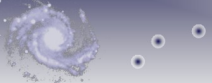


# ... and the muons

Considerations to be made when building a new experiment

Michael Bauer

Kepler Center for Astro and Particle Physics



EBERHARD KARLS

UNIVERSITÄT  
TÜBINGEN



# Overview

- What is EURECA?
- Why do we need it?
- Backgrounds in EURECA
- Hall design options
- Simulations of muon-induced background
- Conclusions

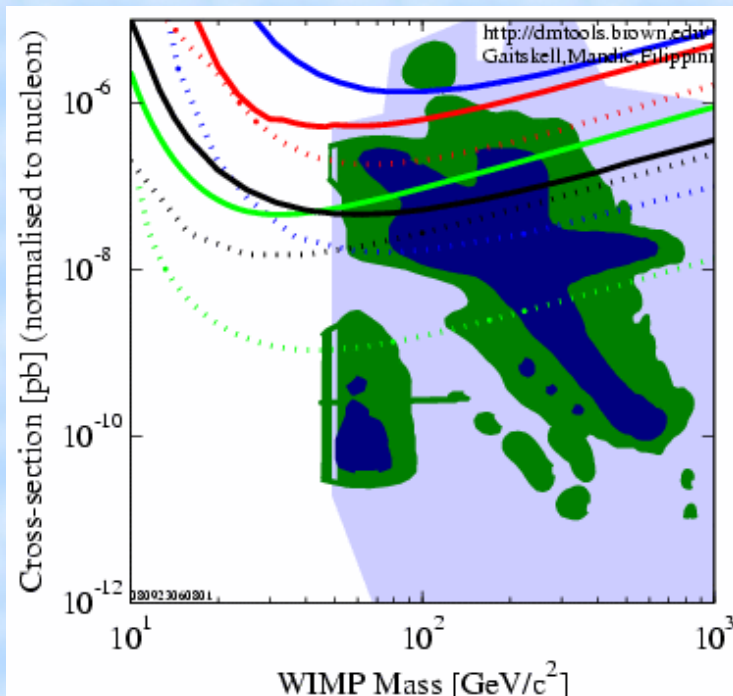
# What is EURECA?

- European Underground Rare Event Calorimeter Array
- a future direct dark matter search experiment
- ton-scale
- cryogenic
- combines techniques from CRESST and EDELWEISS
- different targets (WIMP signature)
- planning to start 2013/2014

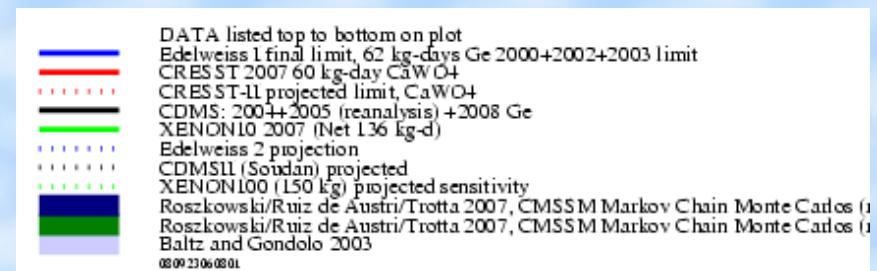
# Why do we need EURECA?

sensitivity required to cover most of SUSY parameter space:  $10^{-10}$  pb

current experiments will just not reach this!



EDELWEISS  
CRESST  
XENON  
CDMS



# Sensitivity requirements

CRESST: 3 event candidates in  $\sim 50 \text{ kg*days}$

=> WIMP limit:  $\sim 5*10^{-7} \text{ pb}$

to reach  $10^{-10} \text{ pb}$ , one has to be better by a factor of  
5000

=> a few events per ton per year!

=> background has to be even smaller than that:  
about 1 event/ton/year

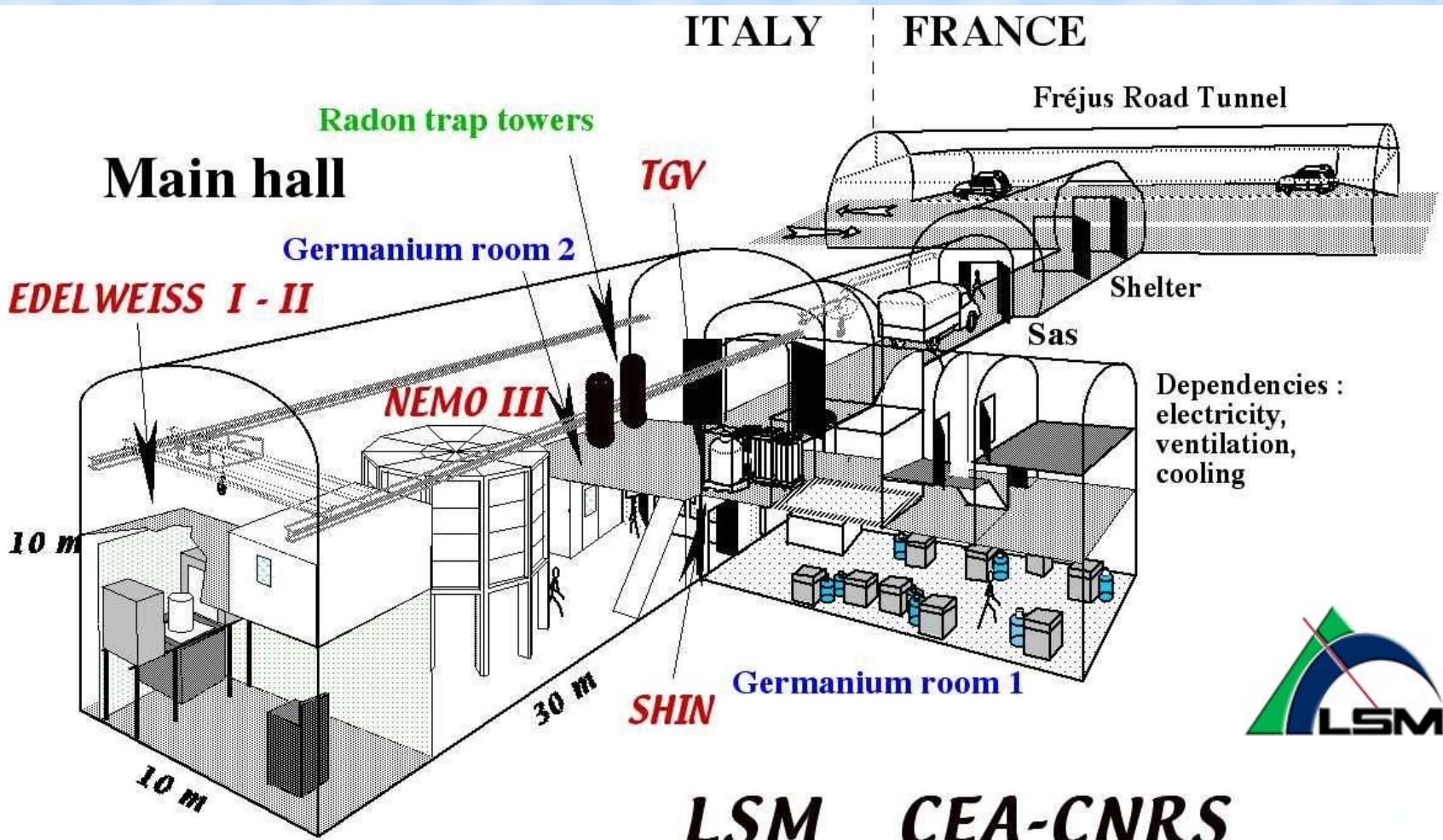
# Backgrounds

detectors will be able to discriminate  $\beta/\gamma$  from neutrons/WIMPs  
=> main background will be neutrons

- low energy neutrons from local radioactivity:
  - induced by fission and  $(\alpha, n)$  reactions due to U and Th activities in the surrounding rock and concrete
  - induced by fission in the shielding material and the experimental setup
- high energy neutrons induced by cosmic ray muons:
  - in the rock (=> spallation in shield => additional n's)
  - in the shielding material

My work: Simulation of muon-induced background

# Where will it be?

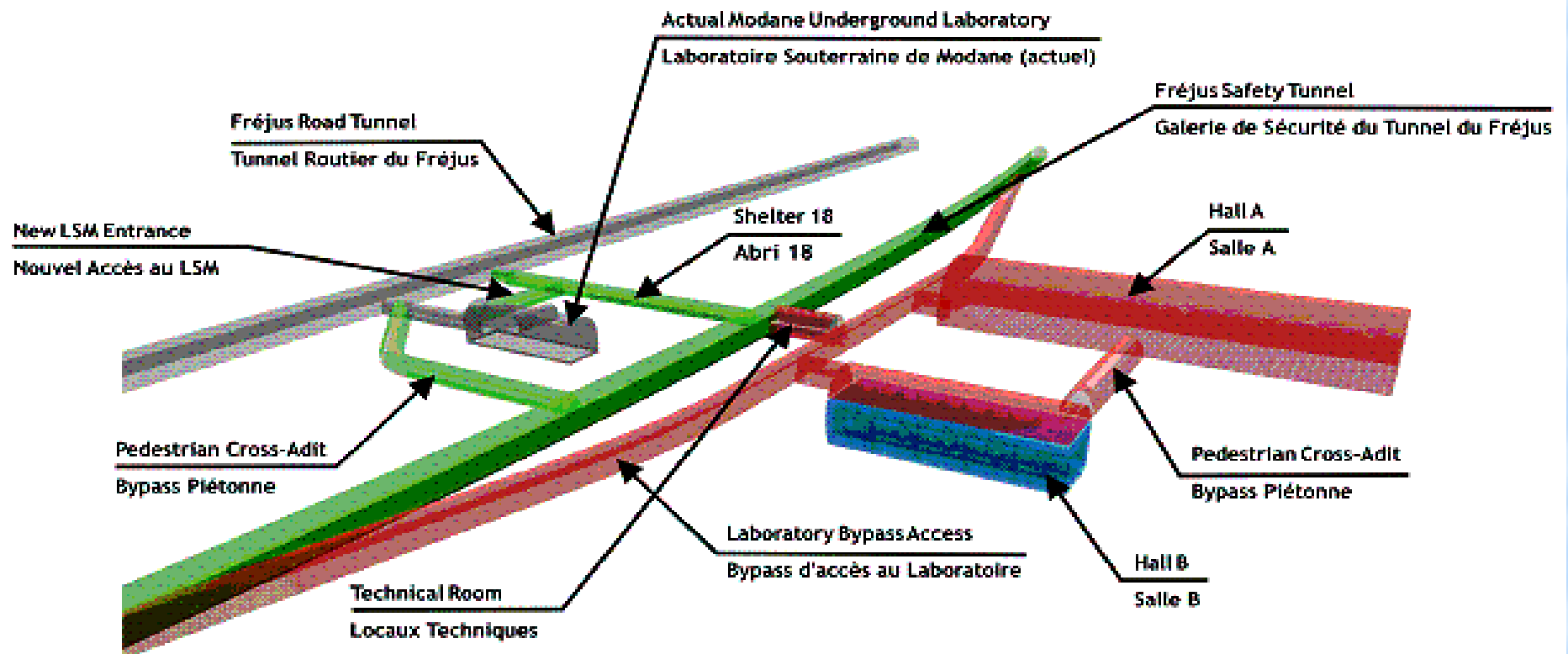


**LSM CEA-CNRS**

# Lab extension plans

MODANE UNDERGROUND LABORATORY 60'000 m<sup>3</sup> EXTENSION

LABORATOIRE SOUTERRAINE DE MODANE AGRANDISSEMENT 60'000 m<sup>3</sup>



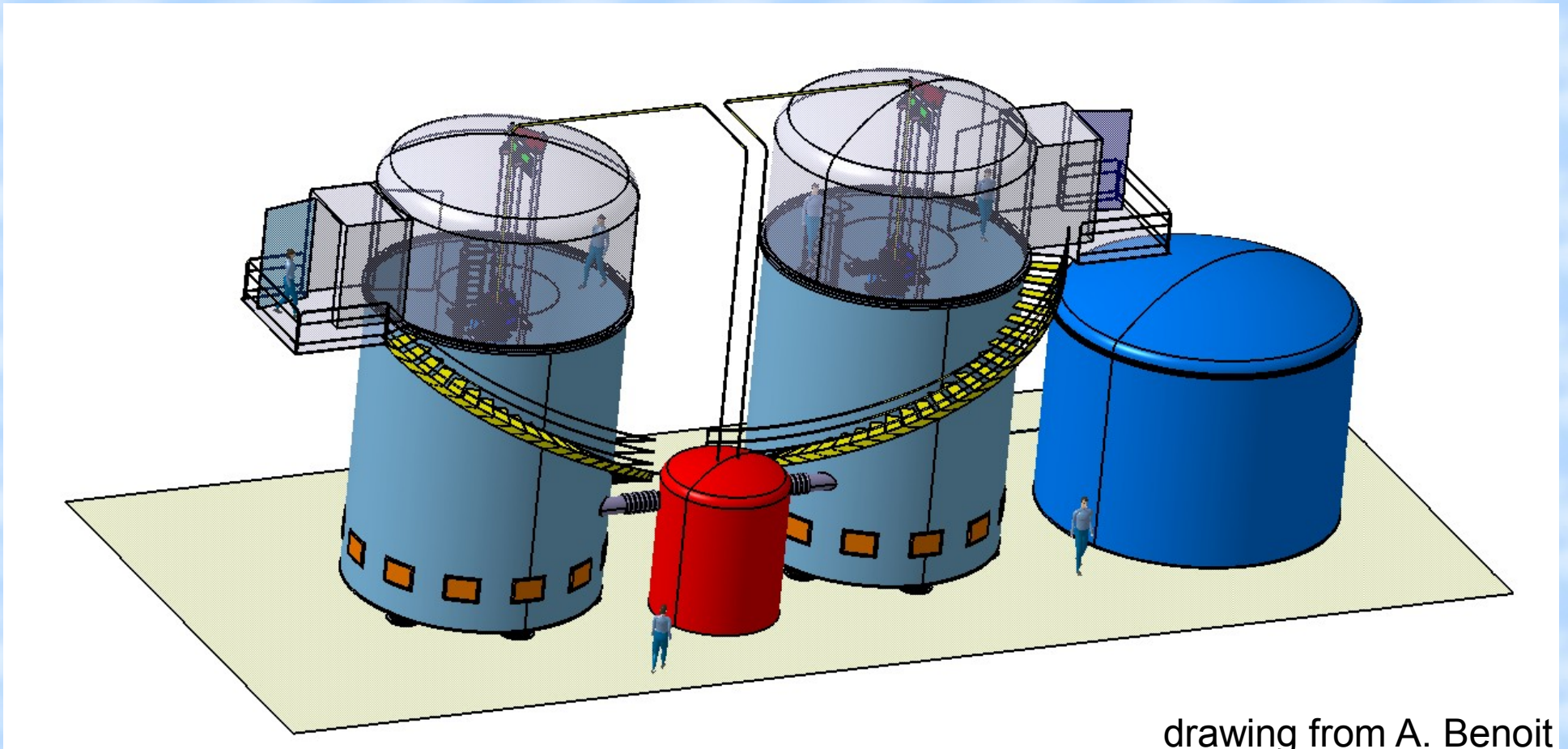


# ... or swimming pool?

Put the cryostat in water

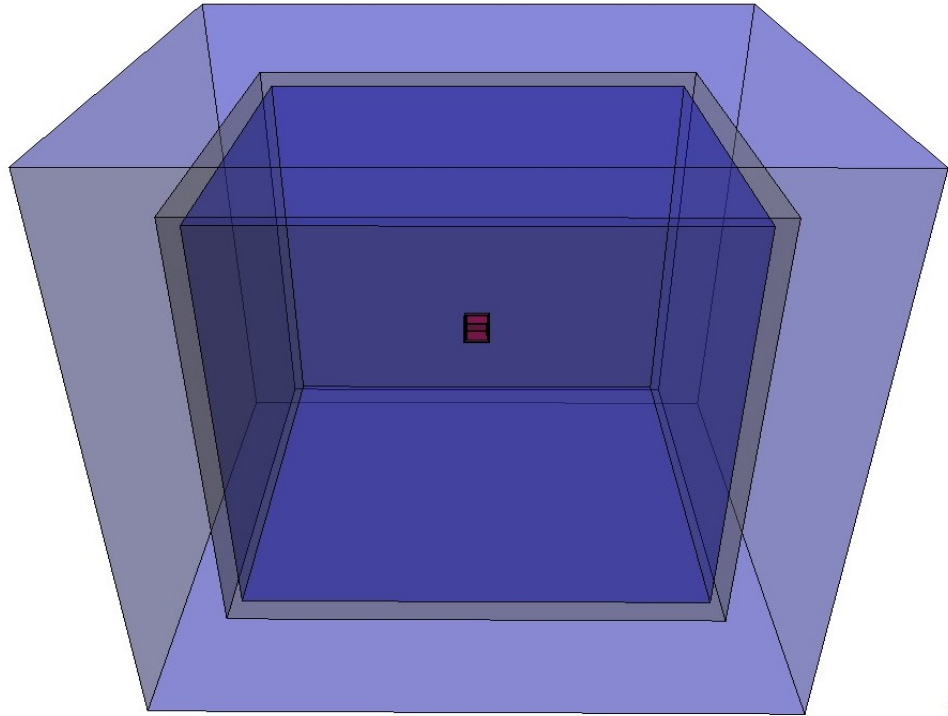
either directly in a cavern in the rock, or in some tanks inside a hall

Advantage: No stainless steel wall between water and cryostat

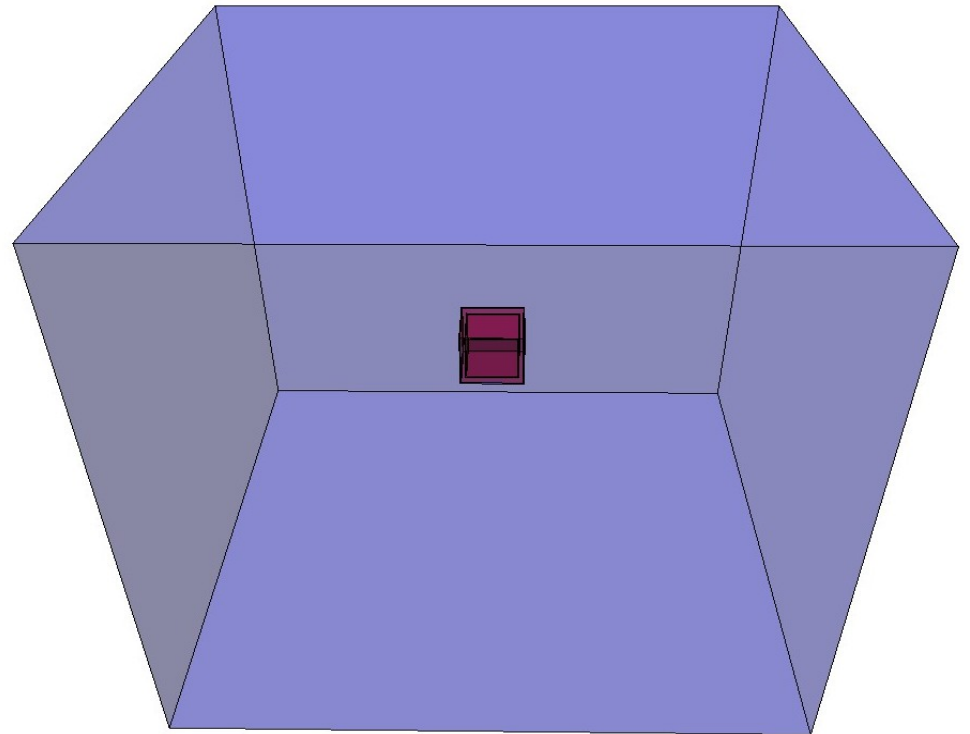


drawing from A. Benoit

# My work: Simplified hall designs

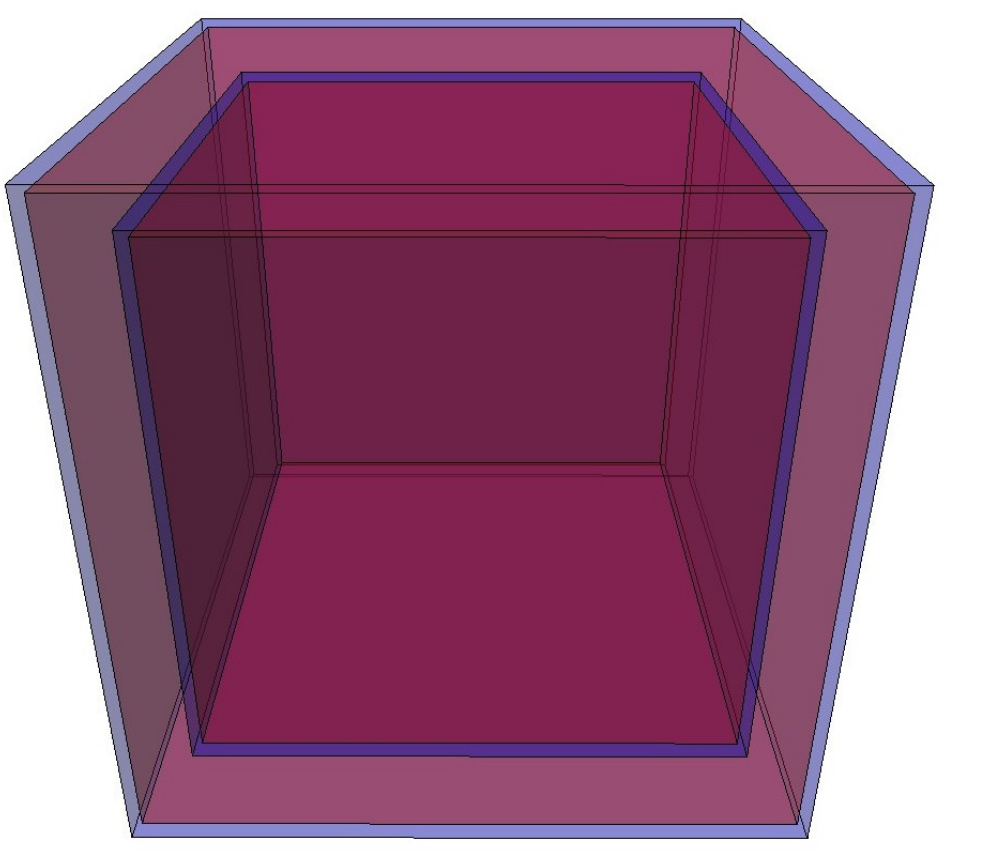


◀ Submarine:  
hall (13 m edge length)  
4 or 40 cm steel wall  
2 m water shielding/veto



Swimming pool: ▶  
cryostat directly in 3 m of water

# Detector



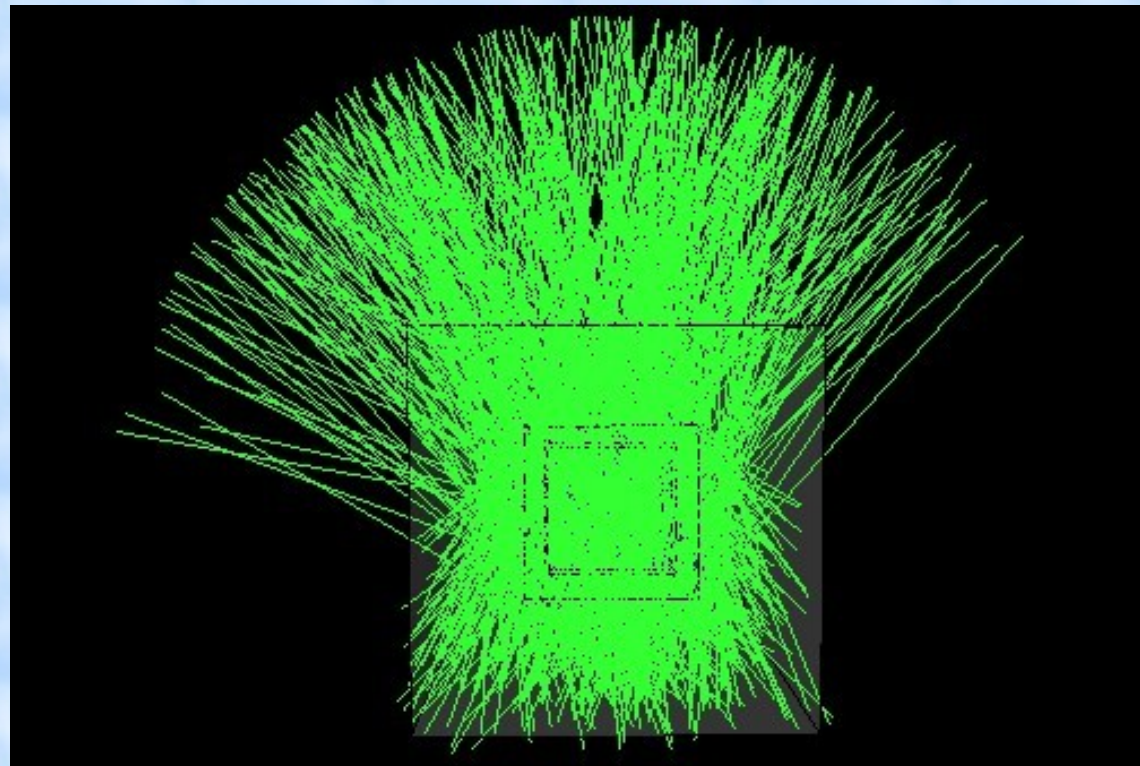
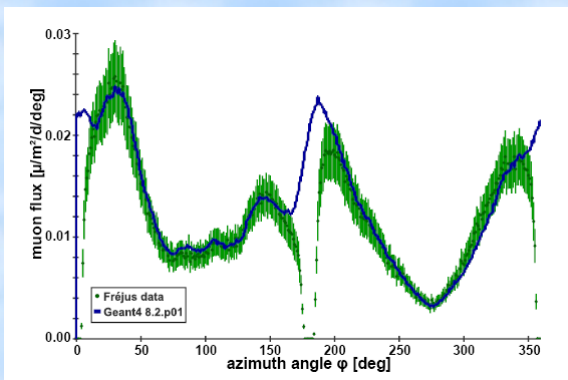
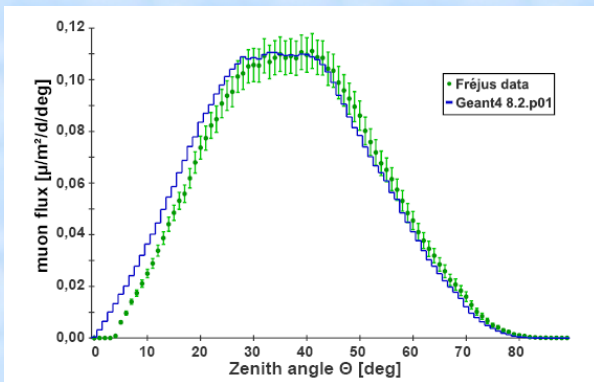
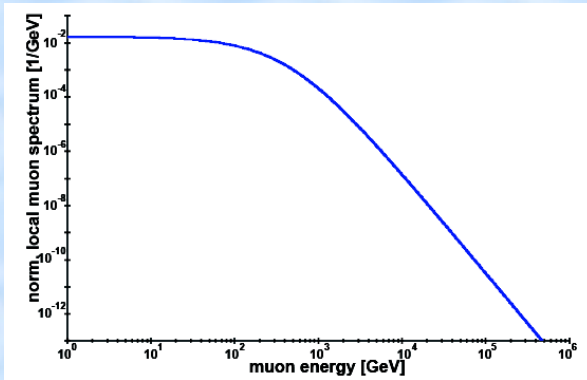
Detector:  
natural Ge cube  
60 cm edge length  
segmented into 3x3x3 pieces  
during analysis  
placed inside simplified cryostat  
(1 mm Cu, 5 cm LHe, 3 mm Cu  
or 1 cm Cu, 5 cm LHe, 1 cm Cu)

All simulations: 10 m of Frejus rock around the setup

Simulation toolkit: GEANT4 9.1.p1 / QGSP\_BIC\_HP

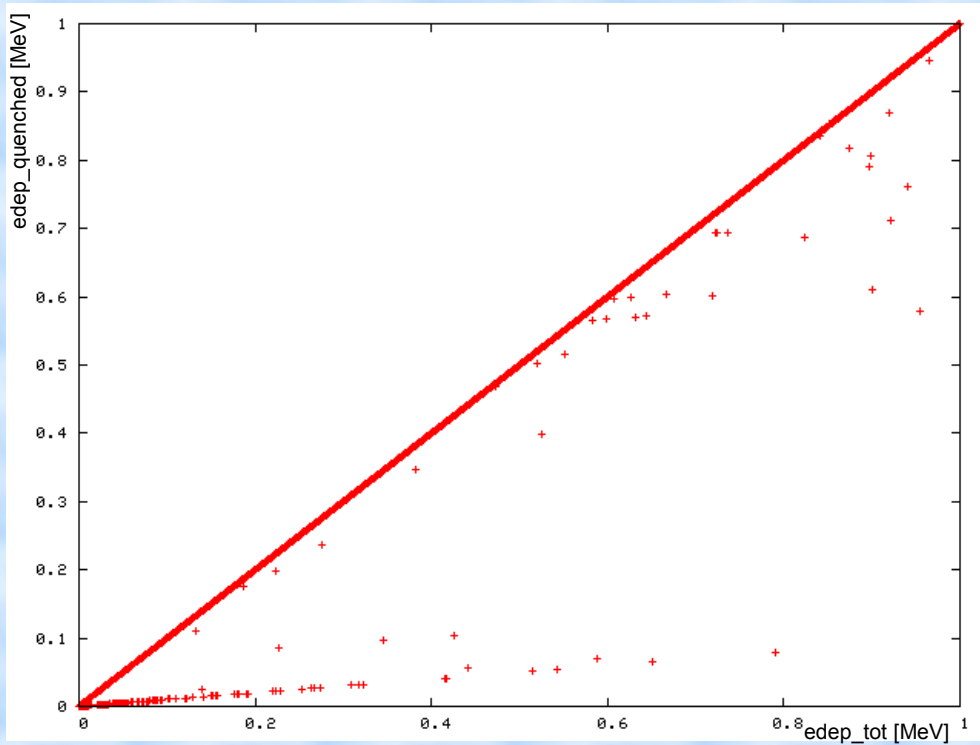
# Muon generator

From Markus Horn (PhD thesis, U Karlsruhe)  
Frejus spectrum  
shooting from a hemisphere (50 m radius)  
to the center of the geometry (15 m smearing)

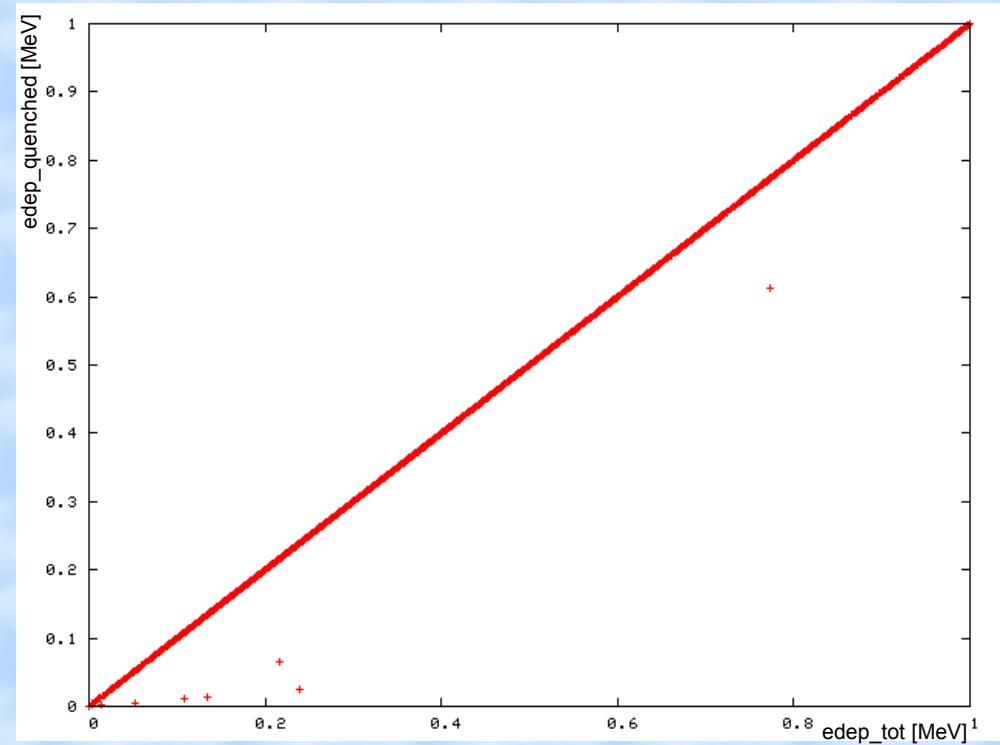


# Results

quenched vs unquenched signal (e.g., phonon vs light) in detector



submarine



swimming pool

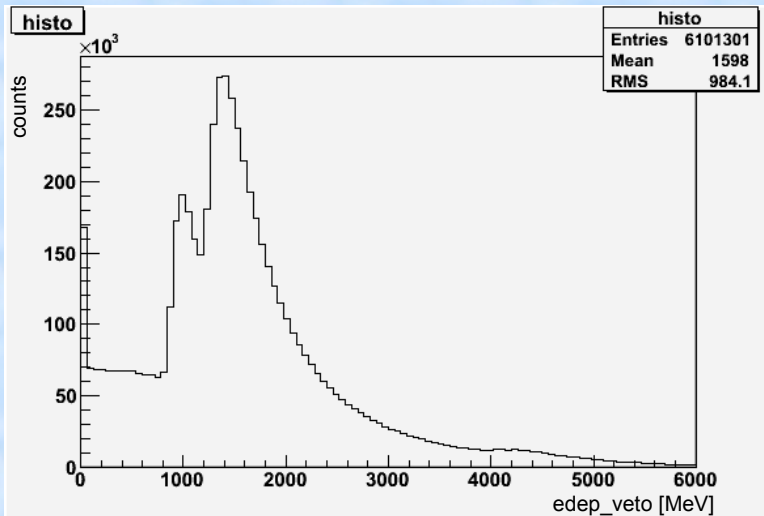
both with thick cryostat; submarine with thin steel wall

# Results

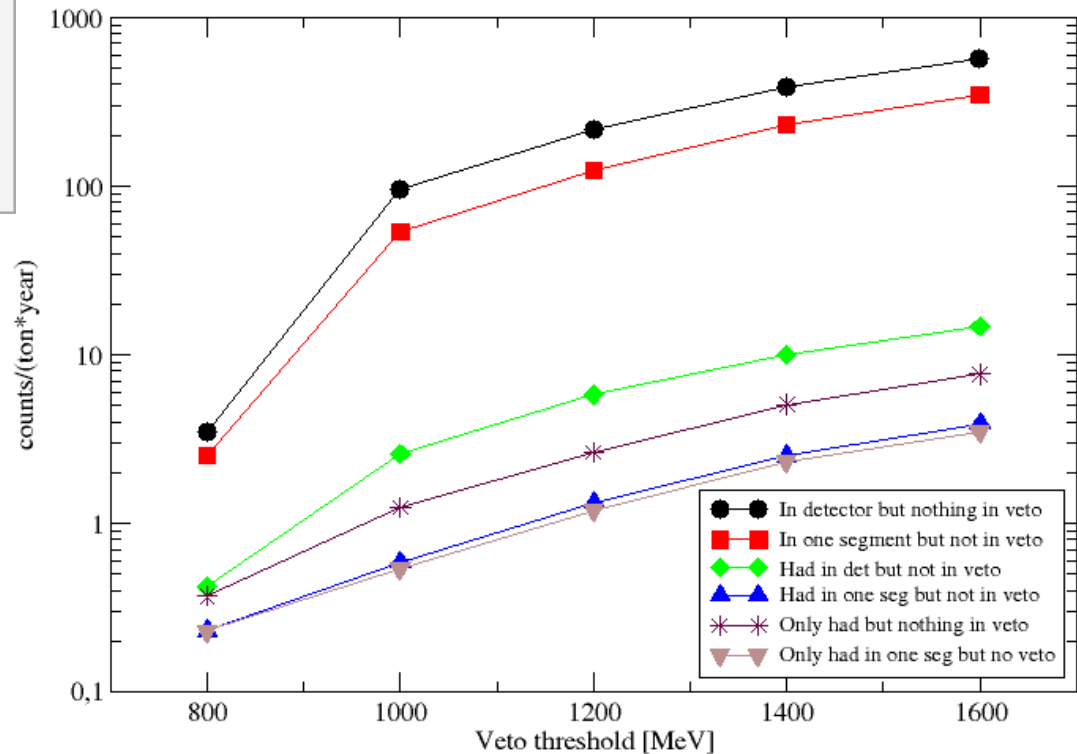
counts/(ton*year)	Swimming pool	Submarine	
		Thin steel wall	Thick steel wall
all with thick cryostat			
Simulated time [yrs]	87,61	69,6	40,74
Seen in detector	274,15	653,24	637,57
In det but not in veto	45,45	49,91	81,11
Only hadronics in only one segment	0,03	0,69	8,09
Only had in one seg not in veto	0	0,01	0,58

„hadronics“: any particle depositing energy that is not an e-/e+, mu-/mu+ or gamma

# Influence of veto threshold



Example: Submarine [ cts/(ton\*year) ]



Selected 1000 MeV:  
change from 800 MeV  
to 1000 MeV is the  
steepest

# Analysis of results

all muons:

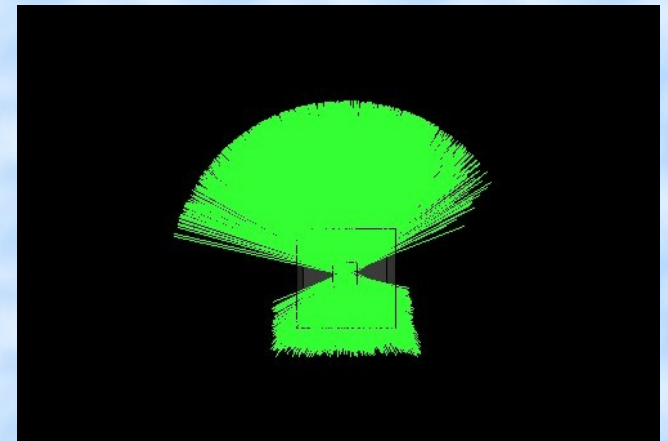
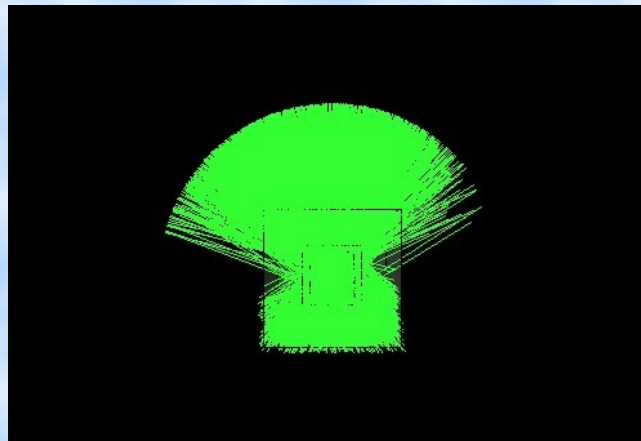
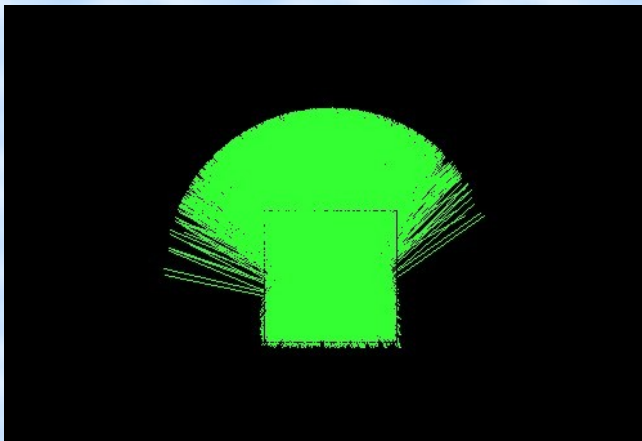
muons seen in the detector:

submarine

swimming pool

thick cryostat, thin steel wall

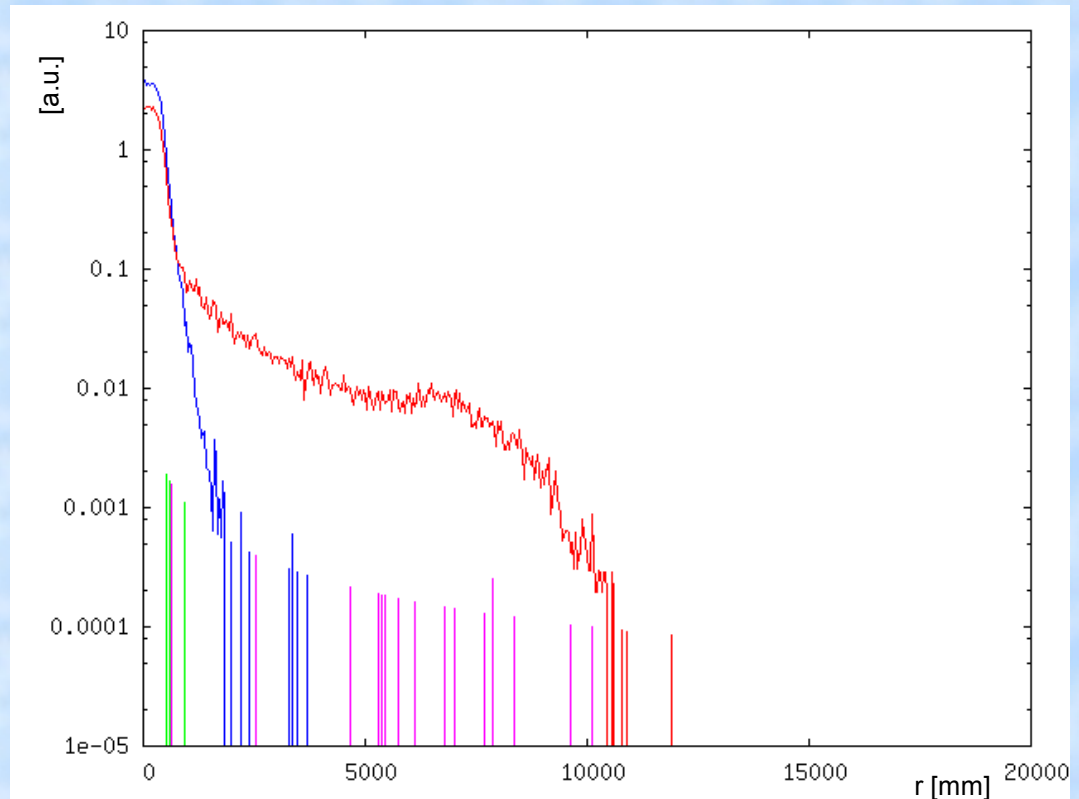
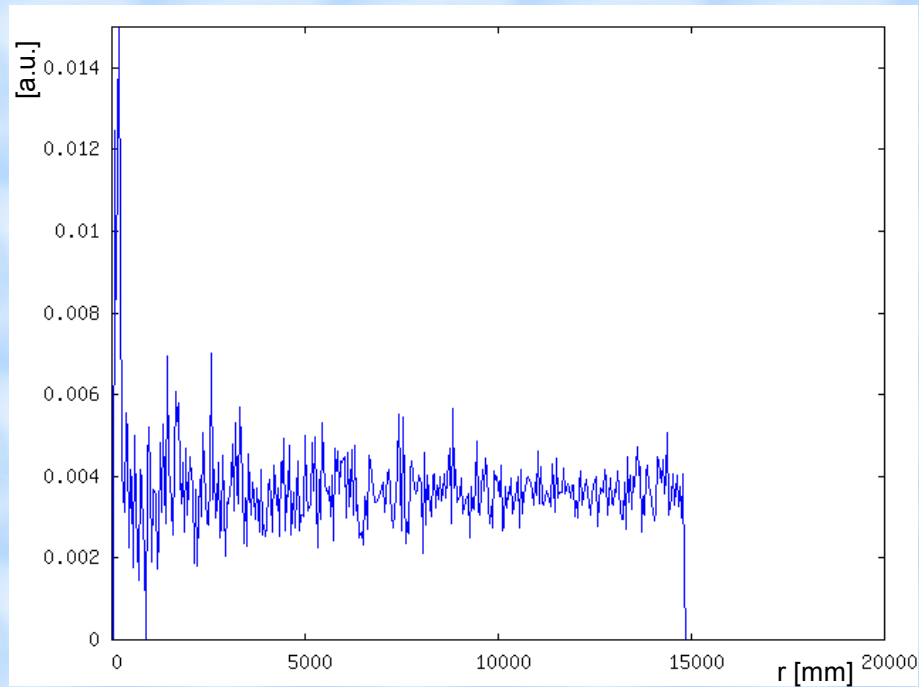
thick cryostat



„dangerous“ muons seem to pass mostly close to the detector especially in swimming pool

# Analysis of results

radial distance of muon flight direction  
from center of detector



all muons, for swimming pool

seen in detector, for submarine

seen in detector, for swimming pool

only had / one seg, for submarine

only had / one seg, for swimming pool

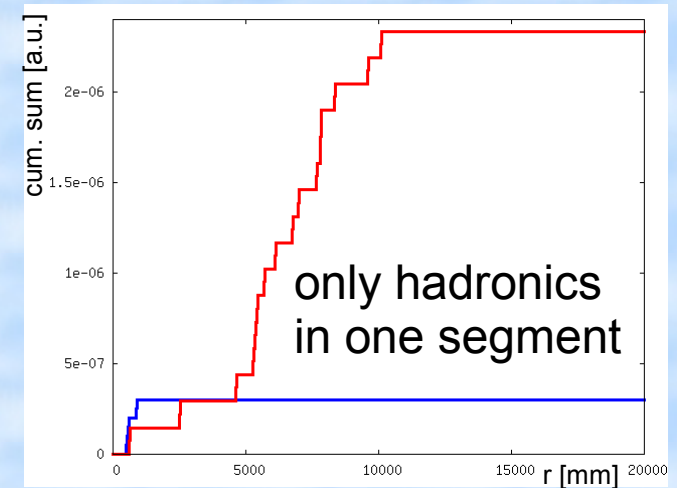
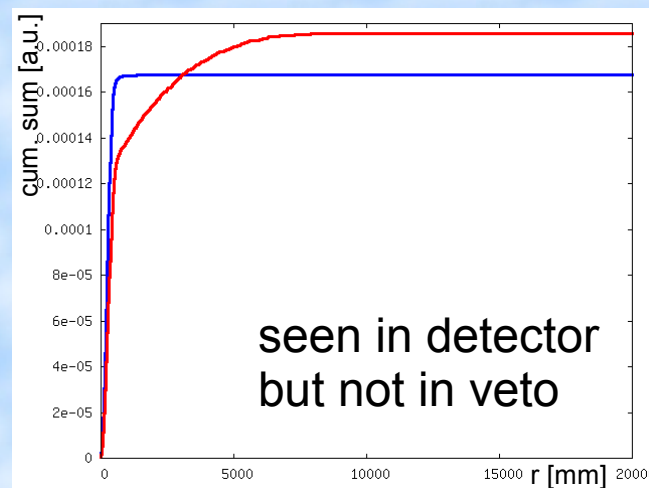
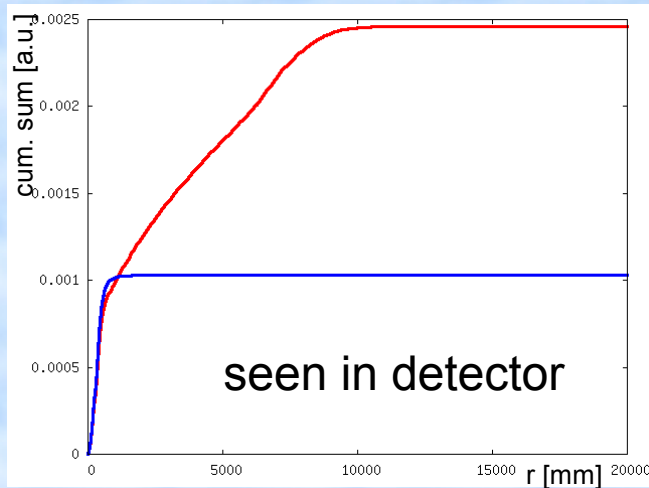
all with thick cryostat

submarine with thin steel wall

# Submarine vs swimming pool

total number of muons depending on distance to center of detector

Submarine, thick cryostat, thin steel wall - Swimming pool, thick cryostat



Background from vicinity of detector almost the same for both designs  
but the submarine adds a lot from further away  
=> The veto is a lot more important in the case of the submarine.

# A closer look: Submarine results

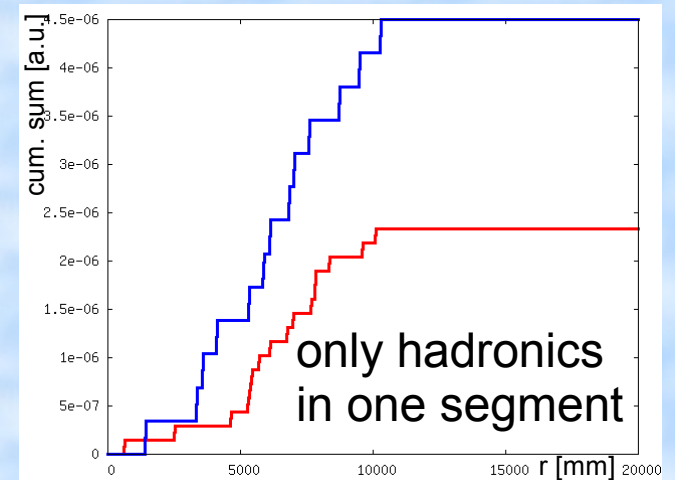
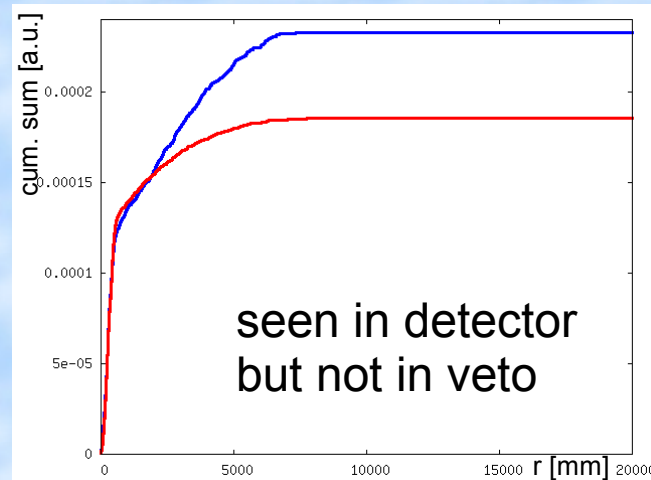
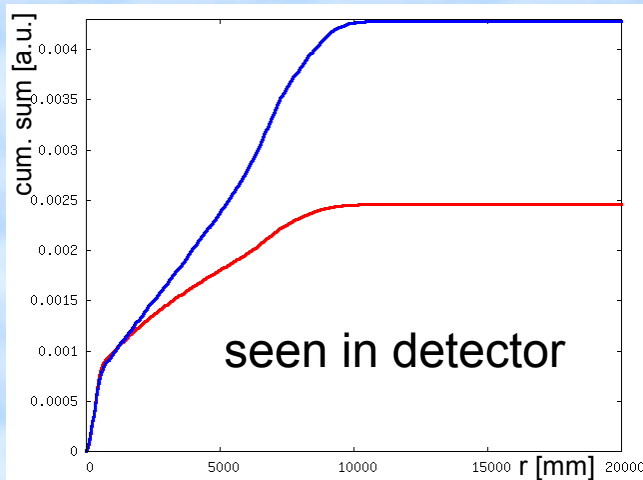
counts/(ton*year)	Thin steel wall		Thick steel wall	
	Thin cryostat	Thick cryostat	Thin cryostat	Thick cryostat
Simulated time [yrs]	38.04	69.6	47.77	40.74
Seen in detector	1138.32	653.24	1102	637.57
In det but not in veto	58.9	49.91	118.11	81.11
Only hadronics in only one segment	1.33	0.69	11.29	8.09
Only had in one seg not in veto	0	0.01	0.73	0.58

„hadronics“: any particle depositing energy that is not an e-/e+, mu-/mu+ or gamma

# Analysis of submarine results

total number of muons depending on distance to center of detector

thin cryostat, thin steel wall - thick cryostat, thin steel wall

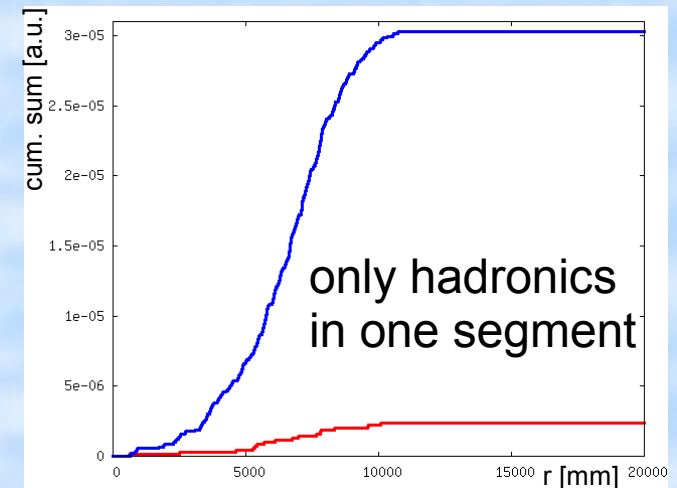
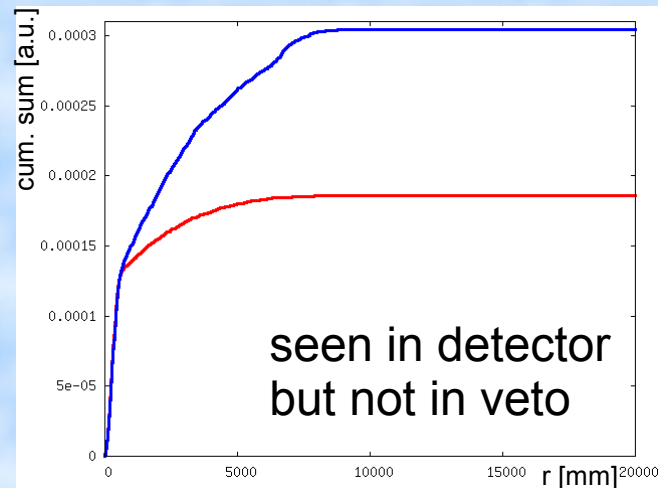
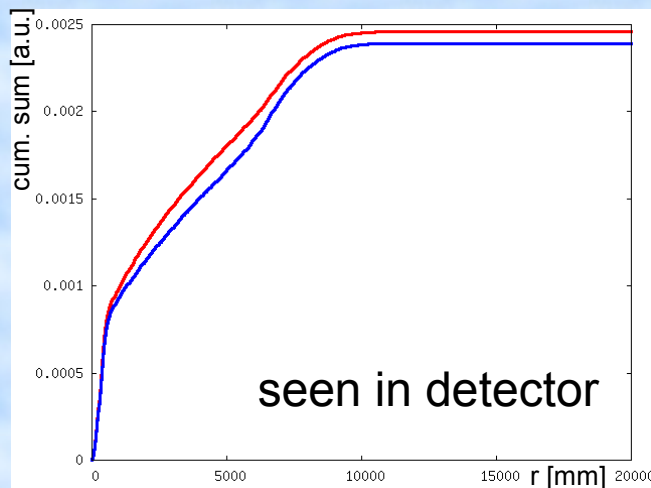


A thick cryostat acts as a shielding against events from outside  
=> will not be a problem with respect to muon-induced events,  
but of course radiopurity has to be taken into account

# Analysis of submarine results

total number of muons depending on distance to center of detector

thick cryostat, thick steel wall - thick cryostat, thin steel wall



Total number of events seen in detector is only slightly influenced by the thickness of the steel wall... BUT:

Number of events not seen in the veto as well as number of dangerous events „hadronics in only one segment“ are significantly increased with thicker wall!

# Radioactive contaminations

Simulations by Vitaly Kudryavtsev, University of Sheffield  
(using his own simplified version of the hall geometry)

## Electron recoils

from U, Th, K impurities

rock, 3 m water	48
concrete, 3 m water	1300
concrete, 2 m water	103000

Cu of cryostat (320 kg)	6677
SS of cryostat (347 kg)	400000

2 cm SS vessel	800000
from $^{60}\text{Co}$	430000

## Nuclear recoils

from U, Th, K impurities

all numbers:

single electron / nuclear recoils  
in 10-50 keV energy range  
per year per 103,68 kg Ge

Cu of cryostat (340 kg)	0,04
SS of cryostat (19,7 kg)	1,1

2 cm SS vessel	17,2
----------------	------

SS: stainless steel

The radioactive background from the submarine hall is 8 times as high as what is left from the concrete of the hall after 2 m of water  
=> Swimming pool preferable also with respect to radioactivity!  
=> Esp. with submarine, need discrimination power on the order of  $10^6$ !

# Conclusions

counts/(ton*year)	Swimming pool	Submarine	
all with thick cryostat		Thin steel wall	Thick steel wall
Simulated time [yrs]	87,61	69,6	40,74
Seen in detector	274,15	653,24	637,57
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„hadronics“: any particle depositing energy that is not an e-/e+, mu-/mu+ or gamma

At least with respect to muon-induced background,  
EURECA can most probably reach its sensitivity goal!

# Summary

- EURECA will be built in an extension of the Frejus underground laboratory
- Swimming pool option is better than submarine with respect to muon-induced background as well as local radioactivity
- Both designs can satisfy the background requirements with respect to muons (at least if the steel wall is not too thick and the veto is working properly)
- Accessibility of cryostat also has to be taken into account when making the decision
- Now we are all eagerly awaiting (and working for) the start of EURECA and hoping to see some WIMPs with it

**Thank you for your attention!**