Week 9: Chap.20 (Gamma ray) Backgrounds

Other Semiconductors and Geometries

(Gamma ray) backgrounds …
-- Natural radioactivities
--- spectra properties and shielding
-- Cosmic rays
--- imaging

Neutron detection

Hey dude, what's that in the background?

Chap. 20 – Background & Shielding

Nuclide	T ½	Source
^{235}U	$7x10^8$ yr	0.72% of all natural uranium
^{238}U	$4x10^9$ yr	99.2745% of all natural uranium; 0.5 to 4.7 ppm total uranium in the common rock types
^{232}Th	1.41×10^{10} y	1.6 to 20 ppm in the common rock types with a crustal average of 10.7 ppm
^{226}Ra	1.60×10^3 yr	0.42 pCi/g (16 Bq/kg) in limestone and 1.3 pCi/g (48 Bq/kg) in igneous rock
^{222}Rn	3.82 days	Noble Gas; annual average air concentrations range in the US from 0.016 pCi/L (0.6 Bq/m^3) to 0.75 pCi/L (28Bq/m^3)
^{40}K	1.28×10^9 yr	soil - 1-30 pCi/g (0.037-1.1 Bq/g)
^{14}C	5730 yr	Cosmic-ray interactions, $^{14}N(n,p)^{14}C$, 6 pCi/g (0.22 Bq/g) in organic material
^{3}H	12.3 yr	Cosmic-ray interactions with N and O, spallation from cosmic-rays, ^6Li(n, alpha)^3H , 0.032 pCi/kg (1.2×10^{-3} Bq/kg)

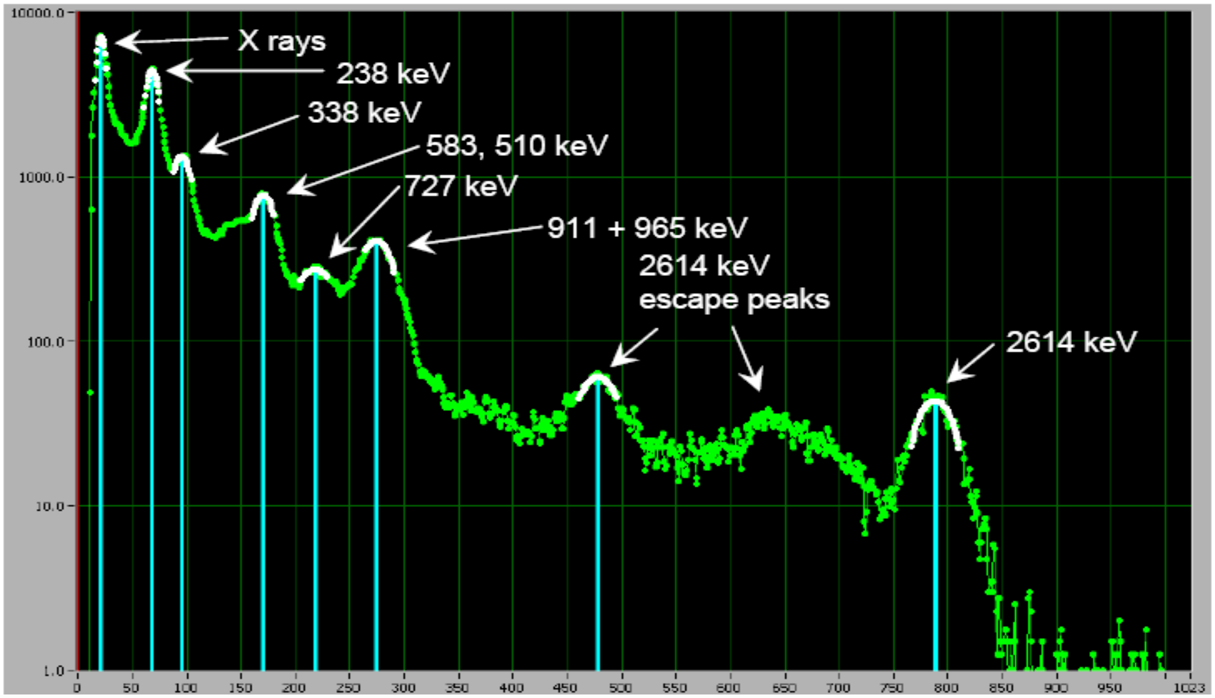
70 kg person

Nuclide	Activity
U : 90 μg	1.1 Bq
Th : 30 μg	0.11 Bq
Ra : 31 pg	1.1 Bq
^{40}K : 17 mg	4.4 kBq
^{14}C : 22 ng	3.7kBq
^{3}H : 60 fg	37 Bq

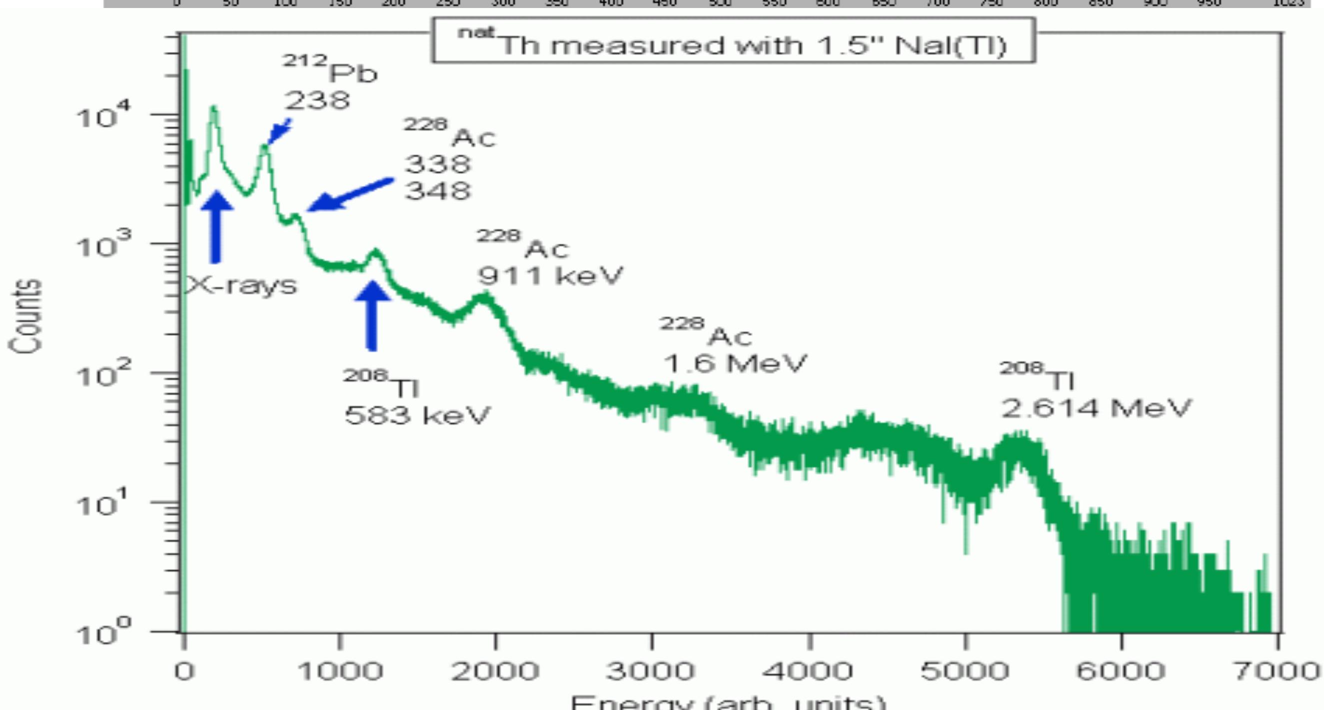
http://www.physics.isu.edu/radinf/natural.htm

http://meteo.nipne.ro/logger/lastweek.html

^{232}Th spectrum .. The ^{208}Pb line



^{232}Th (4n series) spectrum with a small $CdWO_4$ survey device



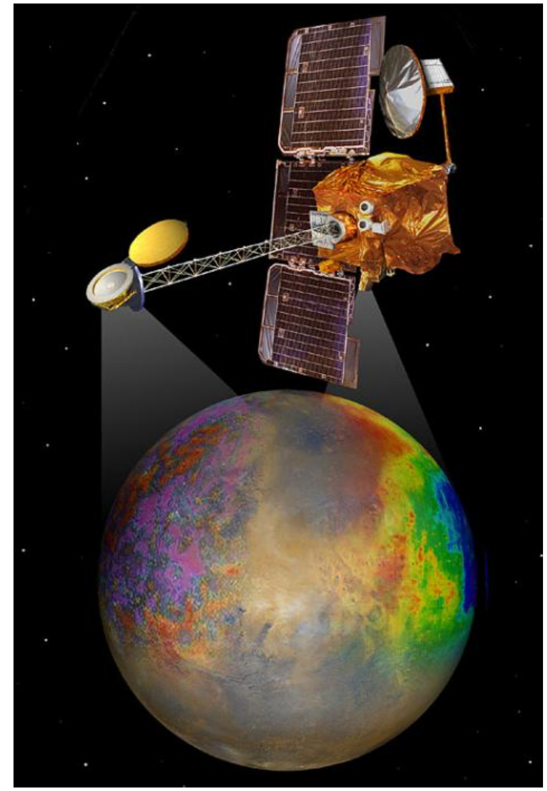
^{232}Th (4n series) spectrum with a small NaI(Tl) survey device

Th on Mars … Odyssey Mission

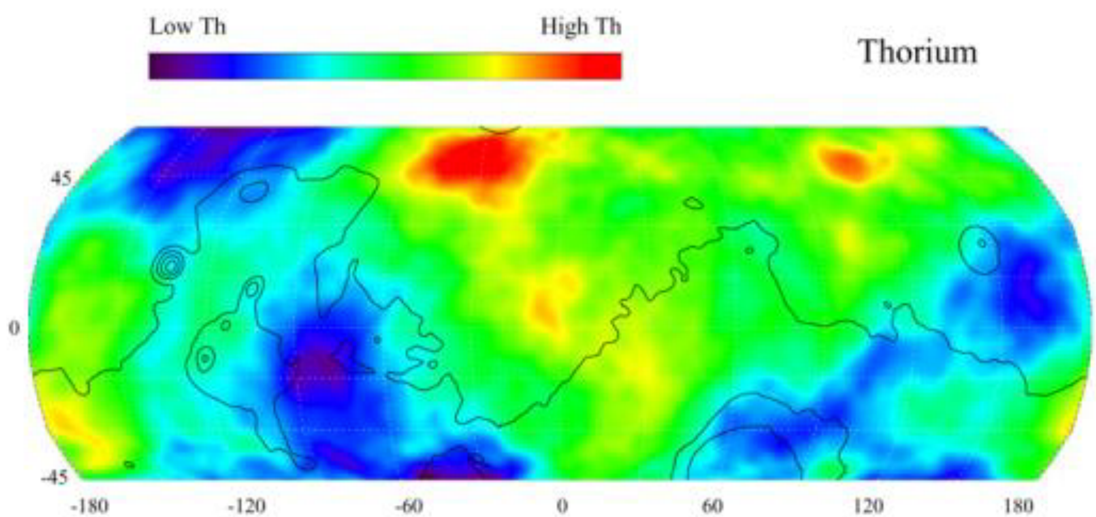
The gamma-ray spectrometer was provided by the Univ. of Arizona. The gamma ray detector is a large (1.2 kg) high-purity Germanium (Ge) crystal. The crystal is held at a voltage of approximately 3000 volts. Little or no current flows (less than one nanoAmp)… The cooler has a door which opens in flight, exposing a radiator, allowing the sensor to cool to below 90 Kelvin for science data collection. The thermal shield and door are needed to allow us to periodically warm up the sensor head to 100 Celsius to anneal radiation damage to the crystal. … most elements to be determined with a precision of about 10%.

Source of γ's? Decay plus nuclear excitation by Cosmic Rays

https://grs.lpl.arizona.edu/content/about/gamma



PIA04257: Map of Martian Thorium at Mid-Latitudes



jpl.nasa.gov Th on Mars

Target Name:	Mars
Is a satellite of:	Sol (our sun)
Mission:	2001 Mars Odyssey
Spacecraft:	2001 Mars Odyssey
Instrument:	Gamma Ray Spectrometer Suite
Product Size:	2068 x 947 pixels (w x h)
Produced By:	University of Arizona
Full-Res TIFF:	PIA04257.tif (2.505 MB)
Full-Res JPEG:	PIA04257.jpg (174.9 kB)

Background & Shielding: Singles

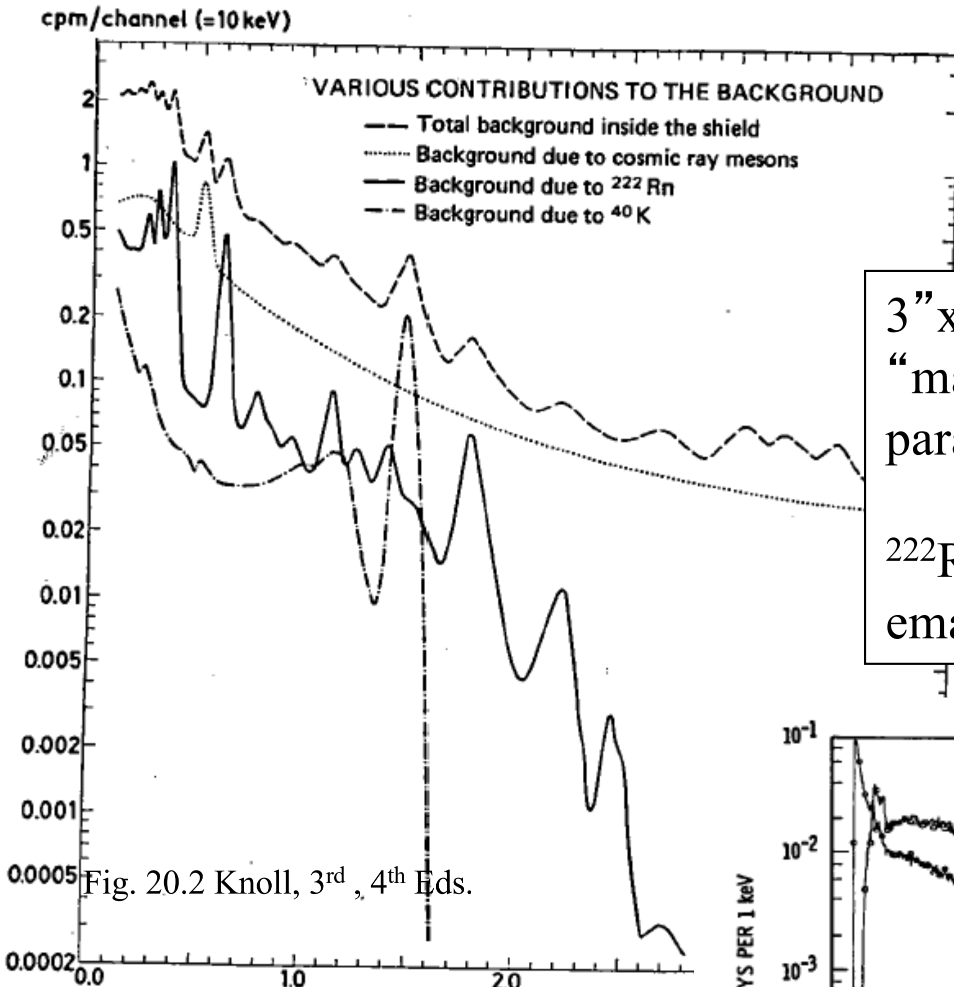
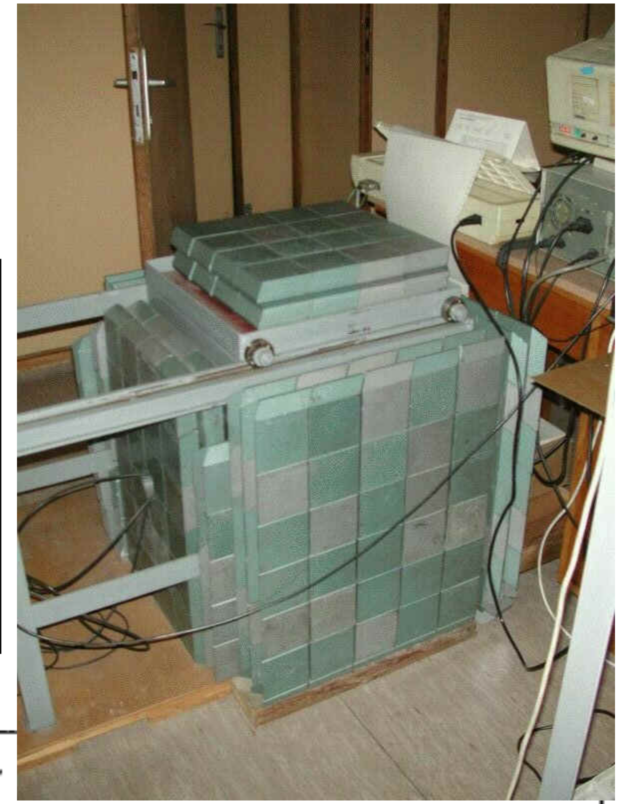


Fig. 20.2 Knoll, 3rd , 4th Eds.

3”x3” NaI(Tl) inside a “massive” lead/borated-parafin shield

^{222}Rn (4n+2 series) gas emanation from ^{238}U



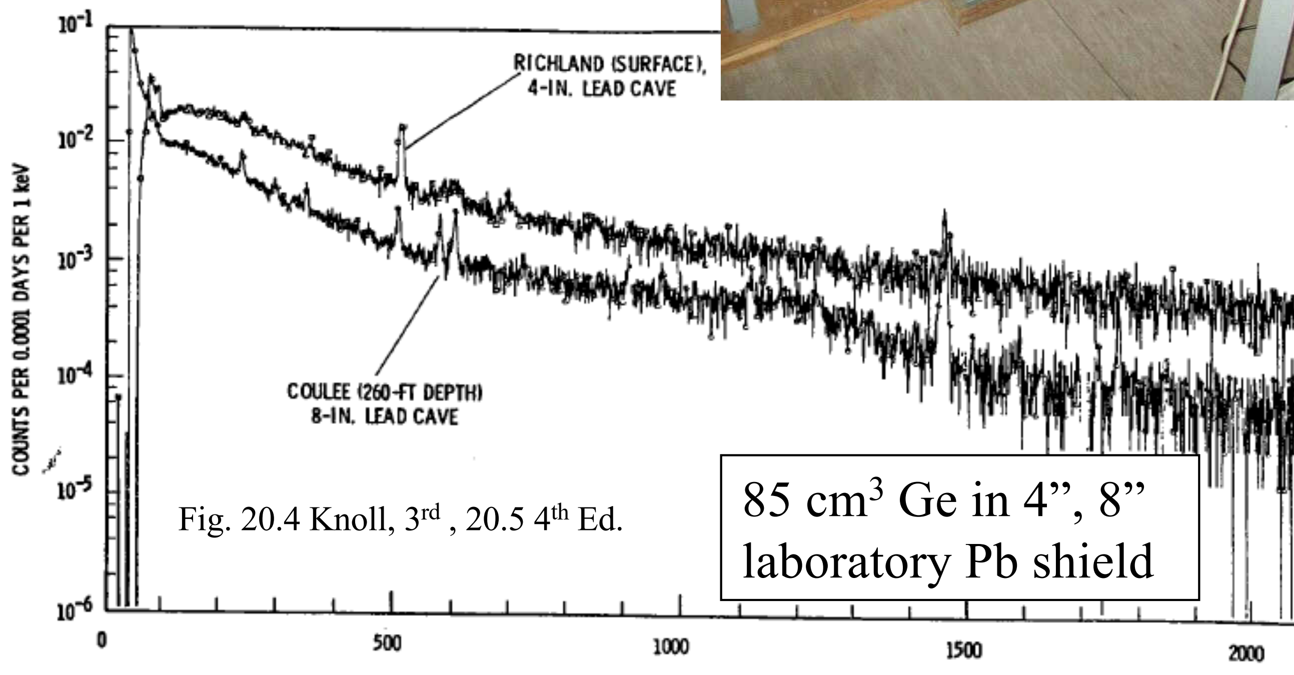


Fig. 20.4 Knoll, 3rd , 20.5 4th Ed.

85 cm^3 Ge in 4”, 8” laboratory Pb shield

Background & Shielding: Coincidence

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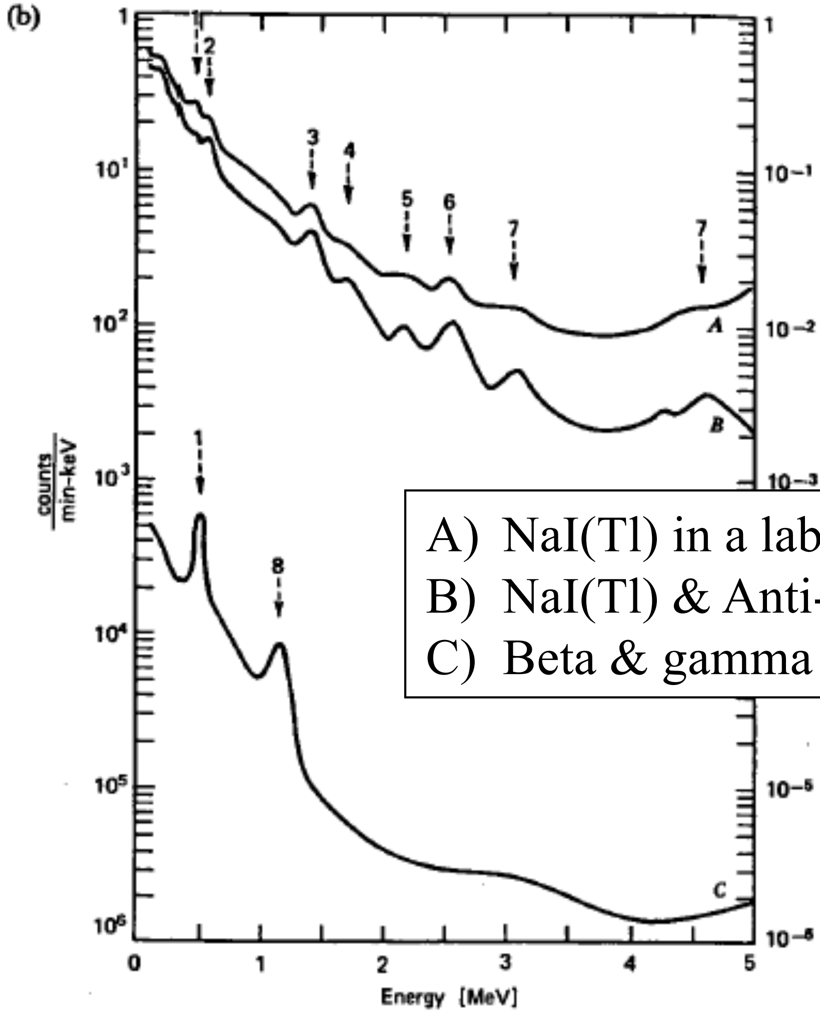
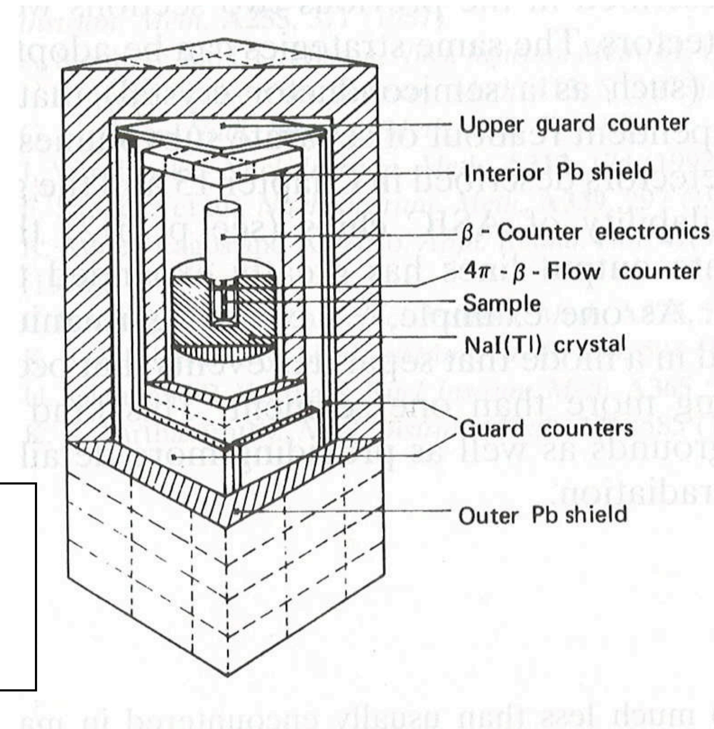


A) NaI(Tl) in a laboratory shield
B) NaI(Tl) & Anti-cosmic
C) Beta & gamma & Anti-cosmic

Fig. 20.10 Knoll, 3rd , 20.12 4th Ed.



Use the time dimension to make a cut on the data.

$\Delta t \sim 10^{-6}$ s is called ‘slow’ coincidence

$\Delta t \sim 10^{-8}$ s is typical ‘fast’ coincidence for modern experiments .. except for Ge detectors.

Background: Cosmic Rays

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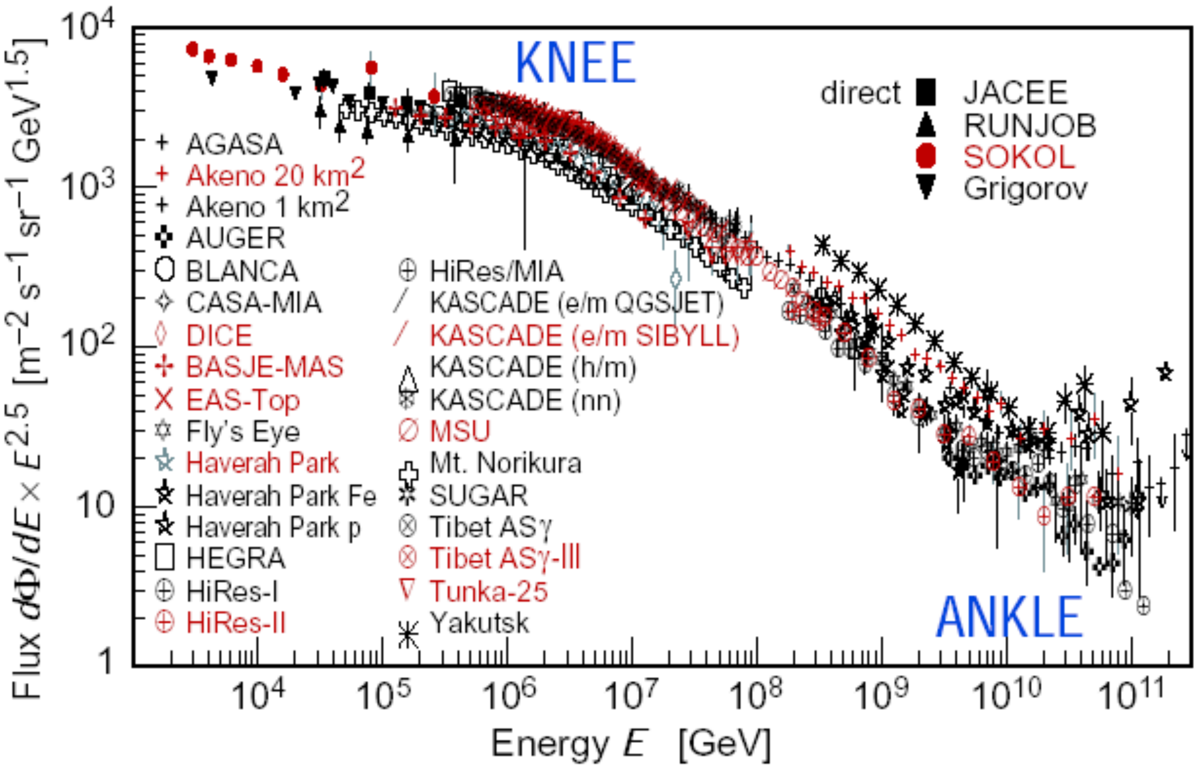
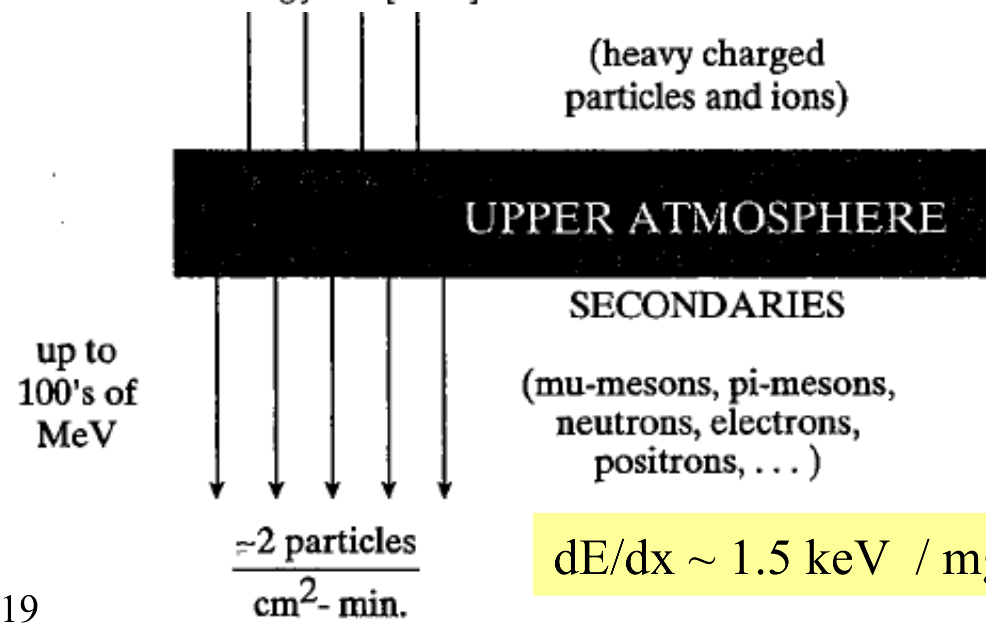
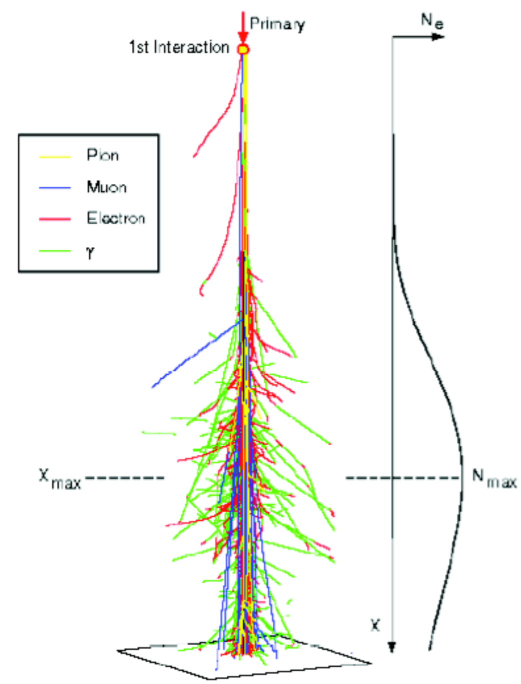


Scaled distribution at the top of the atmosphere

~$\cos^2 \Theta$ angular distribution

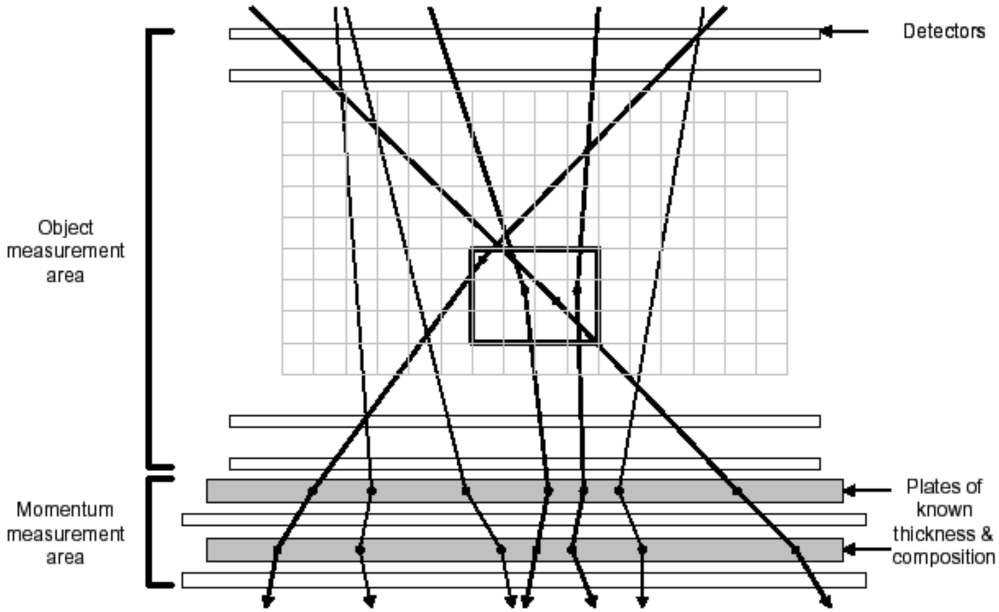


dE/dx ~ 1.5 keV / mg/cm^2

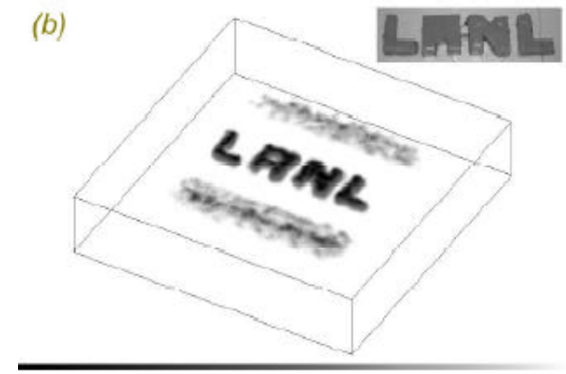


R. Chartrand, et al. LANL

Background: Cosmic Ray Radiography



K.N. Borodzin, et al. Nature 422 (2003) 277



1” Pb-stock, 10^5 muons

Q: How long did it take?

See also early work: Search for Hidden Chambers in the Pyramids, L. Alvarez, et al. Science **167** (1970) 832.

Recent work: Cosmic Ray Radiography of the Damaged Cores of the Fukushima Reactors, K. Borozdin, et al., Phys. Rev. Lett. **109** (2012) 152501 (6 week measurement proposed)

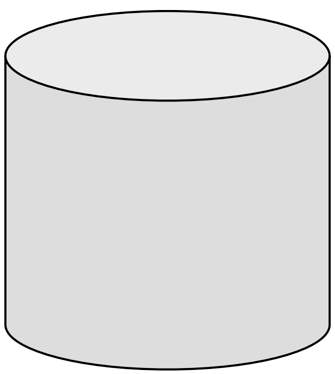
Chap. 20 – Background & Shielding Question

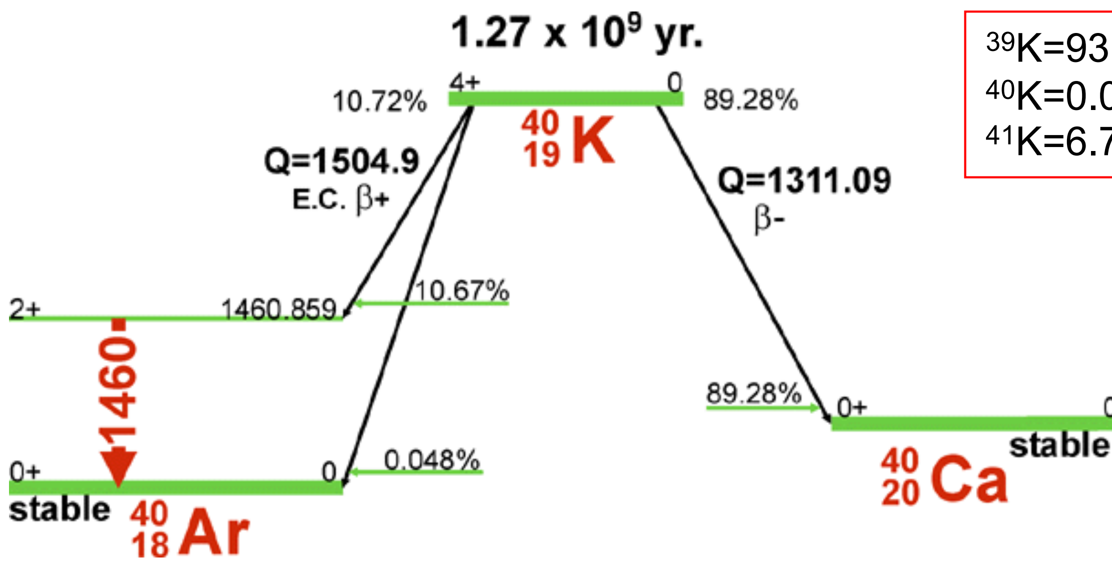
MICHIGAN STATE UNIVERSITY

Problem 20.1 – One potential source of background counts from sodium iodide scintillators is ^{40}K from trace level potassium impurity in the crystal [both K and Na are Group 1 alkali metals].

a) Find the maximum potassium concentration (in ppm) if the corresponding background rate from a 7.62 x 7.62 cm cylindrical crystal is to not exceed 1 cps.

b) What is the approximate counting rate from cosmic rays in this crystal?





^{39}K=93.2581%
^{40}K=0.01167%
^{41}K=6.7302%

Michigan State University

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$N\_{}^{40}K = A/\lambda = 1c/s / [\ln(2) / (1.27x10^9 yr * 3.15x10^7 \; s/yr)]$

$N\_{}^{40}K = 5.77x10^{16}$

$N\_K = N\_{}^{40}K / 0.0001167 = 4.95x10^{20}$

$N\_NaI = N\_A * Vol * density / MM$

$= 6.022x10^{23} /mol * (44.6*7.54 \; cm^3) * 3.67 \; g/cm^3 / (23+127g/mol)$

$= 4.95x10^{24}$

$N\_K / N\_NaI < 4.95x10^{20} / 4.95x10^{24} = 9.99x10^{-5}$ or ~100ppm

Probably should divide by 2 for “per atom”

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Lower limit if upright:

area of end = π (7.54 / 2)^2 = 44.6 cm^2 … Rate – Area x 2/cm^2/min = 89/min

(probably should really integrate over angle but that is certainly more complicated)