GEM Foil Quality Assurance For The ALICE TPC Upgrade

RD51 Collaboration meeting / Trieste

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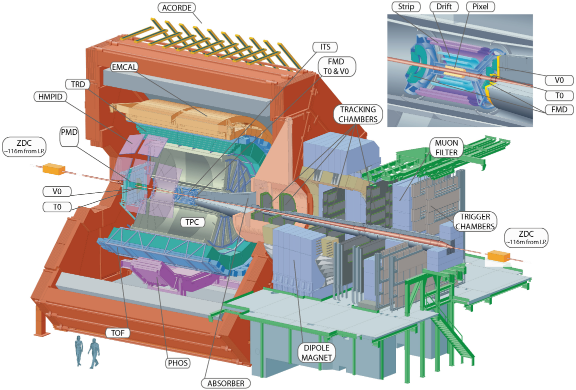
for the ALICE TPC Upgrade Collaboration

October 16, 2015

A Large Ion Collider Experiment at the LHC

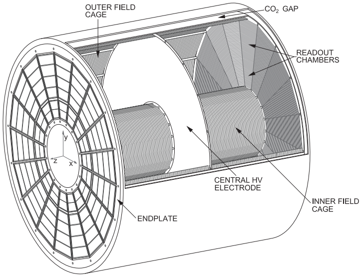
- Dedicated to heavy ion physics, to explore the structure of strongly interacting matter.



Time Projection Chamber

Present TPC

- Gaseous detector (length 5 m, diameter 5 m).
- Acceptance: $|\eta| < 0.9$, $\Delta\Phi = 2\pi$.
- Read out chambers (ROC) based on Multi-Wire Proportional Chambers (MWPC).
- Gating grid prevents backflow of ions (IBF) into the drift (limited to $\approx$ 3.5 kHz).



- Readout rate limited to $\approx$ 500 Hz for Pb – Pb.

Conditions in RUN 3

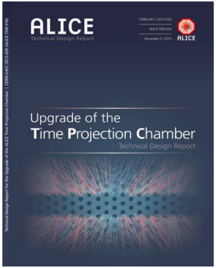
- 50 kHz collision rate of Pb – Pb, pileup of $\approx$ 5 events.

$\Rightarrow$ TPC ROCs need to be upgraded.

Upgrade – new ROCs

Needed

- Continuous readout to cope with the 100 times higher rate.
- Keep energy resolution $\sigma_E/E < 12\%$.
- Keep IBF $< 1\%$ to minimize space charge distortions.
- Reuse of old TPC components (old field cage, gas-system, etc).
- Gain 2000 to keep S/N > 20 (MIP).
- Low discharge probability to guarantee stable operation.



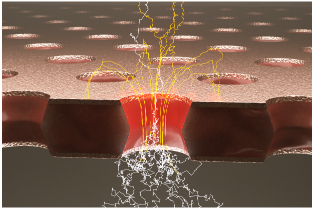
New design

- MWPC will be replaced by Gas Electron Multiplier (GEM)
- Offers continuous readout, high gain (in stack), intrinsic IBF suppression.

Gas Electron Multiplier

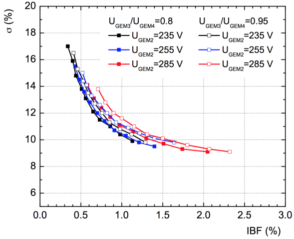
Standard GEM foil

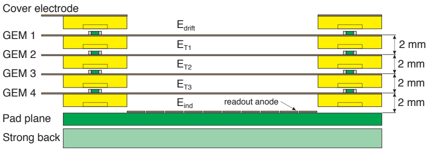
- Copper-polymide-copper sandwich foil (5-50-5 μm).
- Geometrical pattern of etched holes with 140 μm pitch.
- Outer/inner hole $\varnothing \approx 70/50\mu$m.



New design

- Stack of four GEM foils (S–LP–LP–S).
- Gain 2000 in $Ne/CO_2/N_2$ (90/10/5) gas mixture.





ROC Production and Quality Assurance

Design criteria

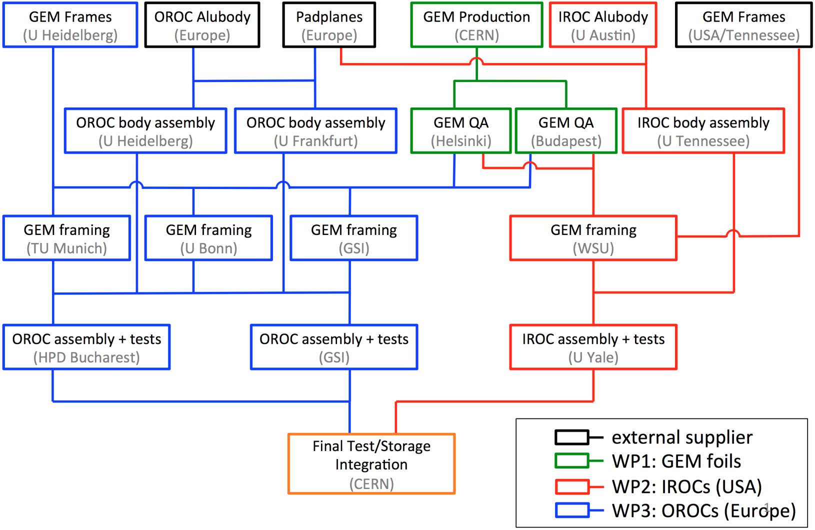
- Gain uniform across active area.
- Low ion back flow into drift volume.
- Keeping energy resolution $\sigma_E / E < 12\%$.
- Stability of operation has to be guaranteed.
- Design criteria are doable but challenging.

$\Rightarrow$ We need to build the ROCs as good as possible, therefore a thorough Quality Assurance is of utmost importance.

Some numbers

- A TPC ROC has ≈ 0.89 m^2 active area, all ROCs together ≈ 32 m^2.
- With 4 GEM foils in a ROC we have 128 m^2 Gem foils
- In total the ROCs will be built of 576 individual GEM foils.
- Total amount of foils to handle, including 50% spares, 864.

Workflow of ROC production



QA of GEM Foils

Basic QA

Fast and simple tests at GEM foil production site (CERN).

- HV cleaning at 600 V in air.
- Coarse optical inspection.
- Leakage current measurement.

Advanced QA

At dedicated QA centers (Helsinki, Budapest).

- (Coarse optical inspection.)
- Advanced HV tests (leakage current, quality factor determination).
- High resolution optical scanning (gain uniformity prediction, provide full optical history of each GEM foil).
- Gain uniformity test (for some foils).

Note: Coarse optical inspection and some HV tests are also done at framing institutes.

Traffic Light System to Classify GEM Foils

To classify the usability of GEMs we introduce a traffic light system.

Traffic light system

- Red light: GEM foil did not pass basic production QA.
- Yellow light: GEM foil did pass basic QA (no fatal defects), but gain uniformity not sufficient, long term HV test (number of sparks too high), leakage currents are not optimal.
- Green light: GEM foil did pass all basic and advanced QA steps.

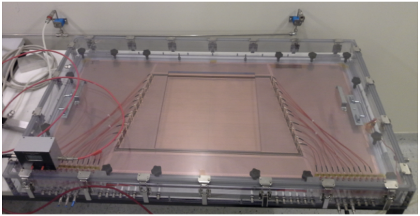
Cross-checks after each production step to see if foil still has green light.

High Voltage Test System

Hardware and tools

One system for all HV related tests (HV cleaning, leakage current, long term stability).

- 24 channel high precision power supply.
- 24 channel picoammeter box (Picologic).
- HV test boxes with gas inlet.
- Custom Labview based control software (integration of iseg PS and pA box).



High Voltage Test System (ii)

High Voltage Test System – Test Methods

Sparking test

High voltage cleaning at GEM production site: GEM foil is ramped up fast to 600 V in air until sparks occur. Criteria to pass:

- Sparks should occur at random places

Leakage current test

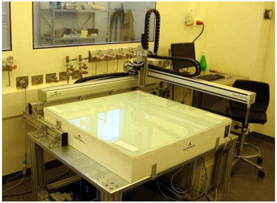
GEM foil is ramped up to 500 V in nitrogen gas. Sparks and current are recorded. Criteria to pass:

- # sparks per sector < x.
- Current per sector < 500 pA for 30+ minutes.

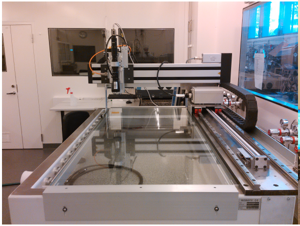
Modifications

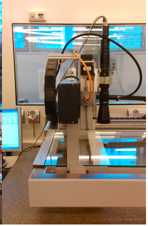
- Recording of spark positions using webcam.
- Quality factor determination, long term leakage current tests.
- Checker board test.

Hardware and tools



- X-Y-Z tables with LED background illumination.
- CMOS Camera with telecentric optics and inline lighting.
- Ring-light option.
- Custom robot control-software based on Labview.
- Data storage.
- Computer for image analysis with custom software.

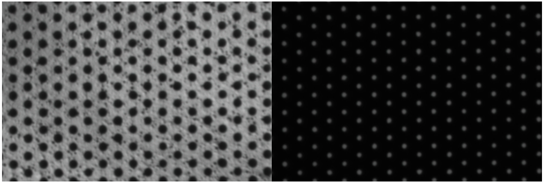




High Definition Optical Scanning (ii)

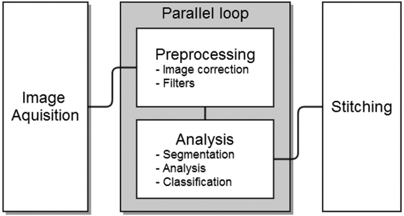
Images

- Images are taken with one or two exposure mode (separate for foreground and background light).



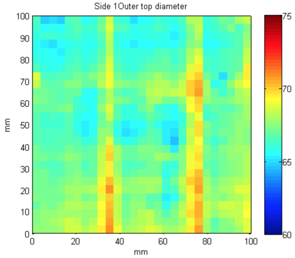
Analysis

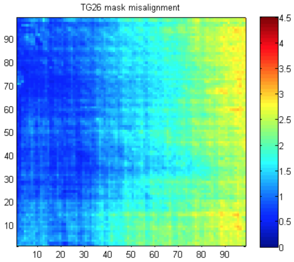
- Pre-processing of images.
- Analysis of images.
- Stitching
- Ploting, histogramming, analyzing defects.

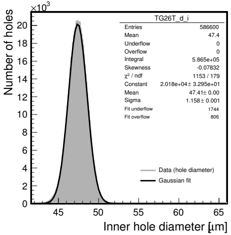


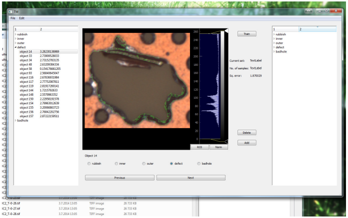
High Definition Optical Scanning (iii)

Results (all measured values in μm)





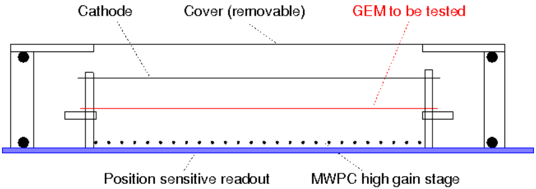


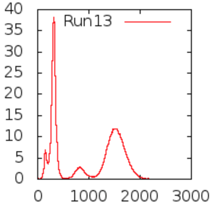


Gain Uniformity Test System

Setup (Dezso Varga, Wigner RCP, Budapest)

Idea: Using a MWPC underneath the GEM foil to measure the local gain by detecting primary ionization above and below test GEMs using ^{55}Fe.

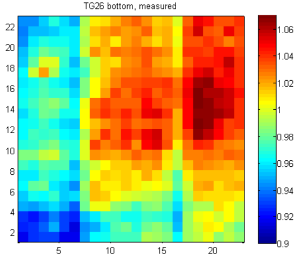


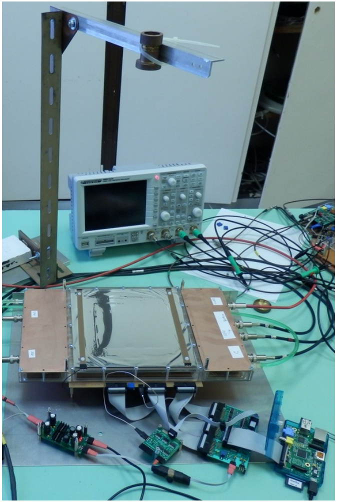


Gain Uniformity Test System (ii)

Prototype

- For 10 × 10 cm GEM foils.
- 12 bit ADC
- 4 kHz rate (4 min for 1M events).



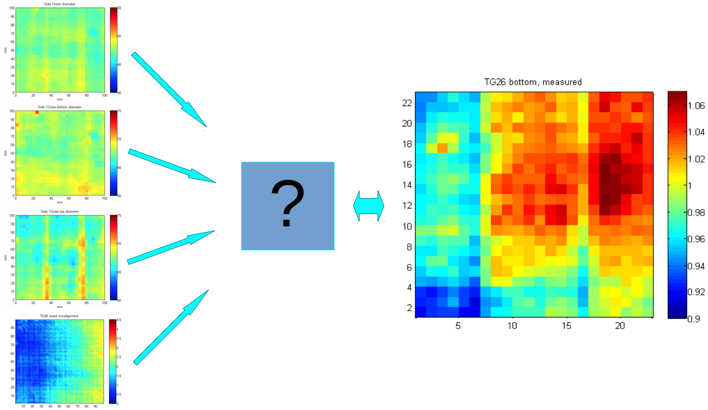


Large scale setup for ALICE

- Right now a setup is being built by Budapest to test full size ALICE ROC GEMs.

Comparing the HD scan results with gain measurements

Can we find a correlation between the geometrical properties and the gain?



Hole Properties to Gain Correlation

Yes we can, gain measurement and prediction from optical scan in good agreement:

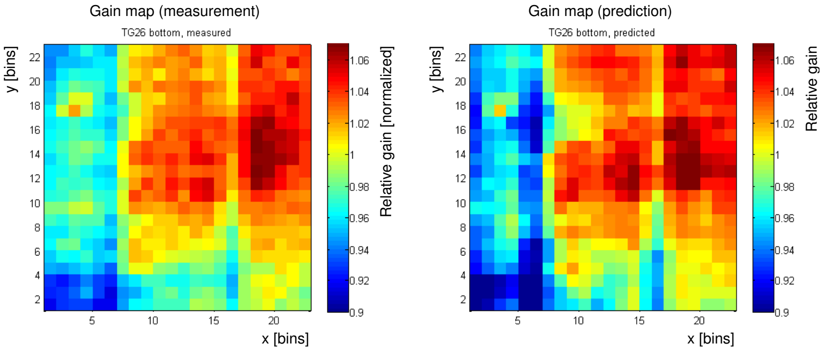
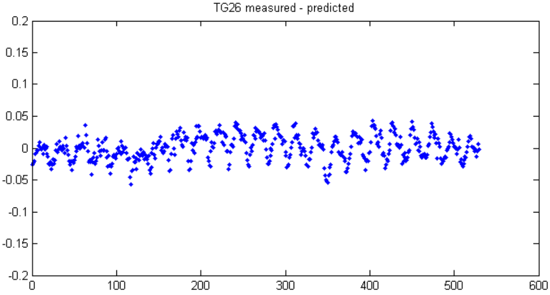


Figure : Gain measurement in comparison with gain prediction from trained neural network. Axis labels represent bin numbers (25bins/10cm). Note: This GEM foil has not been used for training the NN.

Hole Properties to Gain Correlation (ii)

Neural network

- Trained with properties (hole diameters, etc) and the measurement (gain, fields, pressure).
- Trained using 3 different GEM foils, measured with a double GEM detector.
- We predicted the gain of a GEM foil that was not used for training, and measured with MWPC.
- Good results with 10×10 cm double mask foils (proof of concept).



Alice Timeline

Preproduction phase

15 GEM foils of IROC type will be used to:

- Evaluate the existing quality criteria.
- Serve as reference samples with significant statistic (most data so far has been gained by 10x10 cm^2 foils / double mask technique).
- Serve as input parameter for so far unknown hole size distributions, leakage current, quality factor determination.
- Answer questions on practical issues such as the quality of transport behavior.
- Results will be used to define a standard QA protocol.

Production phase

- Production of the GEM foils for the TPC ROCs will start during the first quarter 2016.

Conclusions

- Alice built up an extensive QA program for GEM foils.
- GEM foils will be tested at the production site, at dedicated QA centers and at each framing center.
- Quality assurance scheme for the TPC upgrade of ALICE has been established.
- Currently all participating institutes are successfully building up resp. finalizing their infrastructure
- Automatisation of the methodology is currently finalised.
- Database is under development to be able to follow the history of each individual foil.
- Final open questions about thresholds, measurement time, selection criteria will be finalized within the scope of the preproduction process.
- Great for R&D, because foils will have full history due to the extensive QA.