

# Evidence for a pion condensate formation in pp interactions at U-70

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## Search for collective phenomena at High Multiplicity (HM) region

Bose-Einstein Condensation (BEC),  
anomaly soft photon yield,  
shock waves (Čerenkov radiation),  
fluctuations, correlations ...

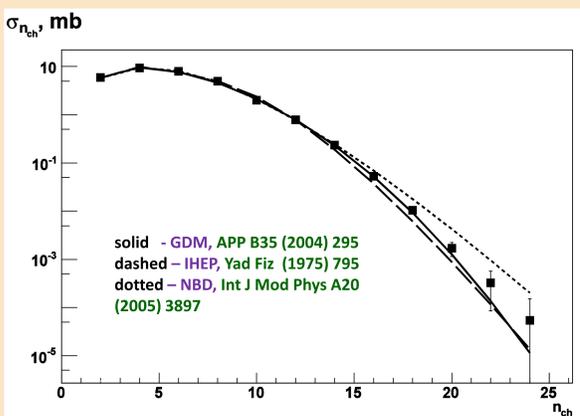
U-70, IHEP, Protvino, Russia  
 $p + p \rightarrow 2N + N_\pi, p = 50 \text{ GeV}/c$

Experiment SERP-E-190

Table 1. Topological cross sections of pp interactions at 50 GeV/c. SVD Collaboration.

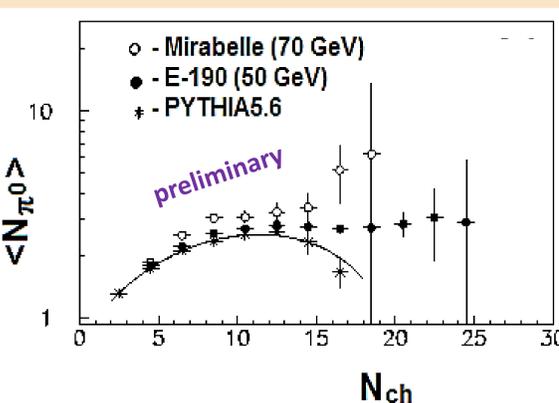
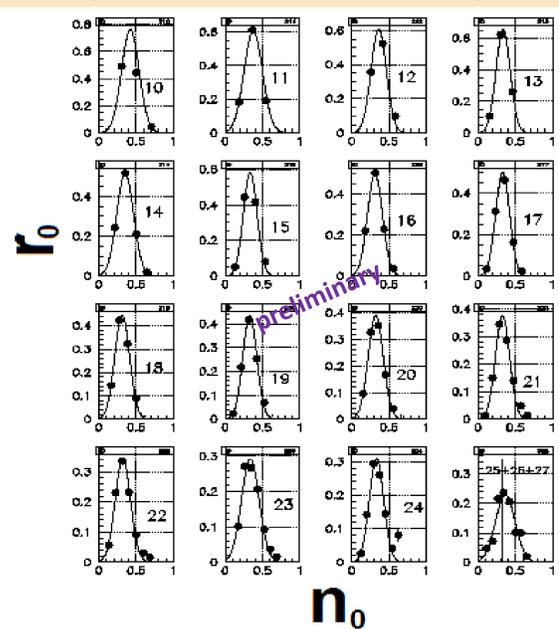
The corrections for acceptance detectors, HM trigger and efficiency have been taken into account. Phys.Part.Nucl.Lett. 8 (2011); ЯФ,75 (2012)

$n_{ch}$	10	12	14	16	18	20	22	24
$\sigma, \text{mb}$	1.685	0.789	0.234	0.0526	0.0104	0.0017	0.00033	0.000054
$\Delta\sigma, \text{mb}$	0.017	0.012	0.006	0.0031	0.0014	0.0006	0.00024	0.000098



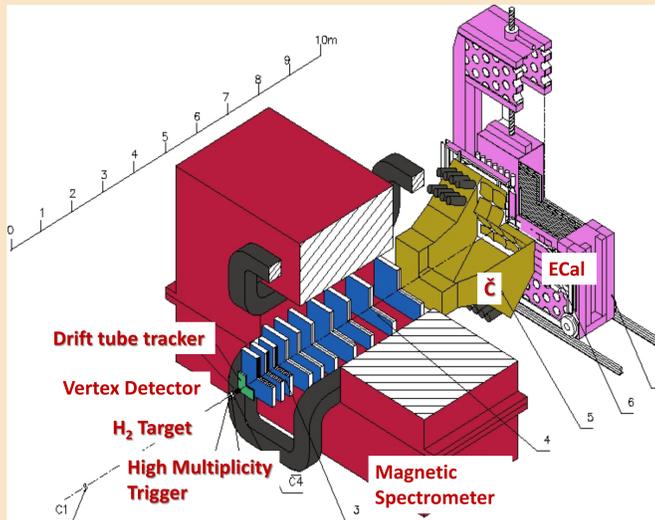
Inclusion of a gluon fission in Gluon Dominance Model (GDM) improves description of  $\sigma(n_{ch})$  at the HM

## Experimental distributions of scaled multiplicity n for given $N_{tot}$ (10, 11, ..., 24, 25+26+27)



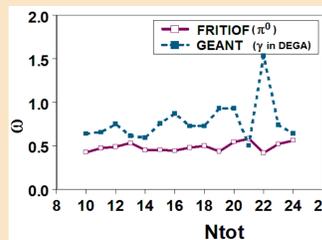
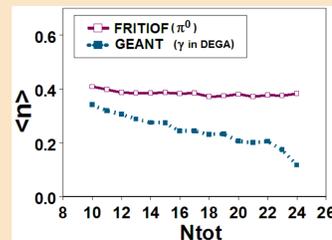
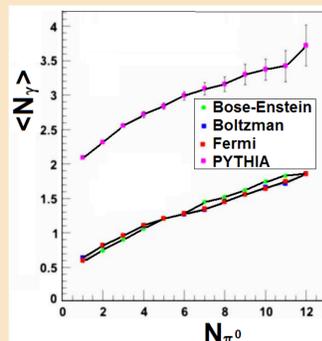
~50% of initial energy turn into mass at HM

## SVD-2 (Spectrometer with Vertex Detector)



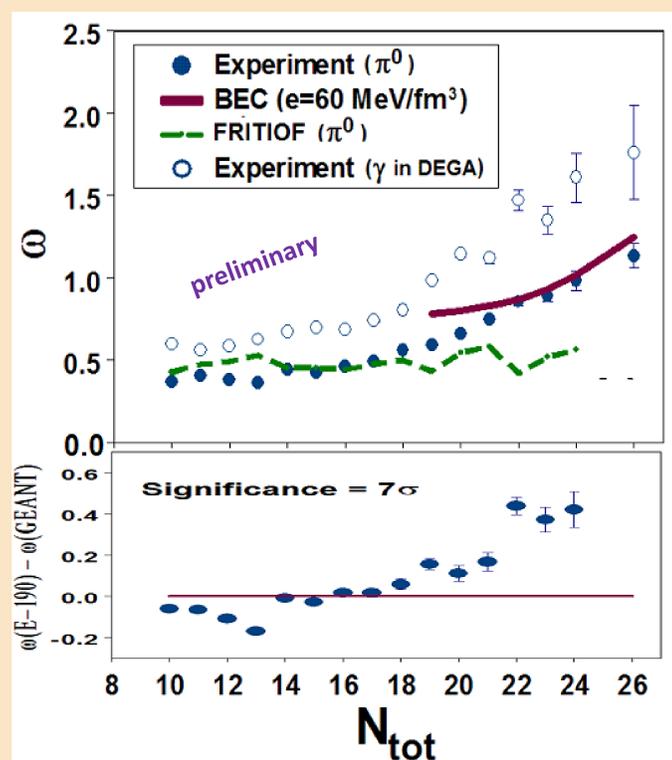
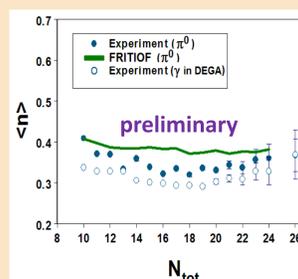
## Simulation of neutral pion detection

$n = N_0/N_{tot}, n \in [0,1]$ ,  
scaled multiplicity;  
 $r(N_0, N_{tot}) = N_{ev}(N_0, N_{tot})/N_{ev}(N_{tot})$ ,  
probabilities at fix  $n_{ch}$ .  
A linear correlation is observed between  $\langle N_\gamma \rangle$  and  $N_0$ .



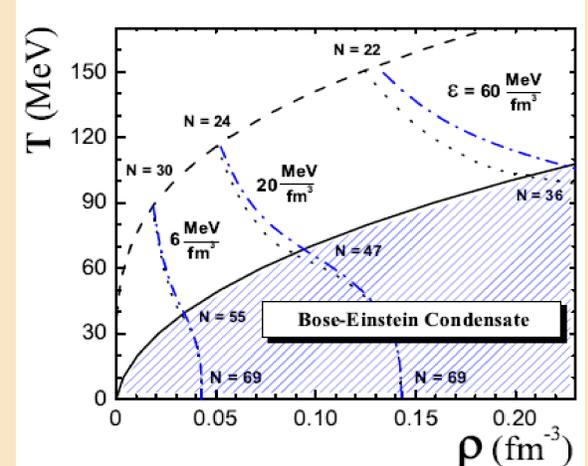
## Experimental results & conclusions

$N_{ev} \sim 1.1 \text{ mln}$ .  $\omega$  increases at  $N_{tot} > 18$ , that indicates approaching to BEC in the HM pion system according to Begun and Gorenstein predictions. This behavior is observed for the first time.

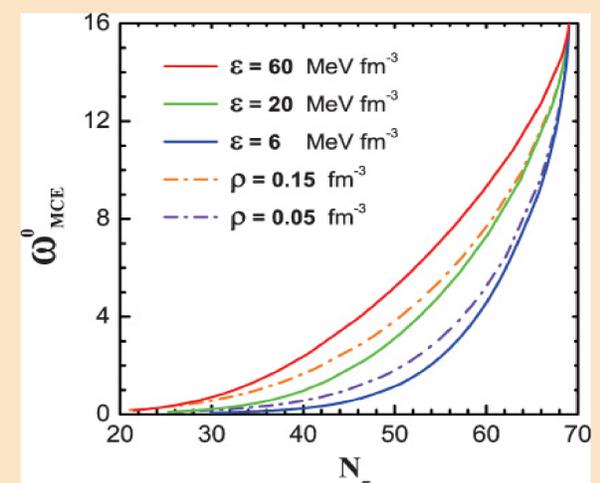


## Neutral pion number fluctuation predictions at HM region in pp at 70 GeV/c

V.Begun and M.Gorenstein have shown within the framework of an ideal pion gas model that sharp growth of the neutral pion number fluctuations will be a signal of BEC formation with the increase of total multiplicity ( $N_{tot} = N_0 + N_{ch}$ ). V.Begun. and M.Gorenstein. Phys. Lett. B653 (2007); Phys. Rev. C 77 (2008).



The phase diagram of the ideal pion gas. The dashed line corresponds to  $\mu=0$ , the solid – BEC at  $T=T_c$  (TL), the dotted lines present the trajectories in the  $(\rho - T)$  plane with fixed energy densities:  $\epsilon = 6, 20$  and  $60 \text{ MeV}/\text{fm}^3$ .  $N_\pi$  – number of pions. The scaled variance of neutral pions,  $\omega$ , as function of the total number of pions, is equal to ratio of variance to mean multiplicity,  $\omega = (\langle N_0^2 \rangle - \langle N_0 \rangle^2) / \langle N_0 \rangle$ .



Estimation of the mean energy of pion:

$$E_\pi = (E_{cms} - 2m_N - n_\pi m_\pi) / n_\pi, \quad (1)$$

$E_{lab} = 50 \text{ GeV}, n_\pi = 30 \rightarrow E_\pi = 0.12 \text{ GeV}$ .  
Condensation critical energy (Stat.Phys)

$$E_{crit} = (3,3/g^{2/3})(h^2/m_\pi)\rho^{2/3}. \quad (2)$$

If fireball radius,  $r \approx 3 \text{ fm} \rightarrow \rho = 0,2 \text{ fm}^{-3}$ ,  
 $E_{crit} = 0,1 \text{ ГэВ}, E_\pi \approx E_{crit}$  ! The max restored  $\pi$ -multiplicity  $N_{tot}=36$  ( $N_{ch}=12 \& N_0=24$ ) E.K. PTPS-193-306. BEC has a chance to be formed in HM region!



SVD Collaboration:  
Belarus-Russia-Ukraine

