Low energy antimatter research: perspectives

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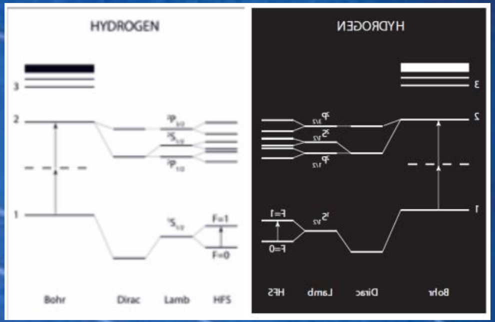
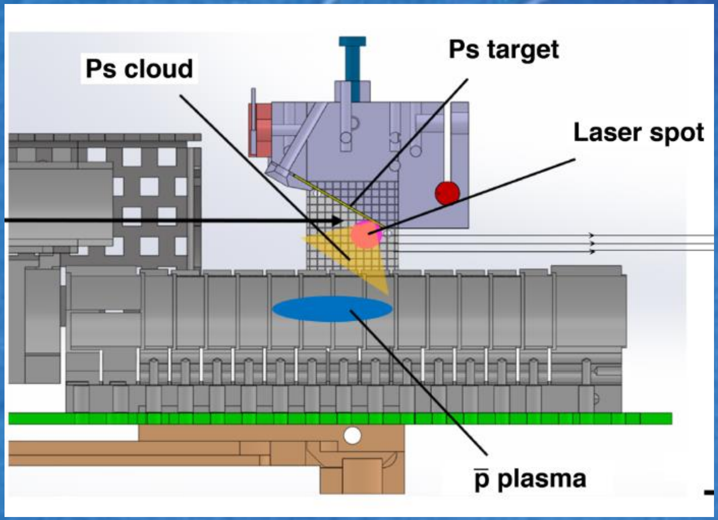
AEgIS antihydrogen

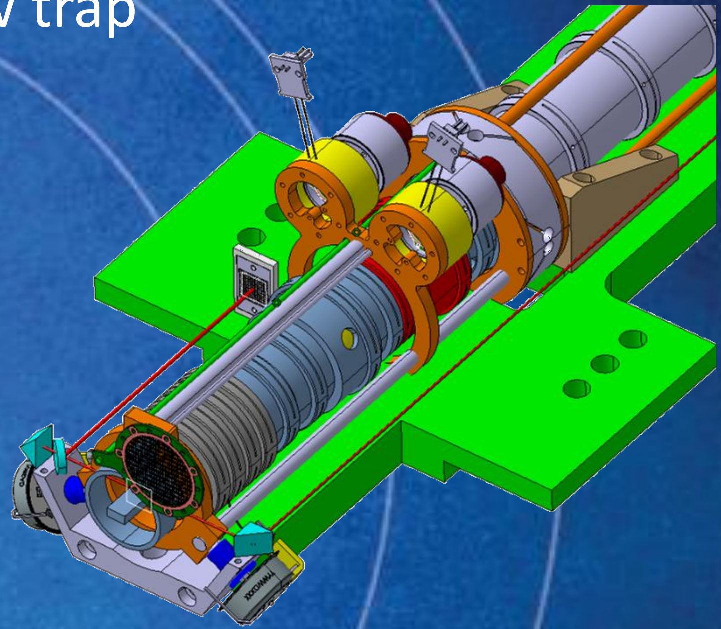
$$\bar{p} + Ps^* \rightarrow \bar{H}^* + e^-$$

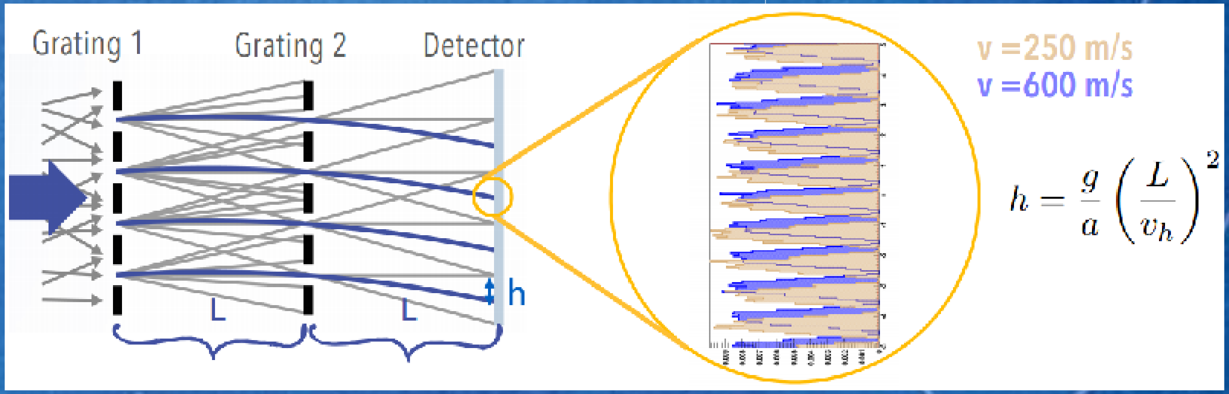


Old trap



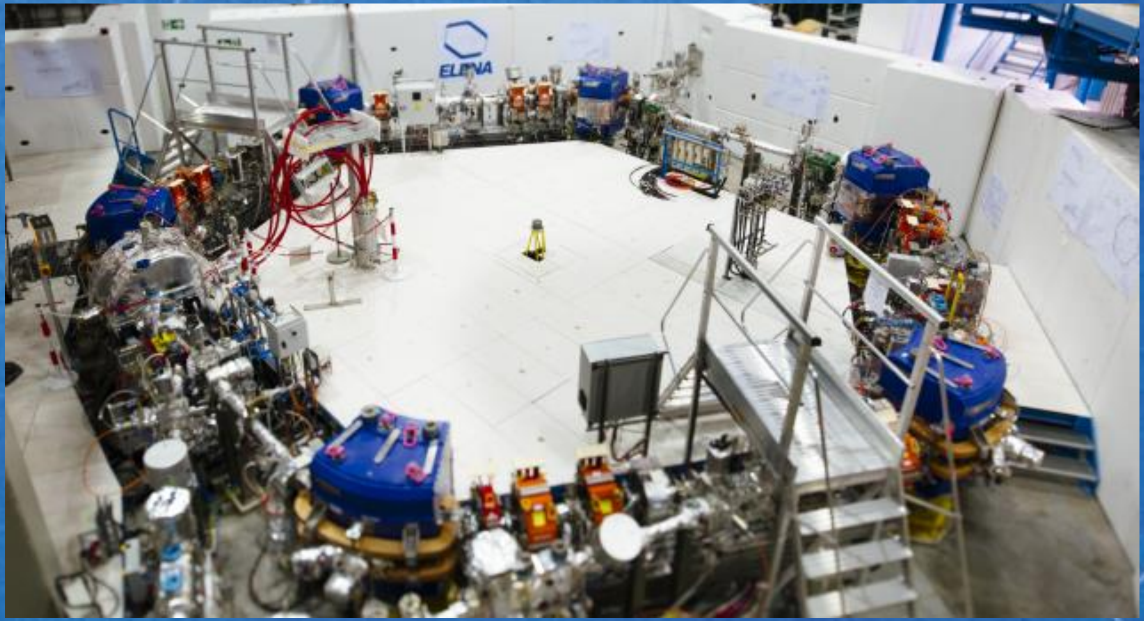
New trap





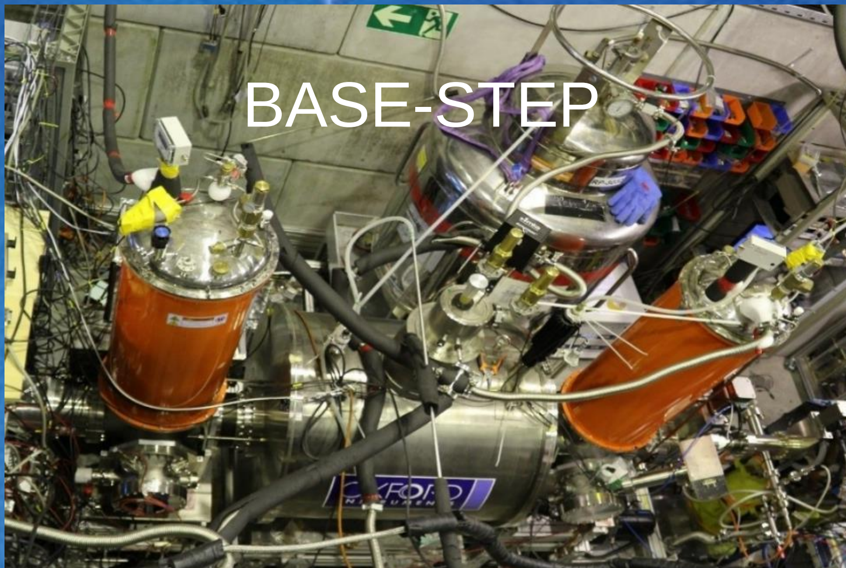
Antiproton Decelerator / ELENA

- Probing the Weak Equivalence Principle on antimatter:
  - ✓ gravity on neutral antimatter
- Search for CPT violation:
  - ✓ antihydrogen spectroscopy
  - ✓ antiproton magnetic moment
  - ✓ antiprotonic helium (masse of antiprotons)
  - ✓ antiproton Electric Dipole Moment

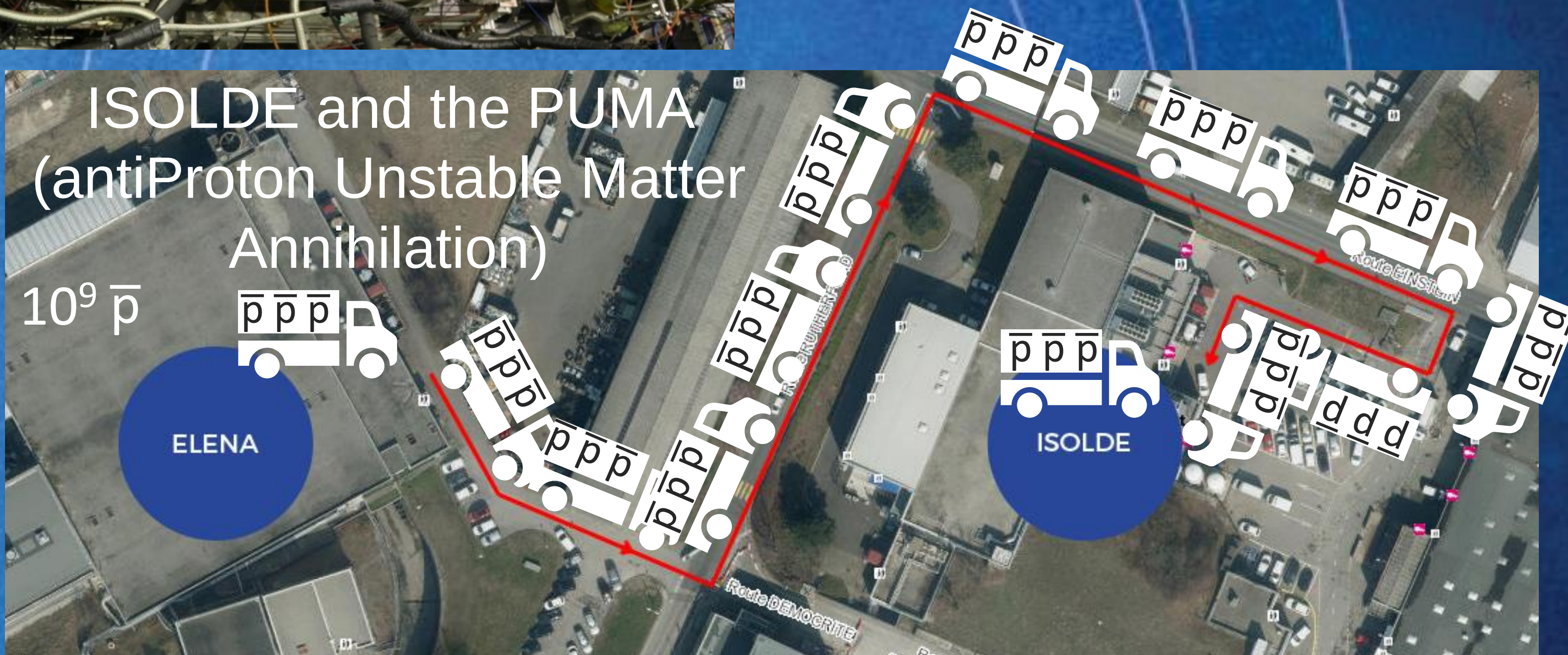


- Ps: purely leptonic system
- $\bar{p}p$ vs $\bar{p}d$ spectroscopy of Z=0 atoms

Nuclear physics with antiprotons



PUMA has the goal of forming antiprotonic atoms of short-lived radioisotopes in order to probe, through antiproton-neutron and antiproton-proton annihilation, the long distance tail of the nuclear potential for unstable nuclei.



Test of CPT for the strong interaction:

is the binding energy of antineutron the same as the binding energy of neutrons?

$$\bar{p}p \rightarrow \bar{n}n$$

$$^{A}_{Z}N + \bar{p} \rightarrow {}^{A+1}_{Z-1}N(\bar{n})$$

$$\Delta\left(m[^{A}_{Z}N] + m[\bar{p}] - m\left[^{A+1}_{Z-1}N(\bar{n})\right]\right) > 0$$

Reaction	Final state energy (u)
$^{7}Be + \bar{p} \rightarrow$ " ^{8}Li"	0.0022u
$^{8}B + \bar{p} \rightarrow$ " ^{9}Be"	0.0202u
$^{11}C + \bar{p} \rightarrow$ "^{12}B"	0.0049u
$^{13}N + \bar{p} \rightarrow$ "^{14}C"	0.0103u
$^{24}Na + \bar{p} \rightarrow$ "^{25}Ne"	0.0004u

Reaction	Final state energy (u)
$^{33}P + \bar{p} \rightarrow$ "^{34}Si"	0.0004u
$^{40}Ca + \bar{p} \rightarrow$ "^{41}K"	0.008u
$^{212}Rn + \bar{p} \rightarrow$ "^{213}At"	0.0051u
$^{216}Th + \bar{p} \rightarrow$ "^{217}Ac"	0.009u

M. Doser, «Antiprotonic bound systems,» review (2022)

Production of slow antineutrons

$$^{A}_{Z}N + \bar{p} \rightarrow {}^{A+1}_{Z-1}N + \bar{n}$$

E($\bar{n}$) down to 375keV compared to >100MeV

$$\Delta\left(m[^{A}_{Z}N] + m[\bar{p}] - m[^{A+1}_{Z-1}N] - m[\bar{n}]\right) > 0$$

Reaction	Final state energy
$^{8}B + \bar{p} \rightarrow$ " $^{8}Be + \bar{n}$"	0.0018u
$^{11}C + \bar{p} \rightarrow$ "$^{11}B + \bar{n}$"	0.0007u
$^{15}O + \bar{p} \rightarrow$ "$^{15}N + \bar{n}$"	0.0016u
$^{18}F + \bar{p} \rightarrow$ "$^{18}O + \bar{n}$"	0.0004u
$^{22}Na + \bar{p} \rightarrow$ "$^{22}Ne + \bar{n}$"	0.0015u
$^{211}Rn + \bar{p} \rightarrow$ "$^{211}At + \bar{n}$"	0.0013u
$^{216}Th + \bar{p} \rightarrow$ "$^{216}Ac + \bar{n}$"	0.0009u

M. Doser, «Antiprotonic bound systems,» review (2022)

Conclusion

- Weak equivalence principle on antihydrogen and positronium
- Spectroscopy of protonium
- Antiprotonic atoms to test CPT for the strong interaction

Additional slide

$$^{7}Be + \bar{p} \rightarrow "\,^{8}Li"$$
$$m[\,^{7}Be] = 7.01692u$$
$$m[\,^{8}Li] = 8.02249u$$
$$\Delta\left(m[\,^{7}Be] + m[\bar{p}] - m[\,^{8}Li]\right) = 0.0022u$$