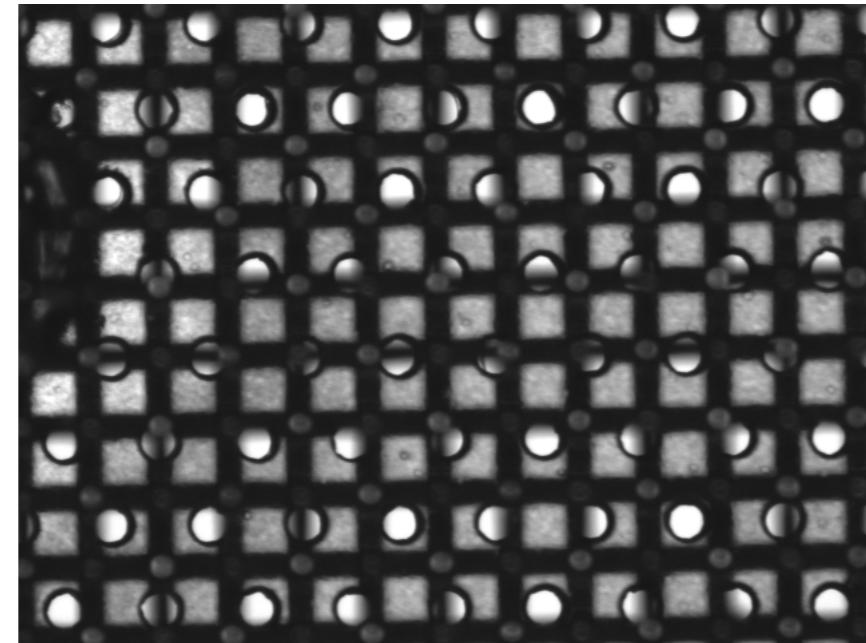


Reducing IBF with a novel MPGD structure combining Micromegas and GEM technologies

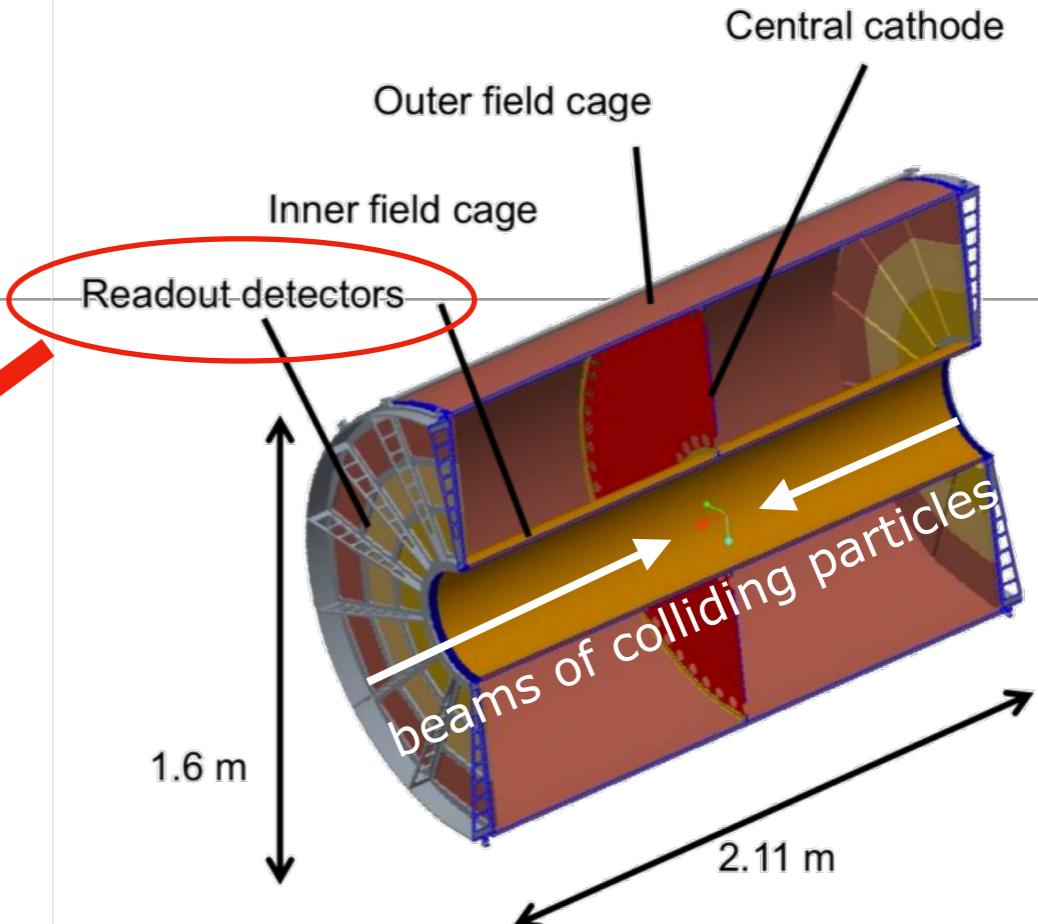


This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 824093

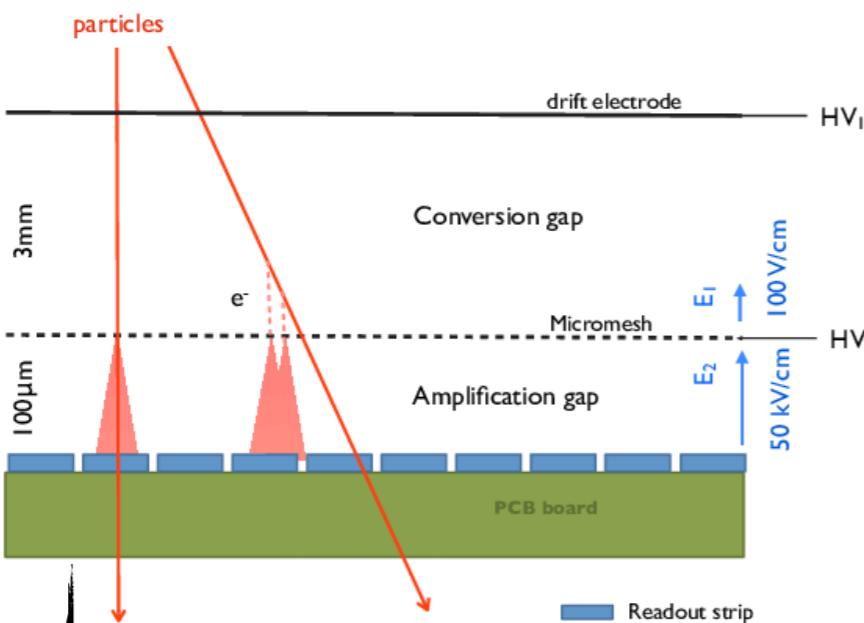
R&D with gaseous detectors

TPC readout detectors:

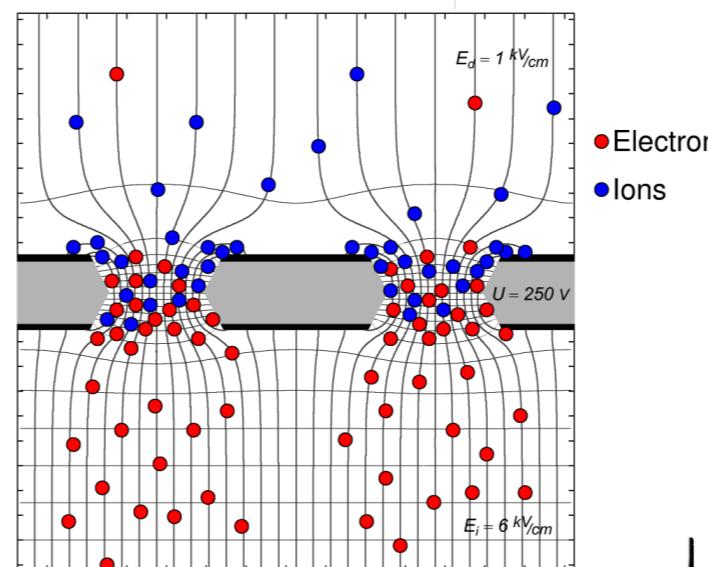
- MWPC (Multi-Wire Proportional Chamber)
- **Micromegas (Micro-MEsh GASEous structure)**
- **GEM (Gas Electron Multiplier)**
- ...



- MicroMEGAS



- GEM



R&D goal: design and test hybrid combination of MicroMEGAS and GEM detectors to reduce ion backflow

Ion BackFlow (IBF) = proportion of ions resulting from the avalanche that end up in the drift space
 → Might induce distortions of the electric field in the drift region → can deviate particle trajectories

Motivation

Generic R&D for TPC application (EIC ? ILC?): test combinations of GEMs and MicroMEGAS

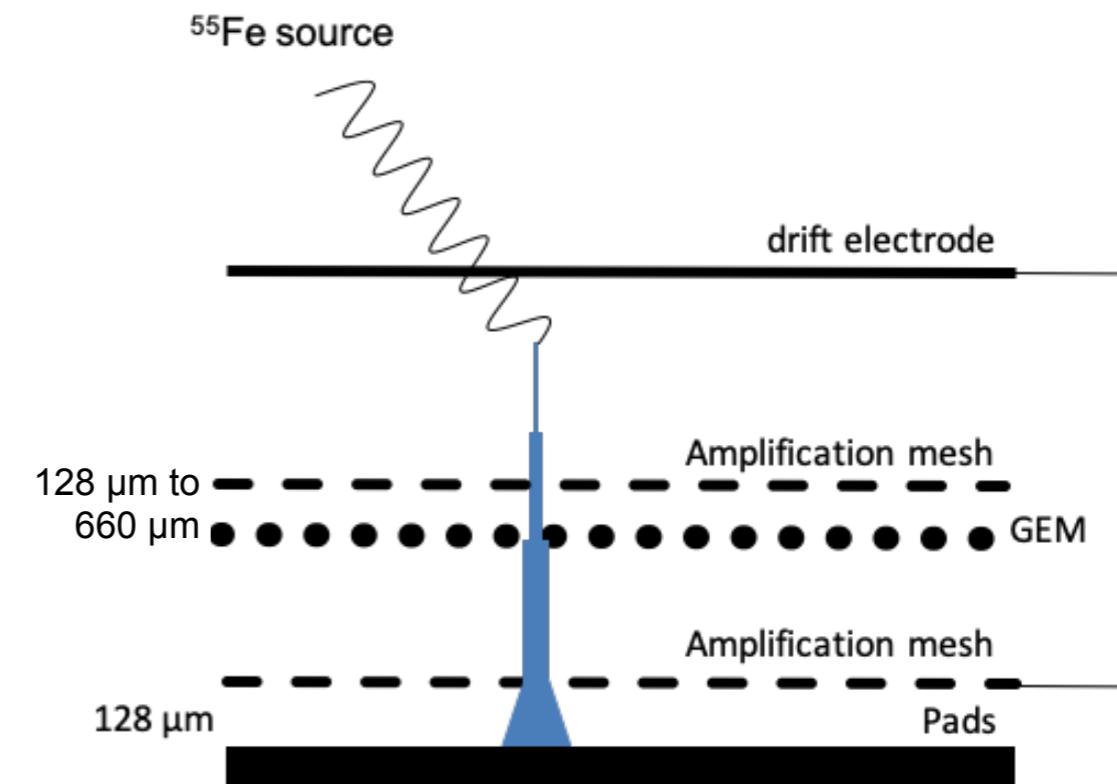
In ALICE and sPHENIX: quadruple GEM

Motivated by:

- Less GEM foils → simpler integration
- Earlier studies (S. Aiola et al., Nucl. Instr. A) indicated that 2x better IBF can be obtained with MM + 2 GEMs compared to 4 GEMs setup.

Standard requirements for TPC readout detectors (ALICE and sPHENIX):

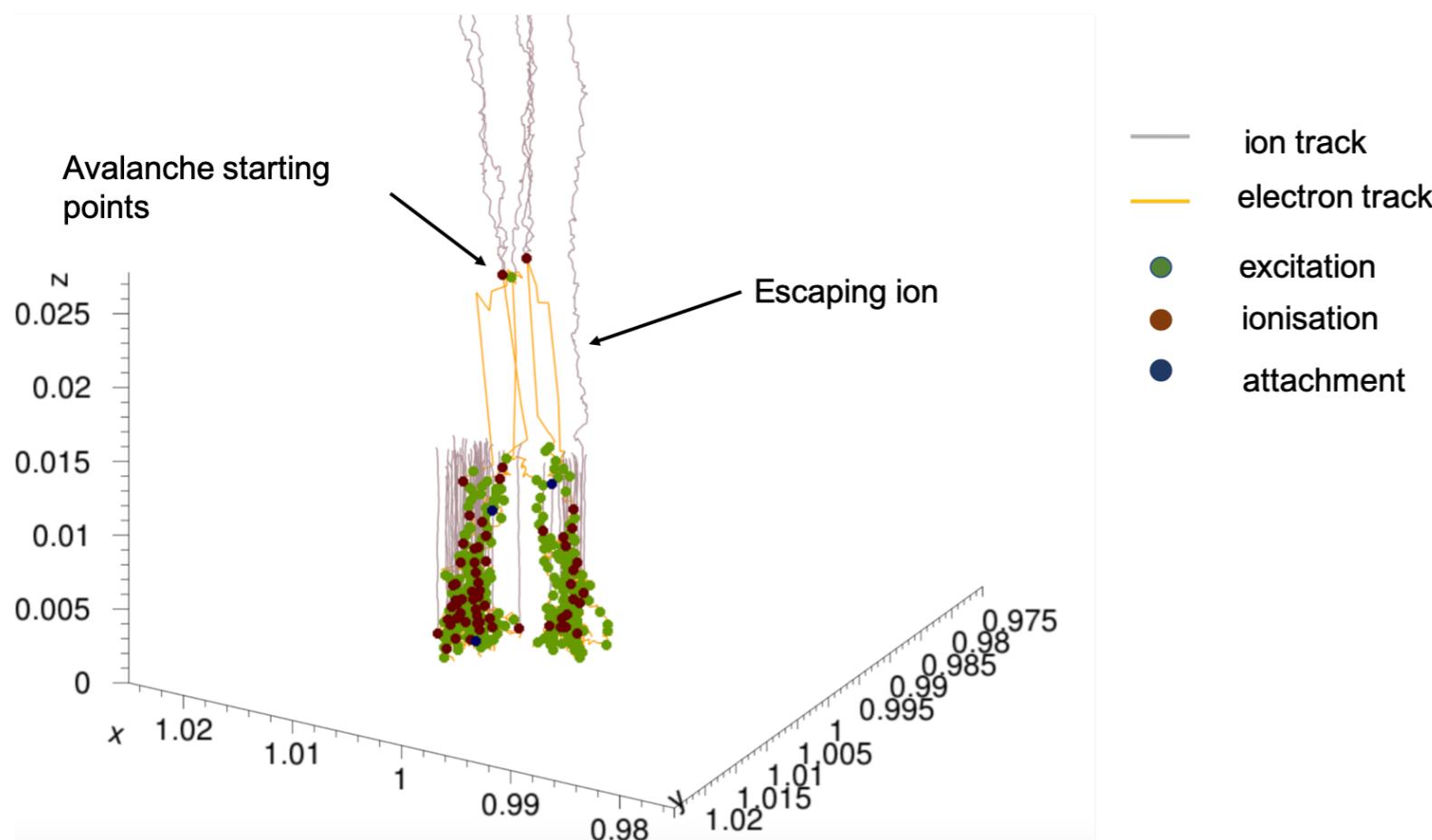
- Drift field = 400 V/cm
- Gain ~ 2000
- IBF < 0.3%



GARFIELD++ simulations for Micromegas R&D

Simulation of a simple Micromegas

- 3D electric fields simulated in COMSOL (geometry replicates a simple Micromegas detector)
- Simulation of an avalanche (gas: Ar-isobutane)
- **Simulation of IBF and gain**

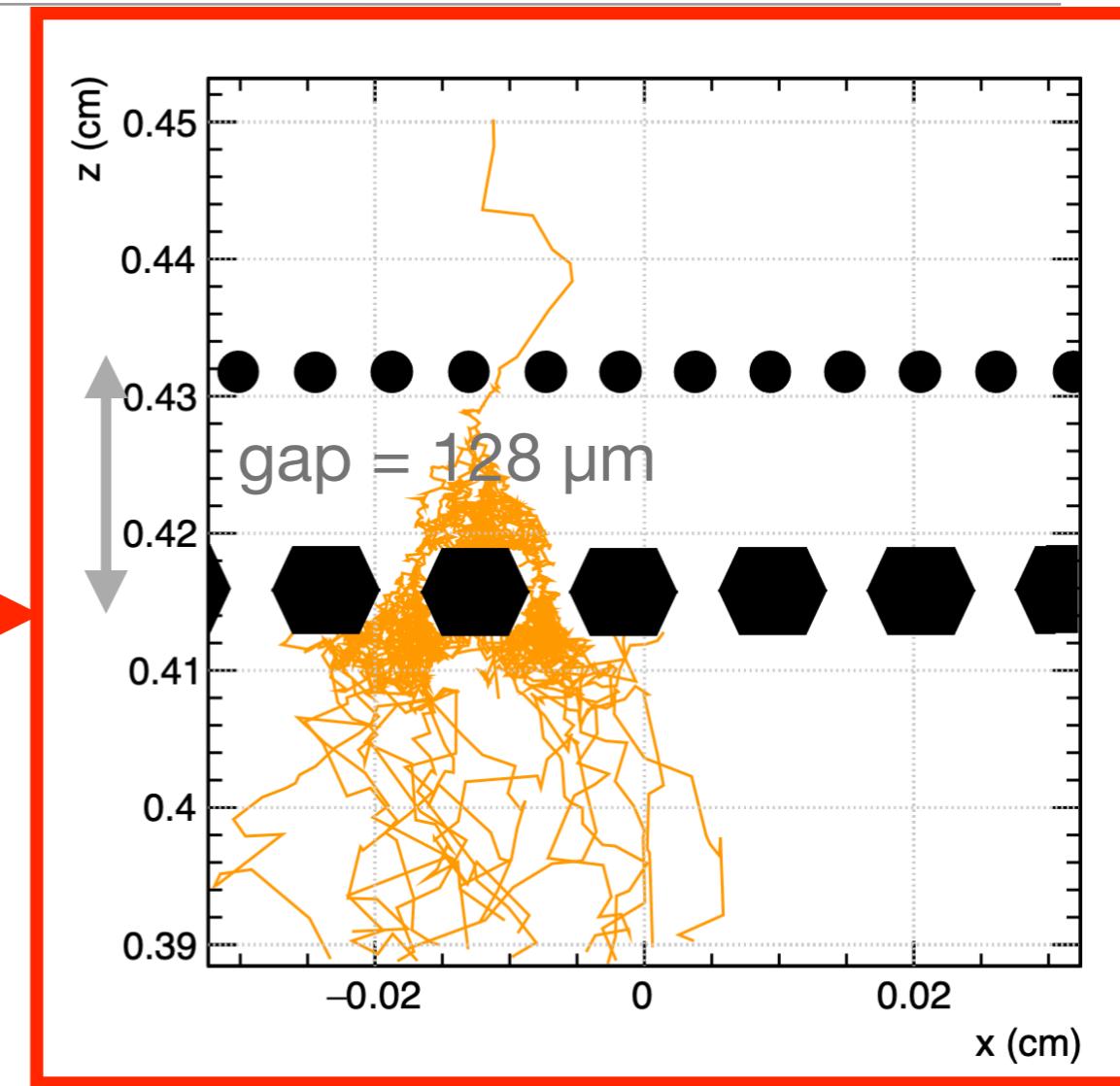
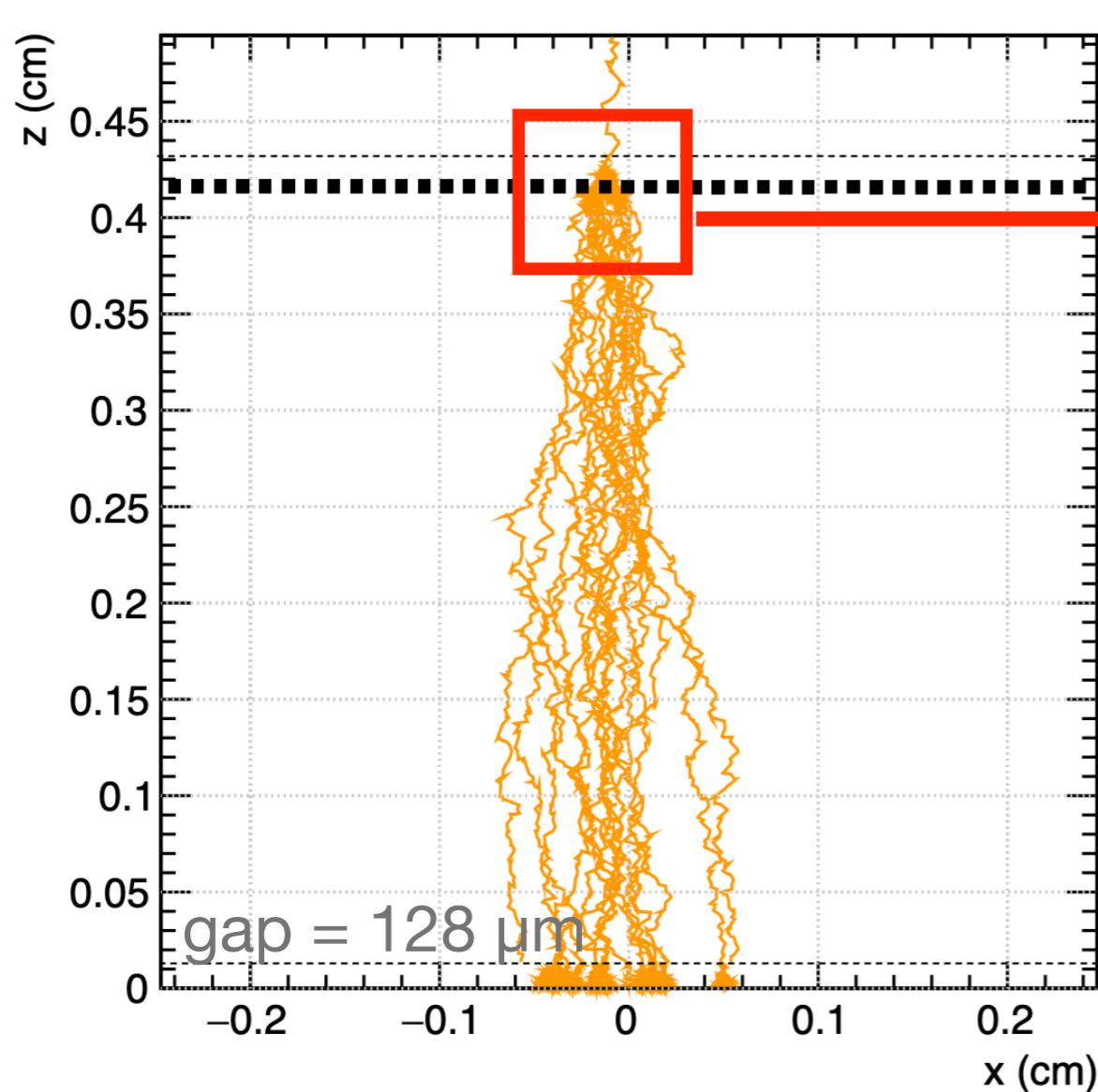


Gain = # ions in the avalanche

$$IBF = \frac{\text{# ions that escaped}}{\text{# ions in the avalanche}}$$

GARFIELD++ simulations for Micromegas R&D

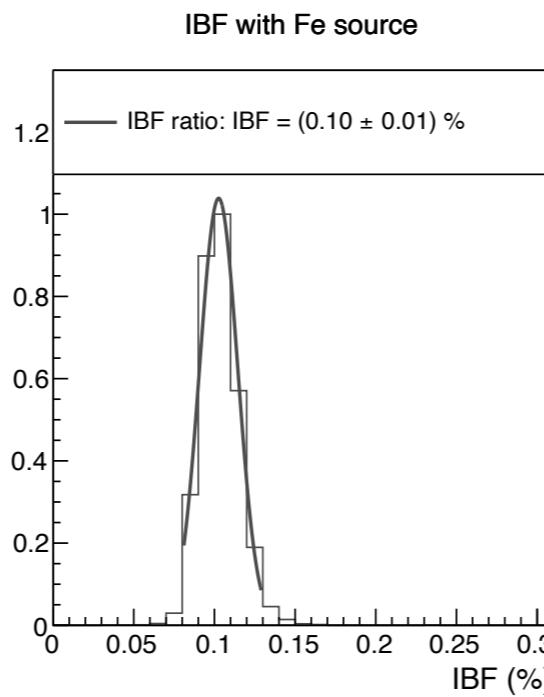
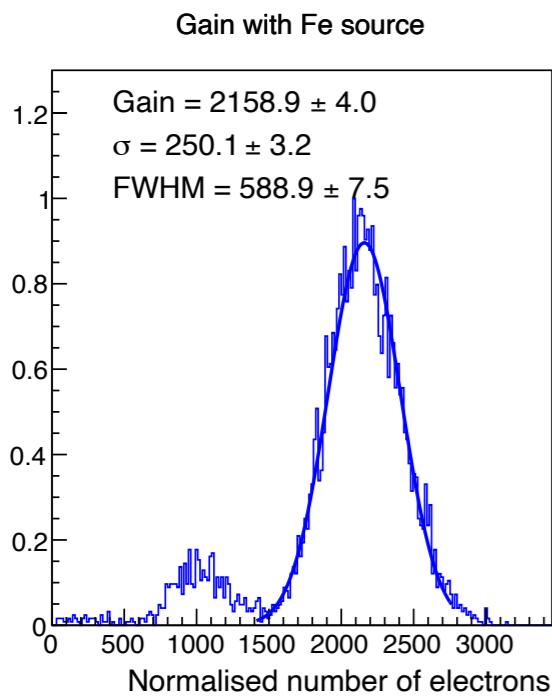
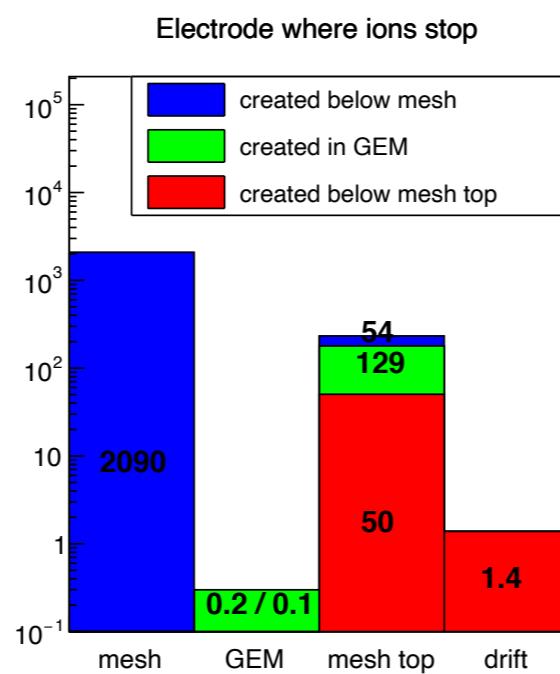
- Simulation of a hybrid GEM and Micromegas detectors



- Variable geometric parameters in the simulations:
- amplification gap between the GEM and the micro-mesh (from 128 μm to 600 μm)
 - mesh hole pitch
 - wire radius

GARFIELD++ simulations for Micromegas R&D

Gas: Ar-iC4H10	
$V_{\text{drift}} = -1060 \text{ V}$	$z = 7.000 \text{ mm}$
$E = 409.8 \text{ V/cm}$	
$V_{\text{mesh top}} = -950 \text{ V}$	$z = 4.316 \text{ mm}$
$E = 21.88 \text{ kV/cm}$	
$V_{\text{GEM up}} = -670 \text{ V}$	$z = 4.188 \text{ mm}$
$E = 33.33 \text{ kV/cm}$	
$V_{\text{GEM down}} = -470 \text{ V}$	$z = 4.128 \text{ mm}$
$E = 400.0 \text{ V/cm}$	
$V_{\text{mesh}} = -310 \text{ V}$	$z = 0.128 \text{ mm}$
$E = 24.22 \text{ kV/cm}$	
$V_{\text{pad}} = -0 \text{ V}$	$z = 0.000 \text{ mm}$



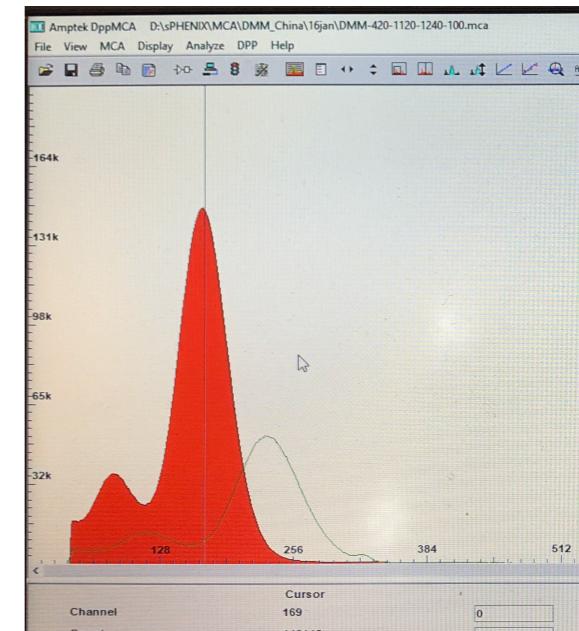
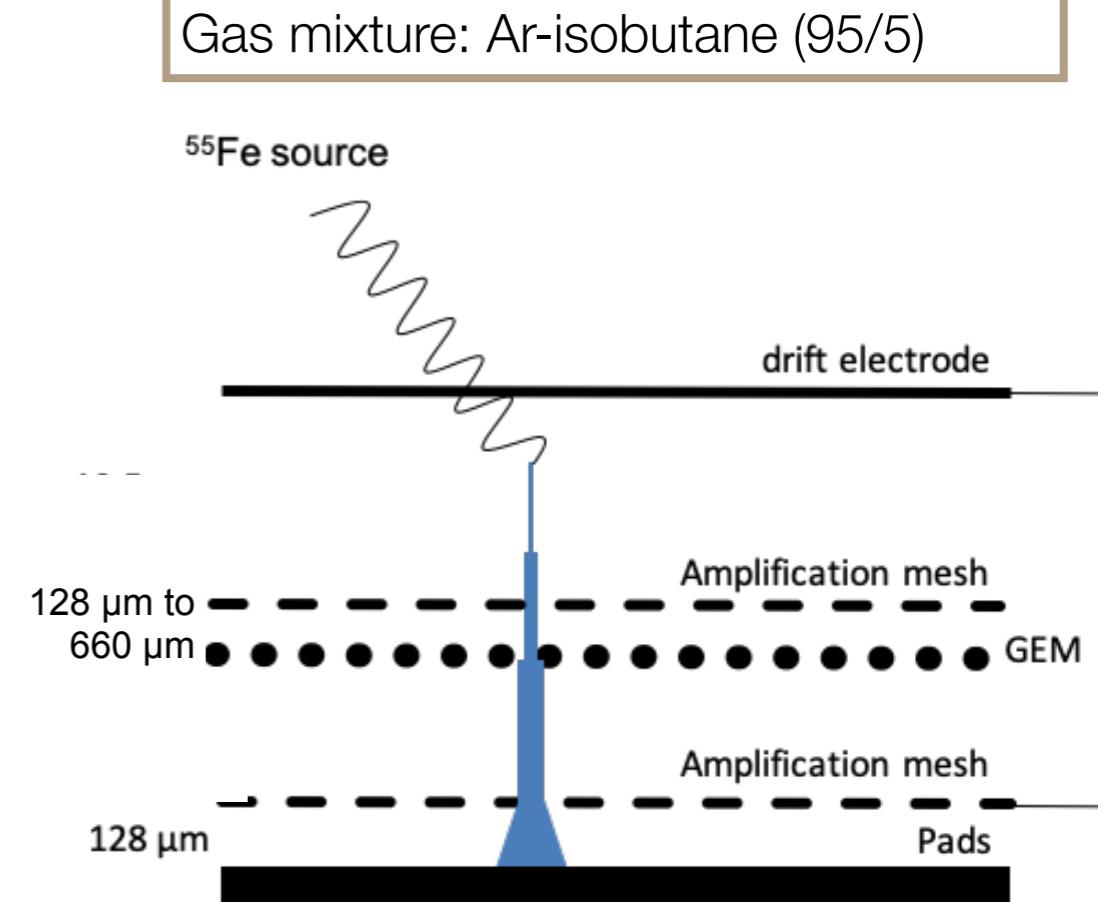
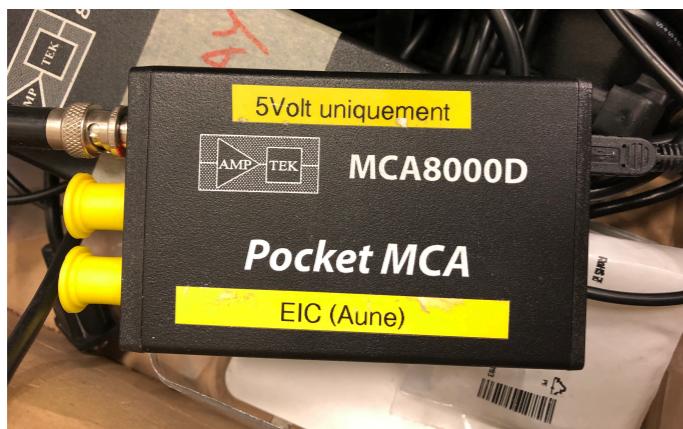
- Promising results:
 - Gain = 2100
 - IBF = 0.1%
 - Resolution = 12%
- Top mesh effective at stopping ions

Next step: build and test prototypes

Two detectors to test: set-up

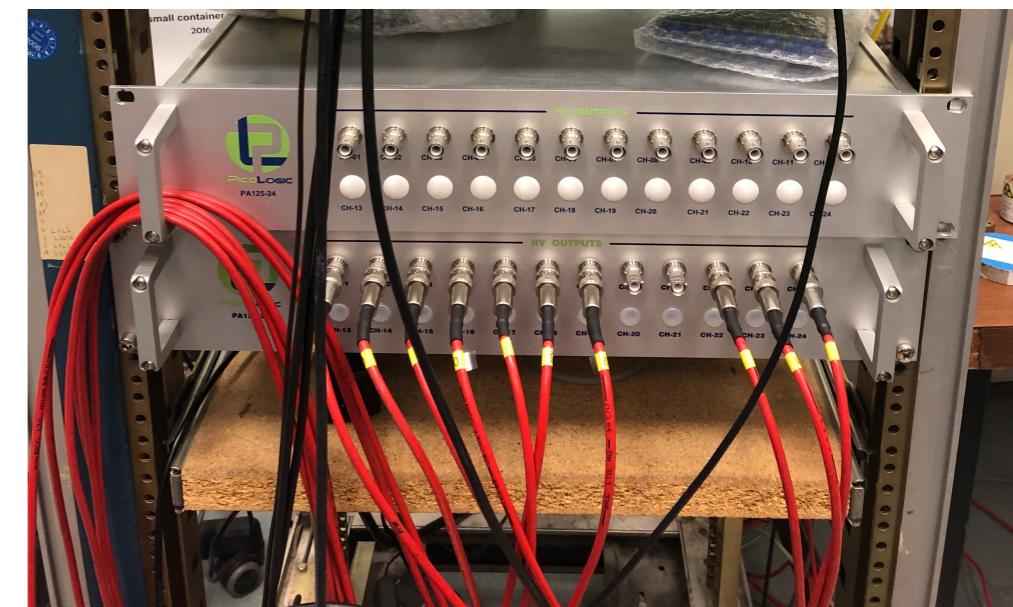
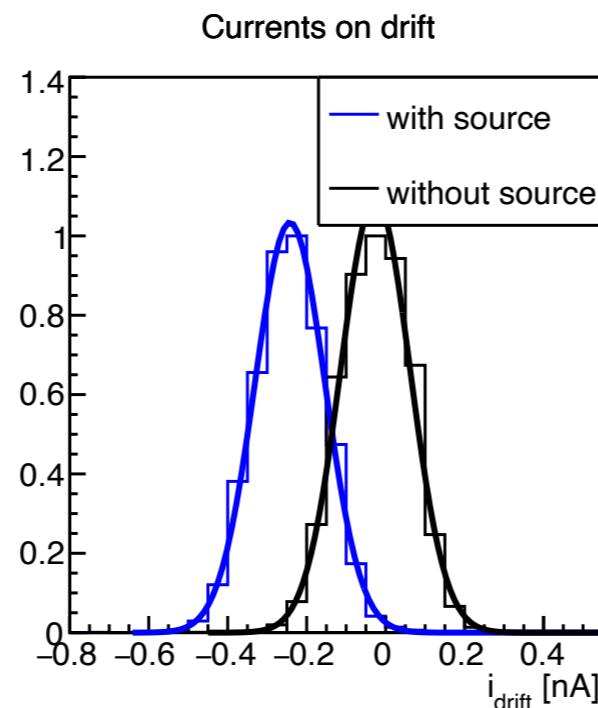
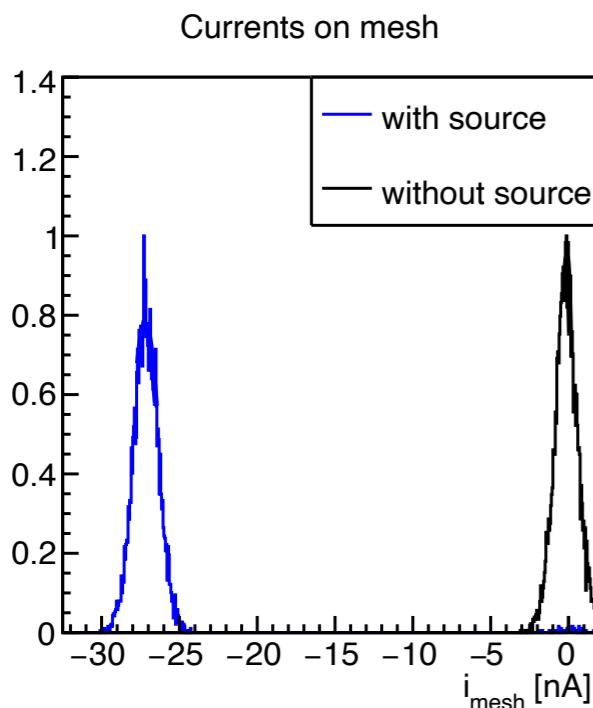
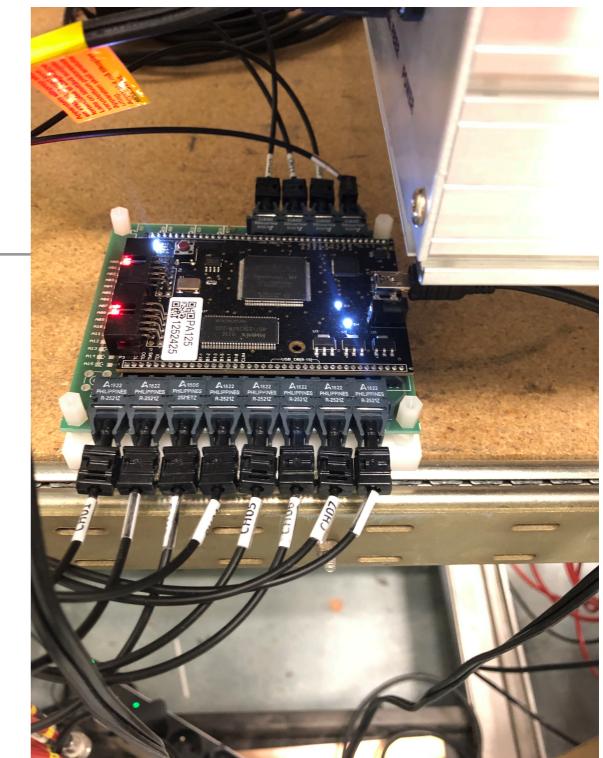
- Tests of 2 hybrid detectors manufactured at CEA
- Mesh bottom specs: 45/18
- GEM specs: 60 µm thick, outer diameter = 70 µm, inner diameter = 50 µm
- First detector: 660 µm gap between the mesh top and the GEM, mesh top specs: 45/18
- Second detector: 128 µm gap between the mesh top and the GEM, mesh top specs: 70/30

- Using ORTEC pre-amp
- Spectra obtained with a MultiChannel Analyzer module (Amptek MCA-8000D Digital Multichannel Analyzer)



Measurement of currents - IBF

- Using a 12 channel PicoLogic ammeter module (Zagreb, Croatia) : readout range approx. from -125 to 125 nA, resolution of approx. 4 pA for the given range (technical information: <http://www.picologic.hr/files/info.pdf>)



$$\text{IBF} = \frac{i_{\text{drift}}(\text{with source}) - i_{\text{drift}}(\text{without source})}{i_{\text{mesh}}(\text{with source}) - i_{\text{mesh}}(\text{without source})}$$

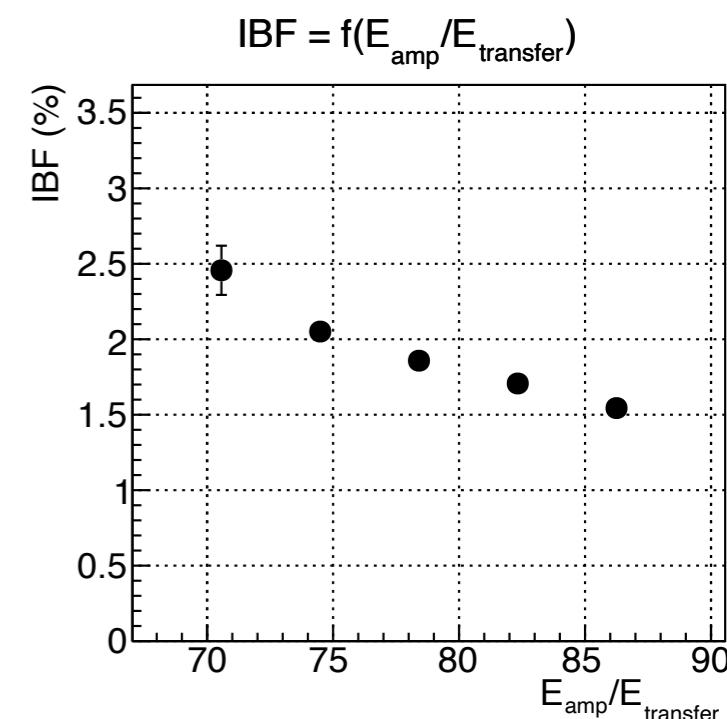
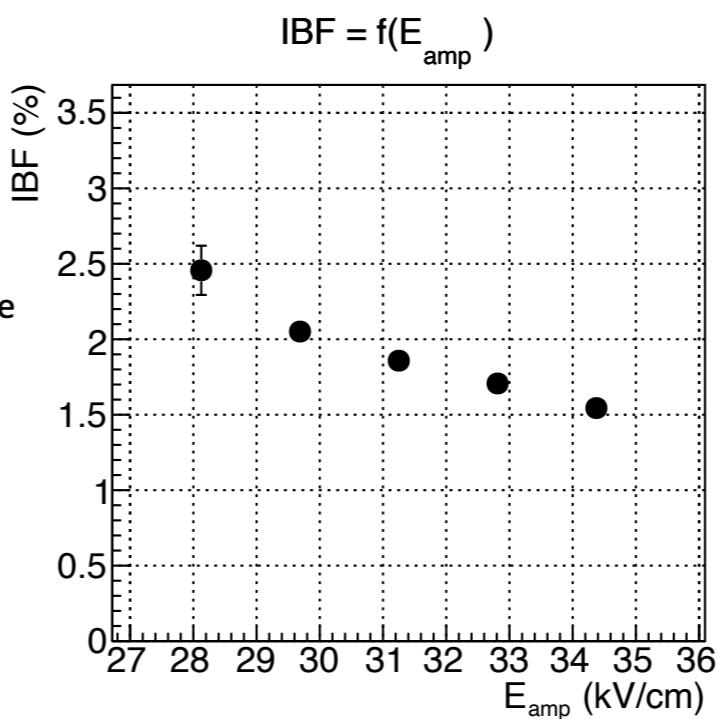
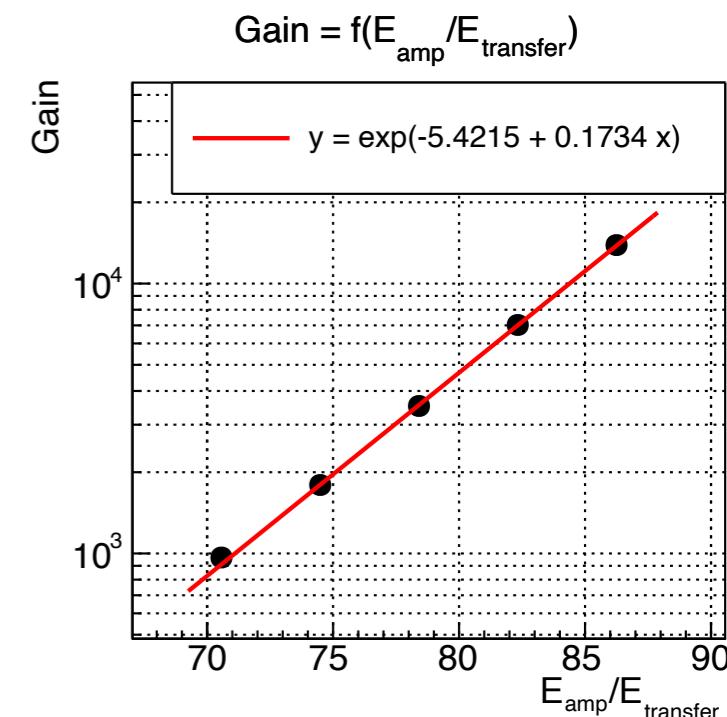
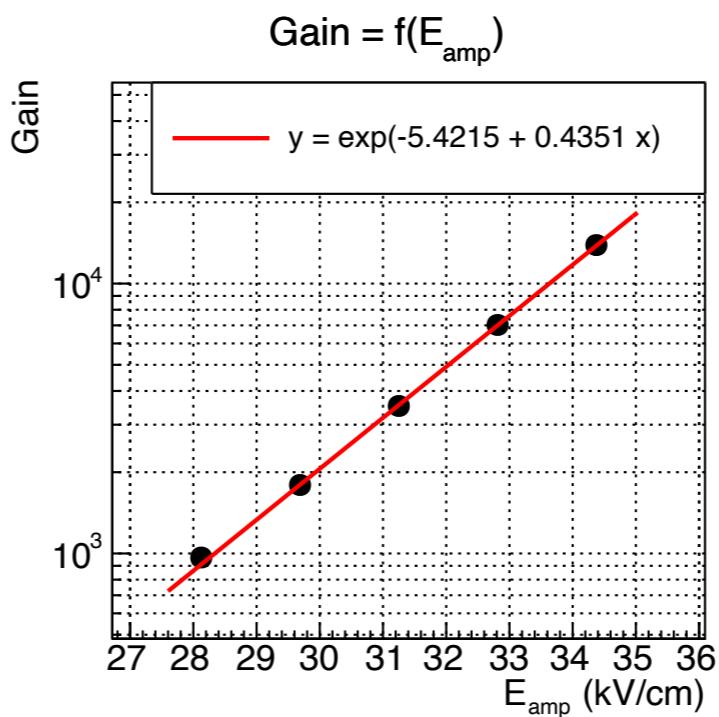
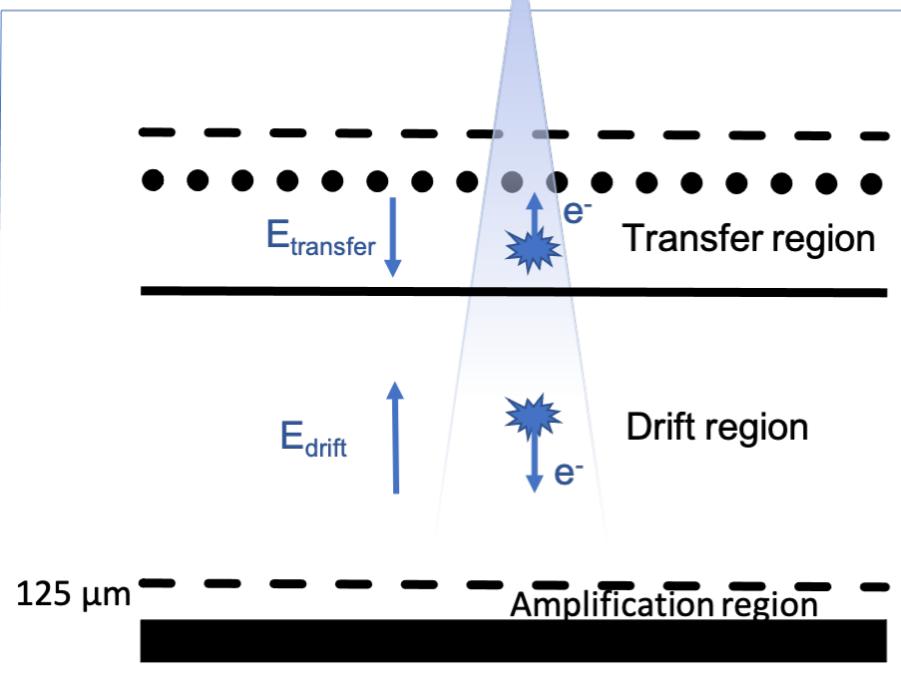
$$\frac{1}{\text{Gain}}$$

to account for primary ionisations of photons

Characterization of the bottom micro-mesh

- Events of interest: above the bottom micro-mesh
- Gain curve + IBF measurements

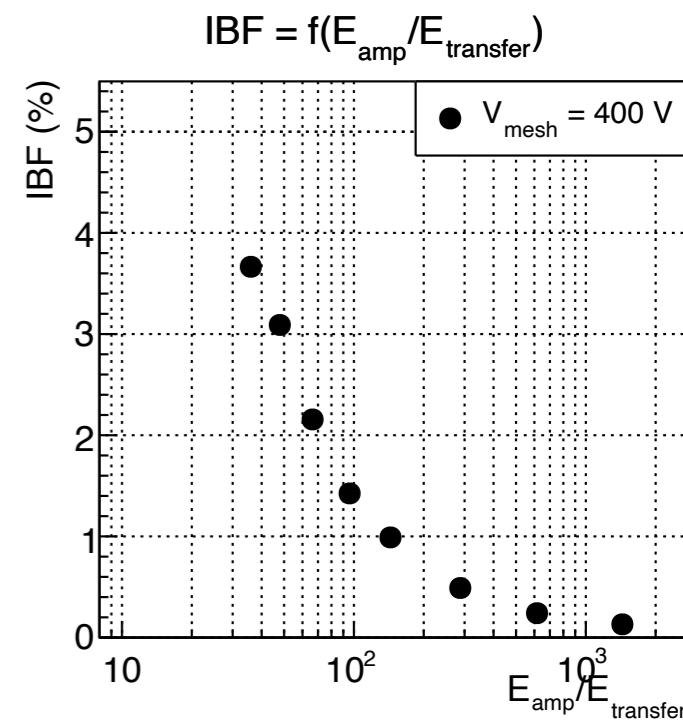
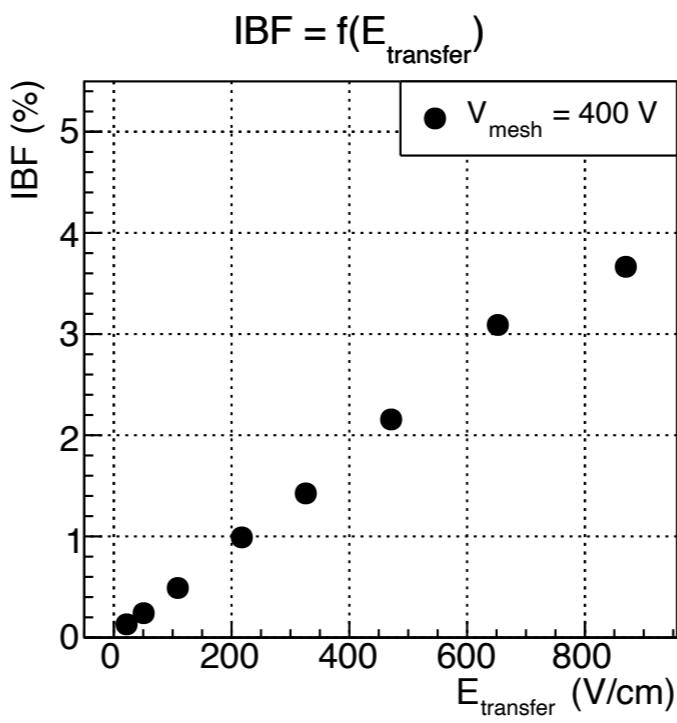
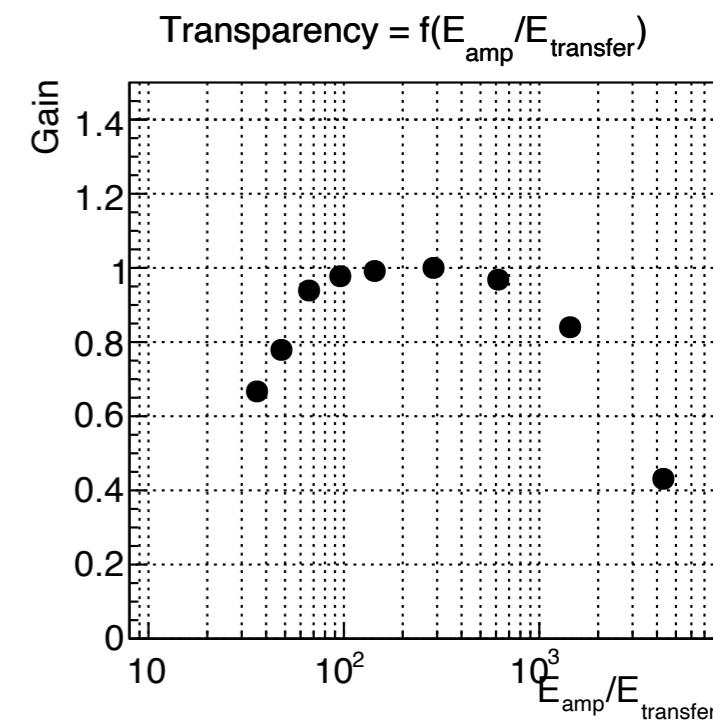
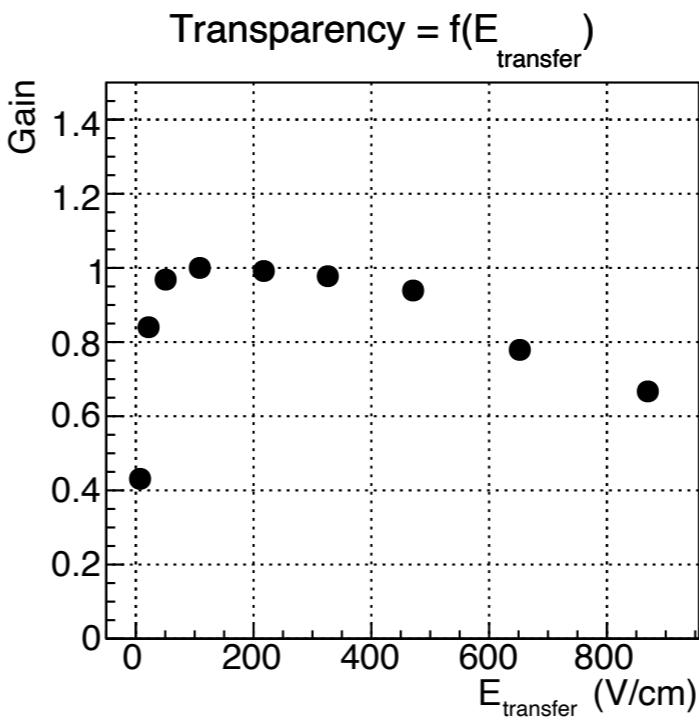
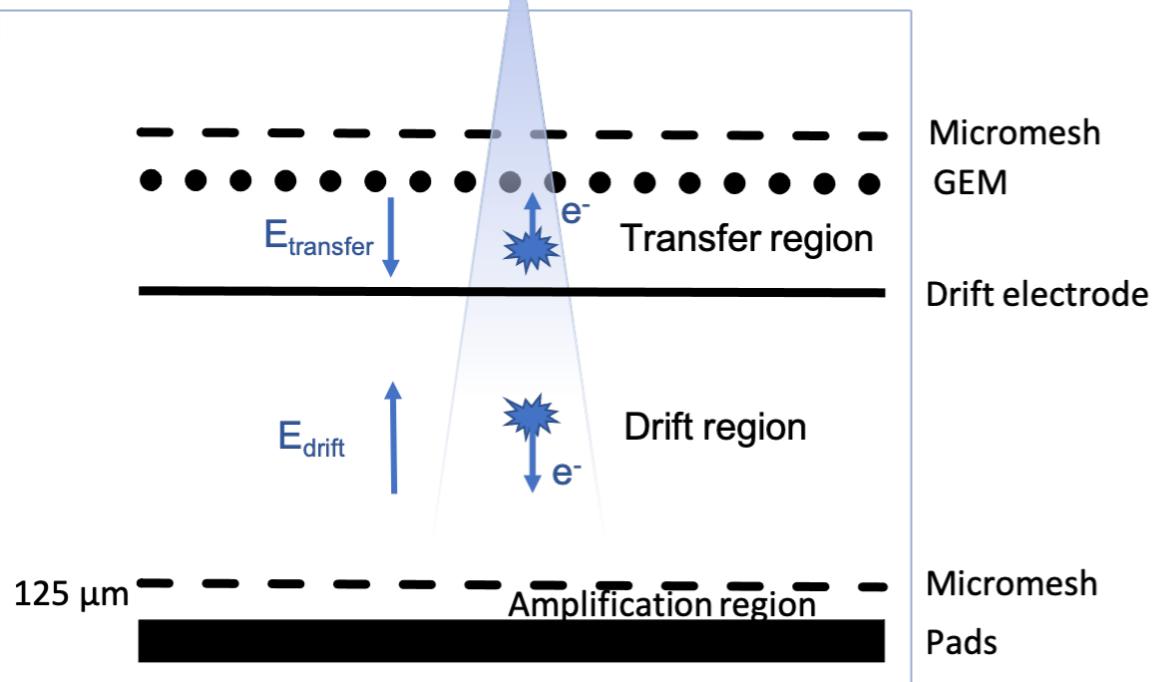
^{55}Fe source



Characterization of the bottom micro-mesh

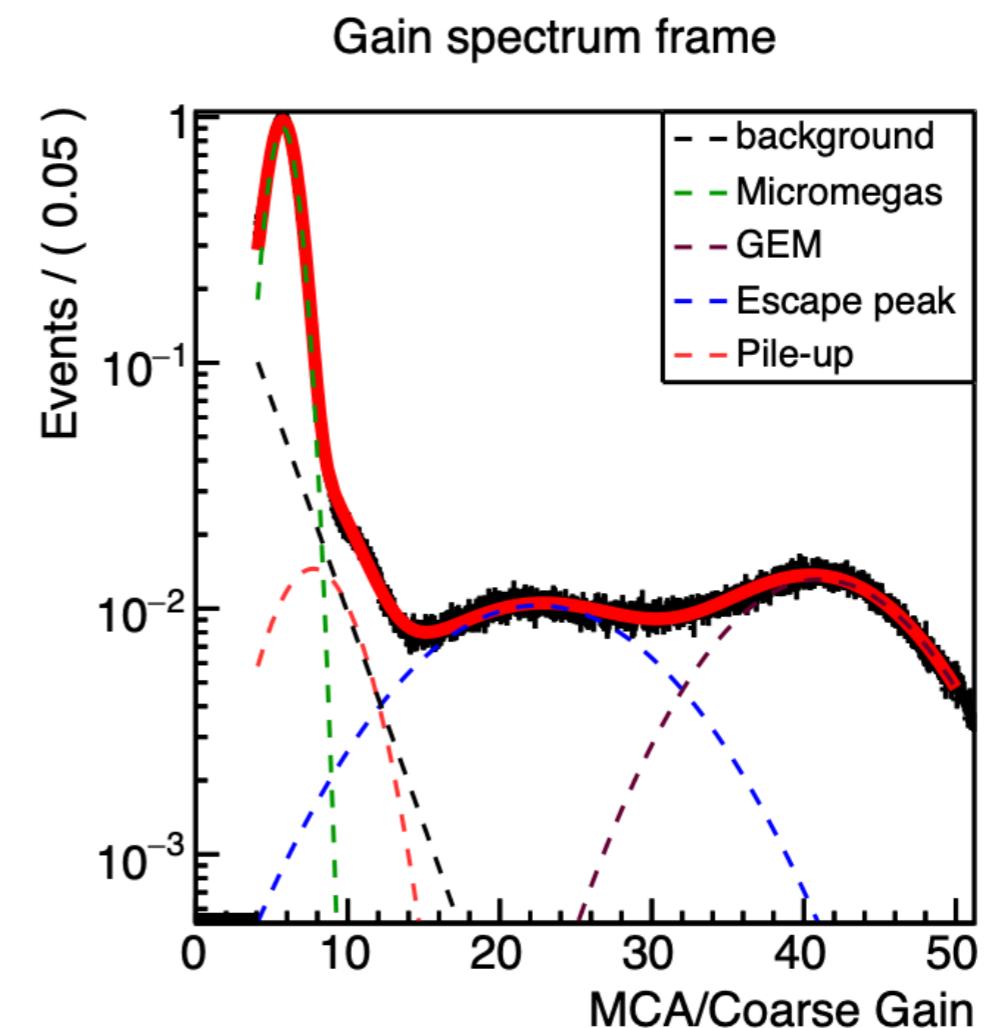
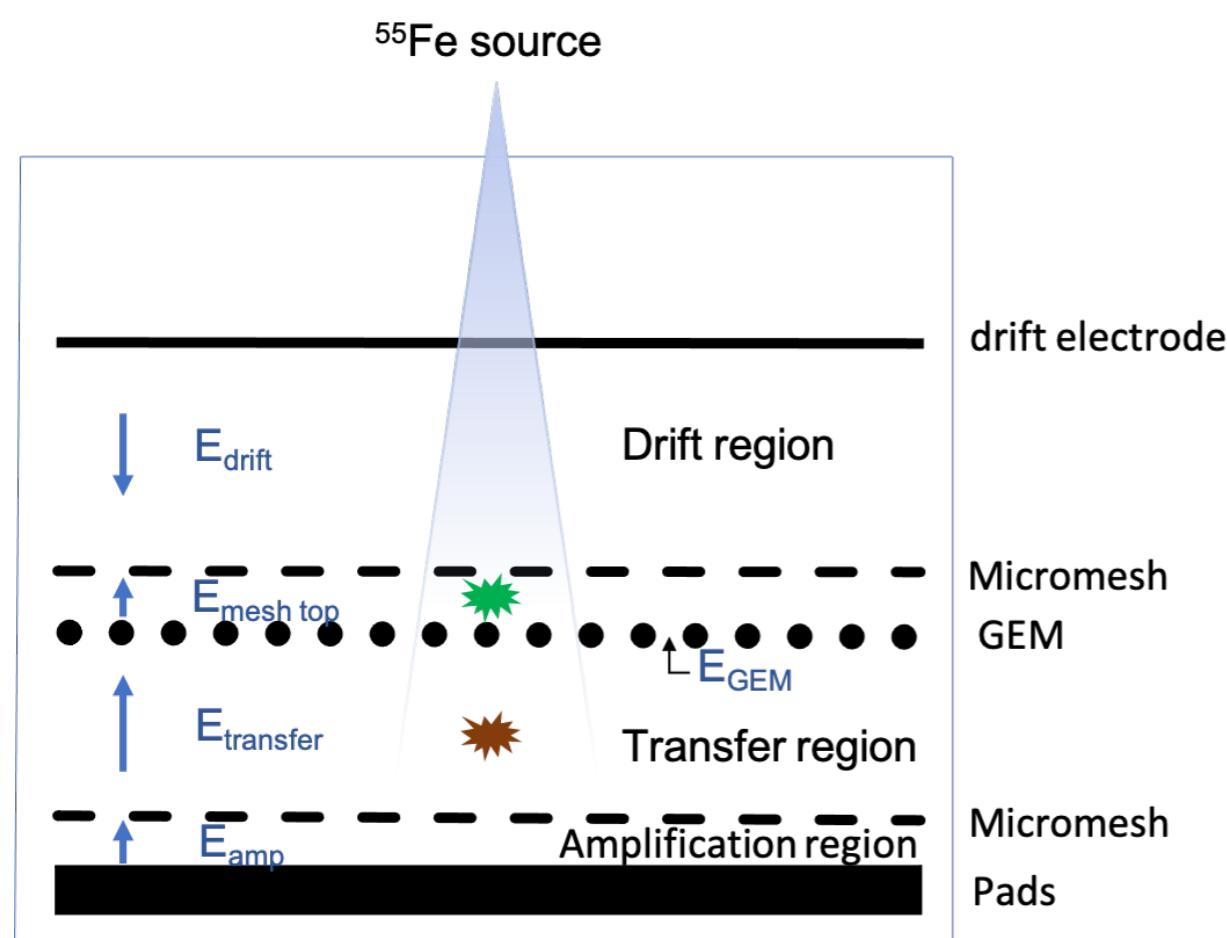
- Events of interest: above the bottom micro-mesh
- Transparency curve + IBF measurements

^{55}Fe source



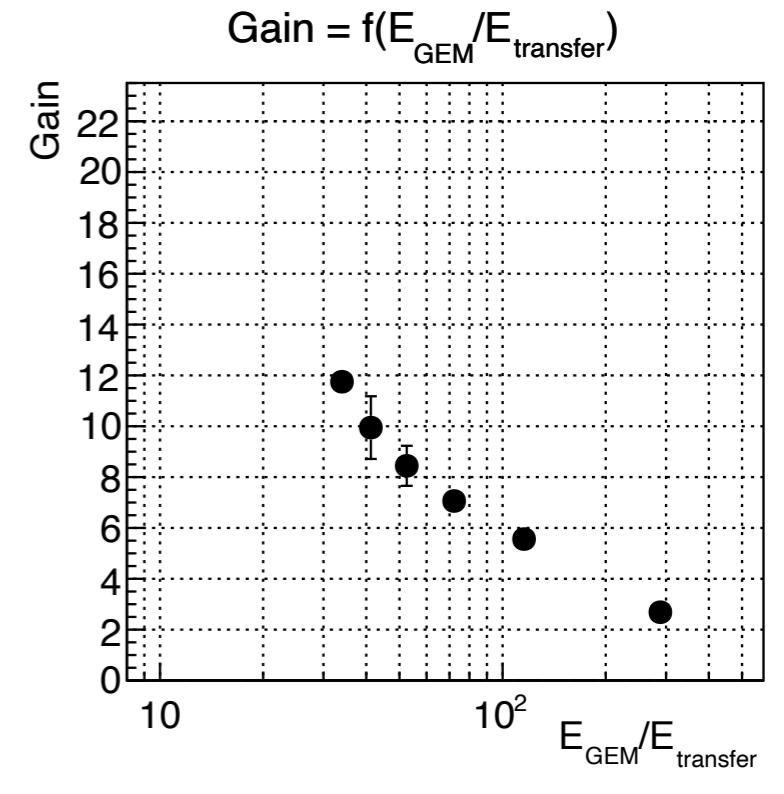
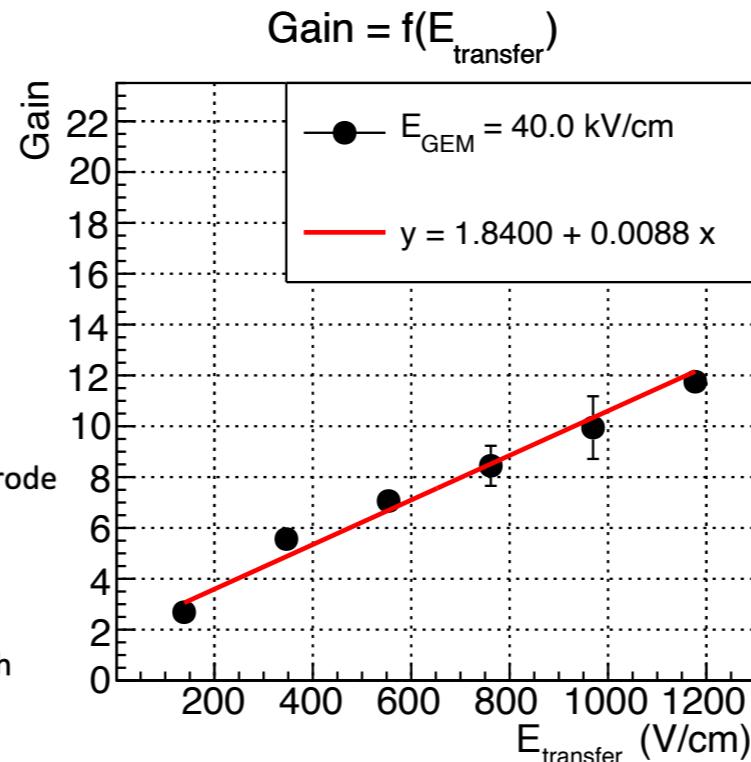
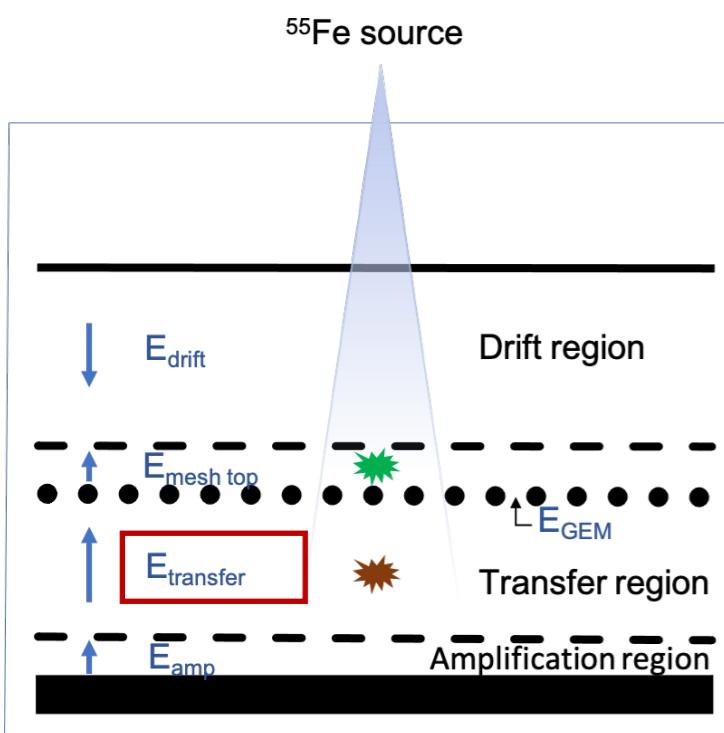
Characterization of the GEM: extraction of electrons

- Events of interest: above the GEM
- Curve of electron extraction by varying E_{transfer} + IBF measurements
- Gain of the GEM x Proportion of electrons extracted =
$$\frac{\text{GEM peak}}{\text{bottom mesh peak}}$$

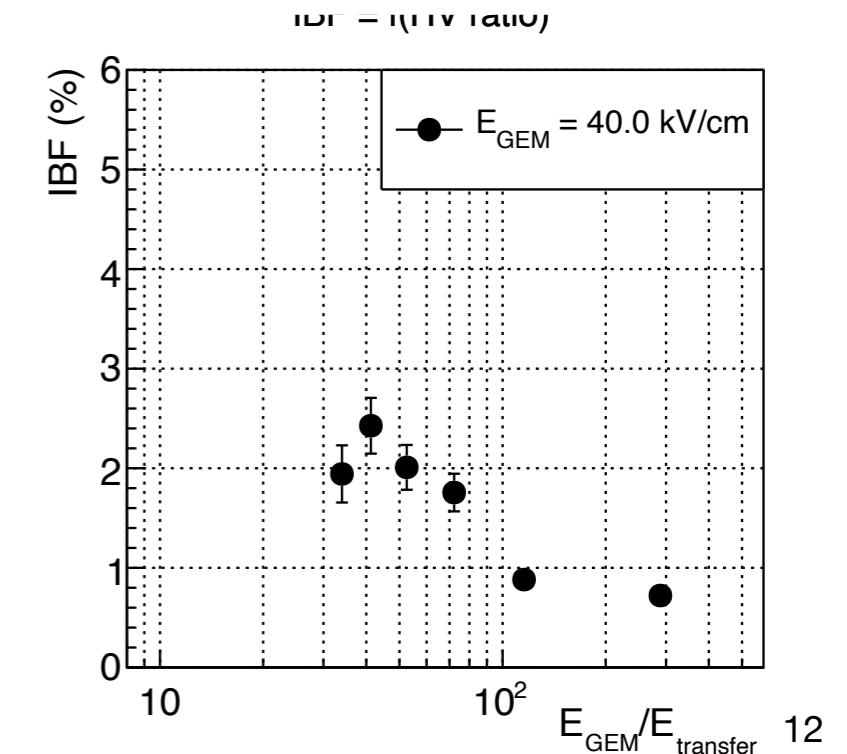
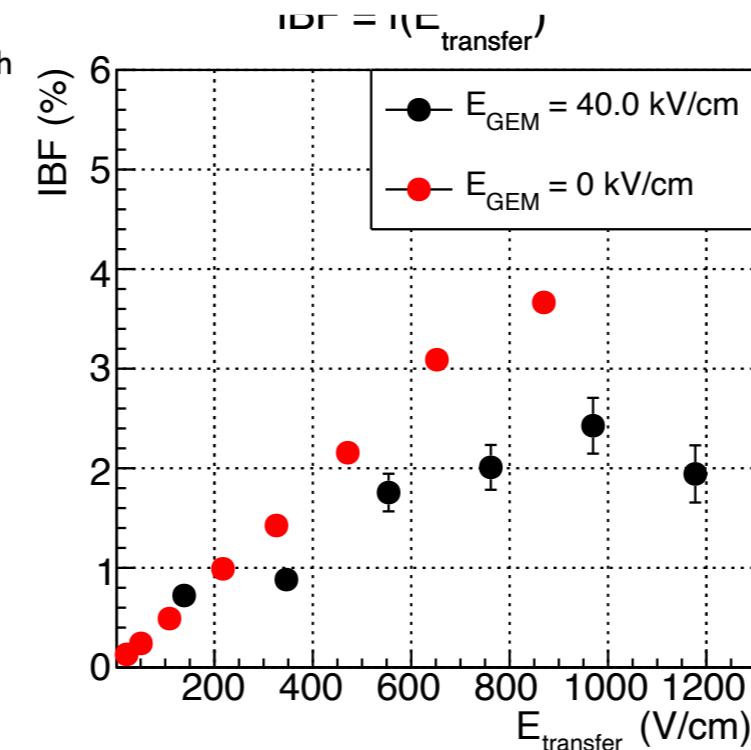


Characterization of the GEM: extraction of electrons from the GEM

- Gain when increasing the transfer field

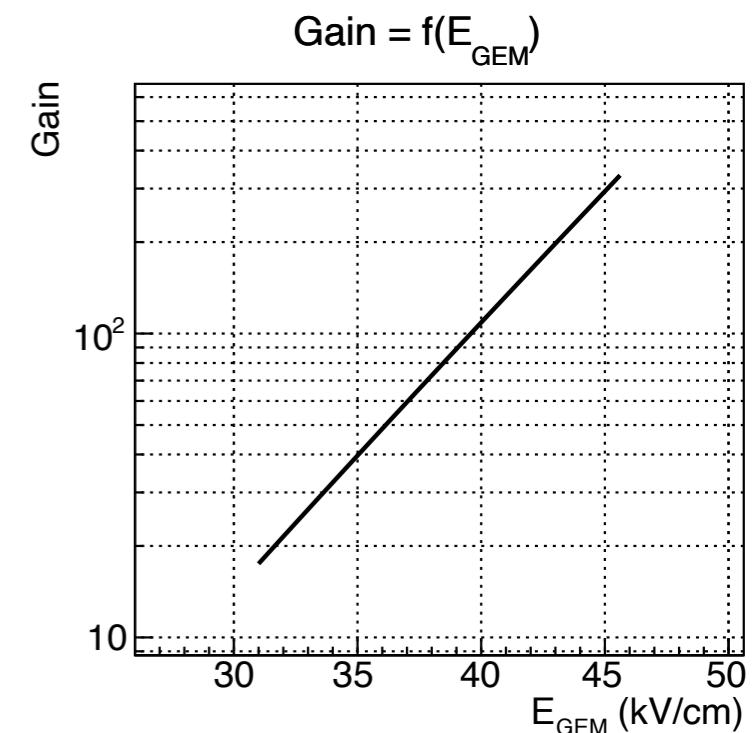
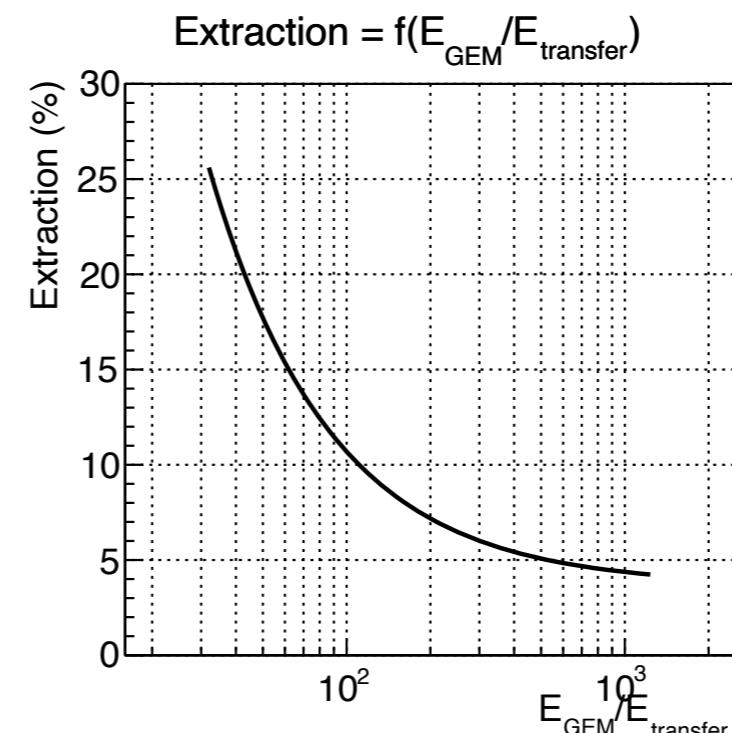
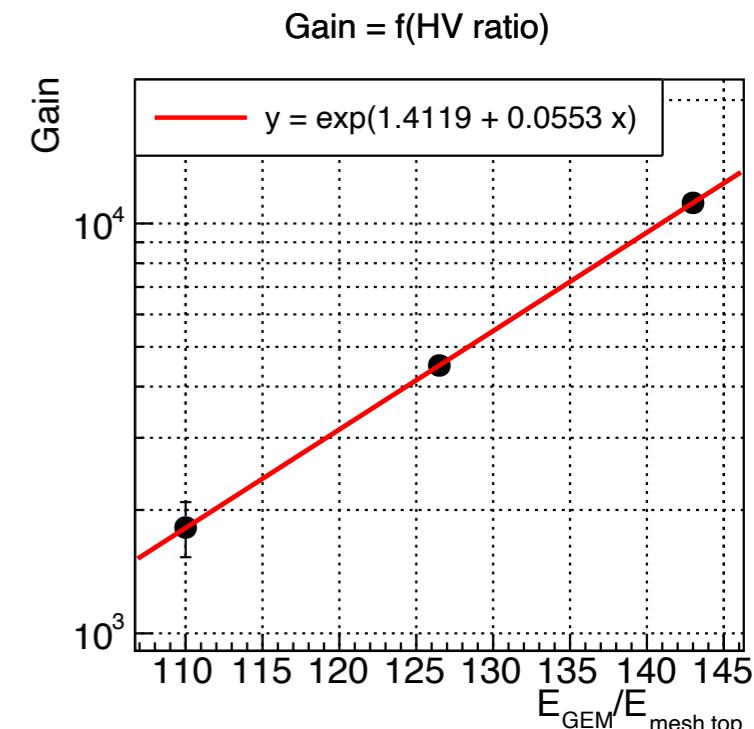
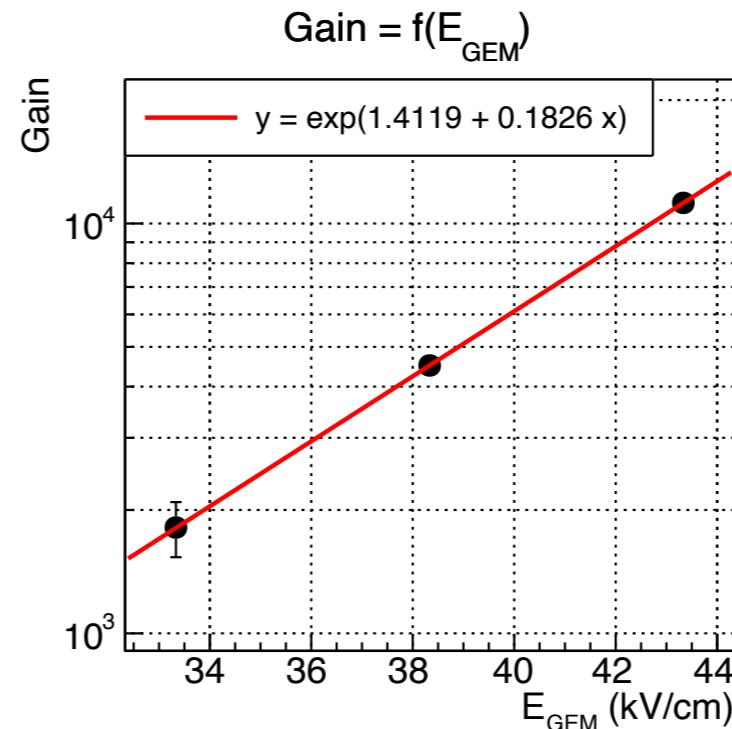
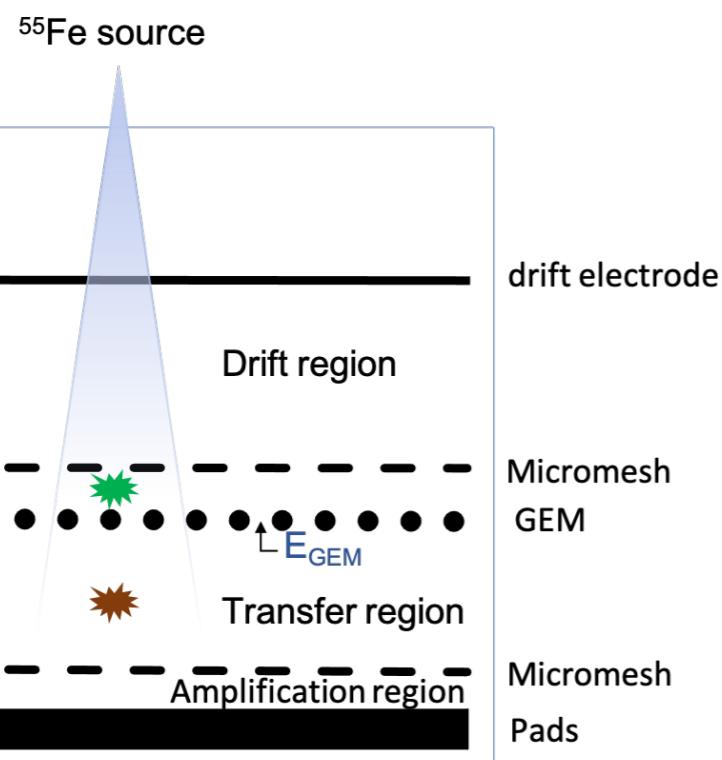


- IBF when increasing the transfer field (compared to without a GEM)



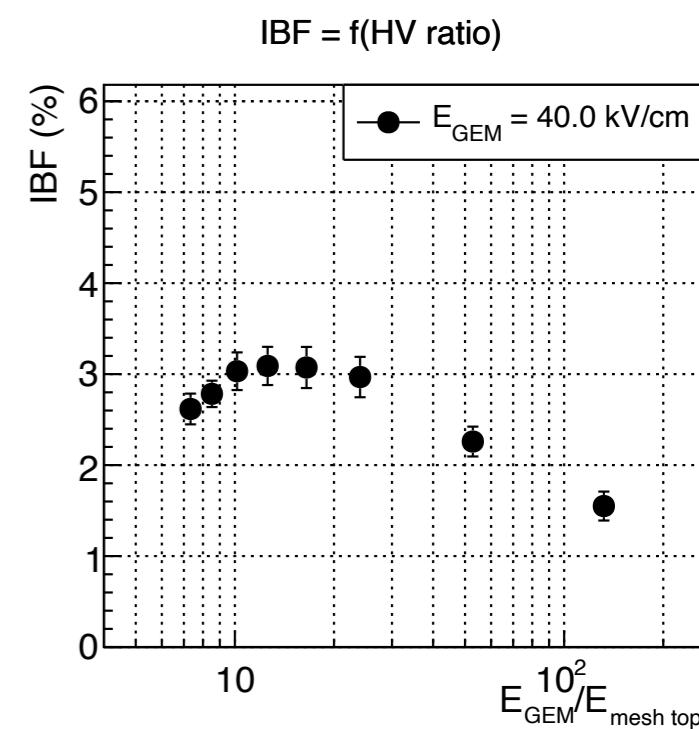
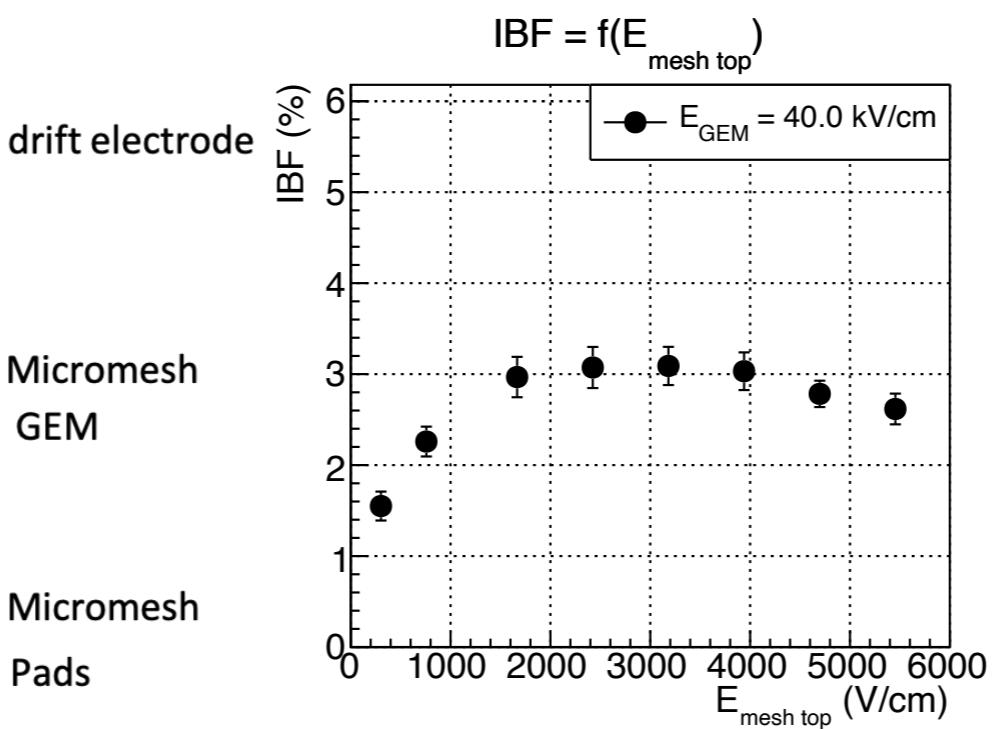
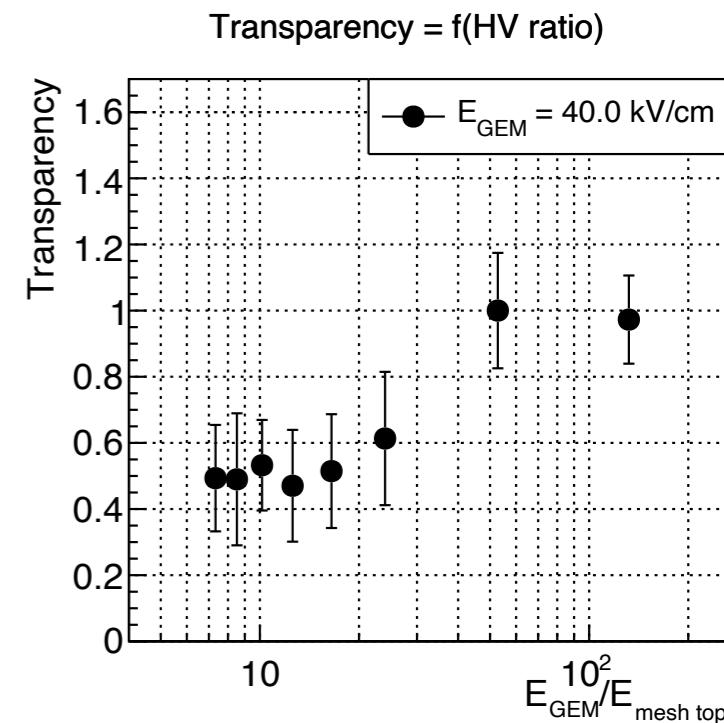
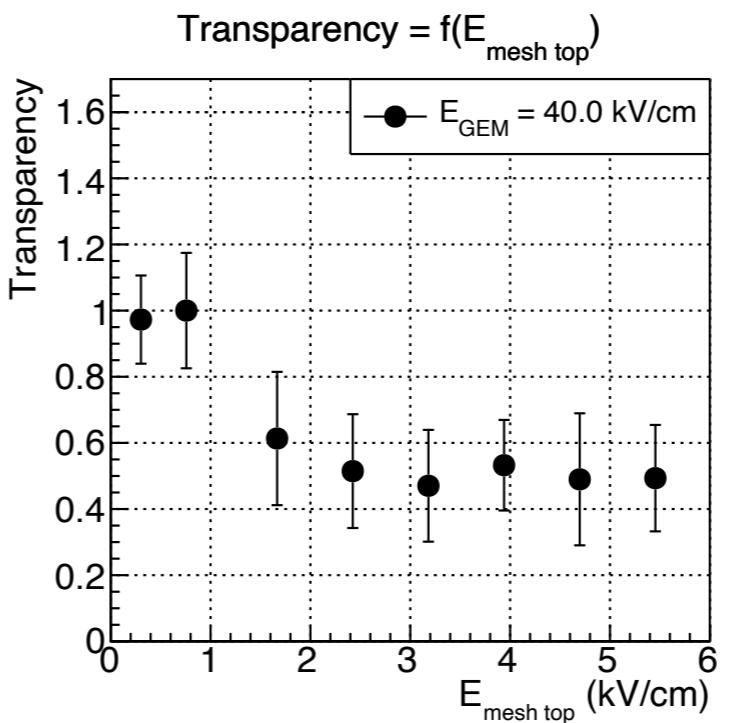
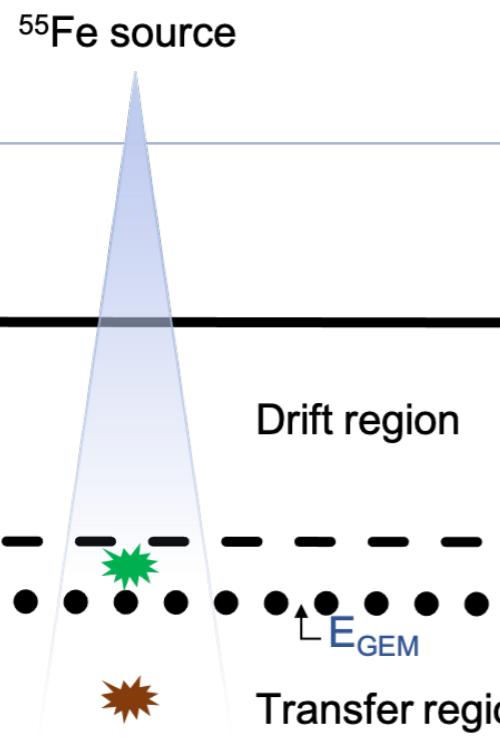
Characterization of the GEM: extraction of electrons and gain

- Events of interest: above the GEM (green object)
- Curve of GEM gain by varying E_{GEM}
- Gain of the GEM \times Proportion of GEM peak electrons extracted = $\frac{\text{GEM peak}}{\text{bottom mesh peak}}$
- Separation of **proportion of electrons extracted** and **gain of the GEM**



Characterization of the GEM: transparency

- Events of interest: above the GEM
- Transparency obtained by varying $E_{\text{mesh top}}$ + IBF measurements



First conclusions

The previous measurements indicate that:

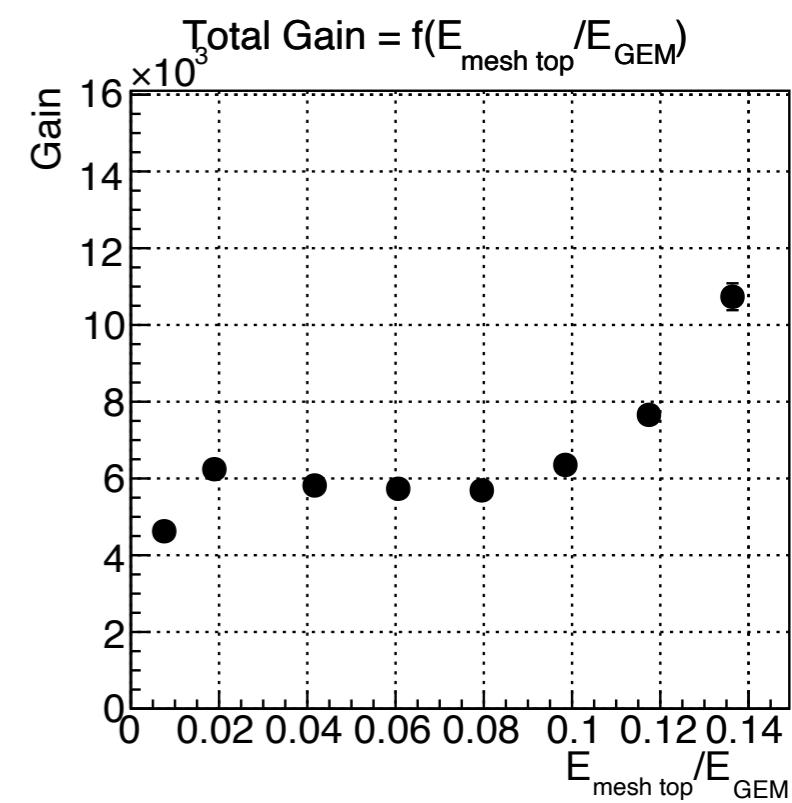
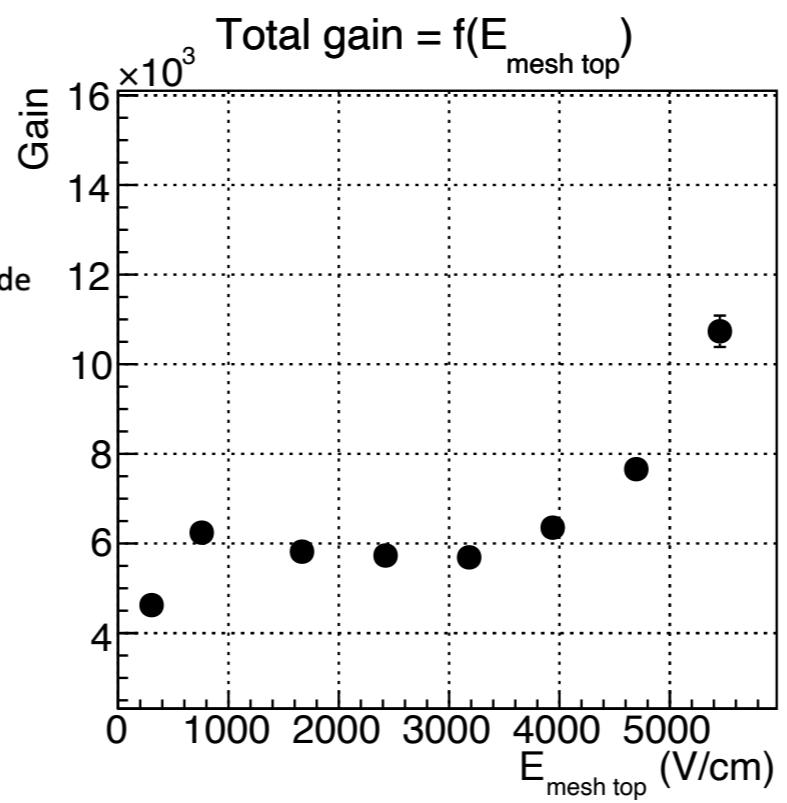
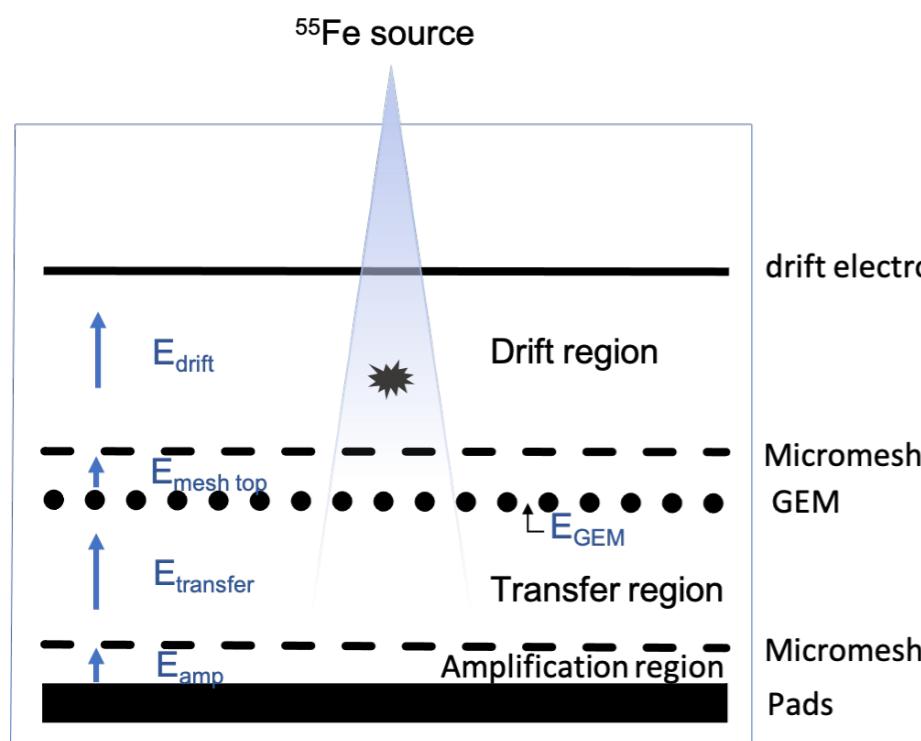
- Transparency of GEM and IBF are better for a strong field ratio $E_{\text{GEM}}/E_{\text{mesh top}}$, around 10^2 .
- Electron extraction and IBF are better for $E_{\text{GEM}}/E_{\text{transfer}} \sim 100 - 200$.
- Transparency of the bottom micro-mesh and the IBF are better for $E_{\text{amp}}/E_{\text{transfer}} \sim 10^2 - 10^3$.

The gain in the bottom micro-mesh and therefore E_{amp} must be adapted so as to satisfy the constraint on the gain. By combining all these constraints, we choose:

- $E_{\text{drift}} = 400 \text{ V/cm}$
- $E_{\text{GEM}} = 40 \text{ kV/cm}$
- $E_{\text{transfer}} = 300 \text{ V/cm}$

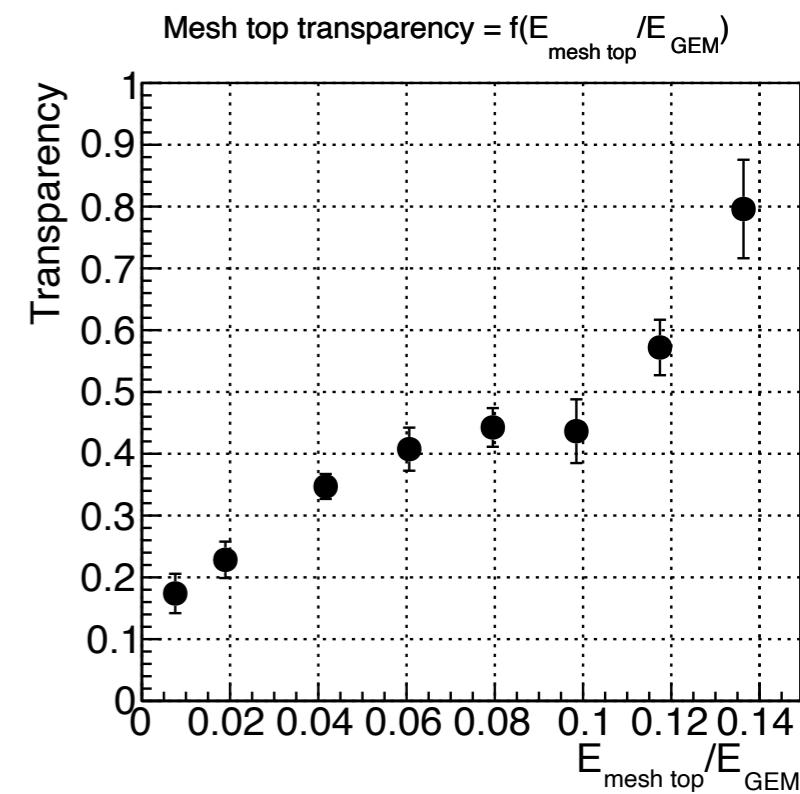
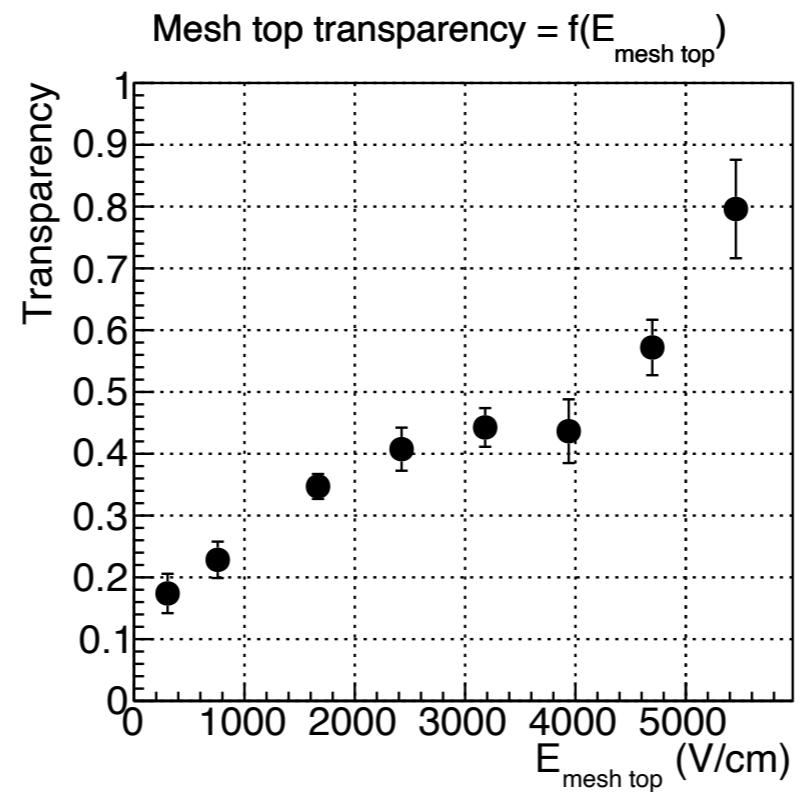
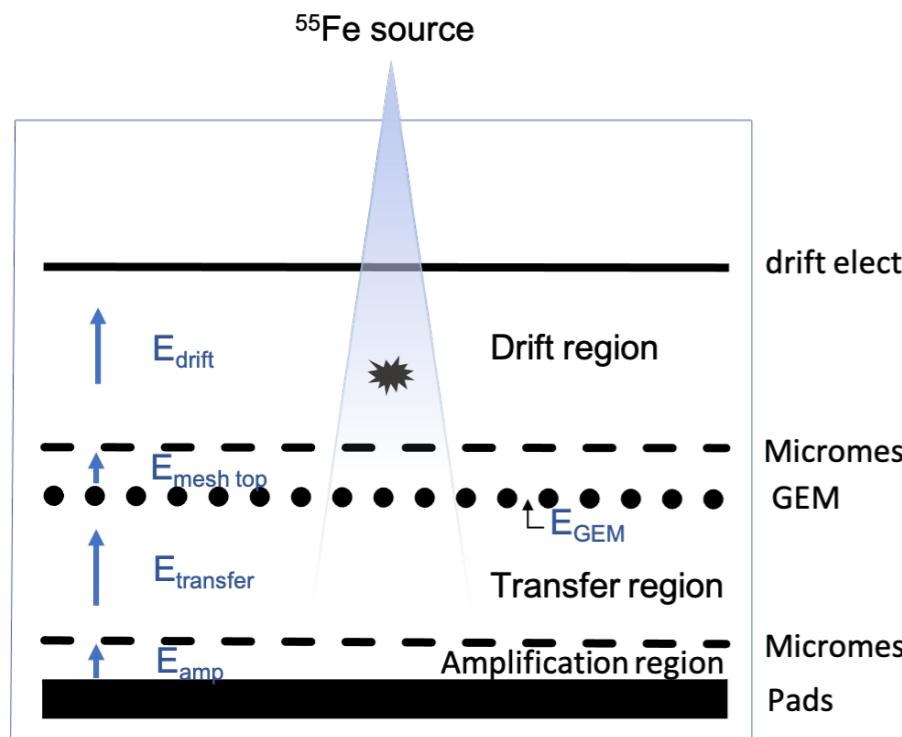
Micro-mesh top: transparency

- Events of interest: above the top mesh
- Transparency of the top mesh = $\frac{\text{gain of the top micro-mesh}}{\text{gain of the GEM}}$
- Multiplication of electrons under the top micro-mesh is not expected, because the electric field is too weak there.
- Transparency obtained by varying $E_{\text{mesh top}}$ + IBF measurements**



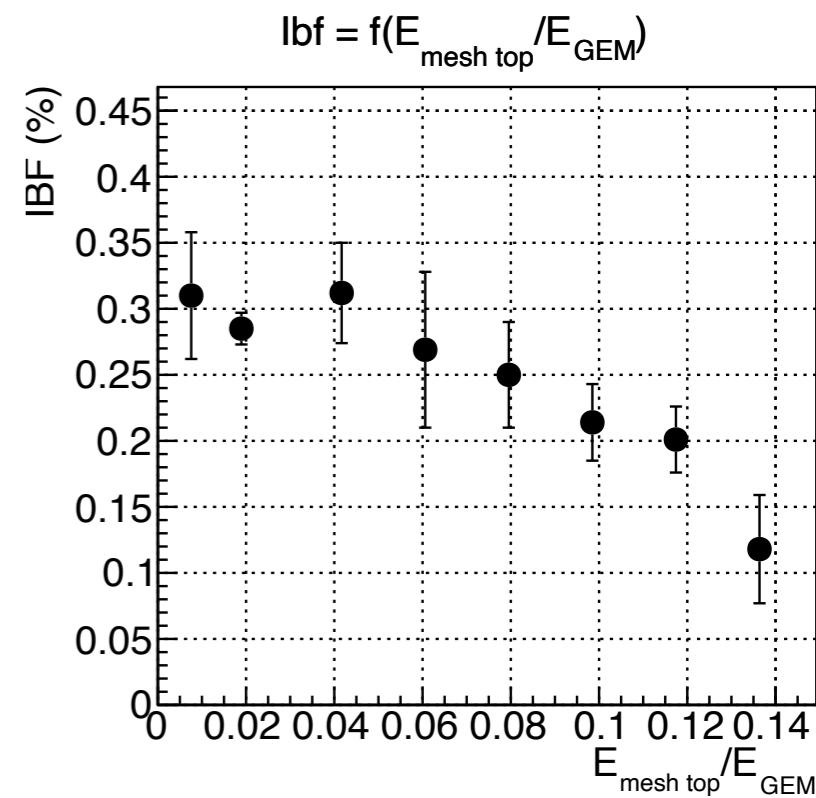
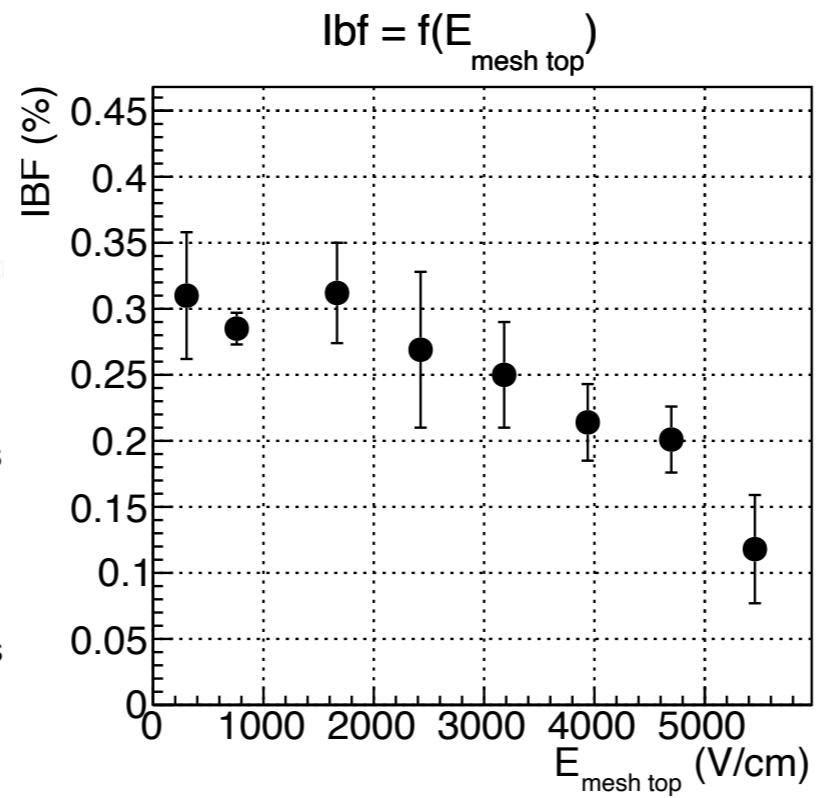
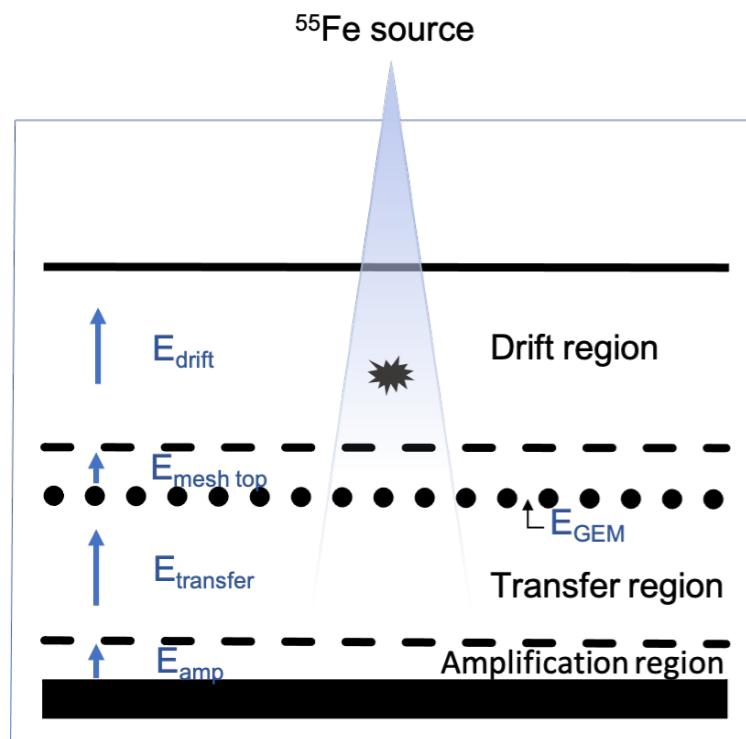
Micro-mesh top: transparency

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- Transparency obtained by varying $E_{\text{mesh top}}$ + IBF measurements**



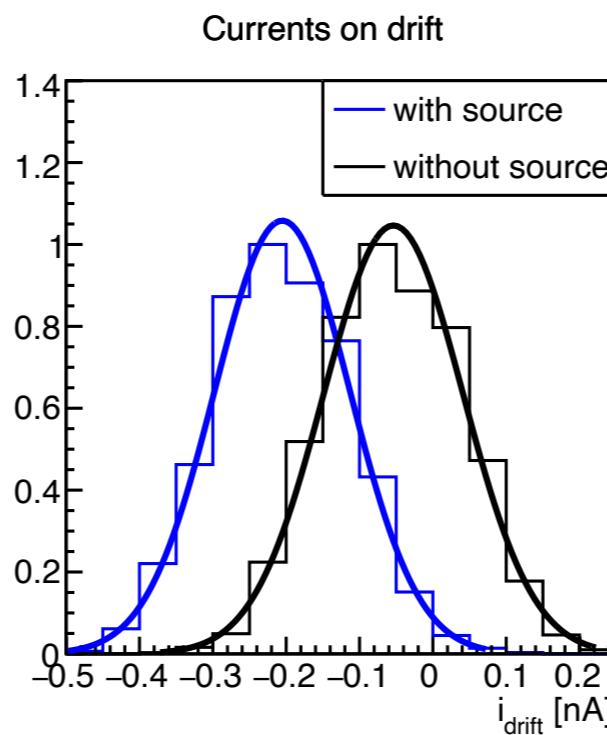
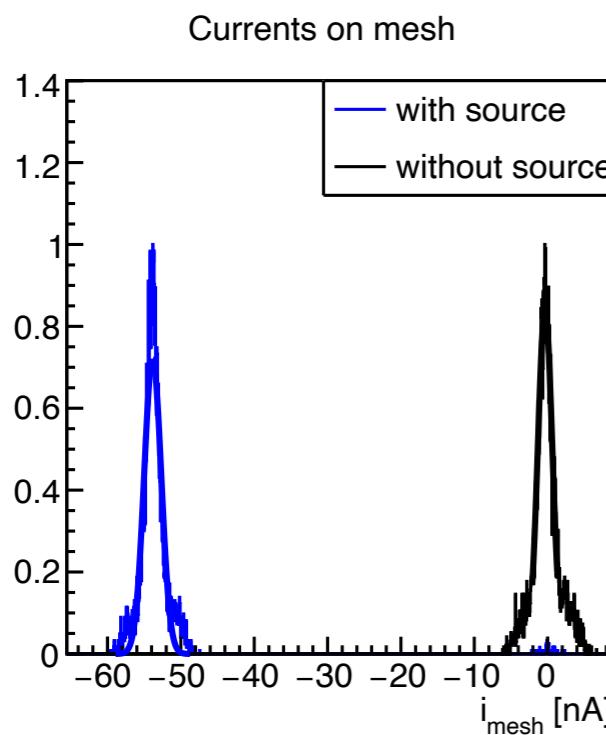
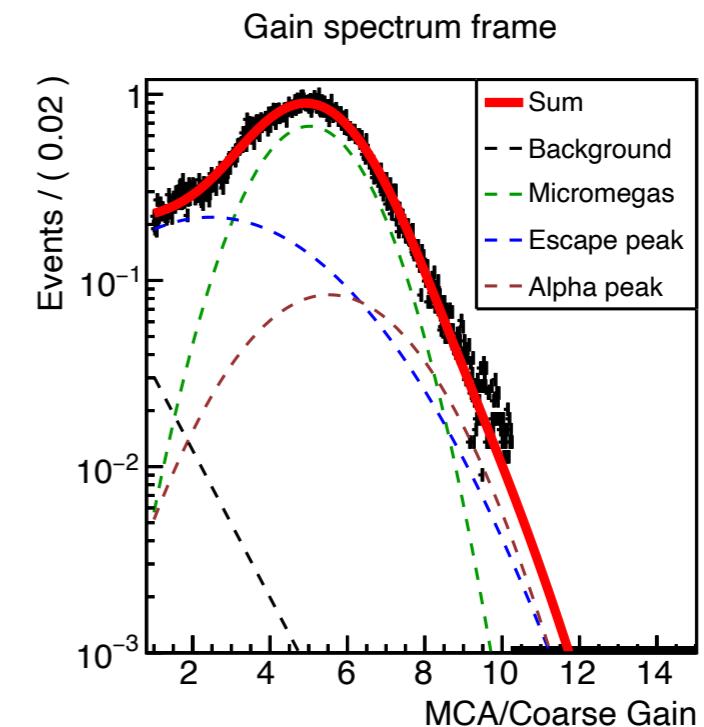
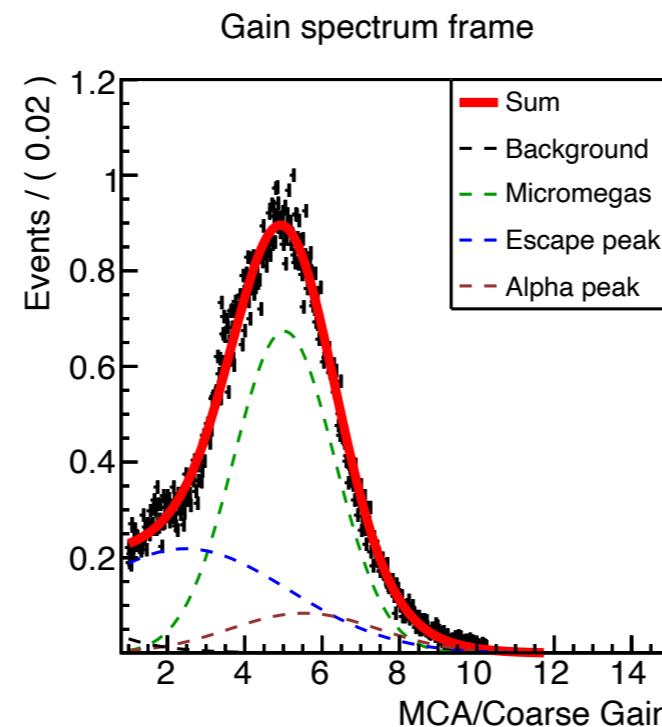
Micro-mesh top: transparency

- Events of interest: above the top mesh
- Transparency of the top mesh = $\frac{\text{gain of the top micro-mesh}}{\text{gain of the GEM}}$
- Multiplication of electrons under the top micro-mesh is not expected, because the electric field is too weak there.
- Transparency obtained by varying $E_{\text{mesh top}}$ + **IBF measurements**



Total gain: example of measurement

Gas: Ar-isobutane (95/5)	
$V_{\text{drift}} = -1540 \text{ V}$	$z = 18.568 \text{ mm}$
$E = 390.5 \text{ V/cm}$	
$V_{\text{mesh top}} = -1130 \text{ V}$	$z = 8.068 \text{ mm}$
$E = 4.39 \text{ kV/cm}$	
$V_{\text{GEM top}} = -840 \text{ V}$	$z = 7.408 \text{ mm}$
$E = 40.00 \text{ kV/cm}$	
$V_{\text{GEM bottom}} = -600 \text{ V}$	$z = 7.348 \text{ mm}$
$E = 304.7 \text{ V/cm}$	
$V_{\text{mesh}} = -380 \text{ V}$	$z = 0.128 \text{ mm}$
$E = 29.69 \text{ kV/cm}$	
$V_{\text{pad}} = -0 \text{ V}$	$z = 0.000 \text{ mm}$



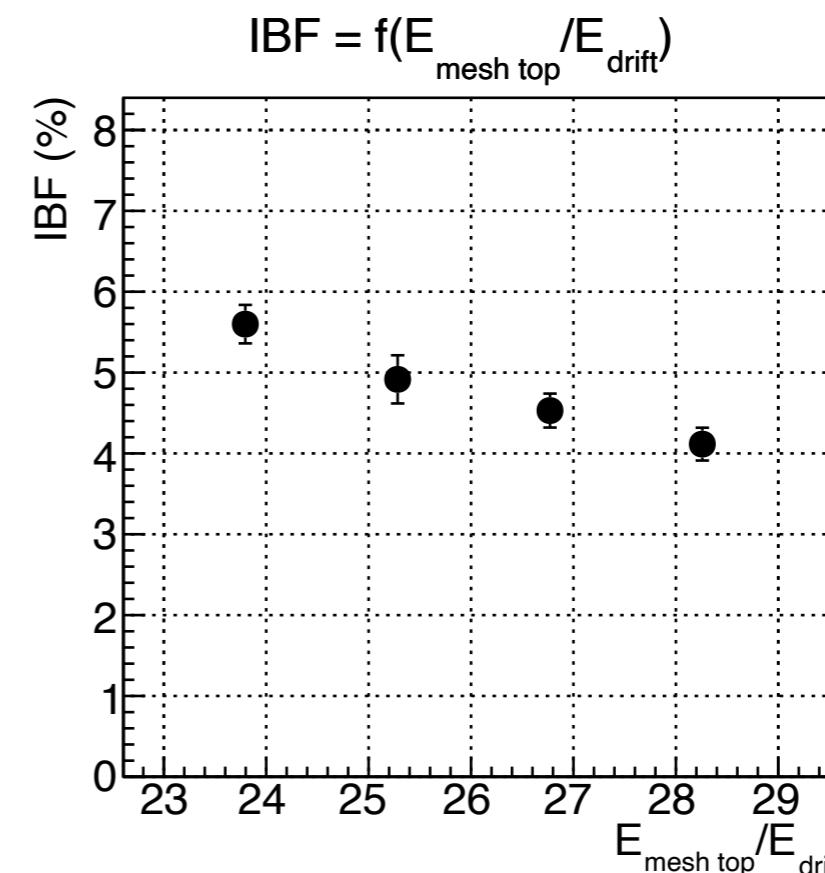
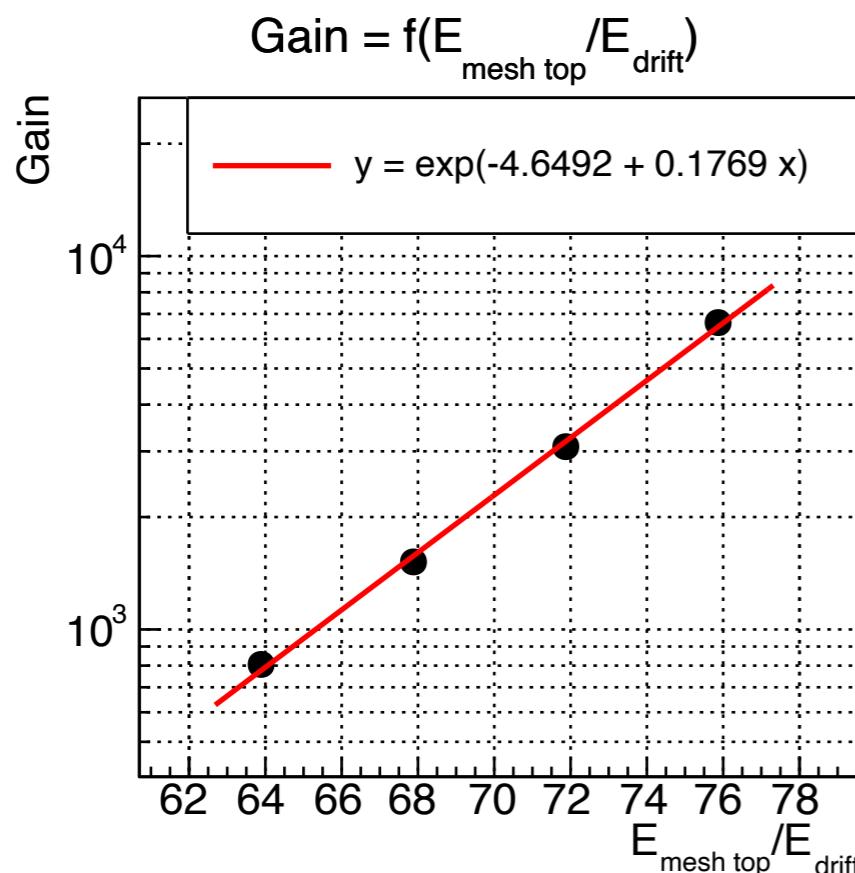
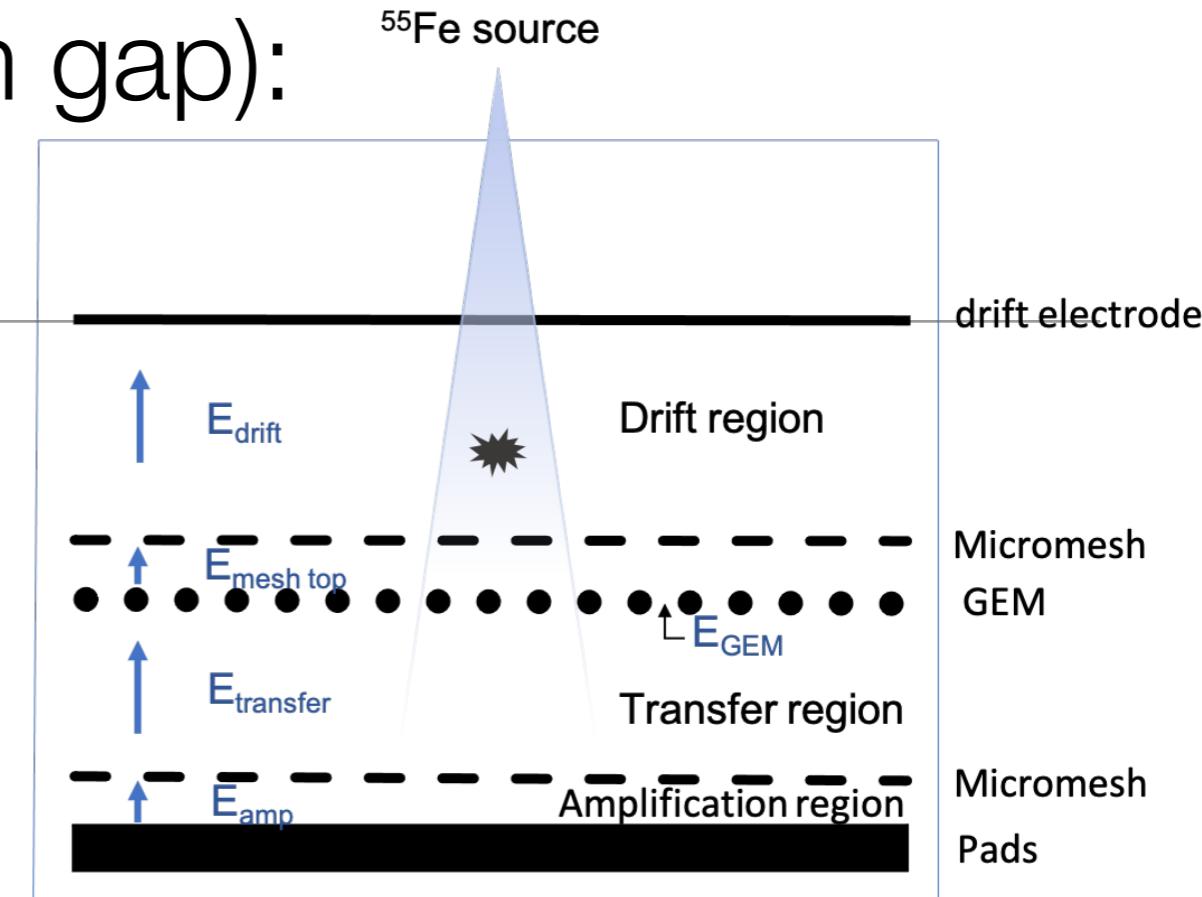
$$\begin{aligned} \text{Gain} &= 2777.6 \pm 158.5 \\ \text{Resolution} &= (25.9 \pm 6.6) \% \\ \text{FWHM} &= (61.0 \pm 15.5) \% \end{aligned}$$

$$\text{IBF} = \left| \frac{i_{\text{drift}}^{\text{with source}} - i_{\text{drift}}^{\text{without source}}}{i_{\text{mesh}}^{\text{with source}} - i_{\text{mesh}}^{\text{without source}}} \right| - \frac{1}{\text{gain}}$$

$$\text{IBF} = (0.248 \pm 0.016) \%$$

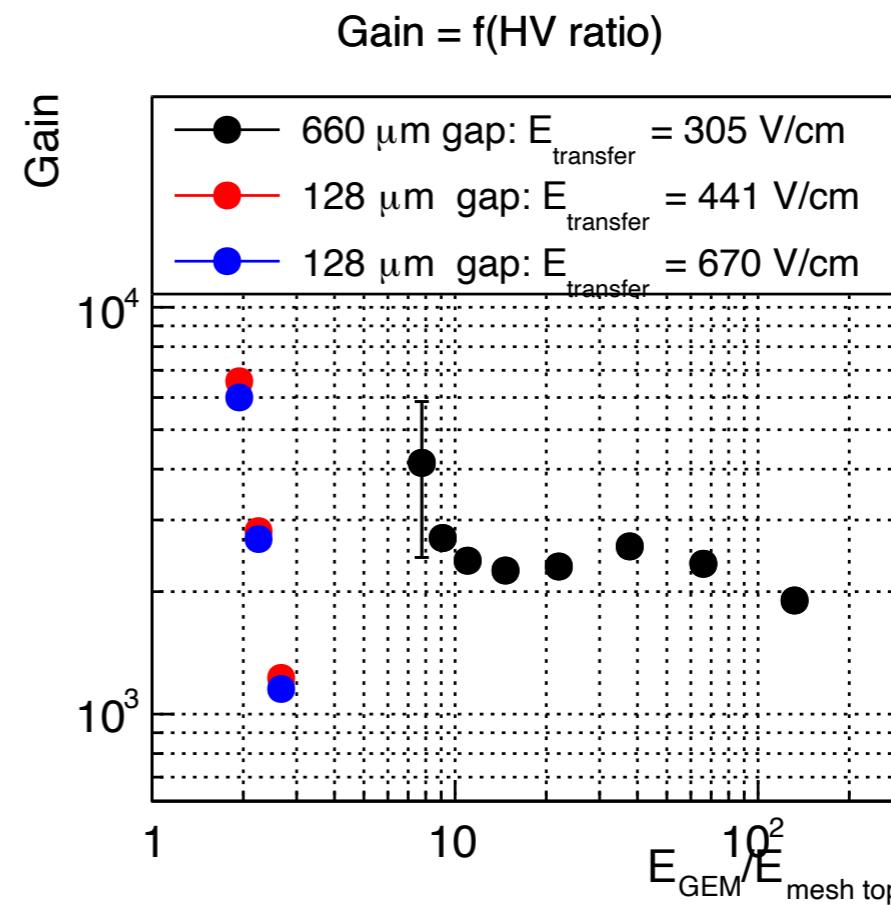
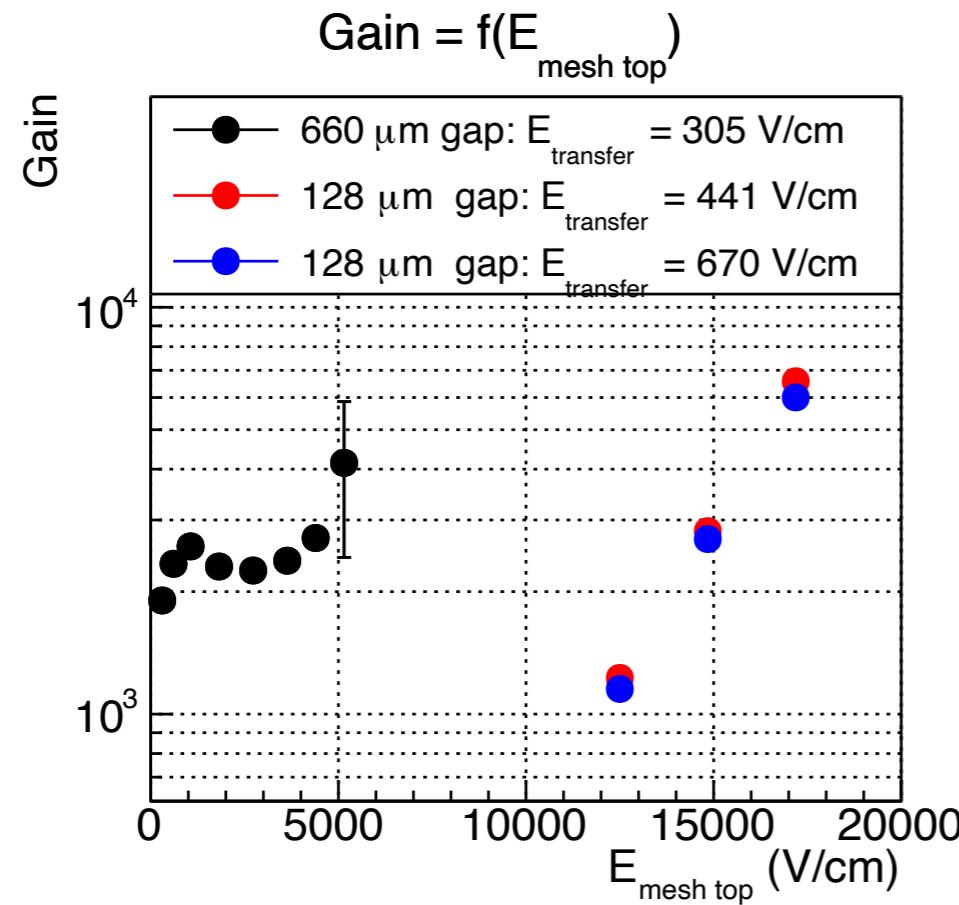
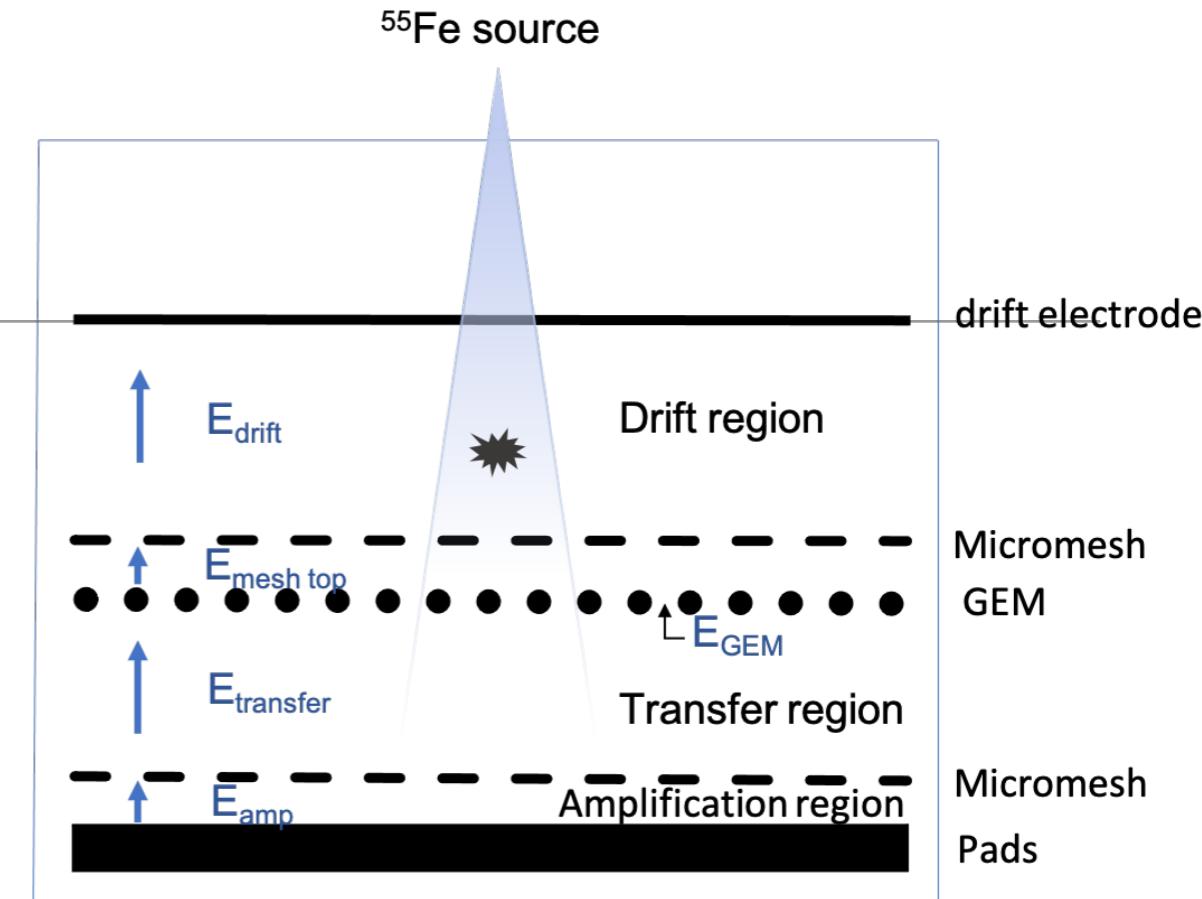
The second detector (128μm gap): study of the top micro-mesh

- Second detector: 128 μm gap between the mesh top and the GEM, mesh top specs: 70/30
- Events of interest: above the top mesh
- Gain curve + IBF measurements



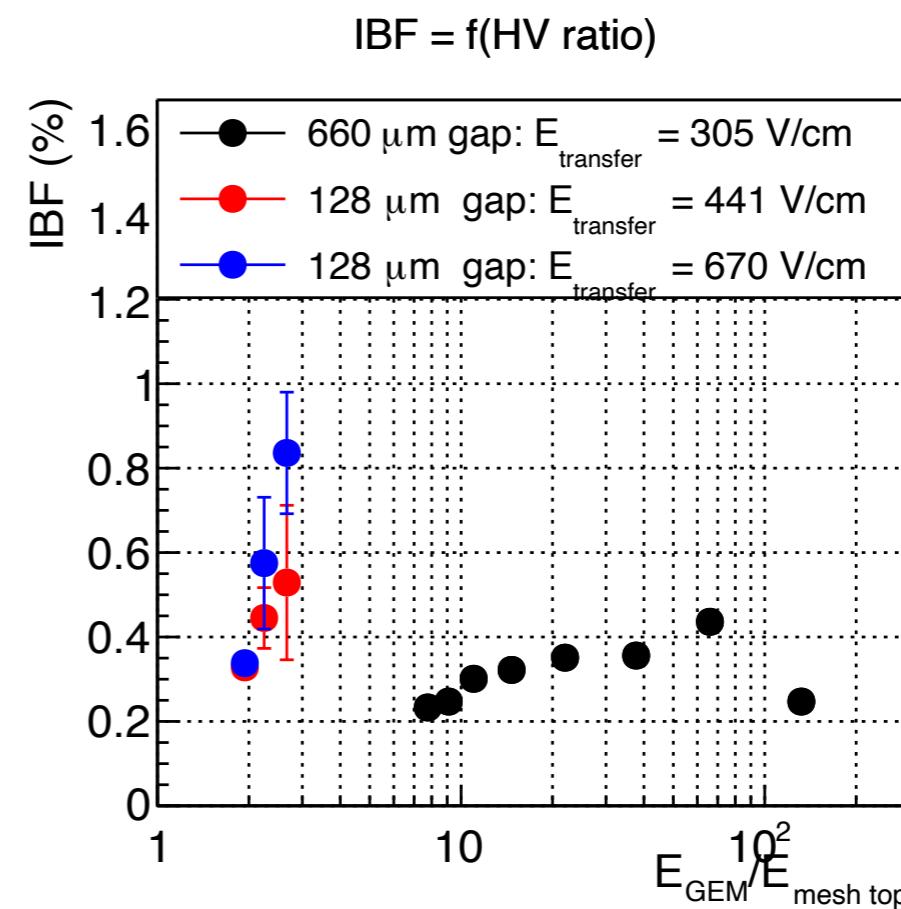
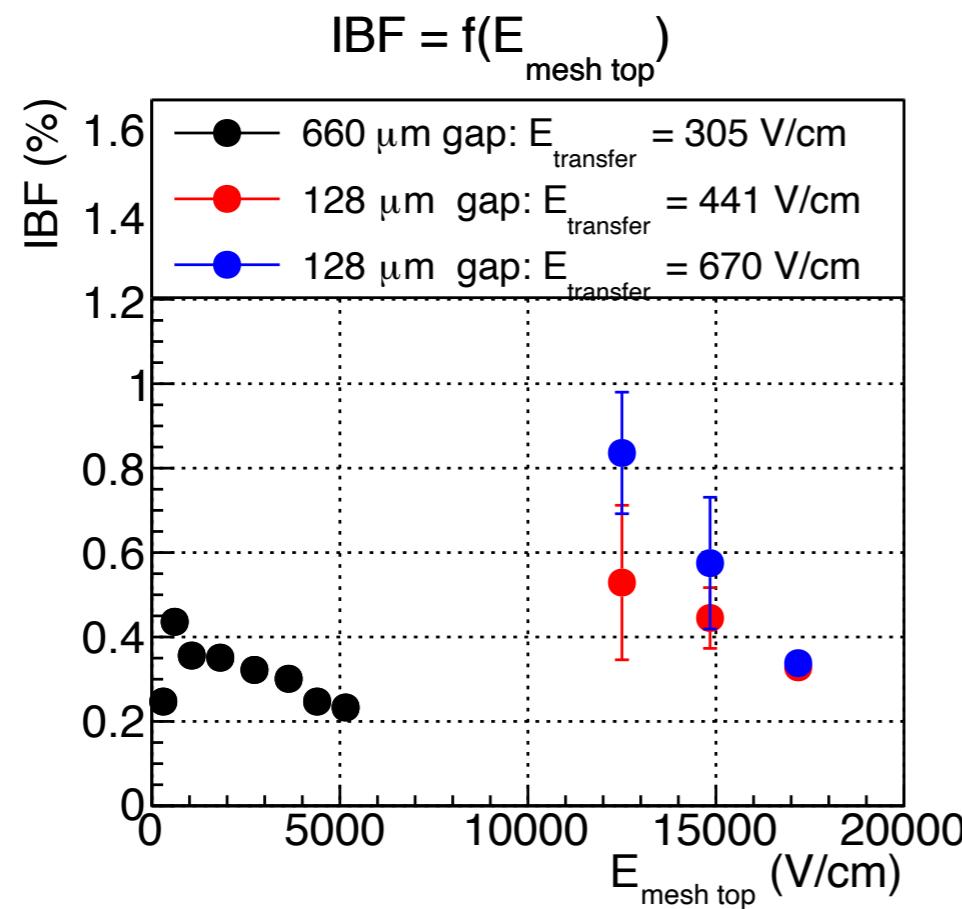
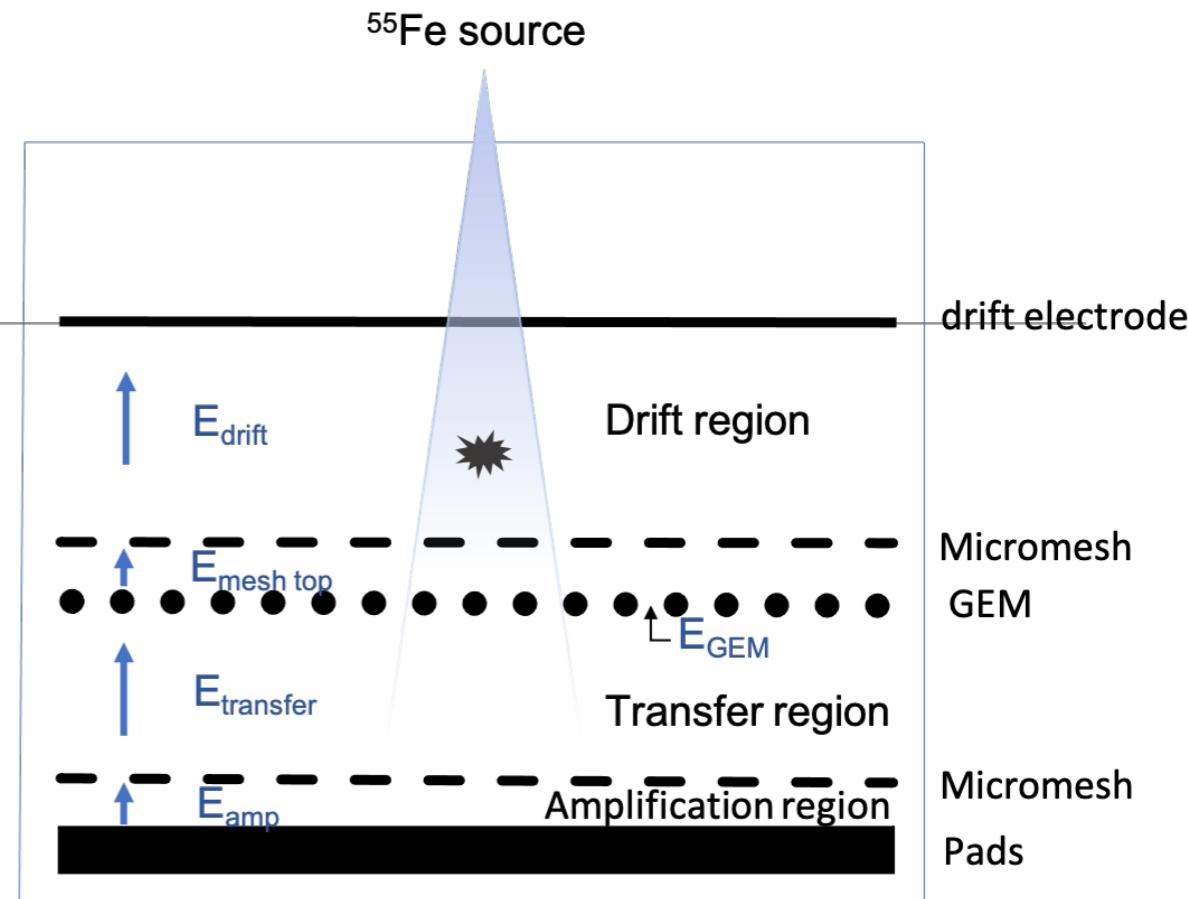
Total gain

- Events of interest: above the top mesh
- Study of gain + resolution + IBF by increasing $E_{\text{mesh top}}$



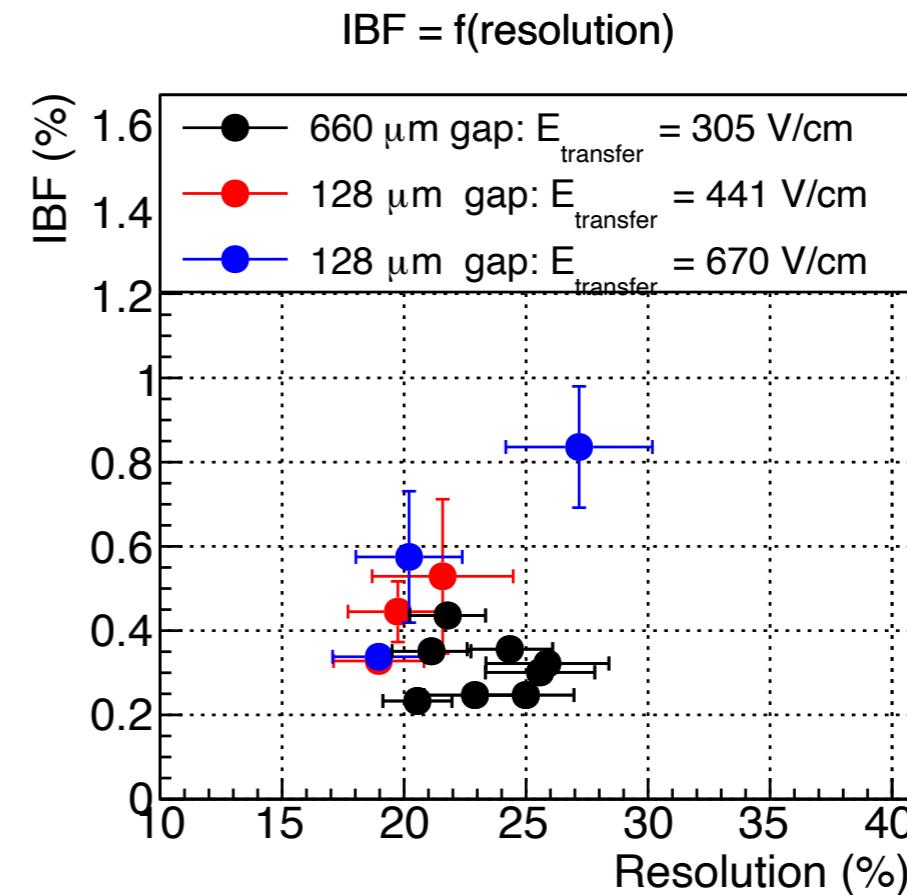
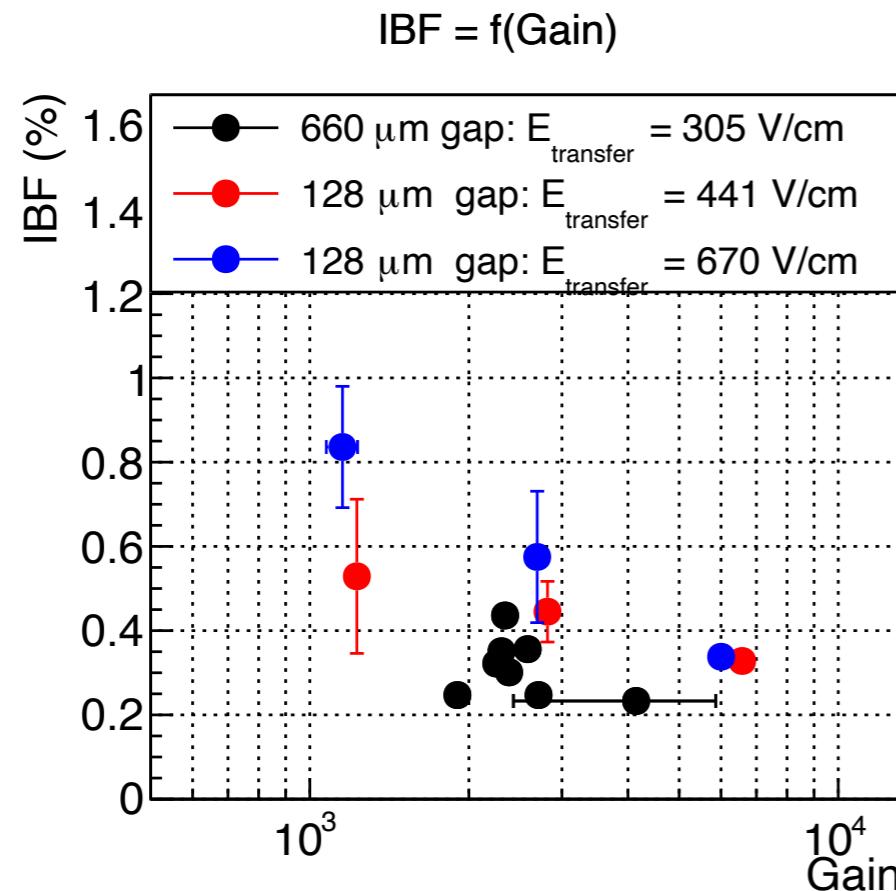
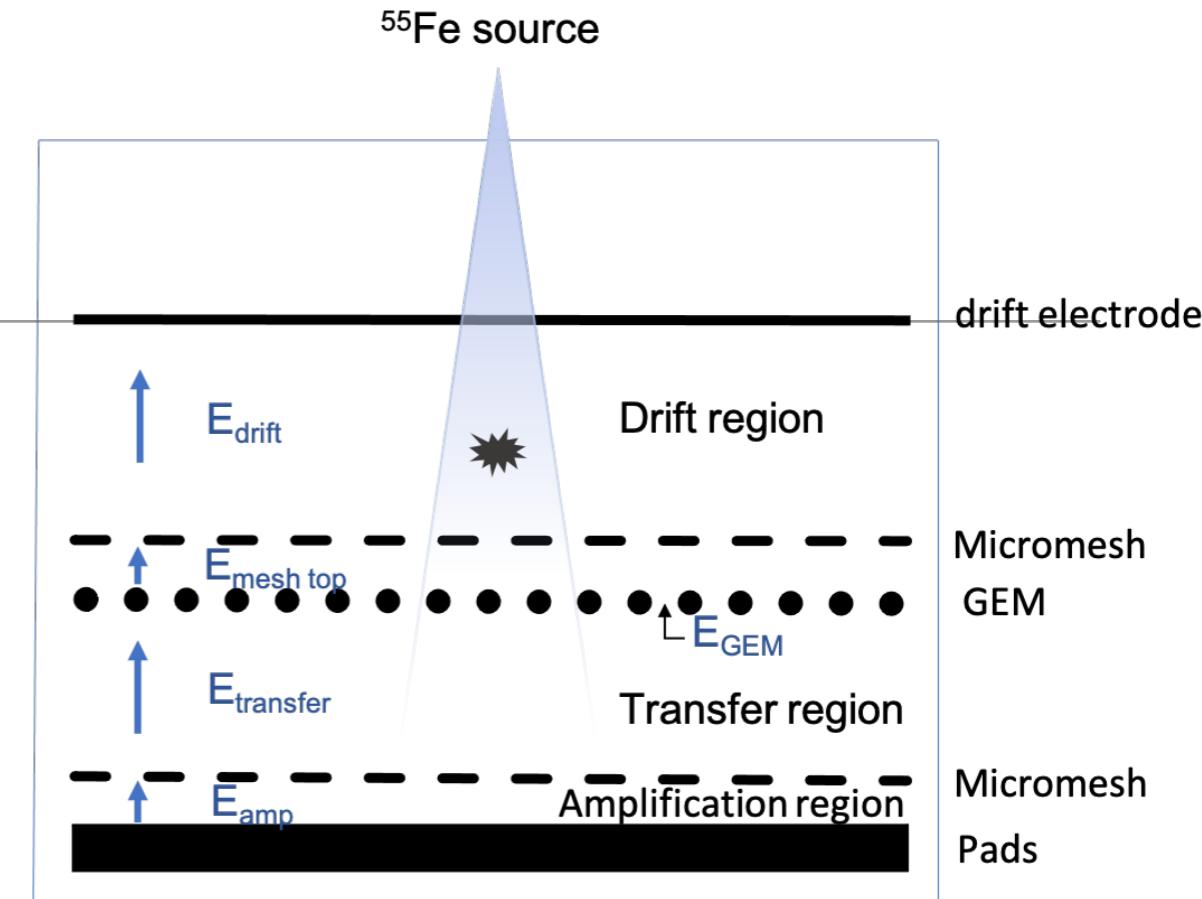
Total gain

- Events of interest: above the top mesh
- Study of gain + resolution + IBF by increasing $E_{\text{mesh top}}$



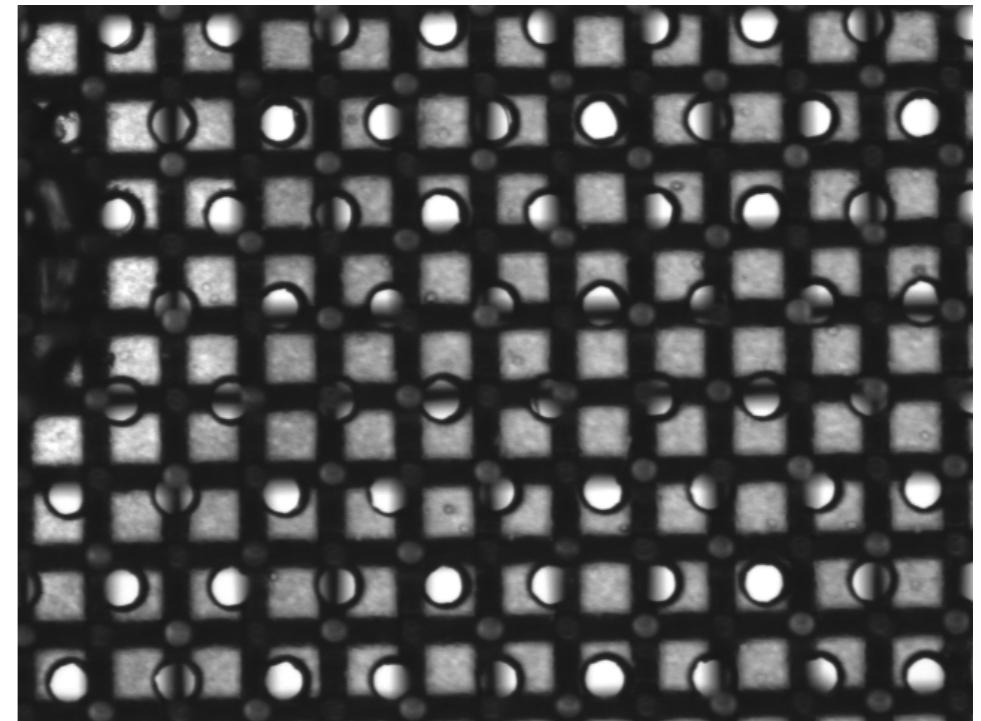
Total gain

- Events of interest: above the top mesh (dark object)
- Study of gain + resolution + IBF by increasing $E_{\text{mesh top}}$



Overview

- We were able to build and test a new hybrid detector able to operate at low gains (~2000 - 4000) while keeping a low IBF ($< 0.3\%$).
- Article submitted on this new type of detector (NIM A).

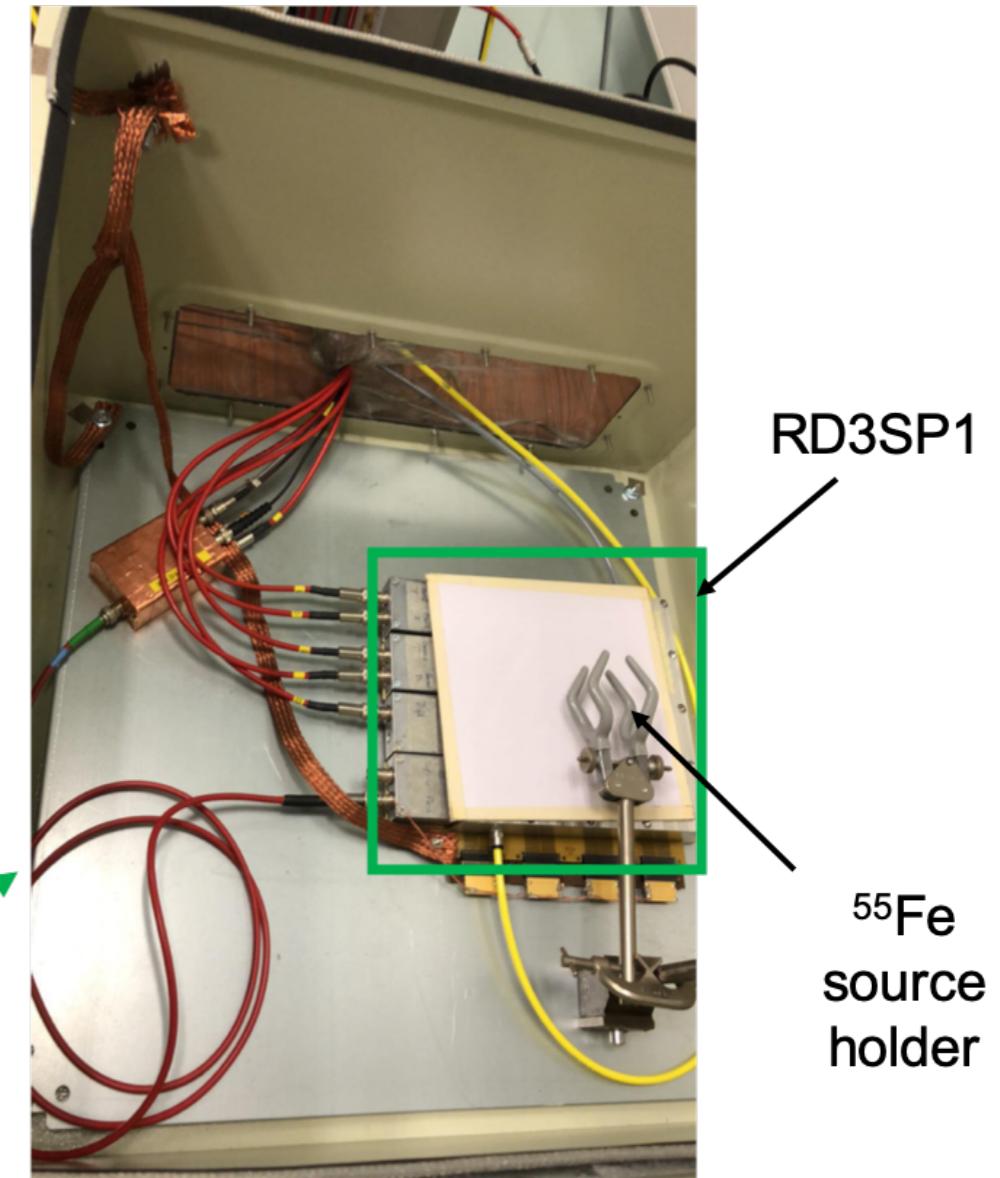
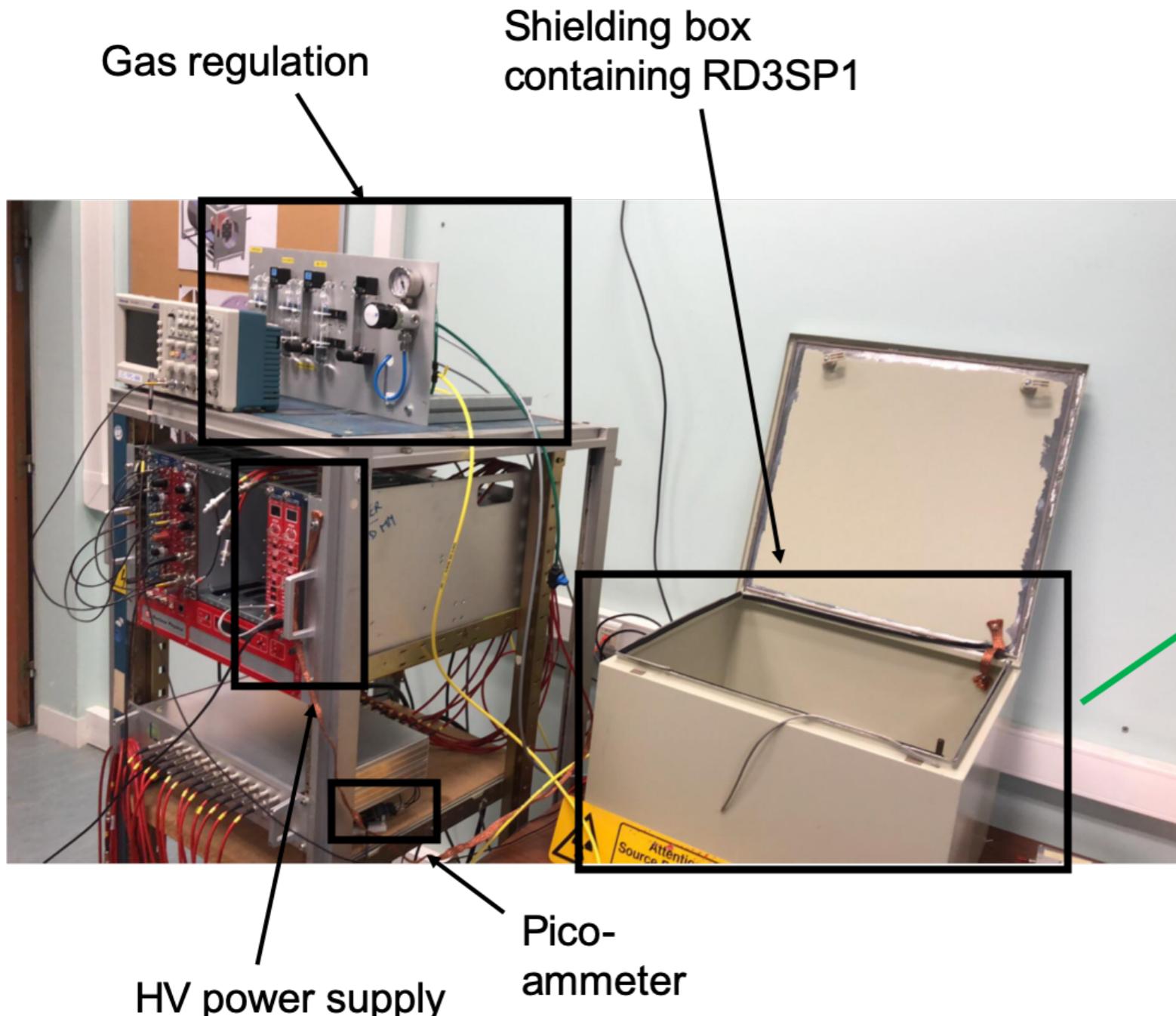


Thank you for your attention!

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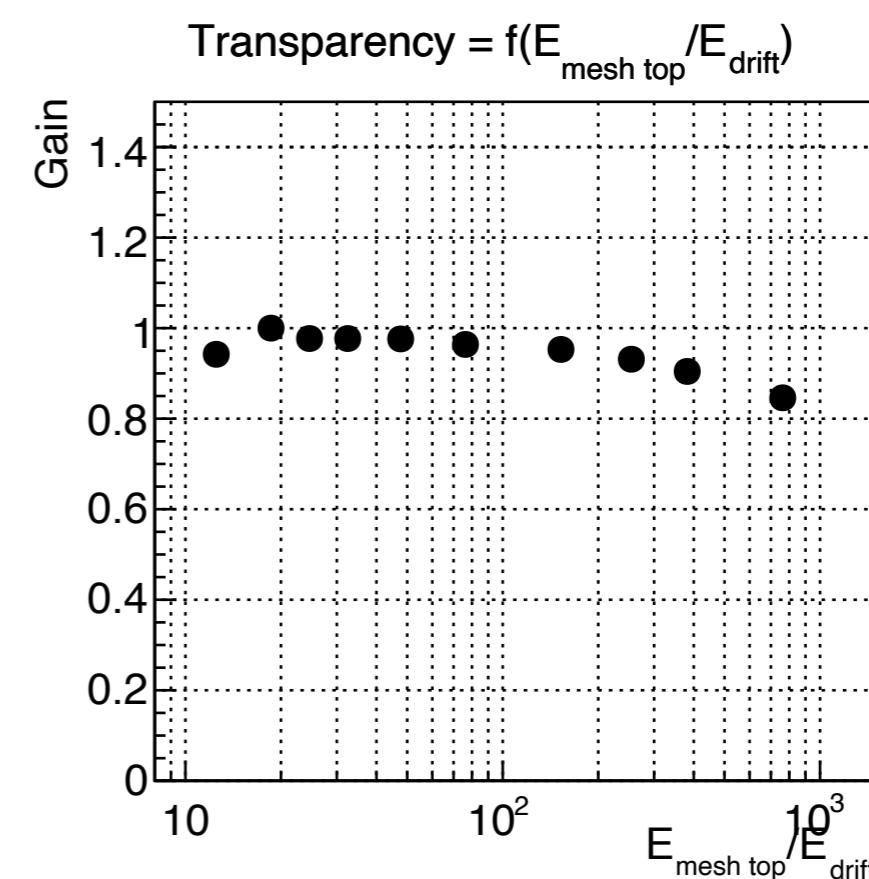
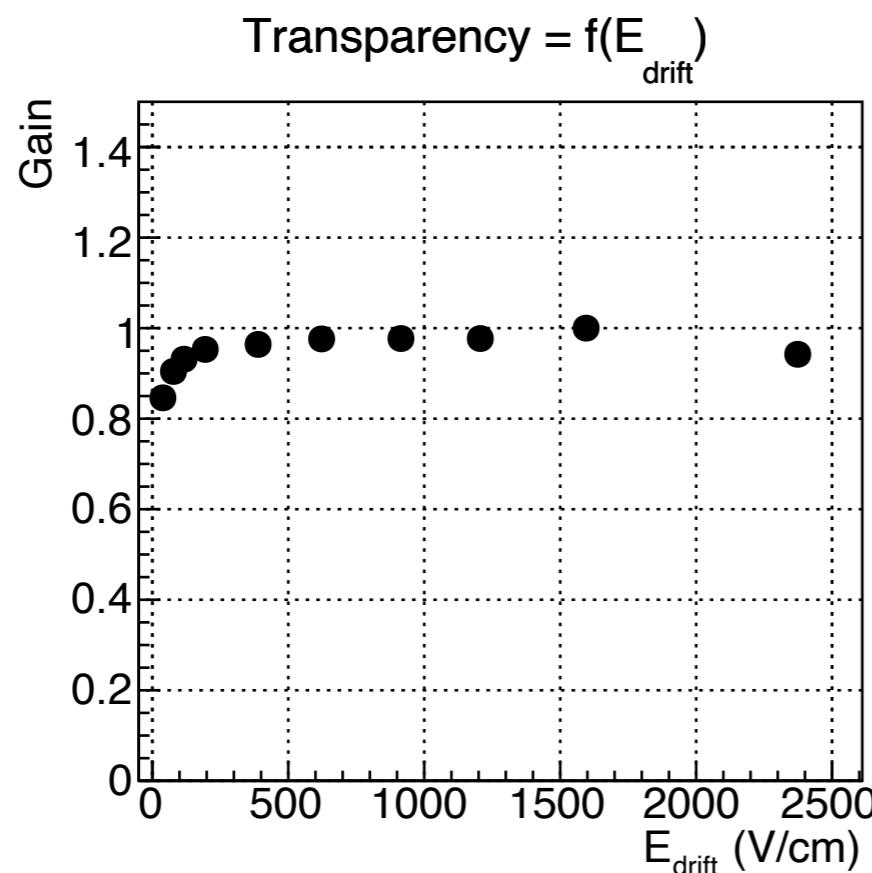
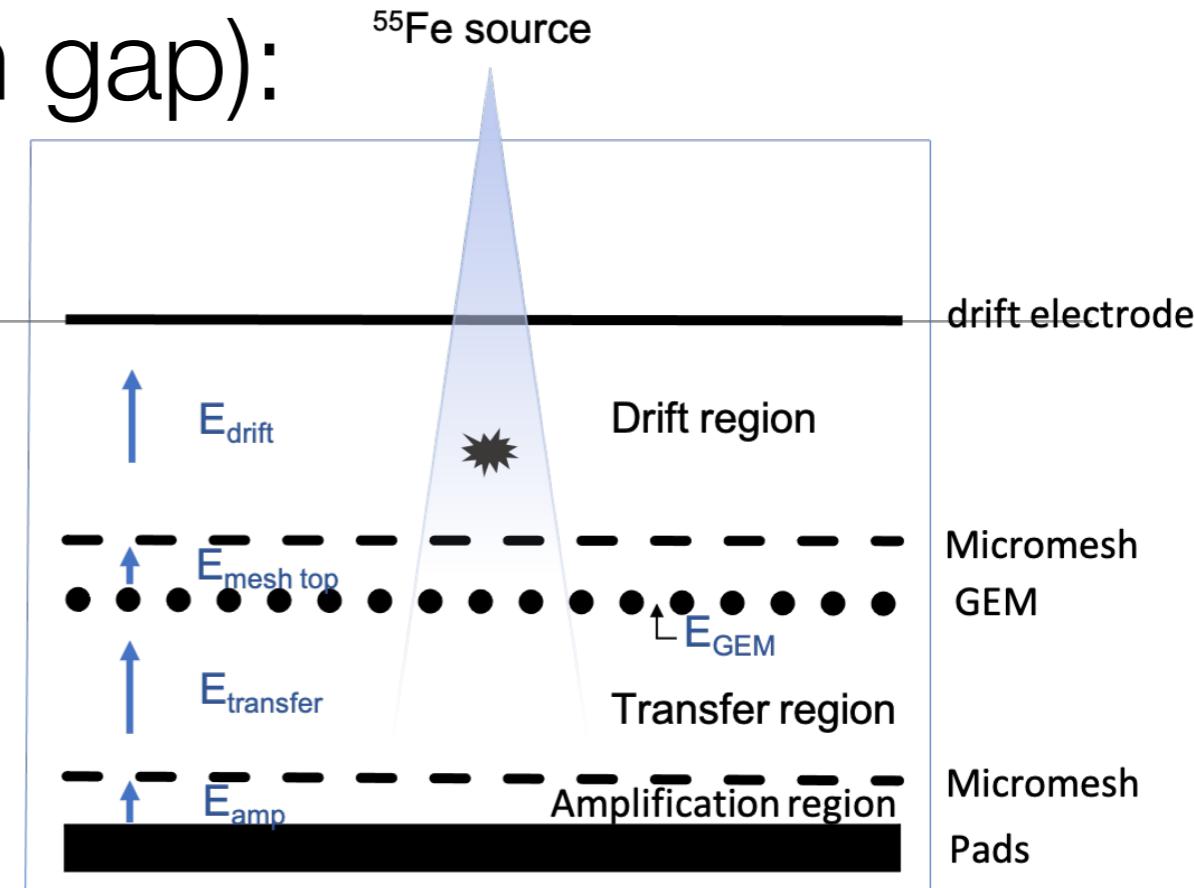
Back-up

Presentation of the setup



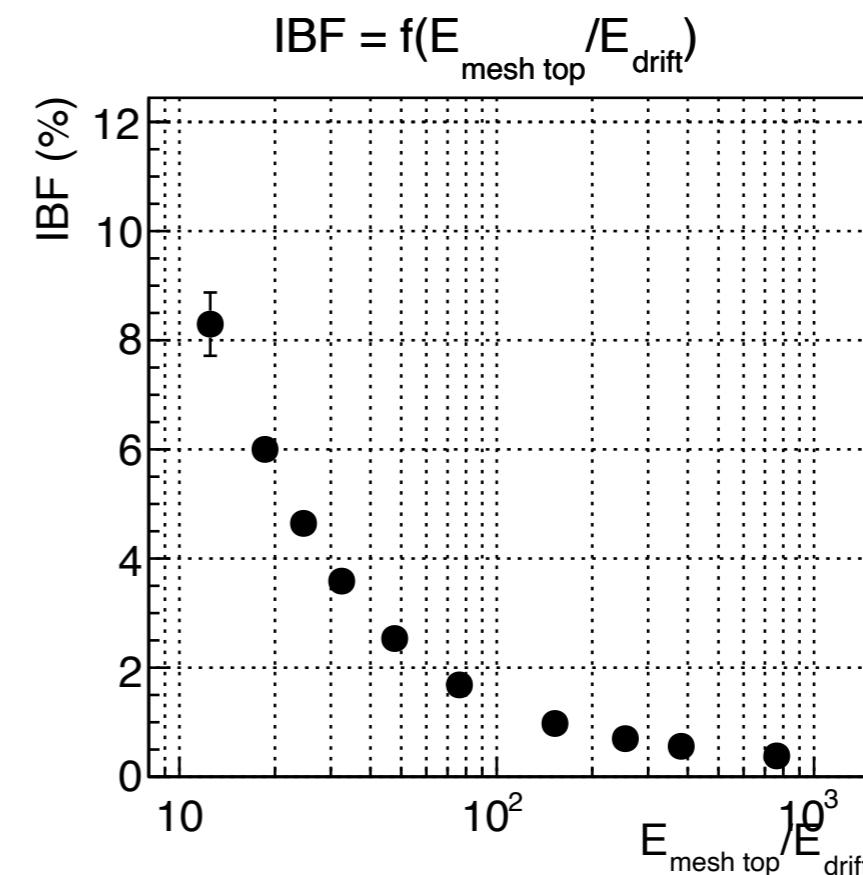
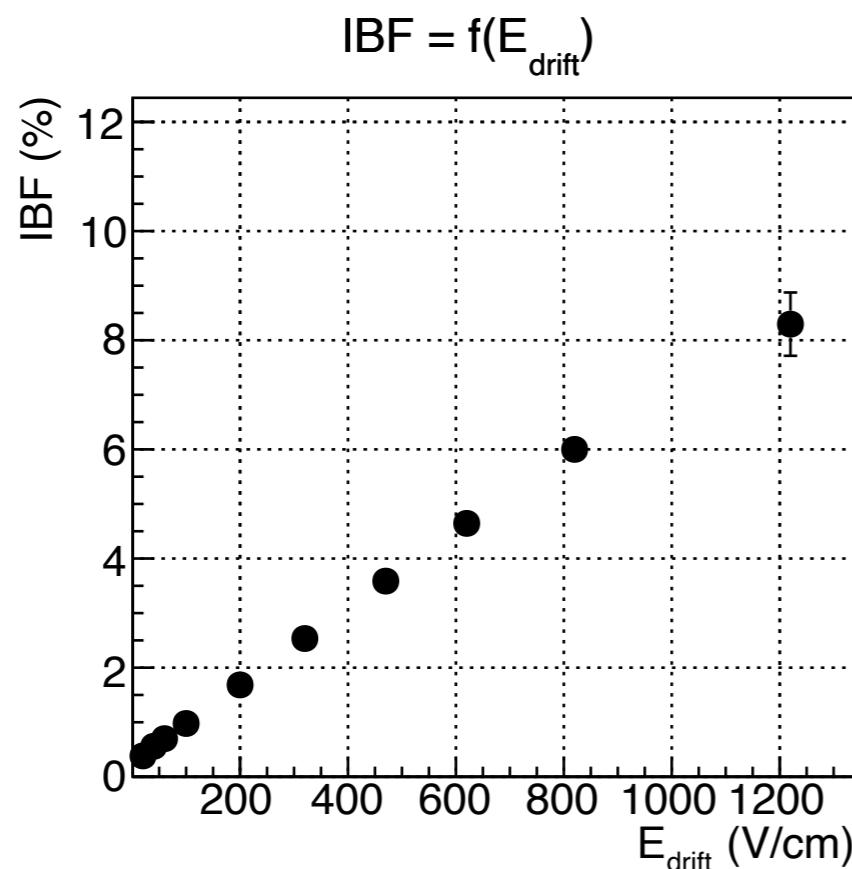
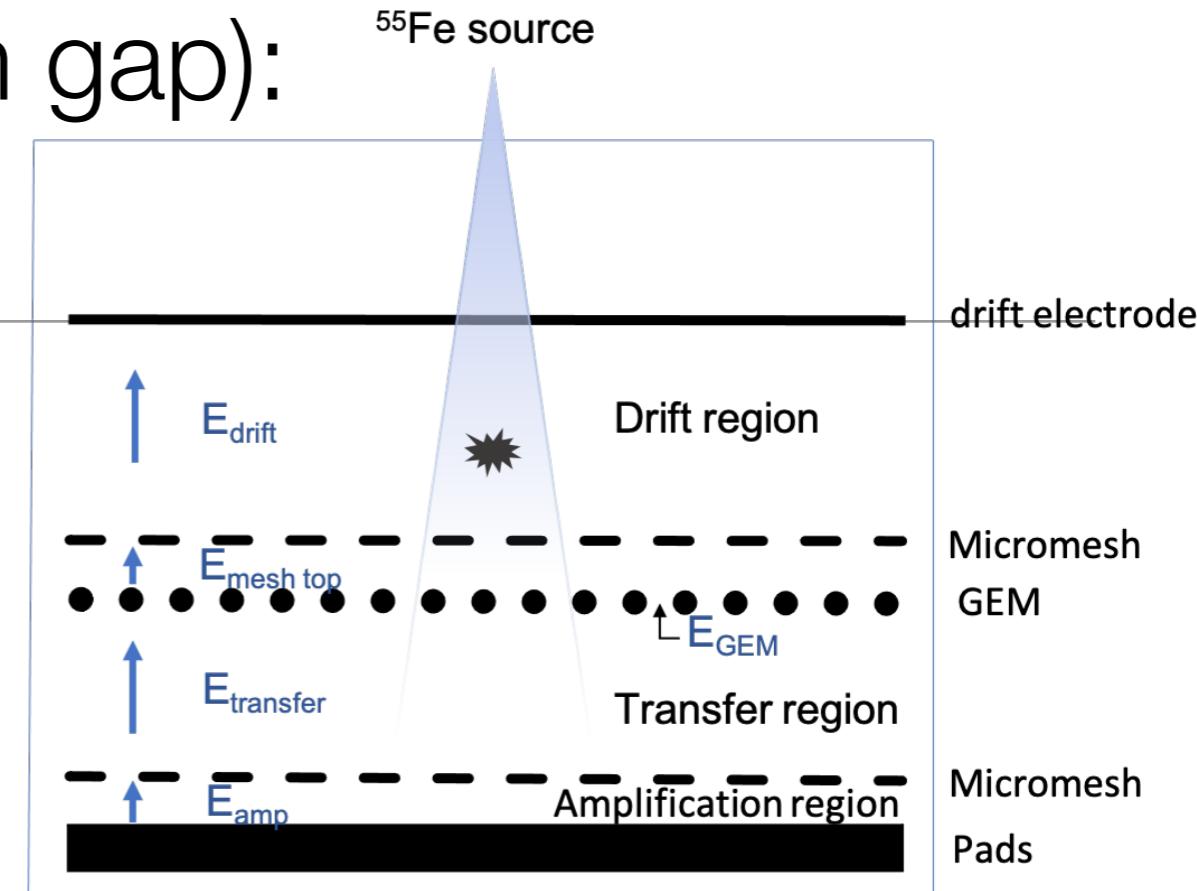
The second detector (128μm gap): study of the top micro-mesh

- Second detector: 128 μm gap between the mesh top and the GEM, mesh top specs: 70/30
- Events of interest: above the top mesh (dark object)
- **Transparency curve** + IBF measurements



The second detector (128μm gap): study of the top micro-mesh

- Second detector: 128 μm gap between the mesh top and the GEM, mesh top specs: 70/30
- Events of interest: above the top mesh (dark object)
- **Transparency curve** + IBF measurements



Bulk Micromegas

https://indico.cern.ch/event/791893/attachments/1830564/2997794/2019_Micromegas_Bulk_resistif_-Olivier.pdf

