Pulse Shape Simulations for the GERDA Experiment

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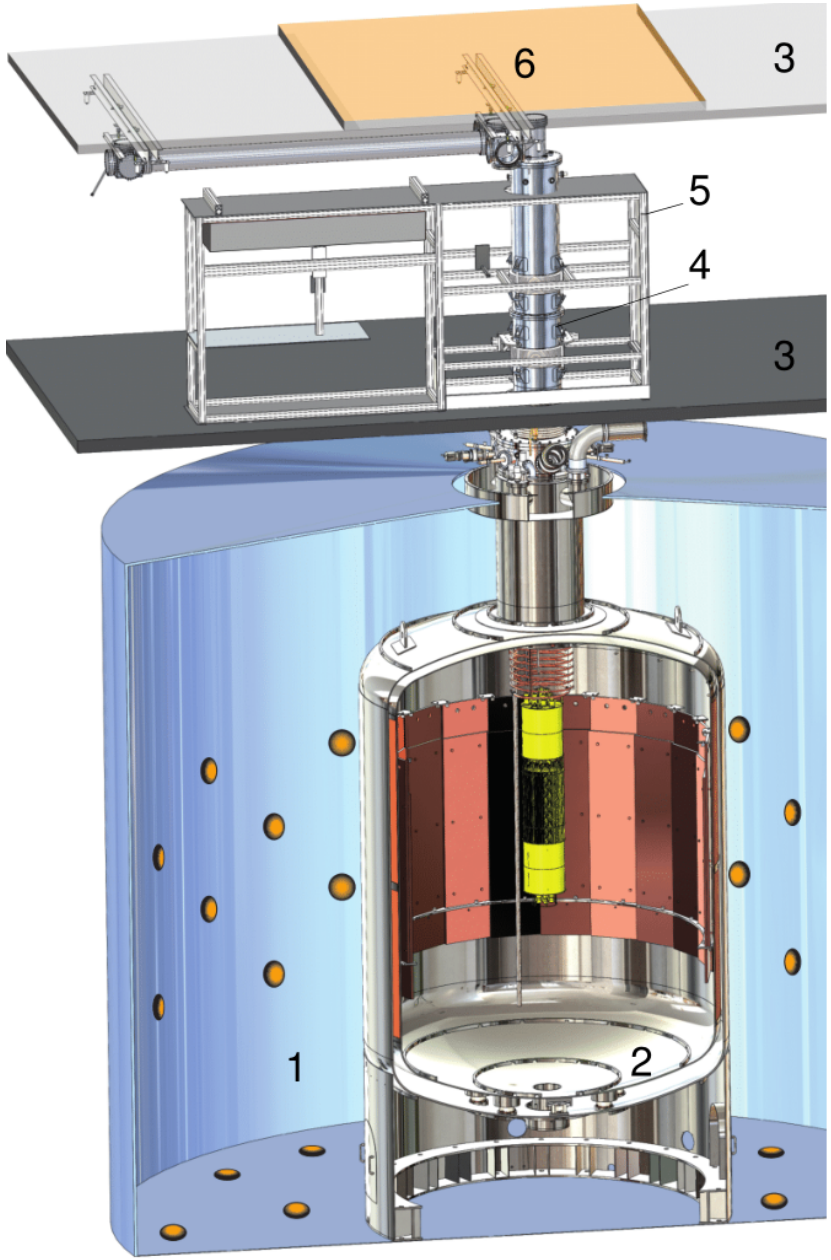
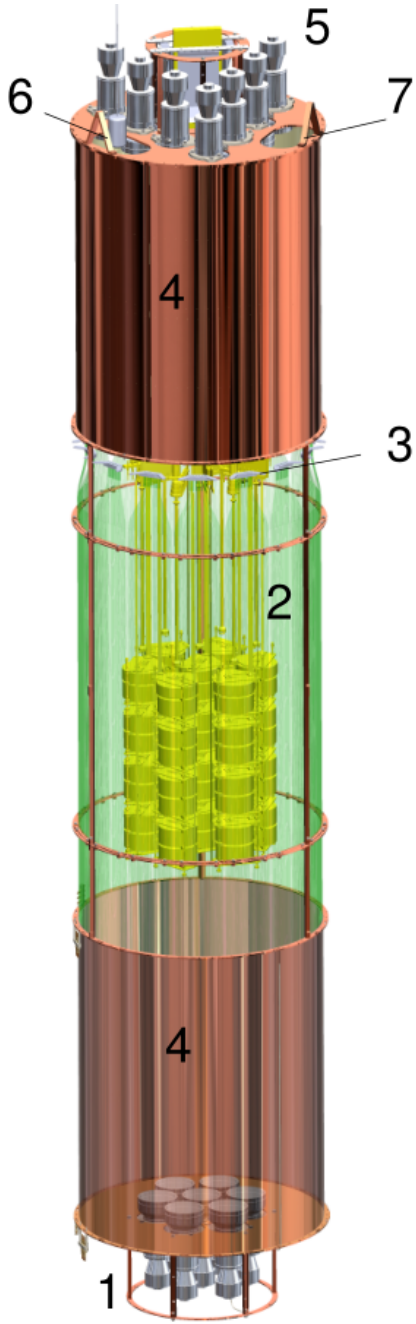
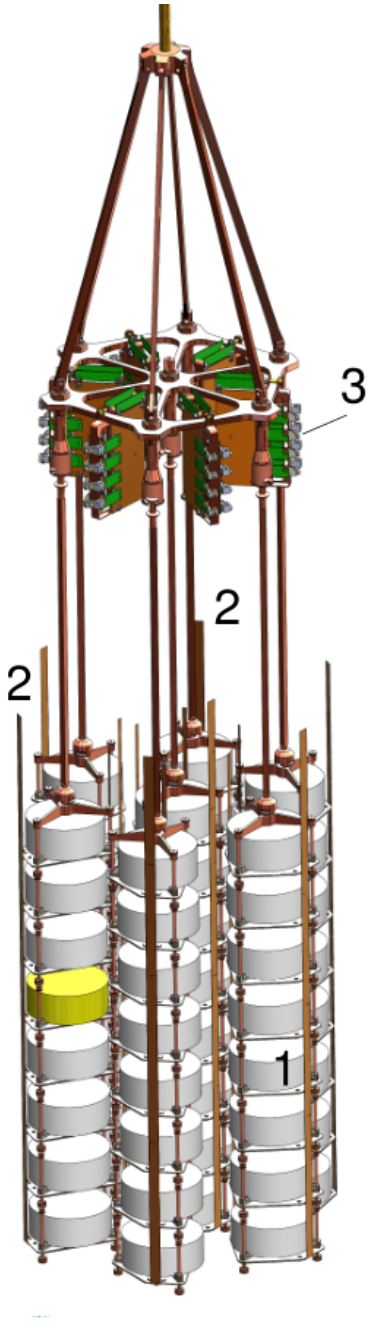
- **Ger**manium **D**etector **A**rray searches for neutrinoless double beta decay ($0\nu\beta\beta$) of ^{76}Ge.
- Ge detectors enriched in ^{76}Ge act simultaneously as **detector** and **source** material.
- Located underground Laboratori Nazionali del Gran Sasso (LNGS) with 1400 m overburden.
- Surrounded by water tank with photomultipliers (PMTs) to detect **Cherenkov light** induced by muons.

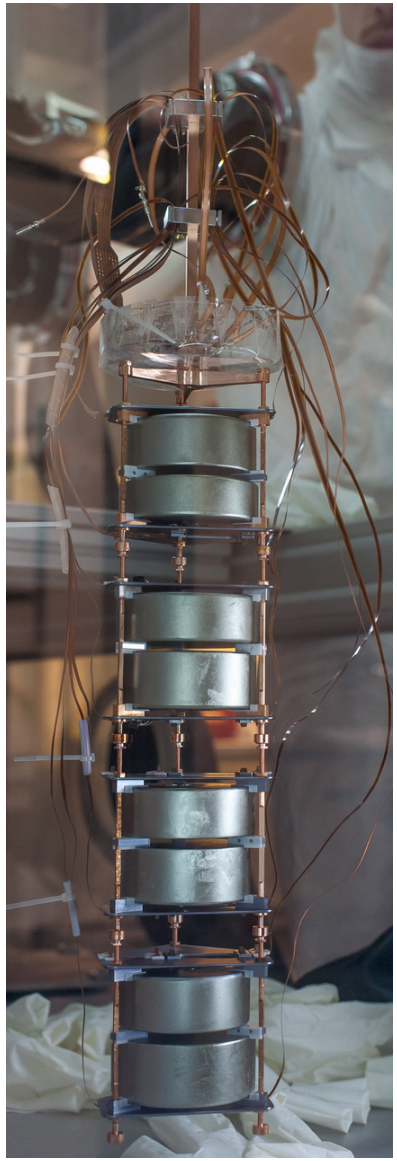


Inside the cryostat: LAr and Ge strings

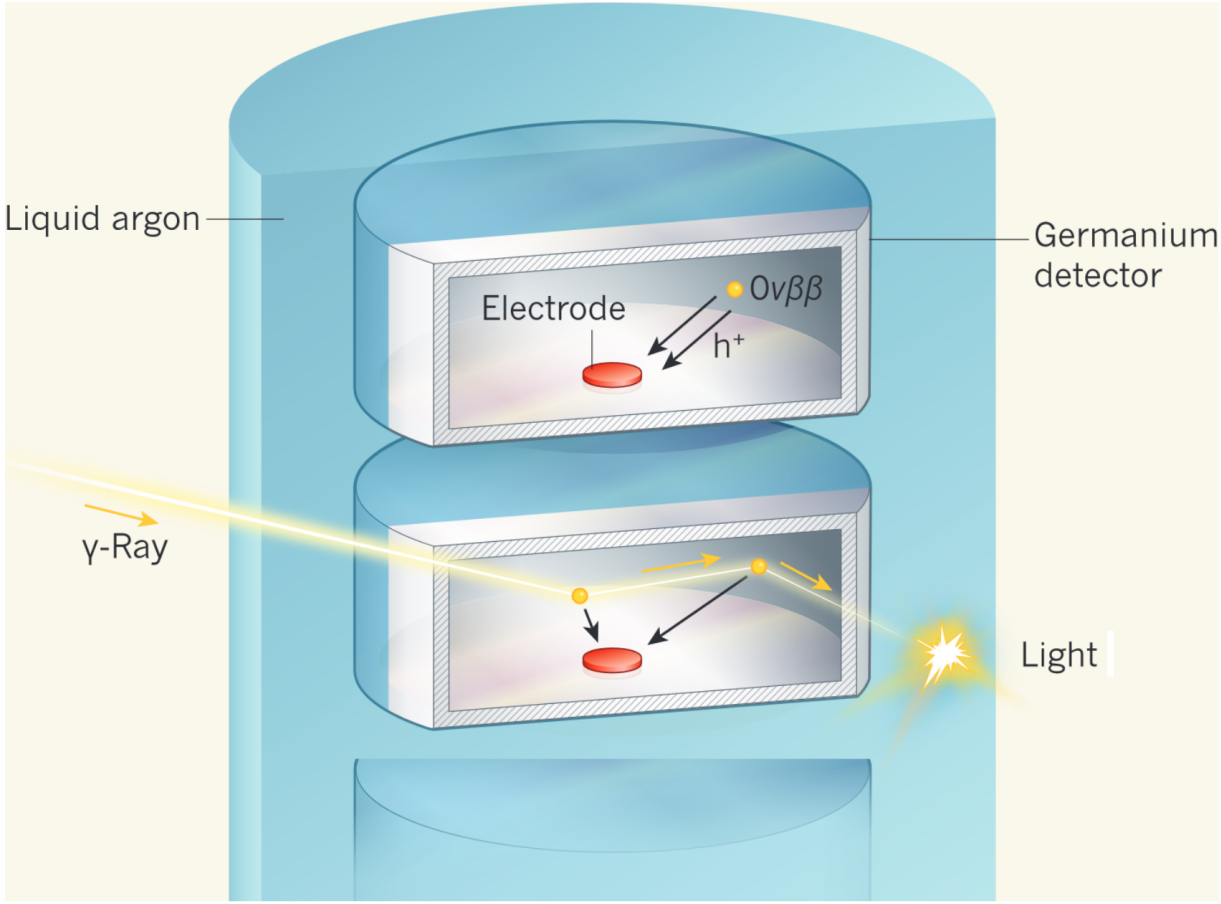




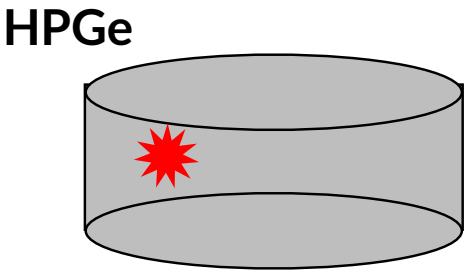
- Cryostat filled with **liquid argon** (LAr) for cooling and shielding.
- PMTs detect induced LAr scintillation light to **veto** background events.
- Ge detectors arranged on 7 strings and directly submerged in LAr.

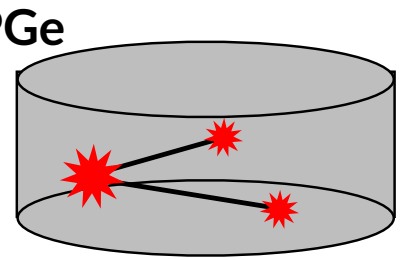


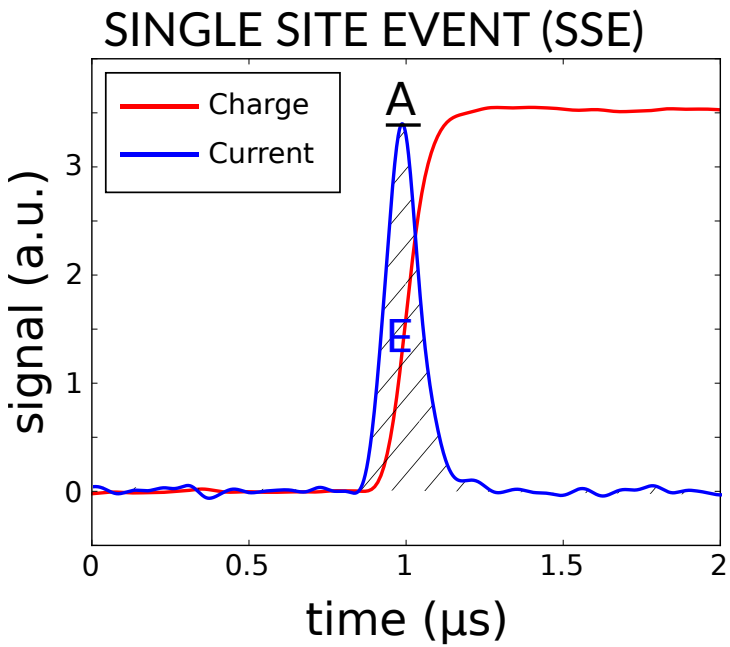
- Incident particles ionise the germanium proportionally to energy producing **charge carriers**.
- Charge carrier drift **induces** charge signal on readout electrode.
- Signal discerns event topologies by:
  - Resolved energy.
  - **Pulse Shapes**.

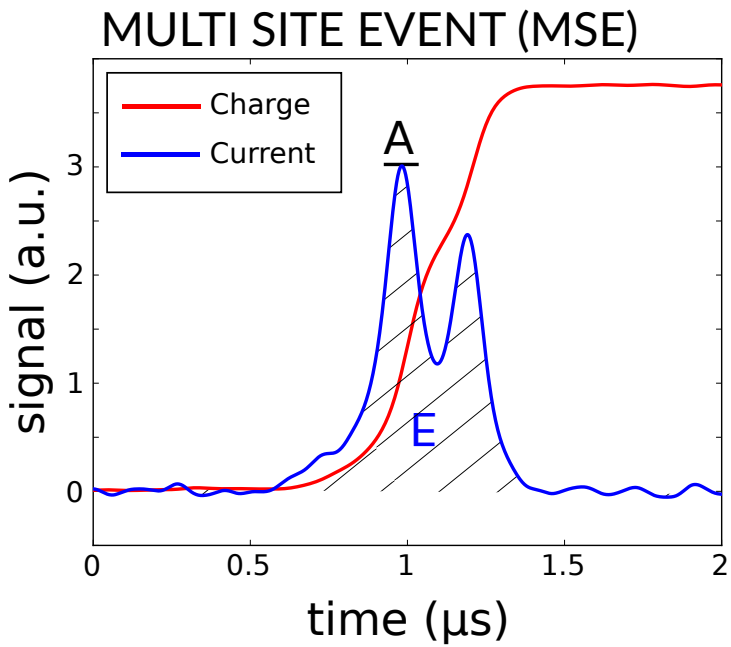


- Pulse Shape differences: **Single** location ($0\nu\beta\beta$) and **multiple** location (γ).



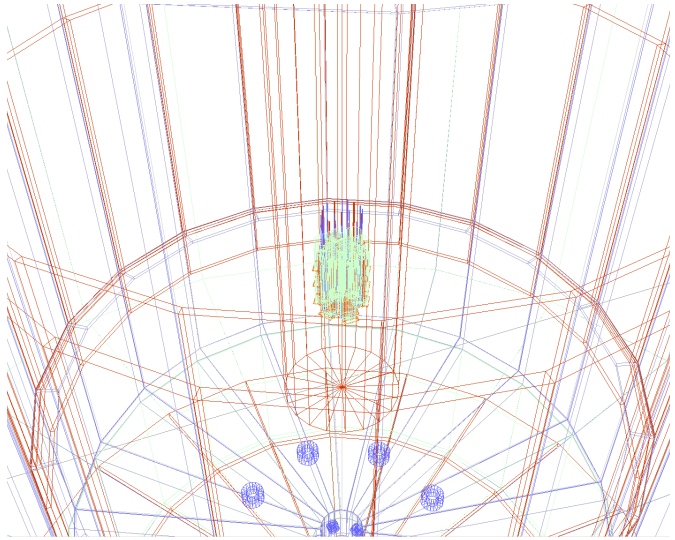




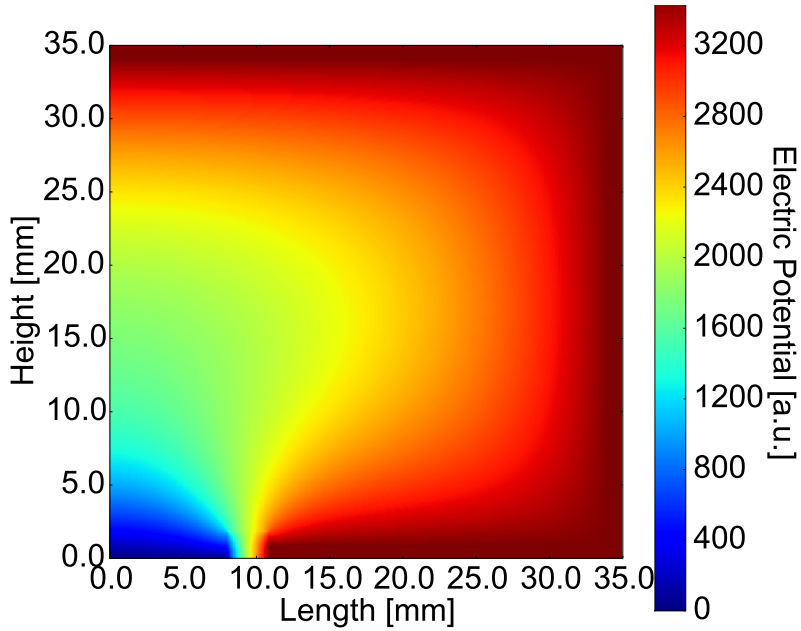


- **Goal**: Simulate induced charge signal of Ge detectors.
- **Consistent treatment**: Simulated & measured signal through same pulse shape selection criteria – e.g. pulse shape discrimination (PSD).

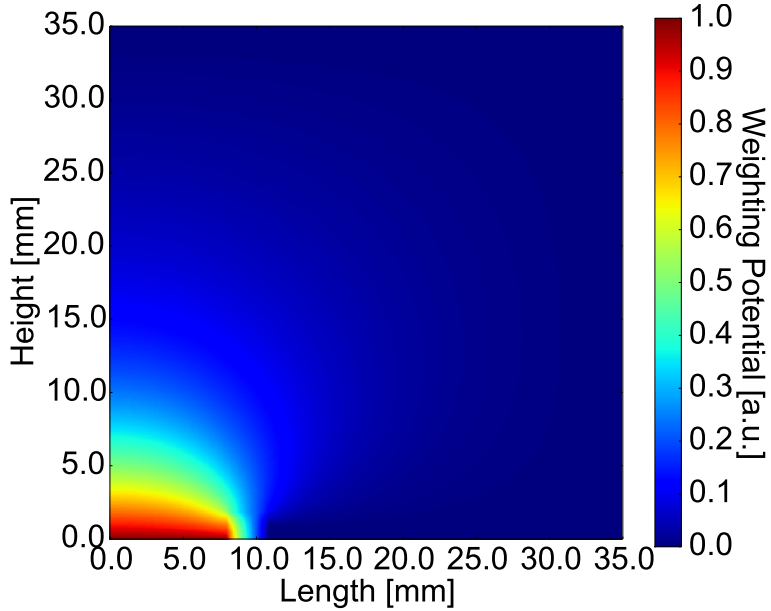
- Interactions and energy depositions first simulated for entire Ge detector array with **Geant4**.



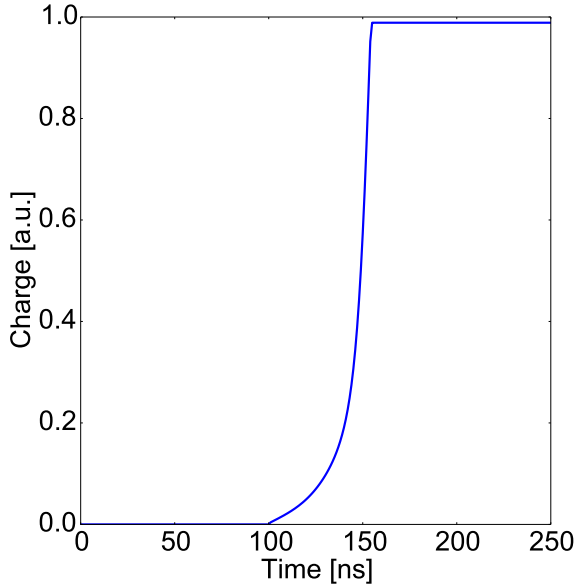
- Hit positions placed inside **simulated** Ge detector electric fields.
- Path of charge carriers depends on **electric potential** inside the detector.



- Induced charge on readout electrode: **Shockley Ramo Theorem**.
  $I = -q \cdot \nabla\phi(x) \cdot v_{drift}$
- Simulation of **weighting potential**. Readout electrode set to unit potential.



- Resulting simulated induced charge pulses in **identical** data format to physics data.
- Can thus be run through identical GERDA **analysis chain**.

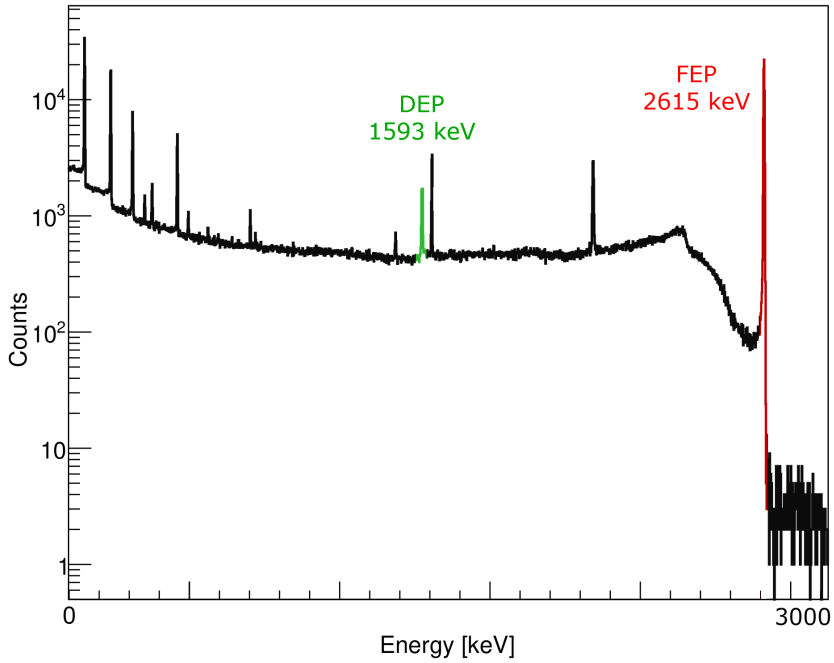


Future Work

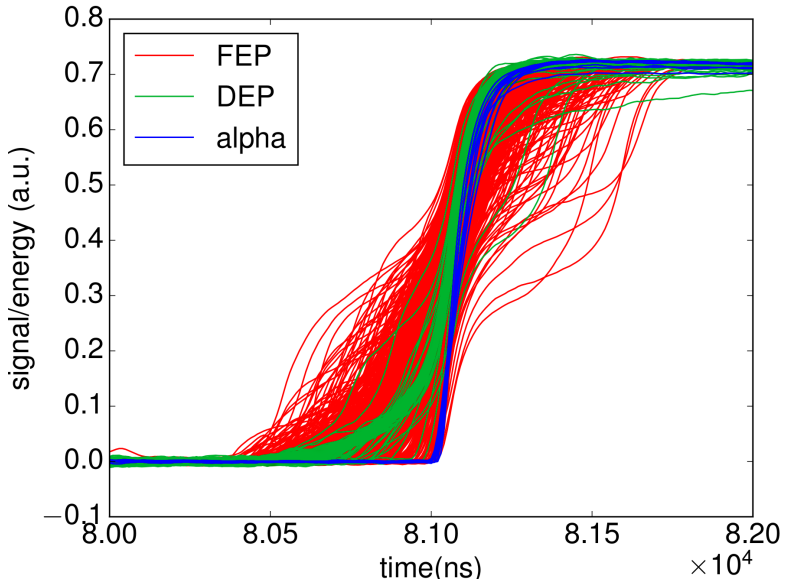
Convolution of simulated pulse shapes with electronics response

$\rightarrow$ Direct **comparison** to real data.

- **Real data** energy spectrum of ^{228}Th calibration:
  - ^{208}Tl Full energy peak (FEP)
  - ^{208}Tl Double escape peak (DEP).

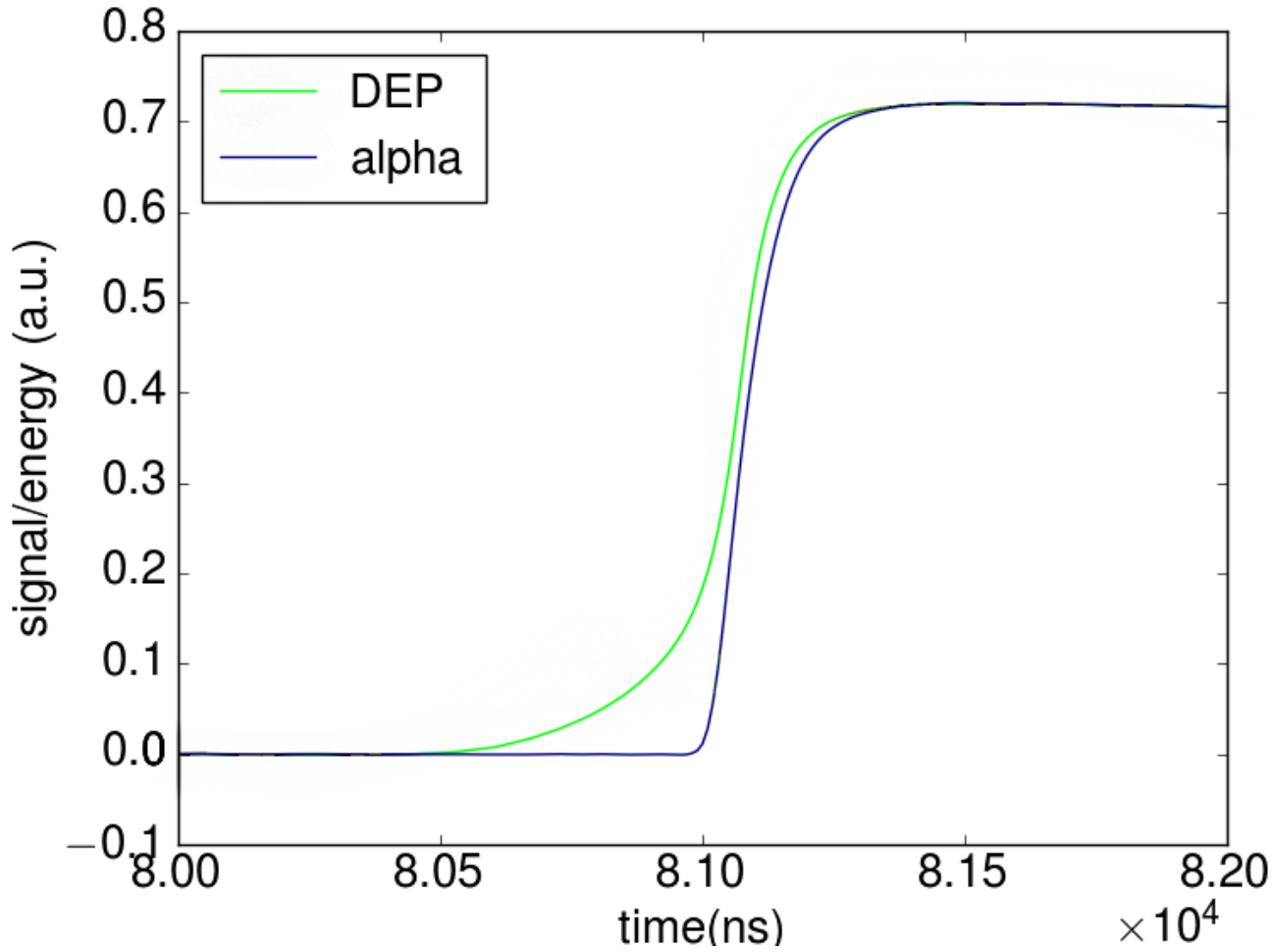


- Stacked real data pulses at FEP & DEP $\rightarrow$ **Characteristic** shape at DEP and α.



- Compare **real** characteristic average pulses shapes with **simulations**.

  $\rightarrow$ **Validate** pulse shape simulations.



Goal

- Complete pulse shape simulation chain with electronic response.

Applications

- Determining PSD **efficiencies**,.
- Possibility to develop **new** PSD methods.
- Obtain **improved** background model.
- Future detector **development**.