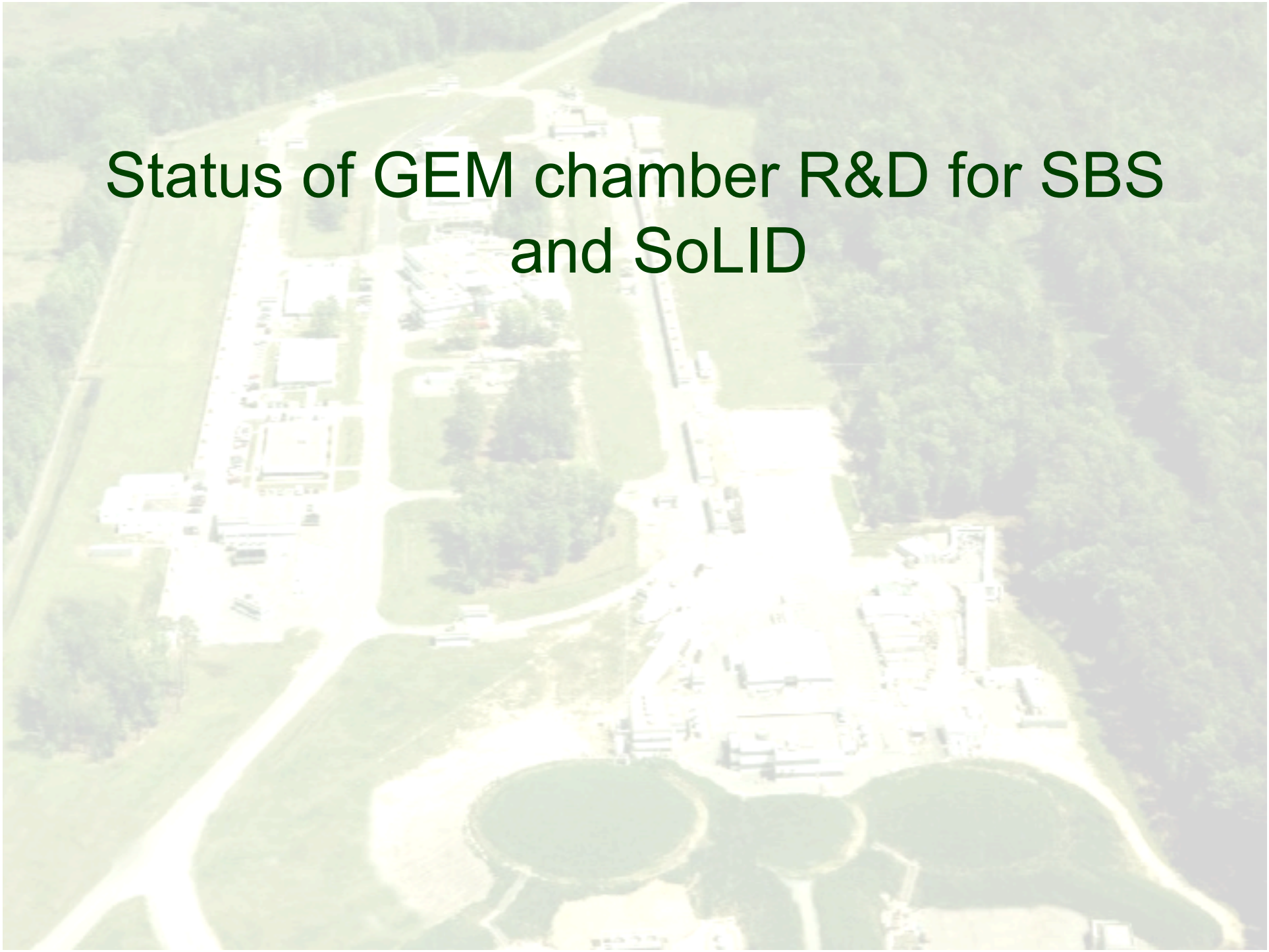
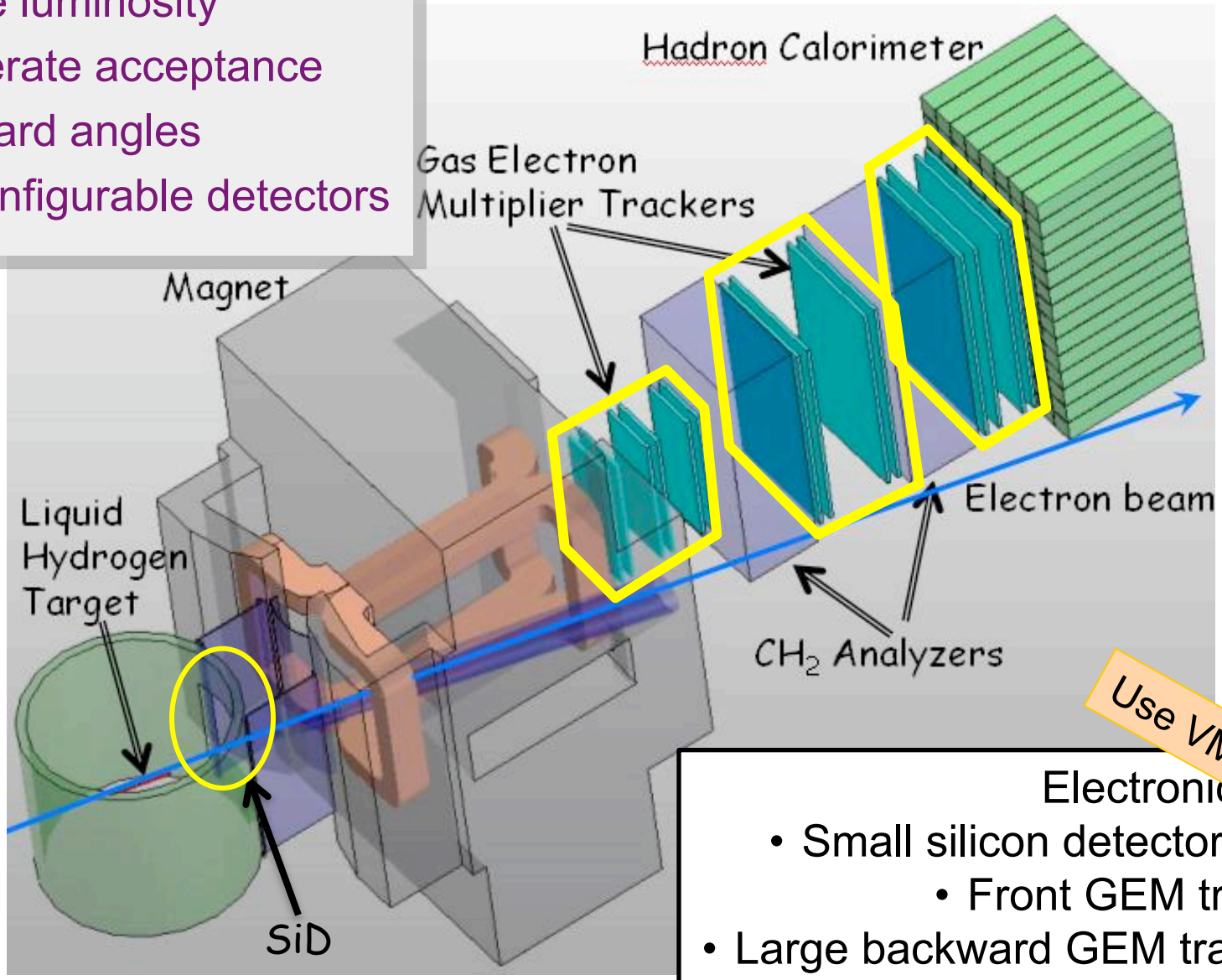
Status of GEM chamber R&D for SBS and SoLID



SBS Spectrometer in Hall A

- Large luminosity
- Moderate acceptance
- Forward angles
- Reconfigurable detectors



Use VME64x

Electronics
- Small silicon detector (SiD)
- Front GEM tracker
- Large backward GEM trackers

⇨ **>100k channels**

Choice of the technology

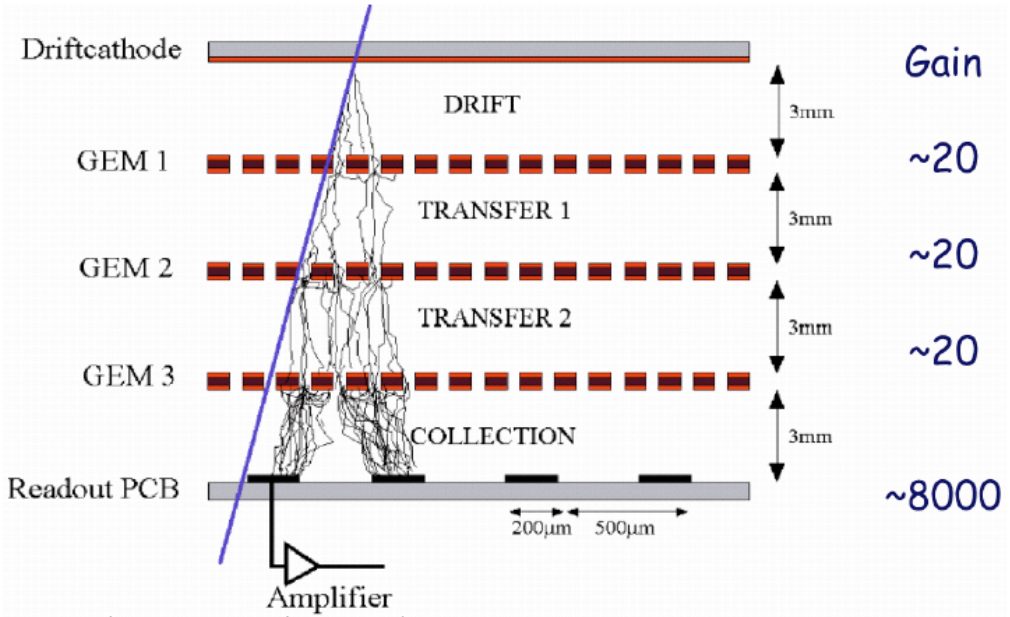
System Requirements	Tracking Technology		
	Drift	**MPGD**	Silicon
High Background Rate (up to): (low energy γ and e) **1 MHz/cm^2**	NO	**MHz/mm^2**	**MHz/mm^2**
High Resolution (down to): **70 μm**	Achievable	**50 μm**	30 μm
Large Area: from 40×150 to 80×300 cm^2	YES	**Doable**	Very Expensive

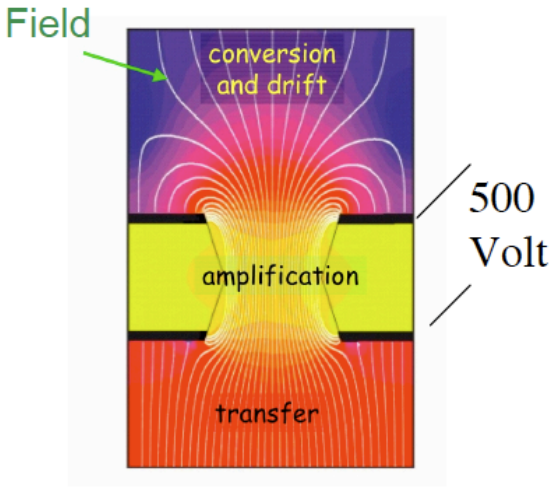
… and modular: reuse in different geometrical configurations

GEM **μMs**

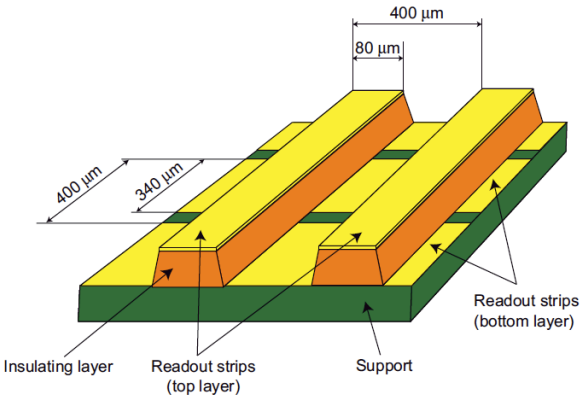
Flexibility in readout geometry and lower spark rate

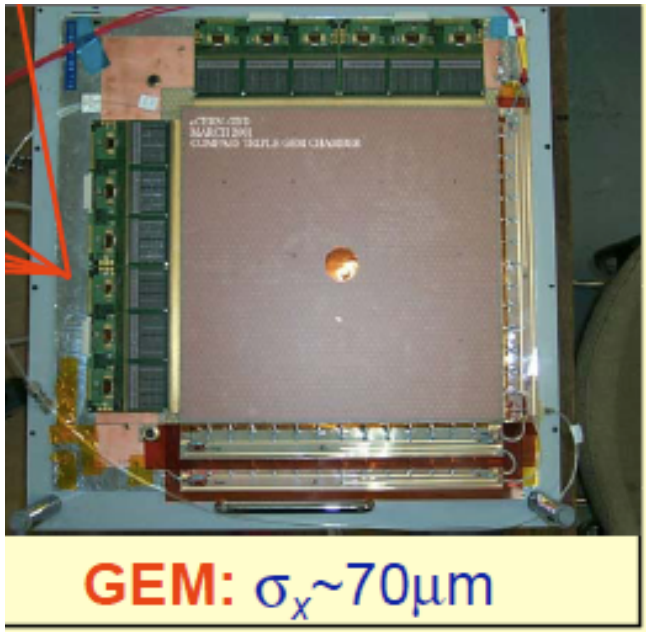
Gas Electron Multiplier- GEM: technology





- Invented by Sauli in the nineties.
- Have been adapted for many applications since.
- Successfully used in COMPASS for a few years.





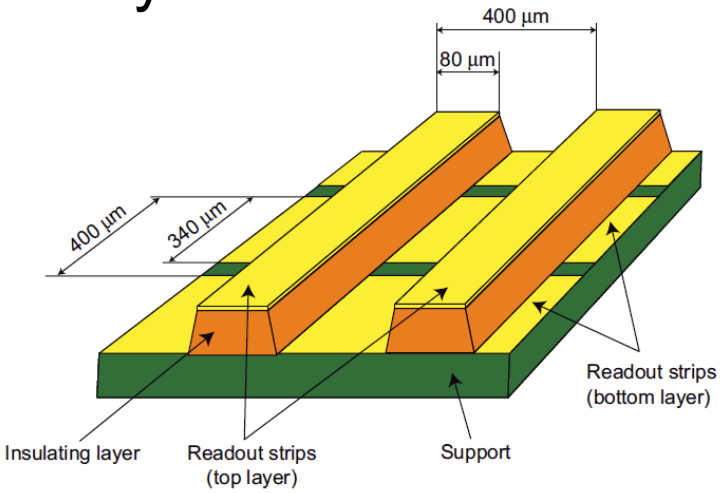
Approach: 40x50 cm^2 3xGEM Module

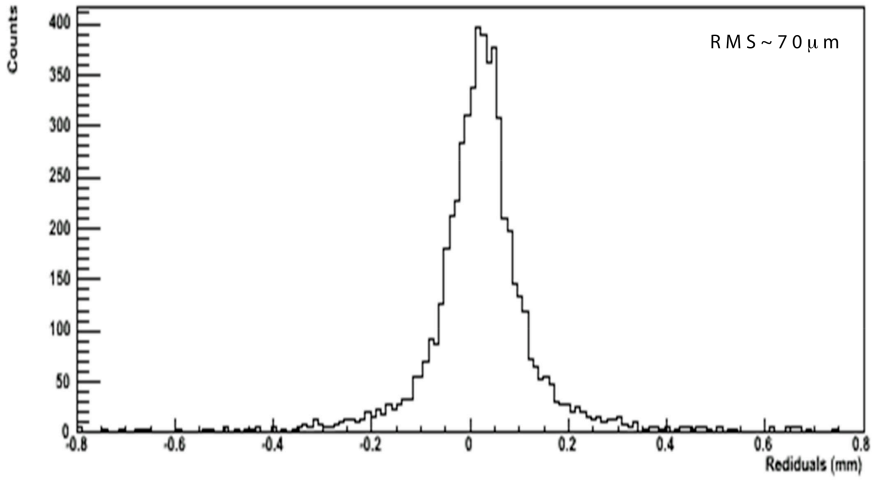
Use the same "basic" module for all trackers types

- Size: 40x50 cm^2 active area + 8 mm frame width
  - FEM study:

Frame width	(mm)	5	6	7	8	9	10
Maximum Sag	(μm)	180	24	21	19	16	12

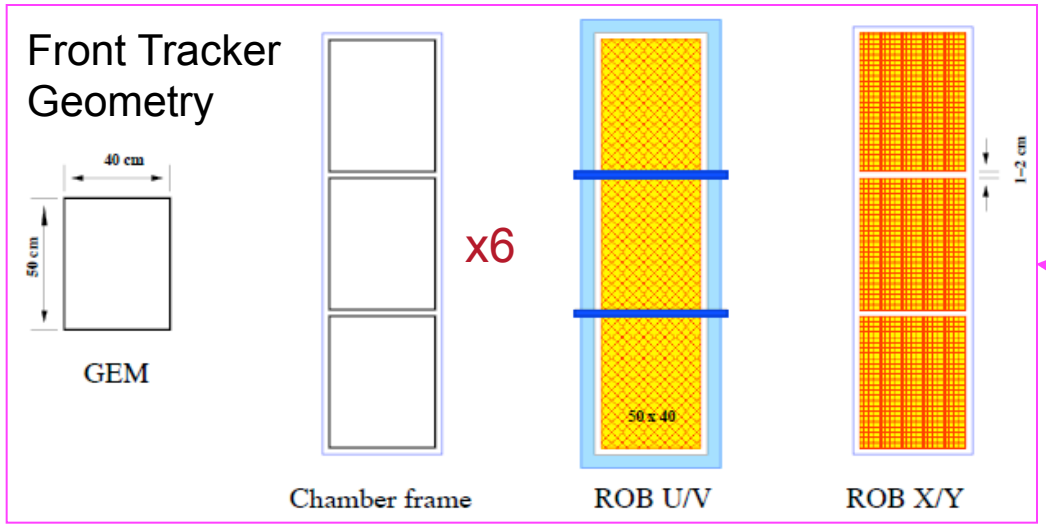
- 3 x GEM foils (double mask) technology
- 2D strip readout (a la COMPASS) - 0.4 mm pitch
- x/y and u/v coordinates

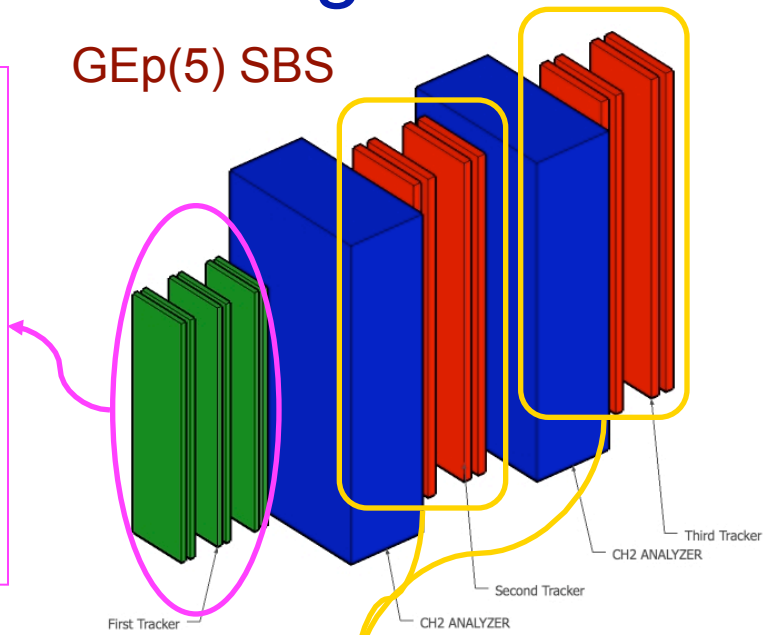




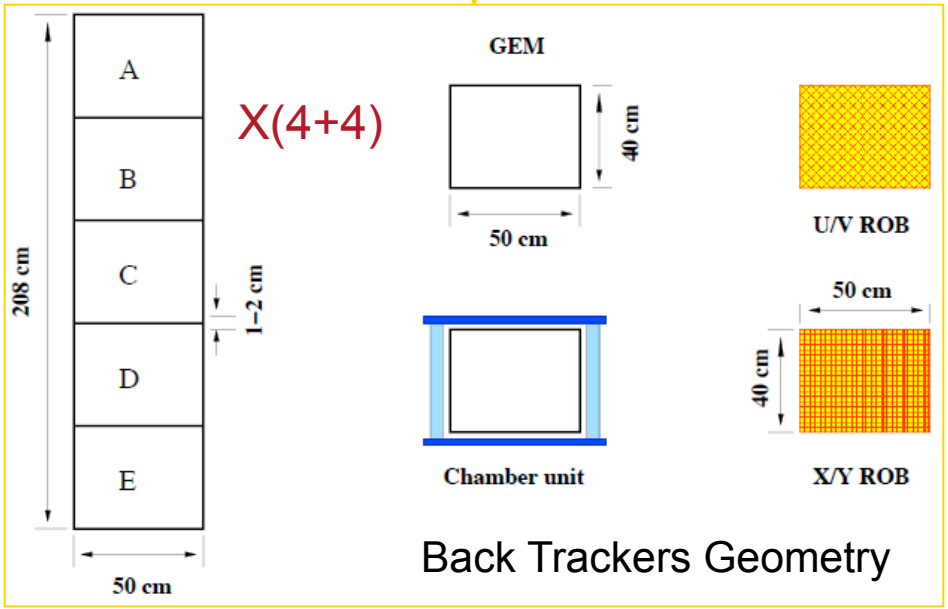
Performances proven in real experiment such as COMPASS and PREX!

SBS Tracker Chambers configuration

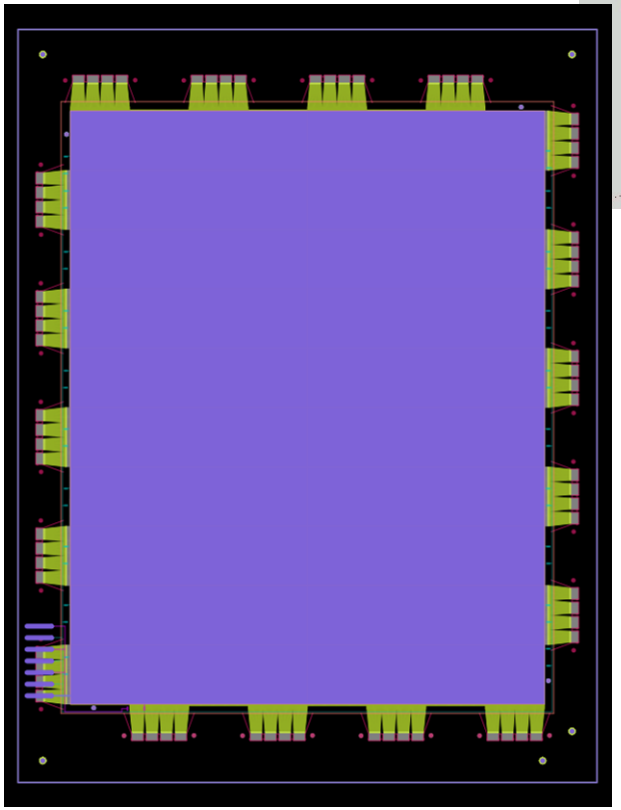


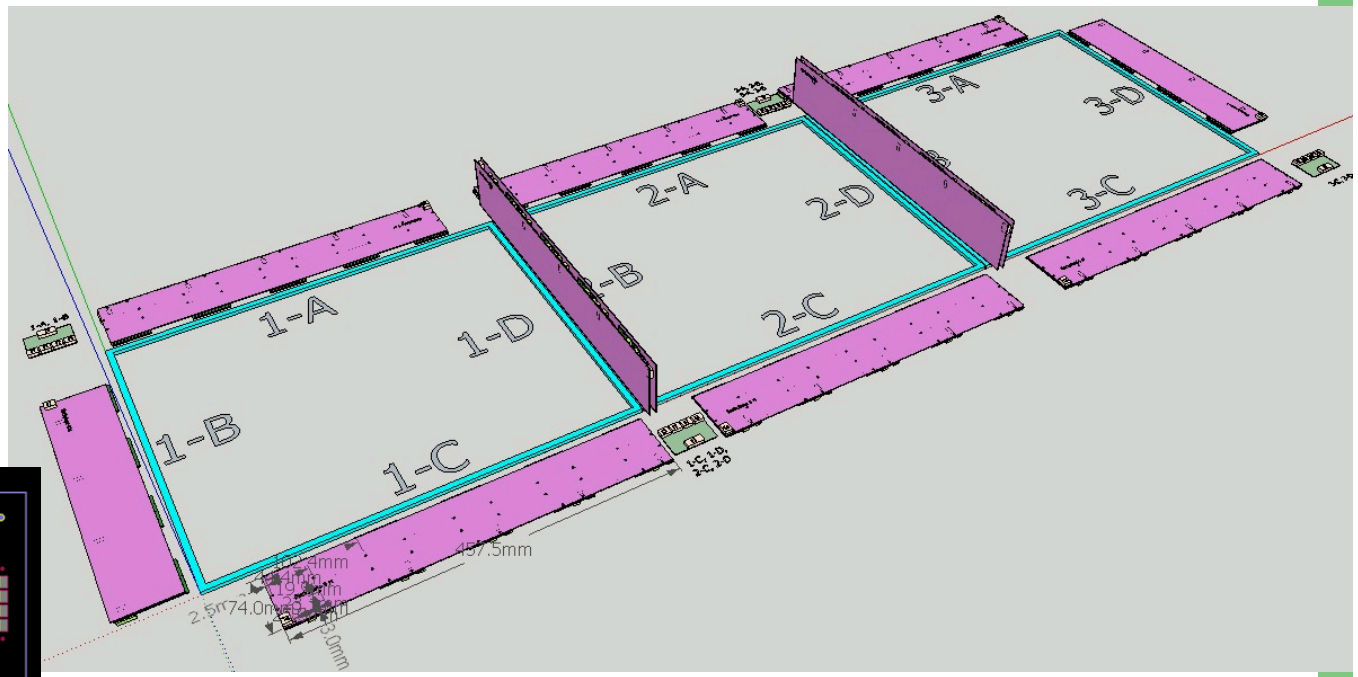


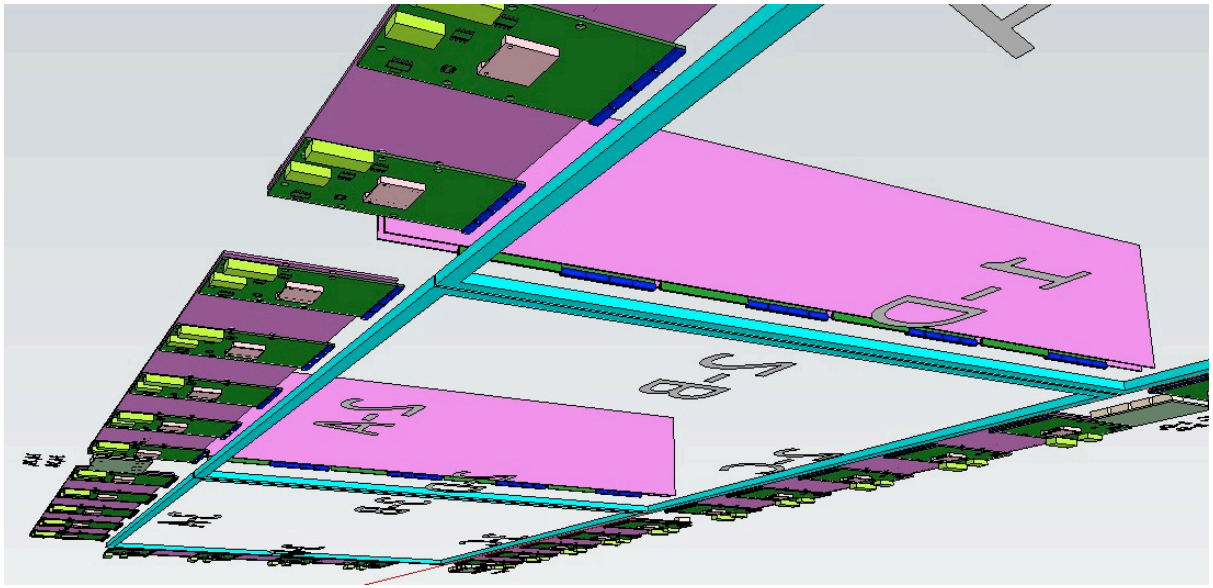
- ✓ Modules are composed to form larger chambers with different sizes
- ✓ **Electronics along the borders and behind the frame (at 90°) – cyan and blue in drawing**
- ✓ **Carbon fiber support frame around the chamber (cyan in drawing); dedicated to each chamber configuration**



Key to Segmentation: making dead areas as narrow as possible



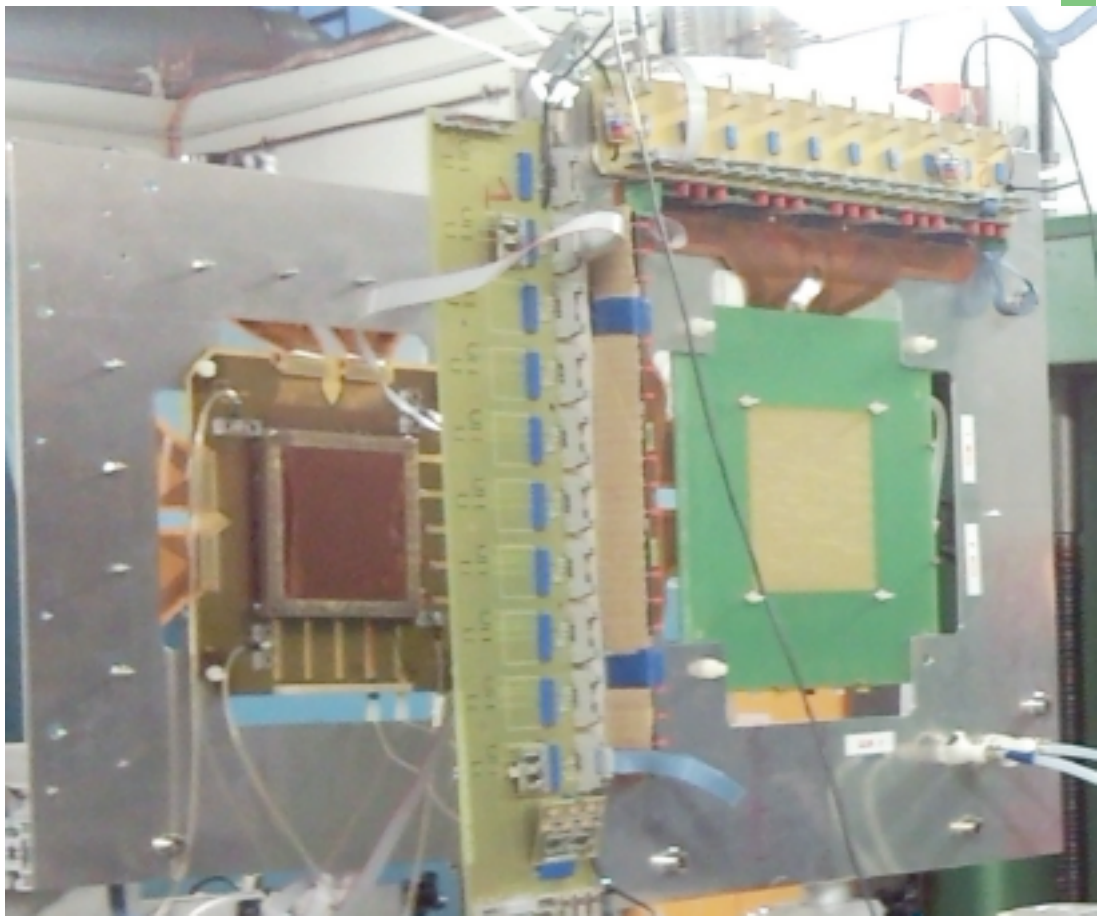




SBS GEM chamber prototyping

- Prototype GEM tracker consisting of five 10 cm x 10 cm chambers built.
- Already tested in high rate conditions during hall A experiments. Data being analyzed now
- More extensive test with APV-25 electronics and under high background rates planed for later this year.

- A 40 cm x 50 cm prototype constructed and tested at INFN.

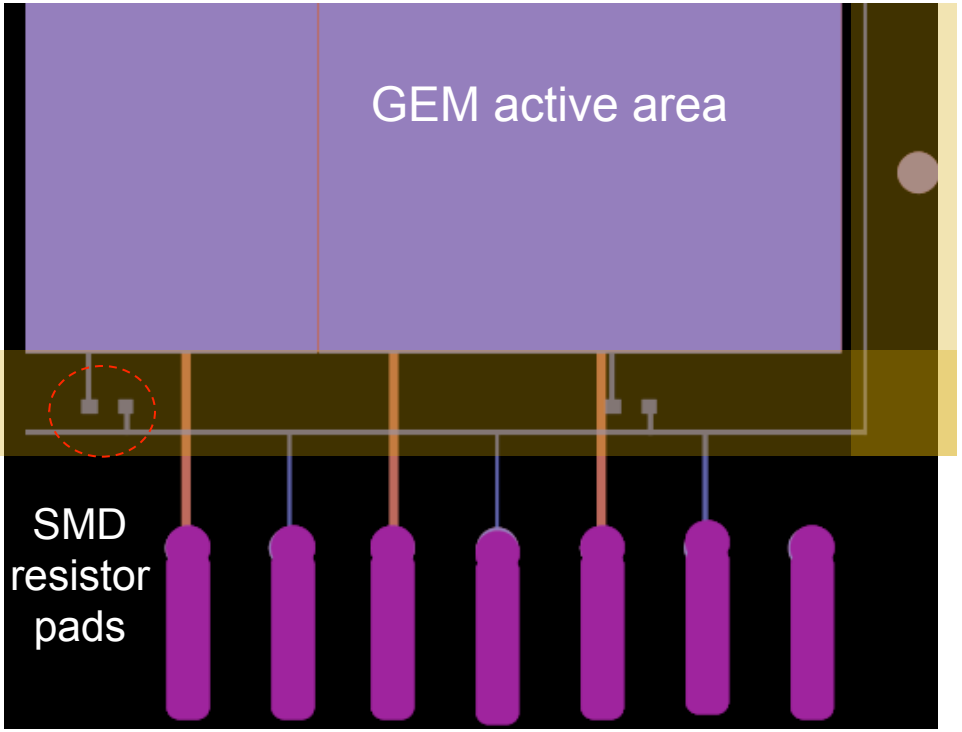


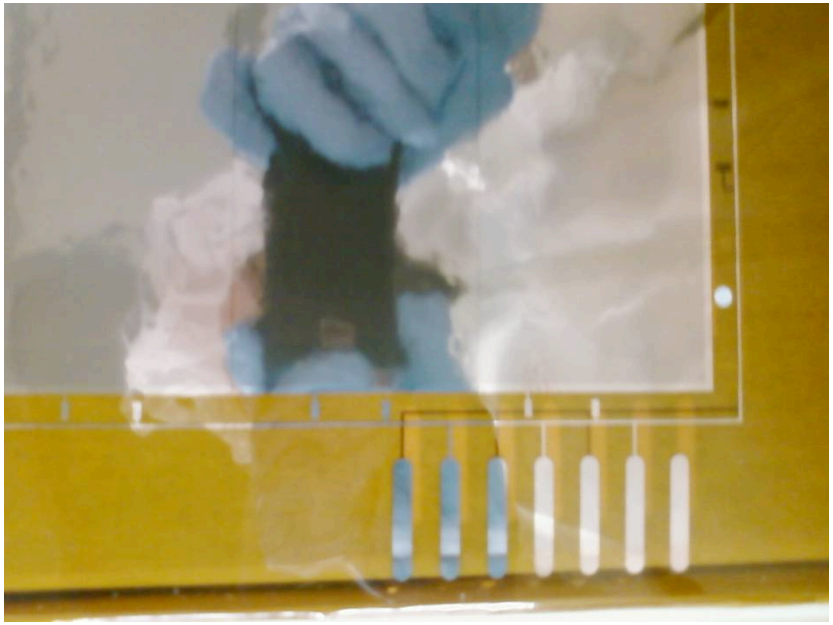
Topics to study

- Tracking under high rates
- Response to low energy photons
- Readout plane size limitations (noise pickup, capacitance etc.)
- Combining readout strips

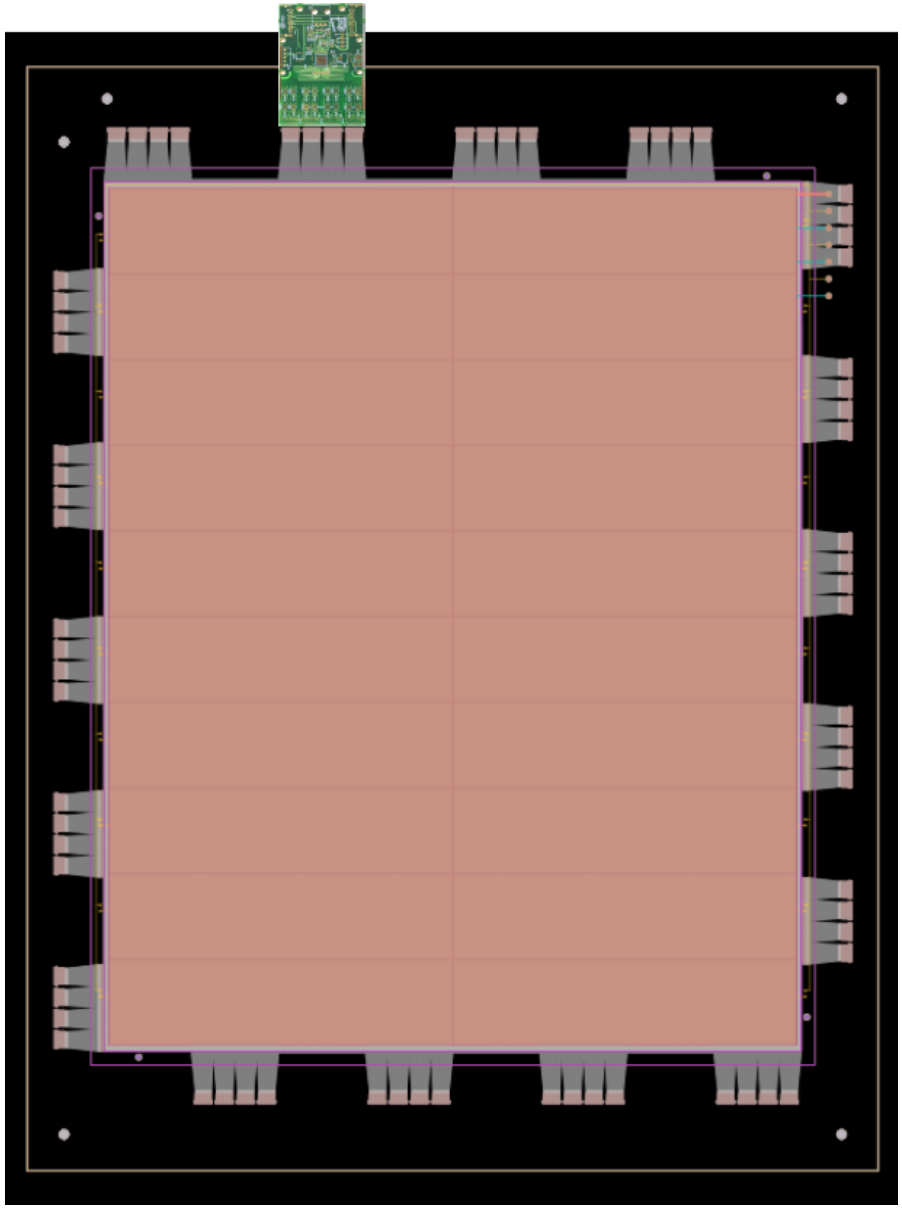
GEM foil (first 40x50 cm^2 / double mask technique)

- **7 independent HV channels** for each chamber (TBC)
- 3 HV identical doublets + 1 for drift (same on all GEM foils); each doublet serves one GEM foil, unused will be cut.
- SMD protection resistors, under the thin frame



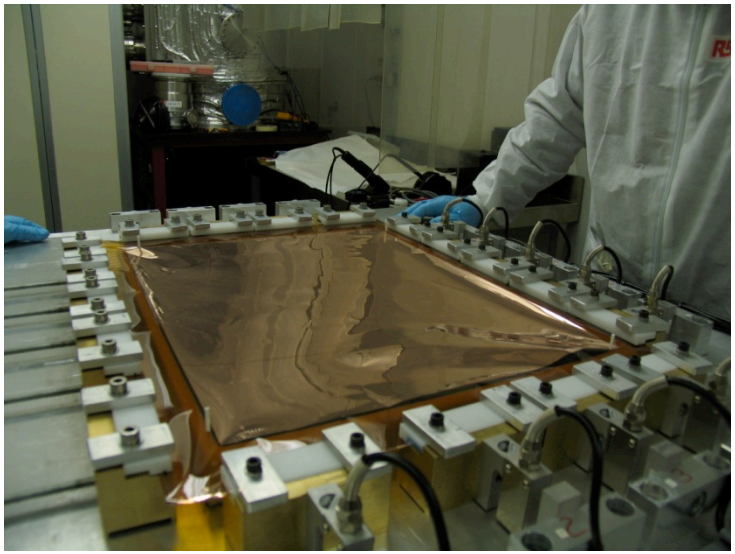


Readout Foil

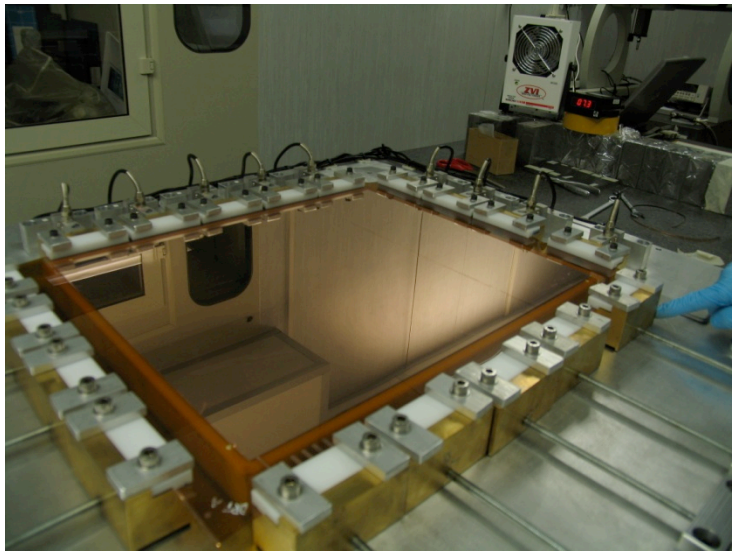


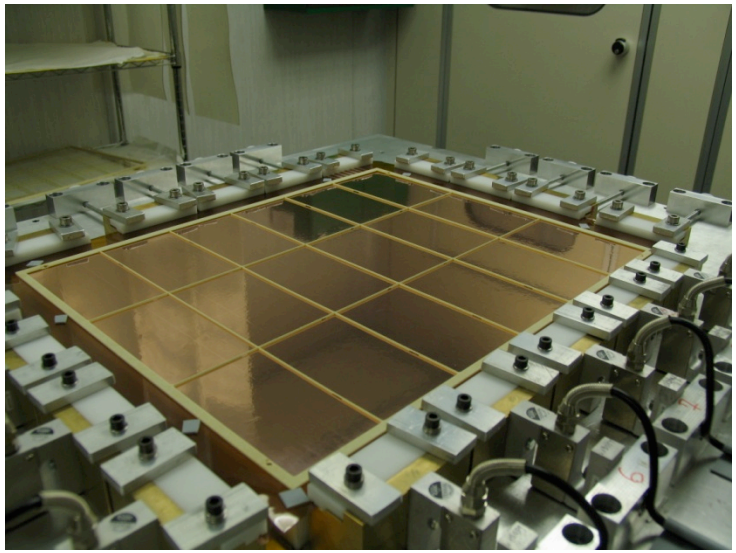
No soldering, very thin connections
Laser cutting required

Assembling the first 40x50 cm2 module



Stretching

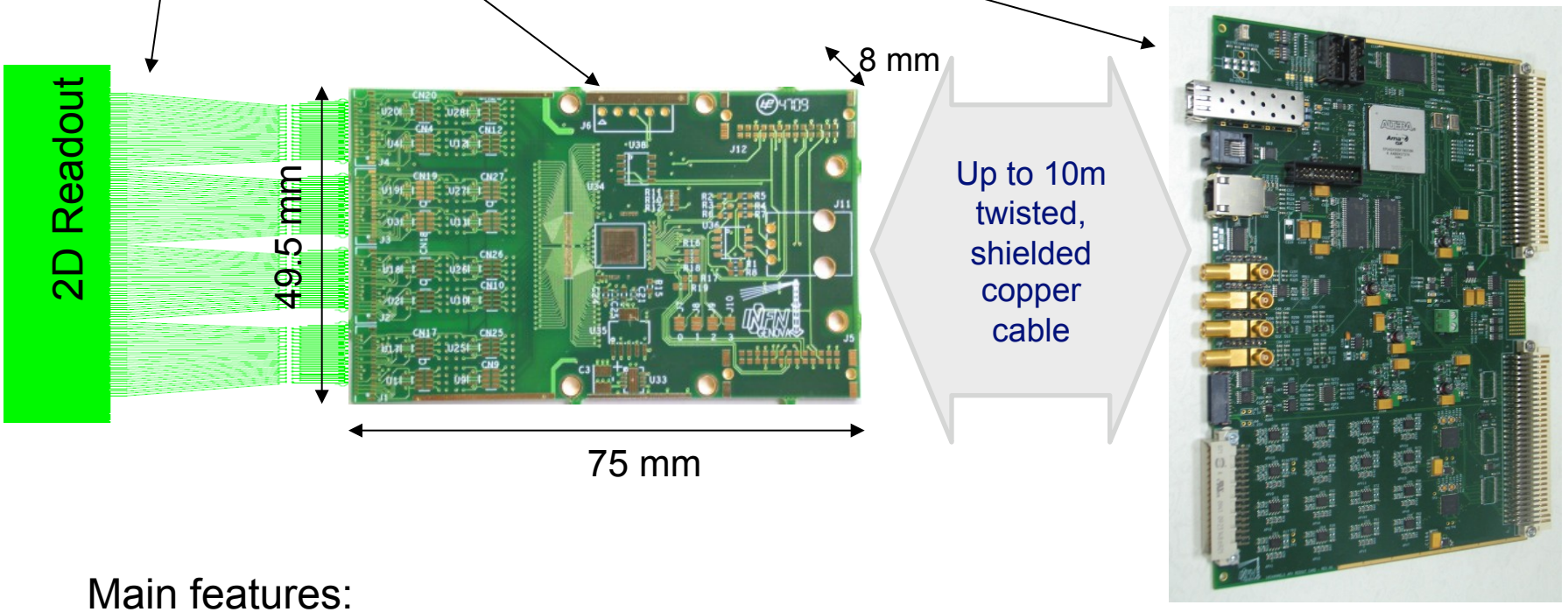




Gluing the next frame with spacers

Electronics Components

GEM ⇒ **FEC** ⇒ **ADC+VME Controller** ⇒ DAQ



Main features:

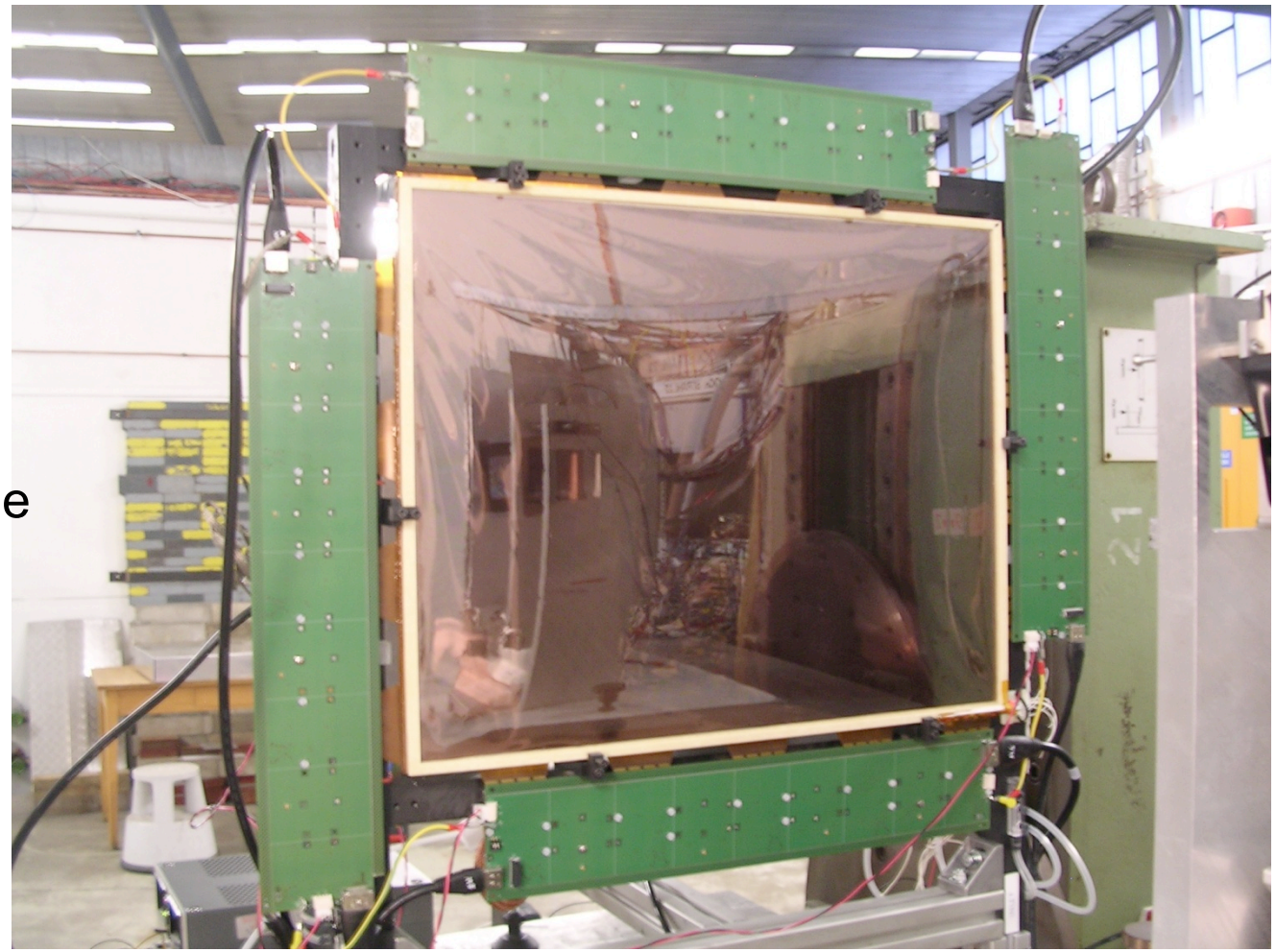
- Use analog readout APV25 chips
- 2 active components: Front-End card and VME64x custom module
- Copper cables between front-end and VME

Beam test @ DESY (EUDET support)

- Fully equiped GEM module
- 18 front-end cards
- 2304 channels

(front end cards on the other side)

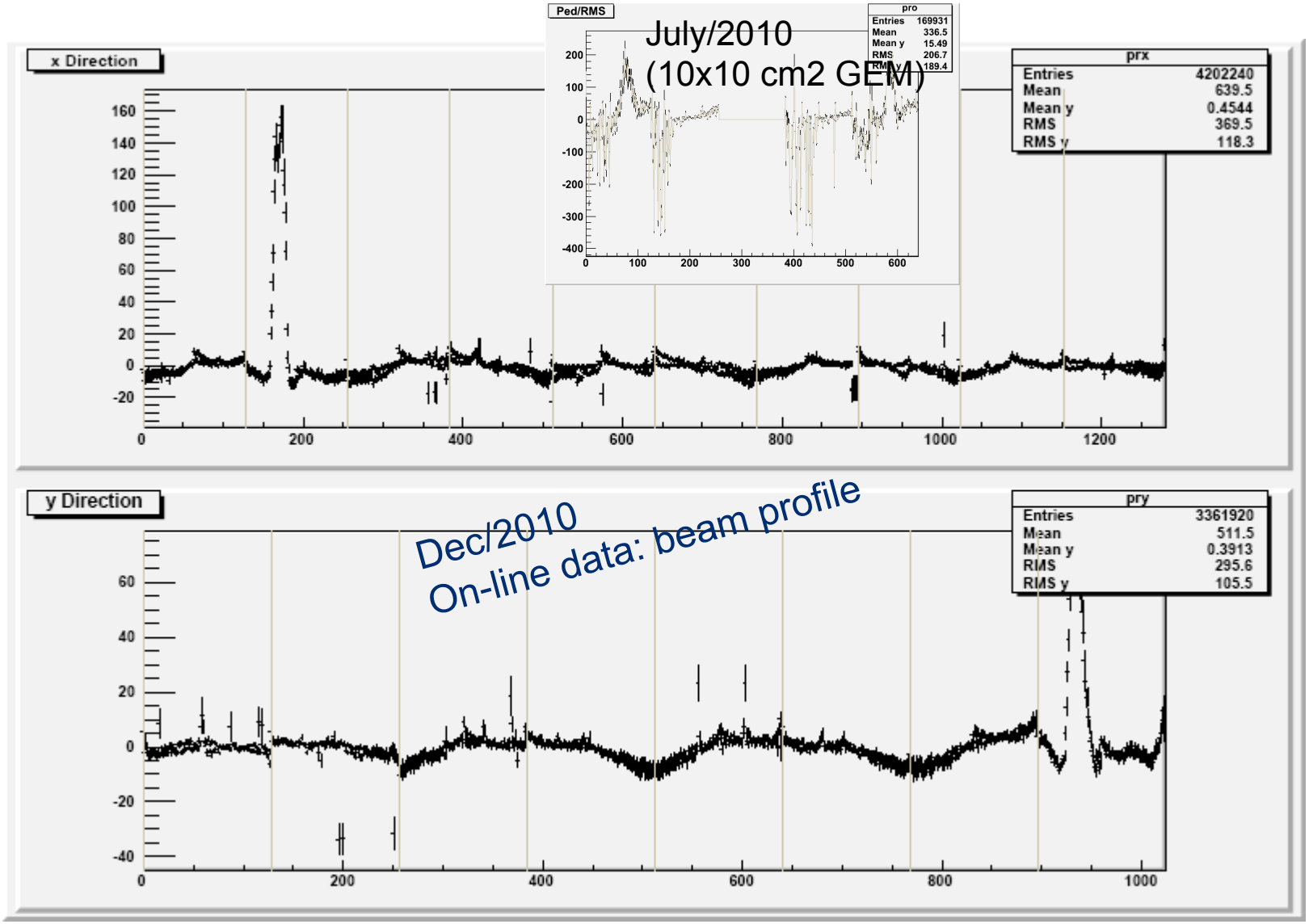
- 7 independente HV levels



2-6 GeV low intensity electron beam / silicon tracker available

Data taking: 28/Nov-3/Dec 2010

Beam test @ DESY (EUDET support)



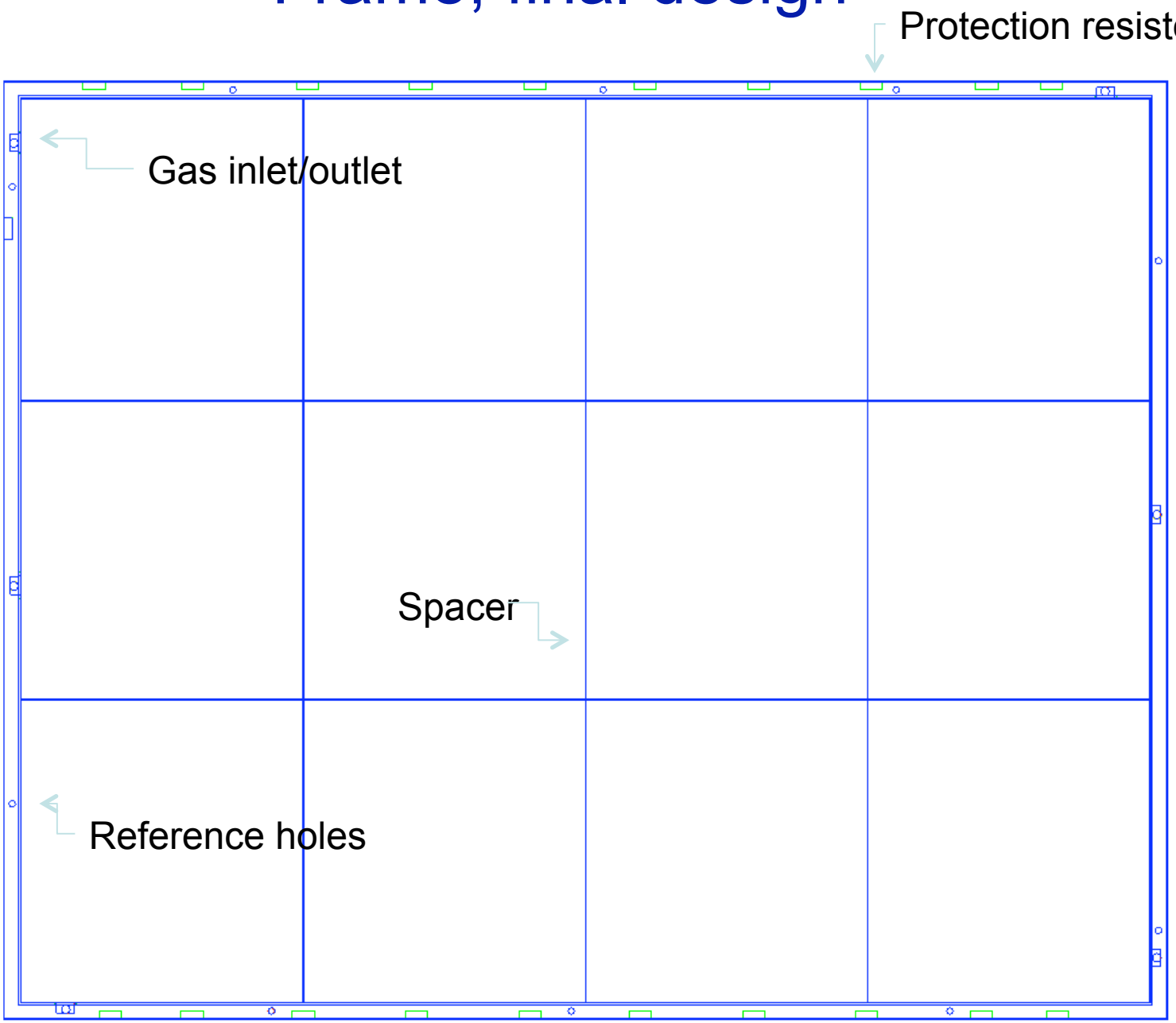
Large improvement from July

Analysis has just started

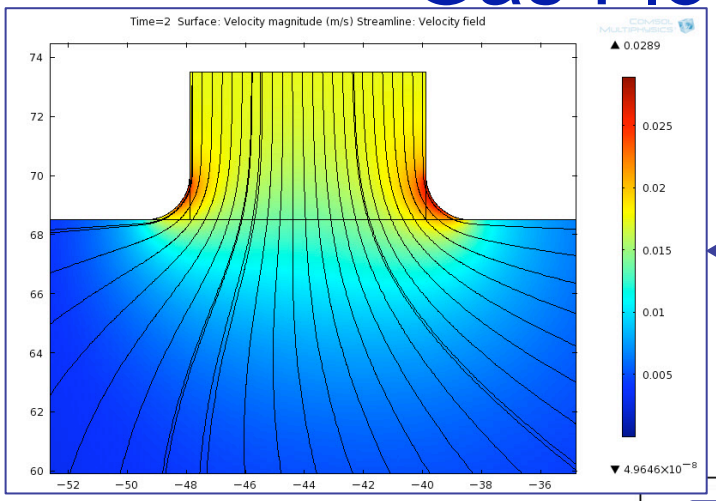
GEM Tracker update

- Simulation
  - MonteCarlo + Digitizer bug fix (thanks to feedback from JLab collaborators)
- Electronics
  - 3rd Front End version (pre-production); minor changes respect to version 2: move FPC connectors on opposite side
  - 3rd version of MPD (MultiPurpose Digitizer) VME module (minor hardware improvement)
  - Main activity on Firmware development
    - Data reduction (common noise removal, baseline subtraction, zero suppression)
    - Use of large data buffer (DDR SDRAM) for larger event builder and improved data transfer
- GEM Foils:
  - Minor changes (protection resistors positions moved to the external side of the frame)
  - Improved HV terminal
- Mechanics:
  - Finalization of the frames design (third iteration, pre-production)
  - Fluid Dynamics Computation of gas flowing
  - New version of the GEM Stretcher in progress
- Test
  - Laboratory test to reduce noise, test electronics choices, fix bugs
  - Beam Test @CERN (in magnetic field) end of June/2011 – 1 week

Frame, final design

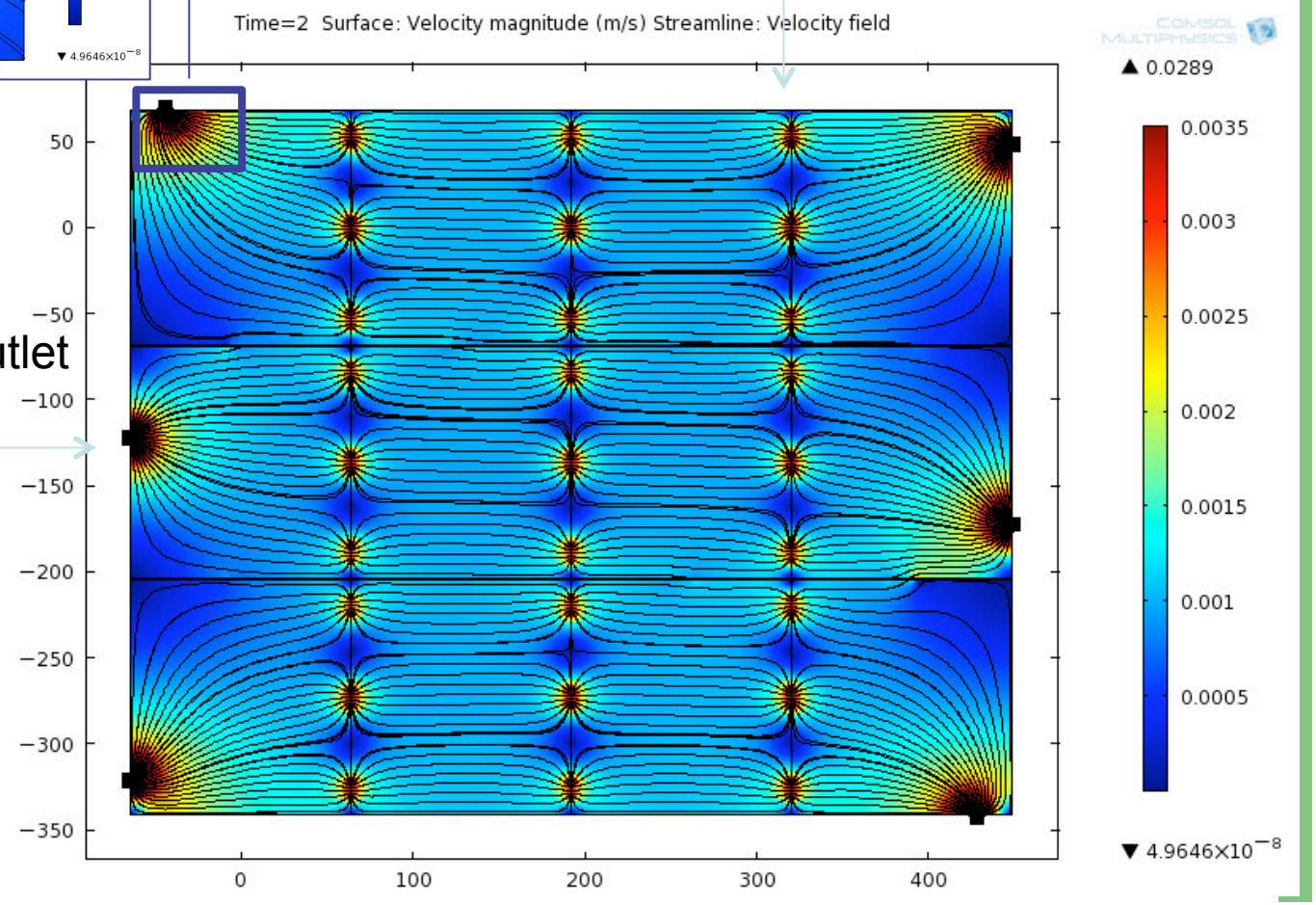


Gas Flowing in GEM module

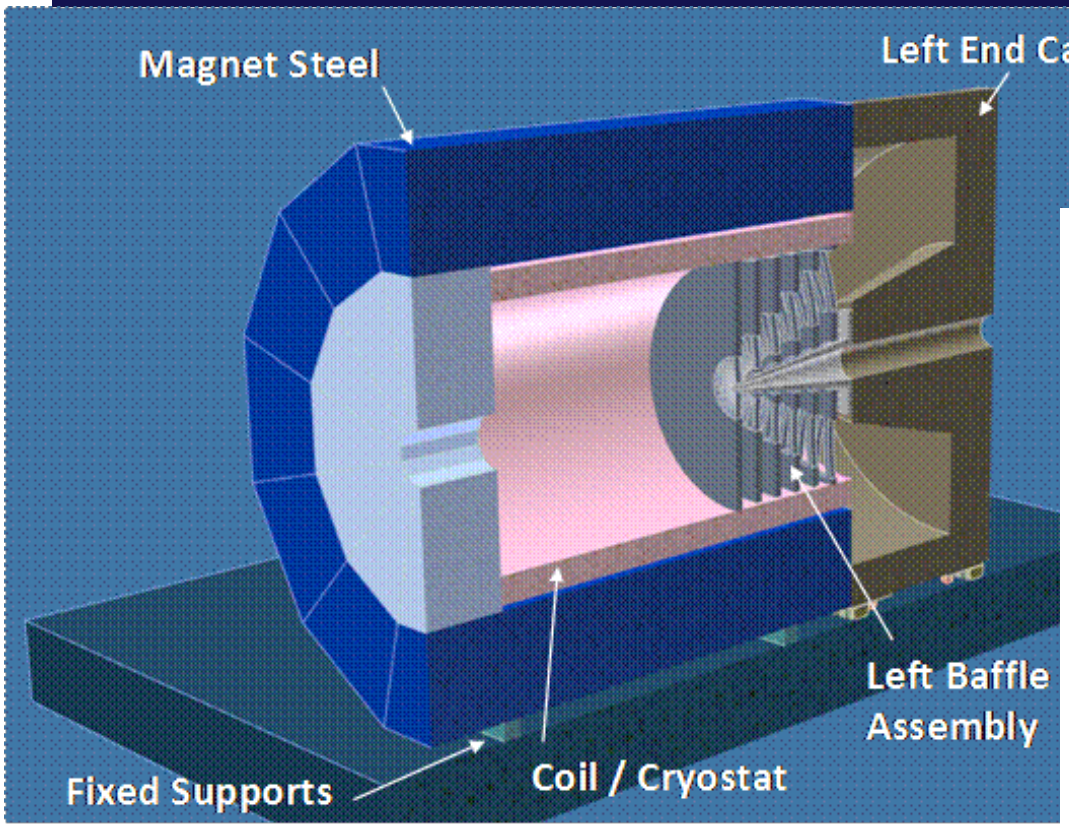


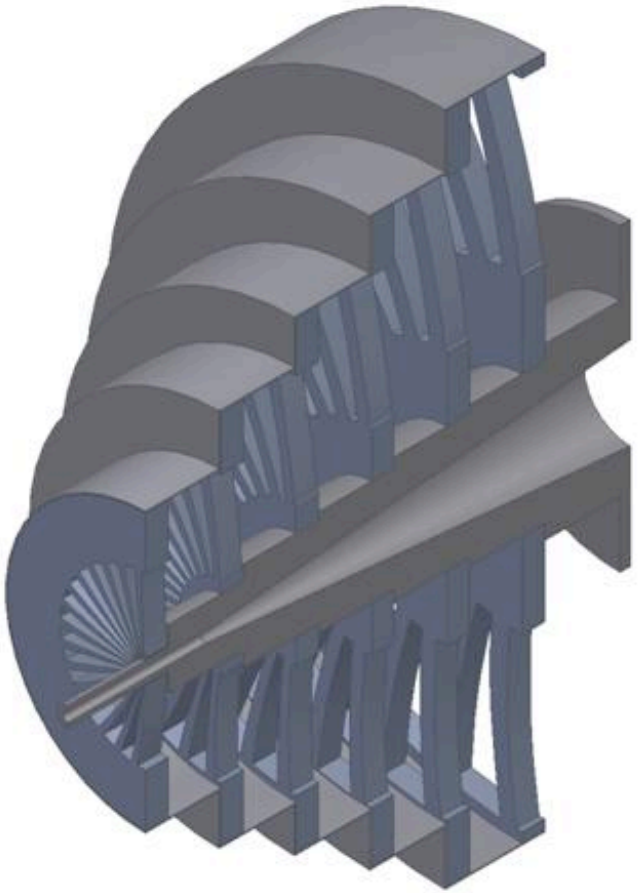
Improved inlet/outlet shape
Improved spacer holes

Added gas 1 inlet + 1 outlet

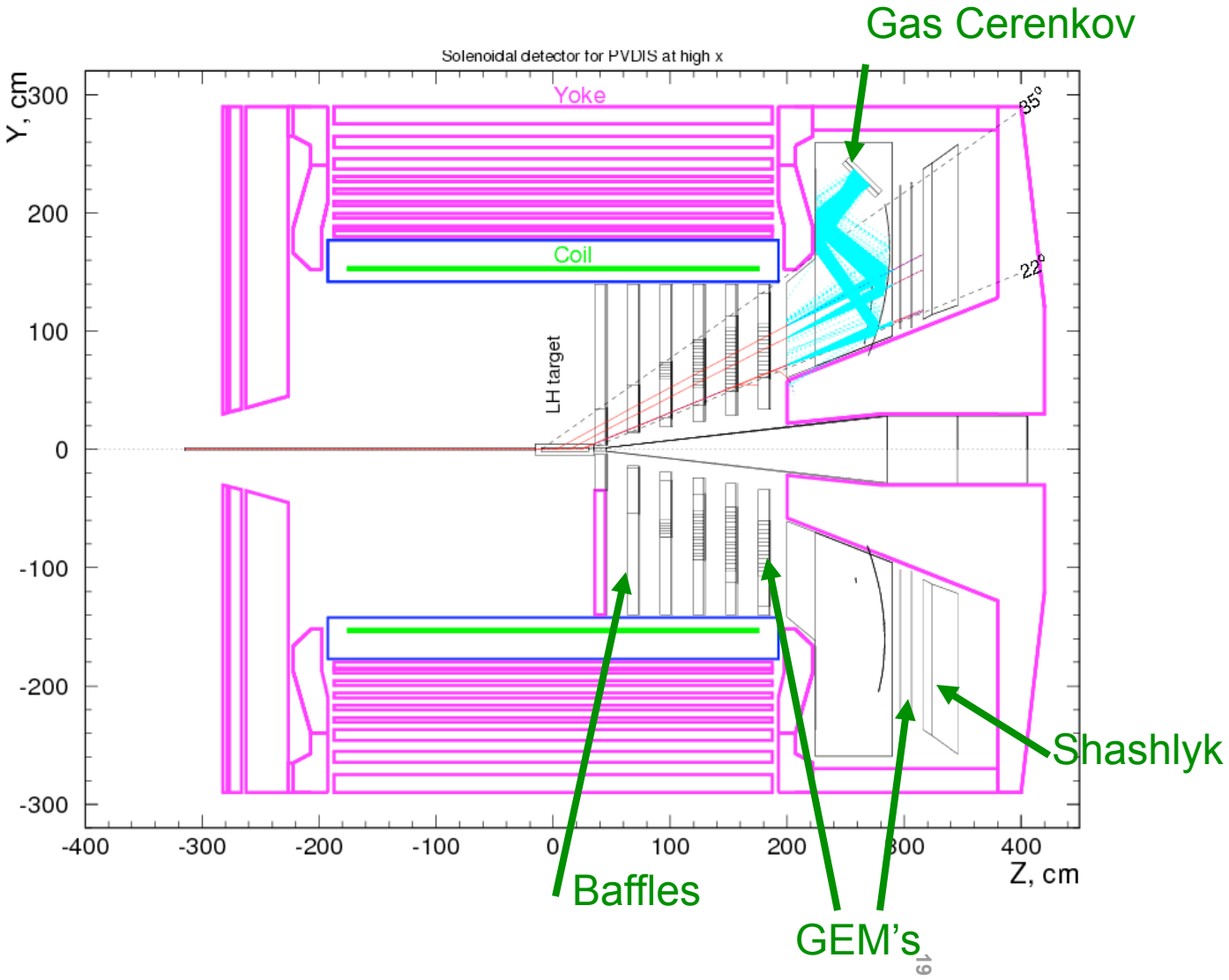


SoLID Spectrometer





SoLID Spectrometer



Main Challenge: large area

- COMPASS GEM chambers only 30 cm x 30 cm; there were total 22 chambers, total area ~ 2 m^2.
- Requirements for SOLID more than an order of magnitude larger.

Plane	Z (cm)	R_I (cm)	R_O (cm)	Total Area (m^2)	circumference (cm) Inner	outer
4	120	39.0	87.2	1.9	245	548
5	150	48.7	109.0	3.0	306	684
6	190	61.7	138.0	4.8	388	867
7	290	94.2	210.7	11.2	592	1323
8	310	100.7	225.2	12.7	633	1414
total:				33.6		

This is the bare minimum: high rates may require multiple chambers at the same location.

- Disk area larger than available GEM foil size (currently ~45 x 45 cm^2) ; need larger foil and segmentation.
- Large total area: most current GEM foil production at CERN shop: can they handle this volume ? Need new foil manufacturing

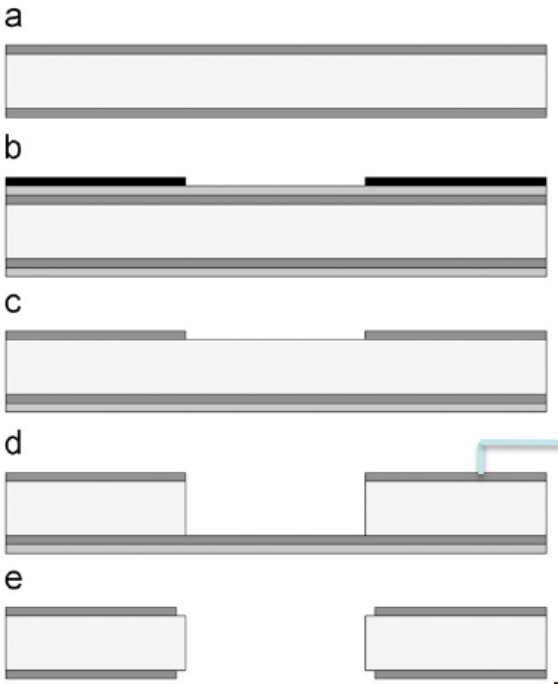
Production at CERN

- GEM size
  - With existing equipments 1.5m x 0.5m active area
  - Mid 2011: 2m x 0.6m active area
- Volumes
  - With existing equipment: 10 GEMs/month.technician
    - We can hire one more technician
  - Mid 2011: 24GEMs/month.technician (240GEM/year)
  - With some offers for large volume production we start to see the limit price of the GEMs : in the range of 600 CHF/sqr.meter

Major recent development at CERN PCB shop towards large GEM foils

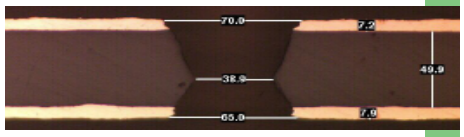
- Base material only ~ 45 cm wide roll.
- Used a double mask technique for etching: hard to the two masks accurately: Max area limited to ~ 45 cm x 45 cm previously.

Double Mask



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

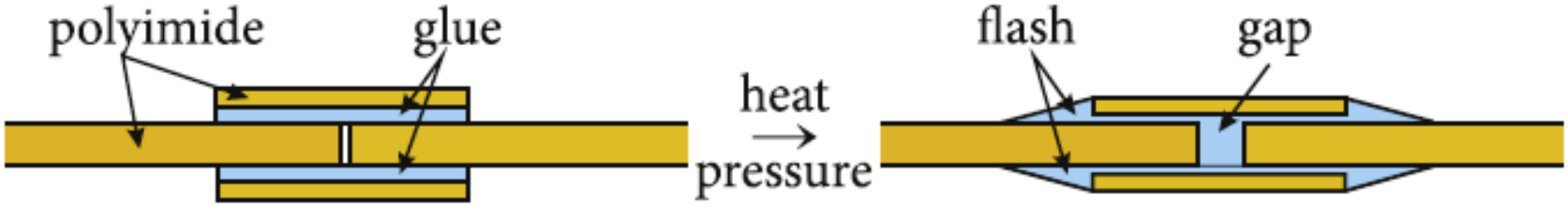
Single Mask

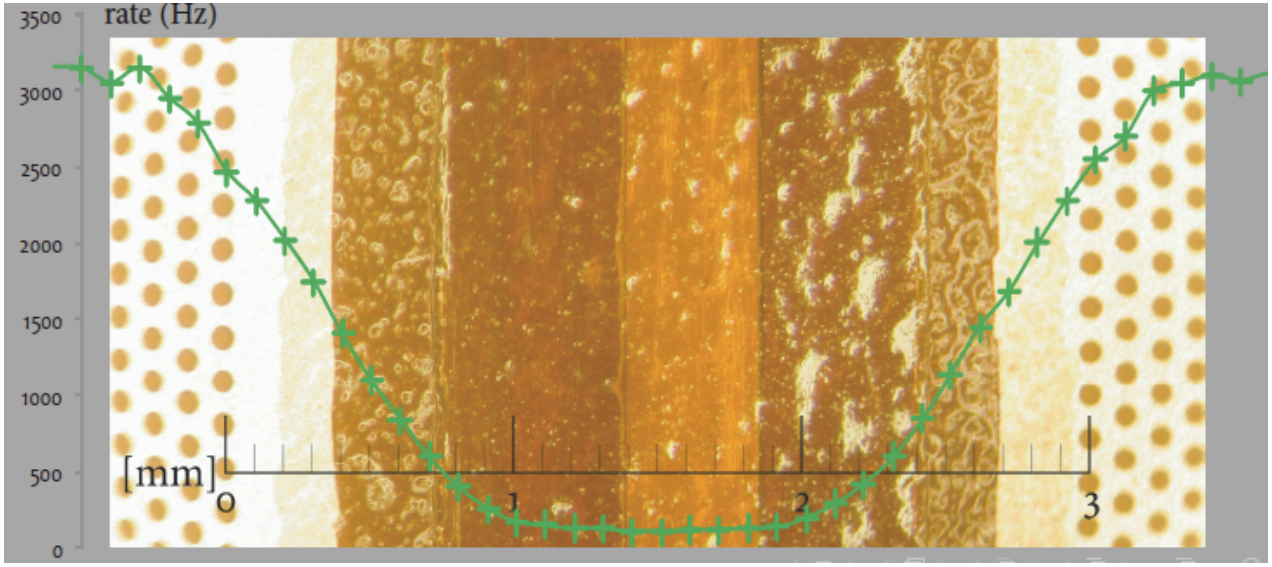


Single Mask technique allows to make GEM foils as large as 200 cm x 45 cm

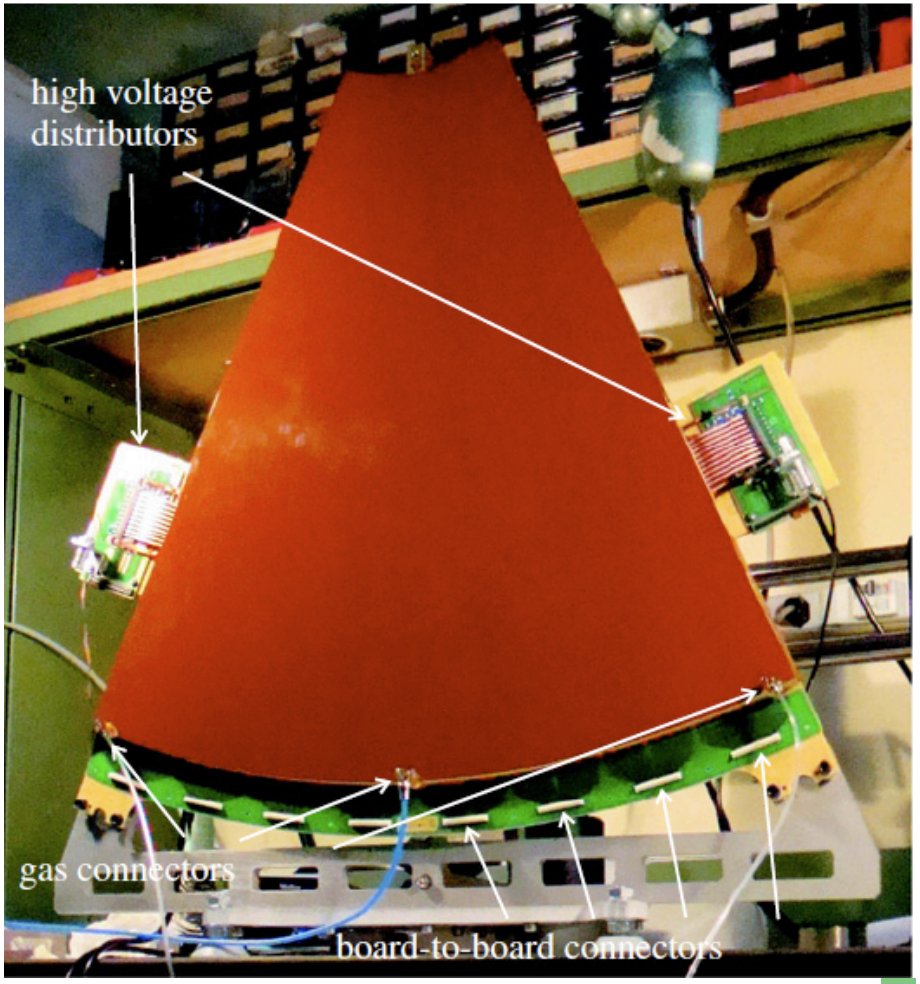
Major recent development towards large GEM foils

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





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



- Base material up to 51.4 cm wide now available
- CERN is now capable of producing 200 cm x 60 cm GEM foil.

This combined with Splicing: 200 cm x 120 cm GEM foil will be possible

M. Villa, et al., Nucl. Instr. and Meth. A (2010), doi:10.1016/j.nima.2010.06.312

M. Alfonsi et al. / Nuclear Instruments and Methods in Physics Research A 617 (2010)

Hall A GEM program timeline

- Summer and Fall 2011
  - INFN group will start building 40 cm x 50 cm GEM modules this summer
  - Finalize APV25 readout card design and start production
  - Finally some R&D funds available to build large area prototypes in the US.
    - Build two 40 cm x 50 cm prototype chambers at Uva
    - Test alternate readout schemes
    - Setup the APV25 readout system at Jlab
    - Test all prototype chambers with APV25 electronics.
- Winter 2011-Spring 2012
  - Continue GEM module production at INFN
  - Test the prototype setup with beam during g2p experiment
  - construct a ~ 1.2 m x 0.5 m prototype chamber
- Summer 2012 and beyond
  - Install INFN GEM modules in Bigbite for A1n experiment.
  - Start UVa GEM module production whenever funding becomes available.

Most of the hall A 12 GeV spectrometers will use GEM chambers: Bigbite, SBS, Moller and SoLID

Hardware infrastructure at UVa ready for GEM testing

- A 3000 chan. APV25-S1 readout system ordered , will be ready soon: speeds are what we need for the final setup, can do tests on rate effects etc.

- A brand-new Iseg-Wiener multi-channel HV system bought; designed for sensitive detectors like Silicon strip and GEM: 16 HV channels to start with, can be expanded to 160 chan.