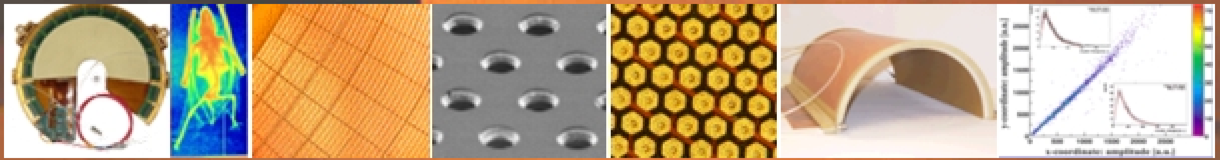
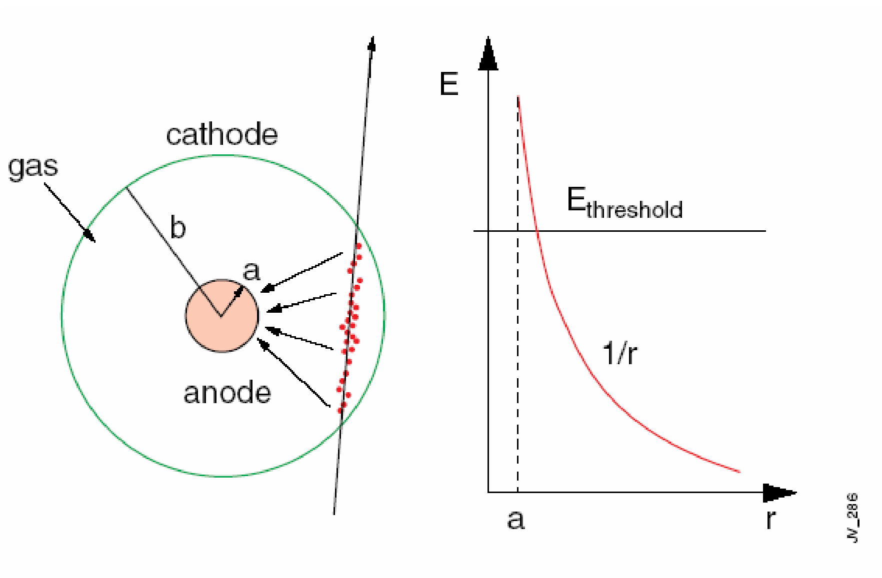
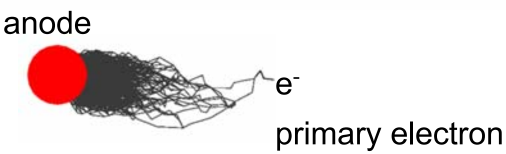
Introduction to TOTEM T2 DCS

Leszek Ropelewski CERN PH-DT2-ST & TOTEM



Single Wire Proportional Chamber





Electrons liberated by ionization drift towards the anode wire.

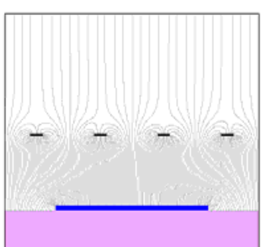
Electrical field close to the wire (typical wire Ø ~few tens of μm) is sufficiently high for electrons (above 10 kV/cm) to gain enough energy to ionize further → avalanche – exponential increase of number of electron ion pairs.

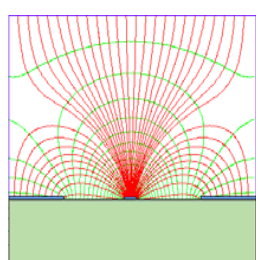
$$E(r) = \frac{CV_0}{2\pi\varepsilon_0} \cdot \frac{1}{r}$$

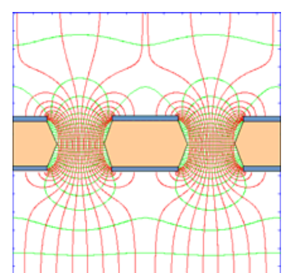
$$V(r) = \frac{CV_0}{2\pi\varepsilon_0} \cdot \ln\frac{r}{a}$$

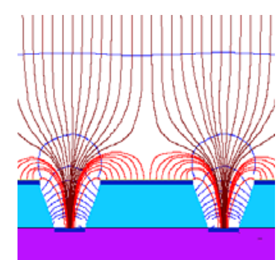
C – capacitance/unit length

Cylindrical geometry is not the only one able to generate strong electric field:

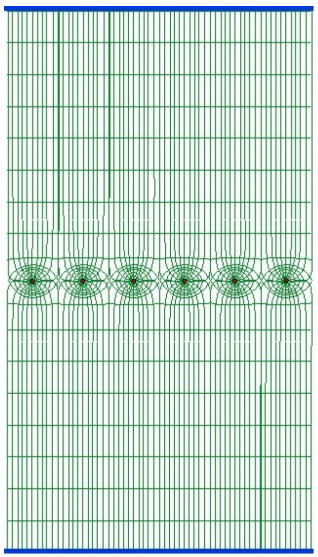

parallel plate


strip


hole


groove

Multiwire Proportional Chamber



Simple idea to multiply SWPC cell : Nobel Prize 1992

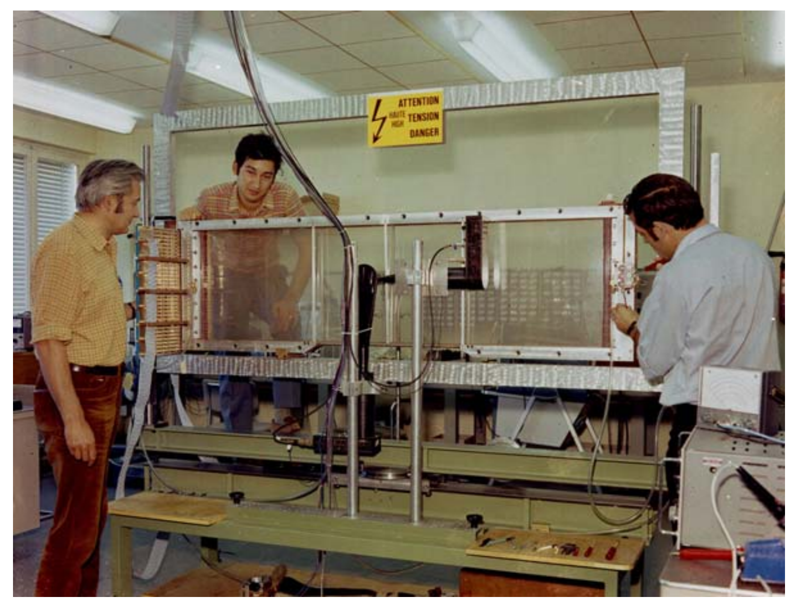
First electronic device allowing high statistics experiments !!

Typical geometry
5mm, 1mm, 20 μm

Normally digital readout :
spatial resolution limited to

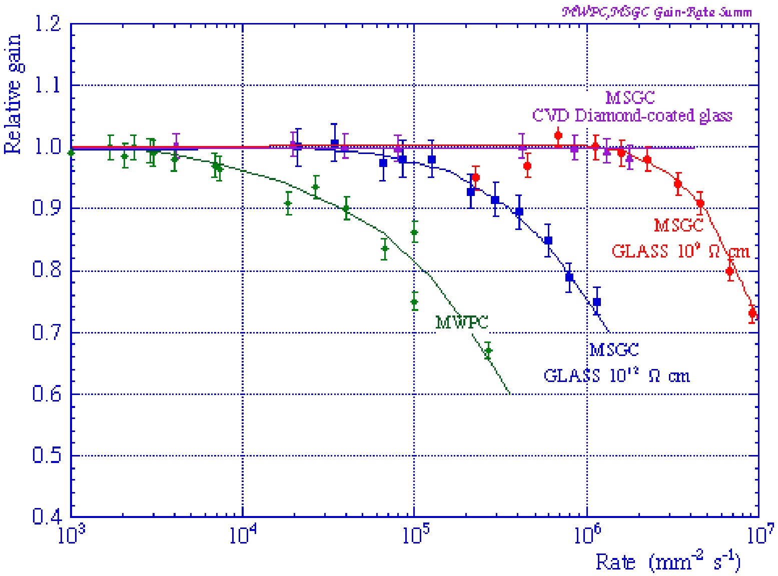
$$\sigma_x \approx \frac{d}{\sqrt{12}}$$

for d = 1 mm σ_x = 300 μm

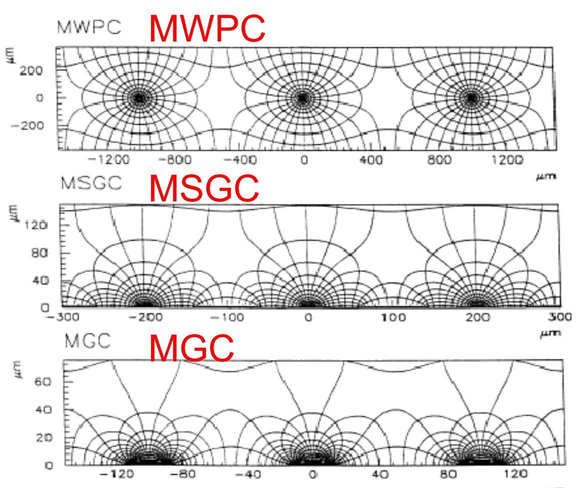


G. Charpak, F. Sauli and J.C. Santiard

Micropattern Gas Detectors



scale factor



1

5

10

R. Bellazzini et al.

Advantages of gas detectors:

- low radiation length
- large areas at low price
- flexible geometry
- spatial, energy resolution …

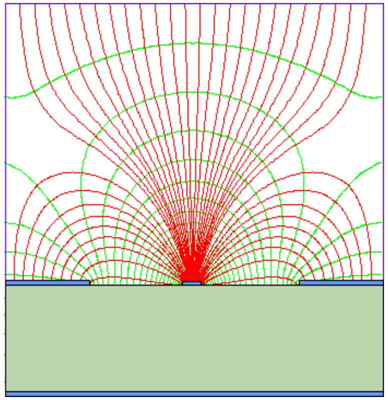
Problem:

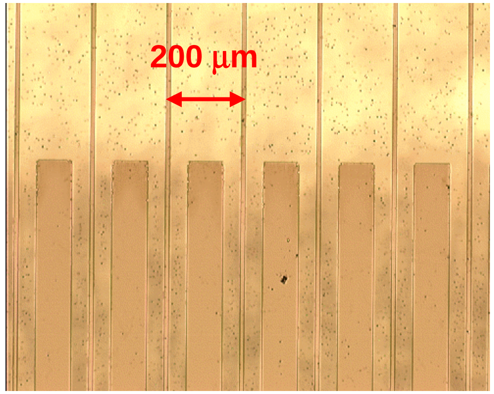
- rate capability limited by space charge defined by the time of evacuation of positive ions

Solution:

- reduction of the size of the detecting cell (limitation of the length of the ion path) using chemical etching techniques developed for microelectronics and keeping at same time similar field shape.

MSGC – Microstrip Gas Chamber



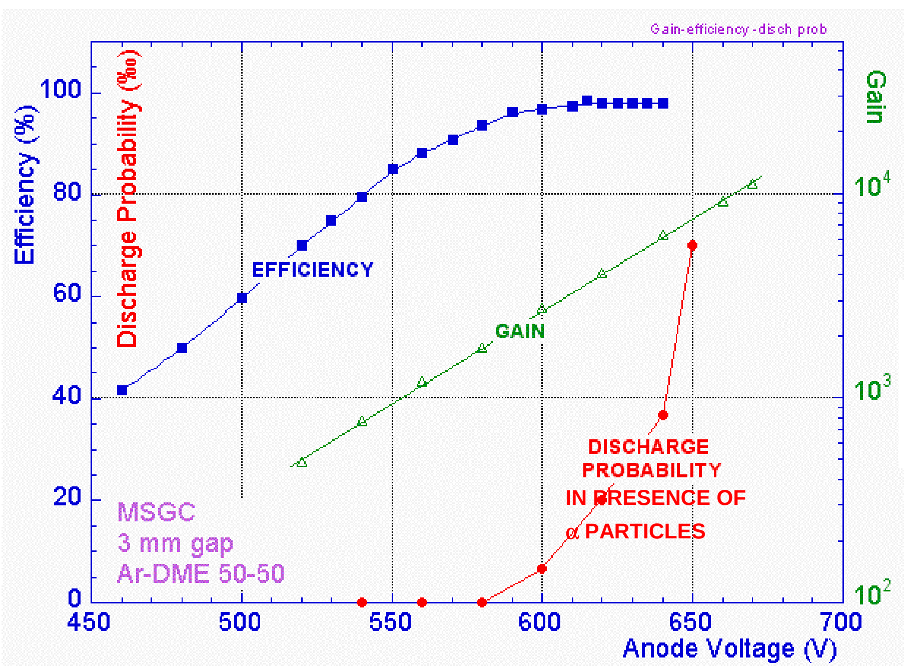


Thin metal anodes and cathodes on insulating support (glass, flexible polyimide ..)

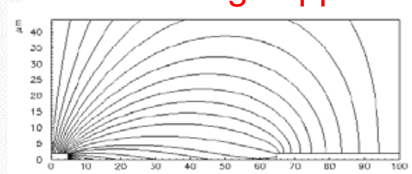
Problems:

High discharge probability under exposure to highly ionizing particles caused by the regions of very high E field on the border between conductor and insulator.

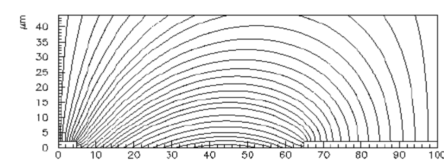
Charging up of the insulator and modification of the E field → time evolution of the gain.



insulating support



slightly conductive support



R. Bellazzini et al.

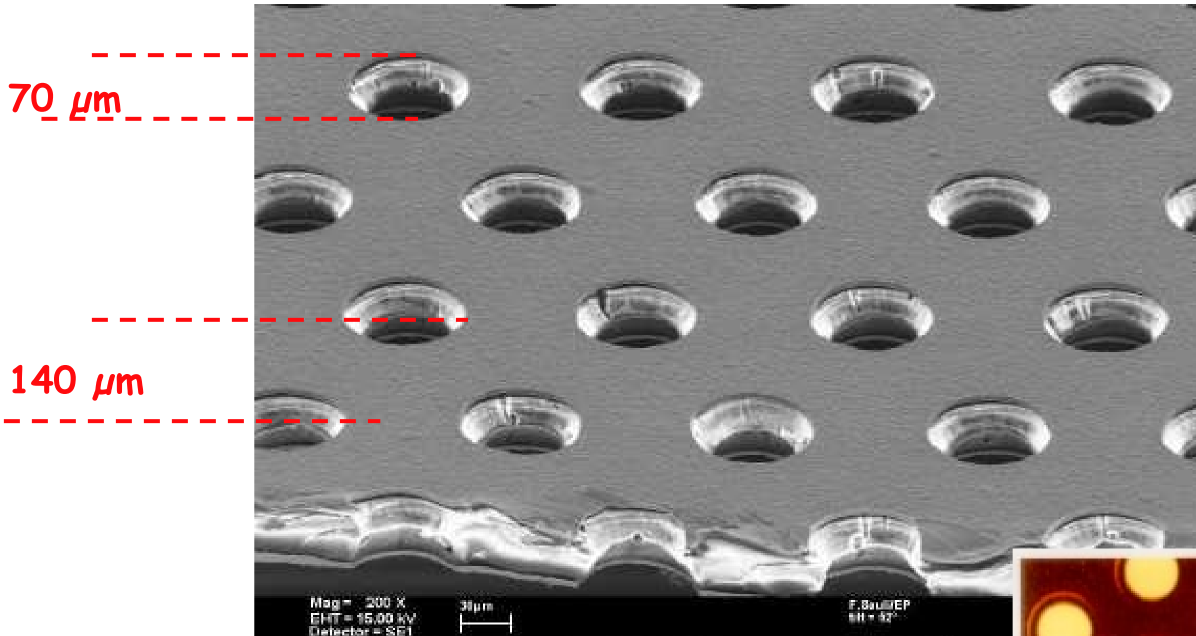
Solutions:

slightly conductive support

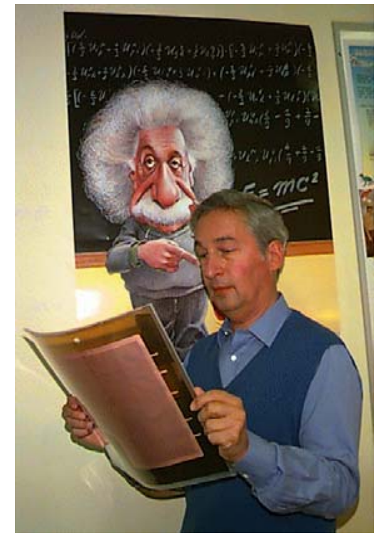
multistage amplification

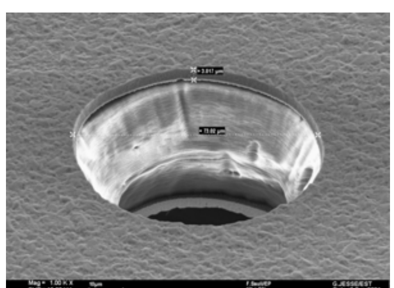
GEM: Gas Electron Multiplier

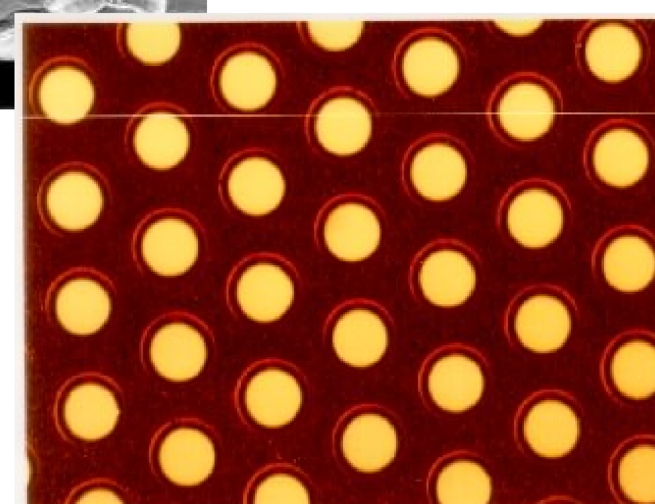
Thin metal-coated polymer foil pierced by a high density of holes (50-100/mm^2)
Typical geometry: 5 μm Cu on 50 μm Kapton, 70 μm holes at 140 μm pitch



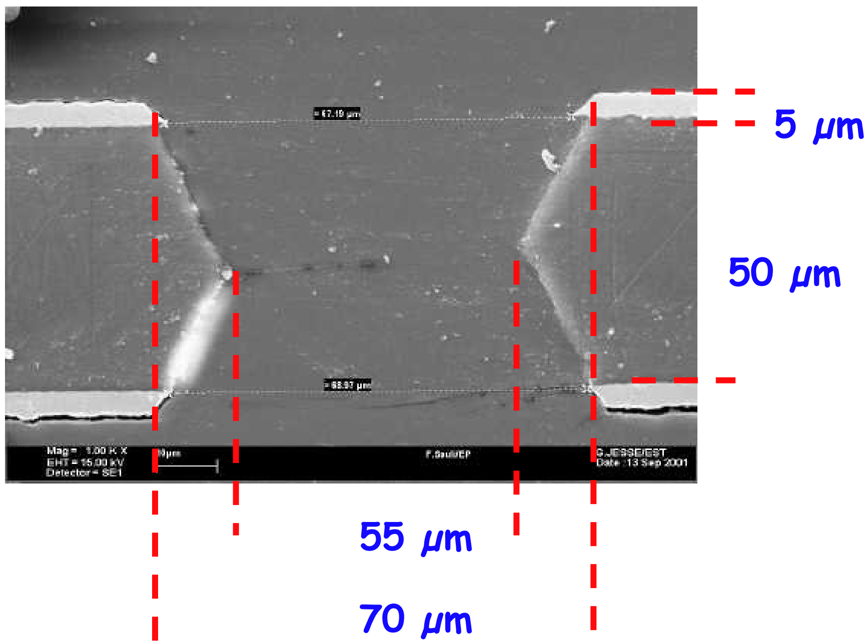
F. Sauli, Nucl. Instrum. Methods A386(1997)531



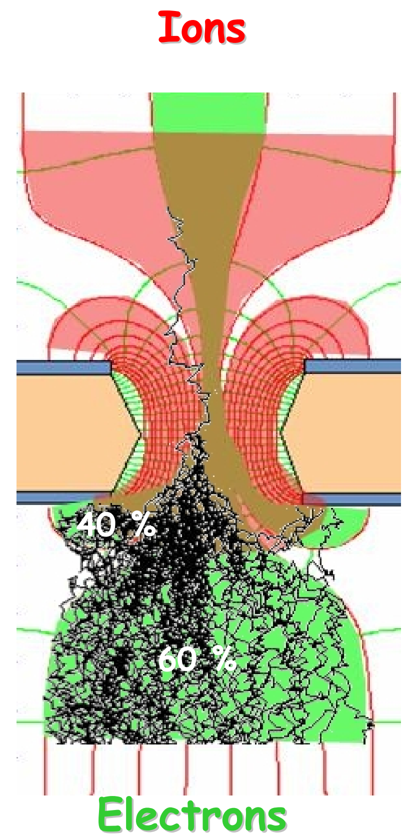




GEM Principle

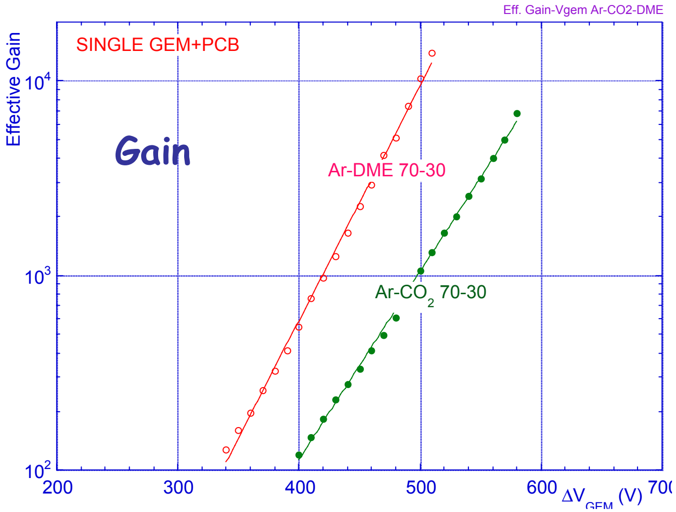


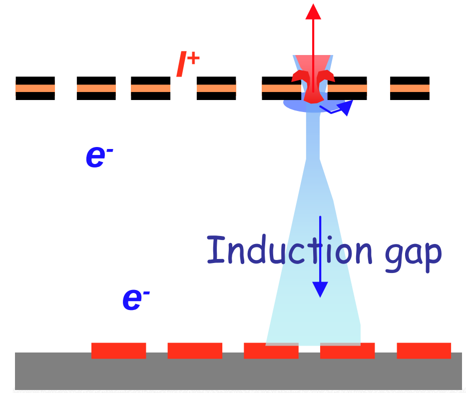
GEM hole cross section

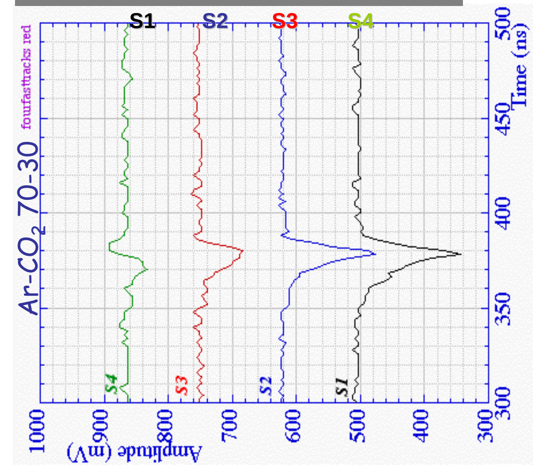


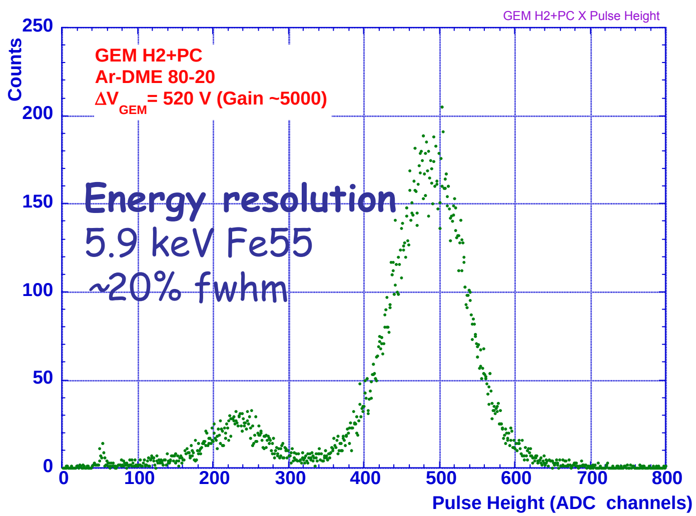
Avalanche simulation

Single GEM Performances





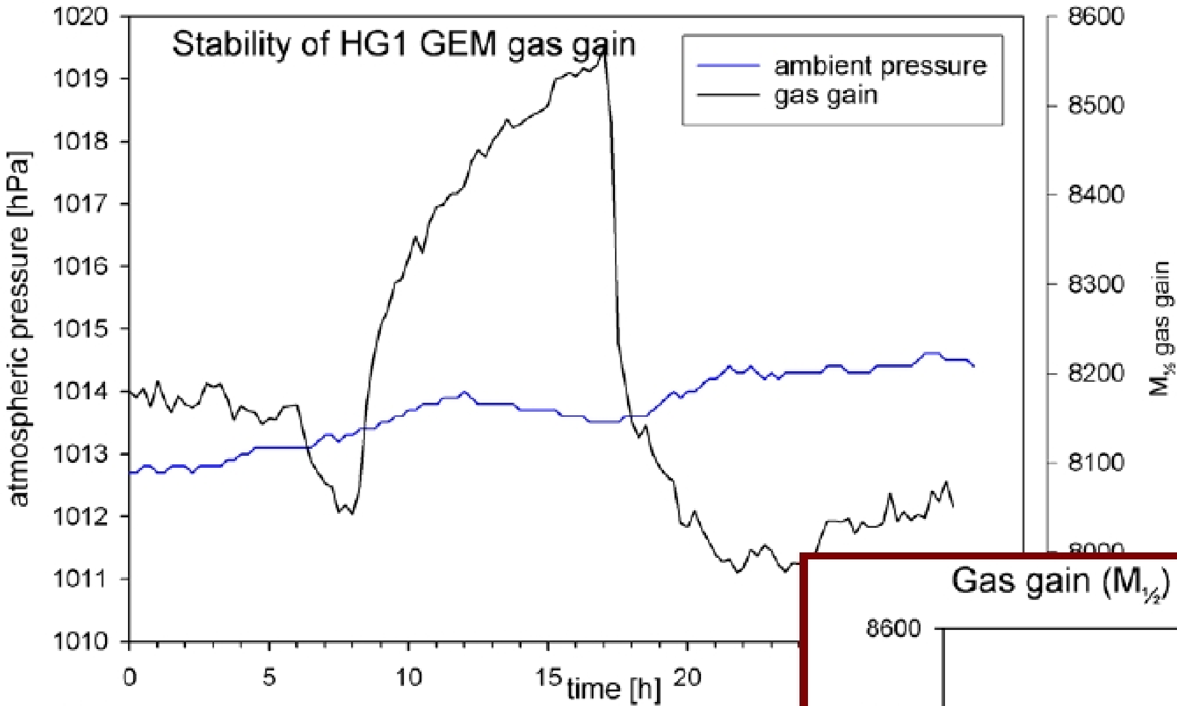


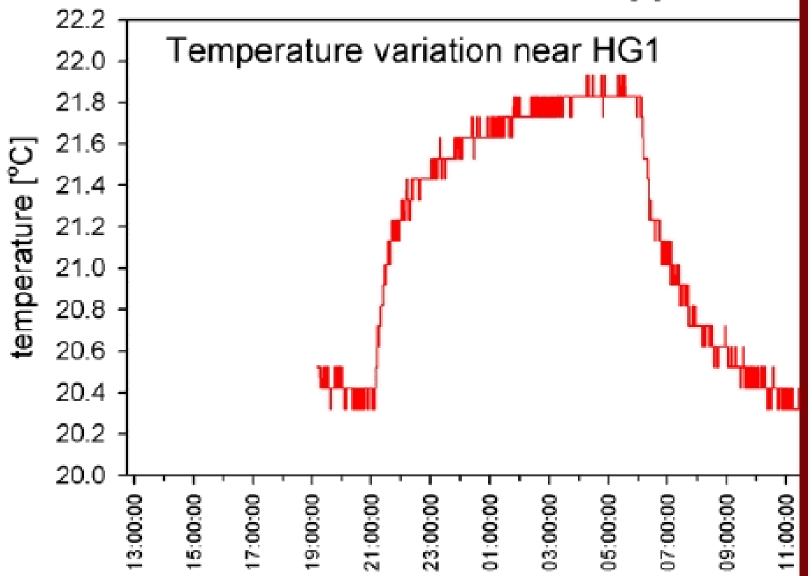


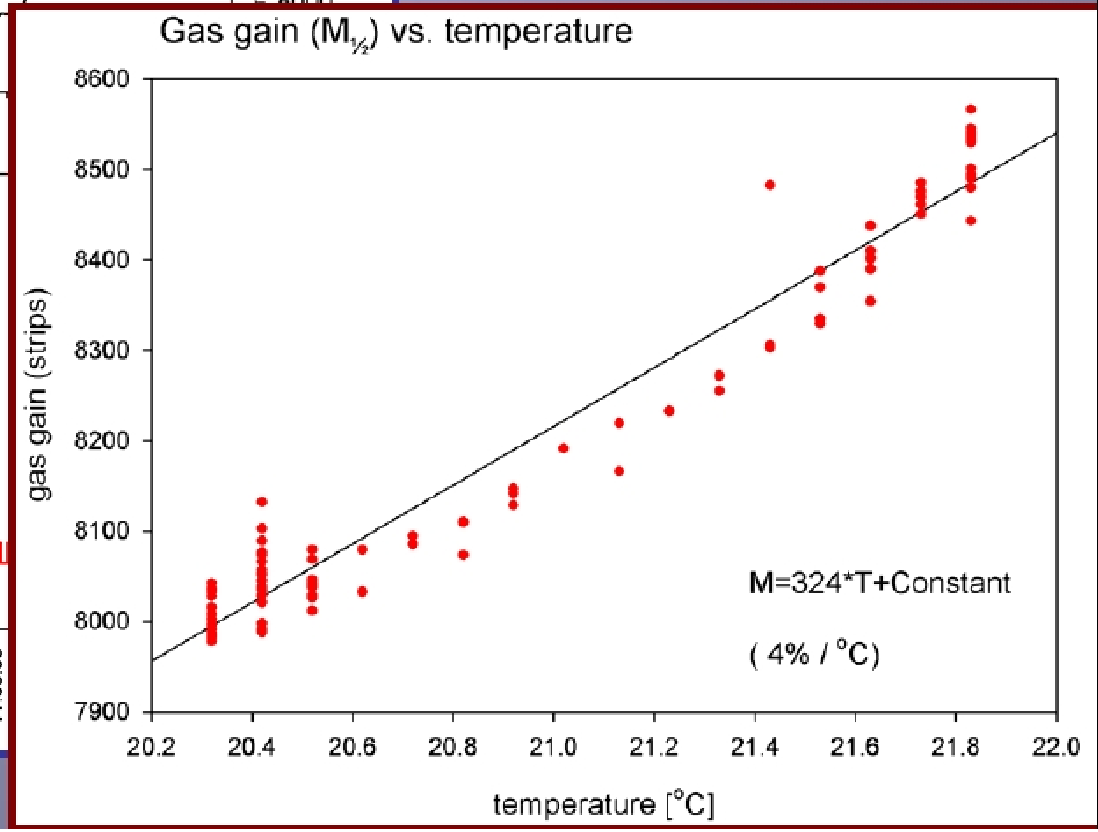
R. Bouclier et al NIM A 396 (1997) 50

Electrons are collected on patterned readout board.
A fast signal can be detected on the lower GEM electrode
for triggering or energy discrimination.
All readout electrodes are at ground potential.
Positive ions partially collected on the GEM electrodes.

GAIN STABILITY

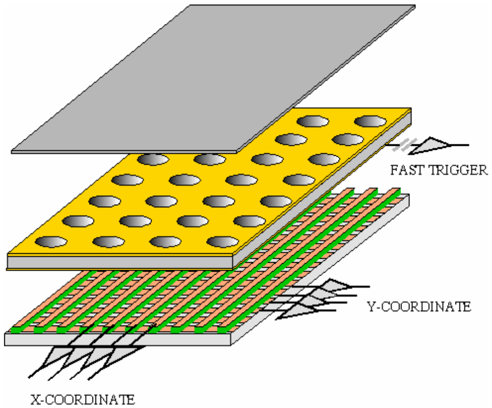




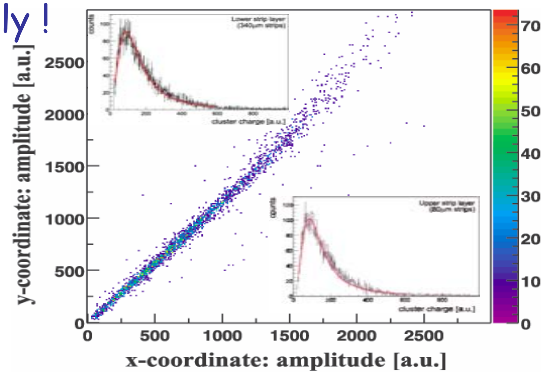


GEM – Gas Electron Multiplier

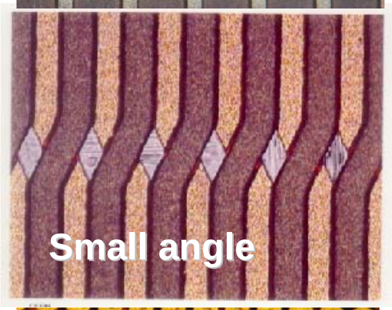
Full decoupling of the charge amplification structure from the charge collection and readout structure.
Both structures can be optimized independently !

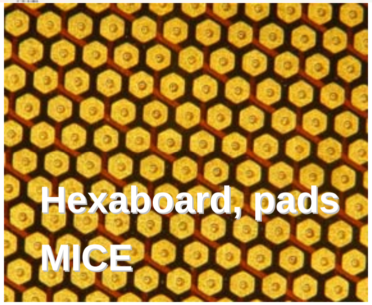


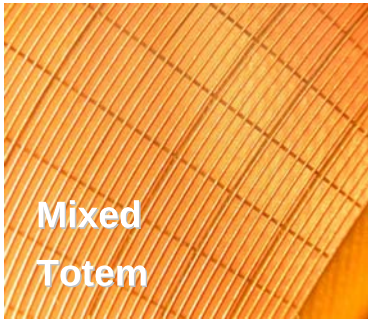
A. Bressan et al, Nucl. Instr. and Meth. A425(1999)254

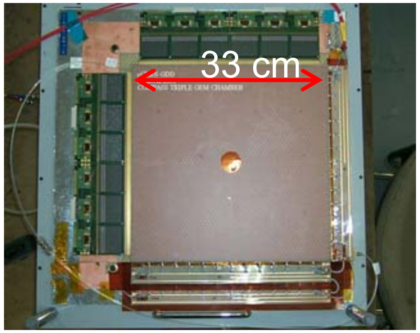


Charge correlation (Cartesian readout)



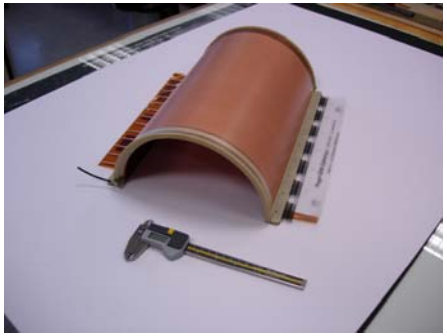






Compass

Totem



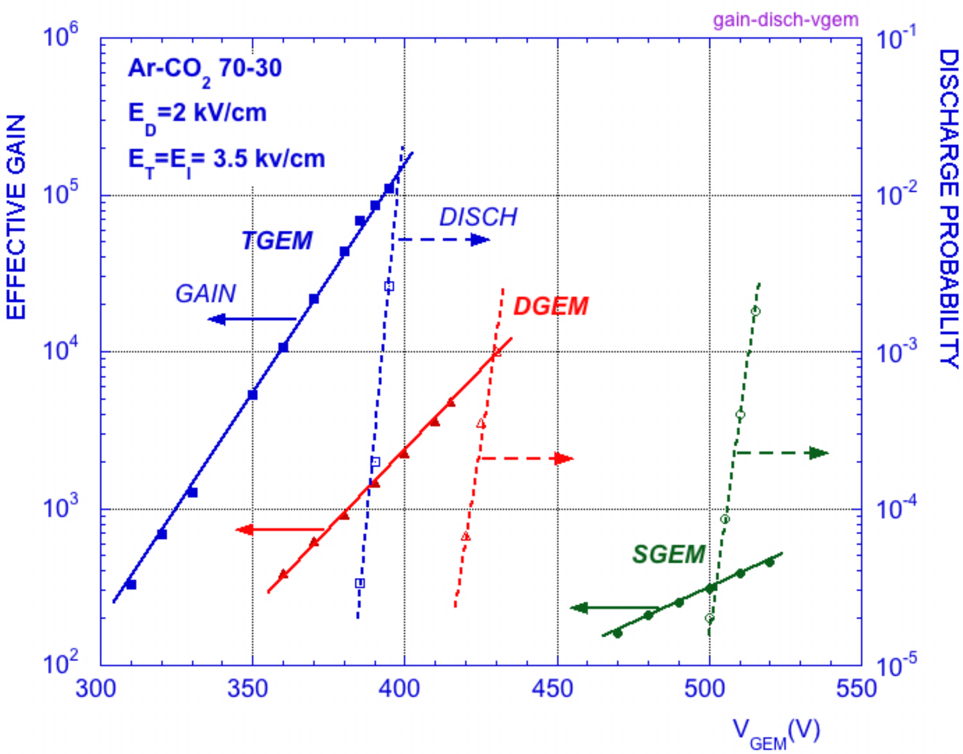
NA49-future

All detectors use three GEM foils in cascade for amplification to minimize discharge probability by reducing field strength.

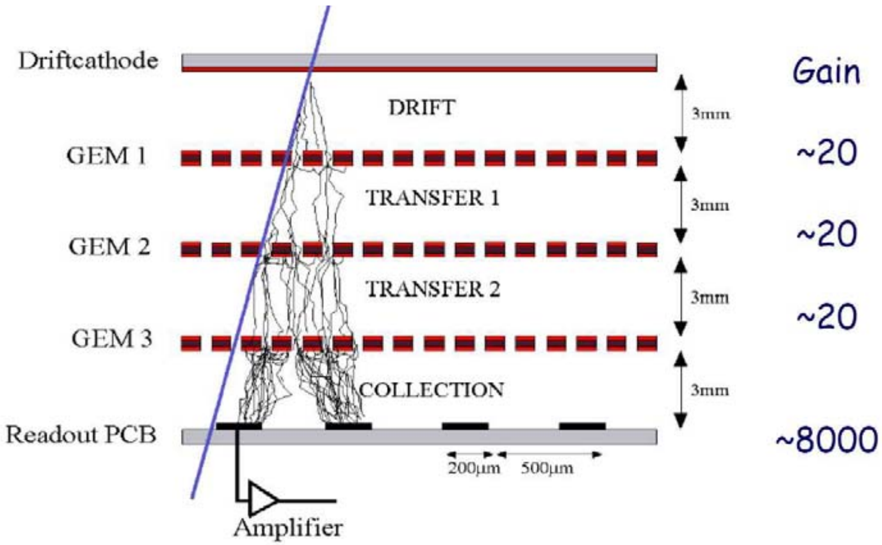
Multi-GEM Detectors

Discharge Probability on Exposure to 5 MeV Alphas

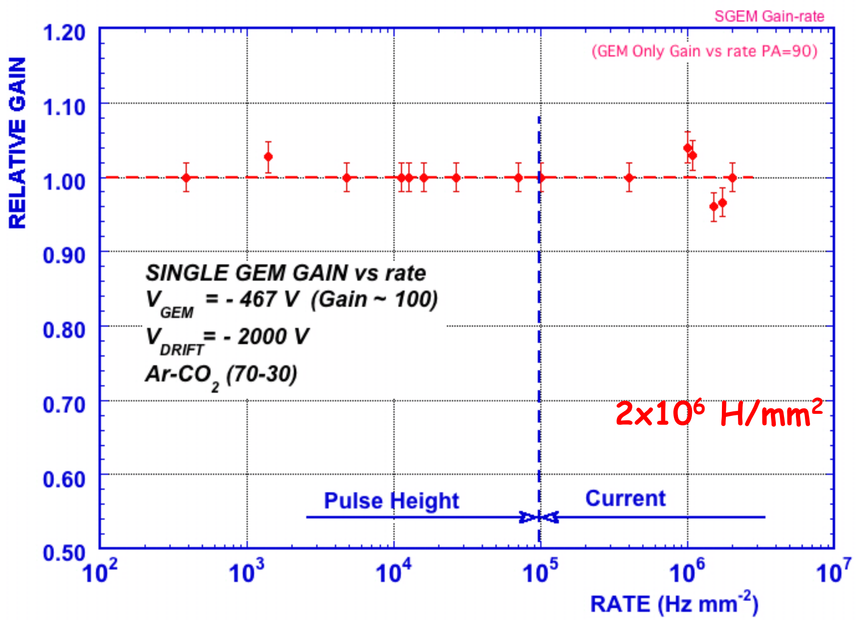
Multiple structures provide equal gain at lower voltage.
Discharge probability on exposure to α particles is strongly reduced.



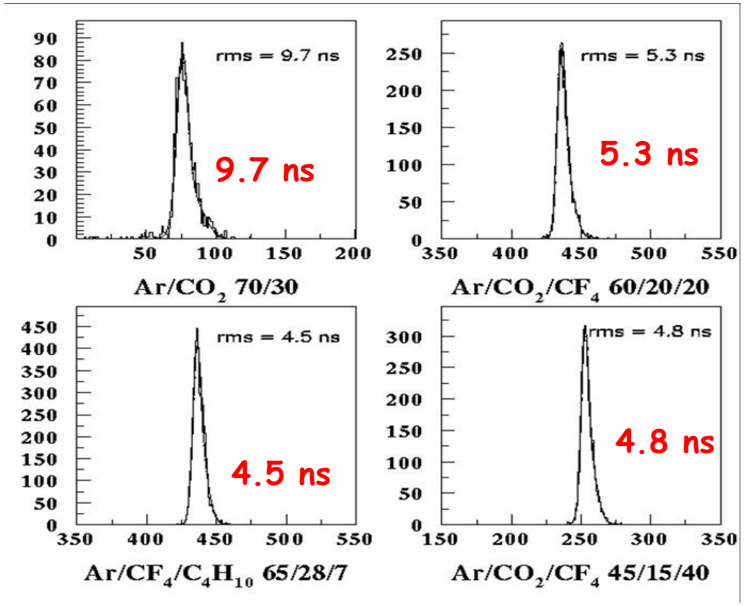
S. Bachmann et al Nucl. Instr. and Meth. A479(2002)294



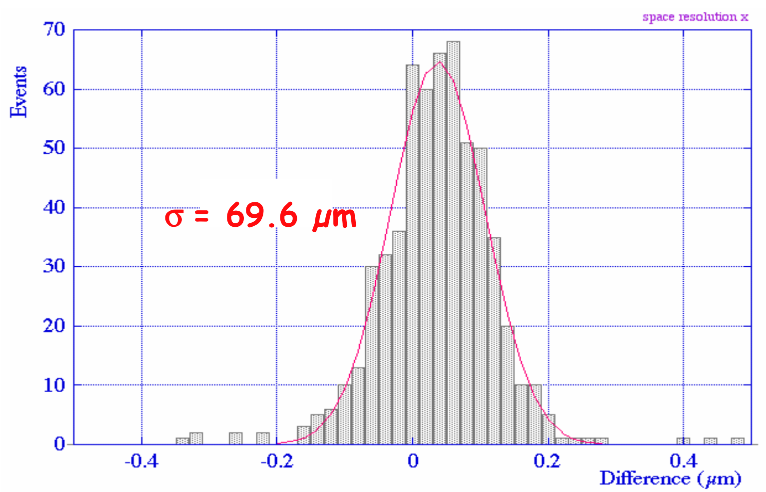
GEM – Gas Electron Multiplier



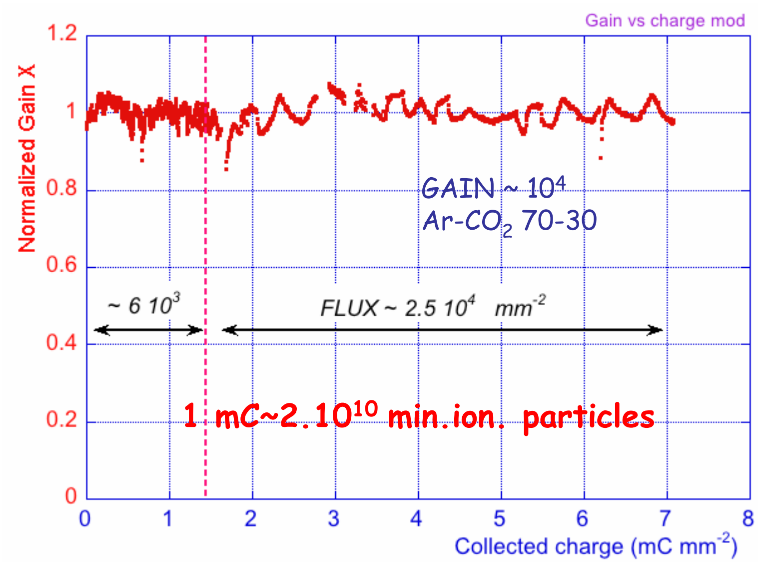
Rate capability



Time resolution



Space resolution



Ageing properties

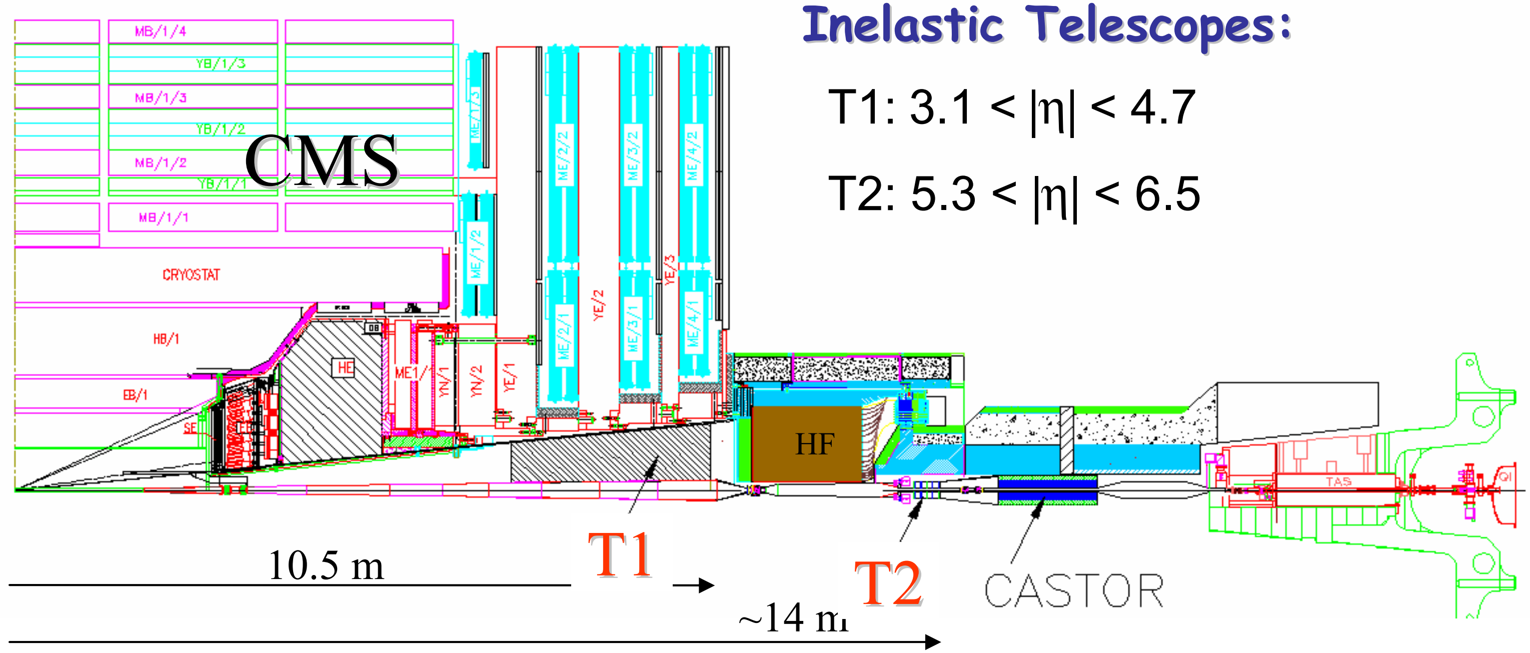
TOTEM Detectors

to measure total pp cross section and study elastic scattering and diffractive dissociation at the LHC

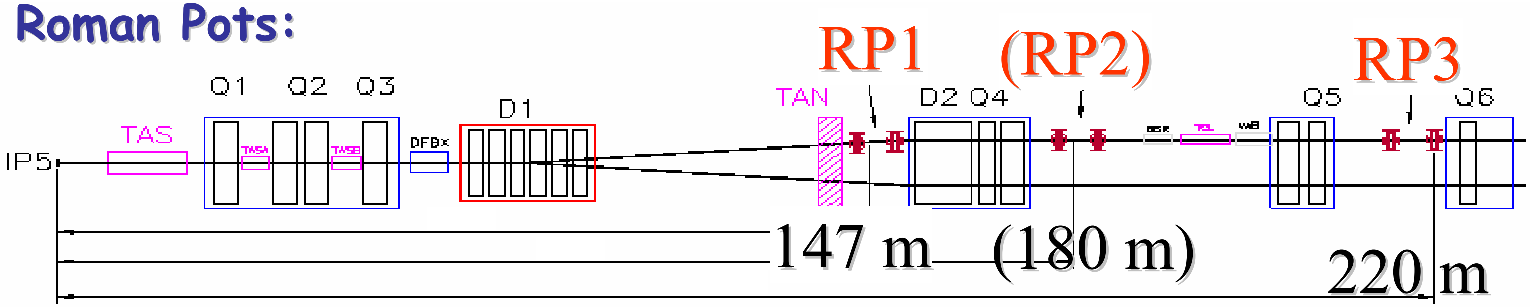
Inelastic Telescopes:

T1: $3.1 < |\eta| < 4.7$

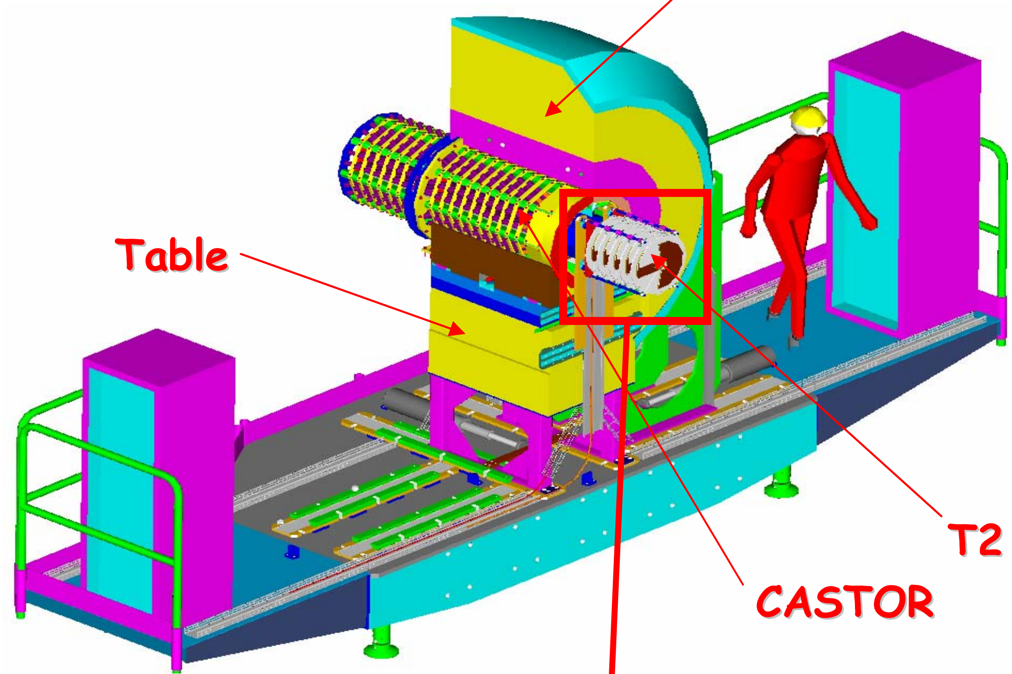
T2: $5.3 < |\eta| < 6.5$

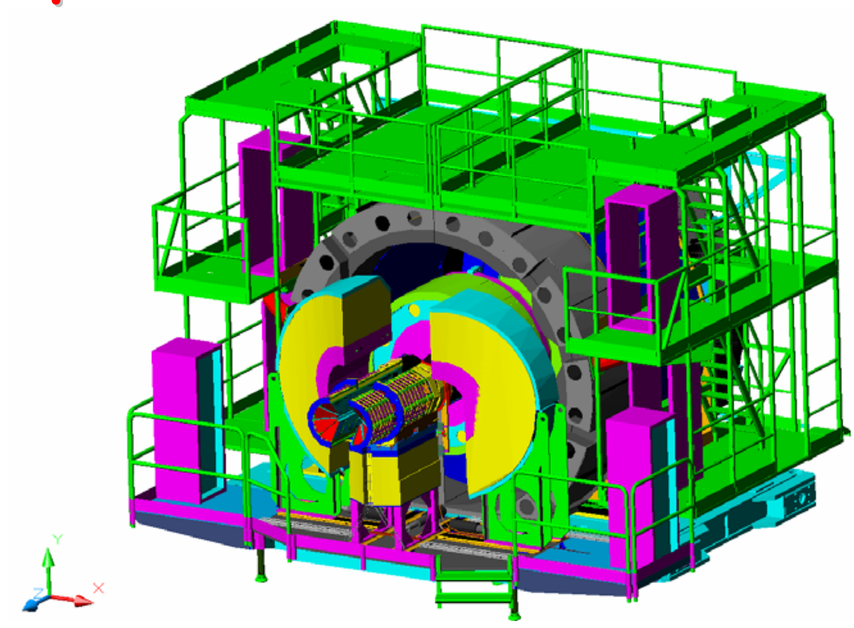


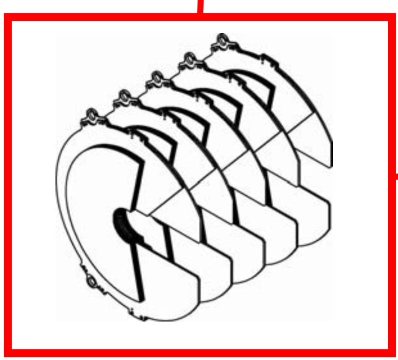
Roman Pots:

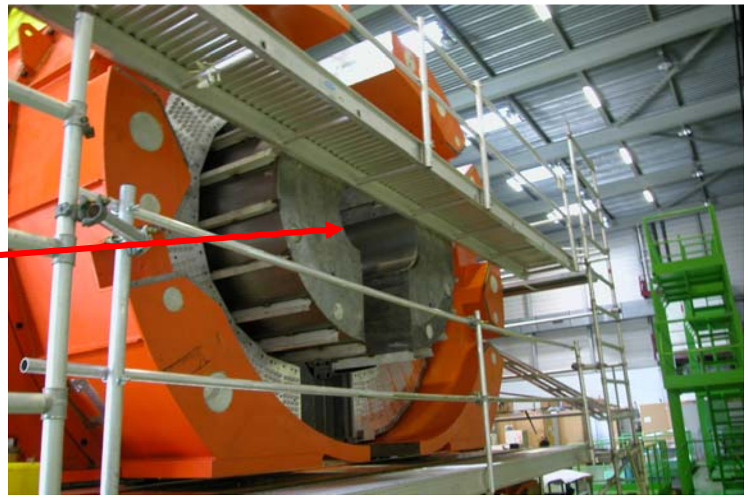


T2 Telescope







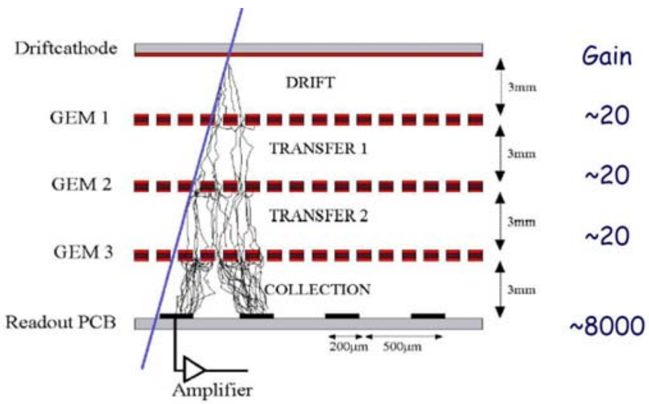


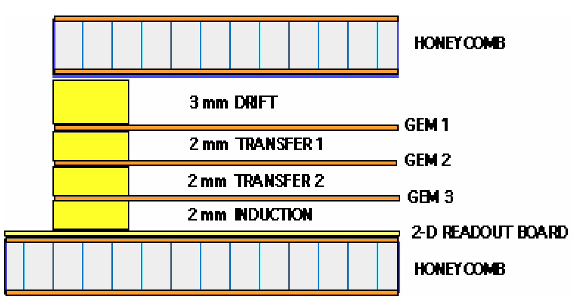
10 detector planes on each side of IP

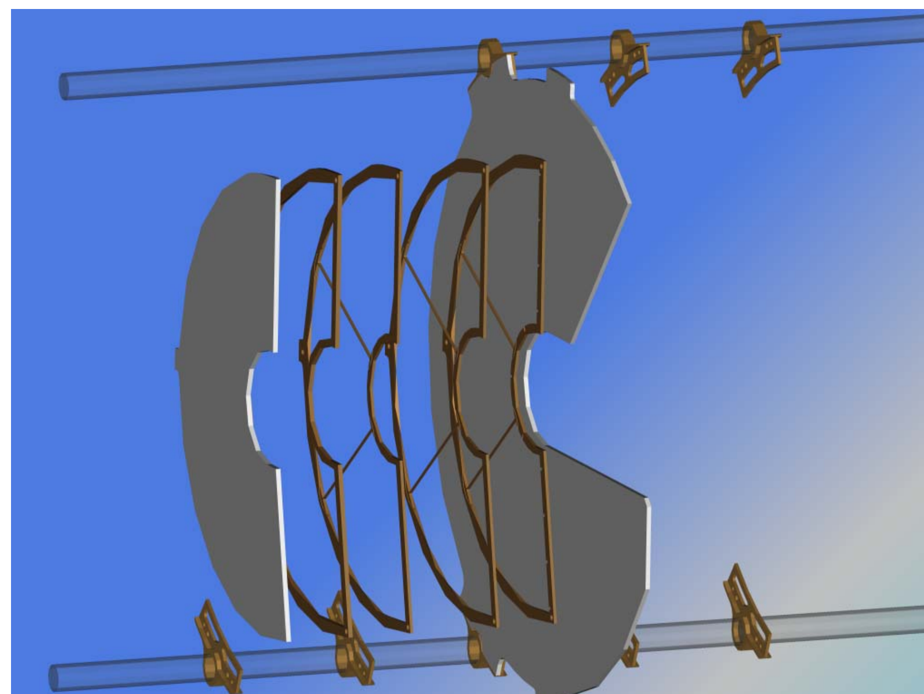
TOTEM GEM : Concept and Design

Detector requirements:

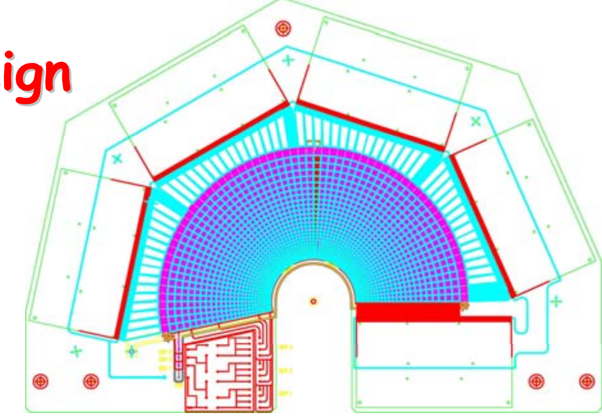
Rate Capability	- Charge particle rates 10^4 p $mm^{-2}s^{-1}$ at $\mathcal{L} = 10^{33}$ $cm^{-2}s^{-1}$
Ageing	- 1 year of continuous operation 10^{11} p mm^{-2} -> 7 mC mm^{-2}
Discharges	- at probability of 10^{-12}/part. -> 10 disch. cm^{-2} $year^{-1}$
Time Resolution	- < 10 ns
Space Resolution	- < 100 μm
Efficiency	- > 97 %







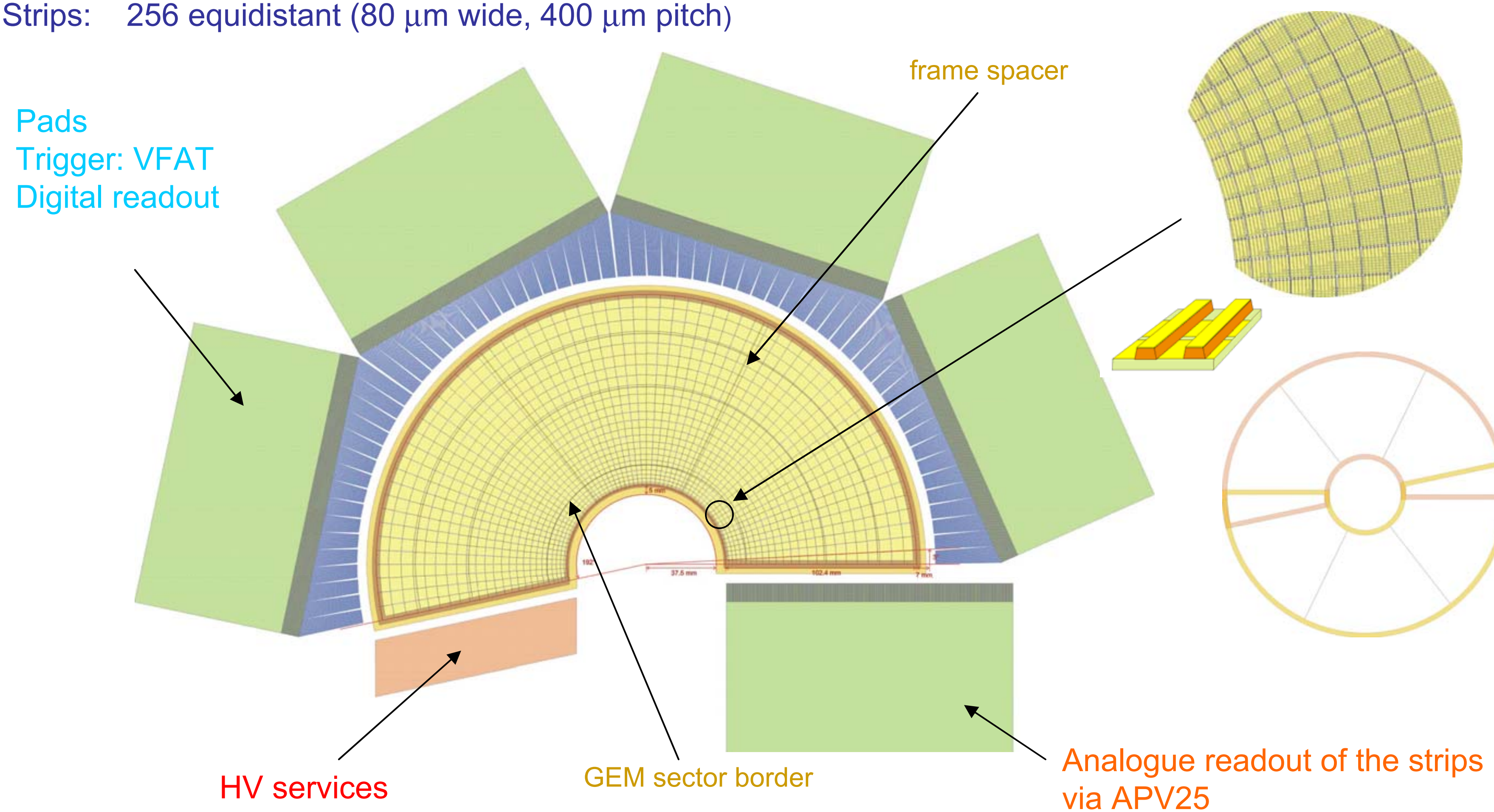
TOTEM GEM 2004 Prototype: Concept and Design



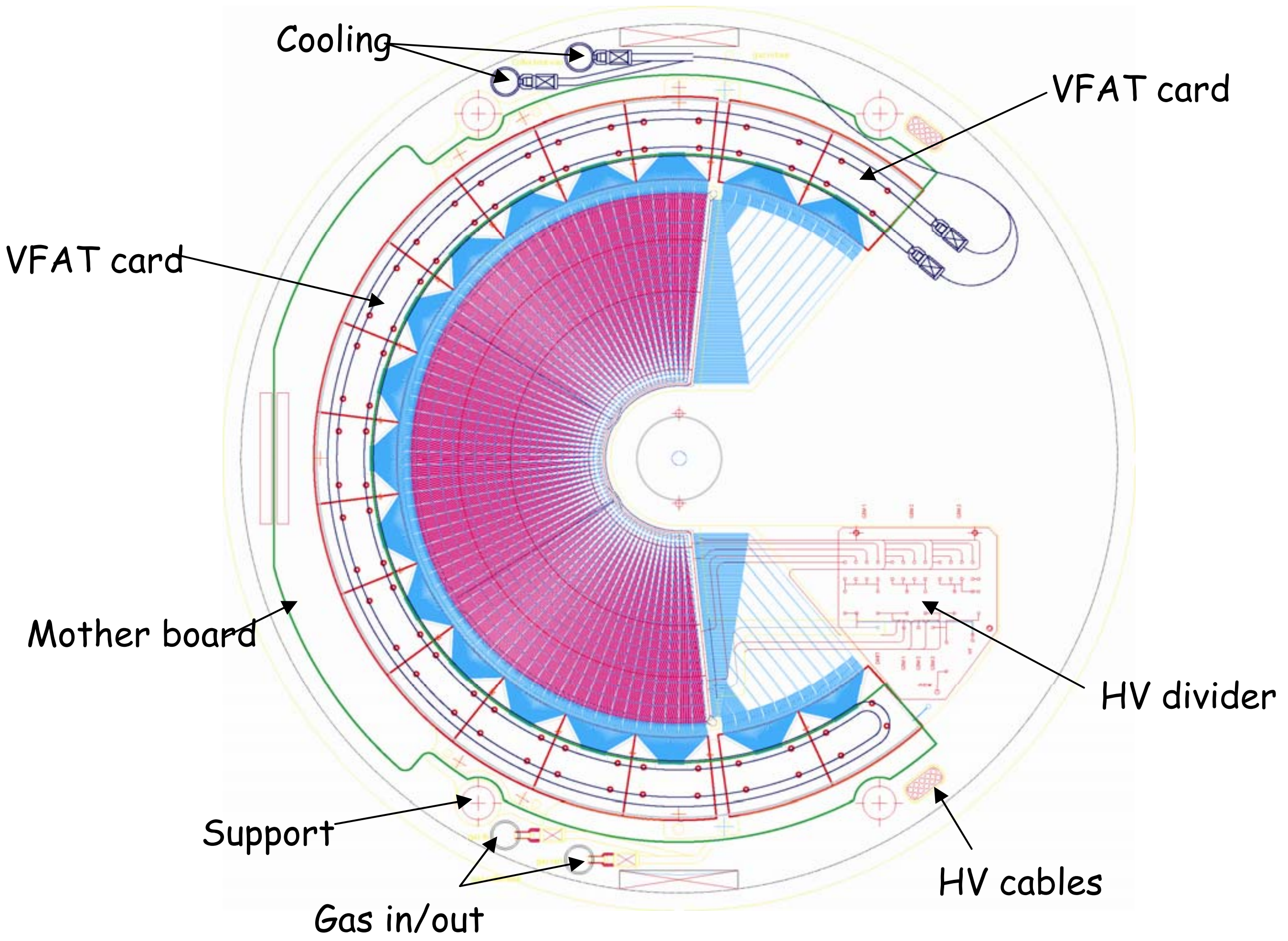
Pads: $65(\varphi) \times 24(\eta) = 1560$ pads

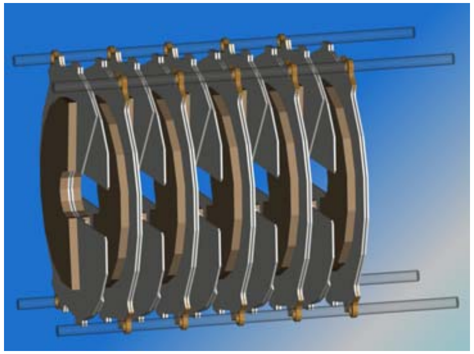
$2\text{x}2\ \text{mm}^2 - 7\text{x}7\ \text{mm}^2$

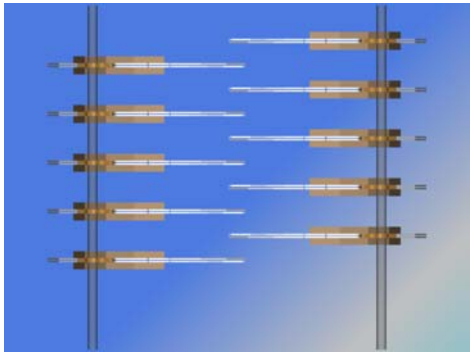
Strips: 256 equidistant (80 μm wide, 400 μm pitch)

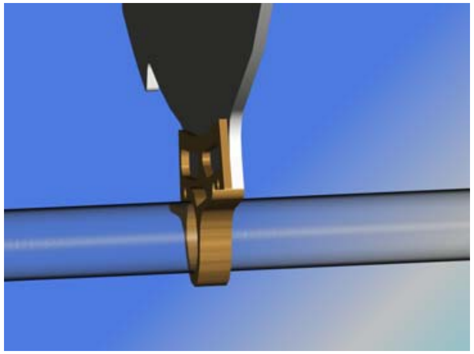


TOTEM GEM Final Detector Module

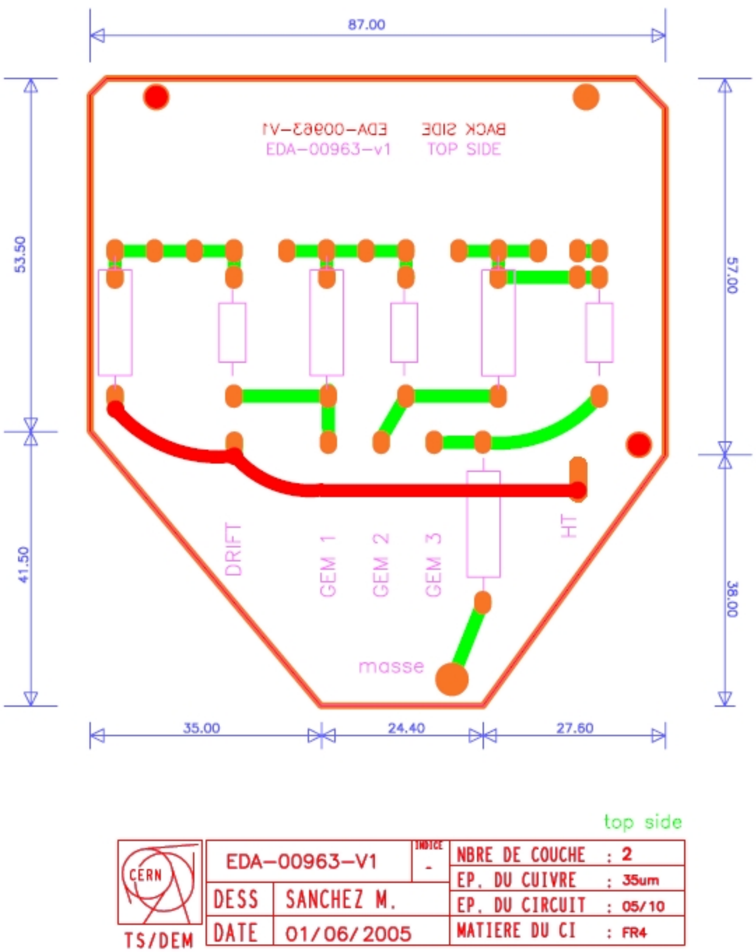


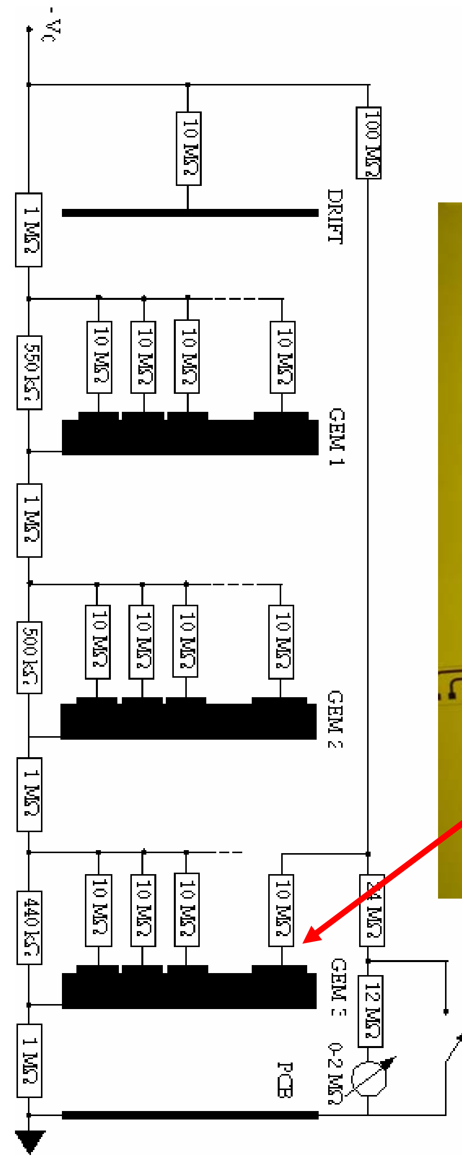


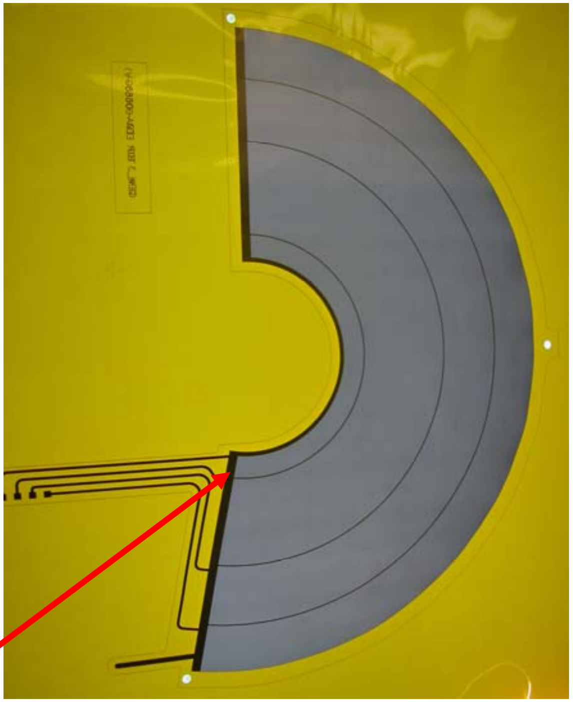




TOTEM GEM HV Divider

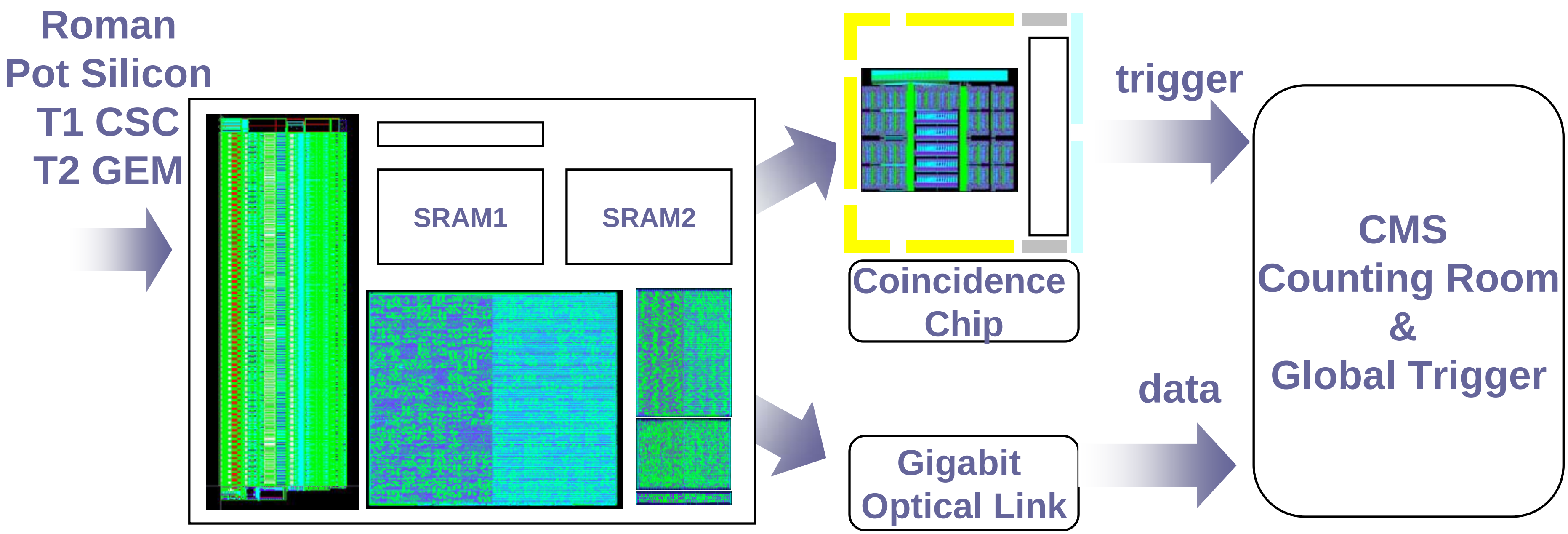






Bottom GEM foil

Electronics



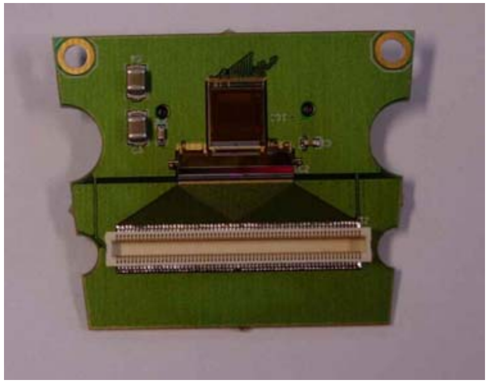
VFAT chip
Designed by PH-MIC in collaboration with C4I

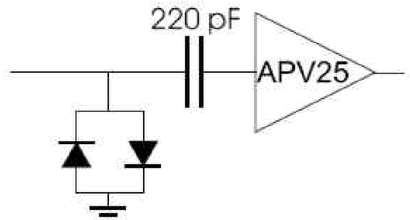
- VFAT and Coincidence Chip very close to submission
- VFAT 128 channels with front end and comparator with adjustable threshold
- VFAT/CC design team: **P. Aspell, G. Anelli, J. Kaplon, K. Kloukinas, W. Snoeys, H. Mugnier, P. Chalmet (CERN-C4i)**

VFAT Front End Specs

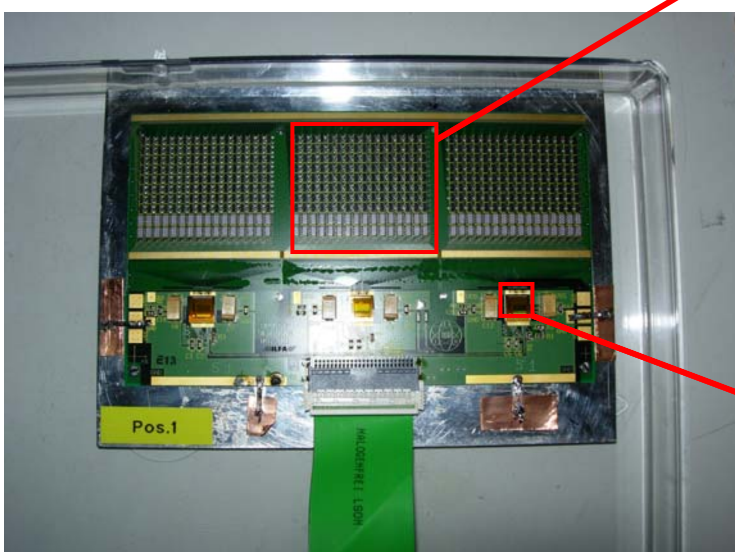
- **Pulse Gain** at discriminator input; 53mV/fC (simulated for maximum charge collection time)
- **Integral nonlinearity error**:
- <1% for input charge 0 to 12fC
- <3% for input charge 0 to 16fC
- **Peaking time**; 22.5ns (simulated for 3.5fC input charge and maximum charge collection time)
- **Power consumption** for nominal bias condition; 1.9mW/channel (250mW for whole front end)
- **Noise** performance for nominal bias condition;
- <1000 e- rms for Cinput = 10pF
- <1400 e- rms for Cinput = 20pF
- **Maximum load of the analogue test outputs**; <5pF

Discharge Protection Circuit

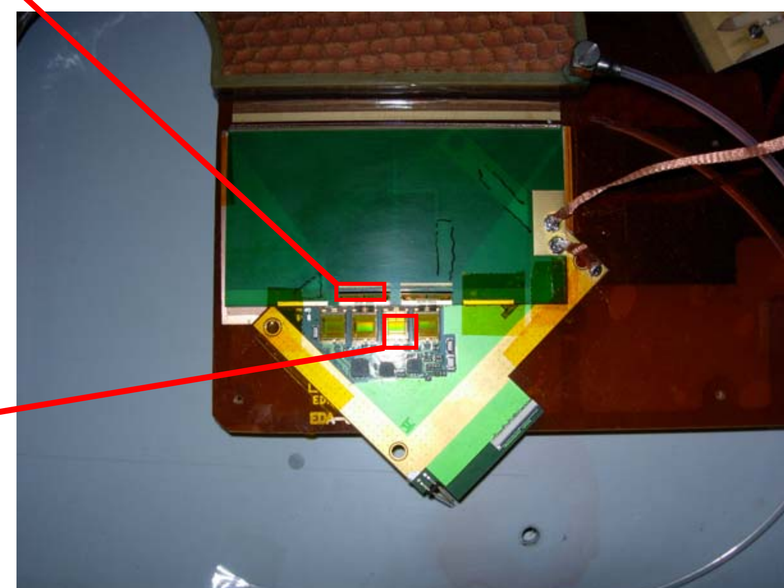




Protection Circuit



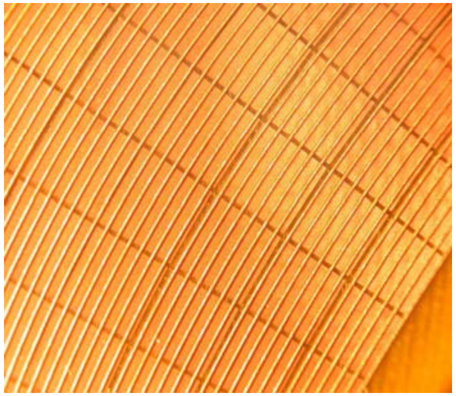
APV chip

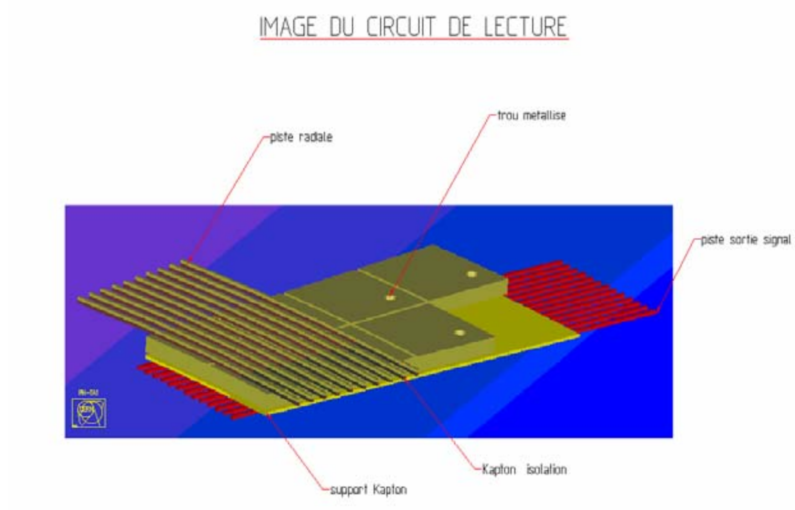


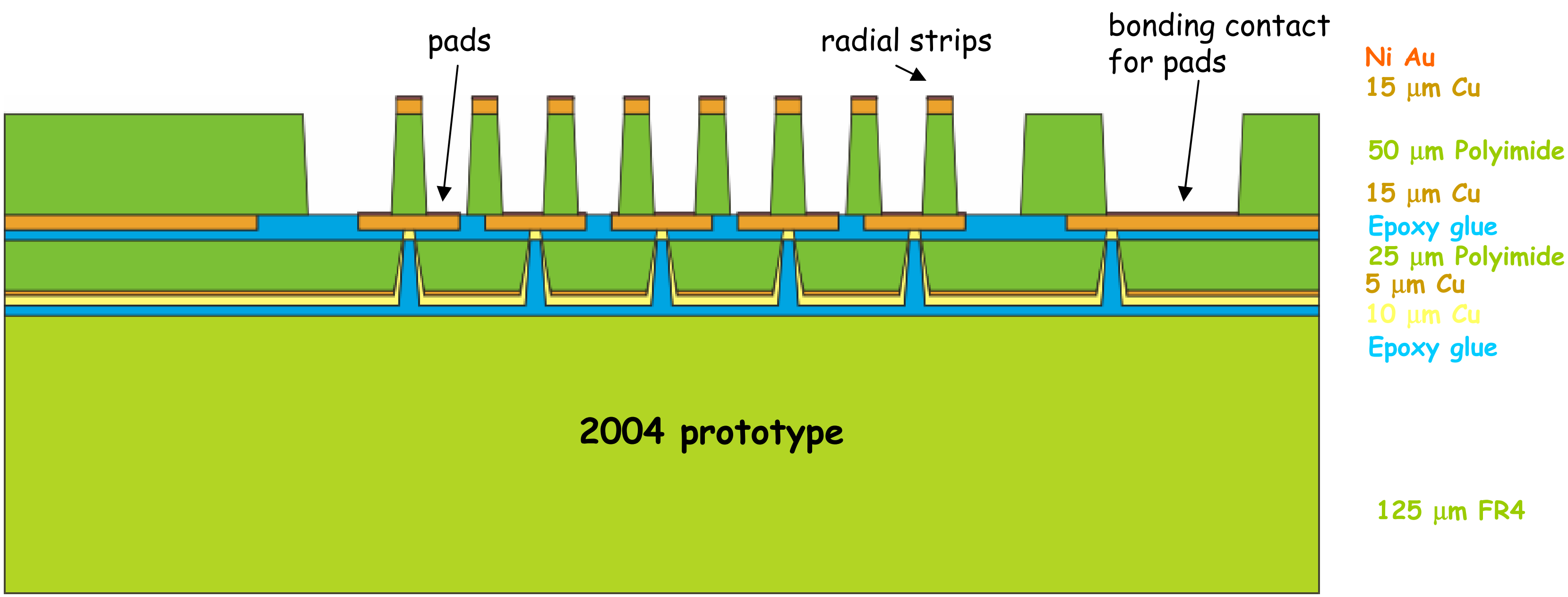
COMPASS

TOTEM

TOTEM GEM - Readout Board

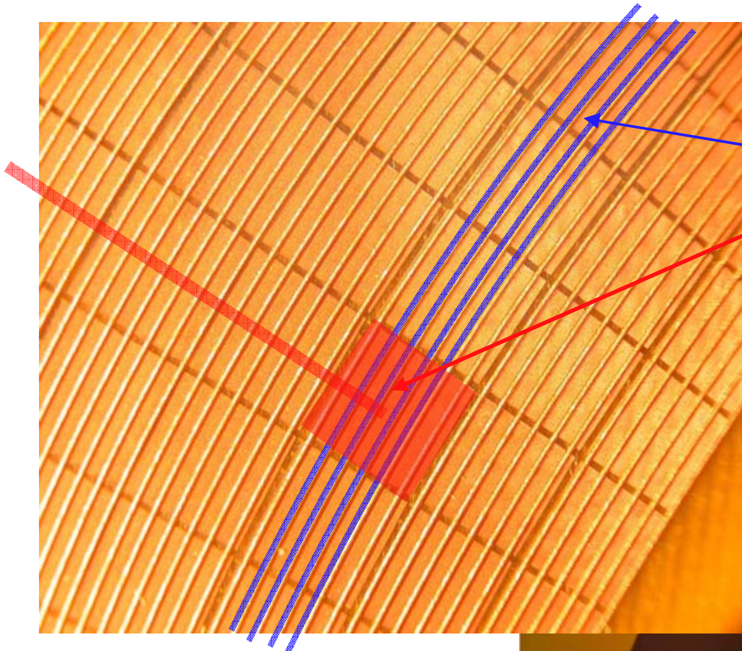




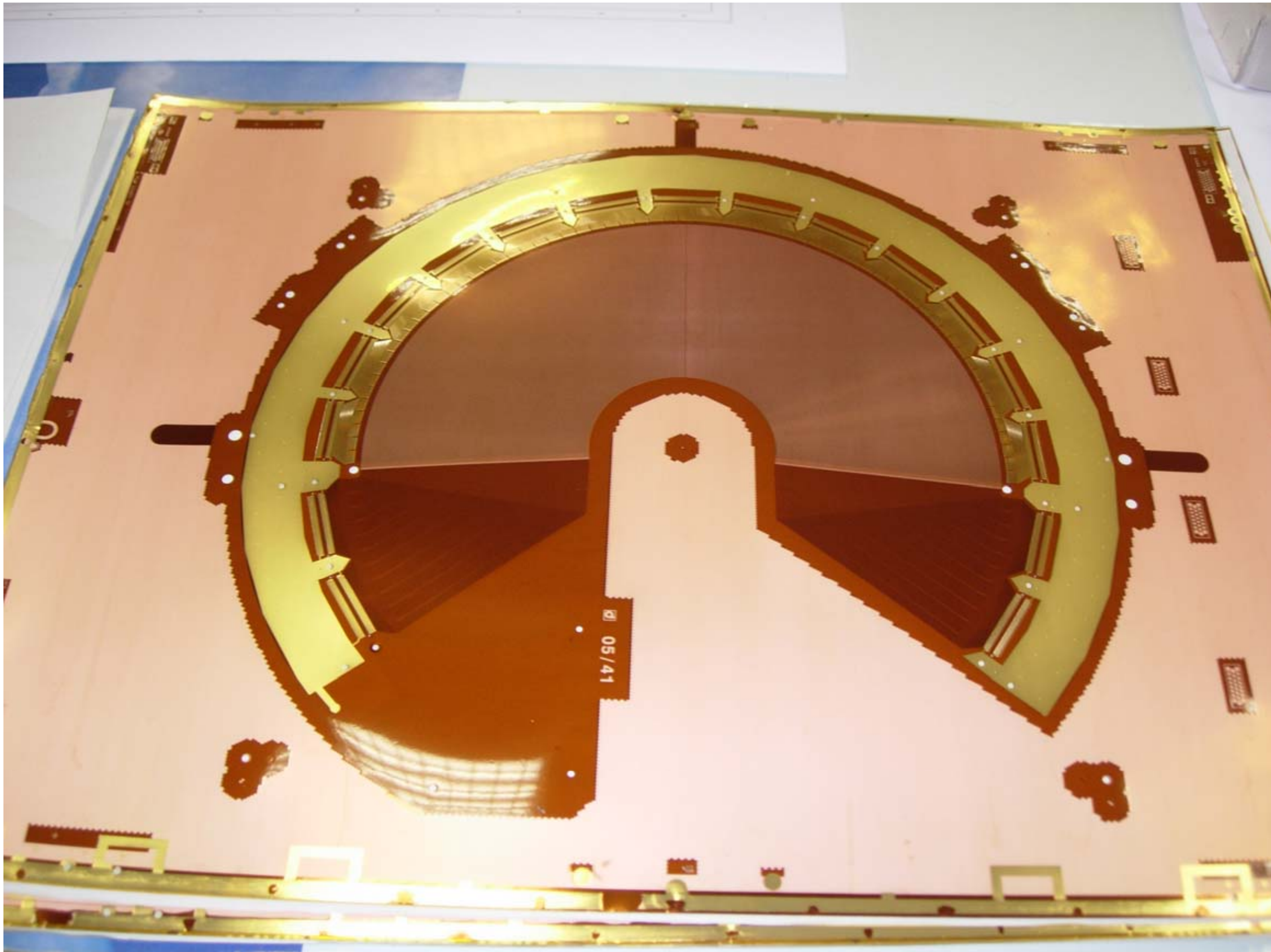


TOTEM GEM - Readout Board

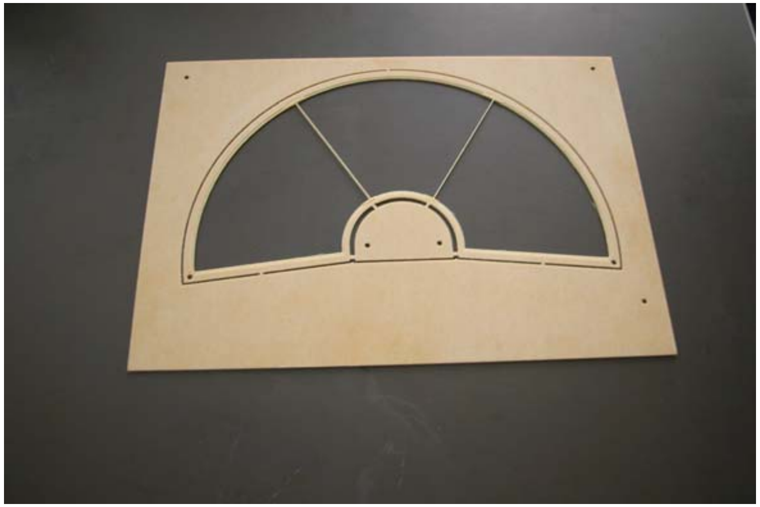
TOTEM READOUT BOARD:
Radial strips (accurate track's angle)
Pad matrix (fast trigger and coarse coordinate)



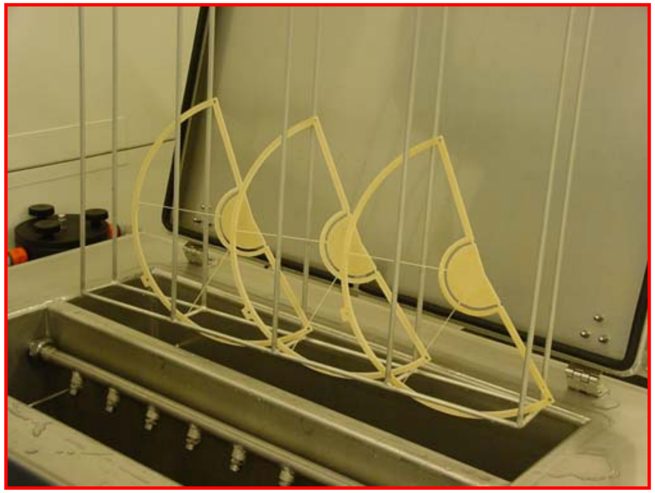
TOTEM GEM - Readout Board



GEM Frames



Machining

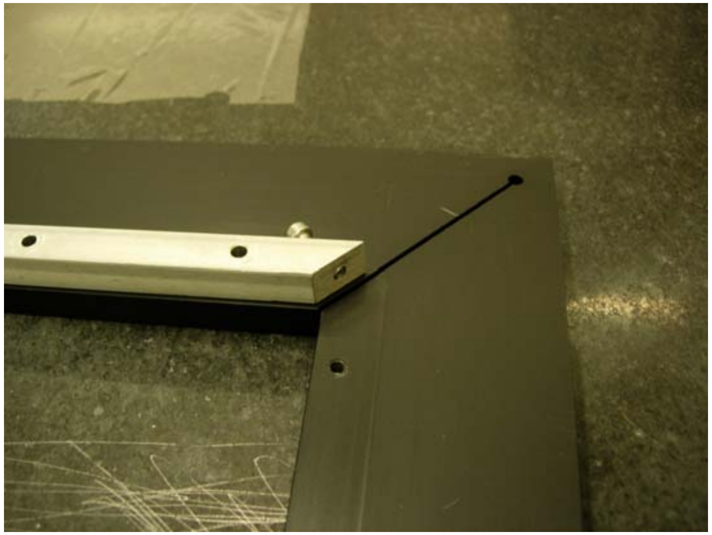


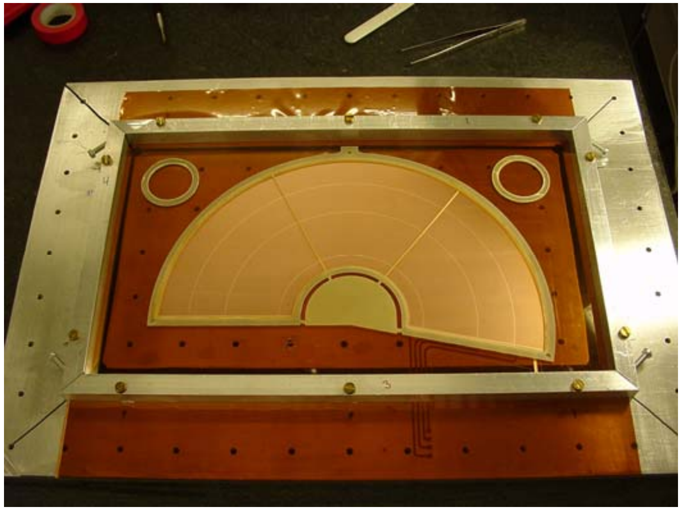
Cleaning

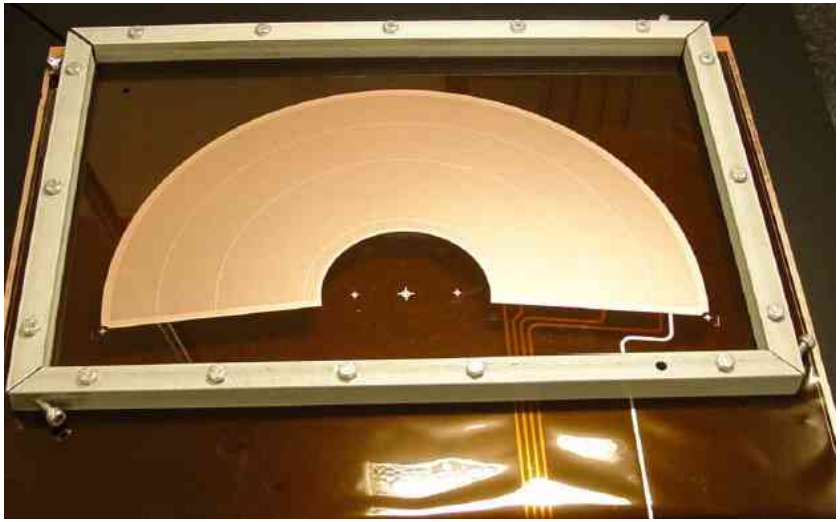
Varnishing and Drying

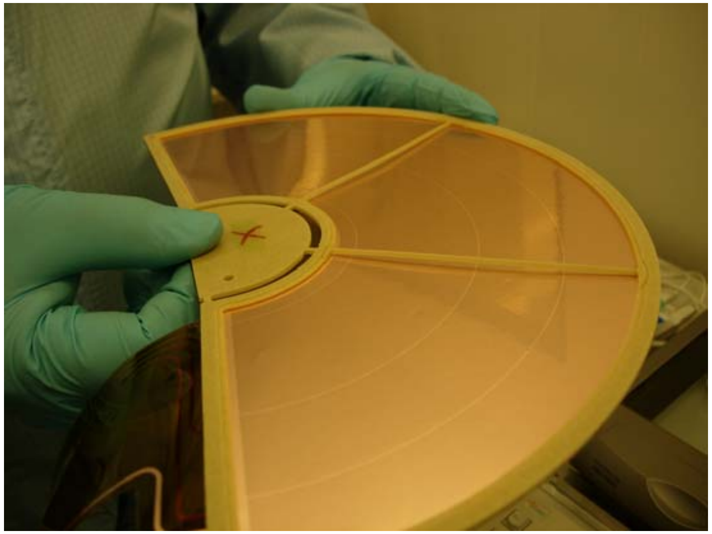
HV Test 5kV

GEM Foil Stretching and Gluing





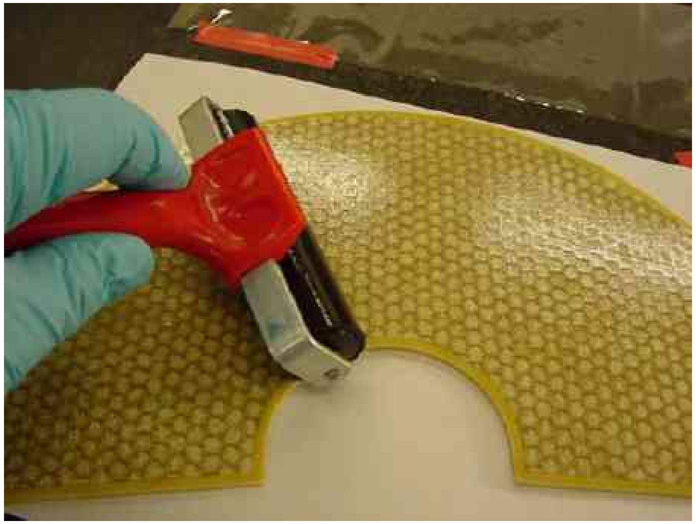




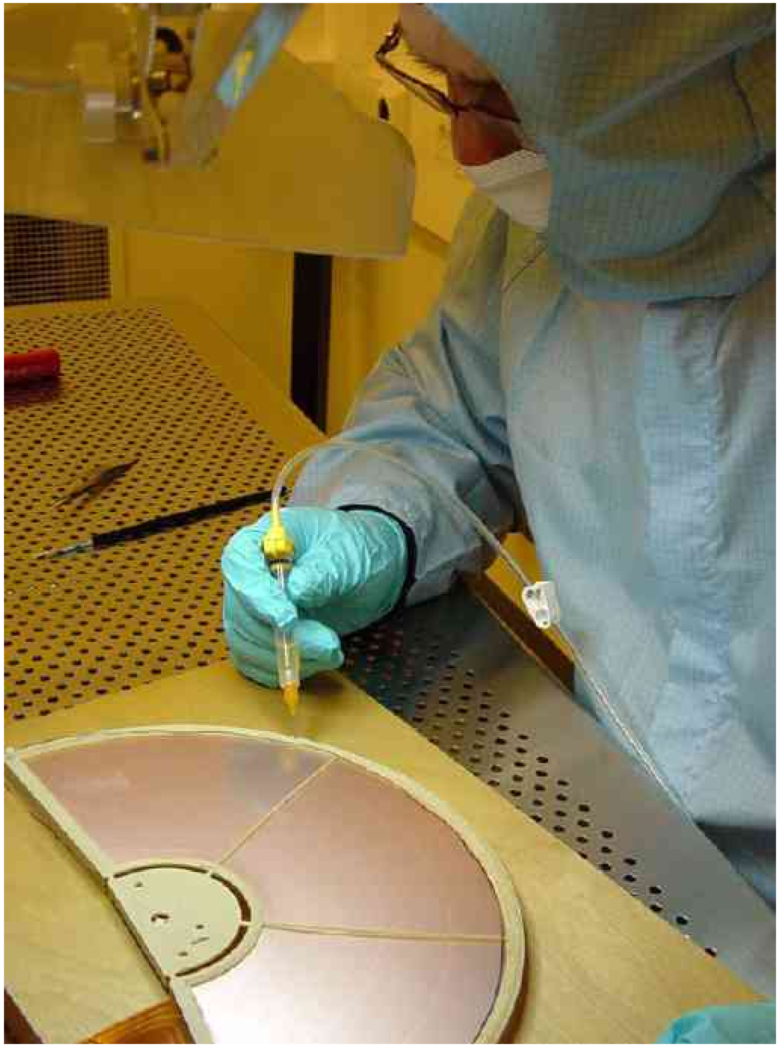
Stretching

Gluing

Support Planes and Sandwich

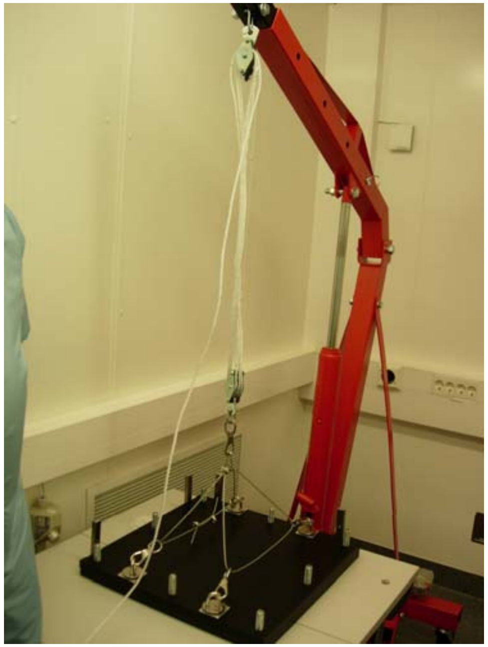


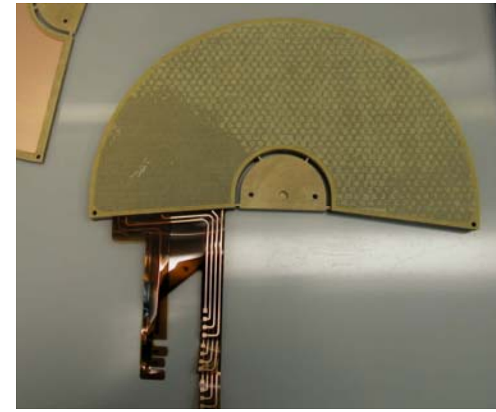
Support and Drift Electrode

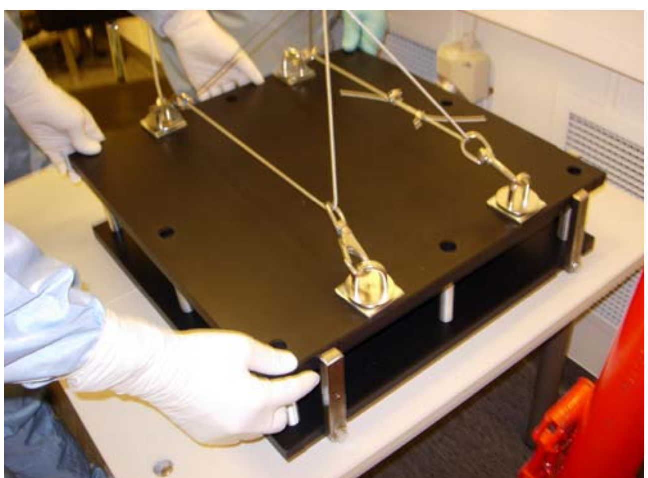


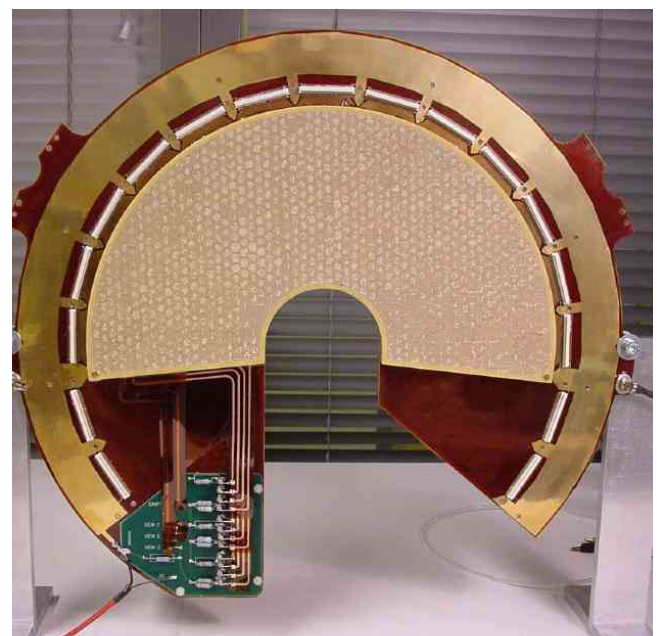
Assembling together

Detector Assembly







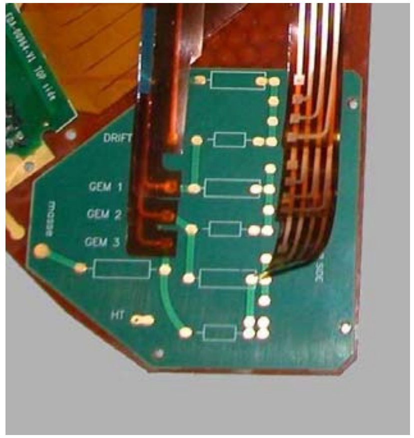


Final Detector Module

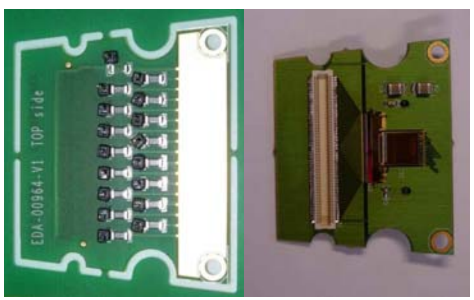
Gas tightness test

HV test with N_2 for external discharges

Performance test with test cards

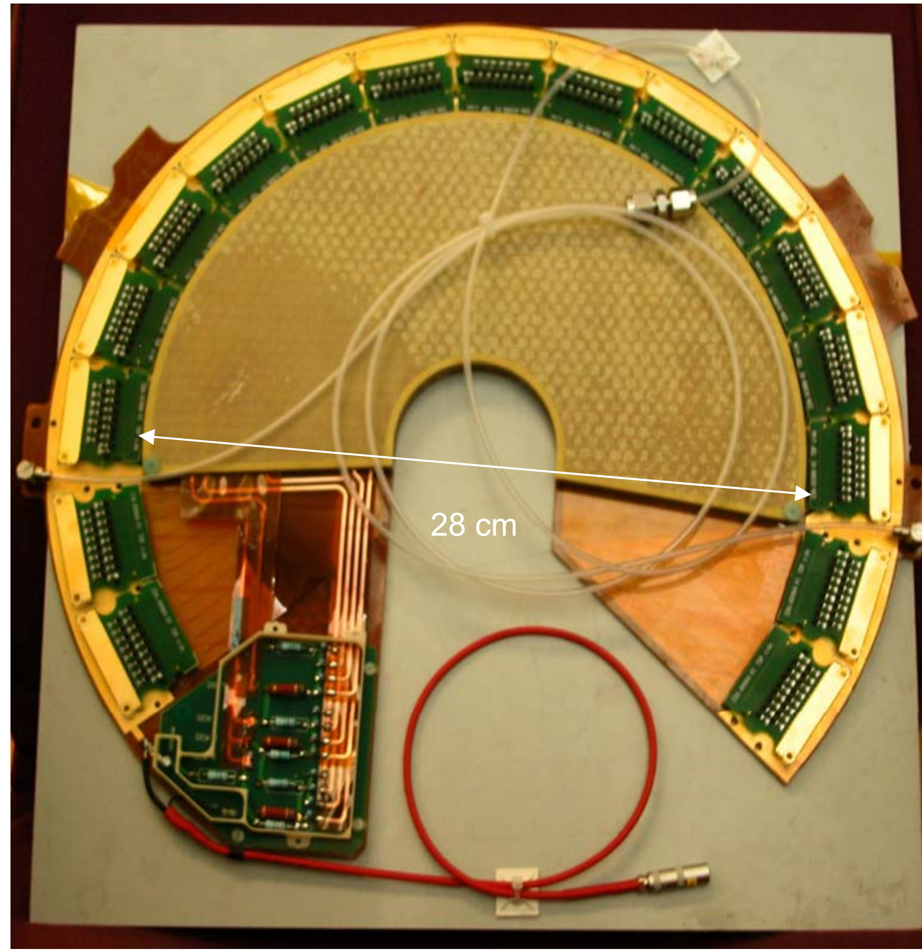


HV resistor divider board



Test Cards

No bonding anymore



T2 DCS Requirements Chart

T2 telescopes

HV subsystem

Functionality:
Power distribution for 40 detector modules

Modules:
2 x 20 channels
CAEN SY527/A1732
12 channels modules
loc: S2B03 or S2B04 in the counting room
2 x 20 HV switches
loc: HV patch panels

Controls:
individual V set
(V tables load)
individual/global V on/off
individual/global occupancy limit set
individual I limit set
(I tables load)
trip/alarm handling

Monitors:
V/I monitor
trip counter (time)
crate T (cooling)

Interlock/alarm data:
trip

Interlock:
gas composition
gas leak
gas flow
trip counter
LV on/off
cooling water leak/ overpressure
beam
B field

Logs:
V/I, crate T

Feedback loop:
environment monitor V/I

Gas subsystem

Functionality:
Gas distribution for 40 detector modules

Modules:
1 Mixer Unit
2 Distribution Modules
10 (+10 return) x 2 lines

Controls:
Gas composition
Gas flow

Monitors:
gas composition
gas flow
gas pressure
water/oxygen content

Interlock/alarm data:
composition for HV
flow for HV
gas leak (oxygen)for HV
overpressure

Interlock:
overpressure

Logs:
composition, flow, pressure, water and oxygen content

Environment monitors

Functionality:
Monitor of ambient T,P,R and level of radiation

Modules:
T monitor
P monitor
R humidity monitor
Radiation monitor

Controls:
on/off

Monitors:
LV for monitors
T, P, R

Logs:
T, P, R, radiation

Feedback data:
for HV system

Electronics Data & Trigger

Functionality:
data & trigger delivery: calibration, threshold, delays settings, chips & channels suppression, gain (HV), gas composition loops

Modules:
FE

Controls:
Programmable chip parameters

Monitors:
Chips, channels status

Logs:
Chips & channels status parameters

LV subsystem

Functionality:
Power distribution for FE

Modules:
4x 2 2.5V 10A
4x2 2.5V 10A
4x1 2.5V 5A
WIENER
12 channels modules
loc: racks close to detectors

Controls:
on/off
V, I

Monitors:
on/off
V,I
crates T (cooling)

Interlock/alarm data:
on/off for HV system

Interlock:
crates T
electronics T
water T
water flow
water leak
water overpressure

Logs:
V,I

Electronics Cooling

Functionality:
Water cooling for the FE

Modules:
Water pressure
Water flow
Water T monitor
T sensors on electronics cards (40 channels)

Controls:
water flow on/off
water flow
water pressure
water temperature

Monitors:
water in/out T,P,flow
electronics T

Interlock/alarm data:
electronics T for LV system
water flow for LV system
leak (flow) for LV&HV systems
water overpressure for LV&HV systems

Interlock:
leak
overpressure

Logs:
water flow, T, P
electronics T

T2 HV Flow Chart