GEM Construction for DarkLight Phase 1(c)

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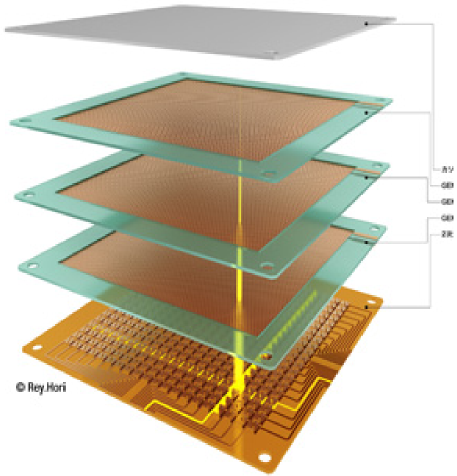
Outline

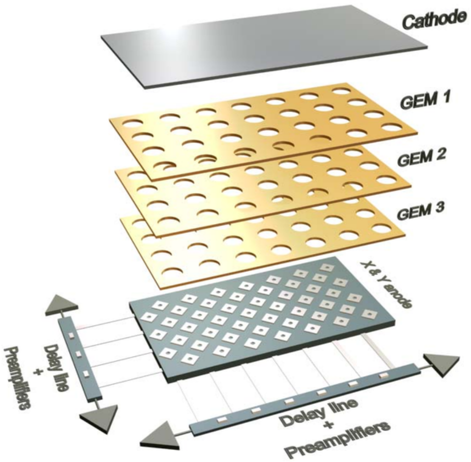
What is a GEM detector?

- A Gas Electron Multiplier detector is a type of a gaseous ionization detector.
- Position detection of ionizing radiation such as charged particles, photons, X-rays and neutrons, in gas detectors.
- Introduced and developed by F. Sauli in 1997 at CERN.

What is a GEM detector?

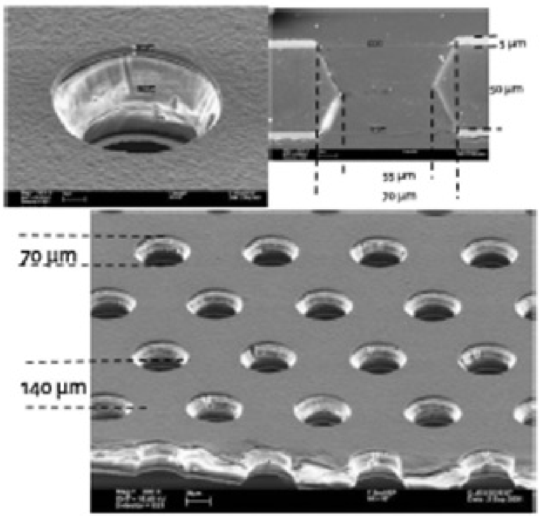
- Typical GEMs are constructed of 50-70 μm thick Kapton foil clad in copper on both sides

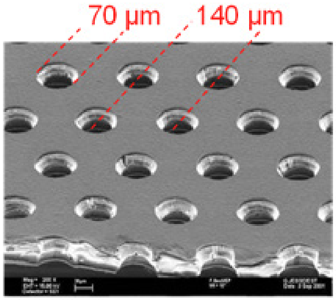


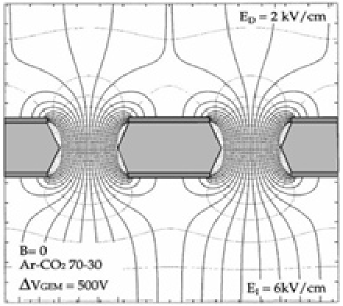


- A photolithography and acid etching process makes 30–50 μm diameter holes through both copper layers; a second etching process extends these holes all the way through the kapton.

- The holes have a double-conical shape With an inner/outer diameter of 50/70 µm arranged in a hexagon pattern with a hole pitch of 140 µm



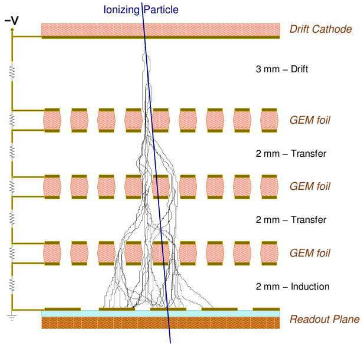




- When a voltage difference around 400 V is applied on both side of the GEM foil, an electric field as high as 100 kV/cm will be created in the holes and result in the charge amplification

How Does it Work?

- A single electron entering any hole will create an avalanche containing 100–1000 electrons; this is the ”gain” of the GEM



Requires several independent voltage settings:

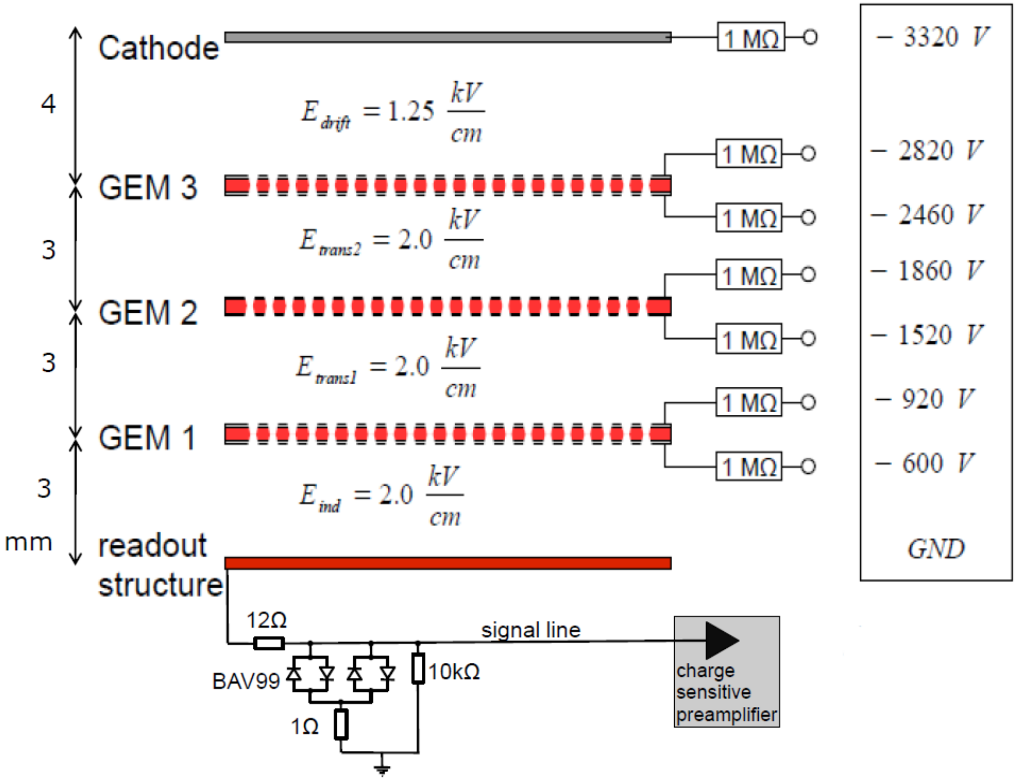
- Drift voltage - to guide electrons from the ionization point to the GEM
- Amplification voltage and an extraction/transfer voltage - to guide electrons from the GEM exit to the readout plane

A detector with;

- A large drift region can be operated as a **time projection chamber**
- A smaller drift region operates as a simple **proportional counter**

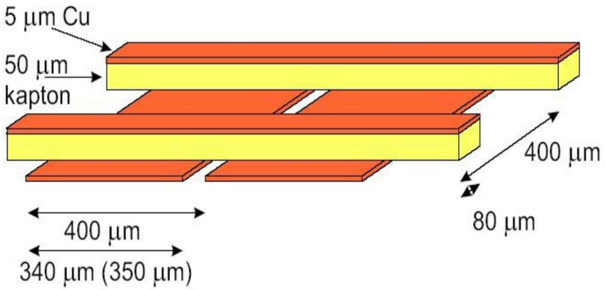
How Does it Work?

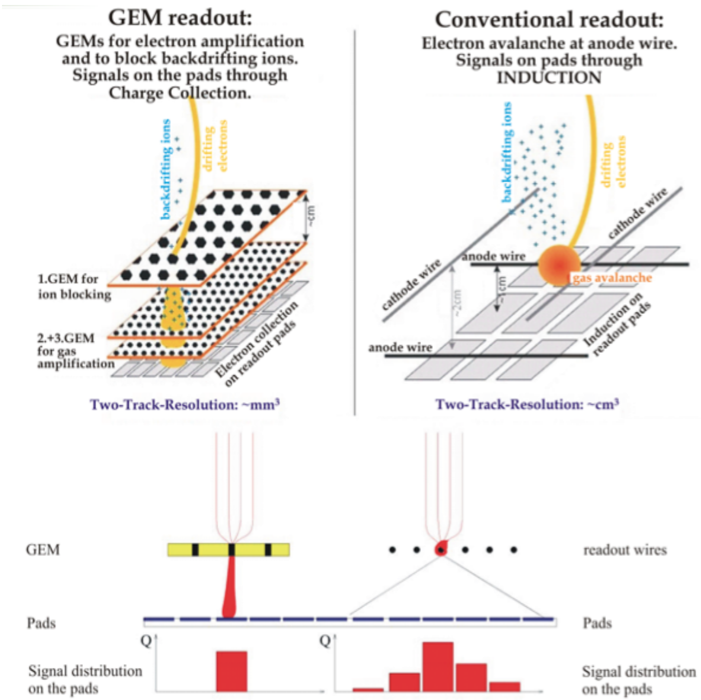
- This shows the voltage supplied to drift foil and each layer of the GEM foils



How Does it Work?

- A GEM chamber can be read-out by simple conductive strips laid across a flat plane. the readout strips are not involved in the amplification process
- They can be made in any shape; 2-D strips and grids, hexagonal pads, radial/azimuthal segments





Why use GEM detectors?

There are many advantages of using GEMs over the other conventional detectors

Characteristics:

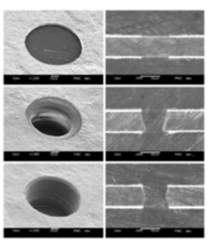
- Relatively low cost
- Radiation hardness
- High rate capability
- Good position resolution
- Flexible detector shape and readout patterns
- Operation with non-explosive gas mixtures
- Can be mass-produced
- Suppression of positive ions

	MWPC	**TPC**
Drawbacks of other detectors	Require labor-intensive Error prone assembly	Positive ions are a source of field distortions at high rates

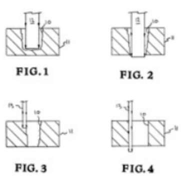
Development over the years..

- The size of GEM foils was limited by the **double-mask etching technique** (40cm $\times$ 40cm maximum)
- In 2010, a new etching method called **single-mask technique** was developed at CERN hence greatly increasing the maximum size (2m $\times$ 0.6m)

2000
Co2 laser
Very precise
Photolithography needed
High cost

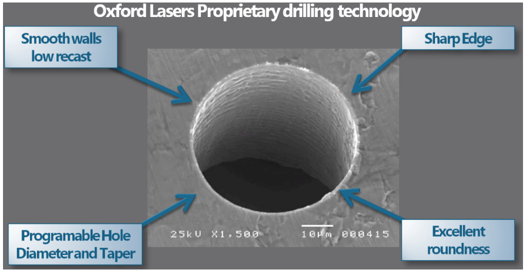


2005
UV laser
Trepanning + cleaning
Very precise
No more photolithography
Low speed 100 holes/s
Medium/high cost



2013
UV Laser
Trepanning + cleaning
Multi beams
Very precise
High speed 1k to 2k holes/s
lower cost

See Orbotech talk WG6



Development of gas electron multiplier foils with a laser etching technique
T. Tamagawa <img alt="Corresponding author contact information" src="http://origin-cdn.els-cdn.com/sd/entities/REcor.gif"> <img src="http://origin-cdn.els-cdn.com/sd/entities/REemail.gif" alt="E-mail the corresponding author">, N. Tsunoda, A. Hayato, H. Hamagaki, M. Inuzuka, H. Miyasaka, I. Sakurai, F. Tokanai, K. Makishima

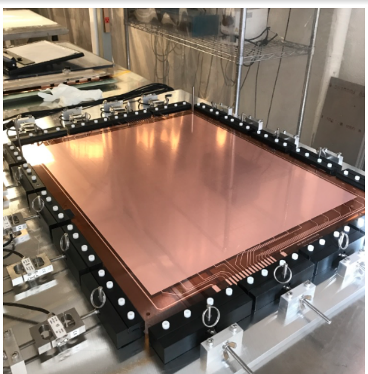
Lawrence Livermore National Security, Llc
US8410396 B1

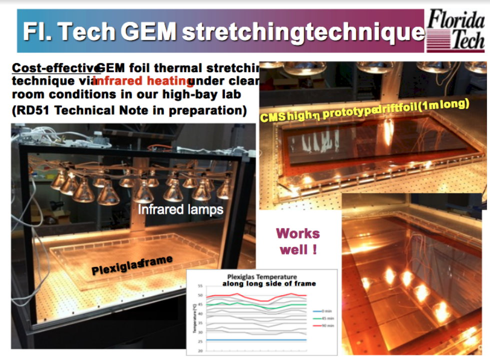
Development over the years..

Techniques for assembling large-area GEMs

To construct large-area GEM detectors, several foil-stretching methods have been developed

- **Gluing technique** - In this method, a stretching device with tension sensors stretches and holds a large GEM foil, a frame is then glued onto the stretched foil
- **Thermal-stretching technique** - This technique employs Plexiglas frames with a different thermal expansion coefficient than GEM foils





A novel technique

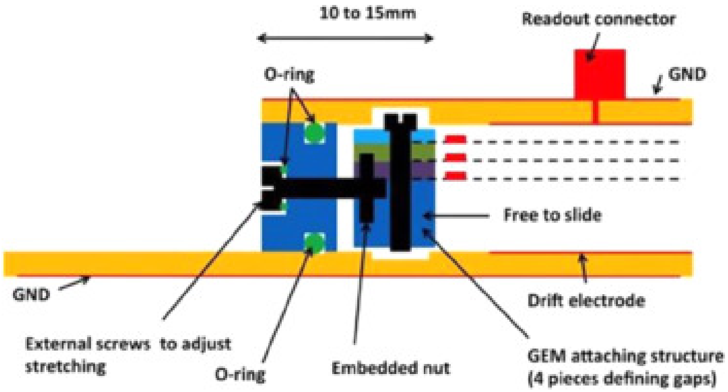
However, there are some drawbacks of these techniques:

1. The assembling process takes a long time and no mistakes are allowed in the process
2. A GEM detector is integrated into a whole un-detachable chamber leaving no possibility of repairing the chamber by replacing any parts
3. More dead area due to spacers

In 2011, CERN developed a new self-stretch assembling technology called **"No Stretch, No Stress (N-S2)"** technique

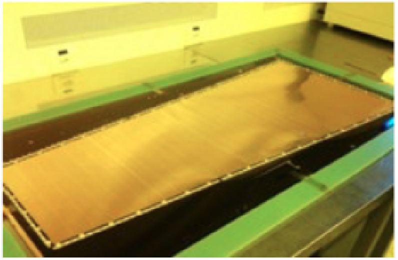
What is NS2 technique?

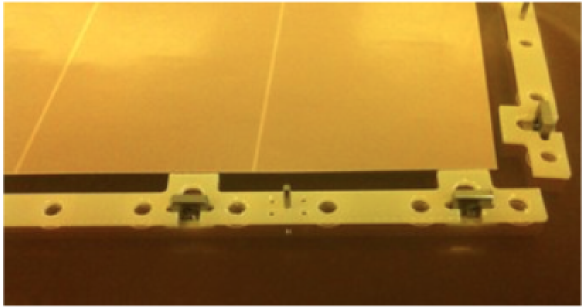
- GEM foils are mechanically fixed by a set of small inner frames, located outside the active area as the first step of the assembly process
- There are screws passing though the main frame fastened by nuts embedded in the inner frames, all the foils are tightened
- The main frame provides the mechanical tension needed for foil stretching and gas tightness for the detector.

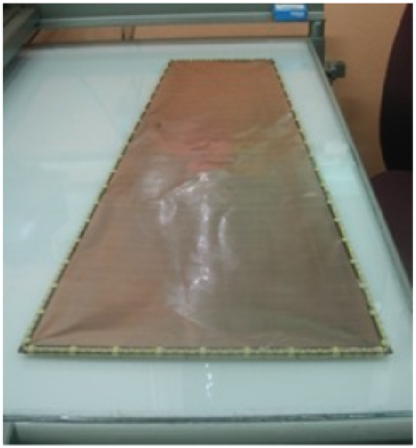


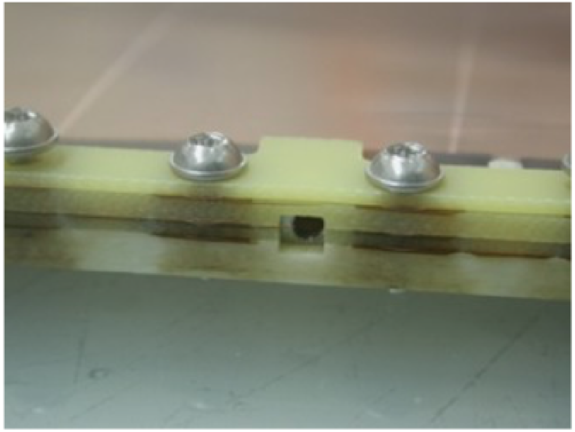
What is NS2 technique?

- This is the GEM chamber of CMS experiment constructed using NS2 technique



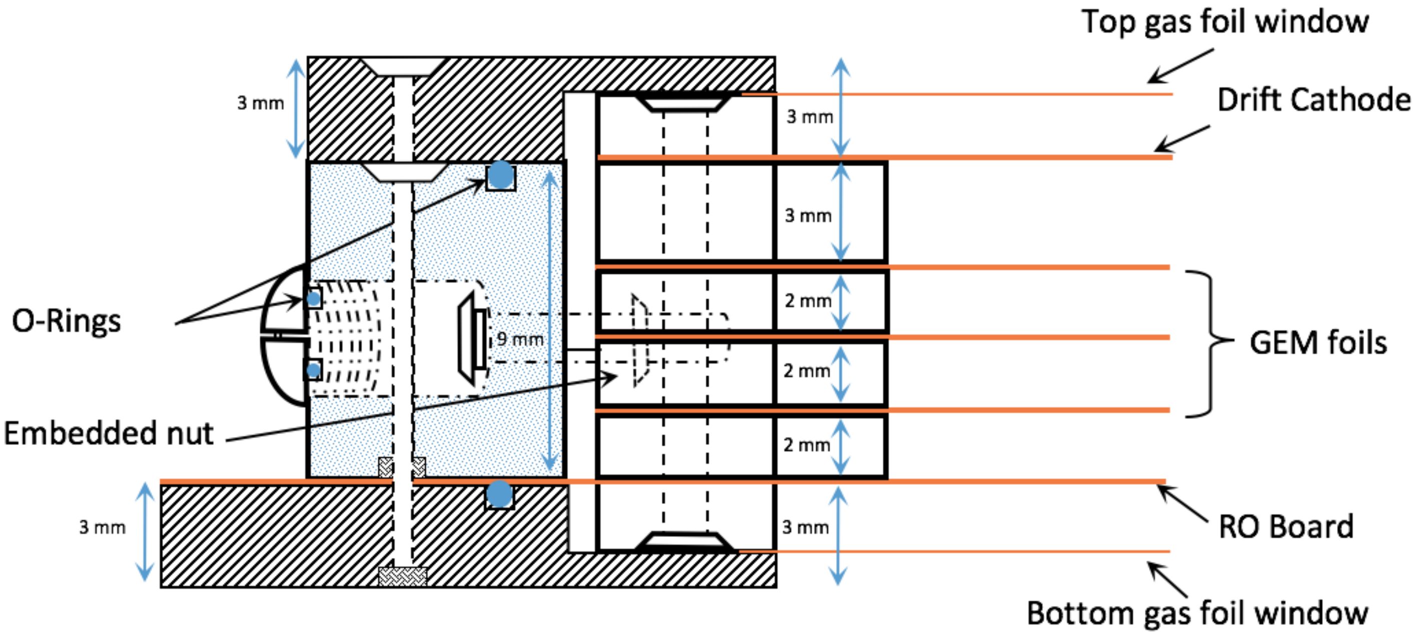






The NS2 design for DarkLight Phase 1(c)

- The side view of the assembled detector - The total height is 15 mm and it has a "3-2-2-2" structure.



Detector Assembly

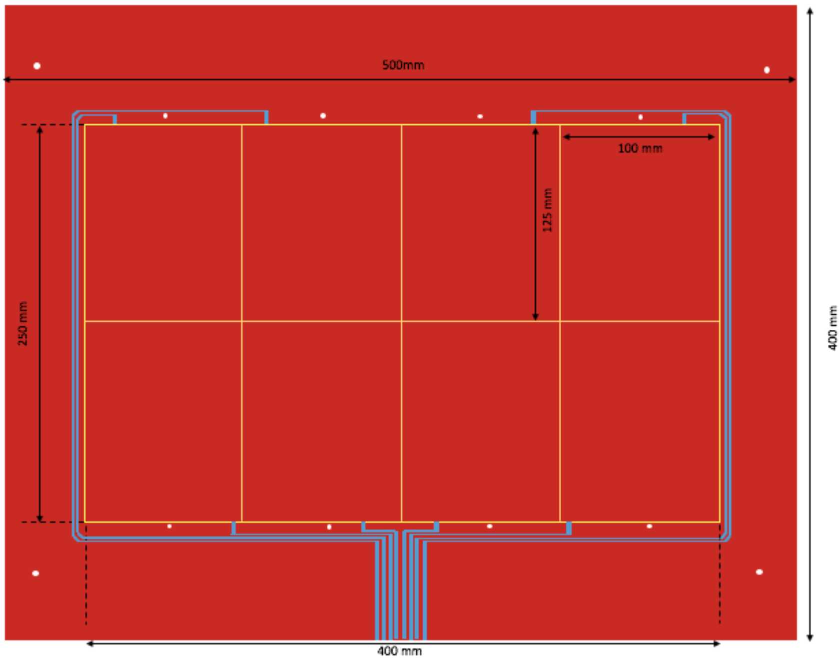
There are 4 steps for the detector assembling:

1. Glue the bottom gas window foils on the bottom main frame
2. Assemble the Drift+ 3 GEM foils + R.O. on the inner frames and fix it to the bottom outer frame
3. stretch the inner frame stack by tightening the screws
4. Glue the top gas window foils on the top main frame and fix it

GEM foil design

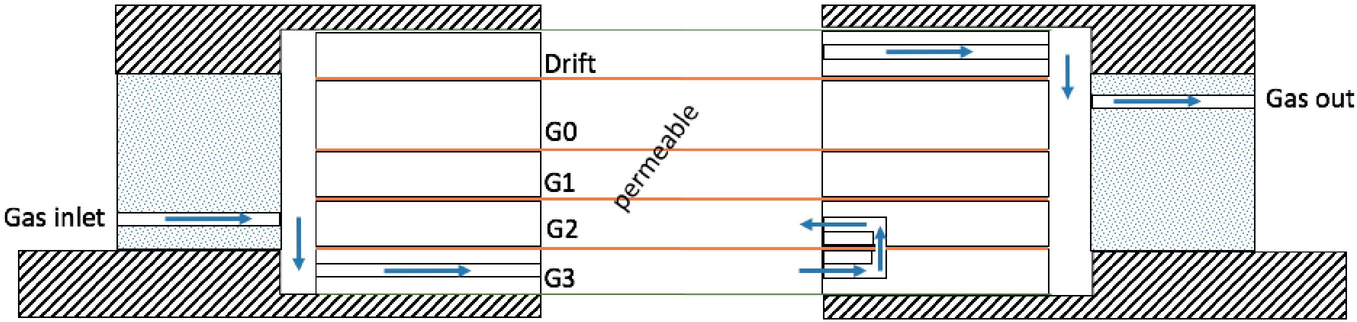
- Active area is 25×40 cm^2
- 8 high voltage sectors - each 125 cm^2

GEM foil with HV sectors



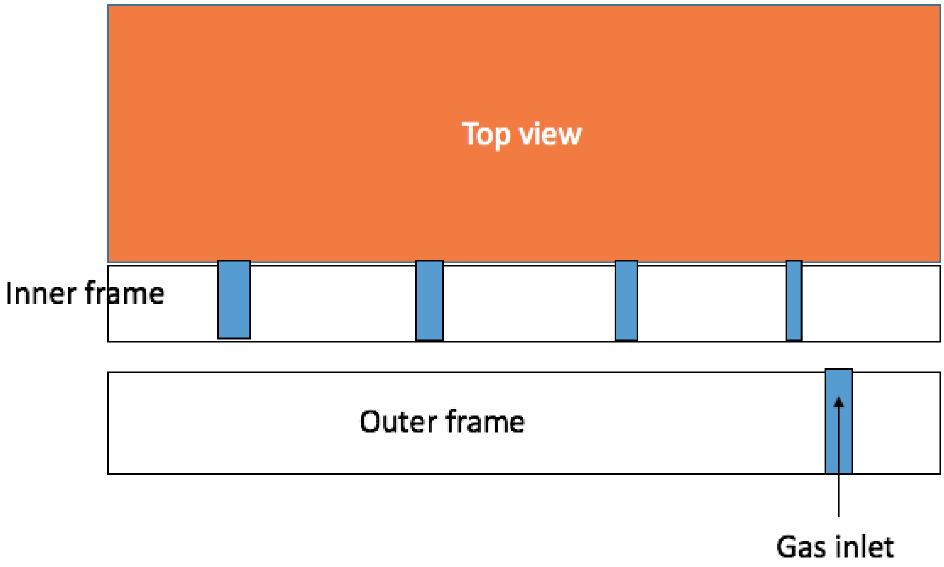
Gas connections

- Gas connections will be horizontal on the outer frame



Gas connections

- Gas inlets in the inner frame will have different diameters in order to supply uniform volume of gas in to the system.



HV connections

- The HV divider is an 8-pin integrated resistor network with the 1st pin connected to the drift cathode, the 2nd to 7th pins connected to the 6 electrodes of the 3 GEM foils, and the last pin connected to the ground
- Each segment connected to a HV line via a protection resistor.
- This design avoids possible damage to GEM foils from discharging and ensure any shorted segments are isolated from the rest.
- HV connections will be rather complex vertical spring-load system.

Conclusion

The NS2 self-stretch technique offers a fast GEM assembling procedure producing a flexible GEM structure.

Advantages

- The assembling procedure is very easy and fast. 1-2 hours
- All the GEM foils are self-stretched with no spacers involved; therefore no dead area inside the active area
- Any detector parts are replaceable. So malfunctioning GEM detectors can be repaired quickly with low cost.