

Surface Events Pulse Shape Simulation for the LEGEND Experiment

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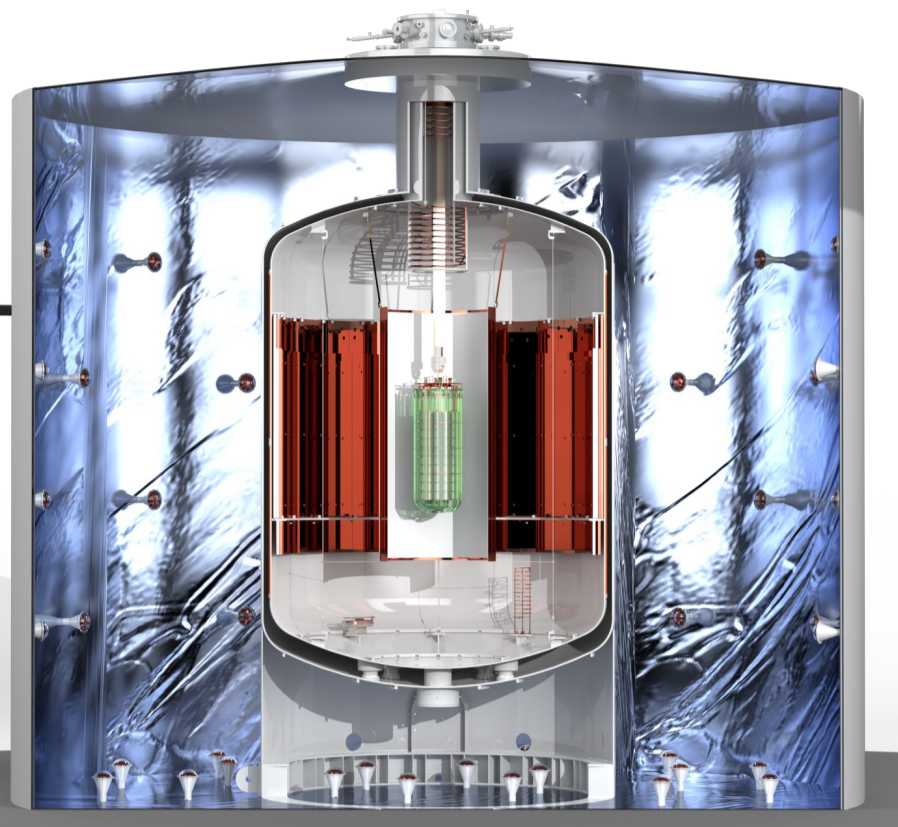
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LEGEND Collaboration

“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.”

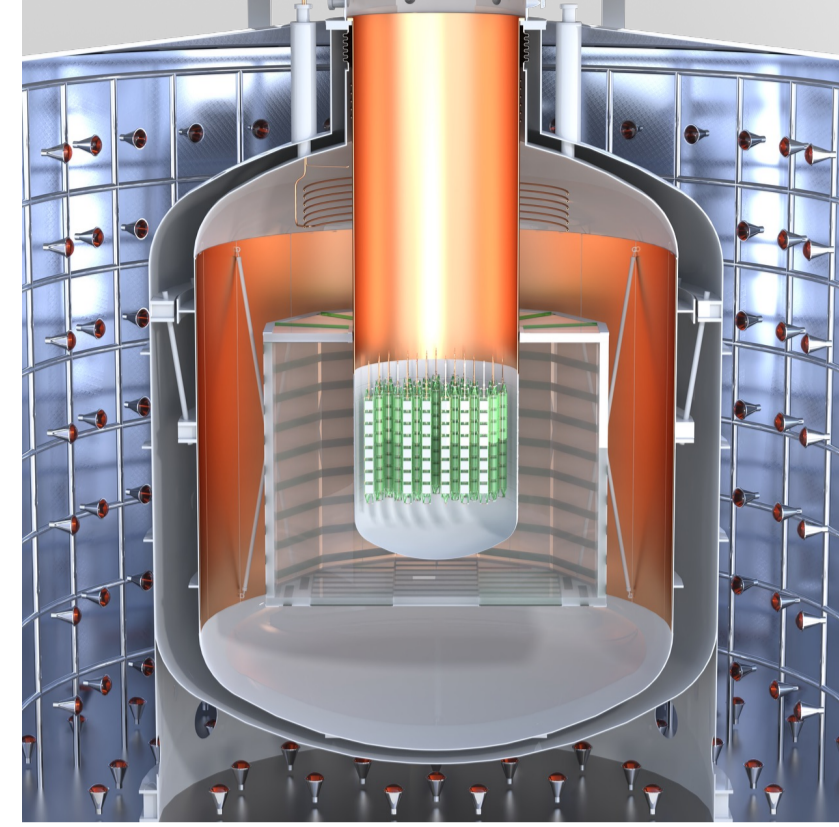


Phase 1: LEGEND-200

- 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)

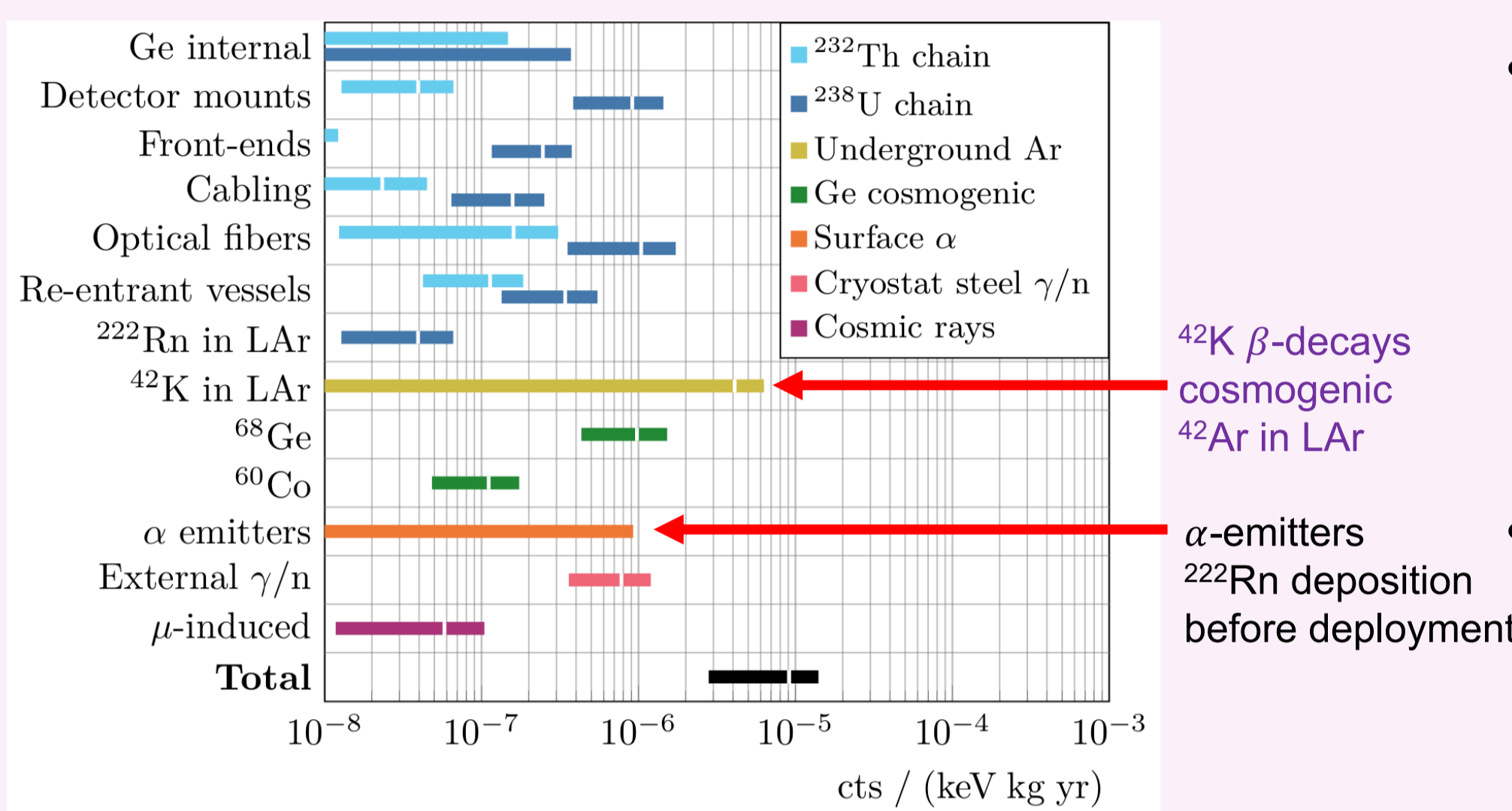
Phase 2: LEGEND-1000

- 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)



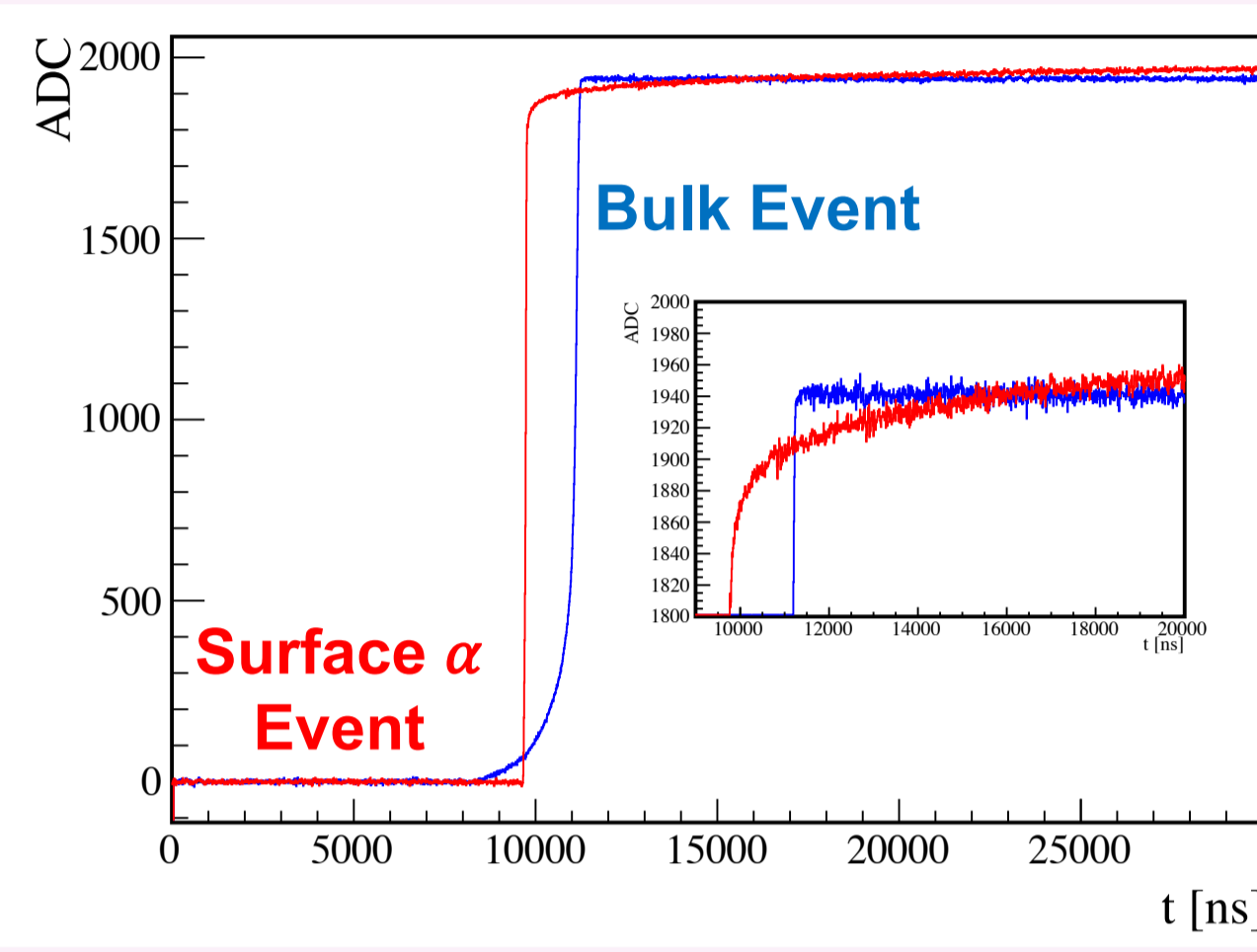
CIEMAT, Comenius Univ., Czech Tech. Univ. Prague and IEAP, Daresbury Lab., Duke Univ. and TUNL, Gran Sasso Science Inst., Indiana Univ. Bloomington, Inst. Nucl. Res. Rus. Acad. Sci., Jagiellonian Univ., Joint Inst. for Nucl. Res., Joint Res. Centre Geel Lab., Naz. Gran Sasso, Lancaster Univ., Leibniz Inst. for Crystal Growth, Leibniz Inst. for Polymer Research, Los Alamos Natl. Lab., Max Planck Inst. for Nucl. Phys., Max Planck Inst. for Physics, Natl. Res. Center Kurchatov Inst., Natl. Res. Nucl. Univ. MEPhI, North Carolina State Univ., Oak Ridge Natl. Lab., Politecn. Univ. of Milan, Princeton Univ., Queen's Univ., Roma Tre Univ. and INFN, Simon Fraser Univ., SNOLAB, South Dakota Mines Tech. Univ. Dresden, Tech. Univ. Munich, Tennessee Tech. Univ., Univ. of California and LBNL, Univ. College London, Univ. of L'Aquila and INFN, Univ. of Cagliari and INFN, Univ. of Houston, Univ. of Liverpool, Univ. of Milan and INFN, Univ. of Milano Bicocca and INFN, Univ. of New Mexico, Univ. of North Carolina at Chapel Hill, Univ. of Padova and INFN, Univ. of Regina, Univ. of South Carolina, Univ. of South Dakota, Univ. of Tennessee, Univ. of Texas at Austin, Univ. of Tuebingen, Univ. of Warwick, Univ. of Washington and CENPA, Univ. of Zurich, Williams College.

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



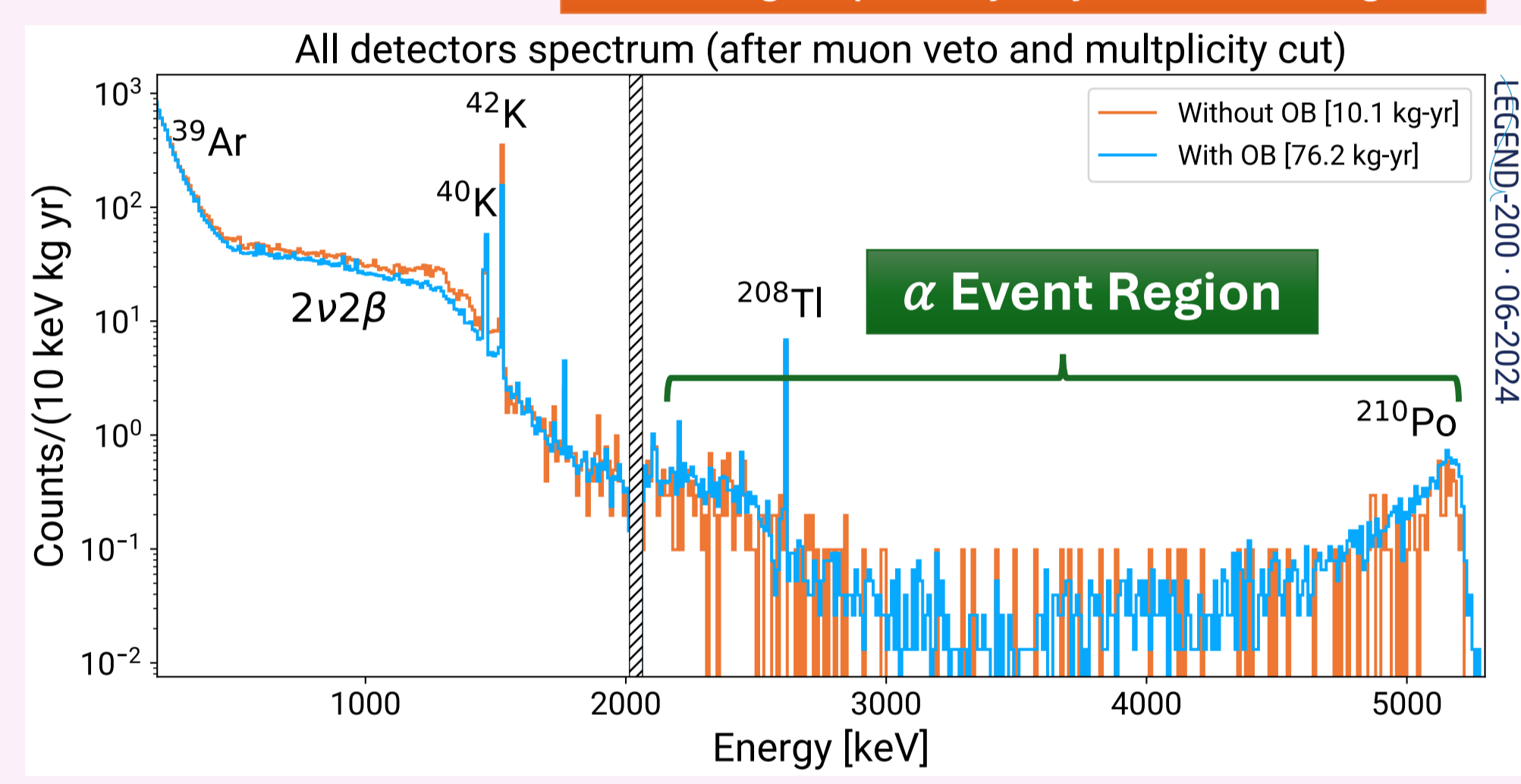
- Slow charge collection observed on the passivated surface
- Charges experience trapping, slow re-release and/or reduced drift speed

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

Simulating Surface Alphas

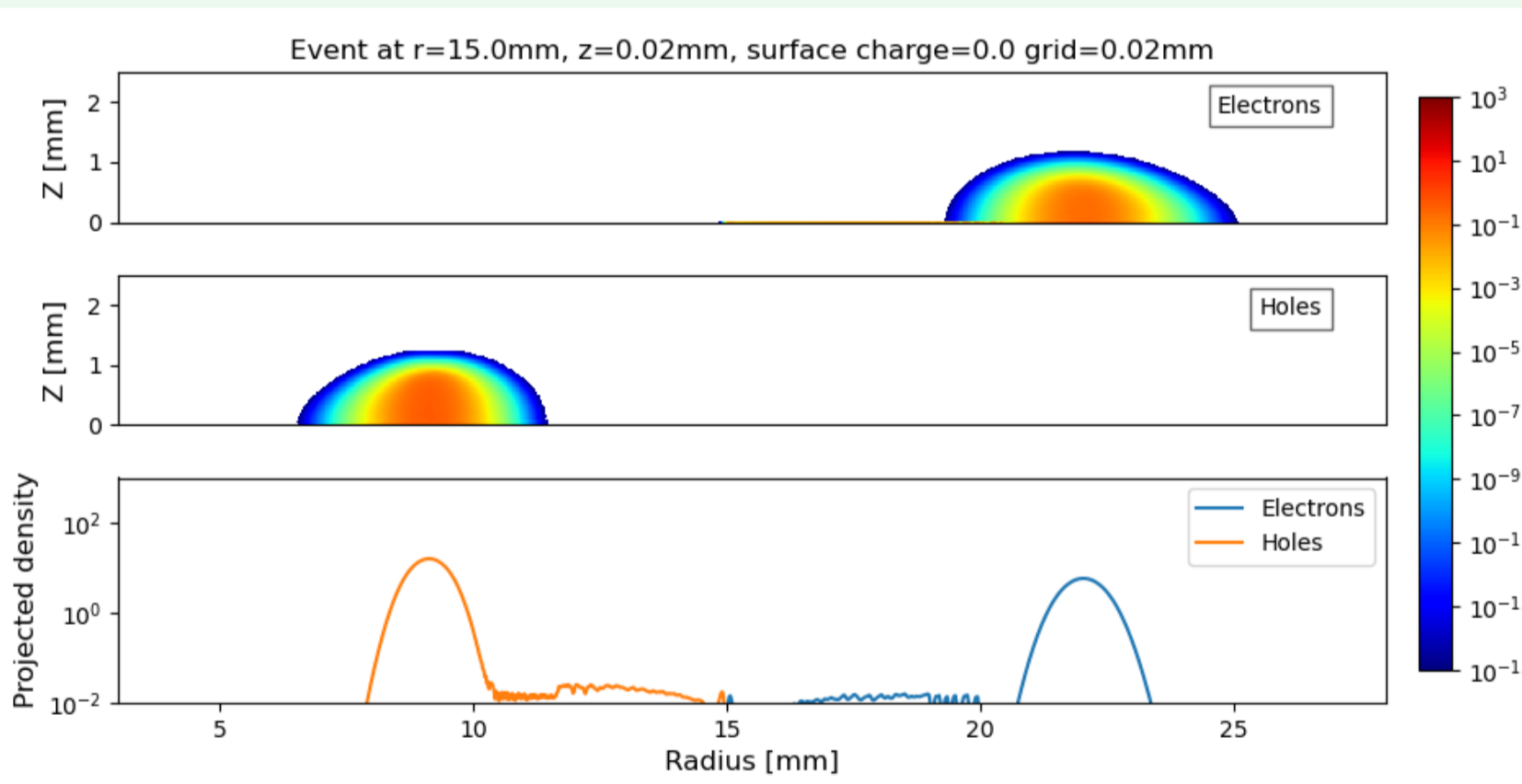
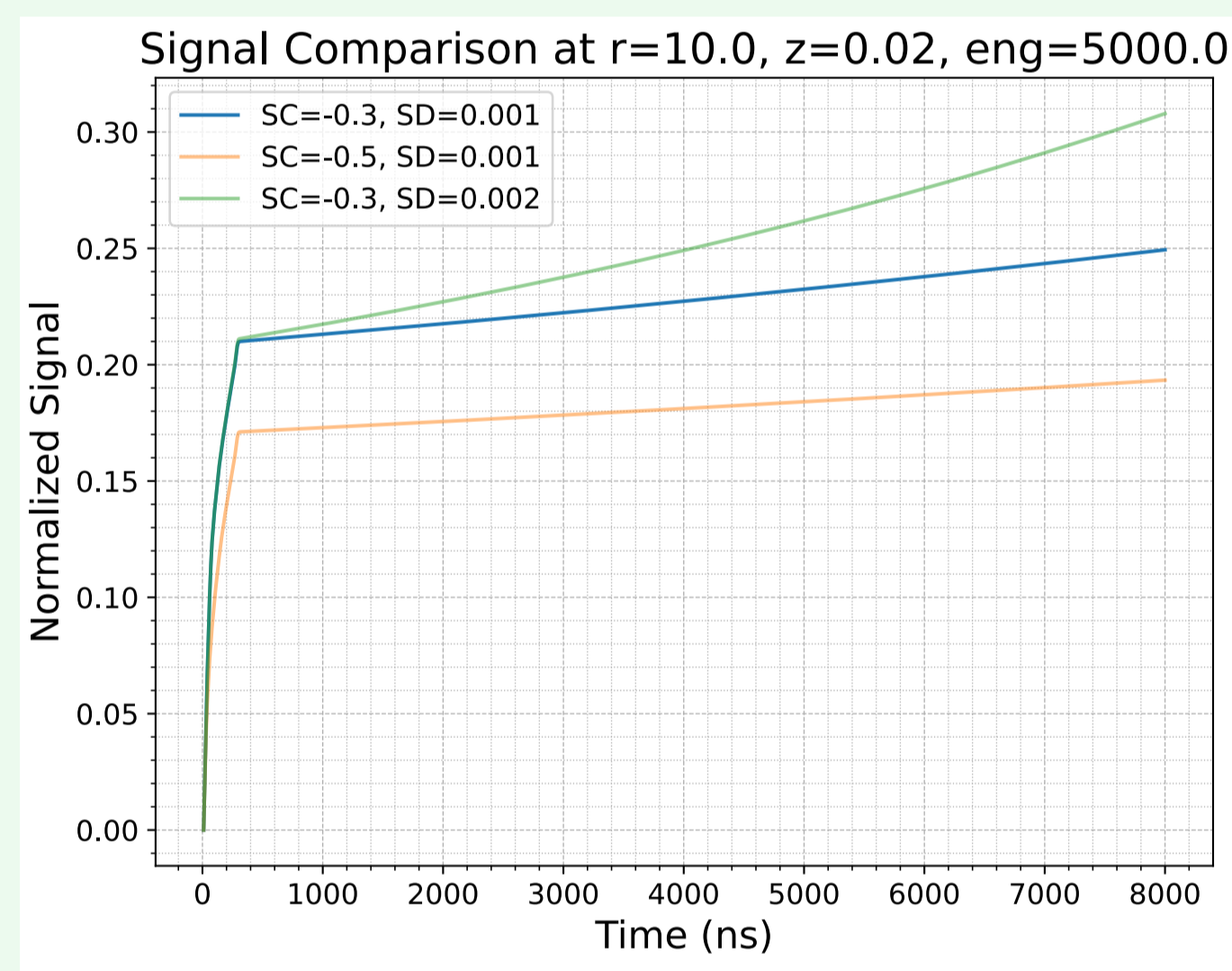
- Charge trapping and rerelease effect is not accurately modeled in current simulations
- α interactions produce a large and dense charge cloud on the surface
- Diffusion and self-repulsion effects are significant
- Charges ending up on the surface could lead to a delayed charge component even without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

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



EH Drift Simulations

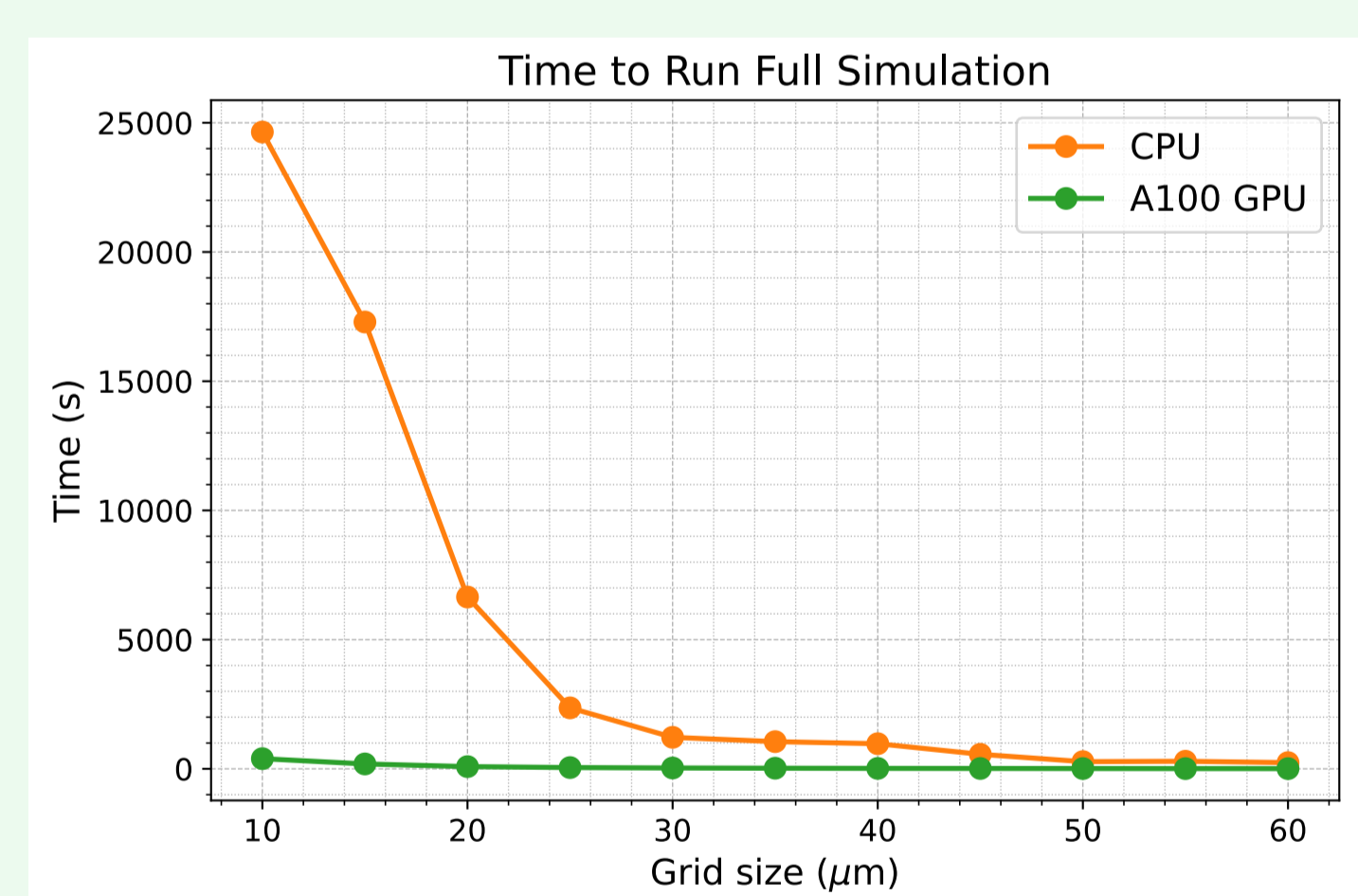
- Developed by David Radford
- Keeps track of charge density at each point
- Incorporates diffusion and self repulsion
- Electric potential recalculated at each step



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

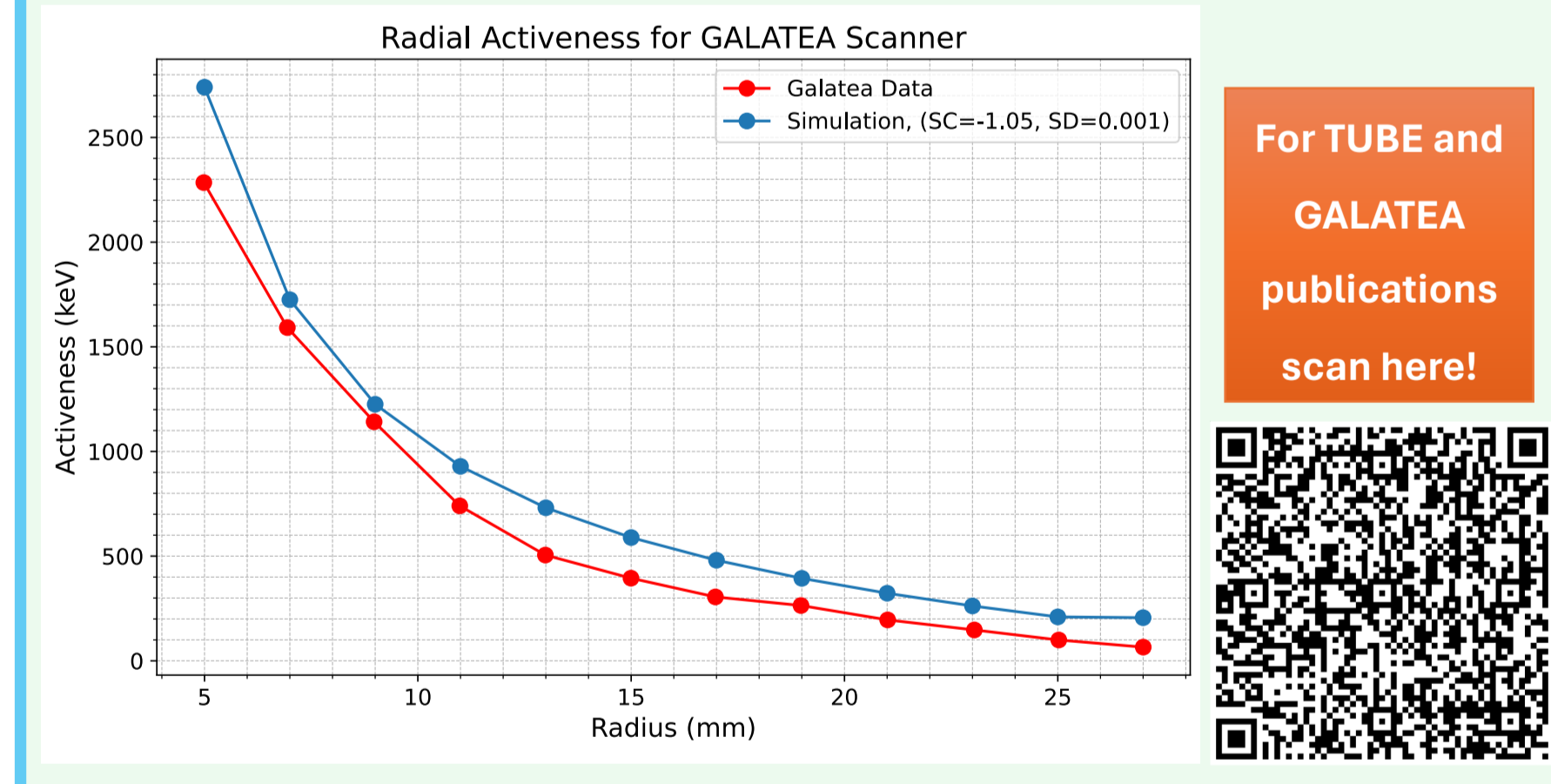
Parallel Computing on GPU

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



Alpha Scanner Results

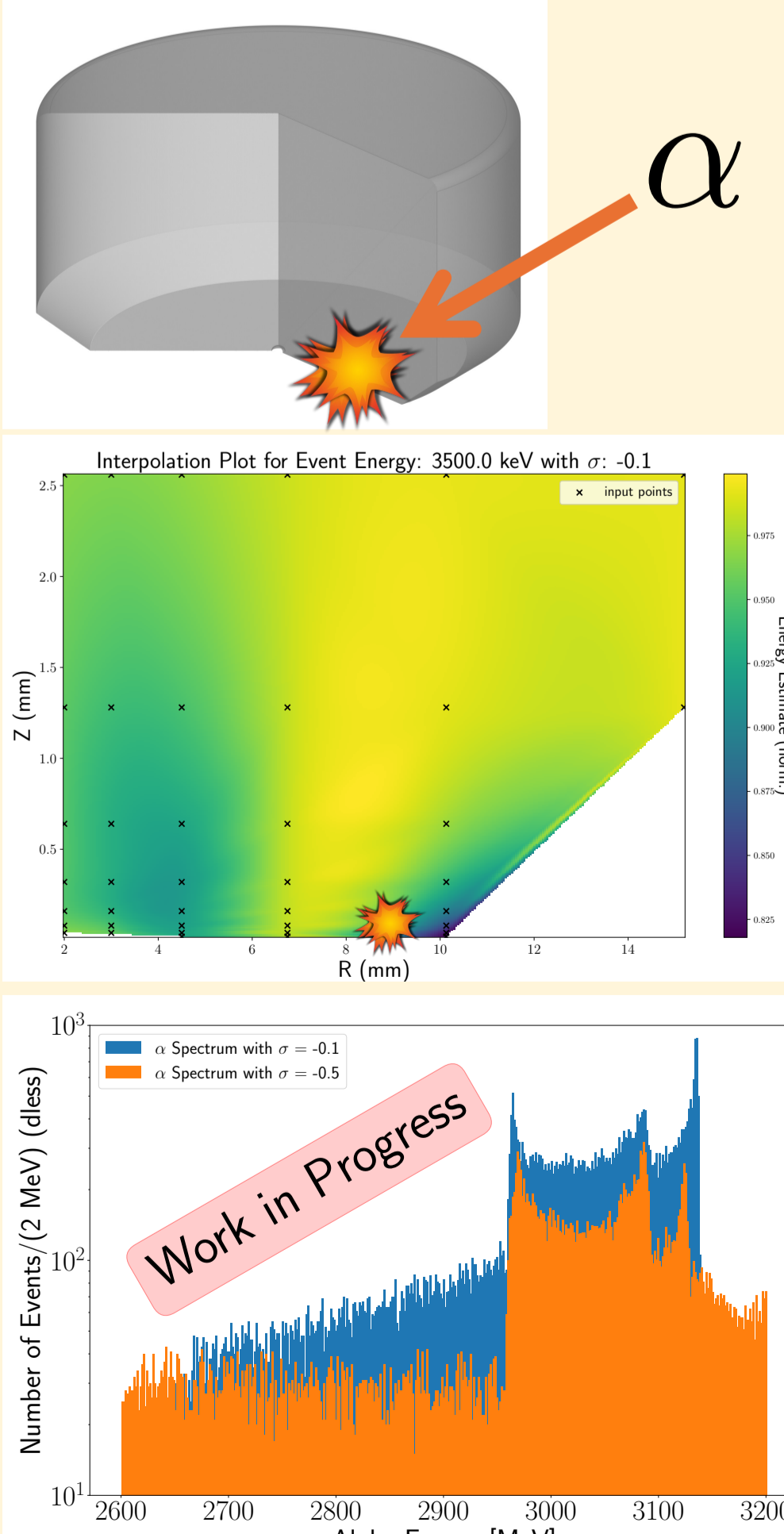
- Dedicated α scans gave conflicting results in energy collection.
- Variation could be driven by charge build up on the passivated surface.
- EH Drift matches the data using combination of surface charge and surface drift



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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