WIMP Direct Detection Searches: Background Techniques

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Backgrounds in Dark Matter Direct Detection

Cosmogenic

- Cosmic rays and secondary reactions.
- Activation products in Shielding and Detectors

Radiogenic

- External natural radioactivity
  walls & structures of site, radon
- Internal radioactivity
  shield and construction materials ← *In common*
  detector contamination in manufacture ← *specific to detector technology*
  naturally occurring radio-isotopes in target material

Beware – You need to know some nuclear physics!

Activity = $A = \frac{dN}{dt} = -\lambda N$

N = number of radioactive nuclei
λ = decay constant, $T_{1/2} = \ln 2/\lambda = \ln 2\ \tau$

A has units of Bq = decay/s
1 Ci = 3.7×10^{10} Bq
which is the activity of 1 g pure ^{226}Ra

Get oriented.

How much radioactivity (in Bq) is in your body? where from?

4000 Bq from ^{14}C (β-decay) and 4000 Bq from ^{40}K (90% β-decay, 10% e-capture)

➔ 8000 ν 8000 e^- 400 γ (1.46 MeV)

How many radon atoms escape from the ground, per sq m, per sec?

7000 atoms/m^2 /s

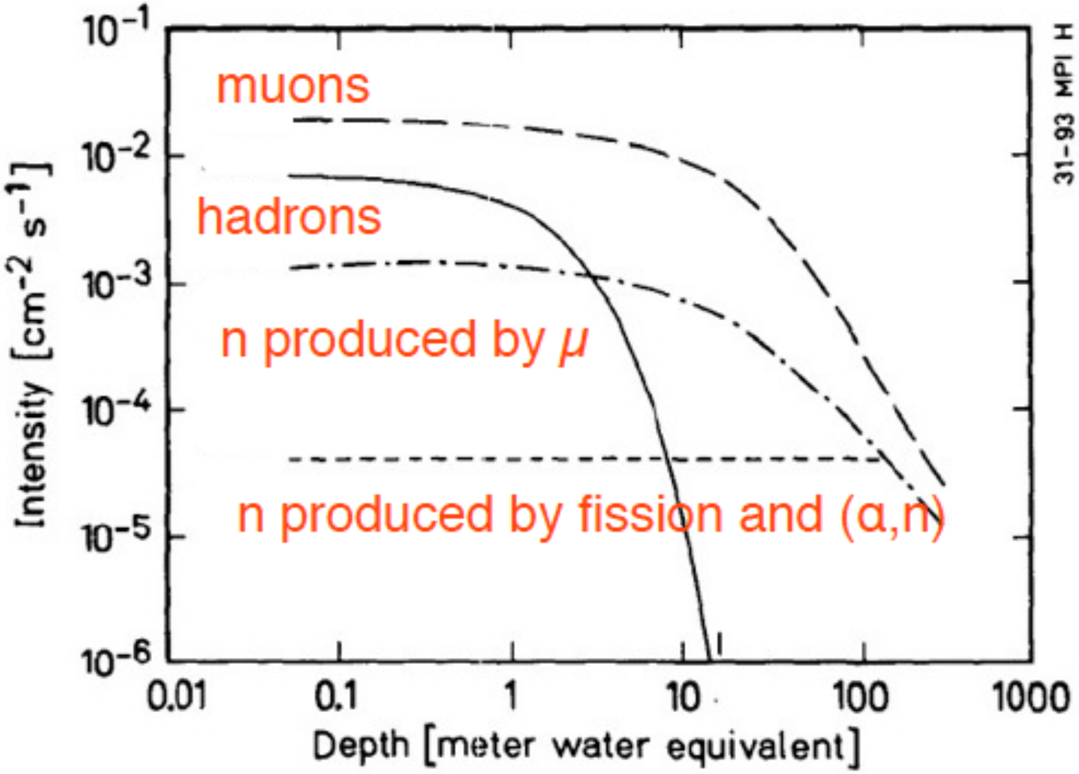
What is the natural fraction of radioactive potassium and carbon?

^{40}K/K = 0.012% ^{14}C/C ~ ppt

how many plutonium atoms do you find in 1 kg of soil?

10 millions (transmutation of ^{238}U by fast CR neutrons), soil has 1 - 3 mg U per kg

Cosmogenic Backgrounds: Cosmic Rays



Lines of Defense

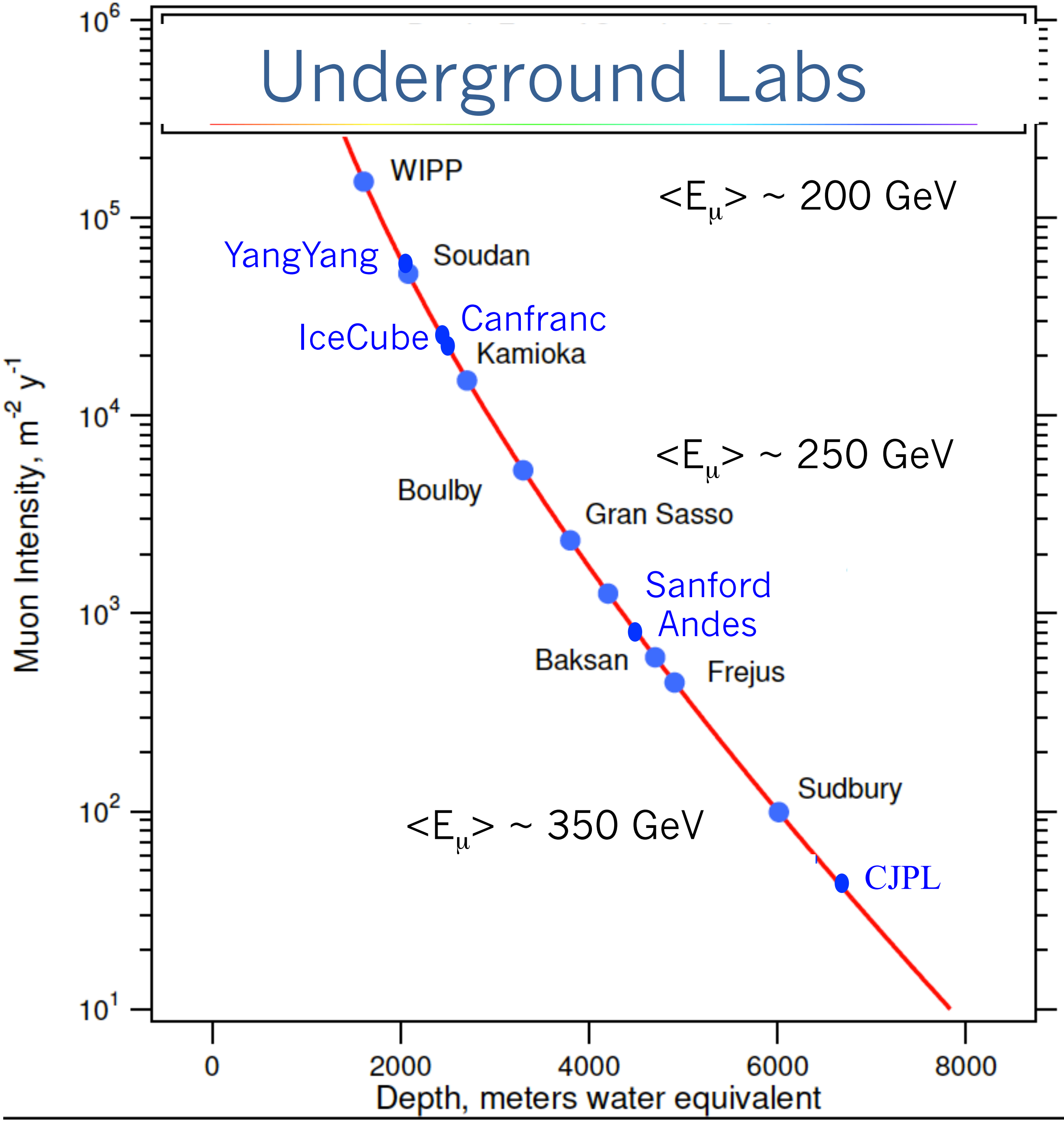
Go deep underground

Passive shielding
    Good for radiogenic, but
    not high-energy cosmogenic n

Use active shielding:
- *Muon veto around detector*
- *Umbrella muon veto*
- *Detect secondaries from shower (e.g. neutron veto)*

Simulation.   Verified with
- *veto-coincident data*
- *underground shower detectors LVD,NMM*
- *muon beam data*
- *nuclear cross sections*

Underground Labs



$\langle E_\mu \rangle \sim 200$ GeV

$\langle E_\mu \rangle \sim 250$ GeV

$\langle E_\mu \rangle \sim 350$ GeV

n-flux: $E_n > 10$ MeV

6×10^{-9} cm^{-2}s^{-1}

1×10^{-9} cm^{-2}s^{-1}

1×10^{-11} cm^{-2}s^{-1}

Cosmogenic Backgrounds: Strategies

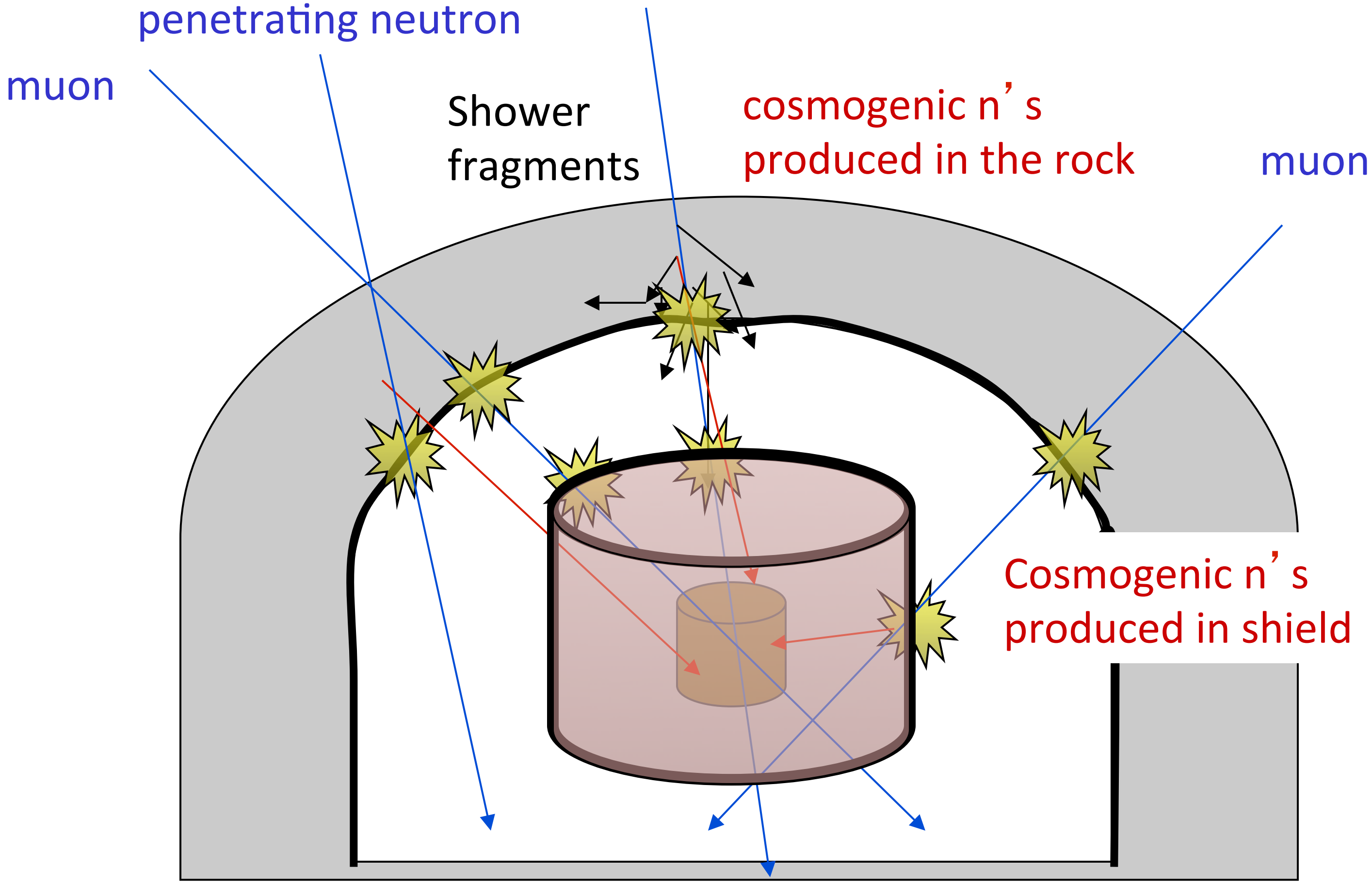
- Muon veto around detector
- Umbrella muon veto

- Neutron detector

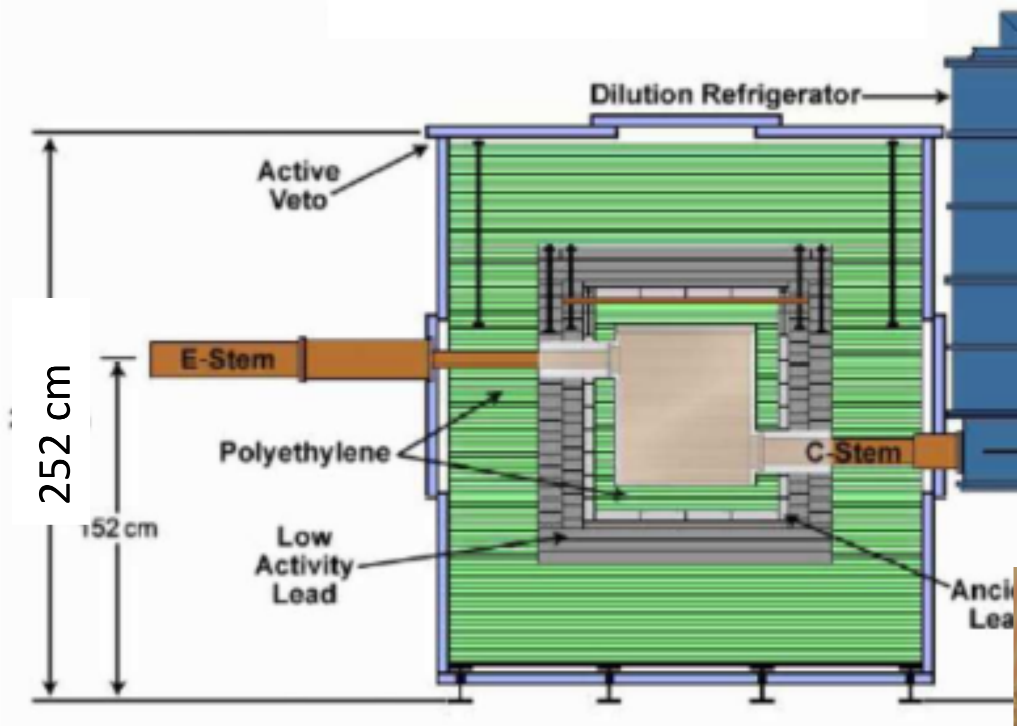
Advantage: sensitive to radiogenic & cosmogenic

Disadvantage: difficult to detect neutrons

Cerenkov, Liquid Scintillator,
n-capture material, He tubes



Shielding Examples

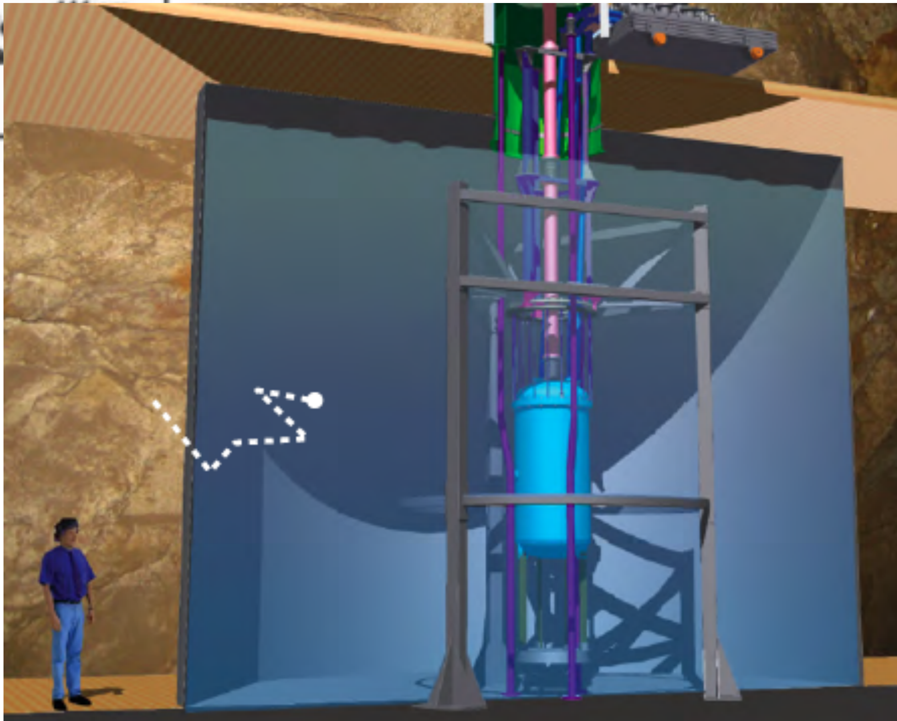


CDMS (Soudan)

Plastic Scint: Muon Veto
Outer Poly: Cosmo n moderation and
Cavern n absorption
Outer Pb: γ absorption (and production!)
Inner “ancient” Pb: γ absorption with
Inner Poly: n absorption
Inner Cu cans : Highest radiopurity

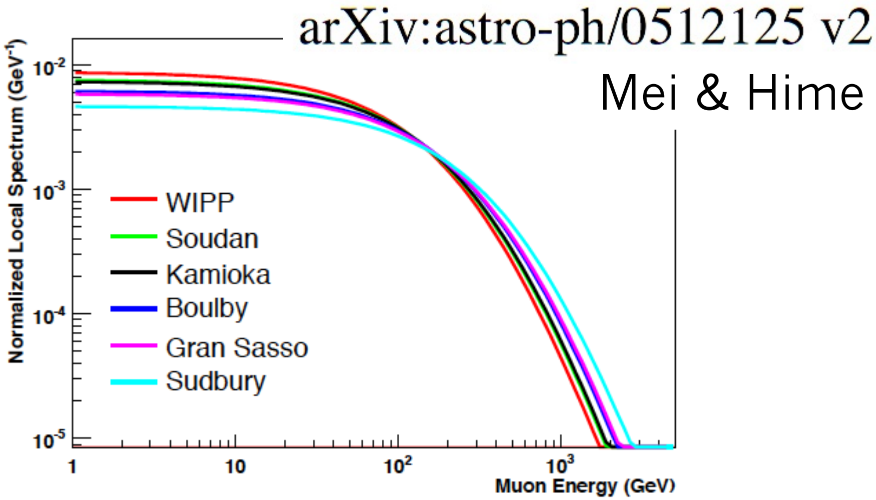
LUX (SURF)

Water Tank: Cosmo and Cavern n absorption
and muon veto
Titanium struts: High radiopurity + strength
Cu Cryostat: Highest radiopurity
LXe: Self-shielding



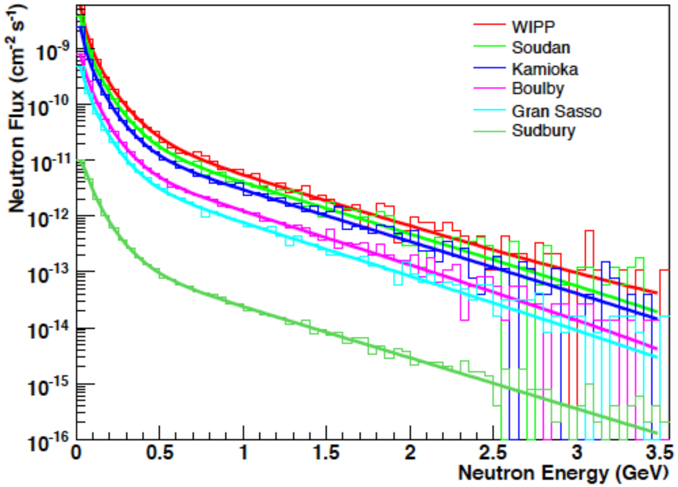
Rely on Cosmogenic Simulations

for the neutrons that still sneak through



arXiv:astro-ph/0512125 v2

Mei & Hime



Parameterizations are not sufficient

- Incident muons depend on both geography and geology
- Need to track every secondary.

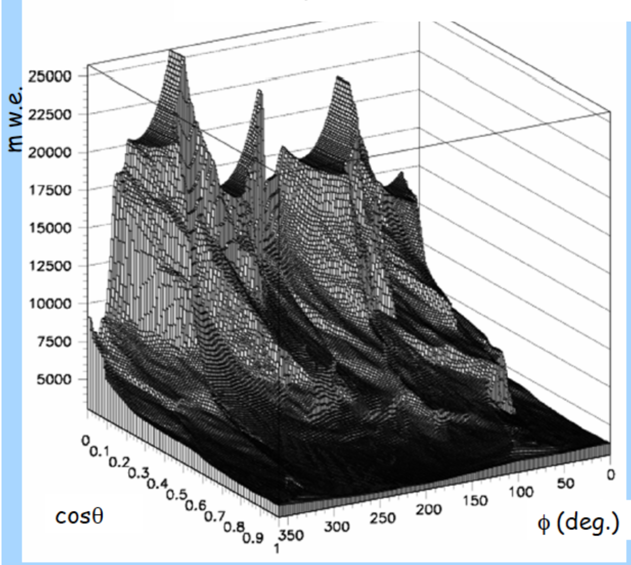
multiplicity is correlated with energy and process

muons don't stop!

hadronic showers repopulate n's

A decade ago, neutron fluxes from Geant4 and FLUKA disagreed by ~ 50% due to issues with physics (muon-nuclear model, cross sections) and implementation. Uncertainties now reduced to ~ 5 %

Gran Sasso is not a flat overburden!



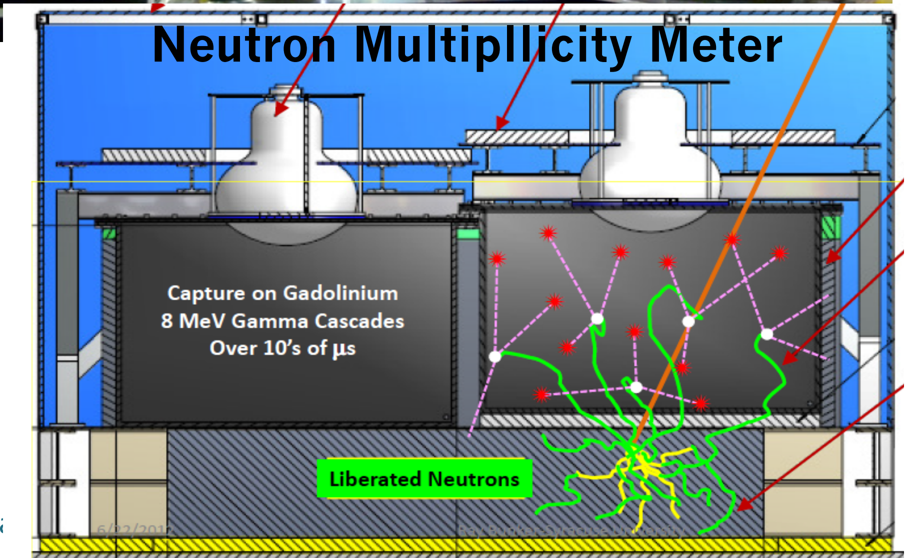
Further Improvements need DATA!

LVD at Gran Sasso
purpose: ν from Supernovae
But also: μ-induced n-capture

LS modules in iron frame

- We measured the neutron yield
  - in LS: $(3.0 \pm 0.4)\ 10^{-4}$ in agreement with other measurement,
  - in SS: $(1.5 \pm 0.2)\ 10^{-3}$ (first measurement ever)
- Comparison with GEANT4:
  - v9.3 slightly underestimate n-production (-30%)
  - v9.5 is in agreement with LVD data

LBCF at Soudan
Soudan-2 prop tube muon veto walls
Time-stamped muon tracks correlated with neutron detection.



Cosmogenic Backgrounds: Activation Products

Cosmogenic activation: Difficult to calculate from first principles

cosmic ray spectrum varies with latitude
isotope cross sections poorly known
production dominated by (n,X) reactions (95%), rest are (p,X)

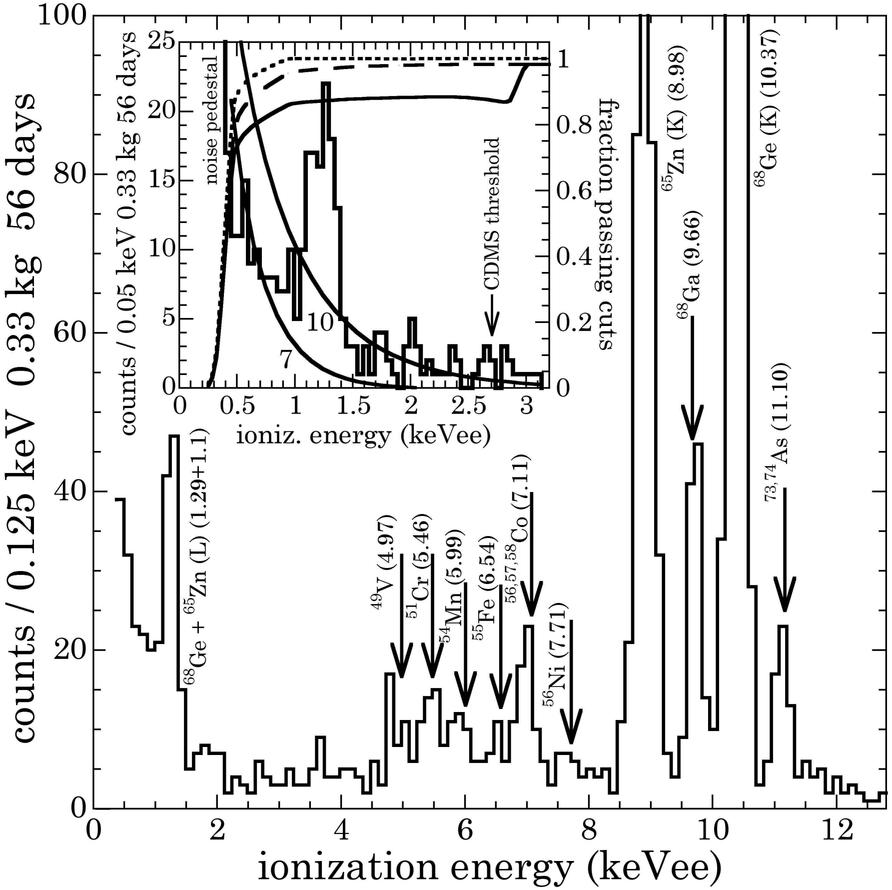
Avoidance

Material without neutron activation channels
(e.g. high purity silica, Al, Si)
Longterm underground storage of Cu, Ge,
Carefully-designed Transport containers
Identify local sources, no air transport

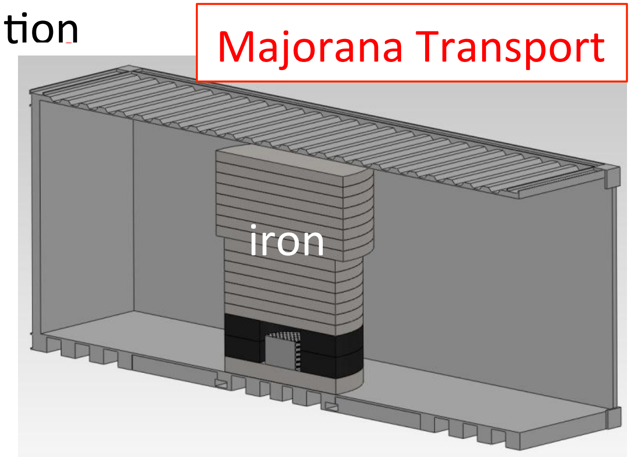
Background subtraction

Energy resolution
Calibration

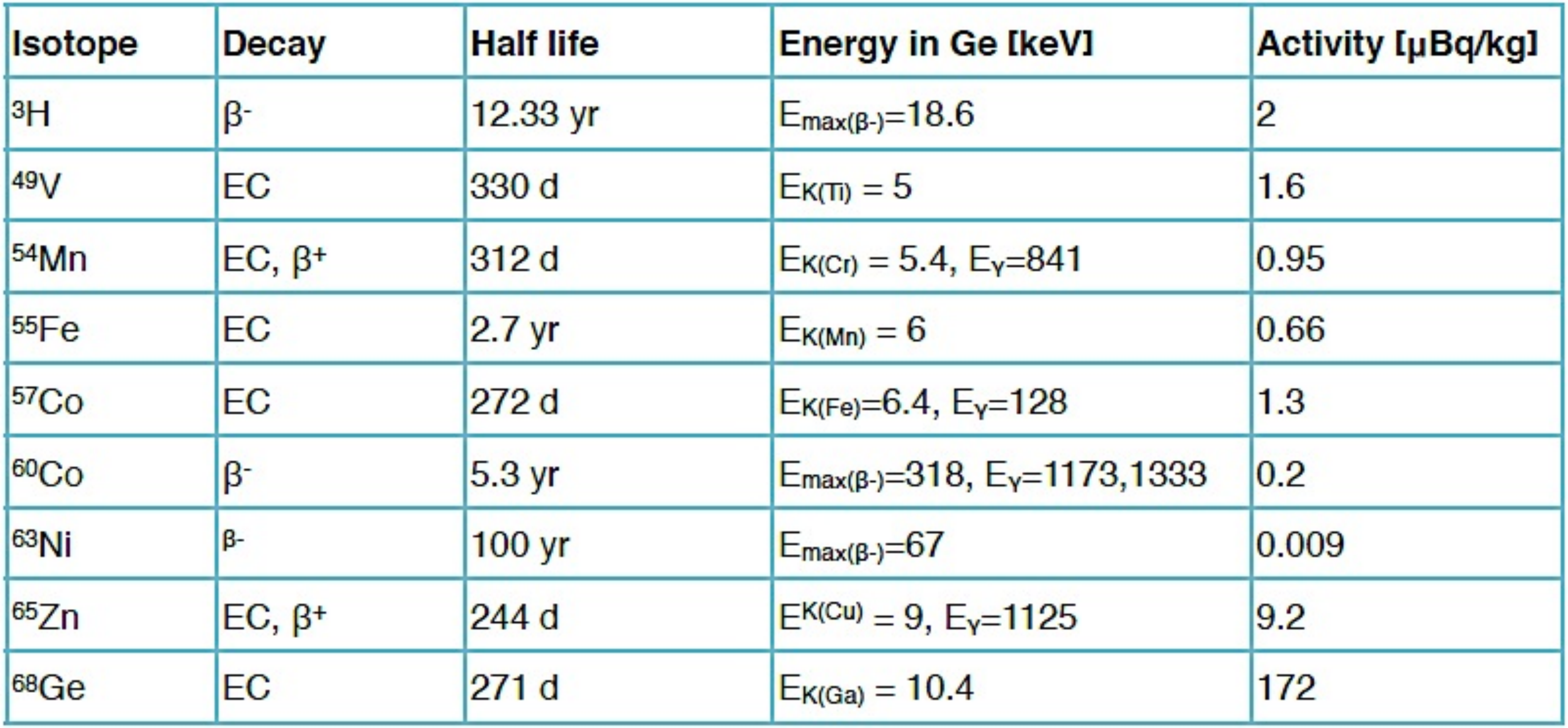
arXiv:1002.4703



Majorana Transport

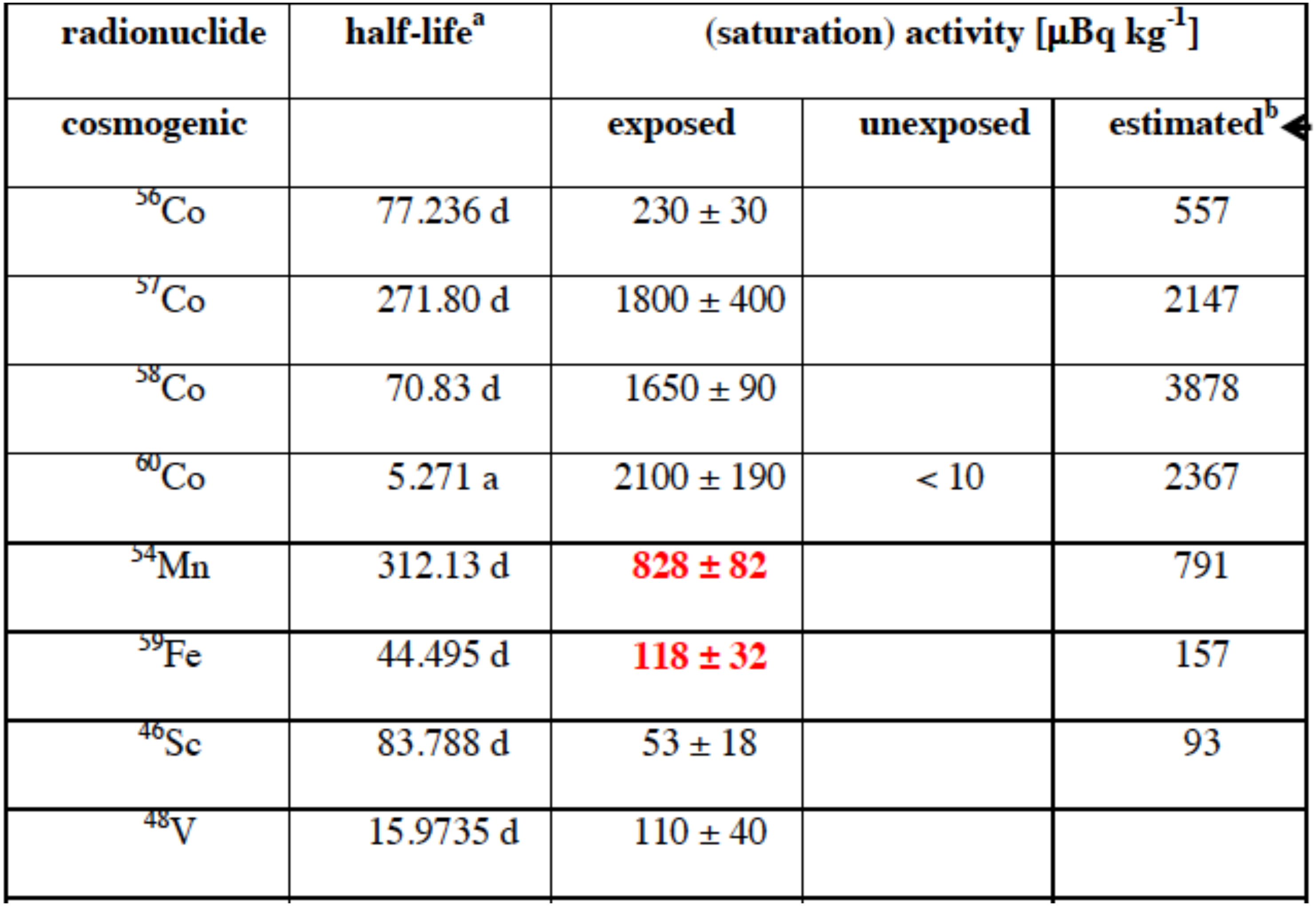


Production in Ge after 30 days surface exposure and 1 year storage underground



Isotope	Decay	Half life	Energy in Ge [keV]	Activity [μBq/kg]
^{3}H	β^{-}	12.33 yr	$E_{max(\beta-)}=18.6$	2
^{49}V	EC	330 d	$E_{K(Ti)} = 5$	1.6
^{54}Mn	EC, β^{+}	312 d	$E_{K(Cr)} = 5.4$, $E_{\gamma}=841$	0.95
^{55}Fe	EC	2.7 yr	$E_{K(Mn)} = 6$	0.66
^{57}Co	EC	272 d	$E_{K(Fe)}=6.4$, $E_{\gamma}=128$	1.3
^{60}Co	β^{-}	5.3 yr	$E_{max(\beta-)}=318$, $E_{\gamma}=1173,1333$	0.2
^{63}Ni	β-	100 yr	$E_{max(\beta-)}=67$	0.009
^{65}Zn	EC, β^{+}	244 d	$E^{K(Cu)} = 9$, $E_{\gamma}=1125$	9.2
^{68}Ge	EC	271 d	$E_{K(Ga)} = 10.4$	172

Cosmogenic Production Rates in Copper at LNGS Surface



radionuclide	half-life[a]	(saturation) activity [μBq kg^{-1}]		
cosmogenic		exposed	unexposed	estimated[b]
^{56}Co	77.236 d	230 ± 30		557
^{57}Co	271.80 d	1800 ± 400		2147
^{58}Co	70.83 d	1650 ± 90		3878
^{60}Co	5.271 a	2100 ± 190	< 10	2367
^{54}Mn	312.13 d	**828 ± 82**		791
^{59}Fe	44.495 d	**118 ± 32**		157
^{46}Sc	83.788 d	53 ± 18		93
^{48}V	15.9735 d	110 ± 40		

S. Cebrian et al.

Astroparticle Physics 33 (2010) 316–329

corrected after publication

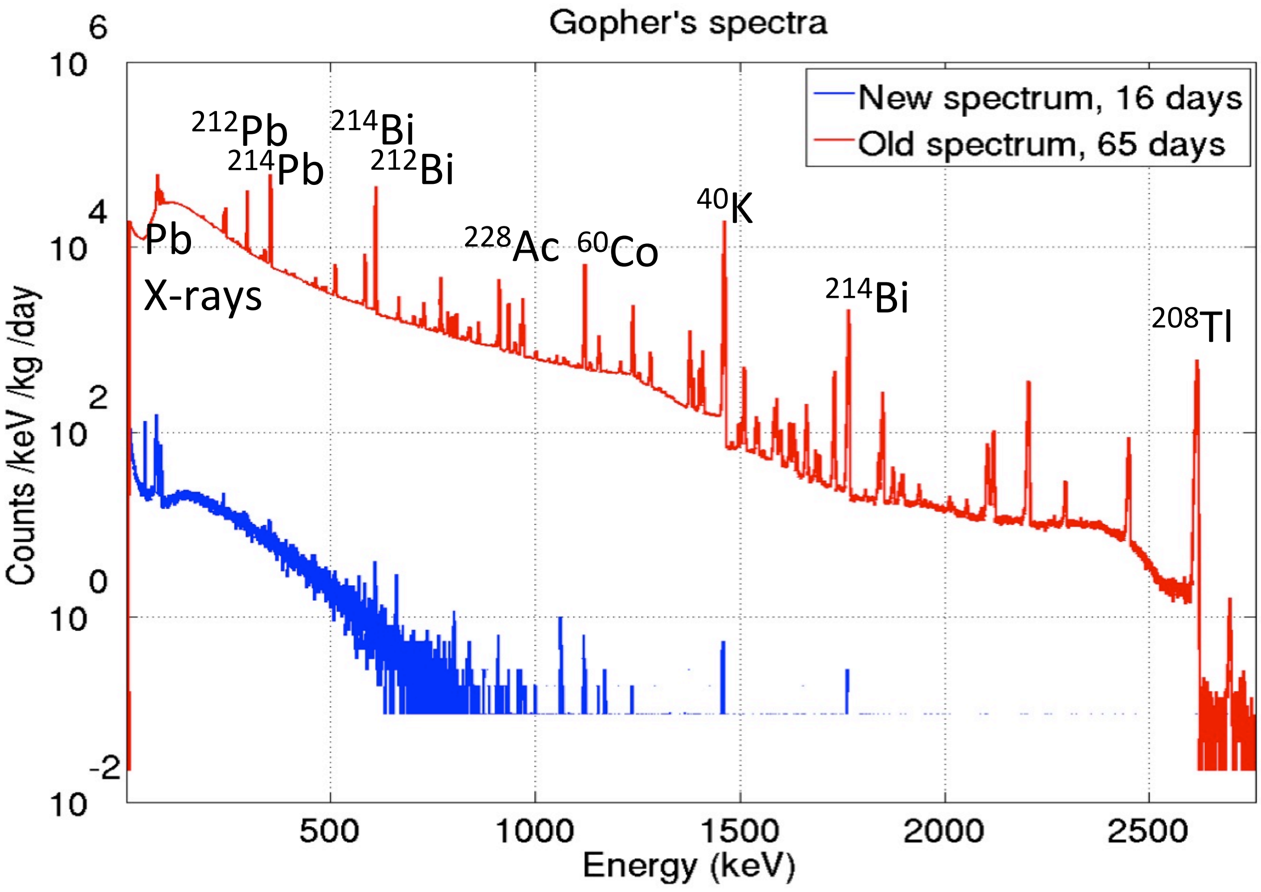
Applied Radiation and Isotopes 67 (2009) 750-754

Radiogenic Backgrounds

External

Cavern rock and shotcrete liners: ^{238}U chain, ^{232}Th chain, ^{40}K , ^{60}Co, ^{137}Cs
mostly gammas, and neutrons from (α,n) and fission reactions
Radon decay in air, Radon daughters on surfaces

Passive shields plus radon exclusion (N_2 purge, vacuum) do a good job



Background spectrum from the Soudan Mine.

30 cm of lead reduces it by orders of magnitude

Radiogenic Backgrounds

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mostly gammas, and neutrons from (α,n) and fission reactions
Radon decay in air, Radon daughters on surfaces

Passive shields plus radon exclusion (N_2 purge, vacuum) do a good job

But shields always introduce

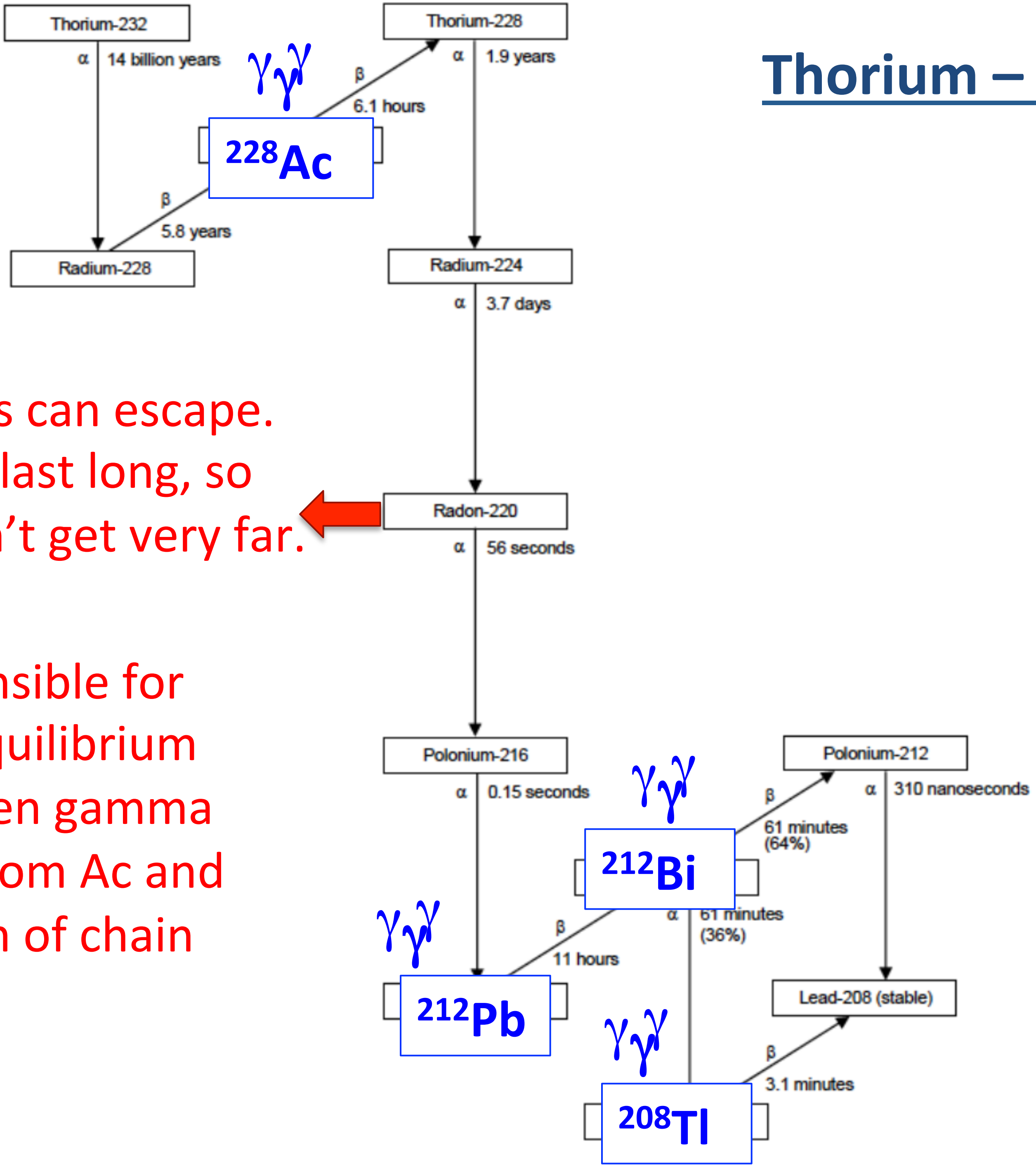
Internal

Cu, Steel, Iron have trace U/Th and also ^{60}Co
Plastics and rocks, concrete all have ^{40}K
Anthropomorphics like Sb, Cs from 1950's bomb test residue, pollution, etc
Naturally occurring isotopes in specialized target material like ^{39}Ar, ^{85}Kr

Lines of defense

Screen materials
Purify materials
Detect backgrounds in situ

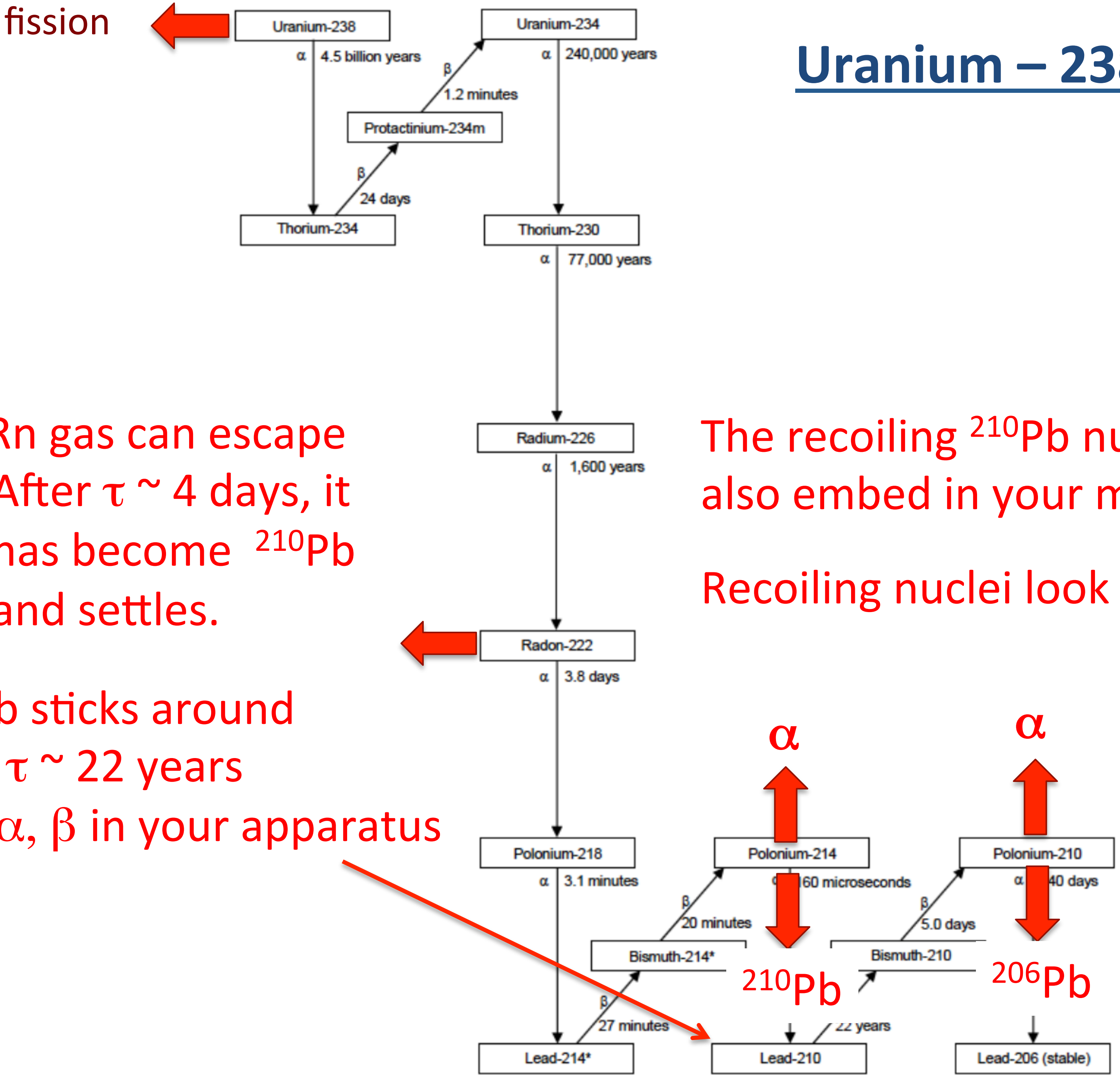
Thorium – 232 Chain



^{220}Rn gas can escape.
Doesn't last long, so
it doesn't get very far.

Responsible for
non-equilibrium
between gamma
lines from Ac and
bottom of chain

Uranium – 238 Chain



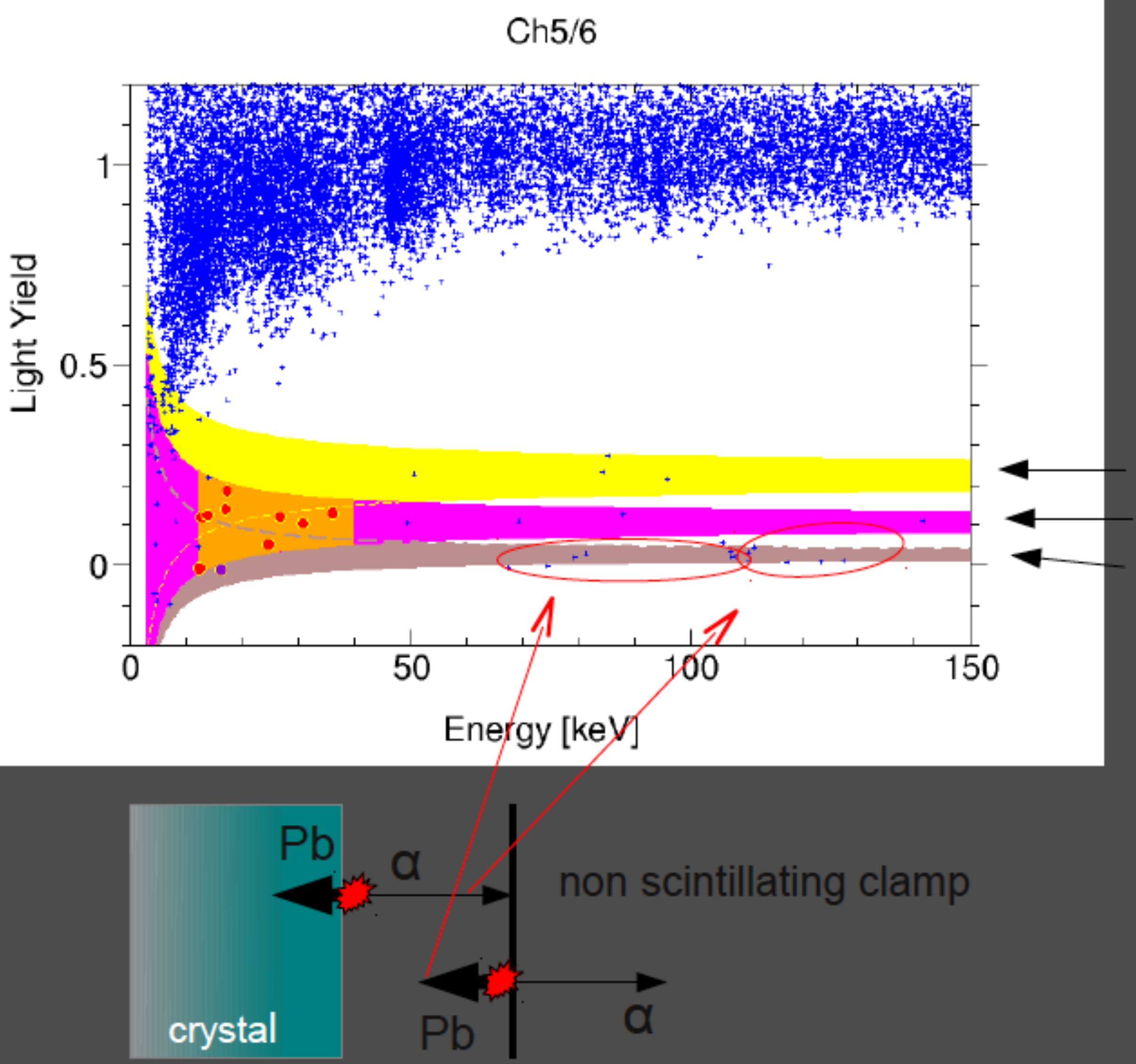
^{222}Rn gas can escape
After τ ~ 4 days, it
has become ^{210}Pb
and settles.

^{210}Pb sticks around
τ ~ 22 years
get α, β in your apparatus

The recoiling ^{210}Pb nucleus can also embed in your material.

Recoiling nuclei look like NR !

Lead Recoils in CRESST



alpha band

oxygen band

tungsten band

Degraded α's in alpha band and ^{206}Pb recoils in W band from contaminated non scintillating clamps used in this run.

Light Yield of W and Pb is too similar to distinguish.
Some leakage of Pb recoil into signal energy range of W band ??

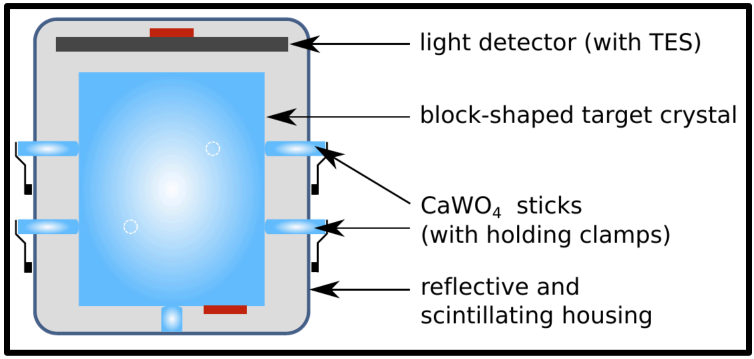
$^{210}\mathrm{Po} \longrightarrow {}^{206}\mathrm{Pb}$ (103 keV) + α (5.3 Me)

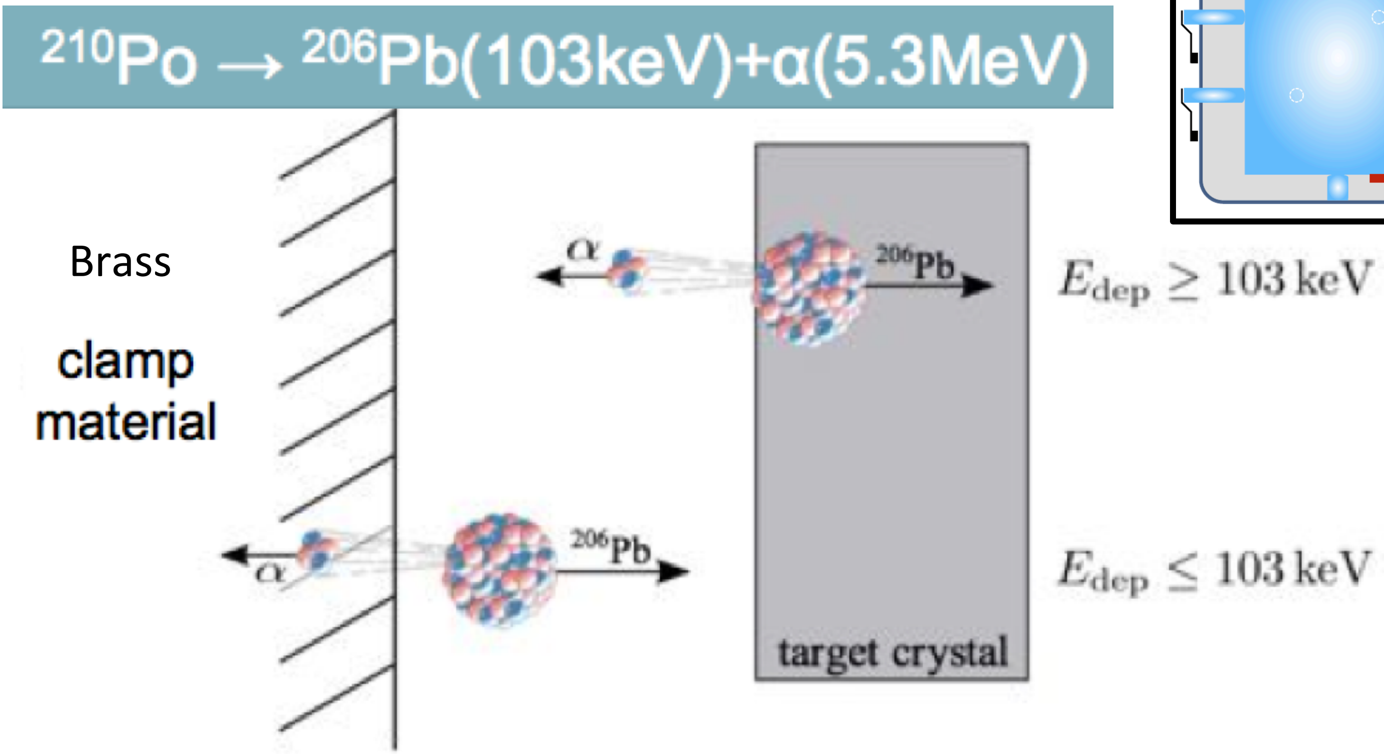
Lead Recoils in CRESST

Usually α is caught and provides a tag, but not if Po decay is from the clamps.

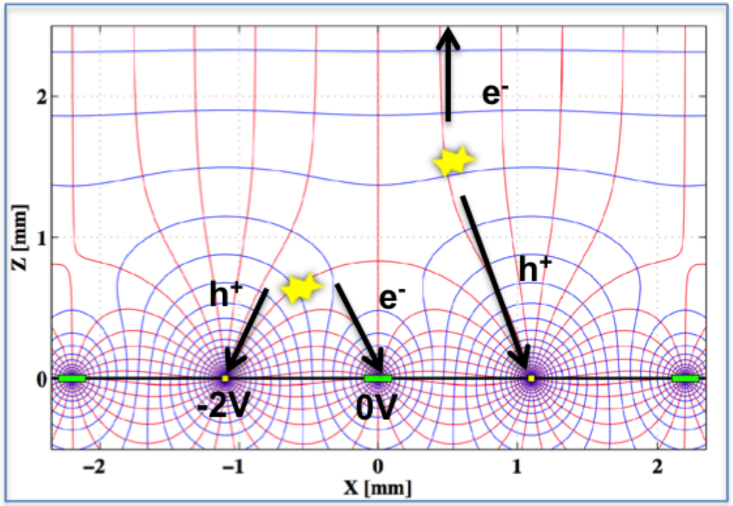
Also outgoing α from clamp sputters clamp material ➔ rough surfaces keep α in place, but low energy ejectiles are detected

New scintillating clamps





Lead Recoils in SuperCDMS

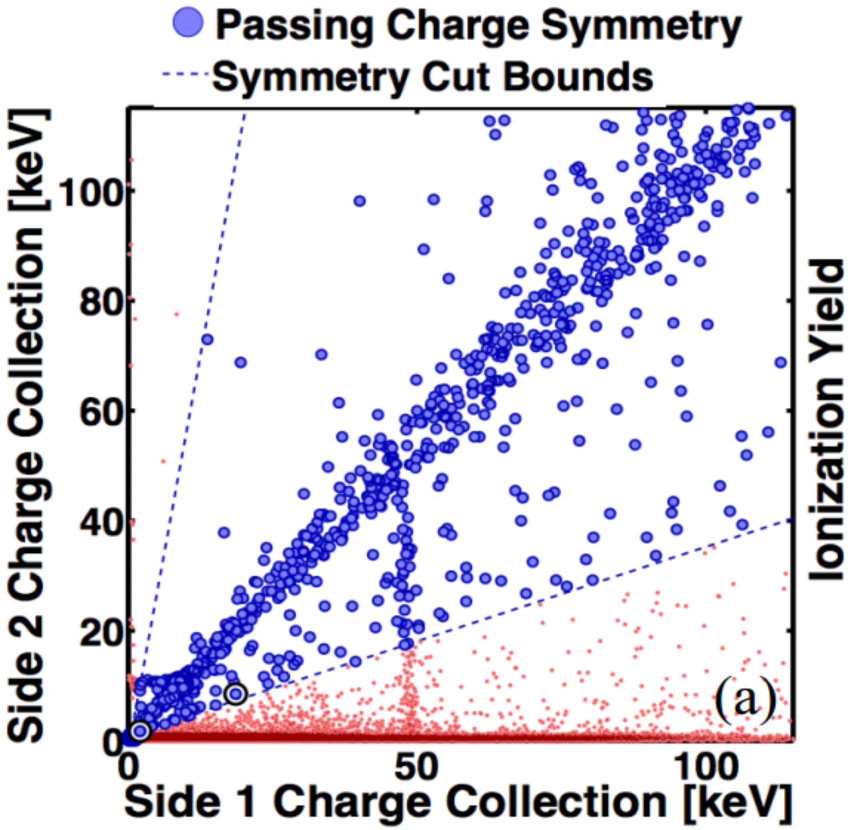


Bulk recoils have charge collected on both faces

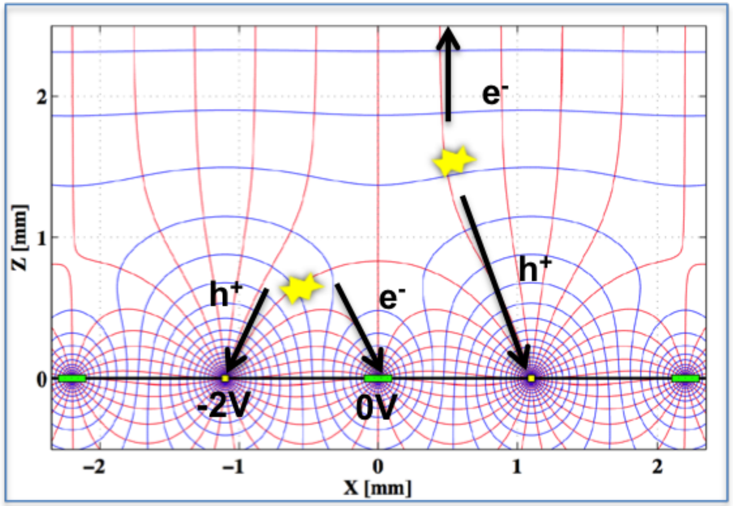
Surface recoils are only on one.

Symmetry cut removes surface events

Source applied to one surface



Lead Recoils in SuperCDMS



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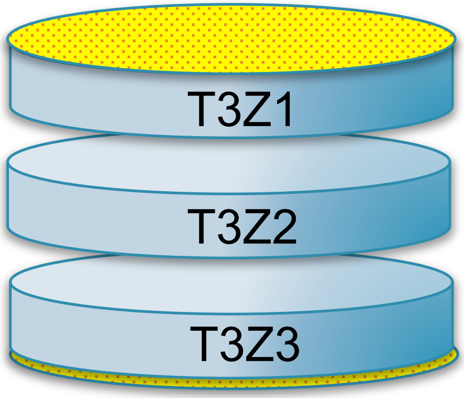
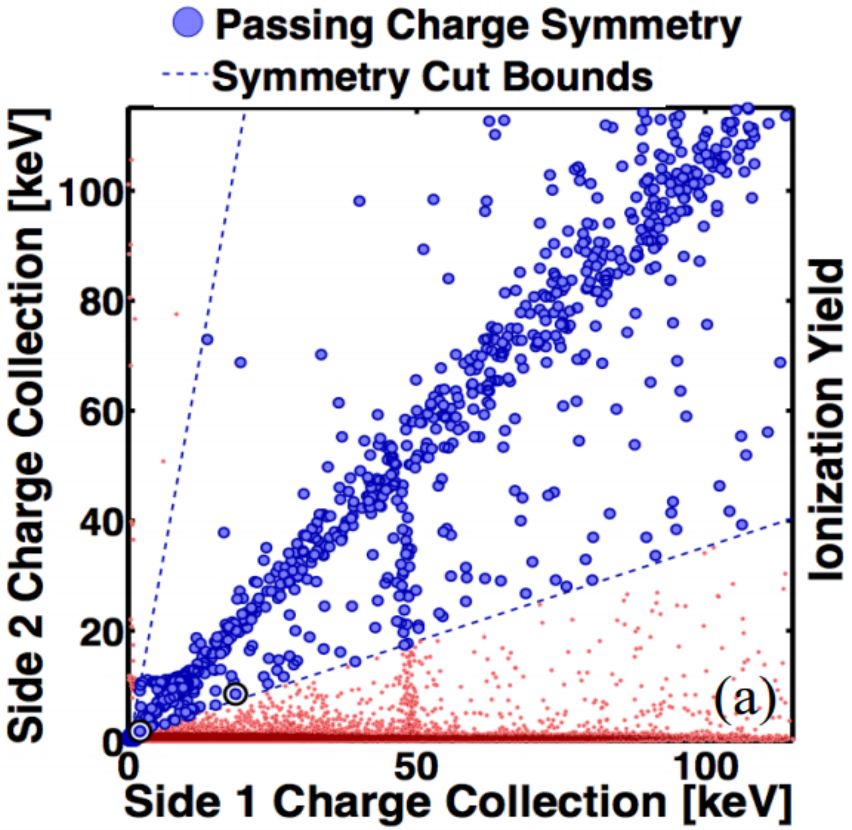
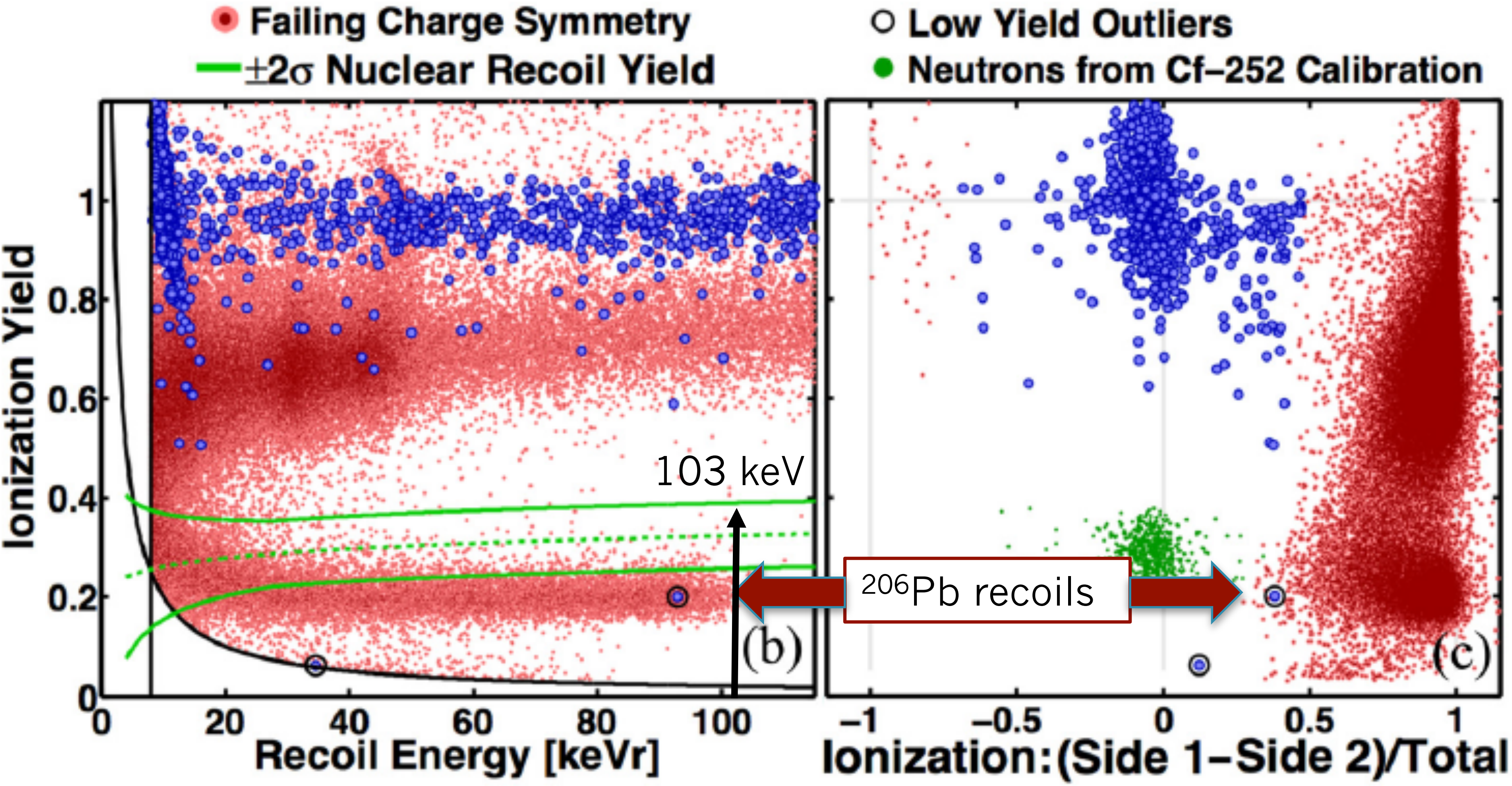


Two Si wafers implanted with ^{210}Pb
(in a box with a 5 kBq ^{226}Ra source)



Lead Recoils in SuperCDMS

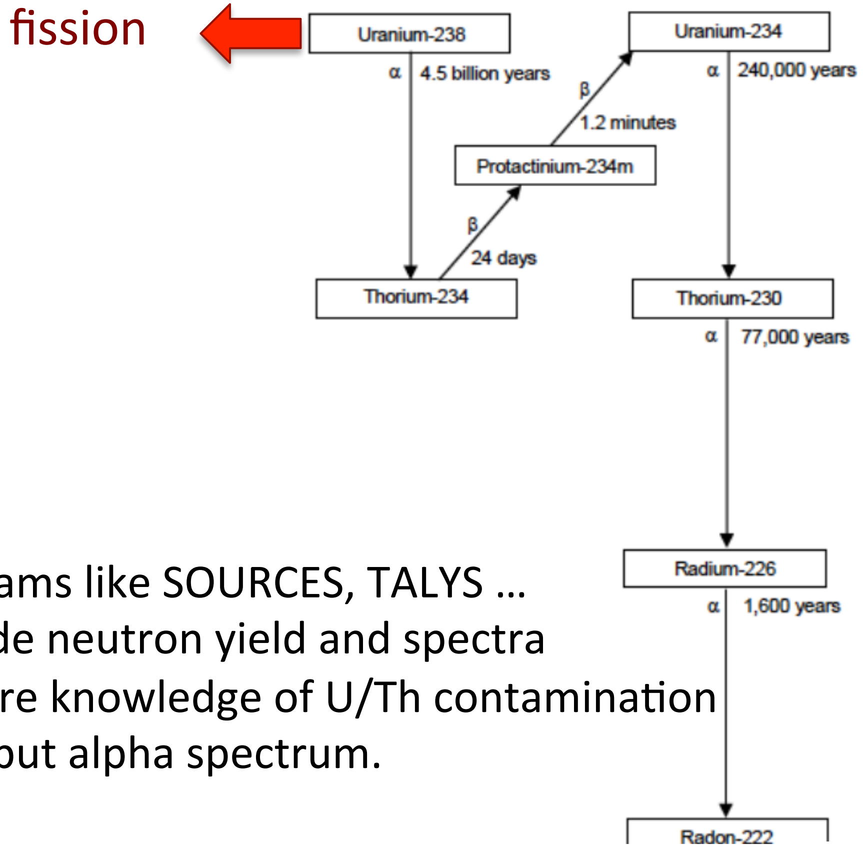
In ~800 live hours, there were NO leakage events
Upper limit of Surface rejection (just for the charge symmetry cut)
1.7 x 10^{-5} at 90% CL



103 keV

^{206}Pb recoils

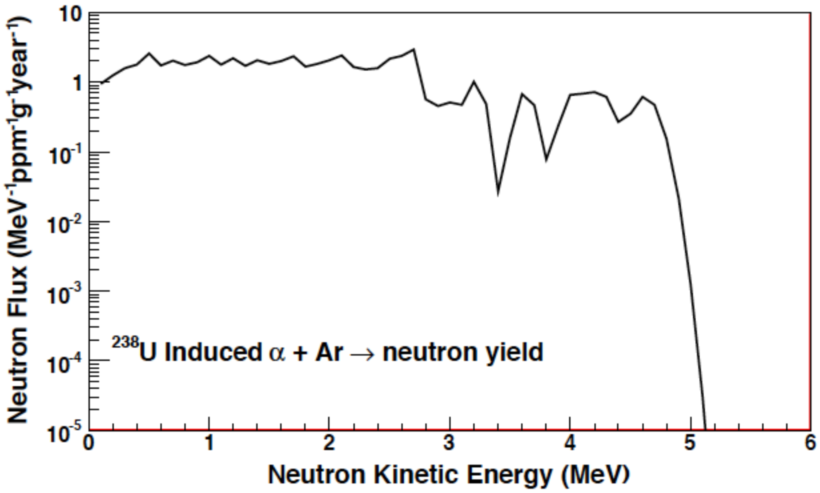
Uranium – 238 Chain

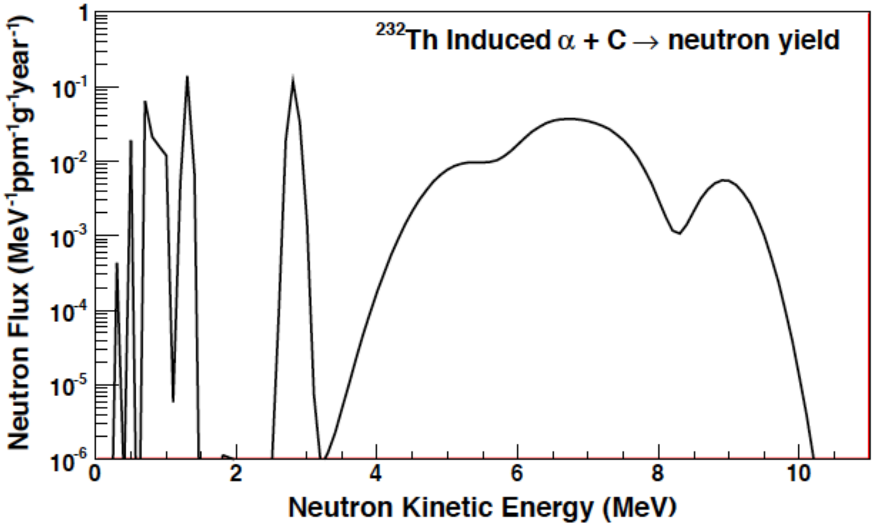


Spontaneous fission is obvious source of neutrons

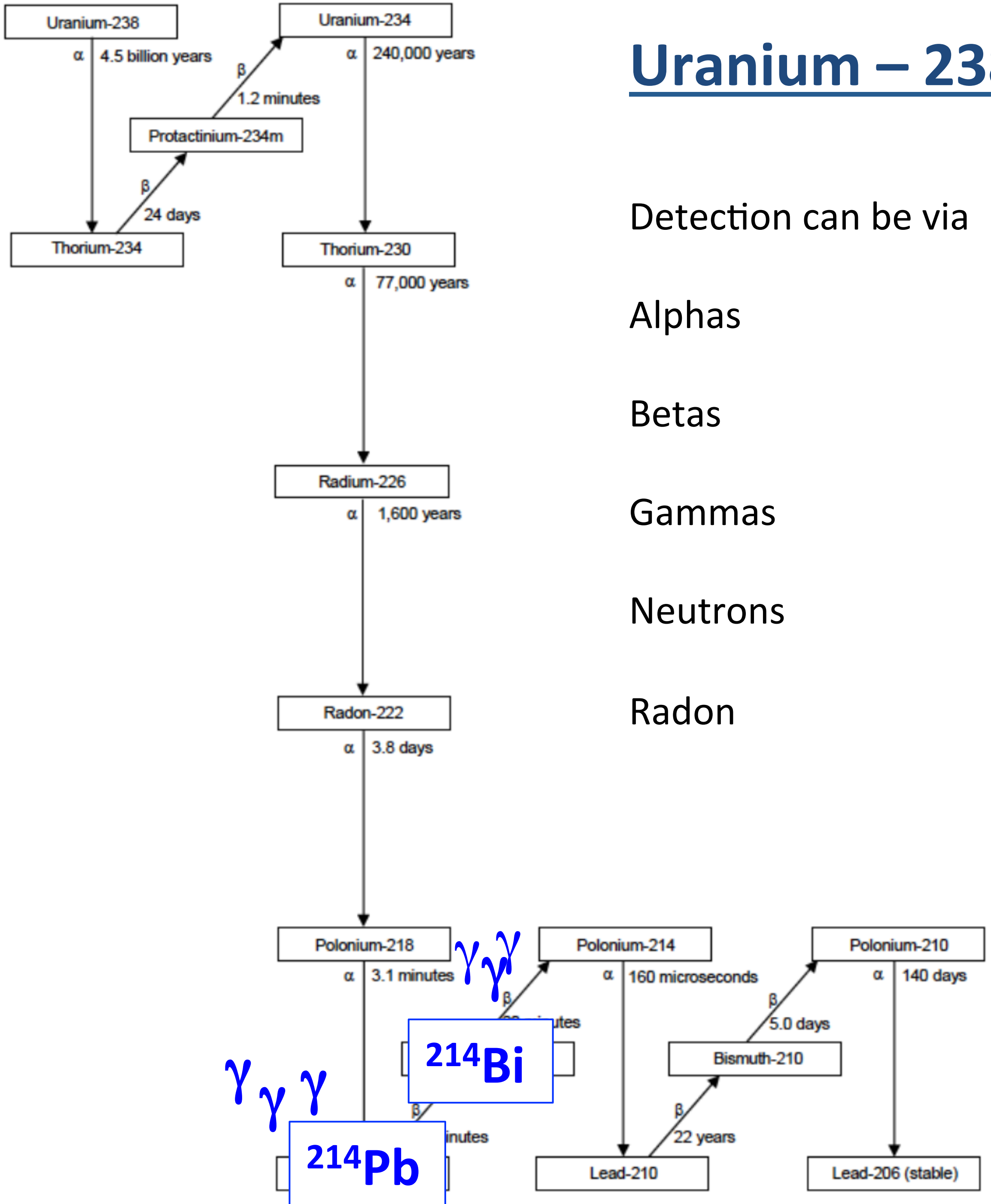
But all those alphas can also induce neutrons when interacting with shield/target materials.

Programs like SOURCES, TALYS …
Provide neutron yield and spectra
Require knowledge of U/Th contamination for input alpha spectrum.





Uranium – 238 Chain



Detection can be via

Alphas

Betas

Gammas

Neutrons

Radon

Screen Materials

Counting techniques

High Purity Germanium Detectors
Neutron Activation Analysis
Alpha/Beta Counters
Radon emanation
Gas proportional Counters (e.g. measure ^{39}Ar)

Non-radiometric

Mass spectroscopy (ICPMS, TIMS, SIMS, GDMS, AMS…)

Surface Analysis

Probe elemental composition, sub-micron position and depth profiles.. using ion or electron beams, X-rays, etc: RBS, XRF, FReS, NRA, Auger, PIXE …

Atom Trap Trace Analysis (ATTA)

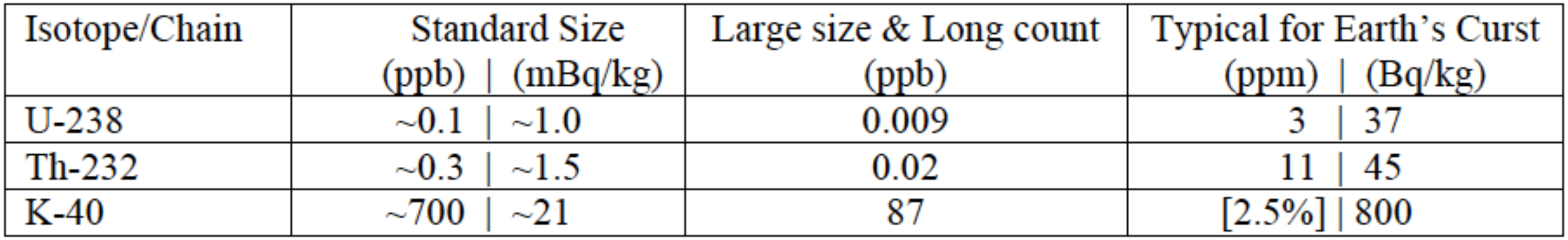
Laser cooling techniques trap atoms, excite them to a metastable state, and then detect their fluorescence. Measure abundance by counting atoms. Example: Measure ^{85}Kr and ^{39}Ar to a few parts in 10^{-14}

Gamma Spectroscopy
High Purity Germanium Detectors (HPGe)

- Elements must have gamma decays between 10 keV to several MeV
- Excellent energy resolution and isotope identification
- Continued improvement of backgrounds
- For best sensitivity, weeks - months of counting

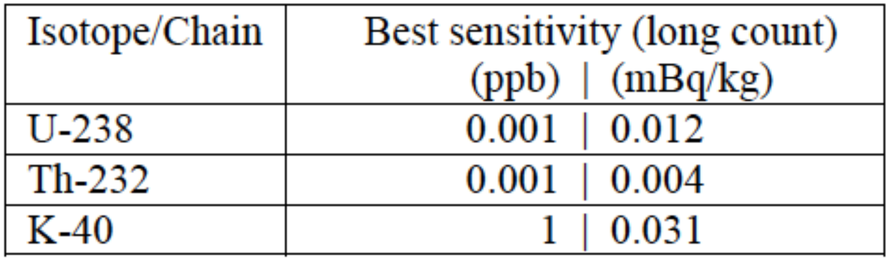
Commercial: few hundred ppb of U and Th

Augmented Commercial: (e.g. custom shield, active veto, underground)



Isotope/Chain	Standard Size		Large size & Long count	Typical for Earth's Curst	
	(ppb)	(mBq/kg)	(ppb)	(ppm)	(Bq/kg)
U-238	~0.1	~1.0	0.009	3	37
Th-232	~0.3	~1.5	0.02	11	45
K-40	~700	~21	87	[2.5%]	800

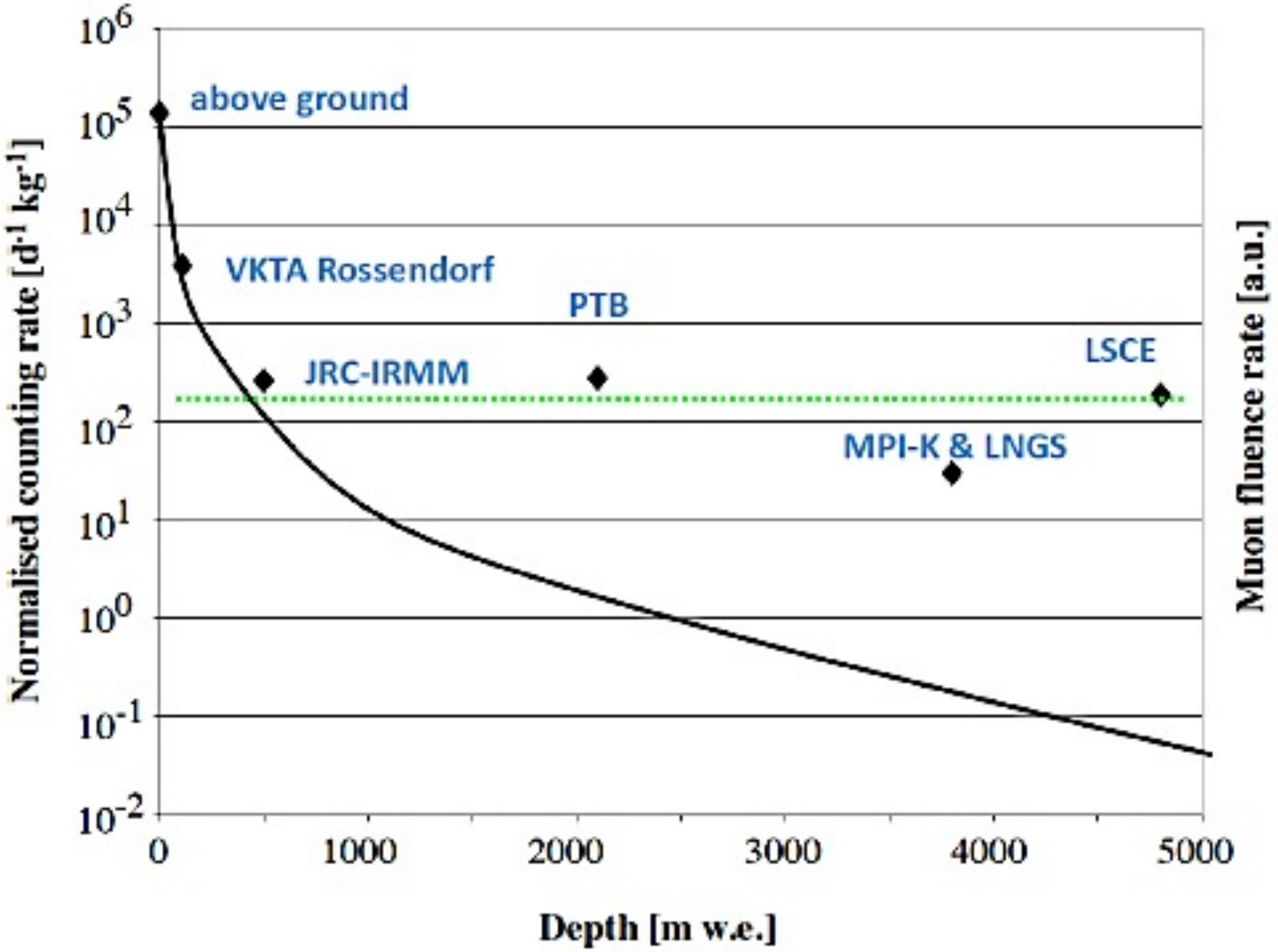
Fully Custom: e.g.GeMPI style



Isotope/Chain	Best sensitivity (long count)	
	(ppb)	(mBq/kg)
U-238	0.001	0.012
Th-232	0.001	0.004
K-40	1	0.031

High Purity Germanium Detectors (HPGe)

At some point, increased overburden no longer matters
The HPGe is limited by internal backgrounds



High Purity Germanium Detectors (HPGe) GeMPI Style

1. Ge-crystal

minimize cosmic ray exposure

fast processing after zone refining

surface transportation and storage underground

2. Cryostat system

made only from screened materials with a radio-purity level below the mBq/kg level

Use NOSV grade copper, stored underground shortly after electrolysis and between machining steps,

e-beam welding, no soldering, crimping of contacts, metal sealing for joints

electro-polishing of metals, acid cleaning under clean room conditions

assembly of detector under clean room conditions

3. Shield

large sample volume

Acid cleaned, ultra-pure Cu liner

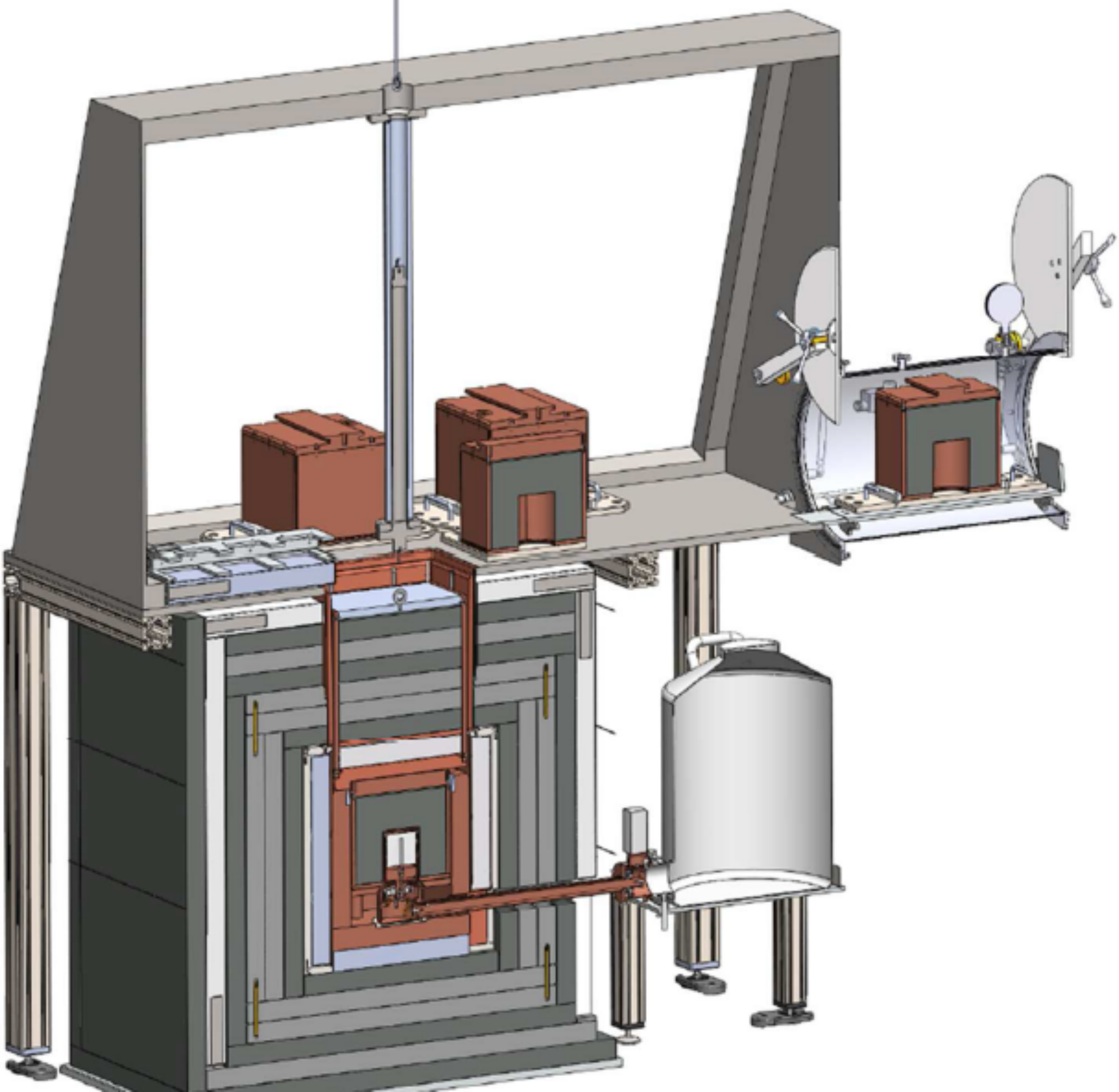
Acid cleaned Pb with 6 Bq/kg ^{210}Pb

Additional Pb layers with increasing ^{210}Pb-concentration

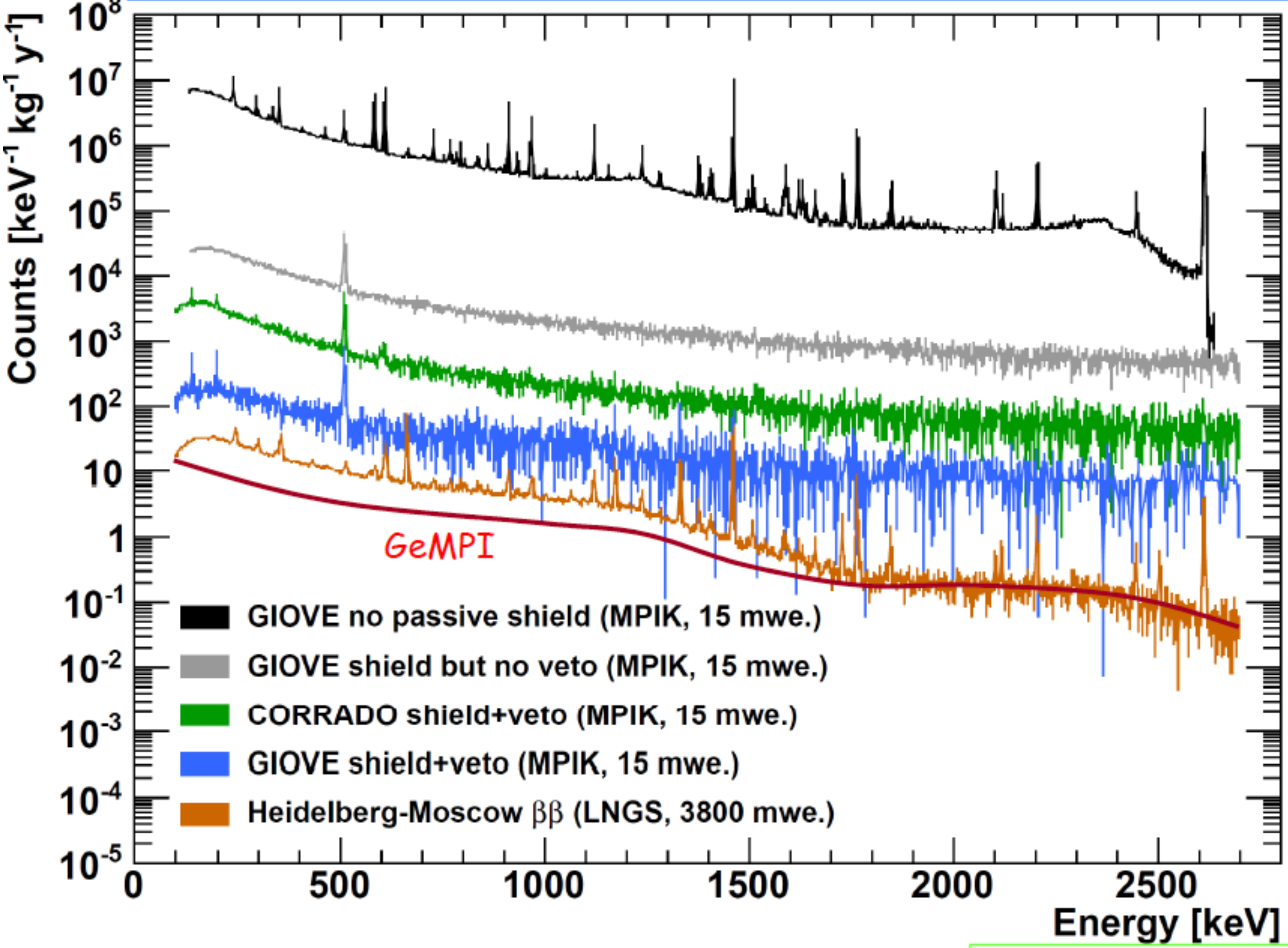
Airtight steel box around shield, pressurized with N_2 gas (Rn protection)

Air lock system for sample insertion

Sample storage and prep



background comparison of GIOVE with other MPI detectors and HDM



G. H. , LRT2013, LNGS, 10.04.2012

Neutron Activation Analysis: NAA

A source of neutrons:

Reactors up to 10^{13} n cm^{-2} s^{-1}

High flux deuterium-tritium plasma generators

Reaction on Sample:

neutron capture, then emission of prompt γ's (PGNAA)

and/or radioactive nucleus which emits delayed γ's

Gamma spectroscopy:

PGNAA in situ at irradiation site

NAA at counting facility

➔ not necessarily high sensitivity HPGe

➔ in fact, most don't want your radioactive samples near their HPGe!

Example:

Count ^{239}Np ($t_{1/2}$ = 2.36 d) and ^{233}Pa ($t_{1/2}$= 27 d) from ^{238}U and ^{232}Th.

Technique limited by the nuclear properties of trace element
(~60% of elements activate) and substrate (activation of substrate masks lines)

NAA Example: LZ program at UC Davis

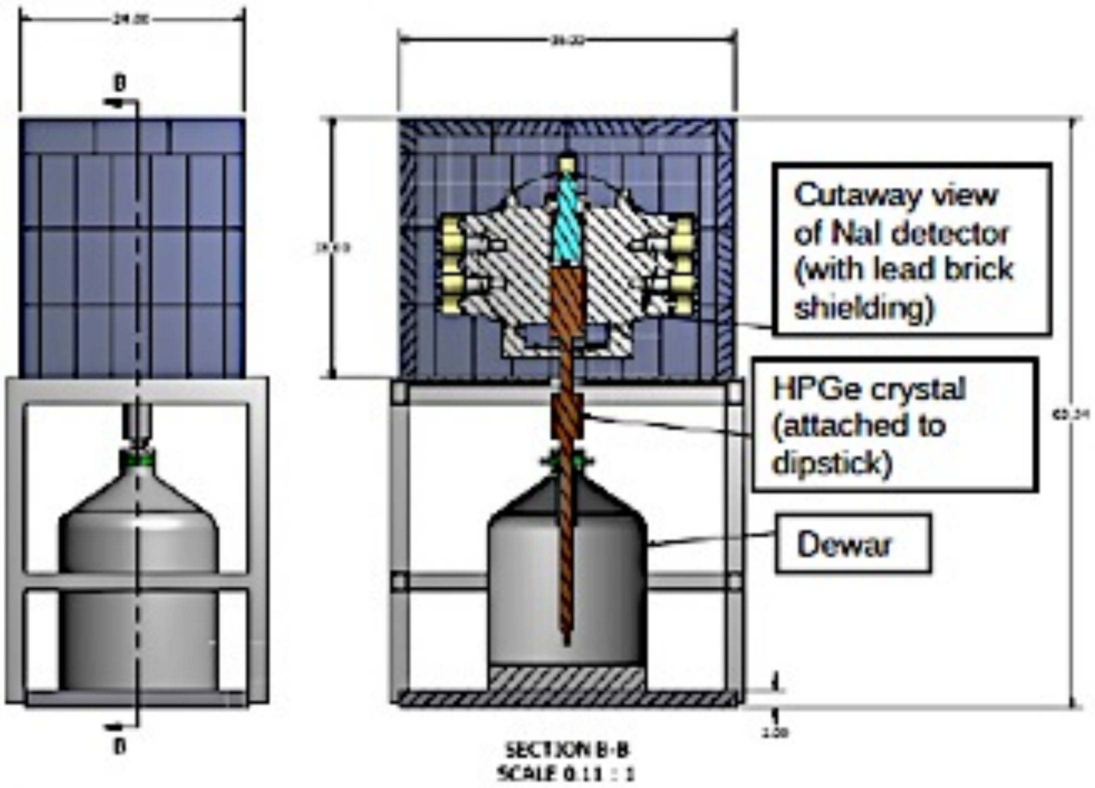
How do we obtain/screen radiopure titanium?

Reactor

McClellan NRC TRIGA Mark-II (2 MW), also UC Irvine Chemistry Research TRIGA (250 kW)

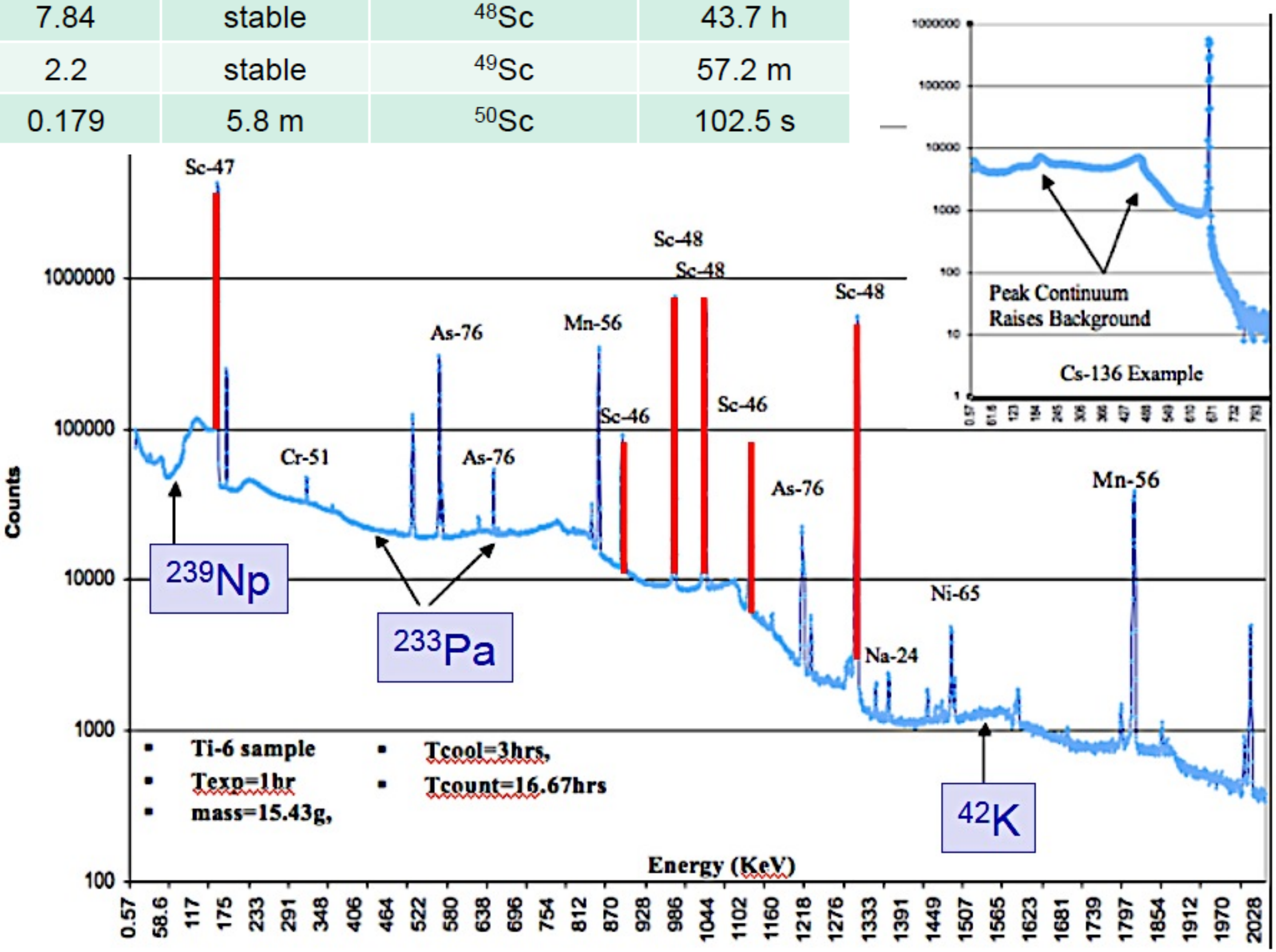
Detector

Commercial HPGe, but add NaI annulus as a Compton Veto
Event-by event readout; 100MHz 14-bit digitization



Backgrounds from fast neutron reactions: ^{A}Ti (n,p) ^{A}Sc

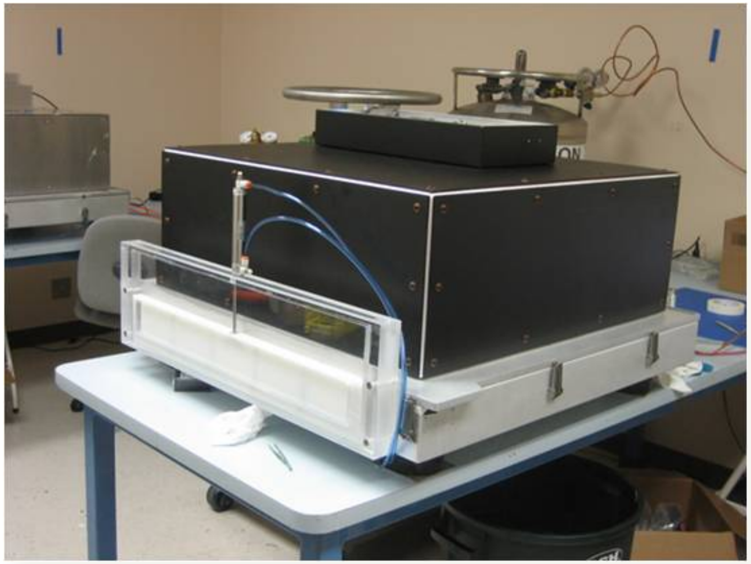
Ti isotope	Isotopic abund.	σ_γ (barns)	(n,γ) daughter $T_{1/2}$	(n,p) daughter	(n,p) daughter $T_{1/2}$
46	8.0%	0.59	stable	^{46}Sc	83.8 d
47	7.3%	1.7	stable	^{47}Sc	3.4 d
48	73.8%	7.84	stable	^{48}Sc	43.7 h
49	5.5%	2.2	stable	^{49}Sc	57.2 m
50	5.4%	0.179	5.8 m	^{50}Sc	102.5 s



- Ti-6 sample
- Texp=1hr
- mass=15.43g,
- Tcool=3hrs,
- Tcount=16.67hrs

Alpha Counting

XIA Ultra-Sensitive Alpha Screener



XIA ultralo 1800 prototype

Units exist at FNAL and SMU

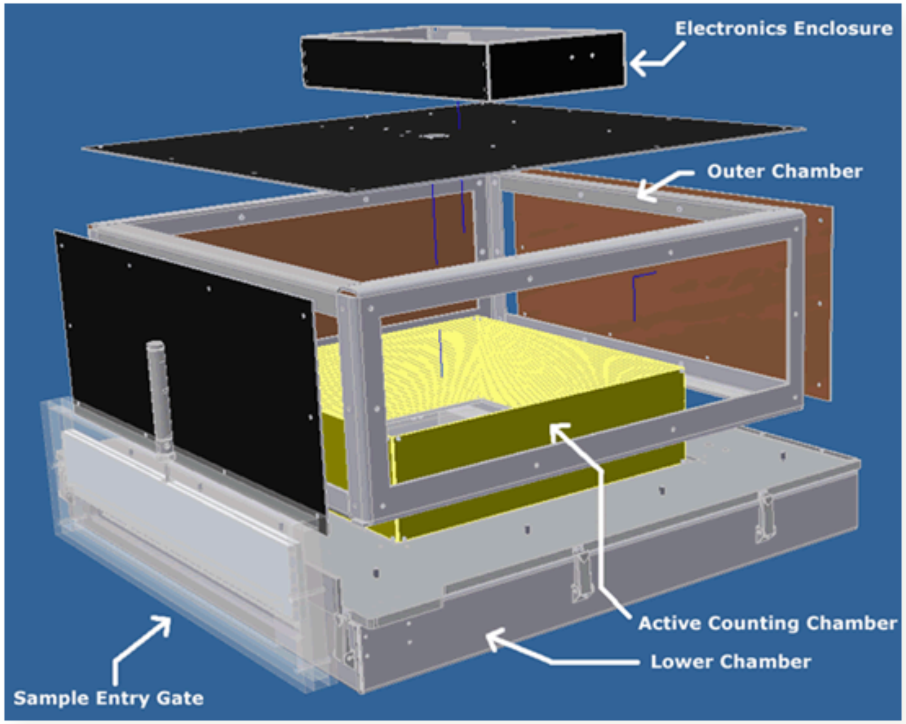
counting area is 1800 cm^2

Sensitivity: 0.2 alphas/detector/day

--> 2×10^{-3} alphas/cm^2/day

scdms goal: 0.32 alphas/detector/day

--> 4.6×10^{-3} alphas/cm^2/day



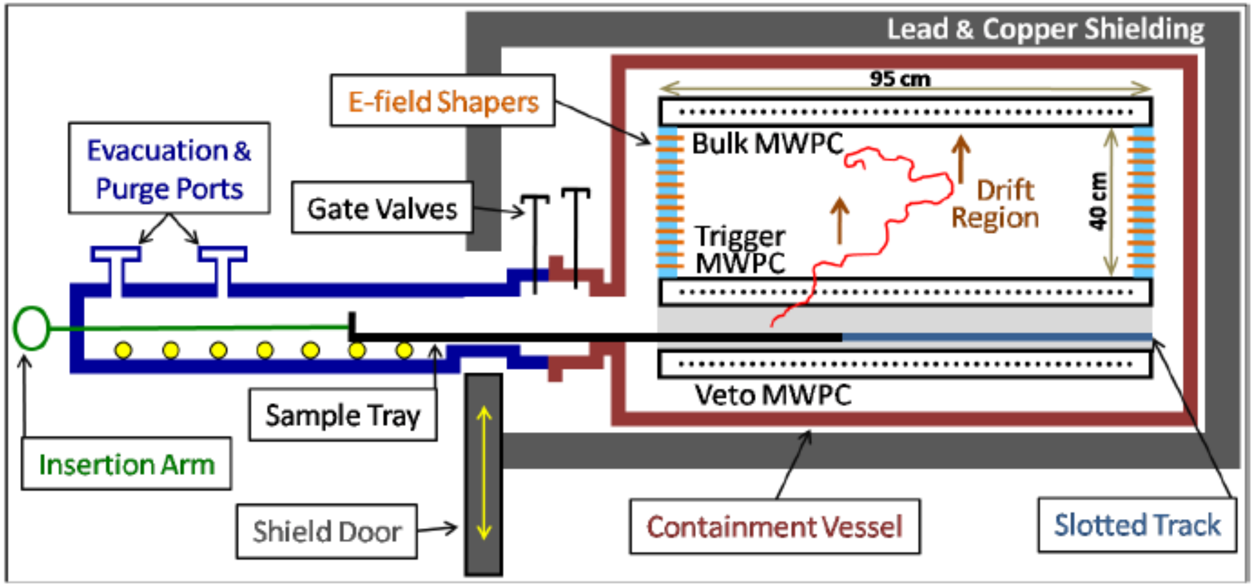
Alpha and Beta Counting

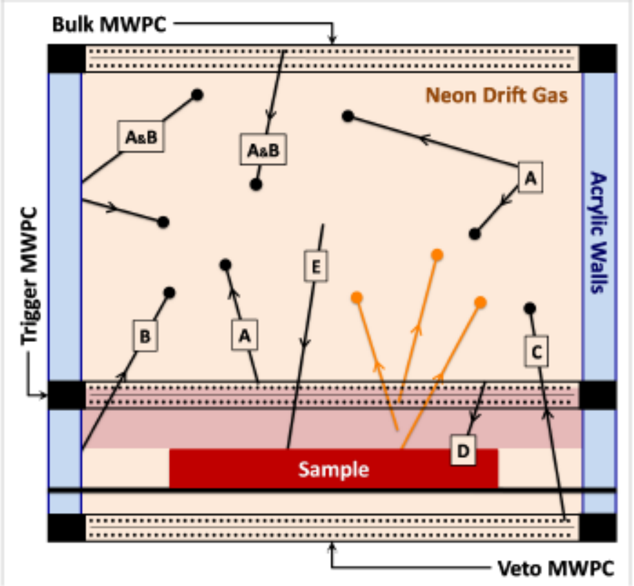
Beta Cage

US Prototype: developed by Caltech, Syracuse – continuing work at SDSMT
Canadian Prototype: Alberta

- Screener for low-energy electron emitters & alpha-decaying isotopes:
- Ne (gas) time-projection chamber with 3 Multi-Wire Proportional Chambers (MWPC)
- 95x95 cm^2 sample area with 40 cm drift region
- Sensitivity goals 0.1 betas (per keV-m^2-day) & 0.1 alphas (per m^2-day)

Factor of 200 better than XIA





Alpha and Beta Counting

Beta Cage

Beta Bkg = Photon-induced

20-cm thick lead shield reduces external γ's

But ^{210}Bi in the inner 5 cm of lead (3 Bq/kg ^{210}Pb) may dominate

Internal acrylic, copper components, Noryl MWPC frames.

Alpha Bkg = RadonDaughters

Plateout on wires (electropolish)

Radon emanation from detector materials

(cooled carbon trap, high flush rate)

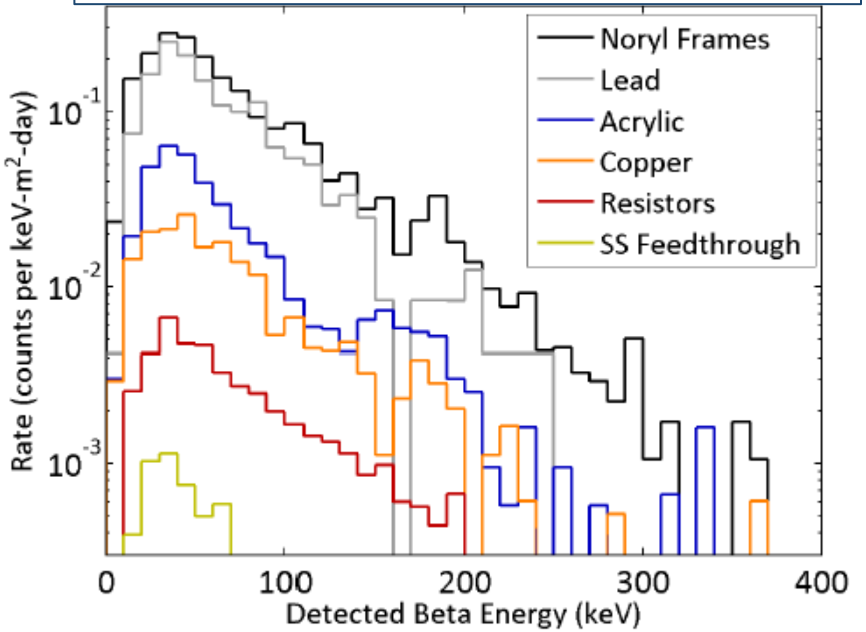
Operate underground

Screening

UMN Gopher HPGe
UC Davis NAA
Caltech ICPMS

^{238}U: 1 mBq/kg
^{232}Th: 3 mBq/kg
^{40}K: 5 mBq/kg

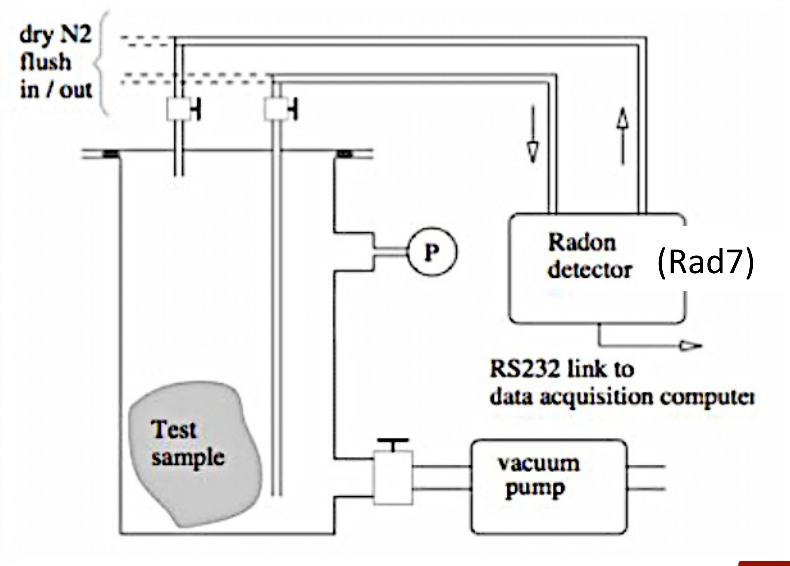
Radiopure construction, see
Ahmed et al. JINST 9 (2014) P01009



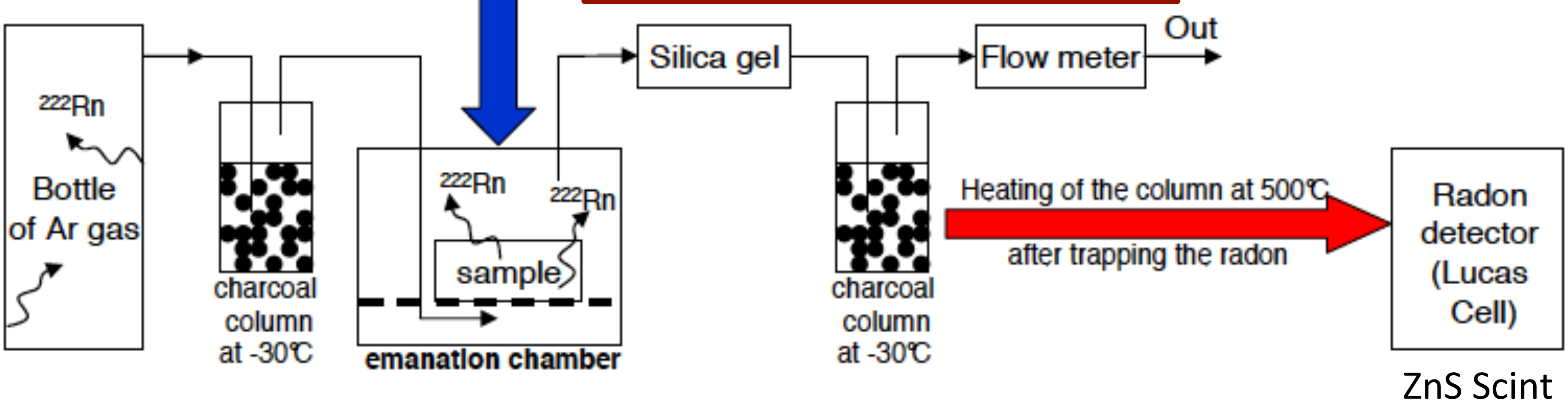
Radon Emanation Chambers

Quantify trace elements by concentrating their emanating radon

Simple one at Boulby Mine

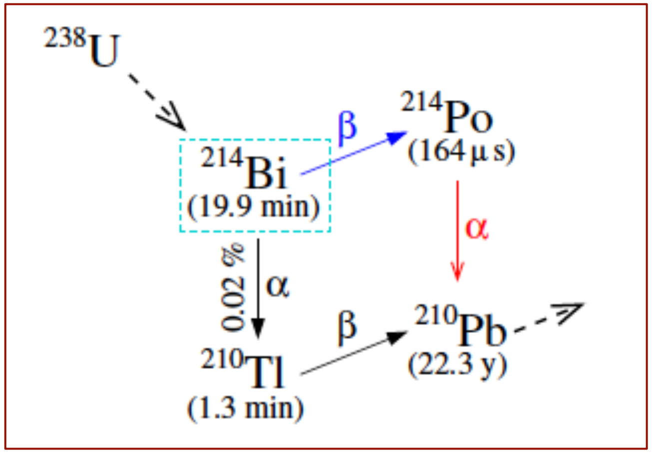


Sensitive one for SuperNEMO

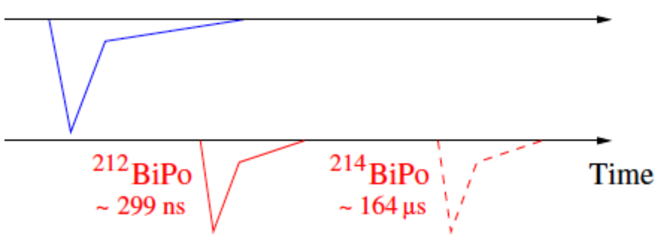


Radon Emanation Chambers

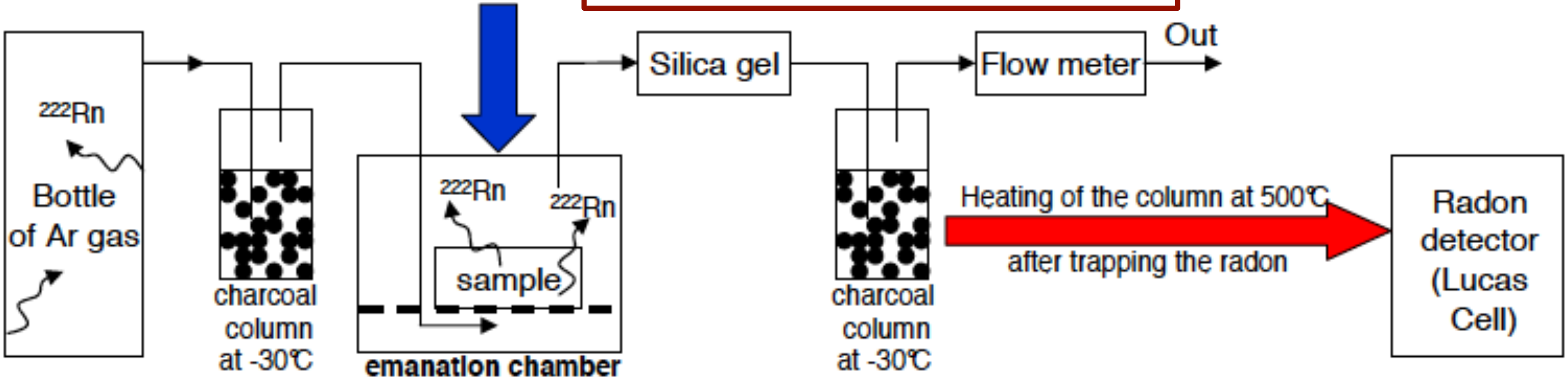
Quantify trace elements by concentrating their emanating radon



Add timing for a BiPo Detector

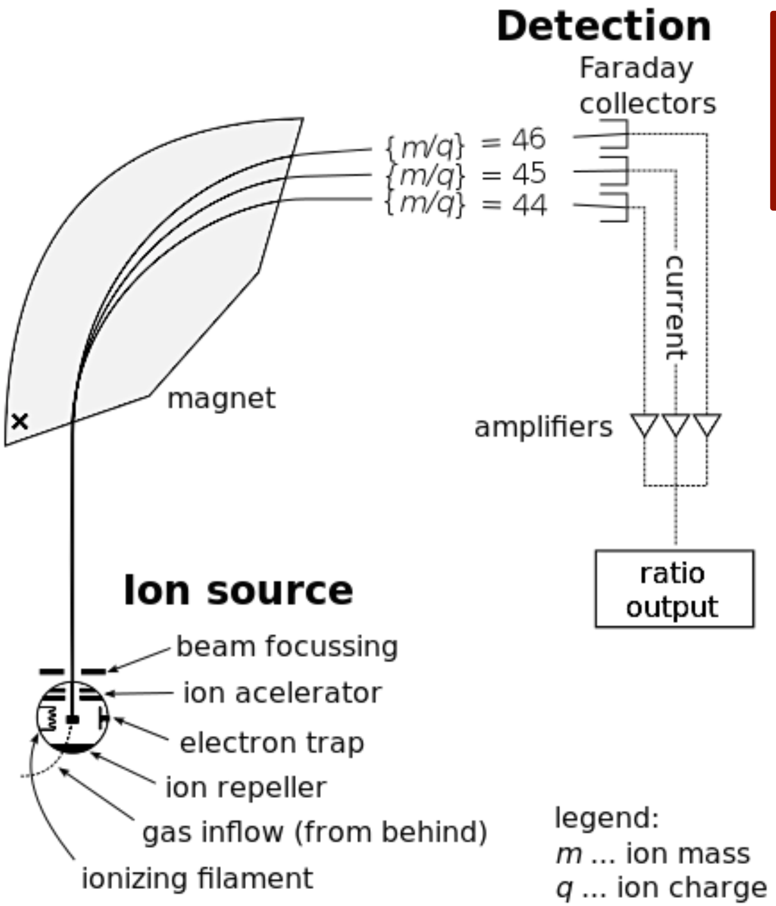


Sensitive one for SuperNEMO



ZnS Scint

Mass Spectrometry



Extract and accelerate charged ions from a sample and measure the trajectory corresponding to the correct charge-to-mass ratio for the element in question.

ICPMS: Inductively-Coupled Plasma
Ar gas creates aerosol out of liquid and sprays it through an argon plasma torch

TIMS: Thermal Ionization
Heat a coated filament

SIMS: Secondary Ion
Ion beam sputters surface to release ions

GDMS: Glow Discharge
DC plasma discharge cell with sample as cathode.

AMS: Accelerator
Often re-tooled nuclear research tandems with ion chambers and MWPCs.
^{14}C dating, parts per 10^{15}. Expensive.

Mass Spectrometry: ICPMS

Quoted sensitivity

depends on magnetic spectrometer and sample dispersion technique

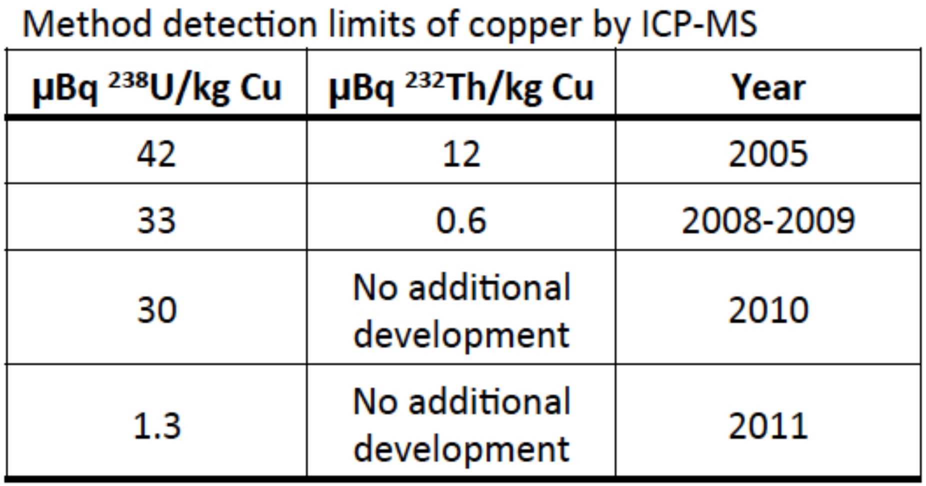
Real sensitivity

depends on sample prep and handling
pure and consistent blanks
innovative means to extract the liquid sample

PNNL has been a leader in assaying a wide variety of materials

- Electronic components such as FET, resistors, cables, epoxies
- Polymers such as PTFE, HDPE, etc.
  - novel digestion techniques to create an acid soluble residue from the polymer

And, of course, COPPER



Method detection limits of copper by ICP-MS

μBq ^{238}U/kg Cu	μBq ^{232}Th/kg Cu	Year
42	12	2005
33	0.6	2008-2009
30	No additional development	2010
1.3	No additional development	2011

HPGe counting vs. destructive assay

- Consider copper assay example (< 50 μBq/kg sensitivity)
  - Assay reduction time: 1/16

24.23 kg OFHC Cu nuggets, 2009

→

GeMPI-2 at Gran Sasso (4 month count or 8 kg-yr):

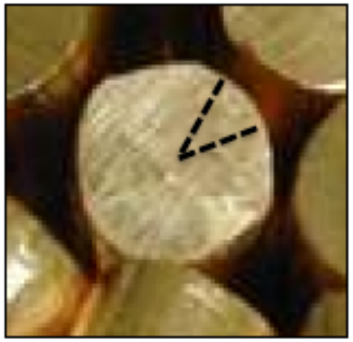
- ^{40}K 190 ± 60 μBq/kg
- ^{226}Ra 20 ± 10 μBq/kg
- ^{228}Th 30 ± 10 μBq/kg

(Thanks to M. Laubenstein)

equilibrium

assumed

0.01 kg OFHC Cu nugget, 2009



→

ICP-MS at PNNL (1 week):

- ^{40}K < 500 μBq/kg
- ^{238}U < 30 μBq/kg
- ^{232}Th 1.3 ± 0.6 μBq/kg

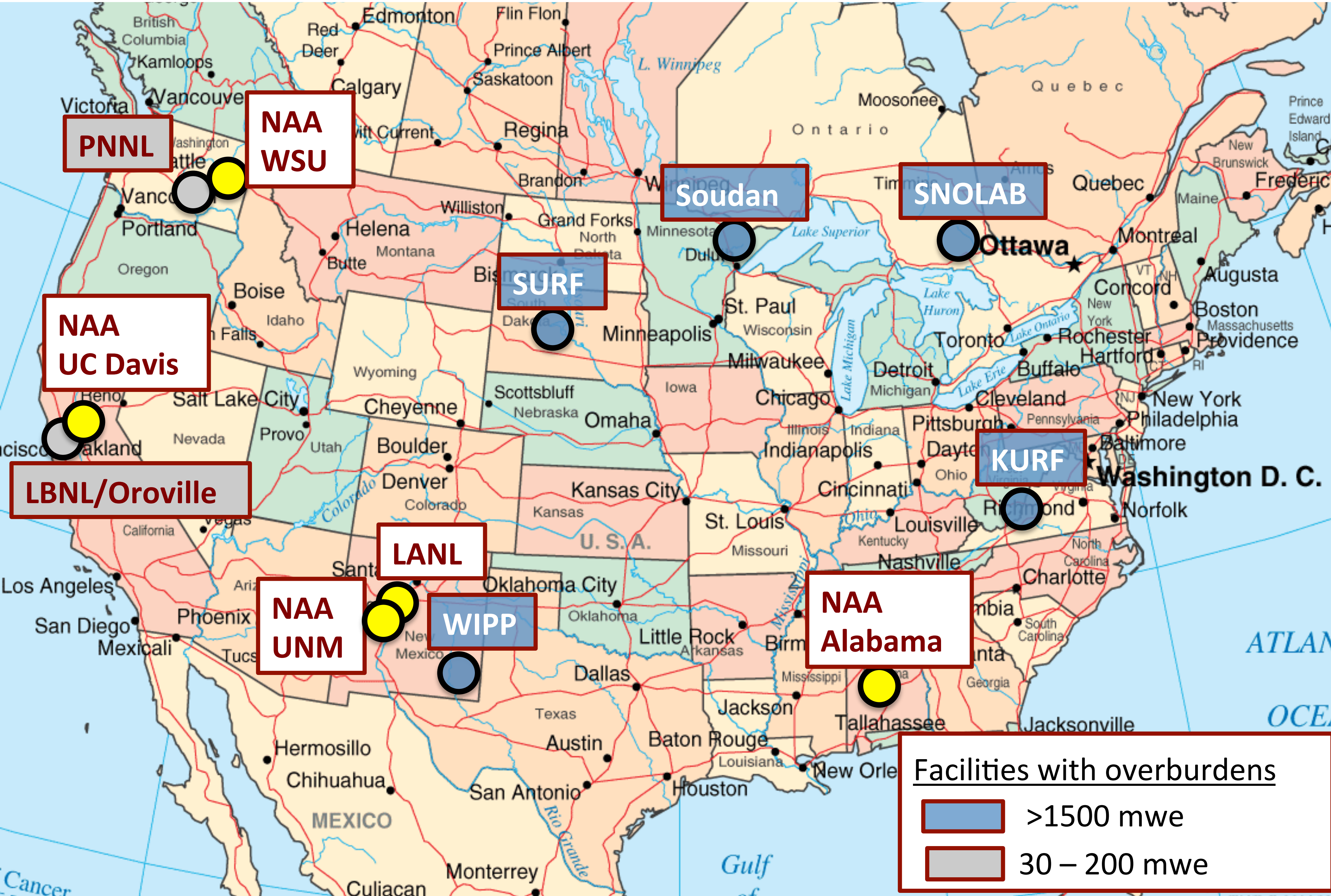
Combined results provided most best information (2009):

- ^{40}K 190 ± 60 μBq/kg
- ^{238}U 20 ± 10 μBq/kg
- ^{232}Th 1.3 ± 0.6 μBq/kg

PNNL ICP-MS now (2013) sensitive to lower levels:

- ^{238}U ~1.3 μBq/kg
- ^{232}Th ~0.6 μBq/kg

North American sites for DM Low Bkgd Characterization



Facilities with overburdens

- 🟦 >1500 mwe
- ⬜ 30 – 200 mwe

Material Purification and Supply

Low activity Lead

Known sources (mines) (e.g. Doe Run)

Purveyors of ancient lead

Copper

OFHC suppliers

Electroformed copper

Produce underground to prevent cosmo activation

e.g. Majorana cryostats and parts at SURF

Inorganic Crystals and Semiconductors

raw materials (custom synthesis)

growing process – cleanliness and overburden

Water, Liquid Scintillator, Cryogens

Purification plants: custom systems built from commercial parts

In situ purity monitoring

Noble Liquids

See examples next page

Example: Removing ^{85}Kr from Xenon

XMASS Distillation tower

6 kg/h, 1 ton in a week

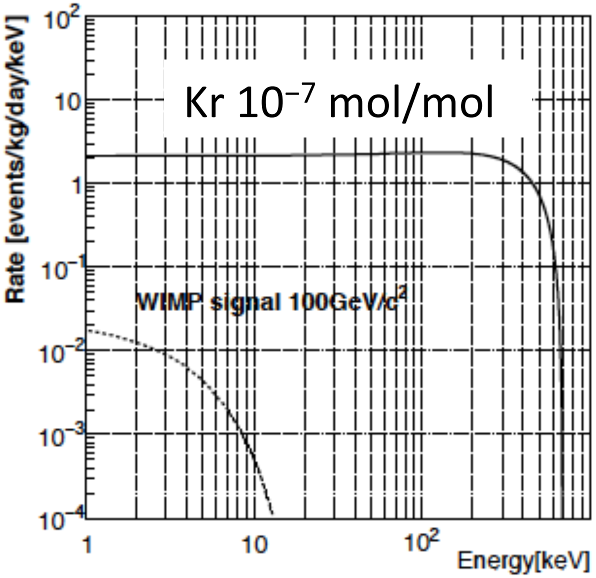
Get to 3.3 +-1.1 ppt

Impurities, like CO_2 or H_2O, in xenon can be removed by adsorption. Distillation can be used to remove Kr O_2 N_2 H_2 He in xenon because their boiling points are lower.

^{85}Kr ➔ rubidium-85 with a half-life of 10.76 years,
emits β rays with a E_{max} = 687 keV
Concentration of xenon in air = 10^{-7} mol/mol
krypton = 10^{-6} mol/mol.

Kr/X ~ 10

Commercial xenon reduces Kr to 10^{-7} mol/mol.
The concentration of ^{85}Kr /Kr ~ 10^{-11}



For a background rate of 10^{-4} events/keV/day/kg
Need a Kr/Xe ratio of less than 10^{-12} mol/mol.

Example: Removing ^{39}Ar from Argon (DarkSide)

Too much ^{39}Ar in Argon sourced from atmosphere

8 x 10^{-16} g/g ➔ decay rate of 1 Bq/kg

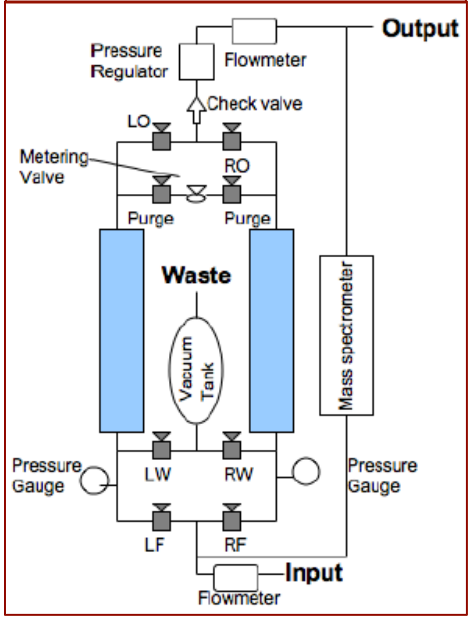
Isotopic removal via centrifugation or thermal diffusion is too expensive. (WARP studies)

^{39}Ar caused by spallation of cosmic rays on ^{40}Ar in upper atmosphere

Find “depleted” Ar in deep wells with low U/TH

Concentrate trace Ar in exhaust streams of mining operations on site using adsorption.

Adsorption Unit

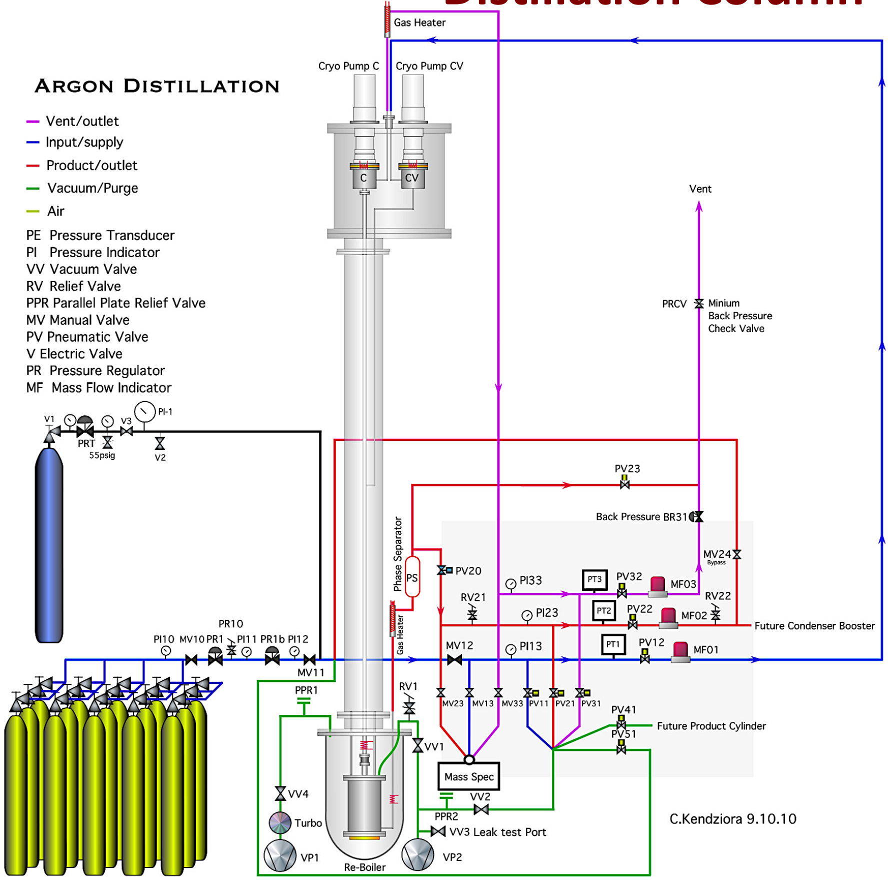


Test for lowest ^{39}Ar

Doe Canyon (Colorado) chosen for full operation

Final purification at FNAL

FNAL Cryogenic Distillation Column



Some Interesting Examples from dark matter bubble chamber and gas detectors

Alphas can be a background too.

Threshold Detector Bkgd: neutrons and alphas

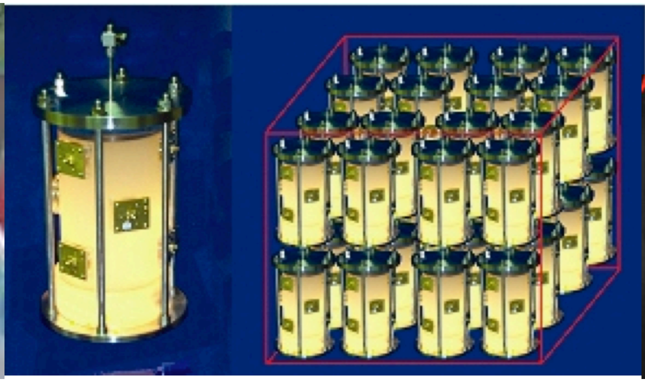
Nucleation Threshold determined by T, P → Insensitive to γ, β

Fill with a flurocarbon: Emphasis on spin-dependent limits via ^{19}F

Neutron dosimeter technology

SIMPLE (Bas Bruit)

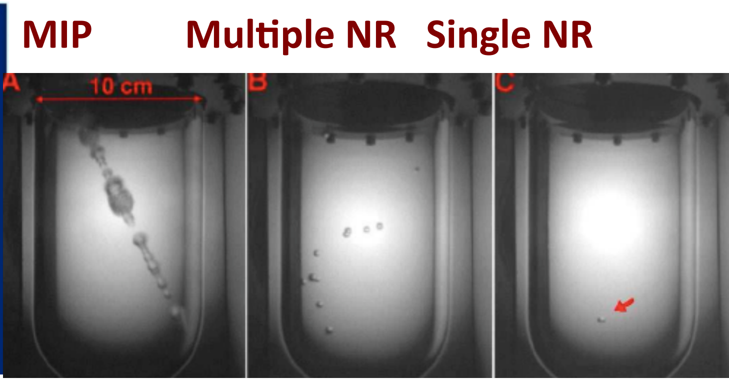
1-4 % suspension of
superheated C_2ClF_5
droplets in gel.
shielded pool, shallow



PICASSO (SNOLab)

0.5% C_4F_{10} droplets
in water-based gel
piezoelectric transducers

Bubble Chamber



COUPP (SNOLab)

Superheated bubble chamber
CF_3I, multiple targets
CCD camera (+ acoustic)

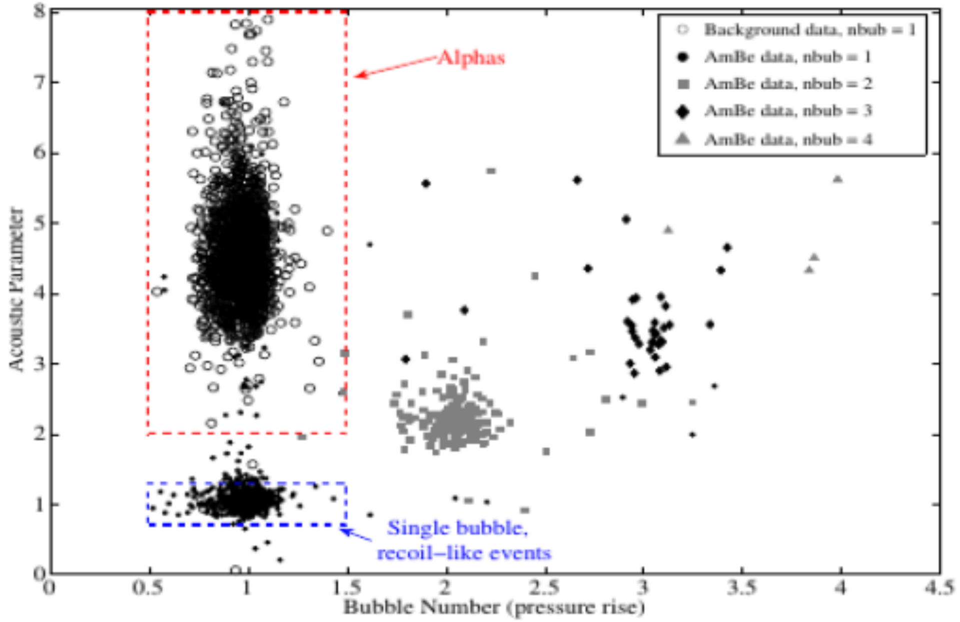
Joined collaborations to form PICO

COUPP needs to get rid of alphas

Acoustic transducer signals digitized with a 2.5 Mhz samplin
rate and recorded for 40 ms for each event.

- AP can be defined as frequency weighted acoustic power density integral (corrected by sensor gain and bubble position).

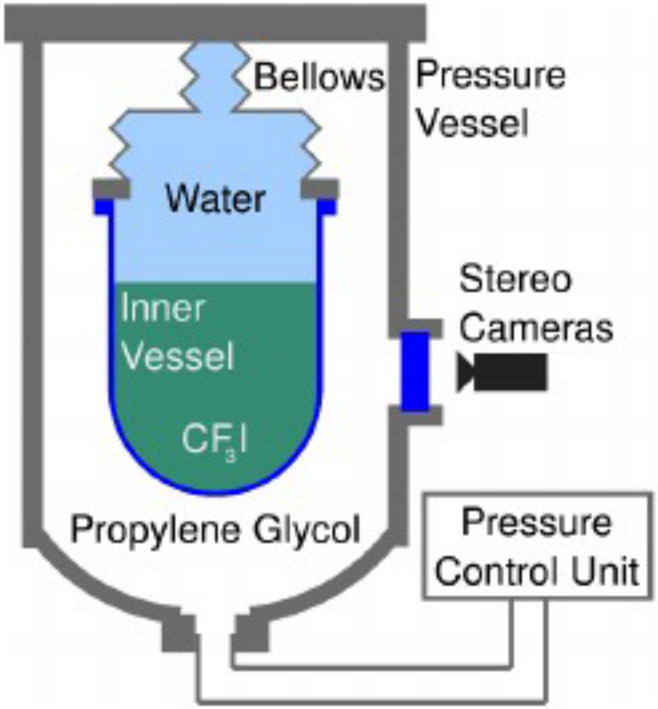
The nuclear recoil acceptance of the AP cut 95.8 ± 0.5%

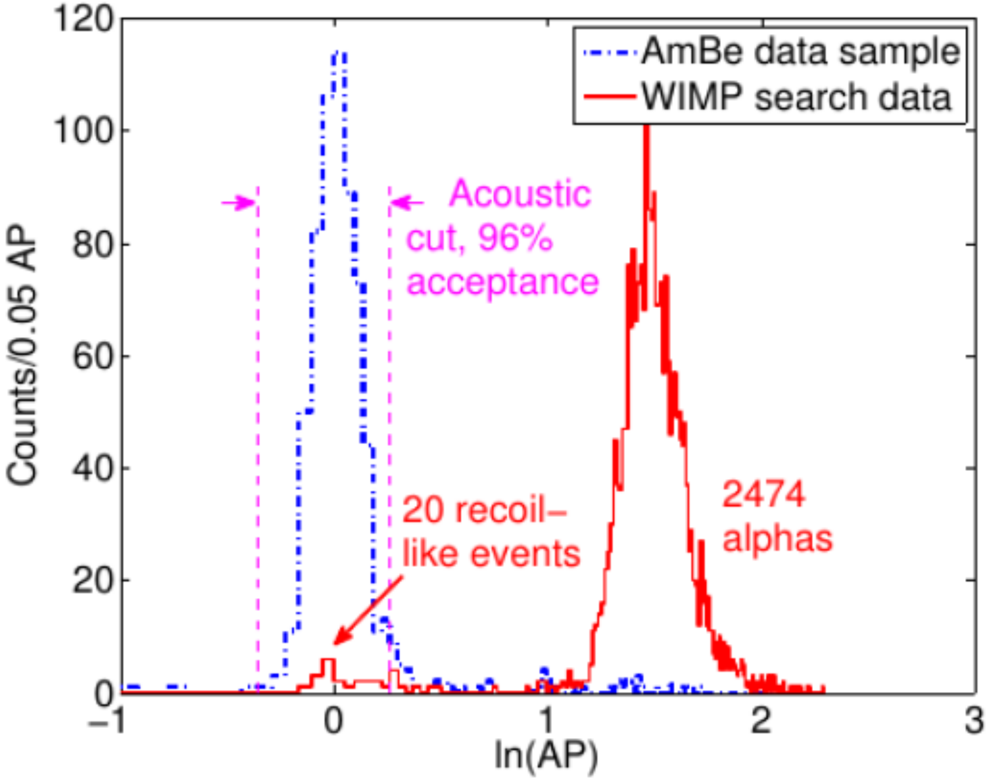


$$AP = A(T)\cdot\sum_j G_j\cdot\sum_n C_n(\vec{x})\cdot\sum_{f_{min}}^{f_{max}} f\cdot psd_f^{\,j}$$

COUPP Installs Acoustic Sensors

Piezo sensors glued to quartz vessel sense acoustic signal
Internal pressure measured by gauge
VGA Cameras record bubble growth





5.3 alpha decays/kg/d
95% from radon

- ➢ 98.9 % a rejection

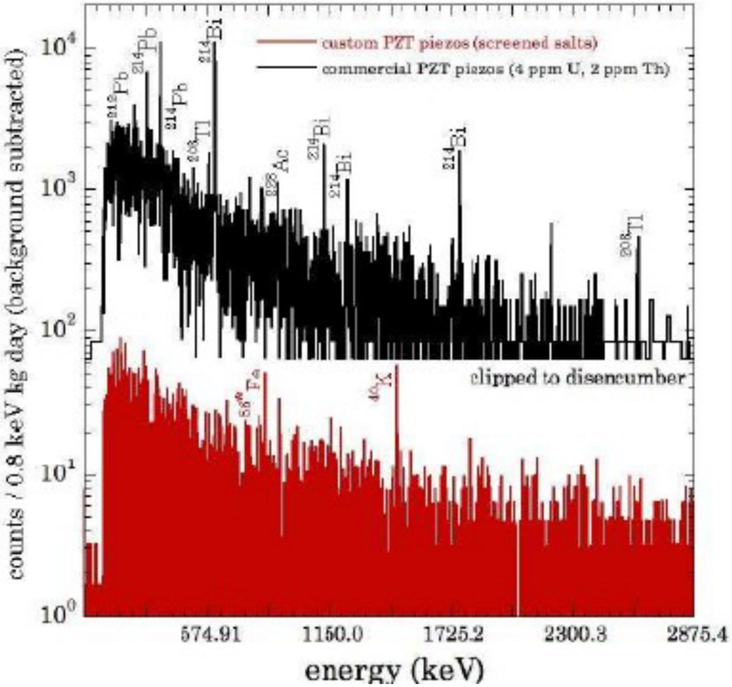
Eliminating the alphas revealed internal neutron sources of background

- View-ports:

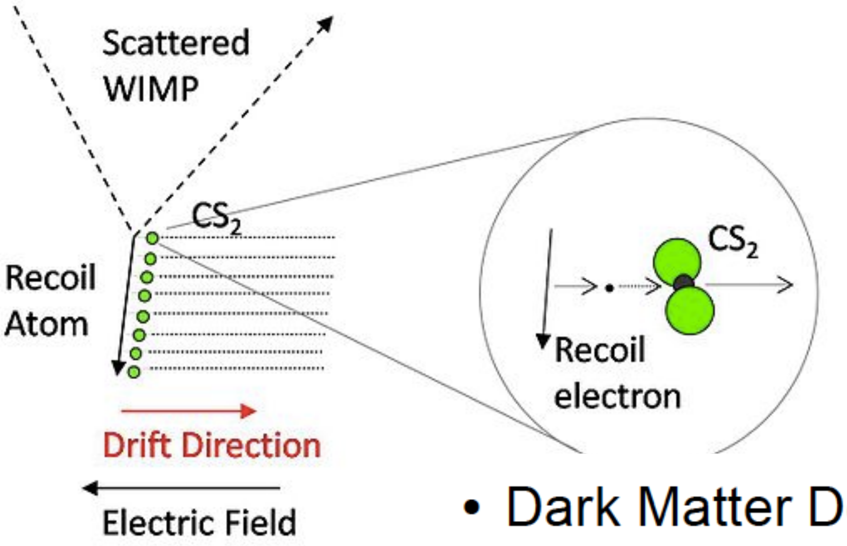
  0.5 ppm ${}^{238}U$ and 0.8 ppm ${}^{232}Th$ (~ 5 events)
- Piezos:

  4.0 ppm ${}^{238}U$, 1.9 ppm ${}^{232}Th$, (~ 2 events)

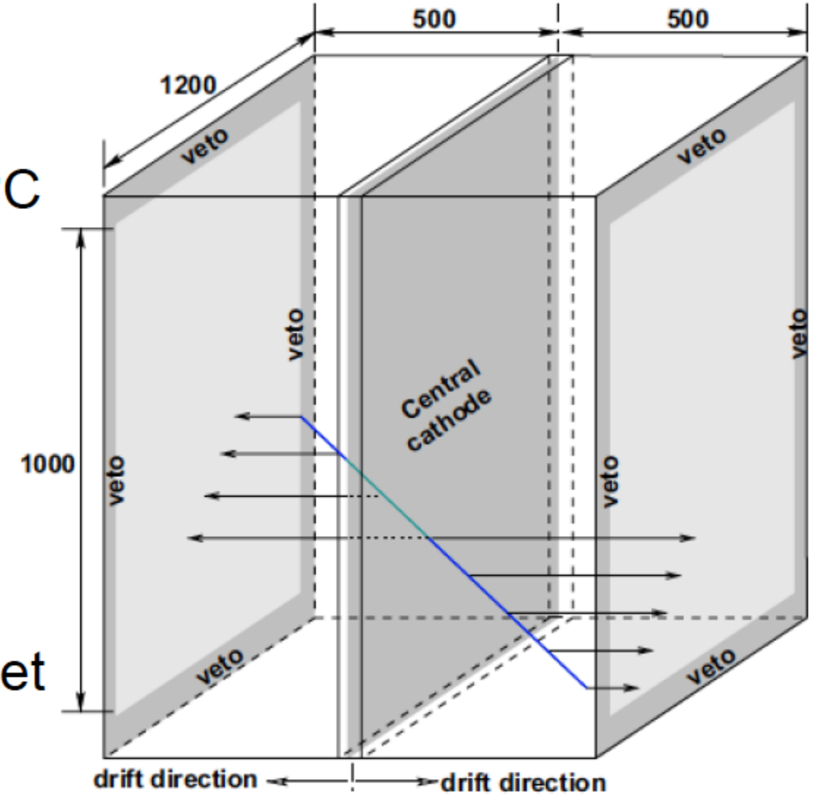
- New piezos built (low background salts)
- New view-ports (synthetic silica)



DRIFT – IId Detector



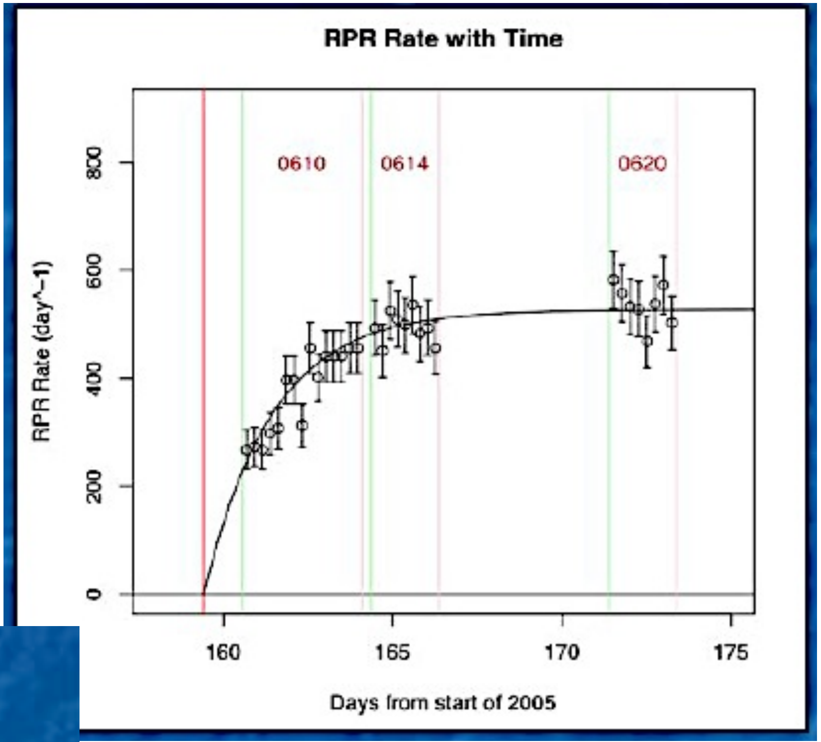
- Dark Matter Detector
  - Directional Sensitive
- Low-pressure gas TPC
- 2 Detector volumes
  - Shared Cathode
  - MWPC Readouts
- Negative-Ion drift
  - 30 Torr CS_2
- Spin-Dependent Target
  - 10 Torr CF_4

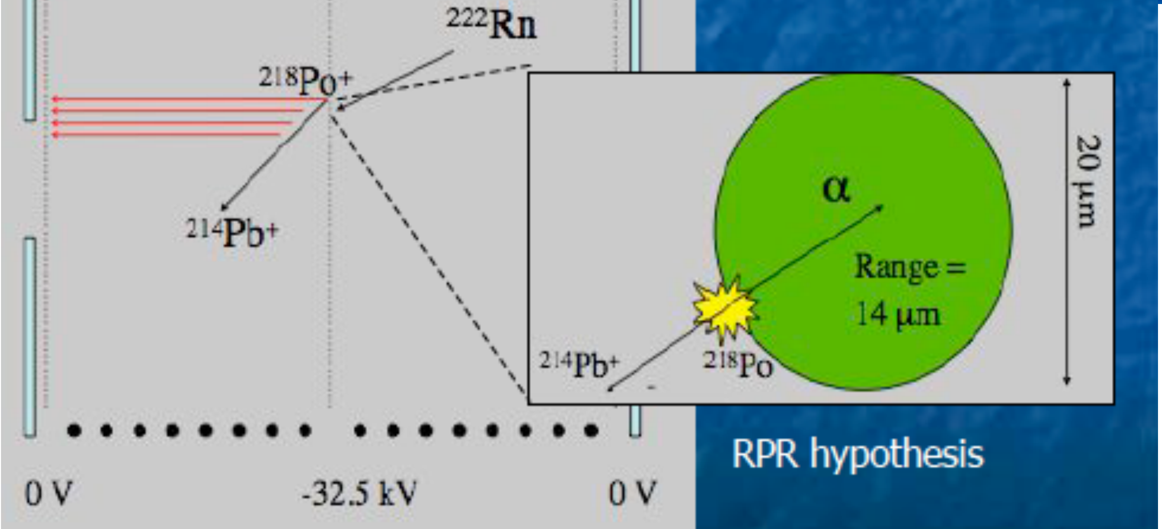


DRIFT – IId Alpha tracks

Fiducially-contained α's with E ~ 6 MeV
Rate consistent with Rn emanation

Much worse –
Recoil-like events at 200-600/day (50-250 keV),
with same time constant

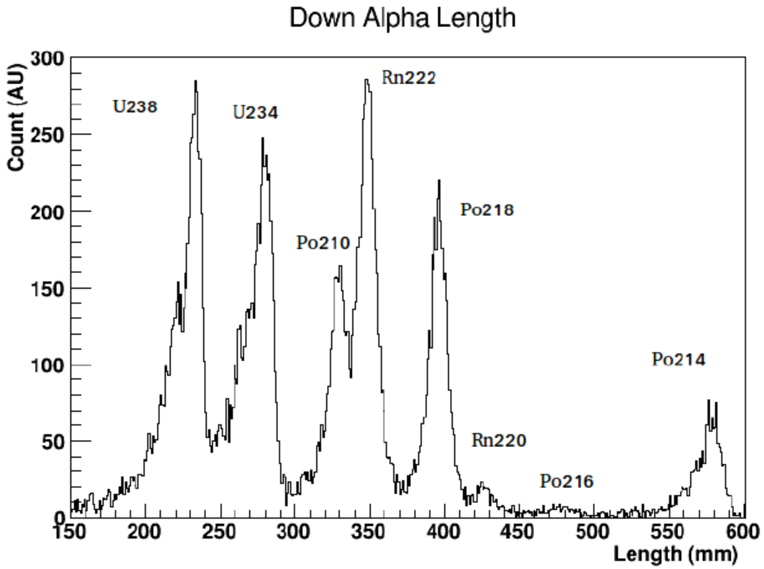




RPR hypothesis

DRIFT – IId Detector

- Alpha length spectrum identifies isotopes



- In-situ identification with alpha spectrometry
- Precision Assay of cathode material
  - Stat. Uncertainty for ^{234}U ~0.1 ppt
- Alphas pinpoint contamination
- Measurements motivate hardware changes
  - RPR Backgrounds reduced from 130/day to 1/day

Isotope	Before	After
^{234}U	61.8 ± 0.6 ppt	3.3 ± 0.1 ppt
^{238}U	777 ± 15 ppb	73 ± 2 ppb