GERDA

The Ge Detector Array for the Search of 0vßß decay in Ge-76

- Status Report -

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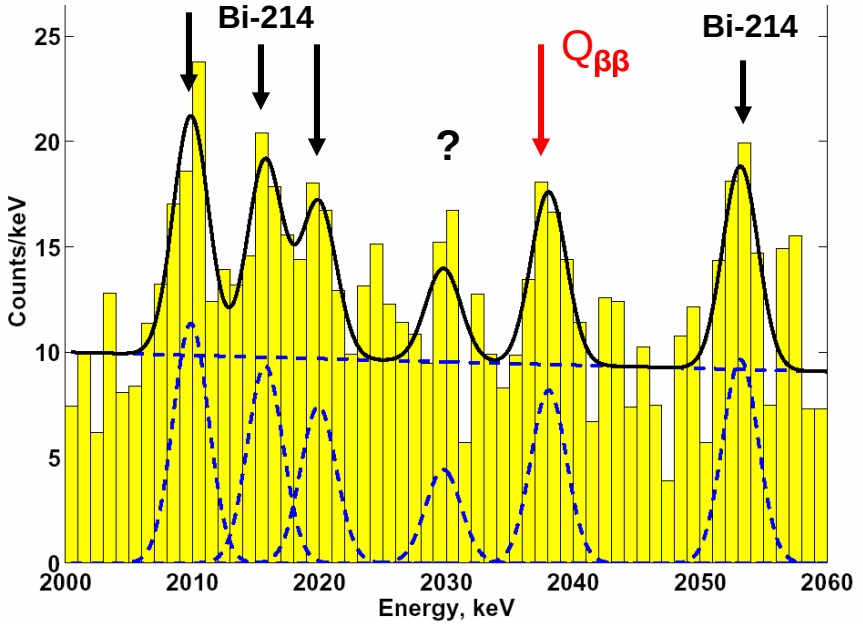
~ 70 physicists
12 institutions
5 countrys

April 2007

$\langle m_{ee} \rangle$ best limits / value

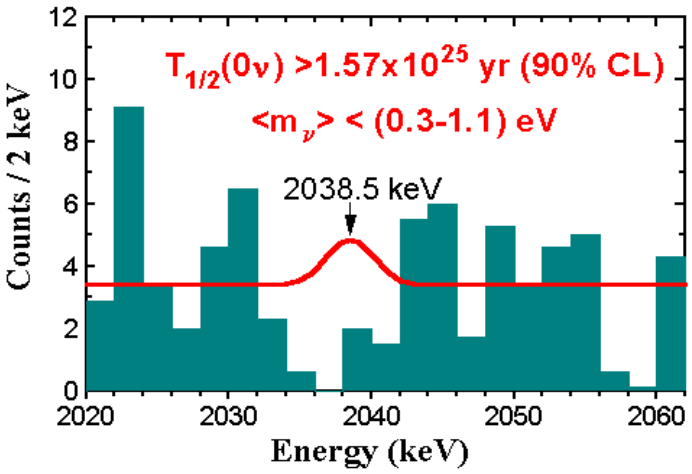
KKDC: H.V.Klapdor-Kleingrothaus, I.V.Krivoshina, A.Dietz, O.Chkvorets, Phys.Lett. B586 (2004) 198



5 enriched Ge-76 diodes (10.9 kg / 71.7 kg·y)
B ~ 0.1 cts / (keV·kg·y)

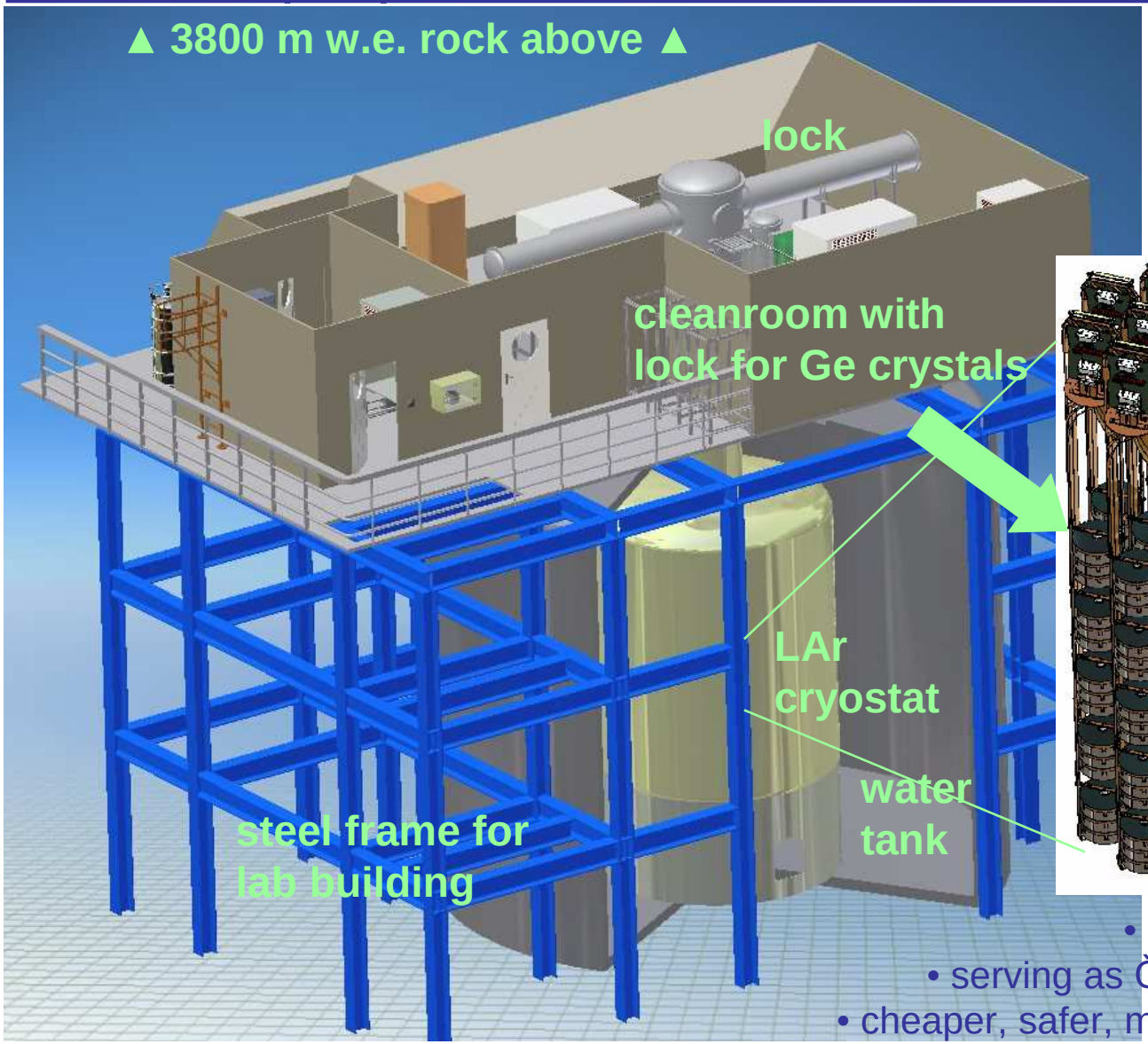
$T^{0\nu}_{1/2} = (0.69 - 4.18) \cdot 10^{25}$ y (3σ range)

IGEX : Gonzales et al., NP B87(2000)278



▶ confirmation needed with same & different isotopes
key: reduce background by *O*(100) for better sensitivity

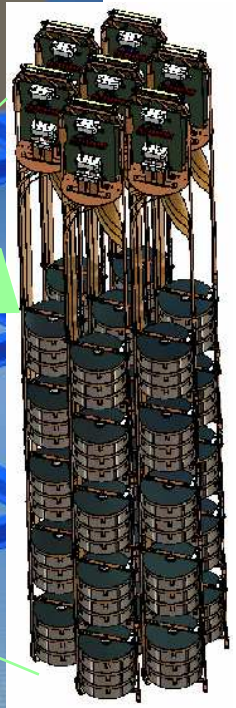
proposed GERDA installation in LNGS Hall A



designed for
external γ,n,μ background
< 0.001 cnts /(keV · kg · y)

Ø 10 m water vessel
Ø 4.2 m LAr cryostat
internal Cu liner

70 m³ of LAr
650 m³ of water



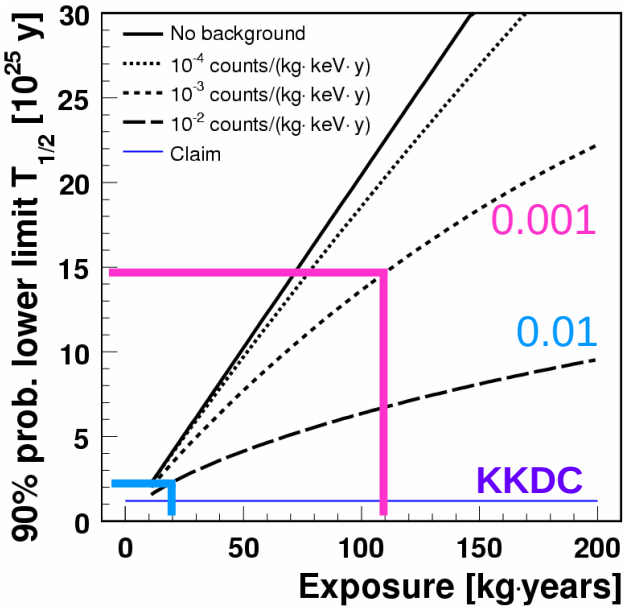
up to five Ge diodes
arranged in strings,
total of 16 strings

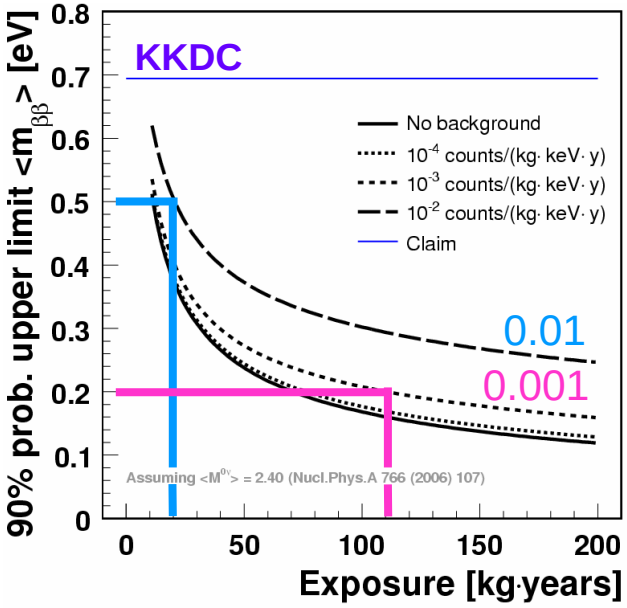
water:
- acting as neutron moderator
- serving as Čerenkov medium for μ veto
- cheaper, safer, more effective than LN2 (LAr)

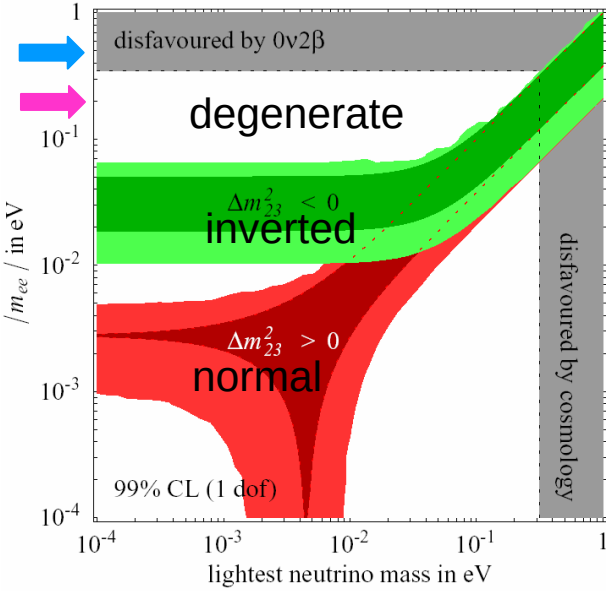
GERDA goals & sensitivity

GERDA's goal : reach background index at $Q_{\beta\beta}$ = 2039 keV of 0.01 / 0.001 cts / (keV·kg·y)

measured → deduced → mass hierarchy







A.Strumia & F.Vissani, hep-ph / 0503246

- phase I : use existing Ge-76 diodes of Heidelberg-Moscow experiment & IGEX (~15 kg)
  ~ 0.01 cts / (keV·kg·y) intrinsic background expected
- phase II : add new enriched Ge-76 detectors, ~20 kg , (37.5 kg enriched Ge-76 bought)
  ~ 0.001 cts / (keV·kg·y) background expected ► 3 y·35 kg
- phase III: depending on results worldwide collaboration for real big experiment
  close contacts & MoU with MAJORANA collaboration established

GERDA Task Groups

- **TG01** **Modification & test of existing Ge diodes**
- **TG02** **Design & production of new Ge diodes**
- **TG03** **Diode readout and signal processing**
- **TG04** **Cryogenic vessel**
- **TG05** **Infrastructure on top of vessel**
- **TG06** **Water vessel**
- **TG07** **Muon veto**
- **TG08** **Infrastructure & logistics for GERDA**
- **TG09** **DAQ electronics & software**
- **TG10** **Simulation & background studies**
- **TG11** **Material screening**
- **Safety**
- **Schedule**

to be discussed: recent progress of TGs

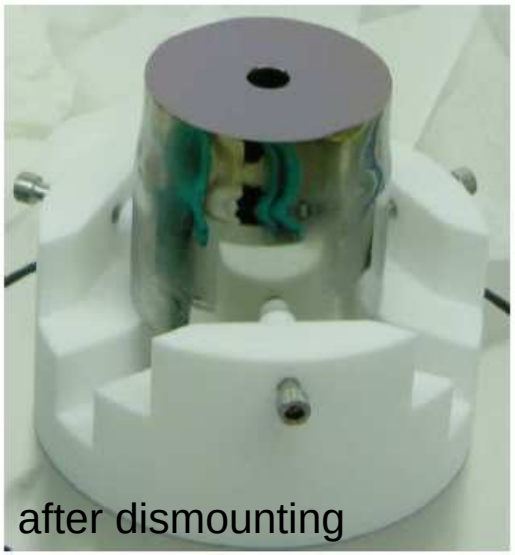
not discussed : LArGe R&D

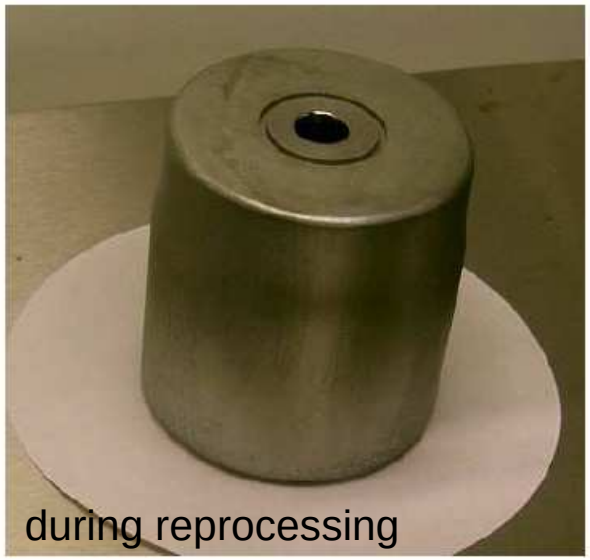
TG01 existing Ge diodes – all p-type

- **enriched** **5 HdM, 3 IGEX :** **total of 17.9 kg**
- **non-enriched** **6 Genius-TF :** **total of 15 kg**

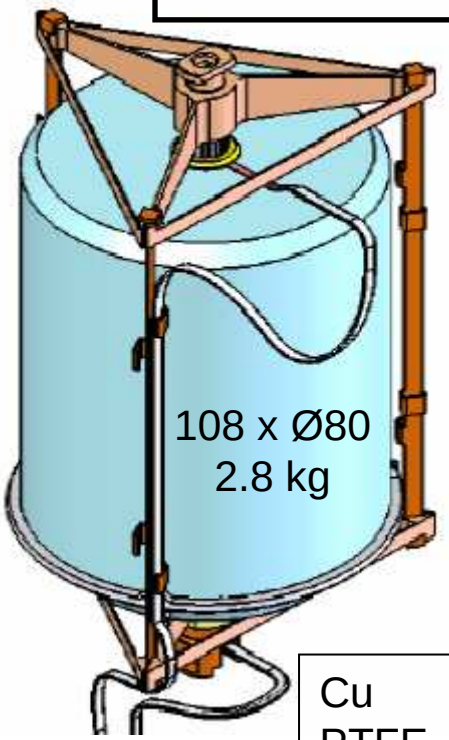
► **all being refurbished by Canberra, Olen, stored underground at HADES**

RG3 (from IGEX)


after dismounting


during reprocessing

low mass mount



Cu	80.8 g
PTFE	6.4 g

► **refurbishment almost done – still lacking:**
implantation & passivation

TG01 long term stability in LN2/LAr

from Abstract*:

"…. After operation of GENIUS-TF over three years with finally six naked Ge detectors … in liquid nitrogen … we realize …..:
(1) Background from Rn-222 diffusing into the setup on a level far beyond the expectation.
(2) Limited long-term stability of naked detectors in liquid nitrogen as result of increasing leakage current. …."

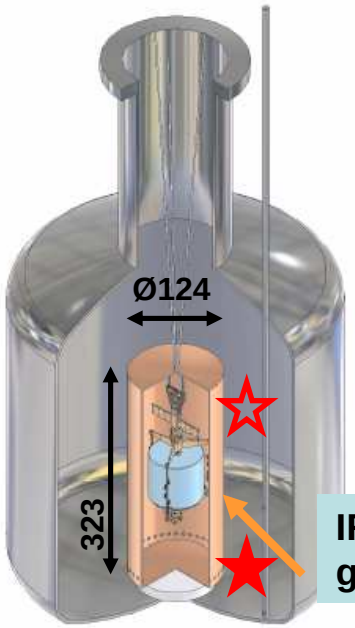
*** "…. - The long-term stability of naked detectors in liquid nitrogen"**
HV Klapdor-Kleingrothaus & IV Krivoshina
NIM A 566 (2006) 472-476

Comments:

@ (1): Also true for state-of-the-art implementation (metal seals, He leak test) ?
@ (2): Problems occur after transfers of diodes from cold-to-warm-to-cold.

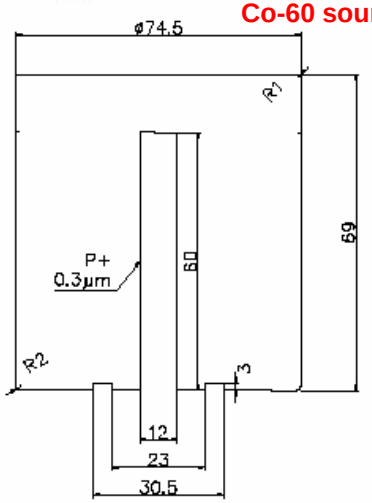
► However, better not to comment but to demonstrate better performance!

TG01 long term tests in LAr

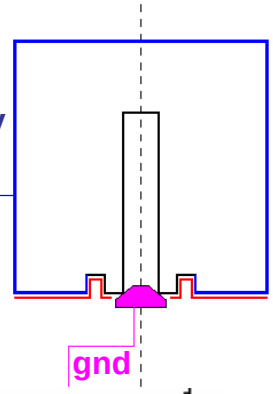


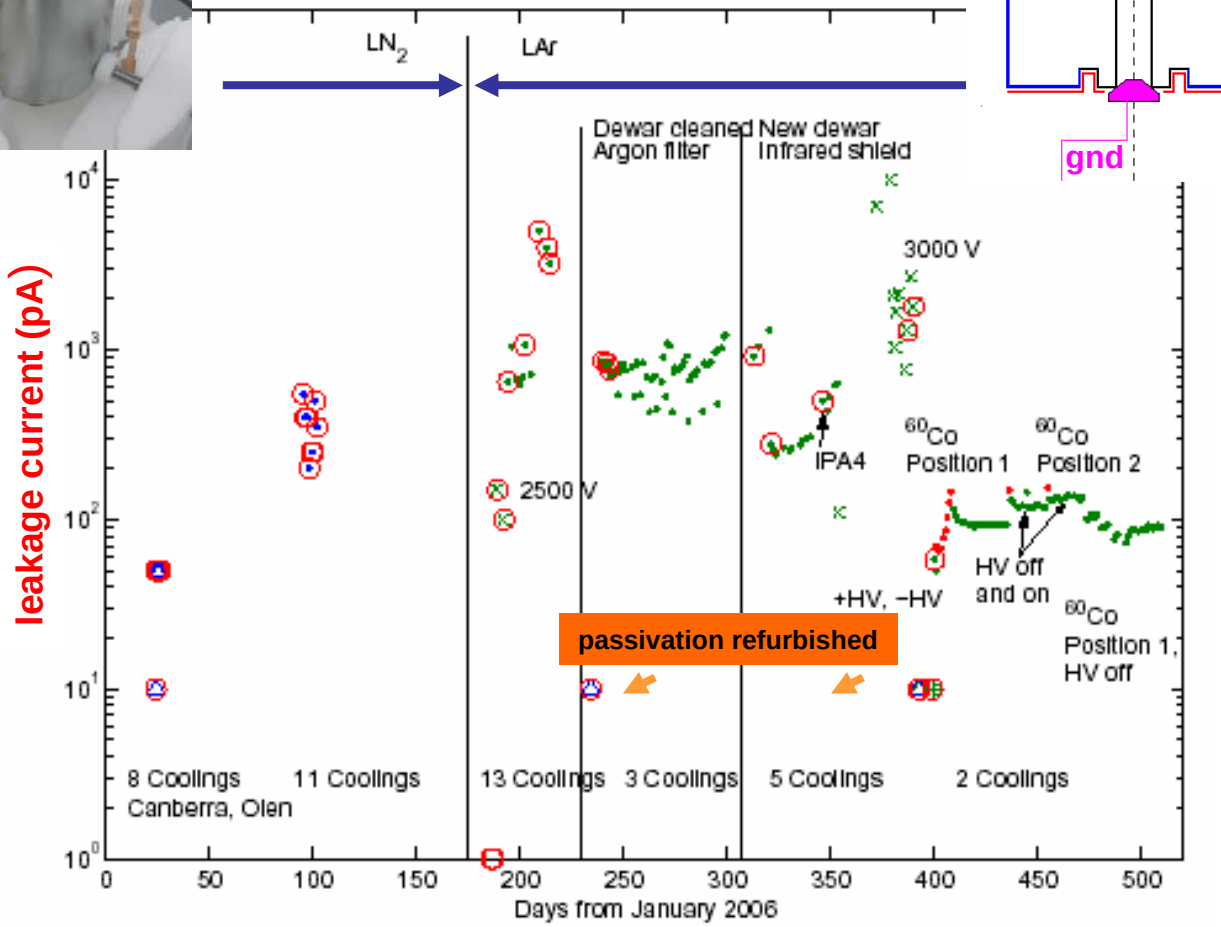
IR shield grounded

Co-60 source



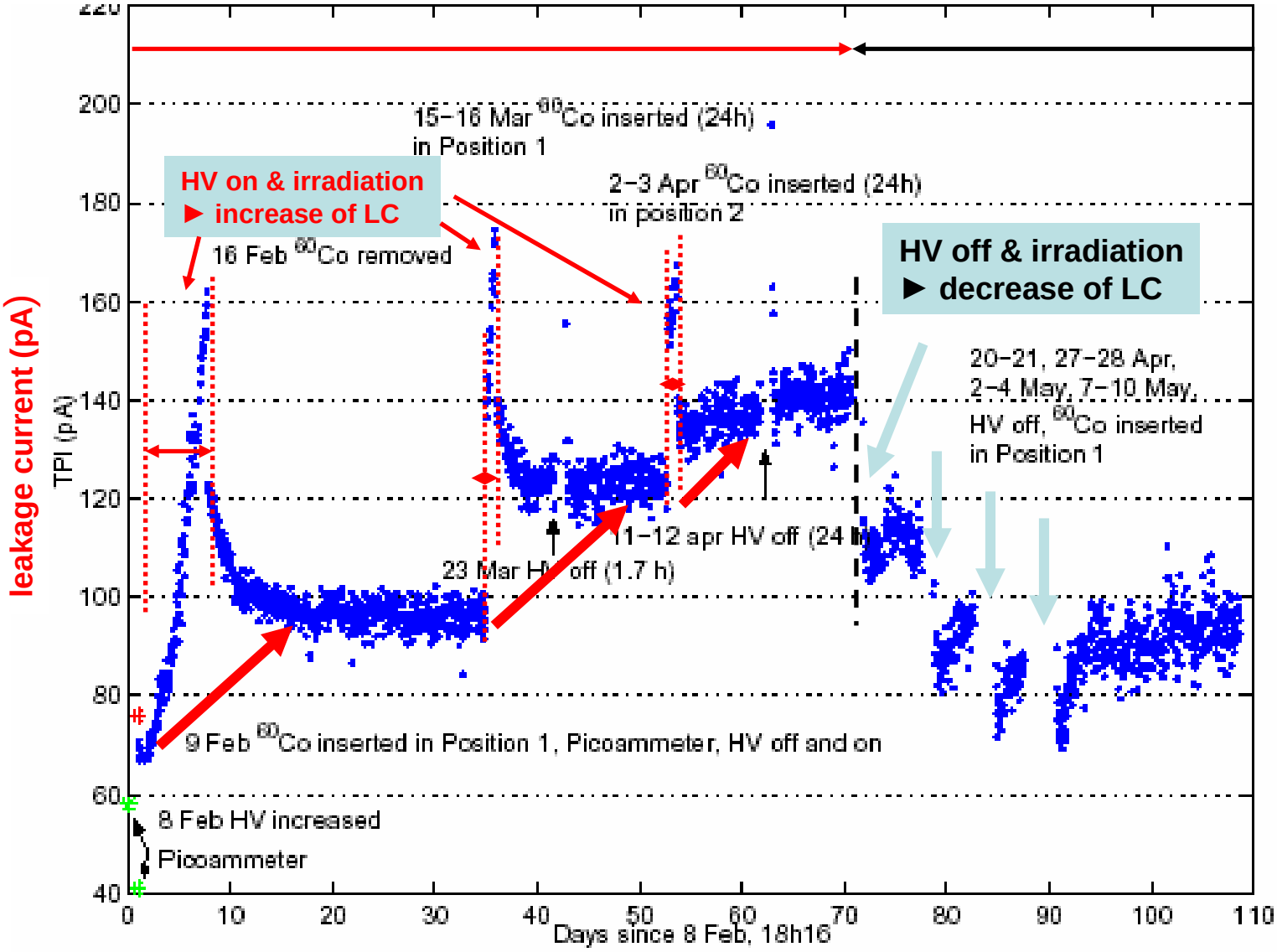
view from below





from Barnabe Heider et al., GSTR-07-005

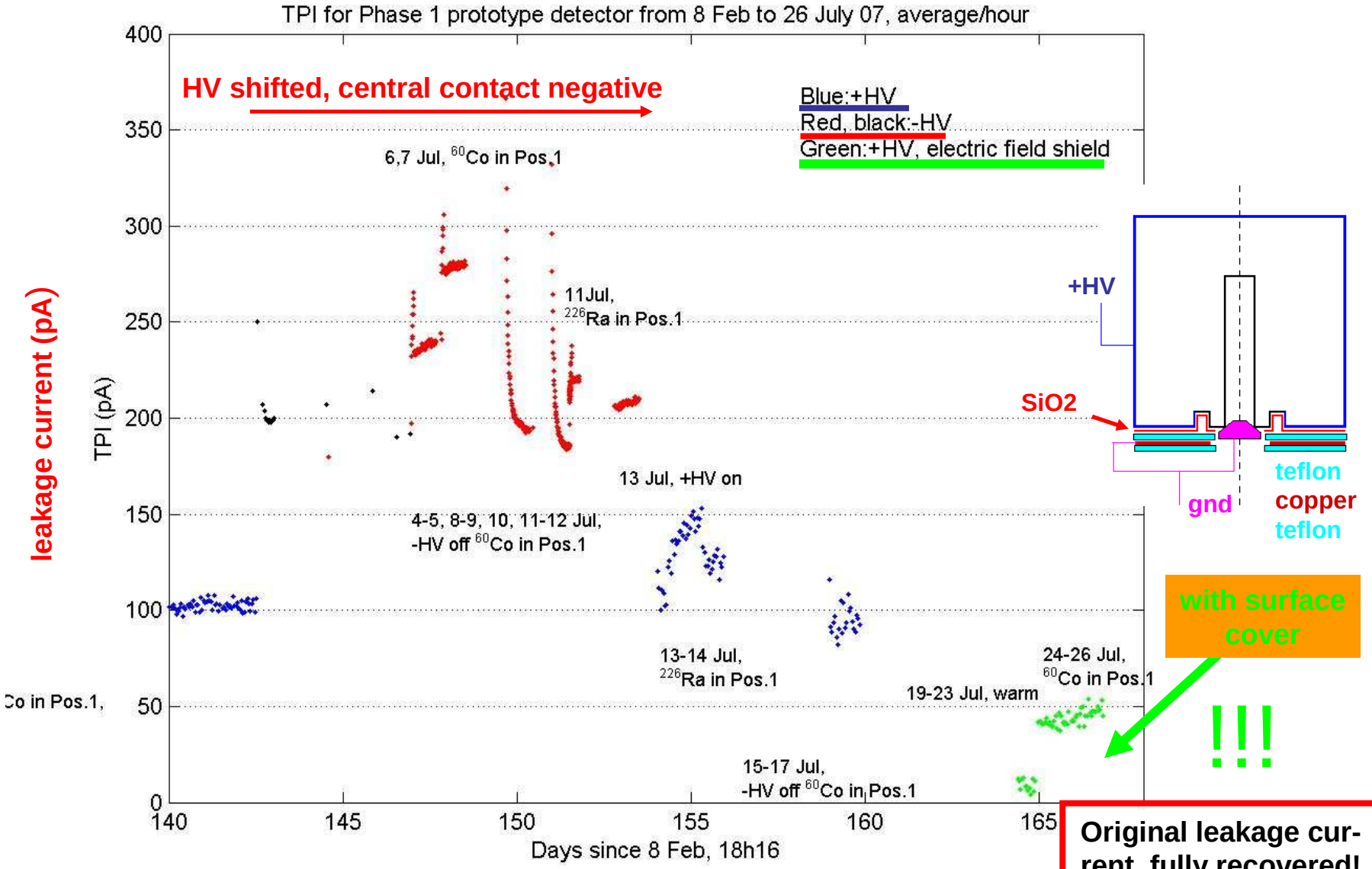
TG01 long term tests in LAr



?

from Barnabe Heider et al., GSTR-07-005

TG01 long term tests in LAr



TG02 design & production of new Ge diodes

- **37.5 kg Ge enriched in Ge-76 to 88% procured**
- **shielded transport & stored underground**
- **optimization of purification in progress**
- **alternatives to commercial Xtal pulling studied**

true-coaxial 3x6 segmented n-type Ge diode

mounting material ~30 g

studies of segmented detectors, pulse shapes, background rejection strategies,… in progress

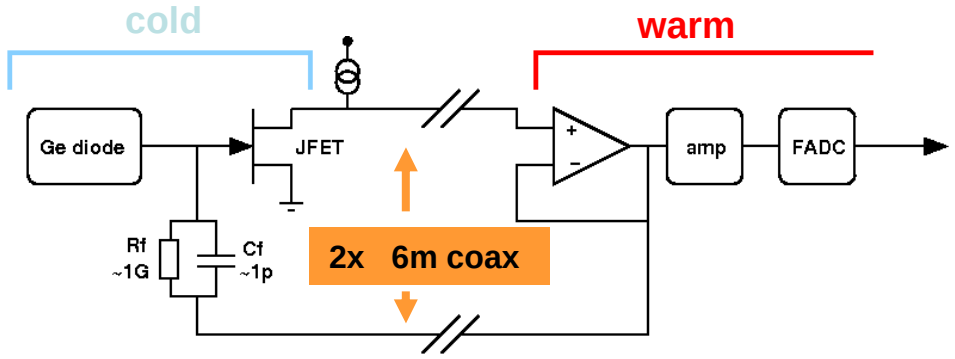
I. Abt *et al.* NIMA **577** (2007) 574
I. Abt *et al.* arXiv:0704.3016 (accepted by EPJC)
I. Abt *et al.* arxiv:nucl-ex/0701005 (sub. to NIMA)
I. Abt *et al.* NIMA **570** (2007) 479

TG03 diode readout & signal processing

phase I : few channels only
discrete approach ok

- **cold FET, warm preamp**
  BF862 + AGATA hybrid
- **cold JFET preamp**
  IPA4 by InterFET
- **cold FET, cold preamp hybrid**
  SK152 + AMPTEK 250

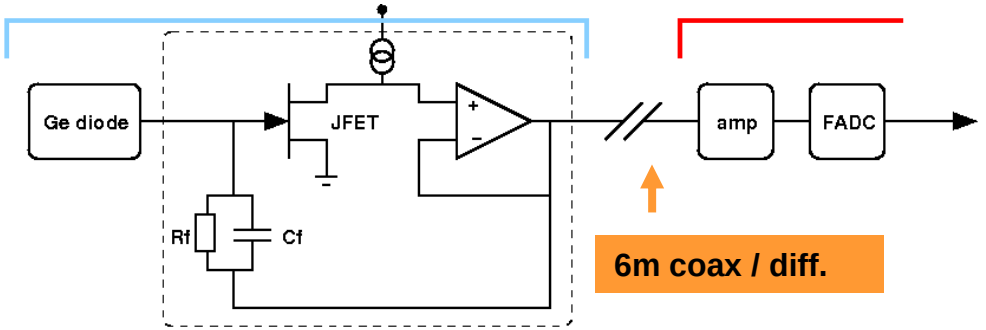
all options: very good test results



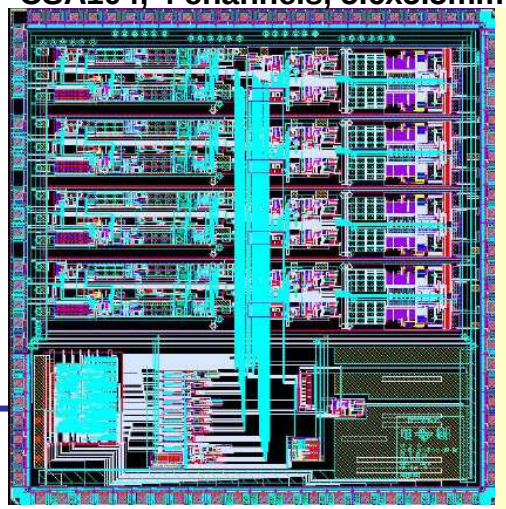
phase II : many segments / channels
integrated preamp
working at 77K

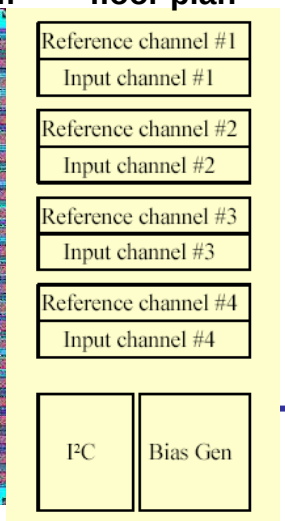
- **ASIC**
  designs/samples by Milano and HD

excellent (M) / fair (HD) test results



CSA104, 4 channels, 5.6x5.5mm² **floor plan**





typ.specs:
ENC 150 e
r.t. 20 ns
gain 150 mV/MeV
d.r. 2000
output diff (100Ω), [coax]

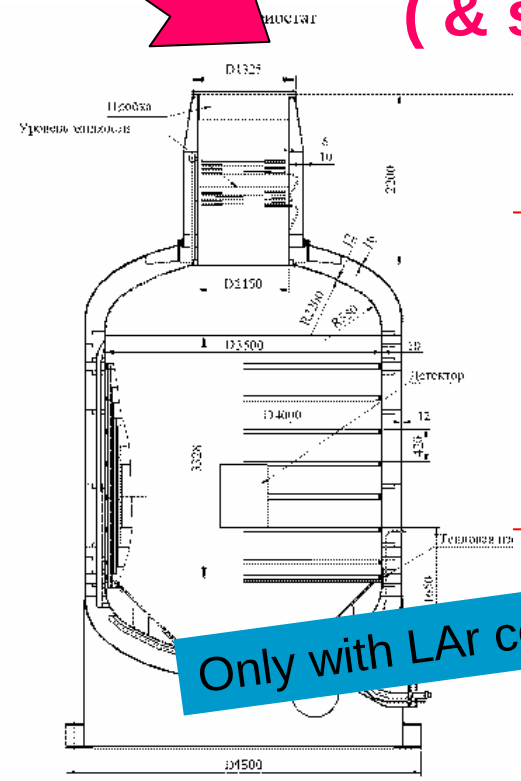
in progress:
test of complete
readout chain

baseline design: **copper cryostat** for LN2 / LAr with superinsulation and 3rd wall requested by LNGS

best from physics point

29 May 2006

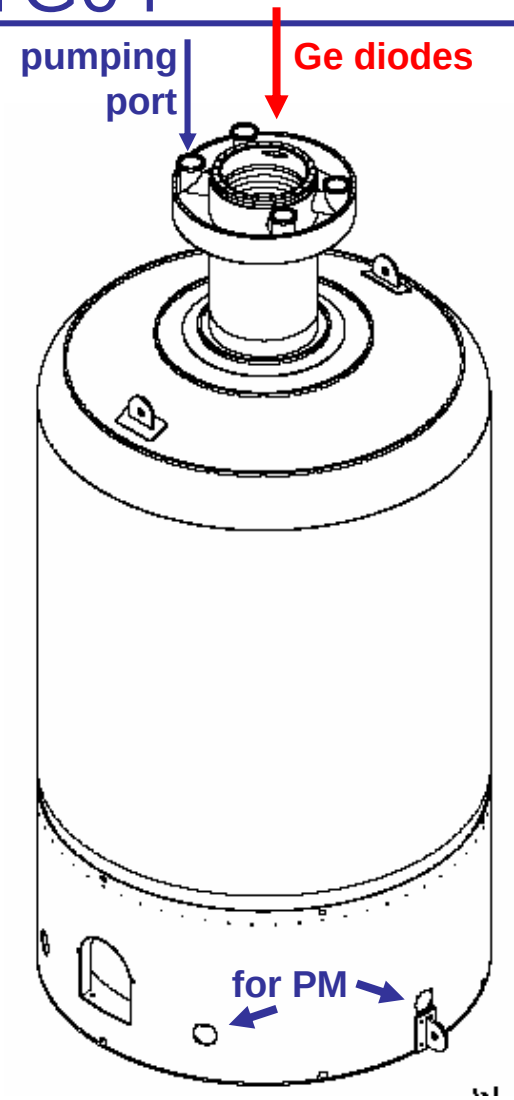
cost !
(& safety concerns)



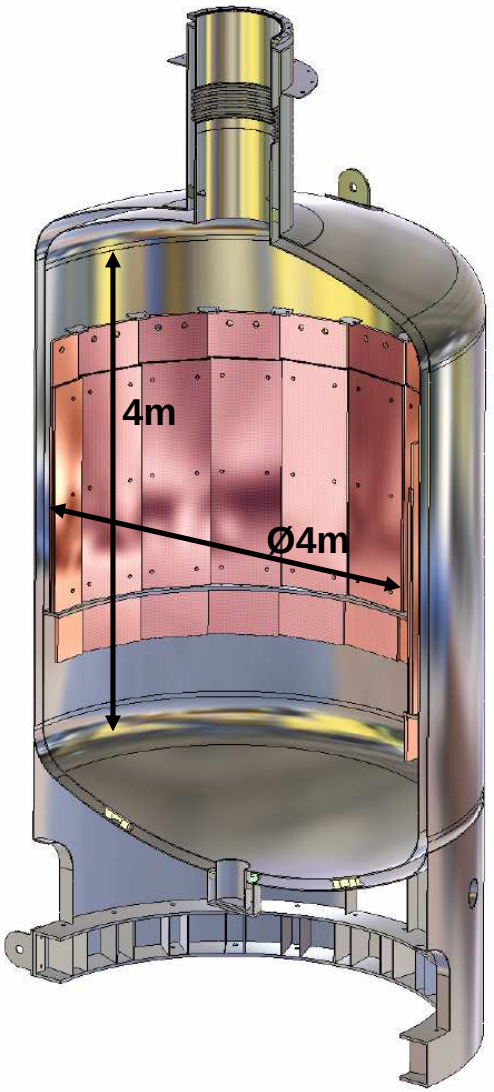
backup design:
stainless steel cryostat with superinsulation & internal Pb/Cu shield – no 3rd wall !

Only with LAr cost effective

TG04 cryostat



overall height	8.9 m
inner vessel height	4.0 m
inner diameter	4.0 m
volume	70 m3
op. weight	175 tons
all. o_pressure	-1/1.5 bar
op. o_pressure	0.2 bar
superinsulated	
material	1.4571
constr. code	AD2000 97/23/EG
e.quake tolerance	0.7g
no penetrations except neck	



OFRP Cu shield	16 tons
thickness	3 or 6 cm

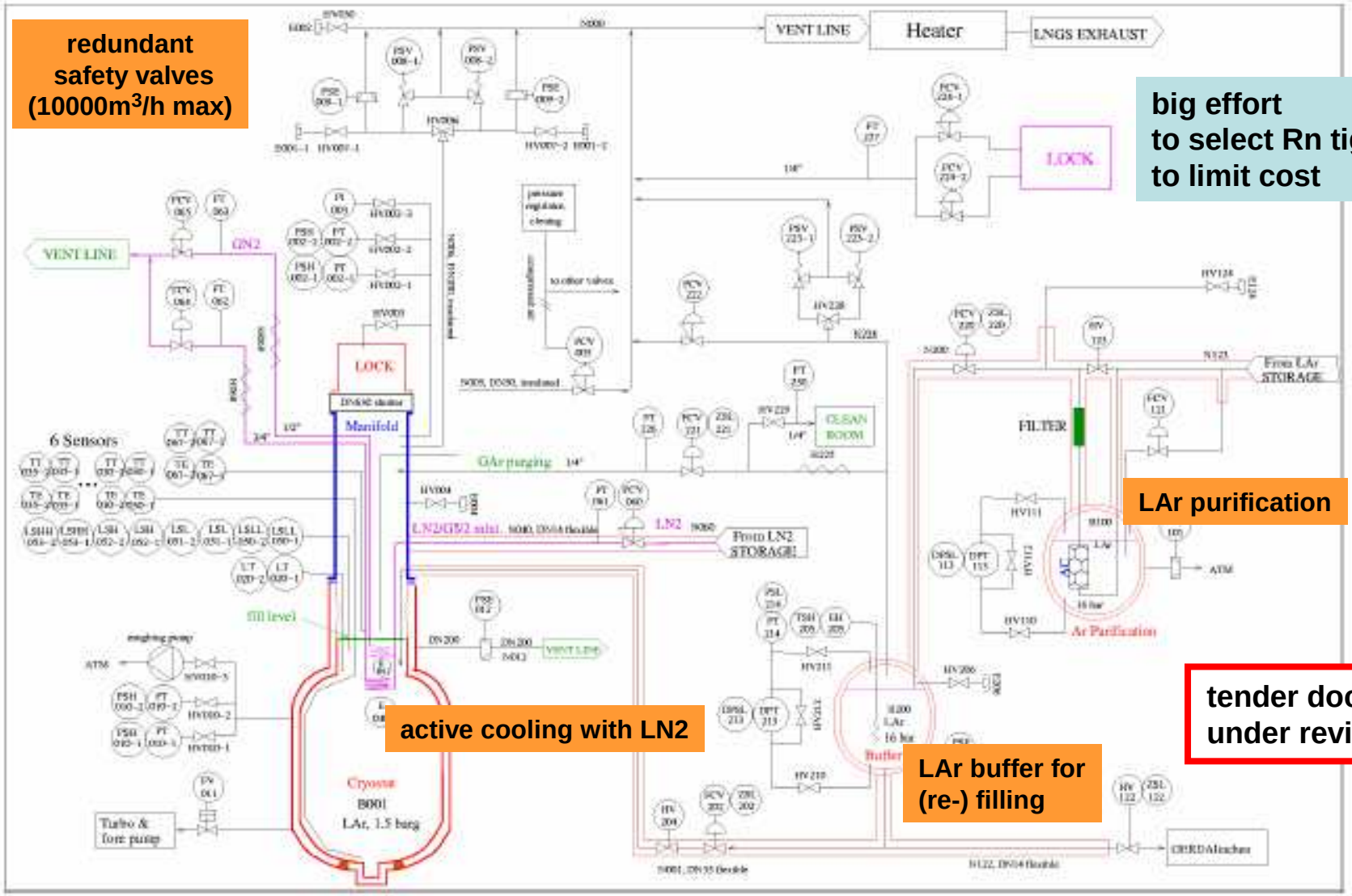
TG04 cryostat


2007 Mar 29 at SIMIC

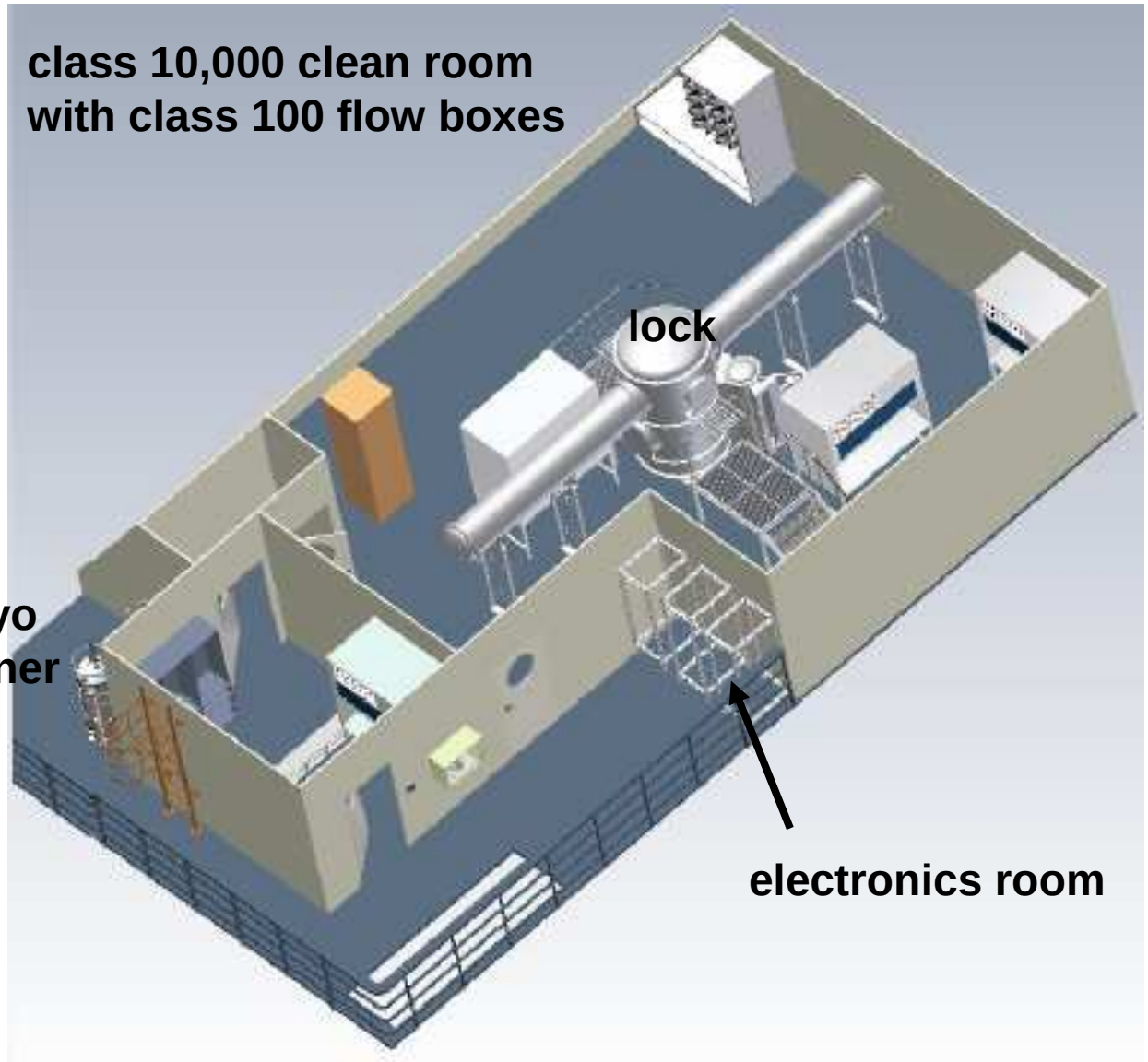
Dec 06	cryostat ordered at SIMIC
Mar 07	3 of 4 vesselheads delivered (delayed)
Jun 07	4th vesselhead repaired
Jul 07	certification for automatic welding failed (notch impact <30J at 77K)
Jan 08	delivery ?


2007 Jun 07 at Antonius

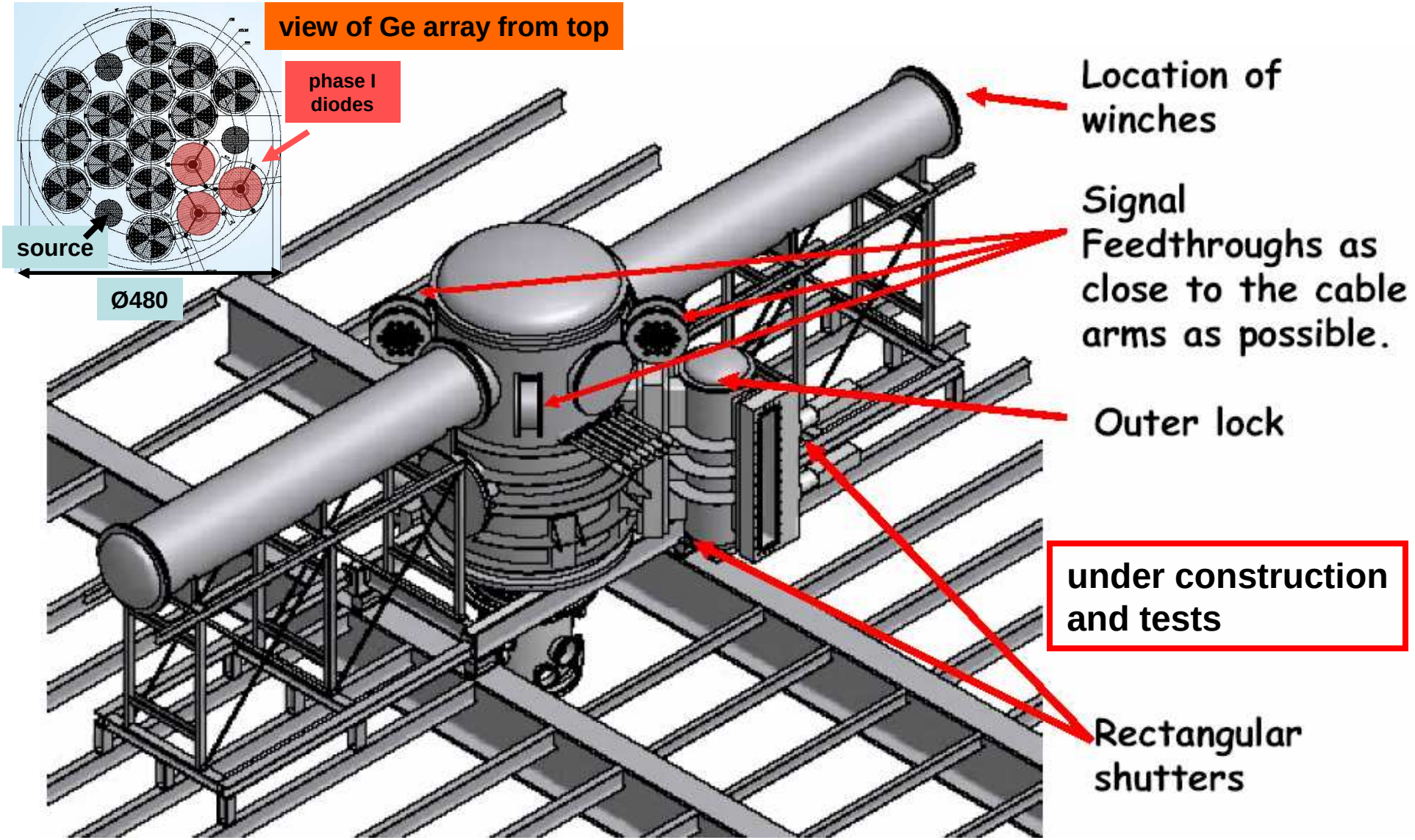
TG04 cryogenics PID



TG05 cleanroom & lock



tender document prepared


view of Ge array from top
phase I diodes
source
Ø480
Location of winches
Signal Feedthroughs as close to the cable arms as possible.
Outer lock
under construction and tests
Rectangular shutters

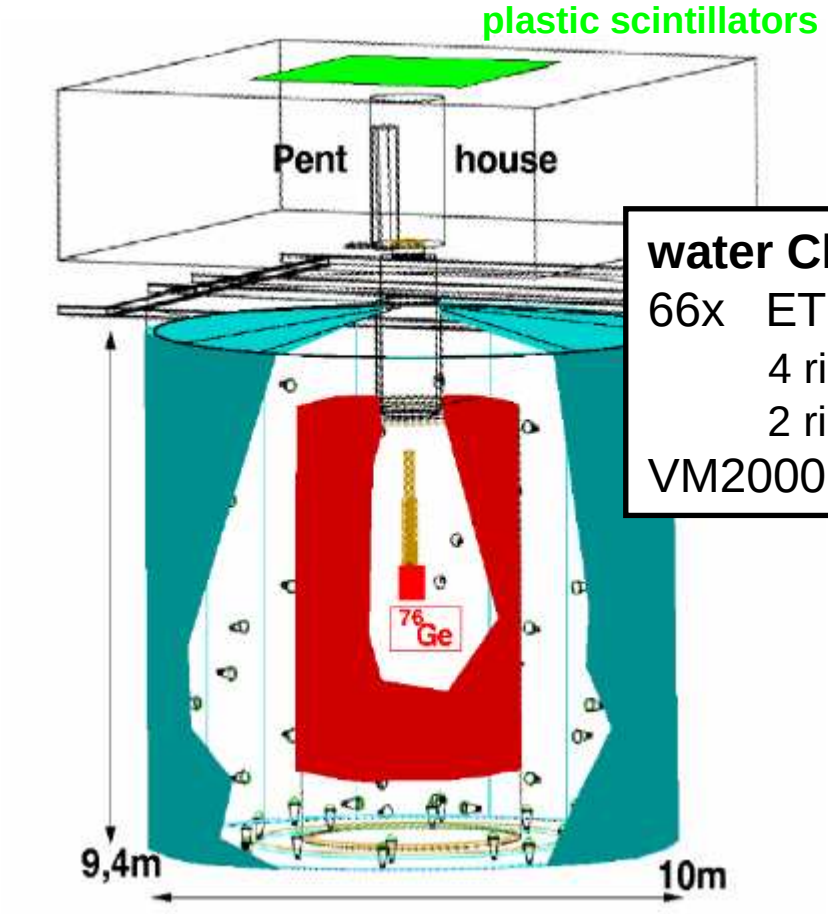
TG06 water vessel

Ready for cryostat installation on bottom plate of water tank (hall A in front of LVD).

diameter	10 m
height	~9 m
nom. volume	~650 m³
water quality	de-ionized Rn stripped

designed,
ordered,
bottom plate installed

fabrication to be continued after cryostat delivery

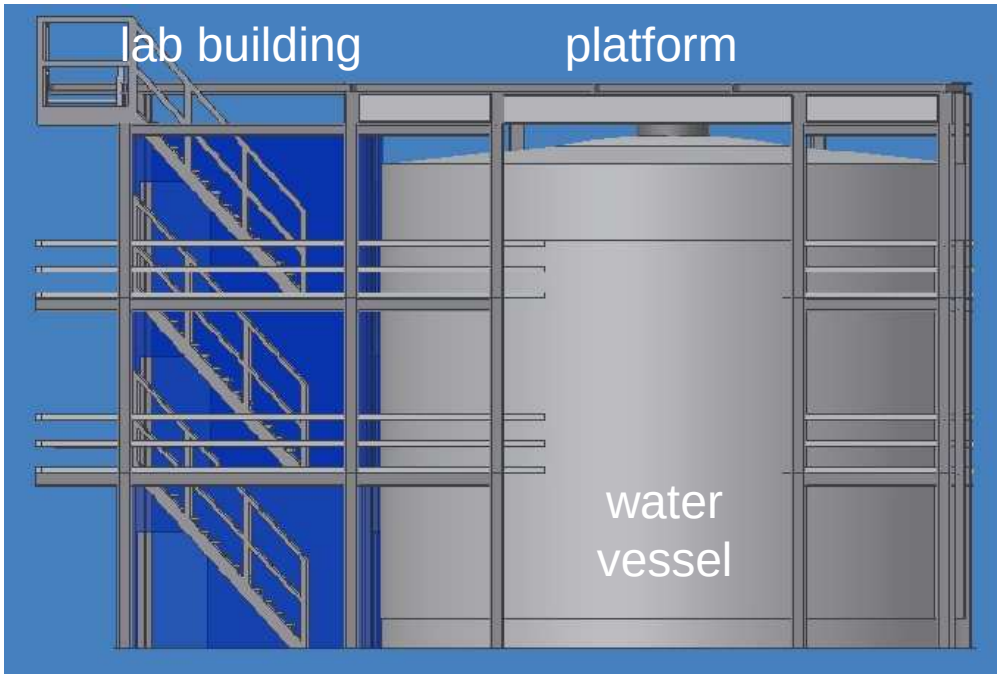


water Cherenkov
66x ETL 8” PMs
4 rings on walls
2 rings at bottom
VM2000 : WLS & reflector

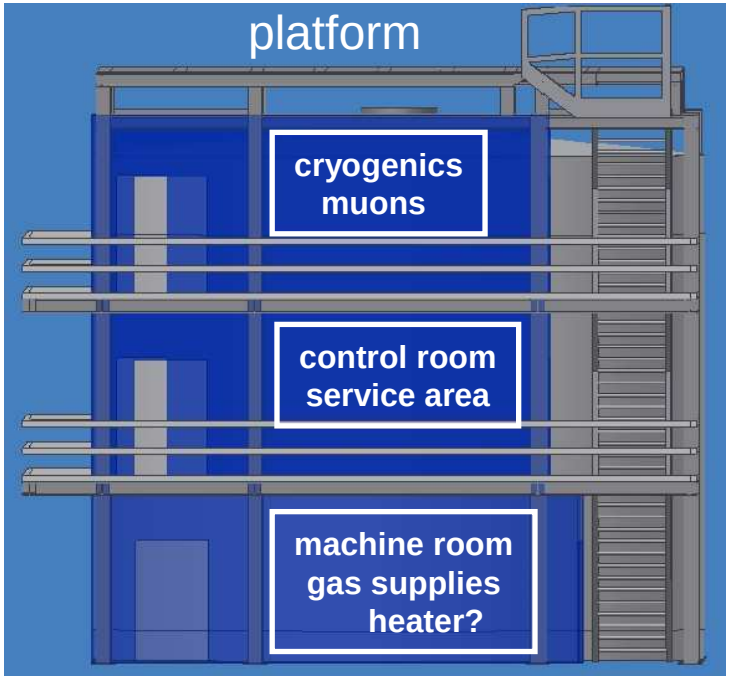
ETL 8” PM inside capsule with oil long term test in water

prototype tests successful,
production along schedule

sideview

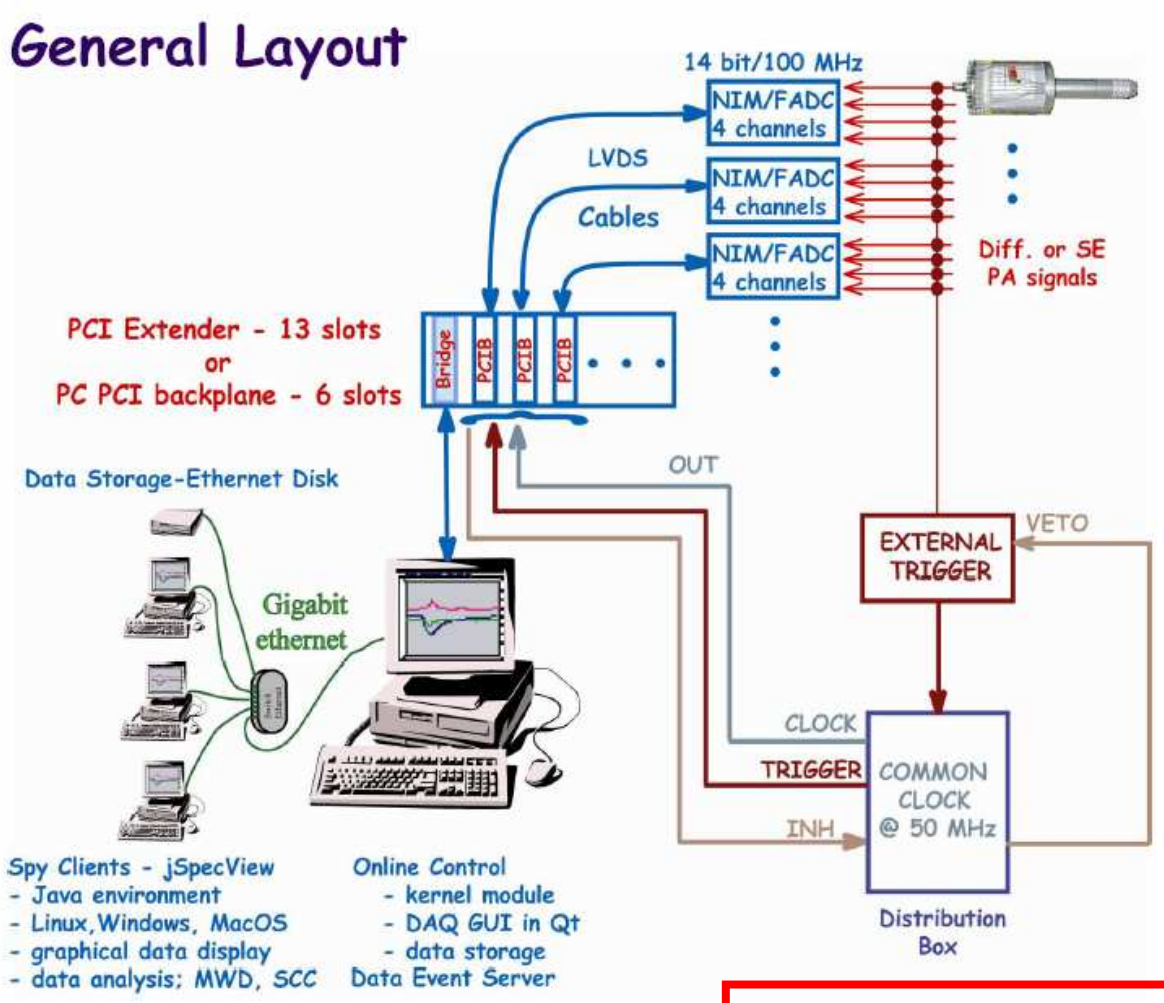


view from back (LVD)



space for LN2 & LAr storage tanks allocated

lab building & platform tendered
equipment not completely funded



feature	MD2S Padova
Channels	4
FADC bits	14 (13)
FADC rate (MHz)	100
FPGA k-gates/ch	100
Internal trigger	no
Trace length (samples)	max 2048
Control & i/f	NIM/PCI
Data xfr	PCI
Max output rate (MB/s)	6

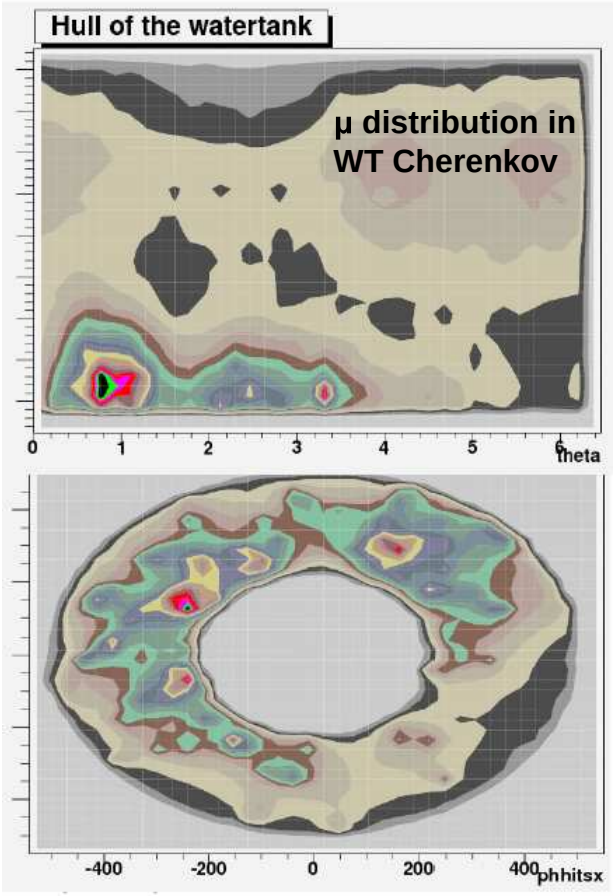
PCI-NIM DAQ system operational (20 ch , phase I)
dto software, “ jSpecView “ for analysis & monitoring

TG10 simulations & background studies

MaGe : common Monte Carlo framework with Majorana collaboration

Muon-induced isotope production

	Nitrogen		Argon	
	nuclei/(kg y)	counts/(kg keV y)	nuclei/(kg y)	counts/(kg keV y)
Isotopes produced in crystals				
^{74}Ga/^{75}Ga/^{76}Ga	<0.08	$<3\times10^{-5}$	<0.1	$<4\times10^{-5}$
^{68}Ge	0.07±0.03	$(4\pm2)\times10^{-6}$	0.08±0.03	$(5\pm2)\times10^{-6}$
^{69}Ge	0.38±0.08	$(1.0\pm0.2)\times10^{-6}$	1.8±0.2	$(5.0\pm0.6)\times10^{-6}$
^{77}Ge/^{77m}Ge	0.05±0.03	$(1.0\pm0.6)\times10^{-5}$	0.51±0.09	$(1.1\pm0.2)\times10^{-4}$
Isotopes produced in cryogenic liquid				
^{38}Cl	–	–	46 ± 1 nucl/day	$(3.3\pm0.1)\times10^{-5}$
^{40}Cl	–	–	2.7 ± 0.1 nucl/day	$(4.0\pm0.2)\times10^{-6}$



detector	5
holder (copper)	4
holder (Teflon)	8
cabling	6
electronics	3
infrastructure	4
muons, neutrons	2
sum	32

example of
phase II background index
for available materials
in 10^{-4} cts / (keV · kg · y)

to be improved!

see e.g. Pandola et al. , NIM A570 (2007) 479

TG11 material screening / purification

Ge γ spectrometers

- Baksan 600 m w.e. (soon → 4900 m w.e.) 4-fold spectrometer
- Hades 500 m w.e. Ge-2 – Ge-9
- MPI-K 15 m w.e. 3 diodes
- LNGS 3500 m w.e. GeMPI 1,2,(3) S : ~ *O*(10[100]) µBq/kg for heavy [light] samples

Rn-222 diagnostics / monitoring

- emanation technique S : 0.5 µBq / m^2 , 10 µBq / kg
- gas purity analysis
- electrostatic chamber : 0.1 – 1 mBq / m^3

α spectrometer

- Baksan (ionization chamber) S : 10 Bq/m^3 (quick), background: 0.002 / (cm^2·h)
- Krakow

ICPMS **(inductively coupled plasma mass spectrometry)**

- Frankfurt U S : U/Th ~ 1 µBq / kg > secular equilibrium? <
- LNGS & commercial

(measured materials: Kapton, Teflon, Torlon, MLI, PMT glass, Cu, steel, Cu/P granulate)

►Challenge: screening of plastic materials at required Th sensitivity

Surface purification studies **(cryostat > 100 m^2)**

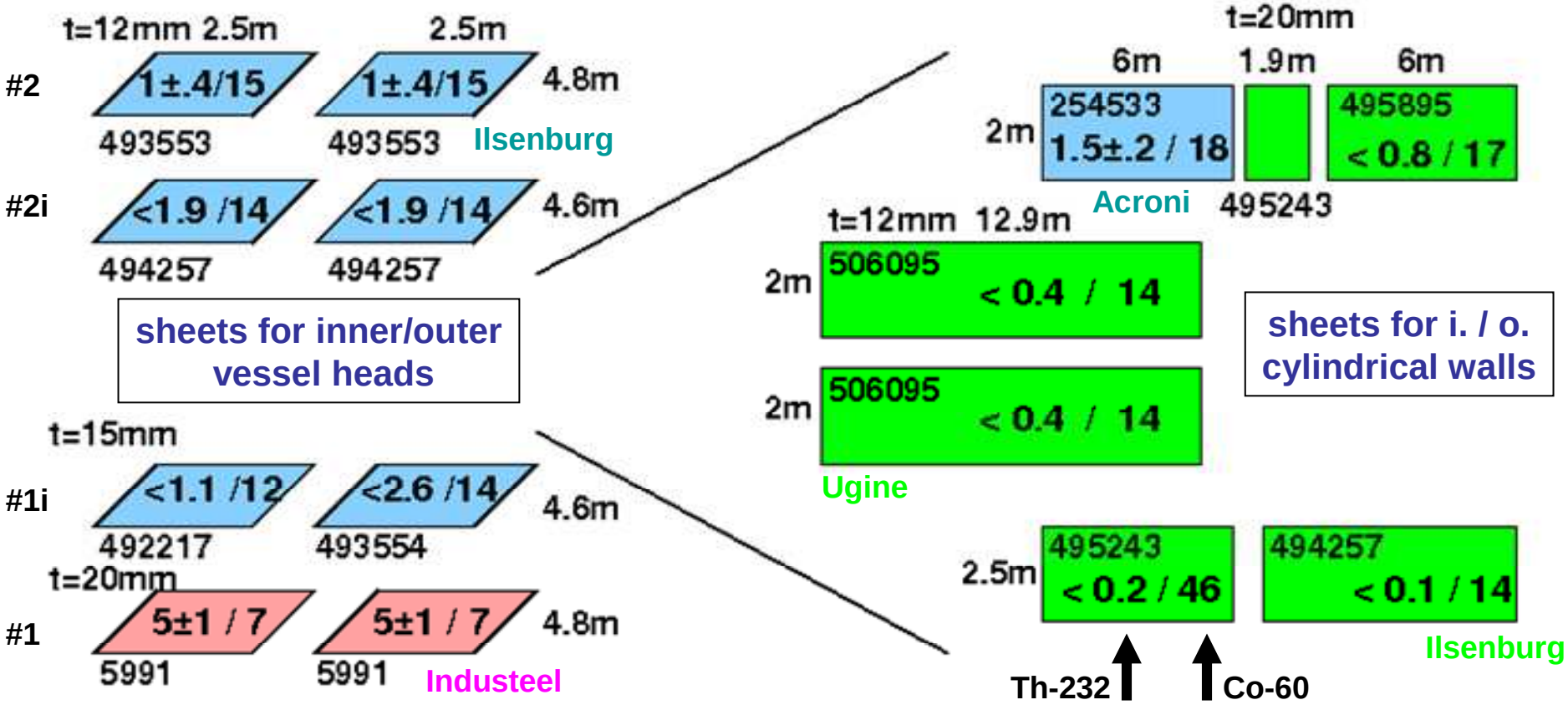
- Cu disks radiated with strong Rn source S : 1 µBq / m^2

TG11 screening of cryostat's ss sheets

results from γ spectroscopy at LNGS and MPI HD

(more data available)

units: mBq / kg



unexpected low Th-232 activity, typ. <1 mBq/kg ► less massive Cu shield needed

TG11 radiopurity of cryostat materials

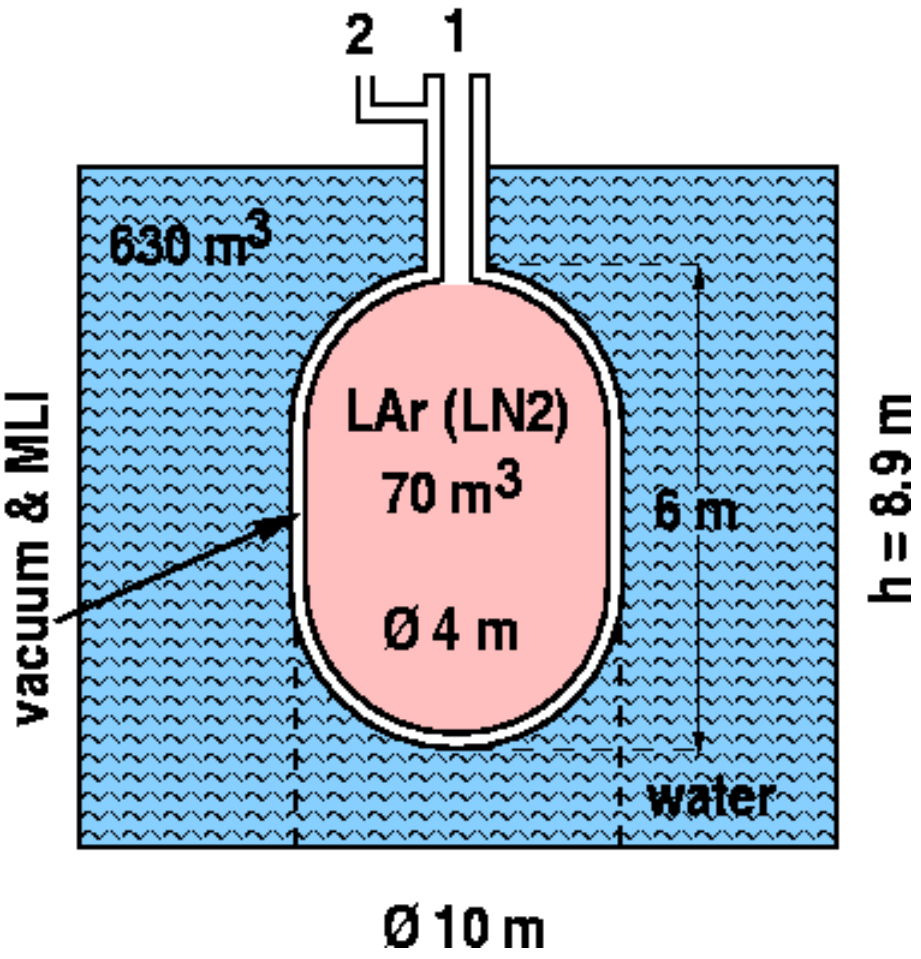
	Material	K-40	Th-228	Ra-226	Ra-228	method
super insulation	alum. Teflon	<16	<6	<4	<8	γ
	NAC-2	81±20	5±3	23±3		γ
	Coolcat 2 NW	150±30	2.3±0.6	1±0.5	2±0.5	γ
	Jehier →	1940±150	<52	231±27	<97	γ
	Makrolon					
	Torlon	<1	<41	<37		NAA

preliminary

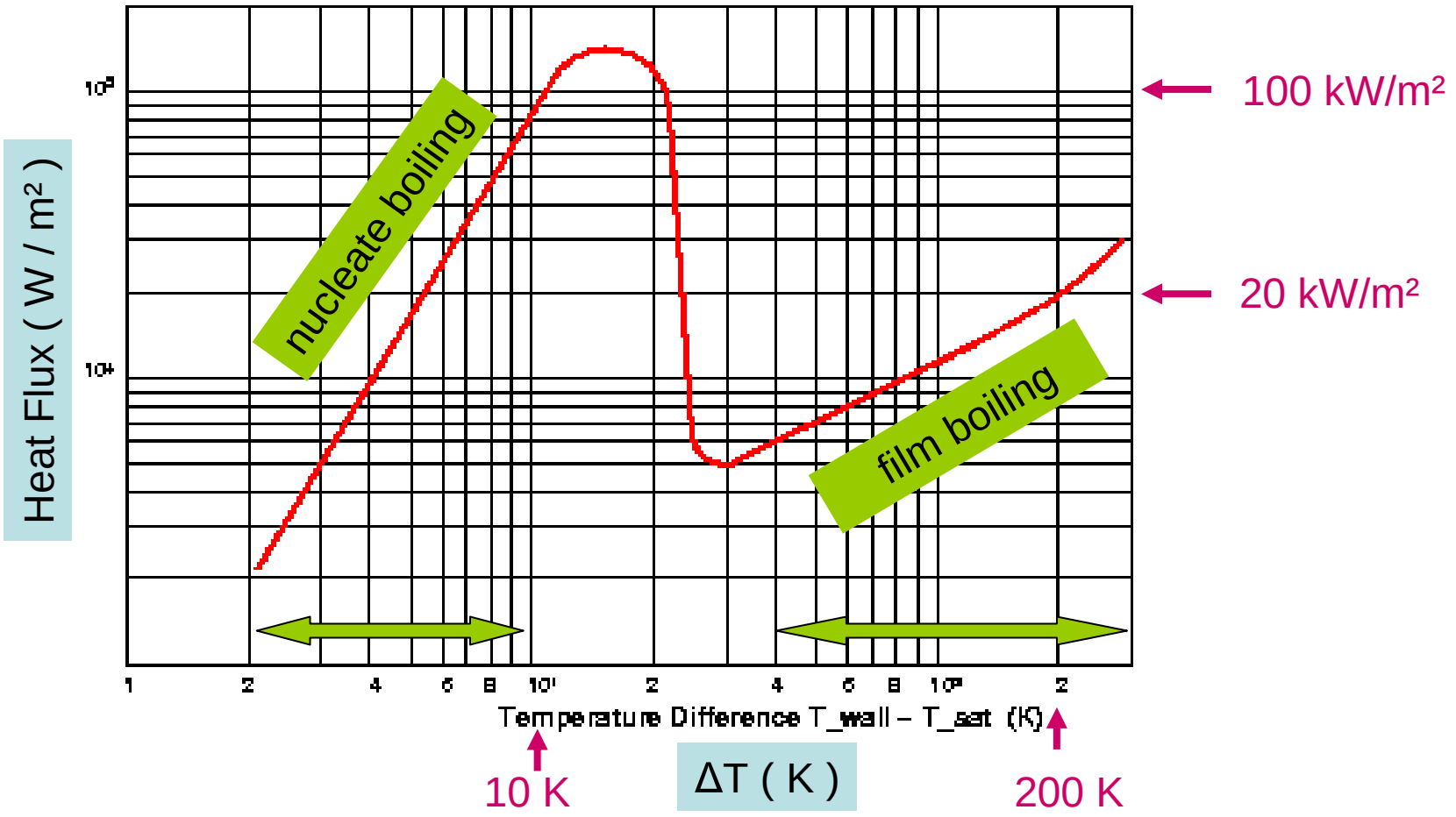
units: mBq / kg

results from γ spectroscopy at MPI HD
(data for more isotopes available)

Safety



LN2 pool boiling heat transfer characteristics



corresponding diagram for LAr not available

Safety

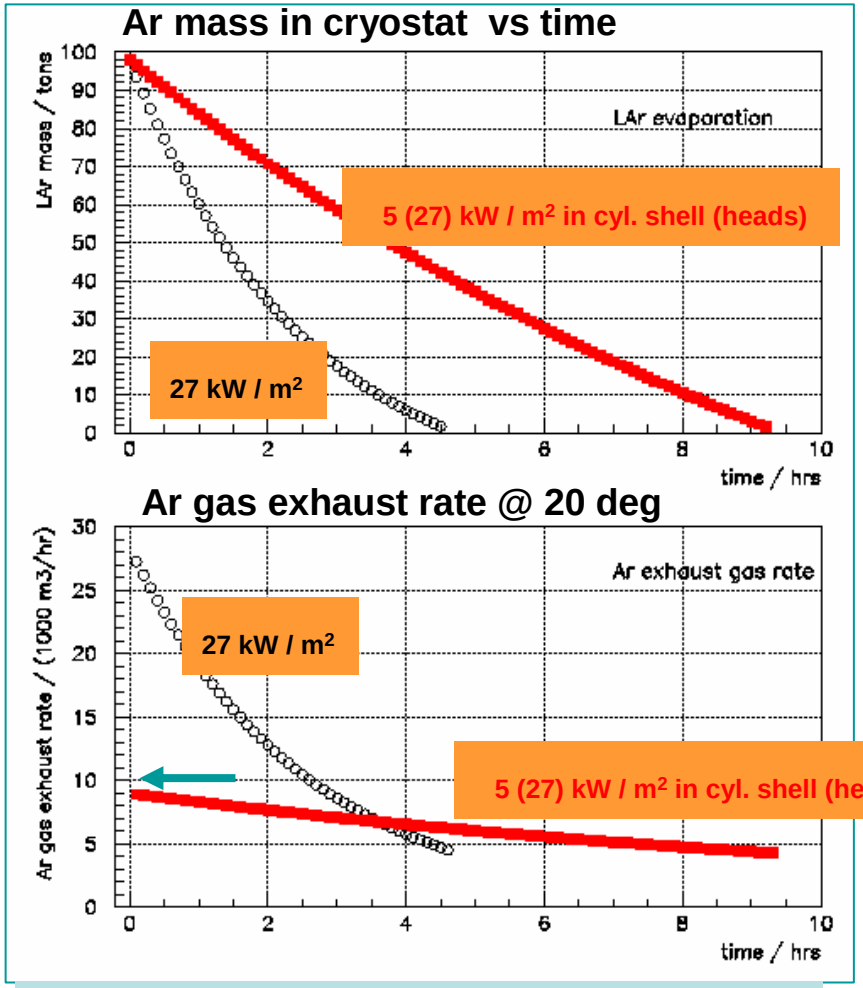
GERDA risc matrix

Consequecy / Event /year	No relevant effects	Minor effects	Serious effects	Major Effects	Mortal (N°1 lethality)	Mortal (N° 2÷10 lethalities)
$1 \div 10^{-1}$	A	T	I	I	I	I
$10^{-1} \div 3^{*} 0^{-2}$	A Event 1		T			
$3^{*}10^{-2} \div 3^{*} 10^{-3}$	A Event 1* - Event 2	A Event 5	T	T	I	I
$3^{*} 10^{-3} \div 10^{-3}$	A	A	A	T	I	I
$10^{-3} \div 3^{*}10^{-4}$					I*	I*
$3^{*}10^{-4} \div 10^{-4}$	A Evento 8	A	A	A	T	T
$10^{-4} \div 10^{-5}$	A Evento 9			A Evento 3 - Evento 6		
$10^{-5} \div 10^{-6}$	A	A	A Evento 10	A	T	T
$10^{-6} \div 10^{-8}$	A	A	A Evento 11	A	A	A
$< 10^{-8}$	A	A	A	A	A	A Top 1 - Evento 7 Evento 3* - Evento 6*

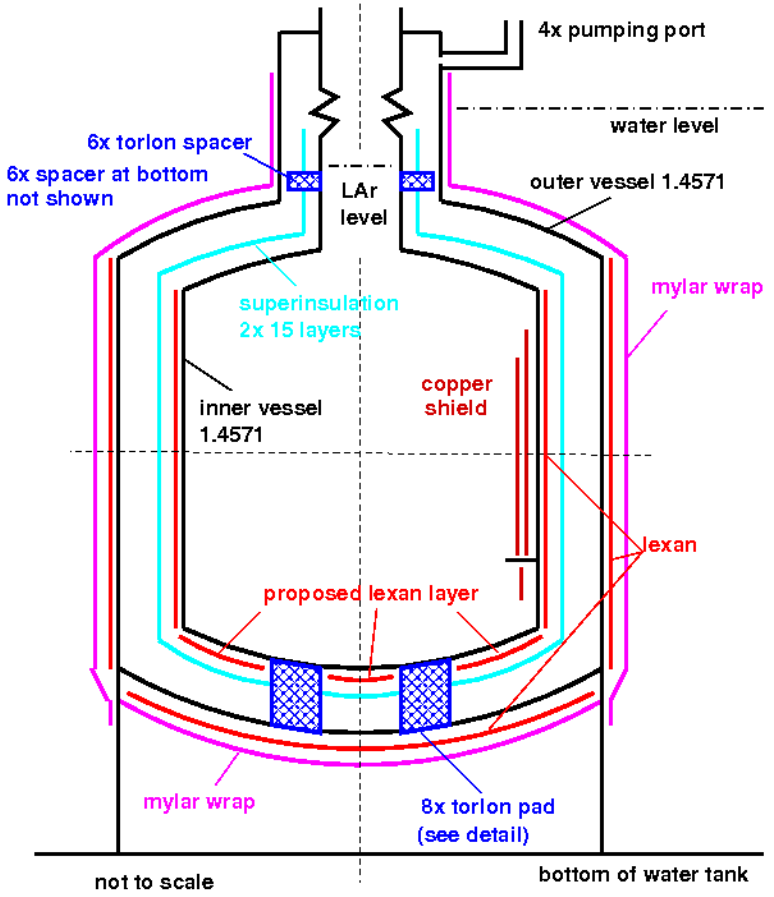
Top1: overpressure beyond design, failure of protection
#7: simultaneous cracks in both cryostat walls
#3*/6*: medium (1”) to large size cracks in outer / inner wall
#3 / 6 : micro cracks in outer / inner wall

 # 10, 8, 9 : water release in hall A
 # 11 : break of venting pipe
 # 5, 2, 1 : loss of insulation vacuum

Safety how to limit evaporation rate



Calculated evaporation of Ar for the case that one wall of cryostat is completely lost.



shields and barriers to be implemented:
- **inner vessel - cylindrical shell: Makrolon 6mm**
- **outer vessel – total area: styrofoam, Makrolon 2x 3mm, mylar wrap**

Schedule

Schedule

Jun 07: GERDA experimental setup officially approved by LNGS

Status of various components:

		on-site install. & test / mo
hall A	ready for installation	
cryostat	delivery early 2008?!	2
cryogenic infrastructure	tender in preparation	
water tank	bottom plate installed	2
platform & lab building	tender done	2
clean room	tender in preparation	} 8
lock	under construction, tests	
muon veto	well on track	
detectors	refurbishment almost done tests in LAr ongoing	
electronics	front end available tests of readout chain in preparation	

14 months after cryostat delivery

At present, schedule driven by delivery of cryostat – delayed by half a year.

The End