Quality assurance of TOTEM T2 GEM detectors

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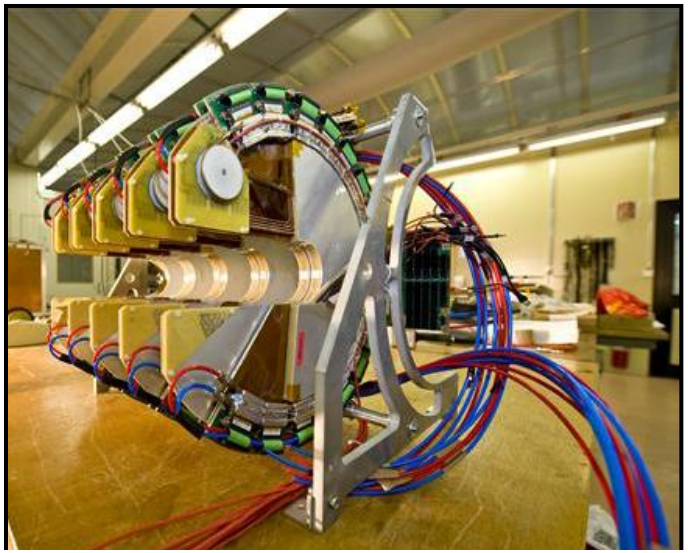
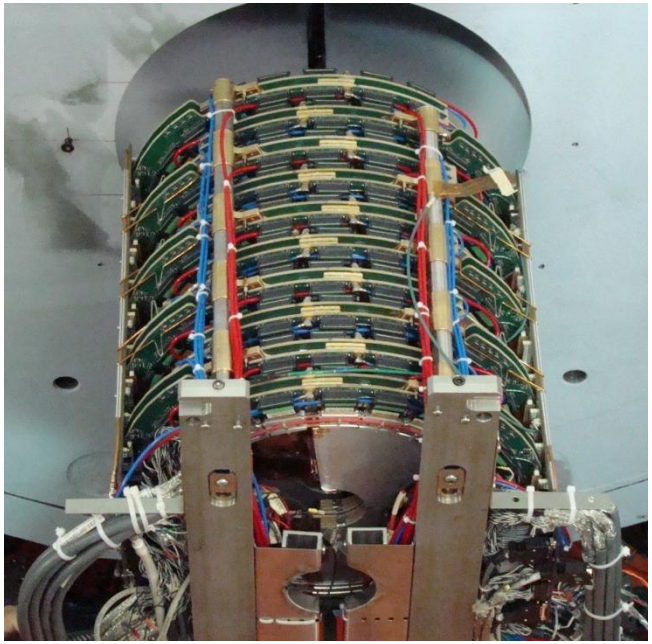
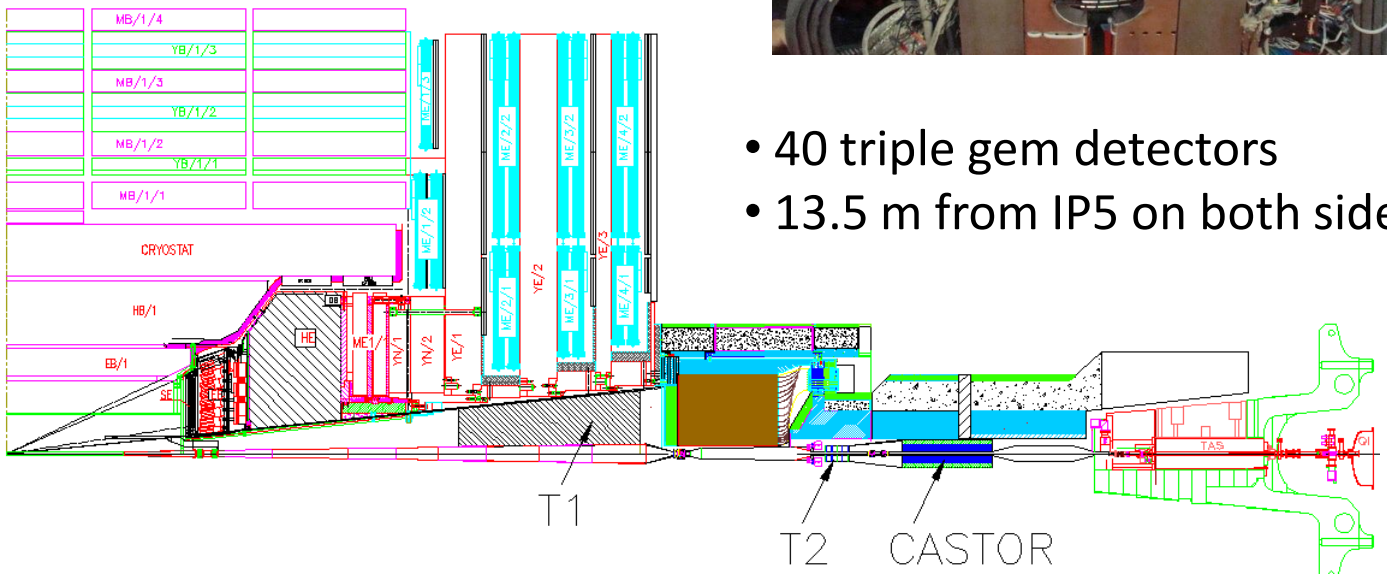
Totem T2







IP5

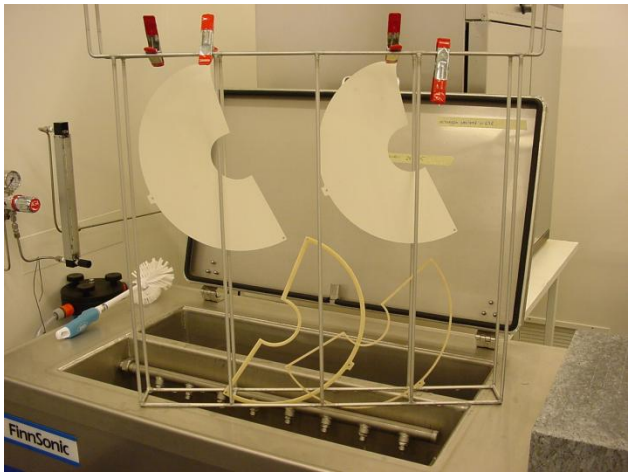
- 40 triple gem detectors
- 13.5 m from IP5 on both sides

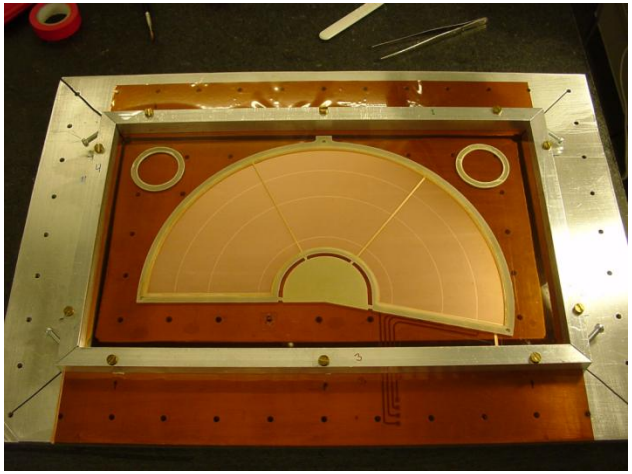
Assembly

- Big production for Detector Laboratory in Helsinki
- Focus in clealiness of the process
- Full production line was set up in a class 1000 cleanroom prior assembly. Foils were mostly handled in class 100 cleanroom
- Storage of gem foils and readout boards in dry nitrogen atmosphere

Frames

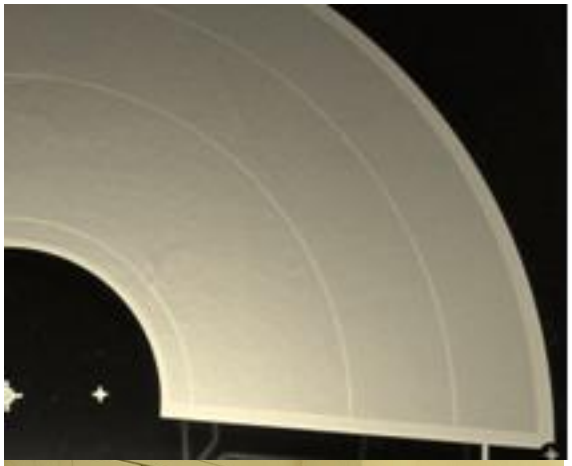
- Cleaning in ultrasonic bath
- Fibers sticking out from the frames after machining - Nuvovern coating
- High voltage tests with 5000 V after Nuvovern tratment
- Foils were stretched with a special stretcher for framing
- Foil tension samples taken occasionally on ring-like frames

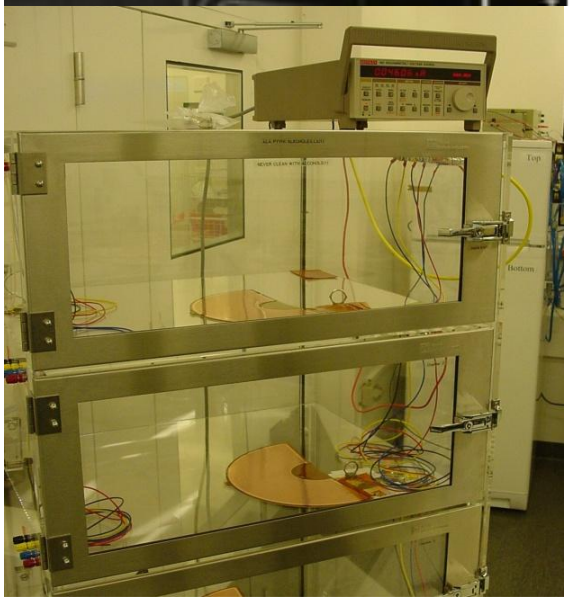




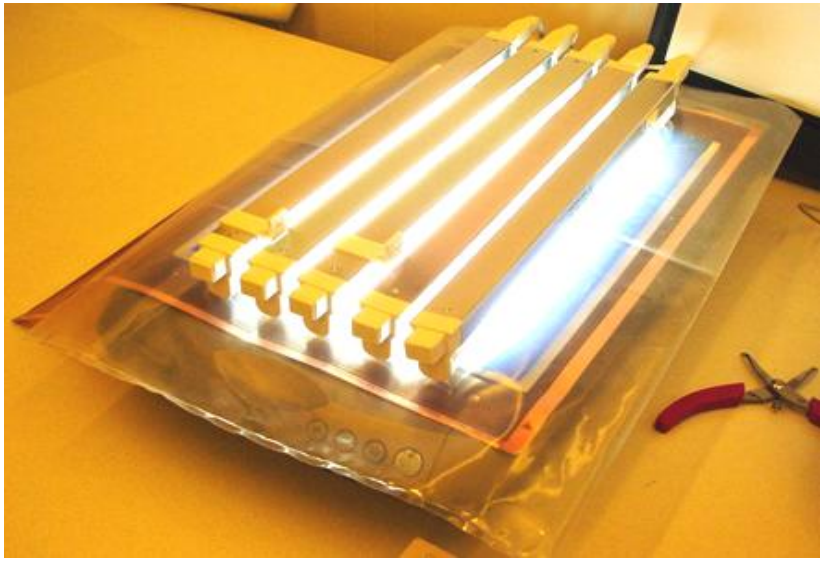
Foils

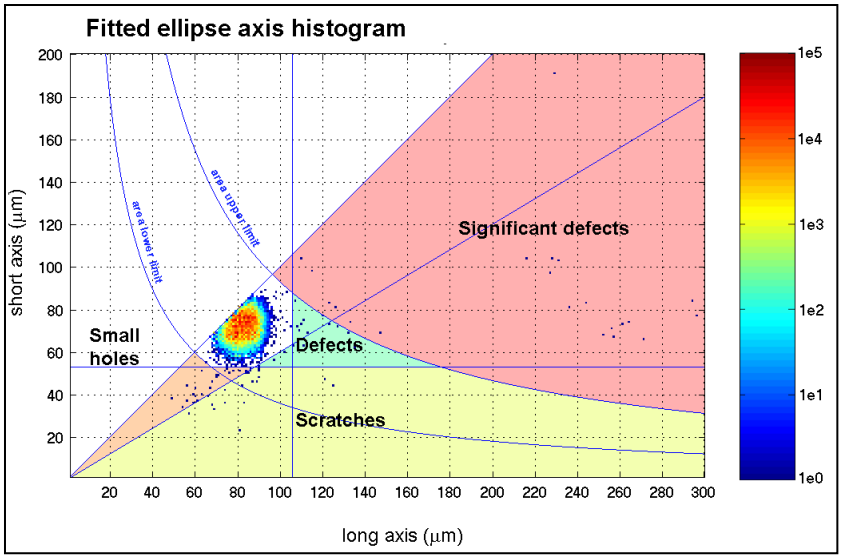
- Gem foil leakage currents were tested in 3 phases of the assembly: Upon arrival, after framing and once the stack was glued together – 36 measurements per detector
- Measurements in dry nitrogen atmosphere inside dessicator
- Approval criterion was set to $I < 0.5$ nA for at least 30 minutes with 500V over the foil
- Perhaps best indicator of foil performance in the operation tests



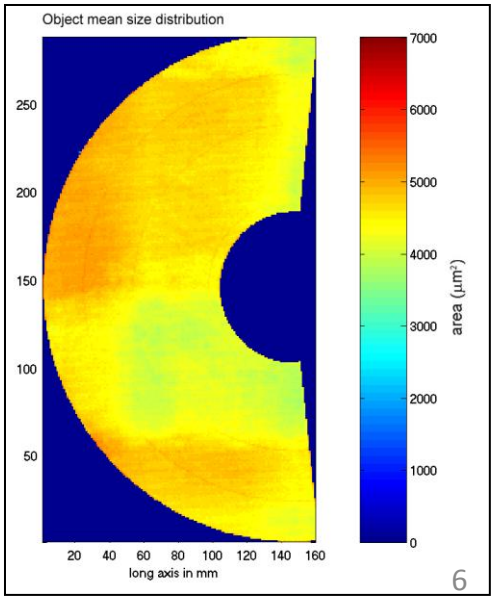


Foils



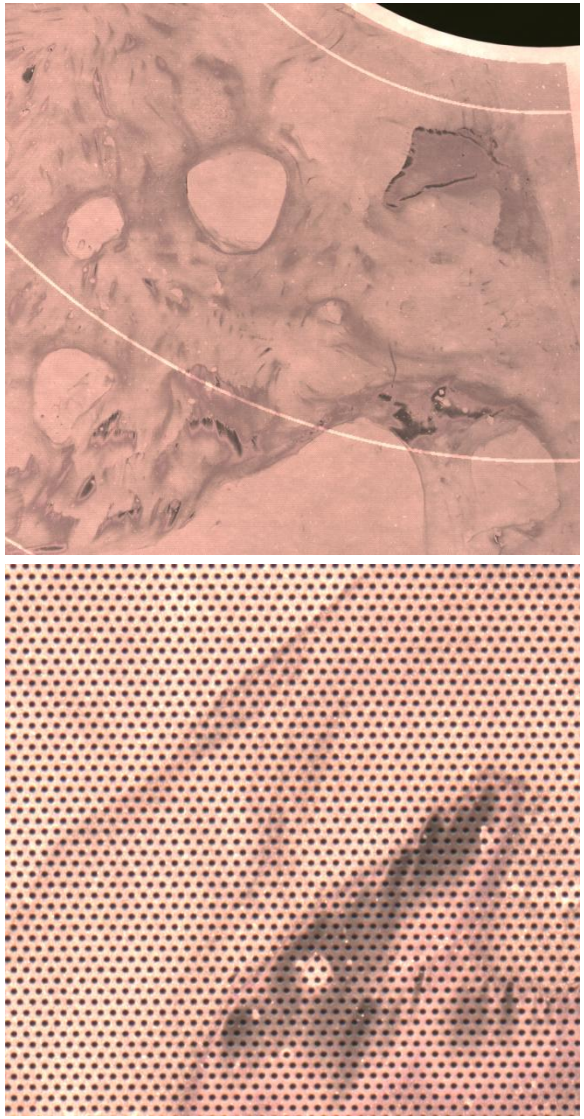


- Optical scanning method was developed utilizing Commercial flatbed scanner with blue diffuser and a background lighting setup
- scanning with resolution of 2400 dpi – pixel size ~10 μm.
- Images archived for later inspection
- more sophisticated system was developed later



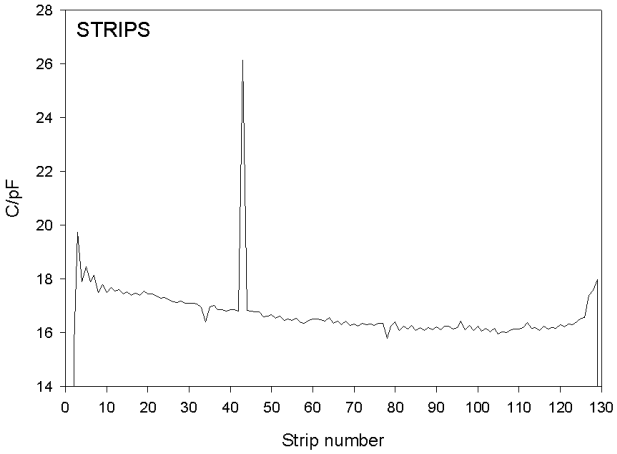
Foils

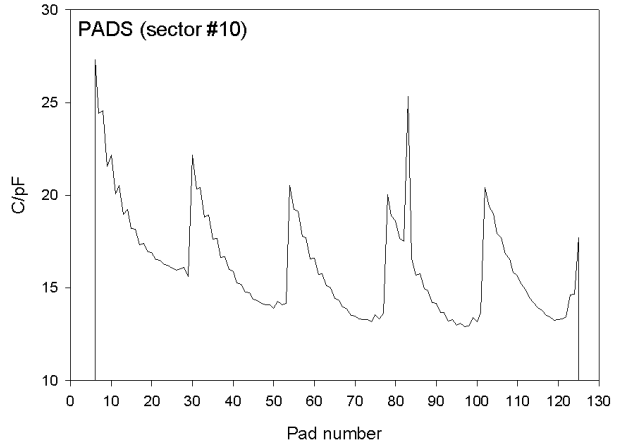
- Few foils had a short circuit
- Some were found dirty and discarded by visual inspection only. These were sent to Cern for cleaning/passivation and recovered.
- Some shorted foils were cured in Helsinki by baking in vacuum oven for several hours.
- 6 foils out of 150 were discarded in total



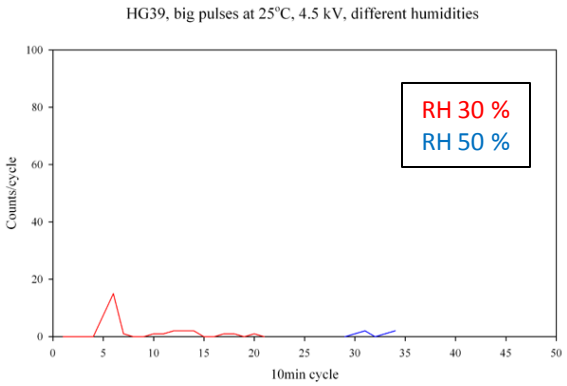
Readout boards

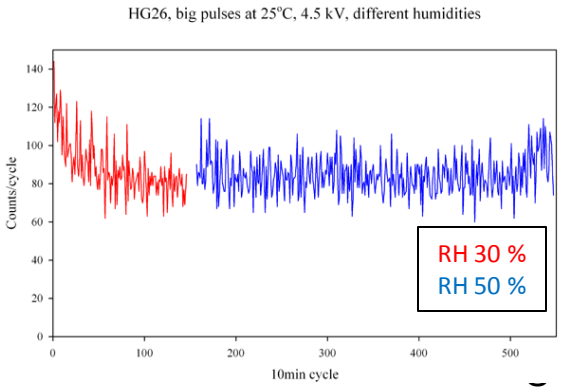
- Readout boards were tested for short circuits and broken strips/vias
- Semi automatic capacitance measurement system with LCR meter and a XYZ-table was developed
- 12 ROBs with 18 short circuits in total were found. 7 were recovered by burning the shorts
- 11 broken strips/vias on 6 ROBs were found
- 7 ROBs had problem with blocked canals for gas.
- Some ROBs had crystallized residue on the electrodes and were sent to be cleaned at Cern
- All ROBs were assembled

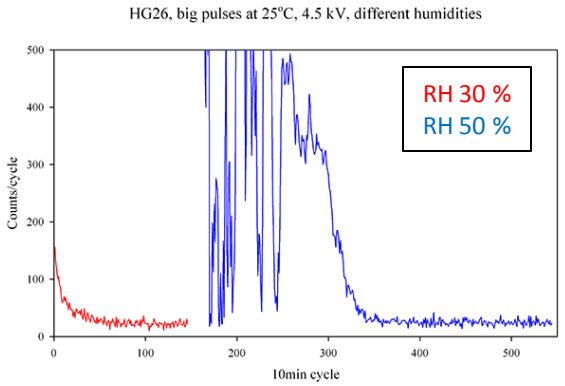




Humidity



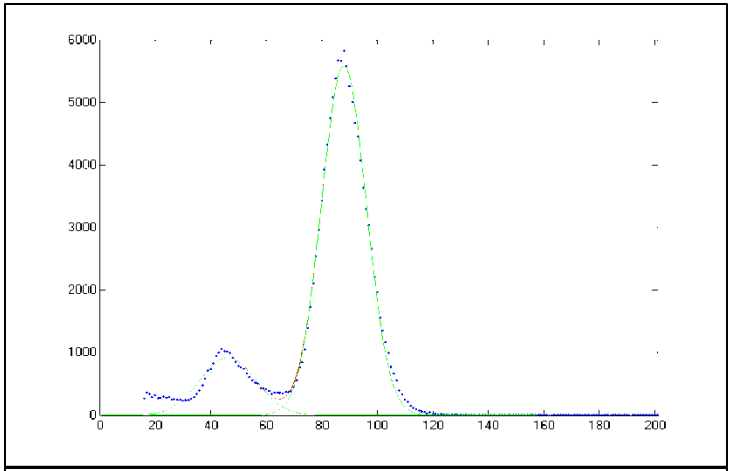


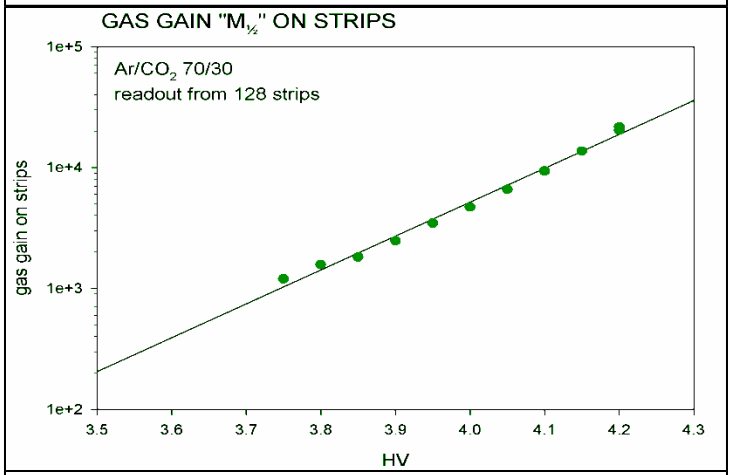


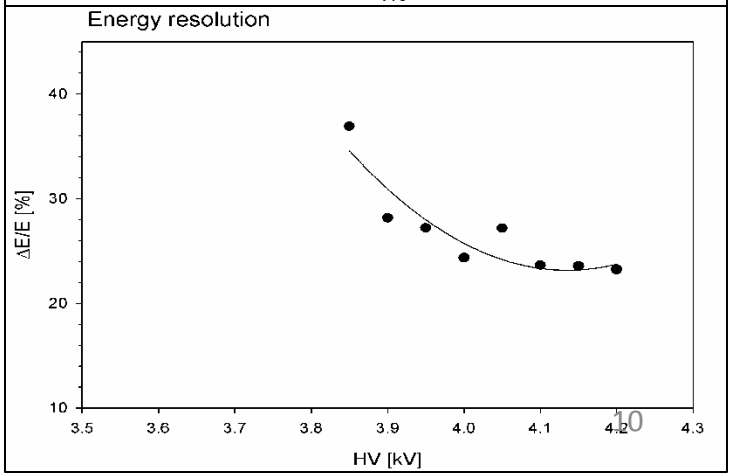
- Problems with HV system in humid conditions
- A layer of Dow Corning conformal coating was supplied over the HV board and the Polyimide HV strips outside the chamber
- Environmental chamber to test the detectors in 50% humidity with nitrogen
- Stability tested for 12 hours in 4.5 kV, eventually ramped up to 5 kV for an hour

Operation tests

- Gain uniformity and operational stability were tested before assembling of the electronics
- Gain and resolution was tested for each sector at nominal gain of 8000 (17 sectors: 4 strips and 13 pads)
- Detectors were tested with ^{55}Fe up to gain of 50000
- Irradiated with ^{55}Fe at nominal gain for at least a week to ensure stable operation
- Tests with final electronics and beam tests at Cern
- RF shielding was added to enhace noise behavior
- New voltage division – increased induction field







Assembling of a T2 GEM detector

1.	**Sandwich**	
	- ready made by CERN	0 h
2.	**Preparation of frames**	
	- cleaning/grinding	1 h
	- ultrasonic cleaning	1 h
	- drying in oven	4 h
	- nuvovern varnishing	½ h
	- curing in oven	2 h
	- HV test	½ h
3.	**GEM foils (3 pcs.)**	
	- visual inspection	1 h
	- optical scanning	1 h
4.	**Leakage current tests of the GEM foils**	
	- 3 foils, 12 segments in total	8 h
5.	**Framing of the GEM foils (3pcs.)**	
	- stretching and gluing	3 h
	- curing in oven	16 h
	- finishin the framed foils	
6.	**Leakage current tests of the framed foils**	8 h
7.	**Gluing the drift foil to the sandwich**	1 h
	- curing in oven	16 h
8.	**Assembling of the GEM stack**	
	- gluing the three framed foils	2 h
	- curing in oven	16 h
9.	**Leakage current tests of the GEM stack**	8 h
10.	**Readout board**	
	- glued to sandwich by CERN	0 h
	- visual inspection	1 h
	- soldering of the connectors	8 h
	- capacitance measurements	4 h
	- burning of the shorts	4 h ?
11.	**Gluing the readout board to the GEM stack**	1 h
	- gluing the gas adapters	
	- curing in oven	16 h
	- removal of the central disk of the ROB	
12.	**Sealing the GEM**	
	- Araldite/Dow Corning	2 h
	- curing in oven	16 h
13.	**Finishing work**	
	- assembling of the voltage divider pcb 2 h	
	- assembling the HV cable	1 h
	- connecting the gas connector	
14.	**Tests**	5 days
	- gas leaks?	
	- environmental chamber, HV-tests	
	- electronic tests	
	total:	**2-3 weeks**

Assuming all the components are available and storage in dry atmosphere!

Yield

- 6 detectors were discarded during assembly:

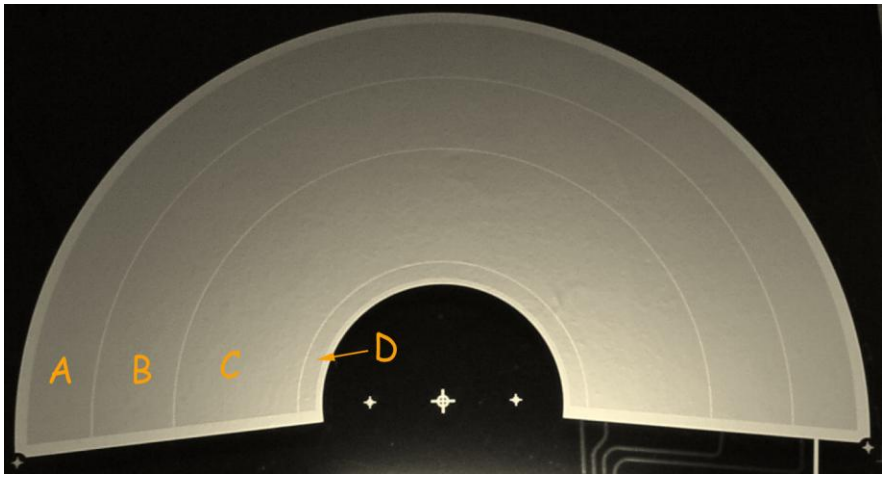
  - 2 had irreparable short circuits inside the chamber

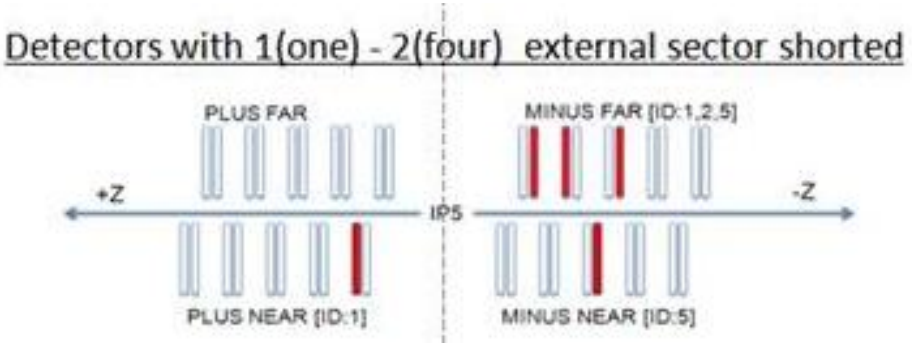
  - 2 had frequent discharges at operating voltage

  - 2 had irreparable discharges outside the chamber

Some notes on T2 performance

- Operated with huge rates down to HV system saturation, and with heavy ions runs with highly ionizing particles
- Lost sectors in 5 detectors (2 external sectors in four detectors and 1 in one) due to short circuits



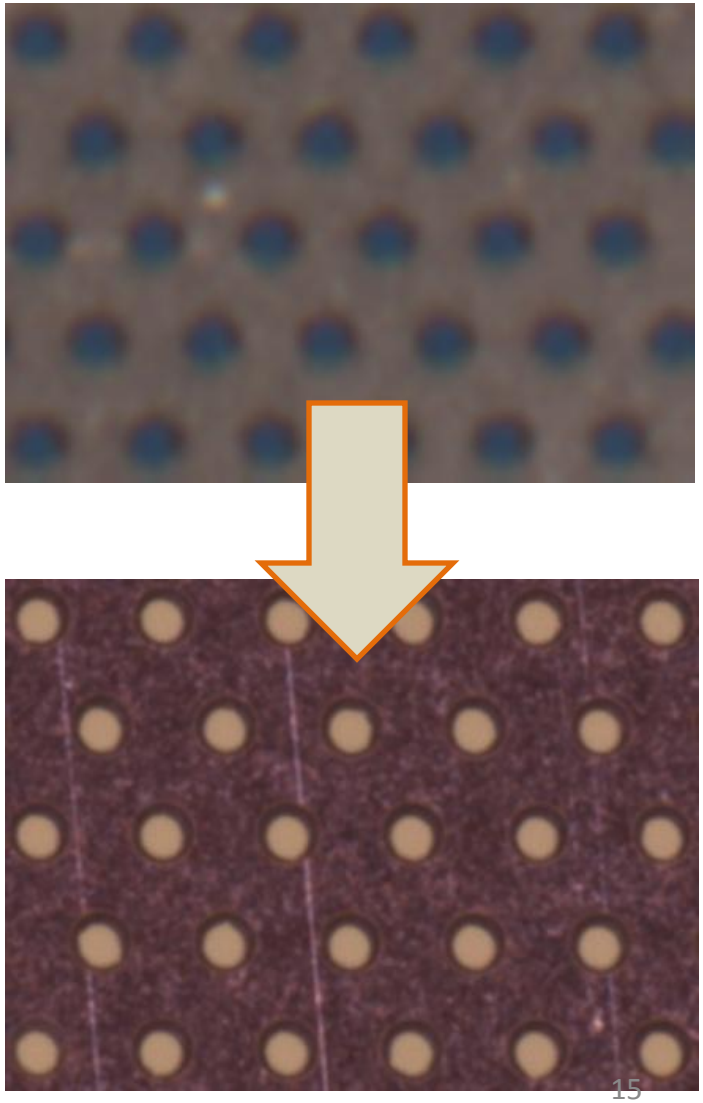


Future

- Production of 4 FAIR TPC prototypes ongoing
- Mass production (32 detectors + spares) foreseen 2016 - 2018
- Other large scale productions?
- QA procedures will be based on T2 experience, but with the new optical scanning system

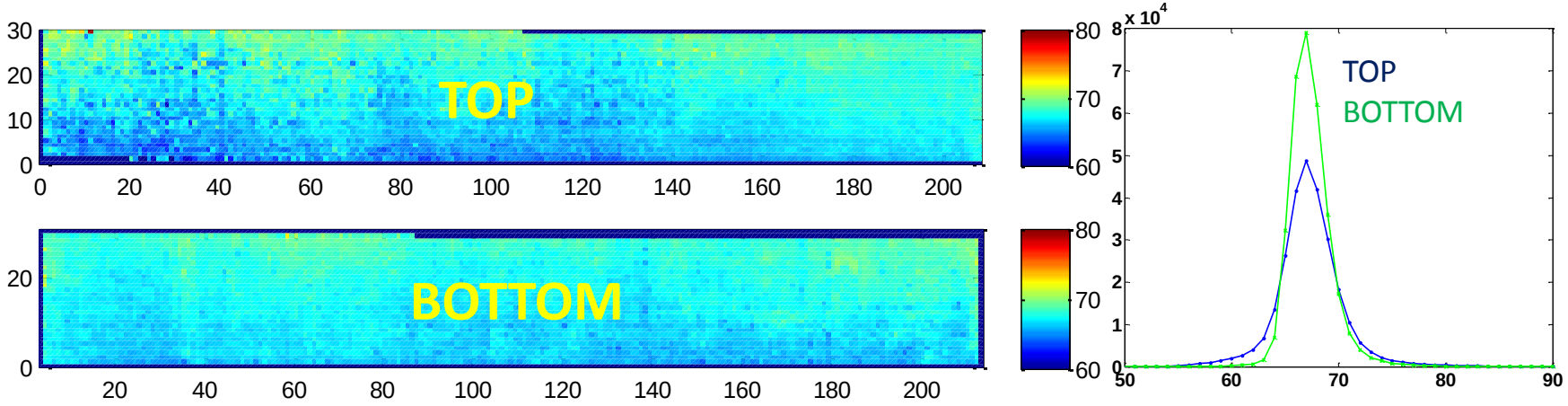
New optical scanning system

- 98 cm x 98 cm XYZ-table with camera and telecentric objective
- Single pixel 1.75 µm square. Resolution of 144 lp/mm – two lines can be resolved if the separation between them is 7 microns
- Analysis software with object classification and stitching of separate images
- Find etching defects, measure hole diameter, pitch etc. Useful for QA in gem detector construction
- Other measurements like hole shape or inner and outer hole alignment for QA in gem foil manufacturing?

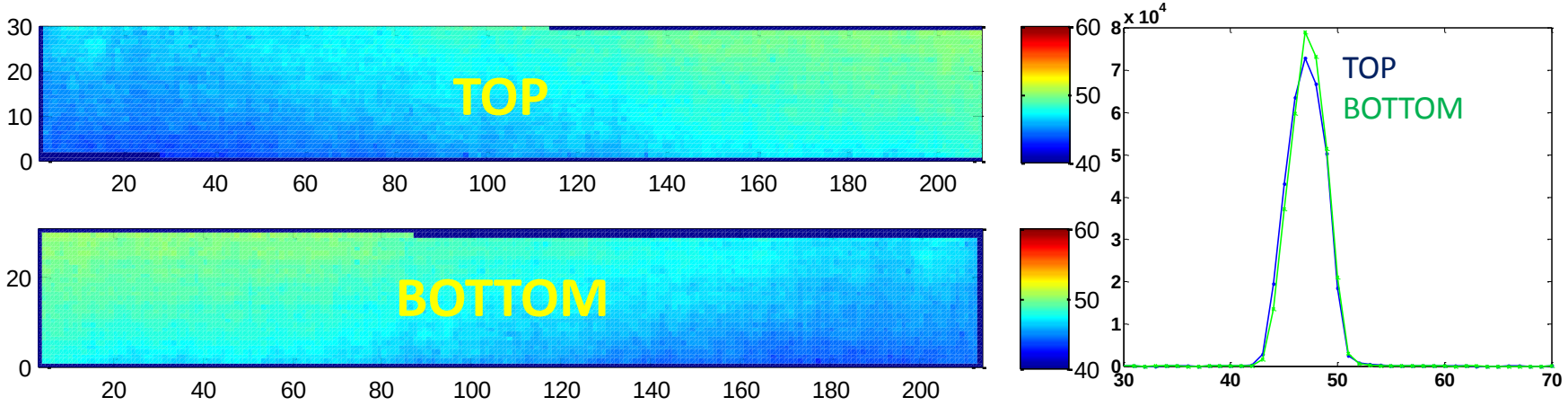


Hole size

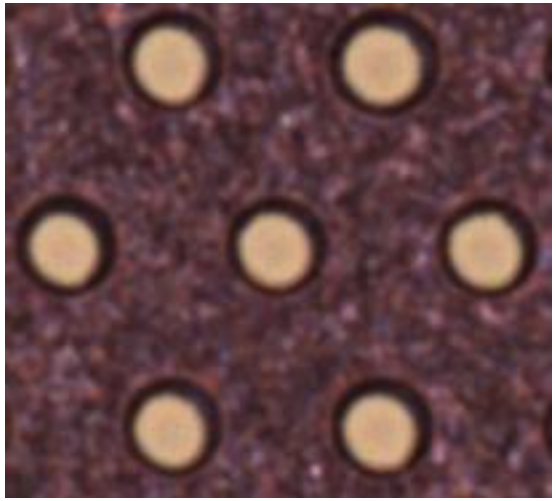
Outer hole diameter

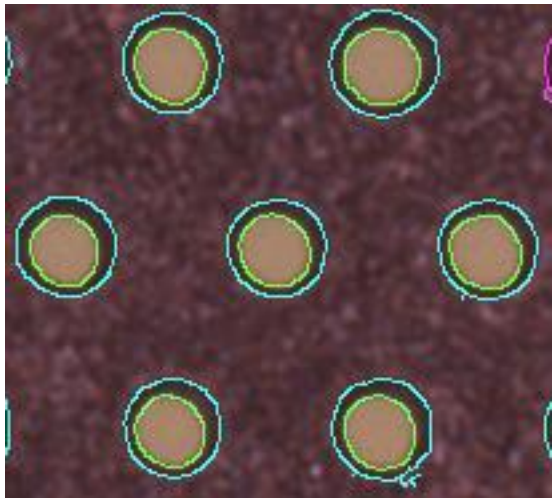


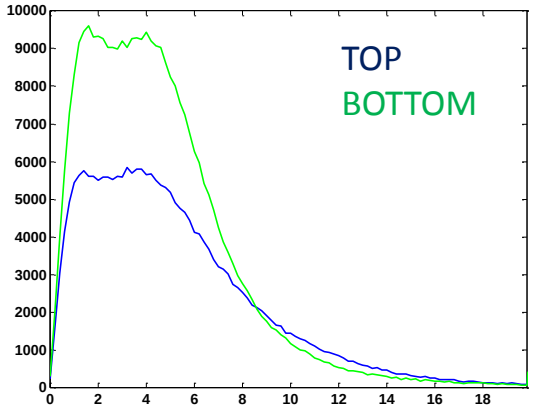
Inner hole diameter



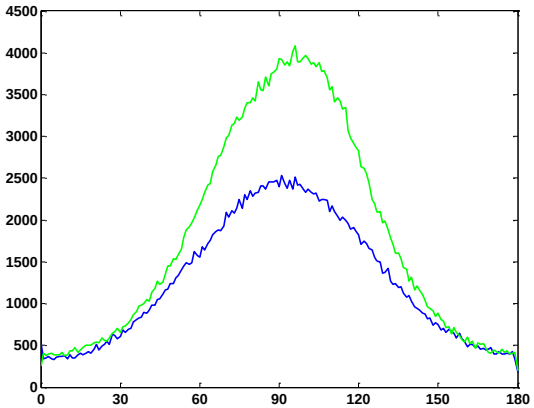
Hole shape







Difference between major and minor axes [µm]



Major axis angle from horizontal [Deg]