茨城大学素粒子論研究室セミナー

講師：萩原 薫 氏 (KEK 名誉教授)
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教室：@E301

Title: Discovering the toponium at the LHC

概要

The toponium is the color-singlet bound state of top and anti-top quarks, just like the bottomonium and charmonium states which were discovered in the 70's.

The ground state mass is predicted to be about 2 GeV below the ttbar pair production threshold: $m(toponium) \approx 2 * mtop - 2GeV$

Its properties, however, are very different from those of the known heavy quarkonion, mainly because of its large decay width of 3 GeV, which is twice the top quark decay width.

Because of the dominant top and anti-top decays, all annihilation decay branching ratios into gg, $\gamma\gamma$, W^+W^-, etc are strongly suppressed.

In addition, the large width covers the whole range of radial excitations and P-wave states which are predicted to exist within about 1 GeV below the threshold.

Its formation and decay has been studied extensively for the future e^+e^- colliders, but little has been known for its impacts at the LHC, except for a rise in the $t\bar{t}$ production cross section at the threshold, which is less than a percent of the total $t\bar{t}$ events. (arXiv:0804.1014 and arXiv:1007.0075)

I would like to explain how I could identify the 3-sigma anomaly in the di-lepton distributions in the 2019 data as a possible signal of toponium formation at the LHC.

Refs) B.Fuks et al, arXiv:2102.11281 and arXiv:2411.18962

Basic knowledge to understand physics of toponium may be as follows

1. Angular momentum of two spin 1/2 states in quantum mechanics

2. Bohr level and radius of hydrogen atom

3. Charge conjugation parity of ortho- and para-positronium

4. Shroedinger equation for Hydrogen atom & positronium
5. Shroedinger equation for charmonium and bottomonium
6. Green function of non-relativistic QCD Hamiltonian (Fadin-Khoze, 1987)
7. Lorentz transformation of spin 1/2 particles in the chiral representation
8. Helicity amplitudes and spin polarization density matrix

I will try to explain each item clearly in my blackboard talk.