TOTEM GEM assembly and quality control procedures

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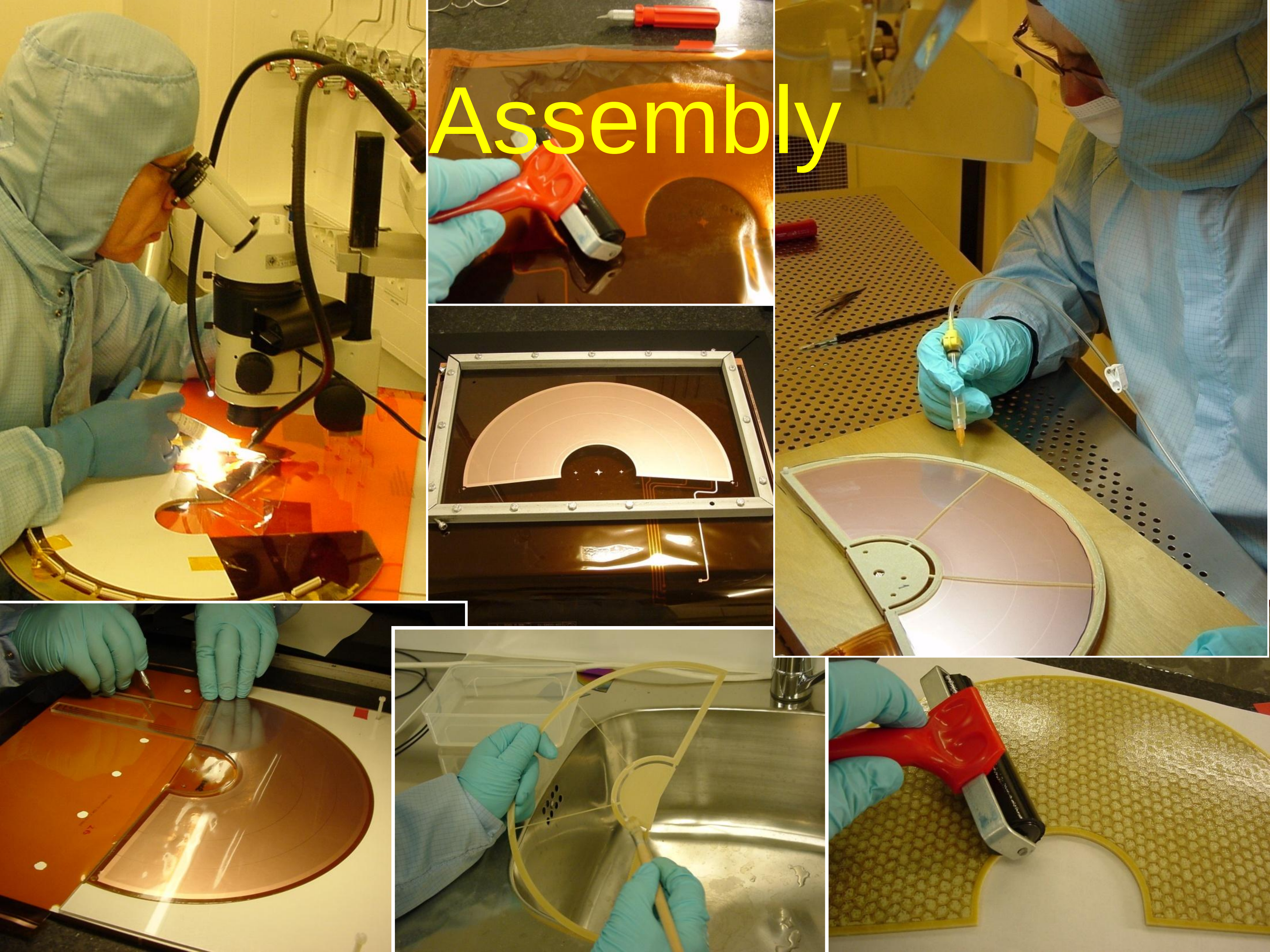
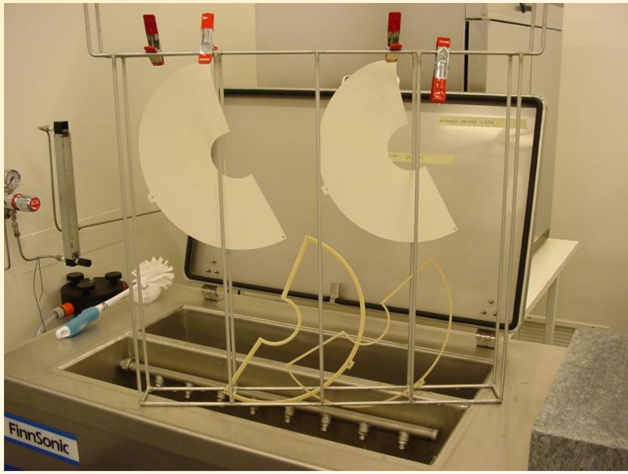
Assembly



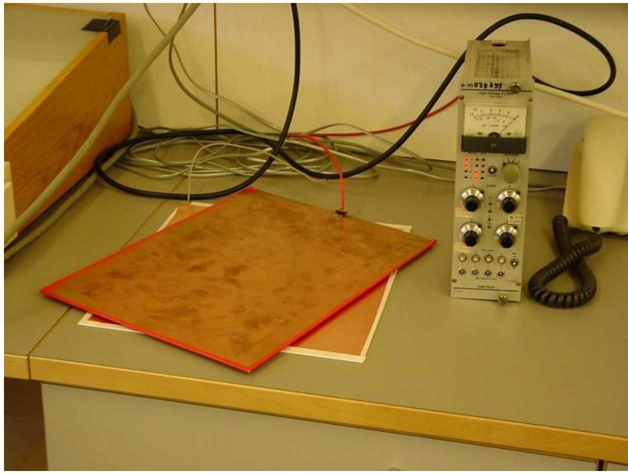
Cleaning and testing of frames and skins

- cutting and finishing of the frames in a separate room next to clean room
- cleaning in ultrasonic bath (di-water+1%IPA)



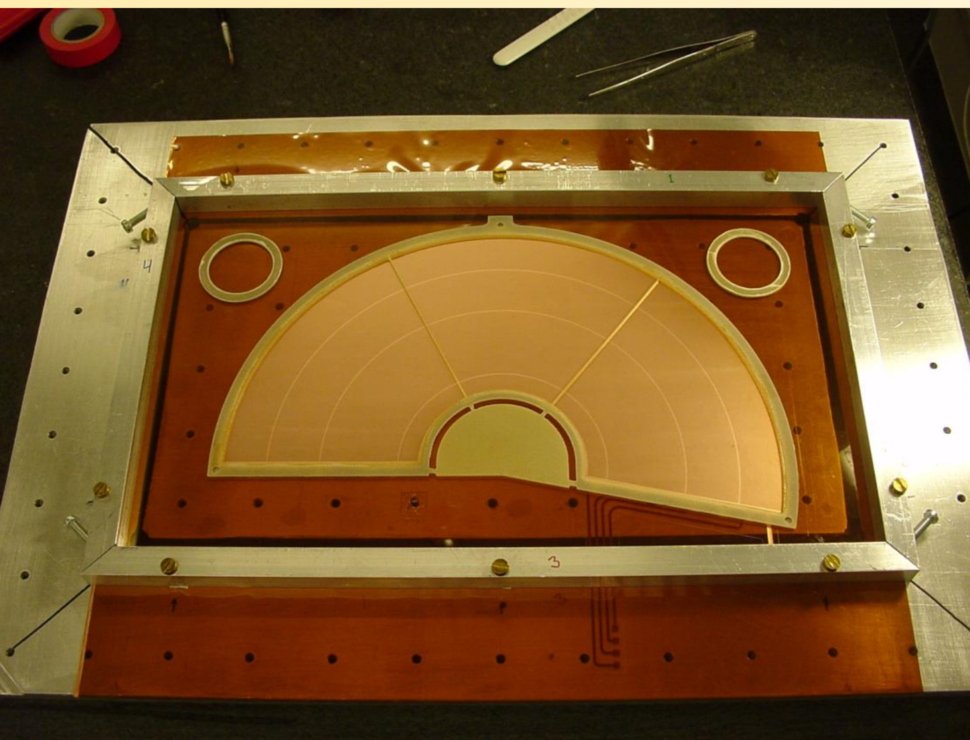
- baking in an oven for several hours @ 60°C (also in vacuum if needed)

- high voltage test @ 5000 V in air before and after Nuvovern treatment



Gluing of the frames

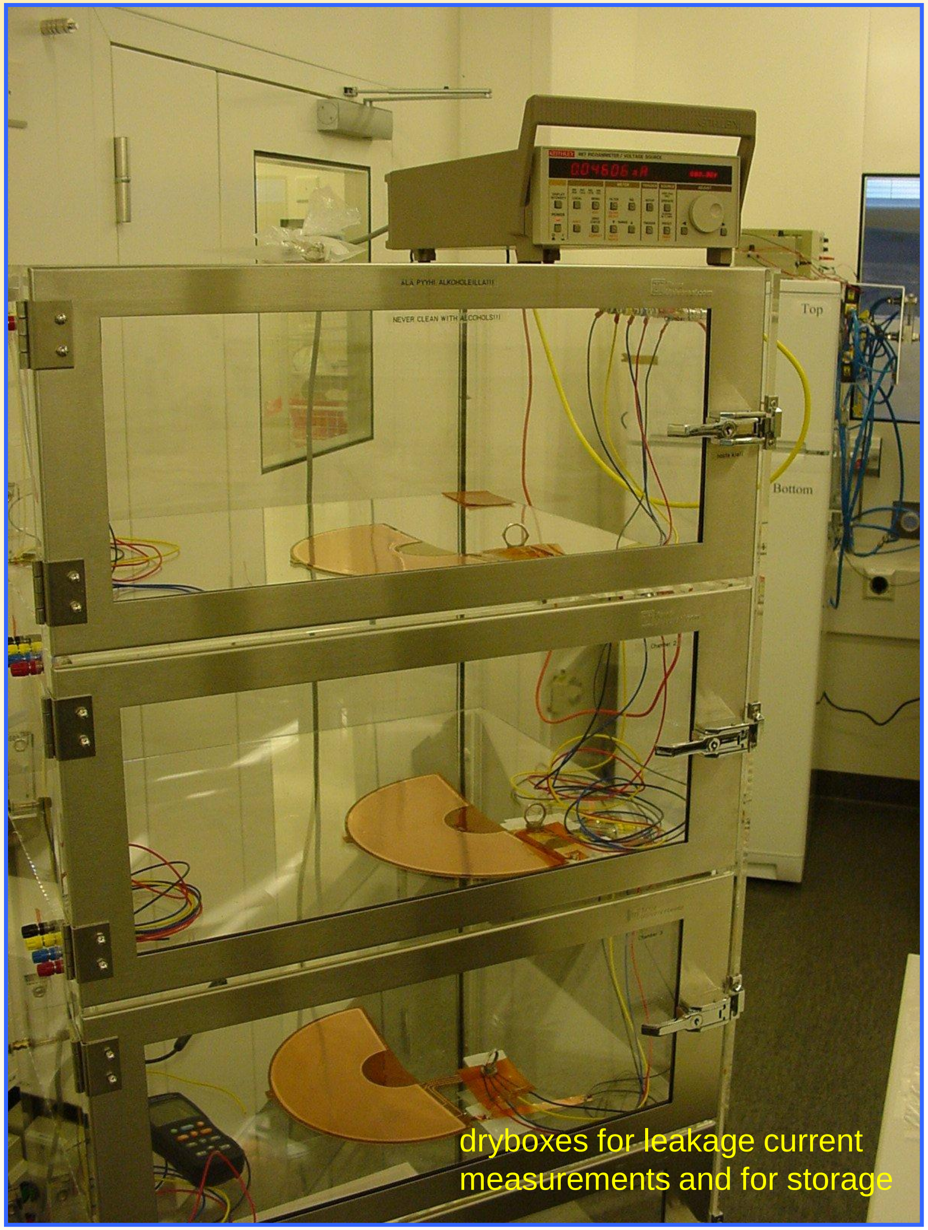
- Araldite AY103+HD991 two component epoxy supplied by glue dispenser (mixing ratio 10:4)
- Amount of glue used is monitored



- foils streched by a special stretcher
- curing in an oven > 16 hours
- tension samples taken occasionally on ringlike laminates

Testing of GEM foils

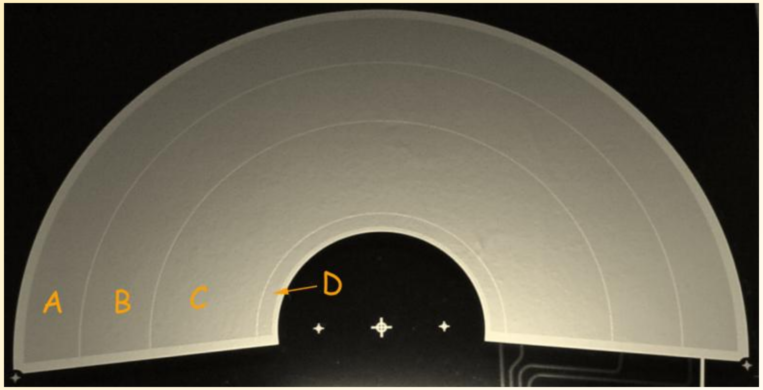
- storage of the GEM foils in a dry atmosphere.
- parallel measurements of leakage currents of several foils.
- leakage currents are measured three times during different assembling stages (as a foil, on the frame and in the GEM).
- Optical scanning and computer based analysis of foils.



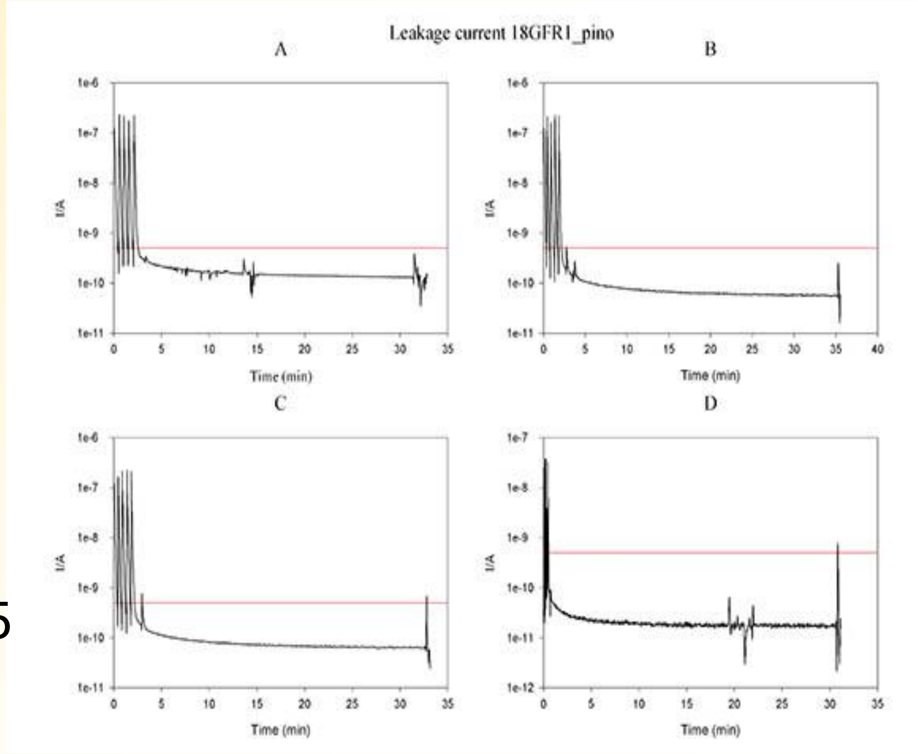
dryboxes for leakage current measurements and for storage

Leakage current measurements of GEM foils

- the four segments (A,B,C & D, see Fig.) of the GEM foils are measured separately by Picoamp /Voltage source device (Keithley 487).



- leakage currents measured three times during assembly (as a bare foil, after framing and after gluing into a stack). 36 measurement / detector

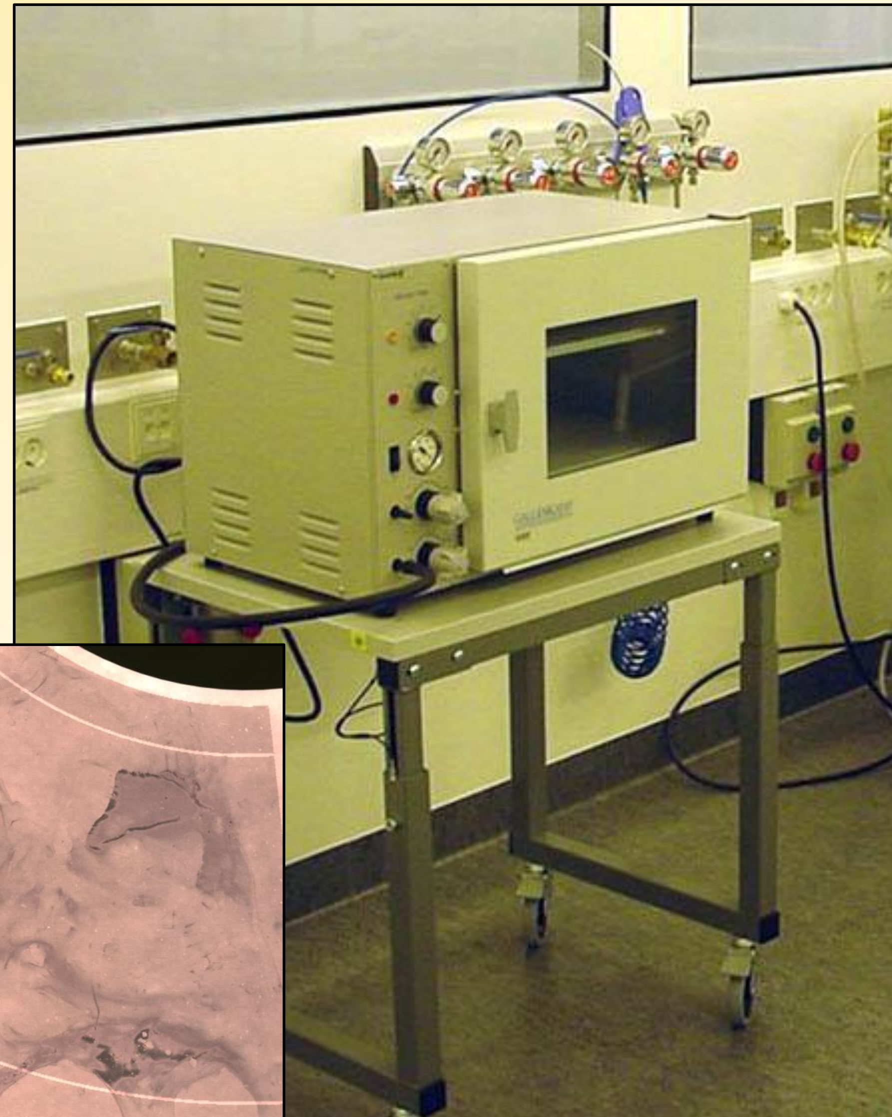


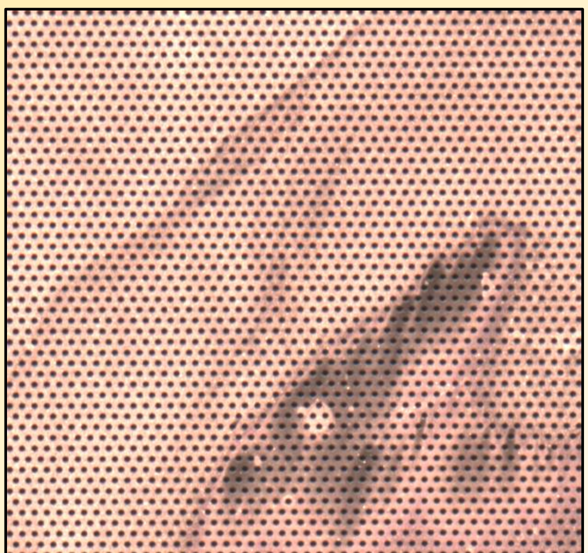
- current limited by 100 MΩ resistor (corresp. max current of 5 mA at 500V).

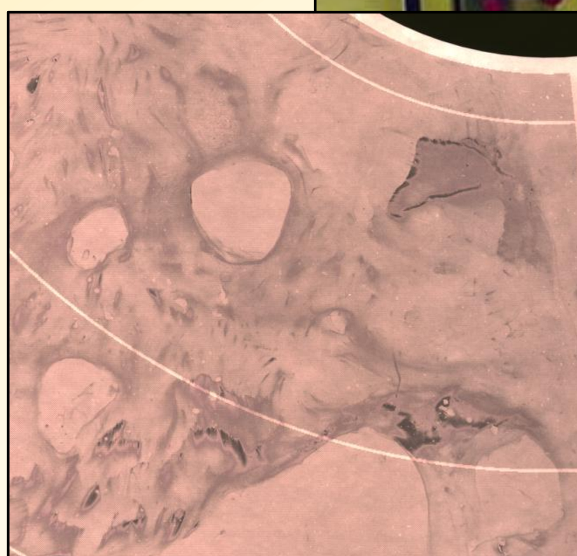
- a foil approved if current stays < 0.5 nA for 30+ min @500V

Curing bad foils

- Several foils were found to have shorts
- Some dirty foils were discarded by visual inspection
- Some were cured in Helsinki by baking in vacuum oven at 50º for several hours
- Some bad foils were sent back to Cern to be cleaned/passivated







Optical scanning of GEM foils

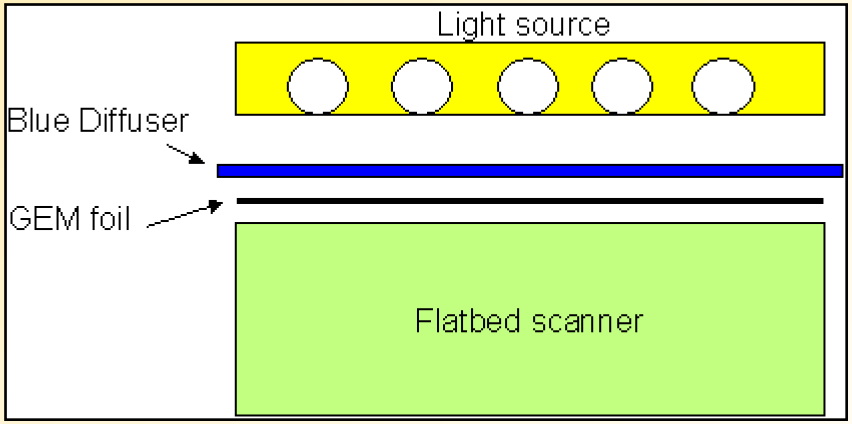
• scanning with resolution of 2400 dpi

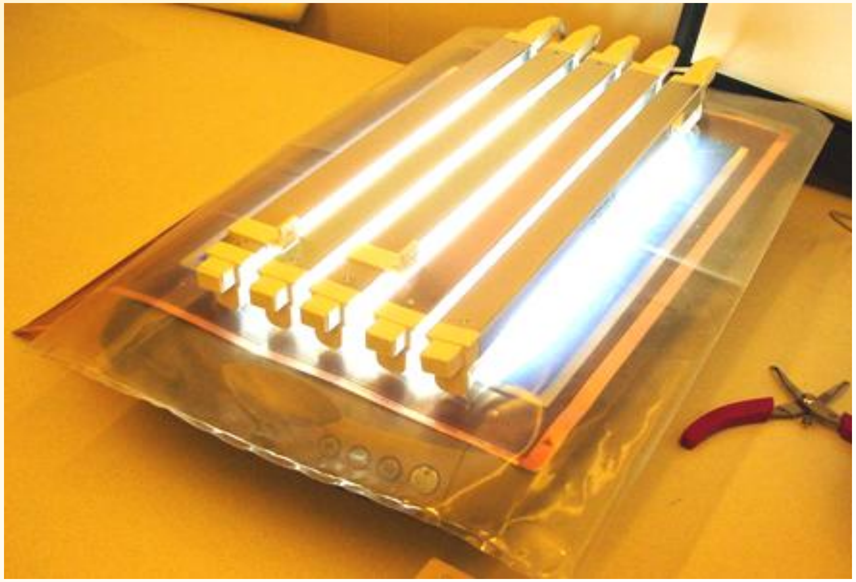
• higher resolutions possible but impractical due to file size

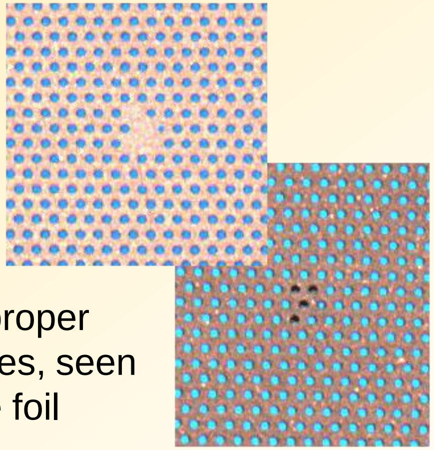
• blue diffuser produces a color contrast between the holes and copper surface

• produced images are large: ~1 GB without packing

• image processing with a custom made program

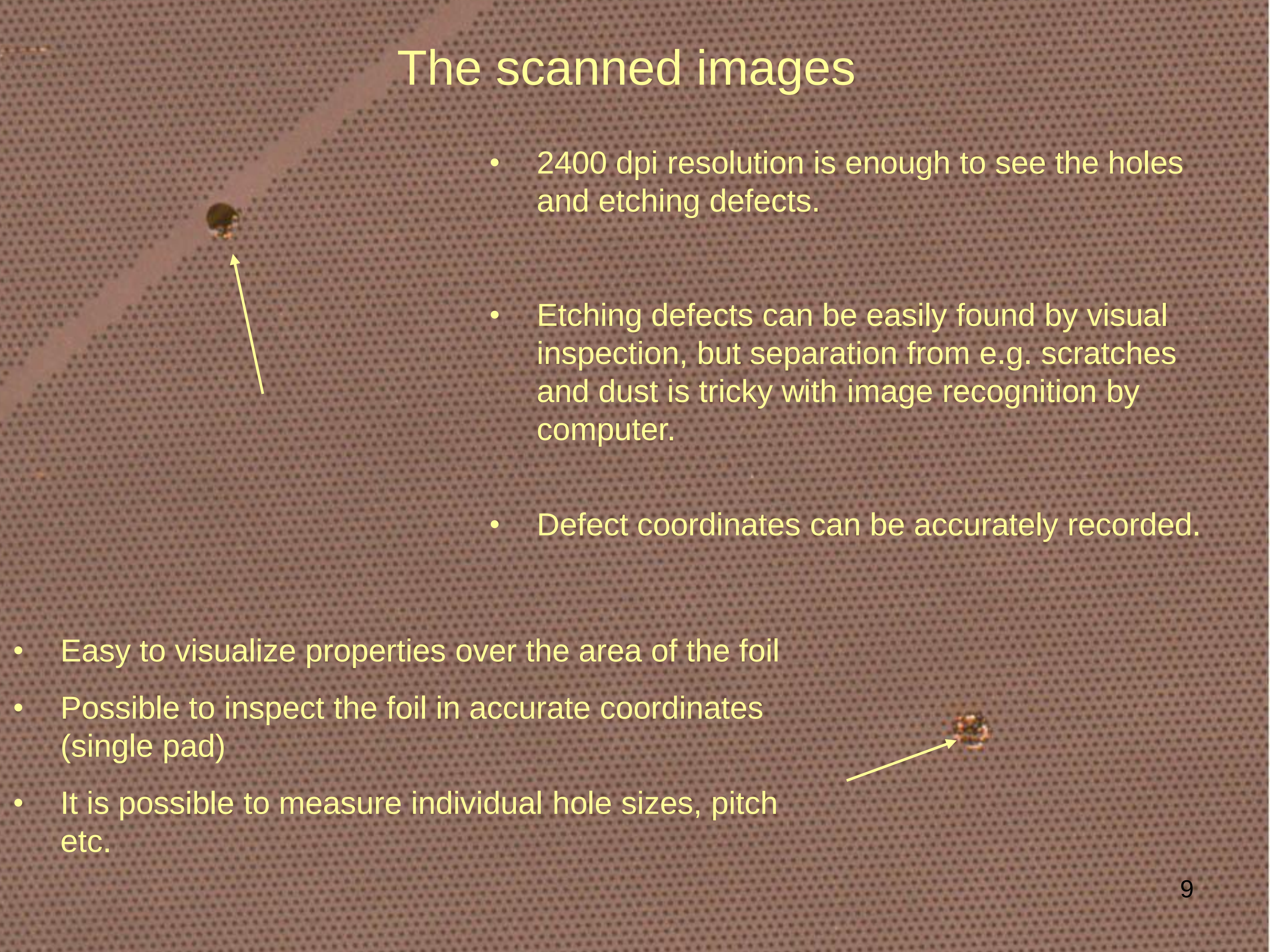






Defect caused by improper etching of several holes, seen from both sides of the foil

The scanned images

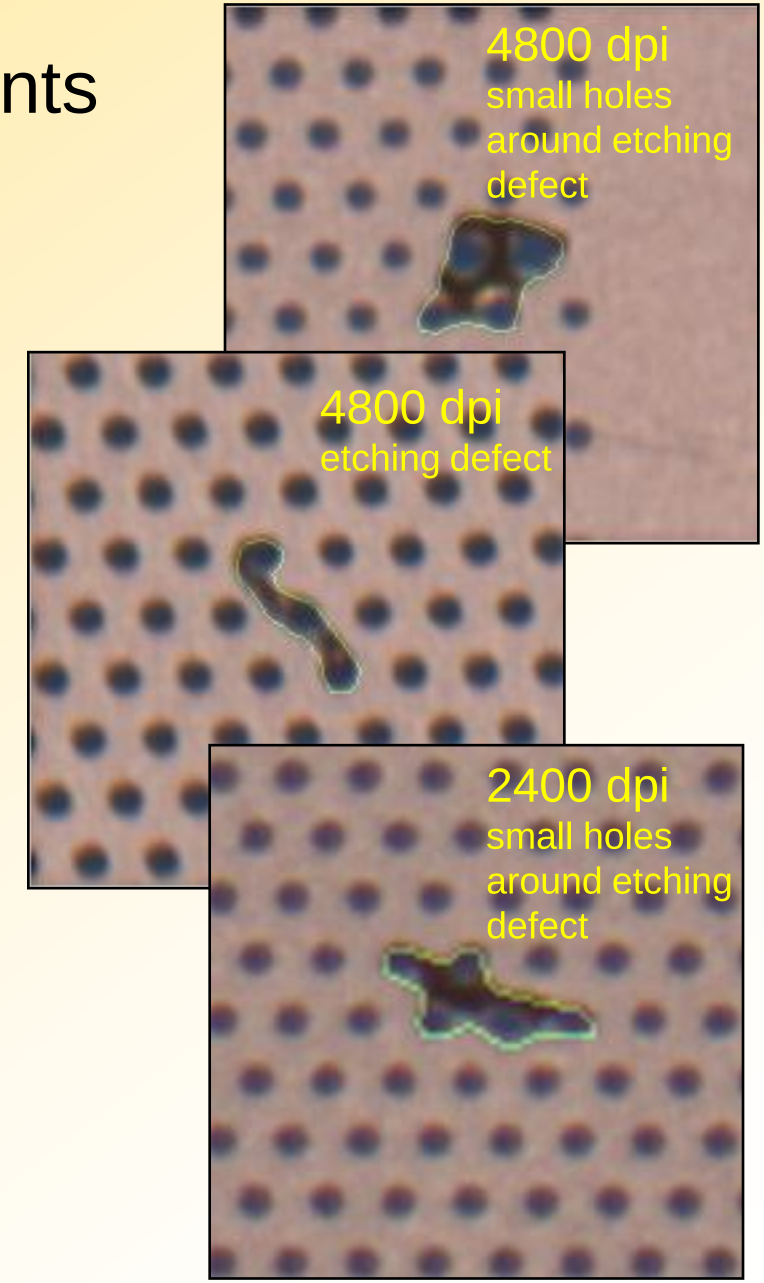


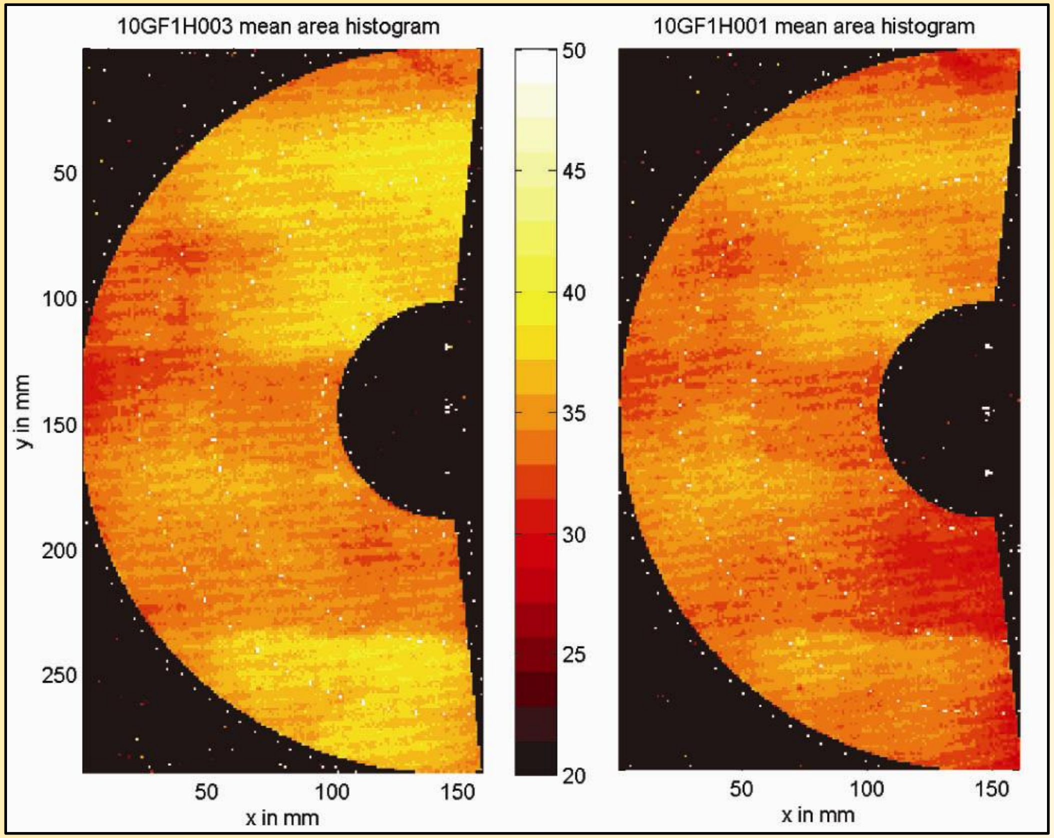
- 2400 dpi resolution is enough to see the holes and etching defects.
- Etching defects can be easily found by visual inspection, but separation from e.g. scratches and dust is tricky with image recognition by computer.
- Defect coordinates can be accurately recorded.

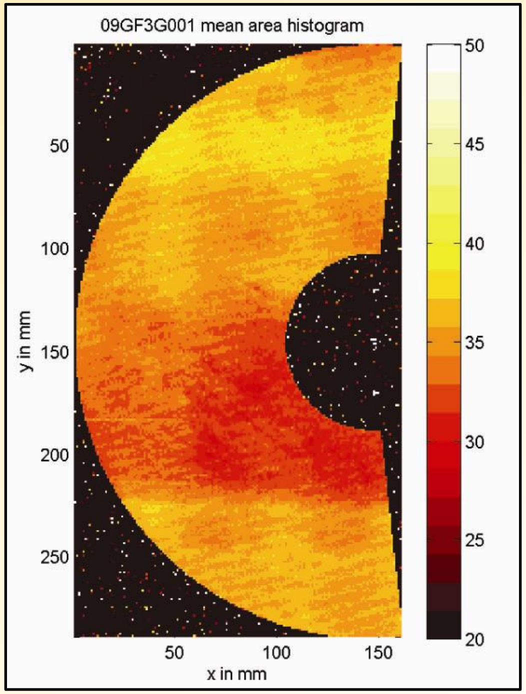
- Easy to visualize properties over the area of the foil
- Possible to inspect the foil in accurate coordinates (single pad)
- It is possible to measure individual hole sizes, pitch etc.

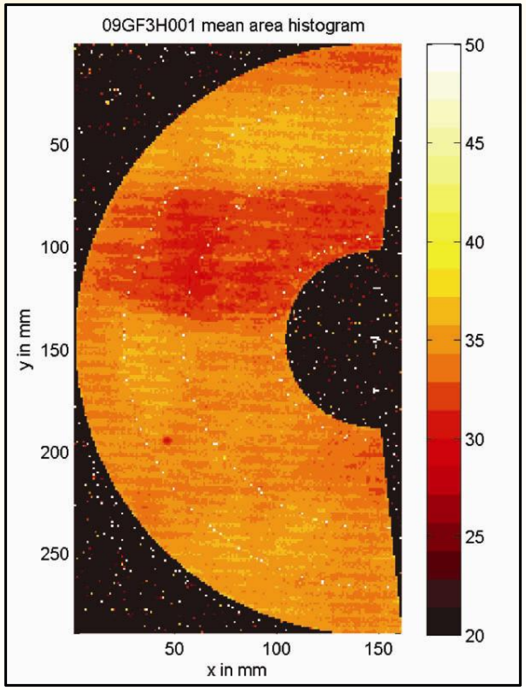
Measurements

- edge along the maximum gradient of intensity – differences in foreground brightness affect edge location
- etching defects are found by their size and shape
- measurement of hole diameter with sub-pixel accuracy (theoretical ~ 1 micron with 2400 dpi resolution, in practice it is worse)
- classification to good holes or one of several defect classes by object area, color and shape







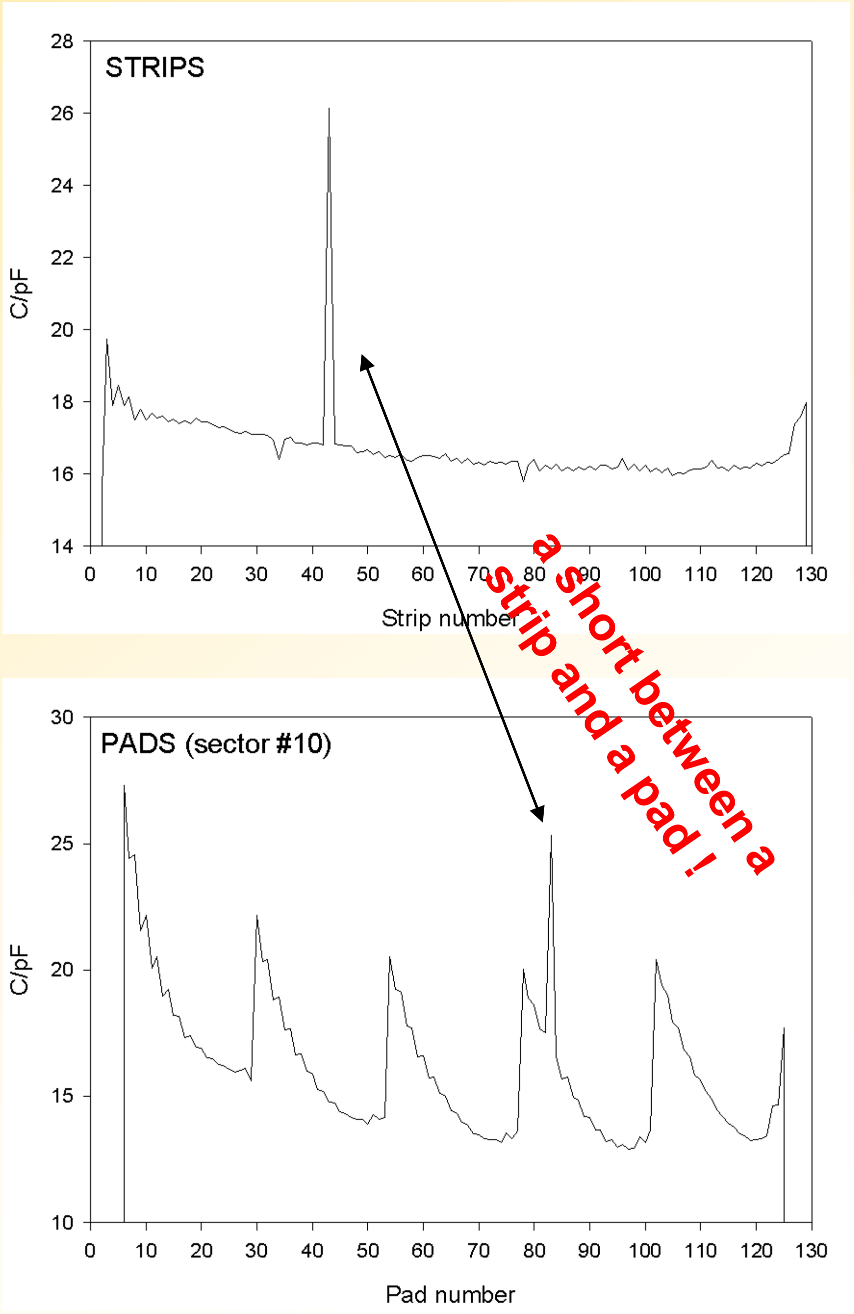


Same foil scanned normally and rotated 180º before scanning. There is a shift of 1-2 pixels in measured area due to difference in foreground brightness.

High-voltage and ground sides of a foil. There is a region of slightly smaller holes.

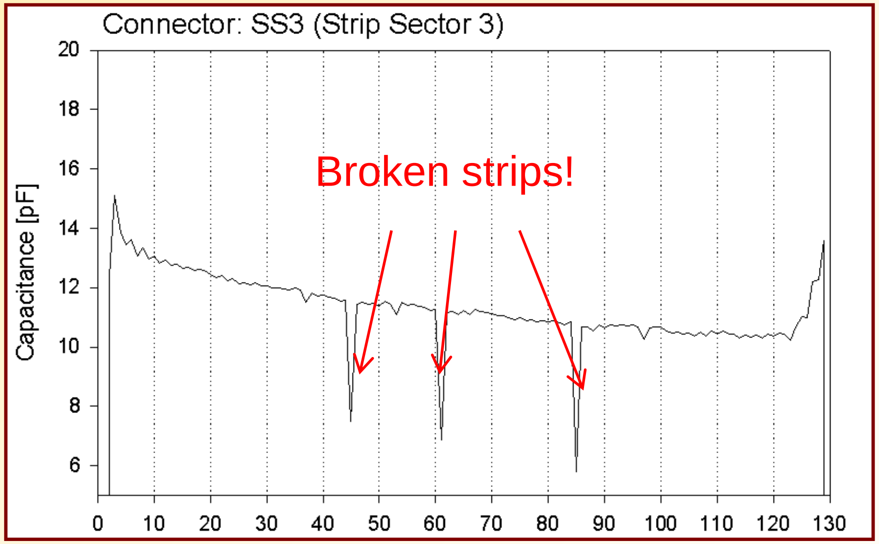
Capacitance measurement of readout boards

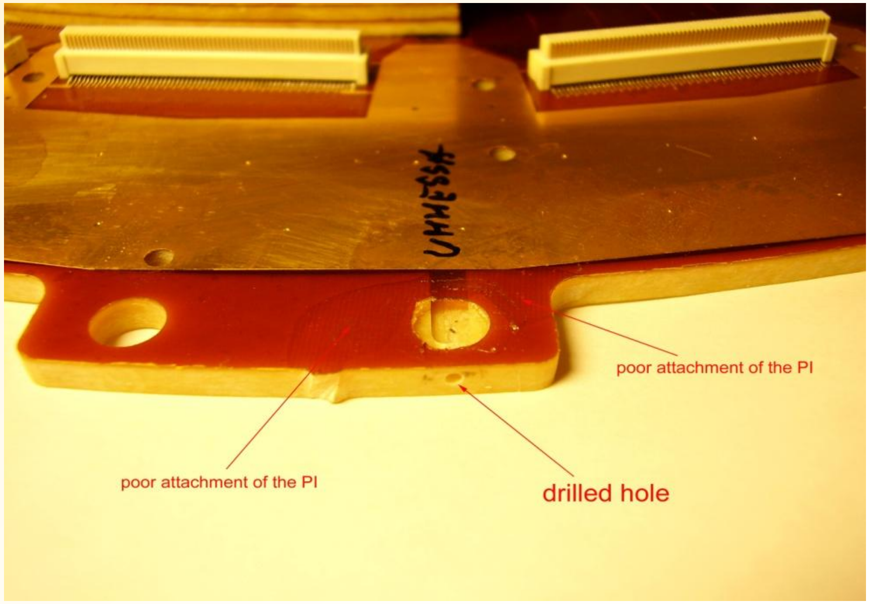
- semi-automatic capacitance measurement systems works eventually well !
- operation based on a GPIB-controlled LCR meter, XYZ table and a special fan-out card with a 130 pin mating connector.
- Measures *relative capacitance variation* from pin to pin.
- measurement time 10 min/conn.
- strip/pad capacitances easily measured also from an assembled GEM.



Bad readout boards

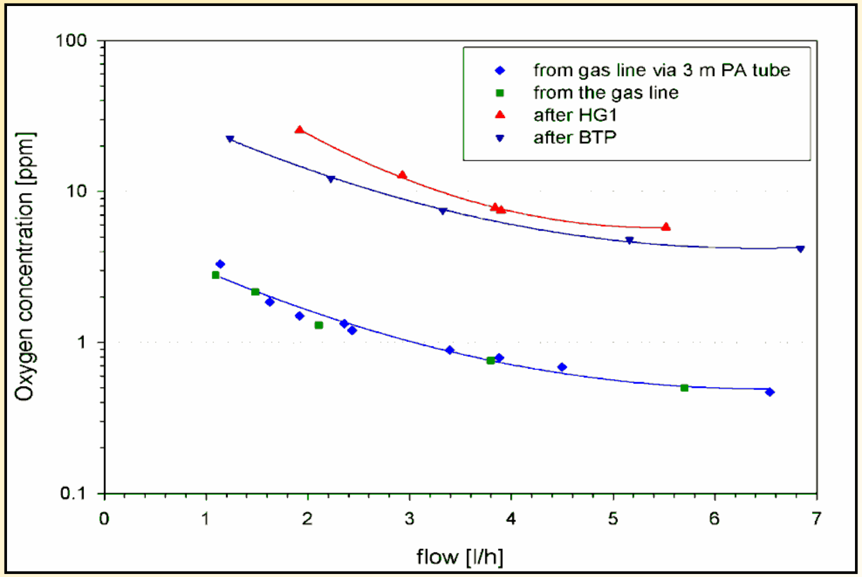
- Some readout boards had shorts (12 ROBs) – 7/18 shorts were successfully burned away
- Few broken strips were found (in 6 ROBs, 11 in total)
- Some ROBs had problems with blocked canals for gas
- Some ROBs were found to have a crystallized residue on the electrodes – cleaned at Cern



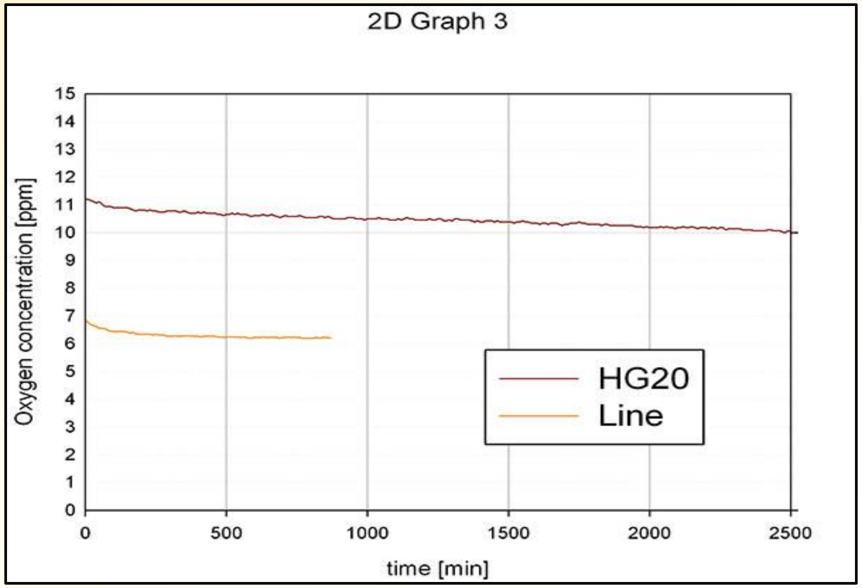


Gas tightness

- Gas sealing of chambers with thick layer of Dow Corning conformal coating
- comparison of in- and outflow / leak detector
- oxygen measurement from the outflow



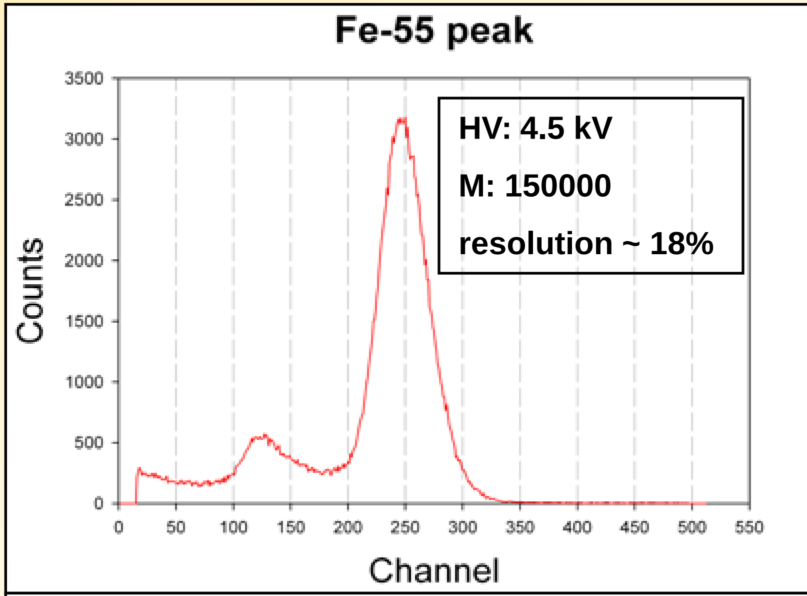
Oxygen content as a function of flow

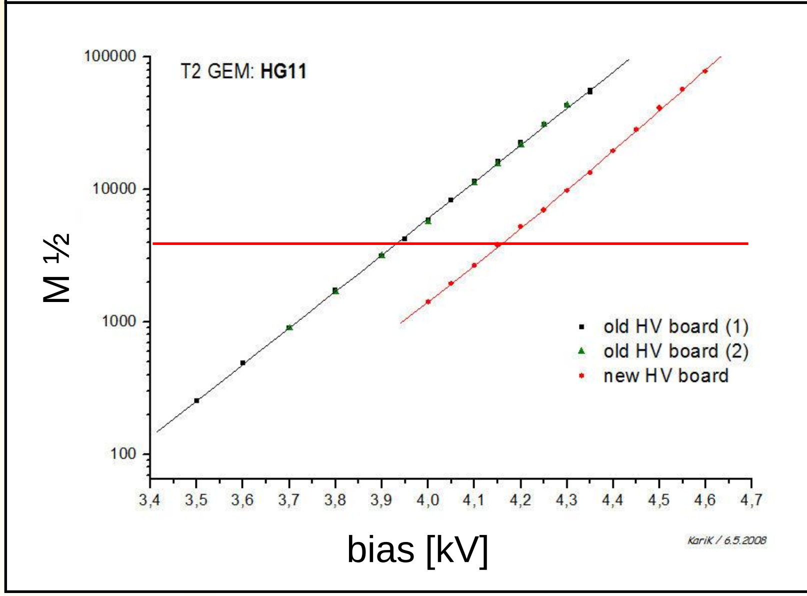


Oxygen content for one detector at 3l/h

Operation testing

- In stability testing all GEMs are kept at nominal voltage (4.15 kV) for several days
- Gain and energy resolution are scanned over active area. 17 sectors per detector to check. All of sector irradiated to see small scale variation.
- A lot of further testing was found to be necessary because of humidity problems outside the detector
- so far, only one bad detector out of 42 have been found





New HV -board

- All GEMs were equipped with new HV-boards, HV-cables and aluminium/ copper shieldings – problems with humidity

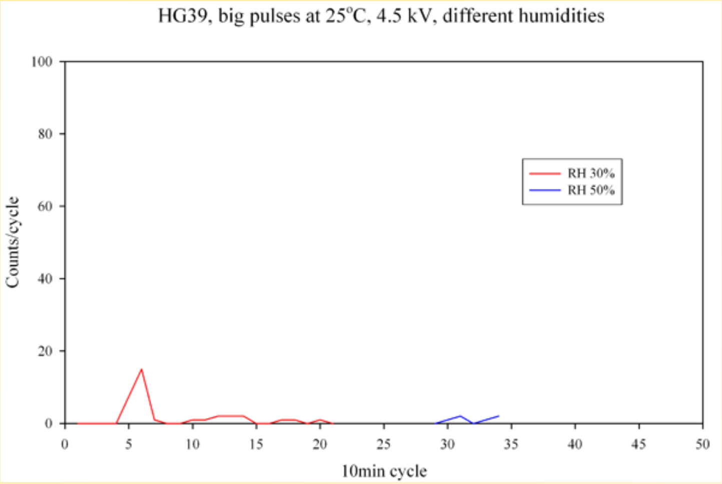
- Additional layer of conformal coating (Dow Corning) supplied over the HV board and strips to prevent leakage current/pulses caused by moisture.

- New testing phase added before tests with Ar/CO2

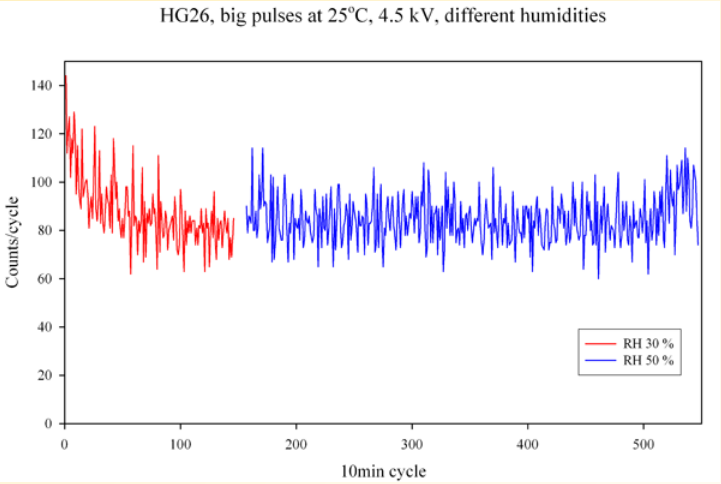
  - Use of environmental chamber to test the detectors in 50 % humidity with nitrogen inside

  - Stability is tested for 12 hours in 4.5 kV, eventually ramped up to 5 kV for at least an hour

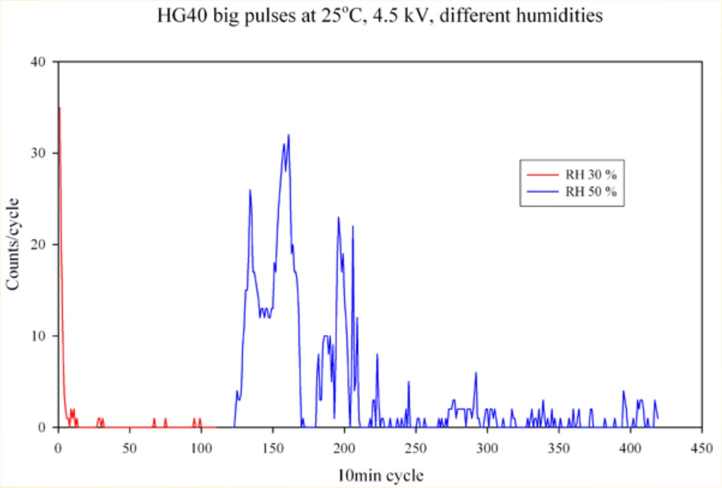
Environmental chamber



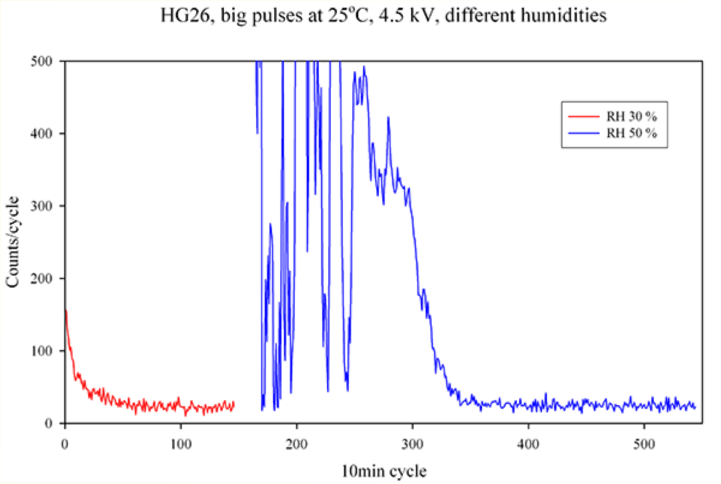
"good" detector



"bad" detector, high base frequency of pulses



reacts to humidity increase



reacts to humidity, small frequency left

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

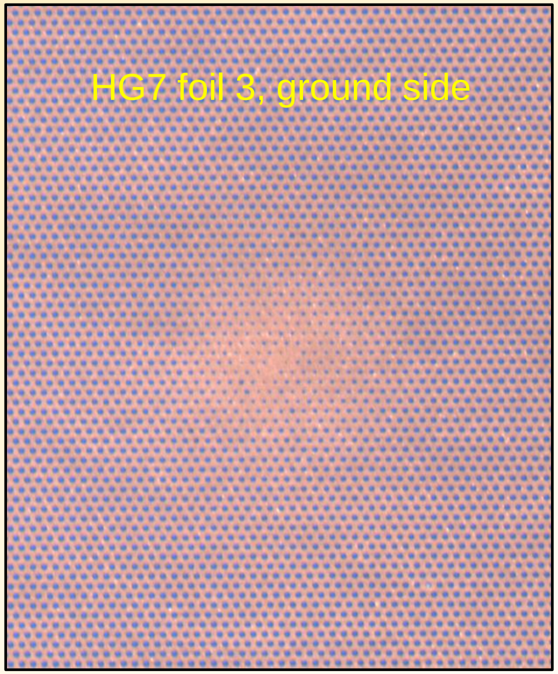
14. **Tests** 5 days
    - gas leaks?
    - environmental chamber, HV-tests
    - electronic tests

total: 2-3 weeks

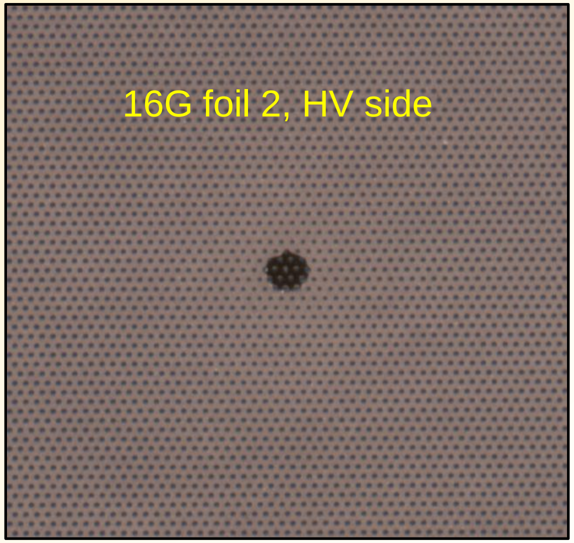
Assuming all the components are available and storage in dry atmosphere!

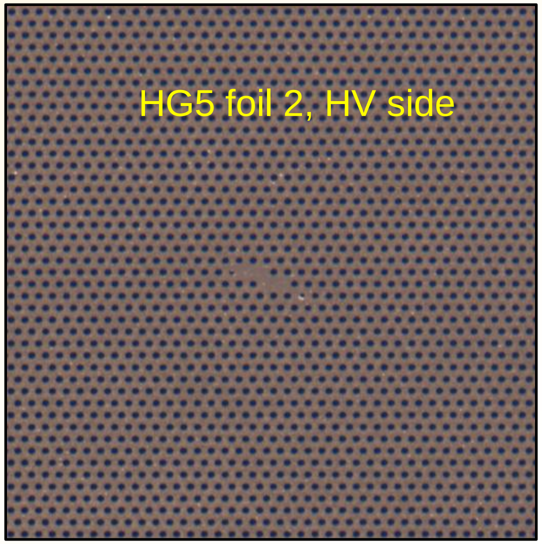
GEM foil statistics

- ~150 GEM foils handled so far
- On the whole the foil quality was found to be very good
- Some foils with different defects were assembled for later testing
- some foils were discarded
  - failure in glueing to the frame (2 pcs)
  - large leakage current + numerous blocked holes (1 pcs)
  - accidents in handling (1 pcs)



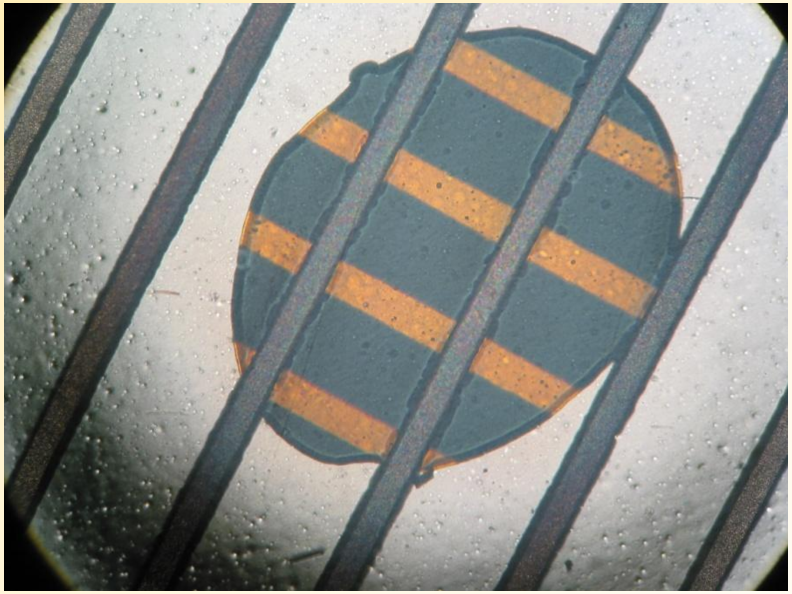
Some examples of defects found with optical scanning system →

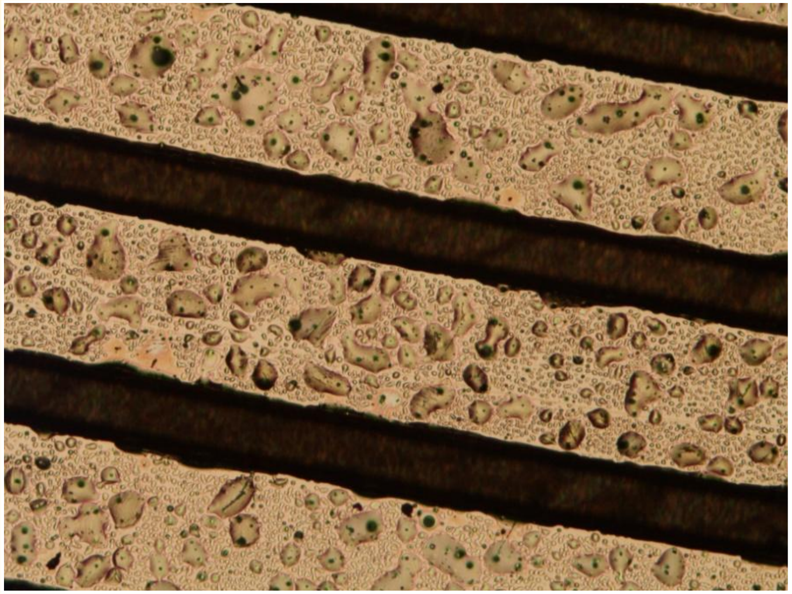




ROB statistics

- 43 ROBs handled so far
- Some ROBs sent back to Cern to be cleaned
- All ROBs have been assembled for later testing.





	broken strips	short circuits (green = burned)	gas channel blocked	alignment holes of the connectors shifted	Others
HG1	PS5/62 PS10/77 PS13/8 PS13/44	PS1/82-84-86 PS4/14-16 PS12/81-82			
HG2		SS4/28-PS13/88 SS3/109-PS13/12 PS1/38-39 PS1/55-59 PS9/95-96			
HG3		PS6/83-SS2/43			
HG4					
HG5					
HG6					
HG7					
HG8					
HG9					
HG10					
HG11					
HG12					
HG13					
HG14	PS9/98				
HG15		SS3/77-PS8/58			
HG16		PS12/118-120			
HG17					
HG18	SS3/45 SS3/61 SS3/85	PS12/105-SS3/45/61/85 ?			
HG19				PS8, PS9, PS10,PS13	
HG20				PS9, PS10, PS11	
HG21					
HG22				SS1	
HG23		SS4/5-PS10/38		SS1, SS2, PS1, PS2, PS3, PS4, SS3,SS4	PS10/W50 hole in metal
HG24		PS10/31-PS10/33	right one		
HG25	PS4/43	SS4/92-PS13/96		PS3, PS4, PS5	
HG26			right one	SS1, SS2, PS8, PS12, PS13, SS3, SS4	
HG27			both ones	PS5, PS7, PS8, PS9, PS11	
HG28					
HG29				SS3,SS4	
HG30	SS1/96			PS9	large capacitance PS10/54
HG31			both ones	PS10	
HG32			right one		
HG33	PS5/43	SS4/80-PS13/46	right one	SS4	
HG34		SS3/13-PS11/78	right one	PS3, PS4	
HG35				SS1, SS2	