THGEM for DHCAL

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& THGEM / MICROROC

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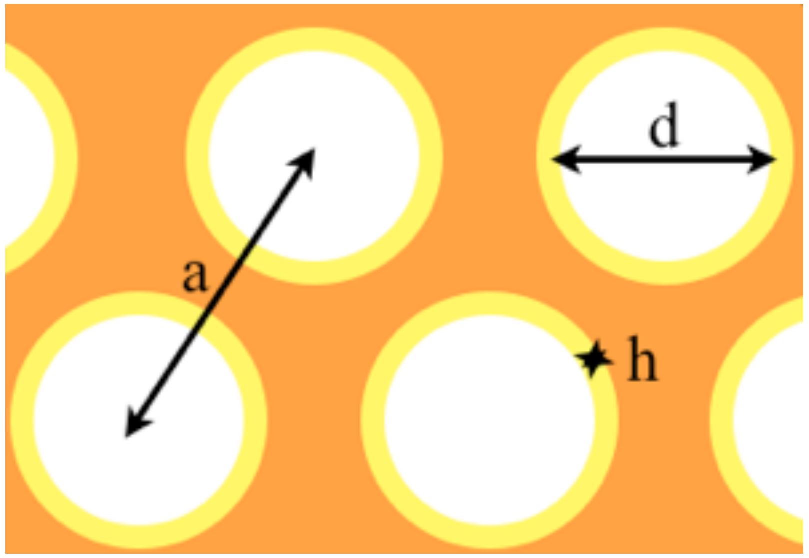
Outline

- Introduction
- THGEM structures
- Laboratory R&D
- Beam test evaluation
- THGEM / MICROROC
- Summary
- Future plans

Introduction

- THick GEM (THGEM) is a 10 folded expanded GEM
  - Typical parameters: a ~ 1 mm, d ~ 0.5 mm, h ~ 0.1 mm
- Main advantages
  - Simple
  - Economic
  - Robust
  - It can be industrially produced over large area using standard PCB technologies
  - No need to stretch (no dead area due to complicated mechanics)



- Growing interest and experience with large scale detectors
  - COMPASS-RICH upgrade
  - ALICE-RICH upgrade

- **A Potential candidate sampling element for the DHCAL**
  - Arazi et al. 2012_JINST_7_C05011 http://dx.doi.org/10.1088/1748-0221/7/05/C05011

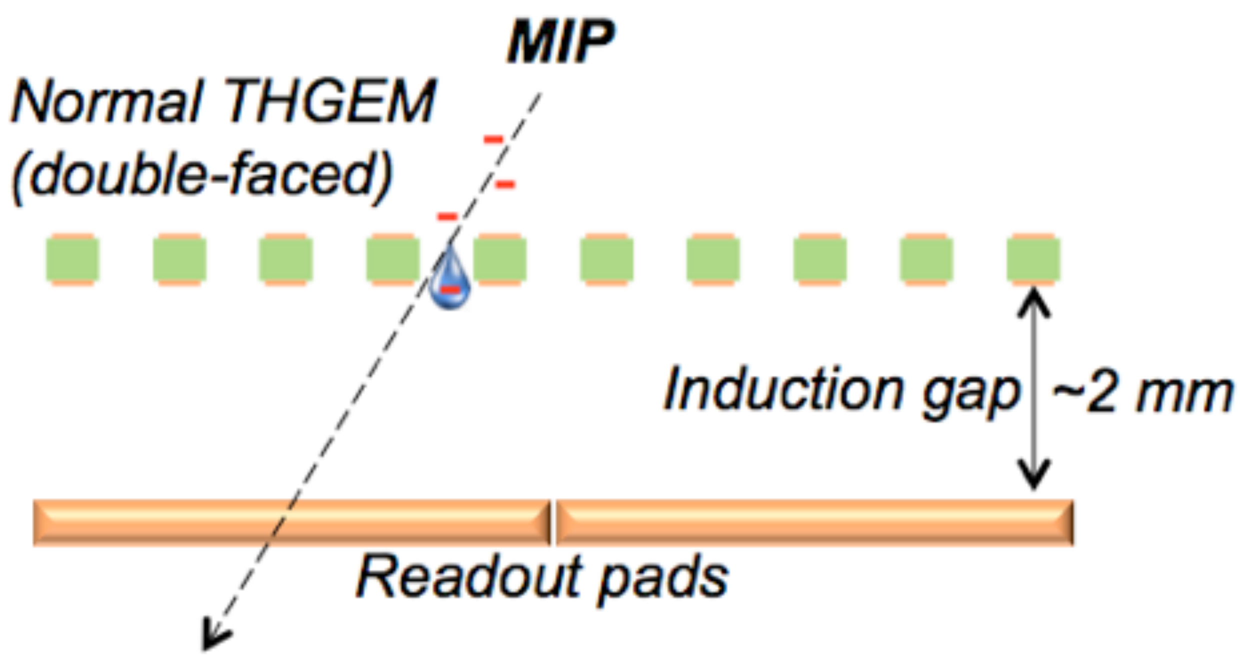
THGEM structures - Standard & WELL THGEM

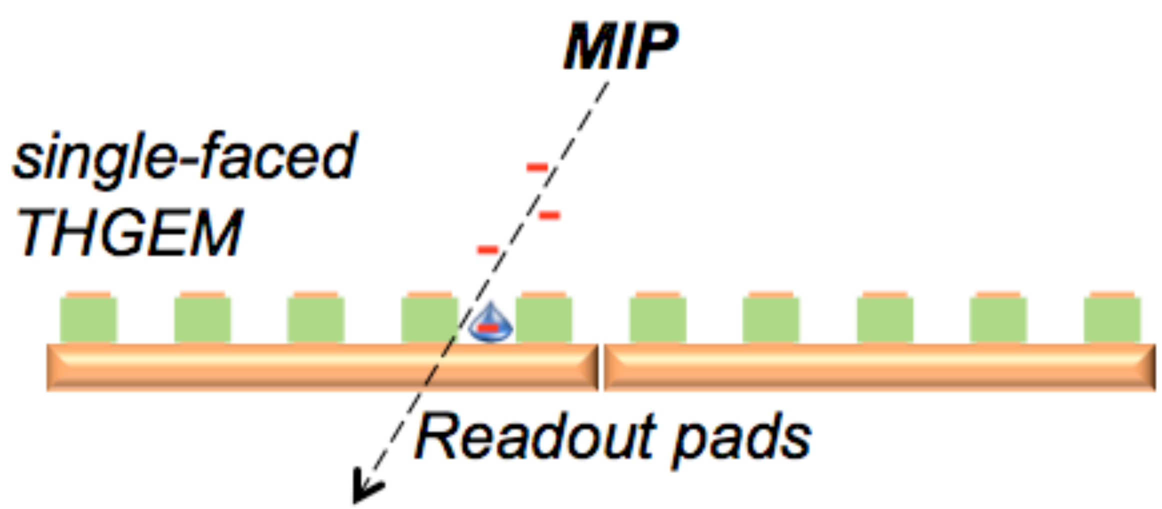
Standard THGEM

- Cu coated in both sides
- Operated with induction gap

WELL THGEM

- Cu coated in one sides
- No induction gap - electrode attached to the anode





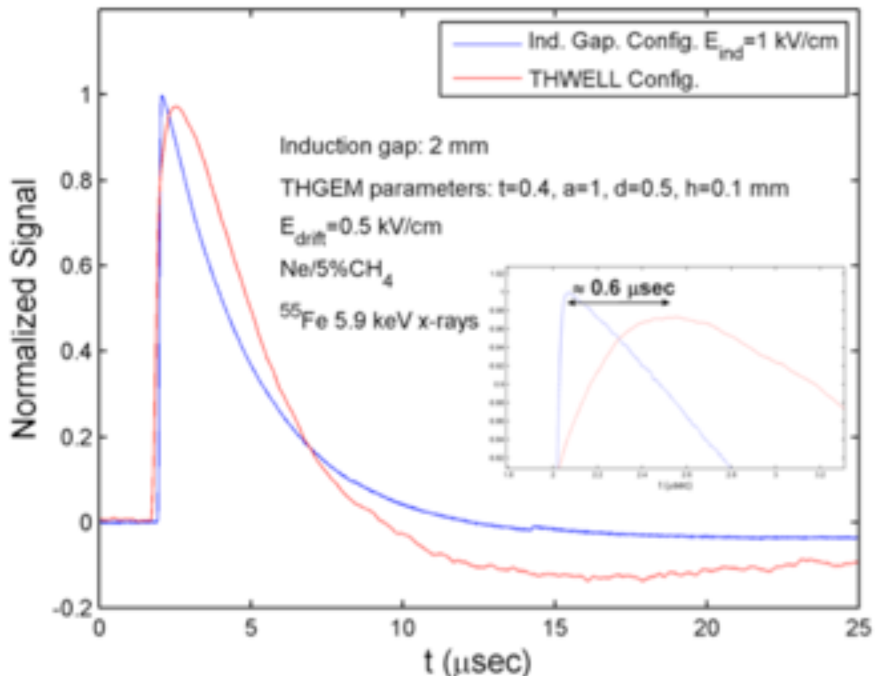
Standard THGEM - thin induction gap

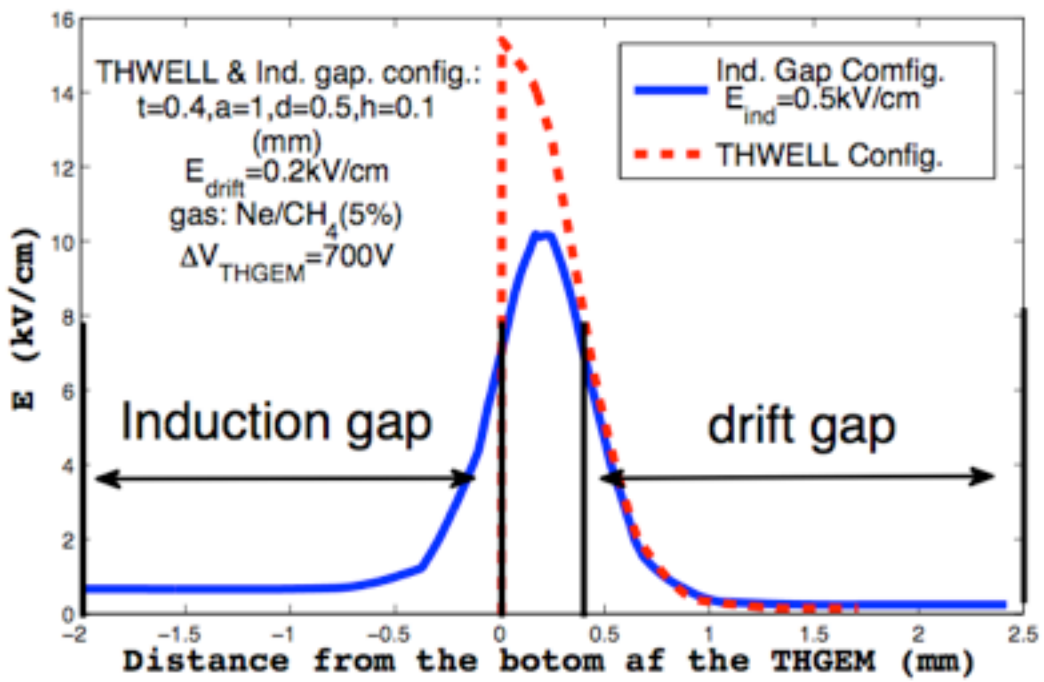
- Allow multiplying in the induction gap
- Smaller avalanche in the hole
- Higher effective Raether limit

THGEM structures - Standard & WELL THGEM

Standard THGEM

- Faster signal raise time
- Better gas circulation

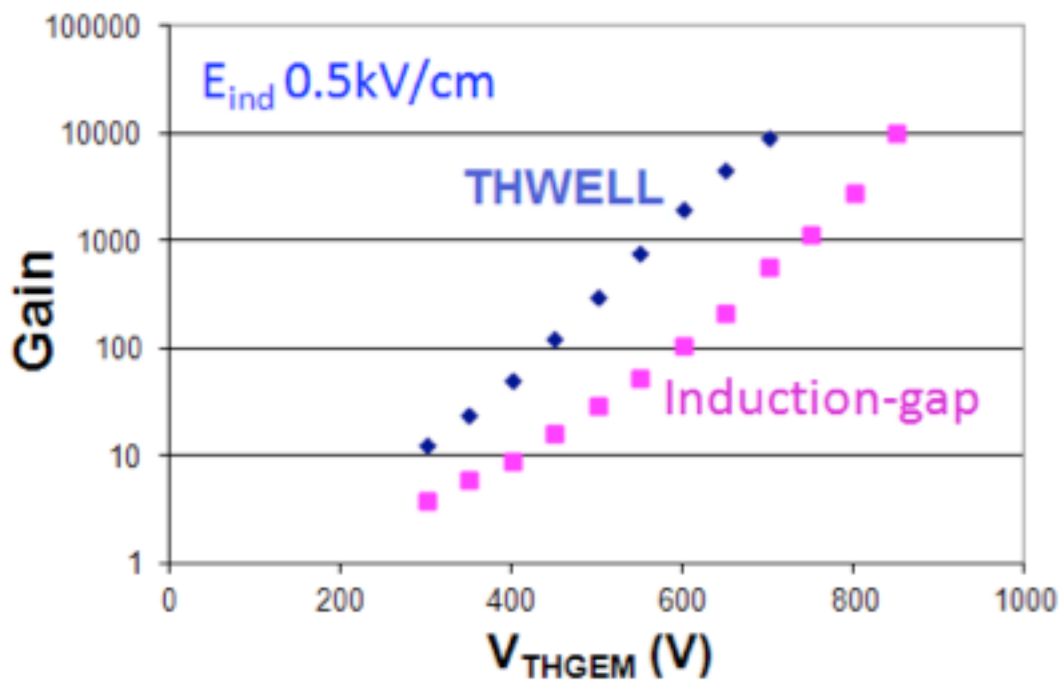




WELL THGEM

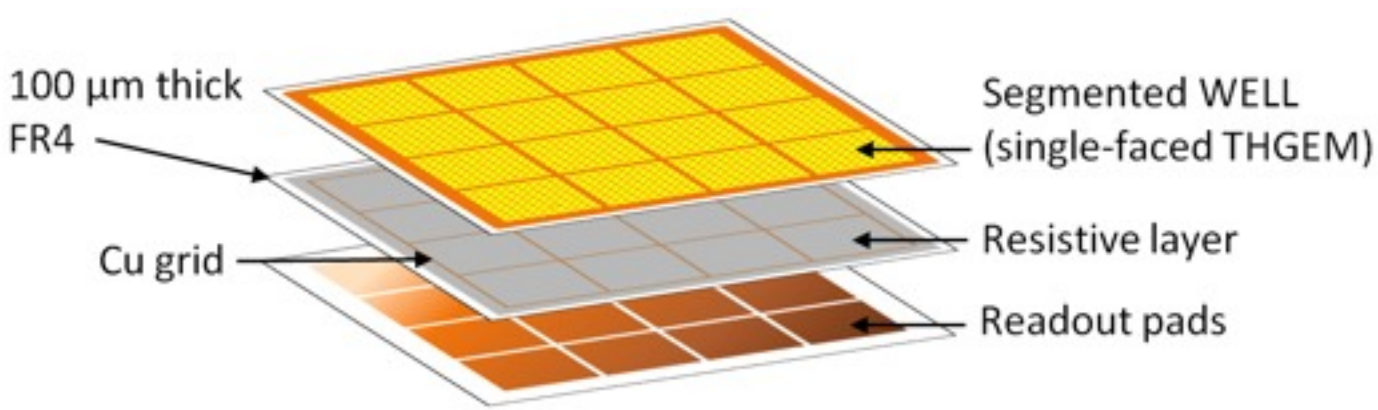
- Much thinner detector
- Higher gain at the same voltage

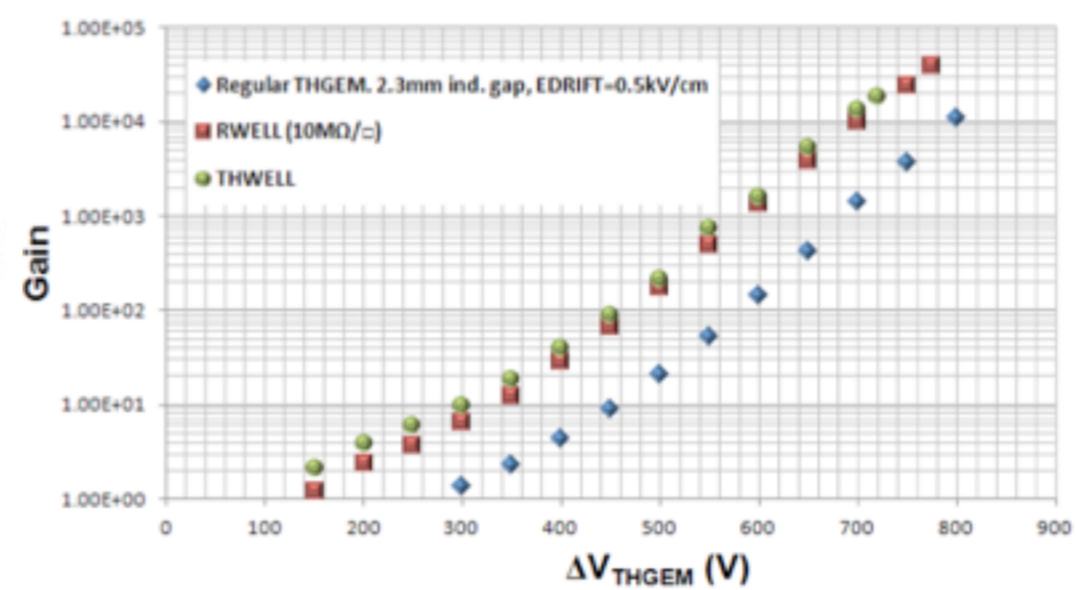
- Incase of a discharge all the energy is forced to the readout



THGEM structures - SRWELL

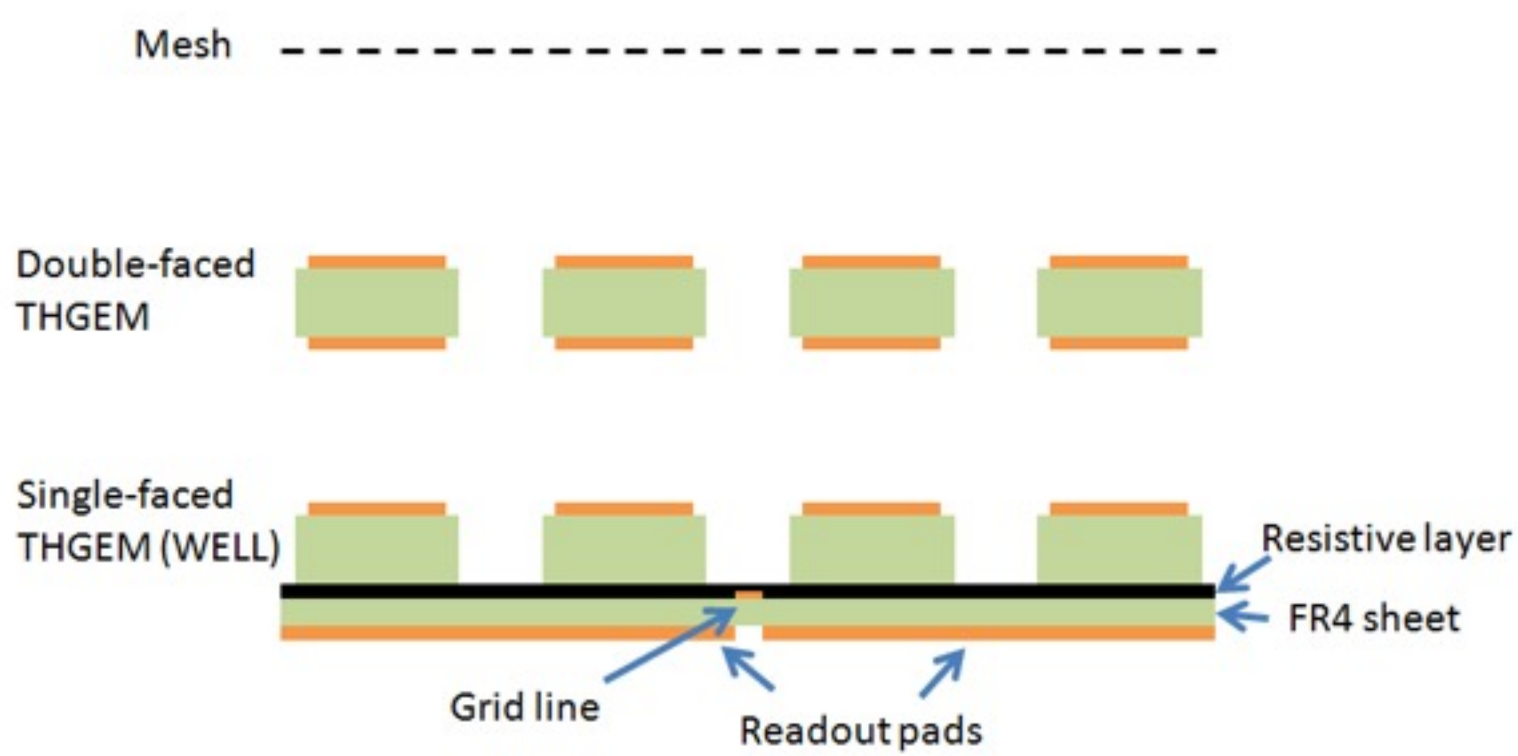
- *Segmented* *Resistive* *WELL*:
  - **WELL** THGEM coupled to a **resistive** layer (RL)
  - The charge is induced on the readout pads
  - The pads are separated from the RL by a thin insulating sheet
  - The RL quench the energy of occasional discharge
  - Cross talk due to charge propagation along the resistive layer is avoided by adding a Cu grid to the resistive layer
  - The electrode is **segmented** accordingly to prevent discharges in holes residing directly above grid lines





THGEM structures - Double-stage

- Multi-stage configurations are commonly used
- Advantages
  - More stable
  - Higher maximal achievable gain
- Disadvantages
  - Results in a thicker configuration
  - More expensive

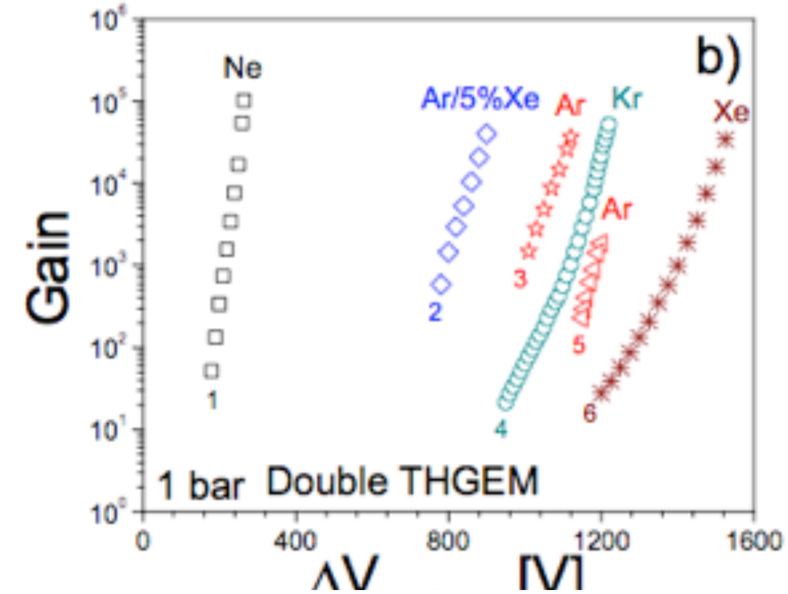


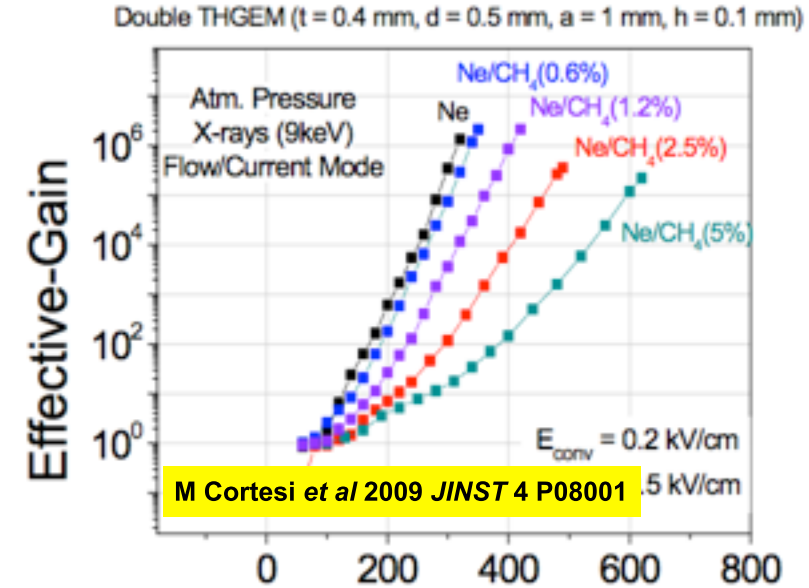
- SRWELL-based double-stage configurations
  - Stable
  - Thin; **$\leq$ 6 mm** including drift gap
  - Will be studied systematically in the lab in the near future

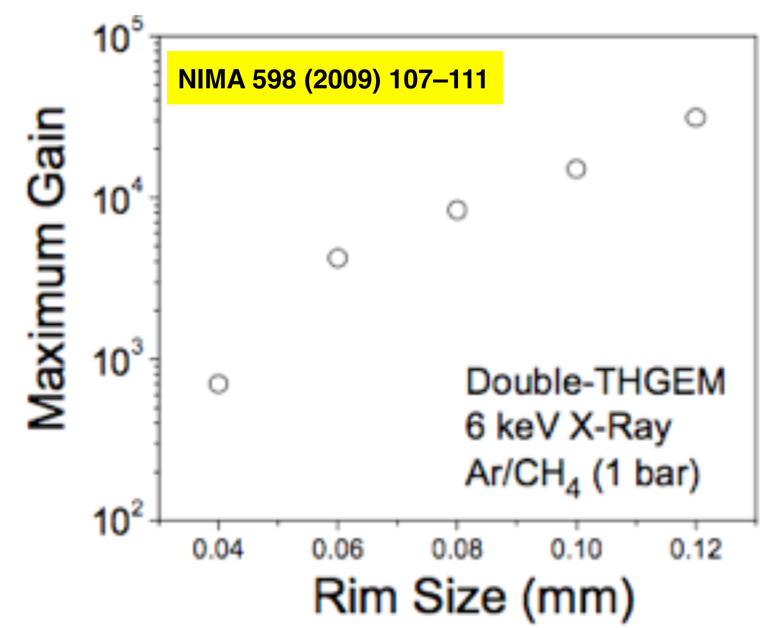
Laboratory R&D - Structure characterization

- Comparative R&D to select optimal structure and operation mode
  - Different geometries (hole diameter, pitch, rim, thickness)
  - Different gas mixtures:
    Ne mixtures → low voltages
  - Single-stage and multi-stage
  - Gain stability
  - Gain Vs. rate / efficiency Vs. rate
  - Different segmentations
  - Different resistivities
  - Different HV configurations
  - Discharge probability

- Single unit characterization protocol
  to ensure reproducible results is foreseen

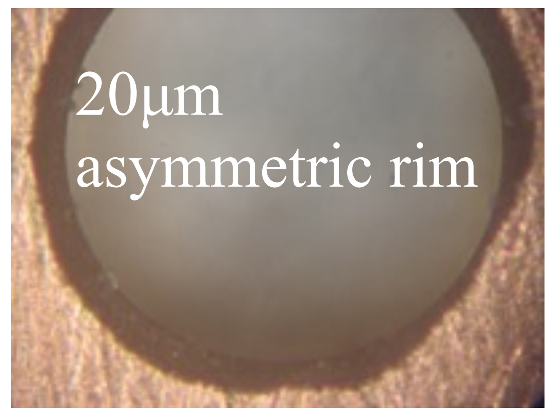


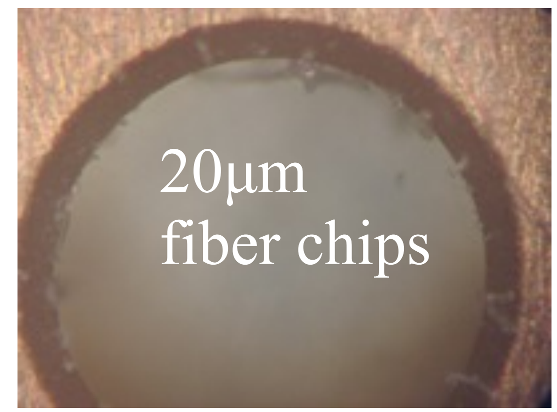




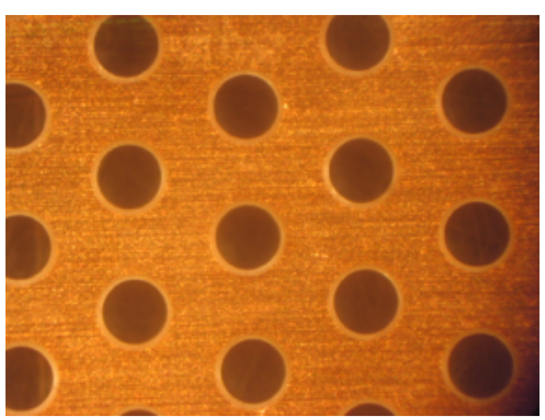
Laboratory R&D - Manufacturing procedure

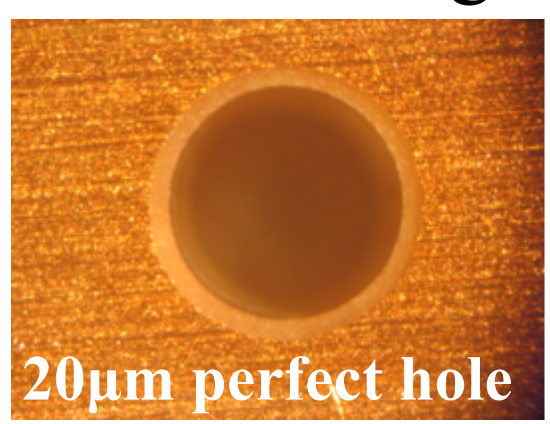
- Different producers
  - Print Electronics (IL), Eltos (IT), CERN
- Long R&D program together with Print Electronics
- First batches: frequent defects of different kinds

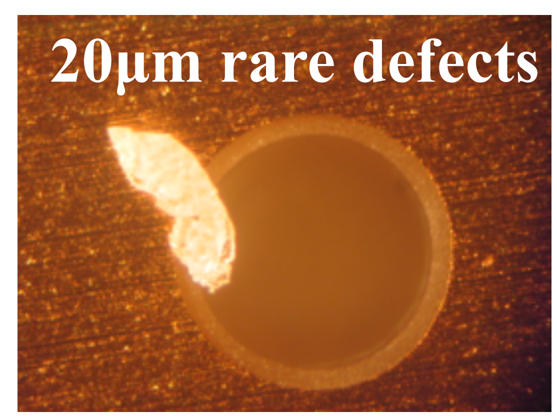




- Last batches (improving the de-smearing stage and further baking):
  - Defects are rare
  - The Paschen breakdown voltages are reached



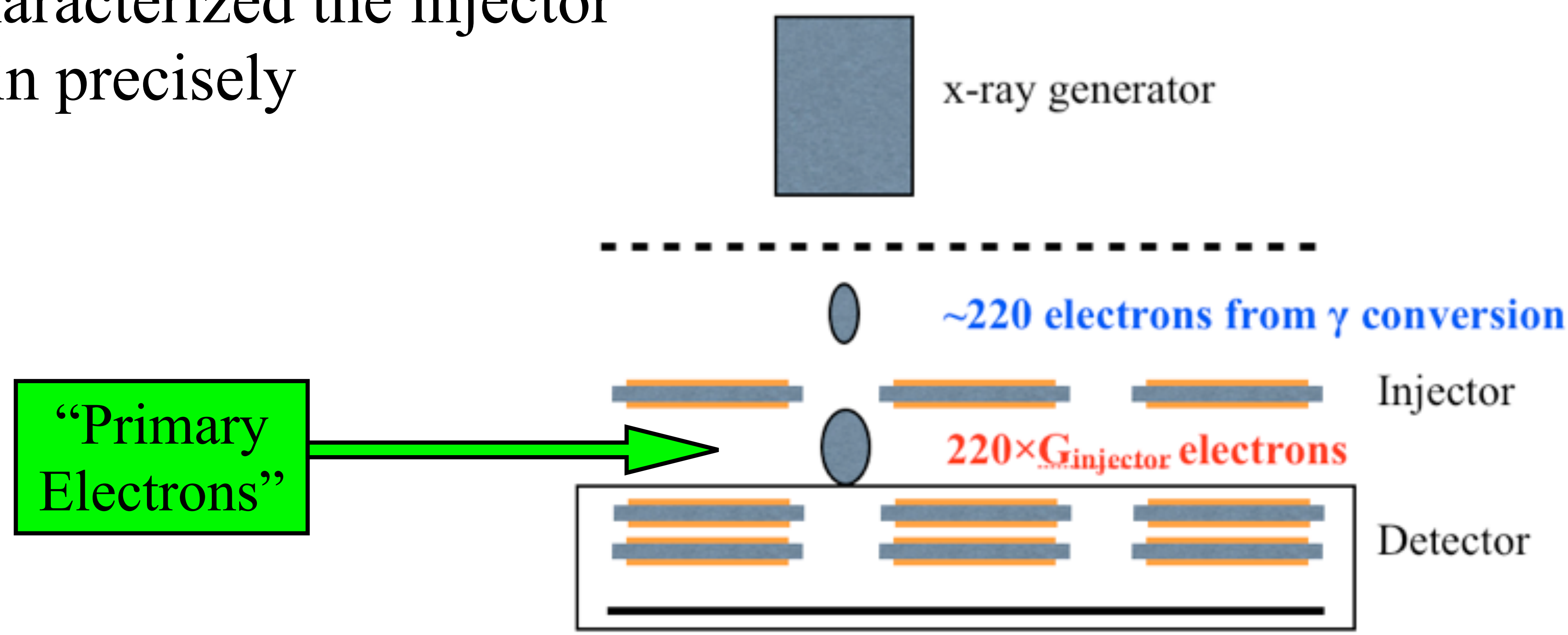




- New manufacturing procedures will be tested

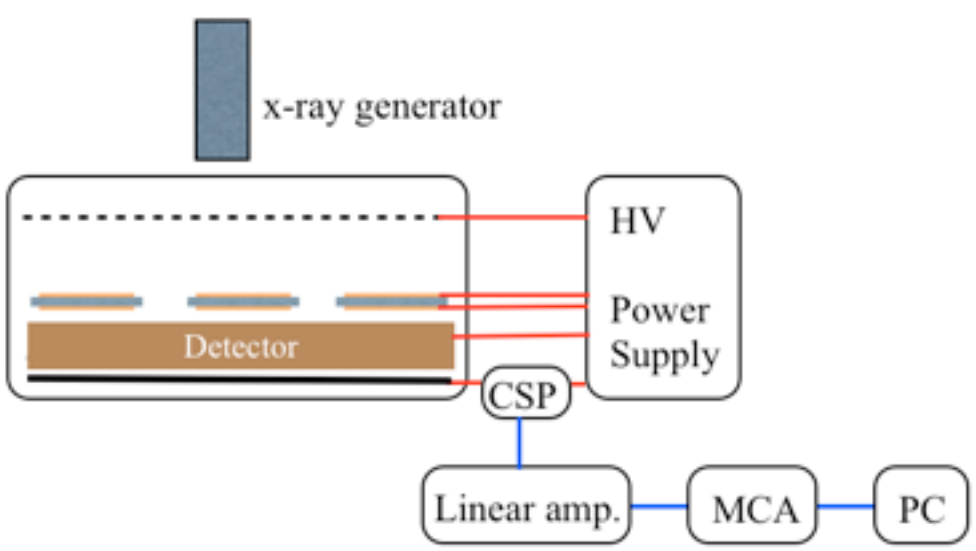
Laboratory R&D - Response to HIPs

- 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

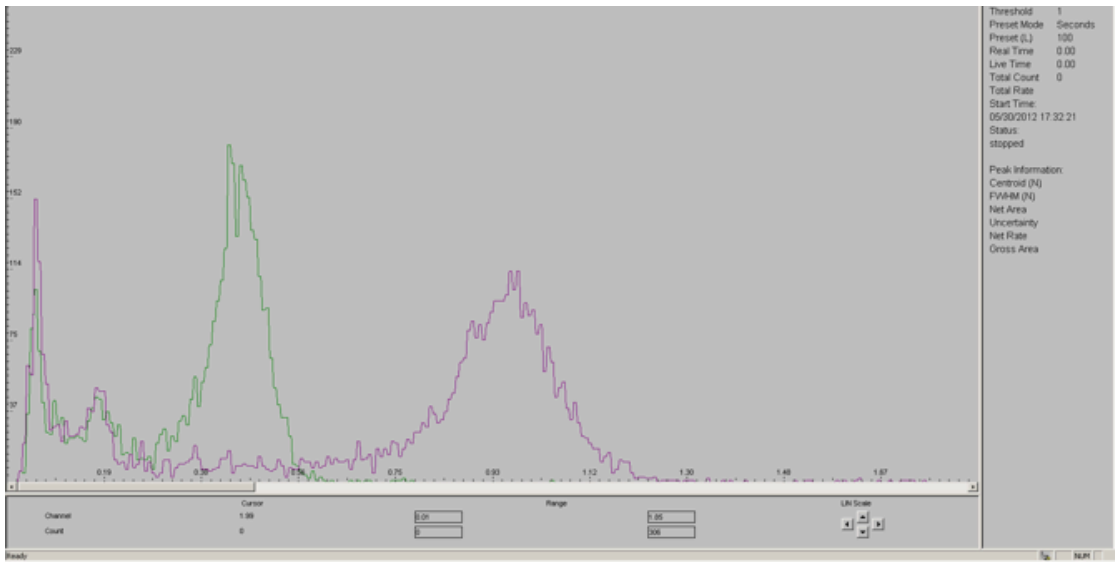


Laboratory R&D - Response to HIPs

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

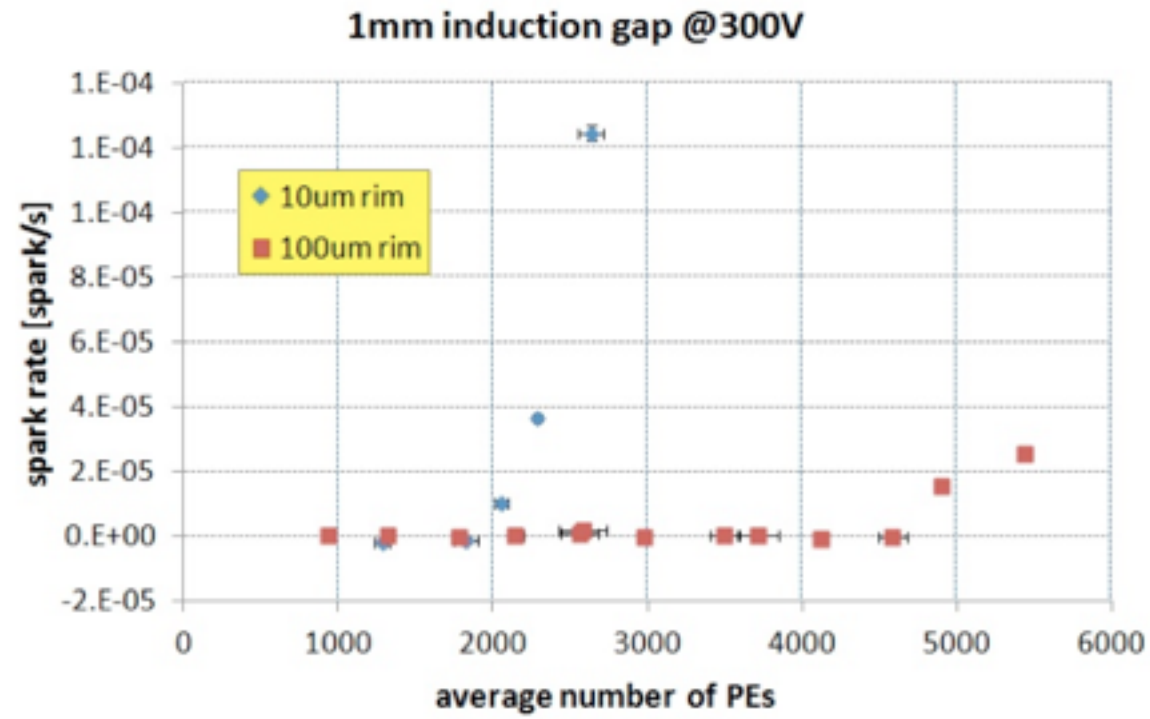


Spectra measured with two different injector gains
The detector gain is not affected by the injector gain

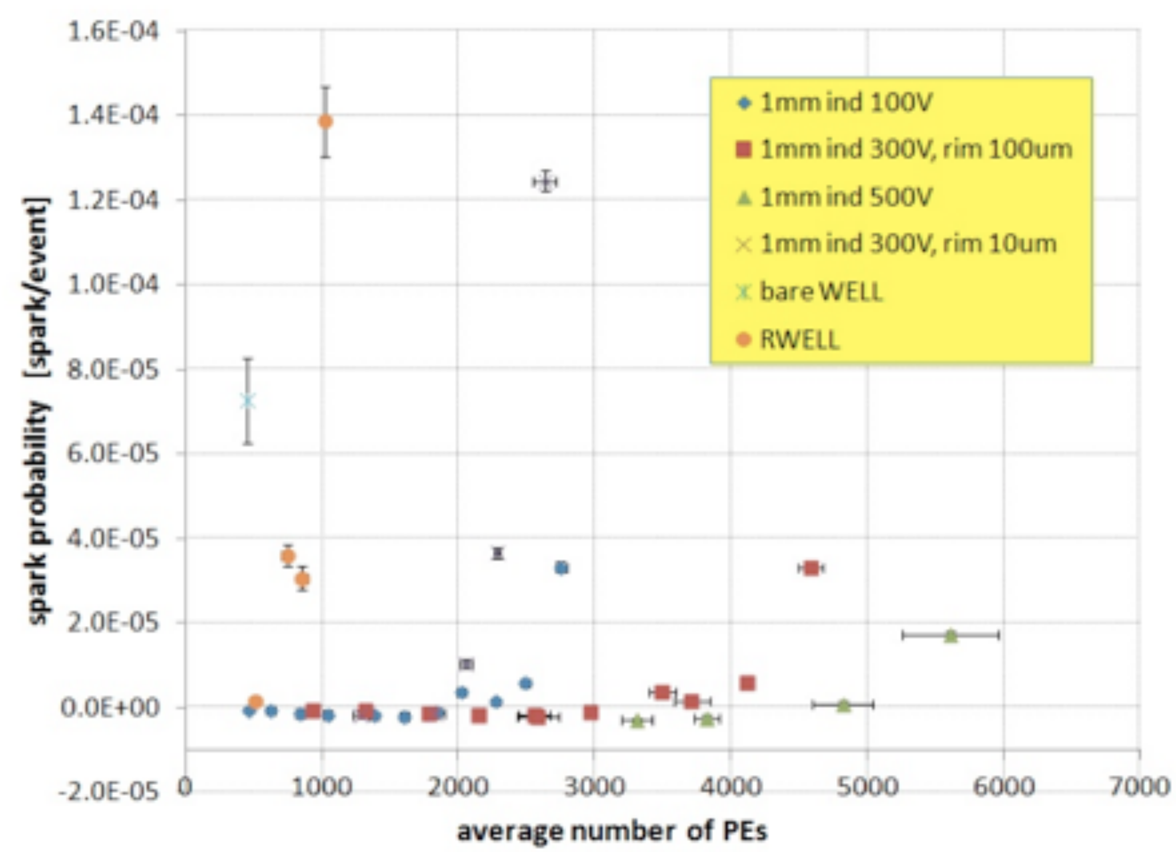


Laboratory R&D - Response to HIPs

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

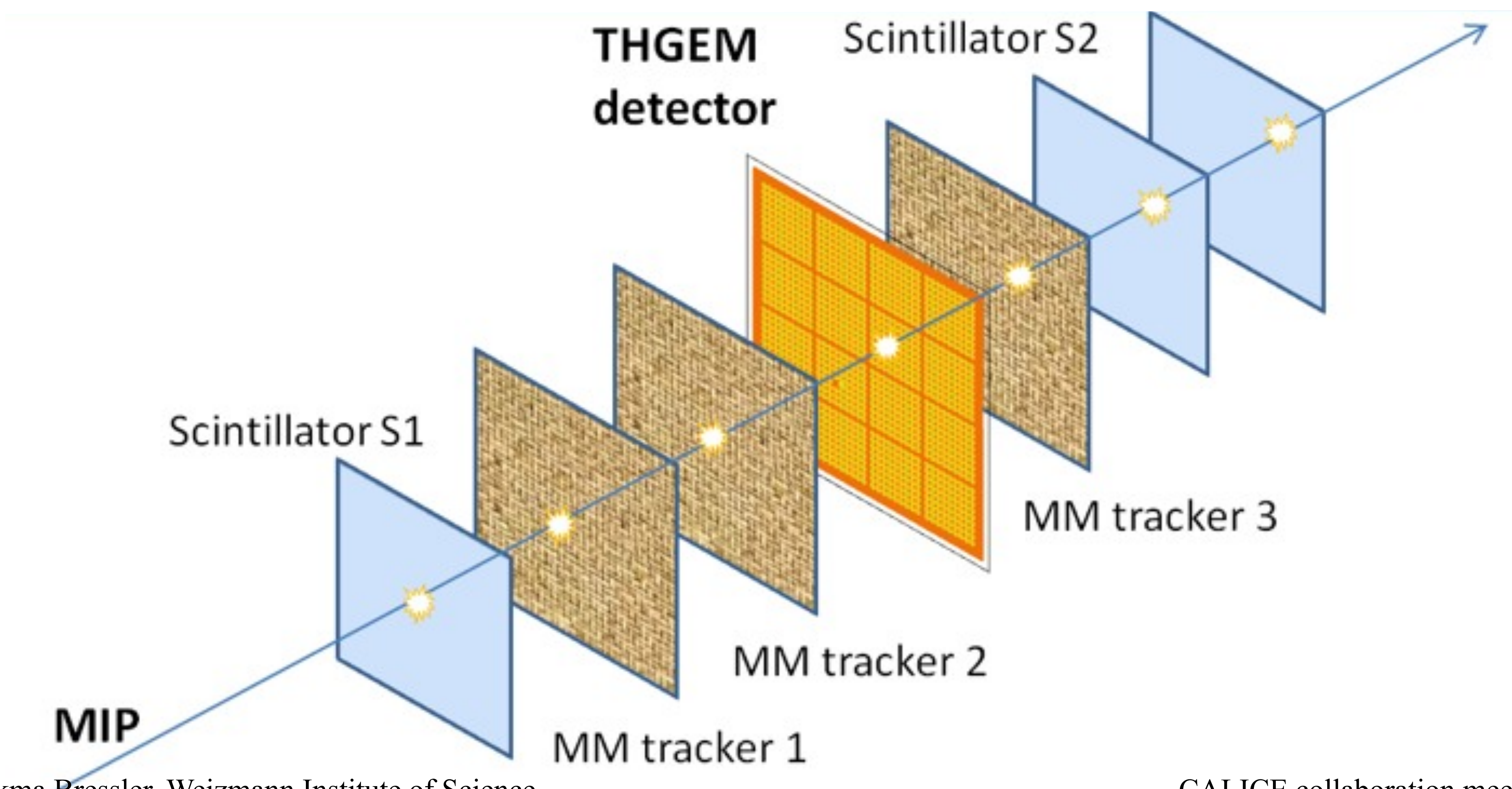


- Detectors with larger rims appear more stable
- Multiplication in the induction gap results in more stable configuration



Beam test evaluation - The setup

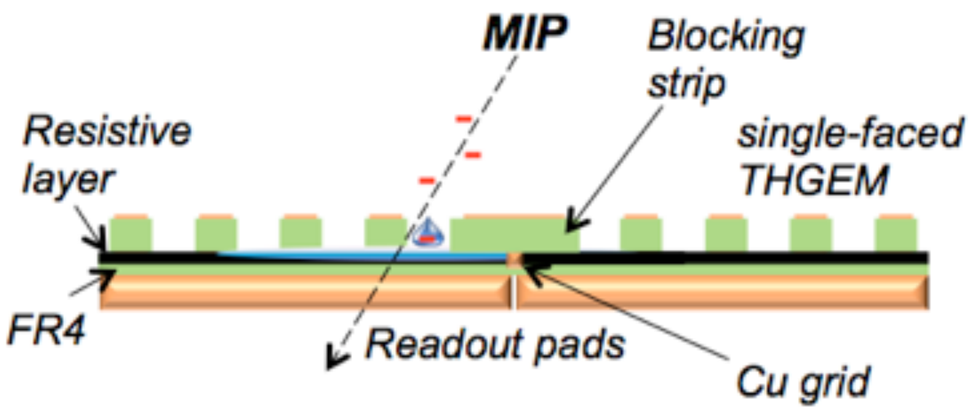
- 100x100 mm^2 THGEM detectors placed along the beam; 80x80 mm^2 coverage
- RD51 telescope
  - Three scintillators for triggering; 100x100 mm^2 coverage
  - Three MM for accurate tracking; 60x60 mm^2 coverage
- Single SRS front and card for the tracker and the detector
- All the measurements are wrt the MM track trajectory

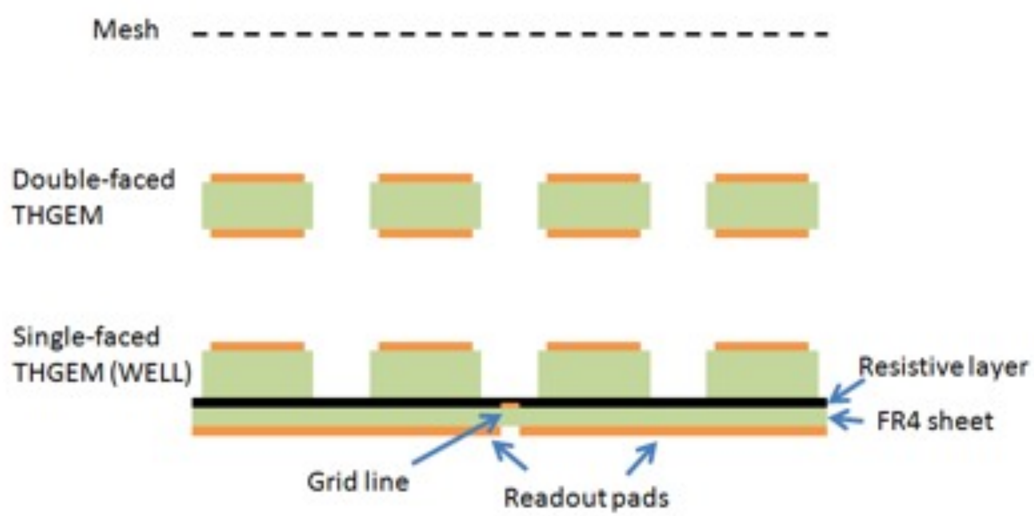


Beam test evaluation - The configurations

- Five configurations were tested
  - Not all of them to the same level of details

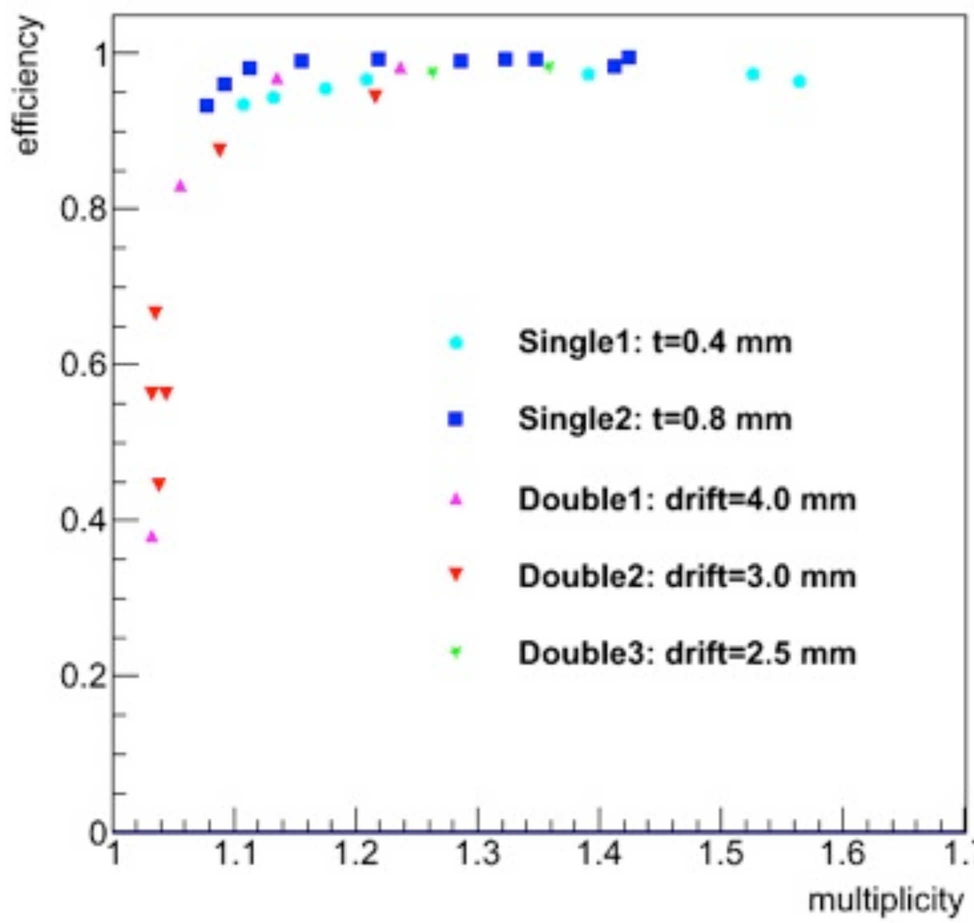
Conf.	Thickness [mm]	Transfer [mm]	Drift [mm]	Total [mm]	Resistivity
Single1	0.4	-	5.5	5.9	10 MΩ/□
Single2	0.8	-	5	5.8	10 MΩ/□
Double1	0.4/0.4	1.5	4	6.3	20 MΩ/□
Double2	0.4/0.4	1.5	3	5.3	20 MΩ/□
Double3	0.4/0.4	1.5	2.5	4.8	10 MΩ/□





Beam test evaluation - Performance in muon beam

- High efficiency and low pad multiplicity were recorded with all the configurations

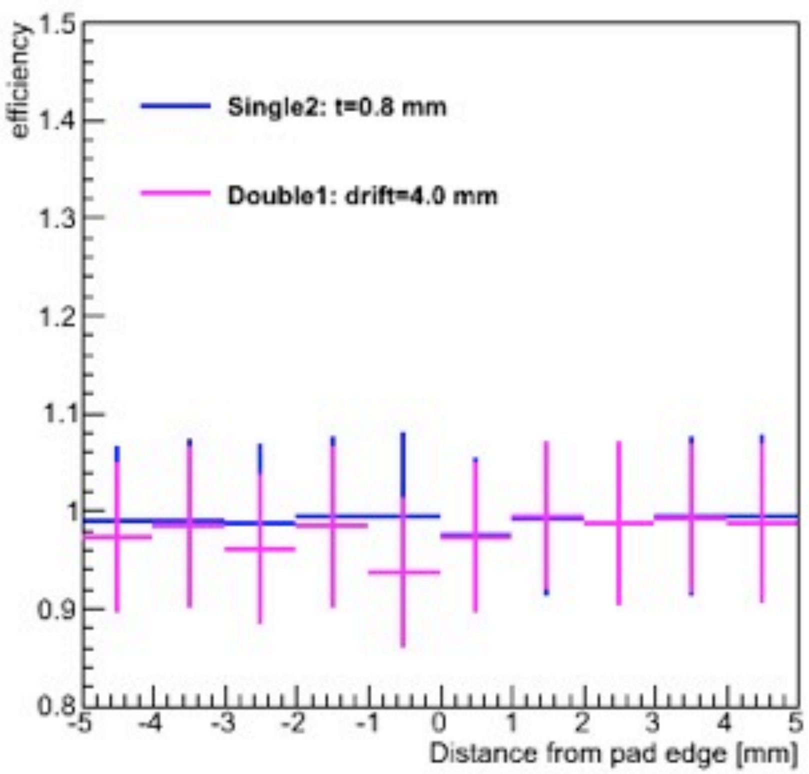


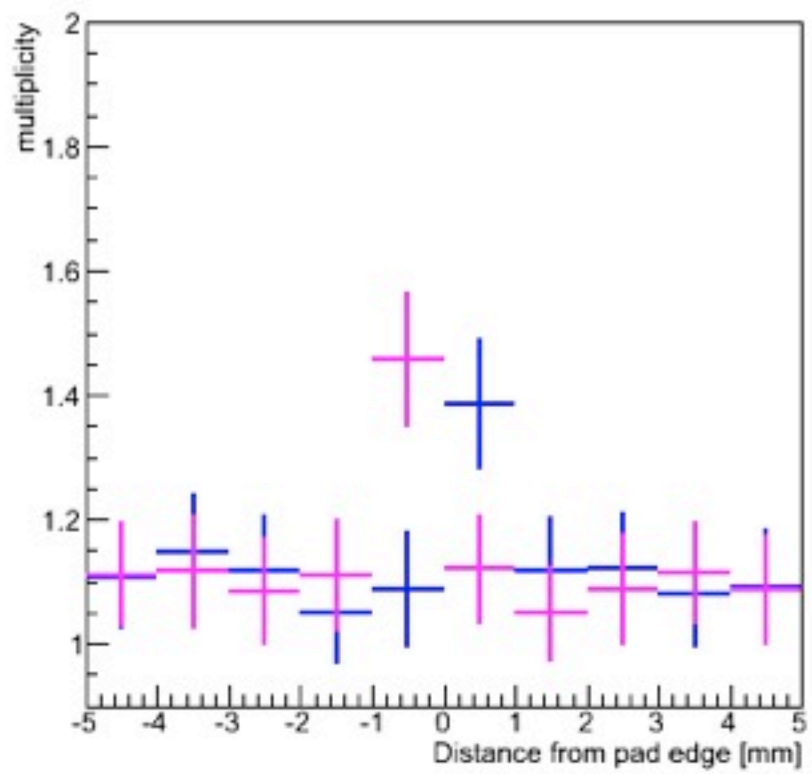
Conf.	efficiency	multiplicity	Eff. gain
Single1	0.97	1.2	1200
Single2	0.98 / 0.99	1.1 / 1.2	2000
Double1	0.98	1.2	6500
Double2	0.95	1.2	8200
Double3	0.98	1.3	4000

- Plenty of room for optimization
  - HV configuration
  - Gaps

Beam test evaluation - Performance in muon beam

- Take advantage of the accurate tracking system
- Measure efficiency and multiplicity as a function of the distance from the edge of the pads
- As expected - small efficiency drop and higher multiplicity close to the edge of the pads



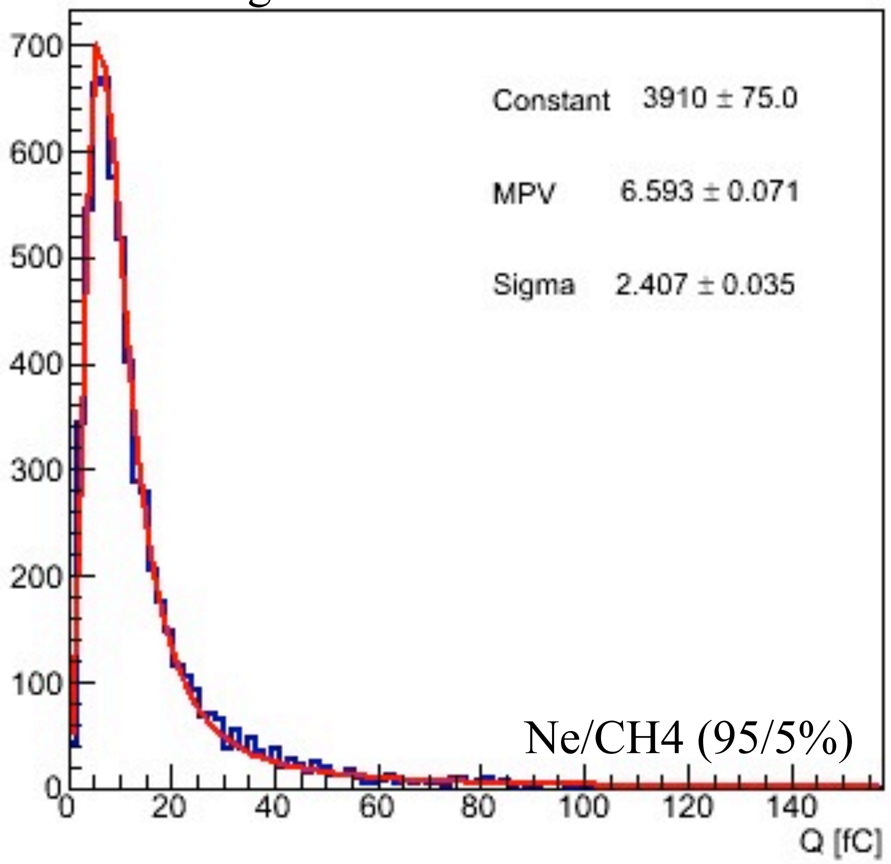


- The pad-multiplicity provides additional information concerning the track position, which could be exploited

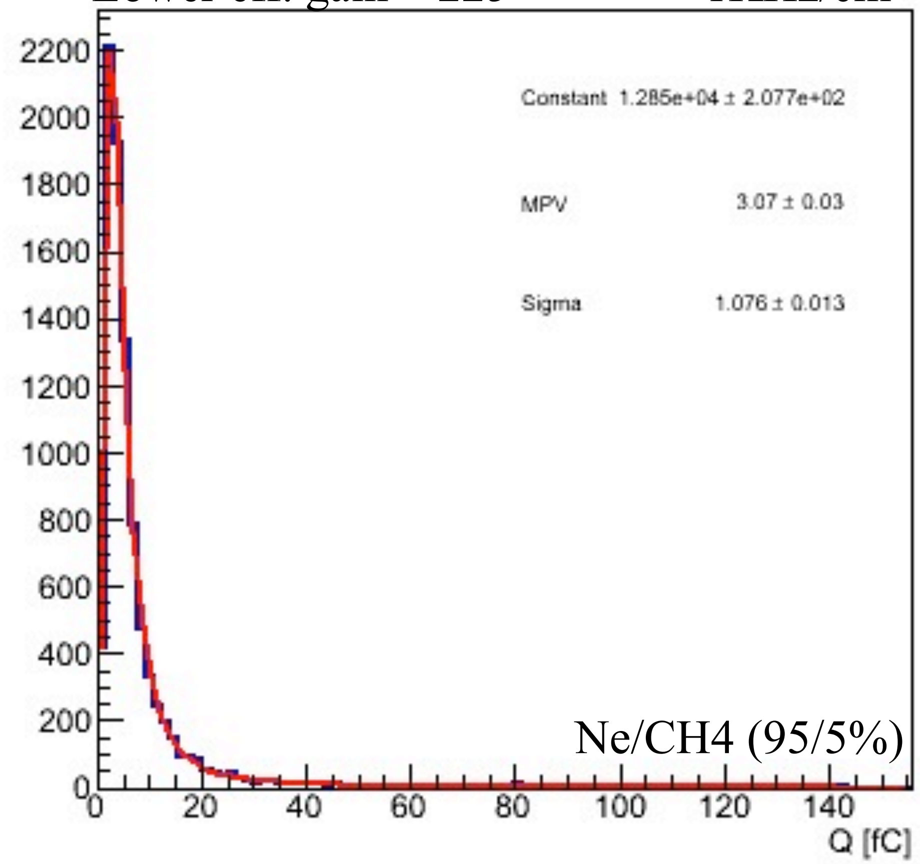
Beam test evaluation - Performance in pion beam

- Single-stage detector:
  - Significant gain drop was recorded in the transition from low rate muon beam to high rate pion beam
  - Under study

Low eff. gain ~ 500 10-20 Hz/cm^2

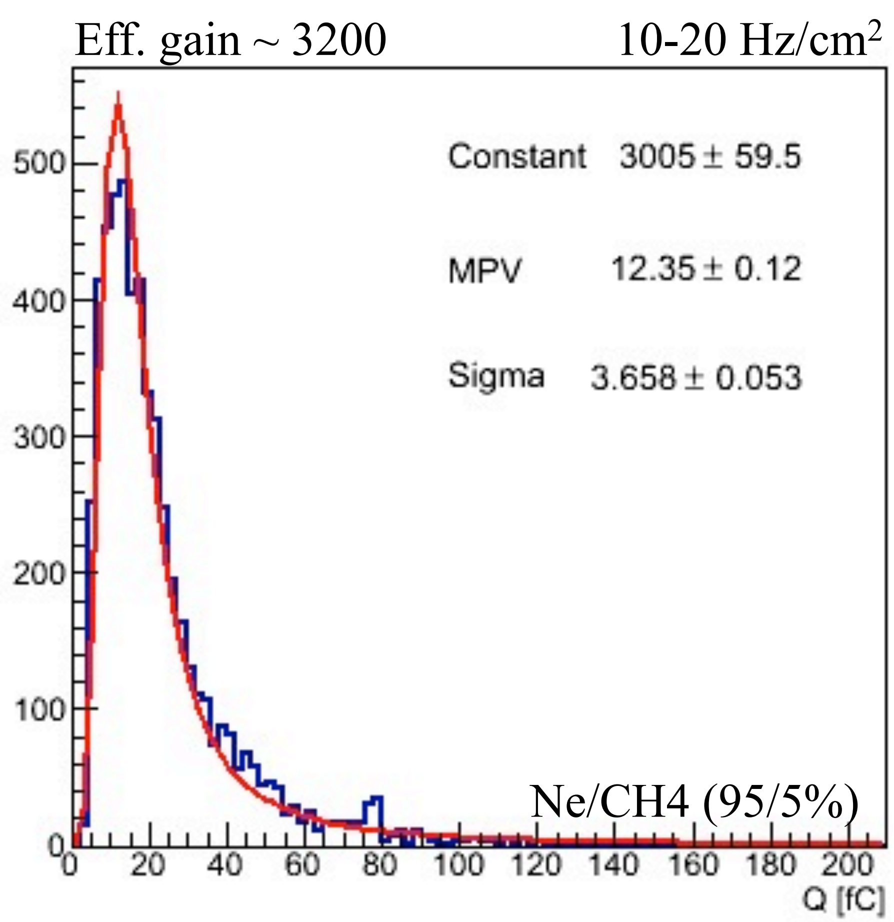


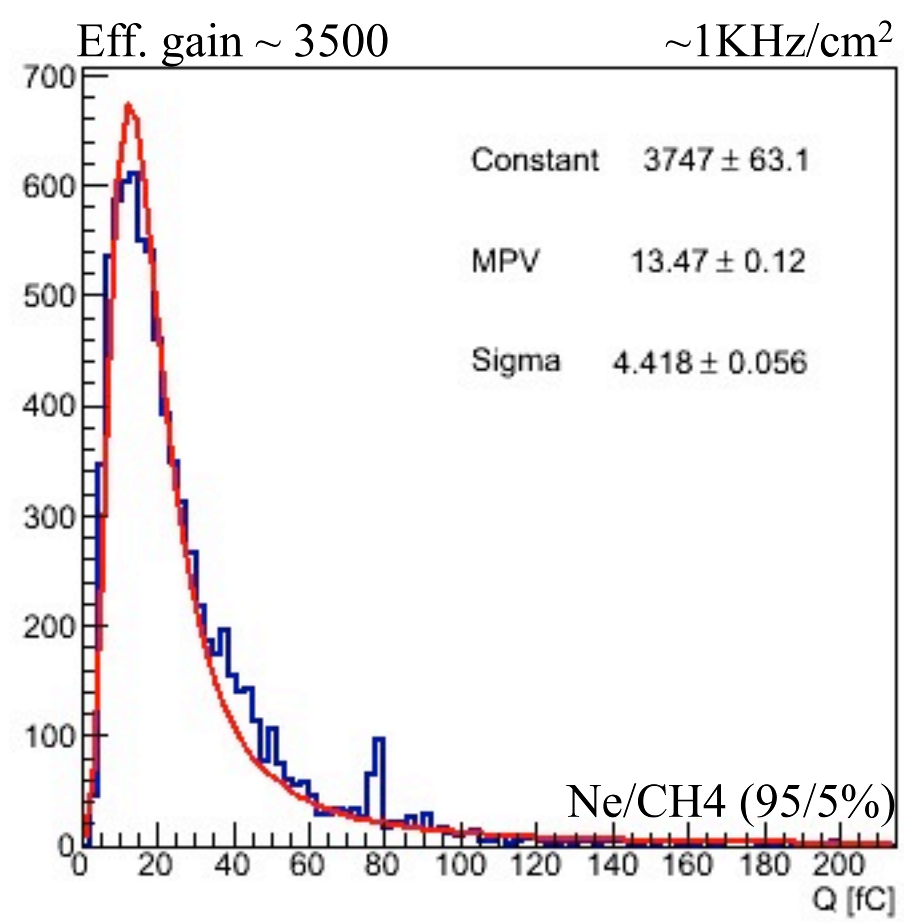
Lower eff. gain ~ 225 ~1KHz/cm^2



Beam test evaluation - Performance in pion beam

- Double-stage detector:
  - Stable and similar operation was recorded both in muon and pion beam
  - No gain drops where recorded
    - With respect to SRWELL - each element has lower HV for the same gain





Beam test evaluation - Discharge analysis

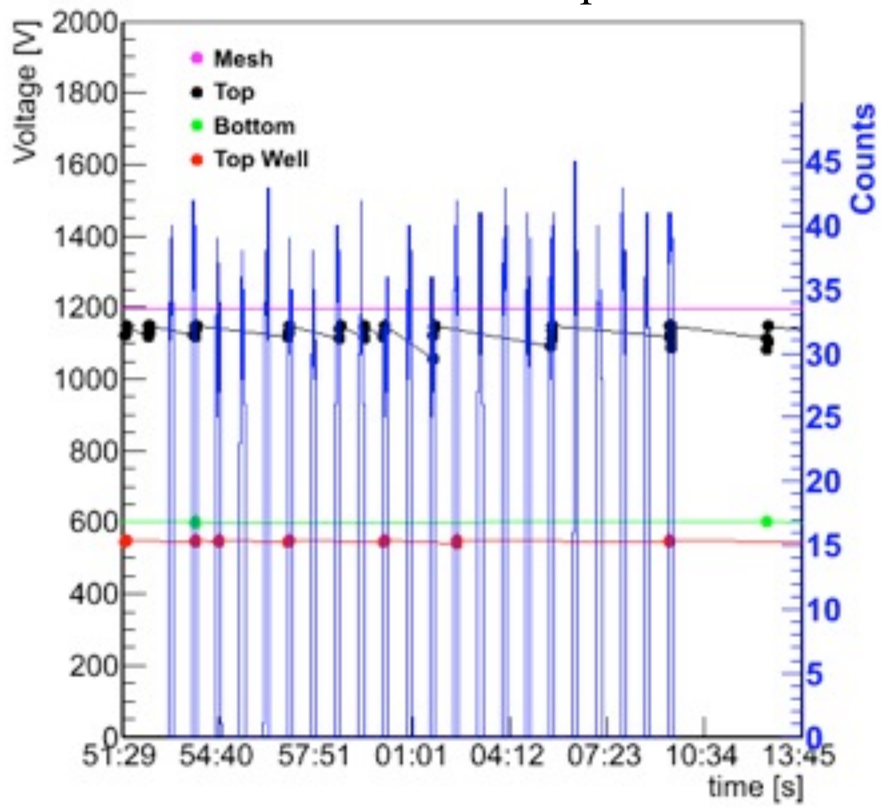
- Two types of discharges
  - *Large*: 50-200 V drop
  - *Micro*: 5-10 V drops

- Single-stage
  - *Large discharge*
    - Probability: 10^{-7} muons, 10^{-6} pions
    - Long recovery time of the power supply
    - In some case, the SRS readout electronics had to be reconfigured
  - *Micro discharges*
    - Probability: 10^{-6} muons, 10^{-5} pions
    - No obvious correlation between the micro-discharges and the gain drop
    - Study is on-going

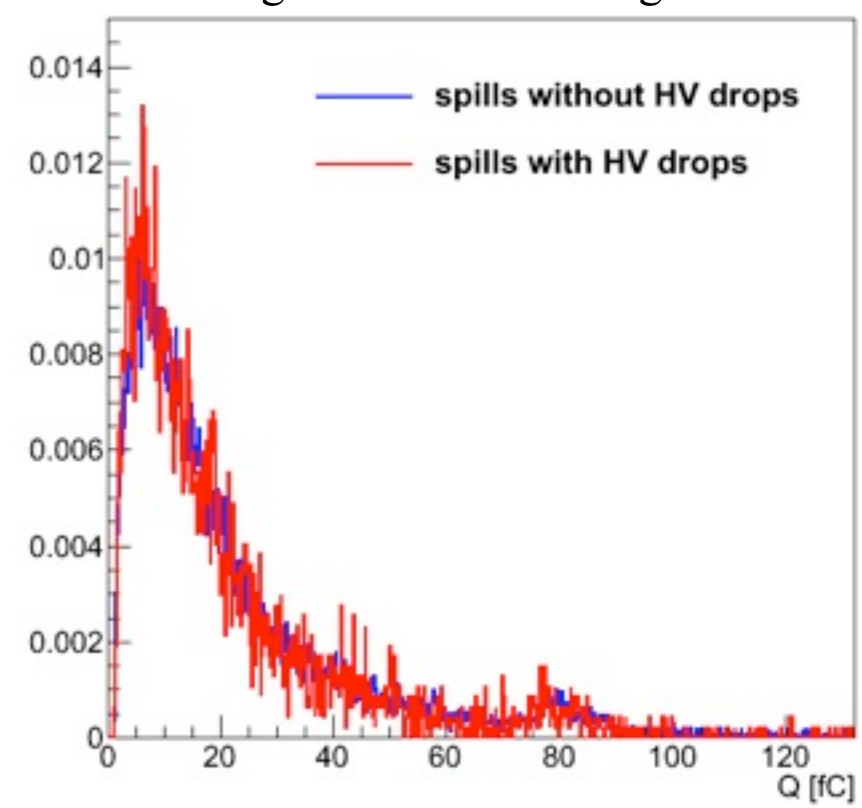
Beam test evaluation - Discharge analysis

- Double stage:
  - No large discharges
  - *Micro discharges*
    - Probability: 10^{-7} muons, 10^{-6} pions
    - Mostly correlated with the beam spills
    - Not all the electrodes are involved
    - No effect on the gain and the efficiency

HV mon. overlaid on the spill's structure

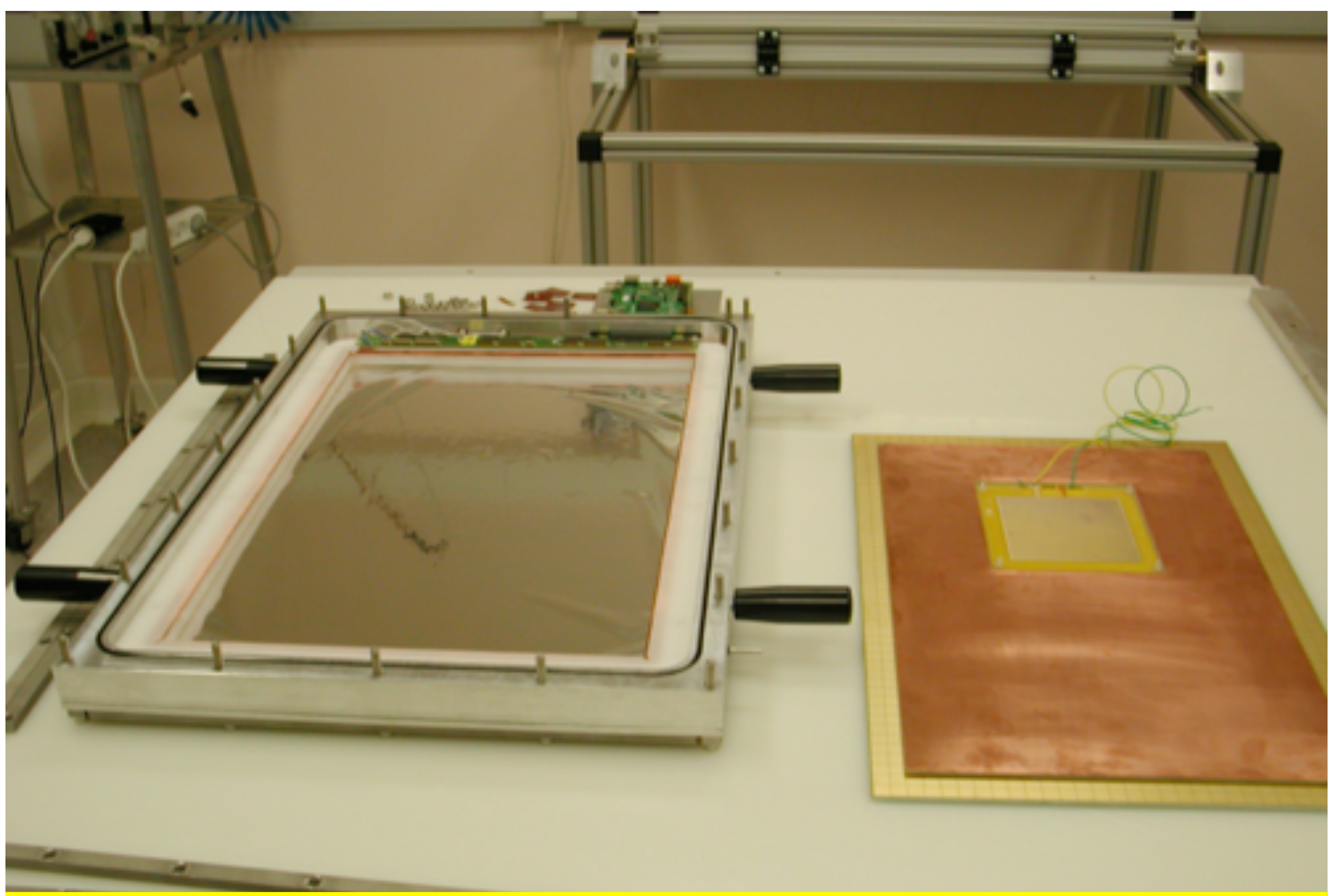


Pulse height distribution in "good/bad" spills

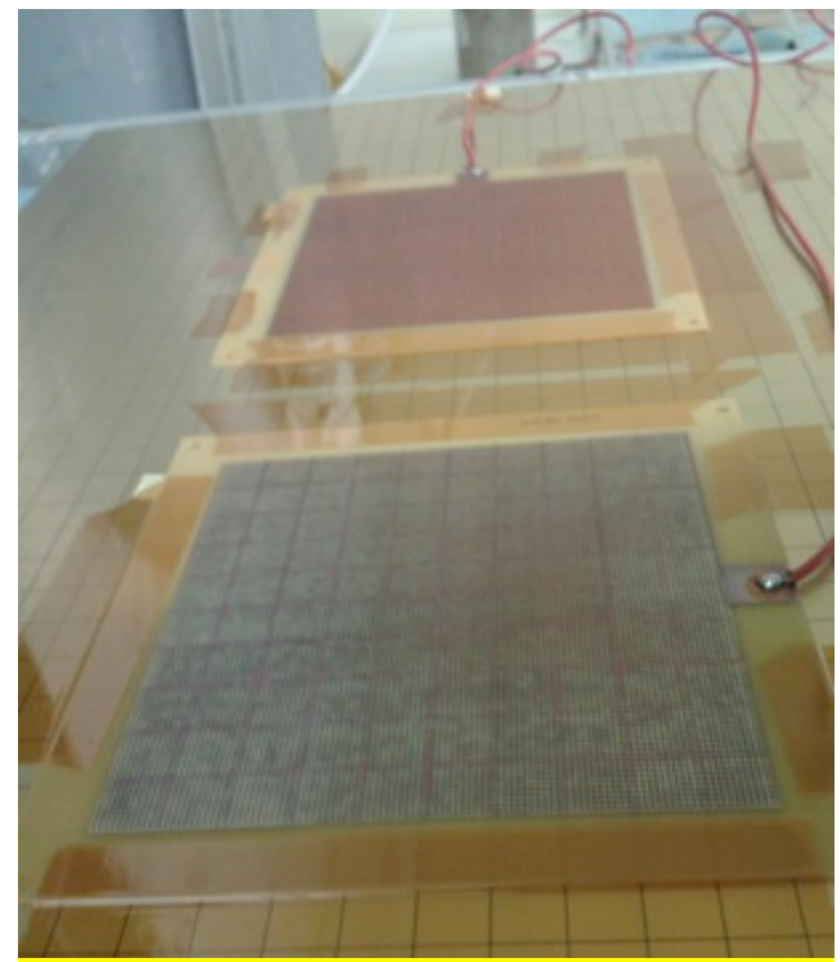


THGEM / MICROROC

- Based on work of many LAPP & Omega people
- Successful preliminary tests of several THGEM-based detectors coupled to the MICROROC chip
  - Standard, WELL, SRWELL
- 100 x 100 mm^2 THGEM electrodes were mounted inside LAPP's 320x480 mm^2 chamber



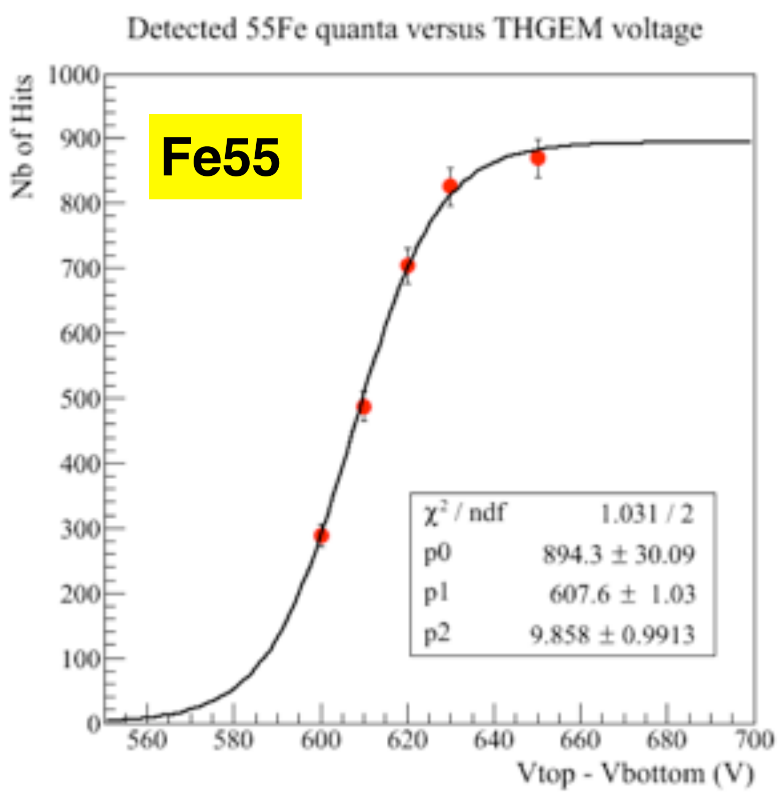
Standard THGEM placed on a supporting device

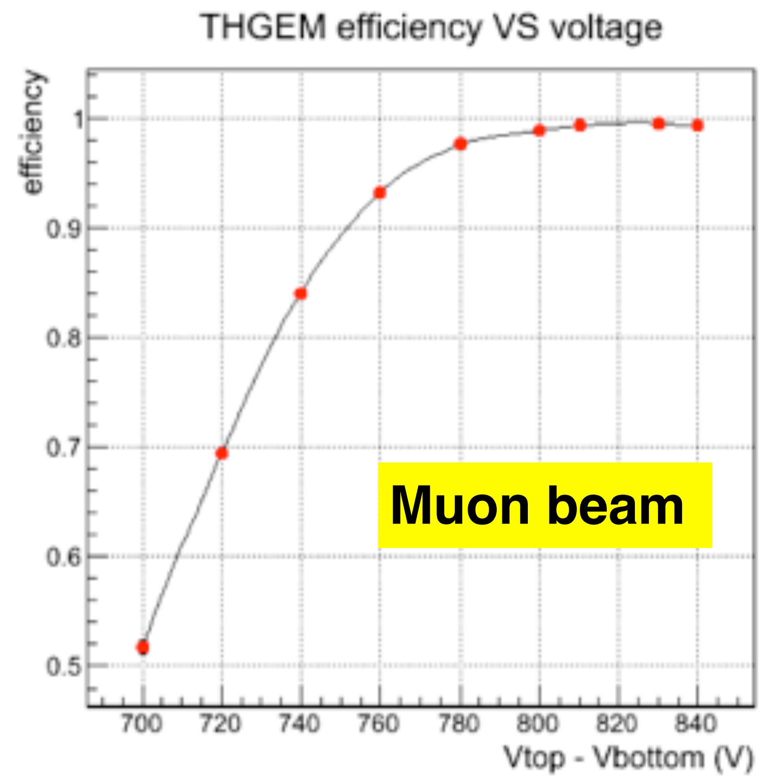


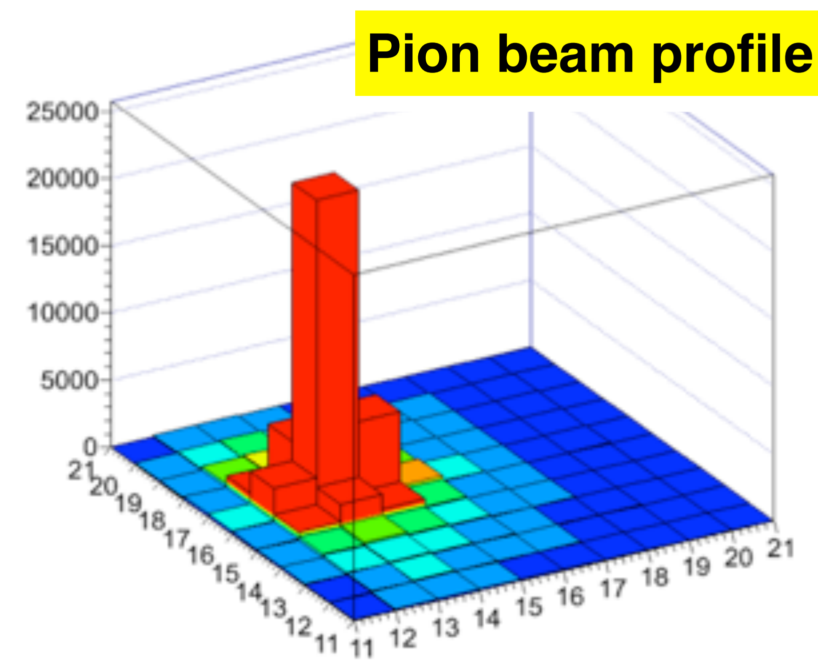
WELL & SRWELL attached to the MICROROC anode

THGEM / MICROROC - Preliminary results

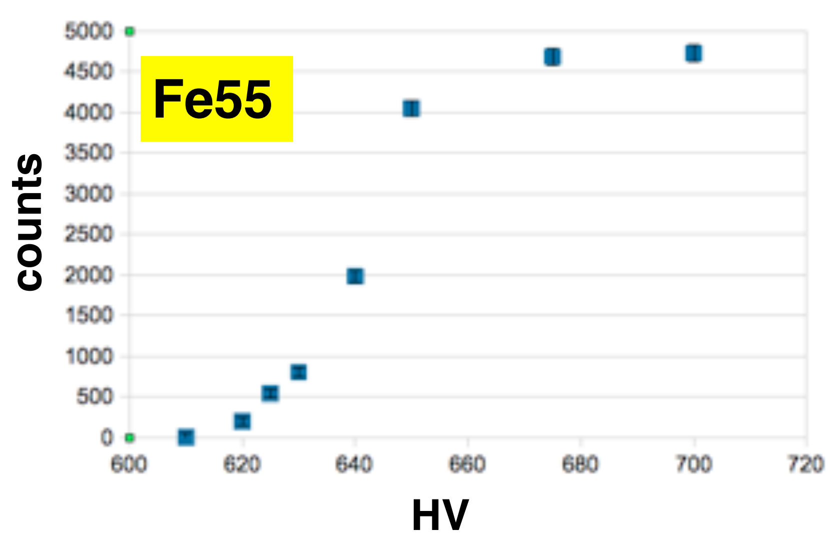
- Standard THGEM: performance similar to MM







- WELL THGEM:



- The THGEM was operated in 150 GeV pion shower behind a 2λ Fe block in a very stable way
- THGEM chamber could be included in the DAQ of the 4 1x1 m^2 during the RD51 test beam

Summary

- THGEM provides with a viable solution for many experiments that require large area coverage, in particular future DHCALs
  - Fully industrialized
  - Robust
  - Cheap
- Growing experience and knowledge is achieved in extensive R&D program
- Positive preliminary results in beam tests
- Positive preliminary results when coupled to the MICROROC chip

Future plans - Towards 1 m^2 prototype

- Start with 300x300 mm^2 detector
  - Chamber, electrodes and a corresponding SRS anode should be ready soon
  - Solve technical difficulties
    - Maintain constant gaps and fields
    - Optimize segmentation to reduce the capacitance
    - ..
  - Repeat characterizations studies
    - Gain stability
    - Gain Vs. rate
    - Response to HIPs
    - ...
  - Consider resuming to the use of Argon based mixtures
    - More primaries
  - Studies in Israel and Portugal in parallel
  - Test beams are foreseen (PSI / CERN / ?)

Future plans - Towards 1 m^2 prototype

- Continue collaborating with the group from LAPP
  - Produce a 320x480 mm^2 segmented electrode to match LAPP's chamber
  - Study grounding issues seen with the resistive layer
  - Use 100x100 mm^2 MICROROC anode in WIS

Future plans - CALICE ?