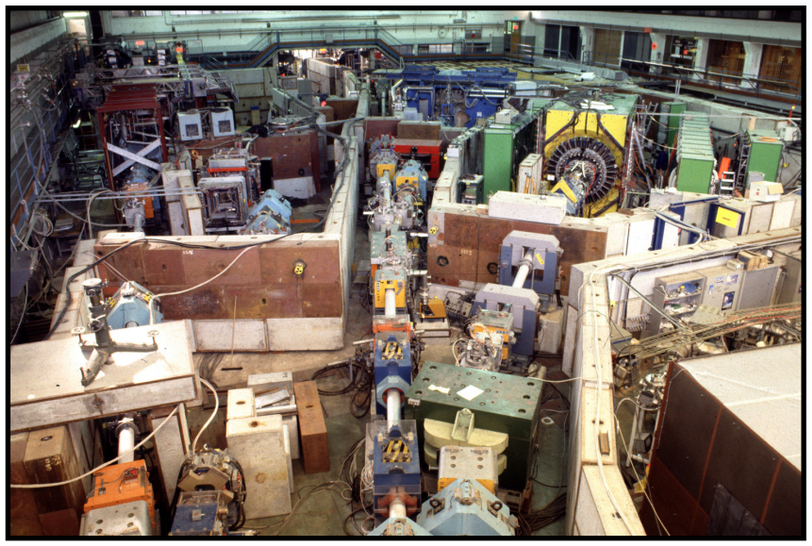
ANTIMATTER IN THE LAB

Q & A SESSION



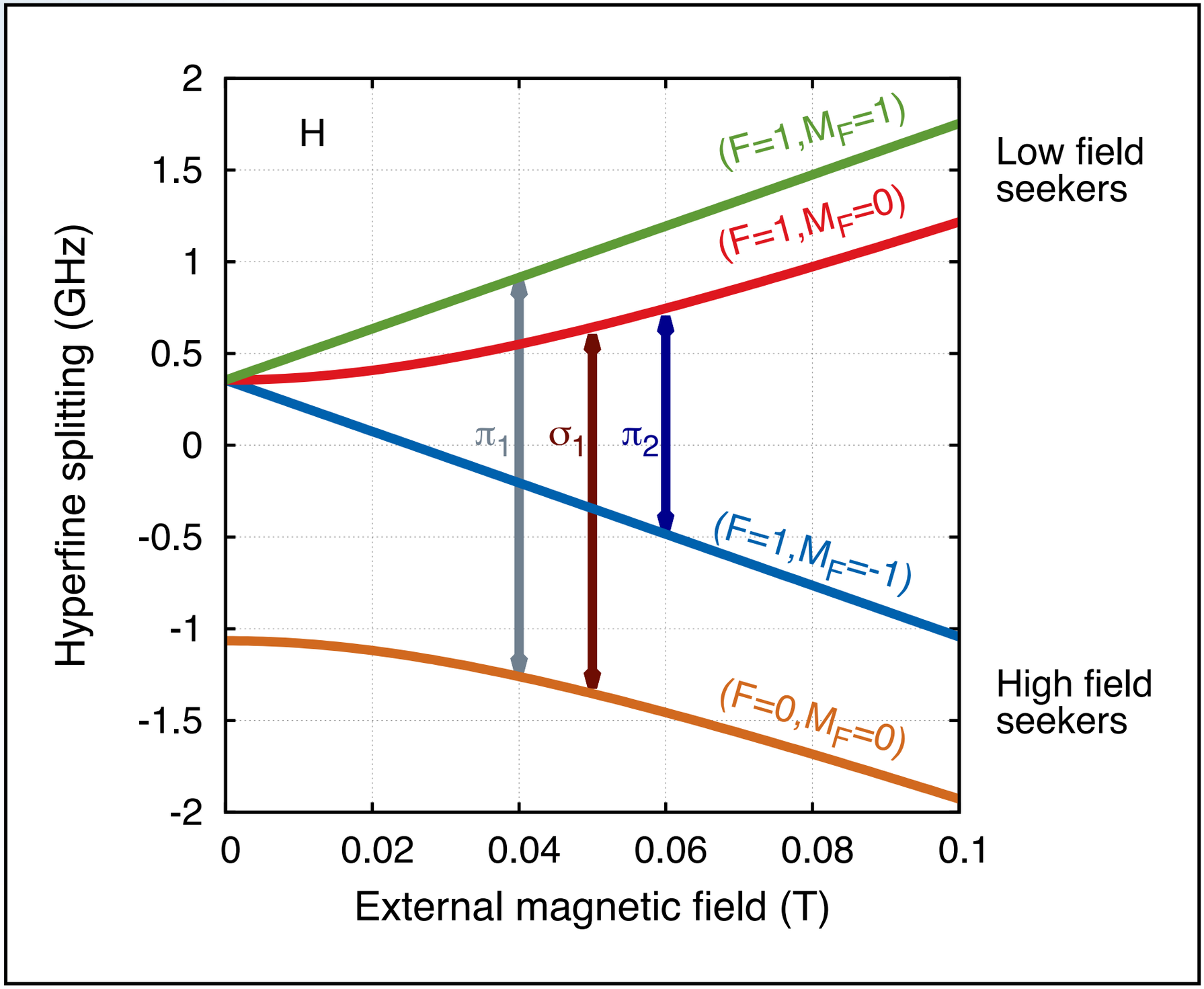
CERN Summer student 2021

Q1: LFS and HFS

hyperfine splitting: electron (positron)-proton (antiproton) spin interaction

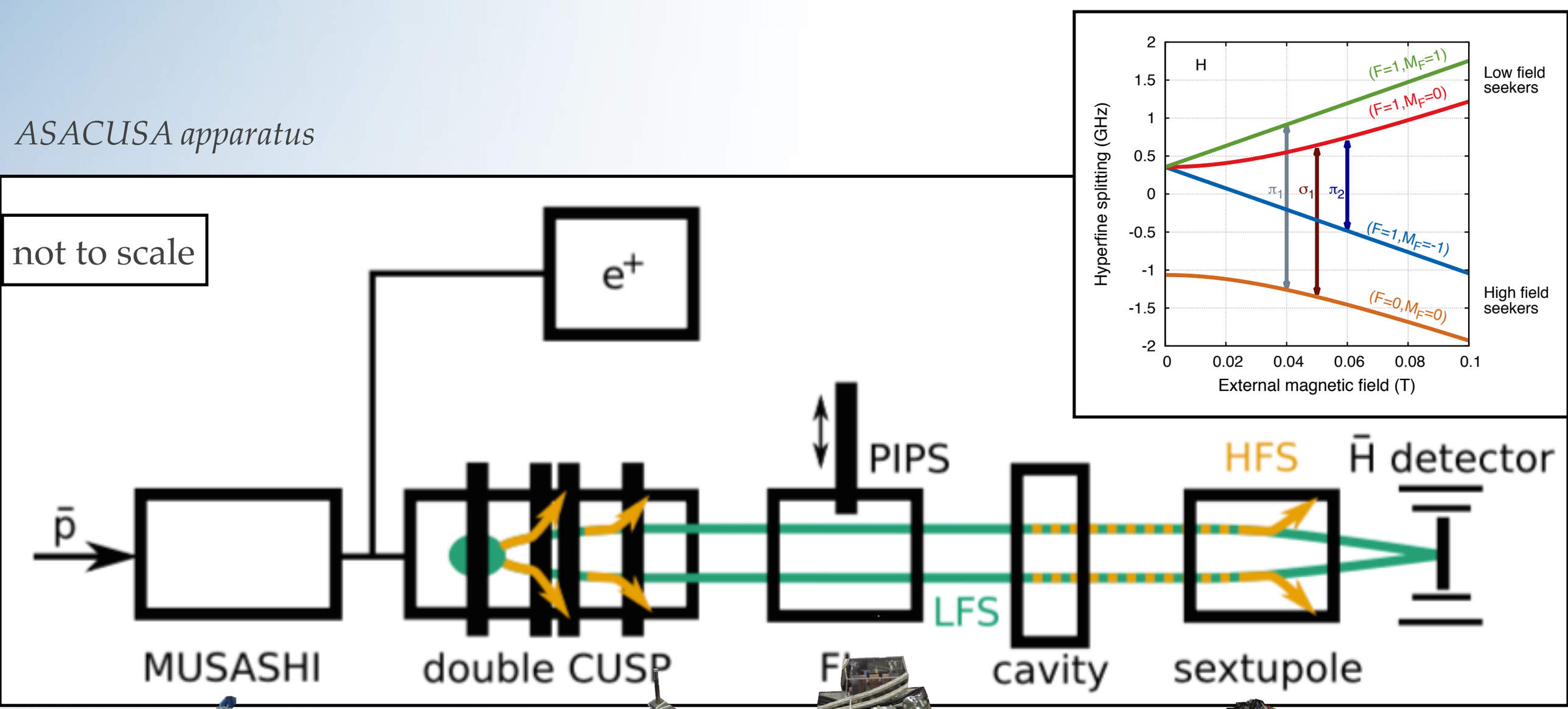
F:total spin

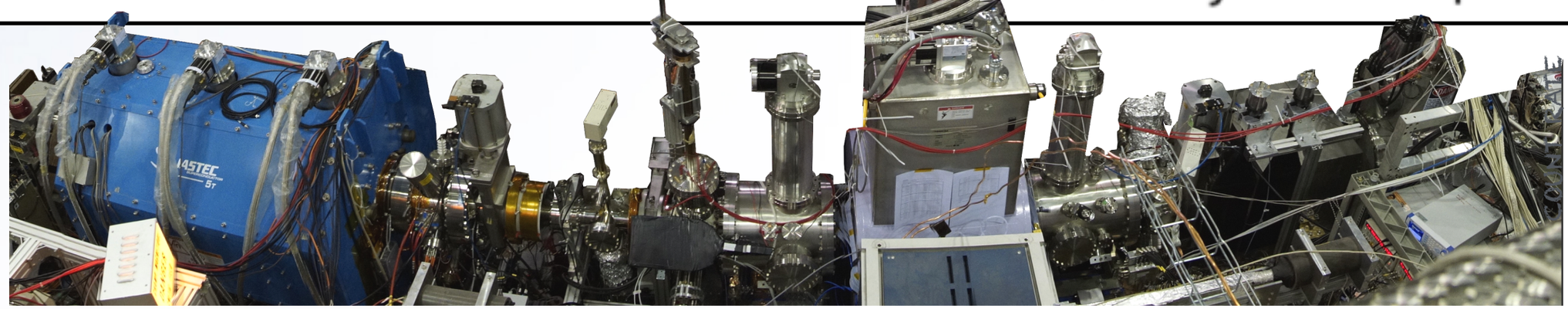
External magnetic field: perturbation of the energy levels -> Zeeman effect

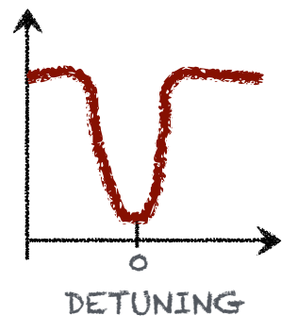


Q1: LFS and HFS

ASACUSA apparatus



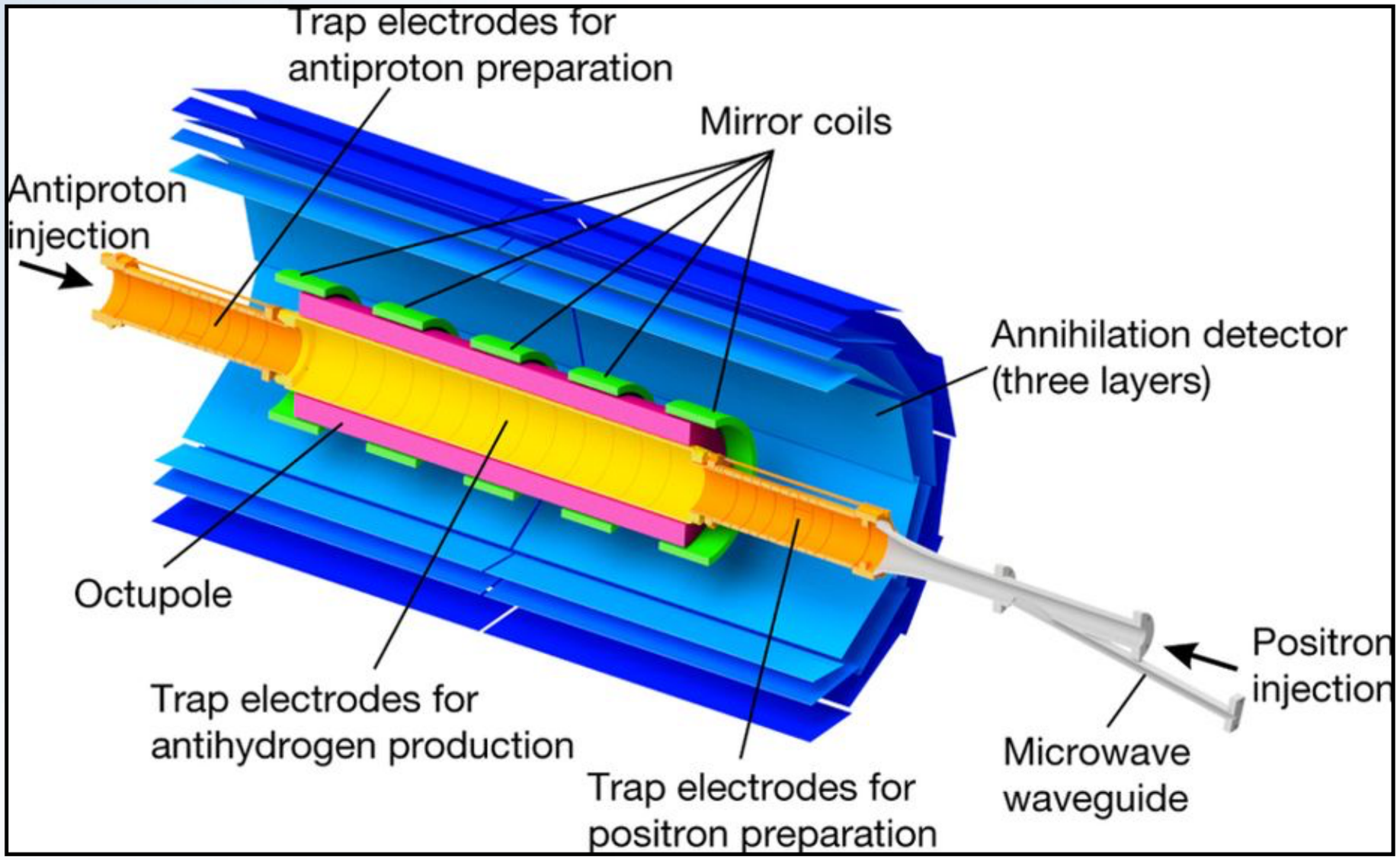




Q1: LFS and HFS

TRAP

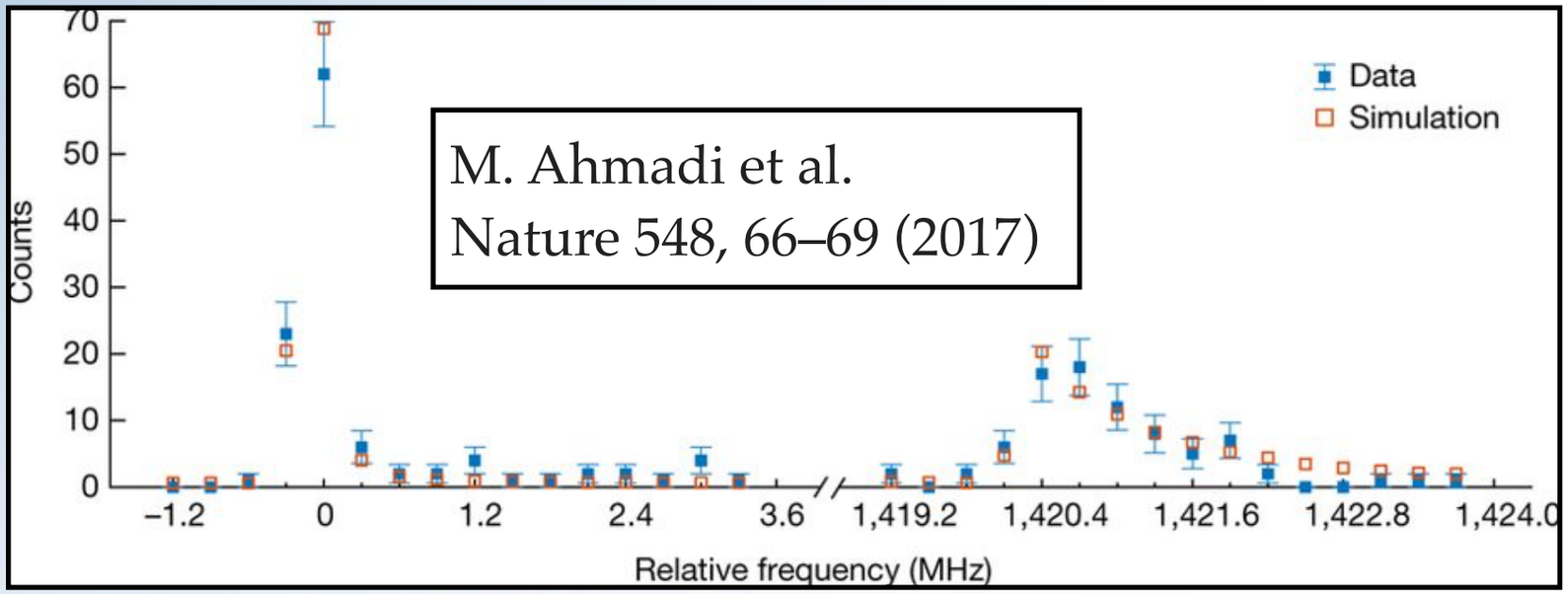
ALPHA-2 apparatus



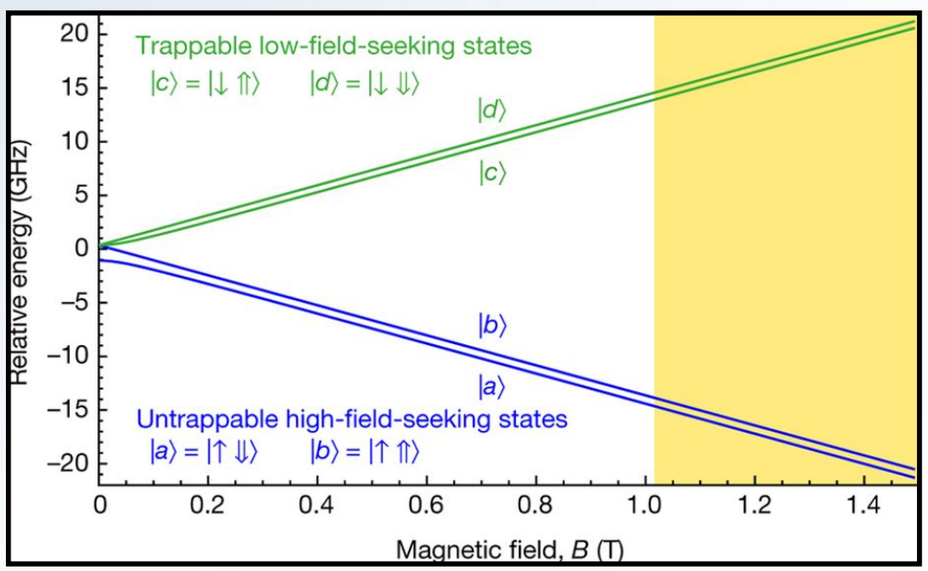
Q1: LFS and HFS

In a TRAP:

Precision of ~ 500 kHz

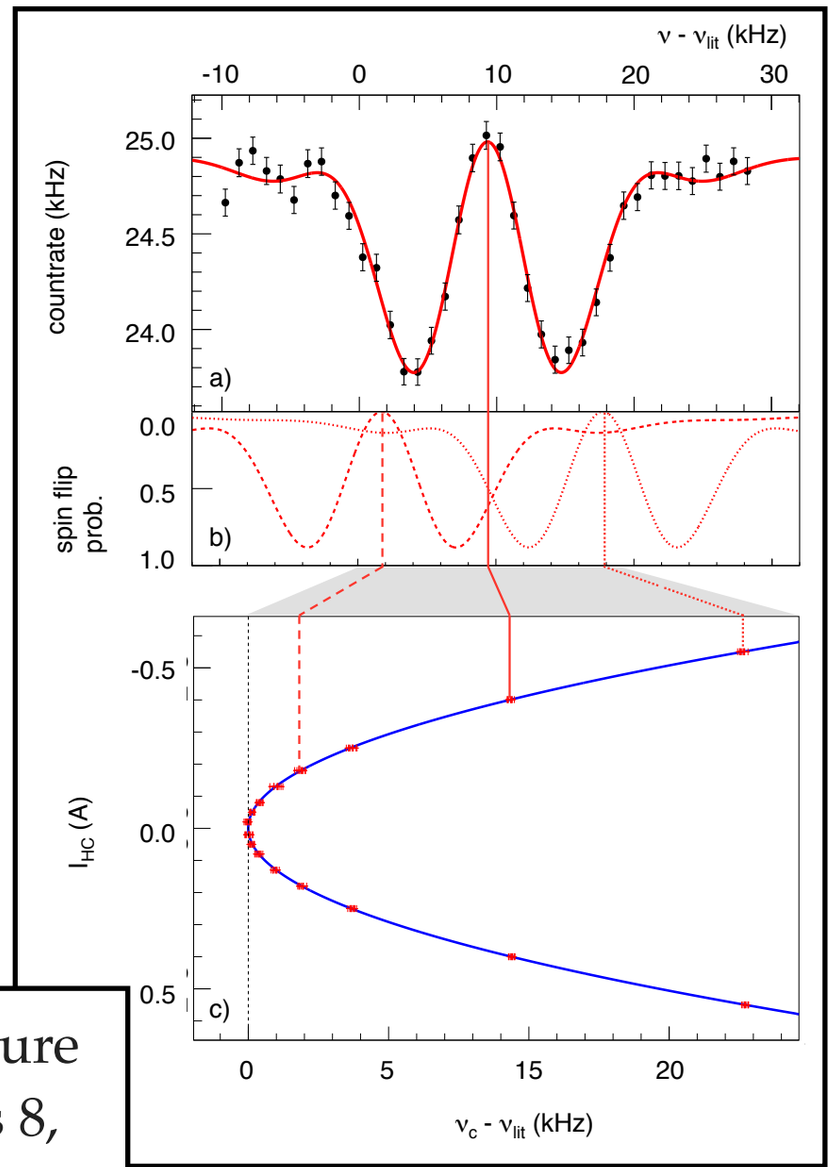


M. Ahmadi et al.
Nature 548, 66–69 (2017)



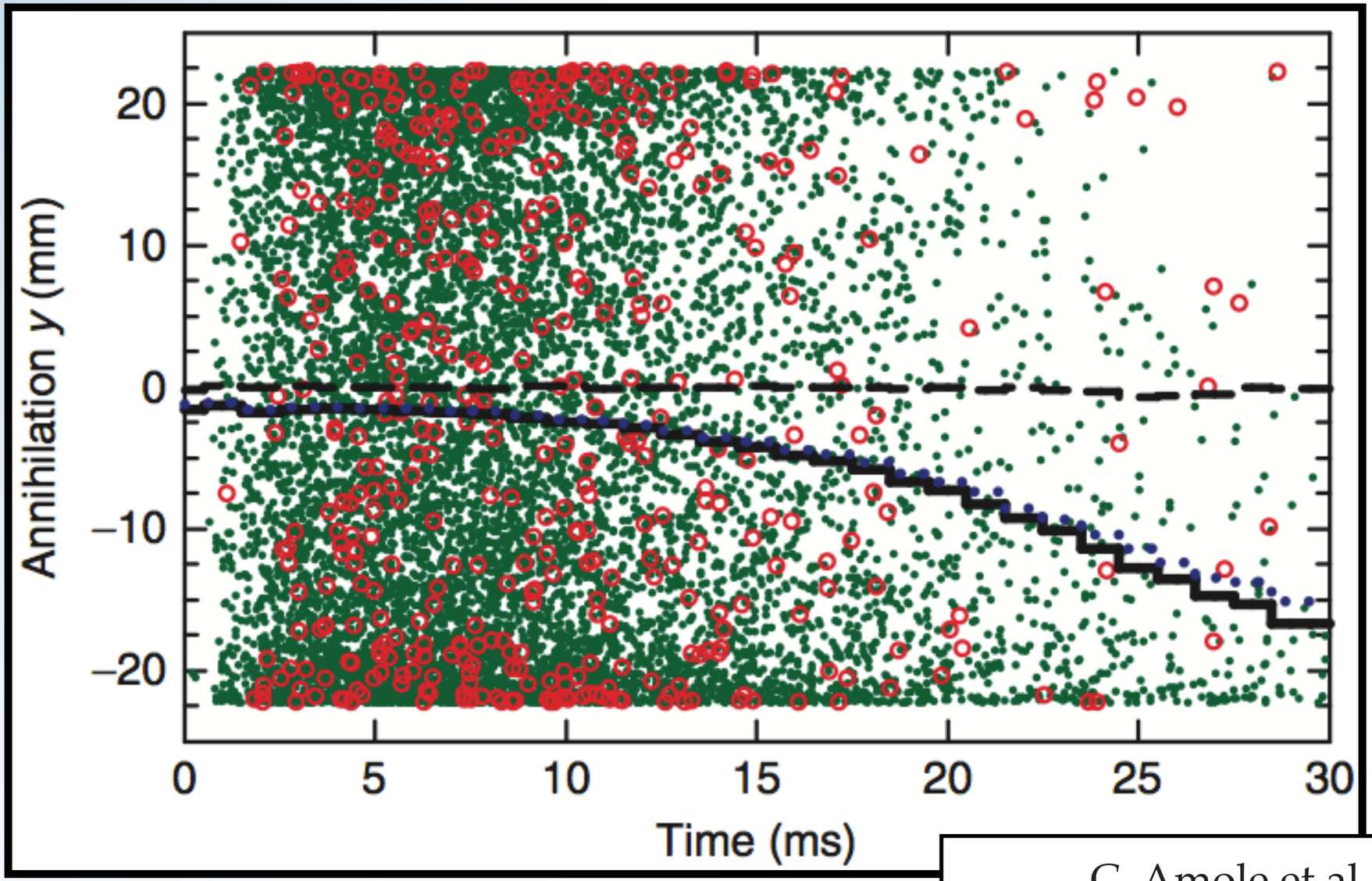
In a BEAM:

Precision of ~3Hz on HYDROGEN



M. Diermaier et al. Nature Communications 8, 15749 (2017)

Q2: Status of gravity measurements



C. Amole et al. Nature Communications 4, 1785 (2013)

-65 < g/ḡ < 110

Green dots---simulated annihilations

Red circles---434 Observed annihilations

Vertical position of annihilation vertex during release of trapping field

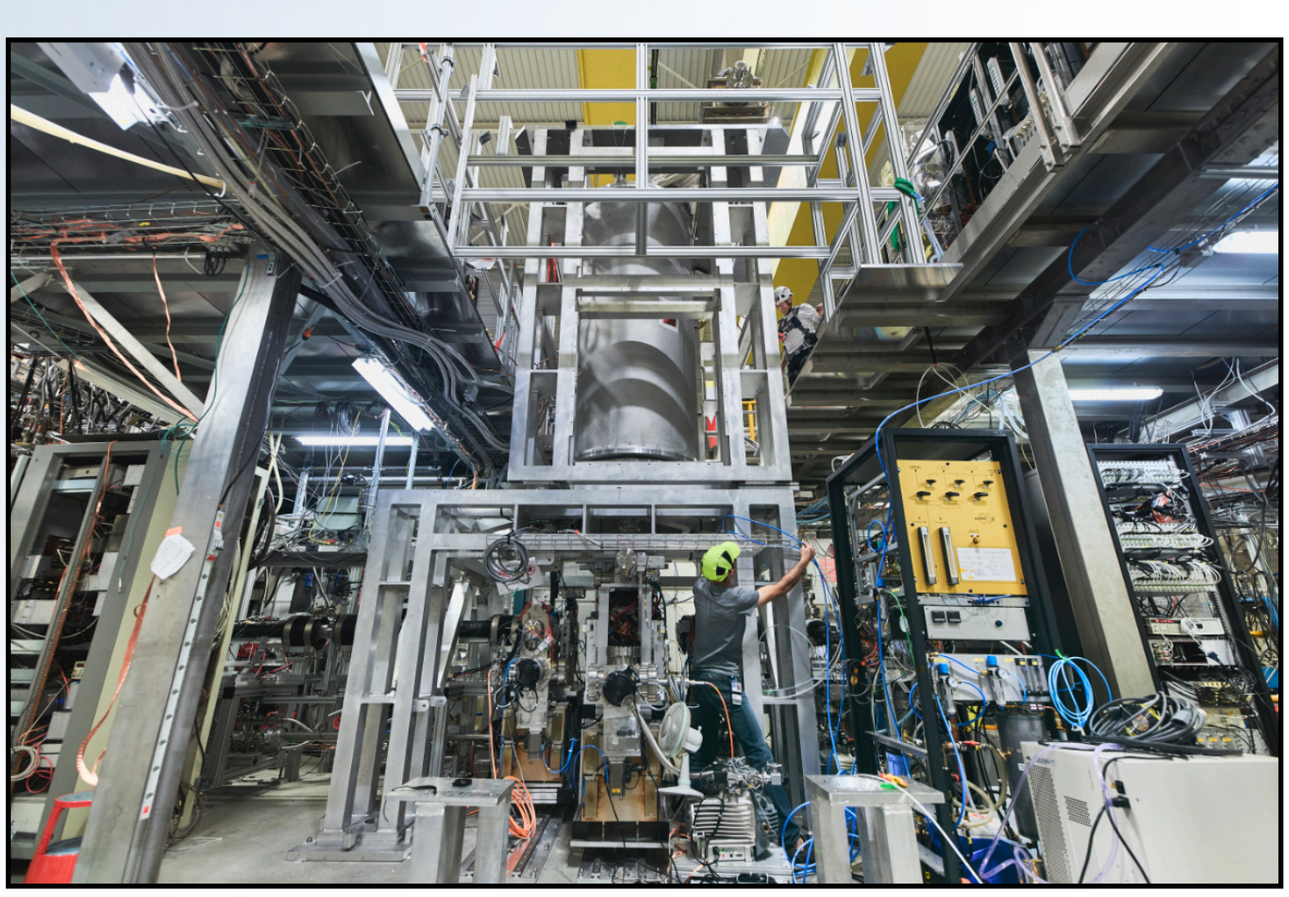
Q2: Status of gravity measurements

New antimatter gravity experiments begin at CERN

The ALPHA-g and GBAR experiments have received their first beams of antiprotons

2 NOVEMBER, 2018 | By Ana Lopes

GBAR & ALPHA-g getting their first beam



Q2: Status of gravity measurements

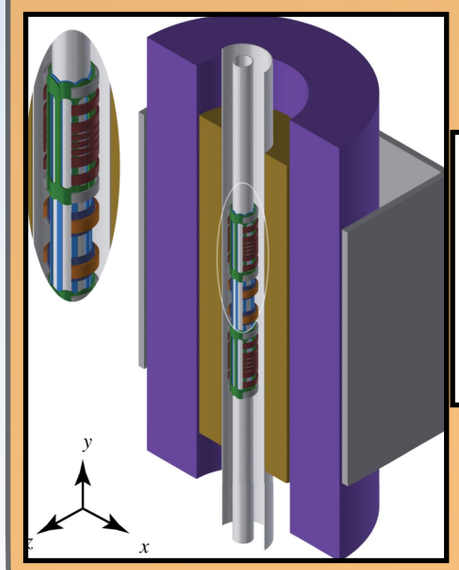
Plurality of approaches

VERTICAL TRAP

- increase up/down sensitivity (up to 1.3m trapping range)
- much improved field control

Sign measurement planned soon

1% targeted $\bar{H}$ cooling to ~20 mK and advanced magnetometry



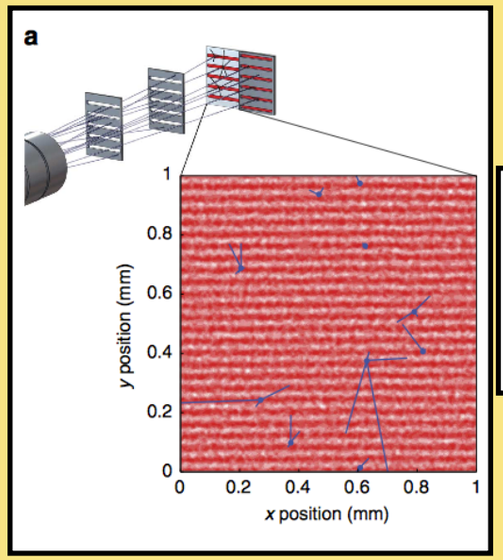
W. A. Bertsche Phil. Trans. R. Soc. A 2018 376 20170265; DOI: 10.1098/rsta.2017.0265. (2018)

ALPHA-G

$\bar{H}$ BEAM

- Sensitivity to ~10 μm deflection needed
- cold antiproton translates in cold $\bar{H}$ thanks to CE mechanism

Sign measurement targeted



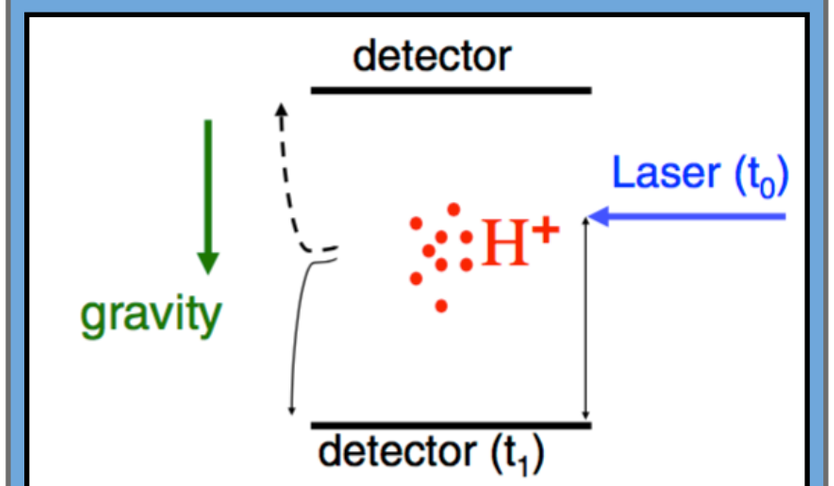
S. Aghion et al. Nature Communications 5 (2014) 4538

AEGIS

$\bar{H}^+$ BEAM

- Cooling below 1 m/s : Sympathetic cooling of $\bar{H}^+$
- opens new horizons

1% measurement targeted



e.g.: The GBAR antimatter gravity experiment
P. Pérez et al., Hyperfine Interactions 233, 21-27 (2015)

GBAR

Q2: Status of gravity measurements

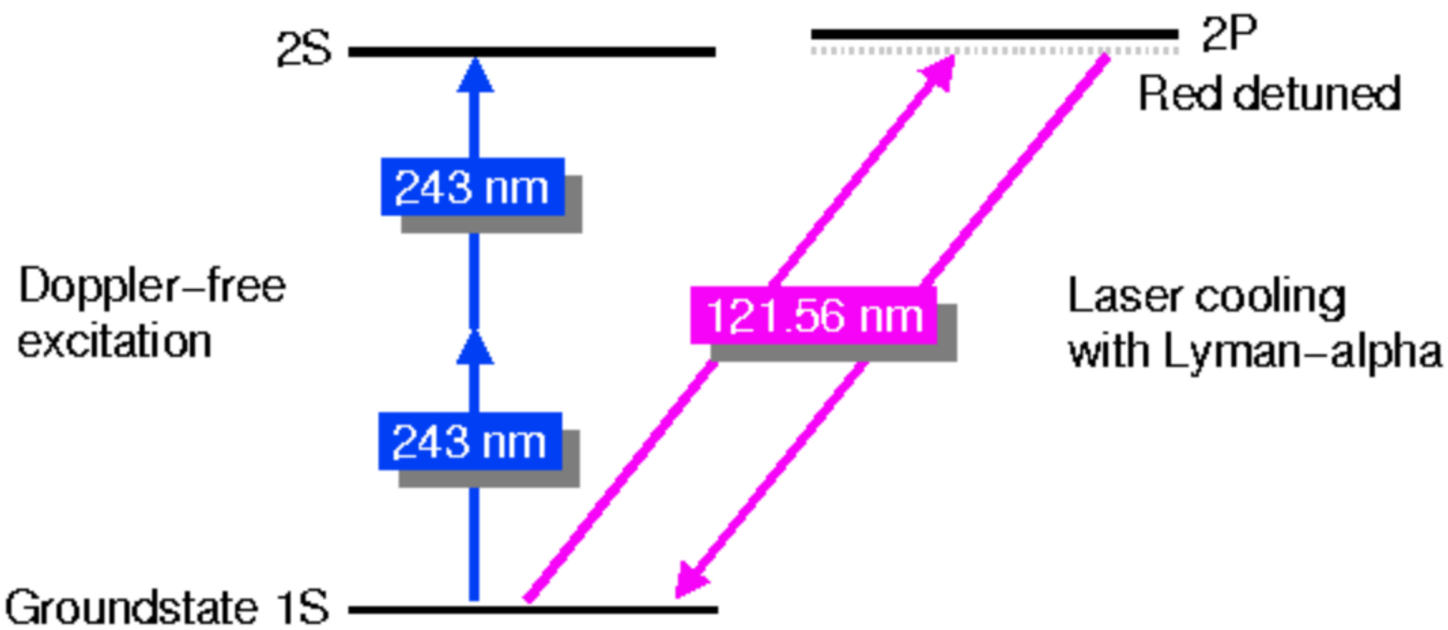
Article | Open Access | Published: 31 March 2021

Laser cooling of antihydrogen atoms

C. J. Baker, W. Bertsche, [...]J. S. Wurtele

Nature **592**, 35–42 (2021) | Cite this article

31k Accesses | **2** Citations | **657** Altmetric | Metrics



Simplified level scheme of (anti-)hydrogen showing only the lowest lying states and ignoring all substructure.

Q2: Status of gravity measurements

ELENA

$\bar{p}$ at 100 keV at improved beam emittance

all experiments gain a factor 10-100 in trapping efficiency

“simultaneous” delivery to almost all experiments

additional experimental zone