Investigation of the Properties of Thick-GEM Photocathodes by Microscopic Scale Measurements with Single Photo-electrons
(The Leopard Project : Trieste-Budapest)

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for the joint group of
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INFN Trieste
Wigner RCP Budapest
Outline

- Micro-pattern RICH
- ThickGEM microstucture
- The Leopard system
- Trieste-Budapest setup
- Data and analysis
- Gain uniformity
- Drift field effects
- Summary
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MPGD Based Cherenkov Detectors

- Gaseous Photon Detectors for Cherenkov detectors
  - Large area at reasonable price
  - CsI cover for UV photon detection
- Advantages vs. MWPC based RICH
  - Reduction of ion back-flow
  - Fast response
  - High rate capability
  - Possibility for MIP suppression
  - No feed-back photons
- PHENIX, COMPASS, ALICE
- Triple GEM, TGEM, TCPD, TGEM+MM
  - in all: GEM-type photoconverting plate
- Efficiency and microstructure?
Microstructure of UV Sensitivity on ThickGEM Surface

- Holes are definitely blind spots (no photoconverter material is there inside)
- Highly non-uniform extraction field (high around the holes, lowest in symmetry points)
- Critical symmetry points (and lines)
- Side-effects of MIP suppression ?
- Large range for the geometrical parameters (diameter, pitch, rim, thickness)
- Choise of the filling gas

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Strategy to Examine the Microstructure

- Single photo-electrons
  PE yield and gain separation
- Focused UV light
- High resolution mapping
  should be better than 0.1mm!
- Combined (and fast) data acquisition

Targeted topics:
- Optimization (and parametrization)
  (hole geometry, voltages, gas mixtures, ...)
- Fine tuning for simulation
What could be seen?

seems like a leopard...
Challenges

- Optical system: 20-100 μm spot size
  => $10^4 - 10^6$ points (spectra) for an area
- Single photo-electrons:
  < 5% PE / event AND 100-1000 PE / point
  => $10^4 - 10^6$ events in each points

Necessary system requirements:
- Efficient focusing of pulsed UV light
- Actuator system (3D): ~10 μm precision, 10ms response
- Fast ADC: >> 10 kHz
- Combined data acquisition system (ADC and actuator)
Actuator System

- Stepping motors for all axis
- Good resolution: 2.5 μm
- Direct control
- Mounted upside-down on a support table

Larger (20cm) and faster version became ready recently

G.Hamar - Leopard Ts-Bp
Optical Setup

- Pulsed UV source: UV LED: SETI UVTOP240
  peak: 243 nm, widths: 10nm
  Photo-electrons from gold surface
- Focusing ball lens cover
- Led Driver Unit
  adjustable oscillator trigger and LED output
- Pinhole (spot size x 2)
  150 μm => 70 μm spot
  Pinhole 30 μm for GEMs
- Quartz window
- Further improvements are still under tests
Data Acquisition : Machine

- Several options tested so far: Camac, PC+LPT
- Recent successful implementation: Raspberry Pi
- **Raspberry Pi** (is a tiny computer)
  - 700MHz ARM CPU + Broadcom 2835 chip
  - Peripherals: USB, HDMI, SD, AV, Audio
- **GPIO pins** (10MHz)
- Low power consumption and low cost
- **Raspbian Linux**:
  - Debian based OS
- WiFi connection
Data Acquisition : HW + SW

- Special **additional board**: fits to the GPIO pins
- Parallel-out single **ADC** (LTC1415)
- **Trigger** reciever and timing (adjustable)
- Signal shaping and amplification (adjustable)
- **Tagging** of rejected triggers
- **Direct actuator control**
  (can be accomodated to any moving controls)

- Software: C,C++ runs on the RPi
- ADC (w DSP), save spectra
- Control 3D table and HV system
- GUI on remote PC (wxWidgets)
Working Tabletop Setup
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TGEM+MM Hybrid as Basic Setup in Trieste

- To compare THGEMs, "single THGEM layer" configuration should be used
- Used Hybrid (from photon view):
  - Quartz window (for UV light)
  - Wire cathode: 100µm / 2mm spacing (along X axis)
  - TGEM in study
  - Bulk micromesh: 45/18 and 128µm for gap (CERN)
  - Padplane: 1D strips of 150/150 µm (along Y axis)
- Gas: Ar/CH$_4$: 30/70 and Ar/CO$_2$ for the long runs during the night
ThickGEMs in Study

- Based on the experience of the INFN Trieste group
- Several different TGEMs were studied to compare: rim, thickness, hole size, production process
- All were gold plated (CsI was not required at this stage)

- Target issues:
  - Uniformity
  - Gain distribution
  - Critical points
  - Charge up

<table>
<thead>
<tr>
<th>ThGEM Name</th>
<th>Hole [µm]</th>
<th>Pitch [µm]</th>
<th>Thickness [µm]</th>
<th>Rim [µm]</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1-III</td>
<td>400</td>
<td>800</td>
<td>400</td>
<td>0</td>
</tr>
<tr>
<td>DESTRO-I</td>
<td>400</td>
<td>800</td>
<td>400</td>
<td>5</td>
</tr>
<tr>
<td>C3HR-II</td>
<td>400</td>
<td>800</td>
<td>400</td>
<td>50</td>
</tr>
<tr>
<td>M2.4-G</td>
<td>400</td>
<td>800</td>
<td>600</td>
<td>0</td>
</tr>
<tr>
<td>M2.1-II</td>
<td>300</td>
<td>800</td>
<td>400</td>
<td>0</td>
</tr>
</tbody>
</table>
TGEM+MM Hybrid with the Leopard Scan System
DAQ (RaspberryPi with LeopardRpiBoard + Motor driver)
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Data and Quantities

- UV light focused onto a 50 μm spot (MP)
- Single photo-electron spectrum in every MP
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- Compute photo-electron yield and gain for every MP
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- Single photo-electron spectrum in every MP
- Compute photo-electron yield and gain for every MP
- Search for holes, compute "hole-level" quantities

- Default plots:
  - Yield map
  - Gain map
  - Hole-gain distr.
Setting the Focus

- Finetuning the focal distance with measurements
- 1+1 (or 2+1) dimension scans
  → select the sharpest slice (image)
The Charge-Up Effect

- Charge up: an **area** or a **single hole**
- The **decrease of gain** has been seen
- Significant increase of the photon yield has been measured
  (Time constant is different from the one in the change of gain)
- Eliminating the charge-up effects:
  Before the scan the area was shone with high luminosity

![Charging up single holes](image1)

![Charging up a single hole](image2)
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Gain Uniformity Studies

- Long runs for statistics on large areas
- Evaluation of the "hole-gain" distribution
- Comparative test for every THGEMs

<table>
<thead>
<tr>
<th>ThGEM Name</th>
<th>Applied average gain</th>
<th>Standard deviation</th>
<th>Number of used holes</th>
</tr>
</thead>
<tbody>
<tr>
<td>M1-III</td>
<td>39900</td>
<td>12.0%</td>
<td>317</td>
</tr>
<tr>
<td>DESTRO-I</td>
<td>24100</td>
<td>11.0%</td>
<td>194</td>
</tr>
<tr>
<td>C3HR-II</td>
<td>47100</td>
<td>21.6%</td>
<td>247</td>
</tr>
<tr>
<td>M2.4-G</td>
<td>76200</td>
<td>21.2%</td>
<td>268</td>
</tr>
<tr>
<td>M2.1-II</td>
<td>24000</td>
<td>8.3%</td>
<td>323</td>
</tr>
</tbody>
</table>
Avalanche Size

- Does the size of the electron avalanche depend on the point the electron enters into the hole?
- Leopard:
  Place of PE emission
  \(< = ? = >\)
  point of entering
- Diffusion ...
- Preliminary results with DESTO-I are compatible with a flat distribution (?)
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Effects of the Drift Field

- Optimization of drift field could be crucial
  - MIP suppression needs reversed drift field
  - PHENIX HBD: close to zero field
  - For the critical symmetry points: non-zero normal drift is needed

- With the Leopard setup the point-by-point and integrated photo-electron yields can be examined
Drift Field Scan

Drift field scan

Reversed bias

Direct bias

0 V/cm  -100 V/cm  -1000 V/cm

0 V/cm  +100 V/cm  +200 V/cm  +500 V/cm  +1000 V/cm

Photo-electron yield
"Critical Line" Scan

- Critical symmetry points and symmetry lines are most the effected by the drift field
- Dependance in the crytical point is measurable (Focused light + HV scan)
- Systematic studies on these kind of points with comparision to the standard points?
  → 1 dimension scan along a line (with several voltage settings)
Critical Line Scan : Samples

- Critical points are clearly visible
- Evolution as expected from former measurements
Critical Line vs. Drift
TGEM Voltage and Yield

- Higher $U_{\text{TGEM}}$ means higher field on the top
- What is the minimal necessary voltage (to have max yield without sparks)
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- **Leopard System**
  - Examine microstructure of MPGD
  - Realized as table-top setup
- **Yield+Gain map, Hole-level behaviour → Simulations**
- **Optimization**: Detailed Studies on ThickGEMs
  - Hole-gain distribution, comparison of different geometries
  - Optimization methods for voltage settings, Critical point/line behaviour
- **Applicability for other gaseous devices as well**
- **Characterization → Novel device for quality assurance**
- **Upgrades and steps towards a large area device**
Extra slides
Sparks

Yield map after a spark

Long runs during nights with Ar/CO$_2$
Normal GEM Foil
Speed: 20 min run

- DAQ rate: 120 kHz achieved with 99.5% events accepted
Gain sharing and separation

- Single TGEM examination
- Underlying structure (post amplification stage) is measureable via shining through the holes