R&D

Fast and lightweight
EIC integrated tracking system

Barrel MicroMegas

&

Forward Triple-GEM

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Outline

- Overview of R&D program
- Motivation
- Simulations
- Forward GEM tracking
- Barrel MicroMegas tracking
- Front-End Readout System
- Summary
Introduction

- **R&D effort focuses on intermediate tracking system:**
  - **Barrel tracking system** based on MicroMegas detectors manufactured as cylindrical shell elements and
  - **Rear / Forward Forward tracking system** based on triple-GEM detectors manufactured as planar segments.

- **R&D effort - Main strategy:**
  - **Design and assembly** of large cylindrical MicroMegas detector elements and planar triple-GEM detectors
  - **Test and characterization** of MicroMegas and triple-GEM prototype detectors
  - **Design and test of new chip readout system** employing CLAS12 'DREAM' chip development, ideally suited for micro-pattern detectors
  - **Utilization of light-weight materials**
  - **Development and commercial fabrication** of various critical detector elements
  - **European/US collaborative effort** on EIC detector development (**CEA Saclay**, and **Temple University**)
Considerations on Tracking System

- Tracking over wide acceptance range: Forward with ~1° and Rear with ~179°, excluding very forward/rear detector regions
- Contribute to reconstruction of event kinematics besides calorimetry in particular at very small energies
- High-rate environment (~10MHz ep collisions)
- Fast time response
- Precision hit resolution, e.g. low $Q^2$ region
- Minimal dead material (~1% $X_0$)
- Cost effective solution for large tracking detector areas
- Profit from world-wide micro-pattern detector development (RD51 Collaboration)

$$E_e/E_p = 0.1$$
Simulations

- EICROOT simulation framework
  - GEANT Implementation of barrel MicroMegas and rear/forward triple-GEM system
  - Resolution studies / Kinematics
  - Dead material studies
  - DVCS physics simulations

A. Kiselev (BNL)
Introduction

- Weekly coordination meetings between Tech-Etch, CERN, FIT, Yale and Temple University:
  - GEM foils and 2D readout foils

- No spacers (e.g. Kapton ring)

- Gas piping in frame

- HV routing embedded in frames

- FEE in larger radial region / DREAM chip
Forward GEM Tracking

- Laboratory facilities at Temple University (Current Department of Physics)
  - Setup of three labs concerning CCD scans, assembly and testing
  - Characterization of GEM foils in terms of leakage current and optical uniformity routinely performed
  - Assembly of triple-GEM test detectors
  - Setup of cosmic-ray test and 55Fe source scanner
  - DAQ and HV system
  - Mechanical design studies on large triple-GEM detector segment
  - Commercialization of large GEM foil production using single-mask manufacturing techniques

![Laboratory facilities at Temple University](image)
Forward GEM Tracking

New Laboratory facilities at Temple University (New Department of Physics)

(a) Class 1,000 Clean Room
   GEM Assembly Lab

(b) GEM testing lab

(d) Science Education and Research Center

5th floor
4th floor
Basement

(c) Basement - Machine Shop
Forward GEM Tracking

- **Highlight:** Commercial fabrication of single-mask produced GEM foils

- Successful fabrication of single-mask produced GEM foils in collaboration with FIT, Temple University and Yale University

- Processing steps:

  - (a) Coating of photoresist and laser direct imaging
  - (b) Removal of unexposed photoresist and etching of copper and removal of Chrome adhesive layer
  - (c) 1st polyimide etching in EDA chemistry
  - (d) Electrolyte etching and removal of backside copper
  - (e) 2nd polyimide etching in EDA chemistry
Forward GEM Tracking

- GEM Foil Electrical tests at Temple University / Leakage current (1)
  - Setup of leakage current measurement at Temple University

- Setup including nitrogen box with HV connections
- ISEG power supply and nA current measurement
Forward GEM Tracking

- **GEM Foil Electrical tests at Temple University / Leakage current (2)**
  - Results for large GEM foil

- Very small currents < 1nA repeatedly measured on several small samples up to 600V
- Above example is for a large GEM foil
Forward GEM Tracking

- **GEM Foil CCD scans setup**
  - 2D scanning table with CCD camera fully automated
  - Scan GEM foils to measure hole diameter (inner and outer) and pitch

![Image](attachment:image.png)
Forward GEM Tracking

- GEM Foil CCD scan results: Small samples (1)

![Graphs showing pitch, inner hole diameter, and outer hole diameter distributions with mean and standard deviation values.](image)

![Deviation from mean images for different sections of the GEM foil.](image)
Forward GEM Tracking

- GEM Foil CCD scan results: Small samples (2)

**Inner Hole Diameter Comparison (Lot# 626524)**

- **Foil Number**: 44, 46, 48, 50, 52, 54, 56
- **Diameter Mean (µm)**: 40, 50, 60, 70, 80

**Outer Hole Diameter Comparison (Lot# 626524)**

- **Foil Number**: 44, 46, 48, 50, 52, 54, 56
- **Diameter Mean (µm)**: 40, 50, 60, 70, 80

Symbols:
- **Red**: Temple
- **Blue**: Tech-Etch
Forward GEM Tracking

- GEM Foil CCD scan results: Large samples

![Images of CCD scan results]

- Inner Hole Pitch
  - a)
  - b)

- Inner Hole Diameter
  - a)
  - b)
Introduction

- Curved Micromegas for barrel based on carbon structure glued on thin PCB
- Idea validated for CLAS12 tracker
- Need to increase size, but studies and simulation are needed: PCB size, mesh tension, capacitance and gain homogeneity
- More R&D needed!
Barrel MicroMegas tracking

- Laboratory facilities at Saclay
  - Recent 12-detector test at CERN
  - Development
  - Saclay Micromegas workshop
  - Insulator
  - Mesh stretcher
  - Laminator
  - Cleaning

- Micromegas detectors
  - build either at outside company (CERN/CIREA) or at Saclay workshop

- Tests done in CLAS12 lab
  - with fully-equipped cosmic-test stand incl. reference detector
Barrel MicroMegas tracking

- Highlight: Assembly and test of curved MicroMegas cylindrical segments (1)

- Successful assembly of small radius prototype

- Challenge:
  - Mechanical stress due to large bending

- C/Z readout structure

- Readout through DREAM chip system
Highlight: Assembly and test of curved MicroMegas cylindrical segments (2)

- First efficiency results are reasonable / Further optimization with operating HV and gap
- Further R&D on mechanical deformation
Barrel MicroMegas tracking

- Front-End Electronics development

- Successful setup of complete new chip readout system ideally suited for Micropattern detectors
- Successful test with MicroMegas detector
- Design of triple-GEM readout system using DREAM chip

### Dream Chip vs. APV25-S1 Chip

<table>
<thead>
<tr>
<th>Feature</th>
<th>Dream Chip</th>
<th>APV25-S1 Chip</th>
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</thead>
<tbody>
<tr>
<td>Number of channels</td>
<td>64</td>
<td>128</td>
</tr>
<tr>
<td>Memory size</td>
<td>512</td>
<td>160</td>
</tr>
<tr>
<td>Latency</td>
<td>16(\mu)s</td>
<td>8(\mu)s</td>
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<tr>
<td>Noise ((e)-RMS)</td>
<td>2100 (On 180pF)</td>
<td>1200 (On 20pF)</td>
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<tr>
<td>Sampling frequency</td>
<td>1-40MHz</td>
<td>10-50MHz</td>
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<tr>
<td>Dynamic range</td>
<td>50-600(\mu)C</td>
<td>150(\mu)C</td>
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<tr>
<td>Input capacitance</td>
<td>150pF</td>
<td>18pF</td>
</tr>
<tr>
<td>Shaping time</td>
<td>70ns</td>
<td>50ns</td>
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</table>
Summary

- **Forward GEM tracking**
  - Characterization of GEM foils in terms of leakage current and optical uniformity
  - Assembly of small (10 X 10 cm²) triple-GEM test detectors
  - Setup of cosmic-ray test and 55Fe source scanner / DAQ and HV system
  - Mechanical design studies on large triple-GEM detector segment and support structure
  - Commercialization of large GEM foil production using single-mask manufacturing techniques
  - Spacer grid studies: Grid and Kapton rings

- **Barrel MicroMegas tracking**
  - Successful assembly of two flat CLAS12 MicroMegas detectors
  - Successful test of light-weight, low capacitance flex cables
  - Test of first DREAM chip production version
  - Test of a small radius chamber

- **Outlook**
  - Design, assembly and test of larger segments
  - **Goal:** Establish US/EU Ph.D. program between Temple University and Paris 6 / Orsay