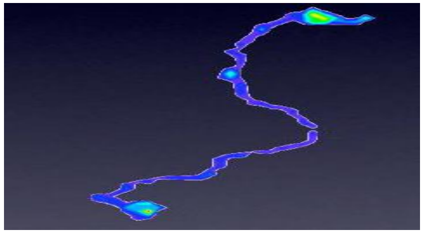
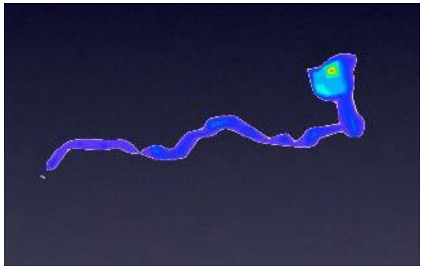




RD51 Academia-Industry Matching Event
Special Workshop on Photon Detection with MPGDs

Photon detection with simultaneous electron reconstruction in High Pressure Xenon

Diego Gonzalez Diaz (Univ. Zaragoza and CERN)

11/06/2015

main characteristics of gas for X- and γ-ray detection

- Competitive energy resolution at the scale of 0.4-1.2%√1/MeV (light readout) and 1-4.5%√1/MeV (charge readout).

- Active medium is easily exchangeable!. Large choice of Z: He(Z=2)->Xe(Z=54).

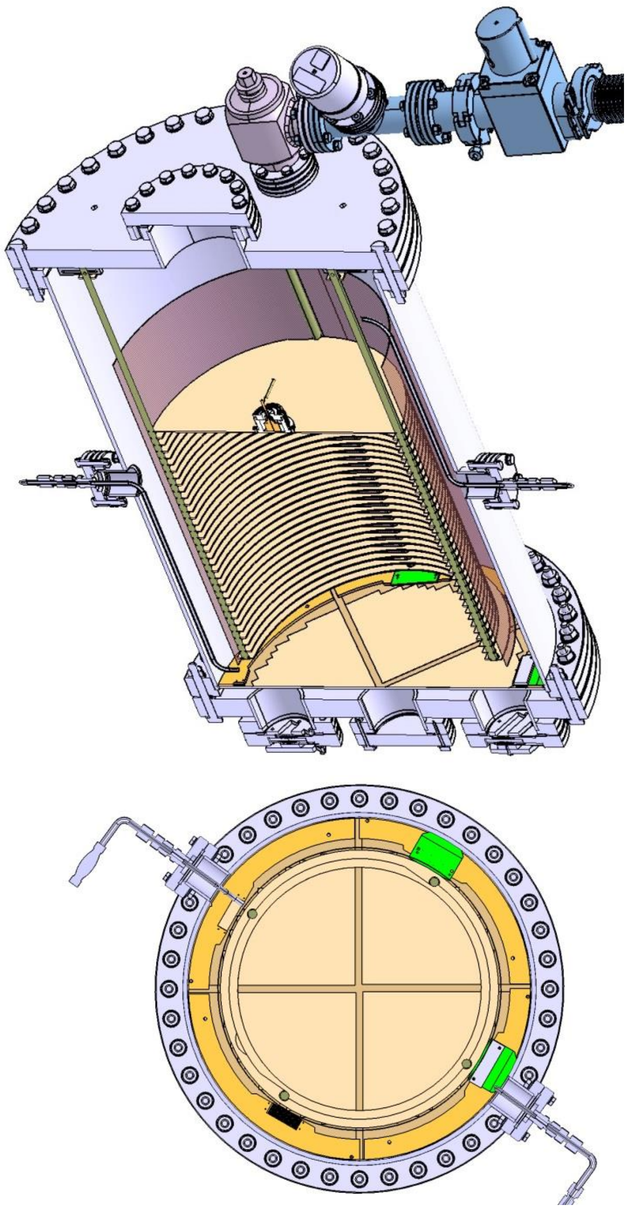
- Relative ease of photo-electron reconstruction, multi-site(Compton) or pair production.

main advantages of Xenon

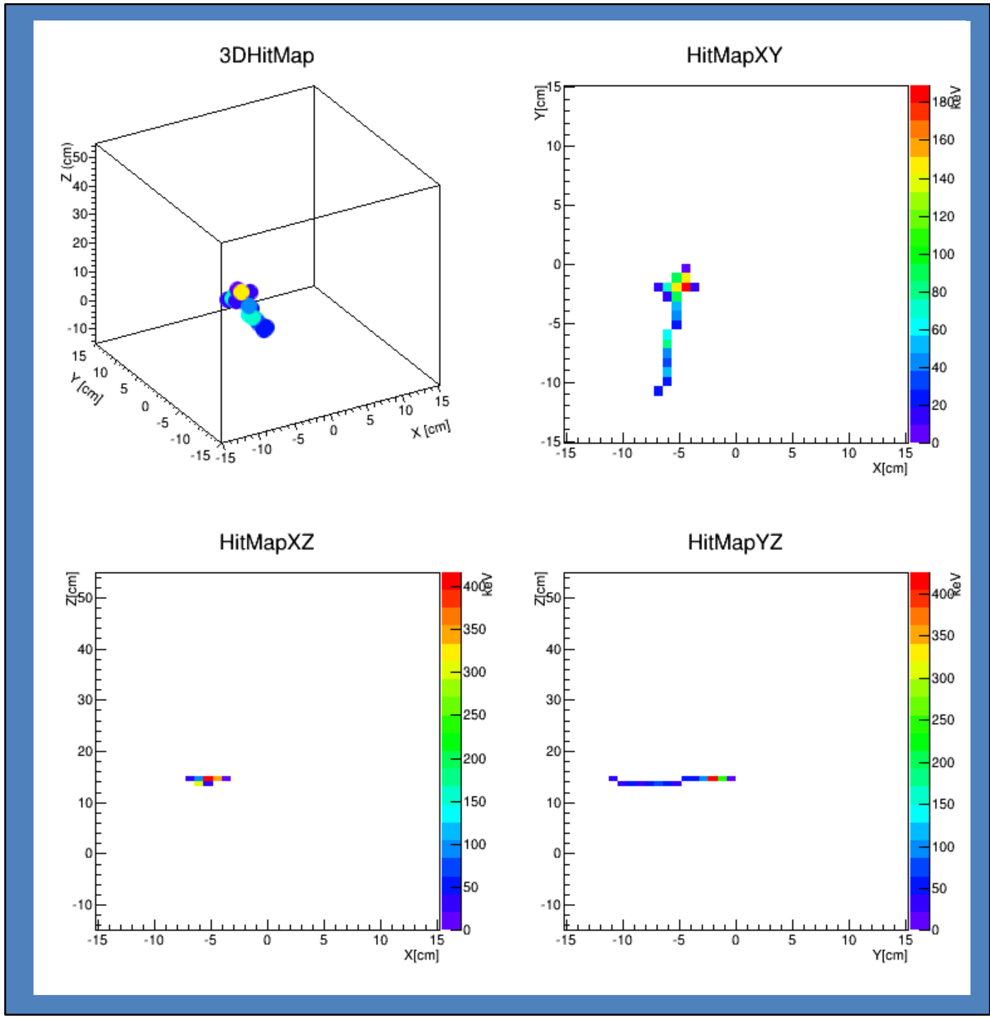
- High density (more compact detector).

- Easily detectable scintillation at 170nm (Xenon works also as wave-length shifter!).

response to γ-tracks in a typical gaseous detector (TPC)



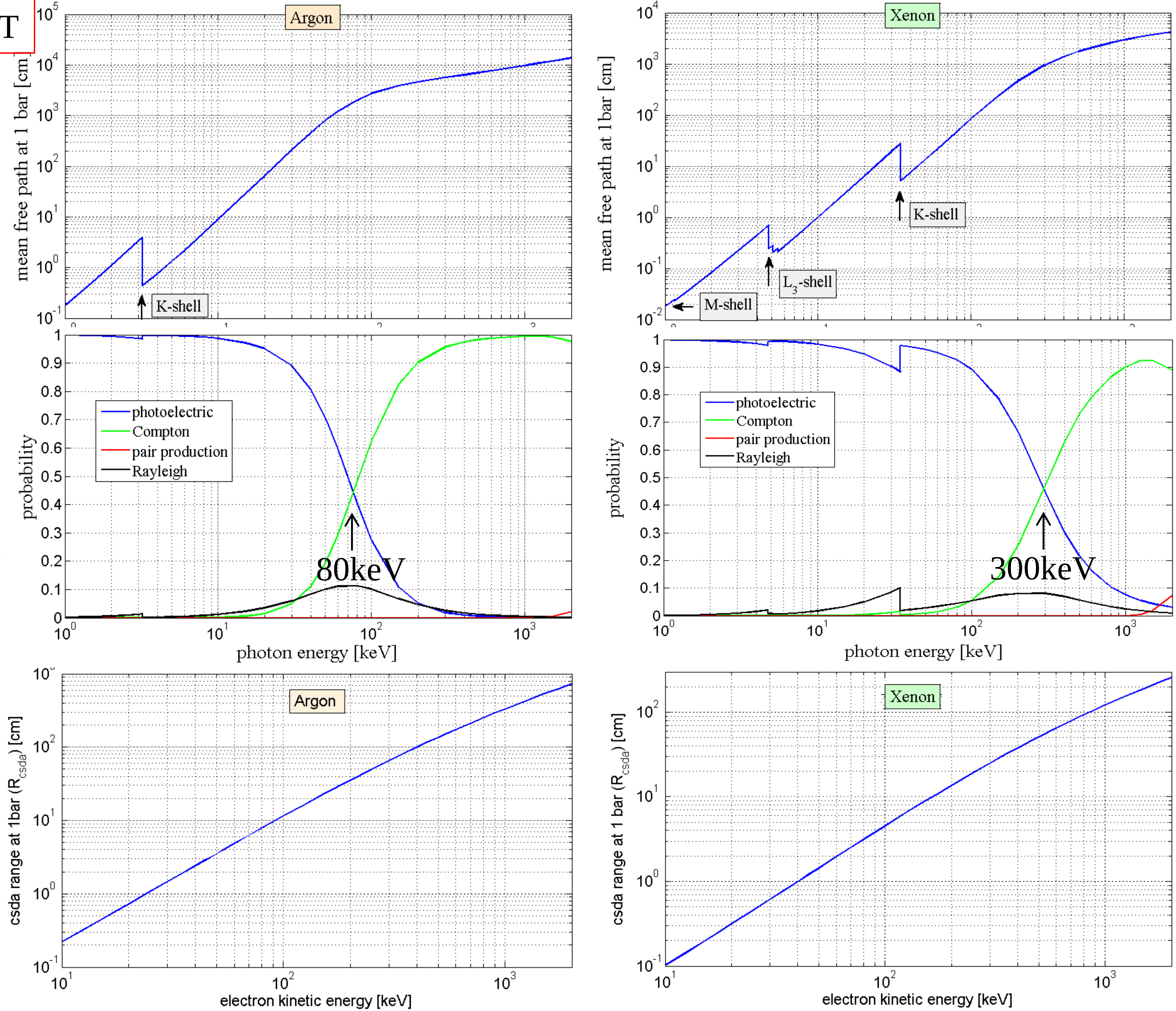
$\varepsilon_\gamma = 1.25 MeV$



From NIST

Ne

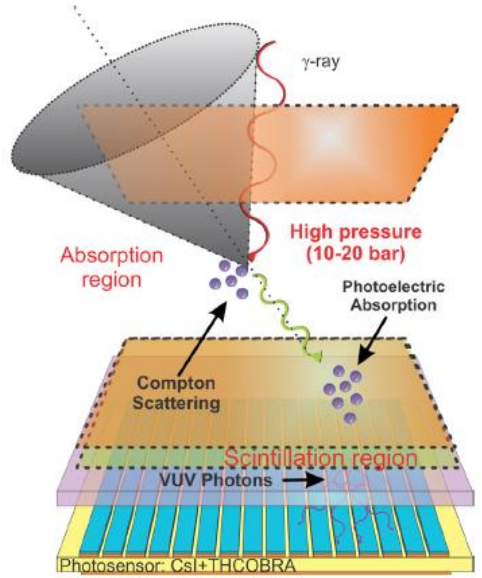
40keV

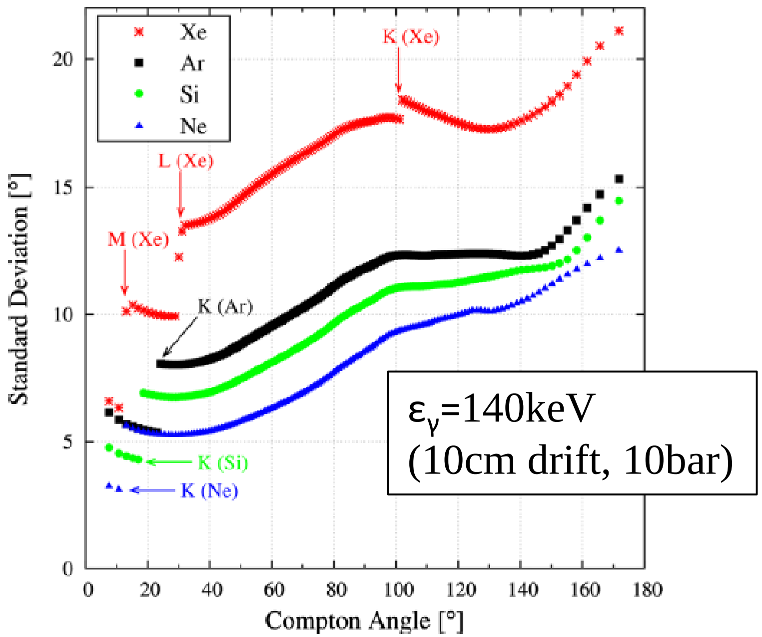


some figures of merit depending mainly on the gas filling

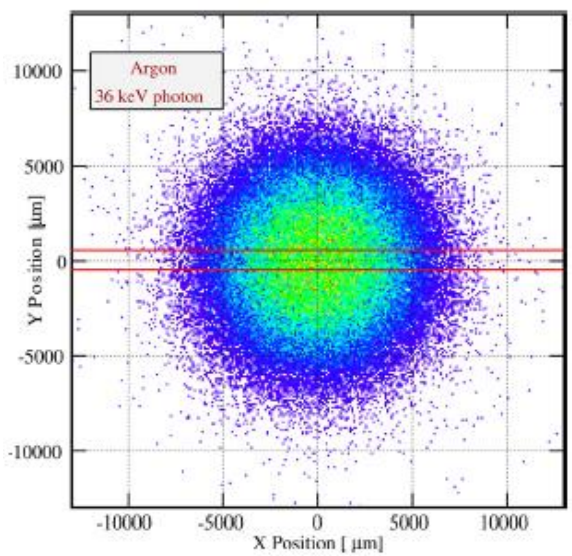
from C. Azevedo and J. Veloso

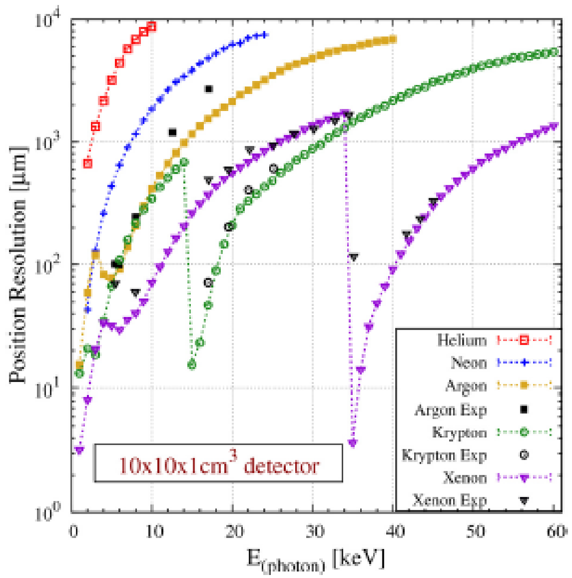
Compton camera





X-ray detector



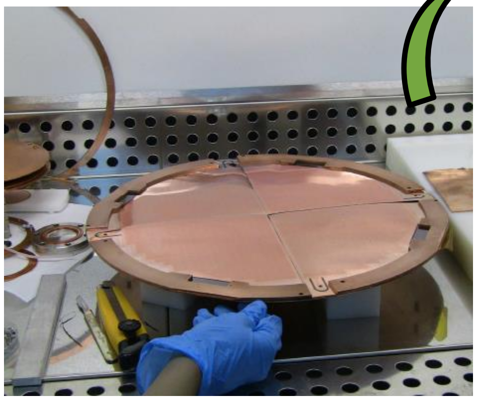


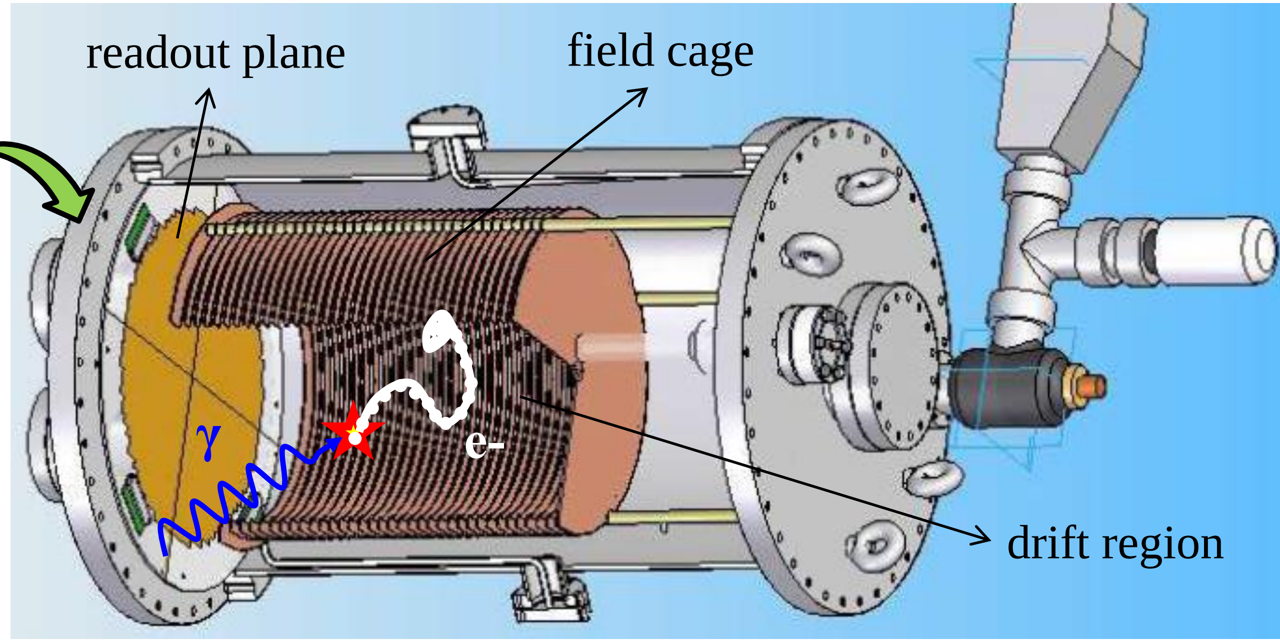
Two main detector technologies for X and γ-ray detection

charge readout

light readout

1. Classical charge-readout TPC

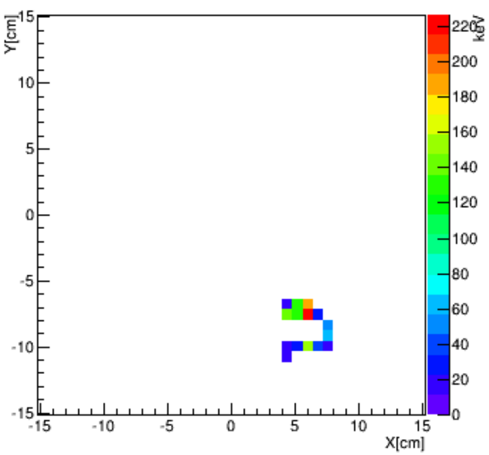


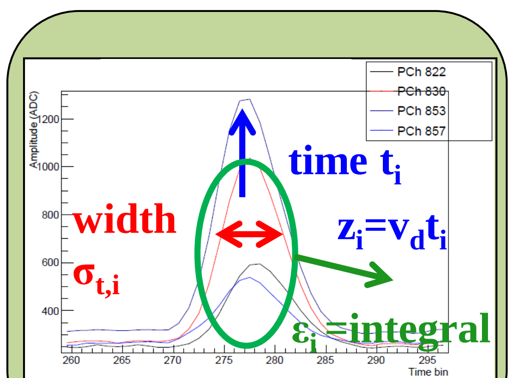


2D information from readout pixelization

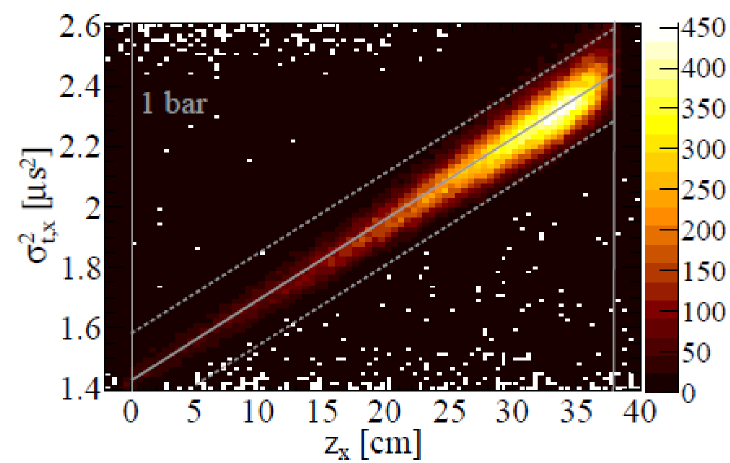
3D information from pulse shape

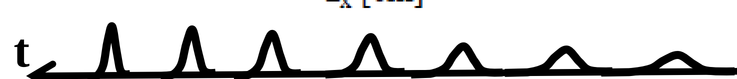
3D-positioning from diffusion of ionization-cloud **(?)**





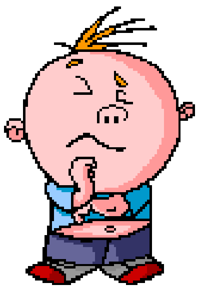
typical x-ray event

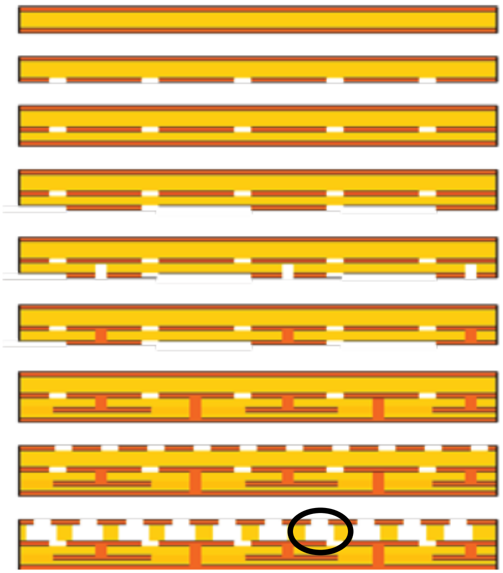




the readout: micro-pattern hole-amplification structure

('microbulk MicroMegas') ⇨ (also standard MM or GEM depending on the conditions)





Double side Cu-coated (5 μm) Kapton foil (50 μm),

Construction of readout strips/pads (photolithography)

Attachment of a single-side Cu-coated kapton foil (25/5 μm)

Construction of readout lines

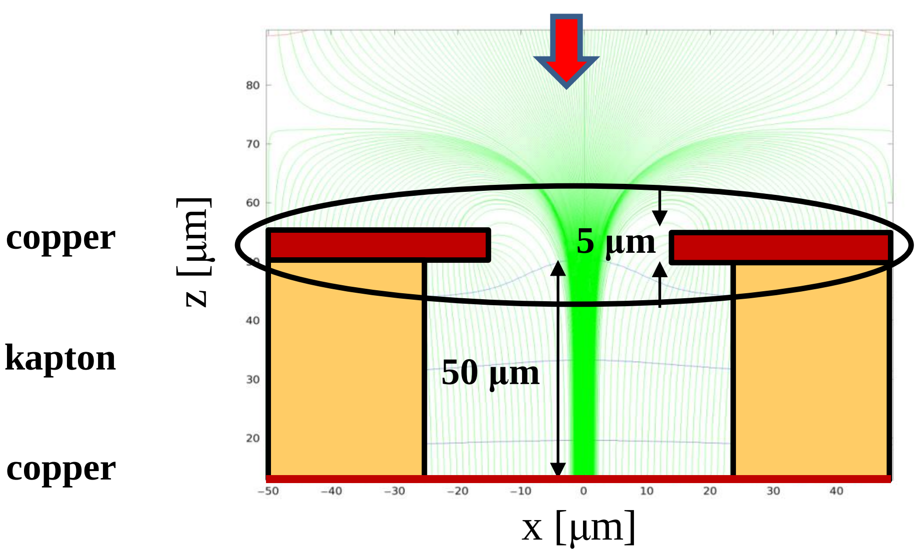
Etching of kapton

Vias construction

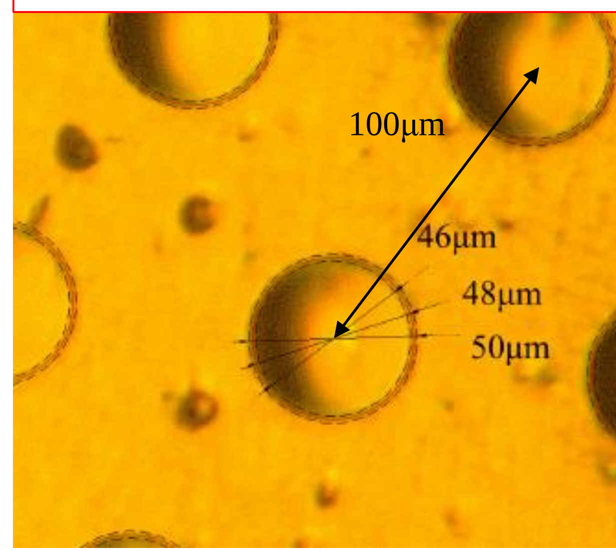
2^{nd} Layer of Cu-coated kapton

Photochemical production of mesh holes

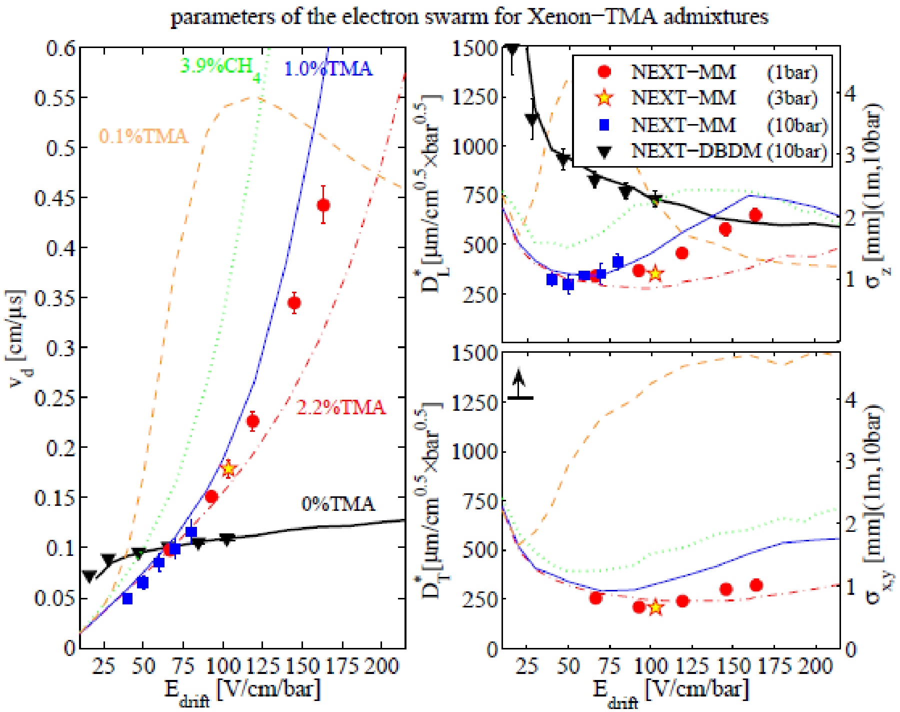
Kapton etching / Cleaning

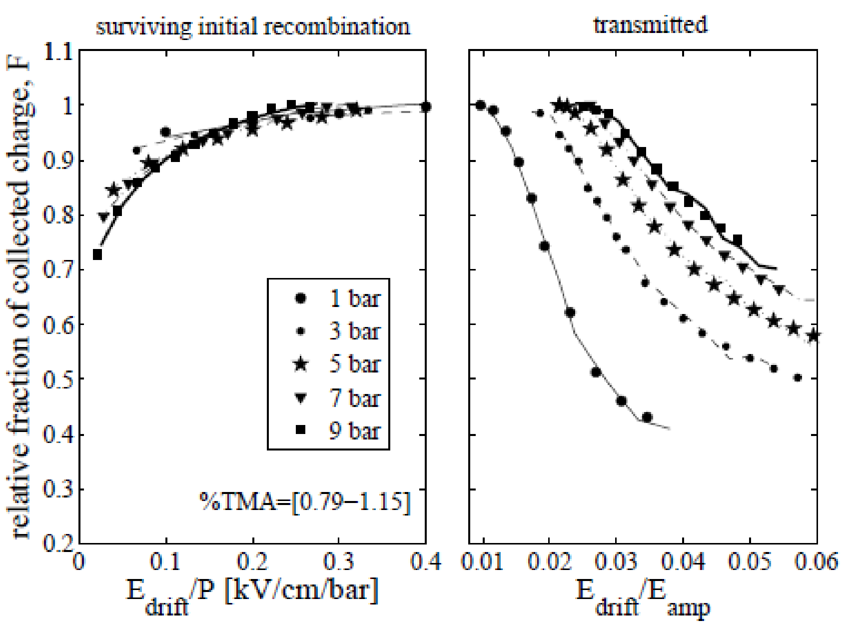


100Mio holes/m^2
Manufacturable in 30cm x 30cm (MM) and 1m x 1m (GEM)

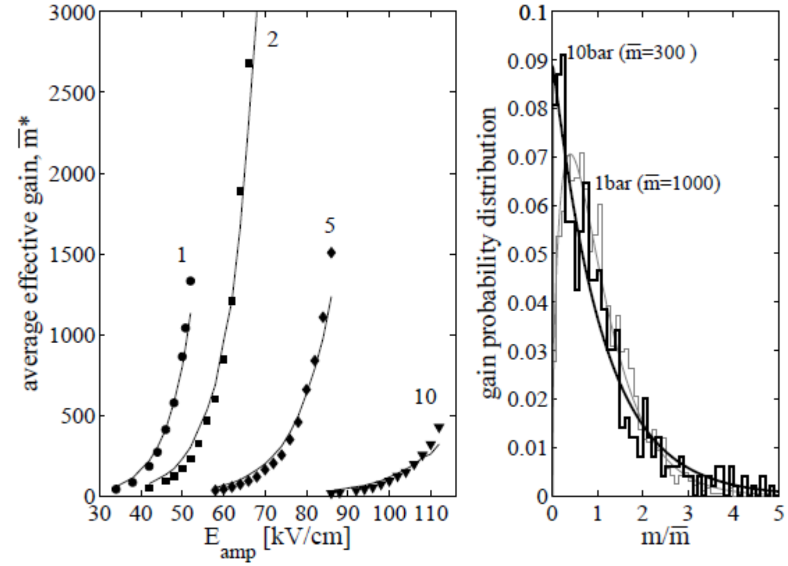


drift and drift-to-readout transition

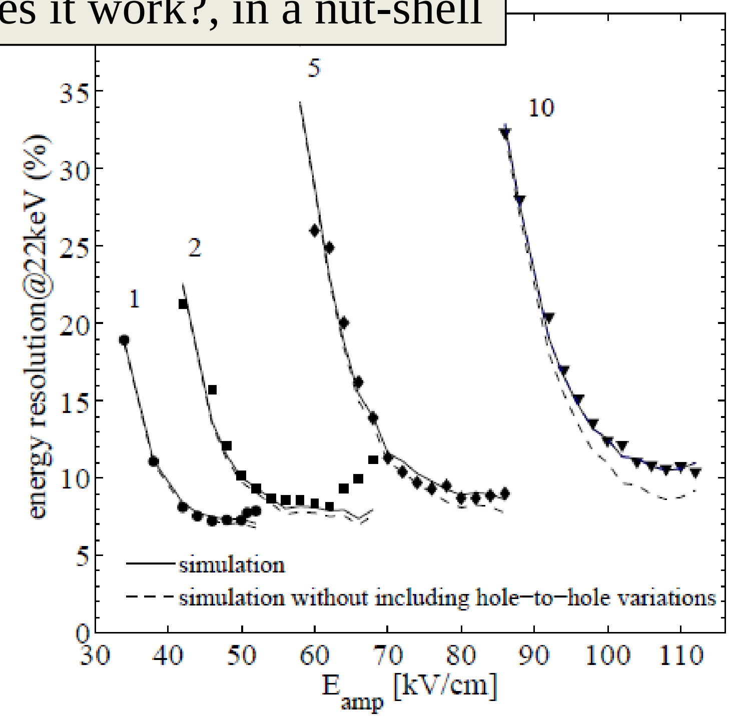




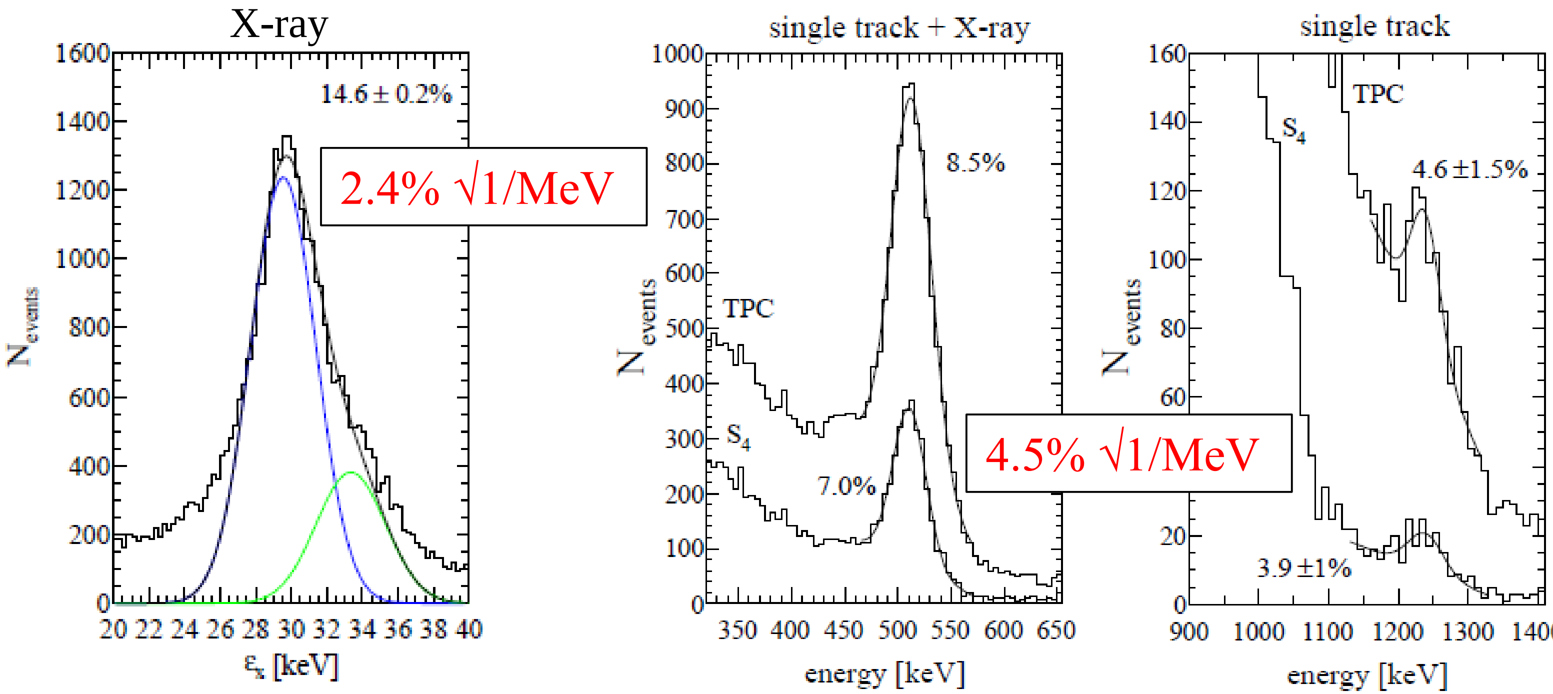
readout

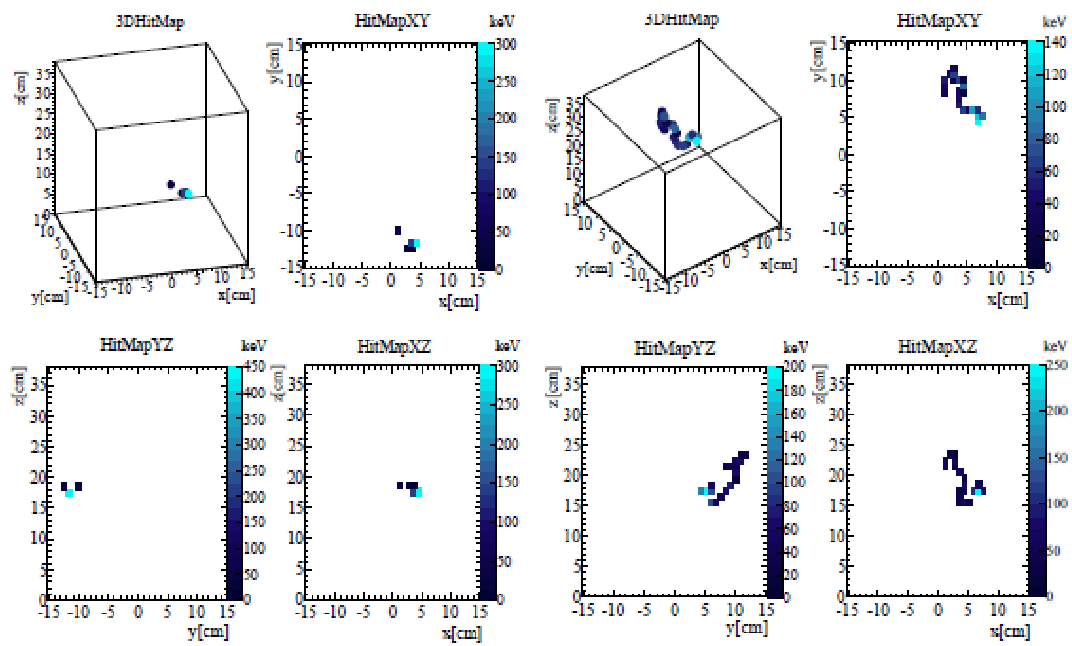


How does it work?, in a nut-shell



final performance in a real-size system with charge-readout





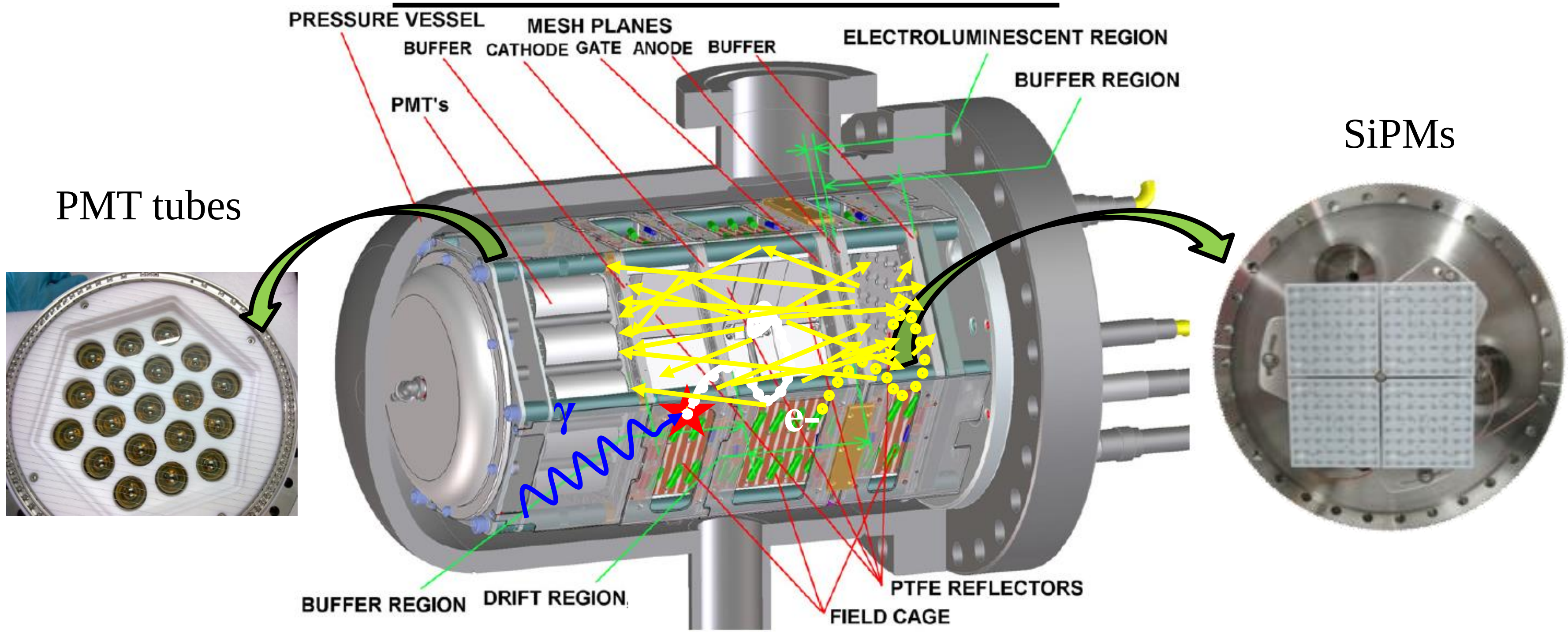
Active volume: 38cm x 700cm^2

P=10bar

Xe/TMA (99/1)

Operation time: 100 live days
(nearly no sign of deterioration)

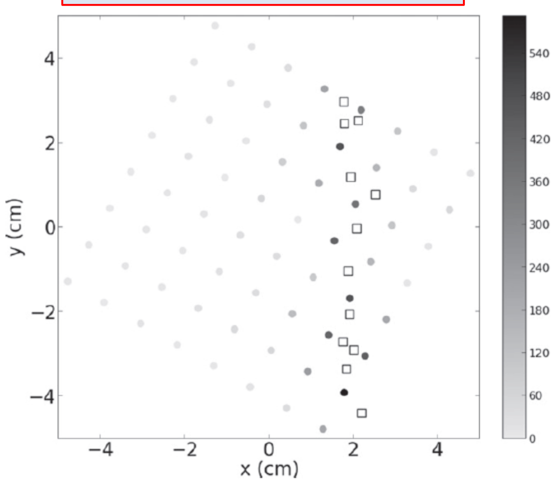
2. Optical TPC

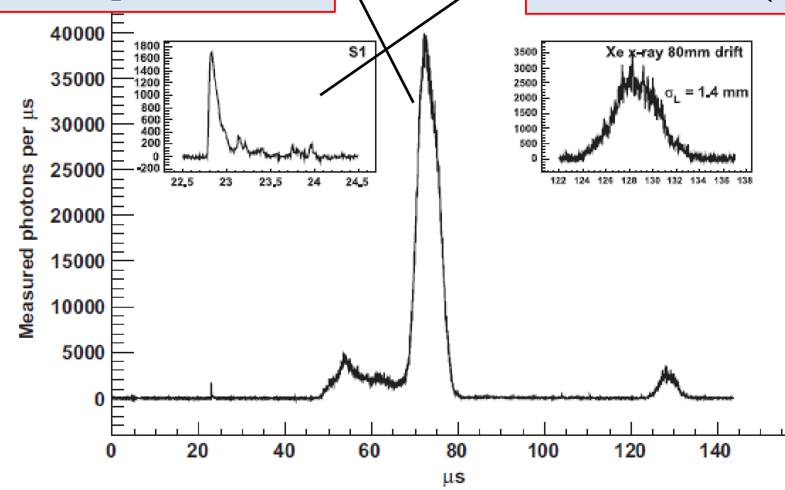


2D information from readout pixelization

3D information from pulse shape

3D-positioning from primary scintillation (S_1)



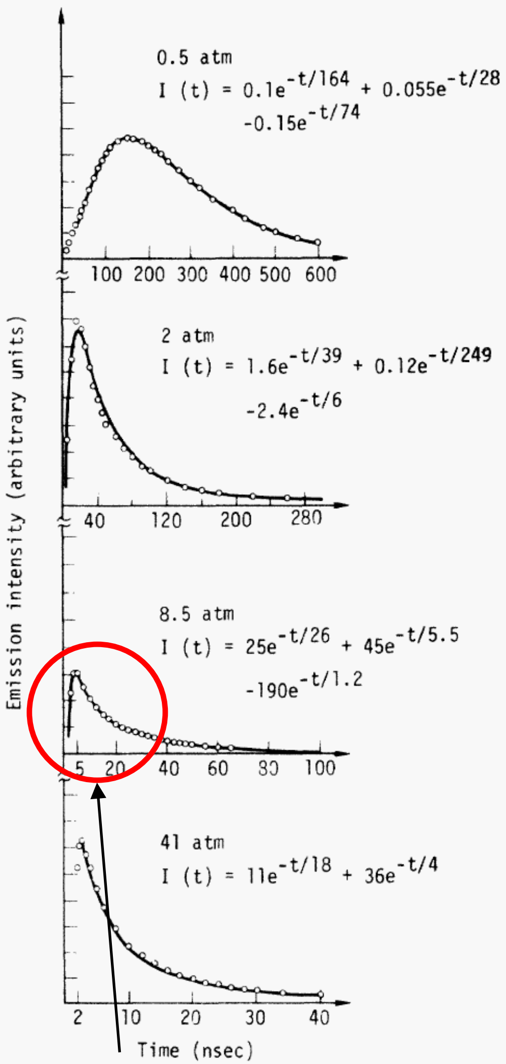


How does it work?, in a nut-shell

primary scintillation

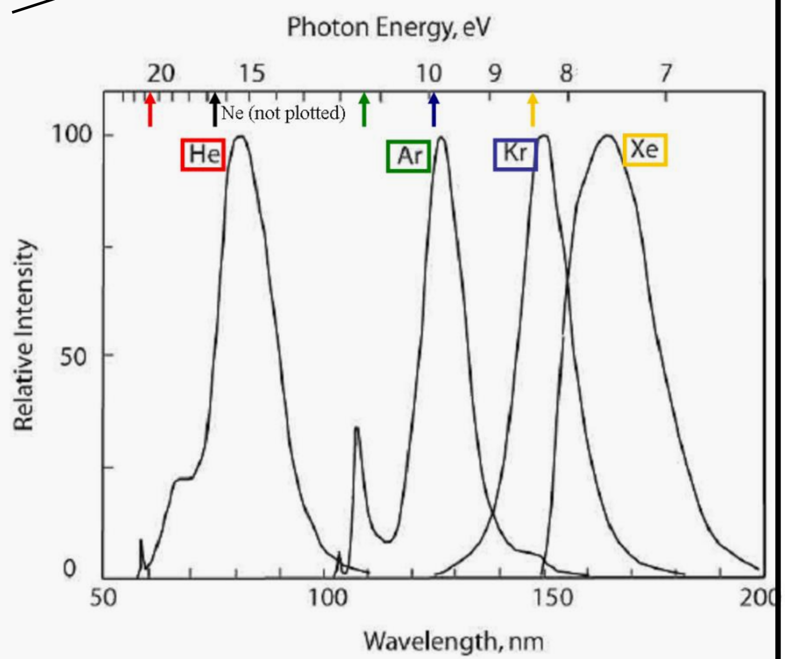
yield: S_1=17000 γ/MeV

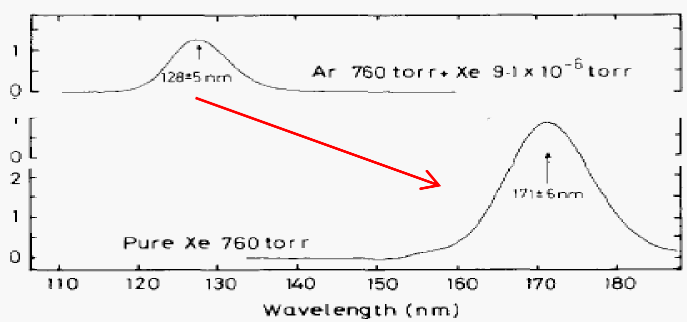
time dependence



very fast at high pressure

emission spectrum

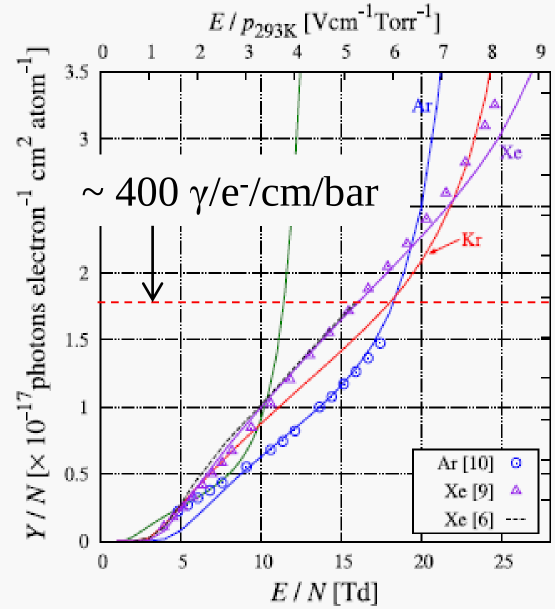




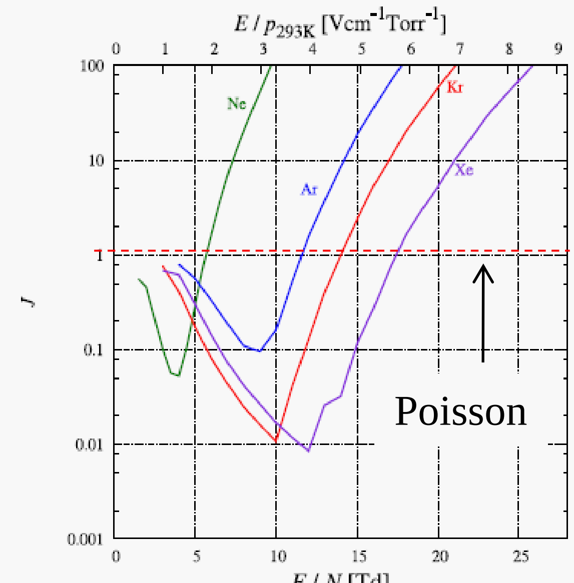
Xenon is an excellent wave-length shifter for other noble gases!

secondary scintillation yield

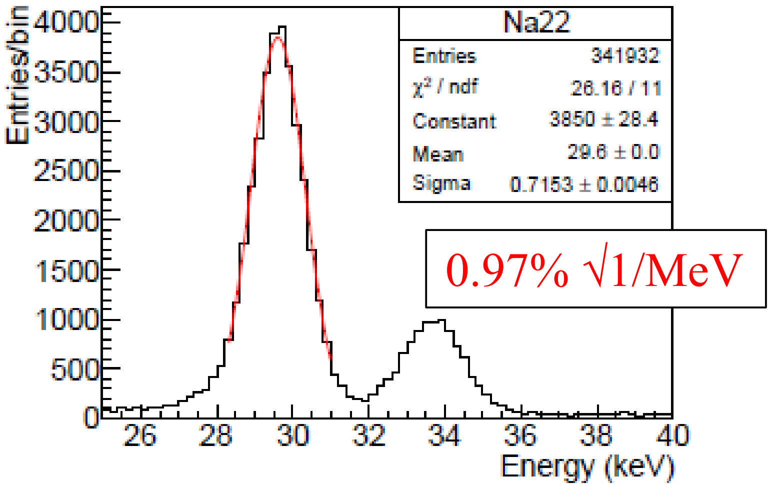
yield

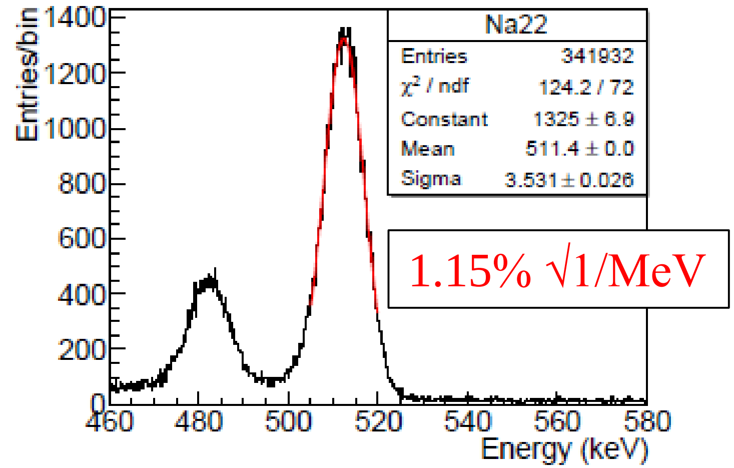


fluctuations



final performance in a real-size system with light-readout



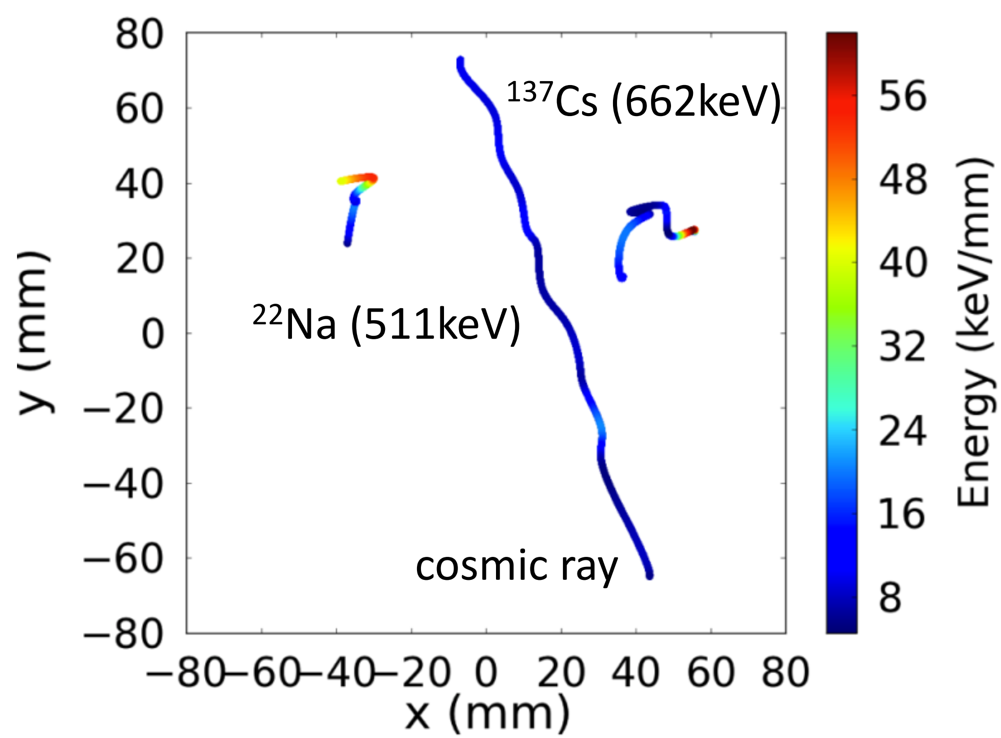


Active volume: 30cm x 150cm^2

P=10bar

pure Xe (99/1)

Operation time: several months



typical cases of interest for γ-reconstruction (photon angle and/or polarization)

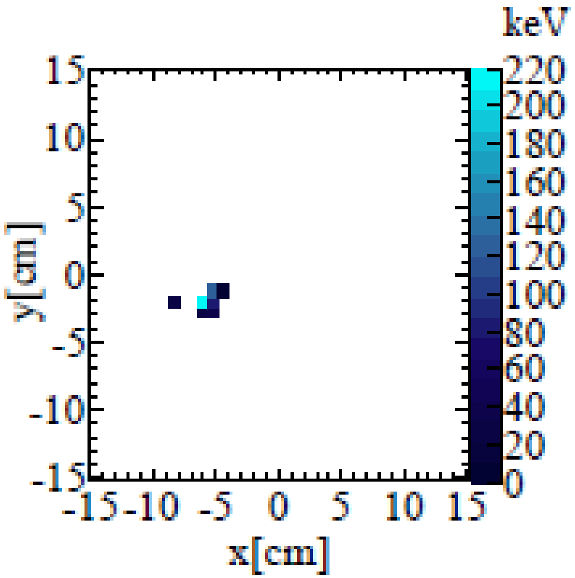
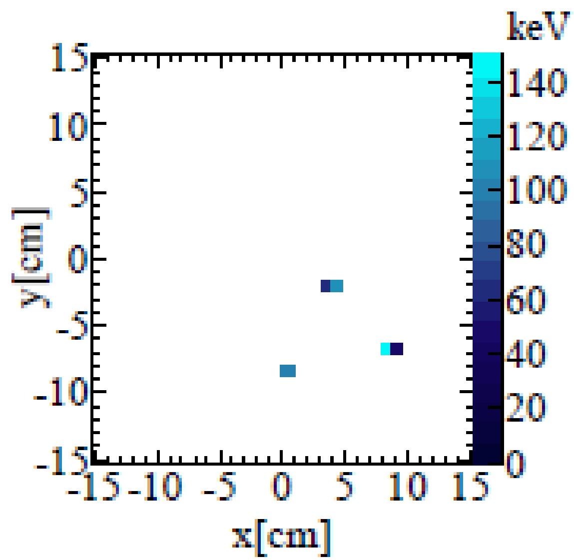


Photo-electron at 511-30keV
and displaced X-ray (30keV)



Multi-Compton event
at 511 keV

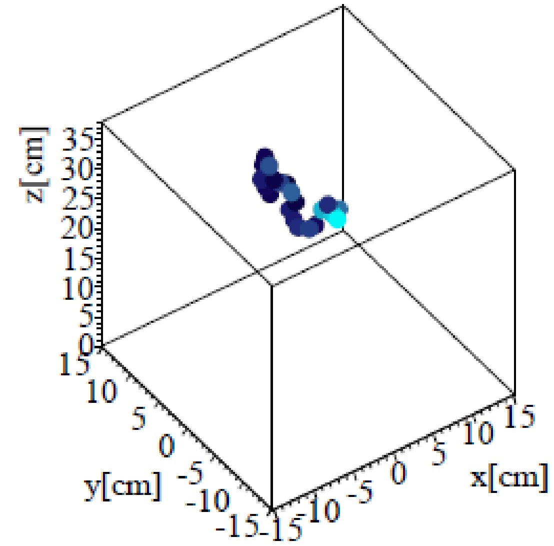
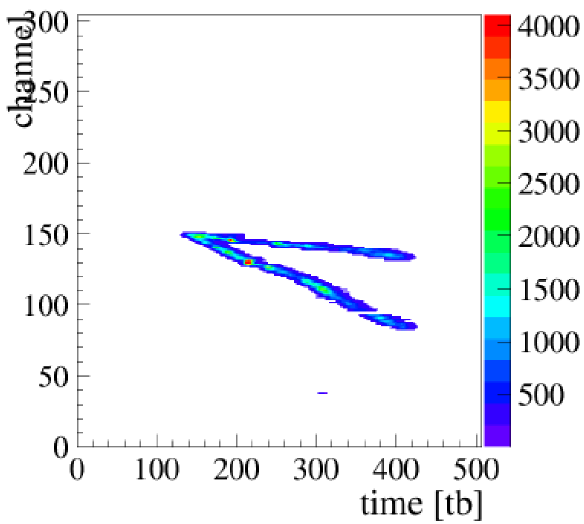


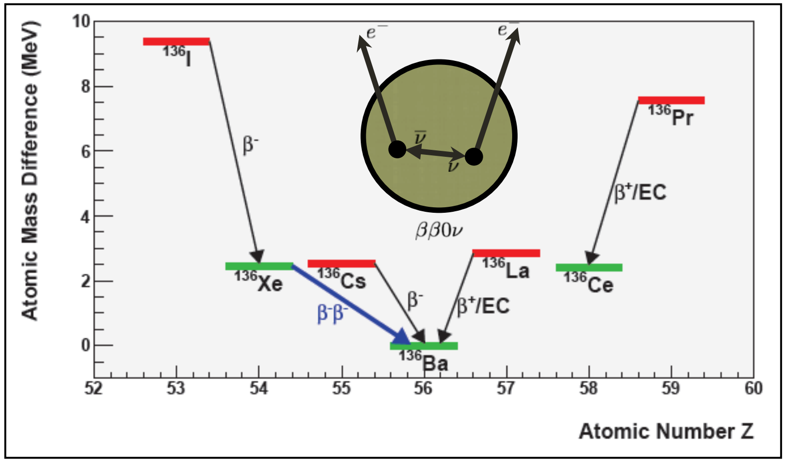
Photo-electron at 1.275 MeV

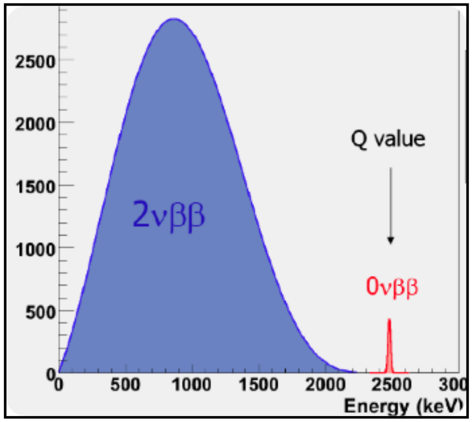


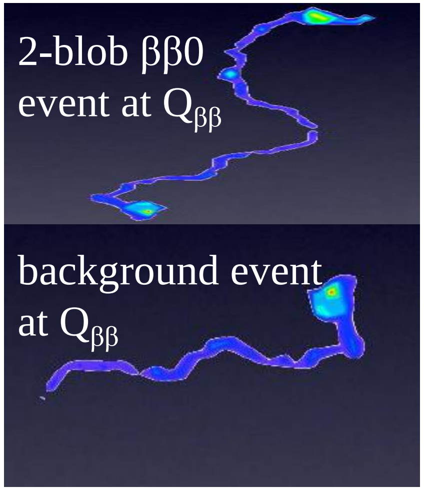
Pair production at 18.00 MeV

(borrowed from HARPO TPC (Argon))

Main present application is indeed fundamental research (ββ0-decay)

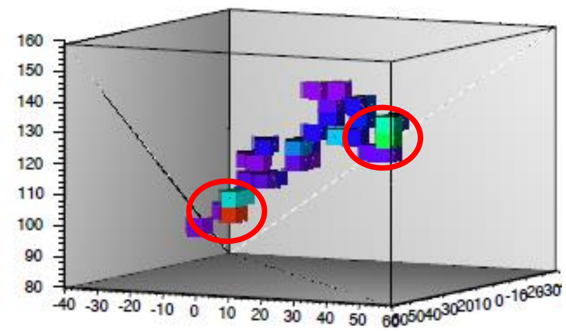


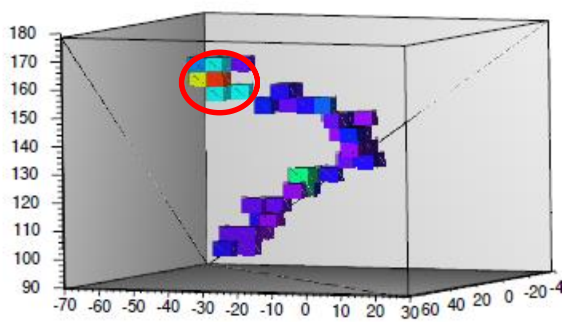




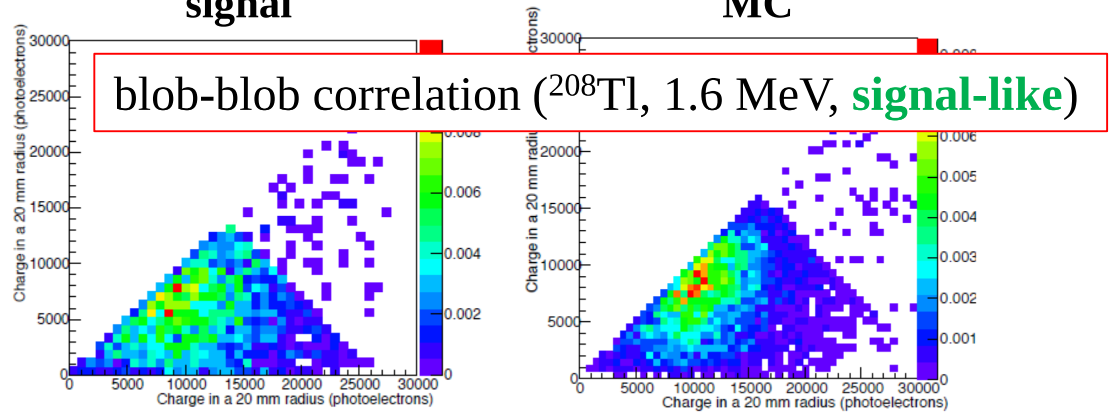
already under installation at LSC

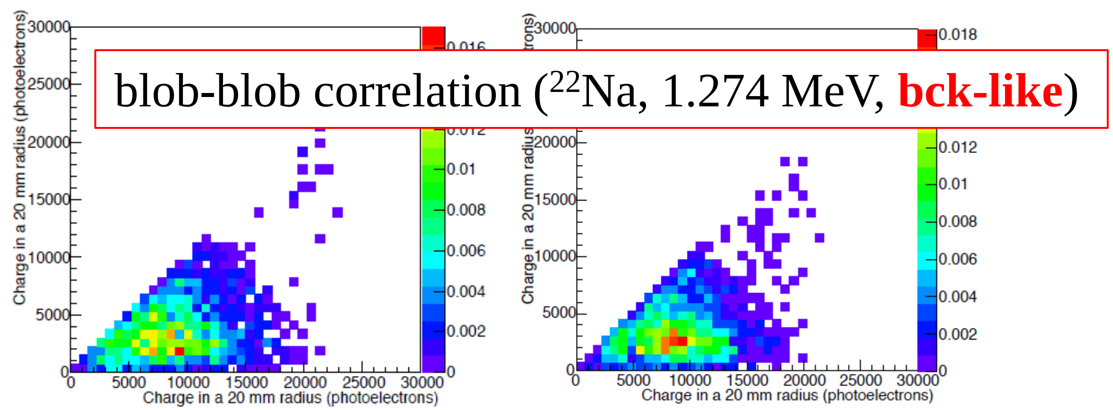
γ-rays are the background… not the signal!!: golden signature is ‘1blob vs 2blob’



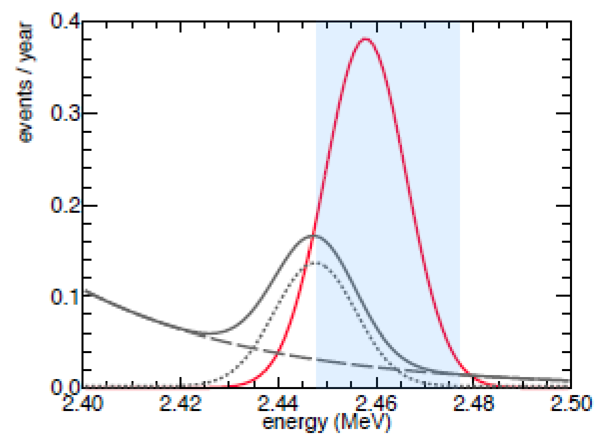


signal **MC**

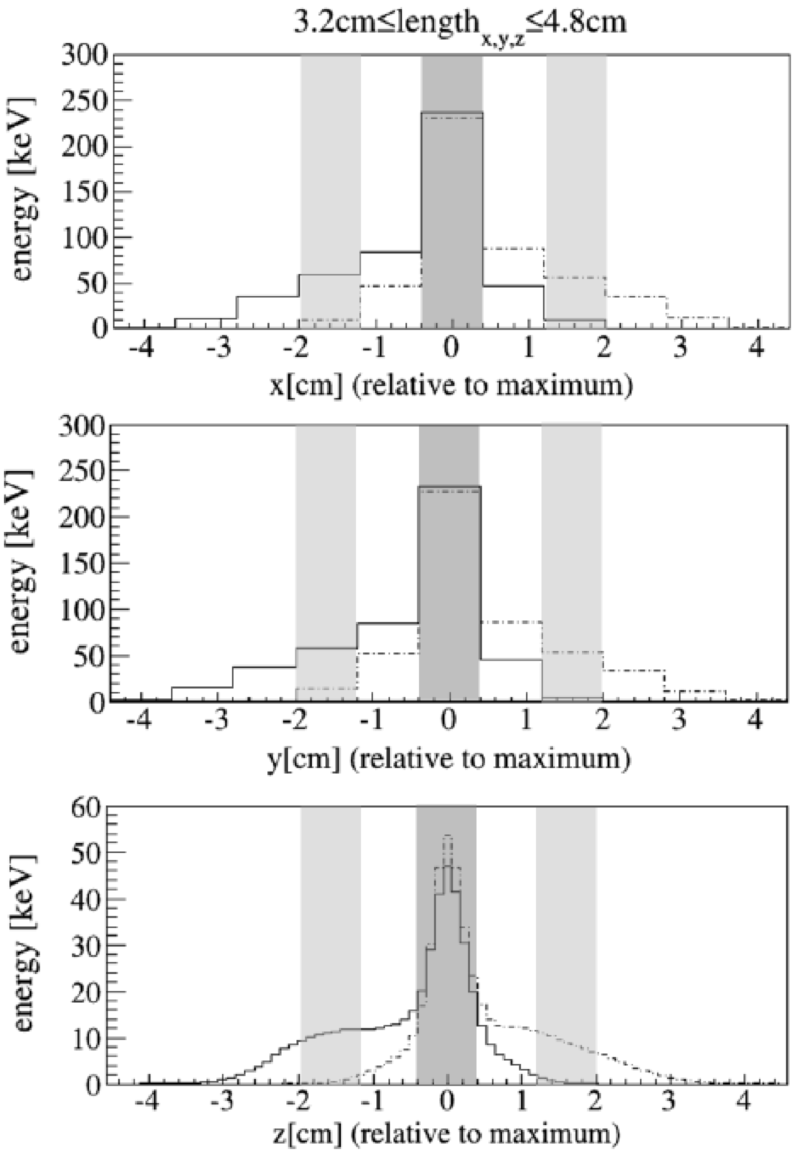


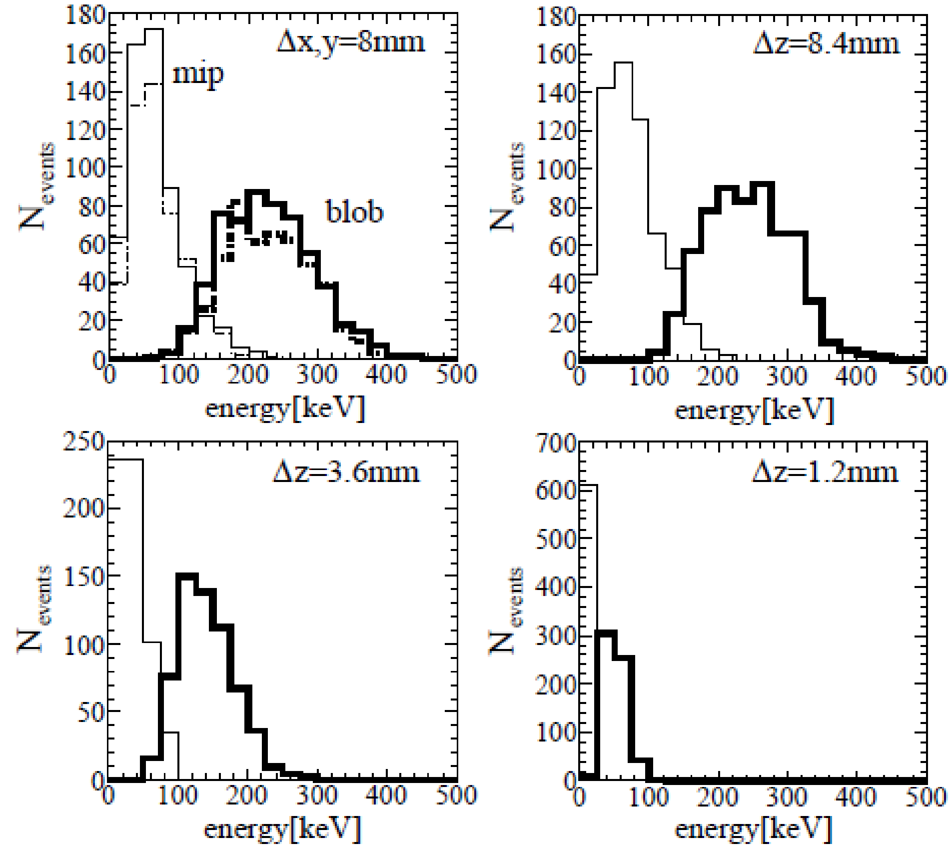


Selection criterion	$0\nu\beta\beta$	$2\nu\beta\beta$	^{208}Tl	^{214}Bi
Fiducial, single track $E \in [2.4, 2.5]$ MeV	0.4759	8.06×10^{-9}	2.83×10^{-5}	1.04×10^{-5}
Track with 2 blobs	0.6851	0.6851	0.1141	0.105
Energy ROI	0.8661	3.89×10^{-5}	0.150	0.457
Total	0.2824	2.15×10^{-13}	4.9×10^{-7}	4.9×10^{-7}



enhanced blob-identification capabilities in a low-diffusion mixture (Xenon-TMA)





Bragg peaks

ongoing ideas

- Look for a convenient ‘Penning-Fluorescent’ wavelength-shifting mixture. Xe-TMA behaves as desired in many aspects, but S_1 yields go down by 1/20. Penning probability is also modest, and no strong reduction of the Fano factor.

- Identify electron-cooling gases (low diffusion) with modest quenching rates. From existing data and simulations, Xe-CH_4 would work.

- Use magnetic field to bend the electrons and increase the identification capabilities.

conclusions and outlook

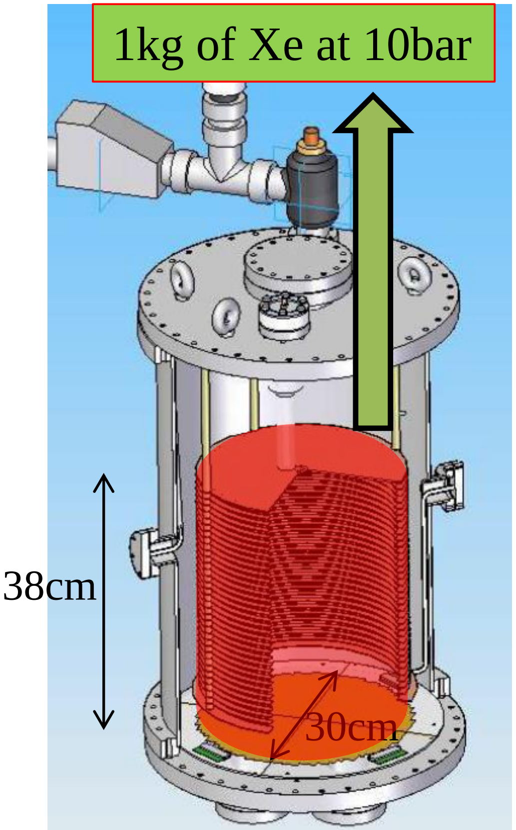
- Very active research on large volume (and high pressure) Xenon TPCs.

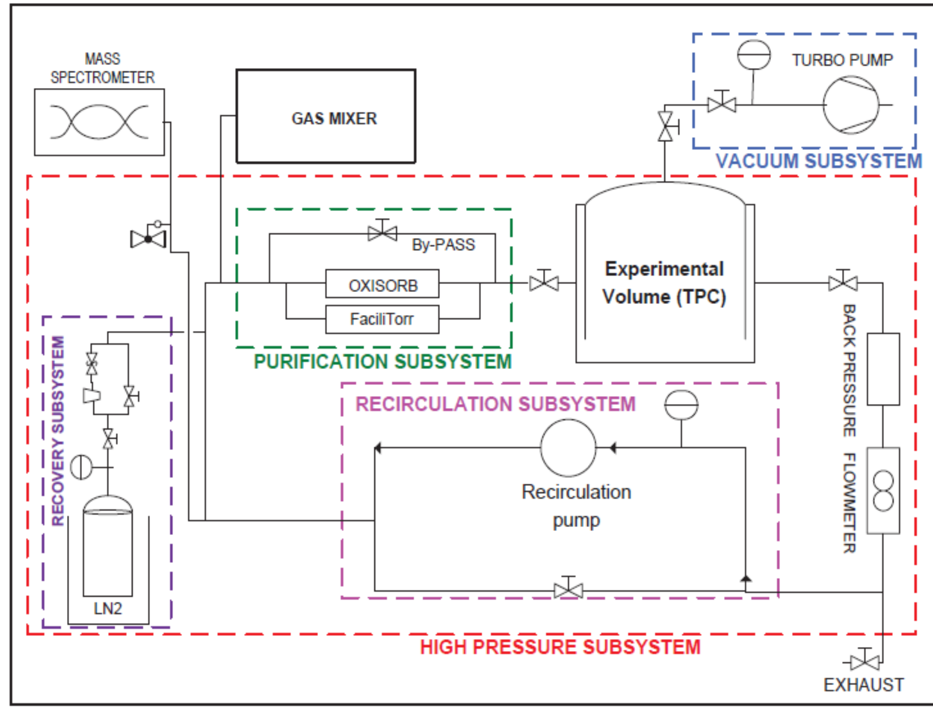
- For operation under pure (or nearly pure) noble gas fillings, they can be replaced and adapted to a new energy range, while the optical characteristics remain nearly the same upon small Xenon additions.

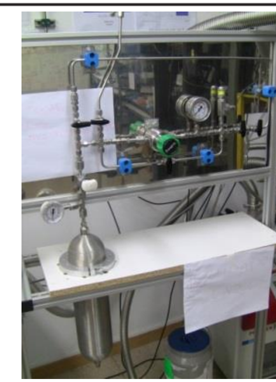
- MPGD charge readouts are inferior in terms of energy resolution, but can compete due to the larger simplicity and easiness of segmentation.

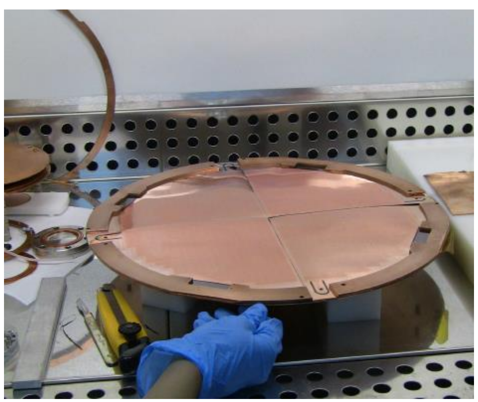
- NEXT is trying to make a breakthrough in $\beta\beta 0$ detection… not necessarily on gamma detection, but who knows?.

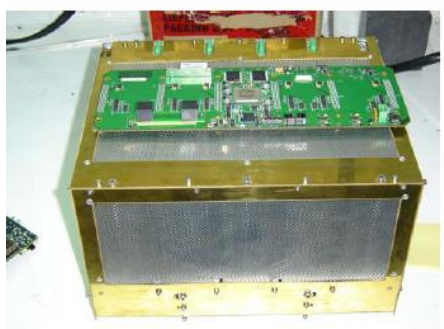
appendix











details in:

JINST 9(2014)P03010, JINST 9(2014)C04015