



The search for Double-Beta Decay

Speaker: Prof. Riccardo Brugnera

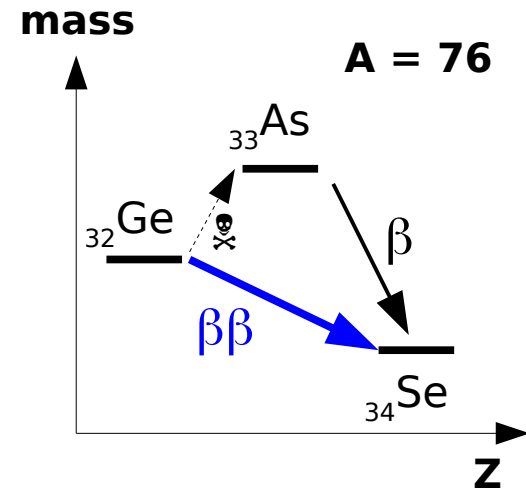
double-beta decay

- ◆ double-beta decay with two neutrinos emission ($2\nu\beta\beta$)

$$(A, Z) \rightarrow (A, Z+2) + 2e^- + 2\bar{\nu}_e$$

2nd order process, observed, $T_{1/2} \sim 10^{19}$ - 10^{24} yrs

$${}^{76}\text{Ge}: T_{1/2} \sim 10^{21} \text{ yrs } (*)$$



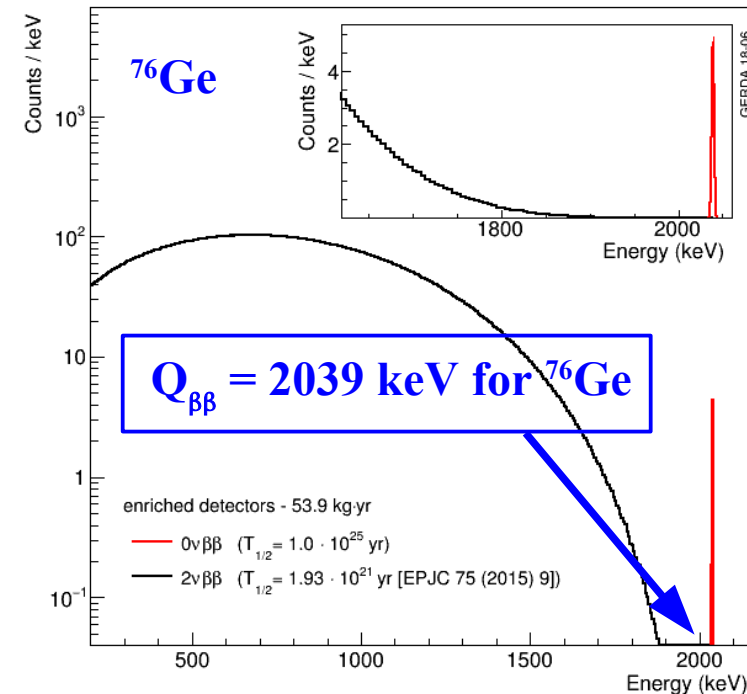
- ◆ double-beta decay without neutrinos emission ($0\nu\beta\beta$)

$$(A, Z) \rightarrow (A, Z+2) + 2e^-$$

forbidden by SM: $\Delta L = 2$, new physics,
 $T_{1/2} > 10^{26}$ yrs (*)

signatures for $0\nu\beta\beta$ decay:

(*) age of the Universe $\sim 10^{10}$ yrs



motivations for $0\nu\beta\beta$ decay searches

- ◆ by far the most sensitive test of lepton number violation $\Delta L = 2$
- ◆ more *physics beyond standard model*
 - the process stands on equal footing with baryon number violation (i.e. p decay)
 - an help to understand the present *asymmetry between matter and antimatter*
 - important to understand the origin of the *neutrino mass*
- ◆ only way to determine if neutrino is its own antiparticle (Dirac or *Majorana particle*)
- ◆ would provide access to *absolute neutrino mass scale*

extremely well motivated from the theoretical point of view!

... the dark side of the moon: the experimental search

Its experimental search is extremely difficult:

- ◆ only few isotopes (even-even nuclei) can decay $2\nu\beta\beta$ and also $0\nu\beta\beta$
- ◆ the decay is very very rare (never seen!): S/N very bad
- ◆ the energy released is small (2-3 MeV): energy region dominated by the natural radioactivity

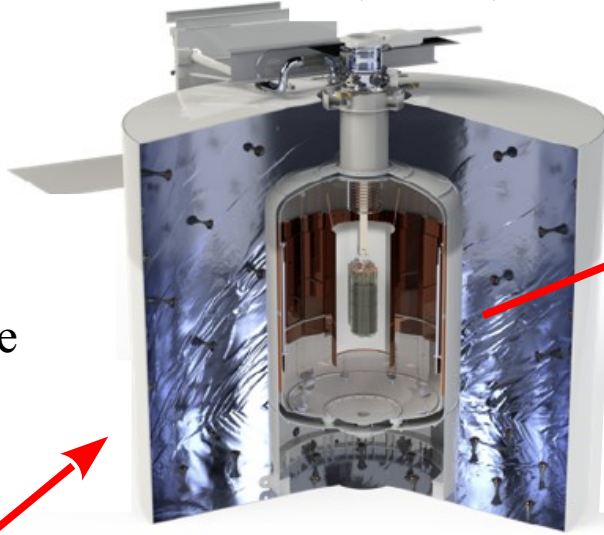
Requirements of the experiment:

- ◆ to be built underground (cosmic silence)
- ◆ made by extremely radio-pure material
- ◆ good or very good energy resolution
- ◆ ability to separate with high efficiency background events from signal candidates
- ◆ large amount of double-beta active nuclei
- ◆ high efficiency

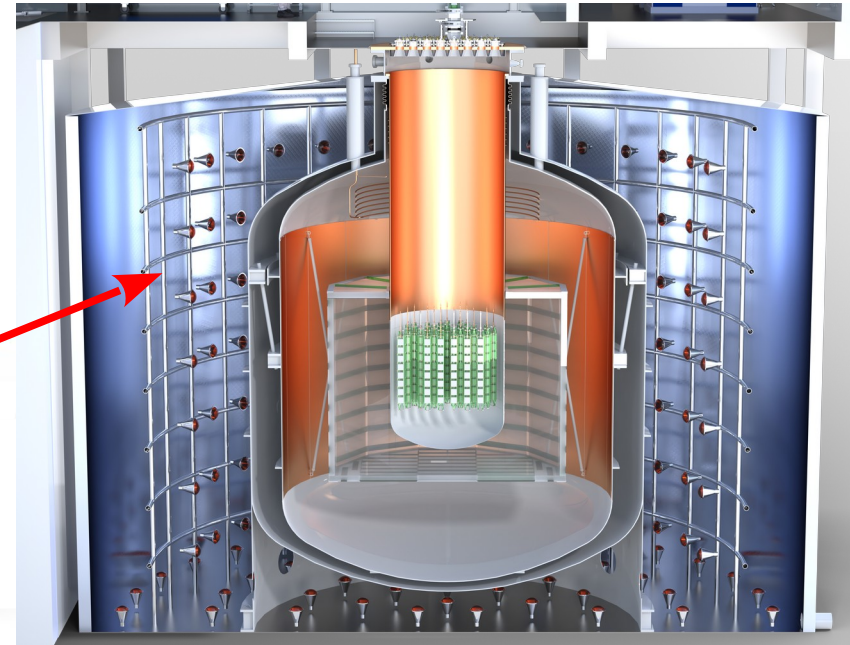
LEGEND experiment: ^{76}Ge the best answer

LEGEND-200 (LNGS)

2023-2029
~200 kg of ^{76}Ge
 $T_{1/2} > 10^{27}$ yrs

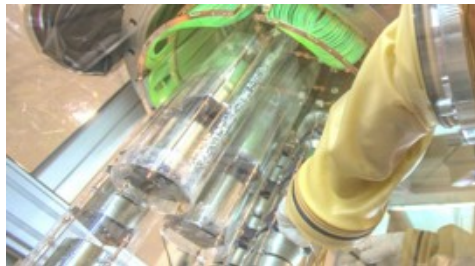


LEGEND-1000 (2030)



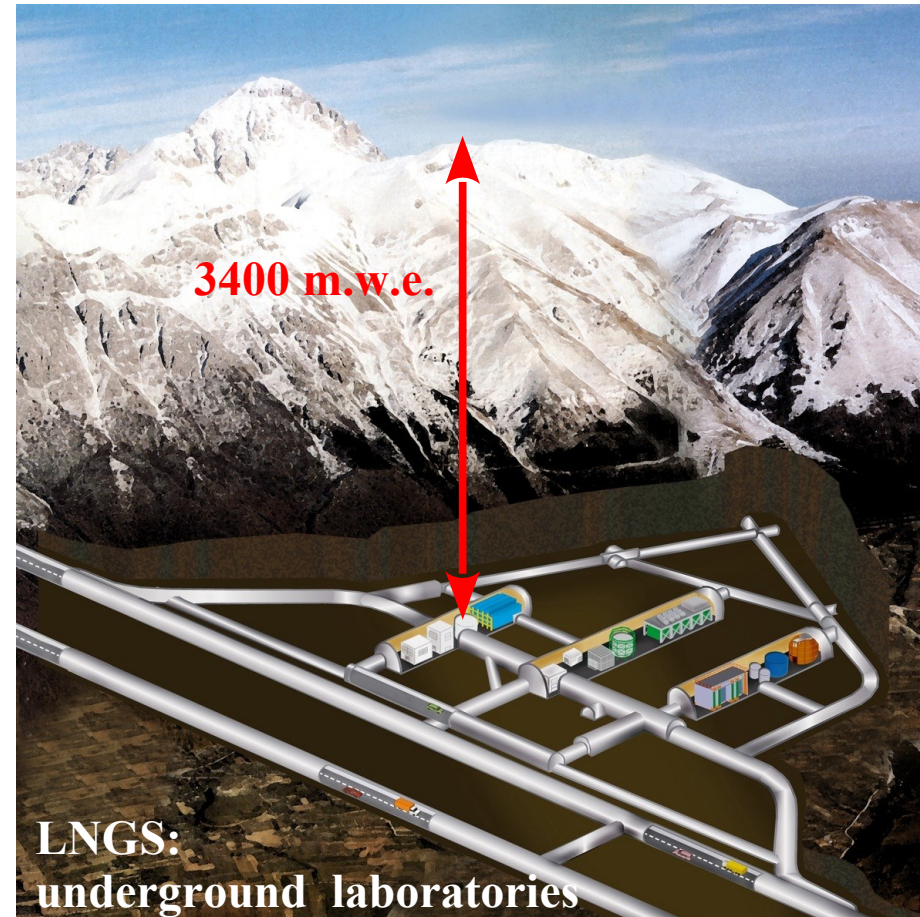
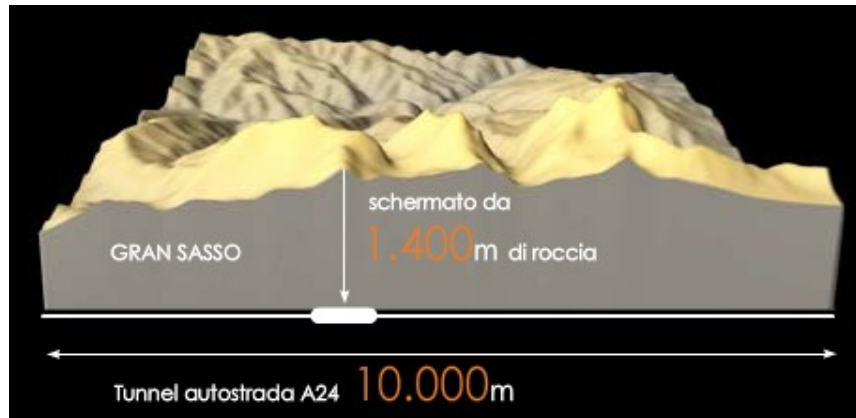
2030 - ...
~ 1000 kg of ^{76}Ge
 $T_{1/2} > 10^{28}$ yrs

GERDA (LNGS)

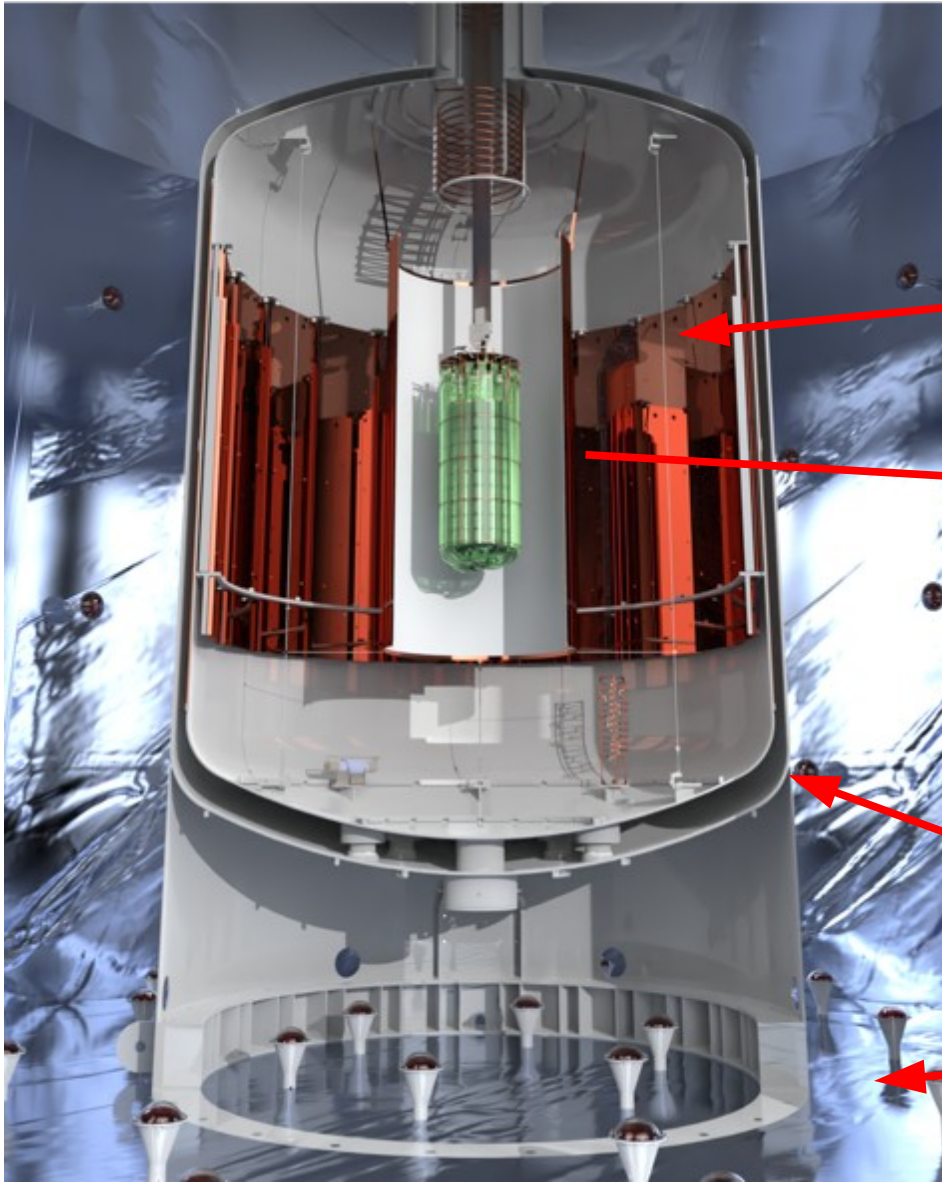


2011-2019
~ 40 kg of ^{76}Ge
 $T_{1/2} > 10^{26}$ yrs

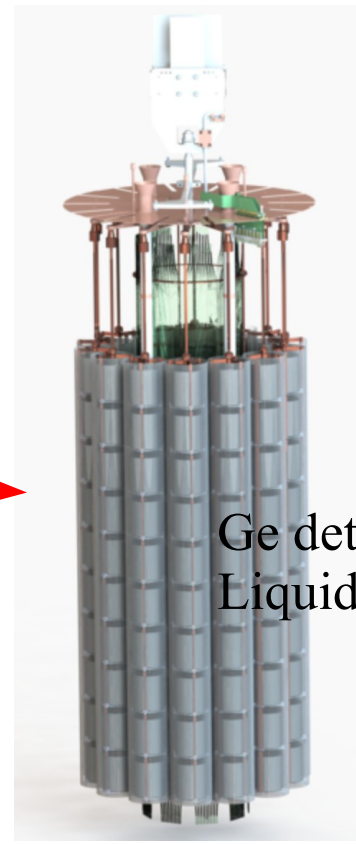
A closer look at LNGS



A closer look at LEGEND-200



copper
slabs



Ge detectors +
Liquid Argon Veto

cryostat filled with liquid
argon

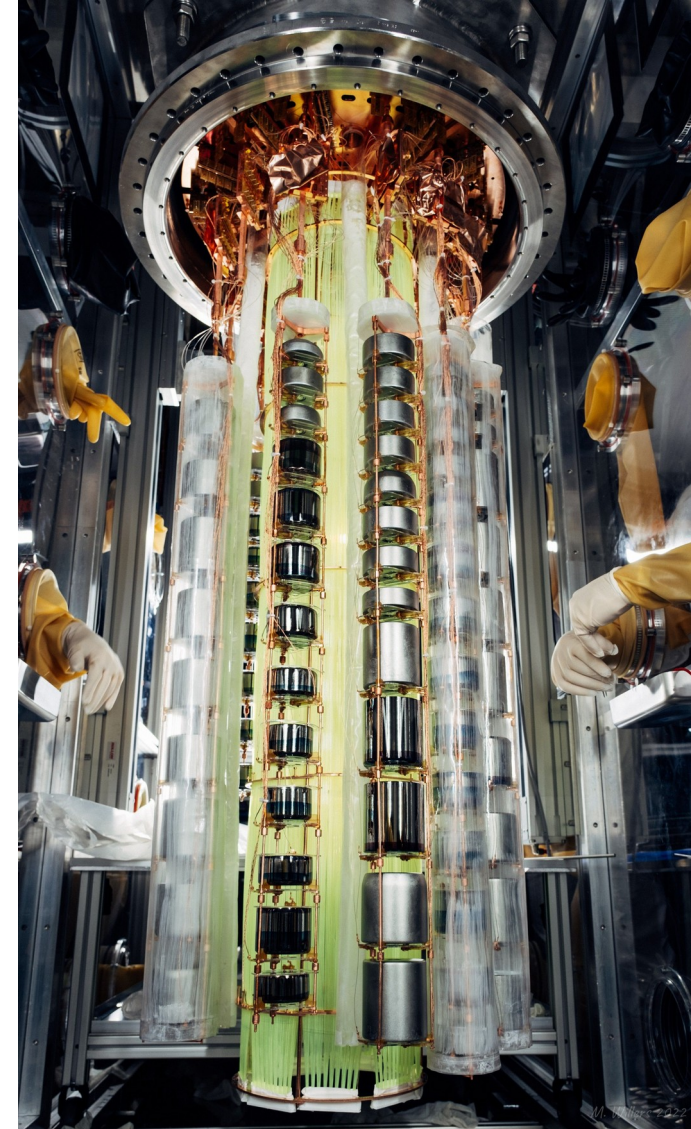
instrumented water tank
to suppress cosmic rays

A closer look at LEGEND-200



Inside the Water Tank

In the glove box of the clean room: assembly of the Ge diodes strings

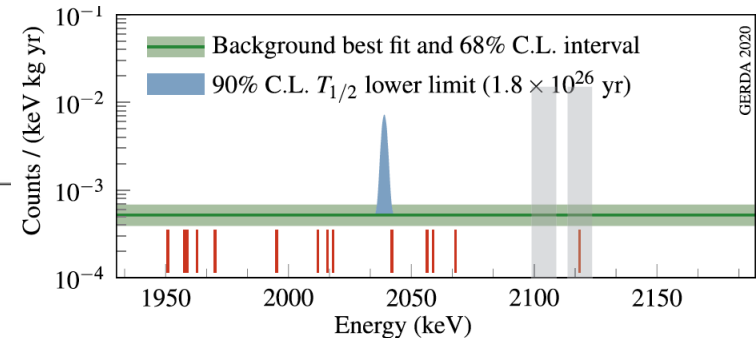
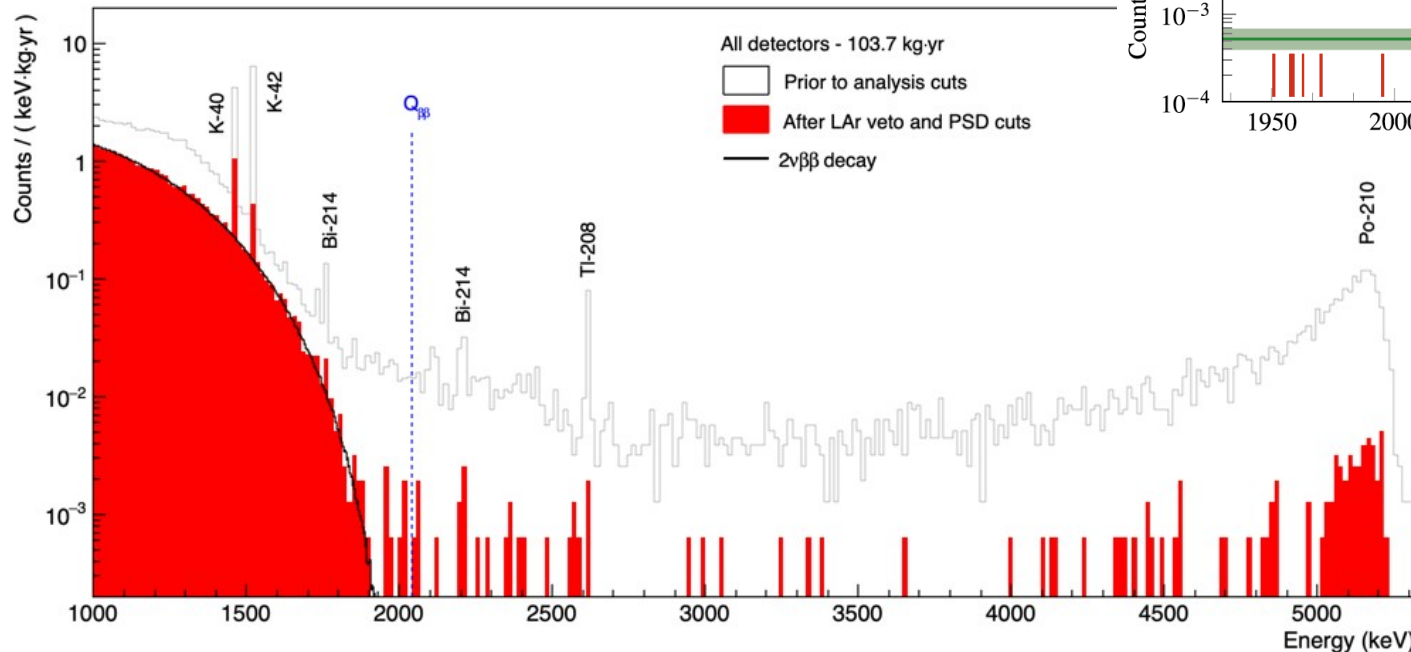


What we can offer to the students

bachelor and
master thesis

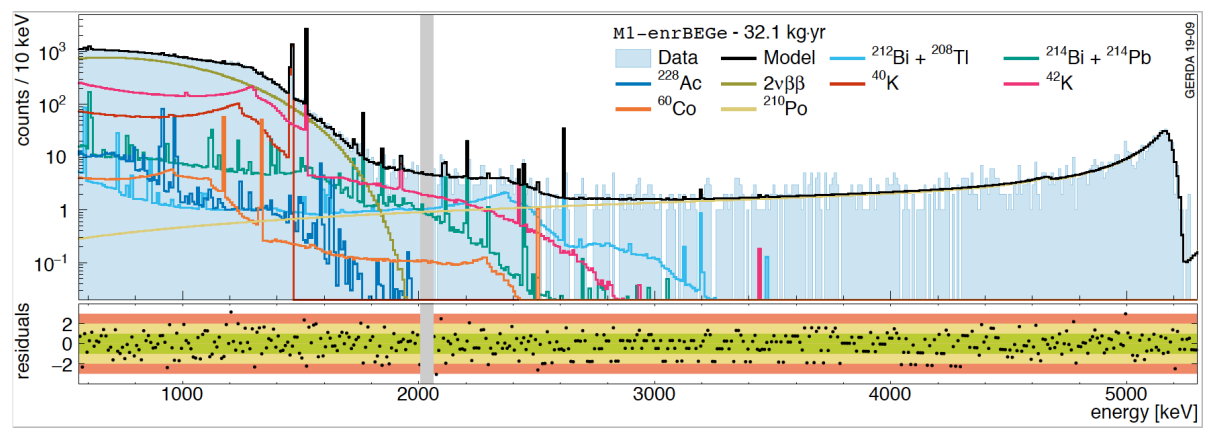
Physics analysis:

- search for $0\nu\beta\beta$ decay
- measurement of the half-life of $2\nu\beta\beta$ decay
- search for the excited states of $2\nu\beta\beta$, $0\nu\beta\beta$ decays
- search for Majorons, sterile ν , CPT violations, ... (distortion of the $2\nu\beta\beta$ spectrum)
- search for exotic physics at low energy (SuperWimps, tri-nucleon decays, electron decay, solar axions, fractionally charged cosmic-rays, ...)
- ...

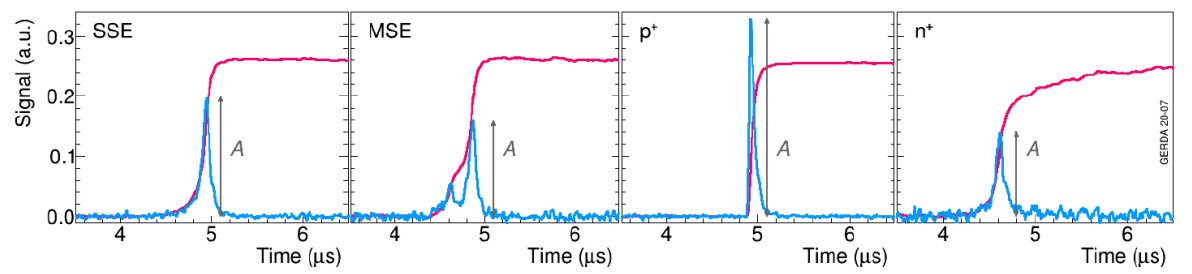


What we can offer to the students

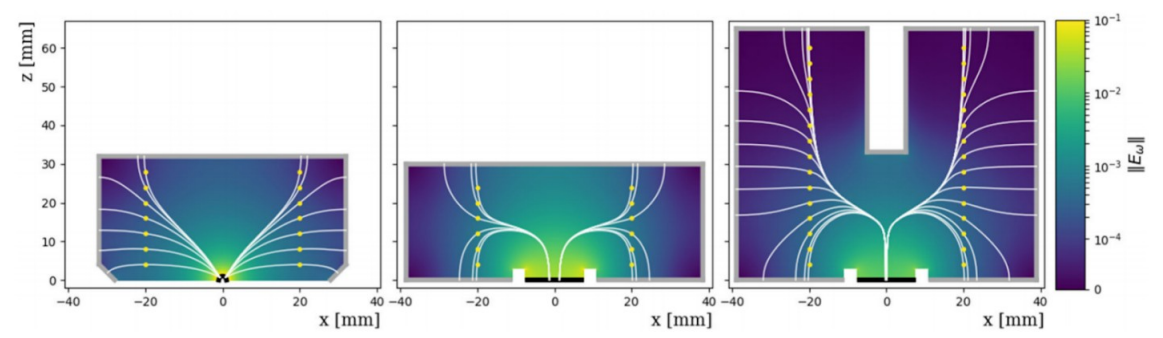
bachelor and master thesis



- background model: understanding of the collected data



- improvements of the pulse shape discrimination analysis



- study of the characteristics of the Ge detectors (depletion voltage, energy resolution, dead layer, ...)

-

Padova members



Riccardo
Brugnera



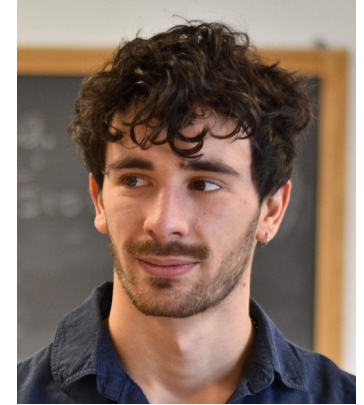
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Double-Beta Decay

12

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