CYGNO PROJECT

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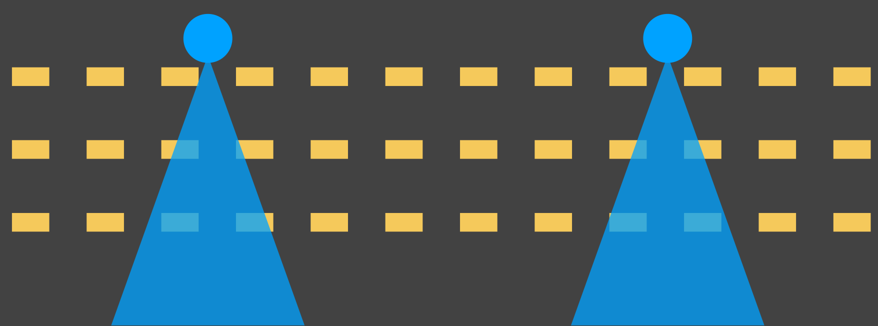
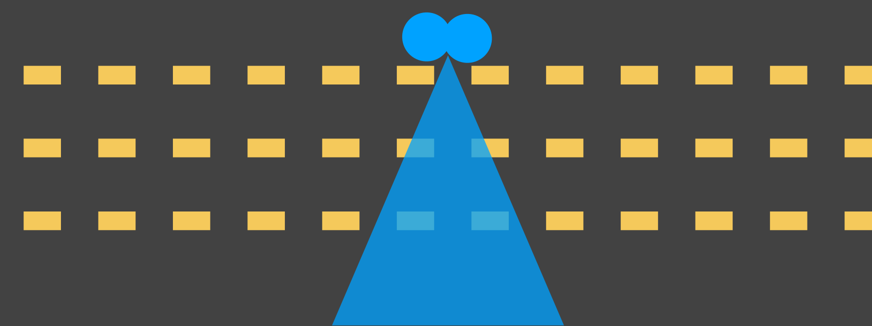
GAIN NON LINEARITY

We discovered a non linear behavior of GEM response;

Gain seems to saturate when the density of electrons (i.e. the number of electrons in each single channel) is too high;



If primary electrons are sparse, GEM gain is linear



If primary electrons are too dense, avalanche can shield GEM electric field and gain is lower

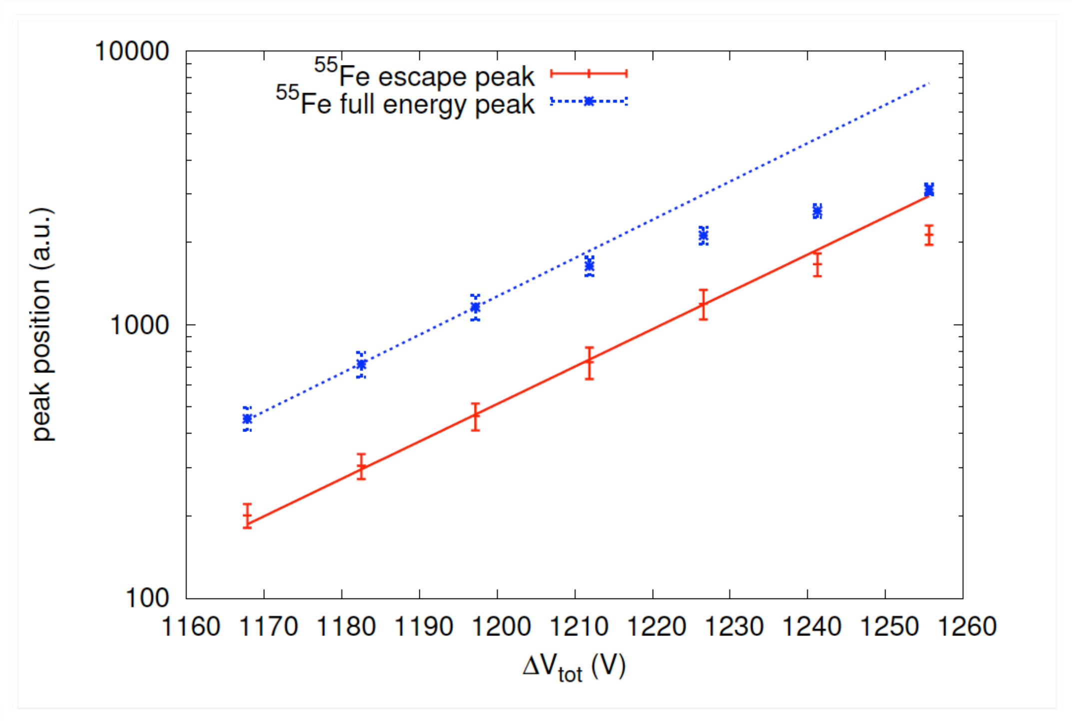
Less secondary electrons mean less light

GAIN NON LINEARITY

This phenomenon was already seen at CERN

Effects of High Charge Densities in Multi-GEM Detectors

S. Franchino[1], D. Gonzalez Diaz[1], R. Hall-Wilton[2], H. Muller[1], E. Oliveri[1], D. Pfeiffer[1,2], F. Resnati*[1,2], L. Ropelewski[1], M. Van Stenis[1], C. Streli[3], P. Thuiner[1,3], R. Veenhof[1]
[1] CERN, Geneva, Switzerland. [2] ESS, Lund, Sweden. [3] TUW, Wien, Austria.



for very high gain (1.7 10^5)

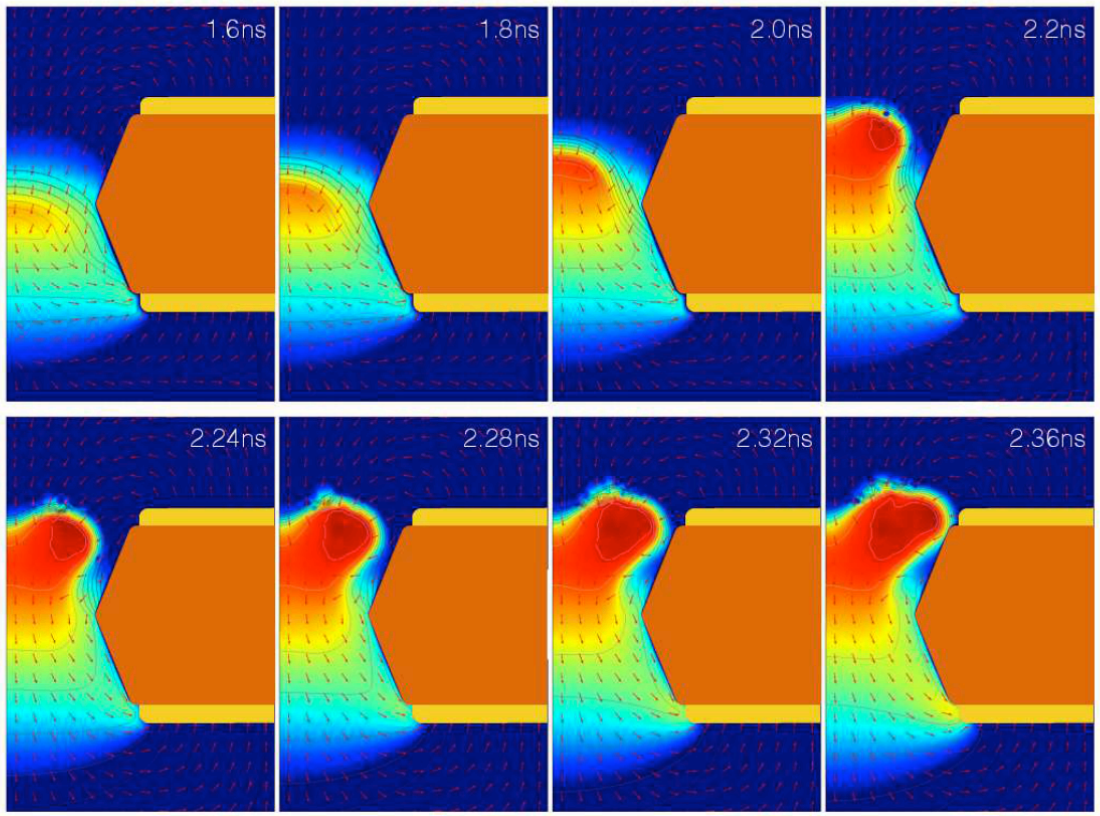
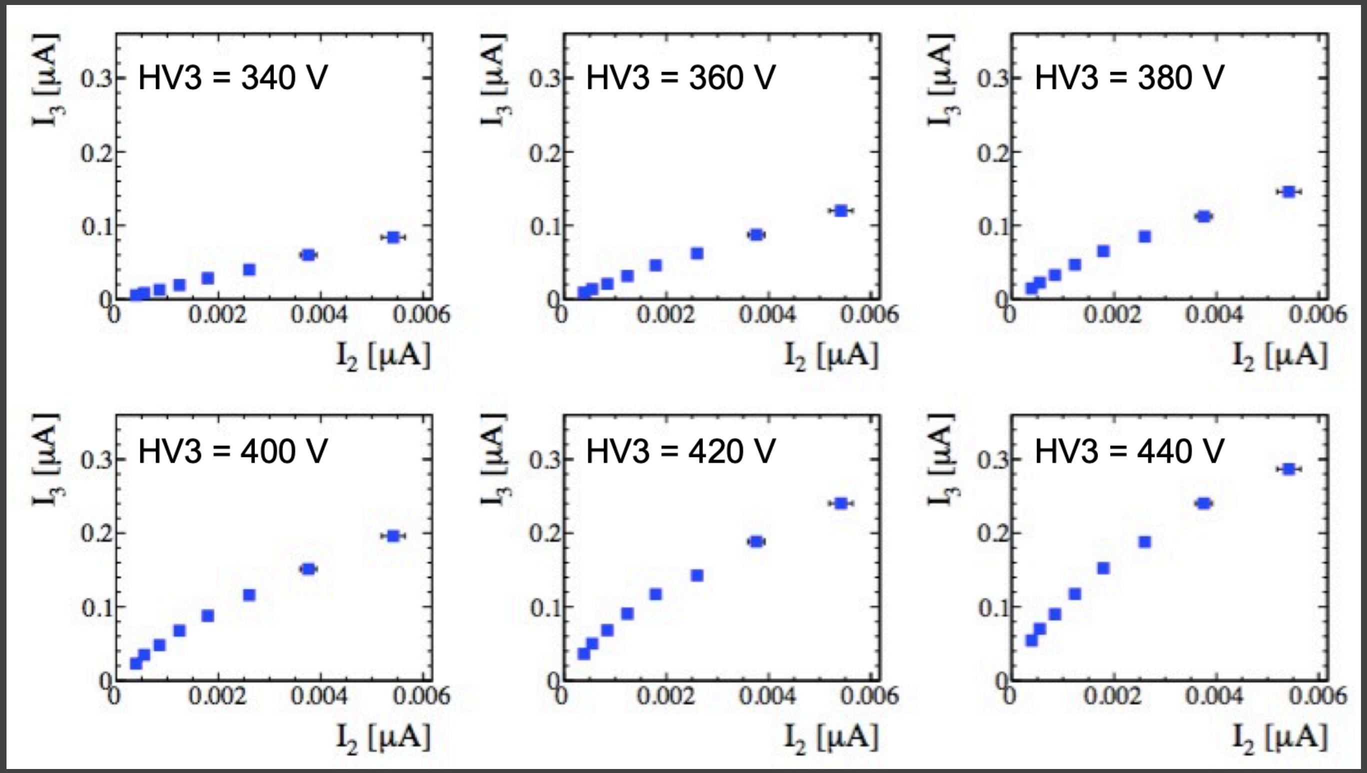
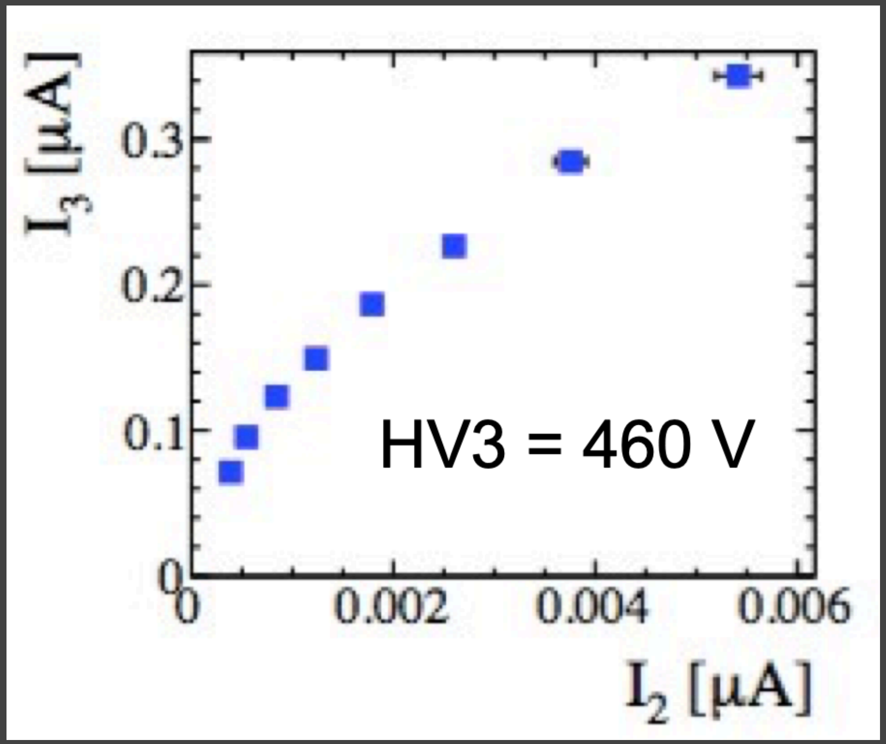


Fig. 6. Formation and propagation of a streamer in a GEM hole in cylindrical coordinates. The colour map represents the ion density in arbitrary units.

GAIN NON LINEARITY

By increasing the gain in first GEM, we simulated different energy releases





These plots give the charge coming out form GEM-3 as a function of the charge coming in. Less linear as long as the V_{GEM} increases; Good linearity with 5 times less gain.

POSSIBLE SOLUTIONS

We studied two possible solutions to the issue:

- exploit electro-luminesce to decrease the electron gain while keeping the same light yield;
- correct data according to performed measurements

Saturation on GEM-3

Karolina Kmieć and Francesco Renga

INFN Sezione di Roma

April 21, 2020

1 Measurements of saturation

The saturation effect have been studied looking at the trends of the currents on GEM-2 and GEM-3 (I_2 and I_3, respectively) as a function of the high voltage applied on GEM-1 (HV_1). Changing HV_1 simulates indeed the effect on GEM-2 and GEM-3 of different energy deposits inside the chamber.

The chamber was exposed to a ^{55}Fe source and the current through the HV_3 bias circuit was measured. Since the bias circuit and the current readout introduce a 25 MΩ resistance in the supply line, and currents up to a few μA are observed in GEM-3, there can be a relevant voltage drop (up to several volts) from the power supply to the GEM. We compensated on the fly for this voltage drop by increasing the set voltage according to the drop predicted by the measured current.

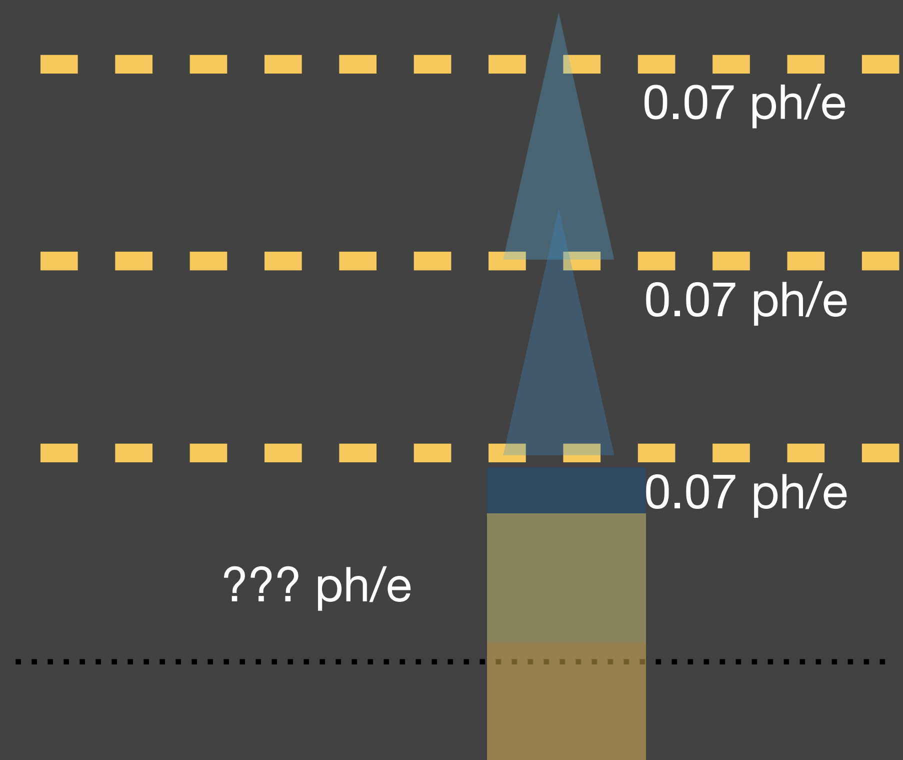
The measurements of I_2 and I_3 have been performed alternatively, switching off the high voltage on GEM-3 (HV_3) when the current on GEM-2 was readout, in order to not have any influence on GEM-2 from the ions going up from GEM-3 when it is on. GEM-2 is always kept at 460 V.

The measurements on GEM-3 have been always performed with a collimator in front of ^{55}Fe source, in order to not have an excessive current through the HV_3 bias circuit, that would have made unsafely large the necessary voltage compensation. Measurements on GEM-2 have been performed both with and without the collimator. In Fig. 1 we show the trends of I_2 versus HV_1. Since the measurements without collimator are affected by large relative errors, we will use the measurements without collimator in the following, but

1

ELECTRO-LUMINESCENCE

In Optical Readout GEM detectors, light is produced by gas molecules hit by electrons in the avalanche;
Since the ratio ph/el is constant, more electrons are needed to have more photons;
Is it possible to stimulate the gas to produce light without ionising it?



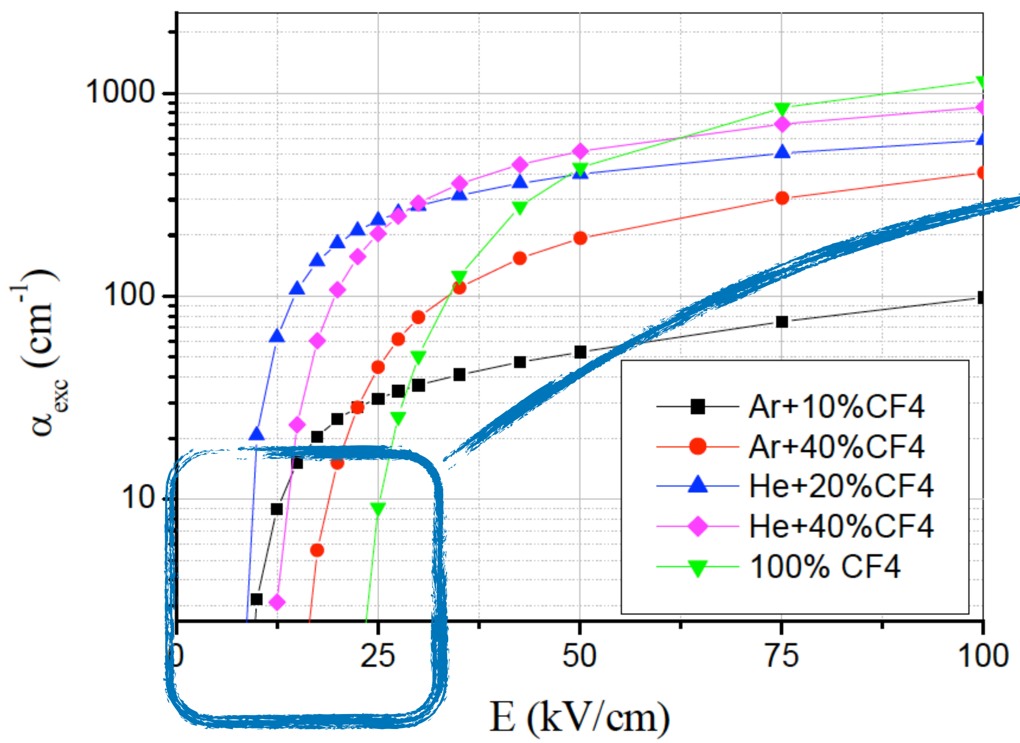
3 mm distance between mesh and GEM
ΔV= tension between mesh and GEM

We added a grid below the third GEM to accelerate electrons

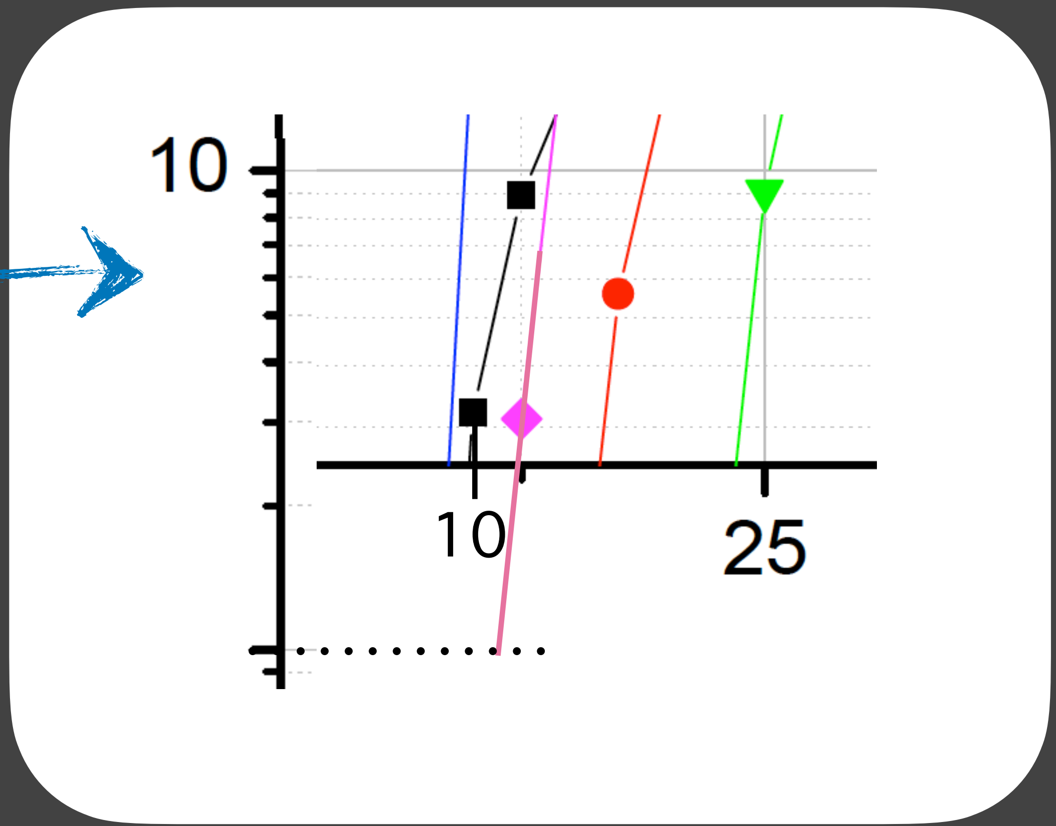
ELECTRO-LUMINESCENCE

The GEM scintillation in He-CF_4, Ar-CF_4, Ar-TEA and Xe-TEA mixtures

M. M. Fraga, F. A. F. Fraga, S. T. G. Fetal, L. M. S. Margato, R. Ferreira Marques and A. J. P. L. Policarpo



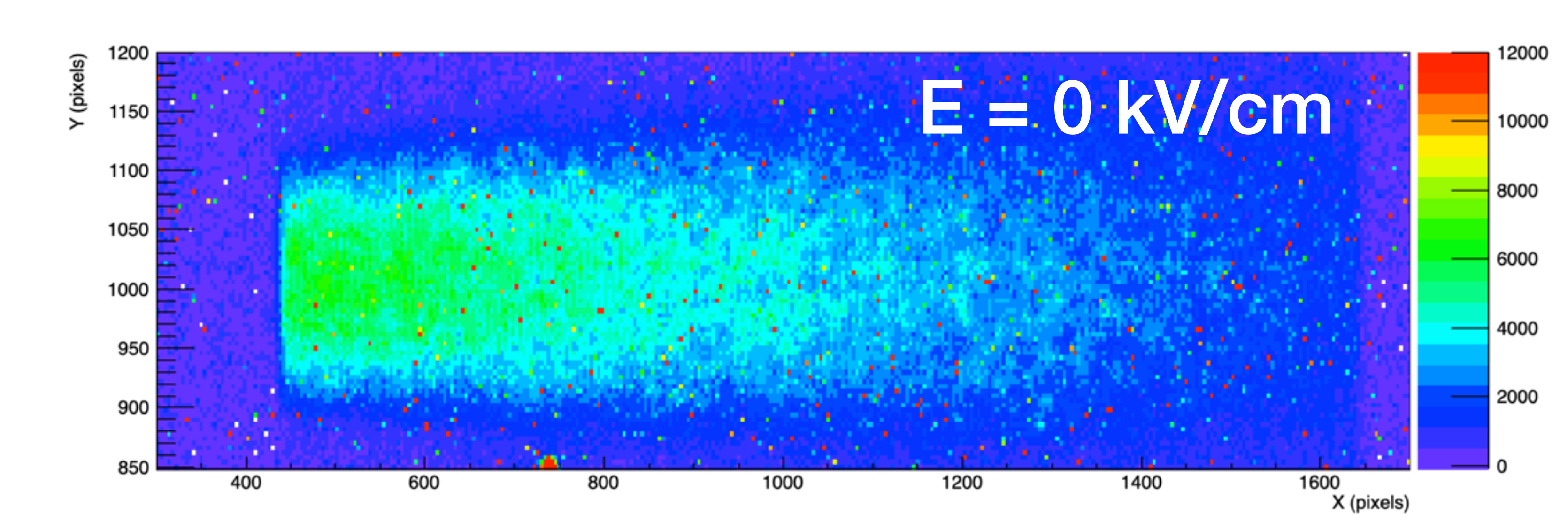
Number of collisions per cm leading to dissociation of CF_4 into neutral fragments, as a function of the electric field.



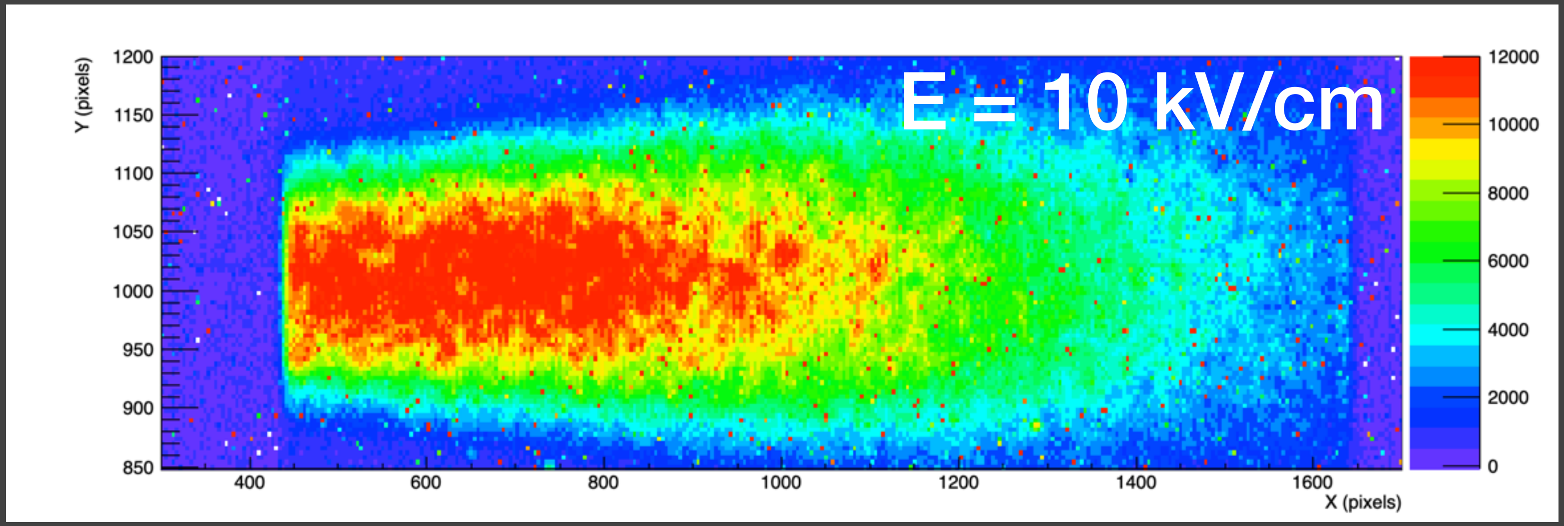
With a field of 10-12 kV/cm we expected 1 ph/el per cm

ELECTRO-LUMINESCENCE

We set a ΔV from 0 to 3.5 kV (unfortunately there were discharges and we stopped there), i.e. an electric field from 0 to 11.5 kV/cm;
Detector was illuminated with a strong ^{55}Fe

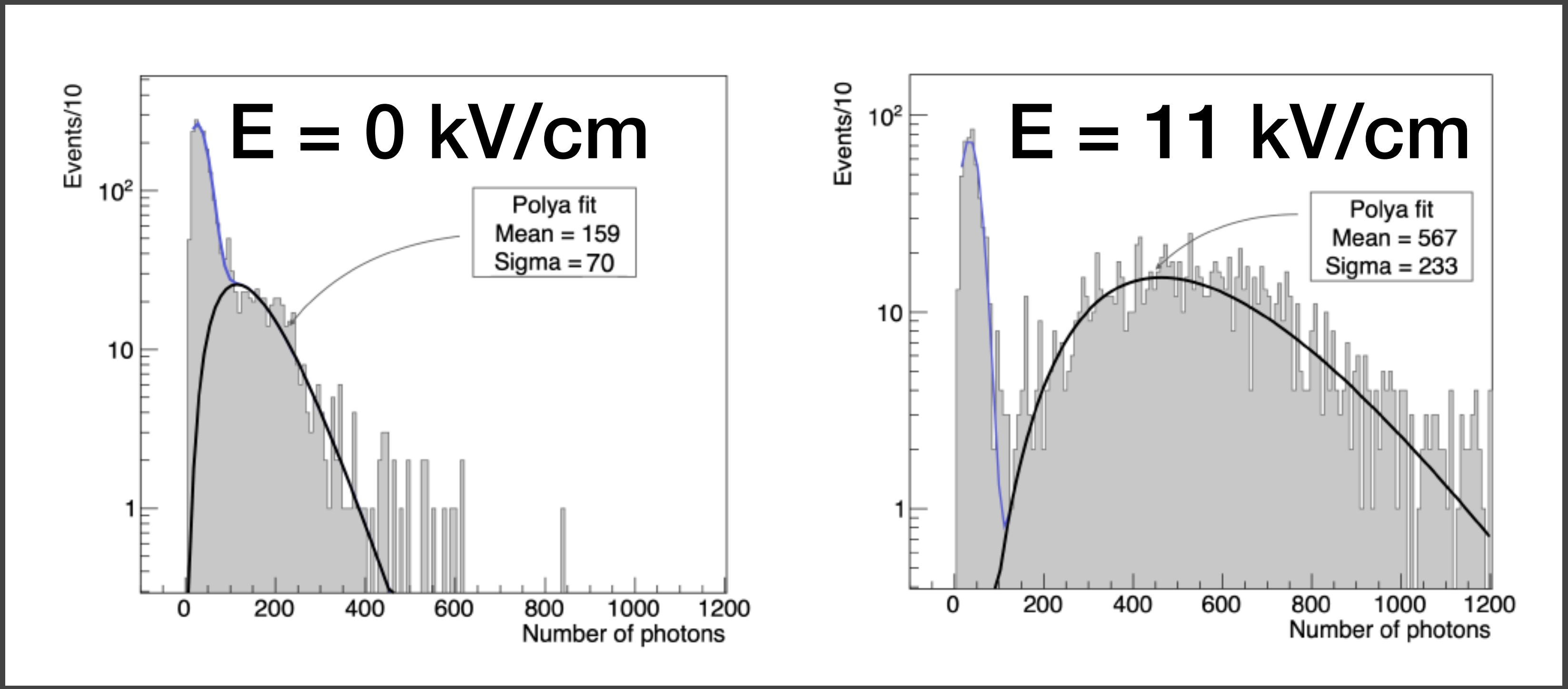


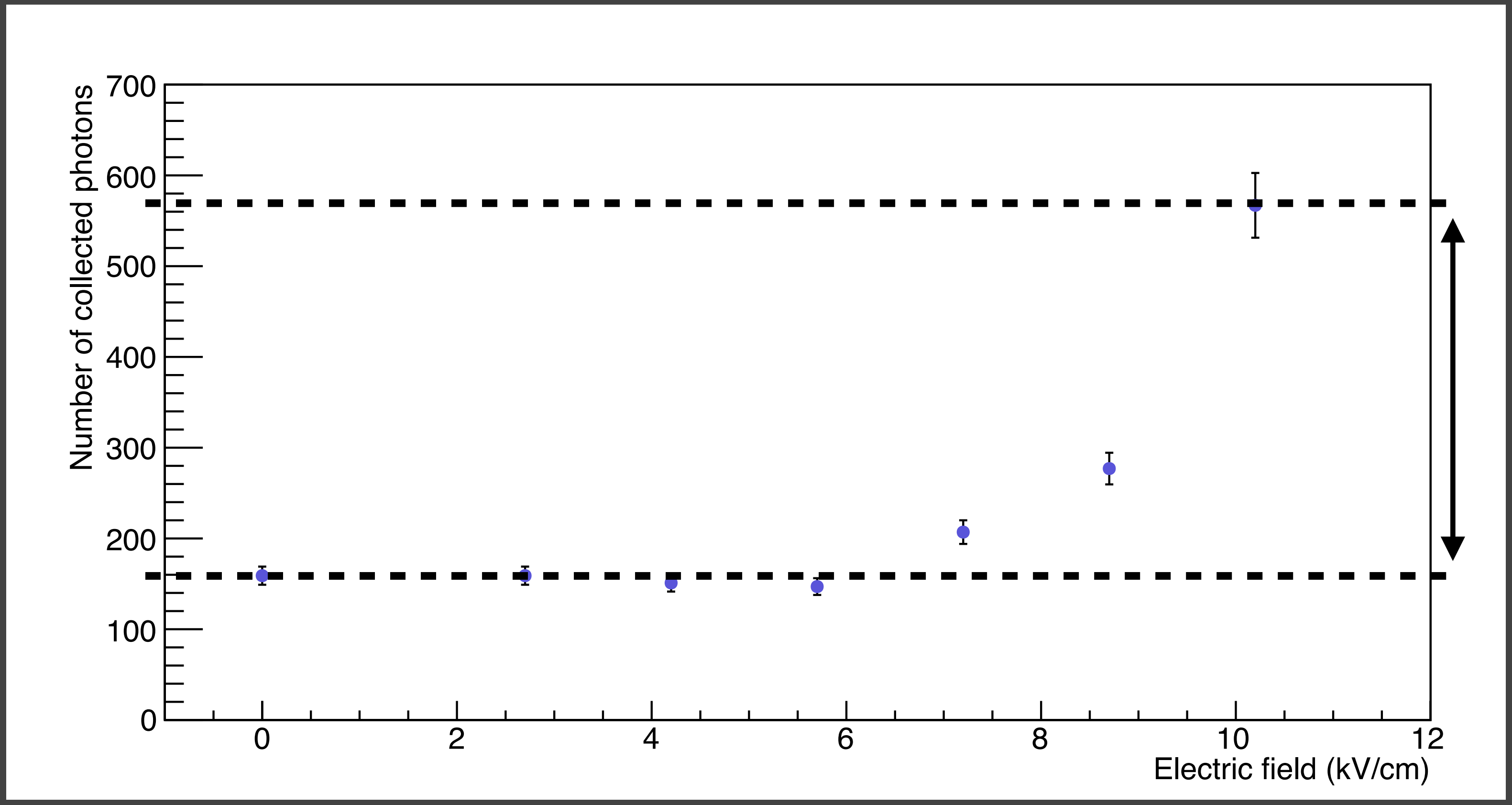
Photon yield visibly increases



ELECTRO-LUMINESCENCE

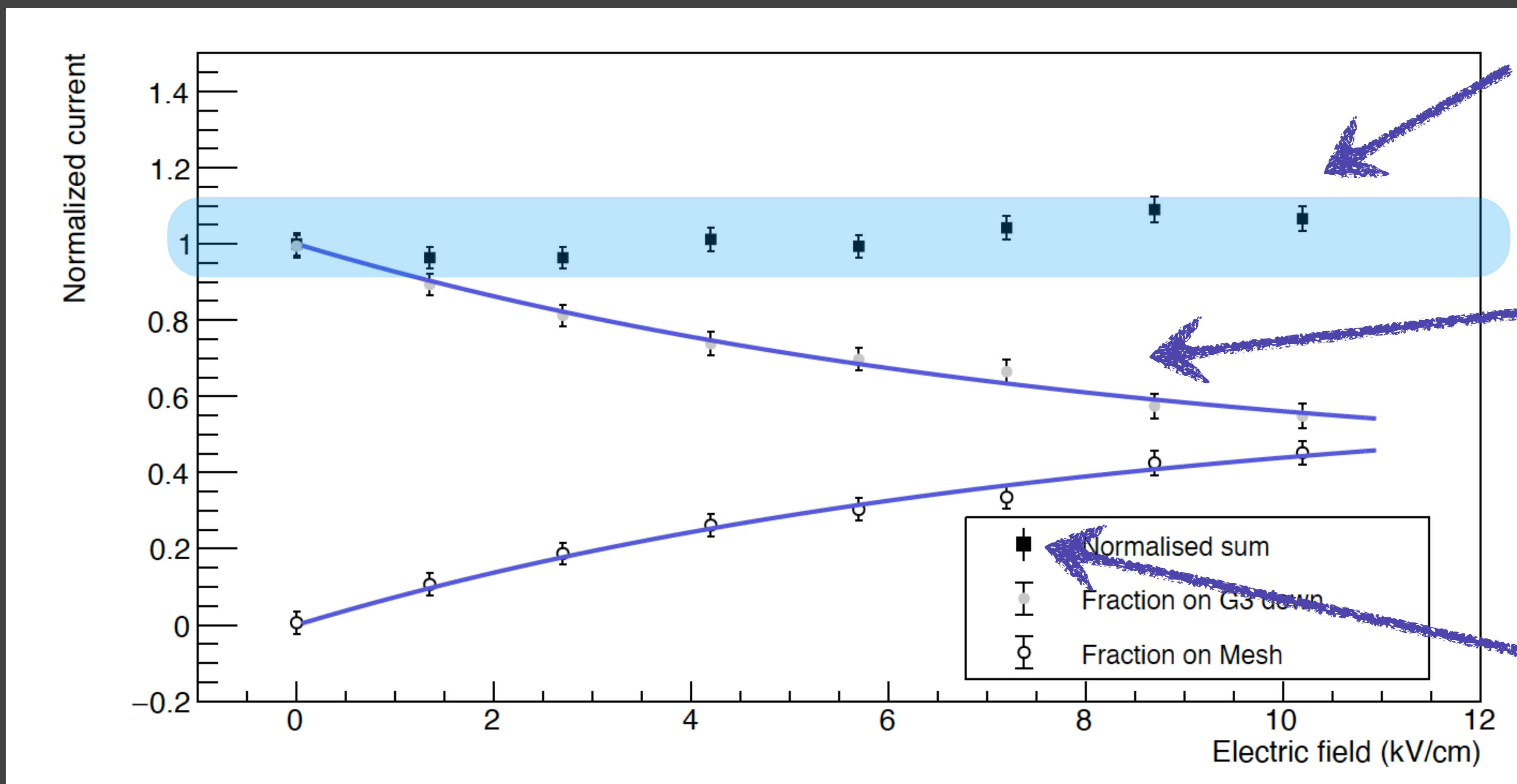
Short exposure data (100 x 0.5 sec) to study in detail the ^{55}Fe peak position;





400 photons more

The currents drawn by the bottom electrode of last GEM and by the mesh were monitored, to check possible increase in total charge, indicating a multiplication process

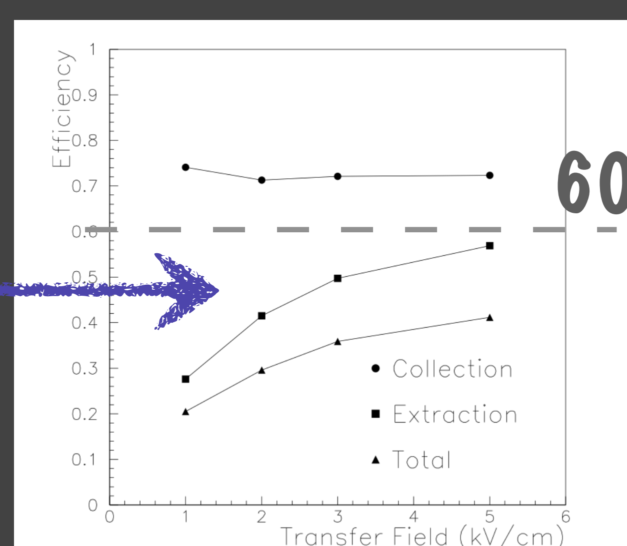


Sum of currents

Fraction of current on $G3_{down}$

Fraction of current on Mesh (at max 60%)

Garfield simu



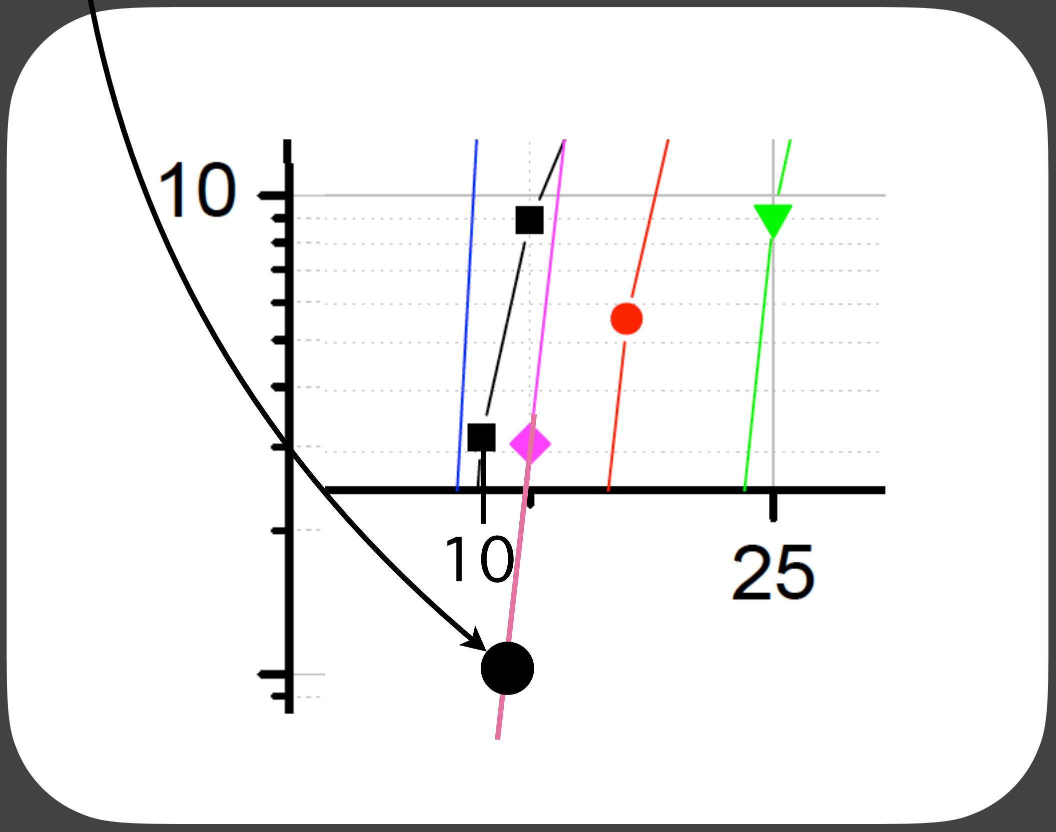
Sum is constant and sharing changes

We can now evaluate the “photon production efficiency”

$$\alpha_{\rm exc}(E_{\rm A}) = \alpha_{\rm GEM} \times \frac{1}{\epsilon_{extr}(E_{\rm A})} \times \frac{1}{\Delta z} \times \frac{n_{\rm exc}(E_{\rm A})}{n_{\rm GEM}} = 1.2 \ \pm \ 0.2 \ {\rm cm}^{-1}$$

0.4 ph/electron in 3 mm gaps, means a mean free path of about 1 cm

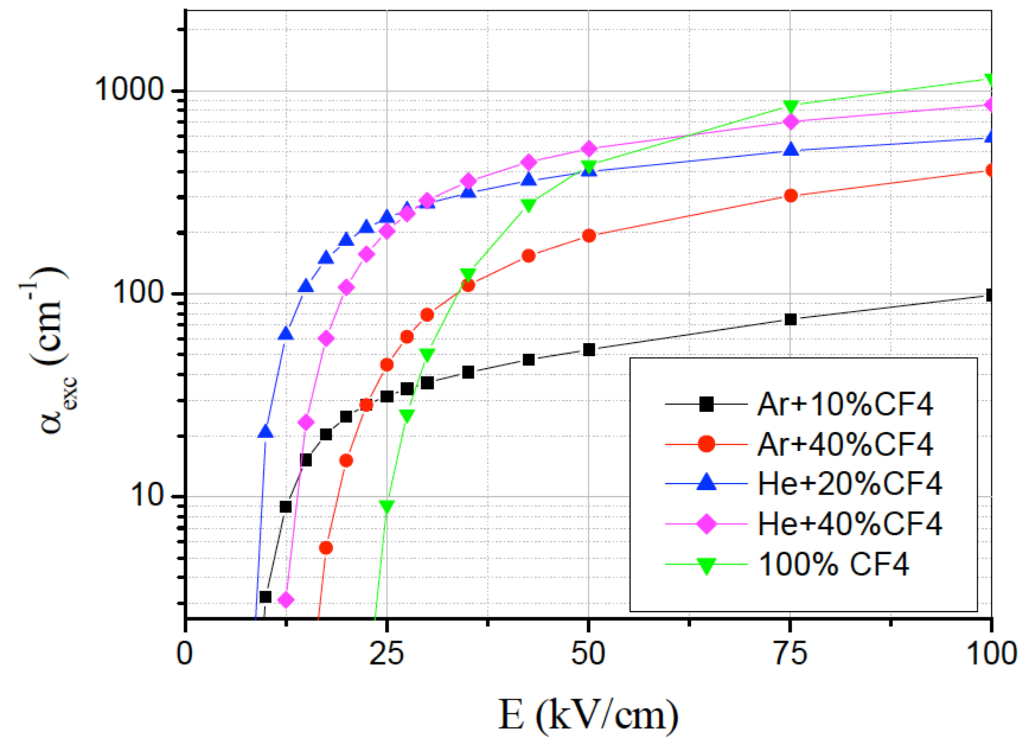
Good agreement



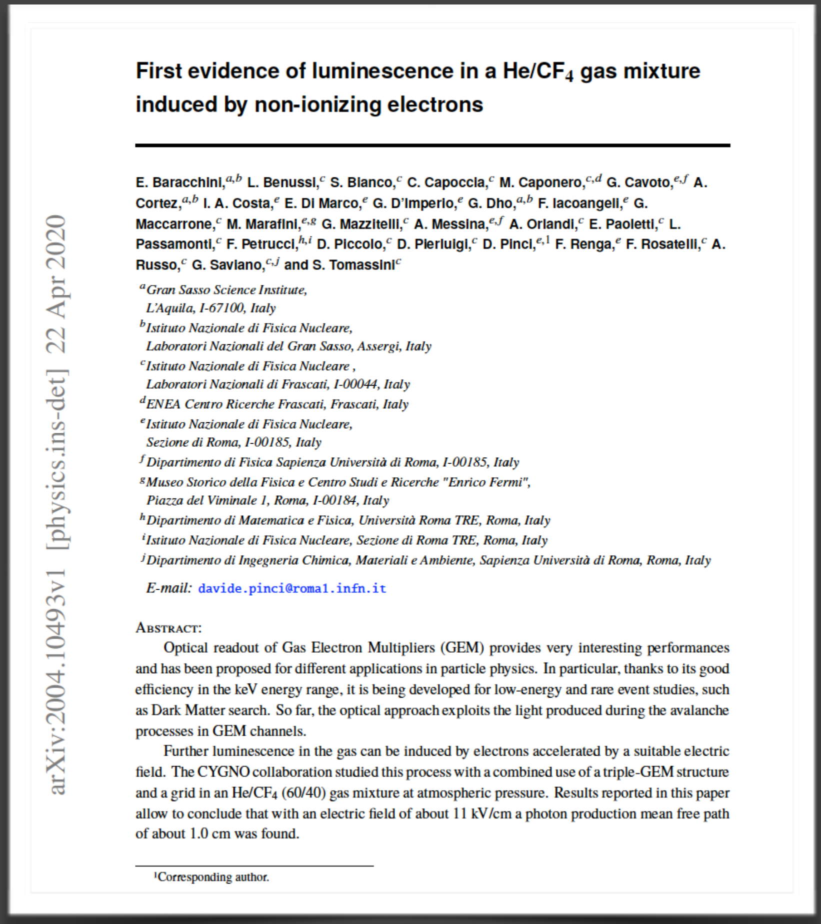
ELECTRO-LUMINESCENCE

Since the production efficiency increase very quickly with the electric field, by putting ΔV to 4.5 kV (i.e. with an electric field of 15 kV/cm) we can have 30 ph/el/cm

Therefore, with a 3 mm distant gap, we should be able to reduce the electron gain by a factor 10 and have a linear behavior;



Number of collisions per cm leading to dissociation of CF_4 into neutral fragments, as a function of the electric field.



First evidence of luminescence in a He/CF_4 gas mixture induced by non-ionizing electrons

E. Baracchini,[a,b] L. Benussi,[c] S. Bianco,[c] C. Capoccia,[c] M. Caponero,[c,d] G. Cavoto,[e,f] A. Cortez,[a,b] I. A. Costa,[e] E. Di Marco,[e] G. D'Imperio,[e] G. Dho,[a,b] F. Iacoangeli,[e] G. Maccarrone,[c] M. Marafini,[e,g] G. Mazzitelli,[c] A. Messina,[e,f] A. Orlandi,[c] E. Paoletti,[c] L. Passamonti,[c] F. Petrucci,[h,i] D. Piccolo,[c] D. Pierluigi,[c] D. Pinci,[e,1] F. Renga,[e] F. Rosatelli,[c] A. Russo,[c] G. Saviano,[c,j] and S. Tomassini[c]

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[b] *Istituto Nazionale di Fisica Nucleare, Laboratori Nazionali del Gran Sasso, Assergi, Italy*
[c] *Istituto Nazionale di Fisica Nucleare , Laboratori Nazionali di Frascati, I-00044, Italy*
[d] *ENEA Centro Ricerche Frascati, Frascati, Italy*
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[f] *Dipartimento di Fisica Sapienza Università di Roma, I-00185, Italy*
[g] *Museo Storico della Fisica e Centro Studi e Ricerche "Enrico Fermi", Piazza del Viminale 1, Roma, I-00184, Italy*
[h] *Dipartimento di Matematica e Fisica, Università Roma TRE, Roma, Italy*
[i] *Istituto Nazionale di Fisica Nucleare, Sezione di Roma TRE, Roma, Italy*
[j] *Dipartimento di Ingegneria Chimica, Materiali e Ambiente, Sapienza Università di Roma, Roma, Italy*

E-mail: davide.pinci@roma1.infn.it

ABSTRACT:

Optical readout of Gas Electron Multipliers (GEM) provides very interesting performances and has been proposed for different applications in particle physics. In particular, thanks to its good efficiency in the keV energy range, it is being developed for low-energy and rare event studies, such as Dark Matter search. So far, the optical approach exploits the light produced during the avalanche processes in GEM channels.

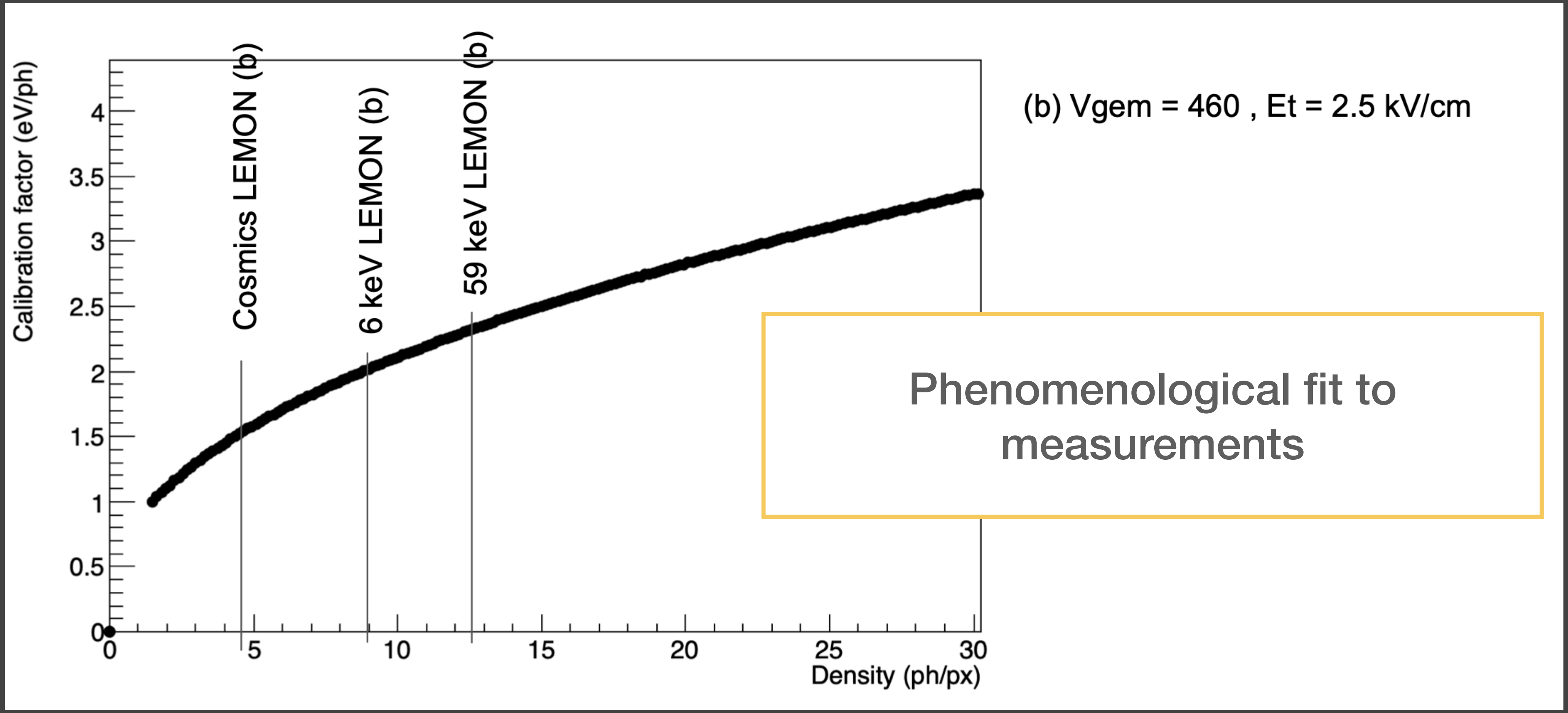
Further luminescence in the gas can be induced by electrons accelerated by a suitable electric field. The CYGNO collaboration studied this process with a combined use of a triple-GEM structure and a grid in an He/CF_4 (60/40) gas mixture at atmospheric pressure. Results reported in this paper allow to conclude that with an electric field of about 11 kV/cm a photon production mean free path of about 1.0 cm was found.

[1]Corresponding author.

arXiv:2004.10493v1 [physics.ins-det] 22 Apr 2020

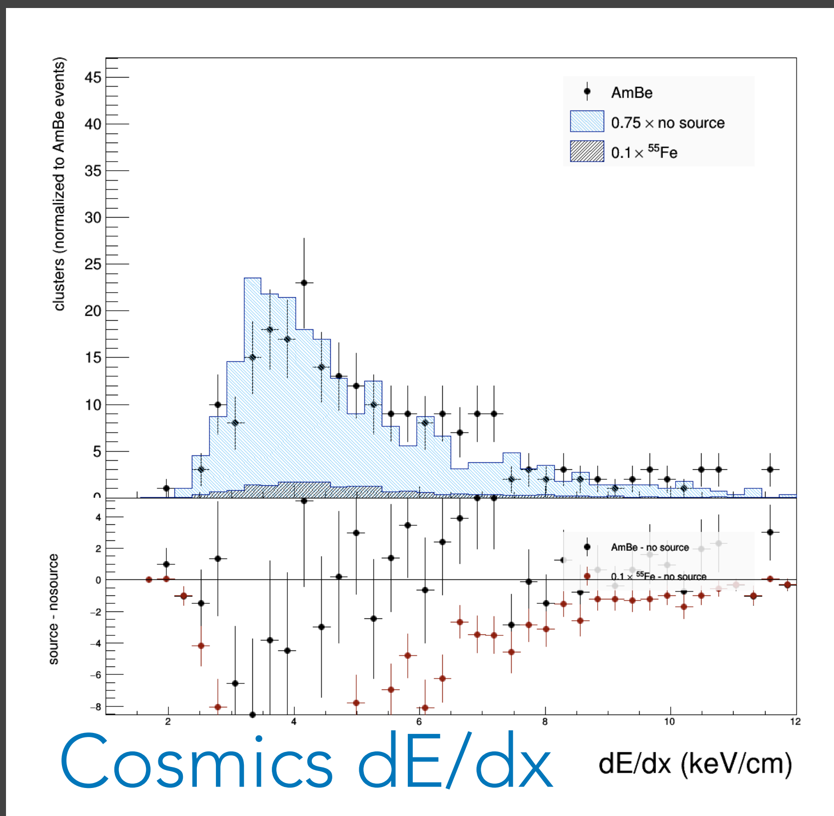
GAIN NON LINEARITY

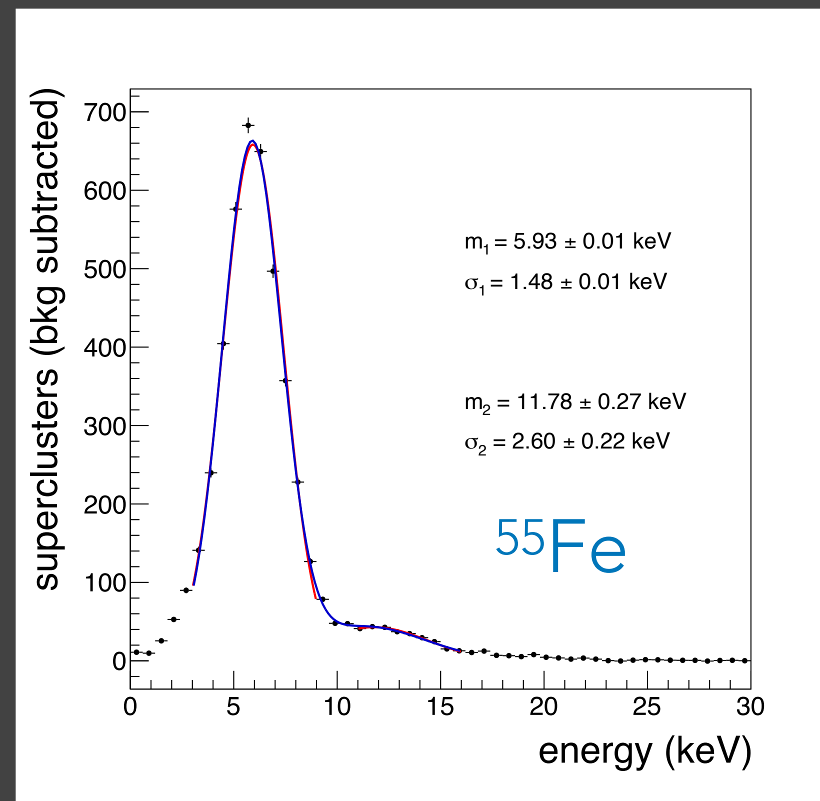
The other method is a "software" compensation of the non linearity based on measurements

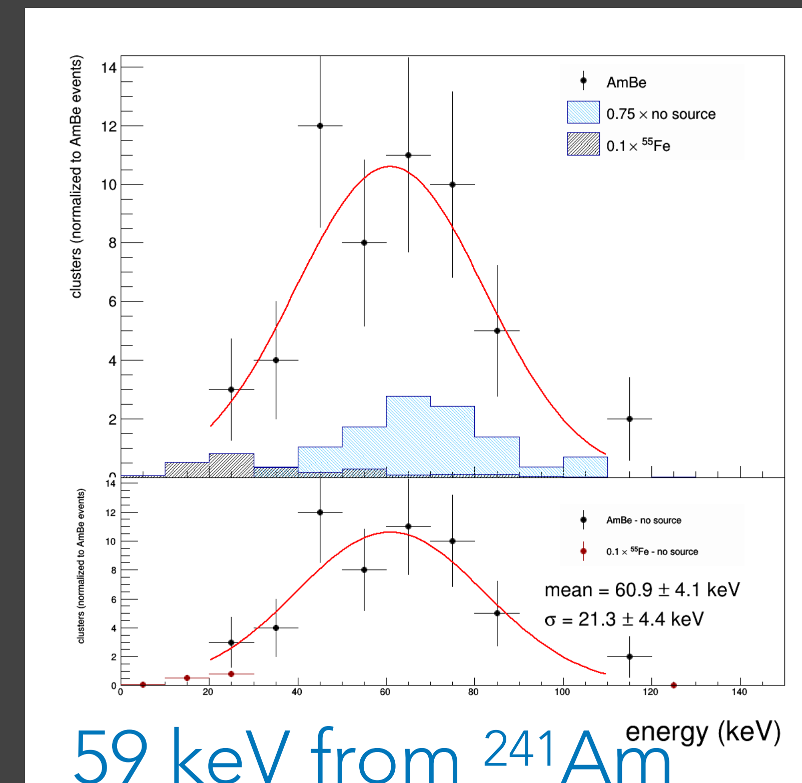


For the moment we tried to use a **running sensitivity constant** (eV/ph) dependent on the light density (ph/pixel) for an average correction of signal energy

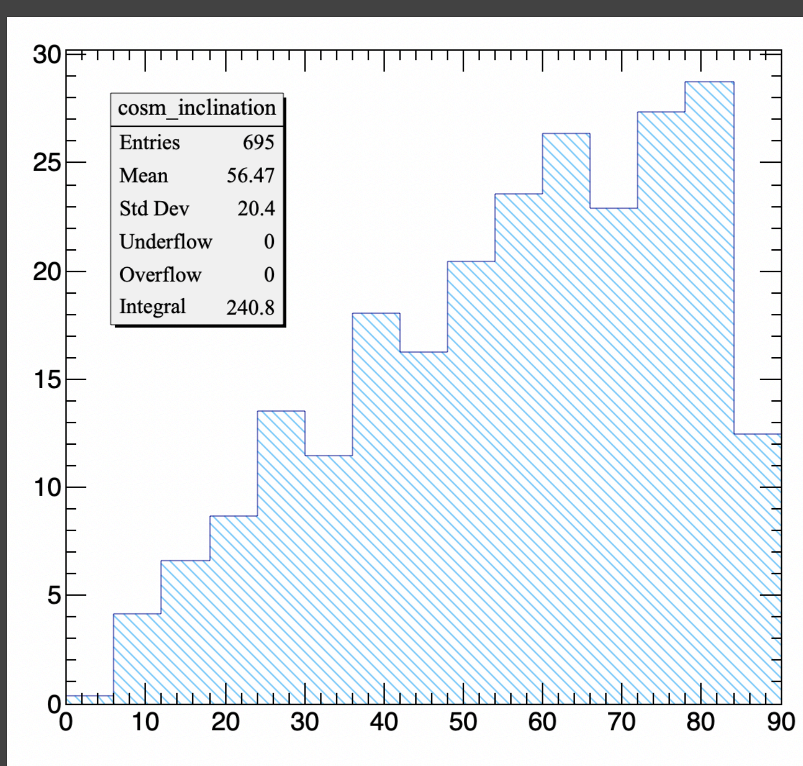
GAIN NON LINEARITY







60.9 keV in good agreement with 59 keV expected



Once corrected by the average angle:

$\text{mode}_{dE/dx}$ = 2.5 keV/cm

(instead of 2.3 keV/cm)

BACKGROUND REJECTION

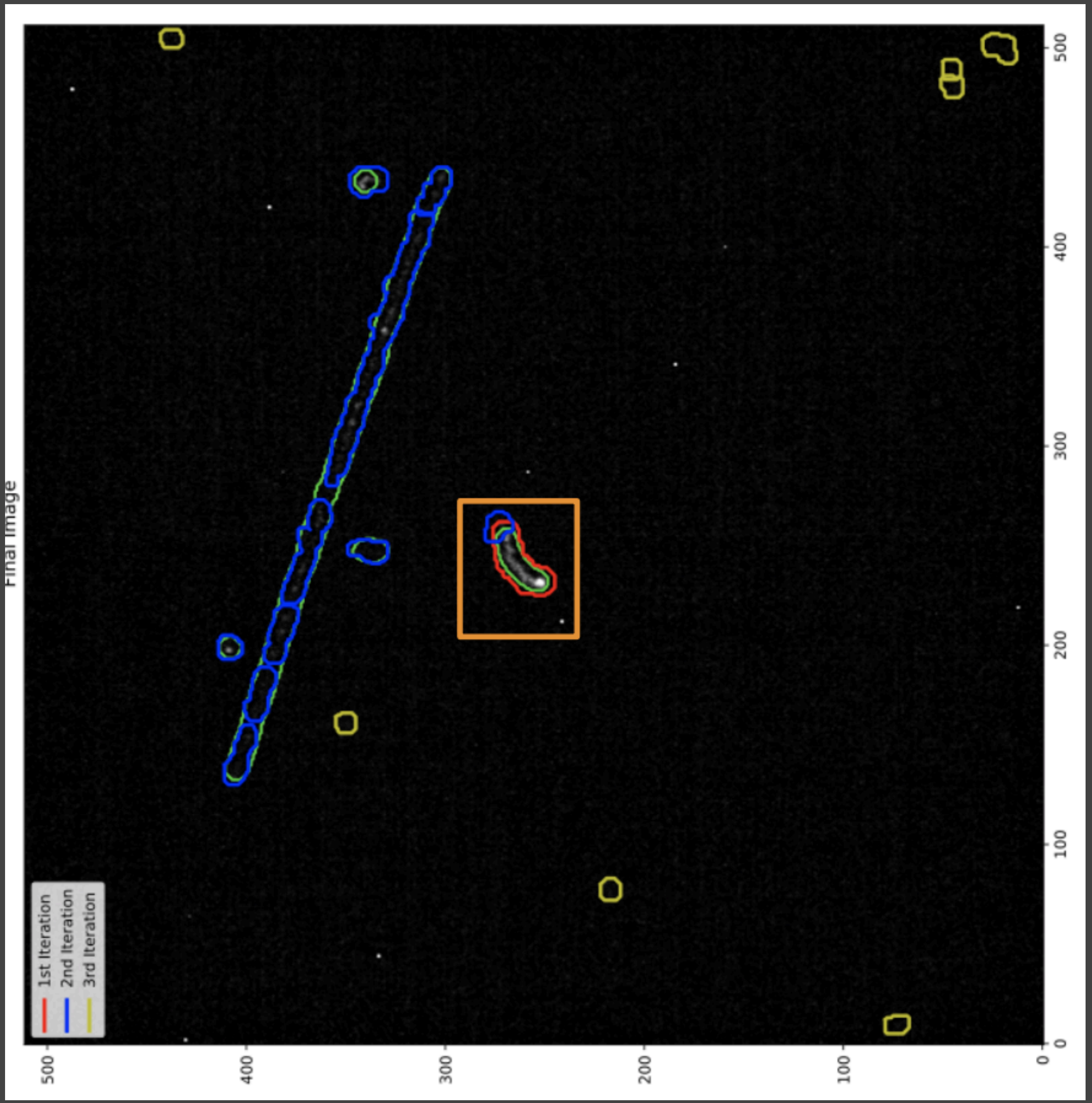
To evaluate the background (electron recoils) rejection capability and the signal (nuclear recoils) efficiency, we tested LEMON with ^{55}Fe and AmBe sources.

AmBe produces:

- 59 keV photons;
- 4 MeV photons;
- 1-10 MeV neutrons;

A 5 cm Pb shield was used

Unfortunately in all cases cosmics and natural radioactivity produce an unknown background that piles-up to signals.
Need to go underground.



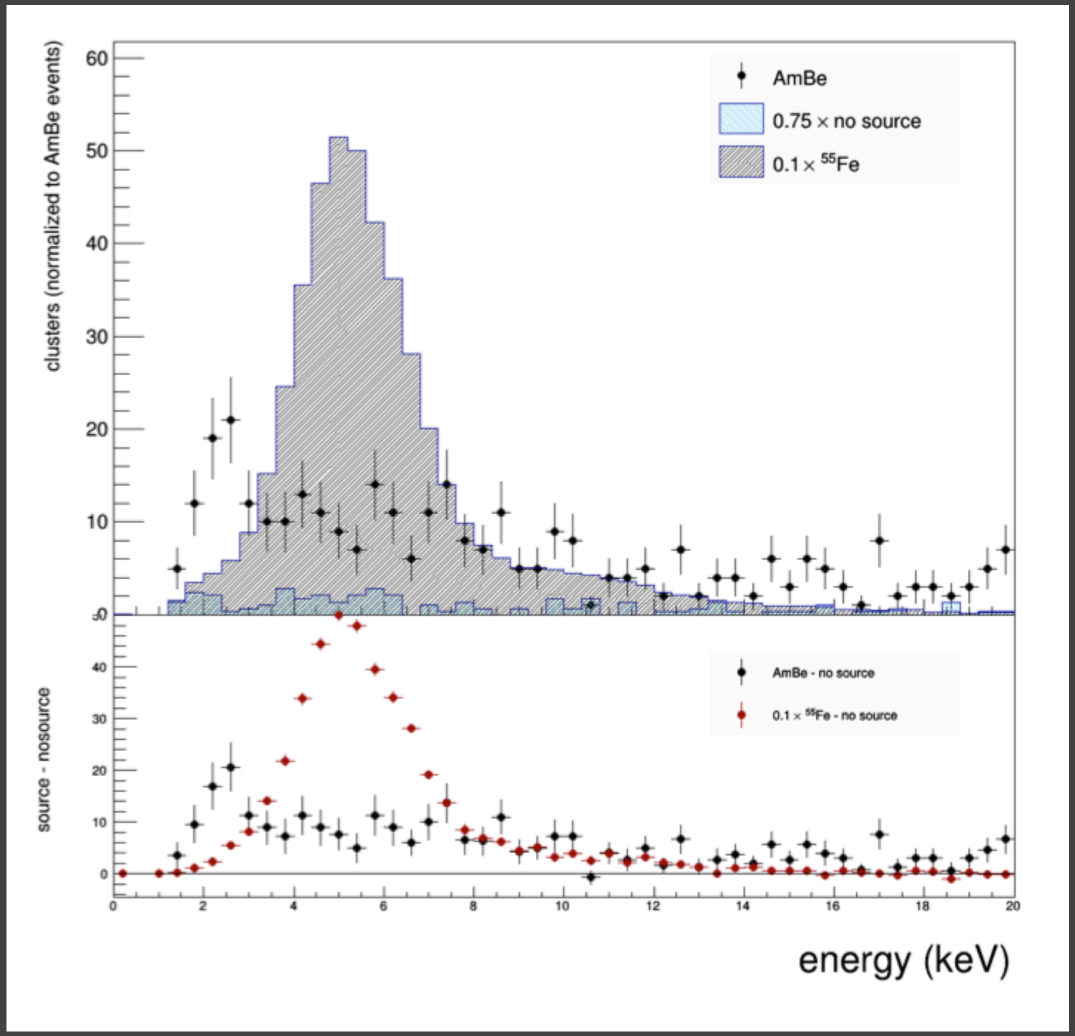
BACKGROUND REJECTION

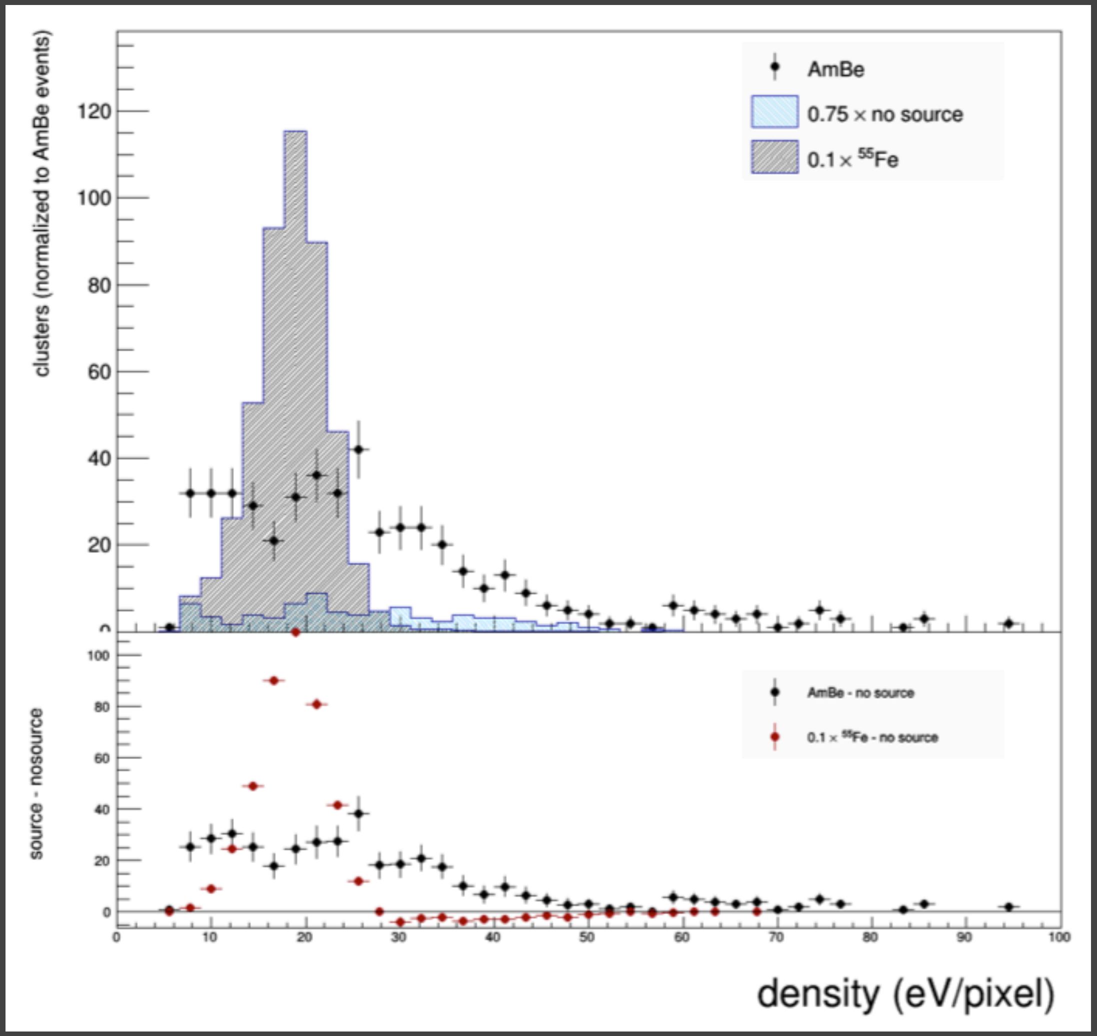
In both cases, after energy re-calibration, a first event selection was applied:

- Field cage efficient region (geometry);
- Track length < 6 cm and slimness > 0.3 (remove cosmics);
- Density > 5 ph/pix (remove residual split cosmic tracks);
- 60 keV component removed;

BACKGROUND REJECTION

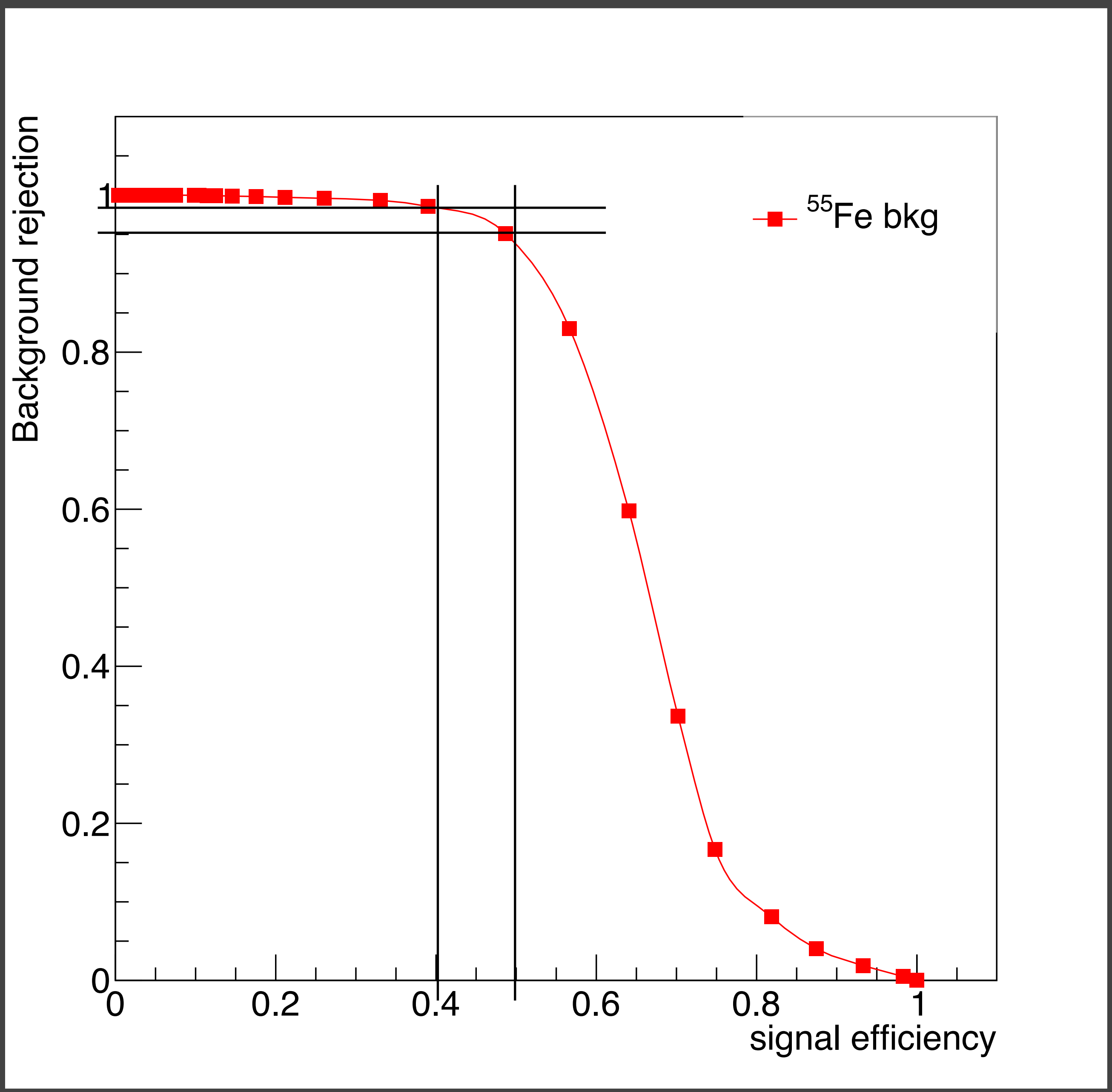
We evaluated the distributions of re-calibrated energy and density for the selected samples





BACKGROUND REJECTION

Adding selection on the final variable (energy density):

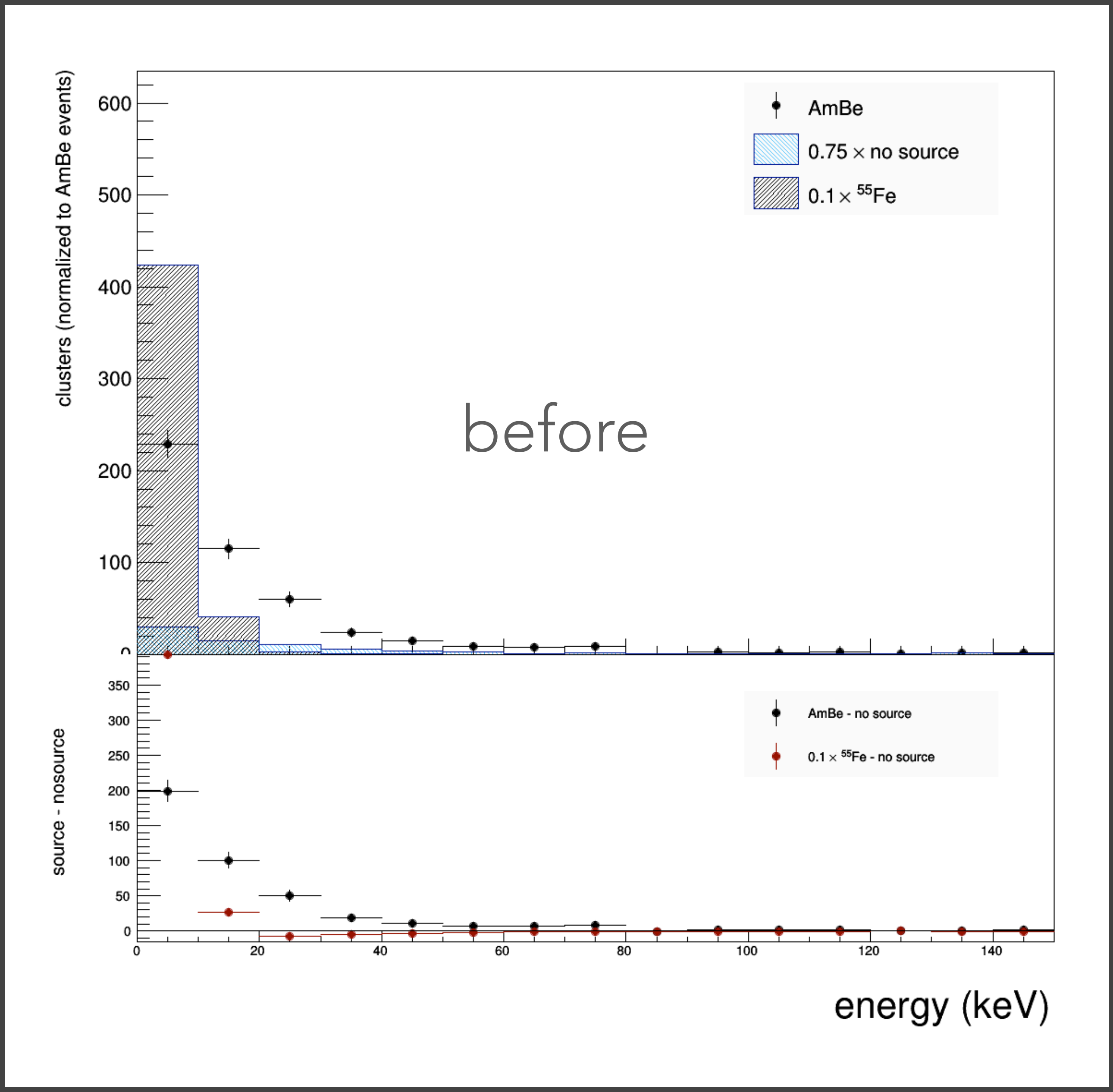


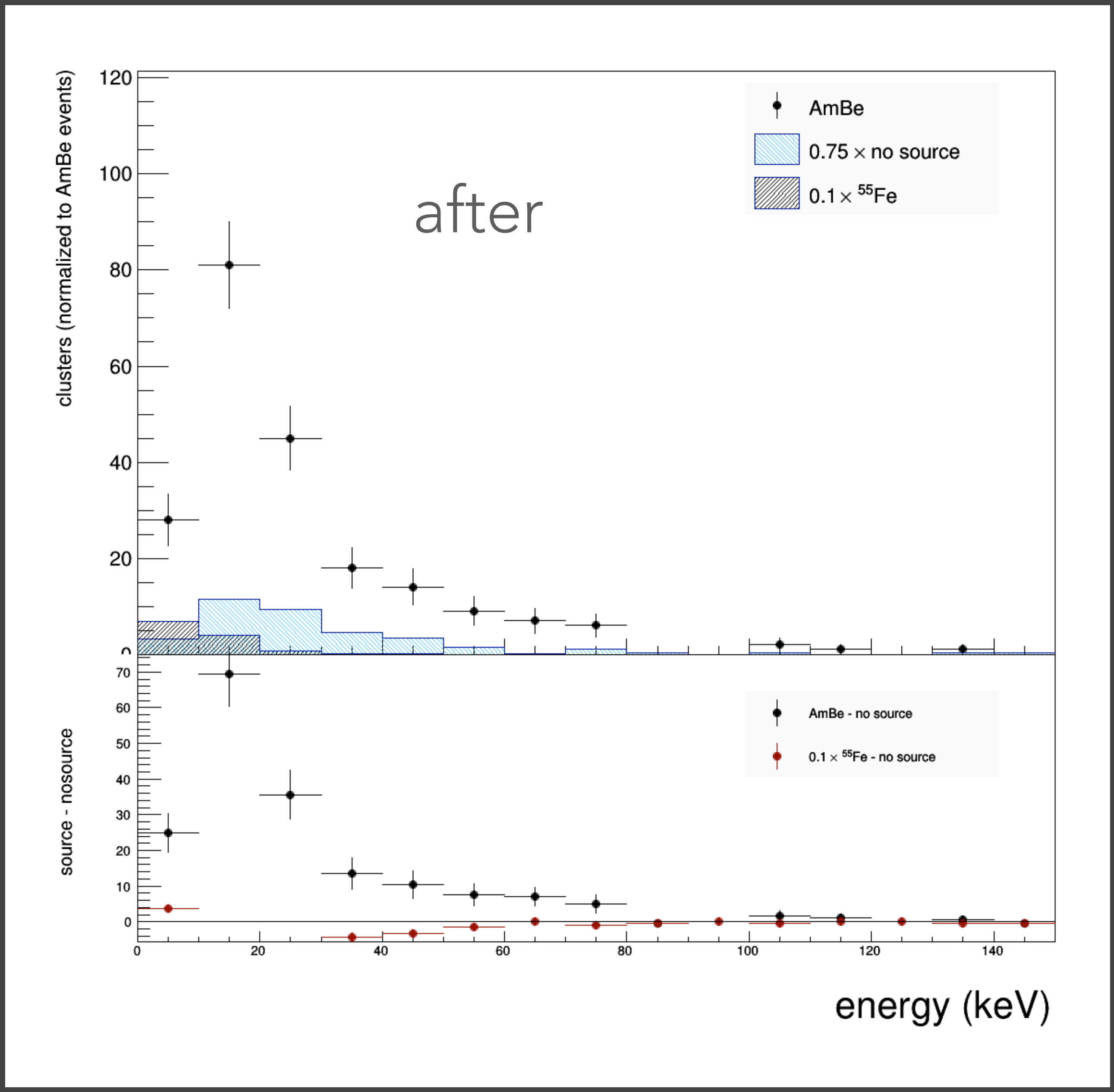
- eff(S) ~ 50% [40%]
- eff(B) ~ 0.88 * 0.05 [0.012] ~ 4% [1%]

Background suppression of 10^{-2} together with a signal efficiency of 40%

SIGNAL EFFICIENCY

Comparing the signal spectra and after the cuts:





SIGNAL EFFICIENCY

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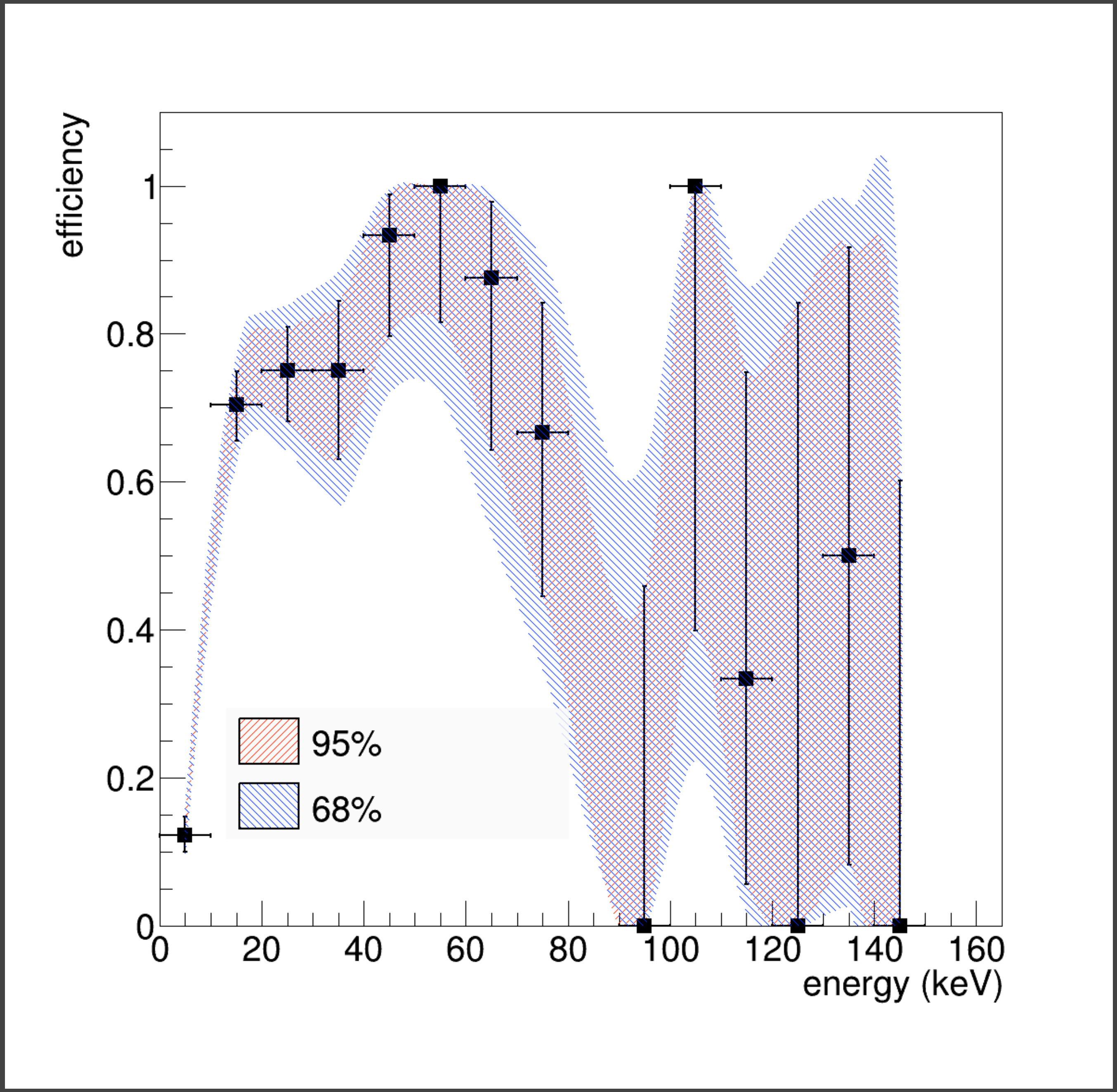
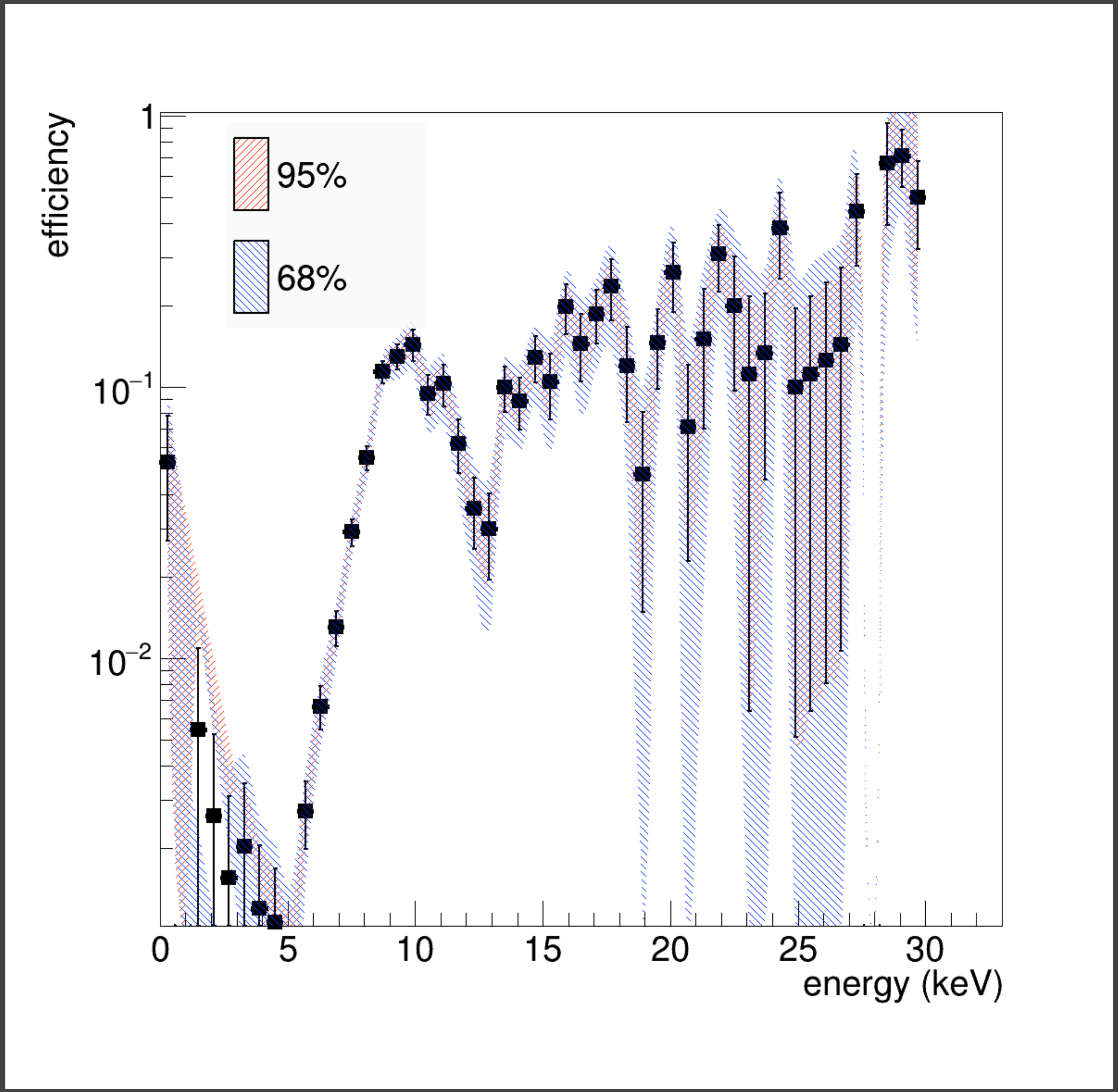




SITUATION AT LNGS

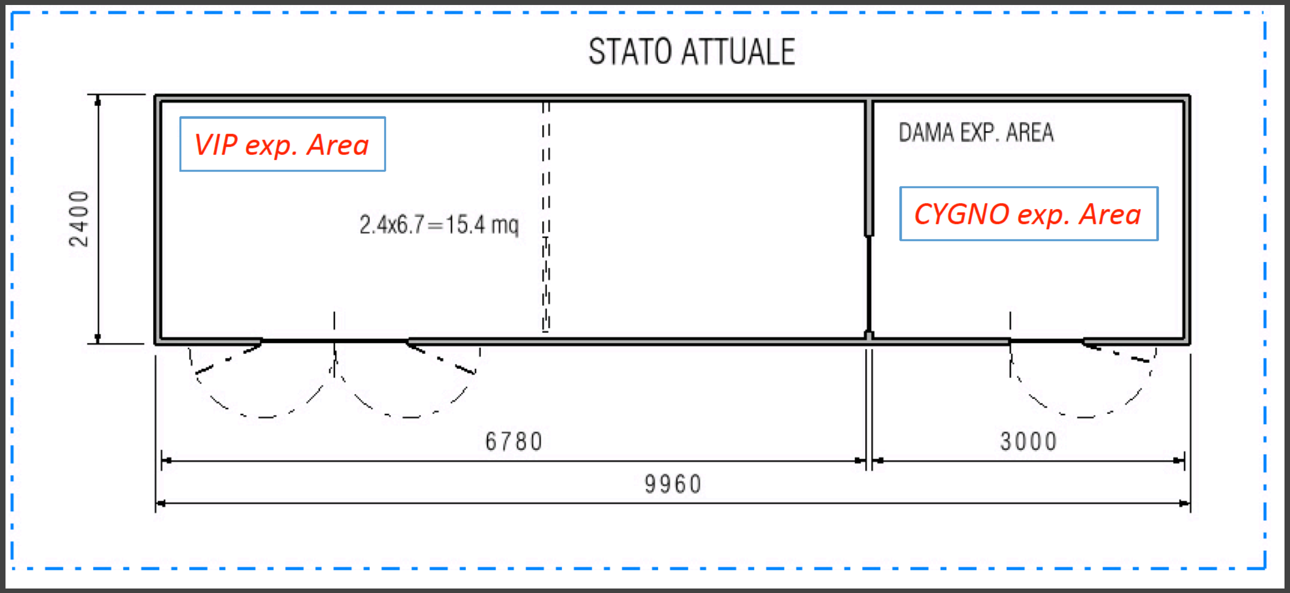
We had a meeting with LNGS Director in November.

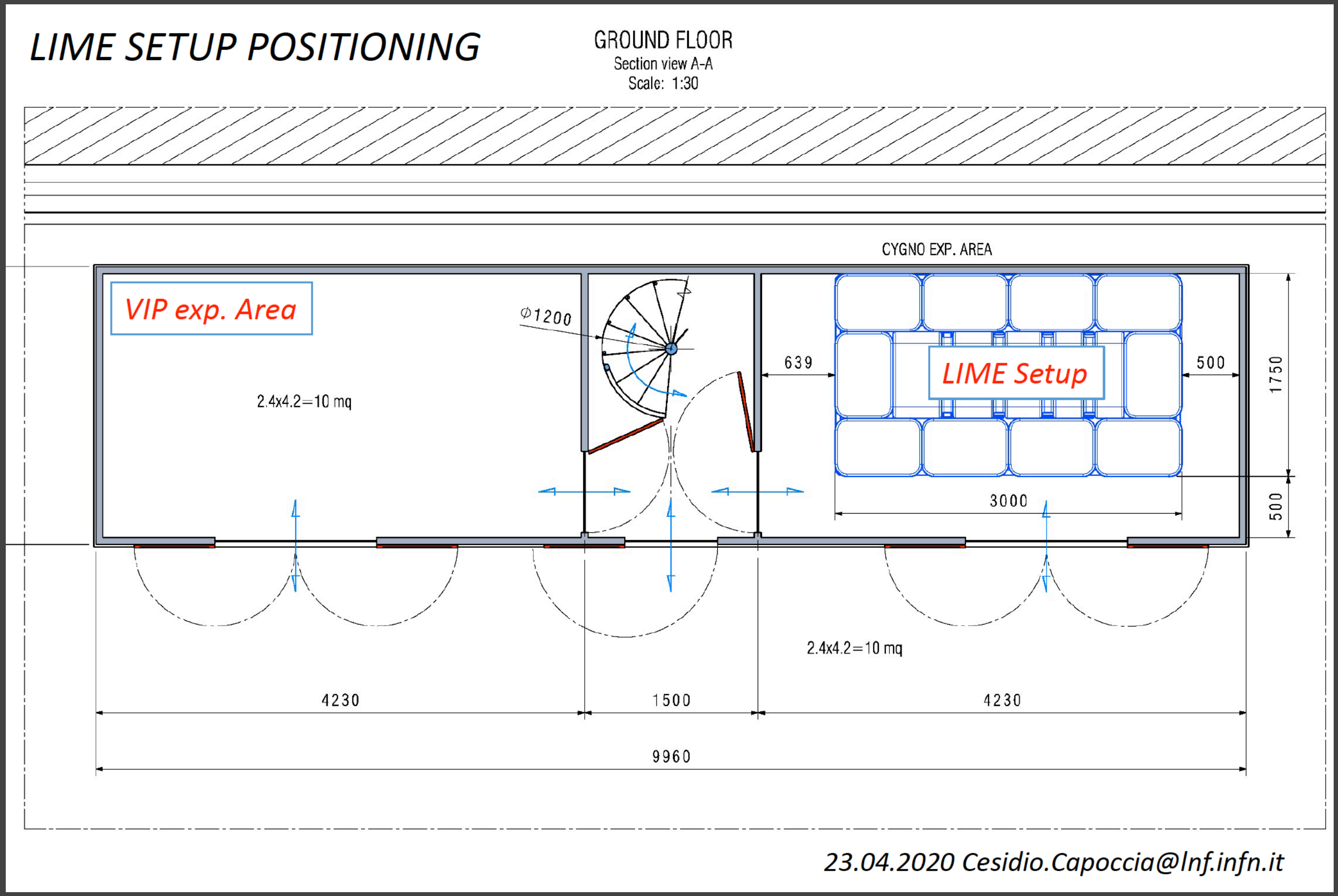
Beginning of February, we made an inspection to Lab proposed for LIME

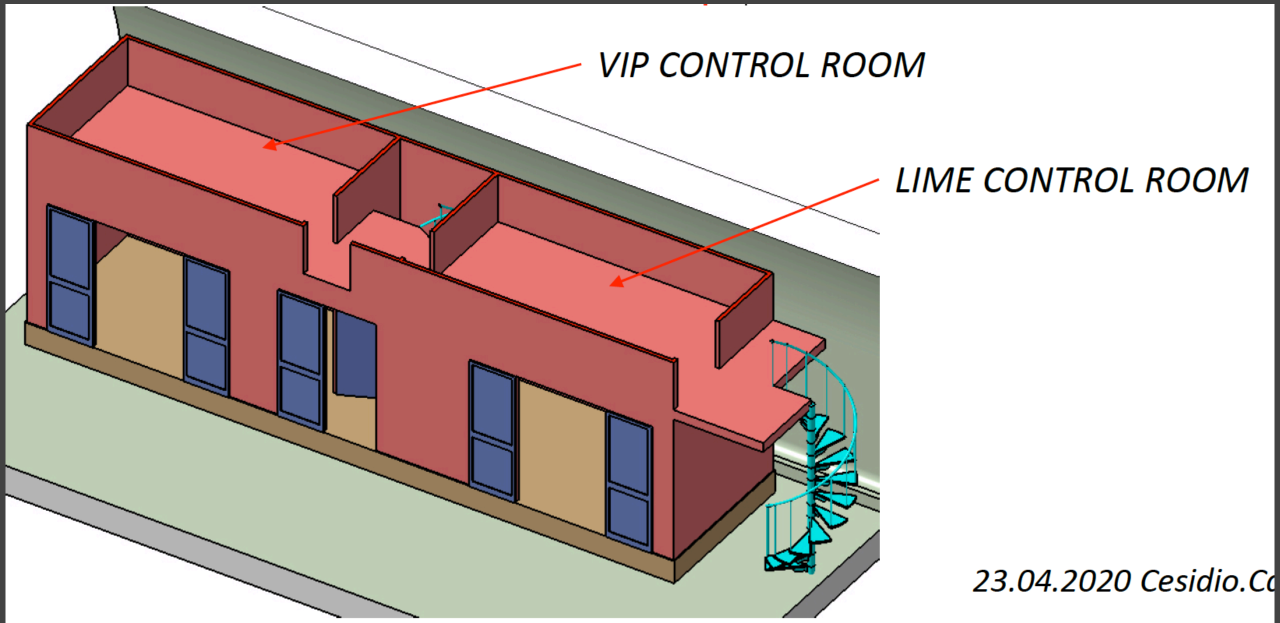
We can easily fit LIME and test shieldings

It's hard to foresee the future of the organisation of room at LNGS

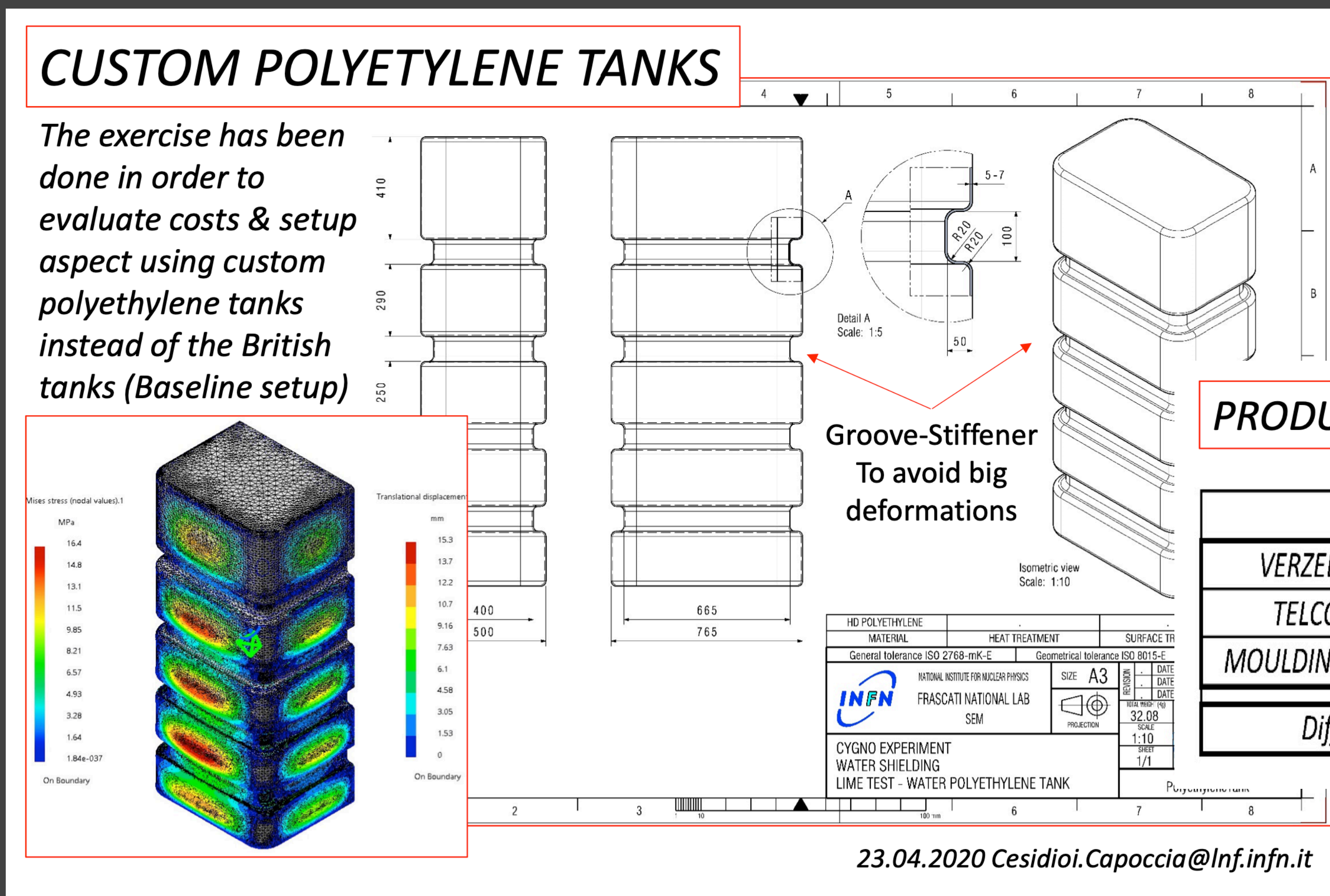
SITE INSPECTION







LIME SHIELD



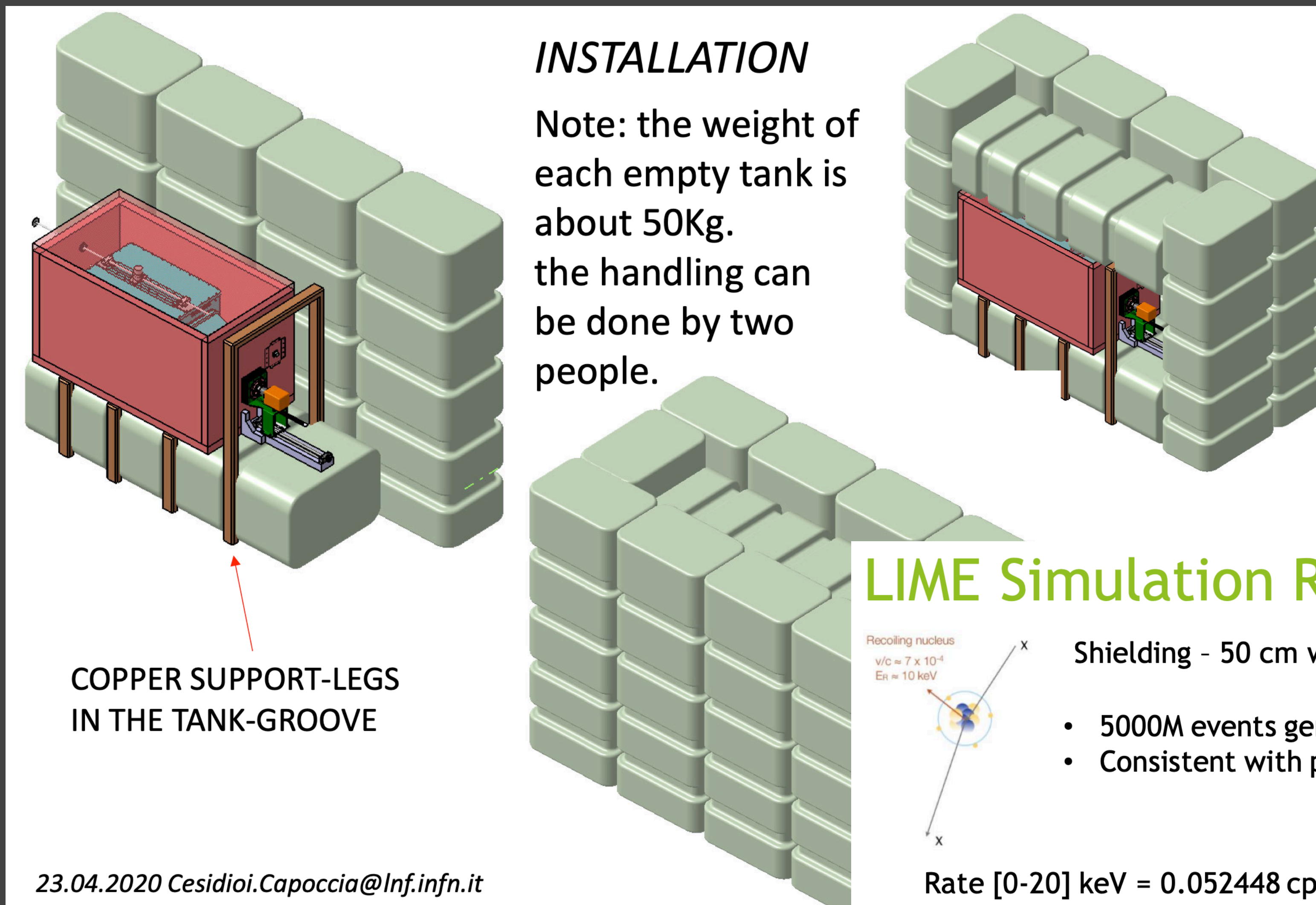
We are investigating the possibility of building custom tanks

PRODUCTION COSTS

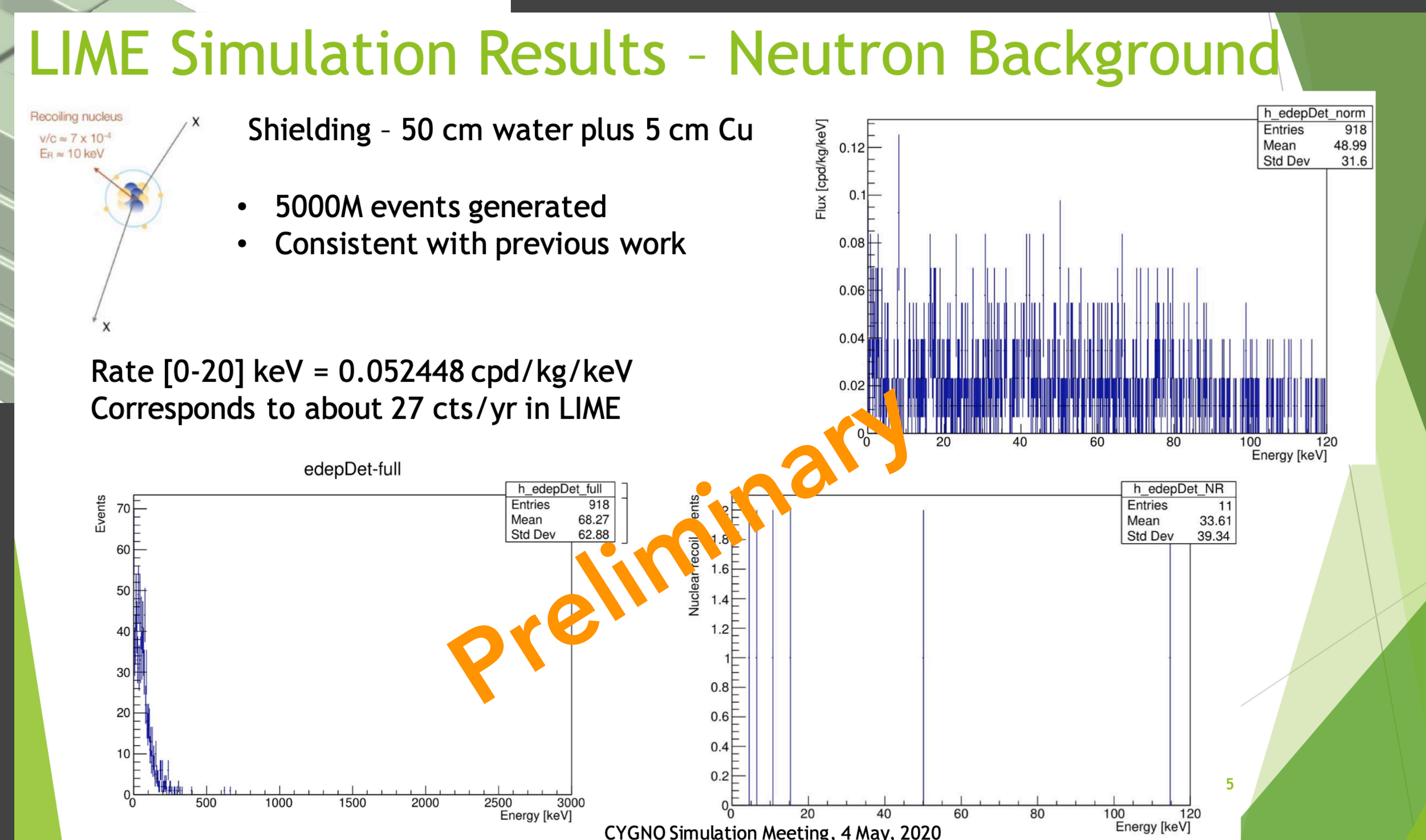
	MOLD-TOOLING	DRAW-DOCUM	ROT. MOULDING	N.TANK	TOTAL
VERZELLESI SRL	Refused to carry out an evaluation due to the low quantity				
TELCOM SPA	€ 42,500.00	€ 3,000.00	€ 260.00	12	€ 48,620.00
MOULDING SERV. SRL	€ 15,900.00	€ 1,200.00	€ 235.00	12	€ 19,920.00
Diff (%)	267%	250%	111%		244%

- LIME shield would cost 20 k€, 16 k€ of "tooling" and 250 €/tank
- this would significantly reduce the cost of CYGNO shield

LIME SHIELD



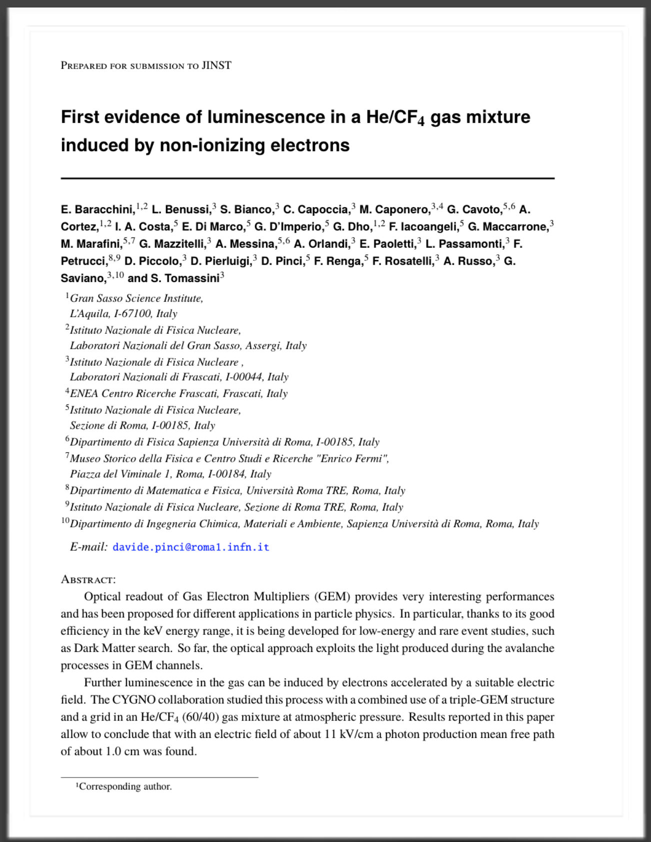
We started studying 50 cm water + 5 cm copper shield



PAPERS AND WORKSHOPS

Two papers submitted


A GEM-based Optically Readout Time Projection Chamber for charged particle tracking


Prepared for submission to JINST

First evidence of luminescence in a He/CF_4 gas mixture induced by non-ionizing electrons

Two papers under internal review


Prepared for submission to JINST

A density-based clustering algorithm for the CYGNO data analysis


Prepared for submission to JINST

Stability and detection performance of a GEM-based Optical Readout TPC with He/CF_4 based gas mixtures

We proposed 3 talks to RD51 workshop in June (on-line only)