# Ultra-High Energy Proton-Proton Collision in the Laboratory System as the Source of Proton, Neutrino and Gamma Spectra in Astrophysics

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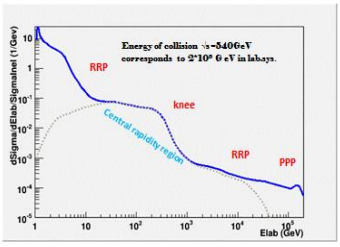
## Abstract

This paper argues that production, collisions, and decays of matter in space result in the form of particle spectra, which are measured in cosmic rays and astrophysics. Protons, nuclei, and dark matter are the known forms of matter in the Galaxy. If we understand how a high-energy proton produces protons in the collision with another proton (or antiproton), we can predict the form of the spectra of secondary particles. This is also the way to clarify the nature of Dark Matter(DM). LHC experiments can provide us with the proton spectrum at the very high energy (VHE) of collision. The suggested method means only to convert this spectrum into the laboratory system of coordinates and to compare it with the spectra of various CR particles. It has been shown that spectra of neutrino and cosmic protons reproduce the form of proton production spectrum at the single collision of the initial proton of ultra-high energy (UHE), which was predicted in Quark-Gluon String Model. The gamma spectrum from Cignus-X3 does not show such specifics, because it is initiated by the production spectrum of $\pi^0$ mesons of lower energies. Though, the spectrum in the entire diapason of gamma energies has distinct bump at the highest energy that is the signature of proton-proton collision.



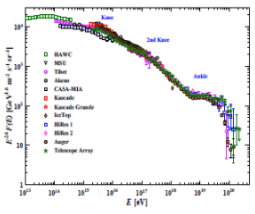
## Specifics of proton spectrum in laboratory system: the "knee" and a bump at VHE






## CR particle spectrum at UHE

Particle Data 19: spectrum-cosmic-rays.pdf




The all-particle spectrum as a function of E (energy per nucleon



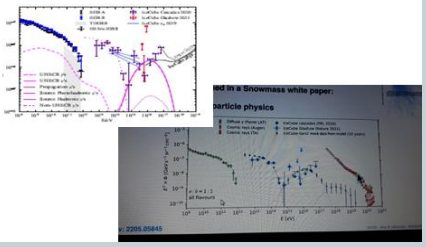
## Outline

- The form of proton spectra within the Quark-Gluon Model : the components of proton spectrum in c.m.s. at √s = 540 GeV: central rapidity table, diquark contribution and triple-pomeron peak
- The procedure of spectrum transfer from c.m. system to laboratory system
- The specifics of proton spectrum in laboratory system: the "knee" and a bump at UHE
- The all-particle spectrum from CR measurements
- Expectations for the spectra of ν's and γ's – recent measurements at UHE
- Gamma spectrum from Cygnus-X3 (1990) as the result of $\pi^0 \rightarrow 2\gamma$ decay
- Entire-range gamma radiation and a bump at the edge of spectrum
- Conclusions



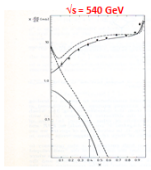
## Probing the environments surrounding ultrahigh energy cosmic ray accelerators and their implications for astrophysical neutrinos

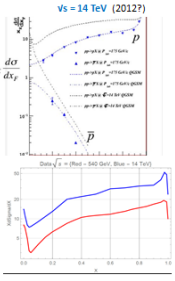
M.S. Musio, G.R. Farrar and M. Unger ArXiv.org: 2108.05512






## Misleading prediction of spectrum for LHC at 14 TeV



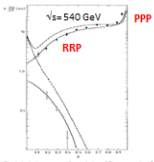




A remark about the predicted spectrum: the spectra should not be just shifted up, they are to be transformed with energy due to the different contributions (vacuum pairs, walking diquark and triple-Pomeron peak).



## The components of proton spectrum

A.B. Kaidalov and O.Piskunova, Zeit. Phys. C**30** (1986), 145




1. Proton production at x = 0 from vacuum diquark - antidiquark pairs is growing with energy
2. The contribution of walking diquark from beam proton (**RRP** term) should decrease with energy
3. Triple-Pomeron peak (**PPP** term) is the permanent contribution from slowed down beam proton.

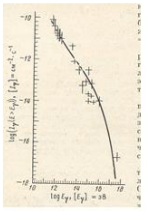
At ultra high energies (UHE) we will have only the fall down from central rapidity "table" and **the visible bump at the end of distribution**



## Gamma spectrum from Cygnus-X3 as the result of $\pi^0 \rightarrow 2\gamma$ decay (1990)

O.I. Piskunova, Sov.Jou. of Nucl. Phys. **51** (1990) 1332

T.C. Weeks and M.F. Cawley, Astrophys. J. **296** (1984)185





## Conclusions

The hadroproduction spectra **in laboratory system** have the power slope.

Each next interaction brings $E^{-1}_{lab}$ to the spectrum .

Proton spectrum has the spesifics: the growing central rapidity density, the triple Pomeron peak at the highest energy and diquark contribution in between.

Proton energy distribution in space are bringing similar spesifics: knee as the central rapidity table, the bump near the end from the triple Pomeron peak, and the second knee because of degenerating contribution of diquark at VHE.

All this observed features tell us that **protons play important role in the particle production in space.**

Secondary particle spectra (neutrino, gamma etc.) reproduce the features of proton spectrum in proton-proton collision.

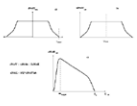
The main implications for astrophysics:
UHE protons appear from relativistic jet bursts as a result of deconstruction of baryonium DM. Such DM is to be packed in SMBH with great potential energy (or with huge hidden mass). The released energy is spent for giving to proton an energy of order $E_p \sim 10^{20}$ **GeV**

The details of suggested **baryonium DM** have been discussed in the preprint:
O. Piskounova, 1812.02691



## Procedure for the transfer to lab. system

### Formulas for spectrum transfer to lab. system



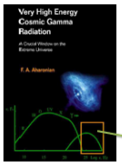
1) $d\sigma/dy = x d\sigma/dx$

2) $d\sigma/dE_{lab} = d\sigma/dy_{lab}/E_{lab}$

For the proton-proton collision the produced proton spectra have the complicated view due to triple-Pomeron peak (PPP).



## Entire-range photon radiation and a bump at the end of spectra




Aharonian F.A., Very High Energy Cosmic Gamma Radiation, Crucial Window on the Extreme Universe, World Scientific Publishing, 2004