COLLECTIVE PHENOMENA IN PP INTERACTIONS WITH HIGH MULTIPLICITY

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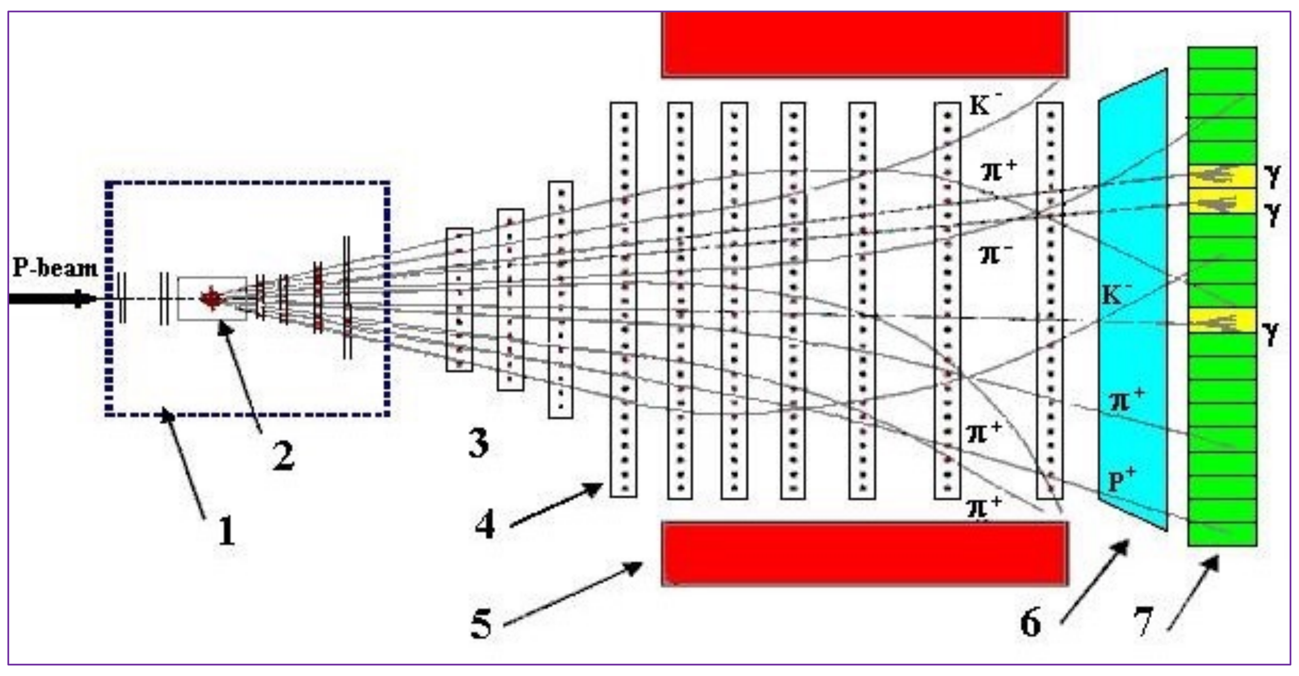
Dedicated to the memory of Kuvshinov Vyacheslav

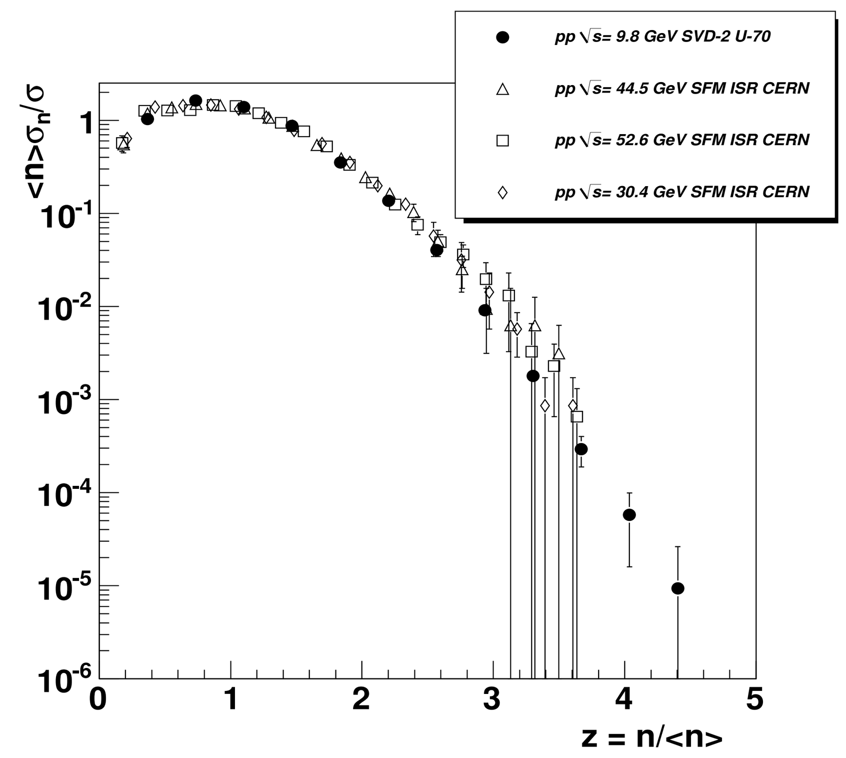
Multiparticle processes is still an actual direction in high energy physics. In high-energy collisions of protons a state consisting of quarks and gluons is formed. We are interested events with high multiplicity. These events are extremely rare. The average multiplicity (the average number of charged particles) producing at proton-proton collisions grows slowly as a logarithm of energy.

Our experiment has been prepared and carried at the U-70 accelerator (IHEP in Protvino). It was aimed at studying of multiparticle production in the region close to the threshold production when almost all kinetic energy of colliding protons spend on the creation of secondaries. At the 50-GeV/c proton beam incident on a hydrogen target, mostly pions are produced, both charged and neutral. Their maximum number is about 59.

We have registered events with multiplicity significantly exceeding the average multiplicity (three or more times). These events are interesting in that one can find in them a manifestation of collective behaviour of secondaries. There are quite a few theoretical predictions that indicate at such phenomena as the pionic (Bose-Einstein) condensate formation, Cherenkov radiation gluons, soft photon excess yield and others.

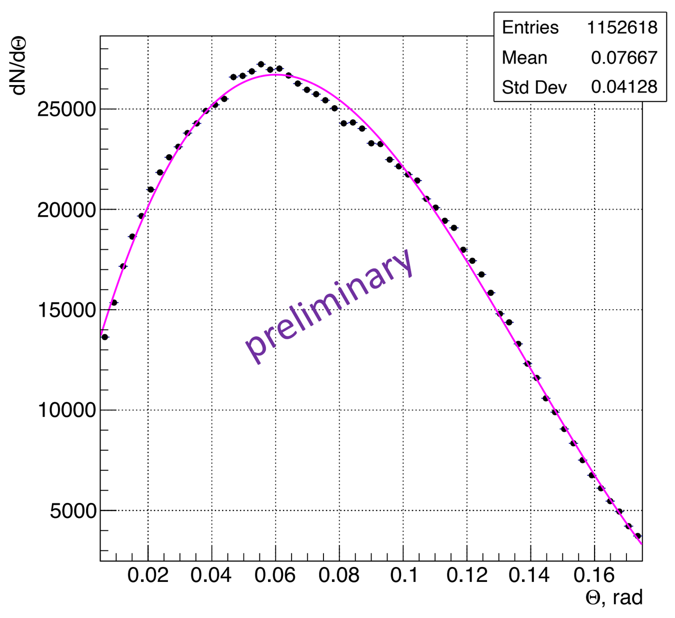


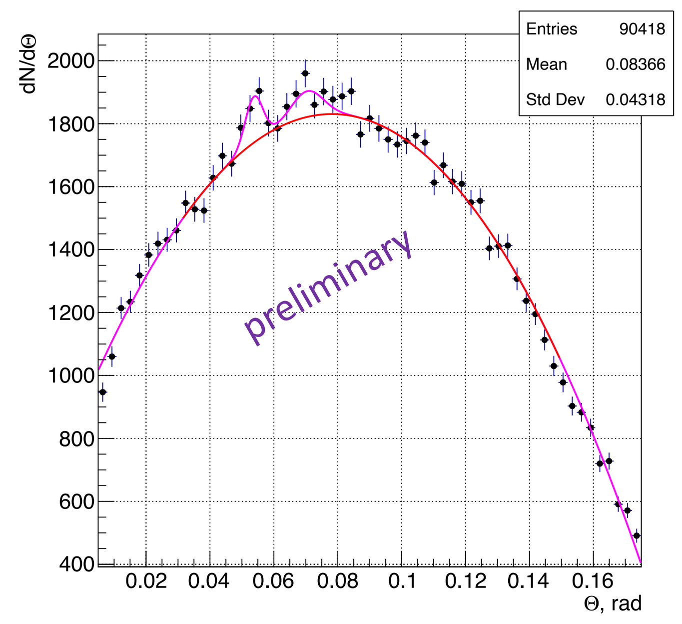
SVD-2 setup: 1 - Si- detector, 2 - H_2-target, 3 - straw tube chambers, 4 - proportional chambers, 5 - magnet, 6 - Cherenkov counter, 7 - electromagnetic calorimeter.



The world KNO distribution with addition of the SVD-2 points (9.8 GeV).

The distributions on the polar angle in two different region of multiplicity have shown that in the high multiplicity region we can observe the two-humped structure which we tried to connect with Cherenkov radiation of gluons. Using formulas for this radiation we calculate the refraction index.





The last measurements of a map of the magnetic field in the magnetic spectrometer and using of the improved algorithm for momentum reconstruction allowed us to present the updated results:

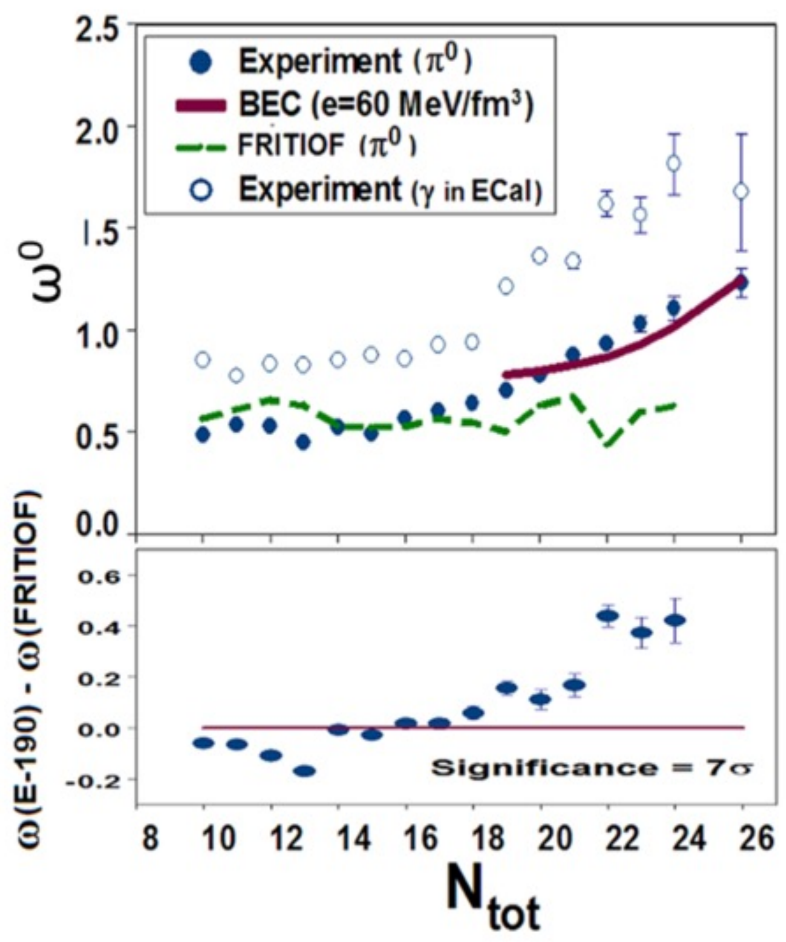
(Left) Polar angle distribution for $N_{ch} > 13$ (fit of two peaks by Gauss function, second degree polynomial for background.

(Right) Polar angle distribution for $N_{ch} > 13$.

Using Cherenkov's formula we estimate the refraction index of medium. Let Θ is the angle between directions of primary and secondary tracks. The position of the left peak is equal to $\Theta_{Cher} = 0.05377 \pm 0.00273$ rad with confidence 3.1. For gluon rings, $\cos\Theta = 1/\beta n_r$, where n_r is the refraction coefficient. For 50 GeV/c have for the left peak $n_r = 1.0016 \pm 0.0001(4)$, i.e. nuclear medium is highly rarefied.

Evidence of Bose-Eintstein condensate formation

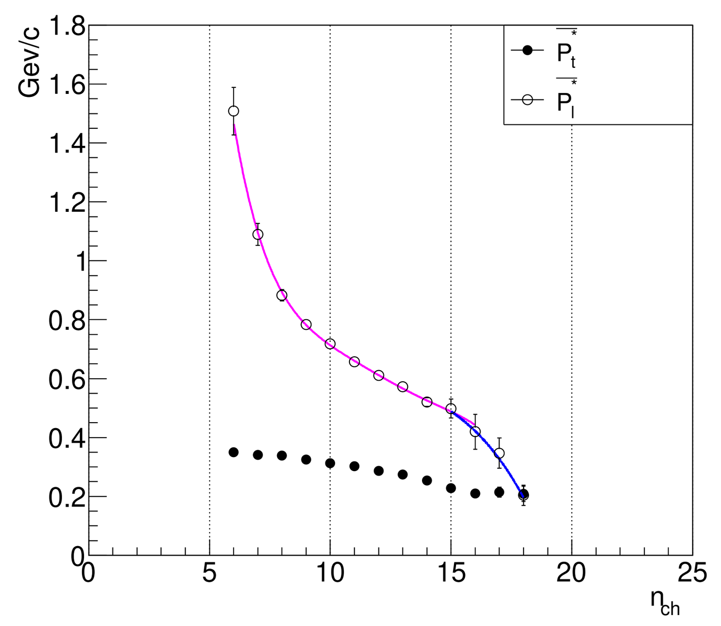
According to Gorenstein-Begun predictions the growth of the scaled variance, $\omega^0 = D/\langle N_0\rangle$ (D-variance of number of neutral pions, $\langle N_0\rangle$ - their average multiplicity at given total multiplicity, N_{tot}) evidences the pionic condensate formation. Our experimental data show a significant growth of ω^0 beginning from $N_{tot} = N_{ch} + N_0 > 18$. See Fig. below.

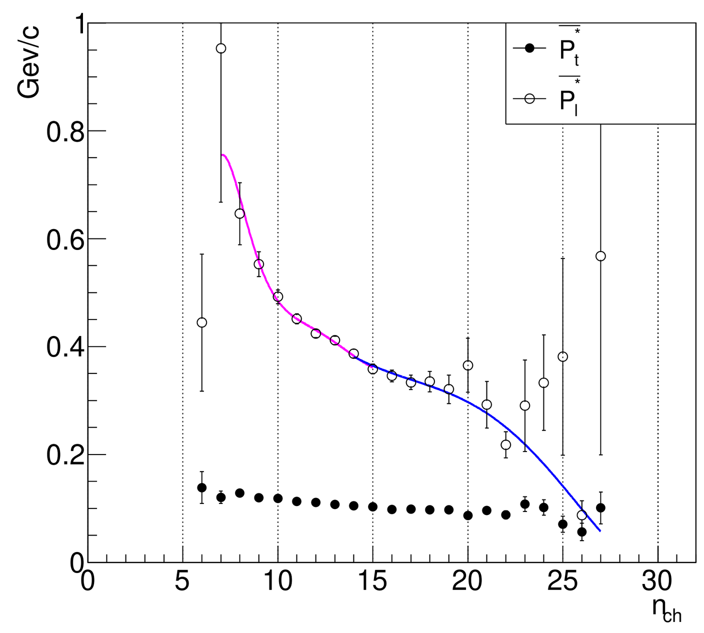


(Top) The measured scaled variance ω^0 versus N_{tot} for π^0-mesons, photons, Monte Carlo code FRITIOF7.02 (the dashed curve) and theoretical prediction (solid curve) (Gorenstein-Begun.

(Bottom) The difference of experimental and the Monte Carlo prediction for π^0-mesons.

We determine the critical region of multiplicity as the region at which both components of momentum (transversal & longitudinal) become indistinguishable with growing of multiplicity





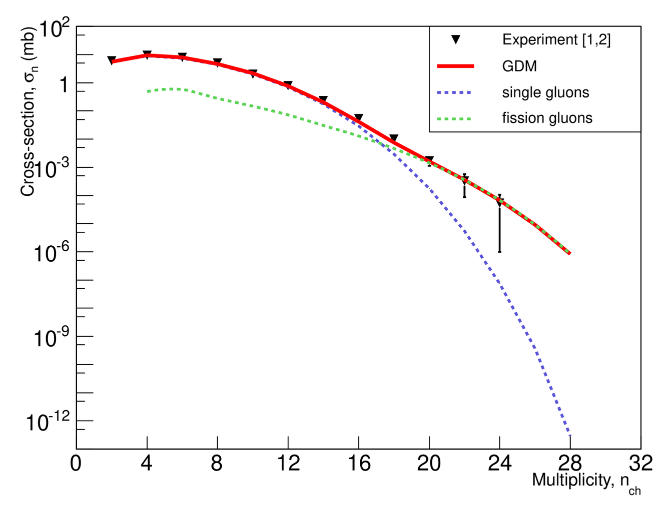
(Left) The average values of longitudinal and transverse components of momentum of charged particles versus multiplicity recovered in Si-detector with the correction for simulative by PYTHIA 8. Red line describes p^*_l for $N_{ch} < 16$ (crossing of components), blue line – more than 16.

(Right) The same dependences for experimental 2008 run data with multiplicity corrections. The region of red and blue lines crossing corresponds to the critical multiplicity.

Our conclusion: at $N_{tot} > N_{crit} = 18$, ω^0 begins its growth. We expect the Bose-Einstein (pionic) condensate formation in the region $N_{tot} > N_{crit}$. At that the effect of leading disappears and the system of secondary particles becomes isotropic in all directions.

Phenomenological description of high multiplicity events by the gluon dominance model (GDM)

We designed the gluon dominance model (GDM). It is a modification of two-stage model for e+e- annihilation and presents convolution of a QCD branching gluons and their following hadronization. Gluon parameters in pp increase as opposed to e+e- annihilation that is the evidence of the implementation of the recombination mechanism of hadronization in quark-gluon medium but not in vacuum. The main sources of secondaries are active gluons and their branching leads to events with high multiplicity.



Topological cross sections σ_n vs charged multiplicity n_{ch} in the GDM model. Blue line describes the contribution of single gluons, green line gluon sources consisting of two gluons of branching, red line is their superposition.