



Antimatter factory and ALPHA

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About me

Poprad, Slovakia → Charles University in Prague (Czechia BSc, MSc, Phd)

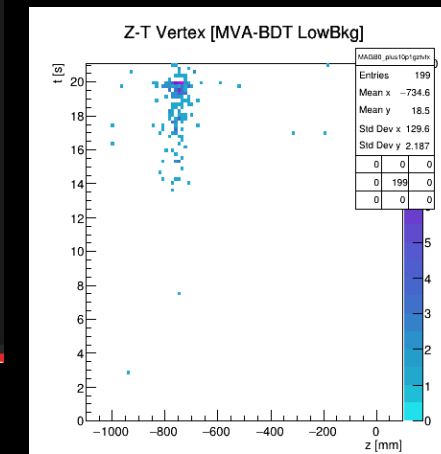
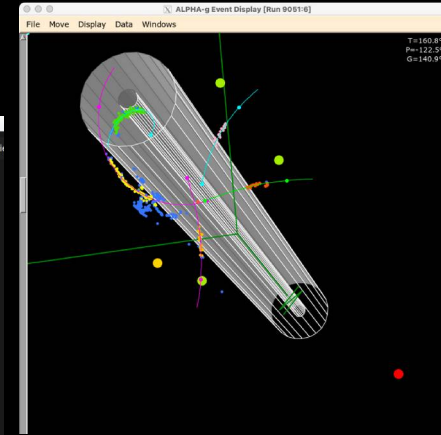
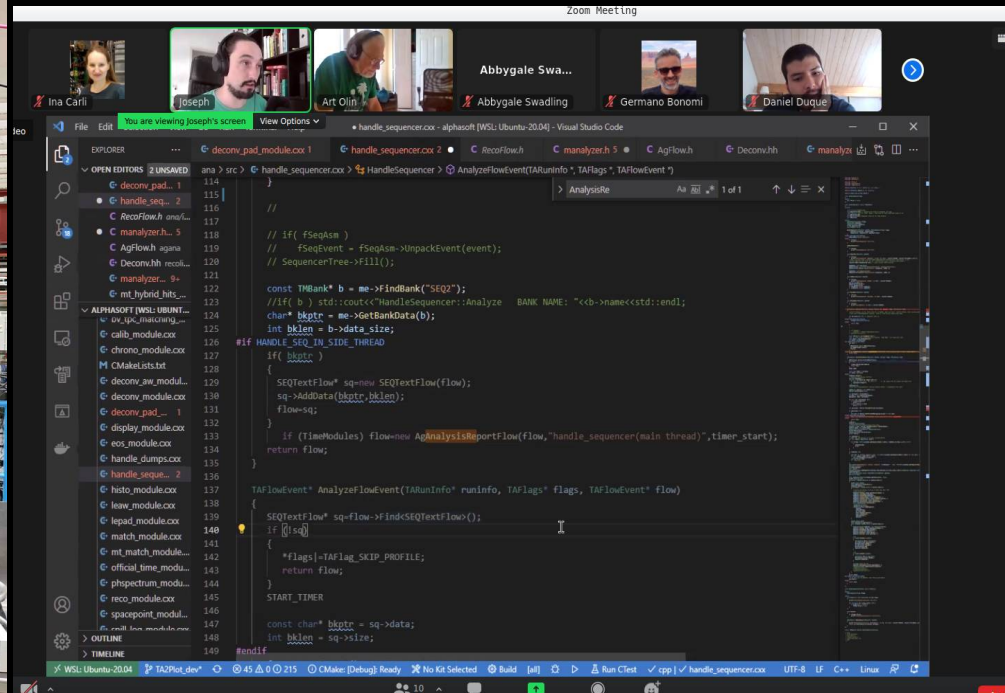
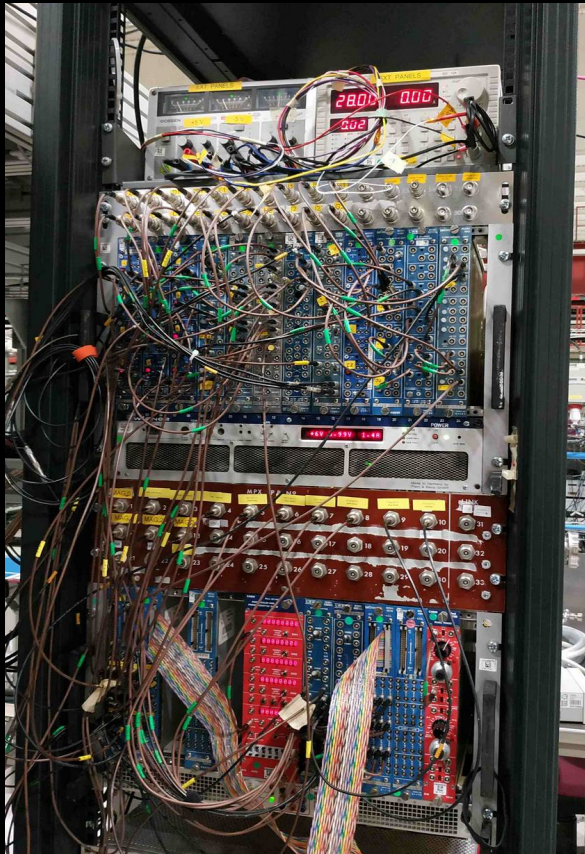
→ CERN (summer student, PhD, postdoc)

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):

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



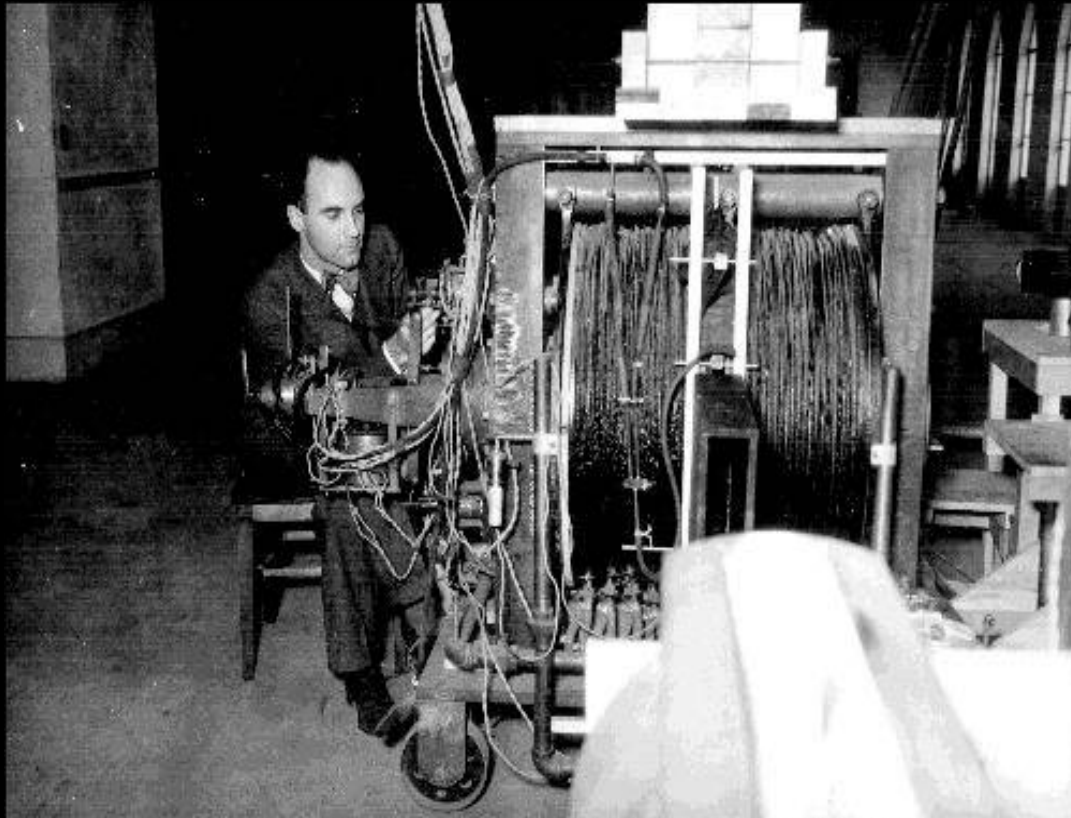
Dirac



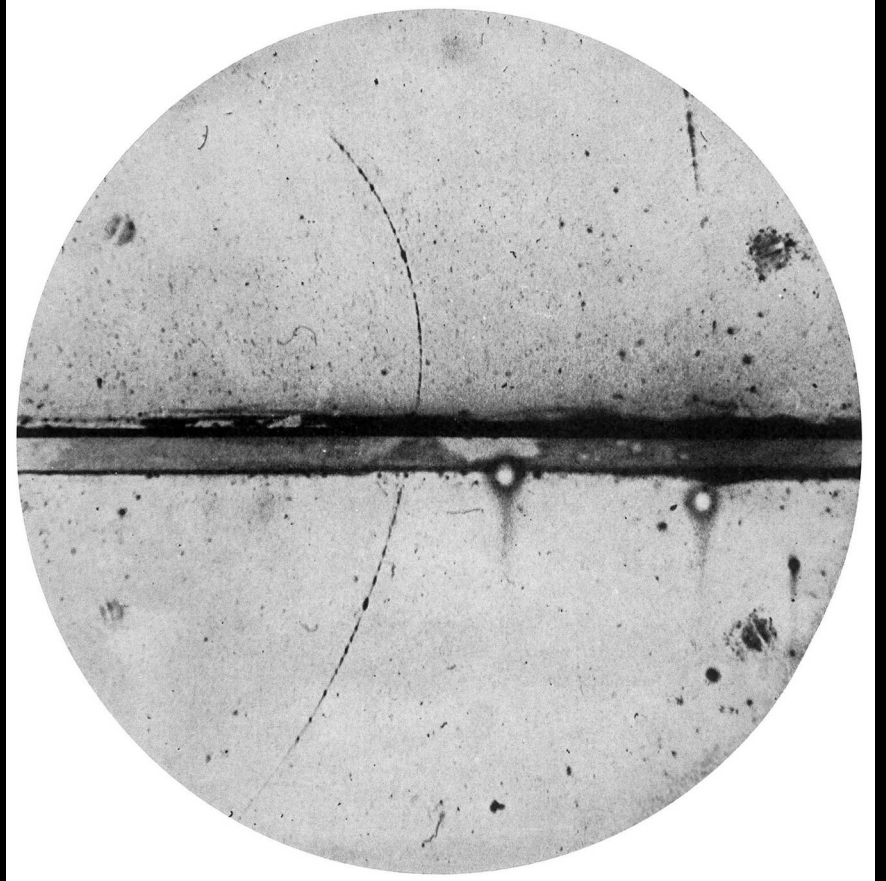
$\overline{\text{Dirac}}$

Observation of first antiparticles

1932: Carl Anderson discovered positrons in cosmic rays

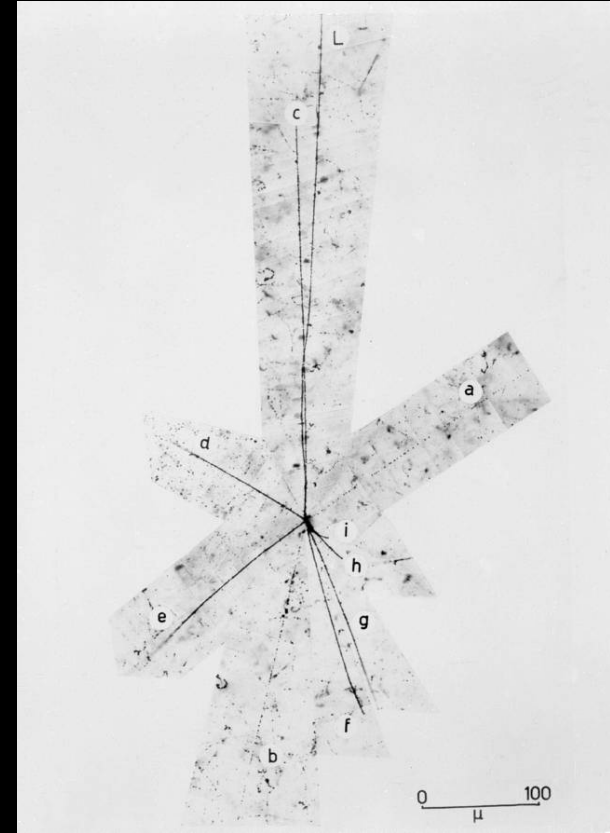


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Observation of first antiparticles

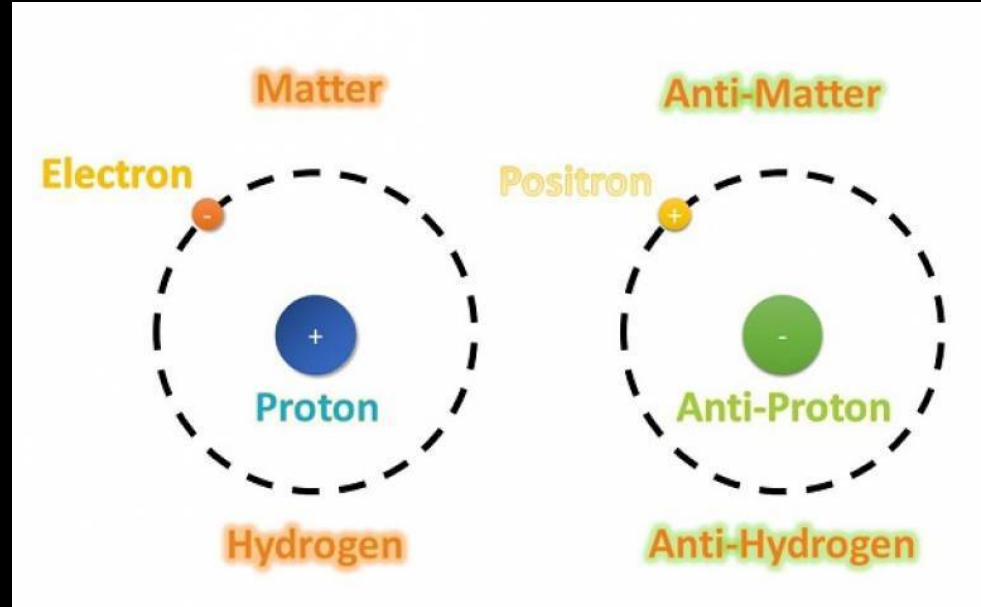
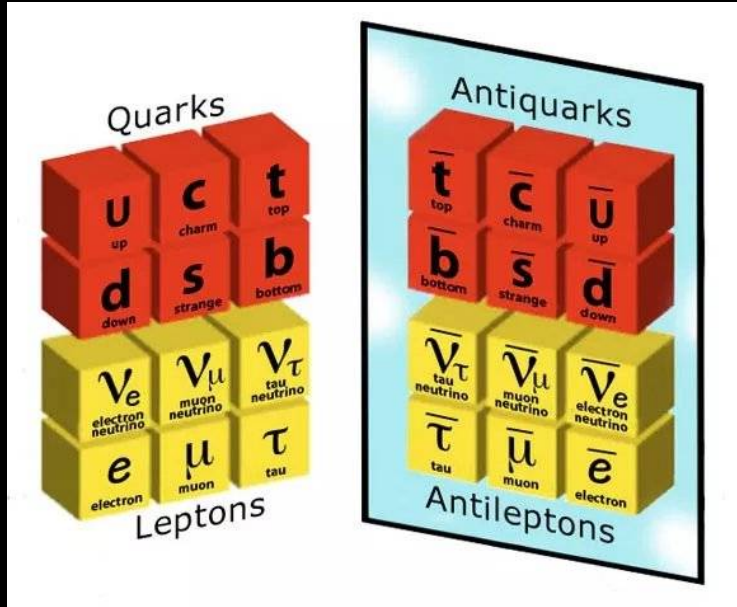
Antiprotons created in collisions of high energy proton beam with fixed target
(O. Chamberlain and E. Segrè, Bevatron 1955)



Antiparticle properties

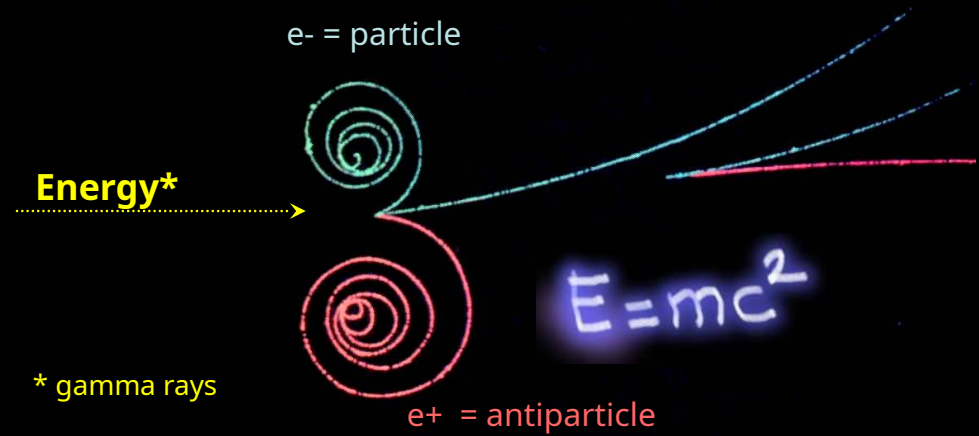
Particles have twins = mirror images

- same mass, oppsite charge, same interactions

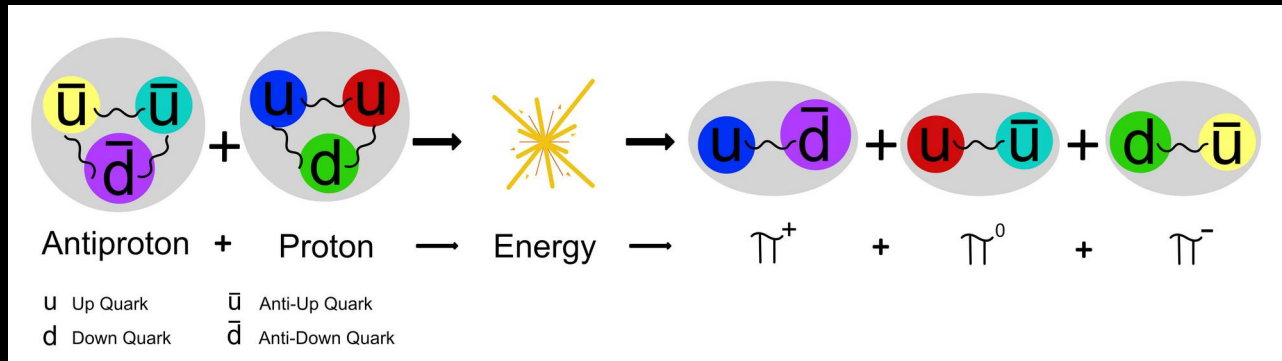
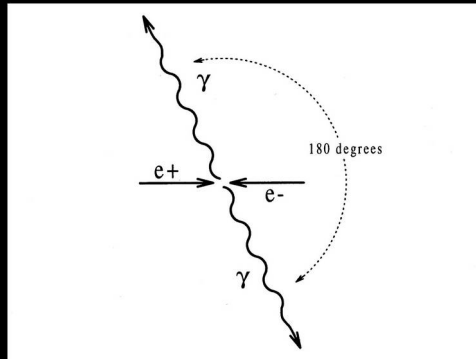


How can we make antimatter?

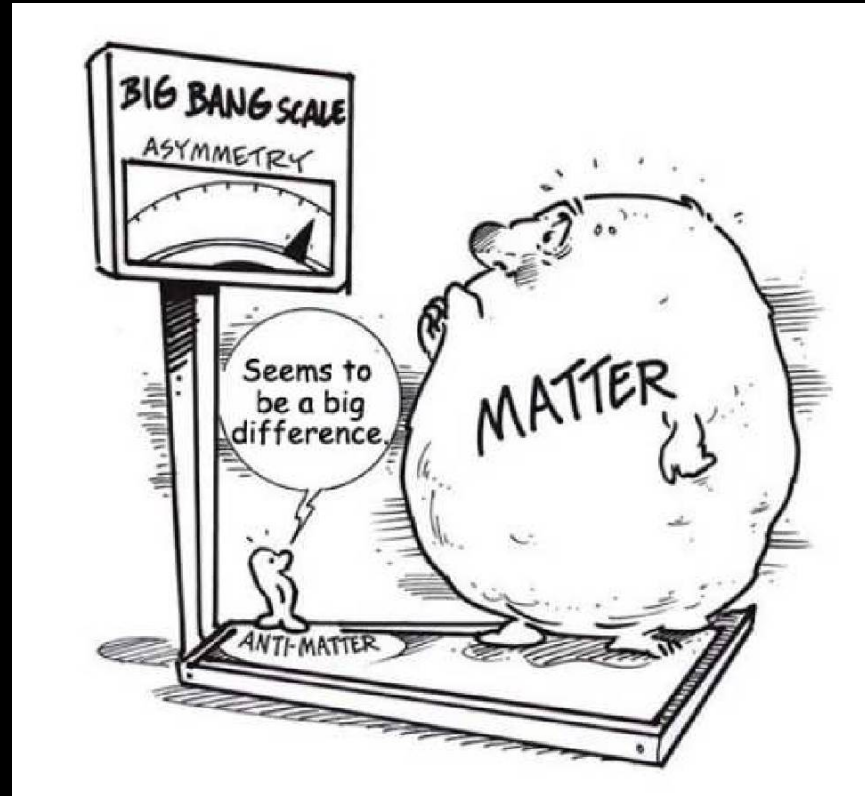
High energy collisions



Opposite process: particle and antiparticle annihilate and turn into energy



But where did it all go?

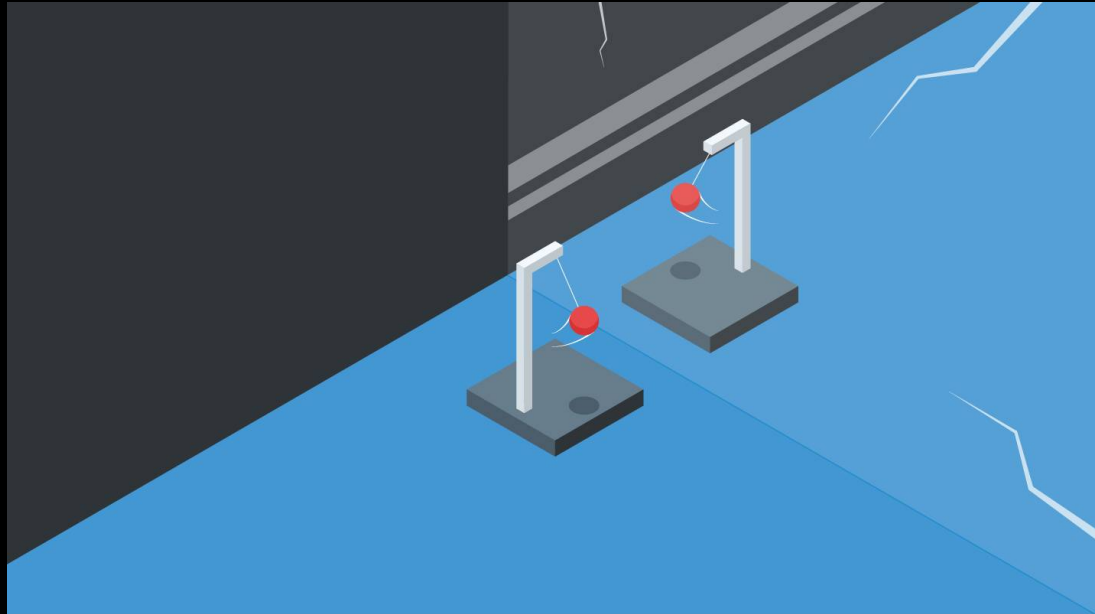


Symmetries in universe

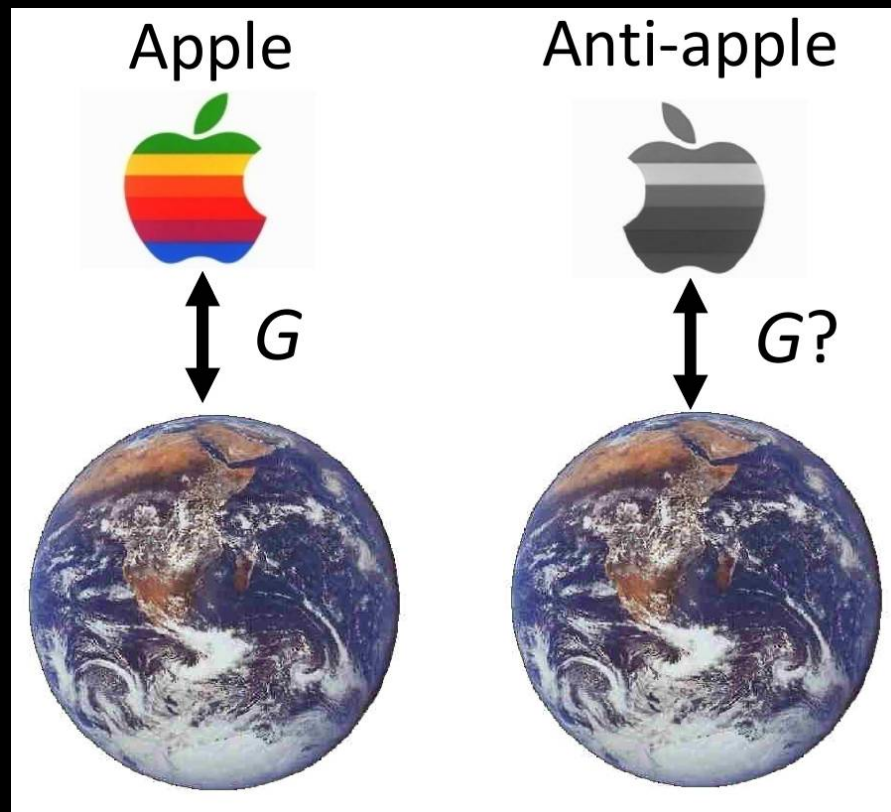
Standard model CPT = charge x parity x time

- 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

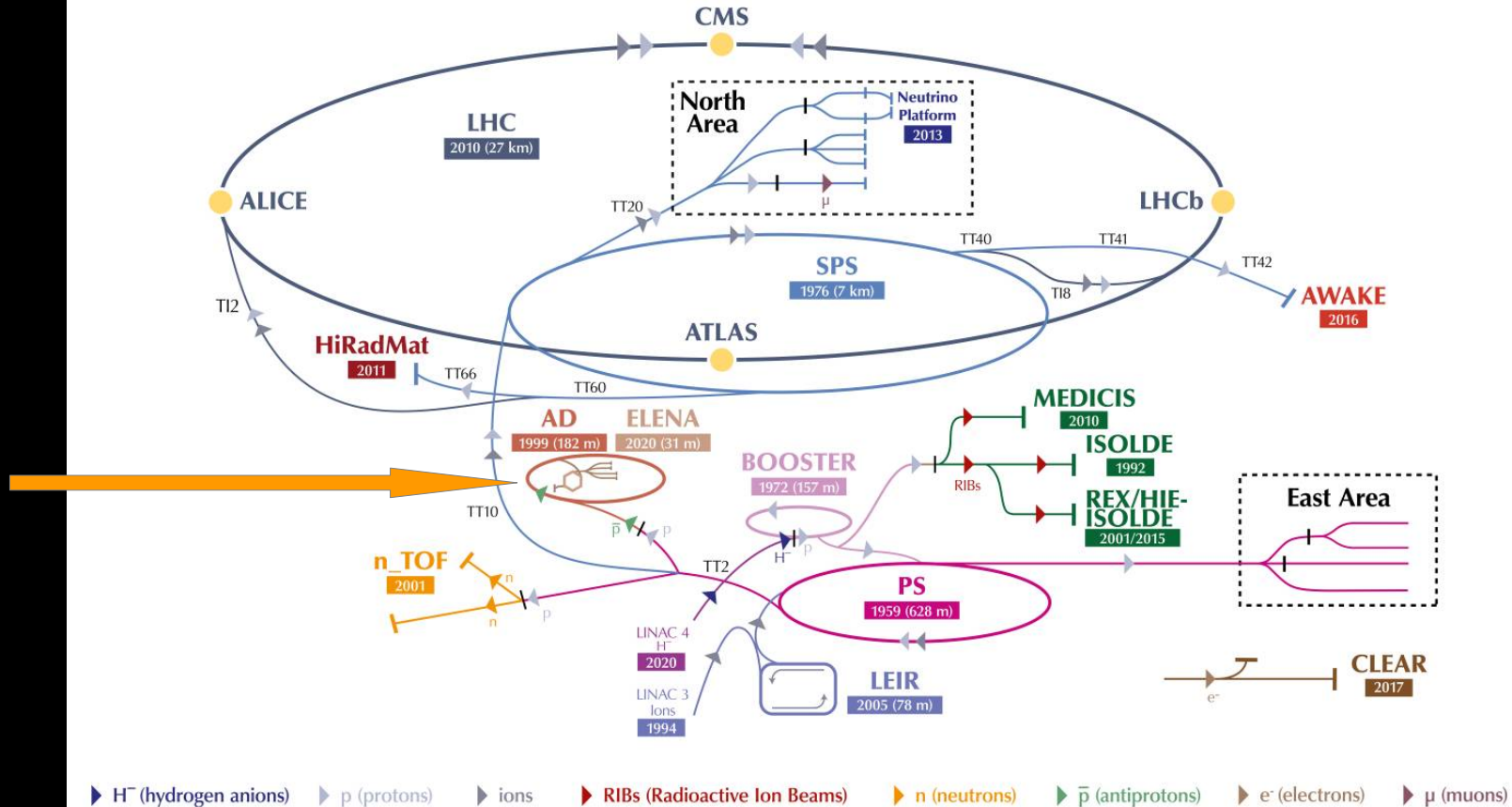
Navigation sidebar with search and options:

- Search bar: Meyrin, 1217, Switzerland
- Destination: Antimatter Factory CERN, 133 Rte A Einstein
- Destination: CERN Data Centre, Rte Rutherford, 01280
- Options: Add destination
- Send directions to your phone
- Route: via Rte A Einstein, 5 min, 1.6 km
- Warnings: This route has restricted usage or private roads. This route crosses a country border. Verify COVID-19 restrictions.
- Explore CERN Data Centre: Restaurants, Hotels, Gas stations, Parking Lots, More

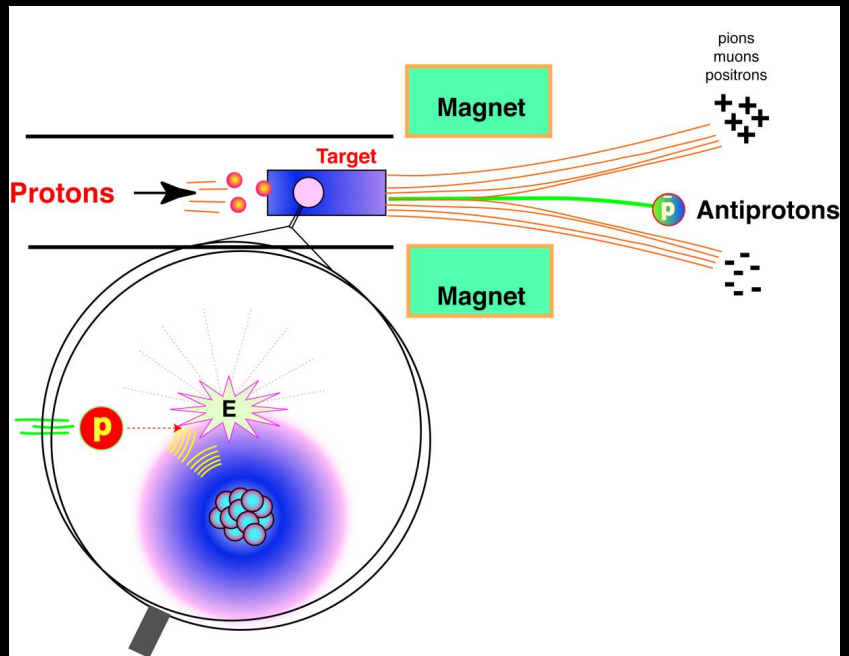
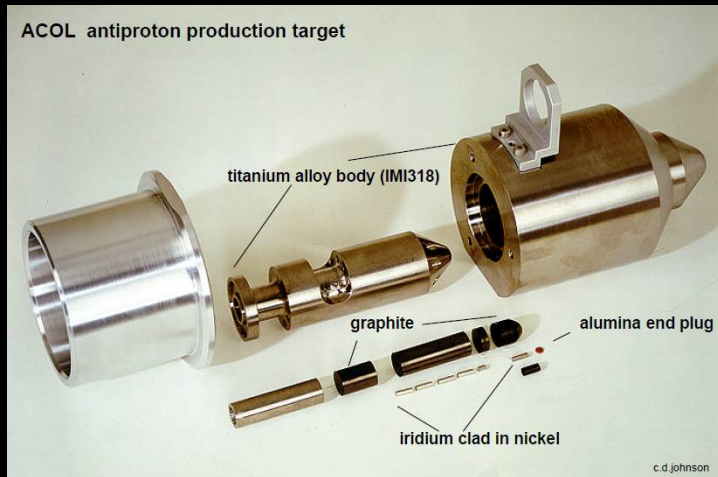


CERN Antimatter factory = Antiproton decelerator + ELENA

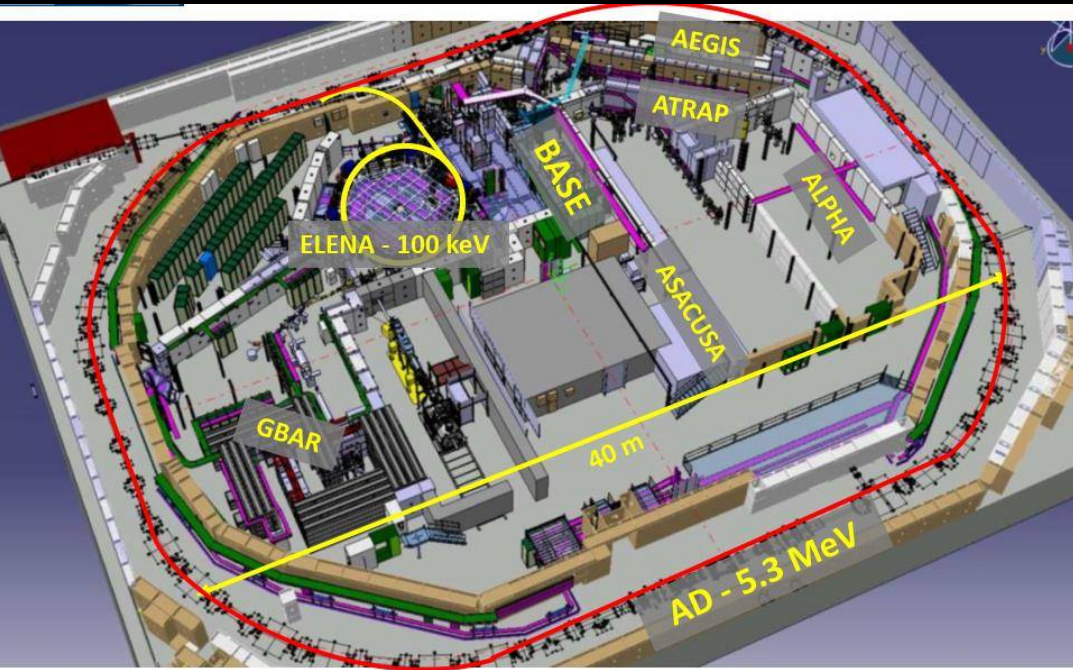
The CERN accelerator complex Complexe des accélérateurs du CERN



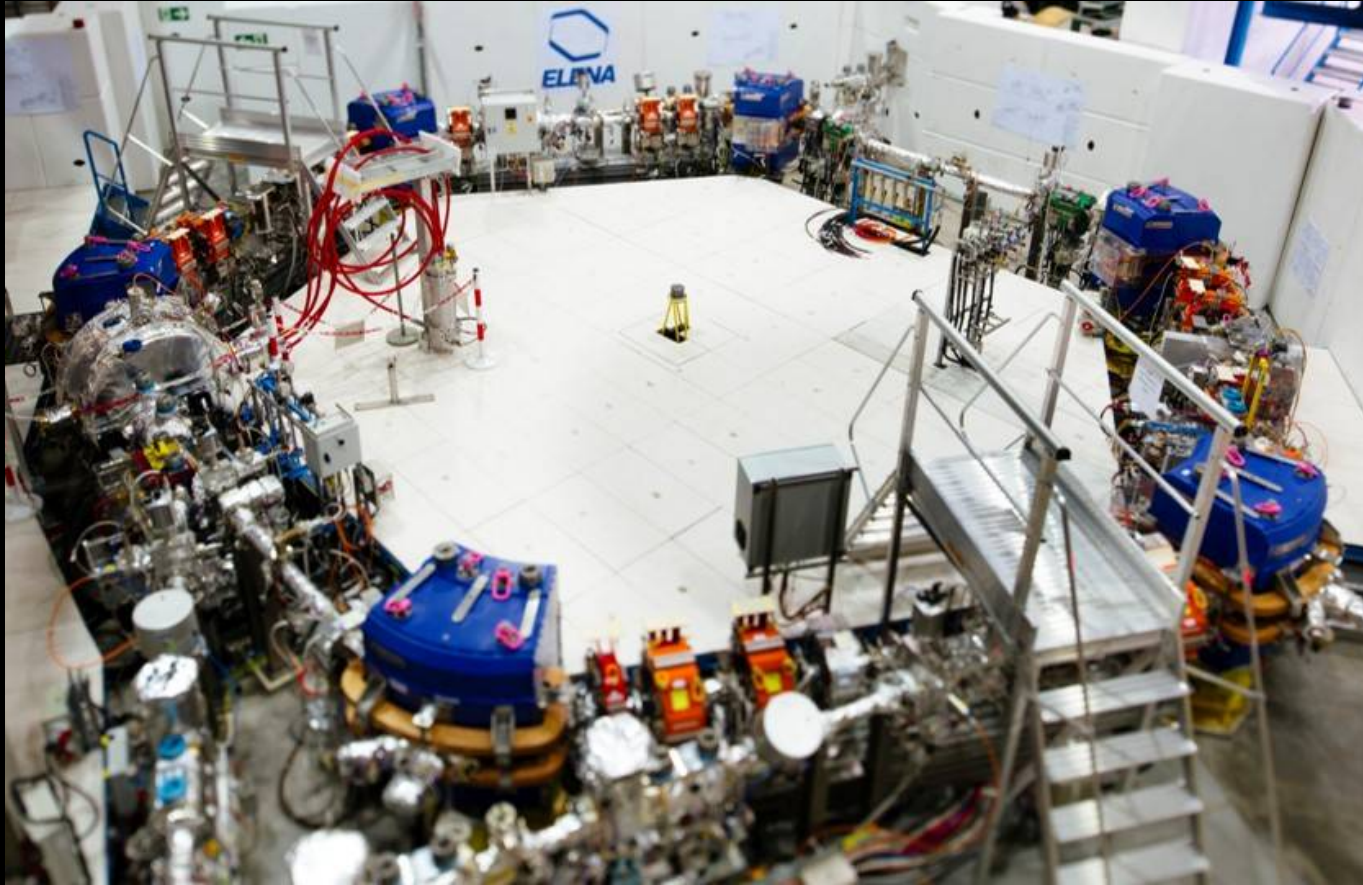
Create antiprotons



Slow them down - AD



Slow them down more - ELENA

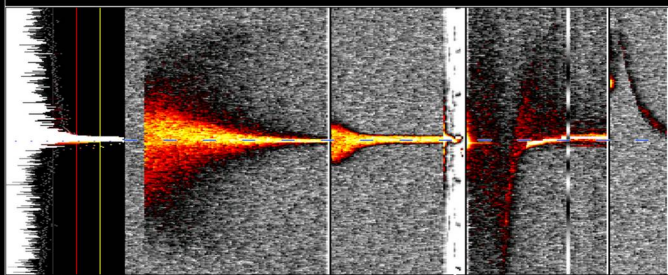


Slow them down more - ELENA

https://op-webtools.web.cern.ch/vistar/vistars.php?usr=ADE 88% ☆ Search

Vistar

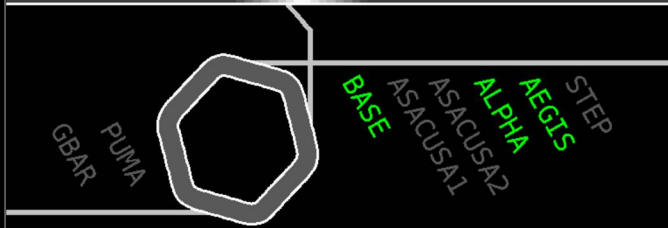
AD-ELENA Anti-proton production Vistar 12°C 27 Oct 2023 W43 00:37:12



Cycle Length 110.4s
Repet. Time 115.2s

296MeV/c

AD	00:36:07	00:34:11	00:32:14	00:30:19	00:28:23
PR.BCT	2004	1988	1999	2006	2000 E^{10}
BCT9012	1854	1841	1863	1862	1858 E^{10}
BCT9053	1753	1724	1738	1741	1739 E^{10}
3570 →	✓	3.93	4.21	4.22	4.22 E^7
3570 →	✓	3.76	4.03	4.05	4.04 E^7
2000 →	✓	3.75	4.03	4.05	4.04 E^7
2000 →	✓	3.76	4.03	4.05	4.05 E^7
300 →	✓	3.83	4.10	4.12	4.11 E^7
300 →	✓	3.76	4.02	4.04	4.04 E^7
100 →	✓	3.66	3.93	3.96	3.95 E^7
100 →	✓	3.46	3.70	3.74	3.71 E^7
Transm.	✓	87.98	87.93	88.59	87.99 %
BCT7049	✓	3.55	3.78	3.85	3.84 E^7



ELENA	00:35:38	00:33:40	00:31:45	00:29:50	
Injection	✓	37.02	39.41	39.88	39.60 E^6
Ejection	✓	33.74	33.89	34.15	34.51 E^6
Transm.	✓	91.1	86.0	85.6	87.1 %
LNE00	✓	7.55	7.72	7.73	7.68 E^6
LNE50	✓	0.00	0.00	7.88	8.20 E^6

Anti-proton injection T-21s

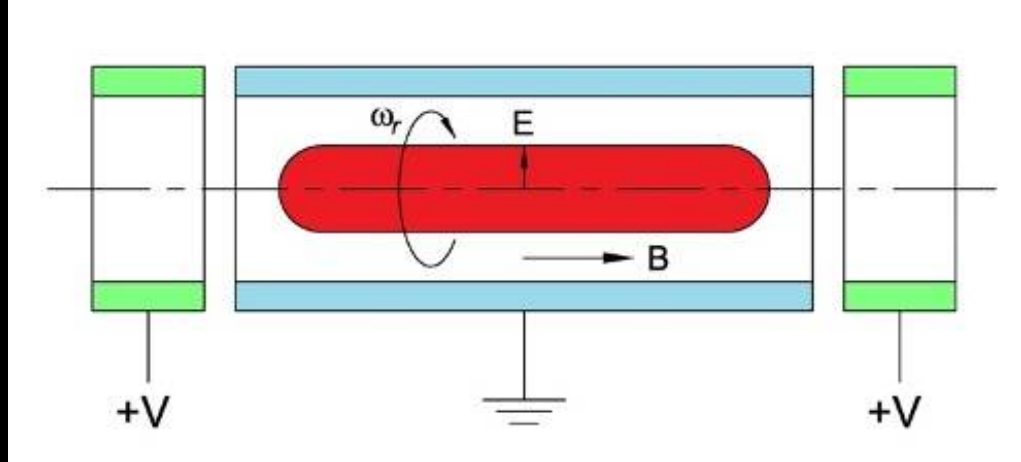
Comments: (26 Oct 2023 - 09:14:00)

A C R: 76688 or 76689 C C C: 76677 (nights & w.e.)
Supervisor: Lajos 164630

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

Series of electrodes in the centre of magnet:

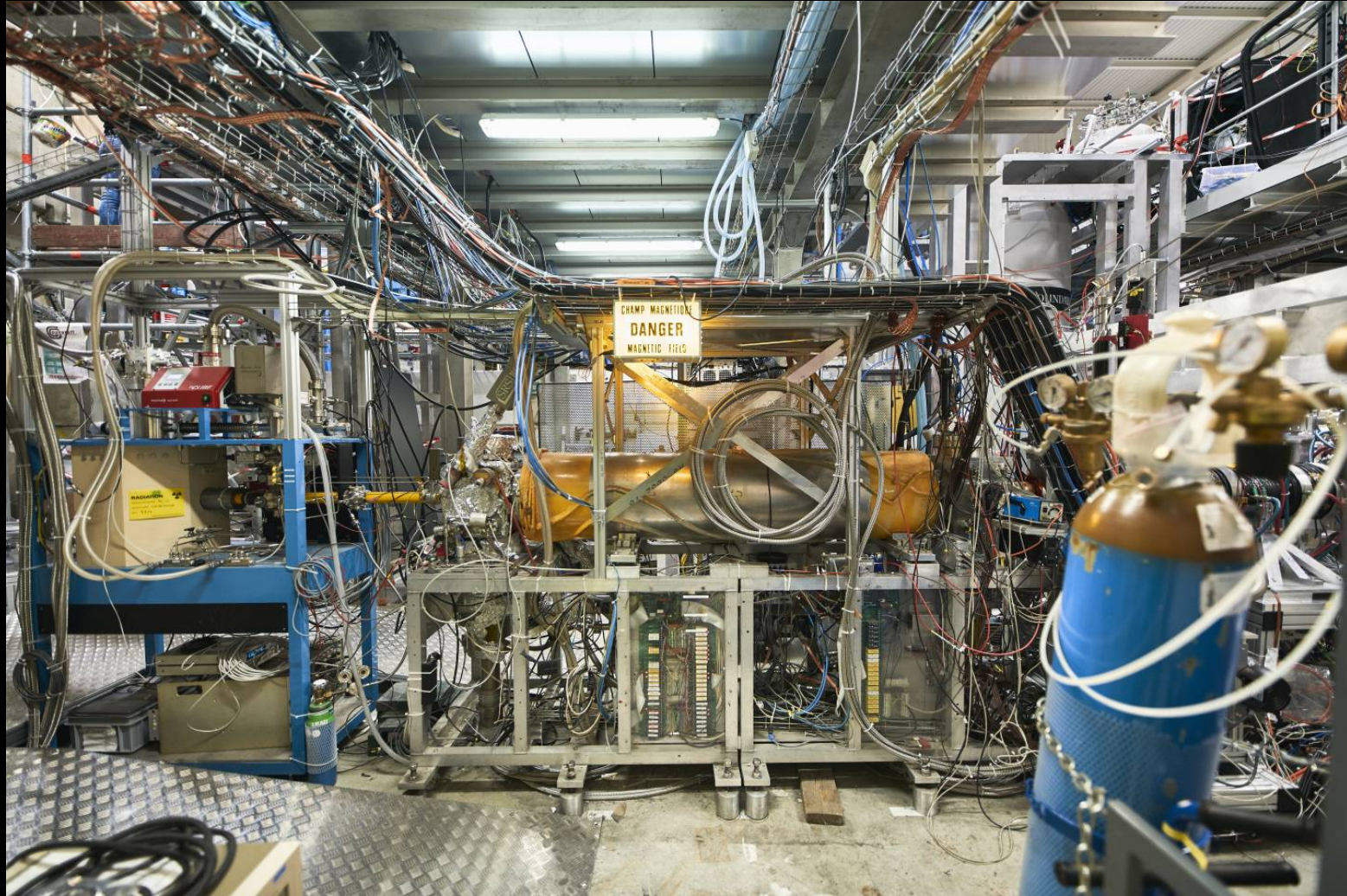
- magnetic field
- electric field



Get positrons: potassium-40

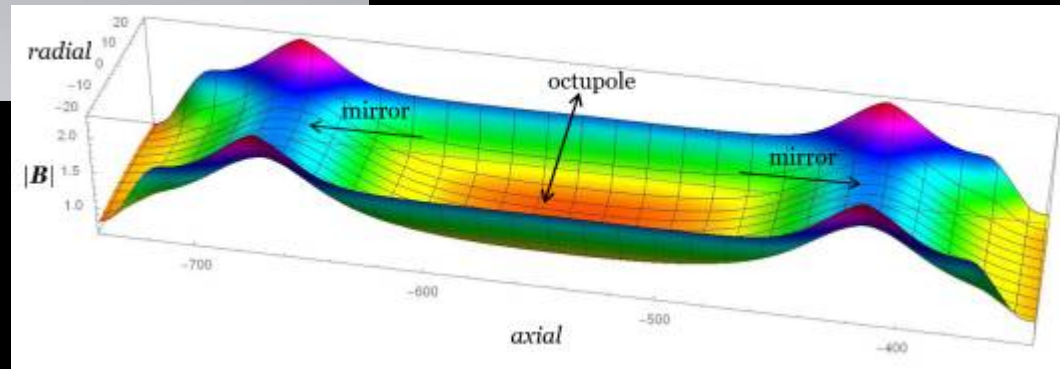
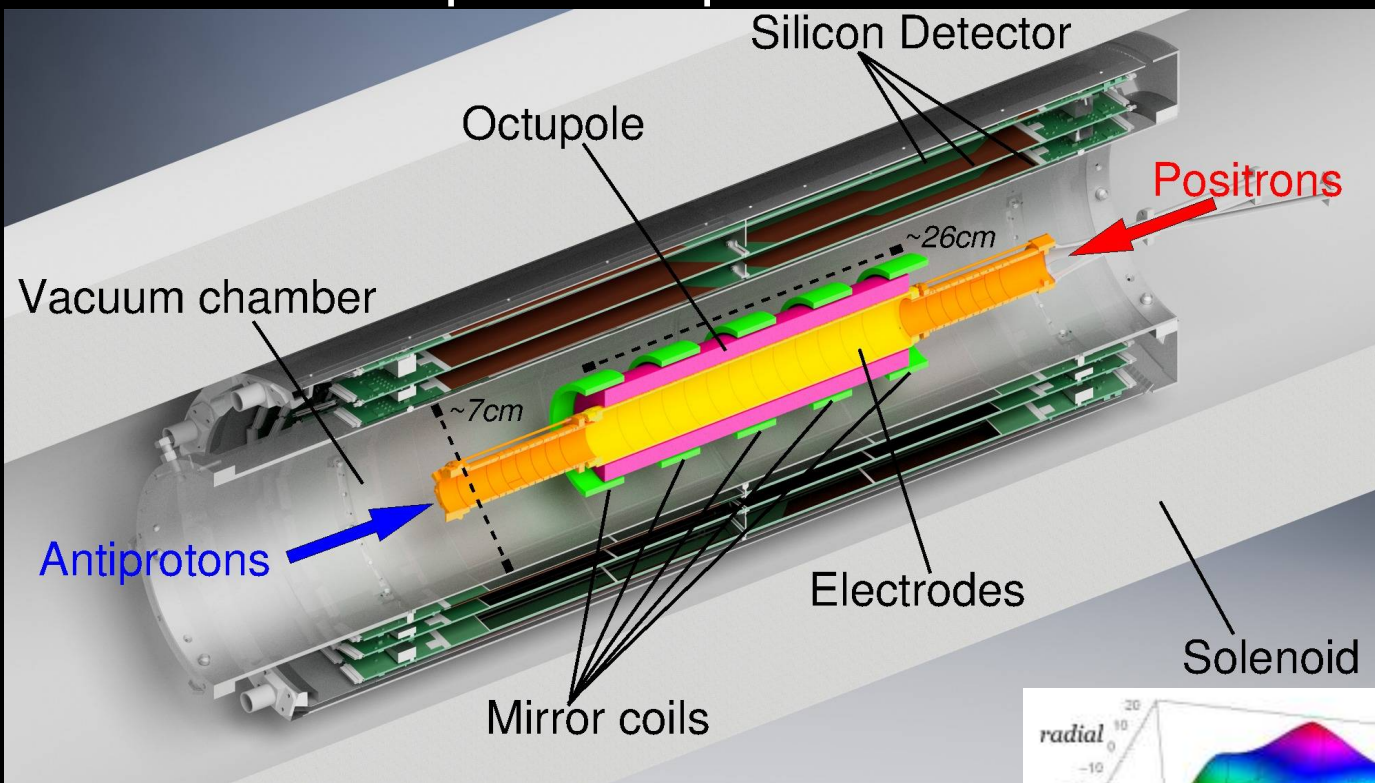


Get positrons: beta decay of Sodium-22

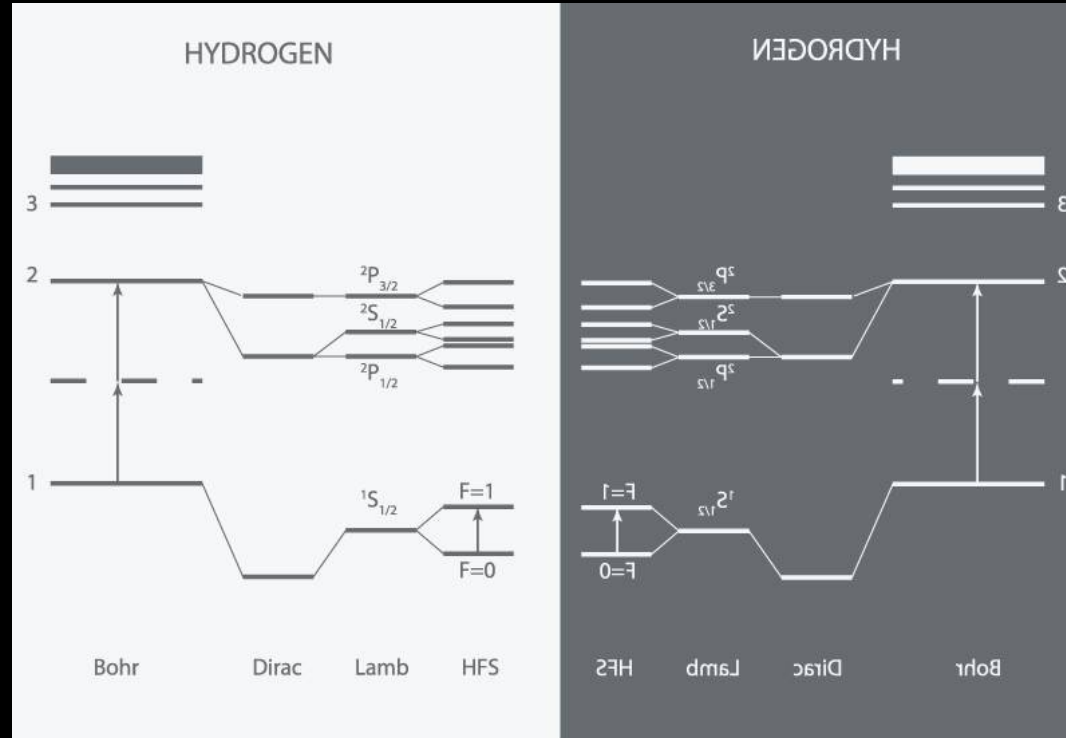


Make antihydrogen

Do it all in one place: experiment ALPHA2



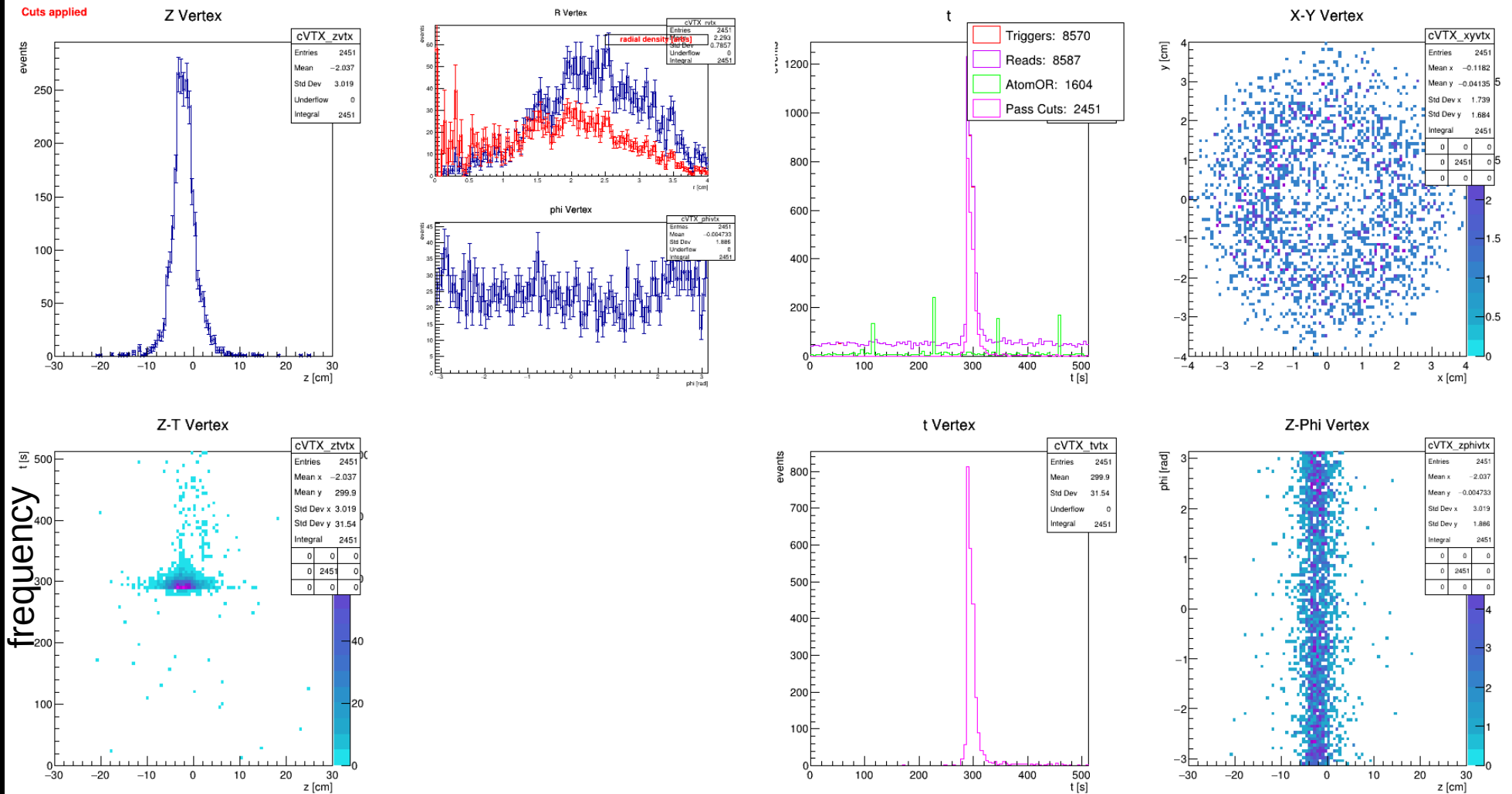
Make physics! Atomic spectra



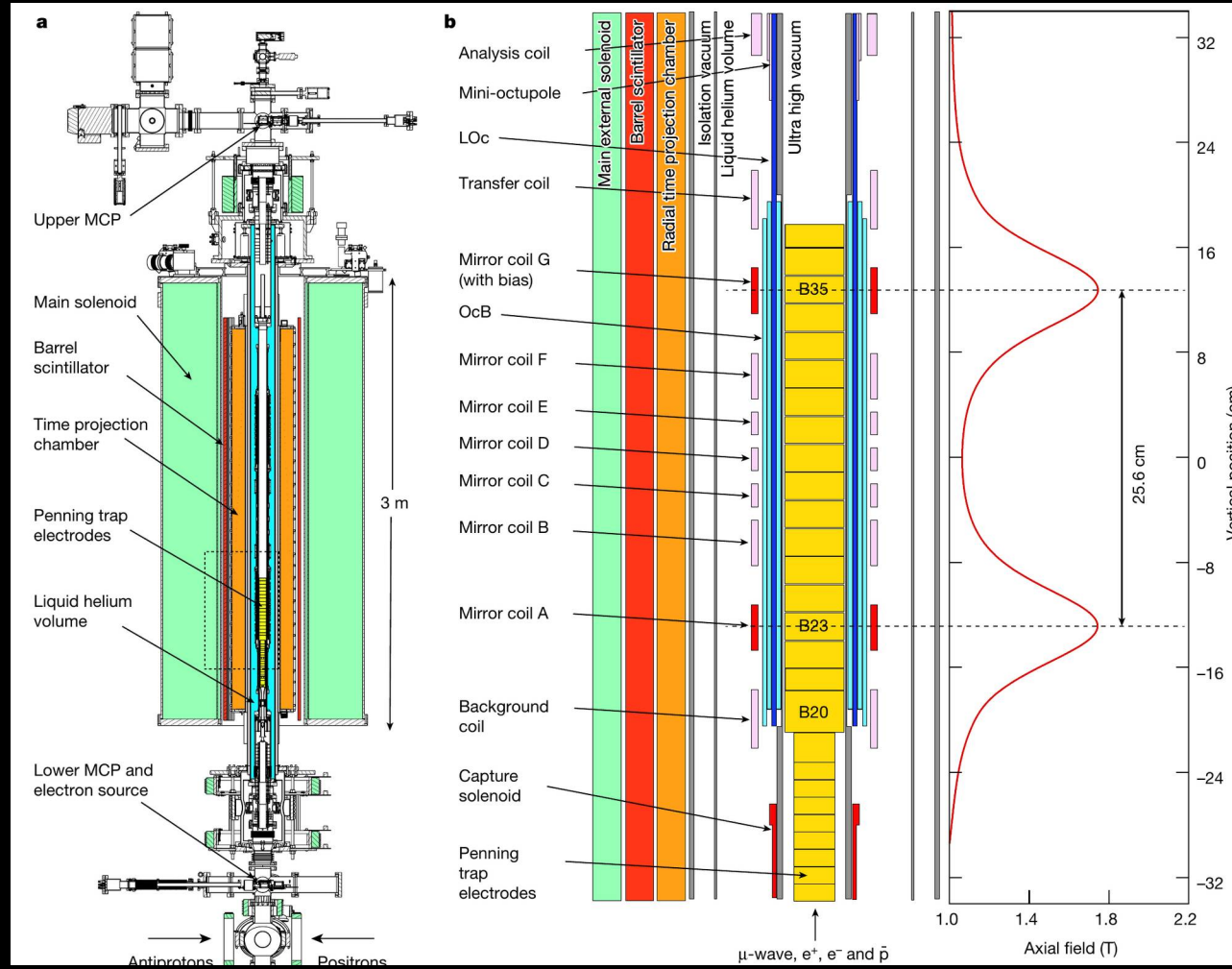
$$f(1S-2S)_{\text{H}} = 2\,466\,061\,103\,080\,300 \pm 10 \text{ Hz}$$

$$f(1S-2S)_{\overline{\text{H}}} = 2\,466\,061\,103\,079\,400 \pm 5400 \text{ Hz}$$

Make physics! Atomic spectra with microwave

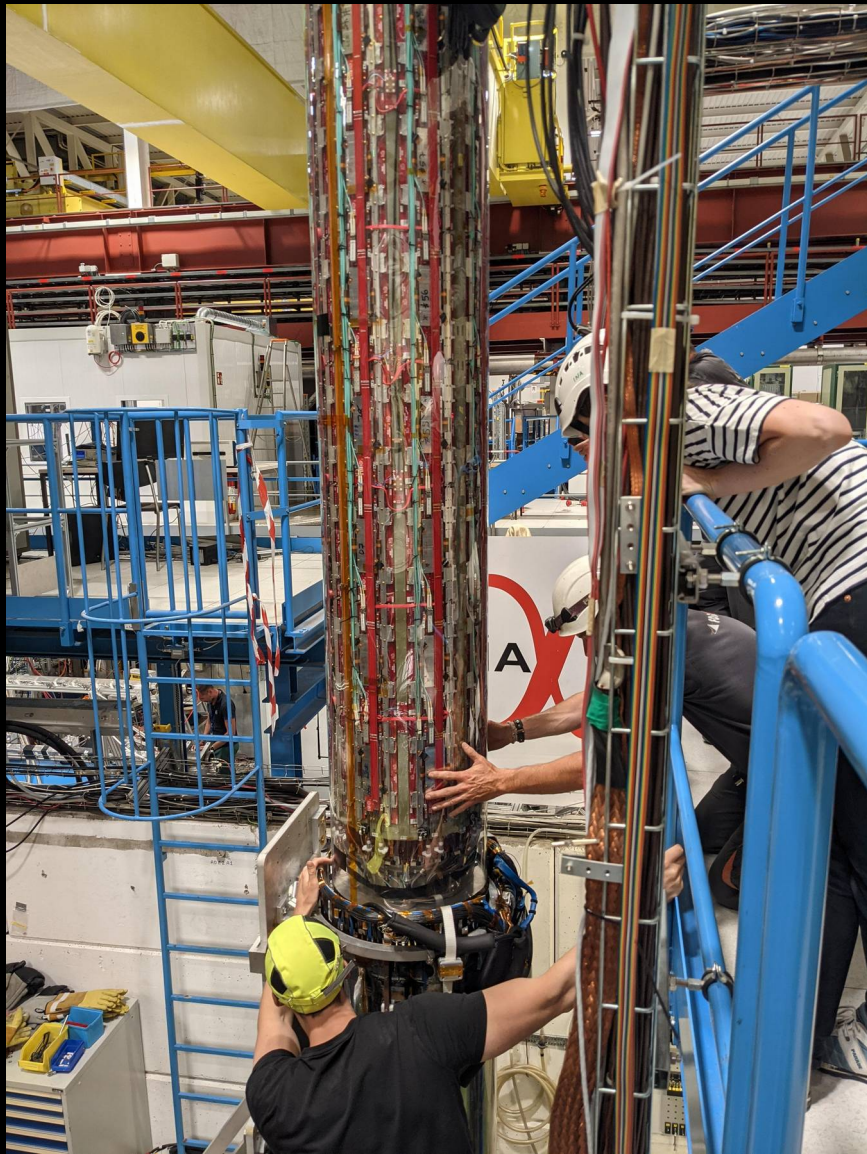


Repeat the same vertically - ALPHA-g

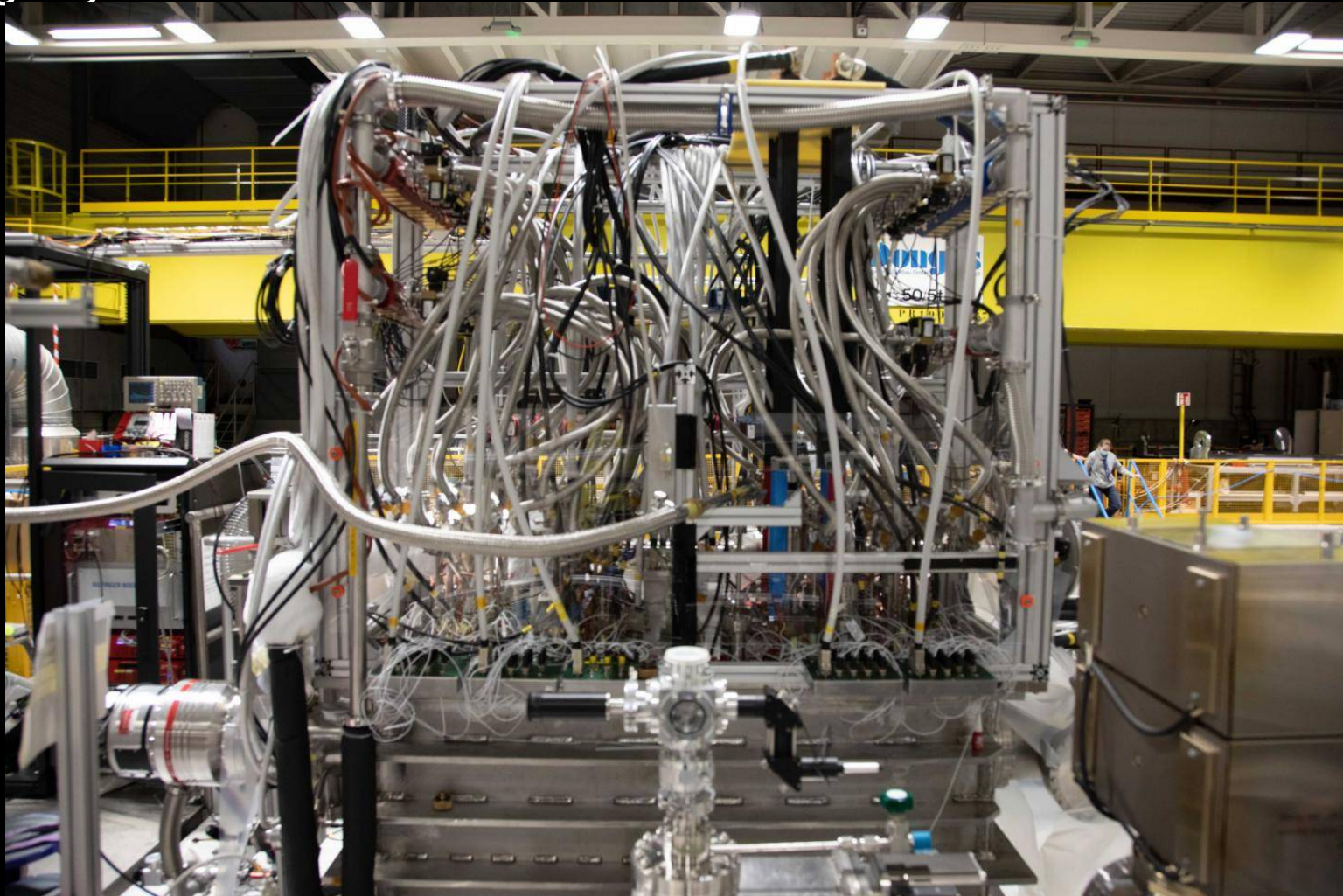


ALPHA-g detectors

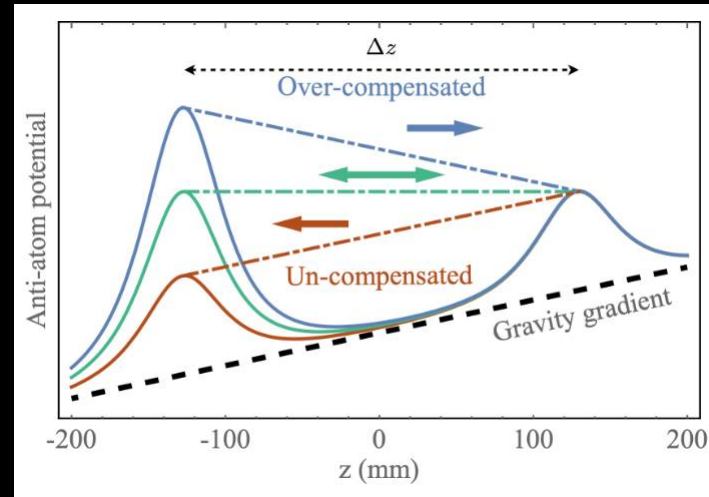
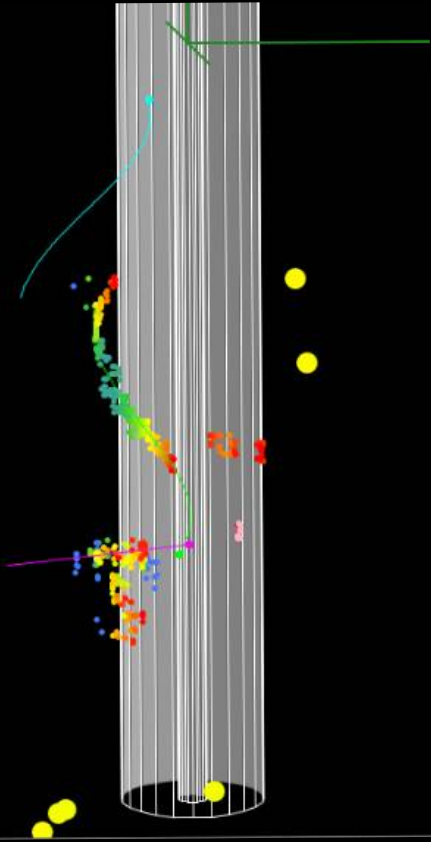




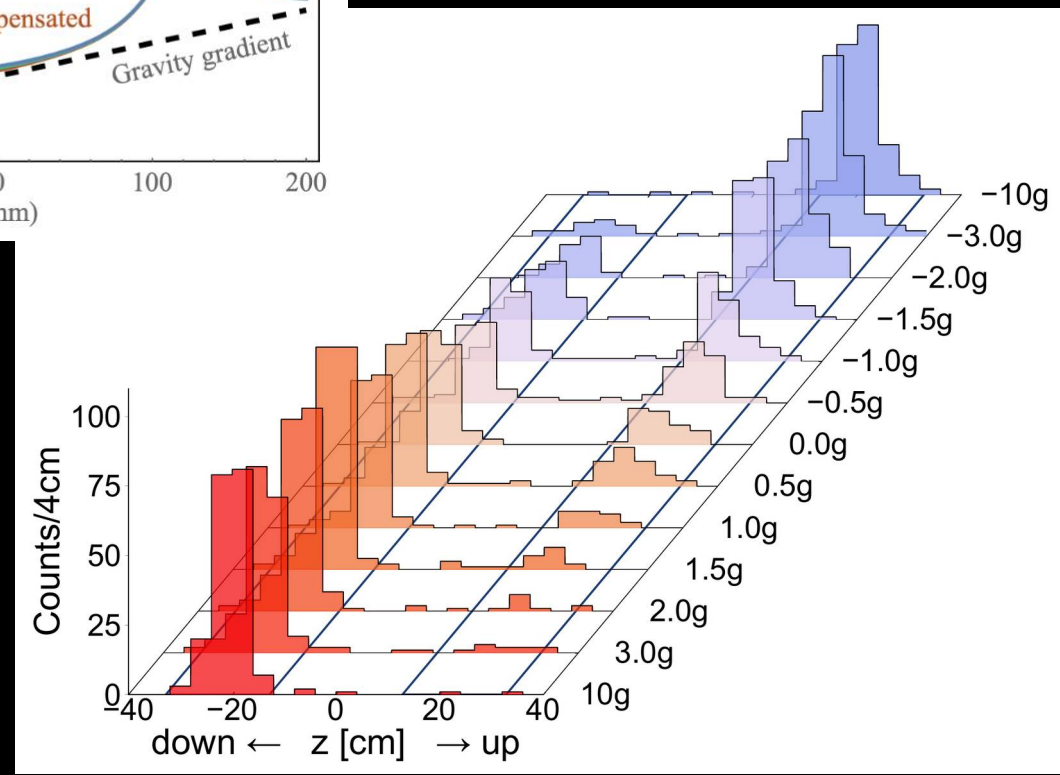
ALPHA-g cryostat



ALPHA-g experiment



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

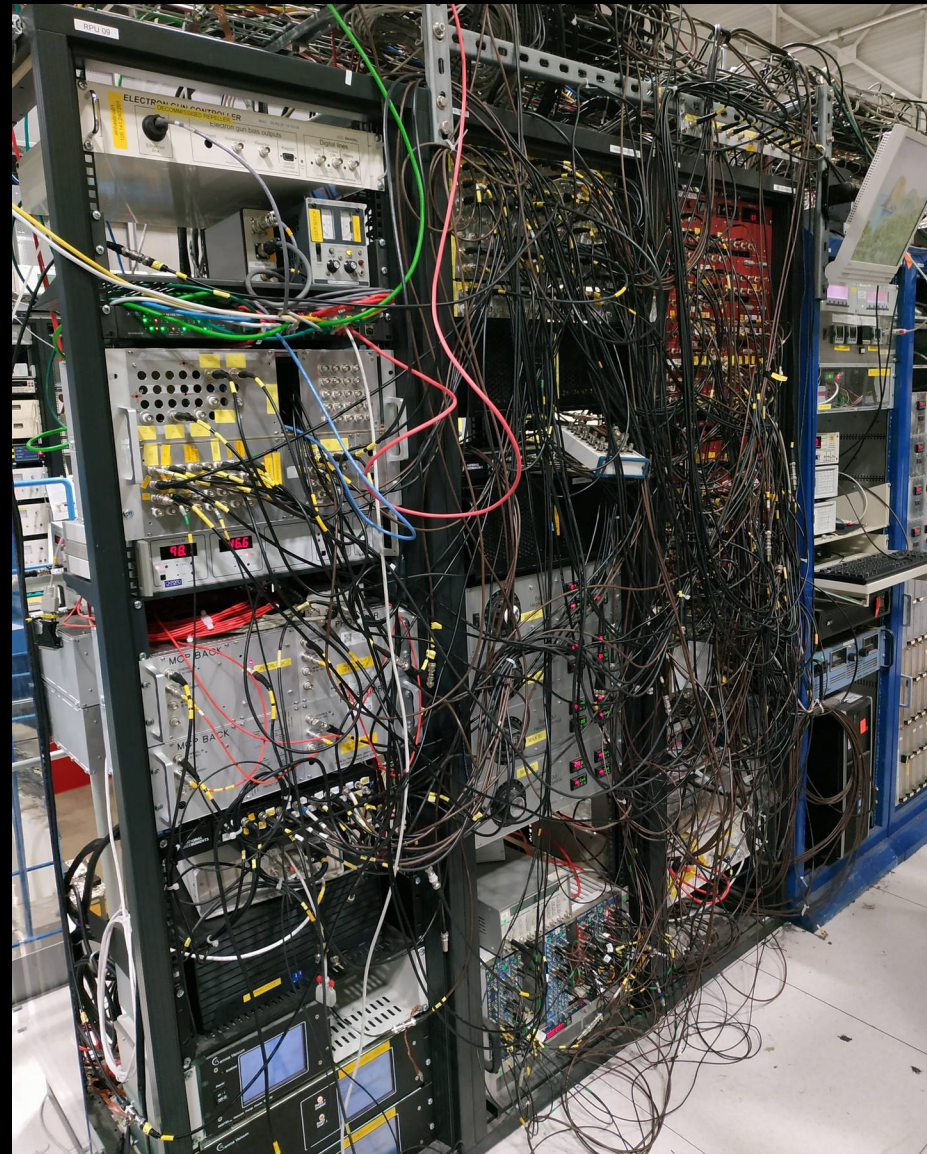


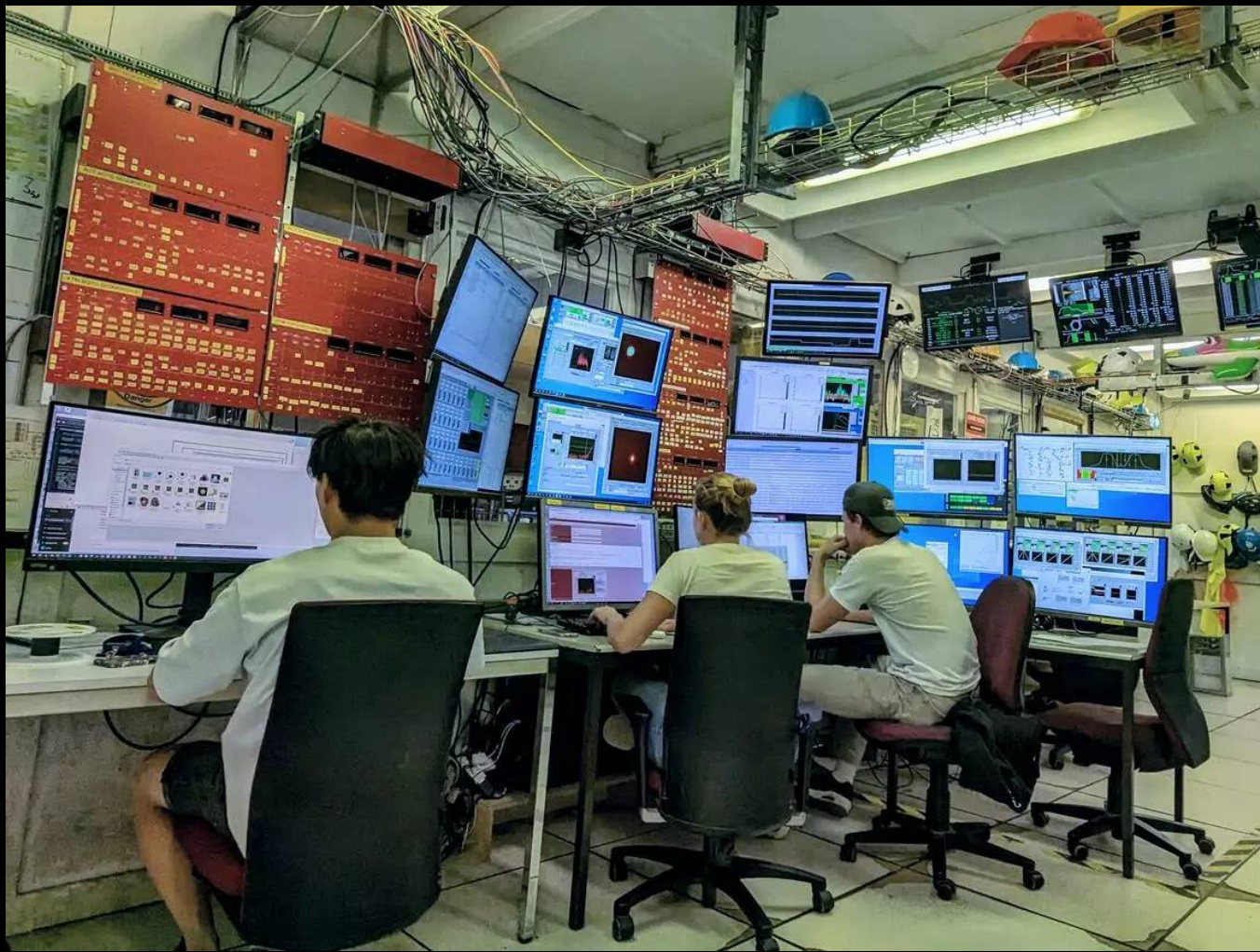
Summary: antimatter is cool!

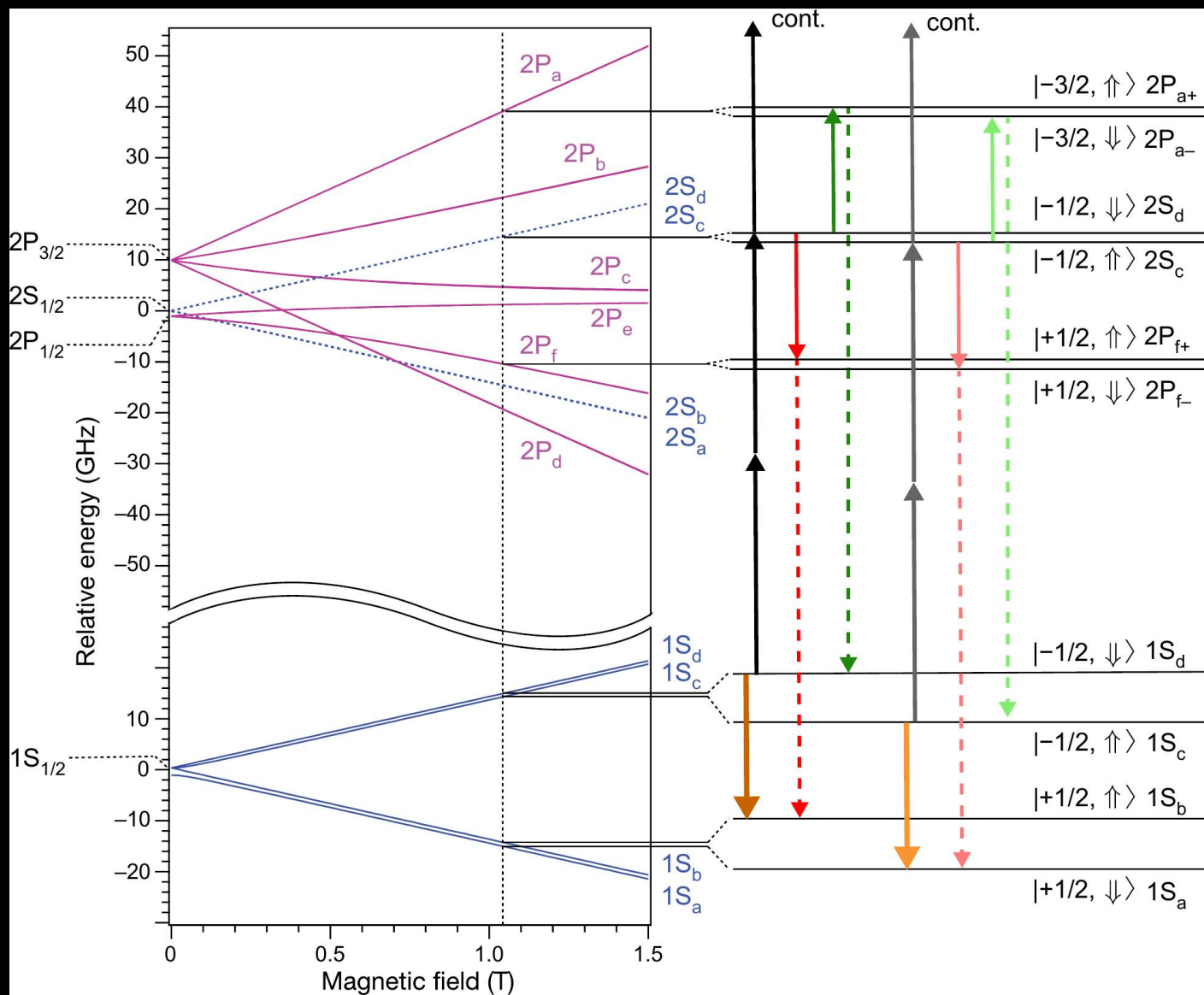
But understanding it is a huge challenge

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

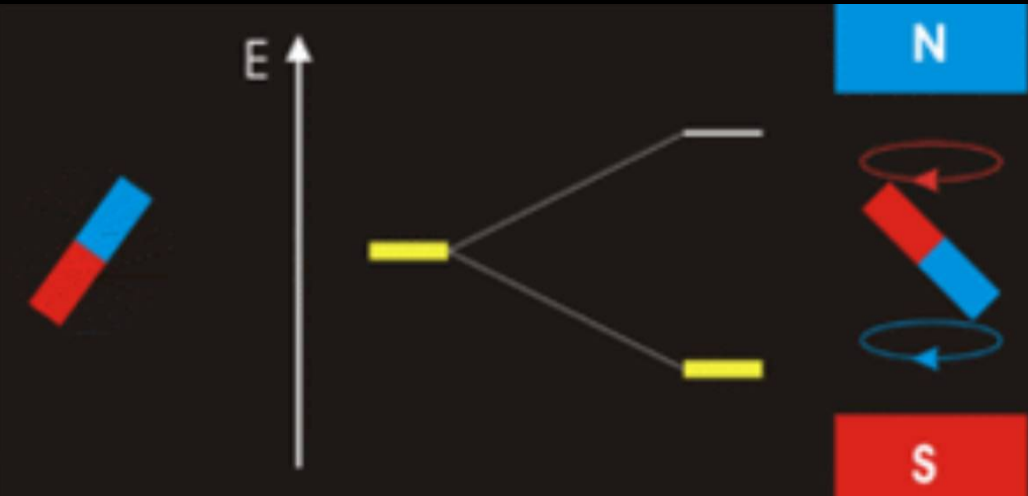
... stay tuned for new spectroscopy results, soon in your news feed



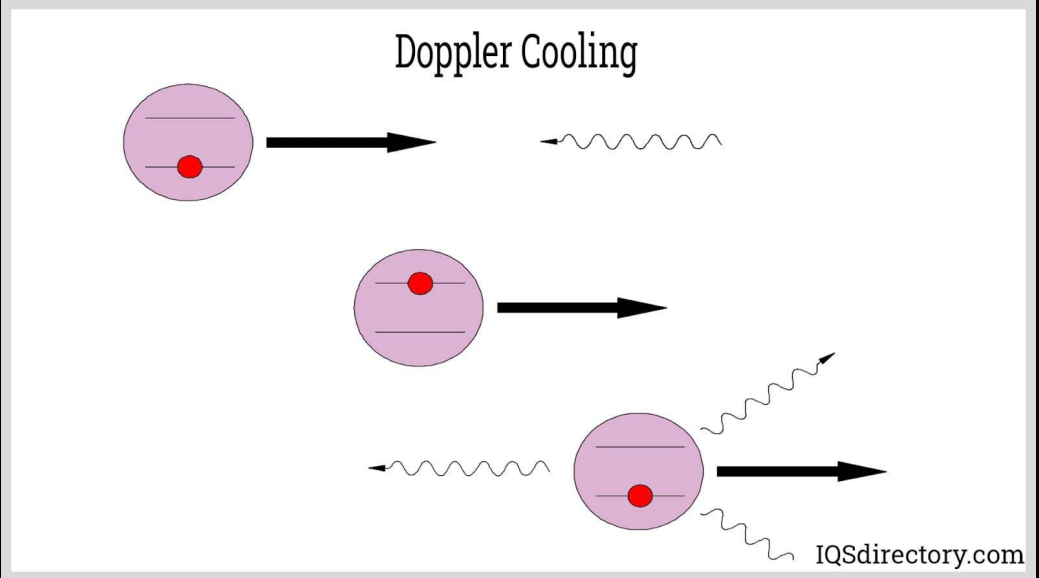




Zeeman splitting



Laser cooling





Alpha-g 0g run

