Surface Events Pulse Shape Simulation for the LEGEND Experiment

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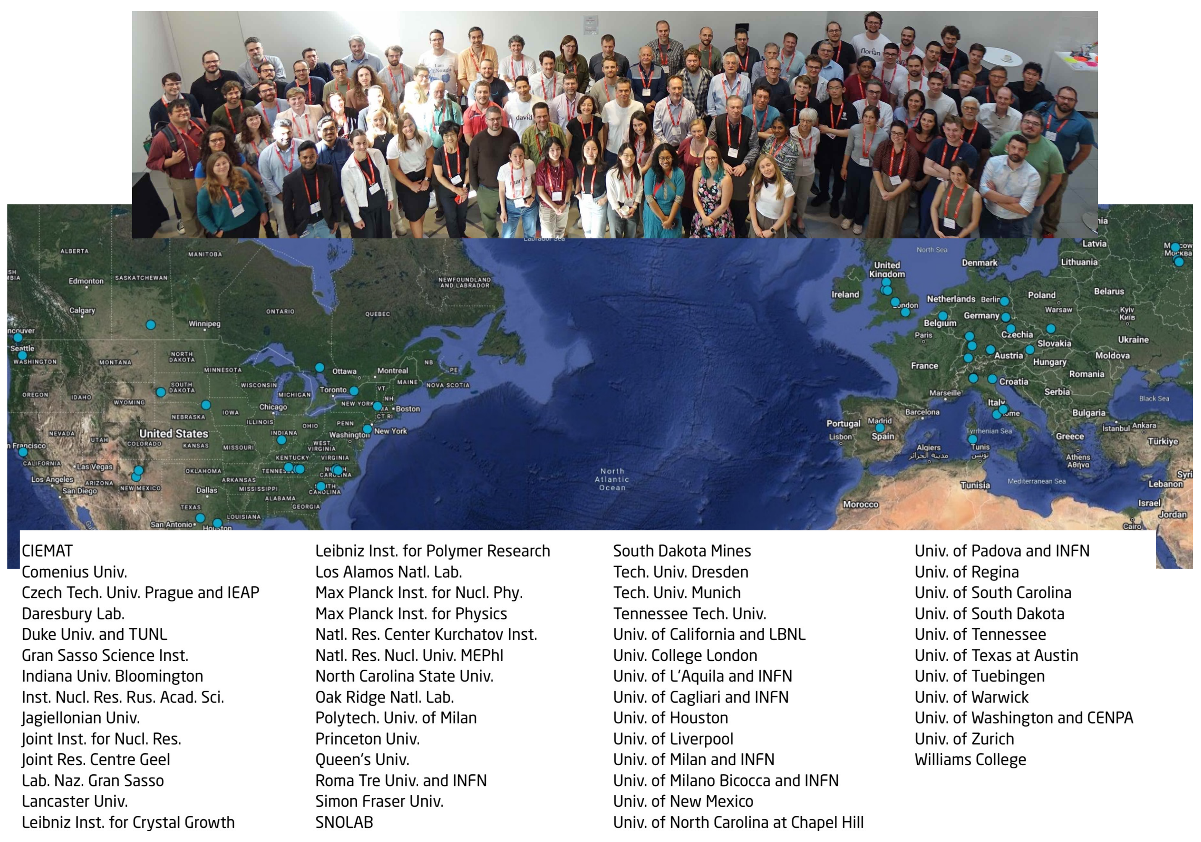
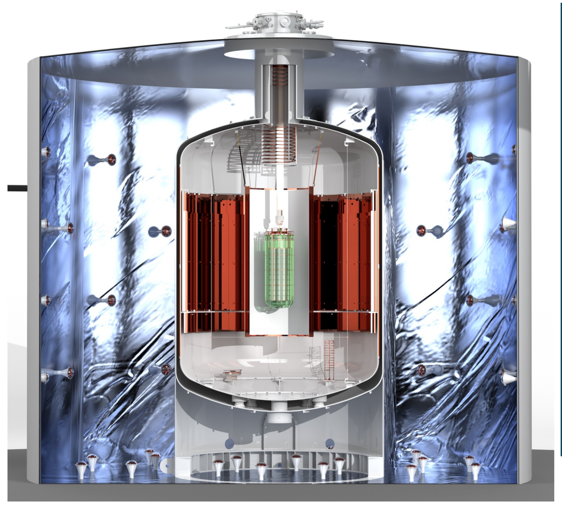
LEGEND Collaboration

"The collaboration aims to develop a phased, Ge-76 based double-beta decay experimental program with discovery potential at a half-life beyond 10^{28} years, using existing resources as appropriate to expedite physics results."



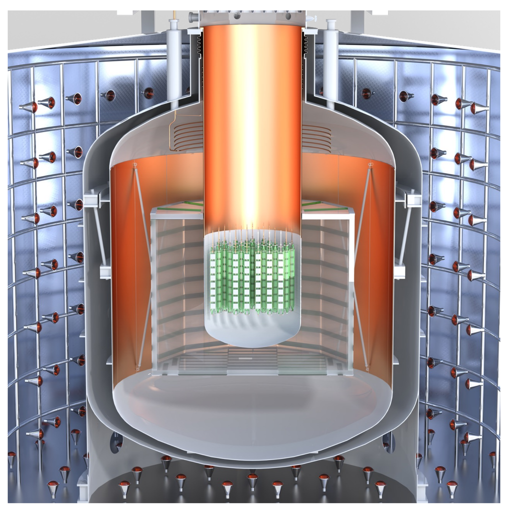


Phase 1: LEGEND-200

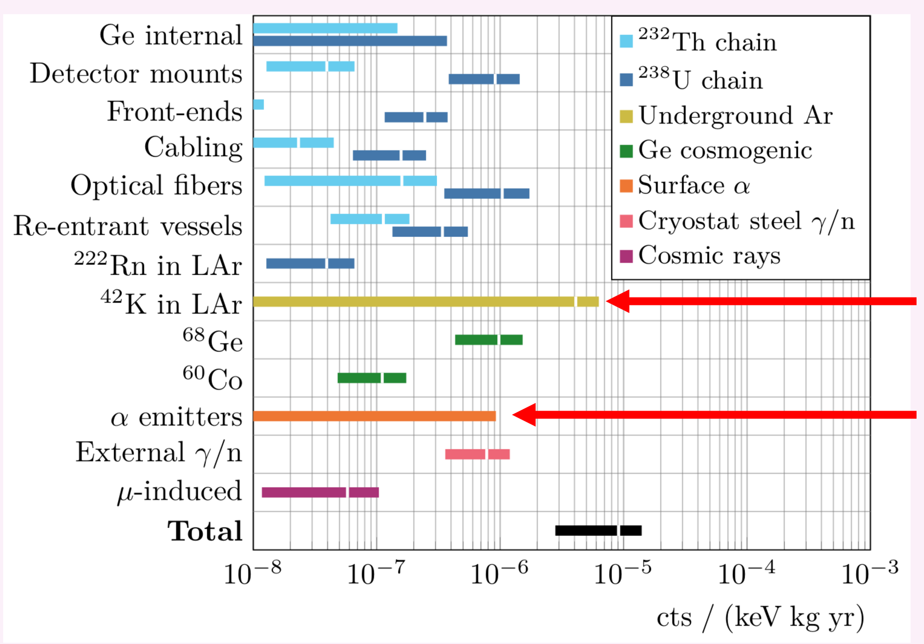
- 200 kg of detectors at LNGS
- Taking data with 142 kg source in atmospheric LAr
- 10^{+3} kg-yr exposure goal
- Background goal: $< 2 \times 10^{-4}$ cts/(keV kg yr)

Phase 2: LEGEND-1000

- 1000 kg of detectors at LNGS
- Enriched ICPC detectors in underground LAr
- 10^{+4} kg-yr exposure goal
- Background goal: $< 1 \times 10^{-5}$ cts/(keV kg yr)

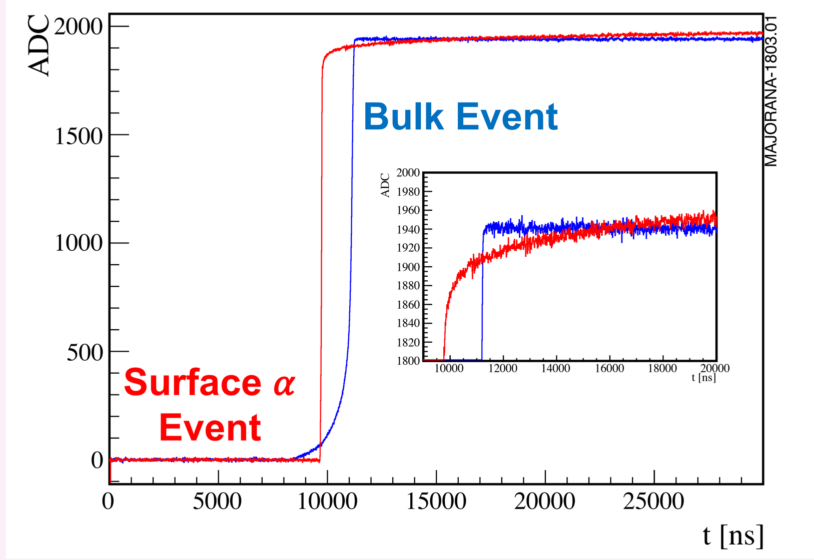


LEGEND 200 Background Model



- Background model after cuts is based on assays, Monte Carlo simulations, and background rejection techniques
- Major background contribution and dominant uncertainty from surface α and beta events

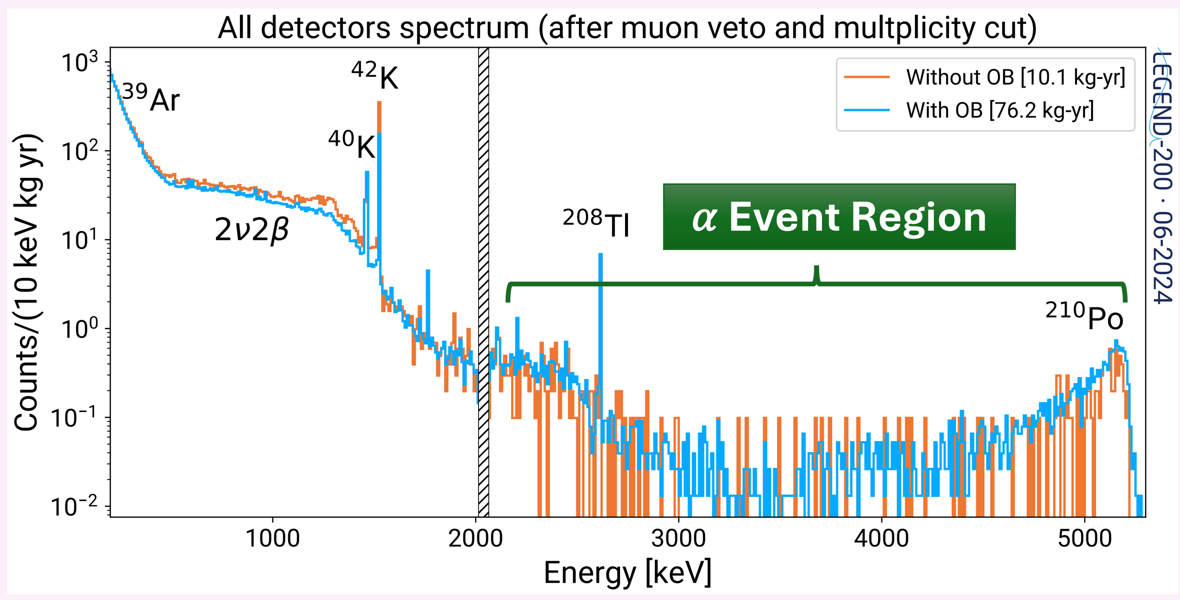
Charge Collection on Passivated surface



- Slow charge collection observed on the passivated surface
- Charges experience trapping, slow re-release and/or reduced drift speed

For more details on LEGEND L200 background modelling see poster by Toby Dixon/ Sofia Calgaro

Degrades α events energies into ROI, allows pulse shape-based rejection

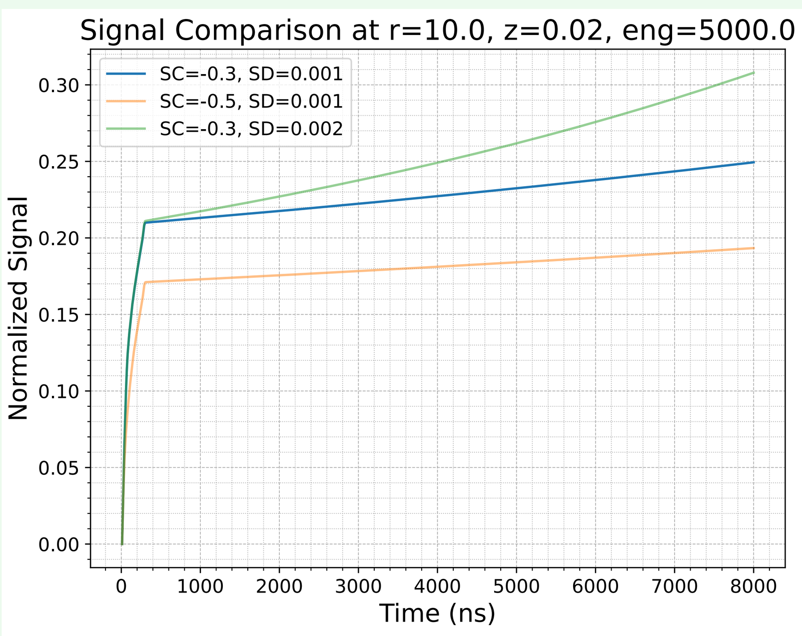


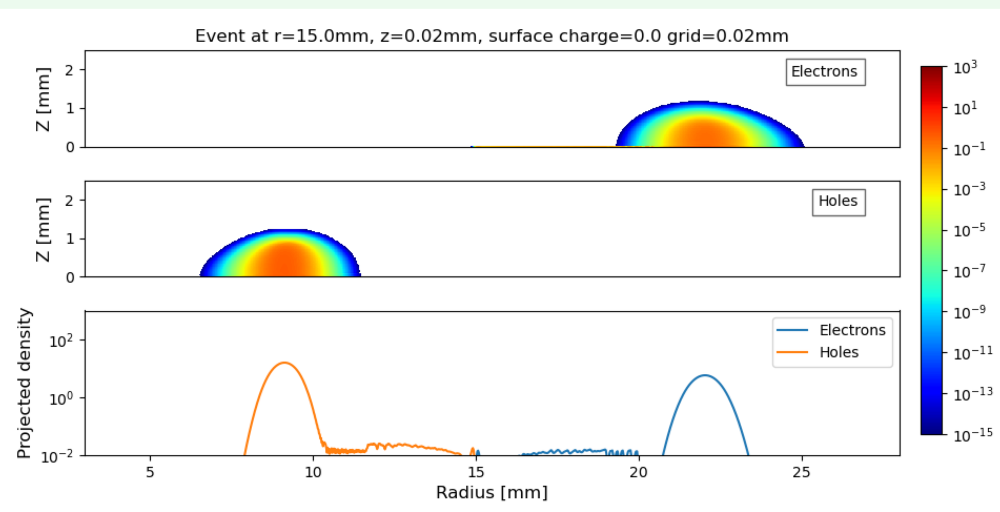
Simulating Surface Alphas

- Charge trapping and rerelease effect is not accurately modeled in current simulations
- α interactions produce a large and dense charge cloud on the surface
- Diffusion and self-repulsion effects are significant
- Charges ending up on the surface could lead to a delayed charge component even without surface charge

EH Drift Simulations

- Developed by David Radford
- Keeps track of charge density at each point
- Incorporates diffusion and self repulsion
- Electric potential recalculated at each step

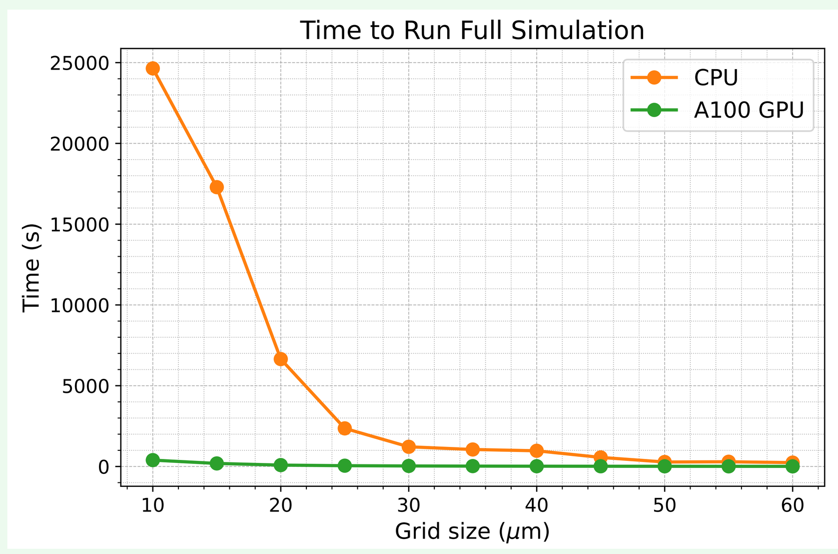




- Charges ending up on the surface drift slower than the bulk
- Resulting waveforms matches α data

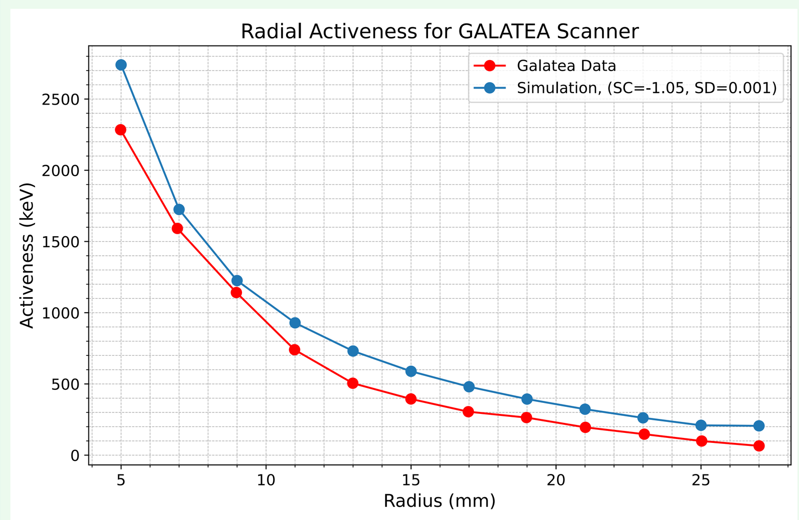
Parallel Computing on GPU

- Implemented the simulation software in parallel on GPU grid using CUDA C++.
- GPU-based calculation dramatically speeds up intrinsically parallel calculations



Alpha Scanner Results

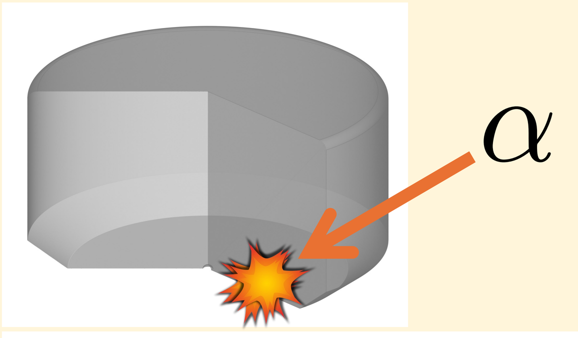
- Dedicated α scans gave conflicting results in energy collection.
- Variation could be driven by charge build up on the passivated surface.
- EH Drift matches the data using combination of surface charge and surface drift



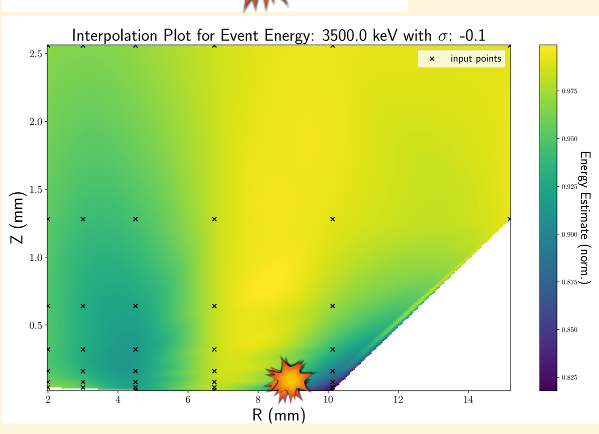
For TUBE and GALATEA publications scan here!

Incorporating into LEGEND Simulation Chain

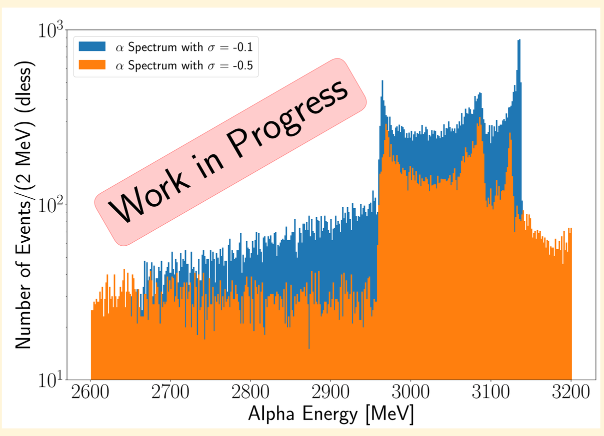
- Work in process
- Given the E&M simulations we can then create a 3D model of the detector response to α events (top plot)
- Then create a library for each type of LEGEND-200 detector
- Can then smear out an expected spectrum of surface α (3200 keV surface α simulated in bottom plot) for different values of σ (surface charge)
- Aiming to generate a series of smeared spectra for use in the LEGEND background model
- Analysis performed by LEGEND analysis suite – MaGe/MPP/MDGO



Simulate Surface α Events



Interpolate Effective Edep from EH Sims



Generate α Spectrum

Conclusion and Future Directions

- Passivated surface events are the large contributors to uncertainty in LEGEND-200 backgrounds.
- Modeling α events requires an accurate modeling of charge collection on the passivated surface
- New waveform simulation technique accurately reproduces observed behavior of α's, and GPU-based simulations show significant speed-up
- Simulations are being integrated in LEGEND simulations workflow to create a background model component for α's

Acknowledgements

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