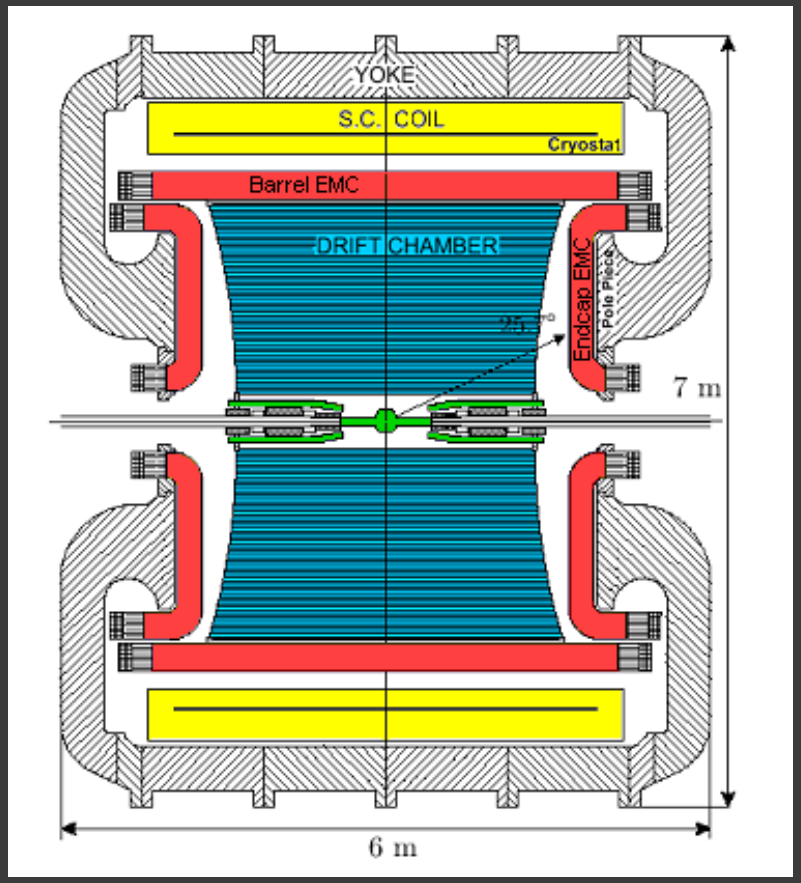
EPS HEP 2013 - Stockholm

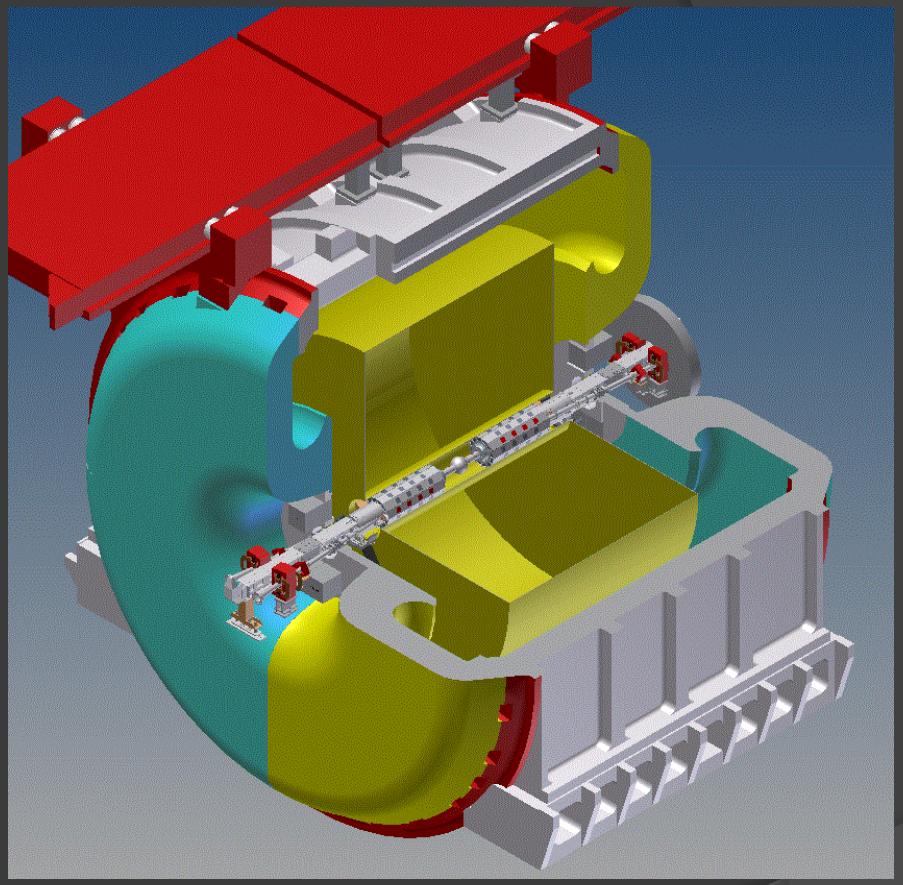
**Danilo Domenici**

on behalf of the KLOE-2 collaboration

# THE NEW DETECTORS OF THE KLOE-2 EXPERIMENT

# The KLOE Detector at Dafne

- 2.5/fb collected at the $\phi$ peak in 2001-2006
- Drift Chamber ($He/iC_4H_{10}$ light gas mixture)
- 0.52 T Magnetic Field (Superconductive coil)
- EM Calorimeter (Pb/SciFi, excellent time resolution)

# KLOE-2 New Detectors

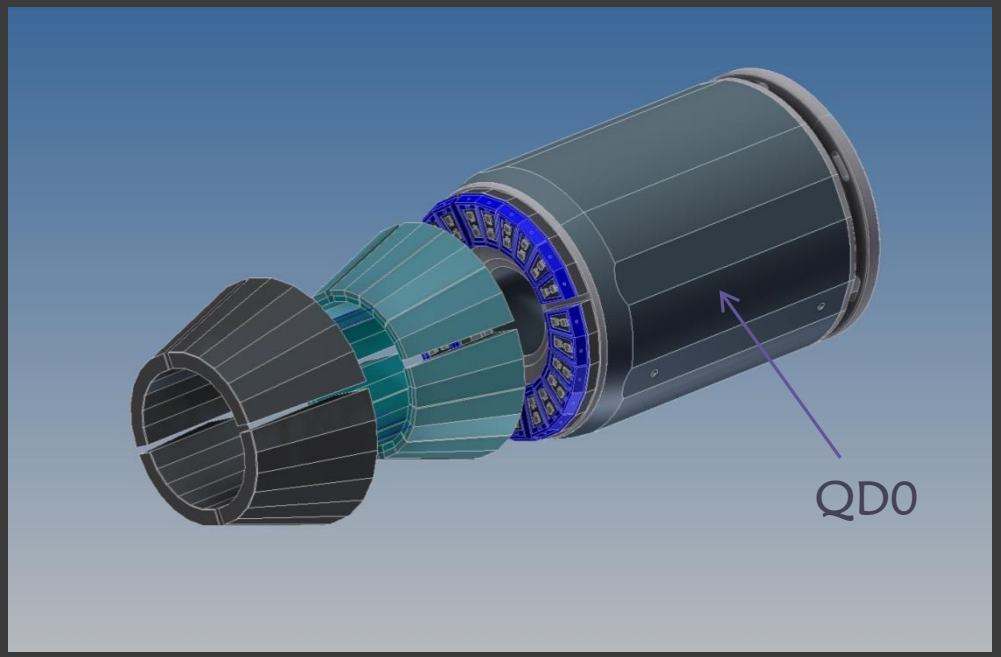

New physics program:
Ks, η, ηs rare decays
Quantum interferometry
Search for Dark photon

**QCAL**
**Quadrupole calorimeter**
efficiency on Ks → $\pi^0\pi^0\pi^0$

**IT**
**Gaseous Inner Tracker**
resolution on Ks → π+π- vertex

**CCAL**
**Low angle Crystal calorimeter**
efficiency on Ks → γγ

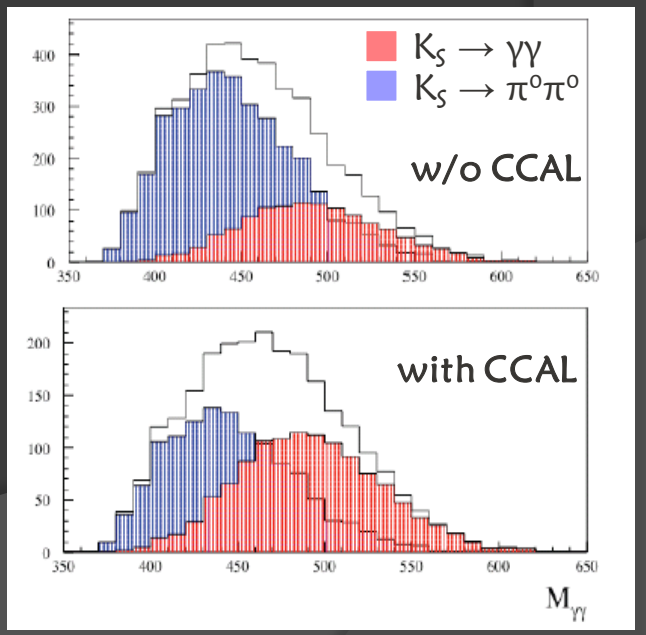
# CCAL: Crystal Calorimeter

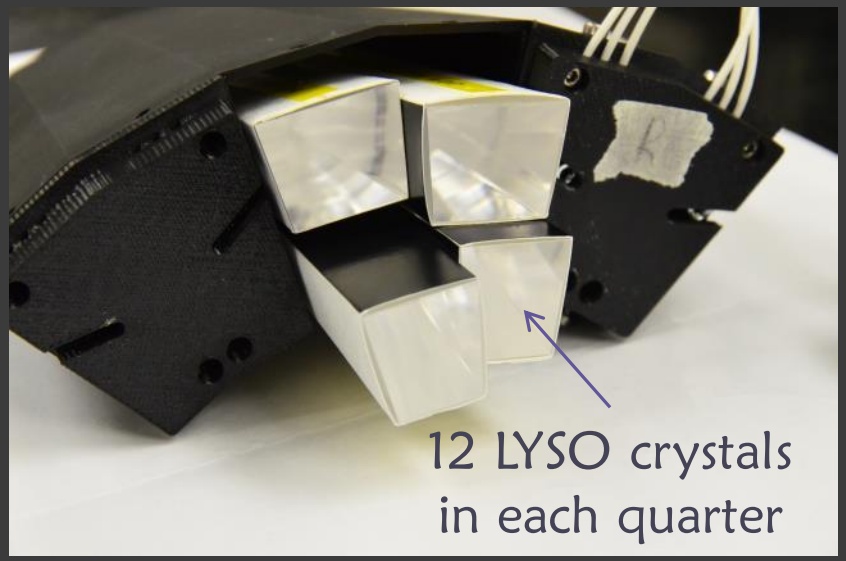

increase acceptance of the central calorimeter from 18 to 10 degrees covering QD0 region

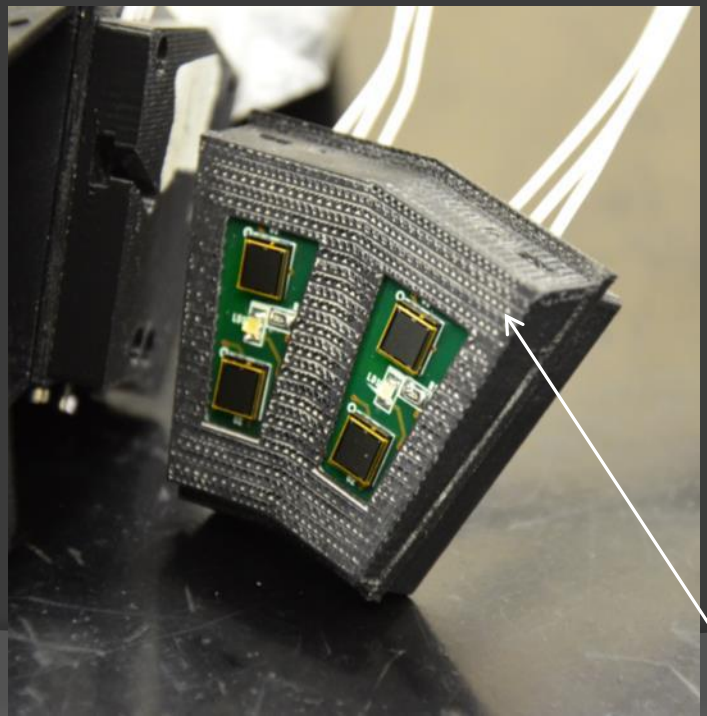
- 2 calorimeters at 20 cm from IP
- 96 LYSO crystals
- SiPM readout
- Enhance S/N for $K_S \rightarrow \gamma\gamma$

- Time resolution: 50÷120 ps @ 500÷100 MeV (for background rejection)
- Spatial resolution: 3 mm
- Energy resolution: 15% @ 100 MeV (shower is not contained)
- Radiations length: 7.3 $X_0$
- Light yield: 300 pe/MeV/crystal



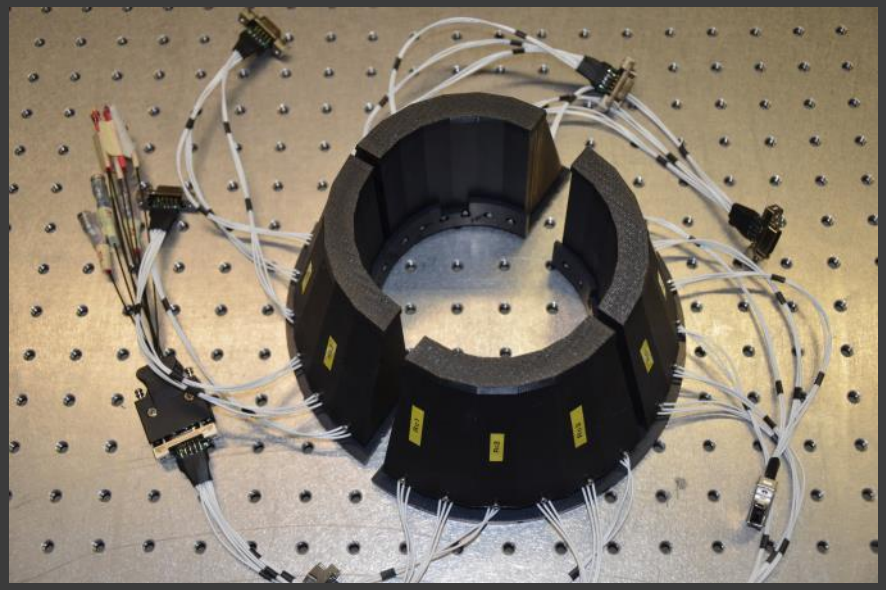
# CCAL Components

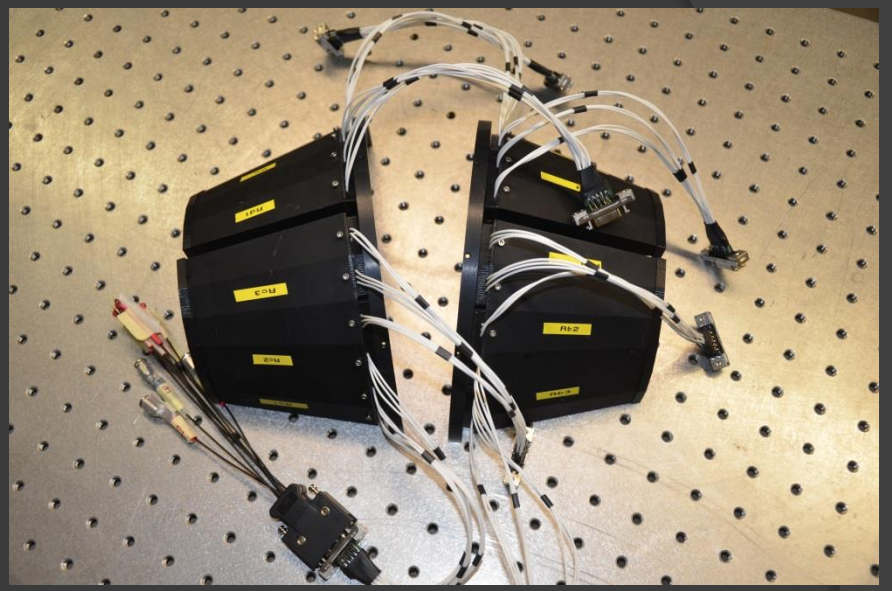


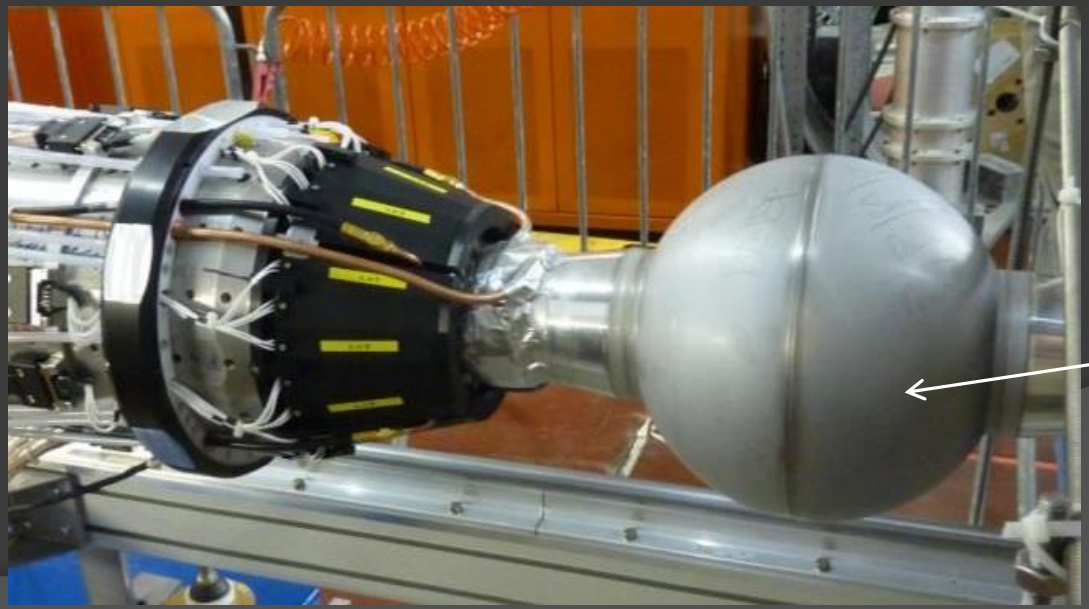



PCB housing SiPM and calibration LED housed by a 3d-printed ABS case

# CCAL Integration

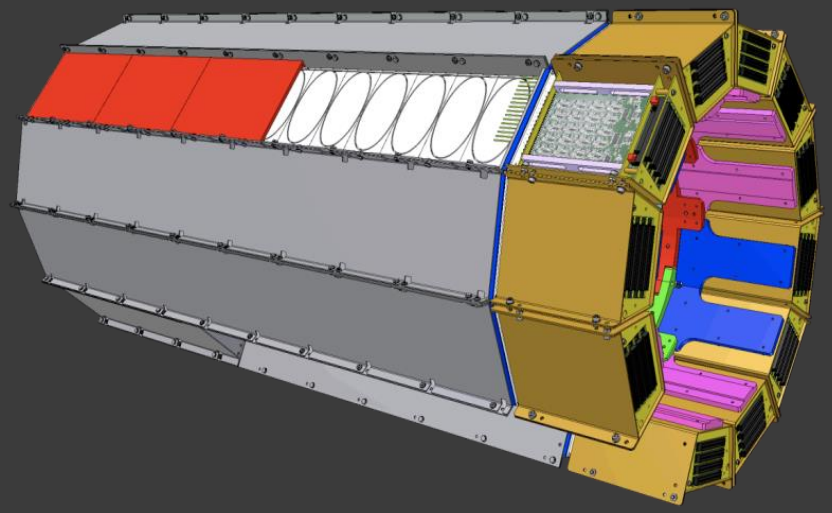







IR sphere pipe

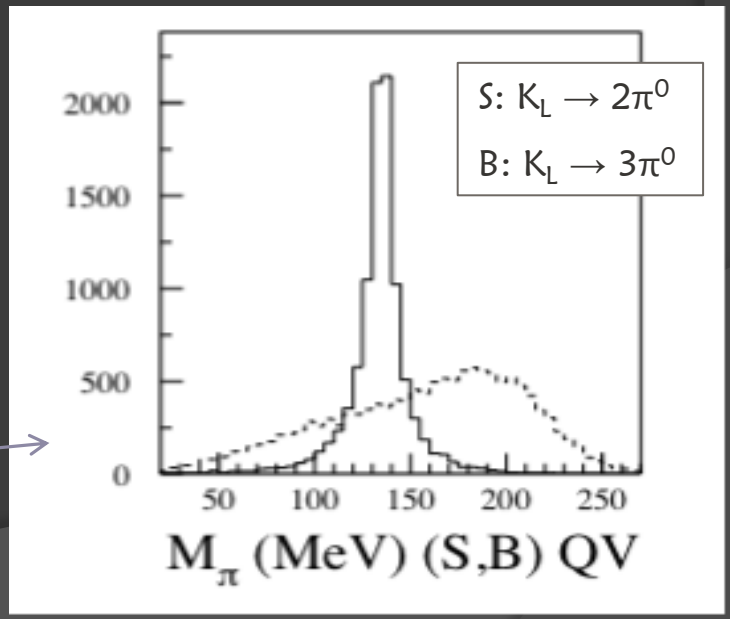
# QCAL: Quadrupole Calorimeter

2 dodecagonal structures covering the region close to the IP

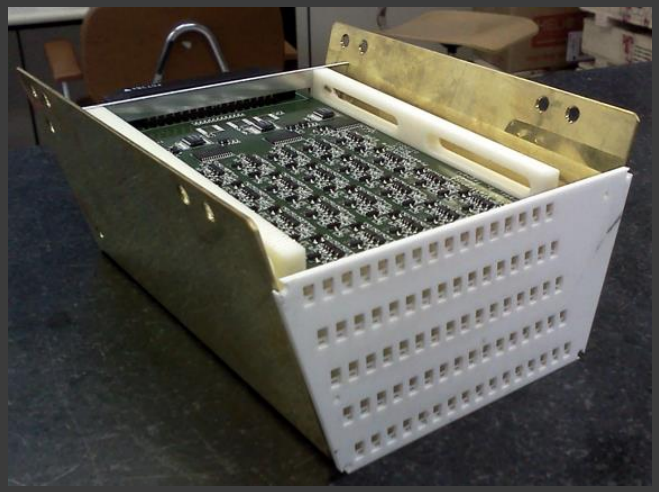
- Each module (1/12) is a sampling calorimeter with 16 towers
- 5 layers of scintillator tiles and 5 layers of W absorber
- Light routed outside by WLS fibers and readout by circular 1.2 mm Ø SiPM

- Time resolution: 750 ps (for background rejection)
- Spatial resolution: 5 cm / √12
- Radiation length: $5X_0$
- Light yield: 24 pe/MeV/tile
- 1920 readout channels
- Enhance S/B for $K_L \rightarrow 2\pi^0$ and $K_S \rightarrow 3\pi^0$

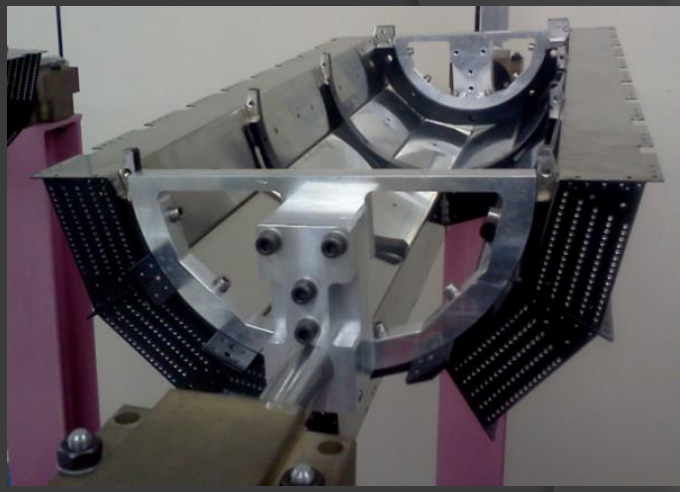


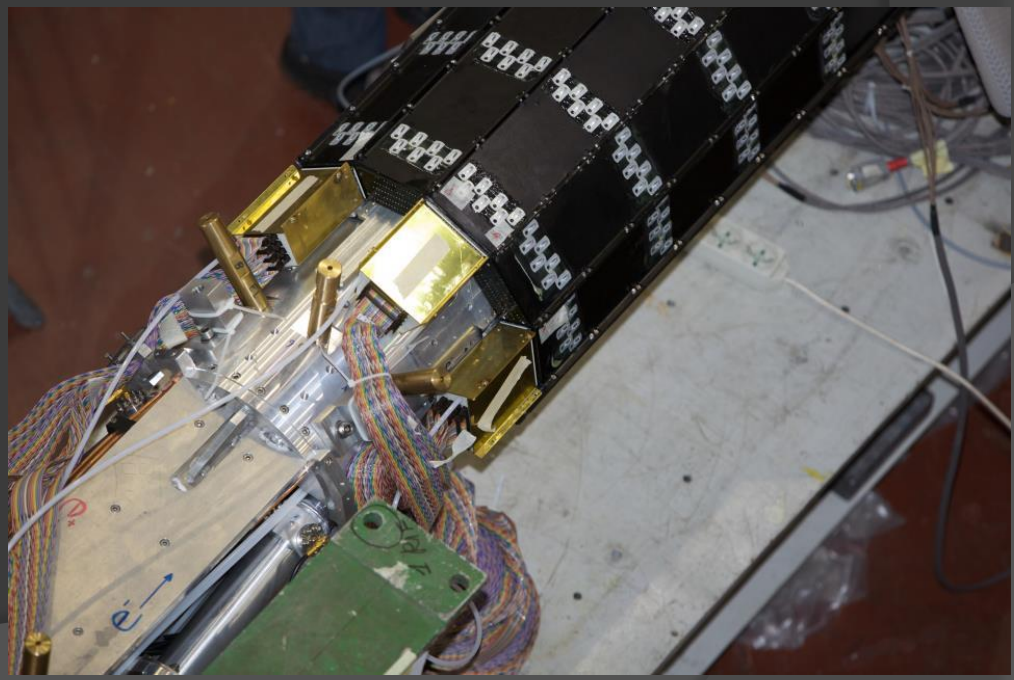
# QCAL Components


tiles coated with reflecting varnish



FEE with HV regulator, preamplifier and splitter





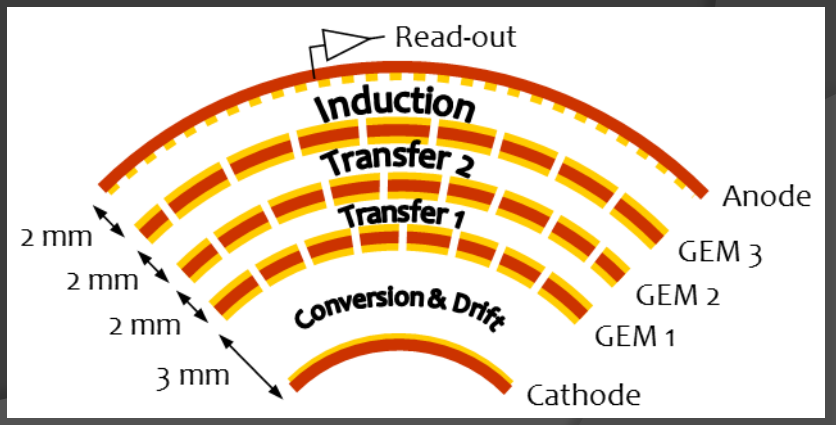
FEE mounted on modules

# Cylindrical-GEM Inner Tracker

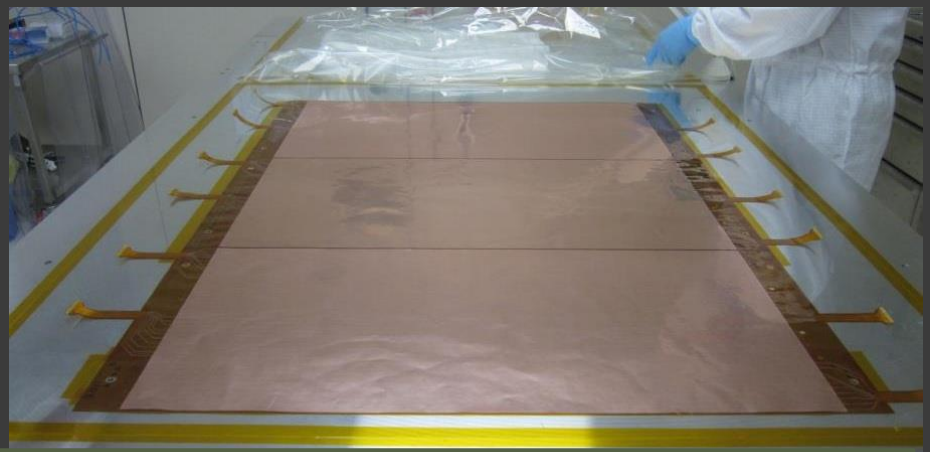

## Cylindrical triple-GEM

- 4 tracking layers at 13/15.5/18/20.5 cm from IP
- 70 cm active length
- 20k readout channels
- 1300 HV channels
- Improve $\pi^+\pi^-$ vertex resolution to $c\tau_S/3$

- Spatial resolution: $\sigma_{r\phi} \sim 250\ \mu m$ and $\sigma_z \sim 400\ \mu m$ in 0.52 T magnetic field
- Material budget: 2% $X_0$ total radiation length in the active area
- Front-End Electronics: digital readout with custom low-power 64 channel ASIC (GASTONE)
- Gas gain: 20000 with Ar/Iso : 90/10



# Manufacturing a C-GEM

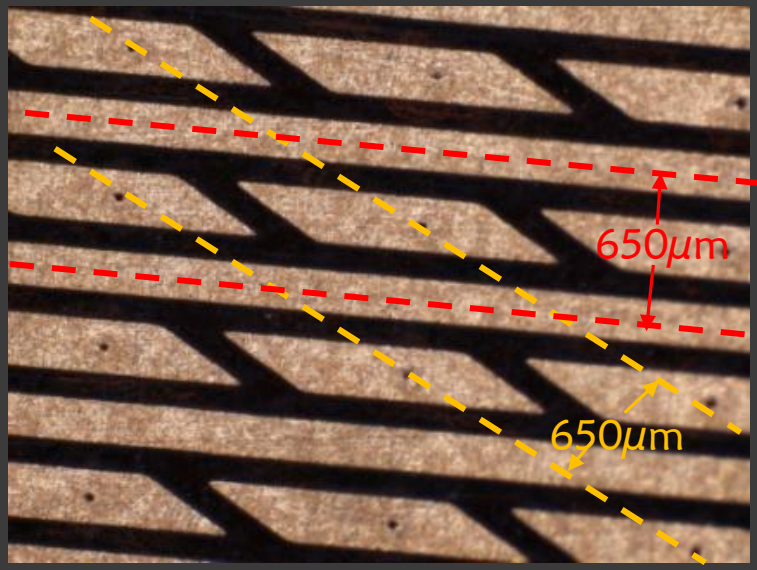
3 GEM foils are spliced together with a 3 mm overlap and closed in a vacuum bag

GEM is wrapped on a cylindrical mold

Vacuum bag is closed

Final cylindrical GEM with internal and external rings

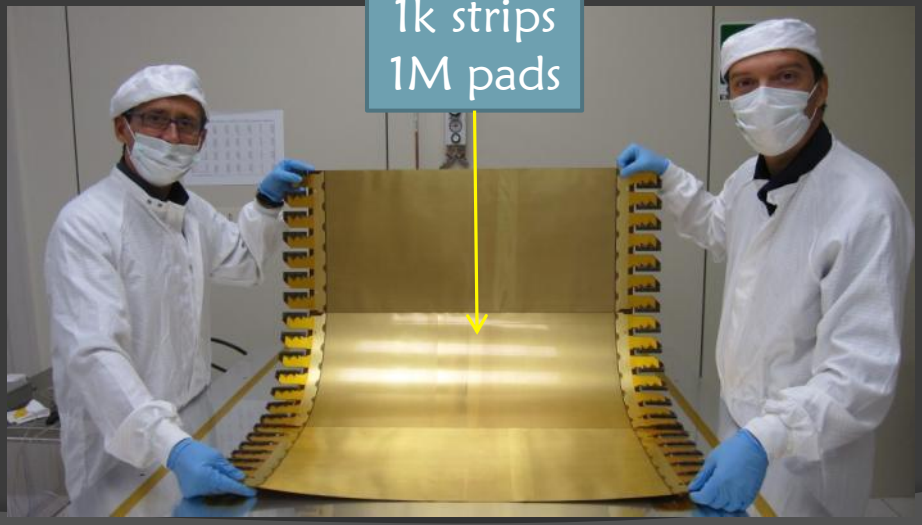
# The Readout Electrode


Built at CERN TE-MPE-EM as a kapton/copper multilayer flexible circuit.

2-D readout with XV strips on same plane:

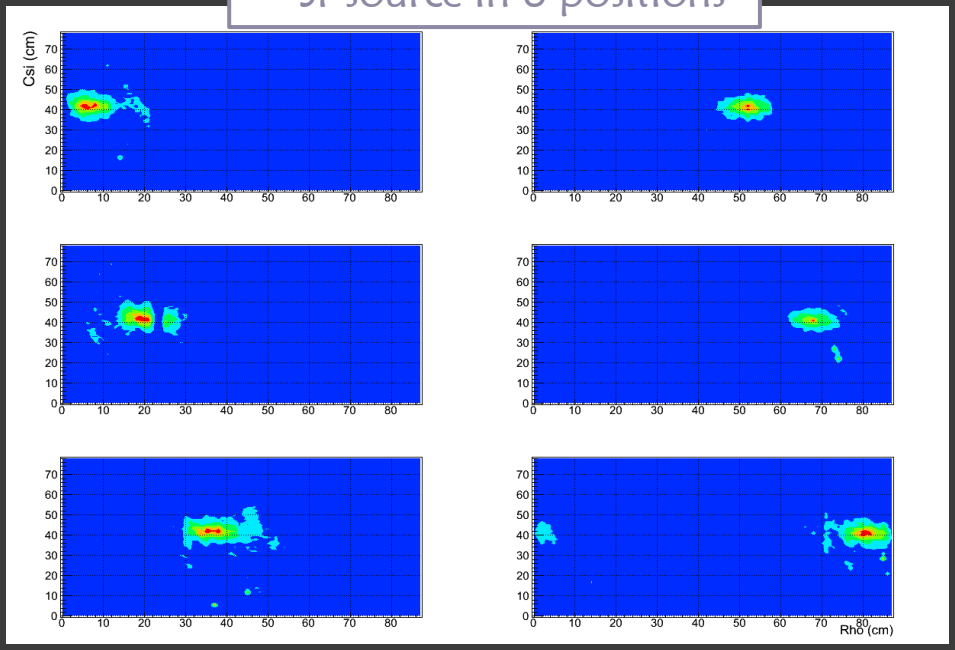
- X are realized as longitudinal strips
- V are realized by connection of pads through conductive vias
- Resolutions are $\sigma_x$=190 μm $\sigma_Y$=350 μm

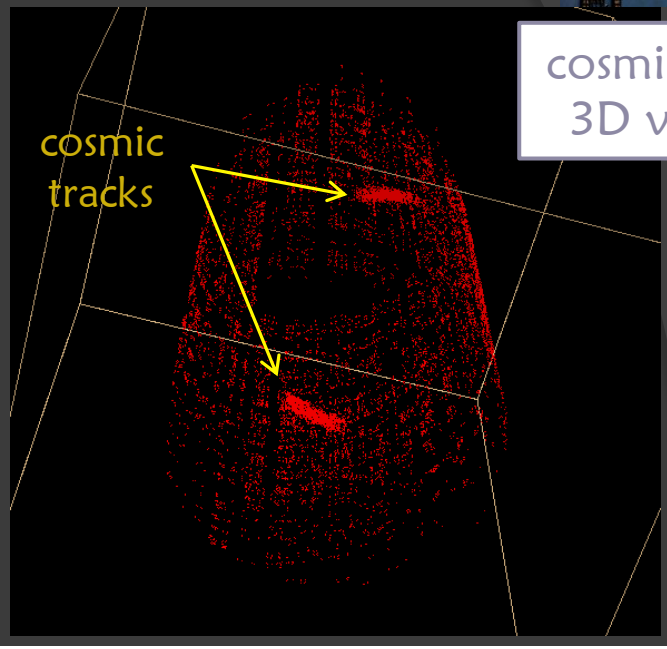



RO is shielded with very ligth Carbon fiber composite structure (180 μm thick)

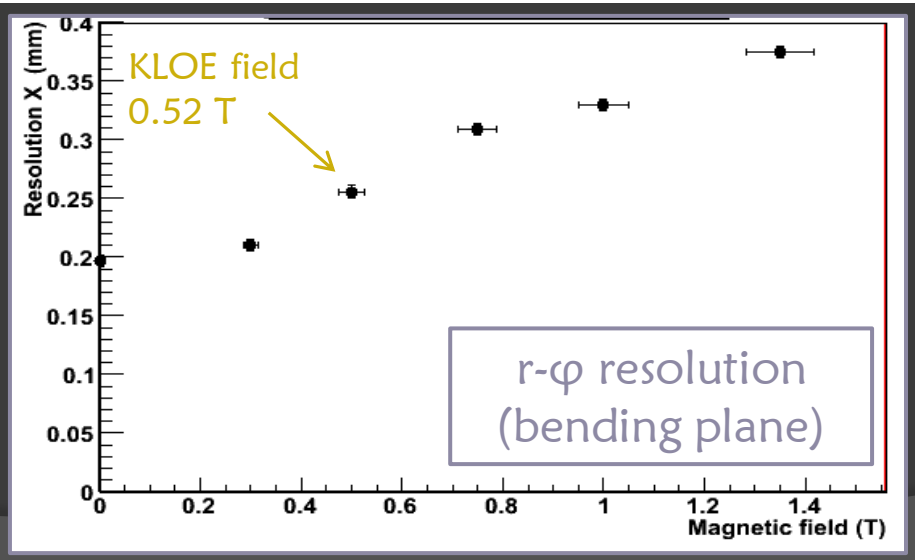
# IT Performance


$^{90}$Sr source in 6 positions

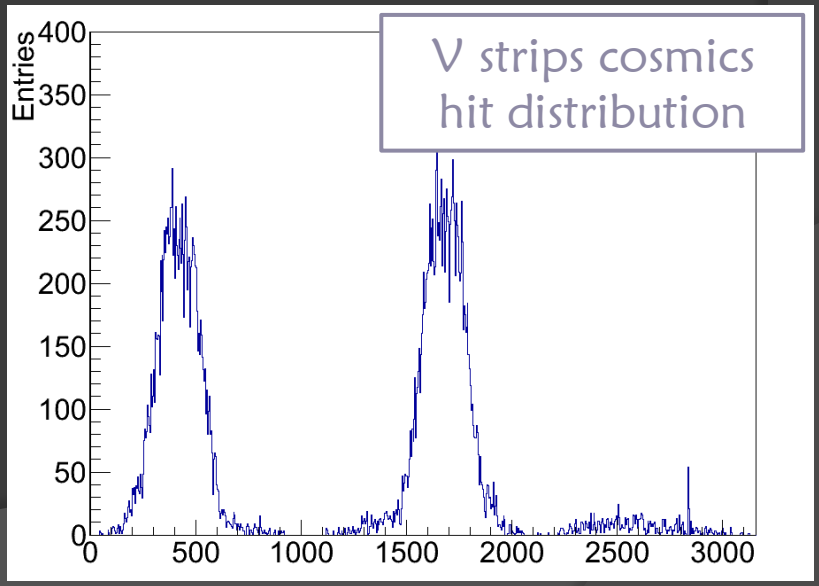



cosmics hit 3D view



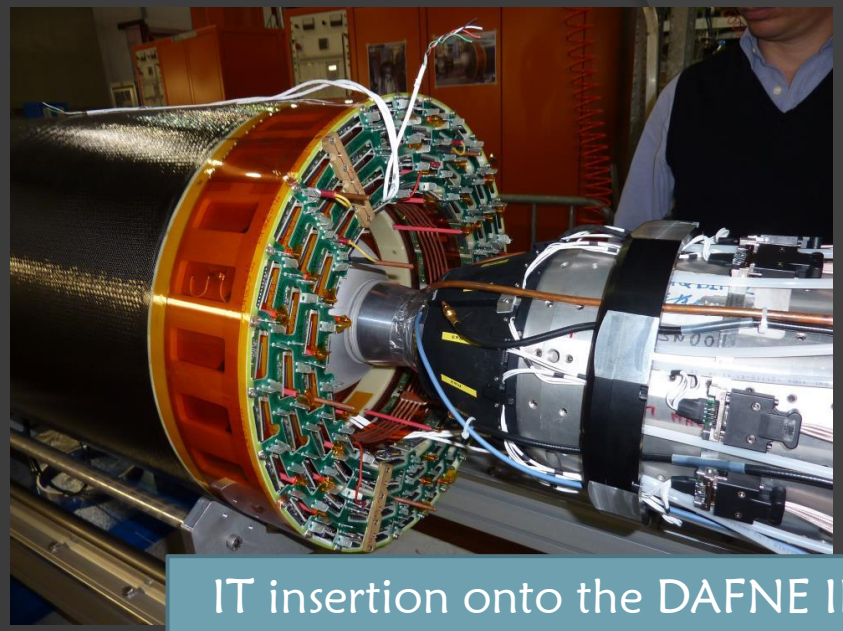

r-φ resolution (bending plane)




V strips cosmics hit distribution

# IT Integration


IT completed with FEE



IT insertion onto the DAFNE IR

IT cabled and shielded

# Interaction Region Detectors

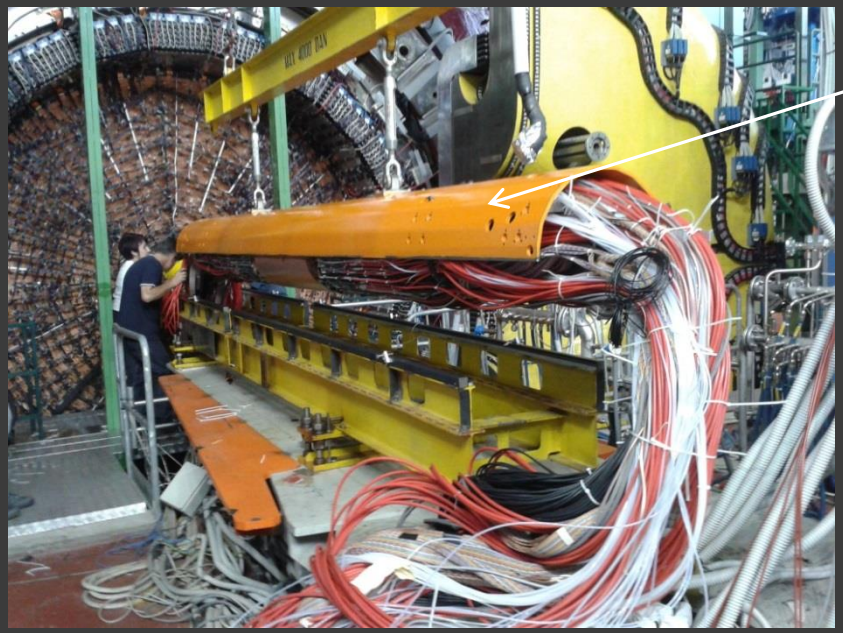

QCAL

IT

QCAL

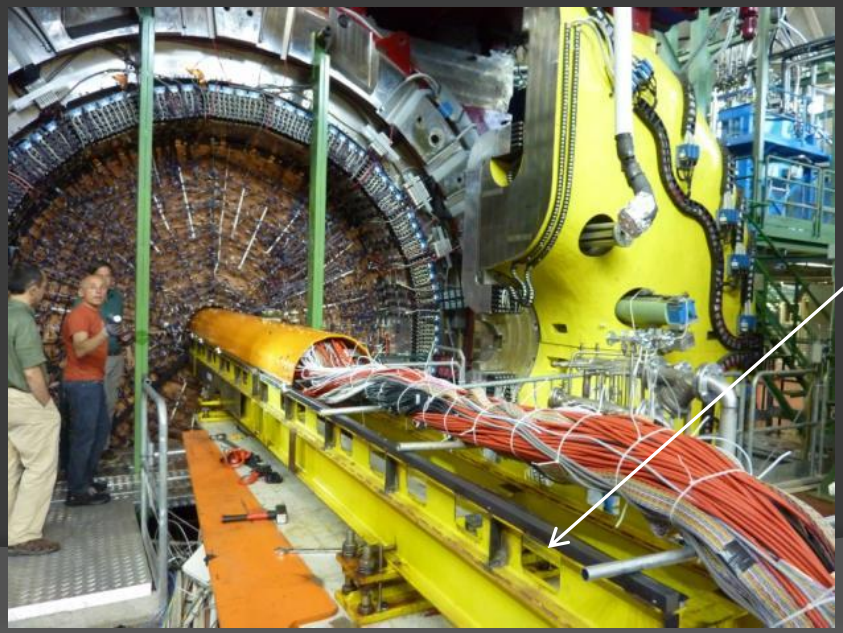
CCAL

# Insertion of IR inside KLOE

Steel shell used to grab the IR

IR inside DC with all the cables outside



Rails to support and insert IR

# Conclusions


- The second run of the KLOE experiment at DAFNE is starting with the aim of 2/3 years of data taking and 5/10 $fb^{-1}$ of integrated luminosity
- The physics program will be based on precision measurement of Ks, η and η' rare decays, quantum interferometry and search for new secluded dark bosons
- 3 new detectors have been realized and successfully installed onto the upgraded DAFNE Interaction Region
  - CCAL is a LYSO calorimeter with SiPM readout covering the low angle region
  - QCAL is a tile calorimeter with SiPM readout equipping the quadrupoles inside KLOE
  - IT is a gaseous central tracker based on the novel technology of cylindrical GEM
- First collisions are foreseen in September


# SPARES

# Material Budget

| Material | Radiation Length (cm) |
|---|---|
| Copper | 1,43 |
| Polyimide - Kapton | 28,6 |
| Carbon fiber | 28 |
| Argon | 14000 |
| Isobuthane | 17000 |
| Epoxy - Araldite 2011 | 33,5 |
| Honeycomb - Nomex | 1250 |
| Fiberglass - FR4 | 16 |
| Air | 30500 |
| Aluminum | 8 |
| Gold | 0,33 |

The KLOE-2 requirement of $X_0 < 2\%$ is fulfilled

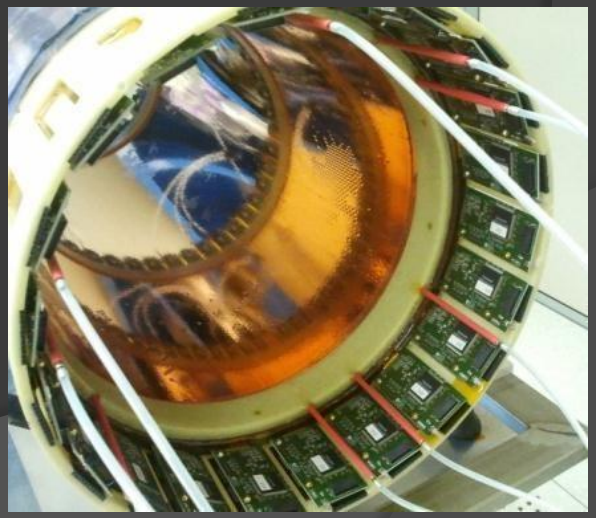
| | Thickness (μm) | Radiation Length (%) |
|---|---|---|
| Copper | 3 | 1,68E-04 |
| Polyimide | 50 | 1,40E-04 |
| Copper | 3 | 1,68E-04 |
| **GEM foil** | **56** | **4,76E-04** |
| Copper | 3 | 2,10E-04 |
| Polyimide | 50 | 1,75E-04 |
| Honeycomb | 3000 | 2,40E-04 |
| Polyimide | 50 | 1,75E-04 |
| Copper | 3 | 2,10E-04 |
| **Cathode foil** | **3106** | **1,01E-03** |
| Gold | 0,1 | 3,03E-05 |
| Copper | 5 | 2,45E-04 |
| Polyimide | 50 | 1,75E-04 |
| Copper | 5 | 1,05E-04 |
| Epoxy | 12,5 | 3,73E-05 |
| Polyimide | 125 | 4,37E-04 |
| Epoxy | 12,5 | 3,73E-05 |
| Polyimide | 50 | 1,75E-04 |
| Copper | 3 | 2,10E-04 |
| Gold | 0,1 | 3,03E-05 |
| **Anode Foil** | **263** | **1,48E-03** |
| Carbon fiber | 90 | 3,21E-04 |
| Honeycomb | 5000 | 2,40E-04 |
| Carbon fiber | 90 | 3,21E-04 |
| **CF Shield** | **3200** | **9,54E-04** |
| Gas (90% Ar – 10% $iC_4H_{10}$) | 9000 | 6,29E-05 |
| **Total 1 Layer** | | **4,93E-03** |
| **Total 4 Layers** | | **1,97E-02** |

# IT FEE: Gastone Chip


| | |
|---|---|
| Technology | 0.35 CMOS - no radhard |
| Sensitivity (pF) | 20 mV/fC |
| $Z_{IN}$ | 400 Ω (low frequency) |
| $C_{DET}$ | 1 – 50 pF |
| Peaking time | 90 – 200 ns (1-50 pF) |
| Noise (erms) | 800 $e^-$ + 40 $e^-$/pF |
| Channels/chip | 64 |
| Readout | LVDS/Serial |
| Power consum. | ≈ 0.6 mA/ch |

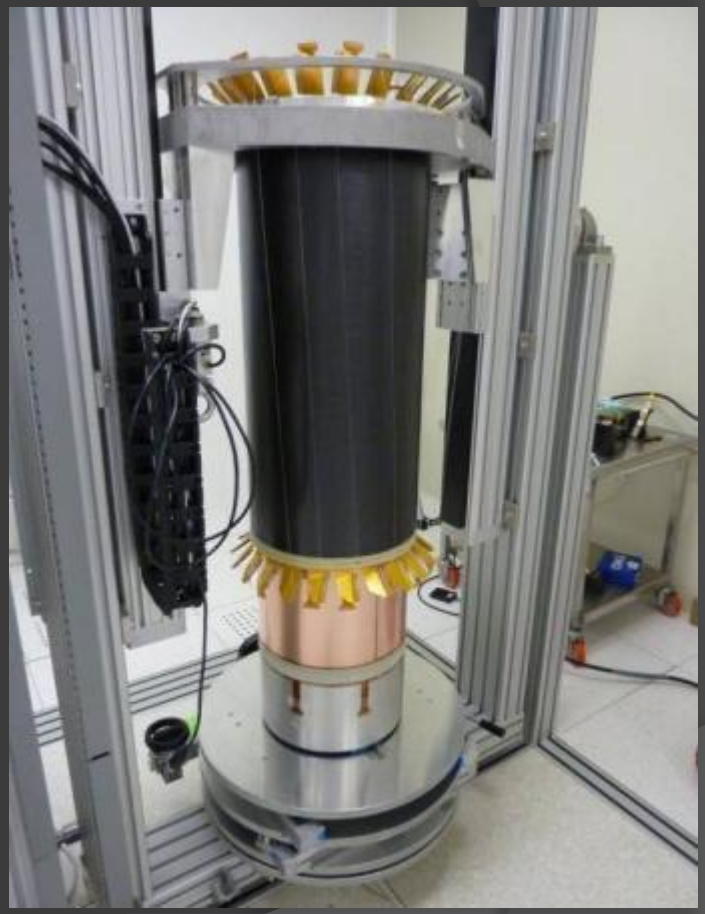
128 channels
GASTONE Board


- Mixed analog-digital circuit
- Low input equivalent noise, low power consumption and high integrated chip
- 4 blocks:
  1. charge sensitive preamplifier
  2. shaper
  3. leading-edge discriminator
  4. monostable



# Assembling a Triple-GEM


The 5 electrodes of a Cylindrical-GEM are then inserted one into the other

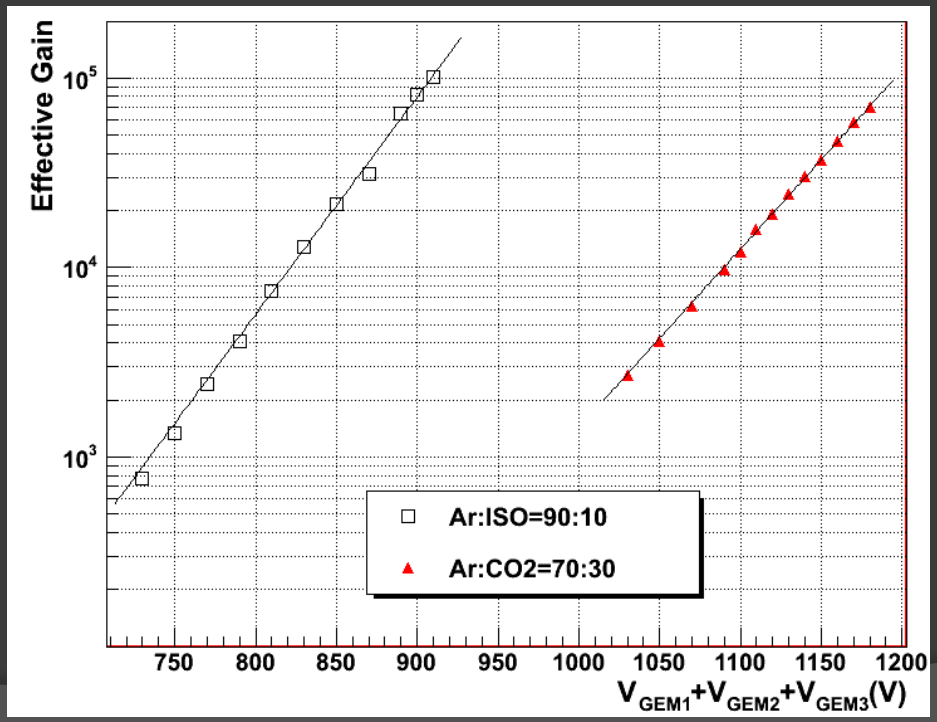
The GEM is placed on the machine with its mold

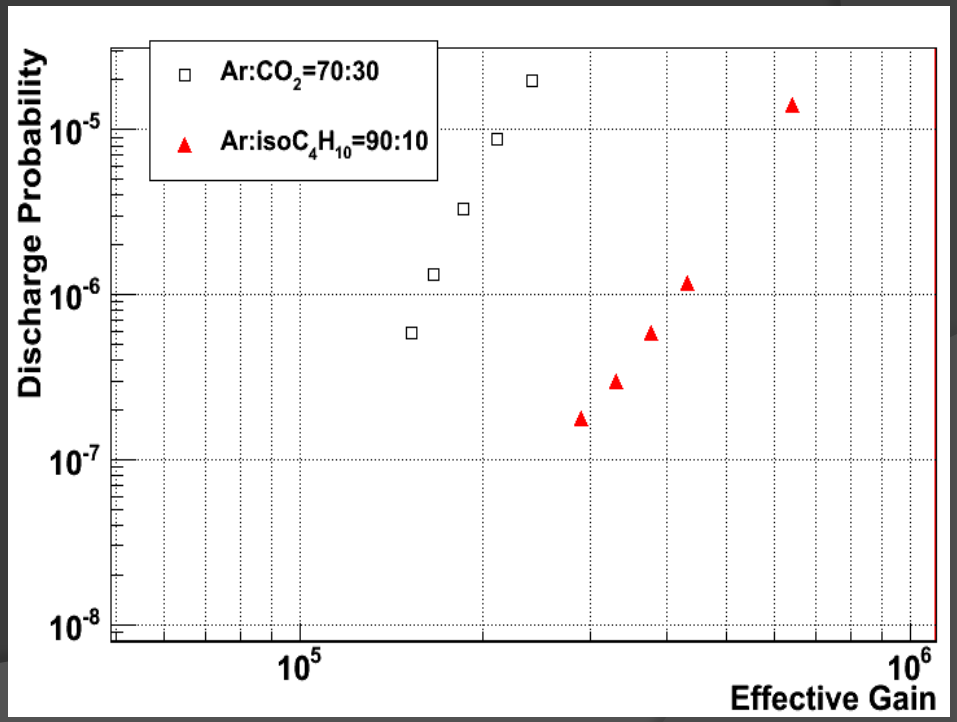
Everything is aligned with an axial precision of ≈0.1mm/1.5m

The Readout is moved down around the GEM

# Gain and Discharges


- Gas gain measurement performed in current mode using as normalization a refernce detector with known gain
- Discharge measurement performed with a $^{141}Am$ $\alpha$ source
- KLOE2 chosen mixture Ar/Isobuthane (90/10) is compared with the standard gas mixture $Ar/Co_2$ (70/30)
- Our working gain will be $2 \times 10^4$



# LET: Low Energy Tagger



2 small calorimeters at 1.5 m from IP

- LYSO crystals
- SiPM readout
- Detect e+e- (150÷350 MeV) escaping beam pipe in γγ processes

- Time resolution: 750 ps (for background rejection)
- Spatial resolution: 5 cm / √12
- Radiation length: $5X_0$
- Light yield: 24 pe/MeV/tile
- 1920 readout channels