Antimatter factory and ALPHA

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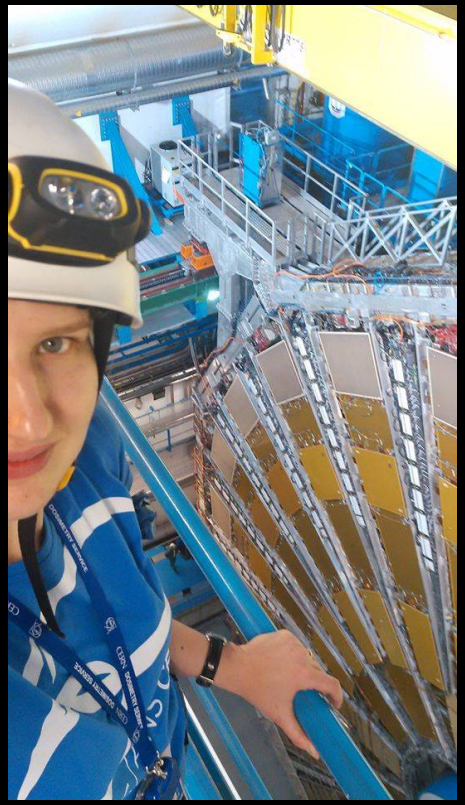
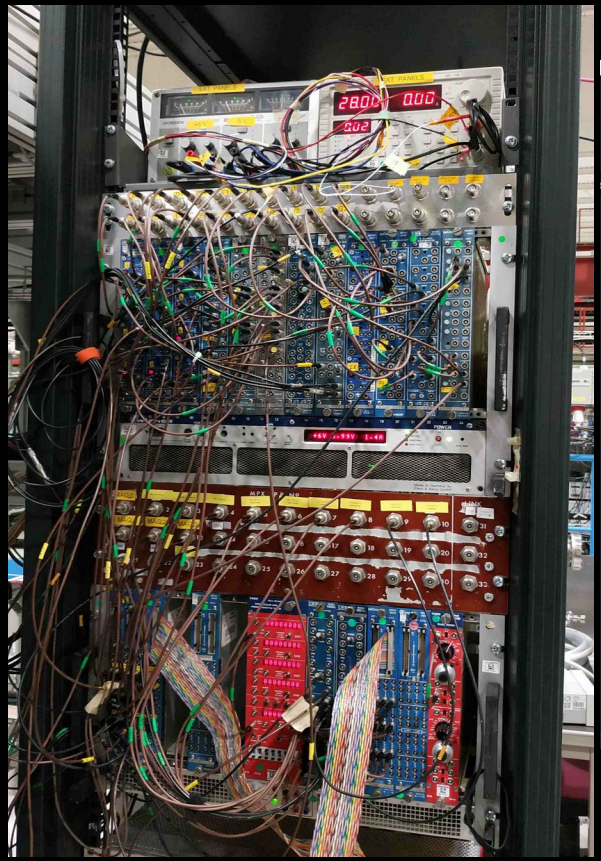
About me

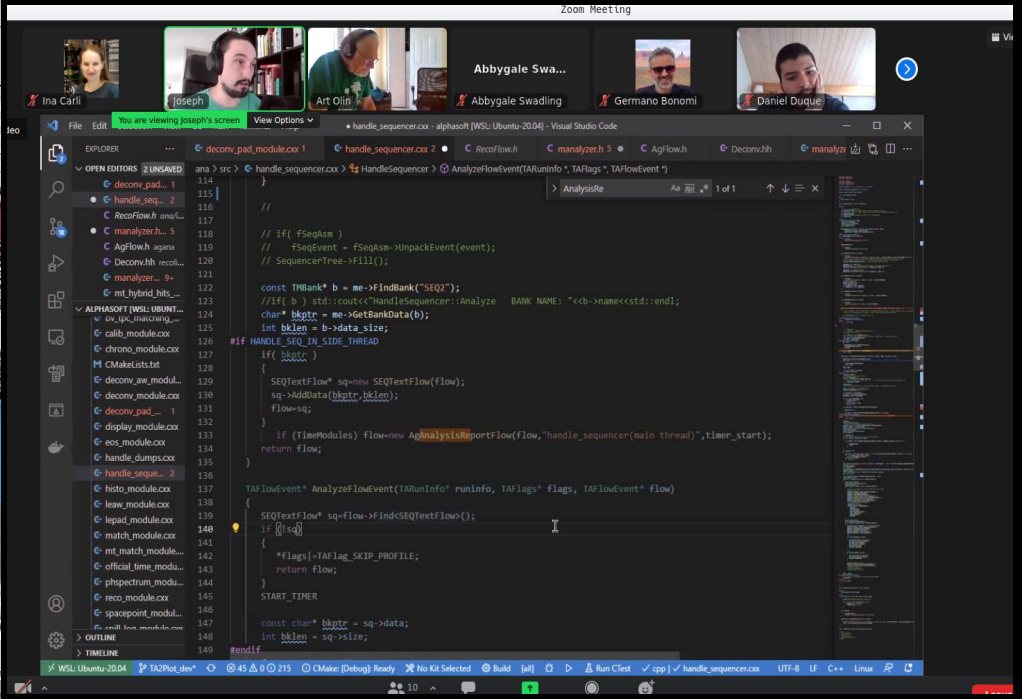
Poprad, Slovakia → Charles University in Prague (Czechia BSc, MSc, Phd)
→ CERN (summer student, PhD, postdoc)
experiments: ATLAS → LHCb → ALPHA

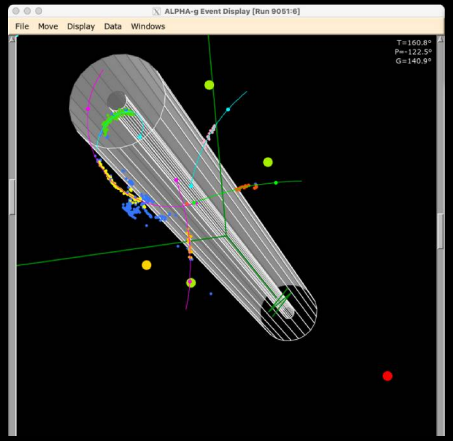


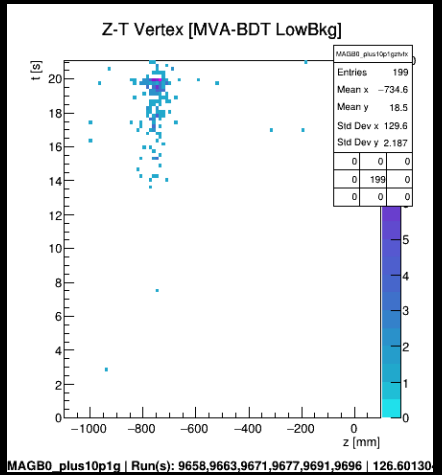
What do I do?

I build and test particle detectors, connect cables, solder, make antihydrogen, record data and analyze them…









What is antimatter?

Paul Dirac's formulation of relativistic quantum mechanics (1928):

$$E^2 = (pc)^2 + (mc^2)^2$$

$$E = \pm\sqrt{(p^2c^2 + m^2c^4)}$$

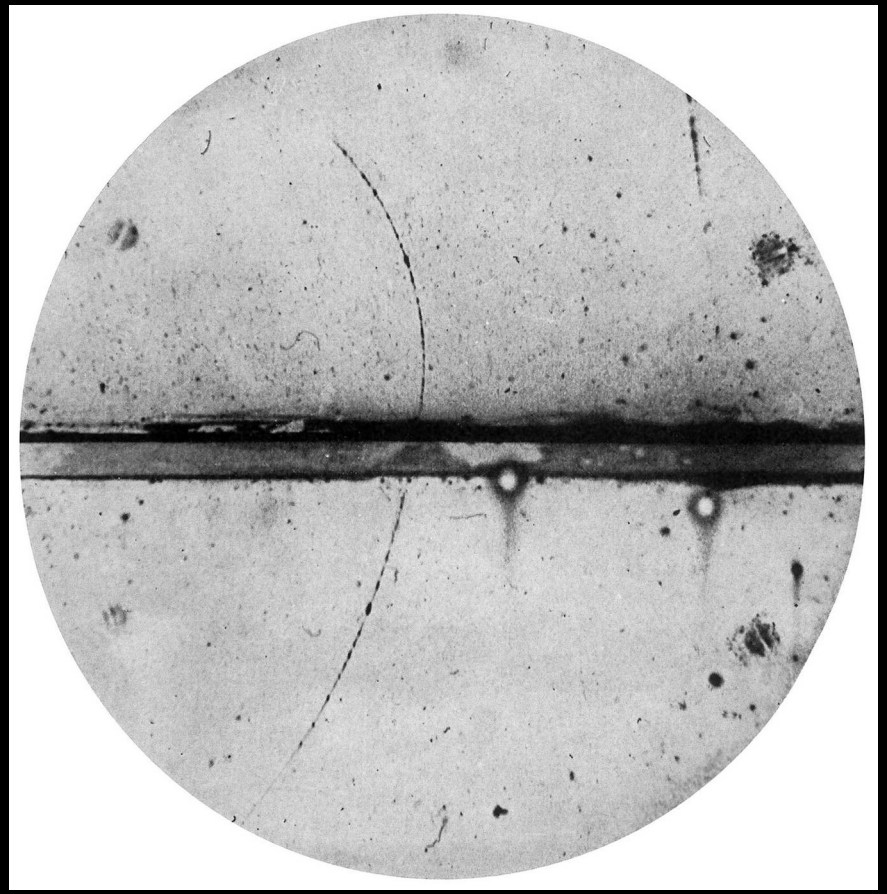
?

Dirac

$\overline{\text{Dirac}}$

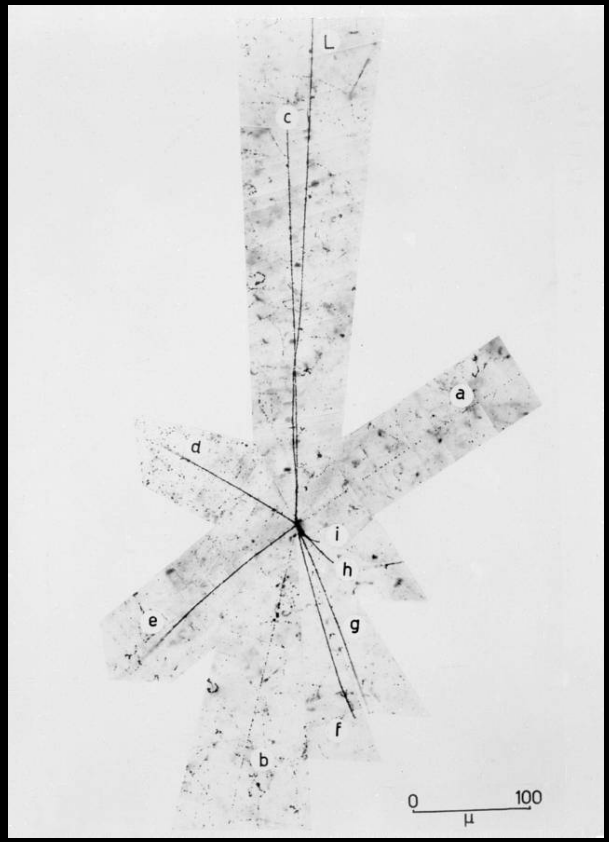
Observation of first antiparticles

1932: Carl Anderson discovered positrons in cosmic rays



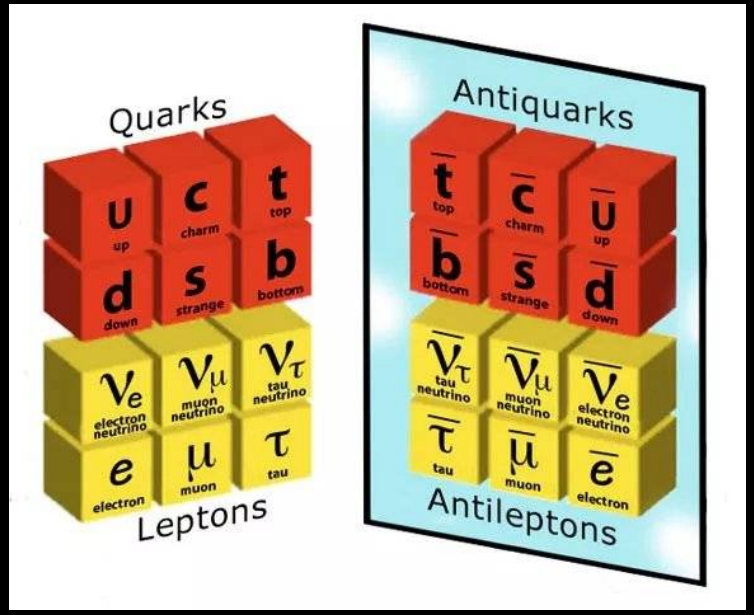
Observation of first antiparticles

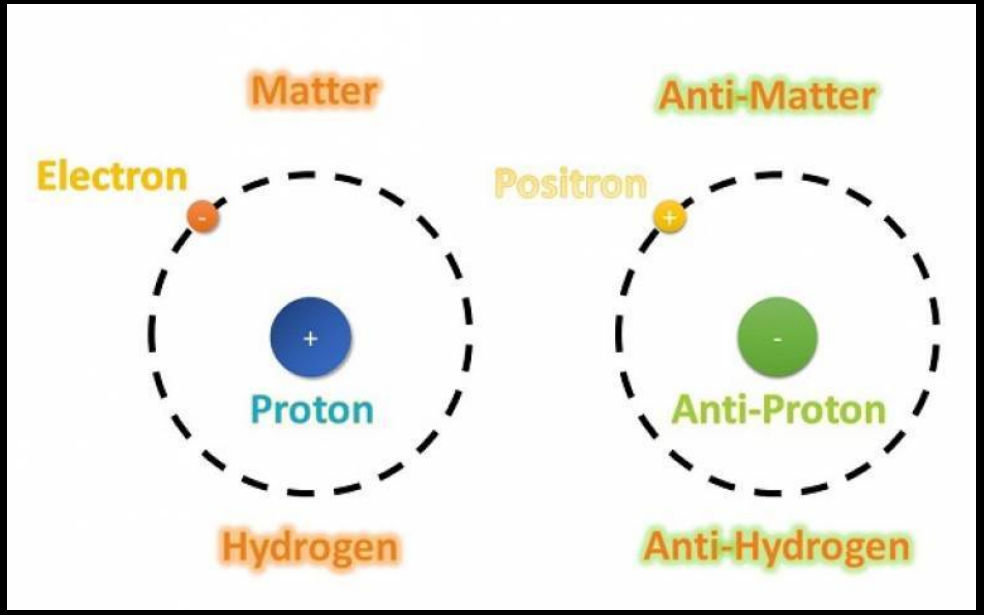
Antiprotons created in collisions of high energy proton beam with fixed target (O. Chamberlain and E. Segrè, Bevatron 1955)



Antiparticle properties

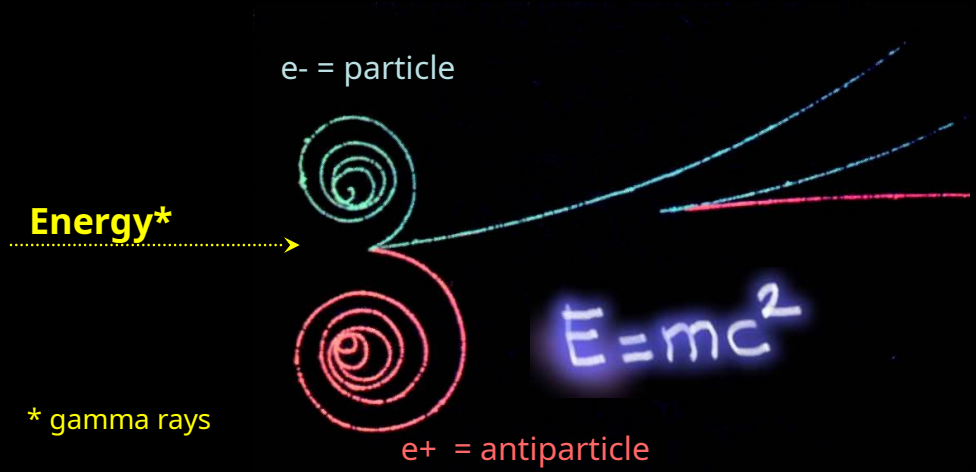
Particles have twins = mirror images
- same mass, oppsite charge, same interactions



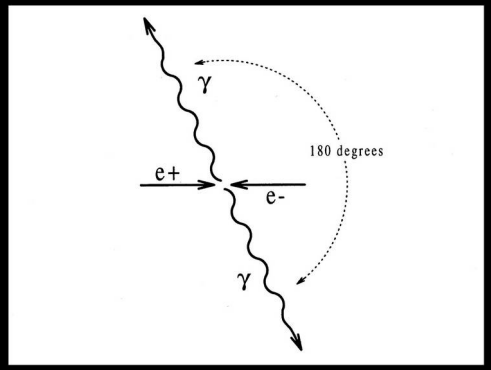


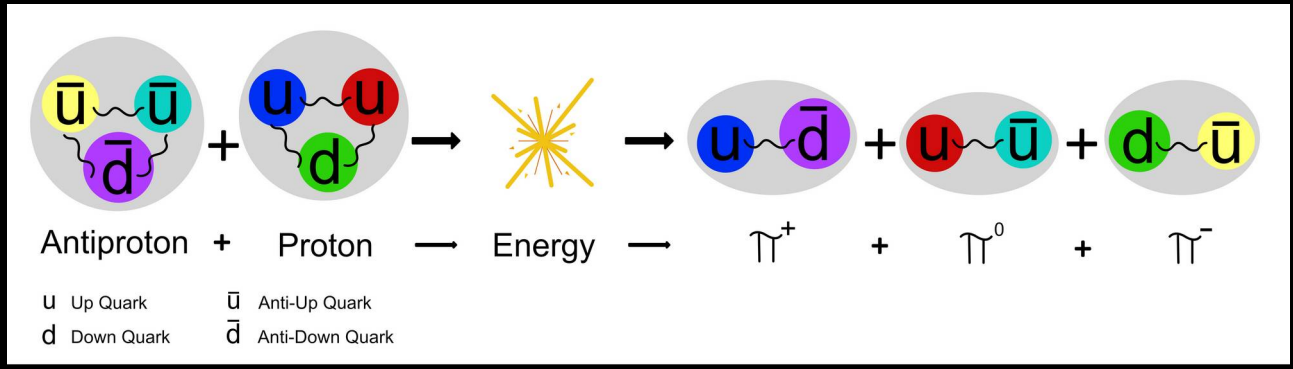
How can we make antimatter?

High energy collisions



Opposite process: particle and antiparticle annihilate and turn into energy



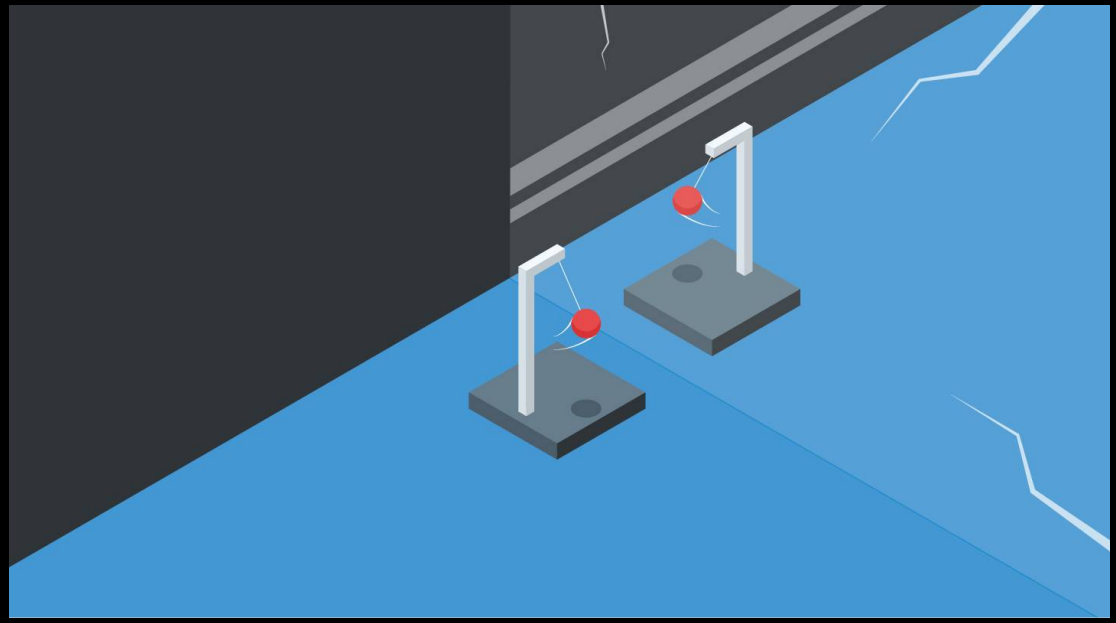


But where did it all go?

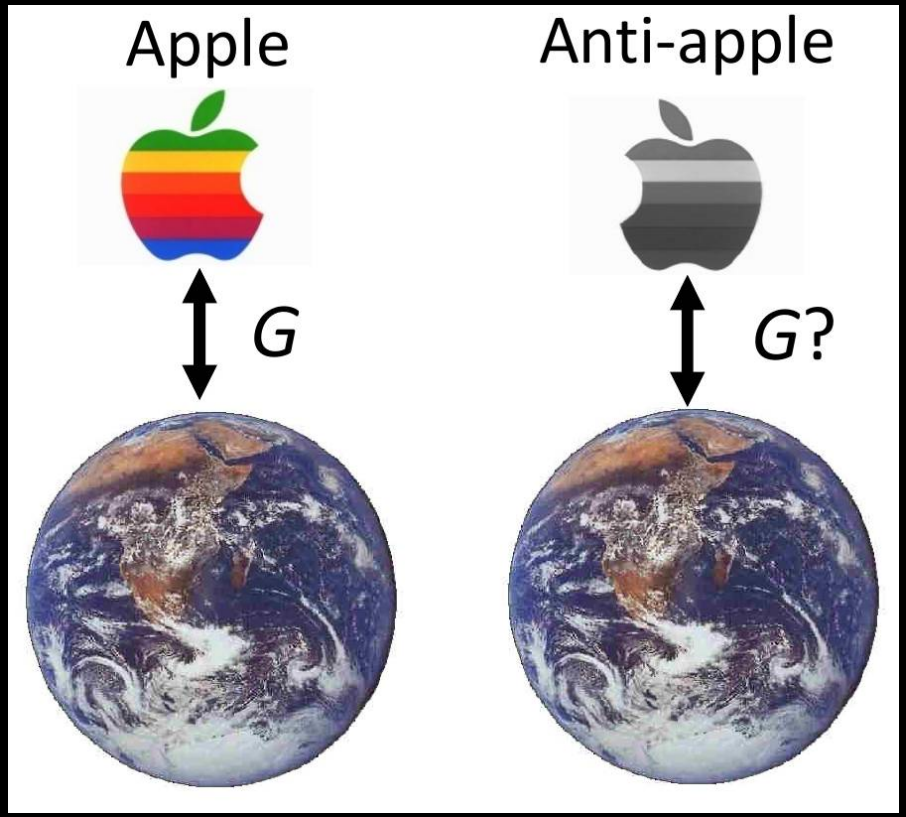
Symmetries in universe

Standard model CPT = charge x partity x time
 - take an experiment, swap particles for antiparticles, look on it in a mirror and run time backward

Some interactions are tiny bit asymmetric – eg. breaking CP symmetry

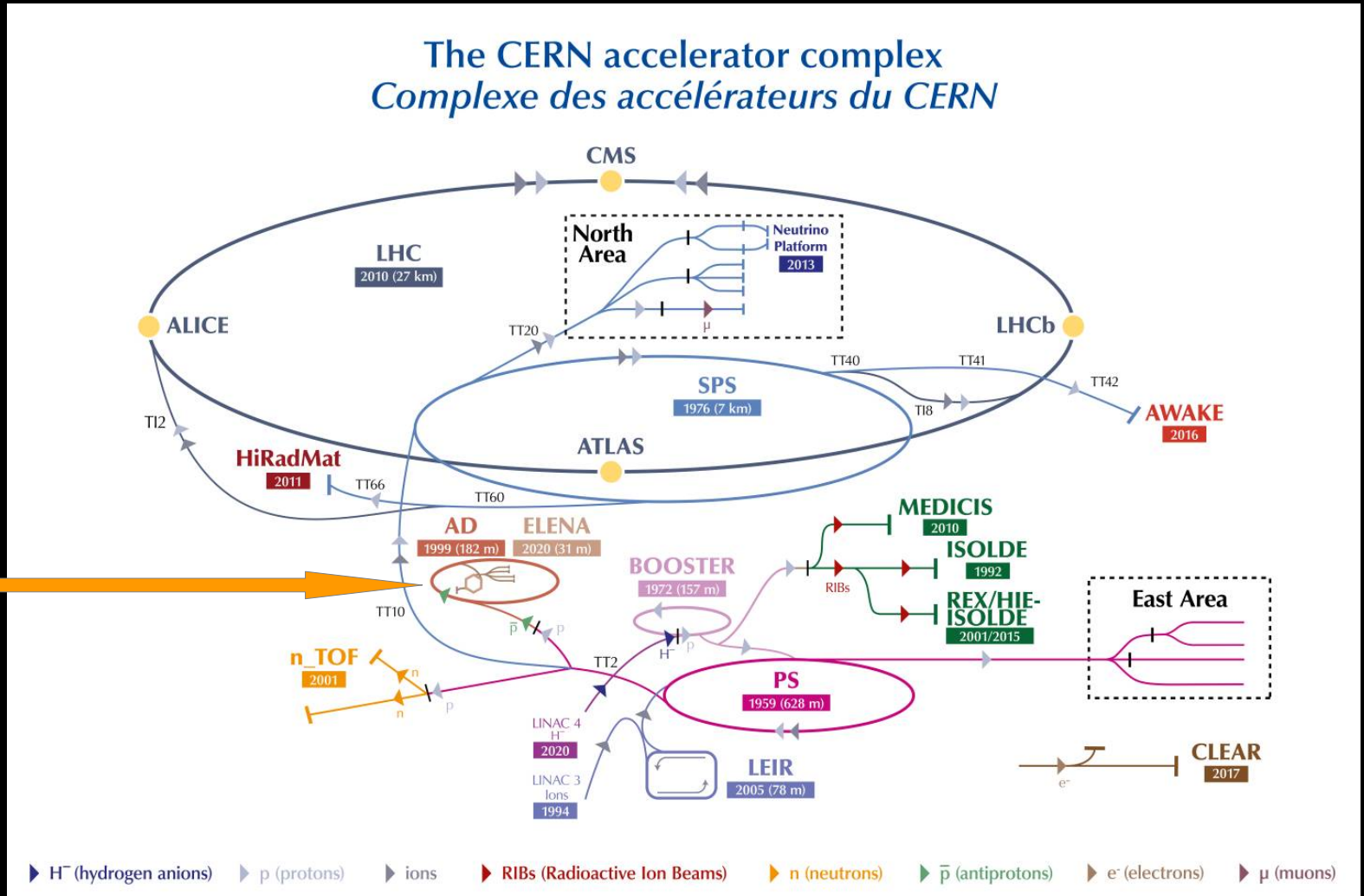


Does gravity work the same for antimatter?

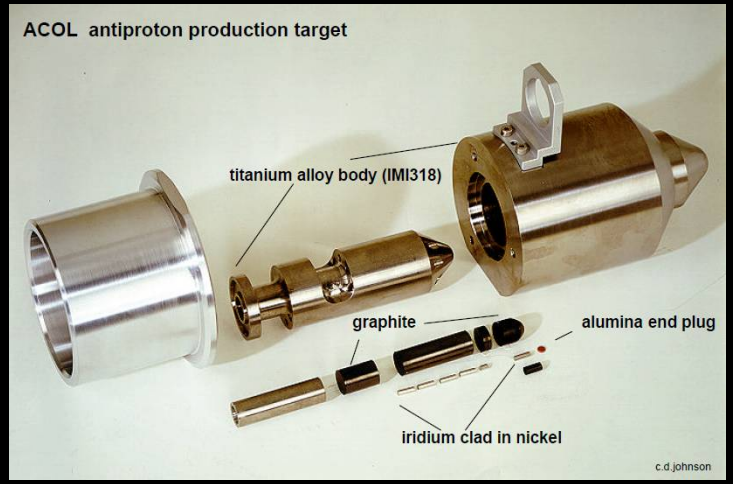


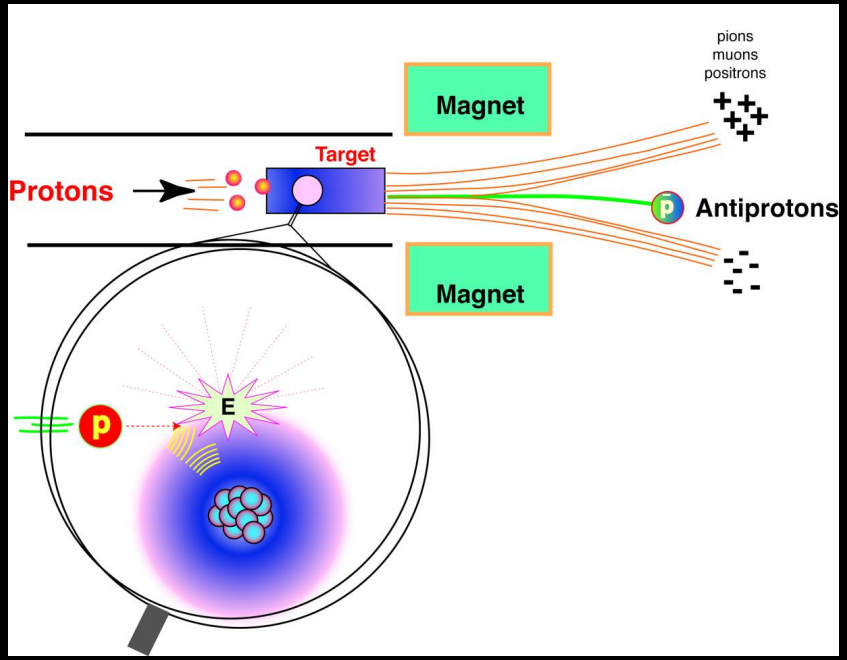
CERN Antimatter factory

CERN Antimatter factory = Antiproton decelerator + ELENA

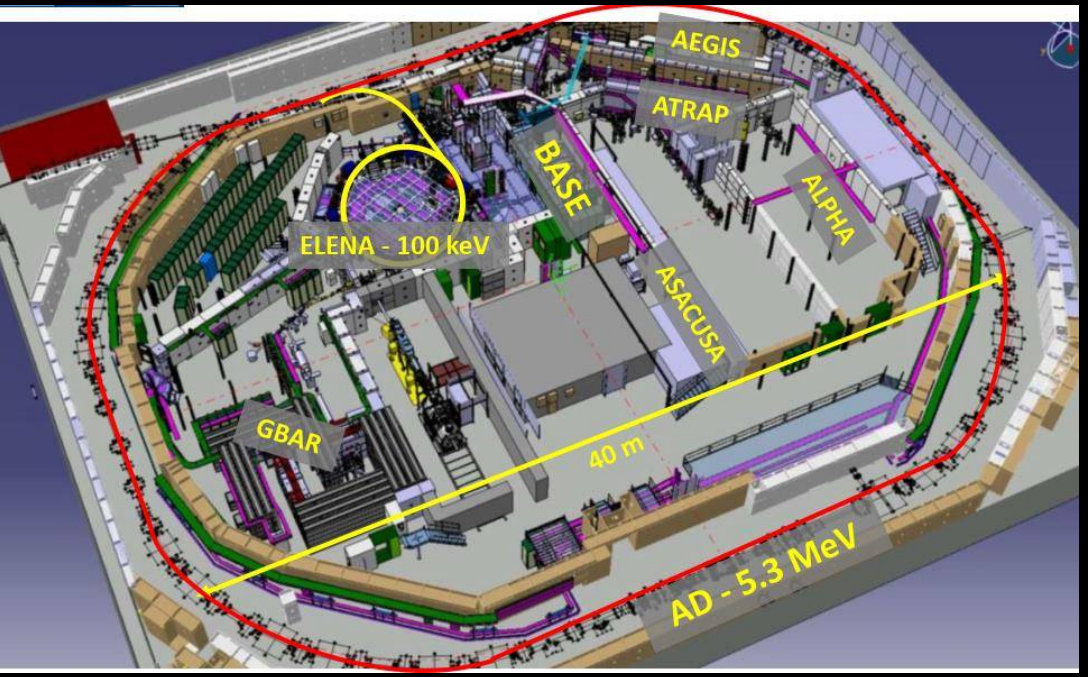


Create atiprotons

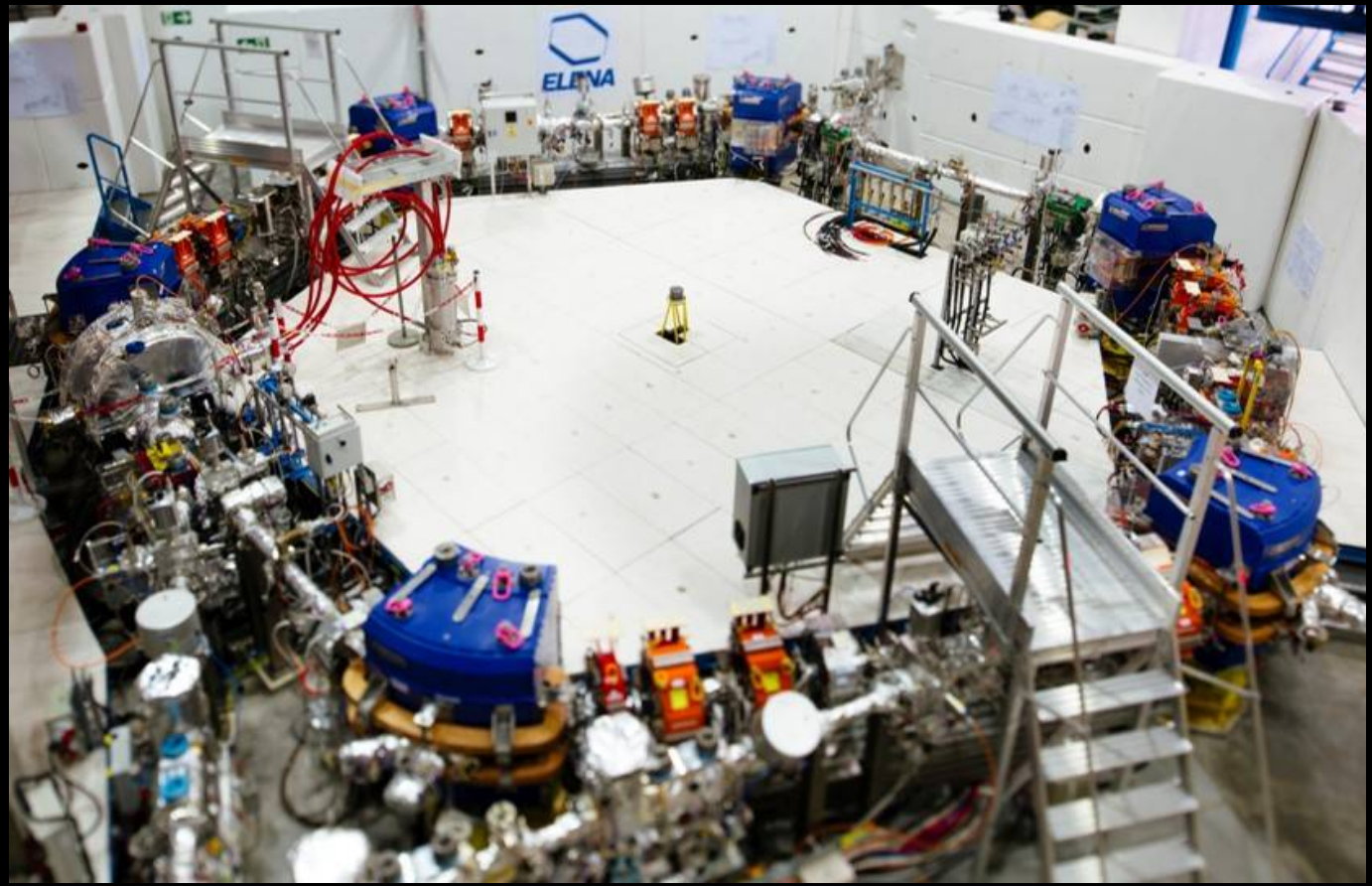




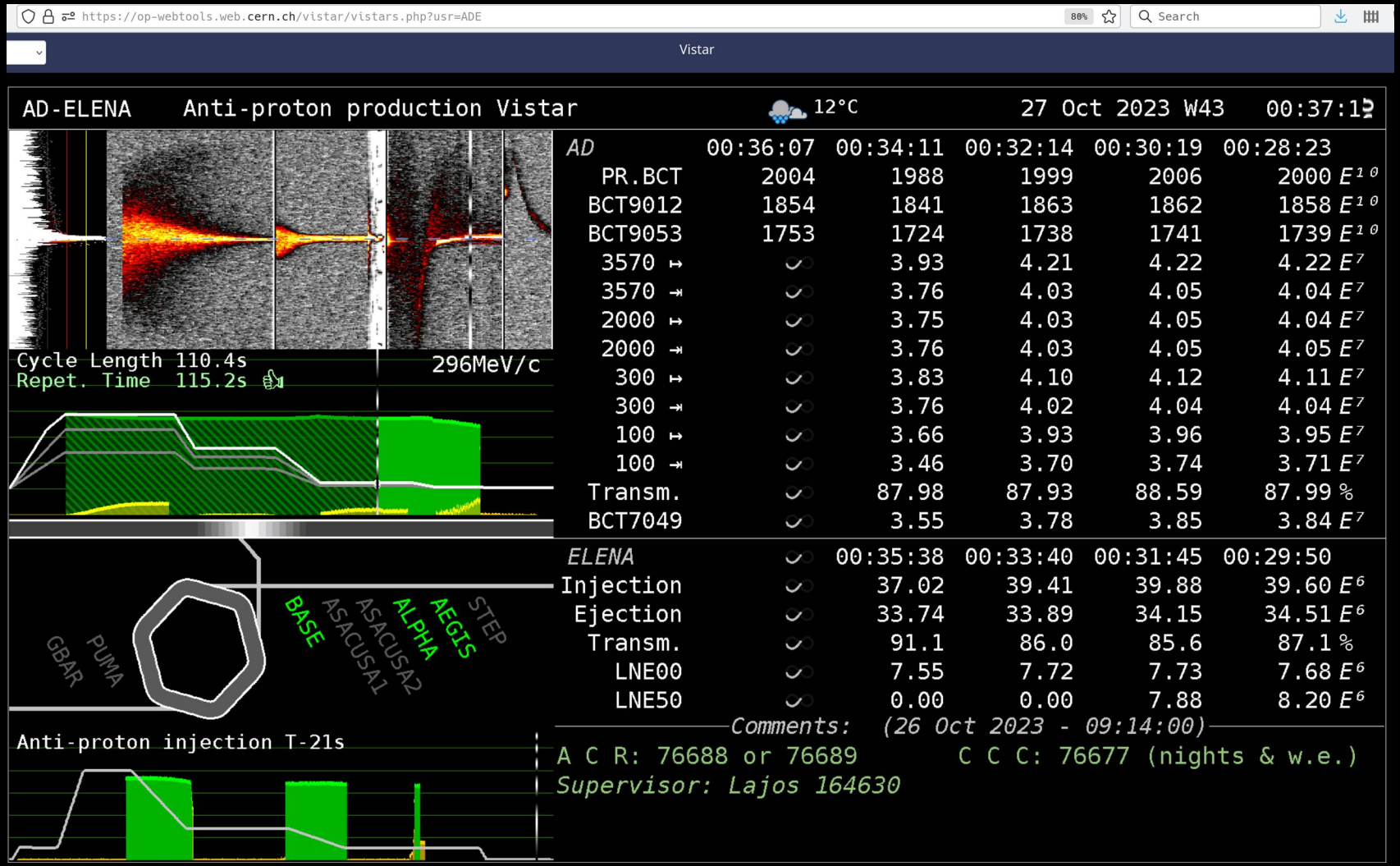
Slow them down - AD



Slow them down more - ELENA

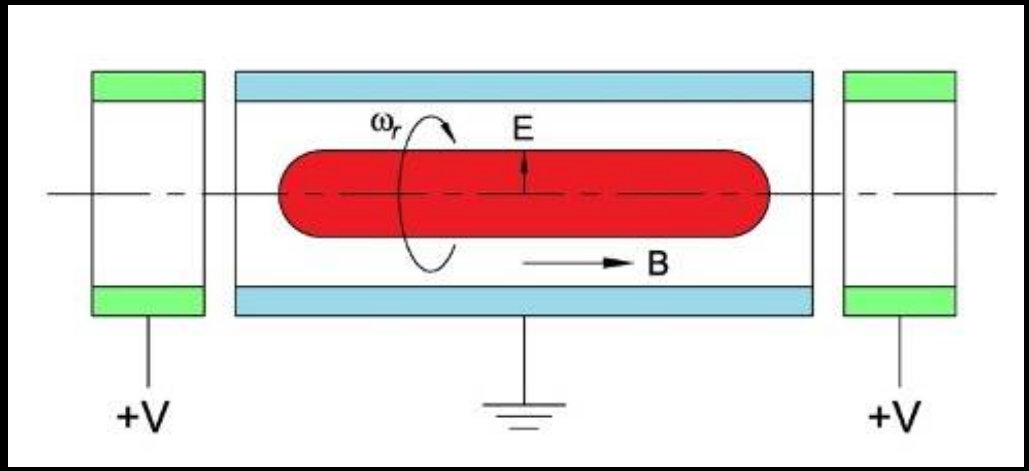


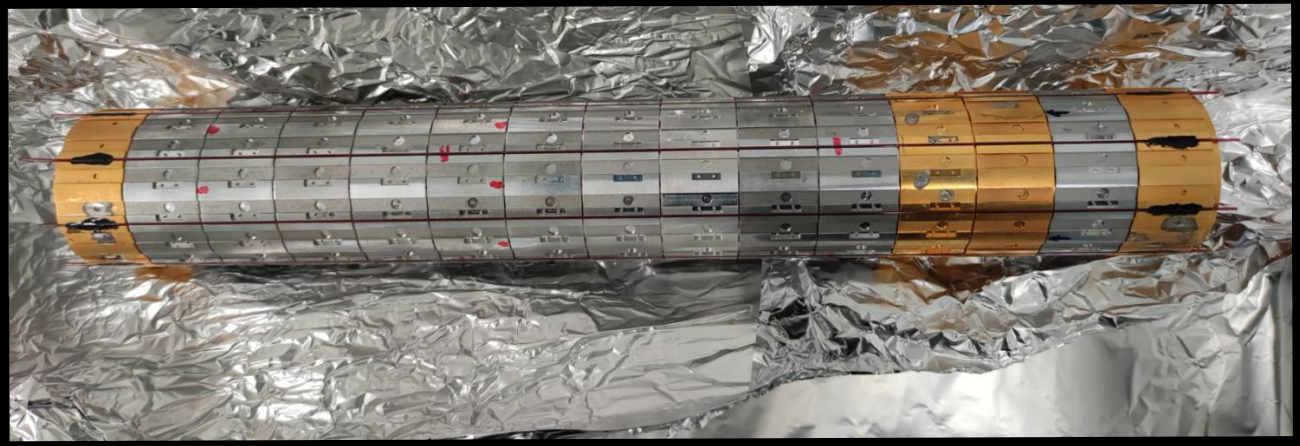
Slow them down more - ELENA



Trap it and cool down even more – Penning-Malmberg trap

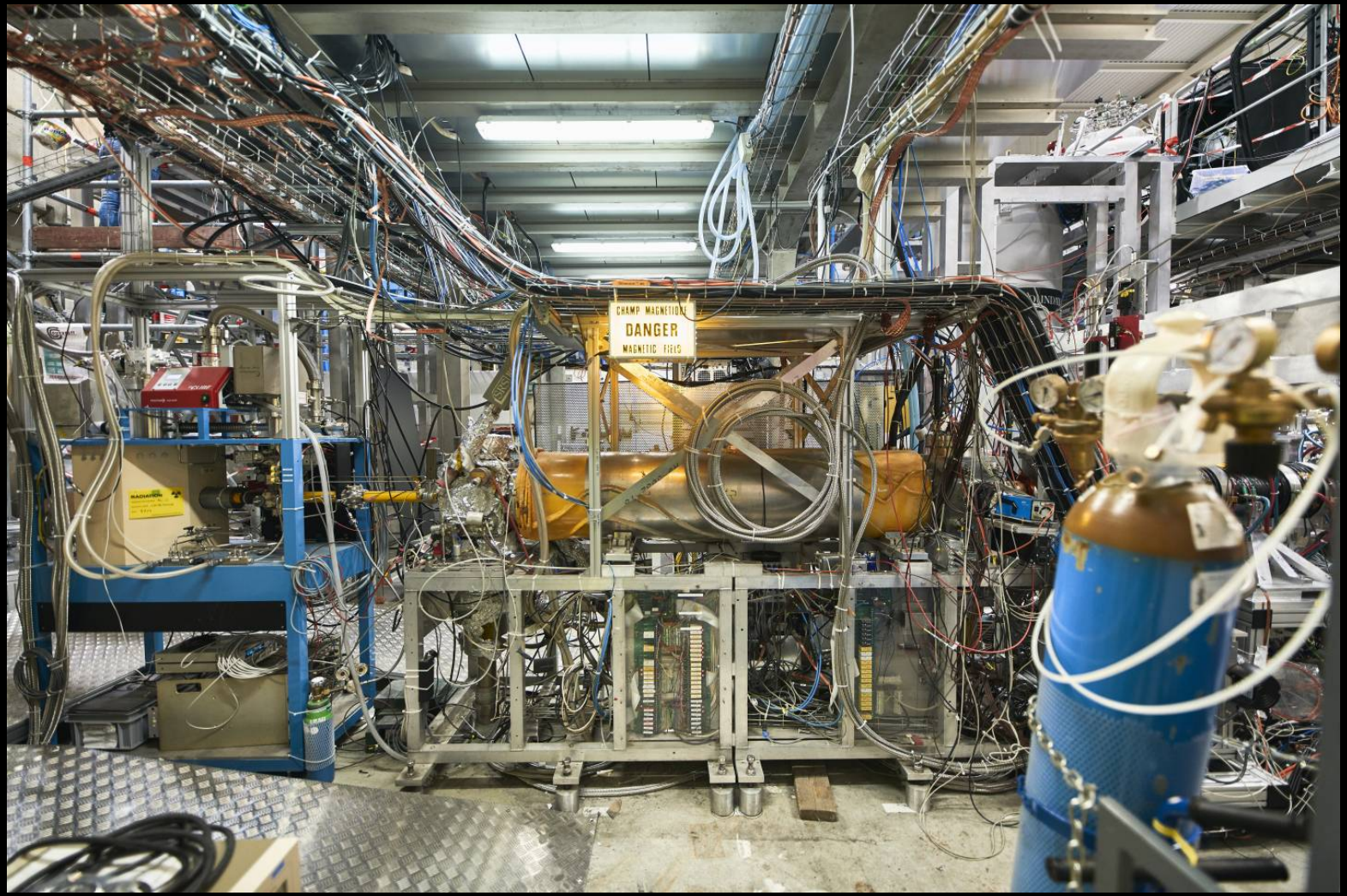
Series of electrodes in the centre of magnet:
- magnetic field
- electric field





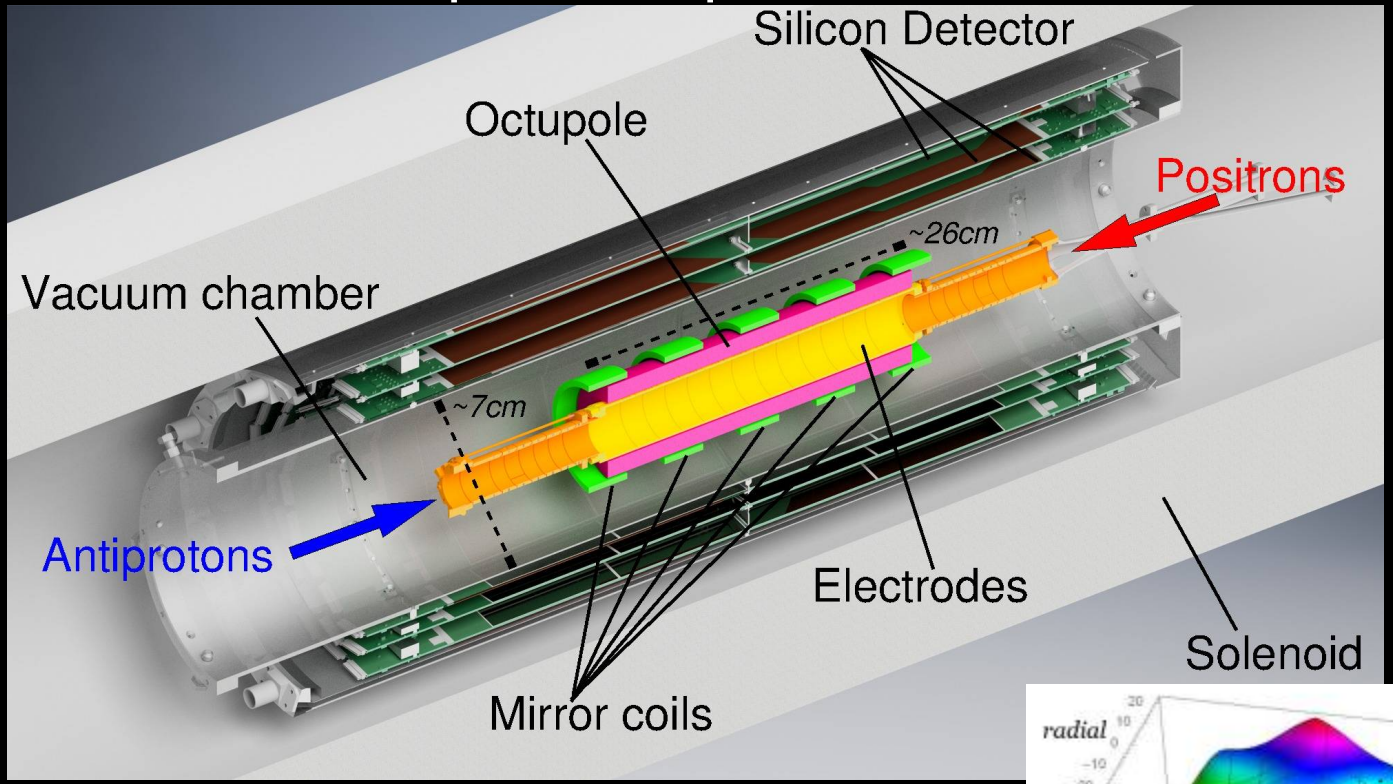
Get positrons: potassium-40

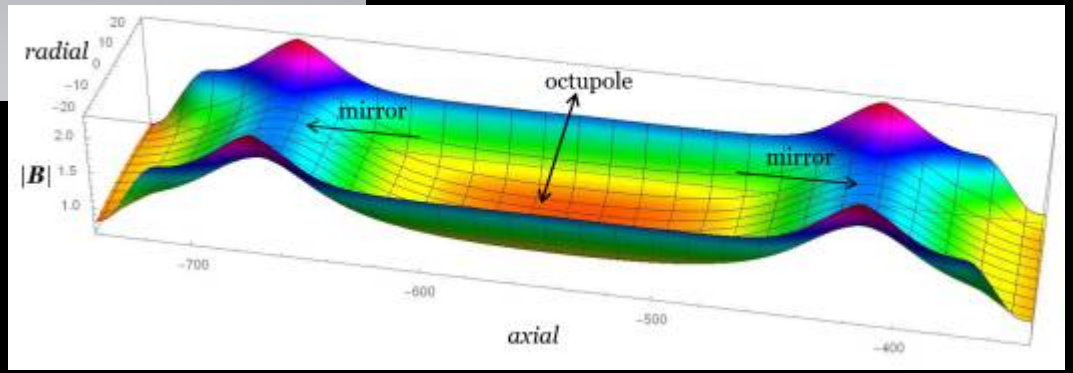
Get positrons: beta decay of Sodium-22



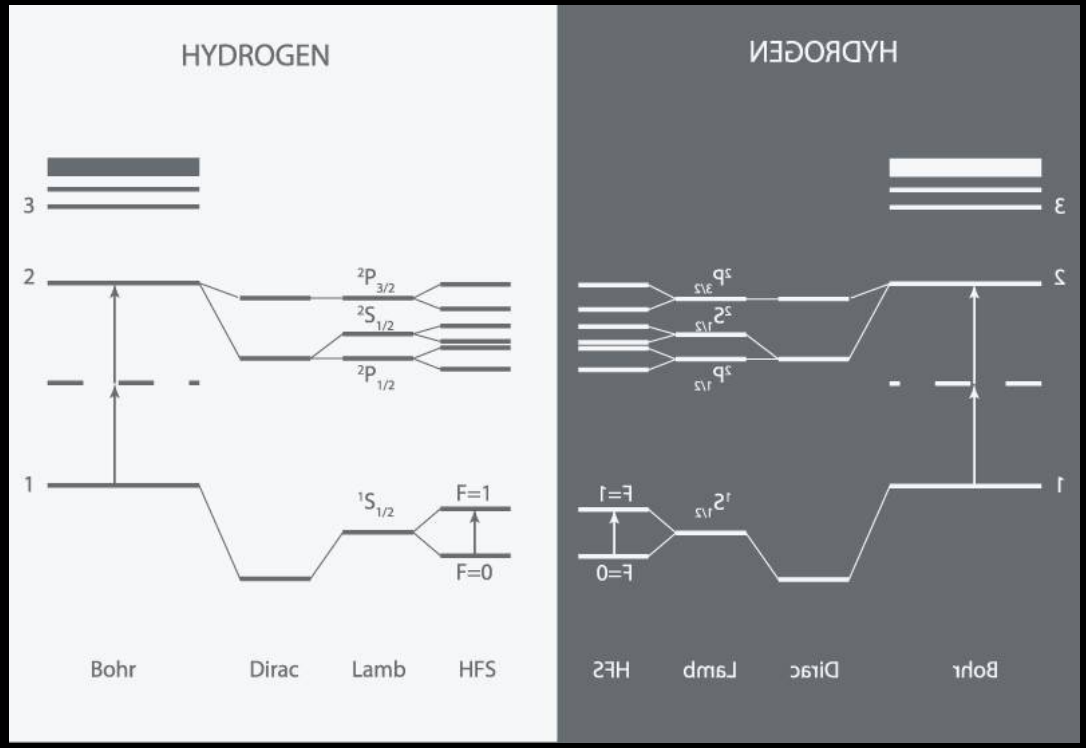
Make antihydrogen

Do it all in one place: experiment ALPHA2





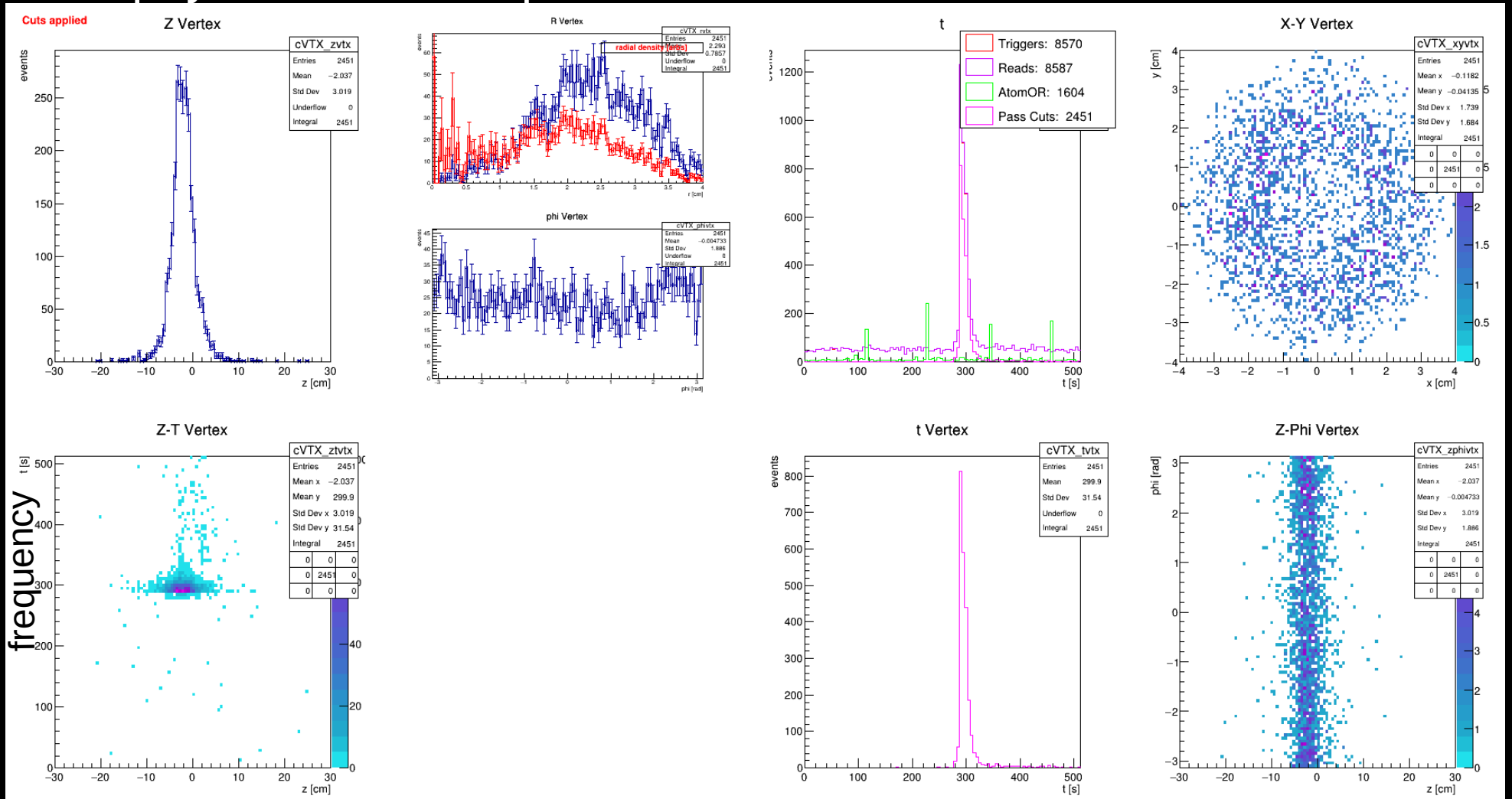
Make physics! Atomic spectra



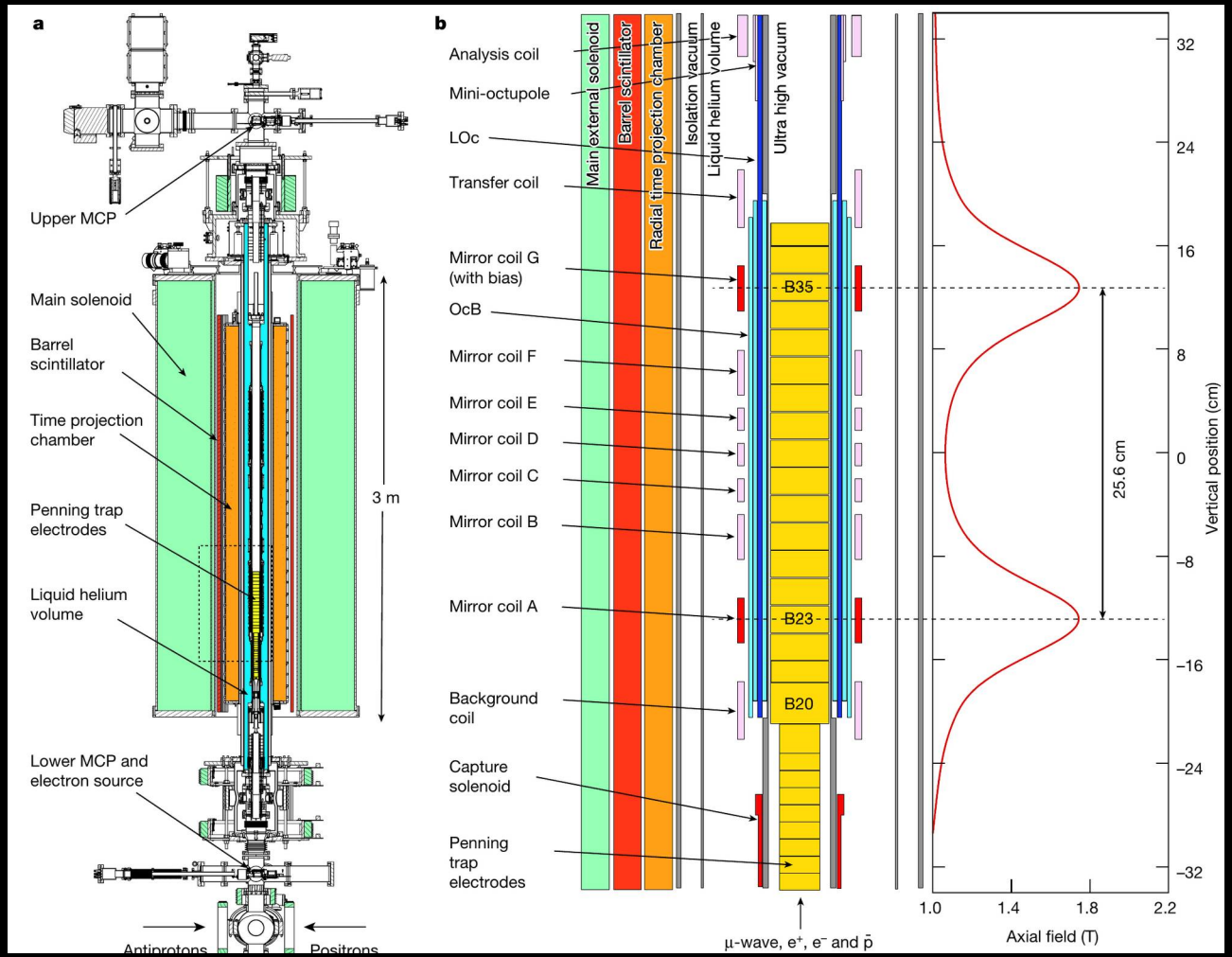
f(1S–2S) $\underline{H}$ = 2 466 061 103 080 300 +- 10 Hz

f(1S–2S) $\overline{H}$ = 2 466 061 103 079 400 +- 5400 Hz

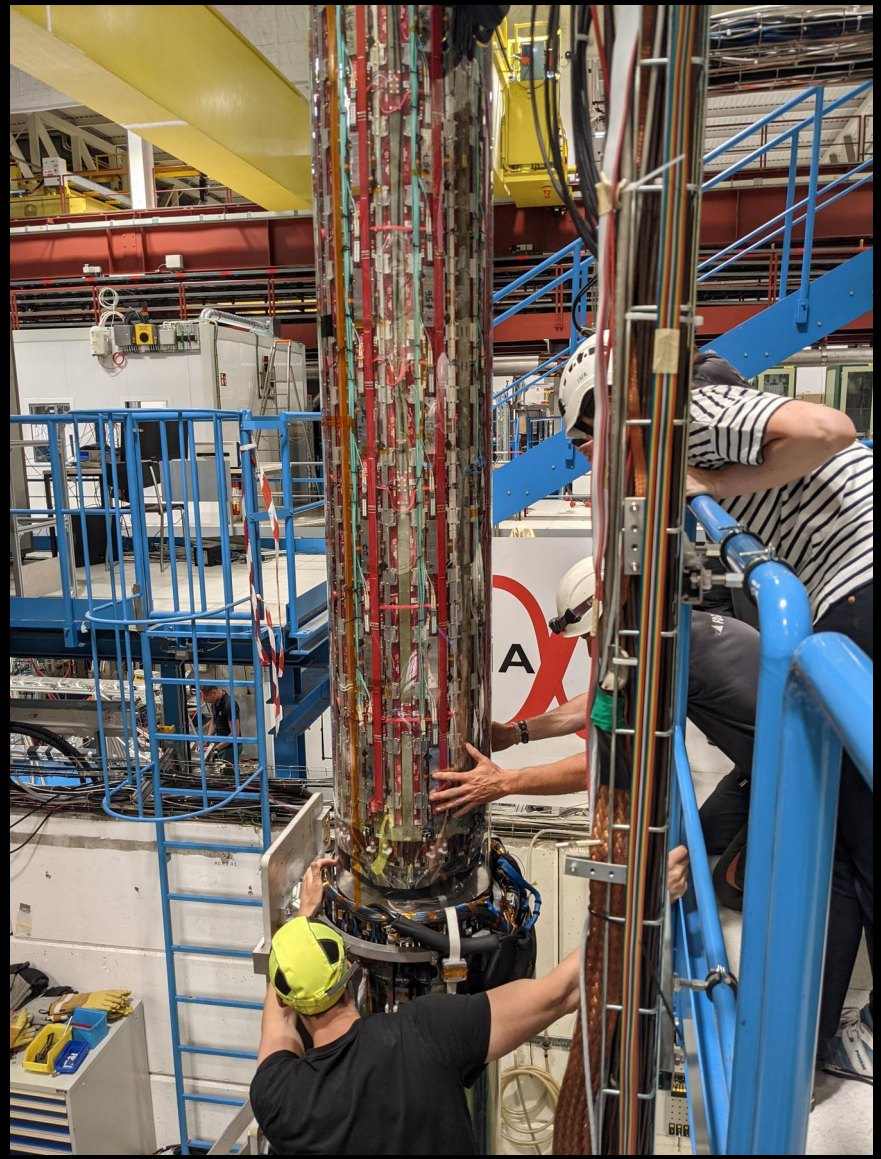
Make physics! Atomic spectra with microwave



Repeat the same vertically - ALPHA-g

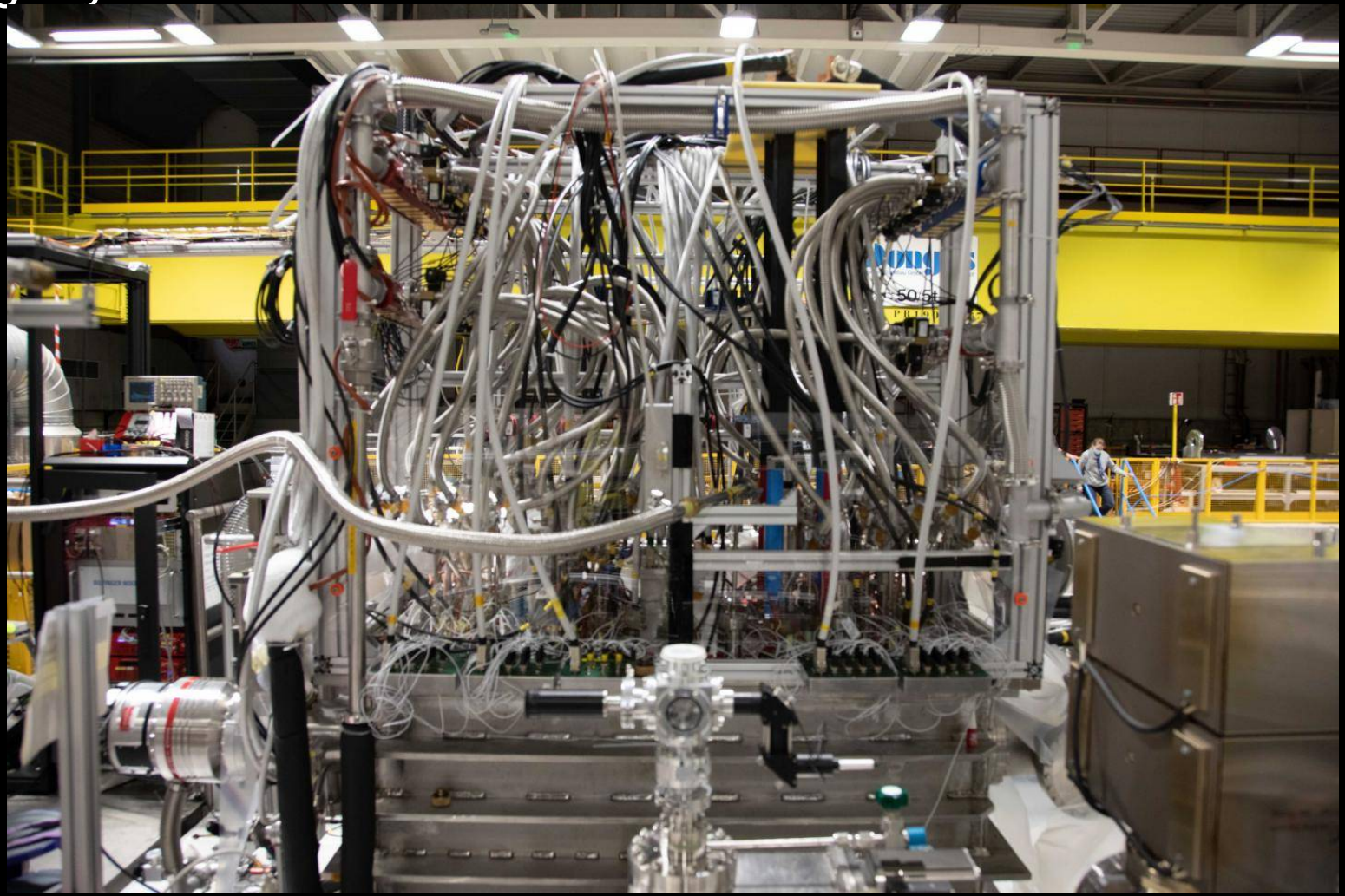


ALPHA-g detectors

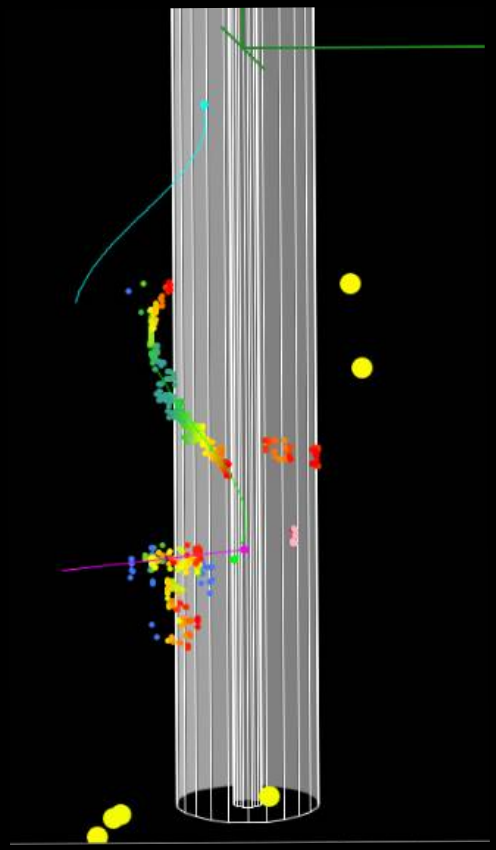


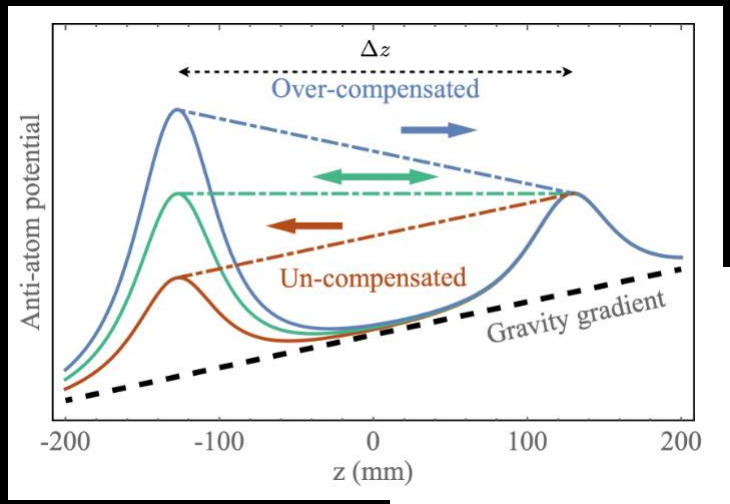

PETZL
EXPANSION VOL

ALPHA-g cryostat

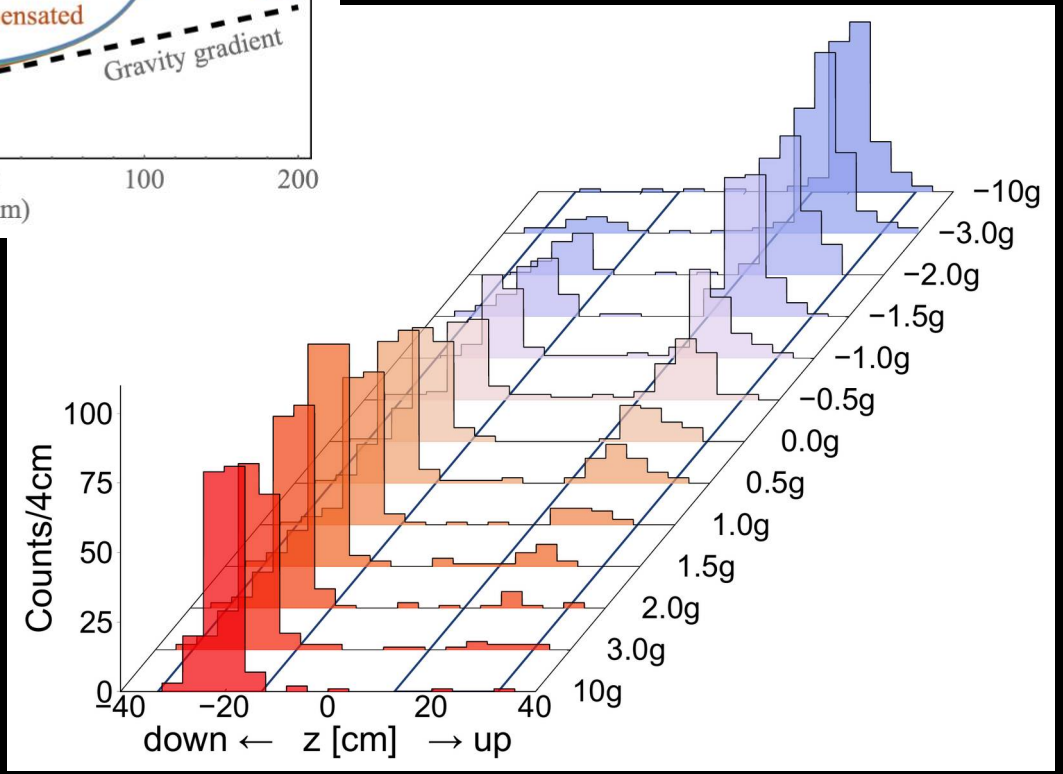


ALPHA-g experiment





$g(\bar{H}) = (0.75 \pm 0.21)\ g(H)$

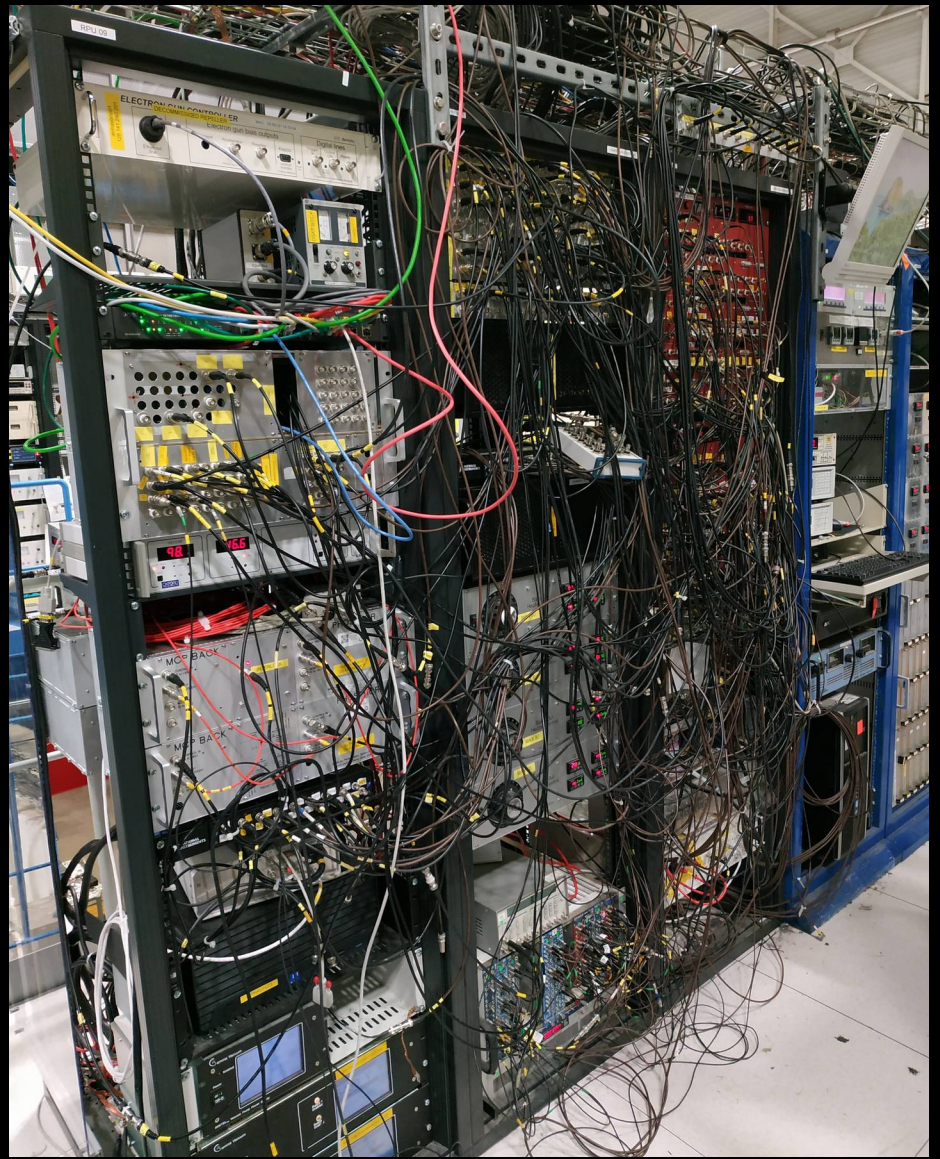


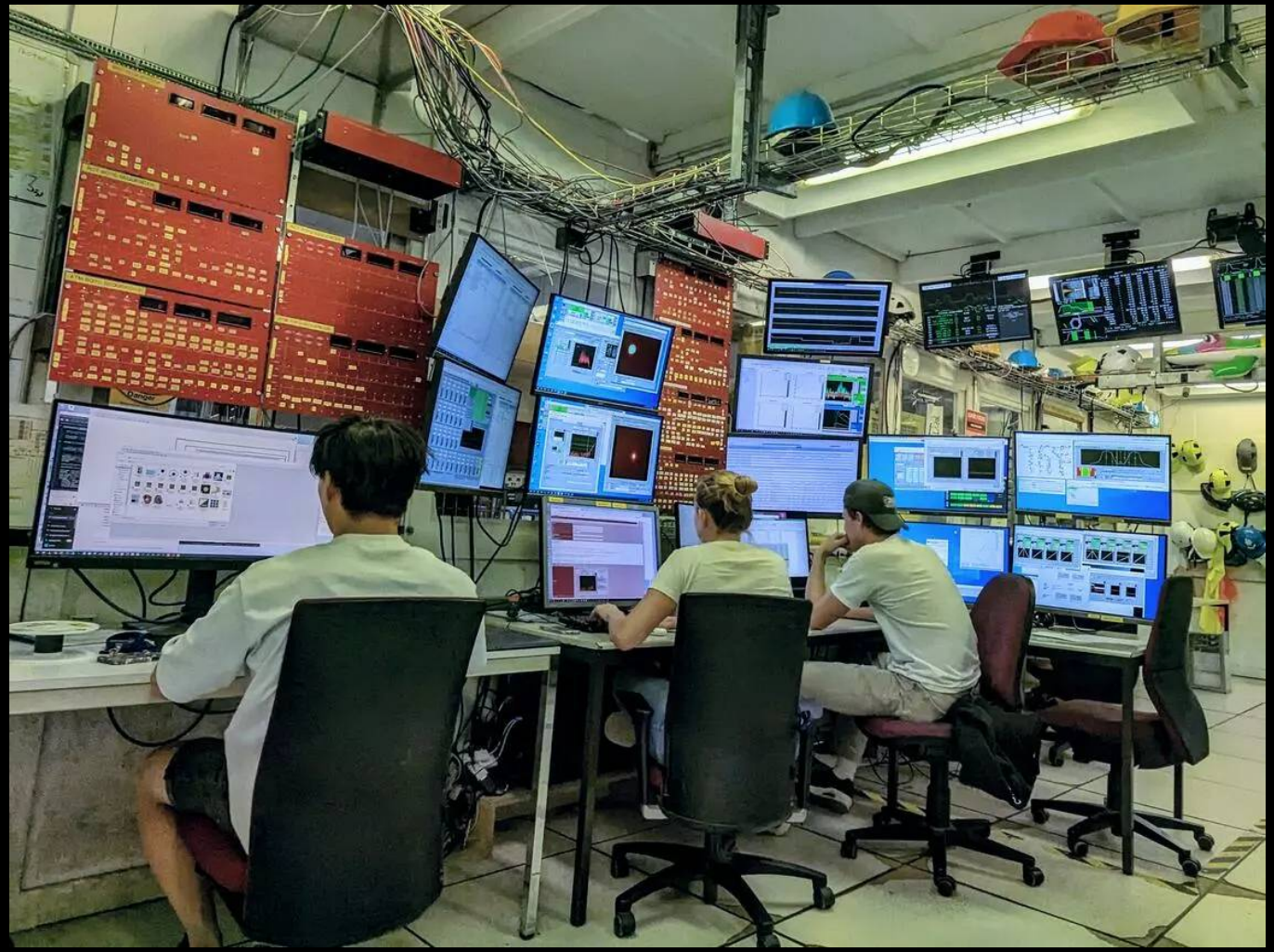
Summary: antimatter is cool!

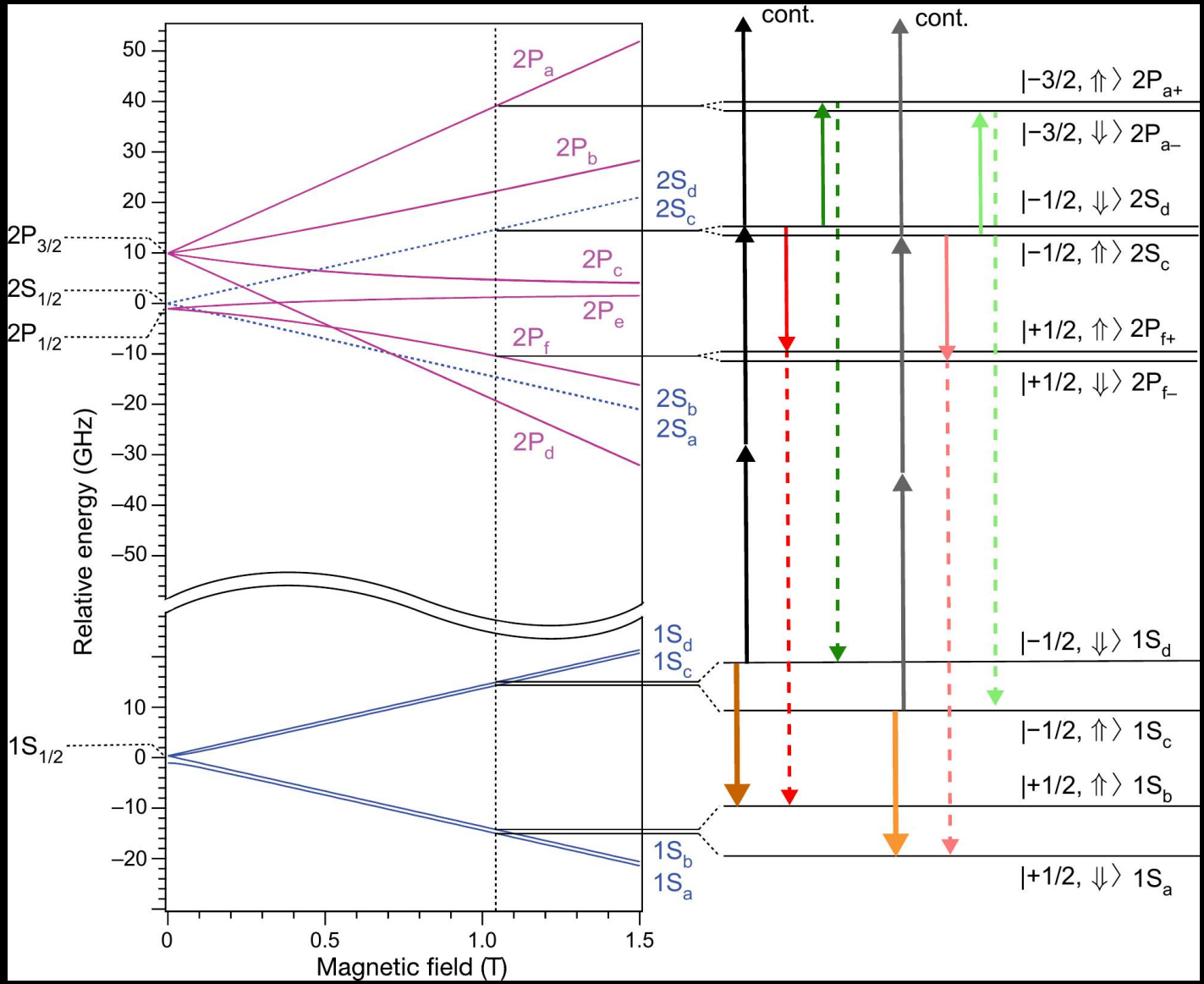
But understanding it is a huge challenge

ALPHA is able to trap antihydrogen and probe it’s spectra and gravitational interaction

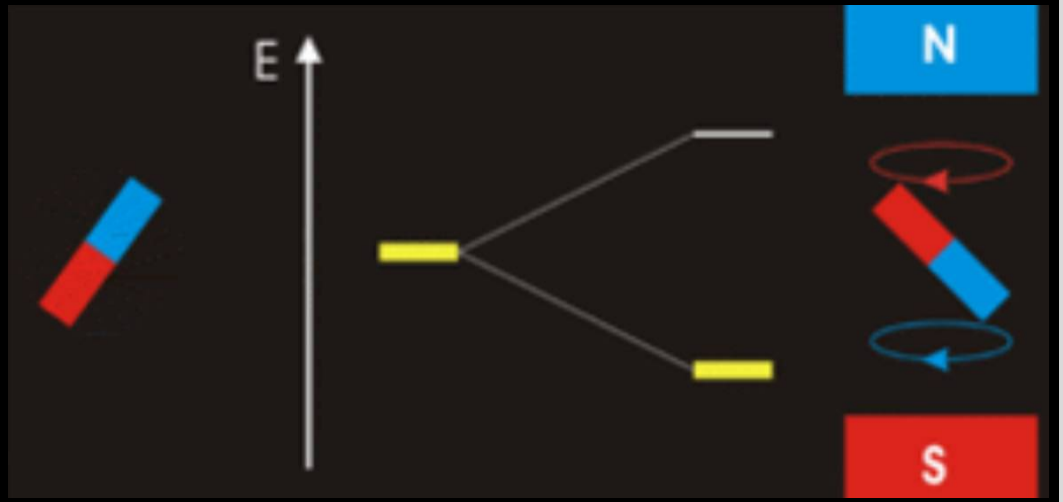
… stay tuned for new spectroscopy results, soon in your news feed



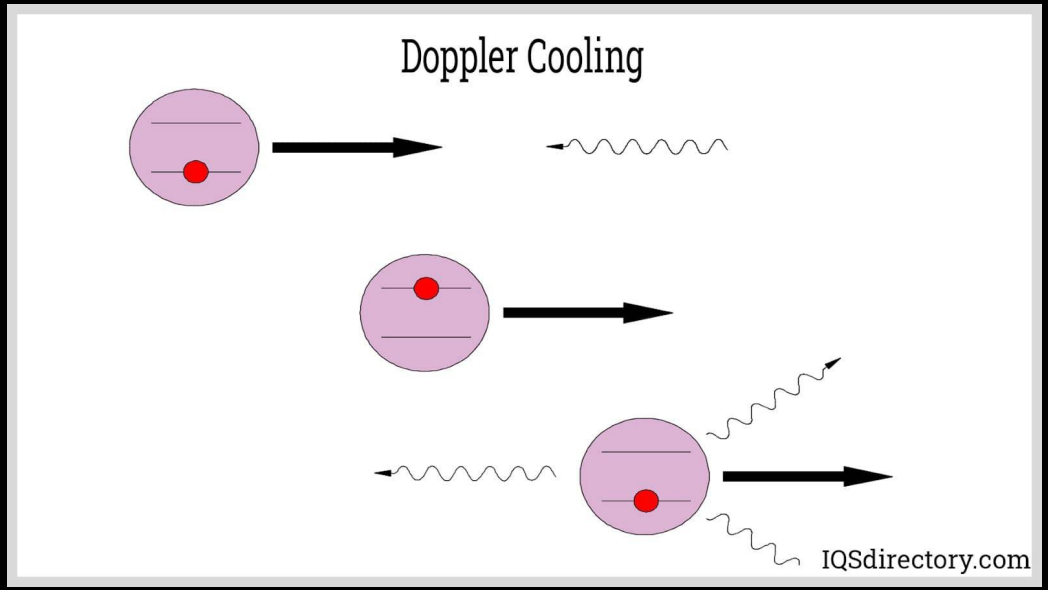



Relative energy (GHz)
Magnetic field (T)
0
0.5
1.0
1.5
50
40
30
20
10
0
−10
−20
−30
−40
−50
2P3/2
2S1/2
2P1/2
1S1/2
2Pa
2Pb
2Pc
2Pe
2Pf
2Pd
2Sd
2Sc
2Sb
2Sa
1Sd
1Sc
1Sb
1Sa
cont.
cont.
|−3/2, ⇑〉 2Pa+
|−3/2, ⇓〉 2Pa−
|−1/2, ⇓〉 2Sd
|−1/2, ⇑〉 2Sc
|+1/2, ⇑〉 2Pf+
|+1/2, ⇓〉 2Pf−
|−1/2, ⇓〉 1Sd
|−1/2, ⇑〉 1Sc
|+1/2, ⇑〉 1Sb
|+1/2, ⇓〉 1Sa

Zeeman splitting



Laser cooling



Alpha-g 0g run