Short Status Report

CGEM project

Collaboration Meeting (Beijing)

June 4-7th, 2013
Outline

- CGEM simulation at BESIII
- Space available for CGEM installation
- CGEM prototype project
- Roadmap toward a CGEM-based IT
- Collaboration activities from IHEP side (proposal)
- Next step for INFN – IHEP both sides (proposal)
CGEM simulation at BESIII

Dong Mingyi, Wang Liangliang, Xiu Qinglei
Yellow: Honeycomb Support (Nomex)
Blue: Cathode (Cu, Kapton)
White: Work Gas of Gem (Ar:CO$_2$=70:30)
Green: Gem Foil (Cu, Kapton)
Red: Readout Anode (Cu, Kapton, Al Shielding)
Grey: Carbon Fiber Support
Detail Structure of CGEM Layer

Single Mask Gem Foil, Single conical hole structure
Hole diameter: 70-60 um
The larger section of the holes facing the cathode.
Hole Pitch: 140um
Preliminary reconstruction with CGEM inner detector

- CGEM fired strips
- Cluster reconstruction
- CGEM true hits
- Smearing
- CGEM hits
- Outer MDC hits
- MDC tracking
- Track in outer MDC
- Kalman track fitter
- Kalman track with CGEM

Quick test with different spatial resolutions
Expected spatial resolution

BESIII B-Field $\sigma_{r\phi} = 330 \, \mu m$

BESIII B-Field $\sigma_z = 400 \, \mu m$

**Readout**

<table>
<thead>
<tr>
<th>Readout</th>
<th>$\sigma_{r\phi} (\mu m)$</th>
<th>$\sigma_z (\mu m)$</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
Momentum resolution

<table>
<thead>
<tr>
<th>$P_{\text{tot}}$ (GeV/c)</th>
<th>0.2</th>
<th>0.6</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_p$ (MDC) (MeV)</td>
<td><strong>0.89</strong> (+2.2%)</td>
<td><strong>2.53</strong> (-0.4%)</td>
<td><strong>5.59</strong> (-4.5%)</td>
</tr>
<tr>
<td>$\sigma_p$ (CGEM 4 layers, type I)</td>
<td><strong>0.91</strong> (+0%)</td>
<td><strong>2.52</strong> (-3.9%)</td>
<td><strong>5.40</strong> (-3.4%)</td>
</tr>
<tr>
<td>$\sigma_p$ (CGEM 3 layers, type I)</td>
<td><strong>0.89</strong> (+0%)</td>
<td><strong>2.43</strong> (-0.8%)</td>
<td><strong>5.30</strong> (-5.2%)</td>
</tr>
<tr>
<td>$\sigma_p$ (CGEM 3 layers, type II)</td>
<td><strong>0.89</strong> (+0%)</td>
<td><strong>2.51</strong> (-0.8%)</td>
<td><strong>5.30</strong> (-5.2%)</td>
</tr>
</tbody>
</table>

Type I and II refer to different layer configurations (cathode/anode reversed)
Vertex resolution in $r$

$$P_{\text{tot}} (\text{GeV/c})$$

<table>
<thead>
<tr>
<th></th>
<th>0.2</th>
<th>0.6</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_r (\text{MDC}) \ (\mu\text{m})$</td>
<td>622 (100%)</td>
<td>215 (100%)</td>
<td>168 (100%)</td>
</tr>
<tr>
<td>$\sigma_r ($CGEM 4 layers, type I$) $</td>
<td>652 (+4.8%)</td>
<td>230 (+7.0%)</td>
<td>169 (+0.6%)</td>
</tr>
<tr>
<td>$\sigma_r ($CGEM 3 layers, type I$) $</td>
<td>650 (+4.5%)</td>
<td>224 (+4.2%)</td>
<td>170 (+1.2%)</td>
</tr>
<tr>
<td>$\sigma_r ($CGEM 3 layers, type II$) $</td>
<td>664 (+6.7%)</td>
<td>228 (+6.0%)</td>
<td>166 (-1.2%)</td>
</tr>
</tbody>
</table>
Vertex resolution in z

<table>
<thead>
<tr>
<th>$p_{\text{tot}}$ (GeV/c)</th>
<th>0.2</th>
<th>0.6</th>
<th>1.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\sigma_z$(MDC) (μm)</td>
<td>2020 (100%)</td>
<td>1531 (100%)</td>
<td>1539 (100%)</td>
</tr>
<tr>
<td>$\sigma_z$(CGEM 4 layers, type I)</td>
<td>772 (-61.8%)</td>
<td>336 (-78.1%)</td>
<td>266 (-82.7%)</td>
</tr>
<tr>
<td>$\sigma_z$(CGEM 3 layers, type I)</td>
<td>757 (-62.5%)</td>
<td>319 (-79.2%)</td>
<td>263 (-82.9%)</td>
</tr>
<tr>
<td>$\sigma_z$(CGEM 3 layers, type II)</td>
<td>742 (-63.3%)</td>
<td>327 (-78.6%)</td>
<td>270 (-82.5%)</td>
</tr>
</tbody>
</table>
Conclusion

CGEM inner detector (VS 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)
Space available for CGEM installation

Mingyi Dong
Mechanical structure of inner MDC

- Inner drift chamber is fixed on the first step ring of MDC through two flanges.
Parts of inner sense wires in z direction are out of the effective solid angle ($\cos \theta = 0.93$)

- Also available space when we consider CGEM installation
Suppose 3 layers CGEM

<table>
<thead>
<tr>
<th>Component</th>
<th>L1(Rin/Rout)</th>
<th>L2(Rin/Rout)</th>
<th>L3(Rin/Rout)</th>
<th>Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cathode</td>
<td>78.0/81.0</td>
<td>120.5/123.5</td>
<td>163.0/166.0</td>
<td>3 mm Honeycomb</td>
</tr>
<tr>
<td>Conversion + drift</td>
<td>81.0/84.0</td>
<td>123.5/126.5</td>
<td>166.0/169.0</td>
<td>3 mm gas</td>
</tr>
<tr>
<td>Transfer 1</td>
<td>84.0/86.0</td>
<td>126.5/128.5</td>
<td>169.0/171.0</td>
<td>2 mm gas</td>
</tr>
<tr>
<td>Transfer 2</td>
<td>86.0/88.0</td>
<td>128.5/130.5</td>
<td>171.0/173.0</td>
<td>2 mm gas</td>
</tr>
<tr>
<td>Induction</td>
<td>88.0/90.0</td>
<td>130.5/132.5</td>
<td>173.0/175.0</td>
<td>2 mm gas</td>
</tr>
<tr>
<td>Readout</td>
<td>90.0</td>
<td>132.5</td>
<td>175.0</td>
<td></td>
</tr>
<tr>
<td>Outer shield</td>
<td>90.0/93.0</td>
<td>132.5/135.5</td>
<td>175.0/178.0</td>
<td>3 mm Honeycomb</td>
</tr>
</tbody>
</table>

- L1 length: 532mm , L2 length: 690mm
- L3 length: 847mm
The gap is about 80mm~100mm between the end plate of MDC inner chamber and the mechanical support of beam pipe.

105mm~235mm in z direction is available for the support structure, readout electronics, cables of CGEM on each side.
Summary

- Space available for CGEM in $r$ direction is about 63 (78?) mm $\sim$ 183.5mm

- If the length of CGEM matches the MDC effective solid angle ($\cos \theta = 0.93$), space available for CGEM in $z$ direction is about 105mm $\sim$ 235mm on each side
CGEM prototype project
June 2012: BESIII-Italy was invited by INFN management to apply for MAE(*) money in a program for Chinese-Italian scientific cooperation

- BESIII-Italy prepared 2 projects:
  - BESIII-To: “mobility of researchers” (physics analysis)
  - BESIII-LNF: “great relevance” (construction of one layer of cylindrical GEMs with analogic readout)

- Both projects have a BESIII-Chinese counterpart, submitted by BESIII-China to Chinese authorities

April 2013: projects approved by MAE for funding

(*) Italian Ministry for Foreign Affairs
The LNF project is for a total amount of 360 k€ divided over a period of 3 years.

Every year MAE, INFN and IHEP contribute a budget of 40 k€ each

MAE contribution for year “N” must be advanced by INFN in “N”, and refunded by MAE in “N+1”

2013: INFN will deliver in June the first 40 k€ of the 80 k€ expected (additional 40 k€ are expected later)

These successes have motivated additional researchers from LNF and Torino and another INFN Institution, Ferrara, to apply for participation in BESIII. Good news! 😊
New anode design

KLOE2 IT – Readout Plane (no more available)

Readout plane is realized at CERN’s PEL-EM
It is a kapton/copper multilayer flexible circuit
Provides 2-dimensional readout with X strips on the same plane
- X are realized as longitudinal segments of conductive holes and a common backplane
- Pitch is 650 μm for both

[Diagram showing X strip, V strip, and configuration details]
COMPASS-type solution: new readout electrodes

- Due to diffusion the charge cloud collected on the readout board is bigger than the strip width (≈ 3.5 x pitch) and a weighting method is used for calculate the exact track position in two dimensions.

- Every single strip versus the other readout coordinate acts as a plate capacitor. With the permittivity \( \varepsilon = 3.9 \) of Kapton and an area of \( 2.27 \cdot 10^{-1} \text{cm}^2 \), **this capacitance is 15.7 pF**.
Prototype roadmap to 2015

- **2013**
  - Cosmic ray setup: construction
  - Clean room preparation
  - Cylindrical prototype: design and tool construction

- **2014**
  - Cosmic ray setup: run and analysis
  - Cylindrical prototype: construction and assembly

- **2015**
  - Cylindrical prototype: test (cosmic rays and beam)
A cosmic test setup (LNF-FE)

- The COMPASS-type readout layer is substantially different from the KLOE2 one
- It must be tested, before employ in a full-scale cylindrical prototype
- KLOE2 can give us a cosmic-ray telescope (3 complete and working planar GEM chambers of KLOE2 type)
- To these we will add a small (10x10 cm$^2$) planar chamber with GEMs, and a COMPASS-type readout layer
- Buy planar GEM chamber kit from CERN
- Prepare support for readout layer
- Design and order COMPASS-type small readout layer
- Procure GASTONE, TOFPET analogic chips, etc.
- Buy boards for DAQ (ADCs or digitizers)
- Start taking cosmic data, beam if possible
- Small rate if few channels: will take time
CGEM Prototype

- Start simulations with Garfield and Maxwell (LNF-FE)
- Test COMPASS-type readout plane with GASTONE analog chips (LNF-FE) and TOFPET using an amplifier
  - GASTONE analog chips can’t be used in BESIII
- Start preliminary operations for construction of cylindrical prototype (LNF-FE)
- Develop DAQ for small test chamber (FE)
- Develop offline for small test chamber (LNF-FE)
- Test rohacell-based technique for cathode construction for the innermost layer and start a mockup CGEM (FE)
Mechanics (FE-LNF-IHEP)

- Refurbish clean room, repair toolings etc
- Evaluate KLOE2 machine for inserting cylindrical layers (BESIII layers may be longer)
- Examine possibility to use KLOE2 molds for BESIII middle layer. Modify or rebuild if necessary!
- IHEP experienced manpower is strongly needed
- Start drawings for COMPASS-type readout layer
Electronics, DAQ, Offline, HV, gas system

- Start ASIC development for BESIII (TO-LNF)
- Design off-detector electronics (LNF)
- Start studying impact on BESIII DAQ and L1 trigger (IHEP)
- Monte Carlo and Offline Reconstruction (IHEP, LNF, FE, TO)
- Plan additions to HV, Gas systems, Slow Controls (IHEP)
IT FrontEnd electronics Plan (TO)

- Readout ASIC for CGEM:
  - Modify/adapt the existing TOFPET ASIC
    (Rolo, Rivetti et al. [http://iopscience.iop.org/1748-0221/8/02/C02050](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 TOFPET

- Migration to a newer and cheaper technology:
  IBM 130nm → **UMC 110 nm**
  should be exportable in China (implemented in Italy)

- Integration and Development of such a Custom ASIC for CGEM
Man Power is a critical Issue:

- VLSI Lab at INFN-TO, led by A. Rivetti, has expertise on HEP applications

- **Required** Man Power to work at VLSI Lab in Torino:
  - 3y*1FTE (PhD with electronics background) for testing/test bed
  - **AND**
  - 2y*1FTE (experienced engineer in electronics) for chip development
 ASIC Basic features:

- UMC 110 nm technology (limited power consumption, to be tested for radiation tolerance)
- Time and Charge measurements by independent TDCs
- TDC 50ps time binning
- Double threshold discrimination
- Time over Threshold (ToT) to measure the charge
- Power consumption ~ 7 mW p/channel
FE and Off-Detector Electronics roadmap

- **2013**
  - Planar GEM telescope instrumentation (signal & HV)
  - Readout electrodes simulation (parasitic minimization study)
  - TofPet asic (IT readout candidate) validation

- **2014**
  - IT prototype anode readout plane design (early 2014)
  - IT HV distribution and signal pick-up engineering (front-end integration)
  - Design of a new version of TofPet asic (different input stage to increase signal sensitivity and SNR) - 2 foundry submission foreseen
  - Off Detector Electronic design (end 2014)
    - Readout boards and Concentrators
    - HV distribution boards (minimize the number of HV primary channels)
  - IT prototype (sectors) instrumentation by means of existing asics developed for analog readout (APV25 ?)

- **2015**
  - New version of TofPet asic validation on CGEM IT prototype
  - Off Detector Electronics e HV design
  - IT front-end (TofPet) integration

- **2016**
  - On Detector (asic & boards) and Off Detector electronics production/test

- **2017**
  - IT instrumentation and validation
Roadmap toward a CGEM-based IT

- 2013
  - start R&D program (cosmic setup, simulations)
  - write a Letter of Intent

- 2014
  - build prototype with IT middle layer layout

- 2015
  - Prototype test and validation
  - TDR
  - IT design and material procurement

- 2016
  - start IT construction

- 2017
  - complete IT, test and validation
Cooperation activities from IHEP side (proposal)

- verification of Manpower for:
  - building prototype
  - designing FE electronics
- implementing simulation and offline
- making DAQ and Slow Controls
- built up HV
- preparing Gas System
- installing CGEM
Next step (proposal)

- Preparation of a Letter of Intent for INFN-IHEP cooperation on CGEM

- Establishing a INFN-IHEP CGEM Steering Committee
Letter of Intent (I)

1. The present BESIII Drift Chamber
   a. Description
   b. Status of Inner Chamber
   c. Present and future (high-Lum) problems for data taking

2. Estimation of backgrounds
   a. Present backgrounds: measurements
   b. Future backgrounds: simulations

3. The Cylindrical GEM technique: advantages and drawbacks
   a. The KLOE2 Inner Tracker
   b. Material budget
   c. Analog vs. digital, expectations and measurements
   d. Projects: geometry and layout

4. Simulation of Cylindrical GEM Tracker
   a. Parametric simulations
   b. Single particle simulations
   c. Problematic channels simulations
5. Frontend electronics
   a. The KLOE2 electronics
   b. Requirements for BESIII

6. Impact on DAQ
   a. Dead time
   b. Disk space

7. Requirements on trigger
   a. Intermediate level trigger

8. Offline reconstruction

9. Money, manpower, times, tasks subdivision.....
Thanks for

谢谢

your attention