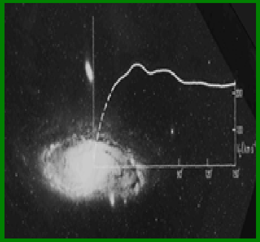
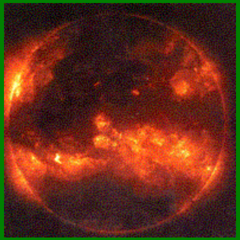
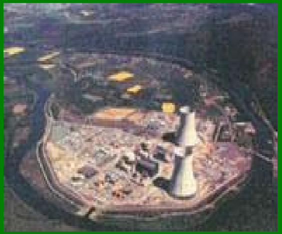
    

Cutting Edge Projects in Low-Energy Particle Physics and Astrophysics: GERDA & Double-CHOOZ

Stefan Schönert, MPIK Heidelberg

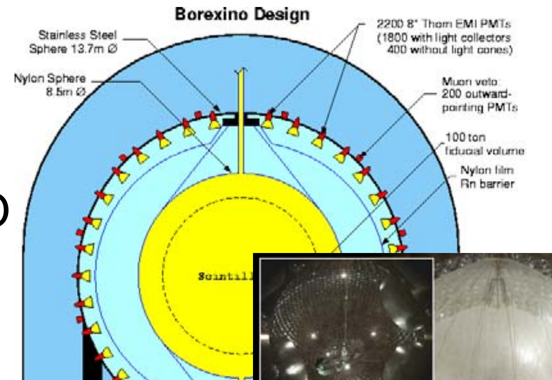
Symposium on ‘Cross Roads in Particle and Astrophysics’

December 2/3, 2004

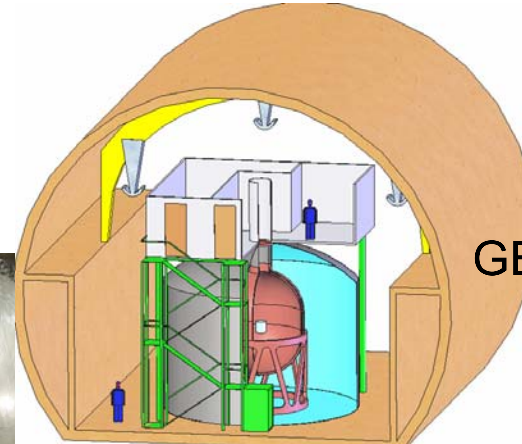
….my

‘Cross roads’

BOREXINO



GERDA



LENS-LBF

Double-Chooz

<u>ν’s as probe for astro/geophysics</u>:

- Solar physics:
  - Be-7⇒ pp: 1%
  - pep
  - CNO cycle
- SN core collapse
- Geo-neutrinos

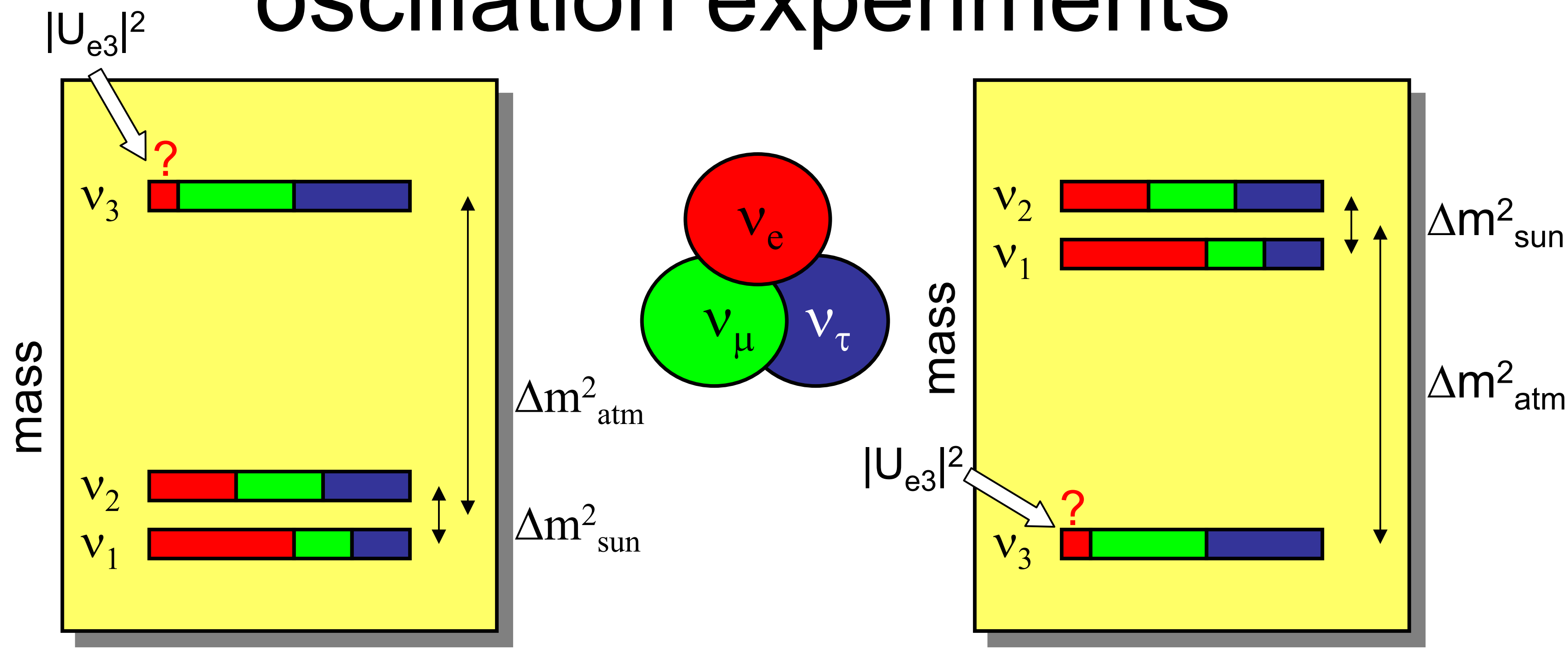
Astrop. Phys. 16(2002)
RSI 75(2)2003
PRL 80(3) (1998)
PLB 558 (2003)
hep-ph/0411002

<u>ν-Properties:</u>

- Double beta decay
- Reactor neutrinos

NPB 70 (1997/99)
Astrop. Phys. 18 (2003)
PLB 558 (2003)
hep-ex/0404039
hep-ex/0405032

Mass spectrum and mixing from oscillation experiments



Normal mass hierarchy | Inverted mass hierarchy

<u>What we don't know:</u>

- |U
- Type of mass spectrum: hierarchic (NH or IH) or degenerate?
- Absolute mass scale
- Majorana particle $(\nu = \bar{\nu})$ or Dirac $(\nu \neq \bar{\nu})$

⇐ Double-CHOOZ

⇐ GERDA

Letter of Intent hep-ex/0405032

Letter of Intent for Double-CHOOZ: a search for the mixing angle θ_{13}

APC, Paris - RAS, Moscow - DAPNIA, Saclay - EKU-Tübingen - INFN, Assergi & Milano - INR, Moscow -MPI, Heidelberg -RRC, Kurchatov - TUM-München - University of l'Aquila -Universität Hamburg

Version 5.0

April 28, 2004

F. Ardellier [5], I. Barabanov[10], J.C. Barrière [6], M. Bauer [7], L. Bezroukov[10], C. Buck[11], C. Cattadori [8,9], M. Cribier [1,3], F. Dalnoki-Veress [11], N. Danilov[2], H. de Kerret [1,12], A. Di Vacri [8,15], A. Etenko [13], C. Grieb [14], M. Goeger [14], Y.S. Krilov[2], D. Kryn [1,12], C. Hagner 16, W. Hampel [11], F.X. Hartmann [11], P. Huber [14], J. Jochum [7], T. Lachenmaier [14], Th. Lasserre [1 ,1,3], C. Lendvai [14], M. Lindner [14], F. Marie [4], G. Mention [1,12], A. Milsztajn [3], J.P. Meyer [3], D. Motta [11], L. Oberauer [14], M. Obolensky [1,12], L. Pandola [8,15], W. Potzel [14], S. Schönert [11], U. Schwan [11], T. Schwetz [14], S. Scholl [7], L. Scola [6], M. Skorokhvatov [13], S. Sukhotin [12,13], A. Letourneau [4], D. Vignaud [1,12], F. von Feilitzsch [14], W. Winter [14], E. Yanovich[10]

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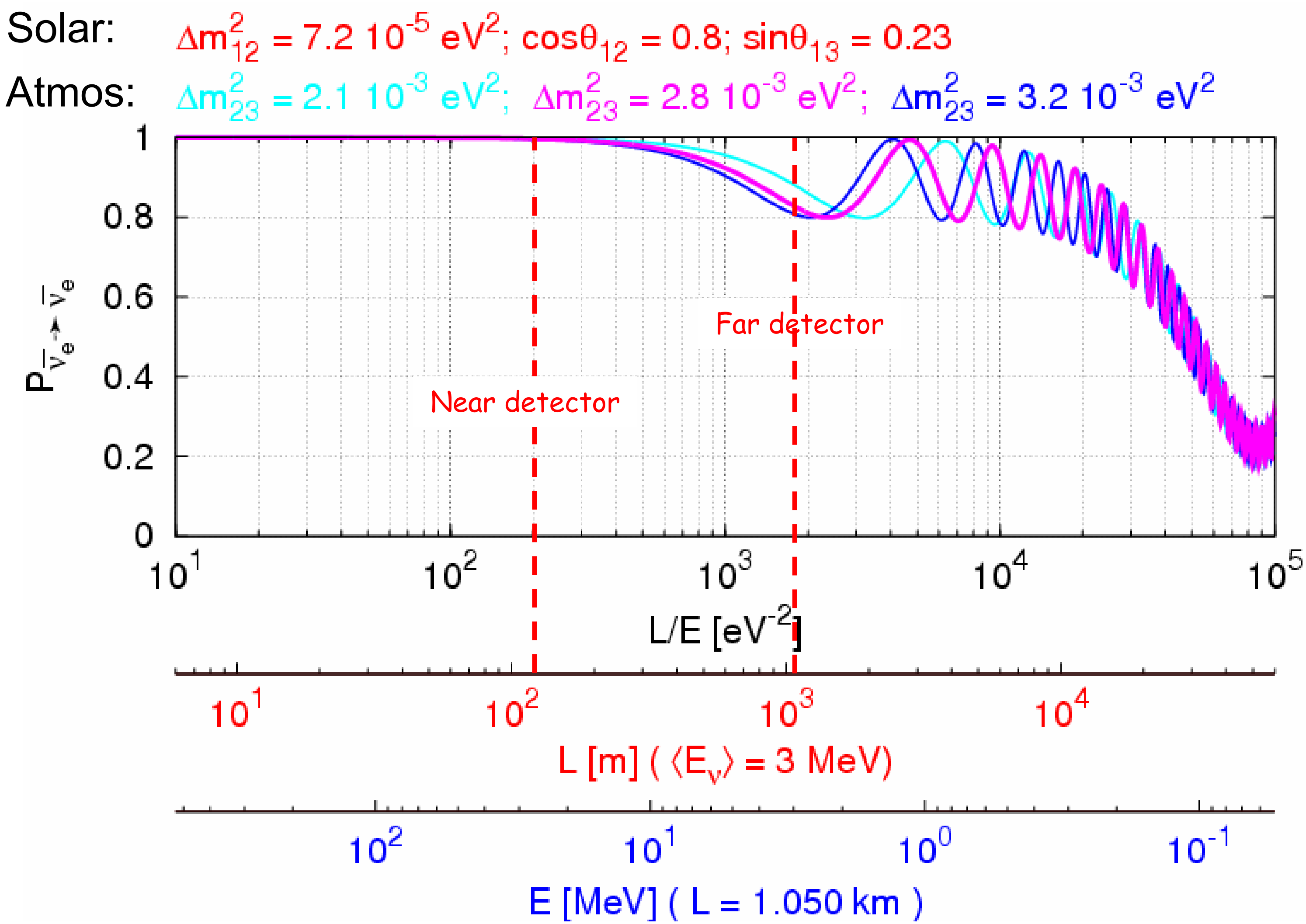
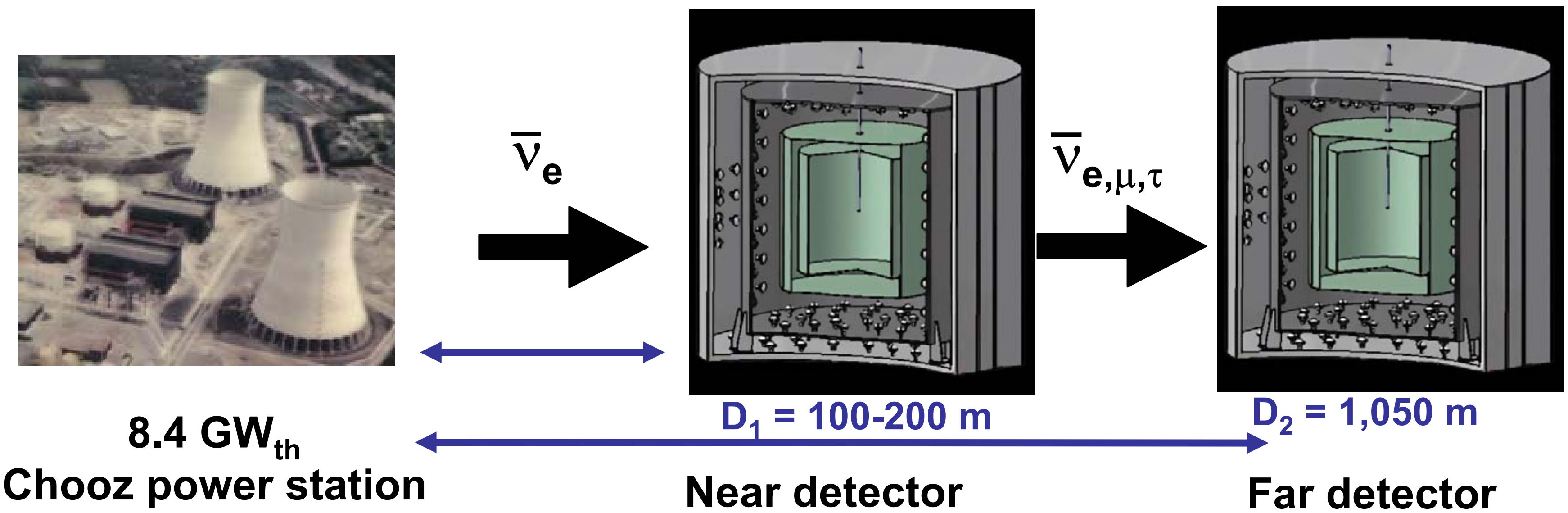
[16] Universität Hamburg, Luruper Chaussee 149, D-22761 Hamburg, Germany

3-ν oscillation: optimal reactor-detector distance for θ_{13} search



The Double-CHOOZ concept



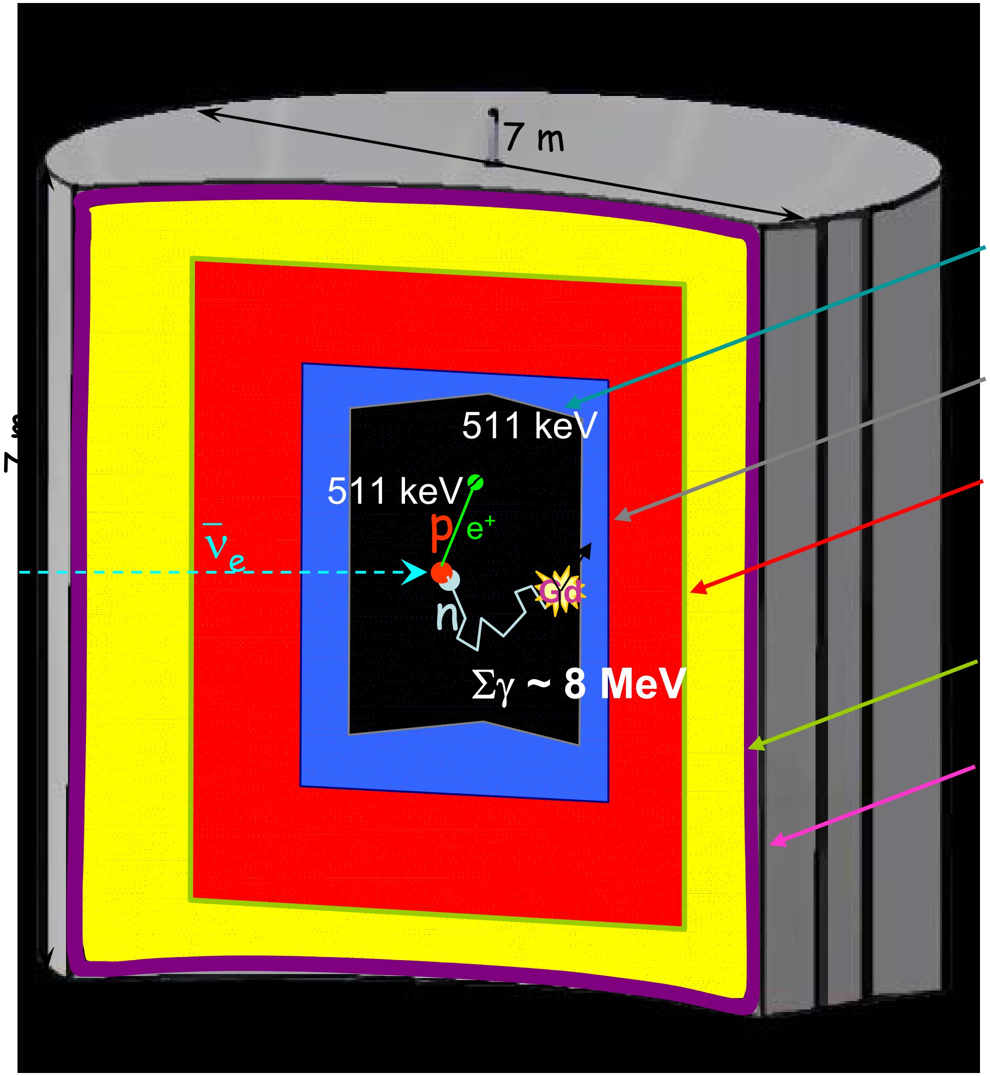
<u>Disappearance experiment:</u> deviation from $1/D^2$ and shape distortion

<u>Goal:</u> improve Chooz sensitivity from $\sin^2 2\theta_{13} < 0.2$ ➔ 0.02-0.03

<u>Challenge:</u> total (relative) systematic uncertainty < 1%

The Double-Chooz detector sites

Detector design



ν target: 80% dodecane + 20% PXE + 0.1% Gd
(acrylic, r = 1,2 m, h = 2,8 m, 12,7 m³)

γ-catcher: 80% dodecane + 20% PXE
(acrylic, r+0,6m – V = 28,1 m³)

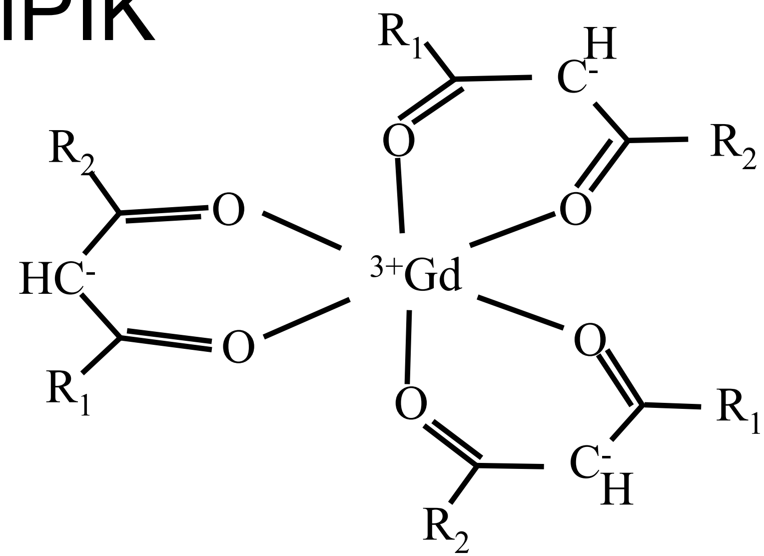
Non-scintillating buffer: same liquid (+ quencher?)
(r+0.95m, , V = 100 m³)

Muon VETO: scintillating oil
(r+0.6 m – V = 110 m³)

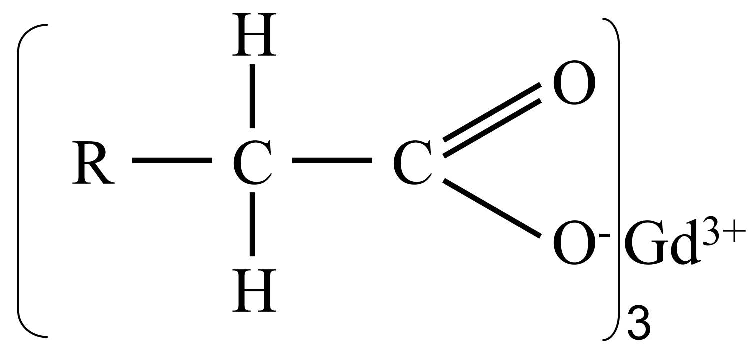
Shielding: 0,15 m steel

Gd-loaded liquid scintillator (LS) development @MPIK

Beta-Diketonates (BDK):



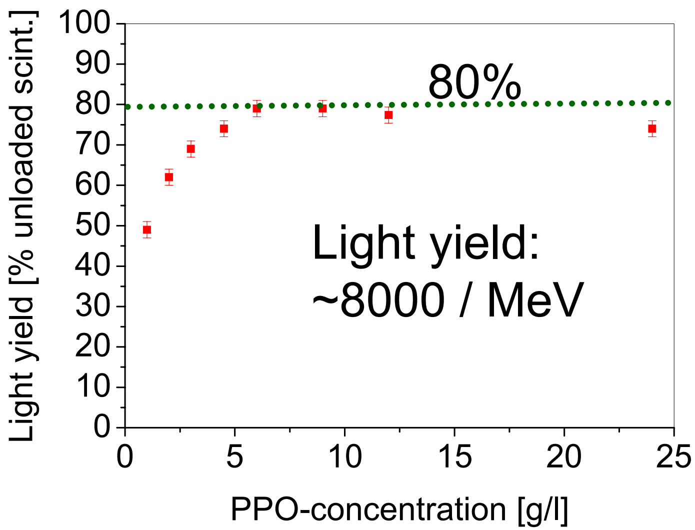
Carboxylates (CBX):
(single CBX, pH controlled)

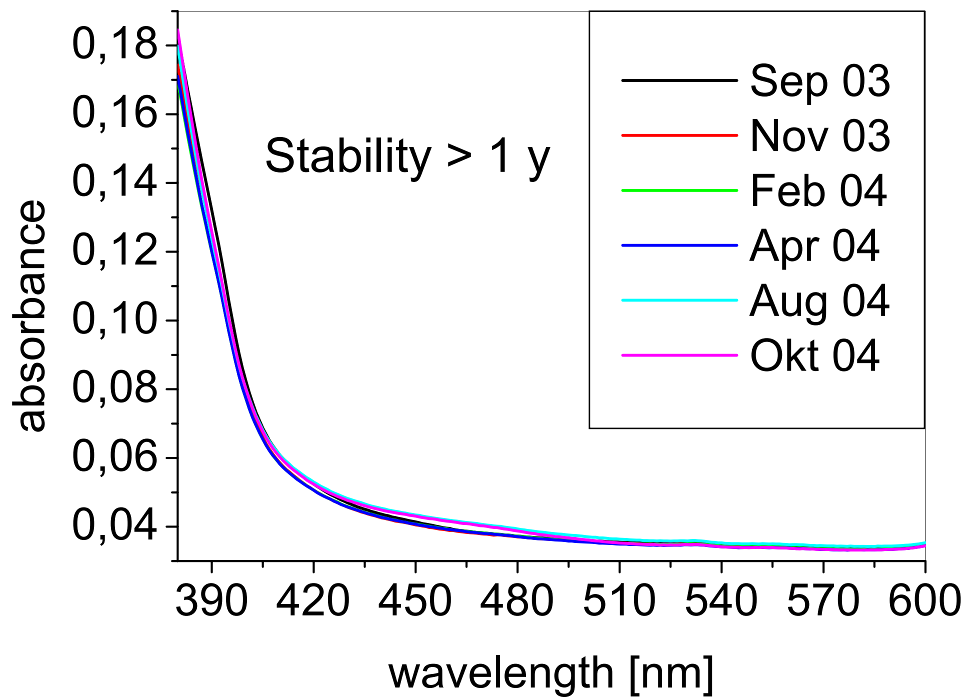


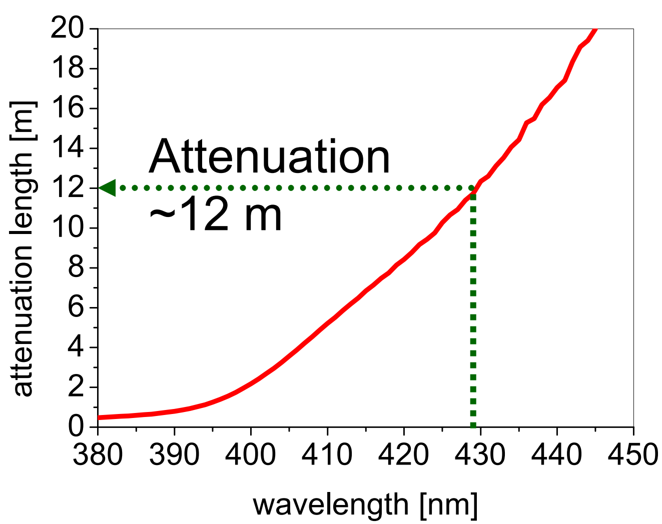
Based on LS development for LENS:

J. Rad. Nucl. Chem 258(2)(2003)
J. Luminesc. 106(1) 2004
Physics/0408032

Example: performance of Gd BDK-LS



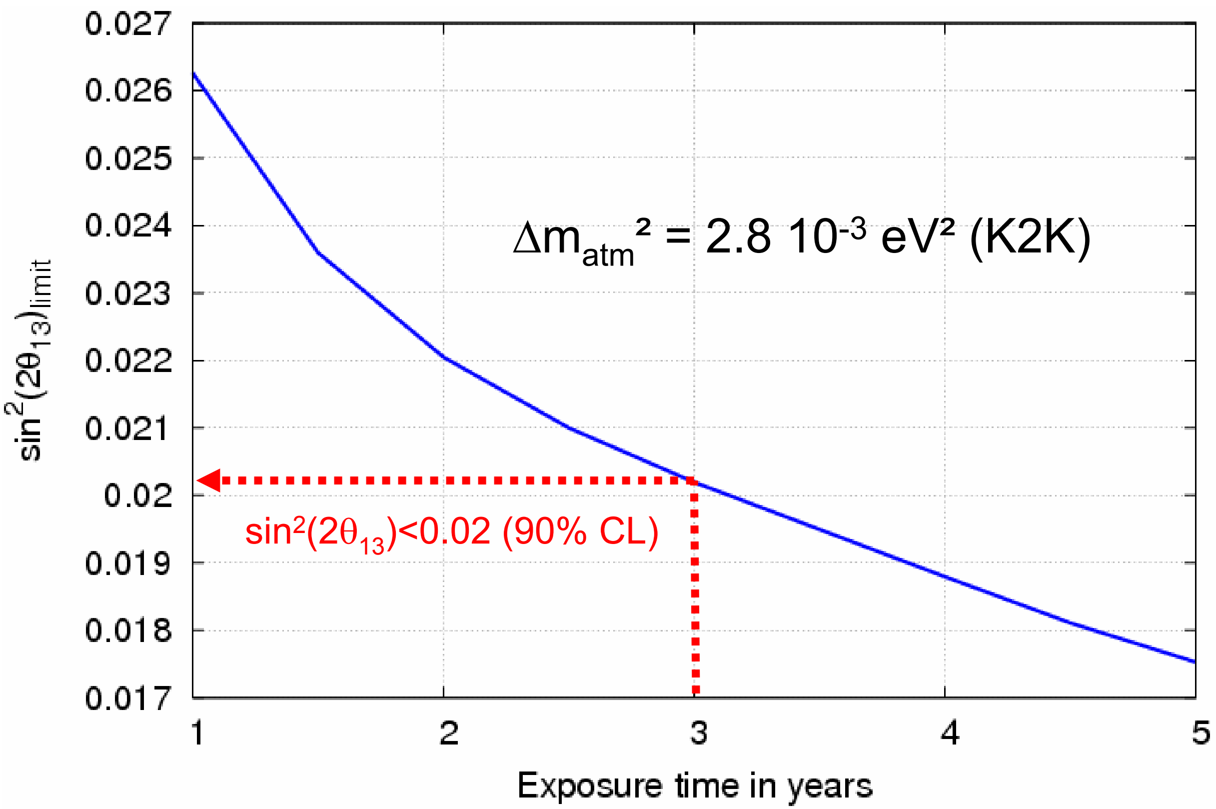




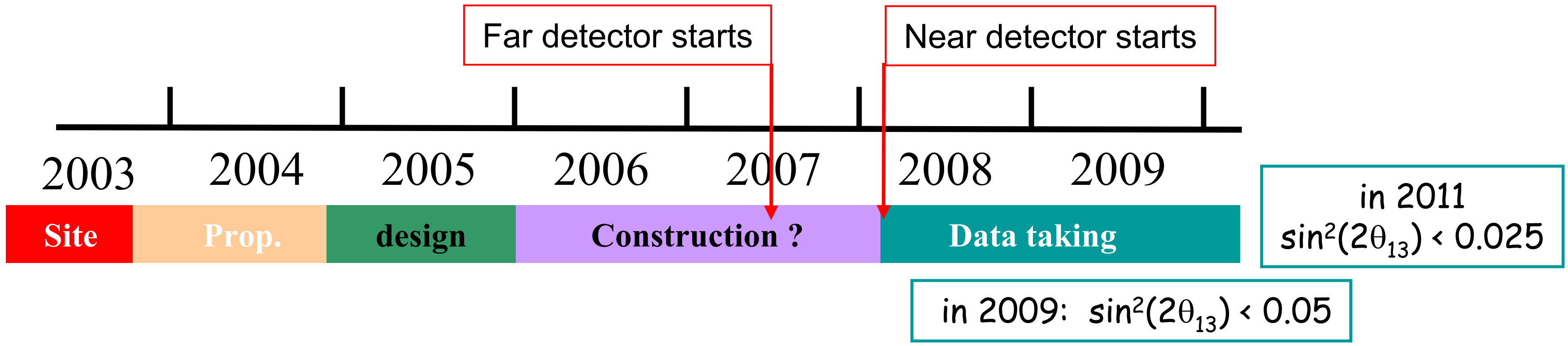
<u>Ongoing research at MPIK:</u>

- Optimization of synthesis
- Impurity analysis
- Stability tests

Double-CHOOZ expected sensitivity

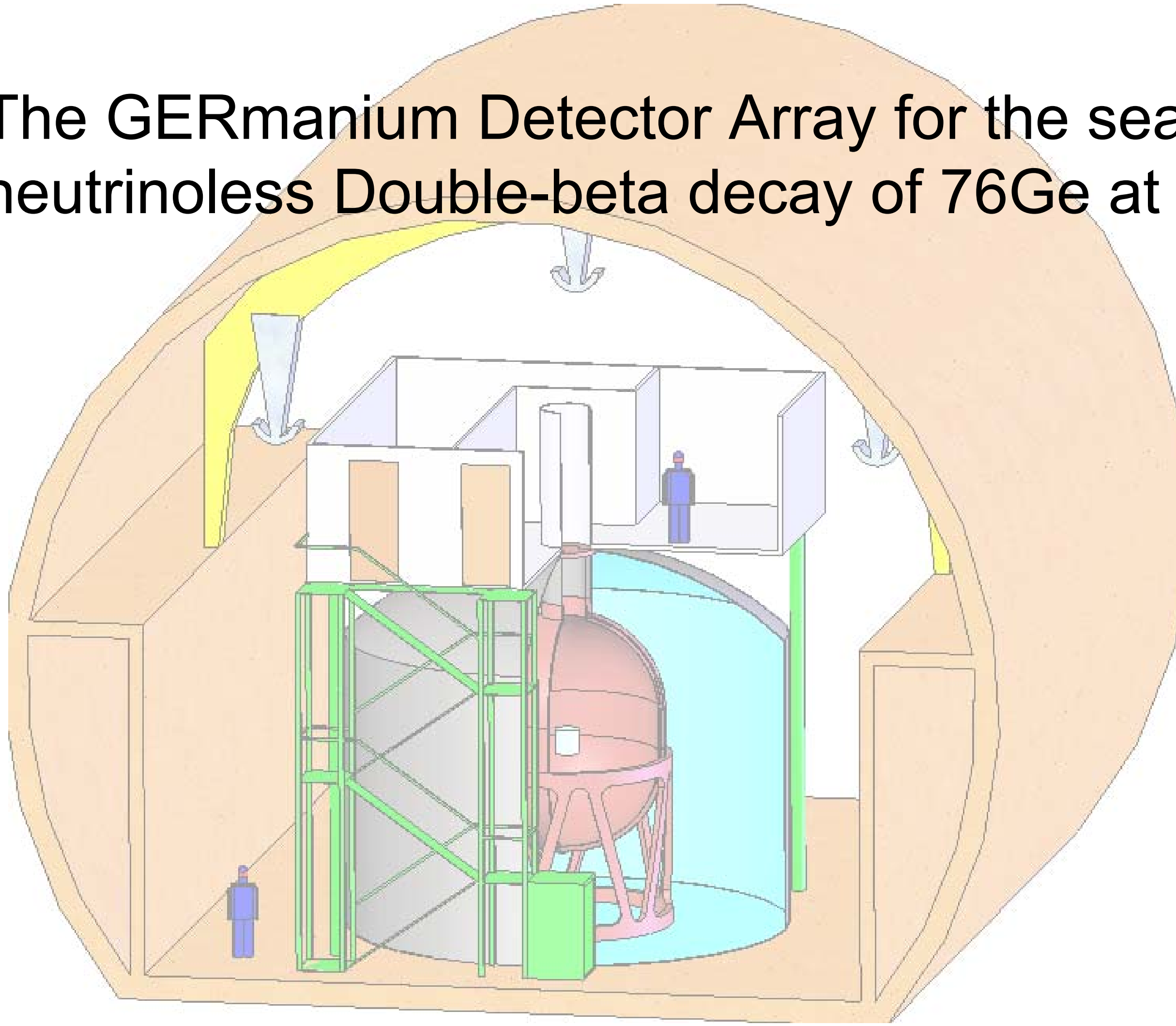


Time schedule



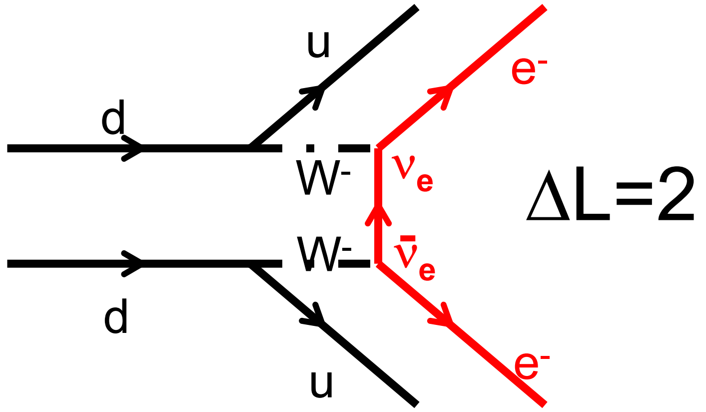
GERDA

The GERmanium Detector Array for the search of neutrinoless Double-beta decay of 76Ge at LNGS



Physics goals of GERDA

Primary Objective:



$0\nu\beta\beta$: $(A,Z) \rightarrow (A,Z+2) + 2e^-$

⇒Majorana nature

⇒Effective mass: $1/\tau = G(Q,Z)\, |M_{nucl}|^2\, m_{ee}^2$, (decay generated by (V-A) cc-interaction via exchange of light Majorana neutrinos)

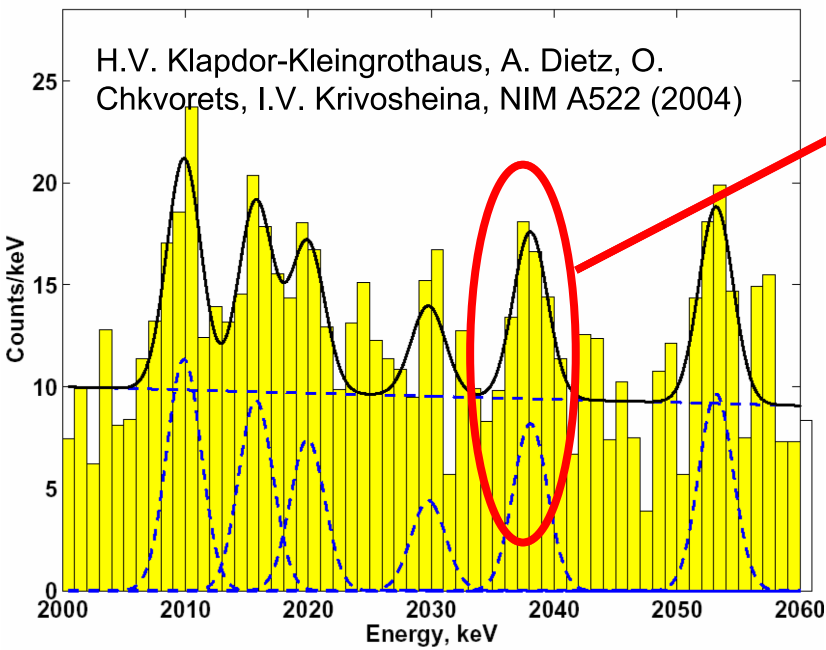
$m_{ee} = |\sum_i U_{ei}^{\ 2}\ m_i|$

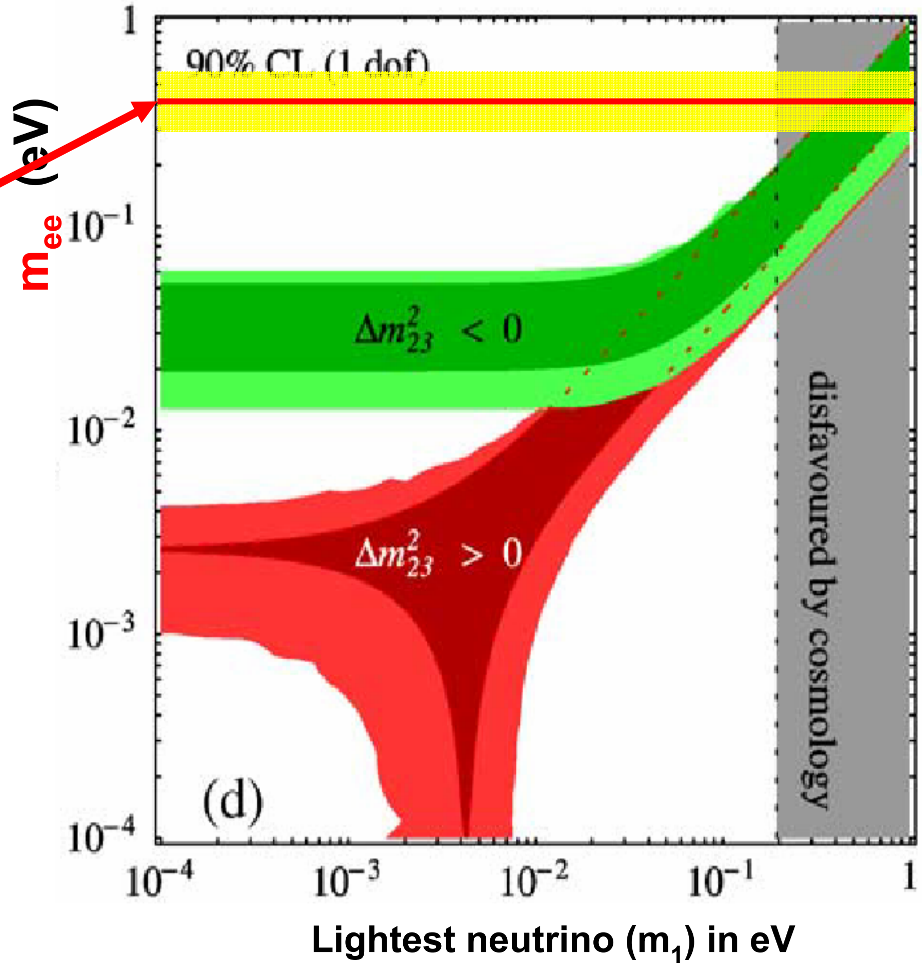
Other Physics: WIMP DM search

Method: Operation of HP Ge-diodes enriched in ^{76}Ge in (optional active) cryogenic fluid shield. Line search at $Q_{\beta\beta} = 2039$ keV

Range of m_{ee} derived from oscillation experiments

$\Rightarrow m_{ee} = f(m_1, \Delta m^2_{sol}, \Delta m^2_{atm}, \theta_{12}, \theta_{13}, \alpha\text{-}\beta)$

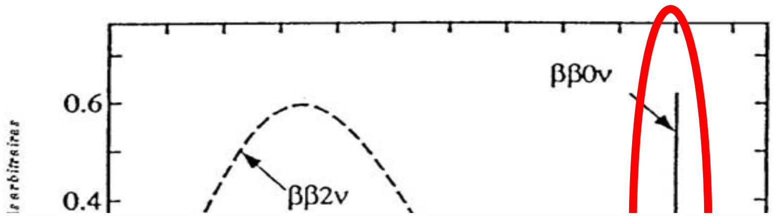




F.Feruglio, A. Strumia, F. Vissani, NPB 659

GERDA @ Gran Sasso: experimental concept

- HP Ge-diodes (^{76}Ge): point-like energy deposition at $Q_{\beta\beta}$ = 2039 keV

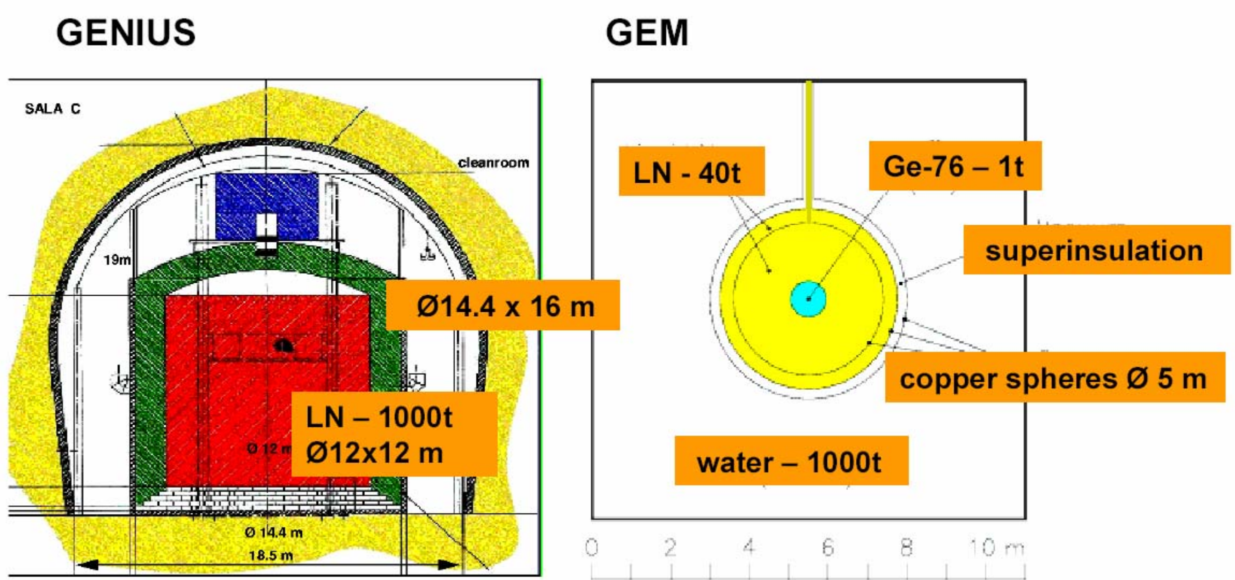


- Operation (... N_2 / LAr shield (Heusser, Ann, Rev. Nucl. ... his idea: GENIUS (H.V. Klapdor-Kleingrothaus e ... enko et al., J. Phys. G27 (2001))

- Baseli ... coincic

- Reduc ...
  - Ha ...
    -
    -

free!



Klapdor-Kleingrothaus., Baudis, Heusser, Majorovits, Päs, hep-ph/9910205

Zdesenko, Ponkratenko, Tretyak nucl-ex/0106021

Why Ge-76 ?

- High resolution (4 keV @ $Q_{\beta\beta}$): no bgd from 2ν-mode
- Huge leap in sensitivity possible …

  …applying ultra-low background techniques

  …novel background / 0ν-$\beta\beta$ signal discrimination methods (ie. point-like vs. compton events)
    - Segmentation & pulse shape (with true coaxial detectors)
    - Liquid argon scintillation read out
- Phased approach: increment of target mass
- Only method to scrutinize 0ν-DBD claim on short time scale: test $T_{1/2}$, not m_{ee} !

GERDA Collaboration

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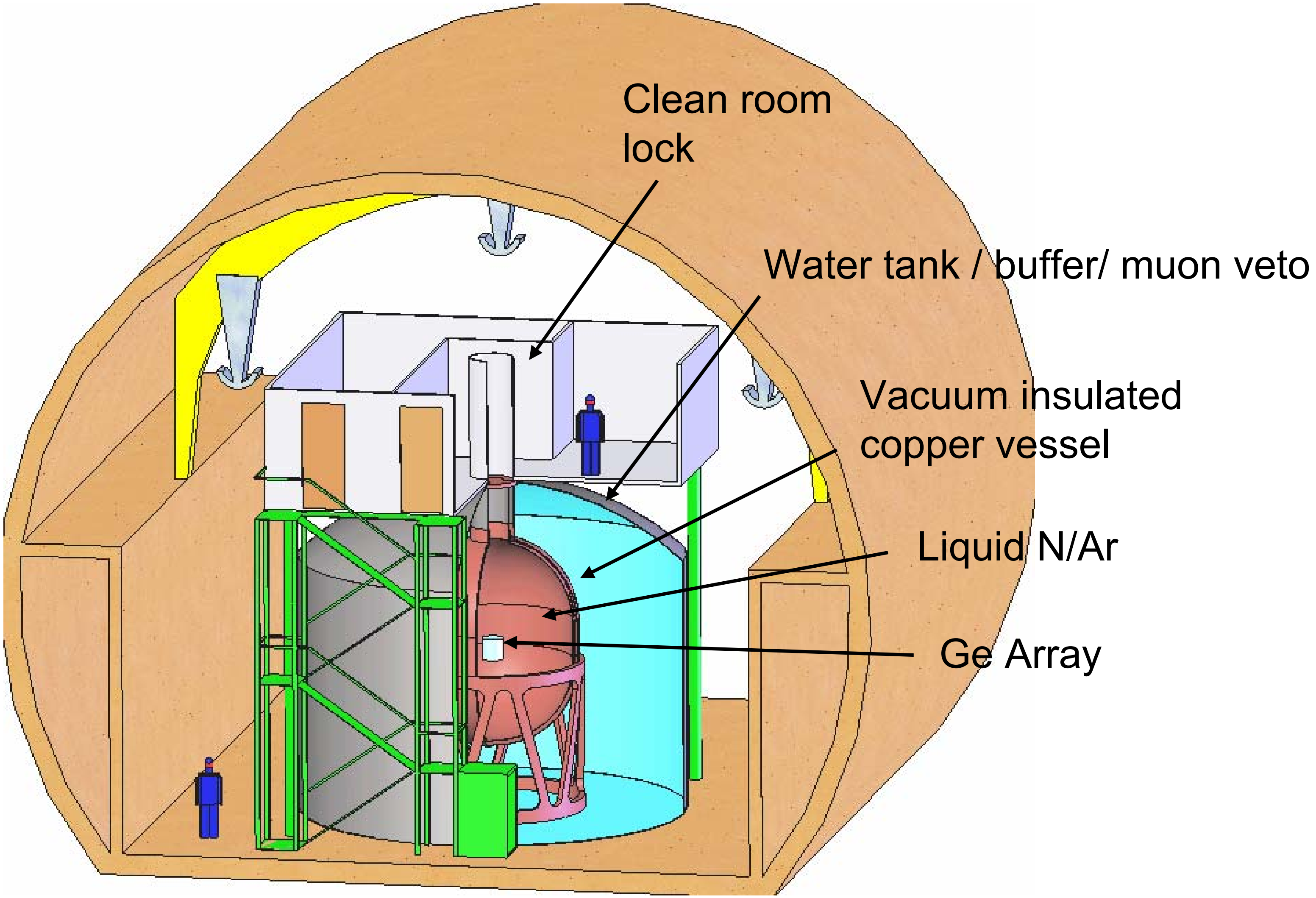
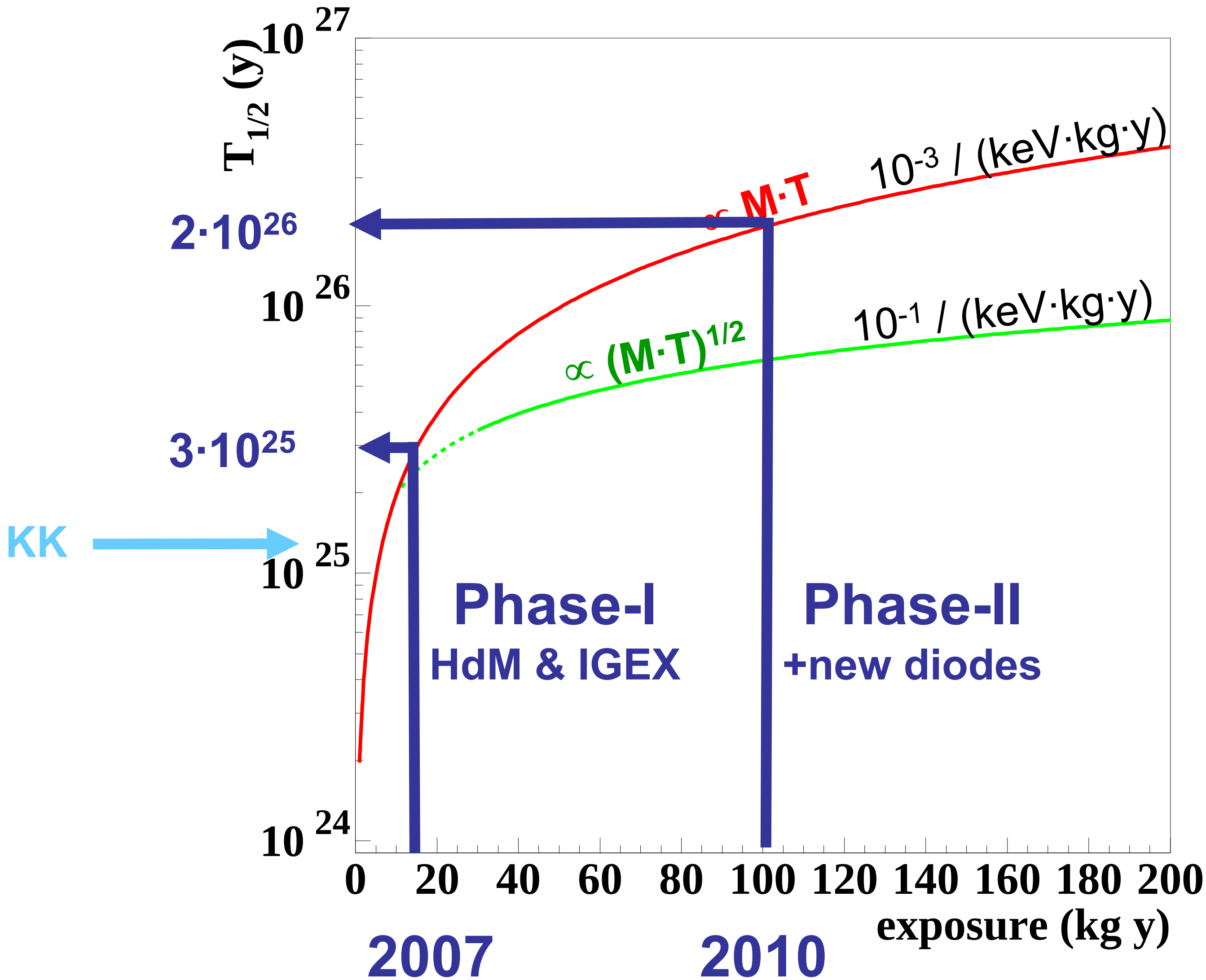
Univ. Tübingen, Germany
M. Bauer, H. Clement, J. Jochum, S. Scholl, K. Rottler

71 physicists / 12 institutions / 4 countries

GERDA: Baseline design

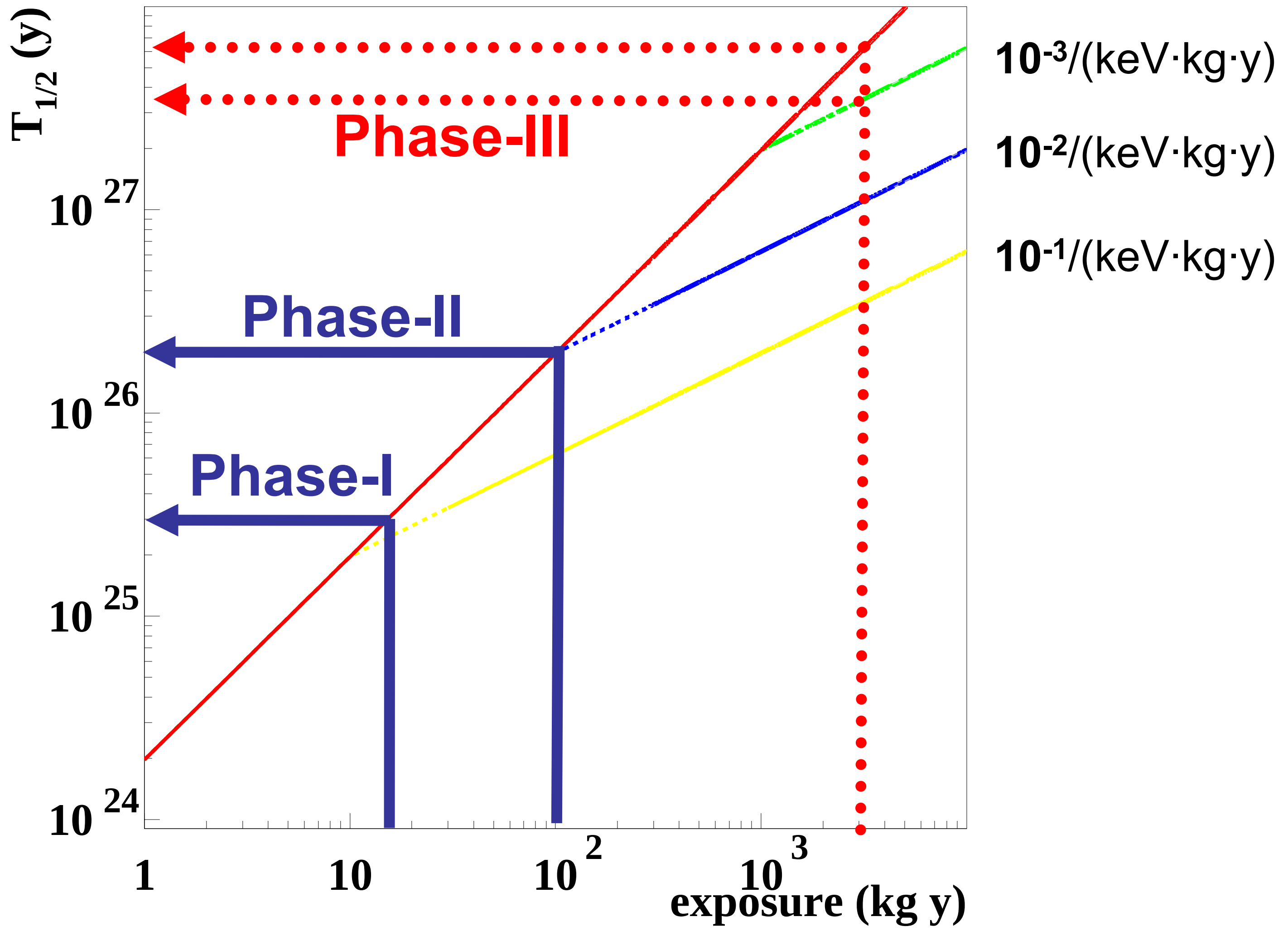


Phases and physics reach of GERDA

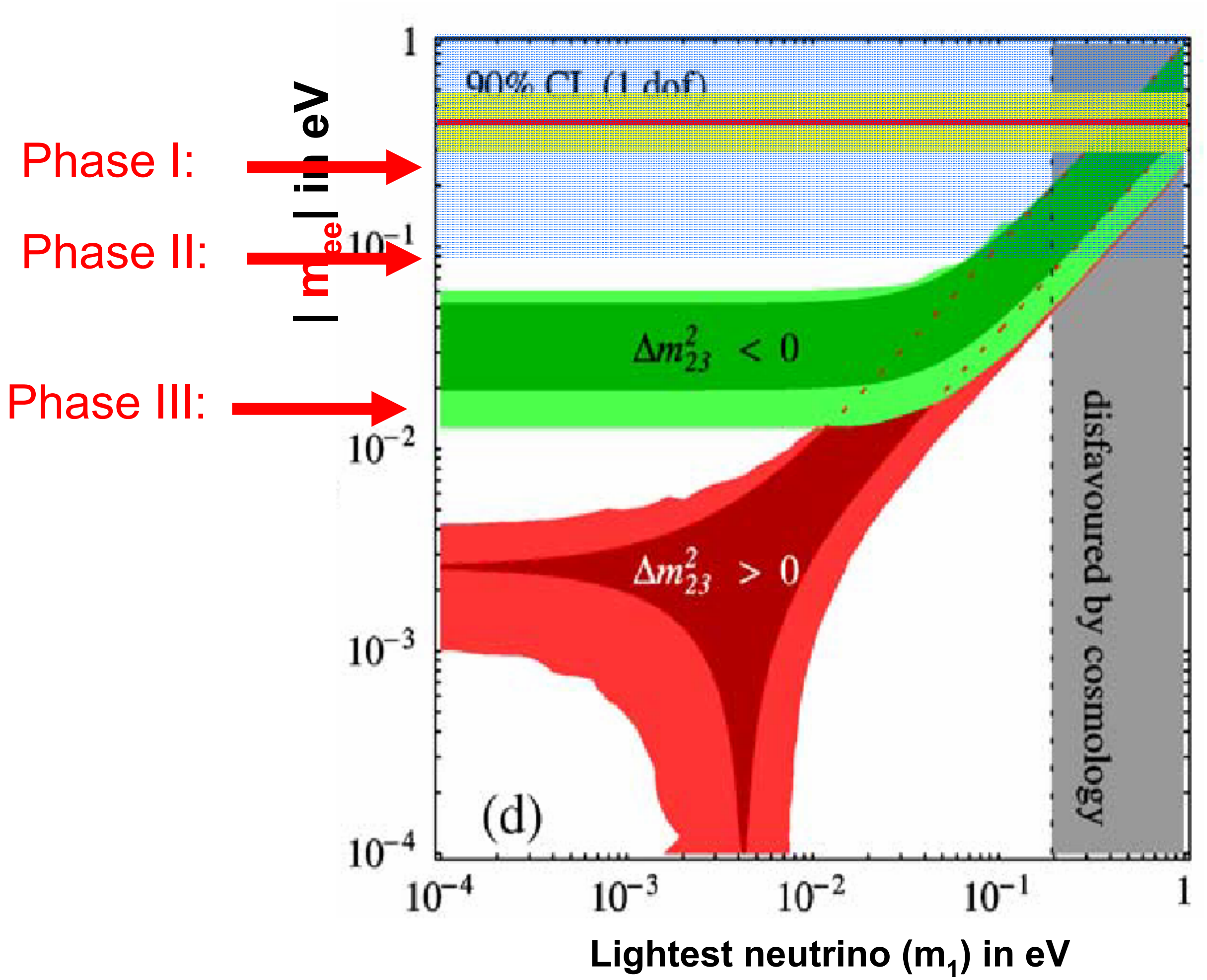


Phases and Physics reach of GERDA

world-wide collaboration needed for Phase-III; coop. with MAJORANA started



Phases and Physics reach of GERDA



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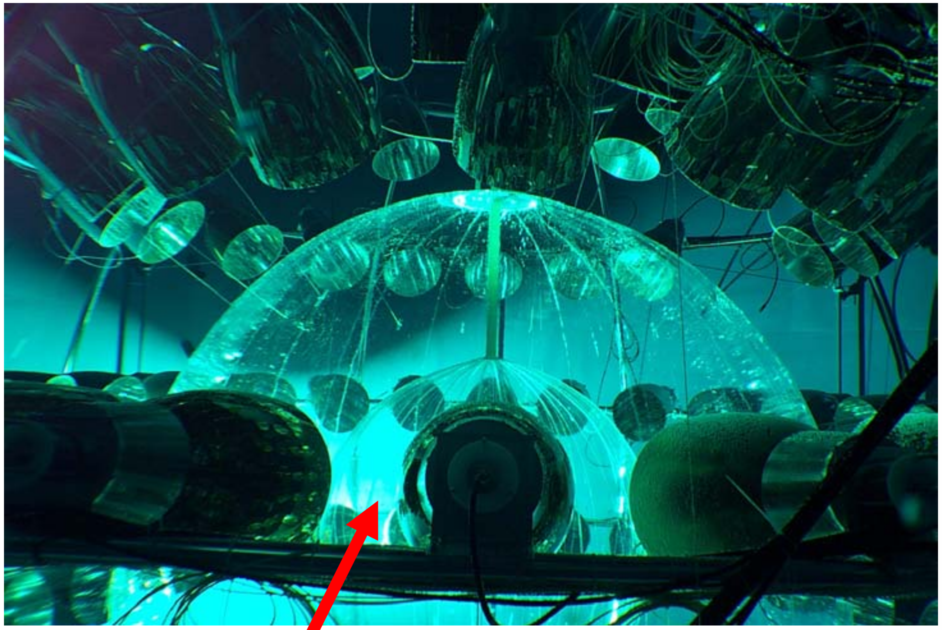
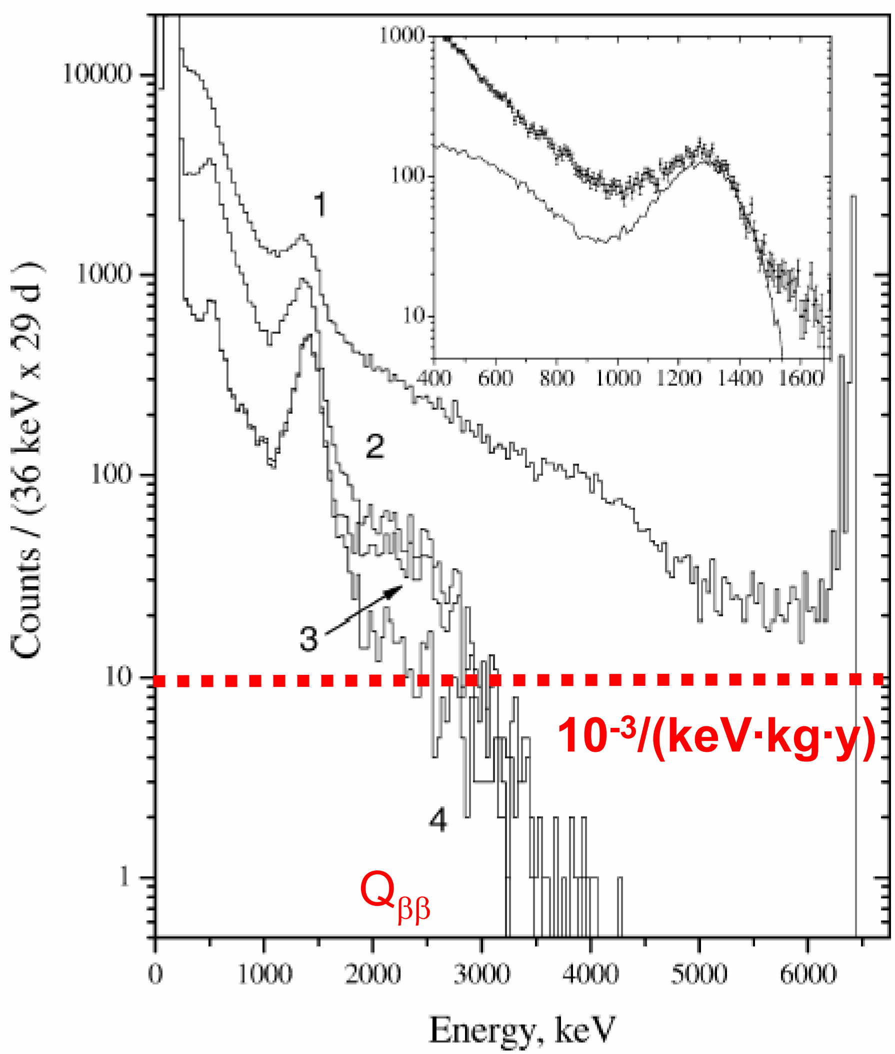
…how to reach $<10^{-3}/(\mathrm{keV \cdot kg \cdot y})$?

BOREXINO Counting Test Facility (CTF)
('world record')



Liquid scintillator target

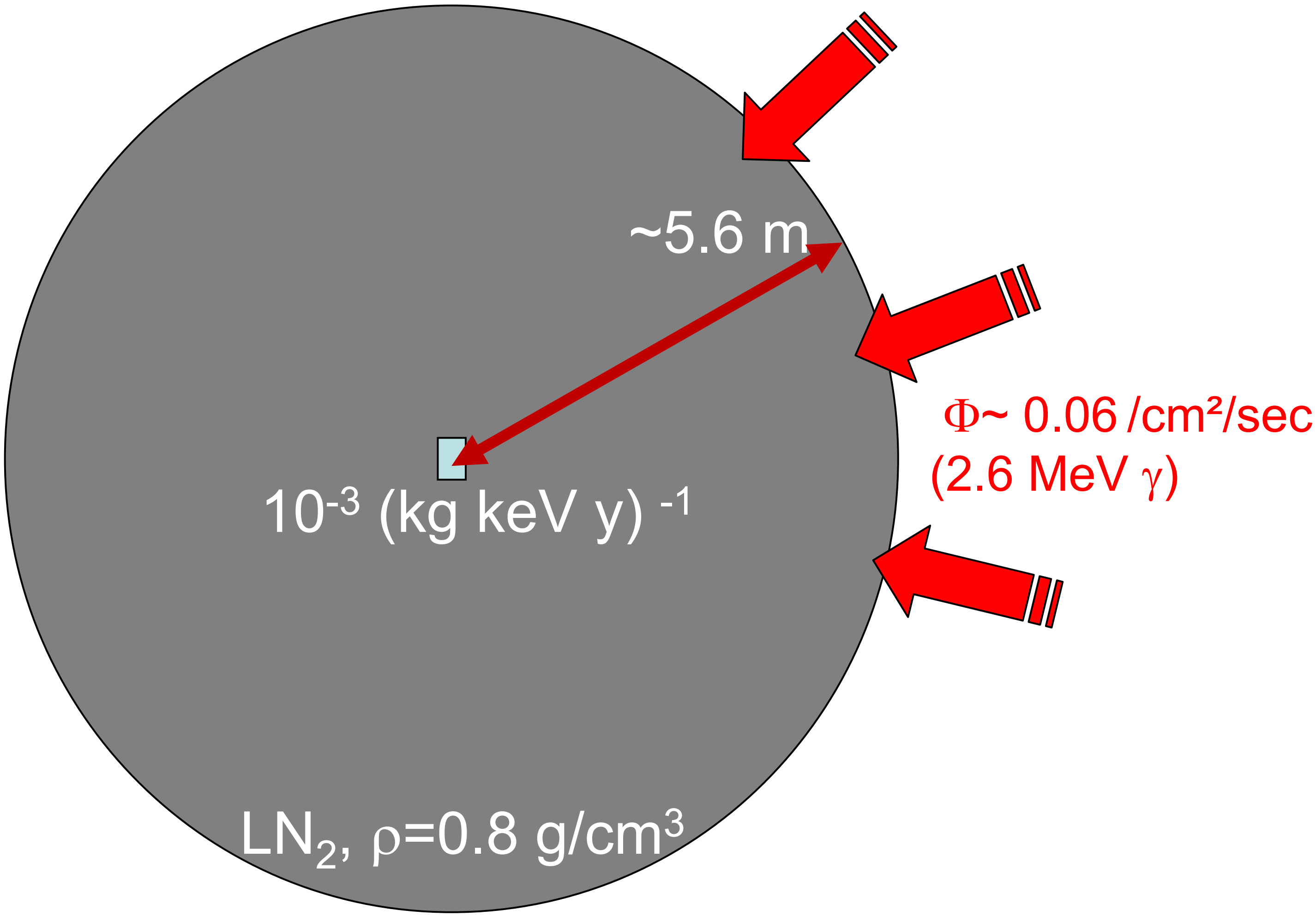


Borexino Collab. PLB 563 (2003)

BOREXINO ⇒~$10^{-5}/(\mathrm{keV \cdot kg \cdot y})$

shielding against ext. γ's à la BOREXINO…

….but with high purity liquid N_2/Ar (**<0.3μBq ^{222}Rn / m^3(STP)**)



Backgrounds in GERDA

Source	**B [10^{-3} cts/(keV kg y)]**
Ext. γ from ^{208}Tl (^{232}Th)	<1
Ext. neutrons	<0.05
Ext. muons	<0.1
Int. ^{68}Ge ($t_{1/2}$= 270 d)	**12**
Int. ^{60}Co ($t_{1/2}$= 5.27 y)	**2.5**
^{222}Rn in LN/LAr	<0.2
^{208}Tl, ^{238}U in holder	<1
Surface contam.	<0.6

derived from measurements and MC simulations

Assumptions:

180 days exposure after enrichment + 180 days underground storage

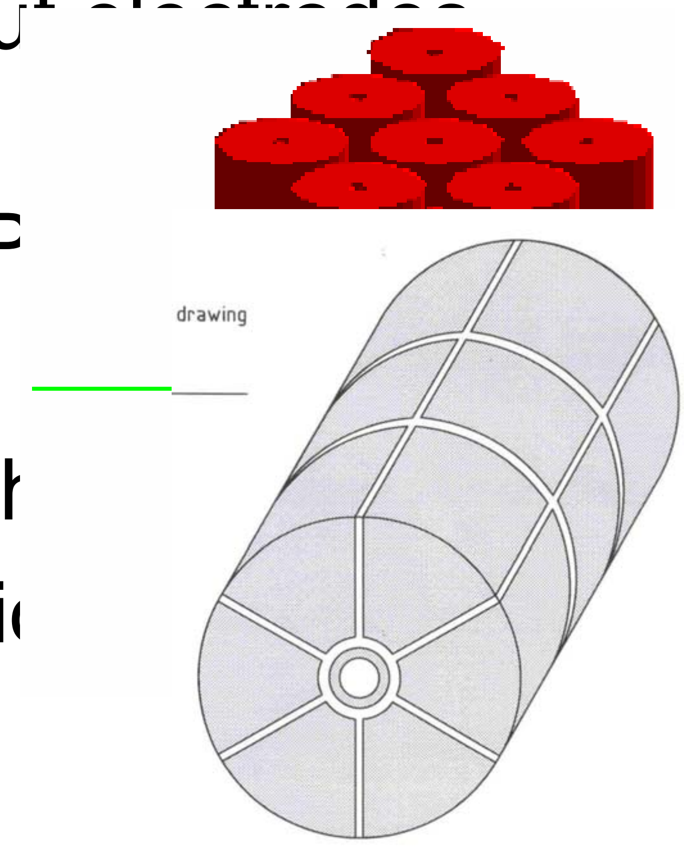
30 days exposure after crystal growing

Target for phase II: B ≤ 10^{-3} cts/(keV kg y)

⇒ additional bgd. reduction techniques

Background reduction techniques

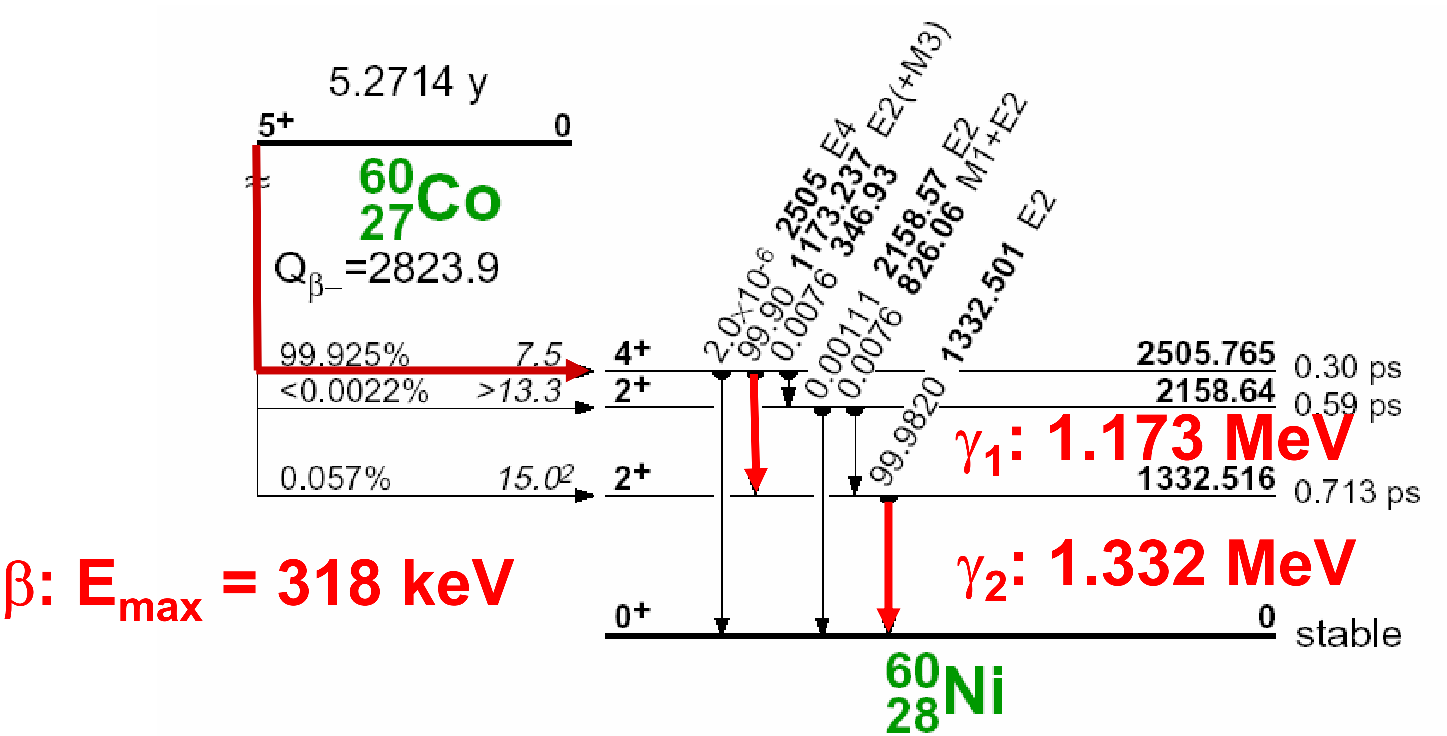
- Anti-coincidence between detectors
- Segmentation of readou
  (Phase II)
- Pulse shape analysis (P
- Waiting (Ge-68, …)
- Coincidence in decay ch
- Scintillation light detecti



Background reduction techniques

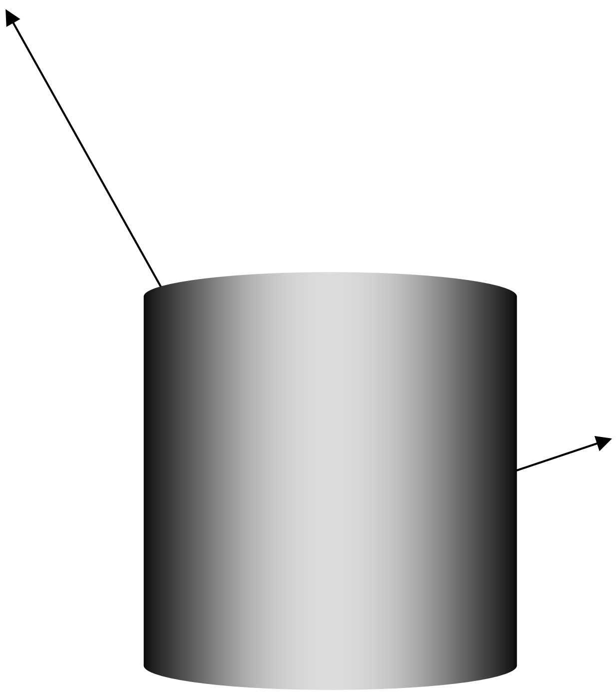
- Anti-coincidence between detectors
- Segmentation of readout electrodes (Phase II)
- Pulse shape analysis (Phase I+II)
- Waiting (Ge-68, …)
- Coincidence in decay chain
- Scintillation light detection (LArGe)

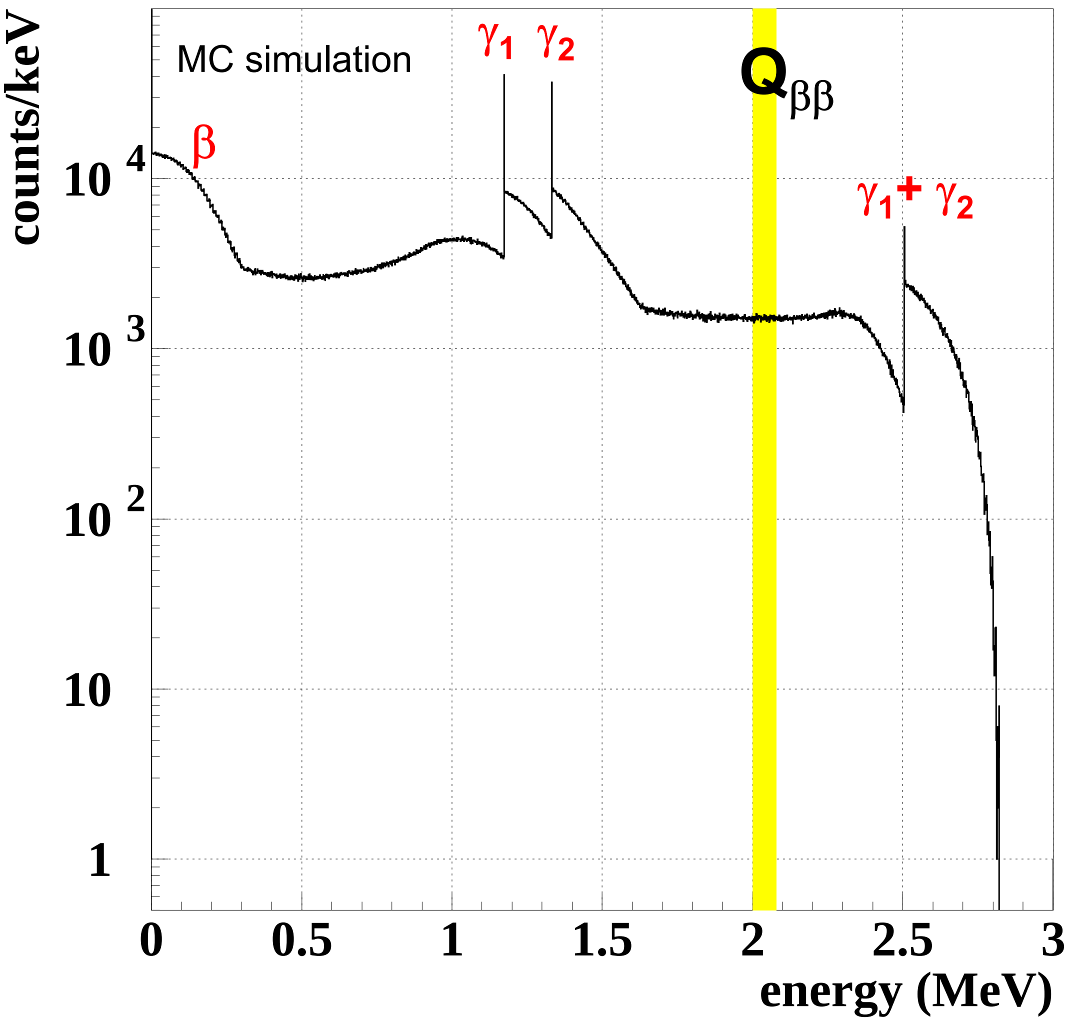
Example ^{60}Co



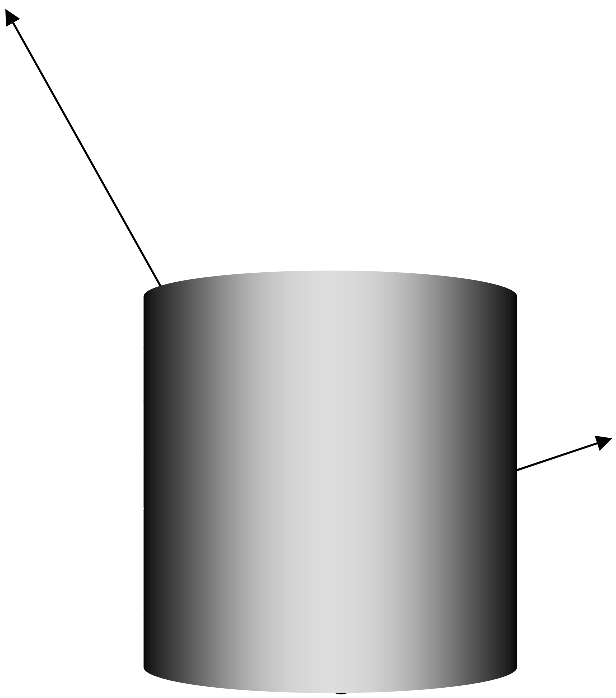
- T_0 : crystal growing
- 0.017 μBq/kg per day exposure
- Test: detector production in 7.4 days
- Assume 30 days ⇒ 2.5 $\cdot 10^{-3}$ / (keV·kg·y)
- HdM: ~5$\cdot 10^{-3}$ / (keV·kg·y) in 2006

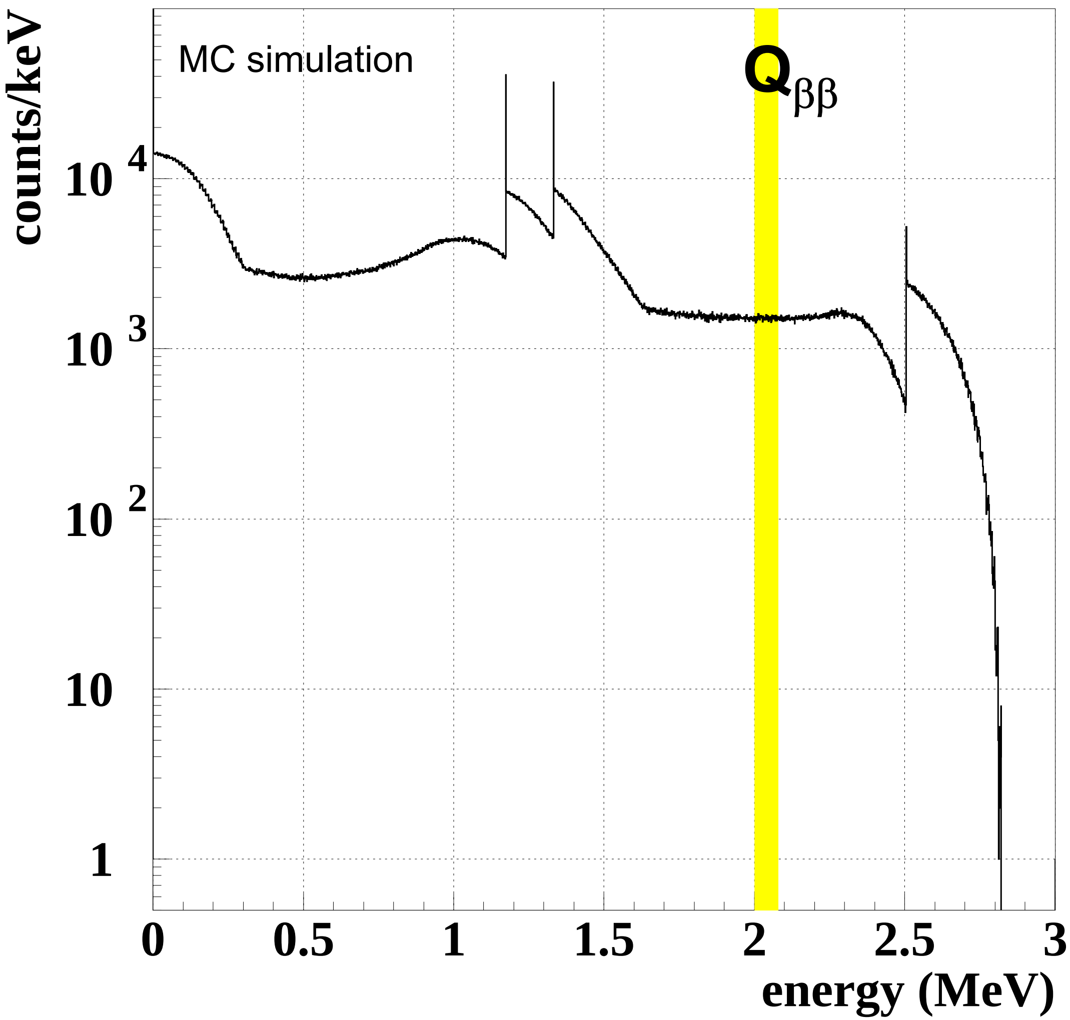
^{60}Co background spectrum



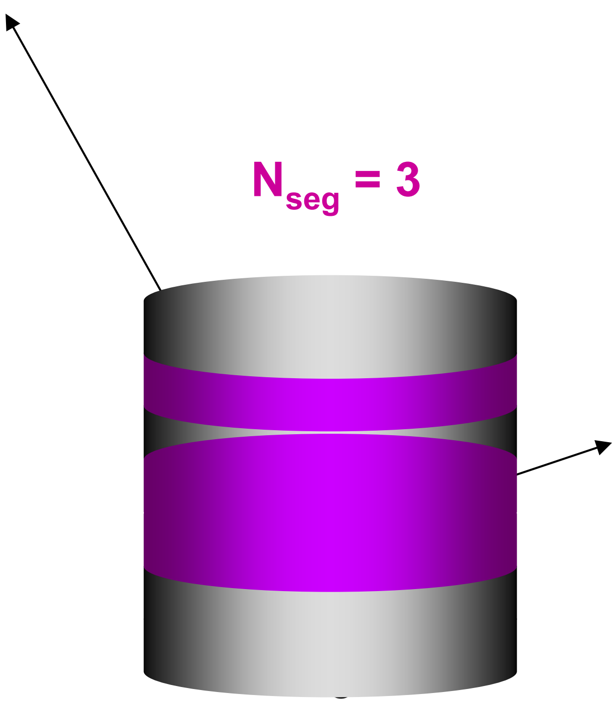


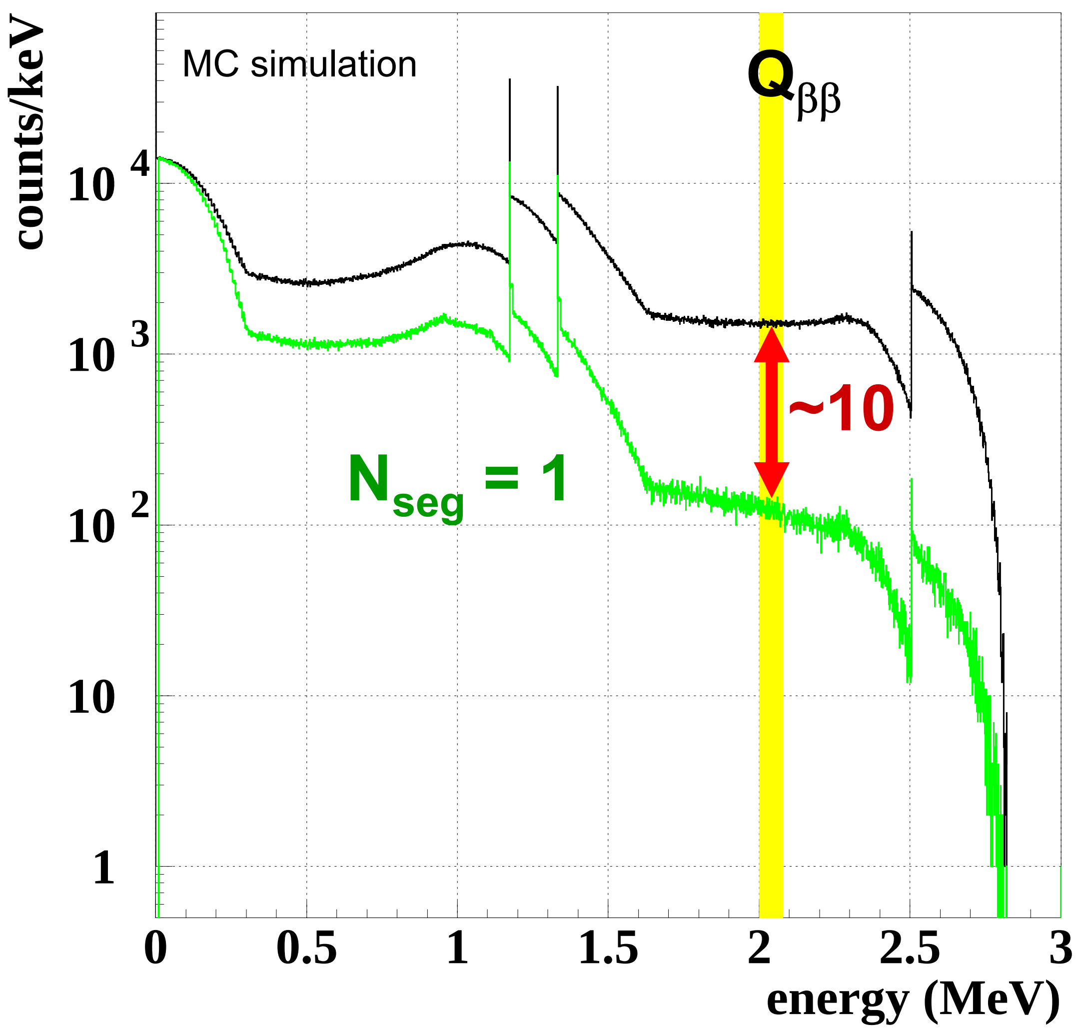
^{60}Co: suppression by segmentation



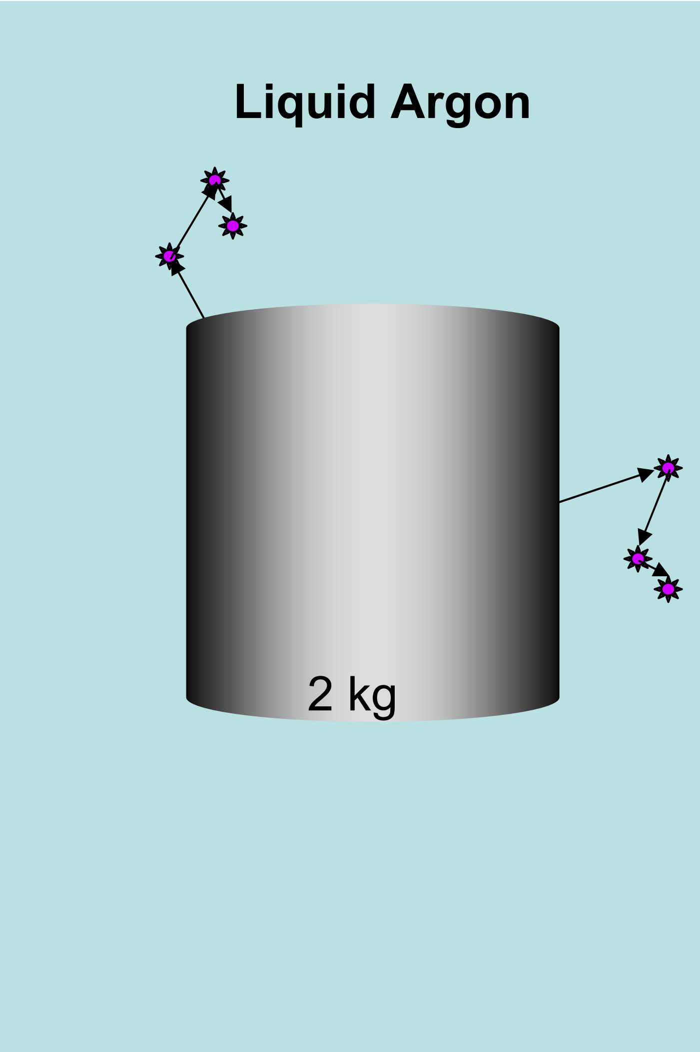


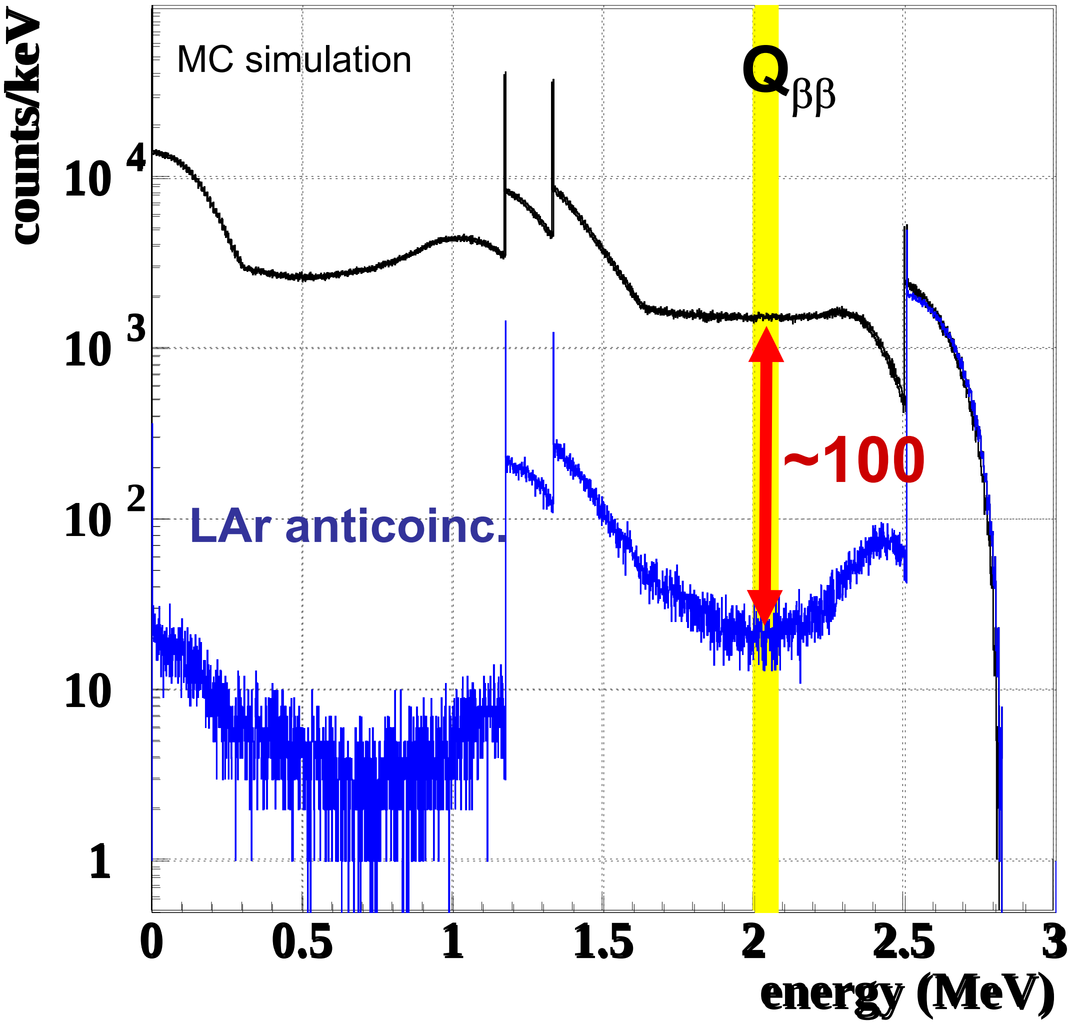
^{60}Co: suppression by segmentation



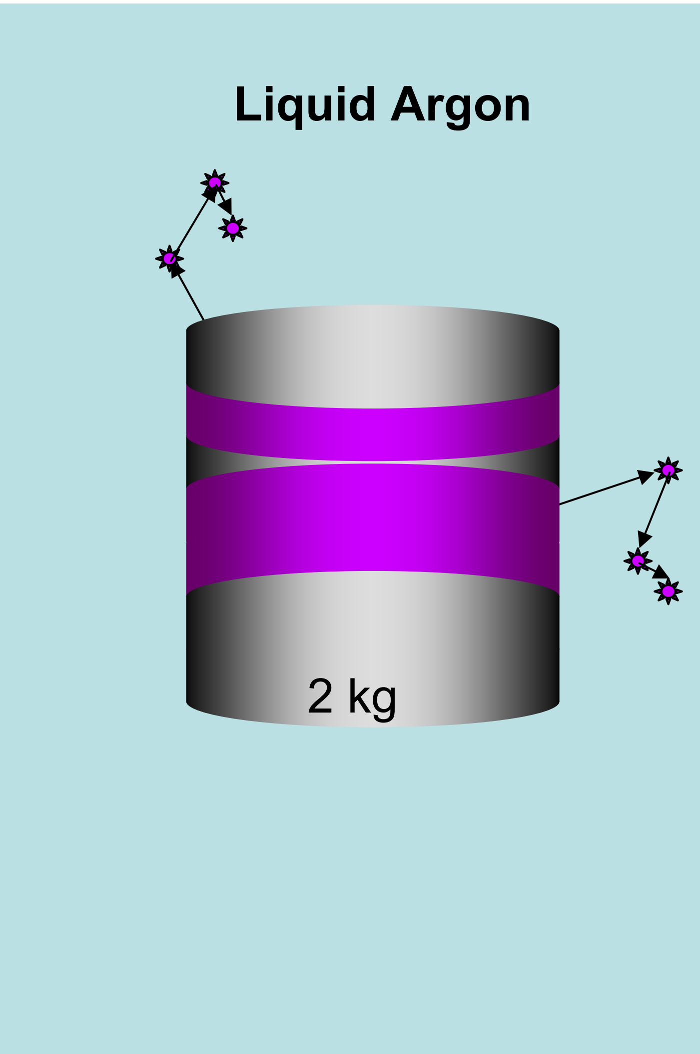


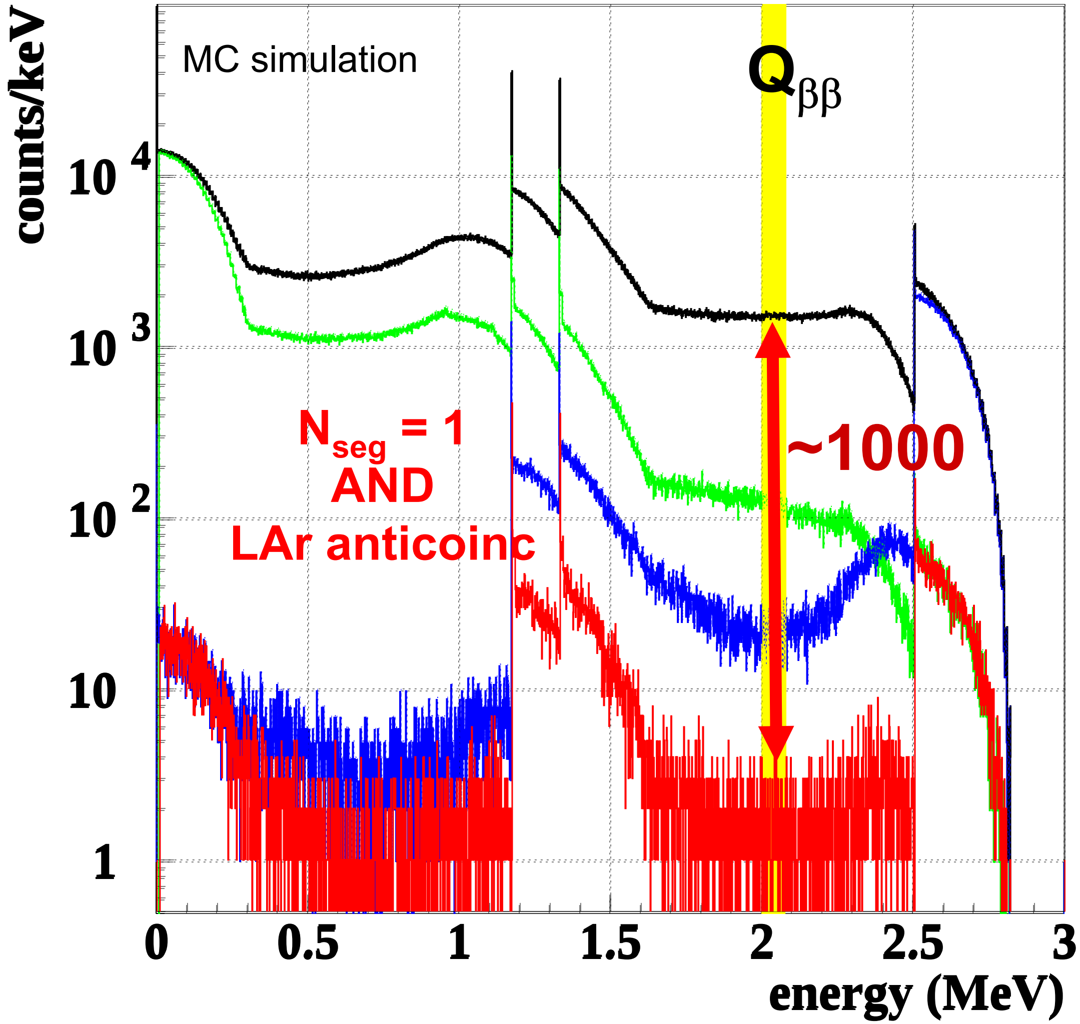
^{60}Co: suppression by LAr Ge-anticoinc.



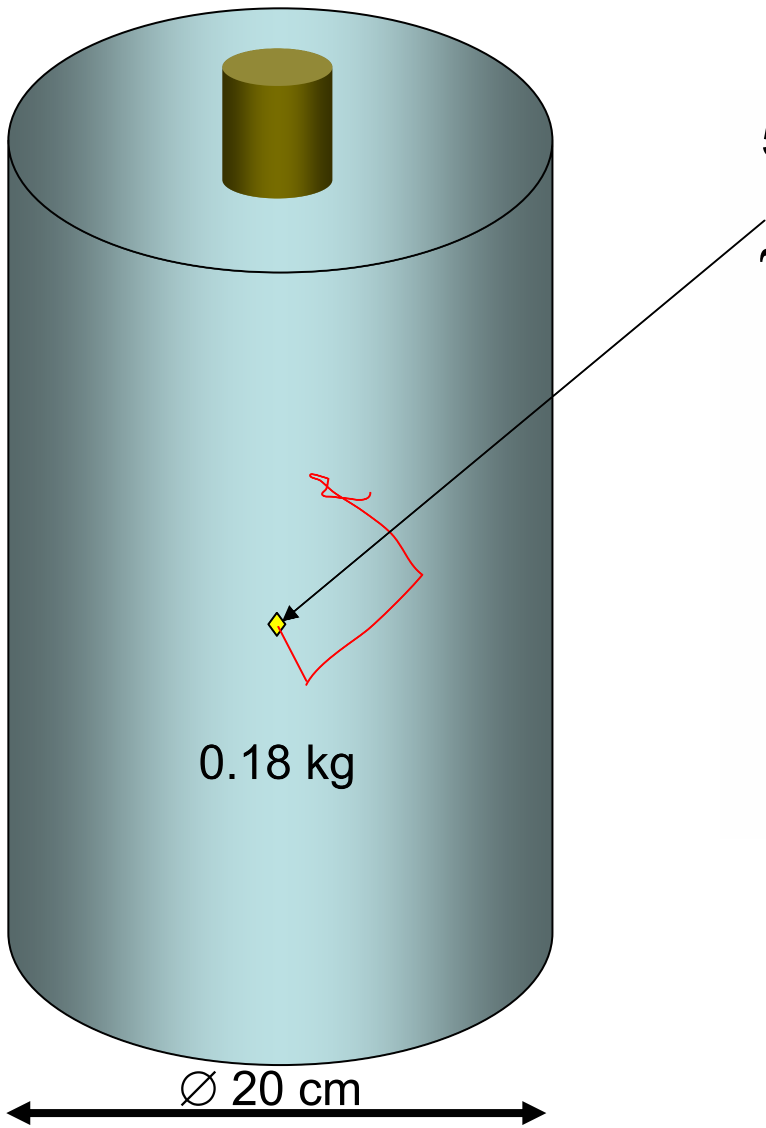


^{60}Co: segmentation and LAr Ge-anticoinc.

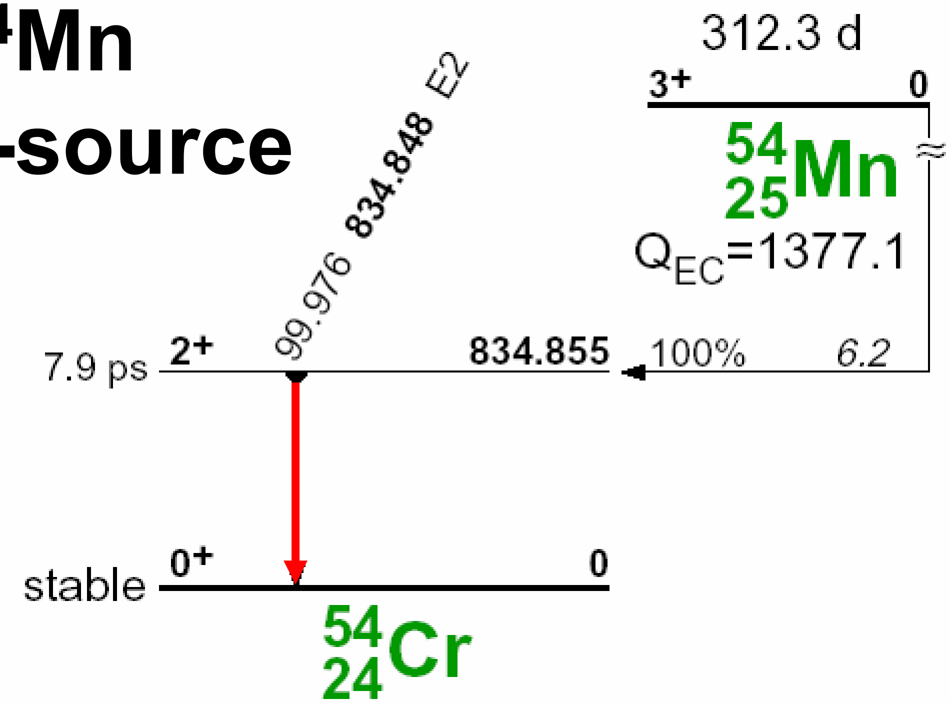




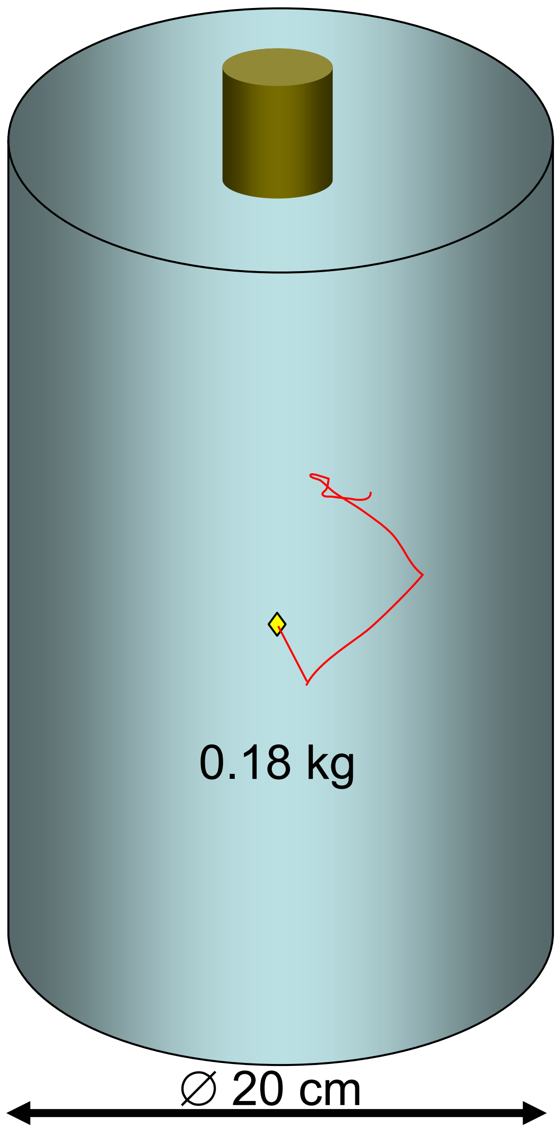
Experiment: LAr Ge-anticoincidence

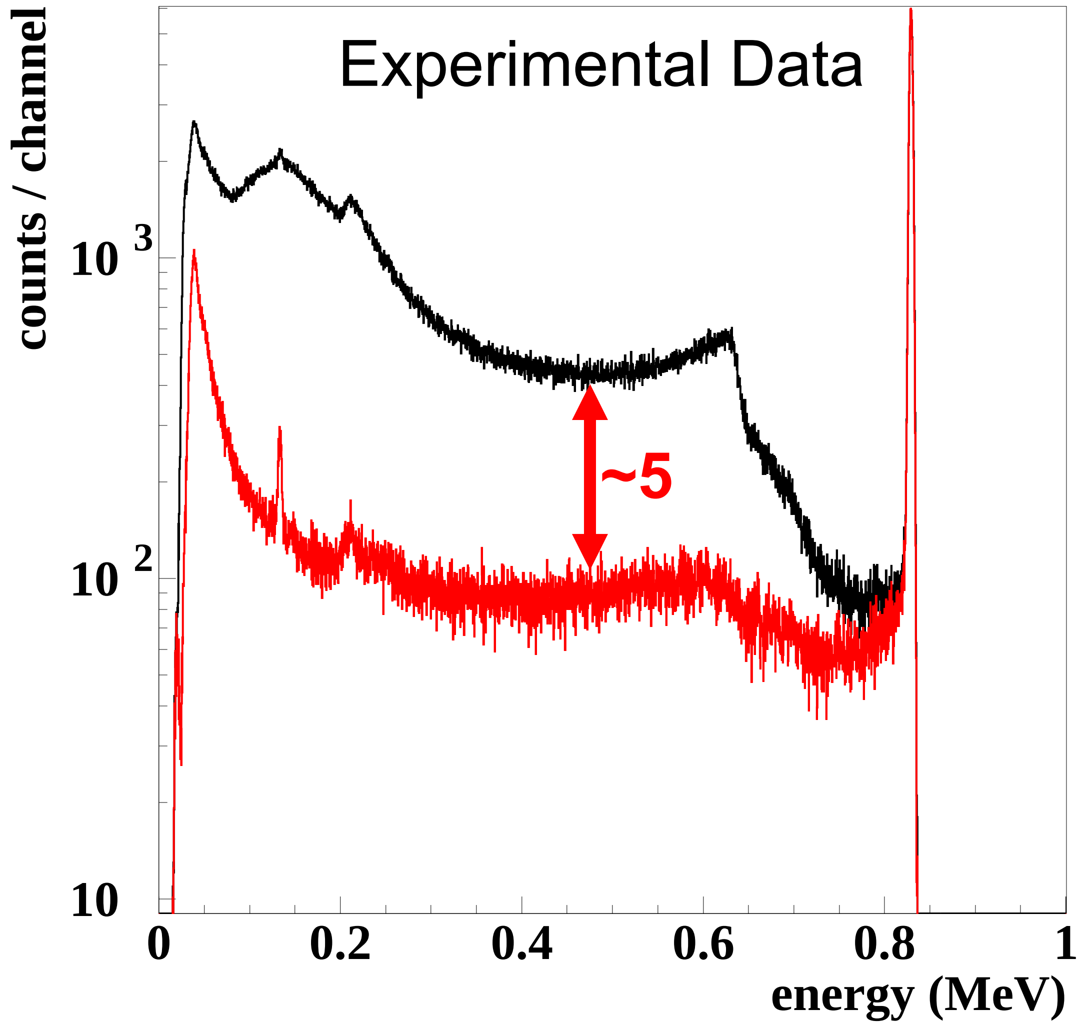


^{54}Mn
γ-source

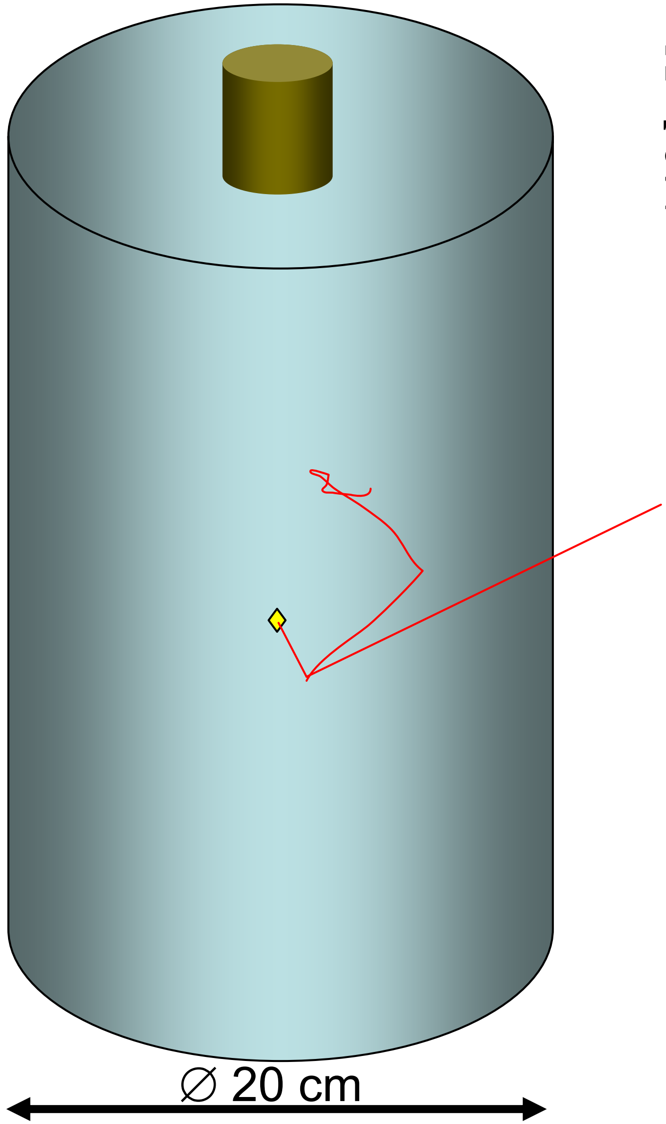


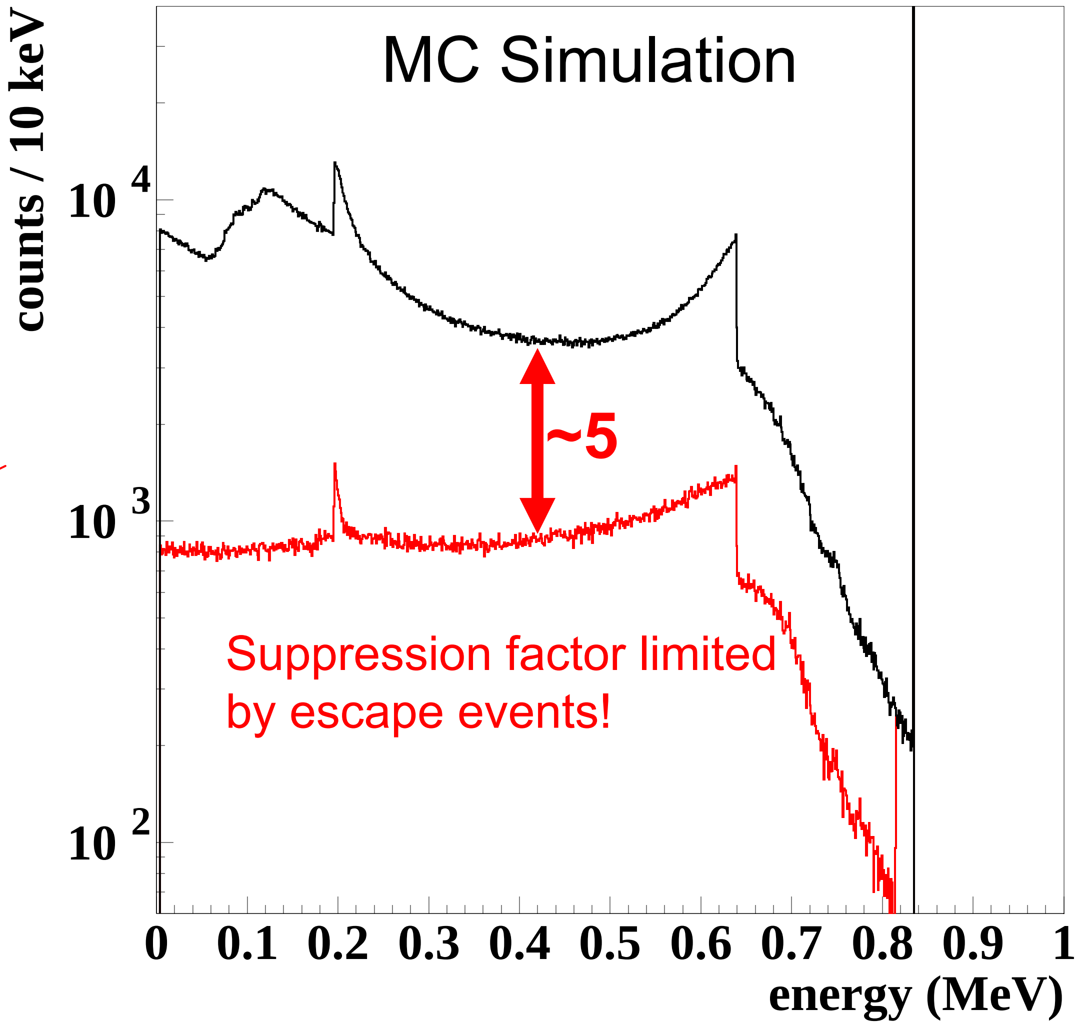
Experiment: LAr Ge-anticoincidence



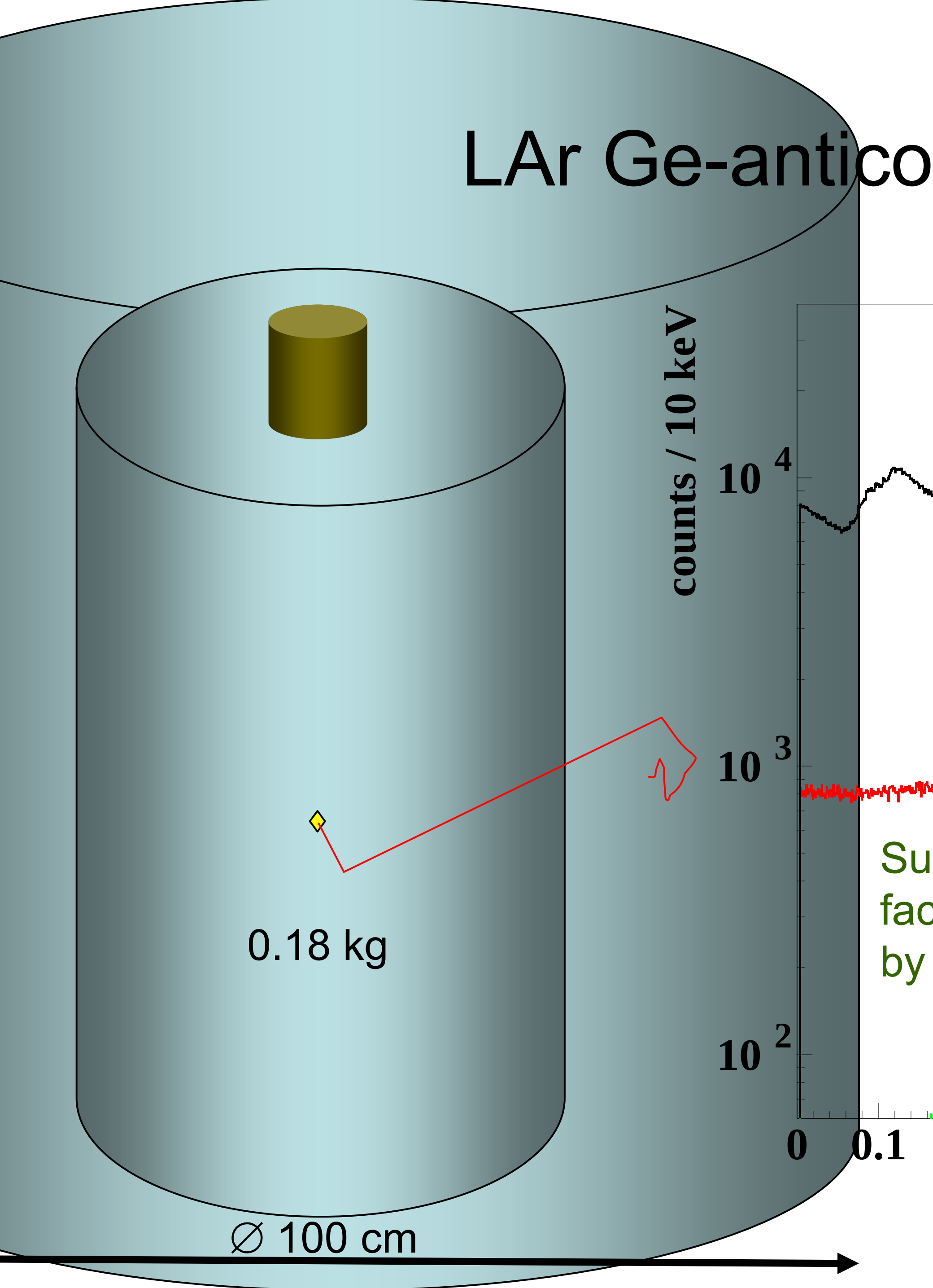


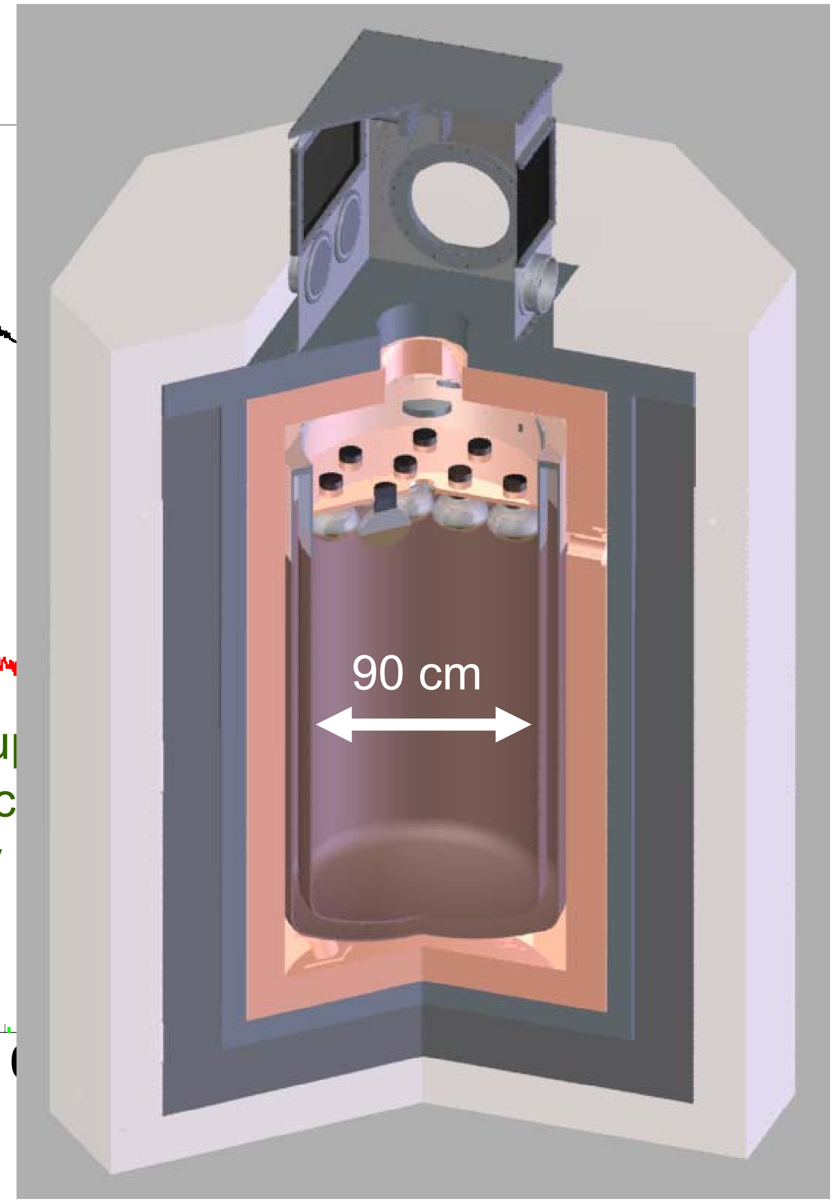
LAr Ge-anticoincidence





LAr Ge-anticoincidence





Background summary

Phase I: external ~ 10^{-3} / (keV kg y)
internal < 10^{-2} / (keV kg y)

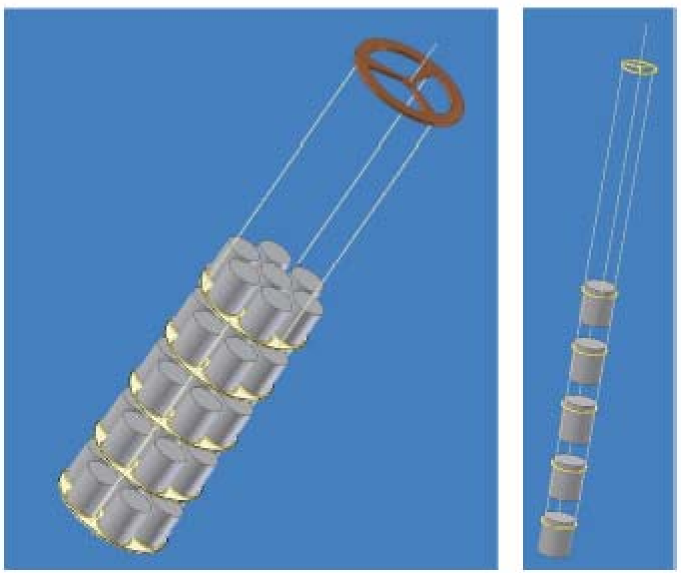
Phase II:

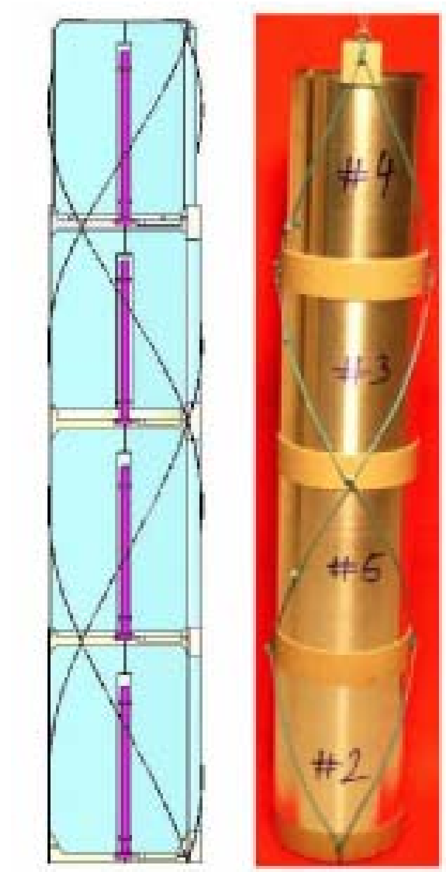
Units: 10^{-3} / (keV kg y)

source	B $\frac{10^{-3}\text{cts}}{\text{keV}\cdot\text{kg}\cdot\text{y}}$	B after bkg. rej. $\frac{10^{-3}\text{cts}}{\text{keV}\cdot\text{kg}\cdot\text{y}}$	B after add. det. segm. $\frac{10^{-3}\text{cts}}{\text{keV}\cdot\text{kg}\cdot\text{y}}$
ext. γ from ^{208}Tl, ^{228}U	1	0.4	0.2
ext. neutrons	≤ 0.05	≤ 0.03	≤ 0.02
ext. muons	≤ 0.1	≤ 0.05	≤ 0.03
internal ^{68}Ge	12	1.1	0.3
internal ^{60}Co	2.5	0.8	0.2
^{222}Rn in LN/LAr	0.2	≤ 0.1	≤ 0.1
^{208}Tl, ^{228}U in holder mat.	≤ 1	≤ 0.1	≤ 0.1
surface contamination	≤ 0.6	≤ 0.1	≤ 0.1

(No segmentation) (With segmentation)

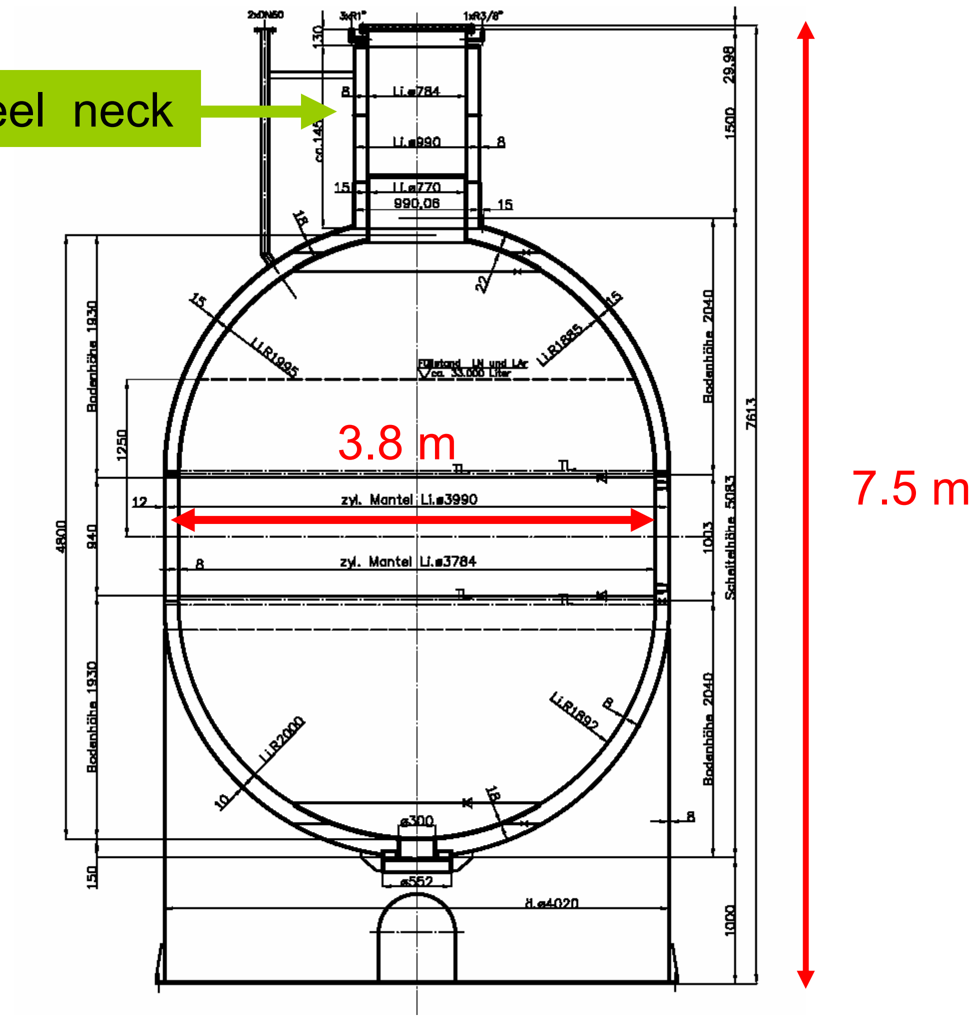
Detector suspension





Purity requirement for support materials < 20 μBq/kg !

Cryogenic Cu-tank



- All copper apart of neck
- Super-insulation
- Earthquake tolerance
  v: 0.5 g / h: 0.6 (LAr)
- Fabrication: EB welding

<u>Status:</u>

engineering study:

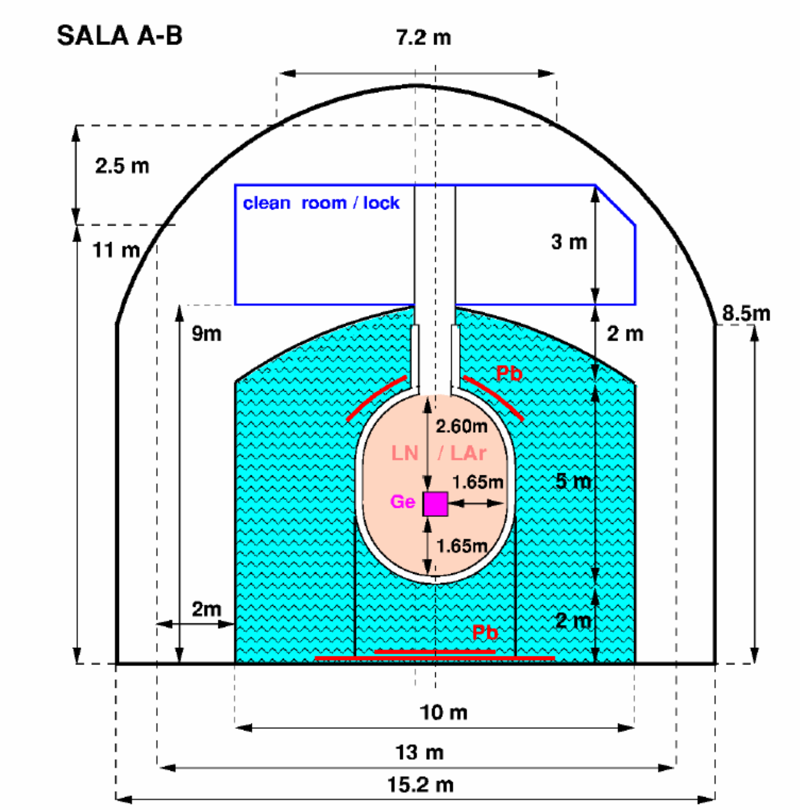
- feasible
- within budget

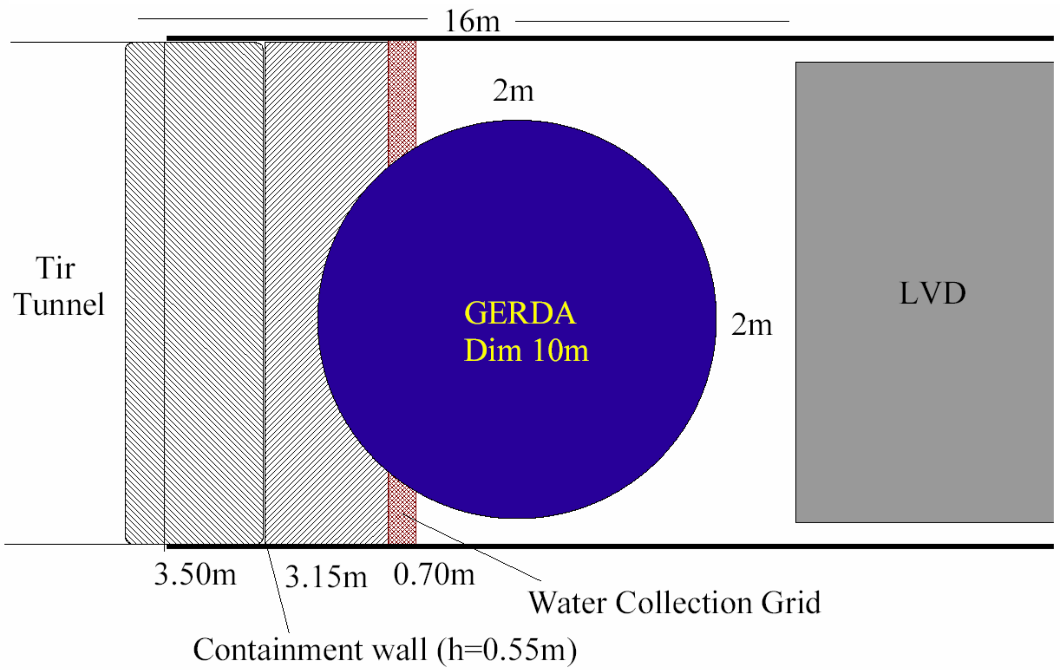
<u>To be optimized/checked</u>:

- radio purity of DIN copper
- Earthquake tolerance

Location in hall A

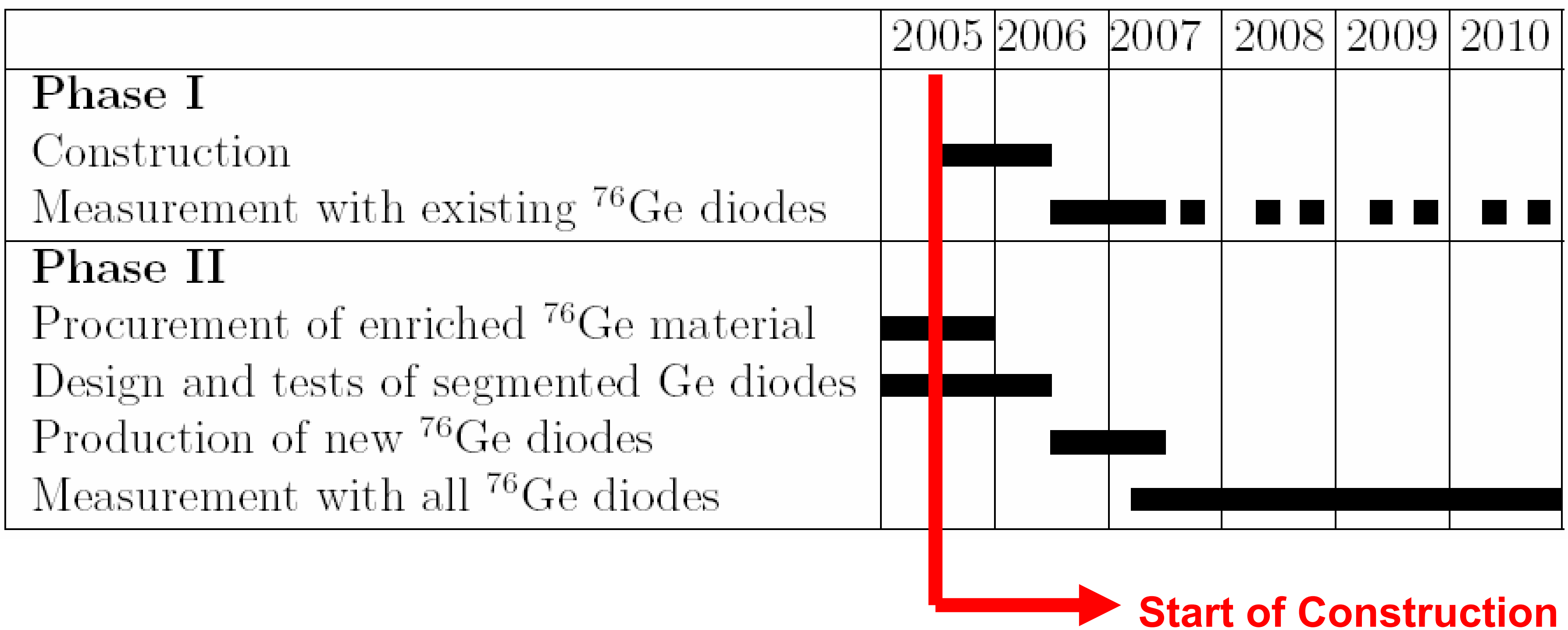
(under discussion with LNGS)





Status, Schedule & Phases

Proposal strongly endorsed by LNGS-SC; expect fast approval by LNGS

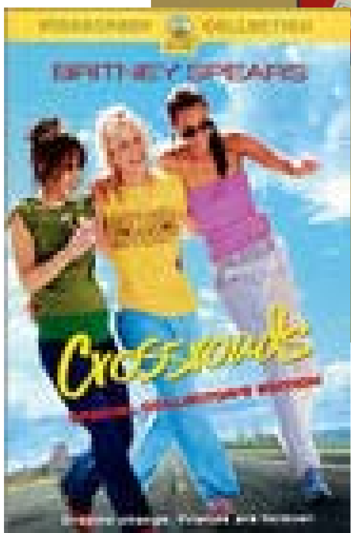


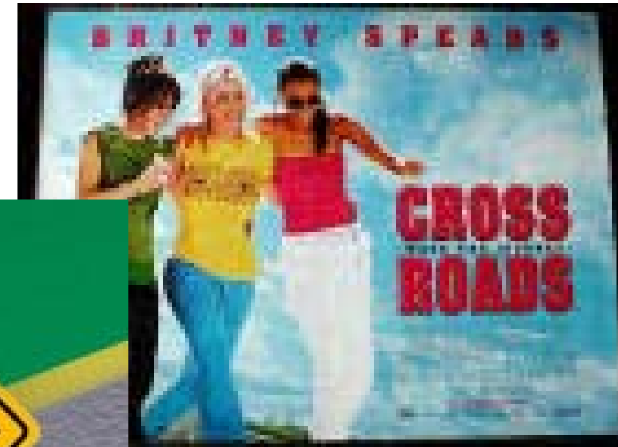

GERDA

Outlook

- Strong future program for study of neutrino properties / neutrino astrophysics at MPIK possible:
  - GERDA (substantial part of funding secured)
  - Double-Chooz (France: ok; US: proposal; Germany: proposal to BMBF in 2005)
  - BOREXINO: rich physics program; despite problems $\Rightarrow$ 2006 start data taking possible!


CROSS
ROADS
DRIVE INN
CHICKEN
SHRIMP
BEER


BRITNEY SPEARS
Crossroads


BRITNEY SPEARS
CROSS
ROADS


SEEKING
DIRECTION?


neon
LEGENDARY CROSSROADS