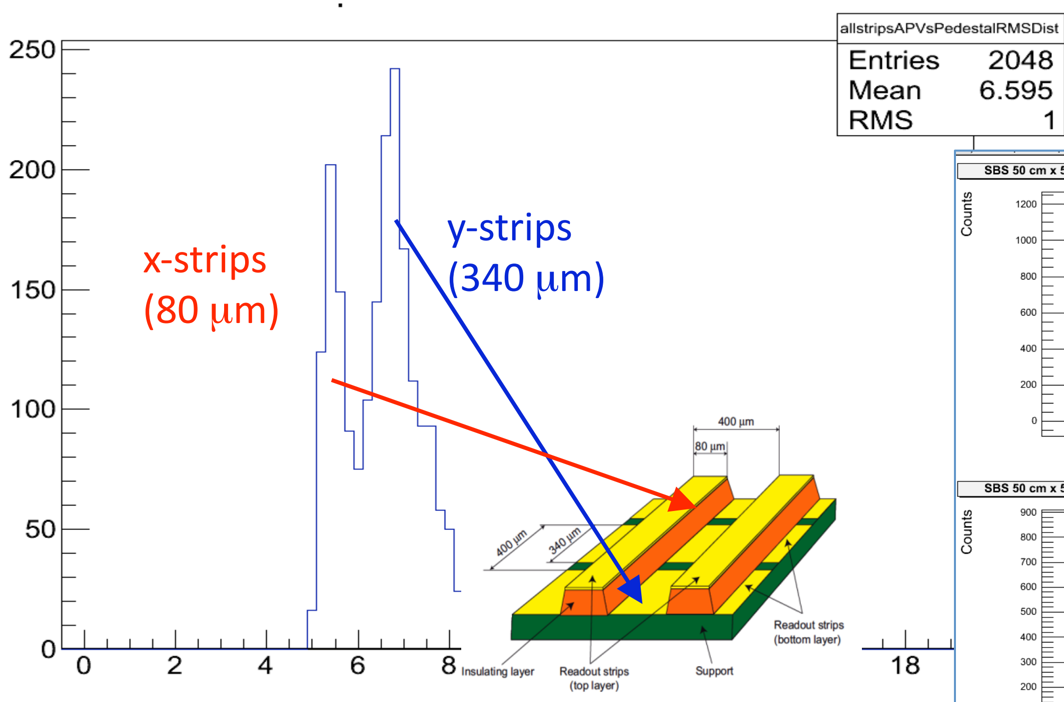
RD-51 plans to commercialize the fabrication; there will be the possibility to get very large systems in the future.

The cost is ~< $ 3/chan

SoLID GEM: Issues

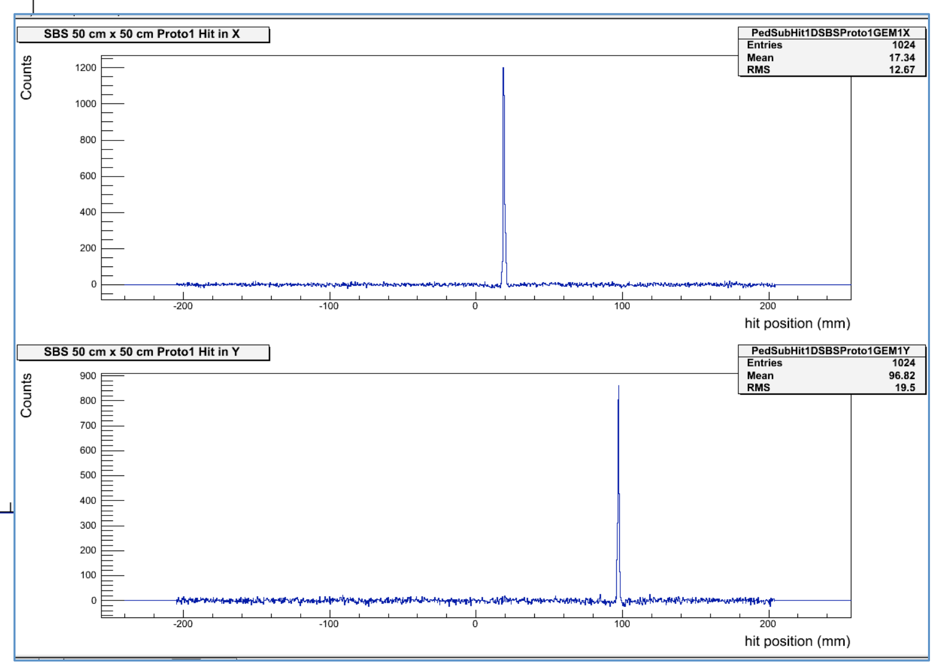
- Large amount of GEM foils needed (~ 100 m^2): CERN shop might not be able to handle: especially if CMS high-eta GEM tracker proposal is approved.
  - Need the large area GEM fabrication in China.
  - Talk to Bernd Surrow: he has a lot of experience in setting up GEM foil production.
- Noise in long (up to ~ 120 cm) readout strips a problem ?
  - This might not be an issue; 50 cm strips, noise well below signal

Pedestal RMS noise distribution



ADC Ch counts

Good S/N ratio at 4200 V



SoLID GEM: Issues – continued…

- High strip occupancy resulting from high rates and long strips.
  - MC show that if a background hit within +/- 35 ns of a good hit on a strip, the good hit is lost: i.e; contributes to chamber inefficiency.
  - Estimates for SoLID conditions indicate strip occupancies of ~ 18%: leading to chamber efficiencies of ~ 80%.
  - A track requires hits in at least 3 chamber locations: so having only 4 chamber locations will give a tracking efficiency of ~ 82% or less.
  - Having at least one more location will increase the efficiency to ~ 95%

- Need to find a suitable readout chip, if APV25 is not fast enough.
  - Look for available chips / try to design our own ?
  - work with Dr. Hans Muller in the The RD-51-readout electronics working group to integrate a new chip to SRS/or develop our own readout ?

- GEM construction techniques: No need to reinvent the wheel
  - Try to benefit from the work done by other groups.

We will be building/testing large GEM modules between Sep. 2013 and Feb. 2014. We would be very happy to host one of two of the Chinese collaborators during that period