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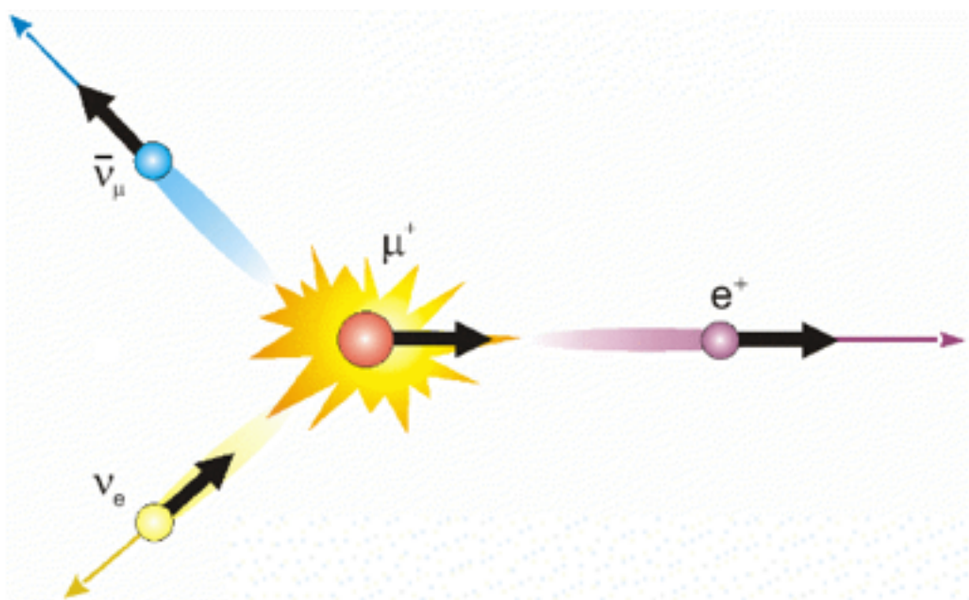
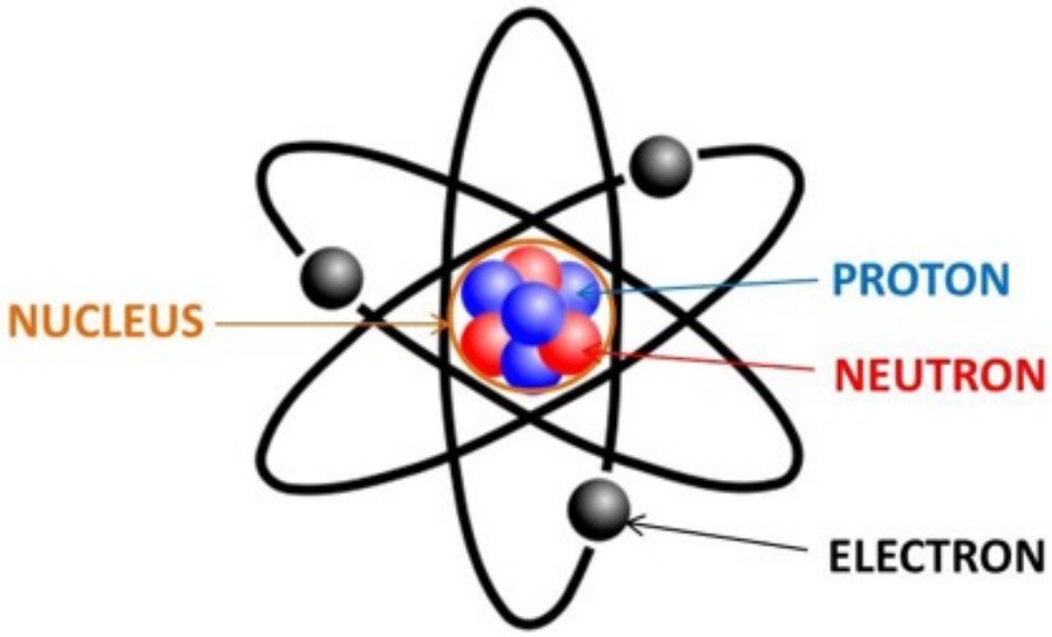
Travaux Pratiques 4

Measuring the muon lifetime



What are muons?

1930s…



All matter

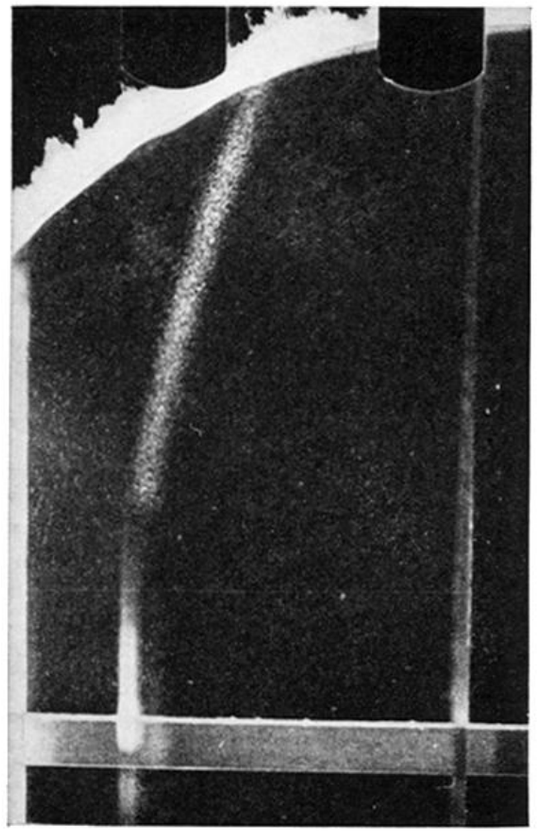
…everything is figured out.

(or so they thought…)

1936:

Completely unexpected:

Discovery of the muon

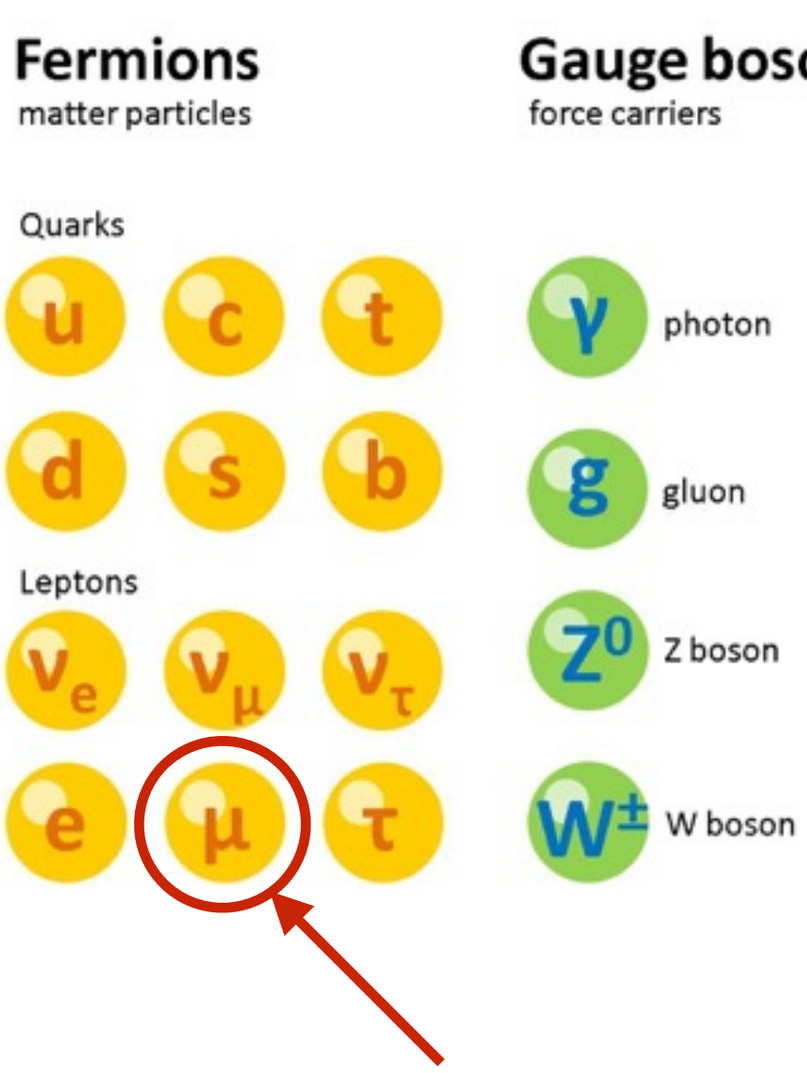


Who ordered that?!

I. Rabi

What are muons?

Standard model



Three “families”

- The muon is the heavier “cousin” of the electron
- Decay:

$$\mu^- \rightarrow e^- \bar{\nu}_e \nu_\mu$$

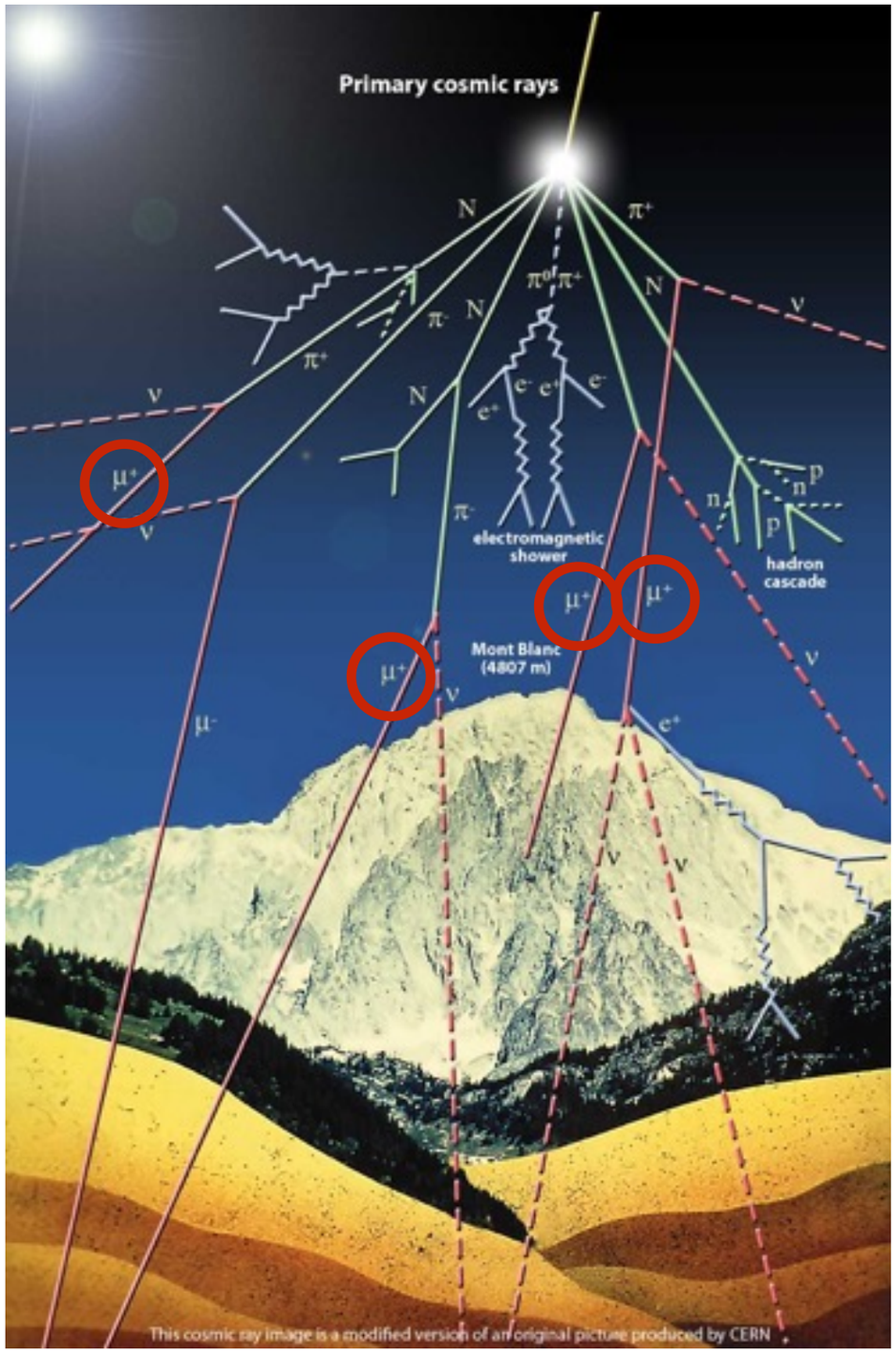
- Mean lifetime:

$$\tau = 2.2\ \mu s$$

that’s quite “long”

Where are muons?

Cosmic ray showers



- Primary collisions: ~15 km altitude
- Muons are among secondary particles

But wait…

if $l \approx 15$ km, and $v \approx c \Rightarrow t = 50$ μs ?!

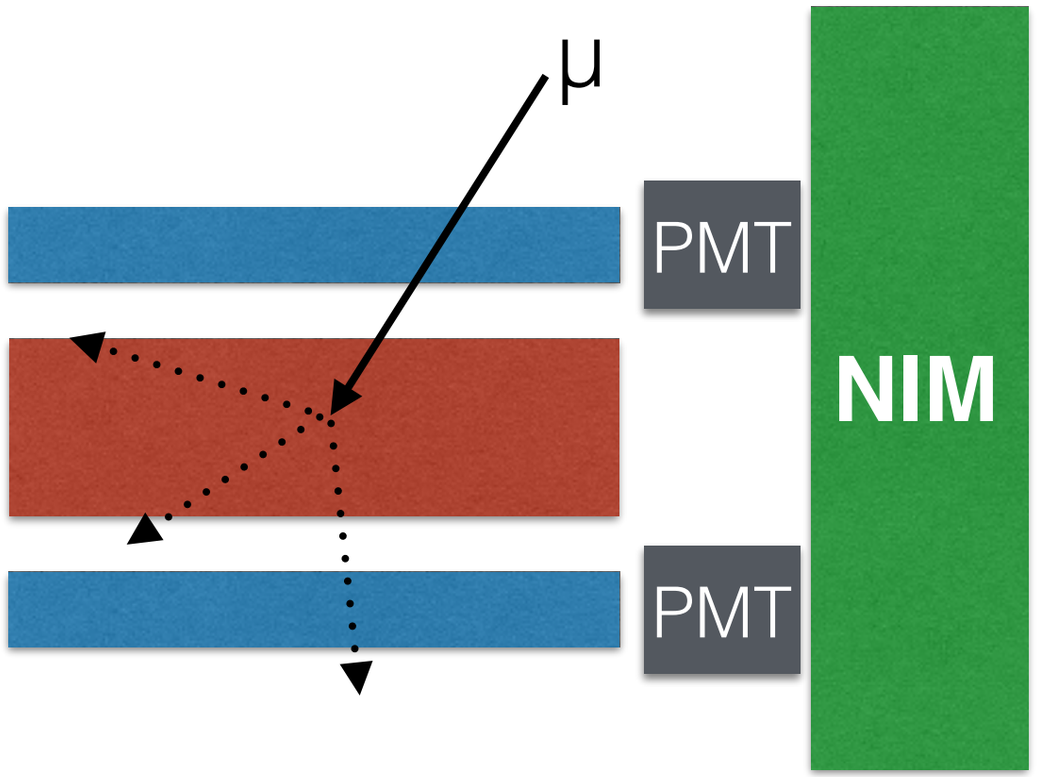
special relativity: time dilation

1 muon/cm²/minute @ sea level

TP4 part 1: measure the muon lifetime

1.
- stop the muons: Cu plate
- muons decay: $\mu^+ \rightarrow e^+ \nu_e \bar{\nu}_\mu$

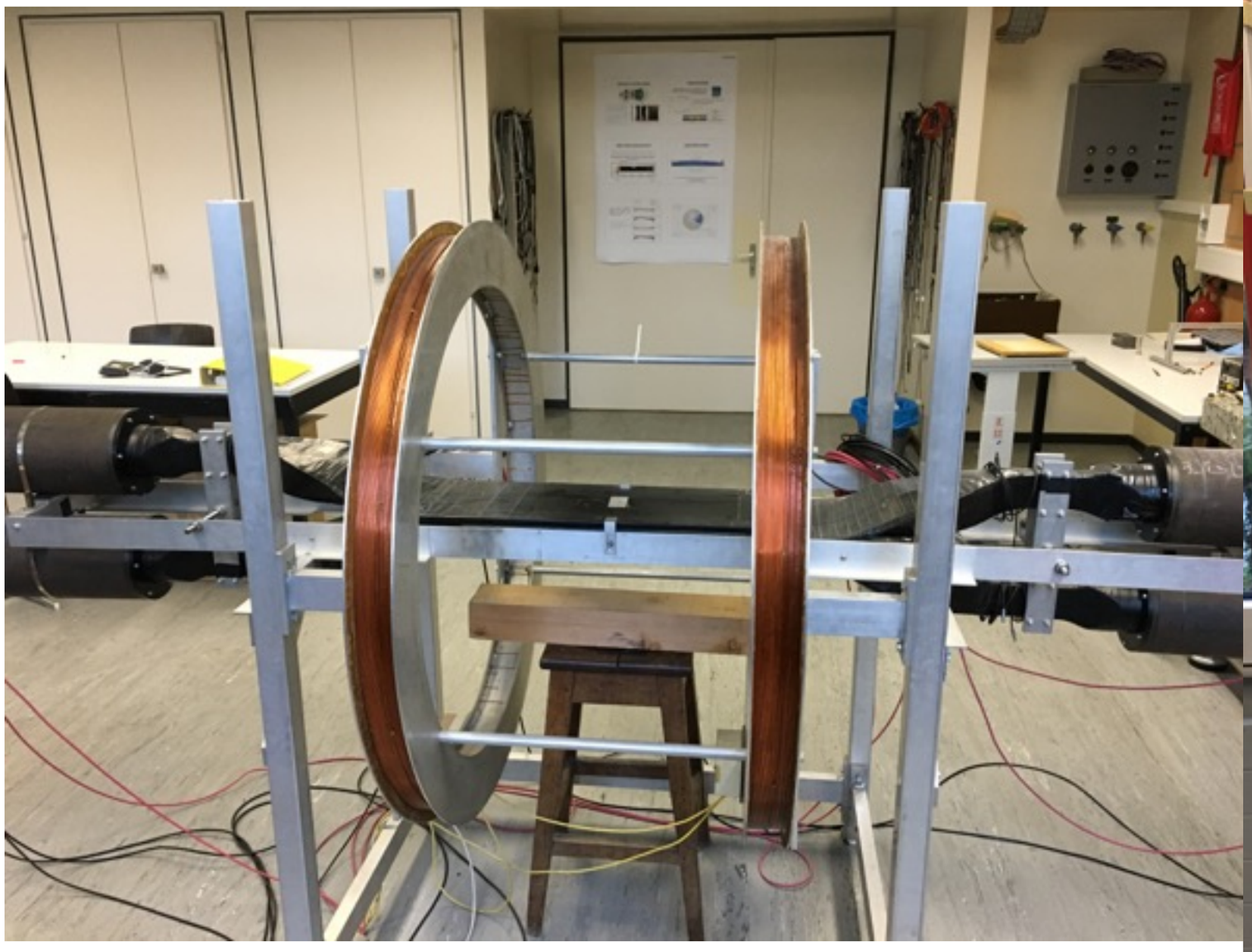
2.
- detect the arrival of the muon, and passage of the decay products
- scintillator + photon detector

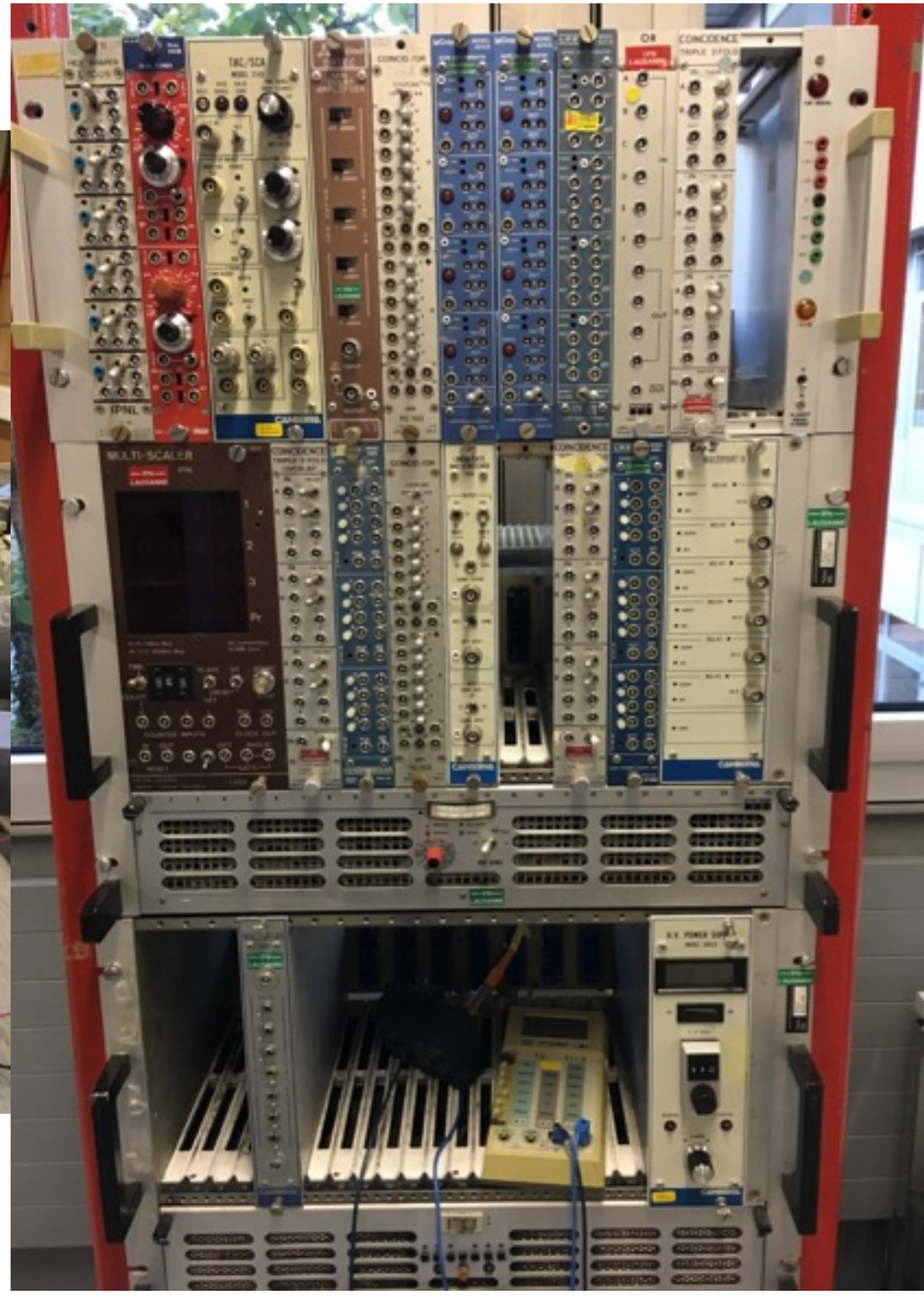


3.
- read the signal and set up a scheme to measure t_μ and t_e

you get to "build" that!

4.
- analyse the data to extract τ

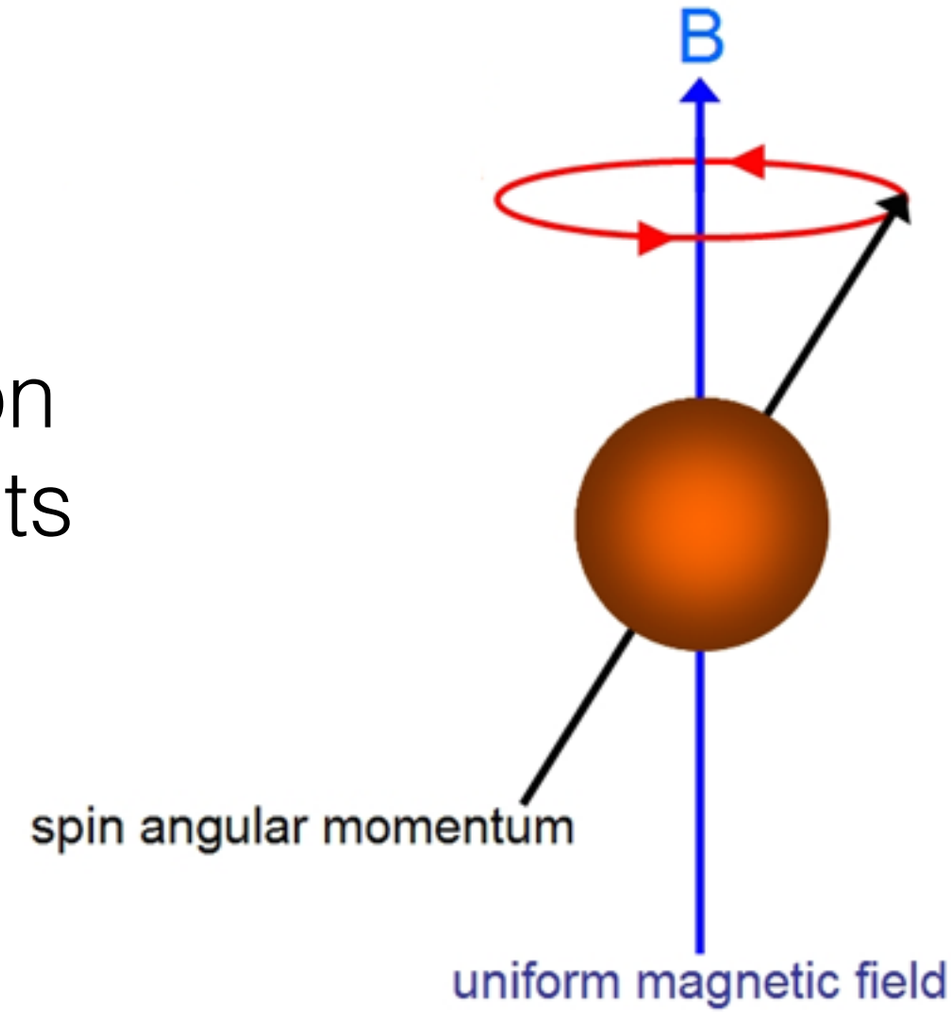



MULTI-SCALER

TP4 part 2: measure the muon Landé factor

- Muons have spin and thus a magnetic moment that is proportional to the spin

$$\vec{\mu} = g \cdot e/2m \cdot \vec{s}$$



- In a magnetic field, spin precession with an established frequency starts
- Cosmic muons are polarised
- The spatial decay asymmetry will rotate with the same frequency (connected to the g-factor)

What you will learn

Theoretical topics

- cosmic rays, relativistic time dilation, muon decay, muon interaction with matter, muon in a magnetic field

Experimental side

- detectors: scintillator + photon detectors (PMTs)
- calibration of detectors
- studying signals with the oscilloscope
- design a trigger and readout scheme to measure t_{start} and t_{stop} (Δt)
- analyse the data: obtain a parameter from a fit to the distribution