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


The BESIII Winter Collaboration Meeting
Huangshang University - November 23-27, 2013

# CGEM-IT project update

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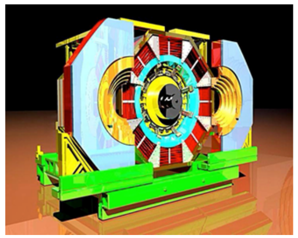
(INFN Ferrara)

on behalf of the CGEM group



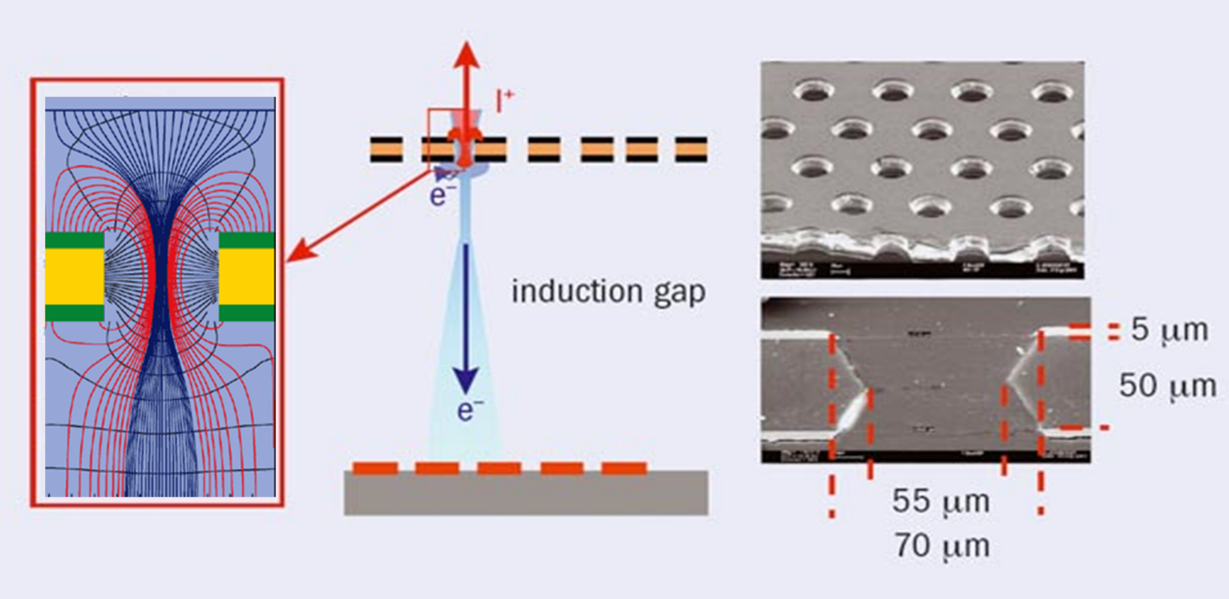
# Outline

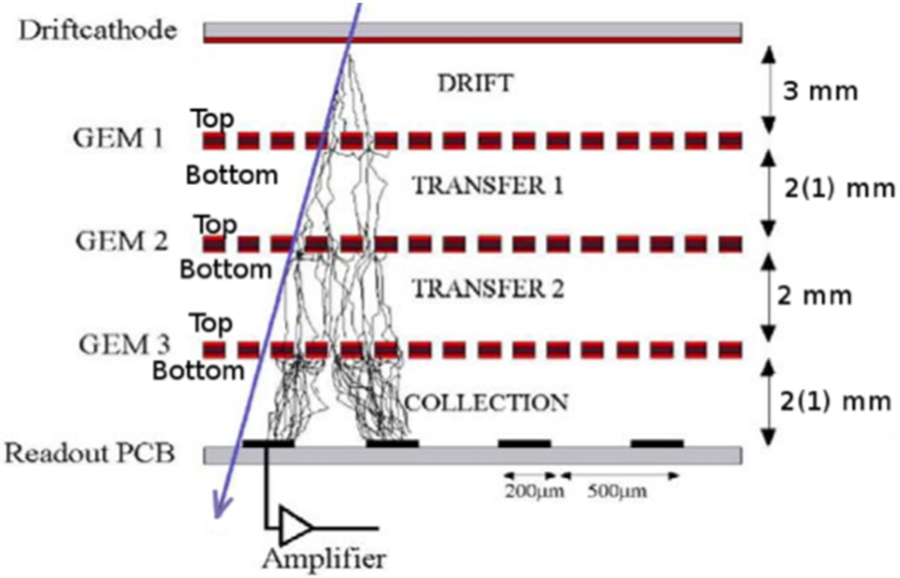
- Introduction
- Mechanics of the detector
  - Mechanical constraint
  - Test cathode construction
  - Layer-2 final design
- Cosmic ray setup for a planar prototype
- Plans for the frontend electronics
- Budget, CDR and schedule

# GEM in a nutshell

A thin polymer foil, metal-coated on both sides, is chemically pierced by a high density of holes.

On application of a voltage gradient, electrons released on the top side drift into the hole, multiply in avalanche and transfer the other side.



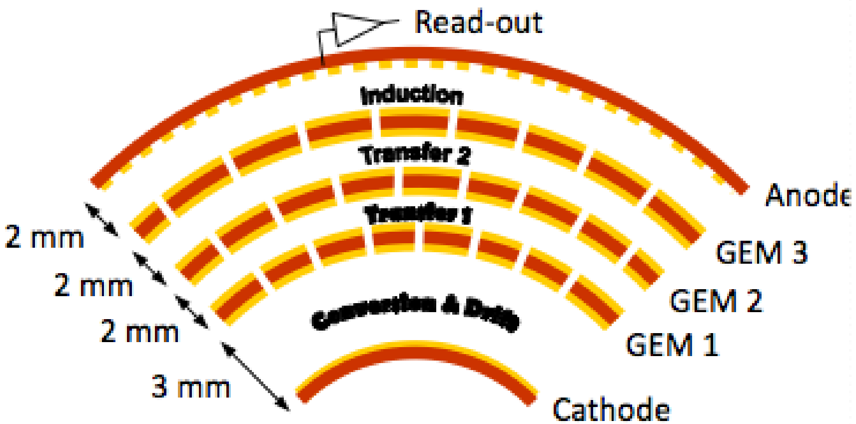

Proportional gains above $10^3$ are obtained in most common gases.

Cascaded GEMs permit to obtain larger gains

Spatial resolution determined by chamber and readout electrode geometries

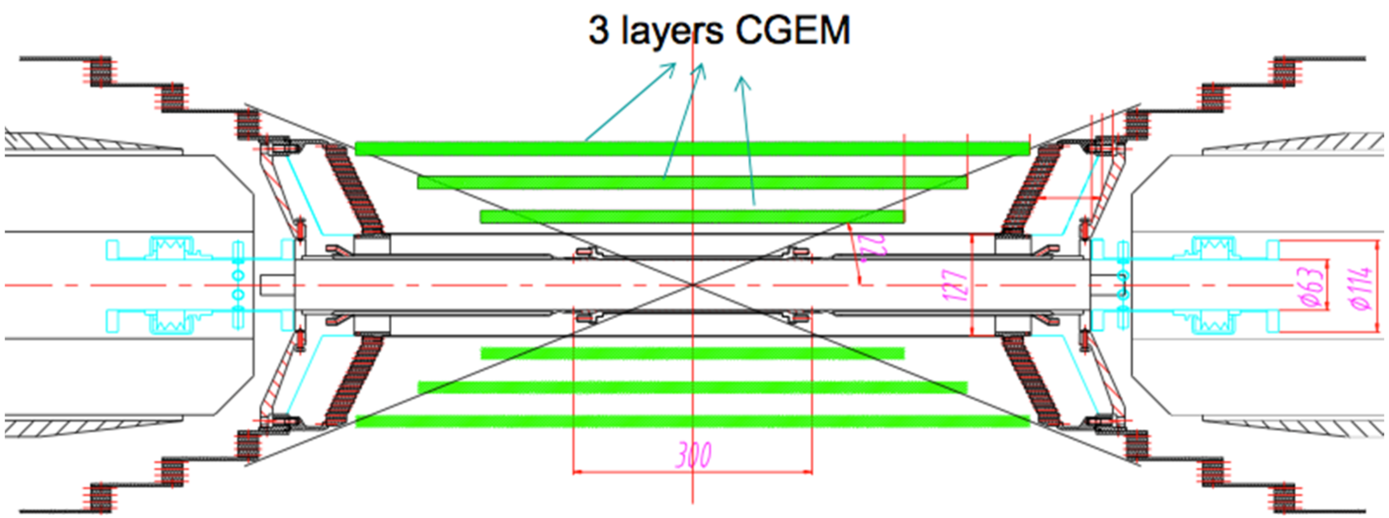
# A CGEM based Inner Tracker

A cylindrical triple GEM




Requirements

- Rate capability: ~$10^4$ Hz/cm$^2$
- Spatial resolution: $\sigma_{xy}$ =~100μm : $\sigma_z$=~1mm
- Momentum resolution:: $\sigma_{pt}/P_t$ =~0.5% @1GeV
- Efficiency = ~98%
- Material budget ≤ 1.5% all layers
- Coverage: 93% 4π
- Operation duration ~ 5 years

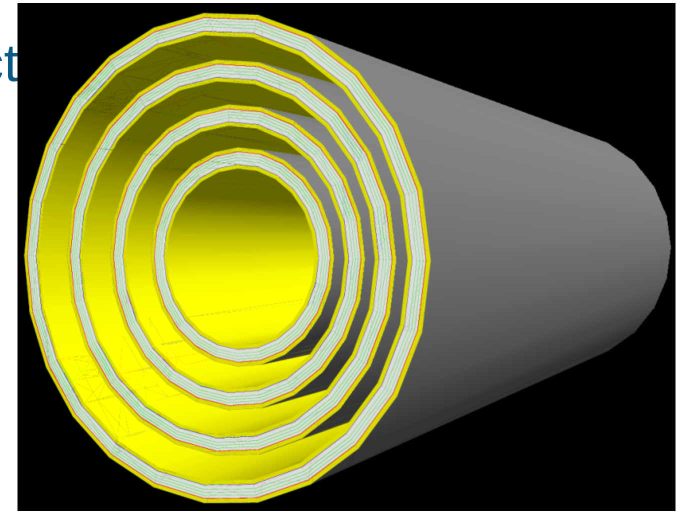



- Three active layers
- Active area
  - L1 length 532 mm
  - L2 length: 690 mm
  - L3 length: 847 mm
- Inner radius: 78

# CGEM expected performance

From GEANT4 simulation

CGEM inner detector (**wrt** MDC inner detect



- **Improves dz resolution significantly** (by a factor of 2.6~6)
- **Comparable dr resolution** (~5% poorer for low momentum tracks )
- **Comparable momentum resolution** (~5% better for high momentum tracks)

From KLOE beam test

| Readout | $\sigma_{rf}$ ($\mu$m) | $\sigma_z$ ($\mu$m) |
|---|---|---|
| Digital readout (Beam test @2009) | 330 | 400 |
| Analog readout (magnetic field effect avoided)* | 80 | 150 |

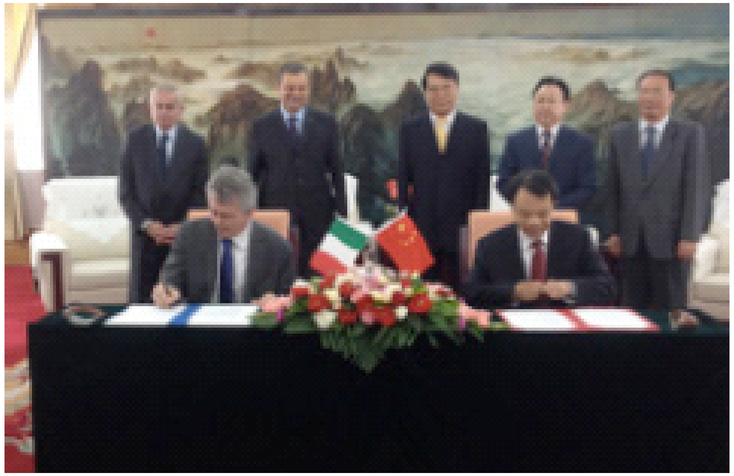
* Taken as expected spatial resolution

# The MAE project

- Design, construction and test of a CGEM prototype and readout electronics funded by the Foreign Affairs Ministry agreement of scientific cooperation for a Joint laboratory " INFN-IHEP".

360,000 euros in three years!

| | | |
|---|---|---|
| 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 | |



BESIII Winter Collaboration Meeting,Guilin

## Status of the project

- 2013 budget almost exhausted (see next slide)
- February 2014: relation to MAE concerning 1st year activities
- March-April 2014: MAE approval of relation, and reimbursement to INFN (40 kEuros)
- April-June: expect 2014 budget available

# Status of MAE budget

- Two budgets have been allocated in 2013 by INFN
  - INFN own financing (40 kE) in July
  - MAE contribution (40 kE) in November, advanced by INFN, to be recovered next spring from MAE and immediately re-advanced for 2014

almost exhausted:

- lab setup and R&D,
- electrodes for construction of the first layer of CGEM

- One extra-budget (20 kE) procured as Ferrara "startup" extra-help

exhausted:

- material and tooling for test cathode construction
- molds and tooling for first layer construction

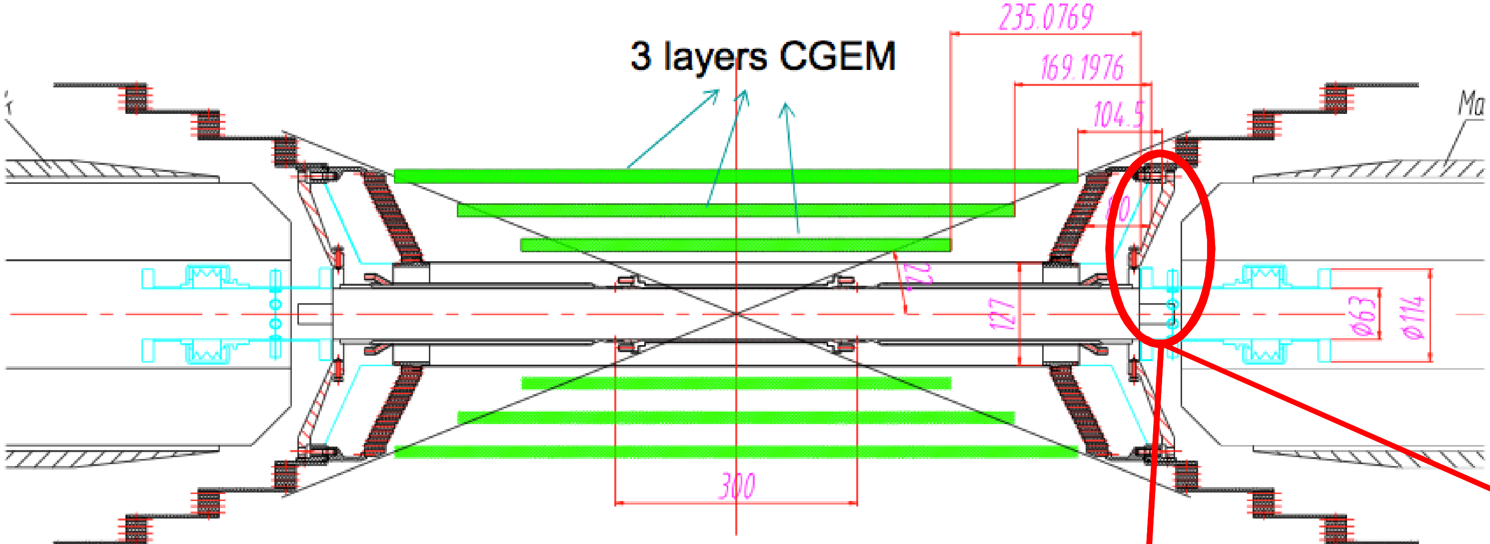
# The path toward a CGEM-IT

To go from one layer to the complete IT there's a long way to walk

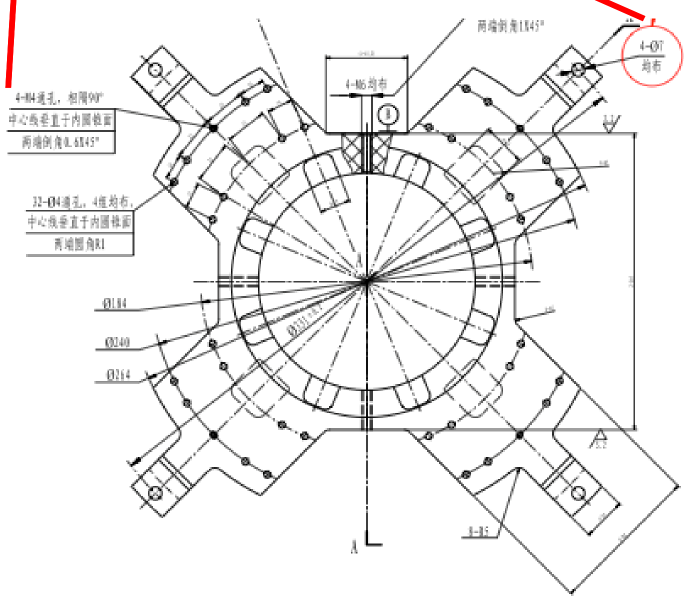
- R&D program (Jun 2013 – Jun 2014) in progres…
- First layer funded under the MAE agreement
  - design (Sep-Nov 2013) completed!
  - construction (May 2014 – Jul 2015)
- **Review of the project and CDR approval by the collaboration (June 2014)**
- Second layer
  - design (Dec 2013 – Mar 2014)
  - construction (Feb-Nov 2015)
- Third layer
  - design
  - construction (Jul 2015 – Mar 2016)
- Test and integration (Jan-May 2016)
- Ready for installation (Jan 1st 2017)

# Activities update

# Mechanical constraints

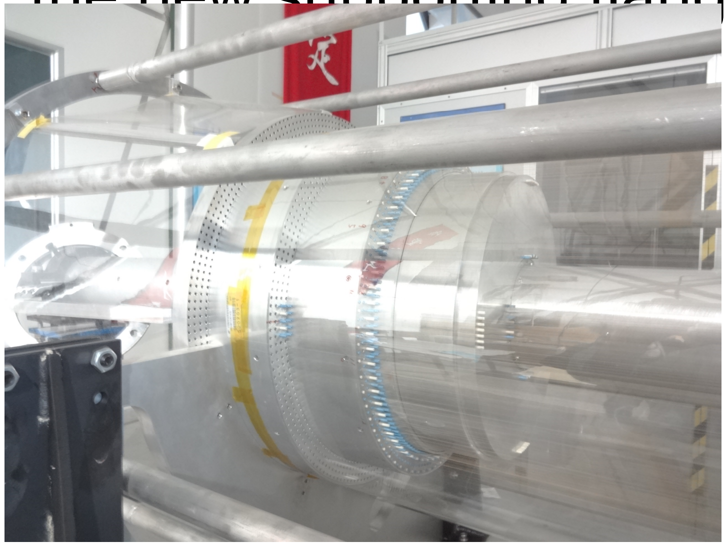



- We had meeting @ IHEP in September where we discussed many integration and installation details.
- Very limited space to play with: the beam pipe supports close most of the space in z direction.
- The outcome of the discussion drove few detector design modifications.

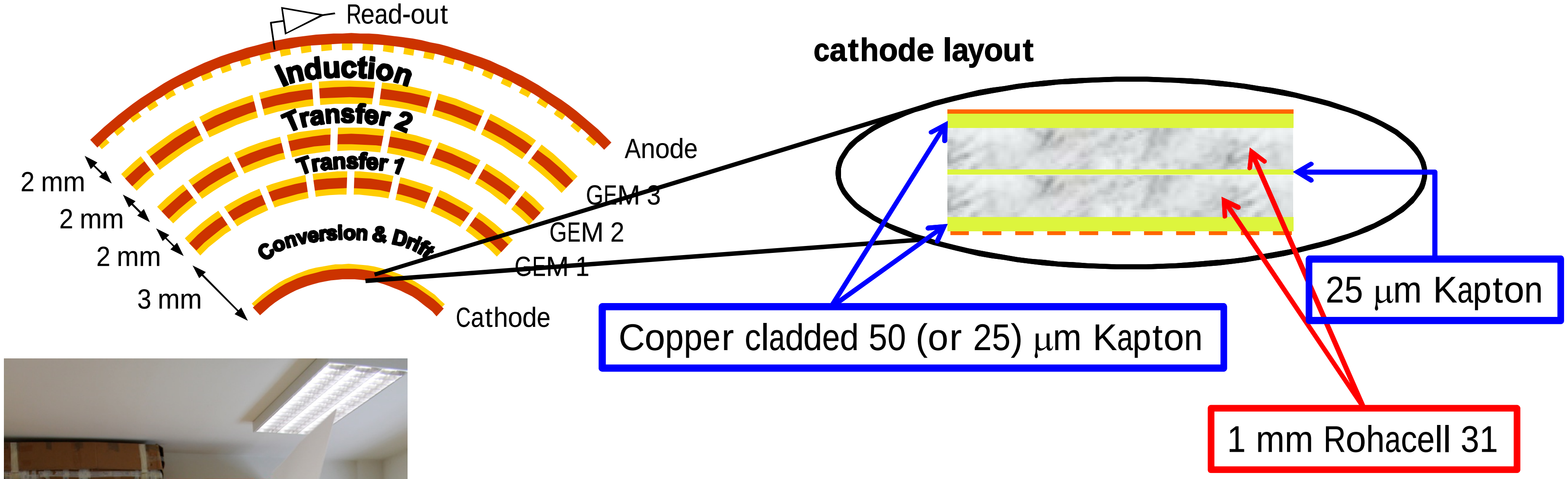


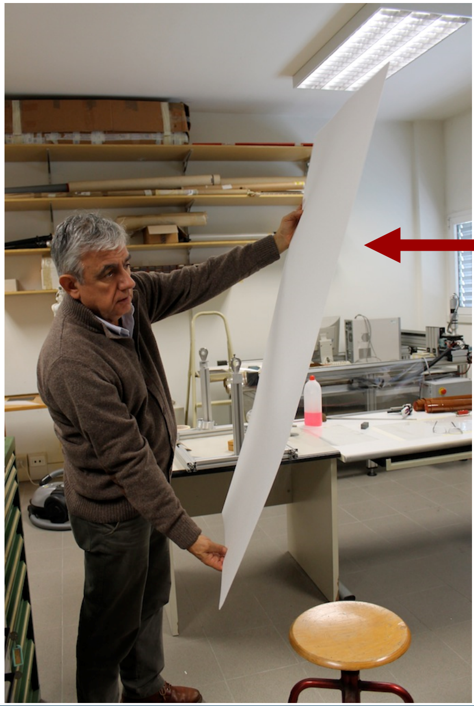
# Mechanical integration

- A carbon fiber cylinder is needed to close the outer drift chamber.
- New supporting flanges to install the CGEM-IT and the carbon fiber cylinder will be designed by Ferrara engineers.
- The drift chamber mockup @ IHEP will be used to test the new supporting flanges and the installation



# A Rohacell based cathode (and anode)



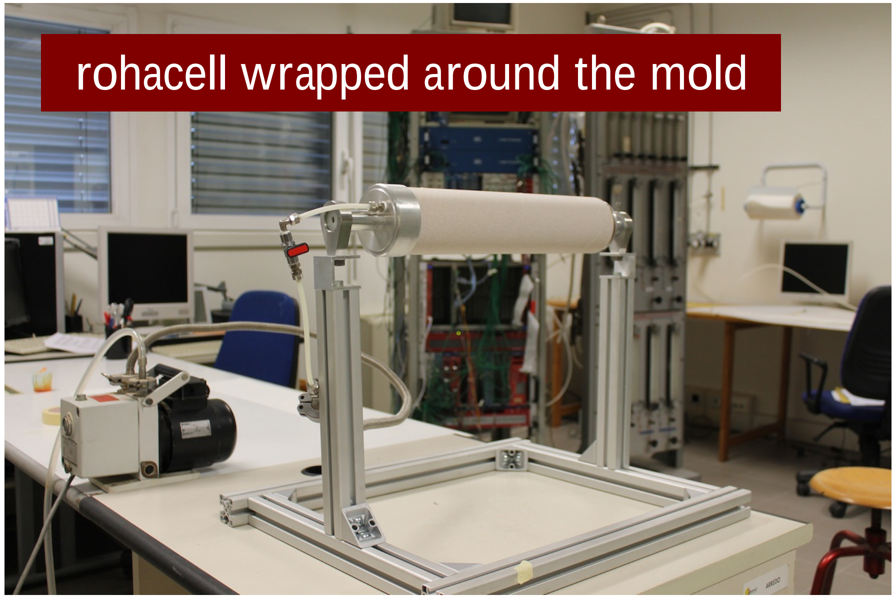



Rohacell is a very light material that will be replace the honeycomb in the cathode and anode construction with substantial reduction of the thickness of the detector

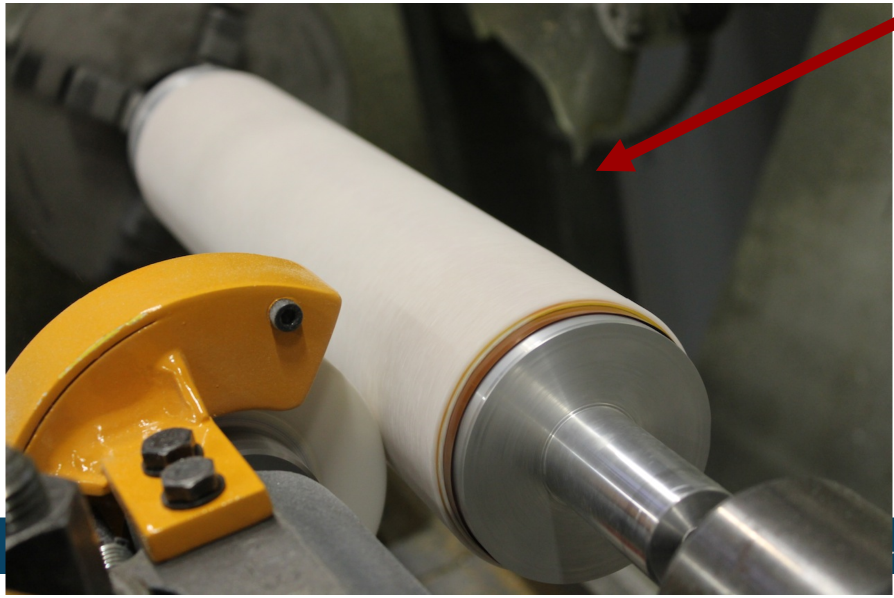
| | Rohacell | Honeycomb |
|---|---|---|
| # of $X_0$ for 1 layer | 0.24 | 0.39 |
| # of $X_0$ for 3 layers | 0.72 | 1.17 |

This technique has been successfully tested in Ferrara

# Rohacell technique tested on a fake cathode





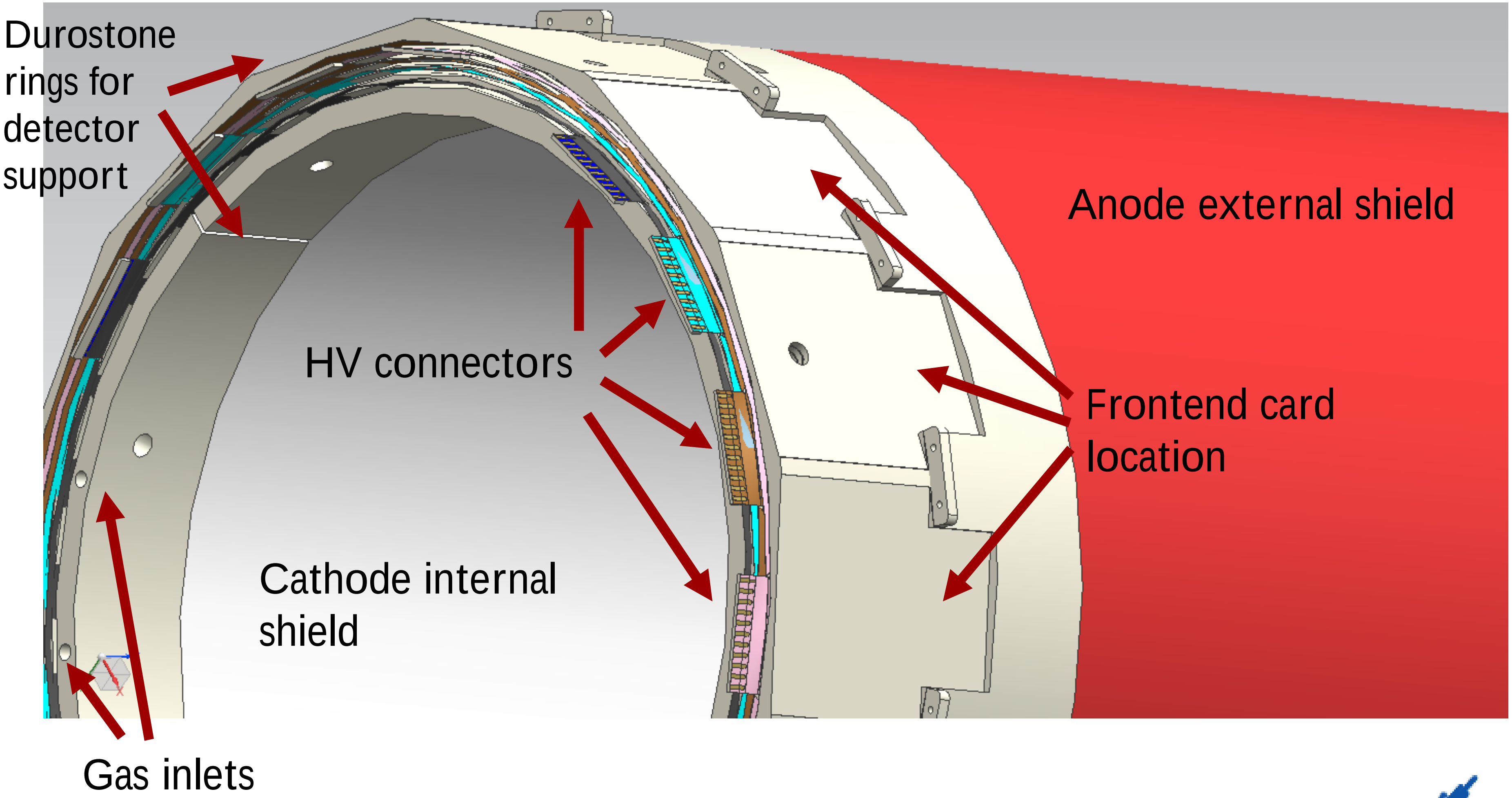


# Detector design

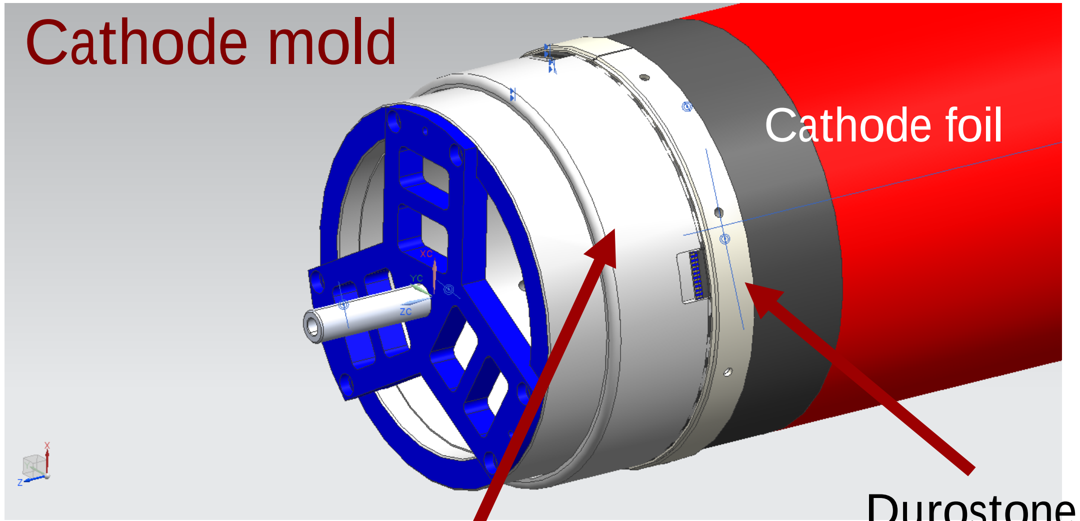
- Several months of ideas, sketches, discussions, designs, assembly simulations, drawing reviews led us very close to the completion of the first layer design (will be layer number 2, the middle one).
- The mechanics (except for the anode design) has been validated last week.
- The tooling for construction and assembly is ready to be manufactured: orders will be placed next week.
- A large area has been allocated in Ferrara for the cathode and anode production that will take place next year.
- The clean room used for Kloe CGEM detector construction in Frascati has been refurbished and adapted for the BESIII detector assembly.

# Layer 2 mechanical design

Assembly of the layer composed by a cathode, 3 GEM foils and the anode, each independently pre-assembled.



# Molds for layer 2 construction

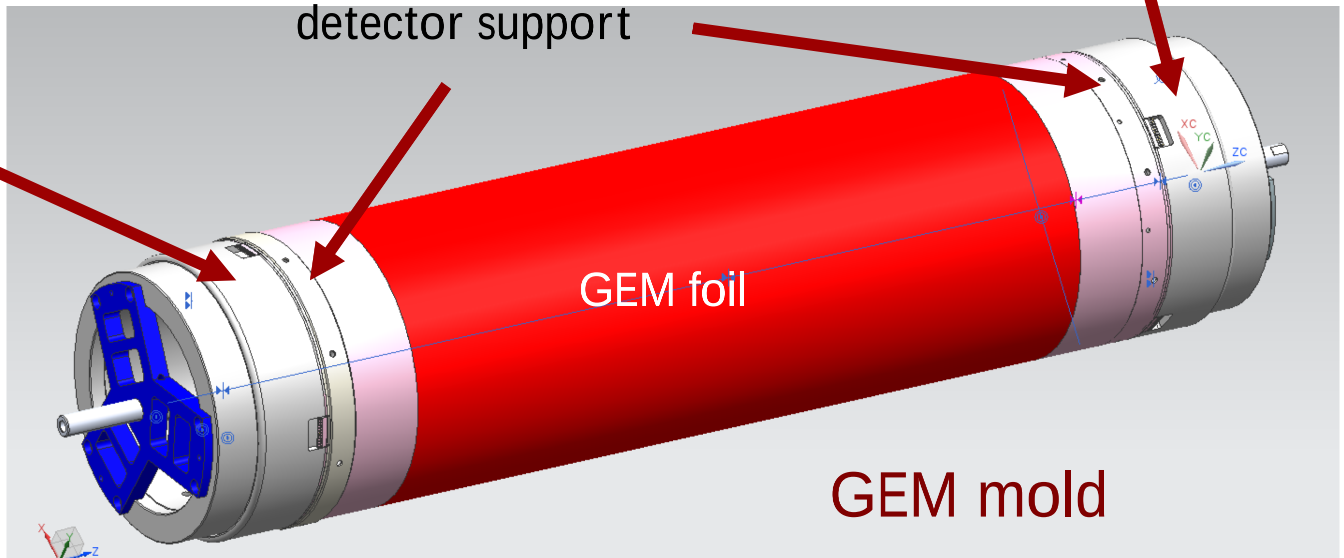



- Each of the five detector skins (cathode + 3 GEMs + anode) is pre-assembled on an aluminum mold.
- Each skin has its own mold

Aluminum ring for assembly

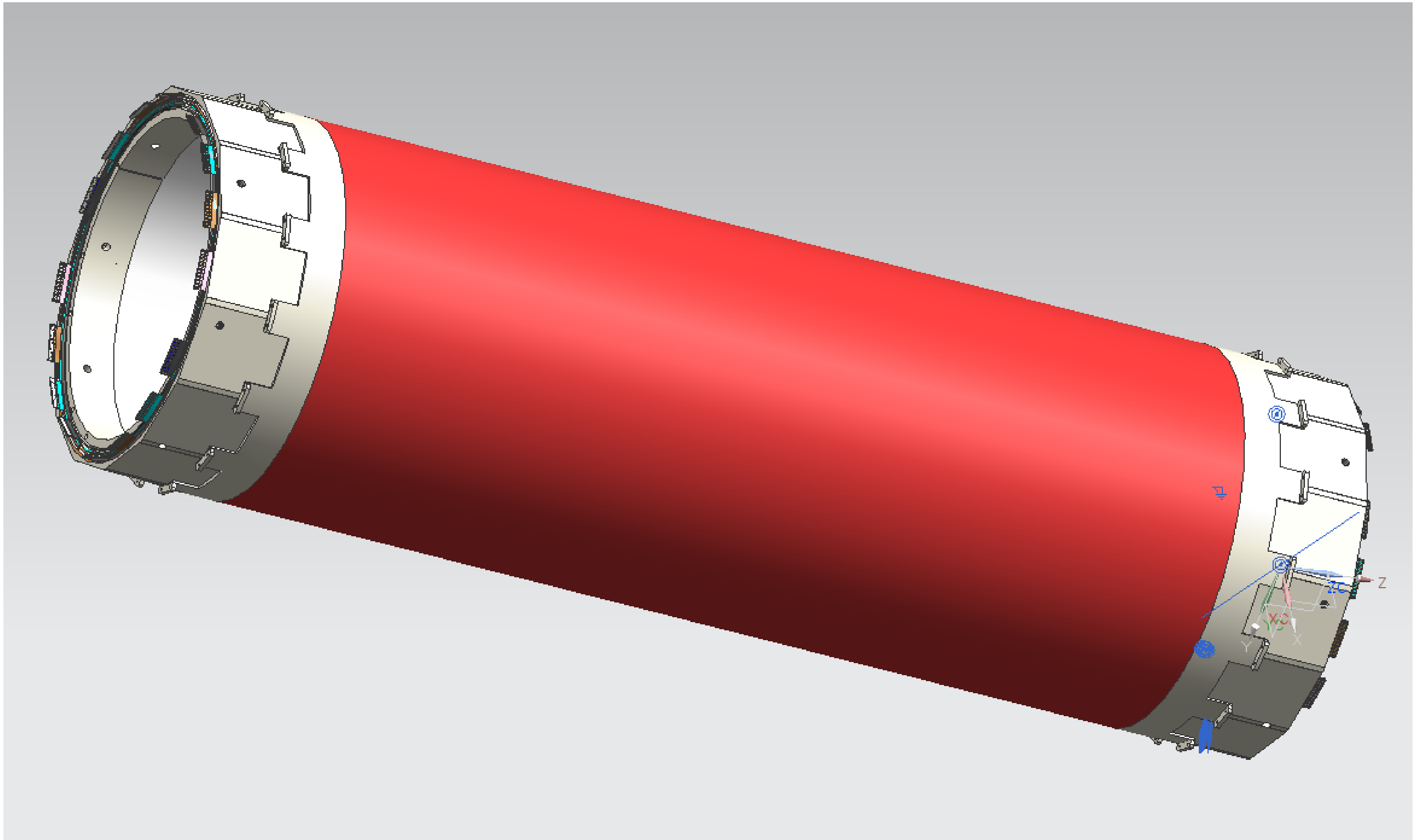
Durostone rings for detector support

Aluminum rings for correct positioning during assembly




**Molds and aluminum ring design ready!**

# How the complete layer will look like

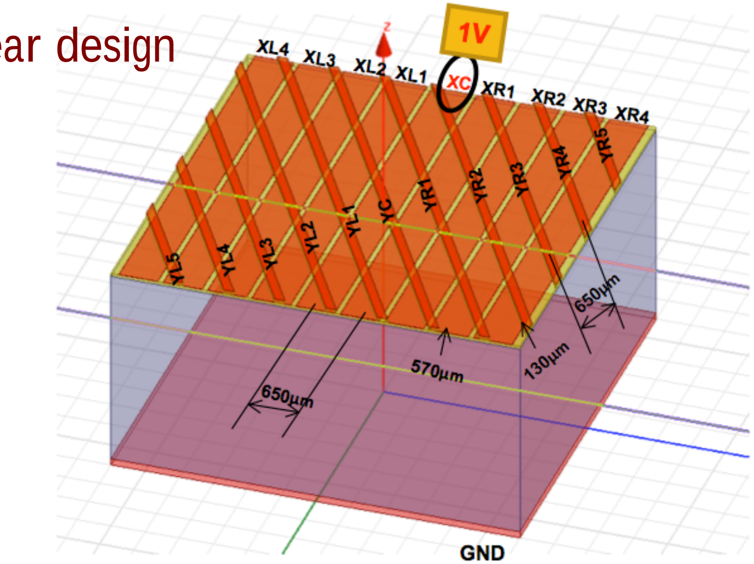


# Anode simulation

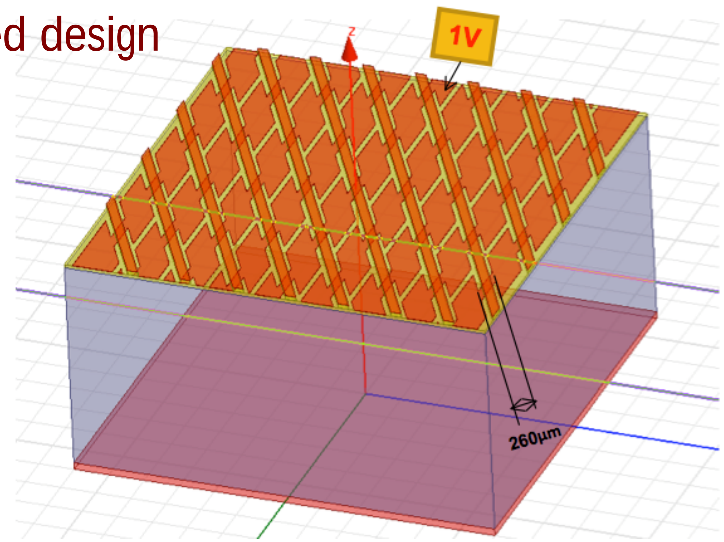
- **The simulation of readout circuit has just started in Ferrara and Frascati in order to study the coupling effects of the strips and ground planes.**

- **Two different anode design have been taken into account for**

Linear design




Jagged design

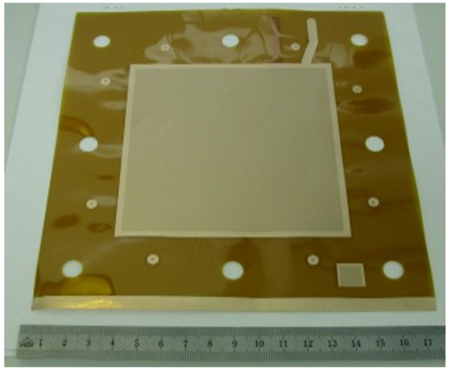



- **Preliminary results show a ~30% reduction in the coupling capacitance for the jagged design.**

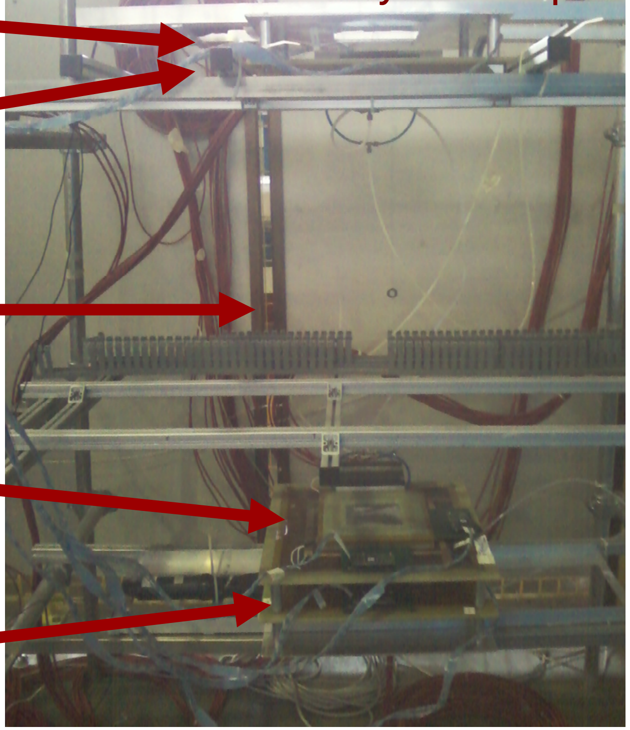
# The planar prototype

- The BESIII readout will be substantially different from the KLOE2 one:
  - it must be tested on a small scale prototype (10x10 $cm^2$ planar GEM chamber).

10x10 $cm^2$ planar GEM



Frascati cosmic ray telescope




- Cosmic telescope is in place @ LNF
- HV and gas system are ready
- Trigger system ready
- Telescope DAQ sw tested in Ferrara
- Analysis software under way
- GEM foils for test chamber purchased from CERN
- Waiting for the readout plane and electronics

# CGEM IT FrontEnd electronics

- Readout ASIC for CGEM:
  - Modify/adapt the existing TOF-PET ASIC

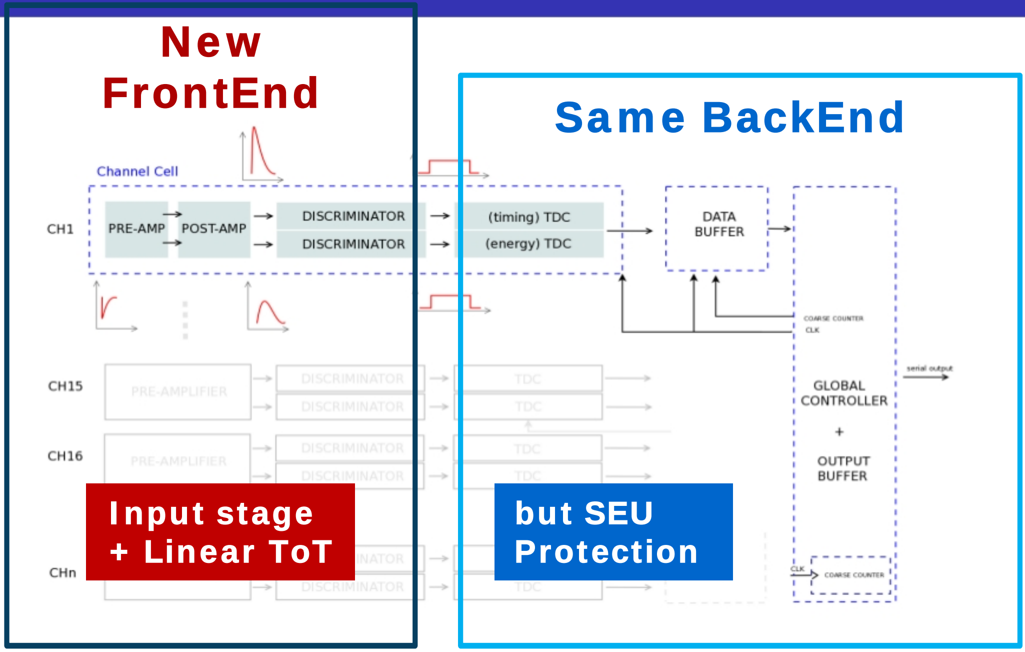
    (Rolo, Rivetti *et al.* **[INFN Turin]** http://iopscience.iop.org/1748-0221/8/02/C02050)

    in IBM 130nm for PET applications
- Re-design a **new analogue FE** (suited for CGEM signals)
- Use of the **same BackEnd** of TOF-PET
- Migration to a newer and cheaper technology:
  IBM 130nm $\rightarrow$ **UMC 110 nm**

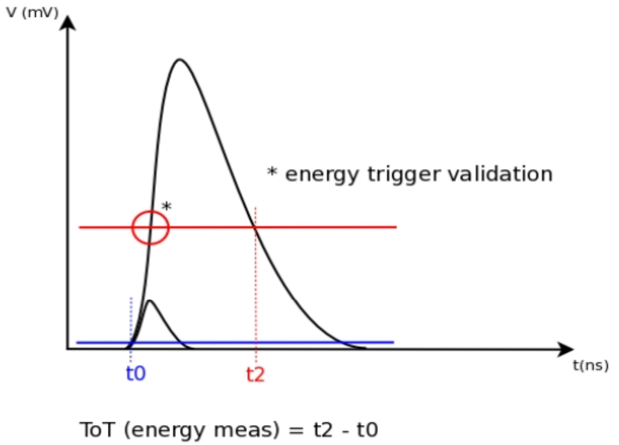
  should be exportable to China (implemented in Italy)
- Integration and development of the new ASIC for CGEM

# From TOFPET to the New CGEM ASIC

## Overview of the channel architecture




**64 Channels but New Pad geometry**




- Time and charge measurements with independent TDCs
- TDC time binning 50 ps
- Charge measured with Time-over-threshold
- Typ. power consumption is 7mW p/channel (**trigger 0.5 p.e.** w/ $SNR > 23dB$ for 9 $mm^2$ MPPC, 40 KHz event rate, 1MHz DCR)

# NEW CGEM ASIC : Basic Features

- UMC 110 nm technology

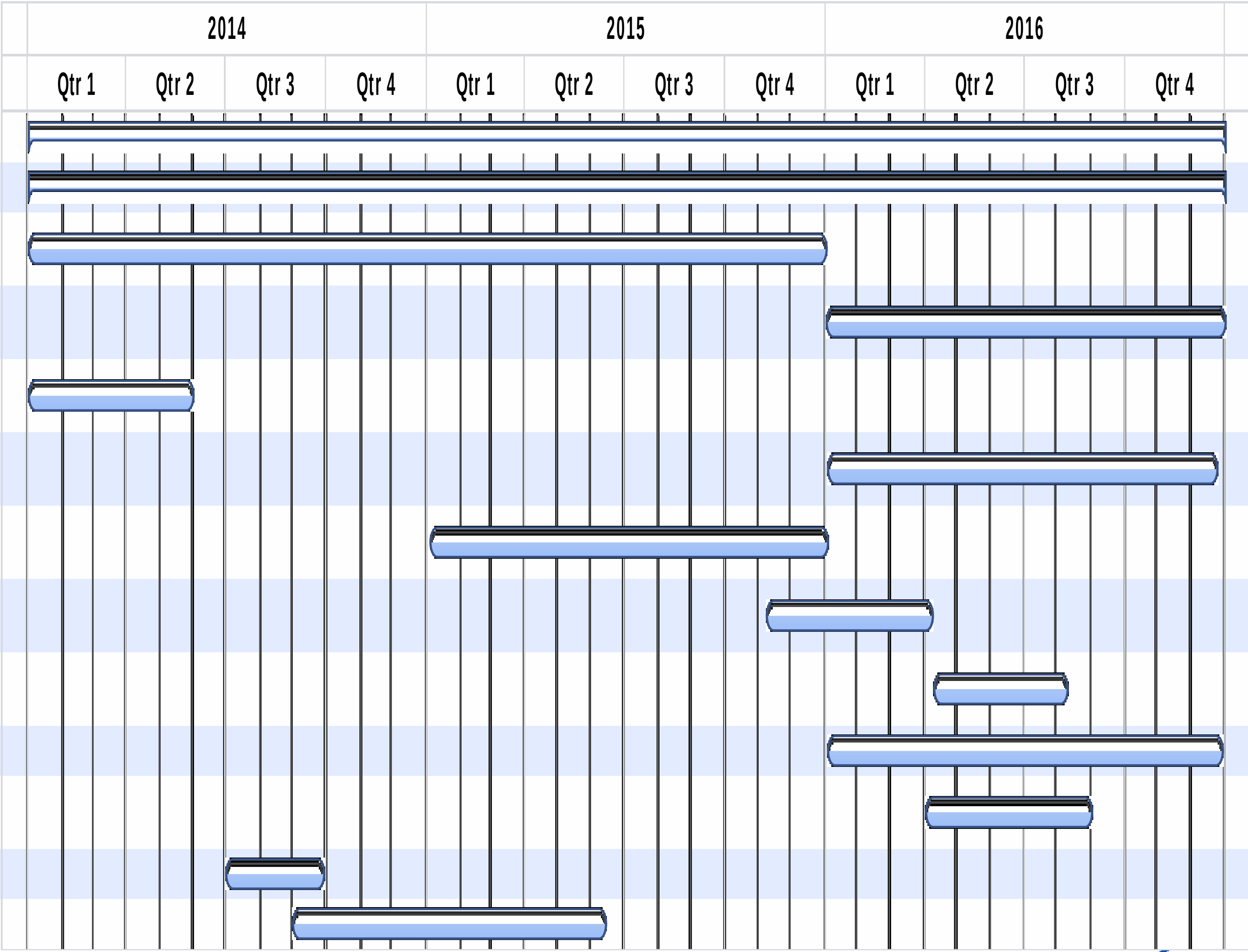
  (limited power consumption, to be tested for radiation tolerance)

  – Input charge: 3-50 fC
  – Sensor capacitance 100-150 pF
  – Input rate (single strip): 7-15 kHz
  – Time and Charge measurements by independent TDCs
  – TDC time binning > 50 ps ⇒ **CGEM needed time resolution ~ 1 ns**
  – Double threshold discrimination
  – Time over Threshold (ToT) to measure the charge ⇒ **CGEM: Linear ToT**
  – Power consumption < 7 mW p/channel ⇒ 4 mW p/channel feasible

# Budget and schedule

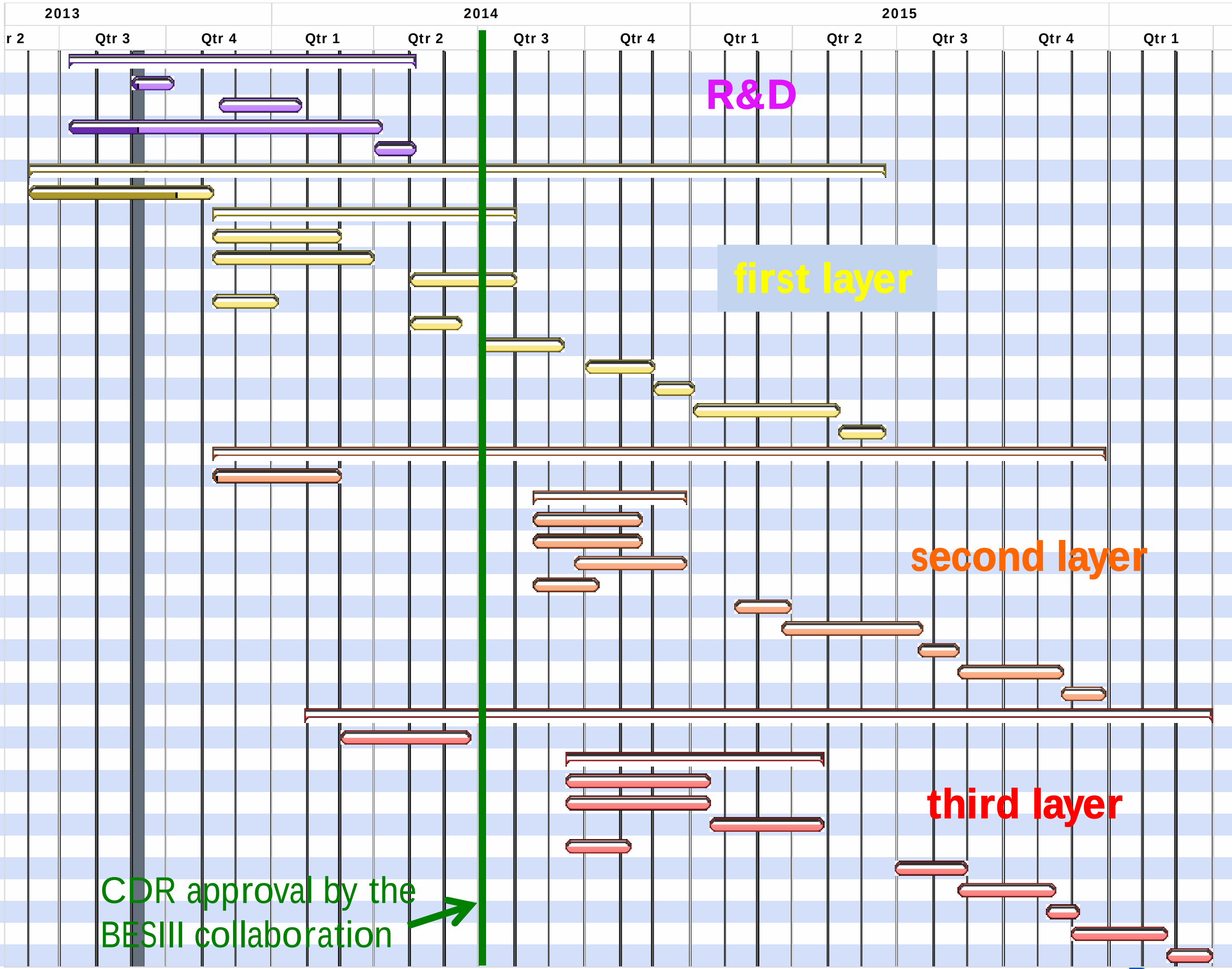
# Schedule for electronics

| Task | Effort |
|---|---|
| 1) Electronics | 2,239d |
| 1.1) ASIC | 783d |
| 1.1.1) TO - Prototypes and test | 522d |
| 1.1.2) TO - ASIC production and QA | 261d |
| 1.2) TO/LNF - on detector boards preliminary study | 108d |
| 1.3) TO - ASIC boards on detector | 255d |
| 1.4) LNF - ReadOut boards (ROBs) | 260d |
| 1.5) LNF - Transition boards (TBs) | 109d |
| 1.6) LNF - ReadOut crates (ROCs) | 87d |
| 1.7) LNF - Concentrator board | 259d |
| 1.8) LNF/FE - Preamplifier-ROB cables | 109d |
| 1.9) LNF/FE - HV system | 64d |
| 1.10) LNF/FE - HV distribution | 205d |



# Schedule for detector construction

| Task | E□ort |
|---|---|
| 1) **R&D** | 296d |
| 1.1) FE - Roahcell fake cathode | 25d |
| 1.2) FE - Assembly tests with Kloe molds | 51d |
| 1.3) FE/LNF - Anode Simulation | 195d |
| 1.4) LNF - Anode finalization and design | 25d |
| 2) **Layer I** | 672d |
| 2.1) FE - Technical design | 115d |
| 2.2) **Material procurement** | 286d |
| 2.2.1) Molds | 80d |
| 2.2.2) GEM foils | 100d |
| 2.2.3) Anode | 66d |
| 2.2.4) Other material | 40d |
| 2.3) FE - Cathode construction | 32d |
| 2.4) LNF - GEM assembly | 52d |
| 2.5) Anode assembly | 43d |
| 2.6) LNF - Assembly QA and validation | 25d |
| 2.7) LNF - Full detector assembly | 90d |
| 2.8) LNF - Detector test and QA | 29d |
| 3) **Layer II** | 563d |
| 3.1) FE - Technical design | 80d |
| 3.2) **Material procurement** | 244d |
| 3.2.1) Molds | 67d |
| 3.2.2) GEM foils | 67d |
| 3.2.3) Anode | 70d |
| 3.2.4) Other material | 40d |
| 3.3) FE - Cathode construction | 35d |
| 3.4) LNF/FE - GEM and anode assembly | 87d |
| 3.5) LNF - Assembly QA and validation | 25d |
| 3.6) LNF - Full detector assembly | 65d |
| 3.7) LNF - Detector test and QA | 27d |
| 4) **Layer III** | 583d |
| 4.1) FE - Technical design | 80d |
| 4.2) **Material procurement** | 290d |
| 4.2.1) Molds | 90d |
| 4.2.2) GEM foils | 90d |
| 4.2.3) Anode | 70d |
| 4.2.4) Other material | 40d |
| 4.3) FE - Cathode construction | 45d |
| 4.4) LNF/FE - GEM and anode assembly | 60d |
| 4.5) LNF - Assembly QA and validation | 20d |
| 4.6) LNF - Full datector assembly | 60d |
| 4.7) LNF - Detector test and QA | 28d |



# Schedule for the CDR

- During the last BESIII-Italy meeting (4 and 5 Sep. 2013) we dedicated a full session to the planning of the CDR.
- Formal approval for the CGEM based IT is needed by BESIII collaboration.
- The CDR will be reviewed during the June 2014 collaboration meeting.
- A detailed structure of the CDR has been prepared and discussed with BESIII colleagues.
- A repository has been setup at IHEP.

# Sharing the effort

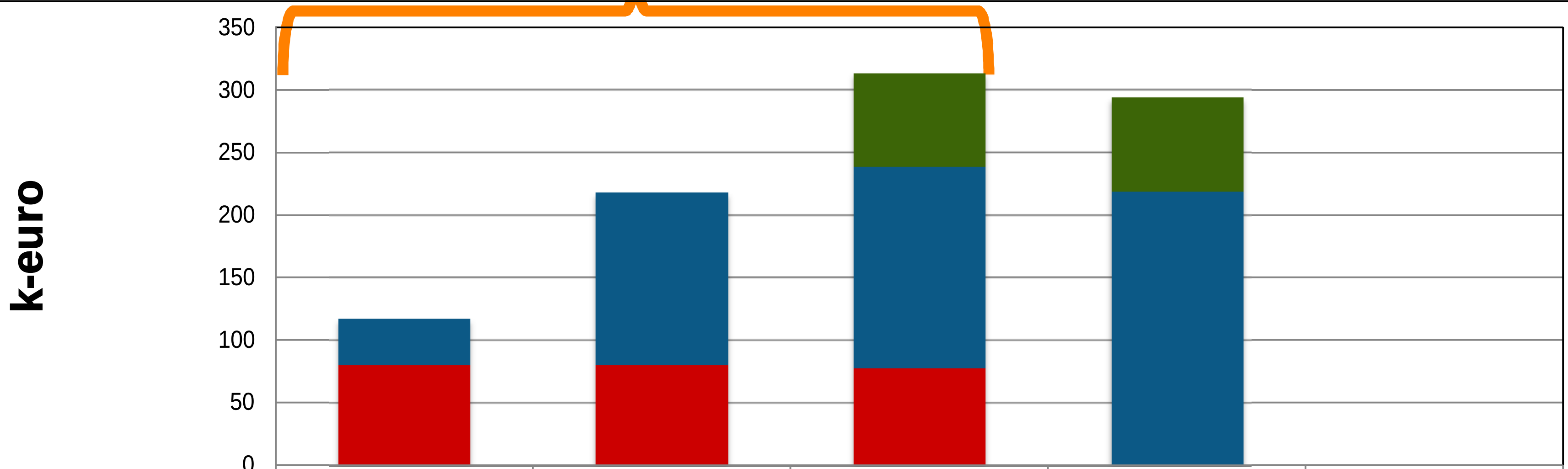
1. **Introduction**
   1. The present BESIII Inner Tracker
   2. Luminosity Issues
      1. Present and expected backgrounds
   3. Inner Tracker Upgrade Requirements
2. **Detector design**
   1. Operating principle of a triple Cylindrical GEM detector
      1. The KLOE2 Inner Tracker: know-how and first results
   2. BESIII CGEM innovations
      1. Rohacell
      2. Anode design
      3. Analog vs. digital, expectations and measurements
3. **The BESIII CGEM-IT**
   1. CGEM-IT vs DC-IT
   2. Mechanical Design
   3. Tooling and Construction
4. **Simulation of Cylindrical GEM Inner T er**
   1. Parametric Simulations (Liang)
   2. CGEM-IT full Offline Reconstruction
      1. Pattern Recognition
      2. Tracking
      3. Acceptance, Resolutions and Reconstruction Efficiencies
   3. Monte Carlo simulation results
      1. Physics Benchmark

5. **Front End Electronic**
   5. Requirements
      5. Power Consumption
   6. System Block Description
   7. On-Detector Electronics
      5. ASIC
   8. Off-Detector Electronics
6. **DAQ and Trigger**
   5. Requirements
   6. Dead time and bandwidth
   7. Possible second level trigger future upgrades
   8. Storage
7. **Integration of the CGEM-IT with the Spectrometer**
   5. Mechanical design
      5. Interfacing with beam pipe
      6. Interfacing with Outer DC
   6. Power Dissipation and Cooling
   7. Gas Systems
   8. HV Systems
   9. Slow Controls
8. **Money, manpower, schedule, subdivision…..**

# Preliminary spending profile

The full construction cost for 3 CGEM layers is about 940 kEuros (not including manpower, integration and installation). INFN has requested an external contribution of ~150 kEuros.

**+ Exec. Prog. 120 kEuros from IHEP for manpower**




| | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Outsource | 0 | 0 | 75 | 75 | 0 |
| INFN | 37 | 138 | 160.5 | 219 | 0 |
| Exec. Prog. Italy | 80 | 80 | 78 | 0 | 0 |
| Total | 117 | 217 | 333.5 | 294 | |

# Summary and outlook

- Many updates, since the last meeting, have been presented here
  – integration, fake cathode, mechanics and planar prototype
- Substantial improvements have been done in the detector design
  – The first big step toward the construction of a layer will be done next week when we'll place the order for the tooling
- We are facing a very intense 2014 with the CDR preparation, the construction of the first layer and the development of the frontend electronics.
- The schedule is very tight but we'll make it; come and join the fun!

thanks

# Preliminary spending profile

| | 2013 | 2014 | 2015 | 2016 | 2017 | Total |
|---|---|---|---|---|---|---|
| Clean room preparation | 20 | 0 | 0 | 0 | 0 | 20 |
| Planar prototype | 49 | 8 | 10 | 0 | 0 | 67 |
| Layer 1 | 38 | 68 | | 0 | 0 | 106 |
| Layer 2 | 0 | 48 | 20 | 0 | 0 | 68 |
| Layer 3 | 0 | 21 | 47 | 0 | 0 | 68 |
| Off-det electronics | 0 | 0 | 146 | 0 | 0 | 146 |
| On-det electronics | 0 | 0 | 43 | 28 | 0 | 71 |
| ASIC | 0 | 45 | 0 | 236 | 0 | 281 |
| Integration | 0 | 0 | 0 | 30 | 0 | 30 |
| **Total** | 107 | 190 | 266 | 294 | 0 | 857 |