AGH University of Science and Technology

Charging up effects in the triple GEM detector

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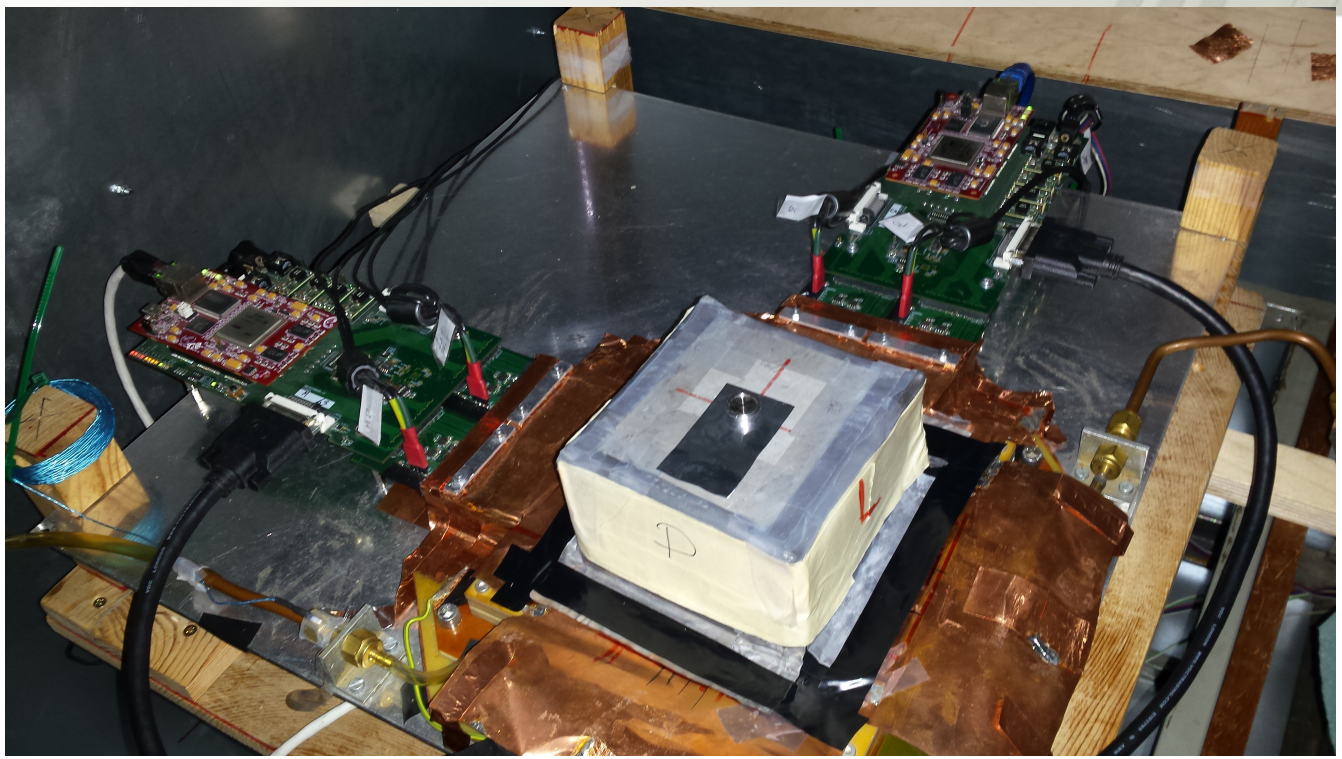
Outline

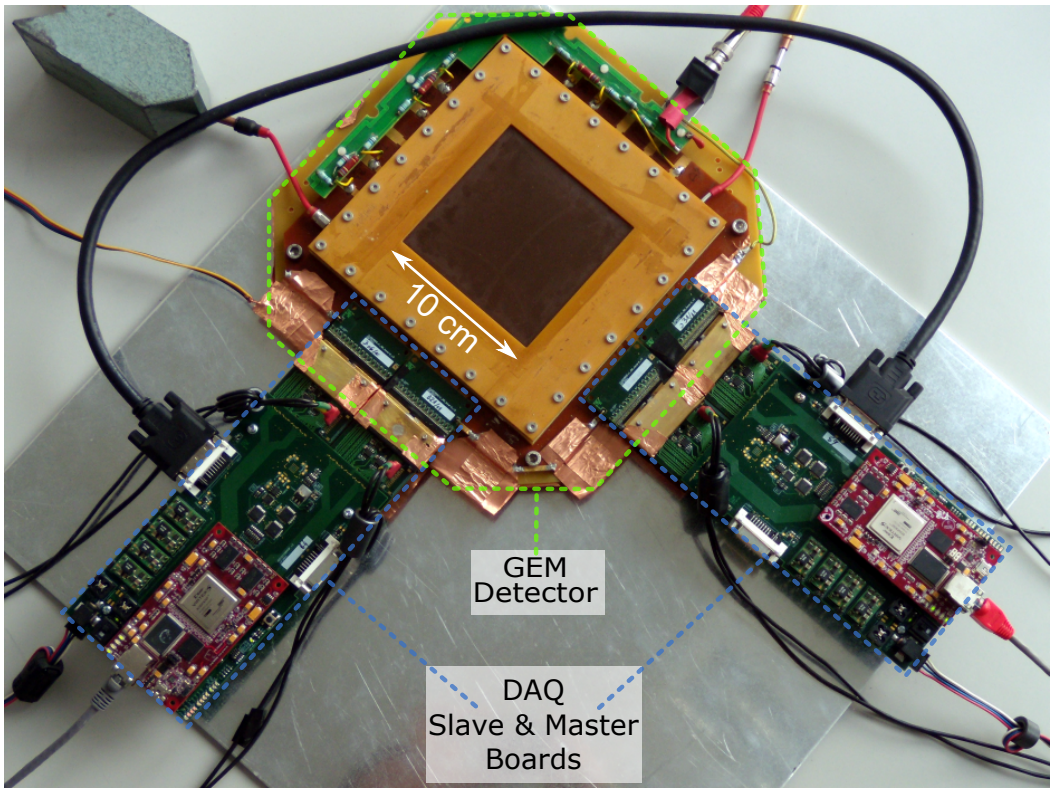
Measurement setup



Main components of the setup:

- Triple-GEM detector with active area $10 \times 10\,\mathrm{cm}^2$ and two-dimensional readout structure.
- Dedicated electronic readout system.
- ^{55}Fe source (7.4 GBq) set in 7 cm distance to detector window.
- Aluminium mask with 9 holes, each one 1 cm in diameter (for local charging-up measurements).

Data Acquisition (DAQ) system

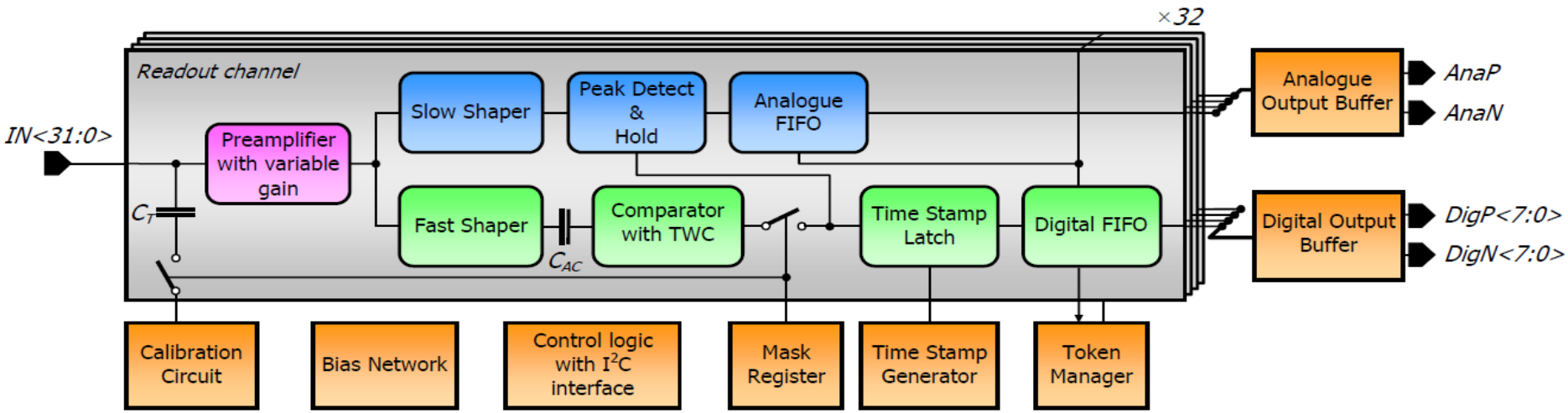


Mindur B. et al. JINST, 8 T01005, 2013.

Components of the system:

- Readout system comprise two DAQ boards (one per coordinate).
- Each DAQ board consists 4 GEMROC ASICs, ADC and FPGA minimodule.
- One coordinate is equipped with 128 readout channels.
- Host PC equipped with C++ based software for communication with DAQ board and preprocessing of incoming raw data.

GEMROC architecture



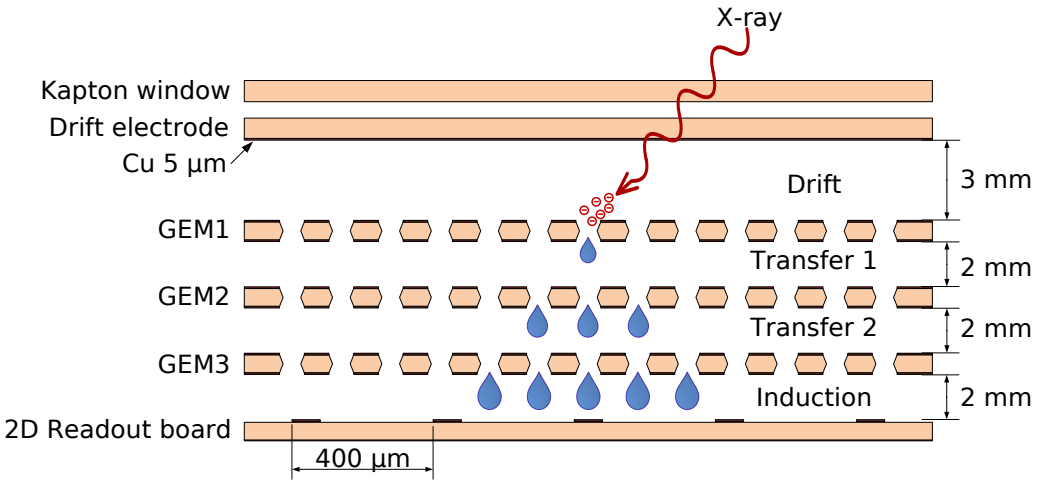
- 32 channels in one ASIC, each channel is split into: slow (energy) and fast (timing) sub-channel.
- Switchable gain (2.5 $\mathrm{mV/fC}$ for low gain, 5 $\mathrm{mV/fC}$ for high gain for slow channel) and signal polarity selection, input charge 0-500 fC.
- Derandomization of data and zero supression in the token-based readout.
- Self triggering mode - readout initiated by the input signals.
- Noise defined as the ENC below 0.5 fC for timing and 0.43 fC for energy sub-channel.
- Minimum discrimination threshold 2.5 fC input equivalent.

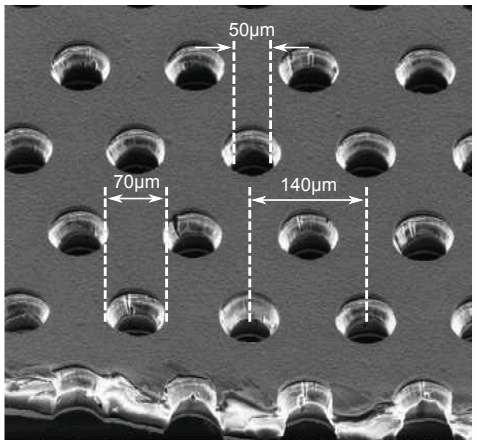
Fiutowski T. IEEE Nuclear Science Symposium Conference Record, pages 1540–1544, 2011.

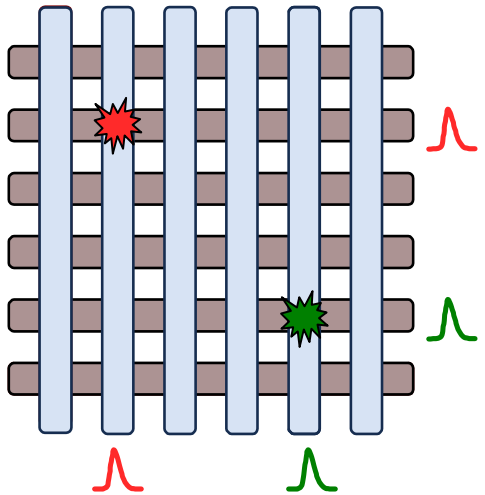
Triple GEM detector

GEM detector parameters

- Active area $10 \times 10\,\mathrm{cm}^2$
- $3\,\mathrm{mm}$ drift gap
- 2D cartesian readout structure 256×256 orthogonal readout strips (128×128 readout channels)
- detector flushed with Ar/CO_2 (70/30%) gas mixture
- Gas gain $\sim 5 \times 10^3$ @ $3{,}950\,\mathrm{V}$
- Gas flow around one detector volume per $4\,\mathrm{h}$

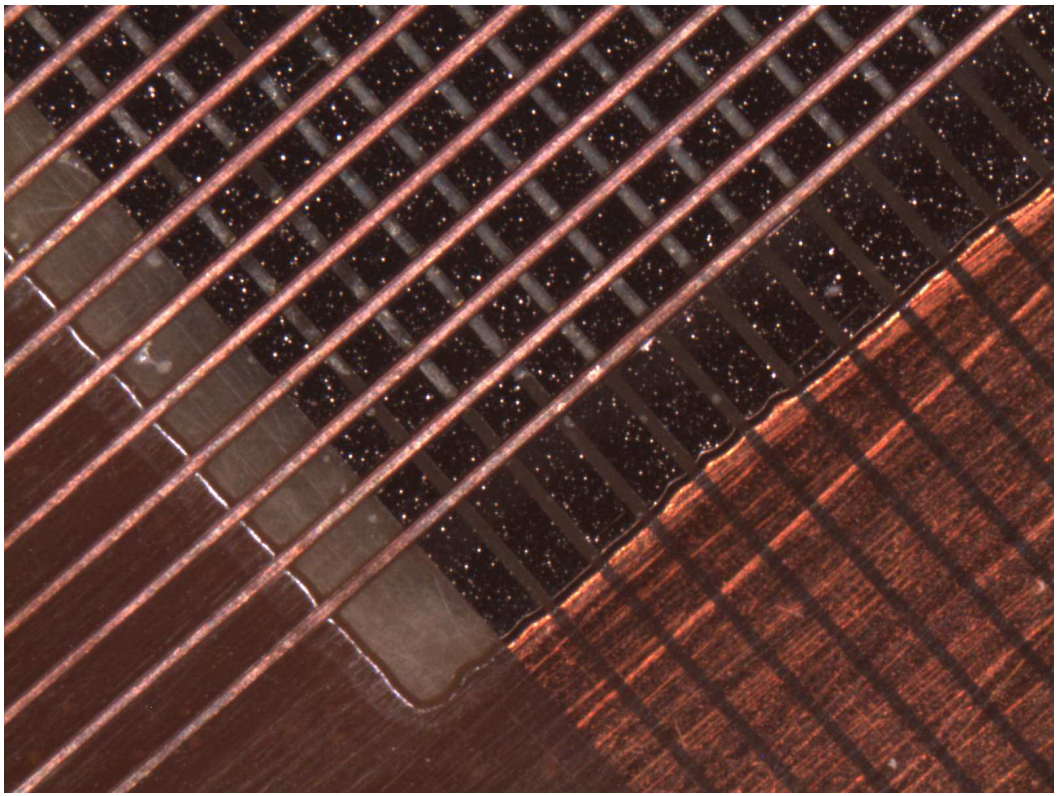






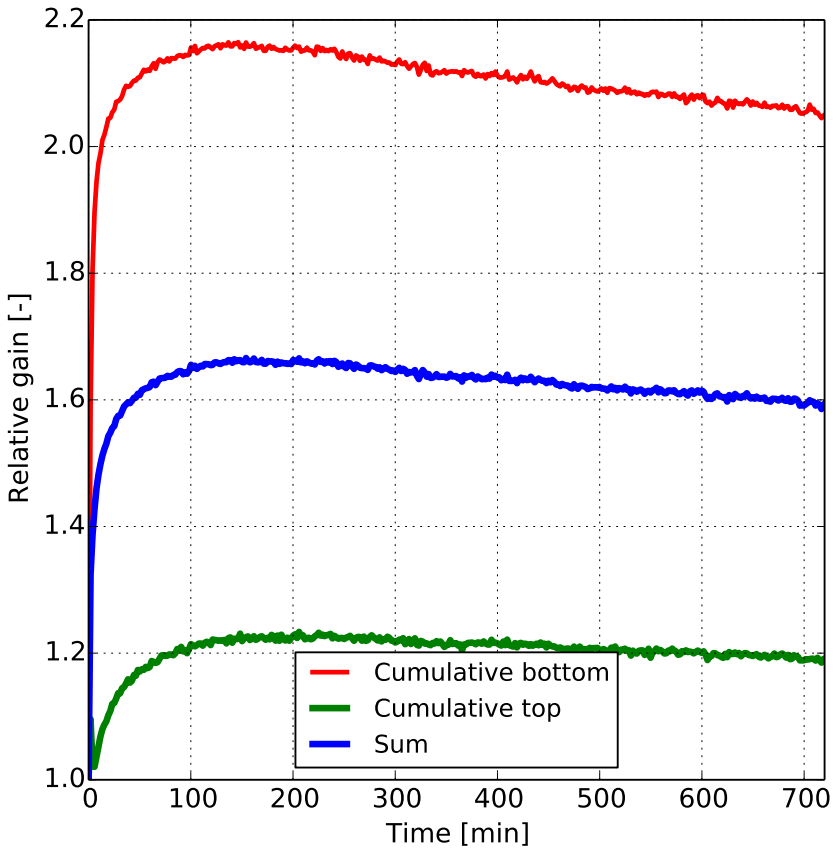
Triple GEM detector – readout structure

Cartesian readout structure



- Pitch $\sim 400\,\mu$m.
- Top strips width $80\,\mu$m.
- Bottom strips width $340\,\mu$m.
- Kapton layer thickness $50\,\mu$m.

Charging-up and discharging - presentation of the results

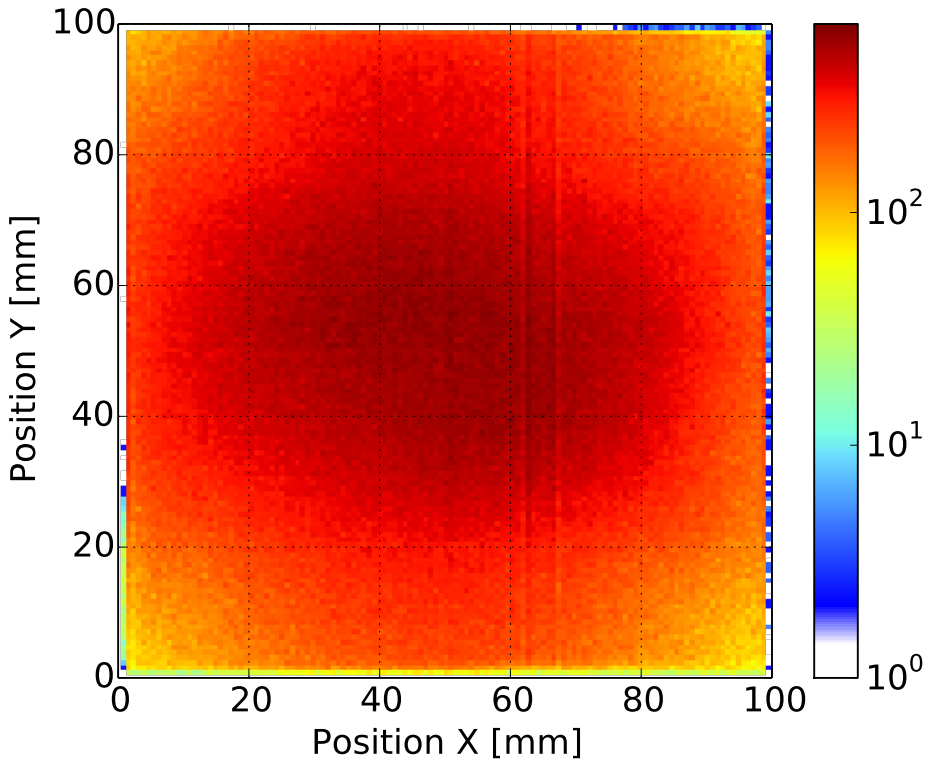


Presentation of the results

- Charging-up and discharging effects shown for three **GEM foils together with readout structure (cumulative effect)**.
- Charging-up and discharging effects shown for **three GEM foils** (readout excluded) as a total charge recorded on the readout structure (top and bottom strips).
- Charging-up and discharging effects shown only for **the readout structure** (GEM foils excluded), for bottom ($\text{RelativeGain}_{Bottom}$ - $\text{RelativeGain}_{Sum}$) and top ($\text{RelativeGain}_{Top}$ - $\text{RelativeGain}_{Sum}$) strips.

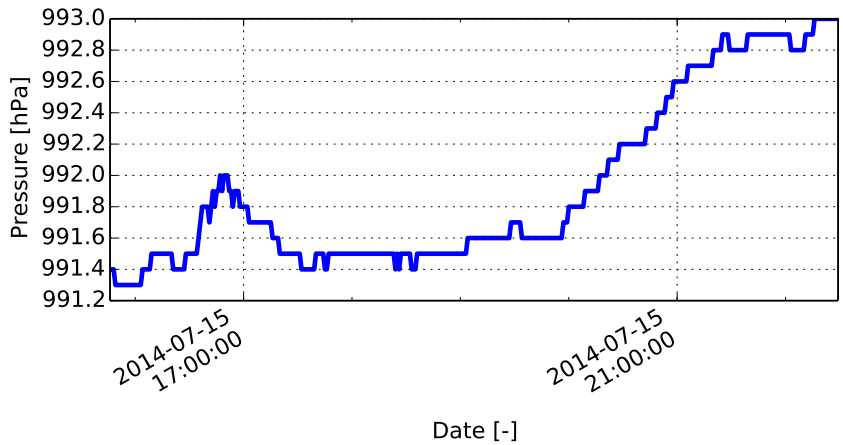
Global charging-up measurements

Intensity map for global charging-up mesurements. The whole detector area illuminated with non-uniform intensity.



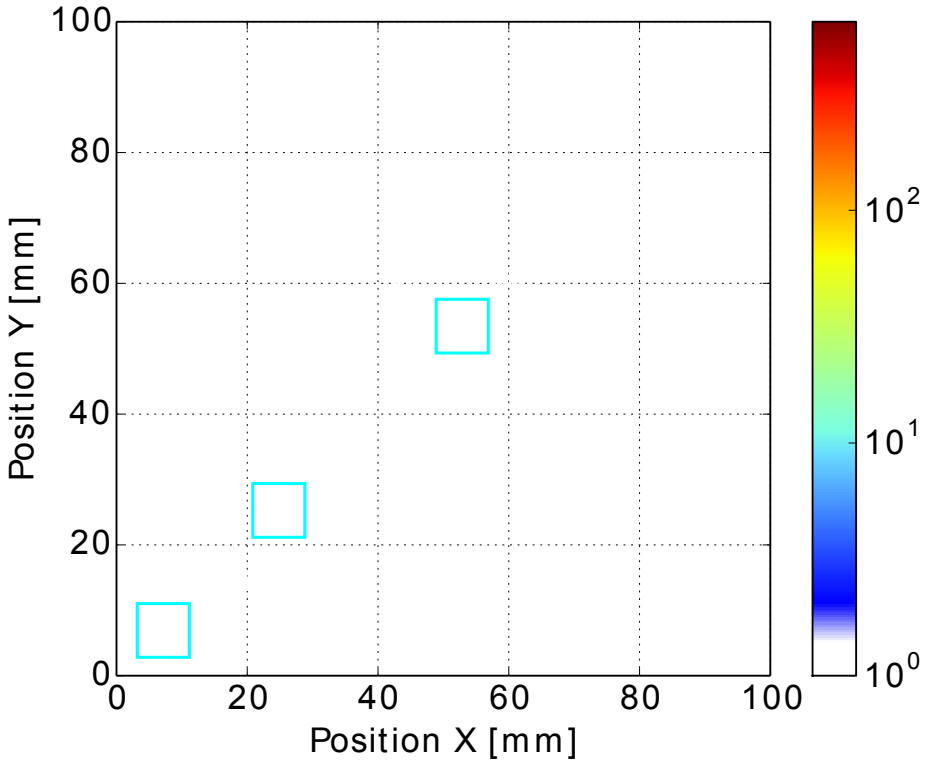
Measurement conditions

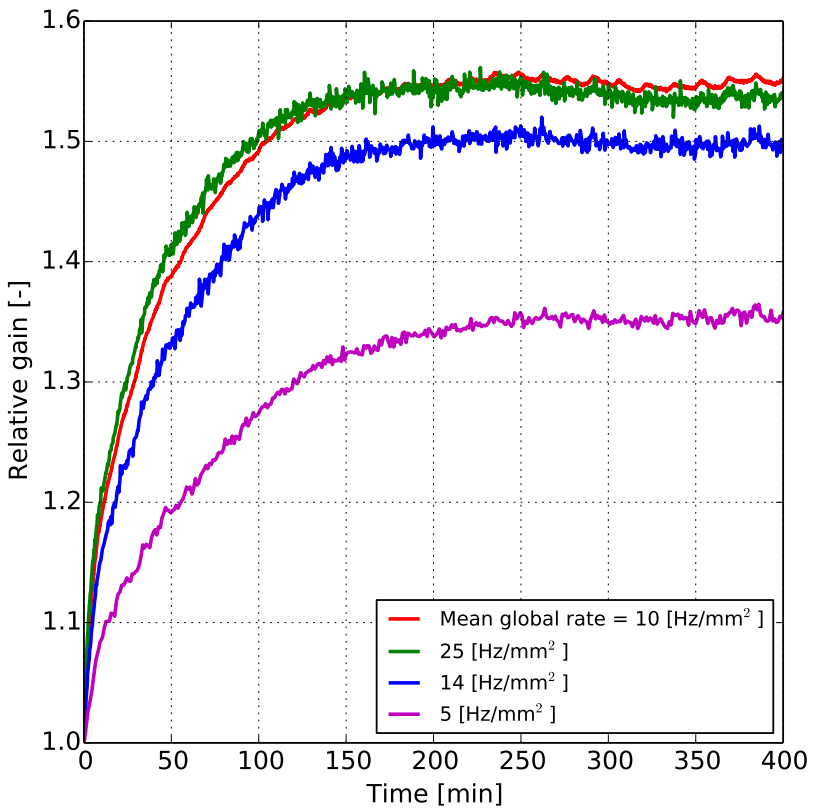
- Fe-55 source.
- Measurement time $\sim 6.7\,\mathrm{h}$.
- Temperature and atmosheric pressure monitoring.



Global charging-up measurements

Charging-up effect for **three GEM foils** for whole detector area (red line) and for three chosen detector locations (around $41\ \mathrm{mm}^2$ each one).

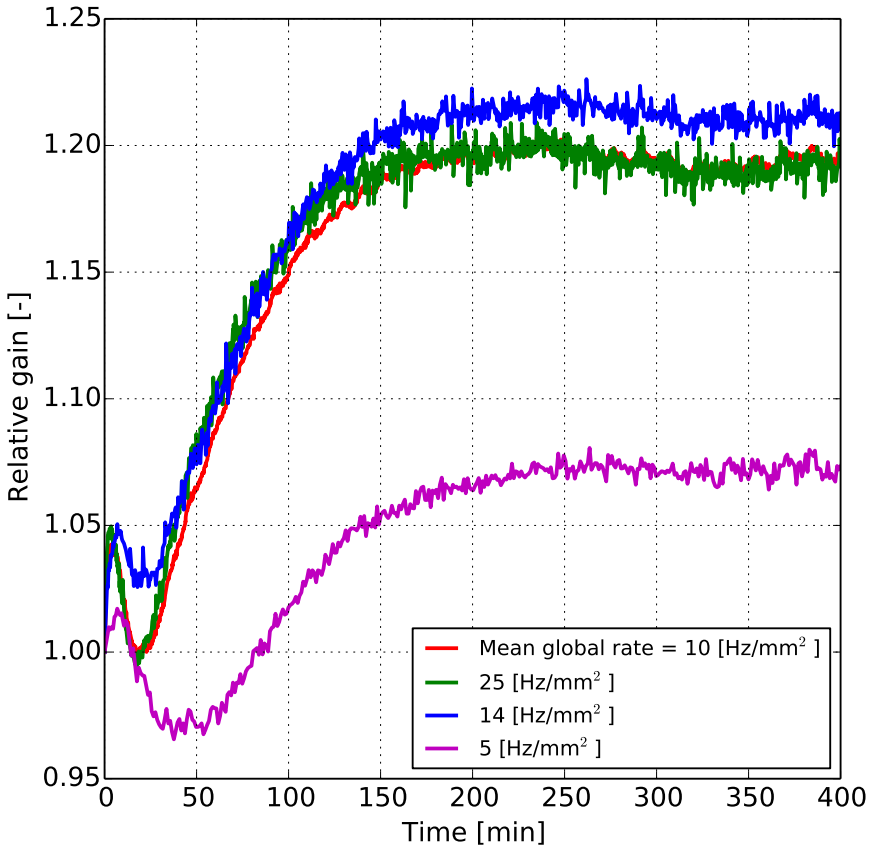




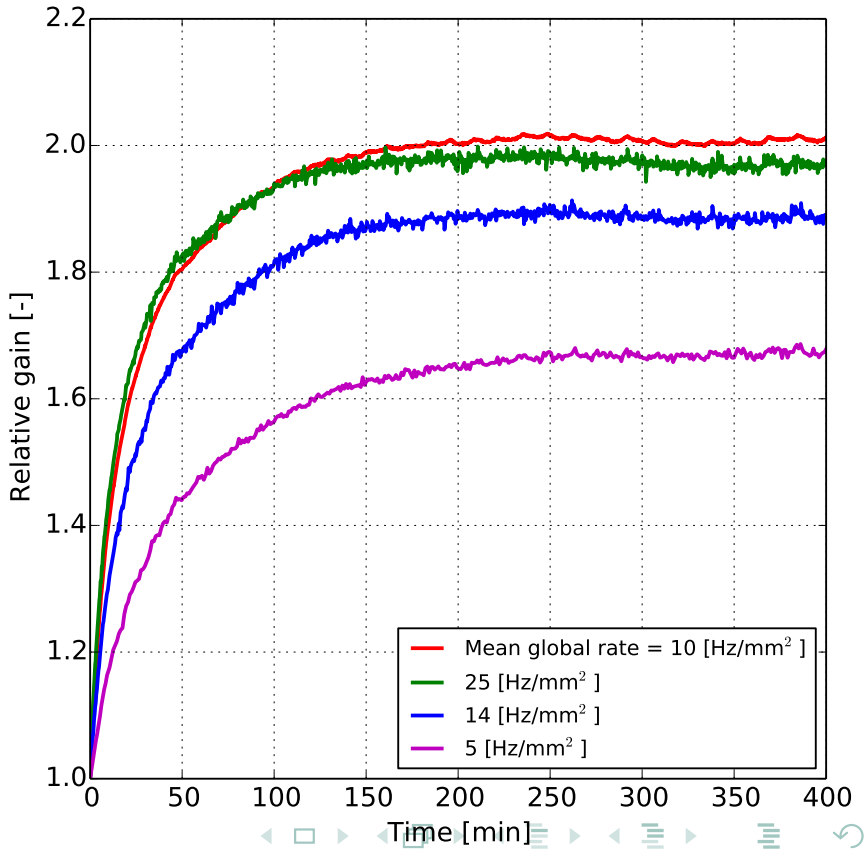
Global charging-up measurements

Cumulative charging-up effect for **three GEM foils and readout structure**.

Top strips



Bottom strips



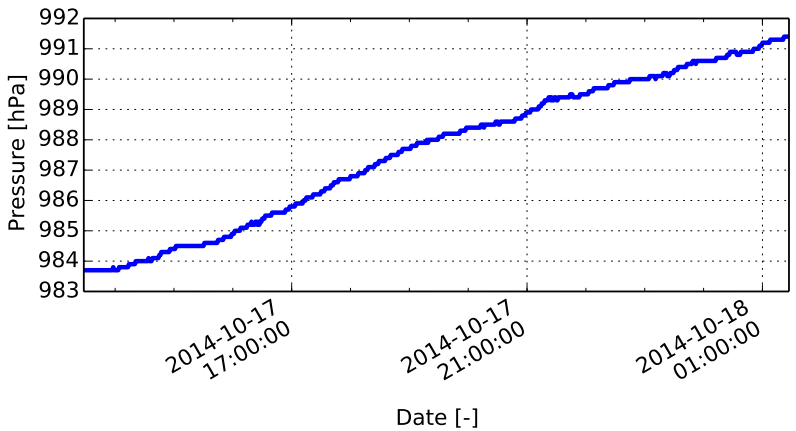
Global charging-up measurements

- Relative gain change for GEMs is 54 % for maximum rate ($25\,\mathrm{Hz/mm^2}$).
- Relative gain change for cumulative effect for top strips is lower then for bottom strips.
  - For top strips is around 22 % (at $25\,\mathrm{Hz/mm^2}$).
  - For bottom strips is around 100 % (at $25\,\mathrm{Hz/mm^2}$).

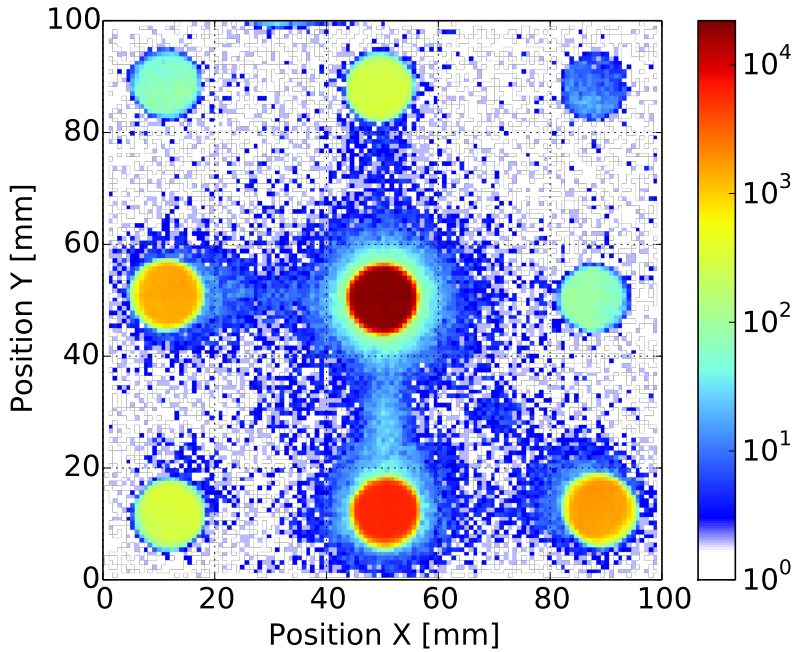
Local charging-up measurements

Measurement conditions

- Fe-55 source.
- Total measurement time 12 h.
- Performed simultaneously for different detector locations at different rates.
- Aluminium mask with nine holes, each one covered with aluminium absorbers of different thickness.
- Temperature and atmosheric pressure monitoring.

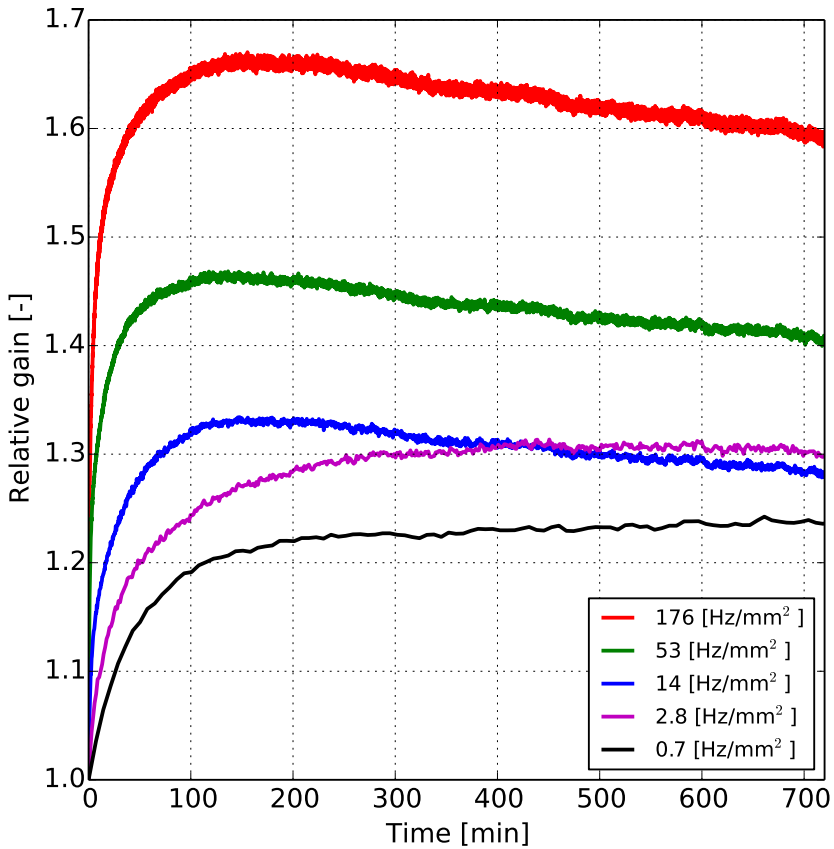


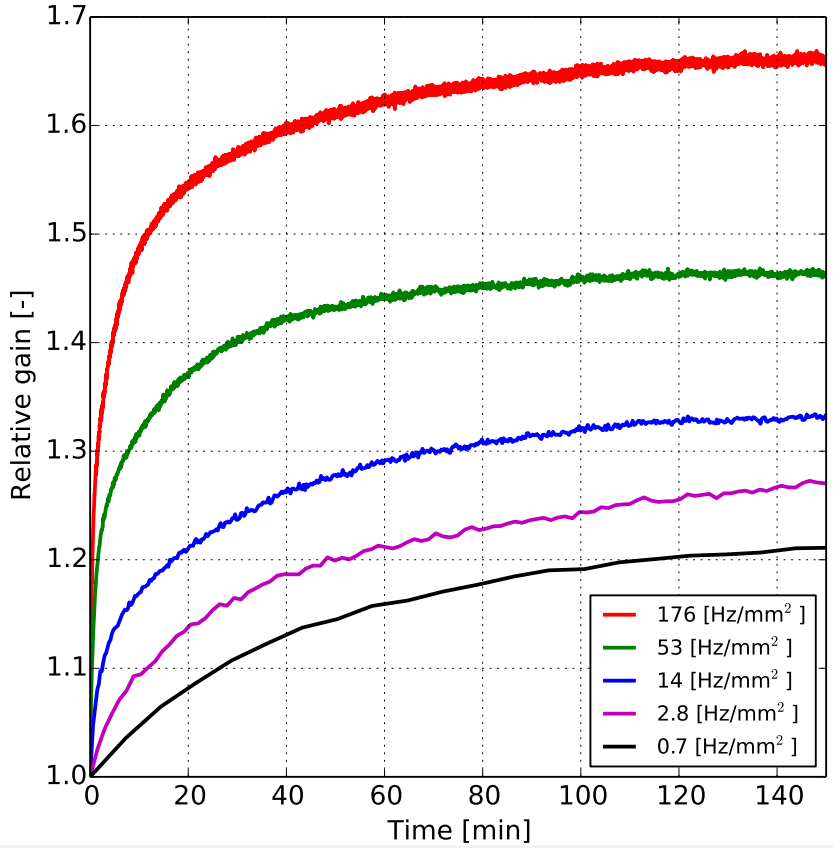
Intensity map obtained for local charging-up measurements.



Local charging-up measurements

Charging-up effect for **three GEM foils** at 5 different rates.





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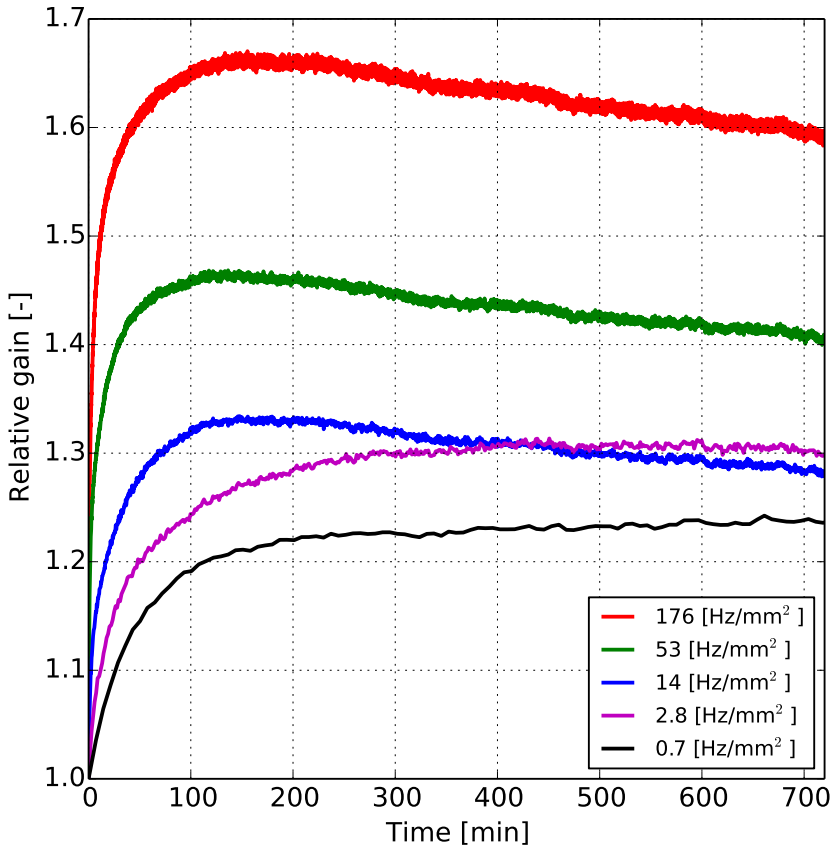
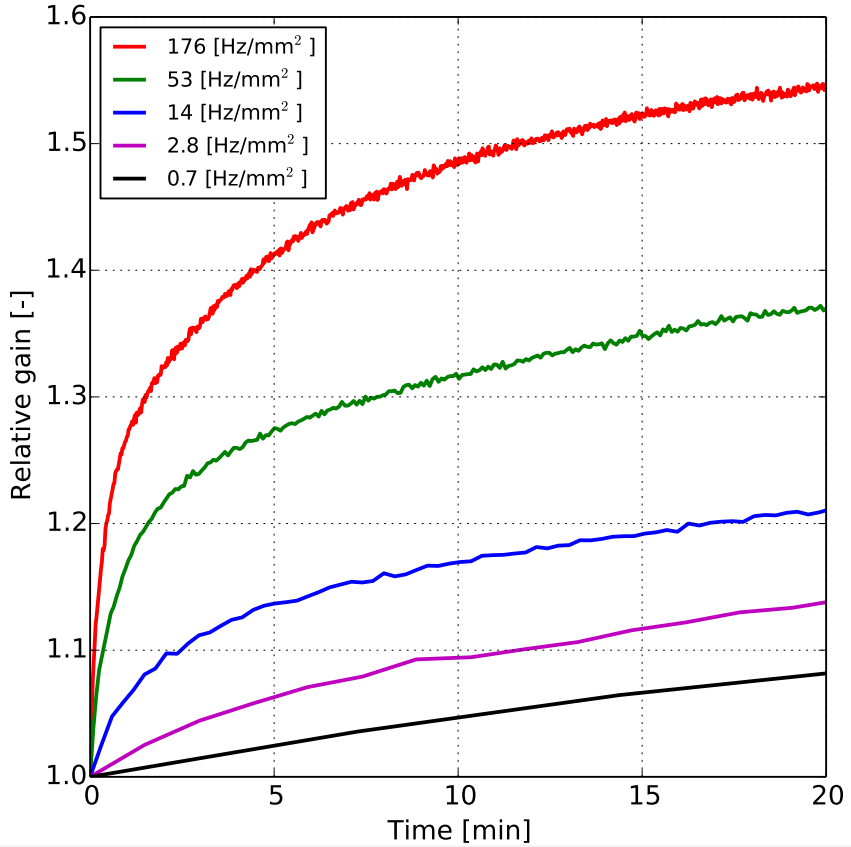
Local charging-up measurements

Charging-up effect for **three GEM foils** at 5 different rates.





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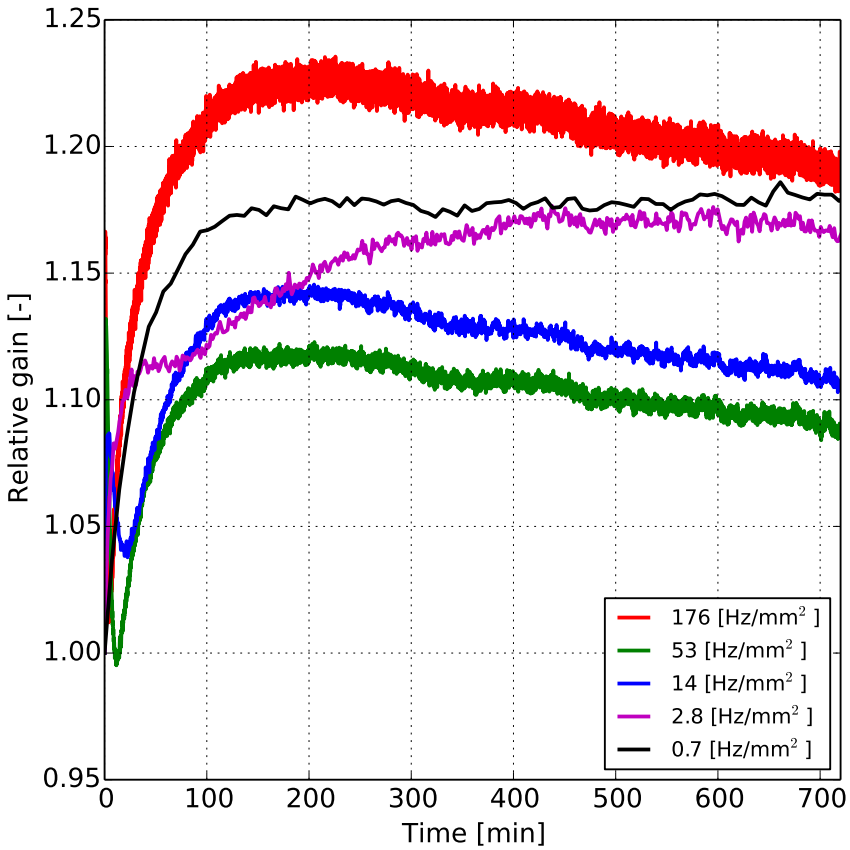
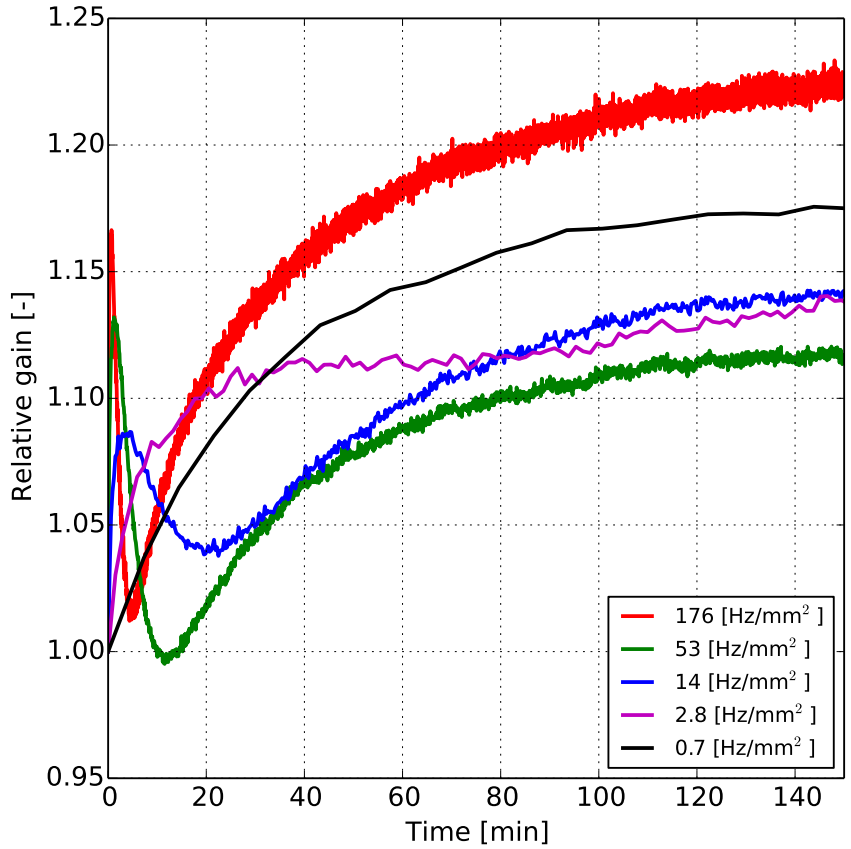
Local charging-up measurements

Cumulative charging-up effect for **top strips** and GEM foils.





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Local charging-up measurements

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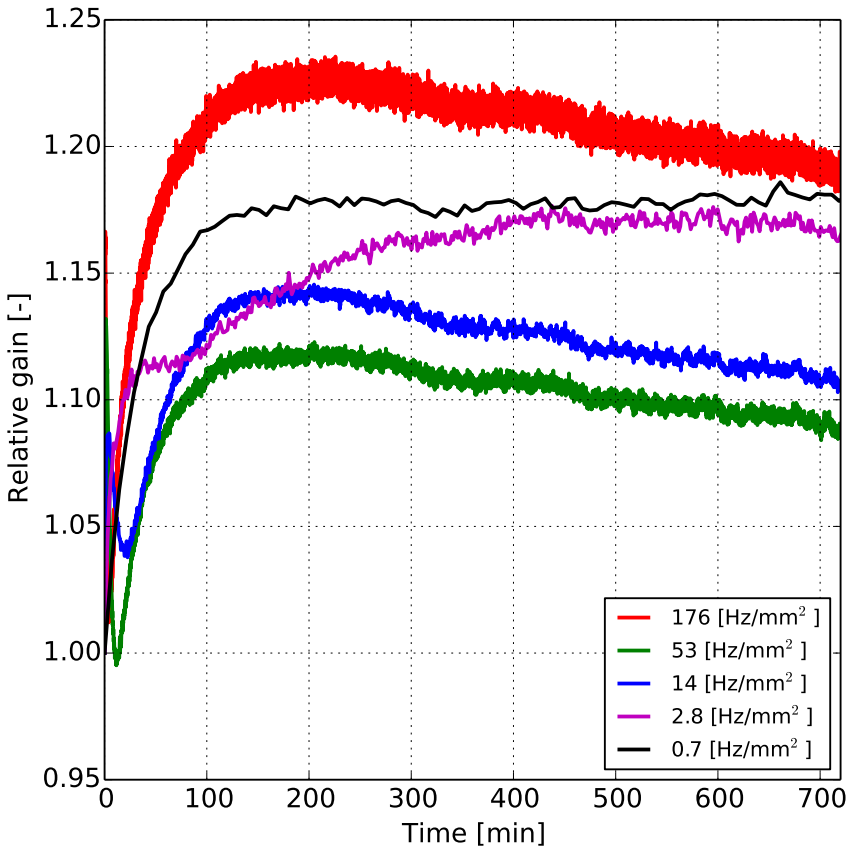

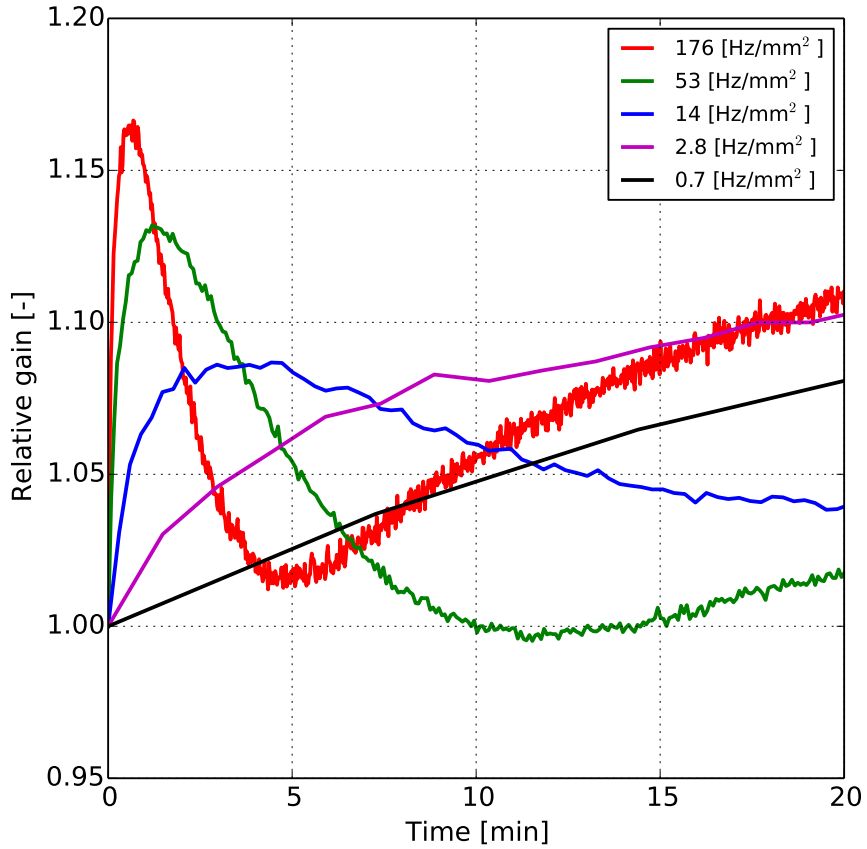

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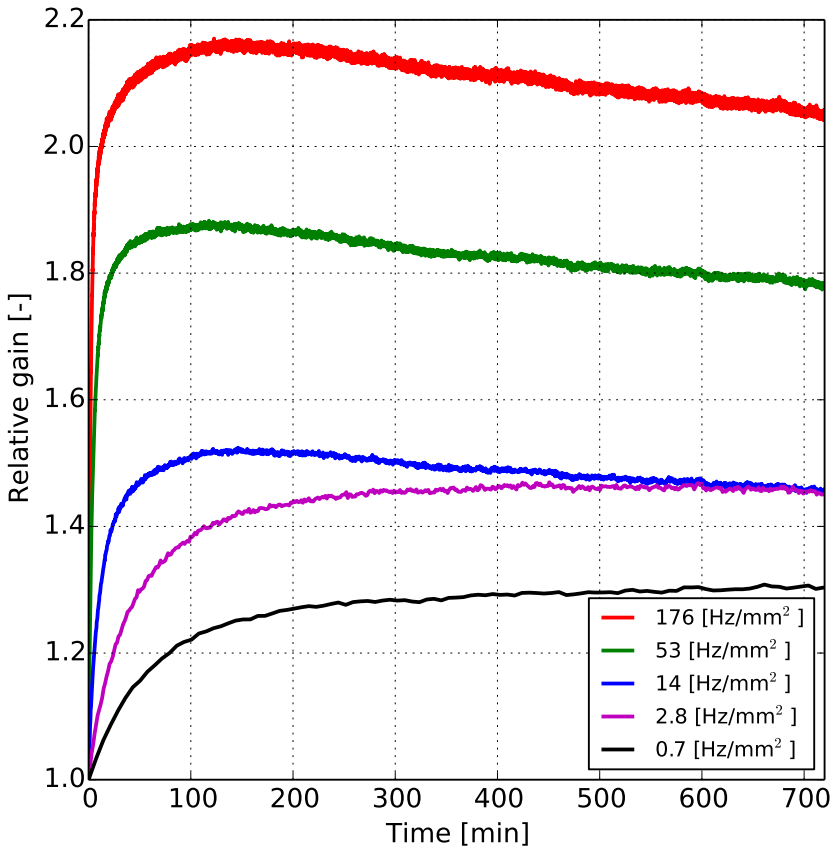
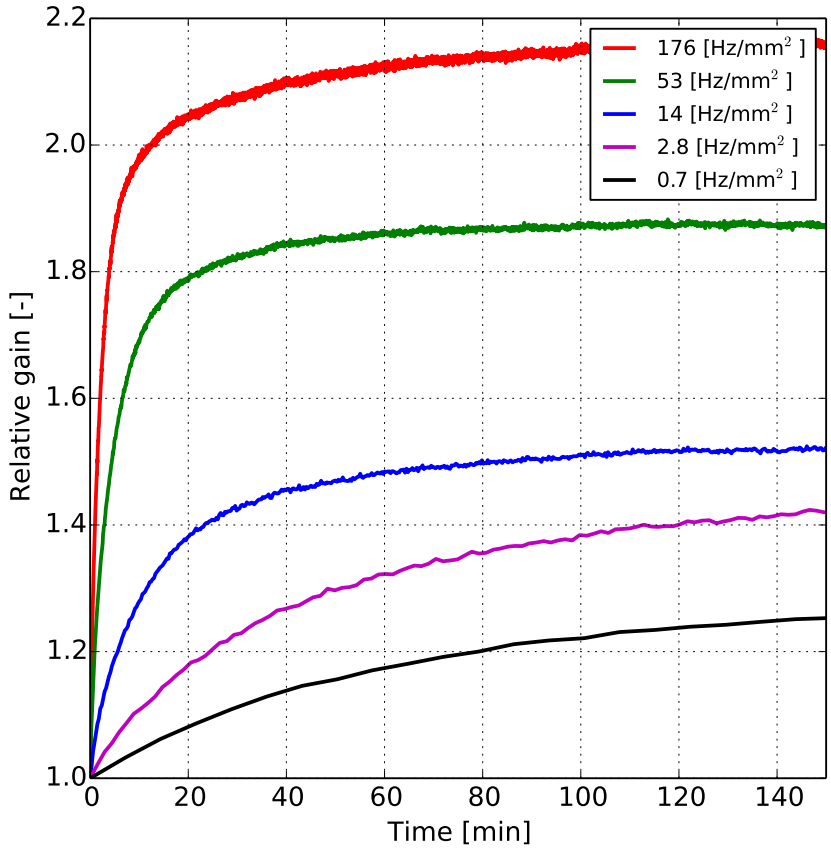
Local charging-up measurements

Cumulative charging-up effect for **bottom strips** and GEM foils.





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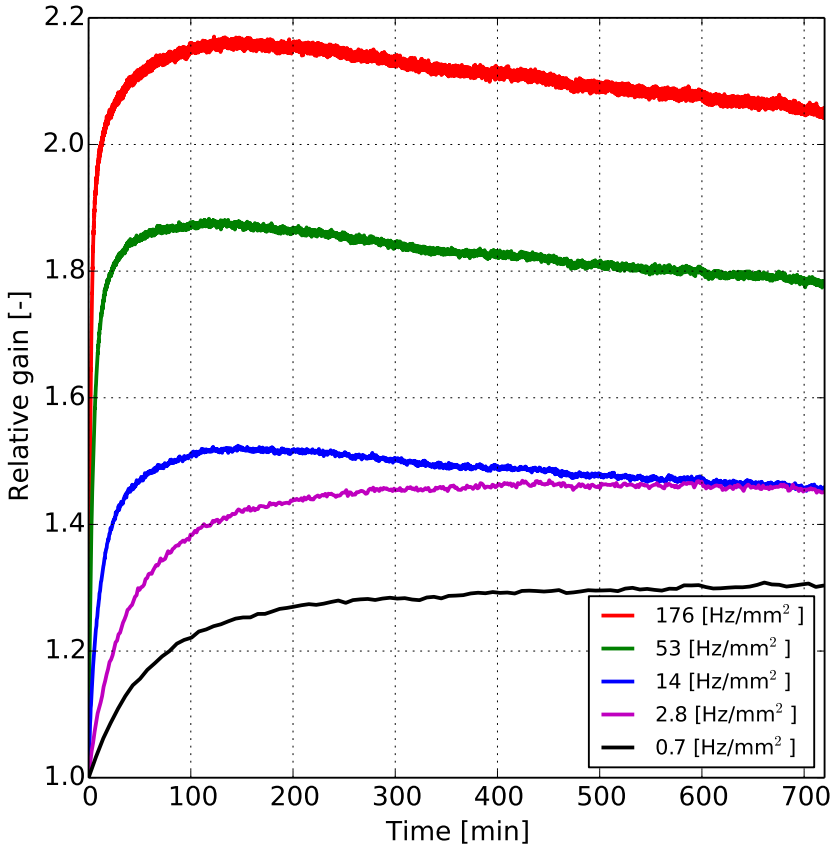
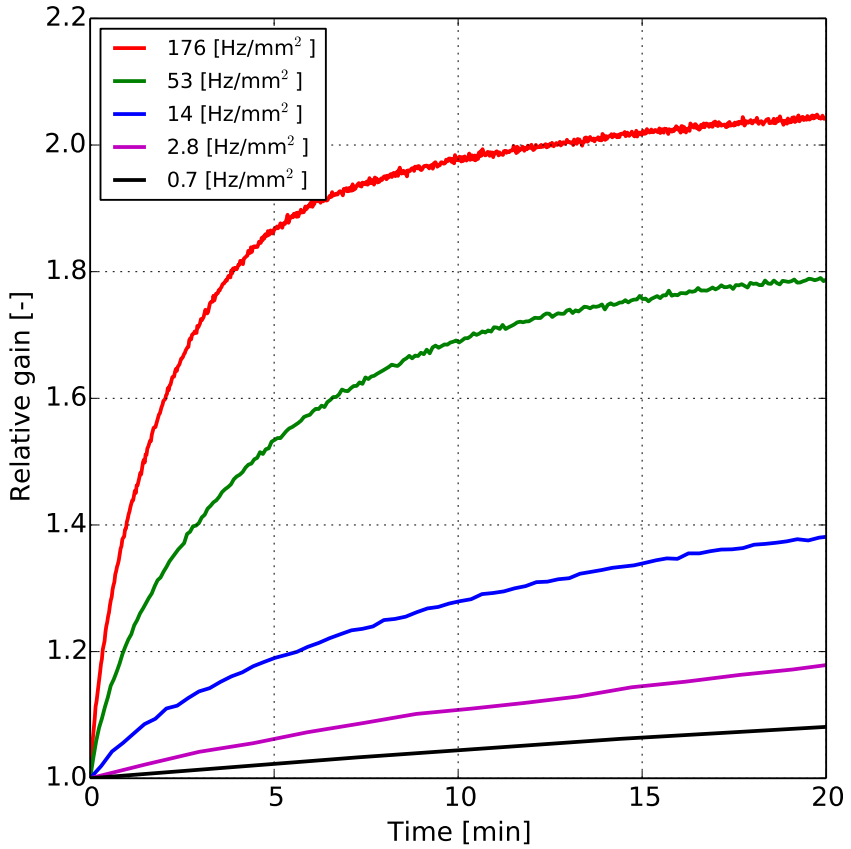
Local charging-up measurements

Cumulative charging-up effect for **bottom strips** and GEM foils.





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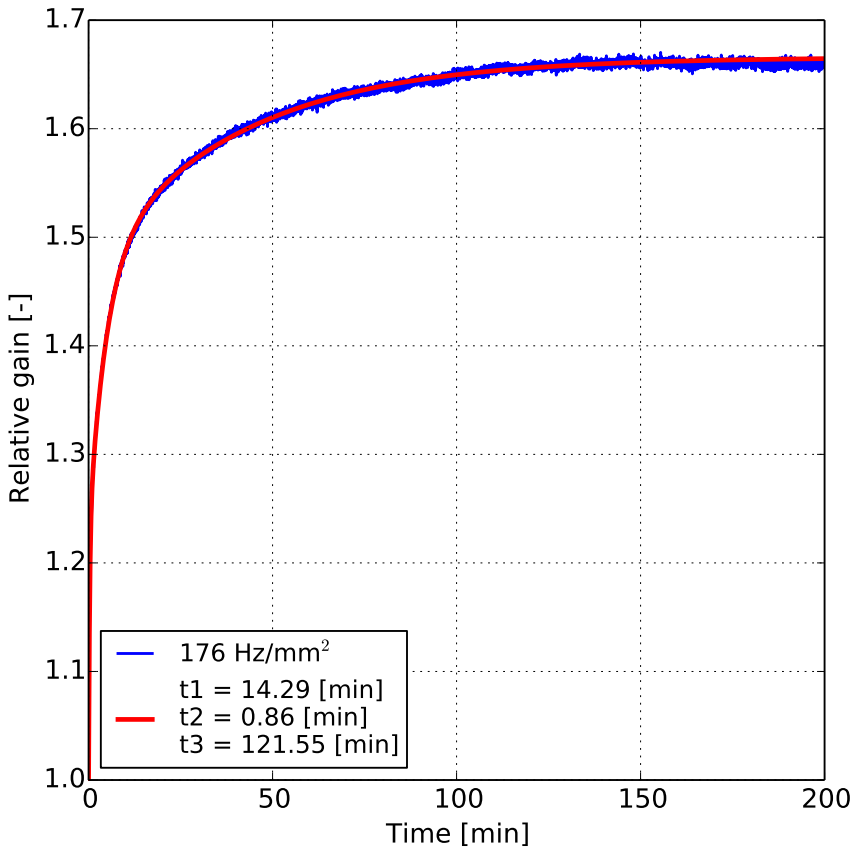
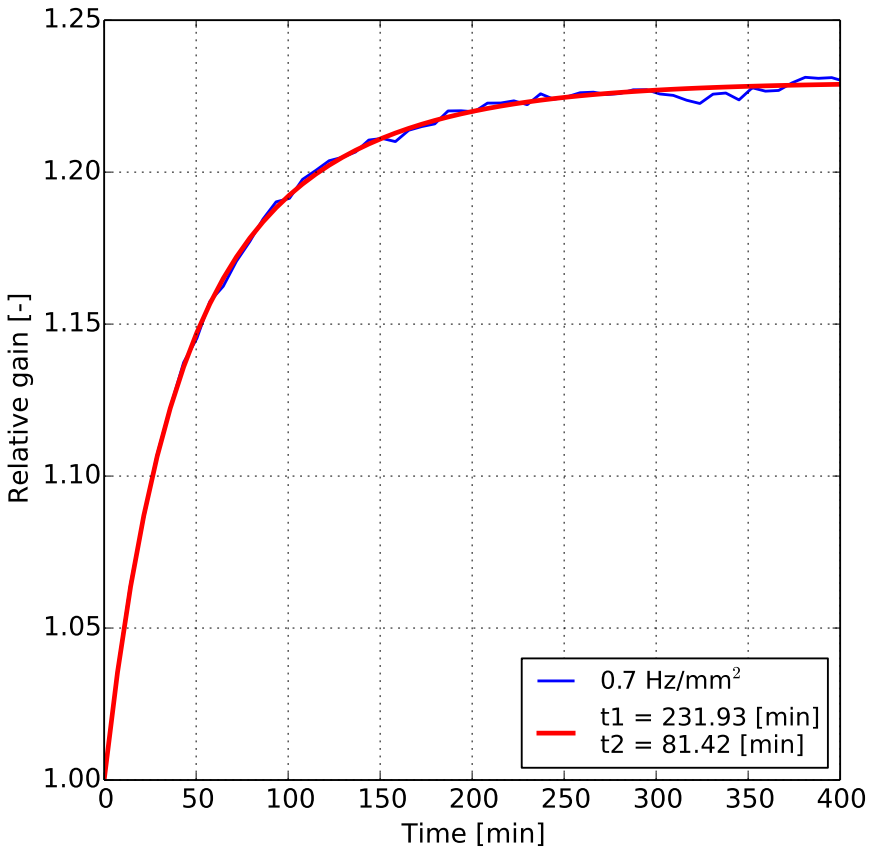
Local charging-up measurements

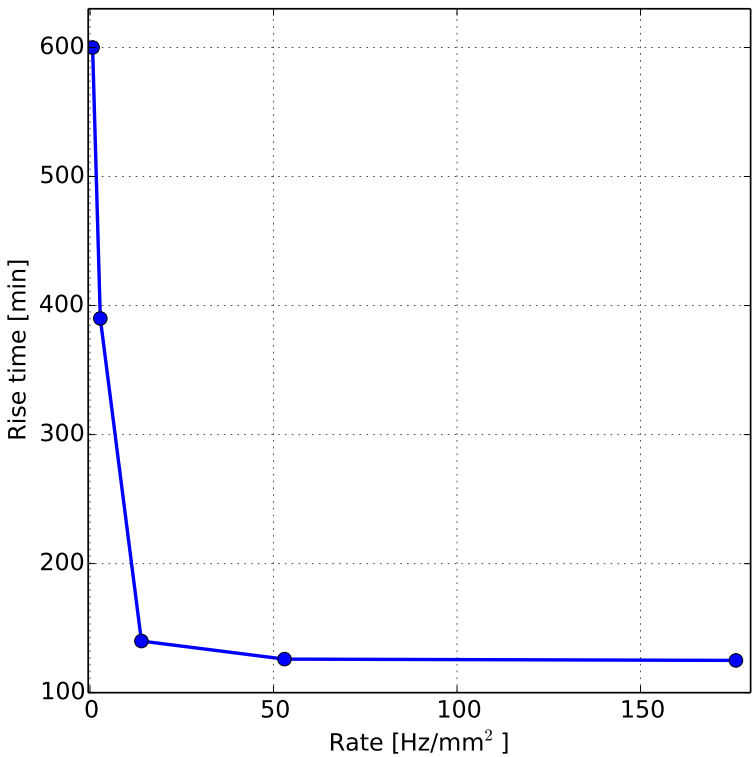
Charging-up time calculated for the highest rate ($176\,\mathrm{Hz/mm^2}$) and the lowest rate ($0.7\,\mathrm{Hz/mm^2}$) for **three GEMs** (sum for top and bottom).

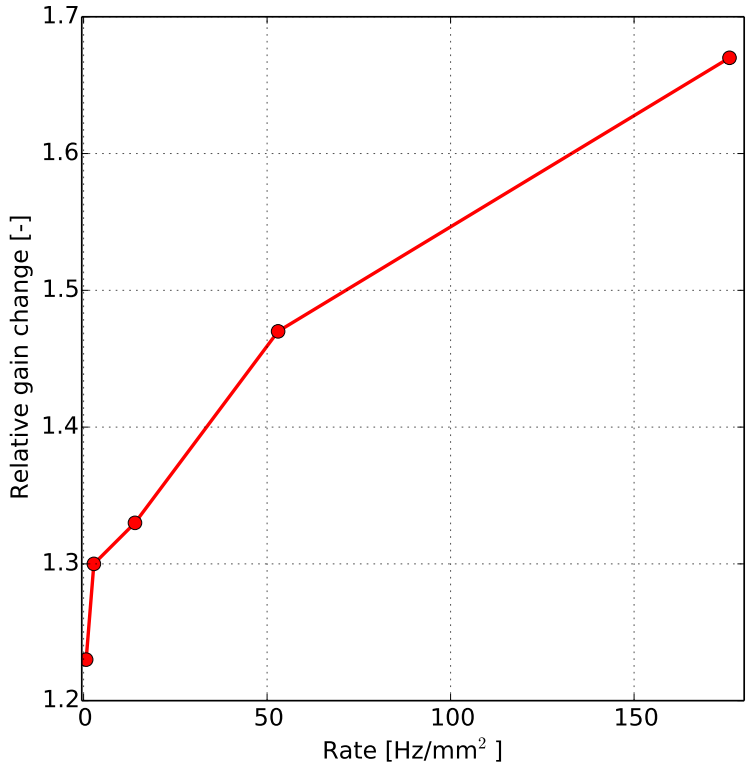




Local charging-up measurements

Dependence of the rise time and relative gain change on rate for **three GEMs** (sum for top and bottom).

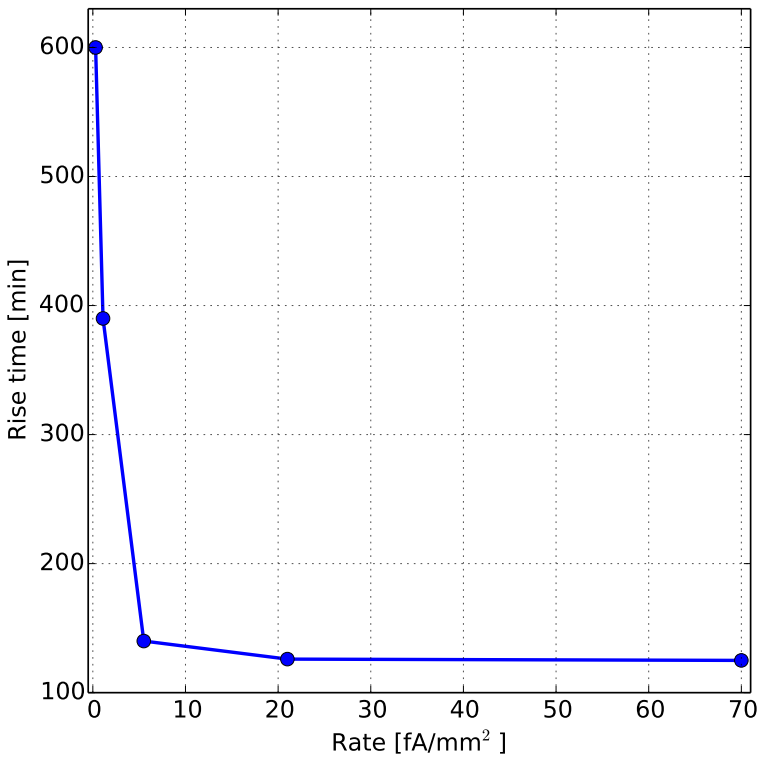


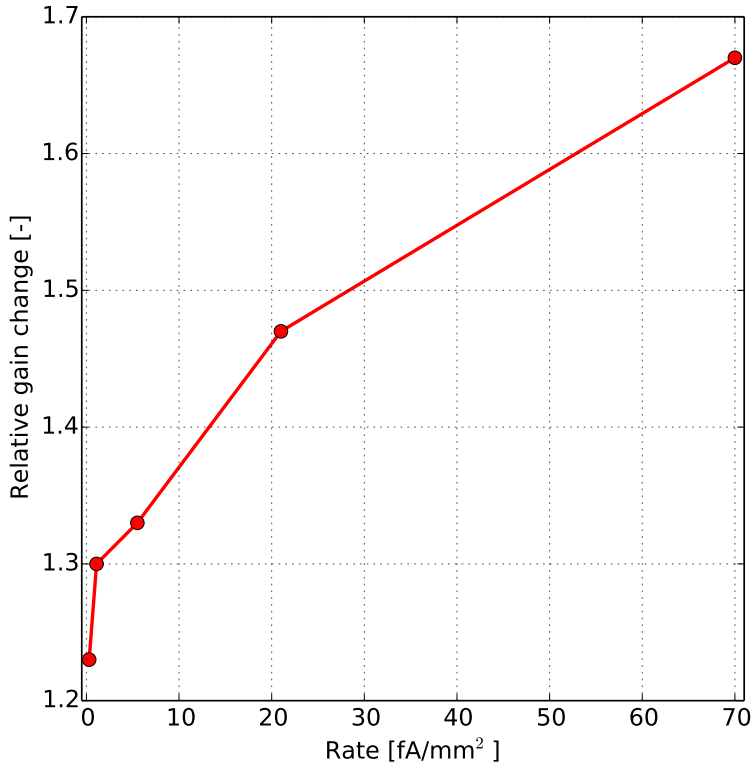


Rise time - defined for 95 % of the maximum value.

Local charging-up measurements

Dependence of the rise time and relative gain change on rate for **three GEMs** (sum for top and bottom).





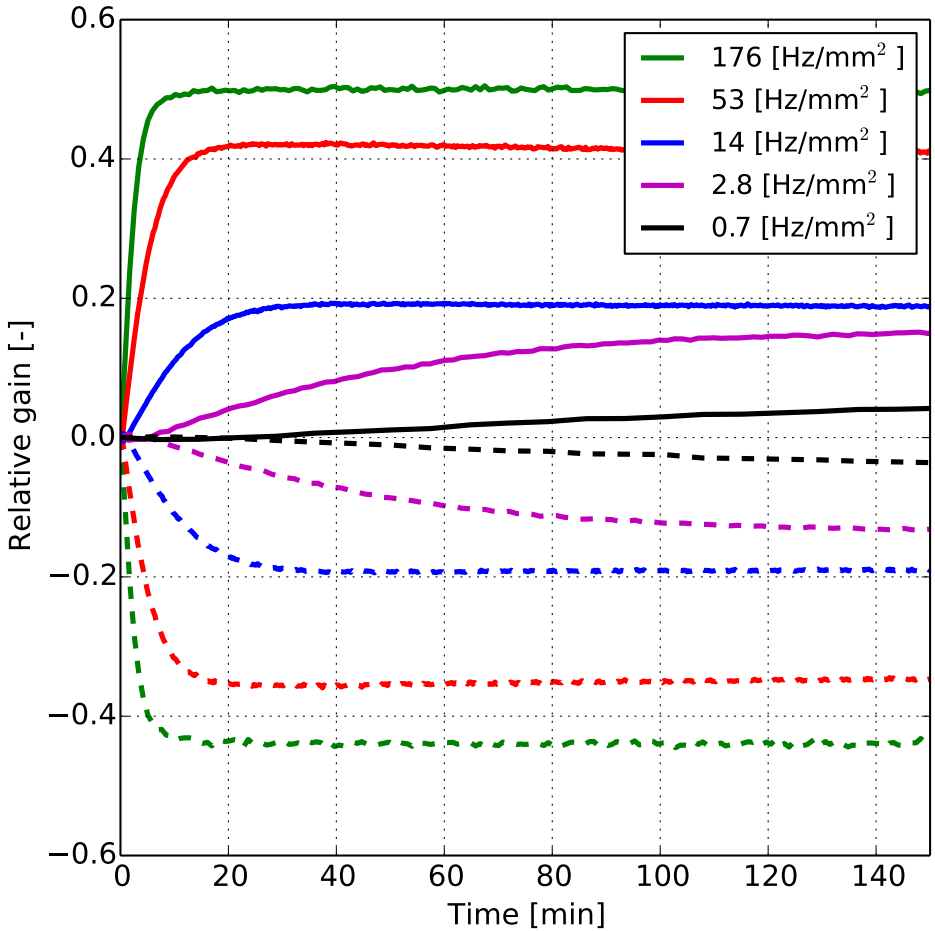
Rise time - defined for 95 % of the maximum value.

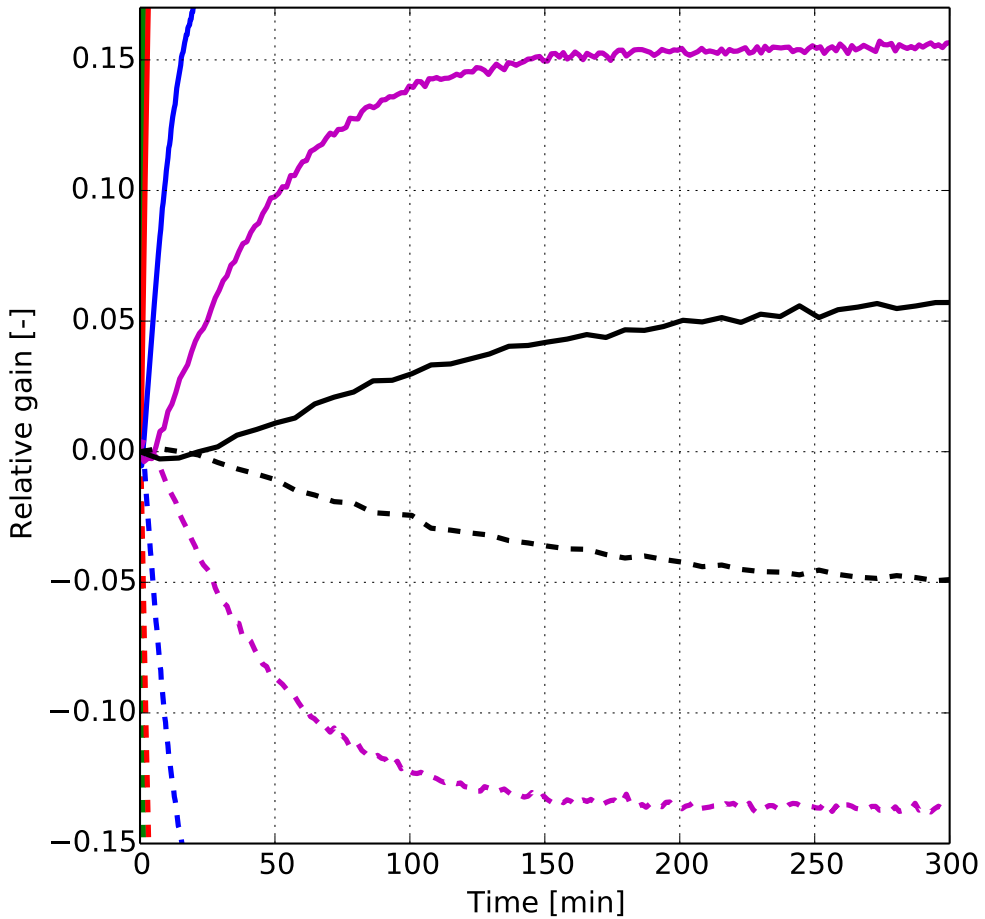
Local charging-up measurements

- Relative gain change for GEMs is 67 % for maximum rate ($176\,\mathrm{Hz/mm^2}$) and 23 % for the lowest rate ($0.7\,\mathrm{Hz/mm^2}$).
- Relative gain change for cumulative effect for top strips is around 23 % and almost 120 % for bottom strips (at $176\,\mathrm{Hz/mm^2}$).
- Charging time is longer for lower rates (around 600 min at $0.7\,\mathrm{Hz/mm^2}$), for maximum rate is around 120 min.

Charging-up of the readout structure

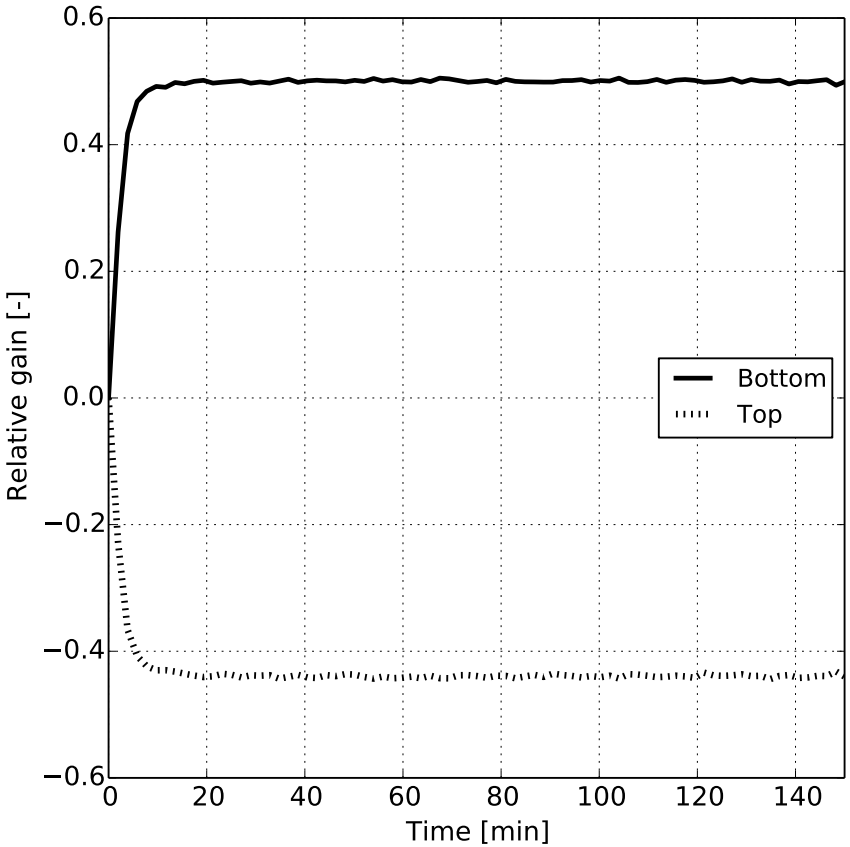
Charging-up of the readout structure for bottom (solid lines) and top (dashed lines) strips.

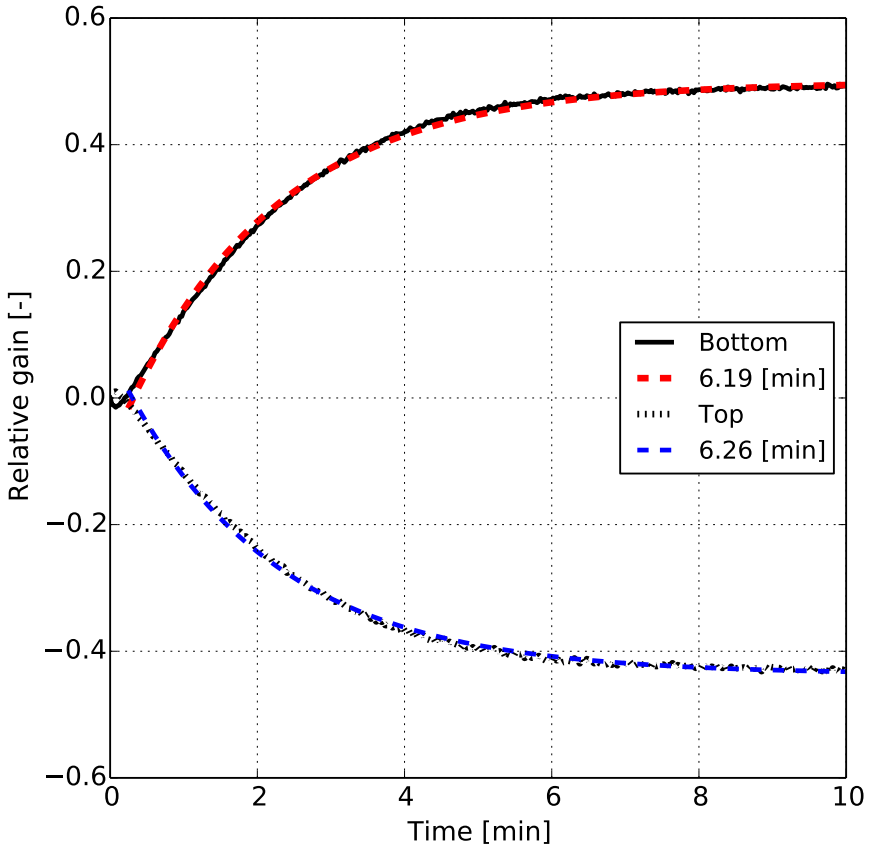




Charging-up of the readout structure

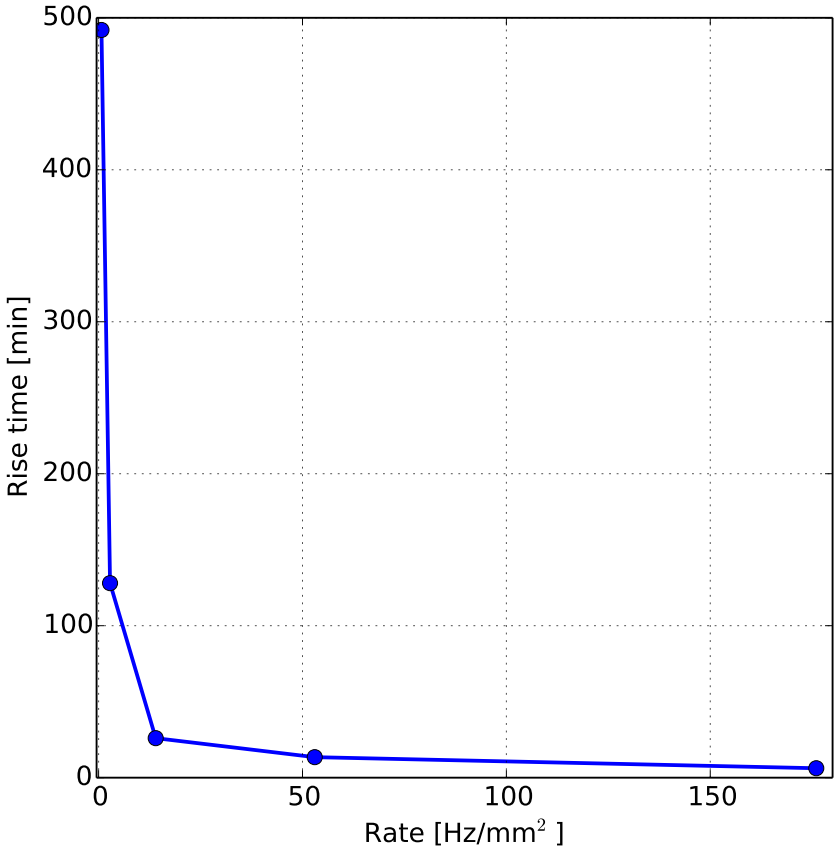
Rate $176\,\mathrm{Hz/mm^2}$

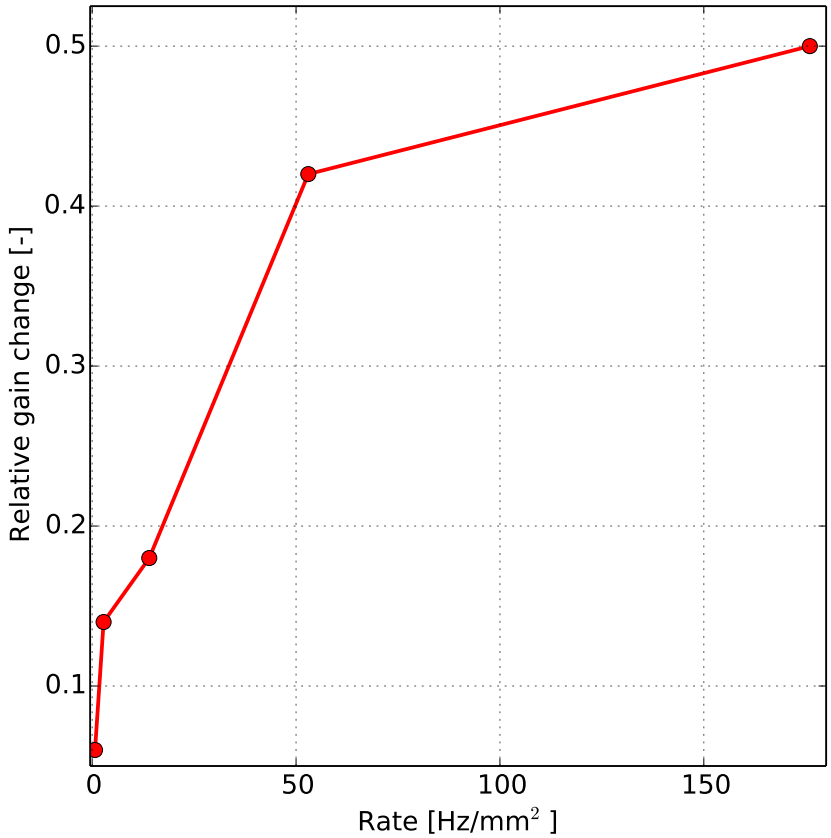




Charging-up of the readout structure

Dependence of the rise time and relative gain change on rate for bottom strips.

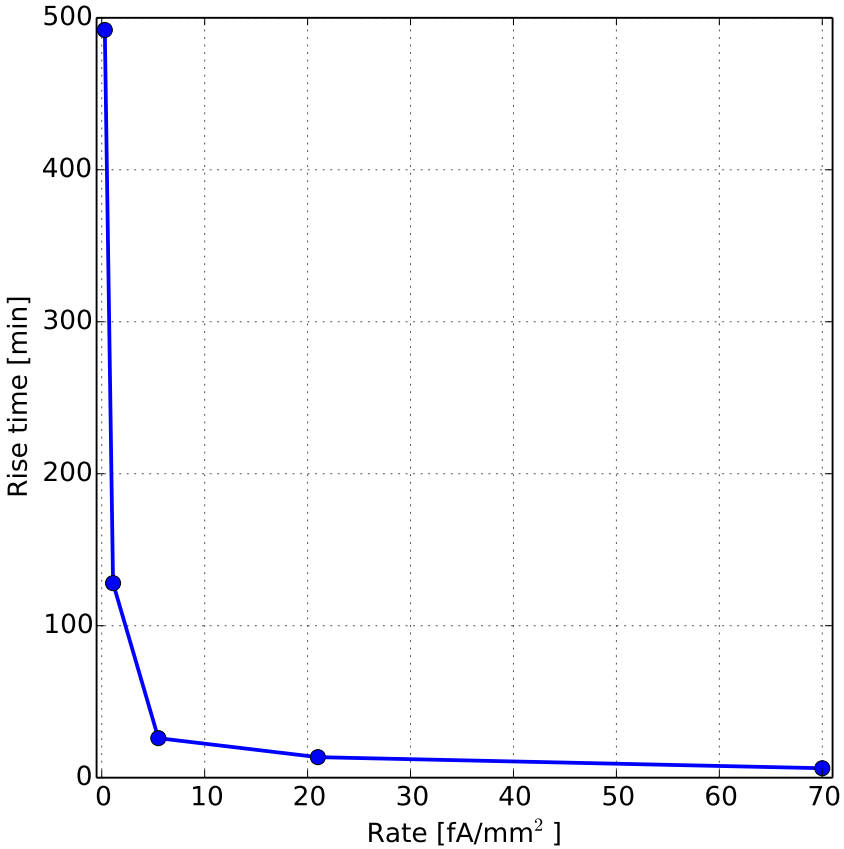


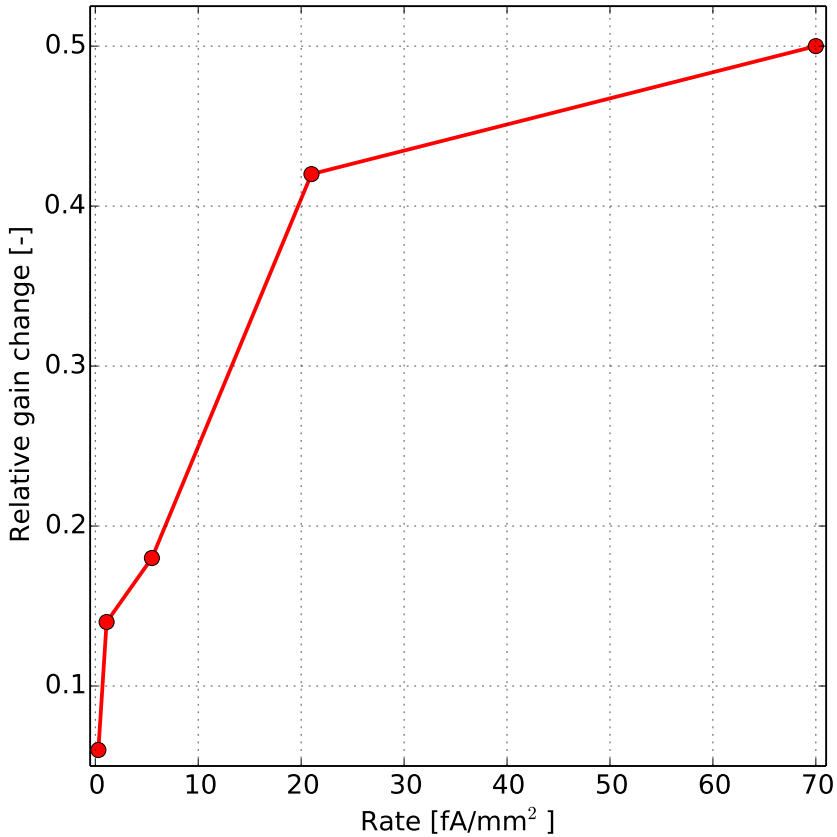


Rise time - defined for 95 % of the maximum value.

Charging-up of the readout structure

Dependence of the rise time and relative gain change on rate for bottom strips.





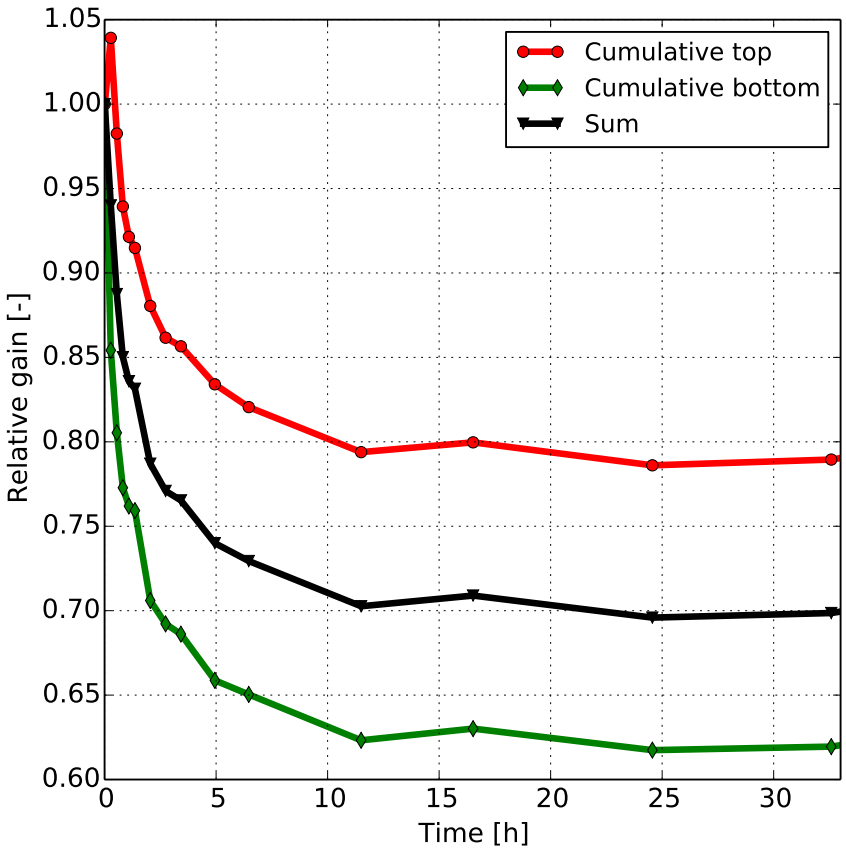
Rise time - defined for 95 % of the maximum value.

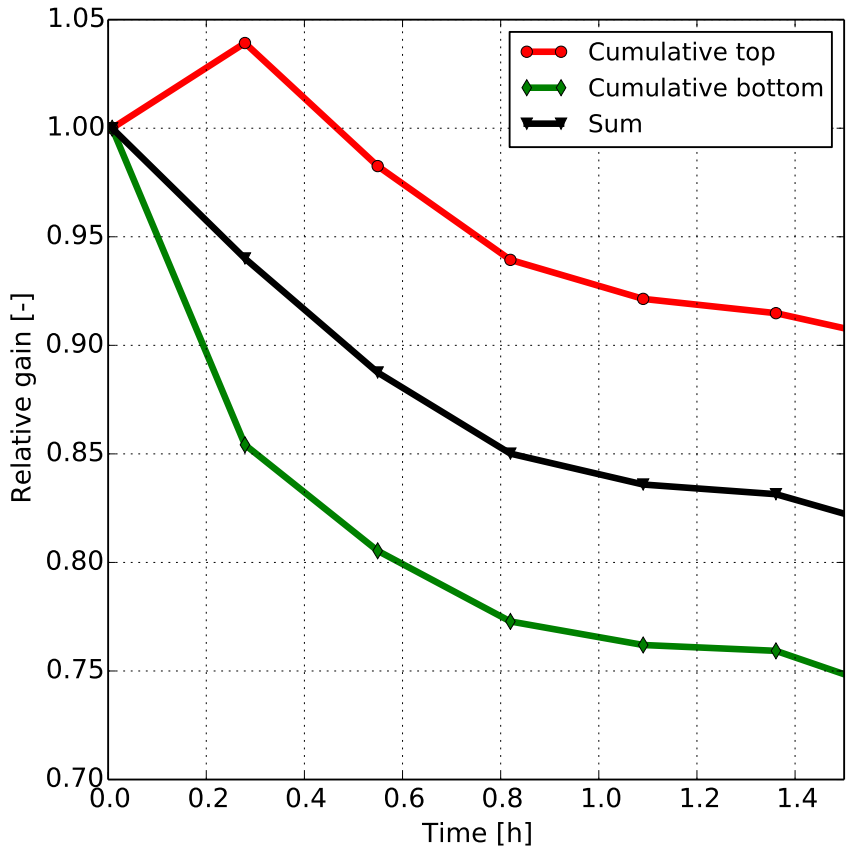
Charging-up of the readout structure

- Relative gain change for the readout structure is around 50 % for maximum rate ($176\,\mathrm{Hz/mm^2}$) and 6 % for the lowest rate ($0.7\,\mathrm{Hz/mm^2}$).
- Charging time for readout structure is shorter than for GEMs charging-up effect, equals around 6 min at $176\,\mathrm{Hz/mm^2}$),

Discharging measurements results

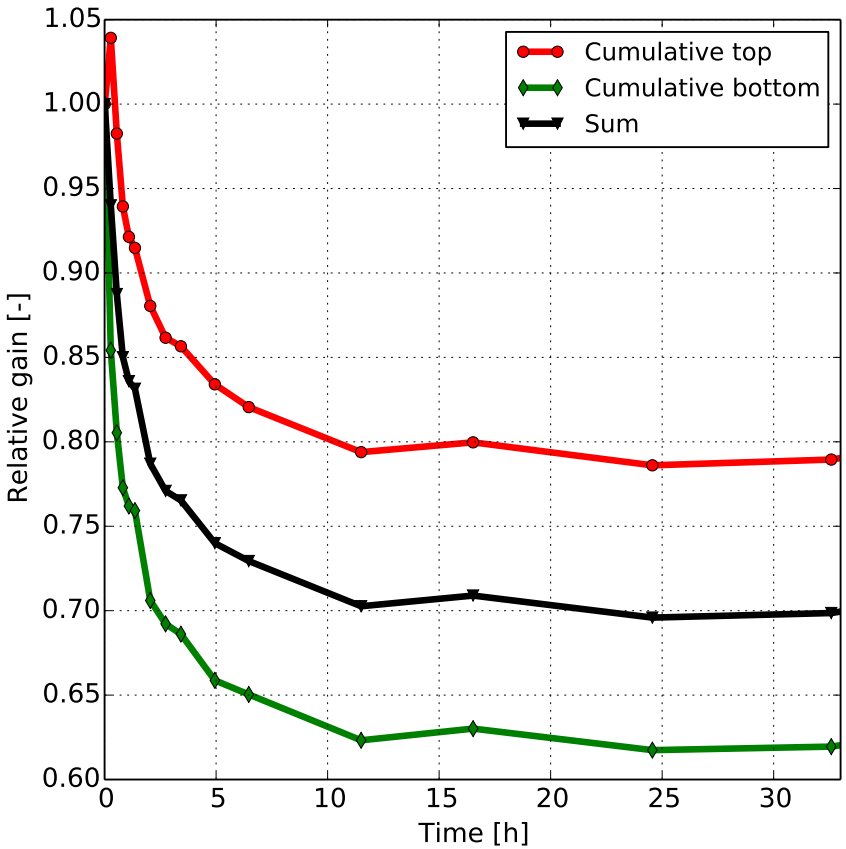
Cumulative discharging curves (top, bottom) and sum – $176\,\mathrm{Hz/mm^2}$.

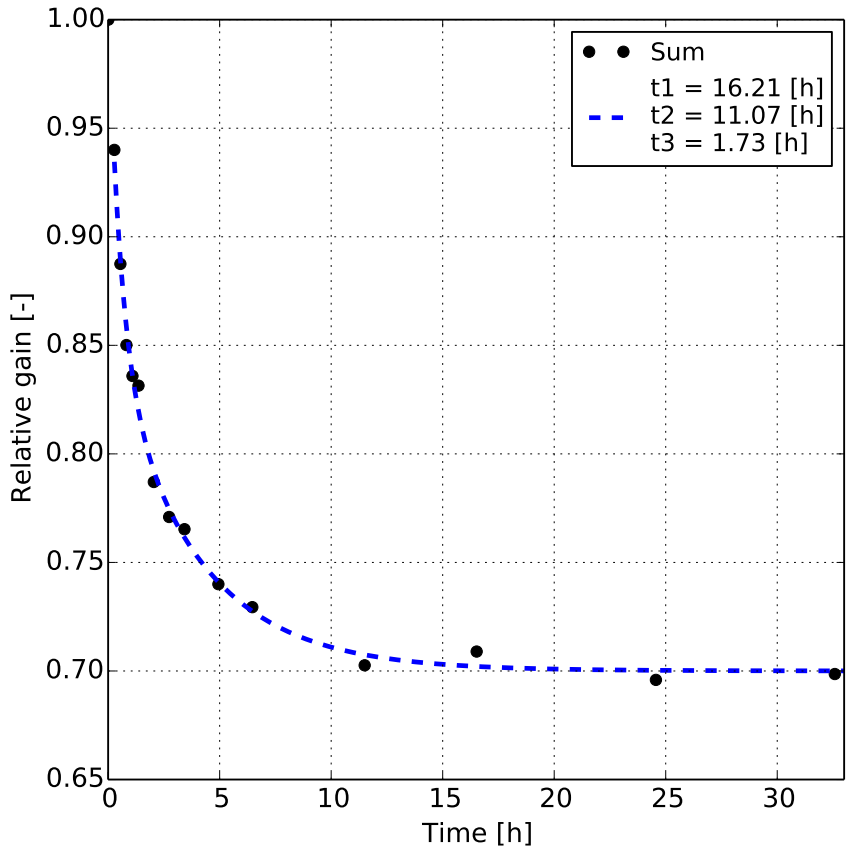




Discharging measurements results

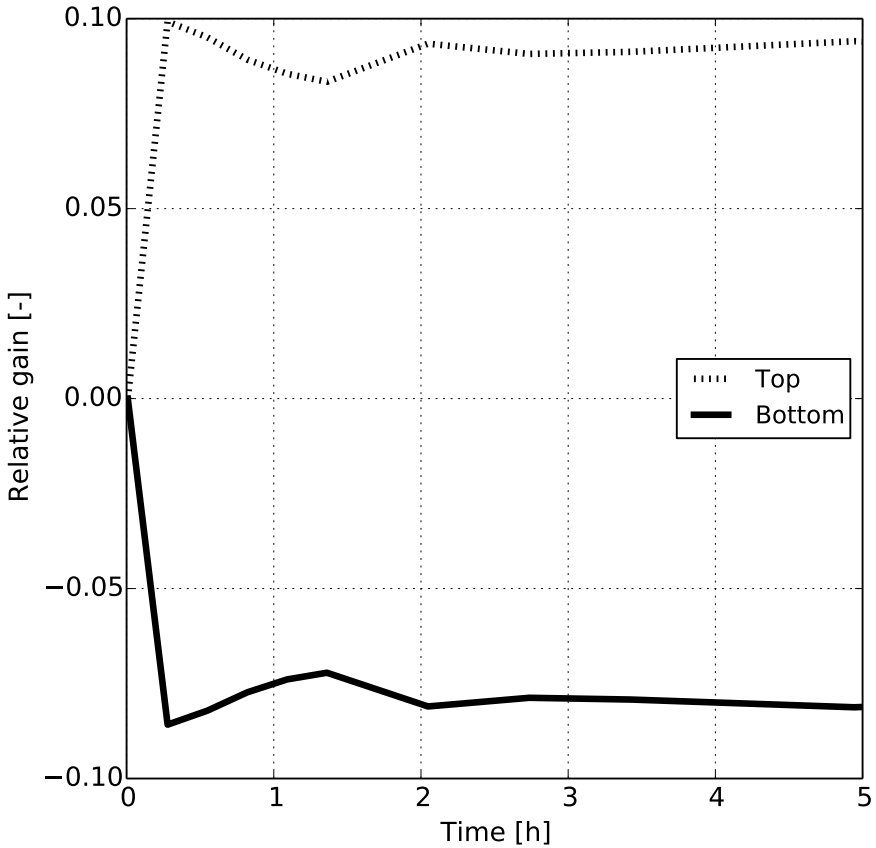
Cumulative discharging curves (top, bottom) and sum – $176\,\mathrm{Hz/mm^2}$.

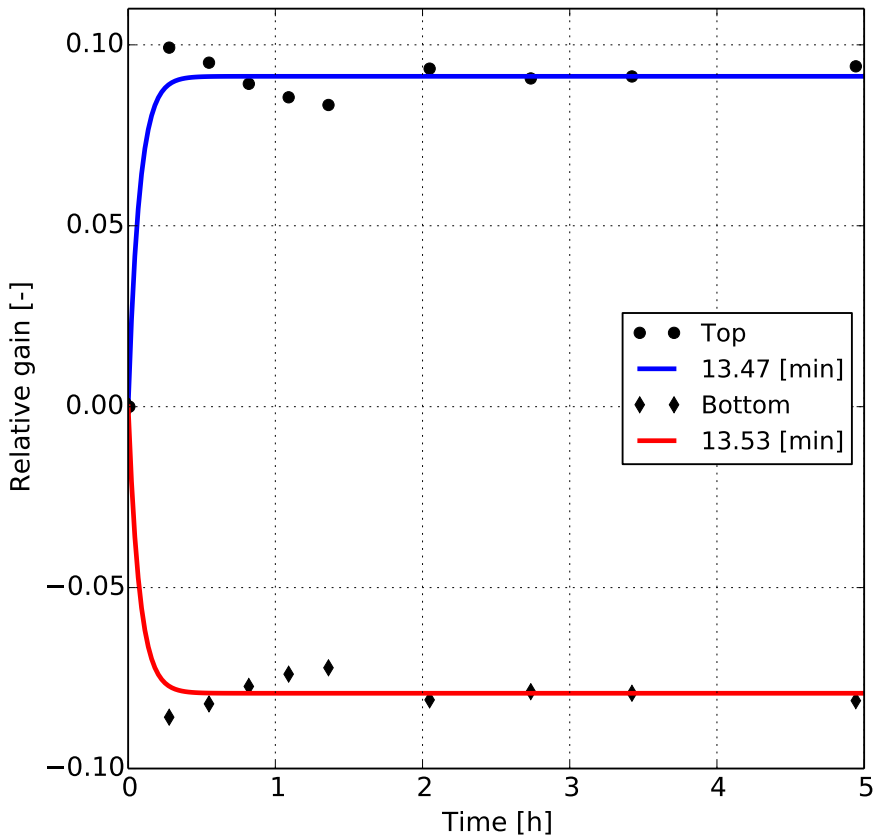




Discharging measurements results

Discharging curves for readout structure.





Summary

Charging-up for three GEM foils (readout structure excluded)

- The largest relative change in gain (67 %) for the highest rate ($176\,\mathrm{Hz/mm^2}$) and the lowest around 23 % at $0.7\,\mathrm{Hz/mm^2}$.
- The longest charging time (around 10 h) is for the lowest rate ($0.7\,\mathrm{Hz/mm^2}$), while charging time for the highest rate is around 2 h.

Charging-up of the readout structure

- The smallest relative change in gain (6 %) for the lowest rate ($0.7\,\mathrm{Hz/mm^2}$) and the largest (50 %) at the maximum rate ($176\,\mathrm{Hz/mm^2}$).
- The longest charging time (492 min) for the lowest rate ($0.7\,\mathrm{Hz/mm^2}$) and the shortest (6 min) at $176\,\mathrm{Hz/mm^2}$.

Discharging – measured at $176\,\mathrm{Hz/mm^2}$

- Discharging time only for GEM foils is over a dozen hours.
- Discharging time for readout structure is around 14 min.

Summary

Future plans

- Further measurement and data analysis in order to understand all the features (especially gain variation on the readout structure).
- We are also focused on preparation of good parametrization factors which can be used for (semi-)online gain correction.
- We are planning the measurements with much higher rates by employing an X-ray tube.

Acknowledgements

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Thank you for your attention!