The Resistive-Plate Well: new materials and measurements

D. Shaked-Renous, A. Roy, L. Moleri, A. Coimbra,
A. Breskin, L. Arazi and S. Bressler

Weizmann Institute of Science

The RPWELL Detector

The Resistive-Plate WELL (RPWELL) is a **robust, single-stage gaseous detector.**

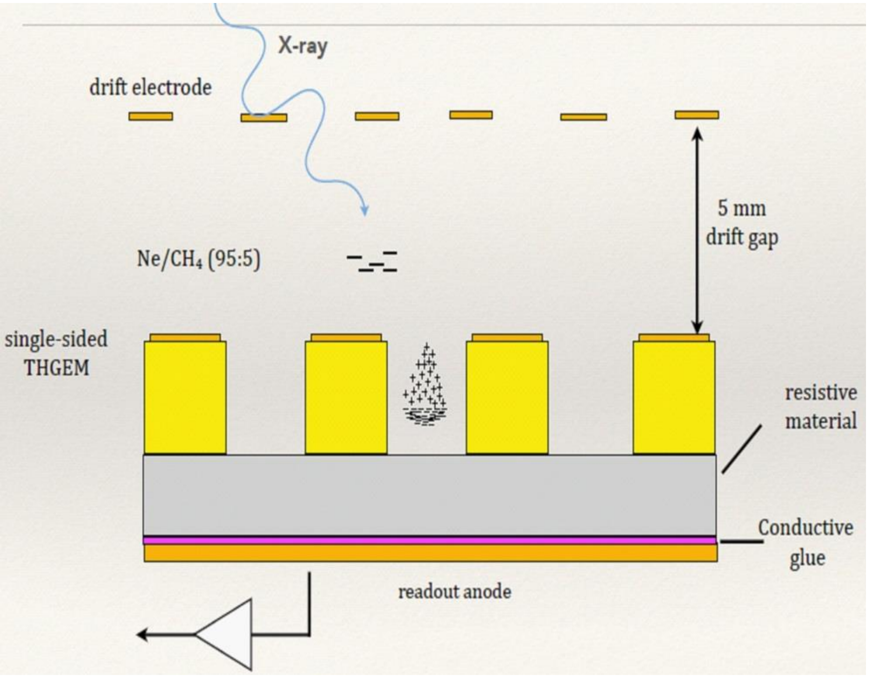
Single-sided THGEM electrode coupled to a readout electrode through a **resistive-plate** of high bulk resistivity ($\sim 10^8 - 10^{12}$ Ω-cm).

The resistive plate leads to **discharge-free operation** at high gain ($>10^4$).

Full detection efficiency obtained for MIPs.

Potential constituent of detector applications requiring cost-effective, large-area coverage.

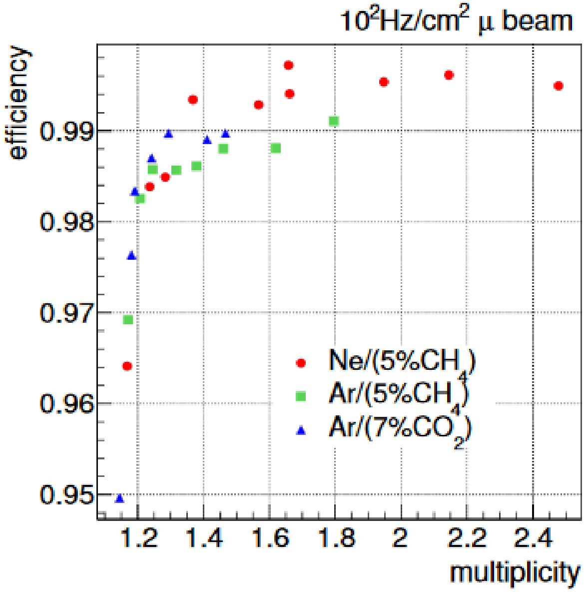
Bulk resistivity $\sim 10^8 - 10^9$ Ω-cm, would permit high counting-rate operation.

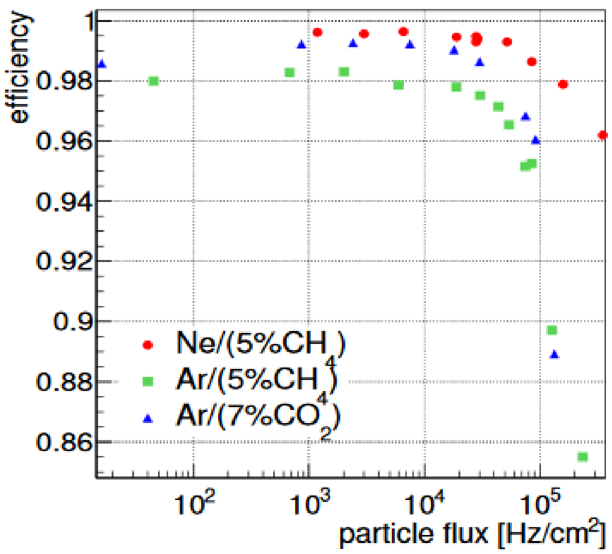


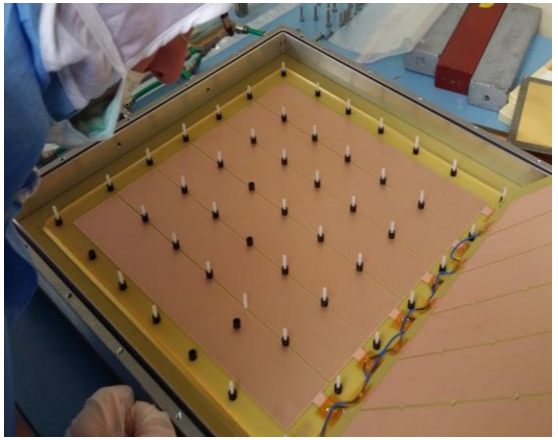
A. Rubin et al, 2013 JINST 8 P11004

The RPWELL – where we stand

Beam test results of the 30x30 cm^2 RPWELL with Semitron Resistive plate, 1 cm^2 readout pads coupled to APV25/SRS electronics







30x30 cm^2 RPWELL

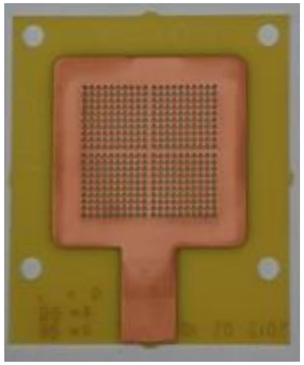
Stable operation with Ar- and Ne-based gas mixtures under high rate muon and pion beams.
Discharge - free operation at high gain.
High detection efficiency at broad range of incoming particle fluxes at low average pad multiplicity **(>98% efficiency , ~1.2 pad multiplicity**).
Competitive detector for applications requiring large-area coverage.

L. Moleri et. al, arXiv:1607.02587v1, submitted to JINST

The RPWELL – the challenges ahead

- ✓ Exploring new production techniques and comparison with existing technologies
- ✓ Study of new resistive materials
- ✓ Working towards understanding the physics aspects of the RPWELL
- ✓ Design/Scalability of large-sized prototypes

Search for new THGEM production techniques



FR4

Existing standard technique – FR4

Mechanically drilled holes

Mastered THGEM technology used by several groups

Large-scale applications (e.g, INFN Trieste group for COMPASS-RICH detectors)

New technologies and materials available

Cu-coated Alumina –
Laser drilled holes - Imperfect production technique

Ni-coated Epoxy –
Photolithography – more promising, tests ongoing

Alumina

Epoxy

For a detailed discussion , see talk by :

Dan Shaked-Renous, RD51 mini-week, June 2016, CERN

Search for new Resistive Materials

Resistive materials we are looking for --

Materials with bulk resistivity ~ 10^{8} – 10^{10} Ω-cm for discharge-free operation at high rates.

Existing material – Semitron ESD 225 (Quadrant plastics, USA), 10^{9} Ω-cm

Shortcomings –
Water absorption
Thermal expansion
Concern about long-term operation

Alternatives available

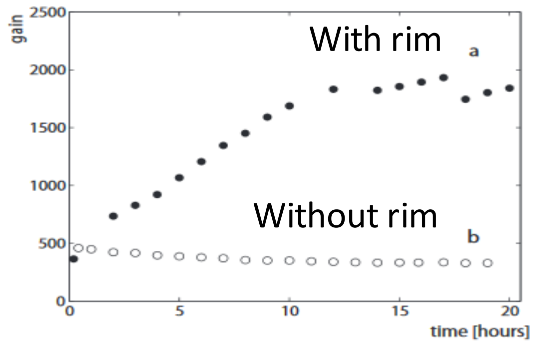
Low Resistive Silicate Glass (Prof. Yi Wang, Tsinghua , 10^{10} Ω-cm)
Si-based Ceramics from Germany (Dr. Lothar Naumann, HZDR, 10^{8} - 10^{9} Ω-cm)
Fe-based Ceramics from Spain (Dr. Miguel Morales, USC/CSIC, 10^{8} - 10^{9} Ω-cm)

All materials tested in RPWELL configuration as the resistive plate

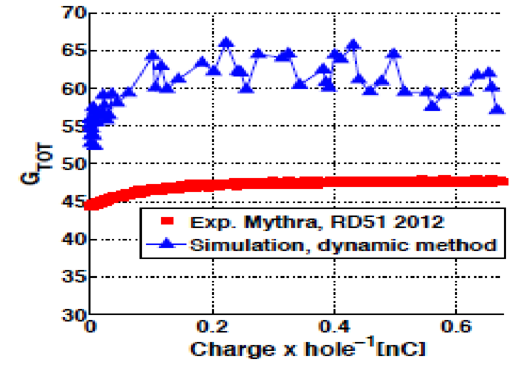
Low Resistive Silicate Glass –
Most Viable alternative so far
Available in relatively large sizes

Towards Understanding the Physics aspects

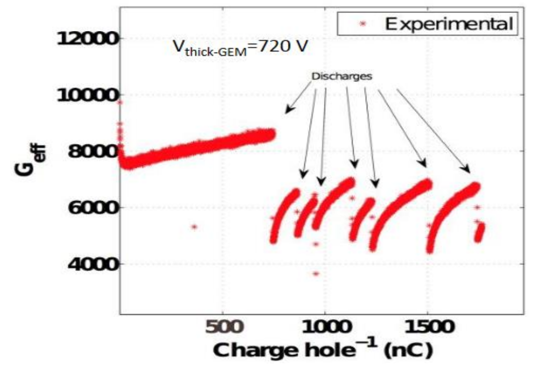
Effect of rims on gain stability with THGEM
Gain monitored as a function of time to understand stabilization
Results indicate gain stabilizes better without the rim
F. Tessarotto et al, 2010 JINST 5 P03009



Gain stability measurement with GEM
Gain vs Accumulated charge to understand the stabilization process
P.M.M Correia et al. , 2014 JINST 9 P07025



Gain stability measurement with THGEM
Gain vs Accumulated charge plot
Several open questions raised
Measurements limited by the occurrence of discharge which prevents gain stabilization.
Talk by P.M.M. Correia, 13th RD51 Collaboration Meeting (THGEM charging up simulation)



Towards Understanding the Physics aspects – many open questions

- ❖ Due to different geometry – RPWELL and its gain stabilization behavior can be different
- ❖ RPWELL – broad dynamic range of gain – allows stress testing at a wide range of conditions

Motivation

- Understanding the relevant stabilization time-scales
- Confirm that at steady state the gain at similar conditions is the same.
- Consistency and reproducibility of measurements

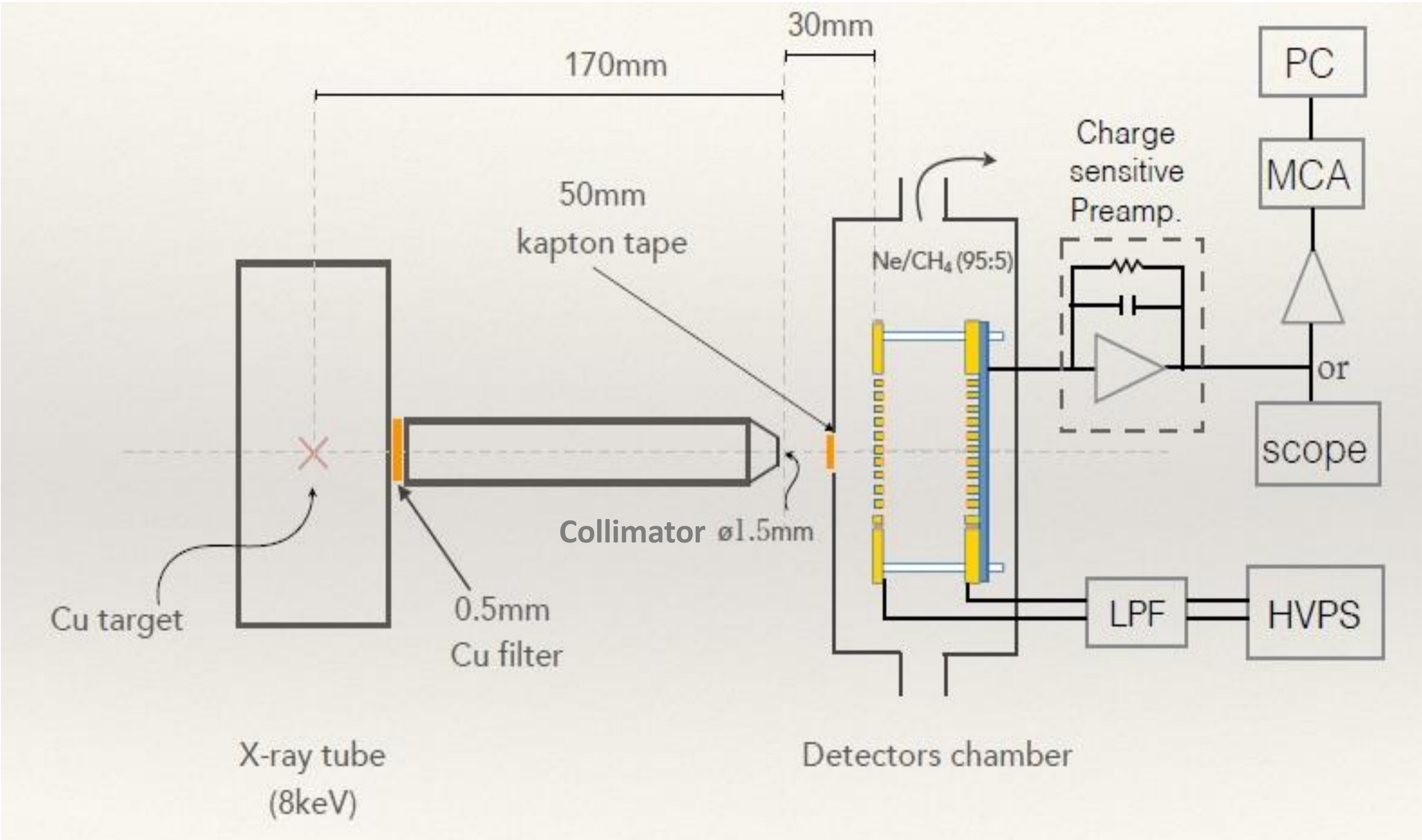
Methodology

- Systematic studies of different RPWELL configurations
- **Long term gain stability and rate dependence of gain**

What are the RPWELL physics questions ?

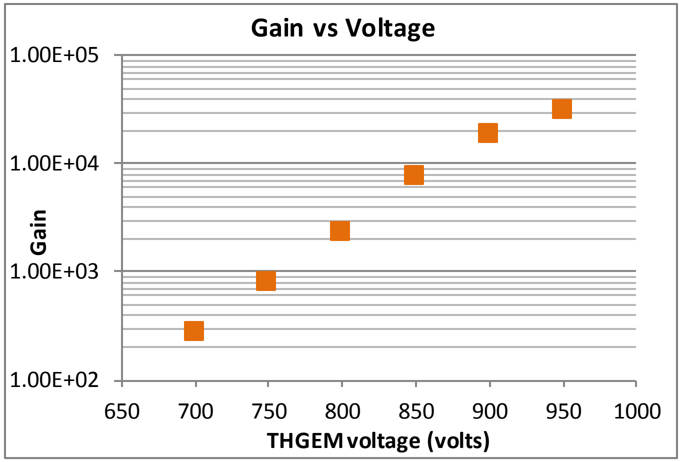
- Long term gain measurements to understand the different phenomena involved in gain stabilization
- Stabilization time-scales at different gains
- The effect of initial conditions on gain stability
- Decoupling actual physics processes from environmental and/or experimental artifacts
- Consistency and repeatability of non-trivial measurements
- Rate effects – relevant time-scales
- Detector gain stabilization at different rates and understanding underlying processes

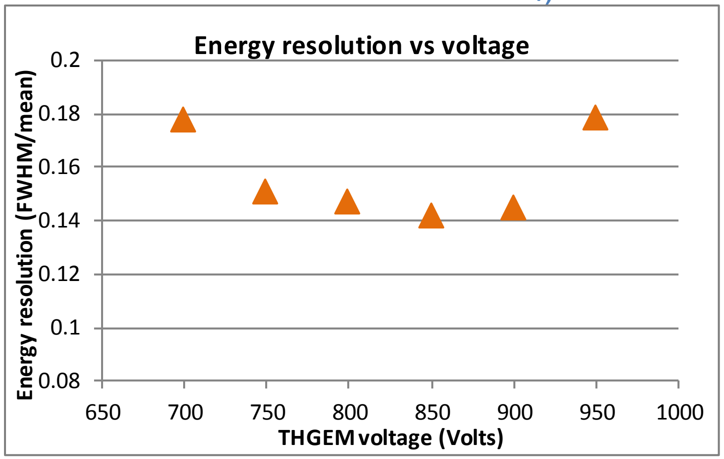
Experimental setup for laboratory tests



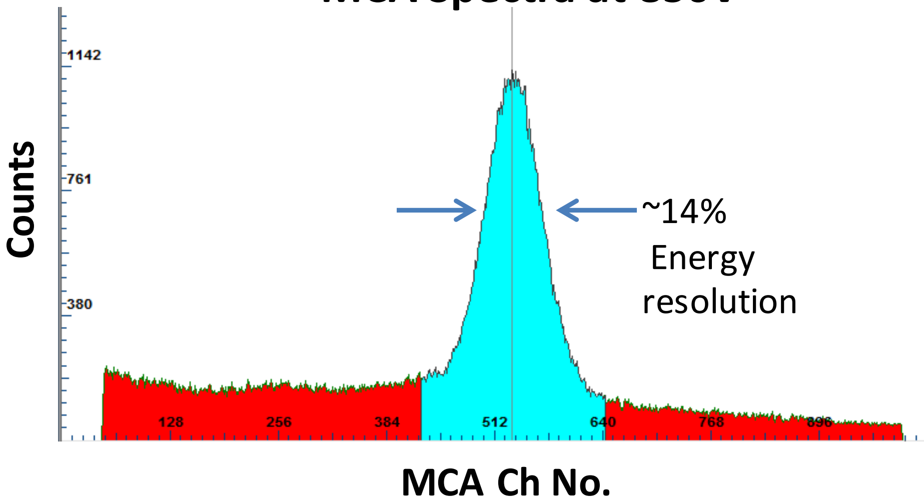
Lab test results of
0.8 FR4 THGEM coupled to 0.7mm Glass

Gain and Energy Resolution with soft Cu Xrays, Ne/(5%)CH_4, 20sccm





MCA Spectra at 850V



>10^4 gain obtained at 950 V

Best energy resolution obtained with the 0.7mm glass ~ 14% at 850V

MCA pulse height spectra at 850V is shown alongside

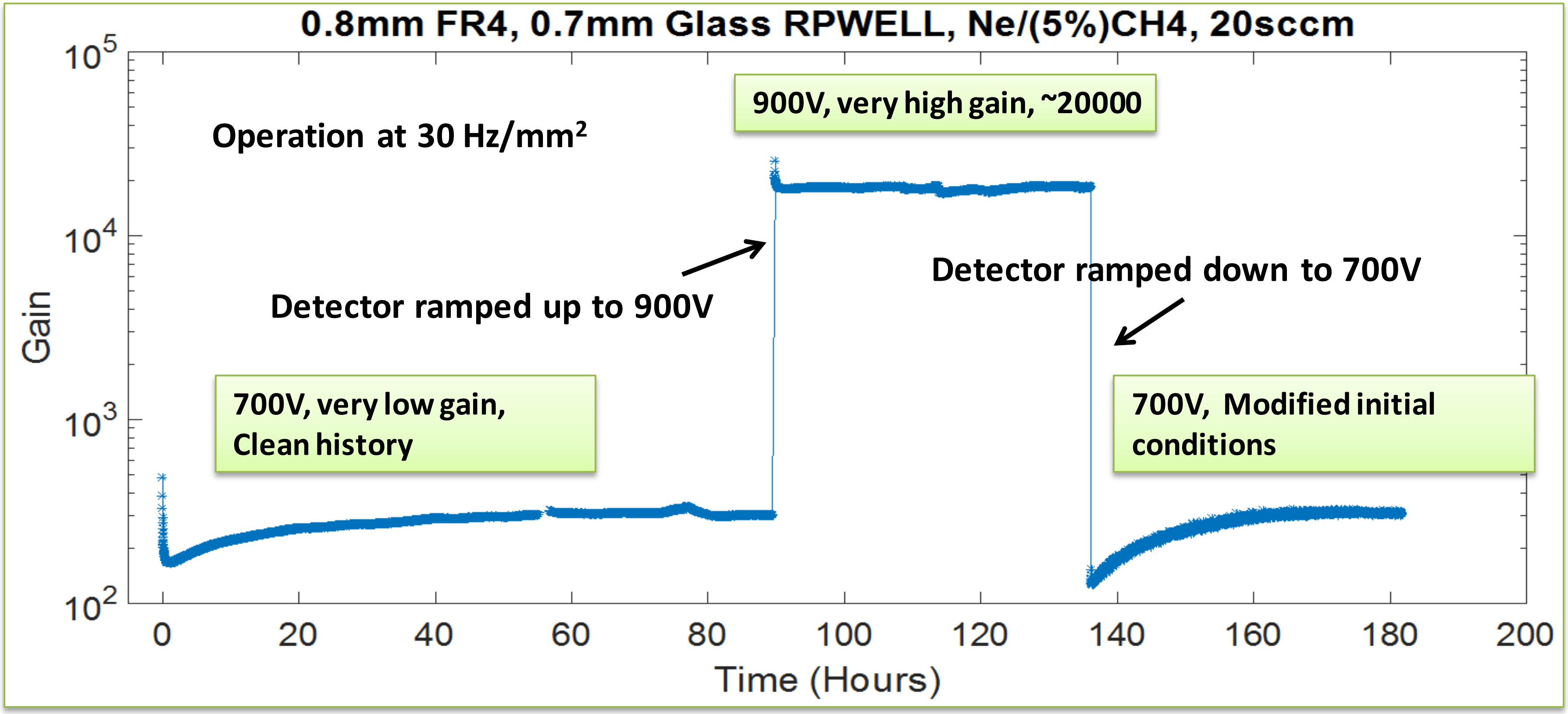
A. Roy, New Materials for RPWELL. RD51 meeting, Aveiro, Sept. 2016

Methodology for long term gain stability

Physics questions that we would like to investigate, translates into the following protocol.

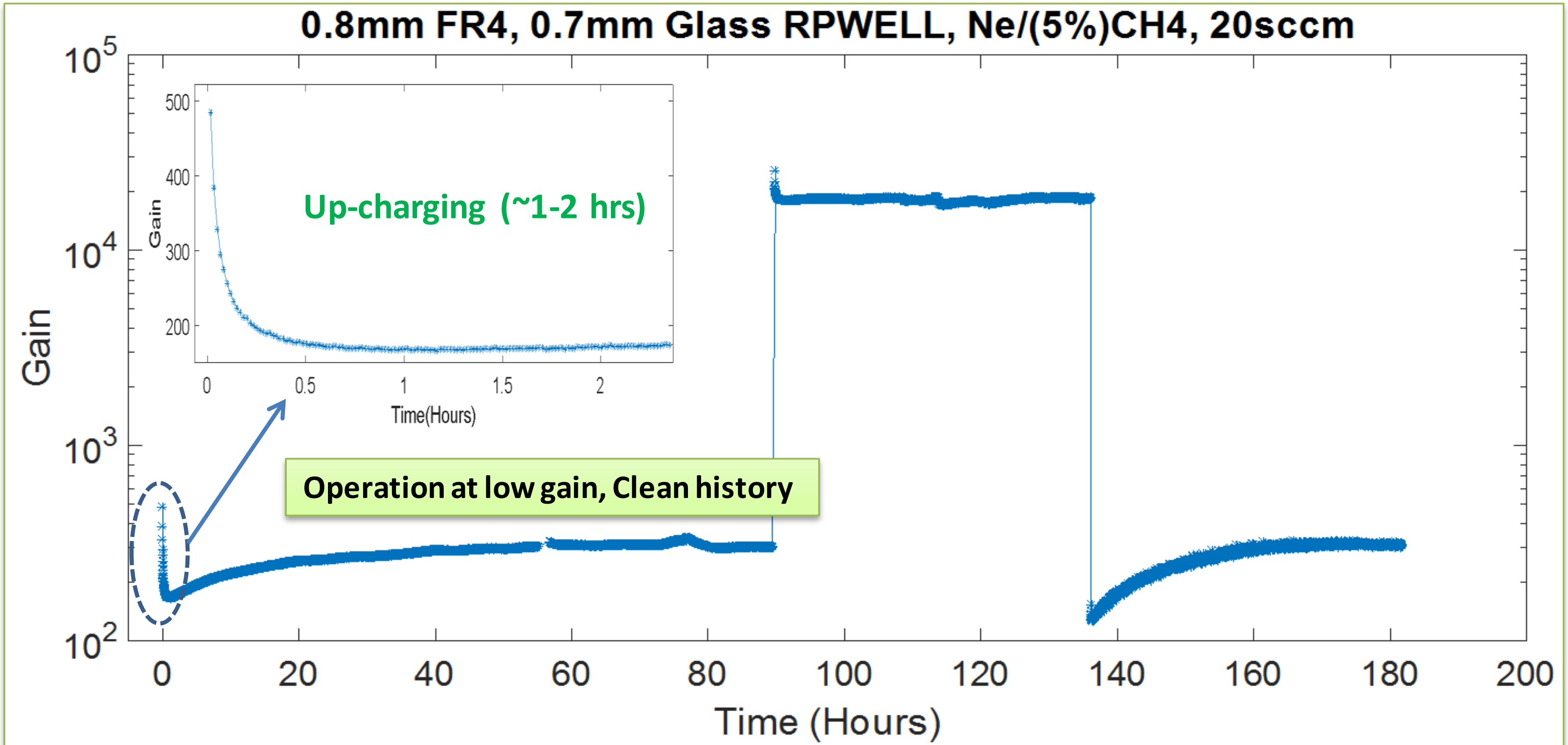
- Detector assembly after cleaning components with an ionization gun
- Pre-mixed Ne/(5%)CH_4 gas flow @20sccm
- Irradiation with 8 keV Cu X-rays at ~30 Hz/mm^2 rate
- Operate detector at very low gain (@700V, clean history), till stability is reached
- Operate detector at high gain (@900V) till stability is reached.
- Reduce detector gain to initial value (@700V, after operation at stressed conditions)
- Investigate gain stabilization and time-scales involved at each step.

Gain stability measurement



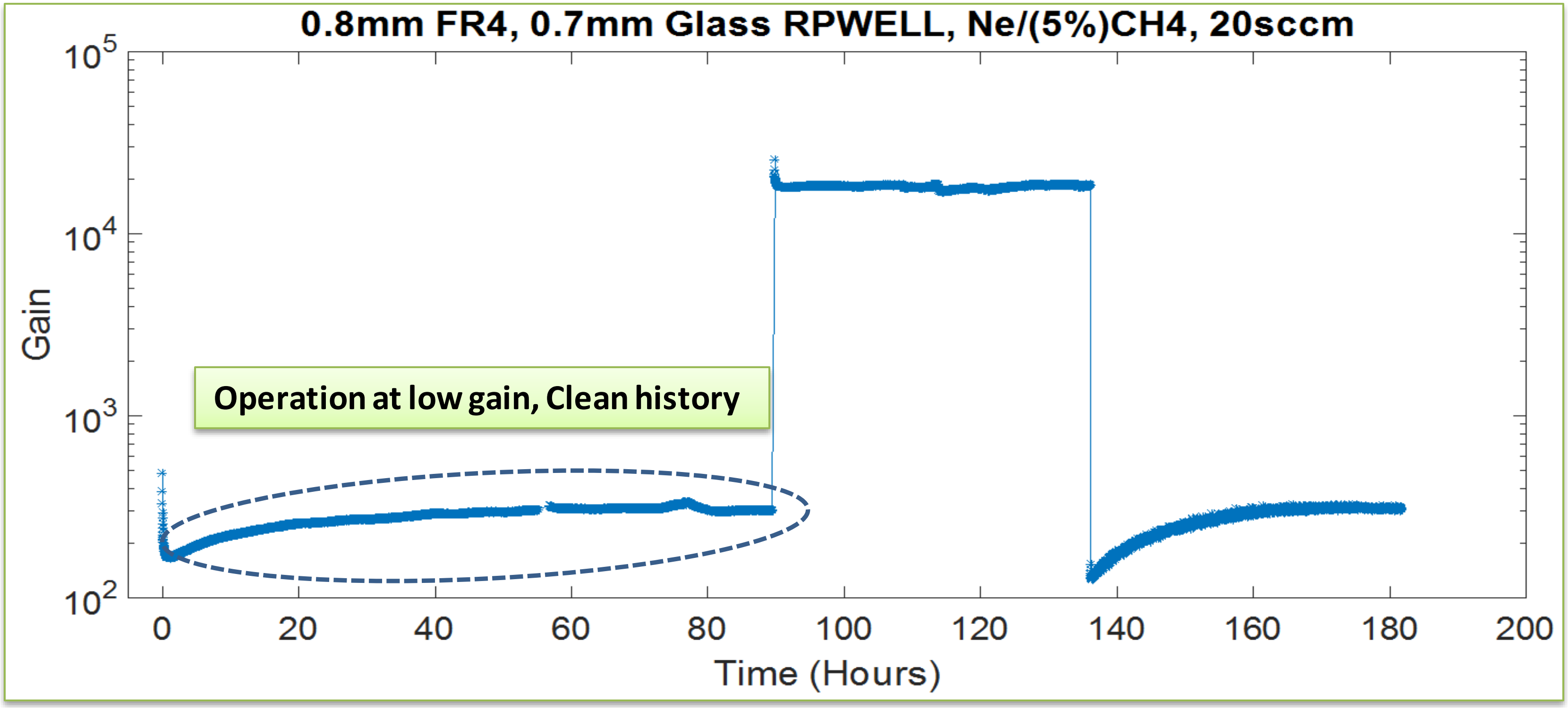
- Long term operation to have a feeling about the different processes involved in gain stabilization.
- Transition from low gain to very high gain and very high gain back to low gain.
- Stressed operation to investigate stabilization, different from normal detector operation

Gain stability measurement



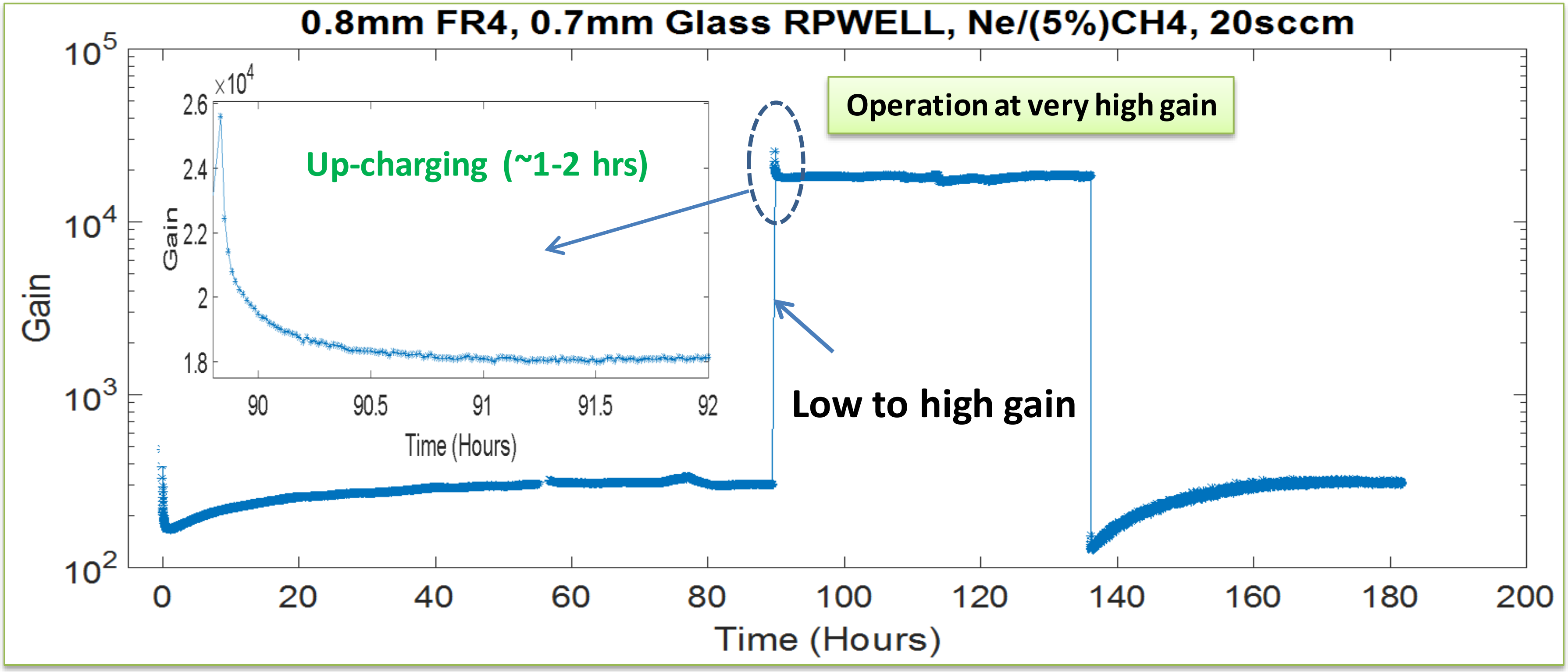
- Detector operation dominated by different regimes.
- Initial stages of detector operation dominated by up-charging of insulator walls.
- Time scale of up-charging ~1-2 hours.

Gain stability measurement



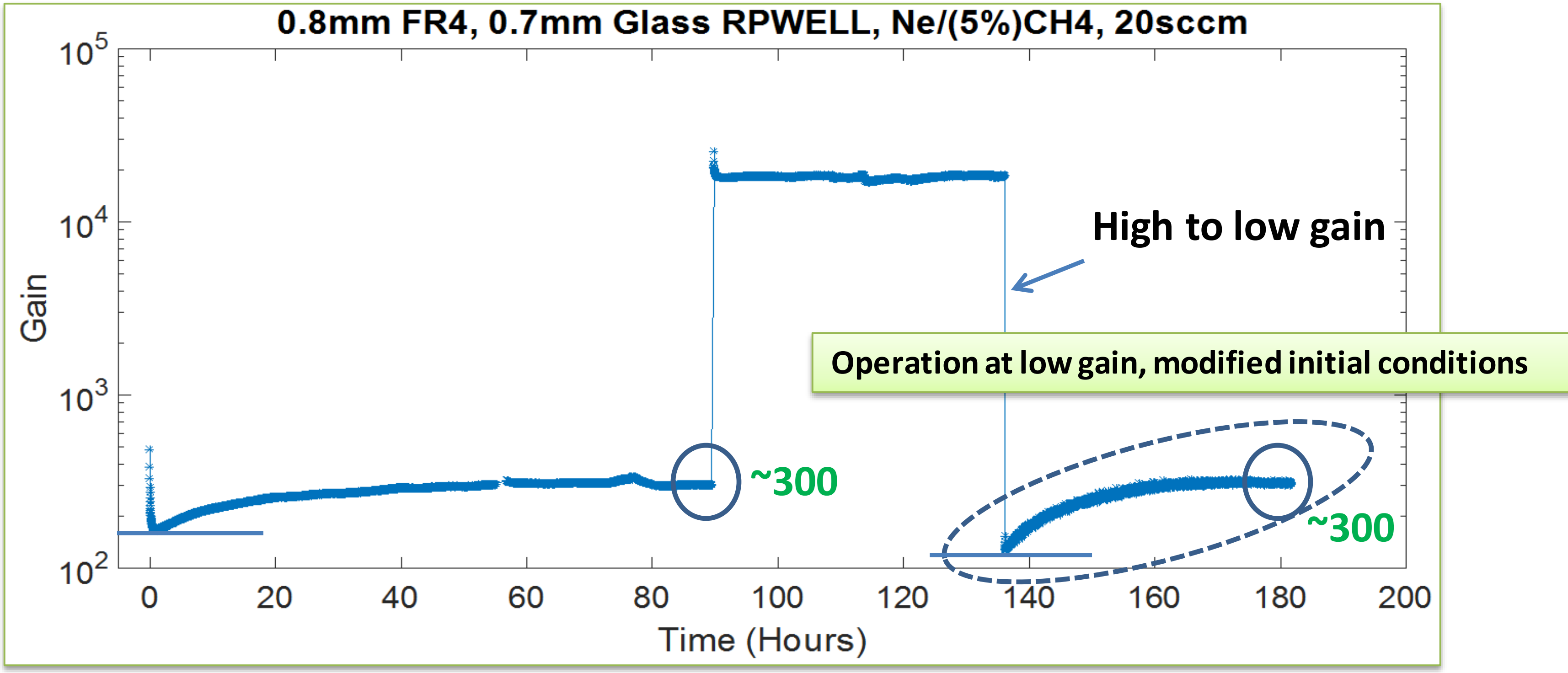
- Later stages of operation at this gain show a slow rise in gain, till it stabilizes (Minor gain fluctuations correlated to temperature variation)
- Total stabilization time ~100 hours
- Similar behavior observed by the Aveiro group
- RPWELL – similar behavior not seen at higher gain
- Could this be due to outgassing ? Investigations are ongoing.

Gain stability measurement



- Detector ramped up to 900V, very high gain ~20000.
- Initial stabilization regime similar to that observed at low gain. Up-charging time-scale ~1-2 hours as observed.
- Slow stabilization at the lower gain not seen in this case. Minor gain fluctuations correlated to temperature.

Gain stability measurement

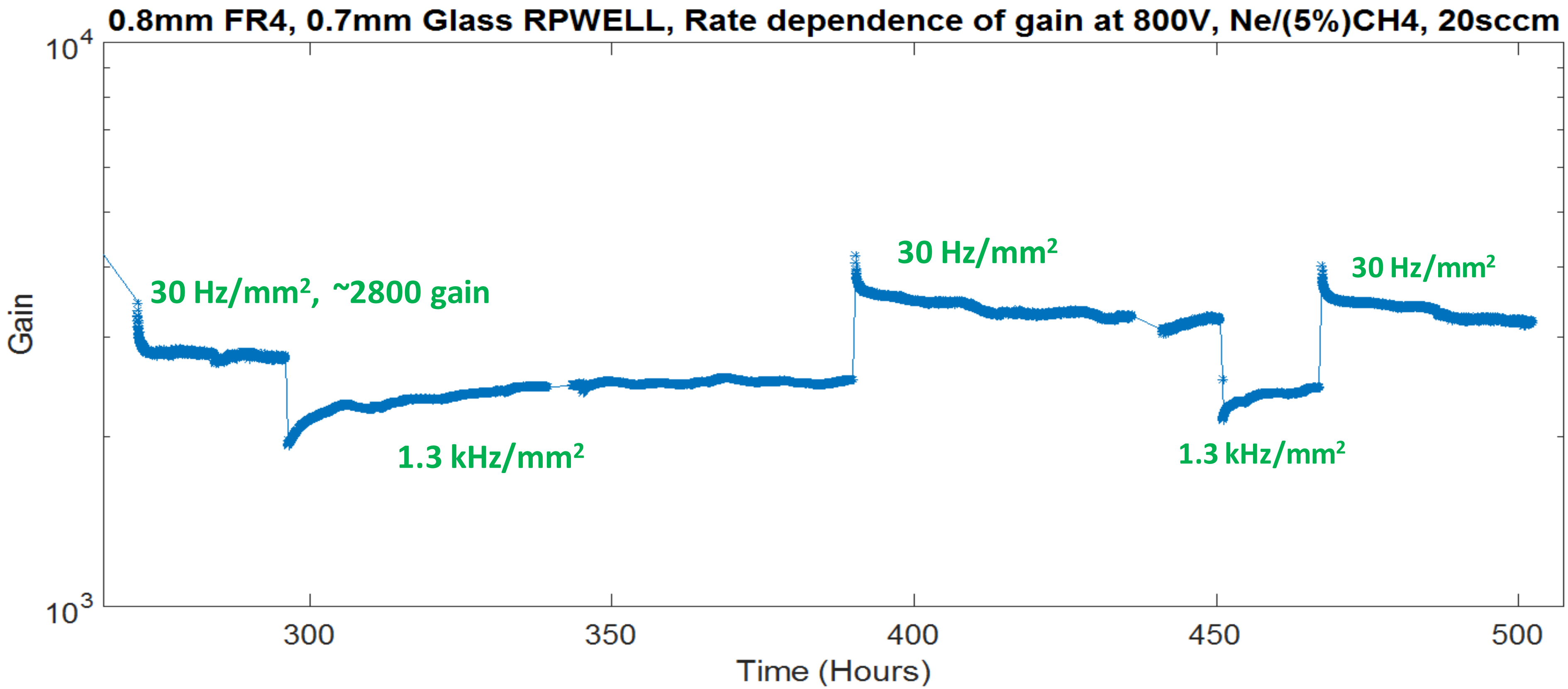


- Transition from very high gain to low gain
- Sudden change in operation conditions, unlike stable detector operation
- Dominant stabilization process at this gain intuitively understood as slow removal of charge from the insulator walls
- Stabilization time ~40-45 hours. Much Slower process compared to up-charging
- Detector initial conditions very different but gain stabilizes at ~300 in both cases
- Gain minima in the 2 cases different. Attributed to operation at high gain

Methodology for Rate dependence of gain

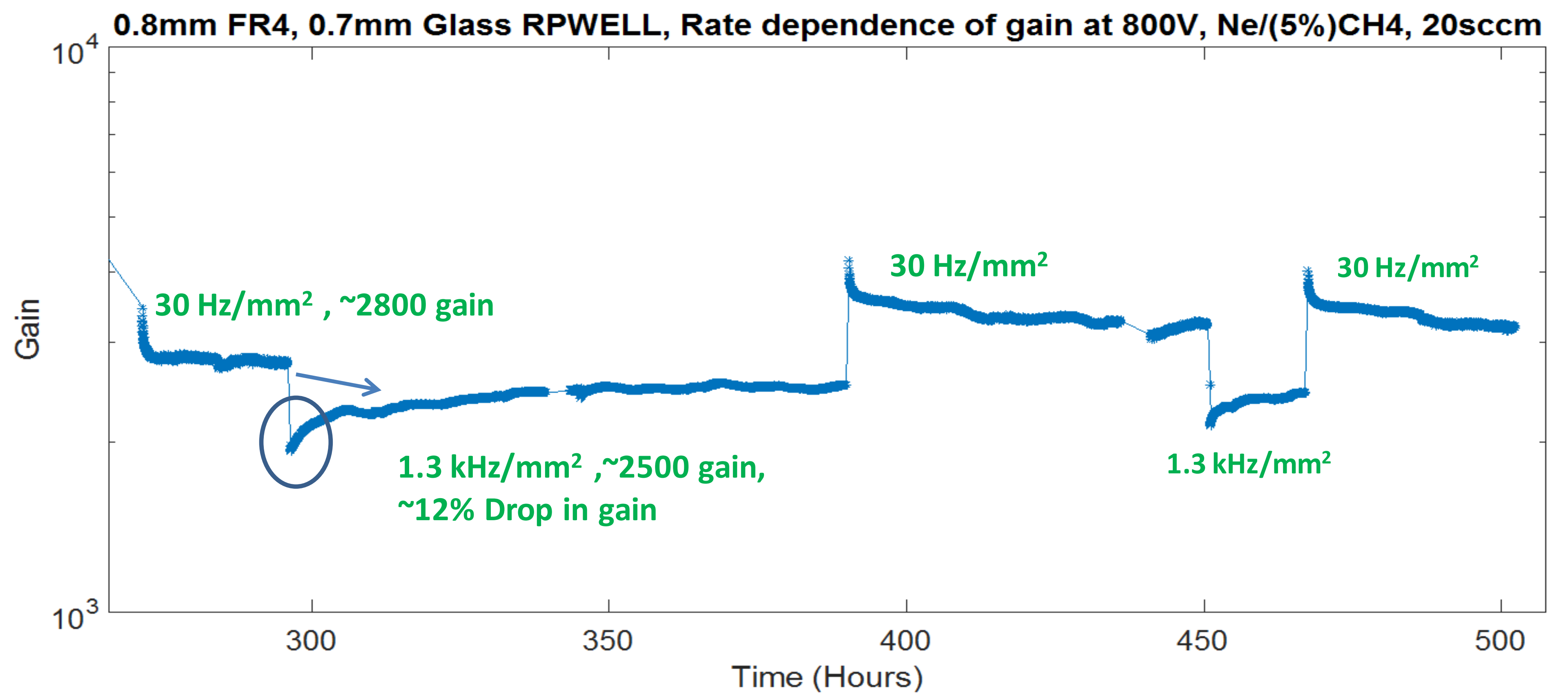
- Detector operation at constant voltage -- 800V @ ~10^3 gain
- Initial operation at a low rate (30 Hz/mm^2)
- Transition from low rate to ~40 times higher rate (1.3 kHz/mm^2)
- Transition from high rate (1.3 kHz/mm^2) to low rate (30 Hz/mm^2)
- Measurements repeated for consistency and reproducibility

Rate dependence of gain



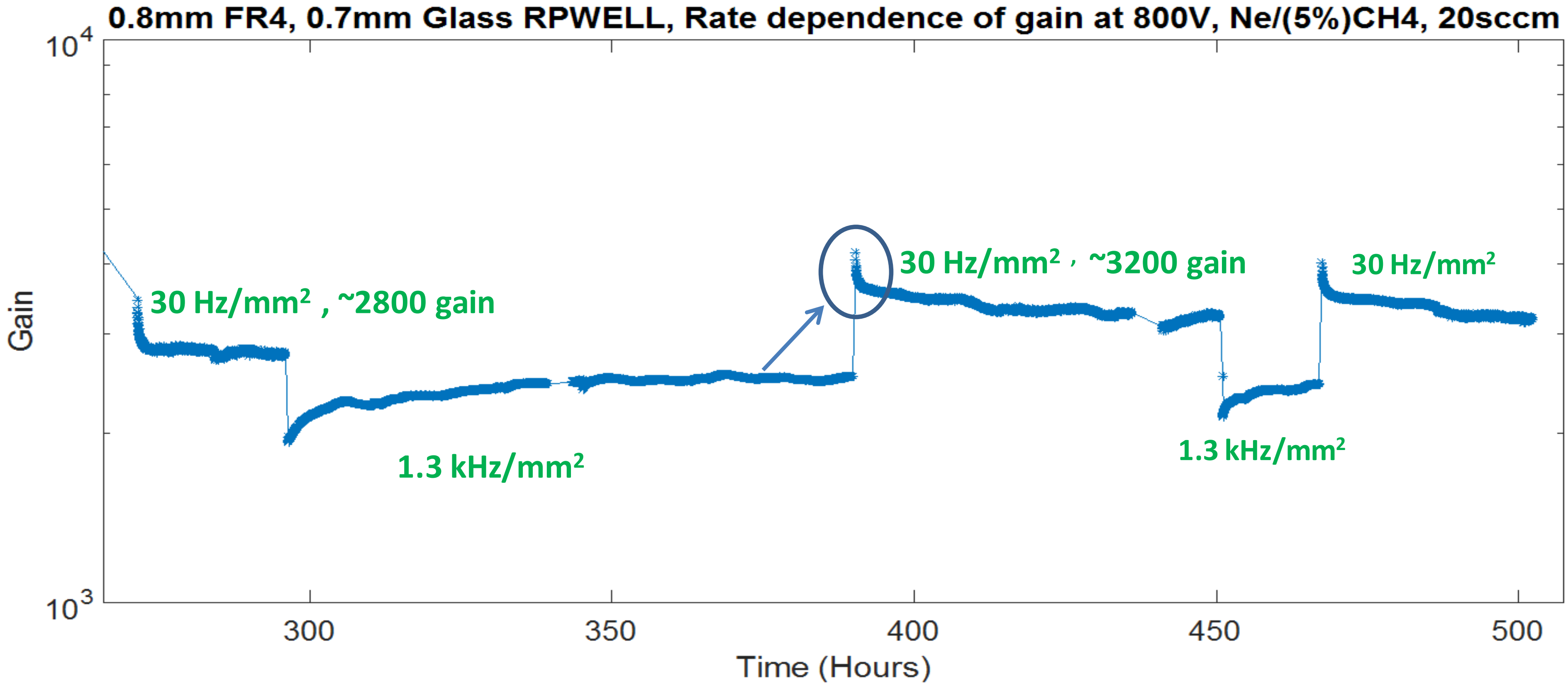
- Initial long term operation at 800 V at 30 Hz/mm^2 rate. Gain ~3000.
- Transition of detector operation from low rate to high rates.
- Stressed operation to understand the underlying physics processes.
- Measurement repeated for consistency and reproducibility

Rate dependence of gain



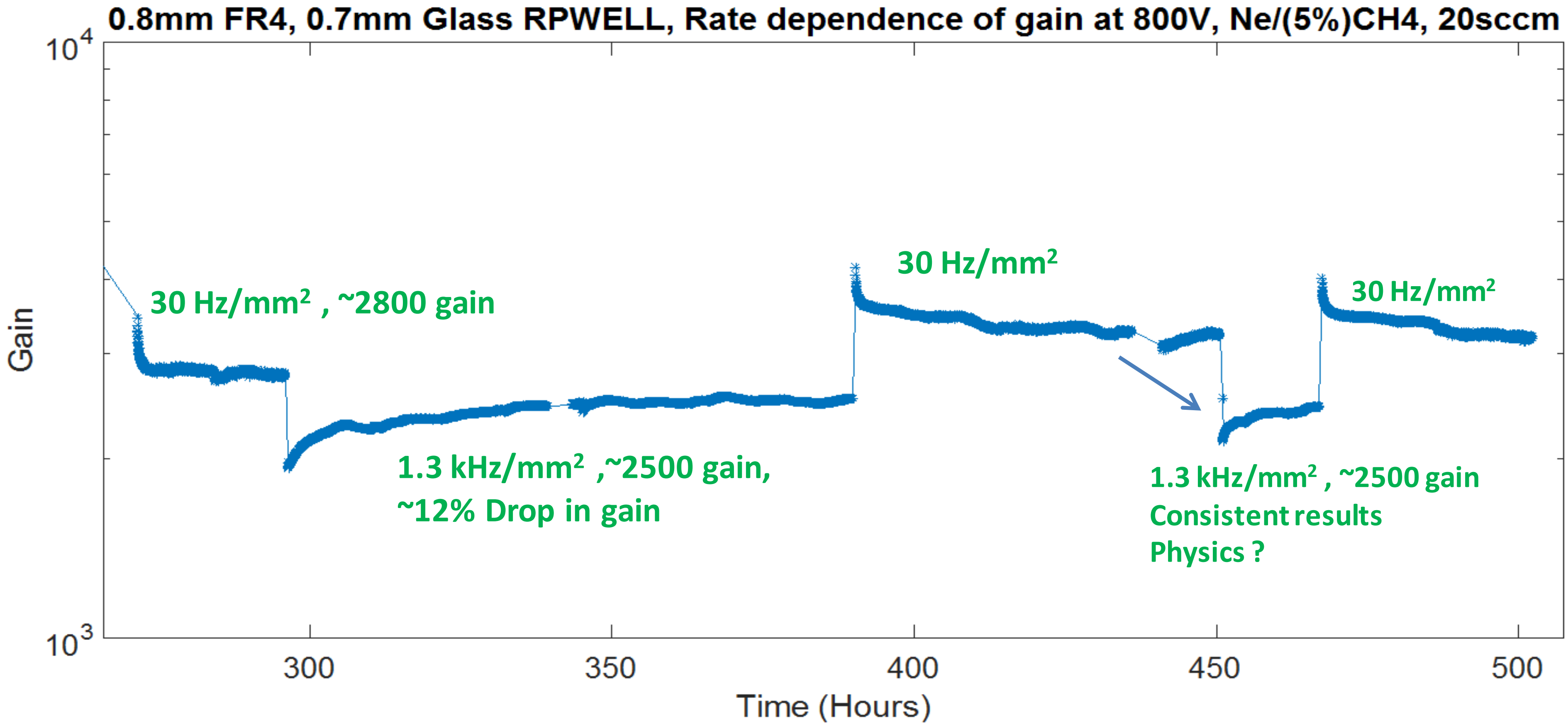
- Change of rate from 30 Hz/mm^2 to 1.3 kHz/mm^2
- ~12% gain drop at 1.3 kHz/mm^2 (10^5 Hz/cm^2). Gain drop consistent with previous results
- Transition from low rate to high rate should provide lot of charge to THGEM holes
- To the contrary, counter-intuitive down-charging behavior observed

Rate dependence of gain



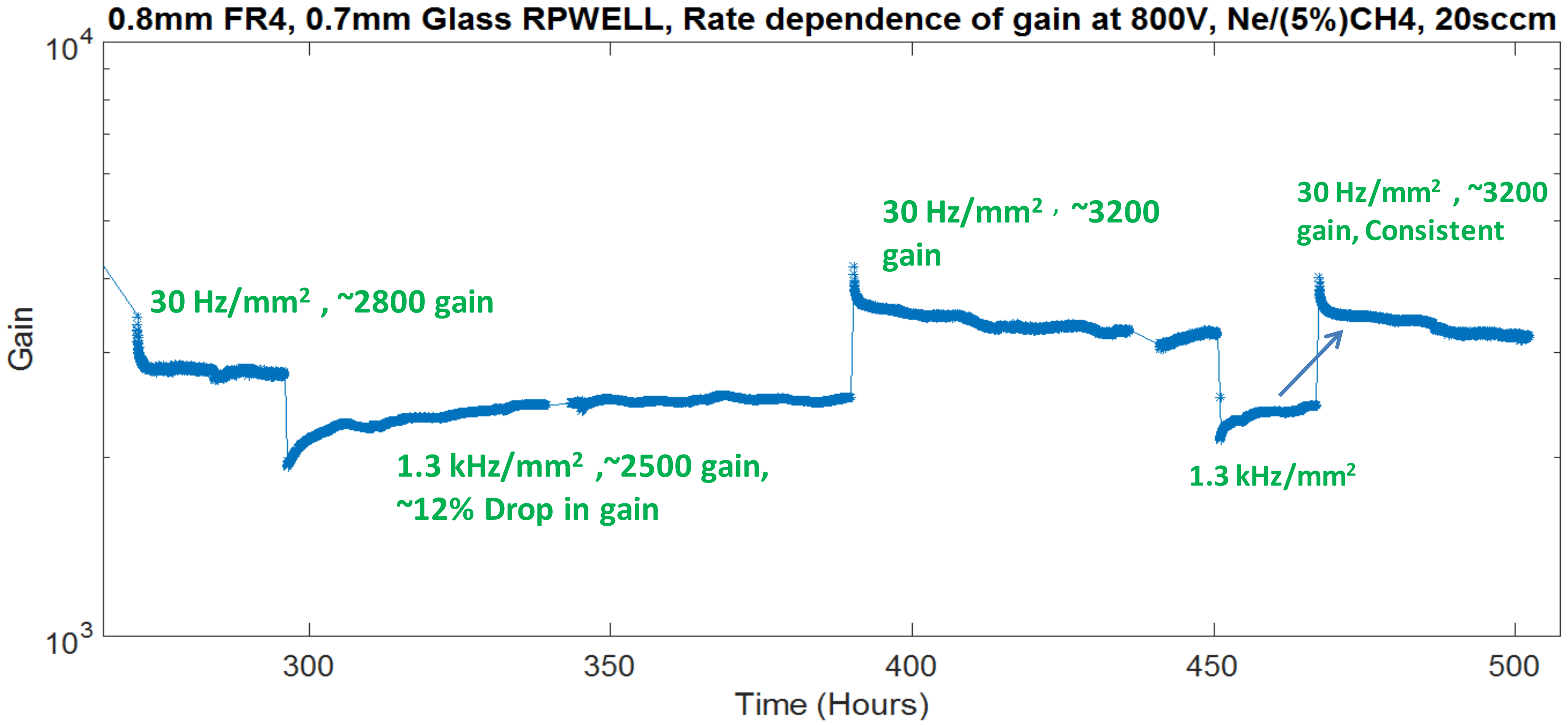
- Transition from high rate to low rate.
- Up-charging behavior counter-intuitive to what expected. Lower rate seen by the THGEM holes should lead to a dominantly down-charging behavior.
- Gain stabilizes at the same voltage and rate at ~3200, slightly different from the previous case.

Rate dependence of gain



- Transition from low rate to high rate.
- Consistent detector behavior noticed. Physics aspect not well understood, under investigation.
- Gain similar to the previous high rate operation.

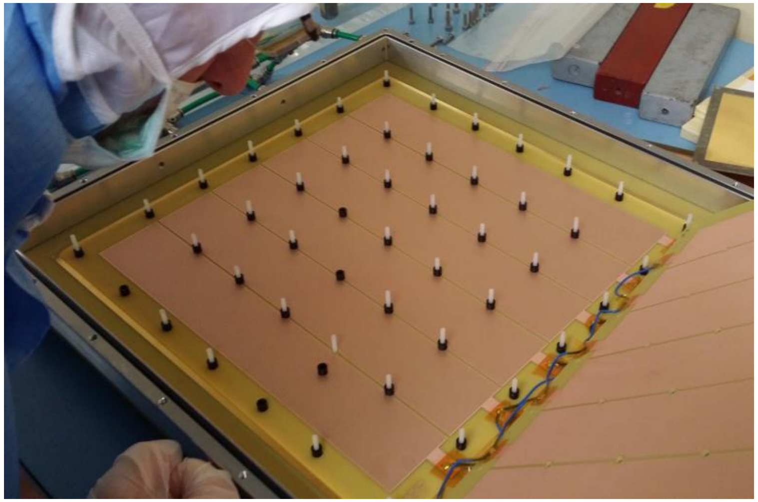
Rate dependence of gain



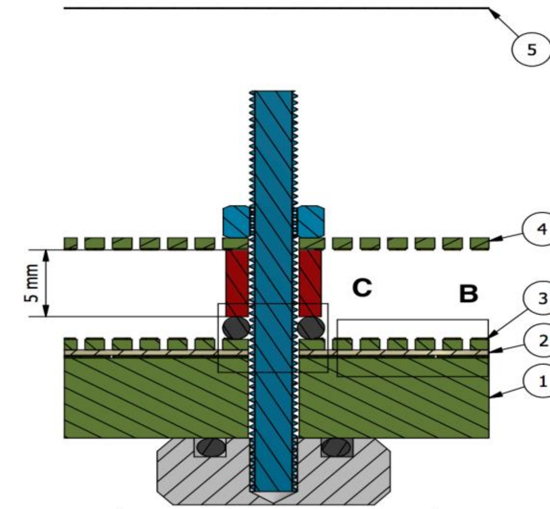
- Transition from high rate to low rate.
- Consistent detector behavior as noticed previously.
- Gain similar to the previous low rate operation.

Design/Scalability of large-sized prototypes and beam-test results

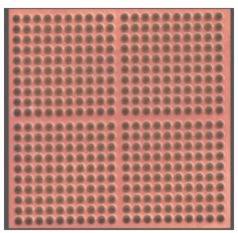
30x30 cm^2 RPWELL detector tested in previous test-beam

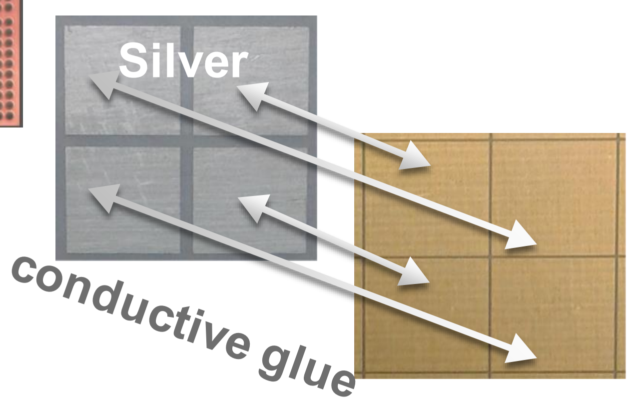


THGEM mechanical assembly



ITEM	ELEMENT
1	Readout Anode
2	Resistive Plate
3	Single-sided THGEM
4	Cathode
5	Chamber Cover

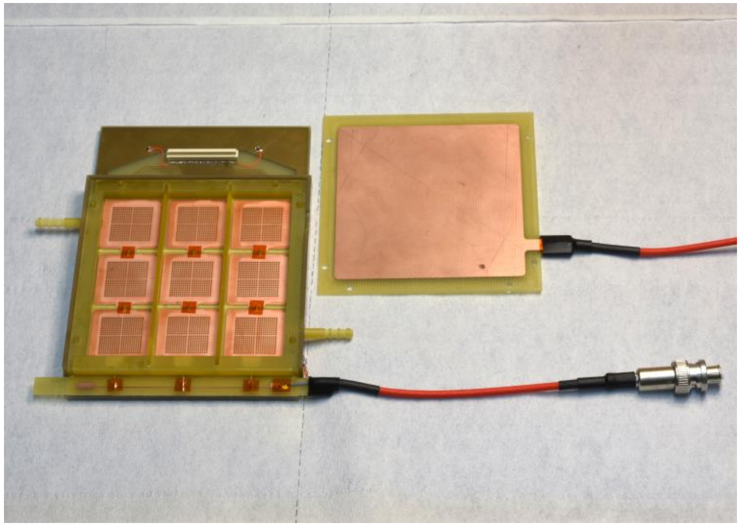


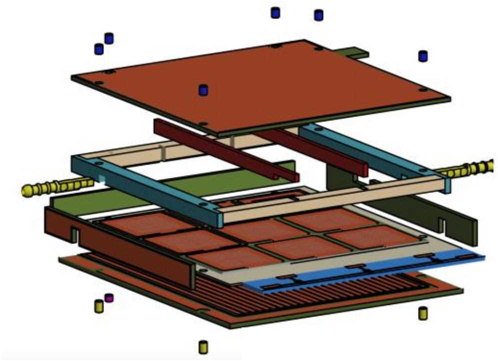


Anode pads coupled one by one to the patterned resistive plate.

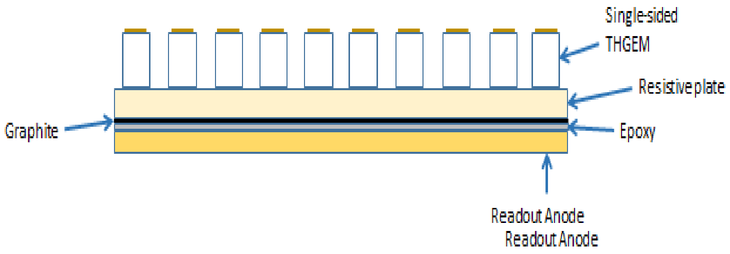
Charge evacuation through the anode

10x10 cm^2 tiled-RPWELL detector for a recent test-beam

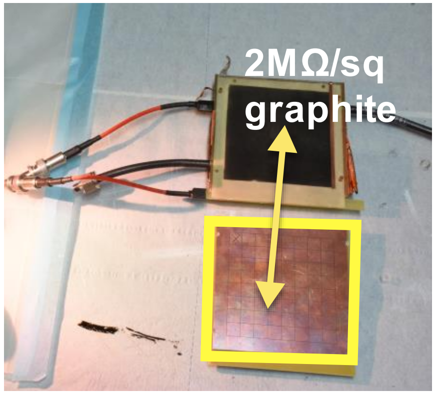




THGEM assembly by gluing



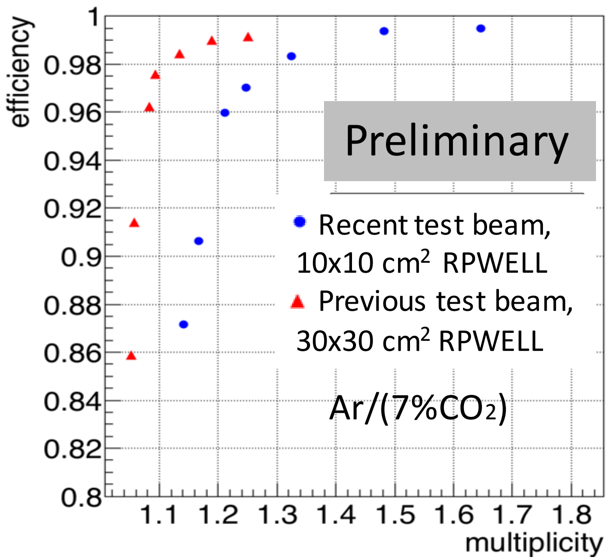
- Anode pads decoupled from Resistive Plate
- Charge evacuation through the graphite layer
- Existing electrodes used for tiling
- Optimization of design ongoing

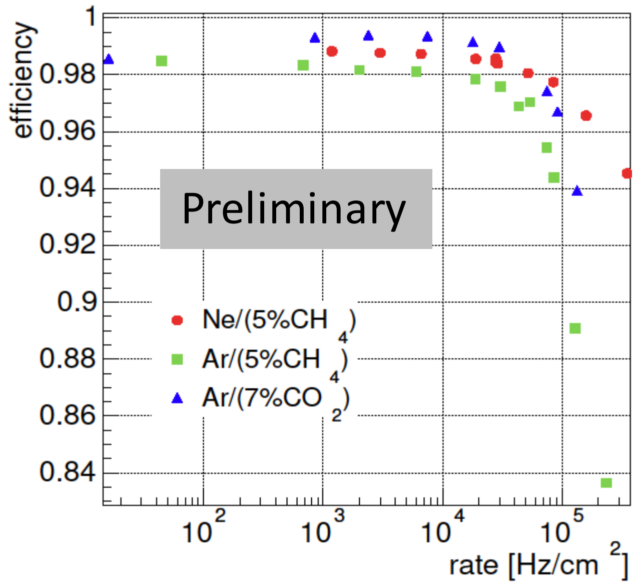


A. Roy, New Materials for RPWELL. RD51 meeting, Aveiro, Sept. 2016

Test-beam results

Goal I – Study new assembly technique (10x10 cm^2 Semitron RPWELL, pad readout)

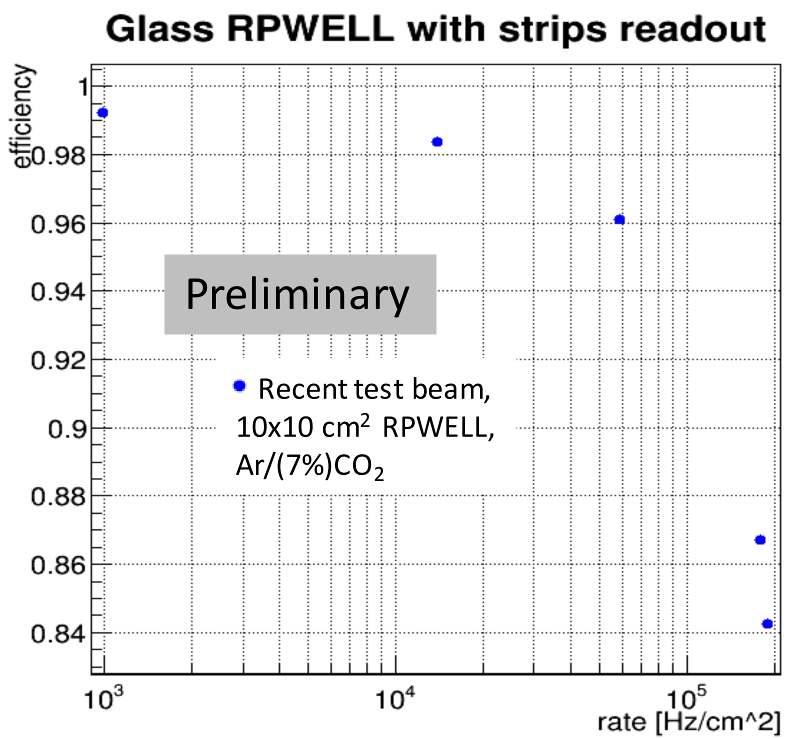




- **Preliminary results** of efficiency vs pad-multiplicity from latest test beam.
- ~98% efficiency at ~1.3 average pad multiplicity (Results similar to previous test beam).
- Slightly higher average pad-multiplicity (1.3 instead of 1.2) under investigation.
- Possible mis-alignment of the detector.
- High detection efficiency at high particle flux.
- Tiling process suitable for upscaling for a future 0.5x0.5 m^2 RPWELL.

Test-beam results

Goal II – Study new material (10x10 cm^2 Glass RPWELL, strip readout)



- **Preliminary results** of efficiency vs rate
- High detection efficiency at high particle flux

Summary

- Long term detector operation is a tool to study RPWELL physics questions.
  a) Up-charging and down-charging have different time-scales
  b) Low to high gain and high to low gain transition results intuitive
  c) Low to high rate and high to low rate transition results counter-intuitive

- Low resistive Silicate Glass seemingly good choice. Search for new materials and production techniques underway.

- New detector upscaling technique (tiling) tested in the test beam. Preliminary results indicate technique suitable for future use.

- Design of the 0.5x0.5 m^2 RPWELL prototype in an advanced stage.

Thank you for your attention!

Backup

Temperature dependence of gain