# LEA – Low Energy Antimatter

con focus su ALPHA

Simone Stracka – 28/6/2021
Preventivi sezione CSN3

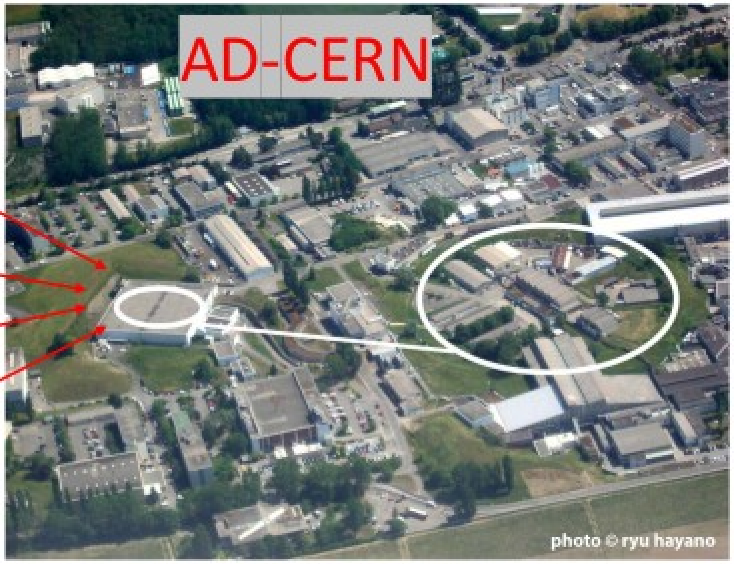
# Sigla LEA (Low Energy Antimatter)

- La collaborazione LEA raggruppa diversi esperimenti in un unico progetto INFN:
  - Anti-idrogeno
    - **AEgIS** : Fascio di Hbar da accelerazione stark. In INFN dal 2010
    - **ALPHA** : Hbar confinato in trappola Joffe-Pritchard. Nuovo per l'INFN
    - **ASACUSA** : Fascio di Hbar da cusp trap (+ altre attività). In INFN dal 2005
  - Positroni e positronio
    - **PsICO**: Fasci pulsati. Spin-off di AEgIS
    - **QUPLAS**: Fasci continui. Spin-off di AEgIS-ASACUSA
- 47 ricercatori, 26 FTE: piccoli esperimenti con temi di ricerca simili, LEA può facilitare la collaborazione in aree di intersezione e la mobilità dei ricercatori più giovani
- **Gli esperimenti restano scientificamente indipendenti gli uni dagli altri (in effetti, sono concorrenti)**
- 1 responsabile nazionale (Luca Venturelli) + 1 responsabile per esperimento (Germano Bonomi per ALPHA)
- Proposta presentata in CSN3 il 12/2/2021: LOI/CDR presentati
  - CDR recente distribuito ai referee il 23/6/2021, prossima riunione con Referee 13/7/2021

# Sede degli esperimenti

## LEA Experiments

- AEgIS — $\bar{p}$ e+ Ps $\bar{H}$
- ALPHA — $\bar{p}$ e+ $\bar{H}$
- ASACUSA — $\bar{p}$ e+ $\bar{H}$ + atomi esotici
- PsICO — e+ Ps
- QUPLAS — e+ Ps





TIFPA-TN


LNESS-CO

A. Alexandrov[1], T. Asada[2], G. Baù[3,4], G. Bonomi[4,5], R.S. Brusa[6,7], A. Calloni[11] R. Caravita[7], F. Castelli[8,9], M. Cialdi[8,9], G. Costantini[3,4], G. Consolati[9,10], N. D'Ambrosio[2], G. De Lellis[1], R. Ferragut[9,11], M. Ferrari[3,4], V. Ferrari[3,4], S. Frabboni[12], G.C. Gazzadi[13], M. Giammarchi[9], G. Gosta[3,4], V. Grillo[13], M. Leali[3,4], G. Maero[8,9], S. Mariazzi[6,7], V. Mascagna[4,14], S. Migliorati[3,4], E. Pasino[8,9], L. Penasa[6,7], L. Povolo[6,7], F. Prelz[9], G. Pozzi[15,16], M. Romé[8,9], G. Rosi[17], L. Salvi[17,18], S. Sharma[7], A. Simonetto[21], L. Solazzi[4,5], F. Sorrentino[19] S. Stracka[20], G. Tino[17,18], V. Tioukov[1], V. Toso[9,11], M. Urioni[4,5], L. Venturelli[3,4], G. Vinelli[17,18], M. Volponi[6,7,22], N. Zurlo[4,23]

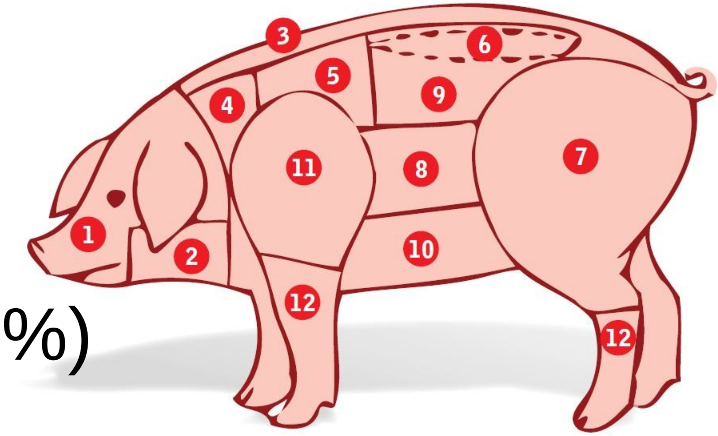
- 47 researchers
- 26 FTE
- 40% of FTE due to young people (PhD or post-doc) paid by institutes/universities
- 1 National Responsible and a Committee composed by 1 member for each experiment

N.B. The increase ot the partecipants will not significantly increase the Common Fund costs (mainly due to engagement in technological activities)

| EXPERIMENT | Researchers # |
|---|---|
| AEgIS | 12 |
| ALPHA | 3-4 |
| ASACUSA | 17 |
| PsICO | 8 |
| QUPLAS | 19 |

N.B: a researcher can be in more experiments

- FTE in ALPHA:
  - Germano Bonomi (UniBs, 30%)
  - Marta Urioni (dottoranda UniBs, 100%)
  - Simone Stracka (INFN Pi, 30%)




17 institutes, ~ 50 researchers

**SOME RESULTS ON ANTIHYDROGEN CONFINEMENT AND SPECTROSCOPY**

o) "*Trapped antihydrogen*" - Nature 468.7324 (2010)
o) "*Confinement of antihydrogen for 1,000 seconds*" - Nature Physics 7.7 (2011)
o) "*Resonant quantum transitions in trapped antihydrogen atoms*" - Nature 483.7390 (2012)
o) "*Observation of the hyperfine spectrum of antihydrogen*" - Nature 548.7665 (2017)
o) "*Observation of the 1S-2S transition in trapped antihydrogen*" - Nature 541.7638 (2017)
o) "*Observation of the 1S–2P Lyman-a transition in antihydrogen*" - Nature 561.7722 (2018)
o) "*Investigation of the fine structure of antihydrogen*" – Nature 578.375 (2020)

ANVUR

# Obiettivi di ALPHA

- Test di CPT con spettroscopia ottica e microonde (confronto H – Hbar su precisioni comparabili)
- Misure di g diretta (con anti-idrogeno)

- Real-life reenactment of Angels & Demons? (JK)

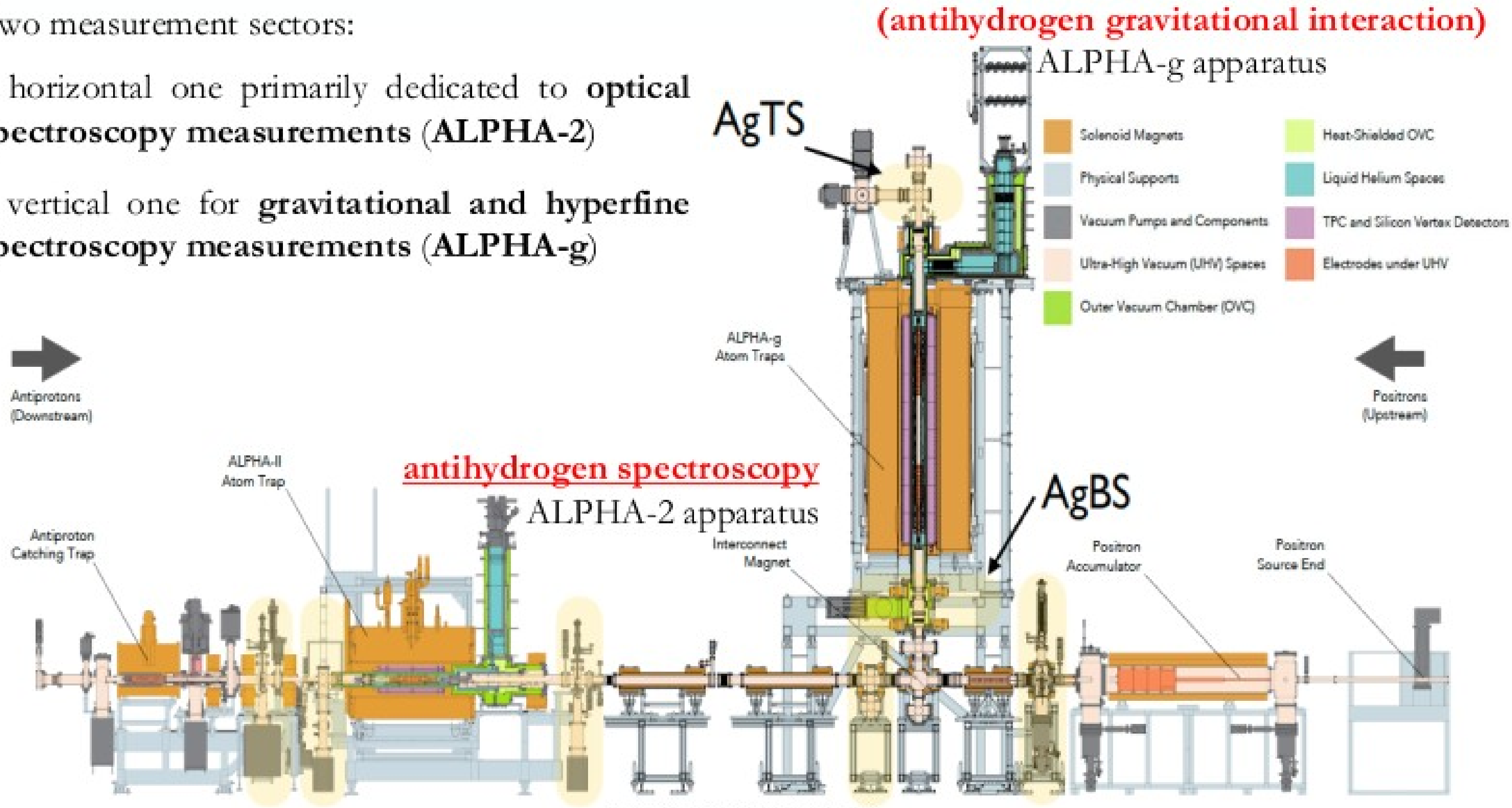
# ALPHA

ALPHA adopted a modular design, in which the antiproton-catching Penning trap is separated from the atomic-measurement regions

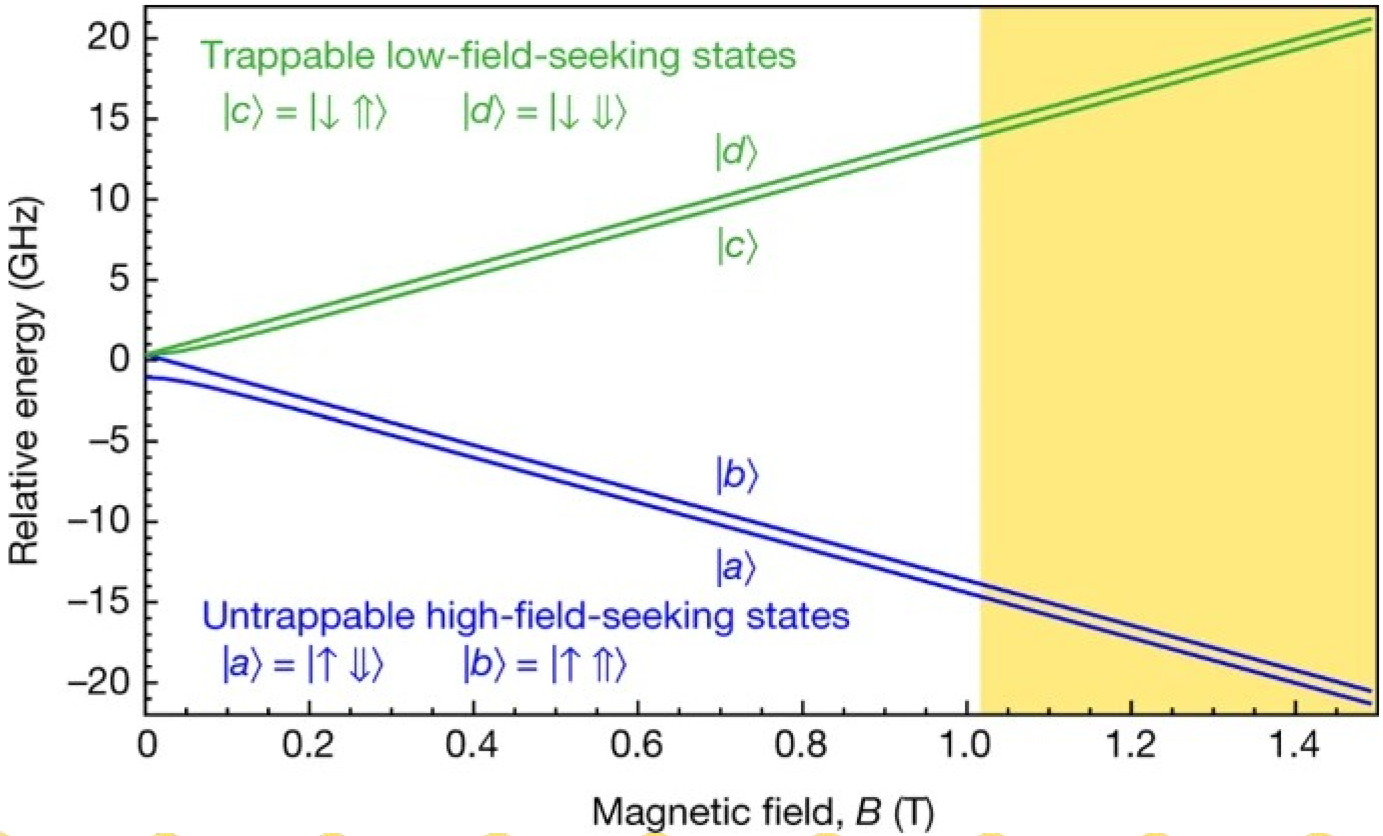
Two measurement sectors:

a horizontal one primarily dedicated to **optical spectroscopy measurements** (**ALPHA-2**)

a vertical one for **gravitational and hyperfine spectroscopy measurements** (**ALPHA-g**)



# Confinamento antiidrogeno



# ALPHA – breve-medio termine

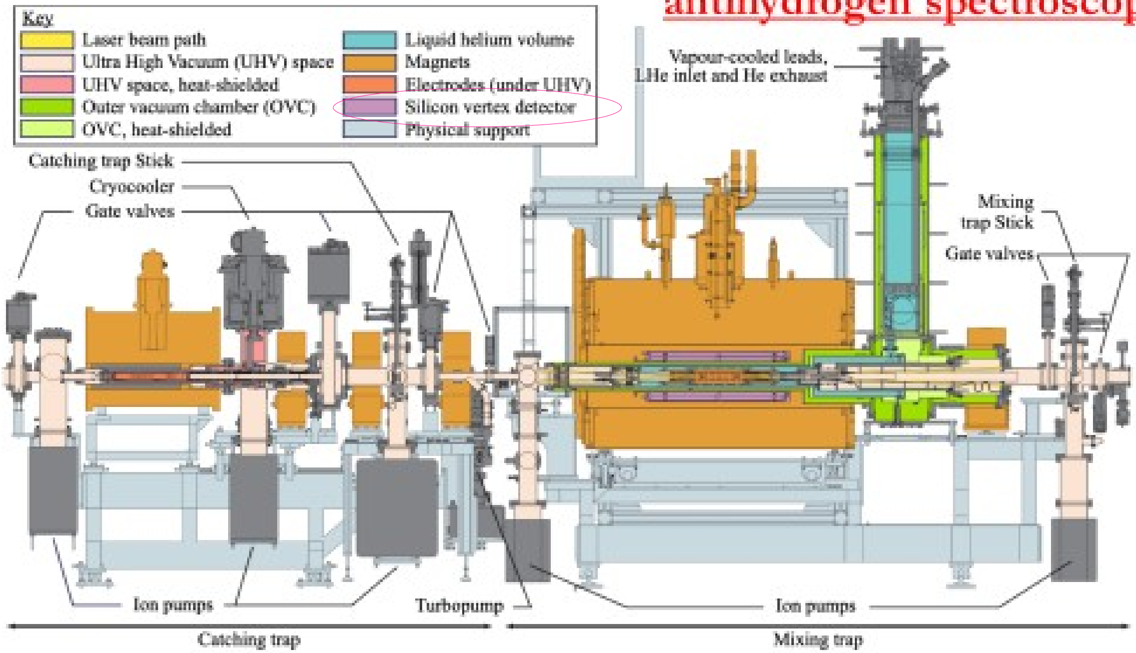
In parallel many improvements and upgrades to the spectroscopy apparatus for more stringent CPT tests. In particular:

o) **upgrade of the optical system** to allow for new laser wavelengths and installation of detectors for fluorescent light inside the cryogenic environment.

o) **new metrology initiatives** for ALPHA spectroscopy will be finalized in the next years. A new laboratory will house a hydrogen maser and the Cs fountain clock that will be used as a primary frequency standard for precision measurements.

ALPHA-2 (=> ALPHA-3) apparatus

antihydrogen spectroscopy




Laser cooling and metrology improvements could give **a factor of 10 improvement in 1S-2S precision** for the measurements in the period 2022-2025.

# ALPHA – breve-medio termine

The highest priority for the next years will be **the first experiments on antimatter gravity** (with the ALPHA-g apparatus). In particular:

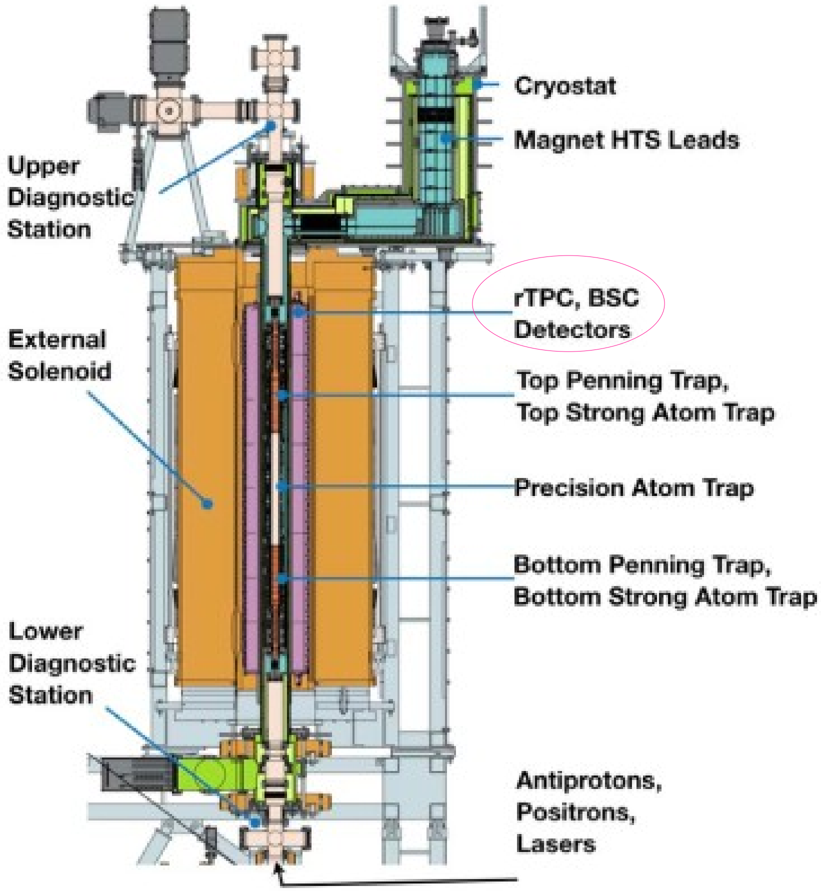
1) commissioning of the antiproton catching with ELENA

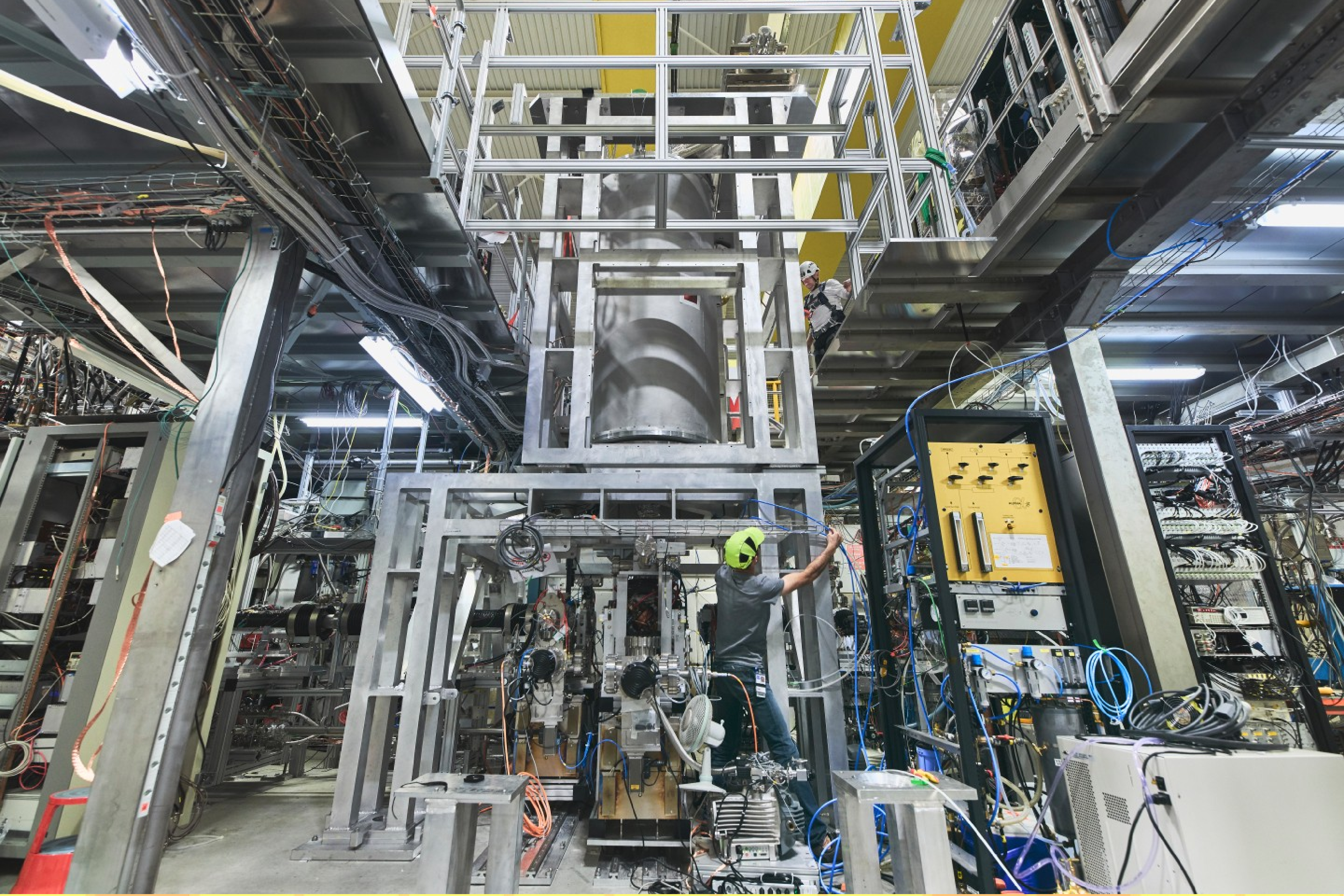
2) the first physics goal is to determine the **sign of the gravitational force**;

3) a more precise experiment is foreseen based on the results of the first measurement.

**(antihydrogen gravitational interaction)**

ALPHA-g apparatus

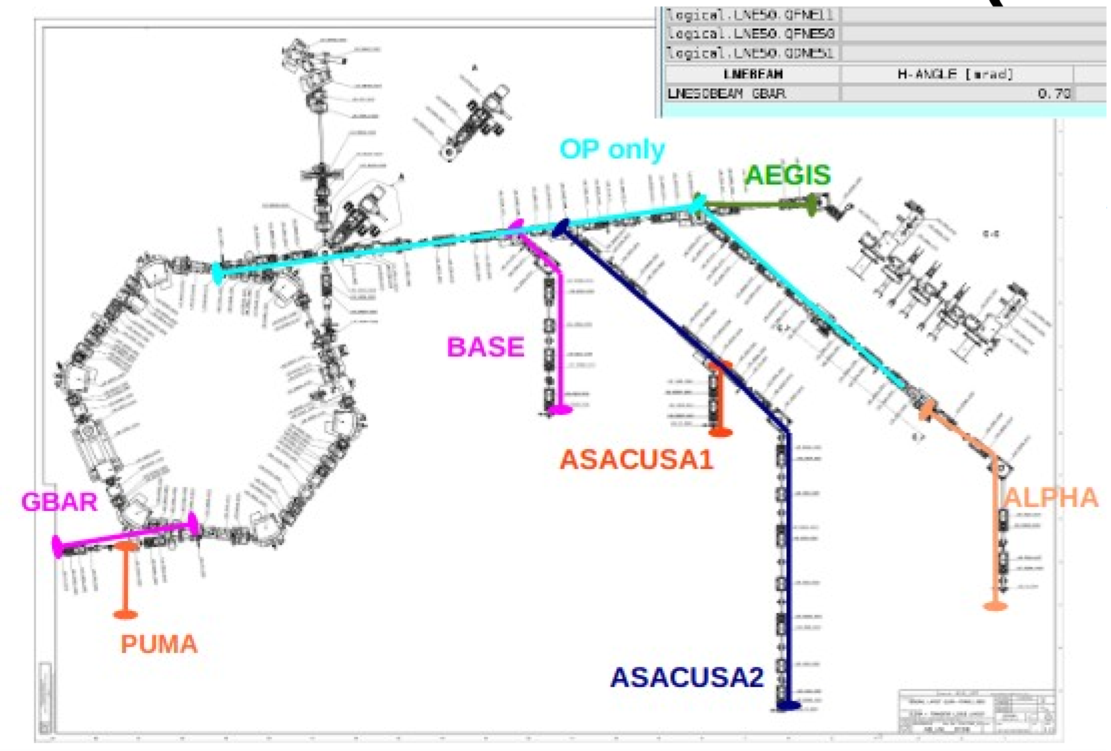




# ALPHA – wishlist misure (2022 - 2025)

| ALPHA | 2022 | | 2023 | | 2024 | | 2025 | |
|---|---|---|---|---|---|---|---|---|
| ELENA beamline and pbar trapping commissioning | x | | | | | | | |
| First measurement of matter-antimatter gravitational interaction (sign of g) | x | x | x | x | | | | |
| Metrology upgrades (hydrogen maser and cesium fountain clock) to achieve 10^{-13} absolute frequency accuracy | x | x | x | x | x | x | x | x |
| Improvements of the Lyman-alpha laser cooling (to achieve antiproton temperatures below 20 mK) | | | x | x | x | x | x | x |
| Precise measurements of matter-antimatter gravitational interaction (up to 1% accuracy) | | | x | x | x | x | | |
| Improvement of the 1S-2S transition measurement (x10) | | | x | x | x | x | | |
| Measurement of the d to c hyperfine [NMR - nuclear magnetic resonance] transition | | | | | x | x | | |
| Improvement of the 1S-2P transition measurement | | | | | x | x | | |

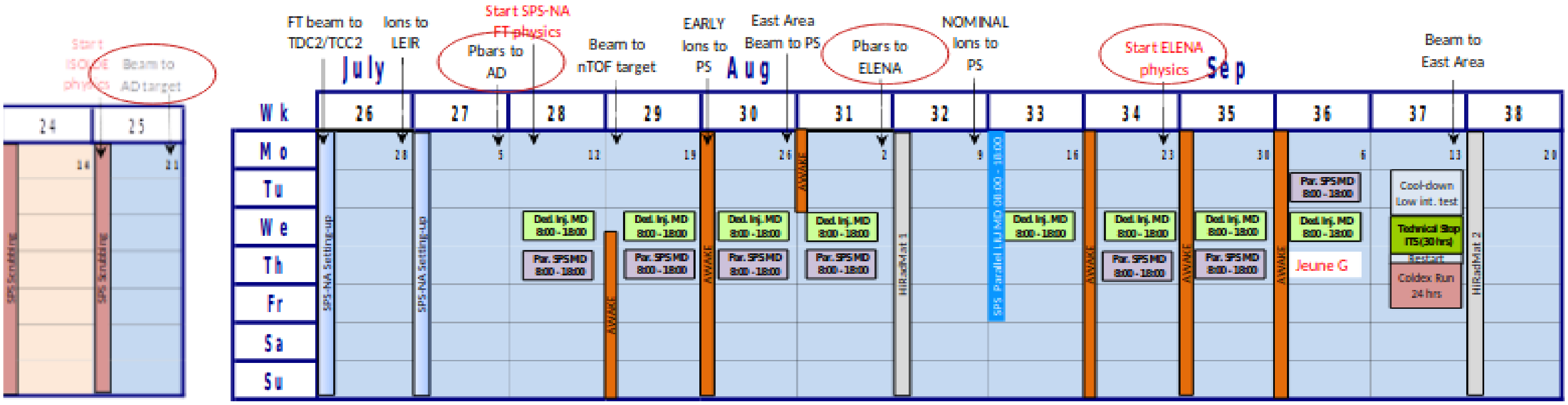
# ELENA (dopo LS2)




Extra Low Energy Antiproton ring

ELENA will serve up to 4 different users per cycle:

- no more 8 hours shift period dedicated to 1 user
- If not more than 4 users, can get beam 24/7



# Preventivi LEA 2022 (kEUR)

- Per ALPHA principalmente CF e missioni
- N.B. missioni ALPHA: esperimento nuovo (training) + turni di presa dati (ineludibili e a persona, non FTE) + 2 beamline + ELENA

| **Esperimento** | **Materiale + Common funds** | **Missioni** | **Commenti** |
|---|---|---|---|
| AEgIS | 125 | 55 | 11 m.u. @ CERN |
| ALPHA | 15 | 38 | 8 m.u. @ CERN |
| ASACUSA | 65 | 50 | 11 m.u. @ CERN |
| PsICO | 55 | 10 | 1 m.u. / FTE @ CERN |
| QUPLAS | 50 | 16 | Missioni Italia |
| **Totale** | **310** | **169** | |

| | 2022 | 2023 | 2024 | 2025 |
|---|---|---|---|---|
| AEgIS | 125 | 145 | 115 | 95 |
| ALPHA | 15 | 20 | 35 | 45 |
| ASACUSA | 65 | 35 | 35 | 30 |
| PsICO | 55 | 65 | 55 | 15 |
| QUPLAS | 50 | 50 | 40 | 30 |
| Total | 310 | 315 | 280 | 215 |

# Attività in ALPHA 2022

- Software (MC, DAQ, Analisi)
  - Allineamento, calibrazioni, …
- Commissioning, maintenance, e presa dati
- Per il 2022 non è previsto l'uso di risorse della sezione

Aug-Nov 2021: runs with ELENA (mainly for commissioning of the new apparatuses)

**2022-2024 physics at AD-ELENA**

2025 → LS3

After upgrades RUN4 (2027-2030)