# single stage THGEM detectors towards test beam

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# Why single-stage detector?

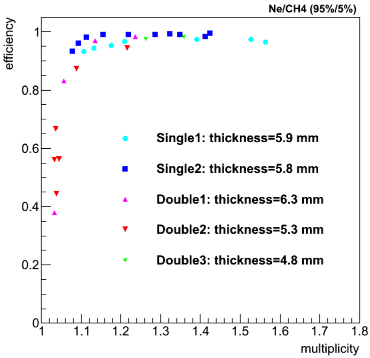
GEMs (and THGEMs) are usually operated in cascade

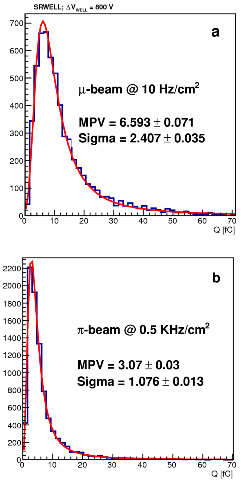
- Allows reaching high gain in stable operation

However single-stage configurations are

- Cheaper - cost scale like the number of holes
- Faster to produce - drilling is time consuming and becomes real limitation when considering large productions
- Easier to build - important factor when consider fully industrial production
- Thinner - significant factor for applications like the DHCAL

# 2012 Test beam: $10 \times 10 cm^2$ single-stage SRWELL



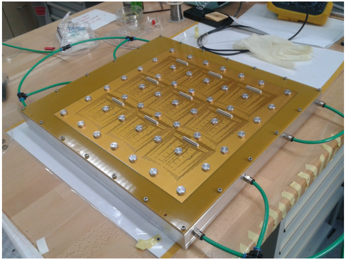



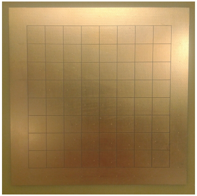

Discharge probability $\sim 10^{-6}$ in muon beam

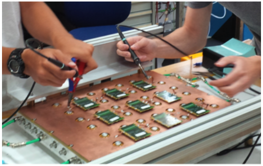
# Readout

All the detectors are readout by the SRS with APV25 chips.

1 cm$^2$ squared pads.







http://iopscience.iop.org/1748-0221/8/03/C03015
http://www.sciencedirect.com/science/article/pii/S0168900201005897

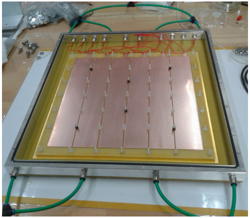
Single stage 300×300 mm$^2$ THGEM detectors.

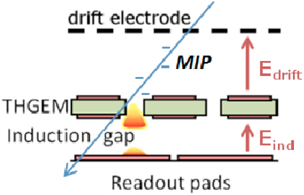
## Detector properties

- 6 THGEM segments 50×300 mm$^2$ independently biased;
- t=400 $\mu$m, h=100 $\mu$m, d=500 $\mu$m, a=1 mm;
- Drift gap 0.5 cm;
- Drift field 0.5 kV/cm;
- Gas: Ne/$CH_4$(95/5);

(t=thickness, h=rim, d=hole diameter, a=hole pitch)

# 1mm induction gap: setup



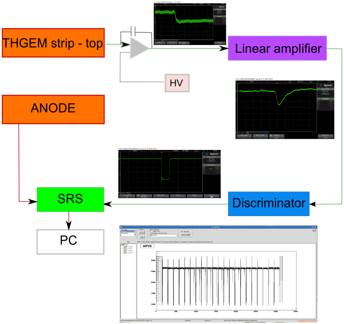



The charge is multiplied both in the THGEM hole and in the induction gap ($G_{ind}$ ∼10).

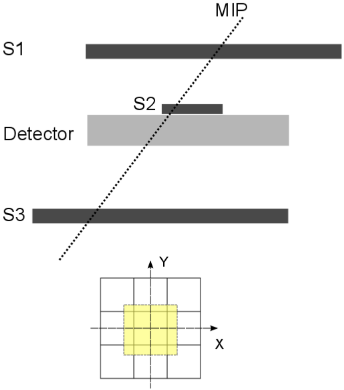
- 1 mm induction gap;
- Induction field 3 kV/cm;
- Gas: Ne/$CH_4$(95/5);

# 1mm induction gap: characterization

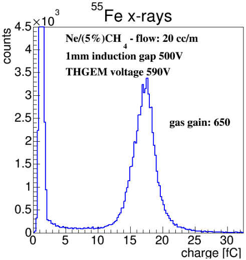
## x-ray detection

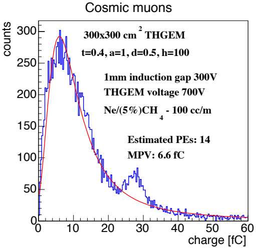


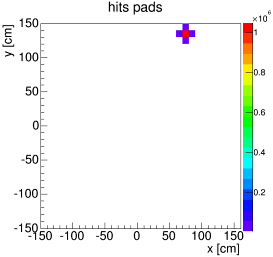

## Cosmic muons detection

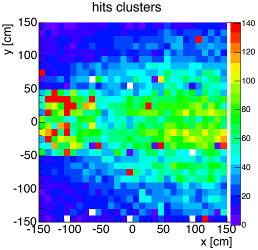


# 1mm induction gap: characterization



# 1mm induction gap: characterization

- At a gain of $\sim$3000 cosmic muon detection efficiency $> 90\%$;
  - Target efficiency $\geq 98\%$ is feasible
- Constant and uniform discharge rate $\sim$20 discharges/strip/h.

# 1mm induction gap: discharges

**What is the origin of the discharges?**

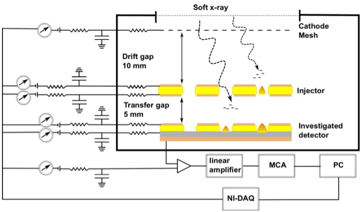
1. Discharge characteristics;
   - × Uniformly distributed - occurring on all strips;
   - × Rate suppressed when the drift field is reversed.
2. FR4 radioactivity;
   - ? Difficult to asses.
3. High energy deposition from cosmic muons.

- Try to reproduce high energy Landau tail.

# 1mm induction gap: discharges

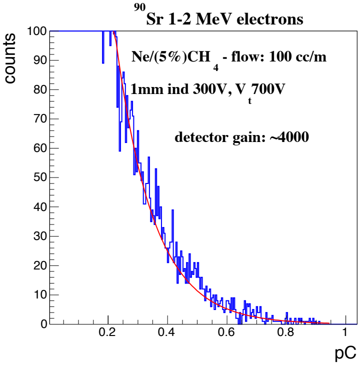
**Try to reproduce high energy Landau tail.**

- Obtain a MIP-like source from $^{90}$Sr $\beta$-source;
- Filter the $^{90}$Sr source with 0.6 mm Cu so that only electrons of 1-2 MeV can escape;
- Multiply the $^{90}$Sr extracted electrons using the Injector method.



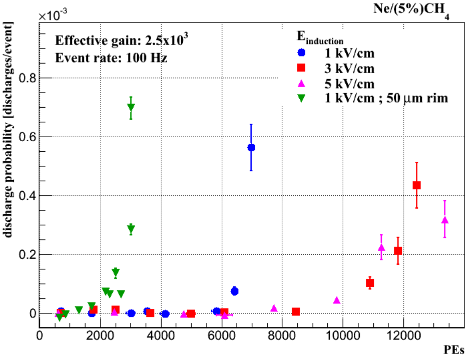

Injector setup (http://iopscience.iop.org/1748-0221/9/03/P03005)

# 1mm induction gap: discharges




Measured $^{90}$Sr energy deposition spectrum in our detector shows no Landau tail. Deposited energy exponential cut at ∼1700 PEs (∼100 times MPV measured with cosmic muons).

- The full injector study of this configuration indicates the starting point of instability at ~10000 PEs;
- Need to multiply the PEs from $^{90}$Sr by a factor of 10.



# 1mm induction gap: discharges

Measured discharge probability with Injector+$^{90}Sr$.

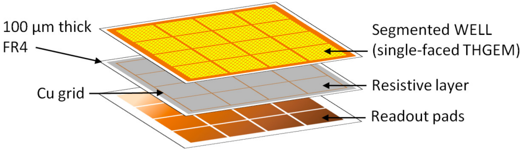
- Background discharges are increasing with injector bias, uniformly for all strips.
- Discharge probability related to the source is compatible with 0 up to $G_{inj}=8$ (∼12500 PEs maximum).

NOTE: When reversing the drift field the background discharge rate drops drastically.

Test beam is needed - will allow to confirm the origin of discharges

- If internal radioactivity - use different base material
- If Raether limit - use this (cheap and robust) detector in low rate application

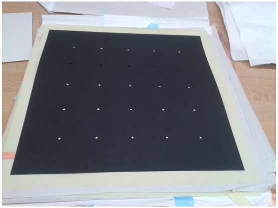
# SRWELL: setup

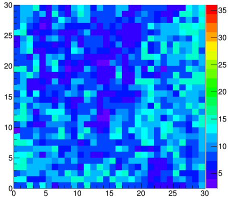



## Resistive layer

Graphite epoxy mixture sprayed on Cu-gridded FR4

- Resistivity: 10 MΩ/sq;
- After manual polishing uniform within 50%.

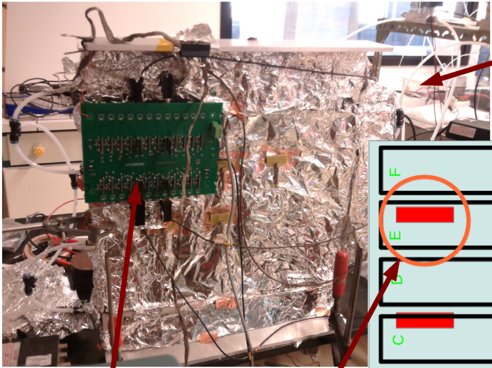




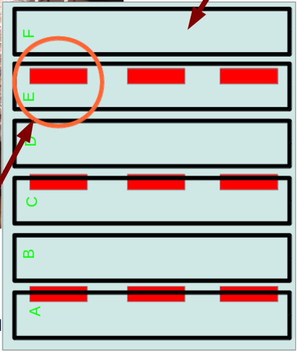
# SRWELL: setup

**Single 0.4 mm WELL,**
**5mm drift,**
**Ne/CH4 (95/5)**

Setup, back view



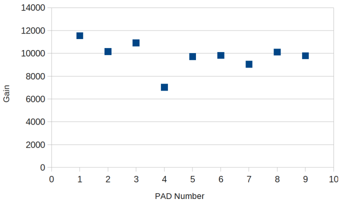
All sectors polarized
except sector A

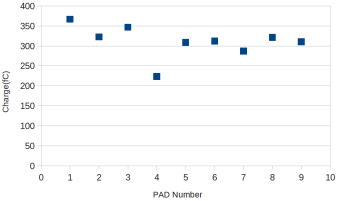


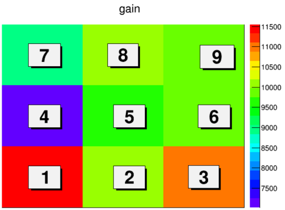

Pre-amplifiers (Cremat cr-110)
board (just four channels used)

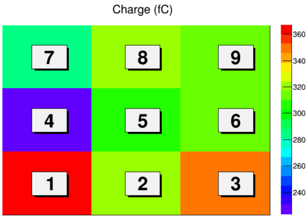
Pre-amplifiers position
4 channels in center of pad

# SRWELL: characterization



- Uniform gain ($\sim$ 30% variations in a non-optimal setup) across the detector area;
- $\sim$40 discharges/strip/h.
    - Higher rate compared to the configuration with induction gap $\rightarrow$ consistent with the injector study

Unstable for operation in test beam environment $\rightarrow$ will not be tested in the beam

Single stage 100×100 mm$^2$ RPWELL detector.

(http://iopscience.iop.org/1748-0221/8/11/P11004)

## Detector facts

- No electrode segmentation;
- t=400 $\mu$m, h=100 $\mu$m, d=500 $\mu$m, a=1 mm;
- Drift gap 0.5 cm;
- Drift field 0.5 kV/cm;
- Gas: Ne/$CH_4$(95/5), Ar/$CH_4$(95/5);

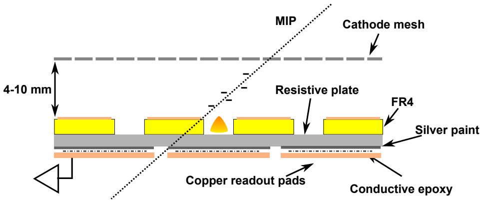
(t=thickness, h=rim, d=hole diameter, a=hole pitch)

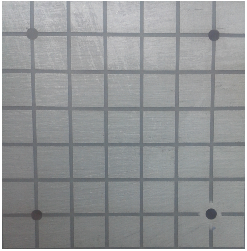
# RPWELL: setup

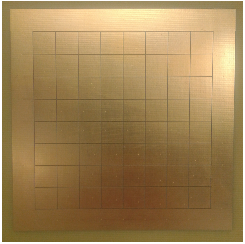
## Resistive plate

0.4 mm Semitron sheet

- Bulk resistivity: 1.6·10$^8$ Ωcm;
- Silver paint pads coupled to anode pads.

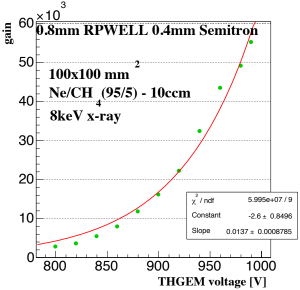


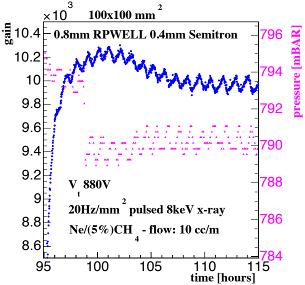





# RPWELL: gain

## Preliminary results

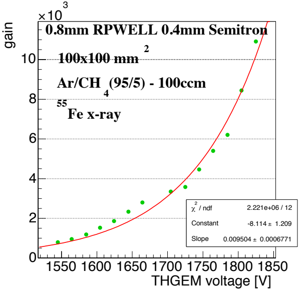



- NOTE: No discharges!
- At maximum measured voltage, 5-15 nA current fluctuations.

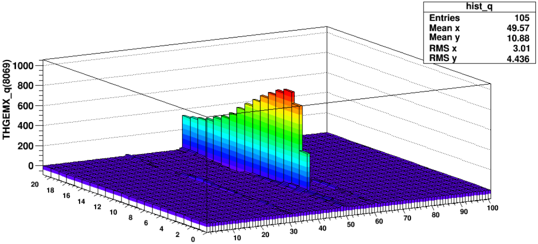
# RPWELL: gain

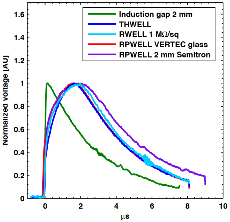
## Preliminary results

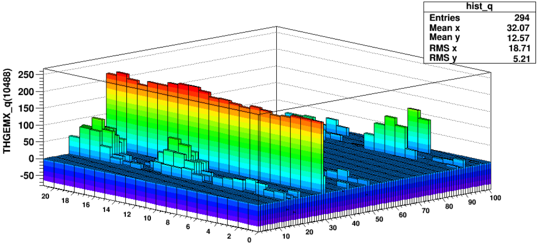



- Reach high gain in Ar based gas mixture
- Measurement was stopped due to discharges in the HV connections (not in the detector).
  - Setup will be fixed

# RPWELL: pulse shape



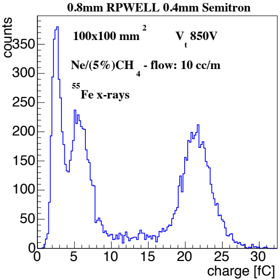



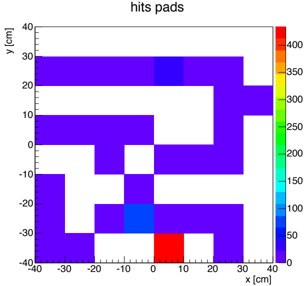

- RPWELL fast rise (∼1/5 signal): ∼80 ns;
- APV25 shaping time: ∼25 ns.

# RPWELL: readout

## Preliminary results

RPWELL successfully operated with the SRS+APV.




The nominal gain at 850V is $\sim 10^4$.
The gain measured by the APV25 is $\sim 3 \times 10^3$.

- Explained by the long rising time of the signal

# Test beam plan

Configurations

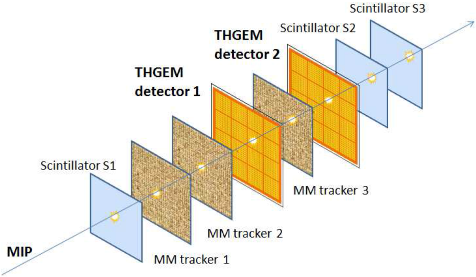
- 1mm induction gap (test beam will complete characterization);
- SRWELL (most likely not);
- RPWELL (either $10 \times 10cm^2$ or $30 \times 30cm^2$);

Measurements

- Efficiency Vs. pad multiplicity
  - $\mu$ and $\pi$ beams
  - High incoming particle flux
  - Along the spill
  - At different incoming particle angle
  - Global and local
- Discharge probability
  - $\mu$ and $\pi$ beams at varied rate
- Response to Hadronic shower (?)

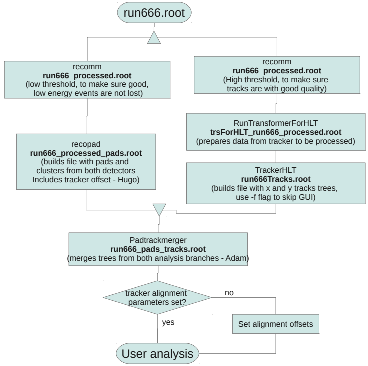
# Test beam setup

Similar to the setup in 2012




- RD51 telescope
  - 3 scintillators (covering $10 \times 10cm^2$) for triggering
  - 3 Micromegas for precision tracking
- Common DCS (HV control and monitoring)

# Analysis suite




- mmDAQ: combined for the tested detectors and the tracker
- recom: initial reprocessing of row data - configuration optimized for each detector separately
  - High threshold for tracker → for high track quality
  - Detector threshold to optimize efficiency and multiplicity
- recopad: custom software → fix alignment and pad geometry
- track_pad: merge data from the detector and the tracker

# Summary

- Goal: conclude about the feasibility to measure MIPs in a single-stage THGEM based configuration
  - Negative answer - though disappointing, will teach us a lot
- Massive stress testing of the different configurations in the lab
- Results are consistent with equivalent measurement with small ($3 \times 3cm^2$) detectors
  - 1 mm induction - constant discharge rate even when irradiated with HIPs
  - SRWELL - high discharge probability

# Summary II

- RPWELL - seems very promising
  - High gain with no discharges
  - Successful operation in Ar based gas mixtures
  - Energy and position resolution similar to WELL
  - Moderate dependent of the gain on the incoming particle flux

$\rightarrow$ Will be tested in the beam for the first time

  - $10 \times 10cm^2$ is operational
  - $30 \times 30cm^2$ can be assembled in time for the beam