Recent advances with THGEM detectors

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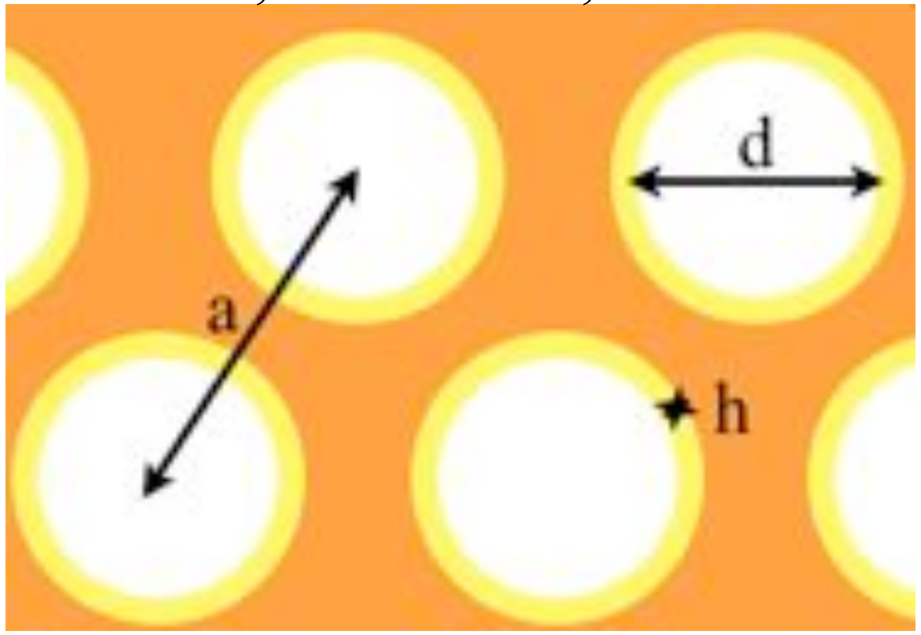
Outline

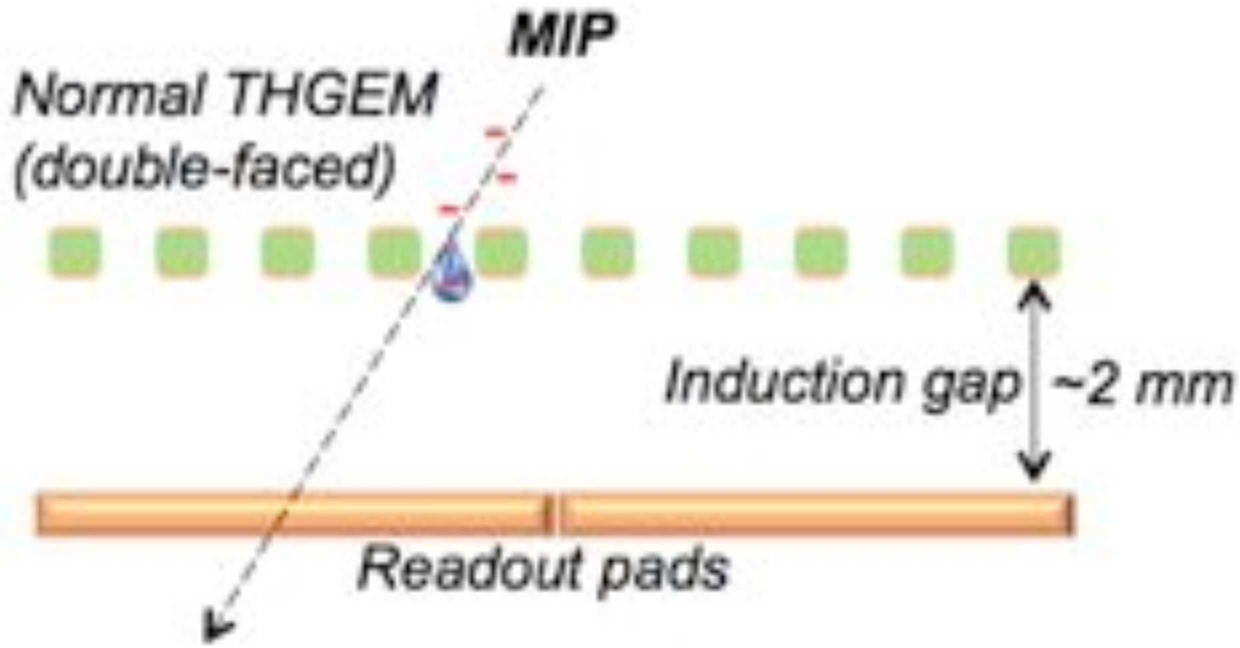
- THGEM-based structures
  - THGEM, THWELL, RWELL, SRWELL, RPWELL
- All in all - Performance
- Response to Highly Ionizing Particles
- Optical investigation of THGEM
  - Electron avalanche asymmetry within a hole
- Summary & Future plans

Typical THGEM parameters:
a ~ 1 mm, d ~ 0.5 mm, h ~ 0.1 mm

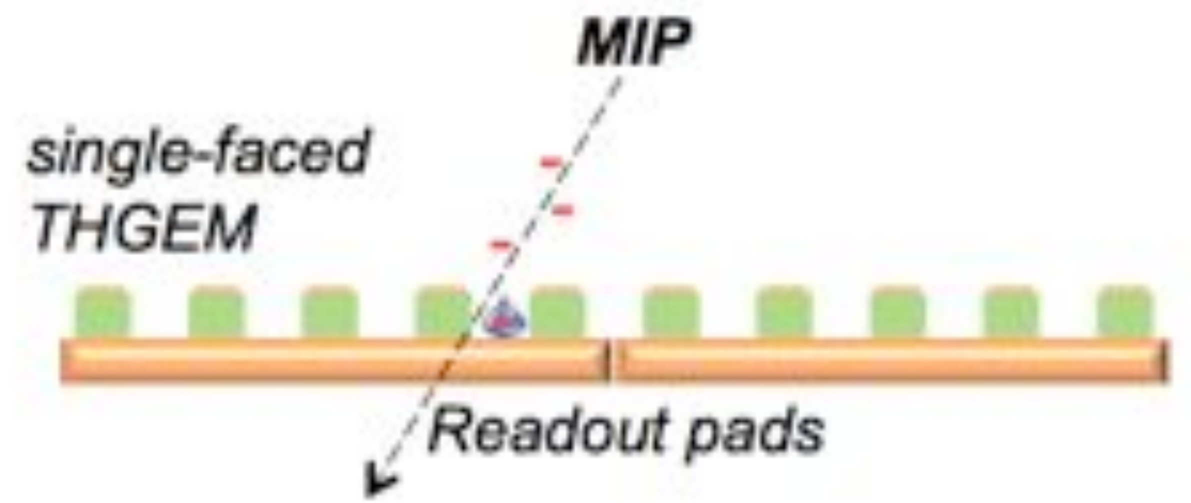


THGEM structures - THGEM & THWELL

THGEM
- Cu clad on both sides
- Operated with induction gap



THGEM WELL
- Cu clad on one side
- No induction gap - electrode attached to the anode

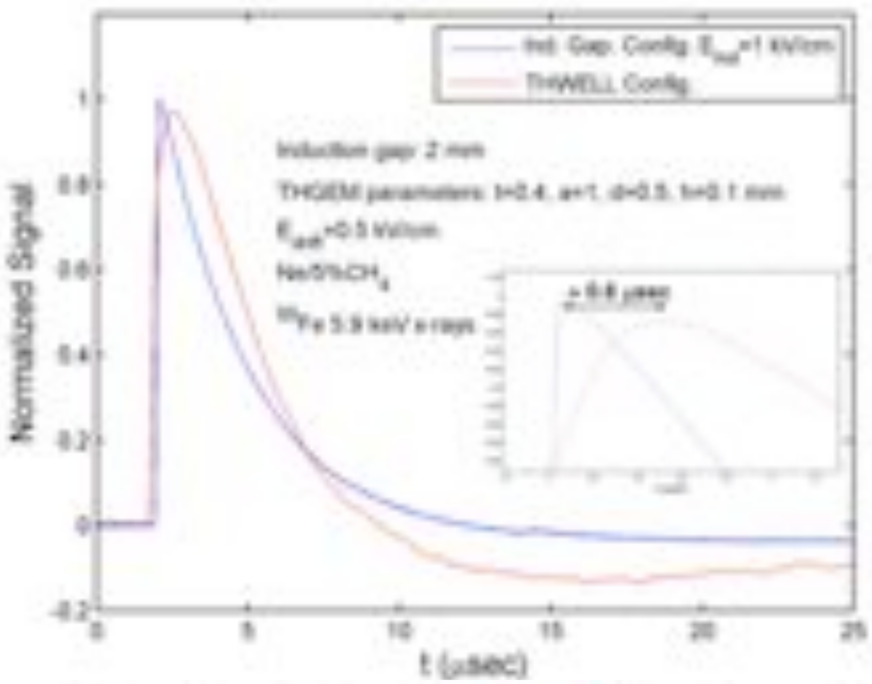


THGEM - thin induction gap
- Allow multiplying in the induction gap
- Smaller avalanche in the hole
- Higher effective Raether limit

THGEM structures - THGEM Vs. THWELL

THGEM

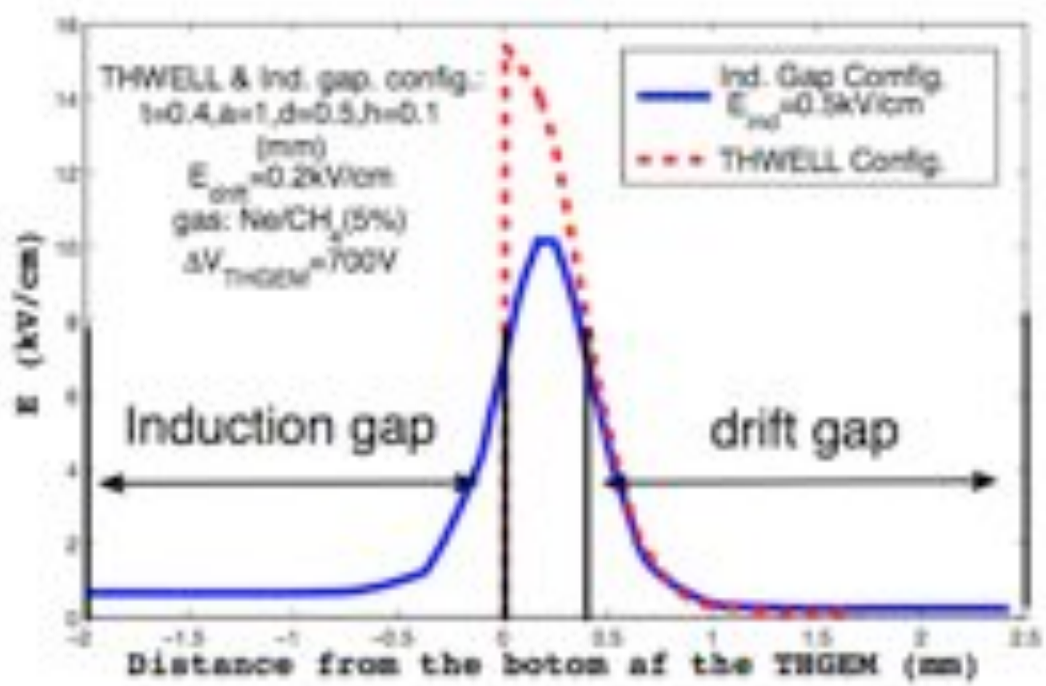
- Faster signal rise time
- Better gas circulation

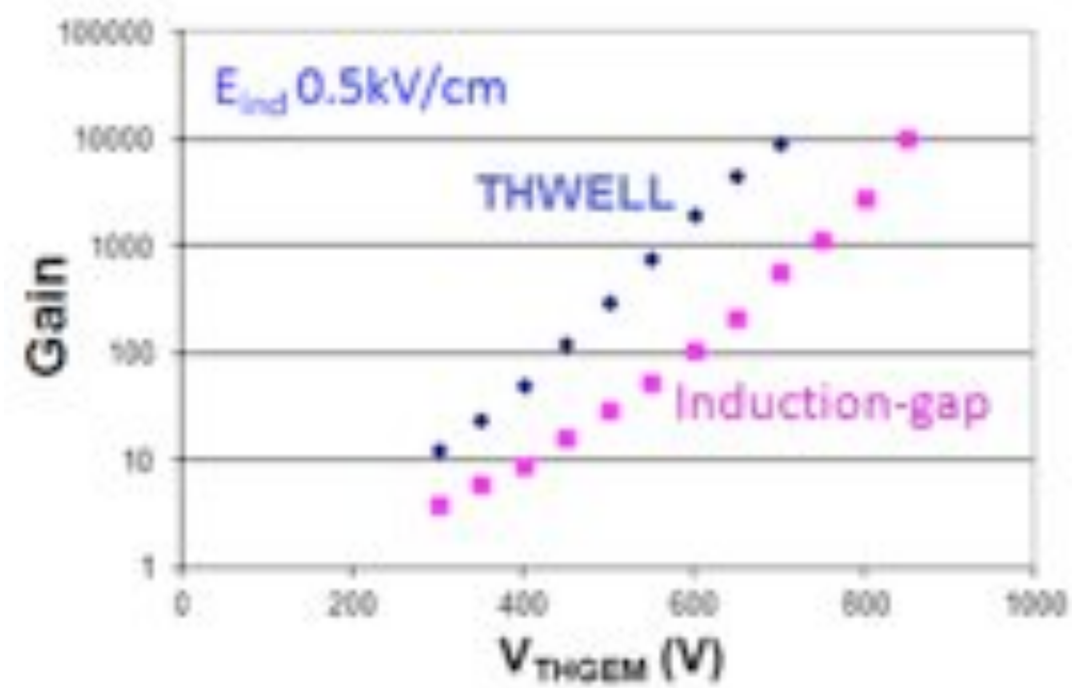


THWELL

- Much thinner detector
- Higher gain at the same voltage
  Higher fields within the hole

- Discharge: all spark energy attains the readout anode

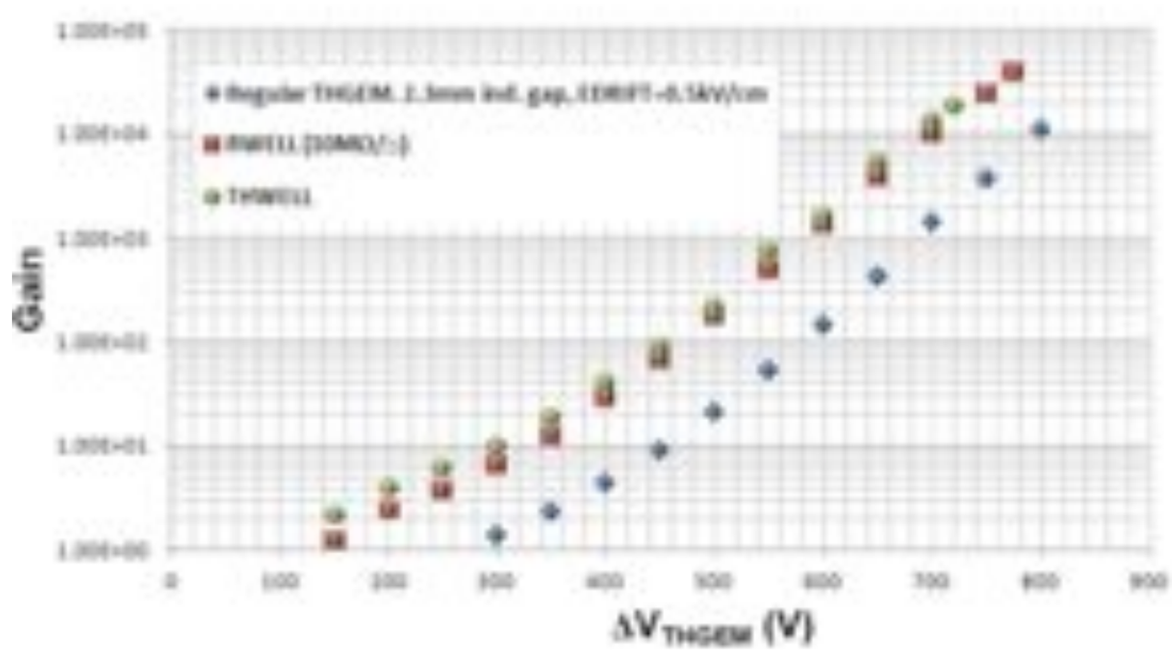


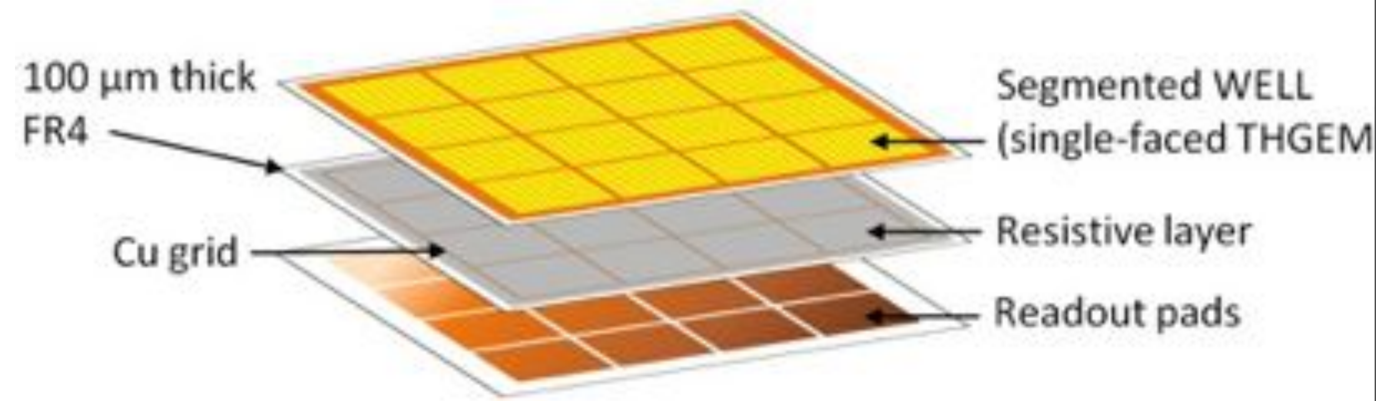


THGEM structures -RWELL & SRWELL

Resistive WELL:
- **WELL** coupled to a **resistive** layer (RL 10-20MΩ/square)
- Pads separated from the RL by a thin insulating sheet
- Charge induced on the readout pads
- RL quenches the energy of occasional discharges

Segmented RWELL:
- Cross talk due to charge propagation across the resistive layer is avoided by adding a Cu grid underneath
- The electrode is **segmented** accordingly to prevent discharges in holes residing directly above grid lines

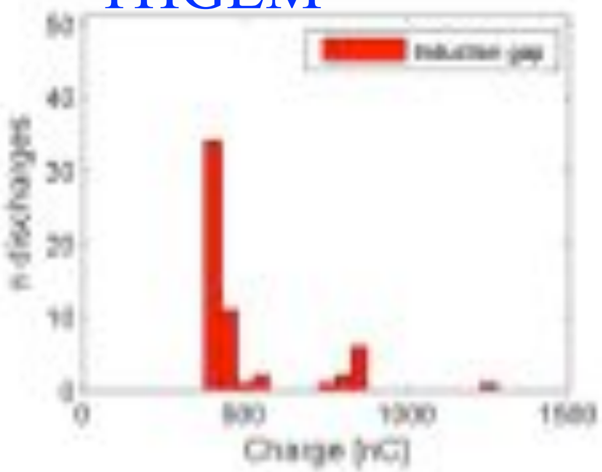




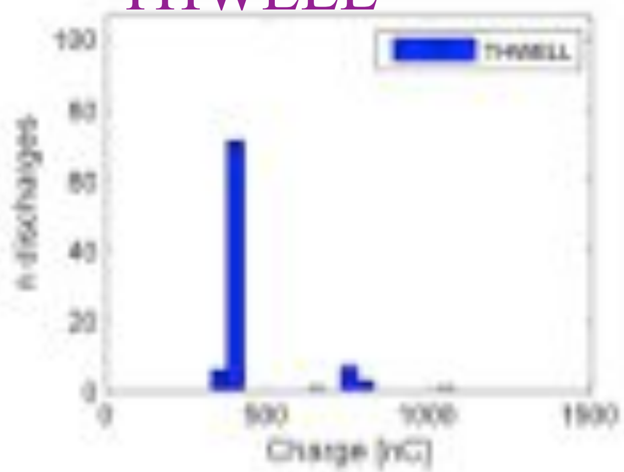
THGEM structures - RWELL & SRWELL

SRWELL* & *RWELL 10×10 cm^2
spark magnitude is quenched by factors of 5 & 20 respectively
The Cu strips reduce the quenching

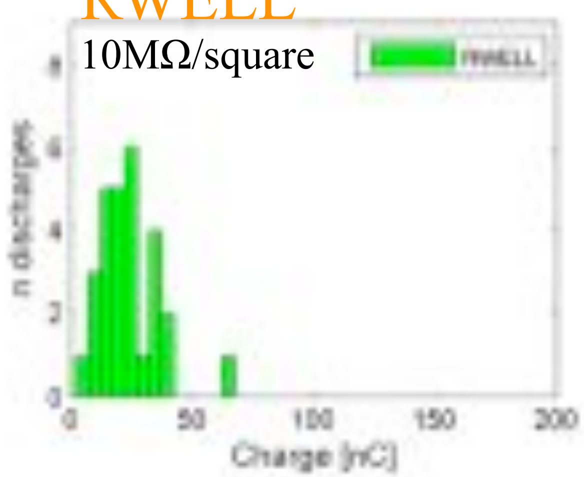
THGEM



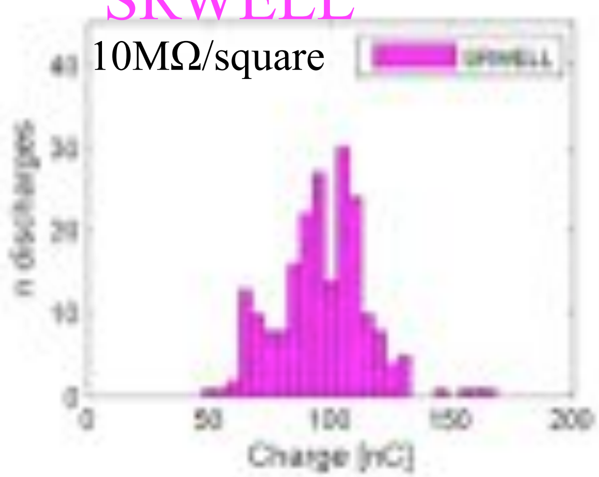
THWELL



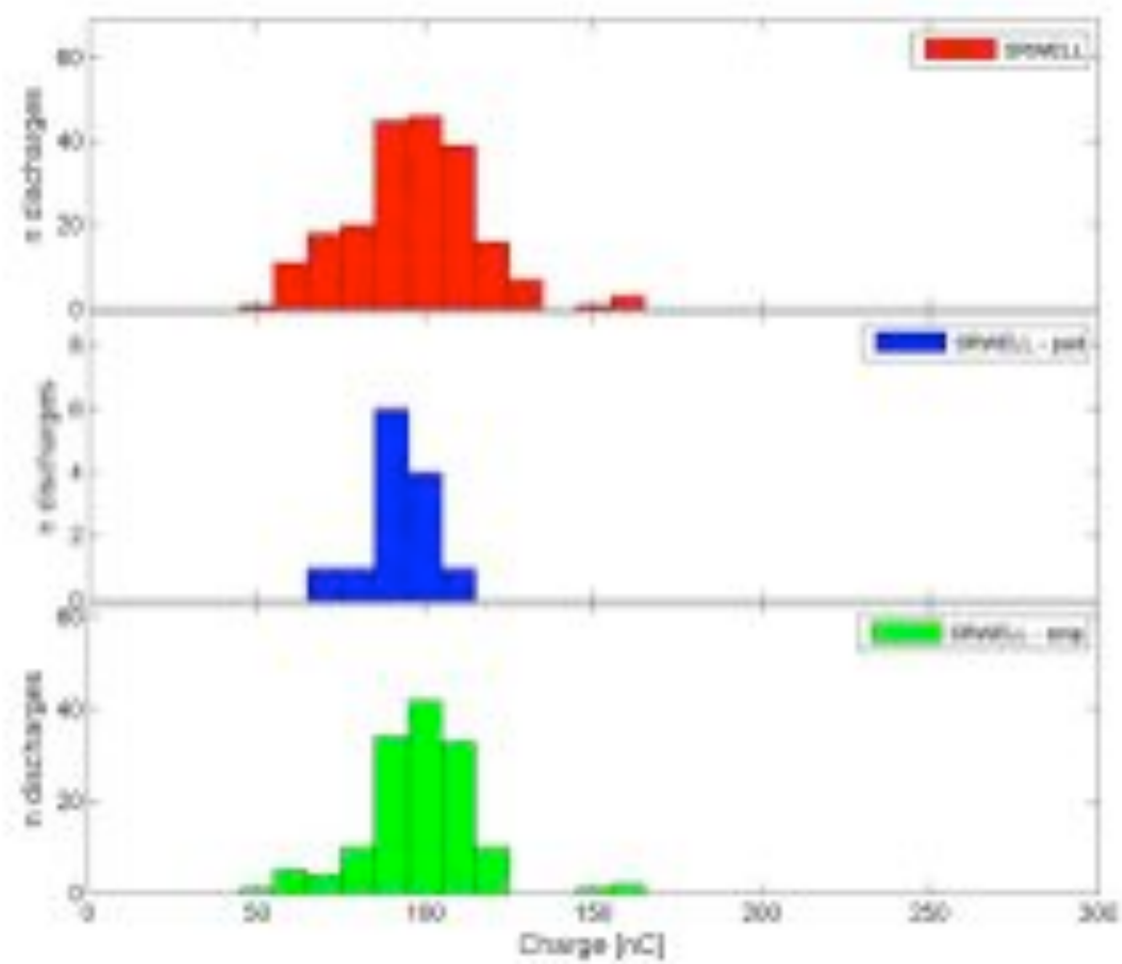
RWELL



SRWELL



SRWELL 10×10 cm^2
The spark magnitude is not affected by the distance from the Cu strip

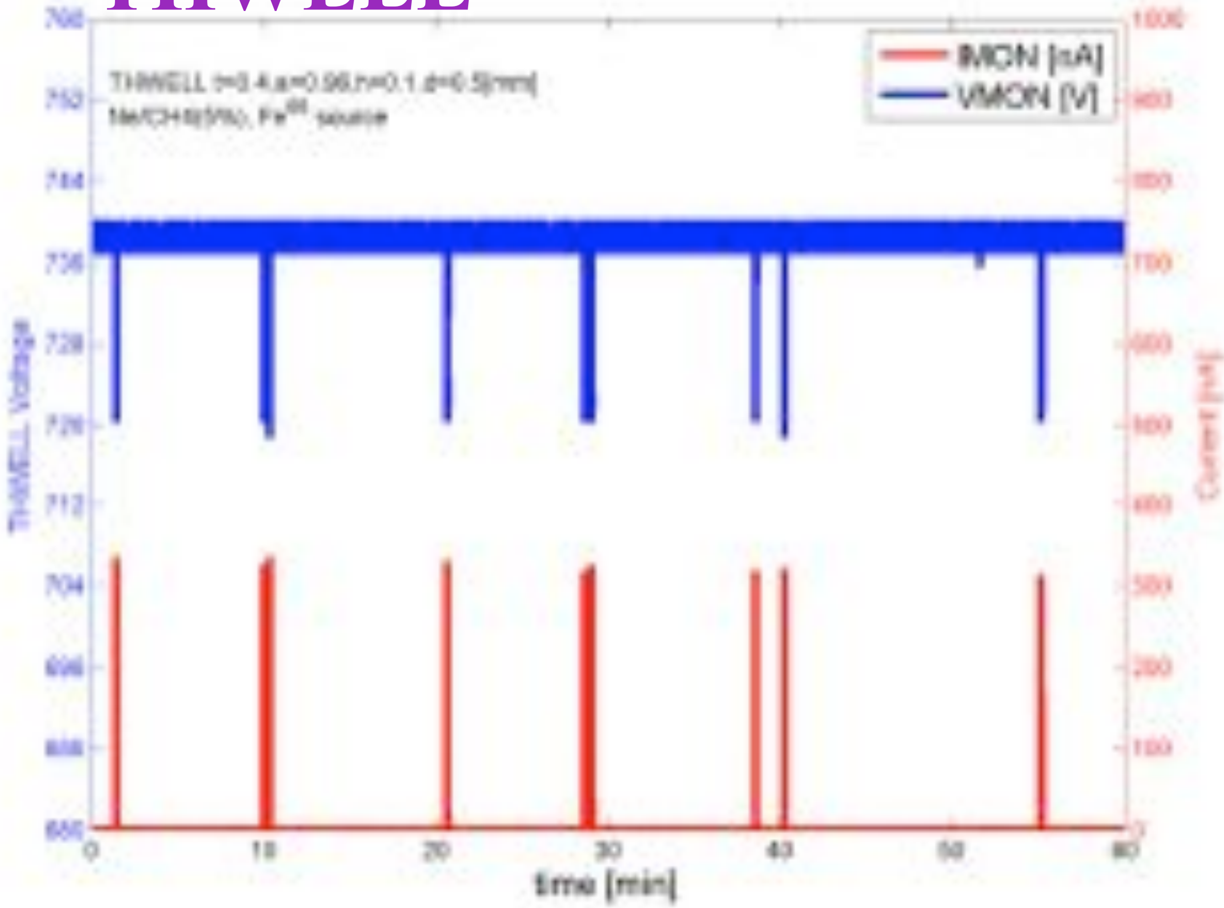


L. Arazi et al. paper in preparation (JINST)

THGEM structures - RWELL & SRWELL

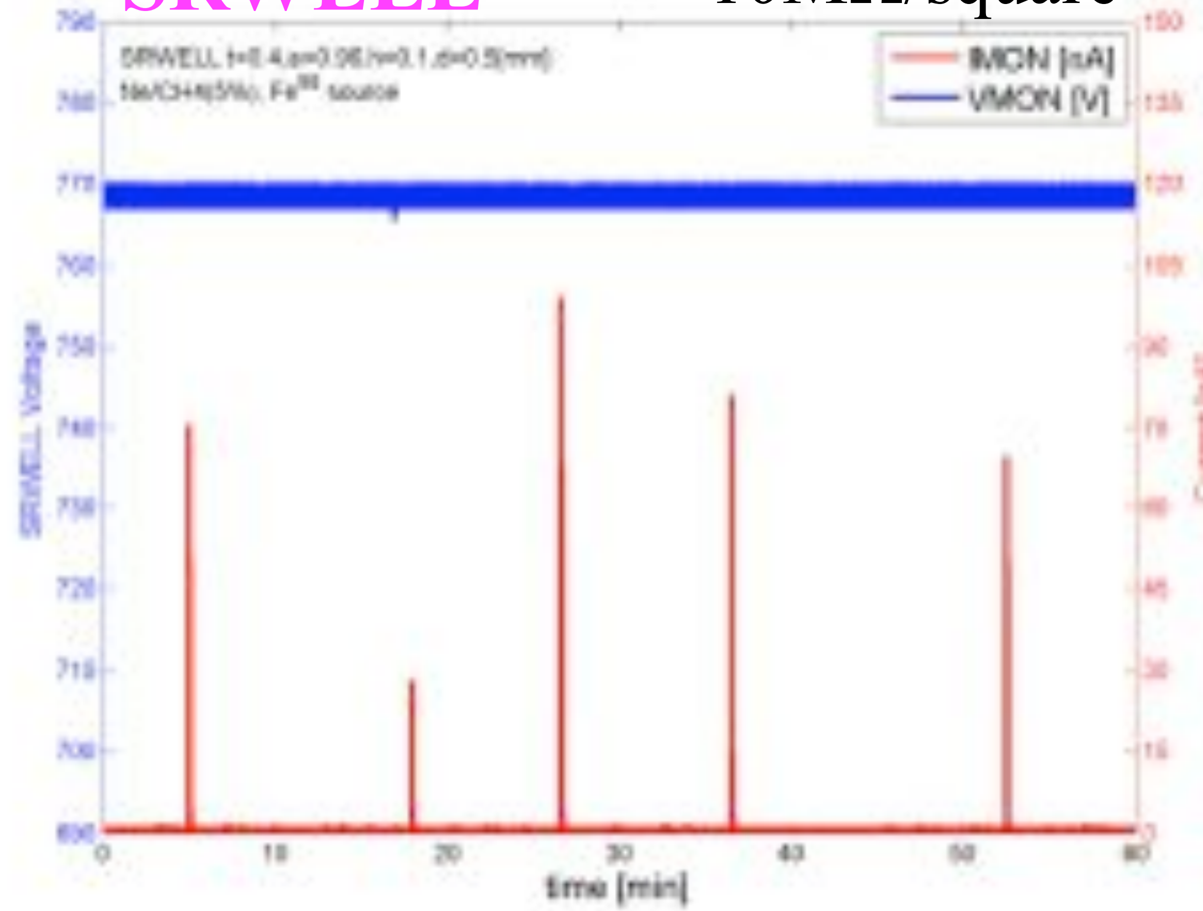
RWELL & SRWELL: No voltage drops after discharge

THWELL



SRWELL

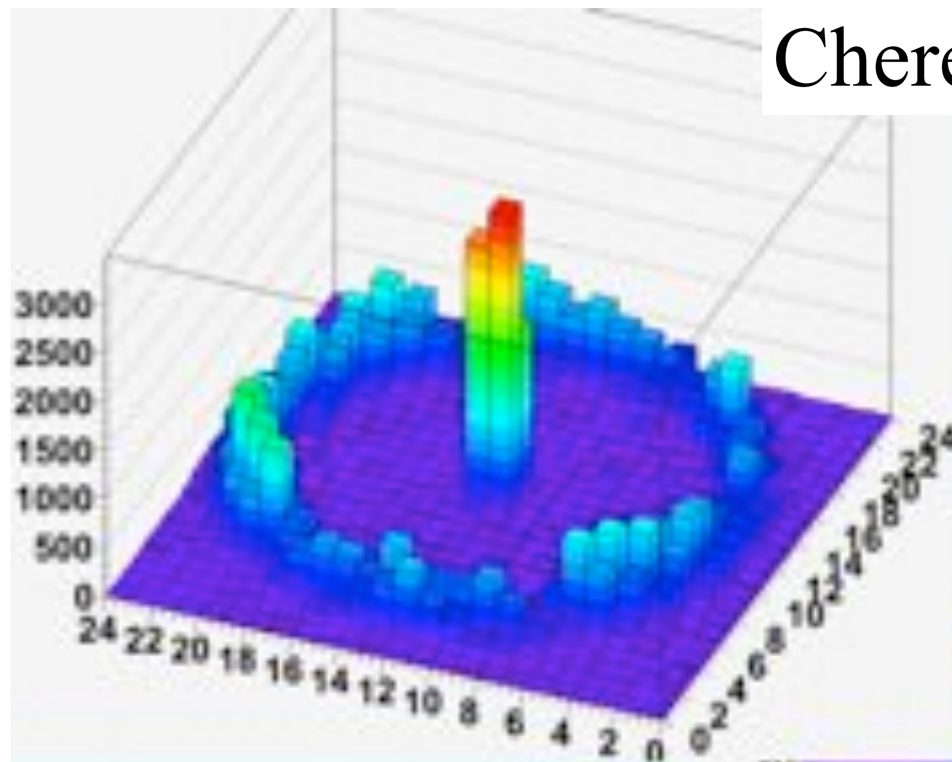
10MΩ/square

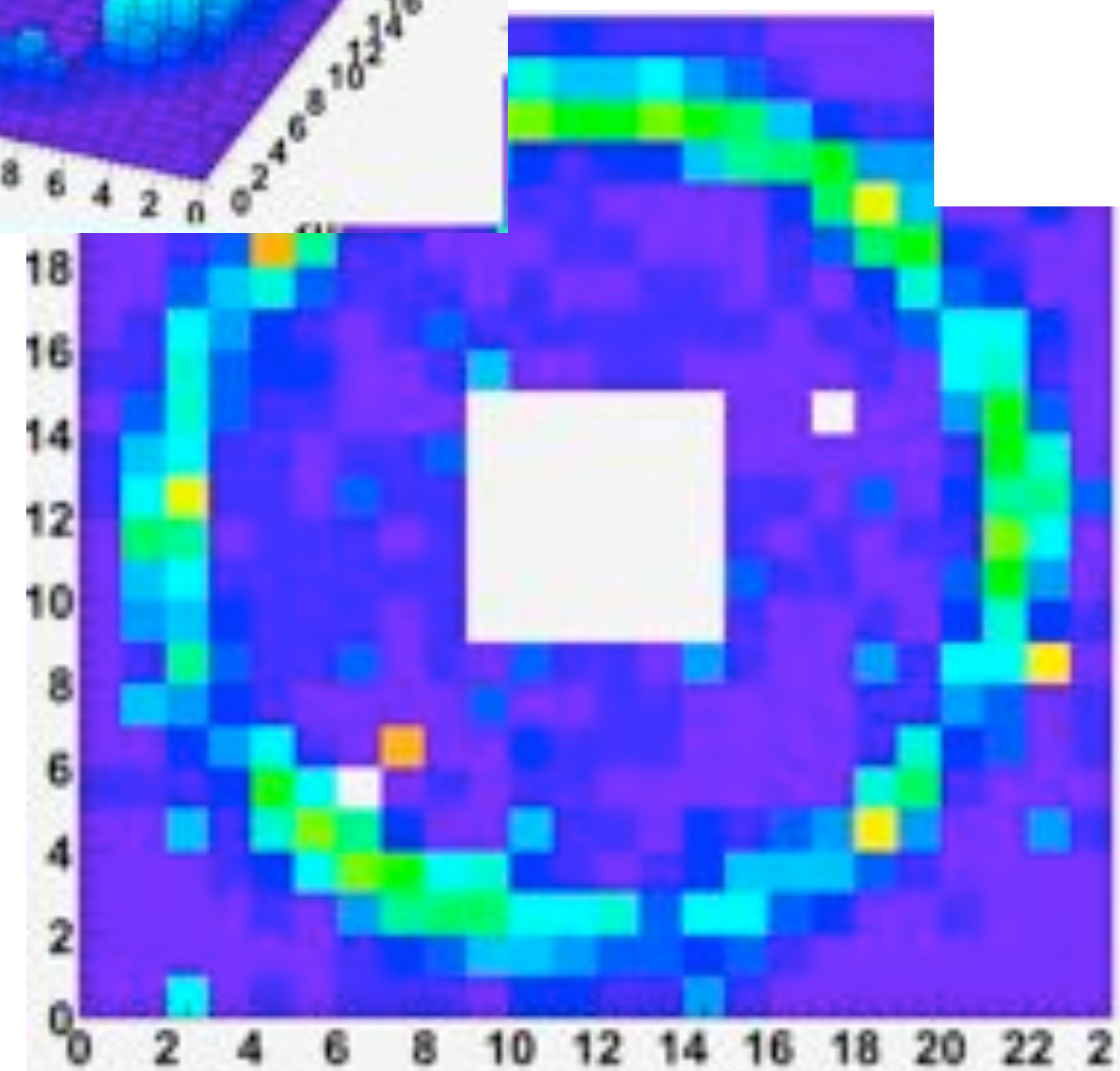


Present applications - THGEM for COMPASS RICH

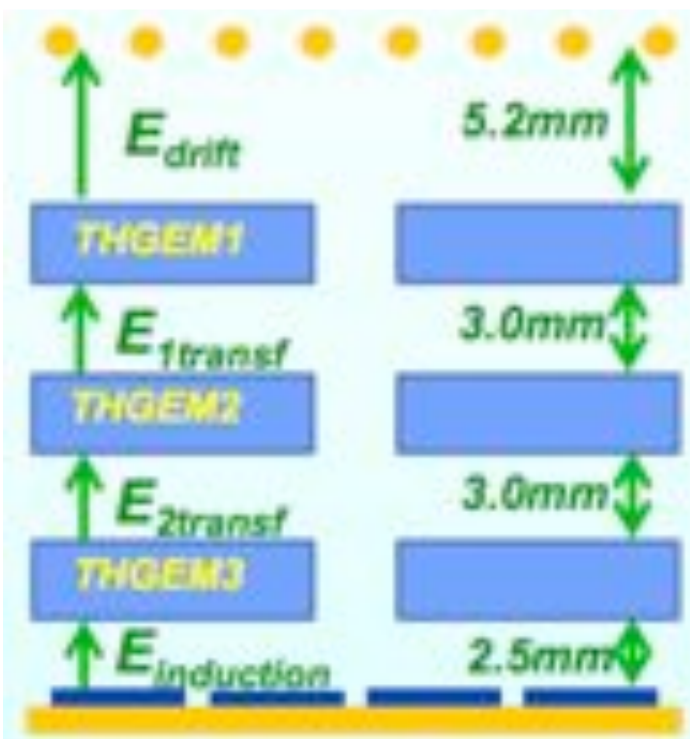
See Fulvio Tessarotto's talk this afternoon

Beam test evaluation:
Cherenkov rings





Triple-THGEM



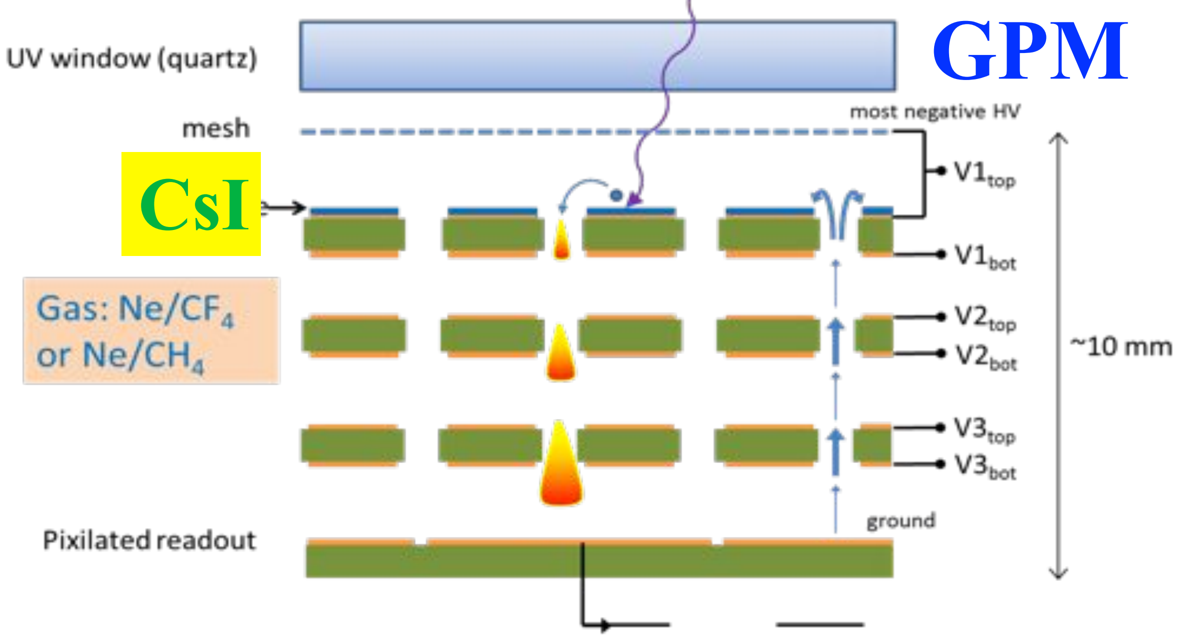
M. Alexeev et al. 2013 JINST 8 P01021

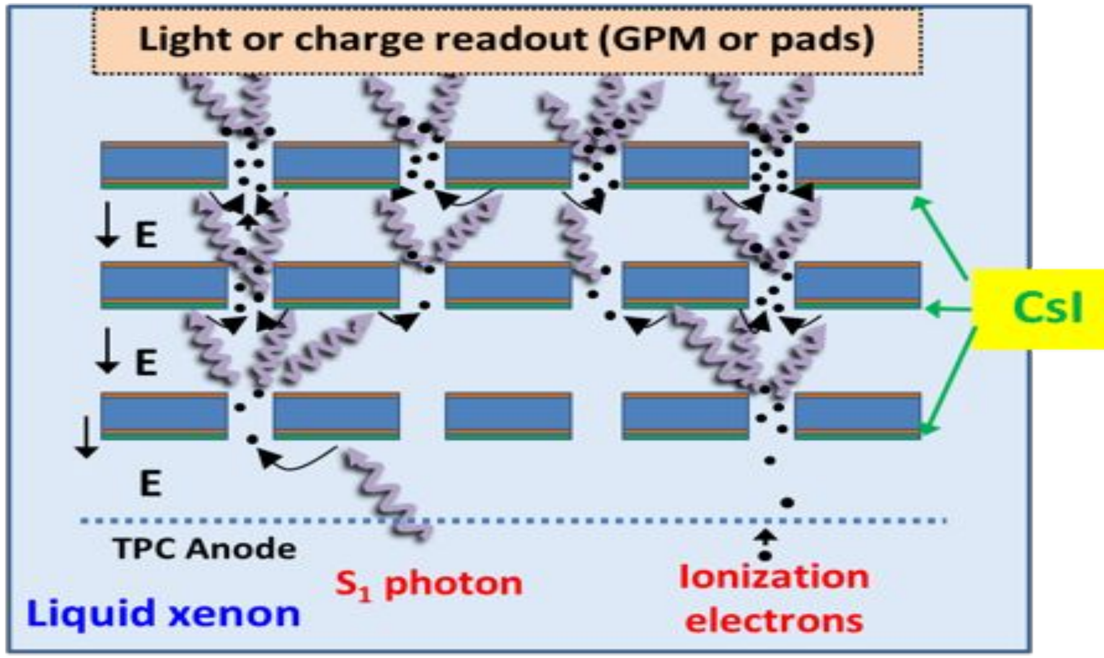
M. Alexeev et al. Physics Procedia 37 (2012) 781-788

Present applications -

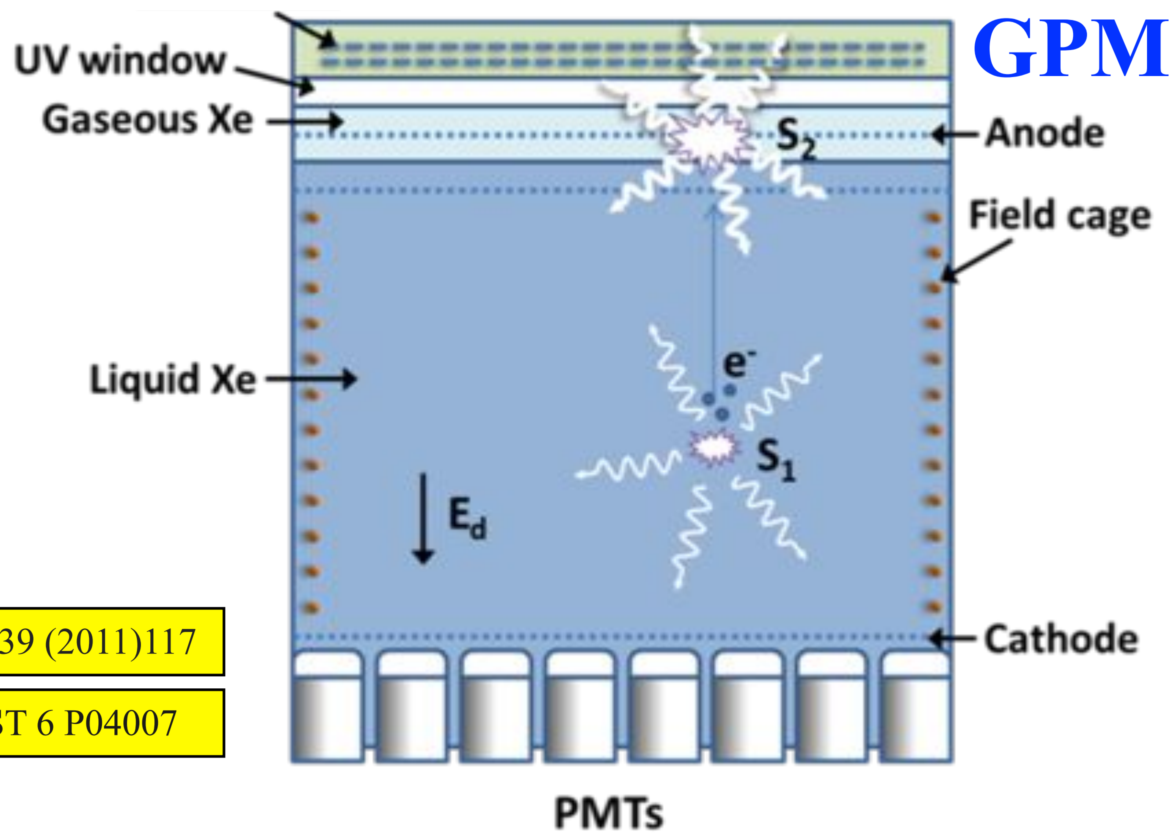
Low T THGEM in noble-liquid TPC (DM etc.)

See Amos Breskin's talk in the following RD51 meeting

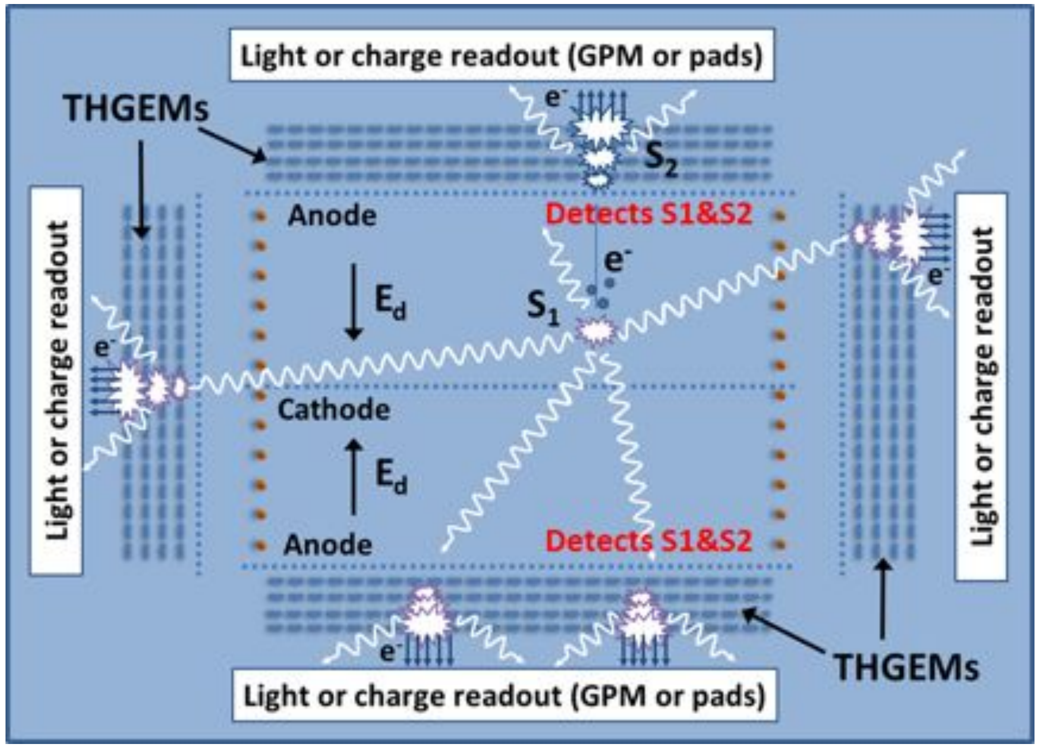




Dual-phase TPC



4π all-liquid TPC



Breskin NIM A639 (2011)117

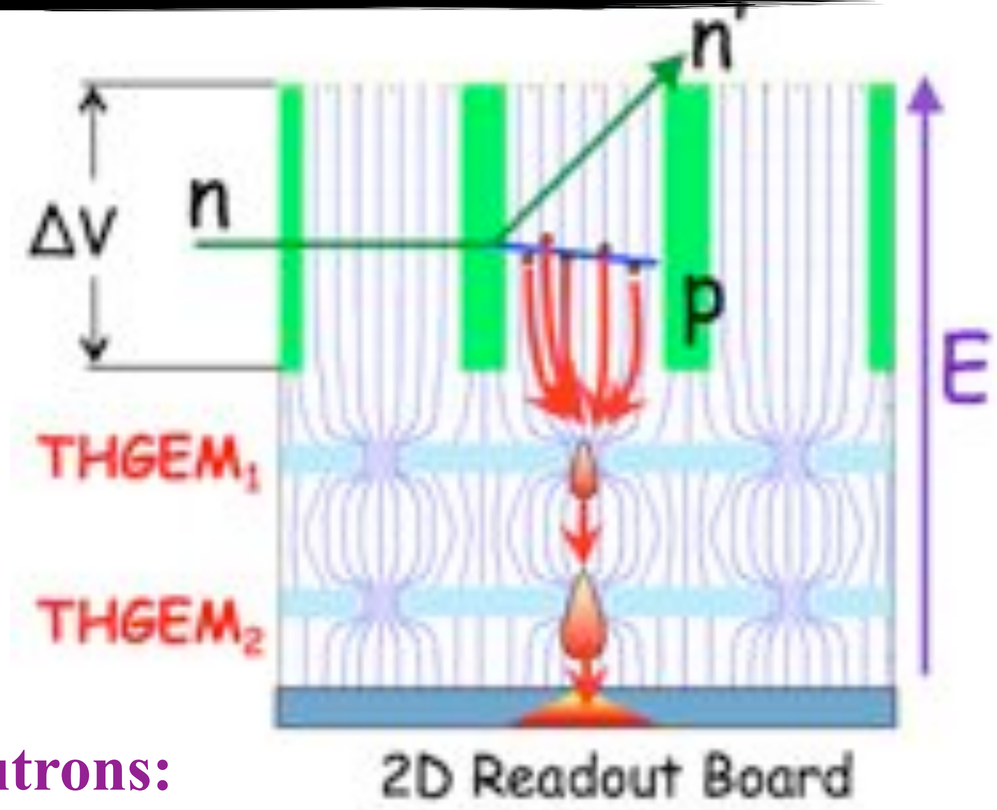
Duval 2011 JINST 6 P04007

Present applications -
THGEM for cold fast neutron imaging

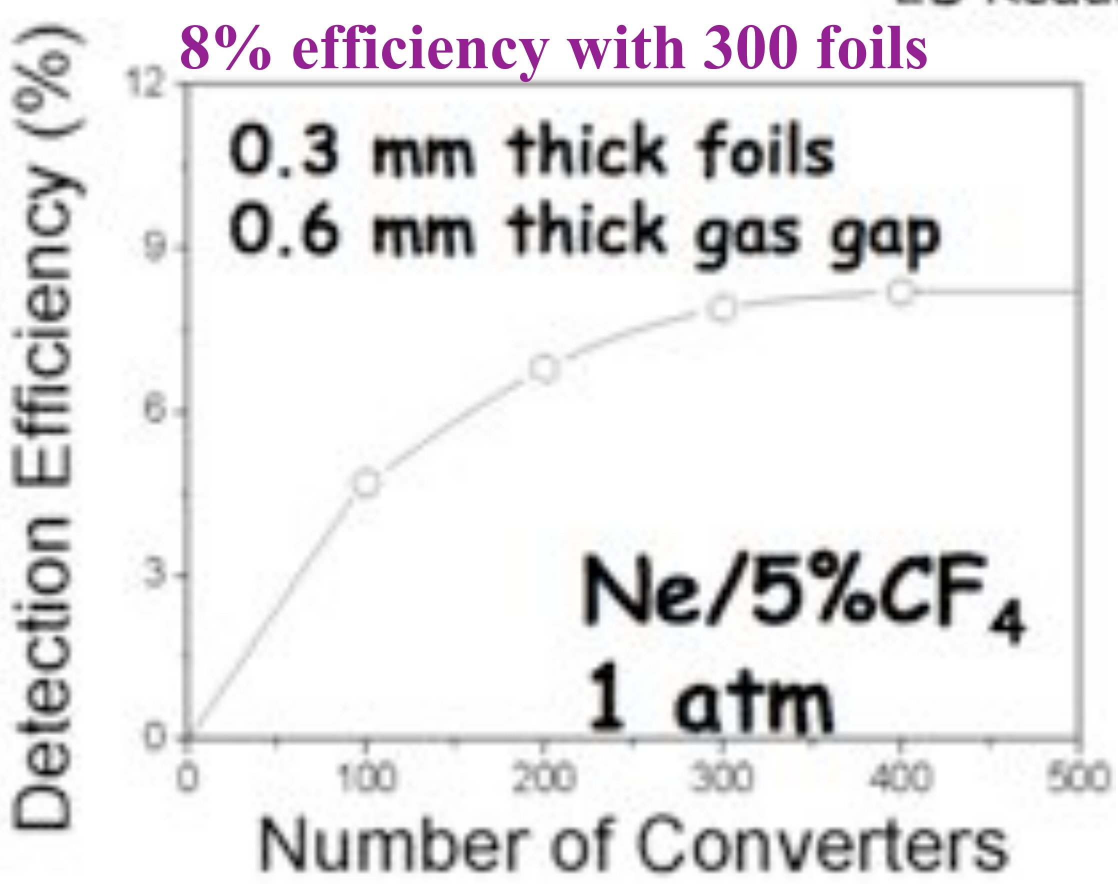
See Marco Cortesi's talk on Wednesday

Requirements:

- High detection efficiency
- Spatial resolution ~ 1 mm^2
- High rate capabilities & good counting rate



2.5 MeV neutrons:
8% efficiency with 300 foils



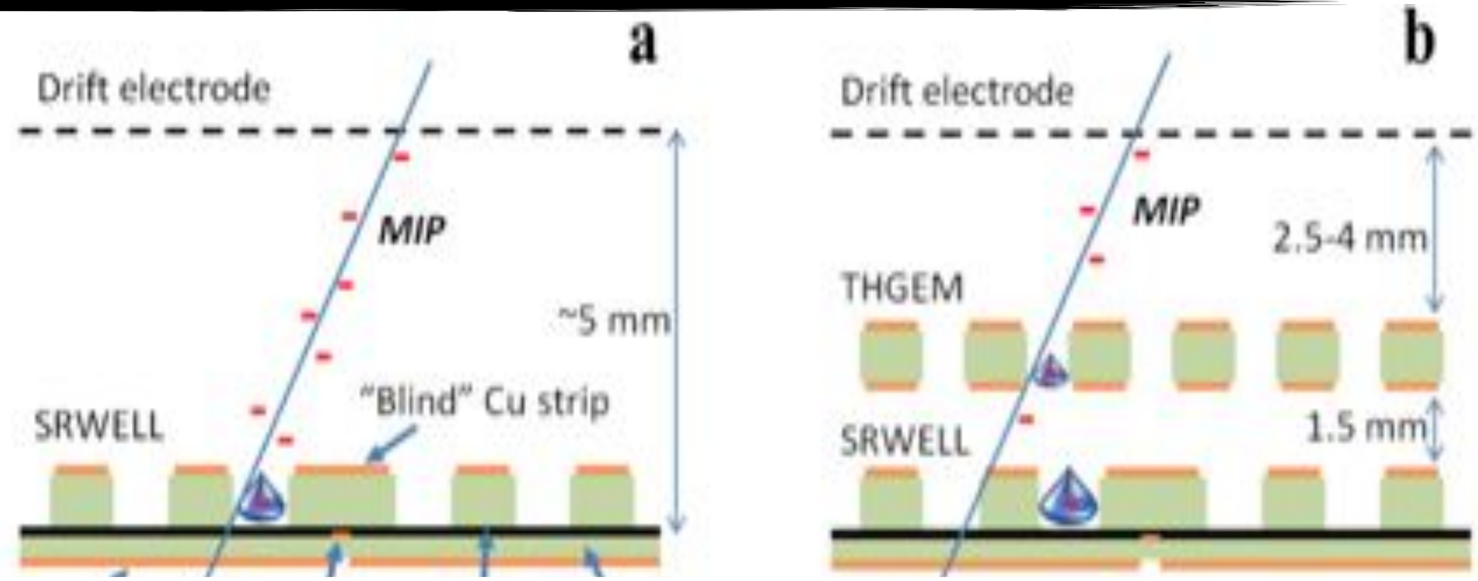
Cortesi et al. 2013 JINST 8 P01016

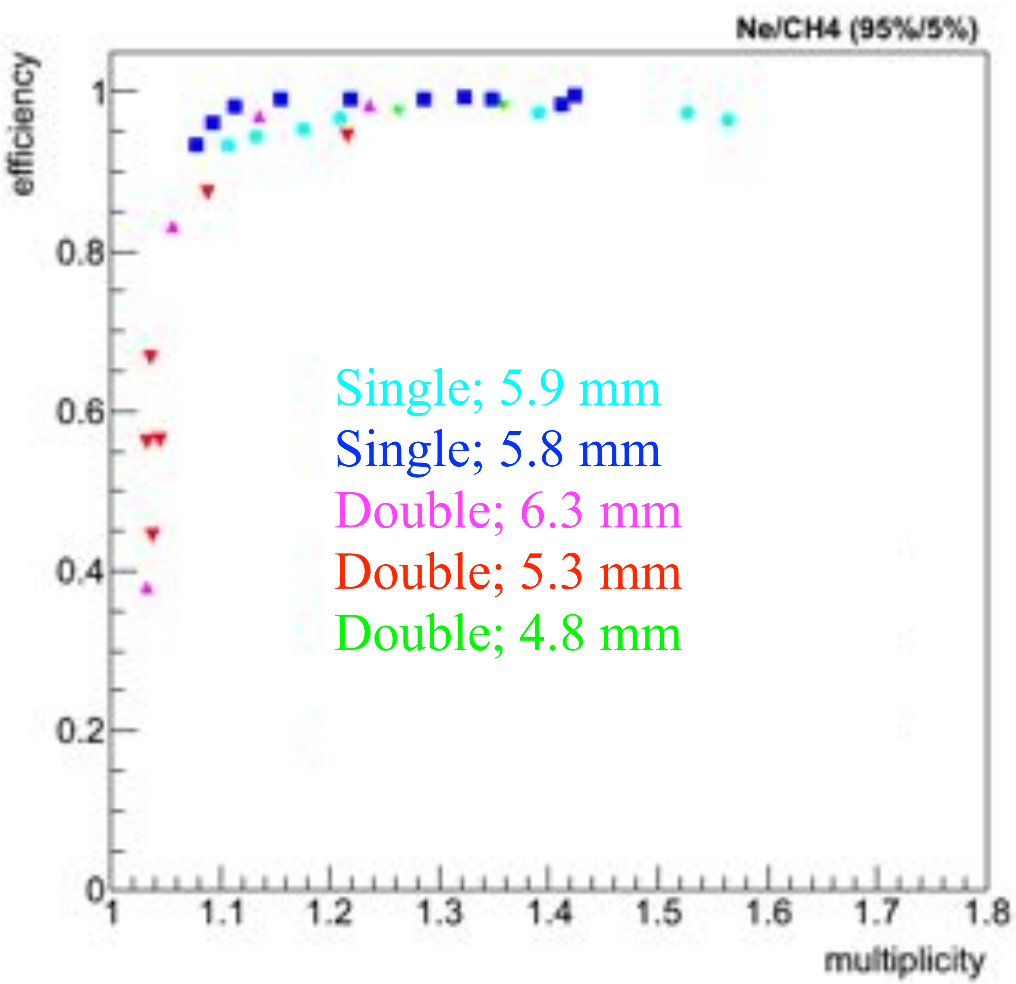
Cortesi et al. 2012 JINST 8 C02056

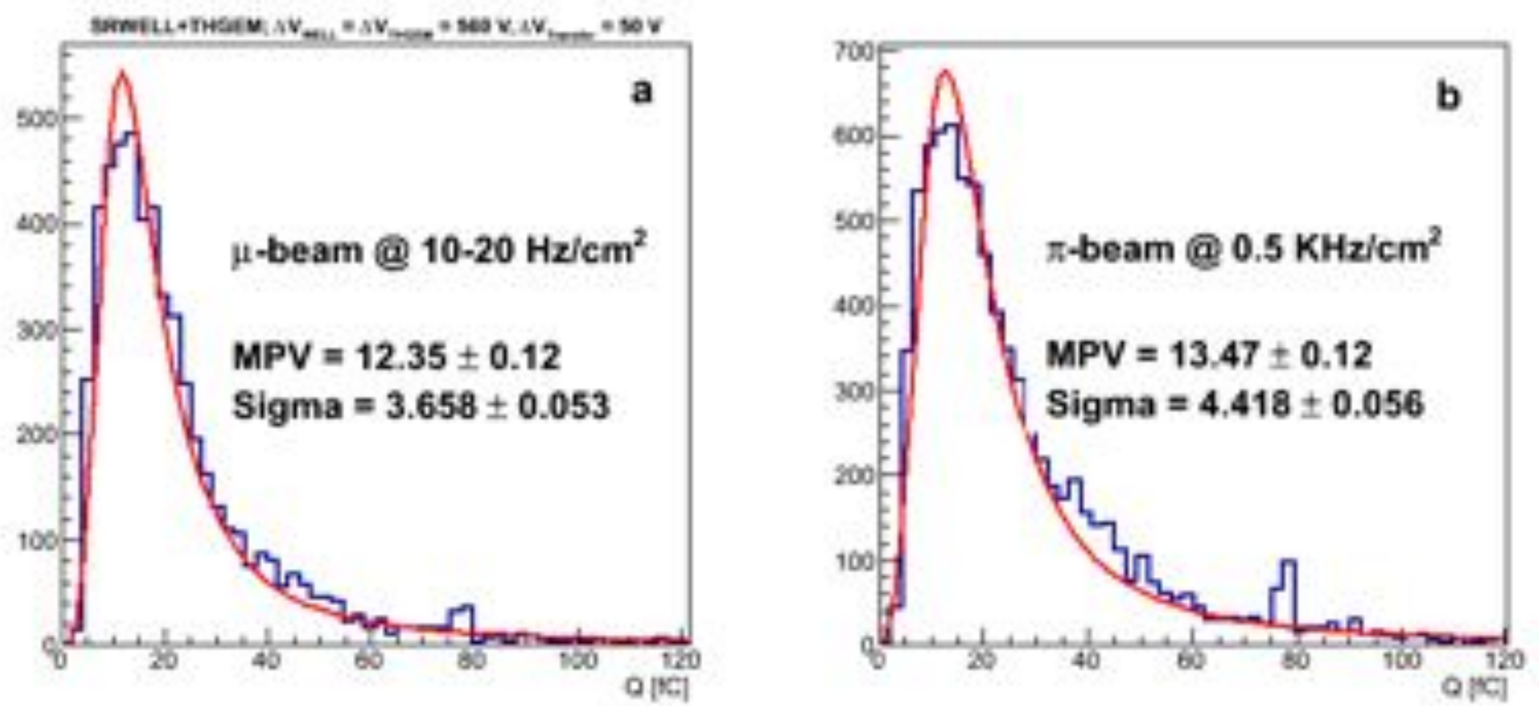
Present applications - SRWELL for (S)DHCAL

Beam test evaluation: SRS/APV readout

- 4.8 - 6.3 mm thick single- and double-stage configurations
- Gains 1000-8000
- Detection efficiency > 95% @ pad multiplicity ≲ 1.2







S. Bressler et al. JINST July 2013 arXiv:1305.4657

L. Arazi et al. 2012 JINST 7 C05011 arXiv:1112.1915

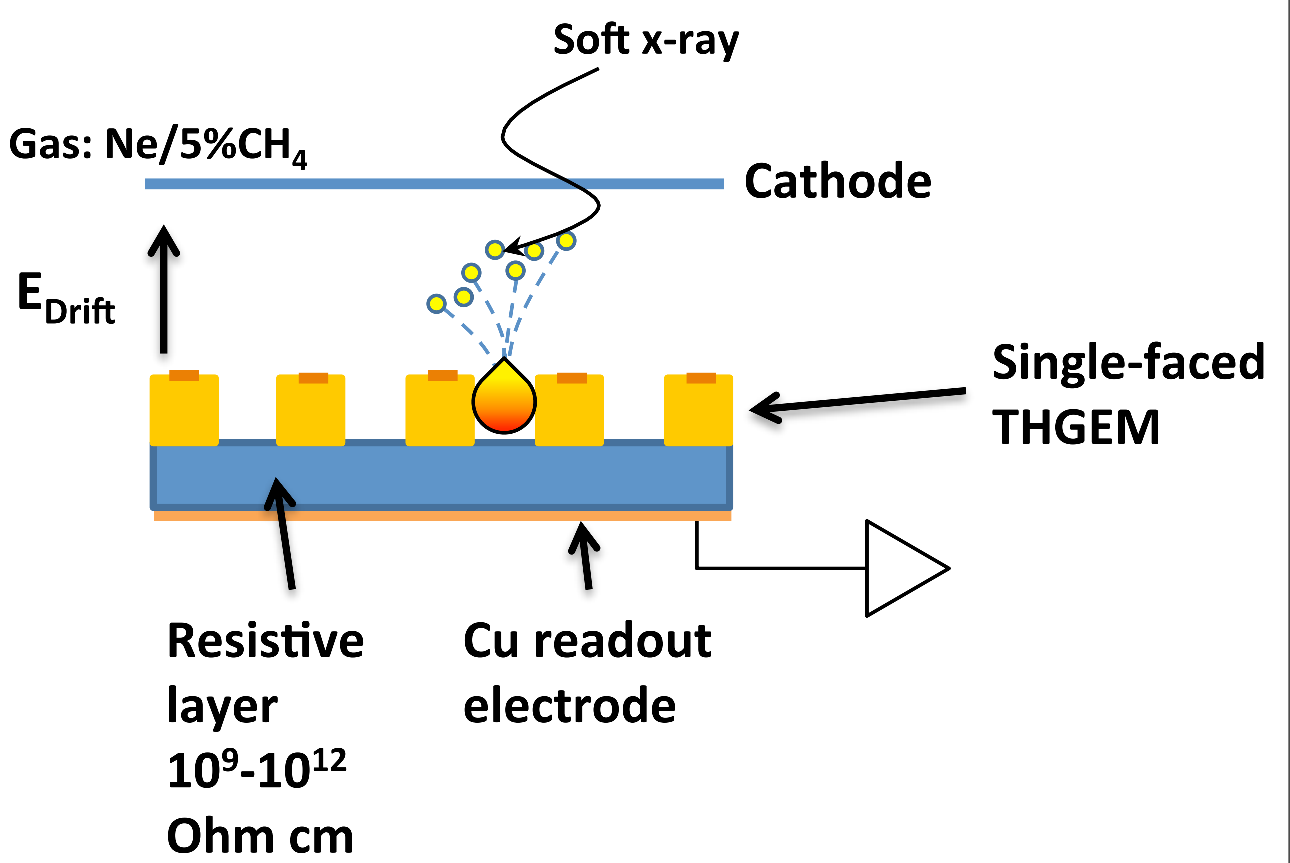
Studies with MICROROC

- **THGEM**/MICROROC: successful operation in μ-beam and π-beam, inc. showers
- **SRWELL**/MICROROC: promising preliminary lab R&D

THGEM structures - RPWELL

Resistive Plate WELL:

- WELL coupled to materials with large bulk resistivity
- The charge is induced on the readout pads
- The avalanche charge flows through the plate to the anode (doesn't propagate sideways)
  - Less cross talk ? (under study)



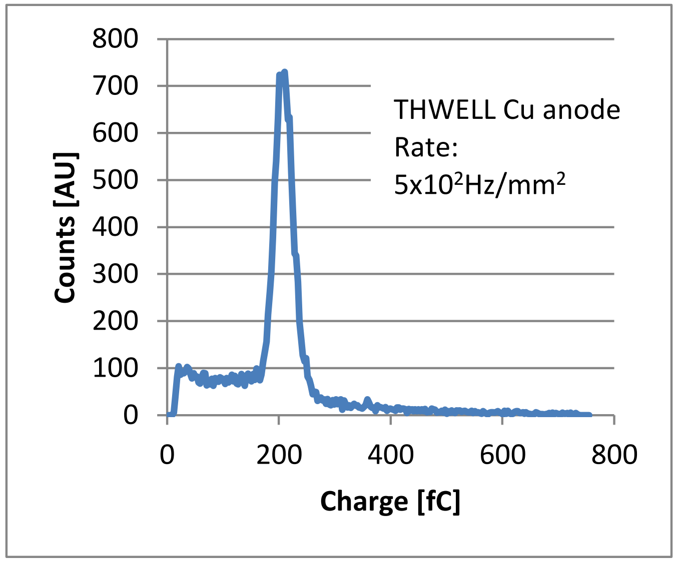
Tested materials

Material	Dimensions [mm]	Bulk resistivity [Ωcm]
VERTEC 400 glass	36×31×0.4	8×10^{12}
HPL Bakelite	29×29×2	2×10^{10}
Semitron ESD 225	30×30×2	2×10^{9}
Semitron ESD 225	30×30×4	3×10^{9}

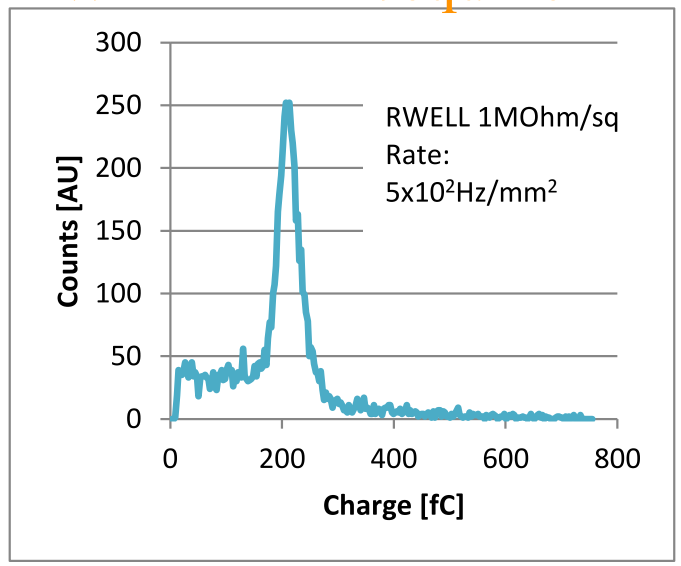
A. Rubin MSc Thesis 2013. Paper in preparation (JINST)

Performance - Typical spectra

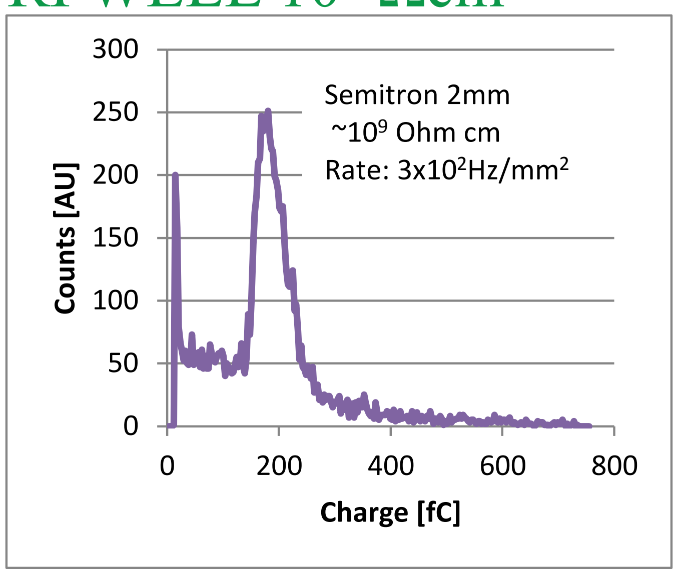
THWELL



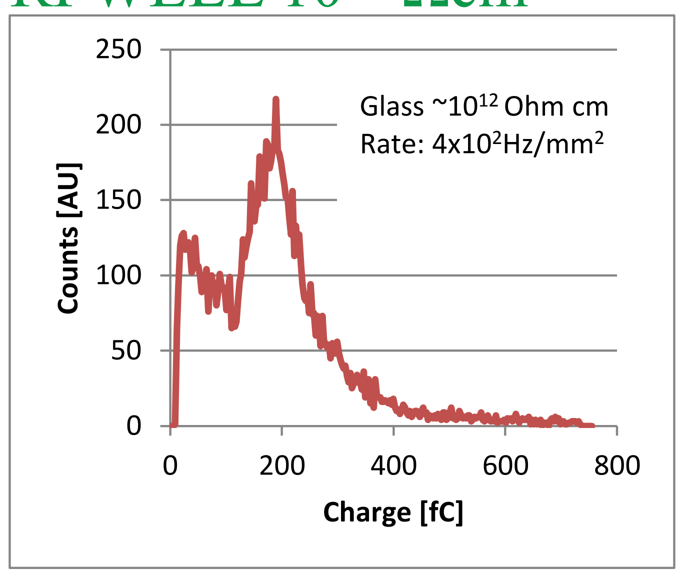
RWELL 1MΩ/square



RPWELL 10^9 Ωcm



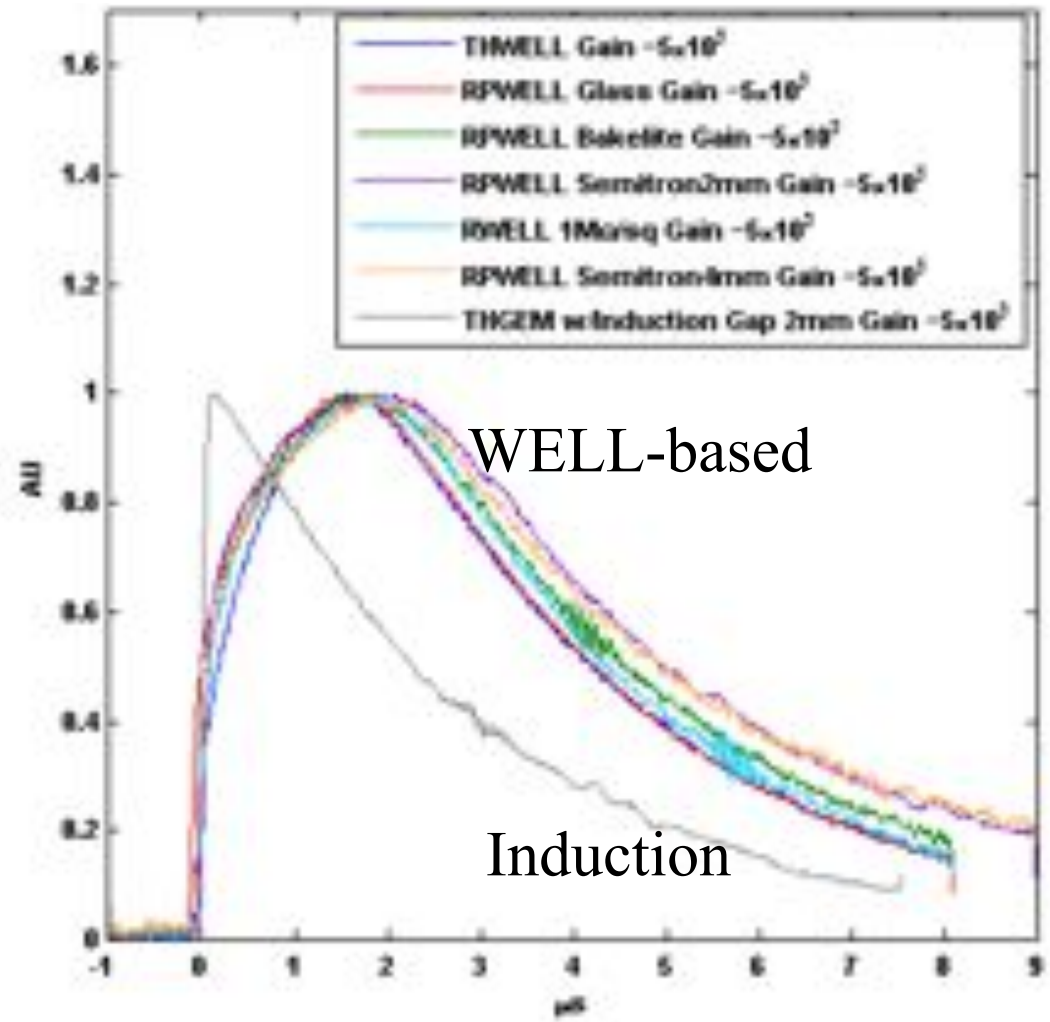
RPWELL 10^{12} Ωcm



Ne/CH4(5%), Cu target x-ray tube with Ni filter, MCA spectrum

The spectrum is well-separated from the noise

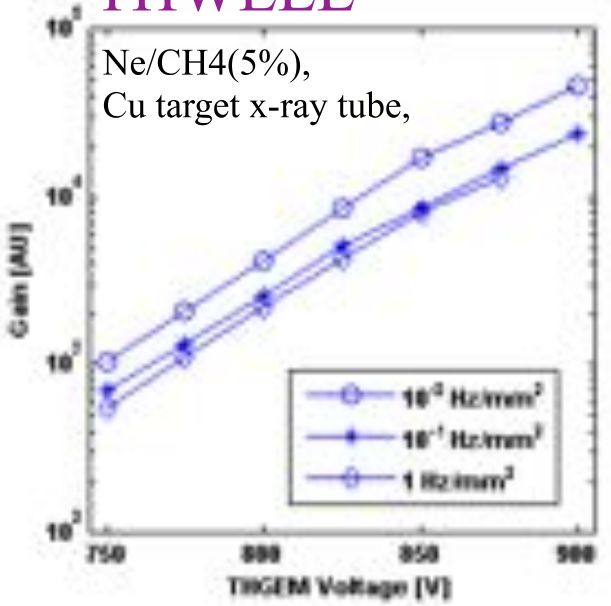
Ne/CH4(5%), Cu target x-ray tube



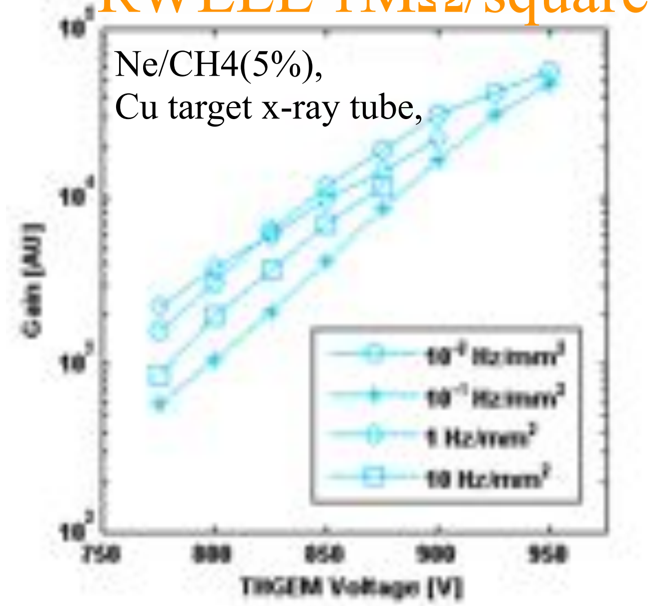
Visible ion component / similar signal shape for all the resistive configurations

Performance - Gain curves

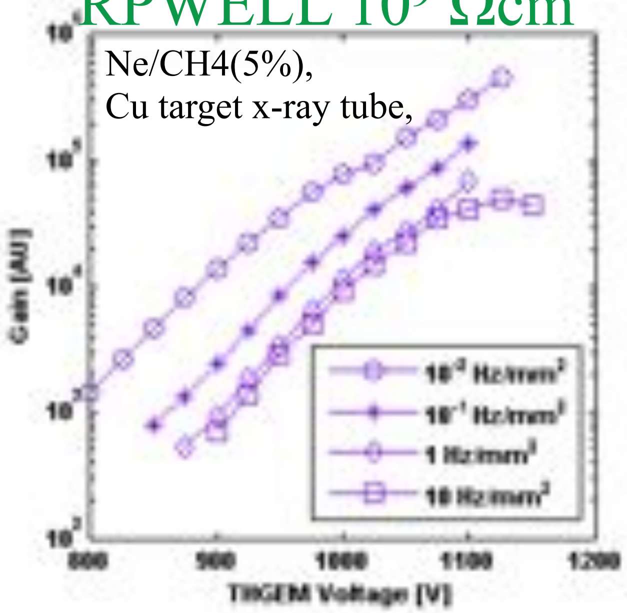
THWELL



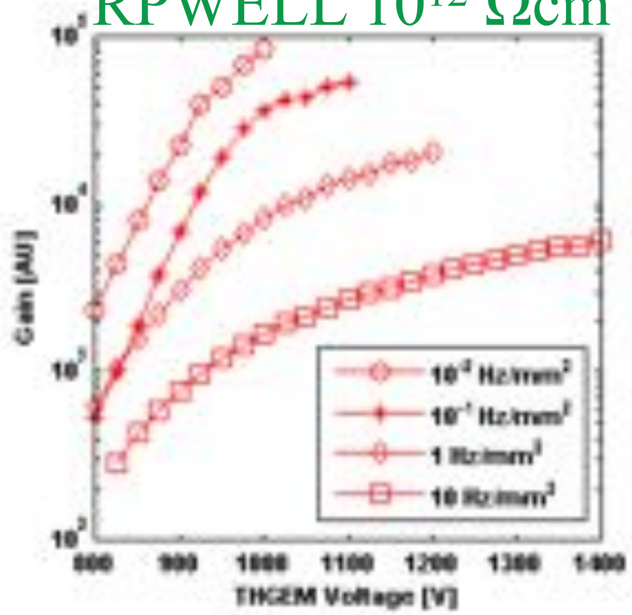
RWELL 1MΩ/square



RPWELL 10^9 Ωcm



RPWELL 10^{12} Ωcm



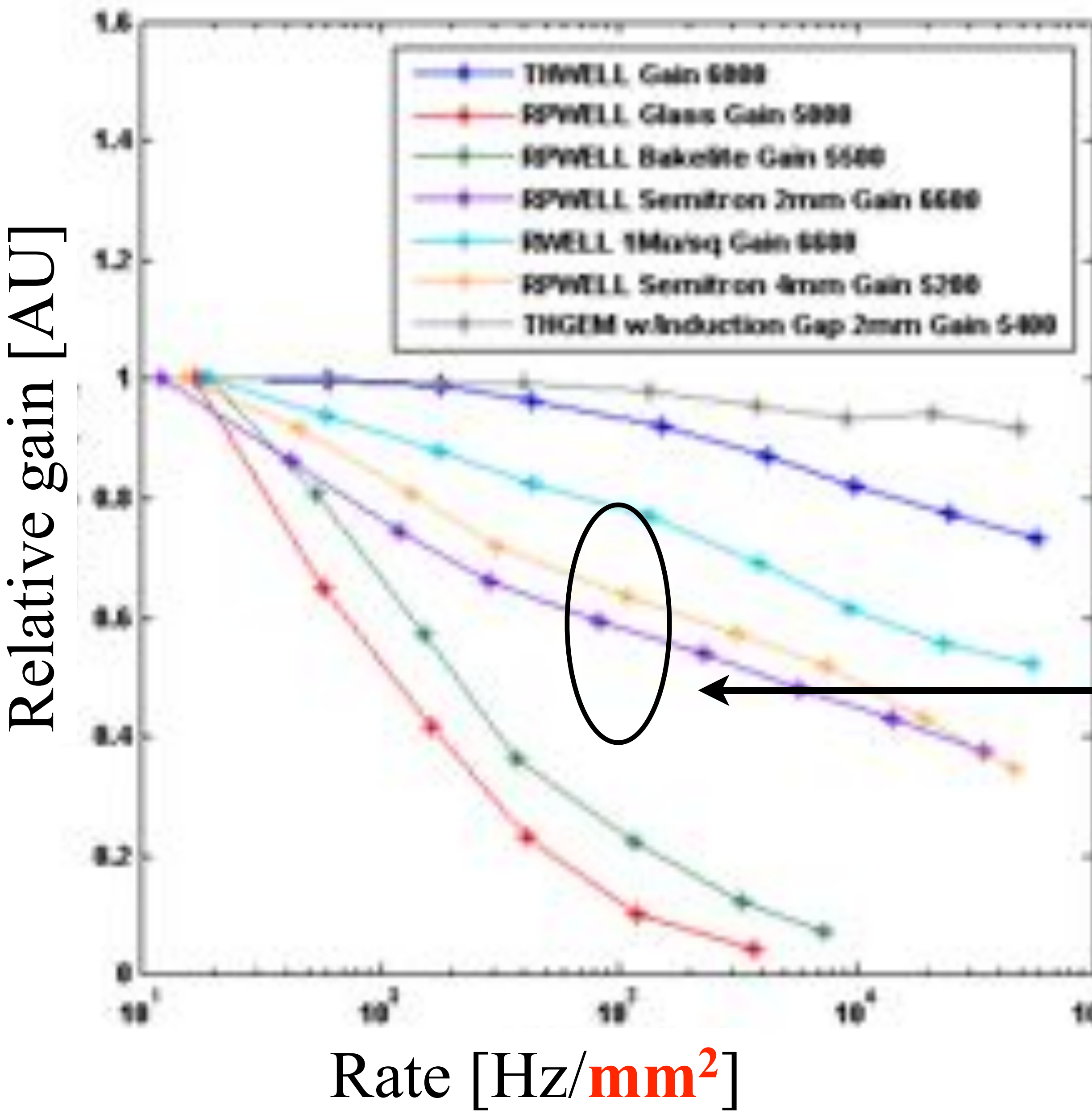
- The Rate dependence of the gain is discussed in the next slide

RPWELL:

- Apparent gain saturation in both configurations
  - Important for some applications (e.g. RICH)
- No sparks at high operation voltages

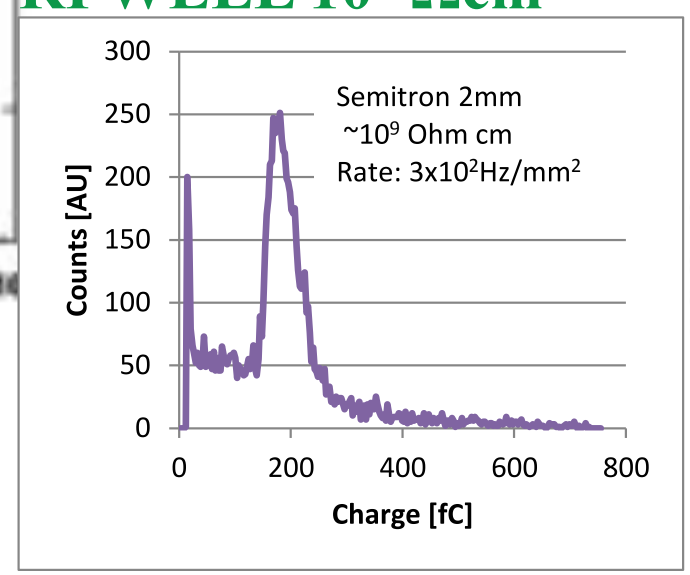
Performance - Gain Vs. Rate

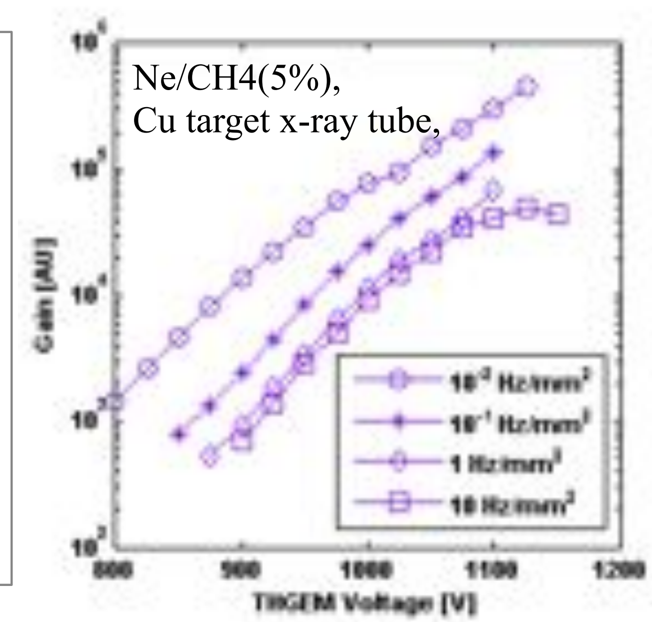
- At rates < 100 Hz/cm^2 gain drops less than a factor of 2
  - Not orders of magnitudes
- Similar performance to other resistive detectors



Most promising configurations - do thinner plates also work?

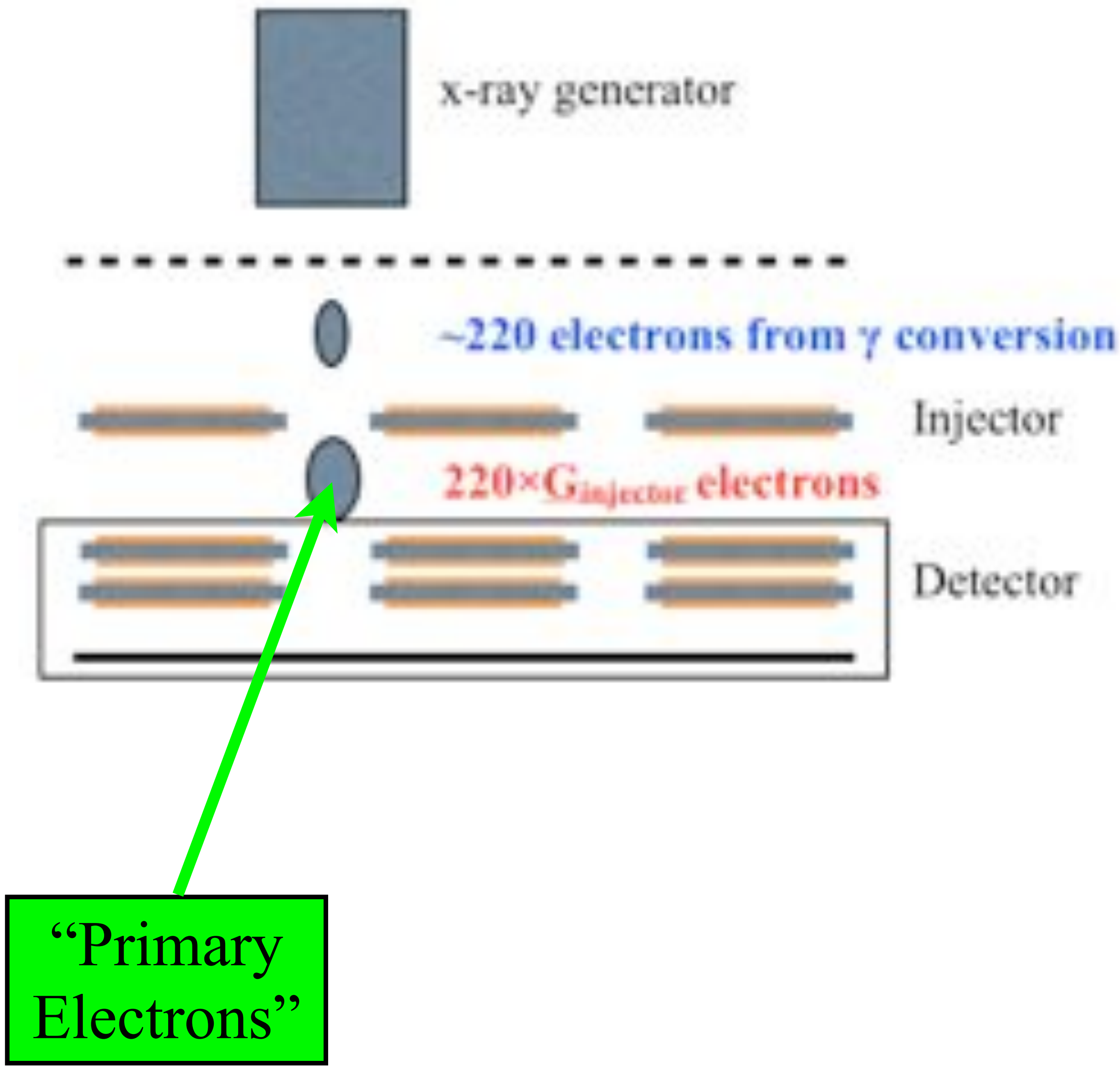
RPWELL 10^9 Ωcm





Response to Highly Ionizing Particles (HIPs)

- Mimic Highly Ionizing Particles in the lab
- Measure the discharge probability as a function of the number of primary electrons

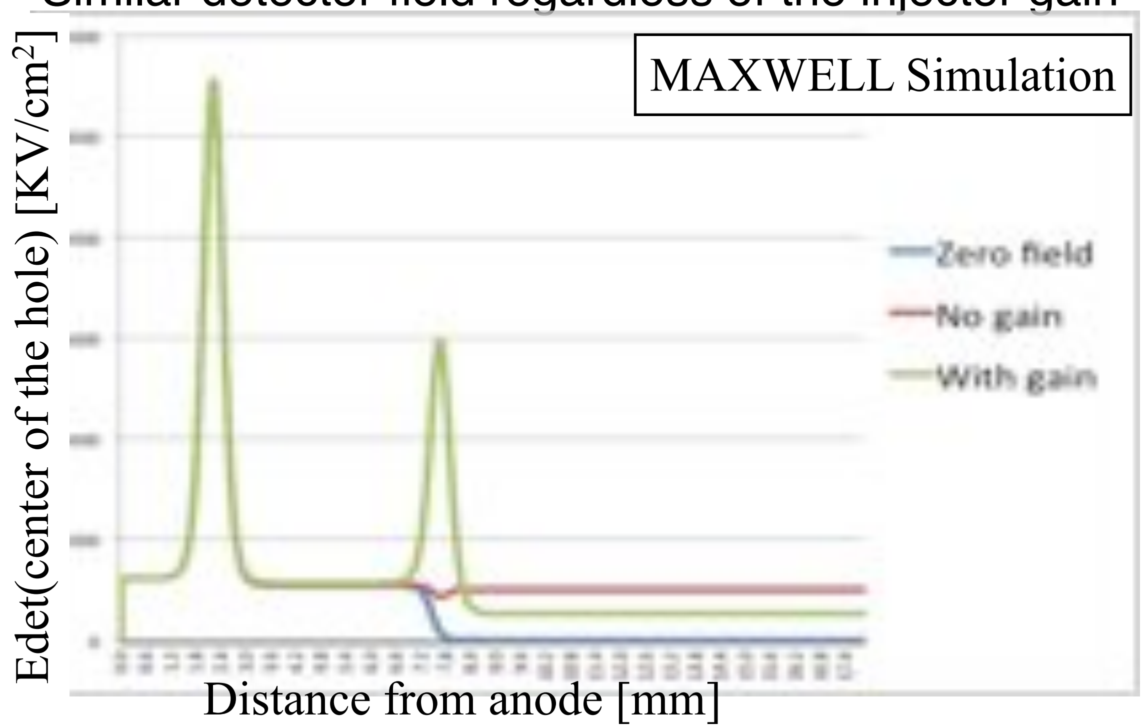


- The *injector* method:
  - Use additional multiplication stage far from the detector
  - Multiply the electron from the x-ray conversion prior to the detector
  - Characterized the injector gain precisely

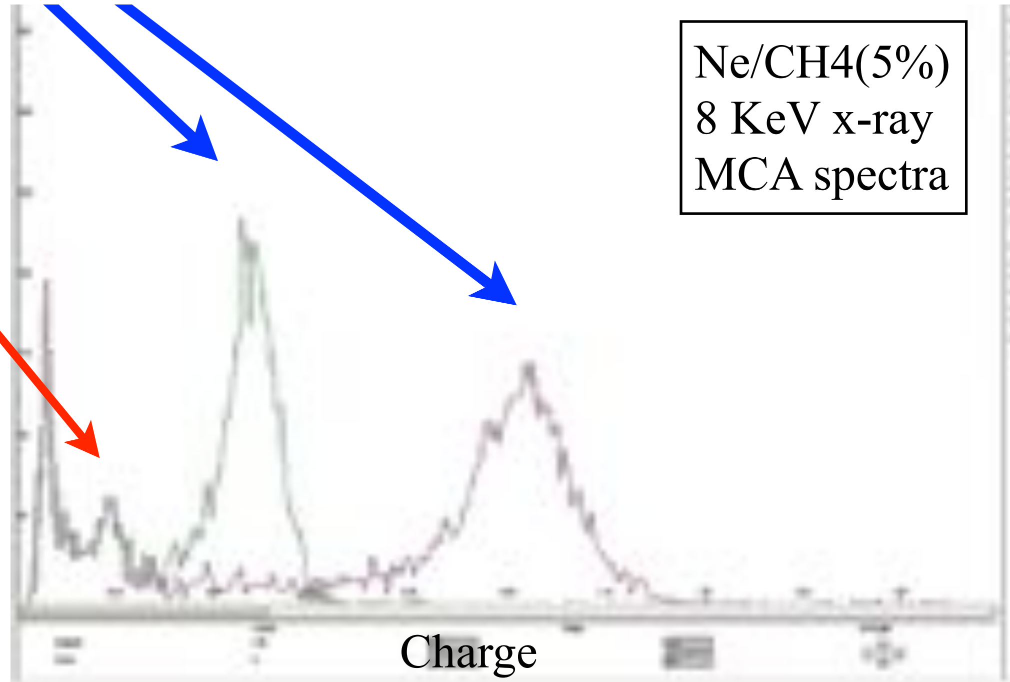
Response to HIPs

- At 5 mm gap, the injector is decoupled from the detector
- A typical spectrum has two peaks:
  - γ conversion before the injector (multiplied in the injector and in the detector)
  - γ conversion between the injector and the detector (multiplied only in the detector)
- Mean injector gain is measured from the ratio between the two peaks
- The width of the number of primary electrons is estimated from a simulation

Cu anode -
Similar detector field regardless of the injector gain

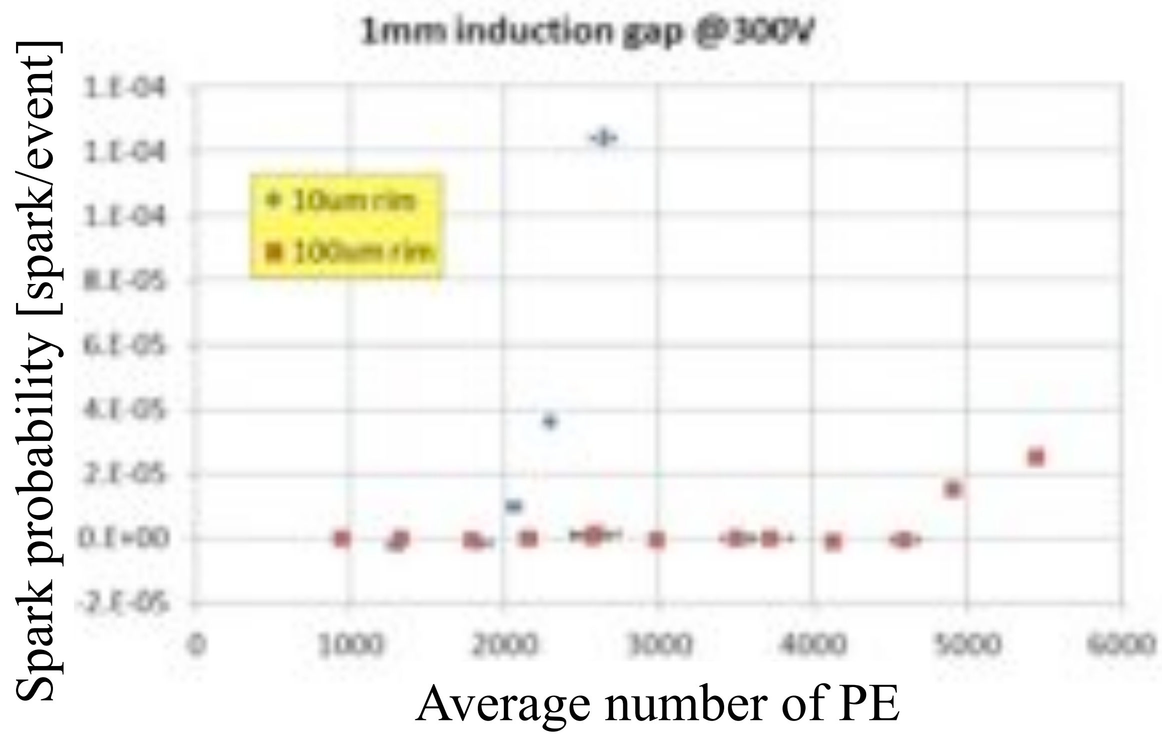


Spectra measured with two different injector gains
The detector gain is not affected by the injector gain

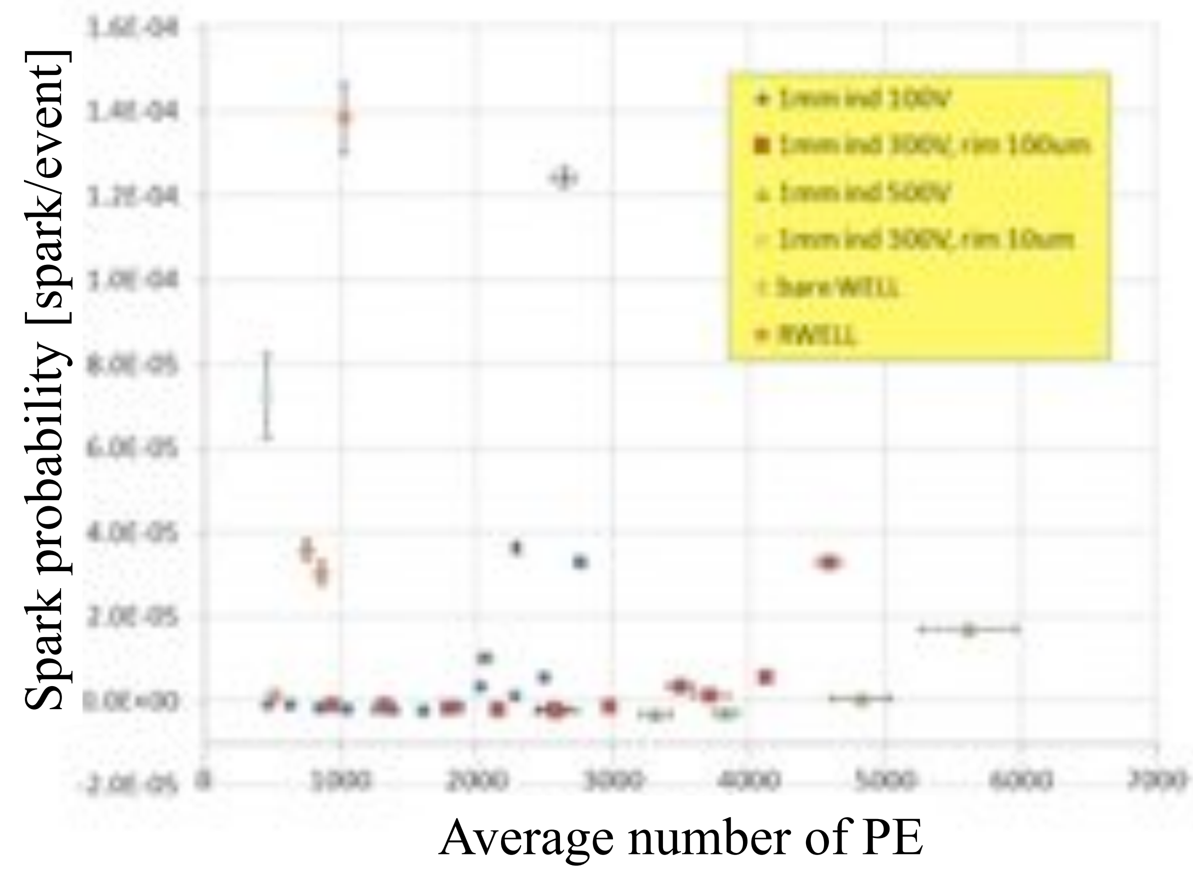


Response to HIPs

- The dynamic range of the detector is studied in conditions more similar to those in the experiment
    - Fixed gain (here ~ 5000)
    - Different ionization conditions

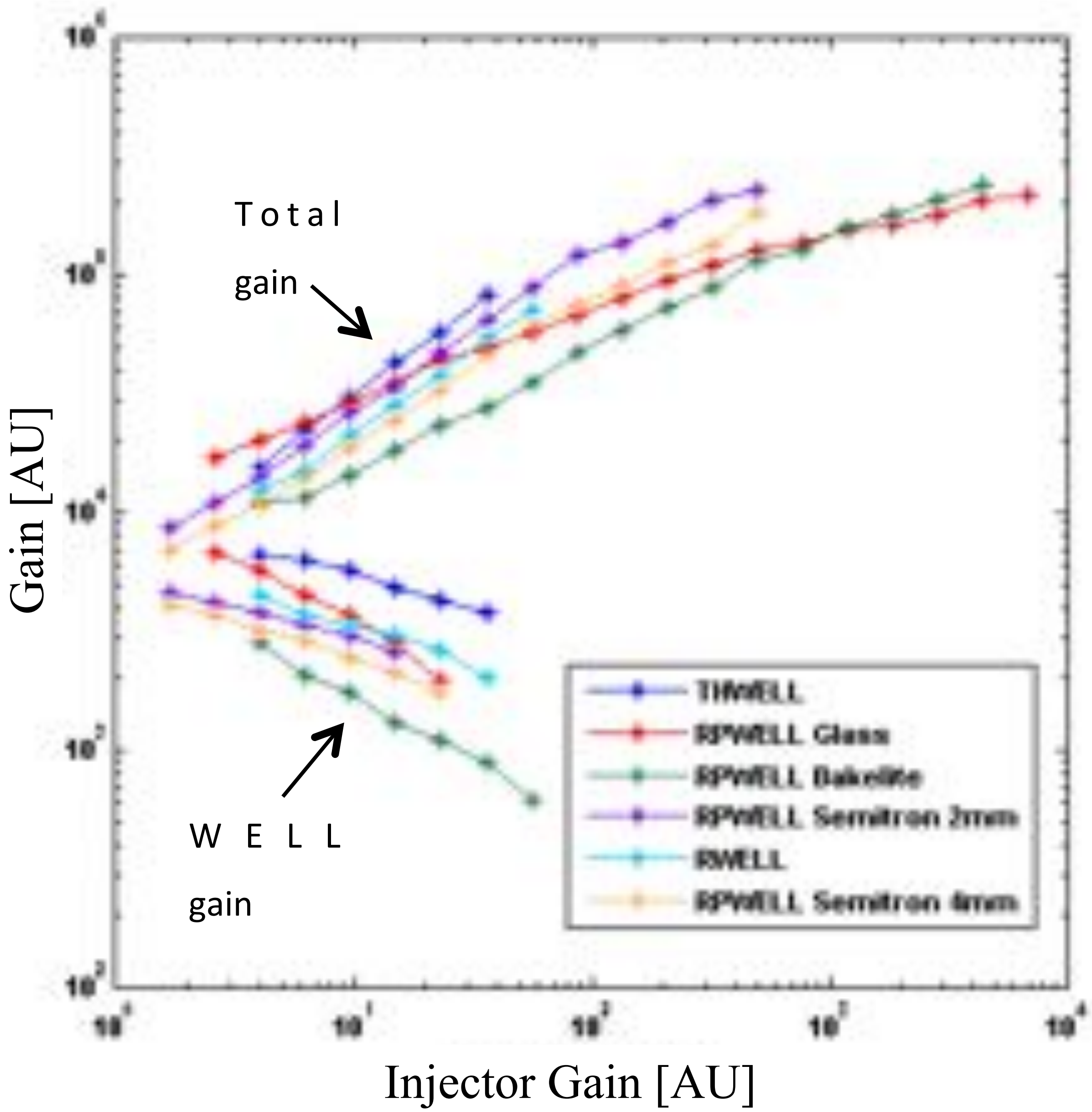


- Detectors with larger rims are more stable
- Multiplication in the induction gap results in more stable configuration



S. Bressler et al. paper in preparation (JINST)

Response to HIPs - The resistive configurations



The measurements were stopped at the occurrence of sparks

RPWELL - wide dynamic range

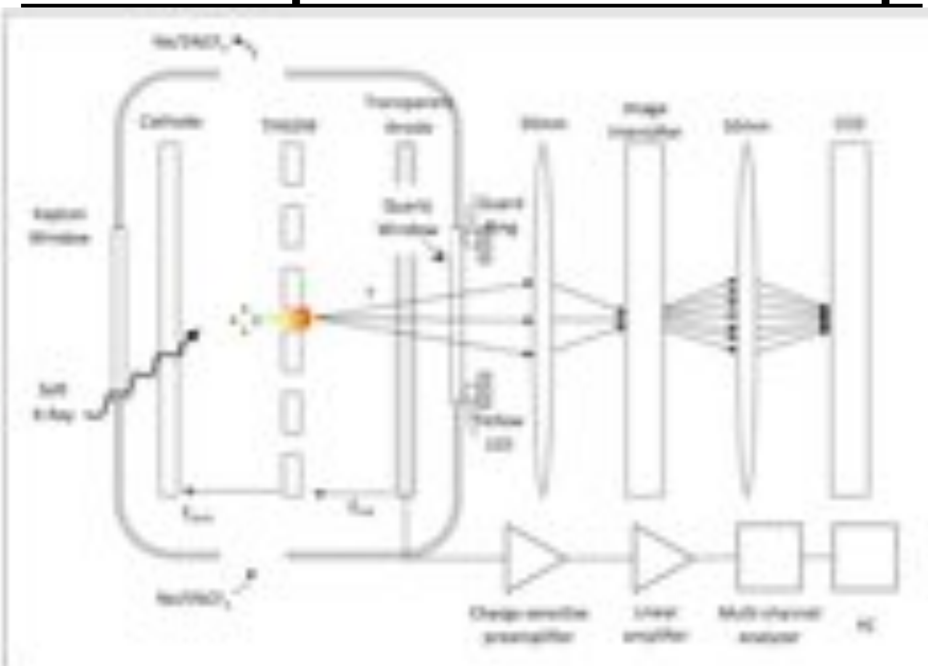
- No sparks also at very high injector gain

Resistive configurations

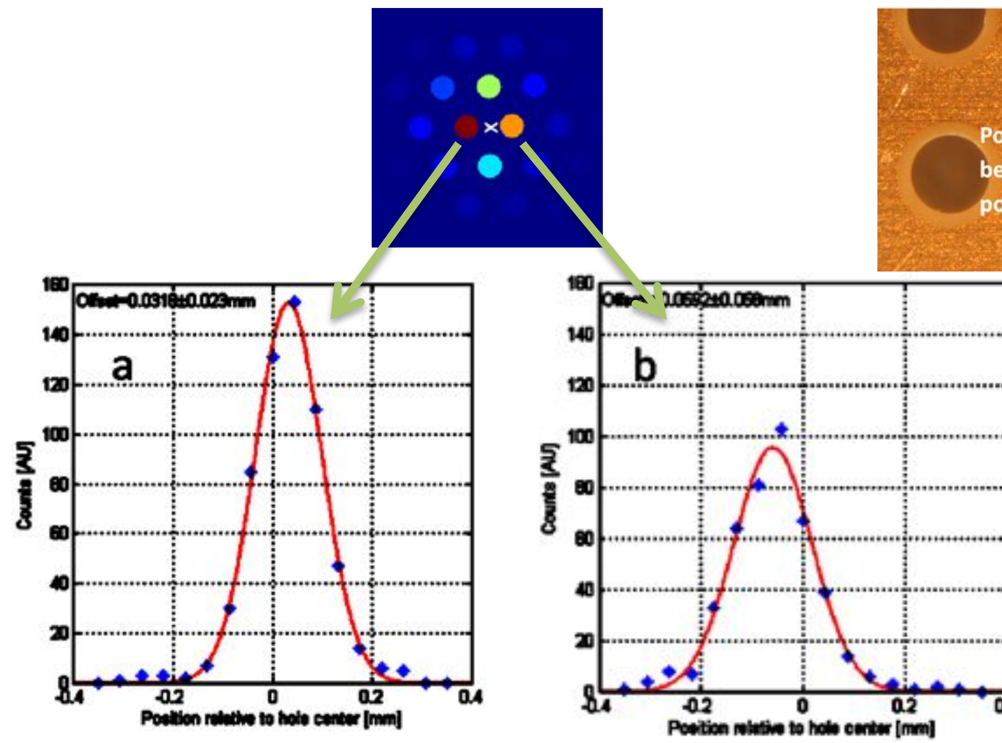
- Accumulated charge on the resistive material modify the field lines and degrade the detector gain
- High HIPs rate is not foreseen in real experiment

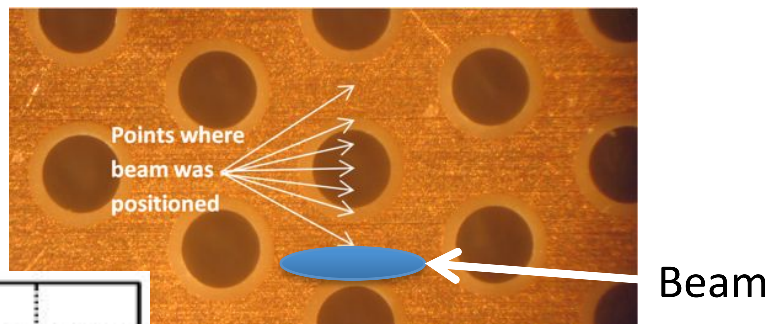
Optical investigation of THGEM

The experimental setup

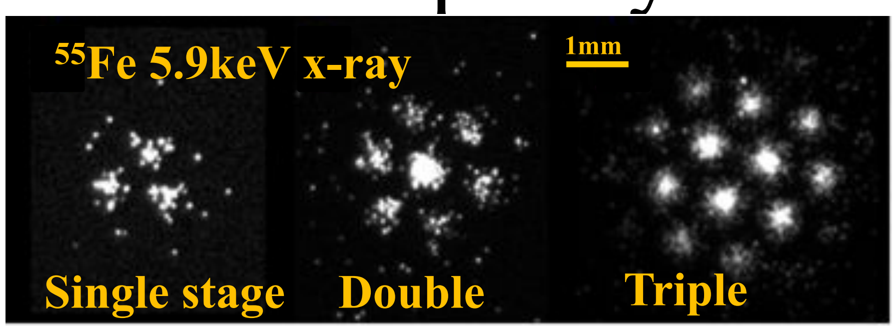


Avalanche asymmetry within a hole

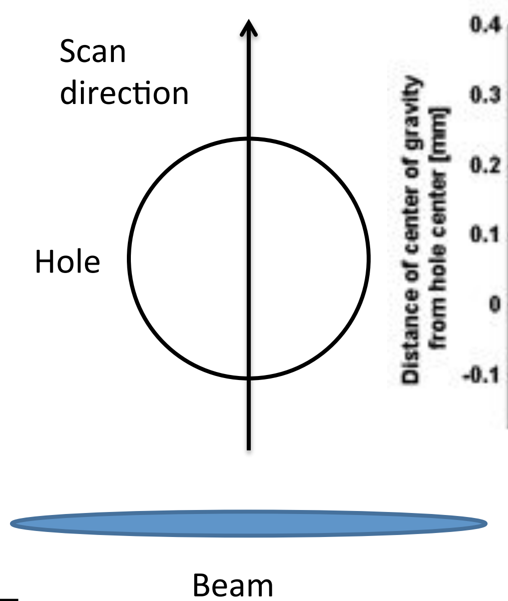


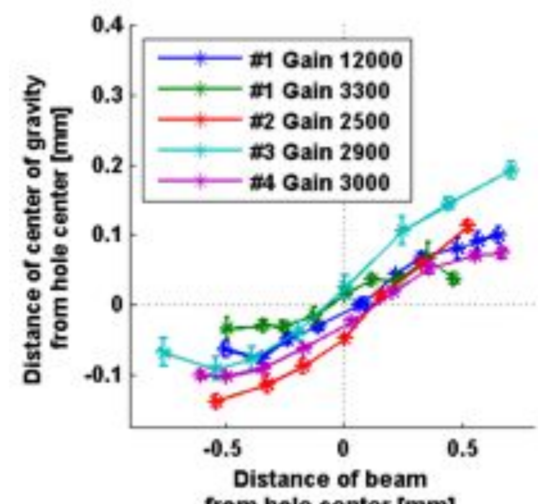


Hole multiplicity



- Larger hole multiplicity in cascade configurations
- The average hole multiplicity depends on the transfer gap and field





The **light's center of gravity** is *correlated* with the **local beam position**

→

Position resolution better than the hole dimension

A. Rubin et. al. JINST July 2013 arXiv:1305.1196

Summary

- THGEM-based detector are used in variety of applications
- Different THGEM-structures were studied and characterized
  - Pulse shape, gain curve, stability, rate capability ...
- Resistive configurations are robust and stable
  - In particular, no sparks were observed with the RPWELL
- New measurements techniques were discussed
  - The injector method: study the detector's response to HIPs.
  - The optical setup: study hole-base phenomena

Future plans

- Focus on resistive configurations
  - RWELL, SRWELL, RPWELL
  - Standard THGEM with resistive layer as anode protection
- RPWELL
  - Complete characterizing: cross talk ...
  - Study thinner plates
    (promising preliminary results with 0.6 mm thick Semitron)
- Large scale THGEMs
  - Systematic study of small THGEM up scaling
  - Address technical issues: optimal THGEM/Resistive(Layer/Plate)/Anode coupling, maintain constant gaps ...
- More THGEM/MICROROC studies
- ...