# TG10: Simulations and Background Studies Summary Talk

Claudia Tomei – LNGS

GERDA coll. Meeting, June 26-28 2006, LNGS

# Outline

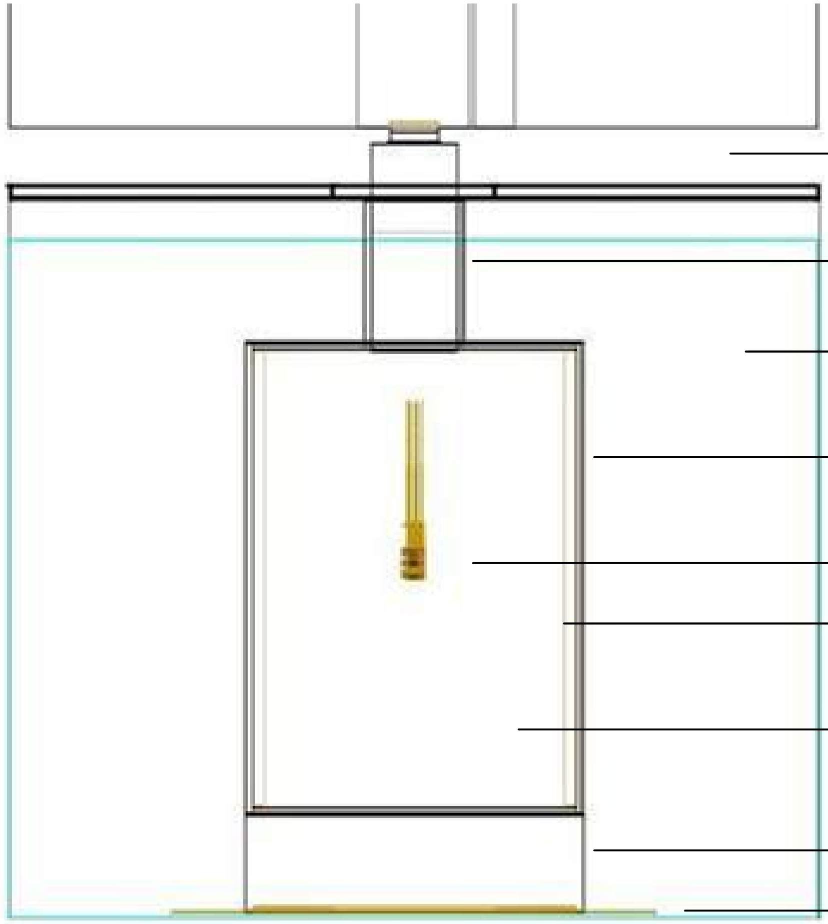
- Changes in GERDA geometry
- New activities on simulations
- Report from TG parallel session
- Conclusions

A joint TG10 (simulations) and TG11 (material screening) parallel session is scheduled for this afternoon to discuss the validation and the accuracy of MaGe with new comparisons between measurements and simulations

# New MaGe Geometry

Assunta di Vacri, Claudia Tomei

## What has not changed
What has changed



Lock and penthouse

Steel, 2 walls
Inner thickness: 1.2 cm - Outer thickness: 1.8 cm
Vacuum insulation: 7 cm
Filled with LN/LAr - 40 cm gas buffer on top

Neck

Water tank and water buffer

Cryostat

Steel, 2 walls
Inner thickness: 1.2 cm - Outer thickness: 1.8 cm
Vacuum insulation: 7 cm
Height: 585 cm – Radius: 210 cm

Detector Array

Cu liner

Thickness: 14 cm

Cryoliquid buffer

Height/radius as cryostat

Cryostat foot

Steel, 1 wall
Thickness: 1.2 cm

Copper plates

# Improving MaGe Visualization

Jing Liu

Visualization is of big importance in debugging complex geometries

Default dumb terminal → TCSH like terminal

More friendly!

| Visualization Drivers | Driver Characters |
|---|---|
| OpenGL | View directly from Geant4<br>Fast response |
| HepRep | Many interactive features<br>Hierarchy of geometry |
| DAWN | Highest quality technical rendering |
| RayTracer | Render any geometry that Geant4 can handle |

```
Idle> /vis/open HepRepFile
Idle> /vis/viewer/flush
```

```
G4Data0.heprep
```

```
$ wired G4Data0.heprep
```

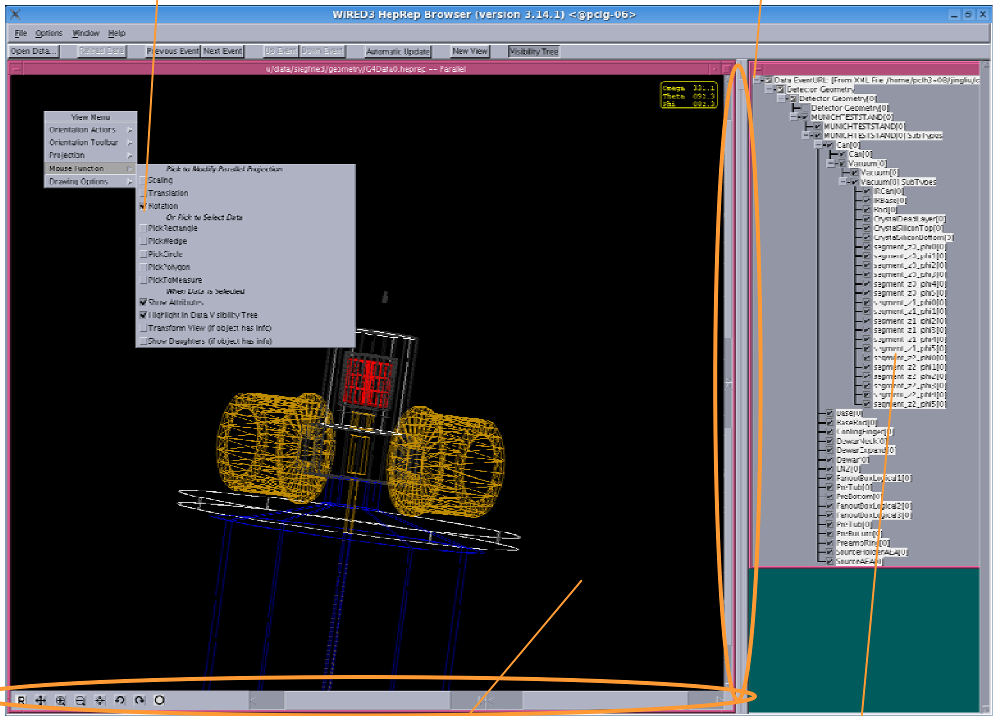
Go further:

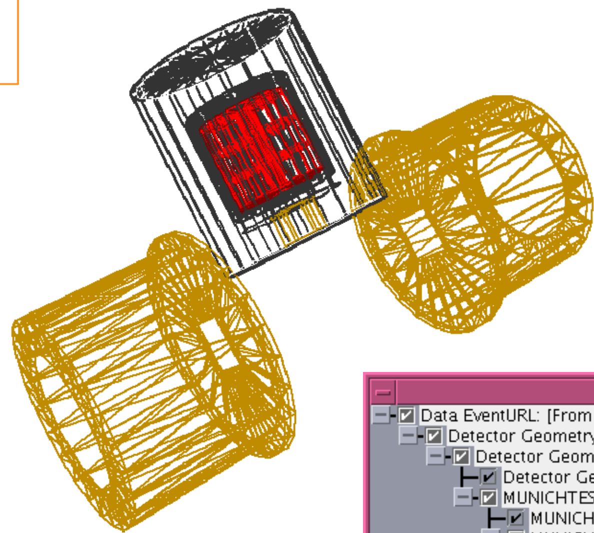
- Geant4 Graphical Geometry Editor
- XML, ASCII …
- CAD -> Geant4

# HepRep/Wired used in MaGe Visualization

Right Click Menu

Control Bars

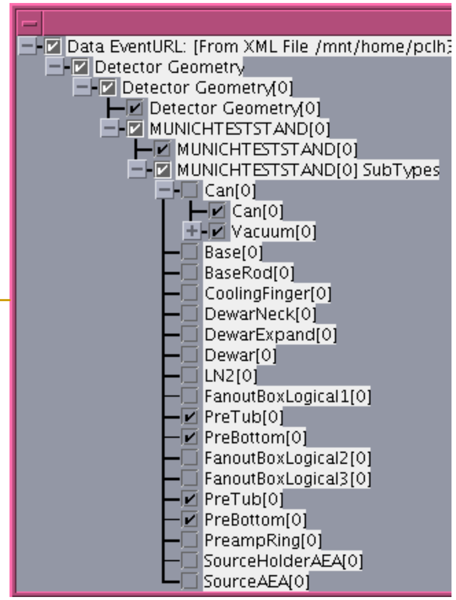




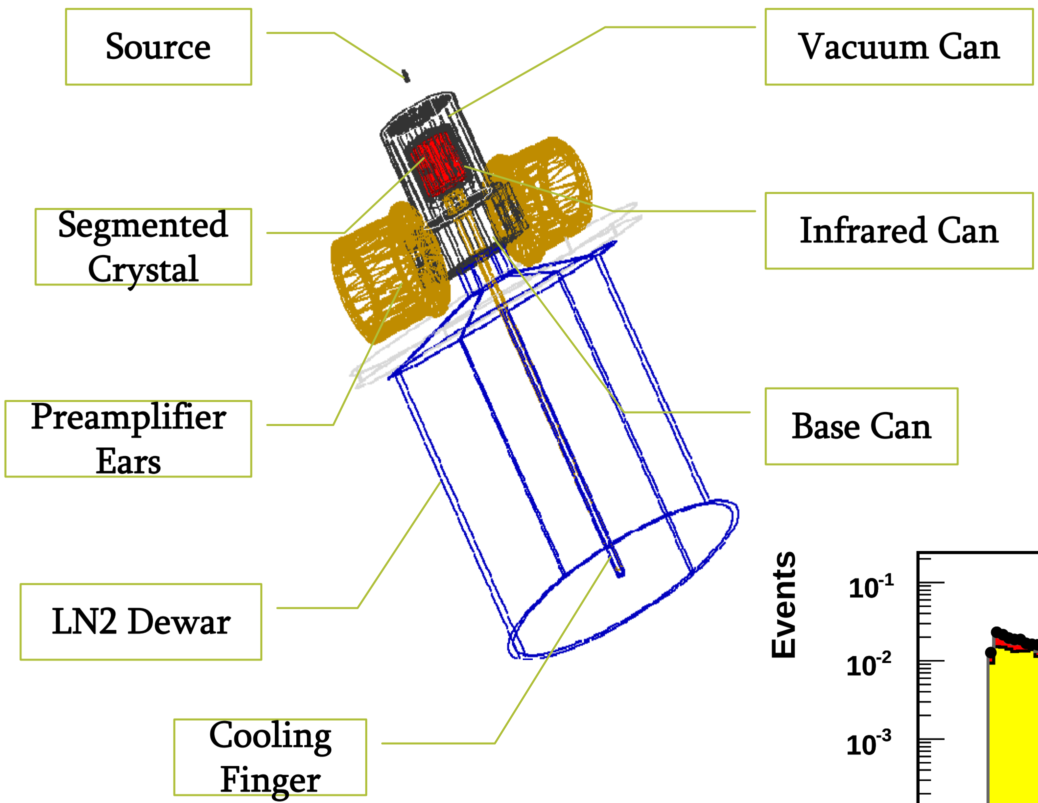
Drawing Canvas

Hierarchy Tree

Relations Display in Wired

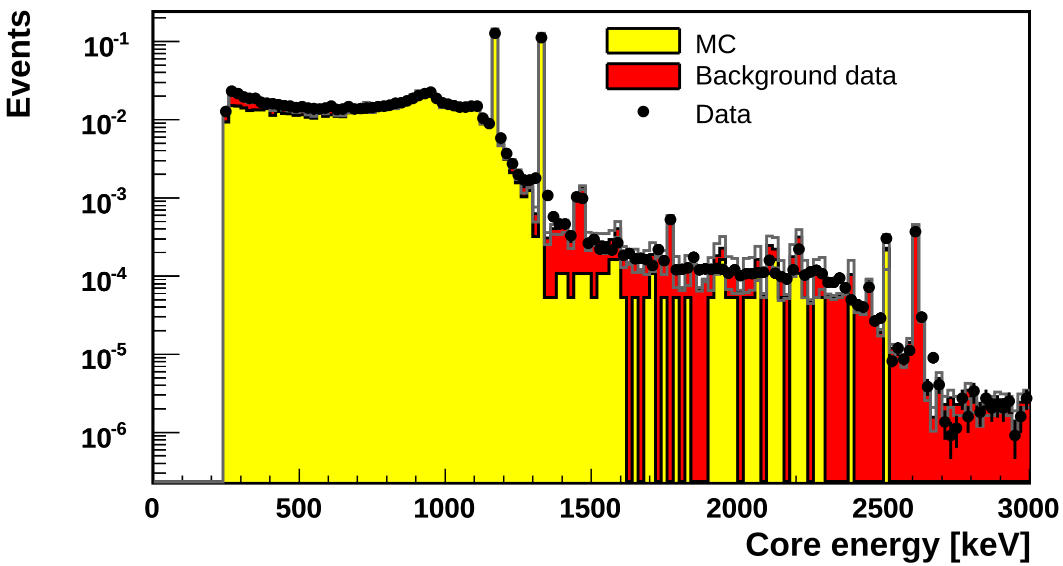


# Application on Test Stand




**Comparison of real & MC data**

Energy deposits in core segment when detector exposed to $^{60}Co$

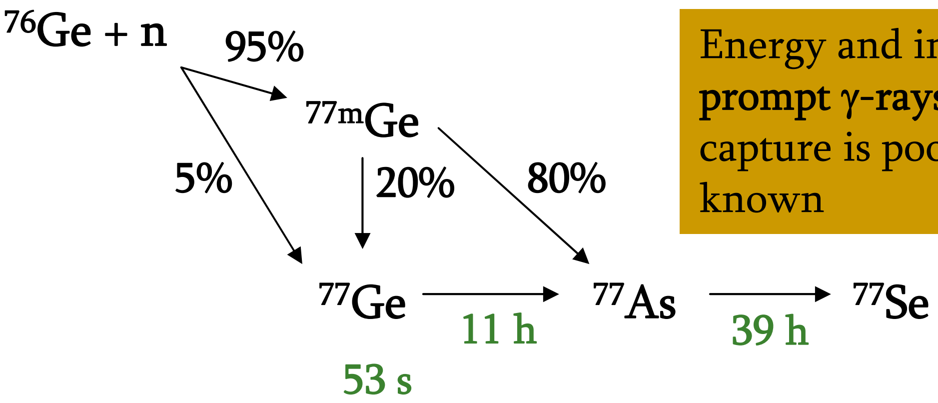


# $^{77}$Ge decay rejection by delayed coincidence

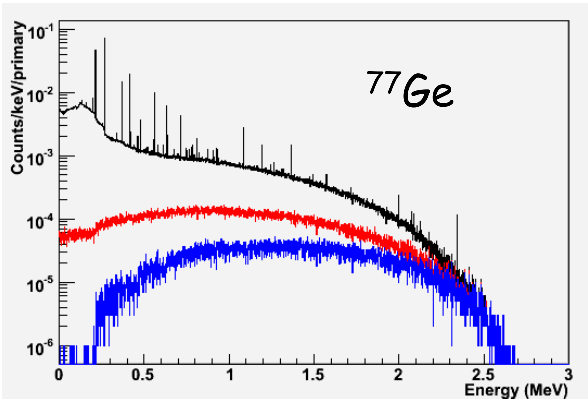
Delayed background: muon-induced interactions can create long-lived (> ms) unstable isotopes in the crystals with $Q > Q_{\beta\beta}$ → cannot be vetoed or shielded against

Most dangerous is $^{77}$Ge from thermal neutrons: no threshold, high cross section (0.14 b), high decay Q-value (2.7 MeV), scales with enrichment.

Production rate: 0.5 – 1 nucl/kg y for LAr → $2 \cdot 10^{-4}$ counts/kg keV y
10 times smaller for LN



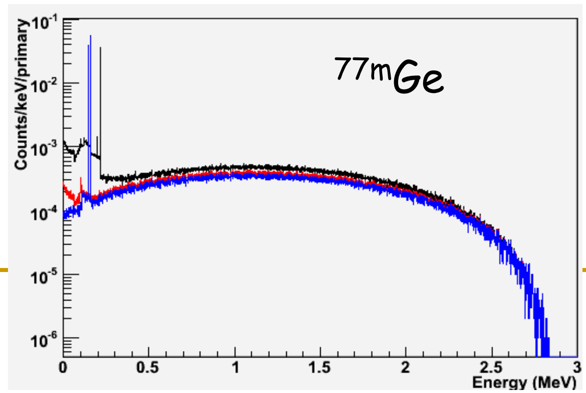

Energy and intensity of **prompt γ-rays** from capture is poorly known




5% $^{77}$Ge → $^{77}$As

76% $^{77m}$Ge → $^{77}$As **no γ-rays**

19% $^{77m}$Ge → $^{77}$Ge → $^{77}$As



# $^{77}$Ge decay rejection by delayed coincidence

Luciano Pandola, Claudia Tomei – GSTR-06-012

## Rejection Strategies

a) 4 minutes dead time after each muon veto trigger → not feasible because of the high countrate: 2.5 counts/minute above 120 MeV (from simulations)

b) 4 minutes dead time after each coincidence muon veto/Ge array → the countrate is 2.5 counts/day in Phase II (mostly e.m. showers) and the dead time is 3%

c) 4 minutes dead time after each energy deposit in Ge above 4 MeV (not related to muon veto) → the dead time is 1%

**Rejection efficiency:** $\varepsilon = (\varepsilon_{MV} \times) \, \varepsilon_{Ge} \times \varepsilon_{dec}$ → 96%

$\varepsilon_{MV}$: > 95%

$\varepsilon_{dec}$: difficult to evaluate since the de-excitation scheme of $^{77}$Ge is poorly known → MaGe simulations

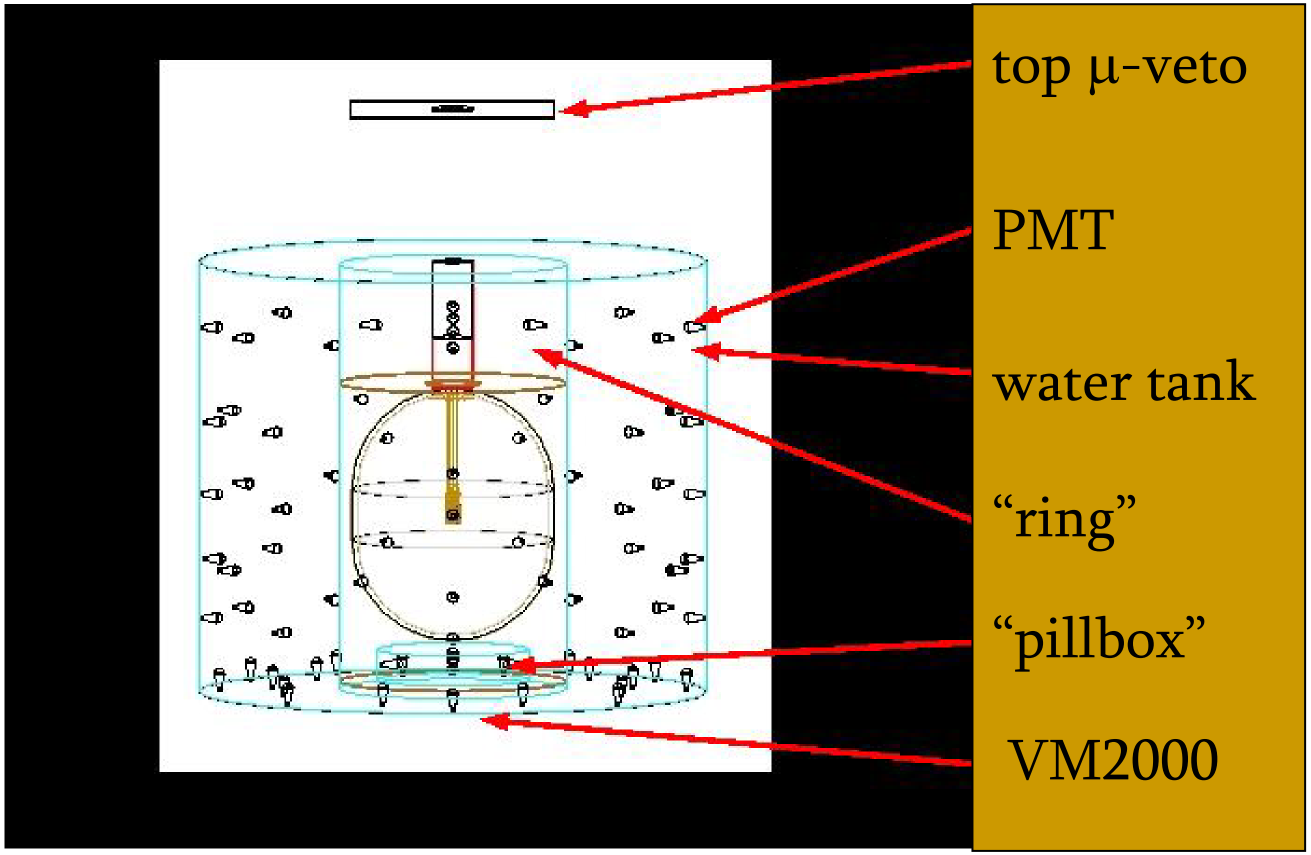
| Detector scheme | γ-rays | ev > 50 keV | ev > 4MeV |
|---|---|---|---|
| All det. | 1 γ, 6 MeV | 56% | 39% |
| All det. | 2 γ, 2 + 4 MeV | 85% | 27% |
| All det. | 3 γ, 2 MeV | 94% | 19% |
| Central det. | 1 γ, 6 MeV | 66 % | 46 % |
| Central det. | 2 γ, 2 + 4 MeV | 92 % | 37 % |
| Central det. | 3 γ, 2 MeV | 98 % | 29 % |
| Peripheric det. | 1 γ, 6 MeV | 54 % | 37 % |
| Peripheric det. | 2 γ, 2 + 4 MeV | 83 % | 25 % |
| Peripheric det. | 3 γ, 2 MeV | 93 % | 17 % |

Cut b - In the most conservative case the rejection efficiency ε is 51%, with a dead time of 3%.

Cut c - In the most favourable case the rejection efficiency ε is 35%, with a dead time of 1%.

# Muon veto simulation update

Markus Knapp



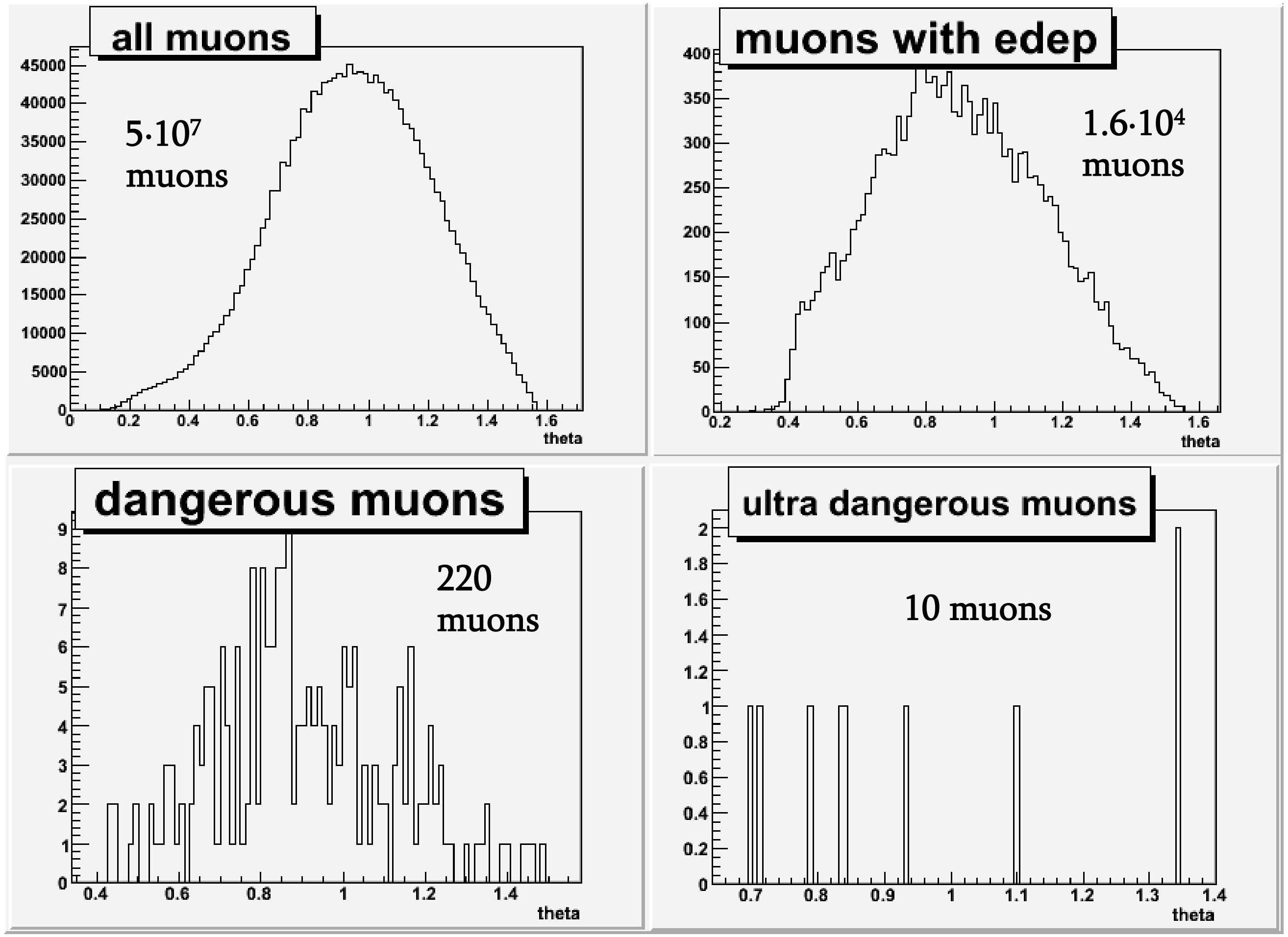

Optical photons tracked within the MaGe framework. CPU-intensive but works ok.

Configurations with 72 and 78 PMTs are being explored.

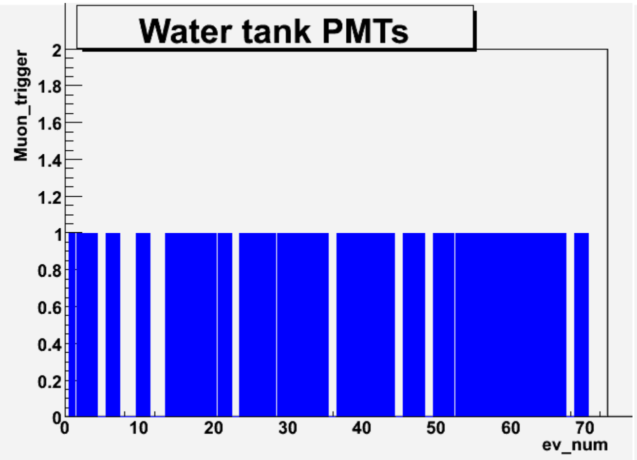
Crytical regions: neck and bottom of cryovessel

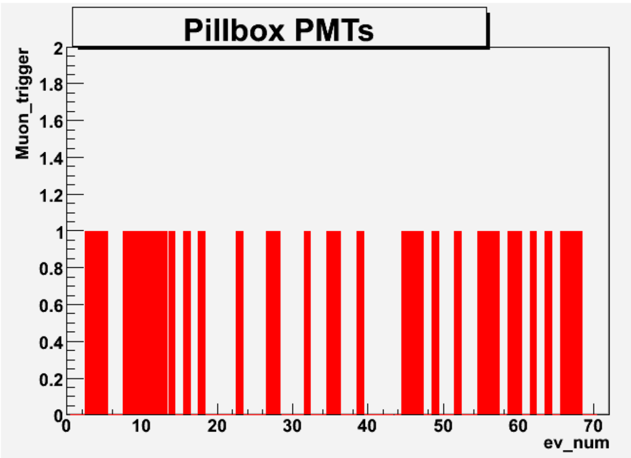
# Muon classification and distribution

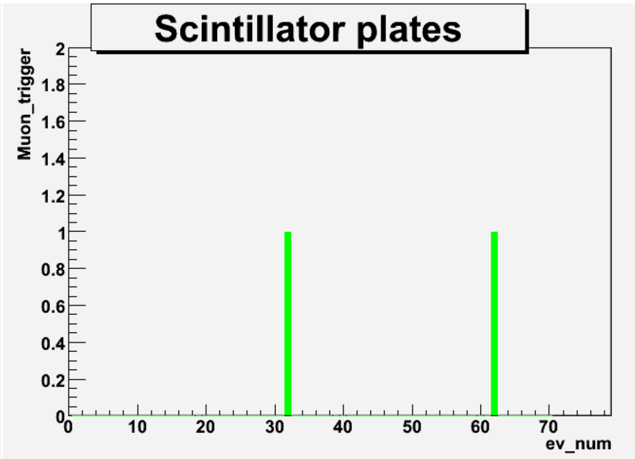
- All muons
- Muons with energy deposition in the germanium detectors
- Dangerous muons with total energy deposition in the range (1.5 – 3) MeV
- Ultra-dangerous muons with total energy deposition in the energy window and only one hit in Ge

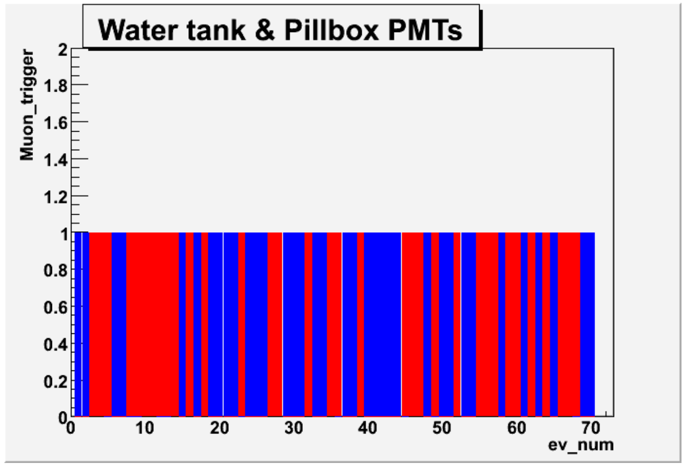


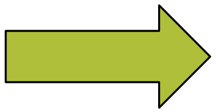
# Muon Veto efficiencies



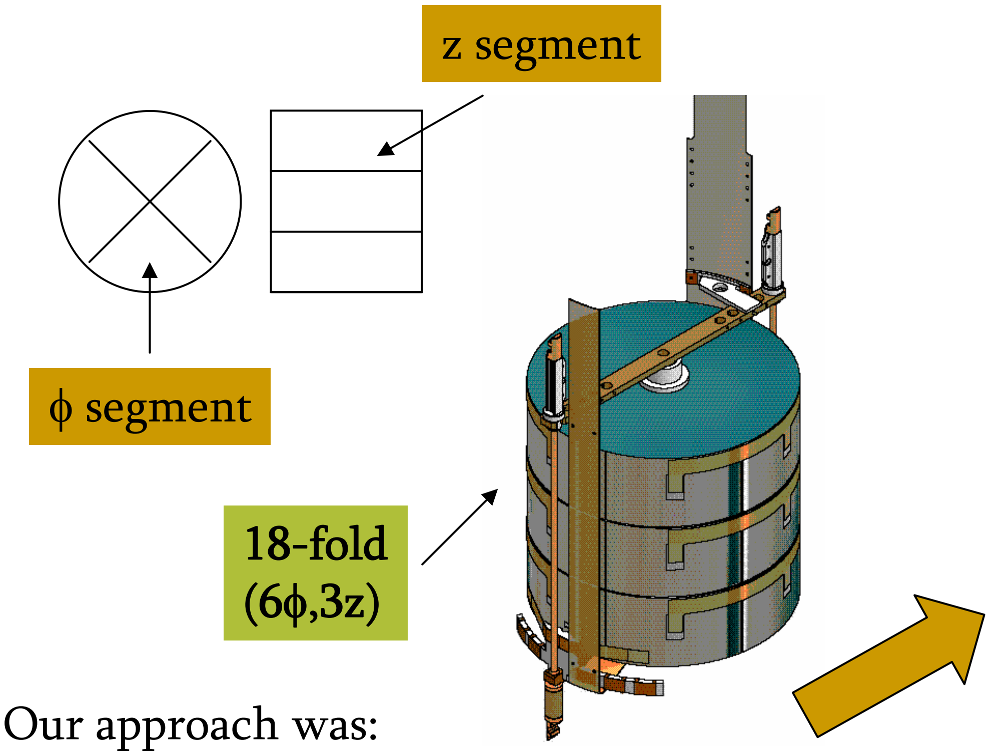



Still the pillbox would be desirable, because it is complementary to the Cherenkov veto in the water tank.

# Simulation of segmented detectors with various segmentation options

Claudia Tomei



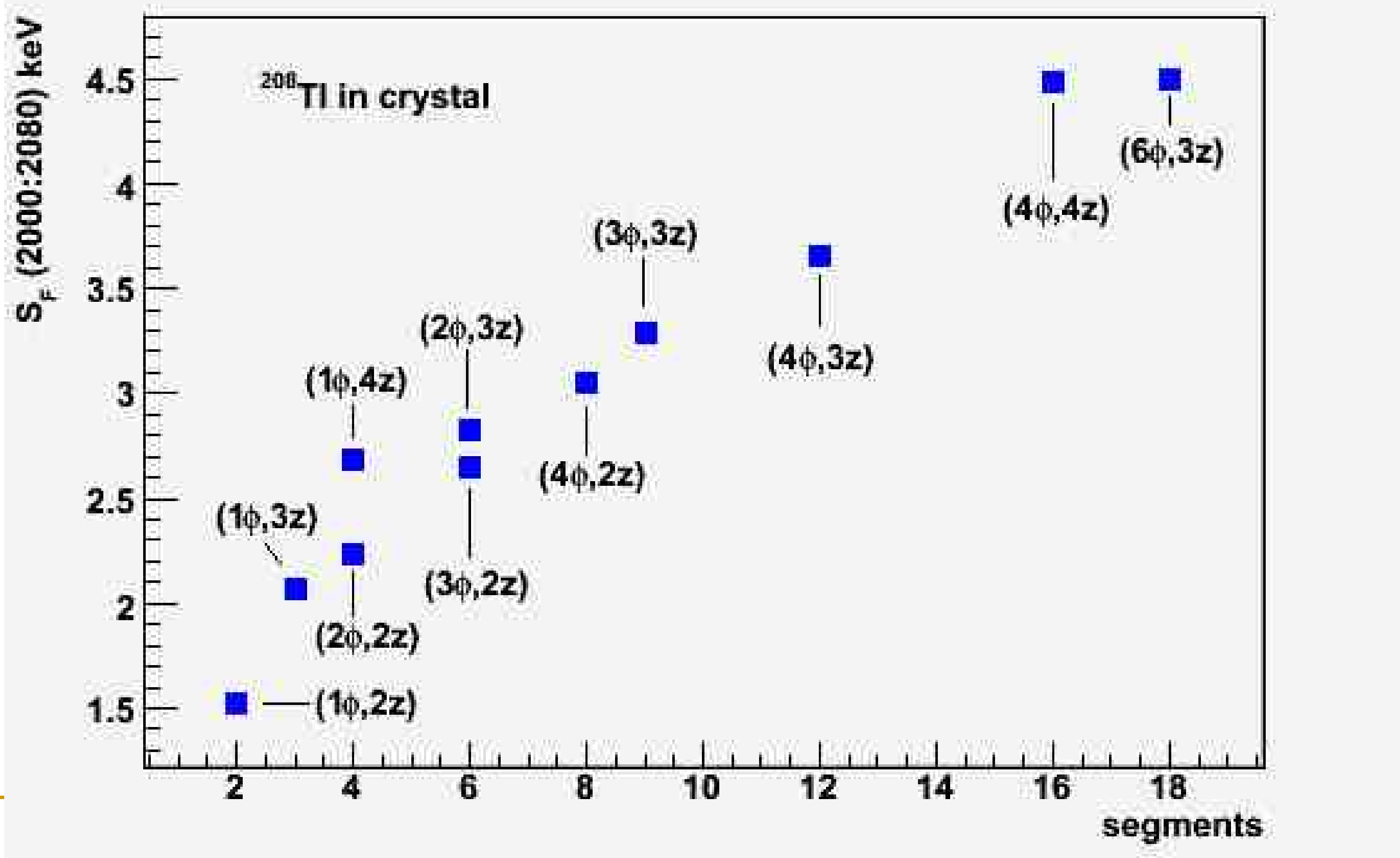

| ϕ | z | Tot | ϕ size | z size |
|---|---|---|---|---|
| 1 | 2 | 2 | 24 cm | 4 cm |
| 1 | 3 | 3 | 24 cm | 2.5 cm |
| 1 | 4 | 4 | 24 cm | 1.8 cm |
| 2 | 2 | 4 | 12.6 cm | 4 cm |
| 2 | 3 | 6 | 12.6 cm | 2.5 cm |
| 3 | 2 | 6 | 8.4 cm | 4 cm |
| 4 | 2 | 8 | 6.3 cm | 4 cm |
| 3 | 3 | 9 | 8.4 cm | 2.5 cm |
| 4 | 3 | 12 | 6.3 cm | 2.5 cm |
| 4 | 4 | 16 | 6.3 cm | 1.8 cm |
| 6 | 3 | 18 | 4.2 cm | 2.5 cm |

Our approach was:

- to study many different options with a simplified geometry (only 1 GERDA detector)
- to focus on 2/3 realistic options and investigate the background suppression factor for GERDA Phase II (21 detectors, full geometry)

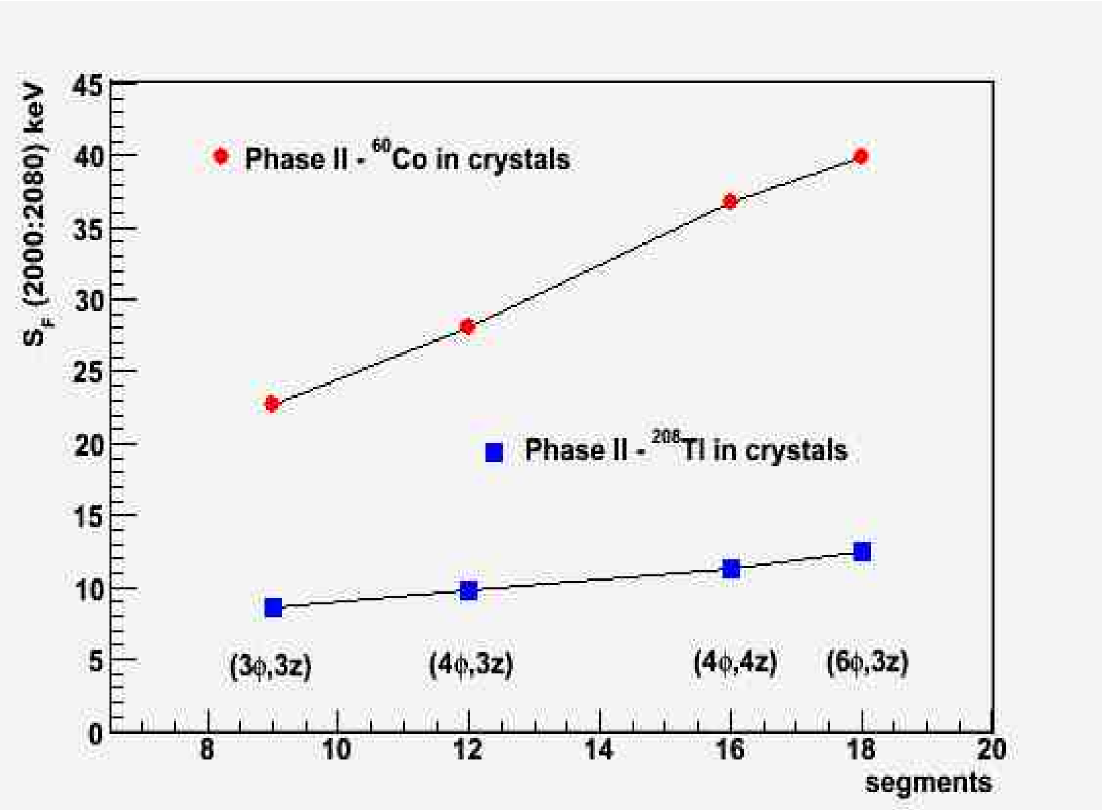
# Background Suppression for 1 Detector

$10^6$ simulated events for each configuration - Ge threshold: 50 keV



# Background Suppression for Phase II

$^{208}Tl$ and $^{60}Co$ inside crystals




Factor 2 difference in $S_F$ when going from (6ϕ,3z) to (3ϕ,3z)

Factor 1.4 difference in $S_F$ when going from (6ϕ,3z) to (3ϕ,3z)

**Liquid Nitrogen**

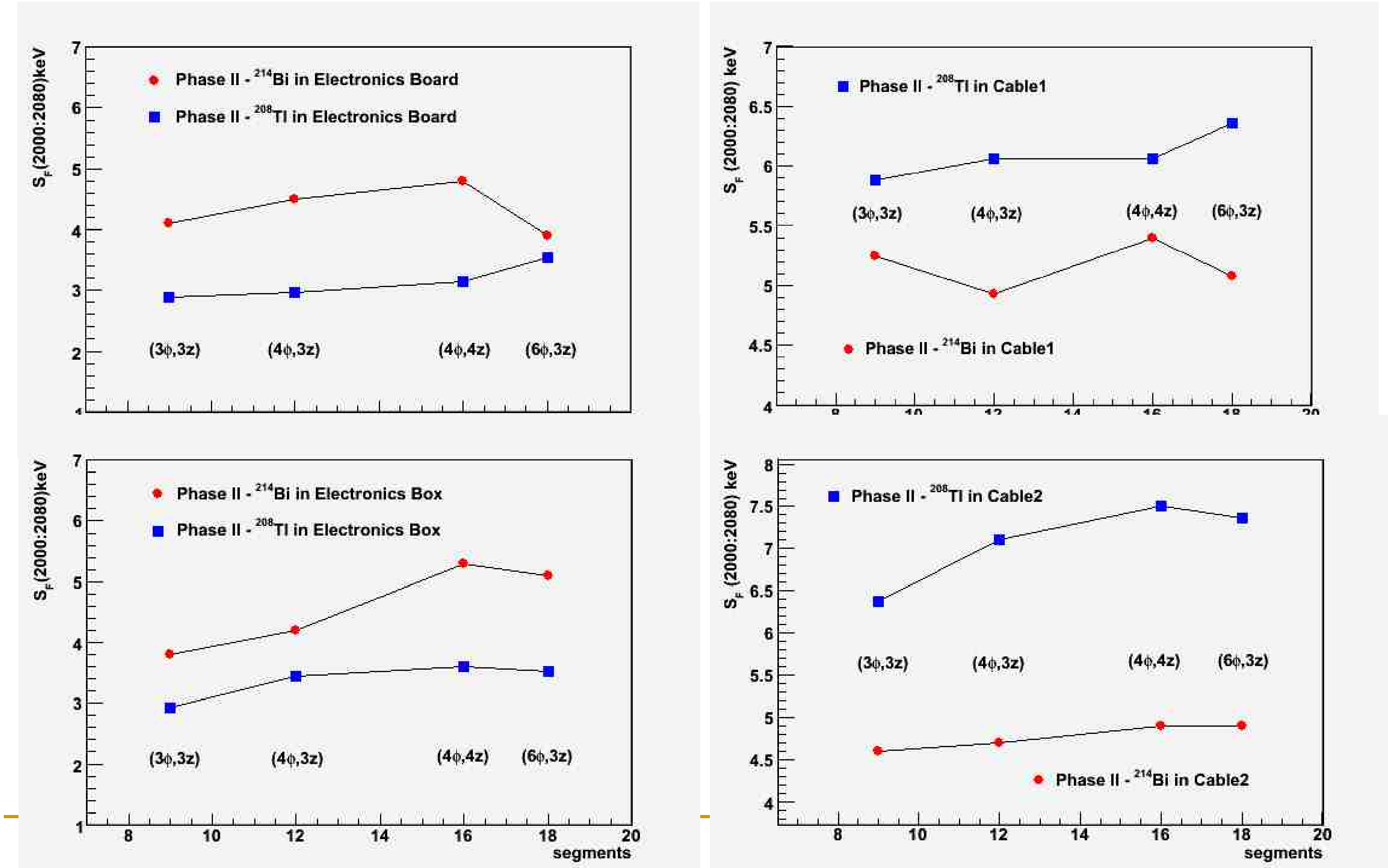
| Seg. | $S_F$ $^{60}Co$ | $S_F$ $^{208}Tl$ |
|---|---|---|
| (3ϕ,3z) | 22.6 | 8.6 |
| (4ϕ,3z) | 28.0 | 9.8 |
| (4ϕ,4z) | 36.8 | 11.2 |
| (6ϕ,3z) | 39.9 | 12.5 |

**Liquid Argon**

| Seg. | $S_F$ $^{60}Co$ | $S_F$ $^{208}Tl$ |
|---|---|---|
| (3ϕ,3z) | 19.3 | 8.2 |
| (4ϕ,3z) | 24.6 | 9.4 |
| (4ϕ,4z) | 34.7 | 11.2 |
| (6ϕ,3z) | 34.8 | 11.2 |

# Background Suppression for Phase II

$^{208}$Tl and $^{214}$Bi impurities in Cables and Electronics




$^{214}$Bi: $S_F$ compatible within the error - $^{208}$Tl: $S_F$ compatible within the error except for (3ϕ,3z)

- GERDA has already a working option for the Ge segmented detectors (18-fold, 6ϕ-3z) which fulfills the requirements in terms of background suppression and induced background
- We think that is nevertheless important to show that we have studied in detail the possibility of other segmentation options which have a lower background suppression factor but are maybe easier to build and require less cabling/electronics.
- From our preliminary results on some of the background sources we show that the decrease in the background suppression power is relevant only for intrinsic impurities
- We plan to continue the investigation for at least a couple of segmentation backup options

# Conferences/Publishing activity of TG 10

- MaGe Poster at TAUP 2005

Proceedings: "MaGe: a Monte Carlo framework for the Gerda and Majorana double beta decay experiments" Journal of Physics: Conference Series 39 (2006) 362-362

Can be used as official reference for MaGe

- MaGe Poster at Neutrino 2006
- Papers to be submitted to NIM

Luciano Pandola et al., Monte Carlo evaluation of the muon induced background in the GERDA double beta decay experiment

Kevin Kroeninger et al., Background suppression in neutrinoless double beta decay experiments using segmented detectors - a Monte Carlo study for the GERDA setup

They will be presented during the meeting

- GERDA Scientific/Technical Reports

# Conclusions…

… let's wait for the TG10 parallel session this afternoon

Thanks!