ESS STAP

F. Monrabal on behalf of the NuESS Collaboration

21st April 2026

About this talk

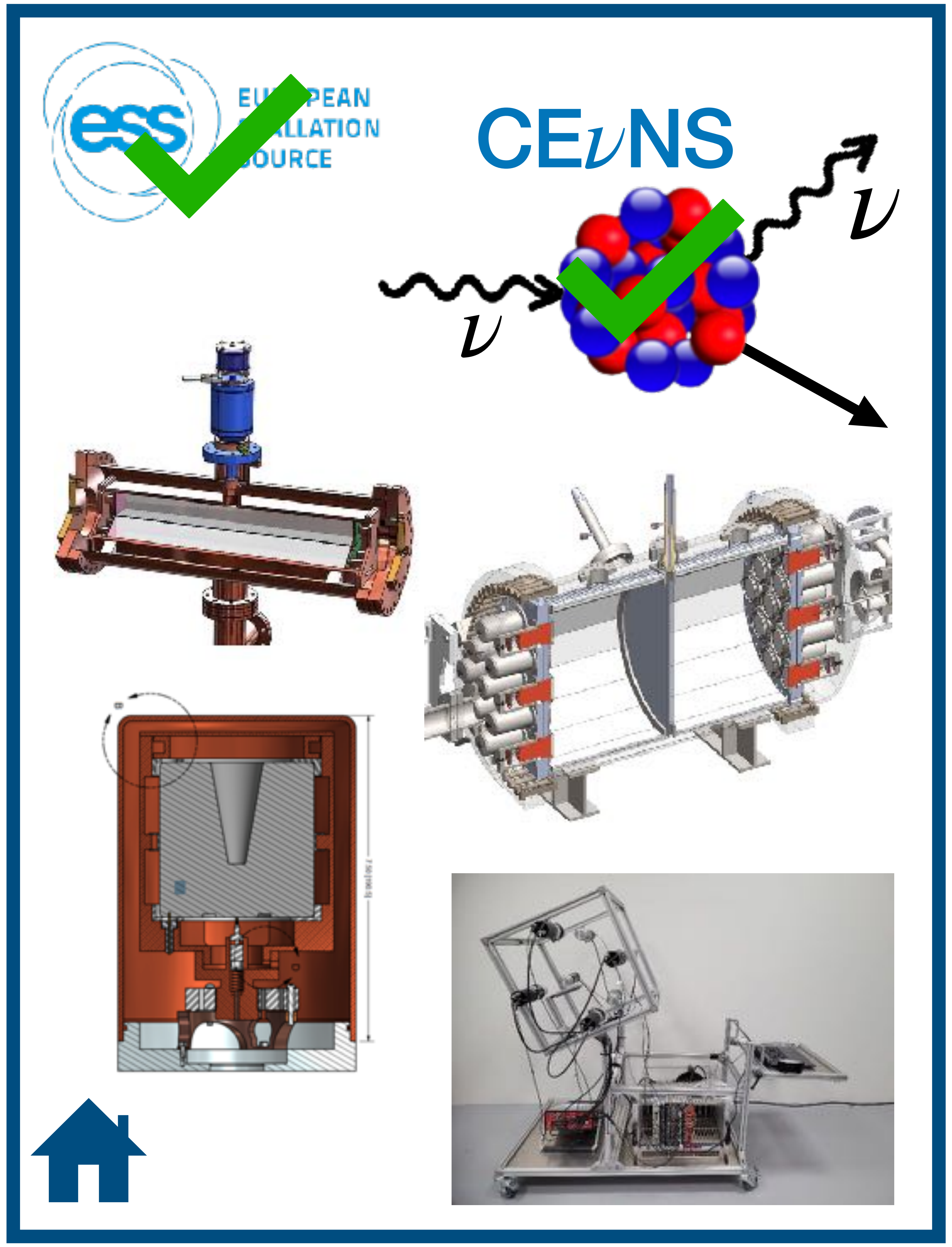
- Detectors: NuESS@DIPC
  - CsI
  - GanESS, status
  - COLINA
- Allocation at the ESS

Detectors technologies

A neutrino hunting project

An ambitious project with a large discovery potential

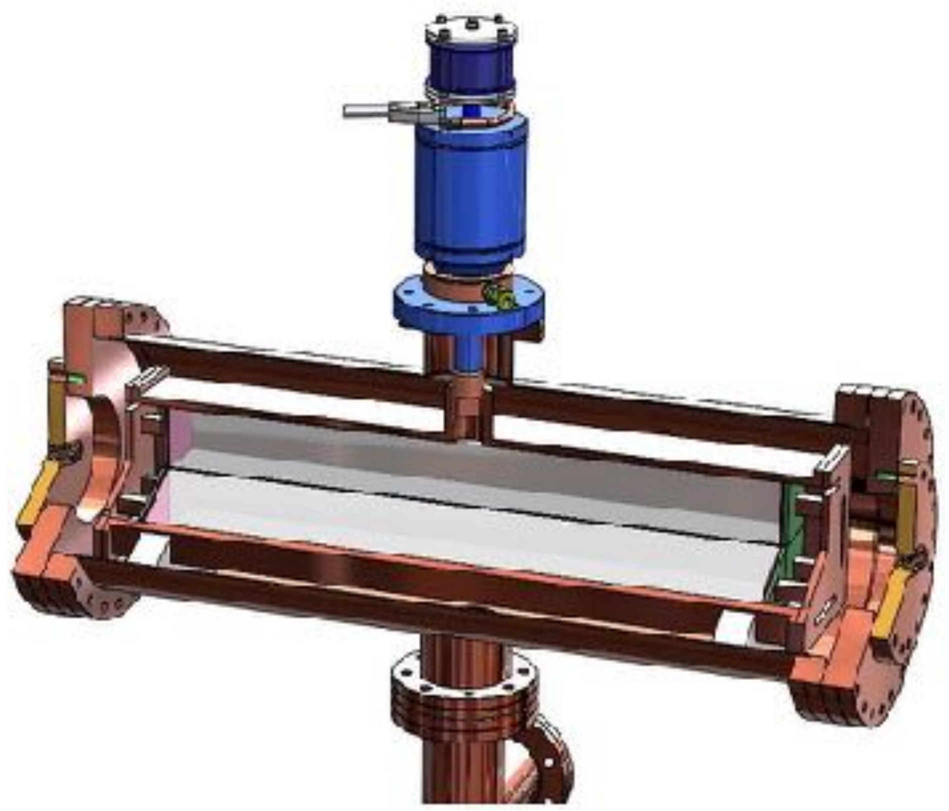
- Goal: study neutrinos and physics Beyond Standard Model (BSM).
- Observable: the result of a neutrino interaction, rate and spectra.
- Detector team: not only 1 technology but many!
- Extra challenge: neutrons will also be present!

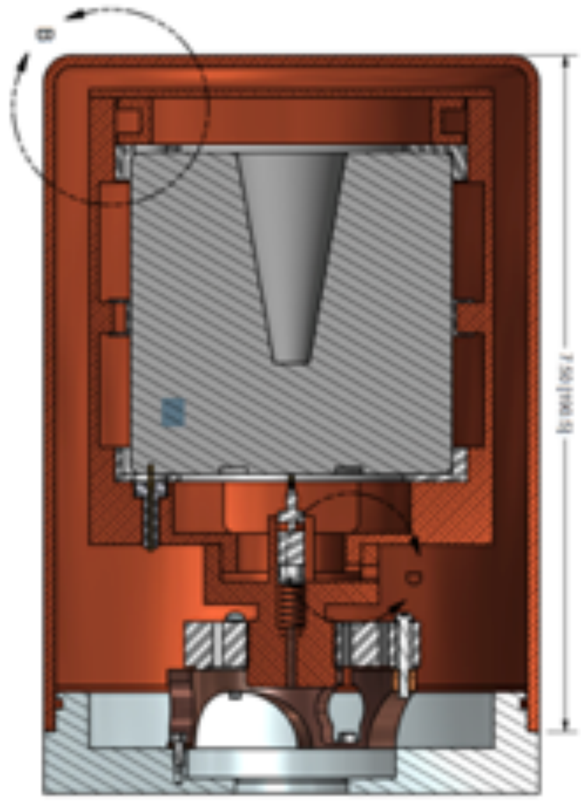


NuESS: The neutrino detector team @DIPC

European Research Council
Established by the European Commission

CºSI



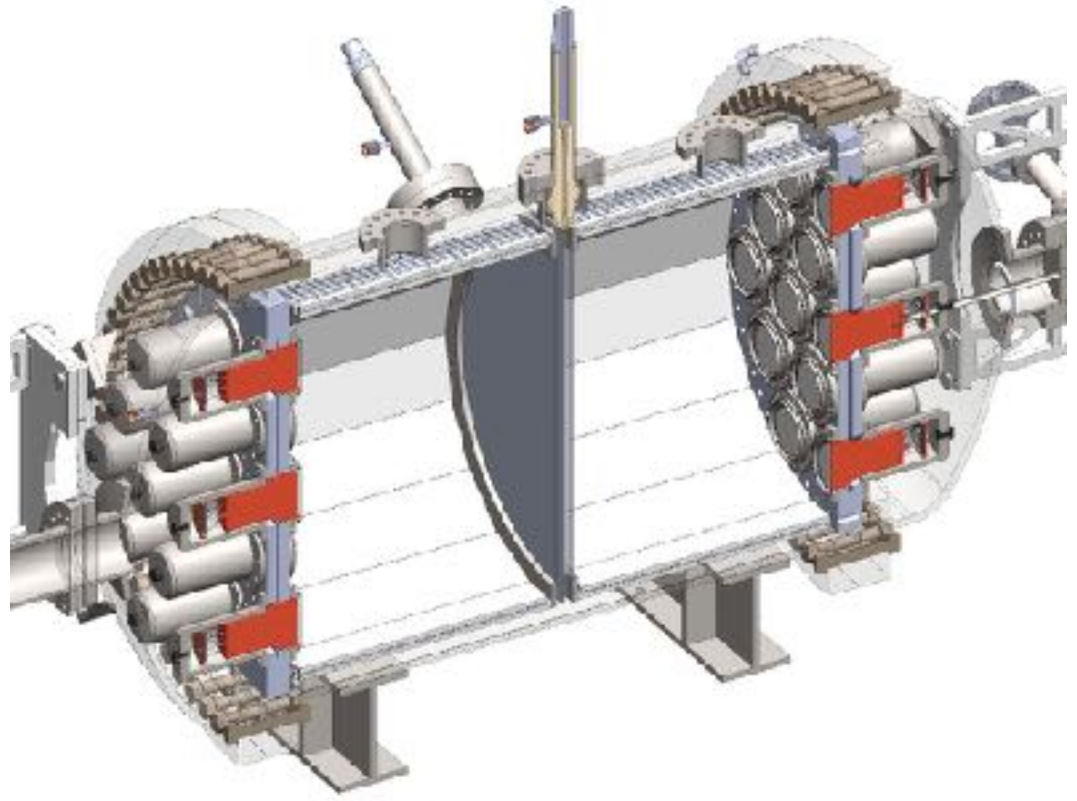


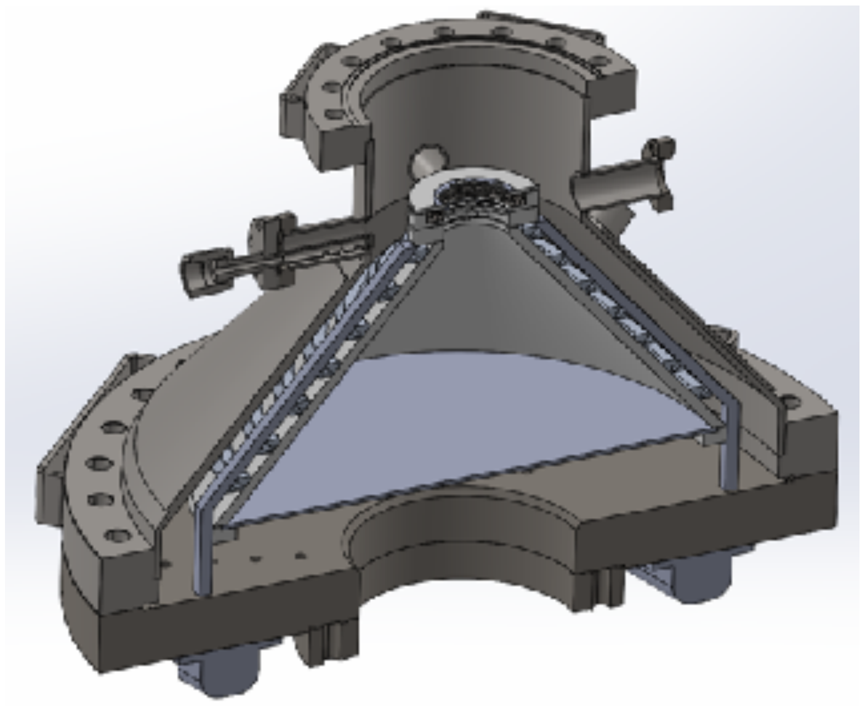
p-type point contact Ge

Cryogenic undoped CsI

GanESS

COLINA



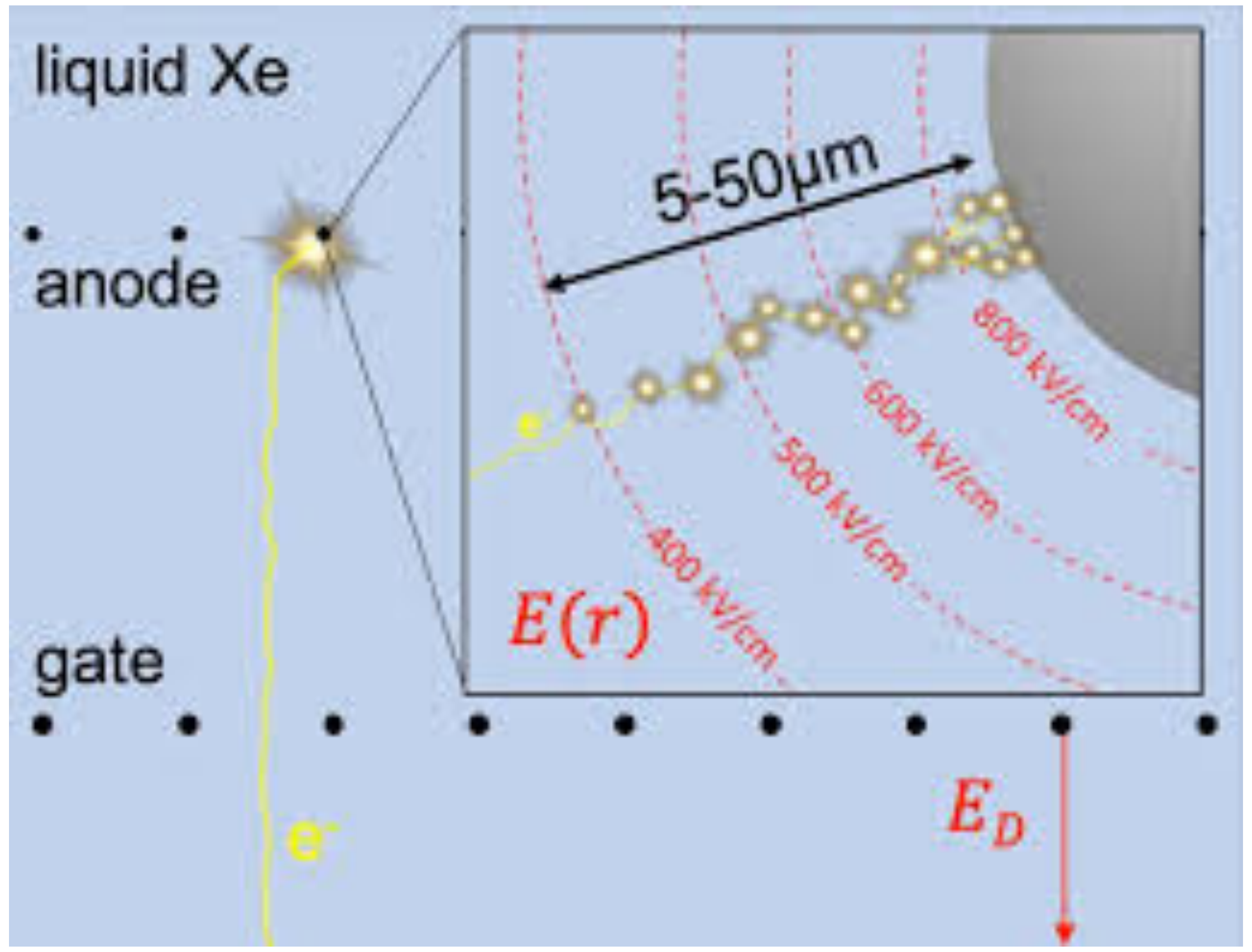


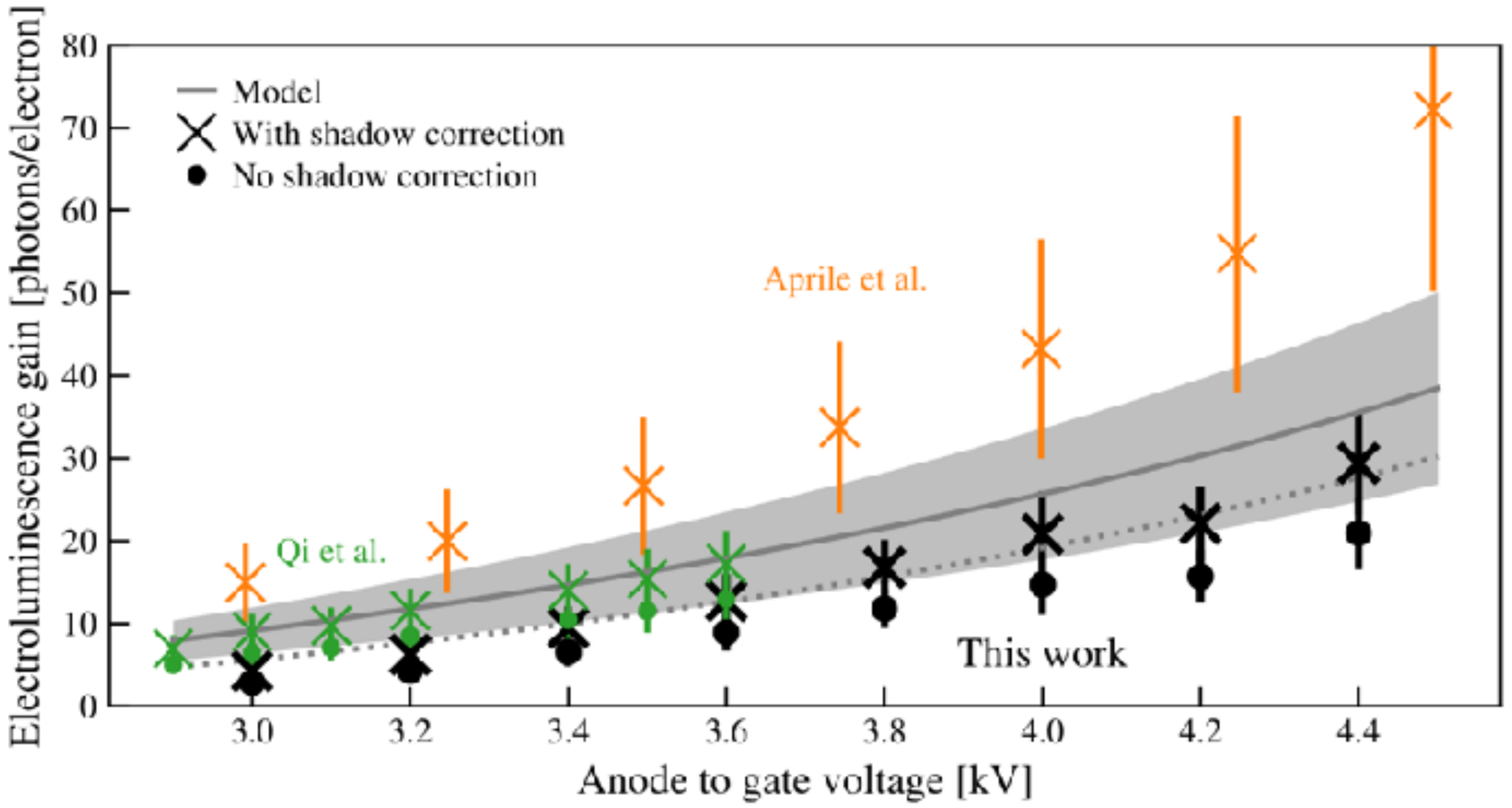
High Pressure Gas TPC

Single phase EL liquid TPC

COLINA:EL amplification in noble liquids: thin wires

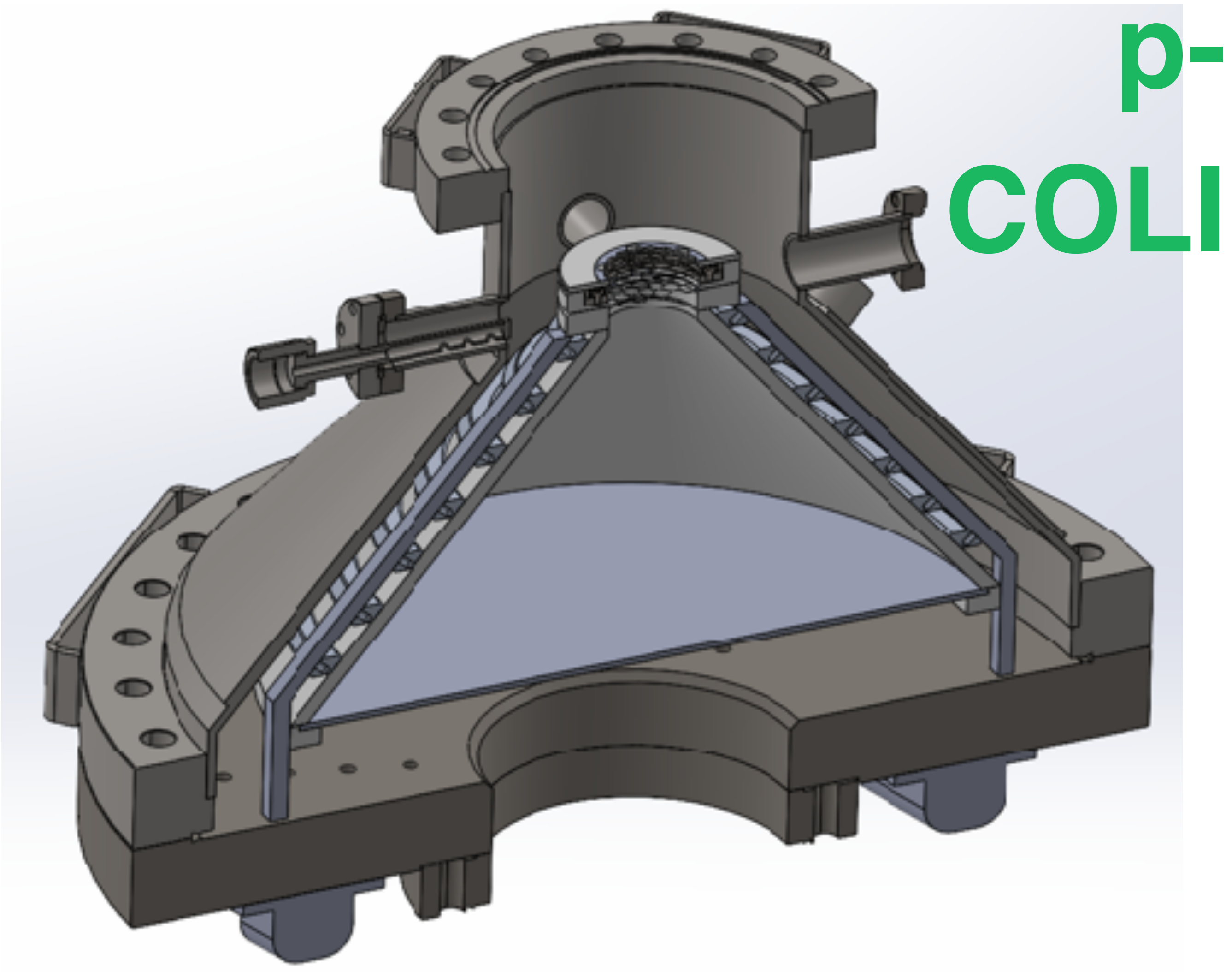
- Most established technology
- ~10 μm ⌀
- E ~ 1/r near the wire
- EL range ~10 μm
  - Short pulse (≈500 ns)
  - Low light yield (≈30 ph/e-)
- Can incur into charge multiplication
  - Compromise with light yield
- Operation of long wires is challenging
  - Limits EL region → limits target volume
  - Tensioning is difficult
  - Electrical instabilities

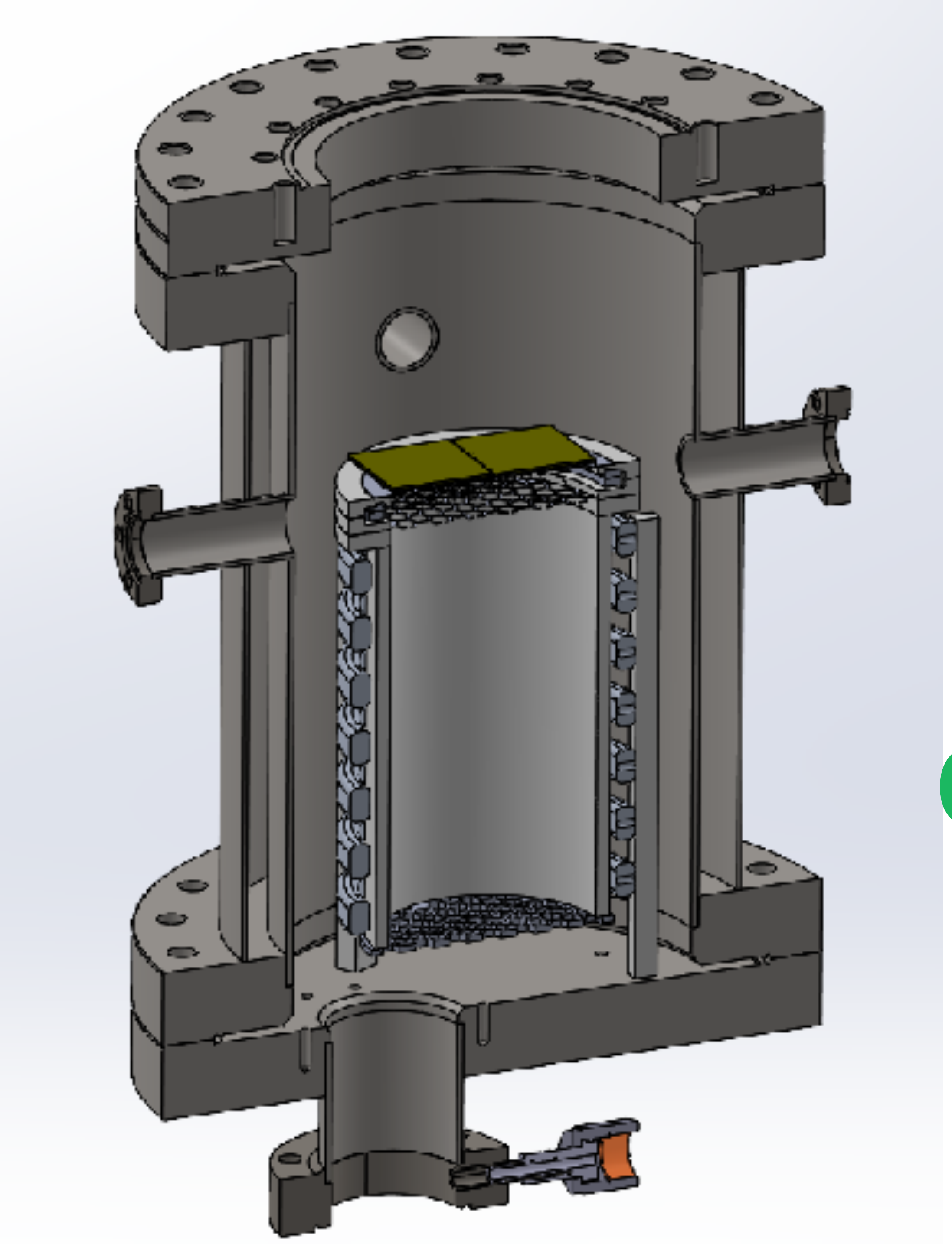




R&D program: p-COLINA and CC

- **p-COLINA**
  - 1:2 scale prototype to demonstrate conical TPC concept
    - Electric field
    - Light collection efficiency
- **CC**
  - Small cylindrical TPC for technology development
    - EL structures
    - Different target media
  - Quenching factor measurements

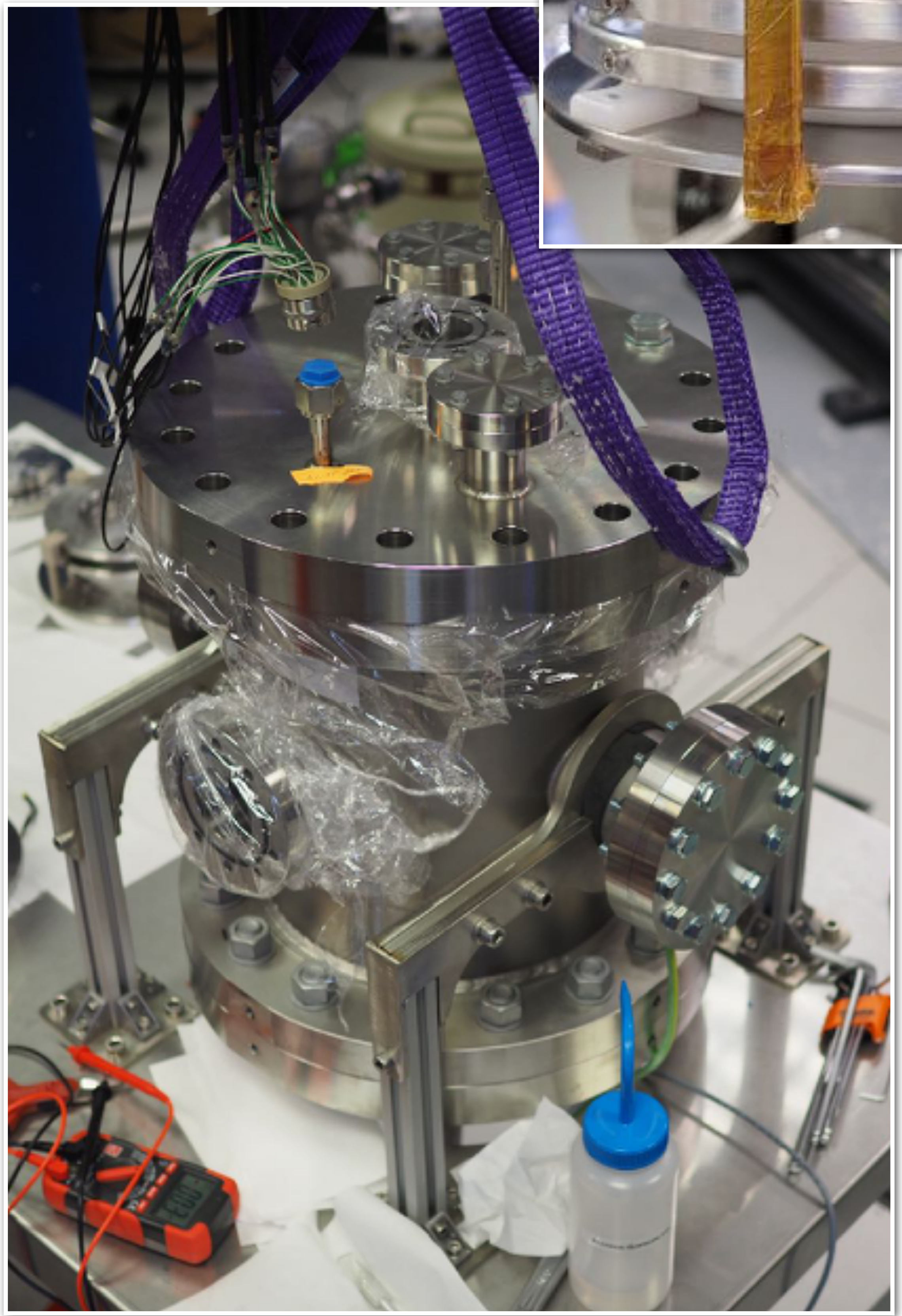


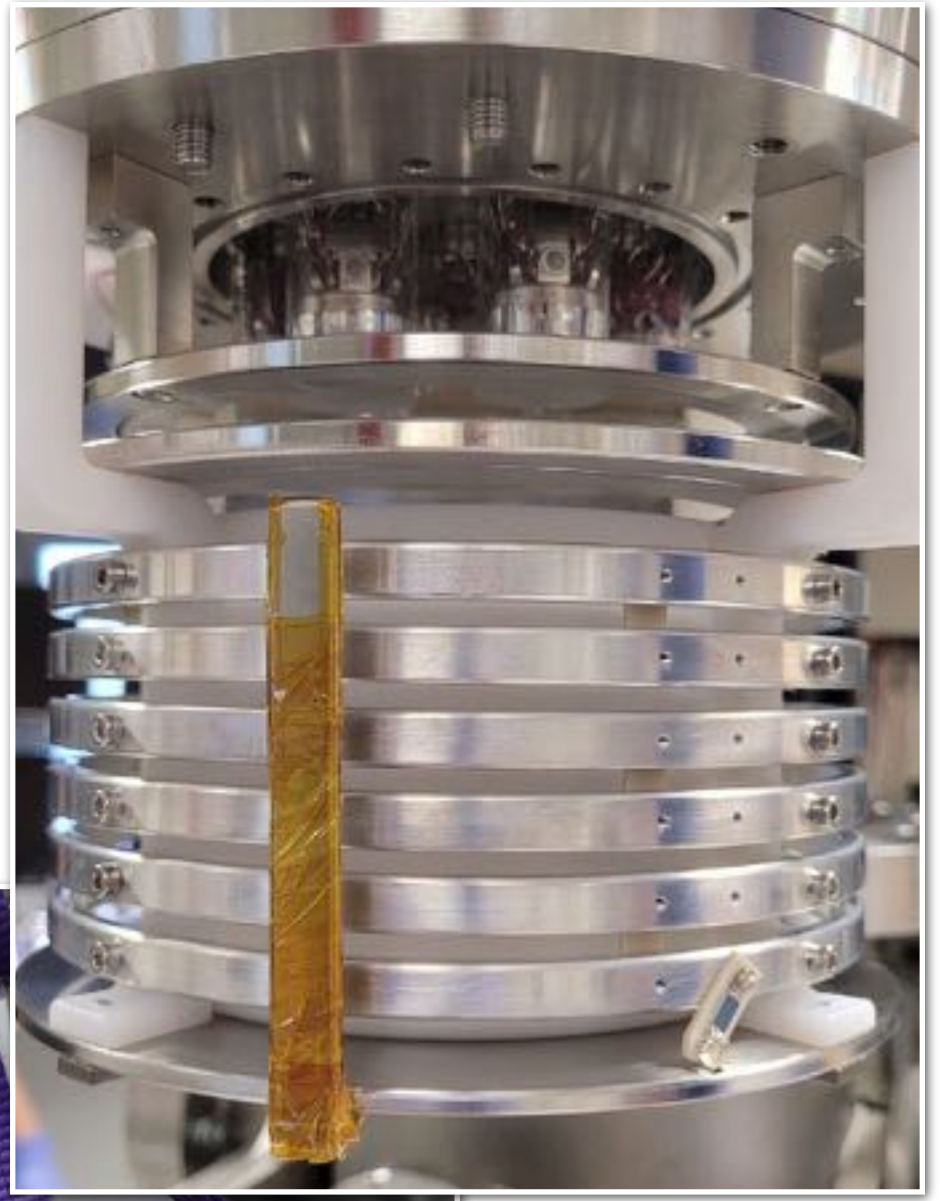


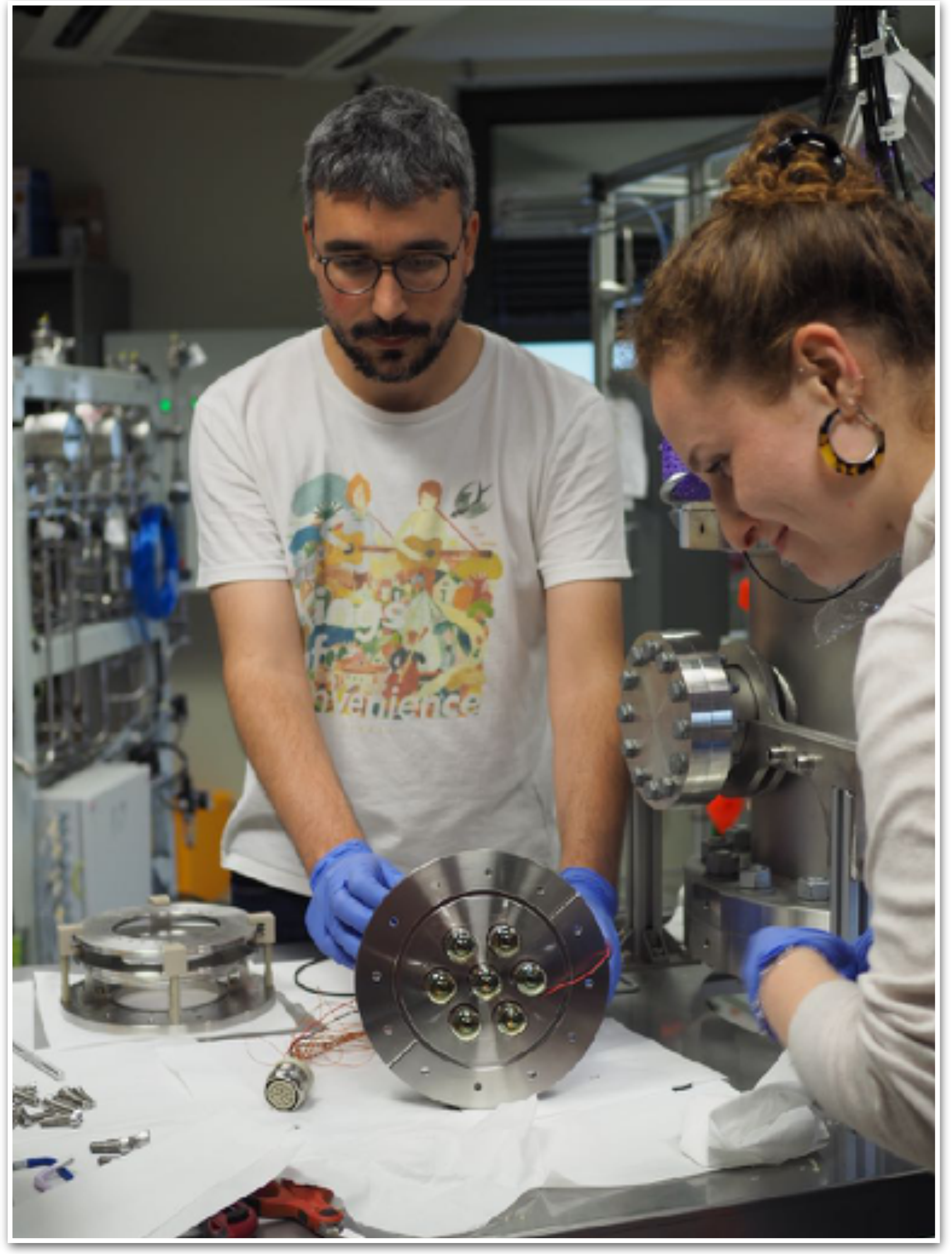
GanESS project: GaP

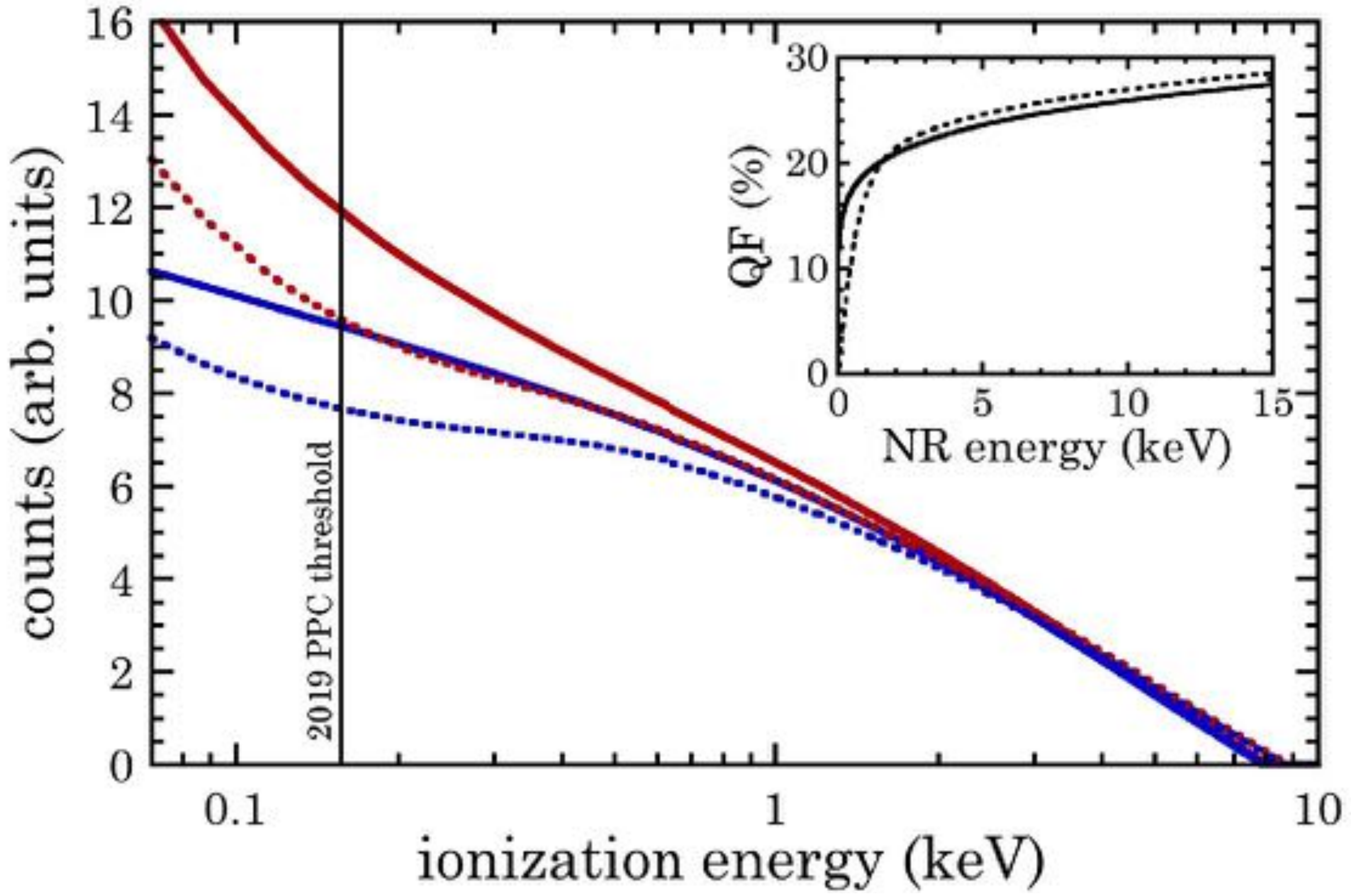
The Gaseous Prototype (GaP) system

- Opportunity to evaluate the technique in different conditions
  - Multiple noble gases: Xe, Ar, Kr.
  - Pressure up to 50 bar.
- Characterization of low-energy **response to nuclear recoils**
  - Quenching factor measurements.
  - Detection threshold.







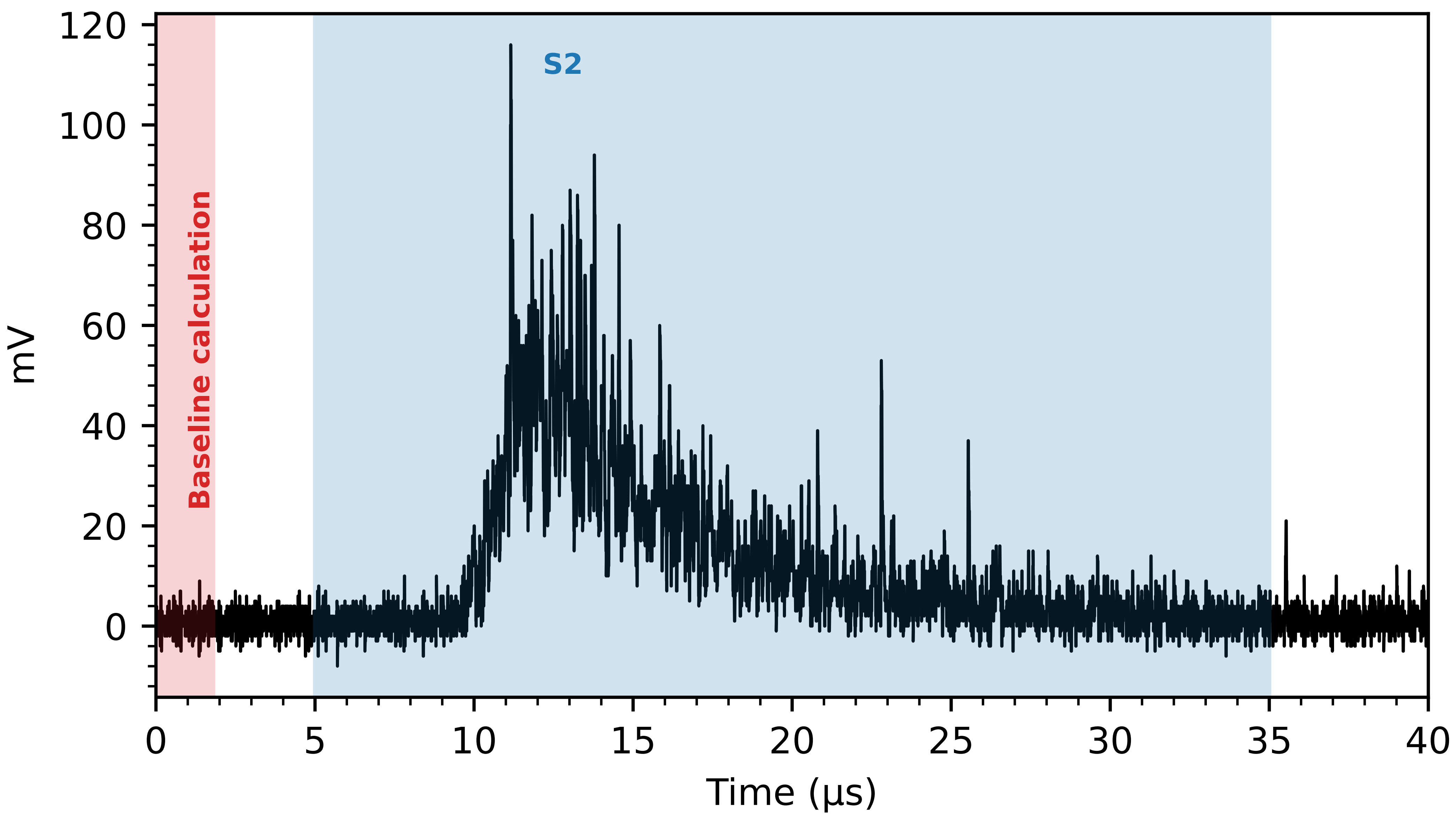


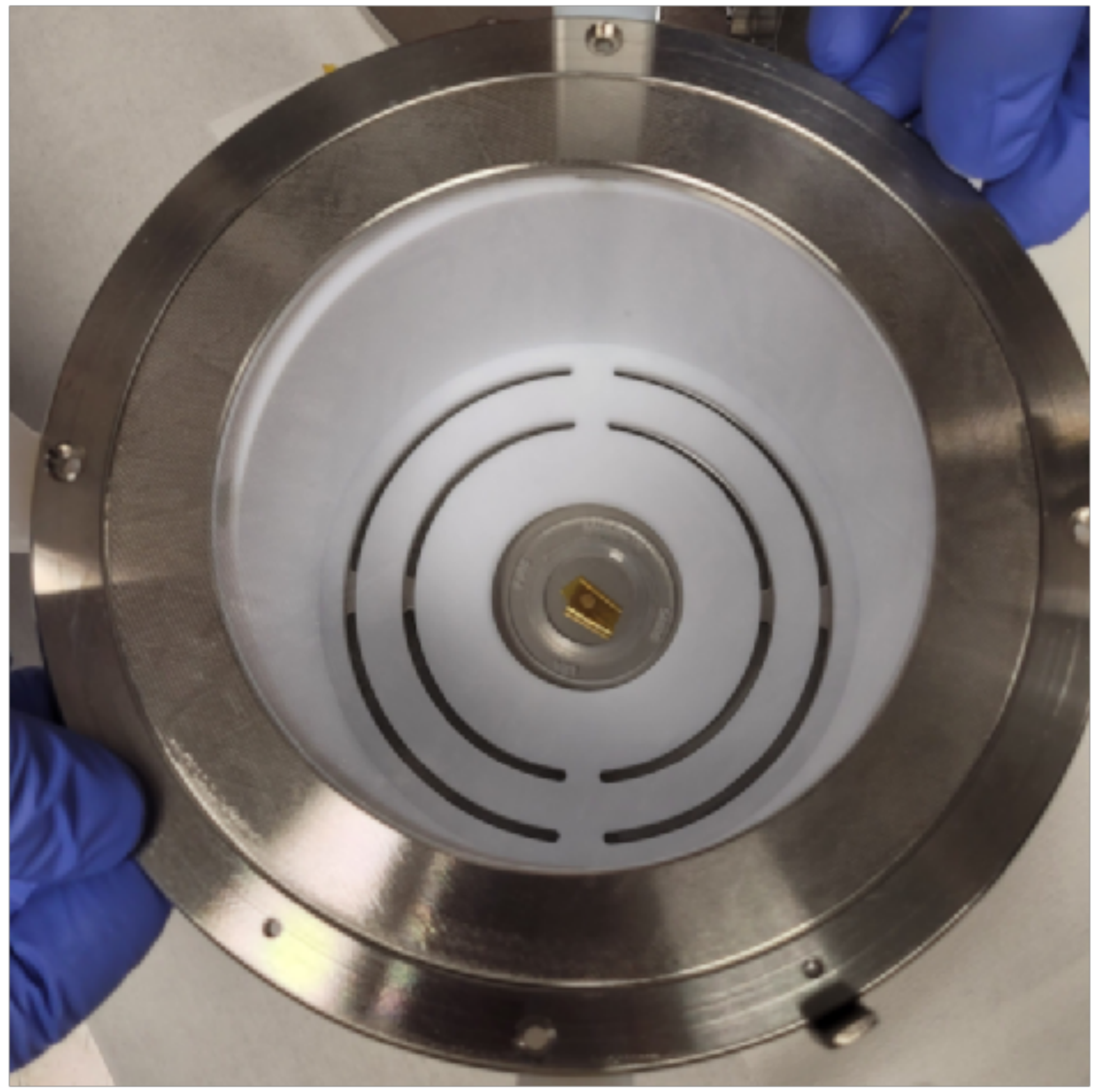
Differences in the expected distributions given different quenching factor models (solid/dashed)

GaP: first run results

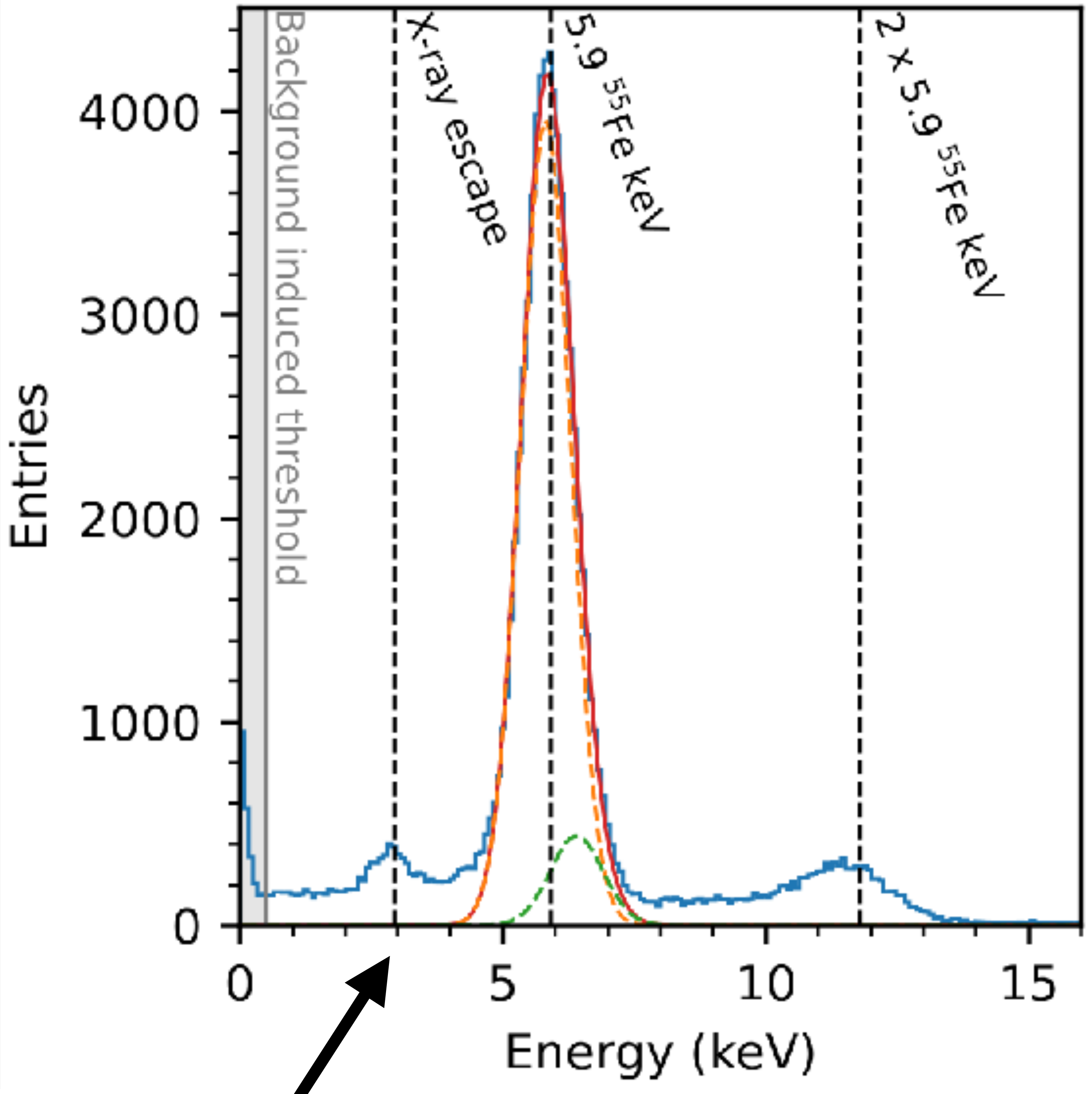
Operation with Ar at different pressures (<10 bar)

^{55}Fe source is visible





5.9 ^{55}Fe keV signal

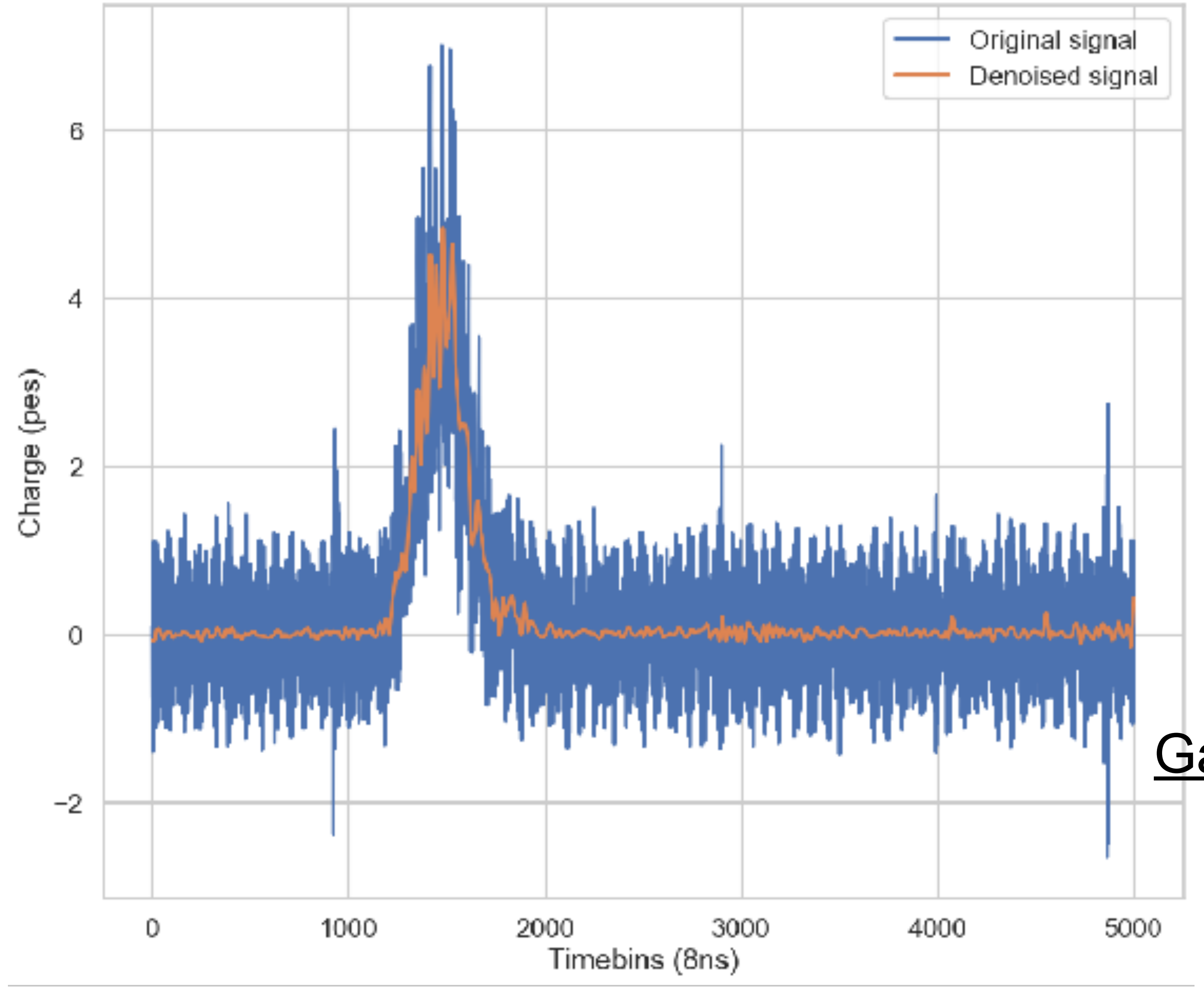


Ar escape peak (~3keV)

Noise reduction

Analysis steps:

1. Reading of raw waveforms:
   a. For each events: 1 array of 7 waveforms (1 per PMT)
   b. We loop on each PMT to apply the calibration and sum the calibrated waveforms
2. We apply a wavelet decomposition to reduce the noise (soft filter)
3. Application of cuts
4. Plots



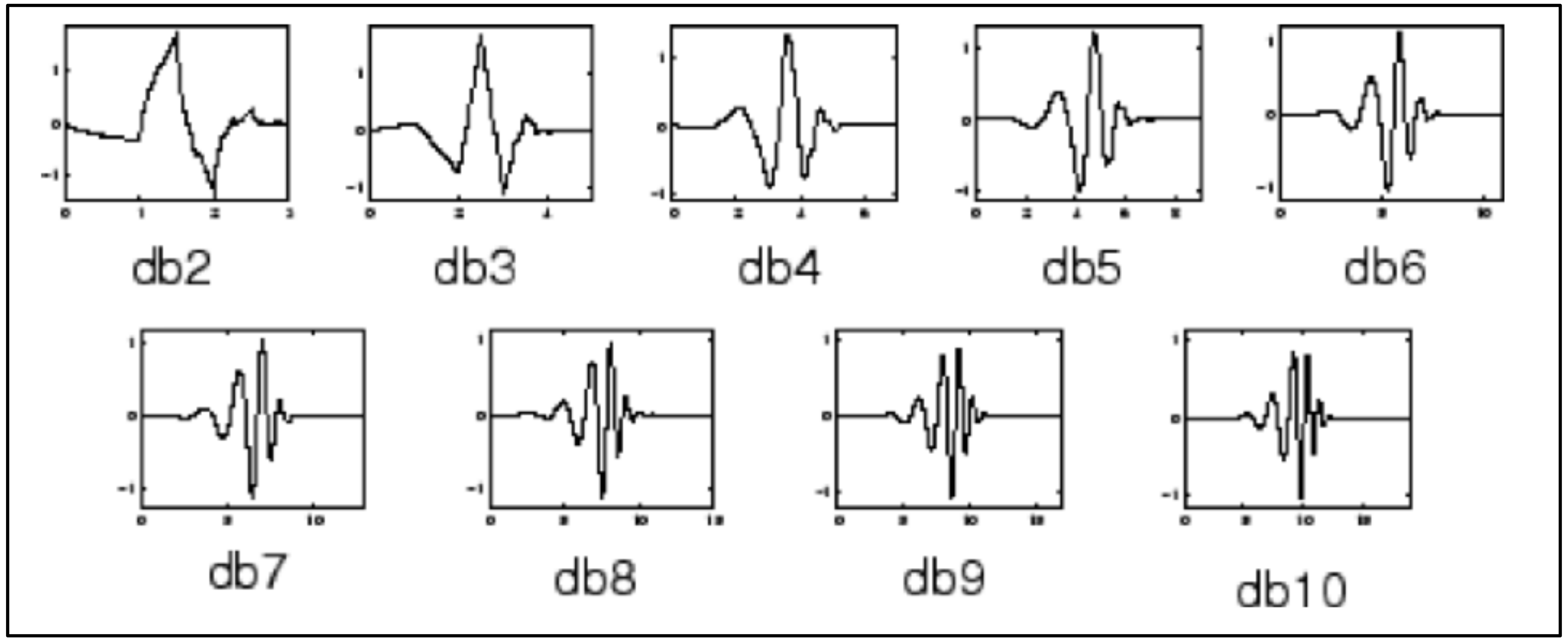
GaP raw waveform before and after denoising using wavelet decomposition.

Noise reduction

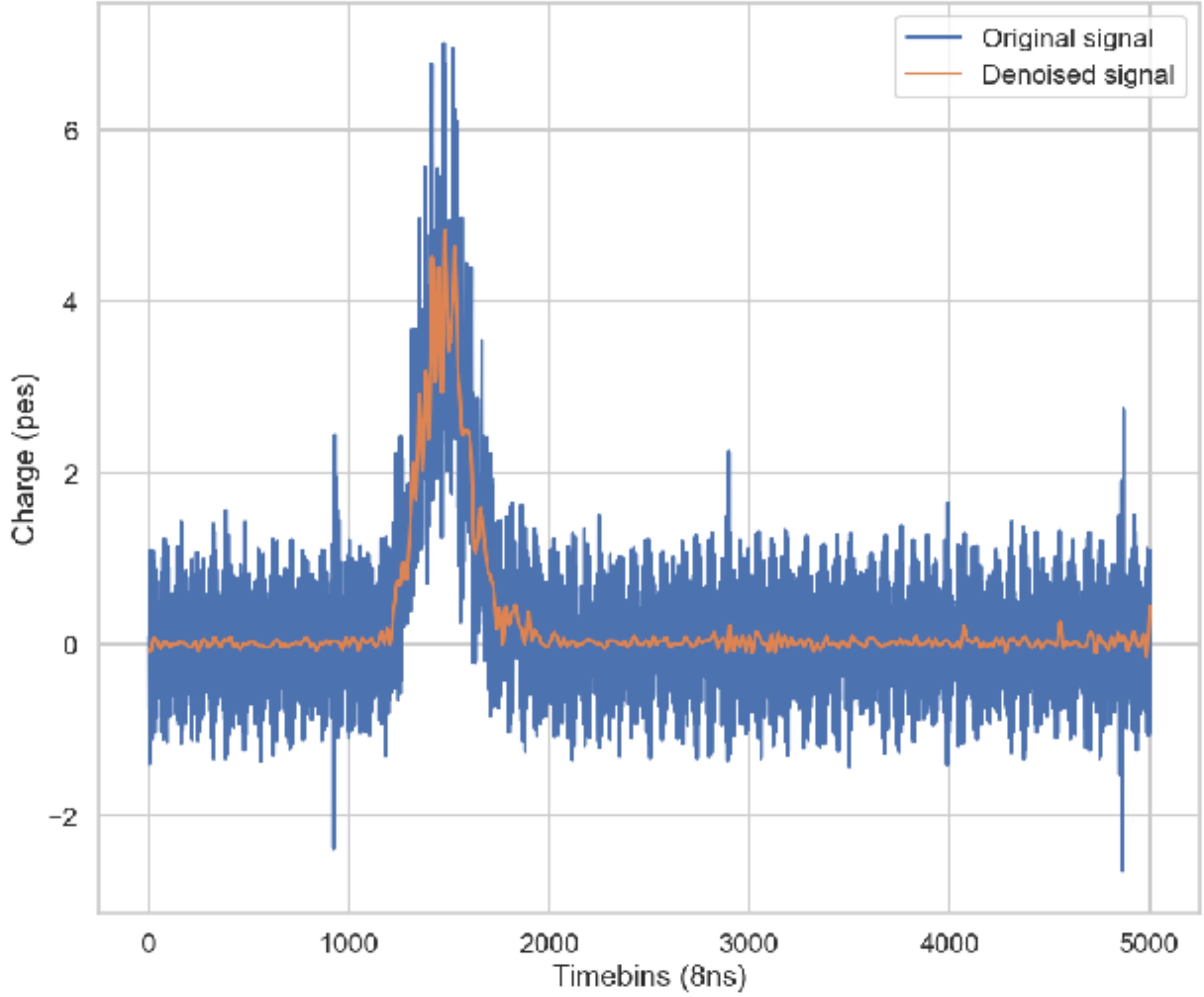
<u>Wavelet decomposition:</u>

1. Useful for denoising a signal, keep important parts and doing a multi-scale analysis
2. We use the level “db4” for “Daubechies 4” => we calculate 5 coefficients (signal convolution with different filters) :

- cA4: low frequency approximation
- cD1 to cD4: different scale of high frequency details



Daubechies wavelets.



GaP raw waveform before and after denoising using wavelet decomposition.

Noise reduction

If Emin <= E <= Emax & Amplitude max >= threshold:
We keep waveforms of interest.

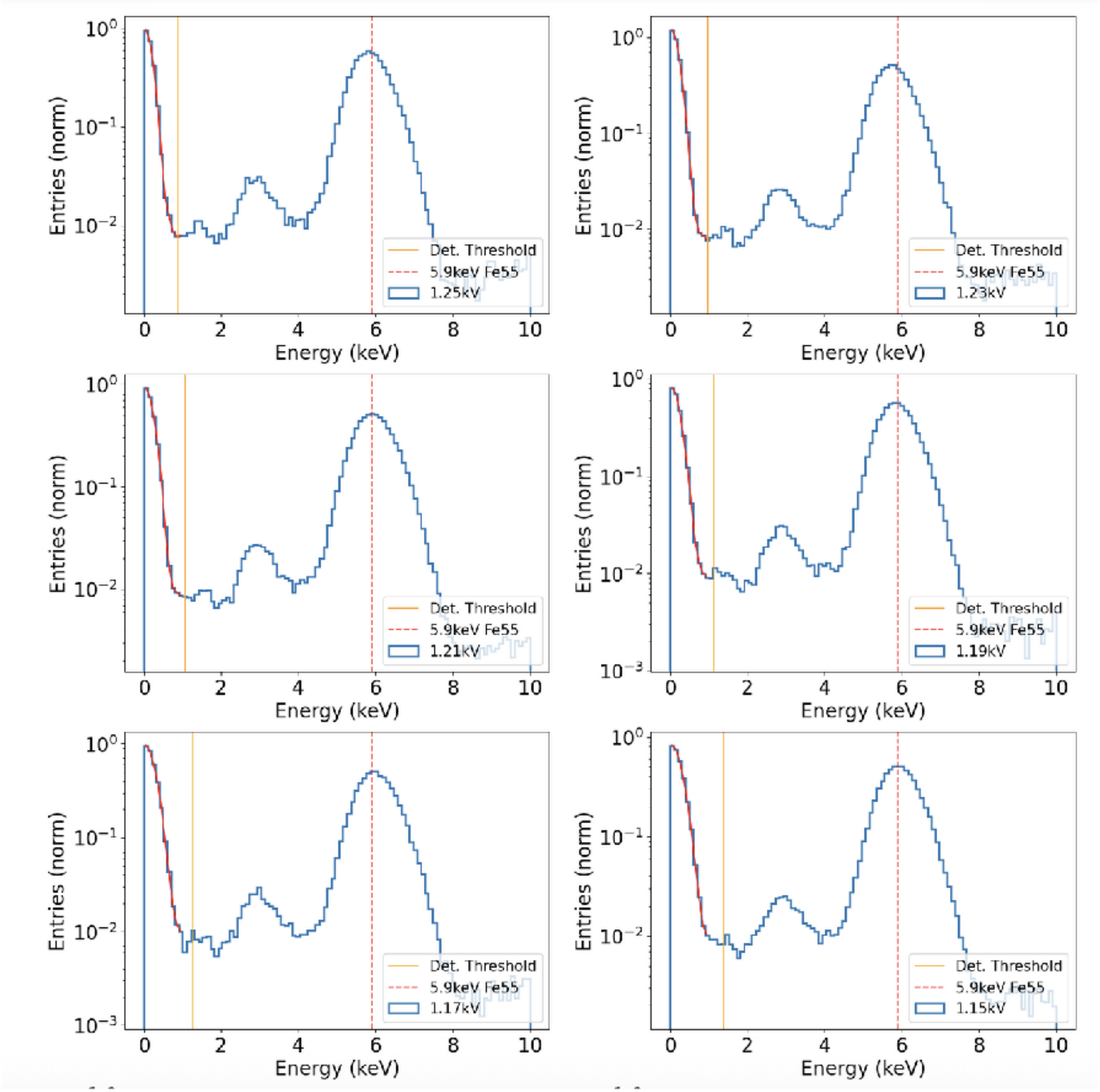
If no amplitude >= threshold in the first and last 1000 timebins:
This cut is to remove events with pulses not fully contained in the window. Then, we store the indexes of the values above the threshold. We do the difference between all.

If the difference of indexes = 1 *(possibility to add ToT)*:
=>1 WF. So we take a window of -600 bins before the smaller index and + 1500 after and we integrate the denoised WF. The values outside of this window are used for noise analysis.

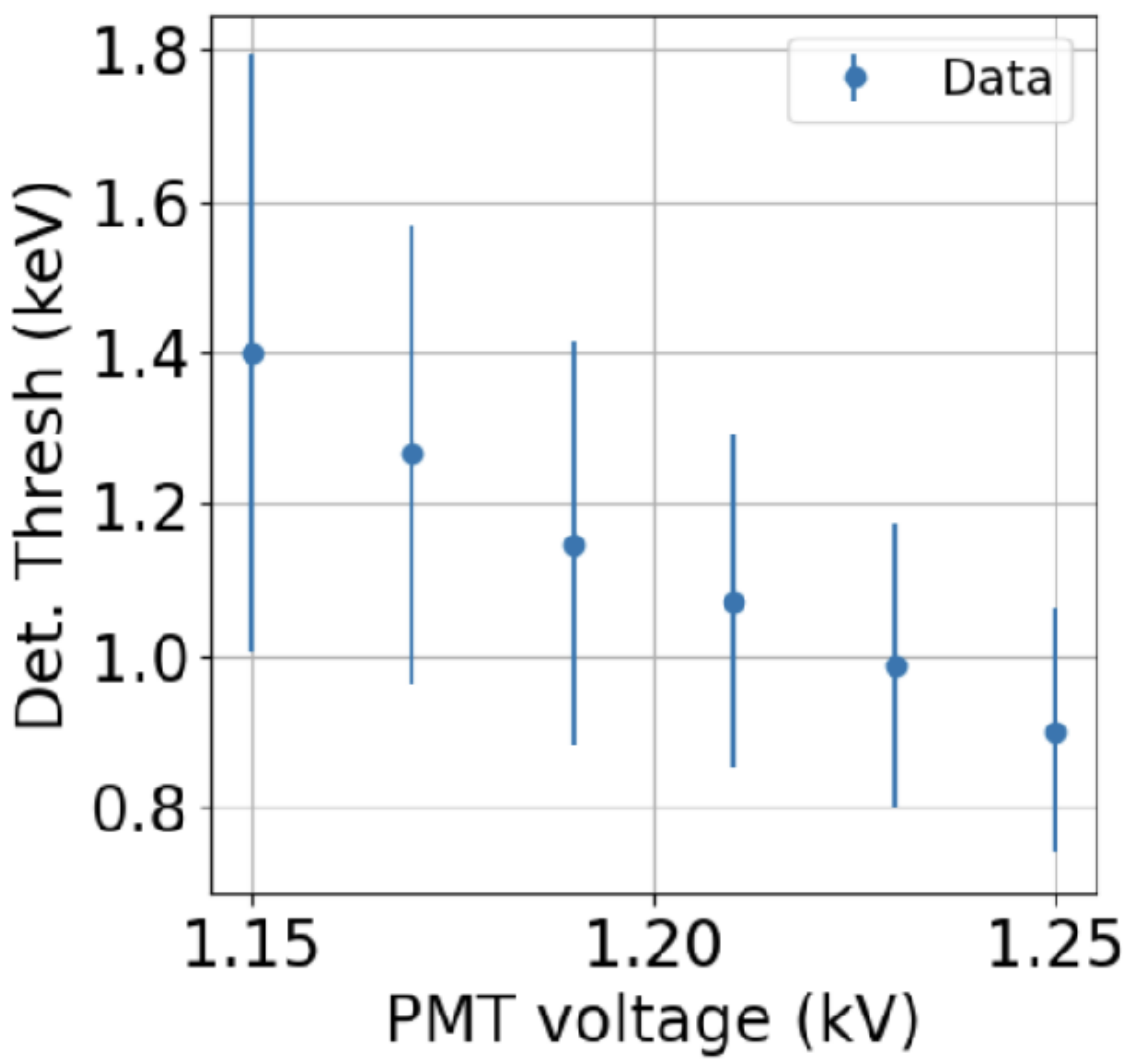
Definition of the threshold:

- We use the 300 first timebins to calculate the baseline
- Threshold = max(baseline) + 0.3

Detection Threshold / Low energy events



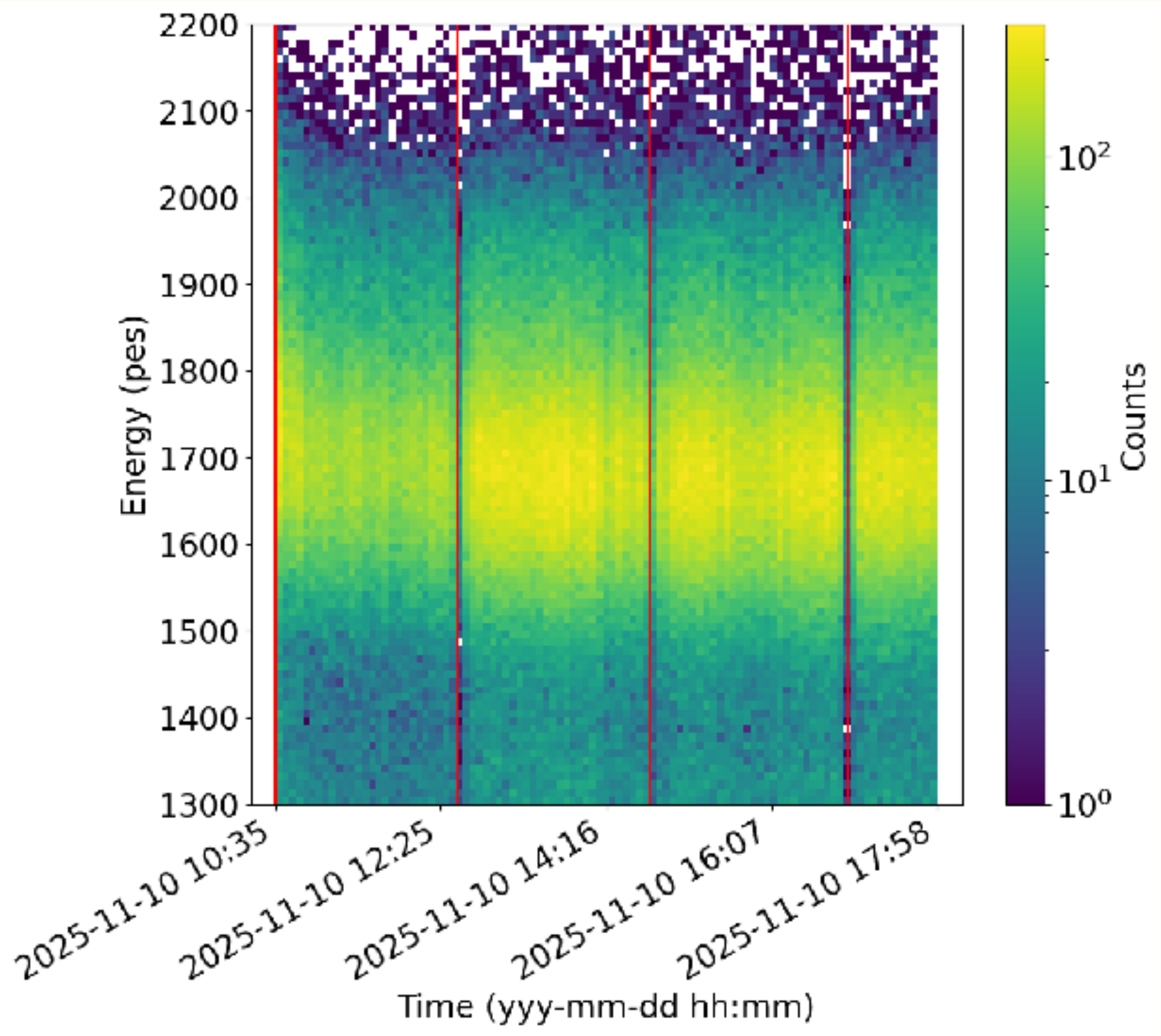
Argon
8.5 bar
12.9kV in Gate (1.49kV/cm/bar)

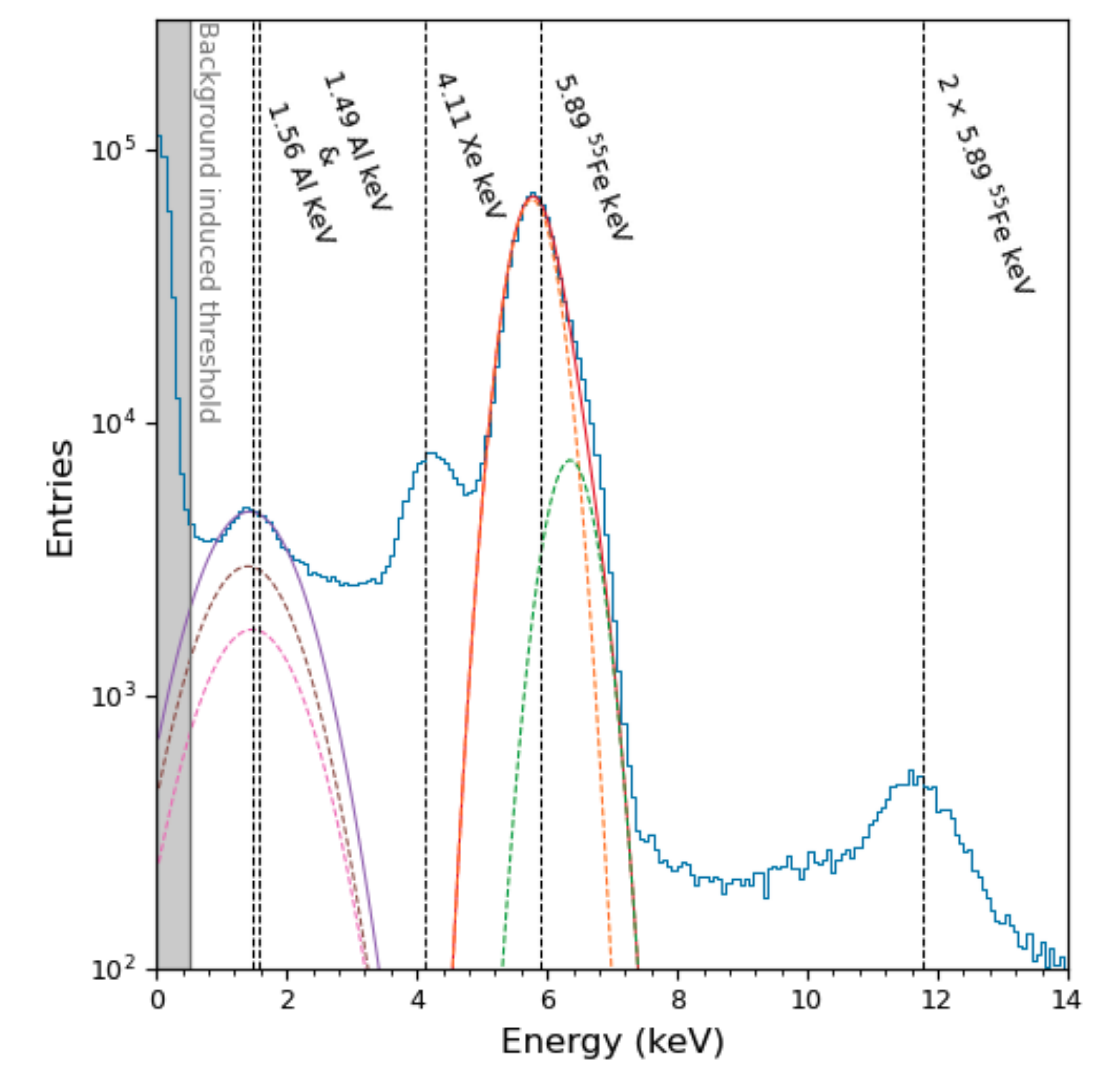


Preliminary results

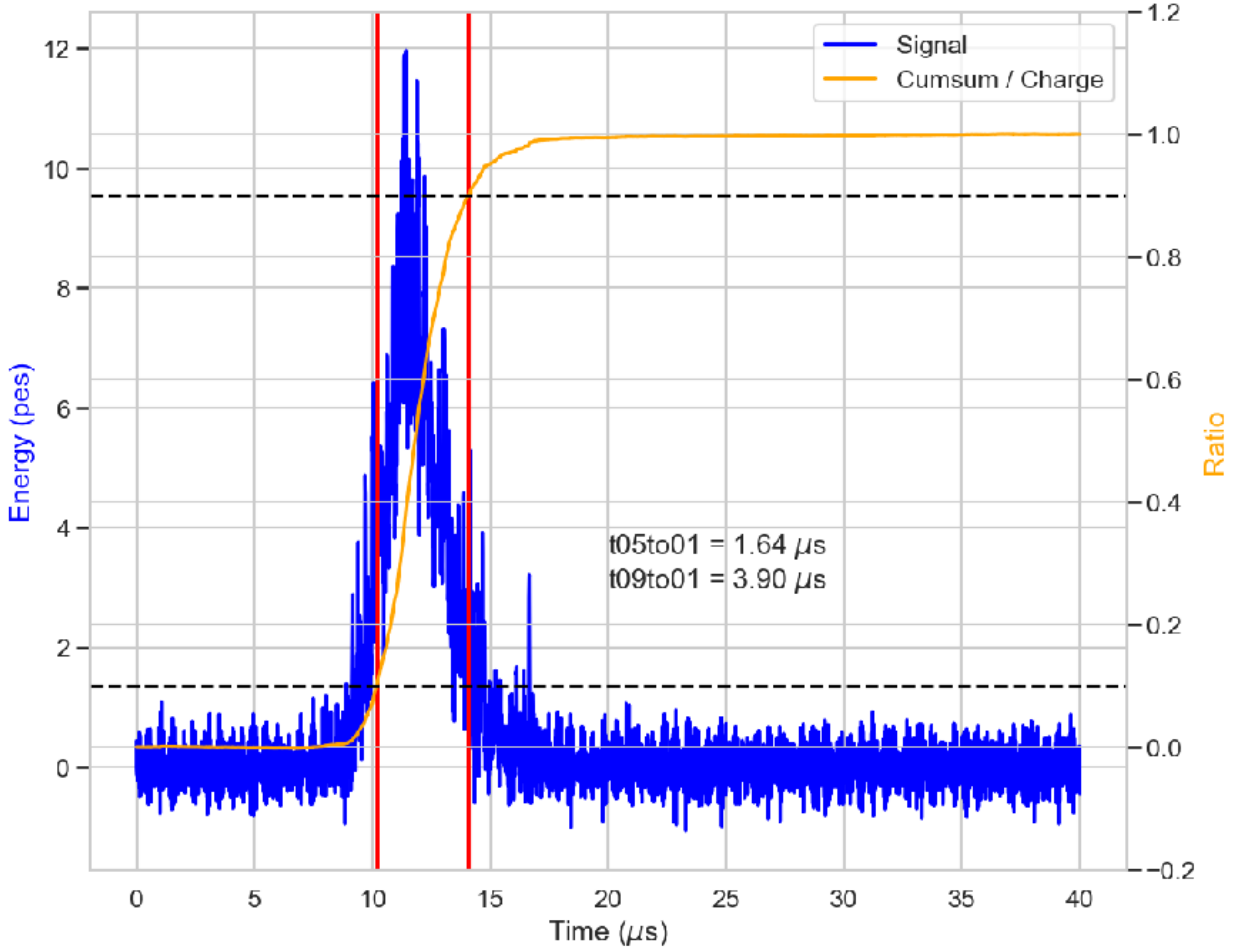
Xenon

Pressure = 8.39 bar
EL field = 1.51 kV/cm/bar
14.9 hours of data taking
1 840 191 events





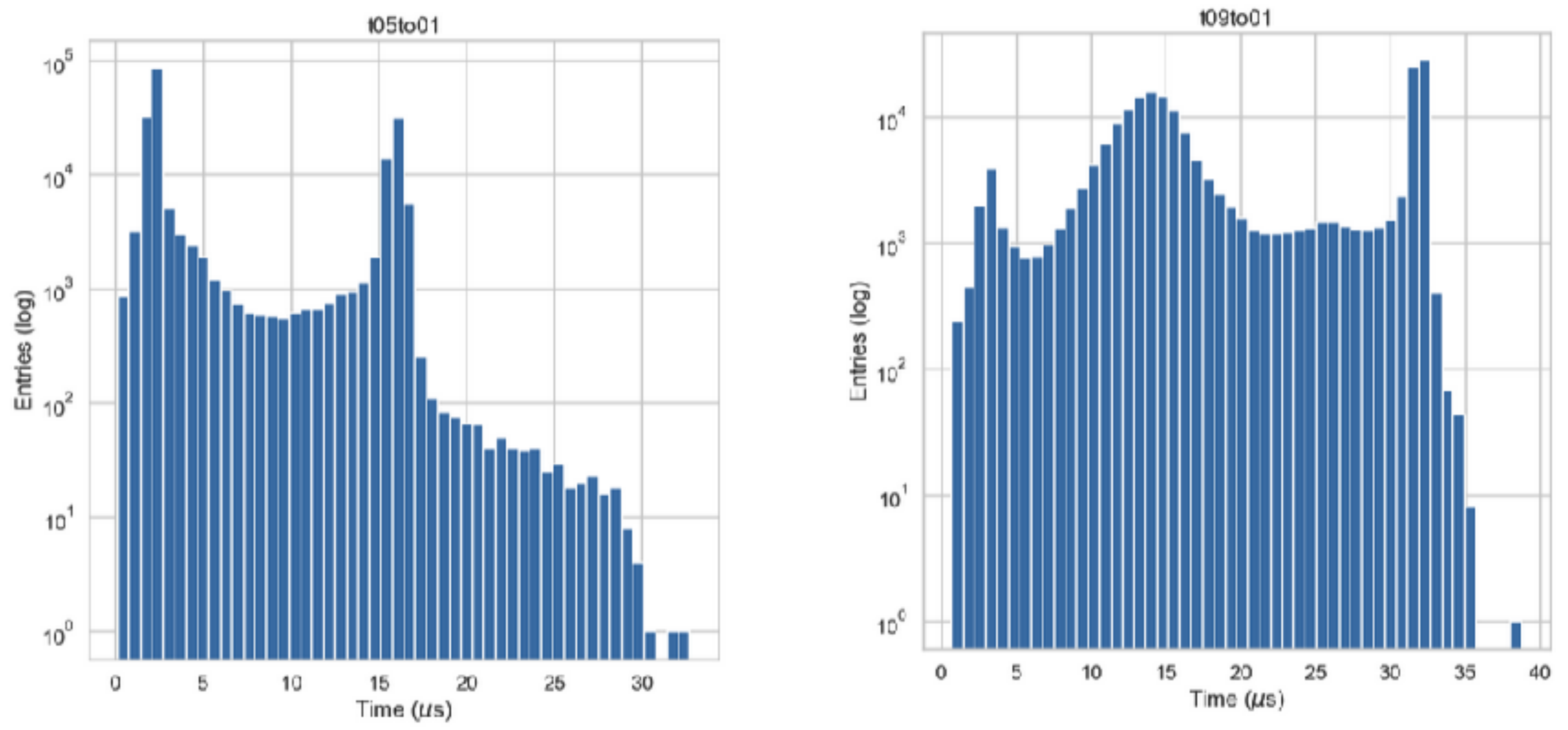
Further signal selection



Exemple of normalized cumulative integrals.

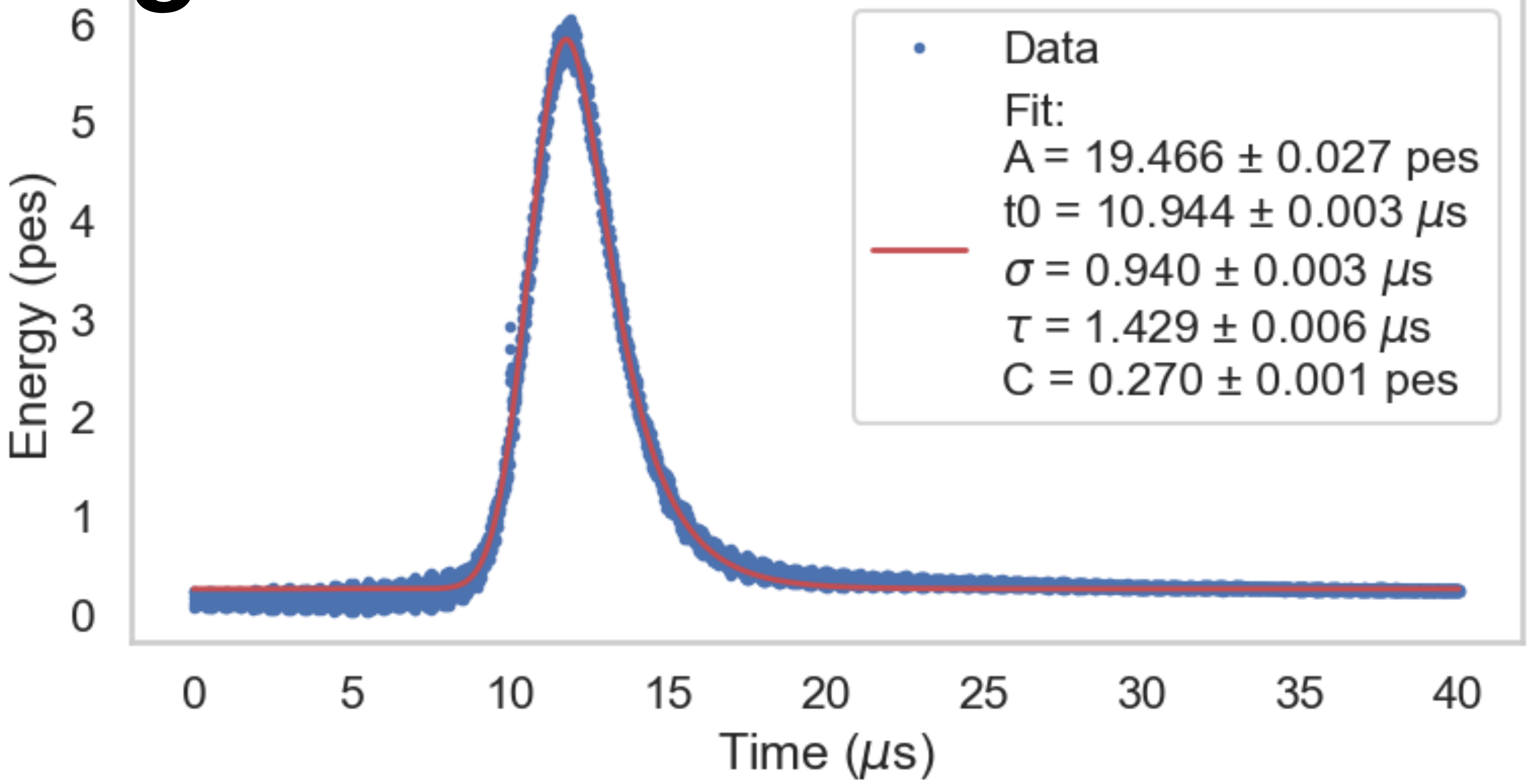
Useful variables to distinguish between S1 and S2 like events:

t05to01 is $t_{0.5}$-$t_{0.1}$
t09to01 is $t_{0.9}$-$t_{0.1}$



Example of distributions of t05to01 and t09to01 for Xe (run 2661).

Argon

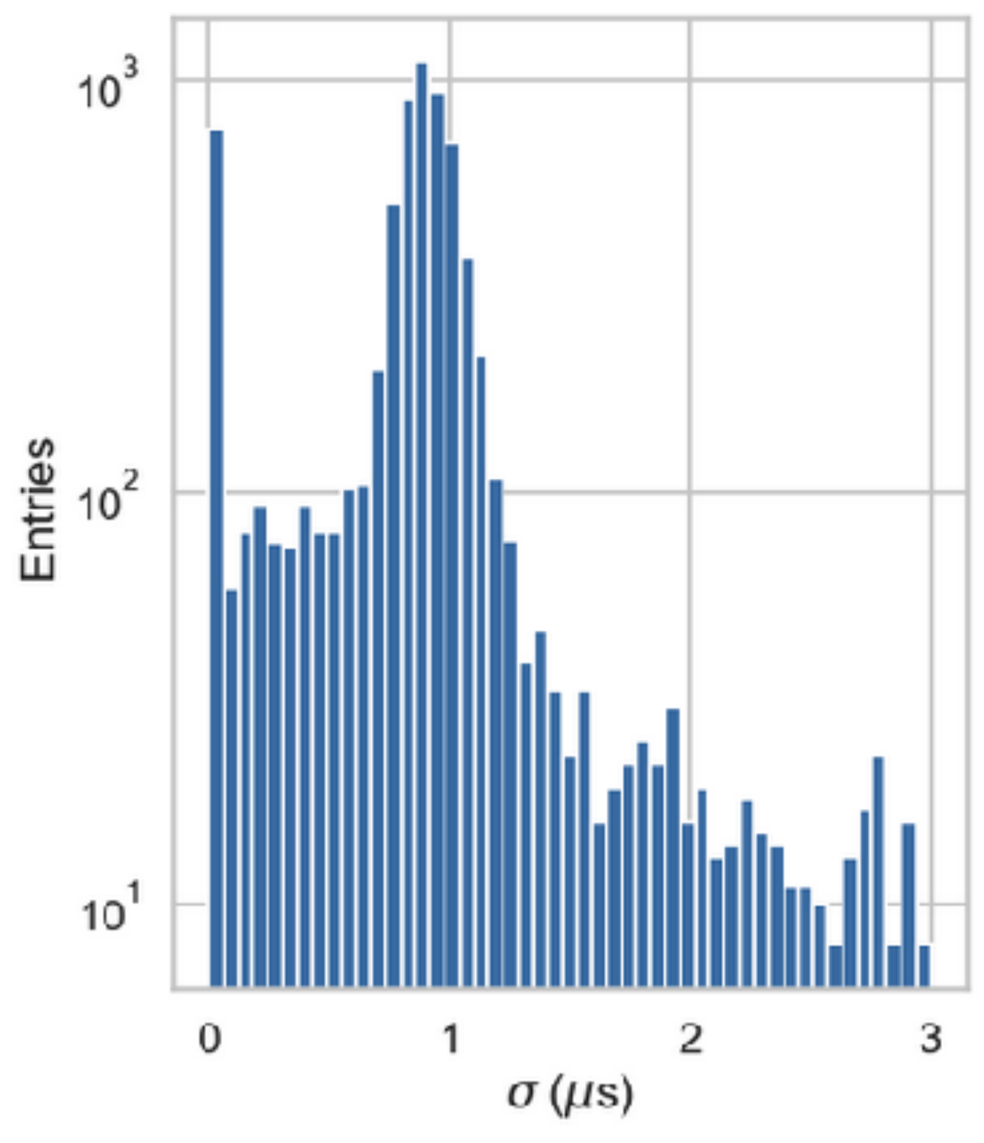


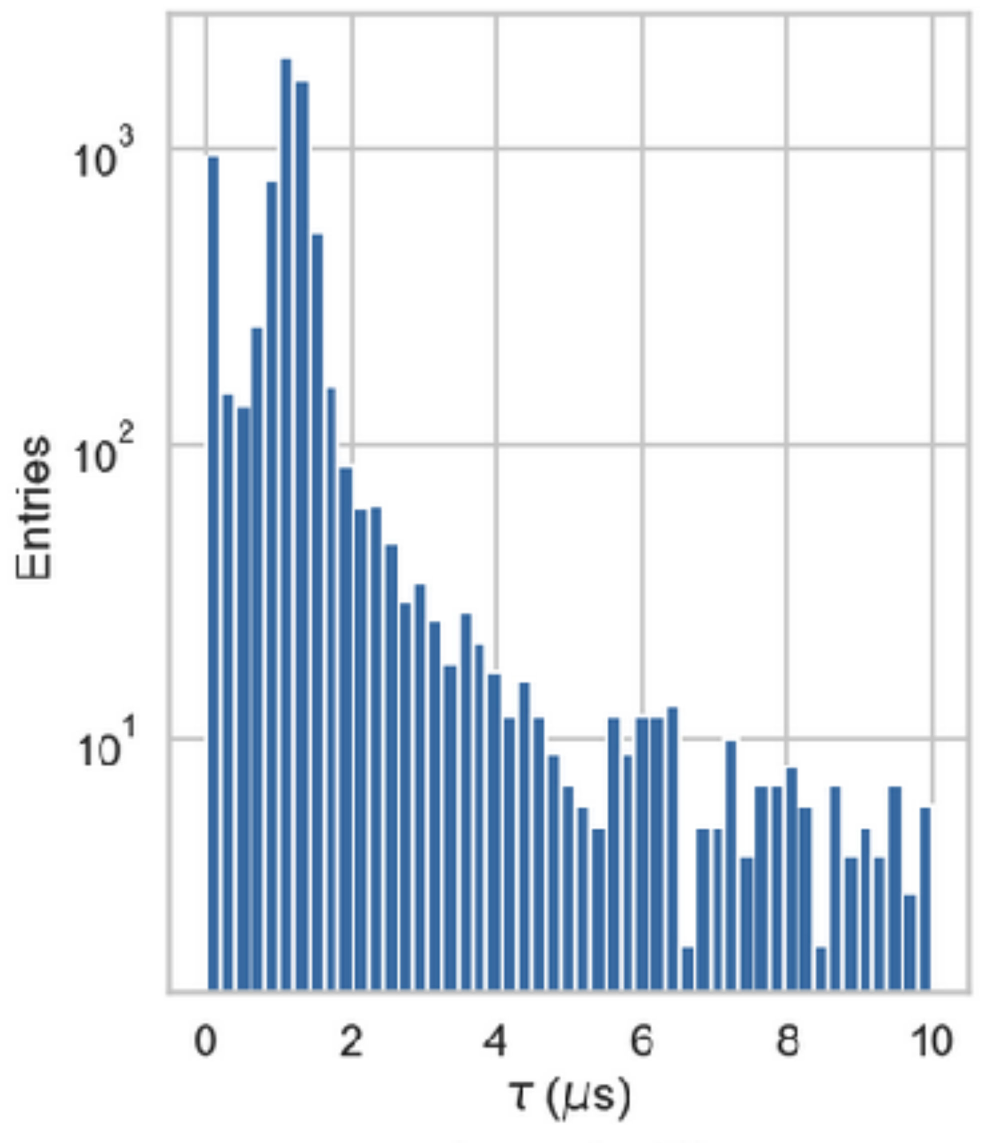
Average WF of the entire sample (no cut).

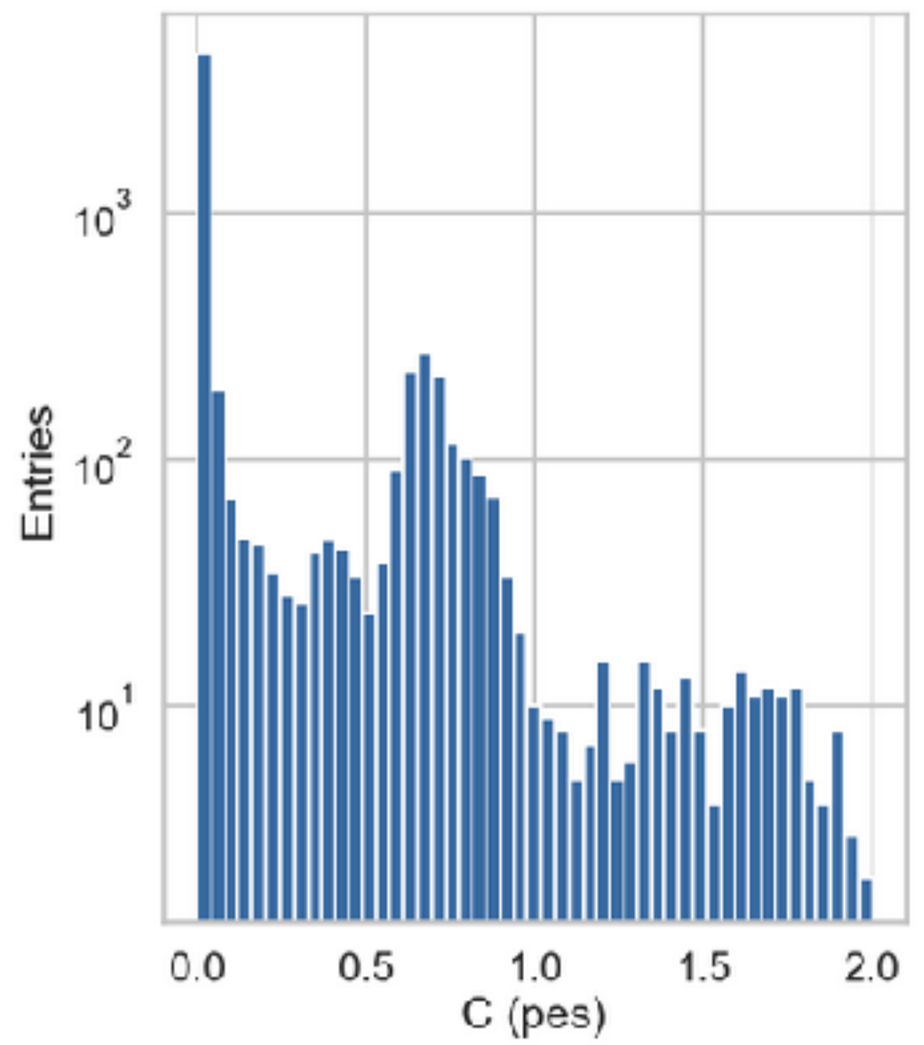
Fitting model:

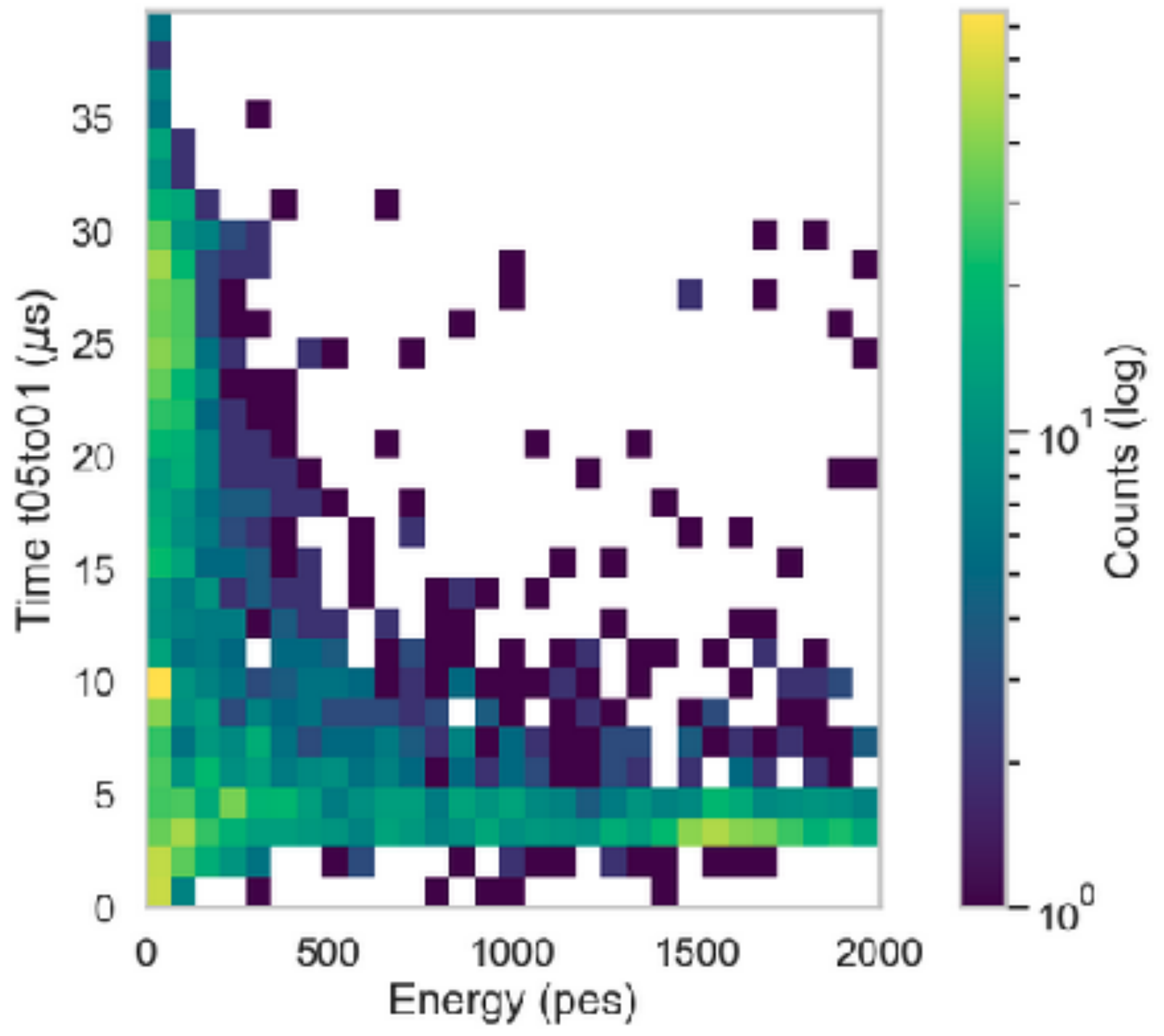
$$f(t) = A\frac{\lambda}{2}e^{\frac{\lambda}{2}(2t_0+\lambda\sigma^2-2t)}erfc(arg) + C$$

$$arg = \frac{t_0 + \lambda\sigma^2 - t}{\sqrt{2}\sigma}$$

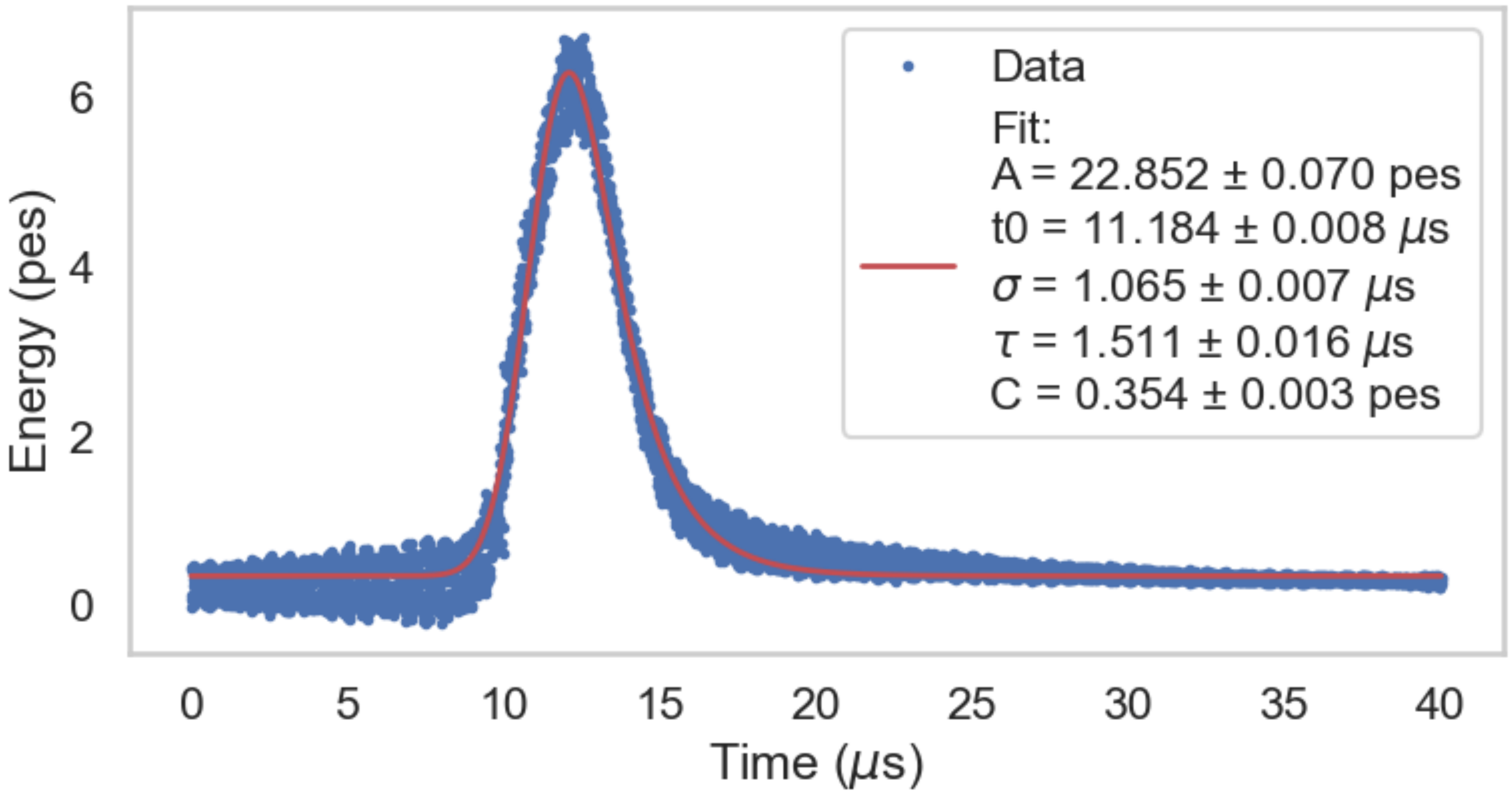




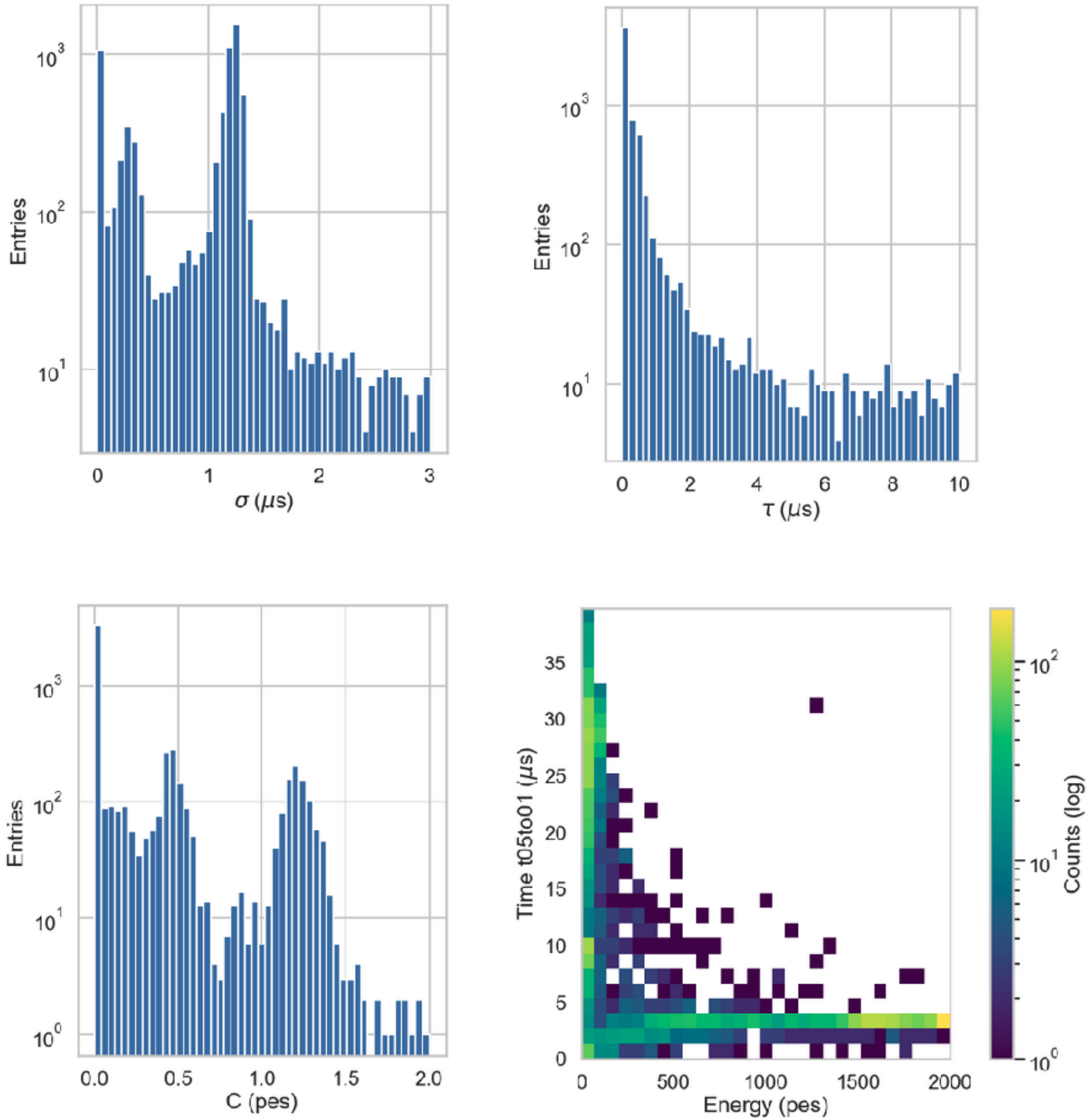




Xenon



Average WF of the entire sample (no cut).



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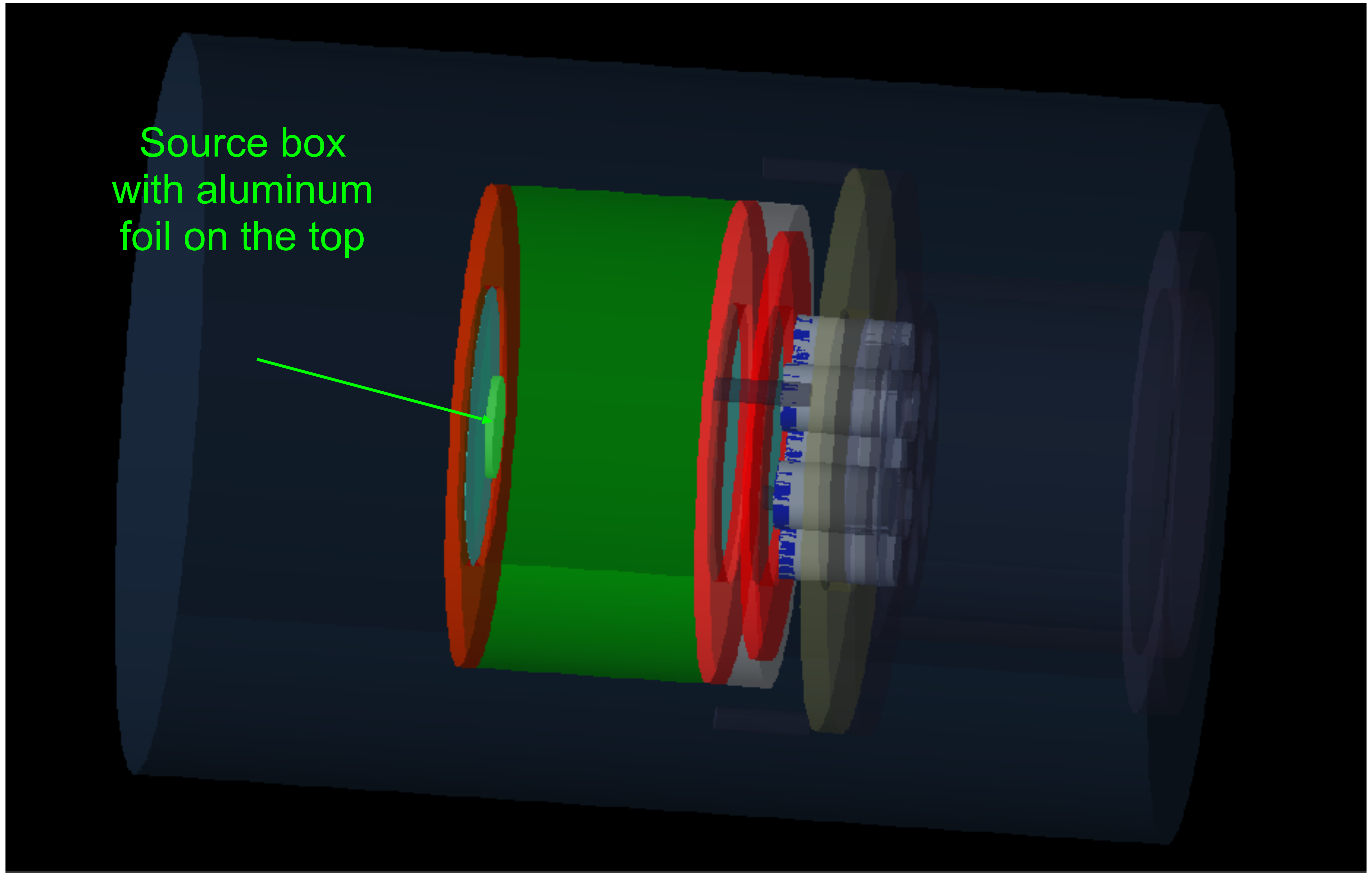
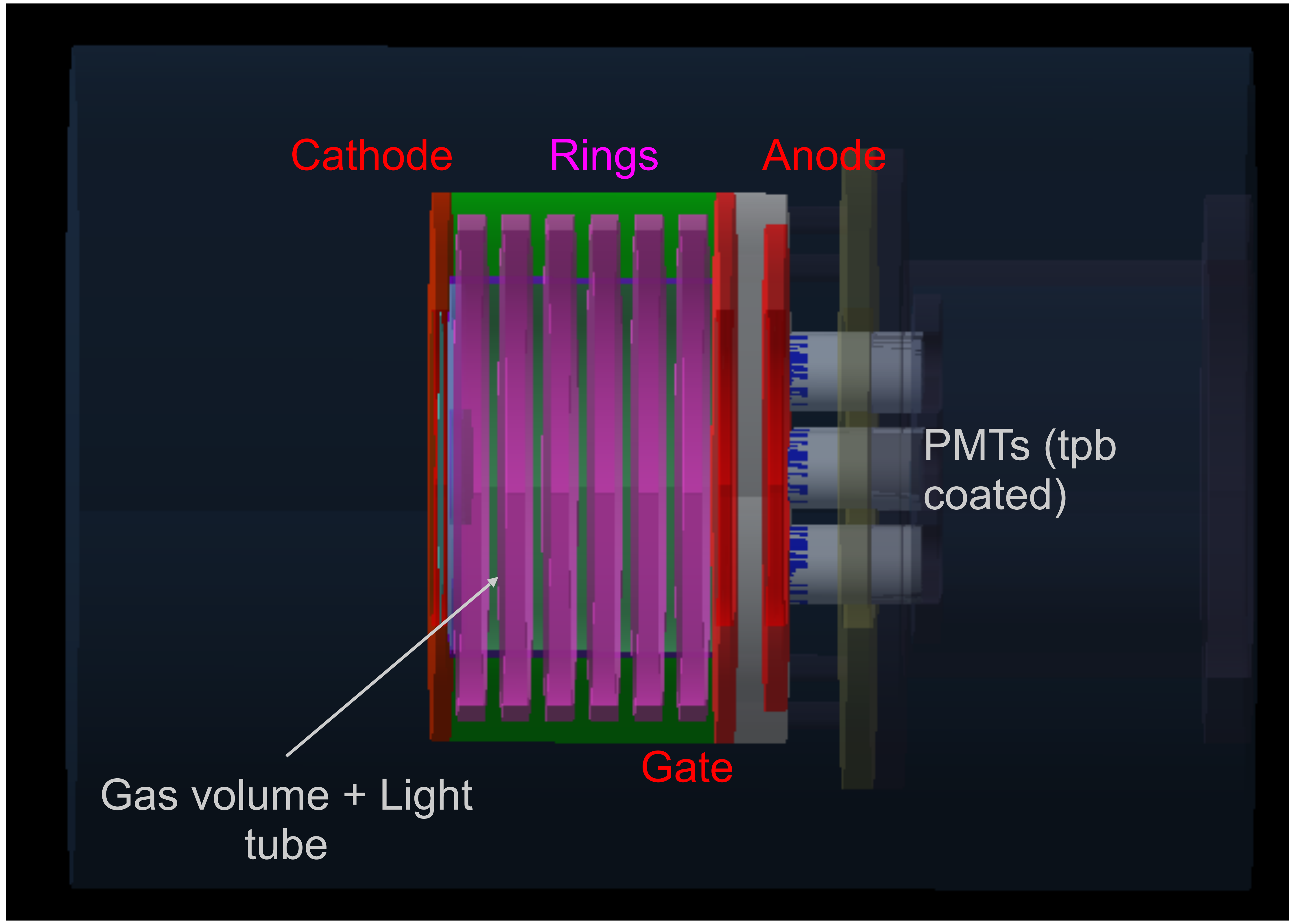
G4 GaP simulation



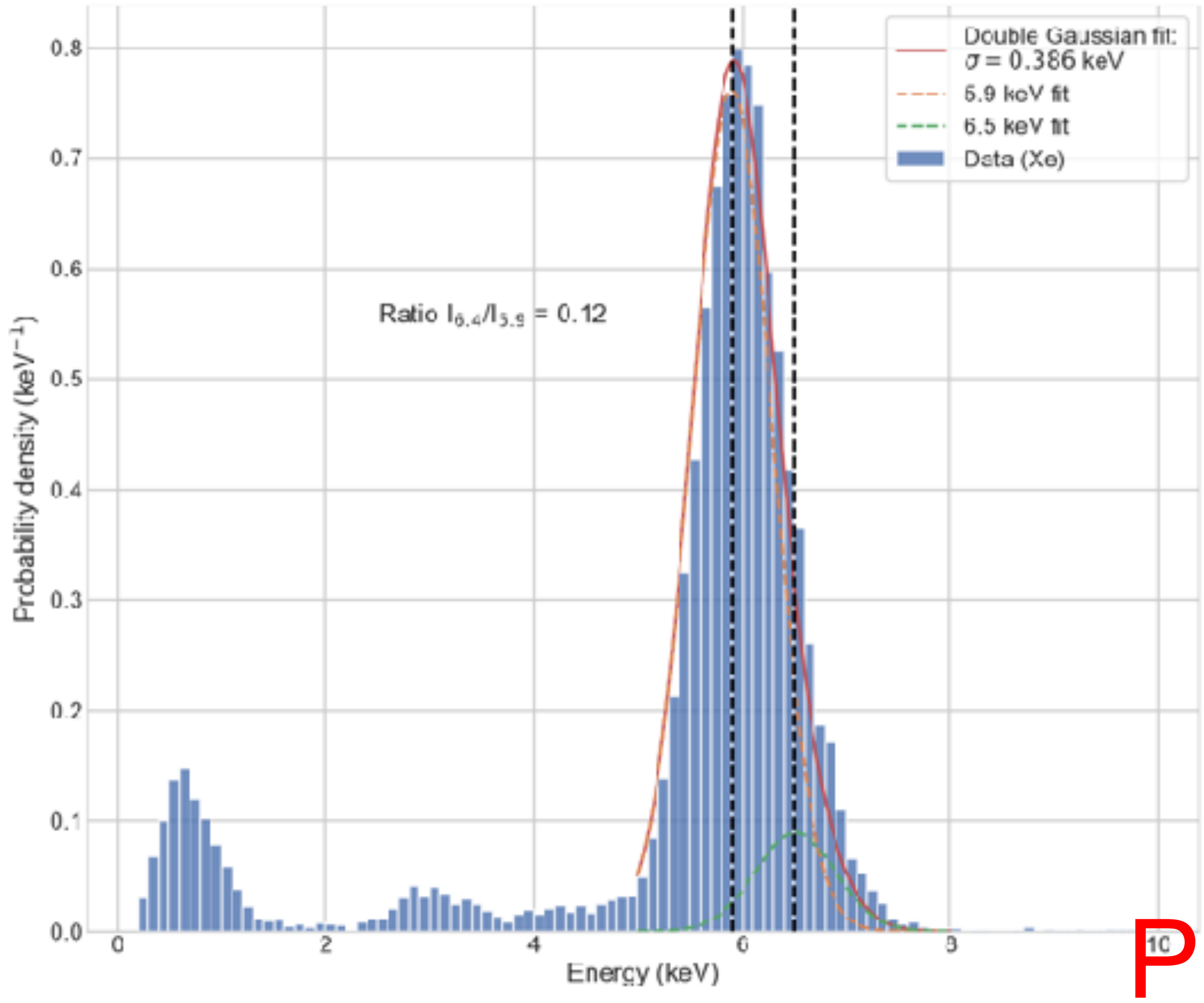


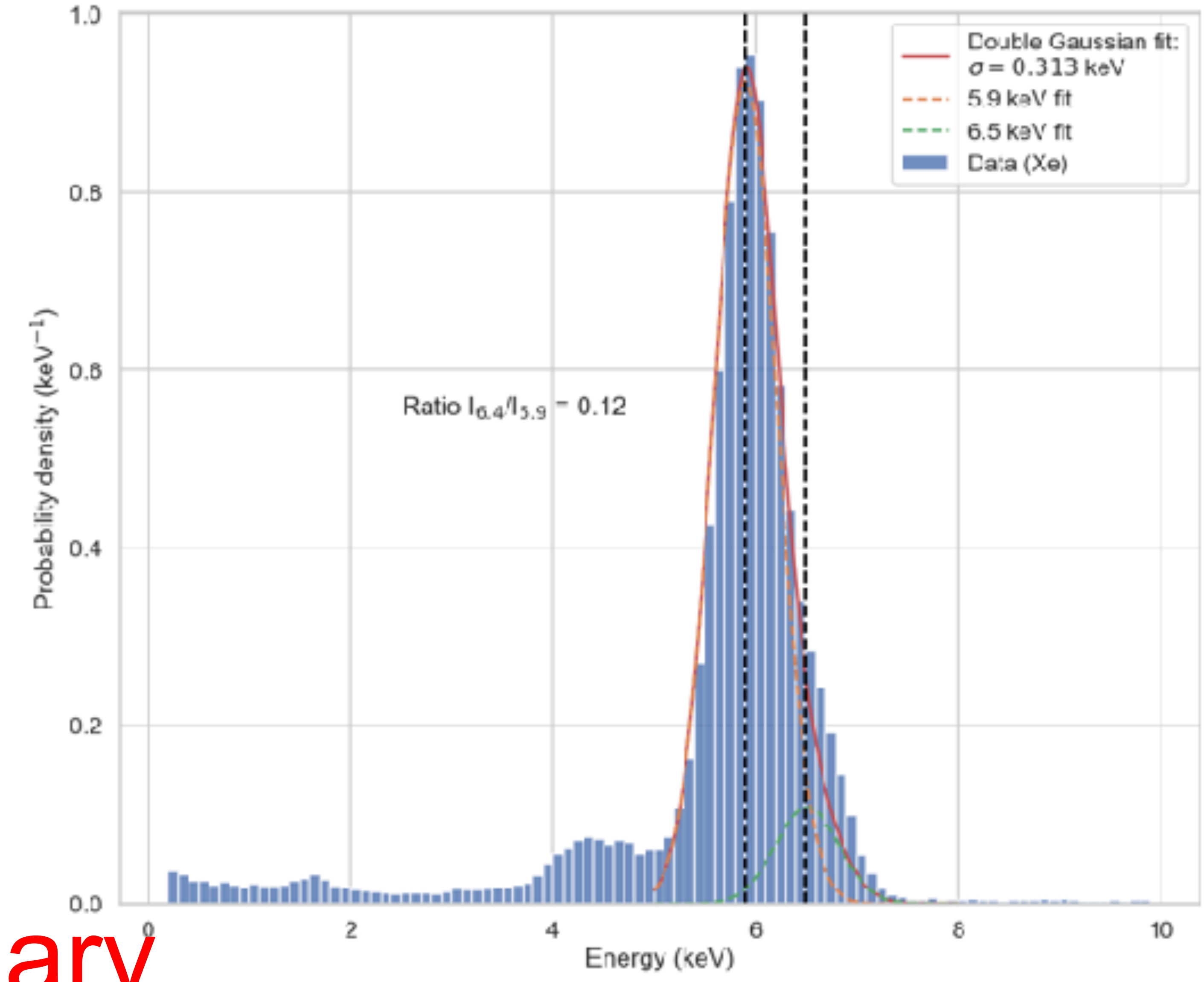
Comparison Data-MC

<u>Smearing:</u>

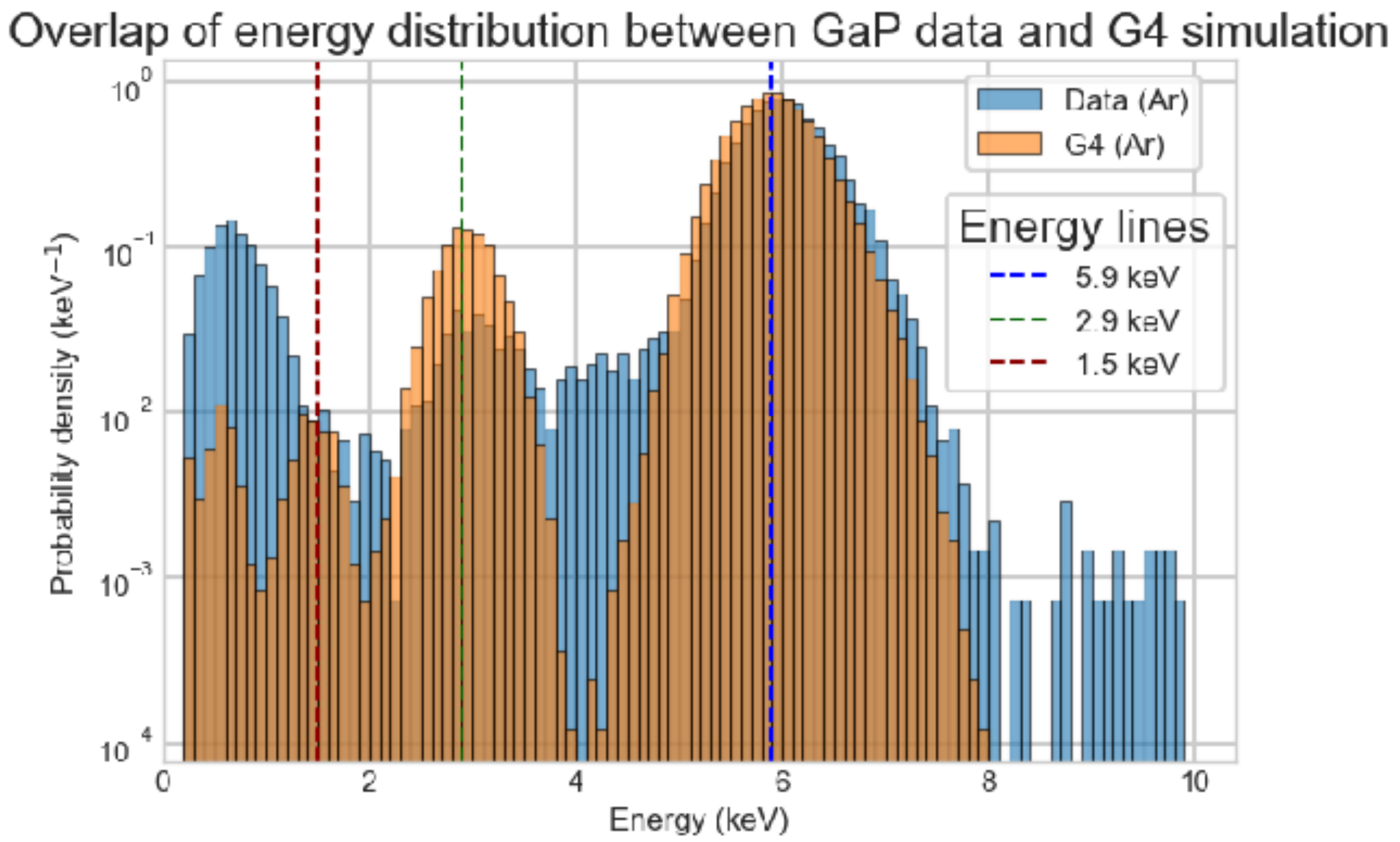
$$\sigma(E) = \sigma_{5.9}(E/5.9)^{1/2}$$

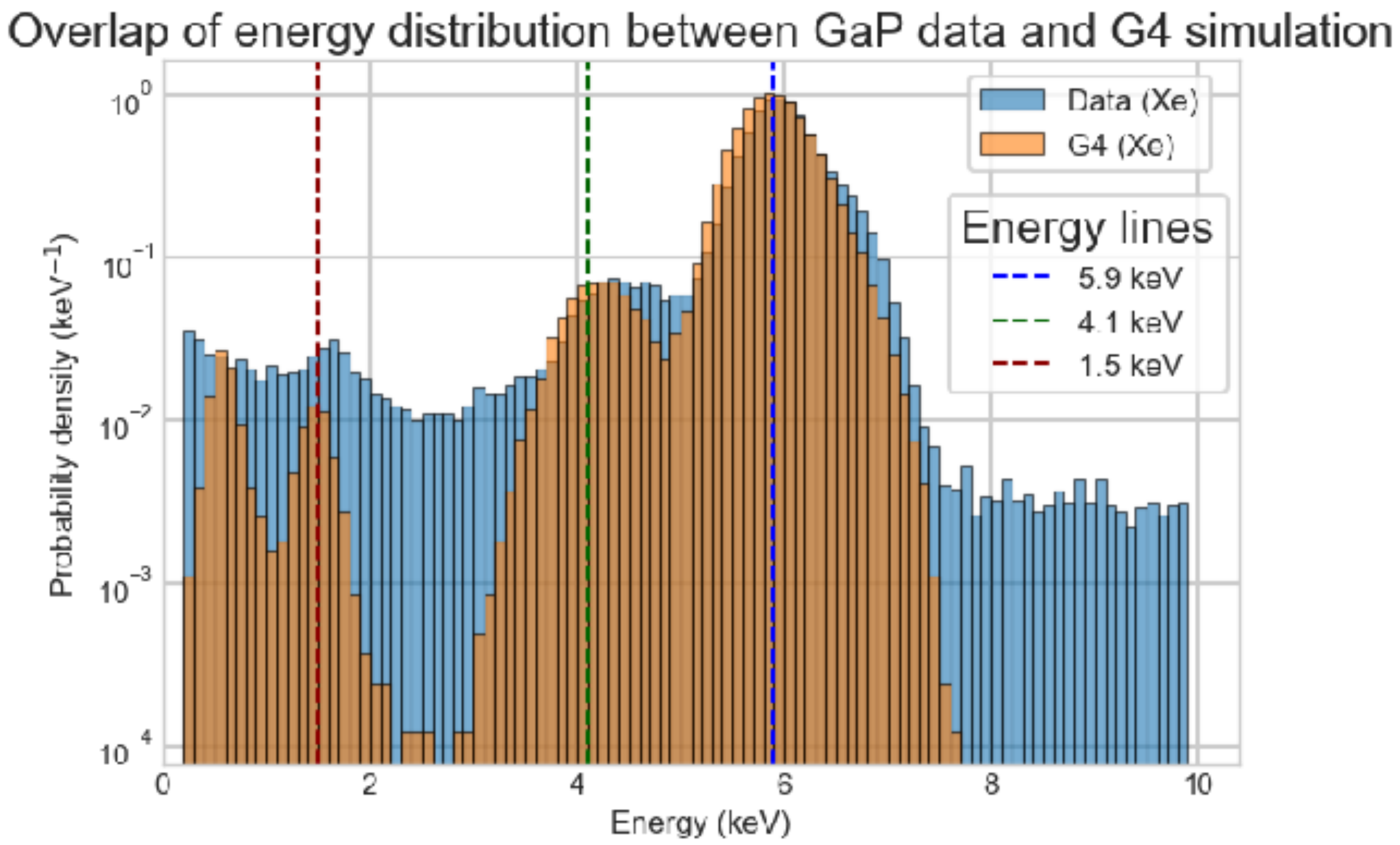
$$E_{smear} = gauss(\mu=E, std=\sigma(E))$$



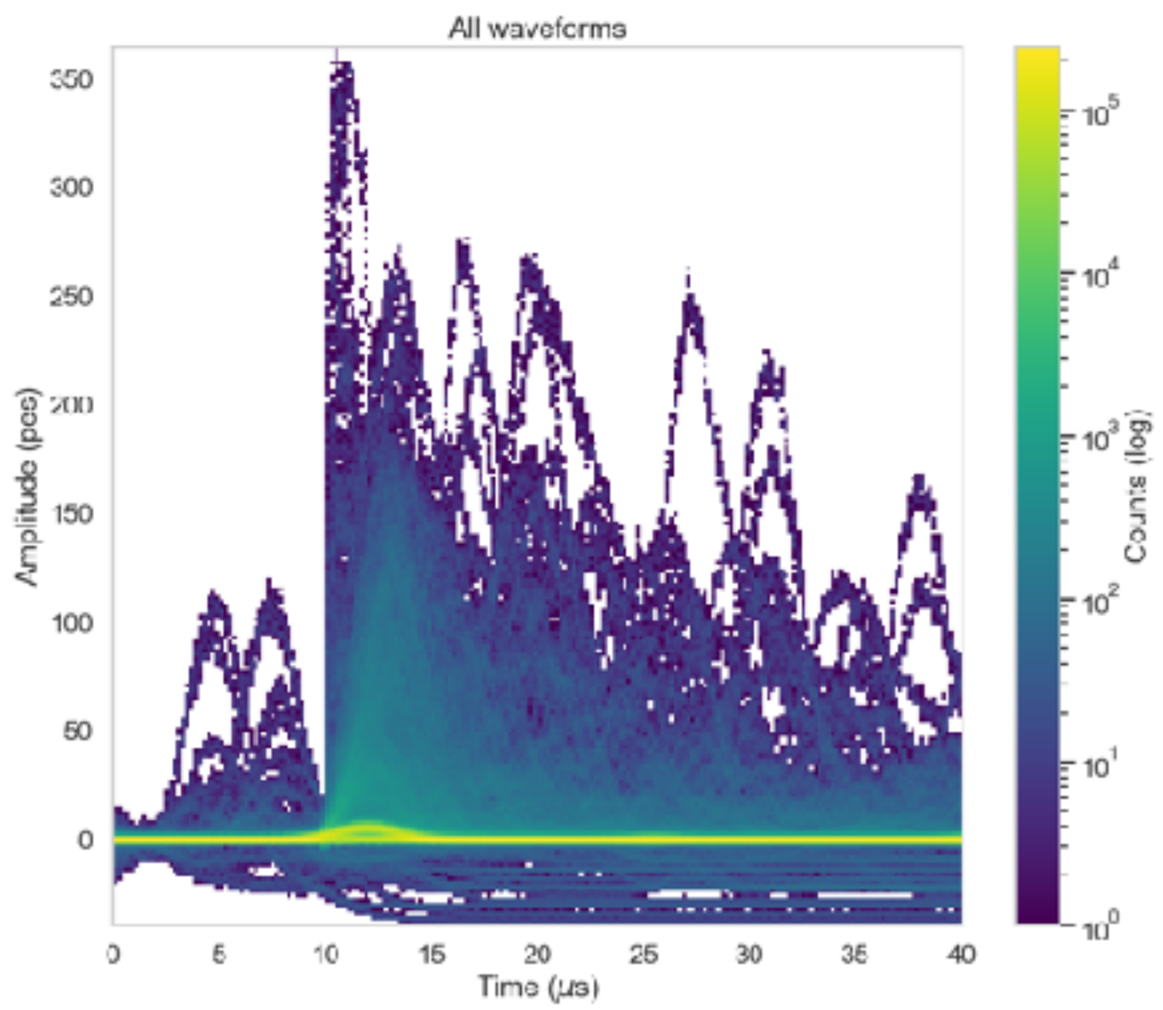


Preliminary

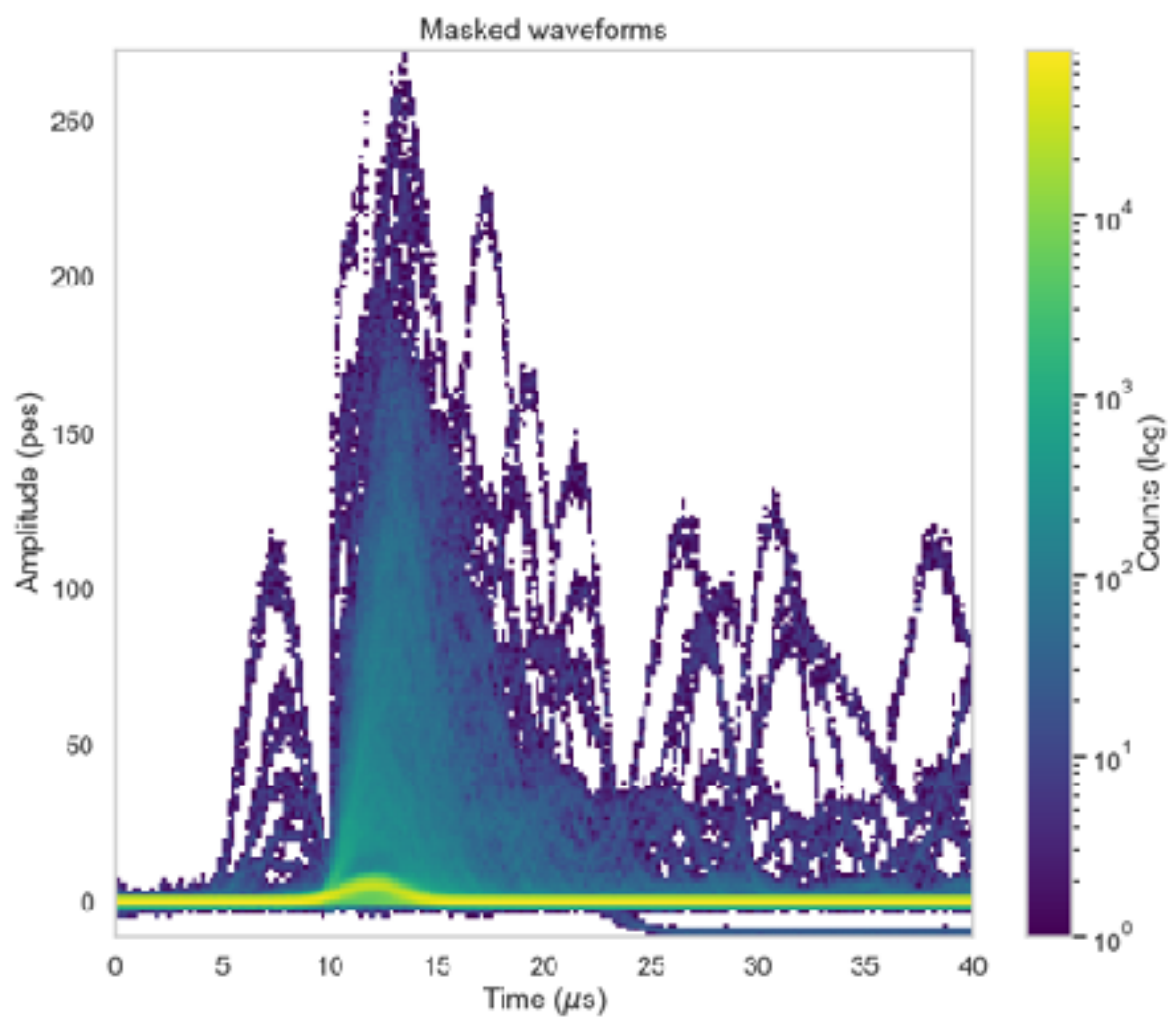




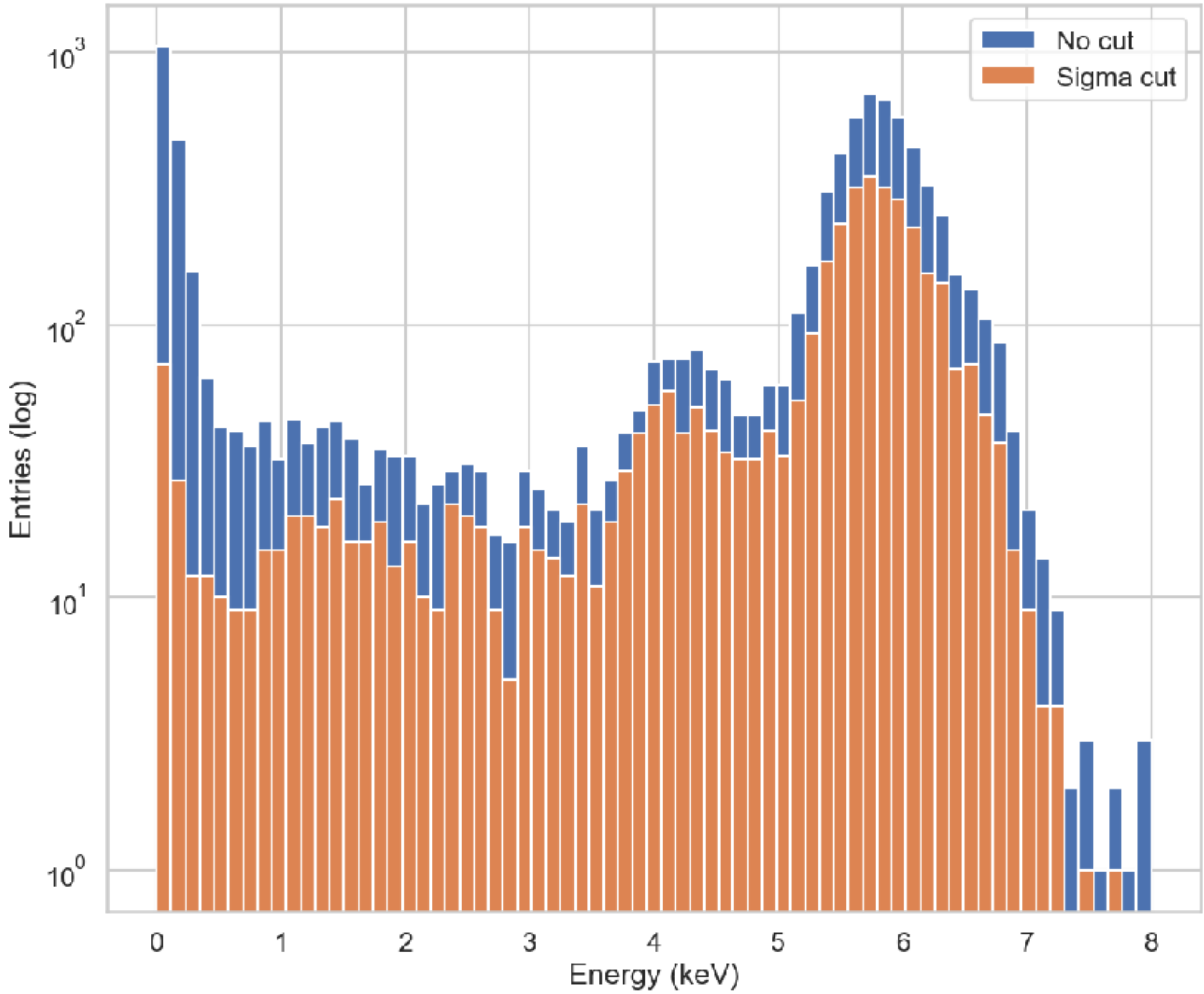
Cuts implementation - xenon



2D histogram of waveforms (no cut).



2D histogram of waveforms (cut on sigma values).



Energy spectrum before and after the cut.

Sigma cut:
By looking at the sigma distribution: we assume the 1st peak to be S1 and the 2nd to be S2. We take +/- 3sigma around the mean of the 2nd peak for the cut (here [0.88, 1.57])

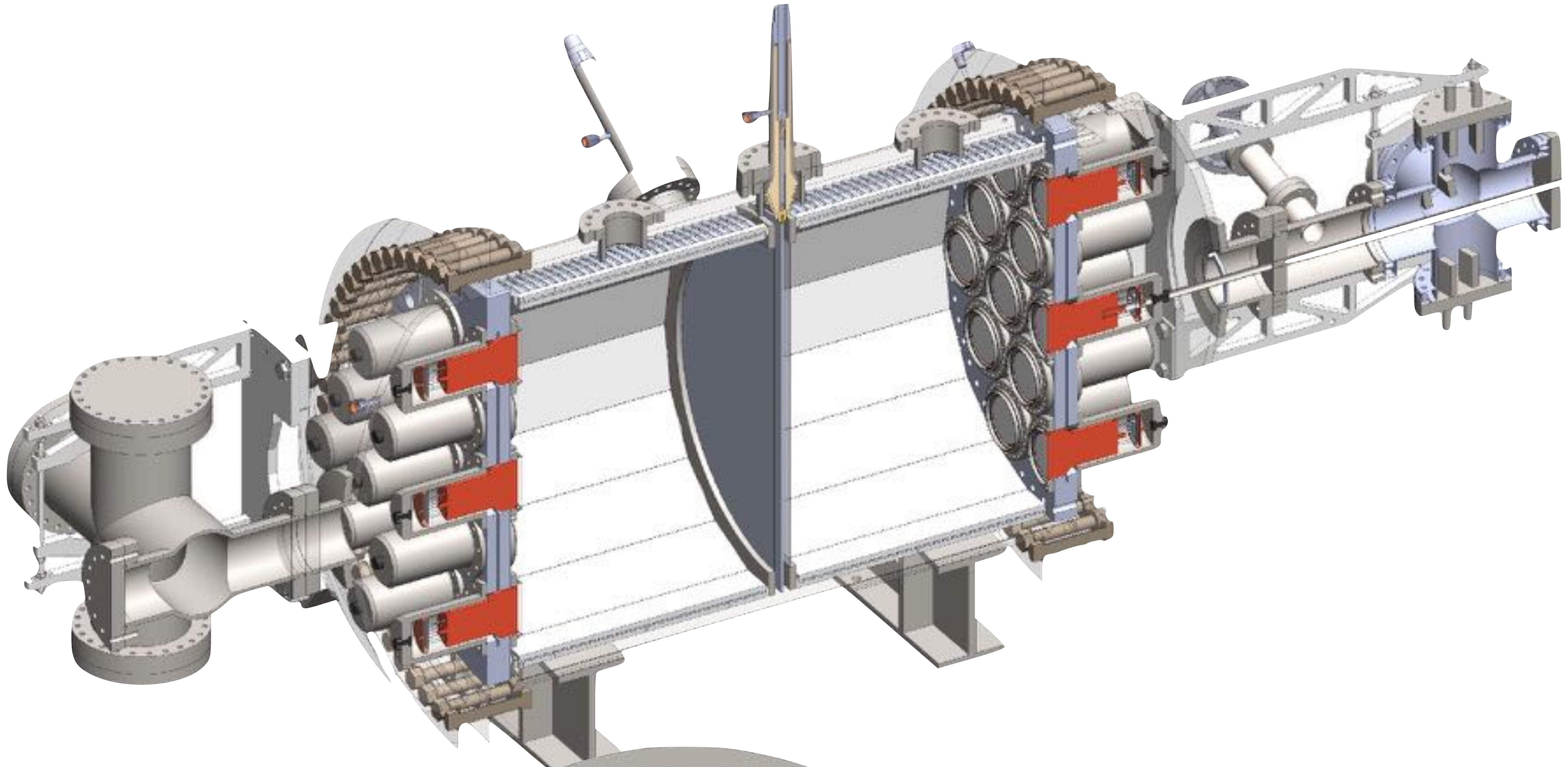
Summary

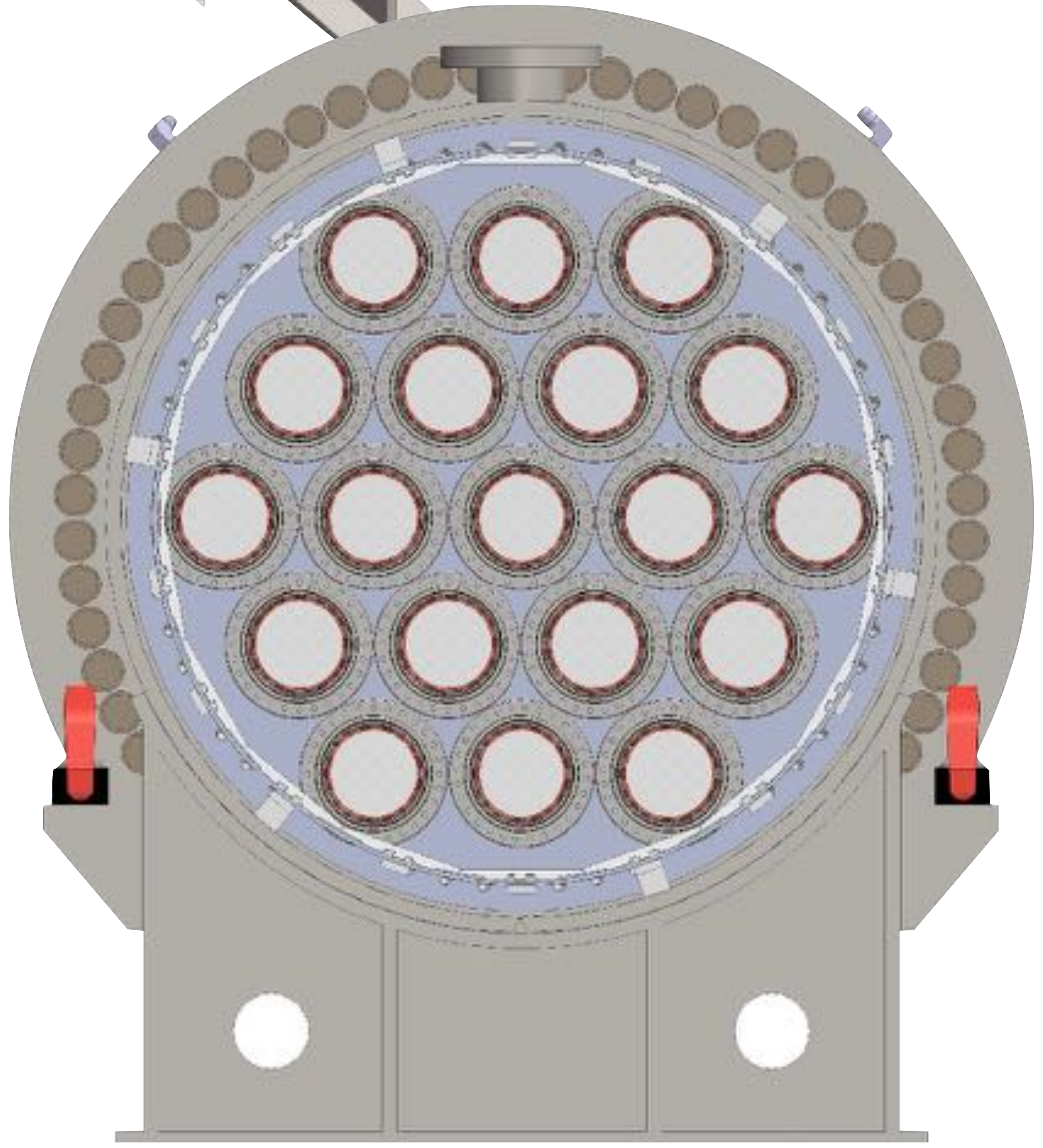
- The selection S1/S2 seems to improve results for xenon, we can still improve it with other variables
- We need to continue to clean the waveforms (notably with the t05to01 variable) and check the waveform characteristic parameters
- Do the same for Argon runs
- Overlap everything with the G4 simulation

From GaP to GanESS

NEXT-NEW

GanESS

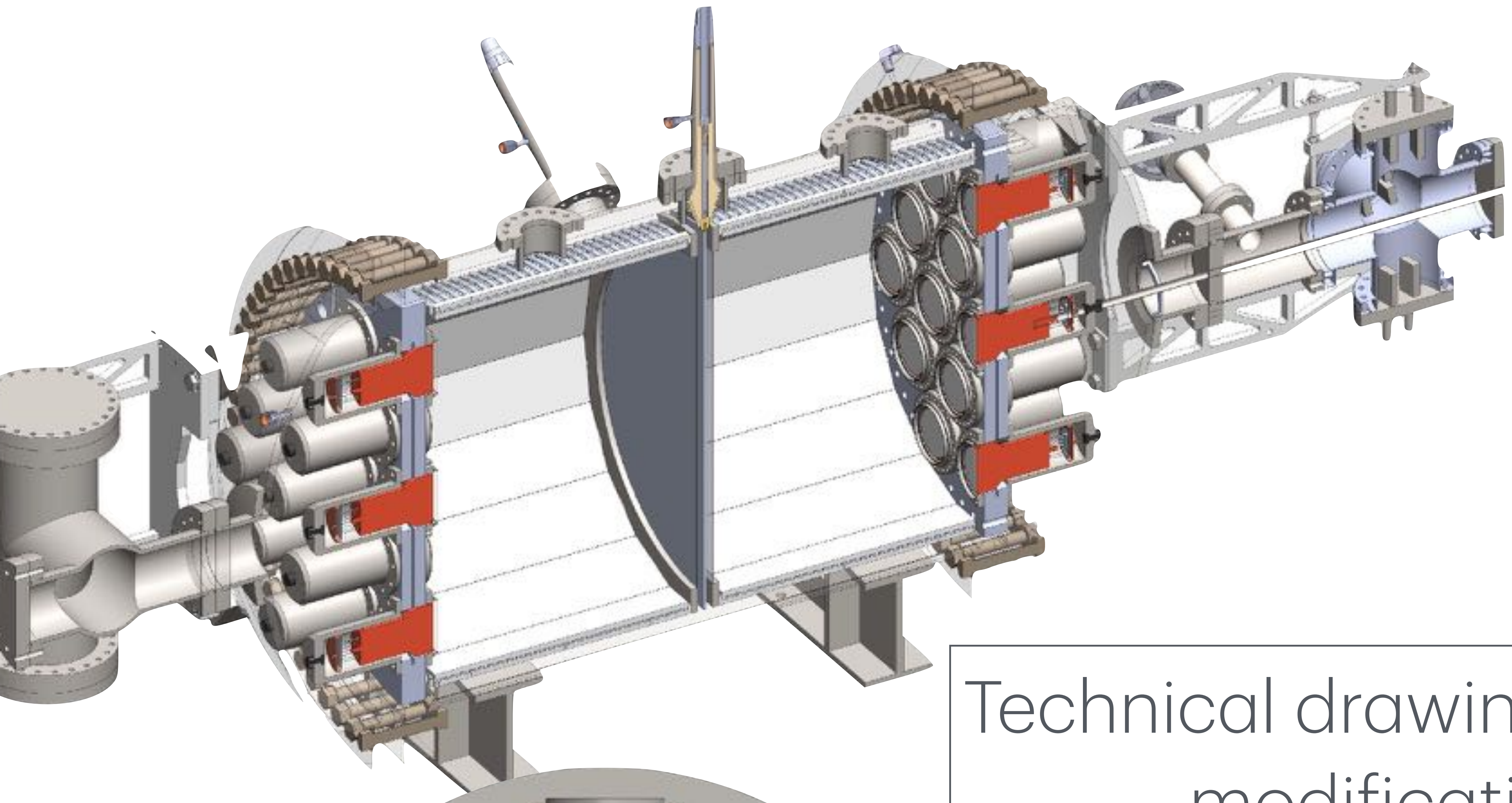


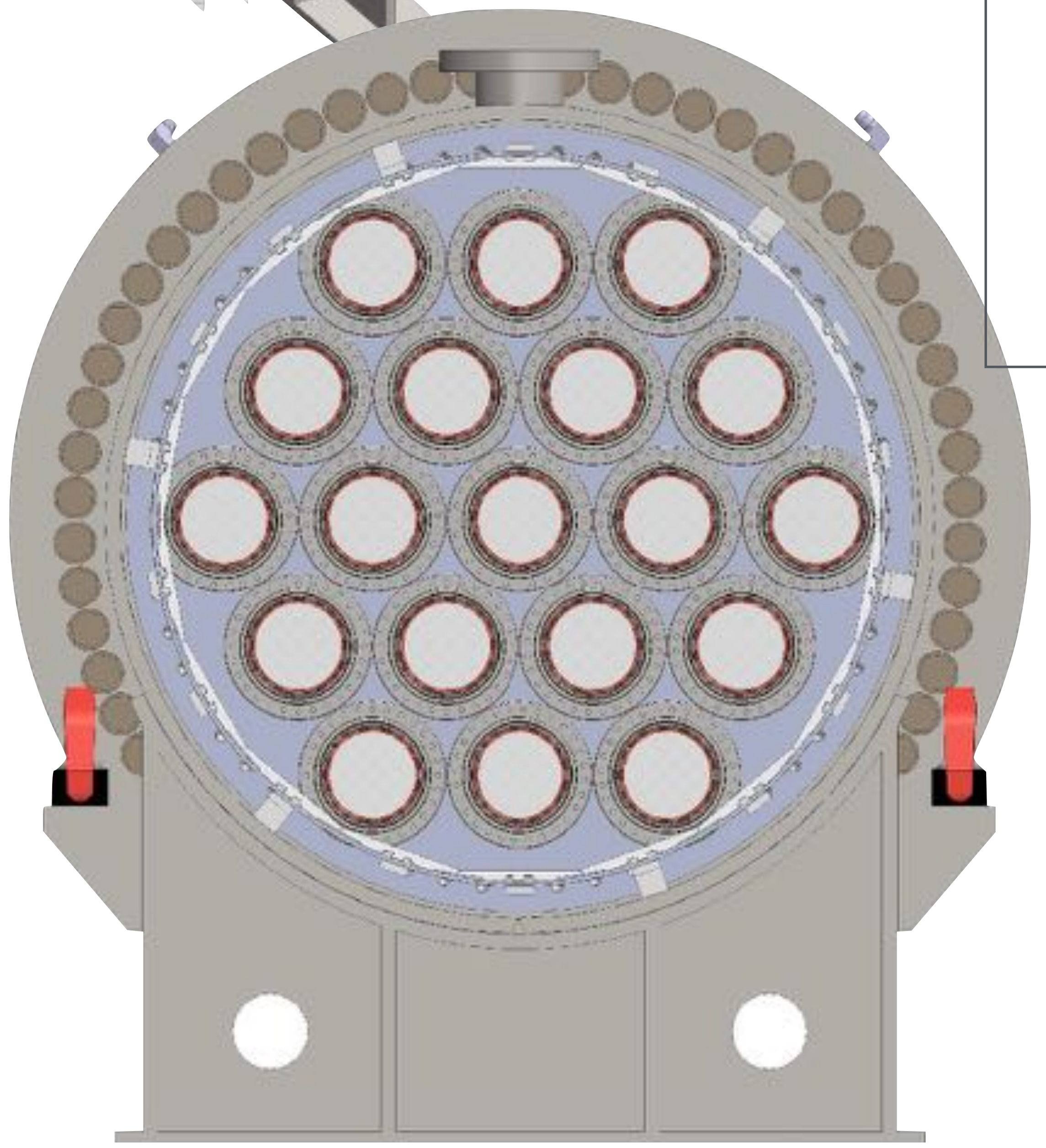


Working on the design, it will need to be updated using MC and information of the R&D phase.

We need to optimise PMT coverage and light collection. Considering the use of fibers as we are doing for NEXT-HD.

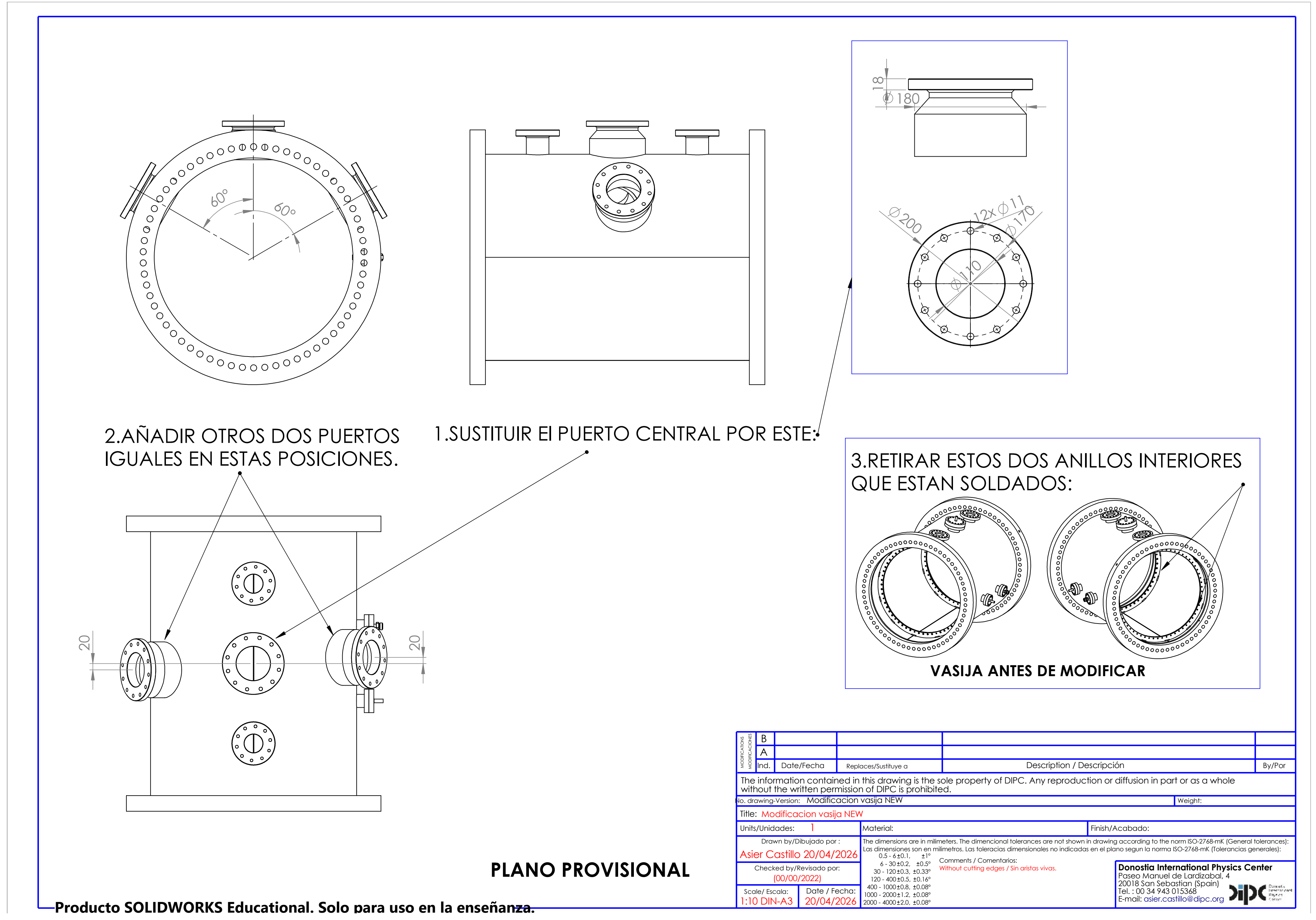
GanESS

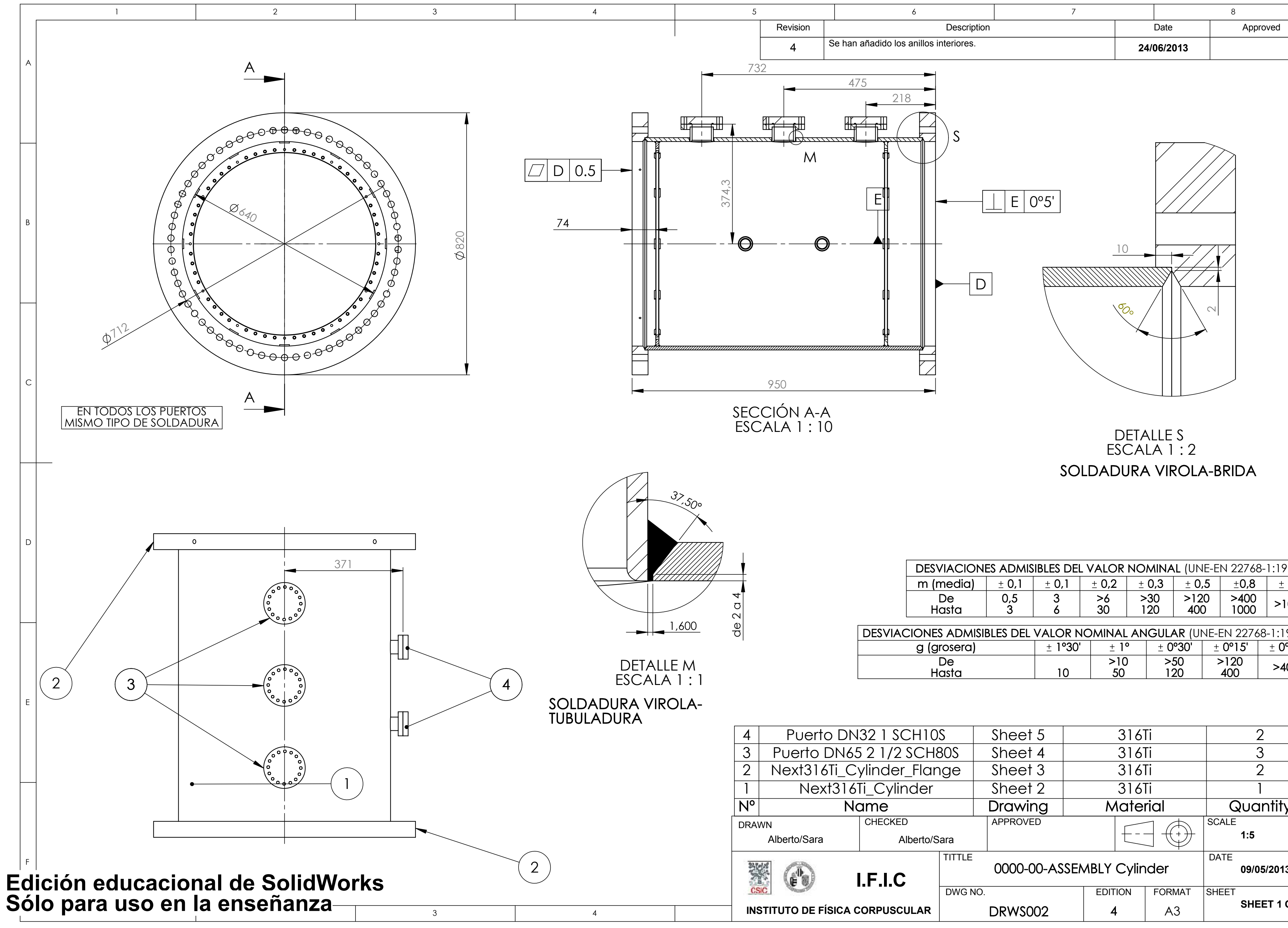




Technical drawings for the vessel modification ready.

Start contacting companies



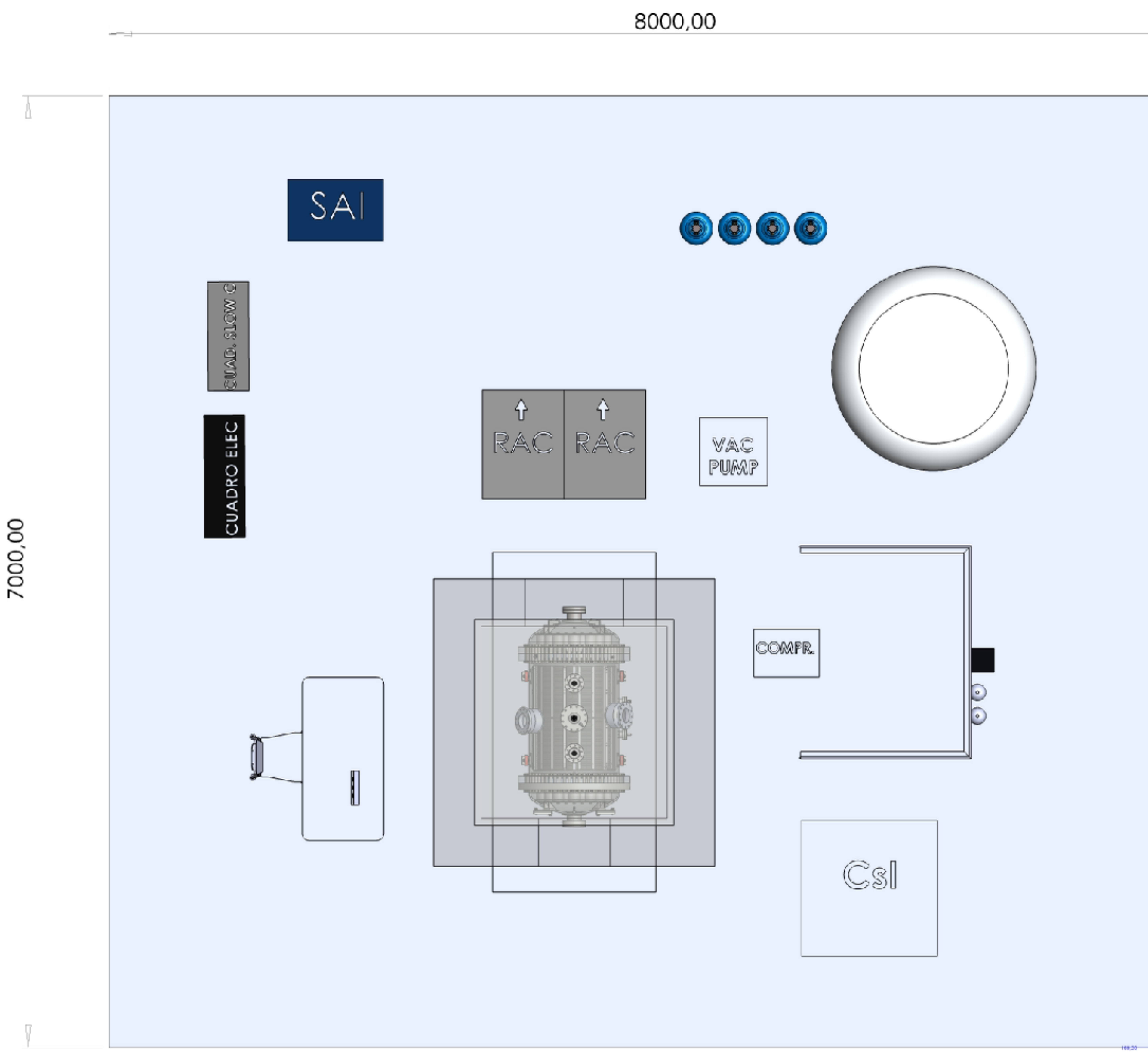


NuESS@ESS

NuESS space

nuESS requires an area of ~56 m².

- The space has been requested to allow the operation of more than one experiment at the same time.
- It includes detectors and operating systems with space to move around the detector, installation,…

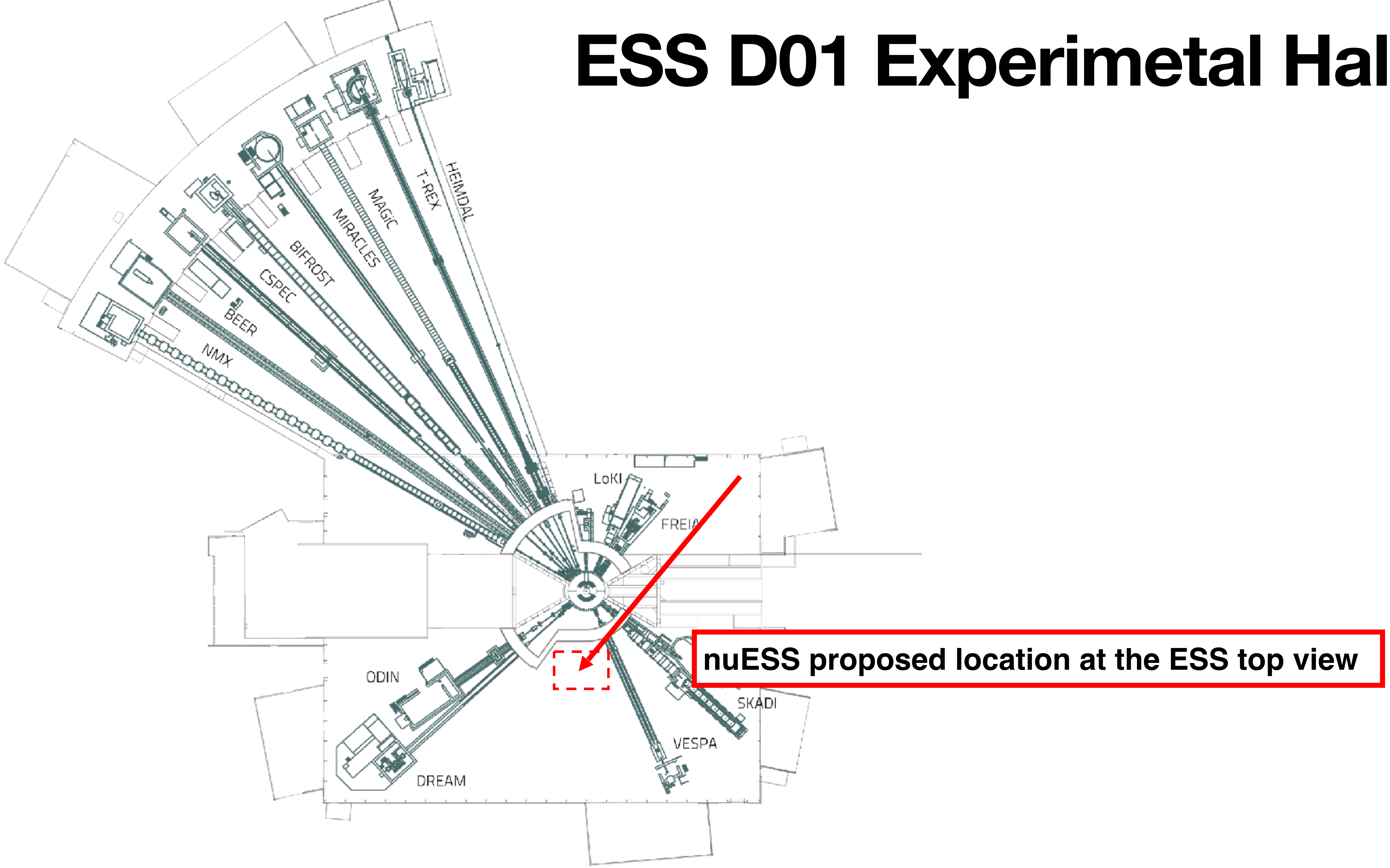


ESS D01 Experimental Hall

nuESS requires an area of ~56 m².

- Proposed location currently available.
- No instruments installed at present. Future instruments be constructed in this area, nuESS will relocate accordingly.
- Construction of new instruments will not happen in the next few years

ESS D01 Experimetal Hall



Change Request

- The formal allocation of the space to the project requires the submission and approval of a Change Request by ESS.
- We are working with Valentina Santoro to prepare this document.

CHANGE REQUEST - FORM FOR ESS CCB

CHANGE DATA			
CR ID		**Date created**	
Title of the CR	Allocation of Experimental Space and Infrastructure for the vESS Project		
Name of Change Leader (Project Manager)		**Change originator**	
Change class Approving entity	☐ Class A, European Spallation Source ERIC Council	☒ Class B, CCB	

CHANGE SUMMARY		**Baseline**	
Reason for change	This Change Request concerns the allocation of approximately 56 m² of experimental space in proximity to the ESS target, together with the required electrical power and infrastructure, to support the vESS (neutrino ESS) project. The vESS experiment aims to measure coherent neutrino–nucleus scattering using a set of complementary detector technologies, requiring a controlled neutron environment and dedicated laboratory conditions. The proposed setup includes detector vessels, gas handling systems, electronics racks, and associated services, with an estimated total electrical demand of approximately 50 kW. The requested location is currently available and not occupied by installed instruments. The allocation is compatible with future facility developments, as the vESS setup can be relocated if required by subsequent installations.		

What we need from the ESS

- Approval from the STAP.
- Contact with some ESS personeel for details of the possible installation sites

From past STAP meeting

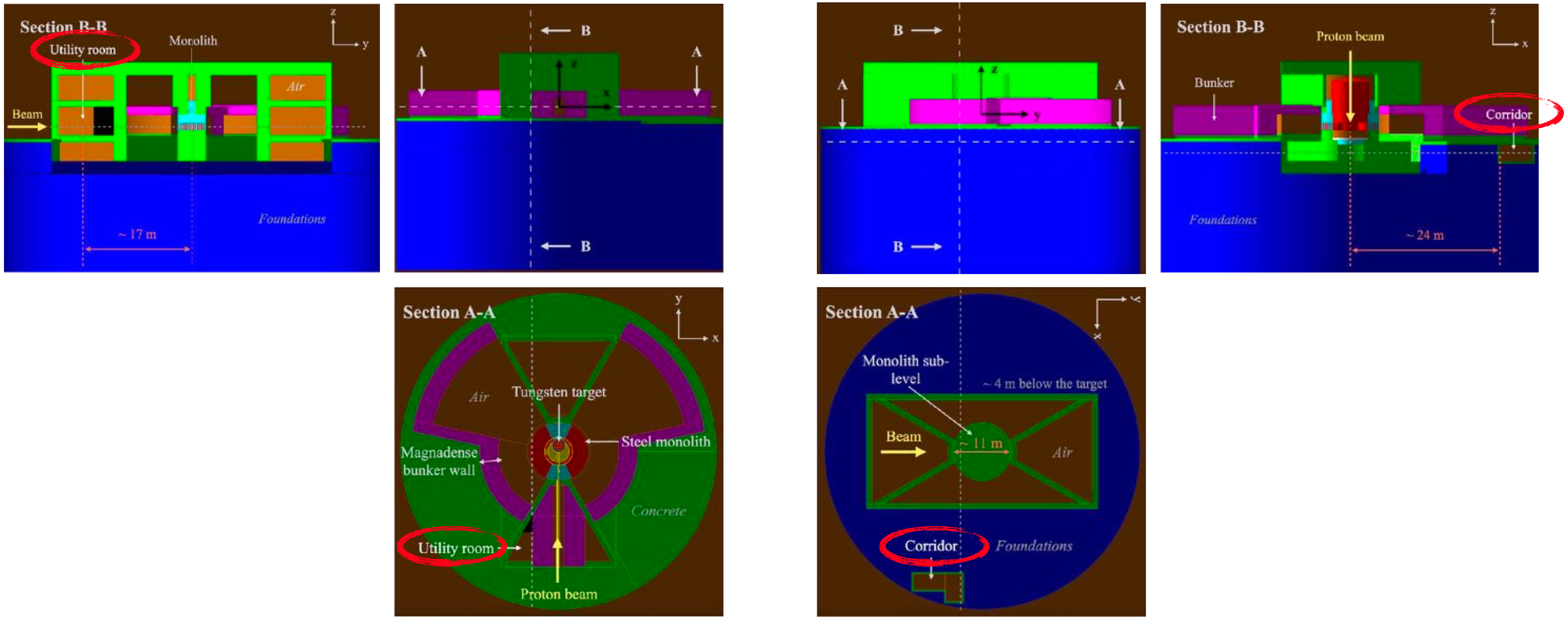
- **Acc**
  - Neutron camera ready to go.
  - Results could be shared with the ESS for an improved characterization of the neutron fluxes in the facility.

What we need from the ESS

- Approval from the STAP. ✓
- Contact with some ESS personeel for details of the possible installation sites, evaluation of spaces. ✓
- **Access for background measurements** on the different areas.
  - Neutron camera ready to go.
  - Results could be shared with the ESS for an improved characterization of the neutron fluxes in the facility.

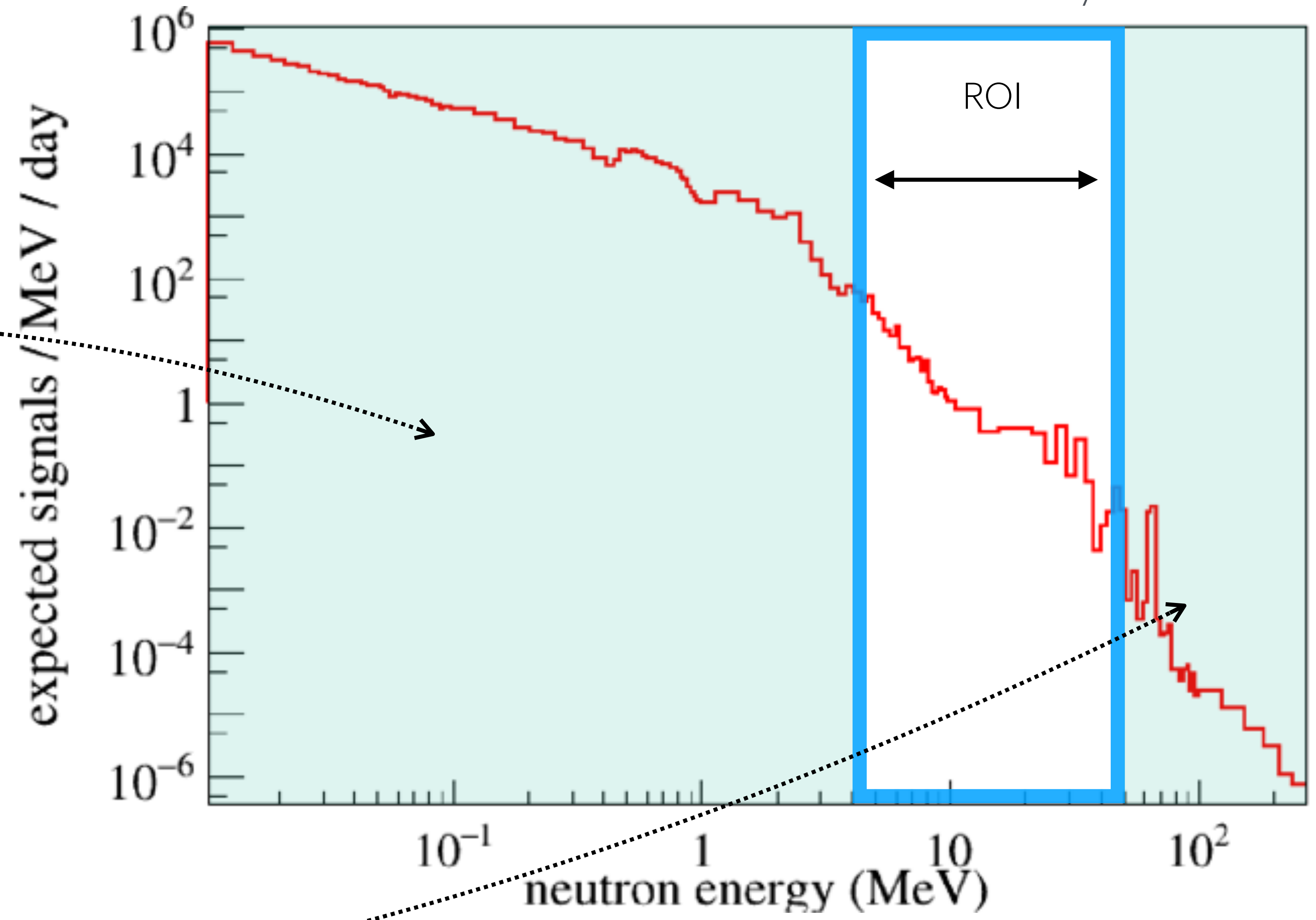
Background simulations

Being adapted to the proposed area.



Neutron Camera

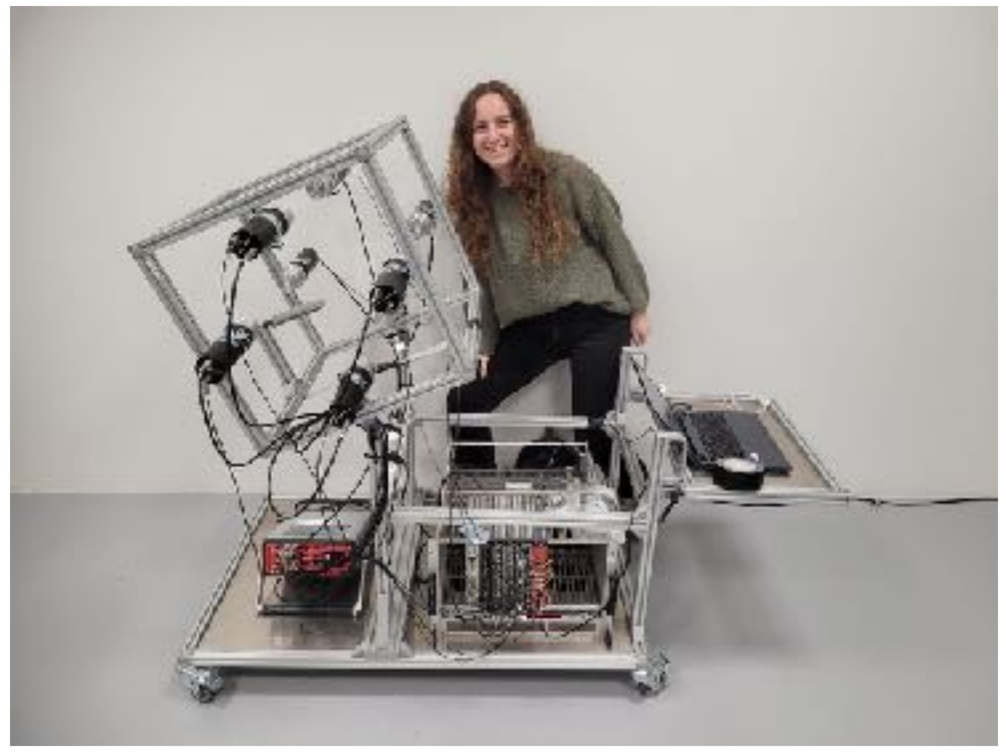
MCNP simulations by S.G. Yoon



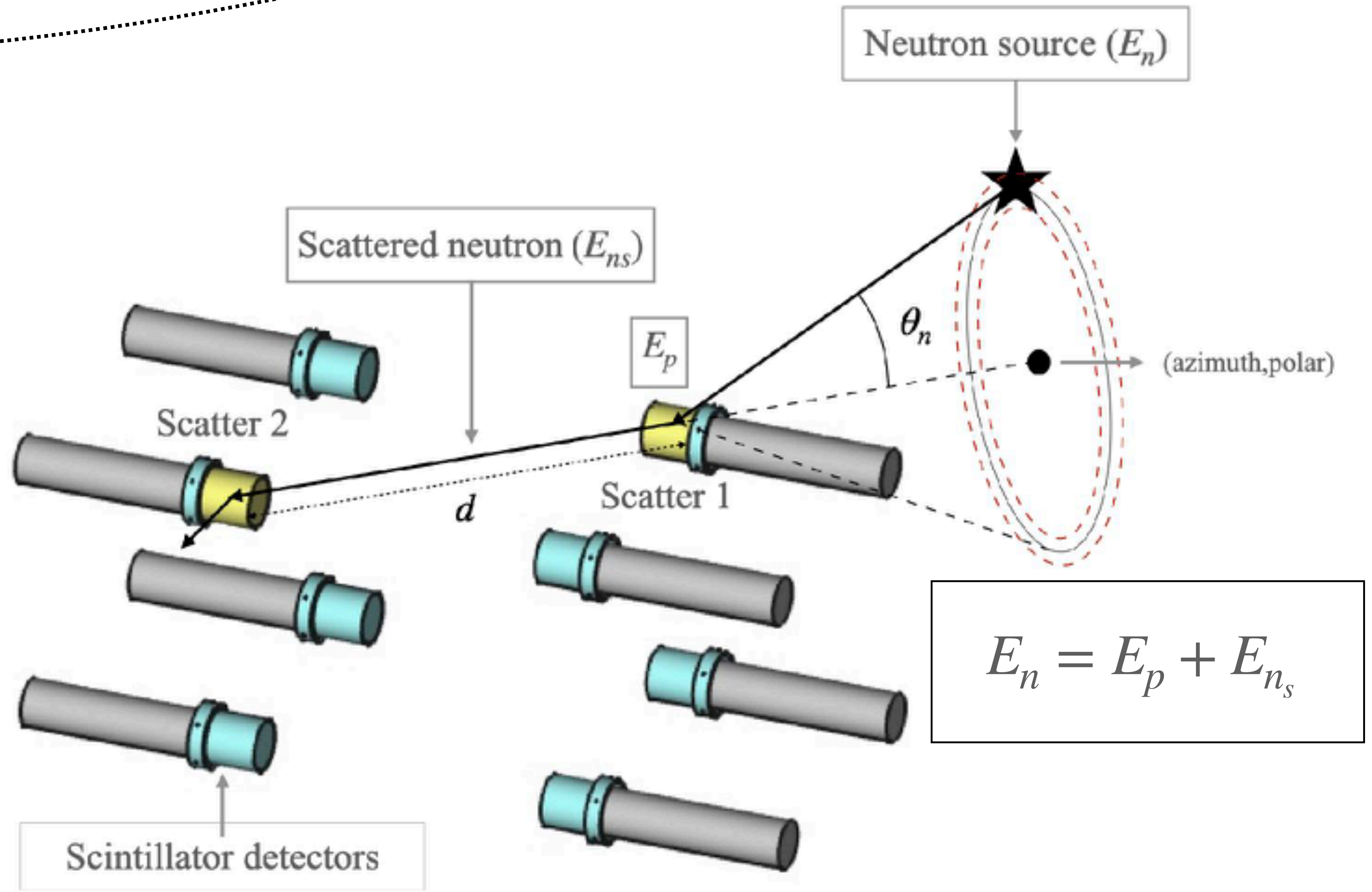
Neutrons energy ranges up ~1 GeV

- < few MeV background neutrons are easy to shield with modest thickness of moderator.
- Ultrafast >50 MeV have small probability of creating keV signals (CEνNS ROI) and have low $\mathbf{\Phi}$.

⇒ ~ 1-50 MeV neutrons are our concern



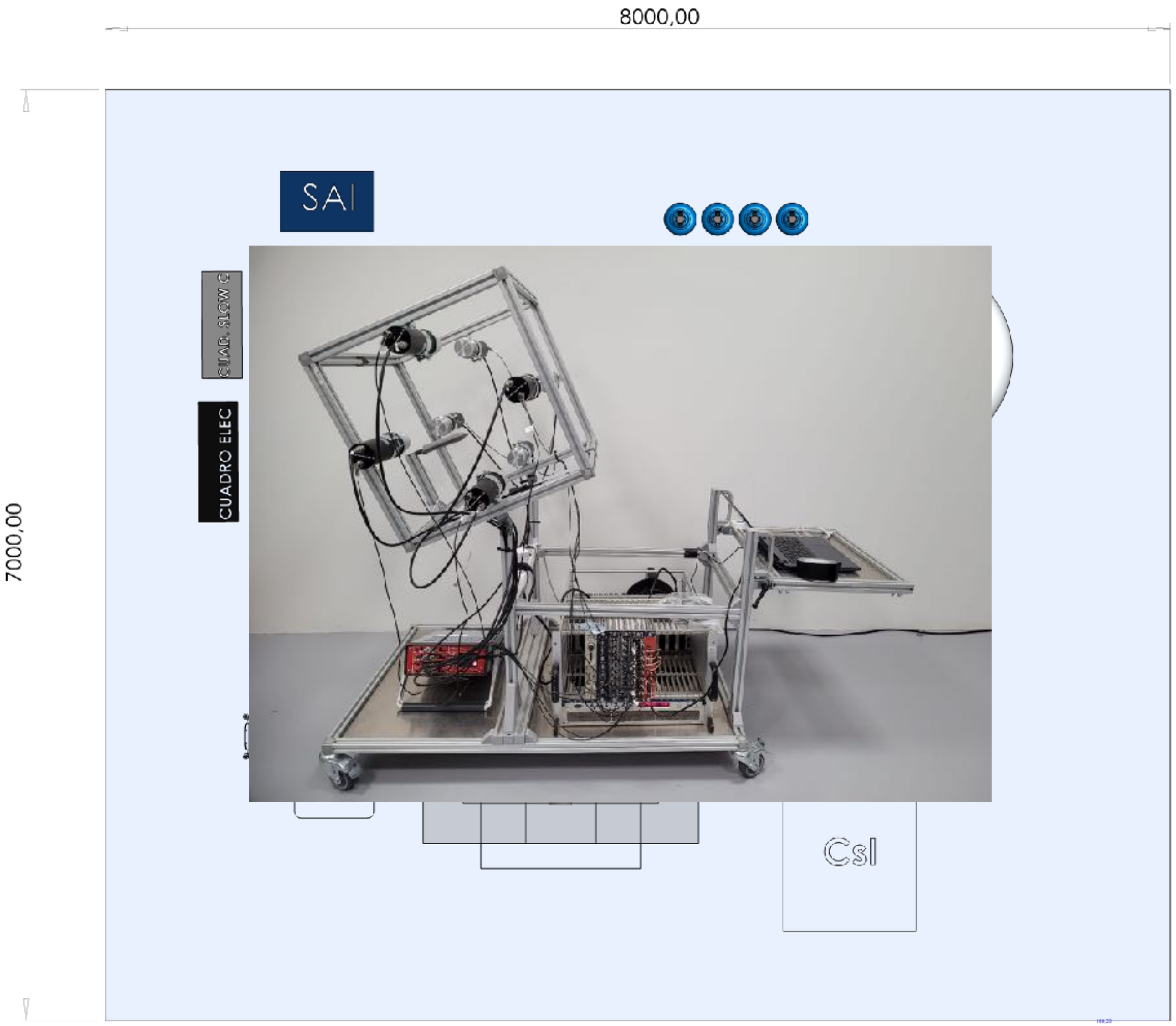
- Design optimization based on simulations relevant to the induced background in CEνNS detectors at the experimental hall.
- 40cm x 40cm x 40cm cubic distribution.
- 8 Polyvinyl Toluene (PVT) scintillators attached to PMTs.



$$E_n = E_p + E_{n_s}$$

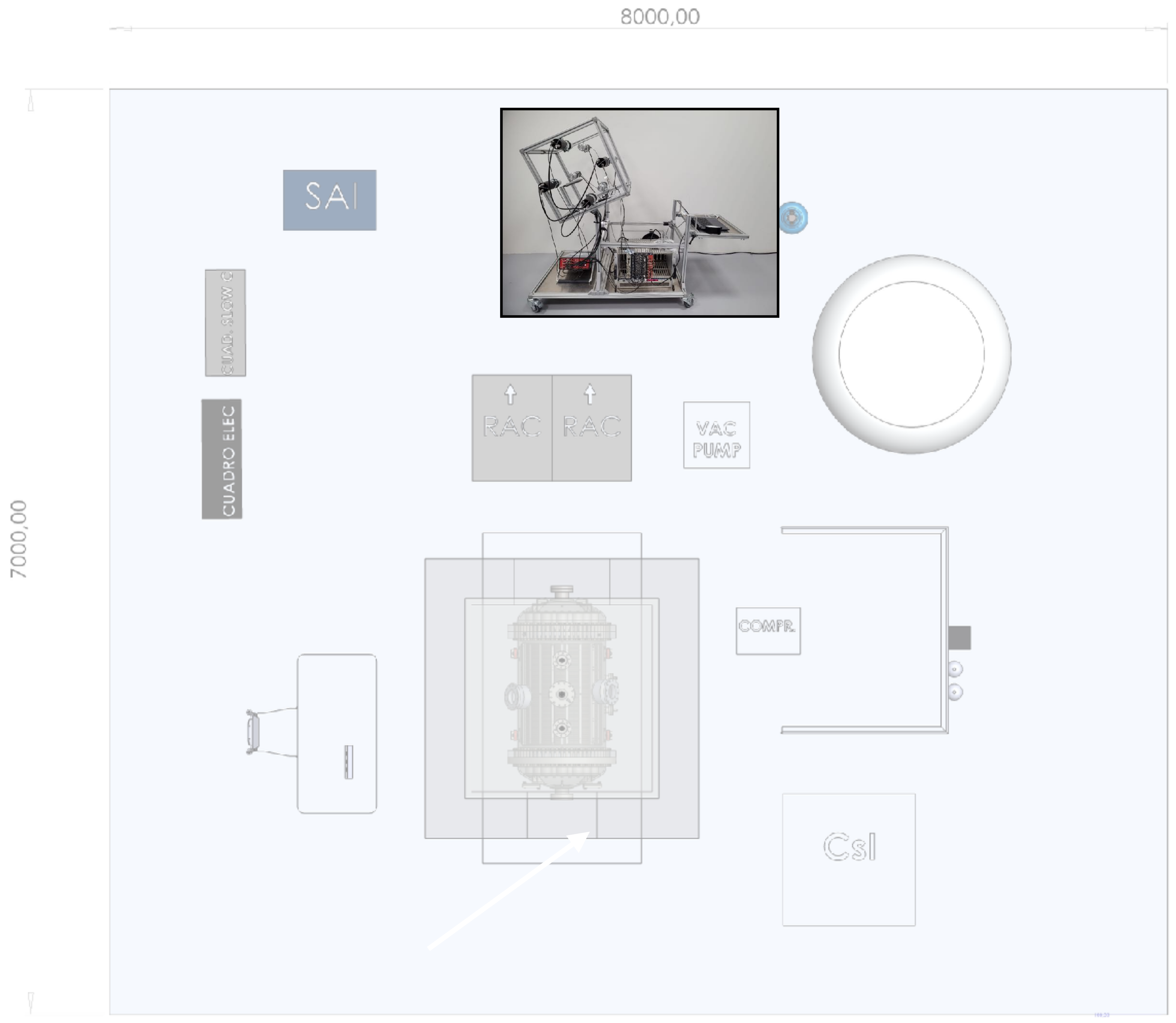
Neutron Camera

Plan to start installation of the neutron camera this summer



Neutron Camera

This will allow for proper commissioning, noise characterization,...



Summary

- Progress in the different prototypes: Demonstration of ~keV Energy threshold.
- New technology in the project: COLINA.
- Space at the ESS already identified.
- Plan to start commissioning of neutron camera ASAP.

Thanks