Solid Instrumentation and GEM chambers

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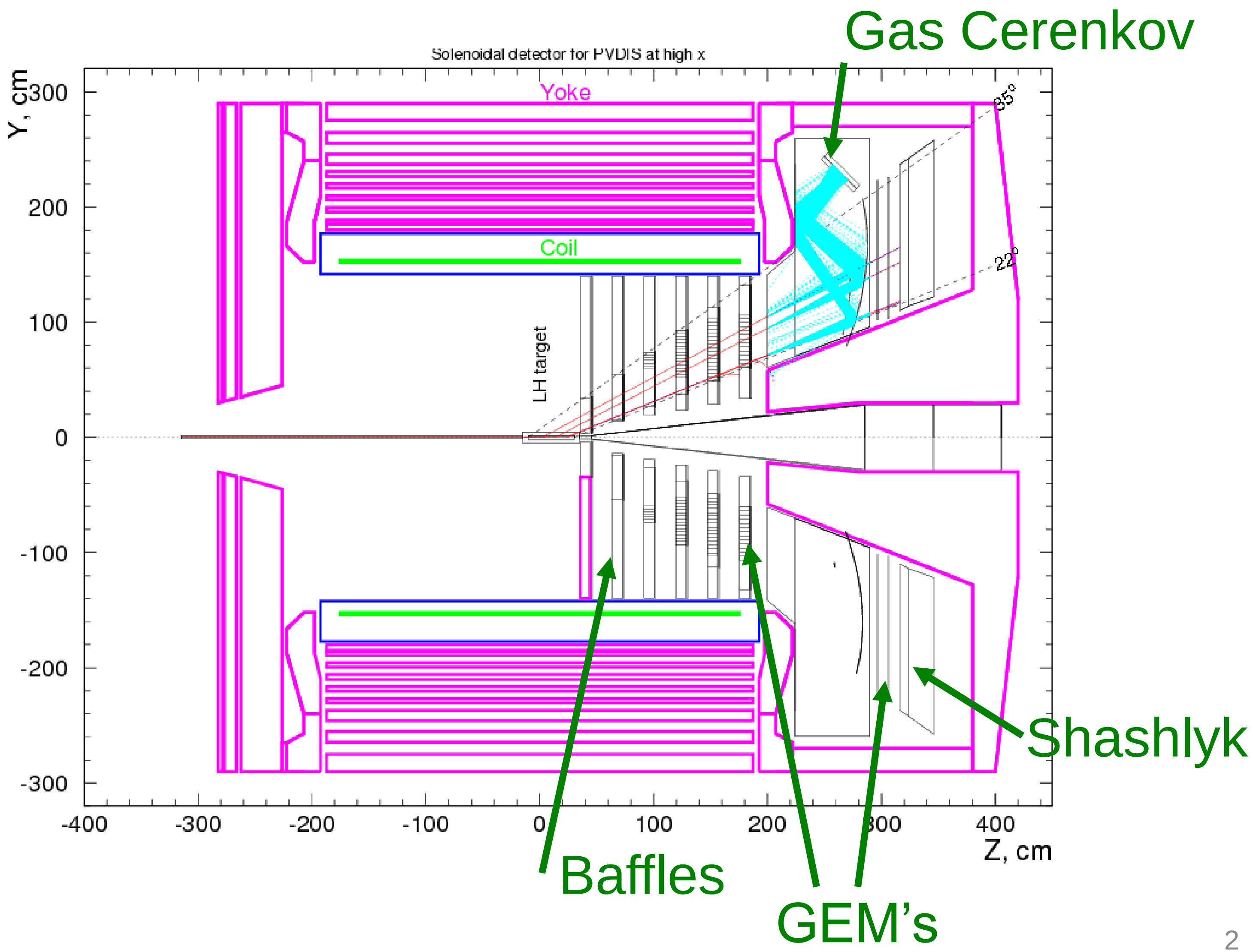
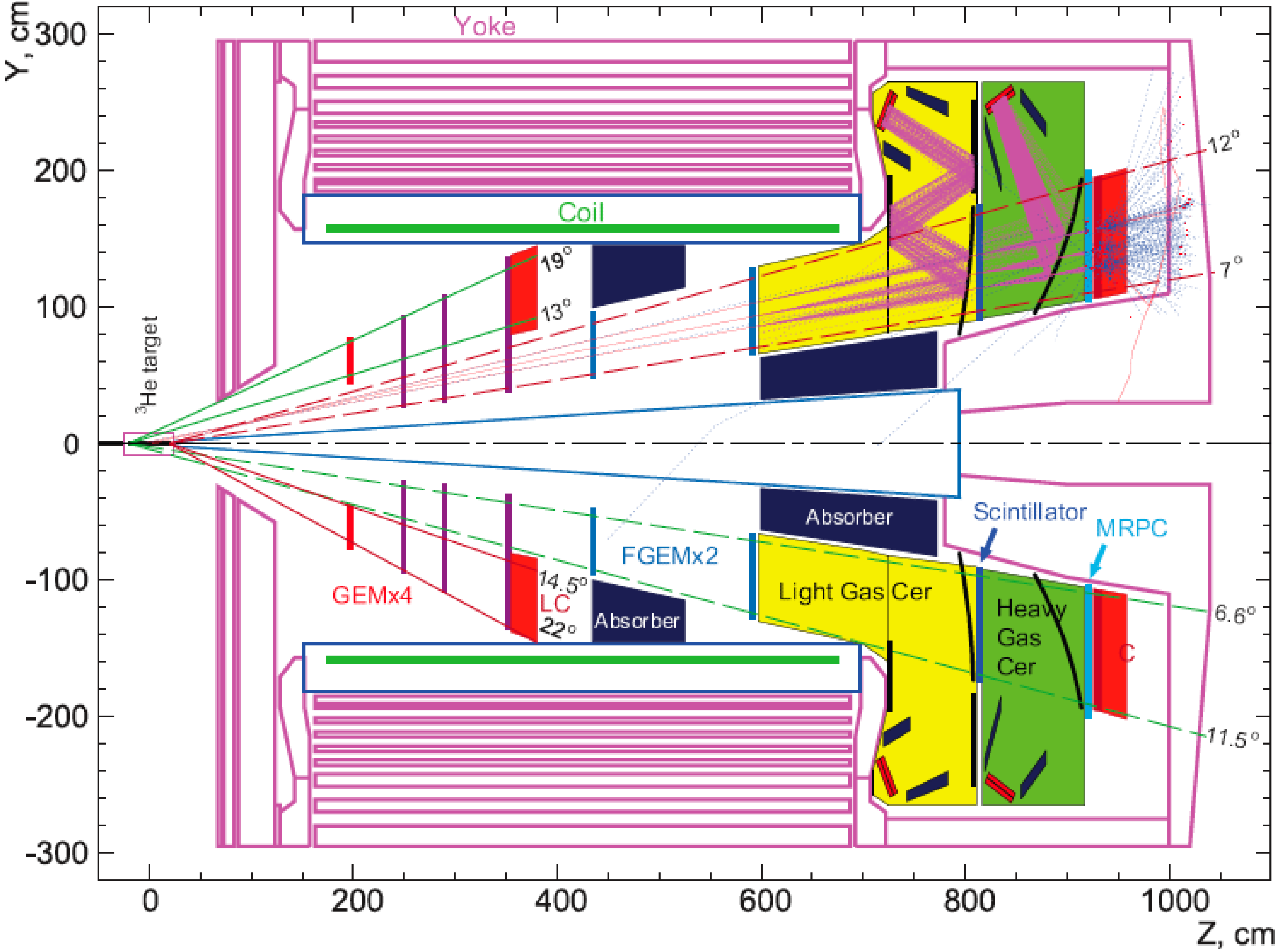
University of Virginia

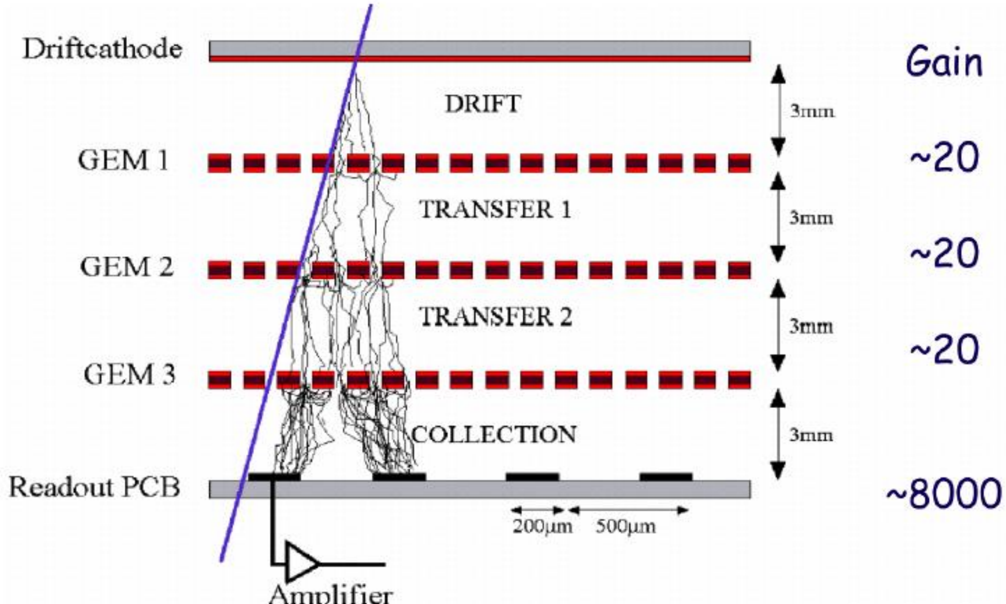
SoLID Spectrometer

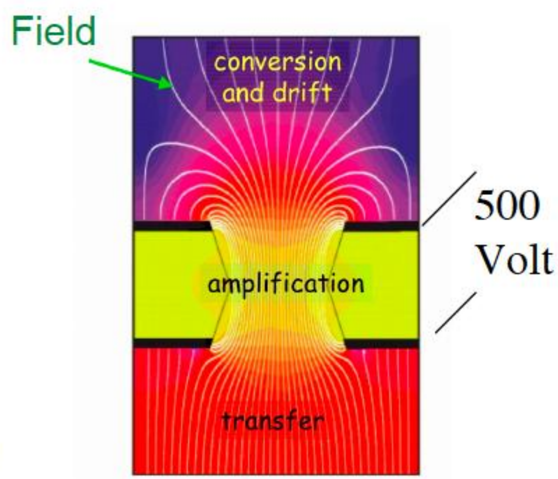


SoLID Spectrometer for SIDIS

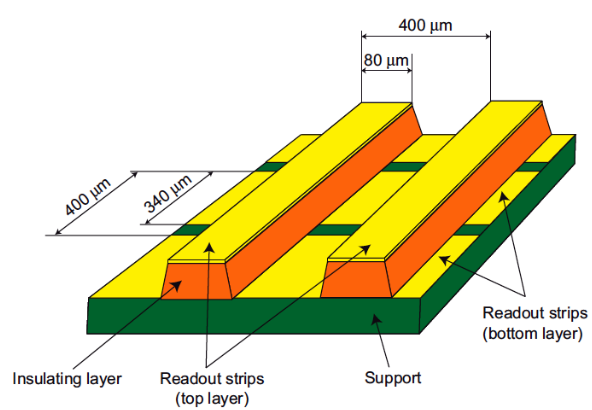


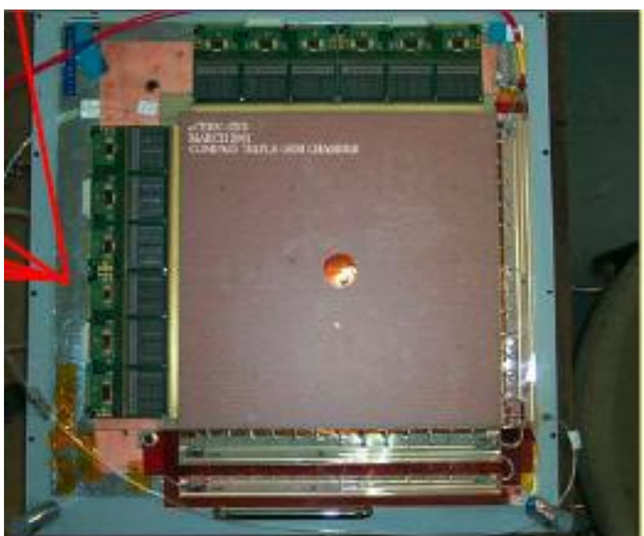
Gas Electron Multiplier- GEM: technology





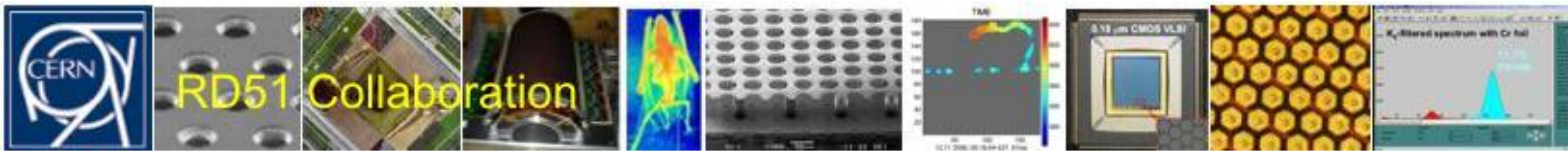
- Invented by Sauli in the nineties.
- Have been adapted for many applications since.
- Successfully used in COMPASS for a few years.





GEM: σ_x~70µm

GEM Research and Development



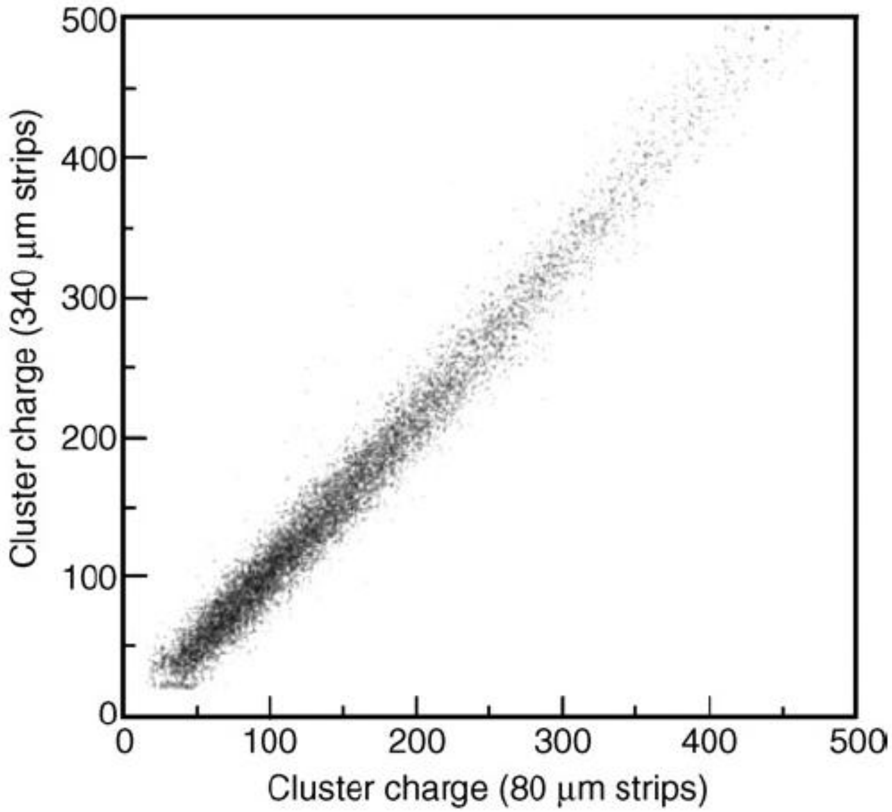
RD51 Collaboration for the Development of Micro-Pattern Gas D

http://rd51-public.web.cern.ch/RD51%2DPublic/Welcome.html

GEM Readout

- Since we plan to cover large areas, need lots of channels: need multiplexing.
- Need fast readout

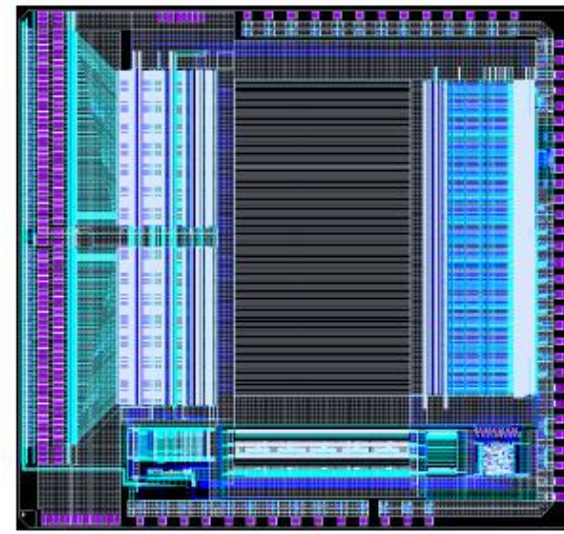
- 1/0 and analog ADC readout has been used in the past.
- Analog ADC readout is more useful:
    - Charge weighted centroid gives better position accuracy.
    - Charge correlation between x and y readout (at ~ 30 – 50% level) can help resolve multi-hit ambiguity.



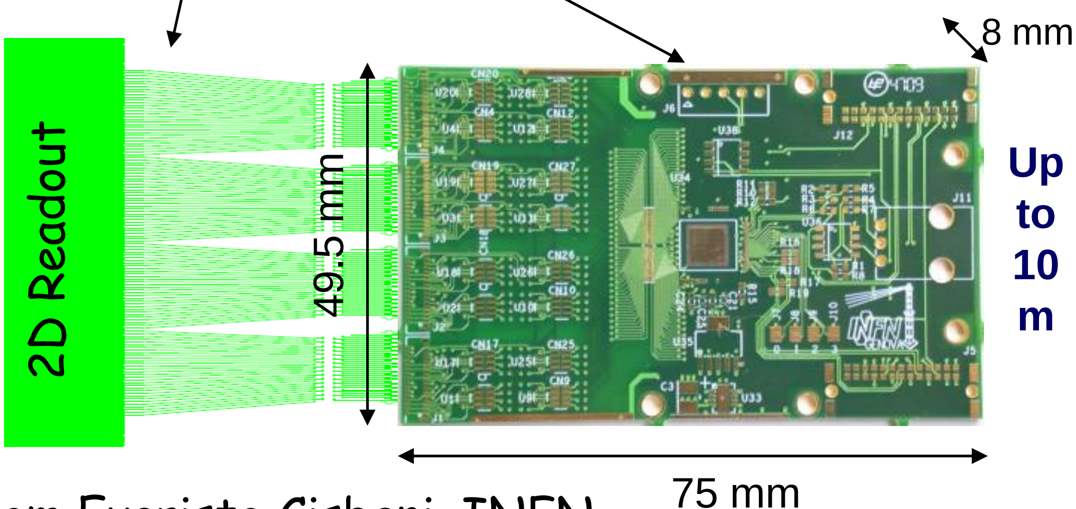
GEM Readout

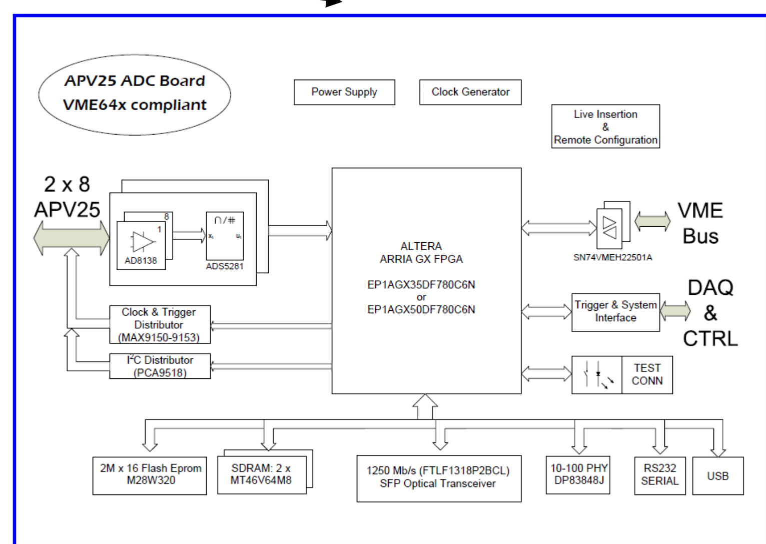
Example: APV-25 multiplexing analog amplifier chip

- Fast, Pipelined readout: read at 40 MHz
- 128 Channels: mutiplexed into a single signal train going to and ADC chan.



GEM ⇒ FEC ⇒ ADC+VME Controller ⇒ DAQ





From Evaristo Cisbani, INFN

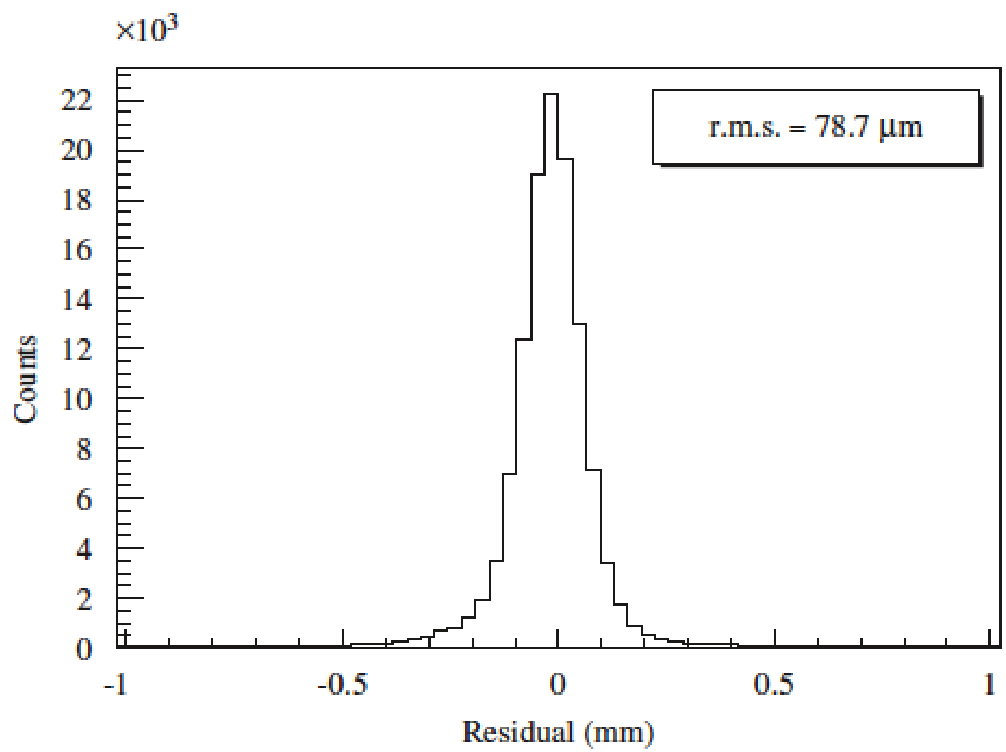
Ideal for high luminosity applications requiring high resolution: like SOLID

• Can tolerate rates up to 50 kHz/mm^2 or more: SOLID needs up to ~ 5 kHz/mm^2.

• Achieved resolutions ~ 60 – 70 μm

• Radiation hardy: no effect after many years of running at COMPASS

• No chamber aging observed up to ~ 7 mC/mm^2: this is about 10,000 hours of running for SOLID:



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.

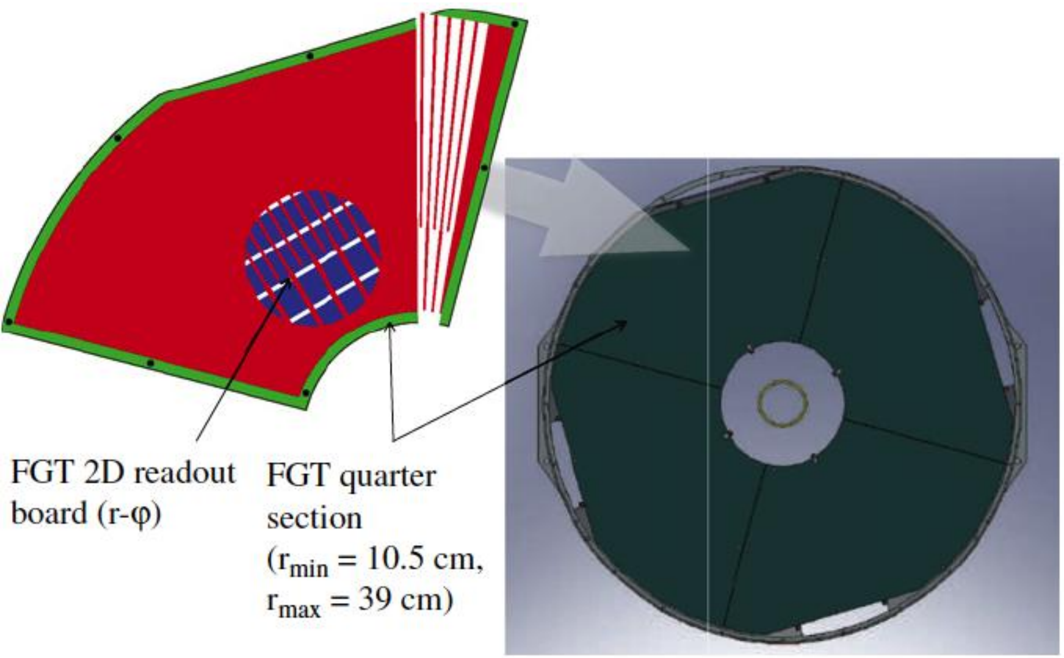
Plane	Z (cm)	R_I (cm)	R_O (cm)	Total Area (m^2)	circumference (cm) Inner	outer
4	120	39.0	87.2	1.9	245	548
5	150	48.7	109.0	3.0	306	684
6	190	61.7	138.0	4.8	388	867
7	290	94.2	210.7	11.2	592	1323
8	310	100.7	225.2	12.7	633	1414
total:				33.6		

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

Several Large Area GEM projects in production or prototyped

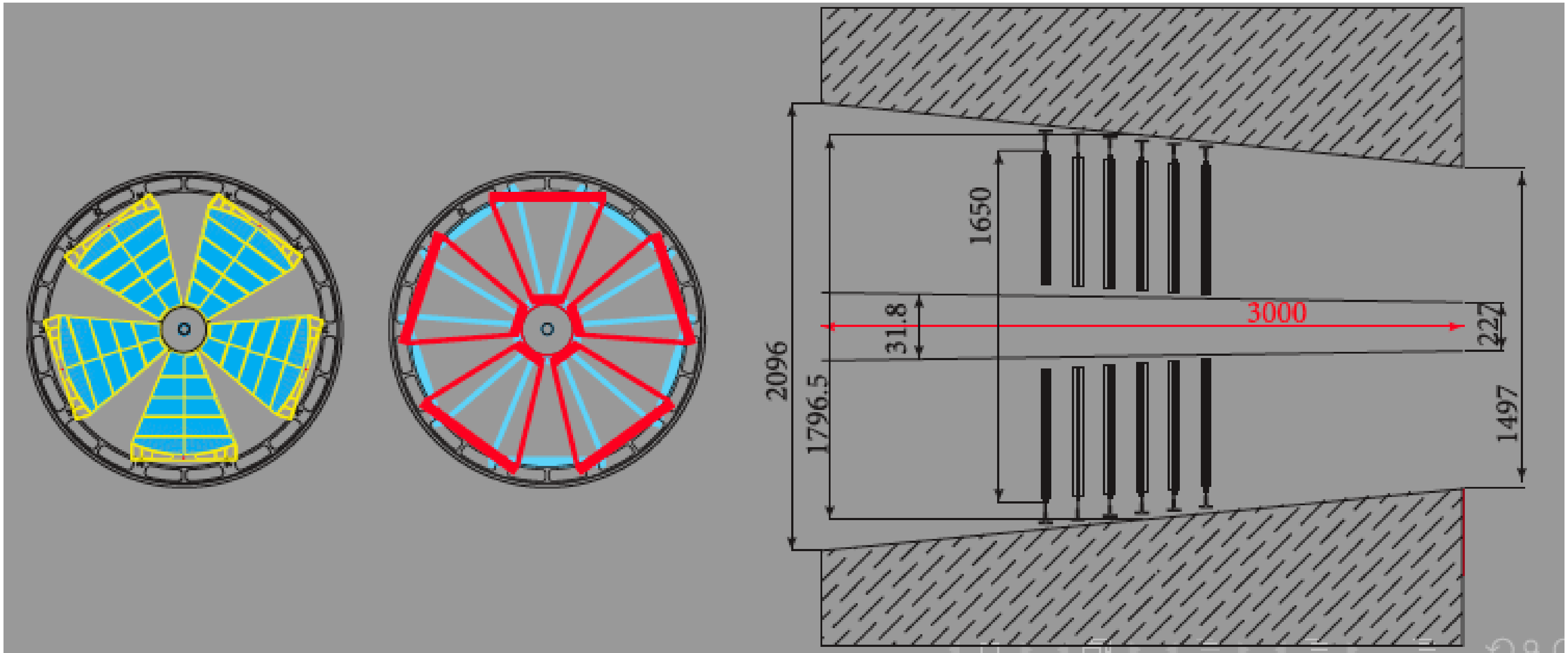
- STAR Front GEM Tracker (MIT, BNL, Yale, Indiana, ANL, Kentucky)
  - 6 triple-GEM disks around beam
  - IR~10.5 cm, OR~39 cm, four 90° wedges, area ~ 0.14 m^2 each
  - total GEM area ~ 3.3 m^2



- Successfully worked with a private company (Tech Etch. Inc, in Massachusetts) to produce all GEM foils
- Readout boards were also locally produced using laser etching (CERN ones are chemically etched)

Several Large Area GEM projects in production or prototyped

- TOTEM T1 upgrade: 6 disks, 85 cm radius.
- Large GEM chambers, each one ~0.2 m^2.
- 2x5 chambers make a disk.
- Total GEM area ~12 m^2



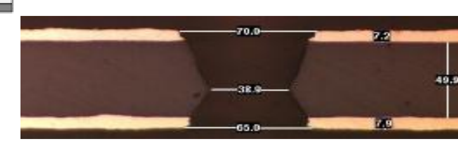
Major recent development at CERN PCB shop towards large GEM foils

- 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

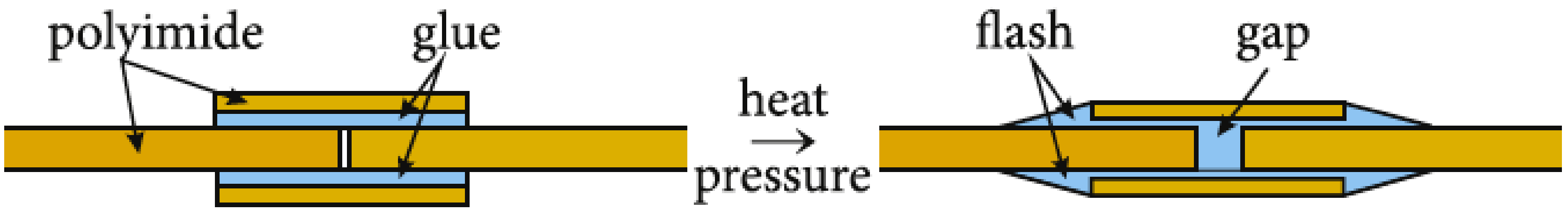
Single Mask

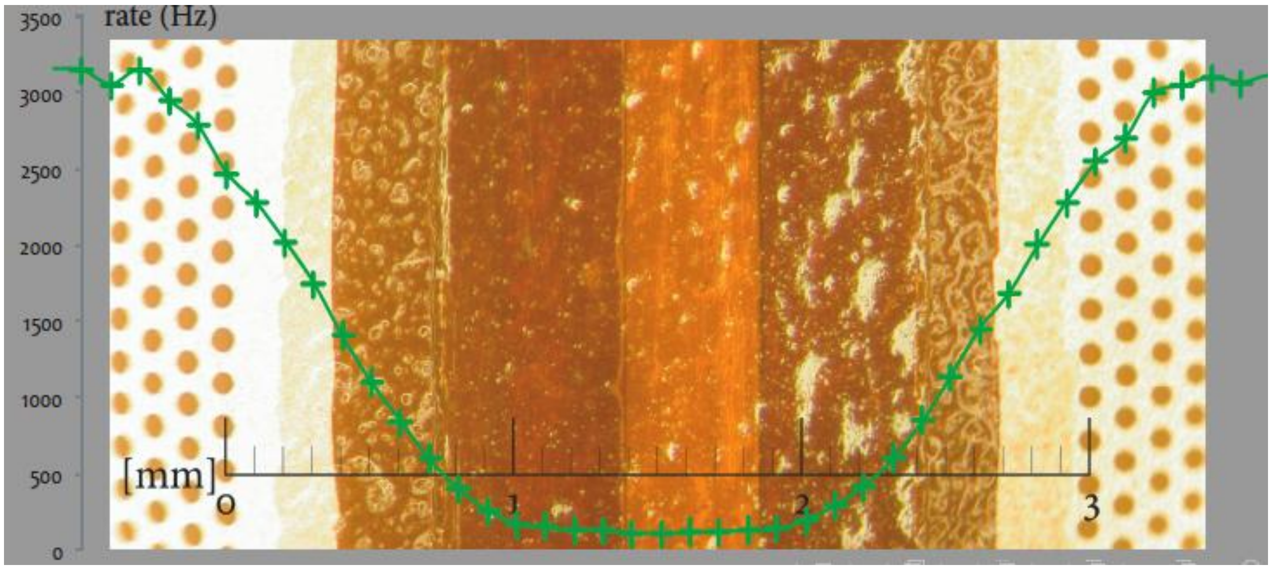


Single Mask technique allows to make GEM foils as large as 200 cm x 45 cm

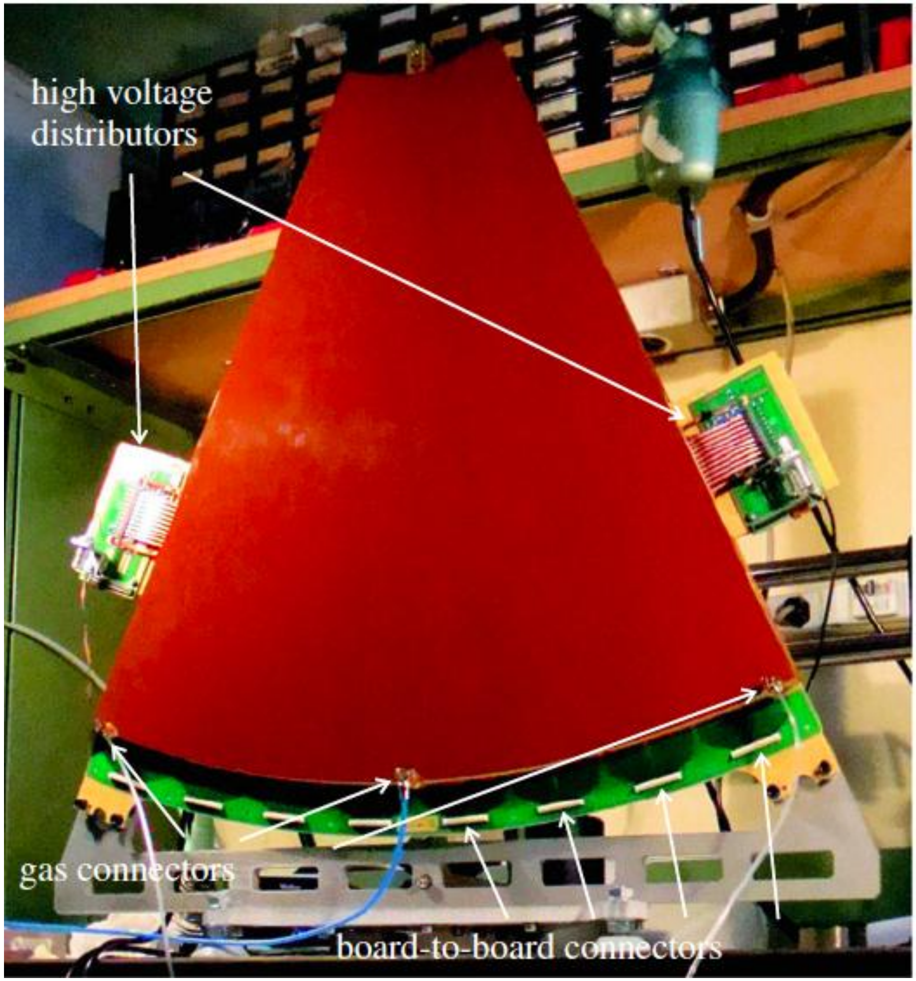
Major recent development towards large GEM foils

- 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 plans to buy equipment capable of producing 200 cm x 50 cm GEM foil.

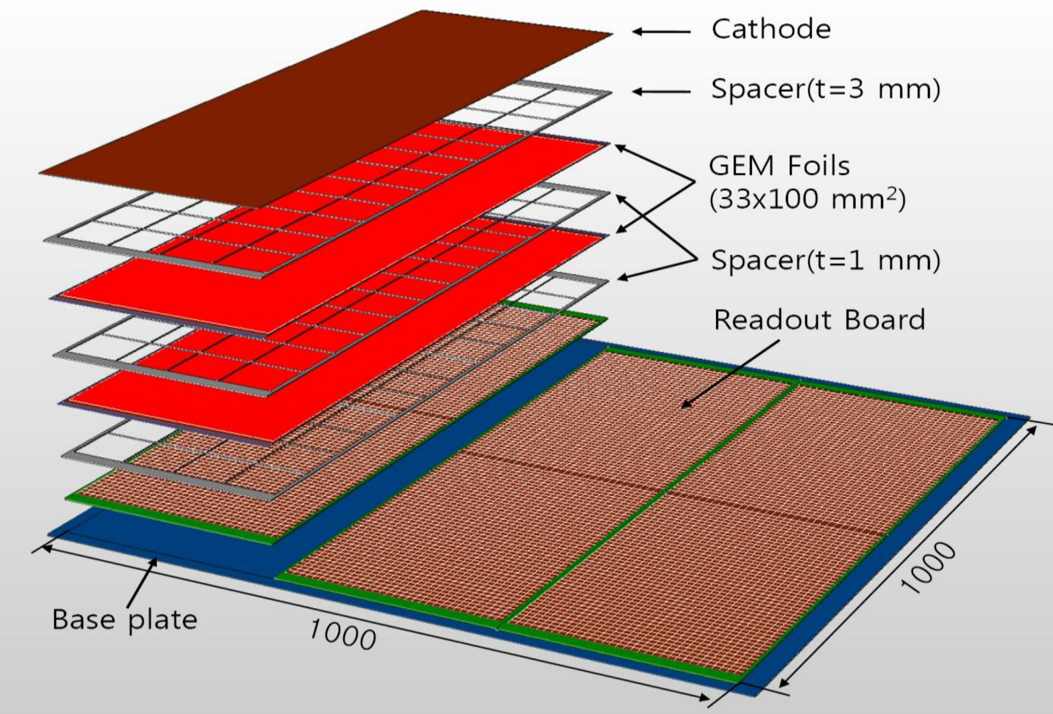
This combined with Splicing: 200 cm x 100 cm GEM foil may be possible in the next two years

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)

Several Large Area GEM projects in production or prototyped

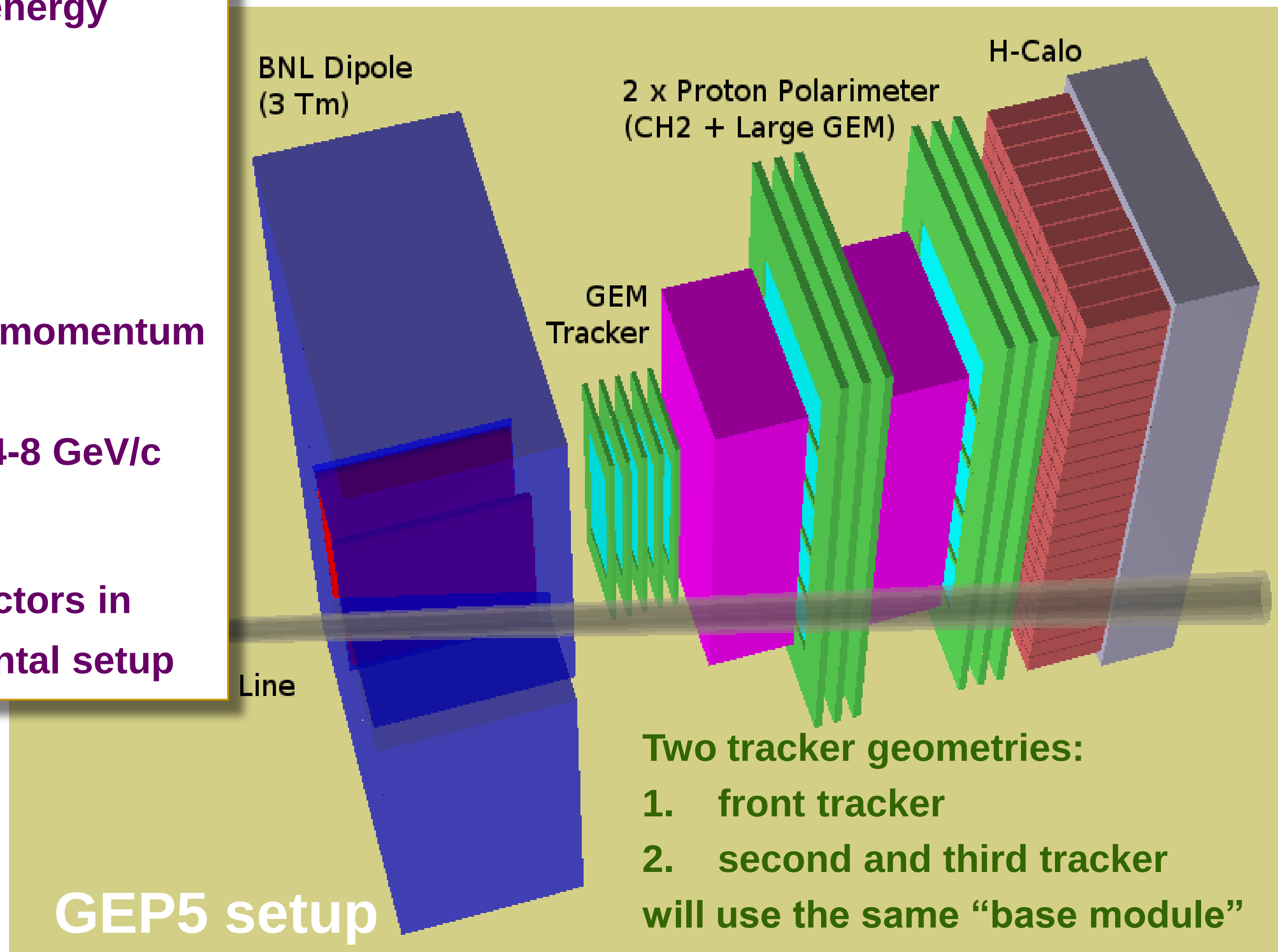
- PANDA at FAIR (Darmstadt, Germany)
    - 3 GEM stations with radii 45, 50 and 70 cm.
    - Each station: 2 half rings: need foils up to ~ 140 cm x 70 cm.
- Large GEM chamber development for Digital Hadron Calorimetry (Andy White, U. of Texas, Arlington)
    - A 33 cm x 100 cm prototype currently under production
    - Plans to build 15 such chambers by end of 2011, to put together five 1 m x 1 m GEM stations.



New SBS Spectrometer @ JLab

- **High Luminosity: 10^{38} /cm^2/s**
- **Support high background: 500 kHz/cm^2 (low energy photons mainly)**
- **Forward angle**
- **Large acceptance**
- **Good angular and momentum resolutions:**
  0.2 mrad, 0.5% @ 4-8 GeV/c
- **Flexibility:**
  use the same detectors in different experimental setup

hallaweb.jlab.org/12GeV/SuperBigBite/

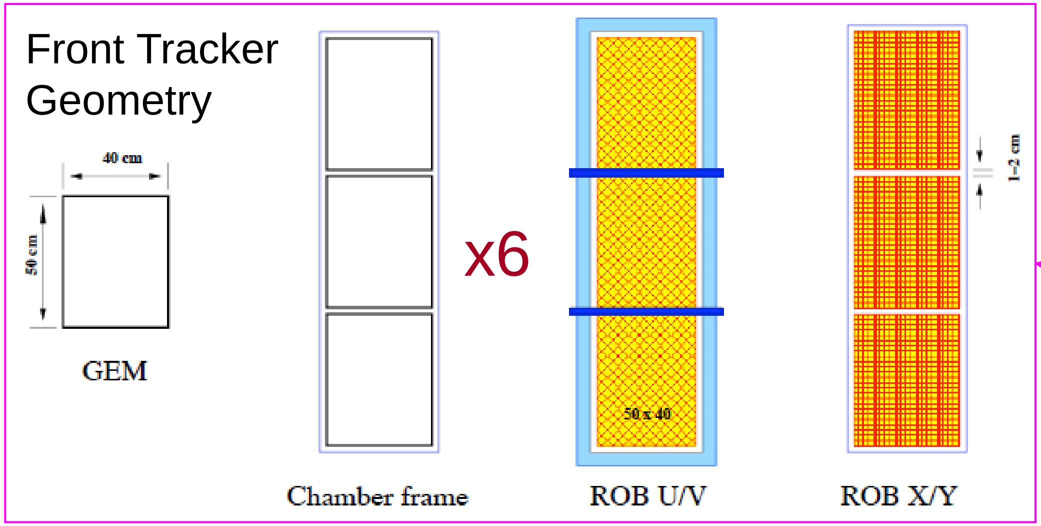


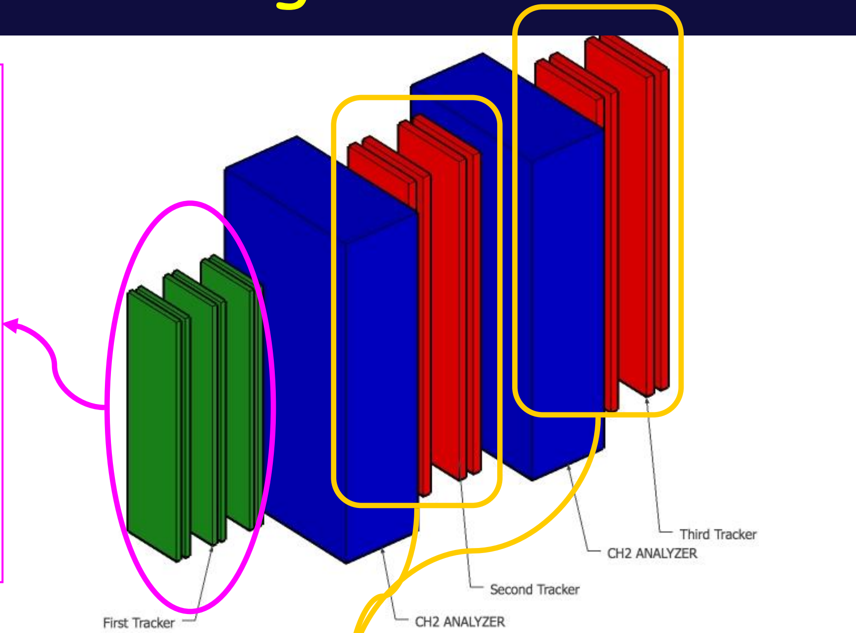
Two tracker geometries:

1. **front tracker**
2. **second and third tracker**

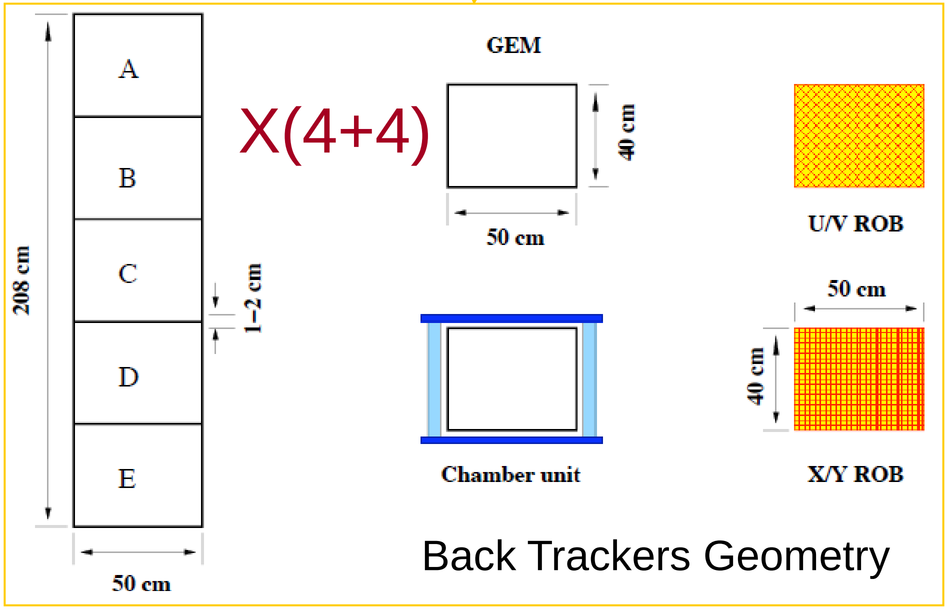
will use the same "base module"

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**
- ✓ **Aluminum support frame around the chamber (cyan in drawing); dedicated to each chamber configuration**



Collaboration

INFN - Roma
Cisbani, Urciuoli, Garibaldi, Frullani, Castelluccio, Capogni, Meddi

INFN – Genova
Musico, Ripani

INFN – Catania
Bellini, Noto

INFN – Bari
De Leo

Front Tracker

GLASGOW
Annand, Hamilton, Kaiser, Ireland, Livingston, McGregor, Rosner, Seitz

Trackers

UVa
Cates, Liyanage, Nelyubin, Riordan, Paschke, Tobias

Polarimeter Trackers

W&M
Perdrisat

BigCal Tracker

Norfolk State
Khandaker, Punjabi

Front-end Electronics

CMU
Franklin, Quinn, Benmokhtar

Dubna
Savin

Hadron Calorimeter

Rutgers
El Fassi, Gilman, Ransome

UNH
Calarco, Slifer

Trigger

Jefferson Lab
de Jager, Hansen, Jones, Pentchev, LeRose, Wojtsekhowski,

Infra-structure, Magnet, DAQ

44 Collaborators from 13 Institutions

SBS Tracker Chambers configuration

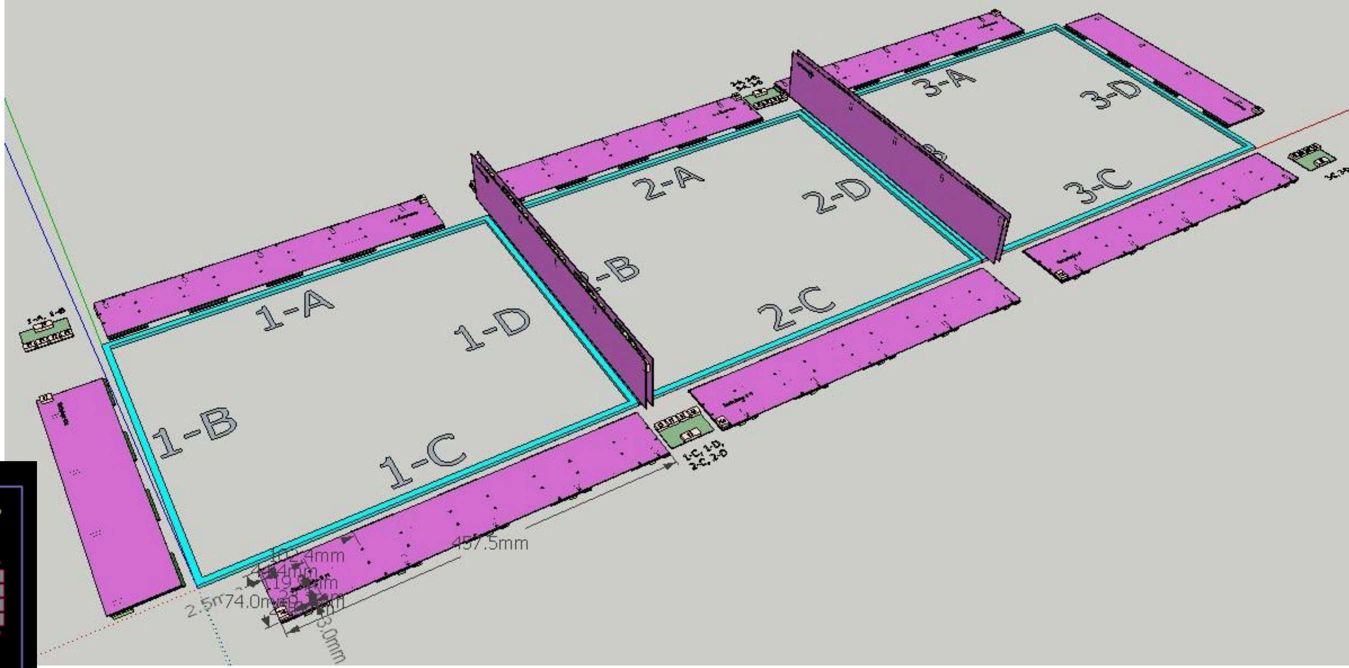
Tracker	Area (cm^2)	Number of Chambers	Readout	Pitch (mm)	Modules/ Chamber	Total Modules	Total Readout Channels
FT	40x150	6	2D 4(x/y) 2(u/v)	0.4	1×3	18	49000 + 13500
ST + TT	50x200	4 + 4	2D 2(x/y) 2(u/v)	4×0.4	1×5	20+20	13600 + 13600
CD	80x300	2	1D y+y	1.0	2×6	24	12000

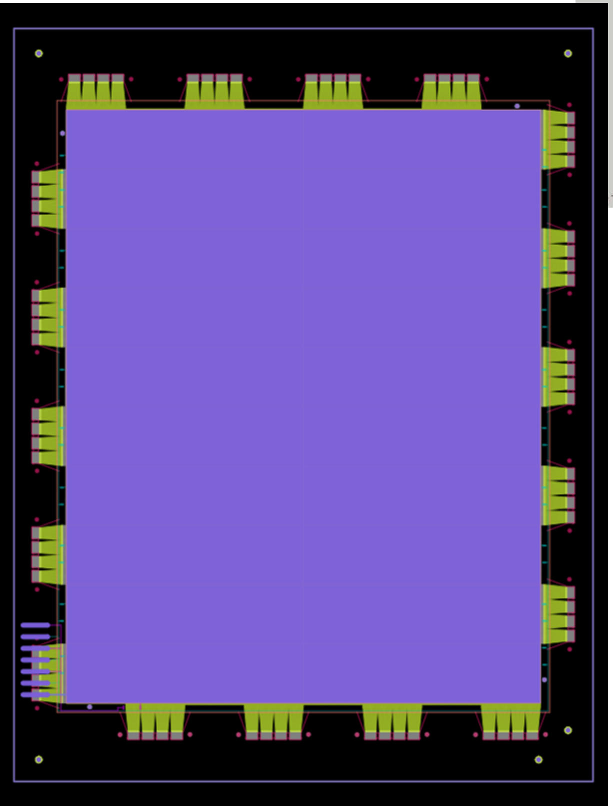
Total chs. 101700

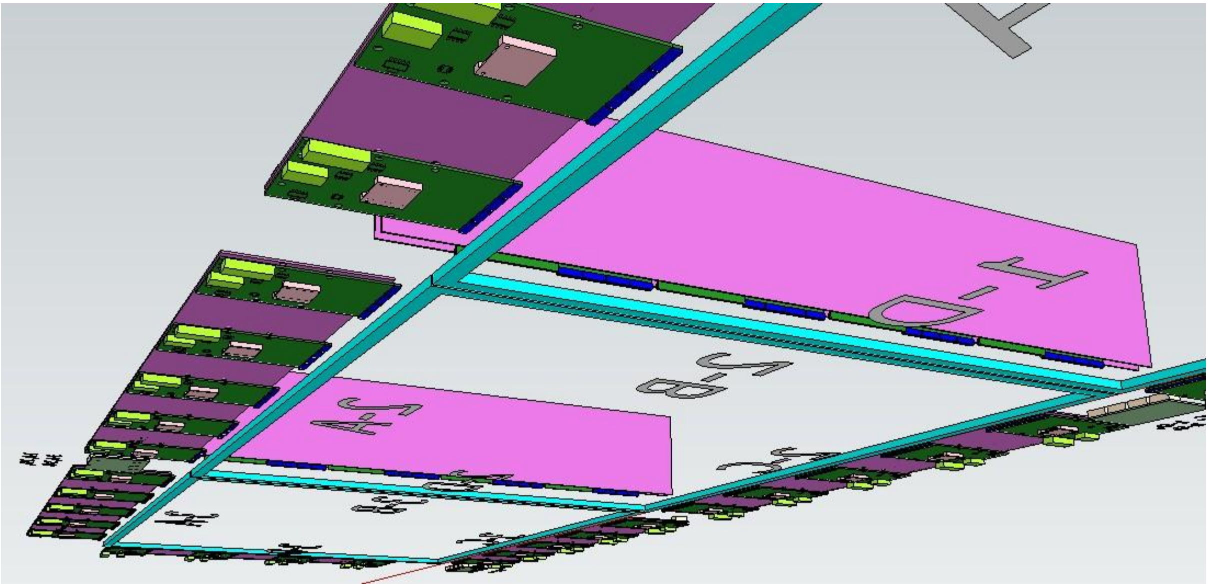
Total area ~ 16.5 m^2

Cost estimate ~ $ 2.7 M

Key to Segmentation: making dead areas as narrow as possible







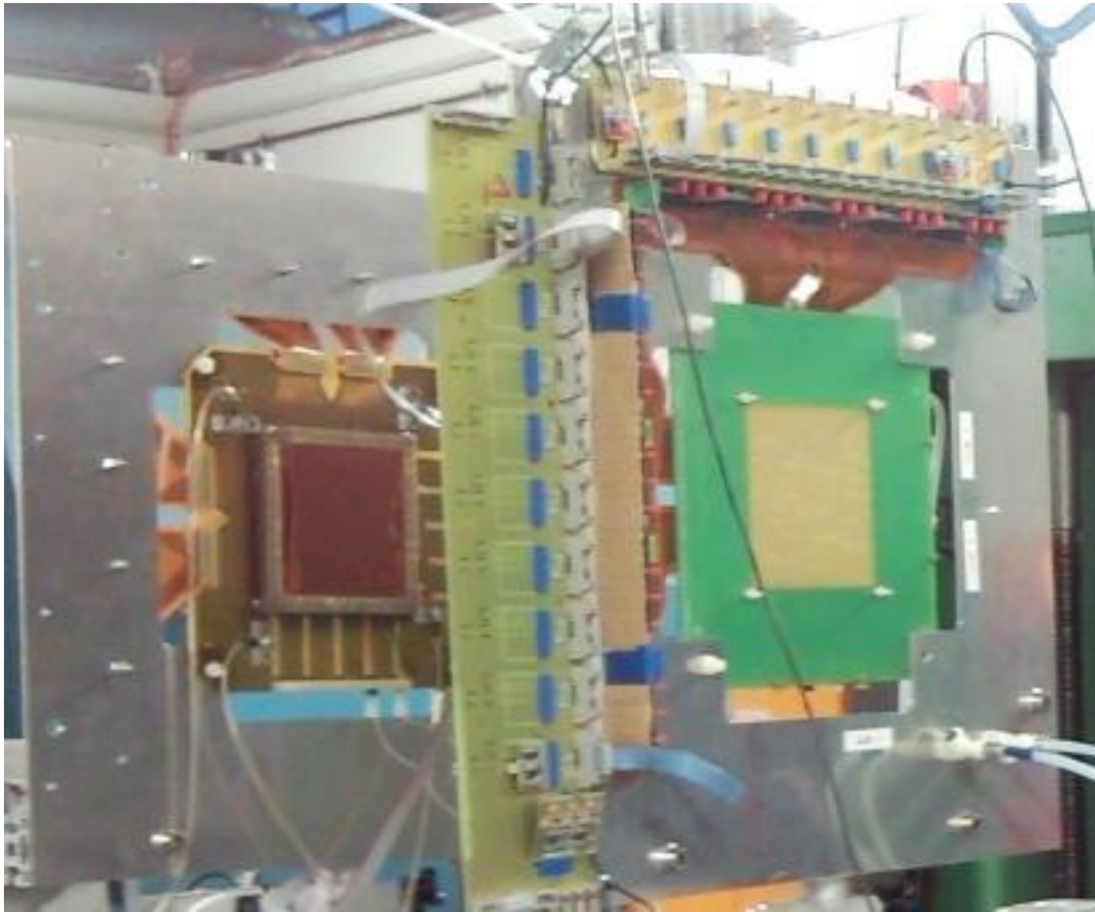
SBS GEM chamber prototyping

•Prototype GEM tracker consisting of five 10 cm x 10 cm chambers built.

• Already tested in high rate conditions during hall A PREX experiment. Data being analyzed now

• More extensive test with APV-25 electronics and under high background rates planed for this Autumn.

•A 40 cm x 40 cm prototype and APV-25 electronics under construction at INFN.



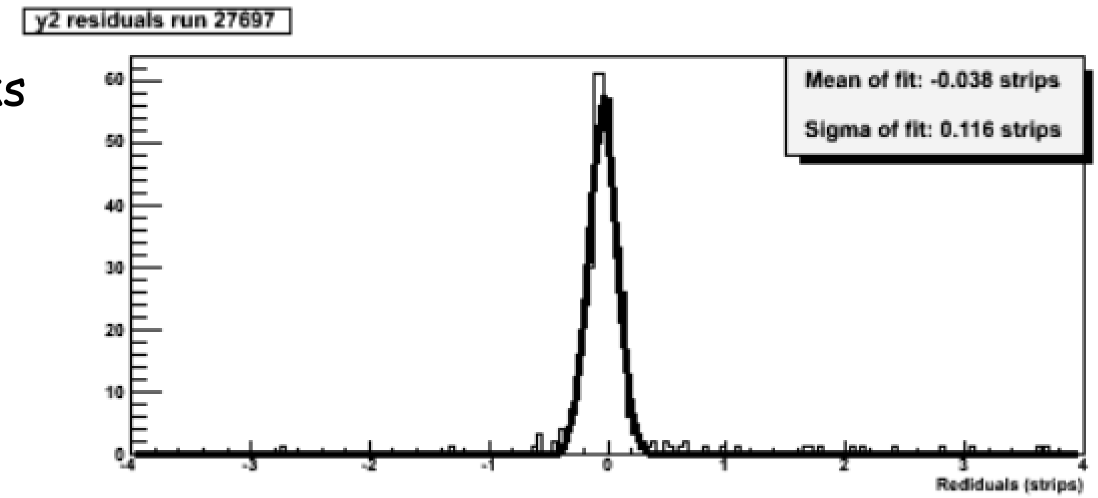
Topics to study

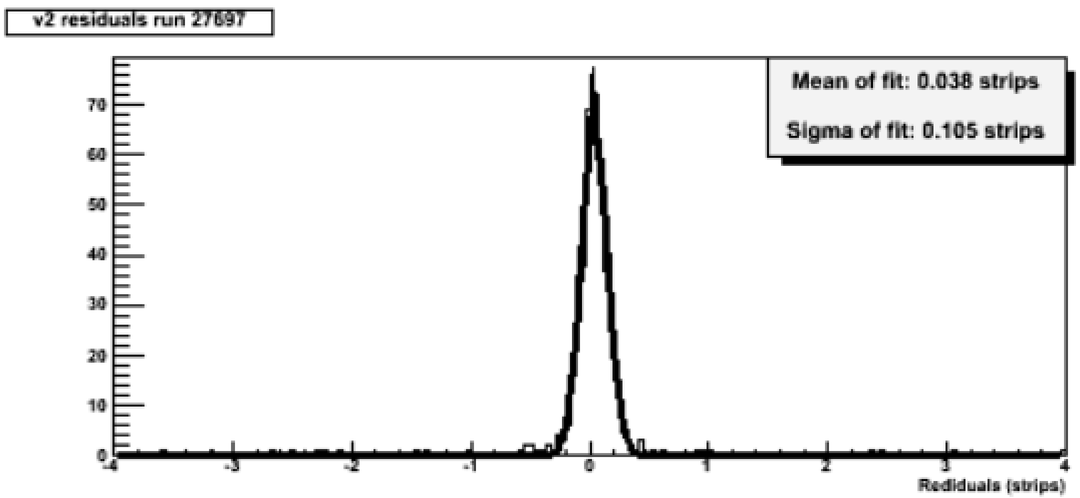
- Tracking under high rates
- Response to low energy photons
- Readout plane size limitations (noise pickup, capacitance etc.)
- Combining readout strips

Expect to start production early next year.

Jefferson lab prototype GEM chamber test during PREX experiment

- Good correlation between tracks projected from VDC and GEM tracks.
- Preliminary resolution (from residuals) ~ 60 microns.





strip pitch is 400 microns

Best ways to learn about GEM chambers

- Build a small Prototype and play with it: cost is ~ $ 2500, CERN detector development group has components (GEM and readout foil) for sale

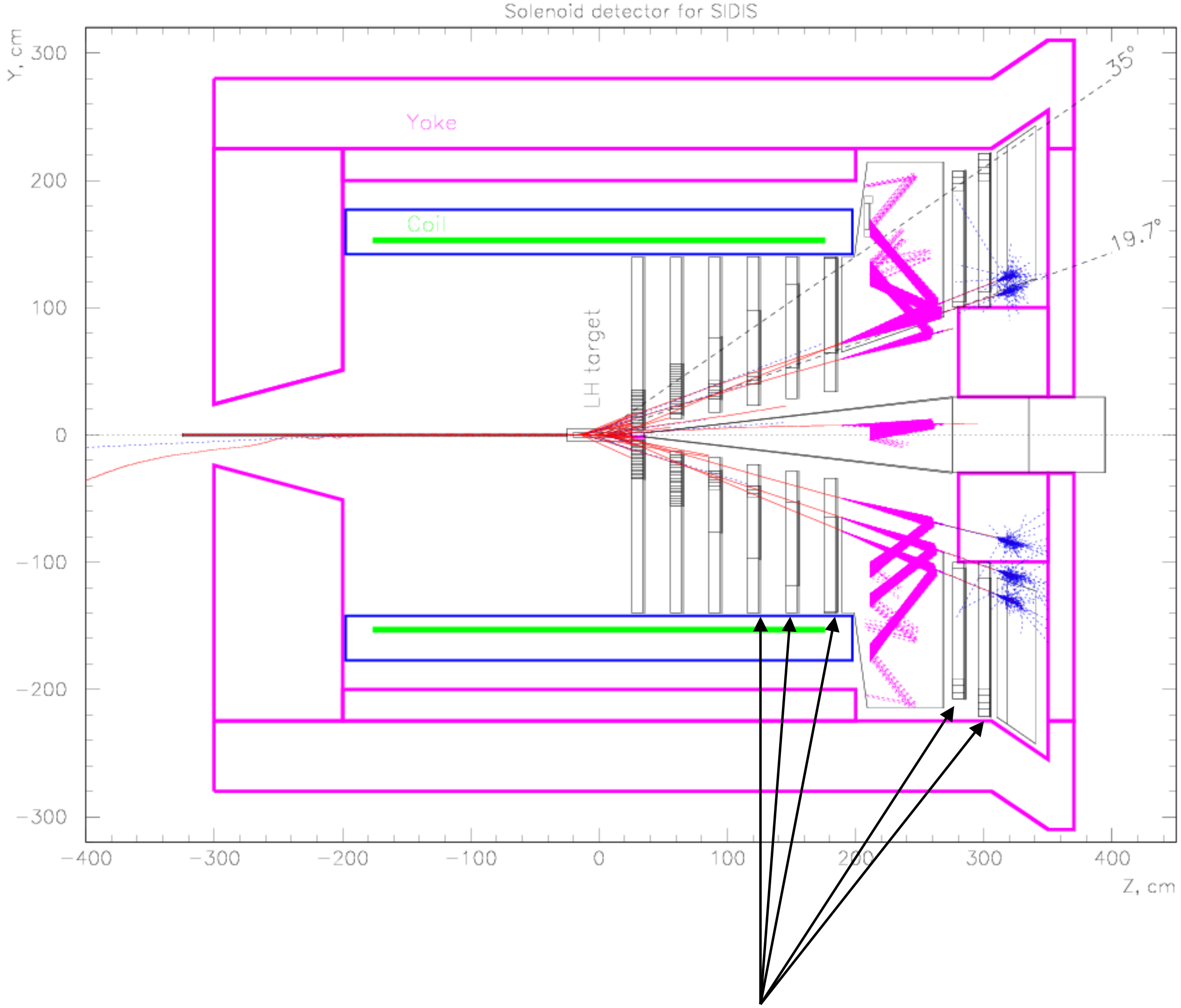
  http://gdd.web.cern.ch/GDD/

- Join RD-51: annual contribution to the research fund $ 2000 ($3000 ?)

Summary

- GEM technology:
  - powerful – high resolution and high rates
  - radiation hardy
  - relatively low cost
  - becoming mature
- SOLID GEM chambers will be the largest in the world.
- Will be challenging but possible.

Solenoid tracking

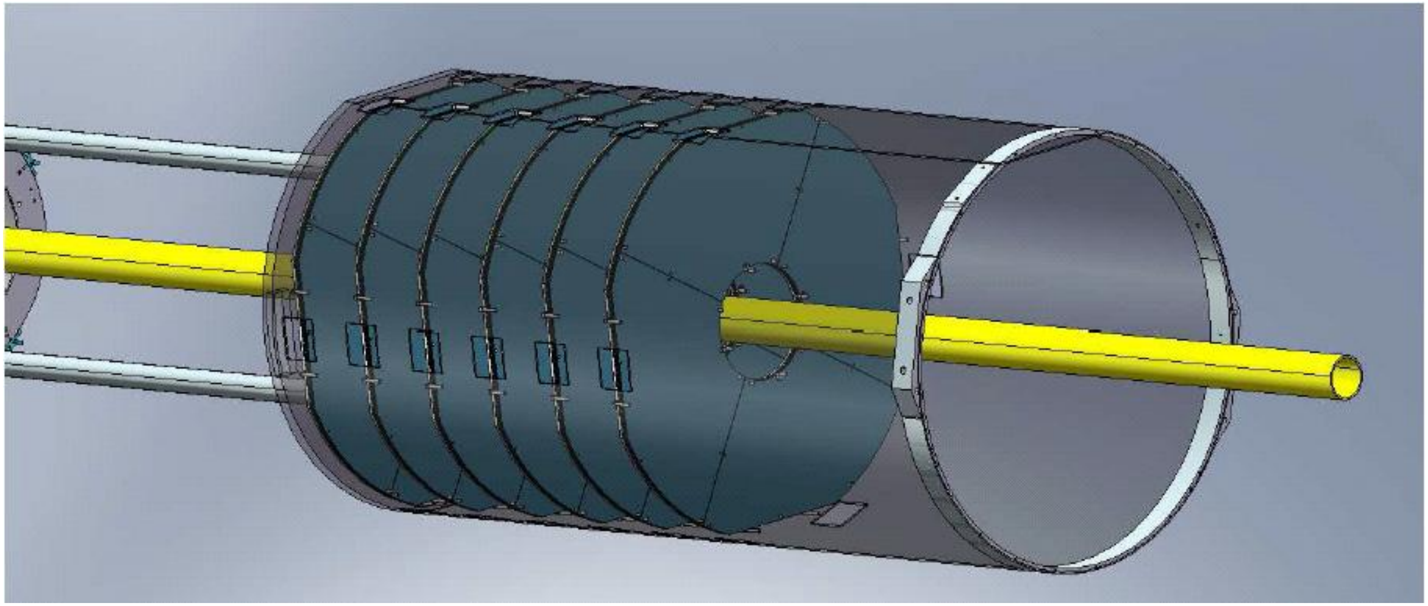


- Nominally planes 4-8 instrumented from 18-36 degrees

STAR FGT (MIT, BNL, Yale, Indiana, ANL, Kentucky)

A pretty good place to start:

- 6 triple-GEM planes, disks around beam
- ID~7cm, OD~40 cm, 4 90^o wedges, area ~ 0.14 m^2 each
- total GEM area ~ 3.3 m^2
- Total budget (including ~ 20%) contingency: ~ $ 2 M (material ~$0.86 M, labor, including ~55% overhead, ~ $1.1 M)



STAR FGT (MIT, BNL, Yale, Indiana, ANL, Kentucky)

About 42 k channels:

cost for FEE and DAQ per chan.: ~$ 16.50

parts: ~$ 4.50

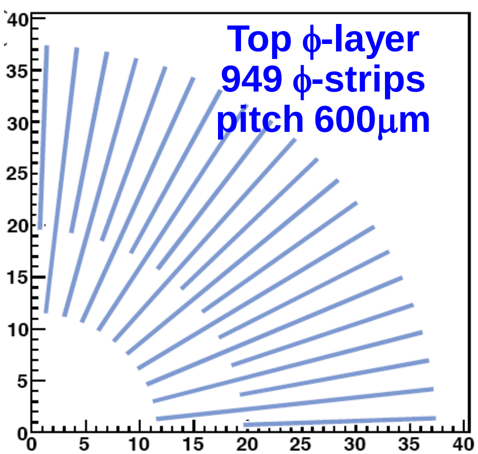
labor: ~$ 7.50

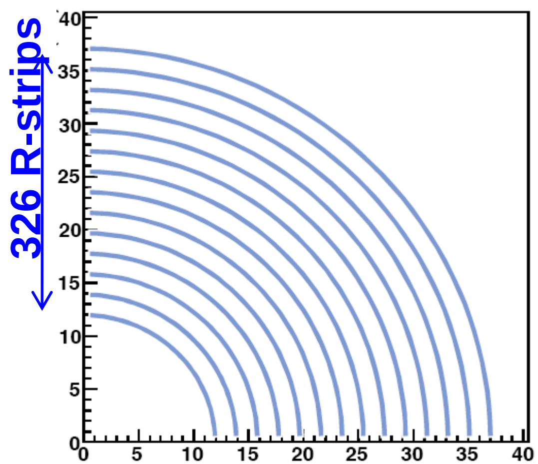
overhead: ~$ 4.50

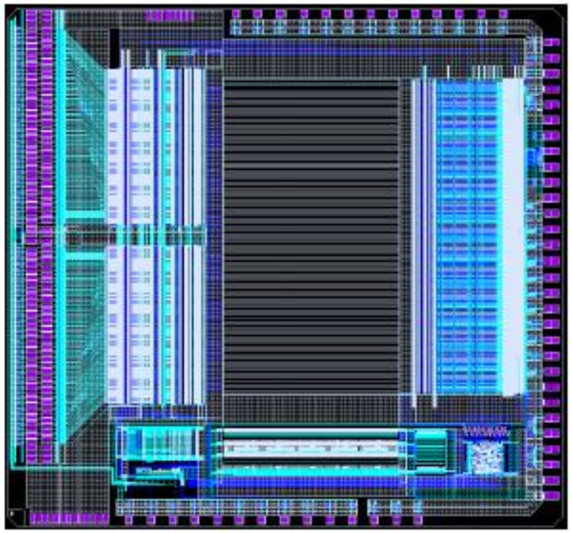
APV-25 CHIP

Fast, Pipelined readout

128 Channels





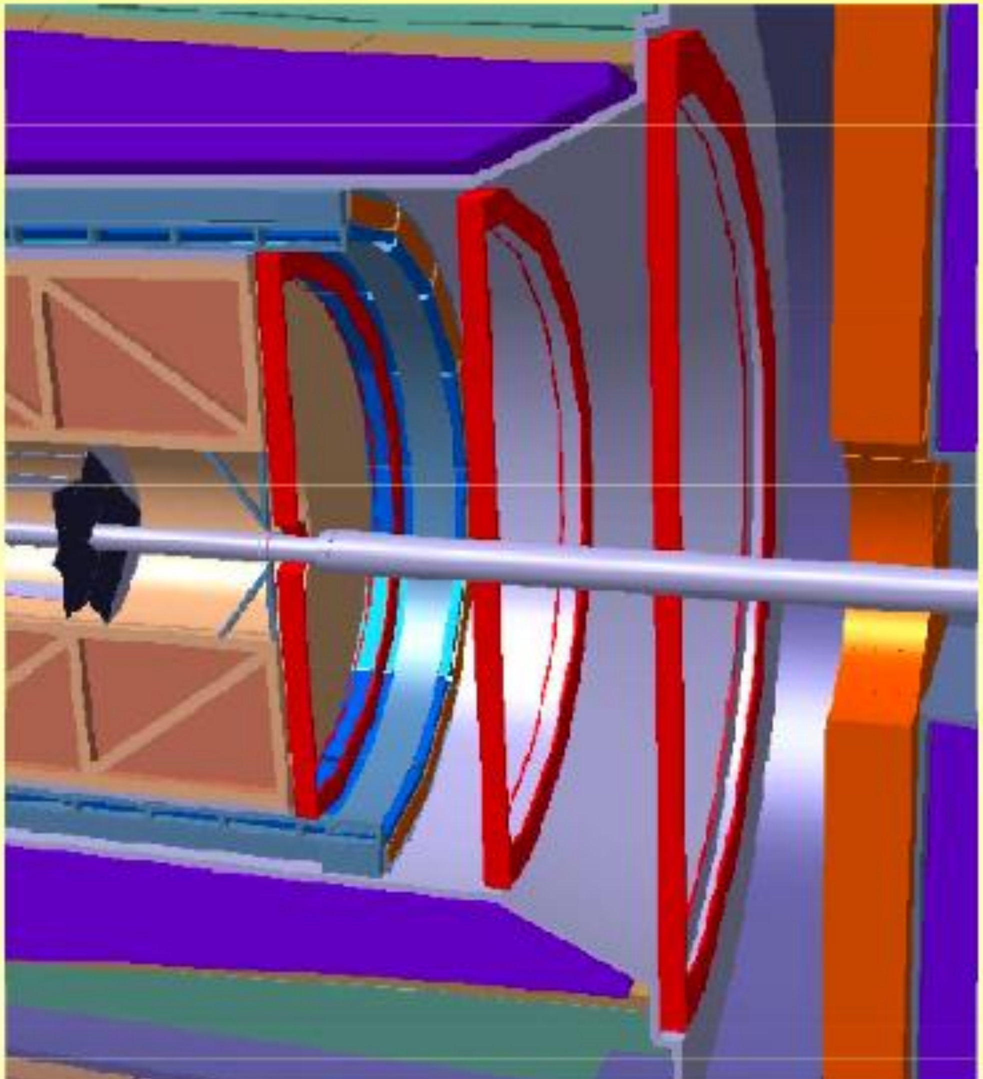


Biggest Challenge: HUGE chamber area

- 100 cm x 40 cm foil may be possible in the near future:
  - R & D at CERN, assumed for large chambers for PANDA at FAIR , TOTEM T1 upgrade at CERN and ILC.
- Planes 4-6 should be possible with azimuthal segmentation: also needs radial segmentation for planes 7 + 8.
- May need 3 way readout to identify hits in high rates: have assumed only 2-way here: need a detailed simulation to study.
- Drift chambers (or straws) to replace planes 7 + 8 ?
  - ATLAS Straw tubes (4 mm dia. 60 cm long) tested well to over 10 kHz/mm^2

PANDA at FAIR

Facility for Antiproton and Ion Research, Darmstadt, Germa



3 GEM stations

2 half rings with R = 45 / 57 / 70 cm

⇨ GEM foil size **~ 140 x 70 cm²**

Hybrid readout structure

- Central region: R = 3 - 7 cm

⇨ **1 mm² pixels** (~13000)

- Peripheral region: R = 7 - 45 cm

⇨ radial+concentric **strips** (~4000)

- Assume largest dimension of GEM foil ~75 cm

Plane	Z	R_I (cm)	R_O (cm)	Total Area (m^2)	inner circumfer ence	outer circumfer ence	Azimuthal segments	radial segments	chamber inner width	Number of chambers
4	120	39.0	87.2	1.9	245	548	12	1	20.4	12
5	150	48.7	109.0	3.0	306	684	12	1	25.5	12
6	190	61.7	138.0	4.8	388	867	12	1	24.2	12
7	290	94.2	210.7	11.2	592	1323	24	2	24.7	48
8	310	100.7	225.2	12.7	633	1414	24	2	26.4	48
total:				33.6						132

Triple-GEM = 100 m^2 foil: $ 0.35 M

Each chamber: readout board ($ 5k), frame ($1.5k)

Supplies: $ 0.1 M

Technician labor ~ 12 FTE: $ 1 M

~300k channels, $ 10 – 15 per chan.: $ 3 – 4.5 M

Support structure, Integration not included.

rough cost

GEM foil	~100 m^2	\$3500/m^2	0.35 M
readout boards	132	5000	0.66 M
chamber support frame	132	1500	0.20 M
FEE and DAQ	300 k	15	4.5 M
cables, power, etc			0.5 M
Gas system			0.1 M
Labor	12 FTE	80 k	1.0 M
support structure and integration			???
TOTAL:			~ 7.5 M
With 33% contingency			~10 M

GEM for only planes 4, 5 and 6: 1/3 of the total area - ~ $ 2.5 M