Spherical GEMS

Development of spherical GEM detector for parallax-free XRD

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CERN-GDD

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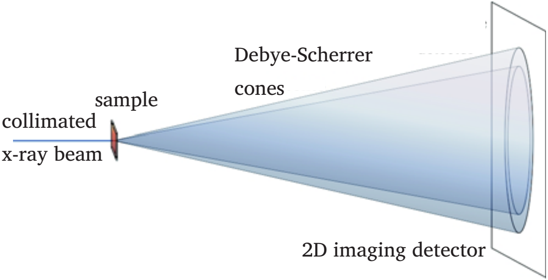
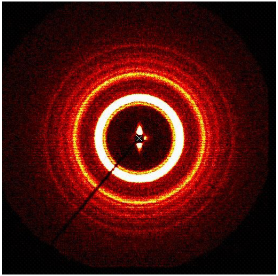
Powder diffraction and detector requirements

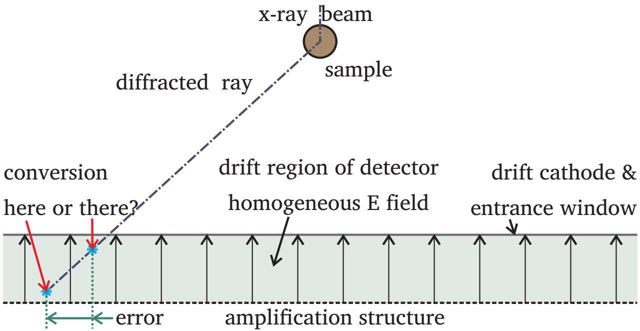




- Circular patterns if sample is powder of randomly oriented cristals.
- Need a large area detector (large for solid state standards)
- Gas detector seems natural solution, but introduces parallax error

X-RAY DIFFRACTION WITH GAS DETECTORS

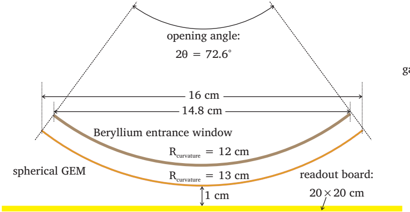
Parallax error & how it degrades resolution

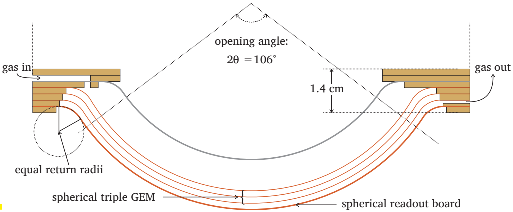


- Efficient x-ray conversion gas reduces the probable conversion depth
- Increase in pressure has same effect, but necessitates thicker window
- Spherical entrance window helps a lot, and allows higher pressure
- Truly spherical conversion gap would be optimal (zero parallax error)

Plans for prototypes

Single and triple spherical GEM detectors





Single GEM

- Spherical Be entrance window
- Can work with 3 bar of Xe
- Spherical GEM creates radial conversion field
- Foresee problems with charge transfer in induction region

Triple GEM

- Overcomes charge transfer issues
- Tighter tolerances
- Need 3 spherical molds
- Spherical readout board is not trivial

STRETCHING GEMs

A few calculations

Surface areas of GEM before and after remolding

$$A_{\text{curved}} = 2\pi \int_0^{\theta_{1/2}} r^2 \sin\theta \, \mathrm{d}\theta = 2\pi r^2 \left(1 - \cos\theta_{1/2}\right)$$

$$A_{\text{flat}} = \frac{\pi d^2}{4} = \pi r^2 \sin^2\theta_{1/2}$$

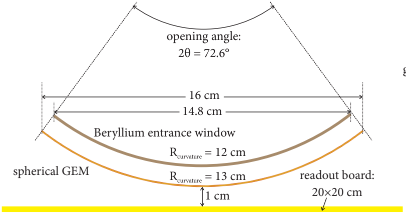
The surface stretch factor is:

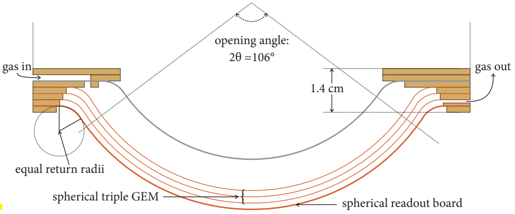
$$\frac{A_{\text{curved}}}{A_{\text{flat}}} = 2\frac{1 - \cos\theta_{1/2}}{1 - \cos^2\theta_{1/2}}$$

Depends only on the opening angle.

Two detecors

Entering a GEM in existing geometry





Single GEM

- Surface stretching: 24.9 %
- Linear elongation: 11.8 %

Triple GEM

- Surface stretching: 10.7 %
- Linear elongation: 5.2 %
- Stretched surface area: 147 cm^2: might need segmentation

Two detecors

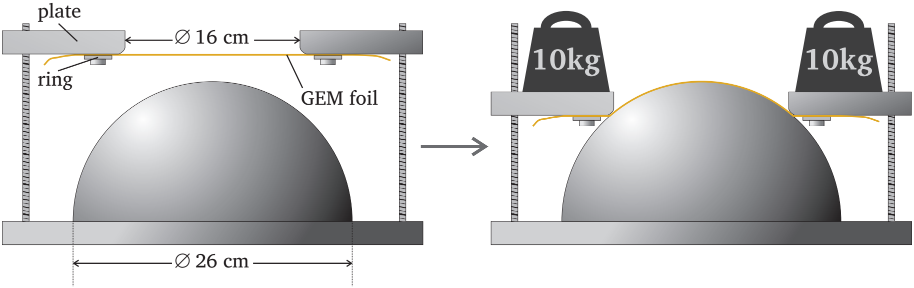
Thoughts about resulting GEM properties

Some considerations

- On average, the aspect ratio (*depth*/*width*) of the holes will decrease with the third power of the linear elongation: 72 % & 86 %. Need to compensate that in the design of the GEM (50/100 & 60/120).
- The area of the electrodes increases with the surface stretching factor; the insulator thickness decreases with the same factor. Hence, the capacitance increases with the square of that factor: 56 % & 22.5 %.

Setup for tests

As simple as possible



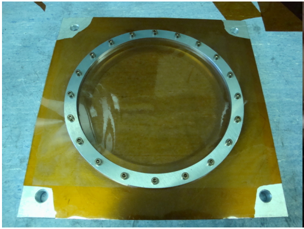
- Minimal custom tooling needed
- The flat GEM is mounted on the plate without possibility to slip
- Opening diameters and radii of curvature can be individually tuned
- Wrinkles, scratches, breaking foils
- Delaminations between copper and polyimide
- Migration of polyimide gives rise to inhomogeneity of thickness
- Oxidation of copper electrodes

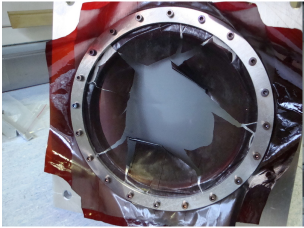
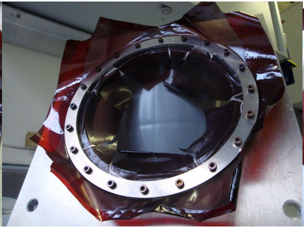
First test

Weight: 1.5 kg

Second test

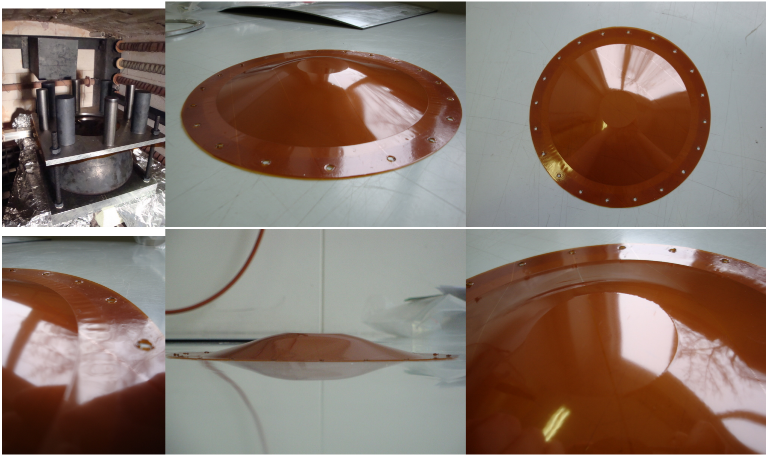
Bare polyimide, weight: 4.2 kg, temperature: 400°C




Third test

Bare polyimide, weight: 5.6 kg, temperature: 350°C

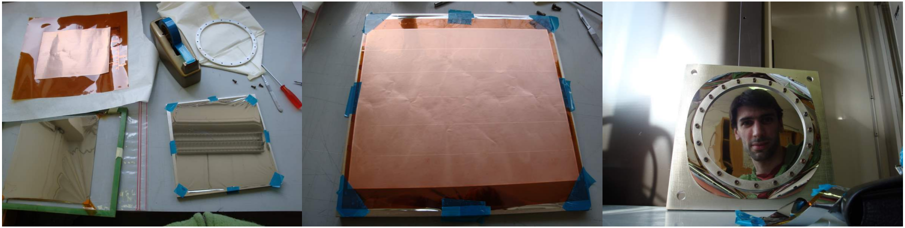


Fourth test

With copper, weight: 7 kg, temperature: 350°C

Fifth test

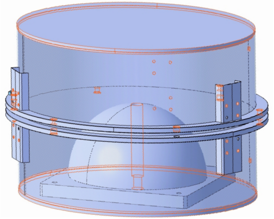
Kapton sandwich to prevent oxidation



- Sandwich kapton/GEM/kapton
- Used 12.5 μm kapton sheets
- Copper removed, but chromium adhesion layer left to prevent outgassing of polymer
- Aluminum parts of construction nickel-plated
- Result not much different from previous test: it oxidizes anyway
- In addition, we observe tough polymer formation on the electrodes

Gas-tight enclosure

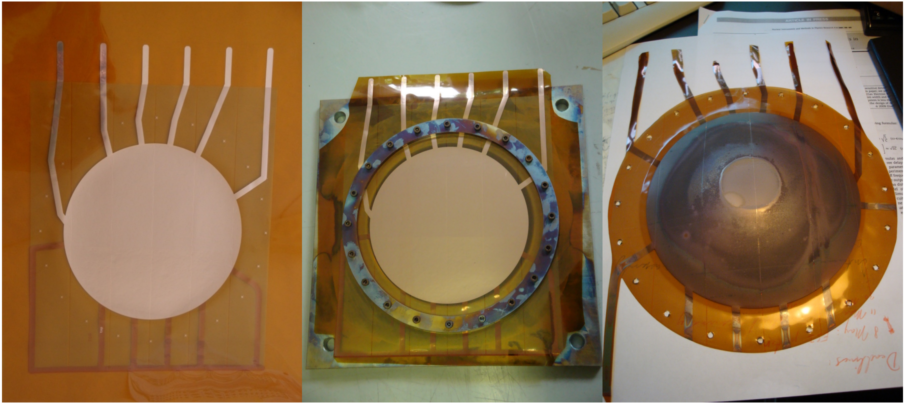
An oxigen-free environment



- Stainless steel box encloses the setup completely
- Fits entirely in the oven, and can still be opened easily
- Flow of argon to prevent oxidation
- Could foresee tests under low vacuum

Test in argon

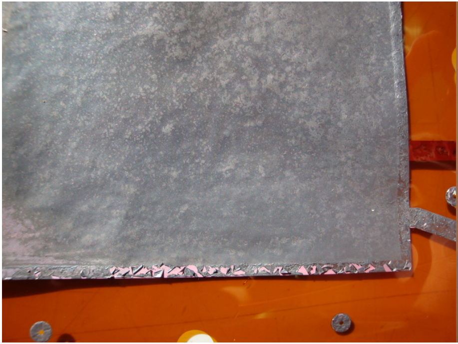
Using a GEM *with modified electrodes*



- GEM bends properly if temp. cycle is ∼ 24 hrs, at ∼ 20 kg of pressure
- It holds high voltage! 650 V in air, few nA leakage
- Major part of deposits on electrodes are in fact polyimide

Deposits

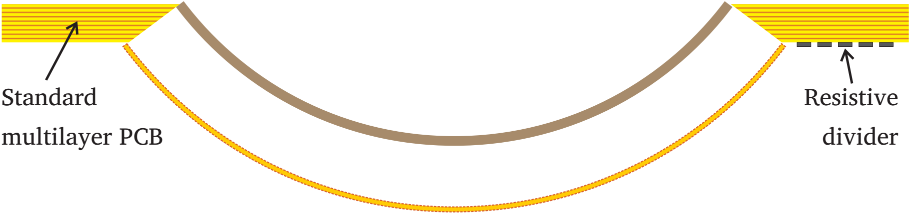
Even in a clean atmosphere




Apart from oxidation, deposits of a polymer are found on the electrodes. Will try heat cycle in moderate vacuum. GEMS may end up clean enough for a sealed detector.

Conversion region

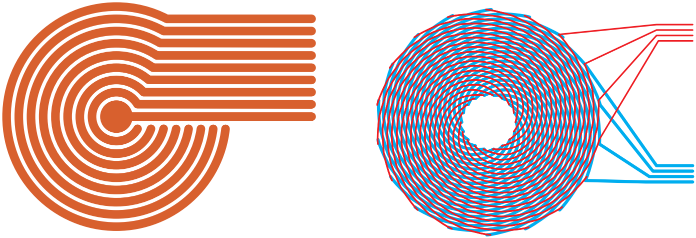
May need some sort of field cage



- Lateral extension of fringe field between the spherical planes is proportional to width of conversion gap
- Radial field quality is critical for parallax-free property
- A field cage could be made of a standard multilayer PCB
- Resistive divider distributes voltages over layers
- The cage could be (part of) the mechanical fixture for the GEM

Spherical triple GEM

Considerations for a readout board



Constraints on spherical readout board

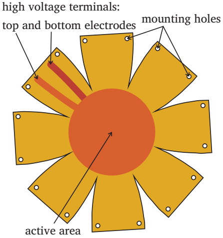
- Vias are less reliable, would need extensive tests
- No traditional X-Y-strips, as adhesive is not compatible with 350°C
- One could pattern 2D strips on the faces of a GEM
- No rigid board. *Or find a method for spherical image transfer*
- Rigid board patterned by mechanical engraving (even vias possible)

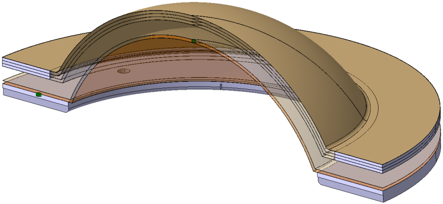
Conclusions & outlook

Still a long way . . .

Steps to proceed (very roughly)

- Find optimal parameters for shaping GEM foils
- Define maximum opening angle
- Design masks for spherical GEMs
- Readout board strategy
- Mechanical design of spherical tripleGEM prototype





MPGD2009

Kolympary, Crete, Greece, 12–17 June 2009