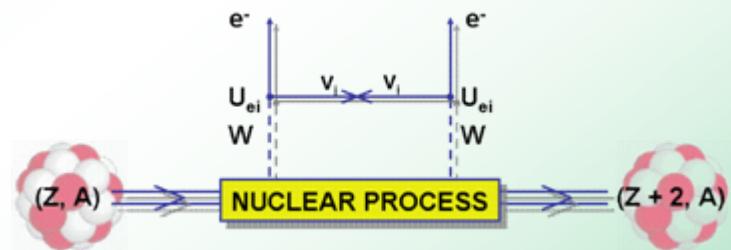
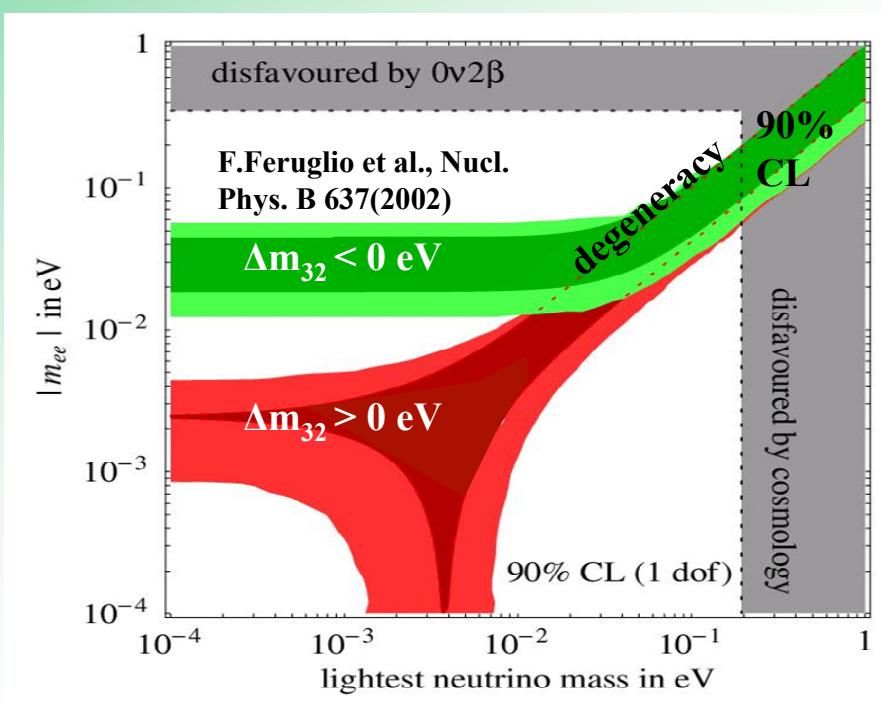


Towards a ton scale $0\nu\beta\beta$ HPGe experiment

Béla Majorovits
Max Planck Institut für Physik



- Sensitivity requirements
- Experimental strategies:
- Avoid Background
- Recognize Background
- Technological challenges

Sensitivity requirements

Figure of merit for a limit sensitivity:

b>0 :

$$T_{1/2} \propto M_{\text{nucl}} a \varepsilon$$

$$\sqrt{m t}$$

$$b \delta E$$

b=0 :

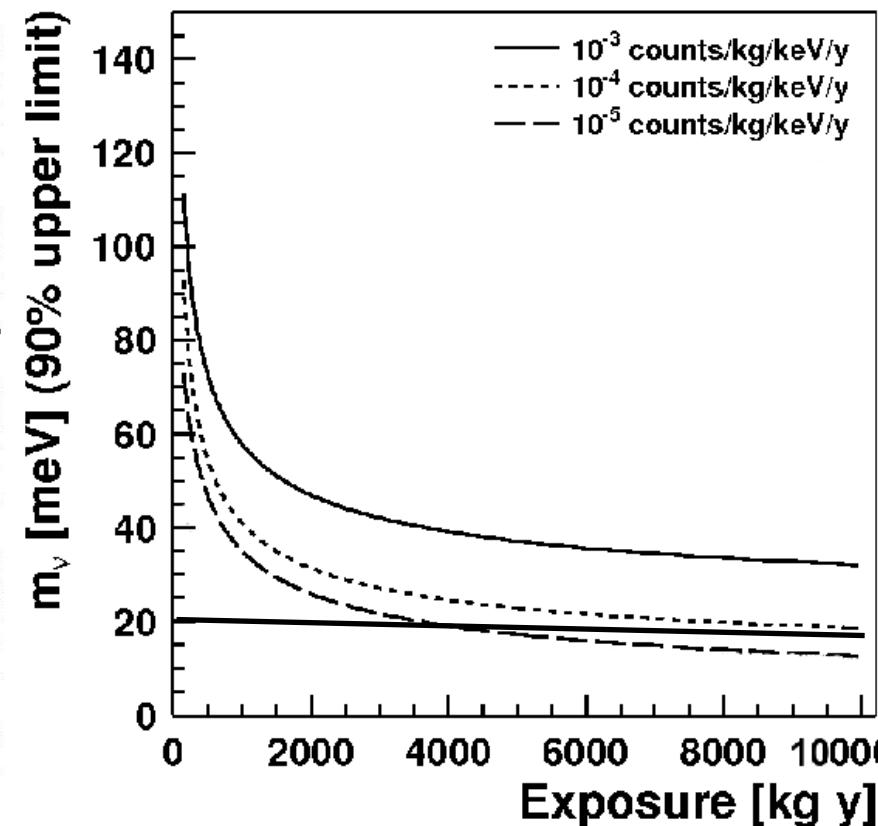
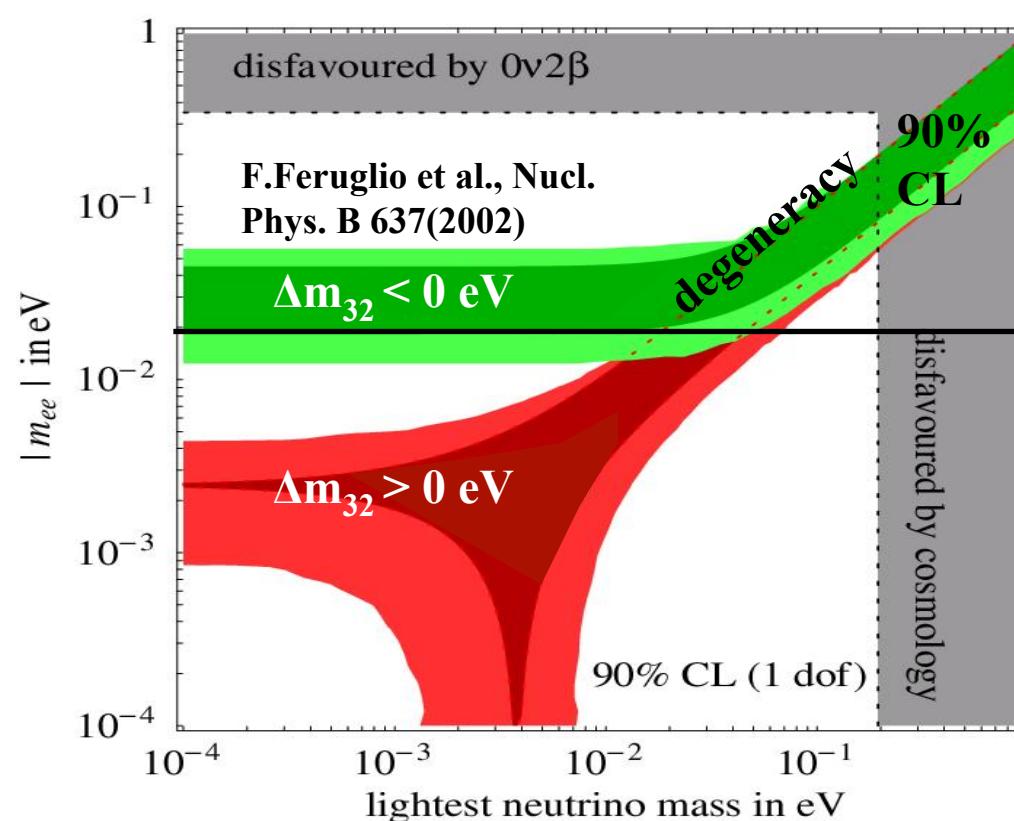
$$T_{1/2} \propto M_{\text{nucl}} a \varepsilon m t$$

M_{nucl}	Nuclear matrix element	Select Isotope
b	background rate of the experiment	Minimize and select material
a	enrichment of isotope under consideration (< 1.0)	Use isotope with high natural abundance or enrich material
m	active target mass of the experiment	Increase target mass
ε	signal detection efficiency (<1.0)	Source =! Detector
δE	Energy resolution	Use high resolution spectroscopy
t	Measuring time (< 20y)	

→ Experimental approach: Improve EXPOSURE and BACKGROUND

Sensitivity requirements:

What exposure and background do we need?



→ To disentangle the hierarchies: 10meV sensitivity

→ 10^{-5} Counts/(kg keV y) & ton scale of ^{76}Ge !

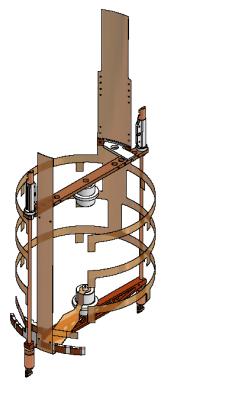
Experimental Strategies

Avoid and/or recognize background:

Avoid Background:

Strategies for background reduction:

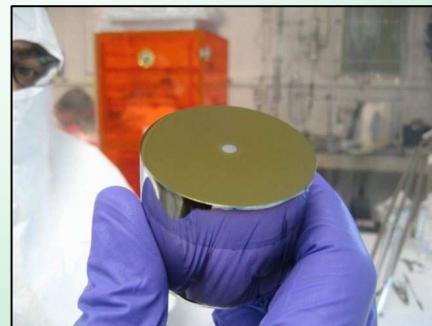
- Work and install in proper surrounding (underground lab)
- Minimize materials close to detectors
- Understand contributions and select appropriate materials (Monte Carlo, material R&D, and screening)



Recognize Background:

Build “intelligent” detectors: Use event topologies

- Detectors with improved pulse shape properties
- Segmented detectors
- Combination of the two?
- External Anti-Compton Veto



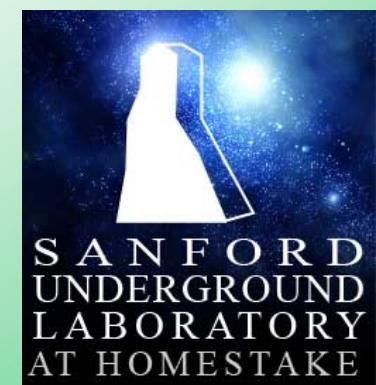
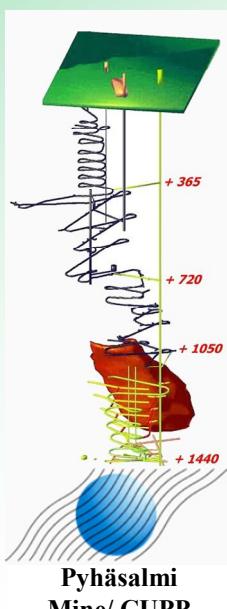
Experimental Strategies

Avoid background:

Proper underground laboratory with infrastructure:

Ideal would be: Dedicated cavern:

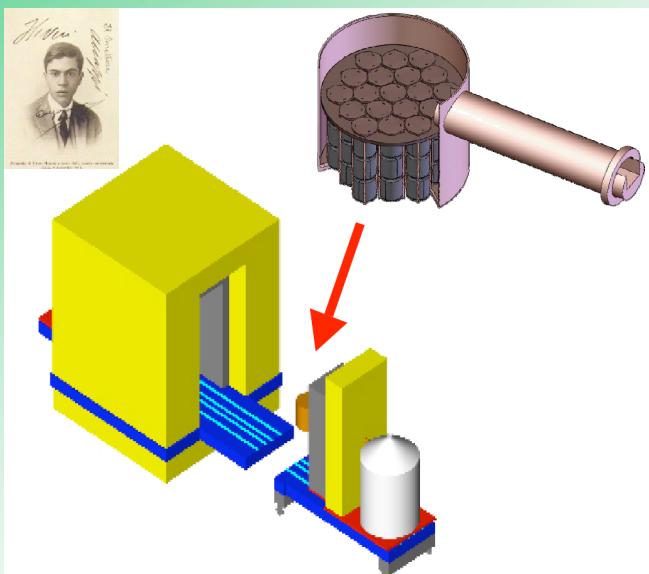
- Actively shielded laboratory hall
- Surrounded by water to remove U/Th and neutrons from (α, n)
- Equipped with muon veto system
- Inside lab only screened materials to avoid U/Th
- Homogeneous overburden



Experimental Strategies

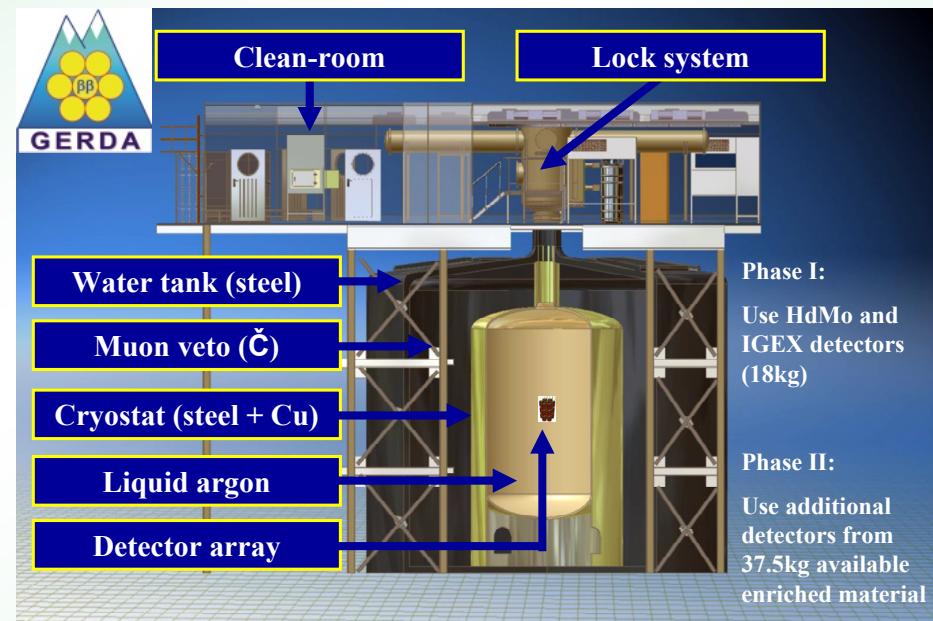
Avoid background:

MAJORANA strategy:



Control radiopurity of surrounding
→ electro-form copper underground
→ Shield and vacuum cryostat made
out of copper

GERDA strategy:



Remove low-Z material from vicinity
of detectors
→ Cryogenic liquid as shield
→ “naked” HPGe detectors in LAr

Majorana and GERDA will merge for the ton scale experiment

Better technology wins

Experimental Strategies

Avoid background:

α contaminations (^{210}Pb , ^{210}Bi) seen in Heidelberg Moscow, Edelweiss, CDMS experiments. Due to HPGe etching during production?

- What are the ^{210}Pb and ^{210}Po removal efficiencies of etching?
- What are the ^{210}Pb and ^{210}Po deposition rates on HPGe during etching process?



Load one disc with ^{222}Rn and measure removal efficiency for ^{210}Pb and ^{210}Po

Load etching solution with Radon and measure ^{210}Pb deposition rate

Etching solution effectively removes ^{210}Pb and ^{210}Po contaminations from HPGe, but deposition rate of ^{210}Pb on HPGe surface is not negligible.

→ Keep your etching solution clean!

→ R&D needed for clean production line!

Experimental Strategies

Avoid background:

natGe → Enrichment

Removes ^{68}Ge .
How efficiently?

→ R&D,
Underground?



zone
refinement &
Crystal pulling

Removes
cosmogenic
isotopes but ^{68}Ge
→ Underground



Be aware:

1 ^{68}Ge nucleus per kg → 10^{-5} Counts/(kg keV y)

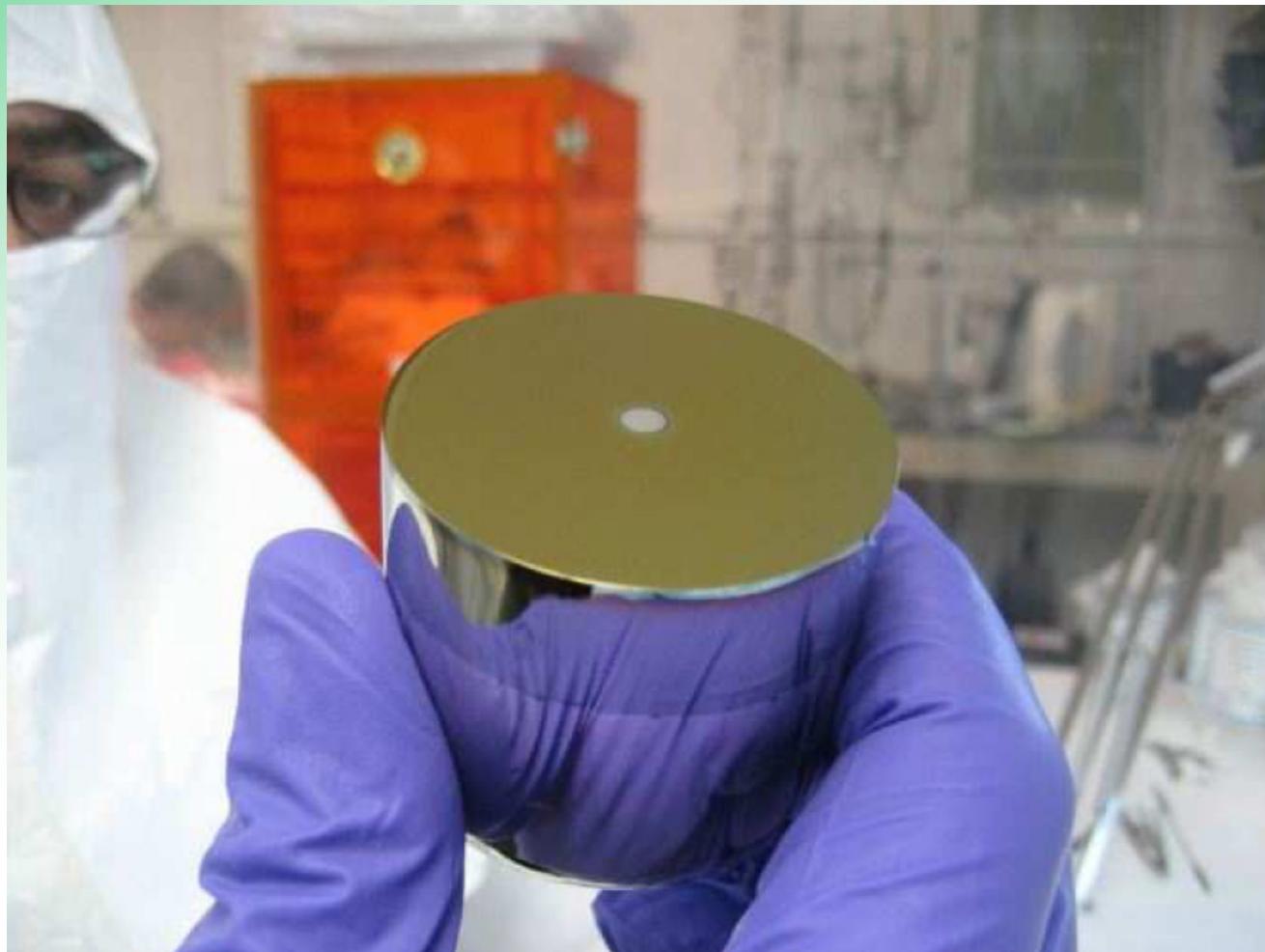
Expected production of ^{68}Ge from ^{enr}Ge above ground:

~10 nuclei per kg per day!

- Need enrichment underground(?) Or can we shield during transport?
- Need to zone refine AND pull crystals underground.
- Avoid exposure above ground
- Best in the same facility as the planned experiment.

Experimental Strategies

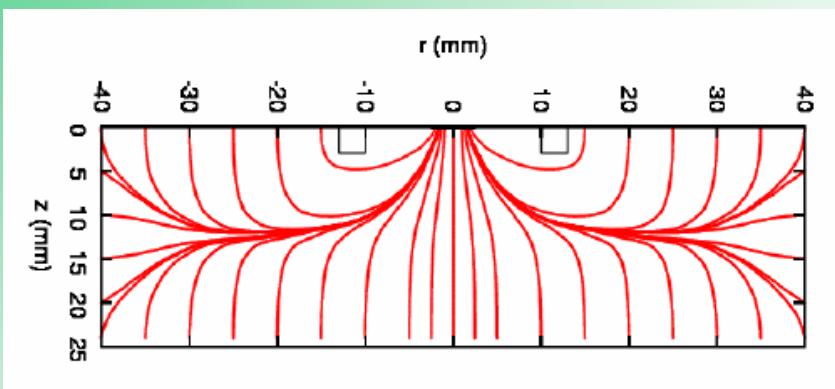
Recognize background:



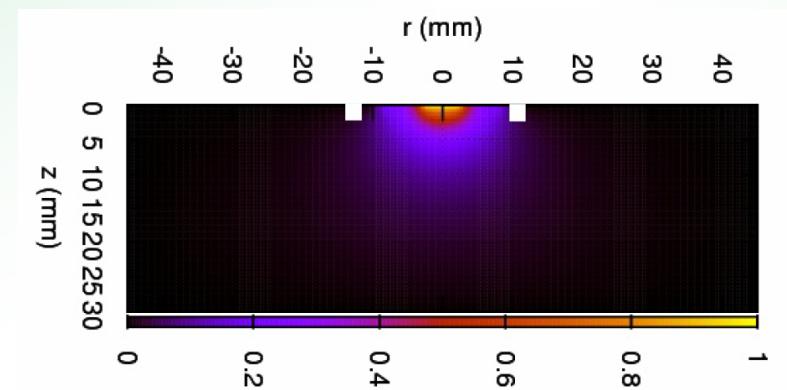
**Point contact detectors have superior pulse shape
characteristics**

Experimental Strategies

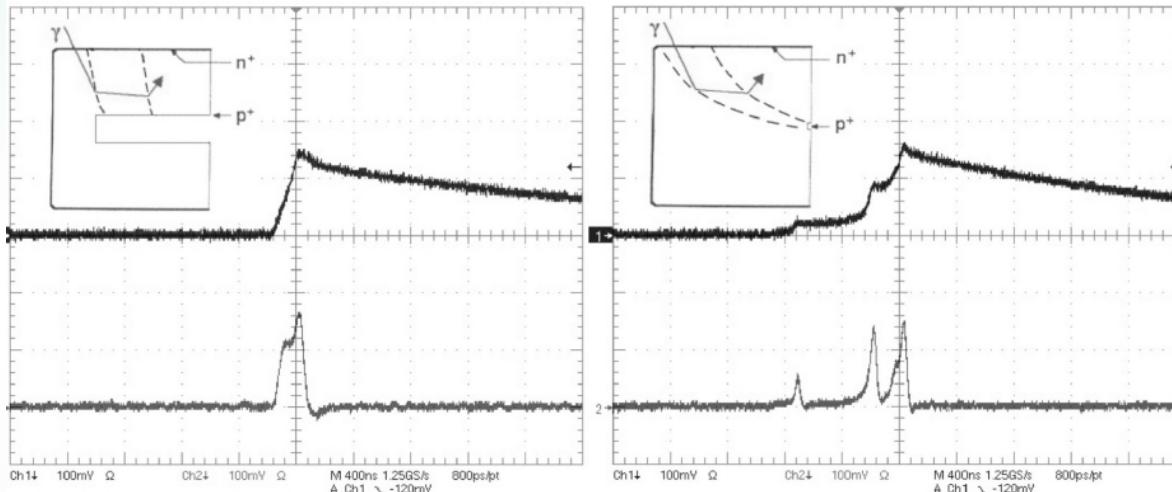
Recognize background:



Drift paths in point contact detectors are longer



Weighting potential is large around point contact and small in the rest of the detector

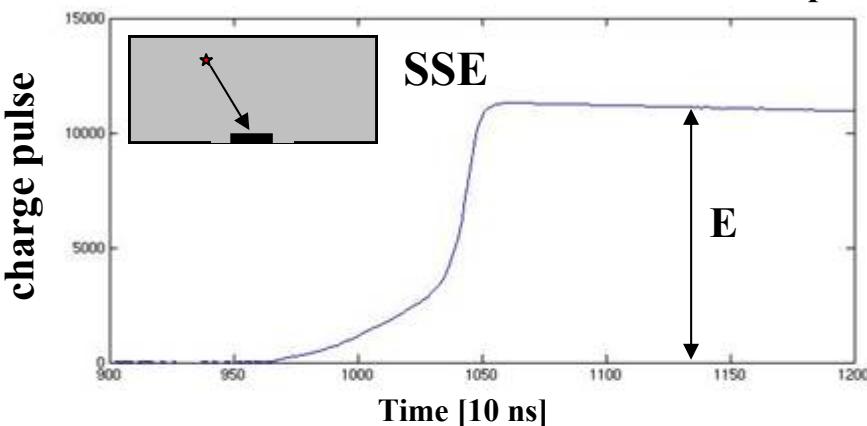


→ Very pronounced structures for individual energy deposits

Experimental Strategies

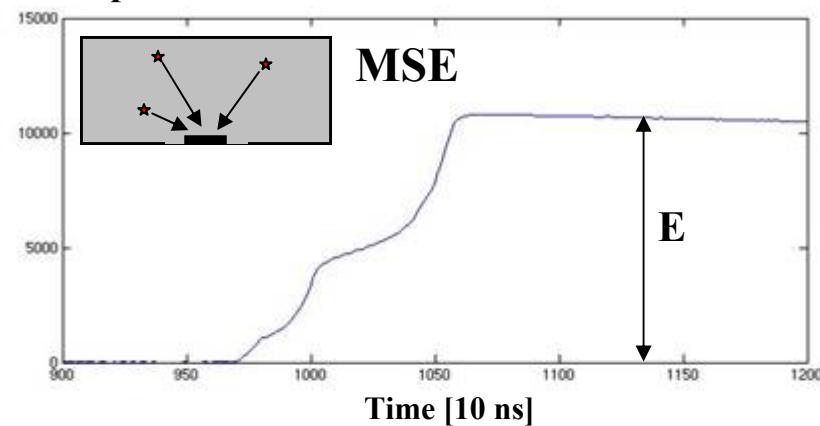
Recognize background:

typical electron event

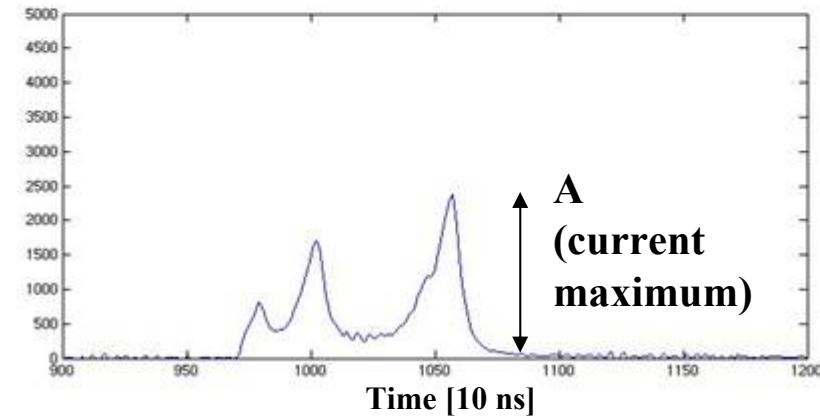
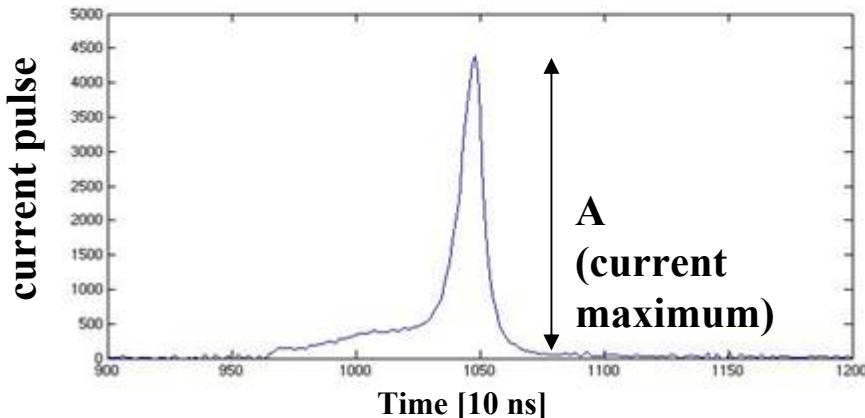


raw preamplifier output:

typical gamma-ray event



after differentiation:



$A / E \rightarrow$ discrimination parameter

Experimental Strategies

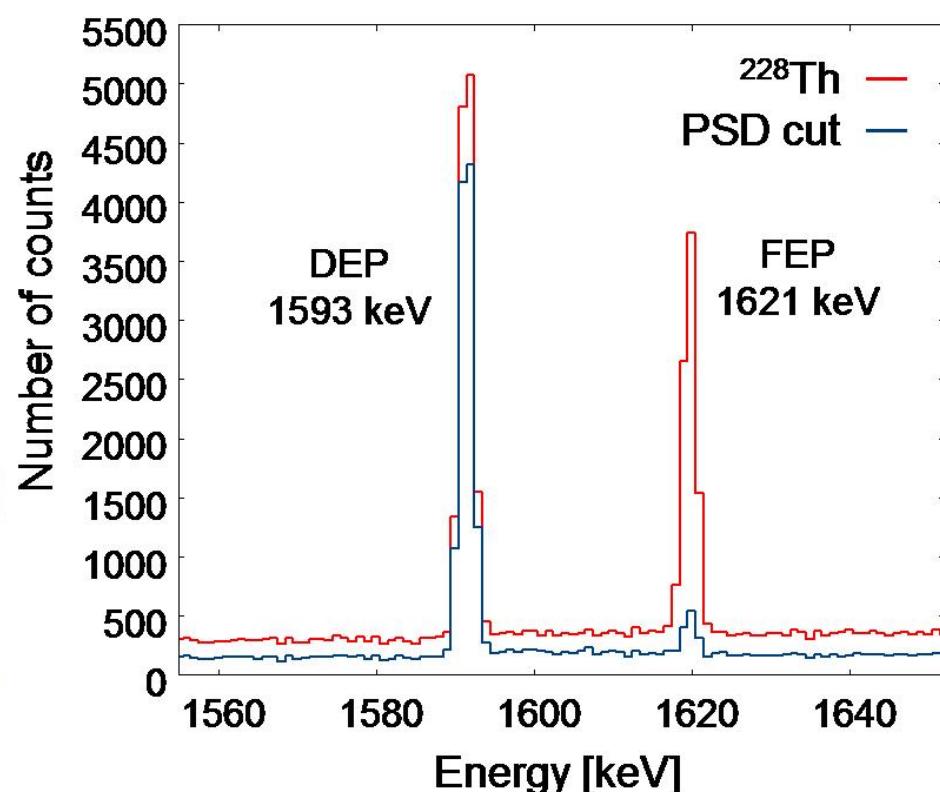
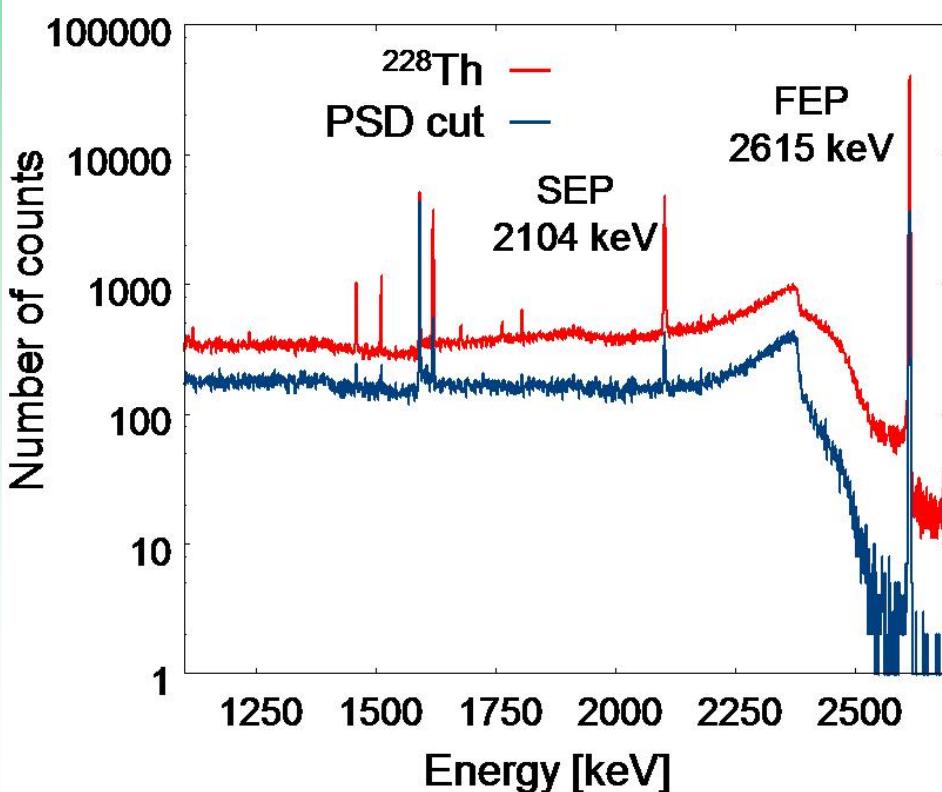
Recognize background:

Standard BEGe detectors:

Excellent energy resolution

High background recognition efficiency

Production chain from GeO₂ to working BEGes has been demonstrated!

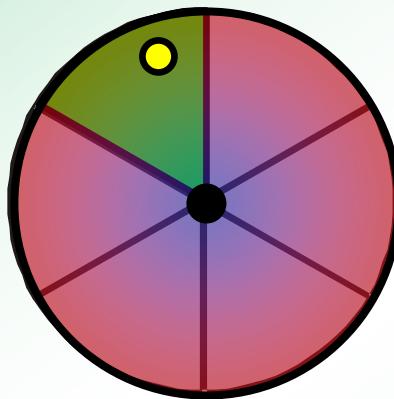


Experimental Strategies

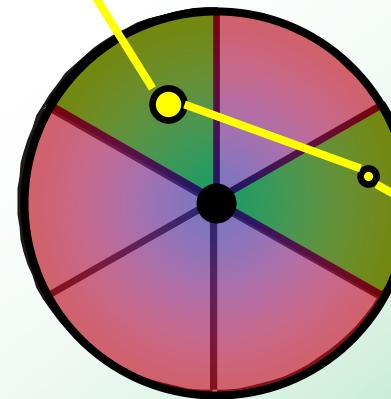
Recognize background:

Germanium (and other) detectors can be segmented
→ Background identification through identification of multiply
Compton-scattered photons by coincidences

Signal:



Background:



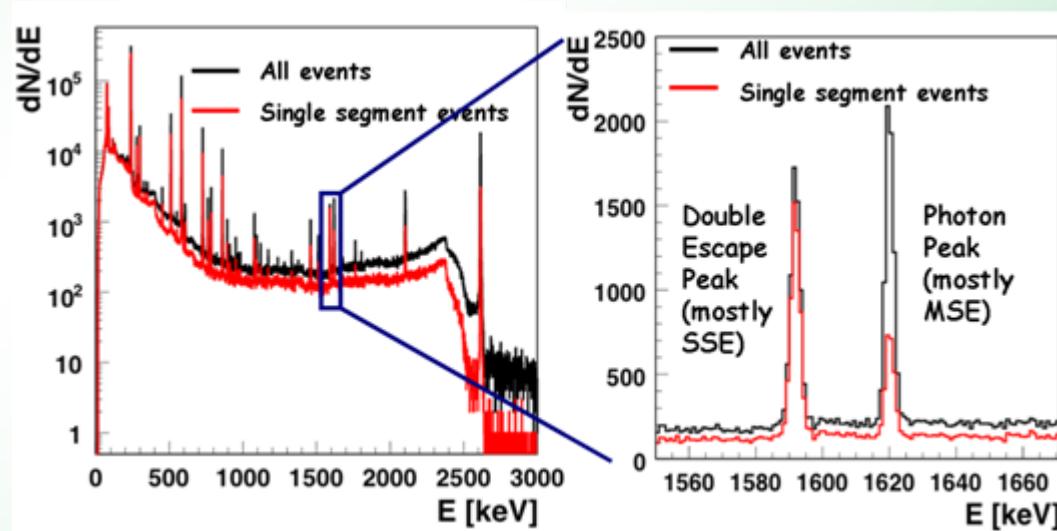
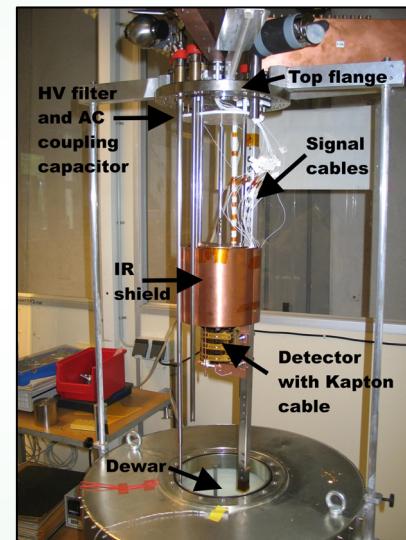
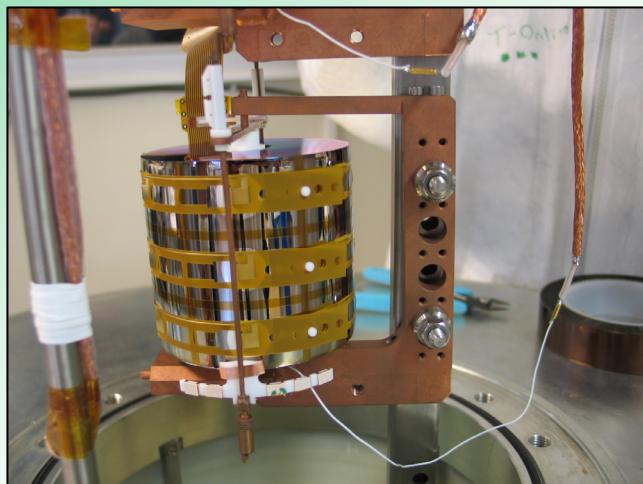
- Robust technique based on “counting” events
- It can be easily simulated
- No pulse data require, ie no bandwidth restrictions (no fiddling with electronics, cables...)
- Needs extra cables however (one per segment)



Experimental Strategies

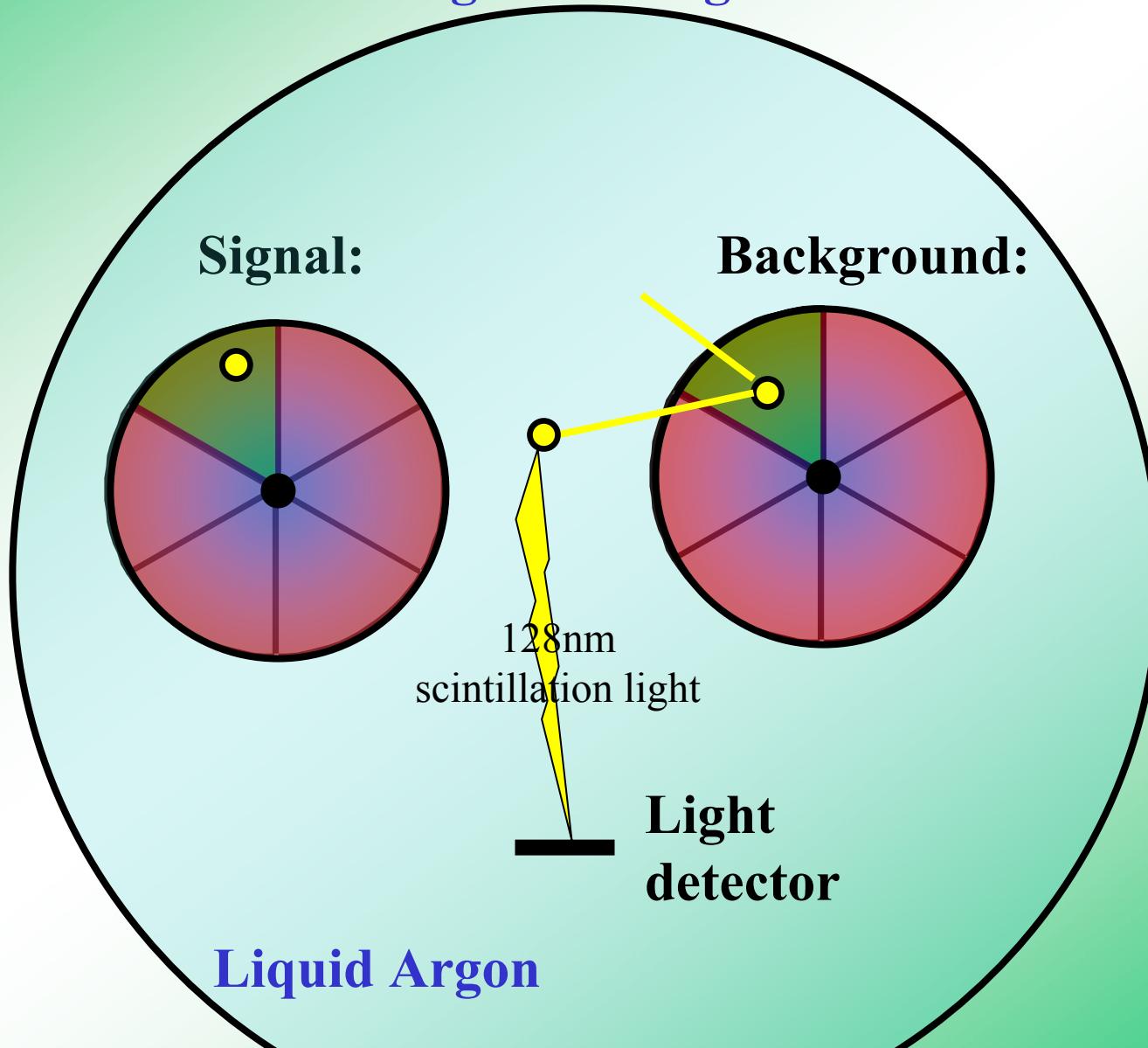
Recognize background:

18-fold n-type segmented segmented detectors work well



Experimental Strategies

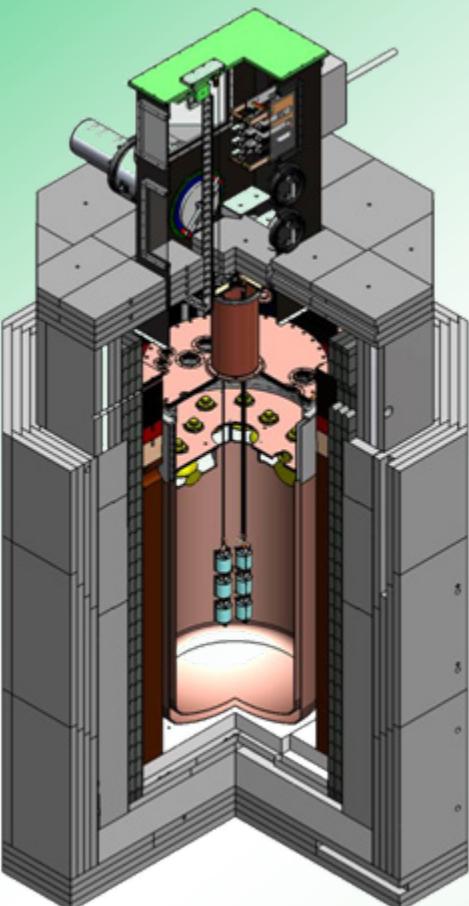
Recognize background:



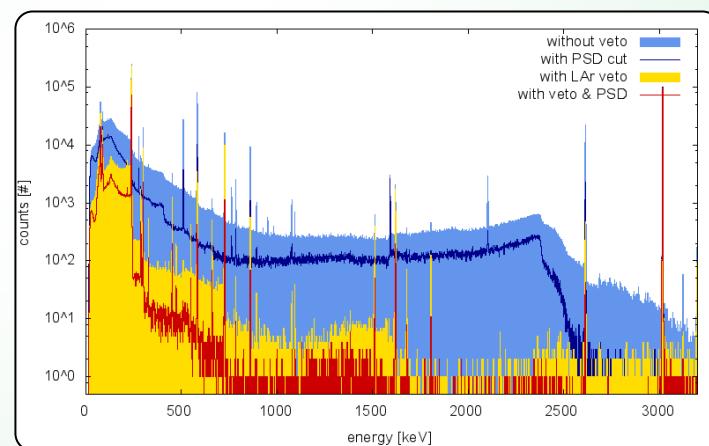
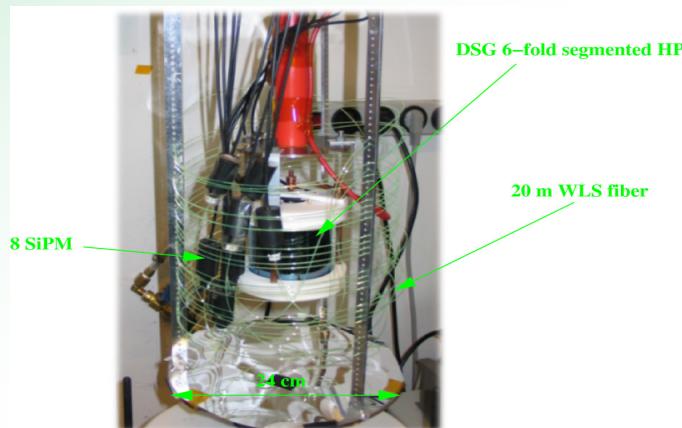
Experimental Strategies

Recognize background:

LArGe @ LNGS



SiPM test stand at Munich



**Proof of principle experiments show:
Viable concept to
reduce single
Compton scattered
background**



Conclusions

Requirements are a real challenge

Worldwide collaboration needed

Proper experimental facilities needed

**Underground crystal production
mandatory**

Material R&D still needed

**Novel technologies seem promising
→ Merge?**

PMT & SiPM R&D