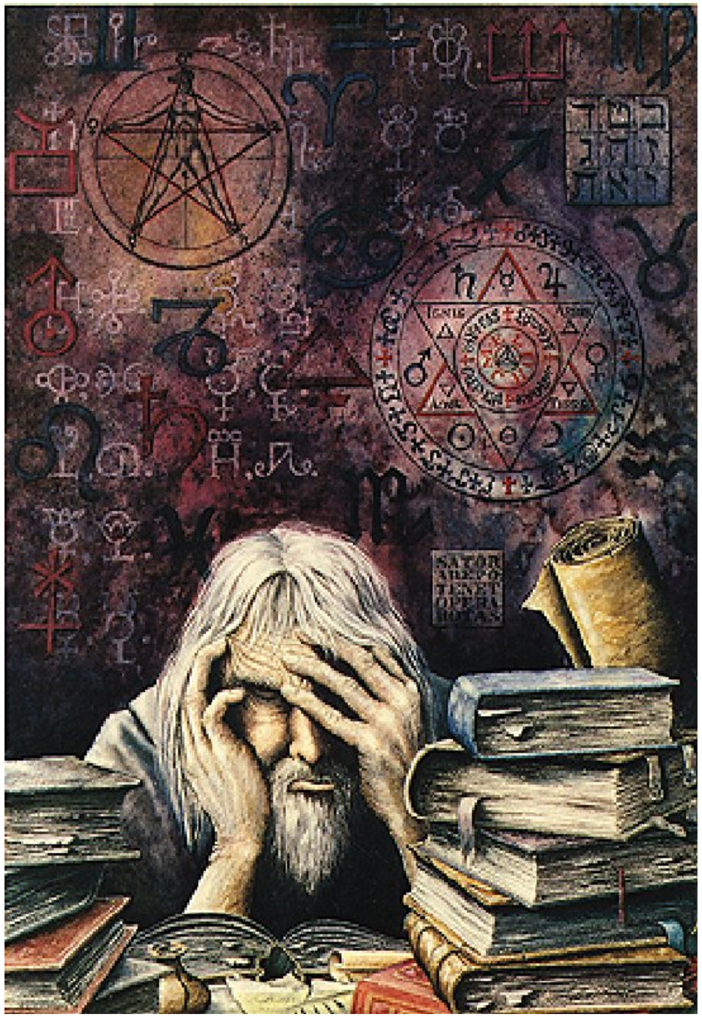
TECHNISCHE UNIVERSITÄT DRESDEN

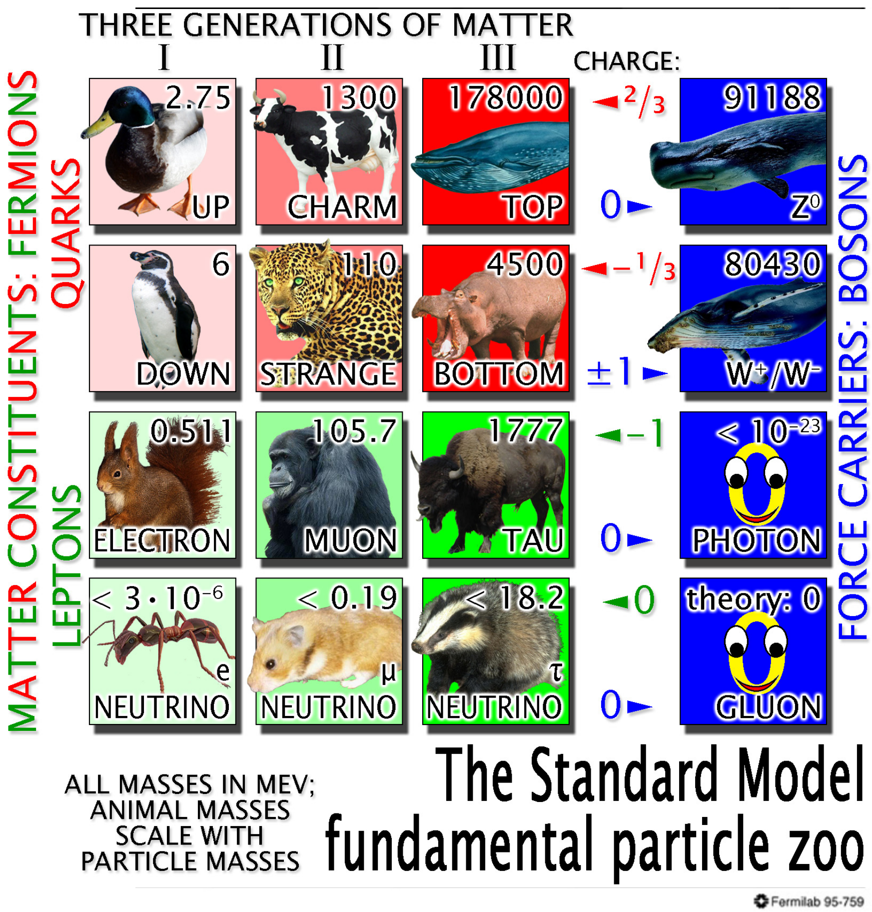
Ultralow background approaches

K.Zuber, 5.11.2010



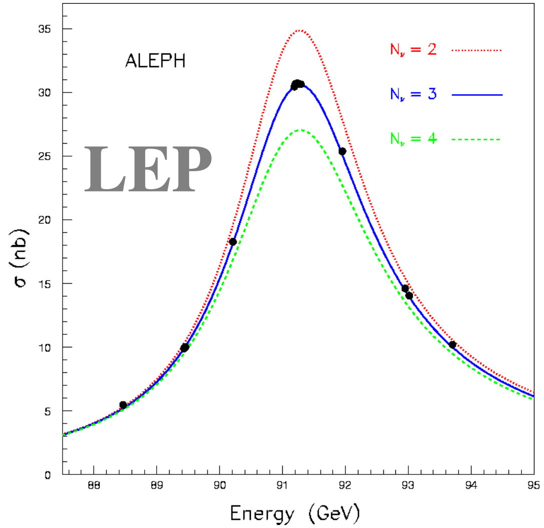
- Why ultralow background physics?
- General issues
- Background components
- Example: DBD with Ge-detectors
- Side application
- Summary

Particle Physics

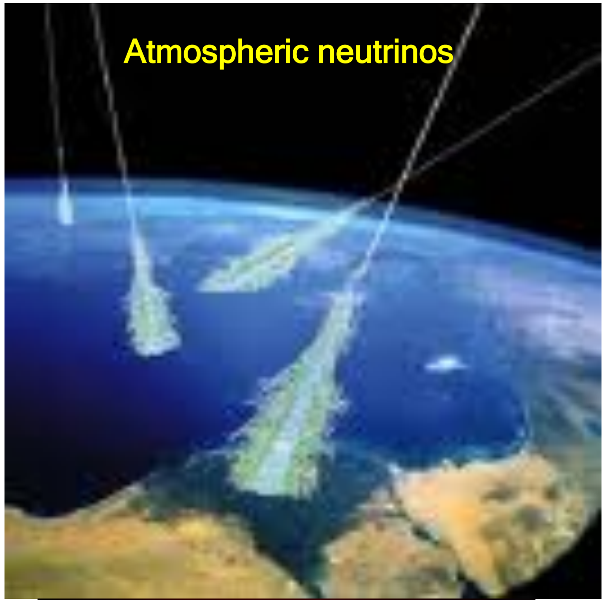


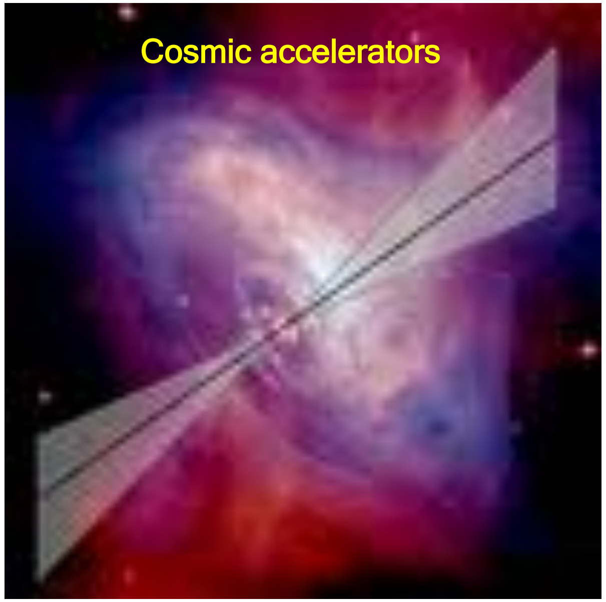
1952: m < 250 eV

Neutrinos are massless in the Standard Model

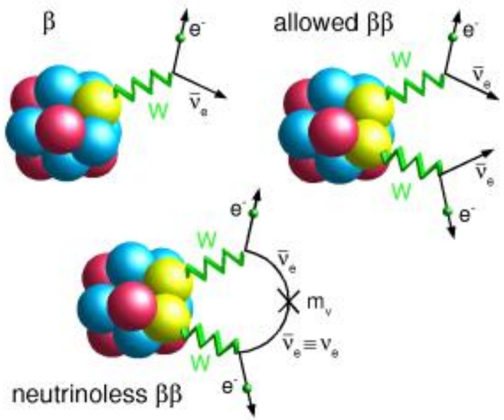


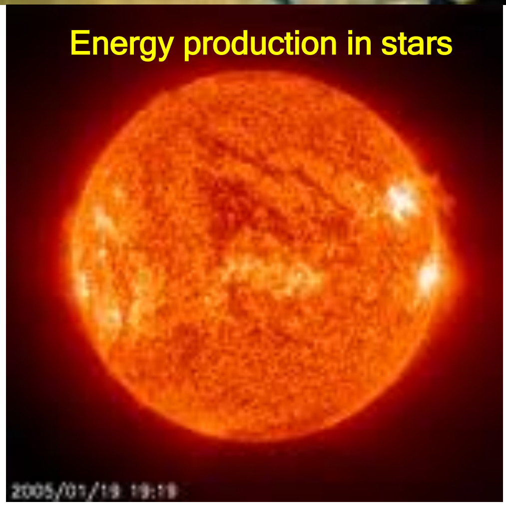
Particle astrophysics





Rare Nuclear Decays and Neutrino properties



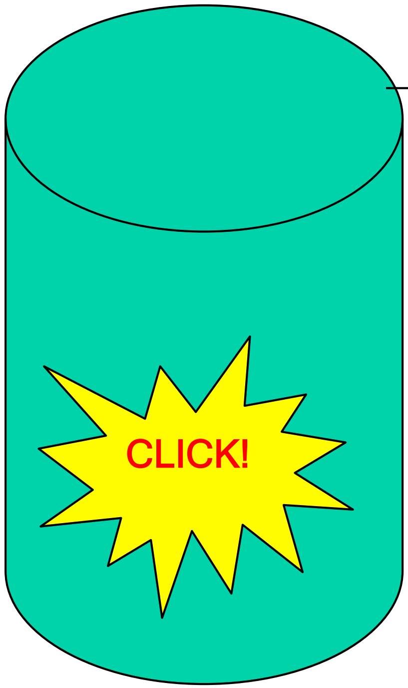


Common problem

I won‘t talk about: Statistics, Cuts, ...

Typical experiment

Some energy deposition in a detector!



Information
f.e. energy
(ADC, MCA)

Is this signal or background?

Two options:

Measure additional information

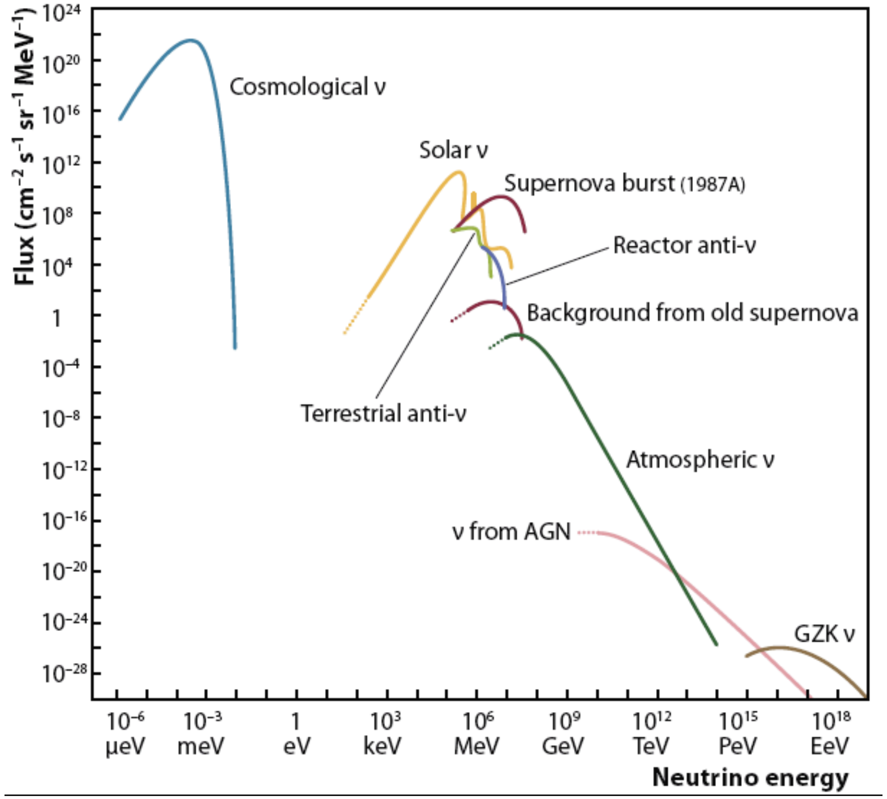
Reduce number of background events

Signal might be 1 event per tonne per year!!!

Signals

Typical: Neutrino Physics, Dark Matter searches, Rare decays

- Dark matter 0-20 keV
- Double beta decay: 0-5 MeV
- Reactor neutrinos: 0-8 MeV
- Solar neutrinos: 0-18 MeV
- Supernova neutrinos: 5-30 MeV
- Proton decay: 100 – 940 MeV
- Atmospheric neutrinos: MeV- GeV



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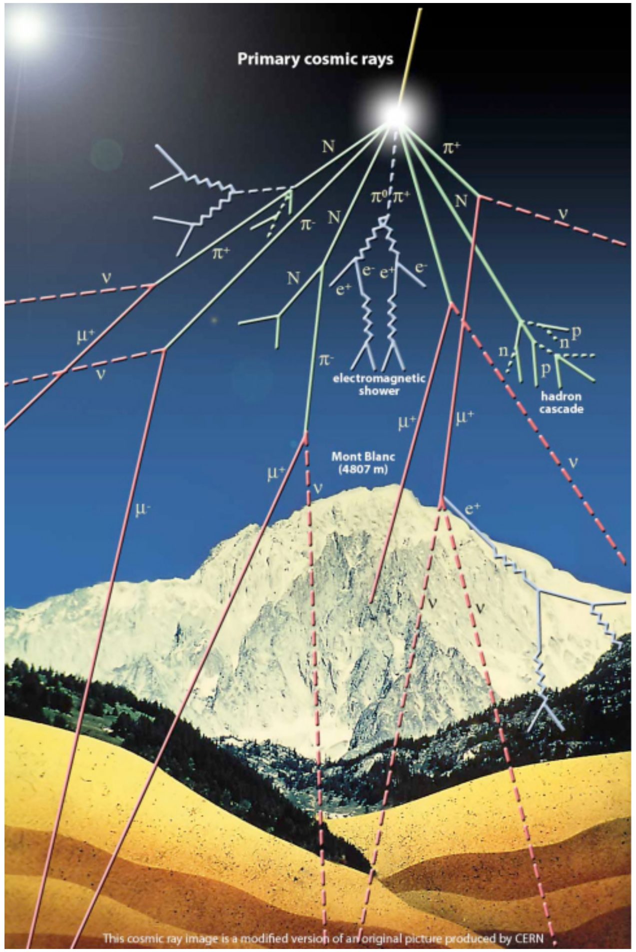
Background components

iktp

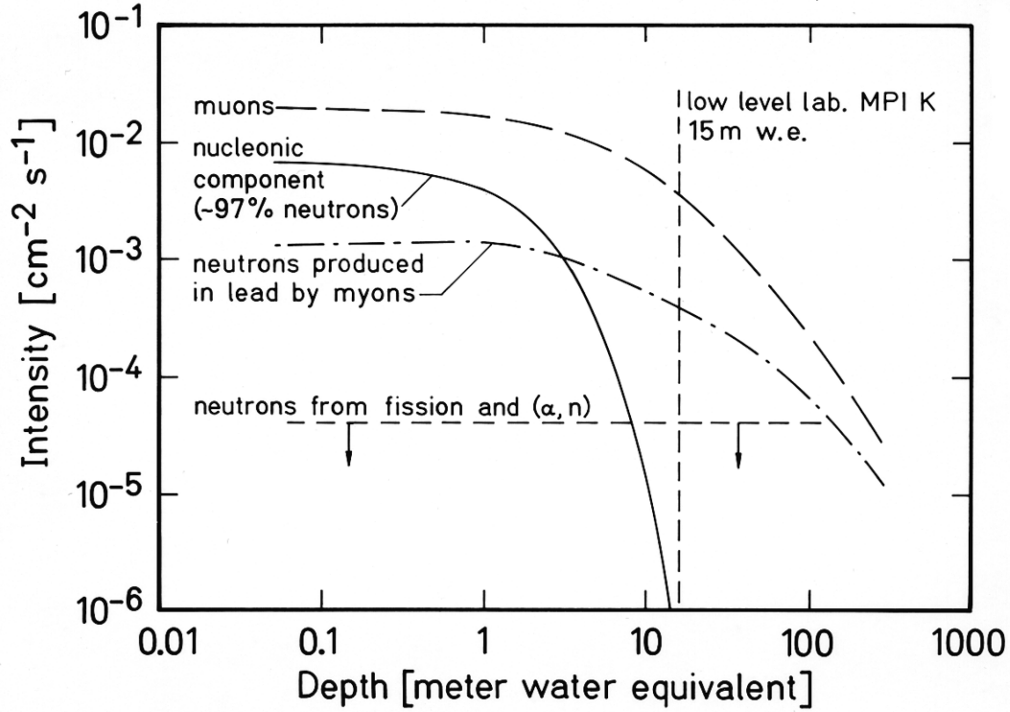
- Cosmic rays
- Atmospheric muons
- Radioisotopes produced by CR spallation (experiment specific)
- Natural Radioactivity (U,Th decay chains, ^{40}K)
- Long living radioisotopes (experiment specific)
- Neutrons
- Other experiment specific background

Cosmic rays

For a large community of people this is the signal!

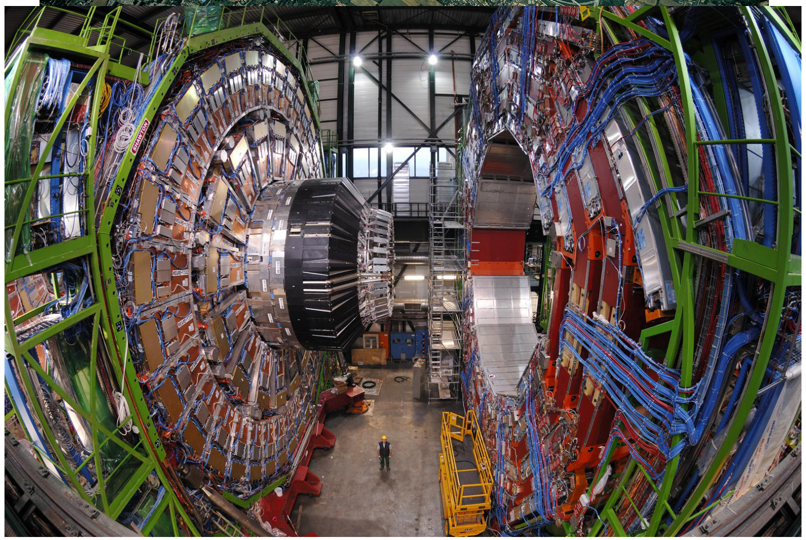


G. Heusser, 1993

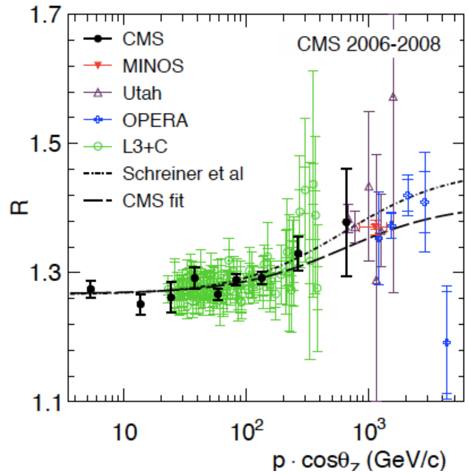


Shallow depth – cosmic rays

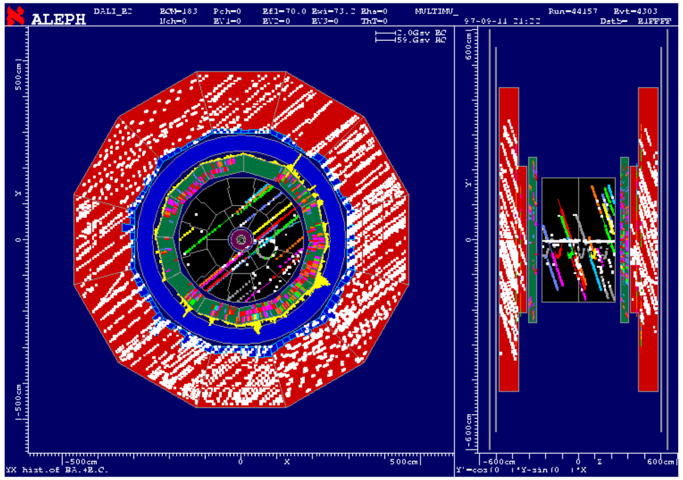
CMS experiment, 89m underground (6-175 mwe) at CERN



Muon charge ratio

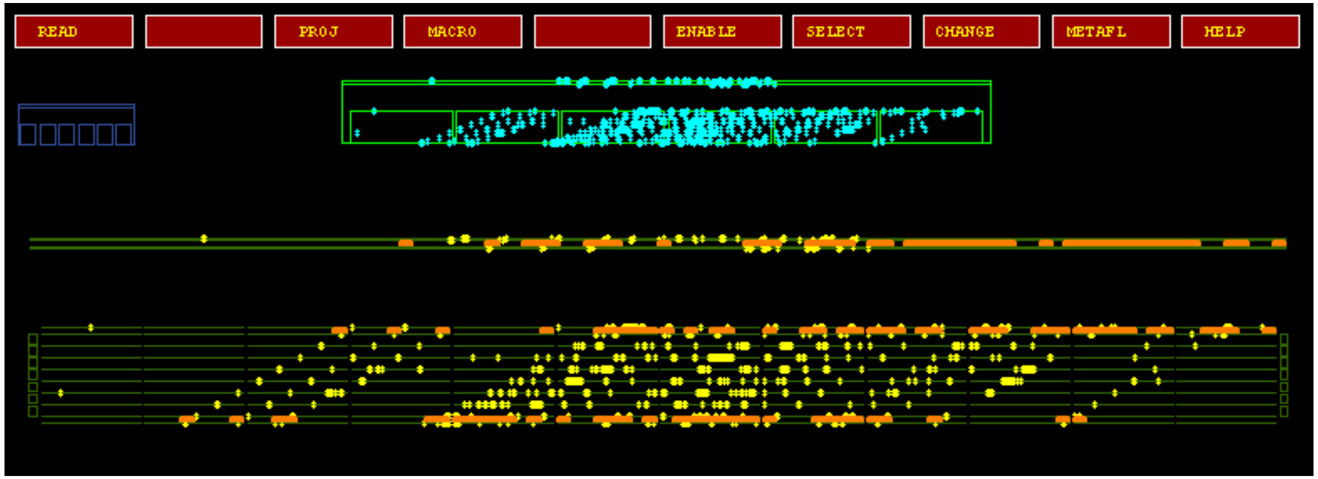


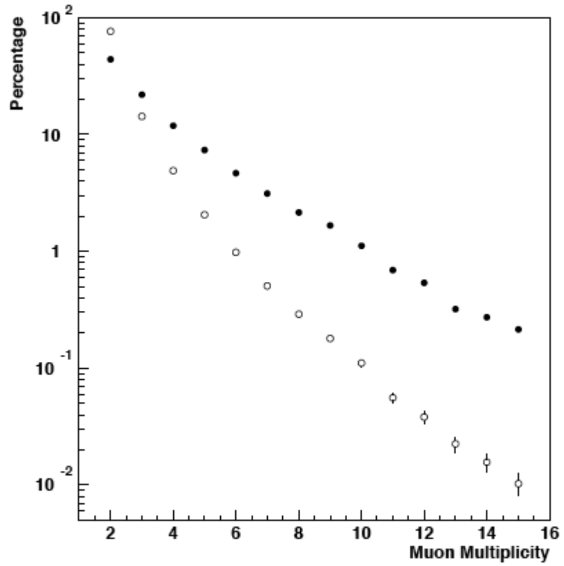
CMS, Phys. Lett. B (2010)



Multi muons at LNGS

Measurements with MACRO in hall B at LNGS





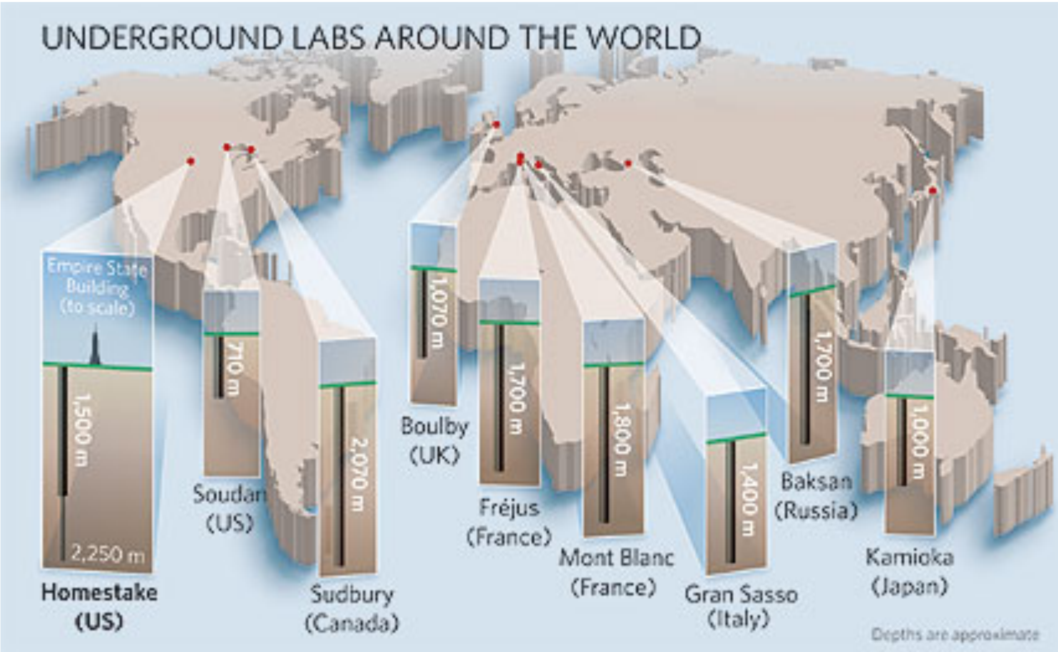
- Muon multiplicity depends on composition of cosmic rays

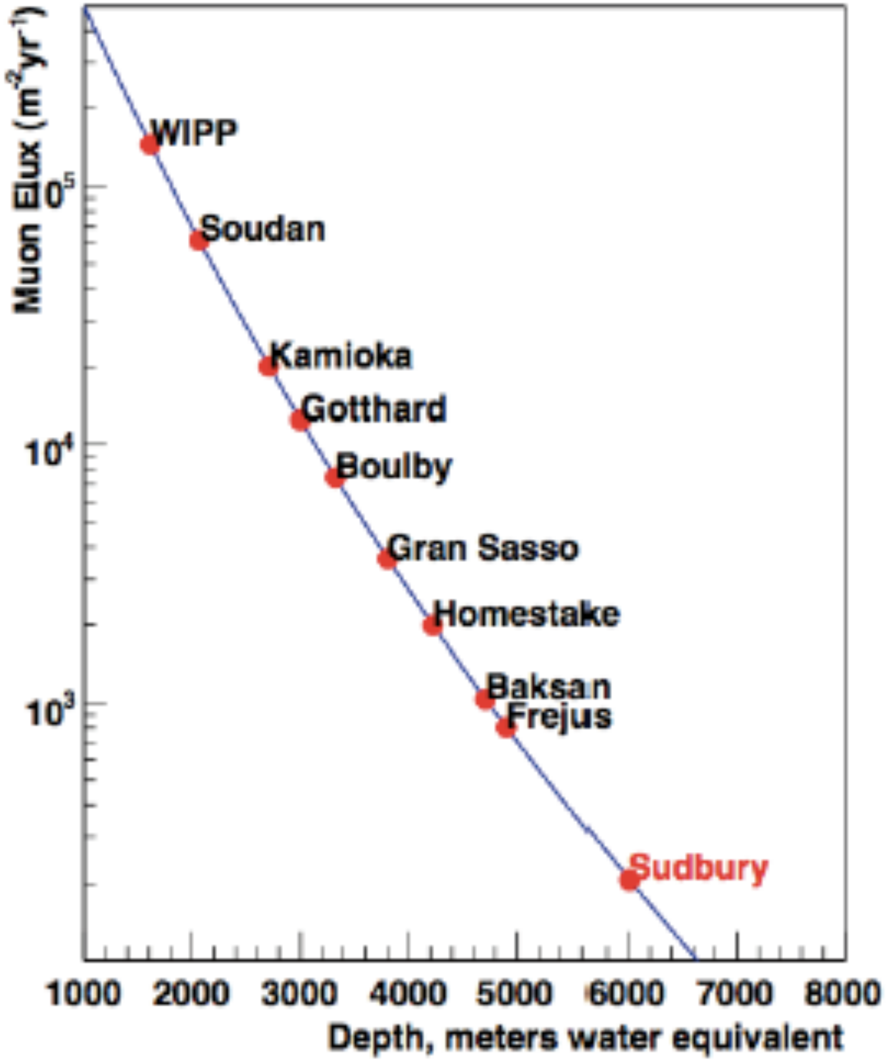
- Description/ simulation of cosmic ray showers can be improved by taking all these data into account

- Muons are the only cosmic ray particles penetrating deep underground

Underground Labs

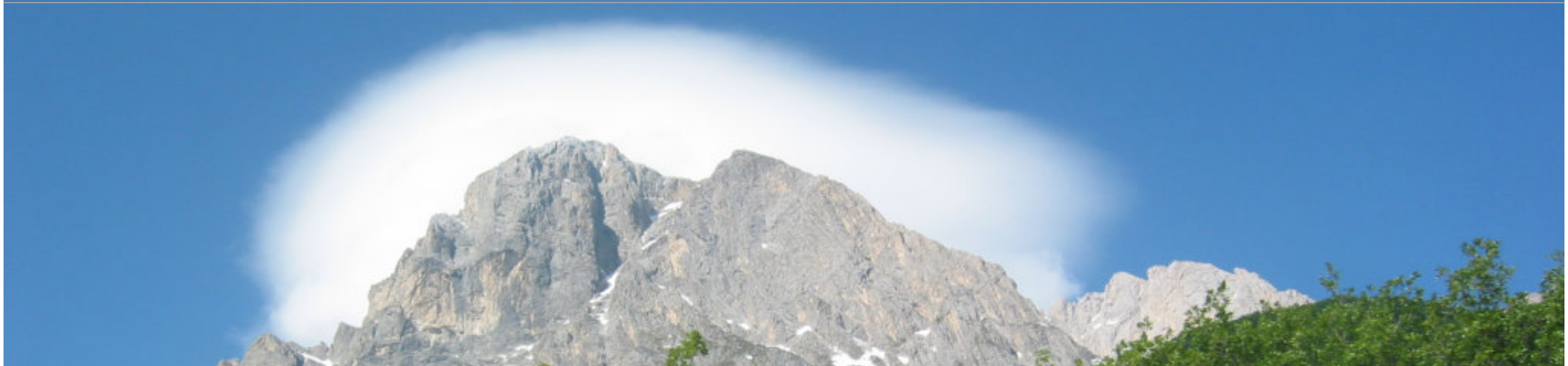
The deeper the better

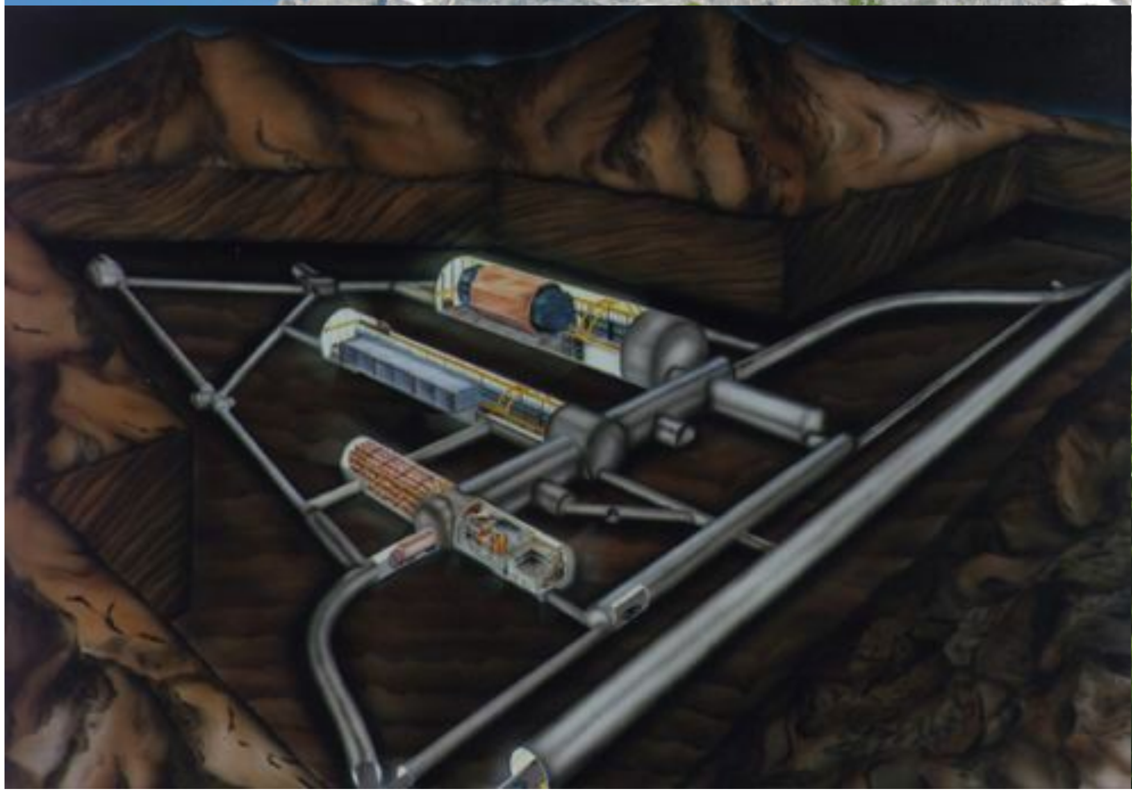


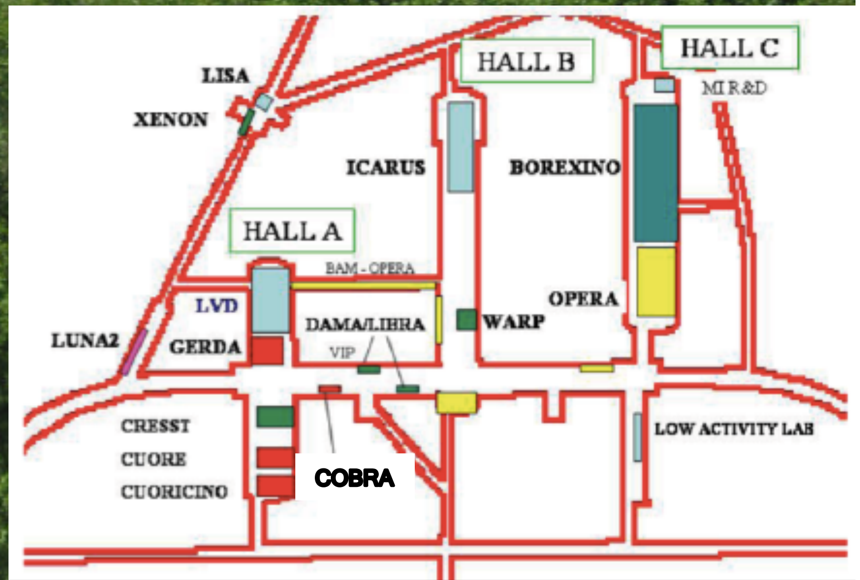


More to come....

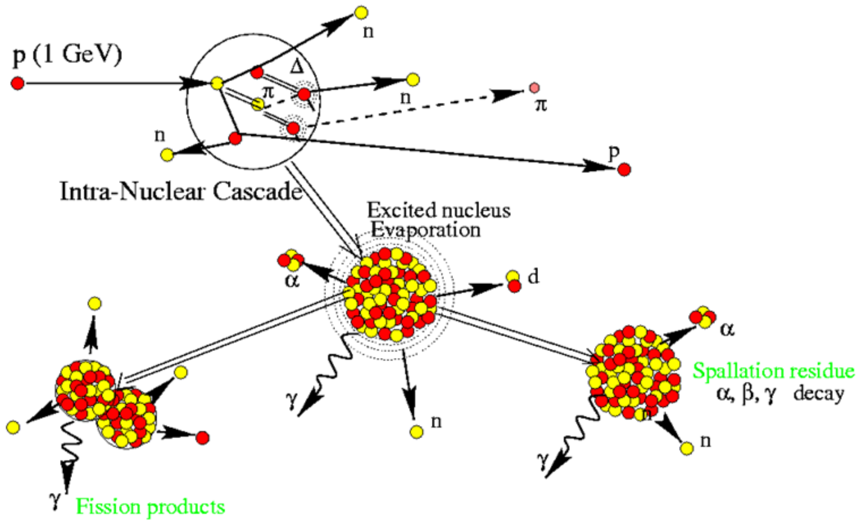
Gran Sasso

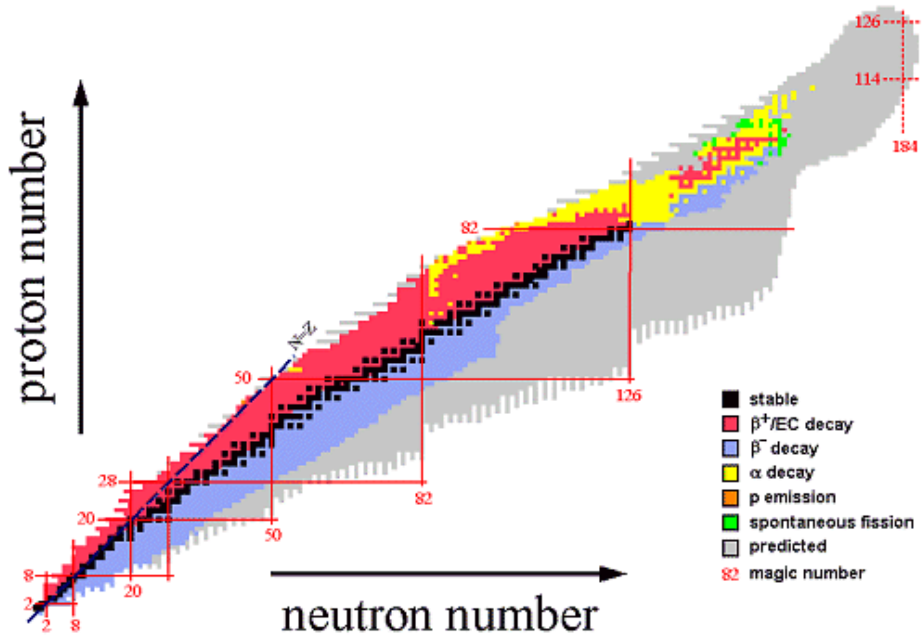





HALL A
HALL B
HALL C
LISA
XENON
ICARUS
BOREXINO
MI R&D
BAM - OPERA
LVD
DAMA/LIBRA
WARP
OPERA
LUNA2
GERDA
VIP
CRESST
CUORE
CUORICINO
COBRA
LOW ACTIVITY LAB

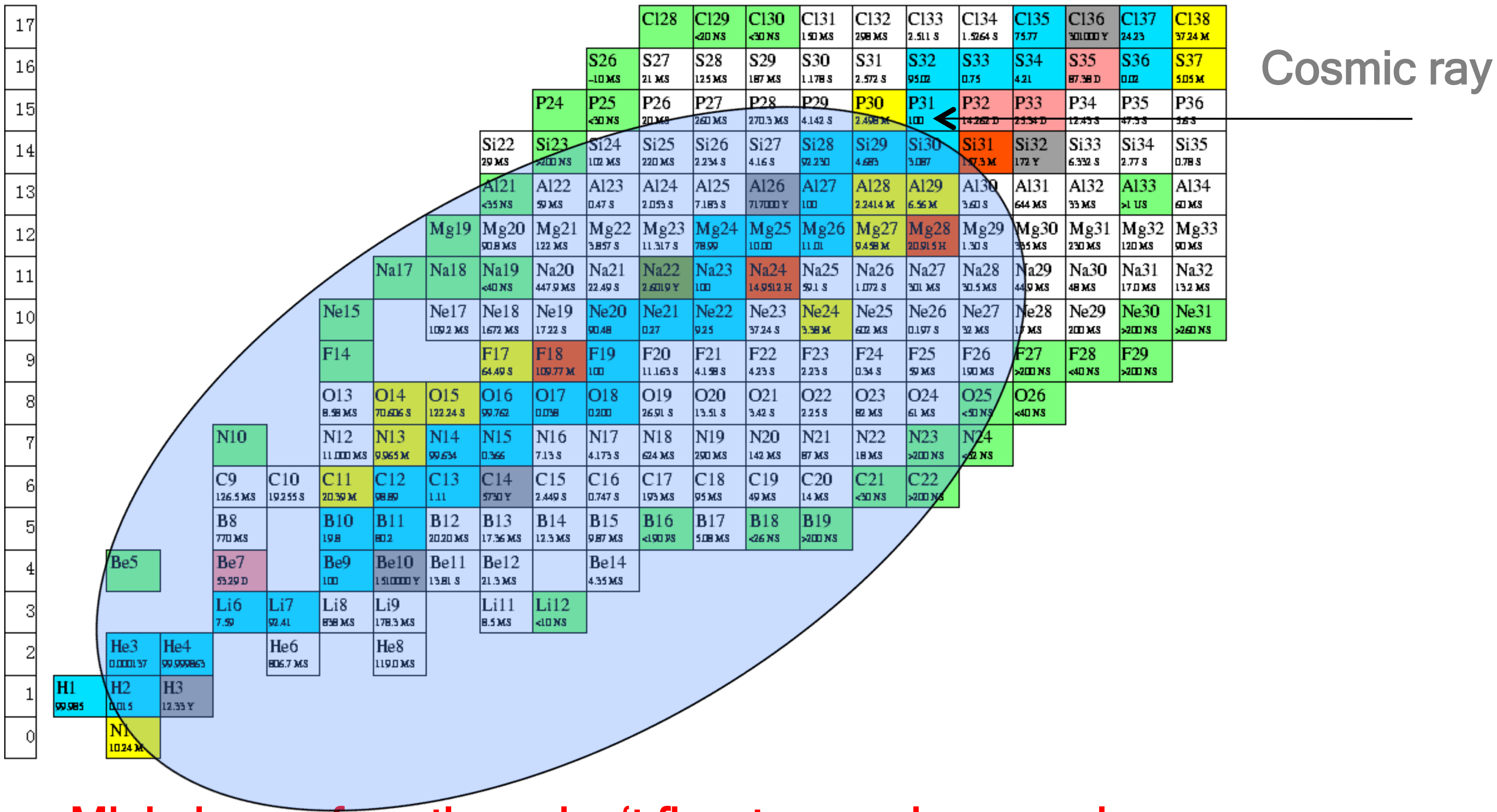
Cosmogenics: Radioisotopes produced by cosmic ray spallation





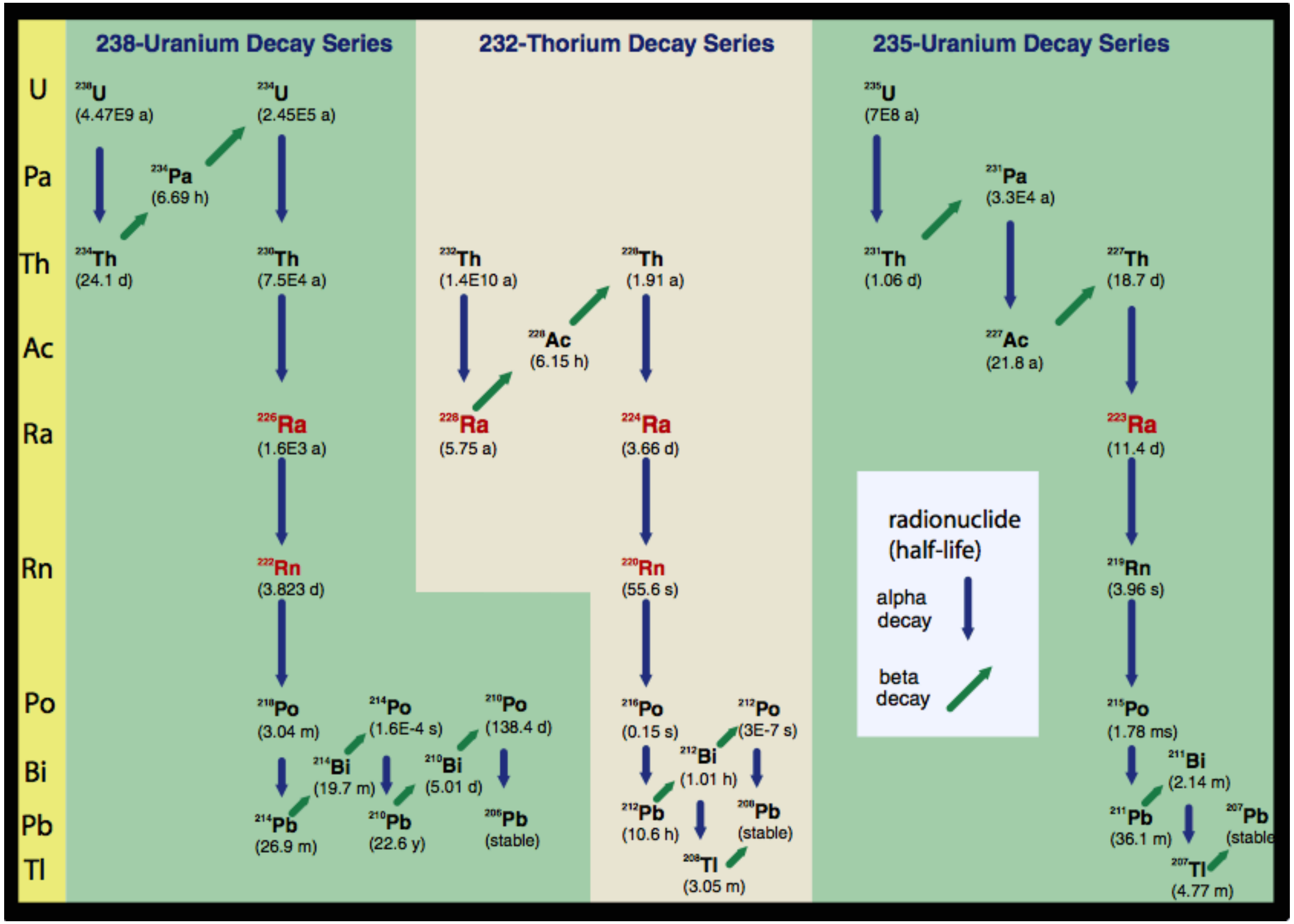
Cosmogenics

Dangerous : Long living ones (depends on decay mode and signal)!



Minimise surface time, don‘t fly, store underground

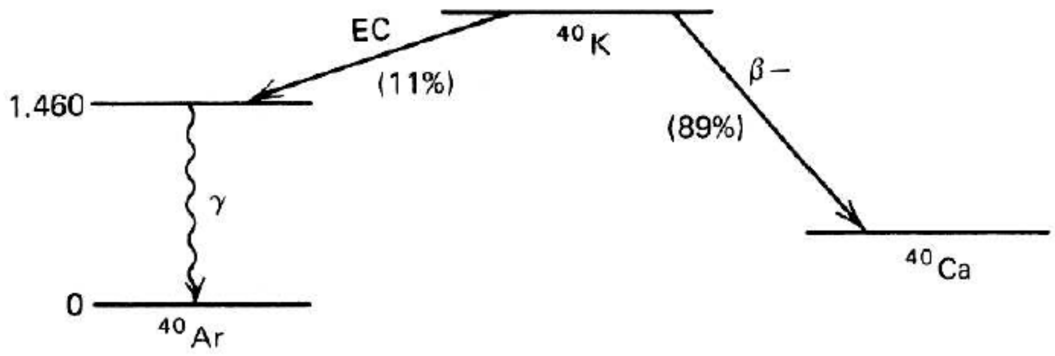
Natural decay chains



Gamma rays not shown

40K, Rn and others

Further primordial radionuclides 40K, 87Rb (no γ):

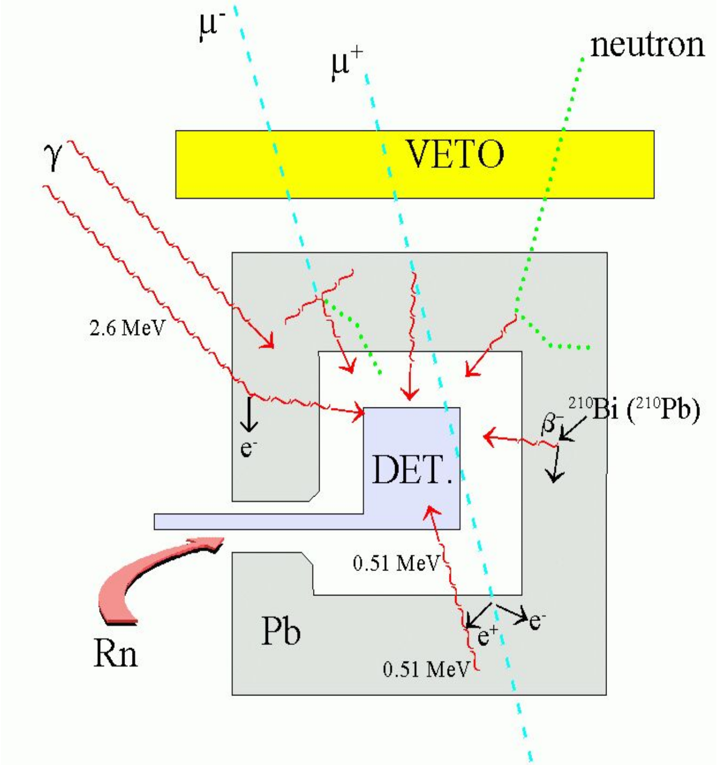


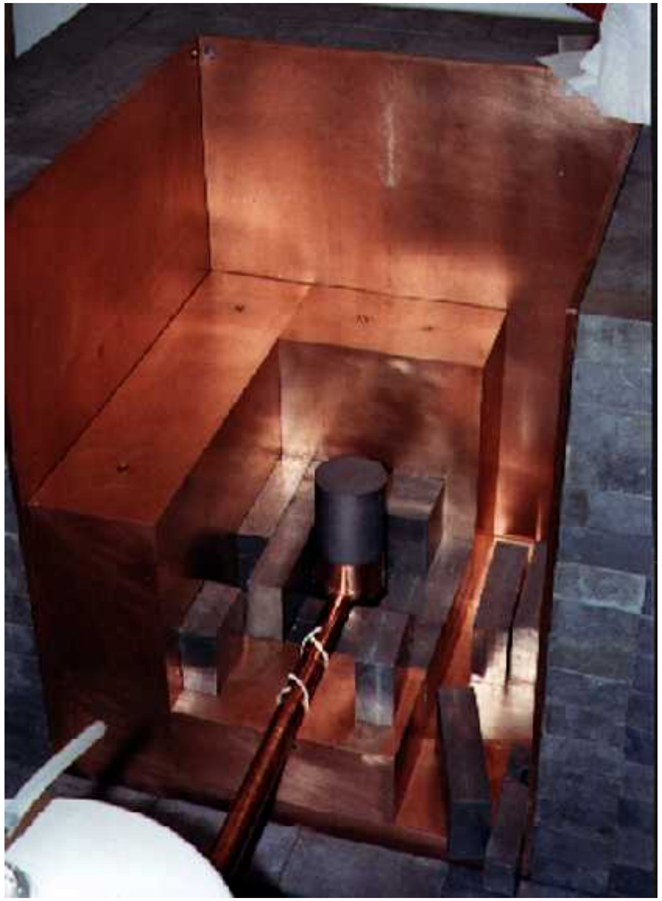
- Avoid Rn by nitrogen atmosphere, radon traps
- Try to minimise material around detectors

Determination of contaminations via Gamma-spectrocopy

Material screening

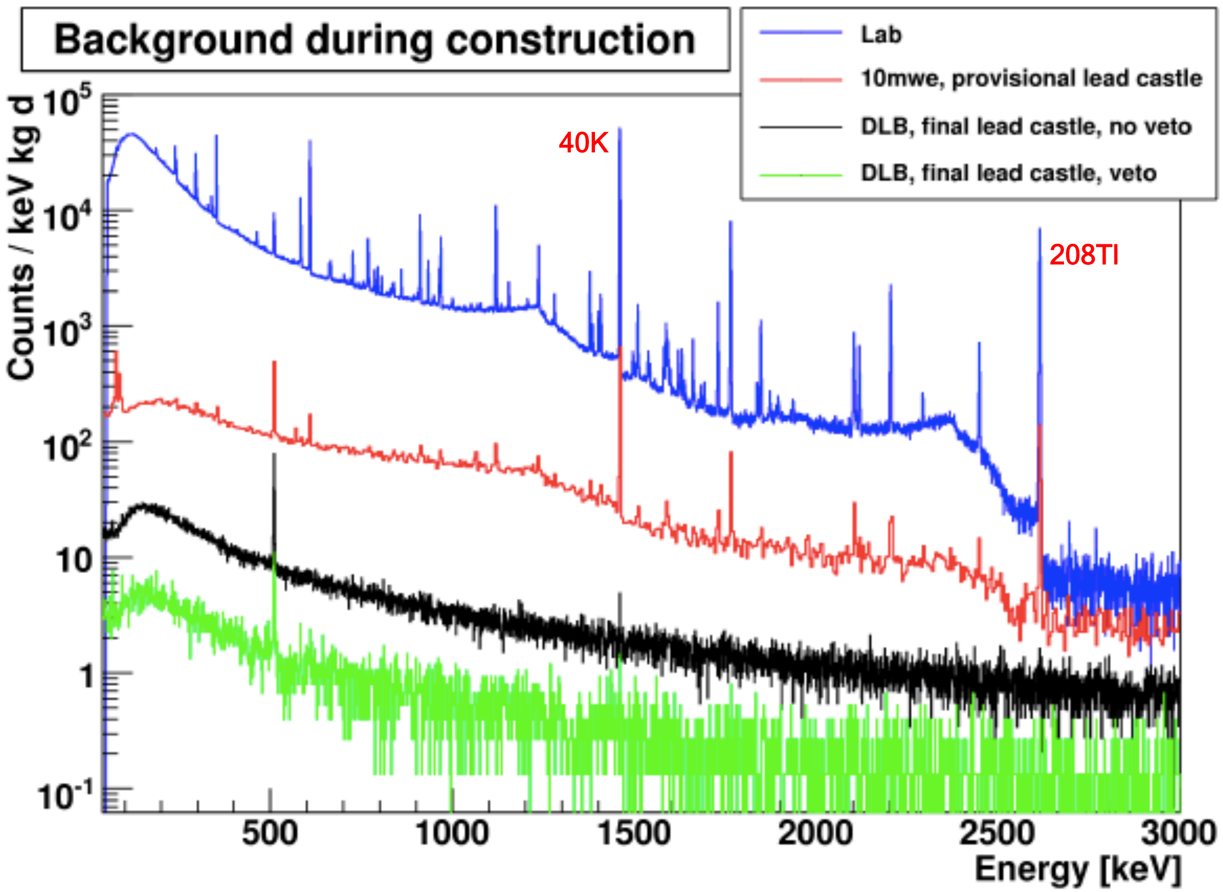
Every (!!!) single device/material has to be measured before you can use it!





Use Ge-semiconductor detectors!!!
Fantastic energy resolution

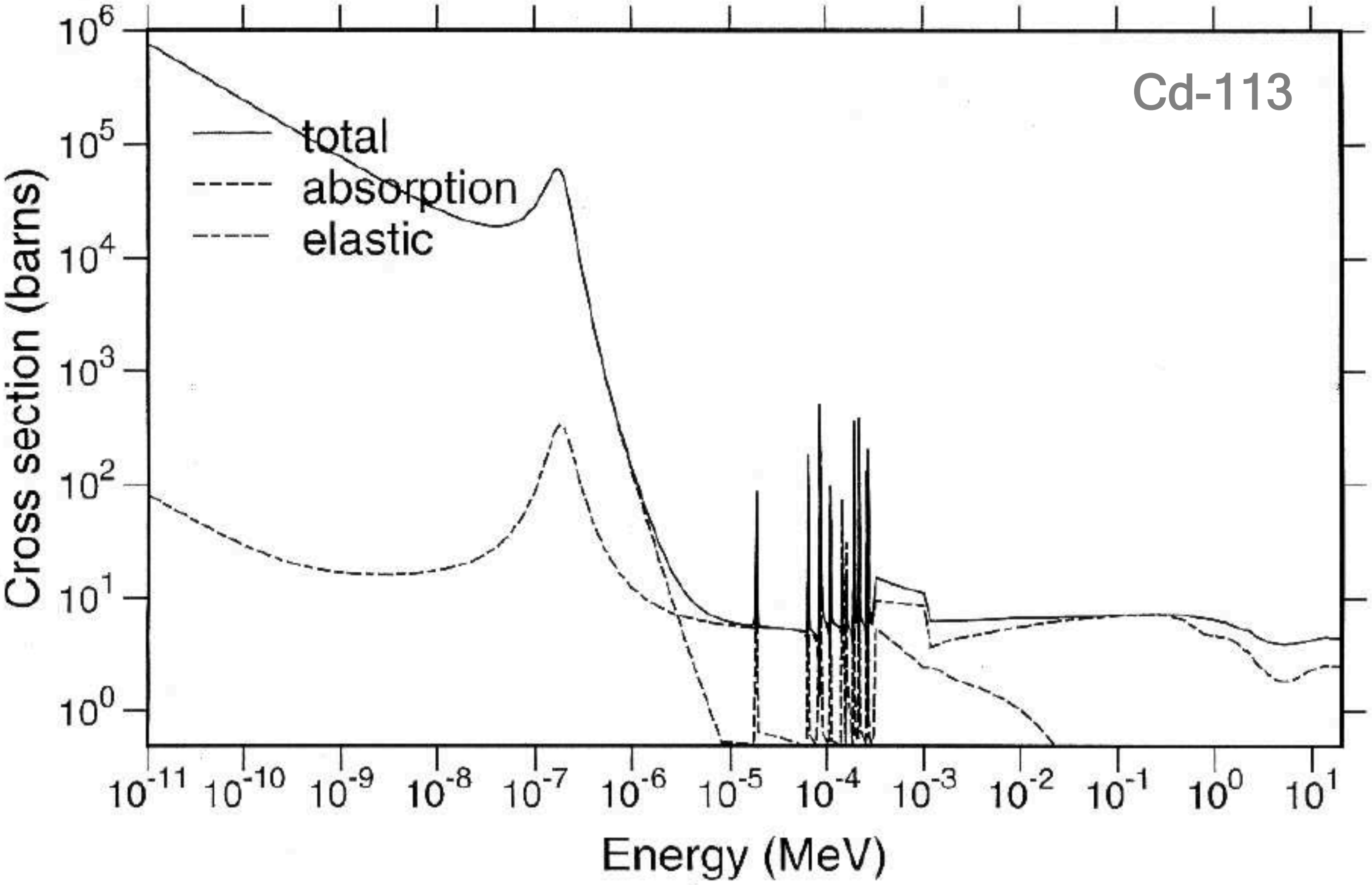
Gamma spectra



Requirements on most materials : < 10 µBq/kg !!!

Neutrons

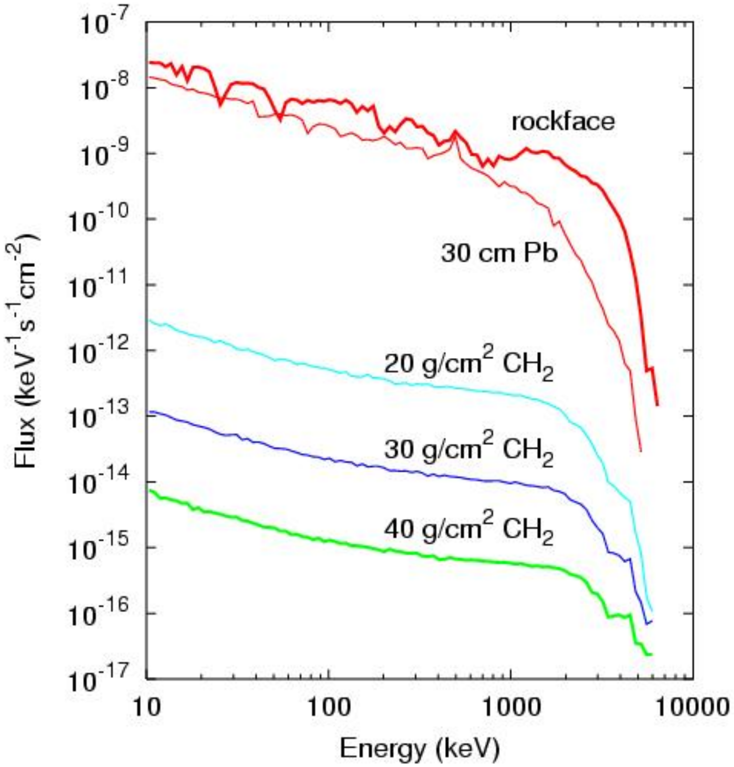
Extremely hard to shield, extremely dangerous for dark matter searches

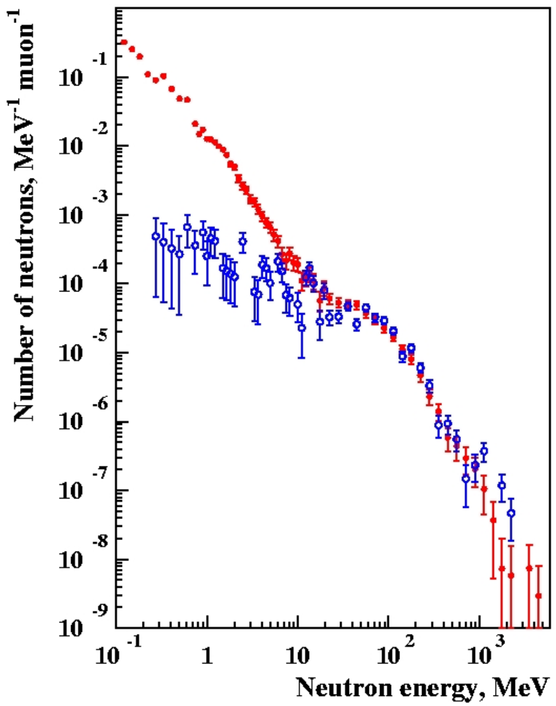


Neutrons

Underground sources: (α,n) reactions from fission, muon-induced neutrons

Shielding strategy: Moderate (paraffine, polyethylene (organic molecules) and capture (n, γ) (Cd, Gd) or (n, α) (B,Li)





Carson et al, Astroparticle Phys. 21, 667 (2004)

Ex.: Heidelberg – Moscow Experiment

- $(A,Z) \rightarrow (A,Z+2) + 2\,e^-$

Neutrinoless double beta decay

Requires a non-vanishing neutrino mass
Requires neutrino to be ist own antiparticle

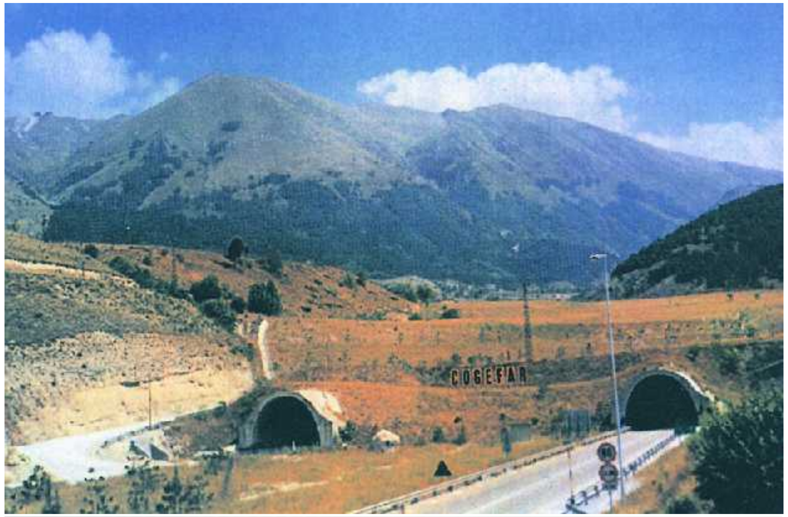
Requires half-life measurements well beyond 10^{25} yrs!!!!

Isotope of interest: 76Ge

- **The detectors are decaying!!**
- **5 isotopical enriched Ge-detectors**
- **Sum energy -> Peak at 2039 keV**

Still only 1 decay per year per 10 kg Ge

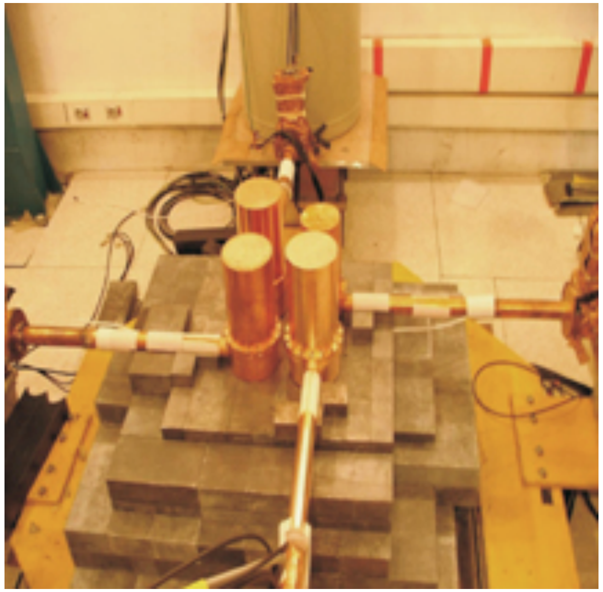
Background should be less than 1 count/keV/kg/yr



Ex.: Heidelberg – Moscow Experiment

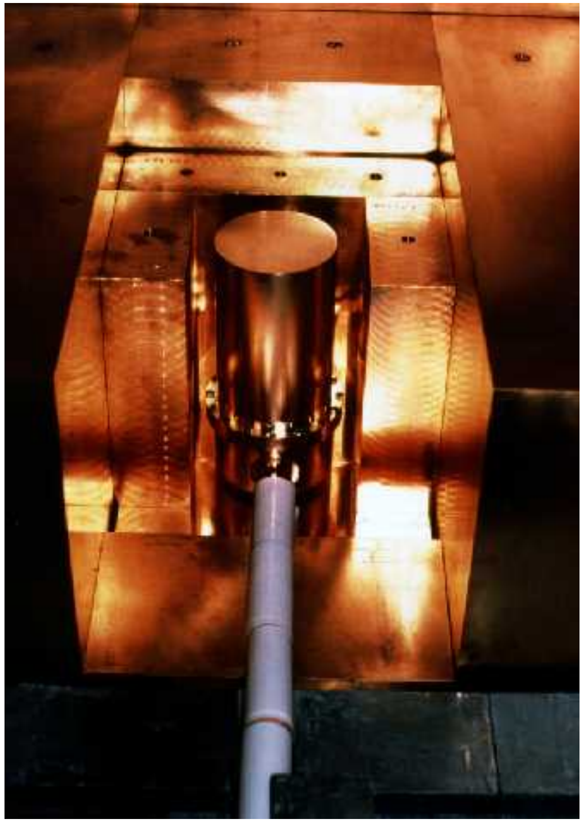
Special selected low activity lead (210Pb)

Side remark: Roman lead for CUORE

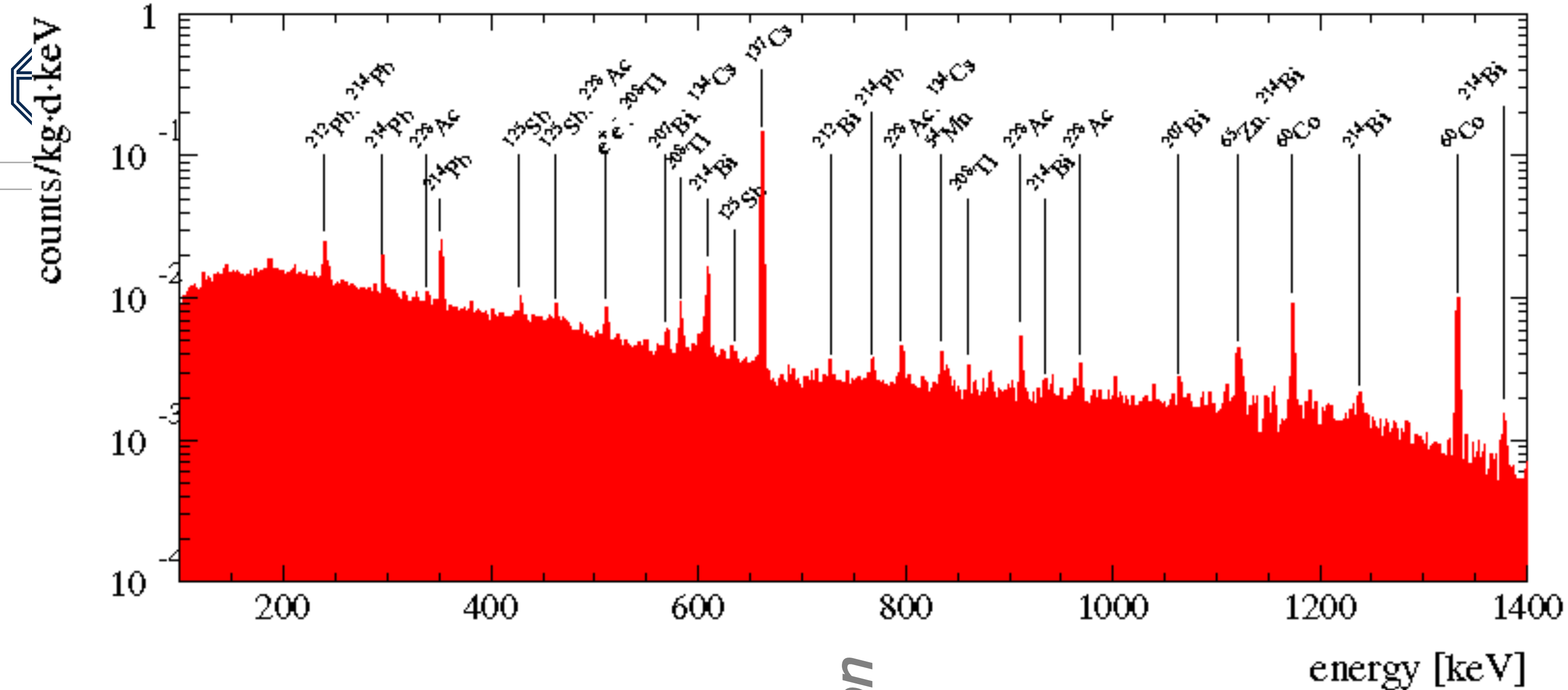


Crystals 2-5 were brought by Bundesmarine from USA, crystals stored well below water surface

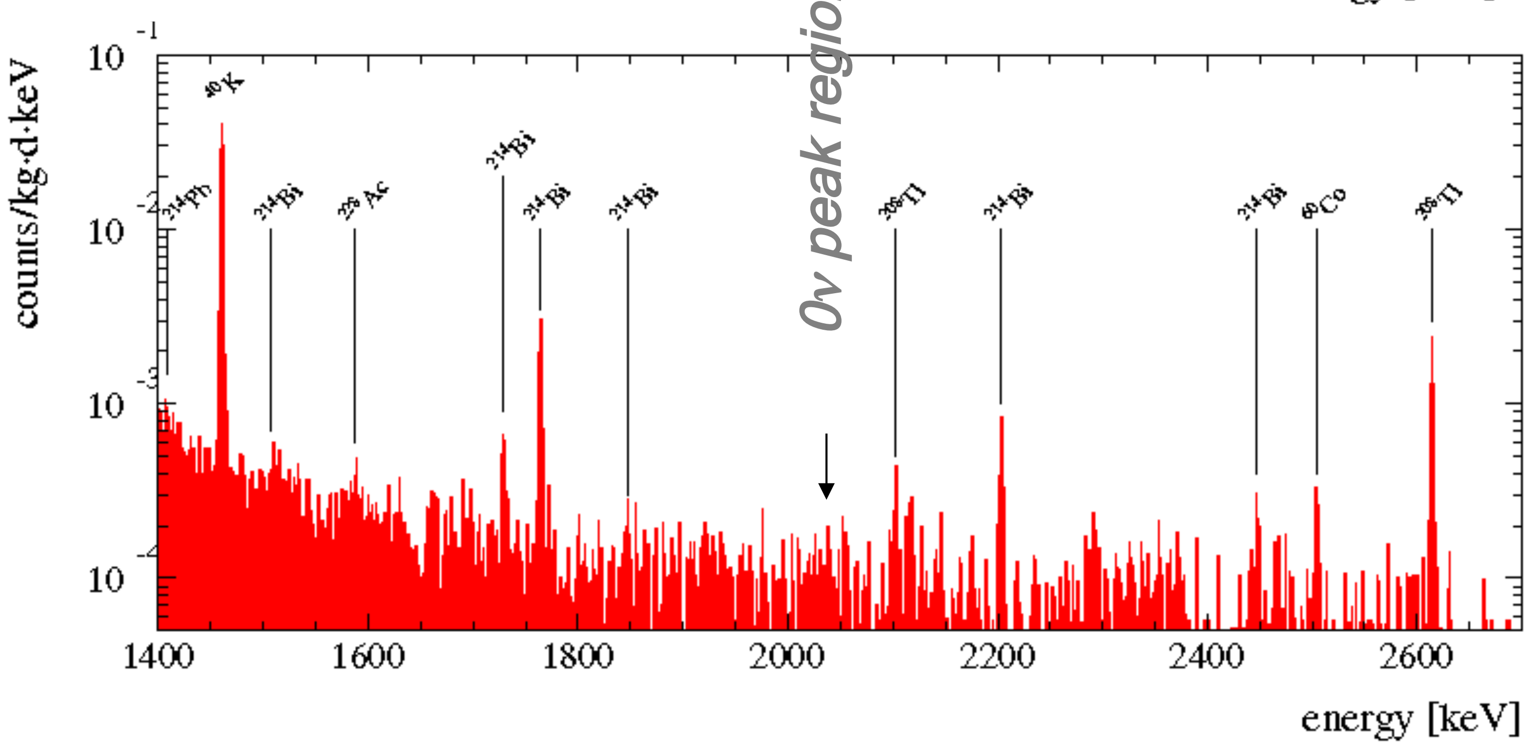
Ex.: Heidelberg – Moscow Experiment



Spectrum



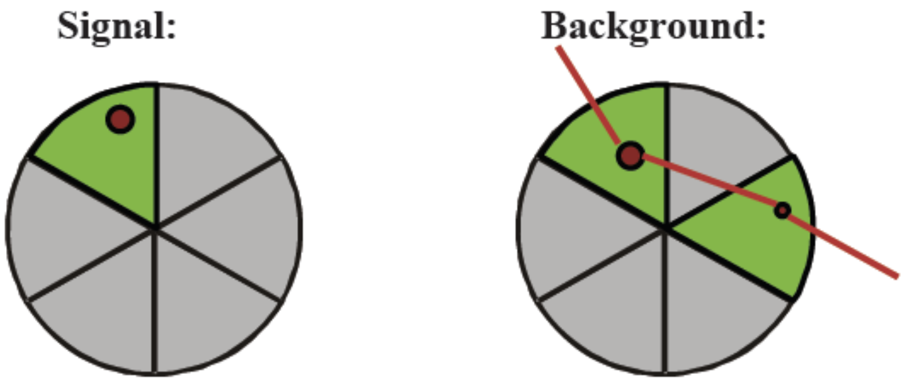
counts/kg·d·keV
energy [keV]
212Pb 214Pb 214Pb 228Ac 214Pb 125Sb 125Sb 228Ac e+e- 208Tl 207Bi 208Tl 134Cs 214Bi 125Sb 137Cs 212Bi 214Pb 228Ac 134Cs 54Mn 208Tl 228Ac 214Bi 228Ac 207Bi 65Zn 214Bi 60Co 214Bi 60Co 214Bi

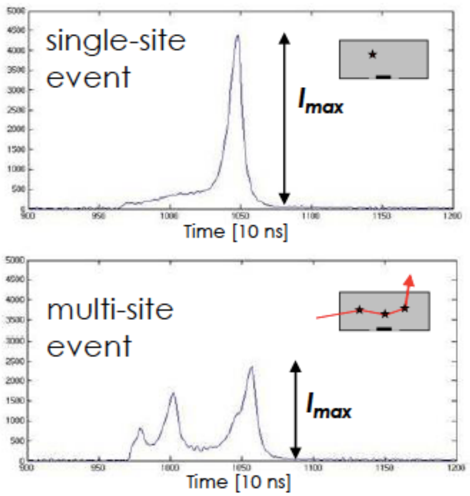


counts/kg·d·keV
energy [keV]
0ν peak region
40K 214Pb 214Bi 228Ac 214Bi 214Bi 214Bi 208Tl 214Bi 214Bi 60Co 208Tl

Pulse shape

Major backgorund: Compton scattered events from higher energy gamma lines





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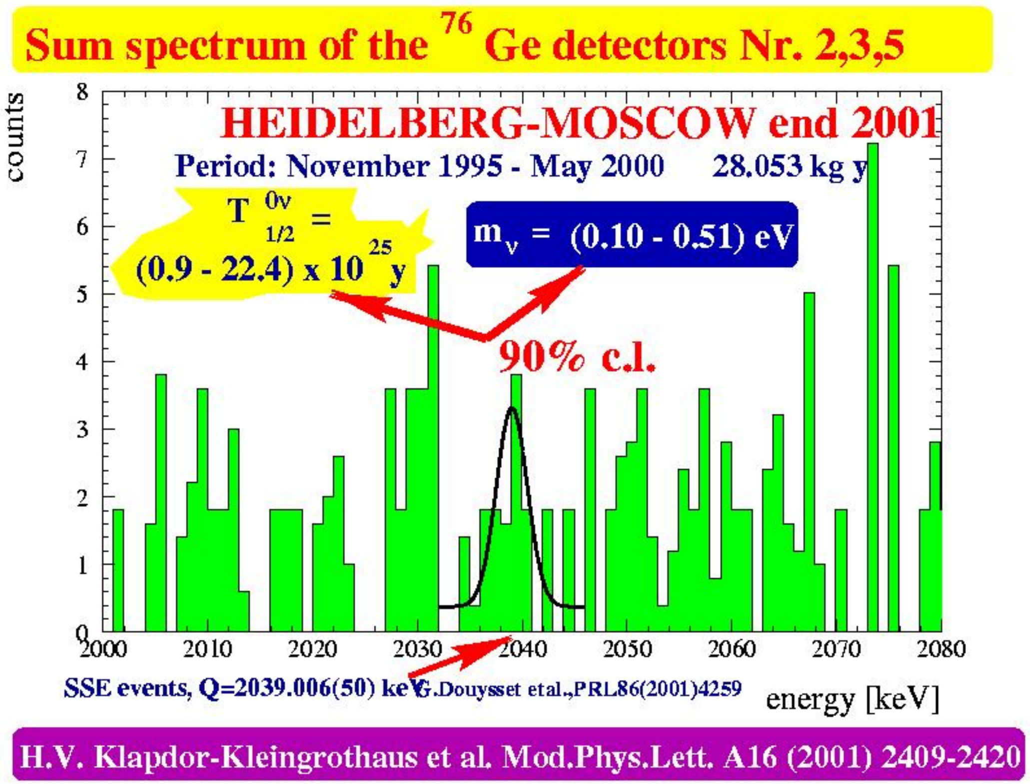
Heidelberg -Moscow



Part of collaboration:

$T_{1/2} = 2.23 \pm 0.4 \times 10^{25}$ yr → m = 0.32 ± 0.03 eV

H.V. Klapdor-Kleingrothaus et al., Phys. Lett. B 586, 198 (2004),
Mod.Phys.Lett.A21:1547-1566,2006

Current aims of double beta searches

Check whether observed peak claimed in ^{76}Ge is true

If yes, observe it with at least one other isotope to confirm that it is double beta decay

If not, next milestone will be 50 meV suggested by oscillation results

If still no observation, down to range 1-10 meV

Remember: $$m_\nu \propto \sqrt[4]{\frac{\Delta E B}{M t}}$$

Heidelberg- Moscow achieved 0.1 counts /keV/kg/yr

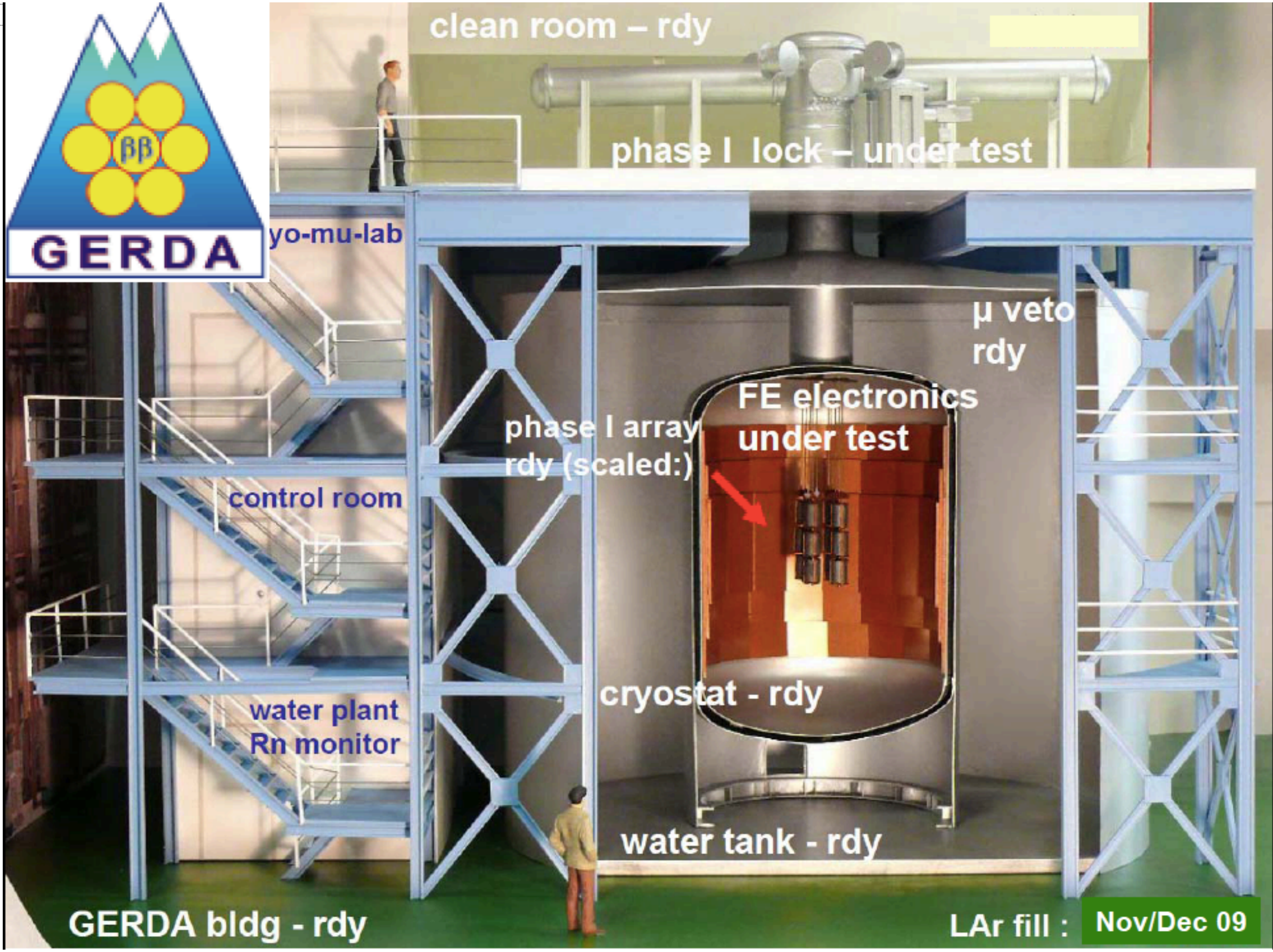
Next step: GERDA

Hd-Mo claim is that dominating background is from surrounding materials

Phase I : Use HD-Mo and IGEX detectors , achieve background of 0.01 counts/keV/kg/yr

Phase II: Add additional 20 kg enriched Ge-detectors, achieve background of 0.001 counts/keV/kg/yr

GERDA-Principal Setup



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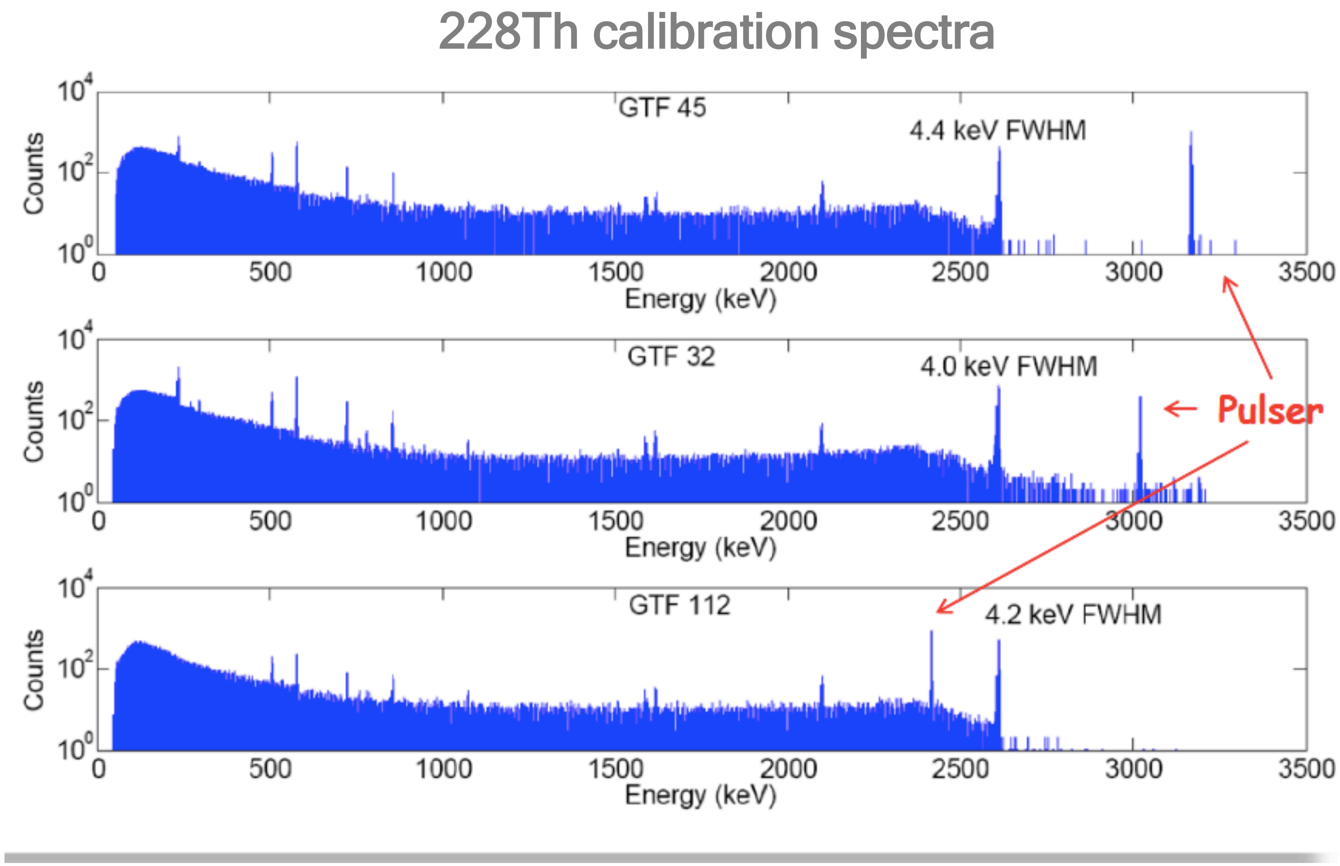
K. Zuber

Status

- **Nov/Dec.'09**: Liquid argon fill
- **Jan '10:** Commissioning of cryogenic system
- **Apr/Mai '10:** emergency drainage tests of water tank
- **Apr/Mai '10:** Installation c-lock
- **13. Mai '10:** 1st deployment of FE&detector mock-up (27 pF) - pulser resolution 1.4 keV (FWHM)
- **This week:** First deployment of non-enriched detector
- **Next:** Commissioning run with ^{nat}Ge detector string
- **Subsequently**: start Phase I physics data taking

June 2010

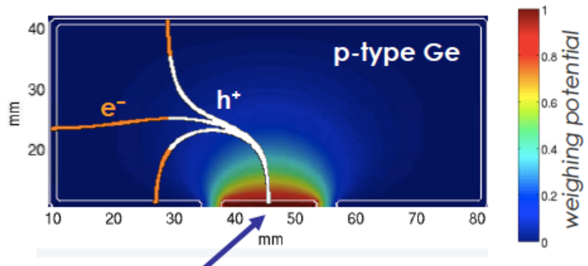
GERDA

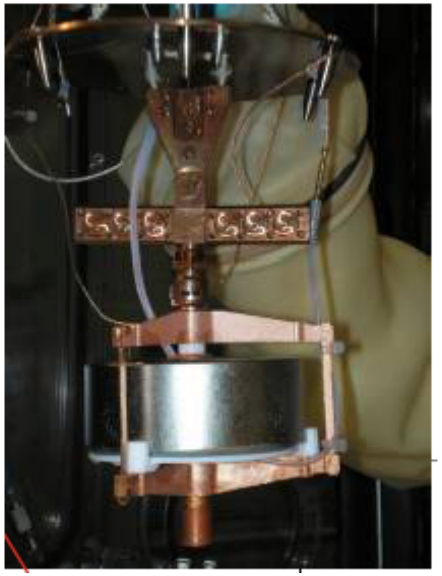

228Th calibration spectra
GTF 45
4.4 keV FWHM
GTF 32
4.0 keV FWHM
GTF 112
4.2 keV FWHM
Pulser
Counts
Energy (keV)
10^4
10^2
10^0
0
500
1000
1500
2000
2500
3000
3500

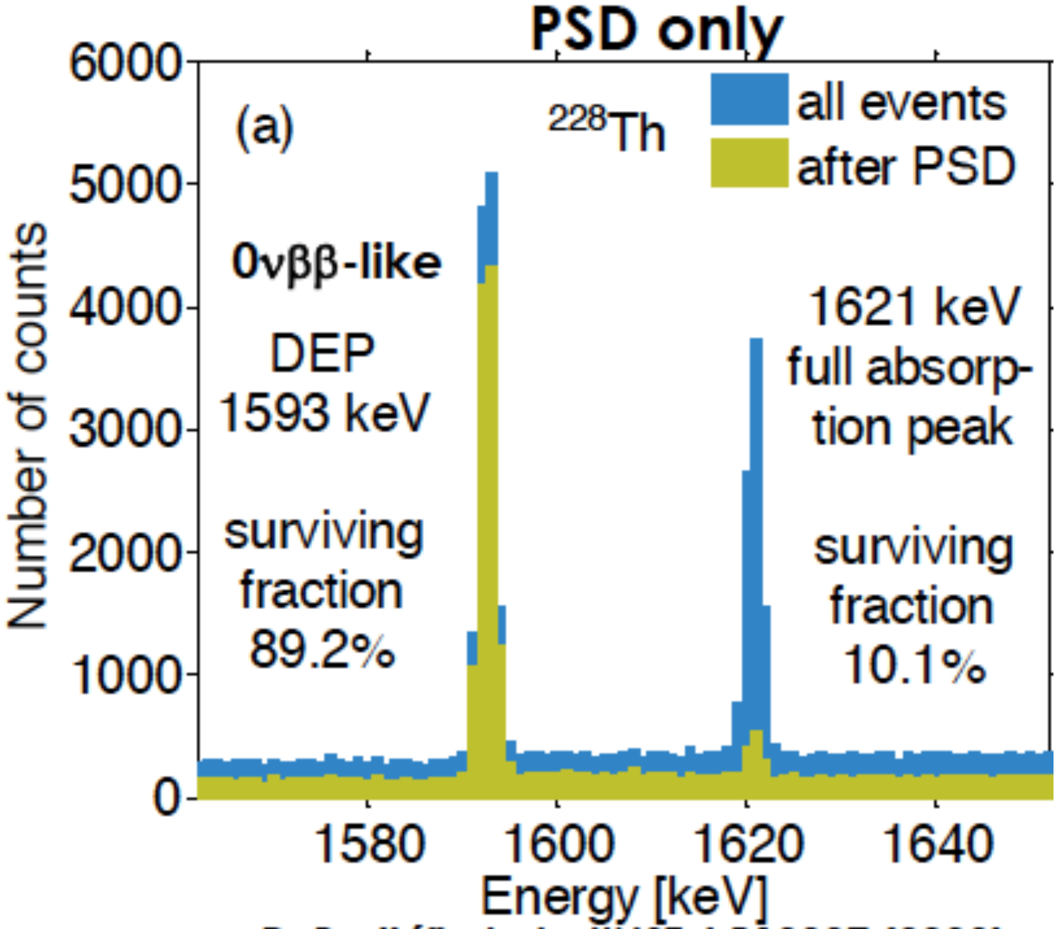
GERDA Detectors – Phase 2

Phase II: 35.4 kg enriched Ge purified to 6N, awaiting crystal growing

Candidate: **BEGe**







D. Budjáš et al., JINST 4 P10007 (2009)

Cosmogenic production

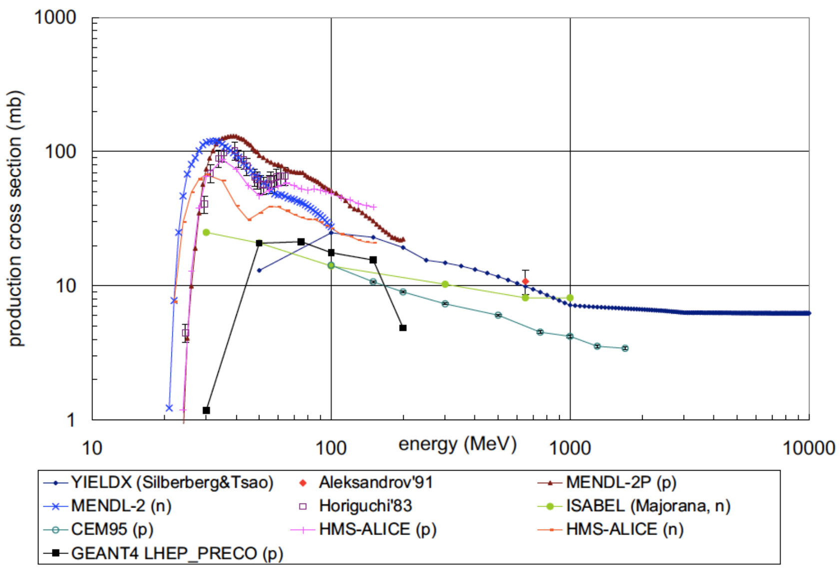
Se70 41.1 m 0+ EC	Se71 4.74 m 3/2-,5/2- EC	Se72 8.40 d 0+ EC	Se73 7.15 h 9/2+ * EC	Se74 0+ 0.89	Se75 119.779 d 5/2+ EC	Se76 0+ 9.36	Se77 1/2- * 7.63	Se78 0+ 23.78	Se79 1.13E6 y 7/2+ * β-	Se80 0+ 49.61	(α,n)
As69 15.2 m 5/2- EC	As70 52.6 m 4(+) EC	As71 65.28 h 5/2- EC	As72 26.0 h 2- EC	As73 80.30 d 3/2- EC	As74 17.77 d 2- EC,β-	As75 3/2- * 100	As76 1.0778 d 2- β-	As77 38.83 h 3/2- β-	As78 90.7 m 2- β-	As79 9.01 m 3/2- β-	(p,n) (p, γ)
Ge68 270.8 d 0+ EC	Ge69 39.05 h 5/2- EC	Ge70 0+ 21.23	Ge71 11.43 d 1/2- * EC	Ge72 0+ 27.66	Ge73 9/2+ * 7.73	Ge74 0+ 35.94	Ge75 82.78 m 1/2- * β-	Ge76 0+ 7.44	Ge77 11.30 h 7/2+ * β-	Ge78 88.0 m 0+ β-	(n,2n), (n, γ)
Ga67 3.2612 d 3/2- EC	Ga68 67.629 m 1+ EC	Ga69 3/2- 60.108	Ga70 21.14 m 1+ EC,β-	Ga71 3/2- 39.892	Ga72 14.10 h 3- * β-	Ga73 4.86 h 3/2- β-	Ga74 8.12 m (3-) * β-	Ga75 126 s 3/2- β-	Ga76 32.6 s (2+,3+) β-	Ga77 13.2 s (3/2-) β-	(n,p),(n,d)
Zn66 0+ 27.9	Zn67 5/2- 4.1	Zn68 0+ 18.8	Zn69 56.4 m 1/2- * β-	Zn70 5E+14 y 0+ 0.6	Zn71 2.45 m 1/2- * β-	Zn72 46.5 h 0+ β-	Zn73 23.5 s (1/2)- * β-	Zn74 95.6 s 0+ β-	Zn75 10.2 s (7/2+)	Zn76 5.7 s 0+ β-	(n,α)

Cosmogenics

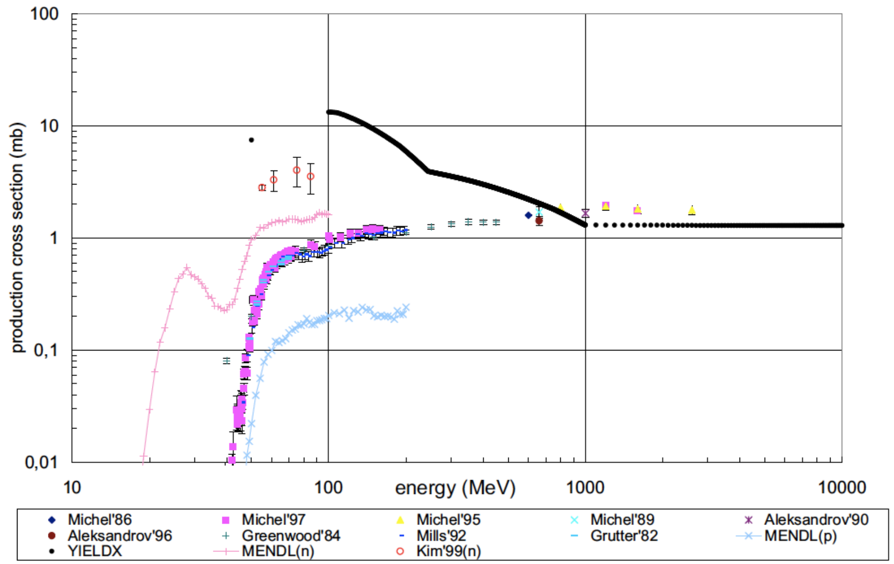
Radioisotope production by cosmic ray spallation in EVERY material you use

Cross sections determine (and neutron/proton fluxes) maximum time on surface

68Ge production in nat. Ge



59Fe production in nat. Cu



Studies within the FP6 ILIAS network

A lot of cross sections are badly known

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Wie alt ist der Rotwein?

Kann man das Alter von Rotwein bestimmen???

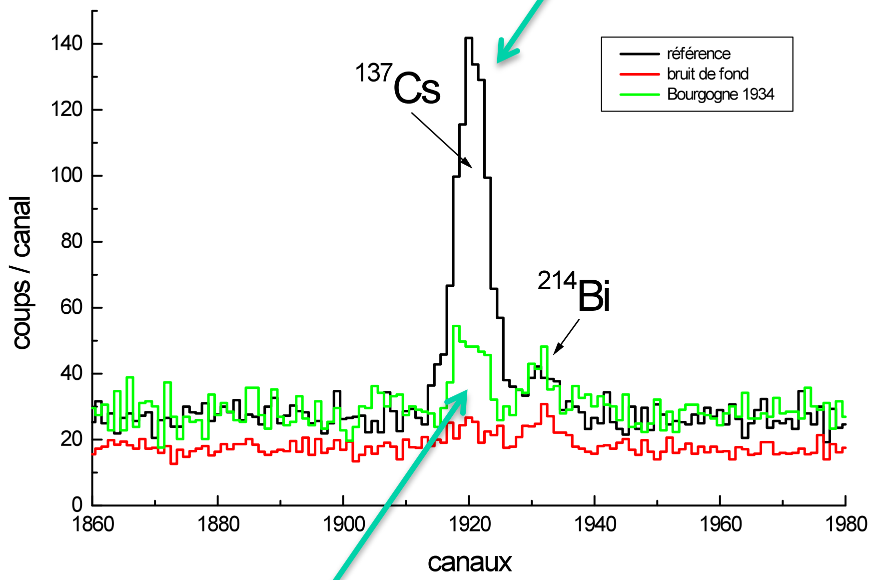
Und zwar ohne die Flasche zu öffnen?

Chateaux Lafite und Margaux 1900 ?

Die Verdächtigen

Test-Messung

Medoc 1963



NEIN!!! Kann kein Wein von 1934 sein!!!

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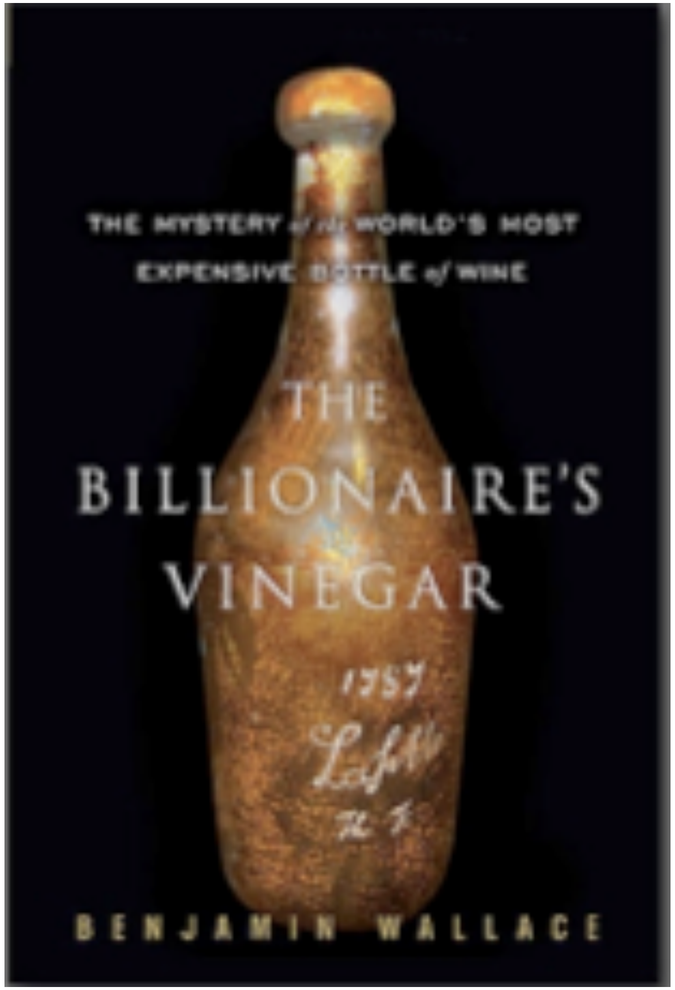
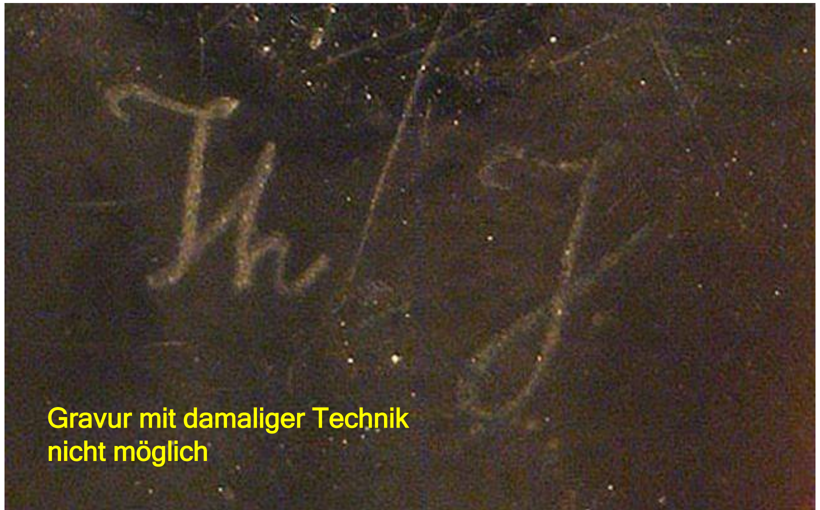


Photographie der Weinflaschen von Thomas Jefferson *höchstwahrscheinlich* aus den Jahren 1784 und 1787. Zwei Flaschen sind vom Chateau Lafite, zwei weitere von Branne Mouton, heute Mouton Rothschild genannt.

Der nächste Fall

Kein Cs137 beobachtet ➔ Älter als 1952



stern.de

http://www.stern.de/wirtschaft/news/unternehmen/entkorkt-der-grosse-weinschwindel-585424.html
Erscheinungsdatum: 25. März 2007, 12:39 Uhr

Entkorkt!:

Der große Weinschwindel

Jahrelang präsentierte Weinguru Hardy Rodenstock immer neue sensationelle Funde aus vergessenen Kellern. Seinen größten Coup, die Jefferson-Weine, hat ein US-Milliardär analysieren lassen. Ergebnis: Die Flaschen sind gefälscht. Nun ermittelt das FBI. ***Von Michael Streck, Stephan Draf und Bert Gamerschlag***

stern.de

http://www.stern.de/wirtschaft/news/unternehmen/hardy-rodenstock-der-grosse-etikettenschwindel-646400.html
Erscheinungsdatum: 23. November 2008, 15:01 Uhr

Hardy Rodenstock:

Der große Etikettenschwindel

Er schmückt sich mit Prominenten, und Prominente schmücken sich mit ihm. Für einen Abend mit Hardy Rodenstock zahlen Kenner große Summen. Er serviert echt uralte Weine - wenn man den Etiketten trauen darf. Das war mindestens einmal nicht der Fall. Nach *stern*-Recherchen hat Rodenstock Aufkleber jahrelang nachdrucken lassen. ***Von Stephan Draf, Bert Gamerschlag und Jörg Zipprick***

Warnung an alle: Sagen Sie den Winzern und Weinverkäufern nicht, dass sie low-background Kenntnisse haben!!!!

Die Geschichte geht weiter...

stern.de

http://www.stern.de/lifestyle/lebensart/das-raetsel-um-die-jefferson-flaschen-jefferson-im-westerwald-1560286.html
Erscheinungsdatum: 23. April 2010, 11:05 Uhr

Das Rätsel um die "Jefferson-Flaschen":

Jefferson im Westerwald

Die "Jefferson-Flaschen" machten Hardy Rodenstock weltbekannt. Aber fand er sie wirklich in Paris, wie er behauptet? *stern*-Reporter sind auf Graveure im Westerwald gestoßen, die behaupten: Moment, solche Flaschen haben wir doch gemacht! ***Von Stephan Draf, Bert Gamerschlag und Jörg Zipprick***

Diese Jefferson-Flaschen stammen laut den Jahreszahlen aus dem 18. Jahrhundert, die Gravurtechnik aber aus dem 20.
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Es war einmal ein Weinliebhaber im Westerwald, im beschaulichen Bad Marienberg. Im März 1985 klingelte sein Telefon. "Arr ju Misterr Rrroddenstock?", fragte ein Mann auf Englisch mit hartem französischem Akzent. Hardy Rodenstock bejahte. Er rufe aus Paris an, so die Stimme, und habe alte Weine entdeckt: Sind Sie interessiert?

Nach einem Beziehungsdesaster war Rodenstock, Exmanager der Schlagersängerin Tina York und anderer Barden, damals gerade dabei, sich von der Schlagerbranche auf den Handel mit Weinraritäten zu verlegen. Anrufe wie dieser konnten Einkünfte bedeuten.

TECHNISCHE UNIVERSITÄT DRESDEN

Summary

Search for rare events (neutrinos, dark matter, rare decays) is an essential part of particle physics and particle astrophysics, complementary to accelerator activities.

Expected event rates are extremely small (less than 1 per day in a big detector) normally covered by overwhelming backgrounds

However, field has done enormous progress over the last two decades in selecting clean materials, measuring contaminations in the order of μBq/kg, purification procedures, shielding designs

The excitement and interest in the field is reflected by the fact that more and more countries plan or build underground labs (US, China, Poland, Finland, Romania,...)

RECENT ADVANCES IN LOW LEVEL COUNTING TECHNIQUES[1]

By Ernest C. Anderson and F. Newton Hayes

Biomedical Research Group, Los Alamos Scientific Laboratory, University of California, Los Alamos, New Mexico

Ann. Rev.Nucl. Part. 6, 1956

Big issue: 14C: 5000 years

LOW-RADIOACTIVITY BACKGROUND TECHNIQUES

G. Heusser

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Ann. Rev.Nucl. Part.45, 1995

Big issue: DBD: 10^{25} years