PET and single electrons at AstroCent and Cagliari U.

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Dark Wave

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Single electrons

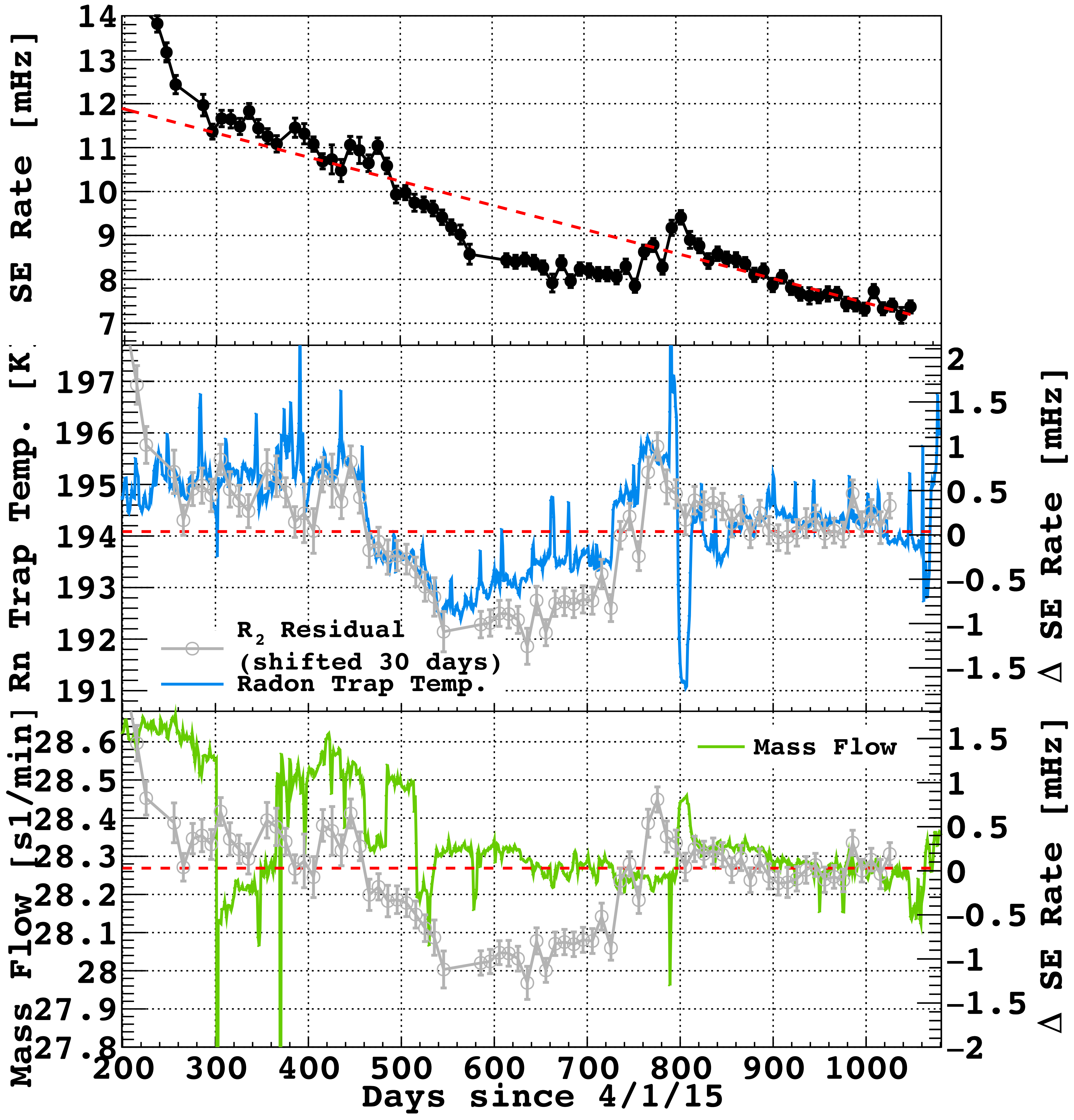
BG in low mass dark matter searches

- **Single/spurious electrons (SE)** are at the lowest energy range in our dark matter searches and **define our energy threshold**.
- Understanding and lowering the BG are crucial to achieve the world best sensitivity.
- From DarkSide-50 experiment, we know large fraction of the **SE events are from impurities**, but we couldn't identify the species of impurities.
- We want to identify the impurities based on the time constants we observed in DS50, and establish **reliable methods to mitigate SE events**.

Single electron study

Identification and mitigation

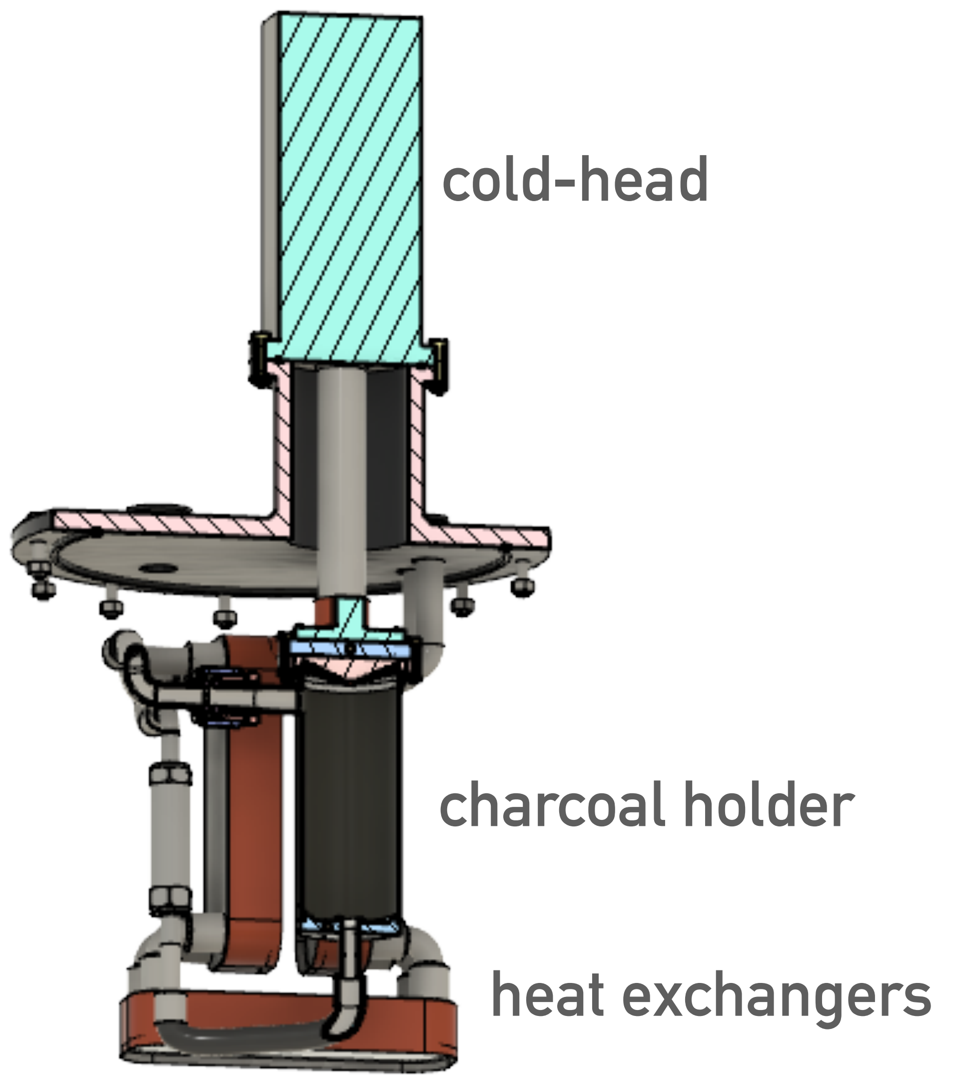
- We want to build (or use/borrow) a TPC sensitive to single electrons.
- By introducing known amount of impurities such as N_2, O_2, Kr, etc., we study time constants of those SE relative to previous events.
- By building a cold trap with charcoal, we establish a way to remove those impurities.
- The hint of impurity reduction is there in DS50 data.



Correlation between the SE rate and Rn-trap temperature in DS50

A Cold trap for SE mitigation

- We plan to build a cold trap with full temperature control.
- With a mass spectrometer, first, we will evaluate the performance by measuring the breakthrough times for several impurities as a function of temperature.
- Then, connect to the TPC and evaluate the performance with SE rates.



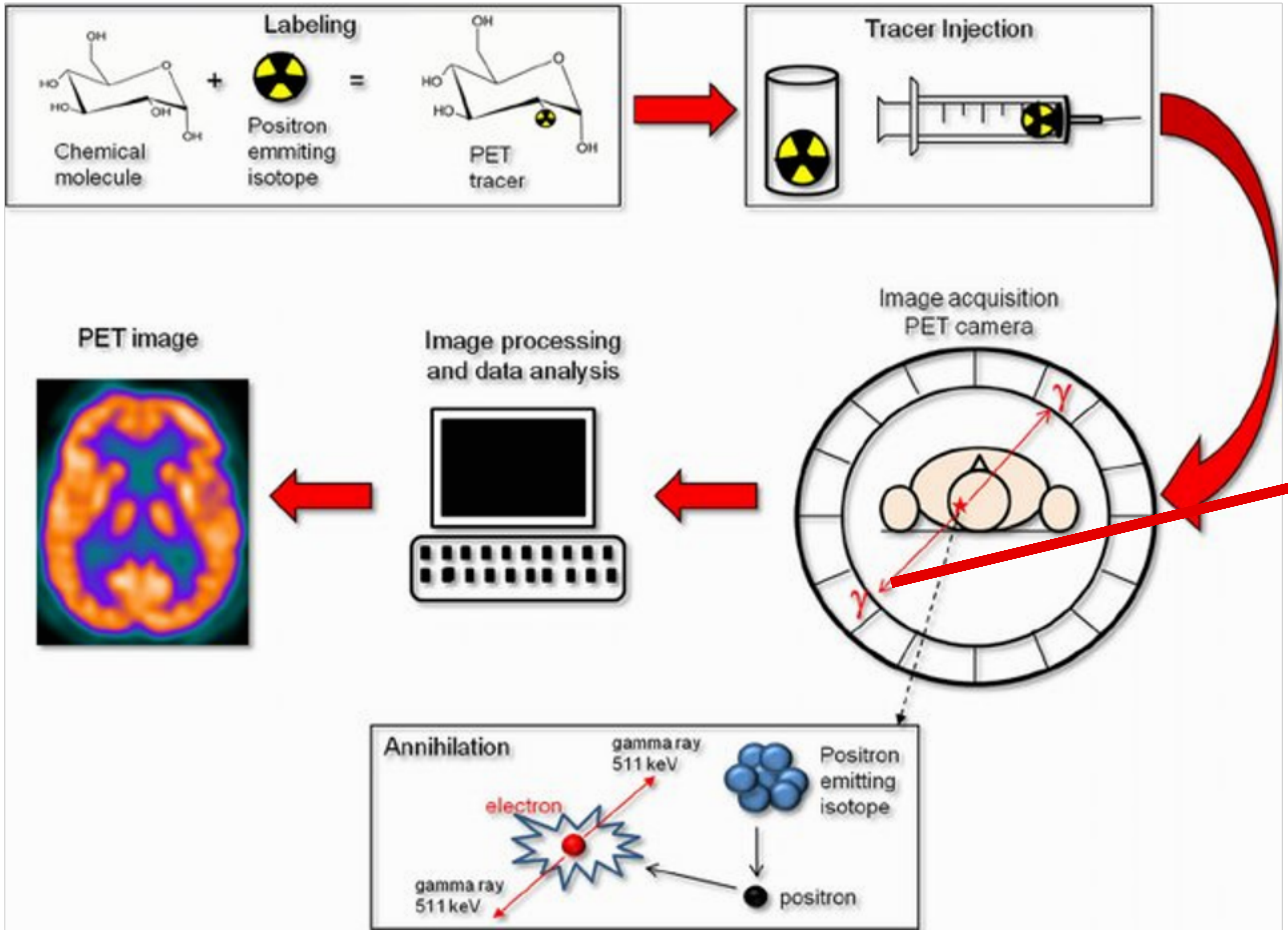
Cross section of Kr cold trap

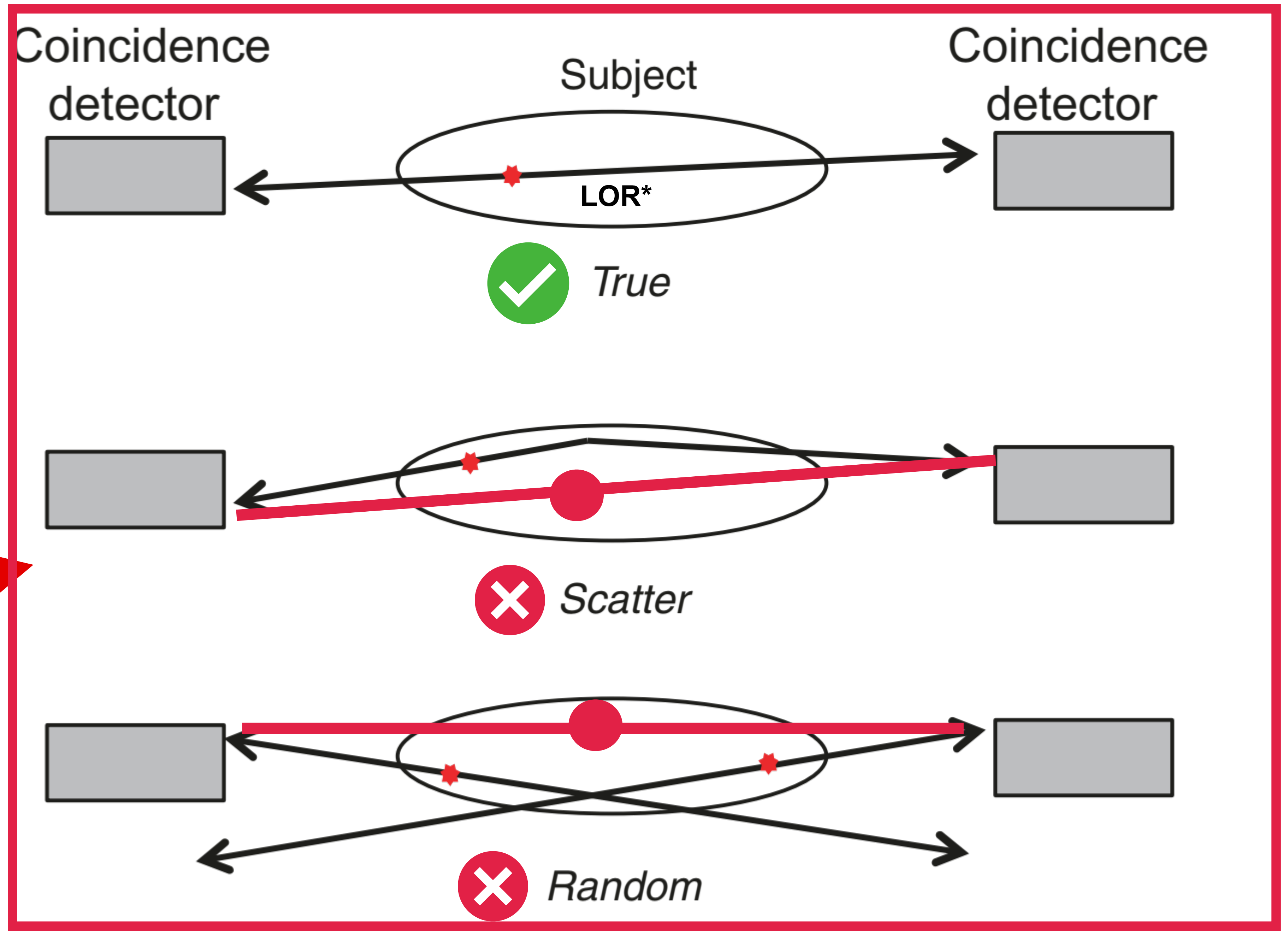
Positron Emission Tomography

Medical application

- In the University of Cagliari, we received a funding €340k, which is finishing in this Sumer, for PET development.
- Building a prototype PET scanner with SiPM+ASIC readout.
- Cryogenic system large enough to handle a PET scanner.
- Ongoing effort to measure the time resolution of SiPM + ASIC.

What is Positron Emission Tomography (PET)?
How does it Work?





* Line Of Response

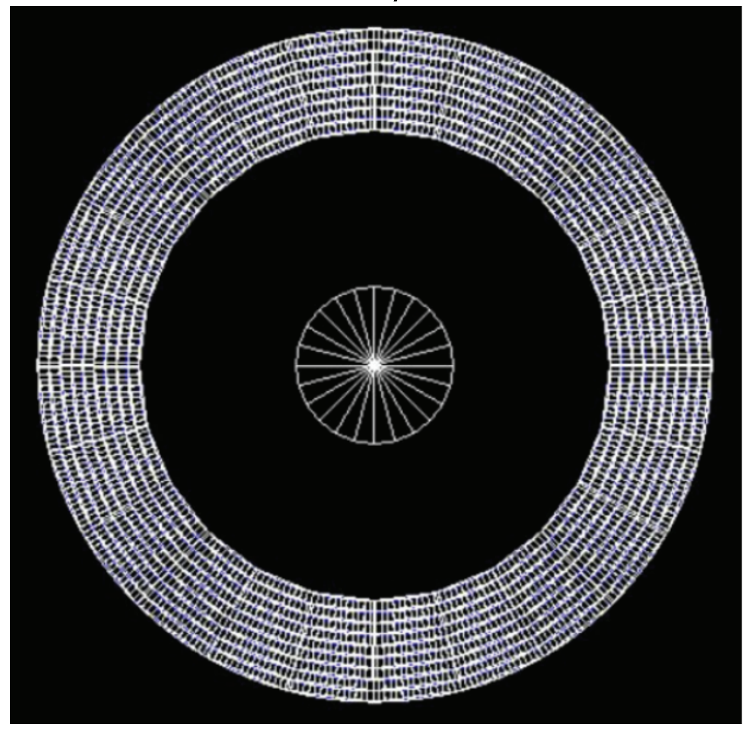
Three types of coincident events

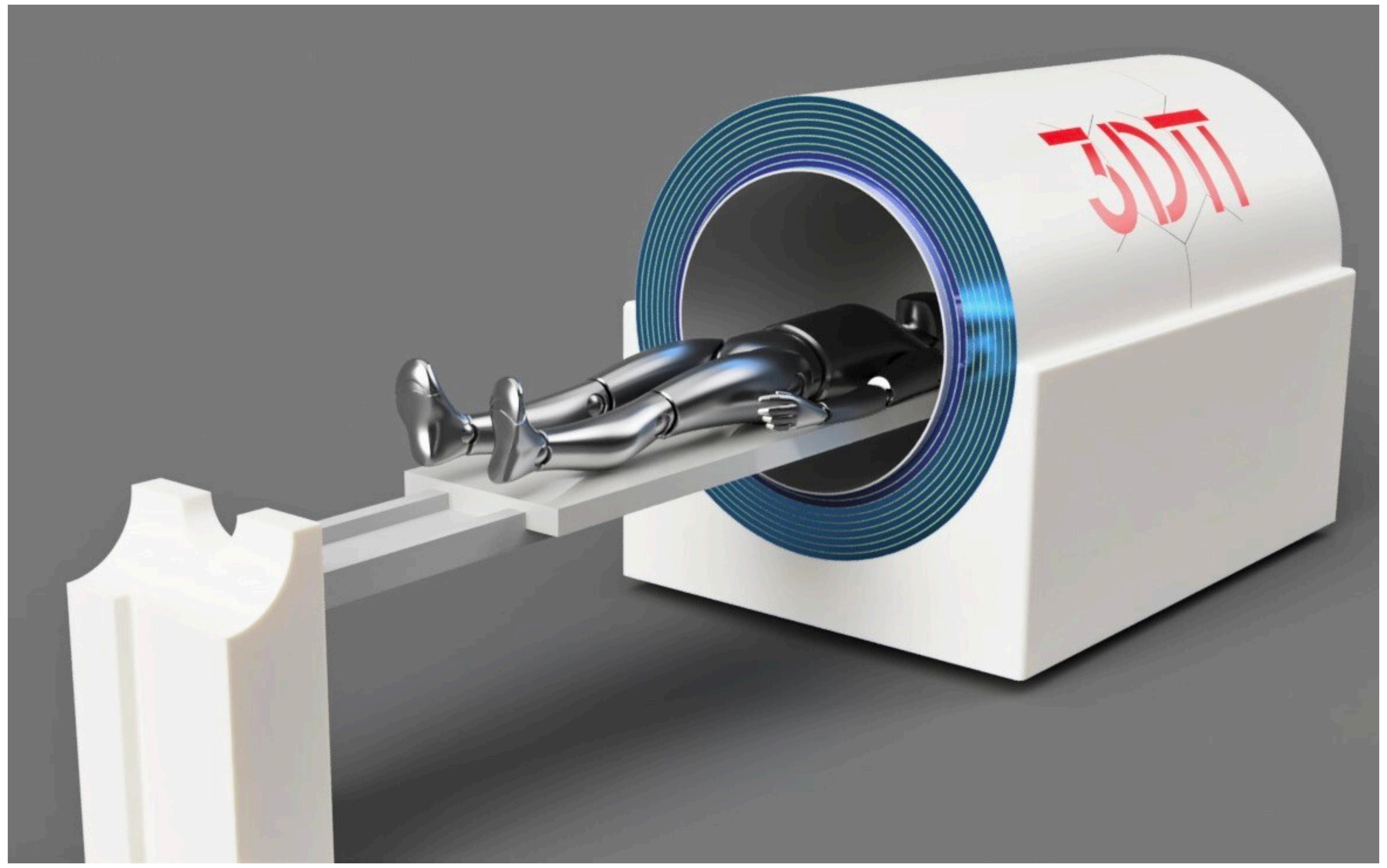
Credit: https://www.researchgate.net/publication/262189675_PET_imaging_in_multiple_sclerosis

Our 3-Dimensional Positron Emission Tomography scanner (3DPi) Monte Carlo Simulation

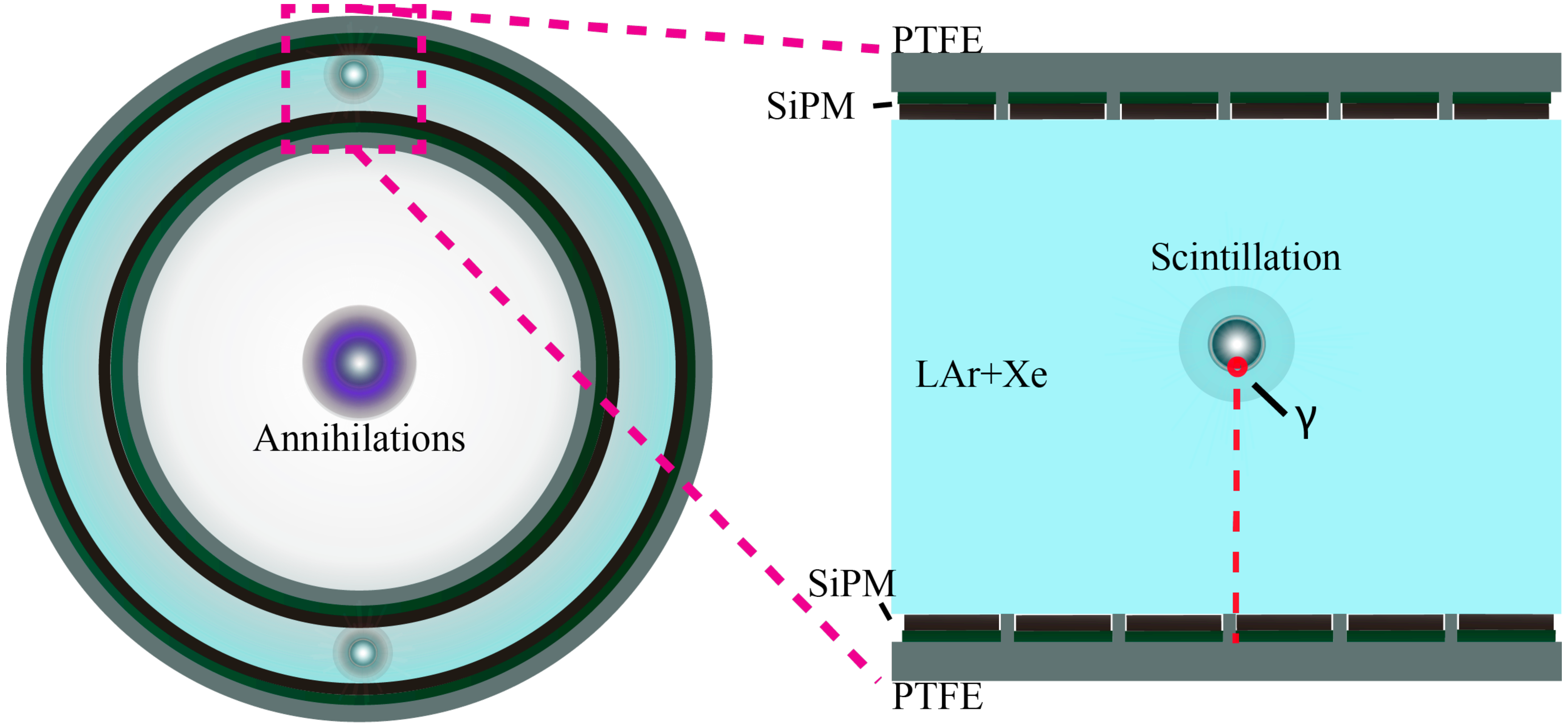
- Length: 2 m (Total Body)
- Inner radius: 45 cm
- Outer radius: 64 cm
- 9 annulus detection rings (Multiple layers)
- Each ring has Liquid Argon sandwiched Between two layers of SiPMs
- SiPM size: 10×10 mm^2
- Number of SiPMs ~10^6 channels
- PTFE (Teflon) supporting structure

Geant4 Geometry Cross-section





Fusion 360 CAD model render of the 3Dπ geometry

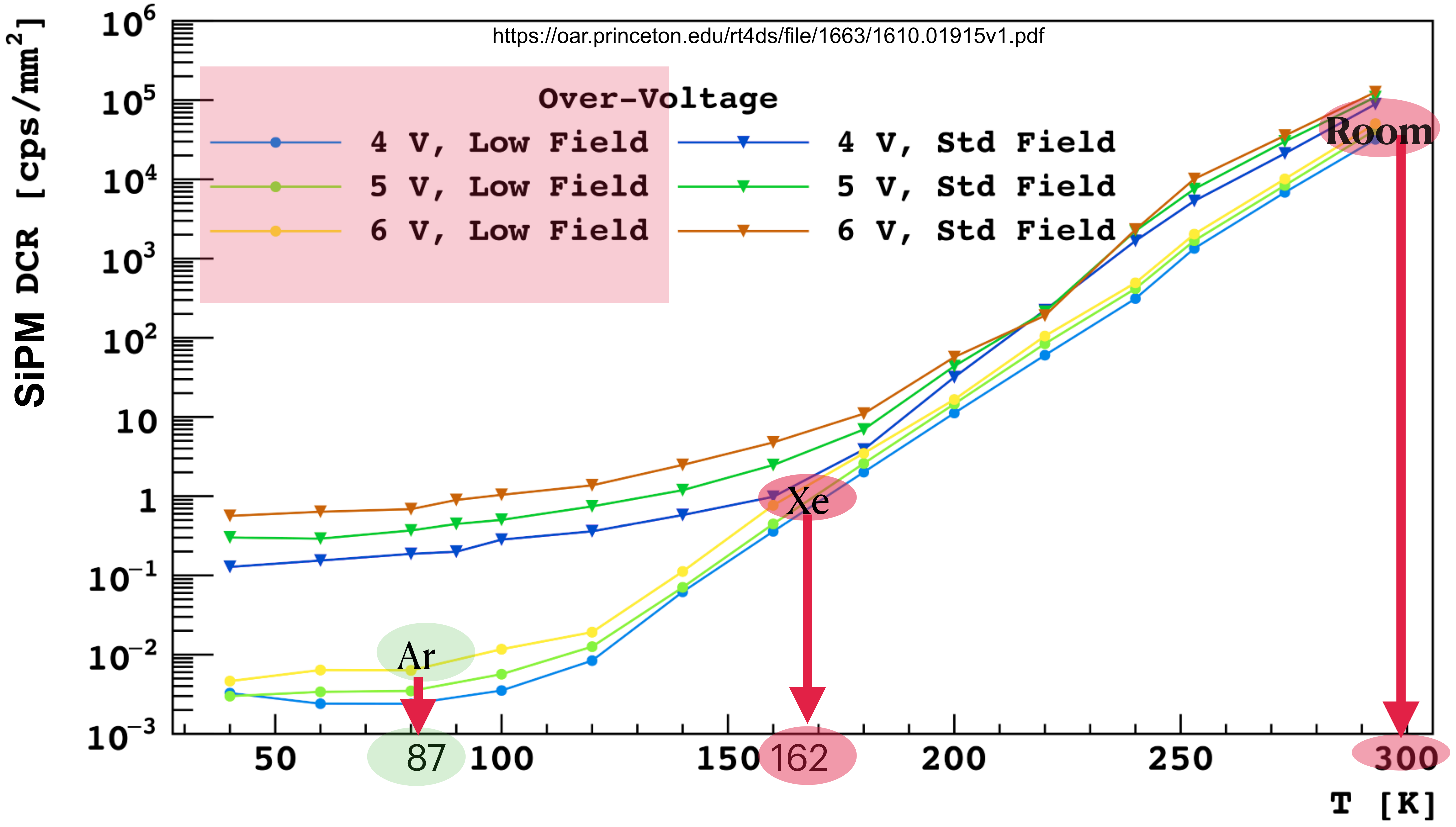


(A)
Single detection layer of the 3Dπ detector with the LAr+Xe scintillation conguration.

(B)
Each detection layer contains bottom and top layer of PTFE supporting material with an array of SiPMs.

Credit: arXiv:1403.0525

Property	LAr	LXe	LAr+LX
Fast decay time (ns)	7	4.3	~6
Slow decay time (ns)	1600	22	~100
Light yield (Photons/keV)	40	42	41
Wavelength (nm)	128	175	~175
Density (g/cm3)	1.40	2.94	~1.40
Temperature (K)	87	162	87
Cost (US$/kg)	~2	~2000	~2



Reduction in the dark count rate improves the timing capability of the devices

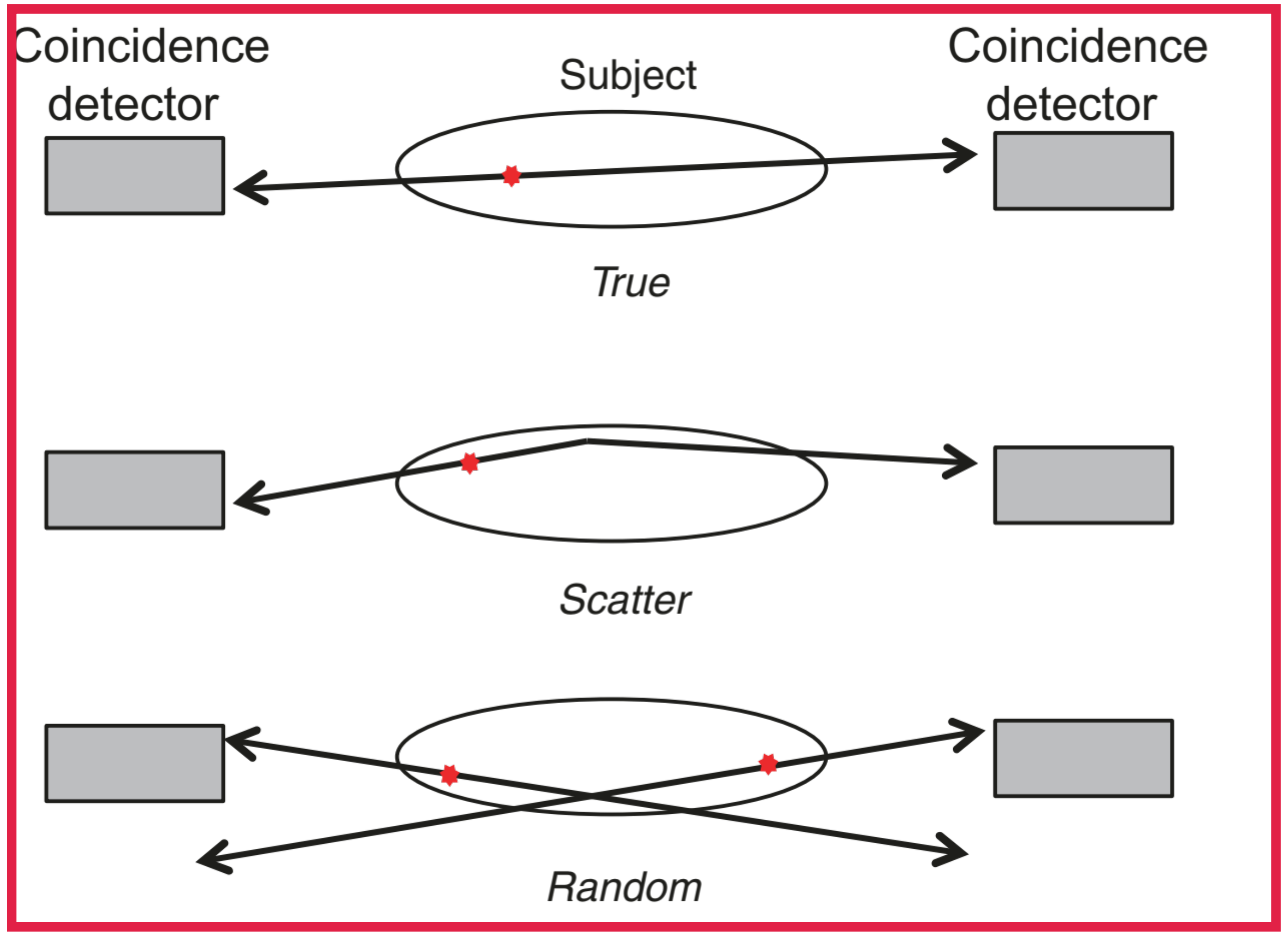
Combine the advantages of both ===>Xenon-doped Liquid Argon (Xe concentration ~100 ppm)

- Scintillation light at a wavelength of 175 nm (as a WLS)
- Operation at temperatures close to the argon boiling point, so don't need cooling down and have lower DCR
- Shorter slow decay time than the pure liquid argon

Noise Equivalent Count Rate (NECR)

$$\frac{T^2}{T+S+R}$$

T: True coincidences count rate
S: Scattered coincidences count rate
R: Random (accidental) coincidences count rate

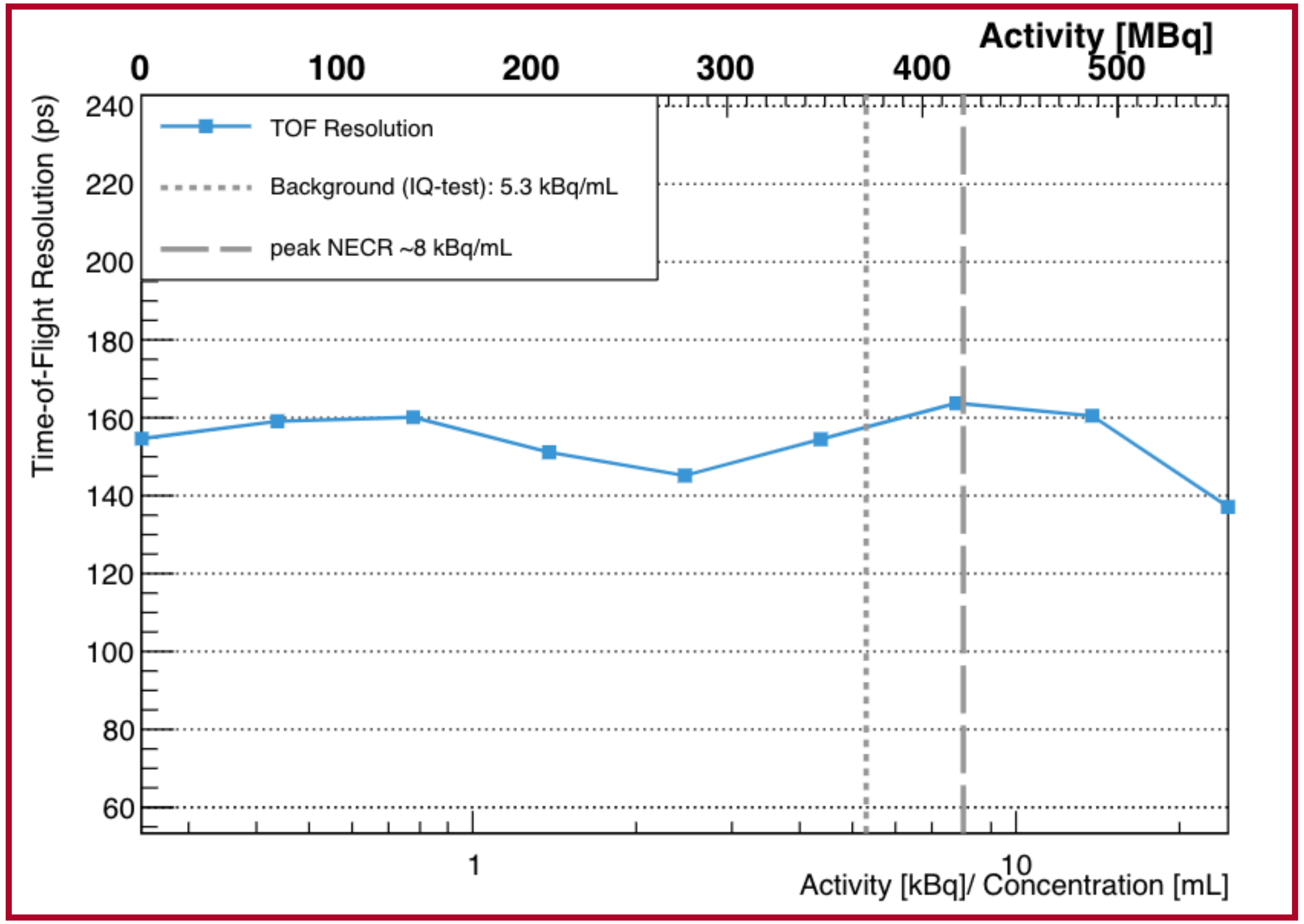


Three types of coincident events

Scanner	Peak NECR	Activity concentration at peak	Scatter Fraction at peak
Our PET (MC) (Preliminary)	~8.75 Mcps	~8 kBq/mL	45.2%
EXPLORER TB-PET/CT (Actual)	~1.5 Mcps	17.3 kBq/mL	37.4%
J-PET-TB (MC)	630 kcps	30 kBq/mL	36.2%
GE SIGNA PET/CT (Actual)	218 kcps	17.8 kB/mL	43.6%
CareMiBrain PET (Actual)	49 kcps	~14 kB/mL	48%
VRAIN PET (Actual)	144 kcps	9.8 kBq/mL	19%

Higher NECR at lower activity decay rate means extremely reduction radiopharmaceutical dose

The time-of-flight (TOF) resolution of a system defines the uncertainty in detecting the arrival time- difference of two photons in a coincidence event.



Scanner	Peak NECR	TOF resolution at peak
Our PET (MC) (Preliminary)	~8 kBq/mL	~163 ps
EXPLORER TB-PET/CT (Actual)	17.3 kBq/mL	505 ps
J-PET-TB (MC)	30 kBq/mL	500 ps
VRAIN PET (Actual)	9.8 kBq/mL	229 ps