CGEM-IT project update

Gianluigi Cibinetto
(INFN Ferrara)
on behalf of the CGEM group
Outline

• Introduction
• Mechanical development
• Anode readout design
• Electronics
• Software upgrade
• Group composition, CDR, budget and schedule
requirements:
- Rate capability: $\sim 10^4 \text{ Hz/cm}^2$
- Spatial resolution: $\sigma_{xy} = \sim 100\mu m$
- $\sigma_z = \sim 1\text{ mm}$
- Momentum resolution: $\sigma_{pt}/P_t = \sim 0.5\%$
- Efficiency = $\sim 98\%$
- Material budget $\leq 1.5\%$ all layers
- Coverage: 93% $4\pi$
- Operation duration $\sim 5$ years

The GEM concept

A cylindrical triple GEM

Three layers of CGEM for BESIII
CGEM expected performance

From GEANT4 simulation

CGEM inner detector (wrt MDC inner detector)

➤ 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

These simulation results need to be updated with a more detailed description of the detector and of the digitization and reconstruction process. Work performed by IHEP group.

<table>
<thead>
<tr>
<th>Readout</th>
<th>$\sigma_{rf}$ (µm)</th>
<th>$\sigma_z$ (µm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digital readout (Beam test @2009)</td>
<td>330</td>
<td>400</td>
</tr>
<tr>
<td>Analog readout (magnetic field effect avoided)*</td>
<td>80</td>
<td>150</td>
</tr>
</tbody>
</table>

* 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!

<table>
<thead>
<tr>
<th></th>
<th>1st year</th>
<th>40000 €</th>
<th>33.3%</th>
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<tbody>
<tr>
<td>INFN 1st year</td>
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<tr>
<td>Italian Ministry of FA</td>
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<td>33.3%</td>
<td></td>
</tr>
<tr>
<td>Foreign institution</td>
<td>40000 €</td>
<td>33.3%</td>
<td></td>
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<tr>
<td>More funds</td>
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<td></td>
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<tr>
<td><strong>1st year project cost</strong></td>
<td>120000 €</td>
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Status of the project

- 2013 budget: exhausted
- report to MAE concerning 1st year activities: completed
- March-April 2014: MAE approval of report, and reimbursement to INFN (40 kEuros)
- April-June: expect 2014 budget available
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 progress…

• First layer funded under the MAE agreement
  – design (Sep-Nov 2013) completed!
  – construction (May 2014 – Jul 2015) starting soon!

• Review of the CDR by the BESIII collaboration for the final approval of the project (June 2014)

• Second layer
  – design construction (Feb-Nov 2015)

• Third layer
  – design construction (Jul 2015 – Mar 2016)

• Test and integration (Jan-May 2016)

• Ready for installation (Jan 1st 2017)
Each detector layer is composed by five cylindrical elements:
- one cathode (conversion/drift)
- three GEM (amplification)
- one anode (signal collection)

To assemble each element then many other components are needed:
- aluminum molds
- fiberglass supporting rings
- cathode, GEM or anode foils
- plus small parts, connectors, etc…

Even small modifications to one element can have fallout on the overall design.
Molds for layer 2 construction (solid model)

• Each of the five detector parts (cathode + 3 GEMs + anode) is pre-assembled on an aluminum mold.

- Cathode mold
- Cathode foil
- GEM mold
- GEM foil
- Aluminum rings for correct positioning during assembly
- Aluminum ring for assembly
- Durostone rings for detector support
- GEM foil
Executive drawings have been prepared, validated and given to the mechanical factory for the production.

Molds will be ready by May for the beginning of the construction.

A huge amount of work have been done in the last few months in order to prepare and validate all the cathode and GEM mechanical parts and the assembly procedure.
Schedule for the first layer construction
Detector construction

The detector will be constructed in two places:

- **INFN Ferrara**: cathode and anode construction
- **INFN Frascati**: GEM and full detector assembly in the clean room

**construction area @ INFN Ferrara**

**assembly tooling in the LNF clean room**
Due to diffusion the charge cloud collected on the readout plane is bigger than the strip width and a weighting method is used to improve the track position measurement.  

We go for a Compass-like anode.  

For technical reasons the CERN group is no longer providing a KLOE-like readout plane.  

Due to diffusion the charge cloud collected on the readout plane is bigger than the strip width and a weighting method is used to improve the track position measurement.  

analog readout
Readout plane main issues

• Mechanically, the anode plane is not easy to design

1. About 3 mm will be the distance between the readout plane and the ground plane
   – need to assemble ourselves the readout and ground planes in a robust structure.
   – need to merge the ground and the signals in a single connector.

2. Lack of space in z direction

• In addition the BESIII anode will be substantially different from the one used in KLOE2 or Compass
   – Charge sharing, capacitive couplings and geometry have to be studied and optimized before taking the final decision.
   – Simulation and tests with a small planar prototype will lead to the final design.
Planar prototype

• Cosmic telescope is in place @ LNF.
• The test chamber has been built.
• Gas flowing in the telescope and test chambers. Interlock system to be implemented.
• High voltage system operational.
• Readout for the telescope ready.
• Amplifiers and readout for the test chamber to be completed
Maxwell simulation of the anode plane to extract coupling capacitance and to study different strip configurations.

The GEM simulation is used to calculate the electric field used by Garfield for the charge sharing studies.

Simulation results must be tuned with the planar prototype data.
Frontend Electronics kickoff meeting

- The analog readout will be performed by an ASIC chip designed by INFN Turin adapting an existing chip (new fronted, same backend)

- We had a sort of “kickoff meeting” in Turin one week ago to start this activity.

  - basic requirements and features of the ASIC chip that will be used for the readout
  - overall dimension and concept of the PCB that will host the chip.
  - manpower and time schedule

Another meeting today in Frascati to start the work on OFF detector electronics.
ASIC chip main features and requirements

- **UMC 110 nm technology** (limited power consumption, to be tested for radiation tolerance)
- **Input charge**: 0.5-60 fC
- **Sensor capacitance**: ~100 pF
- **Input rate** (single strip): 3 kHz x 5 (safety factor)
- **Time and Charge measurements** by independent TDCs
- **Time resolution**: 1 ns r.m.s.
- **Double threshold discrimination.**
- **Time over Threshold (ToT)** to measure the charge
- **Maximum power consumption**: 5-10 mW p/channel
Software upgrade at IHEP

- New CGEM layout has been added to the BESIII GEANT4 model.

- Reconstruction and tracking algorithm are under development.

- Digitization of the event is very preliminary and will be finalized with the studies of the planar prototype.

- Strong interaction between Italian and IHEP groups to complete the upgrade.
The CGEM group

• Together with INFN (Ferrara, Frascati and Turin) and IHEP, now Mainz and Uppsala are officially part of the project.

• Main responsibilities of the different institutions are:

  – **INFN**: design and construction of the detector and electronics
  – **IHEP**: gas system, slow control and all the software developments needed to readout and integrate the detector into the DAQ
  – **Mainz**: high voltage system and participation to the ASIC foundry cost.
  – **Uppsala**: data concentrator
CDR preparation

1. **Introduction**
   1. The present BESIII Inner Tracker
   2. Luminosity Issues
   3. Inner Tracker Upgrade Requirements

2. **Detector design**
   1. Operating principle of a triple Cylindrical GEM detector
   2. BESIII CGEM innovations
   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 Tracker**
   1. Parametric Simulations (Liang)
   2. CGEM-IT full Offline Reconstruction
   3. Monte Carlo simulation results

5. **Front End Electronics**
   1. Requirements
   2. Power Consumption
   3. System Block Description
   4. On-Detector Electronics
   5. ASIC
   6. Off-Detector Electronics

6. **DAQ and Trigger**
   1. Requirements
   2. Dead time and bandwidth
   3. Possible second level trigger future upgrades
   4. Storage

7. **Integration of the CGEM-IT with the Spectrometer**
   1. Mechanical design
   2. Interfacing with beam pipe
   3. Interfacing with Outer DC
   4. Power Dissipation and Cooling
   5. Gas Systems
   6. HV Systems
   7. Slow Controls

8. **Money, manpower, schedule, task subdivision….”**
• A CVS repository has been setup by Marco Destefanis on lxslc5 machines at IHEP.
• The document tree is in place and ready to be filled.

A presentation with instructions for editors will be sent out by hypernews shortly.
• Aiming to have a first draft by May.
The full construction cost for 3 CGEM layers is about $990\,\text{k\euro}$ (not including manpower, integration and installation). INFN has requested an external contribution of $\sim200\,\text{k\euro}$.

+ Exec. Prog. 120 k\euros from IHEP for manpower

<table>
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<th>Year</th>
<th>Outsource</th>
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</table>

Other Part: IHEP+Mainz+Uppsala (184\,\text{k\euro}), missing 16\,\text{k\euro} – Cost for mold increased by 50\,\text{k\euro}
Summary and outlook

• The status and the advancements in the mechanical design, simulation, R&D, electronics have been presented.

• The project is facing two important turning points:
  – the Conceptual Design Report review
  – the beginning of the construction of the first layer

• New groups joined the enterprise, and the budget is almost totally covered.
Thanks
G. Cibinetto  
BESIII Physics and Software Workshop Beihang University – February 20-23, 2014
A tentative anode mechanical configuration

- Readout and ground plane are connected at the edge of the chamber.
- The readout board could be placed radially between layers.

Readout and ground plane are connected at the edge of the chamber. The readout board could be placed radially between layers.

ground plane
Frontend board
cooling
rohacell cylindrical structure
Anode fiberglass ring
GEM 3 foil
HV connector
signal path
signal connector
output connector

not in scale