TG10
Monte Carlo Status Report

GERDA Meeting LNGS June 2008

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on behalf of TG10

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Overview

Simulation of Background from Strings

Monte Carlo Campaign 2

Pulse Shape Simulation

MaGe-Paper

Calibration — not covered here, dedicated talk afterwards

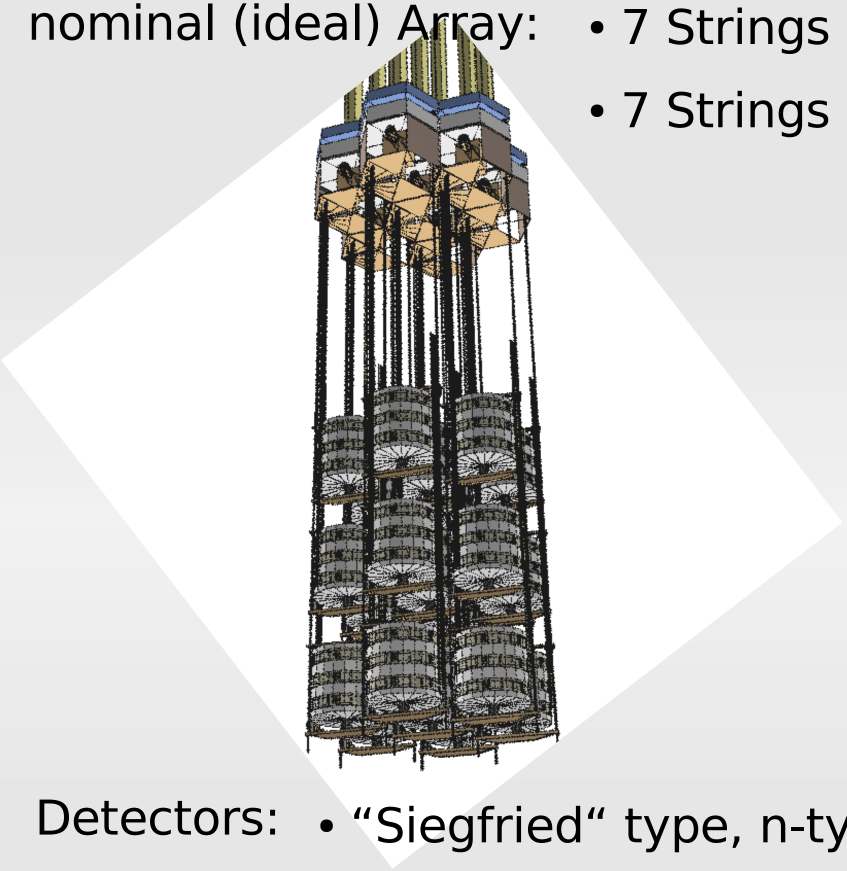
Simulation of Bkg from Strings - Setup

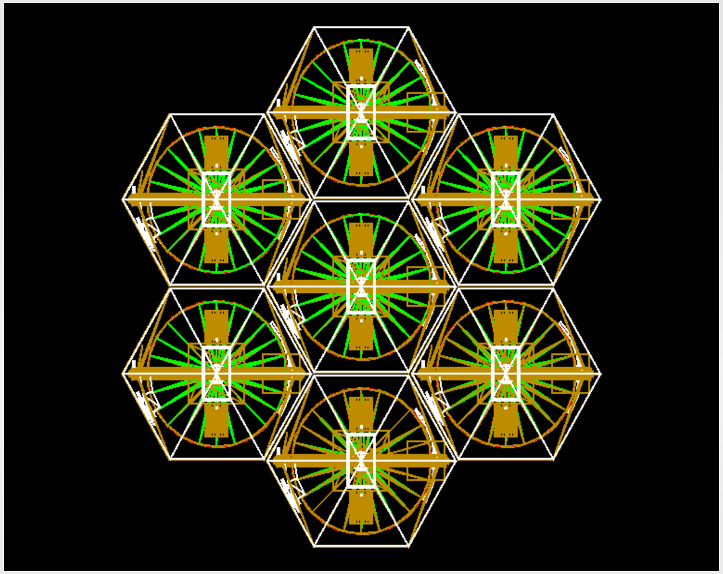
• Simulation of background contribution of strings using nominal (ideal) Phase II Array

nominal (ideal) Array:

• 7 Strings with 3 detectors each

• 7 Strings hexagonally arranged





Detectors:

• “Siegfried“ type, n-type

• 18-fold segmented: 3-fold along z, 6-fold in azimuthal angle

• true coaxial: r_i = 0.5 mm, r_O= 37.5 mm, height = 70 mm

⇒ mass of 1.616 kg ⇒ total enriched Ge mass of 33.9402 kg

Simulation of Bkg from Strings - Sources

Simulation takes into account:

- **natural radioactivity**: whole chains simulated
  - assume secular equilibrium, unless different screening results

- ^{232}Th
  ↓
  - ^{208}Tl: 2614.5 keV
- ^{238}U
  ↓
  - ^{234}Pa: 2072.2 keV
  - ^{214}Bi: many
  - ^{210}Tl: several
- ^{40}K: 1460.8 keV

- **“man made“ radioactivity**
  - ^{137}Cs: 661.6 keV
- **cosmogenic activation**
  - ^{60}Co: 2158.5 keV
    2505. keV (summation peak 1173 + 1332 keV)
- **everything else from screening**: i.e. ^{110m}Ag: some

10 million events generated for each isotope and each part,

factor 100 more than previous simulations

Simulation of Bkg from Strings - Analysis

- Energy smeard with $\sigma = \frac{\sqrt{(0.0405^2 * E + 1.31^2)}}{\sqrt{(ln 2 * \sqrt{(8)})}}$ (REGe detector resolution)

  FWHM(2039 keV) = 3.78 keV

- Energy threshold cut of 10 keV for core and segments

- Energy Cut (ROI) : 2029 keV < $Q_{\beta\beta}$ < 2049 keV

- Segment anti-coincidence

- Contamination taken from screening results

  (http://www.mpi-hd.mpg.de/ge76/internal/tg11_internal/Screening_Results.pdf)

Simulation of Bkg from Strings - Setup

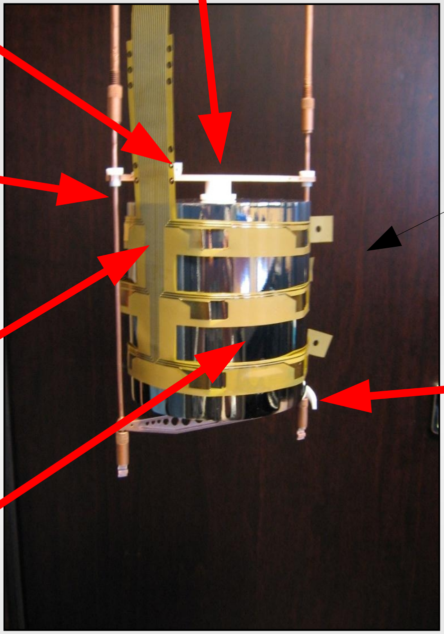
Holder:

4.79g Teflon

1.34g Teflon

1.6 g HV cable (not shown)

31g Copper holder



1.44g Teflon

0.28g Kapton cable
2.64g Copper lines

Cable:

1.62kg Ge

Simulation of Bkg from Strings - Results

Holder: Bkg Color means: only upper limits from screening

overall SS	Copper	Teflon	Signalcable-guide	HVcable-guide	SupportStrings
Mass per Part[kg]	0.0320	0.0048	0.0013	0.0014	0.0125
Mass in Array [kg]	0.6728	0.1006	0.0281	0.4690	0.0875
cts/(kg keV y)	$9.56 * 10^{-5}$	$1.54* 10^{-4}$	$3.39 * 10^{-5}$	$4.05 * 10^{-5}$	$2.75 * 10^{-6}$

Sum Holder: $0.32675 * 10^{-3}$ cts/(kg keV y)

Cable: Assume contmination of Kapton: 0.001 Bq/kg for each isotope

overall SS	Cable	Signal Lines	Signal Connection	Signal Connection Lines	HV Cable
Mass per Part[kg]	0.000353	0.00264	0.00106	0.0029	0.0016
Mass in Array [kg]	0.007405	0.05534	0.00739	0.0.020293	0.0115
cts/(kg keV y)	$1.66 * 10^{-4}$	$1.88 * 10^{-5}$	$5.169 * 10^{-5}$	$2.29 * 10^{-6}$	$2.45 * 10^{-4}$

Sum Cable: $0.48468 * 10^{-3}$ cts/(kg keV y)

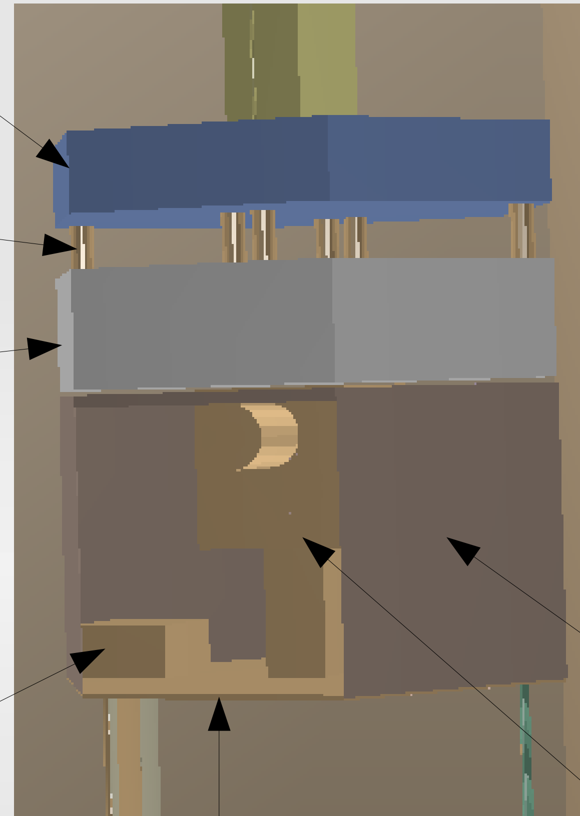
Simulation of Bkg from Strings - Setup

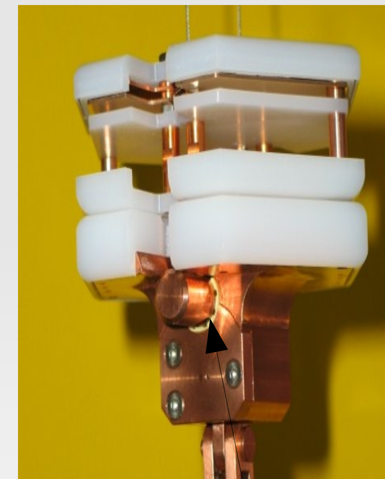
Electronics:

Teflon
Copper

Copper Screws

Pogo Pins
Copper
Murtfeld





Iglidur

Matrix:

Electronics Cable

Electronics Box

Junction Sledge

Junction Board

Simulation of Bkg from Strings - Results

Electronics: Assume contmination of Electronics of: 0.01 Bq/kg for each isotope
Assume contmination of Kapton: 0.001 Bq/kg for each isotope

overall SS	Junctionboard	Electronics box	Kapton Cable
Mass per String [kg]	0.0607	0.0100	0.0068
Mass in Array [kg]	0.4205	0.0700	0.0473
cts/(kg keV y)	$2.75 * 10^{-6}$	$1.95 * 10^{-4}$	$2.85 * 10^{-5}$

Sum Electronics: $0.226 * 10^{-3}$ cts/(kg keV y)

Matrix: 180 Pogo pins included (realistic Phase II setup)

overall SS	Copper	Copperscrews	Iglidur	Murtfeldt	Pins	Teflon
Mass per String [kg]	1.0840	0.0200	0.0040	0.0670	0.0044	0.0340
Mass in Array [kg]	7.5110	0.1400	0.0280	0.4690	0.0309	0.2380
cts/(kg keV y)	$1.91 * 10^{-5}$	$1.57 * 10^{-5}$	$8.209 * 10^{-5}$	$9.48 * 10^{-6}$	$2.18 * 10^{-4}$	$3.01 * 10^{-6}$

Sum Matrix: $0.347 * 10^{-3}$ cts/(kg keV y)

Simulation of Bkg from Strings - Results

Above Matrix:

- statistics too low! → take estimate of decays from GSTR-08-10
- GSTR-08-10: similar setup, for cables: 78.9 * 10^{6} ^{208}Tl decays simulated
- 322 events in 200 keV window

using these information estimate of bkg of Cable Chain above Matrix was done

^{208}Tl(^{232}Th):

Last meter of Stainless Steel: 9.74 * 10^{-5} cts/(kg keV y)

Last meter of Copper: 1.09 * 10^{-6} cts/(kg keV y)

^{214}Bi(^{238}U):

at equal contamination approx. factor 10 less due to branching ratios

Steel: 1.07 * 10^{-4} cts/(kg keV y) **Copper**: 1.2 * 10^{-6} cts/(kg keV y)

Simulation of Bkg from Strings - Summary

Part		Background contribution [10^{-4} counts/(kg·keV·y)]
Holder		3.27
Cabling		4.84
Electronics		2.26
Matrix	Pins	2.18
	Iglidur	0.82
	Screws	0.16
	Copper	0.19
	Murtfeldt + Teflon	0.12
Steel Chain		1.07
Total		14.91

- String saturates full background budget
- Keep in mind that screening limits were used!

Monte Carlo Campaign 2

Goal:
- Produce realistic energy spectrum
- Give estimate of background in ROI

Meeting on 22 – 23 April in Munich

Identified list of backgrounds:

Internal:
- Cosmogenic production
- Internal radioactivity
- Surface contamination

External:
- α-, β-, γ-particles from array
- α-, β-, γ-particles from lAr
- γ from infrastructure

Neutrons:
- n from rock
- n produced in infrastructure

Muons:
- prompt and delayed (including Metastable states)
- neutrons induced by muons

distributed the work

Monte Carlo Campaign 2

- Consider **new**, **subdominat**, background sources and source that **do not contribute** in **ROI** to get **realistic energy spectrum**

  - neutrons in steel cryostat through fission or (α,n) reactions

    background index of **<2·10^{-6} counts/(keV·kg·y)** at $Q_{\beta\beta}$ (no cuts)

    -> can be reduced by a factor >2 by multiplicity cuts

  - external neutrons in neck region, unshielded by water

  - gammas by neutron capture in water tank (up to 9 MeV) or water (2.2 MeV)

    Incoming γ-ray flux by n-captures in WT = 10^{-7} γ/(cm^2·s)

    -> 10^5 times smaller than external 2.6-MeV flux by ^{208}Tl

    2.2-MeV, γ-ray flux by (n,γ) in water **incoming** in the cryostat = 10^{-10} γ/(cm^2·s)

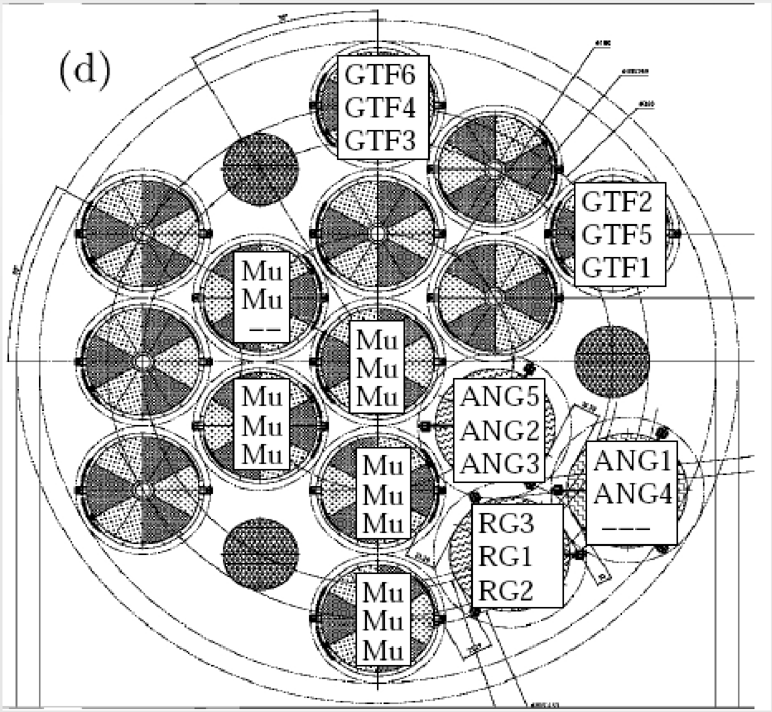
    -> 10^4 times smaller than 2.6-MeV flux by ^{208}Tl in cryostat

How to Group Array

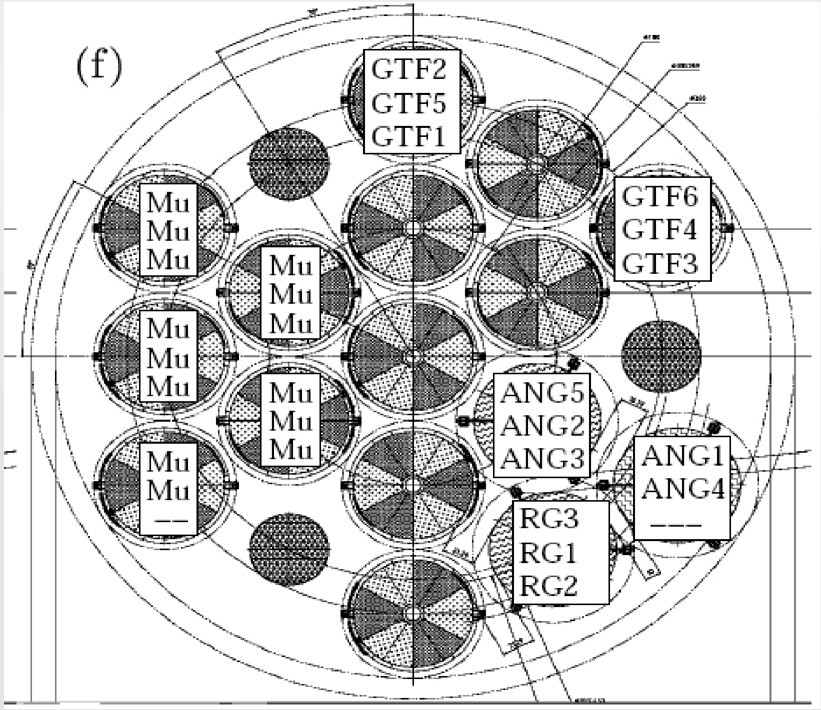
What is best Phase II Array setup?

8 Phase I Crystals + 6 GTF + 14 Phase II Crystals

1) Phase I + GTF close to Phase II

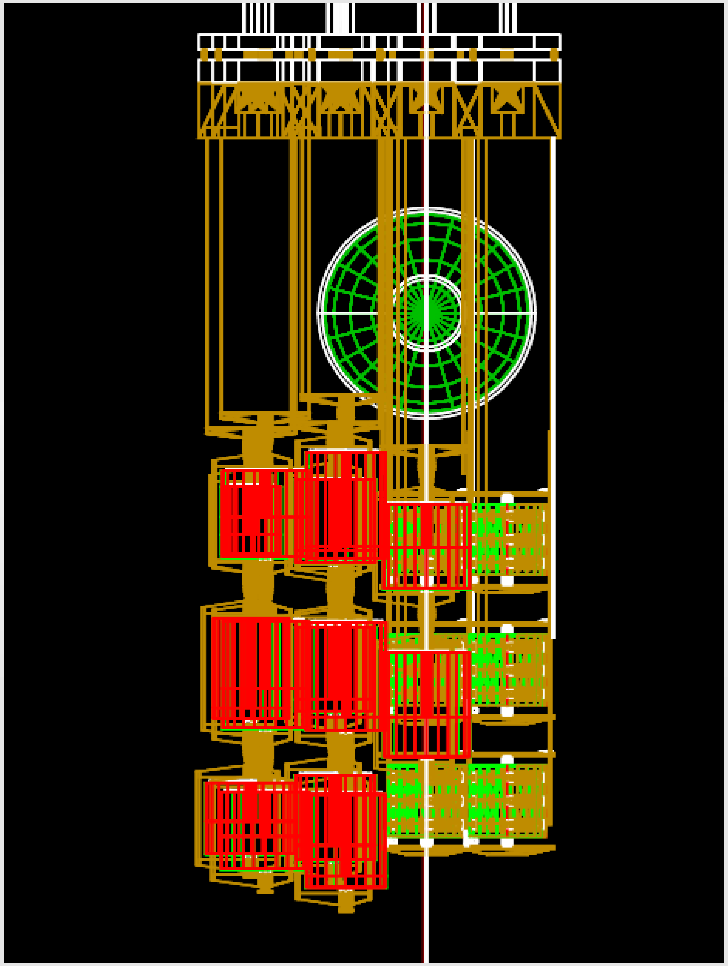


2) Phase I + GTF far away from Phase II

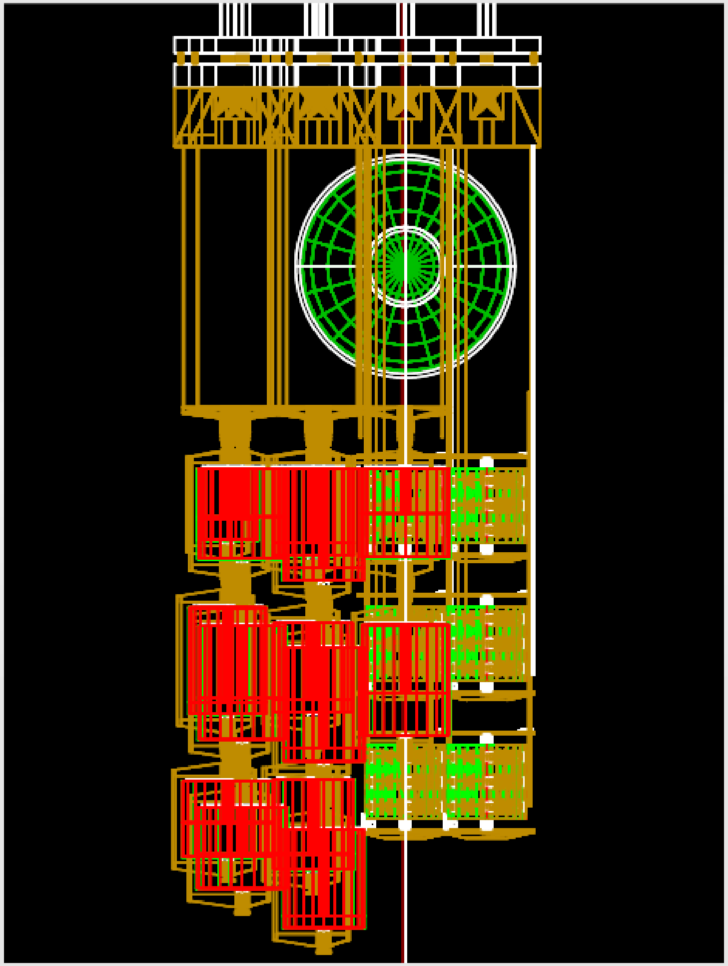


How to Align Array

1) Align center of middle crystal



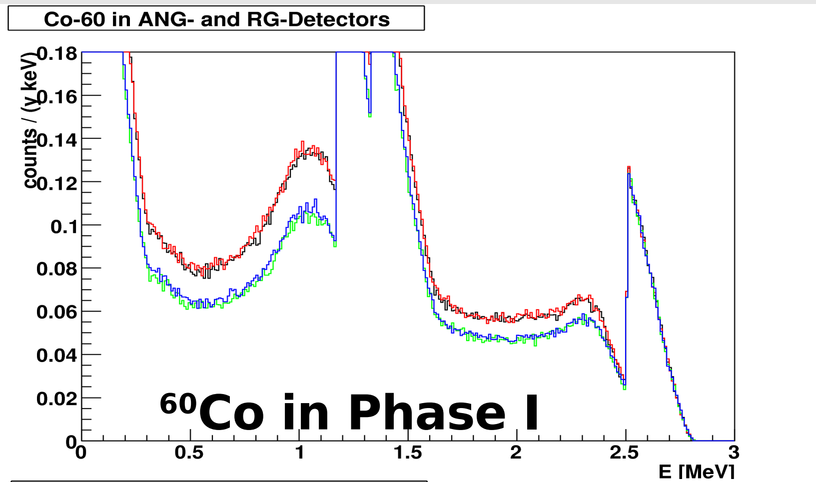
2) Align top of crystals

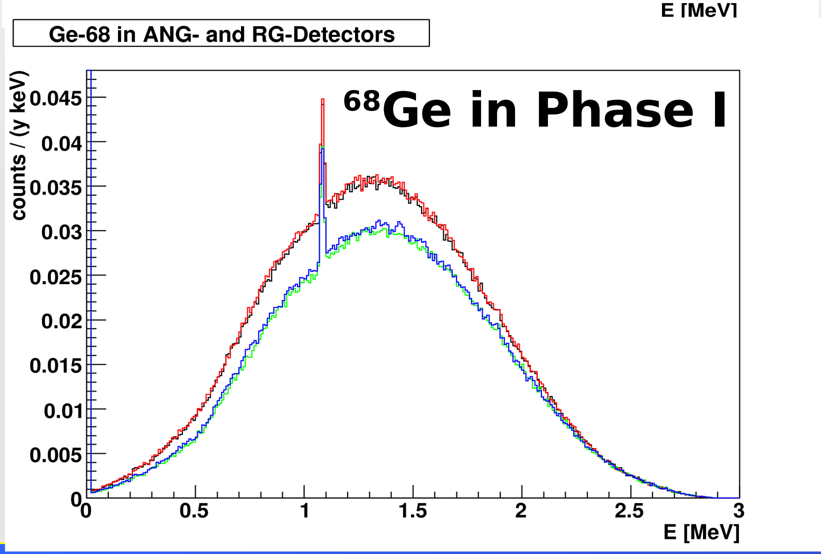


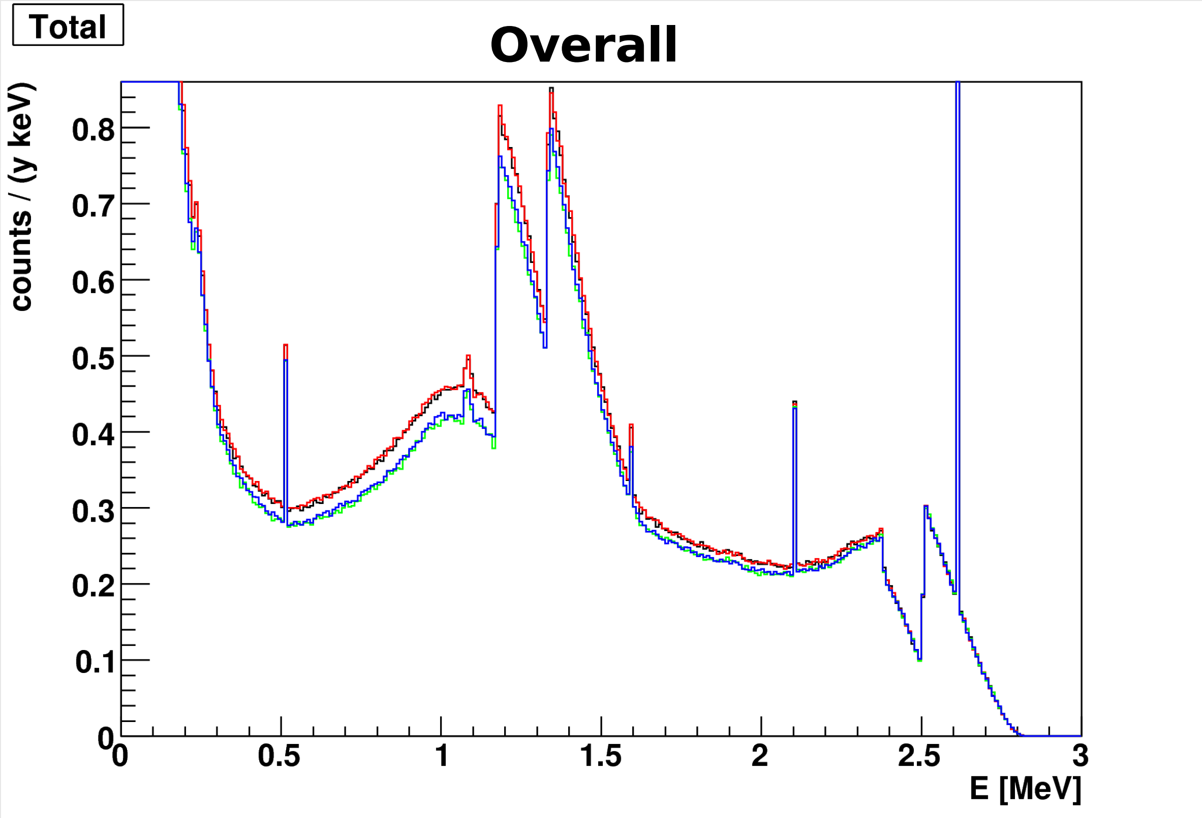
Array Simulation

Simulated:
- ^{68}Ge, ^{60}Co inside crystals
- ^{208}Tl in Kapton cables + copper holders

- seperated sub-arrays, z-centered (black)
- seperated sub-arrays, align top (red)
- tight sub-arrays, z-centered (green)
- tight sub-arrays, align top (blue)





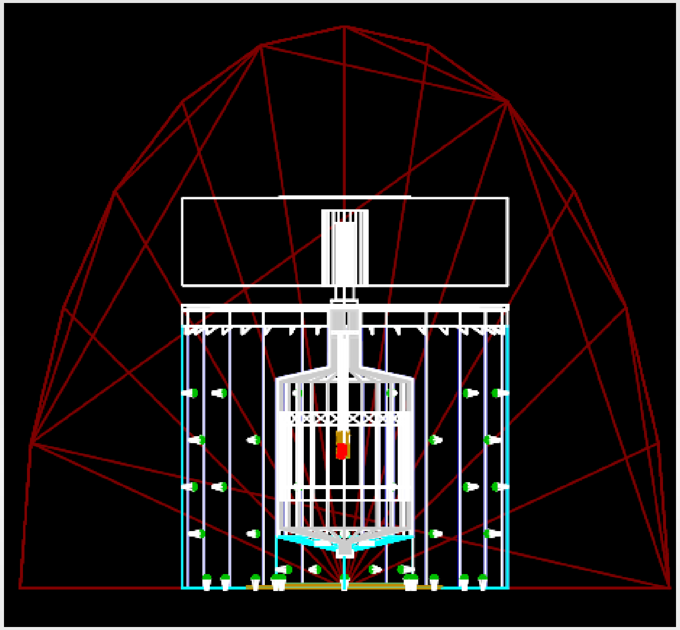


Difference marginal,
slightly better bkg discrimination in tight array

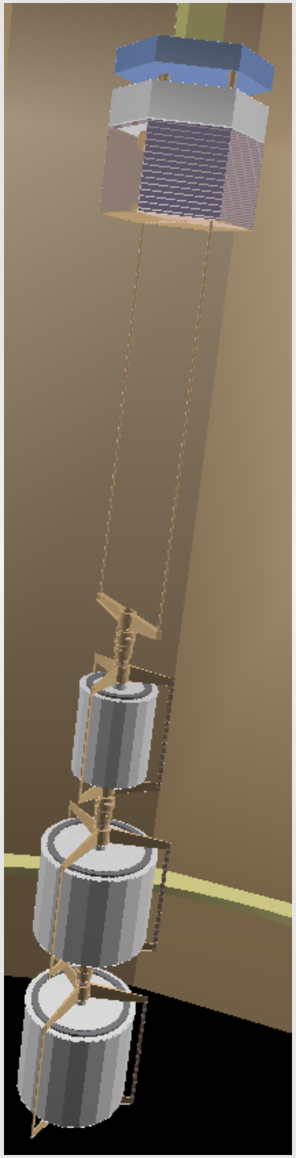
Monte Carlo Campaign 2

Updates of Geometry:

- Hall A implemented



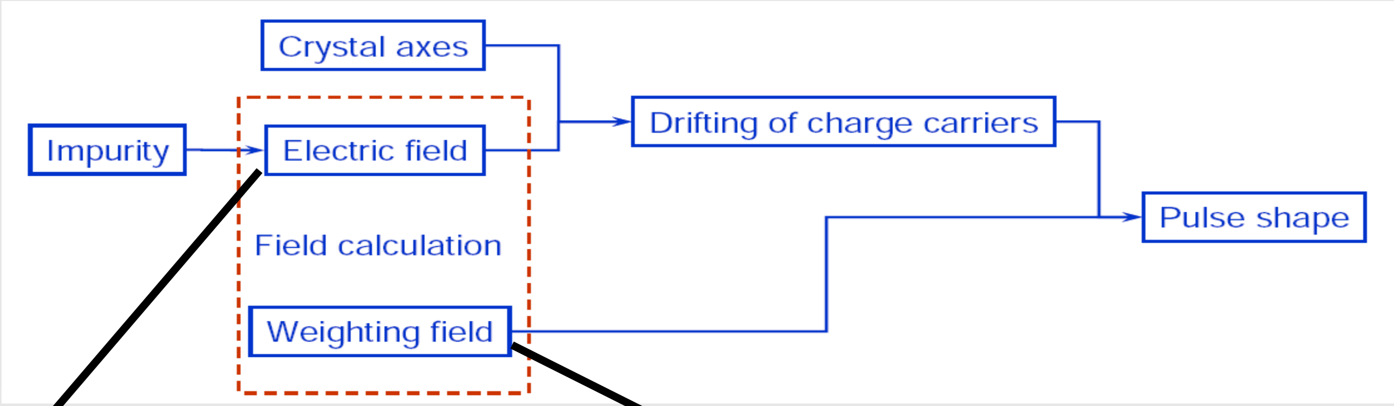
- Phase I string nearly finished
  - Real crystal dimensions
  - Dynamic holder size
  - Teflon parts

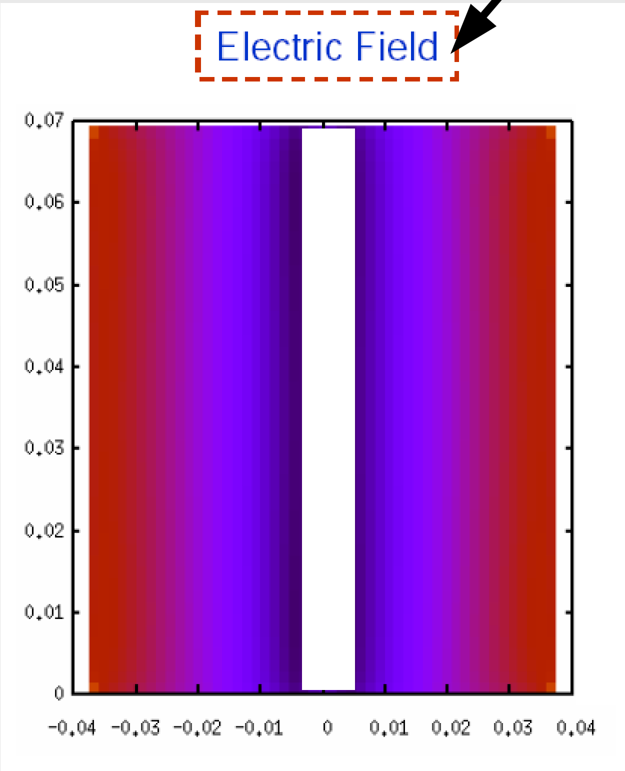


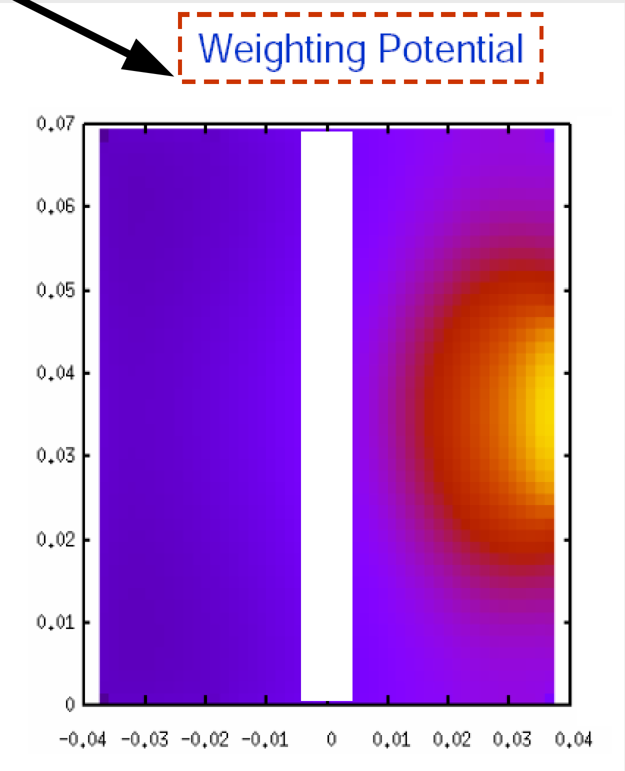
- Further small improvements
- Still work ahead :
  - realistic lock layout (neutrons through neck)
  - infrastructure outside watertank
  - ...

Pulse Shape Simulation

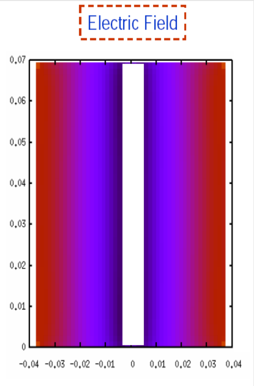
Last Time:

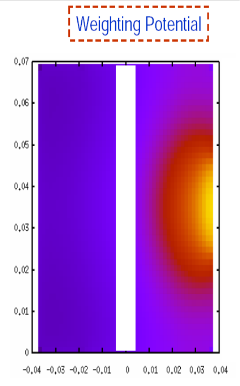


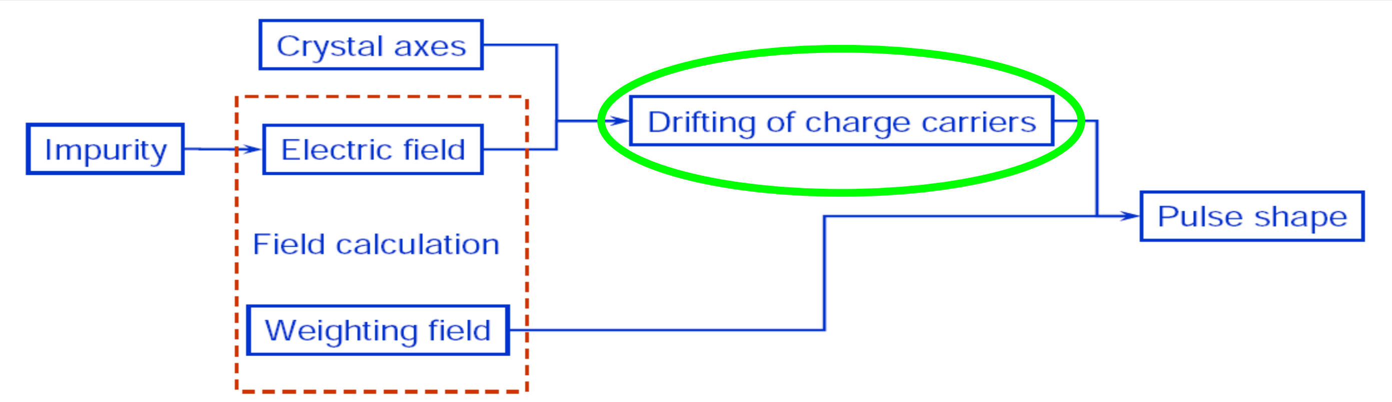


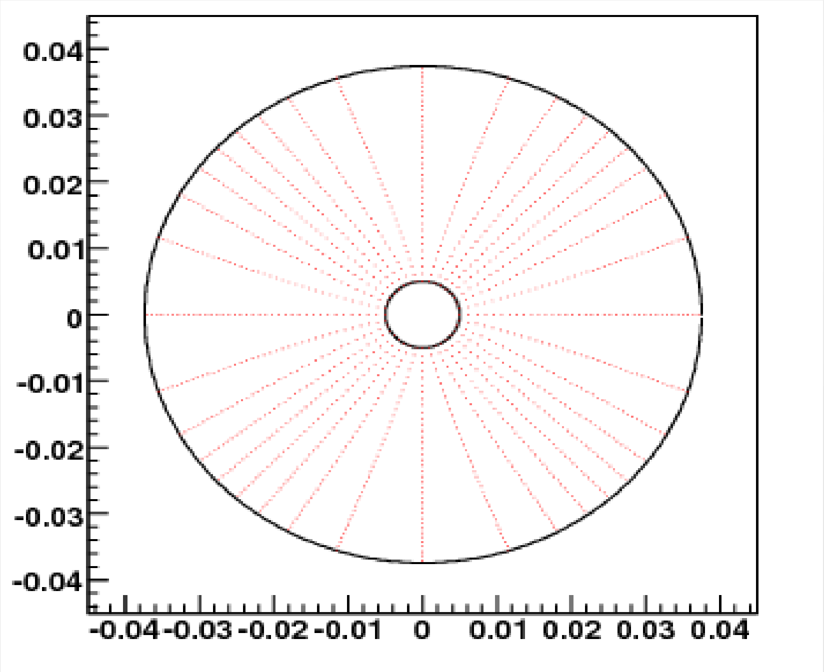


Pulse Shape Simulation

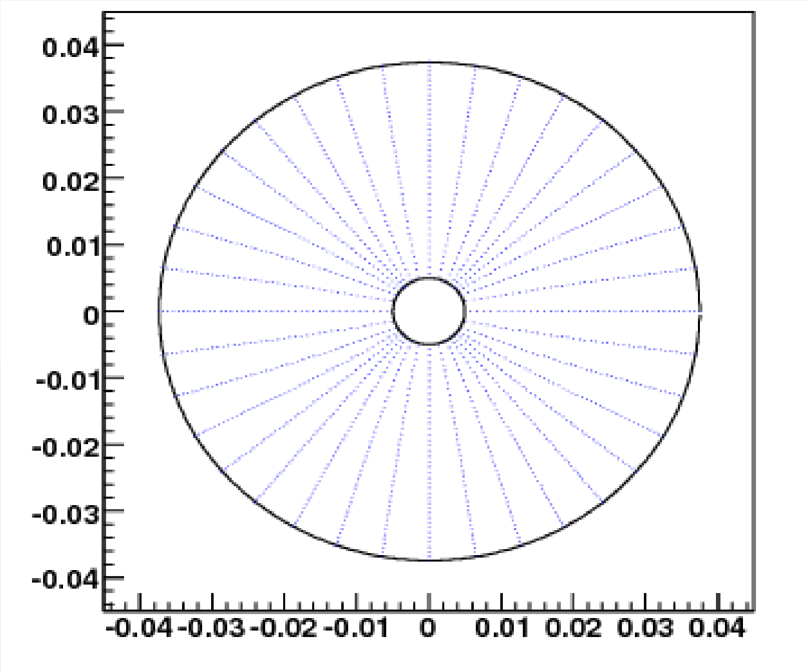






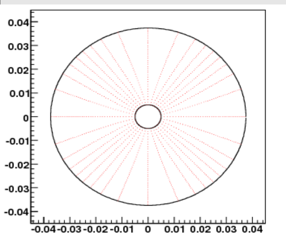


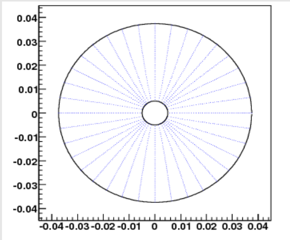
Trajectory of electrons

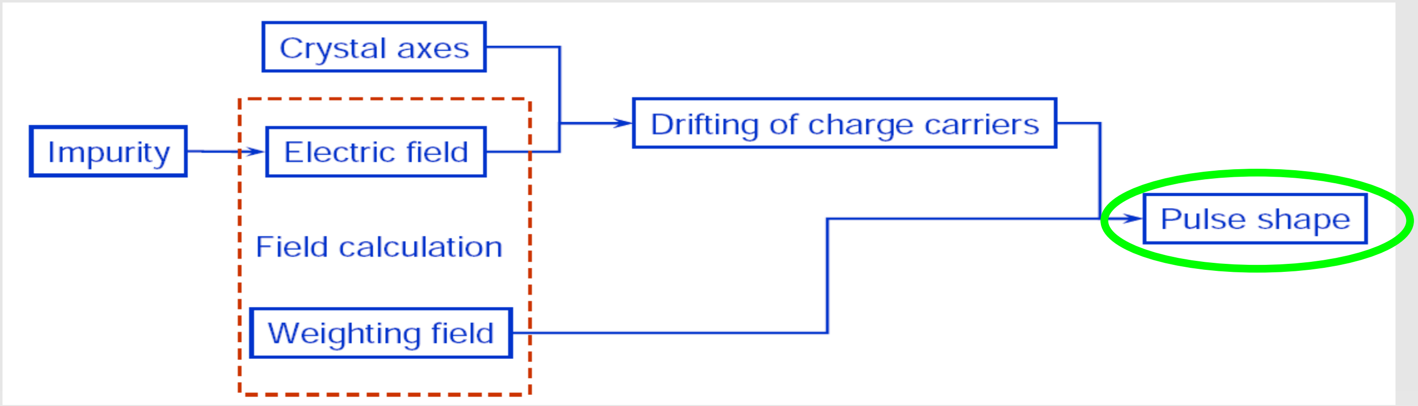


Trajectory of holes

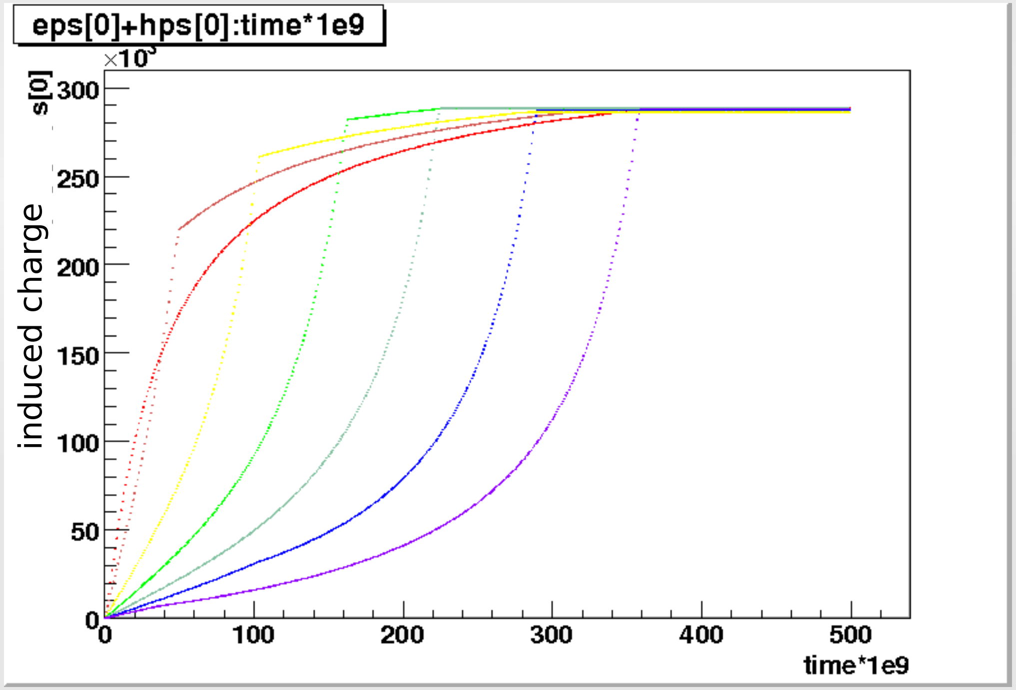
Pulse Shape Simulation



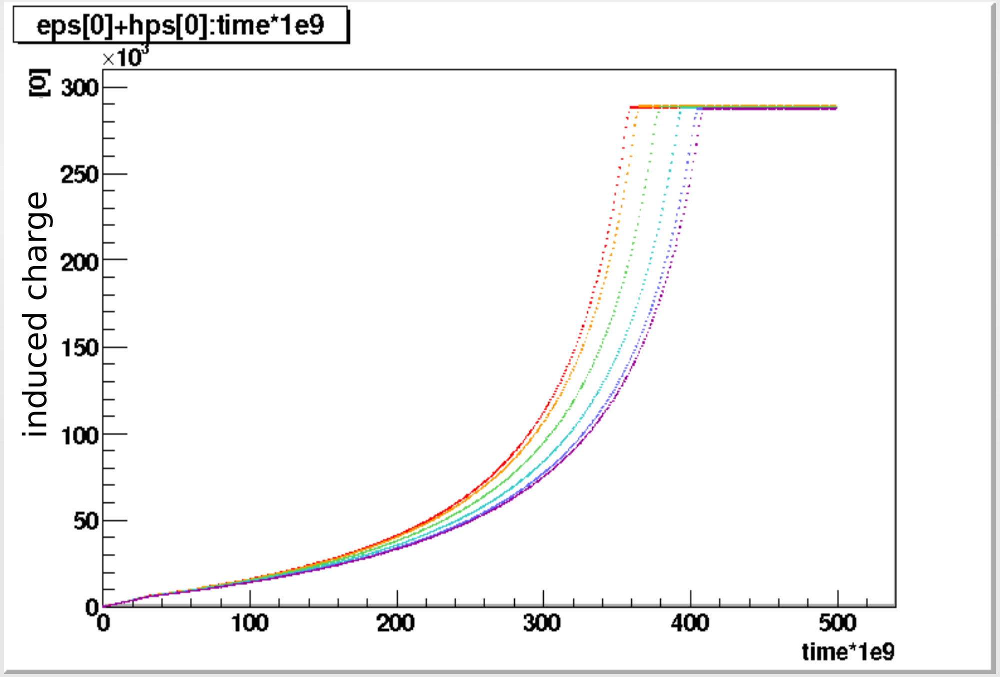




First Pulse Shapes from core



different radii r, fixed phi



fixed r, different phi

MaGe Paper

uploaded on arXiv (0802.0860) on Feb 6th and submitted to IEEE Trans. Nucl. Scie.

TRANSACTIONS ON NUCLEAR SCIENCE (TNS) 1

MAGE - a GEANT4-based Monte Carlo framework for low-background experiments

Yuen-Dat Chan[1], Jason A. Detwiler[1,2], Reyco Henning[1,3], Victor M. Gehman[2,4] Rob A. Johnson[2], David V. Jordan[5], Kareem Kazkaz[2,6], Markus Knapp[7], Kevin Kröninger[8,9], Daniel Lenz[8], Jing Liu[8], Xiang Liu[8], Michael G. Marino[2], Akbar Mokhtarani[1], Luciano Pandola[10], Alexis G. Schubert[2], Claudia Tomei[10]

Reviews from IEEE-TNS disparate: Reviewer 1 “ok” , Reviewer 2 14 pages (!) of comments (some meaningful, some not) and required major revision

Decision taken to withdraw paper and re-submit new manuscript

Focus to real novelties of MaGe, i.e. flexibility, position samplers, interfaces, physics models chosen

Conclusion

Simulation of Strings in nominal Phase II setup results in ~15 * 10^{-4} cts/(kg keV y)

MCC2 is well underway

Differences between tight and separated arrays marginal
Tight array has better background discrimination

Pulse shape Simulation is making good progress

MaGe paper has been withdrawn and will be re-submitted

Backup

Array Simulation

mass holder phase I: 1.0484 kg	^{208}Tl: 445.225 1/kg/y	
mass holder phase II: 0.448 kg	^{208}Tl: 445.225 1/kg/y	
mass cable phase II: 0.0112 kg	^{208}Tl: 22832.1 1/kg/y	

mass crystal phase I: 17.86 kg	^{68}Ge: 4.2 1/kg/y	^{60}Co: 30 1/kg/y
mass crystal GTF : 15.26 kg	^{68}Ge: 4.2 1/kg/y	^{60}Co: 30 1/kg/y
mass crystal phase II: 22.6235 kg	^{68}Ge: 30 1/kg/y	^{60}Co: 10 1/kg/y