GEM chambers for SoLID

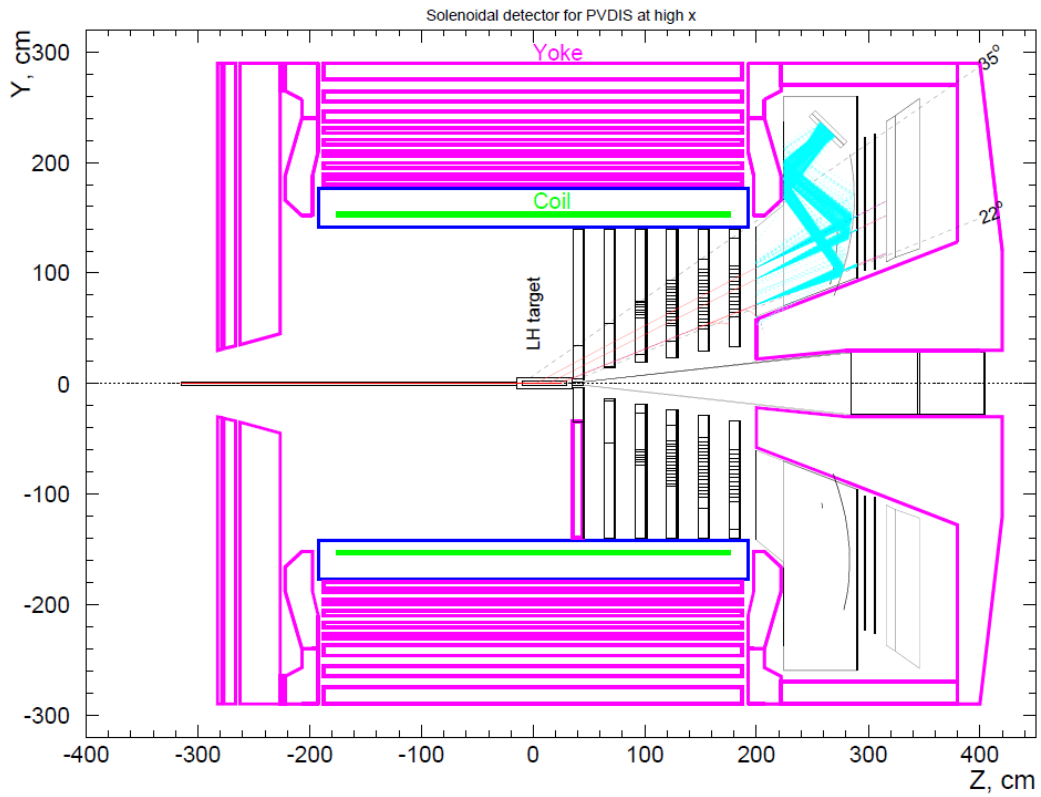
Nilanga Liyanage

University of Virginia

Tracking needs for SoLID (PVDIS)

- Rate: from 100 kHz to 600 kHz (with baffles), GEANT3 estimation
- Spatial Resolution: ~0.2 mm (sigma)
- Total area: 23 m^2 total area (30 sectors x4 planes, each sector cover 10 degree)
- Need to be Magnetic field tolerant

Lumi = $5.4E^{38}$ /cm^2/s



Choice of the technology

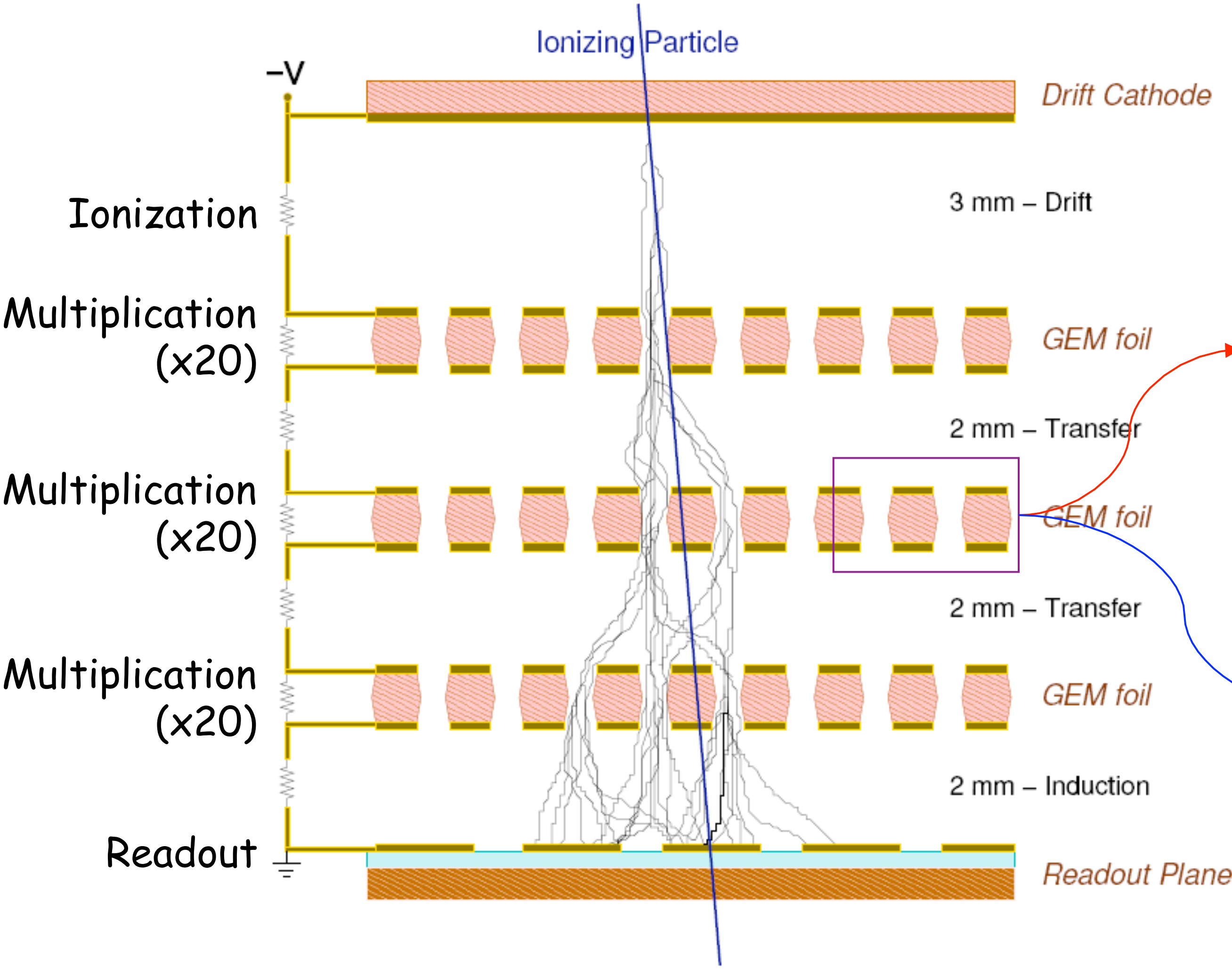
System Requirements	Tracking Technology: Drift	Tracking Technology: **MPGD**	Tracking Technology: Silicon
High Rate (up to): **1 MHz/cm^2**	NO	**MHz/mm^2**	**MHz/mm^2**
Resolution: **200 μm**	Achievable	**50 μm**	30 μm
Large Area: Single chamber up to 0.5 m^2 total 23 m^2	YES	**Doable**	Very Expensive

MPGD → **GEM**, **μMs**

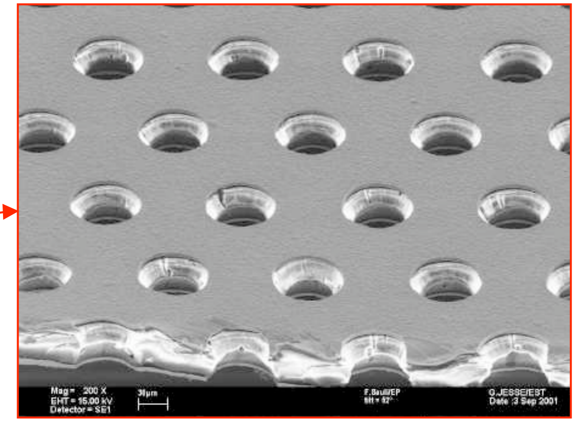
Flexibility in readout geometry and lower spark rate → **GEM**

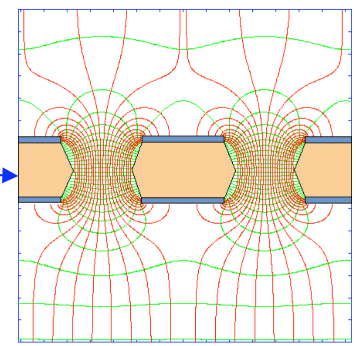
New recent development in resistive μM and GEM + μM to improve spark rate

GEM working principle



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



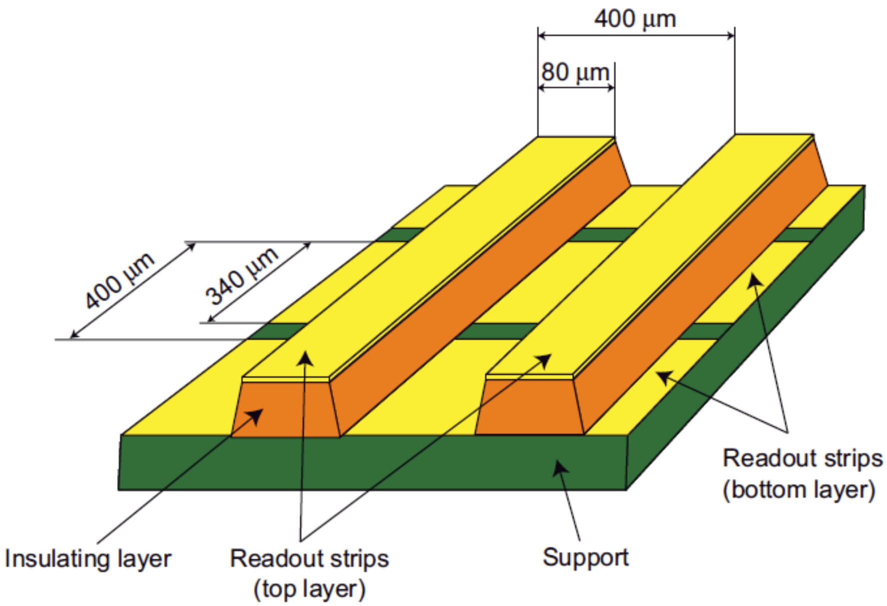


Strong electrostatic field in the GEM holes

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

COMPASS GEM Tracker

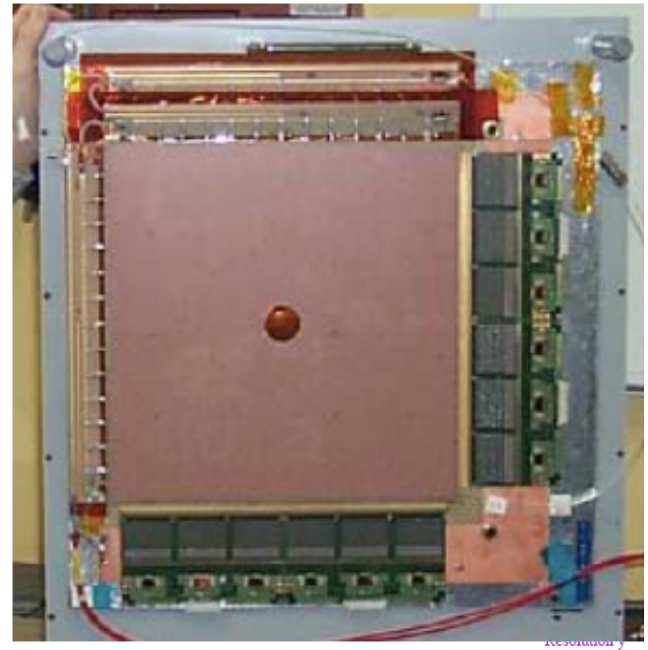
- A tracker of twenty two 31 cm x 31 cm GEM chambers successfully operated for years
- Rates as high as 2.5 MHz/cm^2

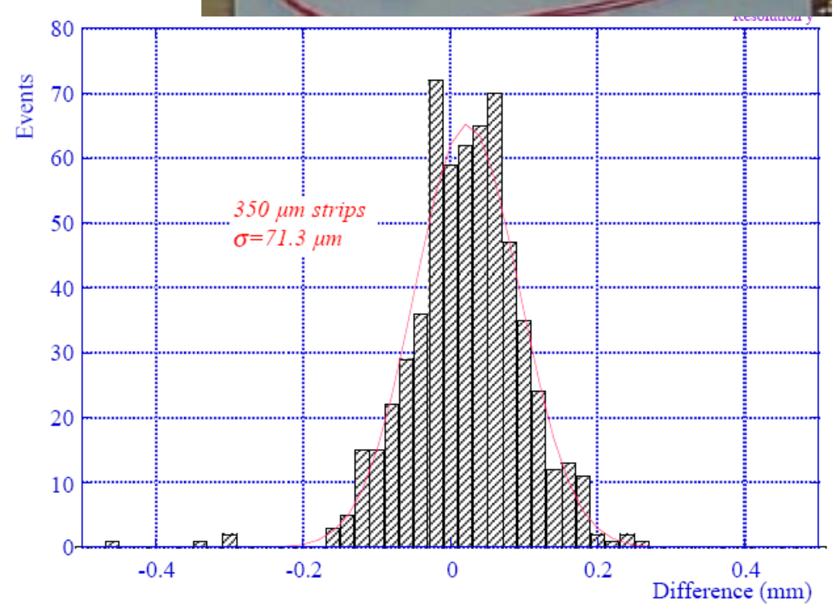


COMPASS readout plane (31x31 cm^2)

70 μm resolution achieved by strips centroid

⇒ **Analog readout required (used the APV25 chip)**

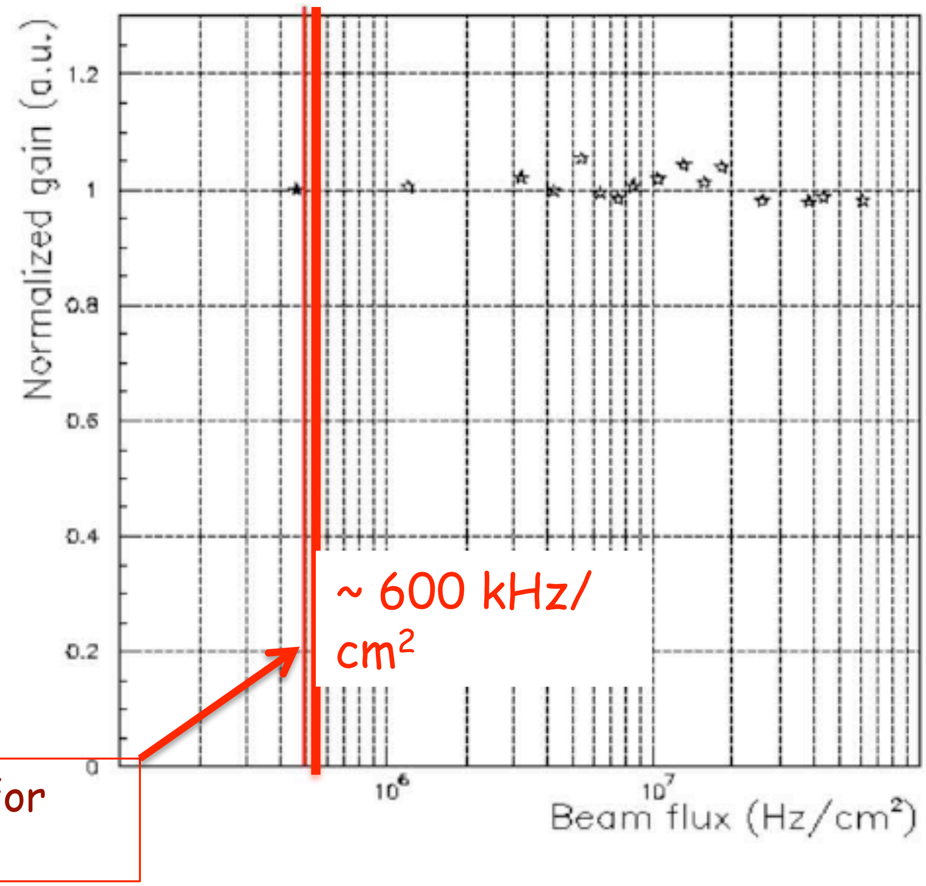




GEM Rate capability

- Multiplication stages shielded from each other: much reduced feed back
- Slow moving positive ions localized to holes, away from the induction region
- Most of the created electrons contribute to signal: can operate at low gains

Much higher rates compared to wire chambers: ~ 50 MHz/cm^2

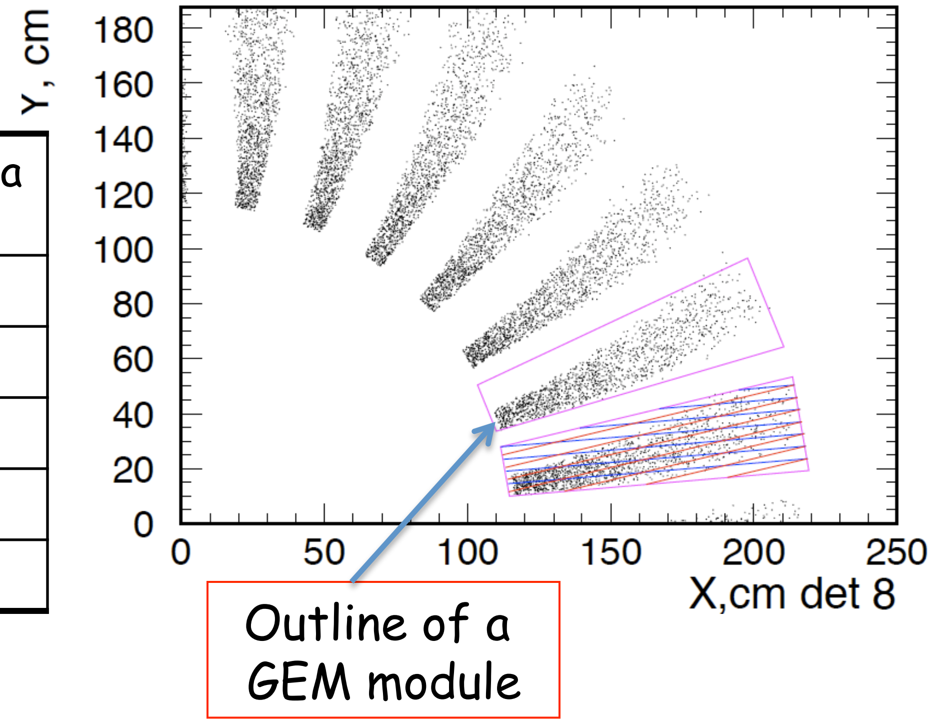


Triple GEM
Poli Lener, PhD Thesis - Rome 2005

PVDIS GEM configuration

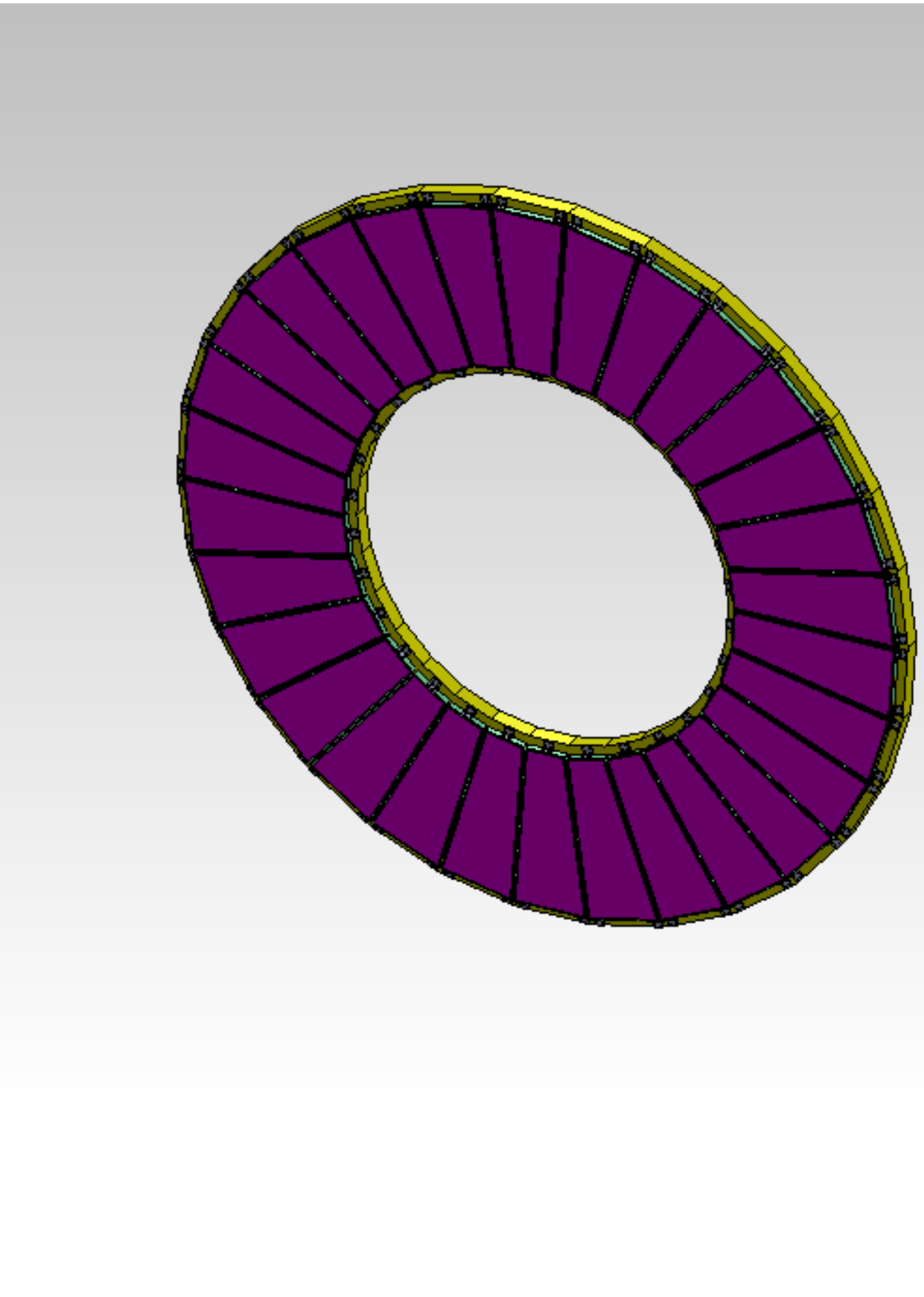
- Current proposal to instrument locations 5, 6, 7, and 8 with GEM:
- 30 GEM modules at each location: each module with a 10-degree angular width.

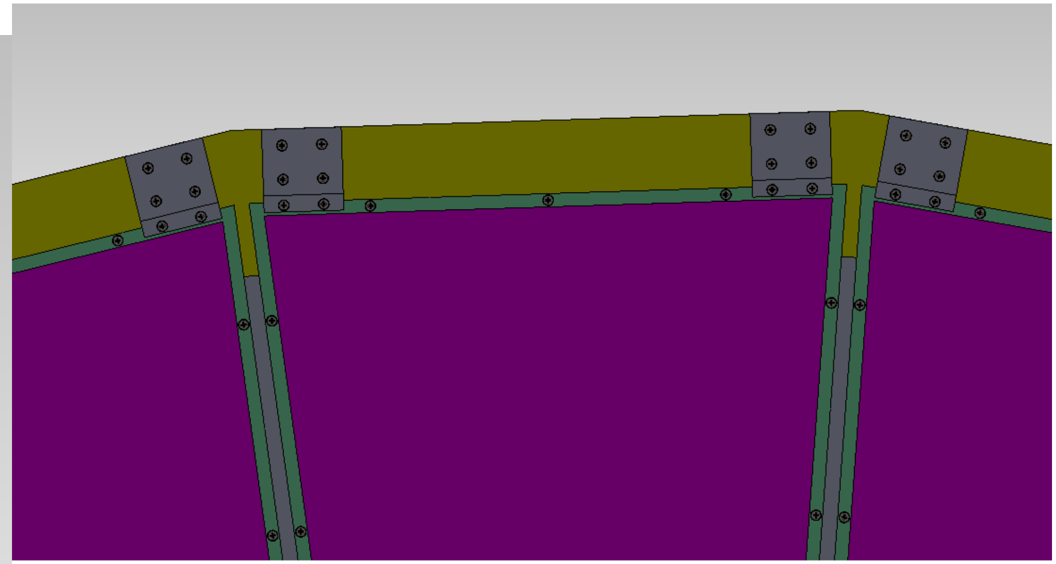
Plane	Z (cm)	R_I (cm)	R_O (cm)	Active area (m^2)
5	150	55	115	2.7
6	190	65	140	4.0
7	290	105	200	7.6
8	310	115	215	8.6
total:				~ 23

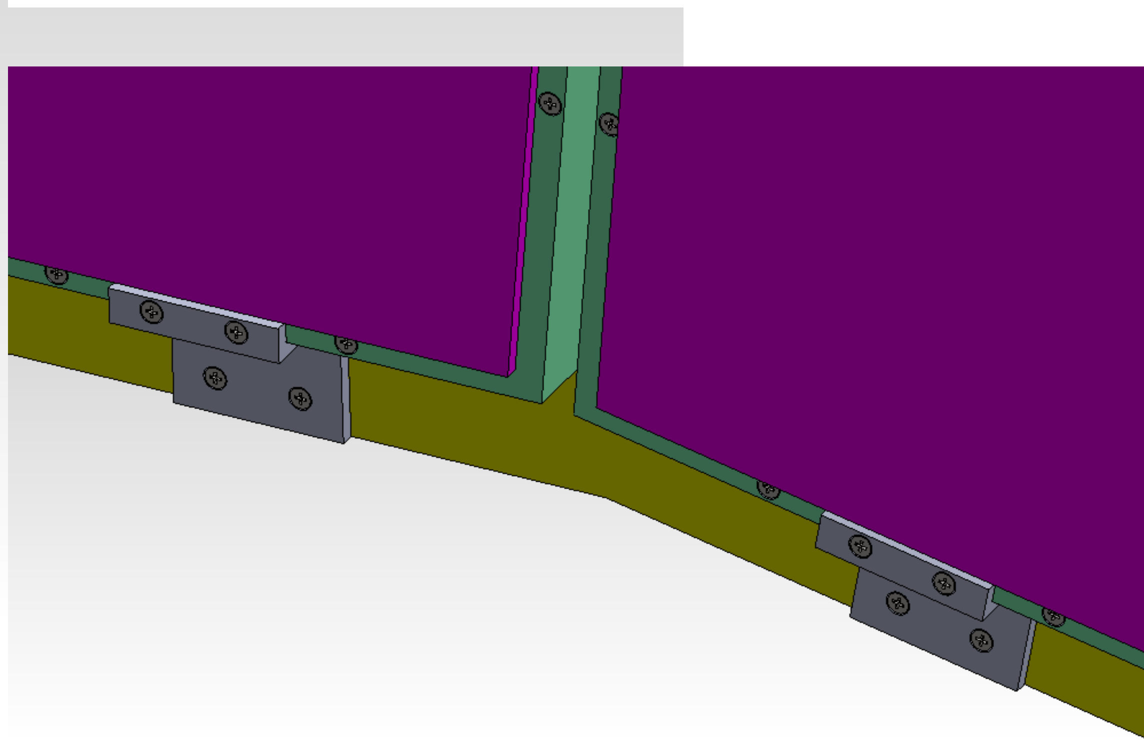


Largest GEM module size required: 100 cm x (20-38) cm

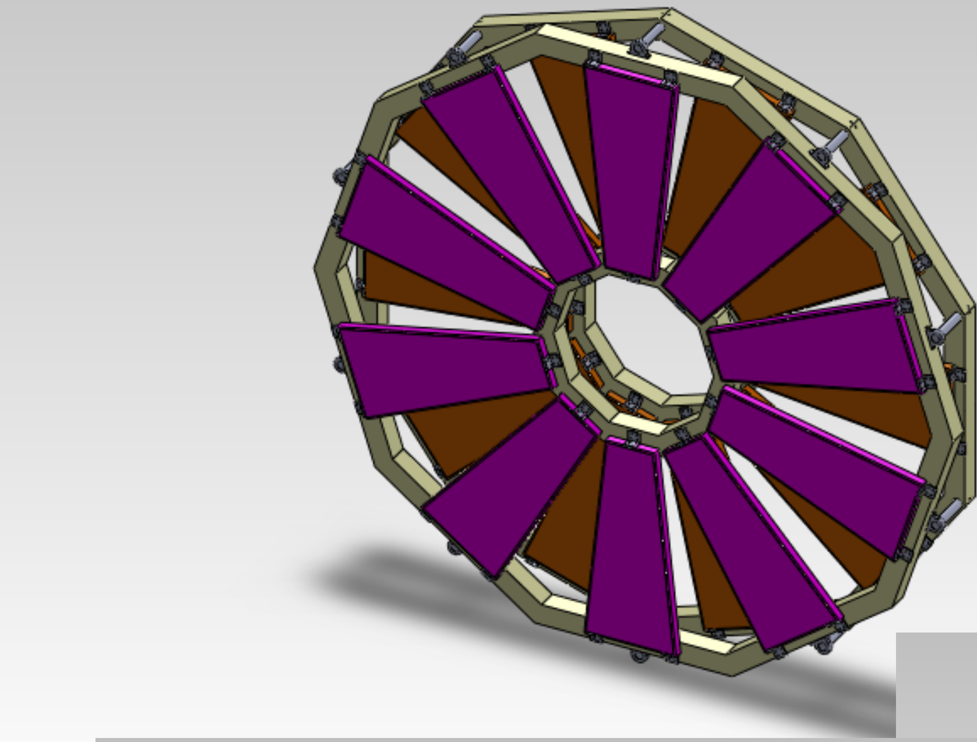
PVDIS GEM configuration

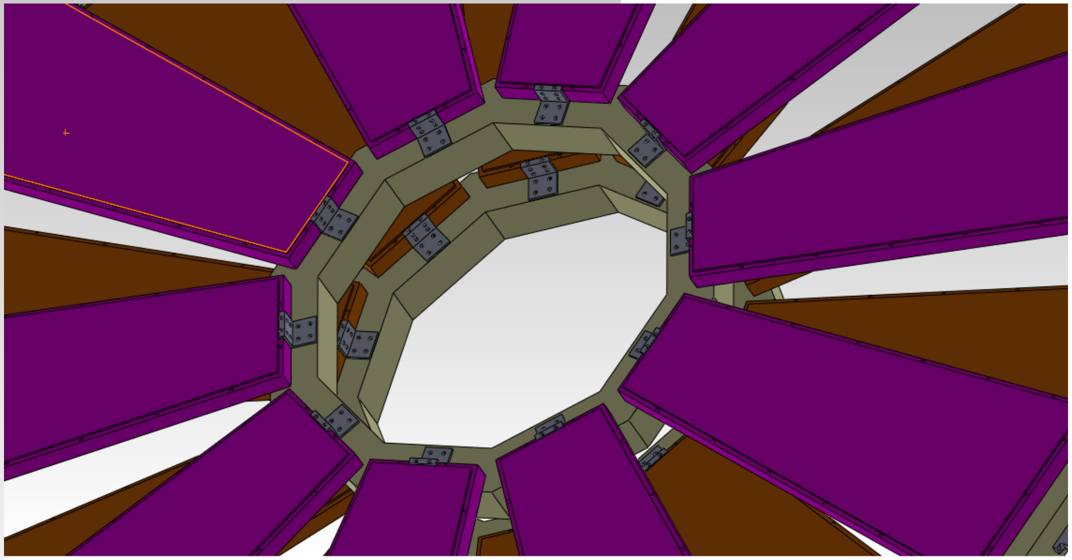


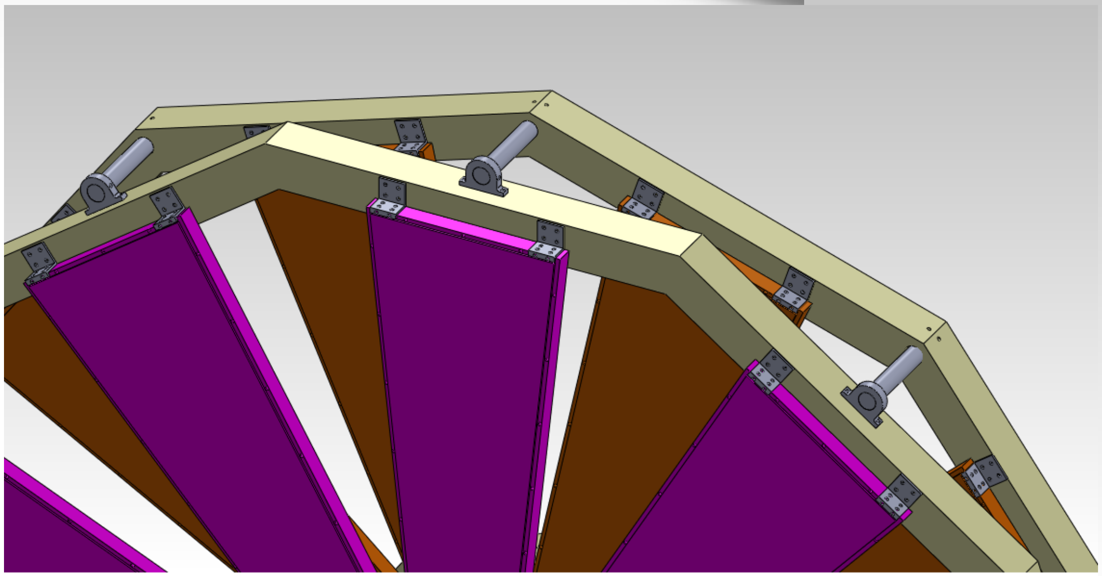


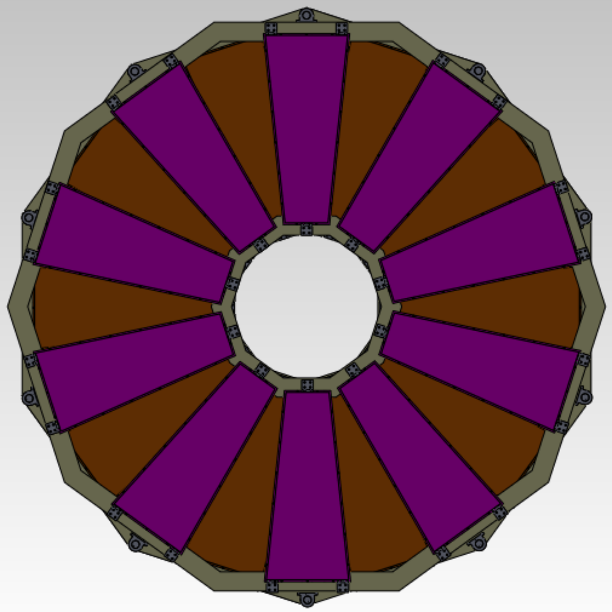


SIDIS GEM configuration



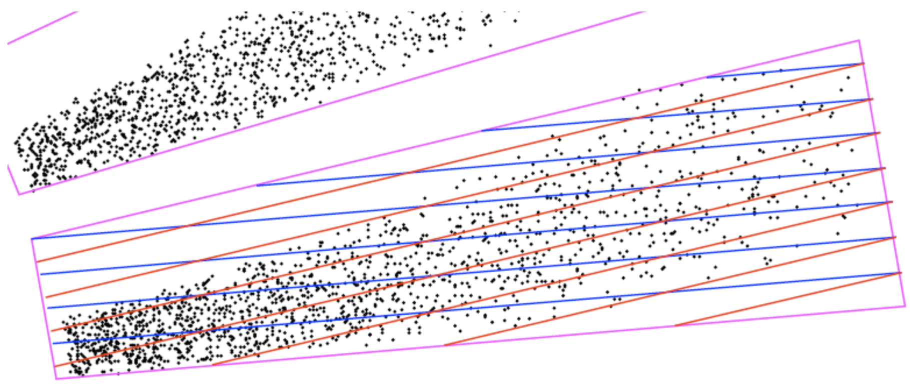






PVDIS GEM configuration

- Suggested readout scheme:
  - a 2D readout optimized to get high accuracy in the ϕ coordinate, lower but sufficient resolution in the **r** coordinate.
  - each set of stripes parallel to one of the radial sides of the module: i.e. stripes at a 10-deg stereo angle to each other.
  - strip pitch is 0.6 mm for locations 7 and 8;
  - 0.4 mm for locations 5 and 6.
  - Issues:
    - High capacitance in long readout strips; will signal to noise ration be an issue ?
    - How well will the 10-deg stereo angle separated strip layers work ? – need to test with prototypes.



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

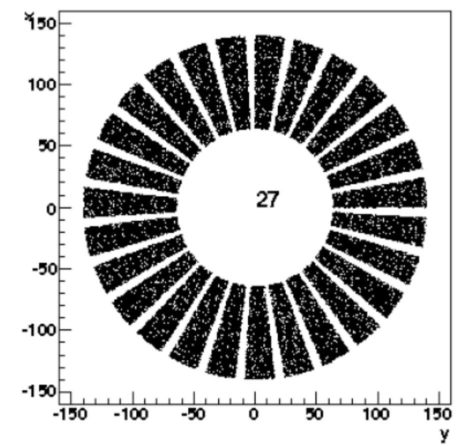
- with 20% spares, we will need about 170 k channels.
- Good news: cost of electronics going down – cost per channel for the RD51 SRS APV-25 based readout is estimated to be ~ $ 2.50 - $ 3.00 + R&D expenses to optimize electronics for SoLID needs.

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

SIDIS GEM configuration

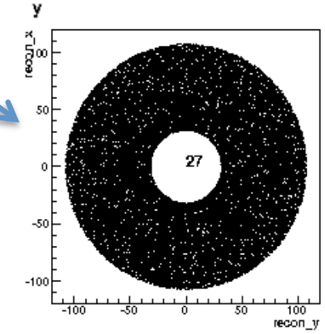
- Six locations instrumented with GEM:
- PVDIS GEM modules can be re-arranged to make all chamber layers for SIDIS. – move the PVDIS modules closer to the axis so that they are next to each other

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



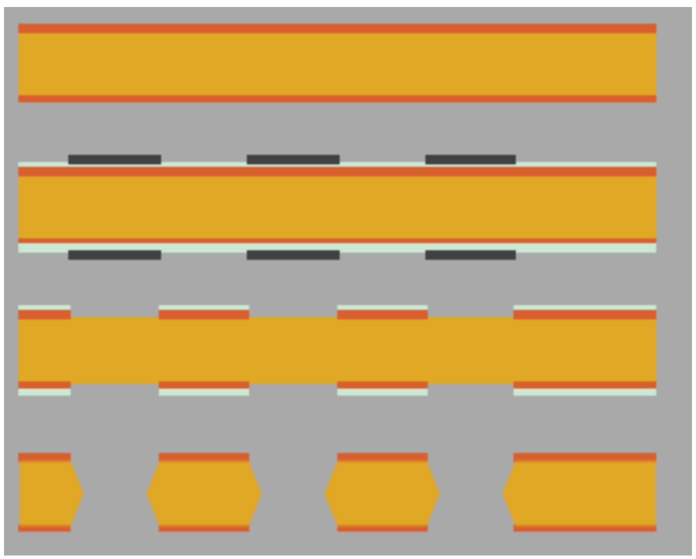
- More than enough electronic channels from PVDIS setup.
- The two configurations will work well with no need for new GEM or electronics fabrication.

large area GEM chamber challenges

- SoLID needs GEM modules as large at 100 cm x 40 cm.
- The biggest challenge used to be the non-availability of large area GEM foils.
- Not a problem anymore: CERN shop can make foils as large as 200 cm x 50 cm now.
- One problem may be the production capacity of the CERN shop: especially if a LHC related large GEM project gets underway.
- Currently work going on to develop large GEM production capabilities in China.

Major recent development at CERN PCB shop towards large GEM foils

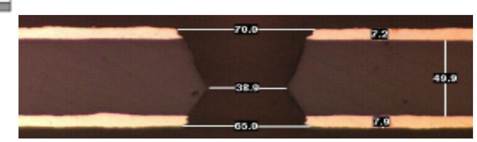
- Base material only ~ 45 cm wide roll.
- Used a double mask technique for etching: hard to the two masks accurately: Max area limited to ~ 45 cm x 45 cm previously.



Double Mask

Bias top surface to – w.r.t chemical bath

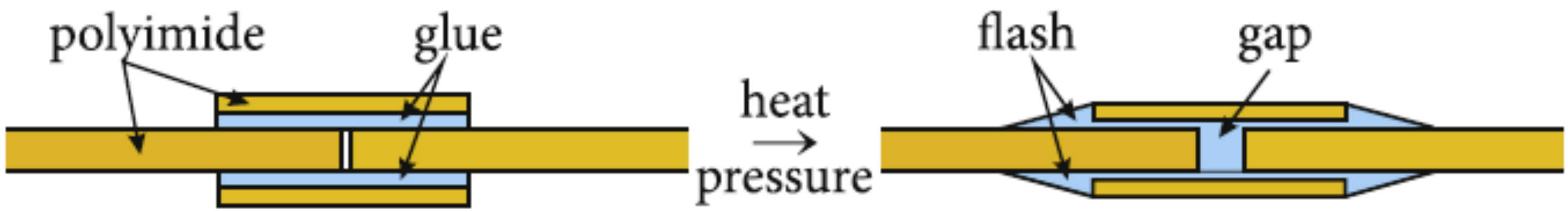
Single Mask

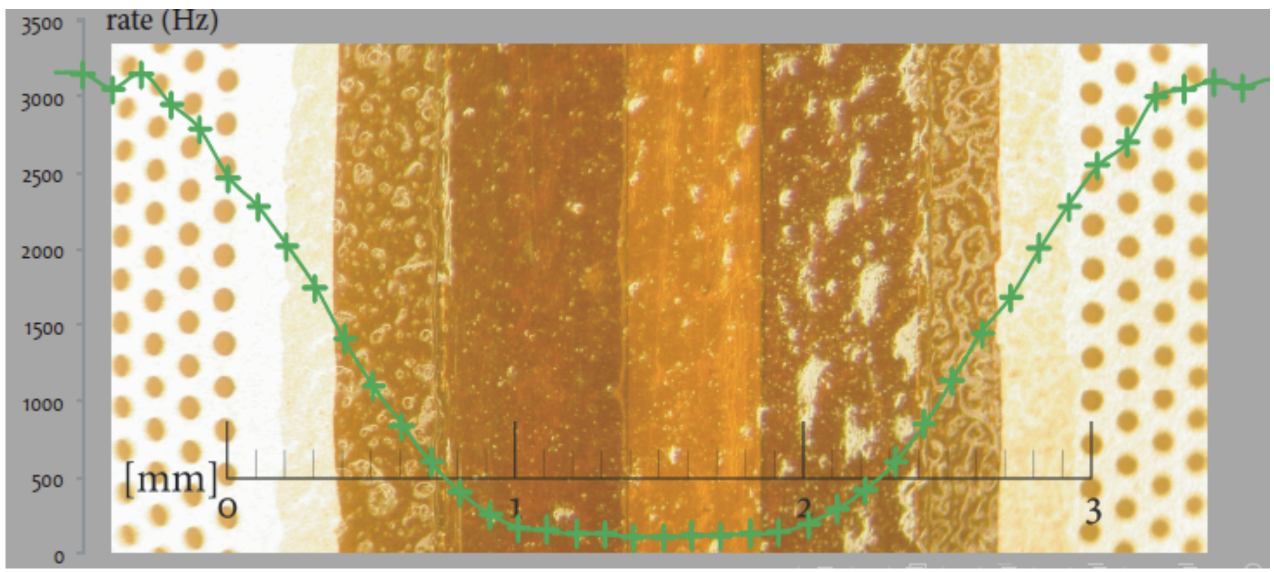


Single Mask technique allows to make GEM foils as large as 200 cm x 50 cm

Major recent development towards large GEM foils

- Splicing GEM foils together: seam is only 2 mm wide
- Performance of the rest of the GEM foil unaffected

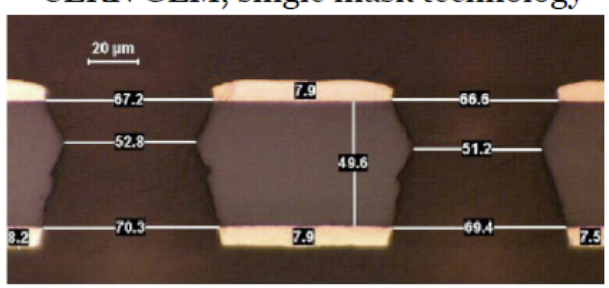




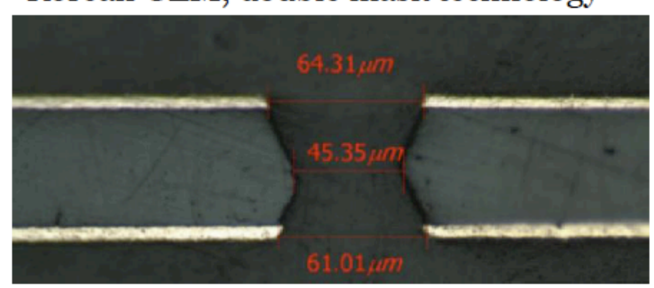
Industrial Production of GEMs

- Many anticipated users of GEMs in the near future; CERN shop can't keep up.
- Several Industrial production around the world starting with CERN technology transfer:
  - TechEtch, Plymouth, MA, USA : GEM foils up to ~ 40 cm; produced all foils for STAR FGT.
  - NewFlex Technology, South Korea: produced the tested foils up to 10 x 10 cm2; plans for large production up to 1 m foils.
  - TechTra in Poland
  - India
  - China
  - …

CERN GEM, single mask technology



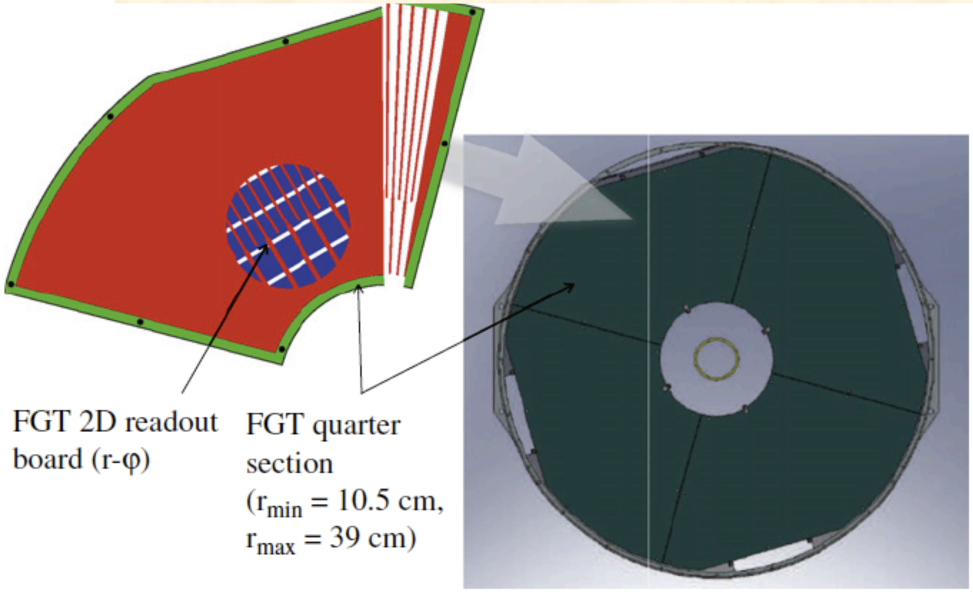
Korean GEM, double mask technology

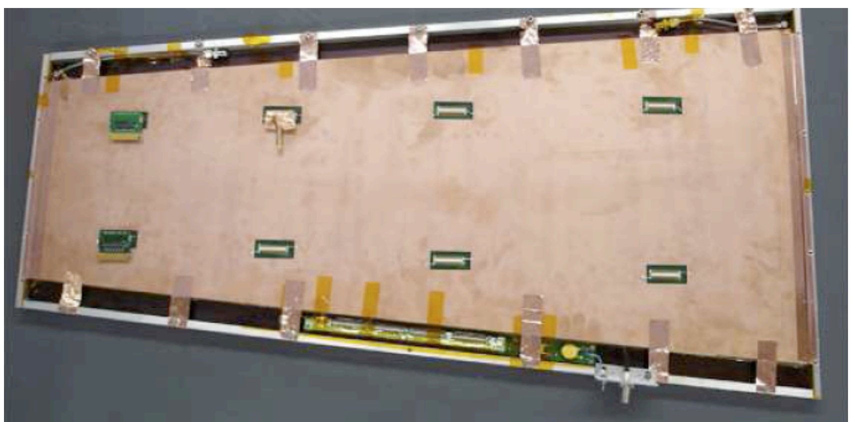


Large GEM chamber projects

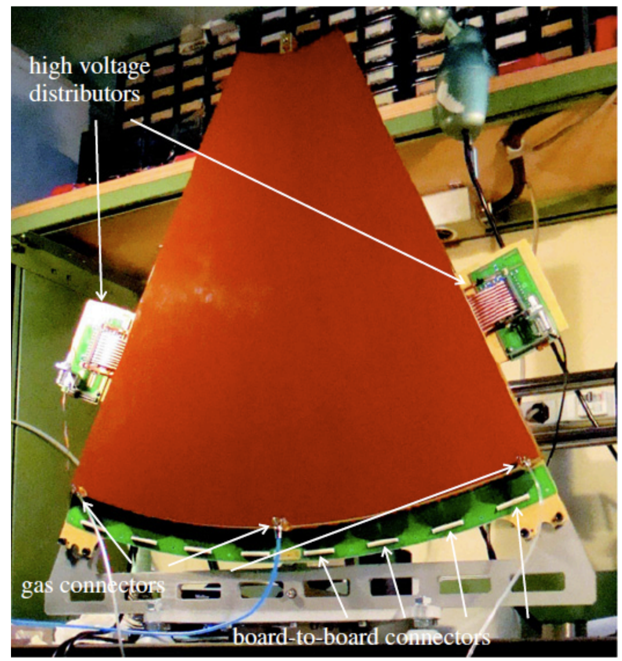
STAR Forward GEM Tracker

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





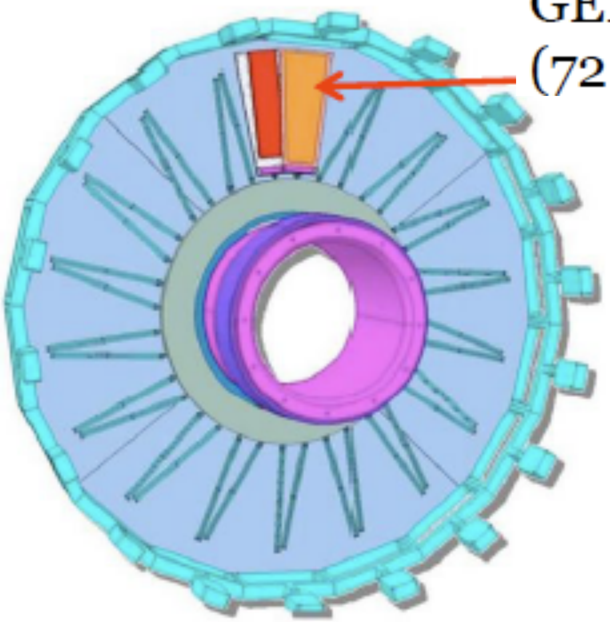
Large prototype GEM module for CMS: 99 cm x (22 - 45.5) cm



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

CMS prototype similar the the dimensions of largest SoLID chambers

CMS high-eta GEM tracker proposal

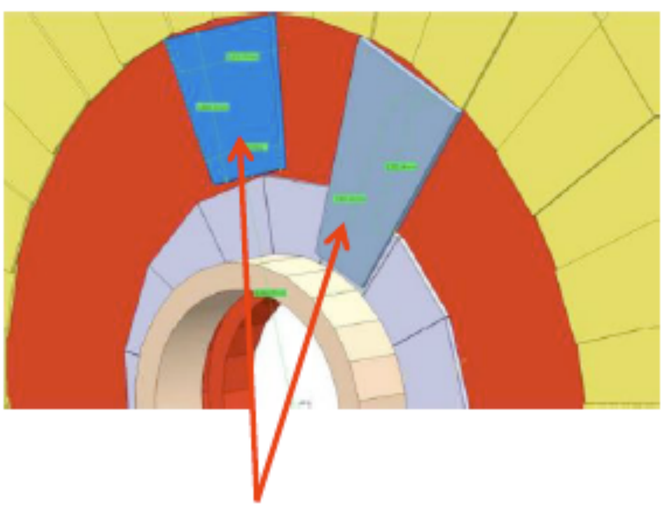


GE1/1 detectors
(72 chambers)

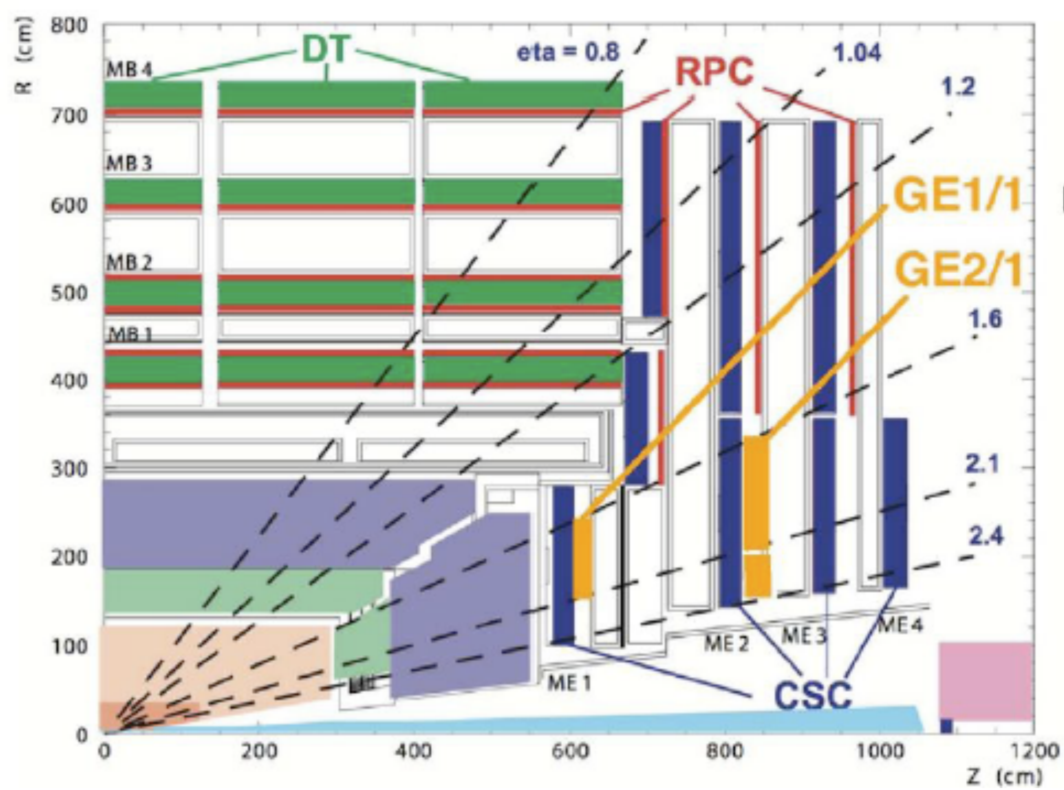
GEM s for triggering and tracking

- Proposal to cover the $1.6 < |\eta| < 2.4$ region with GEMs.
- GEMs for
- 240 GEM chambers

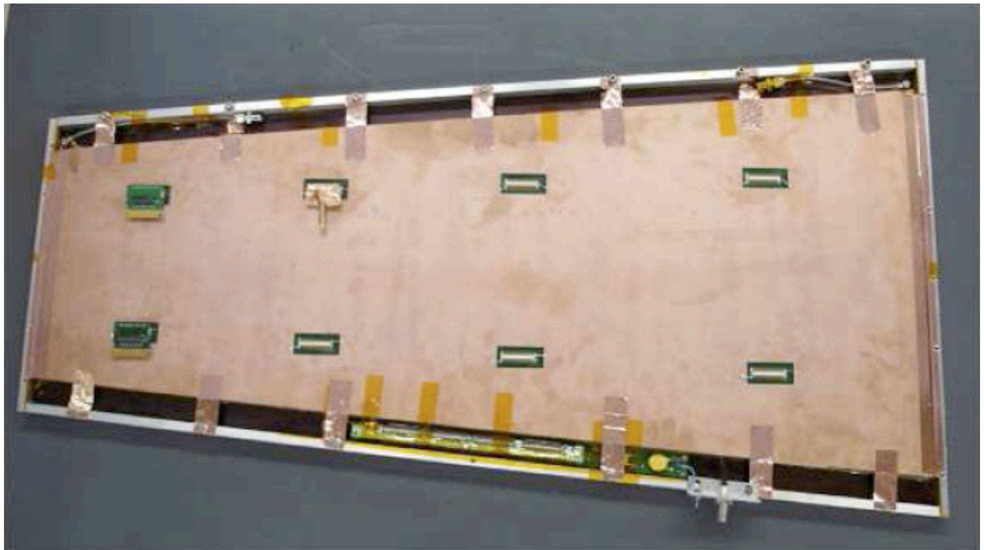
Total active area covered ~ 300 m^2



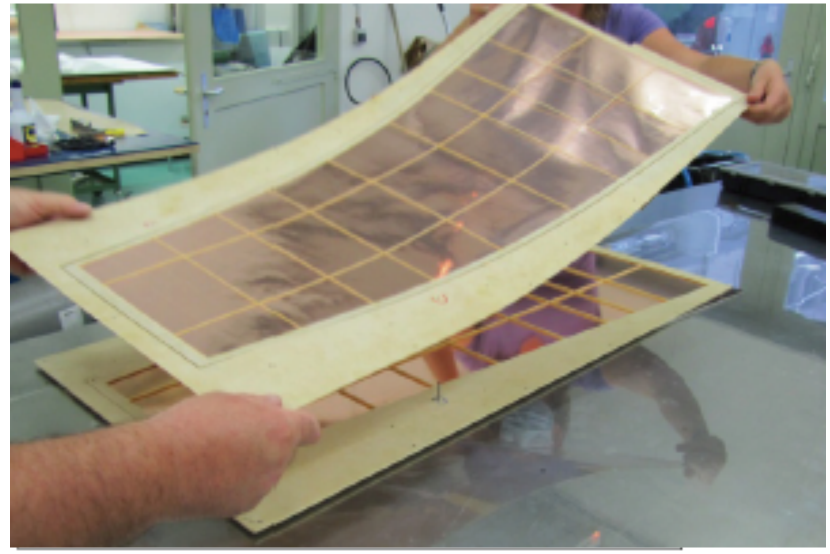
GE2/1 detectors
(144 chambers)



CMS large area prototype GEM construction

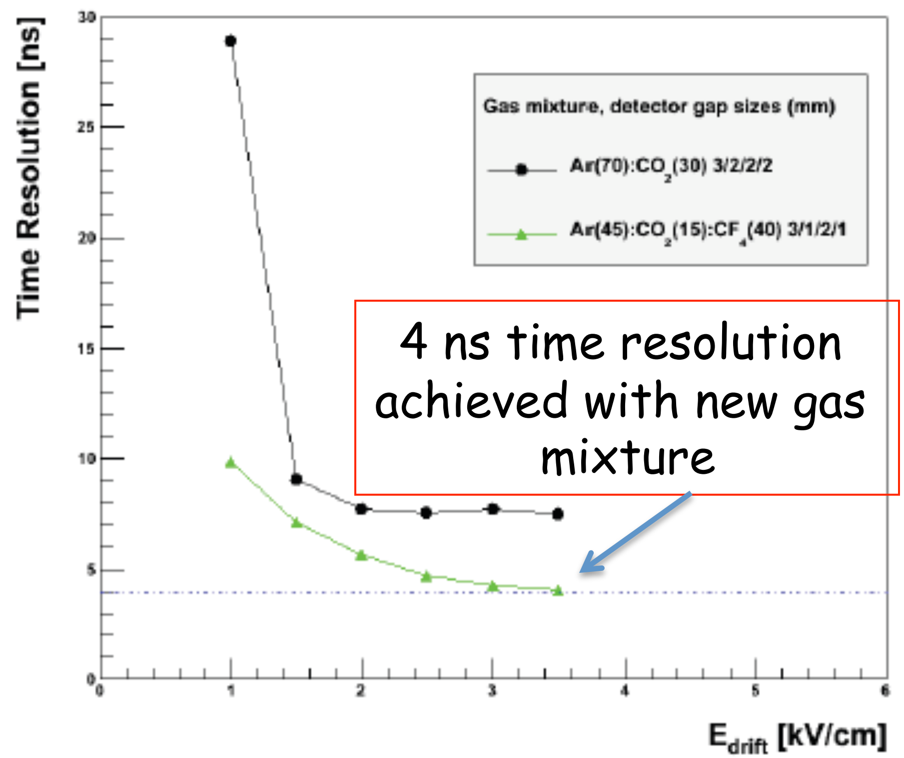


Large prototype GEM module for CMS:
99 cm x (22 – 45.5) cm

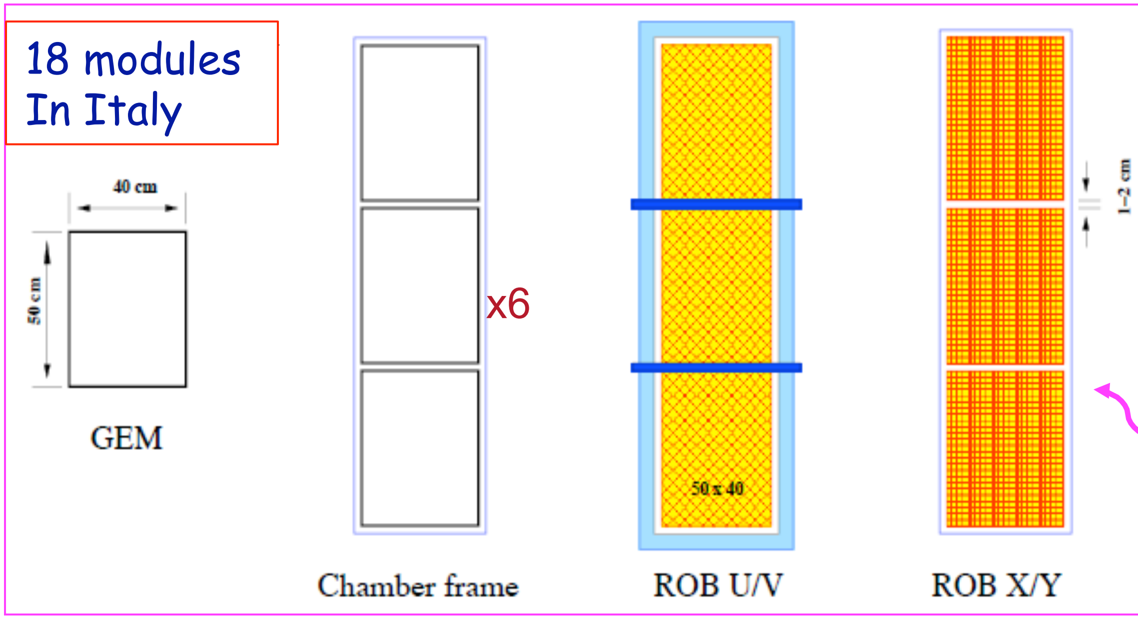


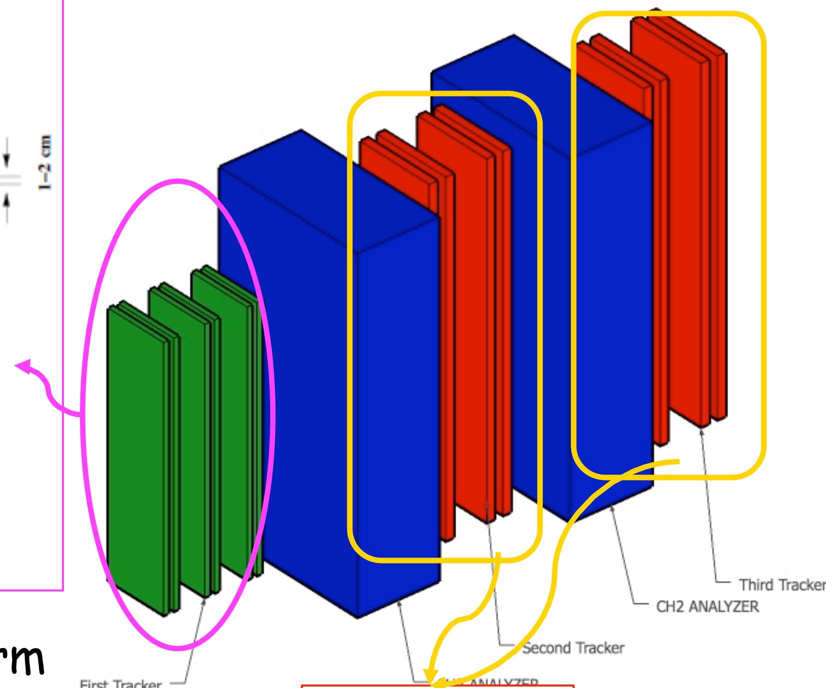
Two full size prototypes already constructed and tested.

- 1D readout
- Differnt GEM gaps to optimize timing (3/2/2/2 mm and (3/1/2/1 mm)
- Single mask.
- Also 5 small prototypes.



Jefferson Lab SBSTrackers - Front Tracker



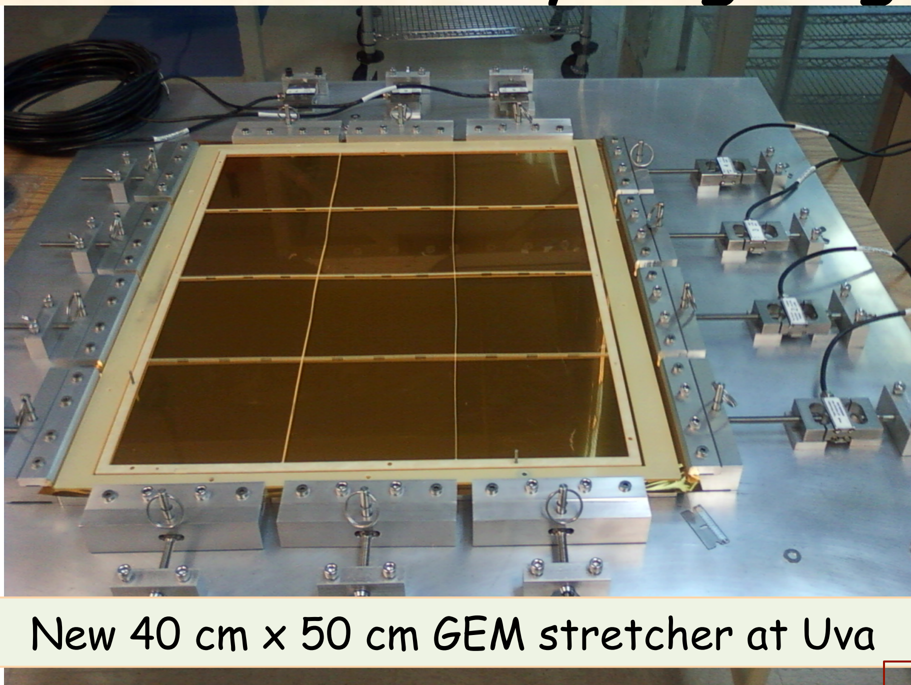


76 modules
In Virginia

- 50 cm x 40 cm Modules are assembled to form larger chambers with different sizes
- Front tracker: Six 40 cm x 150 cm GEM layers
  - INFN Funding: to be built in Italy
- Polarimeter trackers: Eight 50 cm x 200 cm GEM layers
  - to be built in Virginia
- Total GEM coverage of SBS ~ 16 m^2

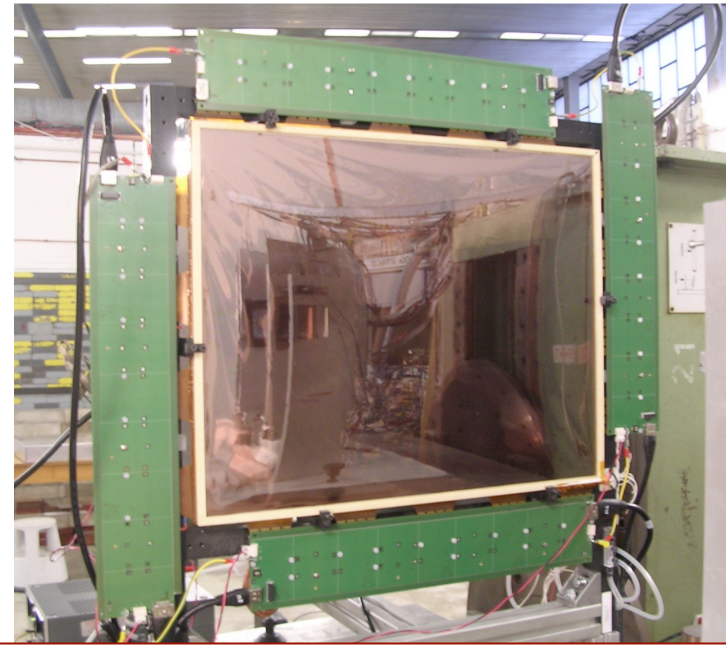
SBS GEM module construction currently going on in Italy and at UVa

The currenty ongoing GEM chamber work



New 40 cm x 50 cm GEM stretcher at Uva

Stretching time ~ 1 – 2 hours
Foil Tension: **T ~ 0.5 kg/cm**



Fully equipped INFN prototype 40x50 cm^2 GEM module for a beam test at DESY

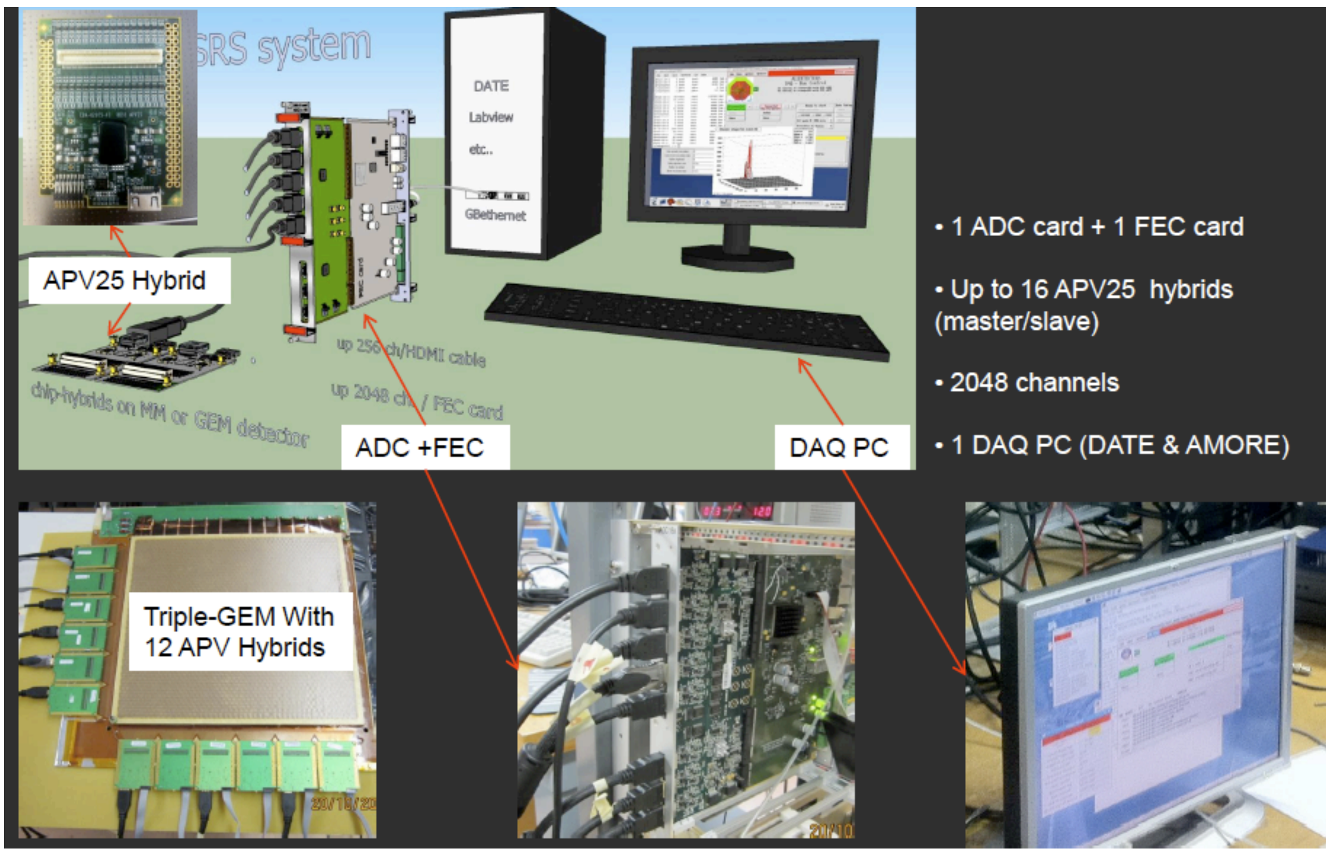
•A 100 cm x (25-40) cm prototype GEM module with 2D readout is currently under design at Uva. (EIC detector R&D effort)

•Expect to construct and test this chamber this Fall - Can learn a great deal for SoLID GEMs from this:

- develop techniques for fabrication of large GEM modules.
- study readout schemes: 10 degree stereo angle
- Study issues of signal to noise ratio for long readout strips.

GEM chamber electronics

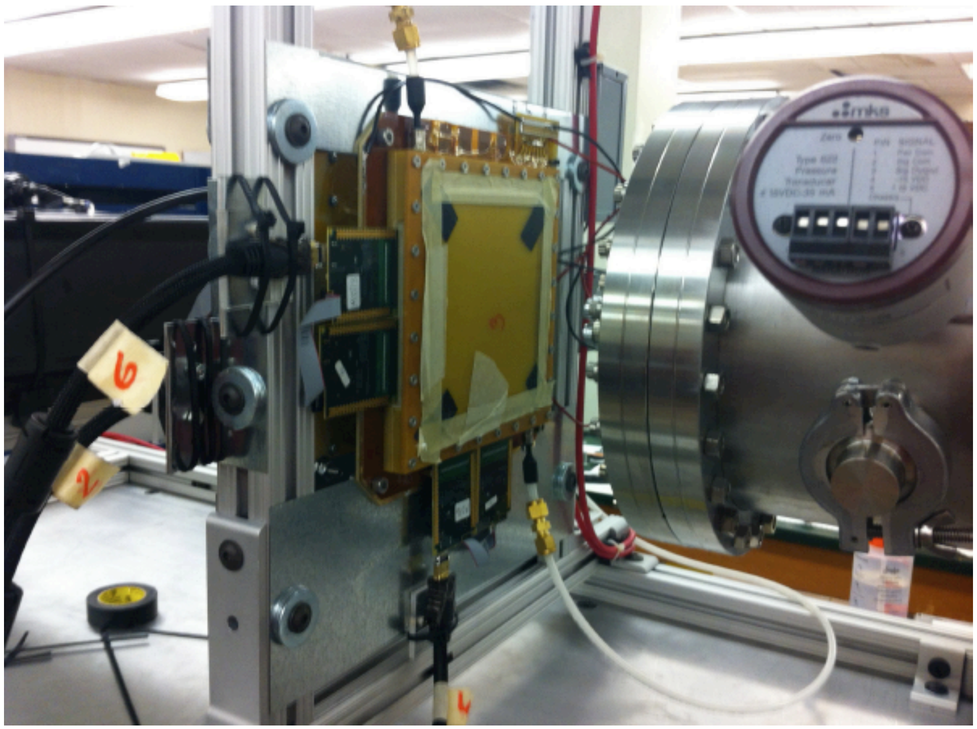
- The RD-51 Scalable Readout System provides a low-cost, common platform that can accommodate different readout chips.
- Currently tested with APV25-S1 chip.
- Drawback with the APV25 chip: may not be fast enough for SoLID
- Need to work on finding a suitable chip for SoLID readout and incorporating it into SRS (?)

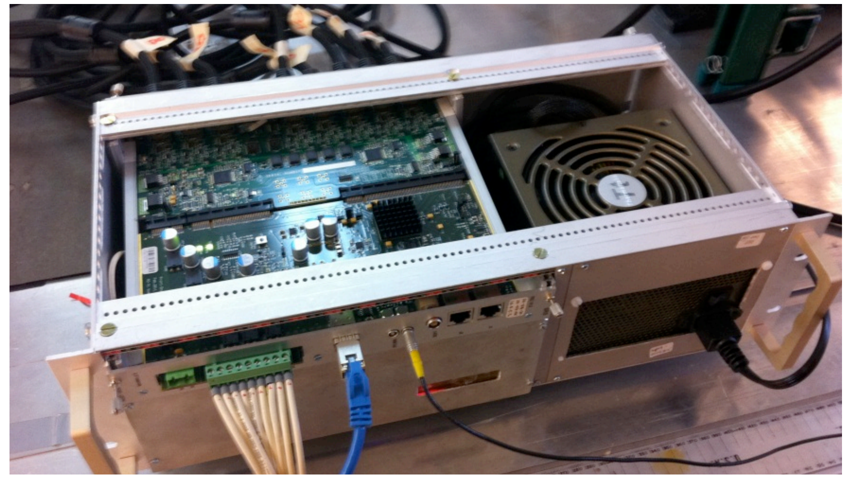


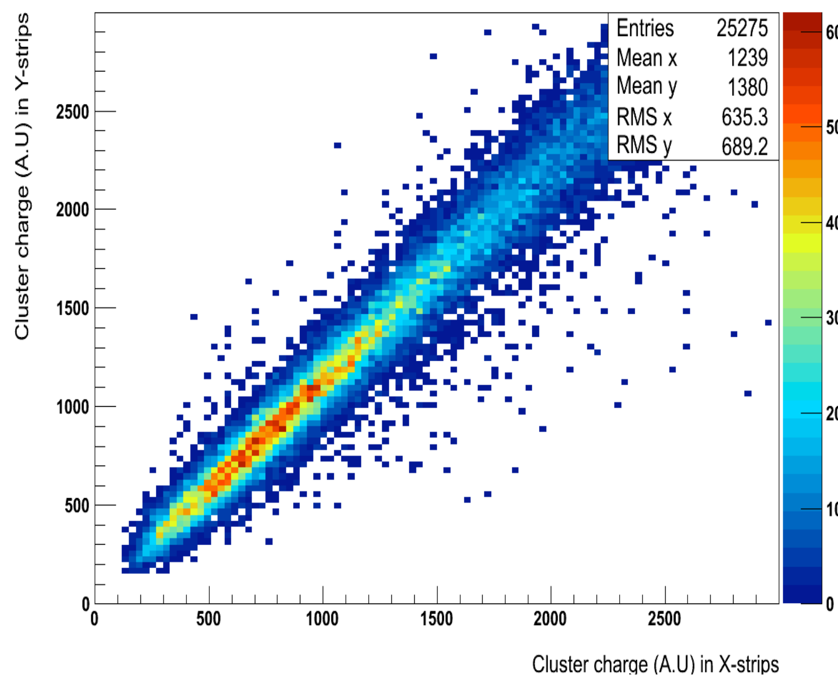
SRS system has the benefit of the large team effort backed by RD-51

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

- Uva group now owns an APV25 system (2000 chan.) from the RD-51 Scalable Readout System (SRS) development.







SoLID GEM chamber Collaboration

- University of Science and Technology of China (USTC)
- Tsinghua University
- Lanzhou University
- China Institute of Atomic Energy (CIAE)
- Institute of Modern physics
- INFN-Rome
- University of Virginia

rough cost estimate

Item	Quantity	Unit cost	Total cost	Material only unit cost	Material only total cost
GEM foil	~100 m^2	\$2000/m^2	0.2 M	\$3000/m^2	0.2 M
readout boards	120	\$ 2500	0.3 M	\$ 2500	0.3 M
chamber support frame	120	\$ 1500	0.2 M	\$ 1500	0.2 M
Supplies and tooling			0.1 M		0.1 M
FEE and DAQ	200 k	\$ 5.0	1.0 M	\$ 3.0	0.6 M
cables, power, etc			0.5 M		0.5 M
Gas system			0.1 M		0.1 M
Labor: Technicians	6 FTE-years	\$ 100 k	0.6 M		-
Labor: Grad students	6 student-years	\$ 50 k	0.3 M		-
support structure and integration			???		???
TOTAL:			**~ 3.3 M**		**~ 2.0 M**
With 33% contingency			**~4.4 M**		**~2.7 M**

R&D and prototyping expenses: ~ \$ 300 k

Bottom-line

- With the strong effort led by RD-51 towards large GEM chambers and readout electronics:
  - Costs are coming down
  - Many technical challenges are overcome
- But SoLID is a very large and very complicated GEM project from any standard; no one has ever done anything even close to this size.
- We are now starting on SBS GEM construction, this is about 70% of the size of the SoLID GEM project.
- So with:
  - large GEM chamber construction for SBS in Rome and at UVa
  - the infrastructure and expertise we gain from large GEM prototyping at UVa, and
  - Expertise gained by our Chinese collaborators.

we will be ready for the SoLID GEM construction in a couple of years.