Week 14, Lecture 2 – Radiation Detectors

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Radiation Detectors

-Gas-filled Devices

-Solid-state Devices

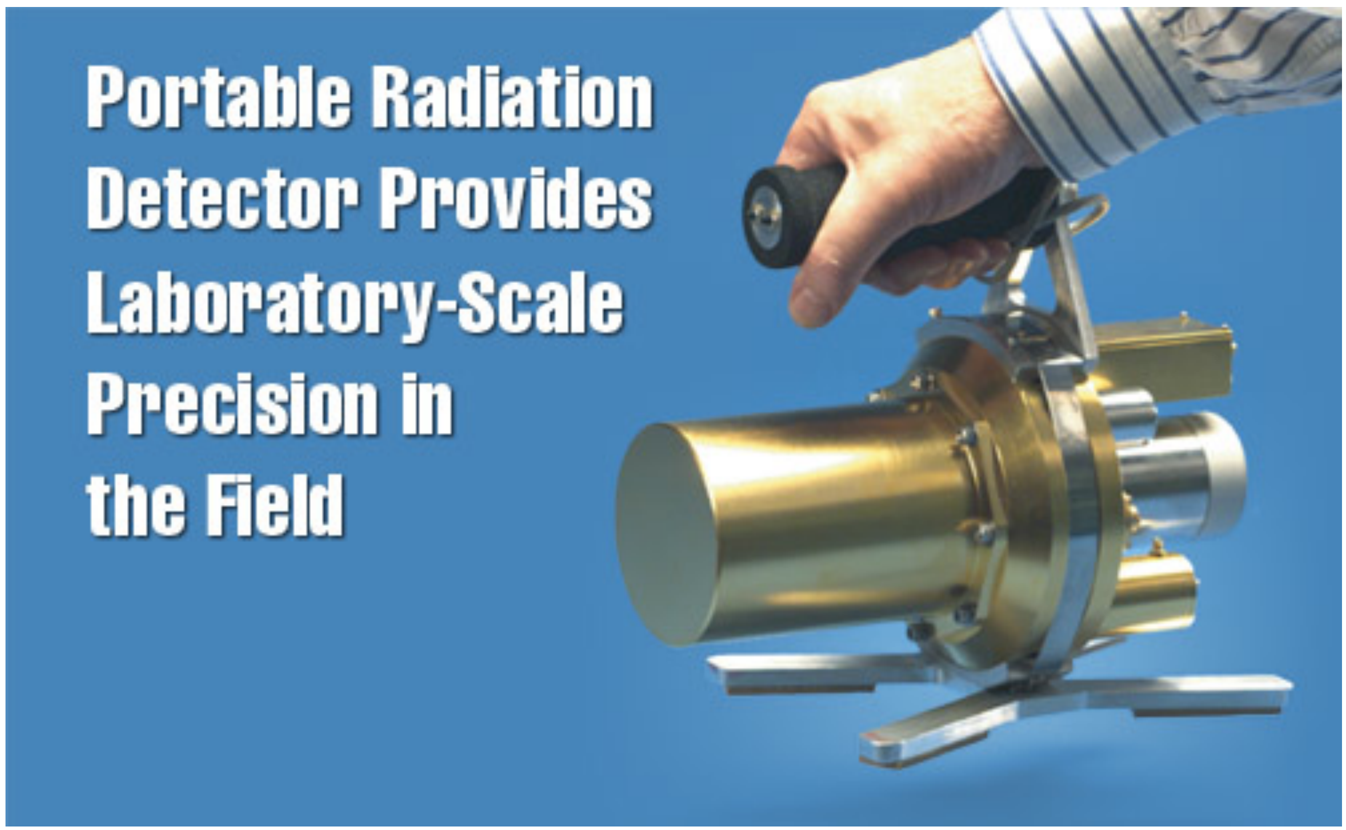
-Background radiation

-Scintillation Detectors

- Homeland security detectors

Accelerators

Practice Exam available soon



Scintillation Detectors – Organics

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Photons can be produced in deexcitation of primary ionization, **scintillation** devices rely on enhancing and detecting these photons. The primary ionization is ignored and these materials are insulators.

<u>General requirements</u>:

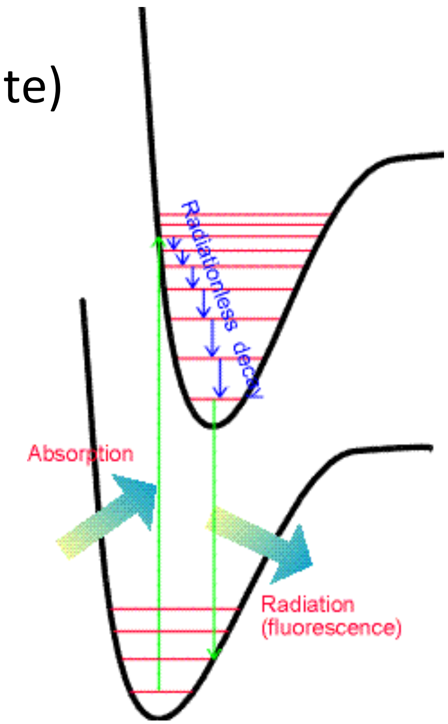
- Linear conversion of dE into photons (some only approximate)
- Efficient conversion into (near) visible light

  (e.g., NaI(Tl): 38k/MeV a value similar to N_{IP})
- Transparent to scintillation photons, good optical medium
- Short decay time for fluorescence (ns OK, ps good)
- Good mechanical properties (n~1.5 for glass)

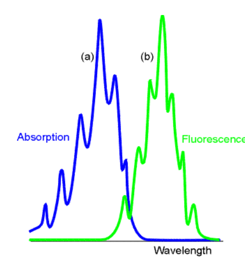
<u>Scintillator classes</u>:

Organic molecules – molecular transitions in fluor

Inorganic materials – transitions in atomic dopants

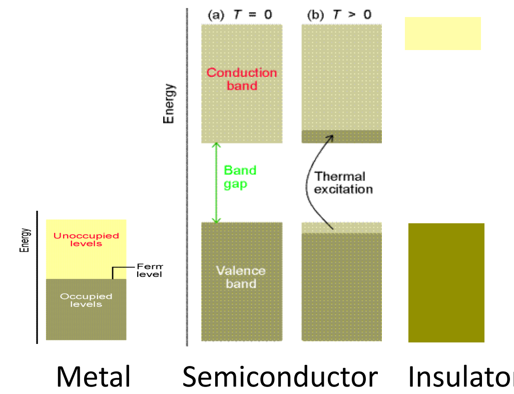


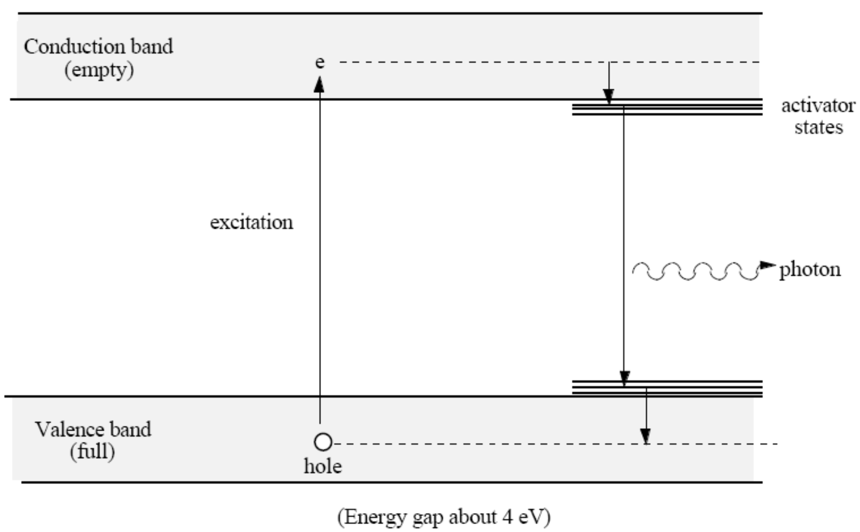
Molecular energy cycle for photon absorption/emission: Notice that there is always a 'red-shift' in the emitted photons – energy loss, inefficiency!



Scintillation Detectors – Inorganics

The primary radiation creates an electron/hole pair which can recombine in various ways depending on the material and dopants or activators. The energy necessary to create a surviving pair is about 1.5-2 times the gap in ionic crystals and twice this in covalent materials. Recall, of course, that insulators have larger band gaps than semiconductors. Thus, the conversion to photons is very inefficient in comparison – lower energy resolution. The light production processes emit photons with energies less than the size of the band gap, generally visible photons.





NaI – transition by *Tl* dopant

Note that the amount of excitation energy will be random, the energy above the bottom of the conduction band is lost (thermalized) as well as that below the top of the valence band. This loss is not important if the remaining energy is efficiently transferred to the dopant and if the dopant has a high quantum efficiency (light output)

Scintillation Detectors – Examples

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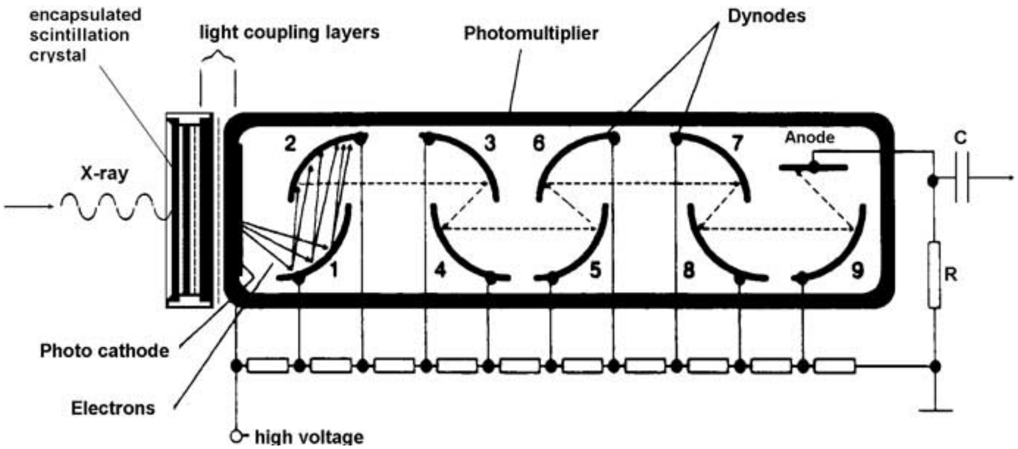

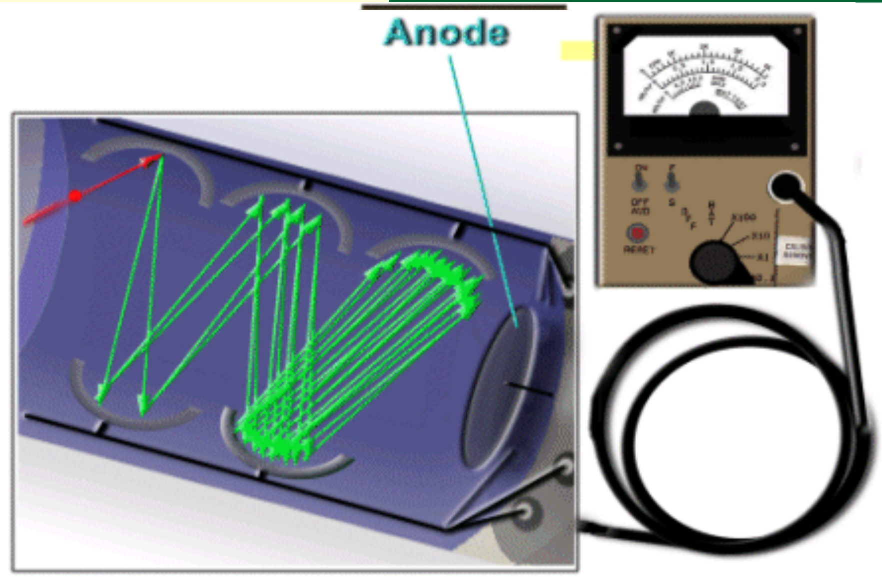

High energy photon gets converted by scintillator
-into many visible photons
-- that get converted into some photo-electrons
--- that get multiplied into a large current pulse
Retains a proportionality to incident energy but with a loss in resolution

http://www.uos.harvard.edu/ehs/radiation/how_surveymeter.shtml

Homeland Security – The Problem and Pager

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"Ways to detect small sources within a large sea of natural background radiation and to do so in such a way that does not impede legitimate commerce and traffic flow. These systems must be suitable for real-world applications-portable, rugged, battery-powered, lightweight, inexpensive, and easy to use by non-experts."
Radiological and Nuclear Countermeasures, Lawrence Livermore National Lab, 5Mar2007
Cf. article by T. Gustafson, http://www.nti.org/e_research/e3_88.html

radiationpager.com

www.homeland1.com/disaster-preparedness/articles/682792

Dec. 18, 2009 By Jeffrey Leib, Chattanooga Times Free Press

The drill completed at DEN on Thursday included training on three pieces of Preventative Radiological Nuclear Detection equipment, Selby said. One is a "mini" device about the size of a pager or PDA that can be worn on a belt. A second is a handheld "radioactive isotope identification device" that can be directed by an agent at a potential radiological source, Selby added. The third piece of equipment that officers will use is a radiation detection backpack. Officers can use the equipment openly at stationary positions, as they were doing at DEN on Thursday -- screening passengers at one terminal entrance -- or they can carry some of the devices covertly as they move about the airport or other facilities, officials said.

www.flukebiomedical.com/

http://www.directindustry.com/prod/bubble-technology-industries/

Homeland Security – Layer 2 – RIID

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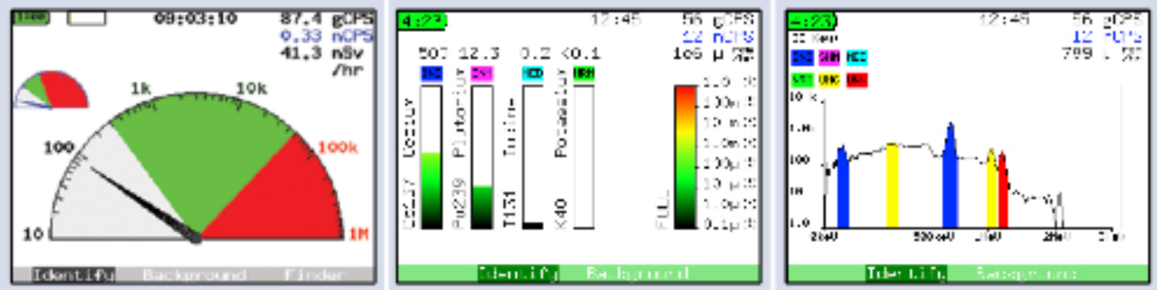
http://www.berkeleynucleonics.com/resources/SAM940_datasheet.pdf



Quickly determines location of materials and where to collect data for further analysis.

Continuously displays detected isotopes, class, and dose rate for multiple source identification.

Color coded peaks depict source category, intensity, and stored data.

Radioactive Isotope Identification Device (RIID)
Isotopes displayed:
^{137}Cs – $T_{½}$ = 30y high yield fission fragment
^{239}Pu – $T_{½}$ = $2x10^4$y fissile nuclide
^{131}I – $T_{½}$ = 8d fission fragment, medical isotope
^{40}K – $T_{½}$ = $1x10^9$y background radioactivity

Passive Screening of Cargo

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A truck passes through an Advanced Spectroscopic Portal before a security booth at a Container Terminal in Staten Island, N.Y., April/2007.

http://www.saic.com/products/security/

Large Chalk River BF_3 neutron Proportional Counter (ca. 1960)

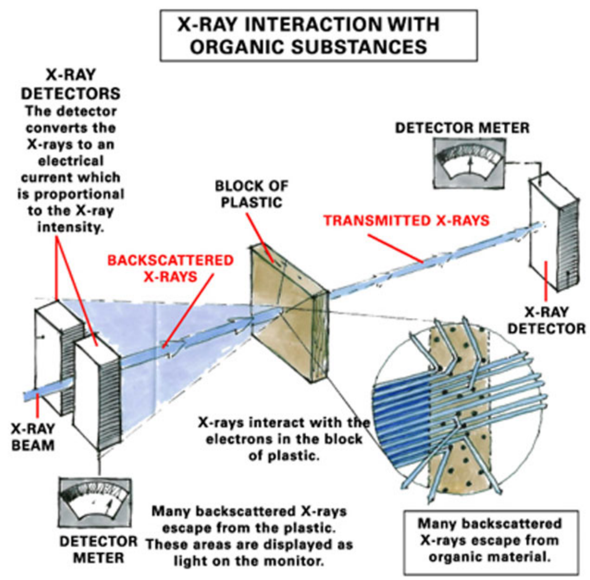
See also, Finland/Russia border: http://www.stuk.fi/ydinturvallisuus/ydinsulkuvalvonta/kuljetukset/en_GB/rajavalvonta/

Screening of Cars

"Passive" radiation detectors at border are most sensitive to gamma radiation.
[99mTc 6hr, ^{131}I 8d]

"Active" screening … create particle beam and look for radiation … many schemes but most effective involves Compton scattering of x-rays.

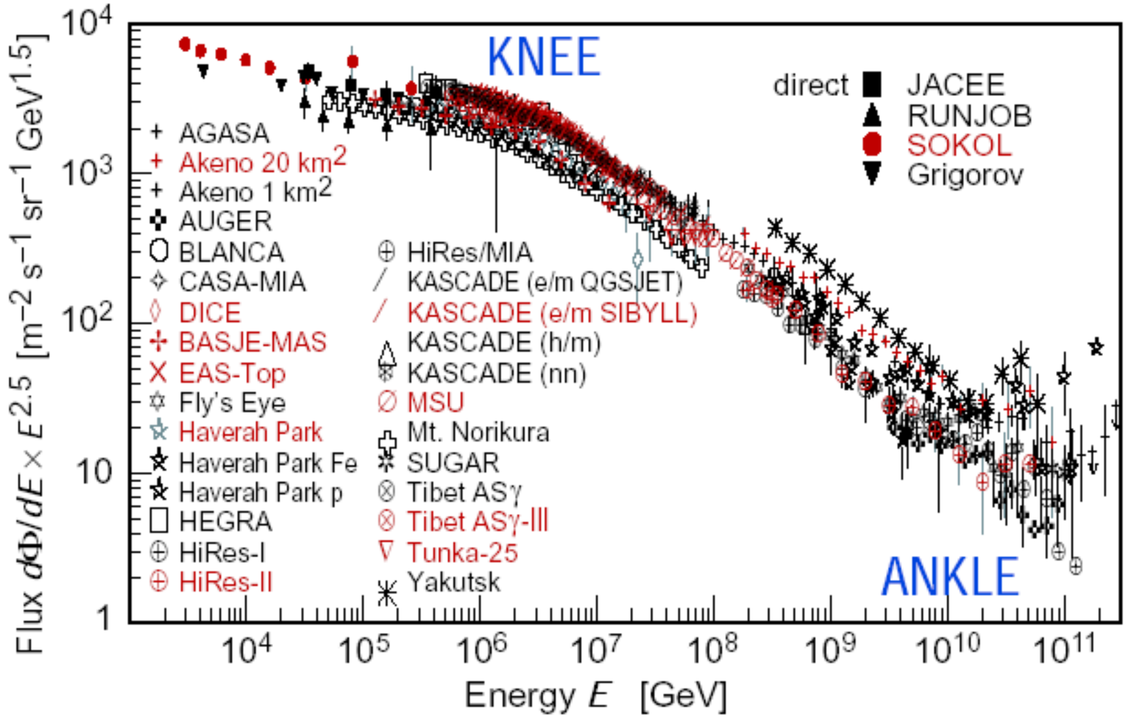
Hi Z elements: σ(PE) > σ (CS) at ~ 100 keV
Lo Z elements: : σ(PE) < σ (CS) at ~ 100 keV



http://www.as-e.com/products_solutions/z_backscatter.asp

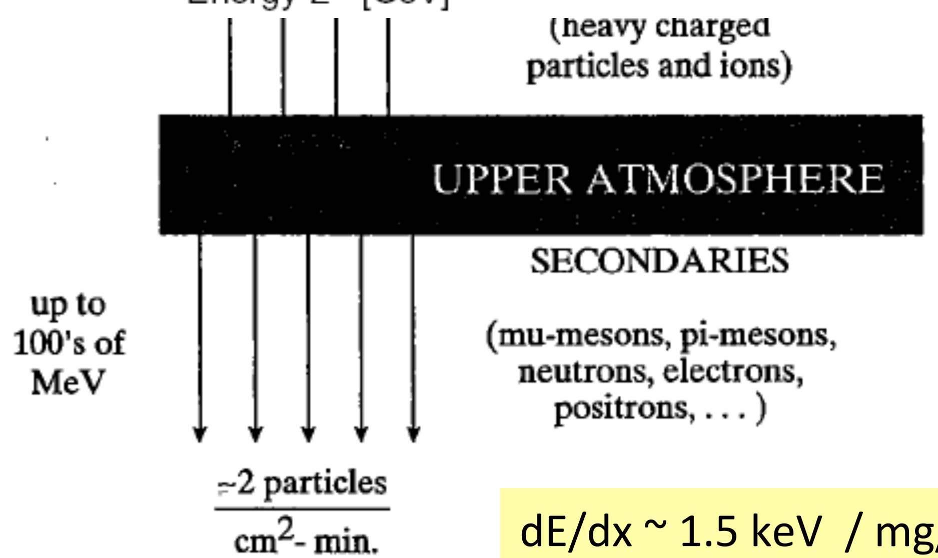
Backscattered (Compton Scattered) x-ray image

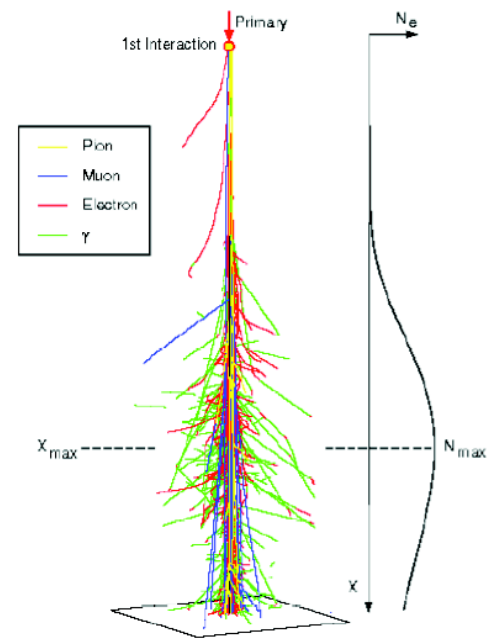
Aside: Cosmic Rays



Scaled distribution at the top of the atmosphere

~cos^2 Θ angular distribution





R. Chartrand, et al. LANL

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

Active Screening: Cosmic Ray Radiography?

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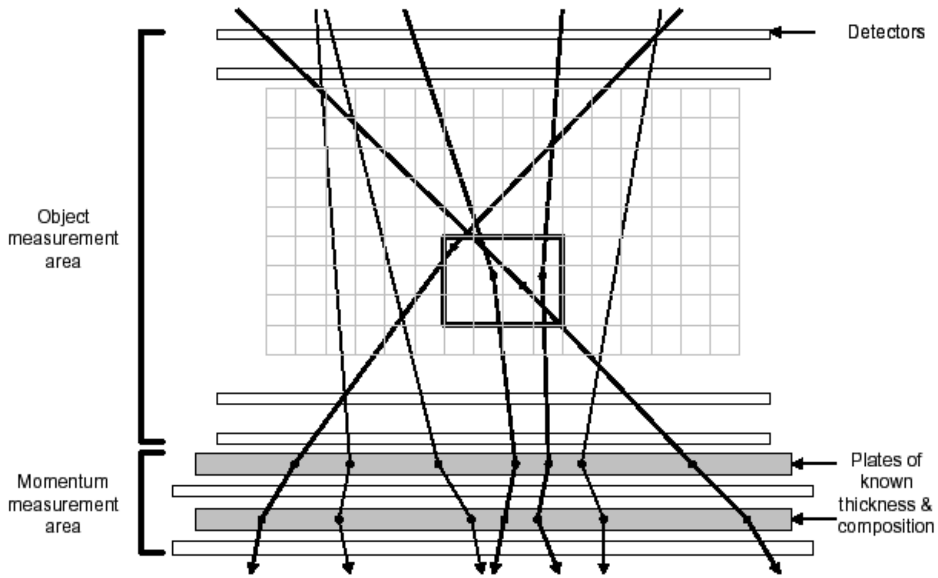
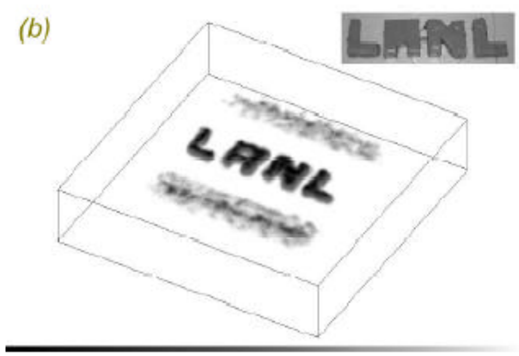
See early work: Search for Hidden Chambers in the Pyramids,
L. Alvarez, et al. **Science** 167 (1970) 832.



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



1” Pb-stock, 10^5 muons

Q: How long did it take?