Development of an X-ray detection system for the characterization of the high voltage conditioning of a multi electrode vacuum insulated system (HVPTF)

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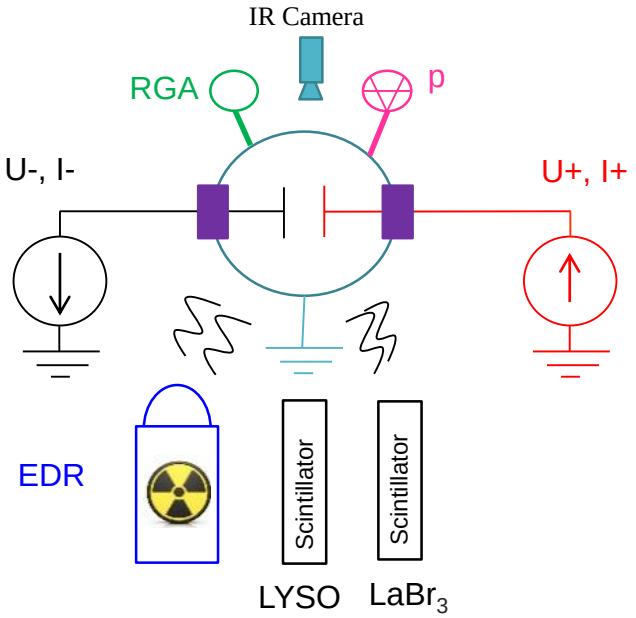
Introduction

In HV vacuum experiments x-rays are produced through the interaction of the electrons emitted from the cathode with the anode (or a lower potential surface) by emitting bremsstrahlung radiation.

Why measure the produced x-rays?

- Possibility to measure very low current (<1μA).
- Only the current carried by electrons flowing through the vacuum are detected (no electrode surface current, no insulator current).
- Possibility to better study the discharge phenomena by measuring the emitted radiation spectrum and its spatial distribution.
- Higher time resolution with respect to standard current measurements.

High Voltage Padova Test Facility (HVPTF)



Stainless Steel vacuum chamber volume 2.4 m^3

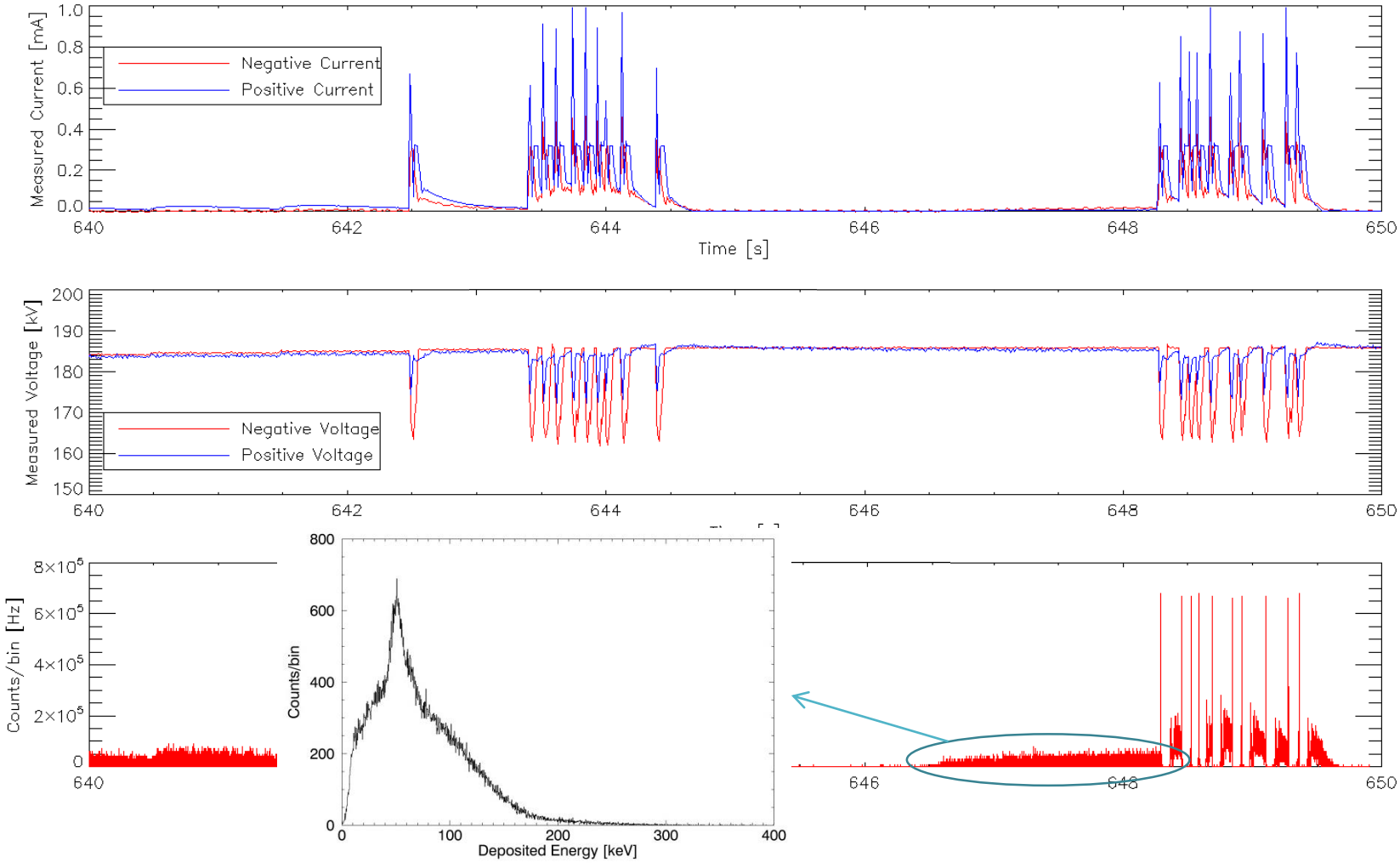
Double polarity configuration
2 Cockcroft-Walton power supplies 400kV_{DC} -1mA (positive and negative unit put in series), Maximum voltage 800kV_{DC}

Vacuum & gas injection system
1 turbomolecular pump 1m3/s baked by a dry scroll pump 0.04 m3/s, pressure from 3e-7 to 1e-02 mbar

Measured quantities:

- Pressure : 1 capacitive, 1 hot cathode and 1 penning pressure gauge [mbar]
- Equivalent Dose Rate (EDR) [mSv/h]
- Voltages (U+ , U-) [kV] , Currents (I+,I-) [mA]
- Residual Gas Analyser (RGA) , 1-100 [amu]
- Infrared Camera [°C]
- X-ray spectra two types of scintillators [keV]

Preliminary measurements

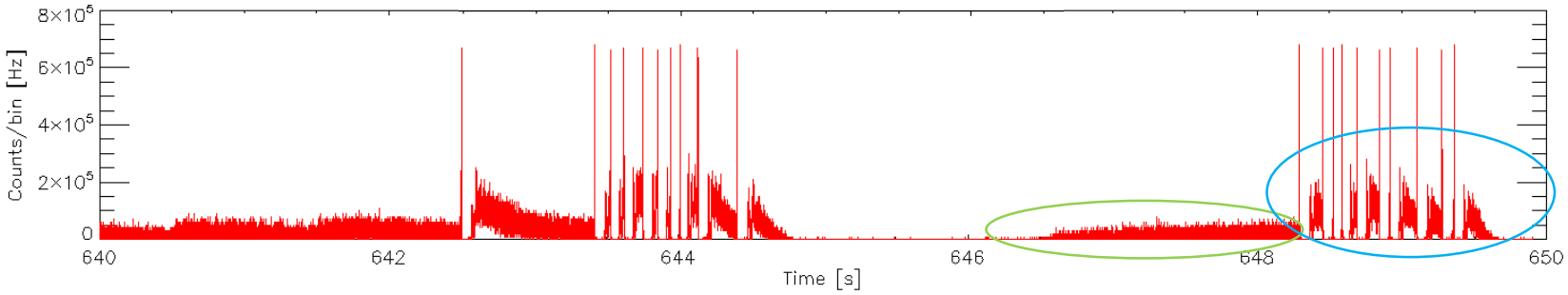


Challenges encountered

Strong variations in the rate:

We need more scintillator detectors installed behind filters of variable thickness so as to be able to measure during the different phases of the discharge.

One scintillator like the current ones to see the pre-discharge phase, and a duplicate scintillator placed behind a filter for measuring during discharge.

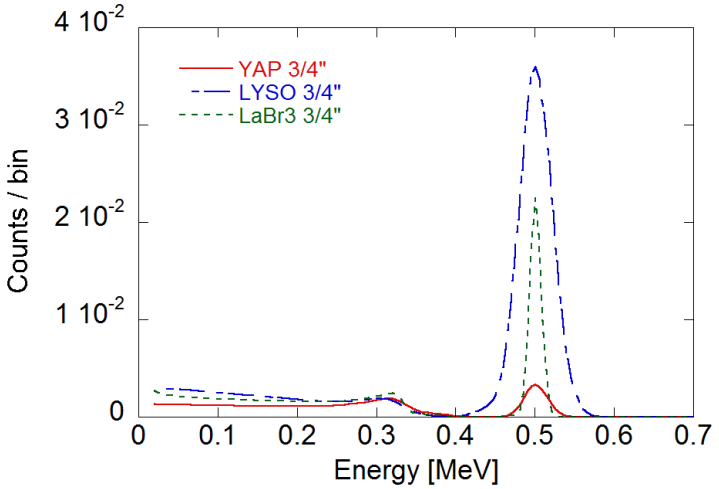


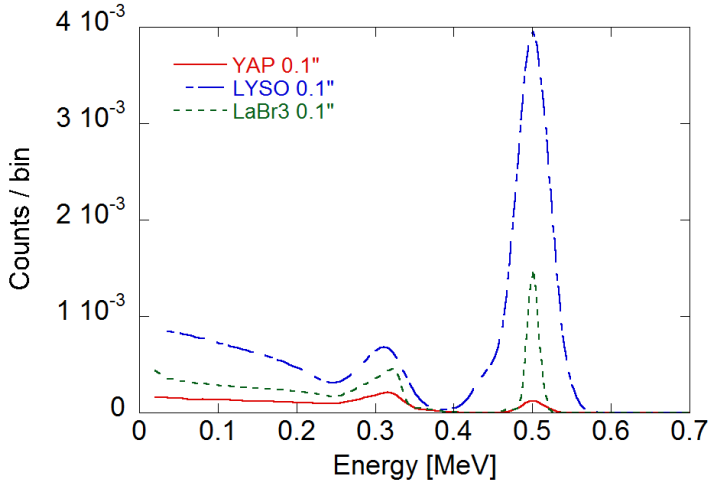
Scintillator selection

Detector efficiency and deposited energy spectra

MCNP simulations

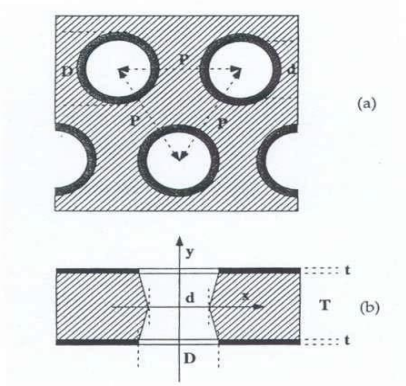
Incoming γ-ray -> γ-ray line of 500 keV

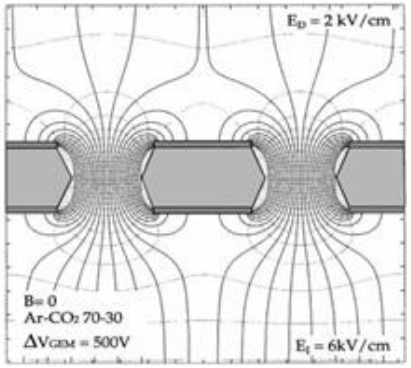




Crystal	Diameter [inch]	Height [inch]	Total Ɛ %	Photopeak Ɛ %
LaBr3	1	3/4	52.2	20.6
		0.1	10.5	2.4
YAP	1	3/4	53.4	11.3
		0.1	**10.8**	**1**
LYSO	1	3/4	73.7	52.2
		0.1	18.2	8.5

Gas Electron Multiplier (GEM)

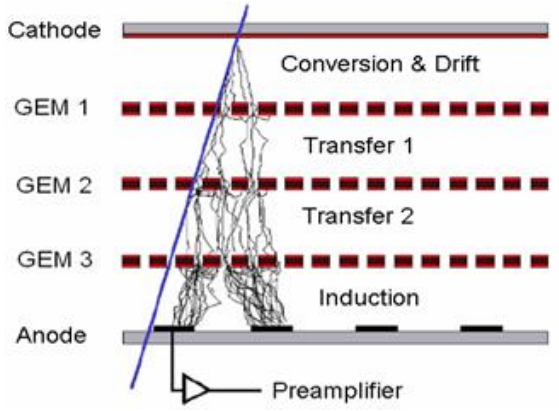




Kapton thickness→50 μm
Copper thickness → 5 μm

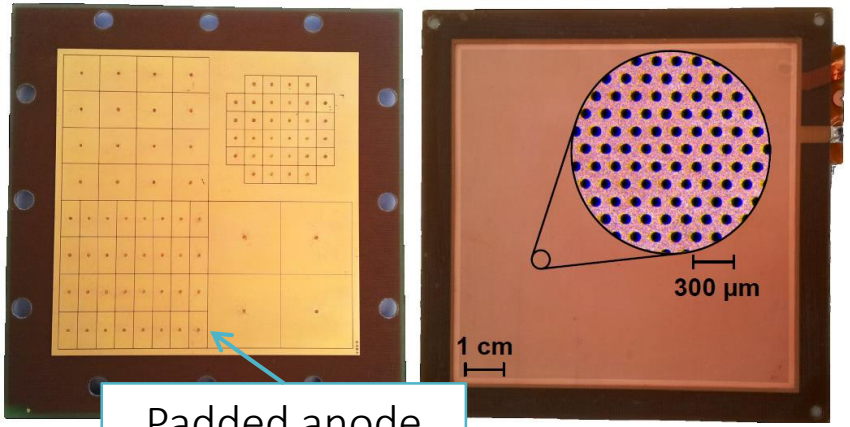
Holes diameter → 70 μm
Holes pitch → 140 μm

Ar/CO_2
70/30%



$$n = n_0 e^{\alpha(E(r))x}$$

n=number of charges produced
α=first Townsend coefficient

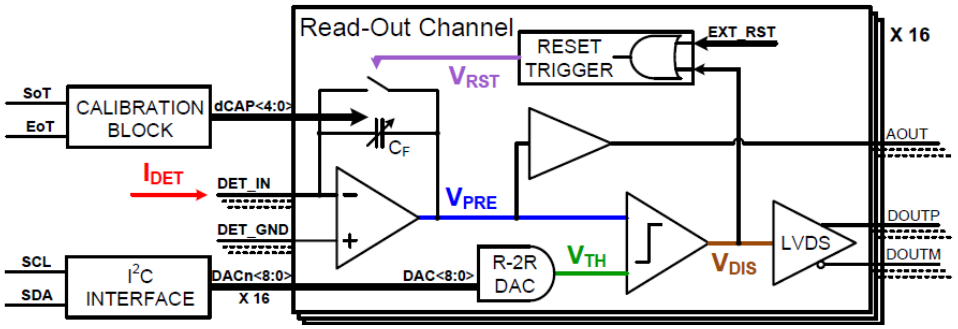


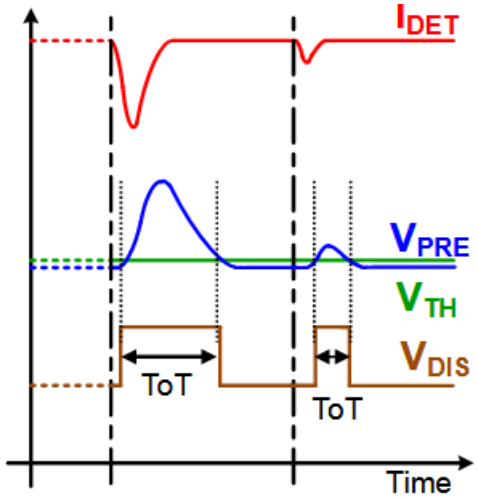
Padded anode

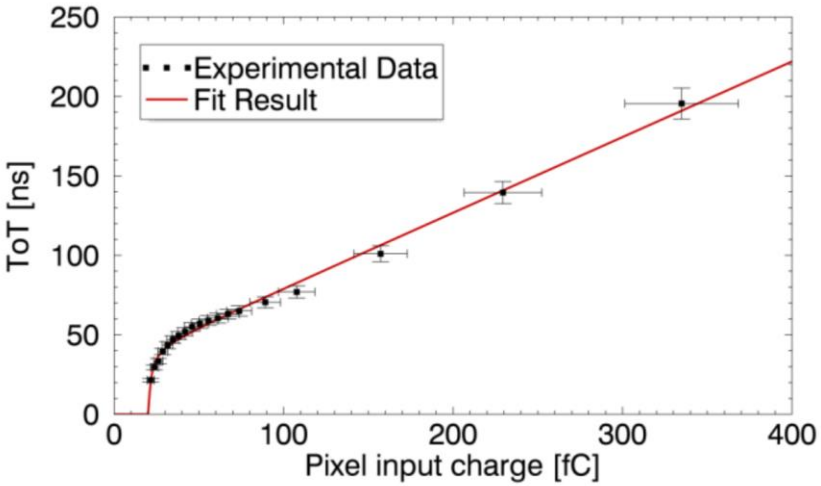
GEMs offer the following advantages:

- High rate capability (up to MHz/mm^2)
- Spectroscopy capability for soft x-rays
- Millimetric spatial resolution
- Imaging capability

Read-out electronics: The GEMINI ASIC





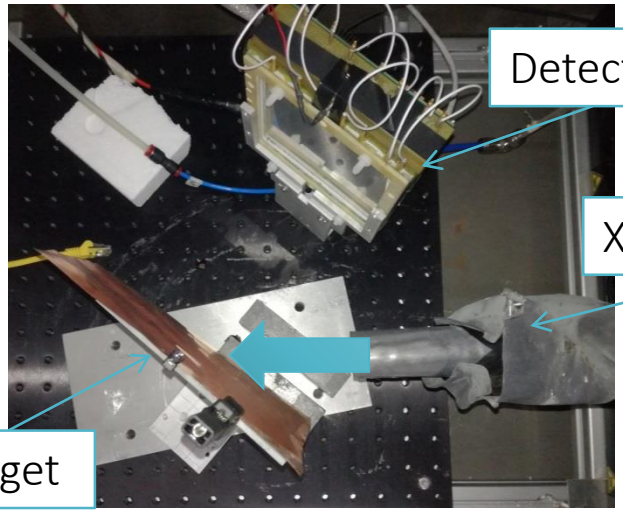


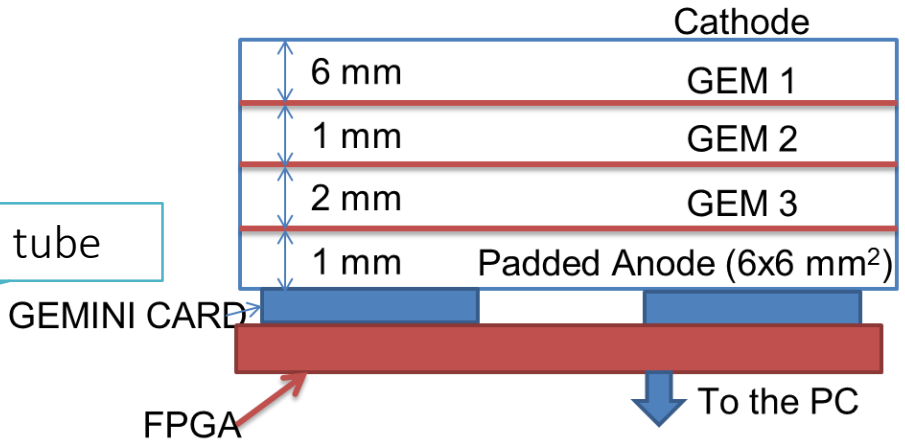
The length (in time) of these digital signals (the GEMINI output) is related to the input charge on the detector pad.

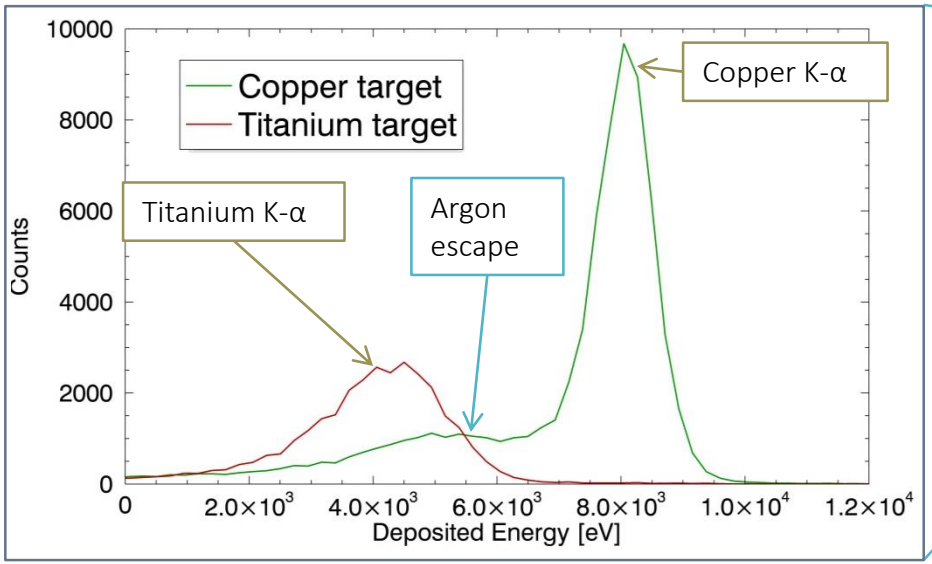
Read out in PHOTON COUNTING MODE: for each fired pad the FPGA send to the PC a 64 bit word containing:

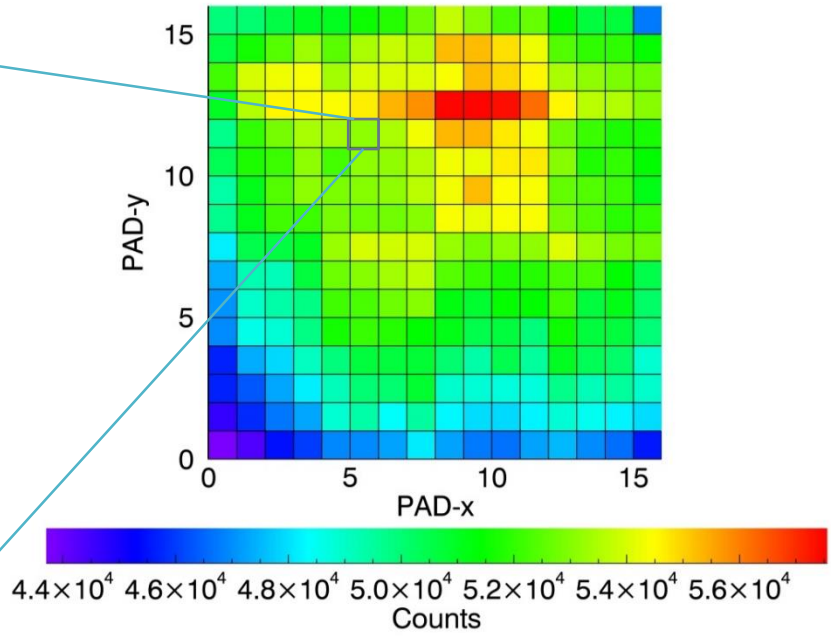
1. Channel ID
2. The Time of Arrival (ToA)
3. The Time Over Threshold (ToT)

First EXODUS prototype: preliminary calibration test









Summary

- Performed preliminary x-ray measurements on HVPTF with a direct scintillator setup.
- Already providing a more detailed picture of the discharge process compared to standard current measurements.
- We propose a two stage solution using scintillators and energy filters for the mid-high energy range, along with the installation of a GEM detector for the low KeV range.