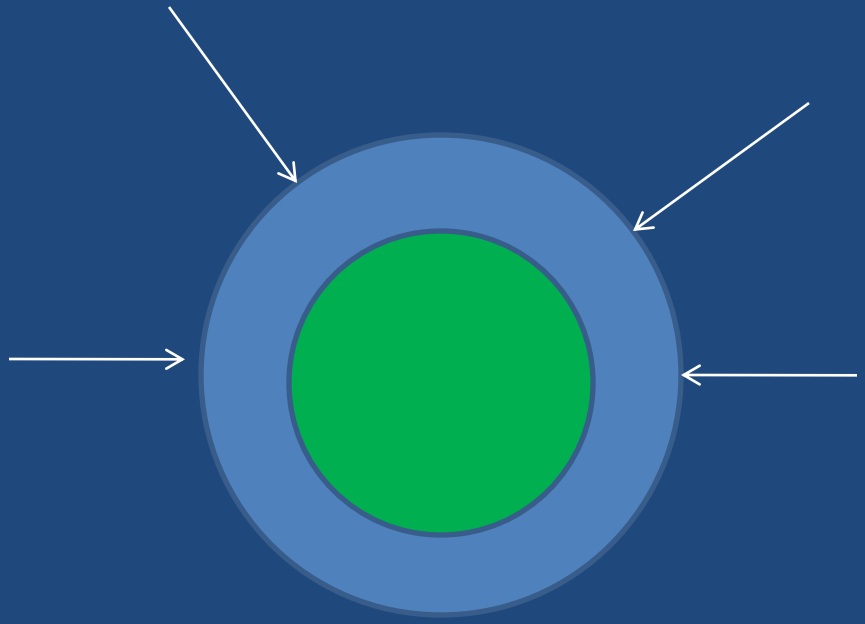
# Cosmic Drizzle

Thomas Coan

- What's a "cosmic ray" (note the "s")
- Origin, propagation and lifetime of CRs
- Digression 1: facts about your mother
- Digression 2: how to measure thickness ( huh?)
- Muons, muons, muons …

# The Primary Drizzle



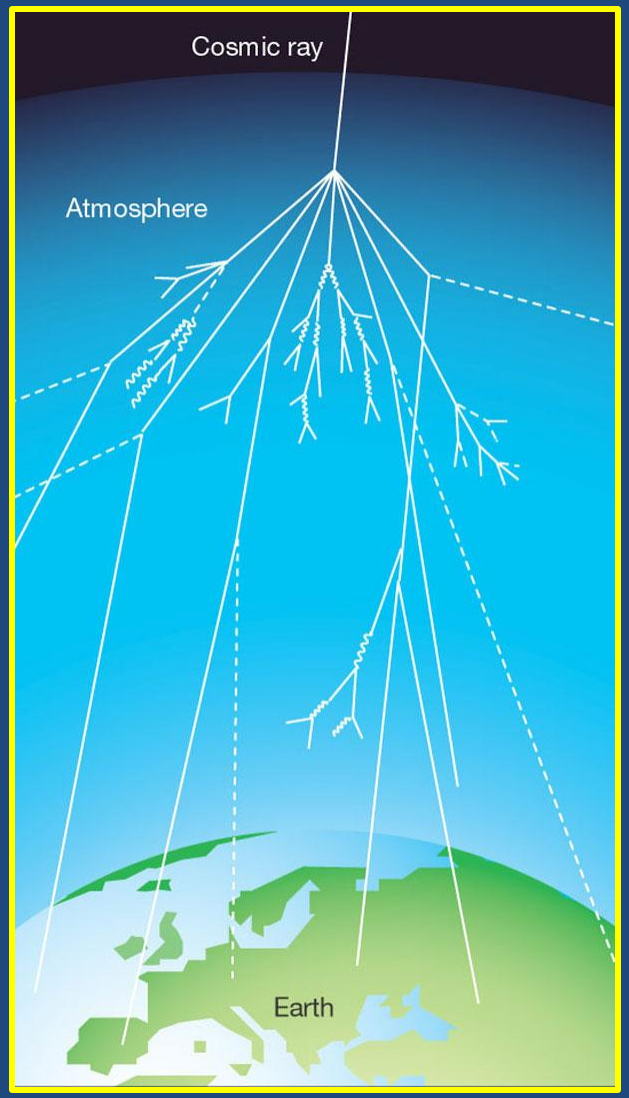
Atomic nuclei strike upper atmosphere. Produce secondaries.

Extraterrestrial origin, mostly outside the solar system

Mostly protons (~95%) & He (~5%). Heavier stuff too.

Long –lived: ~15 Million years.

# The Secondary Drizzle




Secondaries include n, Kaons, pions.

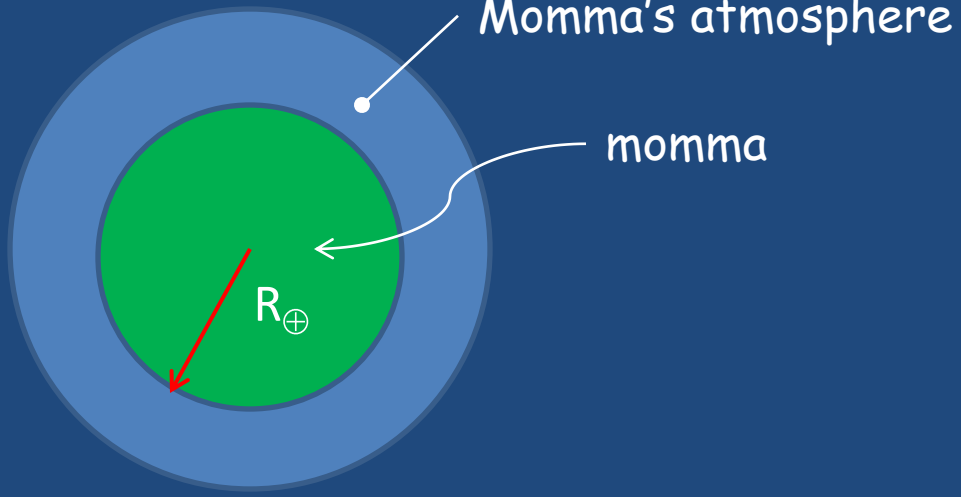
Kaons, pions decay quickly (more later)

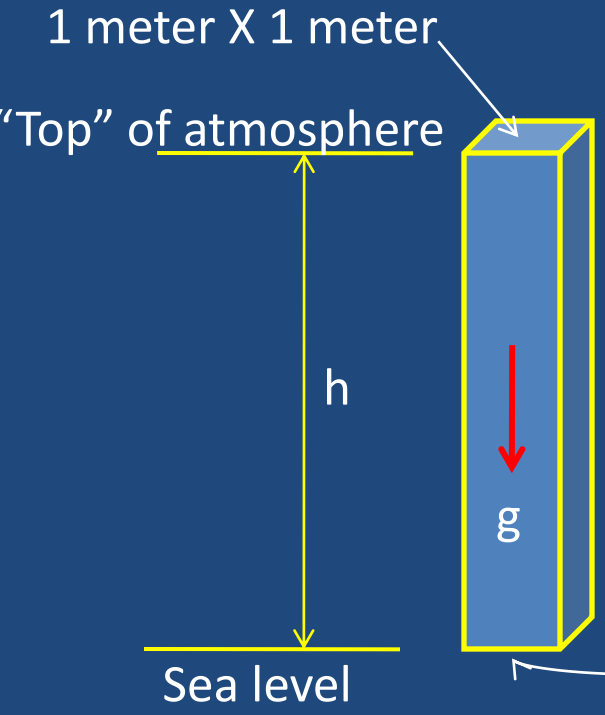
$n + N^{14} \rightarrow p + C^{14}$

Secondary production is a big deal.

e.g., Auger experiment.
(story for another day.)

# Mass of our Atmosphere




## Reminder

Hydrostatic Pressure = weight of stuff pressing on square

P = mg/A (weight of 1 "stick" on stick's base area A)

P = ρAhg/A ( m = mass density ρ X Volume)

$P = \rho g h$

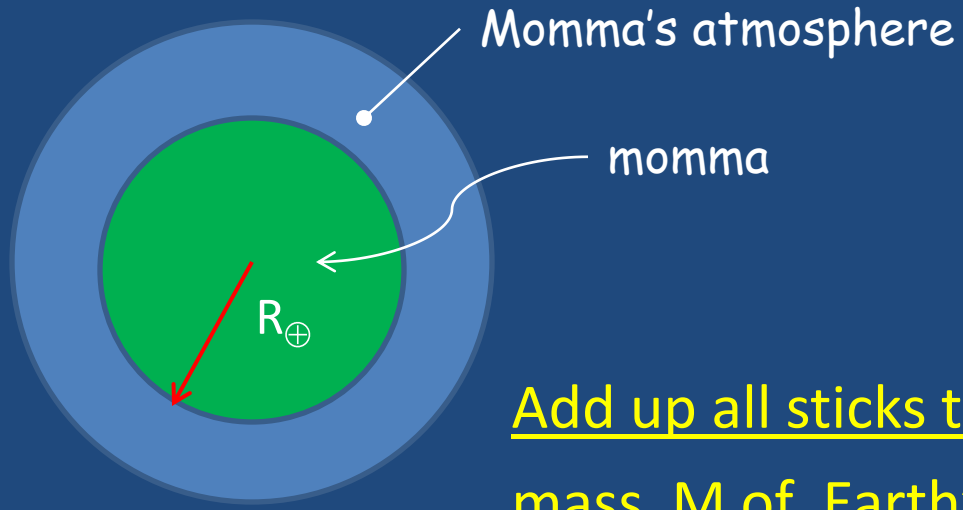
P = atmospheric pressure at sea level

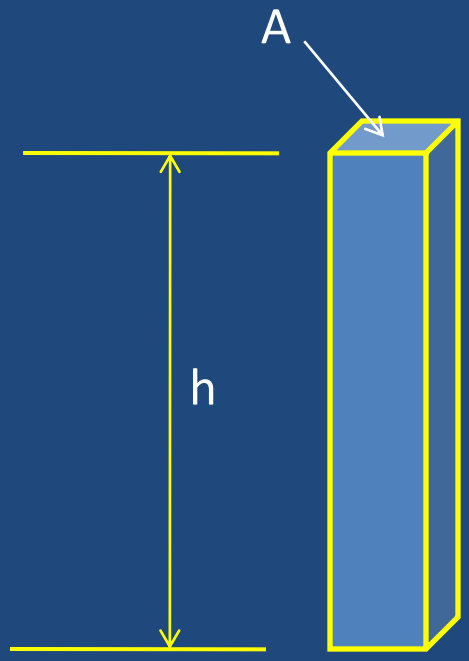
ρ = air mass density

# Mass of our Atmosphere (2)

$P = \rho g h$

$mg = PA$




Add up all sticks to find mass M of Earth's atmosphere

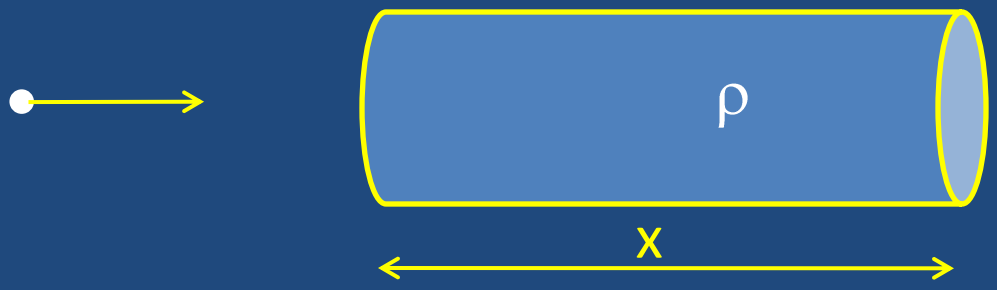
- mass m of 1 stick = PA/g
- Number of sticks = $4\pi R^2/A$

$M = 4\pi R^2 P/g$ (Note: all @ sea level !!)

M = … (do the numbers)

$M/M_\oplus$ = … (aw, go ahead, don't be shy !!)

# How to Measure Thickness




How much stuff ?

For a particle physicist, a material's "thickness" depends on **both** its mass density **and** its length.
Combining density and length better than either alone.

$s = \rho x$ units of s may seem a bit weird, mass per area, e.g., $kg/m^2$

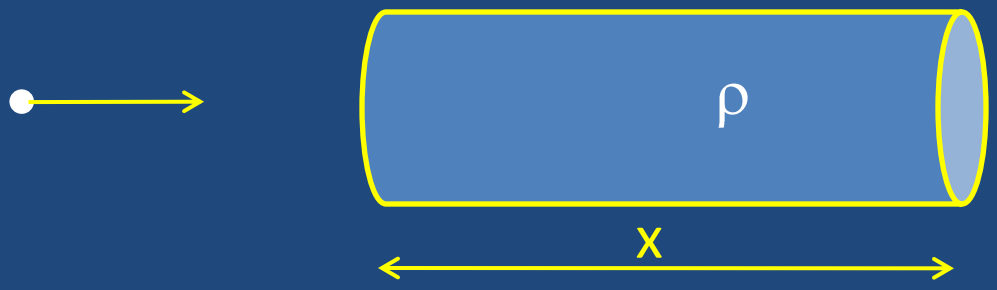
Q: How thick is the atmosphere?

A: $s = \rho h = P/g$ (recall that $P = \rho g h$)

$s \approx 10^5/10 = 10^4 \ kg/m^2 = 1000 \ g/cm^2$

What does this mean?
How much Fe has this thickness?

# How to Measure Thickness




How much stuff ?

For a particle physicist, a material's "thickness" depends on **both** its mass density **and** its length.
Combining density and length better than either alone.

$s = \rho x$ units of s may seem a bit weird, mass per area, e.g., $kg/m^2$

Q: How thick is the atmosphere?

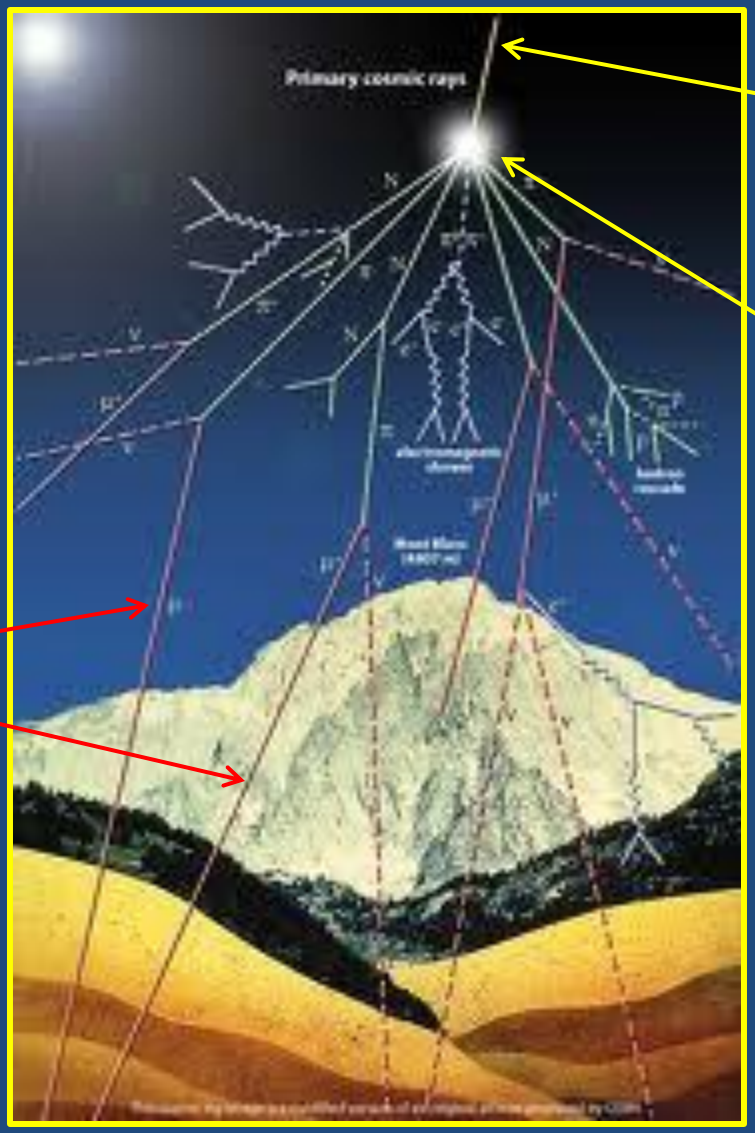
A: $s = \rho h = P/g$ (recall that $P = \rho g h$)

$s \approx 10^5/10 = 10^4 \ kg/m^2 = 1000 \ g/cm^2$

What does this mean?
How much Fe has this thickness?

$\rho(Fe) = 7.87 \ g/cm^3$
$x = s/\rho \approx 10^3/8 = 125 \ cm$

# Muon Drizzle




Incoming proton

Collision w/
air molecule nucleus

Particle cascade

muons

# What is a muon?

**What it ain't:** a "fundamental building block" of the universe

Belongs to the set of particles
Comprising only 4% of Universe's mass-energy.
Story ( a very interesting one) for another day.

**Pragmatic definition:** a heavy, radioactive electron-like particle

Heavy: $m_\mu \approx 210\ m_e$

Radioactive: Half-life = 1.5 μsec ("e-folding time" = 2.2 μsec)

Same electric charge as an electron (can be + or -)

**Both** e & μ are **point-like** (as far as anybody can tell).

# Muons at the beach (er ...sea-level)

Muons produced high (~10 km) in the sky

Muons are in a hurry ($v \sim c$)

Muons don't live forever: $\tau \approx 2.2$ μsec

**WAIT**. Looks like they don't travel very far:

**$V * \tau \approx (3 \times 10^8$ m/sec)*(2.2 X $10^{-6}$ sec) = 660 meters**

Relativity to the rescue:

High velo implies strong time dilation.
(The lifetime is measured in muon's **rest** frame.)

Flux @ sea-level: 1/cm$^2$-min (horizontal surface)

1/thumbnail-min

# BTW, How do you "see" muons?

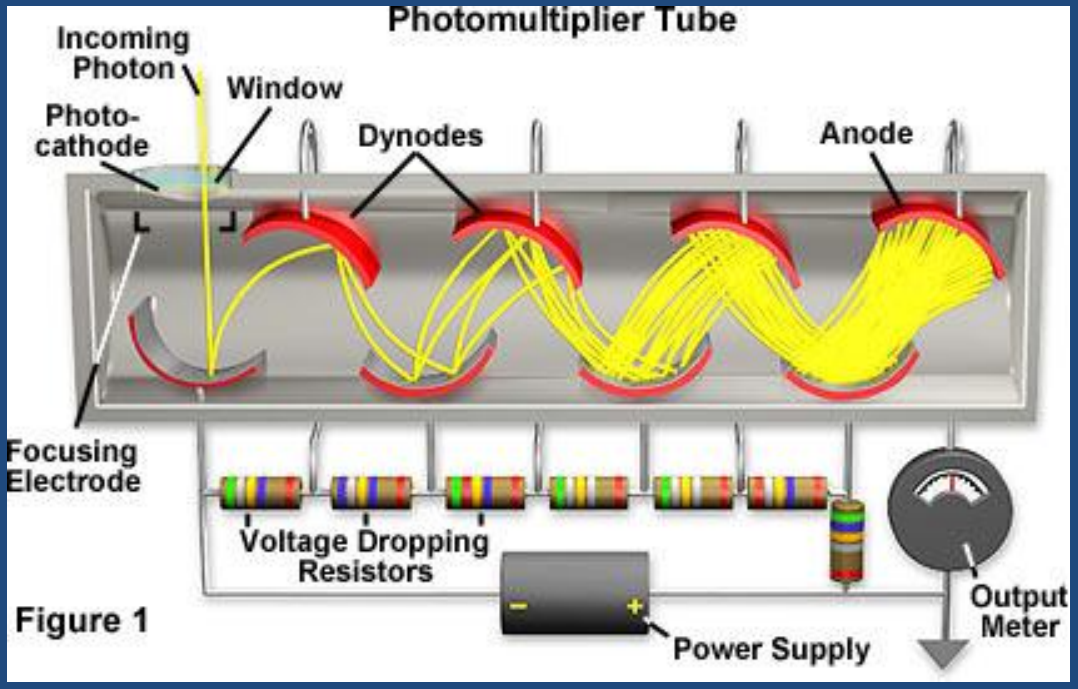
Multiple ways to detect muons. one way is:

- Electric field from muon excites atoms of target
- This costs energy, energy taken from muon's KE
- In special target material (i.e., "scintillator"), excited atoms, emit faint bluish light when they de-excite
- Emitted light is easily detected by a "photomultiplier tube"

"photomultiplier tube" (PMT): a kind of light bulb in reverse

- Feed it light, it spurts a small amount of electricity.
- Quite common, see your grocery check-out counter.

# Photomultiplier Tube




I will pass a few (broken ones) around.

# Working muon detector …hubba, hubba

Ground floor Fondren Science

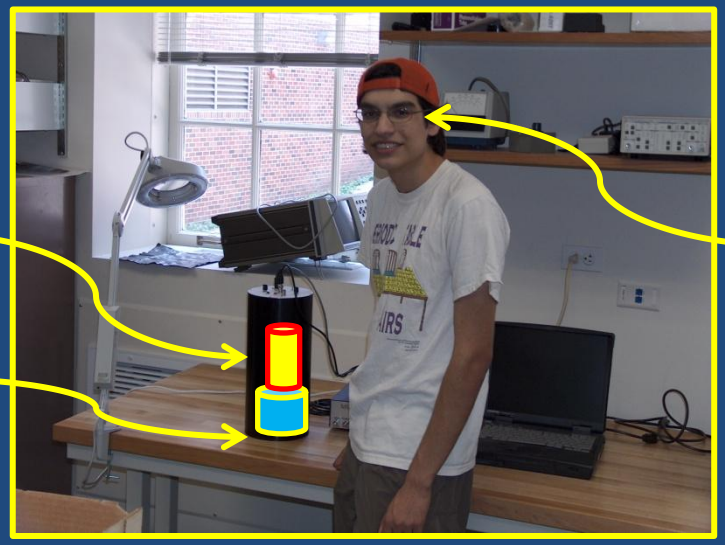
Built by SMU faculty (Jingbo Ye & TEC)

Runs continuously

Measures muon lifetime

Shameless plug

Check it out




# What to Remember

- Where lunch is.
- Extraterrestrial protons drizzle top of atmosphere.
- Atmosphere has appreciable thickness.
- These protons collide w/ air nuclei, produce muons.
- Muons survive down to sea level (time dilation req'd).

- Muon flux @ sea level is 1/cm$^2$-min.
  (1 per minute through your thumb nail)

# What to Remember

- Where lunch is.
- Extraterrestrial protons drizzle top of atmosphere.
- Atmosphere has appreciable thickness.
- These protons collide w/ air nuclei, produce muons.
- Muons survive down to sea level (time dilation req'd).

- Muon flux @ sea level is 1/cm$^2$-min.
  (1 per minute through your thumb nail)

Think SMUon