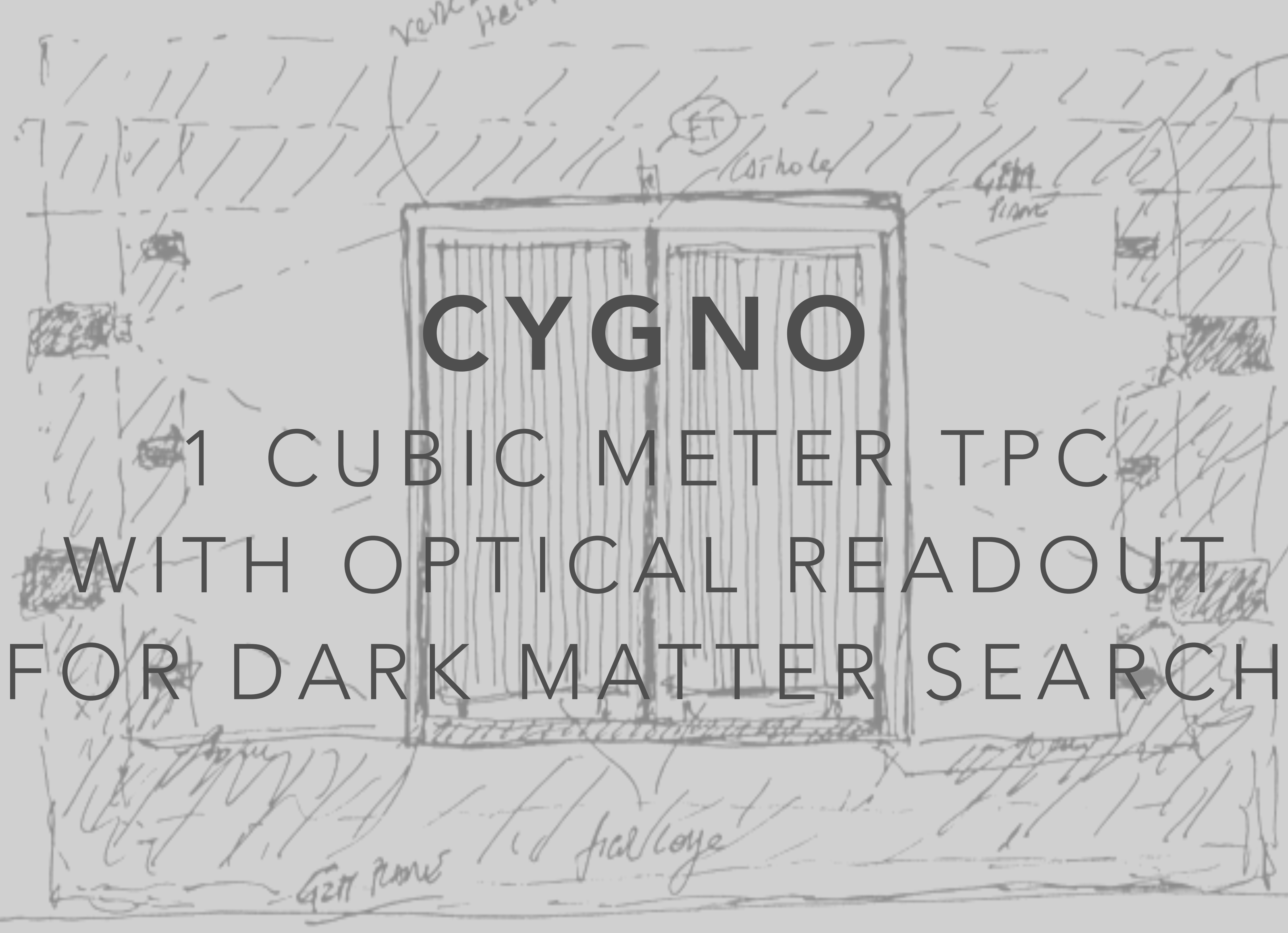


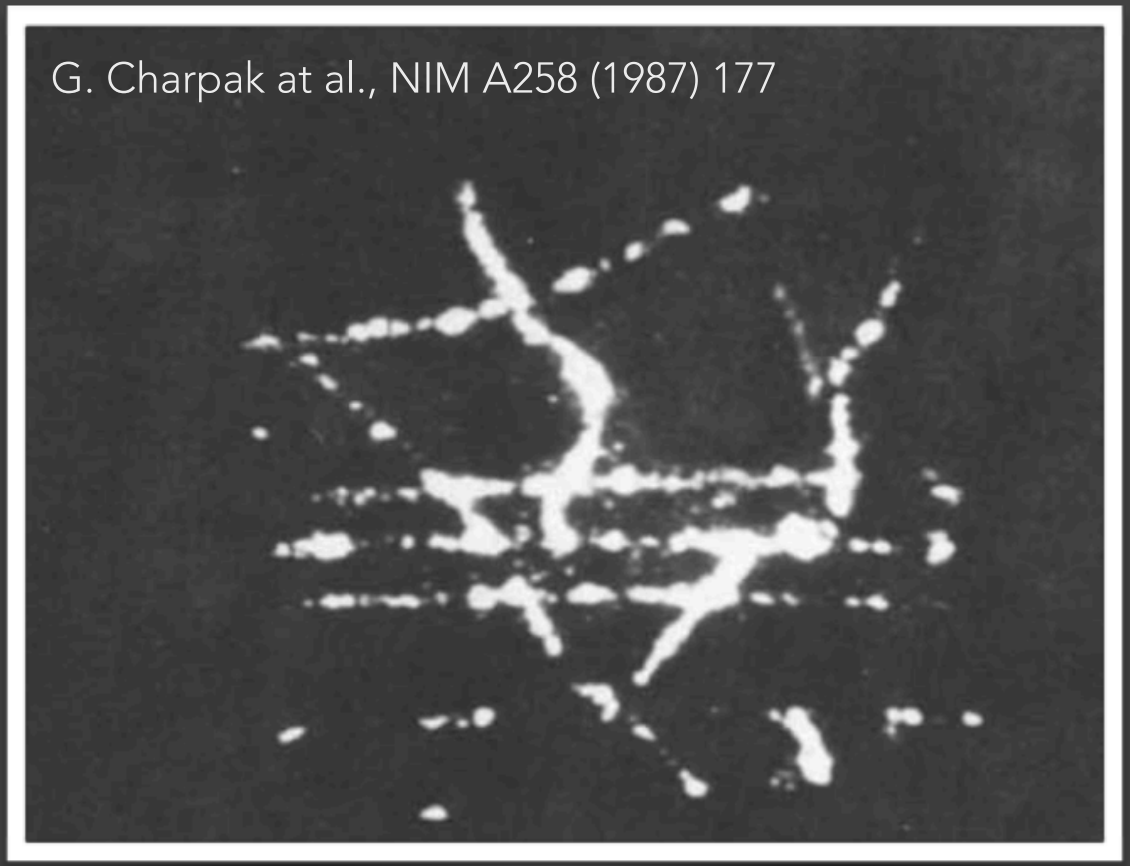
CYGNO

1 CUBIC METER TPC WITH OPTICAL READOUT FOR DARK MATTER SEARCH

LIGHT: A CHANGE OF PARADIGM

During the multiplication process, photons are produced along with electrons by the gas through atomic and molecular de-excitation;

We propose to readout the light instead of electric signal.



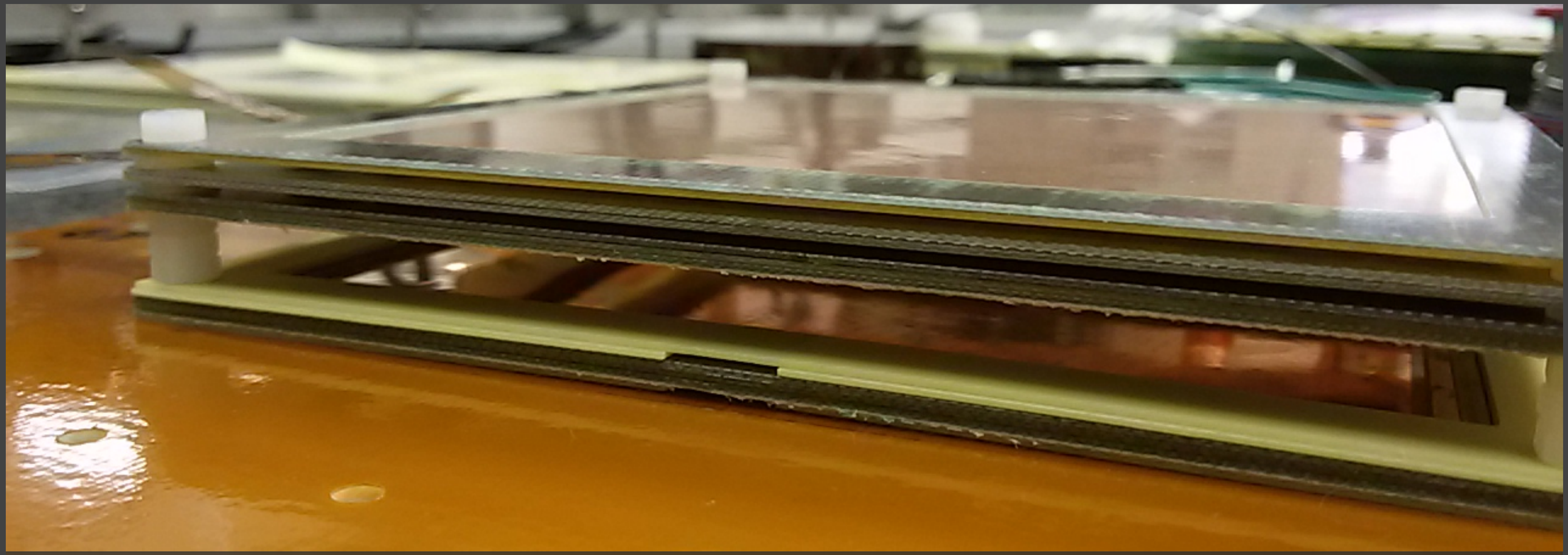
Optical readout of gas detectors offers several advantages:

- optical sensors are able to provide high granularities along with very low noise level and high sensitivity;
- optical coupling allows to keep sensor out of the sensitive volume (no interference with HV operation and lower gas contamination);
- suitable lens allow to acquire large surfaces with small sensors;

ORANGE

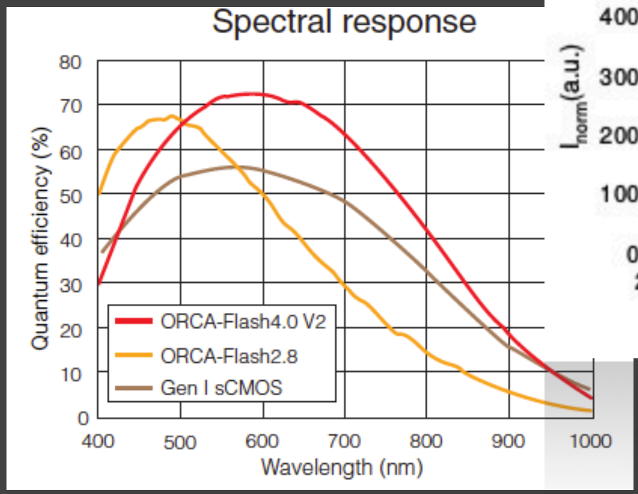
An Optically ReAdout GEM (ORAnGE) device was assembled in Rome in 2015;

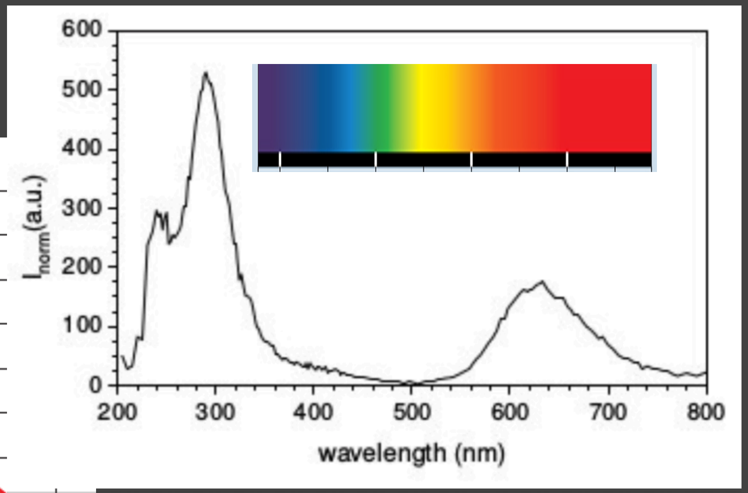
Triple GEM structure ($10x10\ cm^2$) with 1 cm sensitive gap.



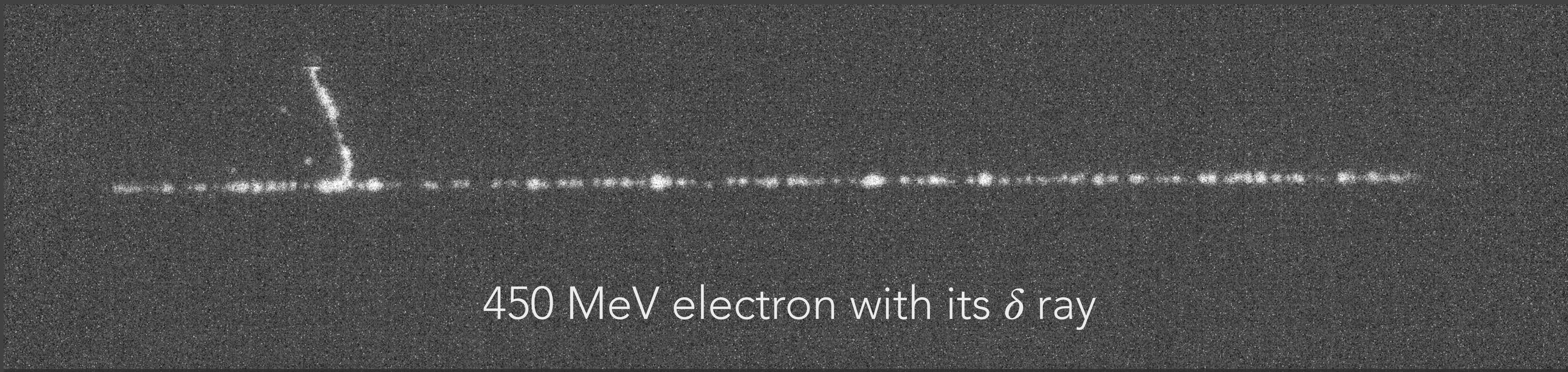
An He/CF_4 (60/40) mixture was used at atmospheric pressure

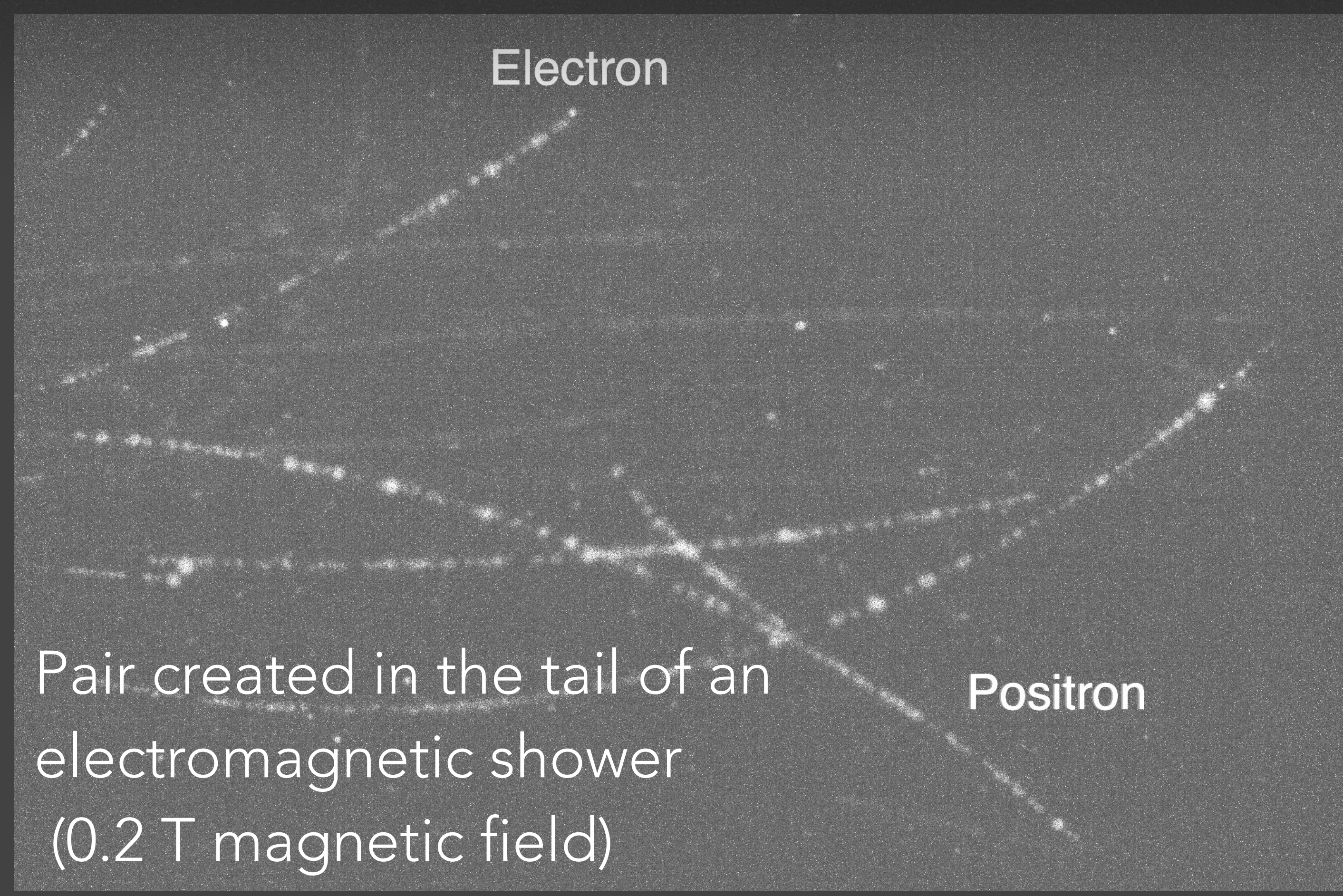
sCMOS sensors provide very low noise and 4MPx granularity and sensitivity



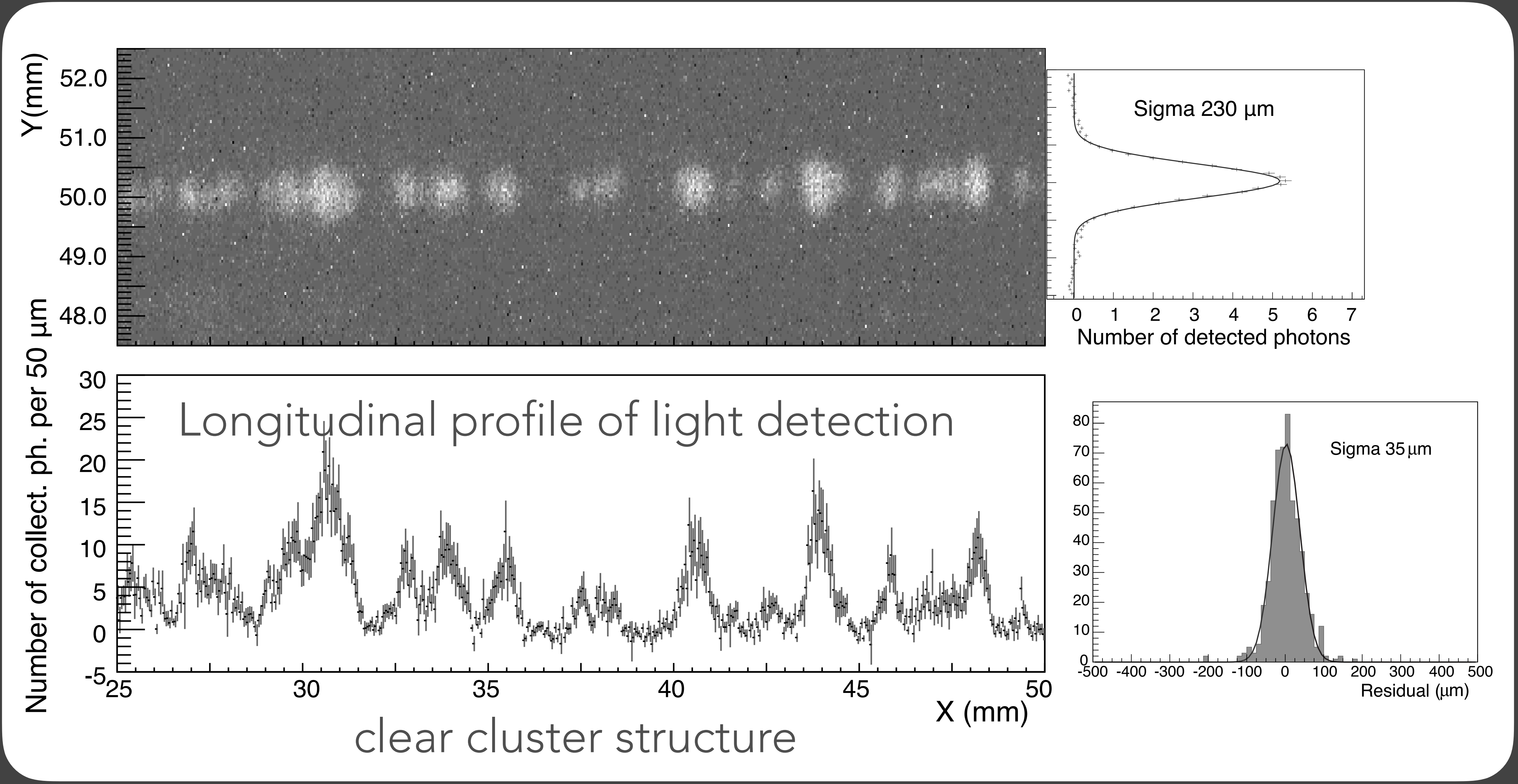


PARTICLE TRACKS



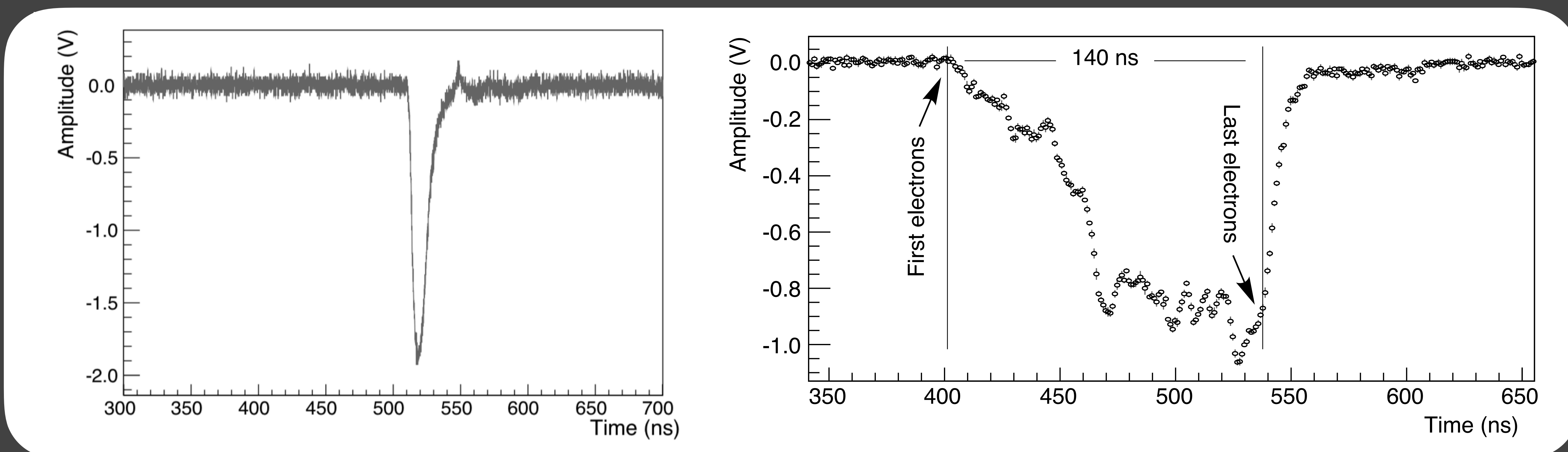


TRACKING PERFORMANCE



About 330 detected photons per track millimetre (for V_{GEM} = 440V), i.e. 50 photons per primary electron (from Garfield).

COMBINED LIGHT READOUT

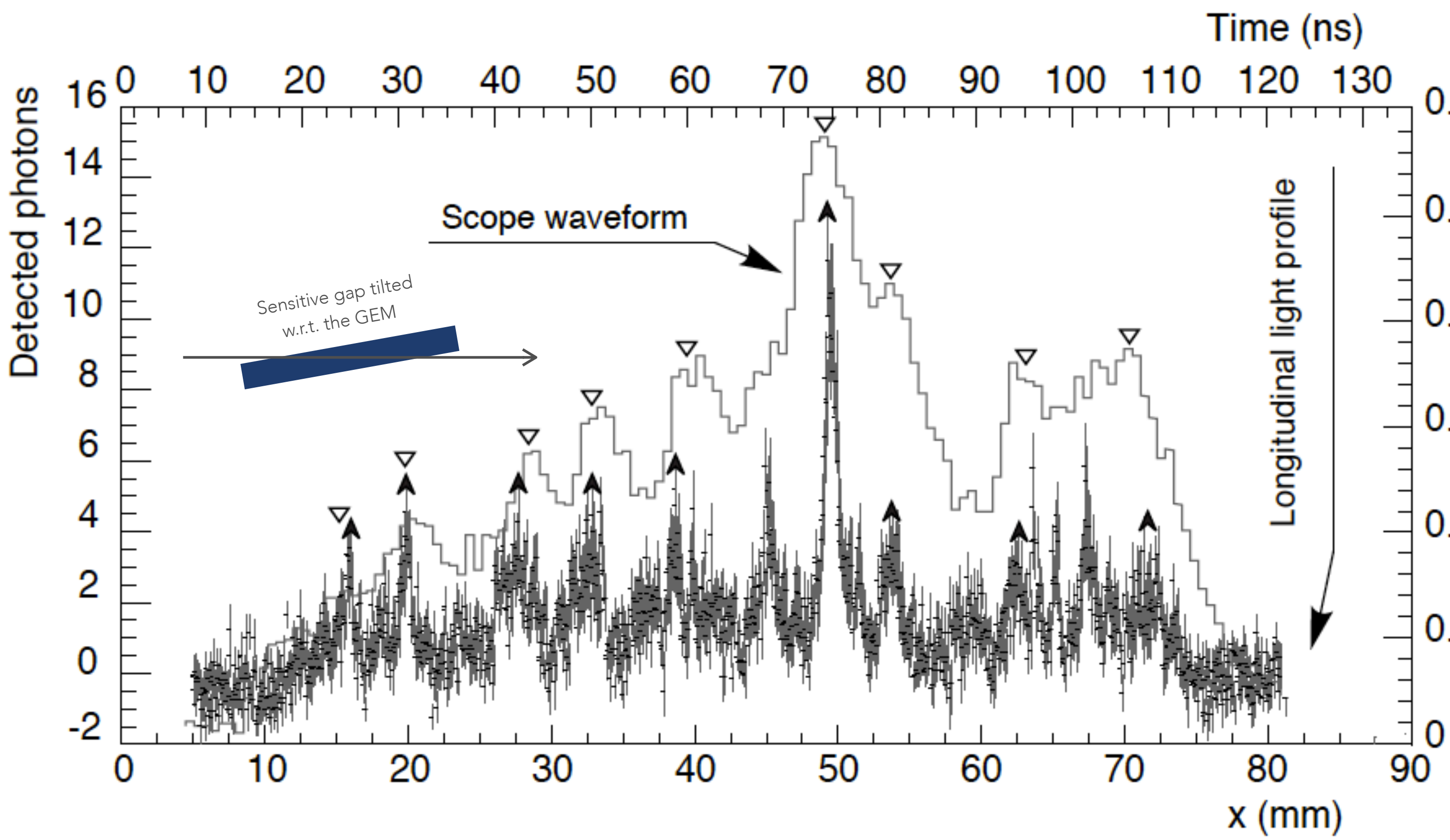


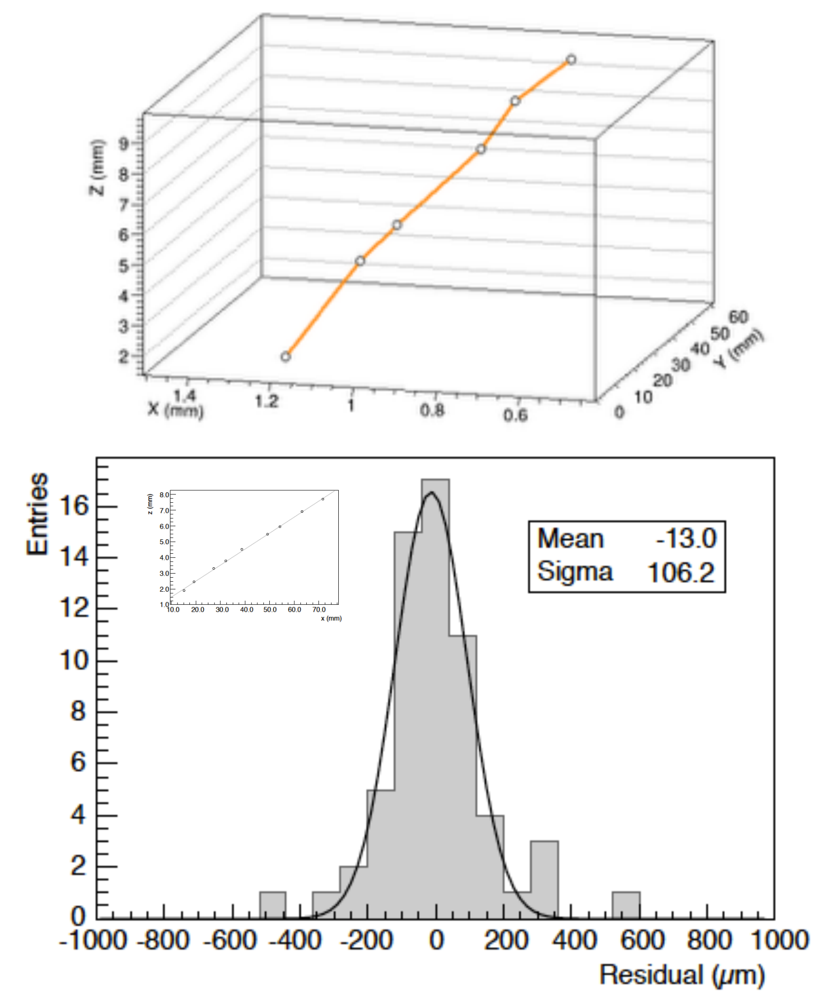
1 cm in 140 ns => drift velocity 7.2 cm/μs in agreement with Garfield expectation of 7.3 cm/μs.

PMT+CMOS COMBINED READOUT

Single cluster 3D position reconstruction can be obtained by comparing the light profile along the track (X, Y) and the PMT waveform (t);

A peak finding algorithm was used to highlight the main cluster signals;





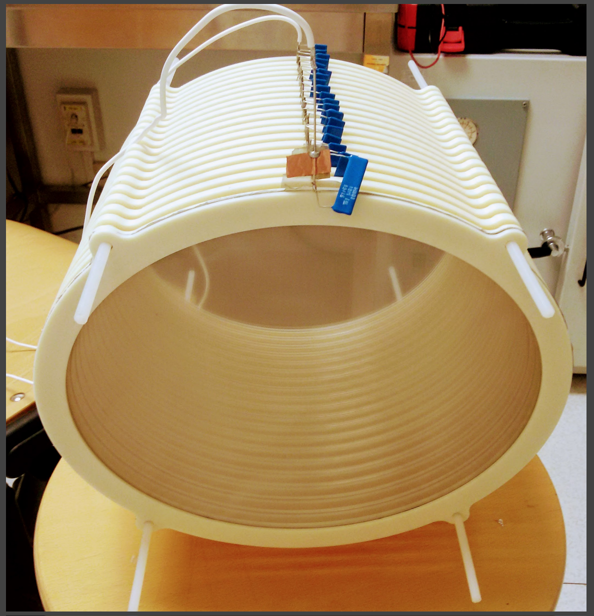
Residual distribution to a 3D fit allows to compute a resolution on Z of 100 μm.

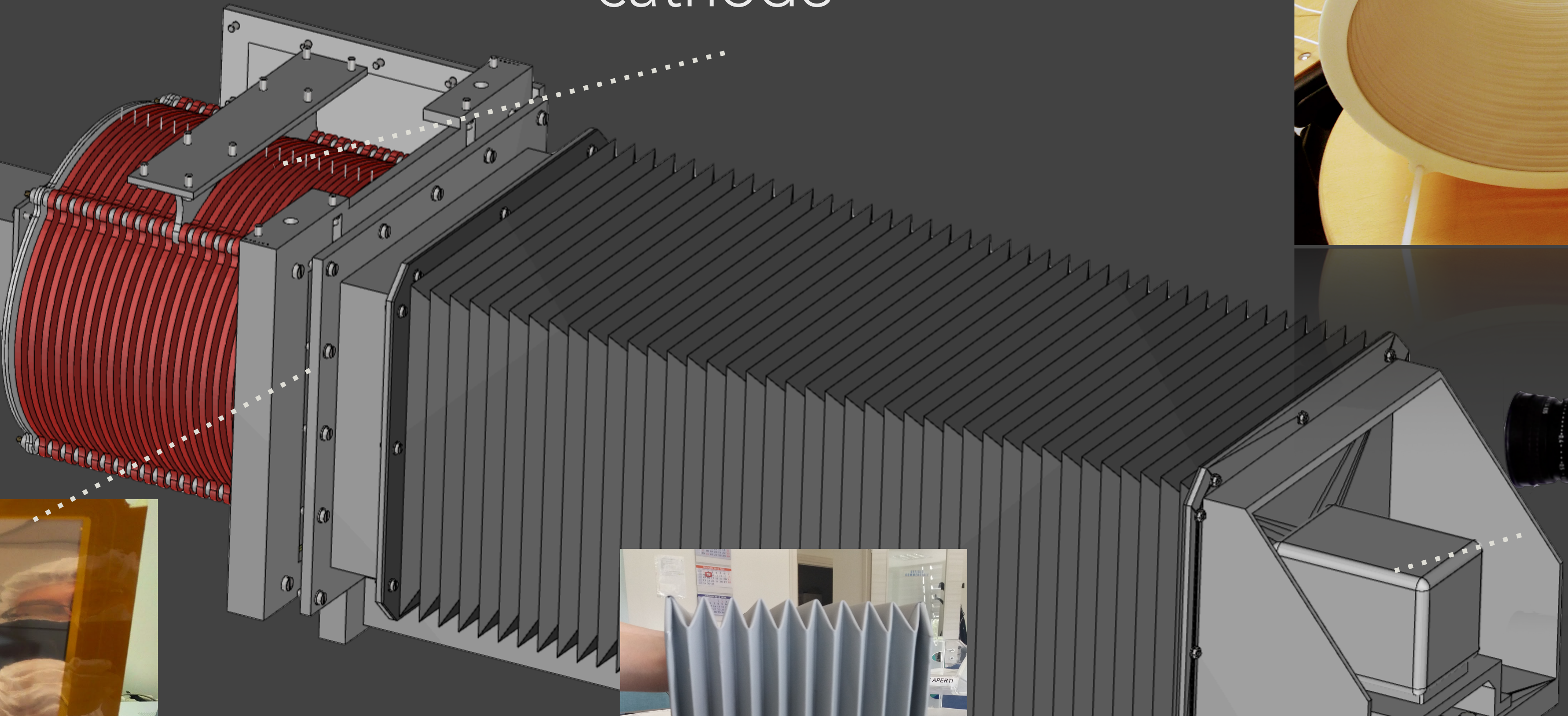
LARGE PROTOTYPE

A new prototype with 7 litre sensitive volume (LEMOn: Large Elliptical Module Optically readout) was built in 2017.

7x7 cm² PMT

Elliptical field cage with semi-transparent cathode



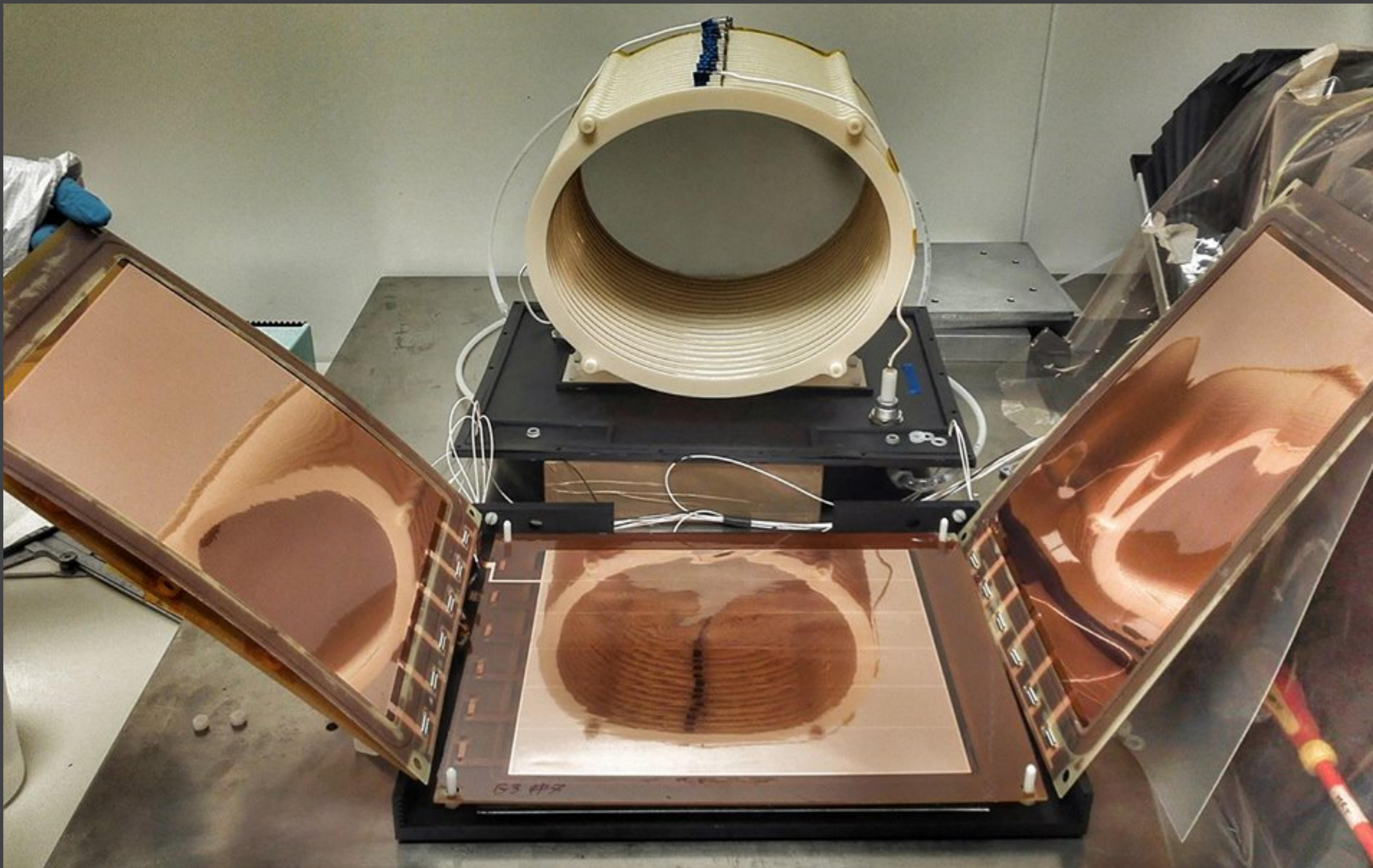


CMOS camera

20x24 cm² GEMs

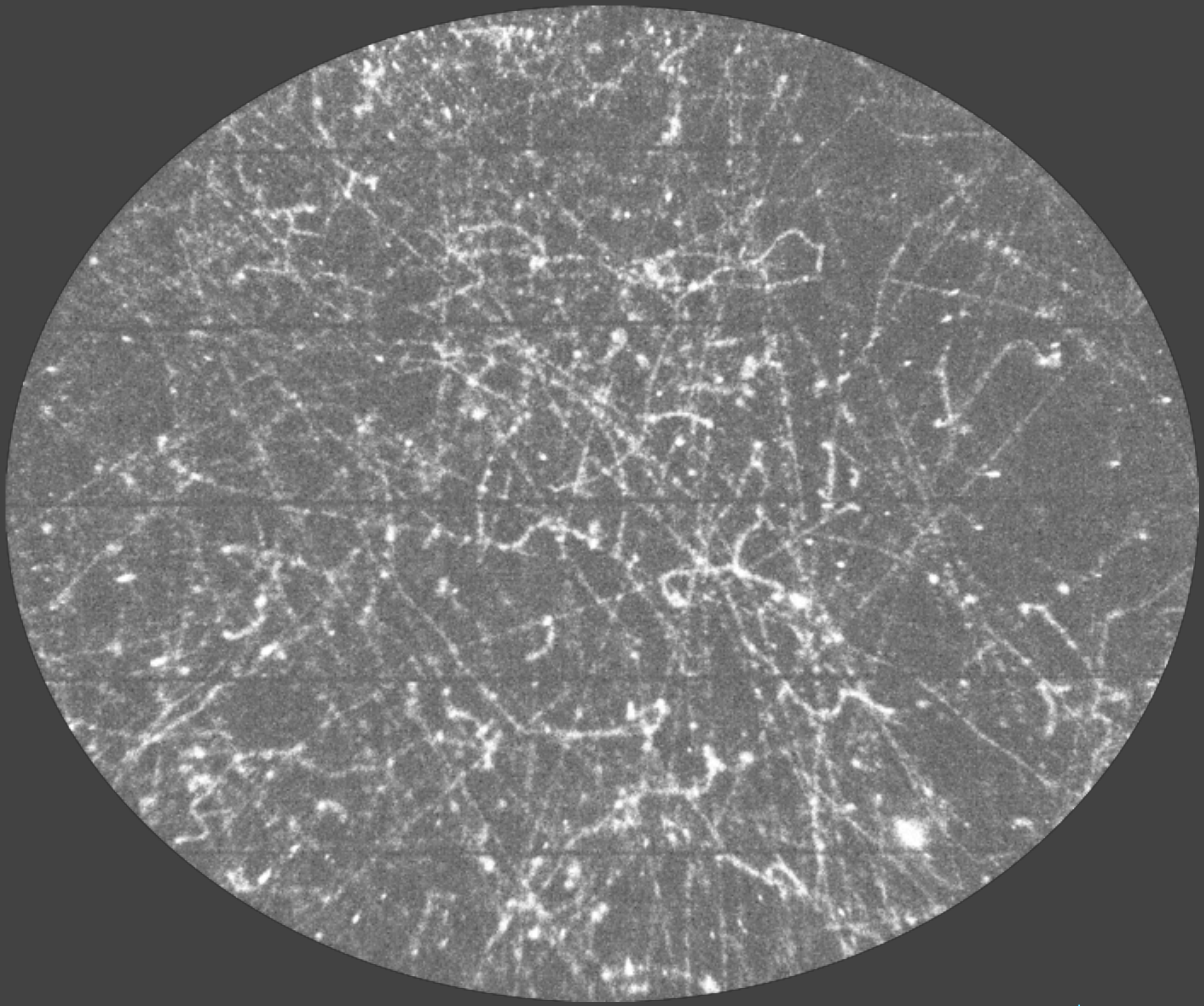
Tuneable bellows

INSIDE THE LEMON PROTOTYPE

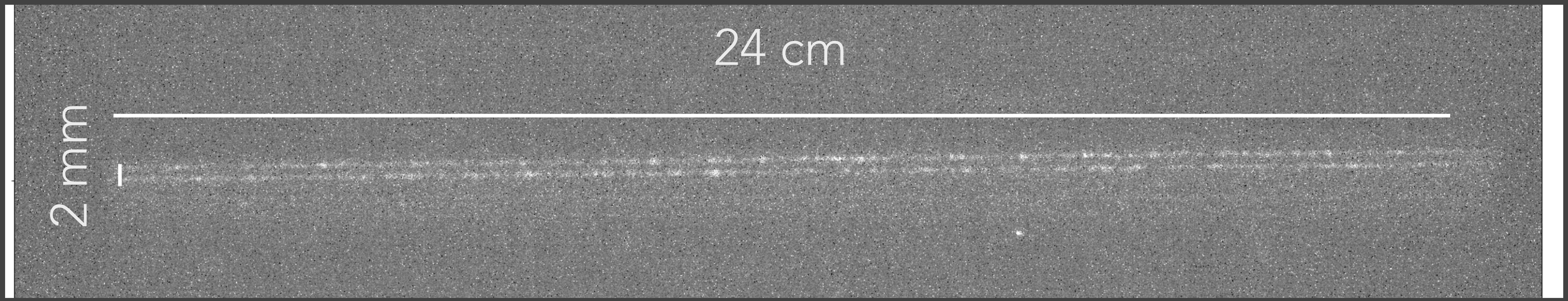


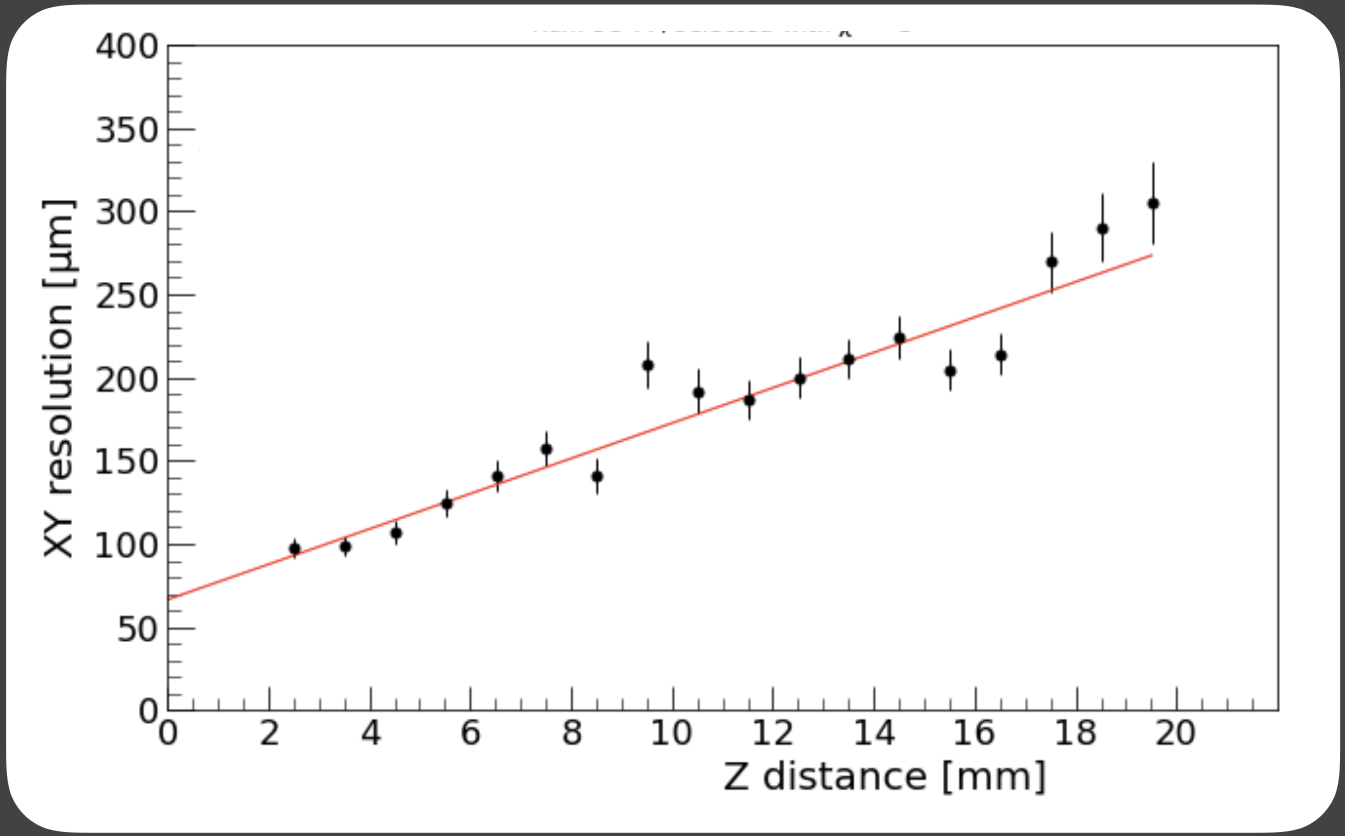
LEMON: FIRST RESULT

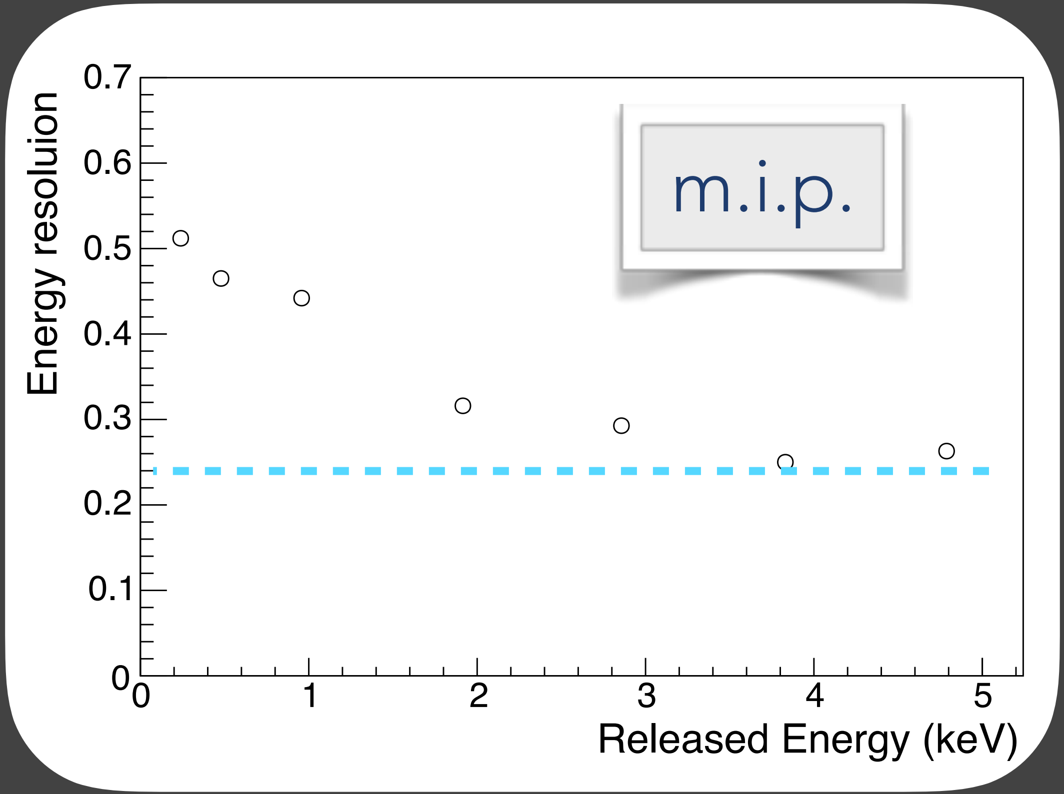
5 sec of natural background



SPACE AND ENERGY RESOLUTION





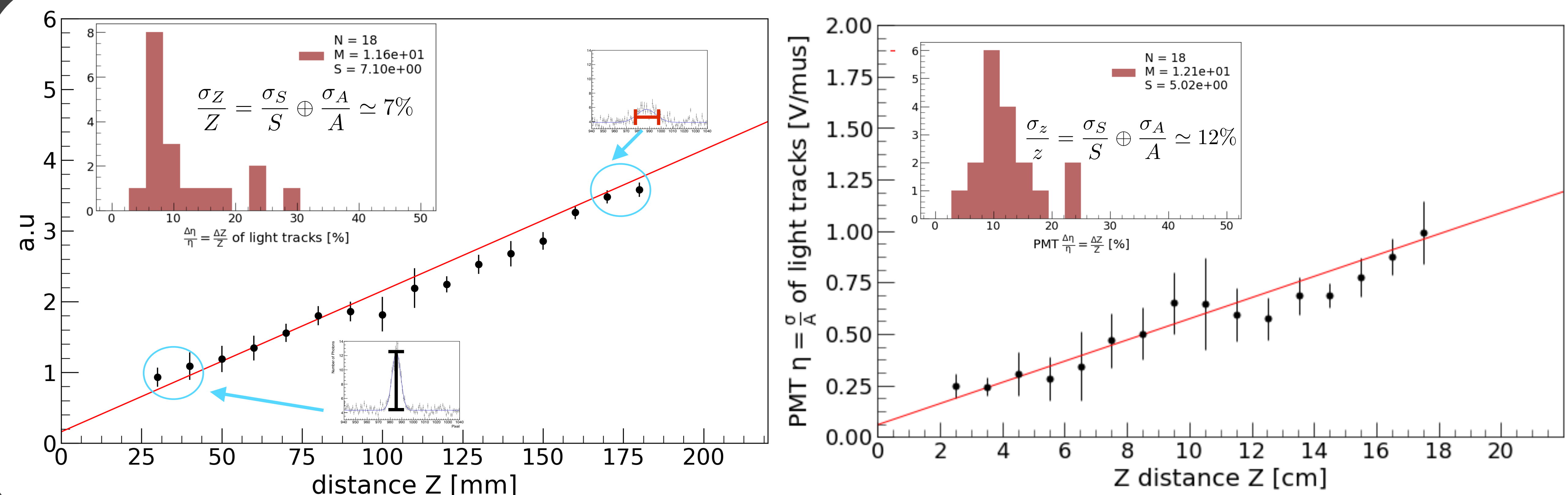


At 1 keV a resolution of 400-500 eV was measured

In the few keV region a relative resolution of 25% is achieved

Z RESOLUTION

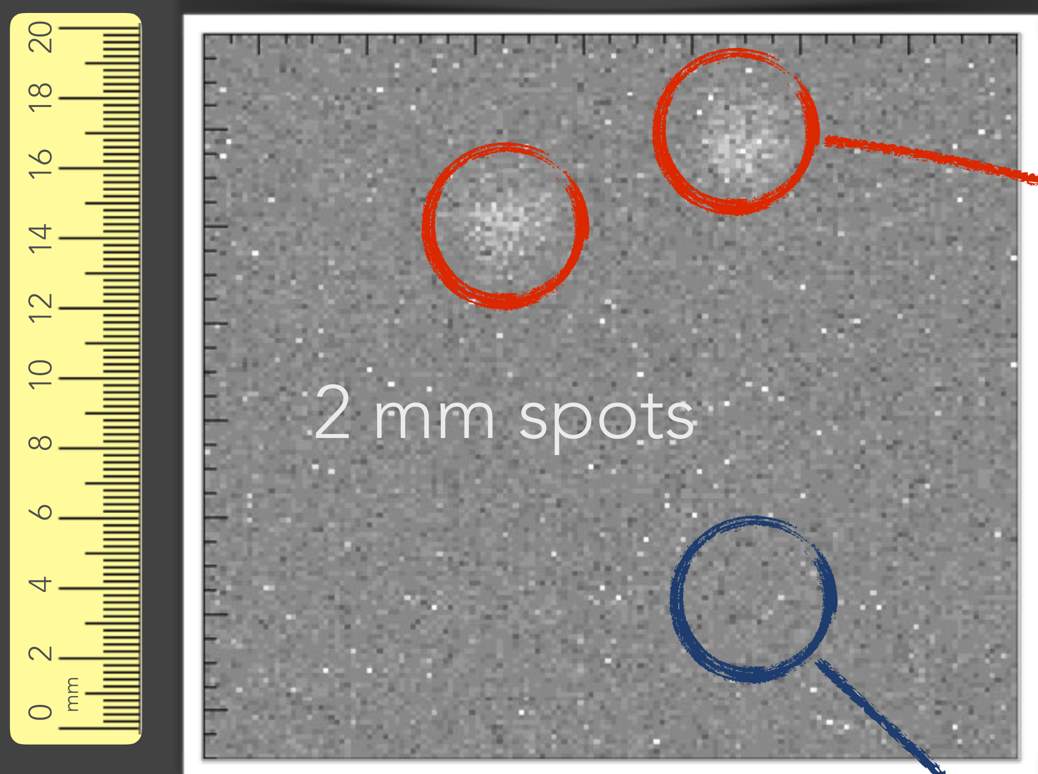
Electron diffusion in the drift gap can be exploited to evaluate the Z of the event. The transverse light profile and the PMT signal waveform are expected to become lower and larger as long as the event is far from the GEM;
Since the width (S) increases and the amplitude (A) decreases with Z, their ratio η = S/A increases (independently from the amount of produced light);



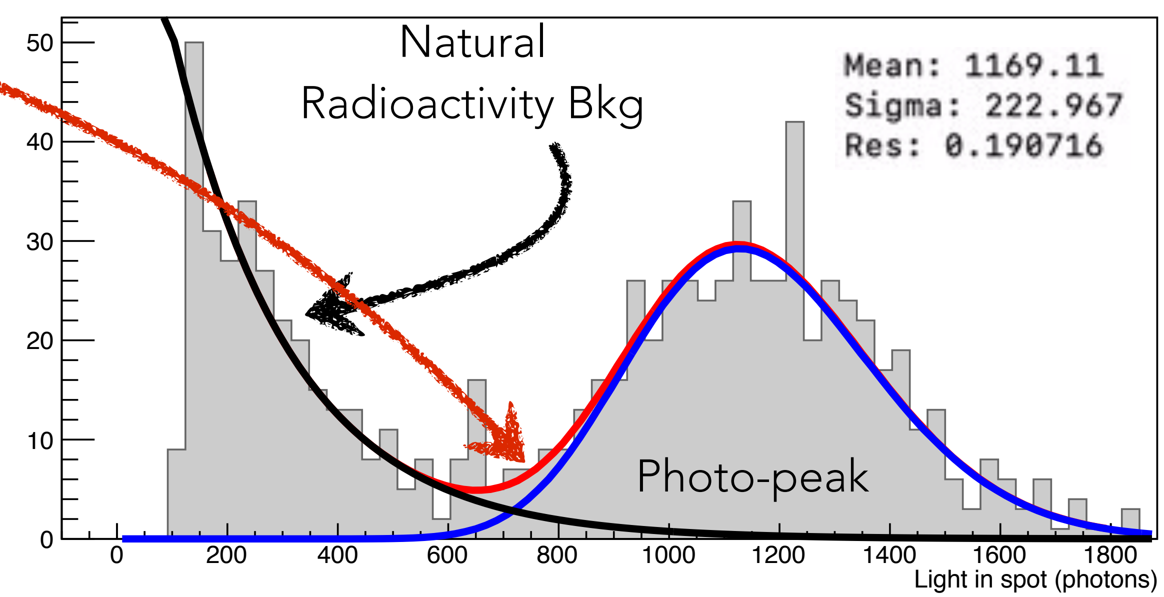
Both methods gives 10% precision: σz ~ 2 cm @ 20 cm

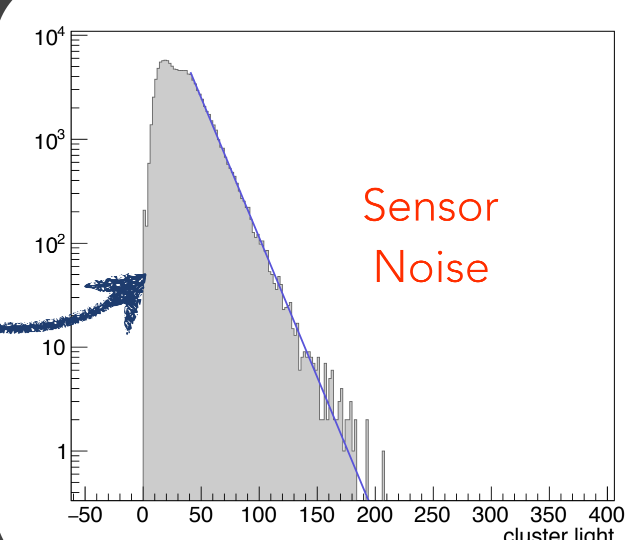
X-RAYS FROM A ^{55}FE SOURCE

Light response to 5.9 keV ^{55}Fe measured with a source 20 cm far from the GEM.



Peak evaluated by a Polya fit

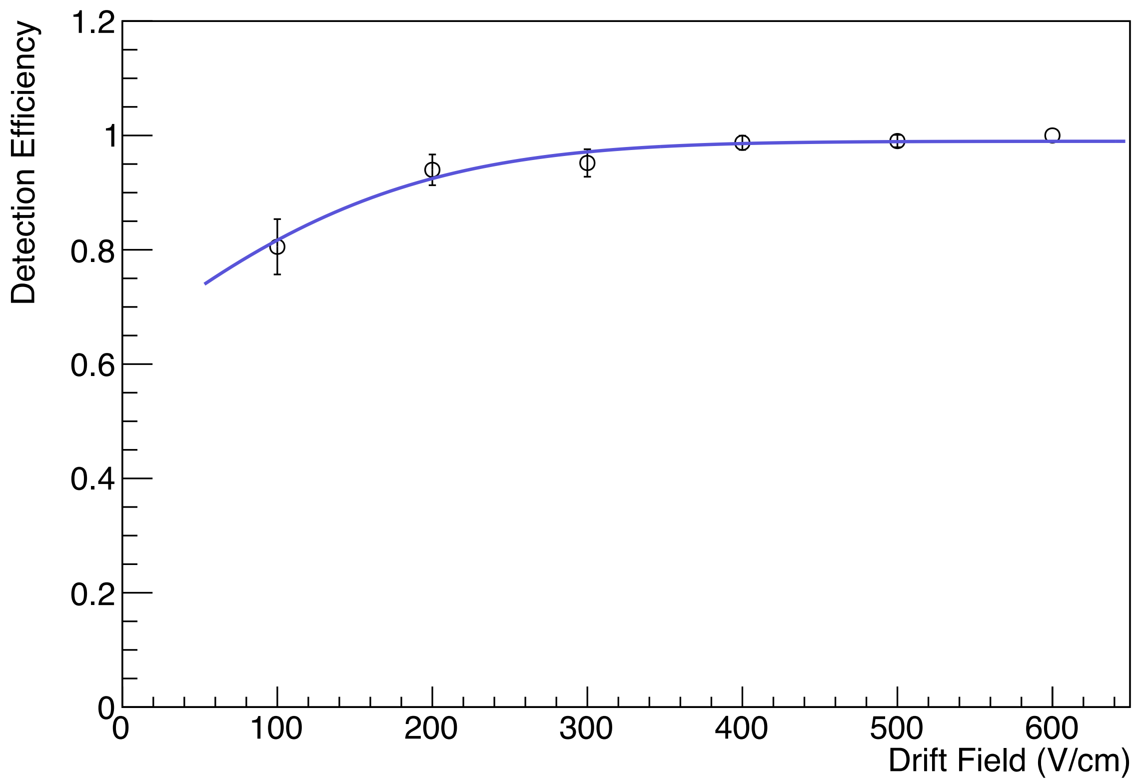




About 1170 photons are detected:
i.e. 1 photon each 5 eV released.

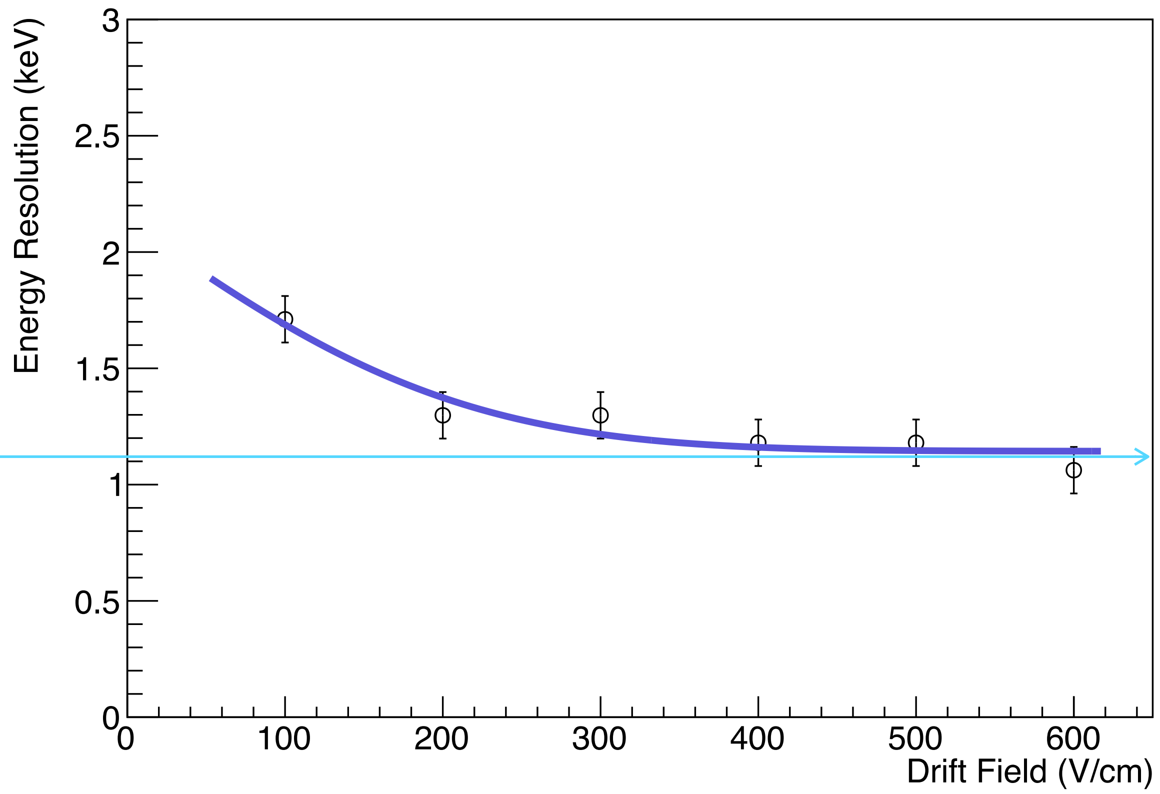
Noise has a slope of 16 ph.
A threshold at 400 ph (i.e. 2 keV) would ensure a fake rate lesser than 10 events/year.

X-RAYS FROM A ^{55}FE SOURCE



Although events happen 20 cm far from the GEM, very good detection efficiency and energy resolution were measured even drift fields as low as 300 V/cm ÷ 400 V/cm

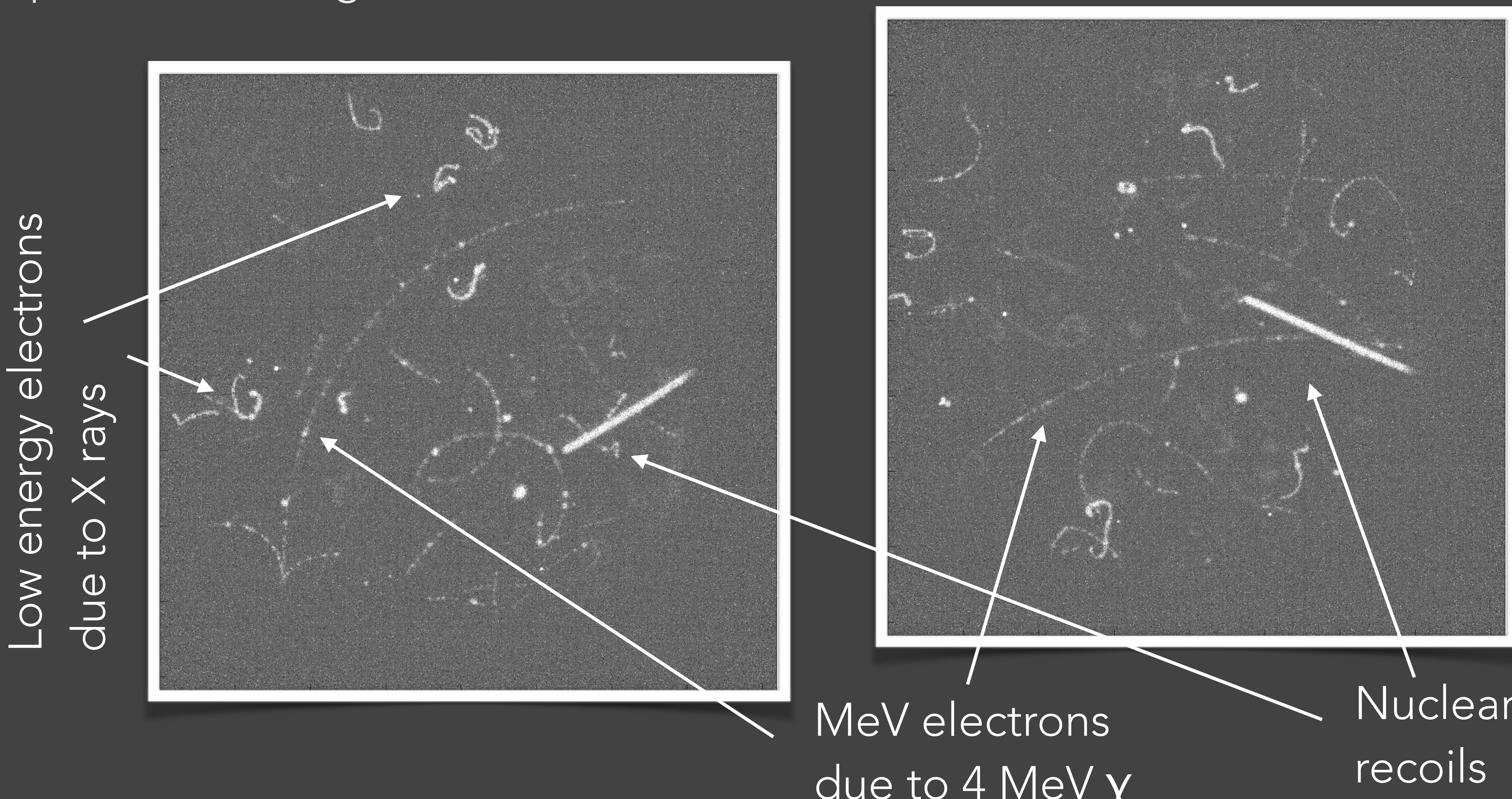
Energy resolution of 18% (1.1 keV) was found



Operating with an energy threshold of 2 keV seems feasible

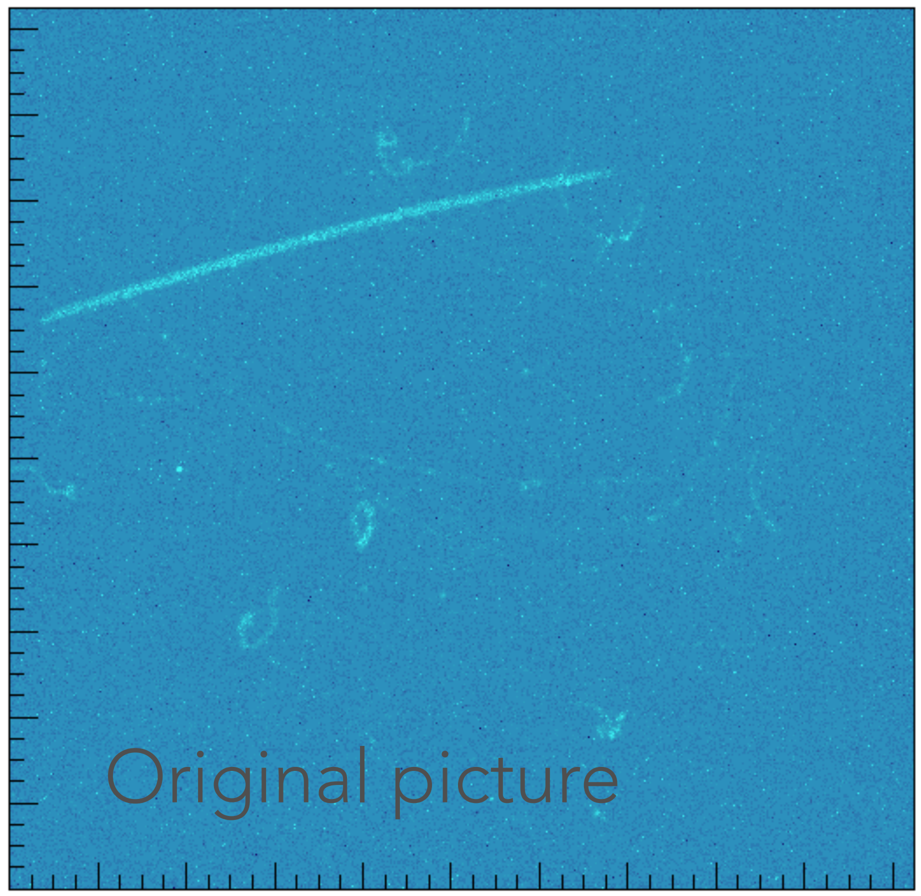
MEASUREMENTS WITH NEUTRONS

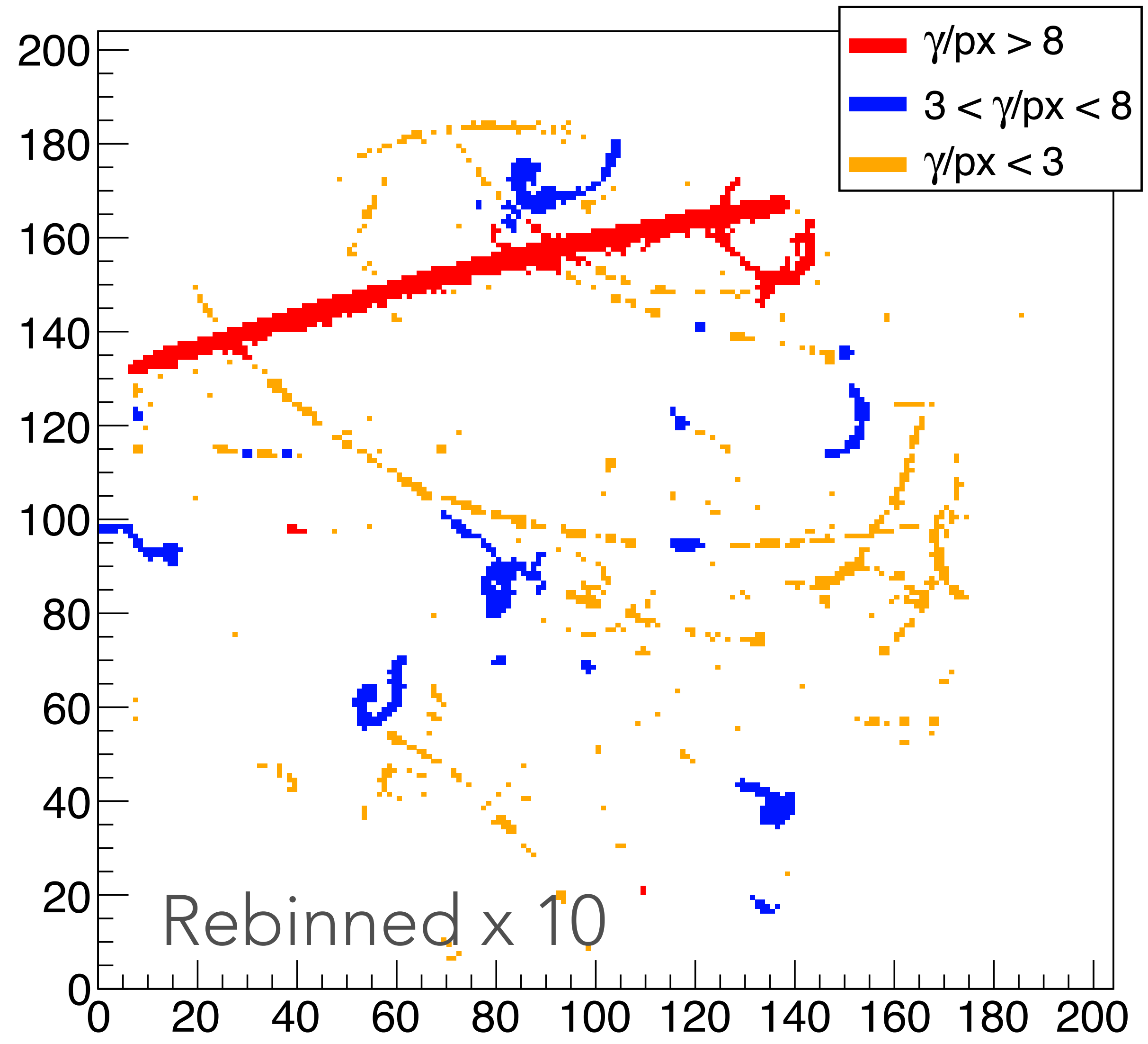
A small prototype was exposed to an AmBe source, providing 1-10 MeV neutrons along with 4 MeV and 60 keV photons.
A 0.2 T magnetic field was present within the drift field provided by a permanent magnet.



PARTICLE IDENTIFICATION

Specific ionisation allows a fast particle identification.



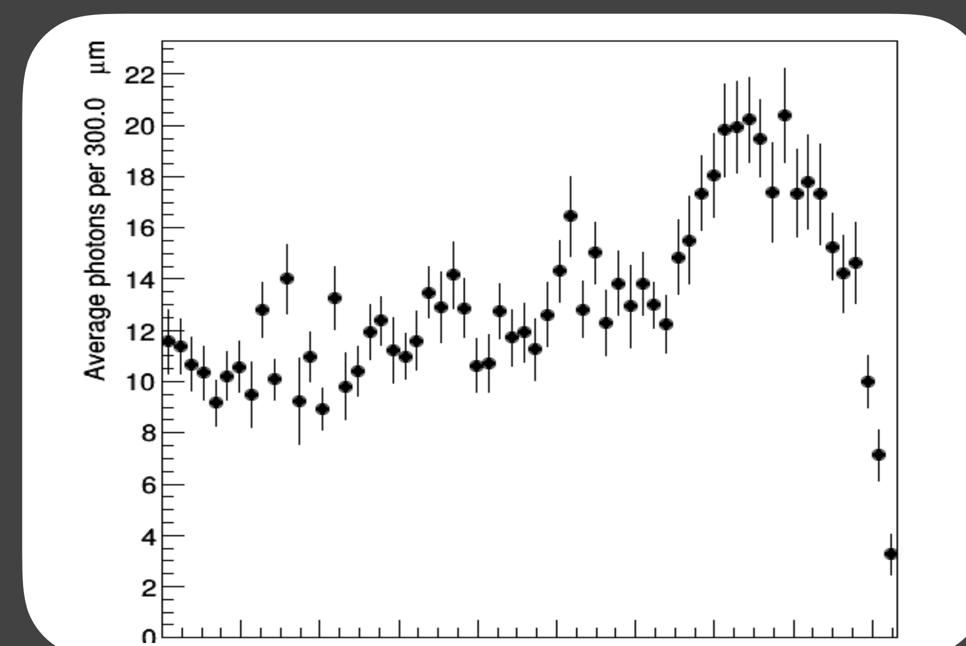


By simply assigning different colours to identified clusters as a function of their average light density, the three species are almost completely separated.

FNG: NEUTRON GUN AT ENEA

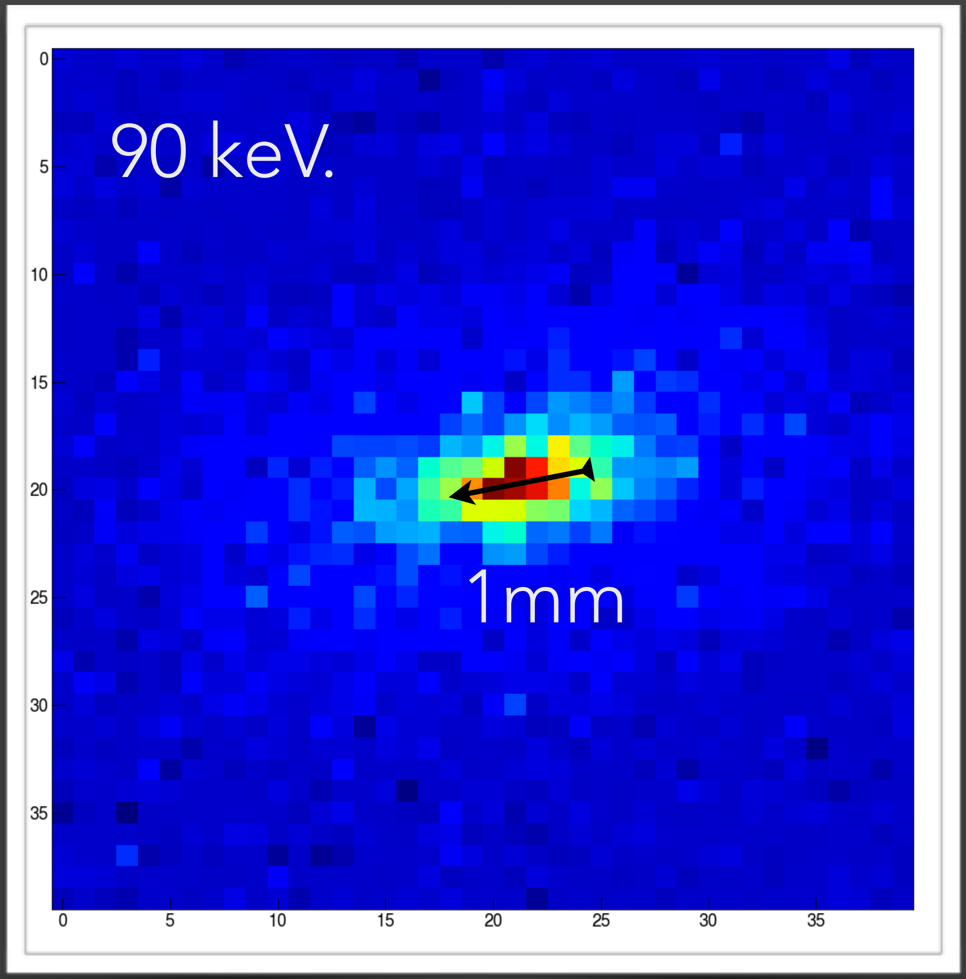
LEMOn was tested with 2.45 MeV neutrons at Frascati Neutron Generator

Nuclear recoil tracks are clearly visible among background induced by soft photons.



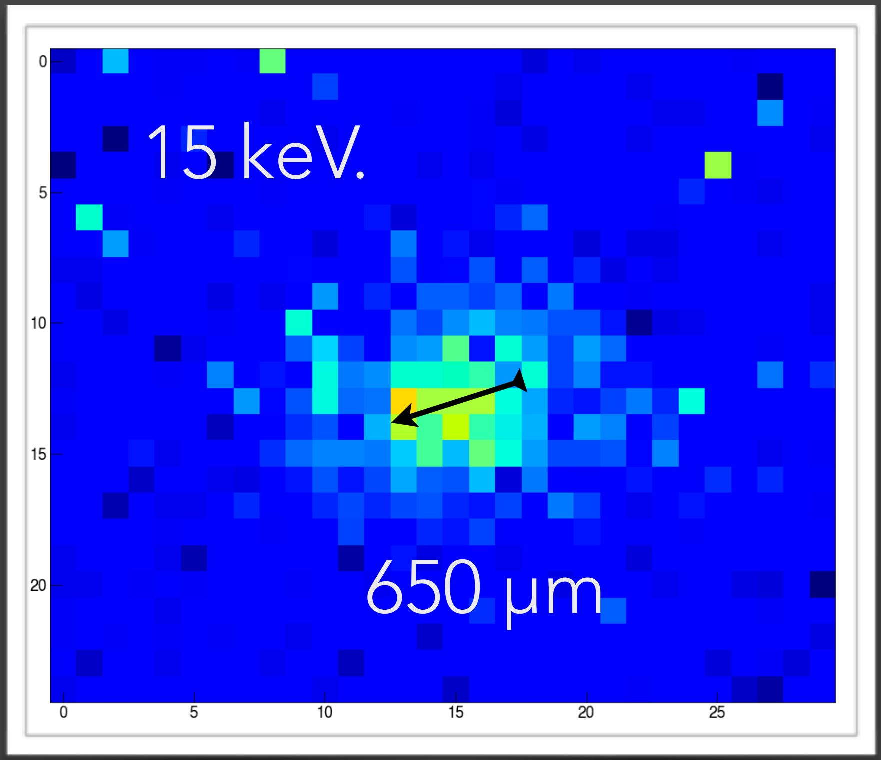
Longitudinal light profile shows a typical Bragg peak shape

FNG: NEUTRON GUN AT ENEA



Examples of He nuclear recoils

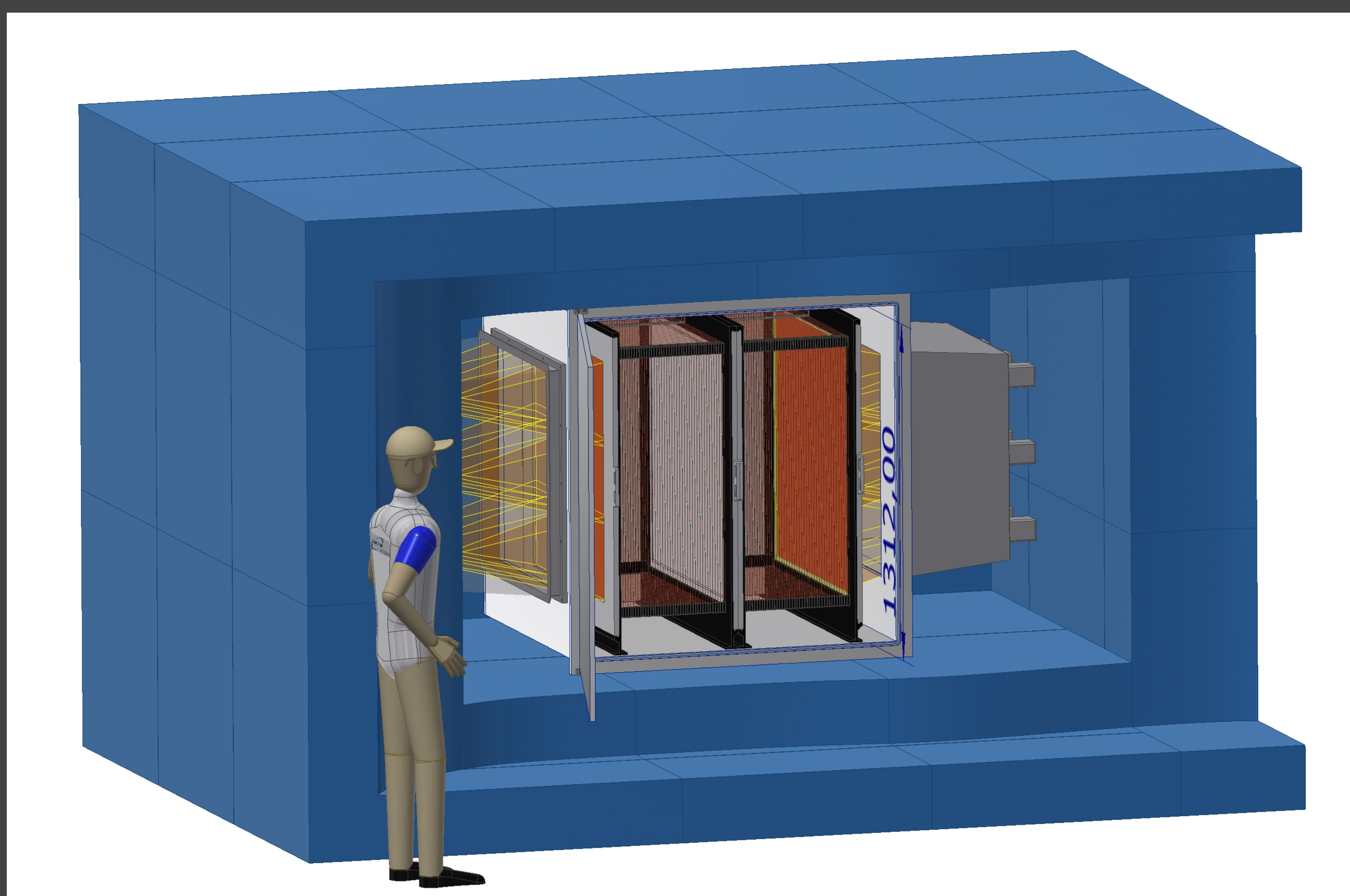
Direction and head/tail asymmetry well visible

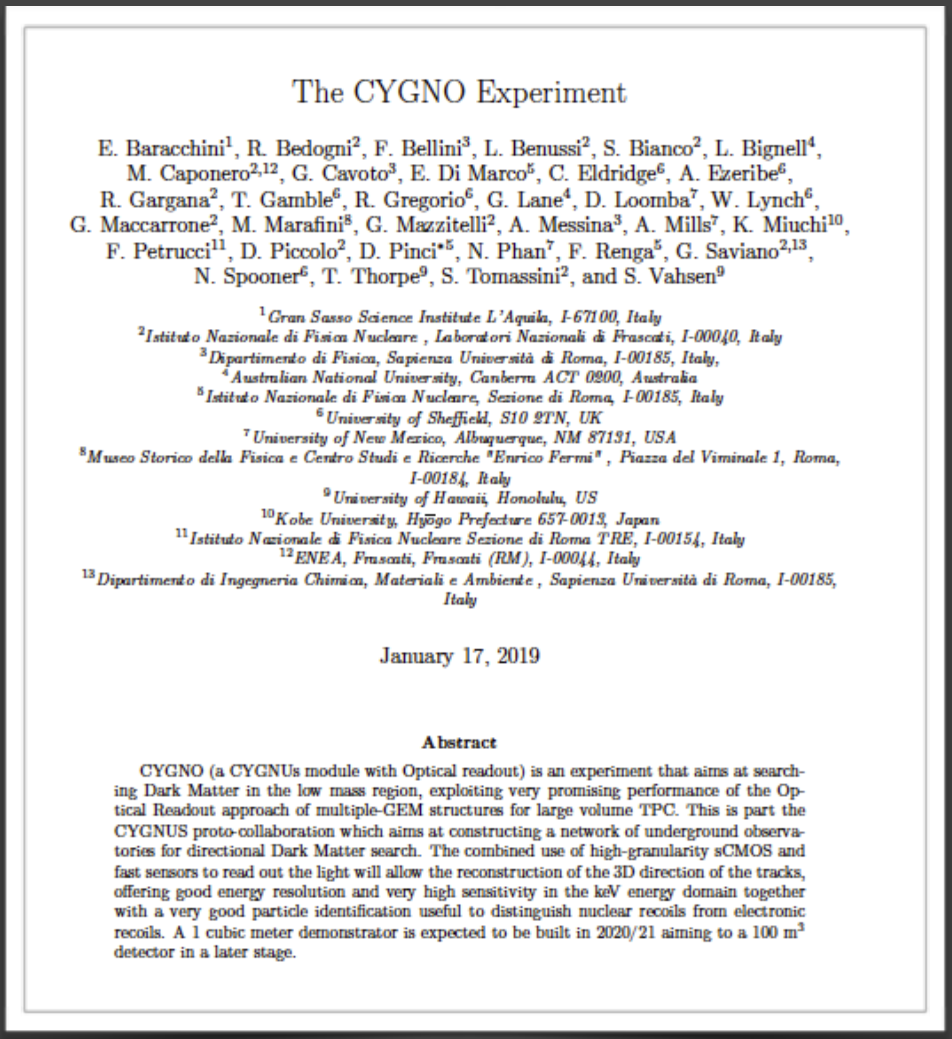


Direction and head/tail asymmetry still visible

PROPOSAL OF CYGNO

We think this technology showed to be really promising to develop a detector for Directional Light Dark Matter search.
The drafting a Technical Design Report was funded to describe a 3/4 year project leading to construction of CYGNO, a 1 m^3 TPC based on optical readout.





The CYGNO Experiment

E. Baracchini[1], R. Bedogni[2], F. Bellini[3], L. Benussi[2], S. Bianco[2], L. Bignell[4], M. Caponero[2,12], G. Cavoto[3], E. Di Marco[5], C. Eldridge[6], A. Ezeribe[6], R. Gargana[2], T. Gamble[6], R. Gregorio[6], G. Lane[4], D. Loomba[7], W. Lynch[6], G. Maccarrone[2], M. Marafini[8], G. Mazzitelli[2], A. Messina[3], A. Mills[7], K. Miuchi[10], F. Petrucci[11], D. Piccolo[2], D. Pinci[*5], N. Phan[7], F. Renga[5], G. Saviano[2,13], N. Spooner[6], T. Thorpe[9], S. Tomassini[2], and S. Vahsen[9]

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[9] *University of Hawaii, Honolulu, US*
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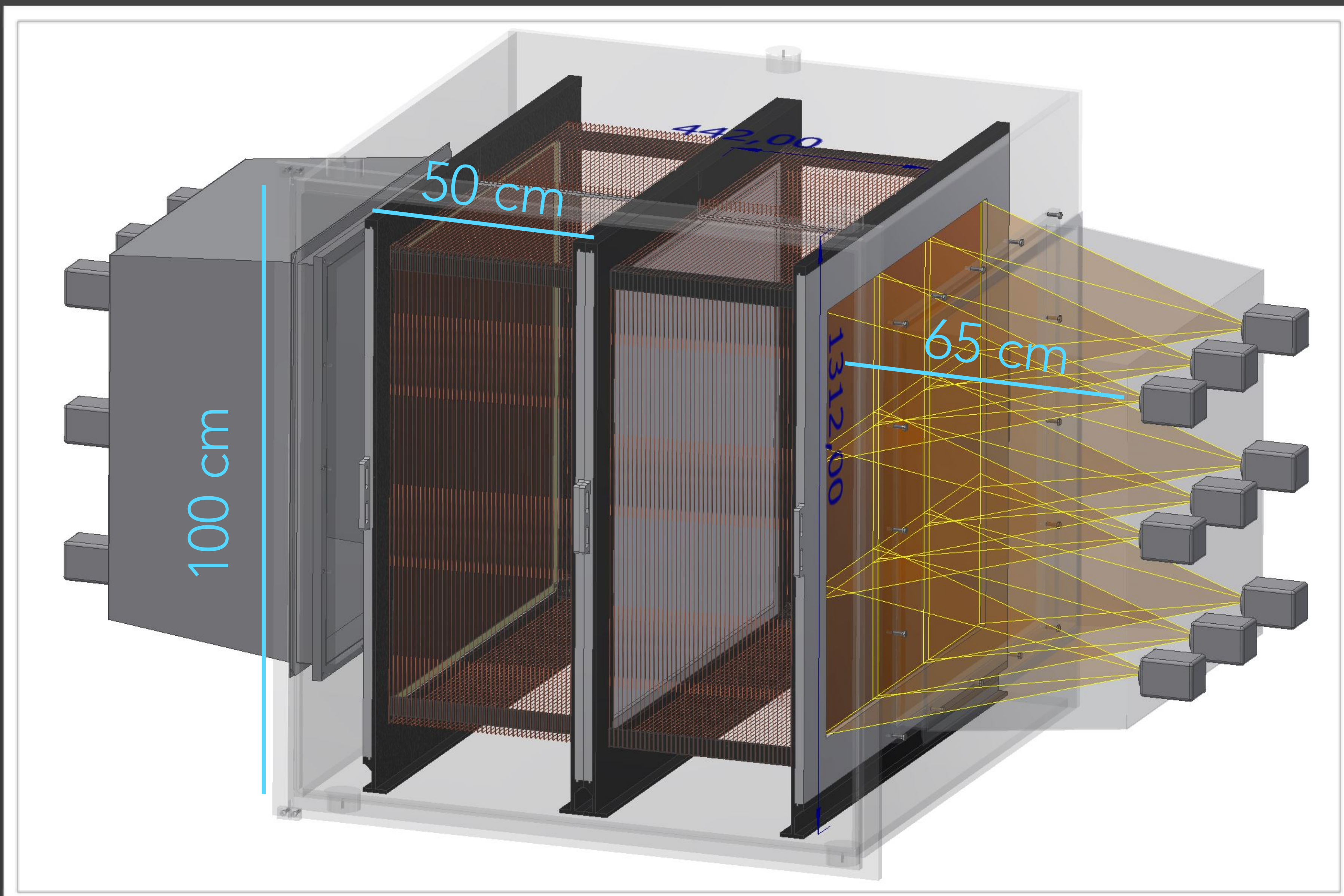
January 17, 2019

Abstract

CYGNO (a CYGNUs module with Optical readout) is an experiment that aims at searching Dark Matter in the low mass region, exploiting very promising performance of the Optical Readout approach of multiple-GEM structures for large volume TPC. This is part the CYGNUS proto-collaboration which aims at constructing a network of underground observatories for directional Dark Matter search. The combined use of high-granularity sCMOS and fast sensors to read out the light will allow the reconstruction of the 3D direction of the tracks, offering good energy resolution and very high sensitivity in the keV energy domain together with a very good particle identification useful to distinguish nuclear recoils from electronic recoils. A 1 cubic meter demonstrator is expected to be built in 2020/21 aiming to a 100 m^3 detector in a later stage.

THE CYGNO APPARATUS

1 m^3 of He/CF_4 60/40 (1.6 kg) at atmospheric pressure subdivided in two 50 cm long parts by the cathode with a drift field of about 1 kV/cm



Each gas volume is equipped by a 3x3 matrix with triple-GEM structure readout by:

- a sCMOS sensor 65 cm away from a transparent window;
- A fast light detector (PMT or SiPM).

A total of 72 10^6 readout 165 x 165 μm^2 pixels.

The active apparatus will be contained in shields for gamma ray and neutrons

RADIOACTIVITY ISSUE

Intrinsic radioactivity of the detector represents one of the most insidious sources of background.

sample:	GEM, copper clad Kapton foil, 12.3 g, CYGNO
number:	2
live time:	1151359 s
detector:	BEGe
radionuclide concentrations:	
Th-232:	
Ra-228:	< 0.19 mBq/pc
Th-228:	< 0.096 mBq/pc
U-238:	
Ra-226	(0.2 +- 0.1) mBq/pc
Th-234	(1.0 +- 0.4) mBq/pc
Pa-234m	< 5.0 mBq/pc
U-235:	< 0.097 mBq/pc
K-40:	< 2.2 mBq/pc
Cs-137:	< 0.050 mBq/pc
Co-60:	< 0.046 mBq/pc @ start of measurement: 21-JUL-2018

1 mBq of ^{234}Th means hundreds of electrons in the volume per day…

GEM foils are placed within the sensitive volume and their radioactivity has to be kept as low as possible;

We measured a sample of a GEM and we are trying to figure out what are the main source of contamination.

Are there any documentation on this item?

Is there any low radioactive GEM production or study foreseen?


Many thanks!

BACKUP