# GEM chambers for SoLID

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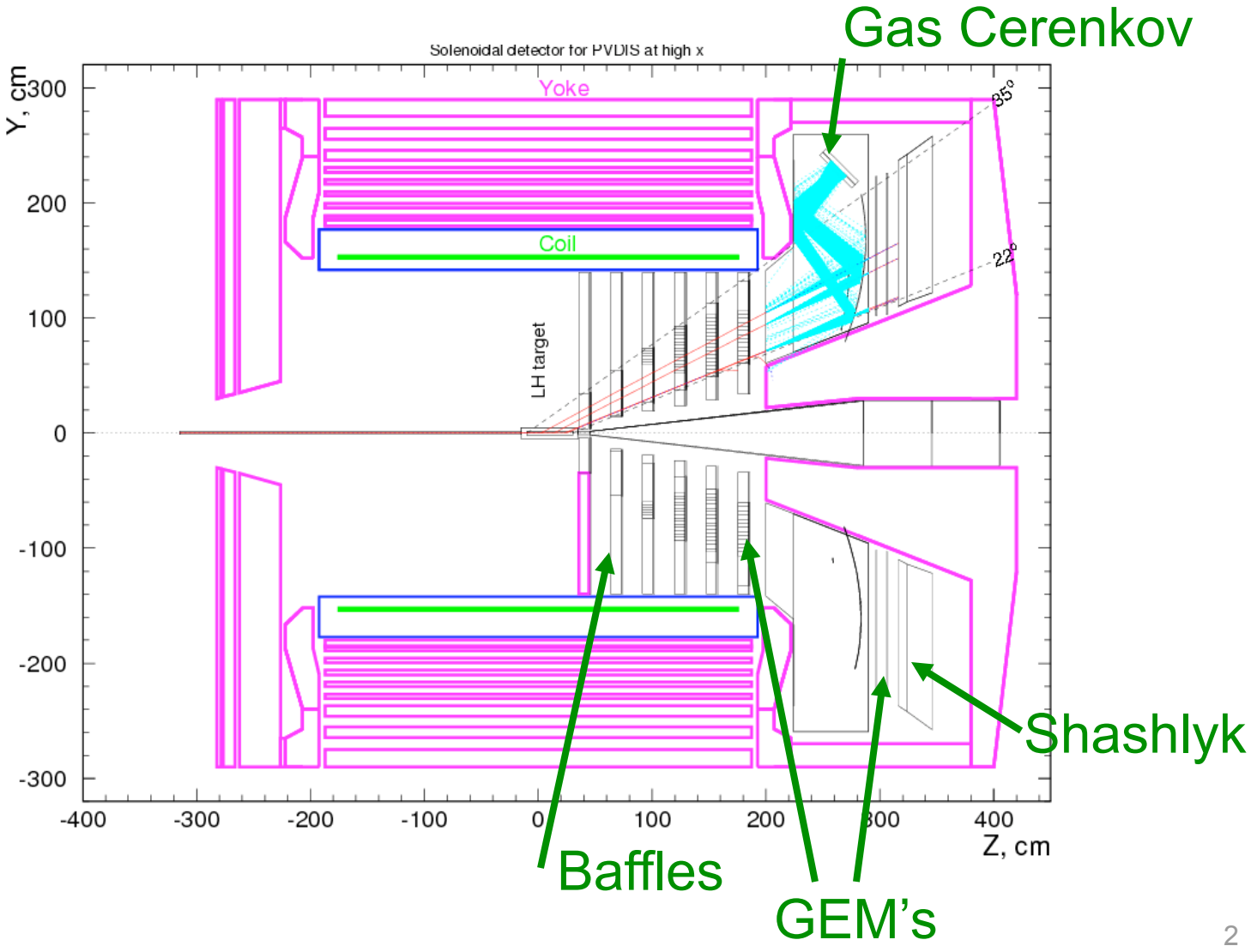
# SoLID Spectrometer



# 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

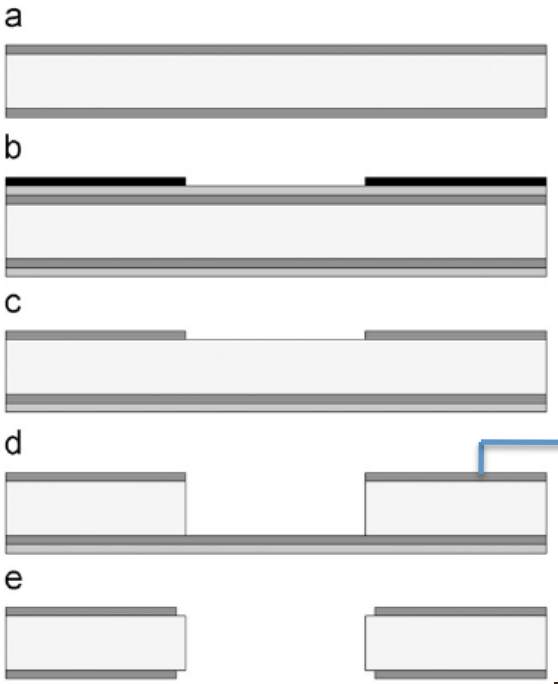
# Production at CERN

- GEM size
  - With existing equipments 1.5m x 0.5m active area
  - Mid 2011: 2m x 0.5m 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

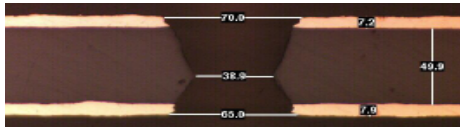
- Base material only ~ 45 cm wide roll.
- Used a double mask technique for etching: hard to the two masks accurately: Max area limited to ~ 45 cm x 45 cm previously.

Double Mask




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

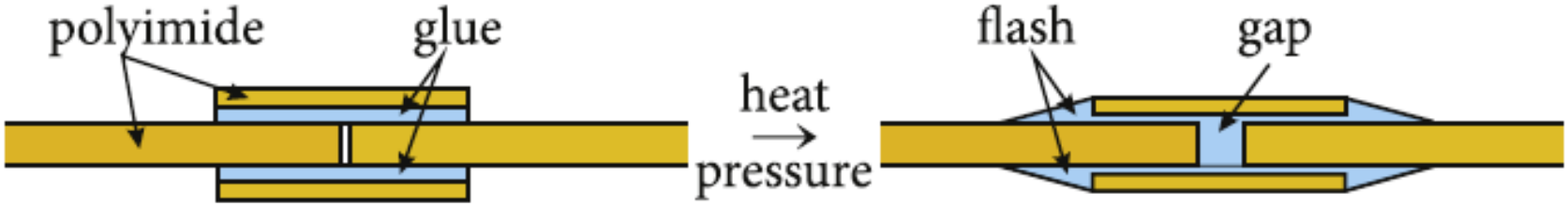
Single Mask

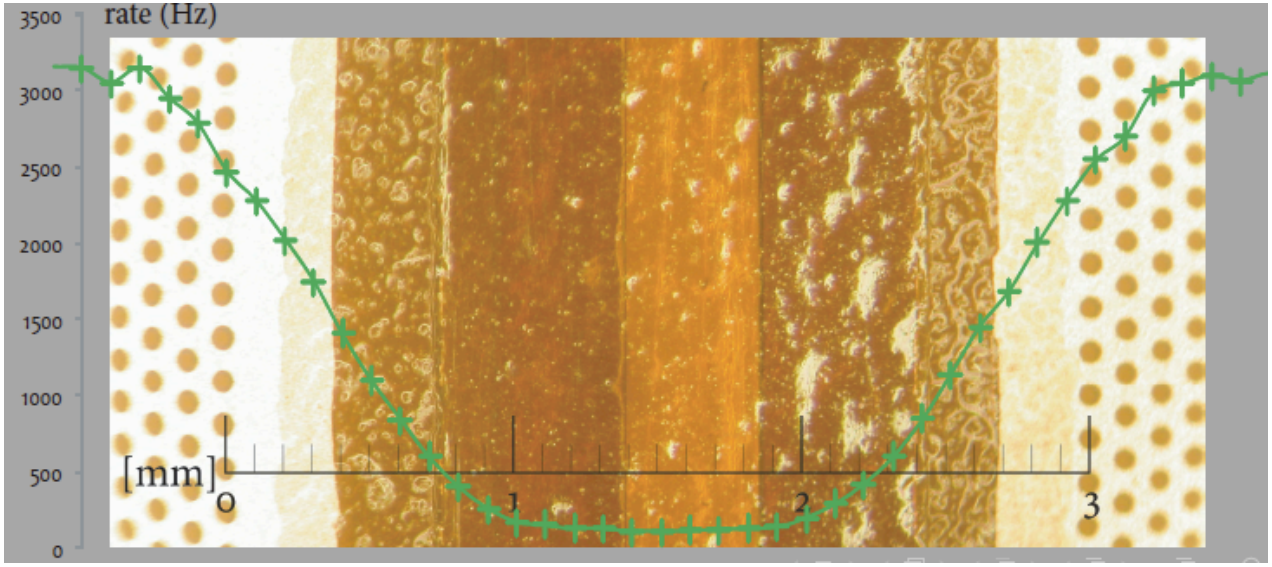


Single Mask technique allows to make GEM foils as large as 200 cm x 50 cm

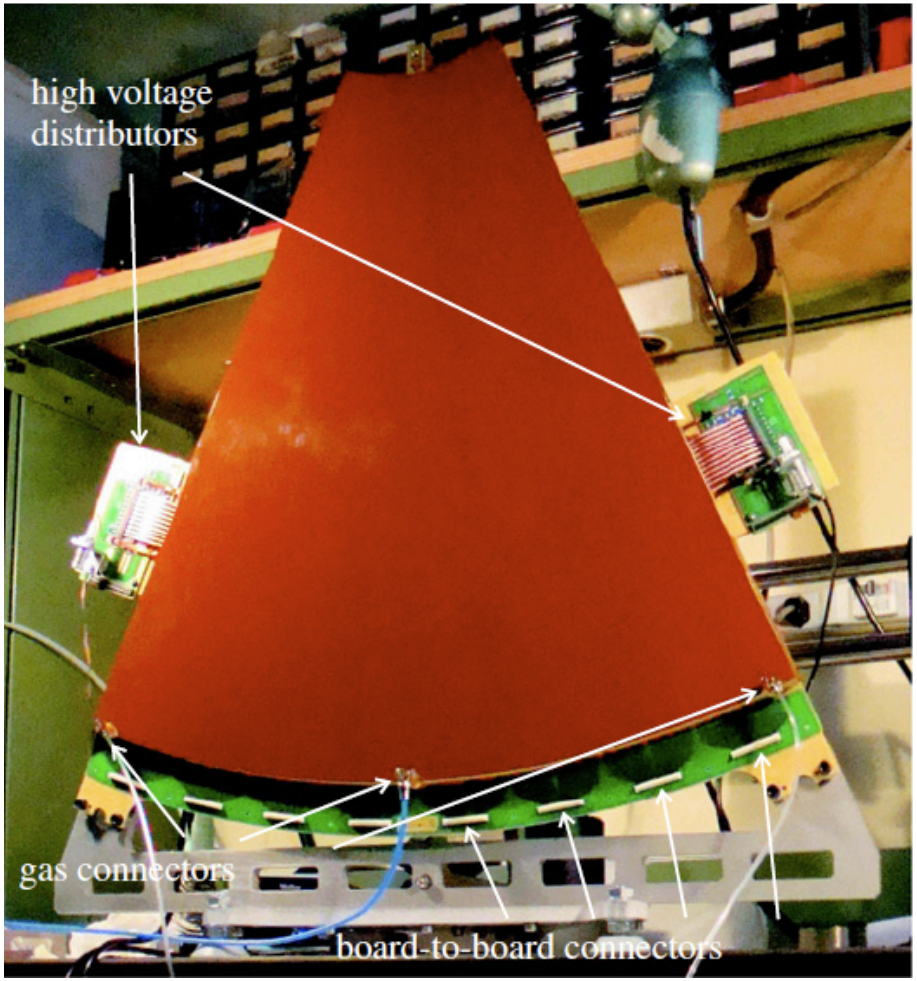
# Major recent development towards large GEM foils

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



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



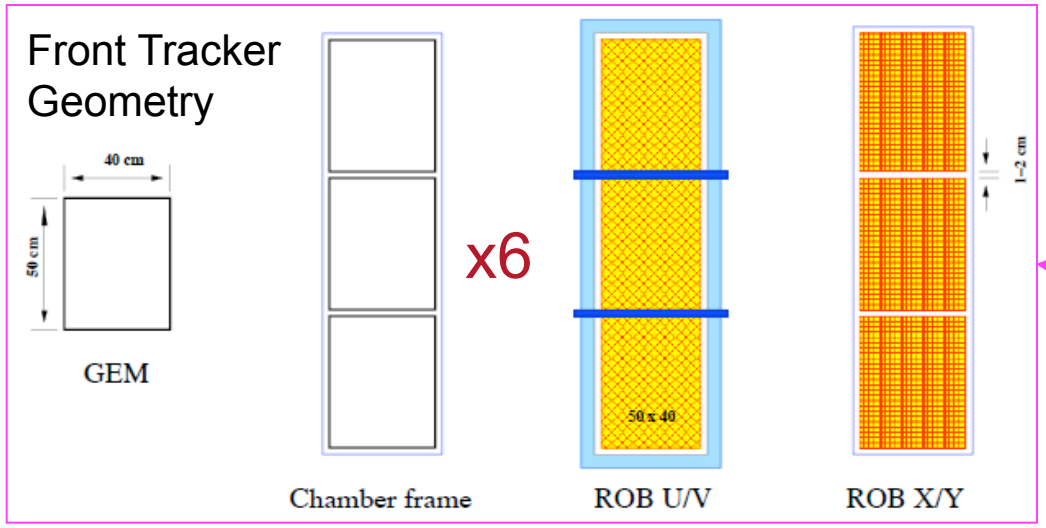

- Base material up to 51.4 cm wide now available
- CERN plans to buy equipment capable of producing 200 cm x 50 cm GEM foil.

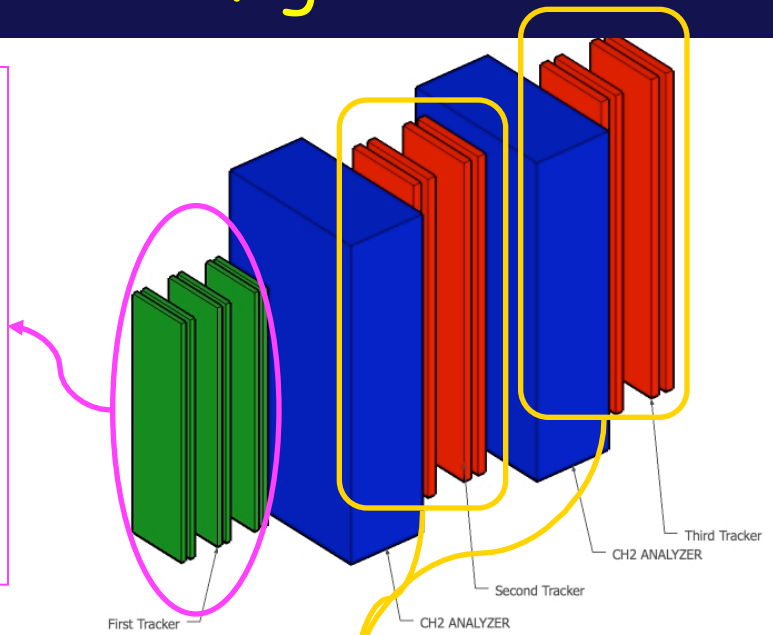
This combined with Splicing: 200 cm x 100 cm GEM foil may be possible in the next two years

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

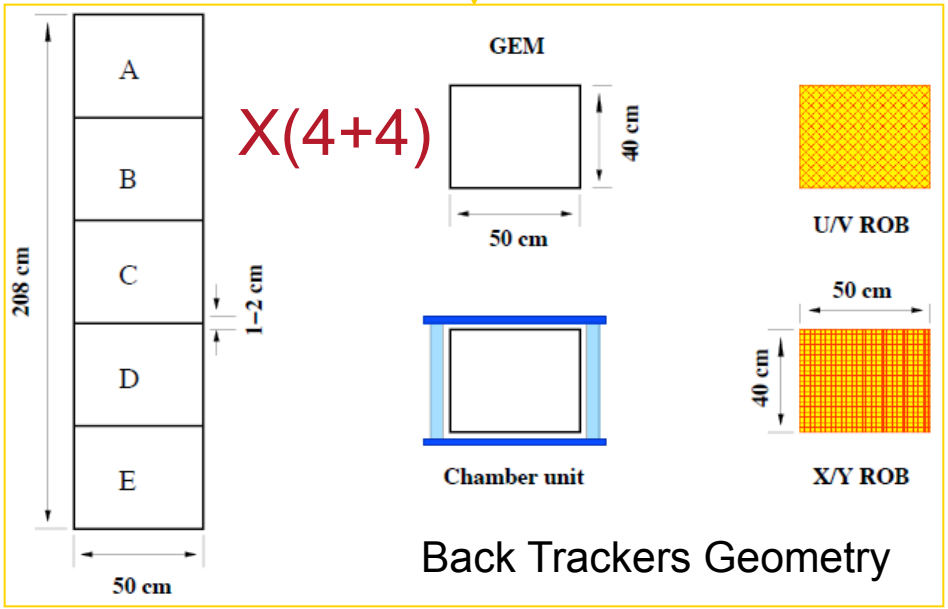
*M. Alfonsi et al. / Nuclear Instruments and Methods in Physics Research A 617 (2010)*

# 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**



# SBS Tracker Chambers configuration

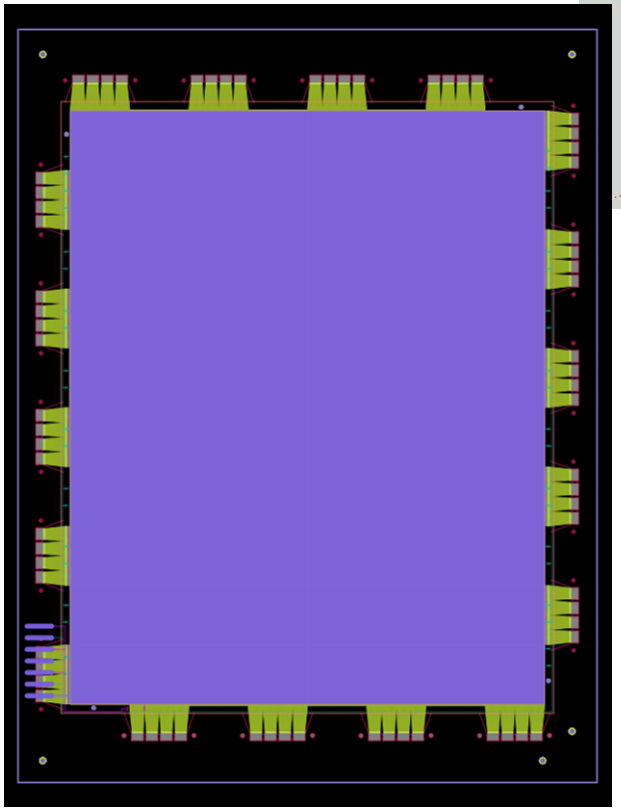
| Tracker | Area ($cm^2$) | Number of Chambers | Readout | Pitch (mm) | Modules/ Chamber | Total Modules | Total Readout Channels |
|---|---|---|---|---|---|---|---|
| FT | 40x150 | 6 | 2D<br>4(x/y)<br>2(u/v) | 0.4 | 1×3 | 18 | 49000<br>+<br>13500 |
| ST<br>+<br>TT | 50x200 | 4 + 4 | 2D<br>2(x/y)<br>2(u/v)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

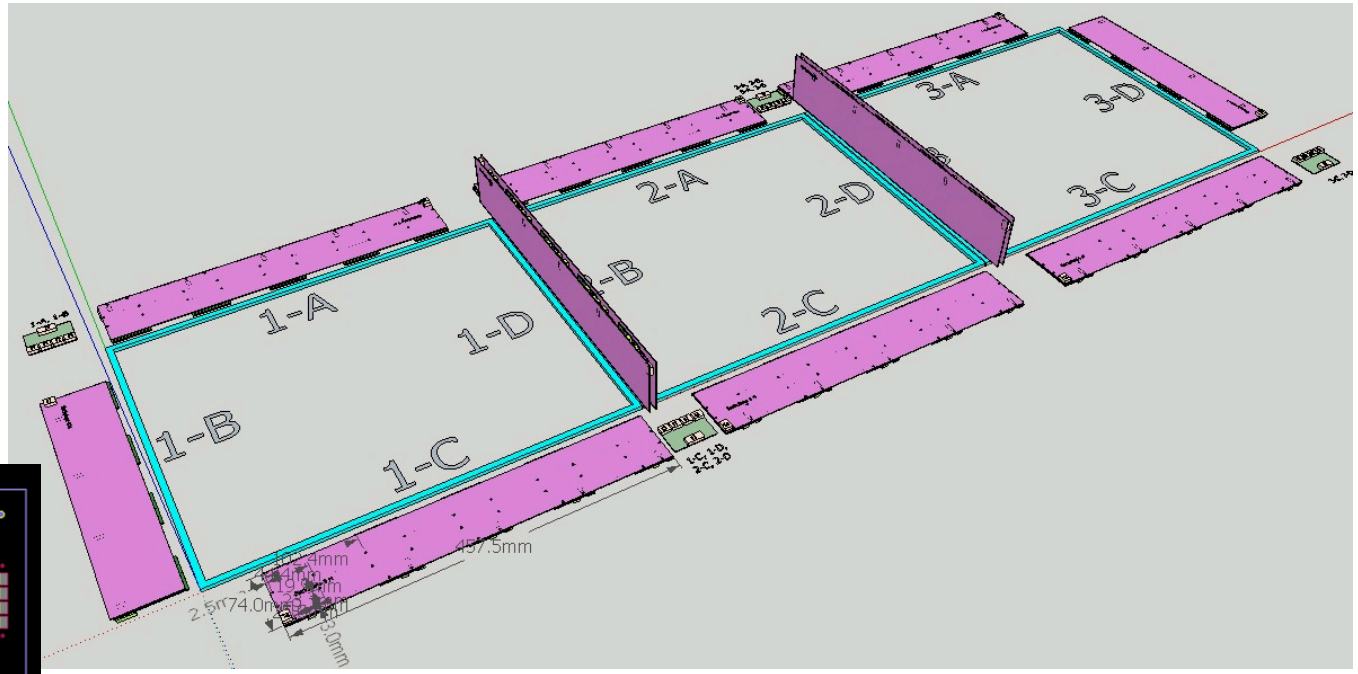
**Total chs. 101700**

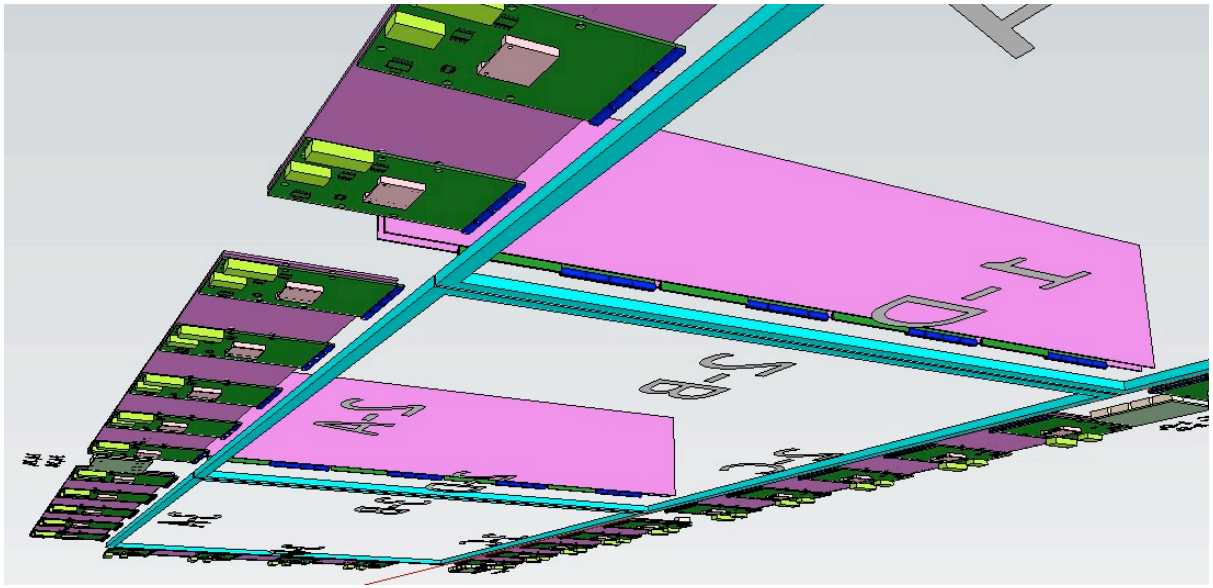
Total area ~ 16.5 $m^2$

Cost estimate ~ $ 3.2 M

# Key to Segmentation: making dead areas as narrow as possible



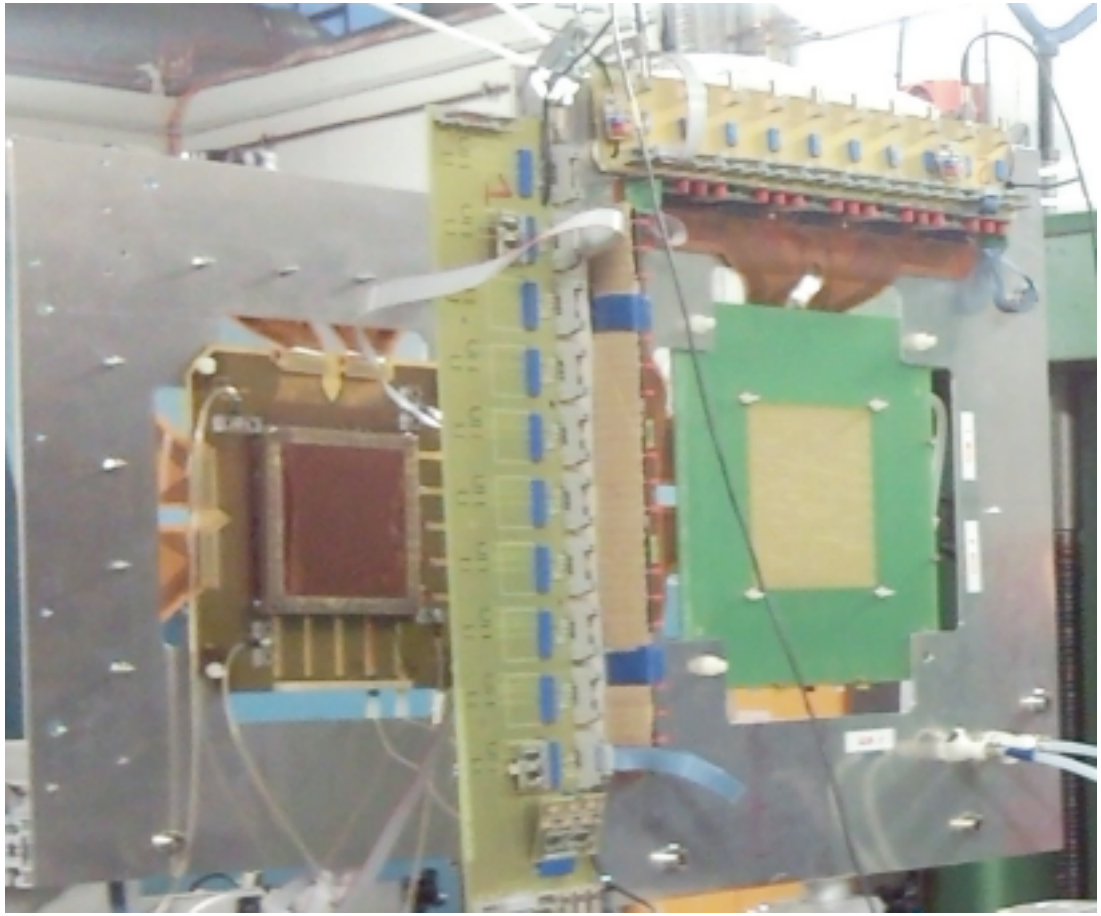


# SBS GEM chamber prototyping

- 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.



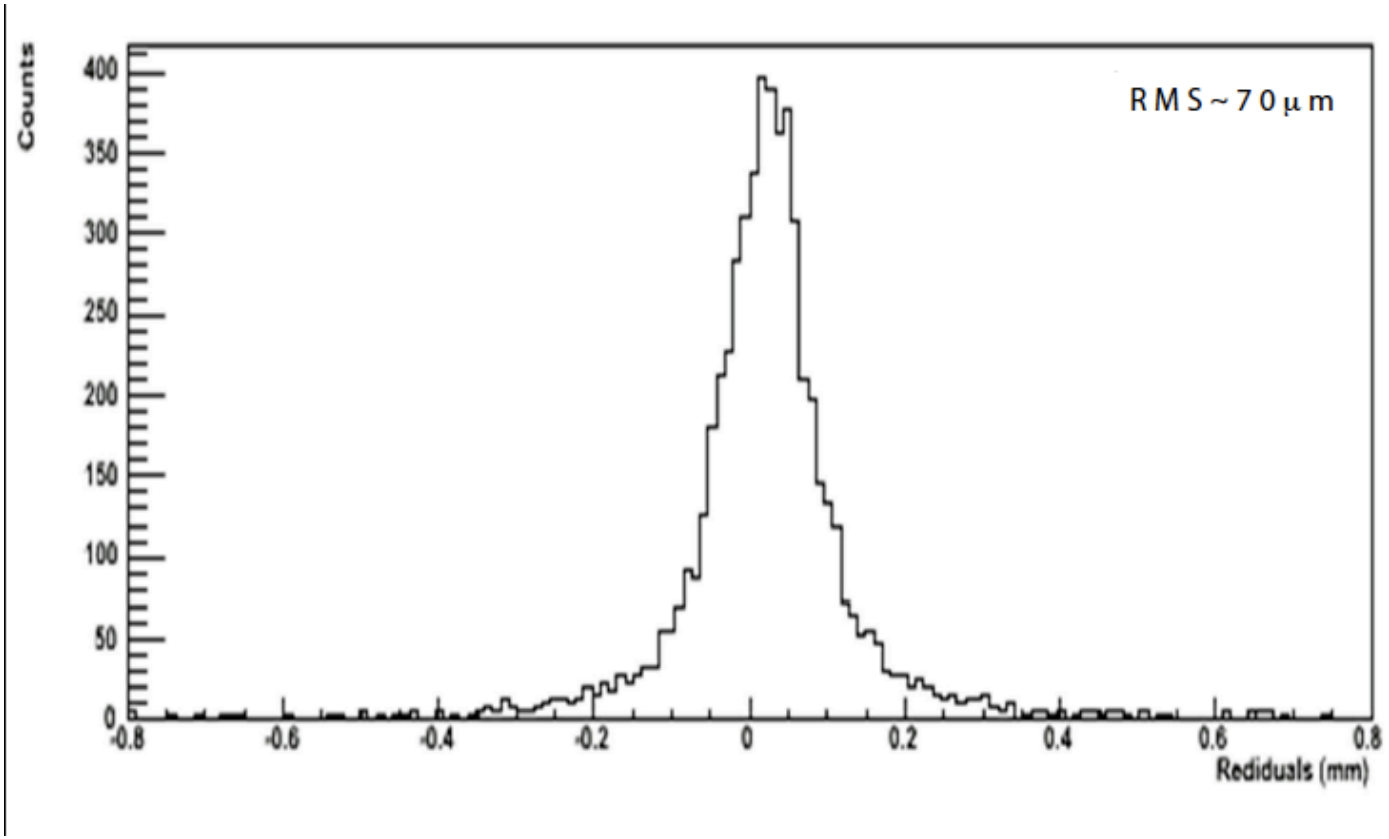
Topics to study

- 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.

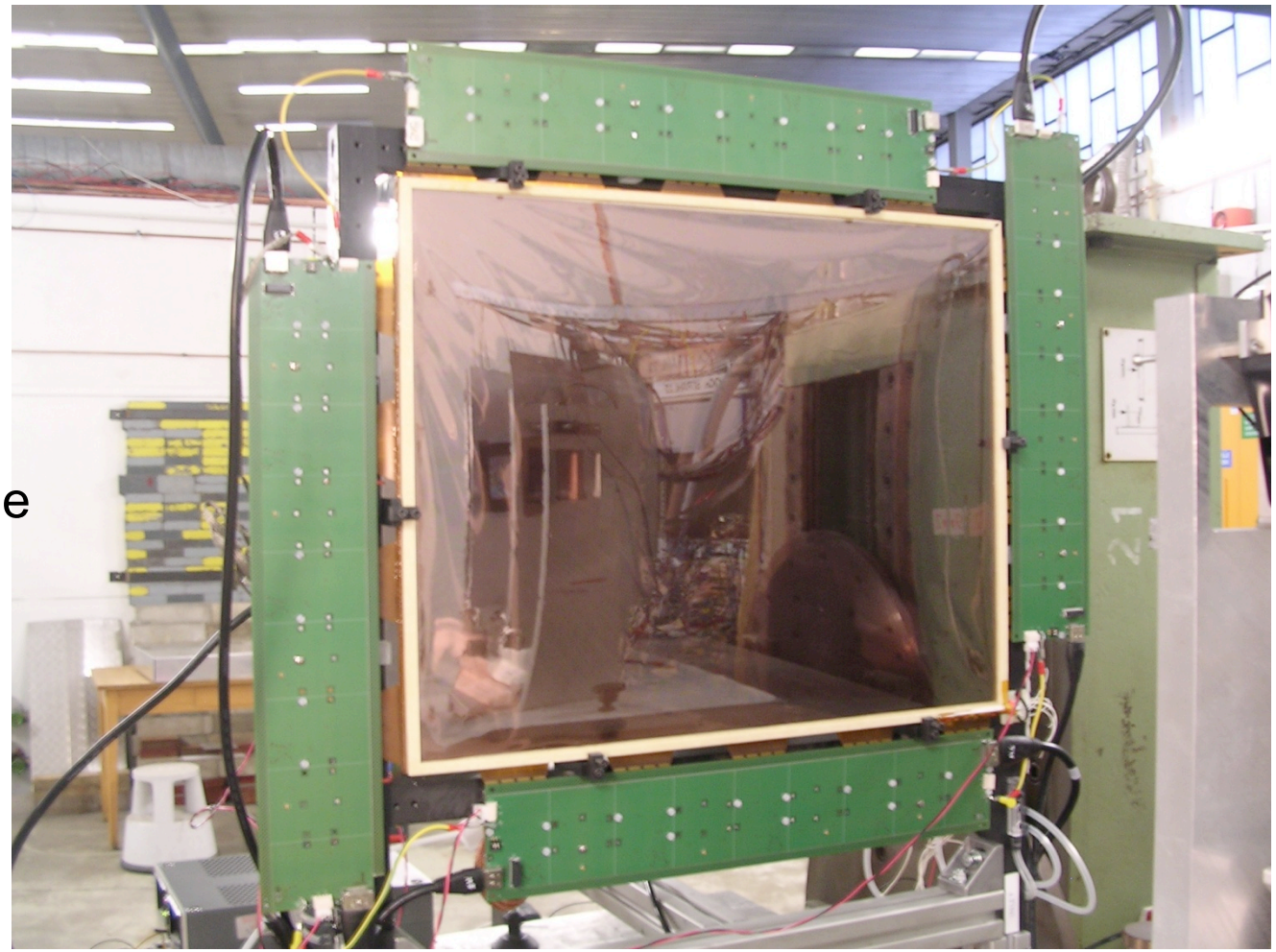


# Beam test @ DESY (EUDET support)

- 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**

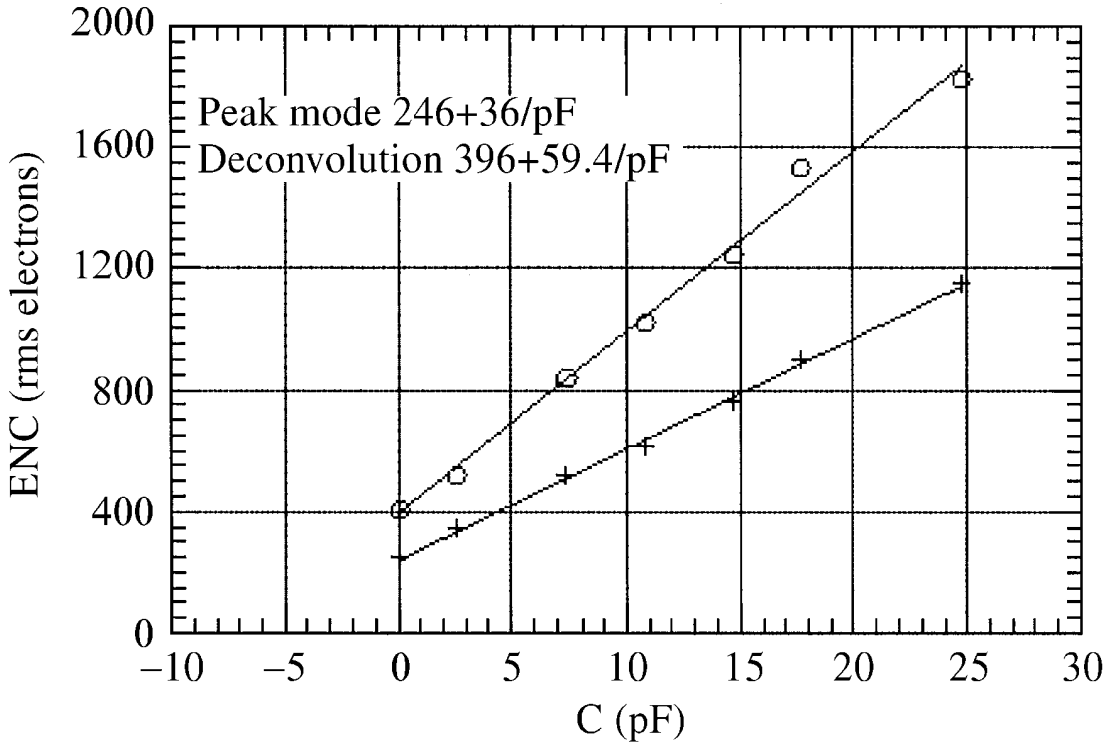
# Hardware infrastructure ready for GEM testing

- A 3000 chan. APV25-S1 readout system ordered , will be ready by June: 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.

# Important things to do now

- Construct a large area GEM chamber approaching the size of a Solid;  ~ 0.5 x 1 m; study and test.
  - Have the infra-structure ready for testing.
  - Need to get some detector R&D money
- Optimize the readout plane: the pitch and the readout strip size.
- Identify readout electronics
  - No more APV25 chips left in the world
  - Define our needs, rate, resolution etc.
  - Look for other similar chips, and their availability.
  - Or design our own and find a manufacturer




| Tracker | Strip length | Capacitance (pF) | ENC ($e^-$) |
|---|---|---|---|
| Front tracker (shortest stripes) | 1 cm | $\sim$ 1 pF | $\sim$ 300 $e^-$ |
| Front tracker (longest stripes) | 70 cm | $\sim$ 20 pF | $\sim$ 1000 $e^-$ |
| Back trackers (4 stripes combined) | 280 cm | $\sim$ 80 pF | $\sim$ 3100 $e^-$ |
| Coordinate detector (1-D readout, 4 stripes combined) | 4 m | $\sim$ 36 pF | $\sim$ 1500 $e^-$ |

- Assume largest dimension of GEM foil ~150 cm x 50 cm

| Plane | Z | $R_I$ (cm) | $R_O$ (cm) | Total Area ($m^2$) | inner circumference | outer circumference | Chamber segments |
|---|---|---|---|---|---|---|---|
| 4 | 120 | 39.0 | 87.2 | 1.9 | 245 | 548 | 8 |
| 5 | 150 | 48.7 | 109.0 | 3.0 | 306 | 684 | 16 |
| 6 | 190 | 61.7 | 138.0 | 4.8 | 388 | 867 | 32 |
| 7 | 290 | 94.2 | 210.7 | 11.2 | 592 | 1323 | 32 |
| 8 | 310 | 100.7 | 225.2 | 12.7 | 633 | 1414 | 32 |
| total: | | | | 33.6 | | | 120 |

# rough cost estimate

| Item | Quantity | Unit cost | Total cost | Material only unit cost | Material only total cost |
|---|---|---|---|---|---|
| GEM foil | ~100 $m^2$ | \$3000/$m^2$ | 0.3 M | \$3000/$m^2$ | 0.3 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 | 300 k | \$ 7.0 | 2.1 M | \$ 4.0 | 1.2 M |
| cables, power, etc | | | 0.5 M | | 0.5 M |
| Gas system | | | 0.1 M | | 0.1 M |
| Labor: Technicians | 12 FTE-years | \$ 80 k | 1.0 M | \$ 80 k | - |
| Labor: Grad students | 6 student-years | \$ 50 k | 0.3 M | \$ 50 k | - |
| support structure and integration | | | ??? | | ??? |
| **TOTAL:** | | | **~ 5 M** | | **~ 2.7 M** |
| **With 33% contingency** | | | **~6.7 M** | | **~3.6 M** |

R&D and prototyping expenses: ~ \$ 200 k ( ~ \$ 60 k year 1, ~ \$ 140 k year 2)

# PVDIS with SOLID