Antimatter Factory

Yoshio YAMAGUCHI

Theoretical Physics Laboratory, RIKEN, 2-1 Hirosawa, Wako, Saitama 351-0198, Japan

It is intended to plan a facility to produce antinuclei and antiatoms as much as heavy (Antimatter Factory).

Antinuclei up to mass number $A = 3$ have been created at CPS, AGS and U-70. Antialpha particles are not yet detected, even though present high energy accelerators/colliders, such as SPS, Tevatron, RICH and LHC, are able to produce, energetically and in principle, much hevier antinuclei, antinucleus production (with anti mass number A) shall be exponentially more difficult with increasing A. This is because hot-spot (fire ball) formed by high energy collisions could produced as many anti-baryons (anti quarks) as compared to baryons (quarks), but emitted hadrons from the surface (hadronization) layers of fire balls shall be dominantly mesons, barions and their antis, only tiny parts of anti barions can form $\overline{d}$, $^3\overline{H}$, $^3\overline{He}$.

To investigate seriously the difference, if any, among matter (nucles, atoms, ...) and antimatter, we may wish to have various antinuclei ($A \geq 4$) and antiatoms. High energy accelerators/colliders at presently running are not able to produce $^4\overline{He}$ and heavier antis. Then it may be better to try to cook heavy nuclei from accumulated antiprotons. In a way our synthesis looks similar to primordial nucleo synthesis just after the Big Bang and nuclear synthesis at central zones of main sequence stars.

However there exist several differences. We can not store antineutrons $\overline{n}$. We can not rely on weak and radiative processes, such as $\overline{p} + \overline{p} \rightarrow \overline{d} + e^- + \overline{\nu_e}$, (p, γ) reactions. Production ratio $\overline{d}/\overline{p}$ at high energies is small $\sim 10^{-3}$. Therefore, it seems we must first mass-produce $\overline{d}$ from $\overline{p}$. Such a production method has already been proposed at GSI, utilizing the reaction $\overline{p} + \overline{p} \rightarrow \overline{N} + \overline{\Delta} \rightarrow \overline{d} + \pi^-$ with the energetically asymmetric $\overline{p} - \overline{p}$ collider. After enough accumulation of $\overline{d}$, $\overline{p} + \overline{d}$ and $\overline{d} + \overline{d}$ shall produce $^3\overline{H}$, $^3\overline{He}$. $\overline{d} +^3 \overline{H}$ and $\overline{d} +^3 \overline{He}$ will produce $^4\overline{He}$. Repeated use of ($\overline{d}, \overline{p}$) and ($\overline{d}, \overline{n}$) we may cook heavire nuclei.

To realize these nuclear reactions we need storage rings (and colliding zone) of several 100 MeV/c and relevant bending magnets.

Such facility, consisting of set of asymmetric colliders (a few GeV/c and a few 100 MeV/c) and beam transports, beam cooling parts, if constructed, may be useful to measure cross sections of many nuclear reactions (including radiative capture process) relevant to nucleo synthesis after Big Bang and of astrophysical importance. Such measurement may also serve to the Fusion Projects for energy production.

Furthermore, μ^+ catalyzed fusion may be tried to produce very light antinuclei.

This facility may cost substantially. But there must be many (used part of) colliders and detectors, already shut down, in the world. Economical use of such parts is the way to cost down.

Eventually I wish to see the synthesis of nuclei (atoms) up to the heaviest. Very accurate test of properties of antinuclei (atoms) must uncover something new different from nuclei (atoms), beside the accurate check of CPT theorem, etc.