GEM foil gain prediction

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Optical scanning system

• Custom built robot with modifiable optics and lighting setup

• Originally using x1 telecentric optics with 1.75 microns/pixel

• Reduced the magnification of the optics to speed up the scans of large foils: 4.4 microns/pixel

• Separate exposures for foreground and background light
Analysis

- Measuring the diameter of the holes by fitting an ellipse to the contour pixels of the hole
- Resolution of 1 micron in diameter
- Need to maintain precise control over lighting conditions for initial contour recognition
- Inner and outer holes are found, along with several defect classes, such as blocked holes and etching defects
Advanced optical QA in ALICE

• Goal is to identify foils with high risk of malfunctioning (exceedingly small holes, sharp corners in copper etc.)

• And to provide a measurement of the uniformity of the foil

• Huge number of foils: >570 GEM foils, >120 m²

• Advanced optical QA in 2 laboratories: Helsinki Institute of Physics in Helsinki and Wigner Research Centre in Budapest
The ALICE traffic light system

• The foils are ranked with a traffic light system based on the hole size measurement.

• Red foils are discarded

• Green and yellow foils will be built. Will try to minimize the number of yellow foils in the future
Red foil

**Segmented**

**Unsegmented**

![Diameter histogram](image1)

![Diameter histogram](image2)
Red foil
Red foil

Segmented

Unsegmented

\( \text{O3}^3_{\text{3.07}} \text{ Diameter histogram} \)

\( \text{O3}^3_{\text{3.07}} \text{ Diameter histogram} \)
Red foil

Segmented

Unsegmented

\[ \text{\( O_3 \cdot g_0 \cdot 7 \_g \text{ inner diameter} \)}\]

\[ \text{\( O_3 \cdot g_3 \cdot 07 \_g \text{ outer diameter} \)}\]

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Advanced optical QA in ALICE

- Powerful tool in other QA tasks, such as spotting a mistake in hole mask pattern of the foils

- Or quantifying defects:
Gain scanner

- Multiwire proportional chamber with y-strip readout

- Large enough to hold ALICE OROC 3 foil with the stretching frame (> 80 cm)

- Measurement resolution 4 mm by 3 mm

- Carefully controlled measurement procedure to get maximum repeatability

- Accuracy ~5 %
Correlation study

• All ALICE TPC foils are scanned optically

• The gain of at least 1 foil from each batch in Budapest is measured

• Foils measured with drift field of 300 (400) V/cm, transfer field of 500 V/cm with 330 (320) V over the foil for standard pitch (large pitch) foils.

• Foils were run with effective gain of ~5 for standard pitch foils and ~8 for large pitch foils.

• Irradiation rate of ~3 kHz over the IROC detector
Correlation

- The hole diameters correlate with the gain
- The gain can be predicted from the hole diameters
Correlation

- Simple inverse linear dependency of outer holes to the gain can be used with very uniform foils

- Here the top and bottom outer holes are averaged and the mean hole is compared to the gain

- Data of four ALICE IROC foils used to fit an exponential function

- Gain varies \( \sim 4 \% \) per micron
Large pitch foils

• Half of ALICE TPC GEM foils are made with pitch of 280 microns

• Large pitch foils have substantially higher gain compared to standard pitch foils
Large pitch foils

• The measurements don’t line up nicely in the plot, but the slopes are similar

• Gain prediction more complicated

• Simple neural network prediction gives hope though
Next steps

• Ultimate goal is to predict the gain of a full GEM foil stack

• Not trivial – simple multiplication of individual foils does not work

• Single foil gain variance seems to always be worse than the combined variance of the detector gain

• Next study the effect of the field setup

• Hole geometry vs. Charge-up