A Liquid Argon Scintillation Veto for the GERDA Experiment

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for the GERDA Collaboration

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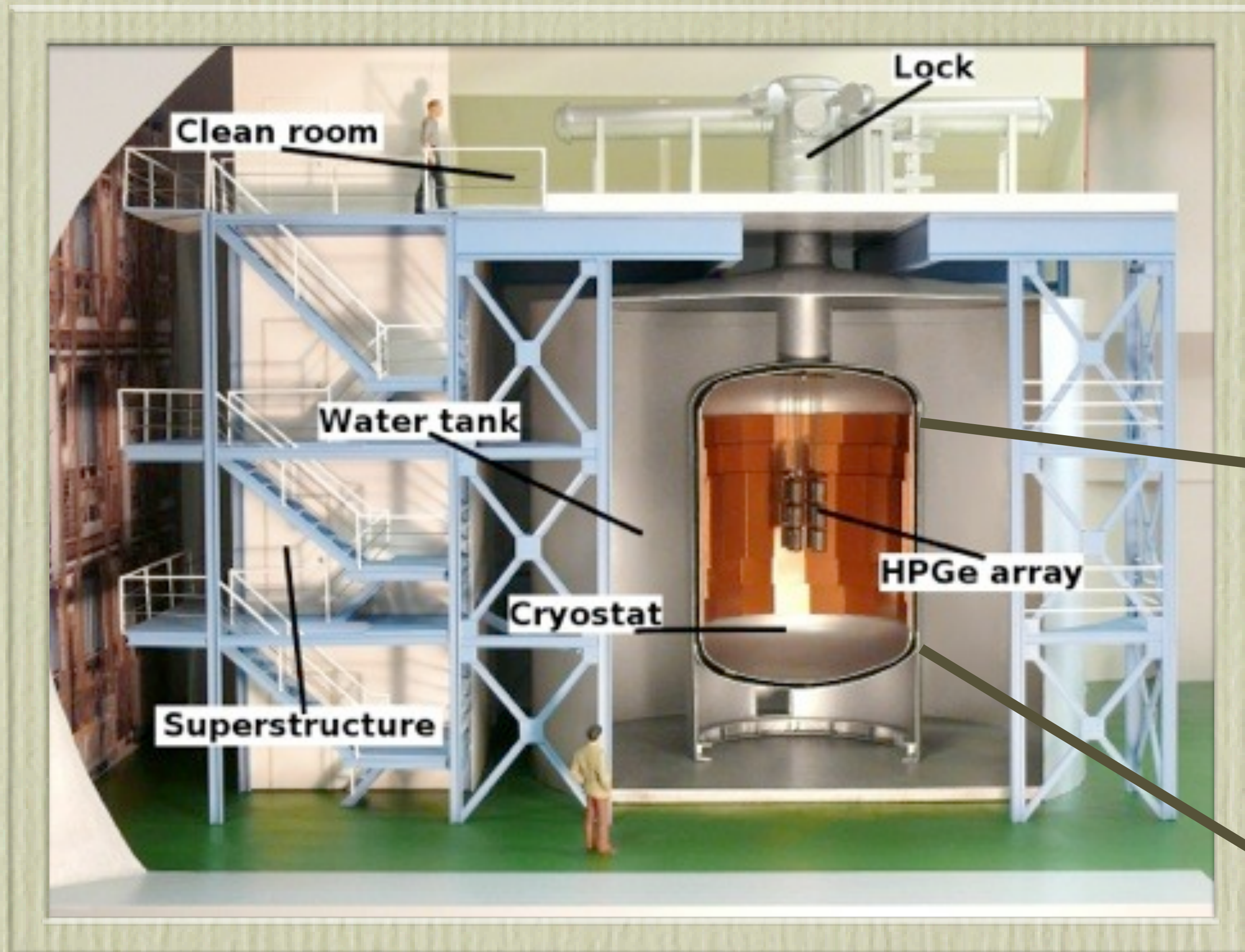
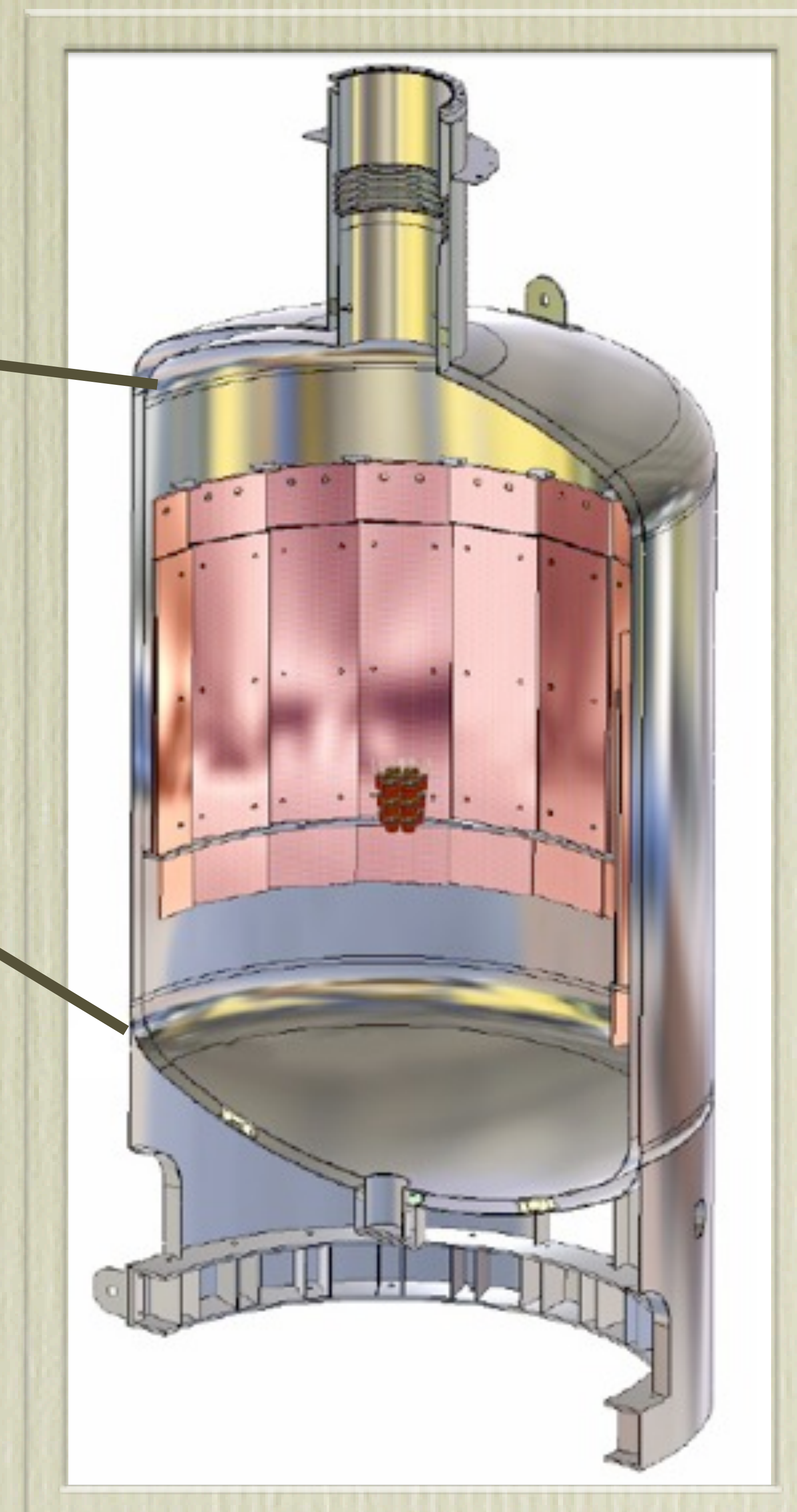
GERDA

TECHNISCHE UNIVERSITÄT DRESDEN

Institut für Kern- und Teilchenphysik

Overview





90 t liquid argon

- **Scintillation in LAr**
- **R&D in LArGe**
- **Two design concepts (Fiber & PMT)**
- **Design comparison**
- **Outlook for Phase II**

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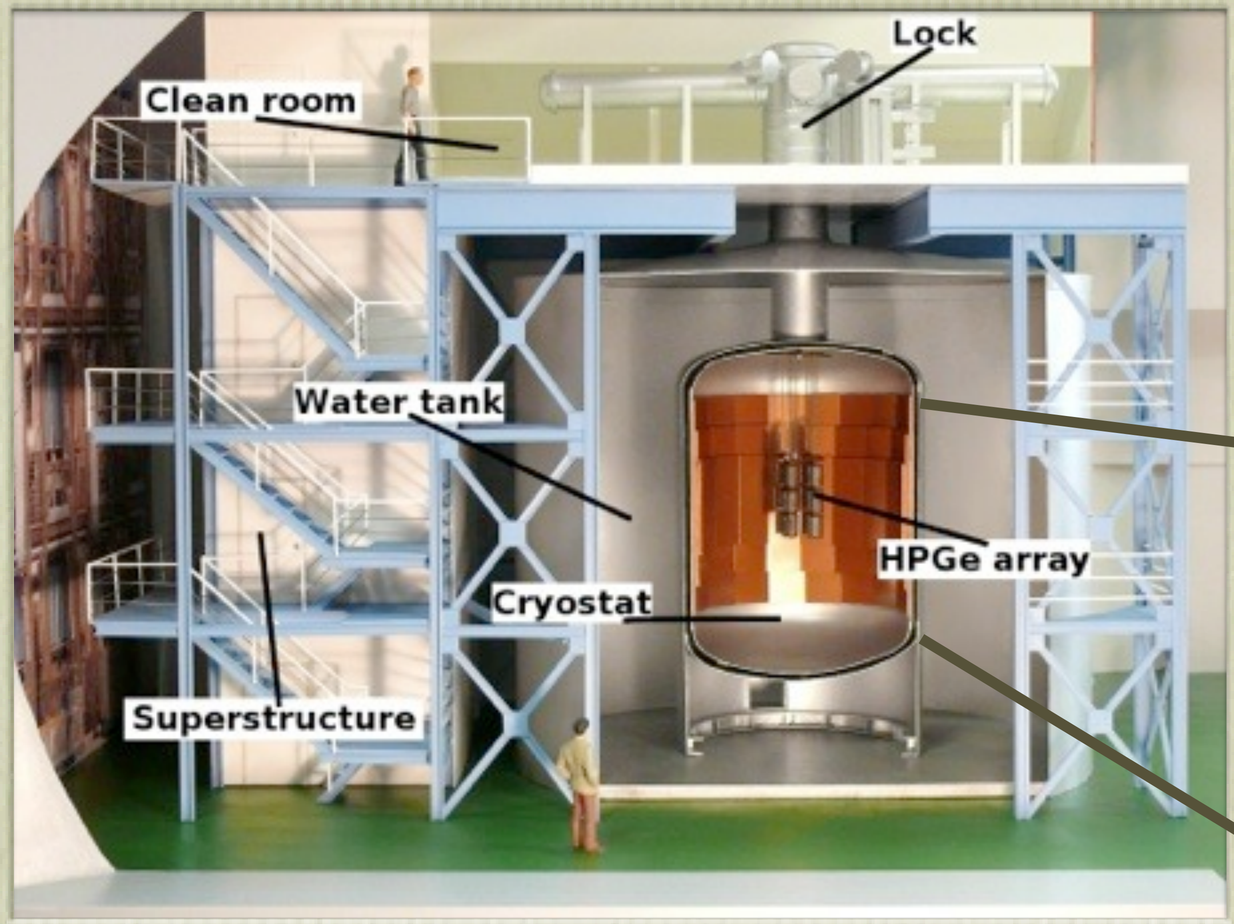

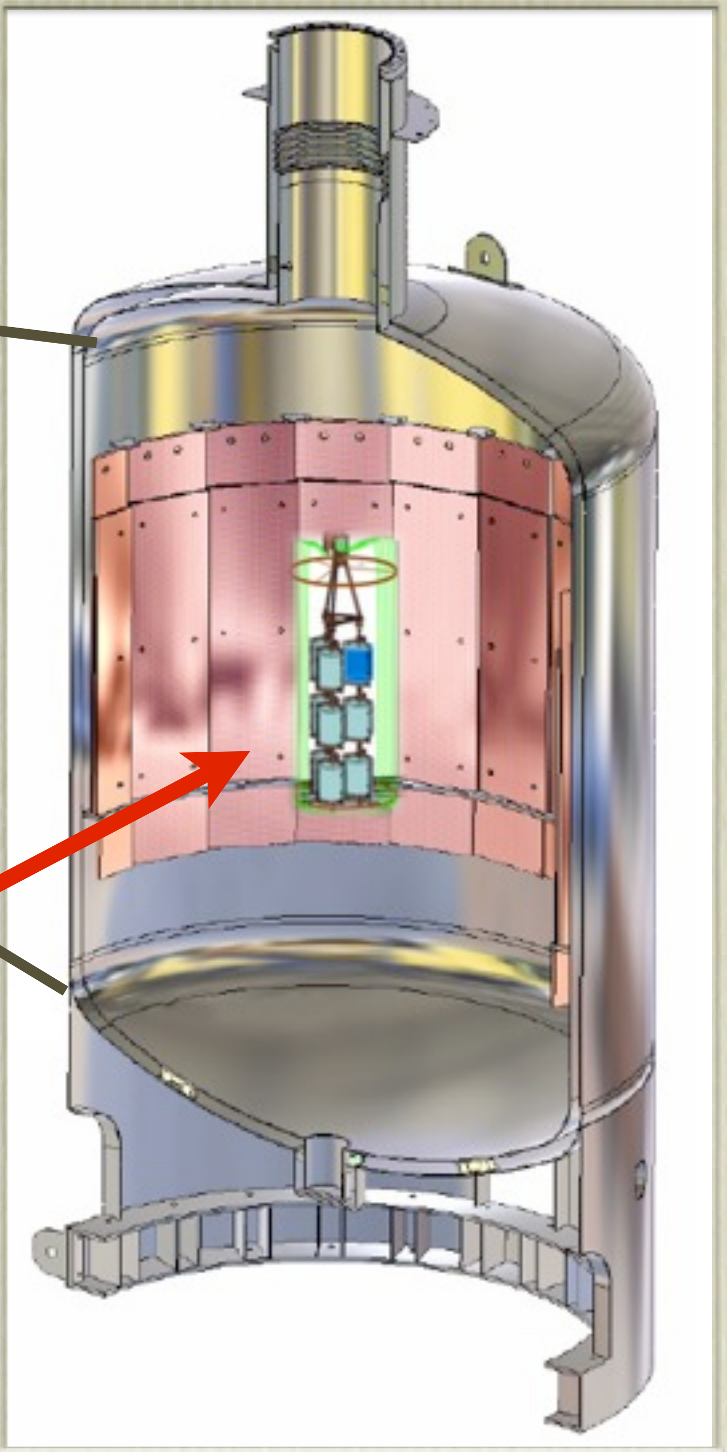

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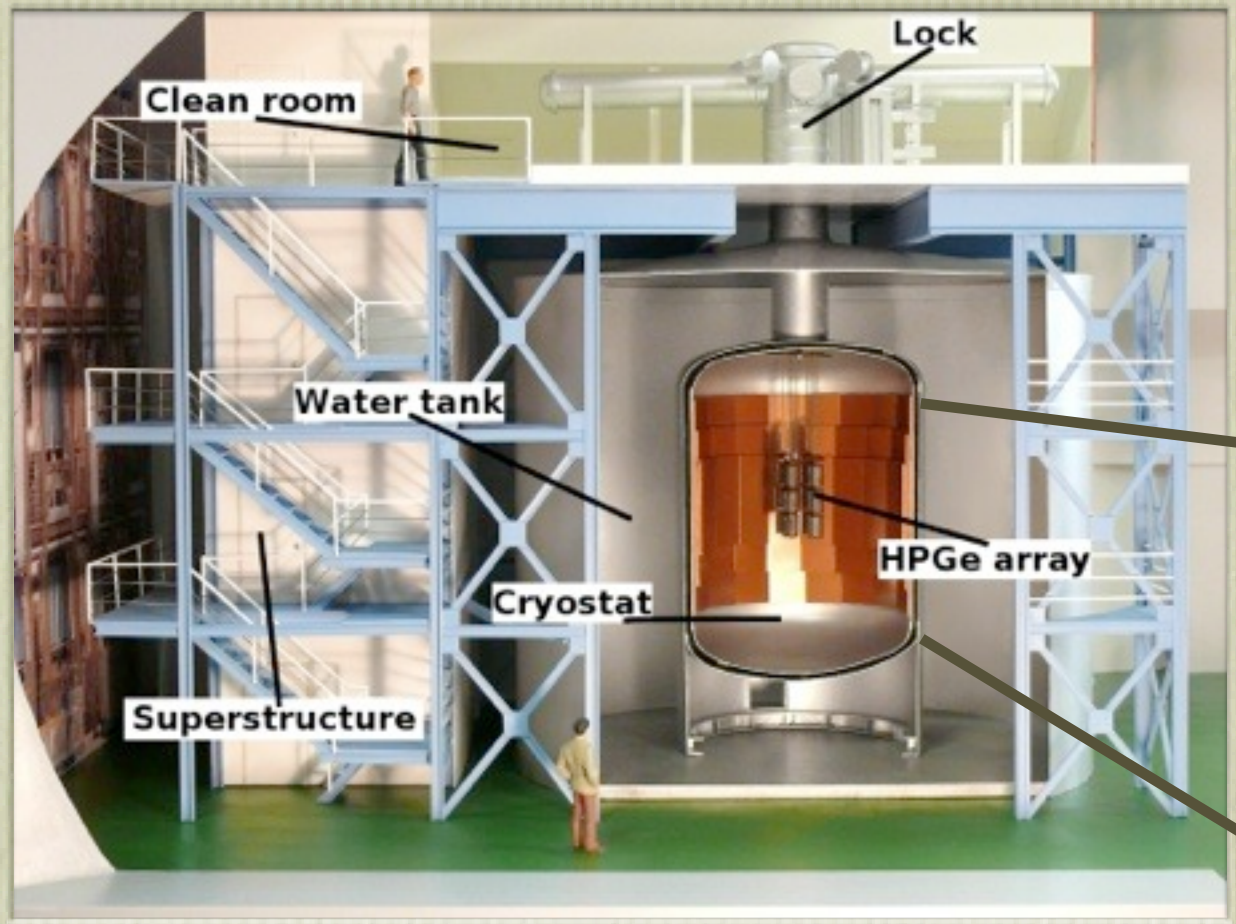

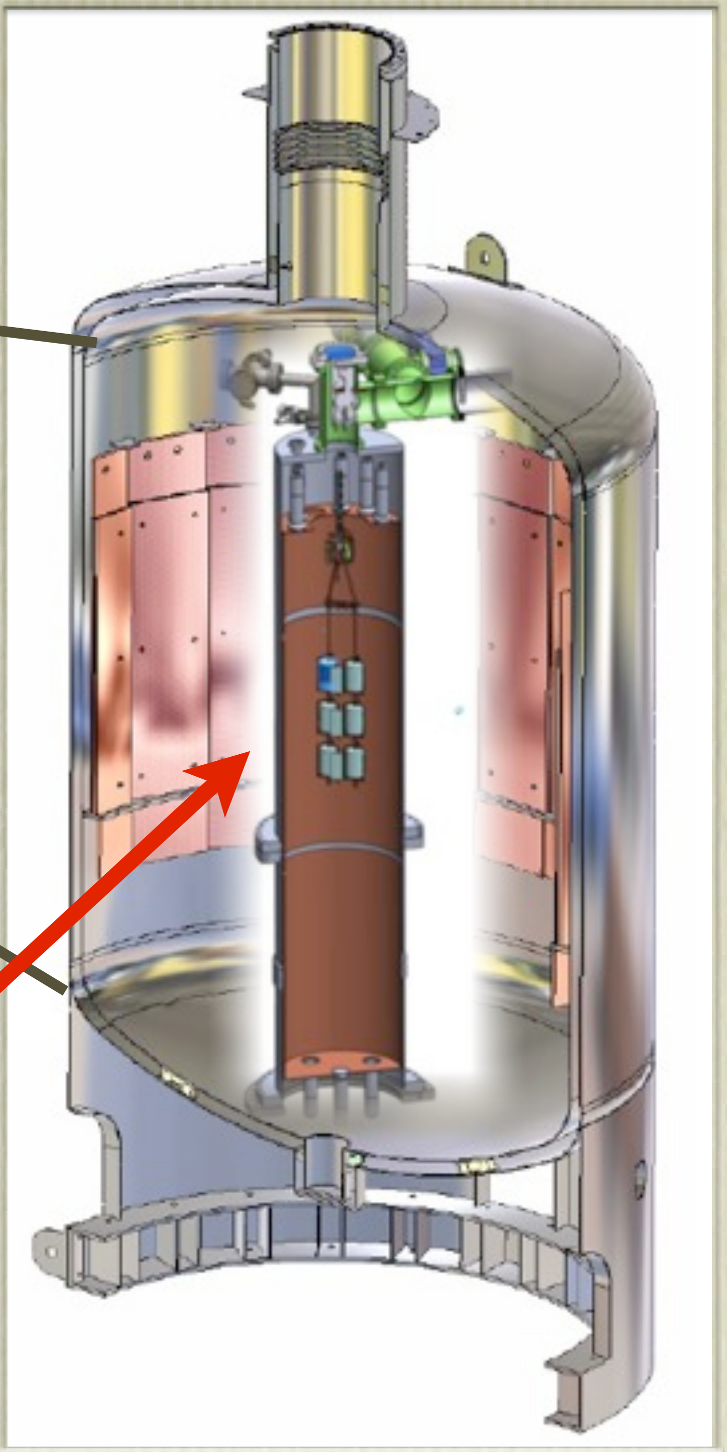

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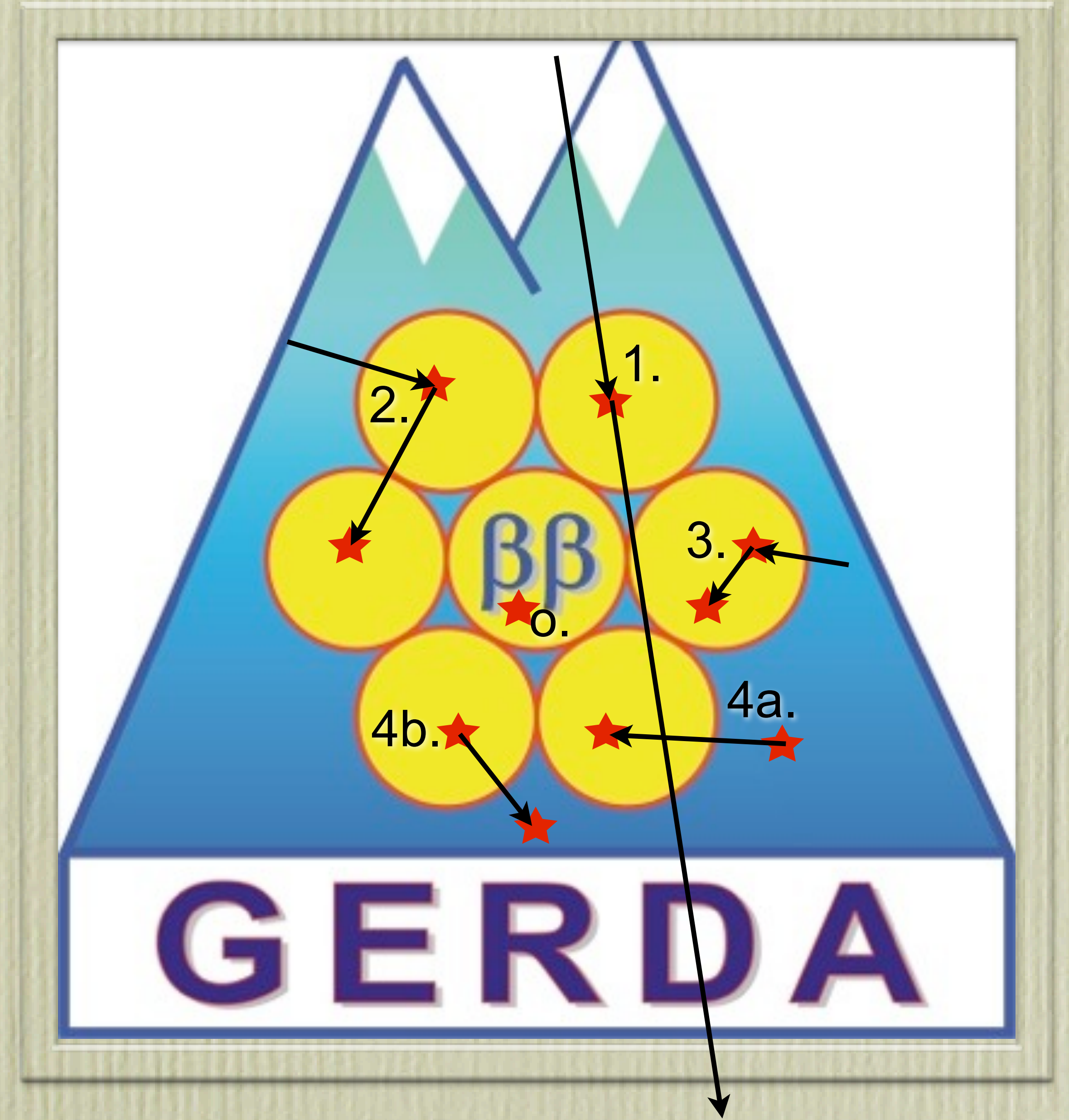
Background Rejection in GERDA



0. 0nubb signal
1. Muon vetoed
2. Anti coincidence vetoed
3. Pulse shape discriminated

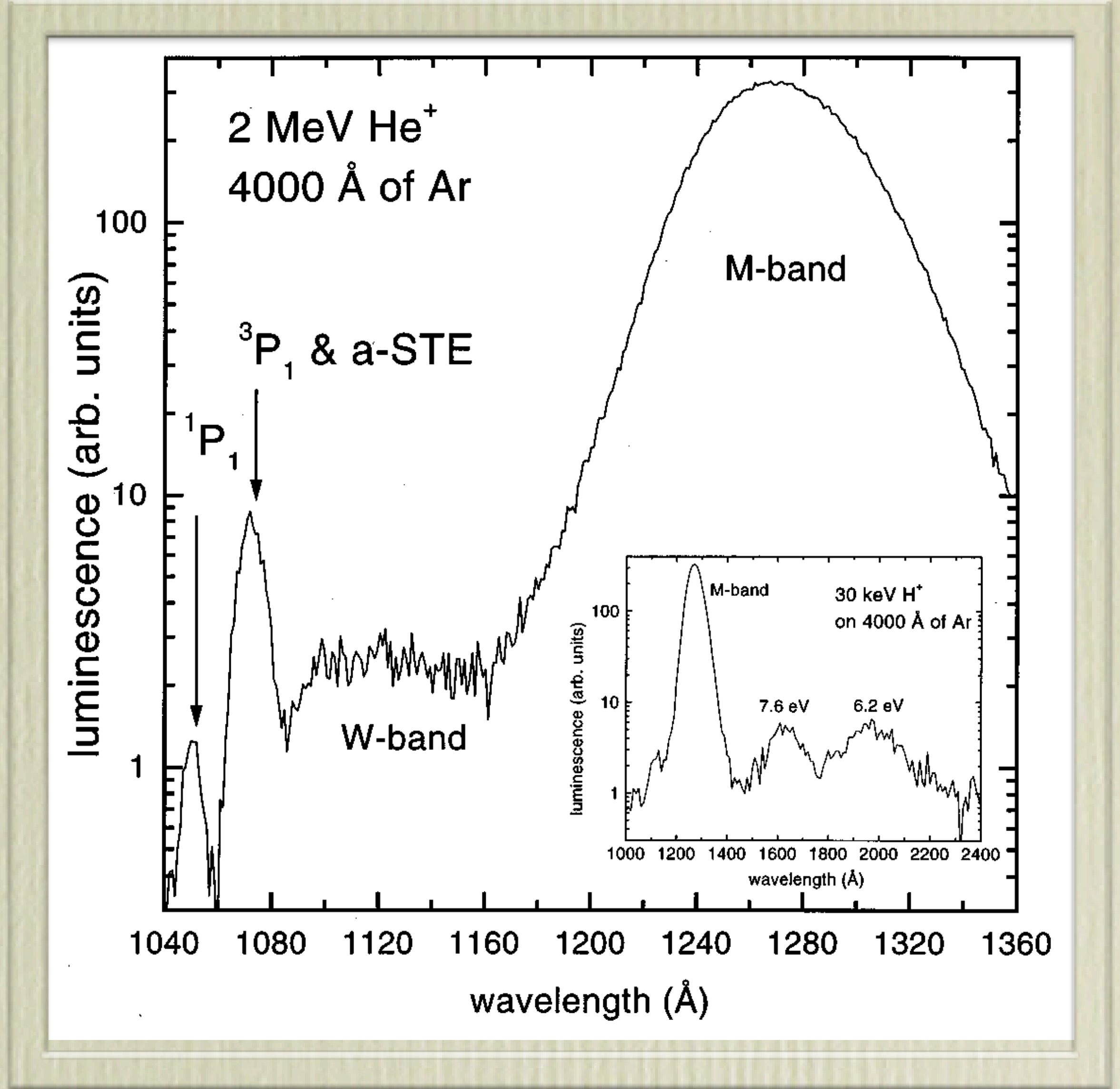
4a. LAr vetoed from outside

4b. LAr veto from inside

- Goal: Optimize LAr veto for main backgrounds in Phase II
  - Tl208 and Bi214 from outside (holding structure)
  - Po210 and K42 on detector surface (point contact)
  - Ga68/Ge68 inside crystals

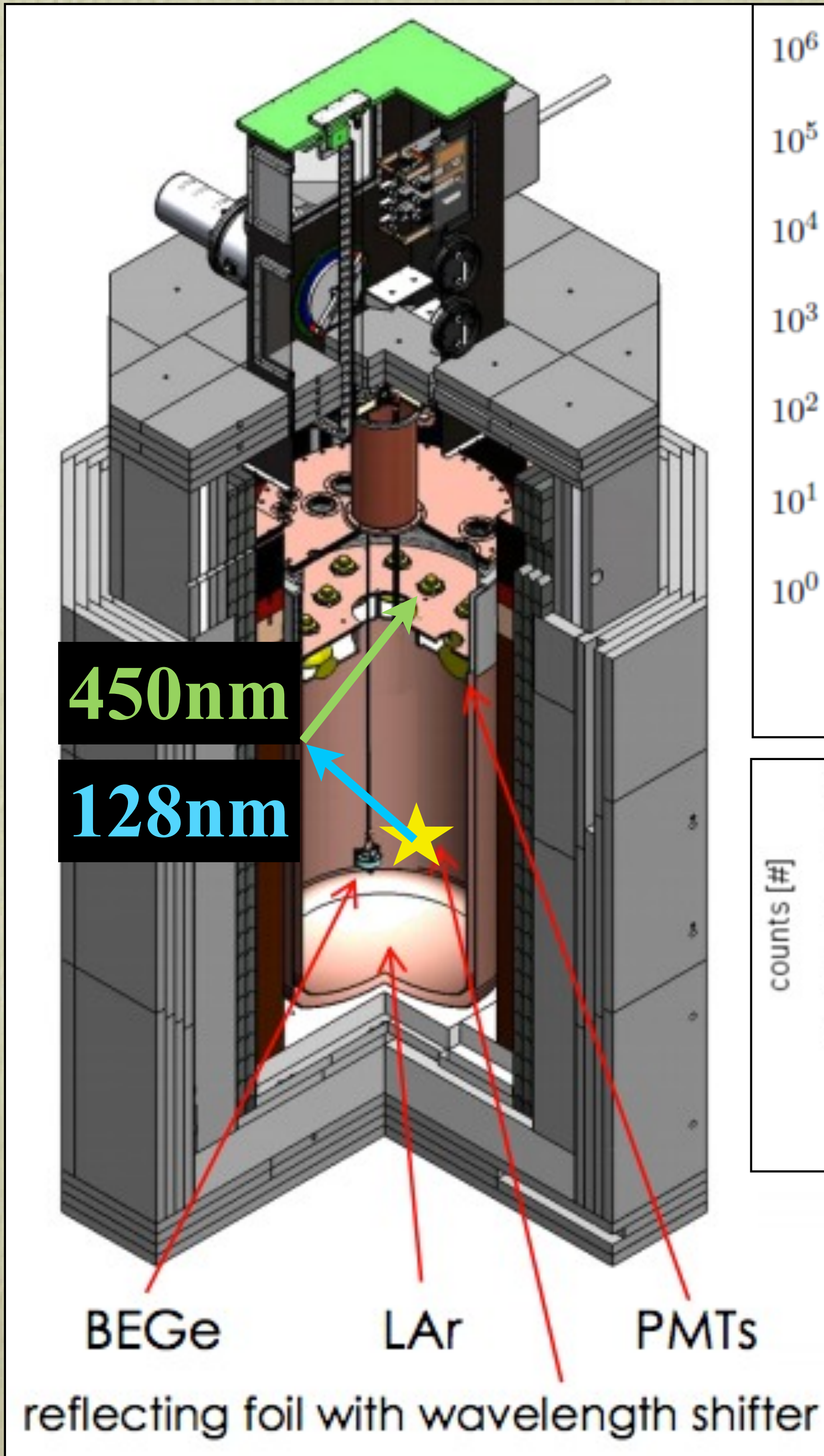
Scintillation in Liquid Argon

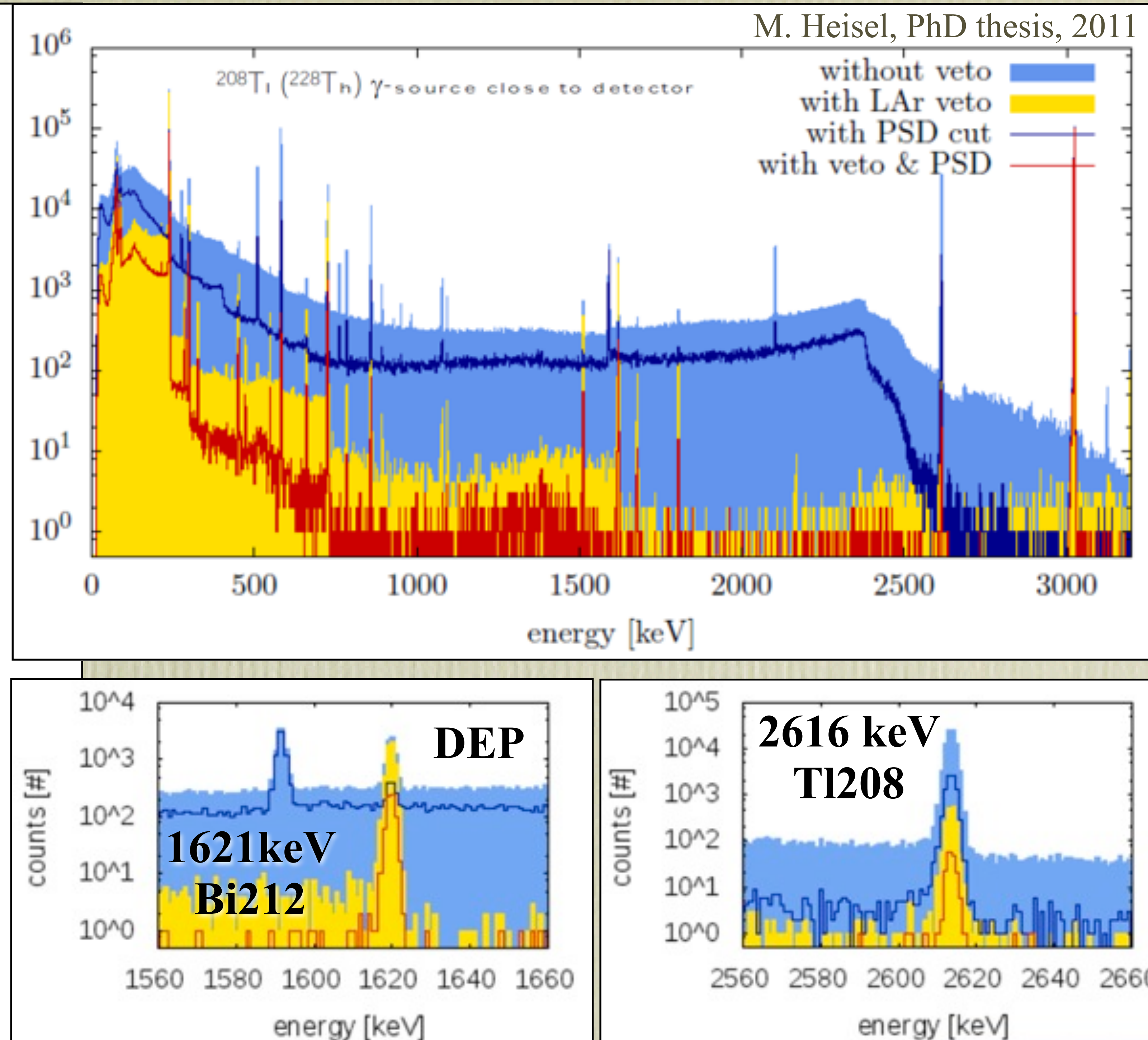
- Light yield: 40.000 γ / MeV
- Single reemission peak (λ=128nm)
  - Not directly detectable
  - Wavelength shifter needed (e.g. VM2000 + TPB)
- Scattering length 128nm: ≈ 80cm
- Scattering length 450nm: > 1km
- Properties highly dependent on impurities: e.g. Xe, N_2



Gosjean, Phys. Rev. B 56 (1997)

R&D with LArGe: Experimental Verification (Th228 source)



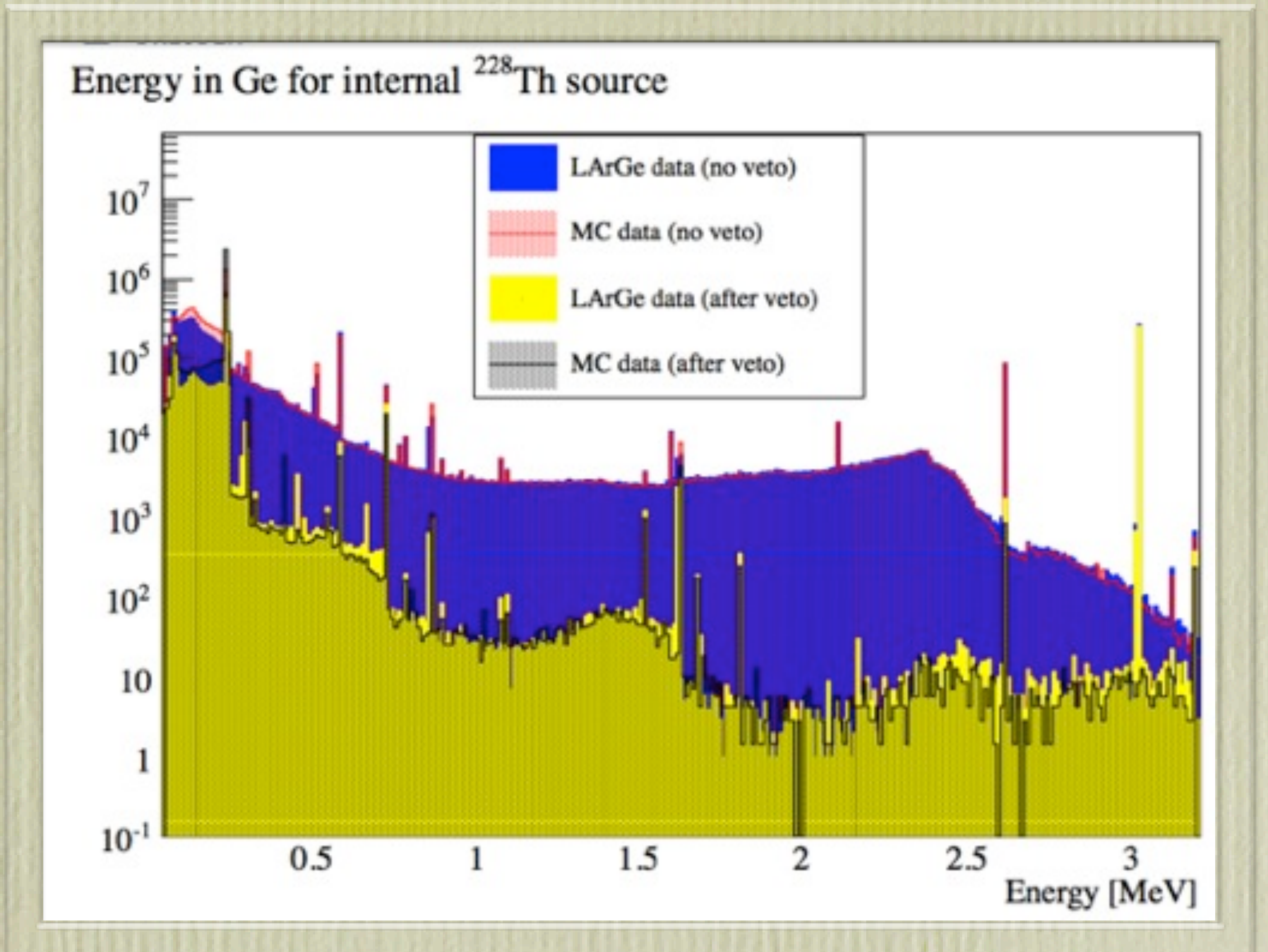


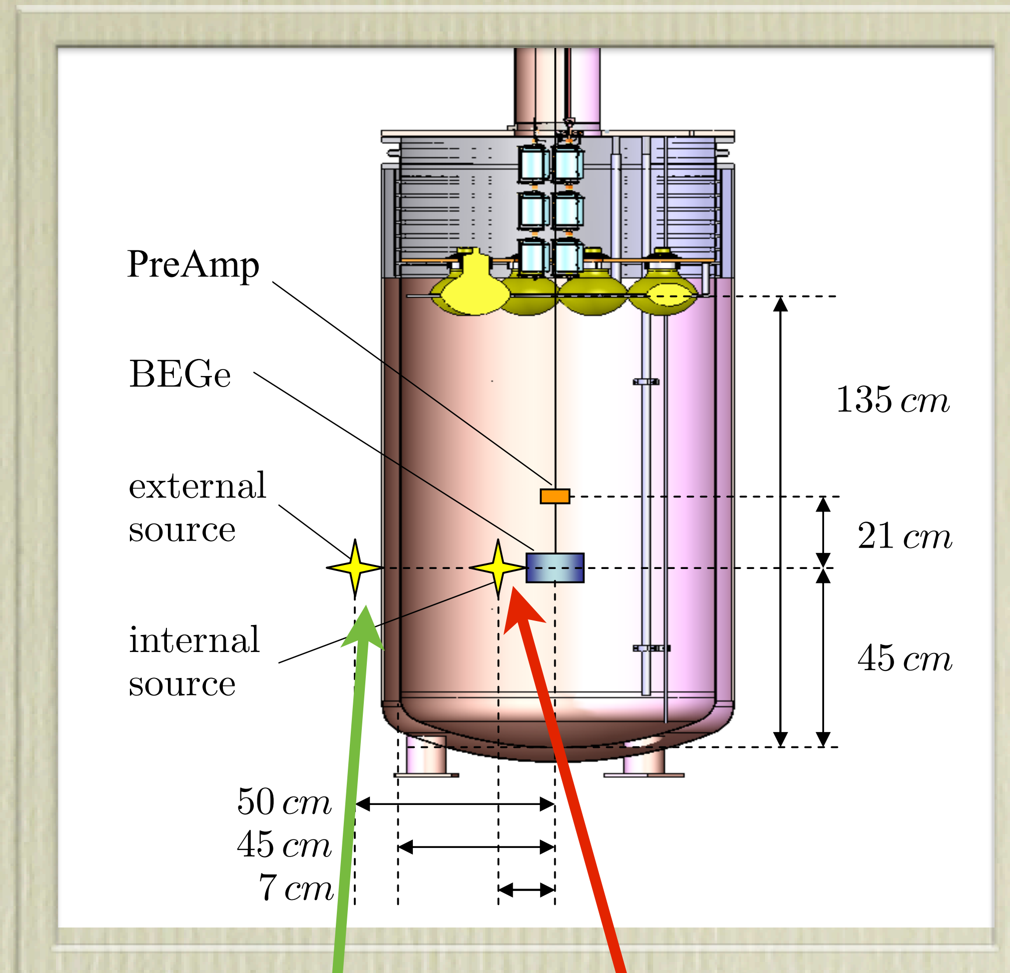
Suppression factors @ Q_{bb}:

Ge events / not vetoed Ge events

LAr: ≈ 1200, PSD: ≈ 2.4, Combined ≈ 5200

R&D with LArGe: MC Verification (Th228 source)



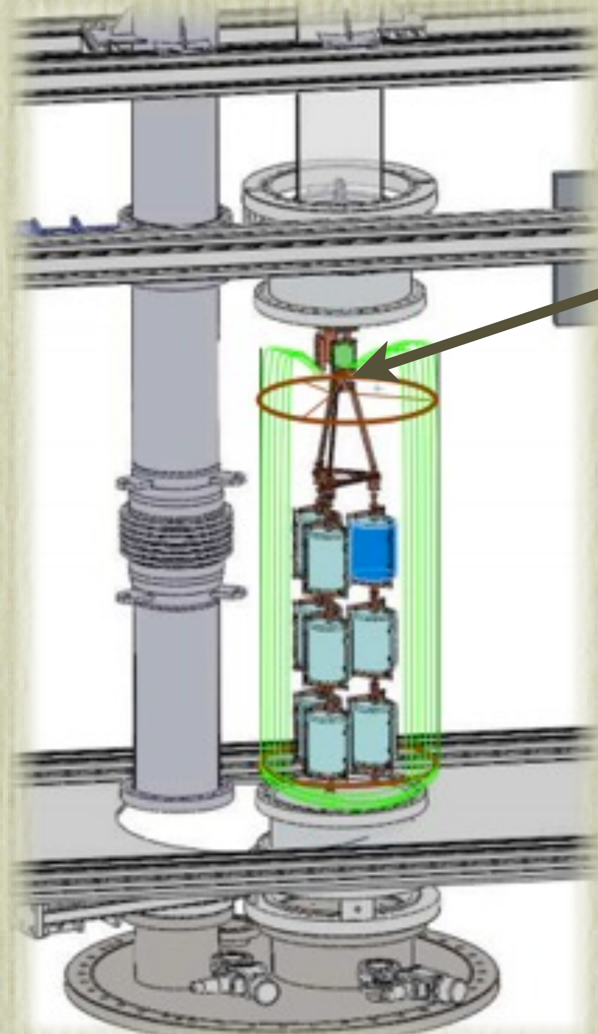


Bg	Exp	MC
Tl208	1180 ± 250	909 ± 235
Bi214	4.6 ± 0.2	3.8 ± 0.1
Co60	27 ± 1.7	16.1 ± 1.3
Tl208	25 ± 1.2	17.2 ± 1.6
Bi214	3.2 ± 0.2	3.2 ± 0.4

LAr suppression factors @ Q_{bb}

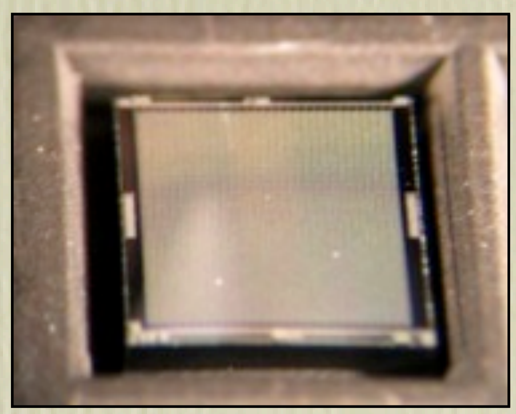
- Tuning of optical properties with MC and auxiliary measurements
  - Material reflectivities (Ge, Cu, VM2000, ...)
  - Absorption and emission spectra
  - LAr attenuation length, light yield and triplet lifetime
- Good MC description for multiple sources after tuning

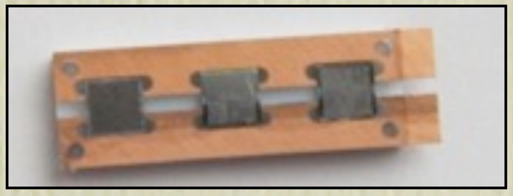
Fiber Design for GERDA



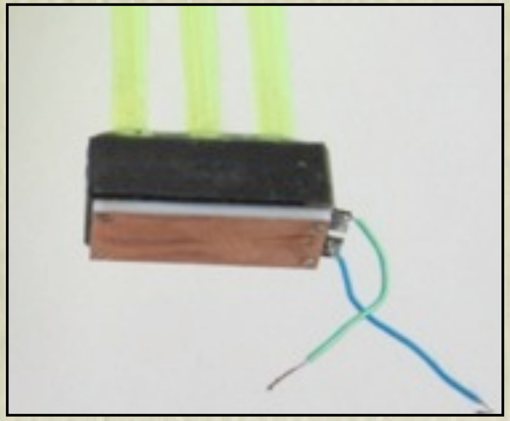
2 x h =100cm d=25cm
0.5kg fibers ≈2m^2 detector
60 SiPM

- Read out with KETEK 3mm x 3mm SiPM in die
- Fibers close to detectors for maximum light collection
- Bg compatible with PII goals even without self veto
  - Fibers: Th232: 58 muBq/kg
- Fiber attenuation length measured and modeled (up to 3.8m)

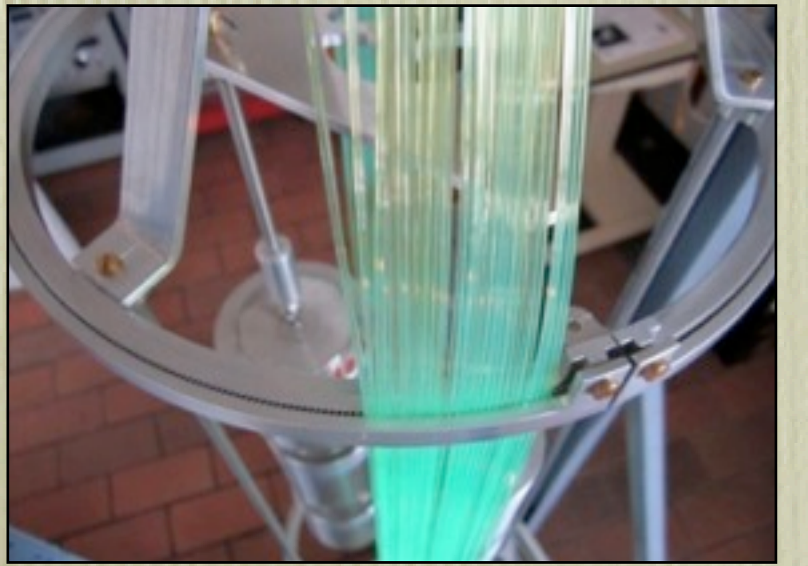


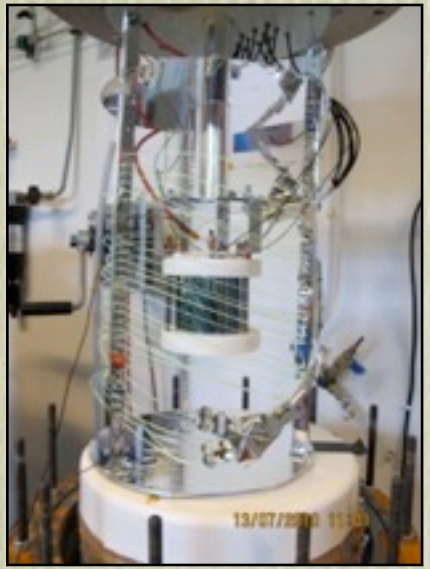


3 SiPM in Cuflon holder

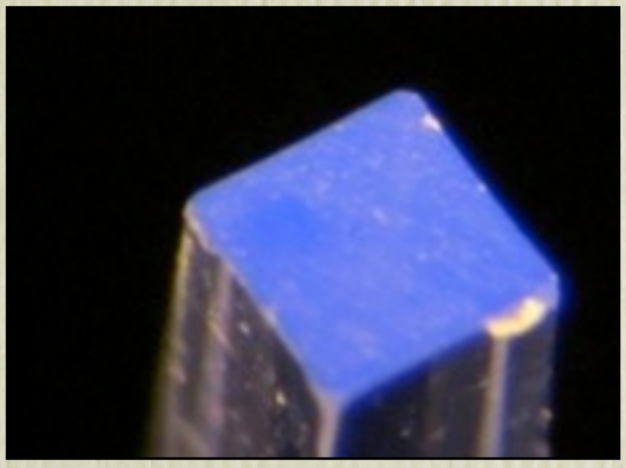


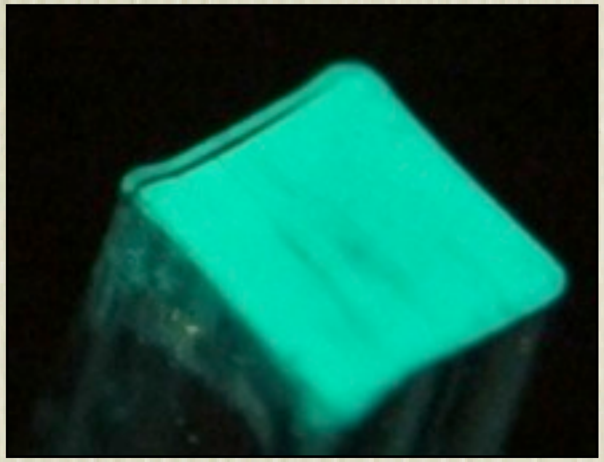
Optical coupling: 9 fibers per SiPM





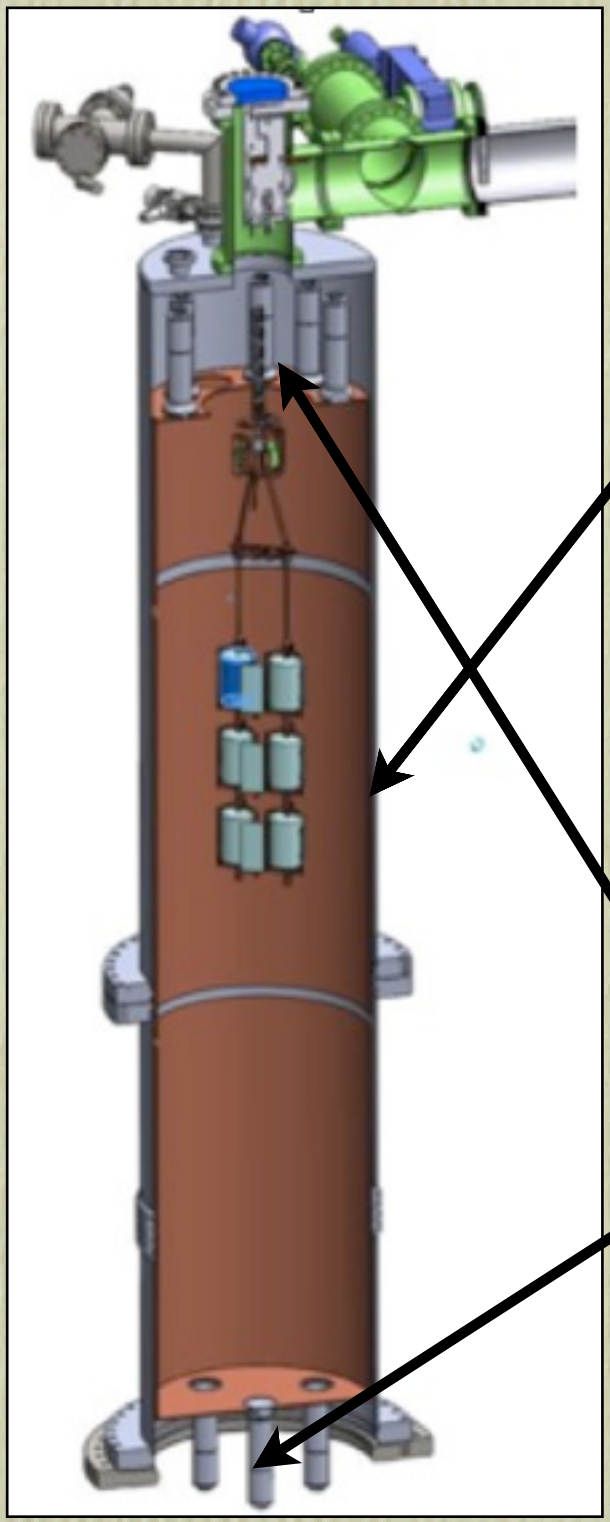
Prototype under construction and tested in small scale





Fibers and coating R&D:
Bare scintillating fiber vs WLS coated fiber

PMT Design for GERDA



3 connected
copper shrouds
h = 210cm, d=50cm

Reflective foil (VM2000)
coated with WLS (TPB)

R11065-10 MOD: (3-inch)
QE 25% @ 420nm
ultra-low bg-version:
2 mBq / PMT (Ra226 & Th228)

- Induced bg compatible with Phase II goals
- Technology proven in LArGe
- PMT long term tests ongoing

low bg voltage divider
operational in LAr

3rd Option:

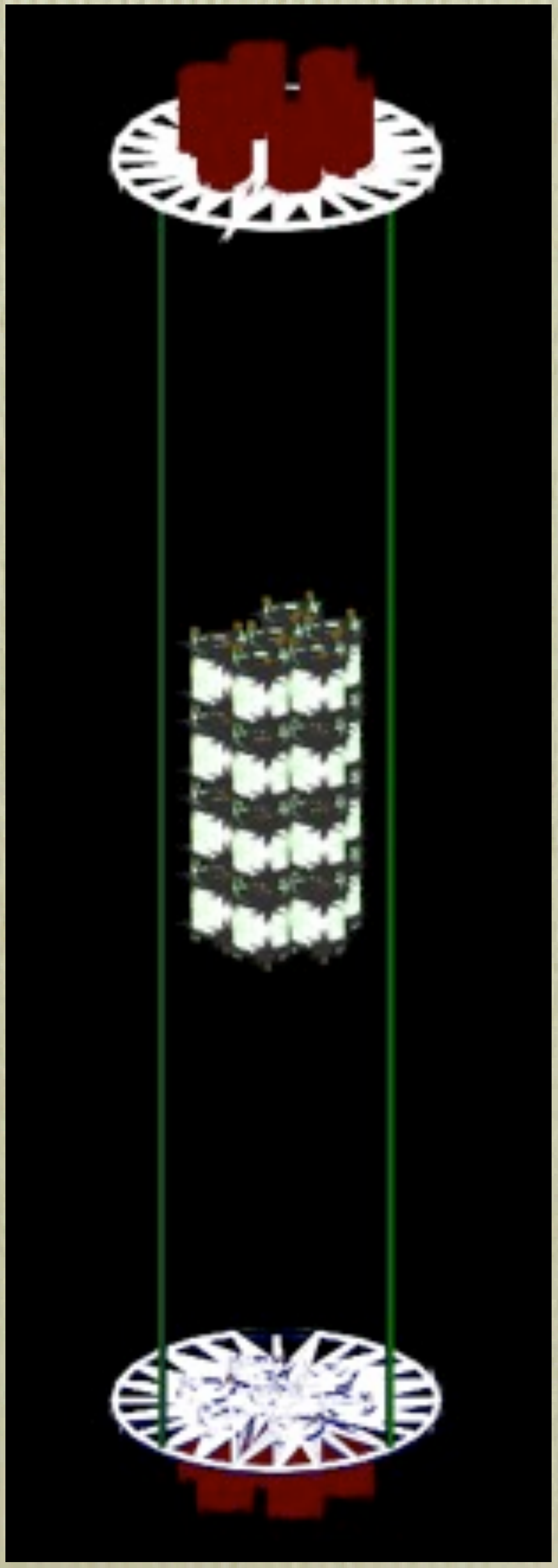
- SiPM / APD close to crystals
- Direct detection of 128 nm photons
- Compatible with Mini Shroud

Design Comparison

Induced bg 10^{-3} [cts/kg/yr/keV]

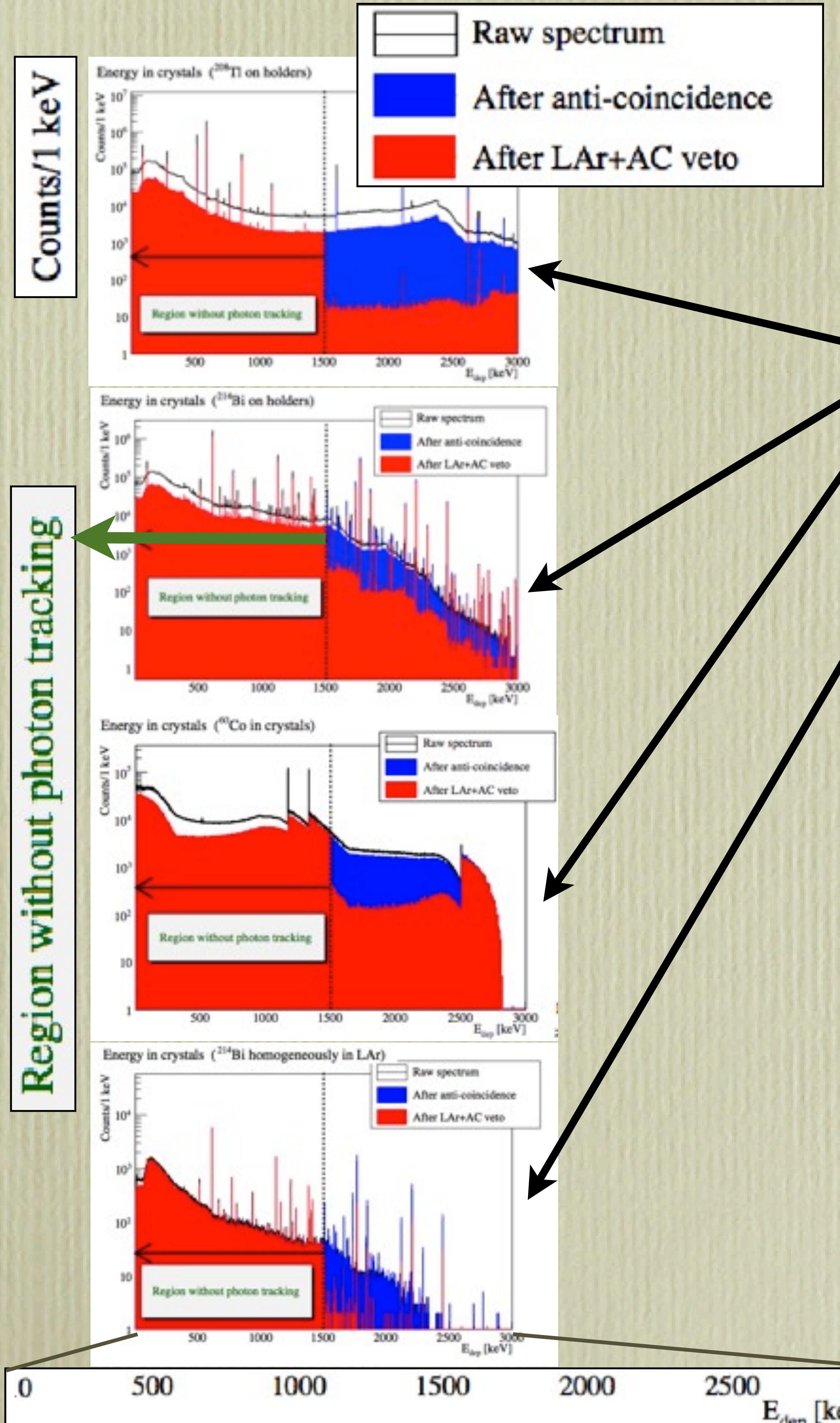
Nuclide	PMT	Fiber
No veto	0.19	0.48
Self veto	0.0017	0.0025

PMT



- Comparison based on:
  - Veto efficiency for different bg sources
  - Instrumentation induced background
  - Hardware availability & stability
- MaGe (Geant4) based simulation of nuclear decays
  - If Ge event passes cuts, optical photons are propagated. Otherwise event is discarded
- Storage of PMT/Fiber hits; Use empirical acceptance model for Fibers
- MC Comparison extremely CPU consuming (600.000 CPUh for comparison)

Fiber



Design Comparison

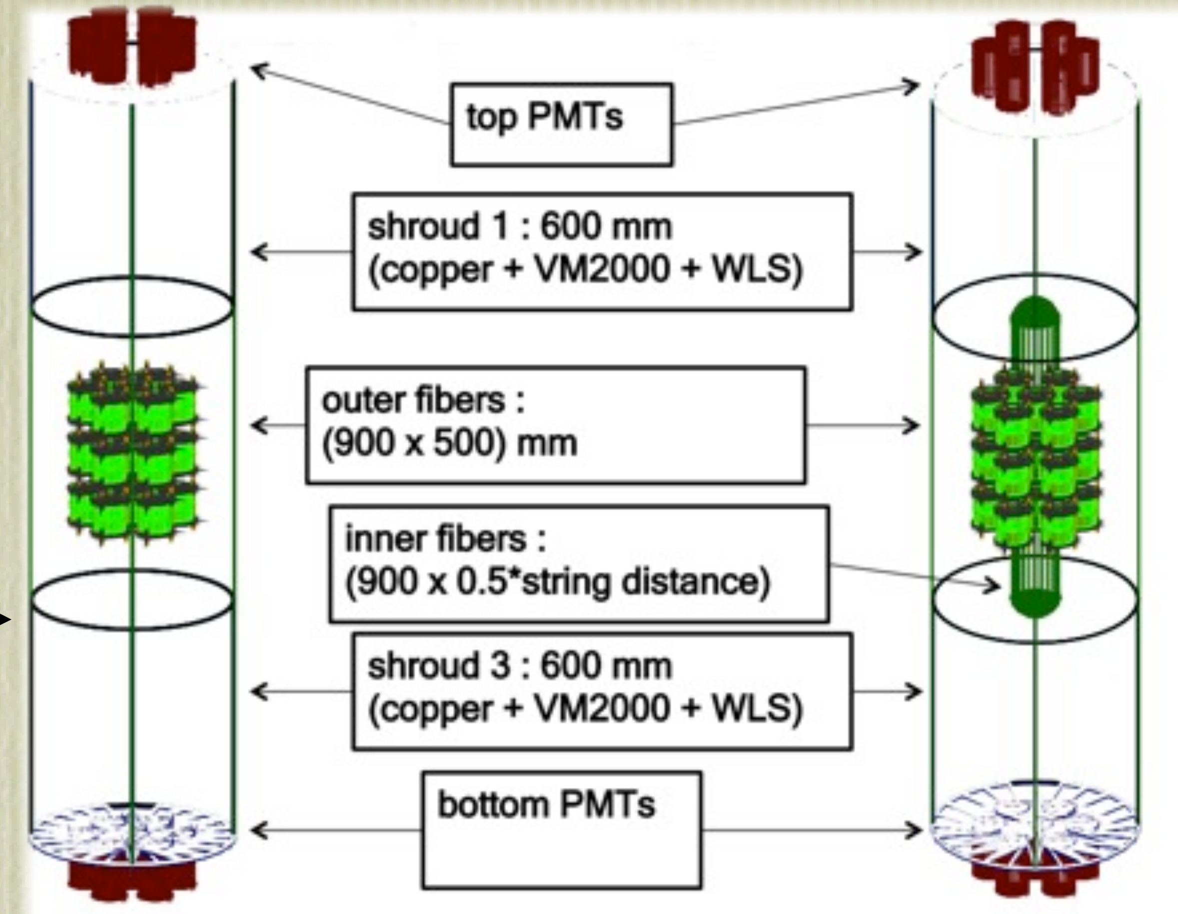
Comparison of suppression factors including **anti coincidence** and **LAr veto**

Nuclide	Position	PMT	Fiber
Tl208	holders	261.8 ± 21.0	581.4 ± 11.8
Bi214	holders	39.3 ± 0.9	12.0 ± 0.1
Co60	crystal	24.9 ± 0.4	15.2 ± 0.1
2.6 MeV	external	12.8 ± 0.2	20.8 ± 0.4
K42	LAr	11.1 ± 1.8	24.7 ± 17.1
Bi214	LAr	N/A	32.5 ± 7.0
Bi214	surface	37.5 ± 5.9	13.0 ± 0.3
K42	surface	1.22 ± 0.01	1.16 ± 0.01

- Fiber design option prevails for Tl208
- PMT design option prevails for Bi214 and Co60
- Not sensitive to alpha and beta decays on detector surface
- Self induced bg agree with Phase II specs
- Both design applicable without LAr drainage

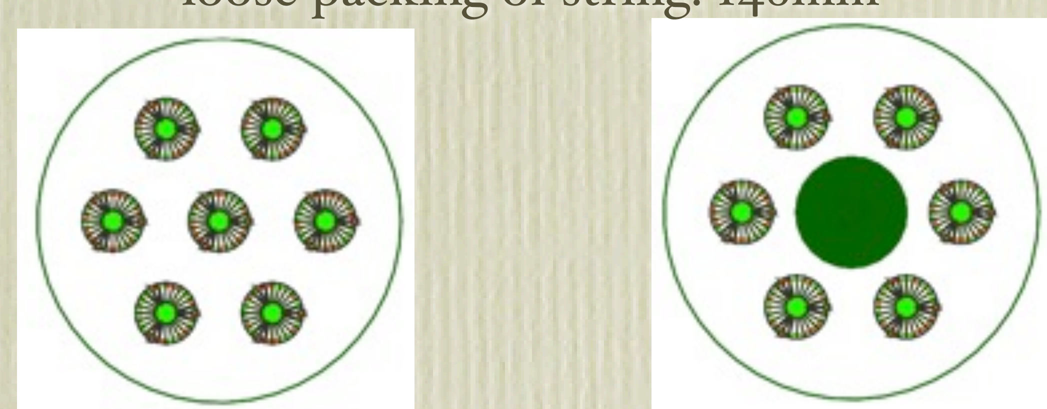
Outlook: Hybrid Design

PMT & Fibers outside | PMT & fibers in & outside



- Collaboration decided to use the 500mm Lock design
- Idea: Integrate both PMT and Fiber design into a “Hybrid” design
- Two options for Fiber / PMT configuration
- Two options for germanium array configuration

loose packing of string: 148mm



dense packing of string: 110mm

- Hardware constraints favor a dense packing
- MC results are very preliminary
  - Suggest that the Hybrid is more efficient than either single design
  - Suppression factors do not differ significantly between the 4 options

Conclusions

- R&D on two LAr veto design options: PMT and Fiber
  - Hardware for both options are available
  - Prototype/test setup construction started
- Monte Carlo simulation set up and verified with LArGe data
- Hybrid design is currently considered and its performance is assessed
- LAr veto suppression factors promising: >200 for Tl208 and >20 for Bi214 with single designs

Thank you for your Attention

Acknowledgement:
We kindly thank the ZIH @ TU Dresden for the supply and support of the CPU farms DEIMOS and ATLAS for the Monte Carlo campaign.

Backup Slides

LAr Veto

Source	PMT design	Fiber design
Tl208 (holders)	71.6 ± 3.6	213 ± 4
Bi214 (hol)	22.1 ± 0.5	8.5 ± 0.1
Co60 (crystal)	11.0 ± 0.2	11.7 ± 0.1
Ext gamma	7.0 ± 0.1	13.5 ± 0.3
K42 (LAr)	10.2 ± 1.6	12.7 ± 9.4
Bi214 (LAr)	N/A	31.4 ± 6.9
Bi214 (surface)	13.2 ± 2.3	9.2 ± 0.2
K42 (surface)	1.102 ± 0.01	1.123 ± 0.01

Anti Coincidence

Source	PMT design	Fiber design
Tl208 (holders)	3.70 ± 0.03	2.725 ± 0.006
Bi214 (hol)	1.77 ± 0.01	1.403 ± 0.007
Co60 (crystal)	2.27 ± 0.02	1.297± 0.004
Ext gamma	1.83 ± 0.03	1.54 ± 0.01
K42 (LAr)	1.1 ± 0.1	1.95 ± 0.54
Bi214 (LAr)	N/A	1.04 ± 0.06
Bi214 (surface)	2.8 ± 0.2	1.40 ± 0.02
K42 (surface)	1.103 ± 0.004	1.03 ± 0.01

LAr and AC

Source	PMT design	Fiber design
Tl208 (holders)	261.8± 21.0	581.4 ± 11.8
Bi214 (hol)	39.3 ± 0.9	12.0 ± 0.1
Co60 (crystal)	24.9 ± 0.4	15.2± 0.1
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