(Irreducible) Backgrounds (specific to HPGe)

The good: Metallization

The bad: Surfaces, ^{68}Ge

And the ugly: Neutrinos, Muons, Neutrons

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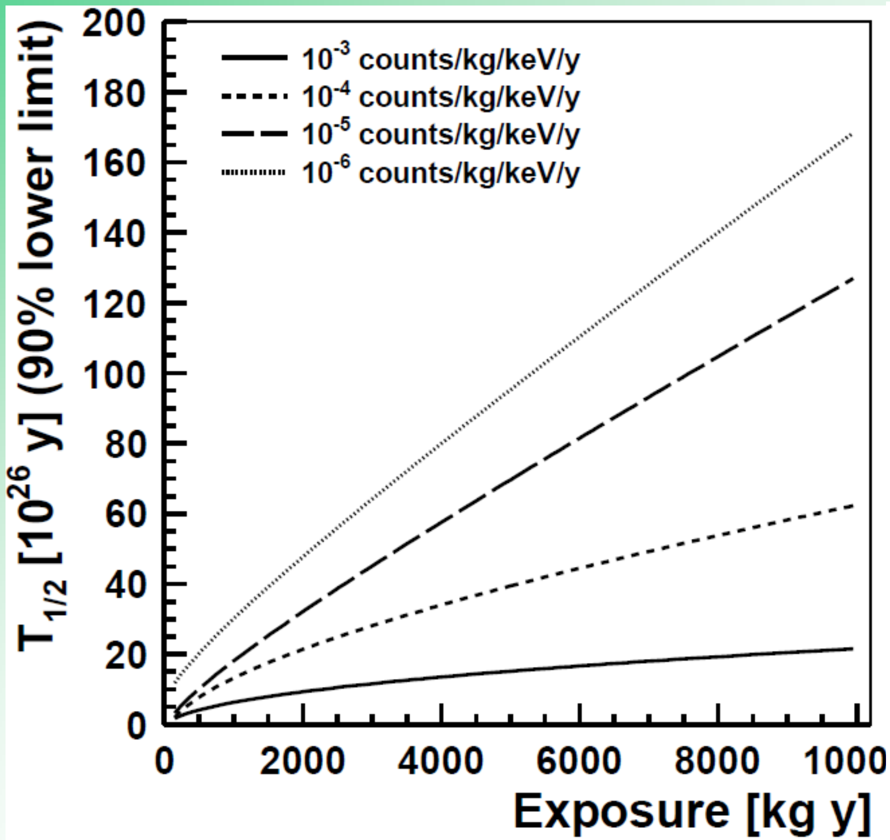
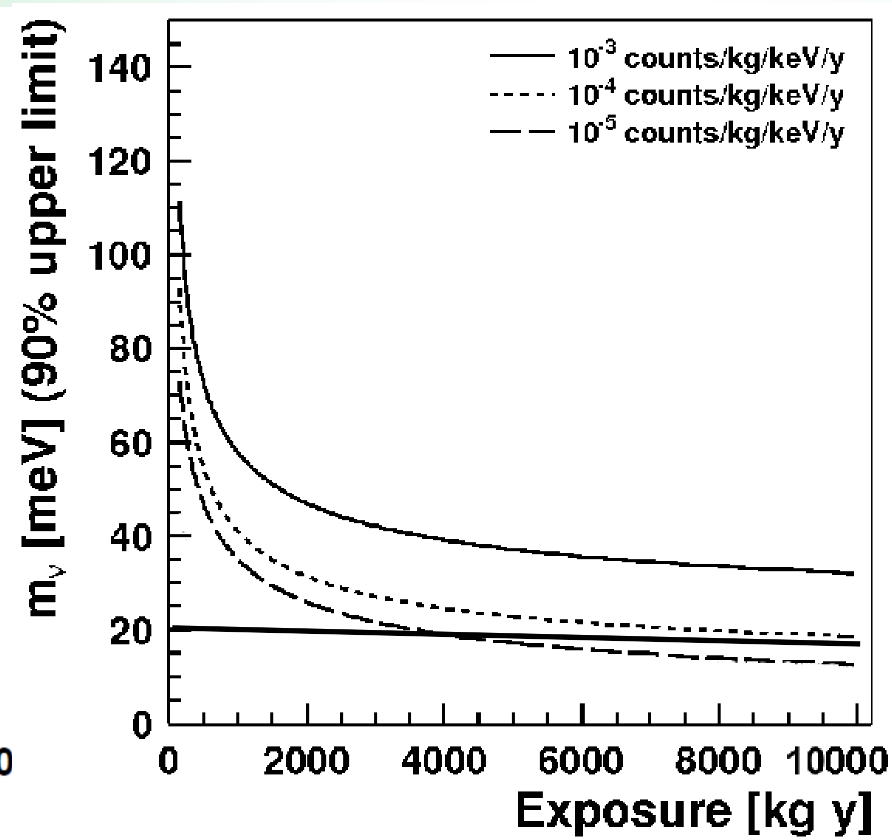
Ton Scale Required Background:





Ton scale experiment requires background of 10^{-5} cts/(kg keV y)

Aluminum as background

Aluminum: used for many useful things

Aluminum as background

Used to metallize HPGe detectors.

Example case:

Full metallization of HPGe type detector with 75 mm diameter and 70 mm height

$$2\cdot\pi\cdot3.75\text{cm}\cdot300\text{nm}\cdot7\text{cm}\cdot2.7\text{g/cm}^3$$

$$=$$

13.4mg

of aluminum on the outer surface

→**Primordials: ^{238}U - ^{232}Th**

→**Cosmogenics: ^{26}Al, ^{22}Na**

Aluminum as background

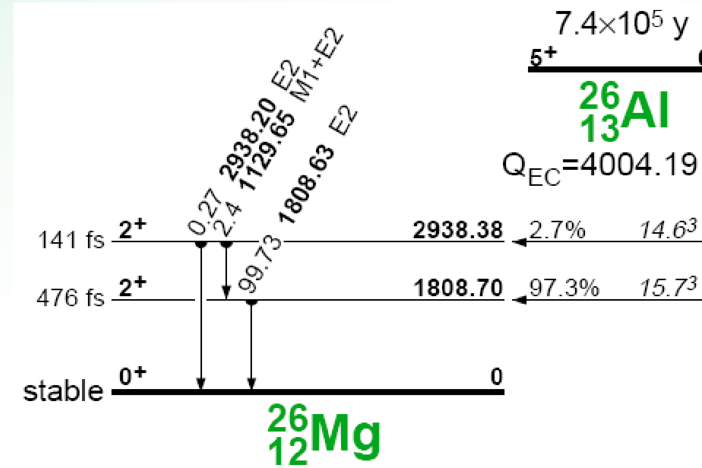
^{26}Al: $\beta+$ decay,

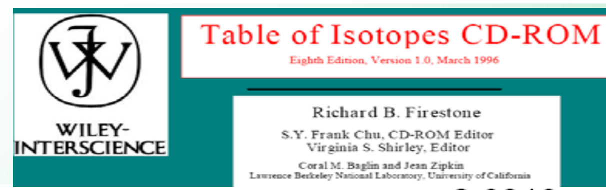
Q-value: 4 MeV,

$T_{1/2}=7.4\cdot 10^5$ years

Can not be removed easily from bulk aluminium

Can not wait for decay



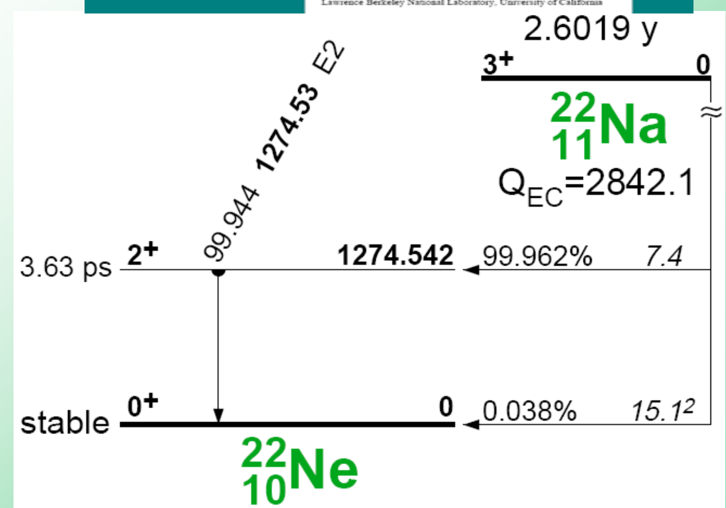


^{22}Na: Q-value: 2.84 MeV,

$T_{1/2}=2.6$ years

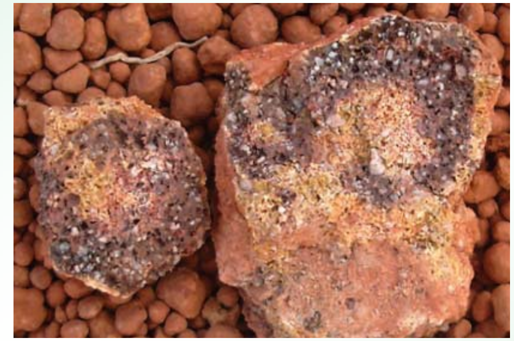
Easily produced if at sea level

Can wait for decay



Aluminum as background

Aluminum is refined from Bauxite.

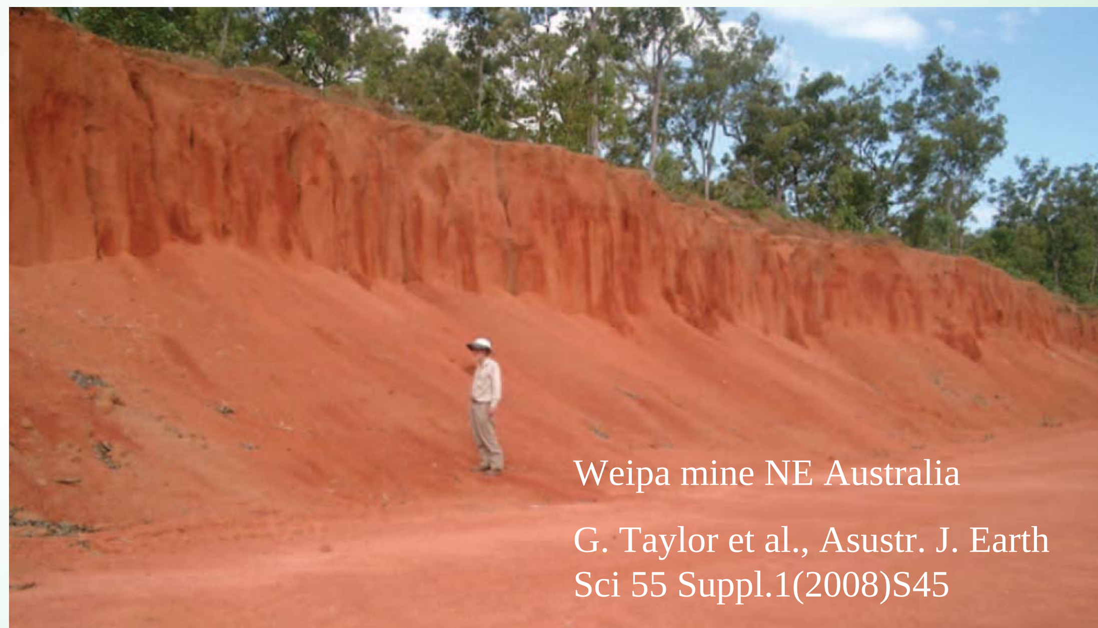


Bauxite mines:

mainly open pits

Top soil overburden: < 1m

Layer thickness: 2m – 4m



Weipa mine NE Australia

G. Taylor et al., Asustr. J. Earth Sci 55 Suppl.1(2008)S45

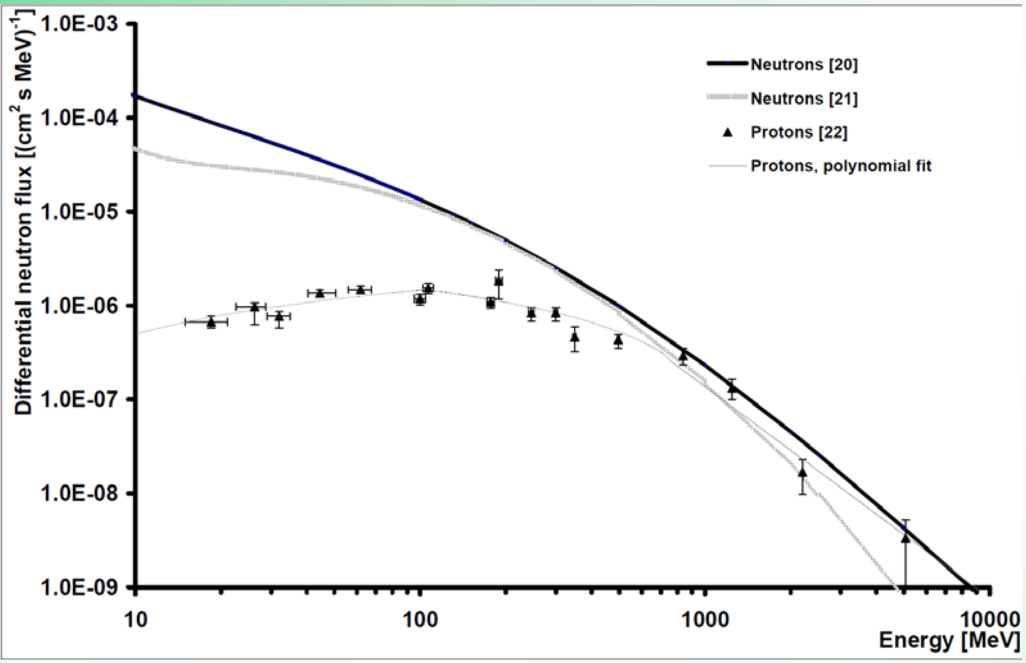
Deposits formed by weathering

→Rested on surface since its formation

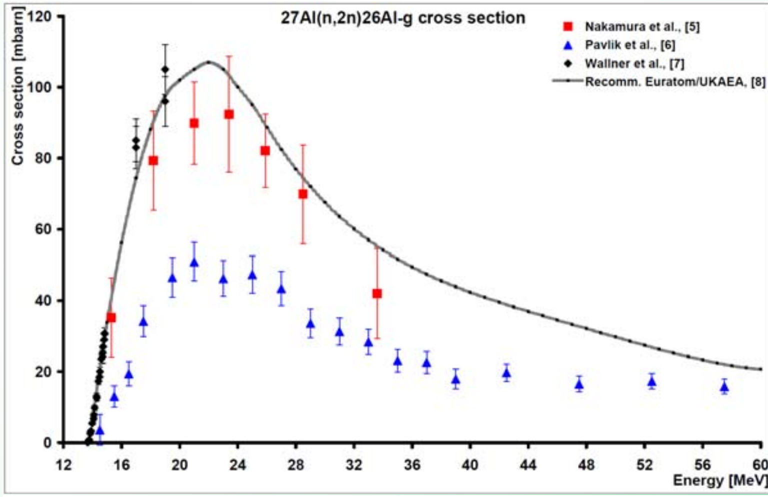
→ Assume full exposure to cosmic rays since millions of years

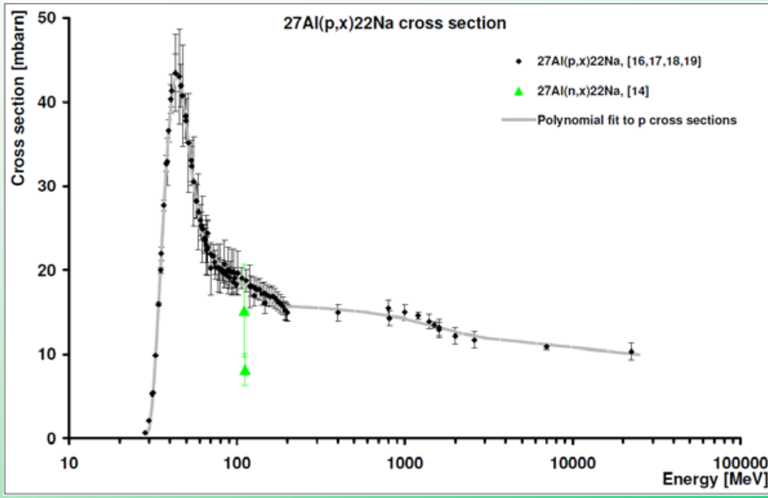
Aluminum as background

Secondary neutron and proton fluxes at sea level, New York:



Excitation functions for ^{26}Al and 22Na

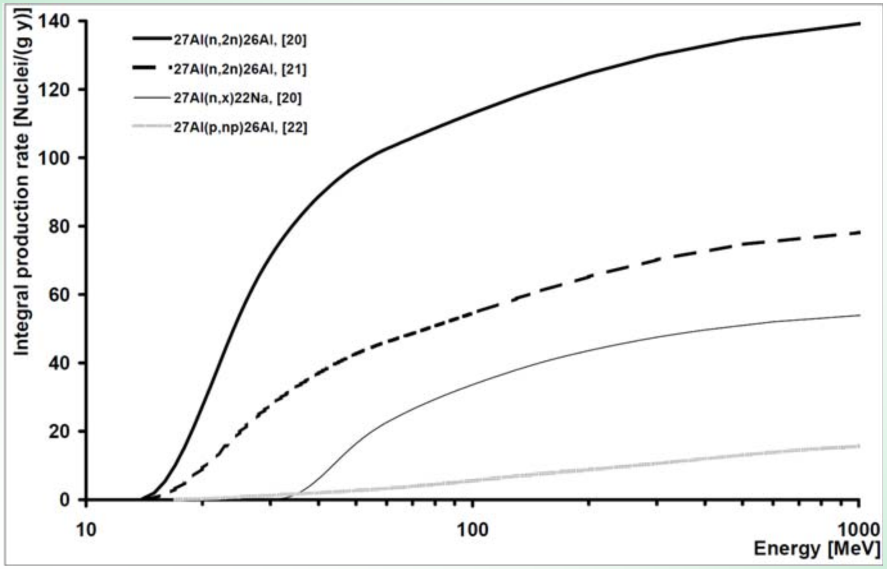


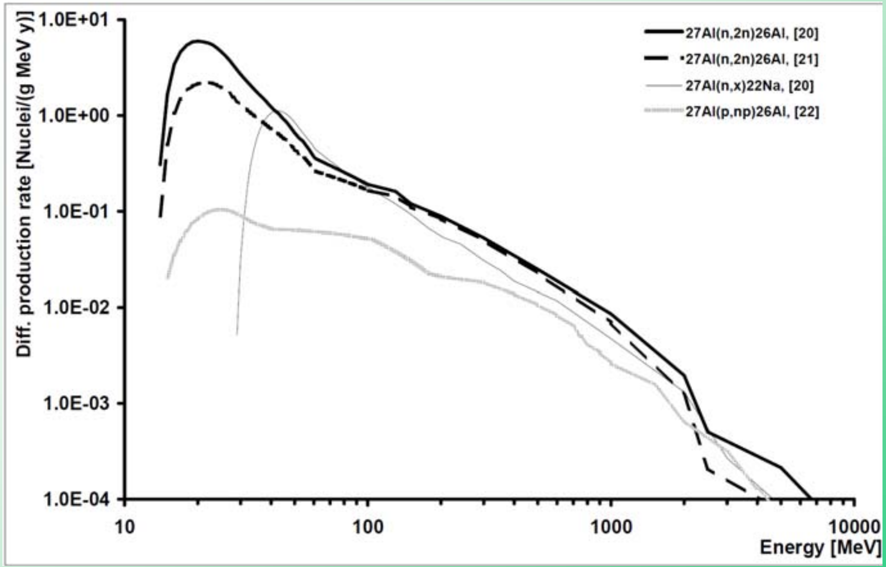


Aluminum as background

Expectations from naïve calculations

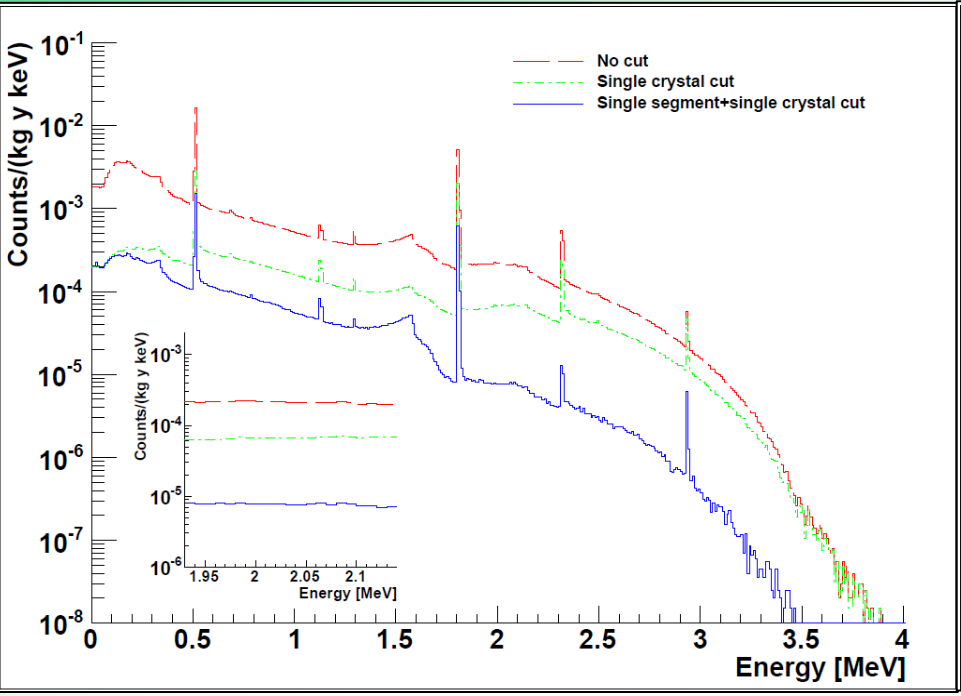
	^{26}Al [(g y)$^{-1}$]	^{26}Al [mBq/kg]	^{22}Na [(g y)$^{-1}$]	^{22}Na [mBq/kg]
n [Ziegler]	142	4.5	56	1.8
n [Gordon et al.]	80	2.5	43	1.3
p	17	0.5	3	0.1

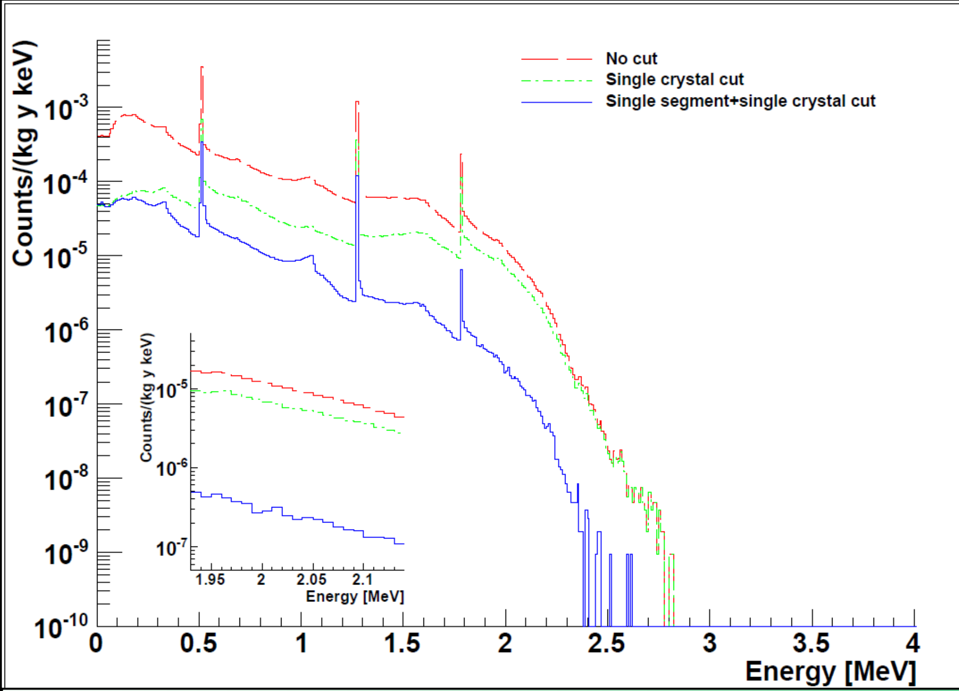




Aluminum as background

MC of ^{26}Al (4.5mBq/kg) and ^{22}Na (0.9mBq/kg)





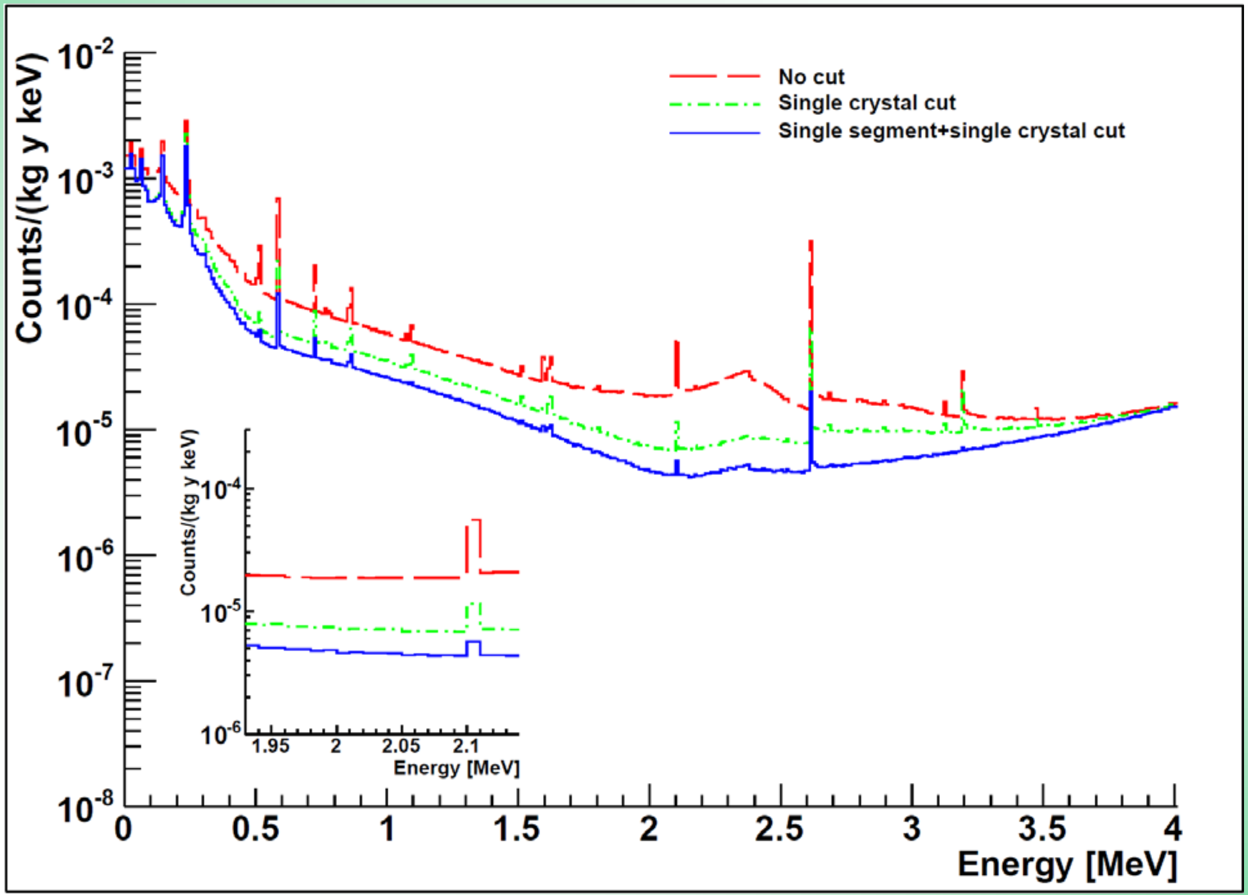
→Relevant background contribution for ton scale experiment even for activity ten times less than naïve expectation!

10^{-6} cts/(kg y keV) → Have to limit ^{26}Al activity to 0.6 mBq/kg

^{22}Na activity to 2mBq/kg

Aluminum as background

MC of ^{228}Th (1mBq/kg)



10^{-6} cts/(kg y keV) → Have to limit ^{26}Al Activity to 0.2 mBq/kg

Aluminum as background

Measurements of ULB Aluminium:
Activities in mBq/kg

Sample	^{26}Al	^{22}Na	^{226}Ra	^{228}Th	^{40}K
Pecheney	$0.38^{+0.19}_{-0.14}$	< 0.18	0.27 ± 0.19	1.4 ± 0.2	$1.1^{+0.2}_{-0.1}$
Pecheney	0.2±+-0.1	< 0.32	<0.7	3.8 ± 0.7	$4.9\ \pm1.8$
Kryal #1	0.6±+-0.3	0.7 ± 0.3	< 0.38	<1.9	<21
Kryal #2	< 0.15	< 0.26	<0.28	<0.58	<22
Highpural	< 0.45	< 0.37	47 ± 5	<3.7	<5.5

^{26}Al and ^{22}Na found in ULB aluminum!

Clean Aluminum does exist!

→HPGe measurements sensitive enough to select ^{26}Al and ^{22}Na "free" Aluminum

Aluminum as background

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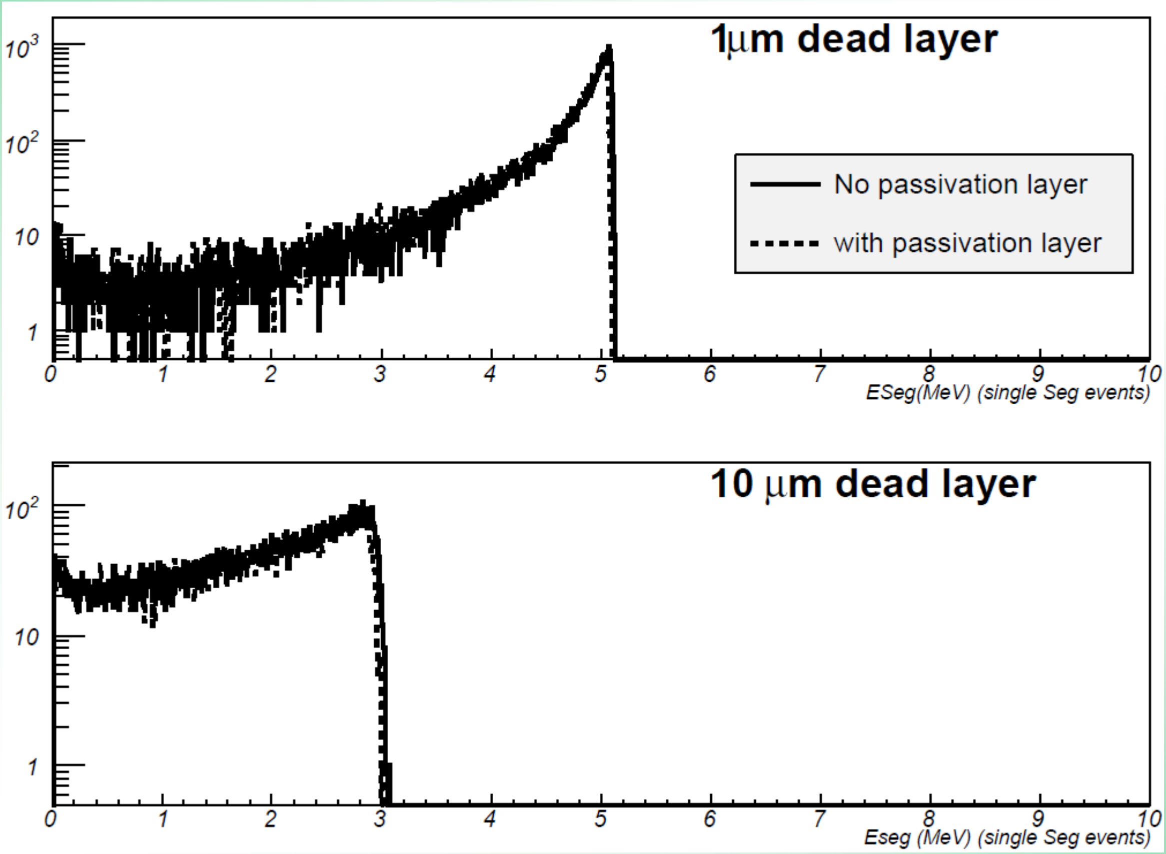
The Good

Contaminations on HPGe surfaces

^{210}Pb lead on surfaces with dead layer <20µm thickness



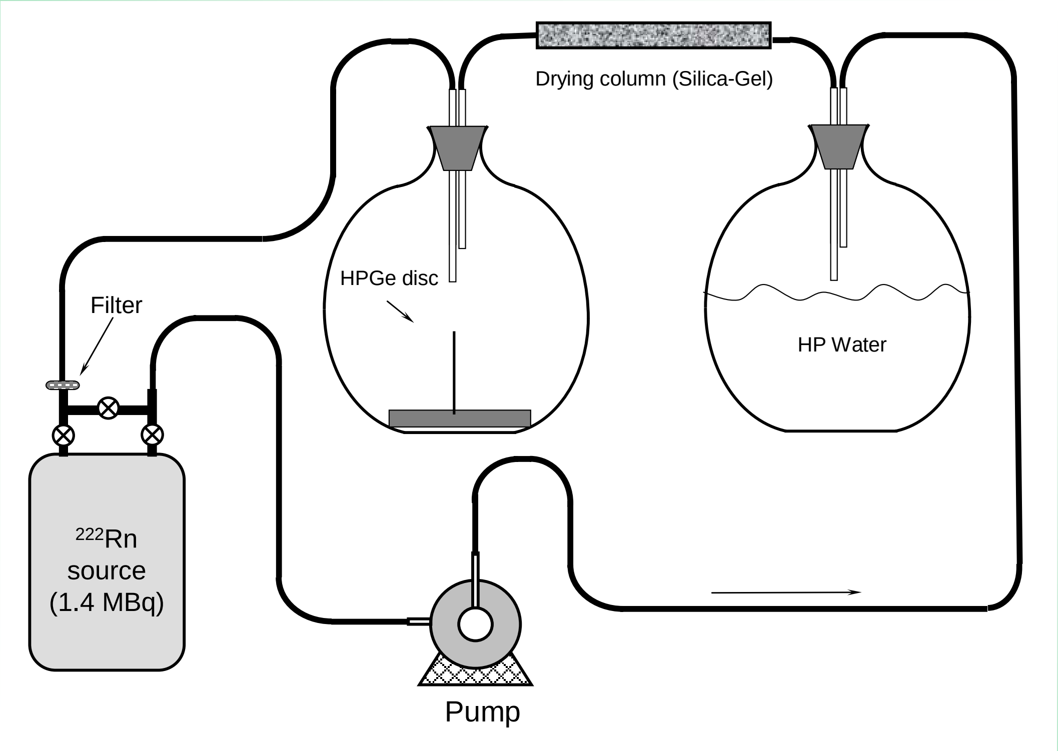
α contaminations (^{210}Pb, ^{210}Bi) seen in Heidelberg Moscow, Edelweiss, CDMS, GERDA experiments.

→ Investigation of surface treatment!

Contaminations on HPGe surfaces

Effect of etching : Removal and deposition efficiencies of ^{210}Pb and its daughters during etching of germanium

(collaboration with G. Zuzel, MPI-K, M. Wojicik, Jagellonian Univ., Cracow and Canberra France, Lingolsheim, France):



1.4 MBq Rn (226Ra) source

10 l gas volume in two excsicators

NPGe / HPGe discs and DI water exposed to ^{222}Rn source for 7 months at MPI-K in Heidelberg

Contaminations on HPGe surfaces

Clean HPGe disc etched in contaminated etching solution

Contaminated disc etched in clean etching solution

Samples were etched by Canberra France-Lingolsheim according to procedure of HPGe detector etching

Contaminations on HPGe surfaces

NPGe disc:

Isotope	Initial count rate [cpm]	Count rate after cleaning [cpm]	Reduction factor R
^{210}Pb	2.09 ± 0.12	–	–
	2.12 ± 0.21	< 0.02	> 106
^{210}Bi	40.7 ± 1.3	–	–
	46.1 ± 1.4	–	–
^{210}Po	50.0 ± 1.5	0.06 ± 0.02	833 ± 279
	47.0 ± 1.4	0.05 ± 0.02	940 ± 377

HPGe disc:

^{210}Pb	0.717 ± 0.011	< 0.001	> 717
^{210}Bi	14.70 ± 0.12	< 0.017	> 865
^{210}Po	11.88 ± 0.19	0.102 ± 0.006	117 ± 7

46.5 keV gamma with HPGe det : 1% est. efficiency

β - particles with Si det: 10% est. efficiency

α – particle with 4π Si det. system: 15% estimated efficiency

Measurements performed at Jagellonian University Cracow by M. Wojicik

Contaminations on HPGe surfaces

Deposition efficiencies on HPGe disc:

Isotope	Initial count rate [cpm]	Count rate after cleaning [cpm]	Count rate increase [cpm]	Number of nuclei on disc	Increase factor B_R
^{210}Pb	0.0163 ± 0.0009	0.023 ± 0.001	0.0066 ± 0.0013	$1.1 \cdot 10^7$	1.4
^{210}Bi	0.111 ± 0.006	0.217 ± 0.007	0.106 ± 0.009	7500	1.9
^{210}Po	0.064 ± 0.005	0.087 ± 0.006	0.023 ± 0.007	$1.7 \cdot 10^4$	1.4

Significant amount of ^{210}Pb, ^{210}Bi and ^{210}Po deposited on HPGe disc

HPGe measurement of ^{210}Pb concentration of DI water (upper limit): A < 20 Bq

Probability of plating onto HPGe from 100ml DI water:

^{210}Pb: > 1.2 %

^{210}Bi: > 1.2 %

^{210}Po: > 0.16 %

Contaminations on HPGe surfaces

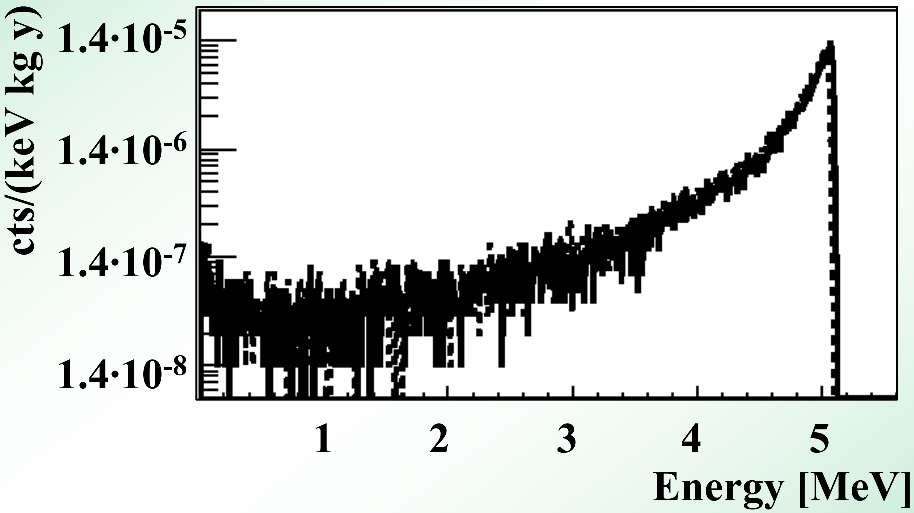
MC simulation: one ^{210}Pb nucleus on detector surface:

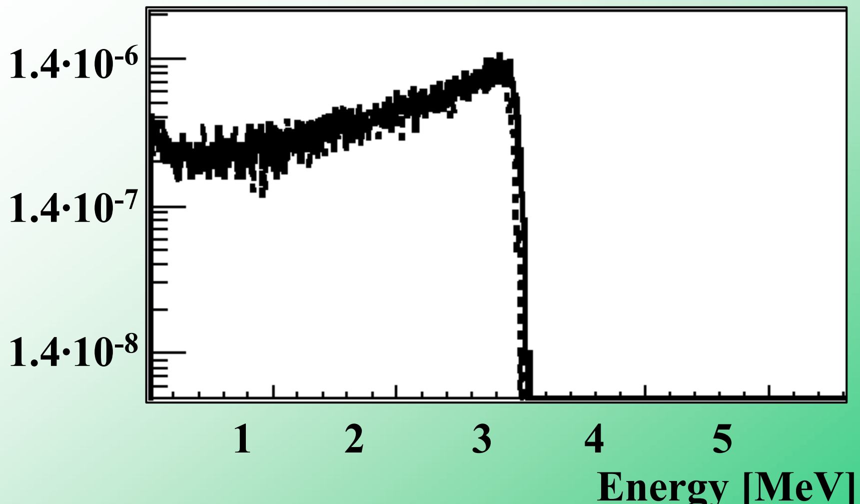
$\sim 10^{-7}$ cts/(kg y keV)

Allowed number of nuclei on active surface:
max. 10 → 0.01 nuclei per cm^2

in etchant (1.2% deposition eff.): ~850 ^{210}Pb nuclei ~10µBq/l!

→ ^{210}Pb Screening methods & Clean etchants needed





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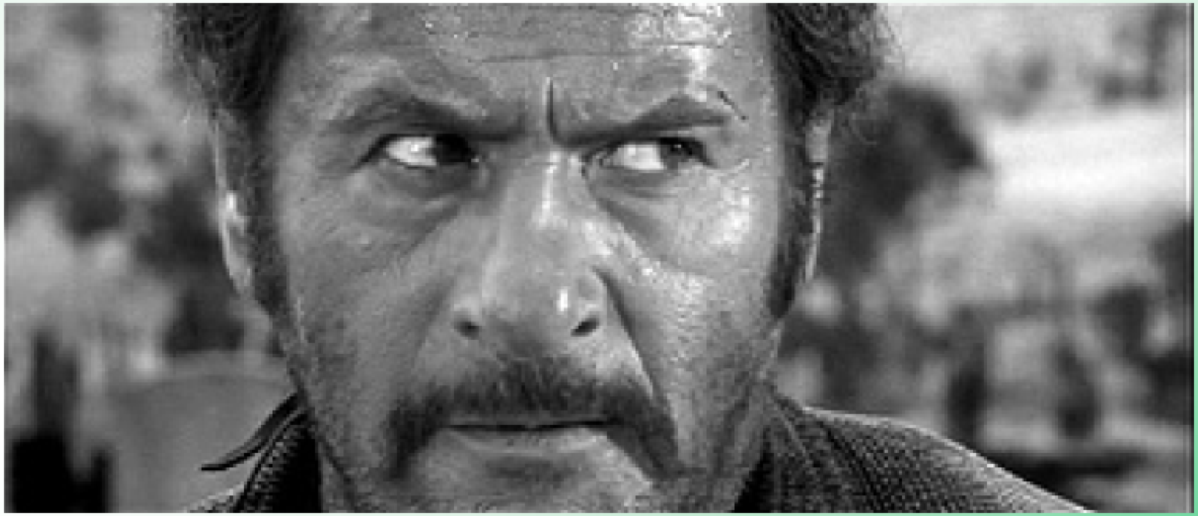
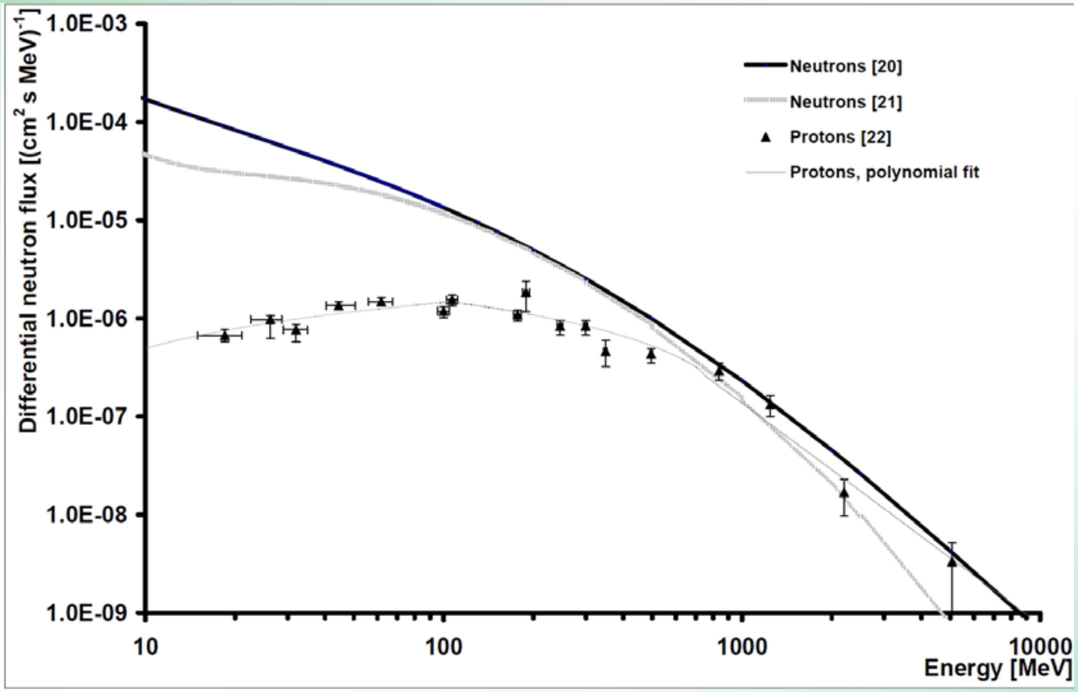


The Bad

Intrinsic HPGe contamination

Expected count rate due to ^{68}Ge in HPGe:
One ^{68}Ge nucleus per kg: $1.8\cdot10^{-5}$ cts/(kg y keV) [K. Kröninger, PhD]

→To keep the level below 10^{-6} cts/(kg y keV):
Roughly 55 ^{68}Ge nuclei per tonne allowed (0.055 per kg).



Production rates :

^{nat}Ge: 50 ^{68}Ge nuclei (kg day)$^{-1}$

^{enr}Ge: 7 ^{68}Ge nuclei (kg day)$^{-1}$

→ Max. 11 minutes above ground!

cosmogenic production of ^{60}Co and ^{68}Ge in germanium can be avoided by storage underground.

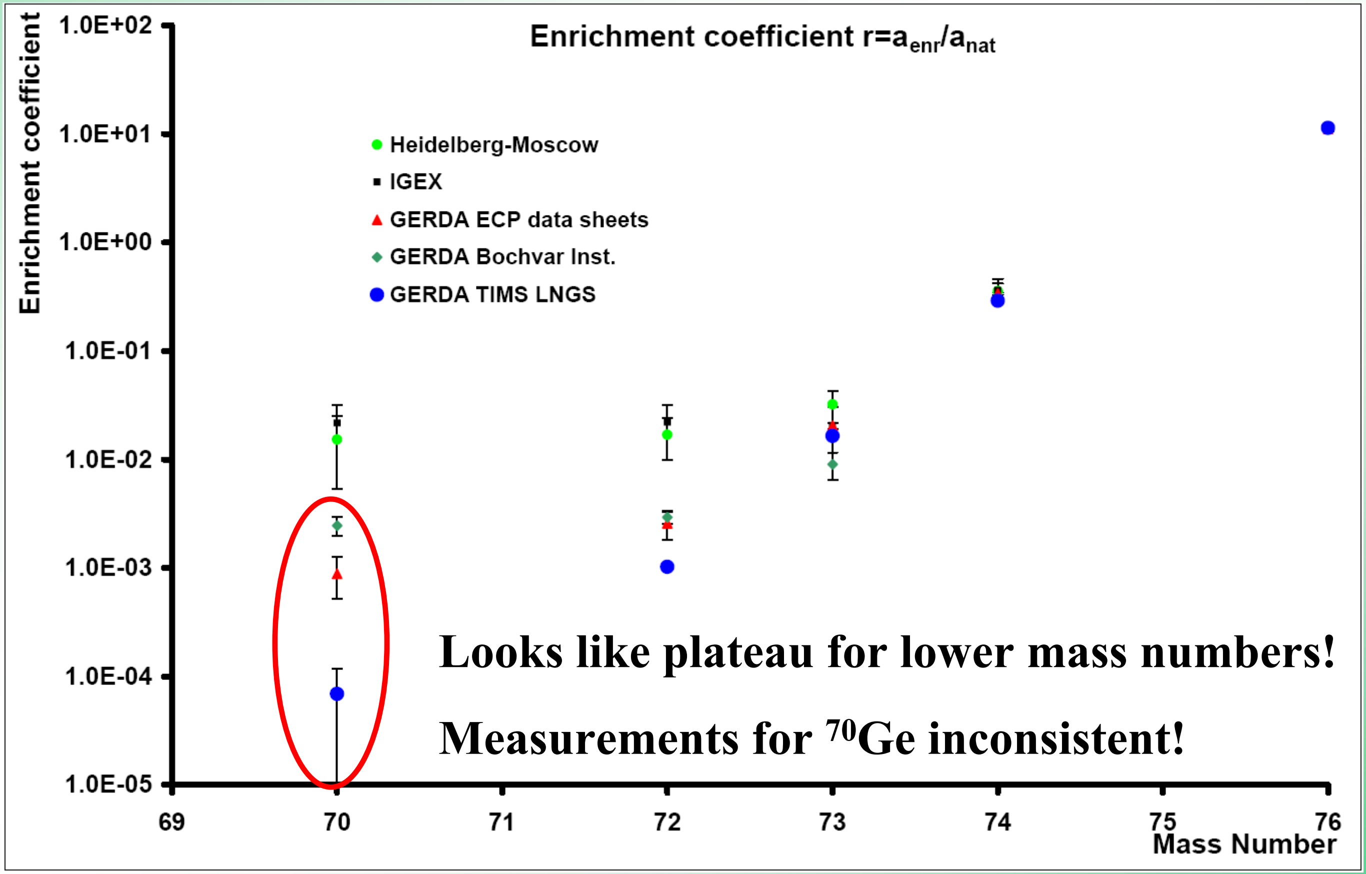
→ Enrichment underground!

Intrinsic HPGe contamination

In equilibrium in ^{nat}Ge: $2 \cdot 10^4$ ^{68}Ge nuclei/kg

Enrichment of germanium does deplete 68Ge content.

But how efficiently?



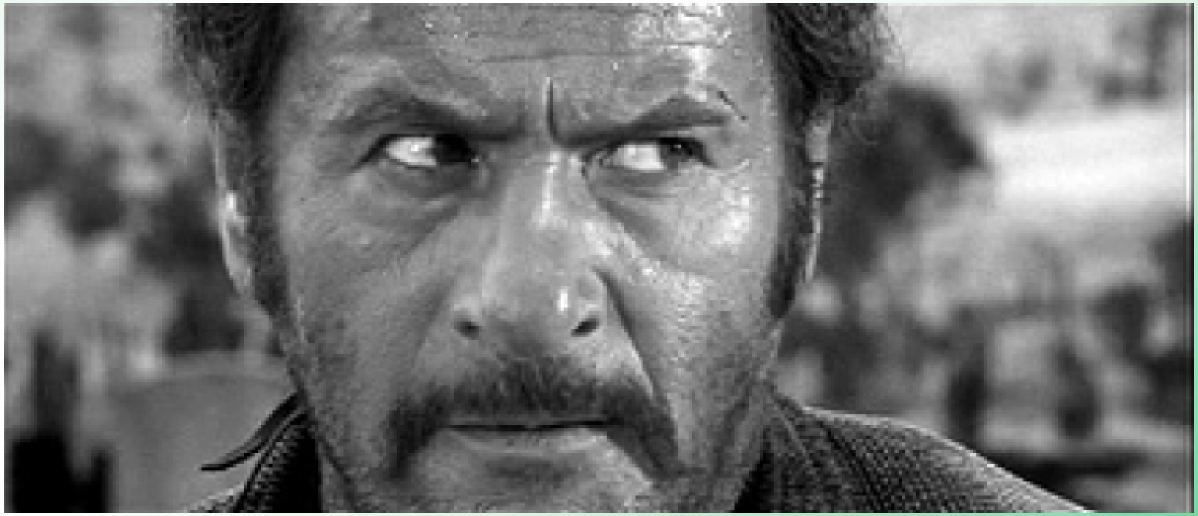
Intrinsic HPGe contamination

Isotope	IGEX [73]	HdMo [51]	GERDA I [73]	GERDA II [52]	GERDA TIMS [74]	GERDA NAA [9]
^{76}Ge	10.9 ± 0.1	11.0 ± 0.4	11.2 ± 0.1	11.2 ± 0.1	11.4 ± 0.1	11.1 ± 0.1
^{74}Ge	0.362 ± 0.001	0.356 ± 0.006	0.334 ± 0.002	0.336 ± 0.008	0.290 ± 0.001	0.358 ± 0.002
^{73}Ge	$(2.1 \pm 0.1)\cdot10^{-2}$	$(3.2 \pm 1.0)\cdot10^{-2}$	$(9.0 \pm 0.1)\cdot10^{-3}$	$(2.0 \pm 0.1)\cdot10^{-2}$	$(1.64 \pm 0.03)\cdot10^{-2}$	
^{72}Ge	$(2.20 \pm 0.04)\cdot10^{-2}$	$(1.7 \pm 0.7)\cdot10^{-2}$	$(2.93 \pm 0.03)\cdot10^{-3}$	$(2.6 \pm 0.8)\cdot10^{-3}$	$(1.02 \pm 0.04)\cdot10^{-2}$	
^{70}Ge	$(2.16 \pm 0.05)\cdot10^{-2}$	$(1.5 \pm 1.0)\cdot10^{-2}$	$(2.45 \pm 0.02)\cdot10^{-3}$	$(8.8 \pm 3.7)\cdot10^{-4}$	$(6.9 \pm 0.5)\cdot10^{-5}$	

Assume (!) deenrichment of ^{68}Ge of 10^{-4} (optimistic (?) for existing technology)

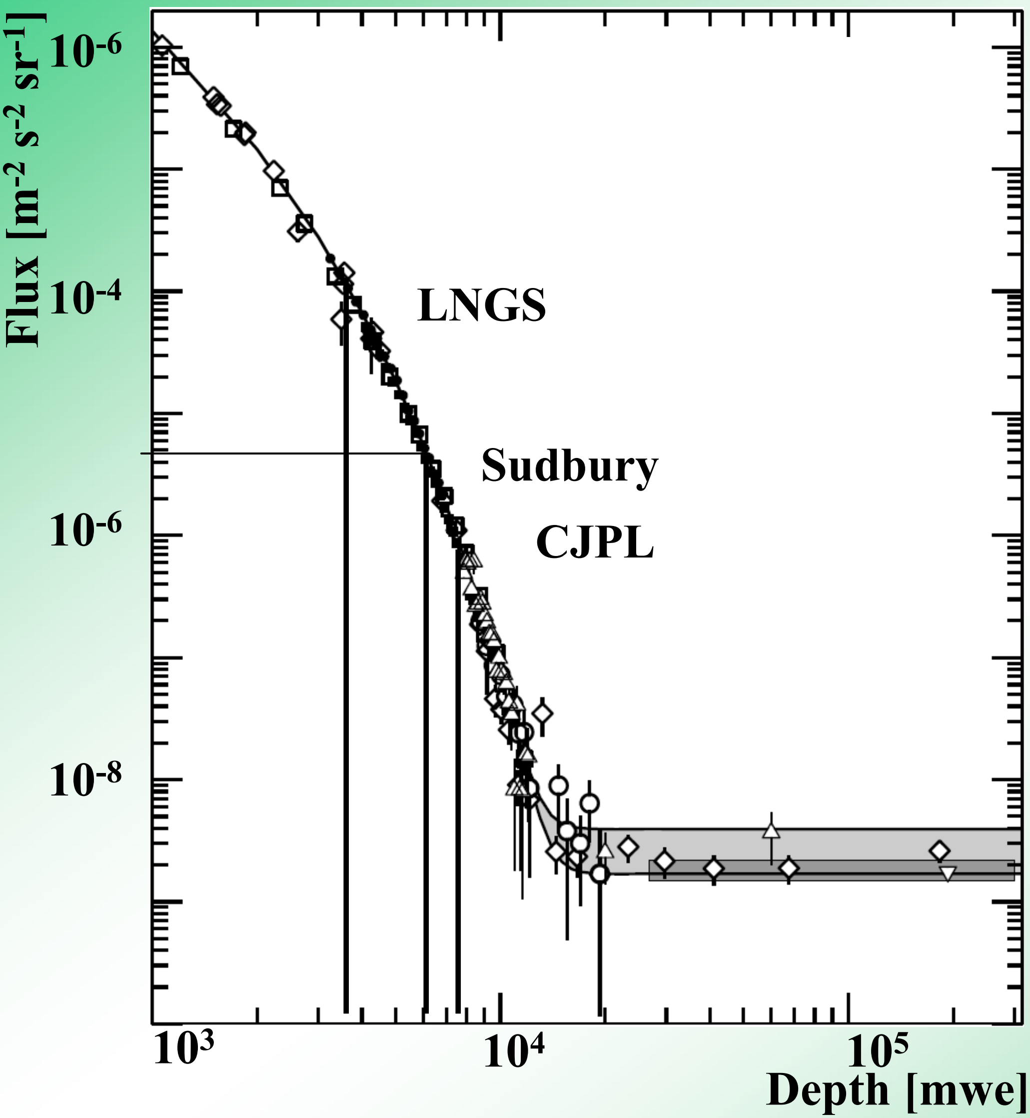
→Expect two nuclei per kg enriched material

→Need to wait 5.18 half lives (3.84 years) to reach 0.055 nuclei/kg limit



The Bad II

The really irreducible: UPWARD MUONS

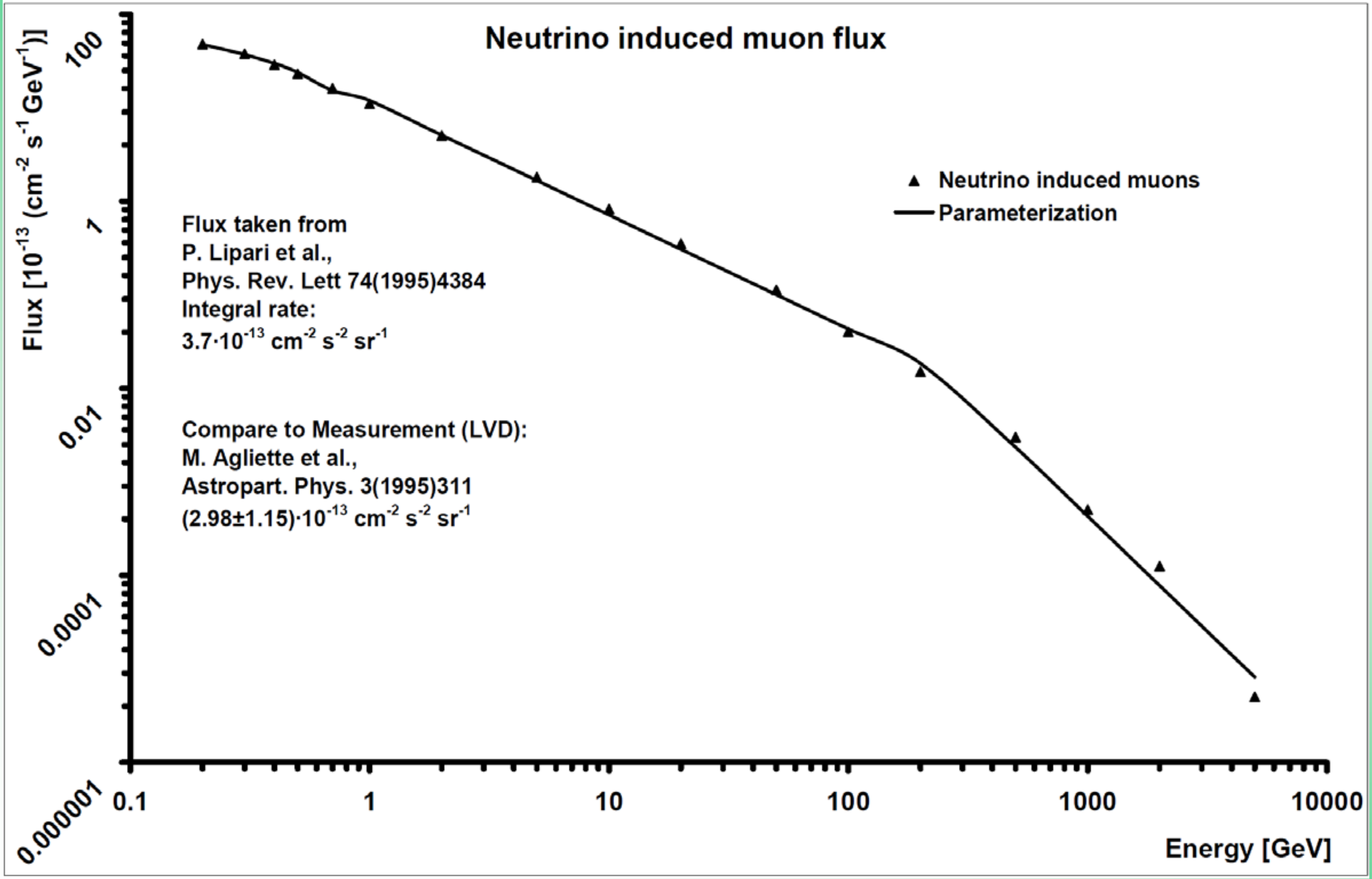


Muon flux at underground labs:

Laboratory	Depth [mwe]	Muon flux [m^{-2} y^{-2}]
LNGS	3500	2000
Sudbury	6000	150
CJPL	7500	20
Minimum	>14000	1

Going deeper does not help: Upward going muons from atmospheric neutrinos!

The really irreducible: UPWARD MUONS

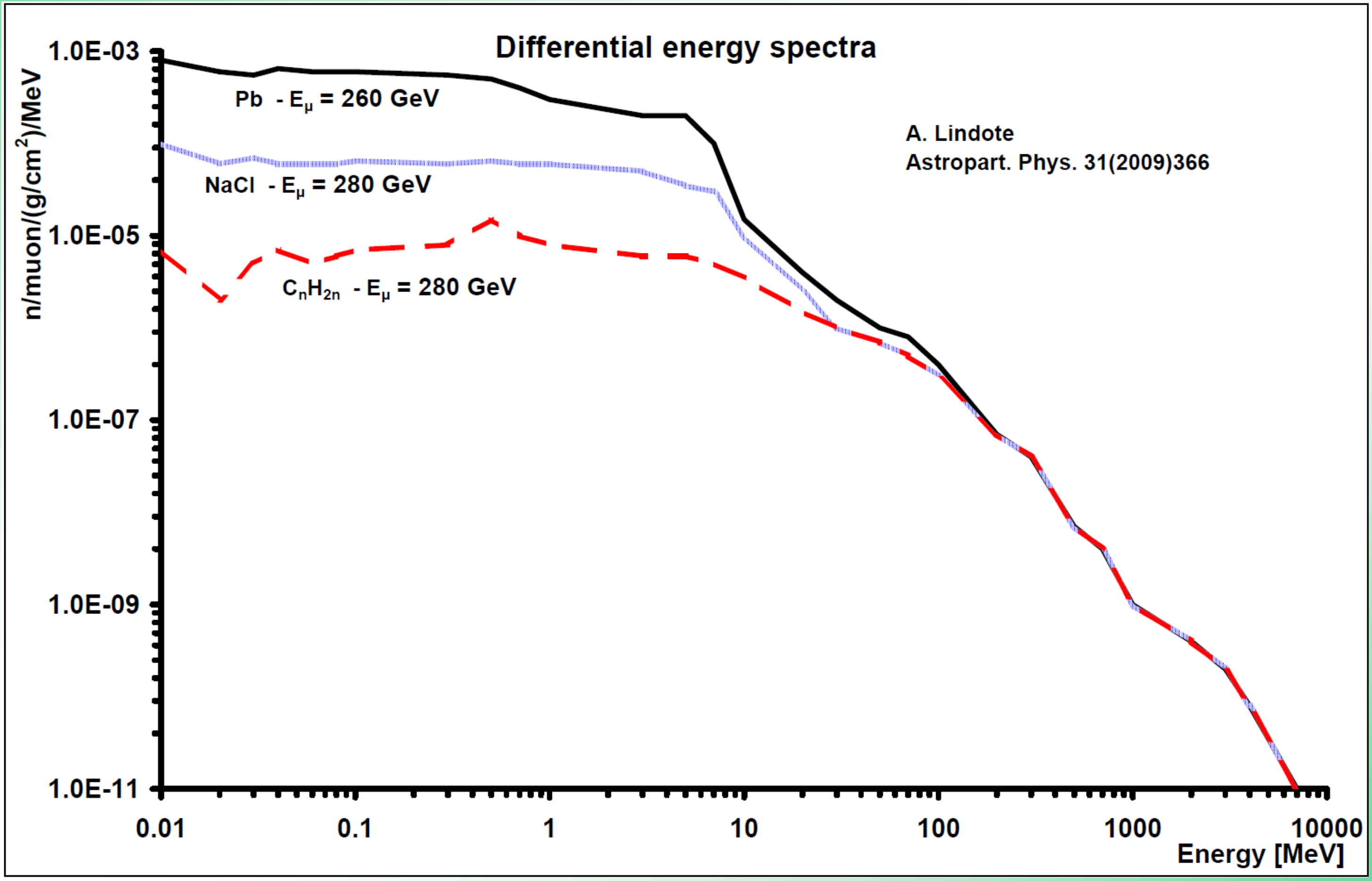


Muons passing matter → creation of neutrons

Assume homogeneous flux from all directions (ignore oscillations)

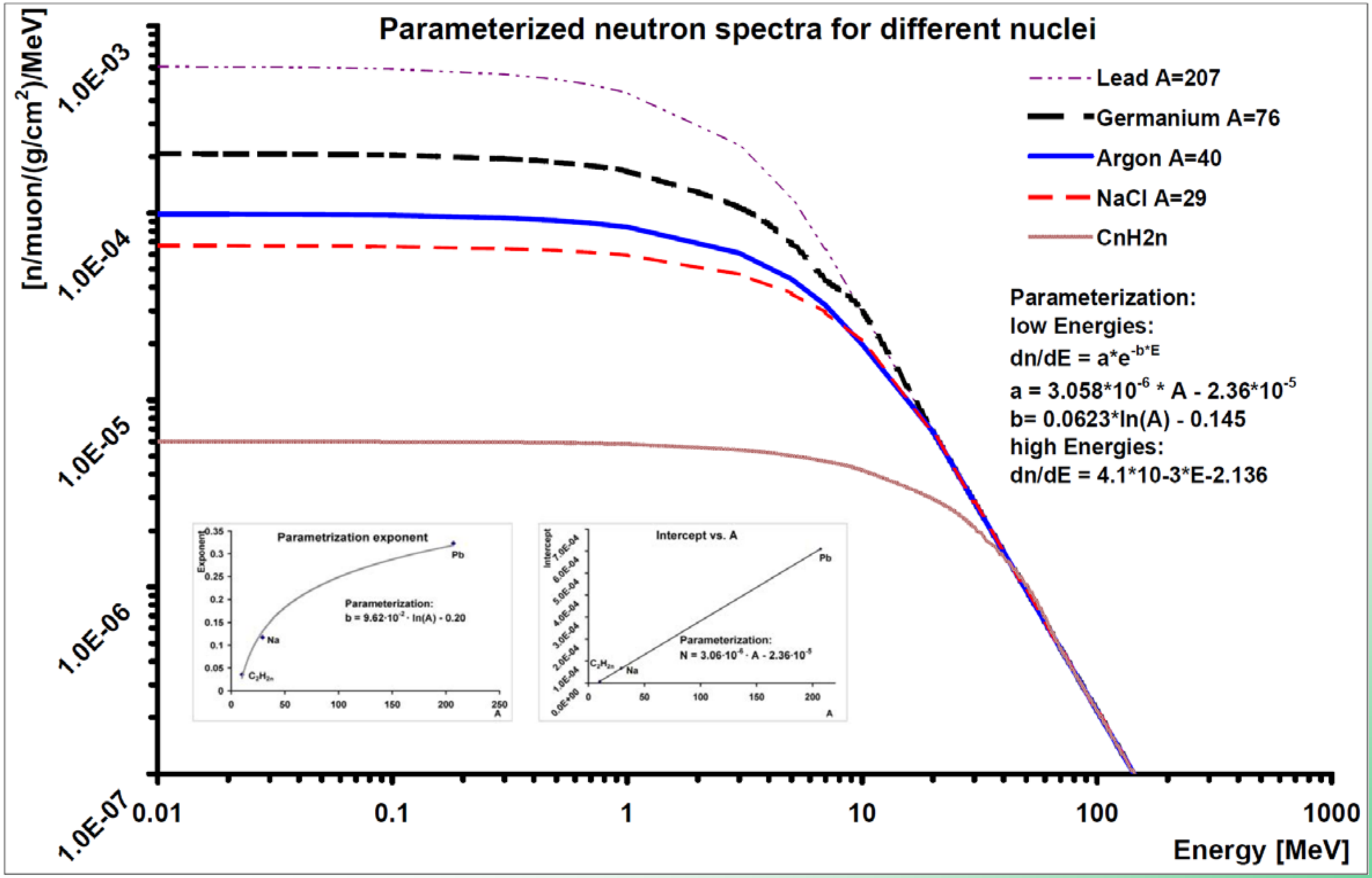
The real irreducible: UPWARD MUONS

Muon induced neutron spectra:



0^{th} order assumption: Neutron spectrum independent of energy 0.1GeV – 10 TeV

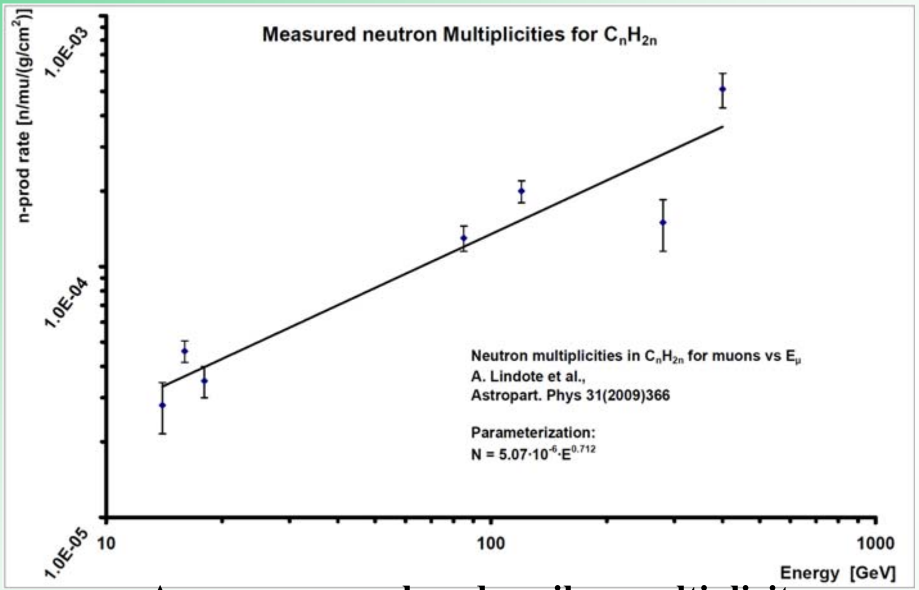
The real irreducible: UPWARD MUONS

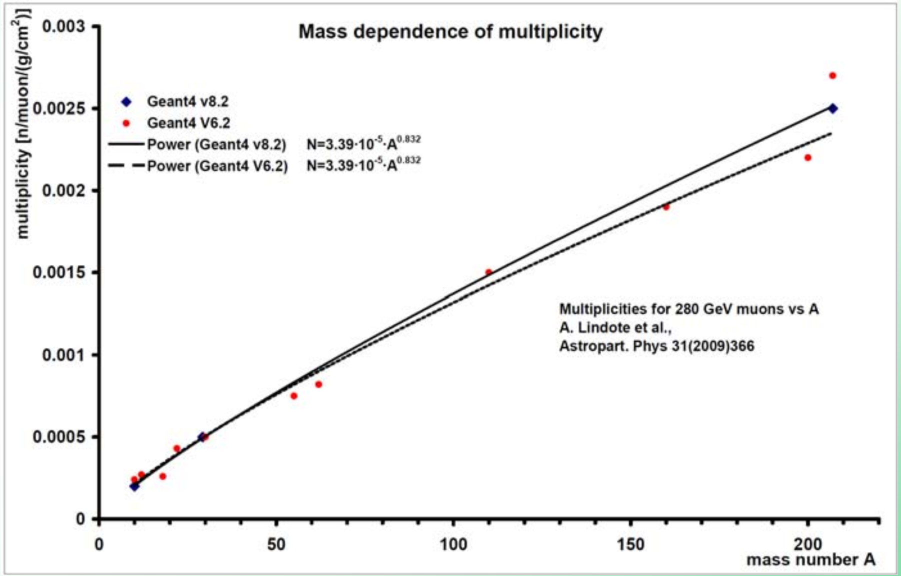


If spectral form known for given mass number → Need neutron multiplicity

The real irreducible: UPWARD MUONS

Multiplicity depends on density of mass number of crossed material and on energy of initial neutron: :





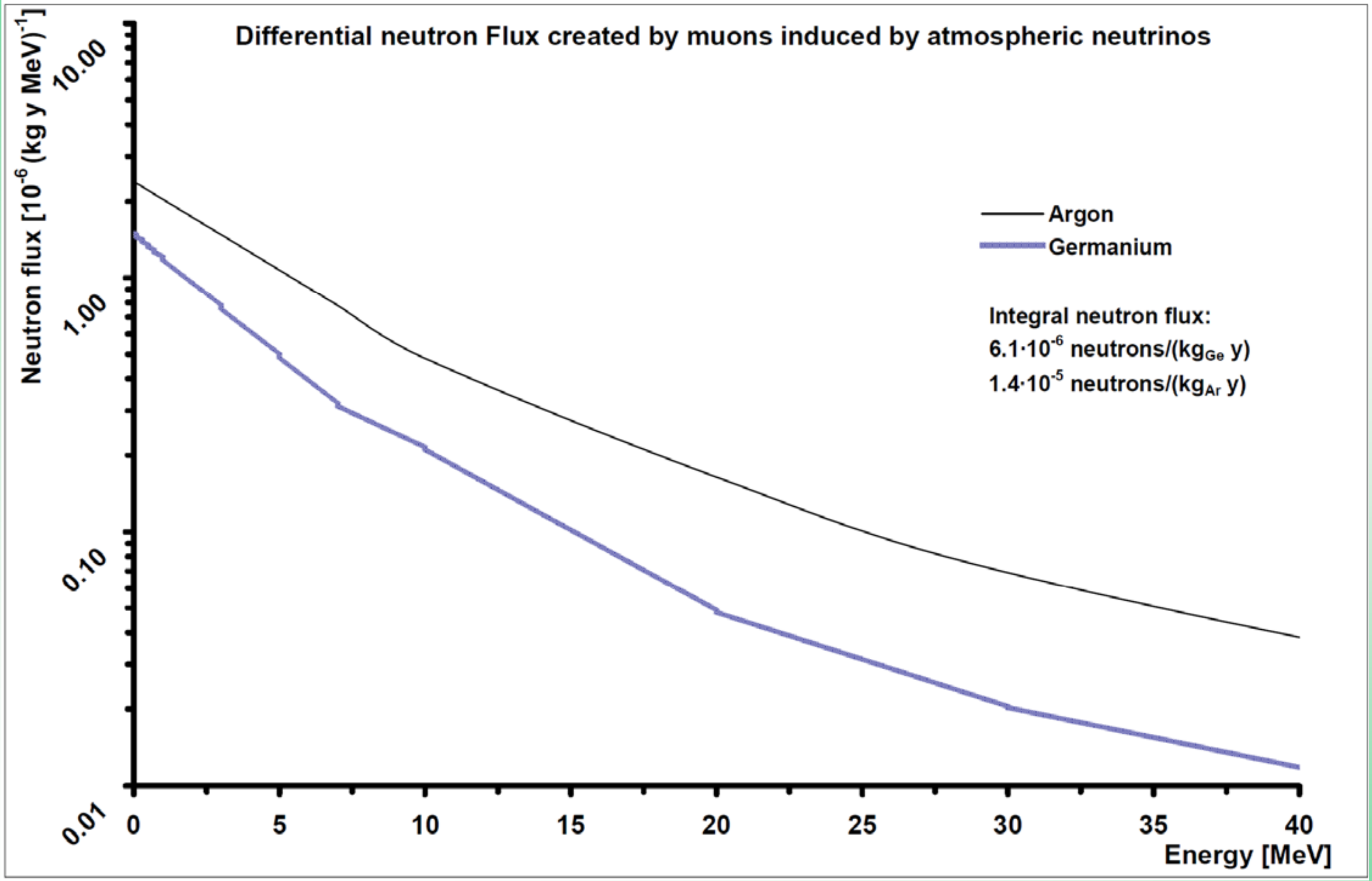
Assume: power law describes multiplicity as function of energy down to 0.1 Gev

Multiplicity known for one energy and mass number:

→Integrated neutron flux for given mass number by convoluting scaled multiplicity

Scale to proper mass number according to parameterization

The real irreducible: UPWARD MUONS



Muon Čerenkov veto can significantly (factor 100) reduce this contribution

But need to consider delayed events!

→ Further investigations necessary!

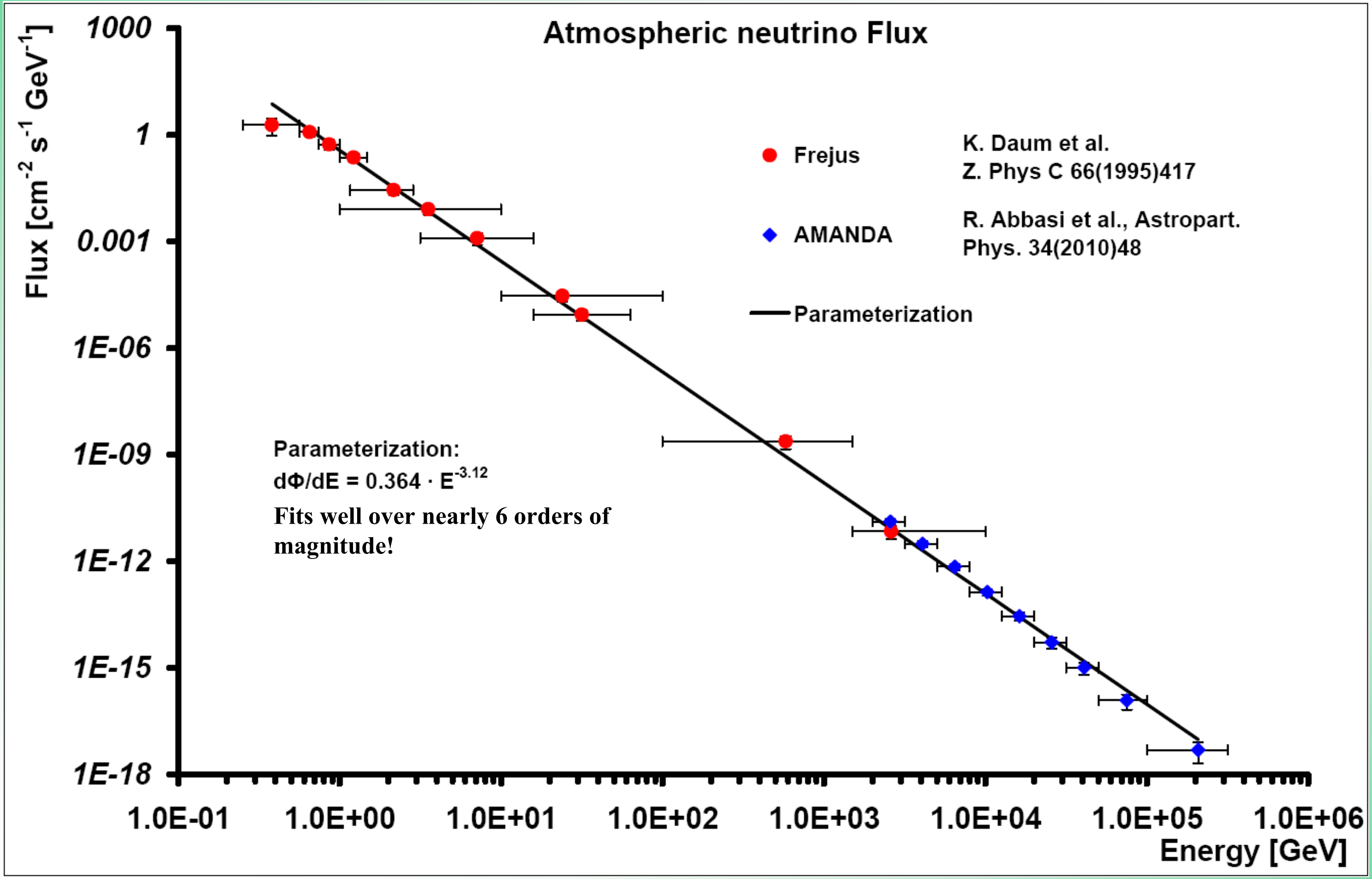
The real irreducible: UPWARD MUONS

The Ugly

Muon Cerenkov veto can significantly (factor 100?) reduce this contribution

But need to consider delayed events!

The real irreducible: Atmospheric neutrinos

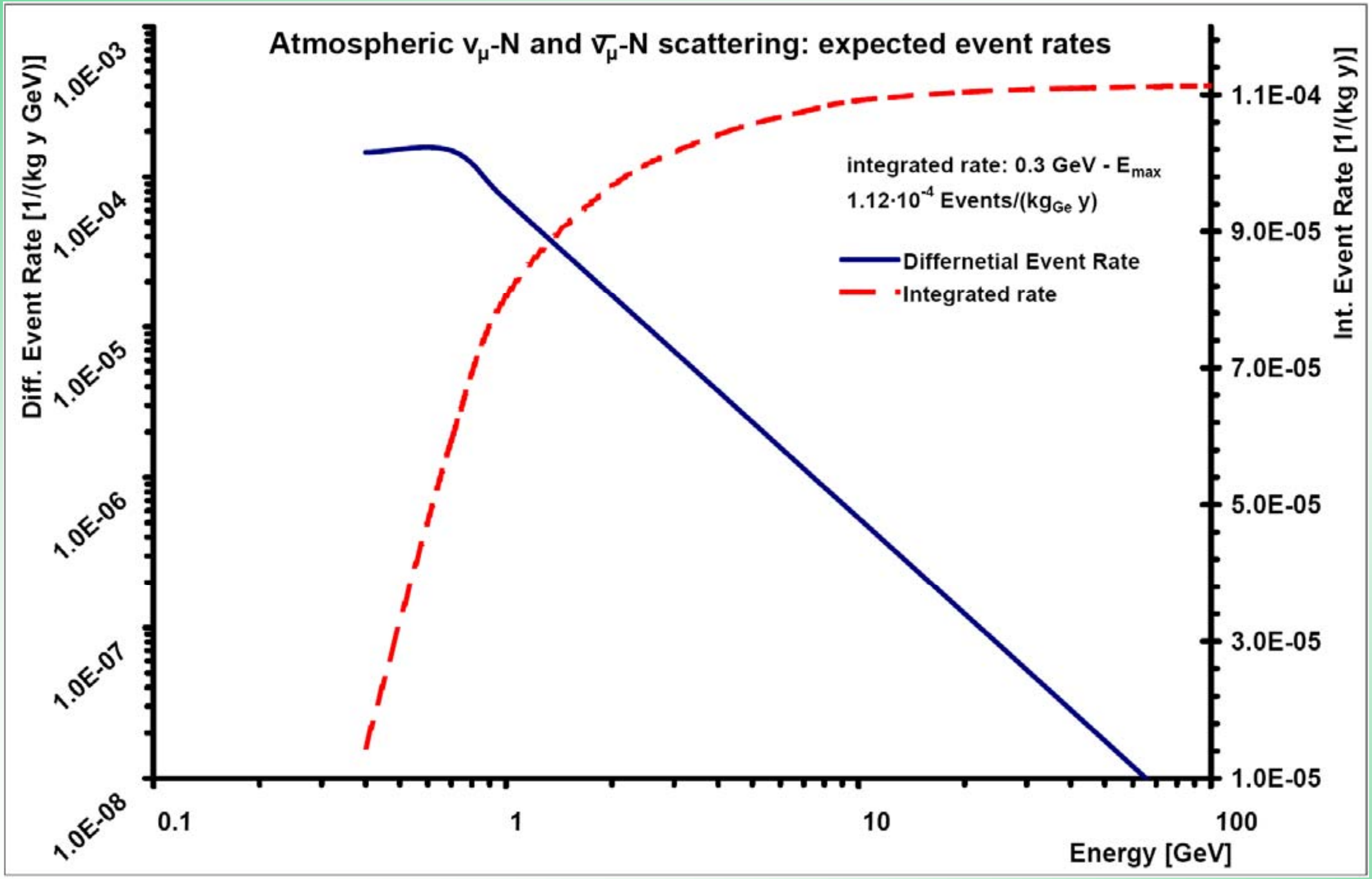


Assume: Neutrino nucleon cross section proportional to E_ν from 0.3 GeV to 10 TeV

Use values from PDG [Phys Rev D 45]:

$\sigma_{\nu N} = 6.82 \cdot 10^{-39}\ cm^2 \cdot E$ $\sigma_{\bar{\nu}N} = 3.38 \cdot 10^{-39}\ cm^2 \cdot E$

The real irreducible: Atmospheric neutrinos



Expect ~ 10^{-4} atm. neutrino induced events per year per kg HPGe!

→ Need further investigation, how well these can be identified (high energy transfer)

The real irreducible: Atmospheric neutrinos

The Ugly II

Expect ~ 10^{-4} atm. neutrino induced events per year per kg HPGe!

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Conclusions:

The Good 	**Metallization:**	**Significant background if not taken care of.** **Can be controlled via HPGe screening of aluminum.**
The Bad 	**Surfaces:** **^{68}Ge:**	**Need clean etchant. R&D for etchant screening!** **Depletion efficiencies have to be studied and improved!**
The Ugly 	**Atmospheric ν-induced muons** **Neutrinos**	**Irreducible after μ-veto and timing cuts. Needs investigation** **Irreducible after veto and timing cuts. Needs investigation**