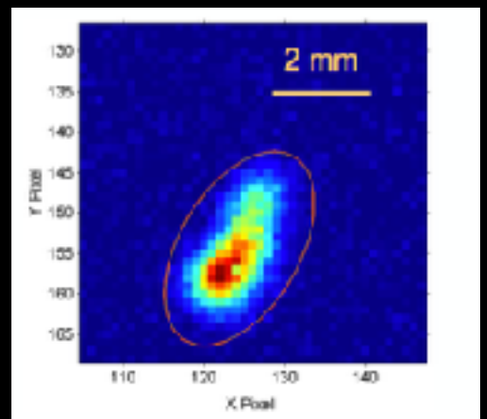
CYGNUS: DEVELOPMENT OF A HIGH RESOLUTION TPC FOR RARE EVENTS

E. Baracchini[3], G. Cavoto[1], E. Di Marco[1], M. Marafini[2], G. Mazzitelli[3], D. Pinci[1], F. Renga[1], A. Tomassini[3], C. Voena[1]

[1]INFN Sezione di Roma & Dipartimento di Fisica della Sapienza Università di Roma
[2]Centro Studi e Ricerche Enrico Fermi
[3]INFN Laboratori Nazionali di Frascati

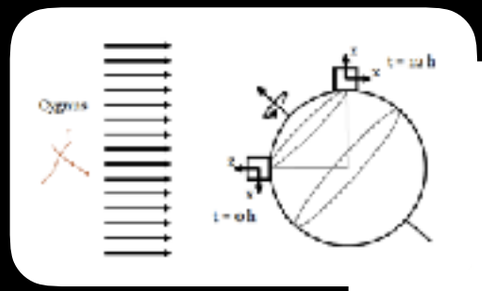
WHY TPC

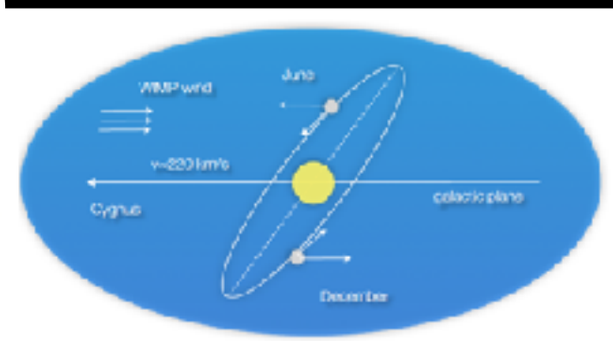
Gas represents a promising target: nuclear recoil tracks can be long enough to be acquired and reconstructed



example high energy F recoil in optical TPC (D. Loomba et al.)

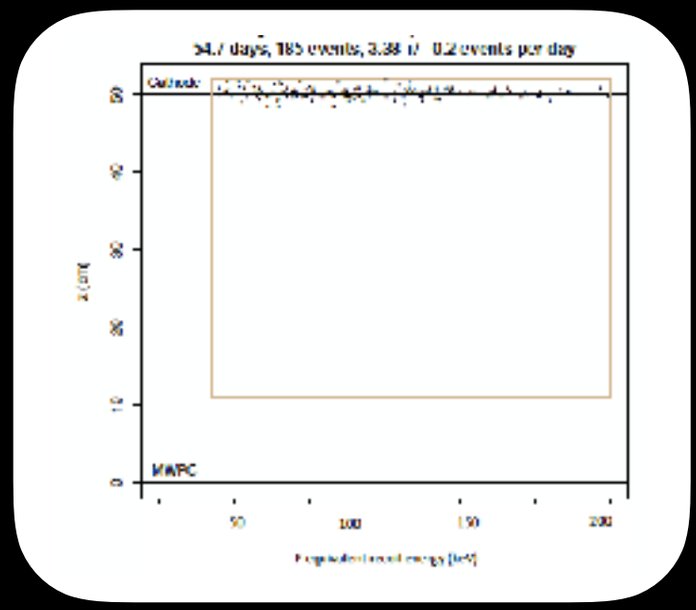
Directionality: to exploit asymmetries and modulation of the Dark Matter signals for background discrimination;





$$v(t)_{DM} = v_{sun} + v_{orb}\ cos\gamma\ cos(\omega(t - t_0))$$

Energy Measurement: total energy and dE/dx (pid, head-tail);

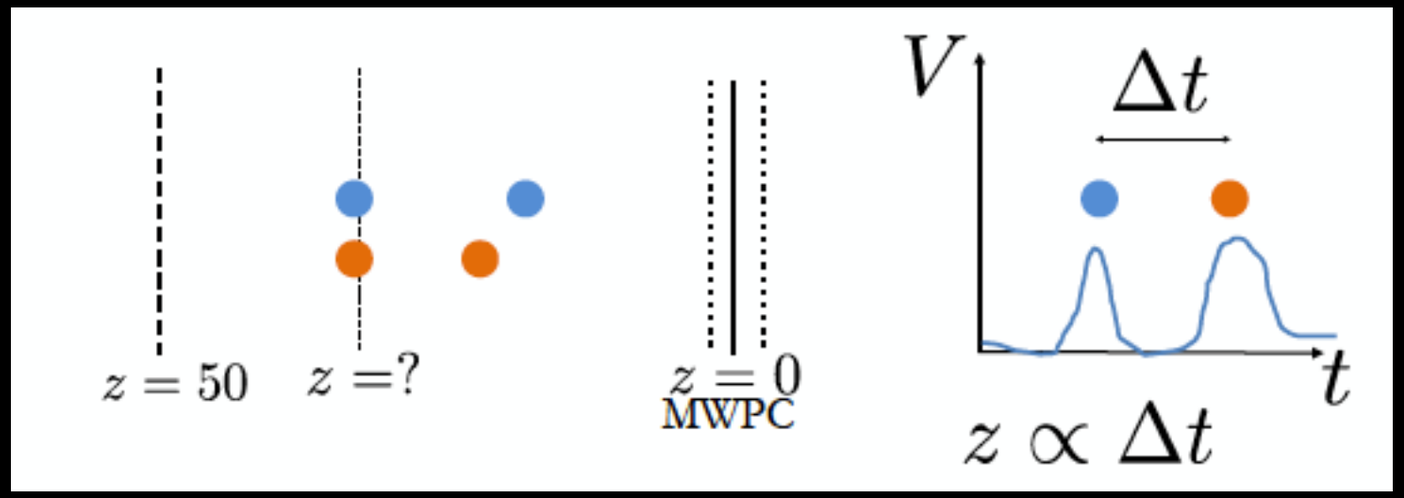


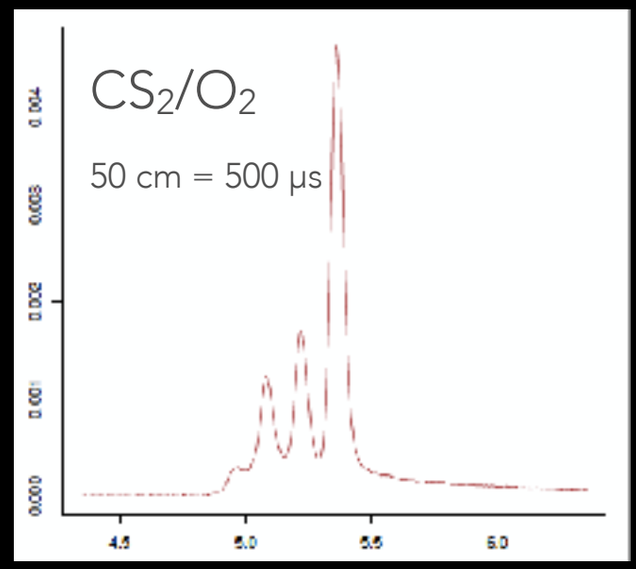
Sensitive Volume Fiducialization: to reject events close the detector walls, due to decays of radioactive materials

NEGATIVE ION DRIFT

With penetrating tracks (e.g. HEP) an external trigger can be exploited to measure the electron drift time to evaluate the event "Z";
In DM applications an alternative technique is the "negative ion drift":

- ionization electrons can be absorbed by a high electronegative component of gas mixture (SF_6, CS_2);
- negative ions start to drift in the electric fields;
- at the multiplication stage, electrons are released and avalanches develop;

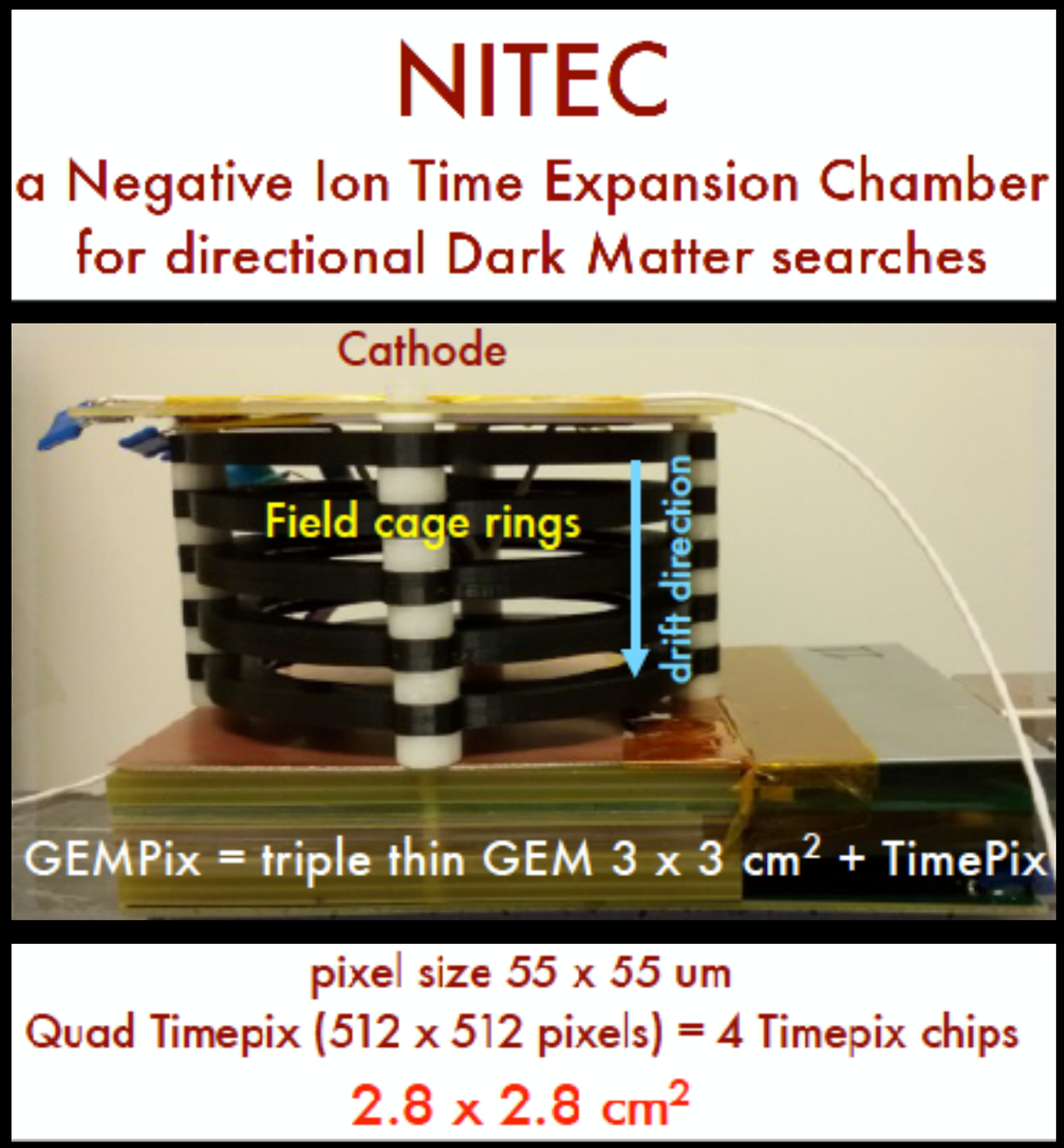




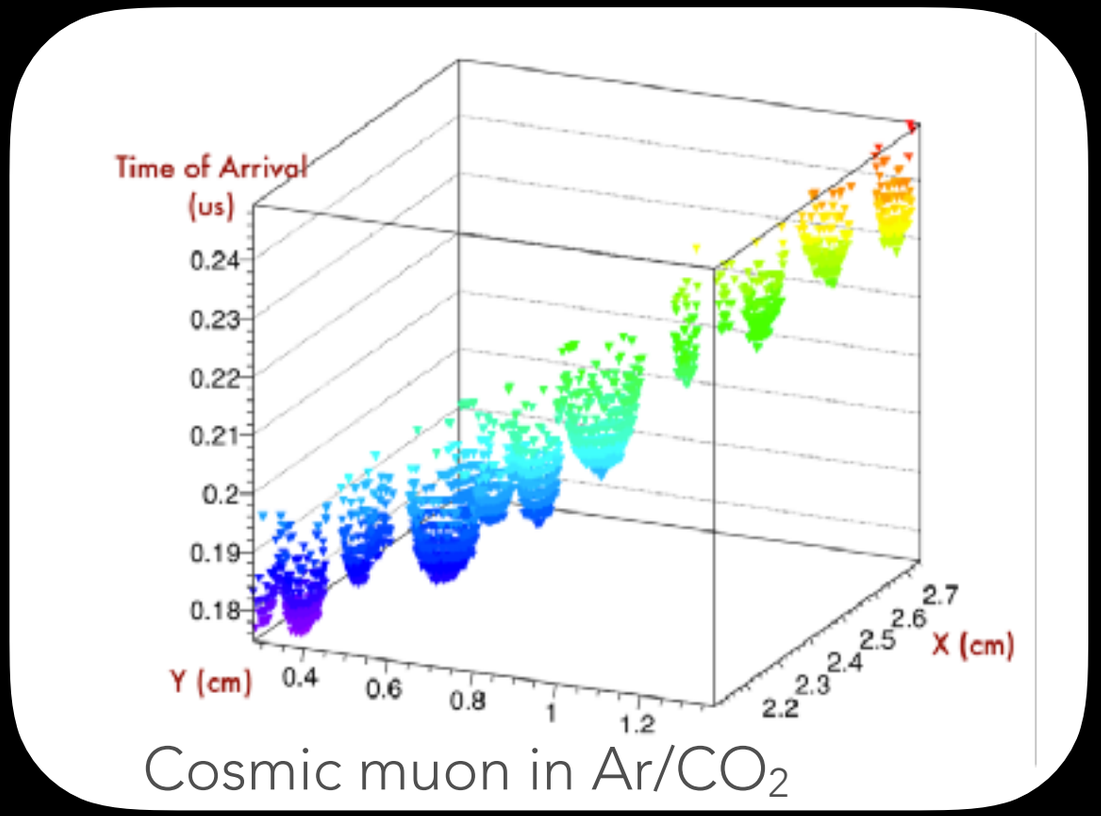
- The Z of the event is evaluated from the measurement of the difference of the time of arrival of ions with different masses and mobilities

NEGATIVE ION DRIFT MEASUREMENTS

Negative ion drift was tested with NITEC prototype, a 5 cm drift gap readout by a 3x3 cm^2 triple GEM structure;



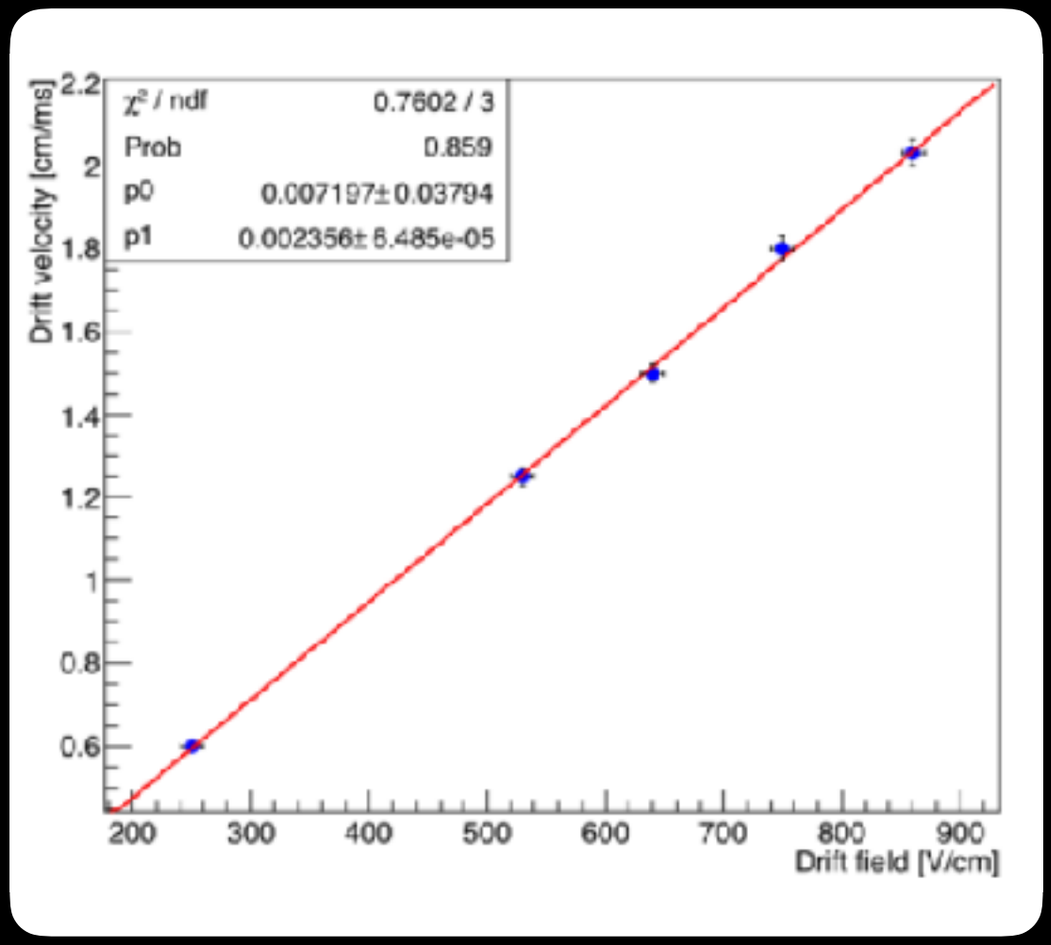
The time and charge of signals induced by the electrons produced in the last GEM are acquired by means of a TimePix



Cosmic muon in Ar/CO_2

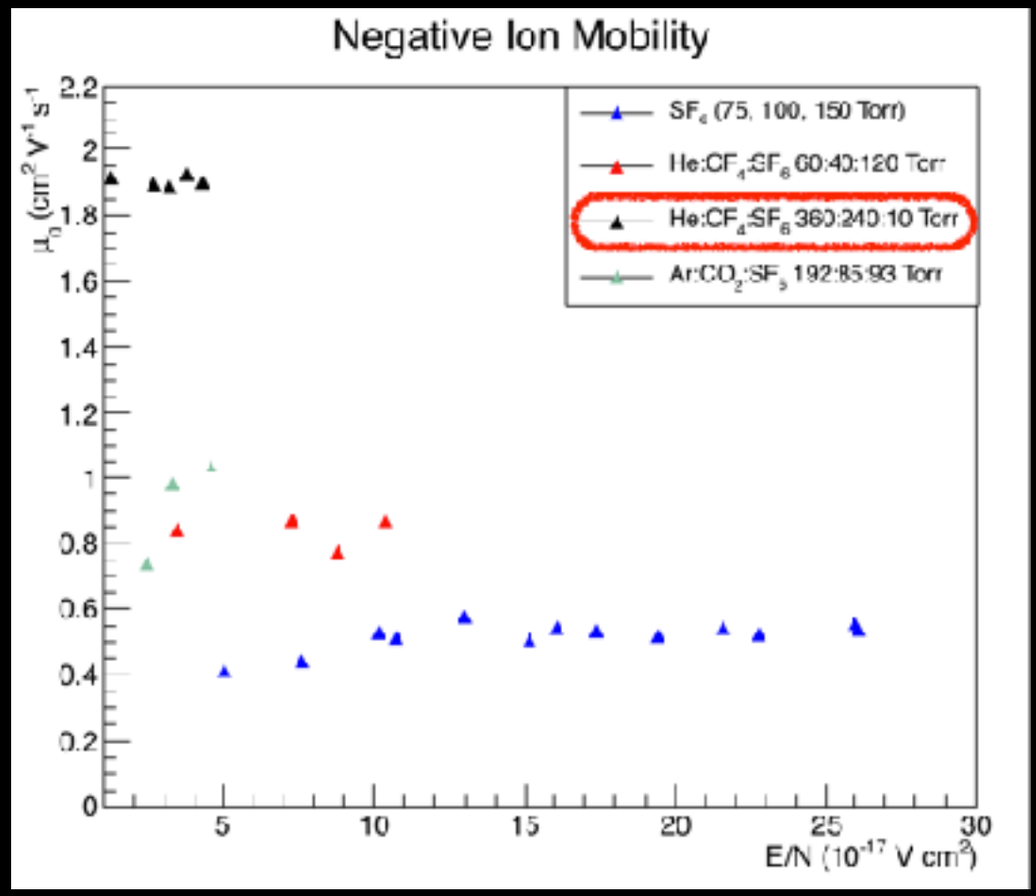
NID AT ATMOSPHERIC PRESSURE

Negative Ion Drift was measured with a He/CF_4/SF_6 (59.0/39.4/1.6) mixture at 610 Torr (0.8 Atm!).



Velocities of cm/ms, typical of ion drift…

For the first time (EVER) NID worked at nearly atmospheric pressure with a low amount of SF_6



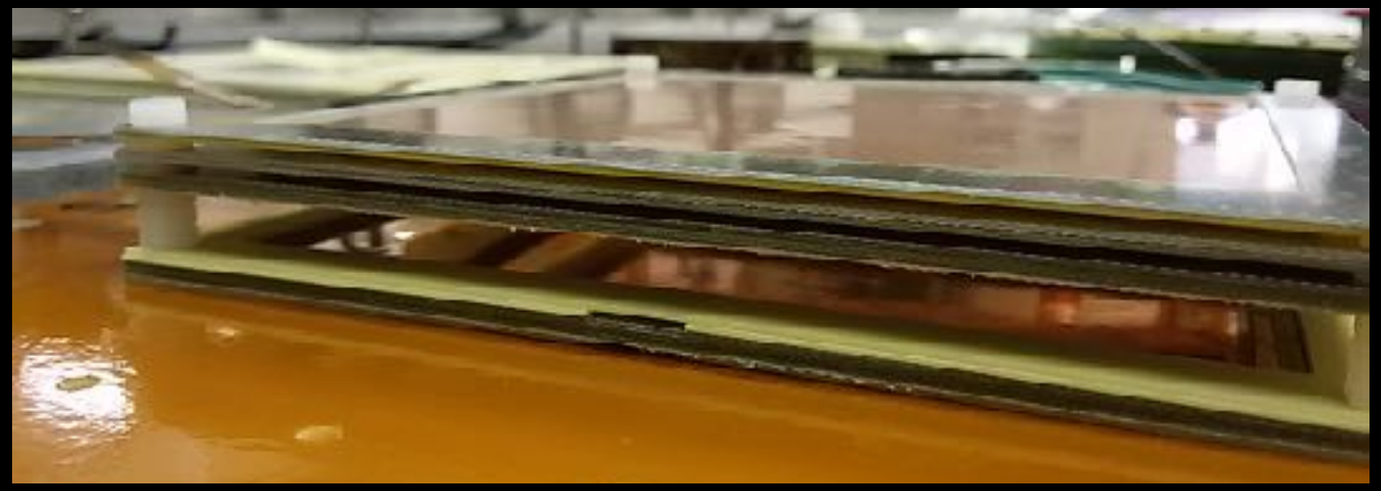
LIGHT: A CHANGE OF PARADIGM

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

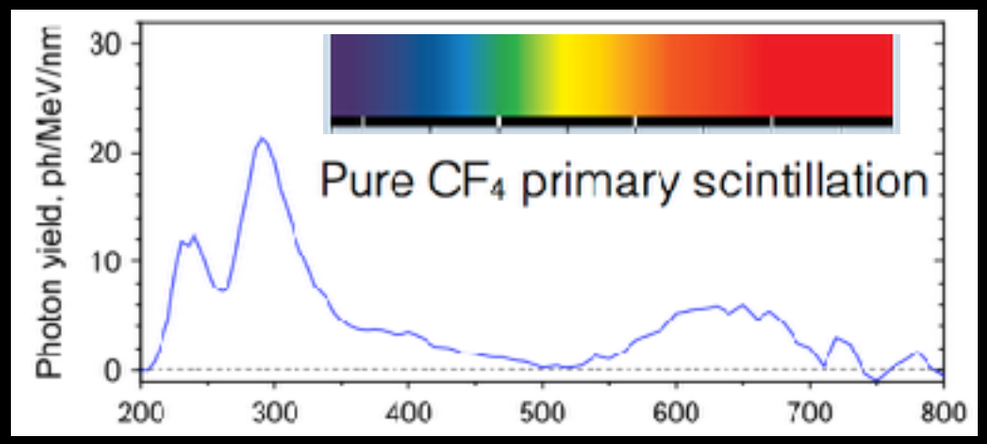
Optical readout of gas detectors offers several advantages:

- optical sensors had a huge development in last years and 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);
- the use of suitable lens allows to acquire large surfaces with small sensors;

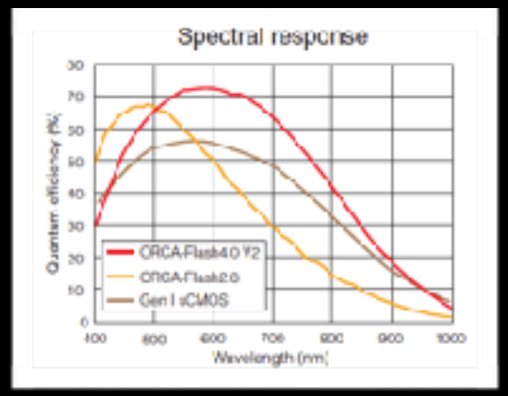
ORANGE



Triple GEM structure (10x10 cm^2) with 1 cm drift gap

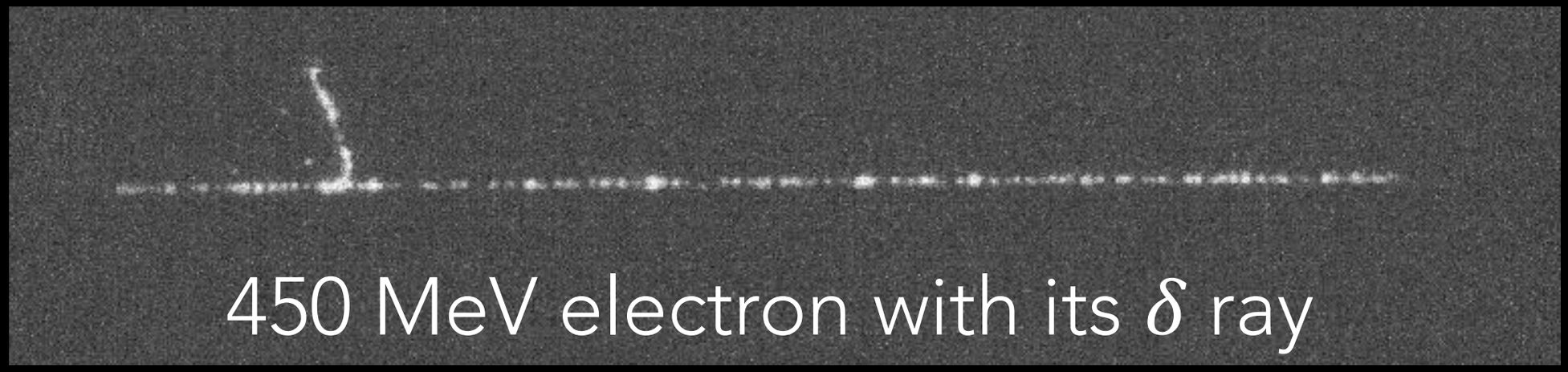


The use of a CF_4 based mixture will produce light around 650 nm

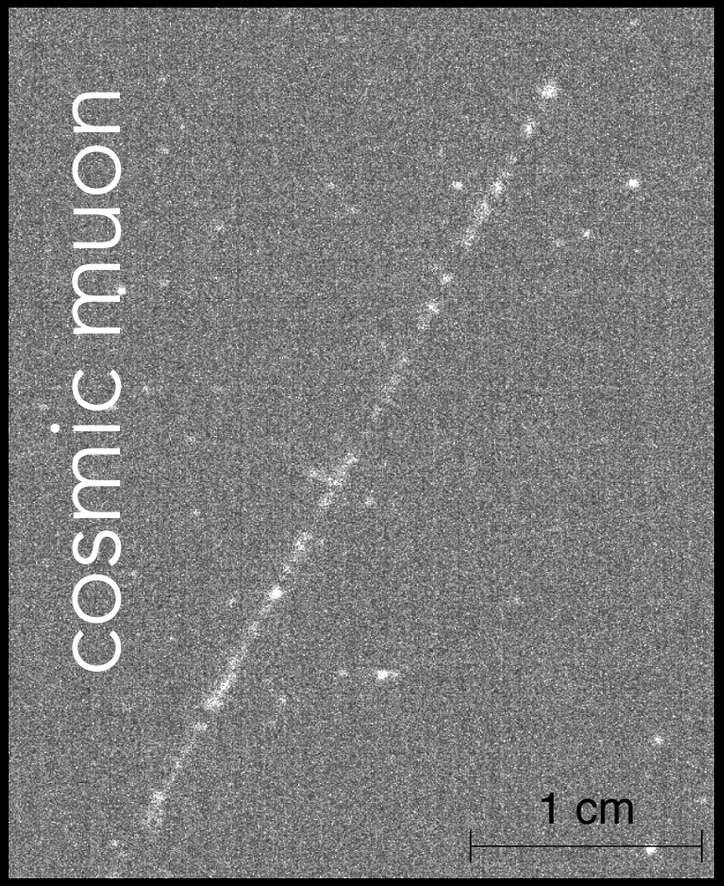


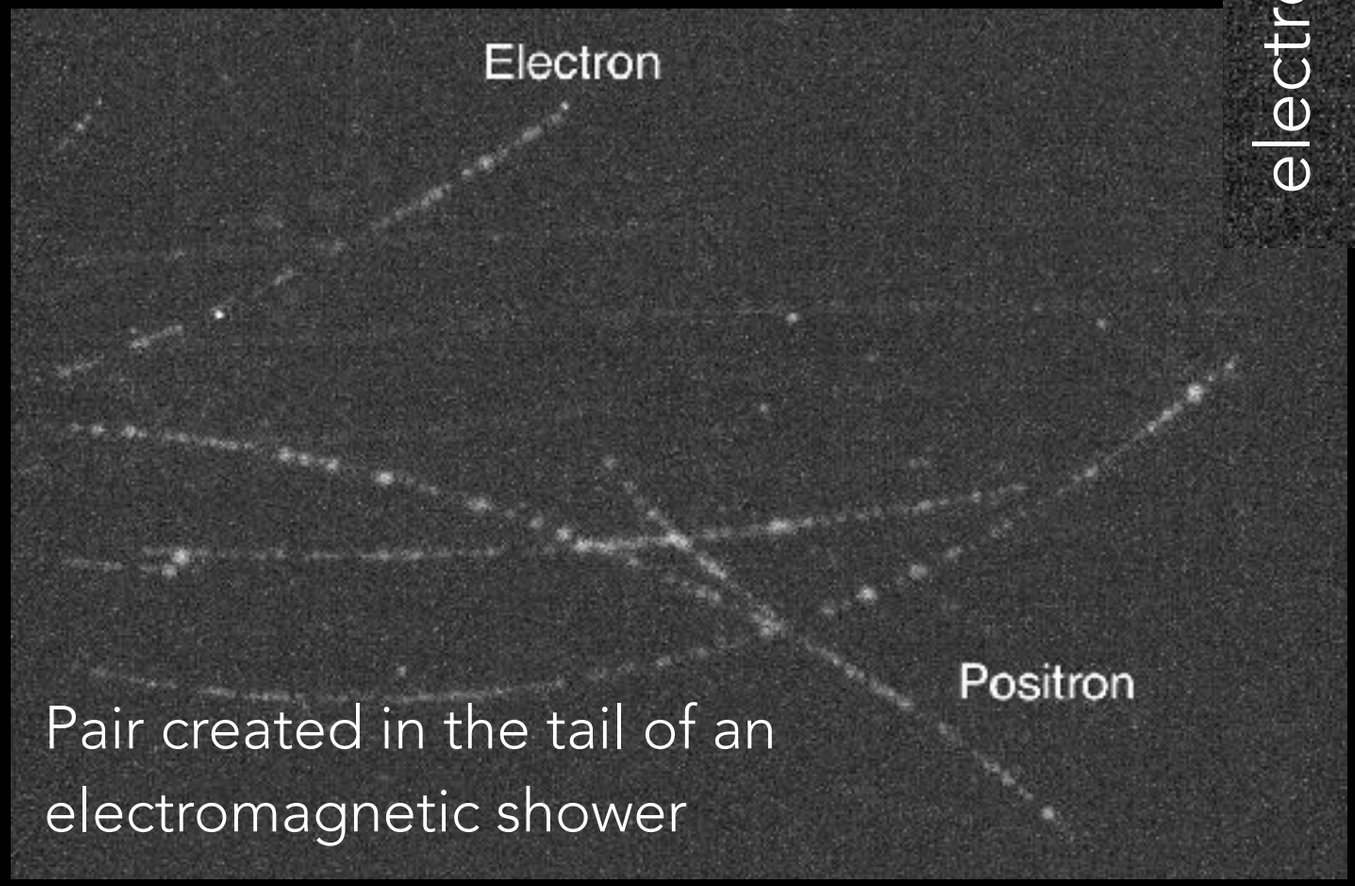
Equipped with a large aperture (f/0.95) lens, it allows to get very clear images of particle tracks

PARTICLE TRACKS

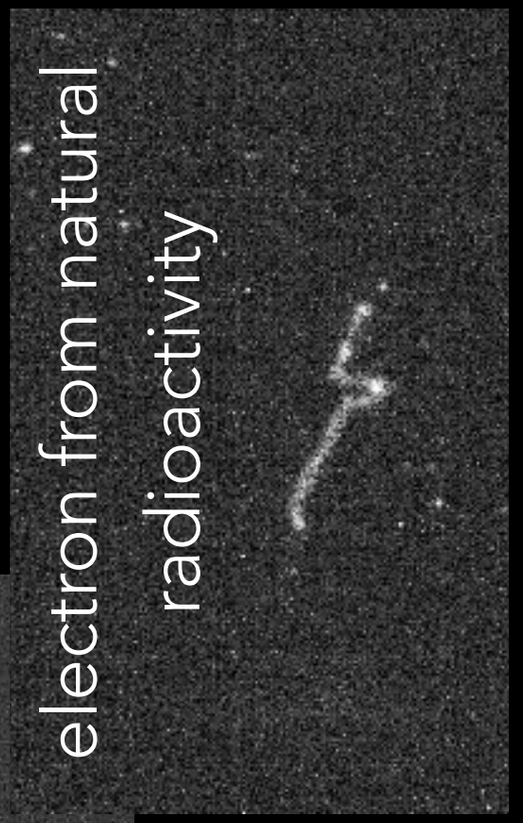


450 MeV electron with its δ ray

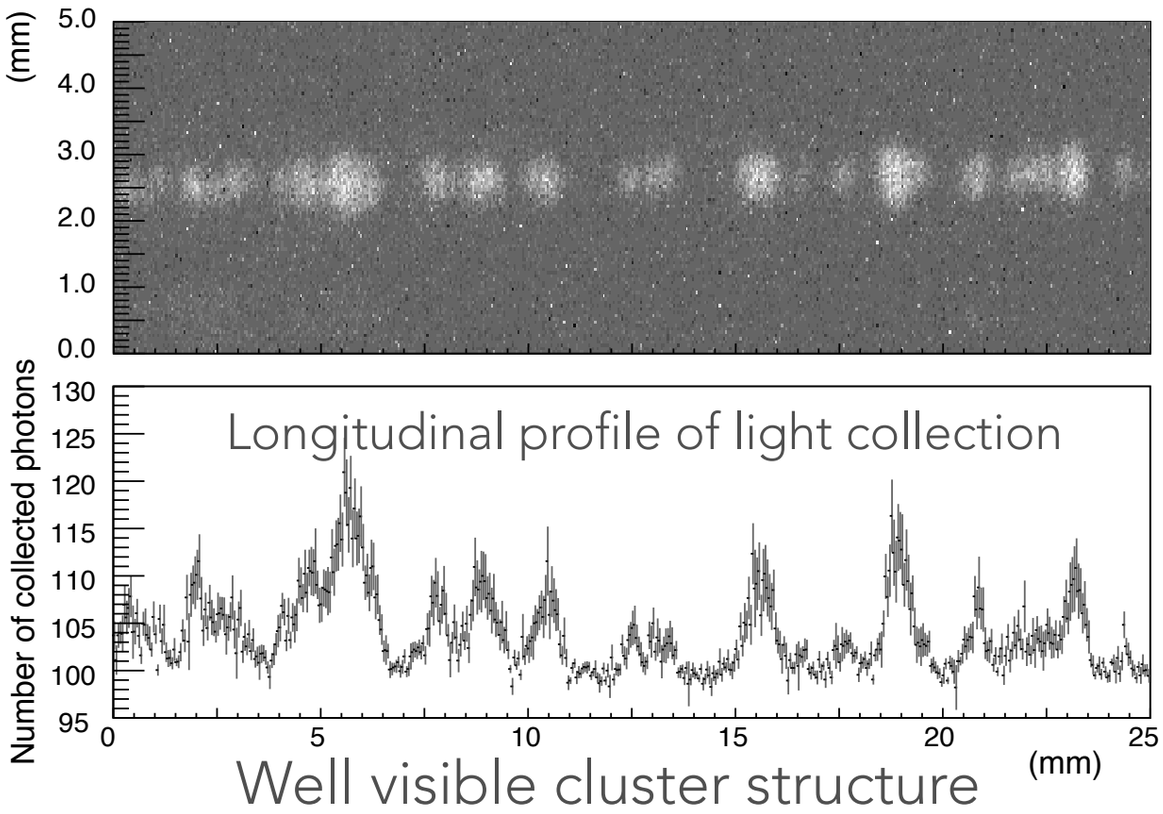


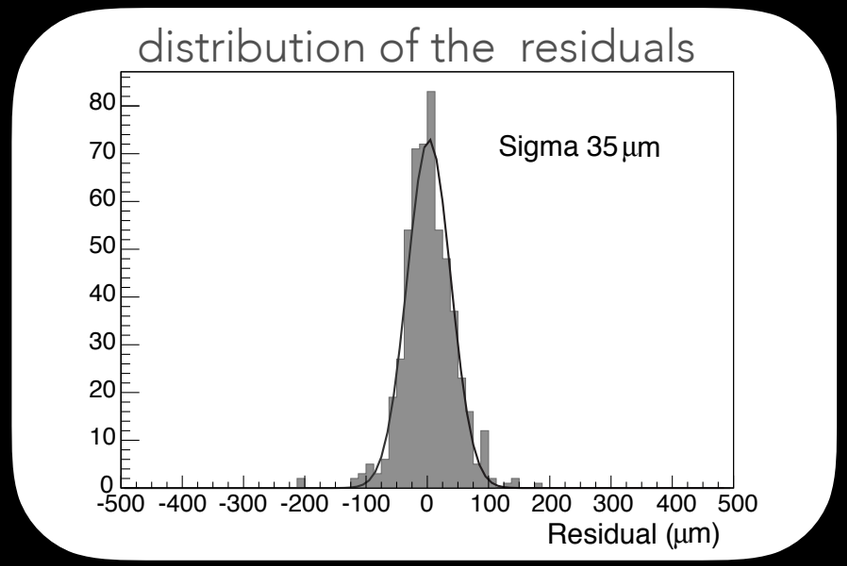


Pair created in the tail of an electromagnetic shower



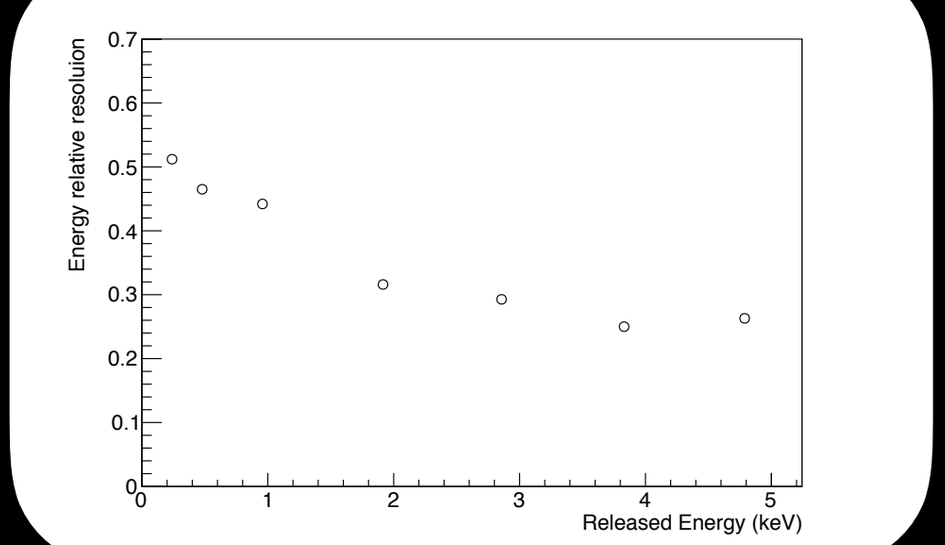
TRACKING AND ENERGY RESOLUTION





A resolution of 35 μm was evaluated.

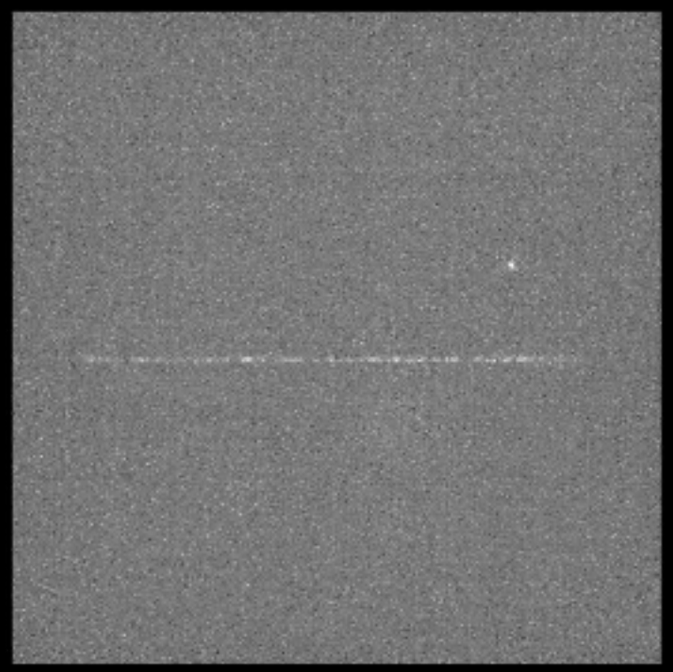
About 1000 collected photons per track mm, 150 per primary electron (i.e. each 30 eV released in gas).

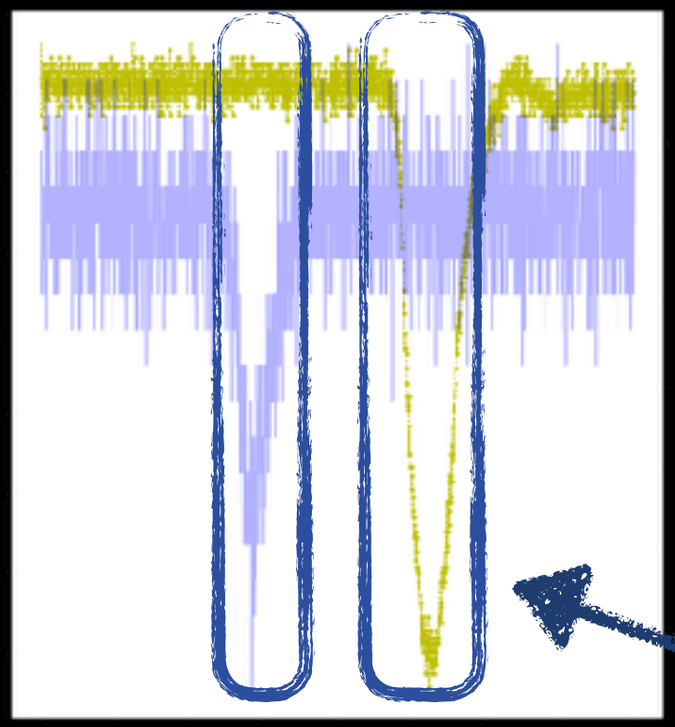


By studying the distribution of collected light in slices of different widths, the energy resolution behavior was evaluated.

CAMERA + PMT + ELECTRIC SIGNAL

In order to get precise information about the time structure of the signal, light can be concurrently readout with a PMT;





The electric signal induced on the bottom electrode of last GEM can be acquired too…

PMT signal

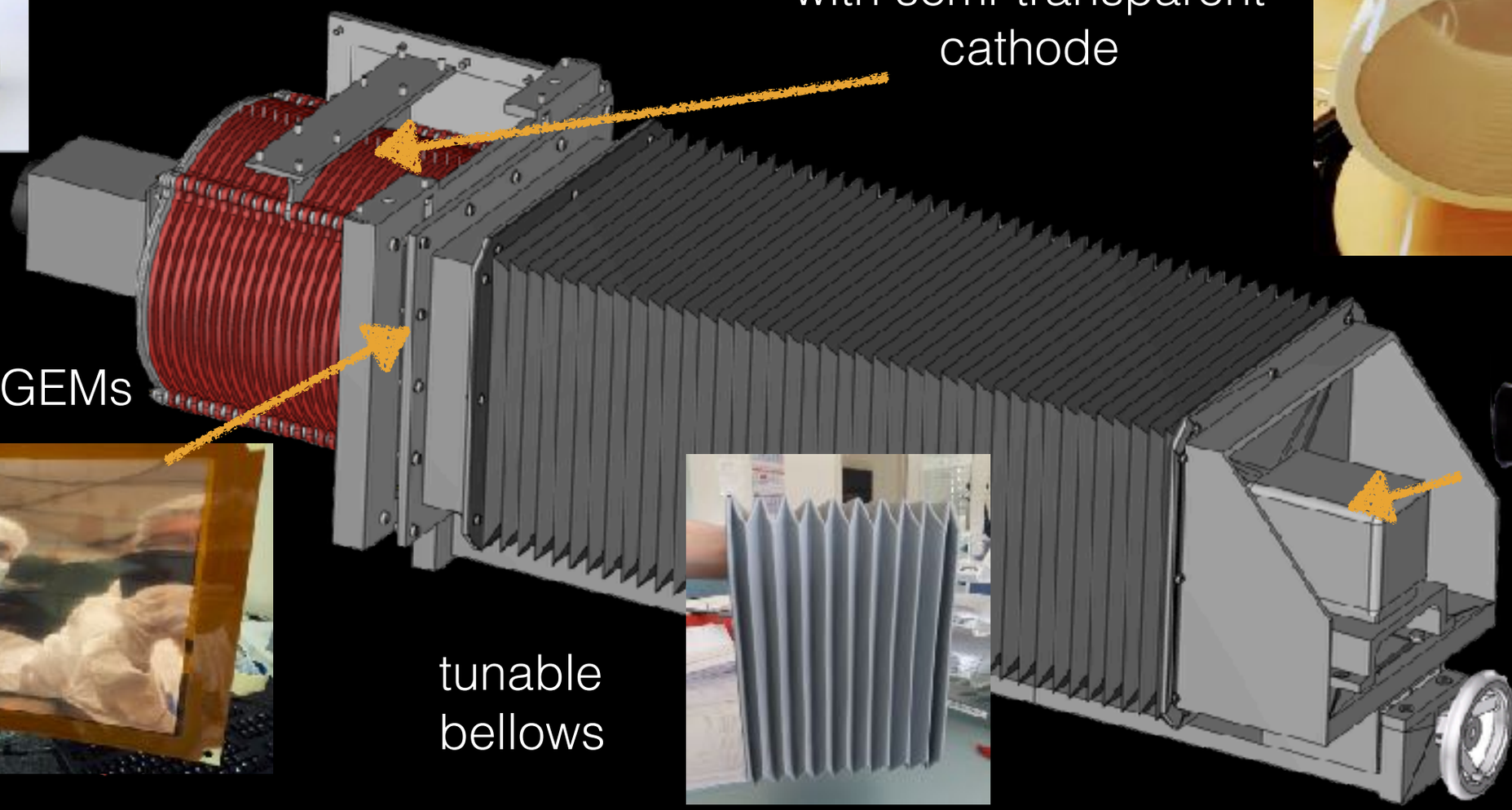
Electric signal induced on the GEM electrode

σ_t ~ 5.5 ns + V_{drift} ~ 7.4 cm/μs

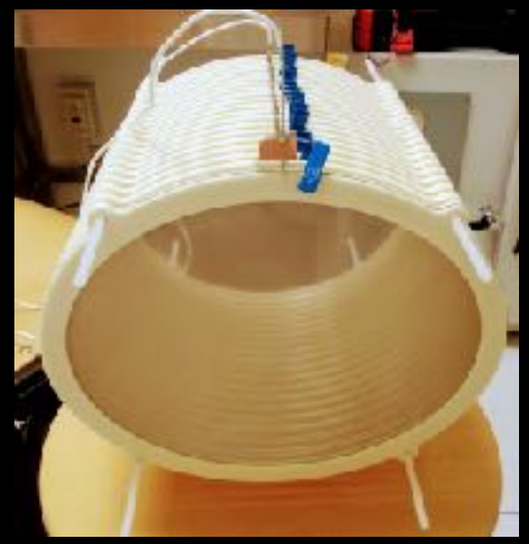
—> σ_z ~ 400 μm

LARGE PROTOTYPE

A new prototype with 7 litre sensitive volume (LEMOn: Large Elliptical Module Optically readout) is under construction and will be tested on electron beam by the end of July.



Elliptical field cage with semi-transparent cathode



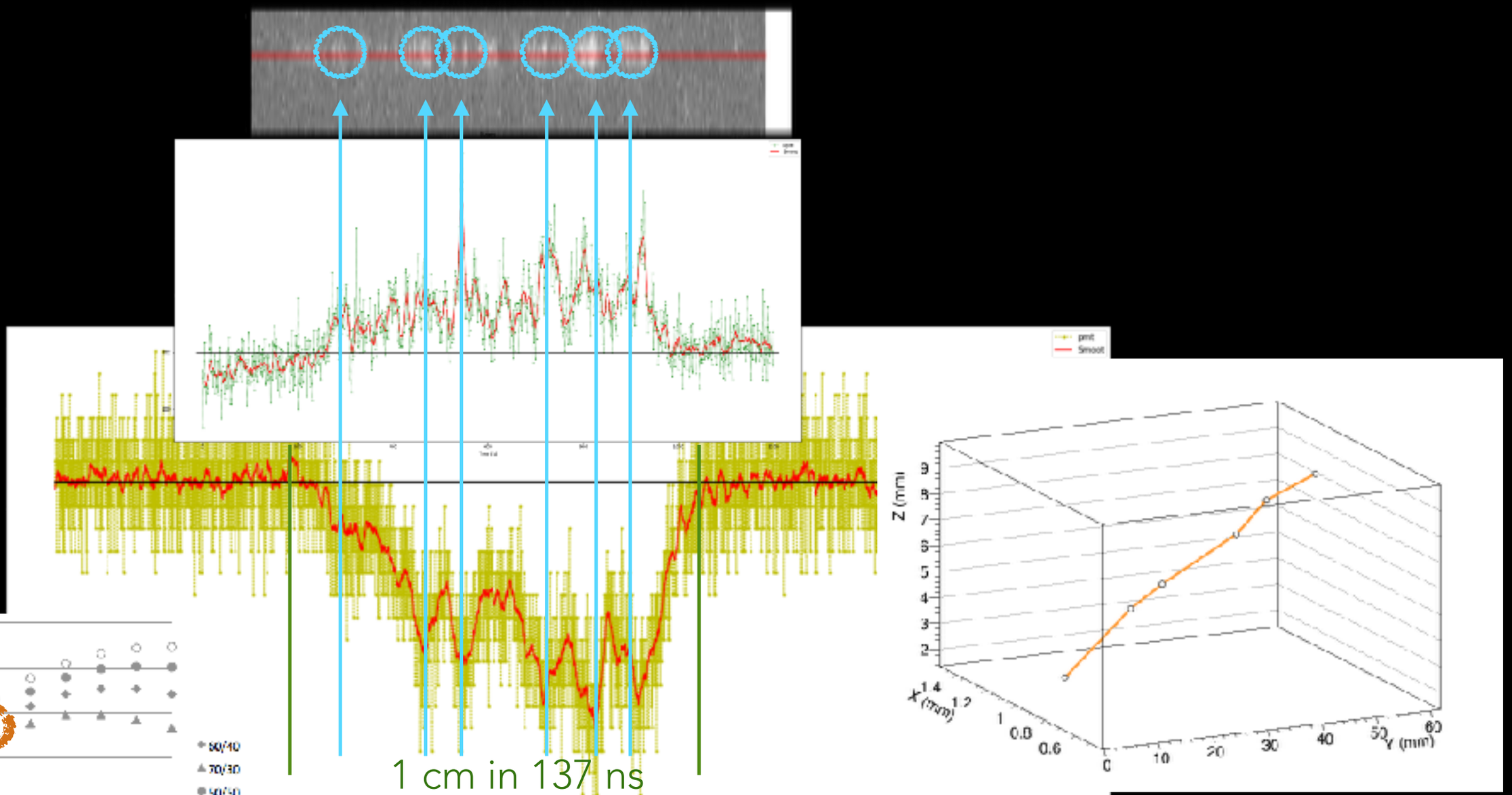
24x20 cm^2 GEMs

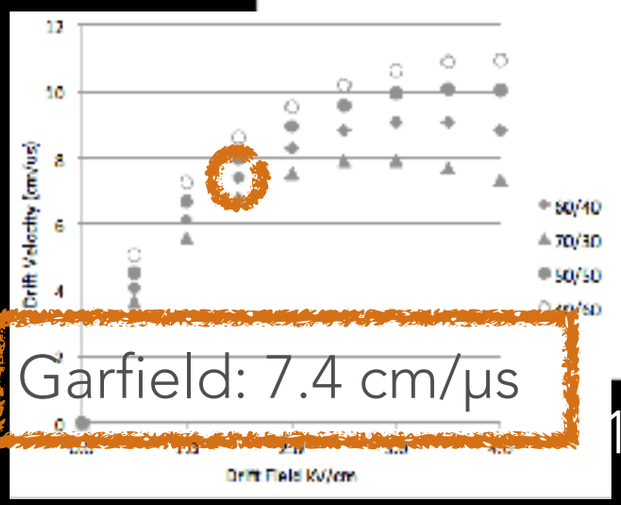
tunable bellows

CMOS camera

THANKS!

INCLINED TRACKS





Garfield: 7.4 cm/μs