Cryogenic Tank Options for a New 0νββ Experiment in Hall A of LNGS

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New Ge-76 0νββ Experiment (1)

- Goal

Reduce external background at $Q_{\beta\beta}$ by 2-3 orders compared to Heidelberg-Moscow experiment :

➡ 10^{-3} to 10^{-4} cts / kg keV y

- Idea (G.Heusser, Ann.Rev.Nucl.Part.Sci. 45(1995) 543)

Operate bare Ge crystals in pure liquid nitrogen (LN) ! Choose LN volume such that external background (10 Bq / kg Th-228: 2.6 MeV γ-rays) is reduced to desired level !

- Needed

➡ 10^{-3} cts / kg keV y : Ø(LN) = 11.5 m

10^{-4} cts / kg keV y : Ø(LN) = 13 m

New Ge-76 0νββ Experiment (2)

- Constraints

  available space
  in hall A of LNGS
  Ø=12m, H=11m

- Solution

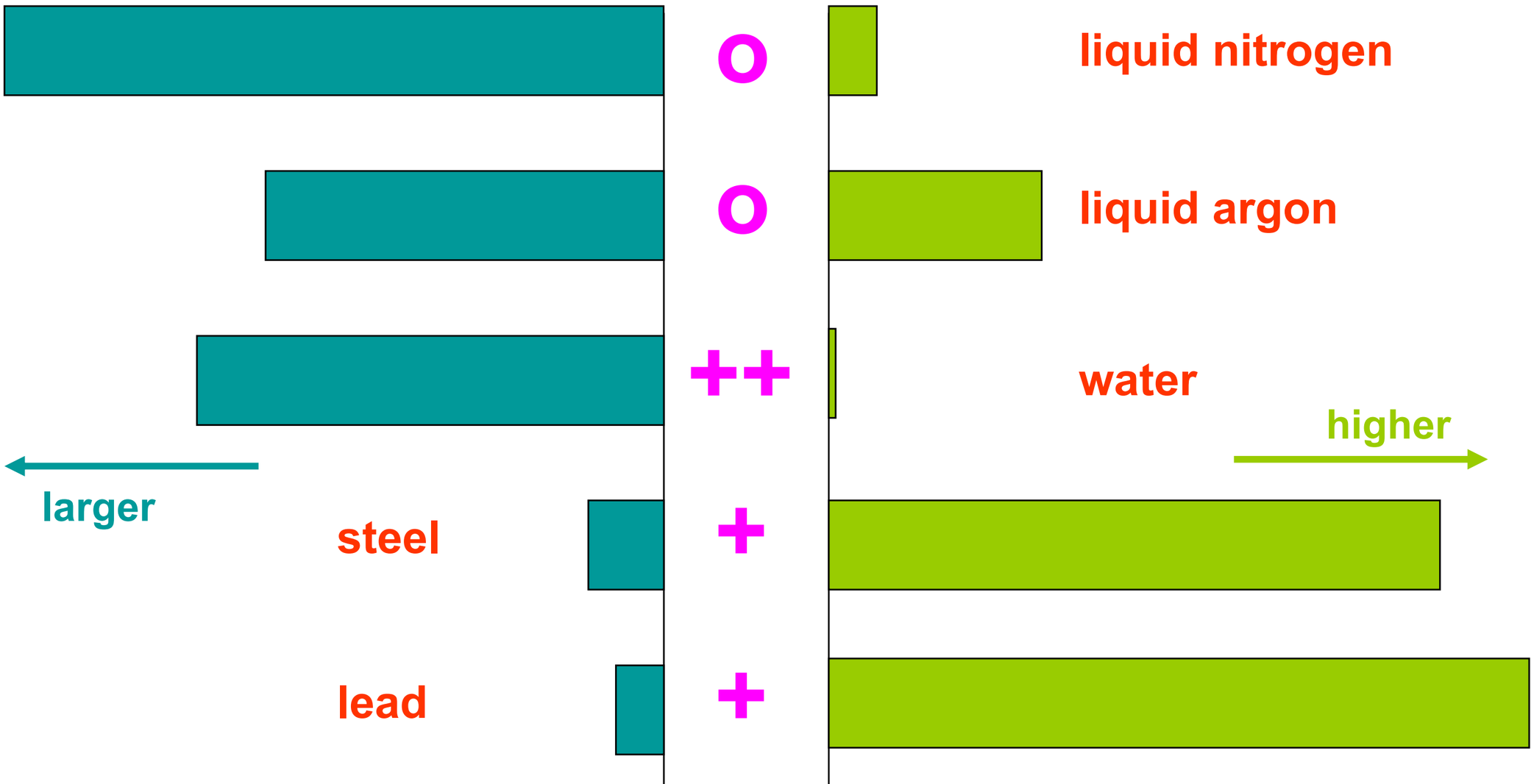
  combine
  conventional Pb/
  water and LN
  (LAr) shields

hall A of LNGS

Optimize !

size safety cost

equivalent shielding thickness **cost per eq. shielding thickness**



Options

odd #: 10^{-4} cts/..
even #: 10^{-3} cts/..

- Additional constraints

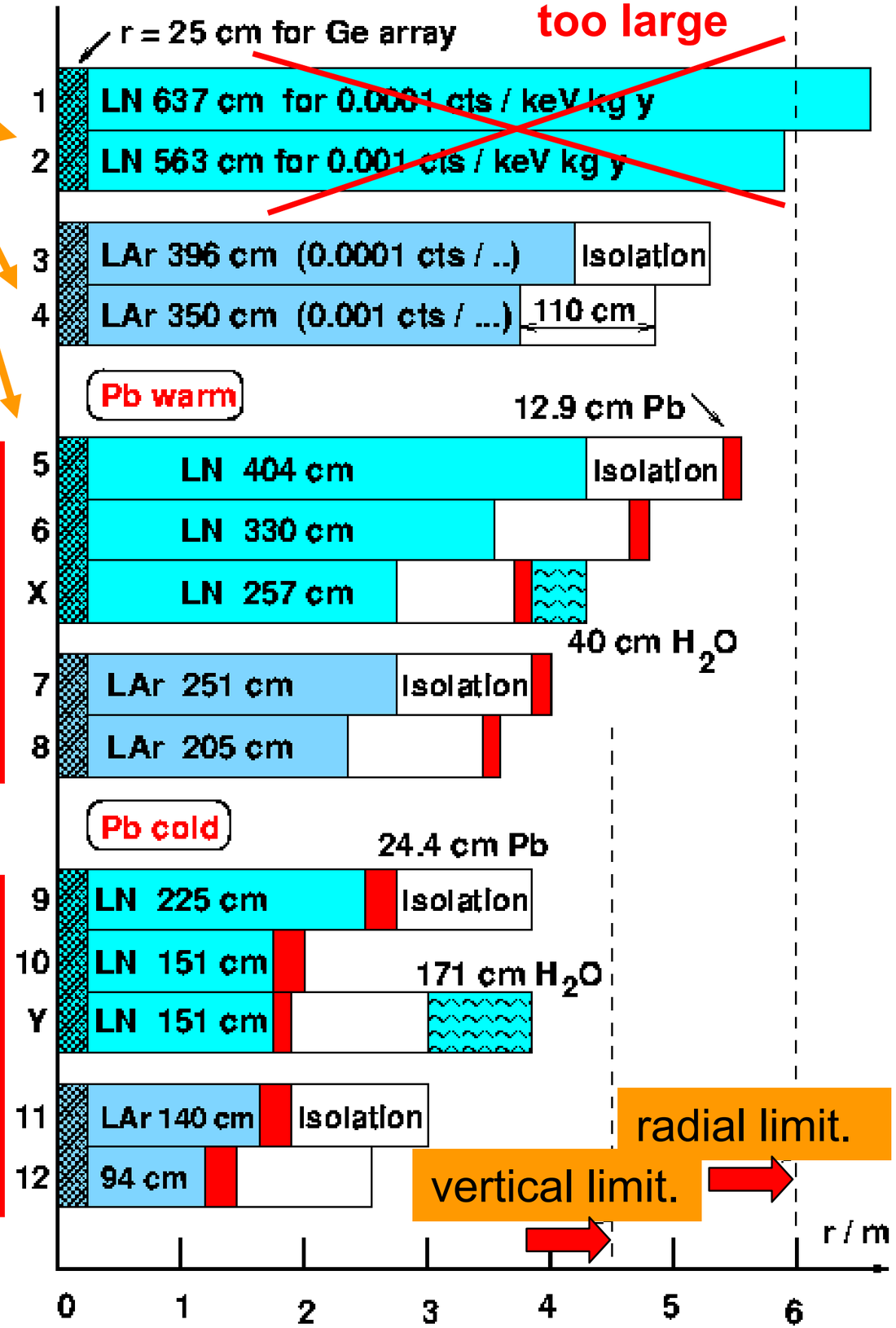
radiopurity of materials prevents free mix of building materials

options 5 - 8

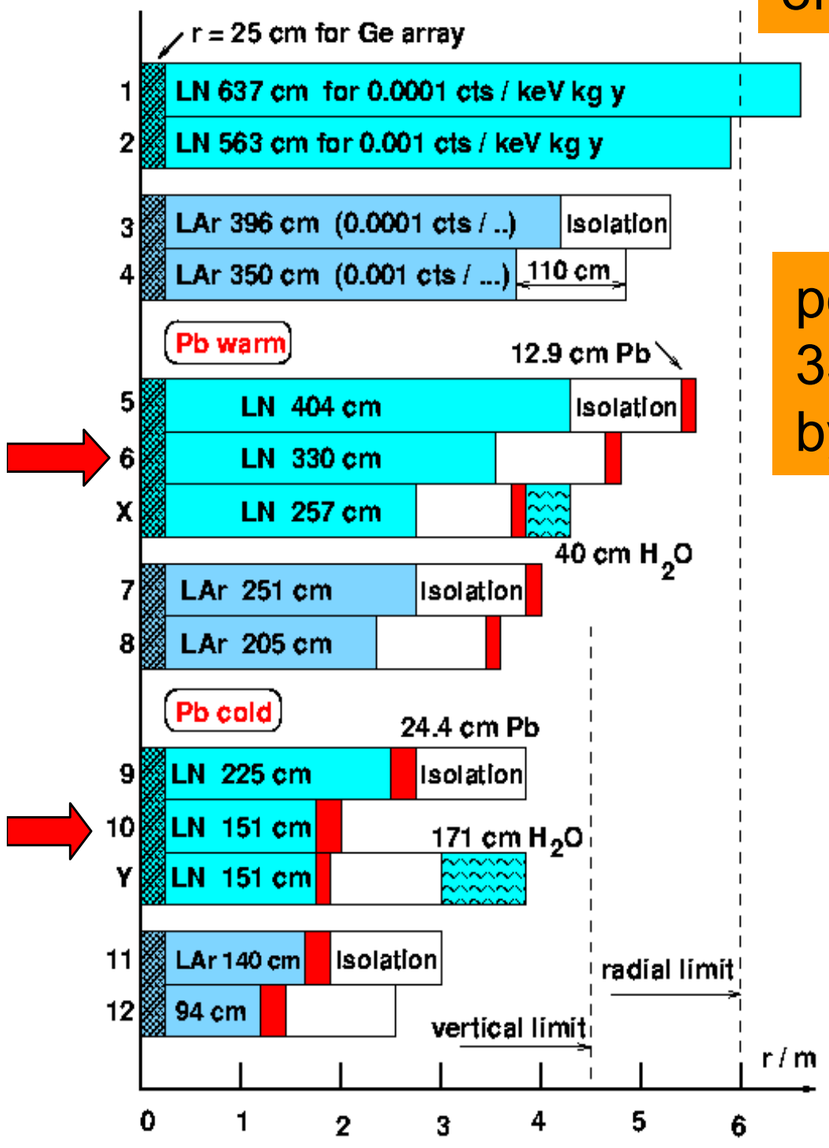
5&6 / 7&8: LN / LAr thickness such to shield steel and isolation of 7 mBq/kg

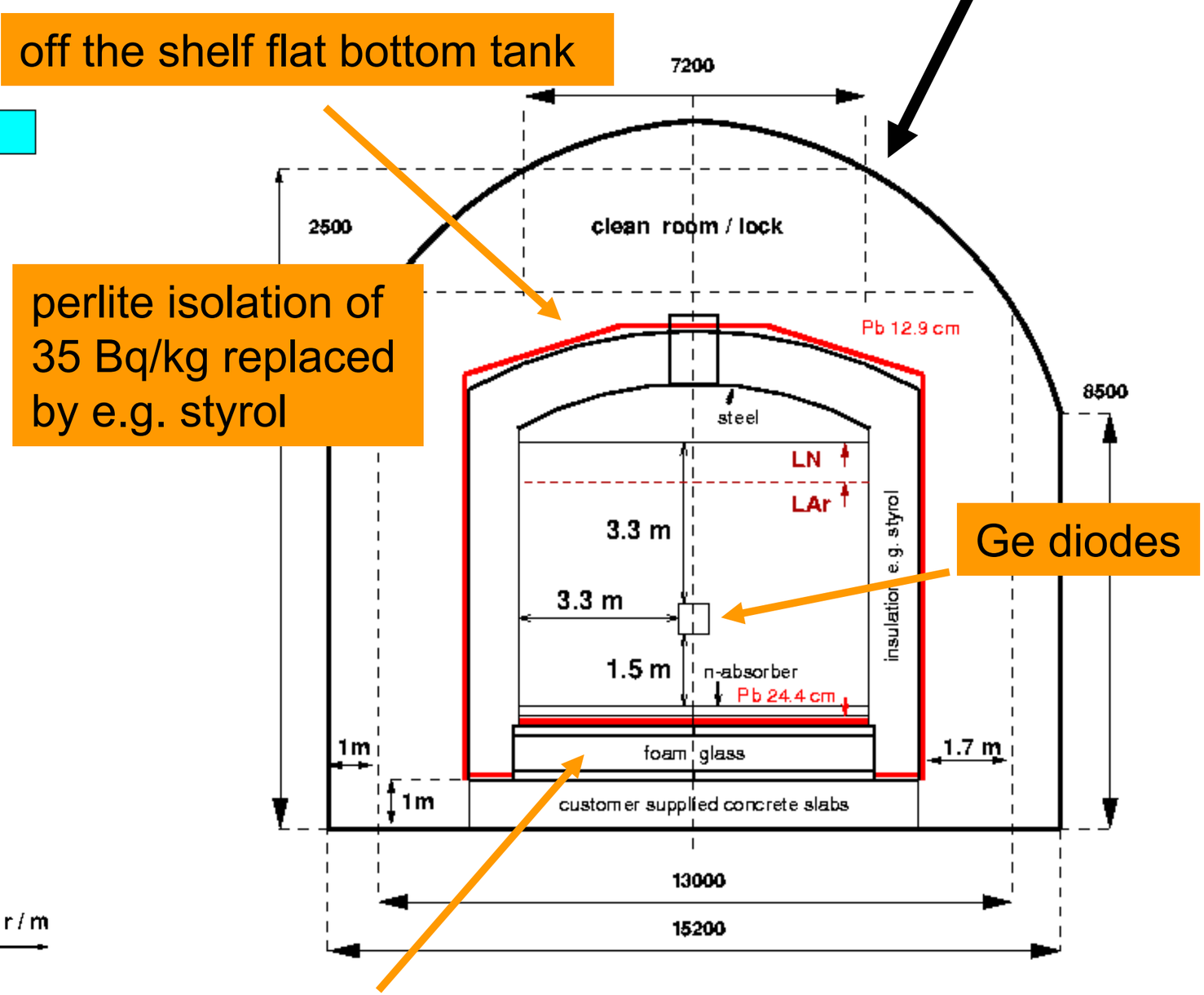
options 9 - 12

9&10/11&12: LN / LAr thickness such to shield lead of 30 µBq/kg



Option 6 / 10





→ option 10 + neutron absorber in cold volume

Options

odd #: 10^{-4} cts/..
even #: 10^{-3} cts/..

- Additional constraints

radiopurity of materials prevents free mix of building materials

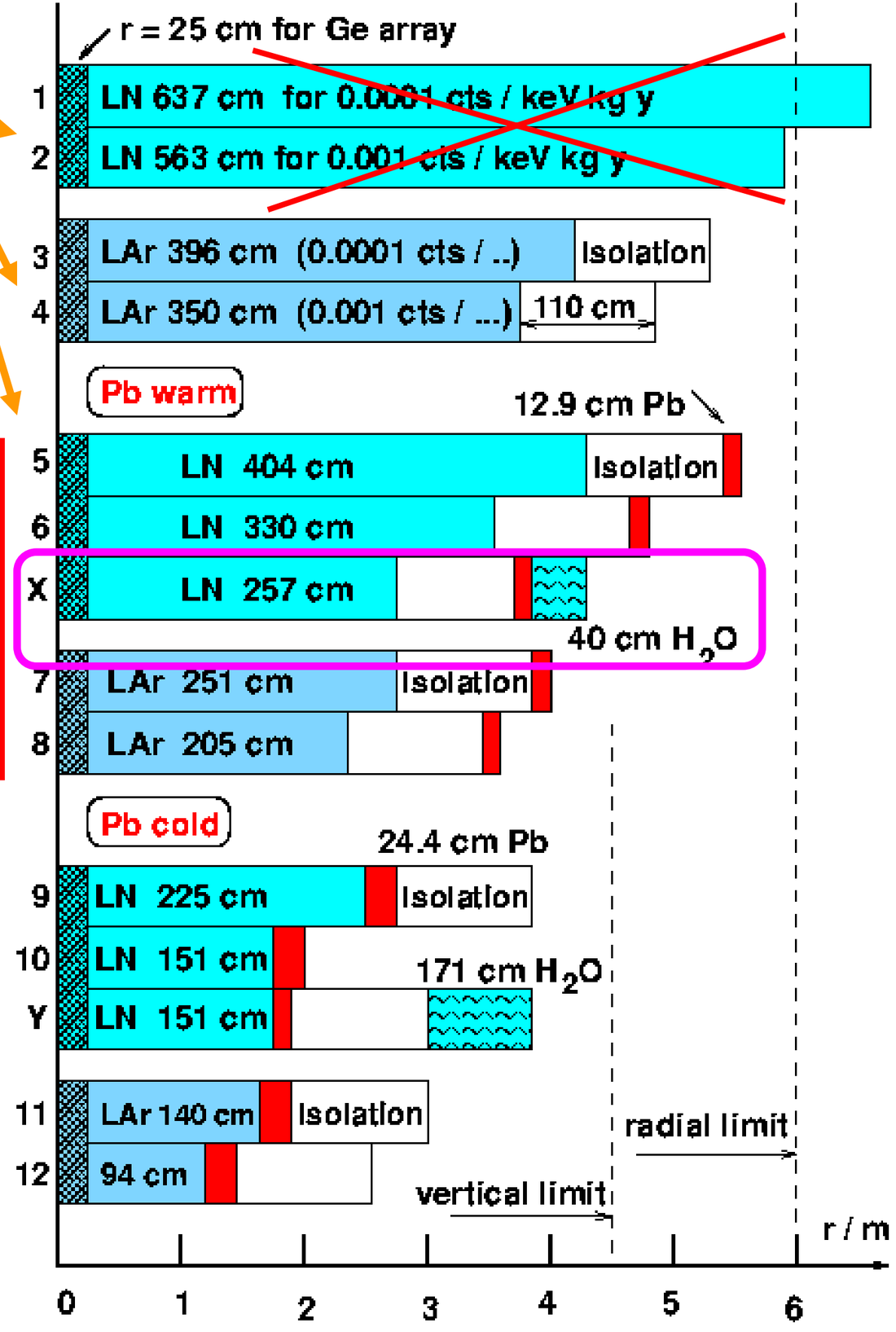
options 5 - 8

5&6 / 7&8: LN / LAr thickness such to shield steel and isolation of 7 mBq / kg

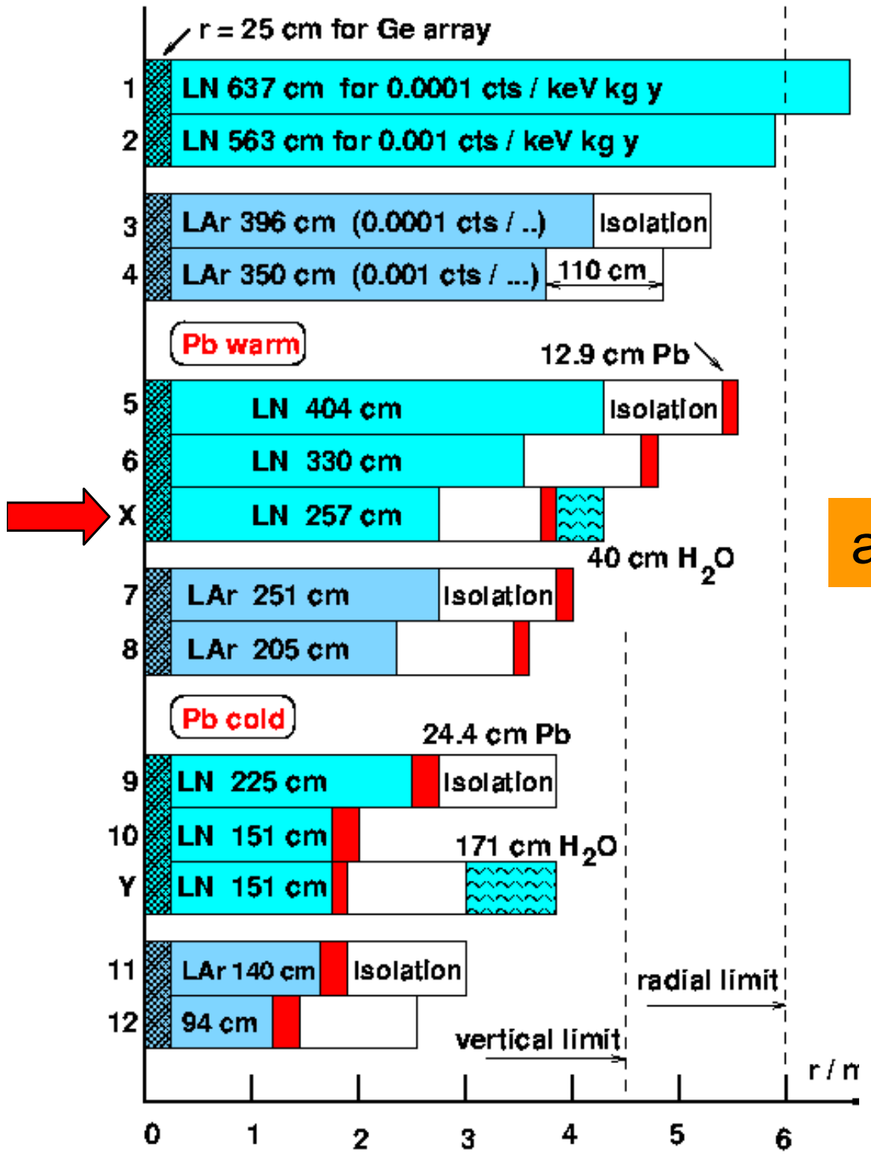
option X

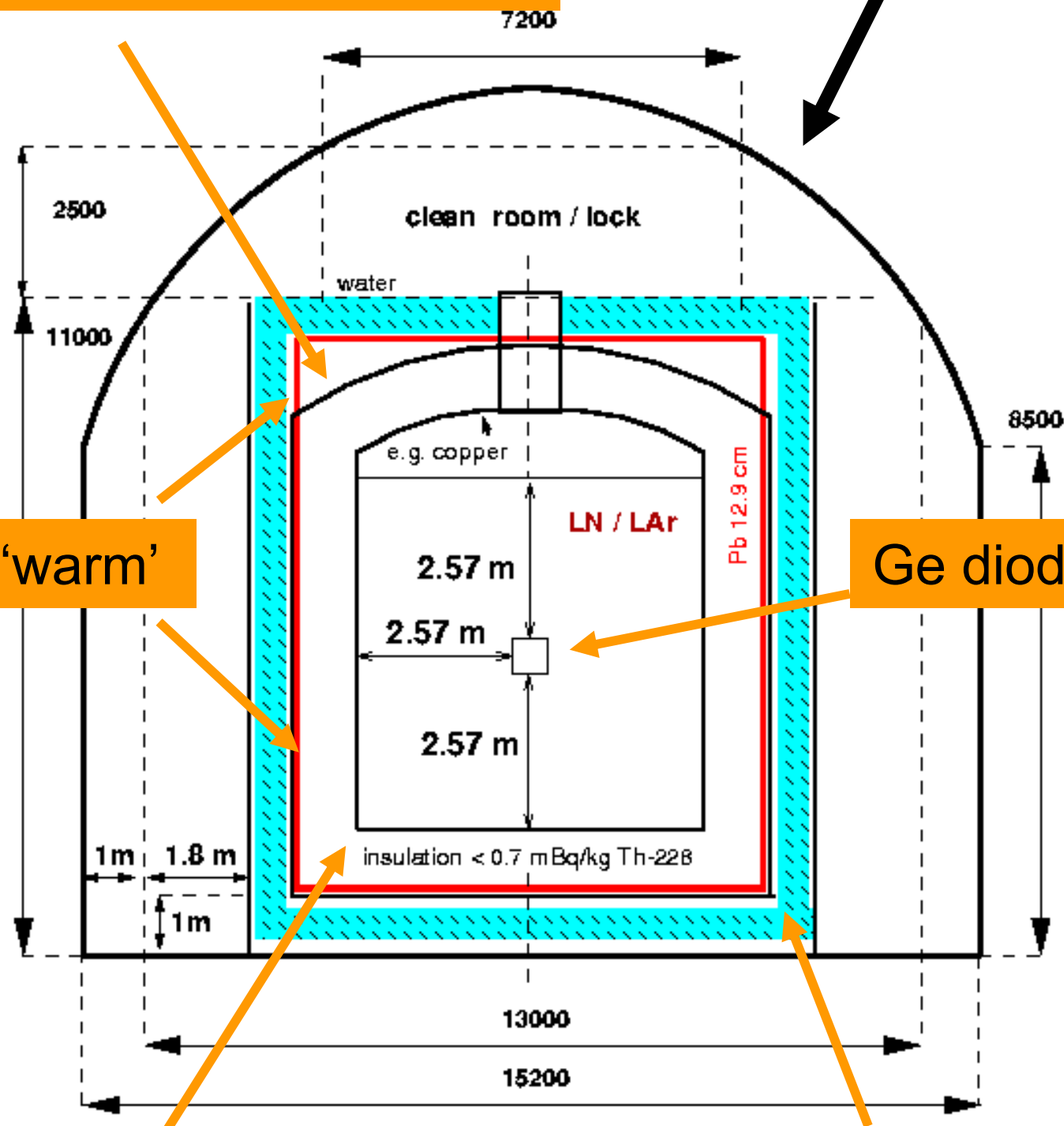
activity of steel and isolation assumed to be 0.7 mBq / kg

LN thickness can be reduced by 73 cm – missing LN is sub-stituted by 43 cm thick water



Option X





contour of hall A/B

off the shelf flat bottom tank ?

all lead ‘warm’

Ge diodes

radiopurity of inner wall and isolation less than 700 µBq / kg

water also neutron absorber and Cherenkov medium for µ-veto system

Options

odd #: 10^{-4} cts/..
even #: 10^{-3} cts/..

- Additional constraints

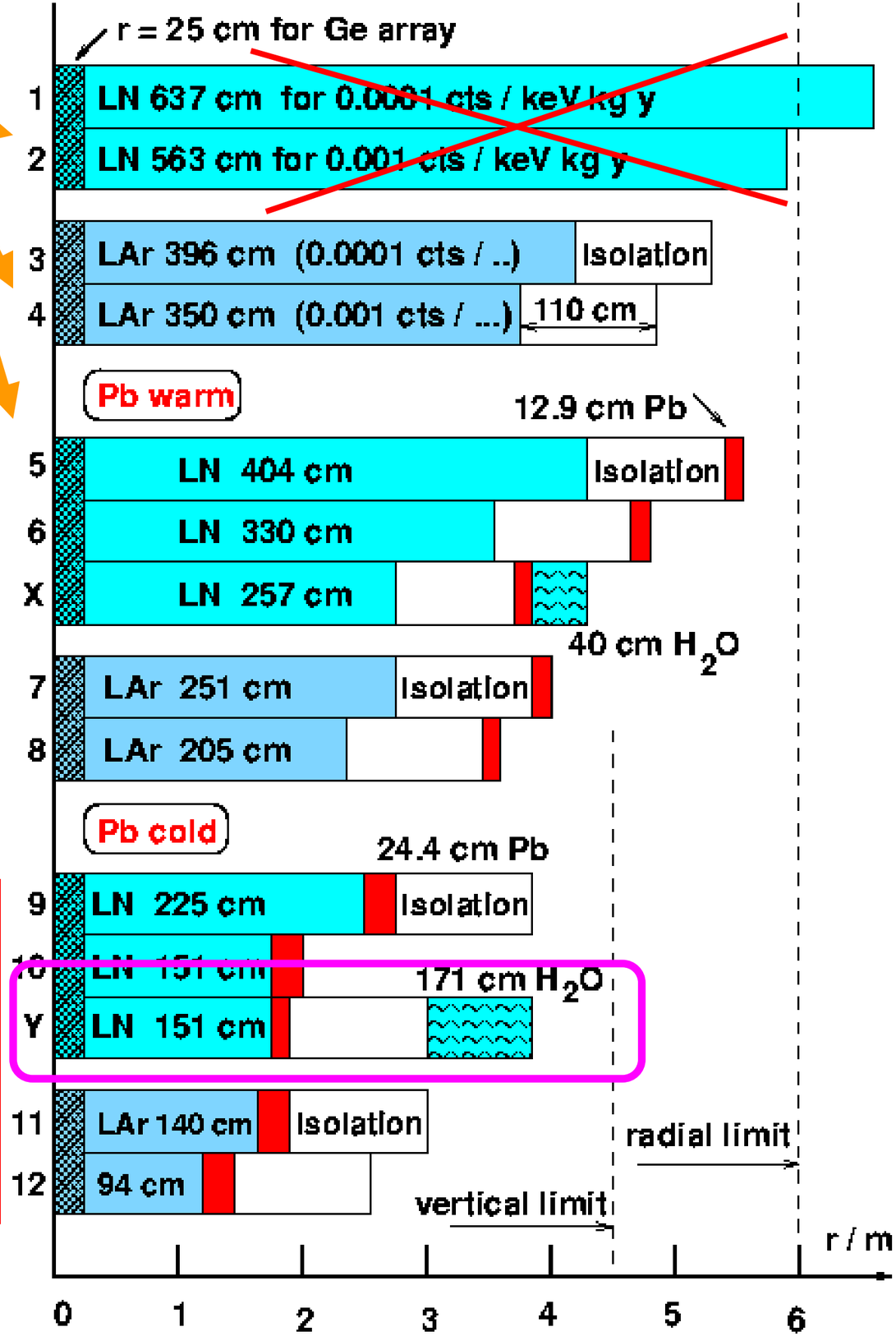
radiopurity of materials prevents free mix of building materials

options 9 - 12

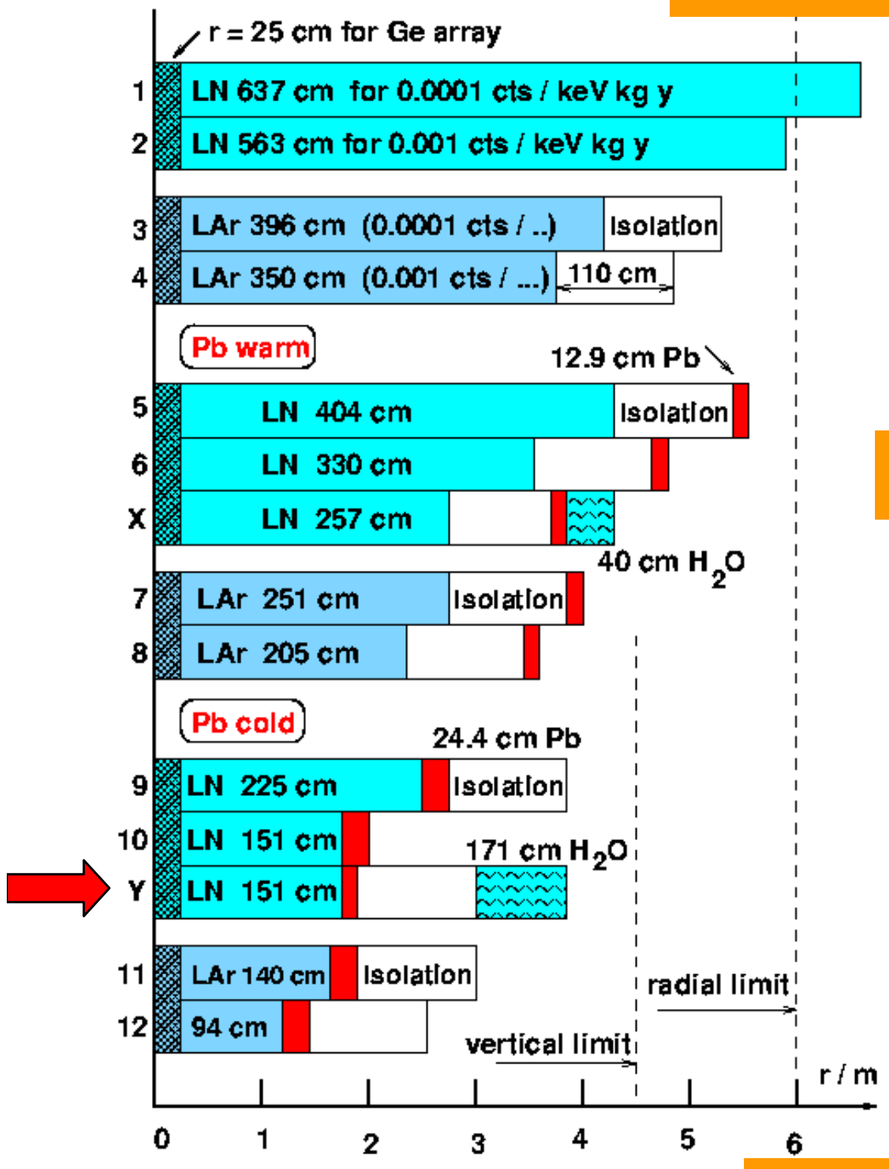
9&10/11&12: LN / LAr thickness such to shield lead of 30 µBq/kg

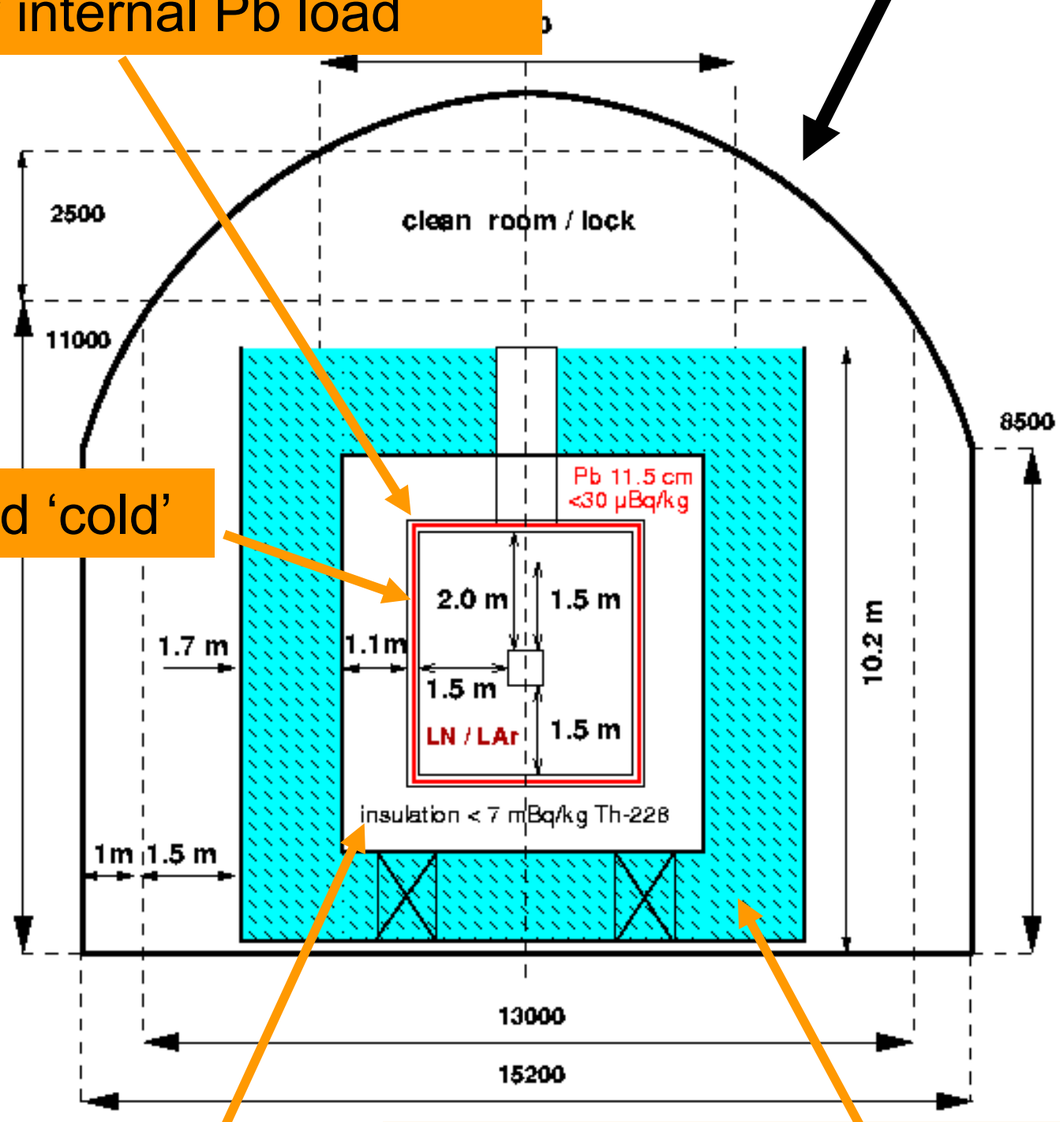
option Y

Lead thickness reduced to shield only steel & isolation (7mBq/kg) - missing lead substituted by 171 cm thick water layer



Option Y



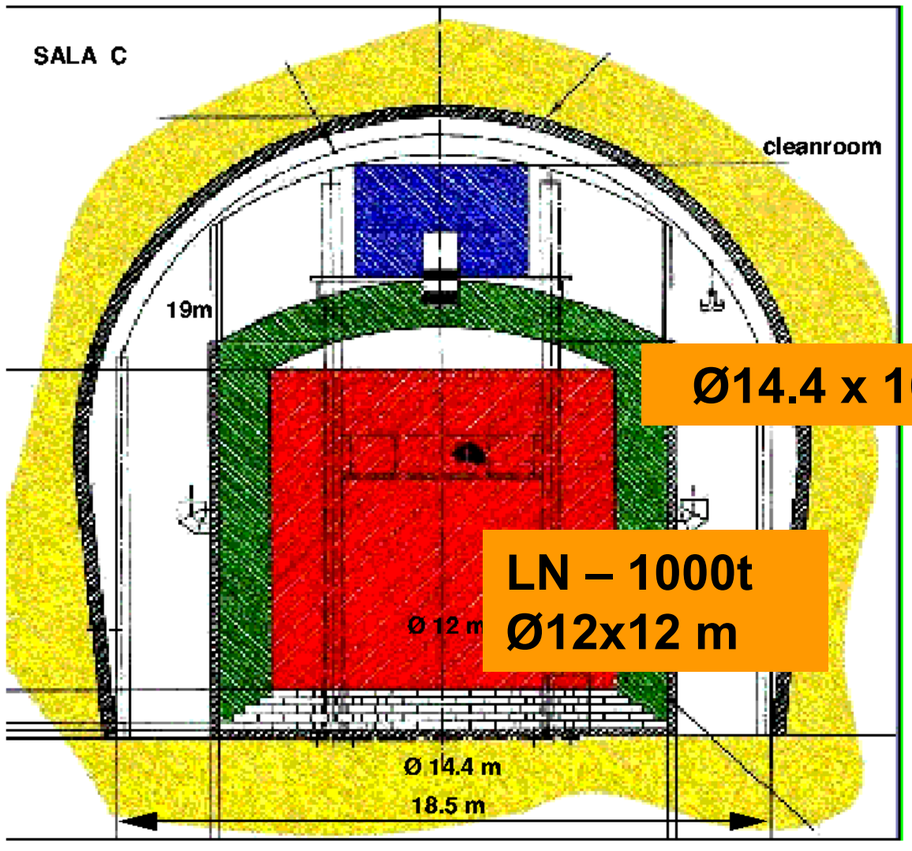


thickness of insulation can be reduced: e.g. by evacuated powder

water also neutron absorber and Cherenkov medium for µ-veto system –
water thickness can be traded against lead thickness

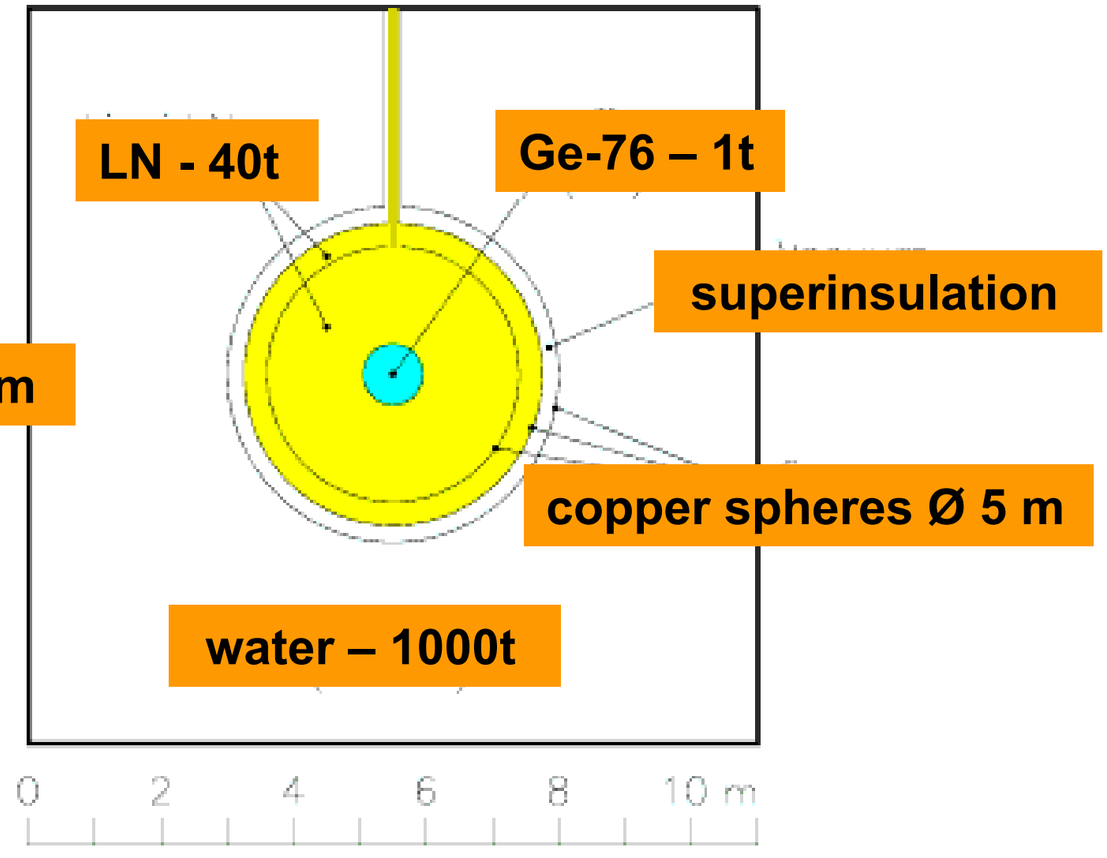
Two Previous Proposals

GENIUS



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

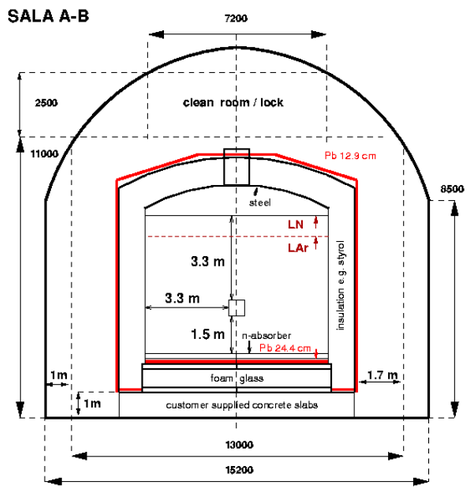
GEM

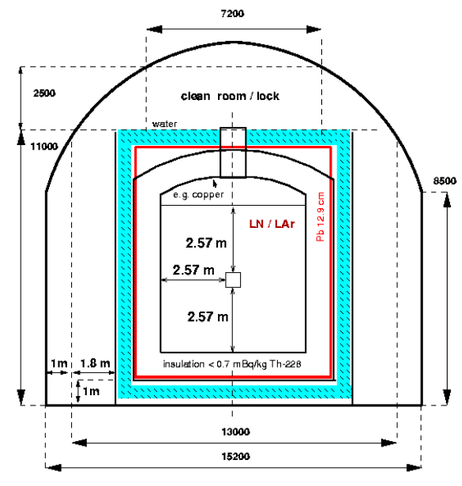


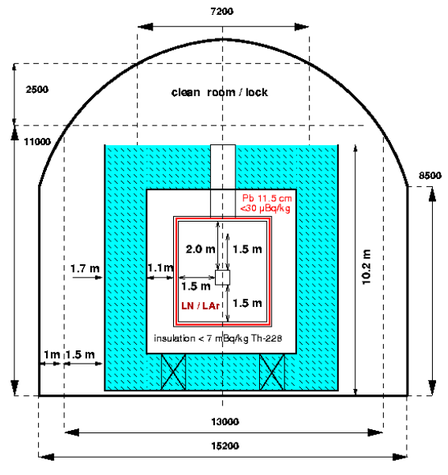
Zdesenko, Ponkratenko, Tretyak nucl-ex/0106021

Comparison of Options

option: **6 /10** **X** **Y**







GENIUS / GEM

Ø x H	**ca.:**	**10 x 11**	**9 x 11** [m x m]	**10 x 10**	**14x19 / 11x11**
LN / LAr		**210 / 178**	**174** [m^3]	**34**	**1250 / 50**
Water		**0**	**145** [m^3]	**500**	**0 / 1000**
Lead		**550**	**500** [tons]	**100**	**0 / 0**

Conclusions (1)

Cryogenic vessel with required shielding power against external γ background can be built and will fit together with neutron absorber and μ-veto system into hall A of LNGS.

For economy, the background level of 10^{-4} cts / kg keV y is obtained only with a LAr fill.

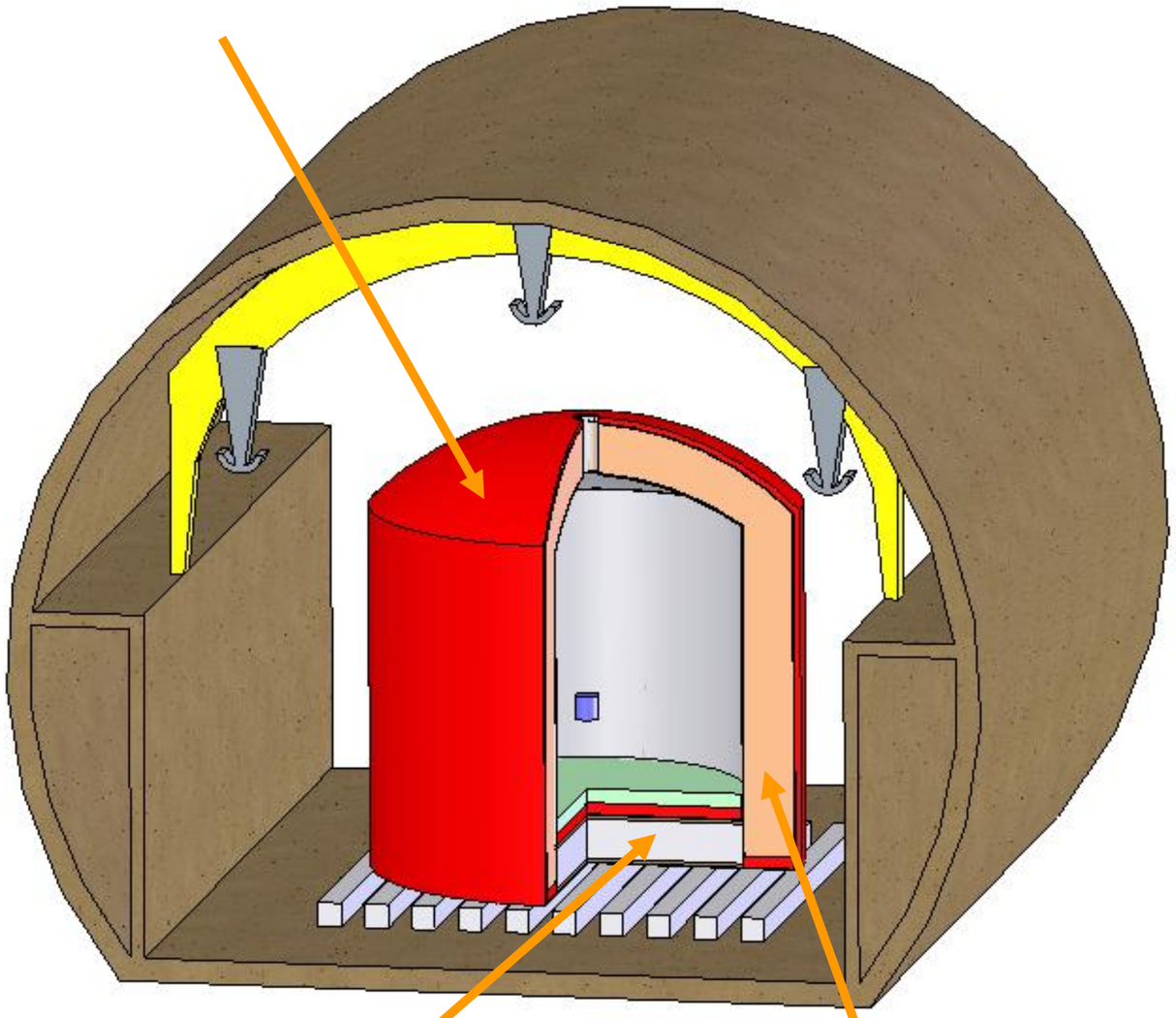
A LN fill provides 10 times worse background level.

Trade-off between shielding materials LN / LAr / lead against water yields space and cost effective system since the water shield will also serve as neutron absorber and Cherenkov medium for the μ-veto system.

Evaluation of different options in contact with industry.

Conclusions (2)

13 cm thick Pb shield



- foam glass 10 Bq/kg

perlite isolation replaced by e.g. styrol

Option 6 / 10

+ off the shelf flat bottom tank with its perlite insulation replaced by e.g. styrol.

IF foam glass cannot be replaced THEN

- part of Pb and neutron absorber in 'cold' volume

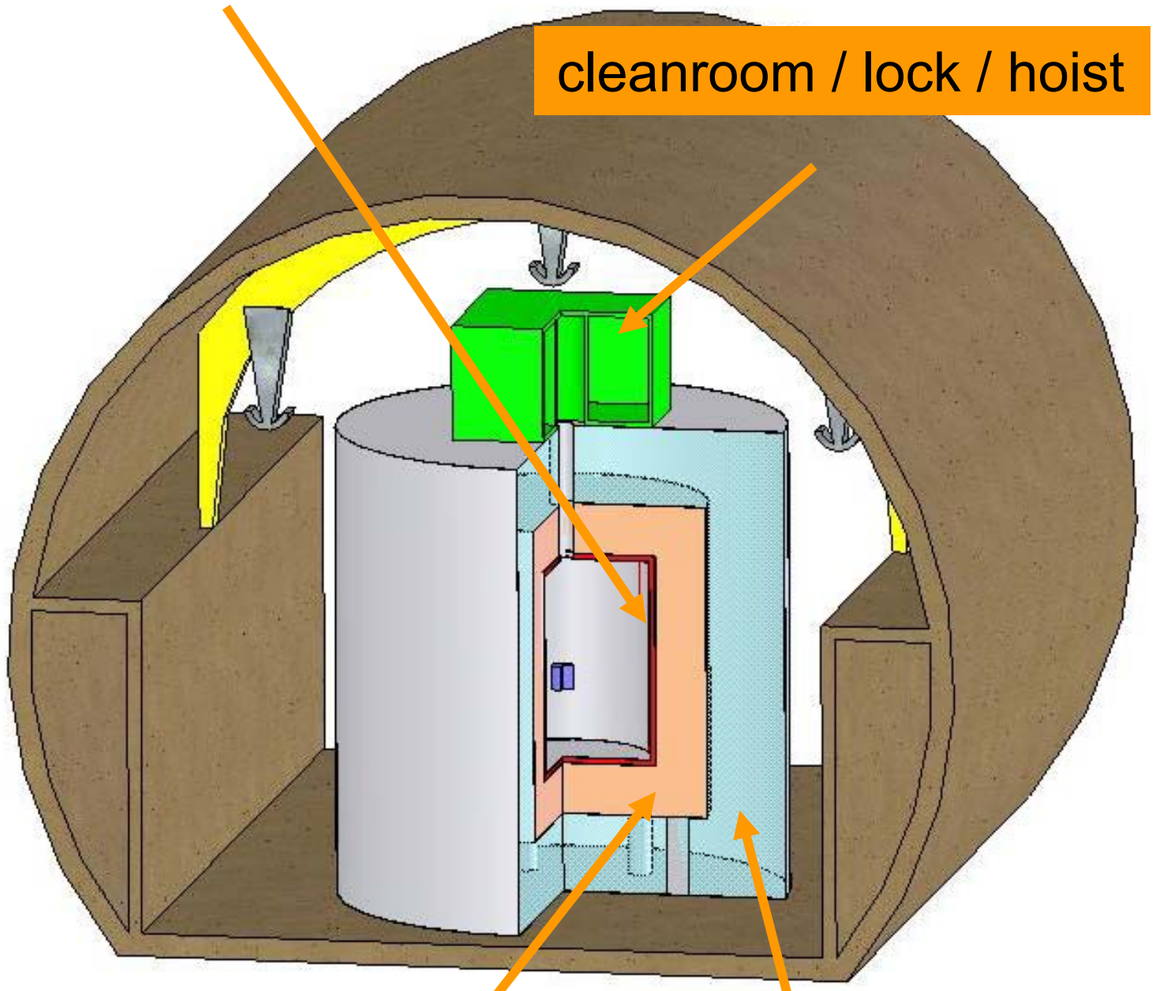
- extra neutron absorber and μ veto system needed

ELSE

+upgrade to option X with integrated neutron absorber and Cherenkov medium possible

Conclusions (3)

11.5 cm thick ‘cold’ Pb



evacuated powder isolation has half the thickness – superinsulation even less!

water thickness can be reduced if lead thickness is increased

Option Y – all lead ‘cold’

+ compact inner vessel - no need to be built underground
+ small LN/LAr volume ➔ safety
➔ ‘easy’ exchange LN - LAr
+ integrated neutron absorber & Cherenkov medium for μ-veto
+ standard radiopurity materials
+ trade-off between water & lead thickness possible

! thermal isolation of high load
! neutron flux at diodes affected by ‘closely’ neighboured lead ?