petalo: positron emission tomography with liquid xenon

Nerea Salor Iguiñiz, LIDINE 2023 – Light Detection in Noble Elements
September 20th - 22nd 2023 Madrid, Spain

What is a PET?

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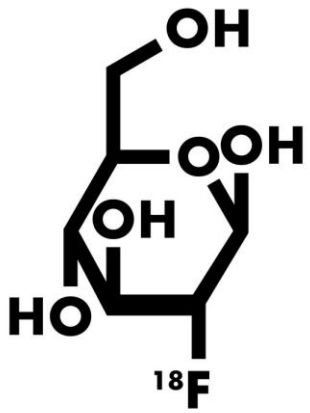

fludeoxyglucose (18F)

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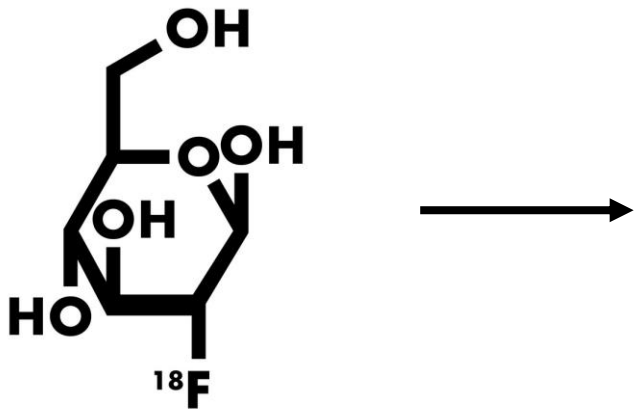

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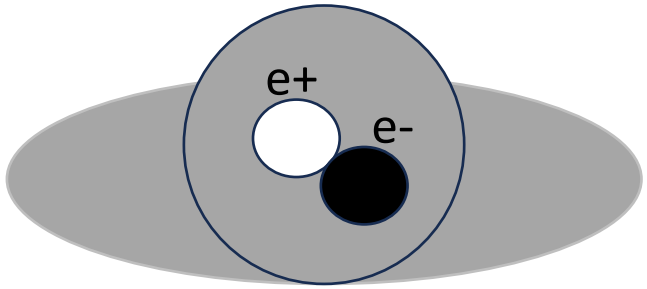

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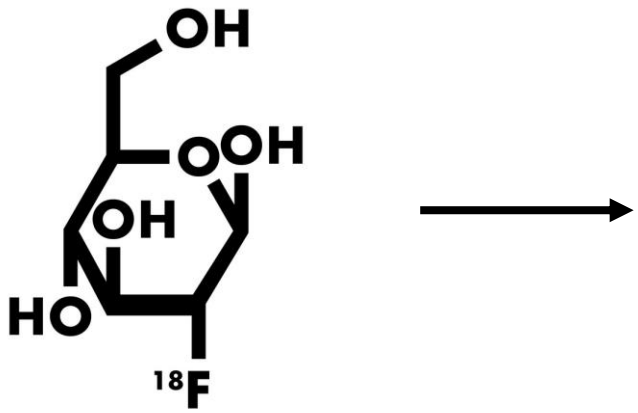

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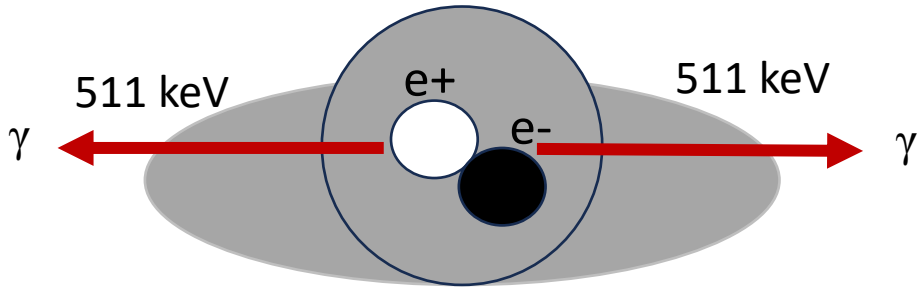

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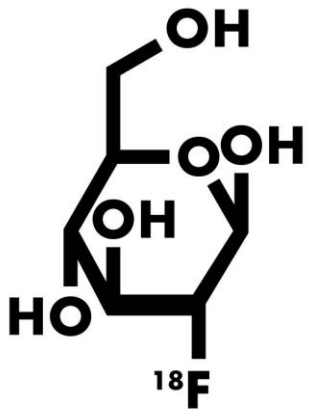

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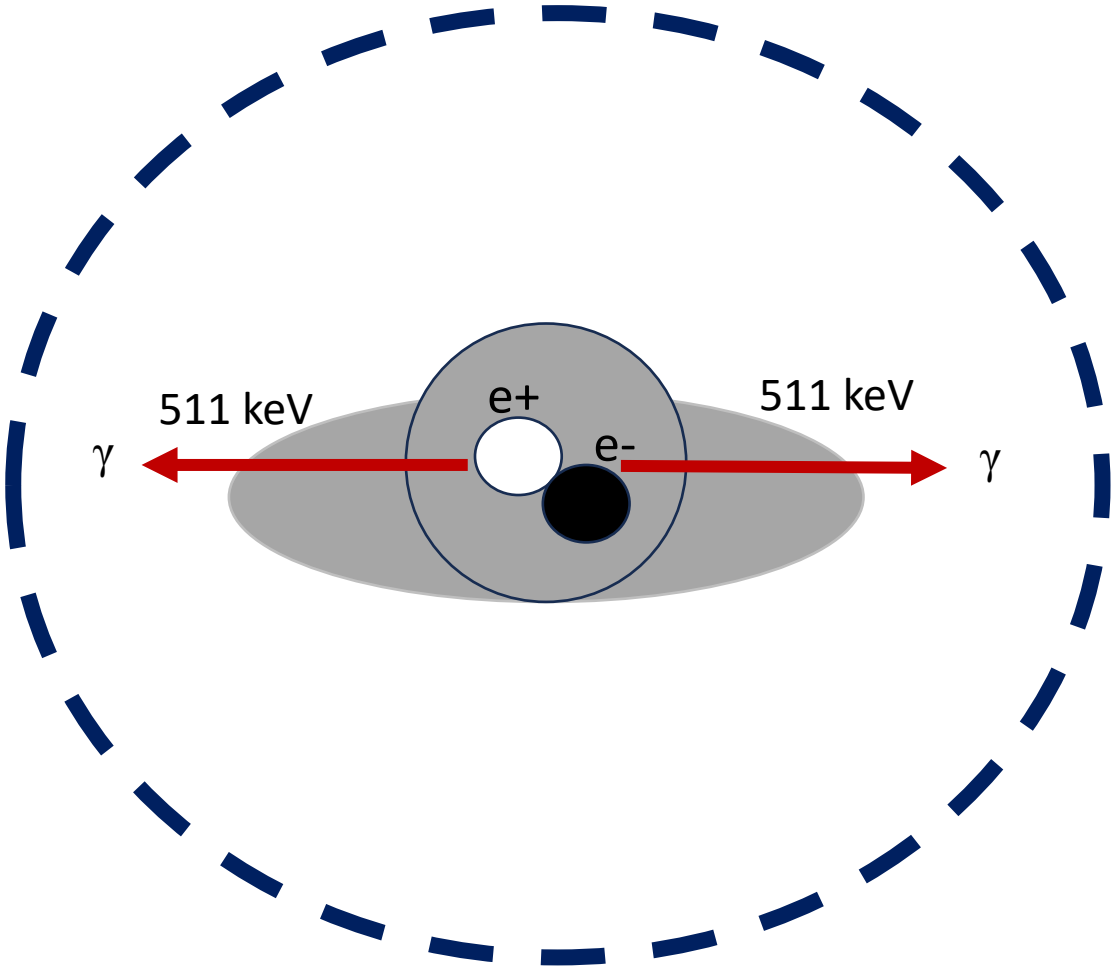

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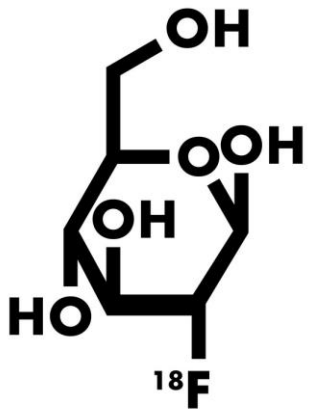

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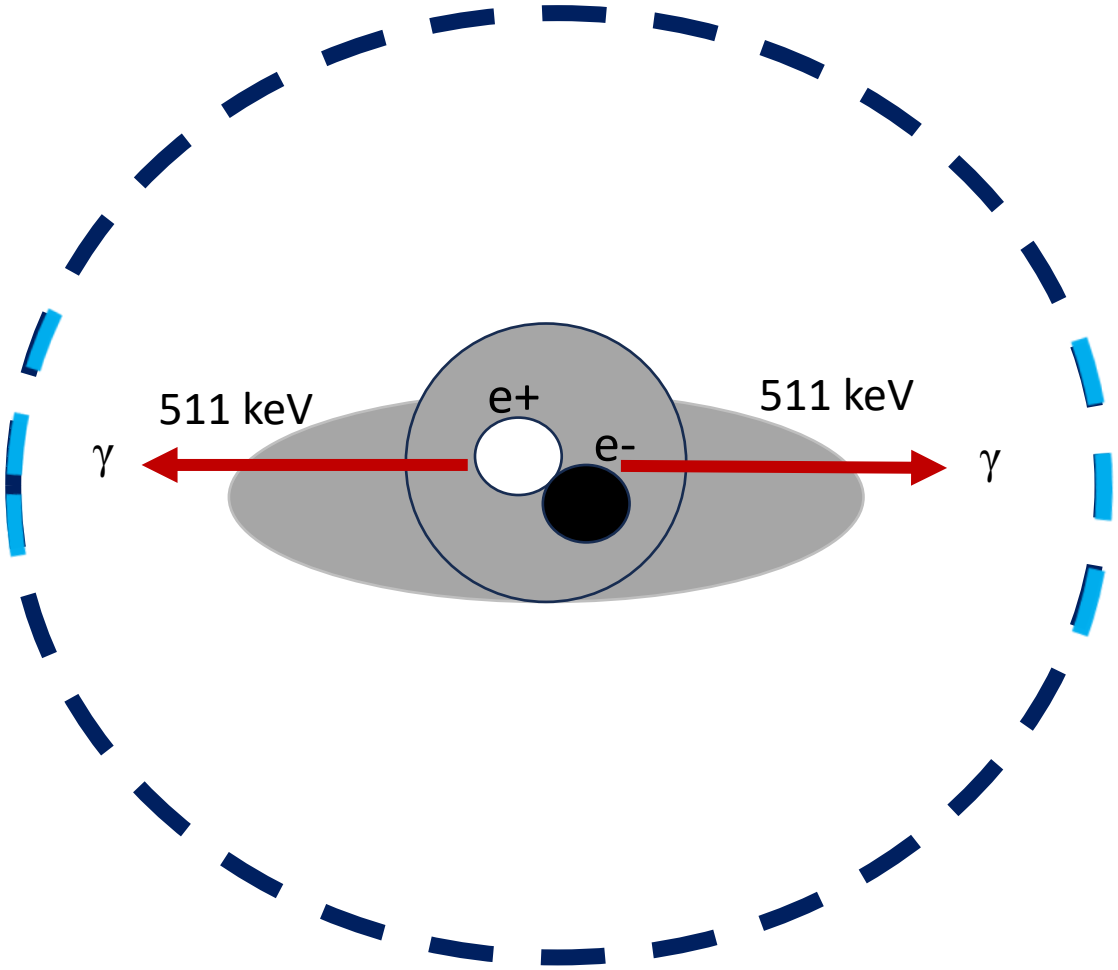

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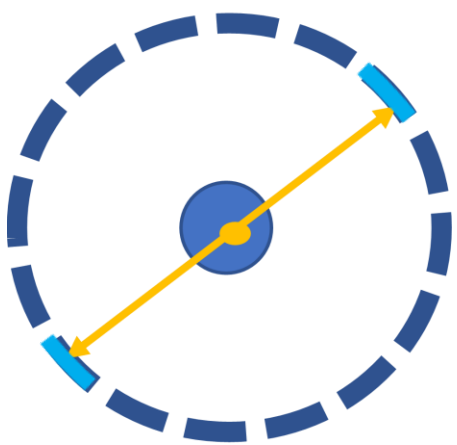
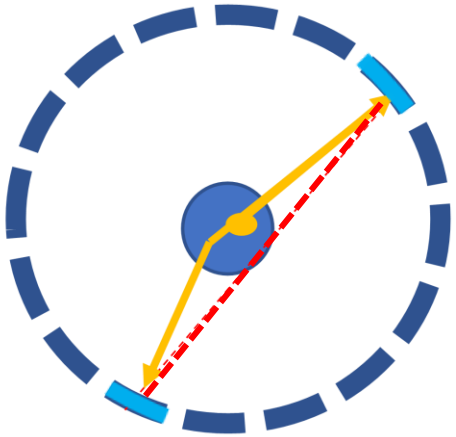
Energy resolution:



True event



Scatter event

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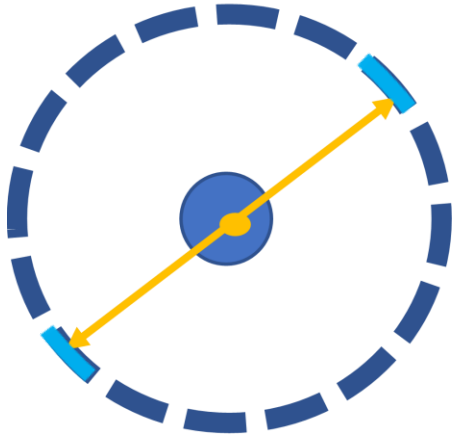

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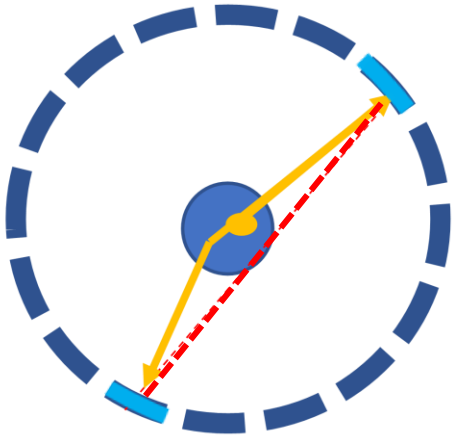
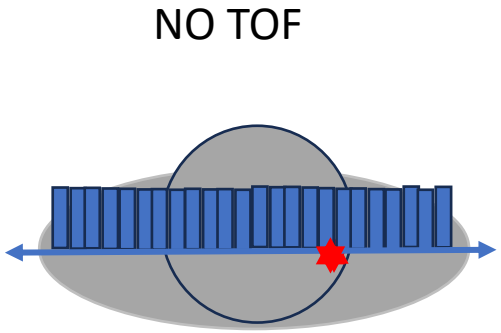
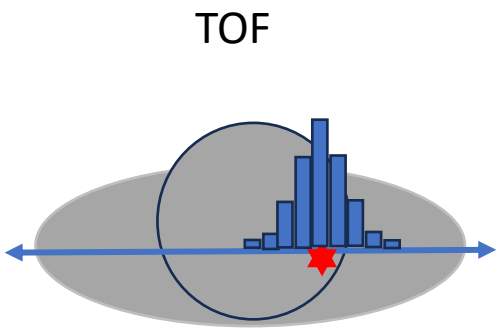


Scatter event

Time resolution:



Same probability in the line of response



Time resolution in the system

PETALO

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Xenon:

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- Good scintillator: 68 photons/keV at 178nm

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- Good scintillator: 68 photons/keV at 178nm
- Fast decay time: 2.2ns
- Transparent to its own scintillation light
- Continuous medium

- Specific UV photosensors
- Liquefy xenon at -110ºC

PETit: first prototype

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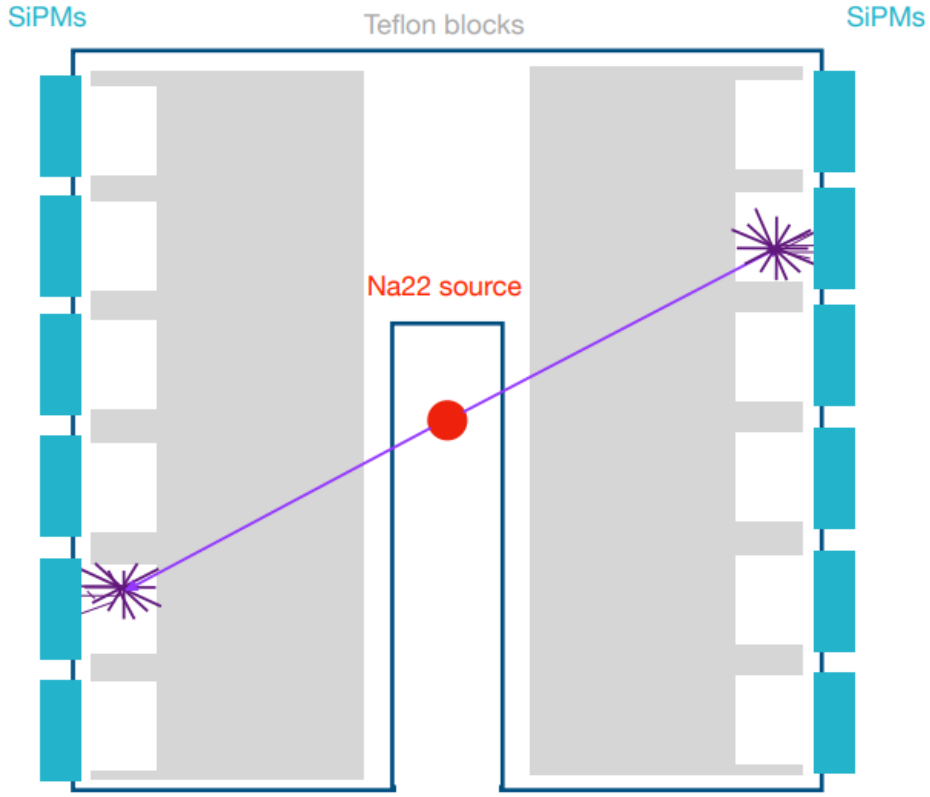

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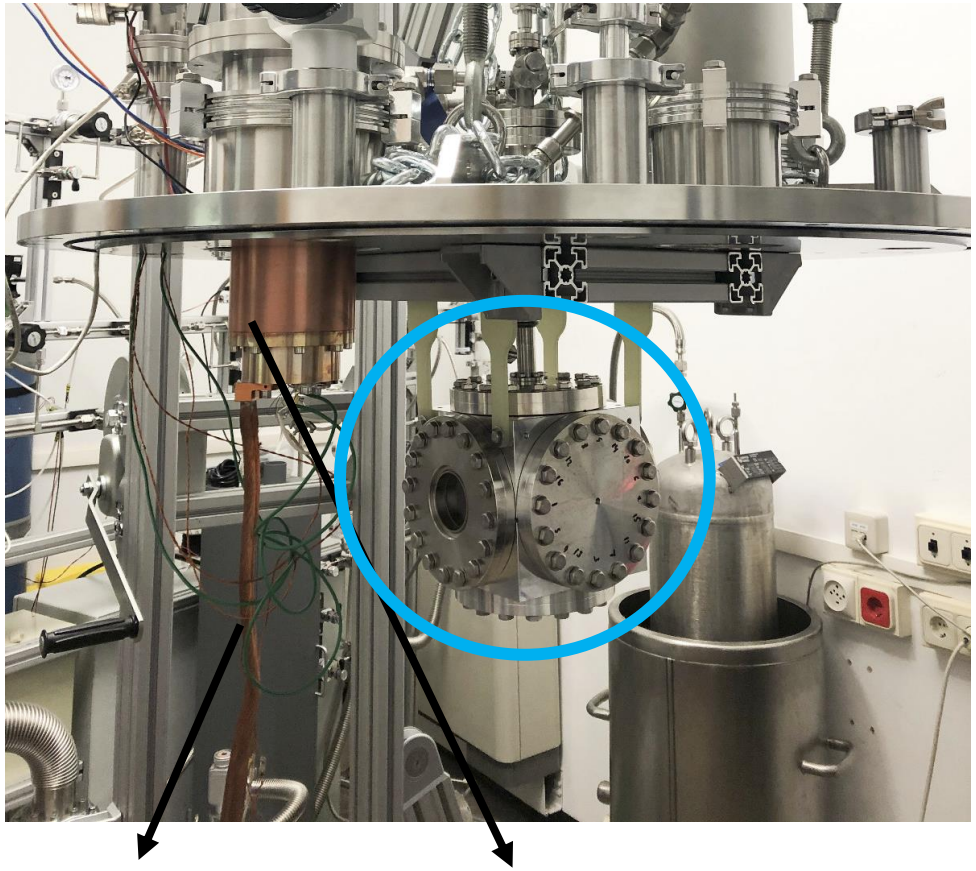

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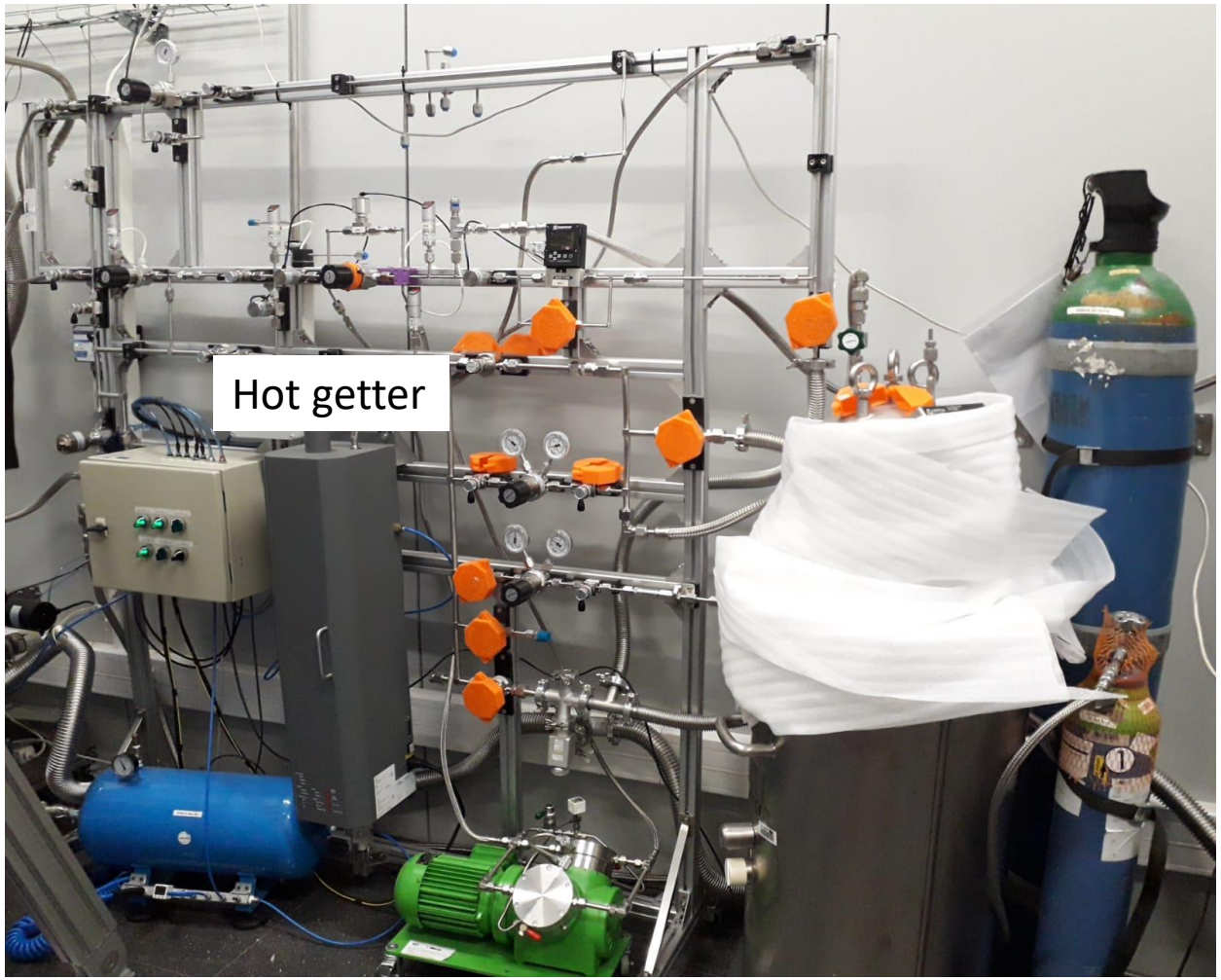

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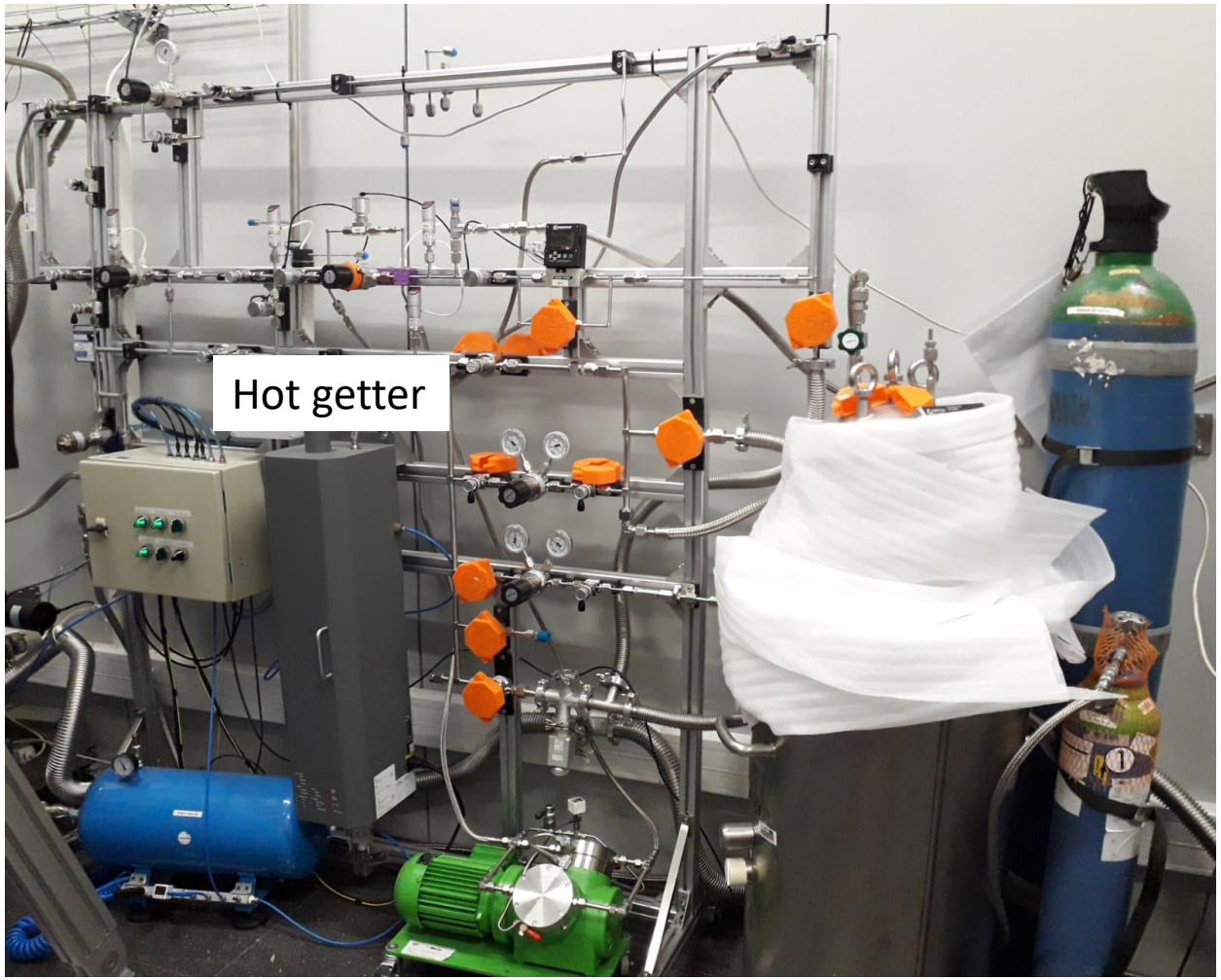
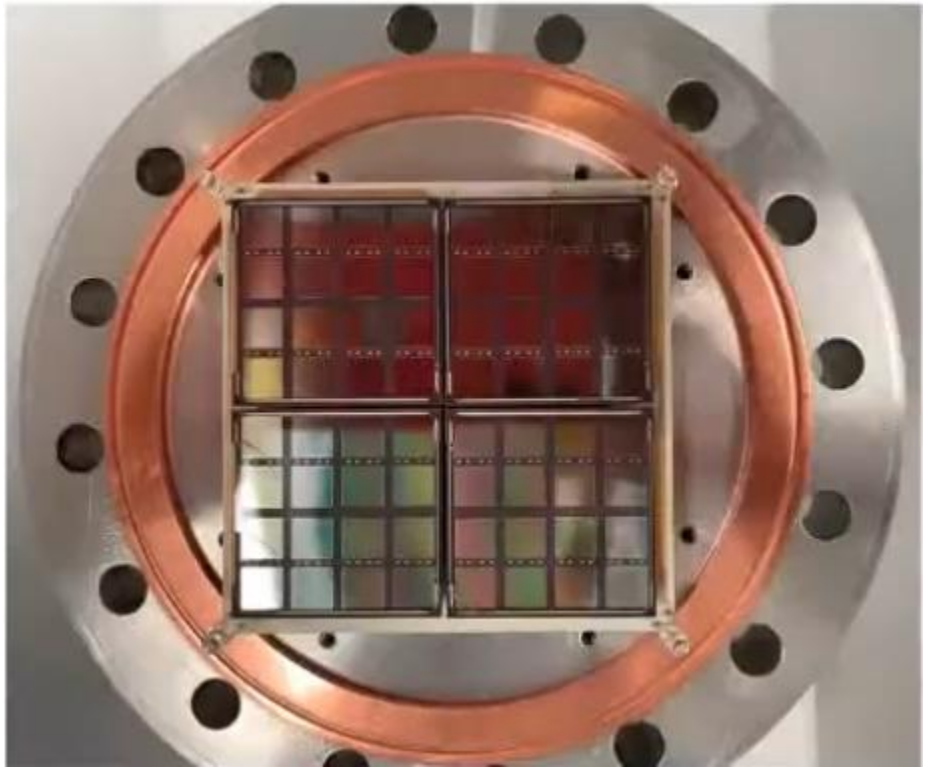
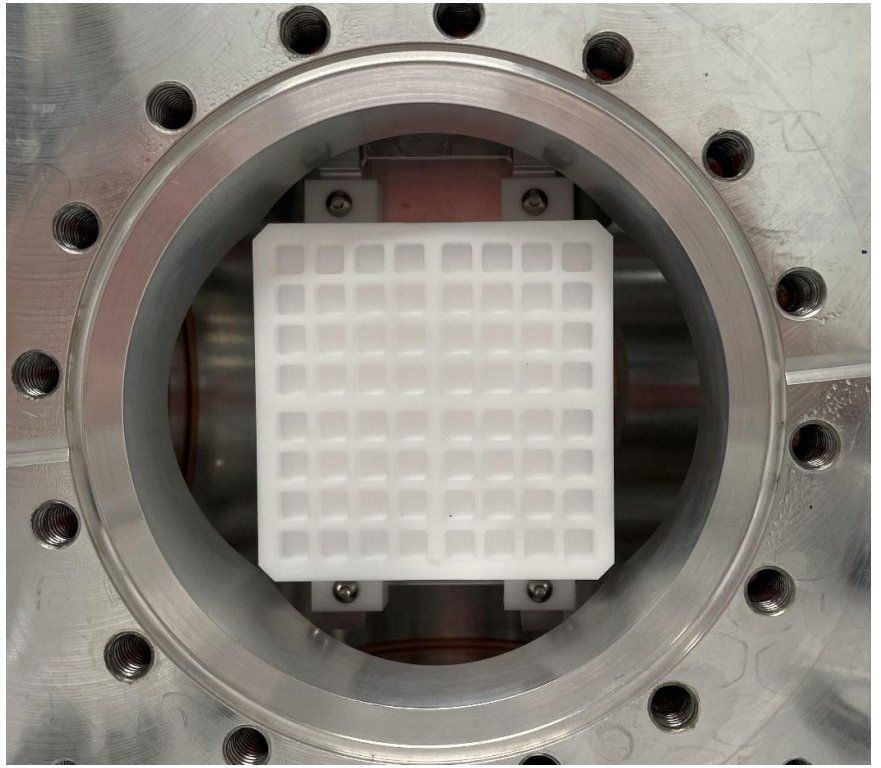


PETit: electronics





Hamamatsu VUV-sensitive S15779,
6x6mm^2 area

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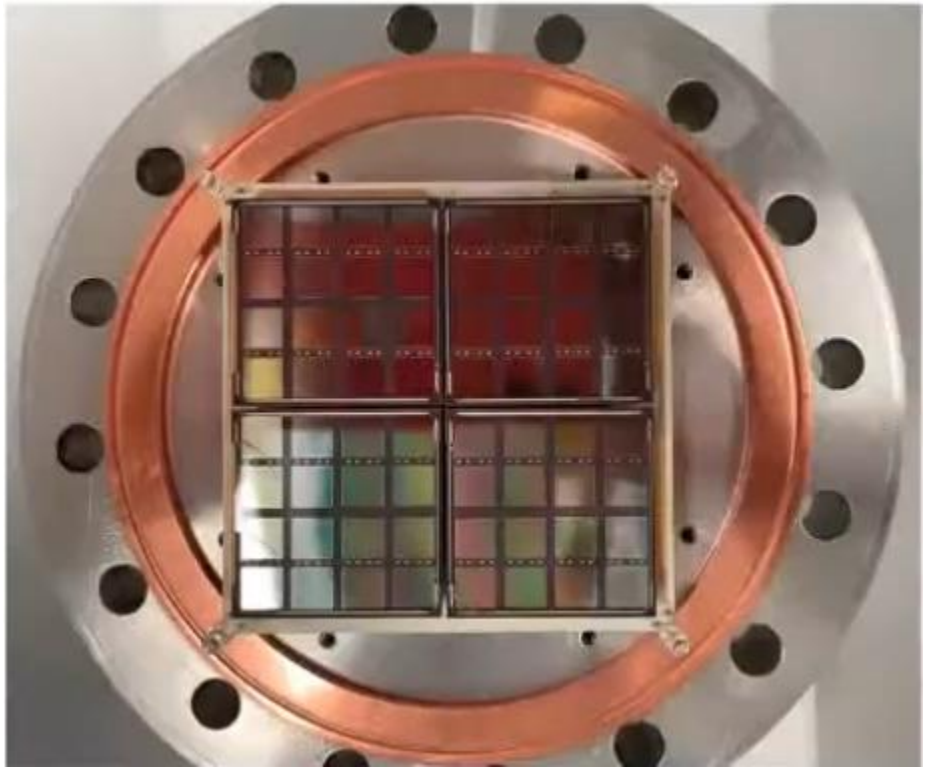

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TOFPET2 ASIC from PETSYS

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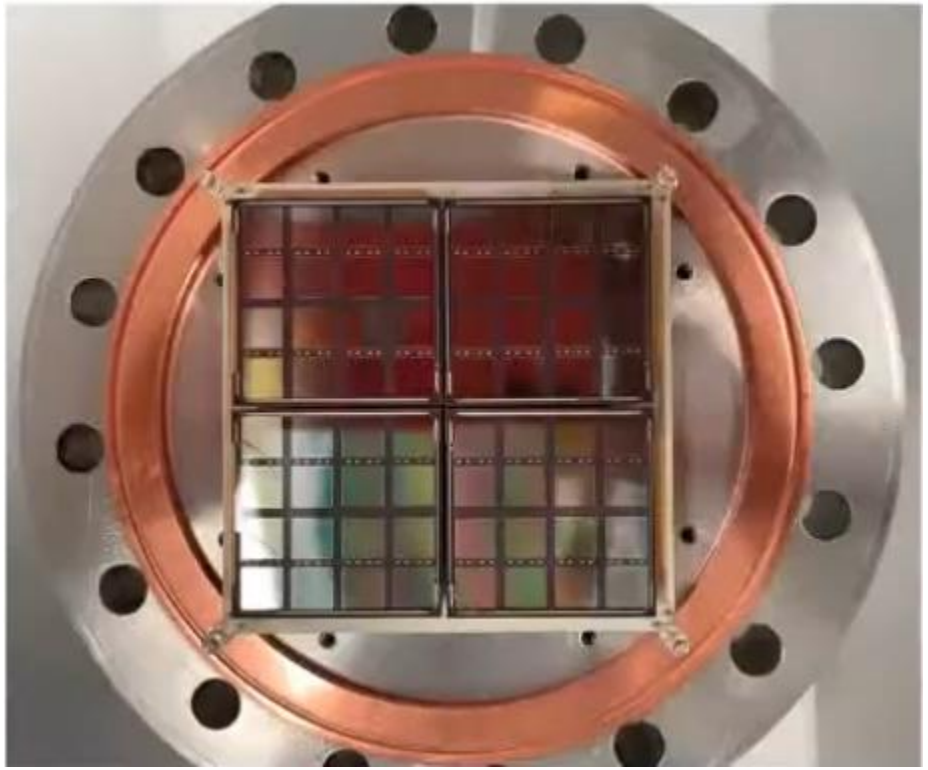

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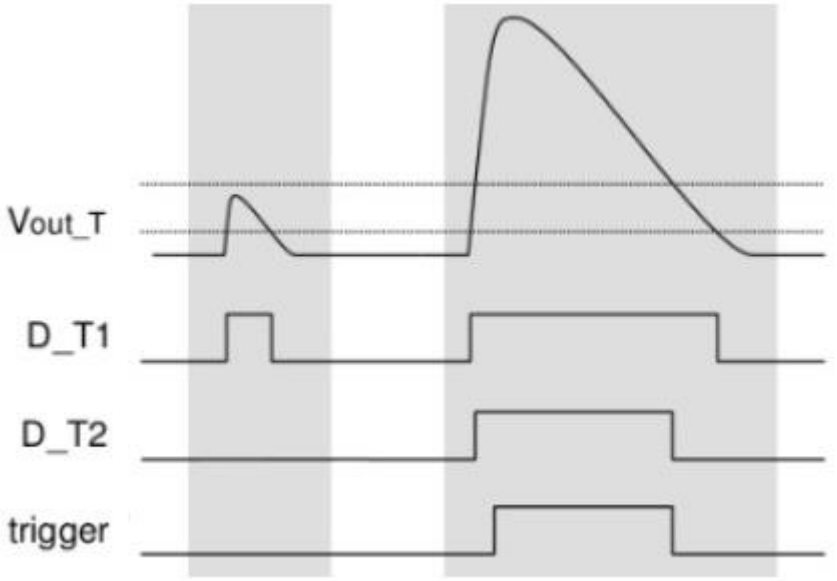

First threshold (T1) : timestamp
Second threshold (T2): charge

PETit: results

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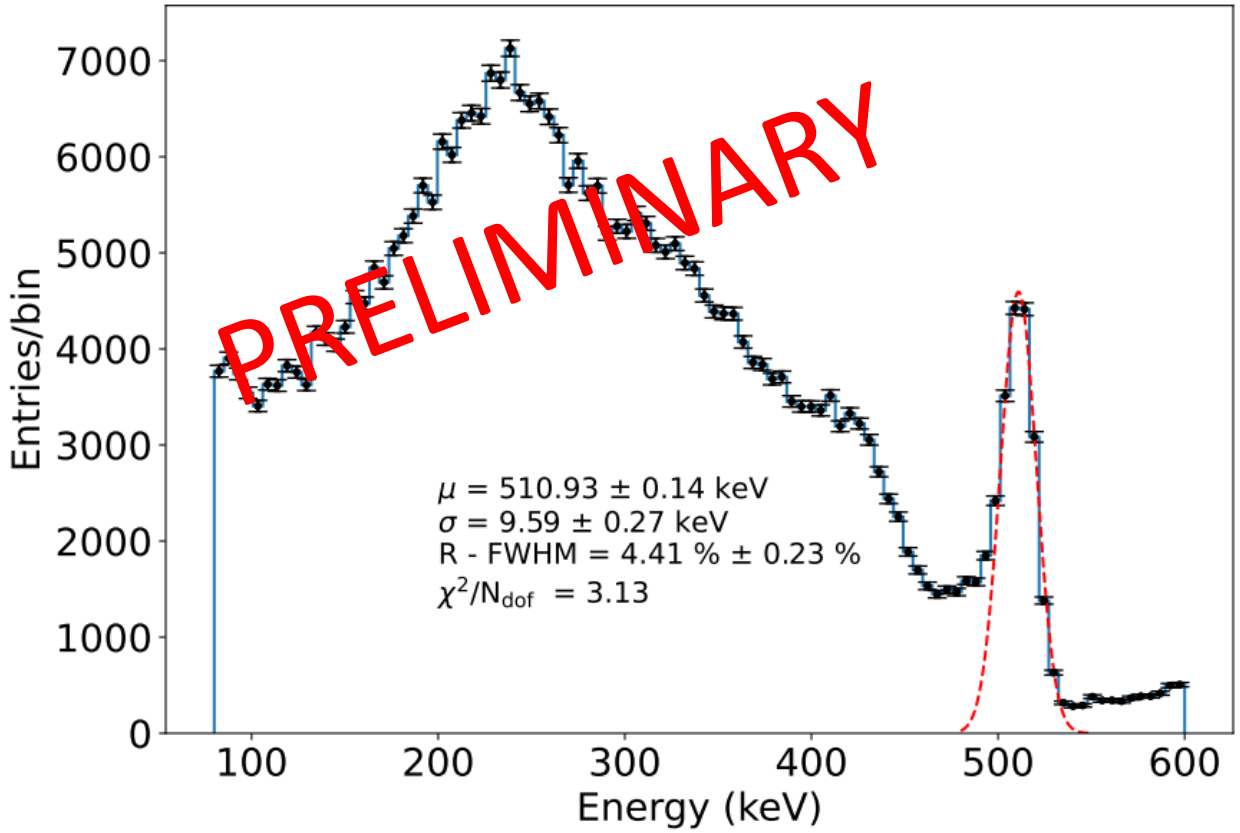


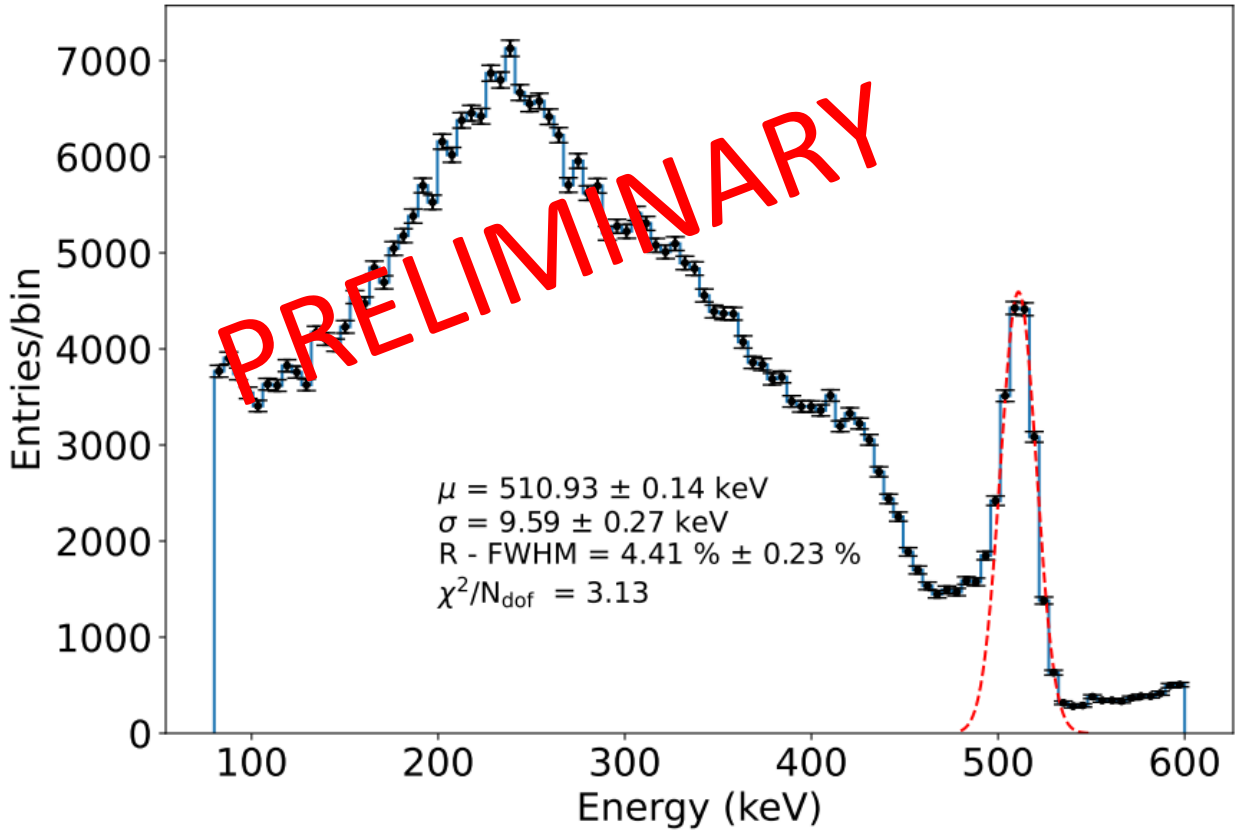
SATURATION:

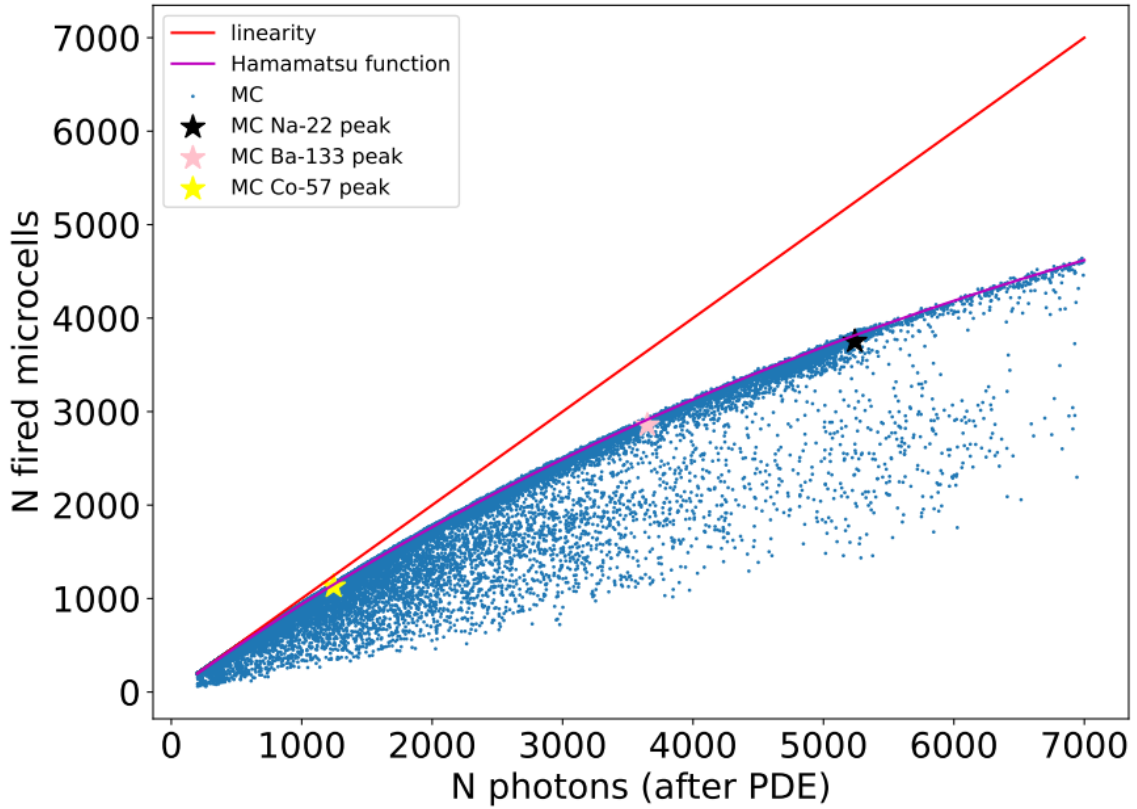
- SiPM with 6162 microcells

- Monte carlo prediction: 5000 photoelectrons

Monte Carlo energy resolution: 5.6% FWHM

PETit: results





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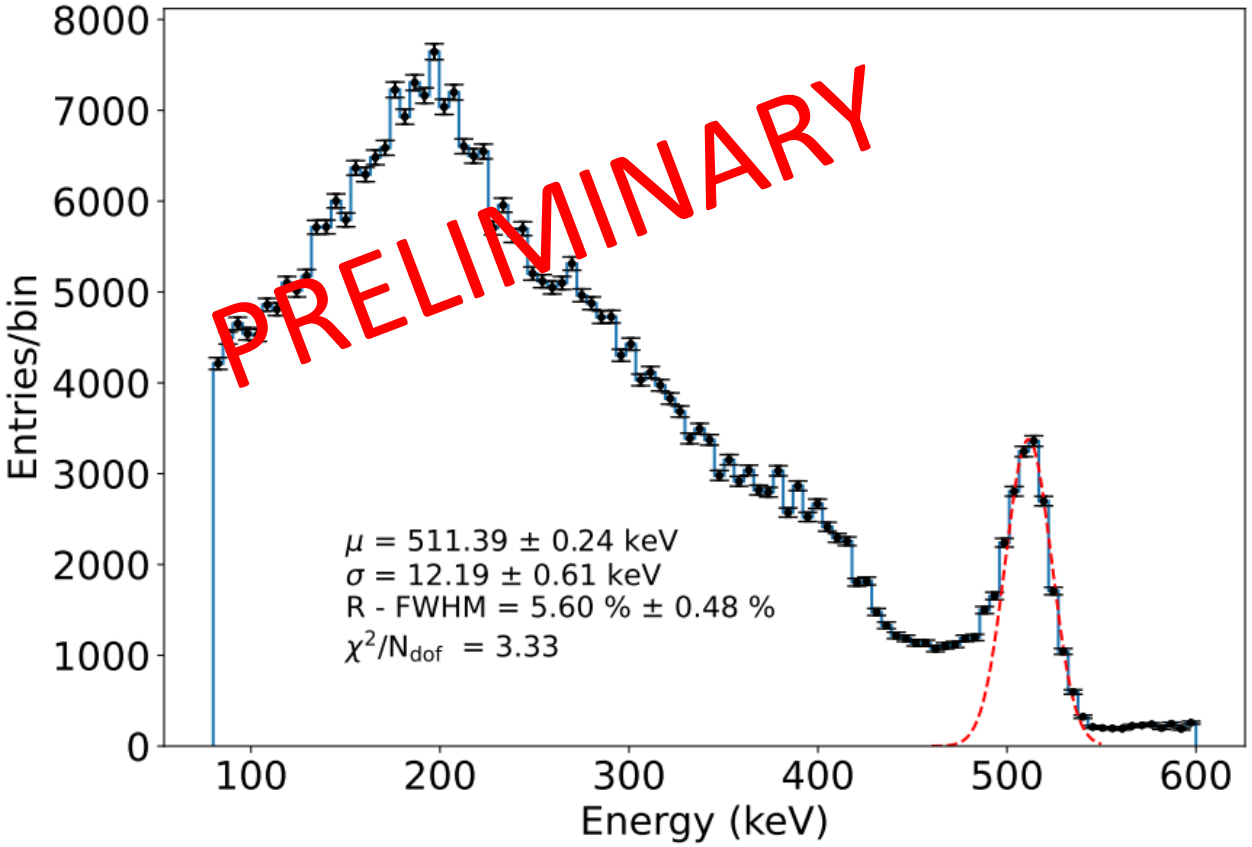

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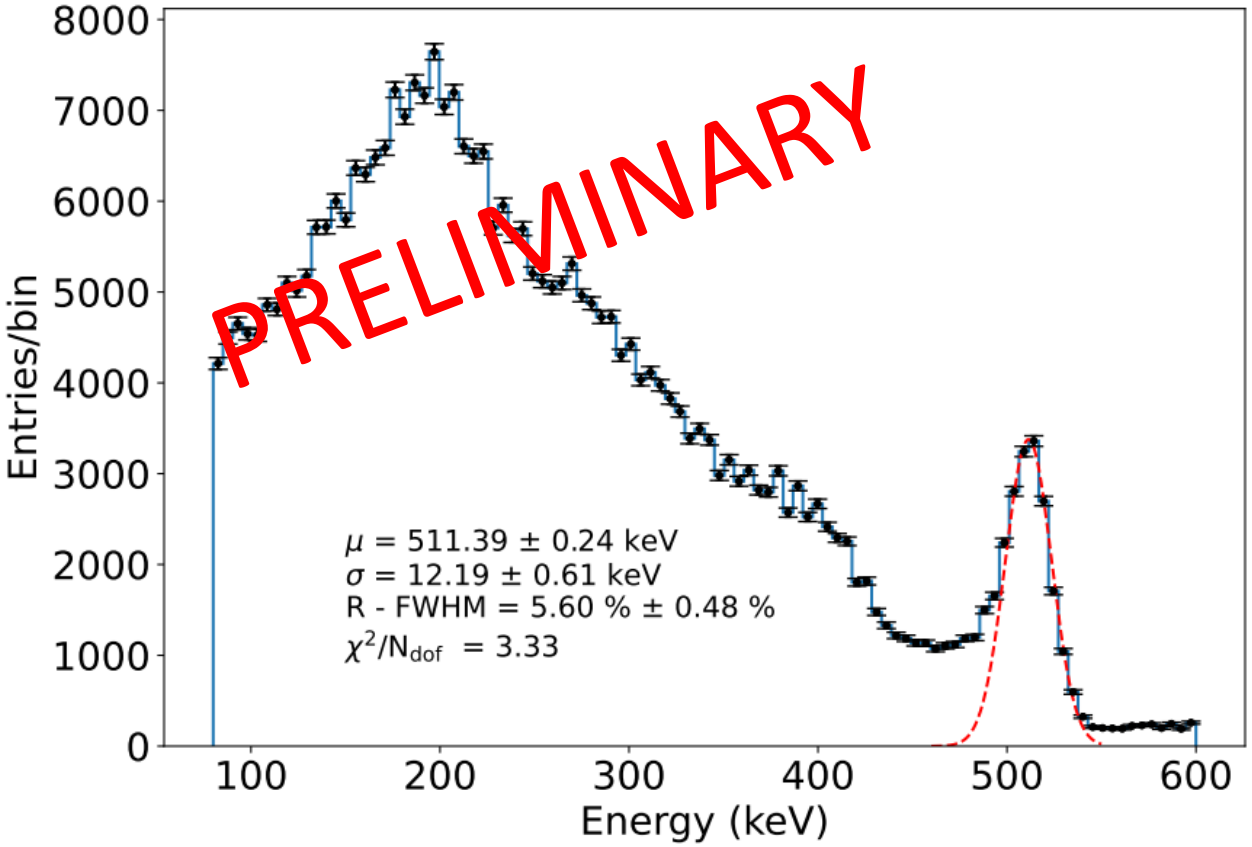

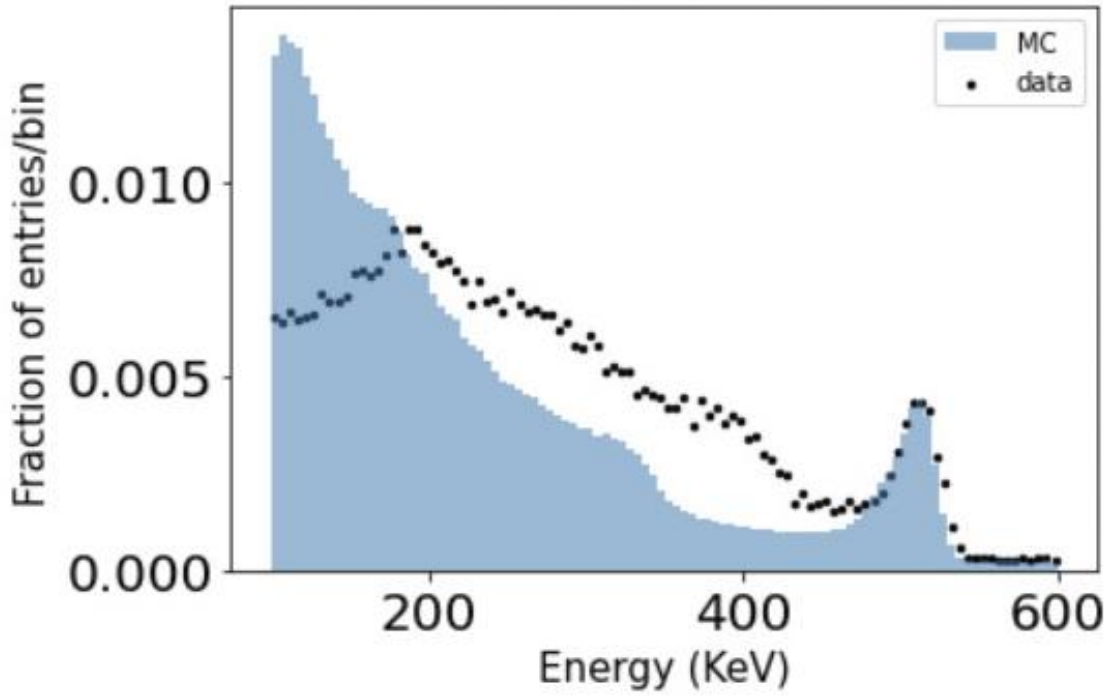

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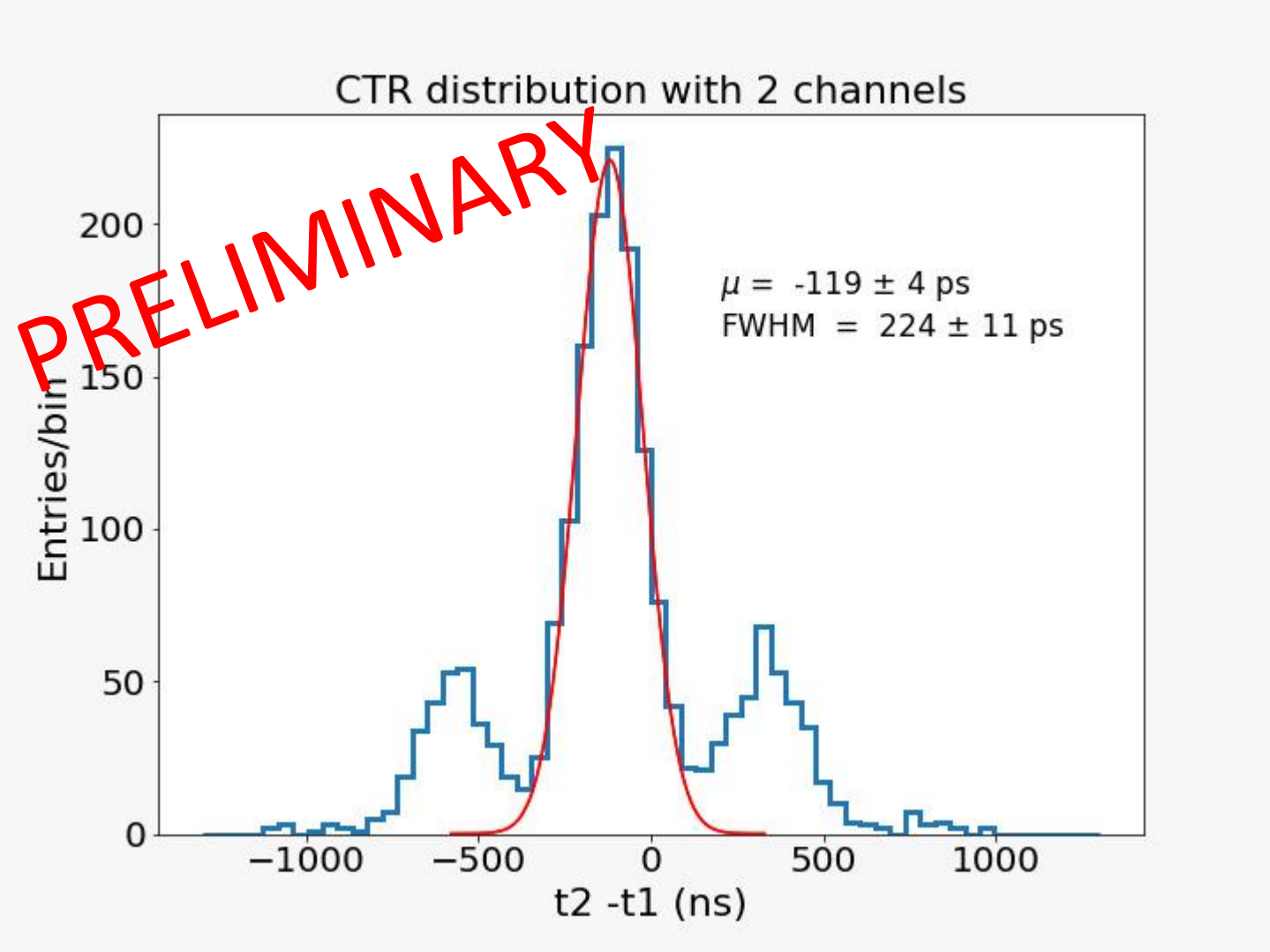


Conclusions

- First prototype built and taking data

- Good energy resolution (still under study)

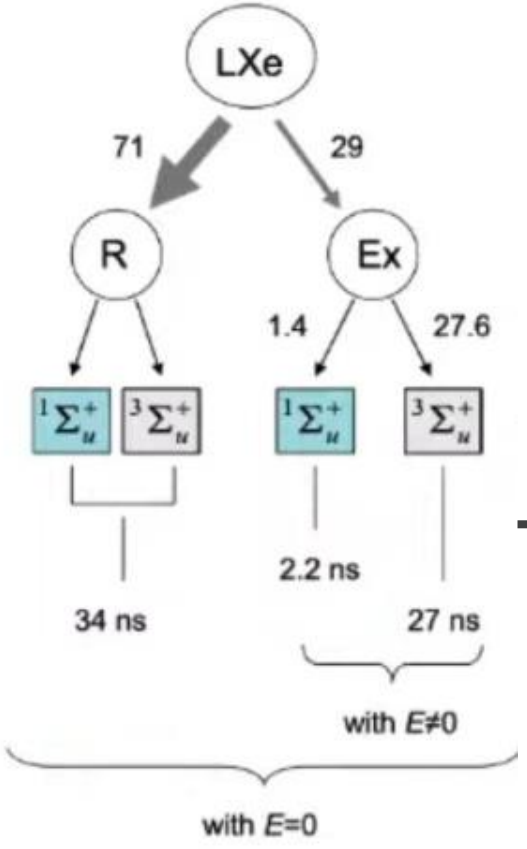
- Good time resolution (still under study)

- Future: test FBK SiPM, parameters that affect CTR, Teflon configurations

THANK YOU!

Back up: xenon

Two responses to the ionizing radiation: scintillation and ionization (anticorrelated)



$$e^- + \mathrm{Xe} \rightarrow e^- + \mathrm{Xe}^*$$
$$\mathrm{Xe}^* + \mathrm{Xe} + \mathrm{Xe} \rightarrow \mathrm{Xe}_2^* + \mathrm{Xe}$$
$$\mathrm{Xe}_2^* \rightarrow \mathrm{Xe} + \mathrm{Xe} + h\nu$$

- VUV scintillating photons emitted from one of the two lowest electronic excited states (singlet and triplet) to the ground state.
- In the absence of electric field, recombination also produces scintillation, at a later time.

Back up: devices brands

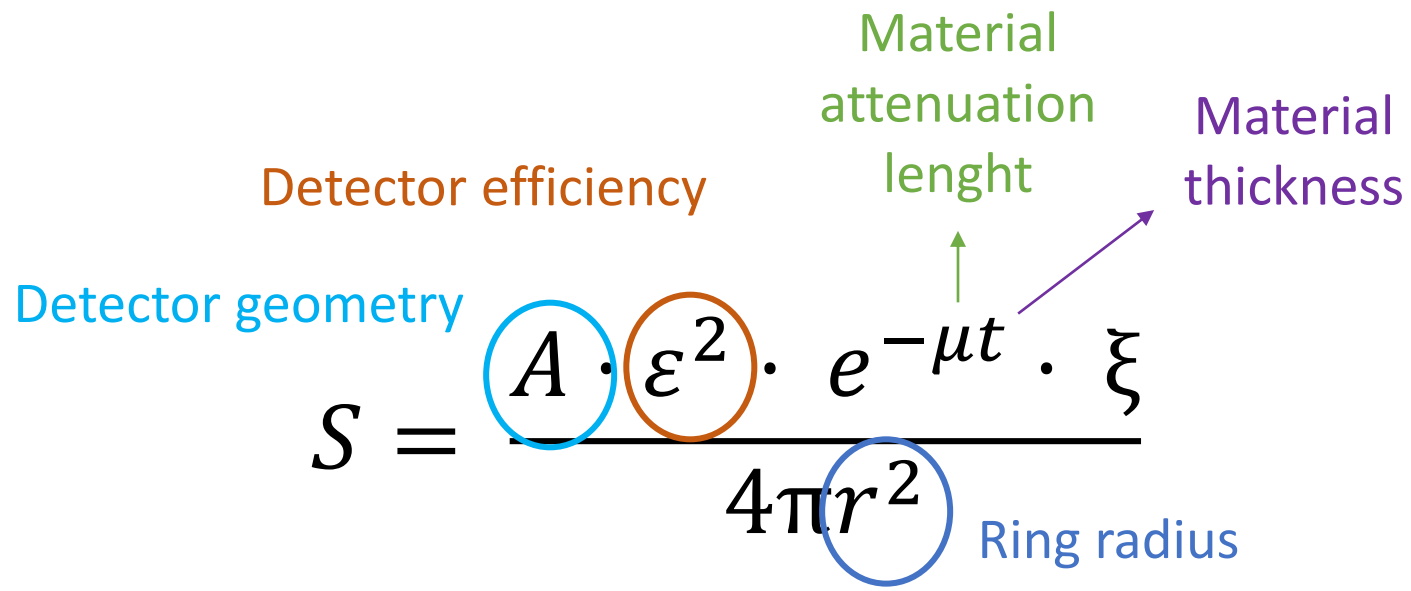
Hot getter from Sigma Technologies
PS4 MT15 R2

Double diaphragm compressor KNF-
N186.1.2SP.12 E

Cold head:
Sumitono CH-110

Vacuum pump: IDP-
7 Dry Scroll Pump

Back up: detector sensitivity



Better:

- Longer detector
- Dense material (higher Z) -> less thickness

Back up: material comparison

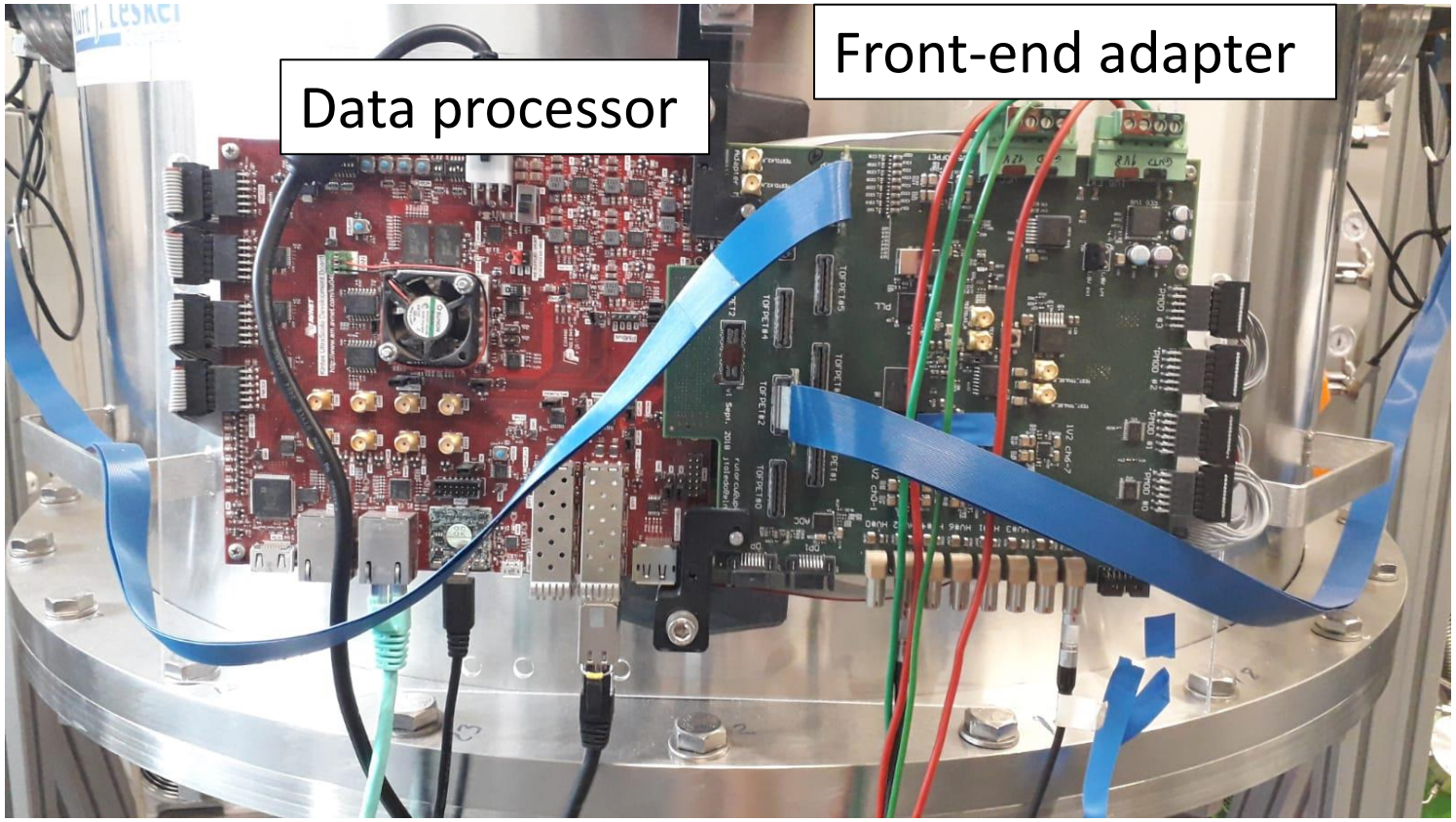
	BGO	LSO	LYSO	LXe
Attenuation length 511keV (mm)	10	11.5	12	36
Yield (photons/keV)	9	26	33	68
Decay time (ns)	300	40	36	2.2, 27
Wavelength (nm)	480	420	420	178
Photo-fraction	40%	30%	30%	20%

Back up: resolution comparisons

- First total body PET now, EXPLORER: Energy resolution 11.7% FWHM and time resolution 430ps.

- With liquid xenon: energy resolution 6% FWHM and time resolution for total body PET in Monte Carlo 300ps, obtained now 220ps

Back up: electronics



- Data processor (Kintex Development Board):
Receives data and sends them to the computer, manages TOFPET configuration, Clock synchronization

- Front-end adapter:
ASIC calibration and reset, controls Tª sensors, SiPMs, clock system control and distribution among chips.

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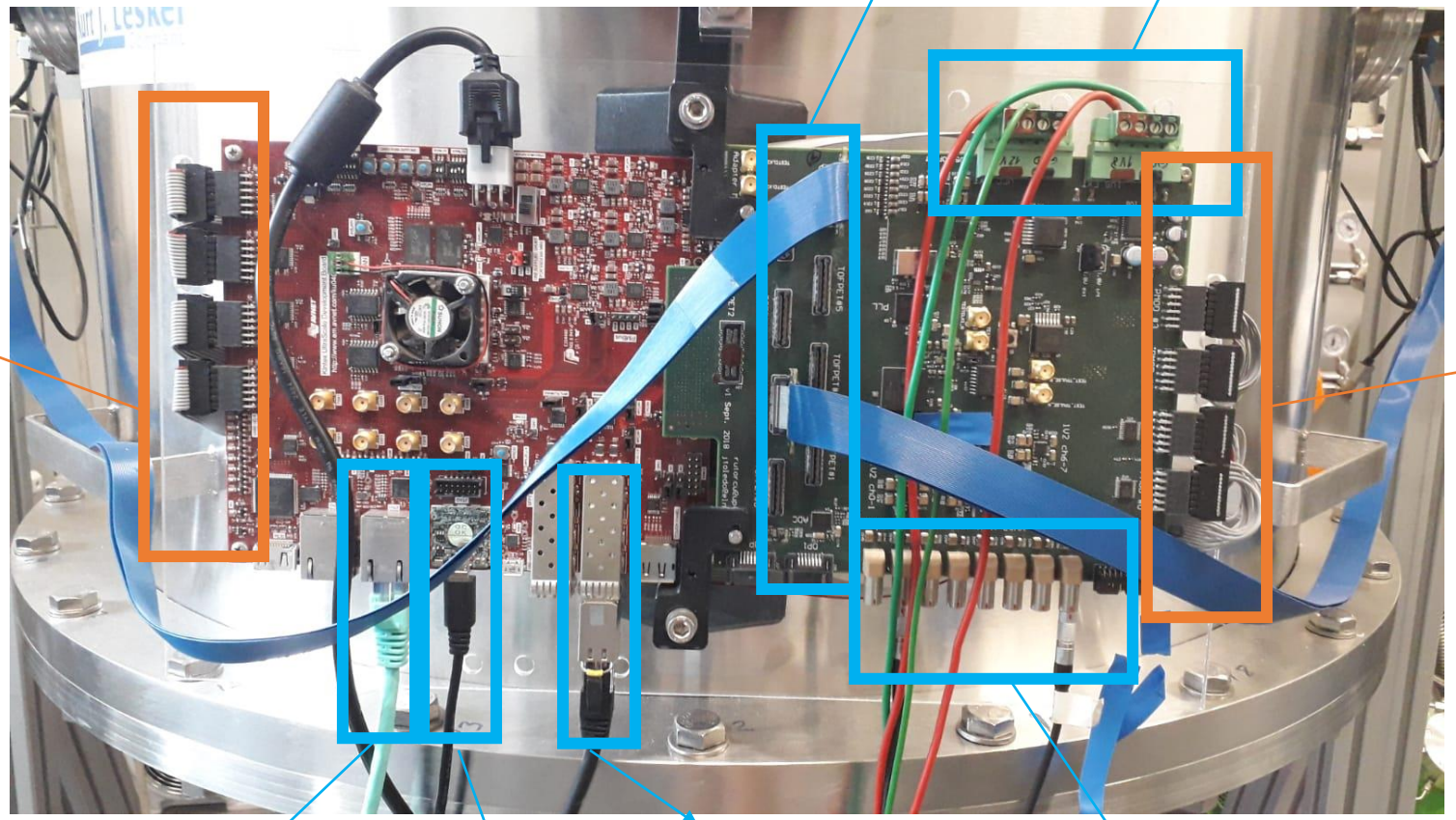

Back up: purification system