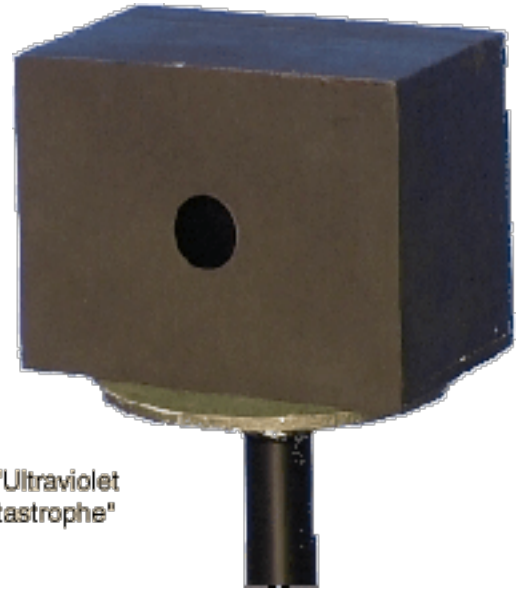

# Antimatter pushing boundaries

Prof. Niels Madsen
Swansea University, UK

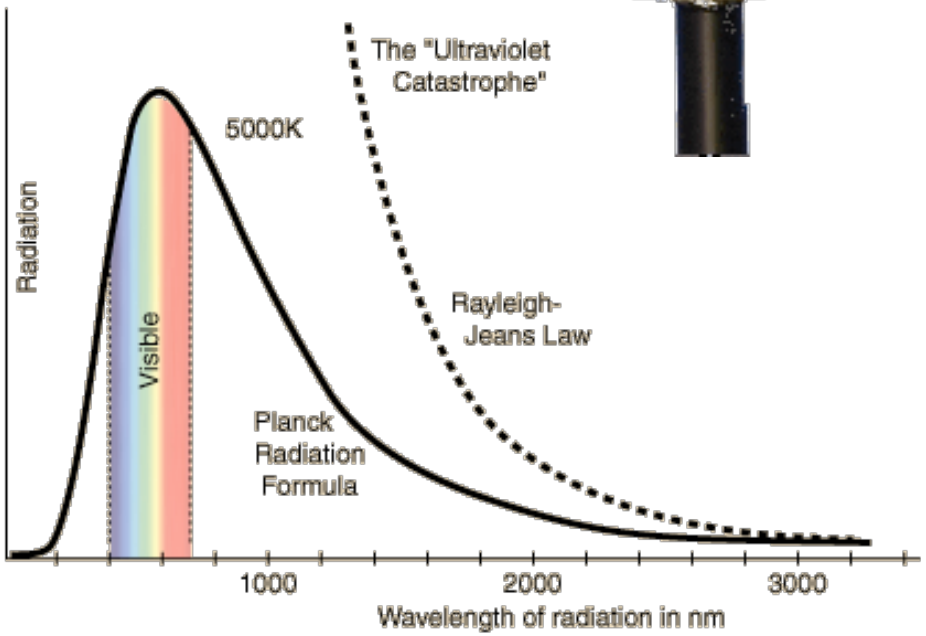
## Science and the unknown

- By elimination of many models we have arrived at the « Standard Model »
- There is a nagging list of stuff that does not quite fit
  - e.g. neutrino mass
- Gravity – being the weakest force of nature (but one we certainly notice!)– is not even included!

## Science and the unknown in year 1900

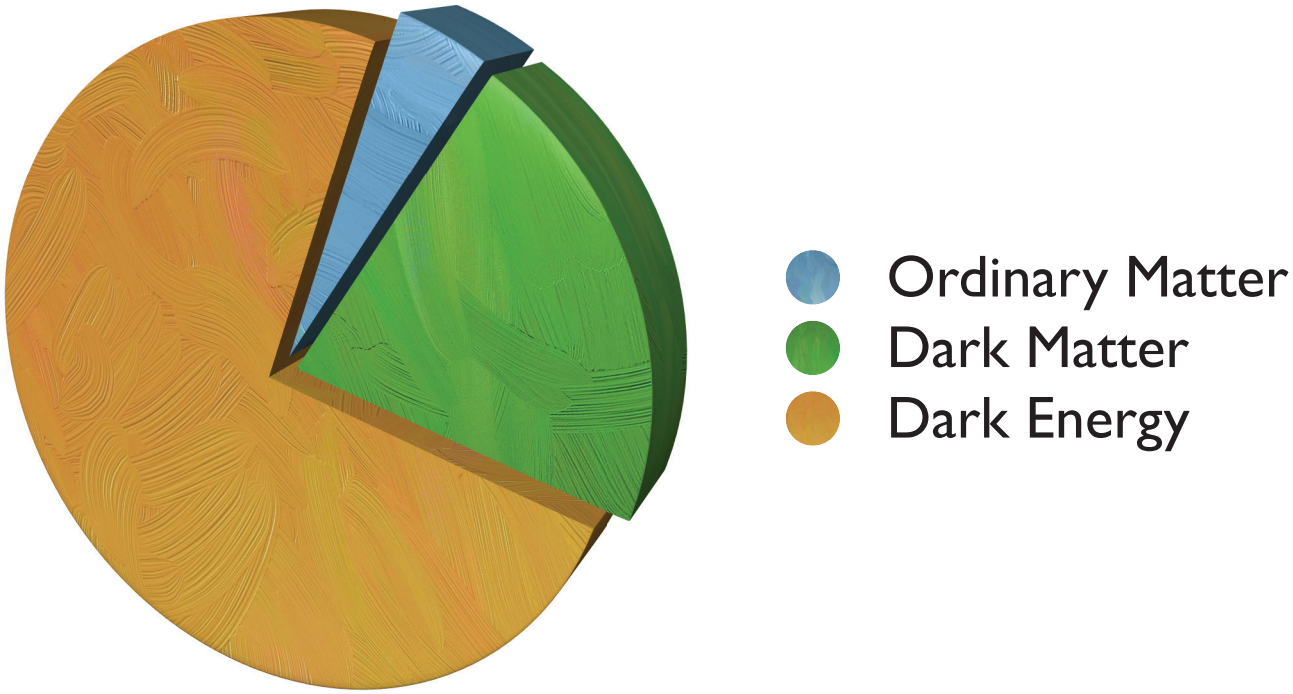


- Light from a hole in a black box (hohlraum)




- Apparently simple discrepancy led to quantization

## The Universe




- We can only account for ~ 4%

Antimatter pushing boundaries

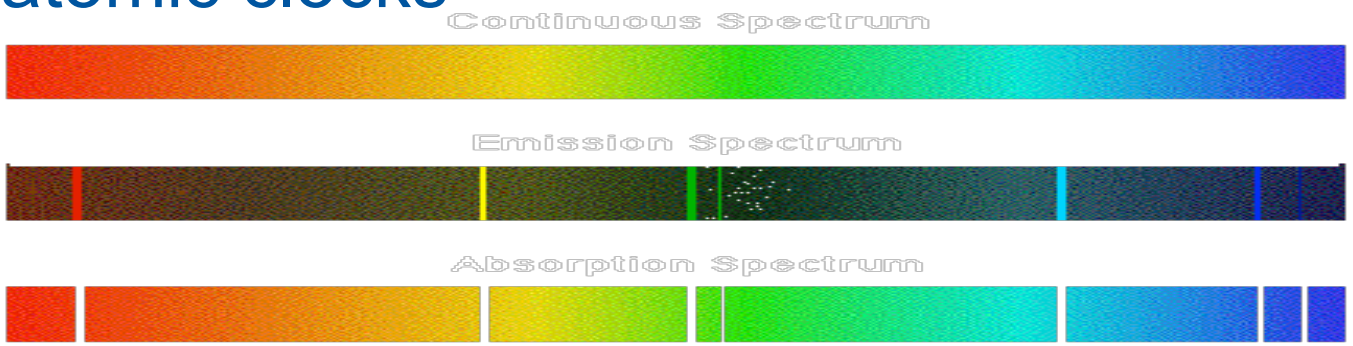
## Fundamental Physics

- Standard (high energy)
  - $E = m c^2$

- Alternative (low energy)
  - look very very precisely (think Wien/Planck!)

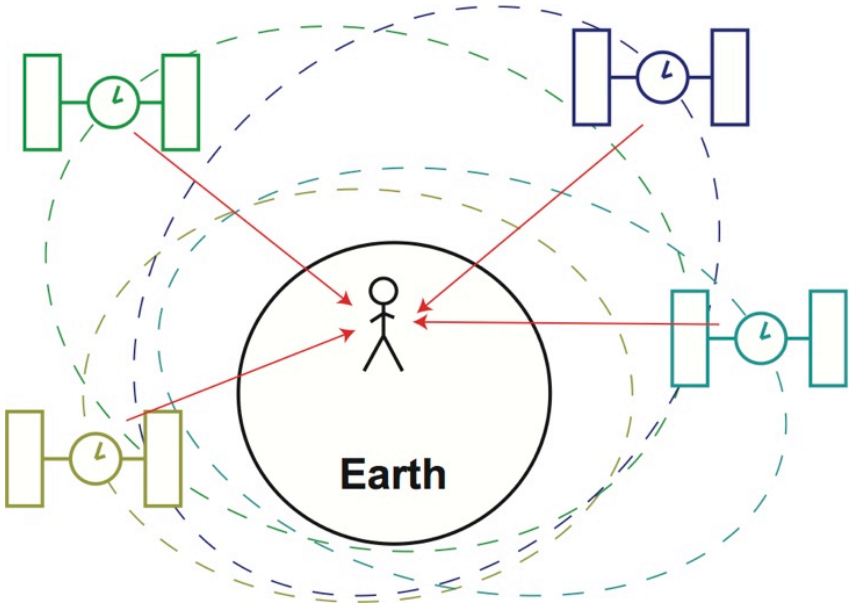
## History of precision

- Precession of the perihelion of Mercury (1919) Einstein “vs.” Newton -> General theory of relativity
- Precision measurements of atomic spectra -> Bohr’s model of the atom -> atomic clocks



## History of precision

- Atomic clocks + GR have made GPS possible.
- (w/o GR : 10km error/day)
  (clocks : ~20ns precision)




- Clock record : $3 \times 10^{-18}$ (~1 sec off if started a $t_{universe} = 0$)

## What is antimatter ?

- Particles have “twins” same mass, opposite charge

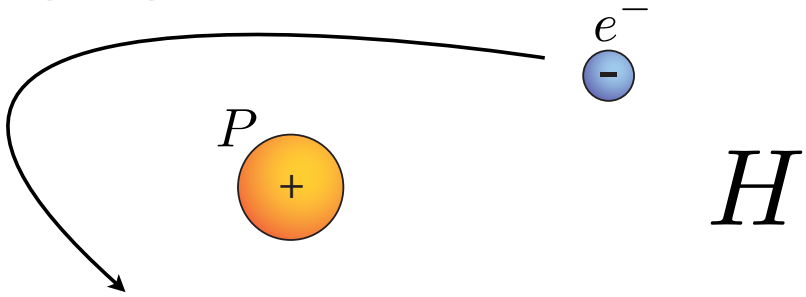
| | Electron | Proton |
|---|---|---|
| Matter: | - <br> $e^-$ | + <br> $P$ |
| **Antimatter:** | **Positron** <br> + <br> $e^+$ | **Antiproton** <br> - <br> $\bar{P}$ |

## What is antimatter ?

- Neutral antimatter atoms

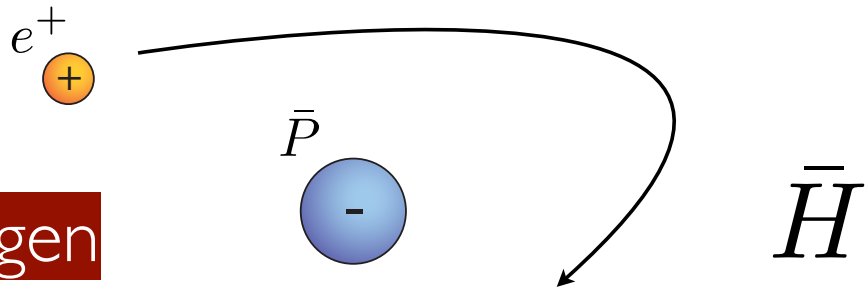
Matter:

Hydrogen



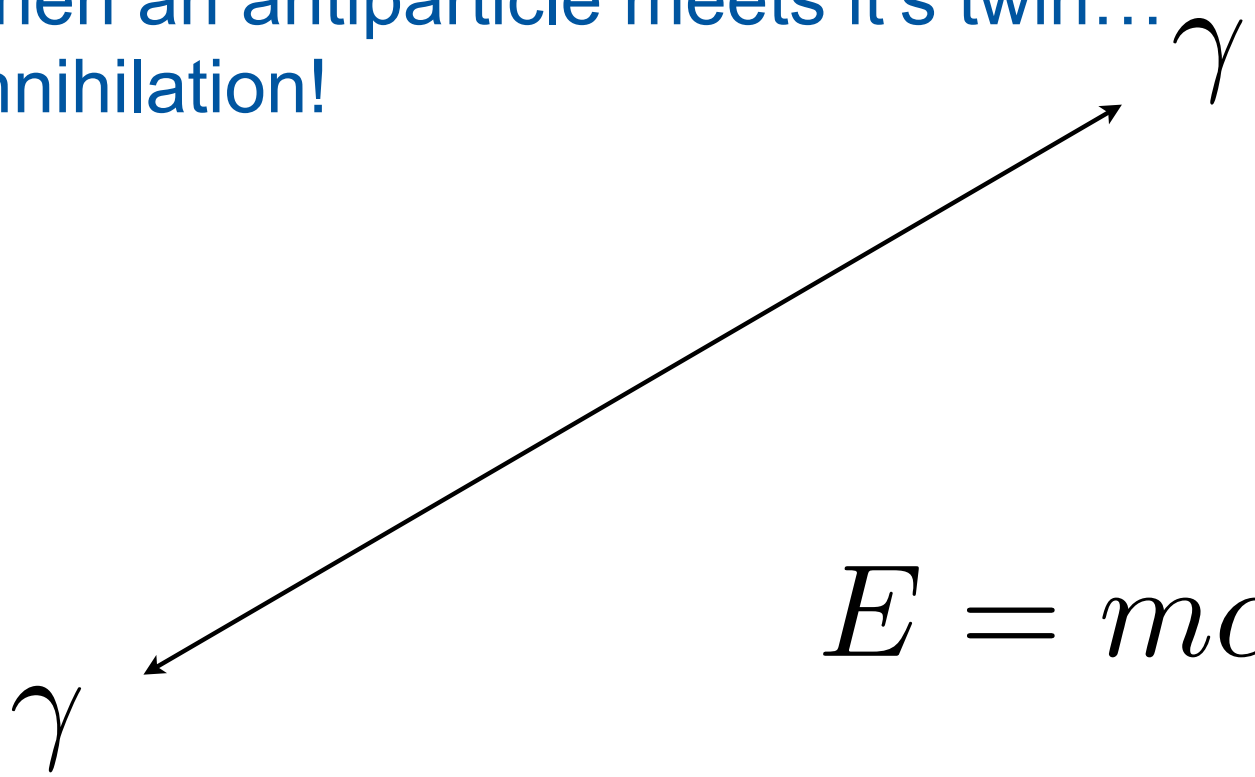

Antimatter:

Antihydrogen



## What is antimatter ?

- When an antiparticle meets it's twin… Annihilation!




$$E = mc^2$$

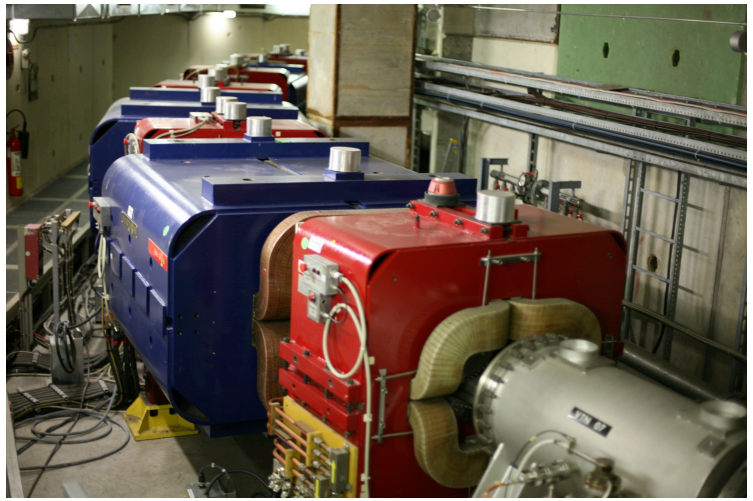
## Antimatter puzzles

- No (bulk) antimatter in the Universe !?
- Antiparticles are “Standard model” – so what about gravity ?
- Is antimatter really a proper twin ?
  - precision measurements!

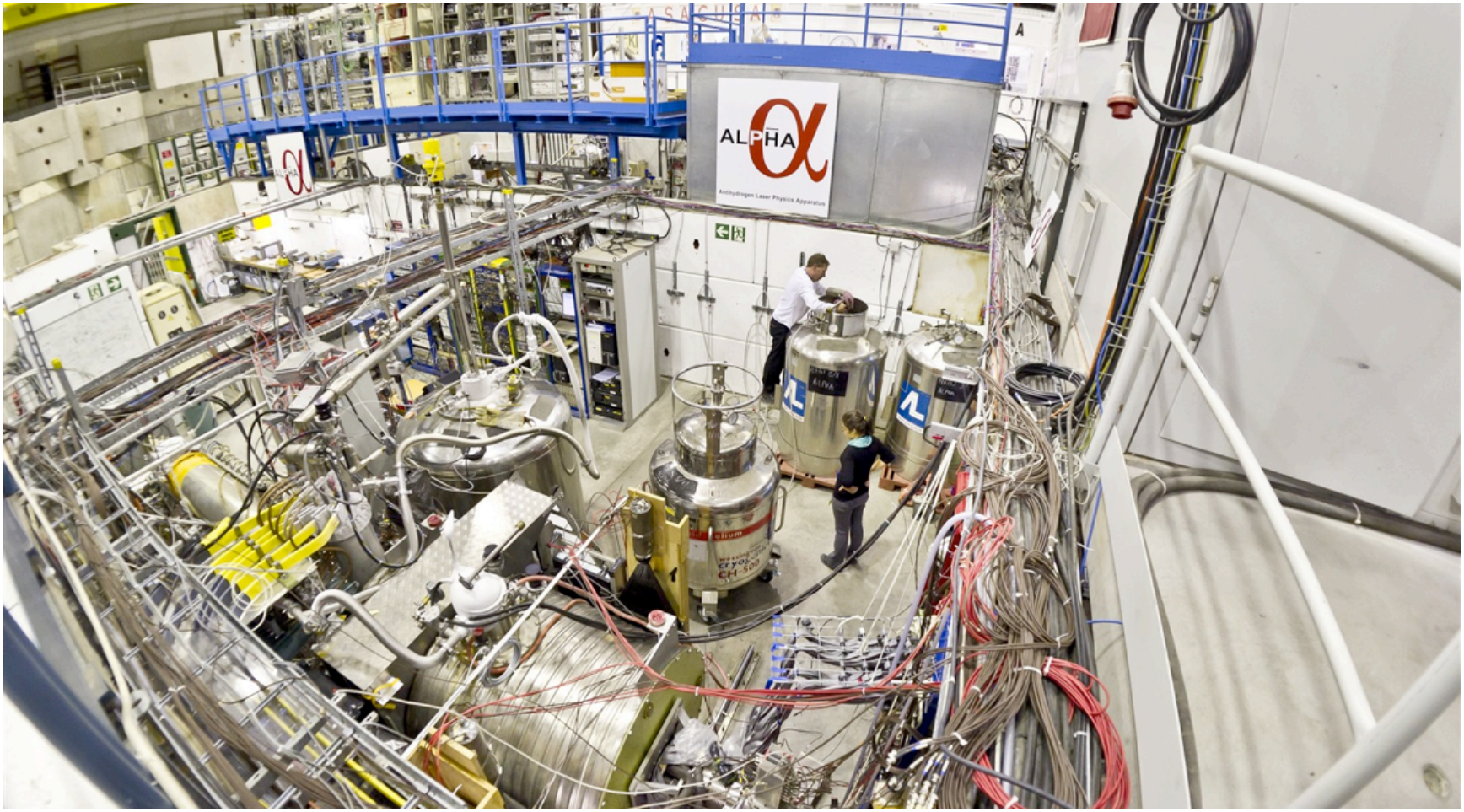
## Experiments with antimatter


- Positrons (β+ decay)
  (not using Ka-40 in bananas)

- Antiprotons (Ex2000) @ CERN
  - Antiproton decelerator (AD)



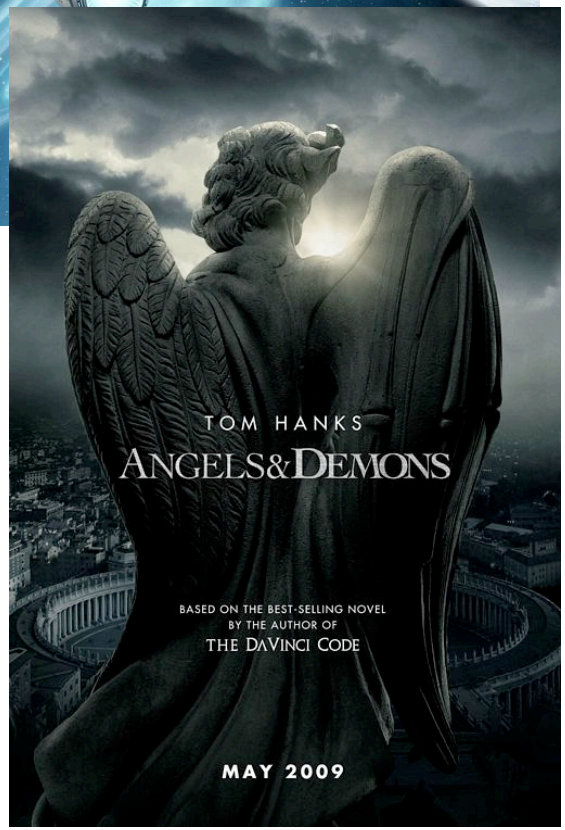
# The ALPHA antihydrogen experiment



# The ALPHA antihydrogen experiment

Antimatter pushing boundaries

## An impossible use of antimatter

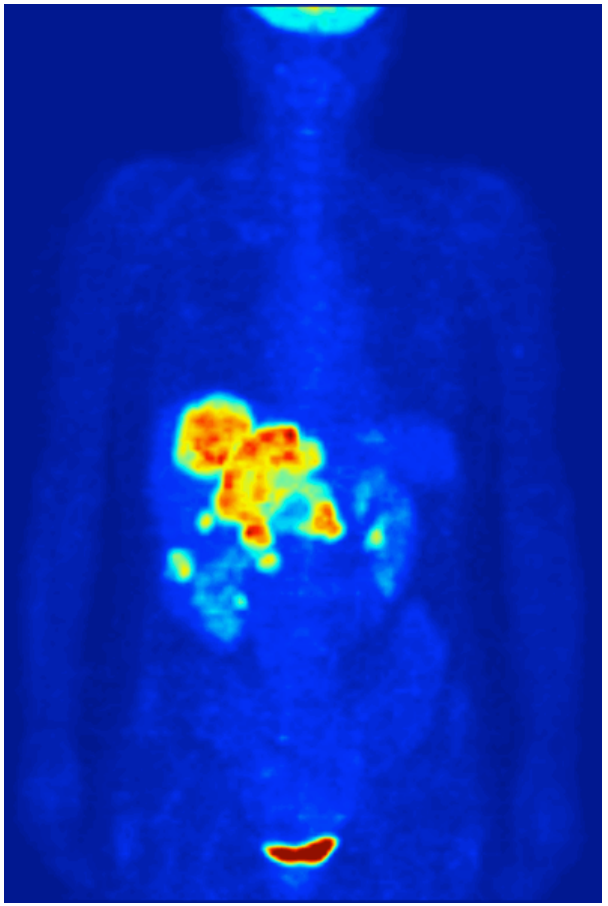



- 1 ton alpha-centauri?
- 1/4g for a bomb ?

- But : no antimatter “mines” and not just $E=mc^2$ in practice.
- E: World energy 50My -> 1g
- Practice: 50000 G years…

## Antimatter already in daily use

- Positron Emission Tomography (PET) scanners
- Positron Emission Particle Tracking (PEPT)



## Summary

- Precision measurements have a history of revealing new aspects of nature.
- New understandings in fundamental physics have had profound impact on daily life.
- Precision studies of antimatter may answers some of the most profound mysteries in physics today.