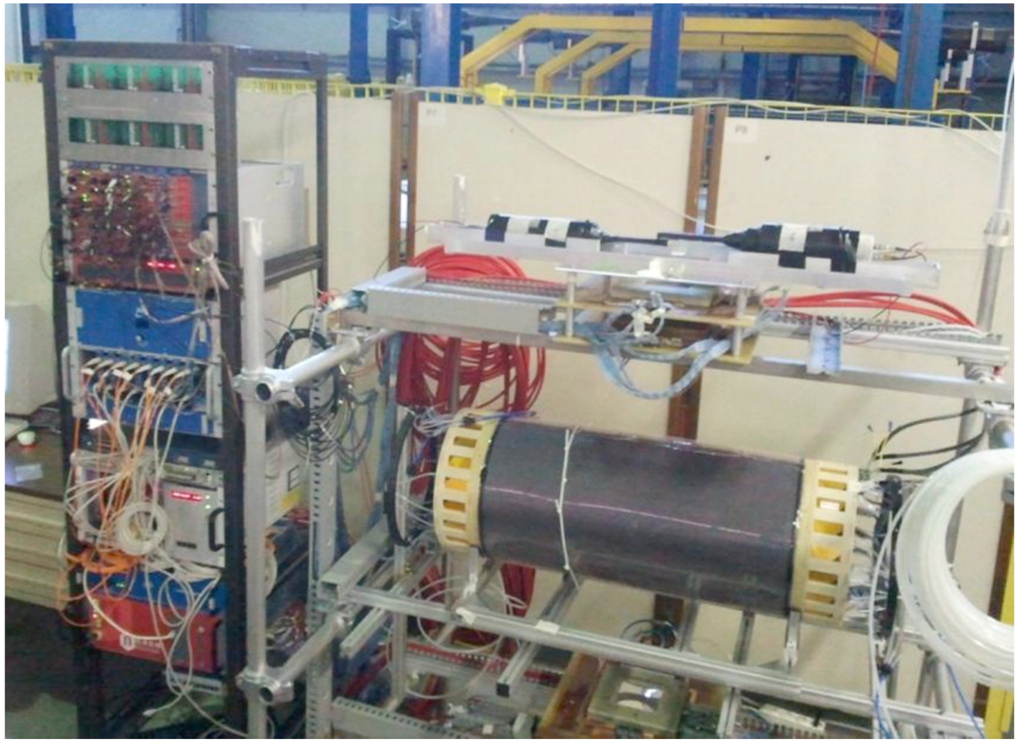
Project Co-financed by the Italian Ministry for Foreign Affairs (MAE)

A CGEM PROTOTYPE for BESIII Inner Drift Chamber Upgrade

BESIII Italian Collaboration



25-29 November 2012, BESIII Winter Collaboration Meeting, Guilin

Outline

- BESIII requirements for a CGEM Inner Tracker
- Prototype targets
- LNF CGEM miniworkshop
- Assembling a KLOE2 CGEM
- GASTONE32 analog readout

Requirements for the inner drift chamber upgrade

- Rating capability: $\sim 10^4$ Hz/cm^2
- Spatial resolution: $\sigma_{xy} \sim 100\mu m$; $\sigma_z \sim 1mm$;
- Momentum resolution: $\sigma_{pt}/ p_t \sim 0.5\%$ @1GeV;
- Efficiency: $\varepsilon \sim 98\%$
- Material budget: < 1.5% all layers
- Coverage: 93% 4π
- Operation duration: ~ 5 years

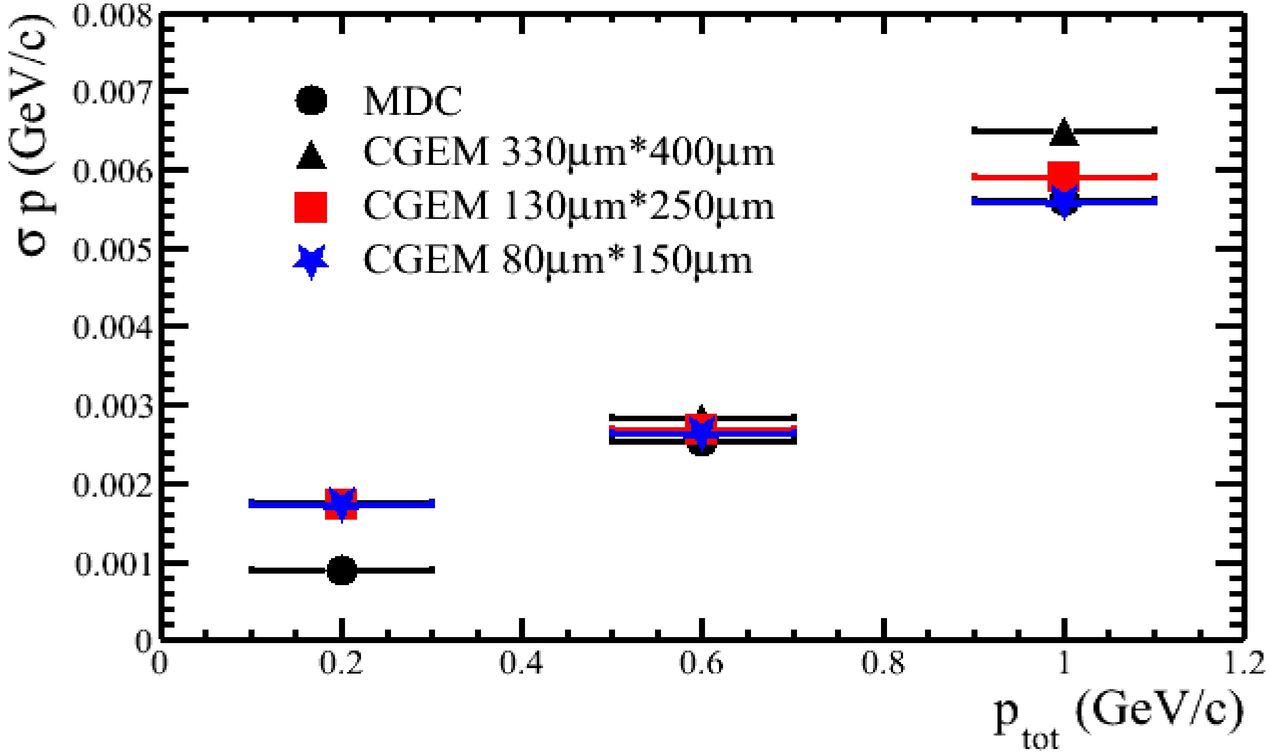
Qun Ouyang at Frascati CGEM workshop

Alternative Options:

- **CGEM:** based on KLOE-2 technology, collaboration between Italian and Chinese groups
- **Monolithic pixels:** CPS developed by IPHC in Strasburg

Momentum resolution σ_p

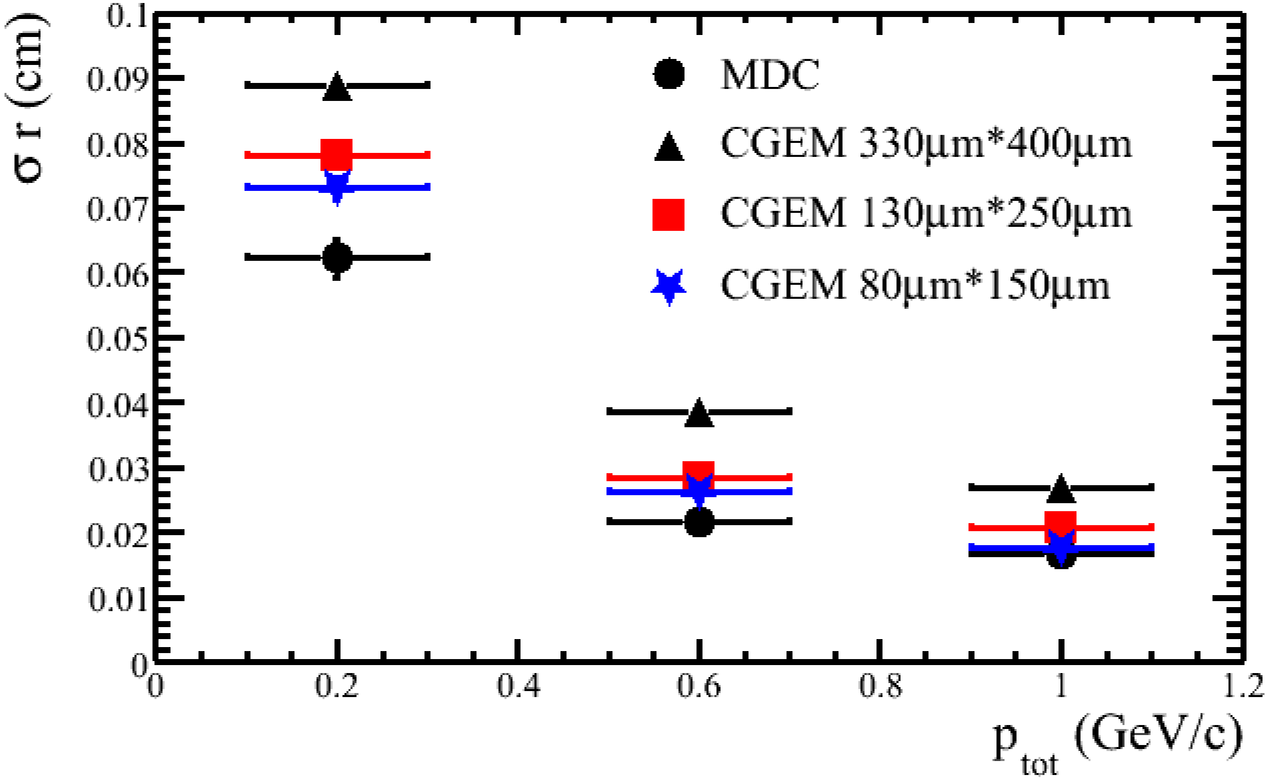
Liangliang talk



P_{tot}(GeV/c)	0.2	0.6	1.0
σ_p(MDC) (MeV)	**0.89** (100%)	**2.53** (100%)	**5.59** (100%)
σ_p(CGEM 330μm*400μm)	**1.76**(+98%)	**2.84** (+12%)	**6.50**(+16%)
σ_p(CGEM 130μm*250μm)	**1.72**(+93%)	**2.69** (+6.0%)	**5.90**(+5.5%)
σ_p(CGEM 80μm*150μm)	**1.72**(+93%)	**2.62** (+3.6%)	**5.58**(-0.18%)

Transverse resolution σ_r

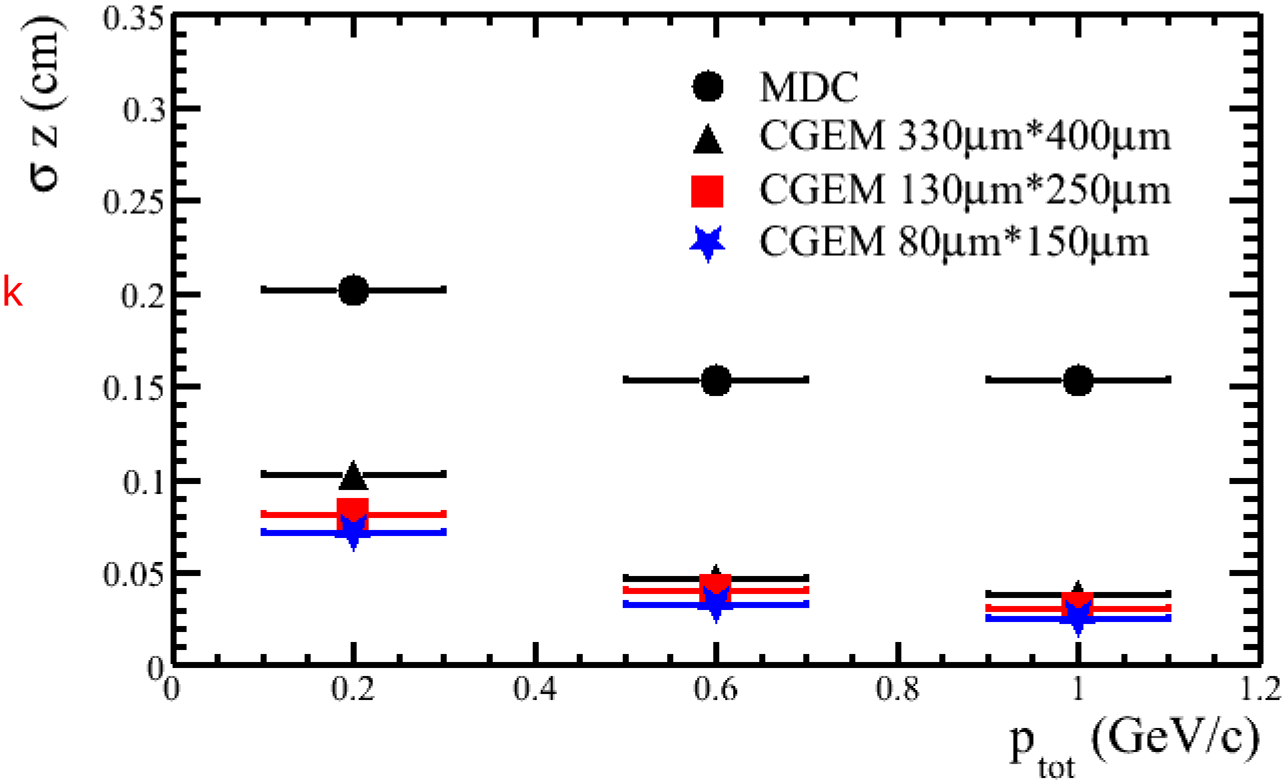
Liangliang talk



P_{tot}(GeV/c)	0.2	0.6	1.0
σ_r(MDC) (μm)	**622** (100%)	**215**(100%)	**168**(100%)
σ_r(CGEM 330μm*400μm)	**887**(+43%)	**385**(+79%)	**271**(+61%)
σ_r(CGEM 130μm*250μm)	**781**(+26%)	**286**(+33%)	**208**(+24%)
σ_r(CGEM 80μm*150μm)	**729**(+17%)	**262**(+22%)	**177**(+5.4%)

Z resolution σ_z

Liangliang talk



P_{tot}(GeV/c)	0.2	0.6	1.0
σ_z(MDC) (μm)	**2020** (100%)	**1531**(100%)	**1539**(100%)
σ_z(CGEM 330μm*400μm)	**1024**(-49%)	**473**(-69%)	**378**(-75%)
σ_z(CGEM 130μm*250μm)	**816**(-60%)	**399**(-74%)	**307**(-80%)
σ_z(CGEM 80μm*150μm)	**713**(-65%)	**323**(-79%)	**252**(-84%)

CGEM expected spatial resolution

❑Digital readout

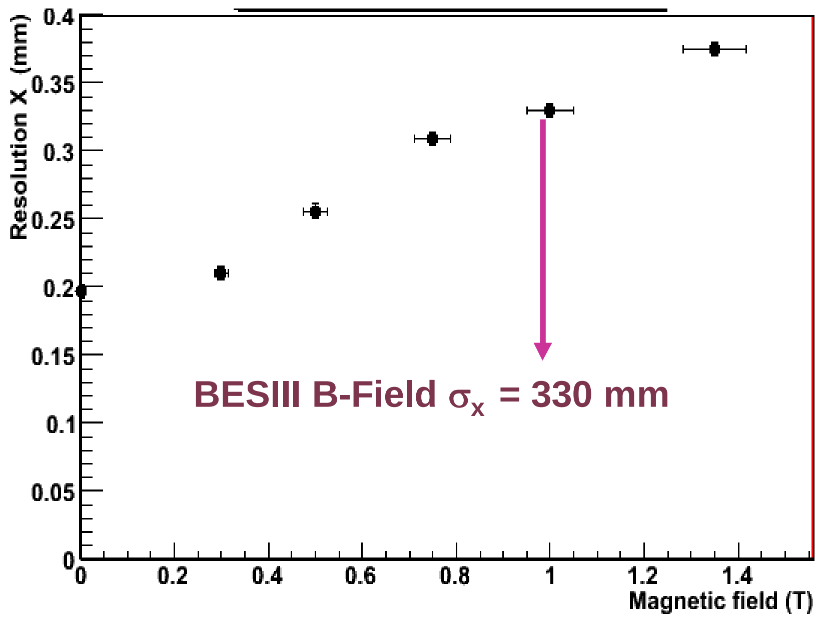
KLOE2 (650 µm pitch)

σ_x =190 µm σ_z ~ 350 µm

Magnetic field effect :

charge spread over the readout plane

190 µm → 330 µm



❑Analog readout

high spatial resolution: down to 50µm

COMPASS (400 µm pitch)

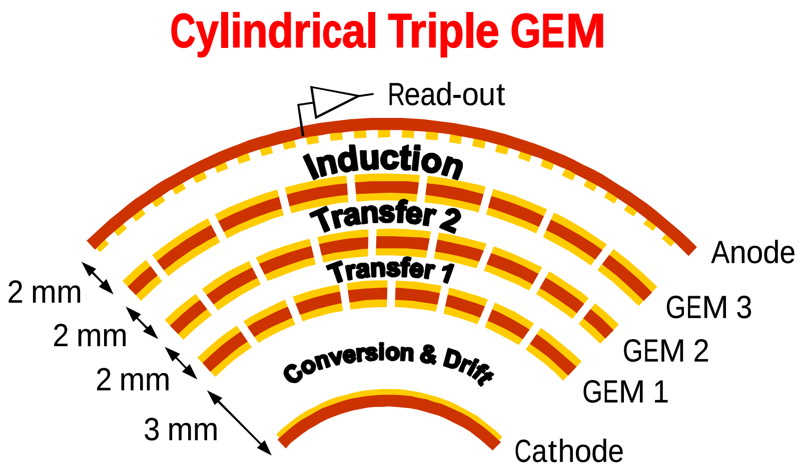
No magnetic Field effect

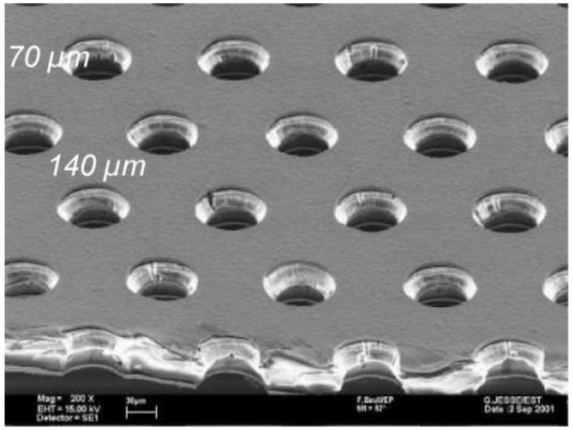
since analog readout measures the centroid of the induced charge

σ_x ~ 650/400 • 50 ~ 80 µm

σ_z ~ 80 • 350/190 ~ 150 µm

CGEM structure





- **light structure**: < 0.4% X_0 /chamber
- **high rate capability:** > 50 MHz/cm^2
- **rad hard:** up to 2.2 C/cm^2

  10 years equivalent over the whole active area

  without damages in LHCb

Material Budget

CGEM KLOE2 Layer

	Times*material*quantity	% of X_0
CATHODE	Copper: 2*3 *1 Kapton: 2*50*1 Honeycomb: 1*3000*1	0.0420 0.0350 0.0240 Total= 0.101
GEM foils	Copper: 6*3 *0.8 Kapton: 3*50 *0.8	0.1007 0.0420 Total= 0.143
ANODE	Copper: 3.5+1.5+3 Kapton: 1*225 *1 Gold : 2*0.1 *1 Epoxy: 2*10 *1	0.0559 0.0787 0.0061 0.0060 Total=0.147
CF Shield	CF: 2*90 *1 Honeycomb: 1*5000*1	0.0429 0.0400 Total=0.0829
		1 Layer= 0.48 4 Layers =1.92

CGEM Prototype

	Times*material*quantity	% of X_0
CATHODE	Copper: 2*2 *1 Kapton: 2*50*1 Honeycomb: 1*3000*1	0.0280 0.0350 0.0240 Total= 0.0870
GEM foils	Copper: 6*2 *0.8 Kapton: 3*50 *0.8	0.0671 0.0420 Total= 0.109
ANODE	Copper: 2.5+1.5+2 Kapton: 1*225 *1 Gold : 2*0.1 *1 Epoxy: 2*10 *1	0.0420 0.0787 0.0061 0.0060 Total= 0.133
CF Shield	Kapton: 2*50 *1 Honeycomb: 1*3000*1	0.0350 0.0240 Total= 0.0590
		1 Layer= 0.39 4 Layers =1.56

Prototype construction targets

- Design,construction and test of a CGEM prototype, in case first layer of a new CGEM Inner Tracking
- Design,construction and test of an analog readout system to achieve < 100 μm xy and < 200 μm z resolutions
- Budget requested to Foreign Affairs Ministry, following the Agreement of scientific cooperation for a Joint laboratory "INFN-IHEP" :

INFN 1st year expenditure	40000	33.3%
Italian Ministry of FA expenditure	40000	33.3%
Foreign Institution expenditure	40000	33.3%
More funds	0	0%
1st year project cost	120000	

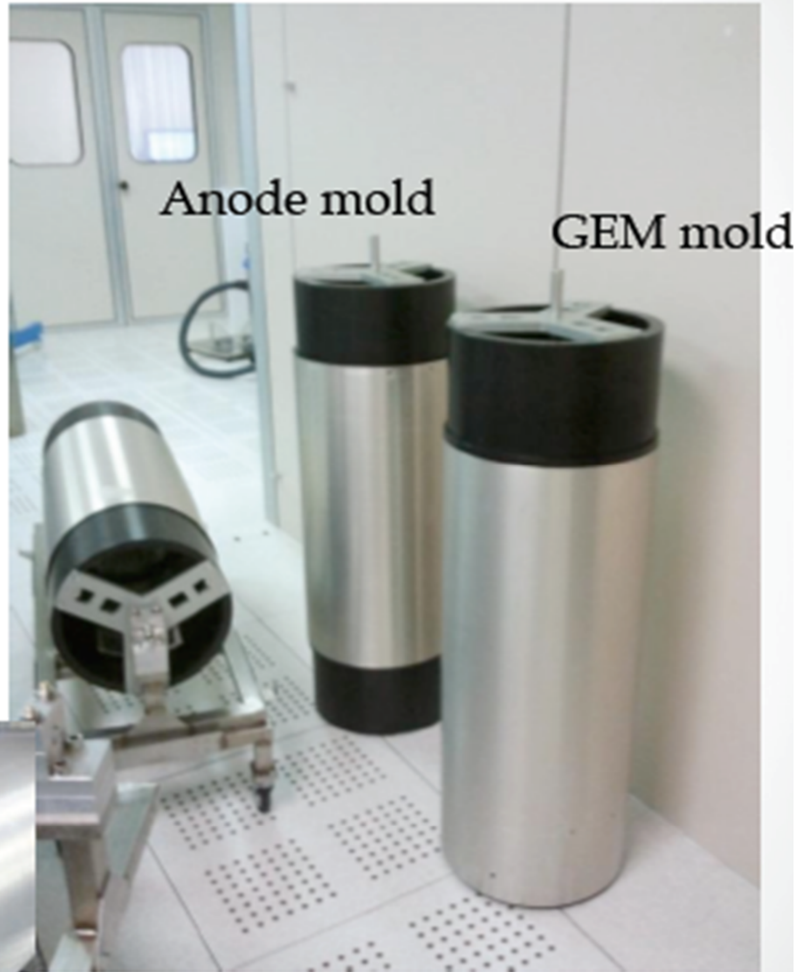
LNF CGEM miniworkshop

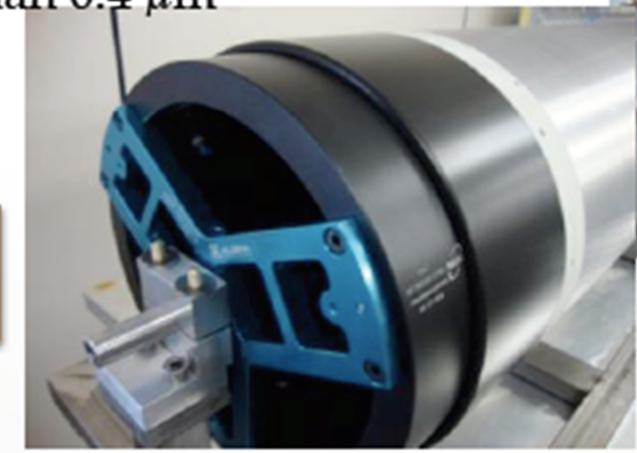
- October 2012 : 2 days Cylindrical GEM workshop at LNF with Chinese collaborators,KLOE2 ,BARI,CMD3 and CERN (Rui de Oliveira)
  https://agenda.infn.it/conferenceDisplay.py?confId=5502
- G. Bencivenni and collaborators presented the status of KLOE2 Inner Tracking CGEM detector
- A. Ranieri (Bari University) presented the analog version of KLOE2 GASTONE digital readout
- The second day was dedicated to visit the CGEM laboratory, where a practical assembly procedures demonstration was given
- The following slides are a summary of D. Domenici and A. Ranieri talks on CGEM construction, assembling and analog readout

Cylindrical Molds

- To obtain cylindrical electrodes we wrap the foils around molds
- There is one mold for each of the 5 electrodes needed in a triple-GEM (cathode/3 GEM/readout): 20 different molds

- Molds are realized in Aluminum with precision machined surface
- A Teflon (HST-FEP-HT) cladding 0.5 mm thick provides a low-friction and non-sticking surface.
- Tolerance on the final diameter is 0.02 mm
- Roughness is less than 0.4 μm

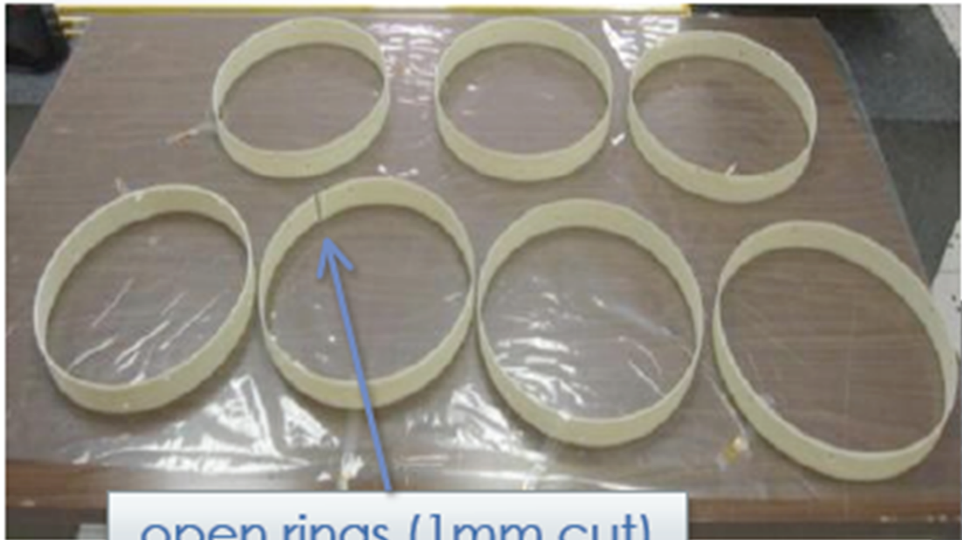




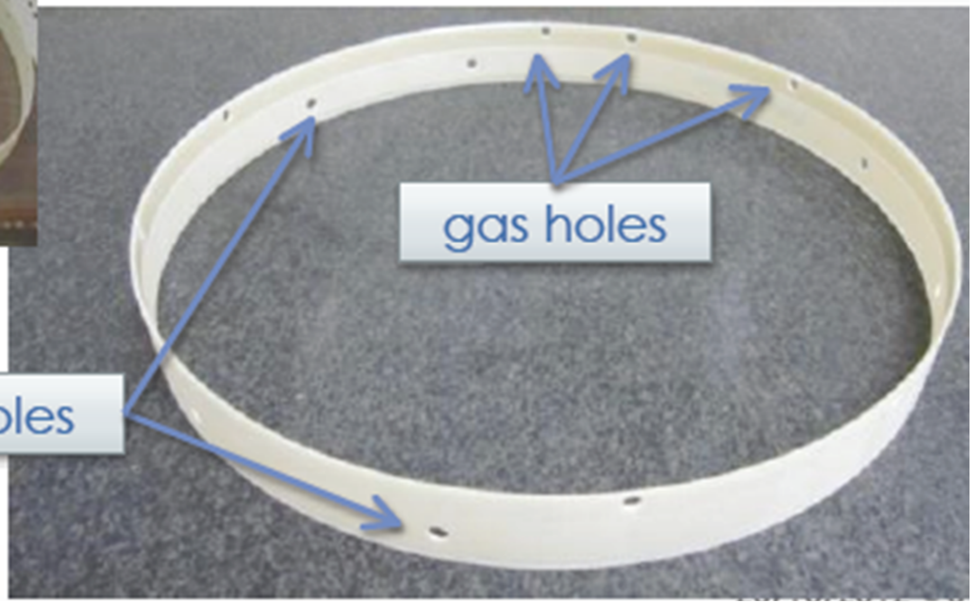
Algra, Bergamo, IT
Cecom, Rome, IT

Fiberglass rings

- At the far ends of the cylinder we place annular rings to provide mechanical support and spacing between the gaps (3/2/2/2)
- They also allow the sealing of the detector and hosts the pinholes for the positioning of the electrodes
- The material is Durostone, a stratified glass epoxy composite (EPGC22)

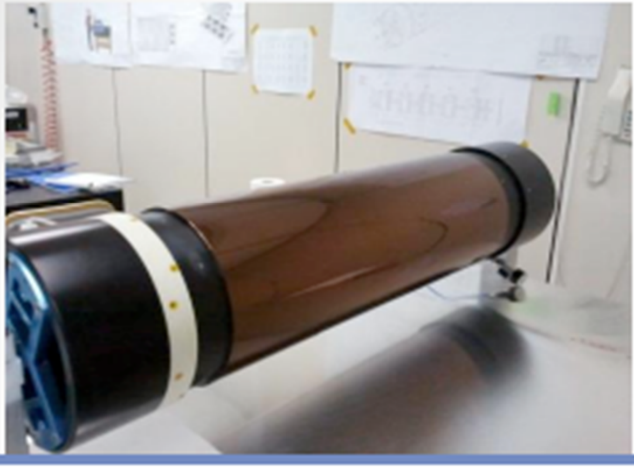


- The preparation procedure foresees: dimensional check, brushing, US cleaning w/DI water, passivation w/Araldite 2011

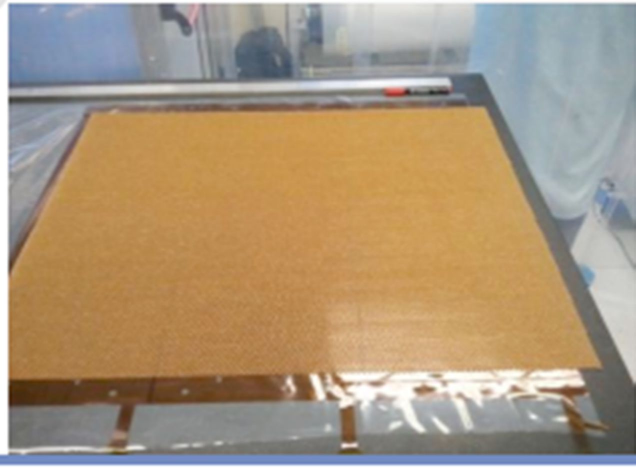


Resarm Engineering Plastics, Barchon, B

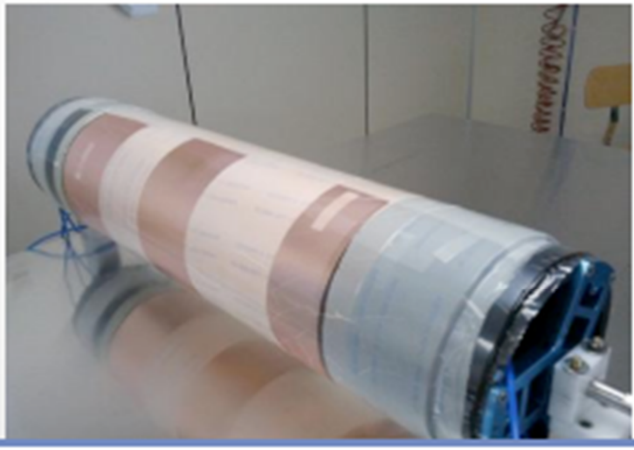
Manufacturing a Cathode



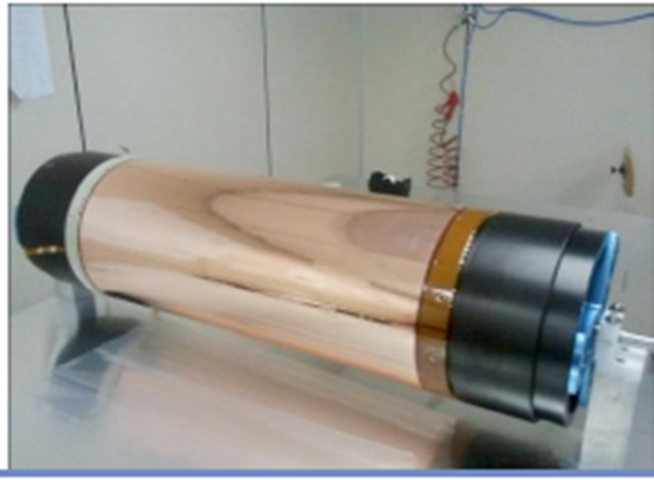
We place an inner cylindrical kapton layer on the mold



Nomex honeycomb 3 mm thick is glued on the back of the cathode



Cathode (made by 3 foils) is wrapped around the mold and closed with a vacuum bag



Final cathode is ready with both internal and external rings

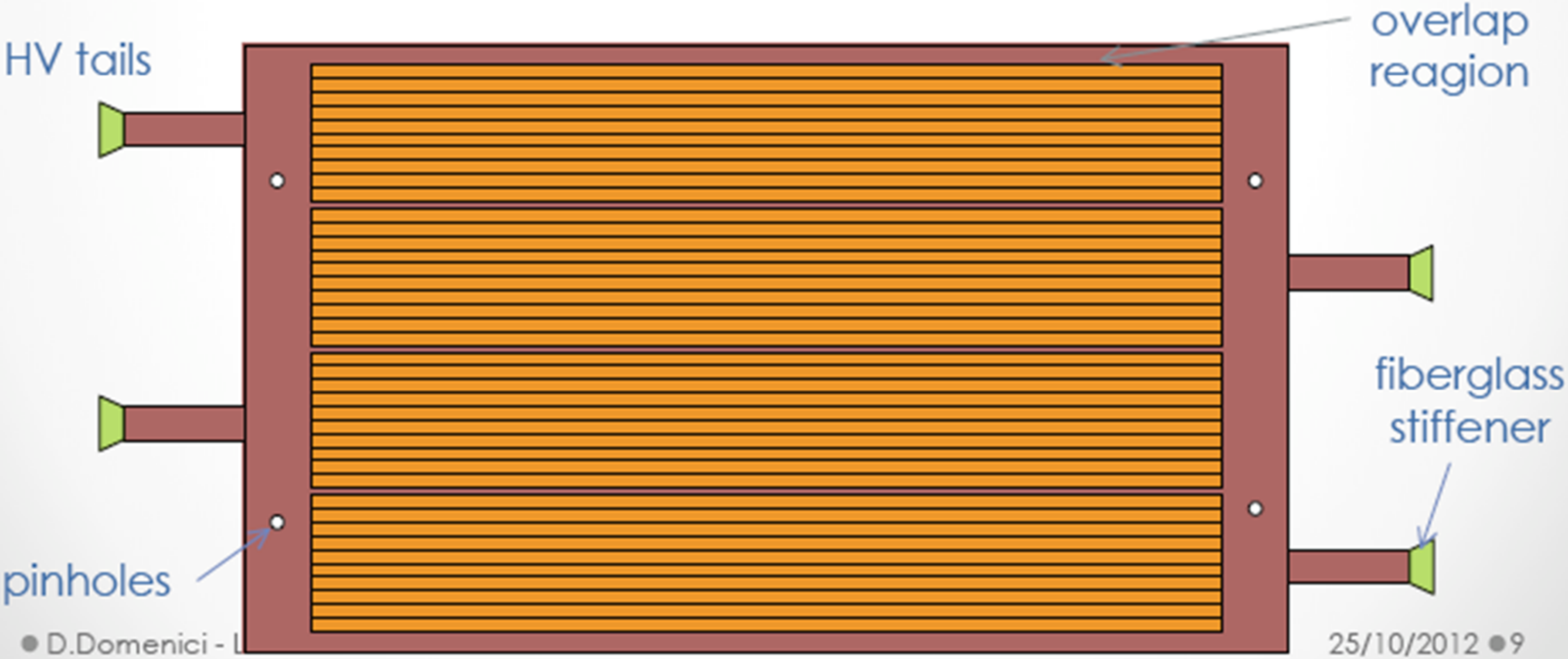
GEM Foils

- GEM foils are manifactured at CERN TE-MPE-EM with a single-mask chemical etching technique tuned to produce large size GEM
- Present size 1.2m x 0.5m (active area) Future max size 2m x 0.5m
- The hole shape is double conical (70-50-70) with a slight asymmetry

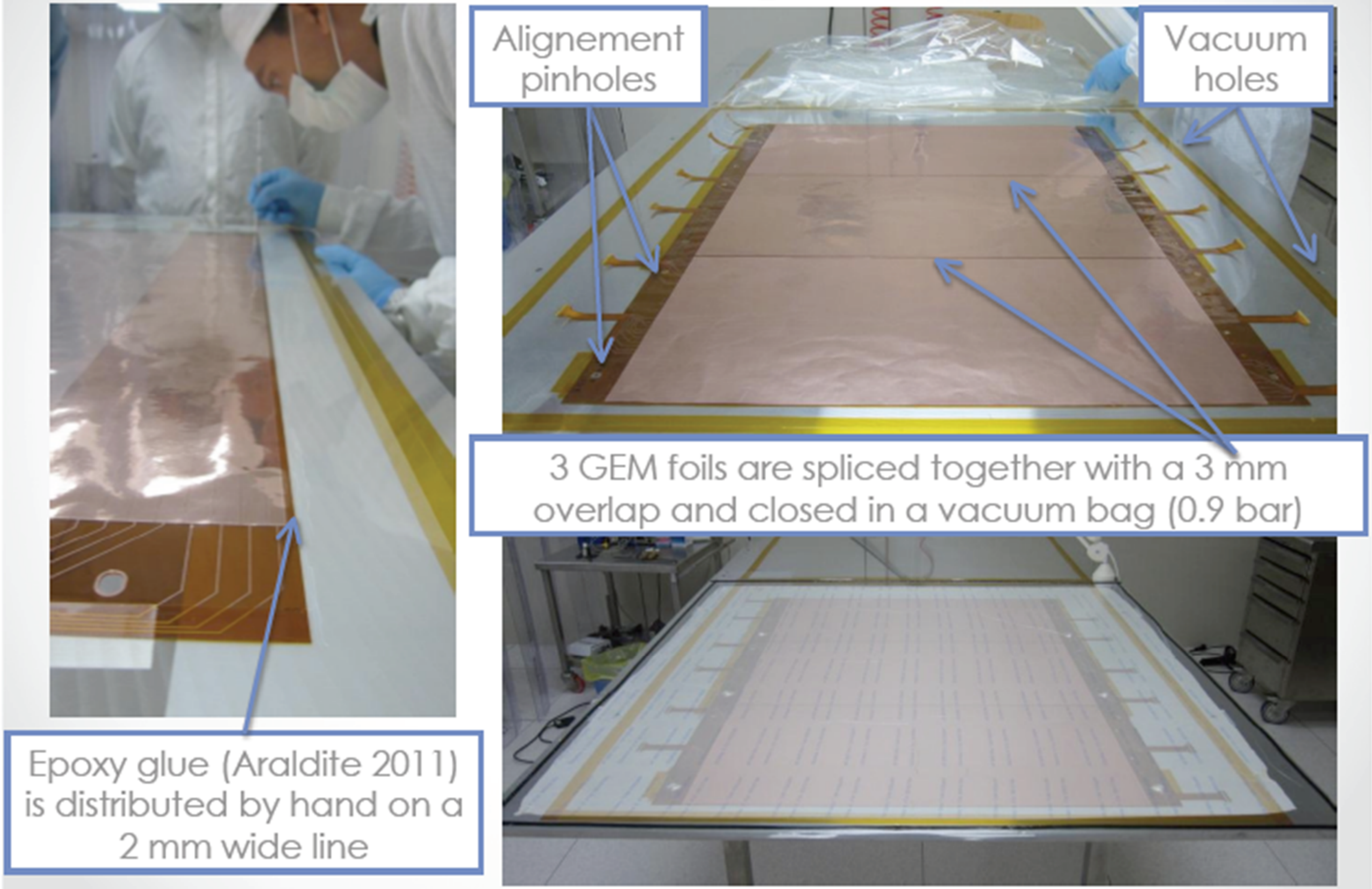
GEM Foil	Thickness (µm)	Radiation Length
Copper	3	2.1E-04
Polyimide	50	1.75E-04
Copper	3	2.1E-04
	56	5.95E-04

Layout of a GEM

- Bottom side of the active area is divided in 4 Macro-Sectors (MS), each with its own HV connection tail
- Top side of MS is furthermore divided in 10 Sectors, all independentely supplied
- HV tails have 11 connections (1 bottom MS + 10 top S) ending on 0.8 mm fiberglass stiffener
- Sectorization is for minimizing damage in case of discharge
- Sector HV independance is for minimizing loss in case of damage: just a single Sector can be turned off

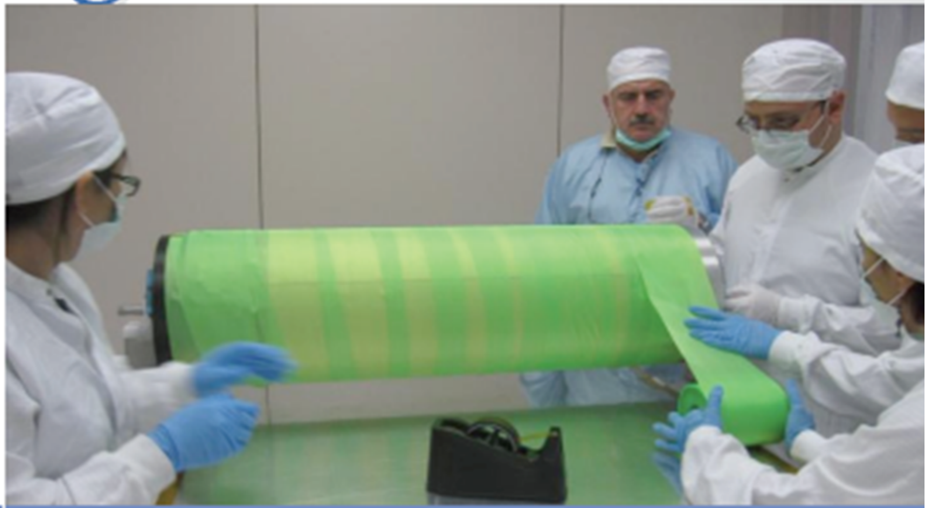


Manufacturing a C-GEM



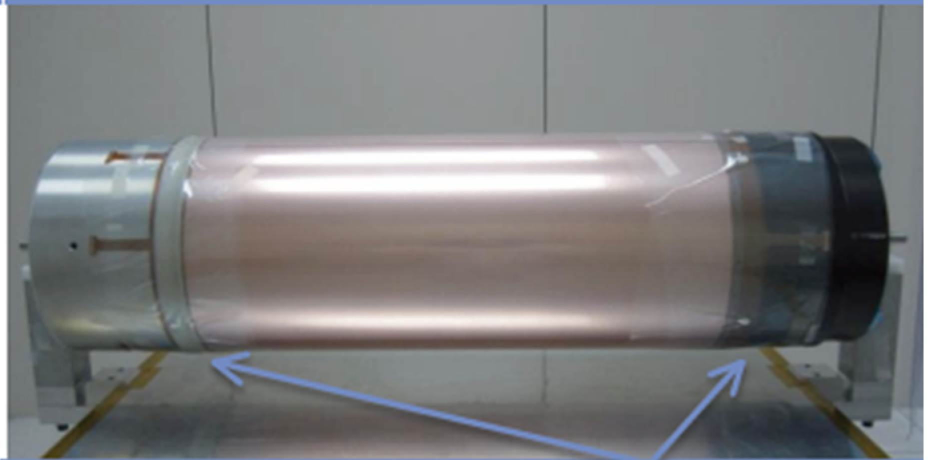
Manufacturing a C-GEM

GEM is protected with a Mylar sheet and wrapped on the cylindrical mold



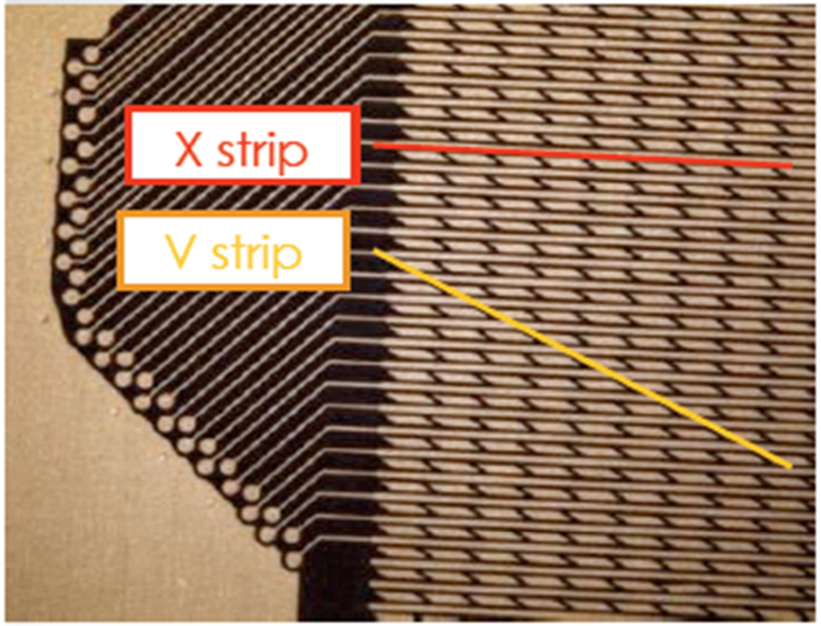
Transpirant tissue (PeelPly from RiBa) is placed around to distribute vacuum

Vacuum bag envelope

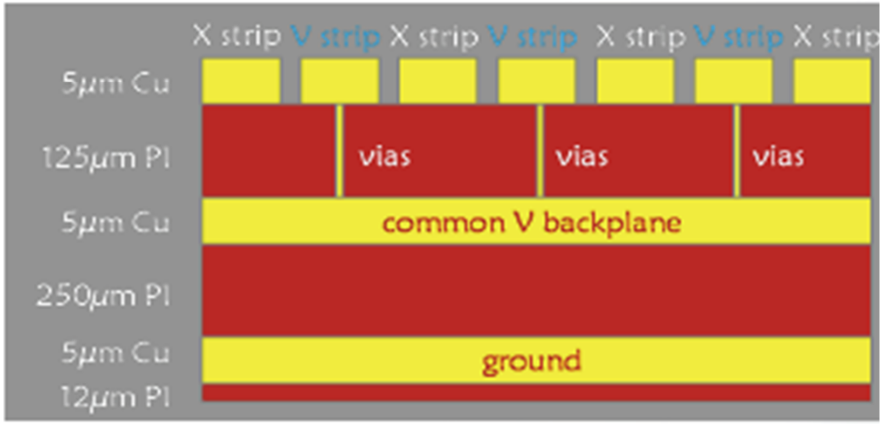


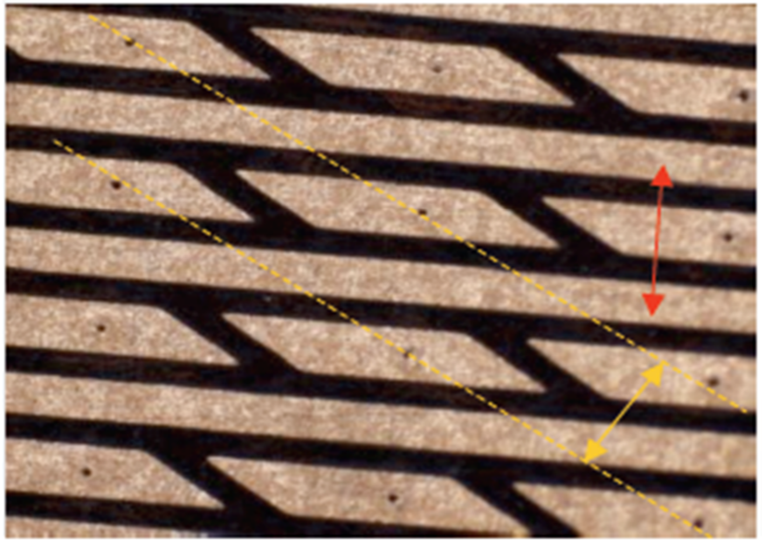
Final cylindrical GEM with internal and external rings

Readout Plane



Readout plane is realized at CERN TE-MPE-EM
It is a kapton/copper multilayer flexible circuit
Provides 2-dimensional readout with XV strips on the same plane
•X are realized as longitudinal strips
•V are realized by connection of pad through conductive holes and a common backplane
•Pitch is 650 μm for both

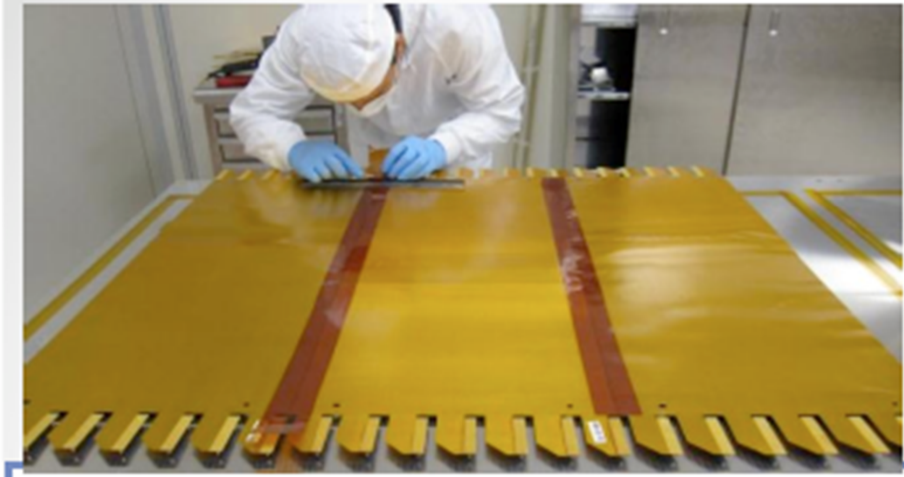




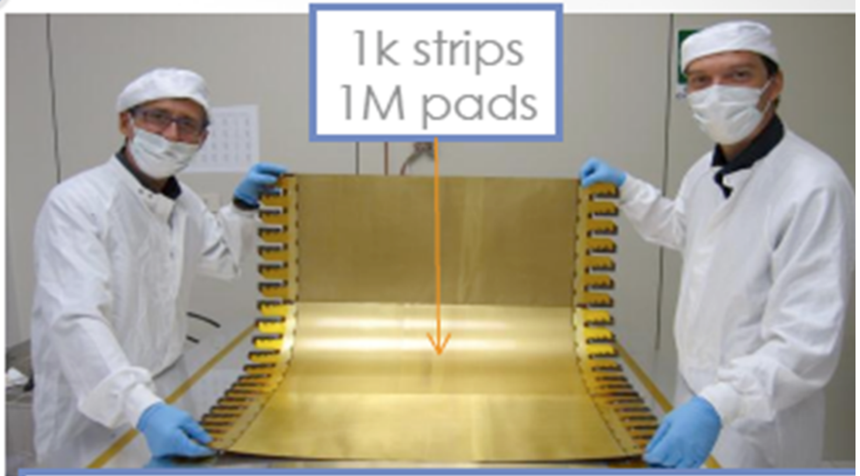
X pitch 650μm → X res 190μm

V pitch 650μm → Y res 350μm

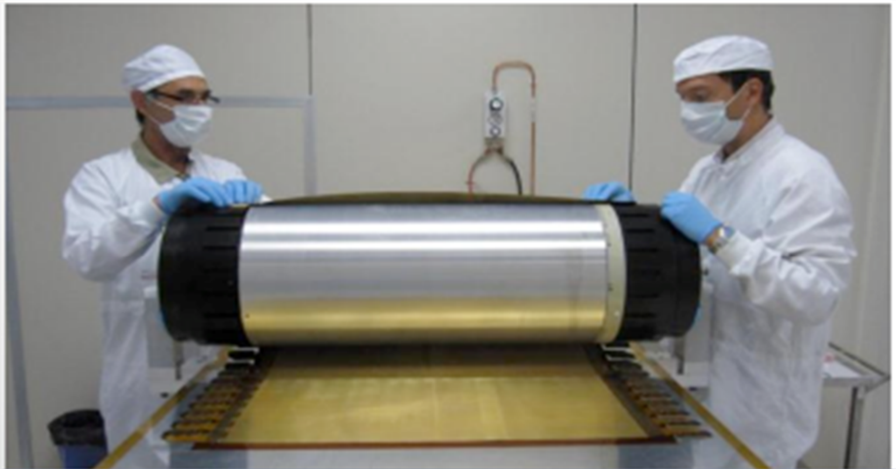
Manufacturing the Readout



3 foils are spliced without overlap:
kapton strips (6 cm) are glued on the back of head-to-head joints



Final foil is ~1m long with three ~1mm wide dead zones



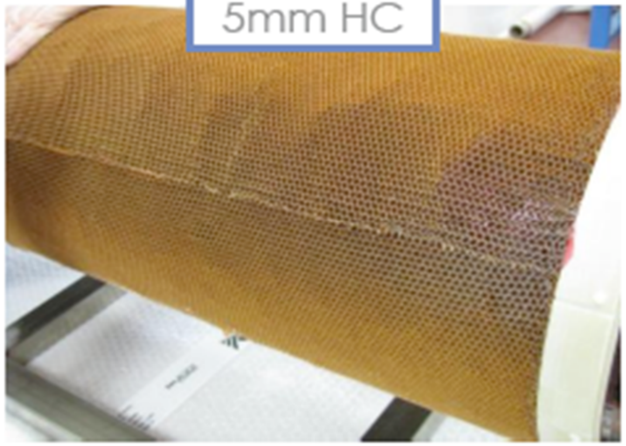
Foil is wrapped on the mold

...to obtain cylindrical electrode

Readout CF Lamination

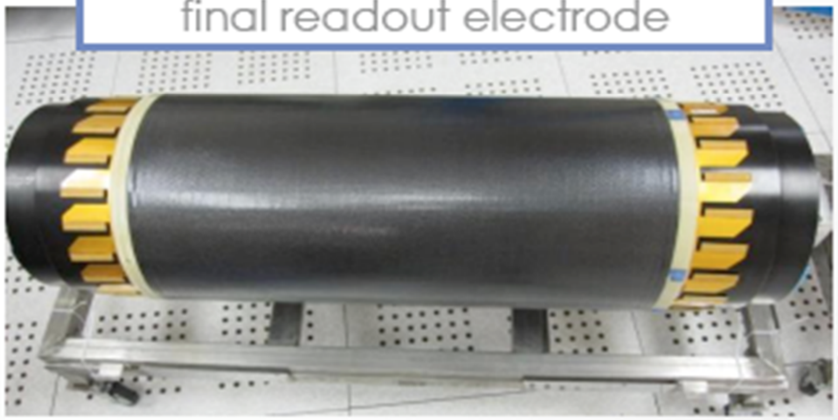
- The readout is shielded with a very ligth Carbon fiber composite structure realized by RiBa Composites, Faenza, IT
- The shield is composed by a sandwich of two 90 μm thick carbon foils prepreg with epoxy (Carbon-Epoxy 90g/m2 58% Fibra T300) spaced by a 5 mm thick Nomex honeycomb (ECA-I 4.8-48 3/16-3.0)


first 90μm CF skin


5mm HC


second 90μm CF skin

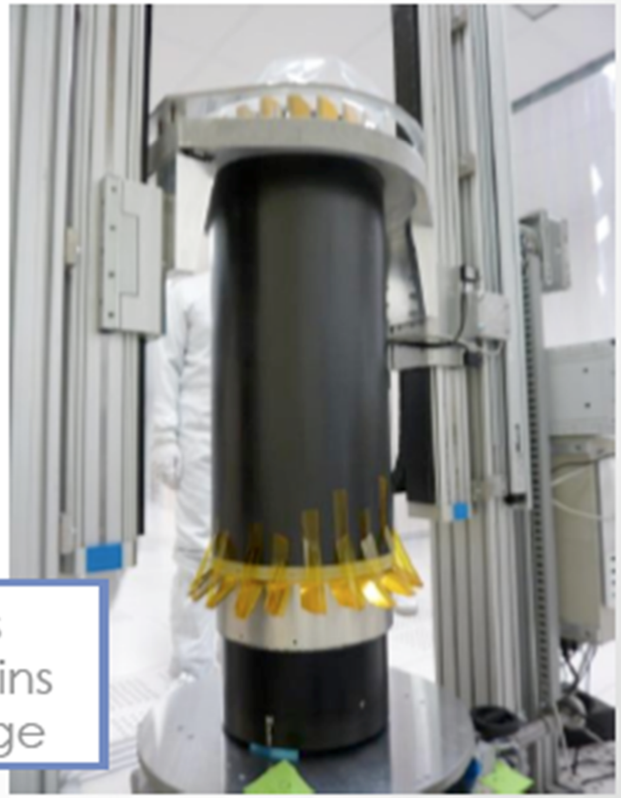

curing 24h in autoclave


final readout electrode

Assembling a triple-GEM

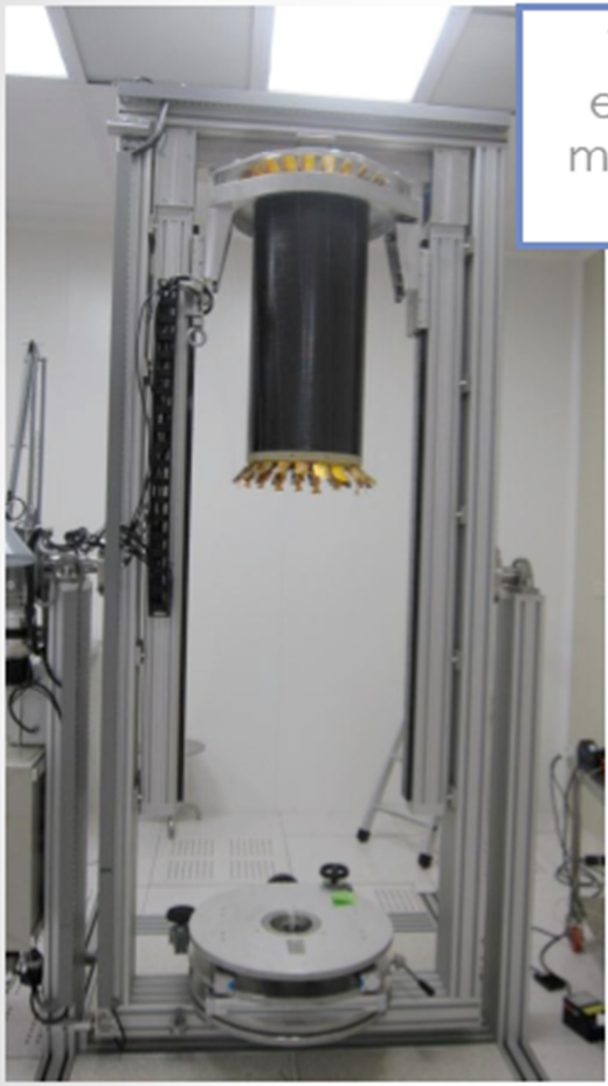
- A dedicated assembling machine has been designed and realized to perform the insertion of the electrodes one into the other
- It is an Aluminum structure with a bottom plate and a top flange running vertically on linear bearings
- Axial alignment has a precision of 0.1mm/1.5m
- The structure can rotate by 180° around its central horizontal axis

The first electrode (the readout) is fixed with its mold on the bottom plate



The top ring is grabbed with pins by the top flange

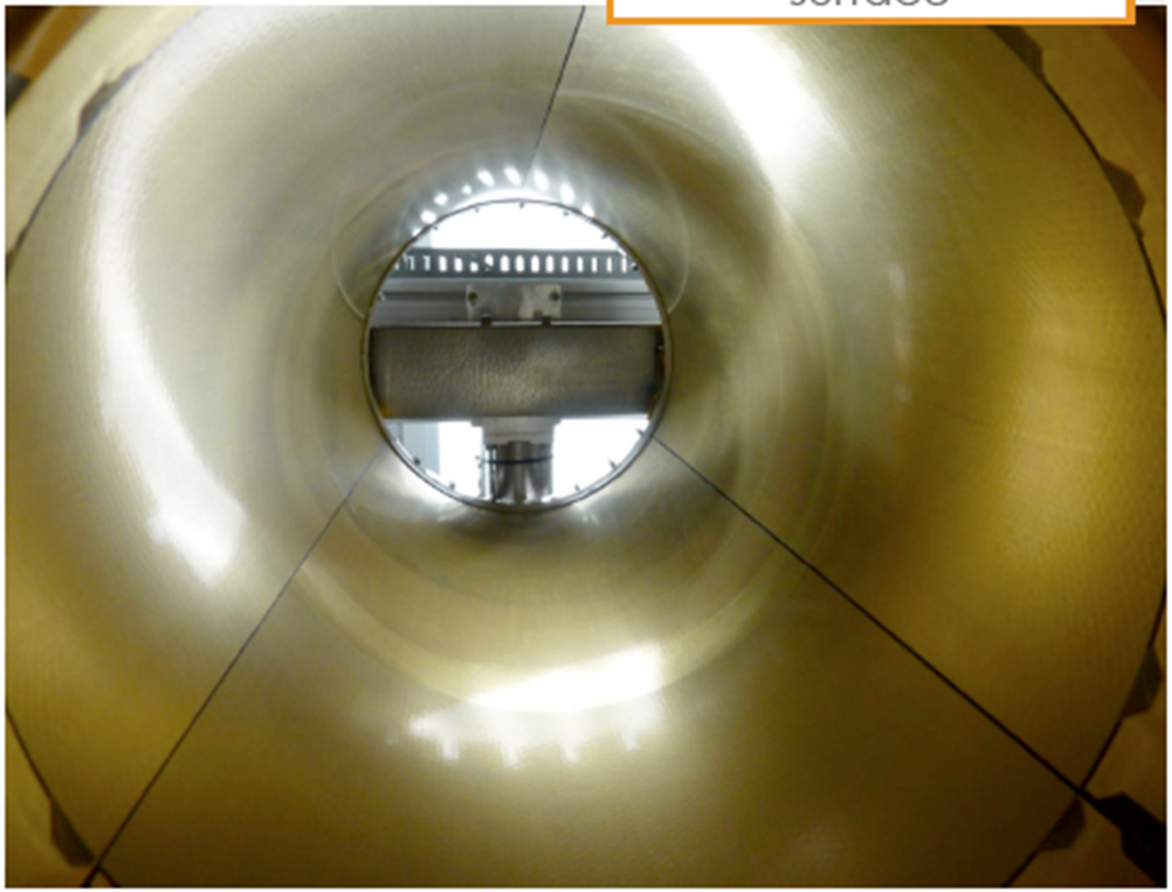
Assembling a triple-GEM



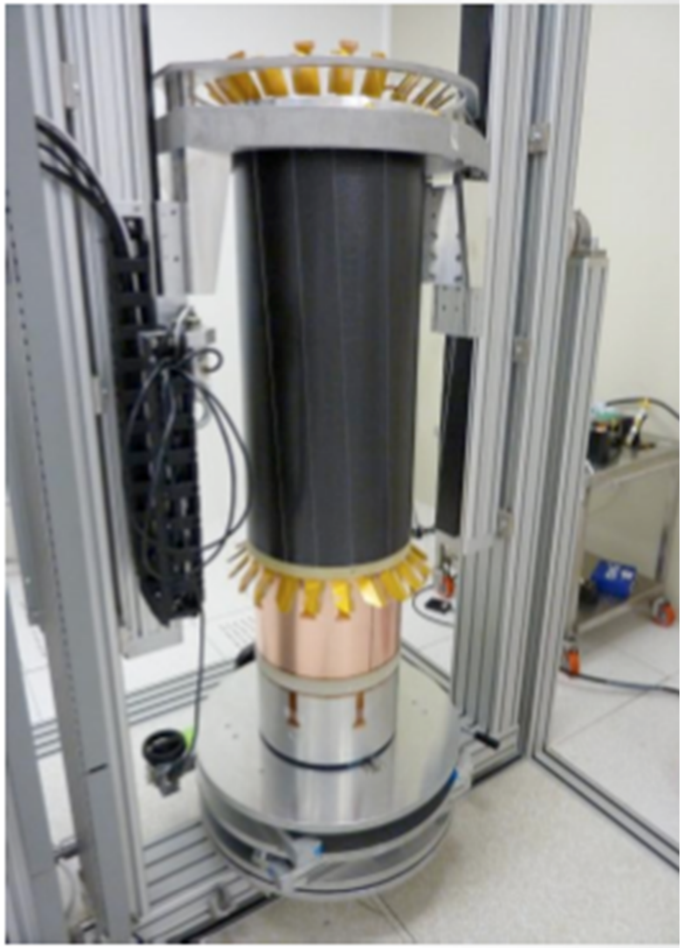
The electrode is extracted from its mold by moving up the flange

- D.Domenici - LNF

internal readout surface

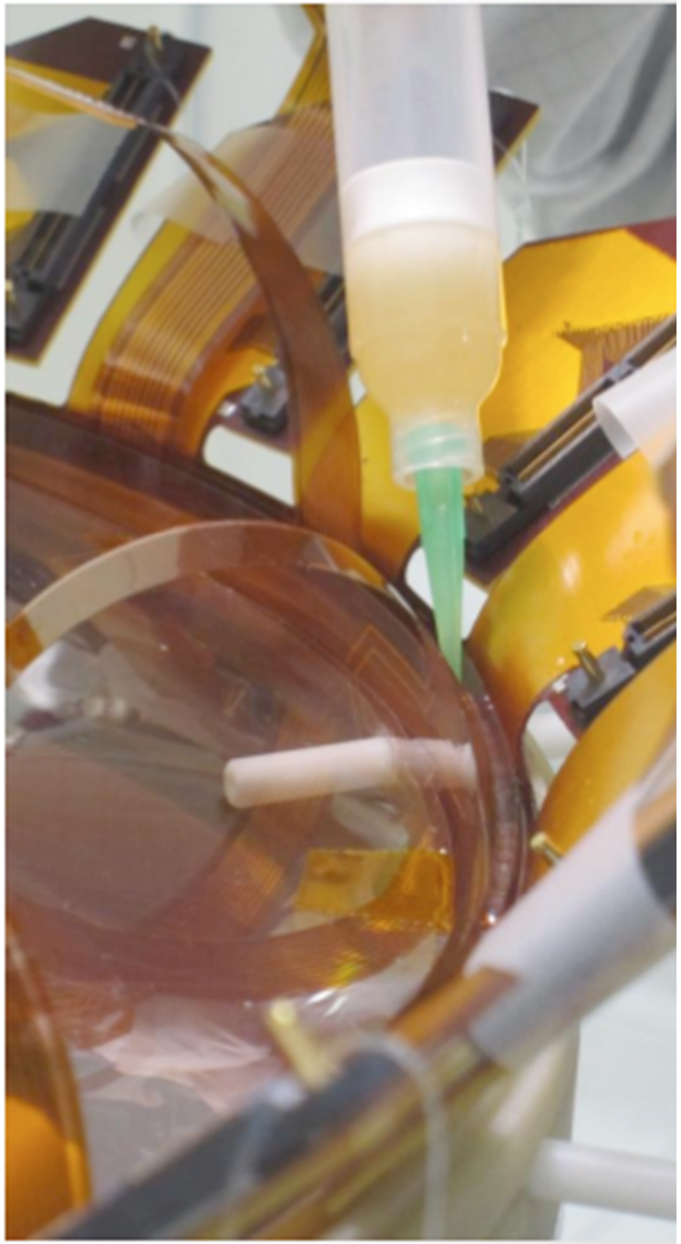


Assembling a triple-GEM



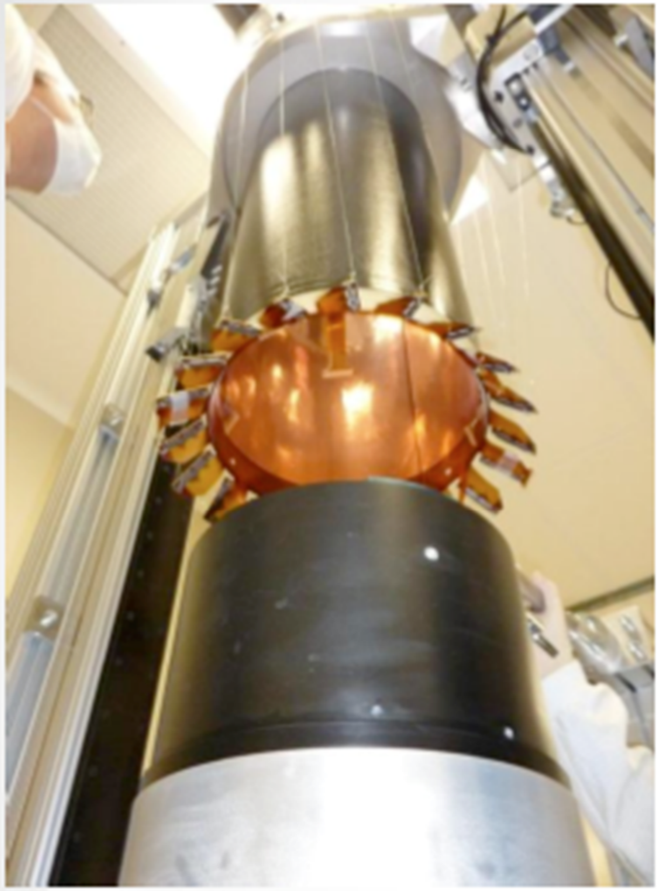
1. The second electrode (GEM3) is placed on the machine with its mold and
2. Fixed to the bottom plate
3. The top flange with Readout is moved down around the GEM

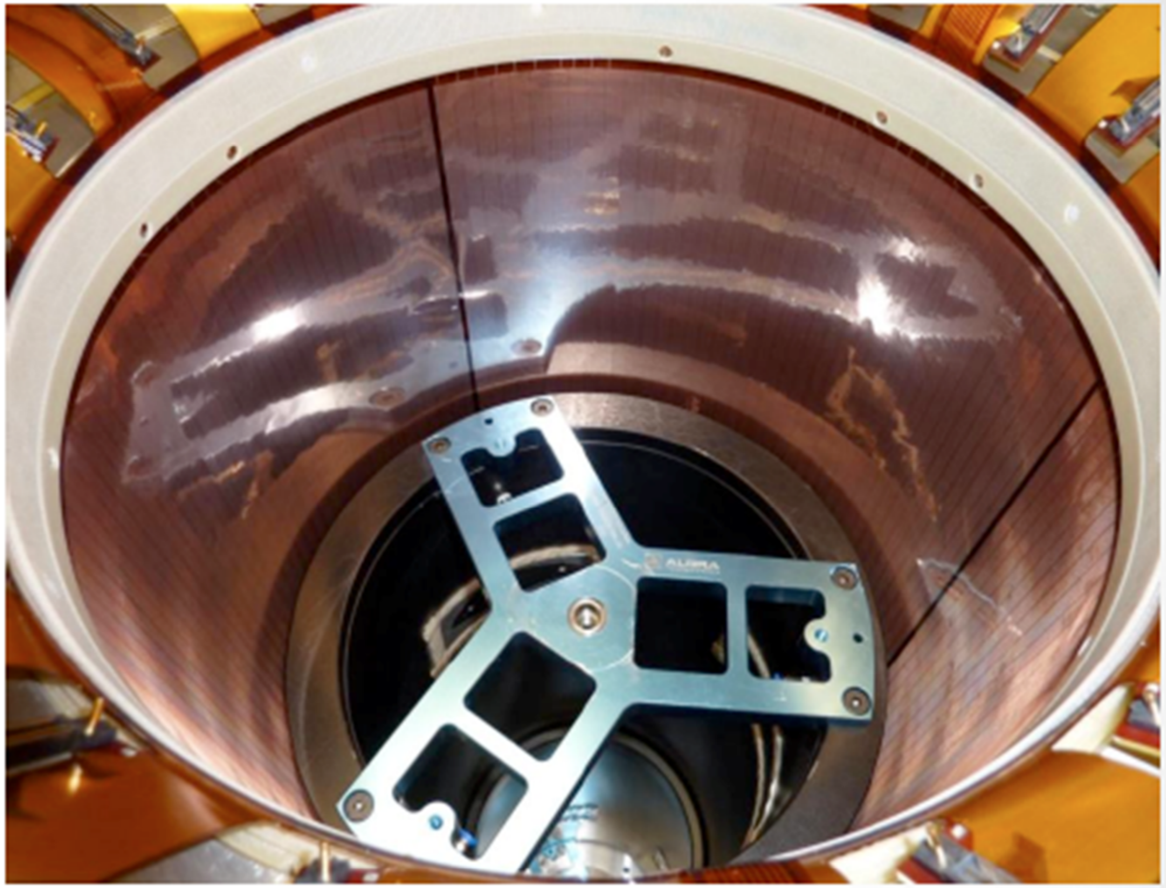
Sealing of the Detector



The top side of the detector is sealed with epoxy adhesive (Araldite 2011) flowed into the 0.35 mm reservoir with a dispencer.
Curing cycle lasts 24h

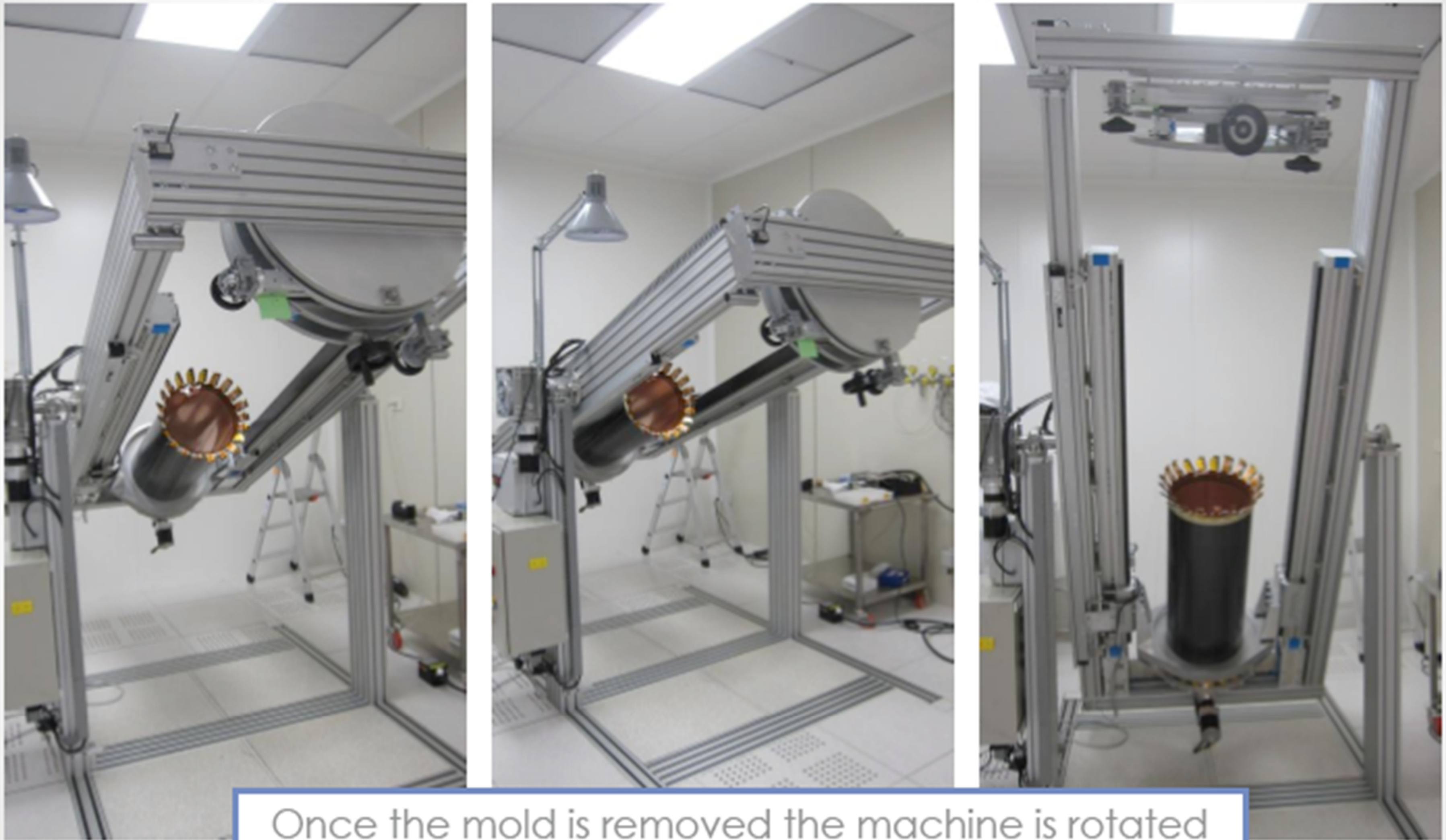
Assembling a triple-GEM





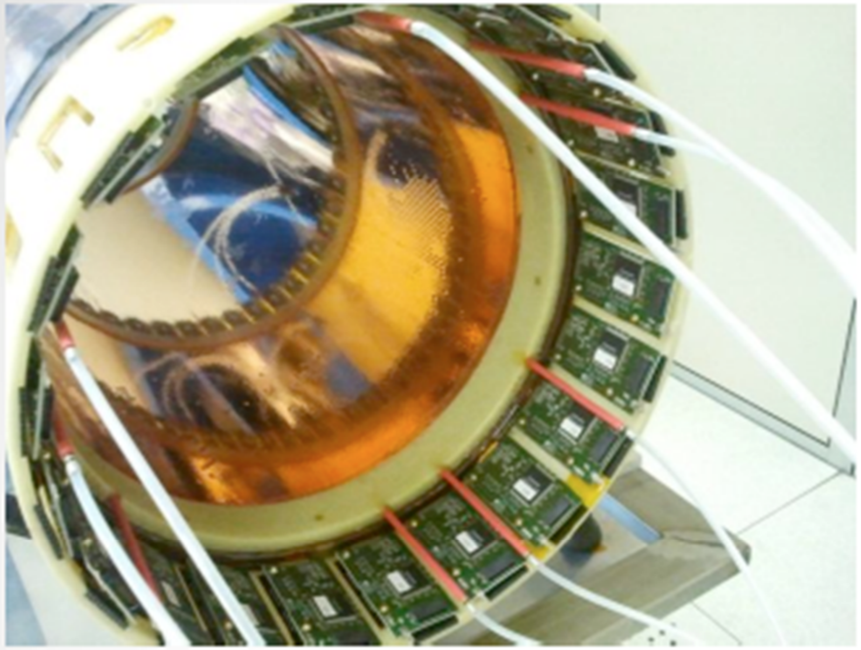
The top flange with both Readout and GEM3 is moved up
The naked mold is left downside

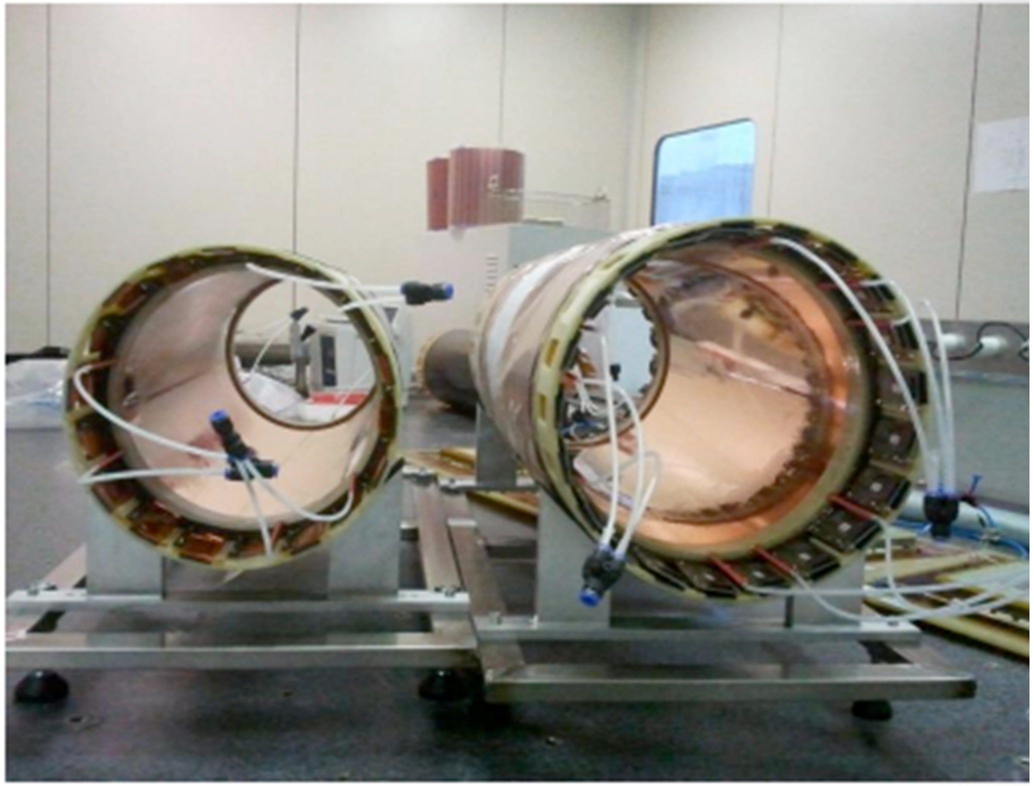
Assembling a triple-GEM



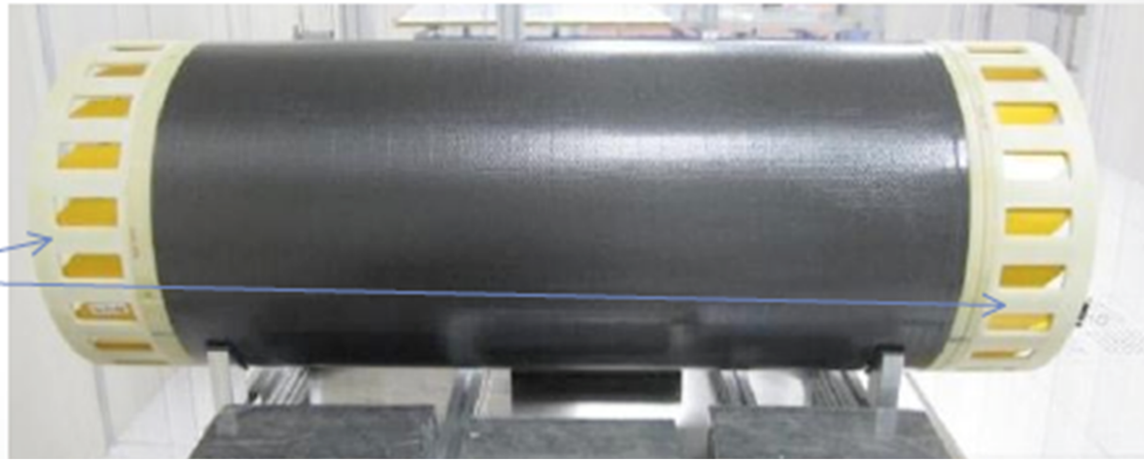
Once the mold is removed the machine is rotated by 180° so that the bottom side becomes accessible and can be sealed

Completed Detector





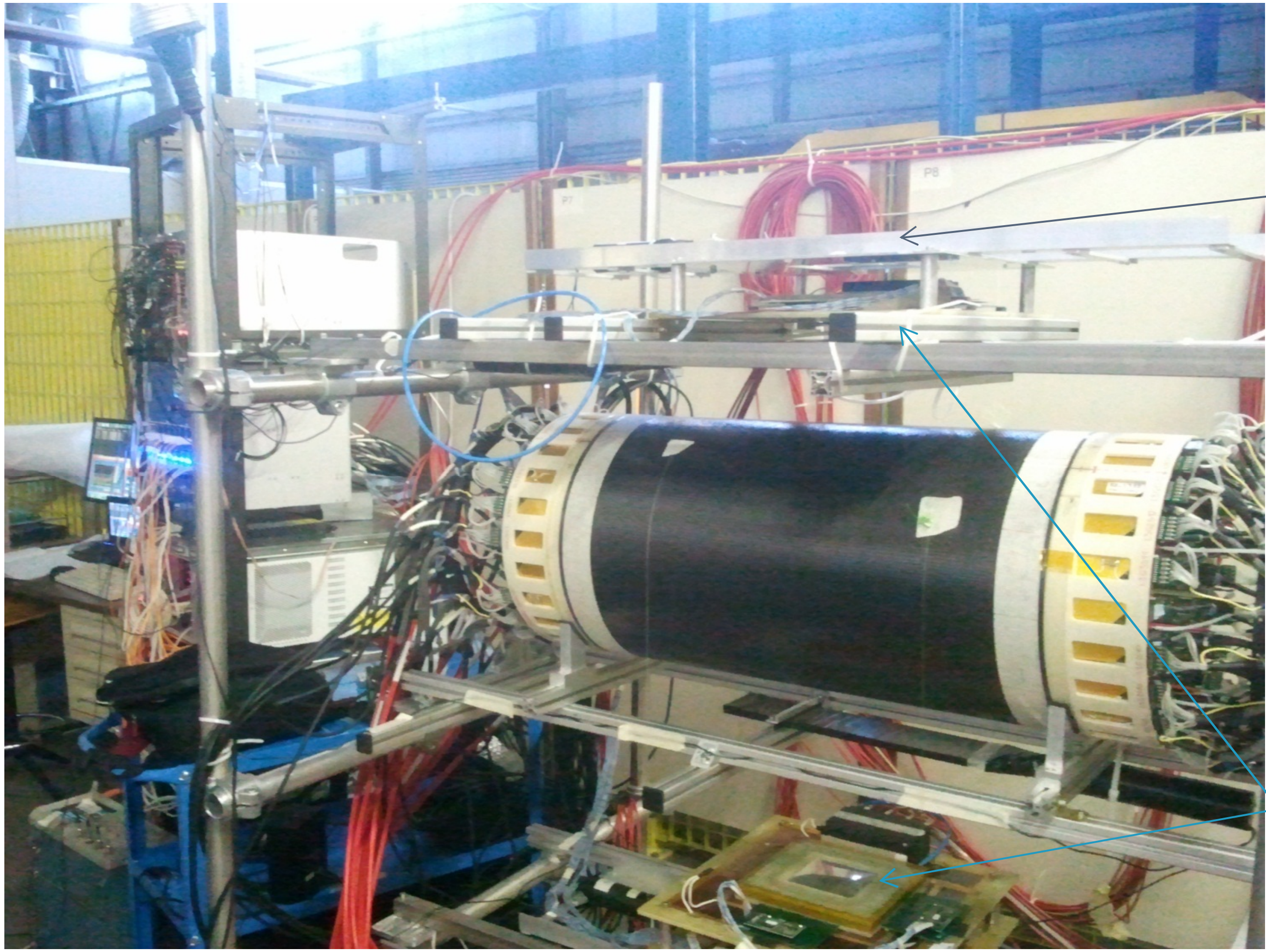
Layer2 equipped with FEE



FEE is supported by 2 fiberglass outer rings

Cosmic rays Test

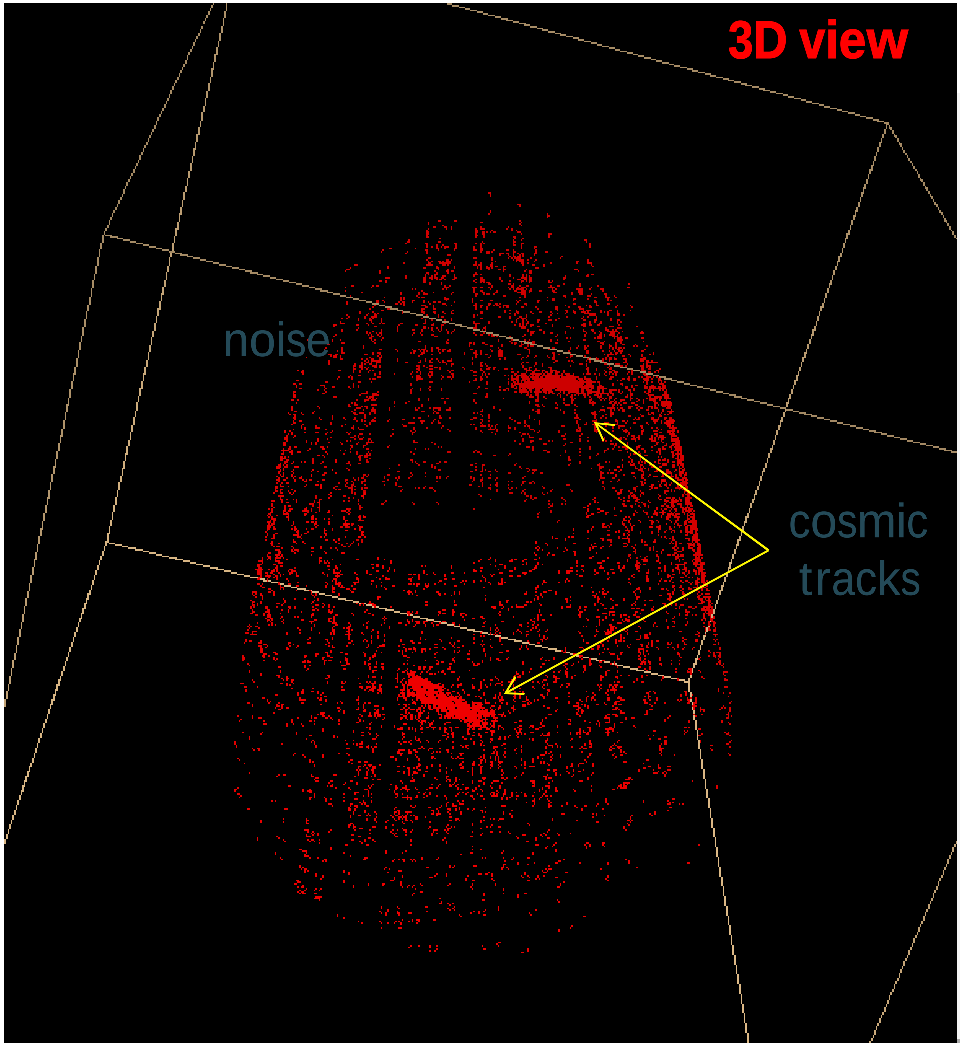
Test with final HV cables and distributors,
final FEE and DAQ system

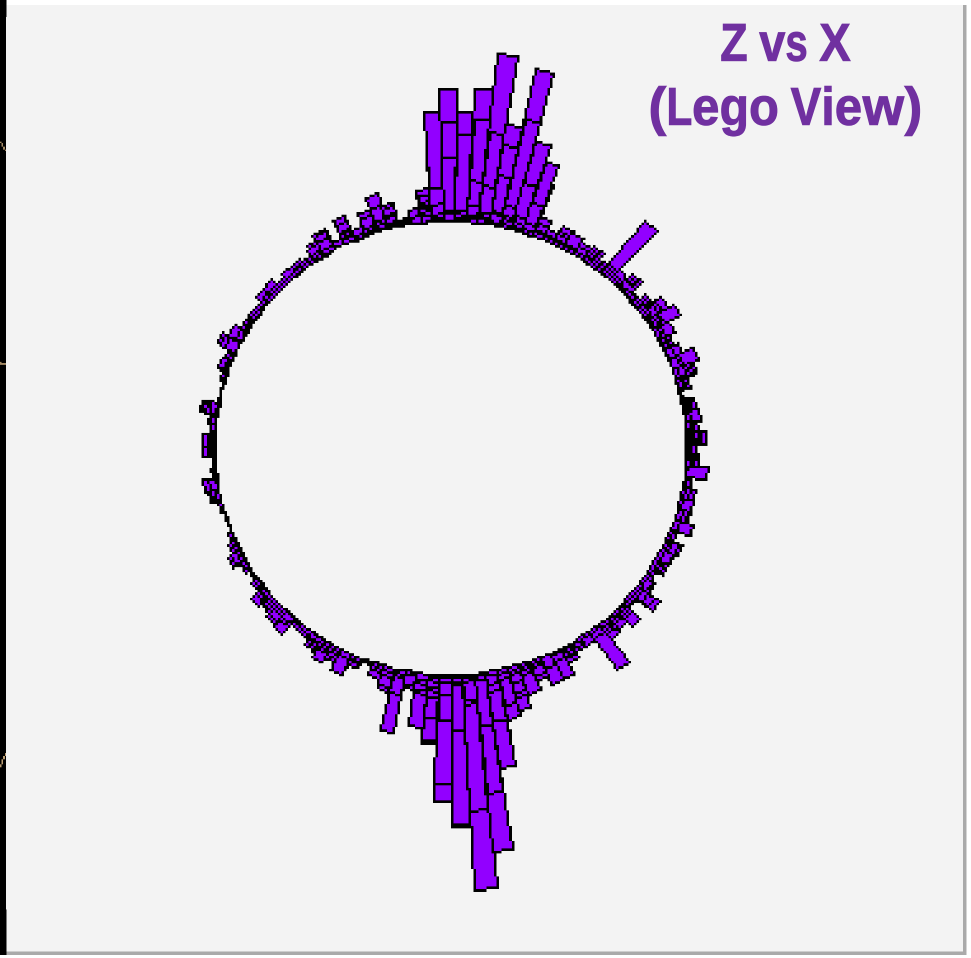


top/bottom scintillators for trigger

tracking provided by external 10x10 cm^2 Triple-GEM

Cosmic rays Test





KLOE-2 IT Detector Construction Status

Layer2

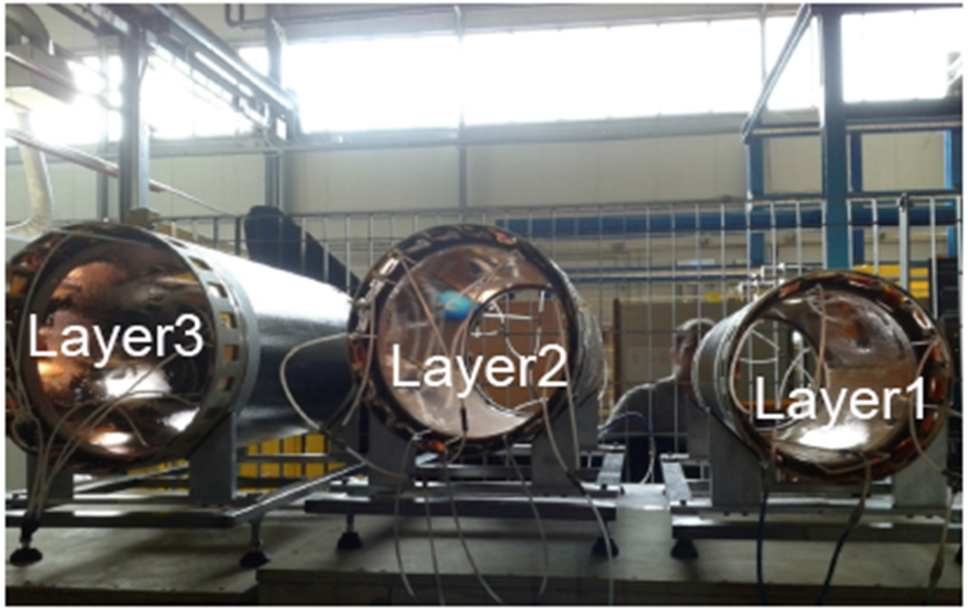
- ❑ Built and sealed
- ❑ Tested with source
- ❑ Equipped with GASTONE-FEE
- ❑ Equipped with Blocking-Capacitor
- ❑ Tested with cosmic-ray muons

Layer1

- ❑ Built and sealed
- ❑ Tested with source in Current Mode
- ❑ Equipped with Blocking-Capacitor

Layer3

- ❑ Built and sealed
- ❑ Spacer grid inserted
- ❑ Tested with source
- ❑ Equipped with Blocking-Capacitor
- ❑ Under Test with cosmic-ray muons



Layer4

- ❑ material delivery from CERN: Nov 2012
- ❑ construction completion : Jan 2013

Layers Integration

- Insertion L1/L2/L3 and test with cosmic-rays: Dec 2012
- Integration of detector w/beam pipe: Mar 2013

Further Possible Improvements

- CERN facilities can manufacture foils with Cu 1μm thick

- CF shield can be replaced by kapton

- Molds mechanical tolerances could be more permissive

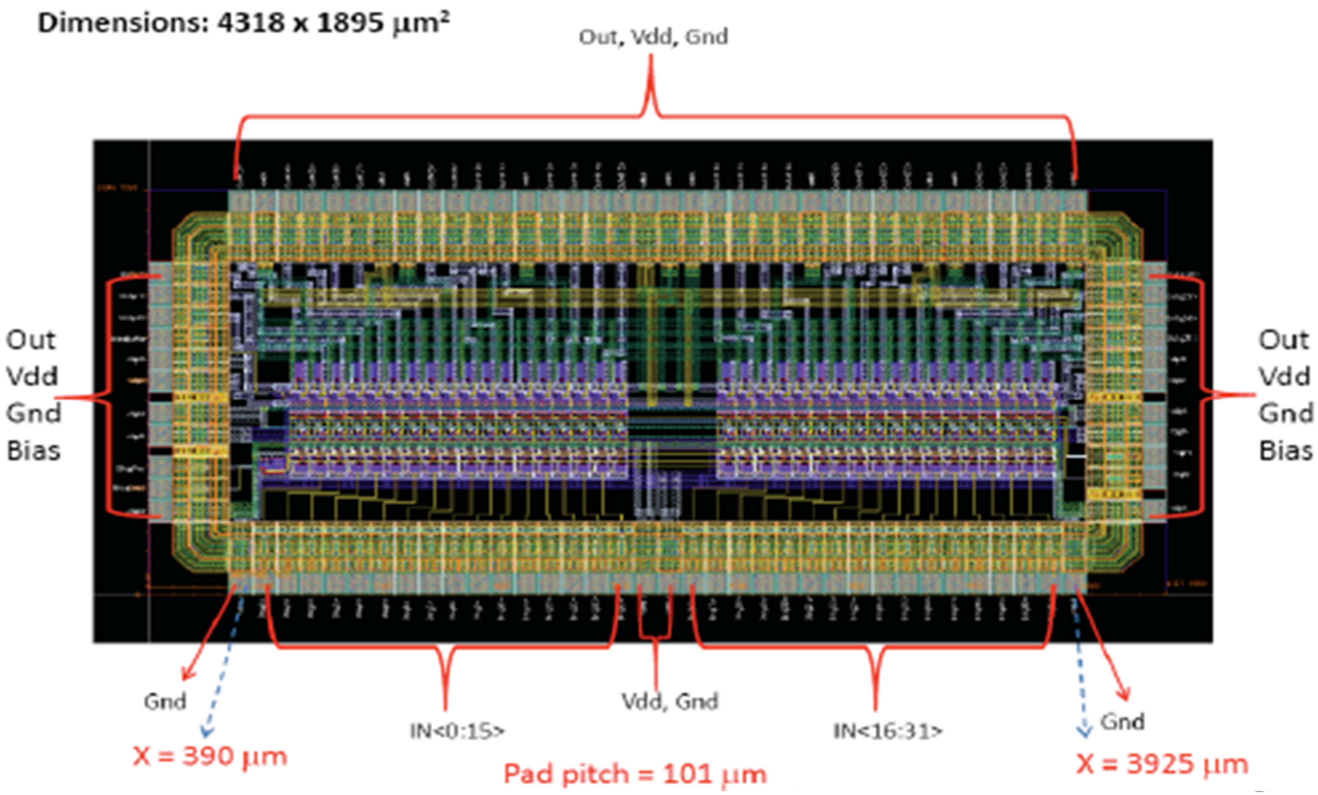
- Experts are investigating a new assembling procedure without molds

GASTONE32 with analog readout

- GASTONE32, a 32 channels board with analog readout, already available.

  It produces an amplified and shaped output of the detector input.

  (See workshop A. Ranieri presentation)
- Funding request to INFN for a small planar (10•10)cm^2 3-GEM

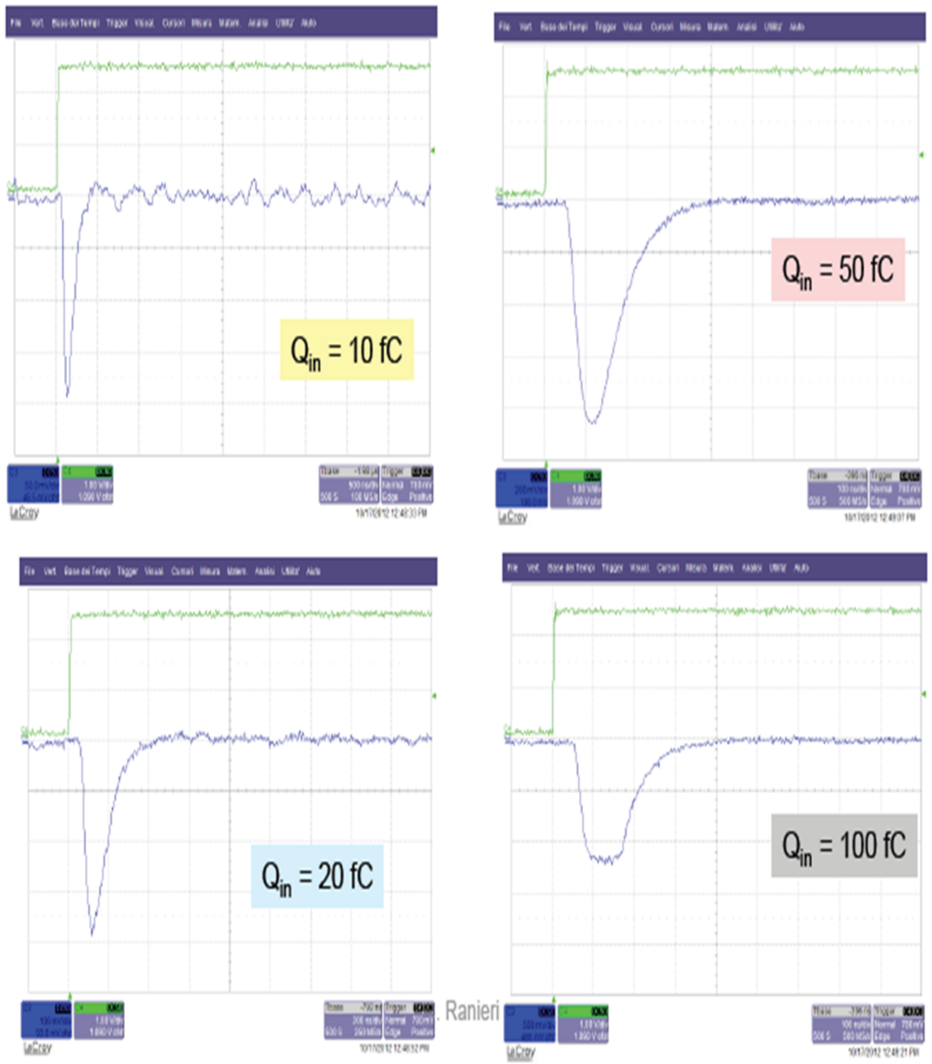


GASTONE32: some test results

- ❑ Ar/CO2=70/30
- ❑ G ~ 10^4
- ❑ 10 primary clusters/3 mm
- ❑ Clsize ~ 2.3 el/primary

Charge/mip ~ 36 fC

Charge/mip/strip ~ 9 fC



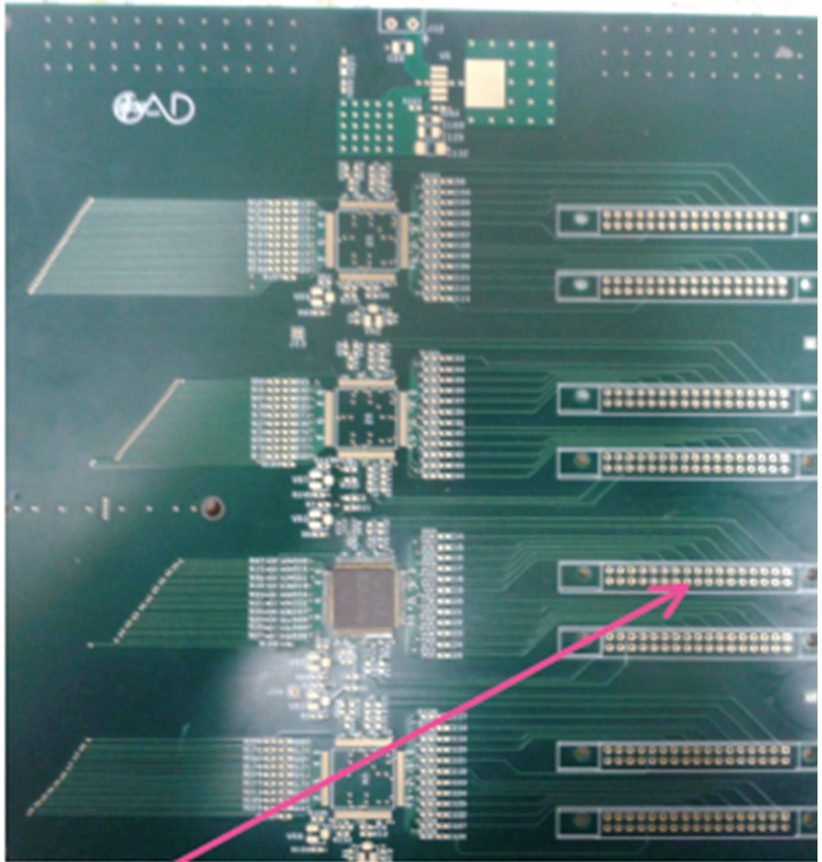
GASTONE32 Board

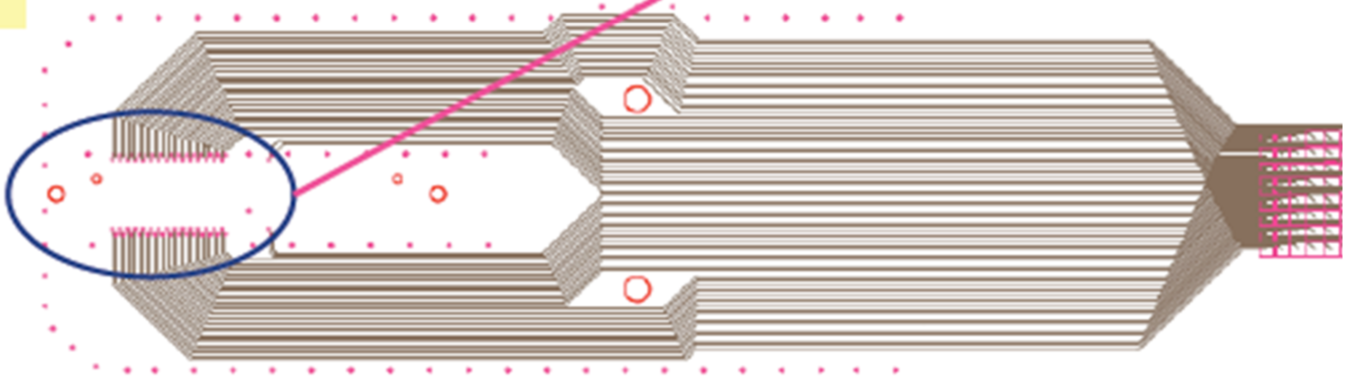
- GASTONE 32 Board ready to be mounted on a small planar 3-GEM with resistive 2x2 mm^2 pad readout; total # pad 8x8=64
total area of 16.5x16.5 mm^2 (*charge dispersion* readout method)

- A total of 128 channels are to be fully instrumented to readout a total area of 272 mm^2

- The analog output will be read out through a "Peak Sensing" ADC for charge *center of gravity* analysis

- It's a project to be further developed for what concern the readout architecture i.e.:
i. Do we need to develop an ADC per channel or for a group of channels?
ii. …and something more





A preliminary guess for layer 1 prototype construction

- BESIII CGEM layer 1 hardware needed:
  - * Construction tools available
  - * Molds 5
  - * GEM planes 3
  - * Anode plane 1
  - * Fiberglass rings 10
  - * GASTONE32 90
  - * Peak sensing ADC 3000
- Construction time : 1-2 years (starting from funding approval)
- Analog readout development should be done in parallel
- A 120 KE budget seems a reasonable estimation

Layer number	Internal diameter (mm)	Length (mm)	GEM foils
1	126	870	3
2	192	870	6
3	258	870	6
4	324	870	6

SUMMARY

- CGEM could be a solution for a new Inner Tracker
- A relevant gain is achieved in the longitudinal view
- Transverse momentum resolution worsening
  is at lower momenta.
  Many particle MC simulations may help to clarify this point
- We are confident that the funding request will be approved
- The prototype construction should be a simple task provided
  we rely in KLOE2 expertise

Thanks again for

谢谢

your attention