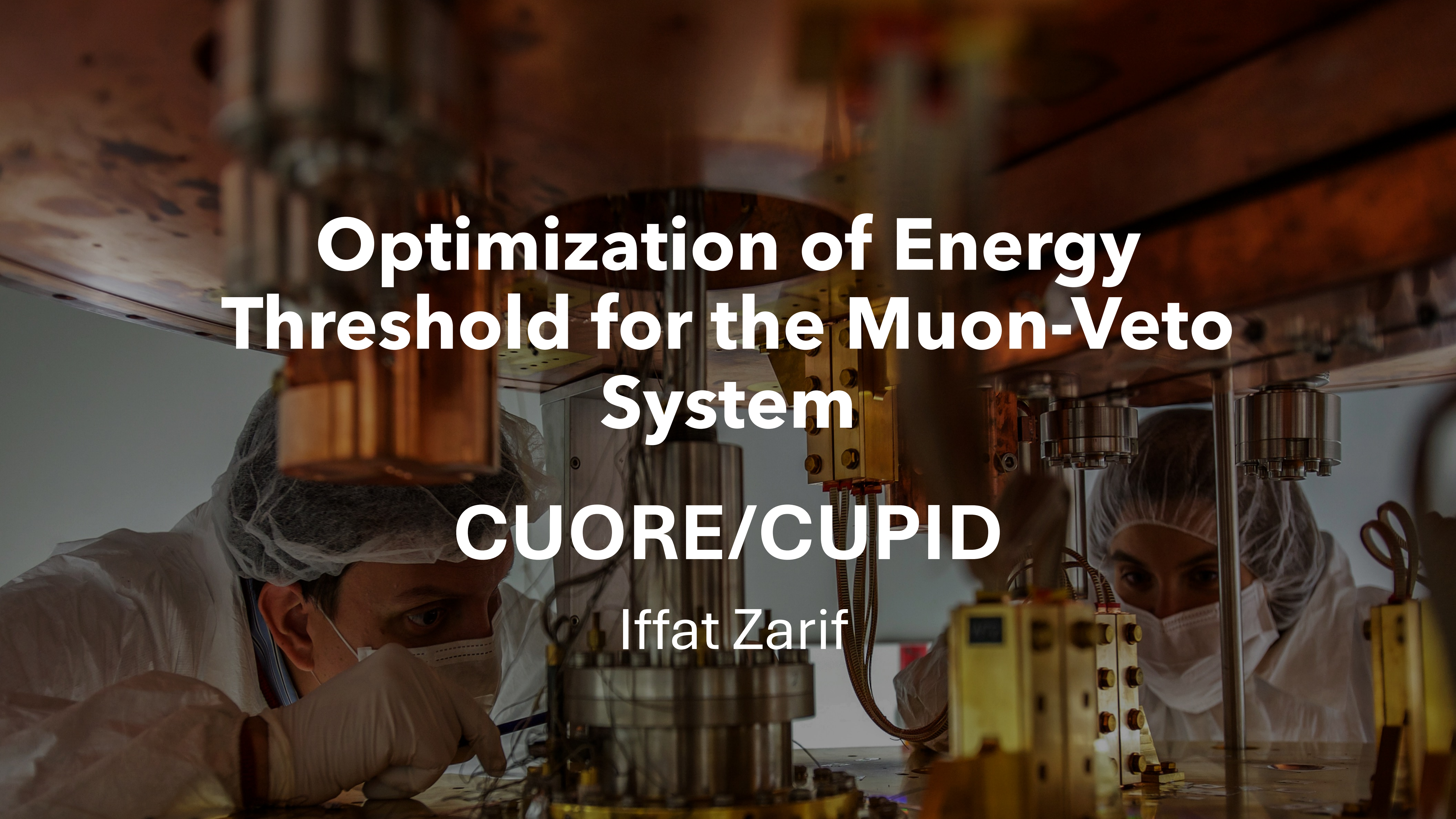


Optimization of Energy Threshold for the Muon-Veto System

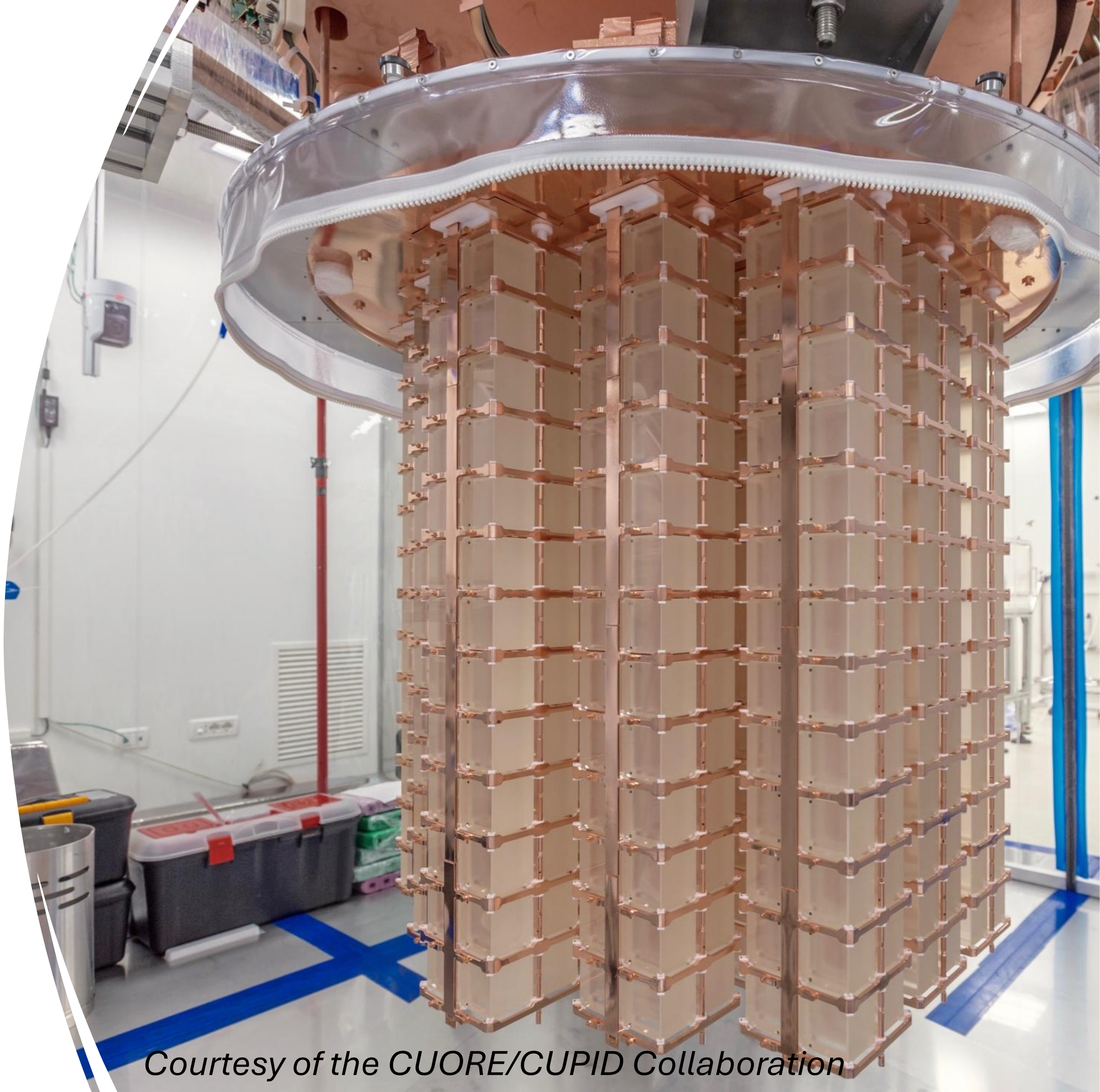
CUORE/CUPID

Iffat Zarif

CUORE/CUPID

CUORE is an underground particle physics experiment, designed to detect a process called **neutrinoless double-beta decay**.

CUPID is the next generation of CUORE, built to be **more sensitive** and to operate at a **zero-background** condition.



Courtesy of the CUORE/CUPID Collaboration

Neutrinoless Double Beta Decay

Beta decay: $\mathrm{n} \rightarrow p^{+} + e^{-} + \overline{\nu}_e$

Standard double beta decay (2vββ):

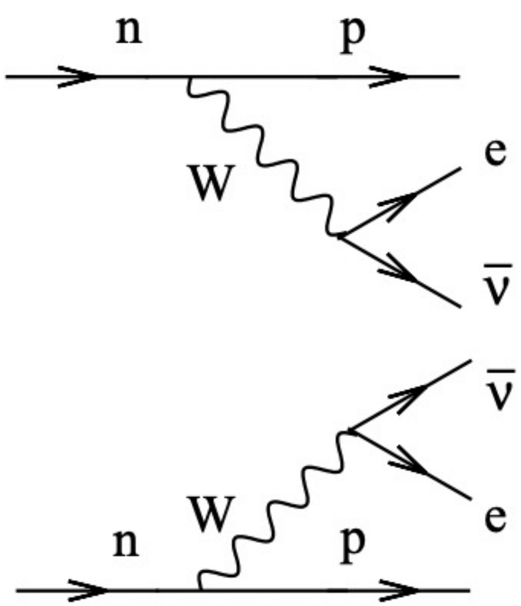
$2\mathrm{n} \rightarrow 2p^{+} + 2\,e^{-} + 2\overline{\nu}_e$

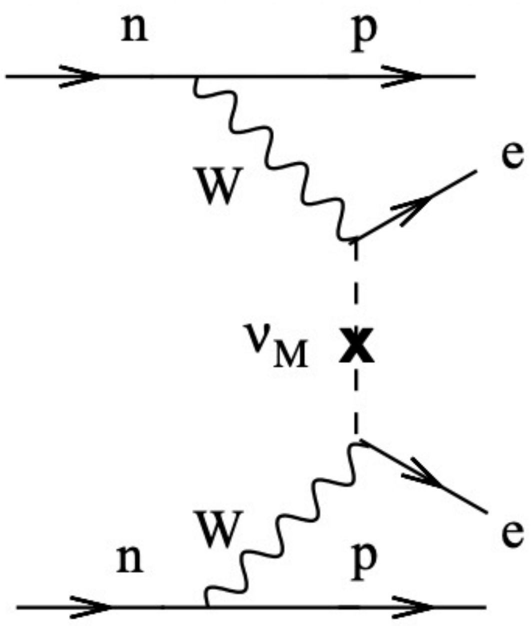
Conserves lepton number.

Neutrinoless double beta decay (0vββ):

$2\mathrm{n} \rightarrow 2p^{+} + 2\,e^{-}$

Violates lepton number conservation.





Implications of 0νββ

1. Neutrinos are Majorana particles:

0vββ is only possible if neutrinos are their own antiparticles – which are called Majorana particles –> neutrinos annihilate

2. Matter-Antimatter Asymmetry:

0vββ is matter-generating and could lead to an explanation of the matter-antimatter asymmetry.

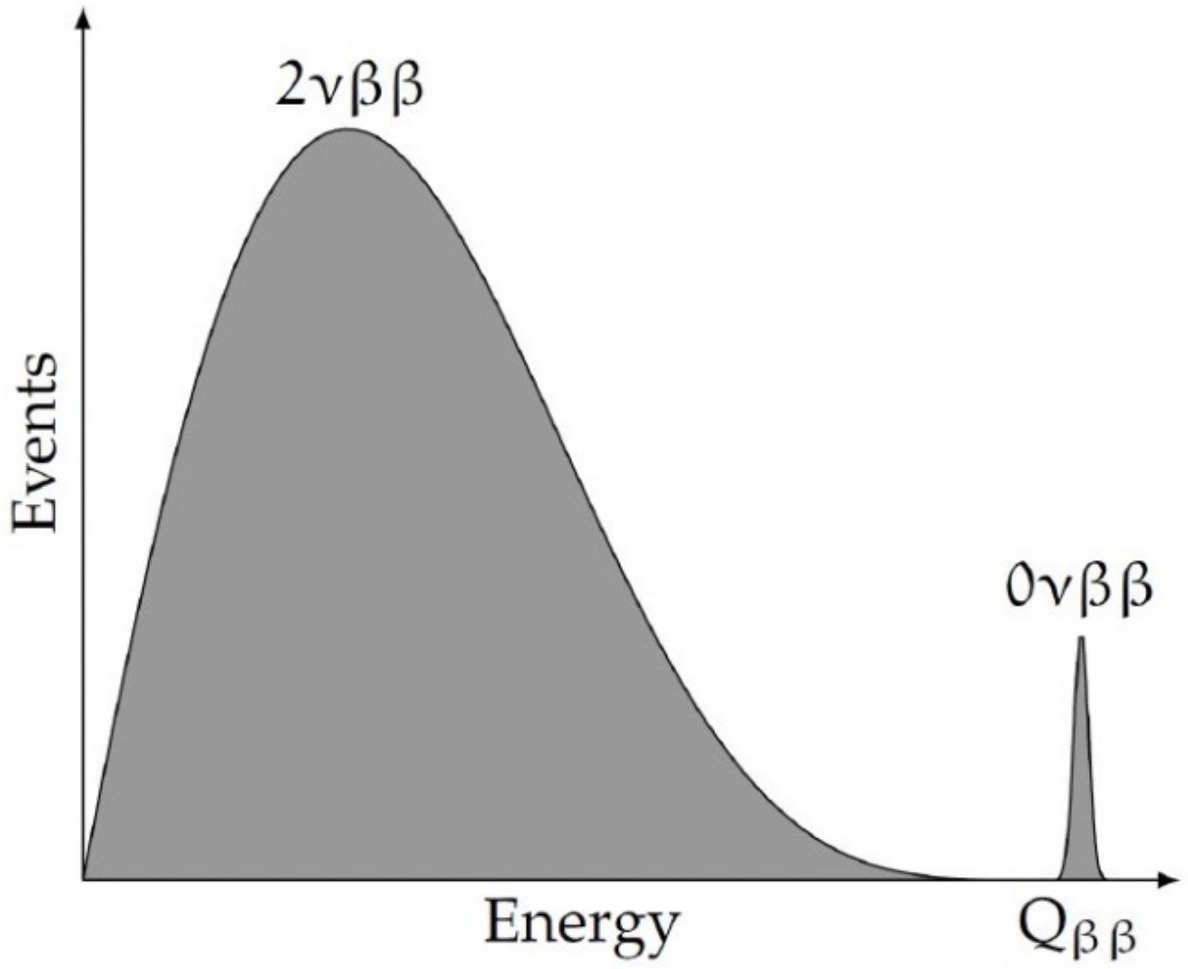
3. Neutrino Mass:

Neutrino oscillation experiments have proved that neutrinos have mass. 0vββ decay rate can be used to find the effective mass of neutrinos.

Expected Signal

If detected the double beta decay should give the signal shown right.

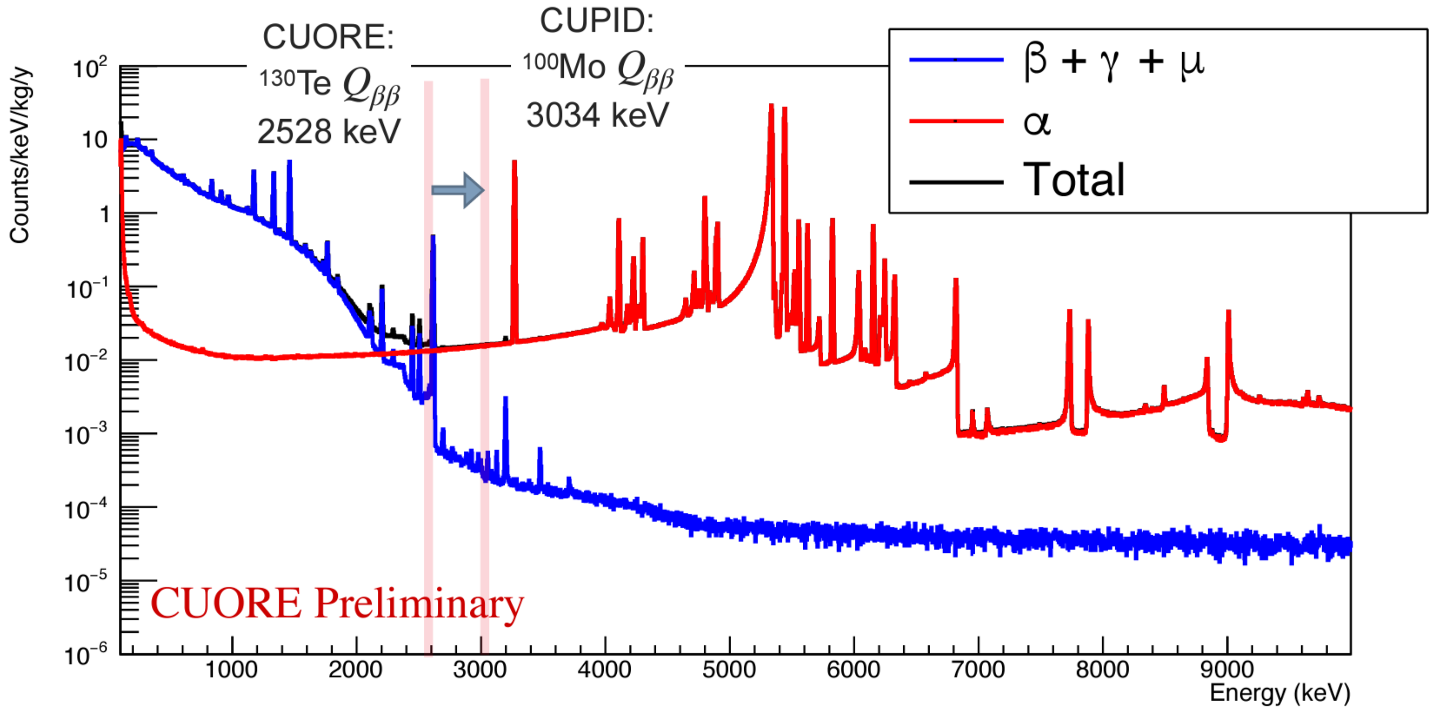
It should be a sharp signal to the right of the 2νββ peak.



Courtesy of CUPID Collaboration

Background Radiation

The CUORE detectors are sensitive to background radiation such as α, β, γ, and μ, which can lead to false positive events or distort the 0νββ signal .



Courtesy of CUORE/CUPID Collaboration

Muon-Veto System

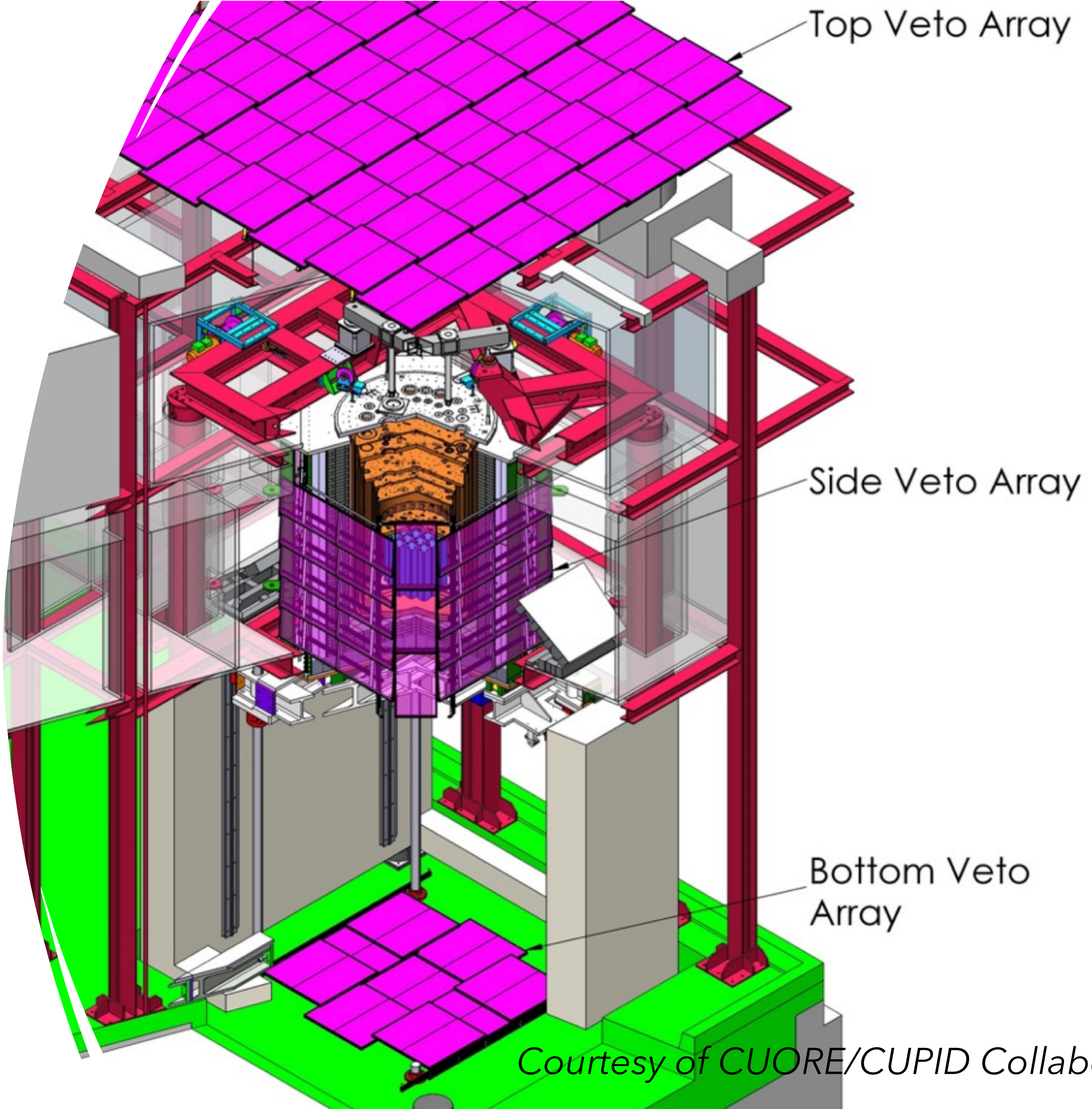
The Yale team is building a muon-tagging system that will be installed in CUPID to **eliminate background**.

The system is built out of **scintillator panels** and **silicon photomultipliers** as counter.

CUPID with Muon-Veto

Panels are designed to be compact due to space constraints of the detector

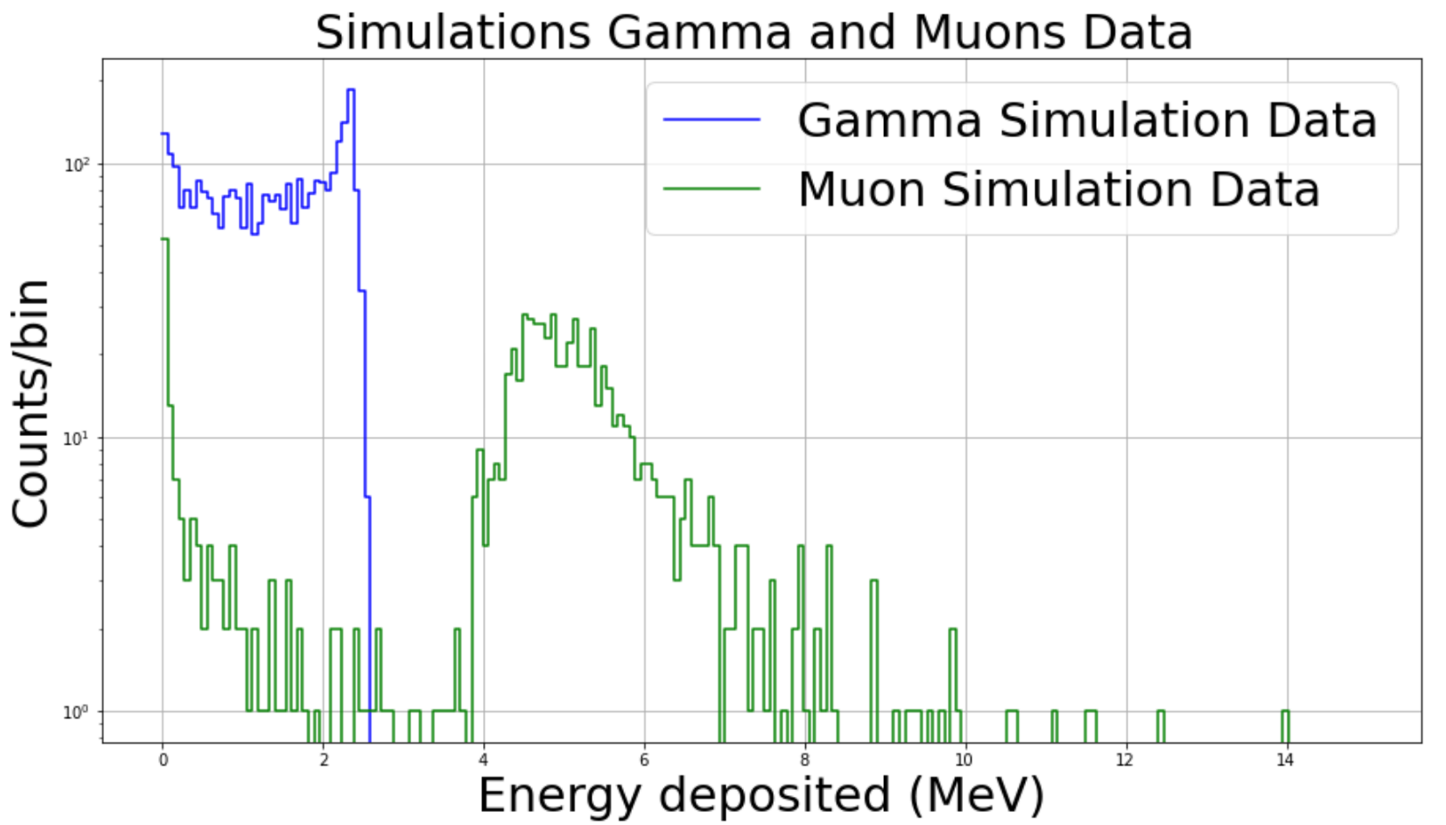
The picture on the right is an illustration of what CUPID will look like with the panels installed.



Courtesy of CUORE/CUPID Collaboration

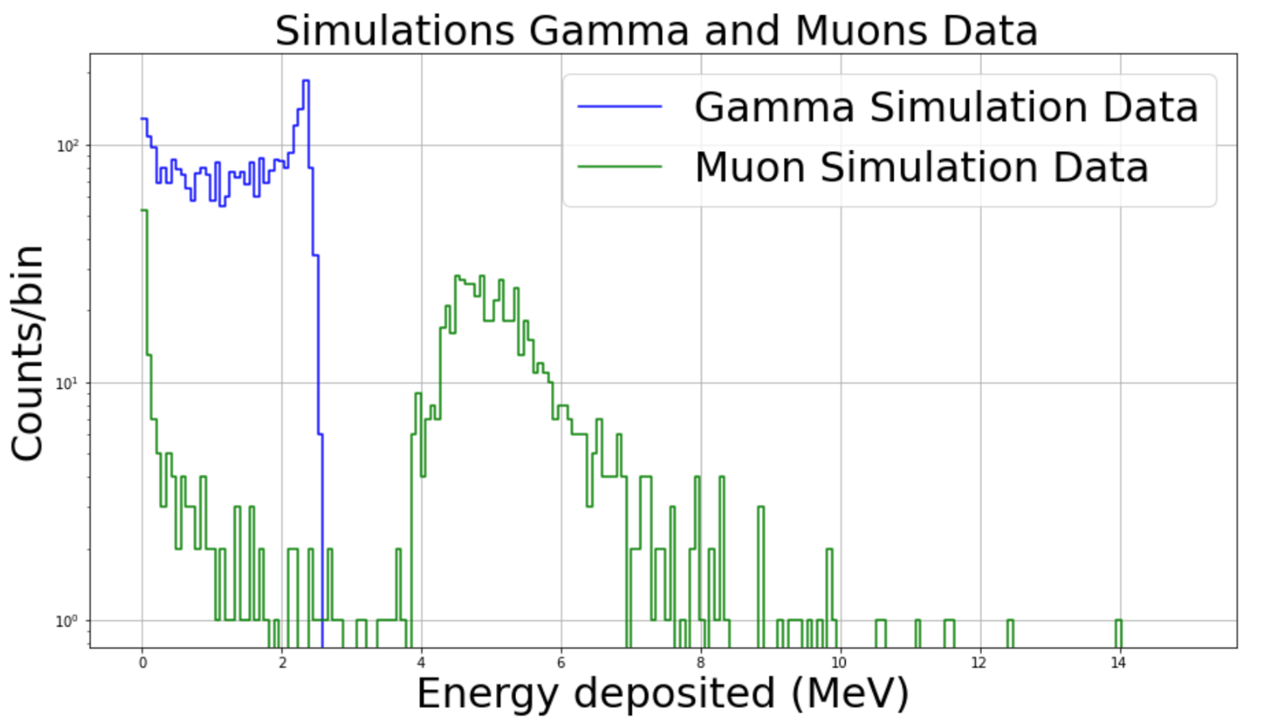
Gamma Background

The muon-veto system has its own background in the form of **gamma radiation** from atmospheric sources. This can be wrongly interpreted as events leading to **false-positive events** that yield **deadtime** in the CUORE detector.



Gamma Background Elimination

1. Simulate gamma and muons data with CUORE's simulations software with on-site conditions.



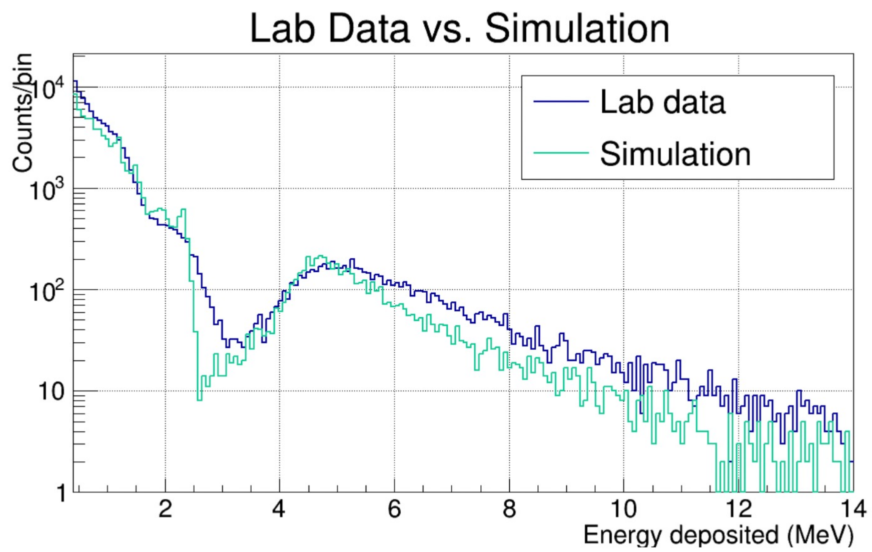
Gamma Background Elimination

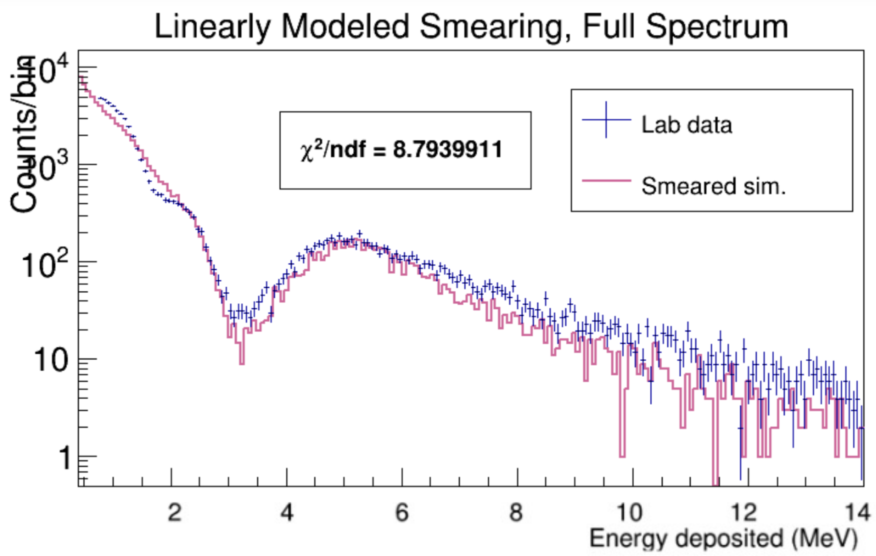
1. Simulate gamma and muons data with CUORE's simulations software with on-site conditions.
2. Use the **system response** of the detector to smear the simulated data so that it better resembles the on-site detector output.

System Response

System response is the detector output. It is distinct from the simulated output due to **smearing** of the signal by detector components.

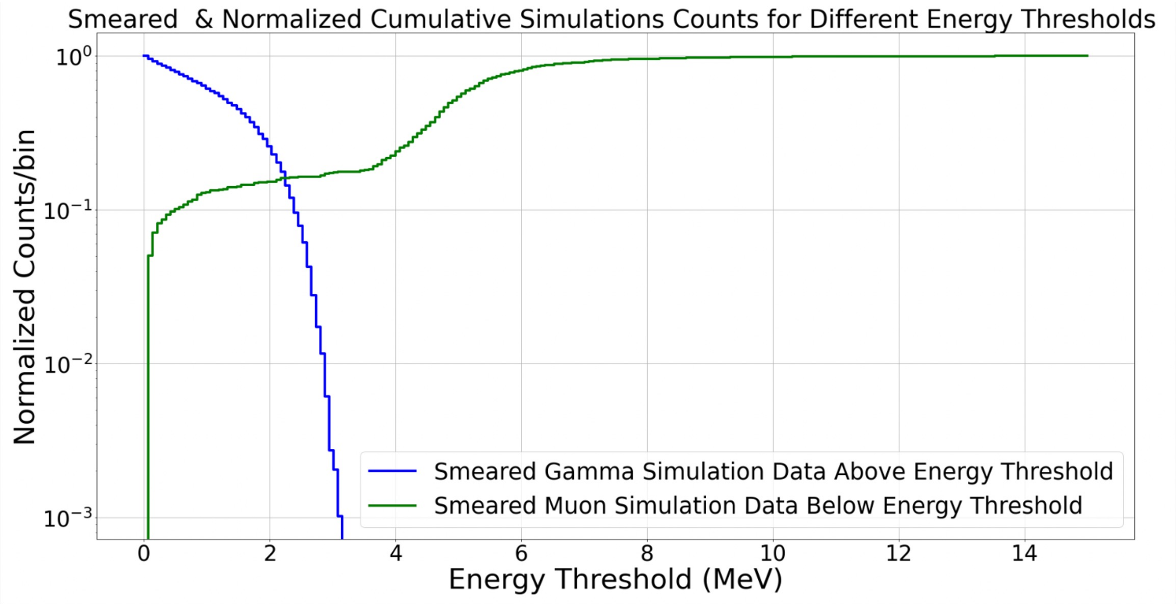
The system response was previously determined using real lab data and simulated lab data by trying **normal distributions** with different standard deviations models (constant, linear, and polynomial) to find the one that **best fit** the simulated data to lab data.





Gamma Background Elimination

1. Simulate gamma and muons data with CUORE's simulations software with on-site conditions.
2. Use the **system response** of the detector to smear the simulated data so that it better resembles the on-site detector output.
3. Draw a **cumulative, normalized counts curve** at varying energy thresholds.

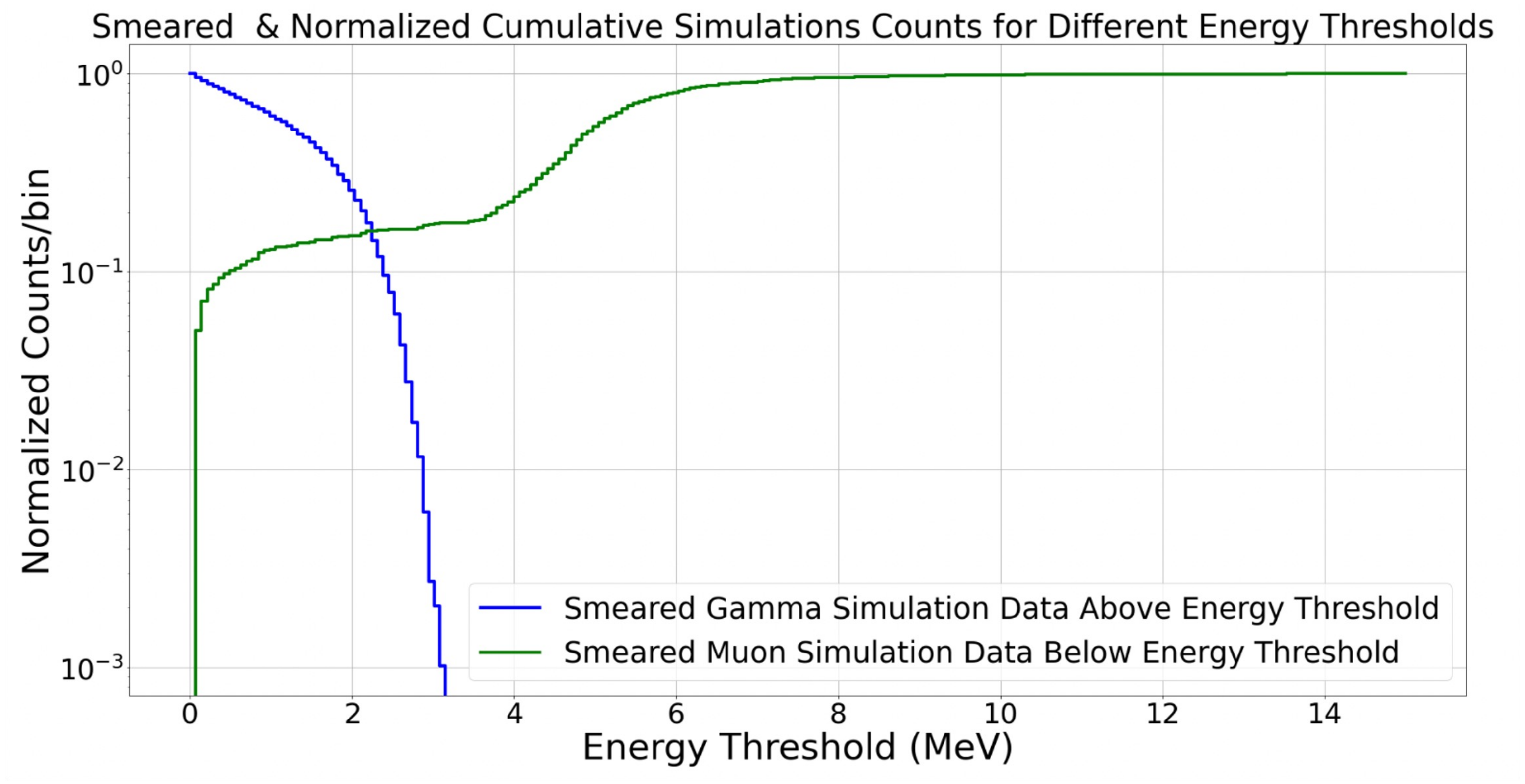


Gamma Background Elimination

1. Simulate gamma and muons data with CUORE's simulations software with on-site conditions.
2. Use the **system response** of the detector to smear the simulated data so that it better resembles the on-site detector output.
3. Draw a **cumulative counts curve** with varying energy thresholds.
4. Find optimal energy to **minimize gamma count, while maximizing muon count**.

Optimal Energy Threshold

The energy threshold is optimized to remove gammas. However, this eliminates some muons as well. We want to minimize both **leftover gamma** and **unwanted muon elimination** and thus those two quantities are plotted against each other.



Next Steps

1. **Improve system response** by adapting to data taken at the Laboratori Nazionali del Gran Sasso (LNGS) in Italy, where the CUORE/CUPID detector is located.
2. Work with **simulated data with higher counts** to determine a satisfactory energy threshold. The goal is to minimize the gamma counts without excessive loss in muon counts.

Conclusion

- Once the optimal energy threshold is determined, the muon-veto system will be configured to discriminate against counts below that threshold.
- The muon background can therefore be measured to reasonable accuracy.
- Finally, the CUORE/CUPID signals can be more background-free and can more precisely observe a $0\nu\beta\beta$ event.

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Principal Investigator: Reina Maruyama

Postdoc: Jorge Torres

Graduate Students:

Samantha Pagan, Emily Pottebaum

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