Status of the TPG

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Outline

• Construction and operation
• Update on performances
• Design aspects
  – Electronics
  – Field-cage
  – Gas choice
• Outlook
Detector schematics

- GEM stage
- solenoid
- drift volume
- field cage
- read-out plane
The GEM foil

- Triple-layer structure
- Each layer divided in 8 regions, independently powered
- Max amplification depends on gas and HV. With good gas it can be as high as $10^6$.\
The hexaboard

- ~710000 hexagonal pads
  - size: 300 μm
  - pitch: 500 μm
- grouped into strips along 3 coordinates at 120 degrees (u, v, w) running at different depths
... to this:

• 2 pad planes of same quality are available
• < 10 anomalies over 576 strips
• all layers have similar production quality
Support structures

1. outer metal ring
2. o-rings for gas tightness
3. stiffener plate
4. GEMs support rings
5. guard ring
Assembling the detector
55Fe source calibration

• Absolute energy, equalization
• Preamp gain calibration is not included yet
• First indications are
  – Despite the lack of gain equalization, the energy resolution is already quite good
  – The plots are very sensitive to the cuts on cluster size, as expected from a properly working detector
$^{55}$Fe source

All clusters

≥2 strips

≥3 strips
U,V vs. W correlations

- out-of-line events are due to lack of gain calibration
- Correlation is important: it can be exploited as an additional tool for getting rid of fake combinations
  - In addition to the use of the 3rd projection
- Compass is able to reject (almost all) fakes by this technique
Low energy tracks

- 500 samples @10MHz
- Ar/CO₂ 90/10, 10cm/μs → total 50cm drift path
- e⁻ from Sr source
- B=0.07T (1/10 nominal)
- Color code gives charge amplitude
• 2 MeV/c electron in B=0.07T
• Transverse diffusion spreads the charge
Intrinsic resolution

- $^{55}$Fe X-ray conversion position can be determined by 2 projections, then cross-checked with the 3$^{\text{rd}}$ one.
- The intrinsic resolution is VERY promising
- This has been obtained with a 3cm drift cell.
- Actual resolution over longer drift depends on gas properties.

\[ \sigma \sim 40\mu m \]
Design improvements

• Electronics
• Ingredients for good resolution
• Gas choice
• Discussion on overall parameters
• A compact emittometer, alias TPG?
Electronics

• New electronics from ALICE
• Higher integration
• Total (including DAQ) 10 CHF / channel
• Digitization is close to detector (less noise)
• Data get out from the detector on a few optical fibers (elegant, simple)
• Large range of possible sampling frequencies up to 40 MHz.
ALTRO EVOLUTION

1998
- CHANNELS / CHIP: 4
- POWER / CH: 120mW
- PRICE / CH: 50CHF

1999
- CHANNELS / CHIP: 1
- POWER / CH: 80mW
- PRICE / CH: 8CHF

2001
- CHANNELS / CHIP: 1
- POWER / CH: 16mW
- PRICE / CH: 5CHF
Digital Conditioning of the TPC Signal

ADC ➔ BC I ➔ TCF ➔ BC II
A possible TPG electronic chain

• From left to right
  – Signal inverter
  – 128-channels ALICE TPC front-end
  – USB readout card
• Addition of protection diodes possible.
• Electronics noise ~ 1K electrons, depending on cable length
  – Total S/N depends on amplification. Can be quite high with good gas mixture.
• Being designed for a different experiment, straightforward application to TPG
Momentum resolution

• Position resolution is driven by
  – Readout pitch (fixed)
  – Diffusion in gas
  – Ionization and gain

• Gas choice is a key point: we should look for larger gain and ionization and smaller diffusions.

• Momentum resolution is driven by
  – Position resolution
  – Number of available points

• From the simple Glukstern formula: 50 points give \( \frac{dp}{p} \) resolution factor only 1.5 better than 20 points.

• If more distant points are affected by more diffusion, we should really consider limiting the number of points and the drift length.
### Shorter field-cage?

<table>
<thead>
<tr>
<th></th>
<th>He/CO₂ 1m</th>
<th>Ne/CO₂ 18cm</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>E</strong></td>
<td>500 V/cm</td>
<td>300 V/cm</td>
</tr>
<tr>
<td><strong>Max HV</strong></td>
<td>50 KV</td>
<td>5.4 KV</td>
</tr>
<tr>
<td><strong>Drift time</strong></td>
<td>60 μs</td>
<td>6 μs</td>
</tr>
<tr>
<td><strong>Drift velocity</strong></td>
<td>1.68 cm/μm</td>
<td>3 cm/μm</td>
</tr>
<tr>
<td><strong>Sampling freq</strong></td>
<td>2MHz</td>
<td>10MHz</td>
</tr>
<tr>
<td><strong>Number of samples</strong></td>
<td>118</td>
<td>60</td>
</tr>
<tr>
<td><strong>Specific ionization</strong></td>
<td>10 e⁻/cm</td>
<td>20 e⁻/cm</td>
</tr>
<tr>
<td><strong>Usable long. Slices</strong></td>
<td>118</td>
<td>20 (shaper limited)</td>
</tr>
<tr>
<td><strong>N. Radiation lengths</strong></td>
<td>6.6 E⁻⁴</td>
<td>5 E⁻⁴</td>
</tr>
<tr>
<td><strong>X-ray abs. Coeff.</strong></td>
<td>2.5 E⁻⁵ cm⁻¹</td>
<td>1.2 E⁻⁴ cm⁻¹</td>
</tr>
<tr>
<td><strong>X-ray abs. probability</strong></td>
<td>1</td>
<td>0.4</td>
</tr>
<tr>
<td><strong>Electronics</strong></td>
<td>HARP</td>
<td>ALICE</td>
</tr>
</tbody>
</table>
Advantages of a short TPG with Ne

- Straightforward “poor’s man” construction
  - 20 cm field-cage made of a small insulating cylinder internally covered by a Cu-clad Kapton foil.
  - Field shaping strips made by Cu etching
  - Moderate HV
    - Simple insulator
    - More friendly for safety
- Lager ionization
  - Better resolution
- Faster mixture
  - Less sensitive to X-ray background
Simulation / reconstruction

• Short (18cm) and long (1m) Ne/CO₂ TPG have been simulated in G4MICE and reconstructed.
  – Thanks to Rikard and Olena

• **Results are very encouraging**, even if – for the moment – the experimental resolution is not reproduced in the MC
  – Maybe due to different gas mixture
  – If X-ray background not a problem, one could go to Ar-based mixtures -> even better TPC performance
    • Slightly more material, but TPG starts from very low amount

• Simulation results should be considered as upper limits.
<table>
<thead>
<tr>
<th></th>
<th>Short</th>
<th>Long</th>
</tr>
</thead>
<tbody>
<tr>
<td>$P_t\text{ rec} - P_t\text{ mc}$</td>
<td>0.53 MeV/c</td>
<td>0.37 MeV/c</td>
</tr>
<tr>
<td>$P_1\text{ rec} - P_1\text{ mc}$</td>
<td>1.63 MeV/c</td>
<td>1.27 MeV/c</td>
</tr>
<tr>
<td>X residual</td>
<td>0.22 mm</td>
<td>0.26 mm</td>
</tr>
<tr>
<td>Y residual</td>
<td>0.23 mm</td>
<td>0.25 mm</td>
</tr>
</tbody>
</table>

- Residuals not in line with measured position resolution (~0.04 mm). Need more studies.
- Notice the better momentum resolution of the longer TPG, compared with the (average) worse residuals
  - “long” is too long, the last part of the track has larger residuals and is practically useless in the fit
- “short” and “long” are extremes
  - Marginal improvement due to $1/\sqrt{N}$ in Gluckstern formula combined by diffusion at long drift path indicates a possible optimum at ~40 point (30 to 35 cm)
Outlook

• New design could allow to build a full detector with simple means and at a very (very) moderate cost
• New electronics has the necessary “grade” for application in the real experiment
  – S/N is OK
  – No rate problems whatsoever (as many muons per spill as you want)
  – More test data taking will be made with the new electronics … But do not expect this for tomorrow
• Simulation/reconstruction is catching up, but needs further study
• TPG is not any more on the critical path, but it keeps moving slowly under the water surface …