Design des GERDA Kryostaten

Design of the GERDA cryostat

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Motivation: what is the nature of Neutrinos?

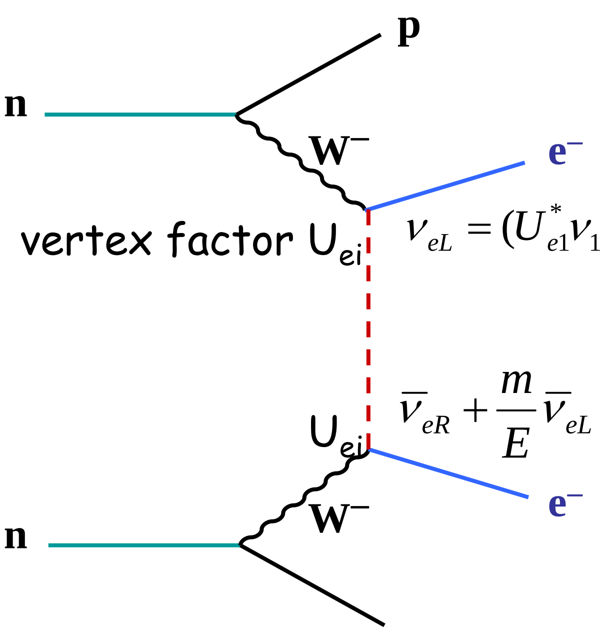
ν oscillations → L_e, L_μ, L_τ violated,
$m_\nu > 0$, → ν_L and ν_R exist
} First non-SM effect

In SM: no symmetry exists to conserve L (more precisely: B-L) !!!

If L violated → "there is no quantum number that makes ν and $\bar{\nu}$ different"

→ in general $\nu = \bar{\nu}$ (Majorana particle)

Is the neutrino its own anti-particle? Yea or nay



$$\nu_{eL} = (U^*_{e1}\nu_1 + U^*_{e2}\nu_2 + U^*_{e3}\nu_3)_L$$

$n\ \nu_{eL} \rightarrow p\ e^-$

$n \rightarrow p\ e^-\ \bar{\nu}_{eR}$

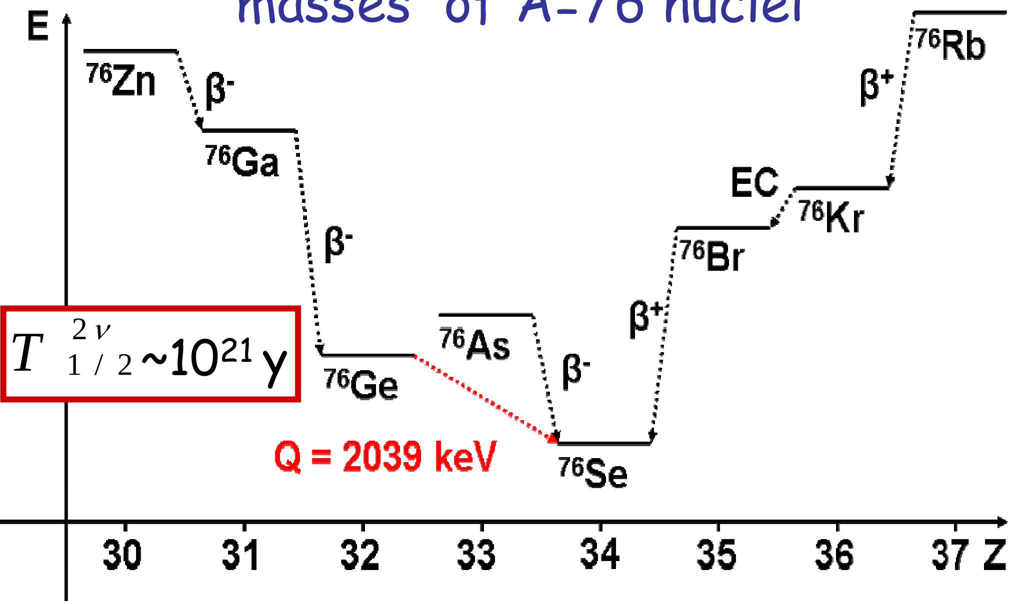
neutrinoless double beta decay

coupling ~ $< m_{ee} > = \left| \sum_{i=1}^{3} U_{ei}^2\, m_i \right|$

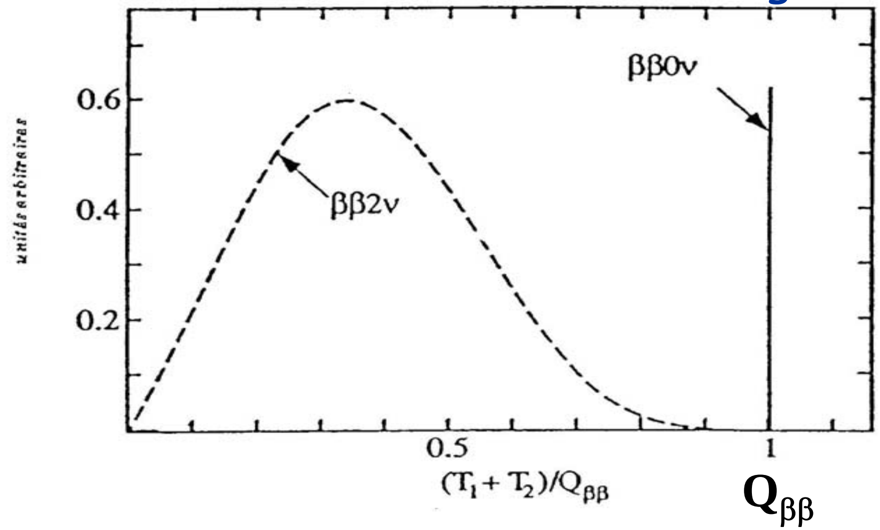
"effective Majorana mass"

What is double beta decay?

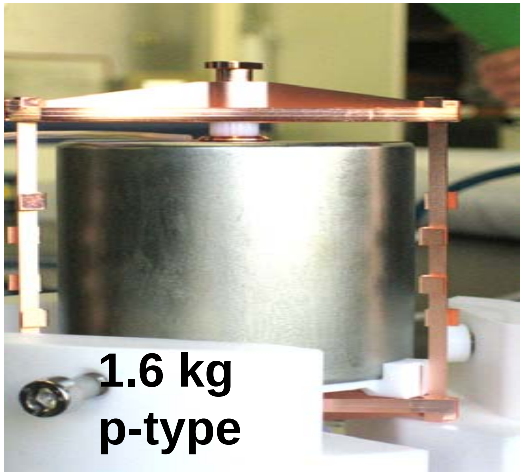
masses of A=76 nuclei



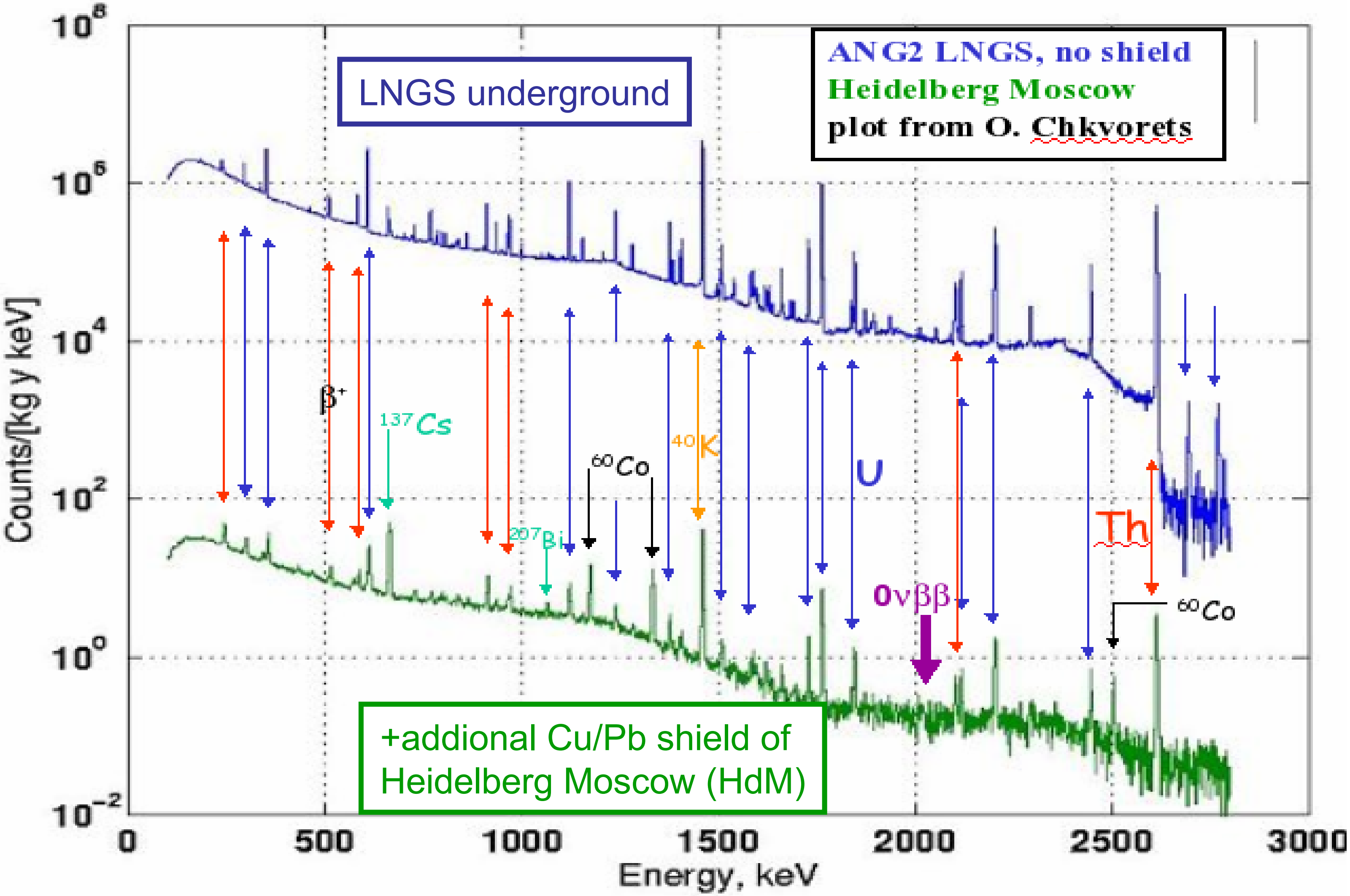
sum of electron kinetic energies



Experimental challenges:
- good energy measurement
- small background index B [counts/(keV kg y)],
- enrich ^{76}Ge isotope: 7.4%(nat) → 86% possible



Background spectrum measured with Ge diode



background dominated by external γ backgrnd (rock, Pb,...)

GERDA goal: 10^{-3} counts/(kg y keV) at 2038 keV

The GERmanium Detector Array collaboration

GERDA mission

continue $0\nu\beta\beta$ search with ^{76}Ge at LNGS
find best solution to reduce backgrounds:
naked Ge diodes in liquid argon
(T87.9 Marik Barnabe Heider)

phase I: use 8 existing enriched Ge diodes
from Heidelberg-Moscow & IGEX
~15 kg, bkg lower than HdM by factor 15

phase II: add new (segmented) detectors
+20 kg, factor 100 lower bkg than HdM

phase I: scrutinize $0\nu\beta\beta$ HdM claim
phase II: factor 10 in sensitivity for $T_{1/2}$

phase III: worldwide collaboration for
sensitivity of $\langle m_{ee} \rangle$ ~ 50 meV,

active communication with MAJORANA coll.

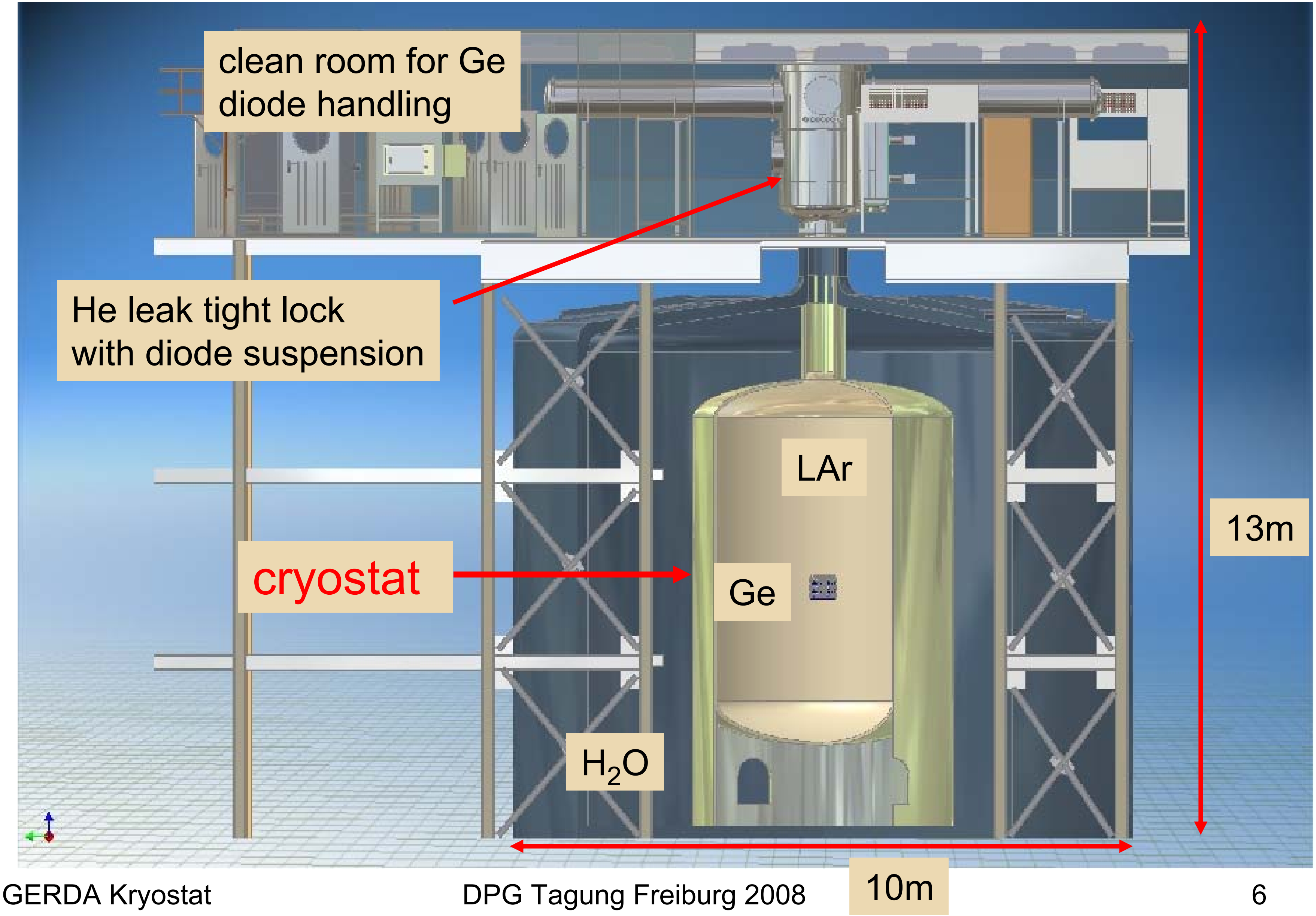
GERDA formed in Febr 2004

List of institutions:

INFN LNGS, Assergi, Italy
Univ. Dresden, Germany
JINR Dubna, Russia
Institute for Reference Materials, Geel, Belgium
MPIK, Heidelberg, Germany
Jagiellonian University, Krakow, Poland
Univ. di Milano Bicocca e INFN, Milano, Italy
INR, Moscow, Russia
ITEP Physics, Moscow, Russia
Kurchatov Institute, Moscow, Russia
MPI Physik, München, Germany
Univ. di Padova e INFN, Padova, Italy
Univ. Tübingen, Germany
Univ. Zürich, Switzerland

~80 physicists, 14 institutions, 6 countries
approved Nov 2004 at LNGS
Spokesperson Stefan Schönert, MPIK

GERDA solution for LNGS Hall A



Cryostat design considerations

Options

.	copper cryostat	stainless steel cryostat
radiopurity*	<20 μBq/kg of ^{228}Th → LN2 (0.8 kg/l) or LAr <1 mBq ^{222}Rn emanation	~1 mBq/kg of ^{228}Th → only LAr (1.4 kg/l) possible ~30 mBq ^{222}Rn emanation (preliminary measurement)
welding	only electron beam (EB)	e.g. tungsten inert gas (TIG)
safety	some concerns	standard material
cost	not affordable	still a lot of money

.* talks on radiopurity measurements:

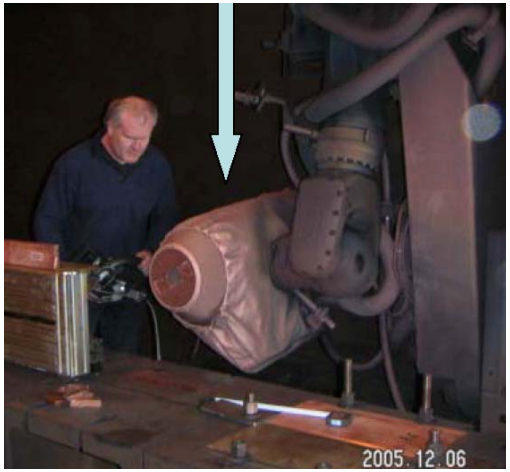
T87.8: W. Maneschg, γ spectroscopy screening of stainless steel

T68.6: H. Simgen, Rn emanation measurements

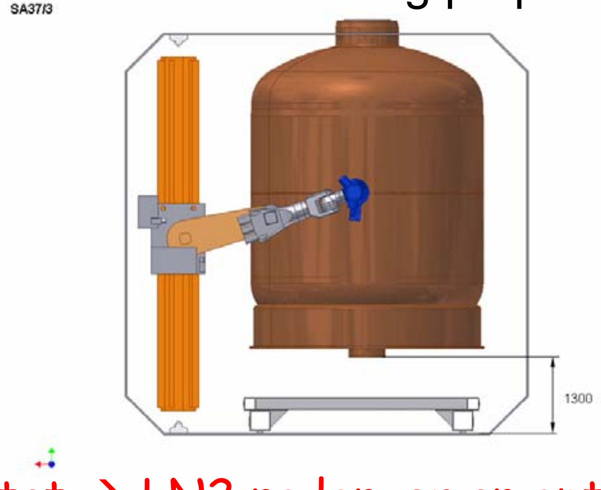
The Copper solution

660 m³ EB facility of pro-beam in Burg

EB gun



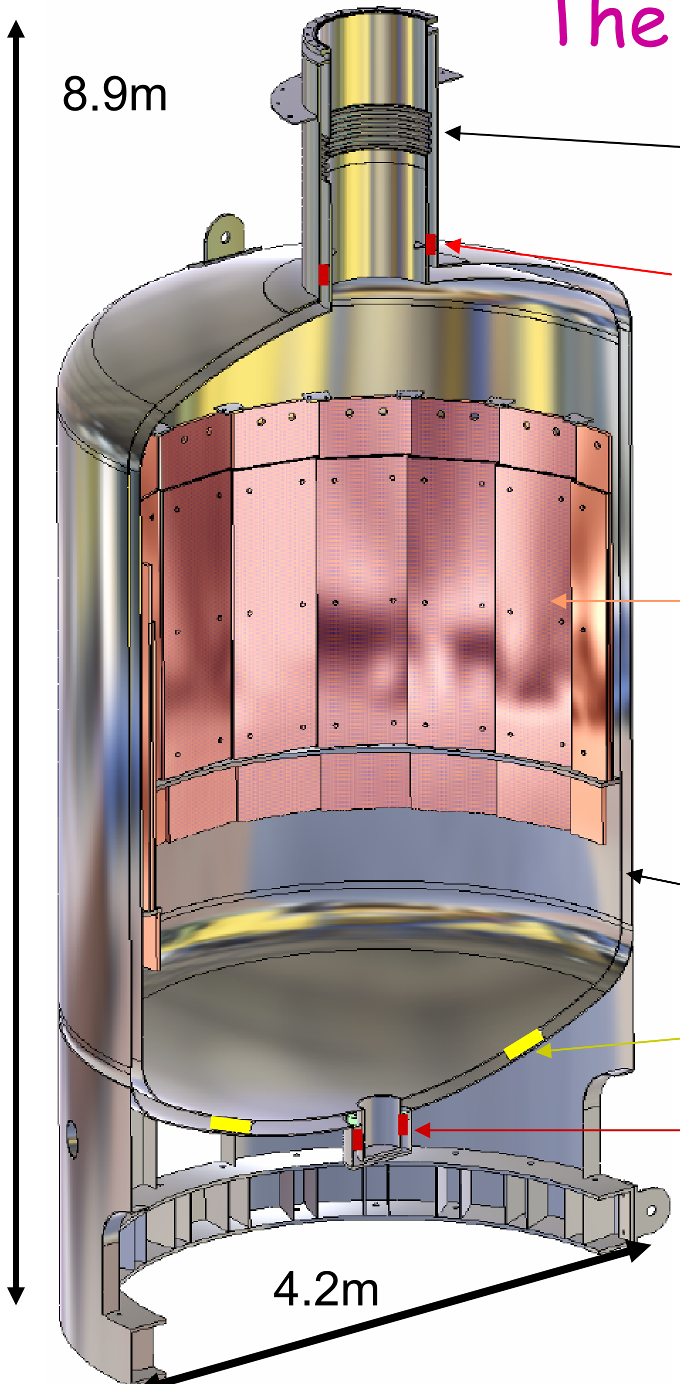
sketch of EB welding preparation



Design was ready, welding certification done, but
- price increase by factor 3-4 after 1 year of R&D, mainly for mechanical preparation
- safety concerns at LNGS

May 2006: switch to standard stainless steel cryostat → LN2 no longer an option

The stainless steel solution



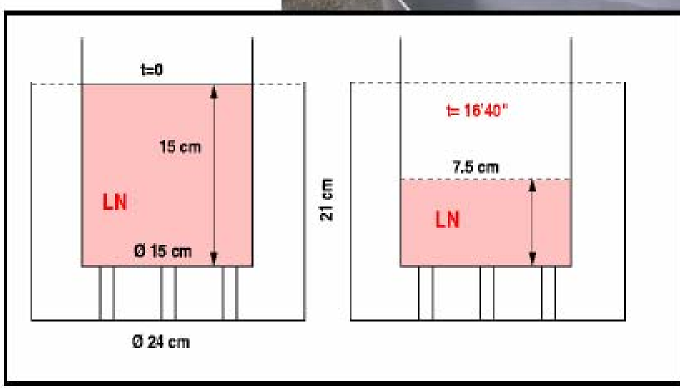
general:
- double-walled out of X6 CrNiMoTi 17-12-2
- 65 m^3 LAr
- 200 W thermal loss
- 1.5 bar overpressure
- 0.6 g earth quake
- 8 m water height
- AD2000 design

safety:
- only 1 opening
- inner vessel supported at bottom
- walls at least 3 mm thicker than required

radioactivity:
- material screened with γ spectrometry → OK
- radon emanation measurement

Safety, safety, …

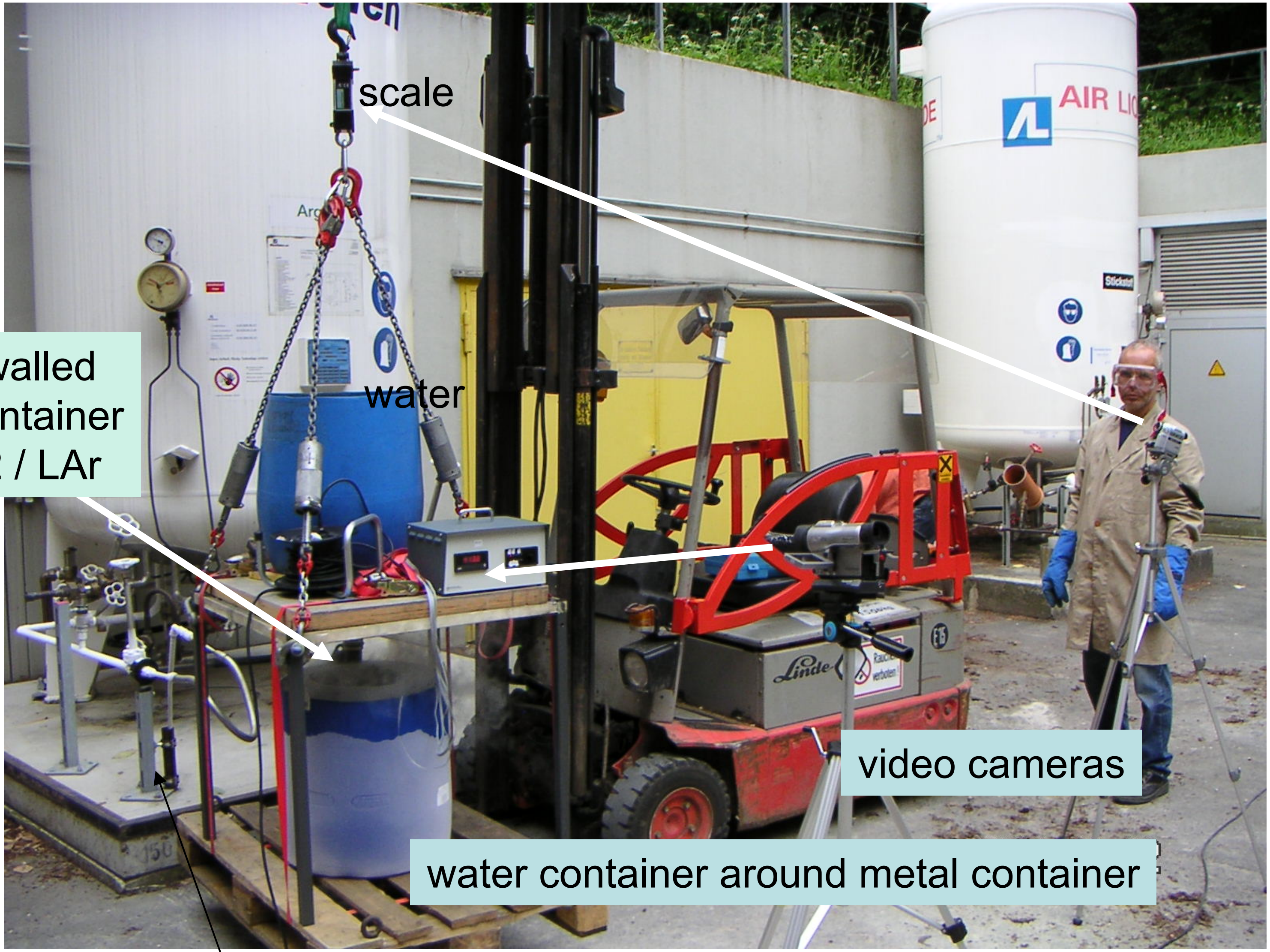
basic risk: cryostat in huge water tank = huge heat reservoir
→ optimize design to avoid mixing of LAr and water
→ many studies, discussions, meetings, ….



scaling factor GERDA / test : 24.4

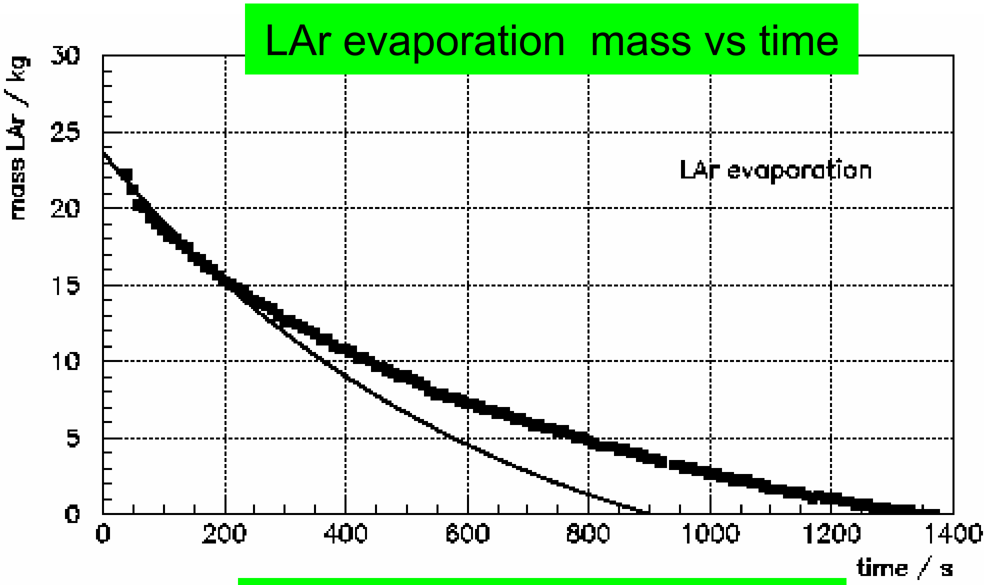
► 24.4•2•16,7' = 13.6 hrs (agrees too well)

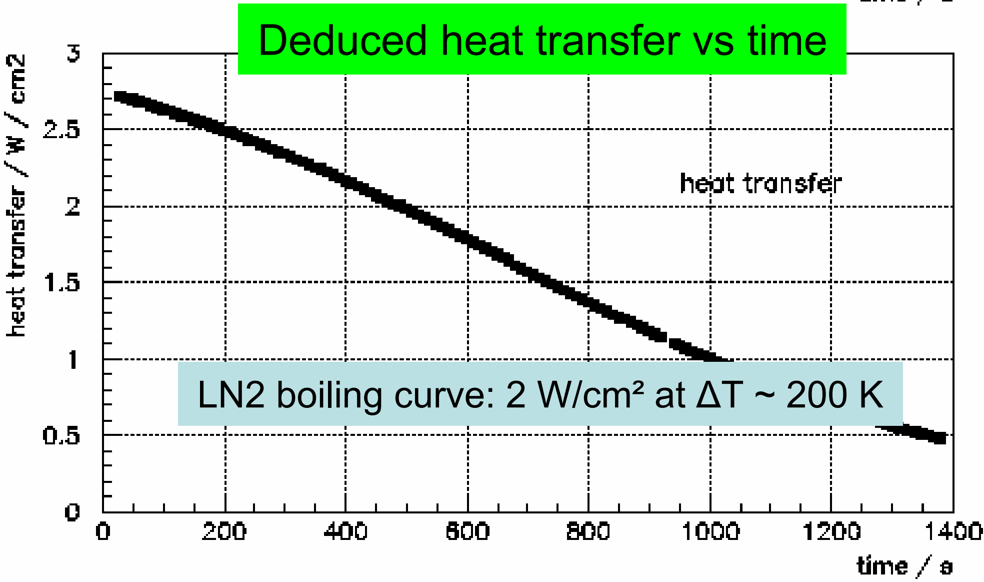
More advanced experiments....



measure : mass & temperature as function of time after water flooding

Measured evaporation rates





Risk analyses

AIR LIQUIDE	N° Chrono : D6035 NT 3 (2) N° Affaire : GERDA N° Client : MPI	Page : 1/23

Risk assessment
FMECA Study report
Gerda Cryostat for MPI

The GERDA Collaboration

TÜV NORD INDUSTRIEBERATUNG
TÜVNORD SysTec GmbH & Co. KG

Expert's Report

Risk assessment concept
for the copper cryostat of the Gerda project

Commissioned by: Max Planck Institute for Nuclear Physics POB 10 39 80 D-69029 Heidelberg	Engineer in charge: Dipl.-Ing. Jörk Dubiel, Dipl.-Ing. Hartmut Wolter	Date: June 20, 2005

Cryogenic and Water Tank System Preliminary Risk Analysis

Phase 3: integration of phase 1 & 2
Answers, additional analysis and implementation regarding the questions put forward at the Geneva meeting

Risk matrix (final NIER report)

Consequecy / Event /year	No relevant effects	Minor effects	Serious effects	Major Effects	Mortal (N°1 lethality)	Mortal (N° 2÷10 lethalities)
$1 – 10^{-1}$	A	T	I	I	I	I
$10^{-1} – 3*10^{-2}$	A Event 1		T			
$3*10^{-2} – 3*10^{-3}$	A **Event 1* - Event 2**	A **Event 5**	T	T	I	I
$3*10^{-3} – 10^{-3}$	A	A	A	T	I	I
$10^{-3} – 3*10^{-4}$					I*	I*
$3*10^{-4} – 10^{-4}$	**A** **Evento 8**	A	A	A	T	T
$10^{-4} – 10^{-5}$	A **Evento 9**			A **Evento 3 - Evento 6**		
$10^{-5} – 10^{-6}$	A	A	A **Evento 10**	A	T	T
$10^{-6} – 10^{-8}$	A	A	A **Evento 11**	A	A	A
$<10^{-8}$	A	A	A	A	A	A **Top 1 - Evento 7** **Evento 3* - Evento 6***

Event 3 = crack in outer vessel, Event 6 = crack in inner vessel
Event 3* = large hole in outer vessel, Event 6* = large hole in inner vessel
Event 7= simultaneous failure of both walls, TOP1 = failure of safety devices & one wall

Status: cryostat on its way to LNGS

cryostat ready
at SIMIC, Italy

waiting for transport
to LNGS

Conclusions

Copper solution failed

Radioactivity of stainless steel cryostat ok for LAr operation
Radon emanation still under evaluation

Safety was(is) a big concern

Cryostat is finished and soon on its way to LNGS

GERDA will be built around the cryostat, completion in one year