THGEM studies
tools & first results

1. Optical readout to study physics of detectors
2. Response of THGEM based detectors to HIPs

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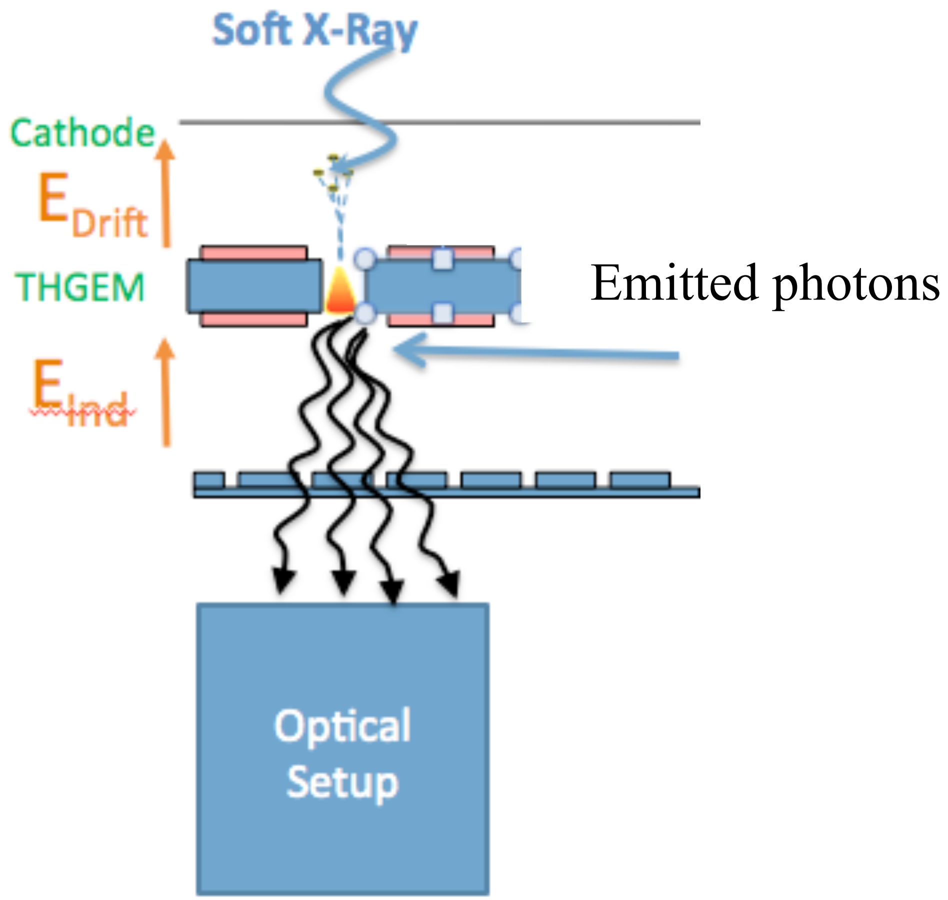
Optical readout to study physics of detectors

Motivation

- Study avalanche formation and macroscopic avalanche properties
- High resolution information on detector response
    - Hole by hole analysis
    - Effect of detector parameters on avalanche dynamics
        - For example, lateral diffusion and hole multiplicity

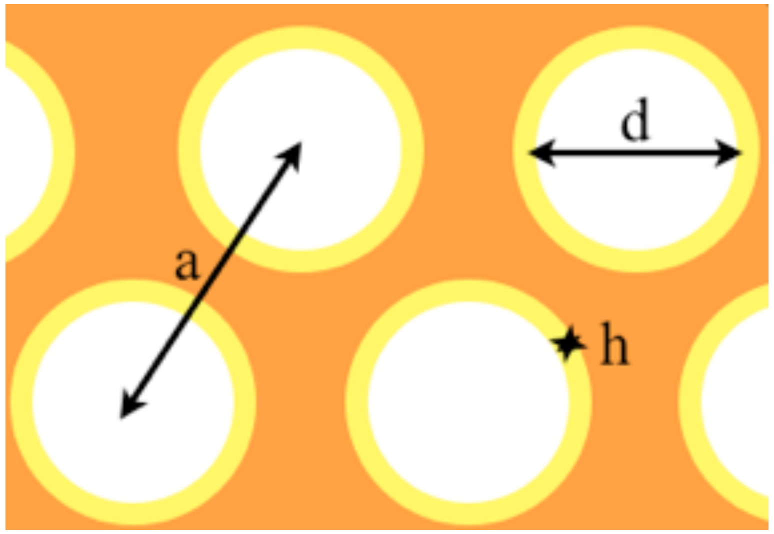
Main concept

- We take advantage of the light emitted by excited atoms to probe them

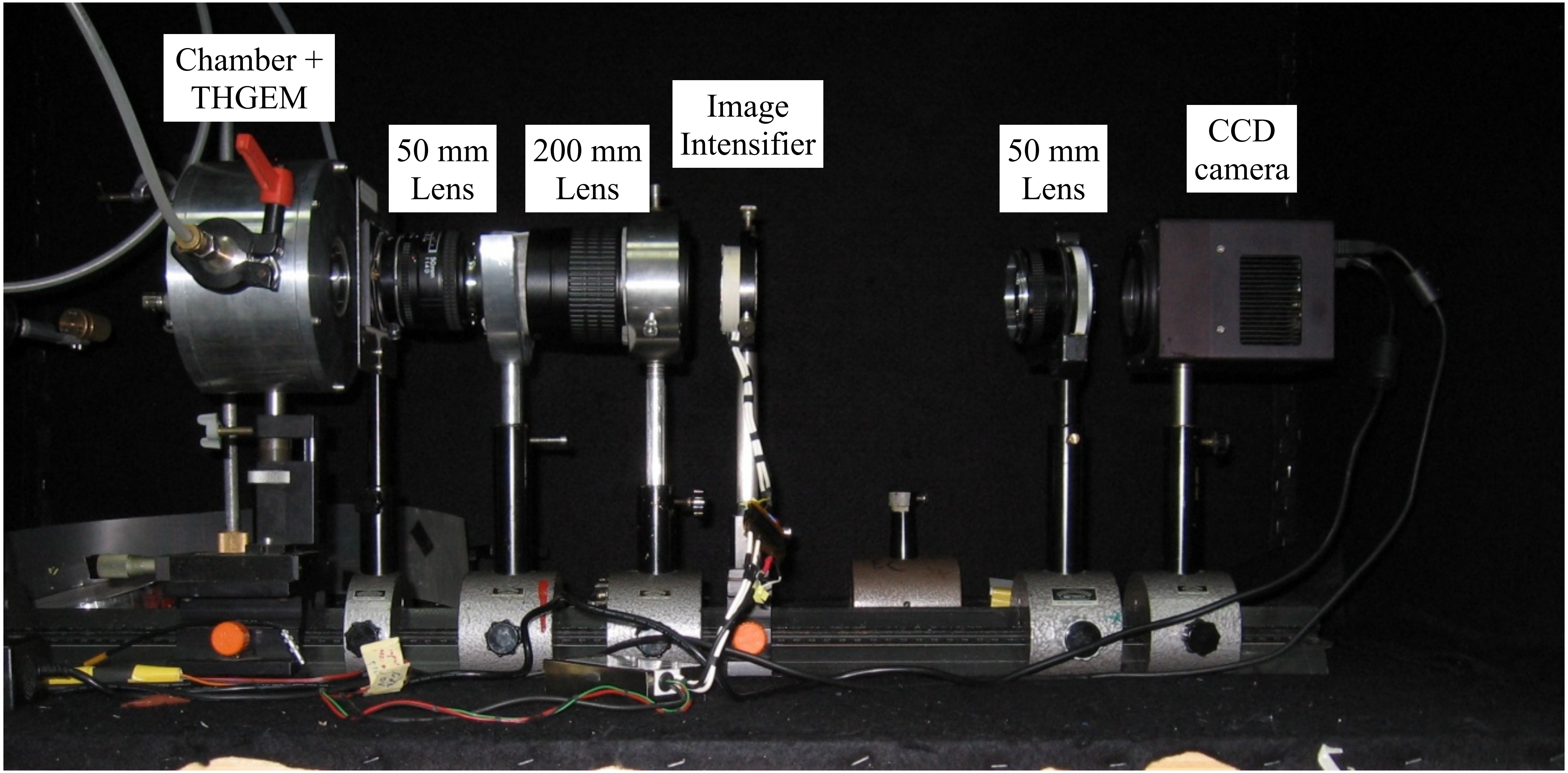


THGEM geometry

- 30×30 mm^2 electrodes
- a = 1mm, d = 0.5 mm, t = 0.4 mm, h = 100 μm

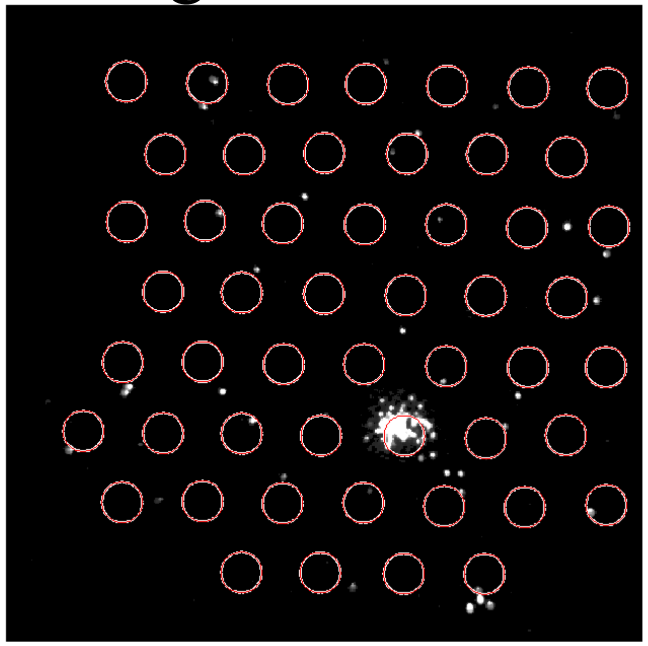


Optical setup



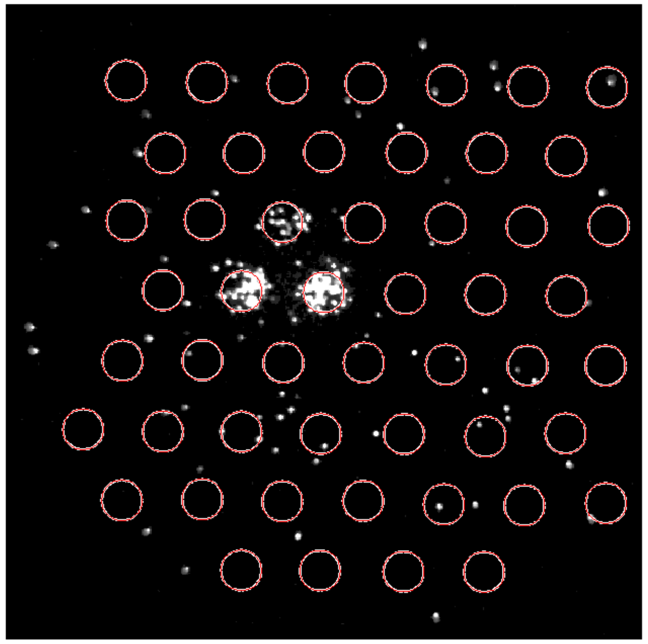
Avalanche visualization

Single avalanche

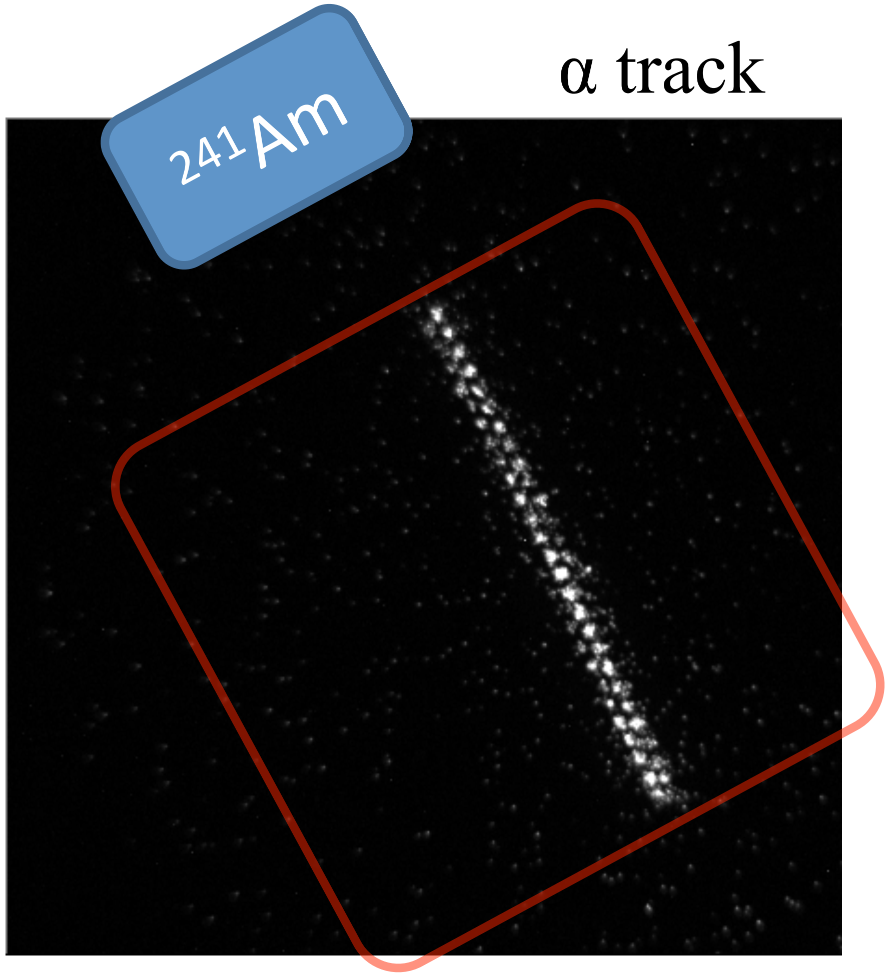


^{55}Fe source

Charge sharing between holes



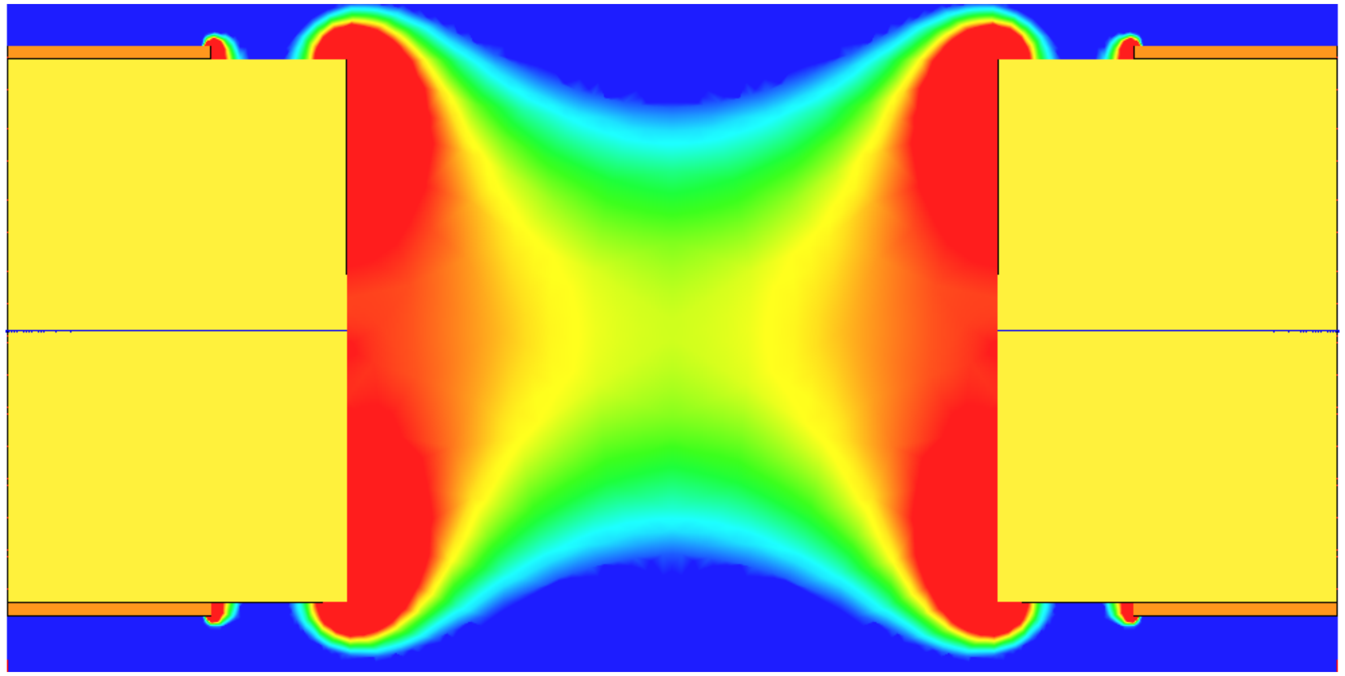
α track

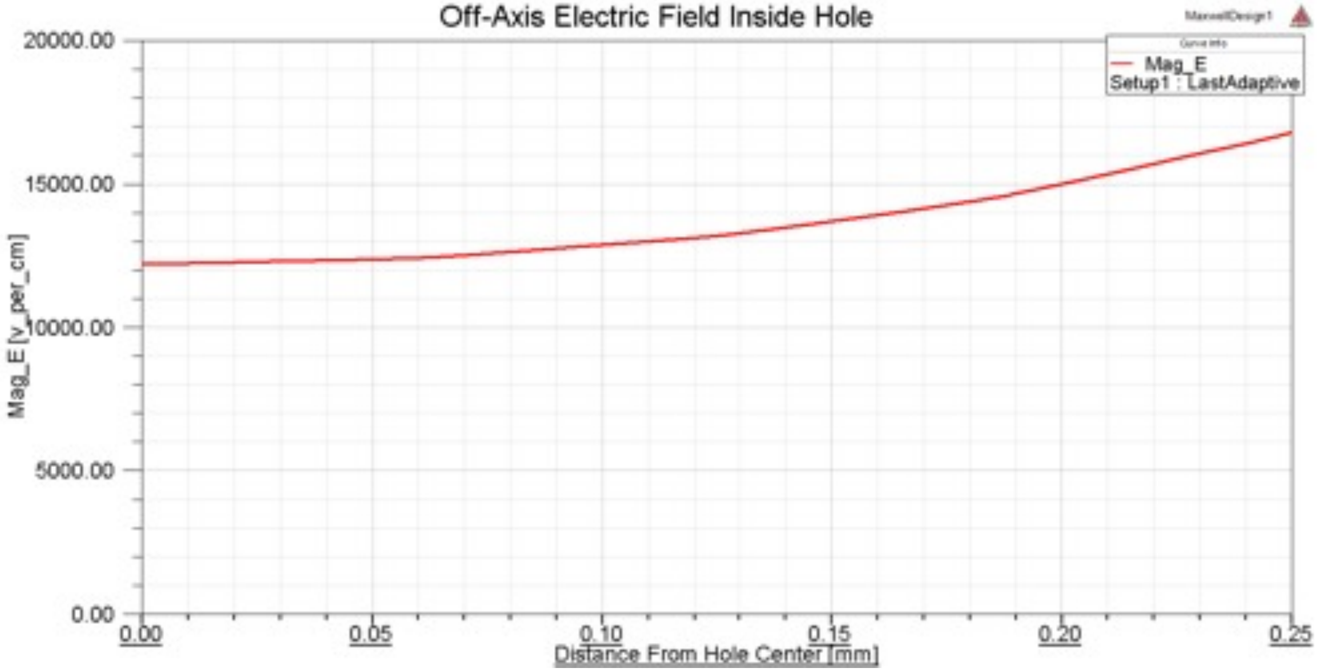


How are avalanches distributed inside a hole?

- field is stronger near the edge (~30%)
- Avalanche may develop near the edge
  - Possible cause of breakdown?

Field map using Maxwell





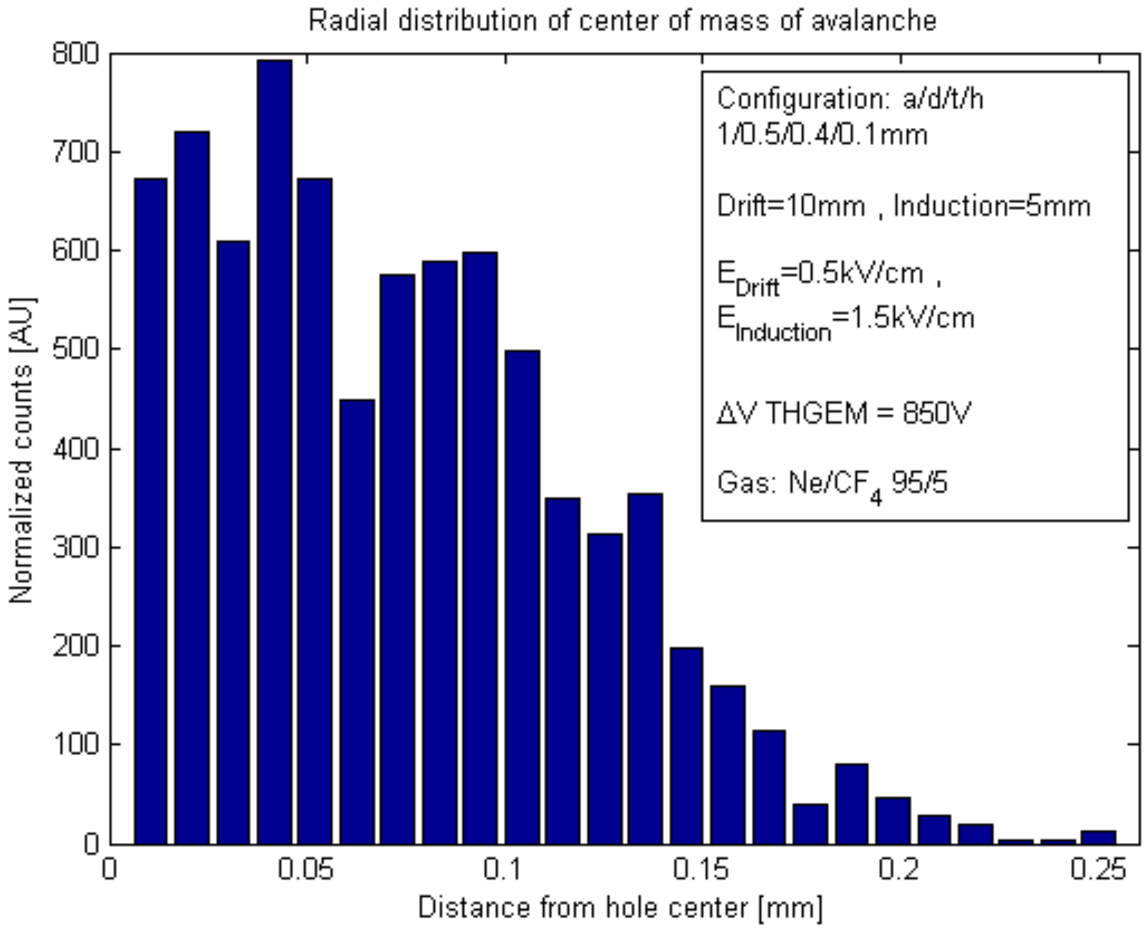
Measurement

- Ne/CF4 95/5%
- ^{55}Fe collimated source
  - total rate: ~10 Hz/detector → ~0.01 Hz / hole
- Short exposure (0.05s)
- Decay time of phosphore screen: 1ms

→ single avalanche in a hole

Preliminary results

- The plot shows the center of mass of the avalanches as a function of distance from the center of the hole



Future plans

- Measure the hole multiplicity of MIPs
- Check gain uniformity of the holes
- Check correlation between the number of holes in an avalanche an the maximal achievable gain

- Detection of defects
  - Location of defects and characterization
- Spark analysis
  - Energy, location

Response of THGEM based detectors to HIPs

HIP - Highly Ionizing Particle

Introduction I

- THGEM has been proposed as sampling element for the DHCAL in the ILC
  - Arazi et al. 2012_JINST_7_C05011 http://dx.doi.org/10.1088/1748-0221/7/05/C05011
- Detector efficiency and pad multiplicity was shown to match the DHCAL requirement
- Single stage configuration had high spark rate
- Double stage configuration was stable but wide
  - Cost consideration motivates the development of narrow sampling element (as narrow as 8mm)

Introduction II

- High energy experiments provides with highly radiated environment
- Some of the radiation composed of highly ionizing particles
  - Close to the Interaction Point: ex. CMS silicon strips tracker mainly slowly moving π's and k's → 100×MIP → 5000 Primary electrons
  - Far from the Interaction Point: ex. ATLAS TGC nuclear recoil (Bragg peak) → 200-300×MIP → 12000 Primary electrons
- A MIP detector is required to be
  - Efficient in MIP detection
  - Robust, as much as possible, against HIPs

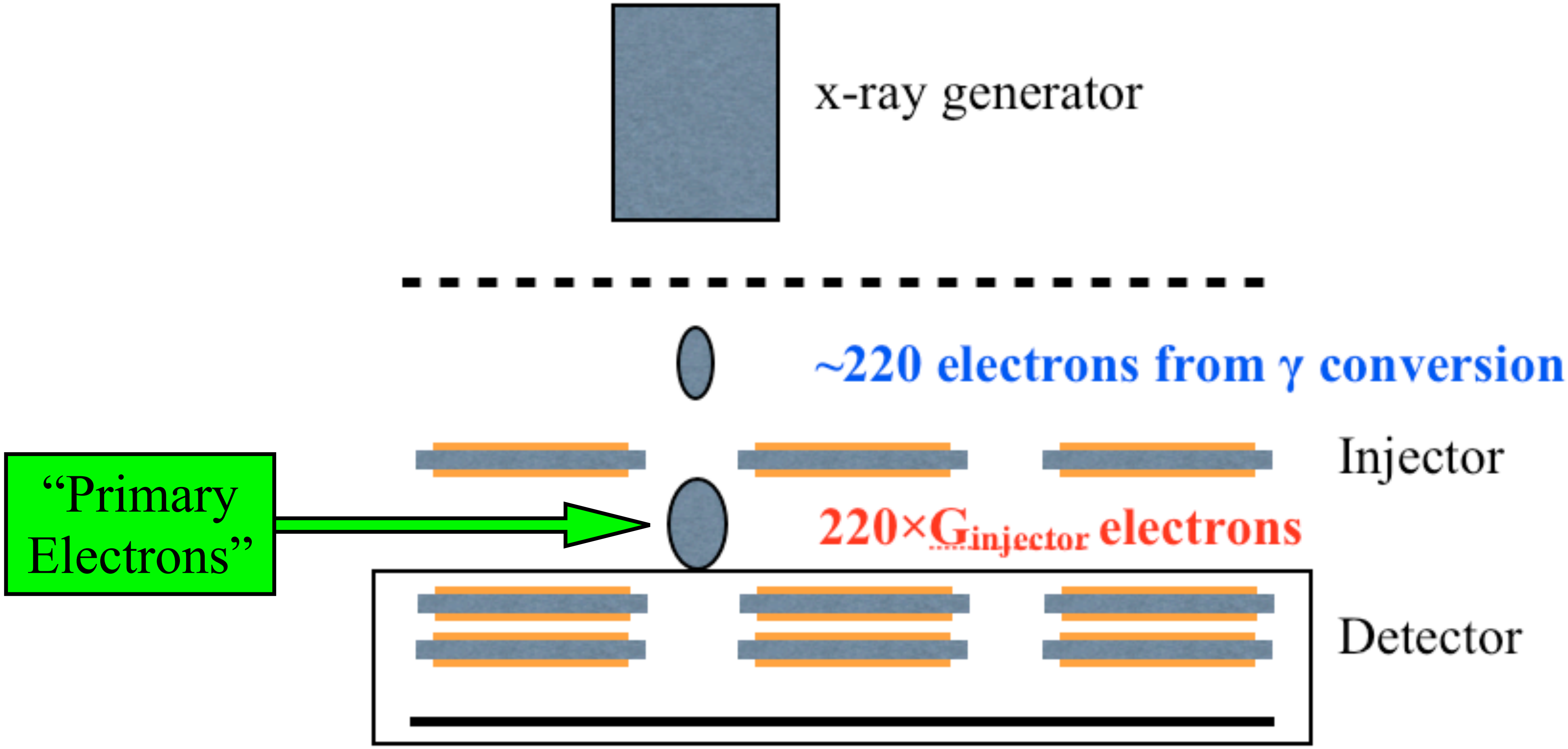
Goals

- Develop a method to mimic highly ionizing particles in the lab
- Measure spark probability as a function of number of PE
- Measure the spark energy devision on the different electrodes

- Use the methods above to optimize a THGEM based detector as sampling element of the DHCAL
- The optimization is with respect to the following parameters:
  - Number of stages
  - Type of THGEM: double / single sided, well, resistive layer
  - Gaps between the electrodes
  - HV configuration
  - Gas mixture

Mimic HIPs in the lab

- Adding an **injector** - a single THGEM used to multiply the electrons prior to the detector



x-ray generator

~220 electrons from γ conversion

Injector

“Primary Electrons”

220×$G_{injector}$ electrons

Detector

Characterizing the injector

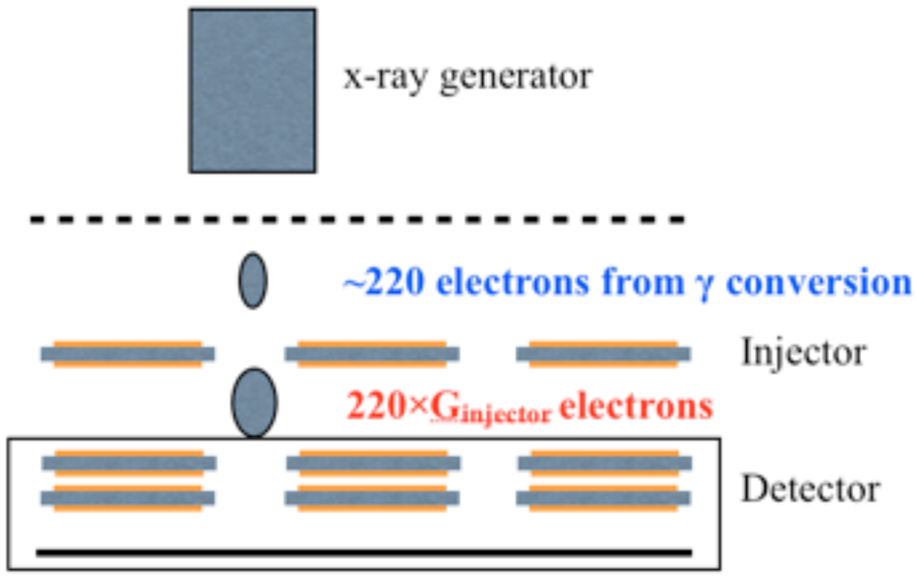
- 3 parameters of interest
  - Injector gain → mean number of PE
  - Typical width of number of PE distribution
  - Number of events in the high tail

- Difficulties
  - Low gain (1-50) measurement → can not be measured in the standard way
  - Use additional multiplier to measure the gain → widen the distribution of the number of PEs

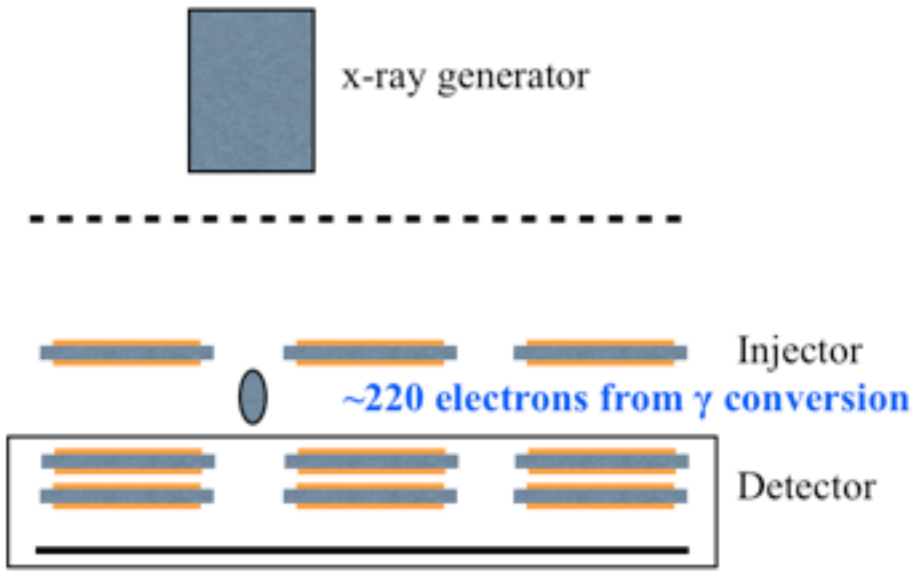
Mean number of PE

- Using the fact that some of the photons are converted between the injector and the detector → producing secondary peak in the spectrum

Main peak

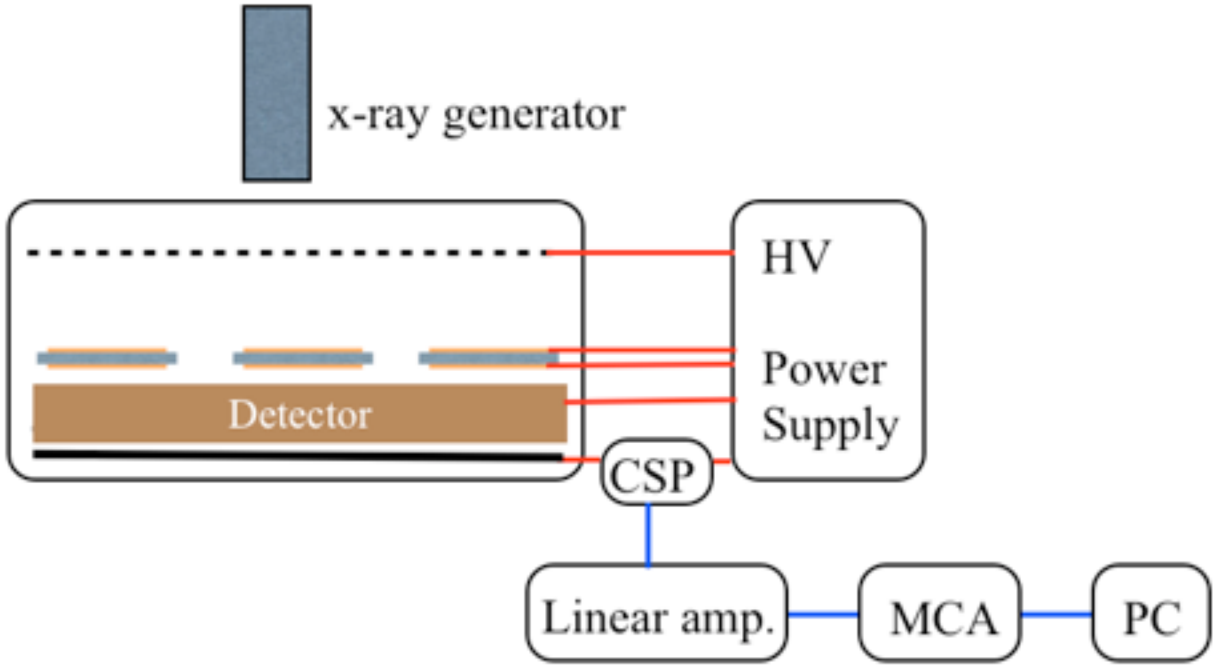


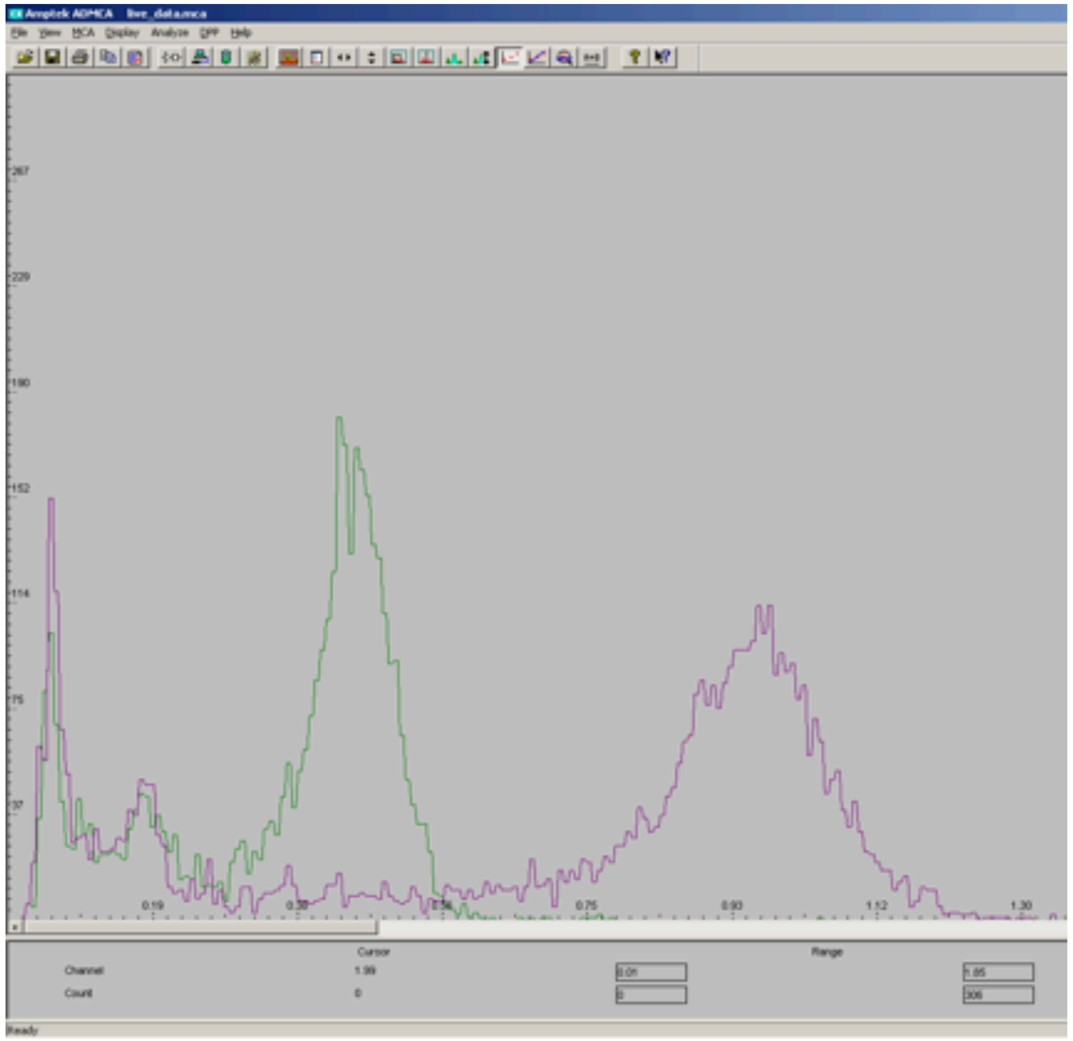
Secondary peak



Mean number of PE

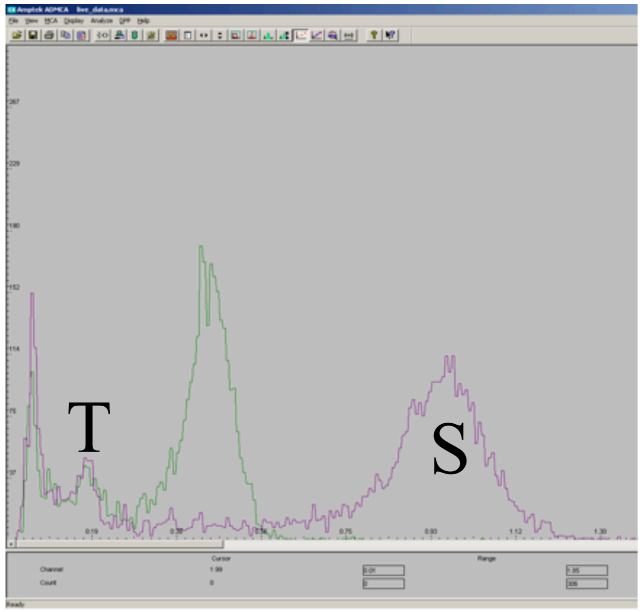
- The gain of the injector is measured from the ratio between the main peak and the secondary peak
  - Shown for 2 different G_{injector}





The width of the PE distribution

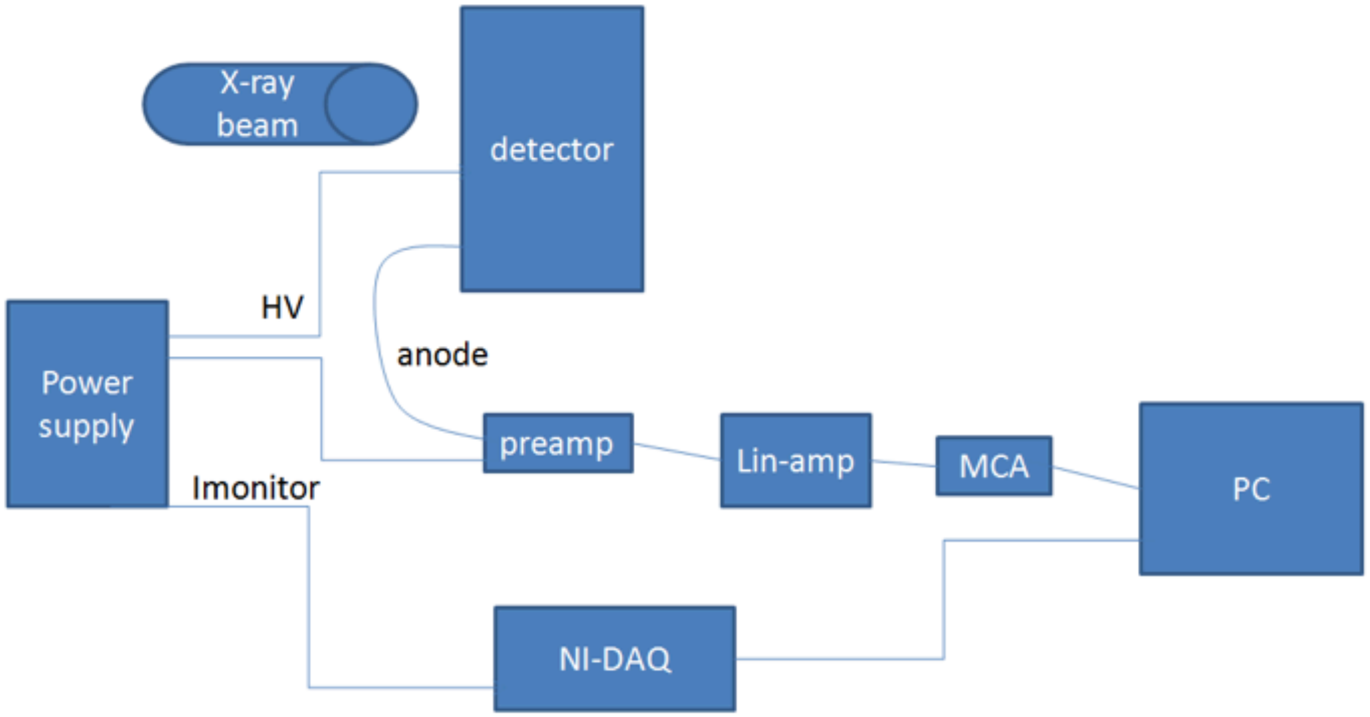
- Define:
  - S = the signal charge distribution
  - C = the distribution of the number of electron from the x-ray conversion
    For now assume C is constant -
    (220 electrons from 8keV x-ray
    conversion in NeCH4(5%))
  - I = the distribution of multiplication in the injector
  - D = the distribution of multiplication in the detector



- $S = C\otimes I\otimes D$ but we are interested in $C\otimes I$
- S is measured from the main peak of the spectrum
- $C\otimes D \equiv T$ is measured from secondary peak
- Take the Fourier transform → $s = i\times t$ (all Gaussians)
- Obtain i and take again the Fourier transform to obtain I

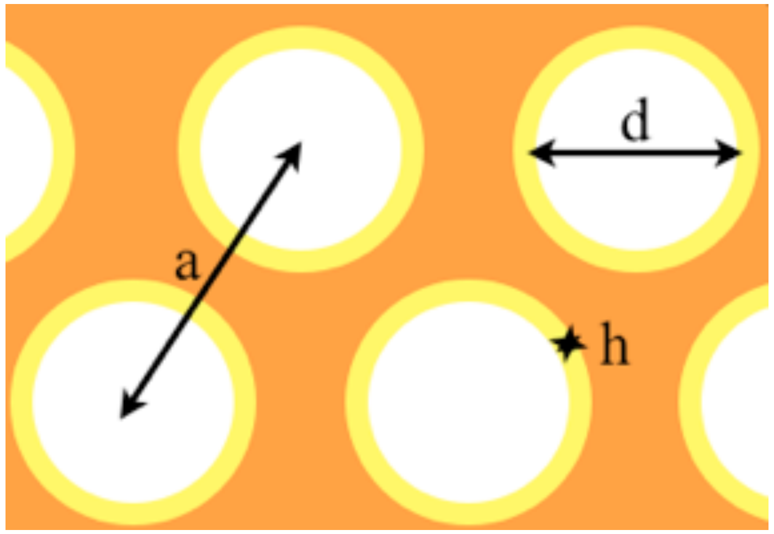
Spark probability - Experimental setup

- Two separate readout chains:
  - Standard amplification chain (CSP + Lin. amp + MCA) to measure the signal from the anode and obtain the spectra
  - NI-DAQ card to count sparks from the current monitor of the power supply



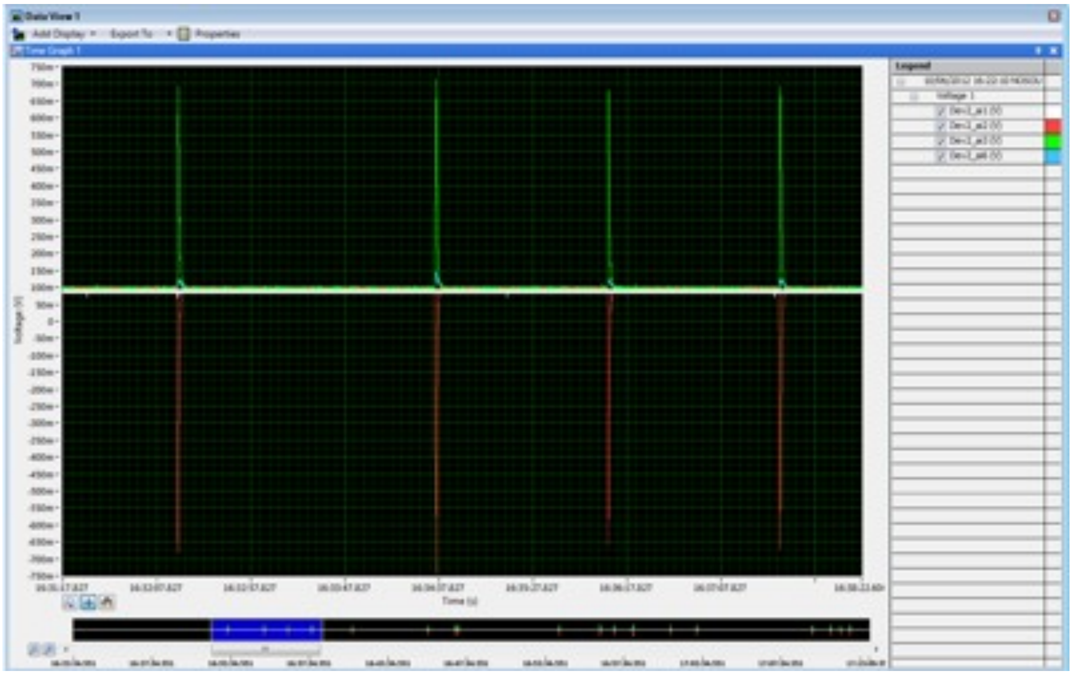
In the next slides THGEM geometry

- 30×30 mm^2 electrodes
- a = 0.7 mm, d = 0.3 mm, t = 0.4 mm

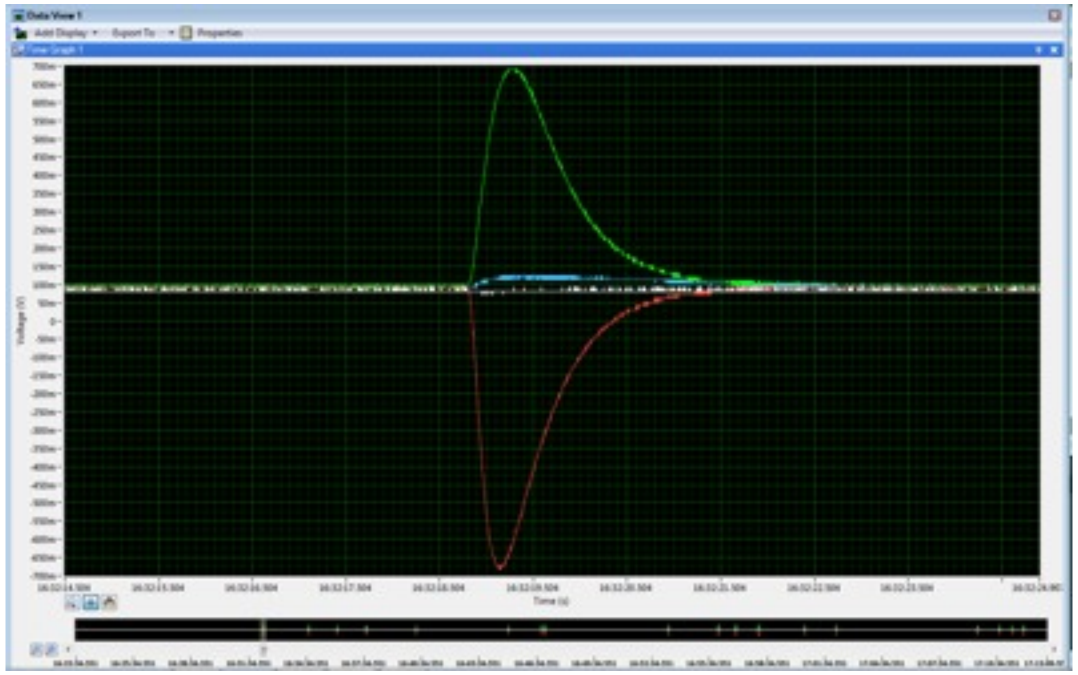


Typical spark rate measurement

- Using “LabView signal express” standard sw



- Number of sparks at a given time

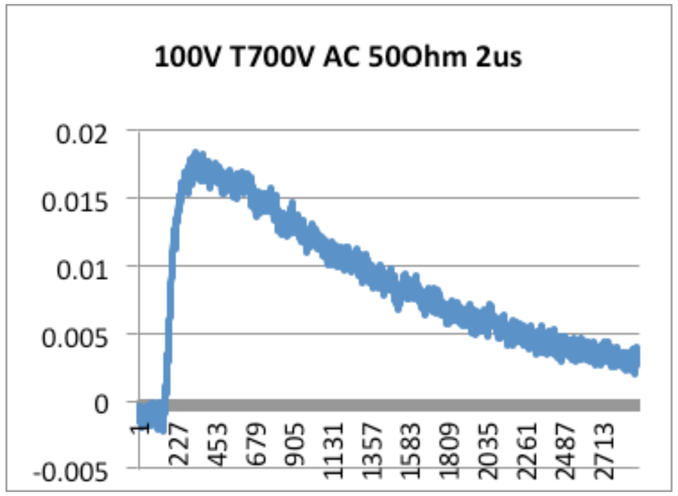


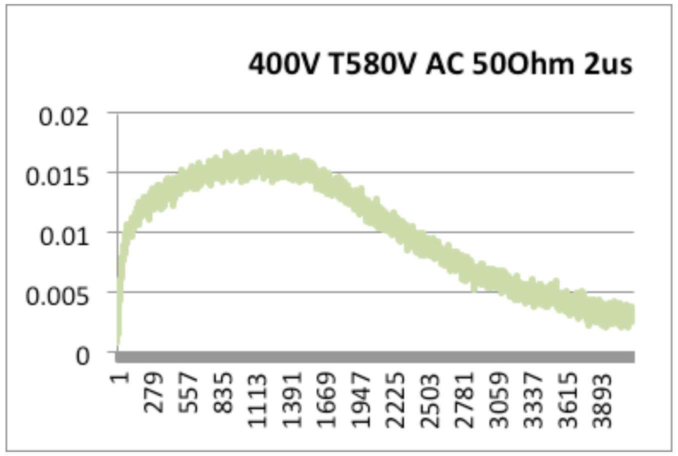
- The charge division on the different electrodes

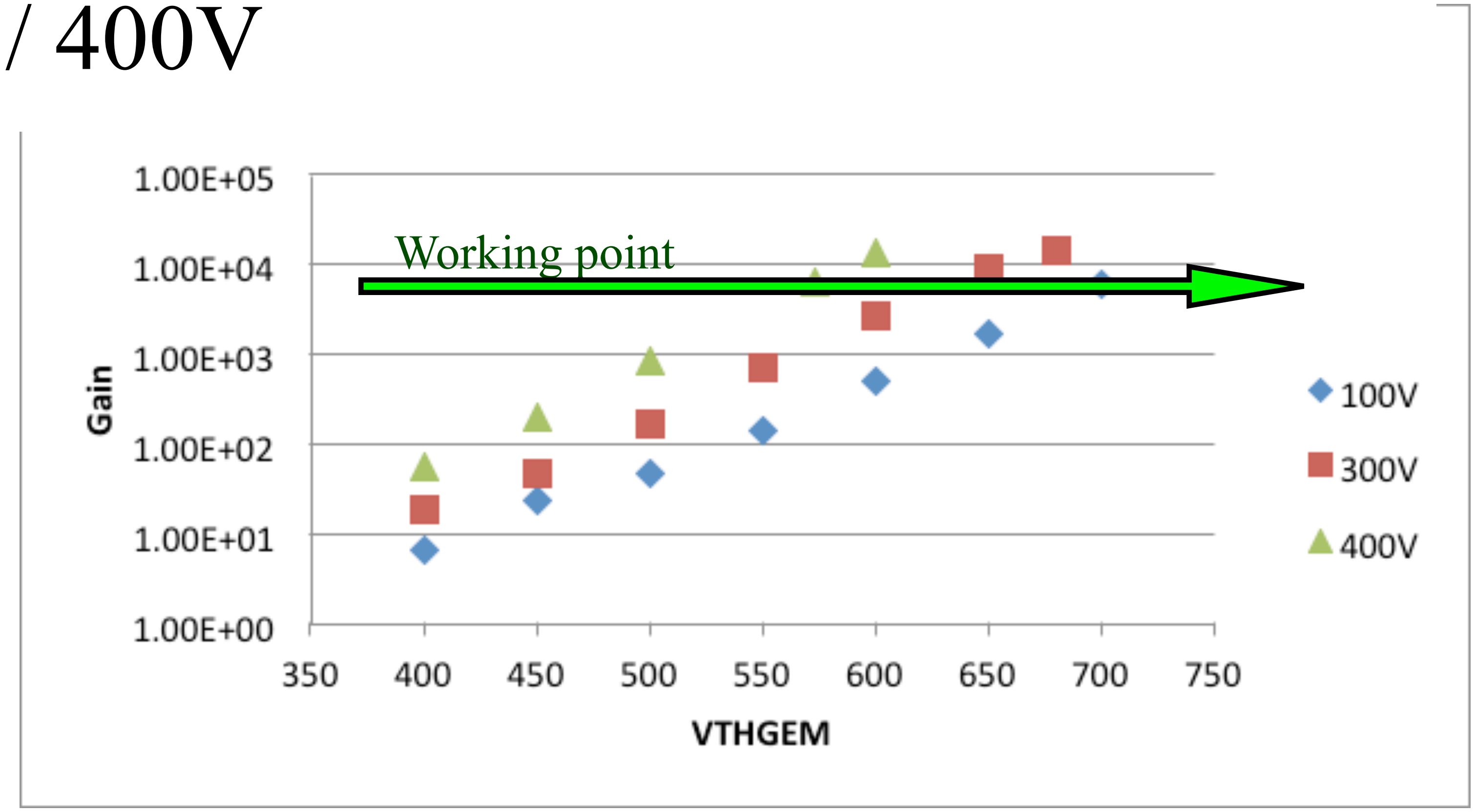
- Sensitive ampere-meter can be used for precise measurement

Spark probability measurement - Step by step

- Step 1: Fixing the gain of the injector and the detector
  - Injector: as explained before
  - Detector: from the secondary peak as the ratio between the charge in the peak and the charge prior to the multiplication ($Q_{\Delta V}$ / $Q_{220\times qe}$)
- Example: single stage THGEM with 1mm induction gap
  - $\Delta V_{induction}$ = 100V / 400V







$\Delta V_{induction}$ = 400V: Both the signal the gain curve indicate multiplication in the induction

Spark probability measurement - Step by step

- Step 2: Determining the event rate
  - Count the number of events, above the noise threshold, in the spectra at a given time
- Step 3: Measuring spark rate without a source
  - Spark without a source are due to cosmic-rays, defects in any of the electrodes, non-perfect setup
  - These sparks are “background noise” to the measurement
- Step 4: Measuring spark rate with the source

- Repeat steps 1-4 with different G_{injector} and similar G_{detector}

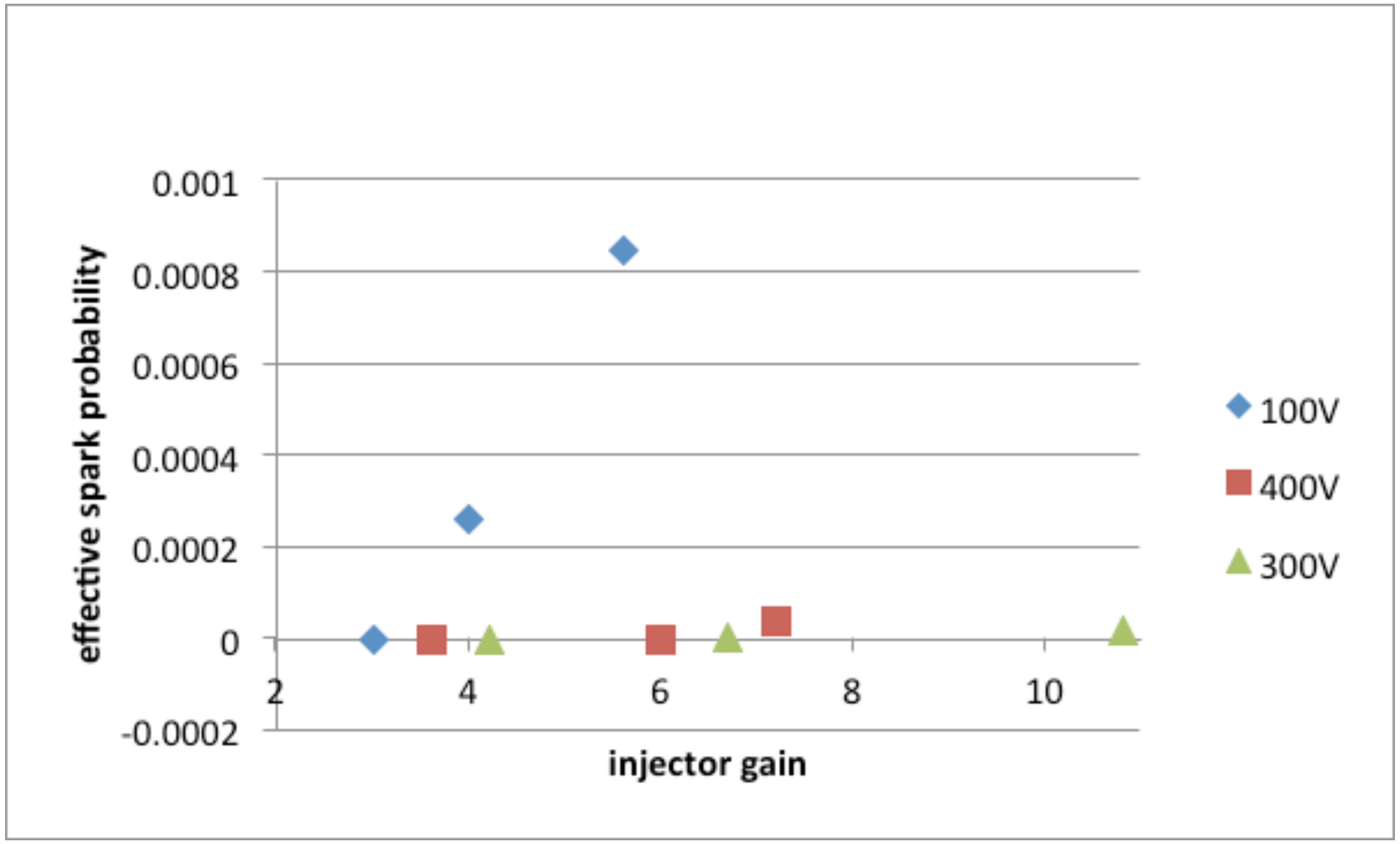
Calculating the spark probability

- Define
  - R : source rate [events/sec]
  - N_s : total number of sparks
  - $t_{effective} = t_{total} - t_{dead}$ [sec] : the effective time of the measurement after subtraction of the dead time
  - N_b : number of spark in the measurement without source
  - t_b [sec] : effective time of the measurement w/o source
  - P : spark probability

- $$P = \left\{ \underbrace{\underbrace{\left[N_s - \underbrace{\underbrace{\left(N_b / t_b \right)}_{\text{rate of background sparks}} \times t_{effective}}_{\text{number of background sparks}} \right]}_{\text{number of ``signal'' sparks}} / t_{effective}}_{\text{rate of ``signal'' sparks}} \right\} / R$$

Single stage THGEM with 1mm induction gap

- The different colors represent different induction fields
- For the same effective gain, multiplying in the induction gap provides with more stable configuration for higher number of PE
- The spark probability decreases when multiplying in the induction gap
  - Higher Reather limit ?



Future plans

- Understand the source(s) of background sparks and suppress its rate

- Study the effect of high charge tails in the PE distribution
  - Can we associate the spark with the main part of the distribution?
- Measure the width of the PE distribution

- Optimize the geometry and HV configuration for DHCAL
- Use the same setup to test and compare new structure of THGEMs