Joint Institute for Nuclear Research

VERY HIGH MULTIPLICITY PHYSICS

International Conference «Hadron Structure 2004»

Smolenice Castle, Slovakia, August 30 – September 3, 2004

Selected Papers of the Conference

Dubna 2005

Multiparticle production process in pp-interaction with high multiplicity at $E_p = 70$ GeV.

Project "Thermalization".

P.Ermolov, E.Kokoulina, J.Manjavidze, V.Nikitin, A.Sissakian, I.Rufanov N.Zhidkov.

Collaboration
GSTU(Gomel, Belarus), JINR(Dubna), MSU(Moscow), IHEP(Prorvino), TSU(Tbilisi)

The main goals of the project.

<u>General task</u>. Investigation of collective particles behavior in the process $pp \rightarrow n_\pi \pi + 2N$, $n_\pi = 20 \div 35$.

<u>At reaction threshold $n_\pi \rightarrow n_{thresh} = 69$</u> all particle momenta in c.m.s. vanish $p_\pi \rightarrow 0$. A number of collective effects may show up in cold gas or condensate due to multiboson interference.

- - Increase of partial cross section $\sigma(n)$ is expected, comparing with commonly accepted extrapolation.
- - The jets formation consisting of identical particles – multiboson interference.
- - Fluctuation of charged $n(\pi^+, \pi^-)$ and neutral $n(\pi^0)$ components (centaurs or anticentaurus).
- - Formation of high density thermalized hadronic system. Transition to pion condensate or cold QGP.
- Enhanced rate of direct photons.
- Search for new phenomena: multipion bound state, events with ring topology, pentaquarks.
- Modernization of SVD setup.

Results in 2003.

- Simulation of SVD is in progress
- Software package for data processing is developed
- Trigger concept was worked out
- Liquid hydrogen target is designed and its manufacturing is in progress
- Drift tubes tracking system is developed and is under construction
- Monte Carlo generator of the thermalized hadron system and phenomenological studies in progress

Plan for 2004 -2006.

- Hardware and software modernization
- Data taking at the accelerator runs
- Data analysis and publication preparations
- The theoretical study of dynamics of hh and hA interactions at 70 GeV in QCD and phenomenological models
- Investigations of collective behavior of particles at higher energy with taking into account obtained results

Literature

The VHM physics phenomenology:

- *J.Manjavidze & A.Sissakian,* JINR Rap. Comm., P2-88-724, 1988; 5/31 (1988) 5; 2/281
- (1988) , *A.Sissakian,* Physics – Uspekhi, 46, (2003) 323

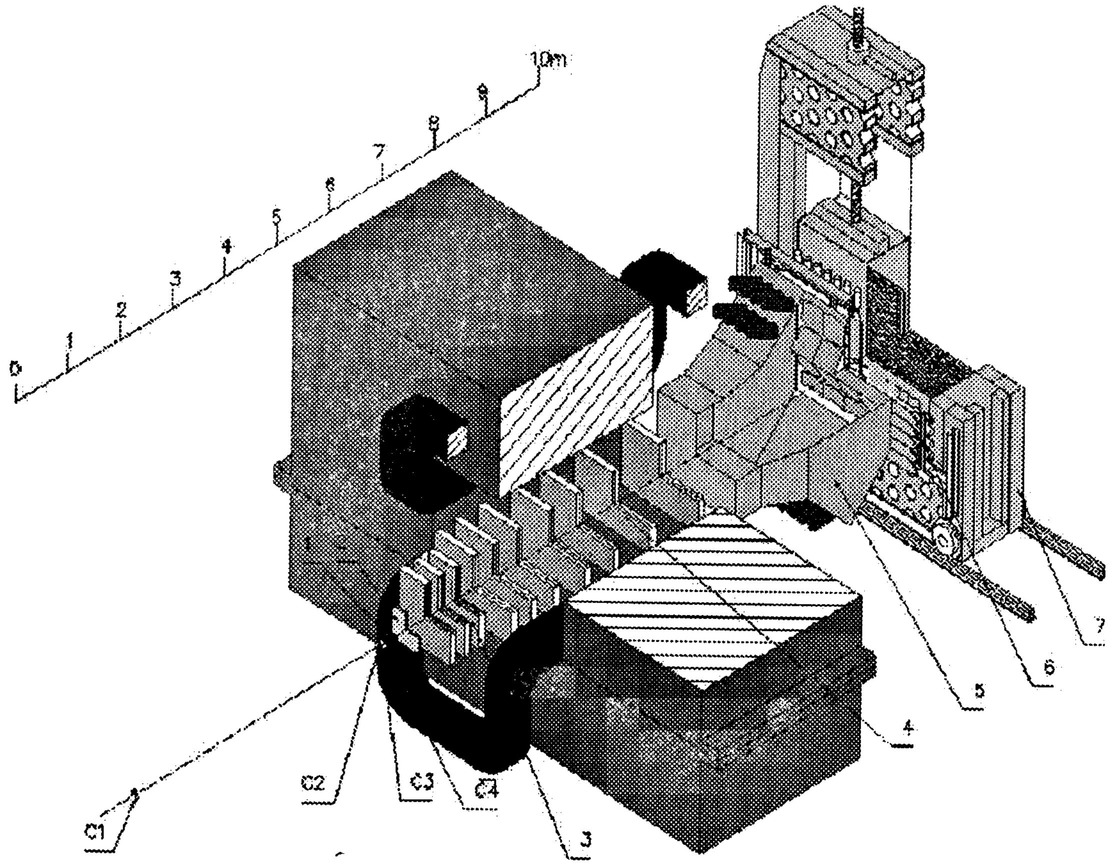
Introduction into the multiple production thermodynamics:

- *J.Manjavidze & A.Sissakian*, Phys. Rep., 346 (2001) 1.

- Models.
- M.K.Volkov, E.Kokoulina, E.A.Kuraev. Excitement of physical vacuum. Ukr. Jour. of Physics. **48** (2003) 1252; hep-ph/0402163
- E.Kokoulina, V.Nikitin. The description of pp-interactions with very high multiplicity at 70 GeV/c by Two Stage Gluon Model. Int.sem. "Problems of Microworld Phys., Gomel, Belarus, 2003; hep-ph/0308139

- Experiment.
- P.F.Ermolov et al. Proton –proton interaction with high multiplicity … (proposal). Nucl.Phys. (Rus.) 67, #1 (2004).
- A.Aleev at al. Observation of narrow baryon resonance decaying into pK in pA interactions at 70 GeV…Prep. NPI MSU 2004-4/743, hep-ex/0401024

Lay-out of the SVD setup at U - 70.



The main components of the setup.

- •Silicon vertex detector.
- •Drift tubes tracker.
- • Liquid hydrogen target.
- •Magnetic spectrometer.
- • Threshold Cherenkov detector.
- •EMC.

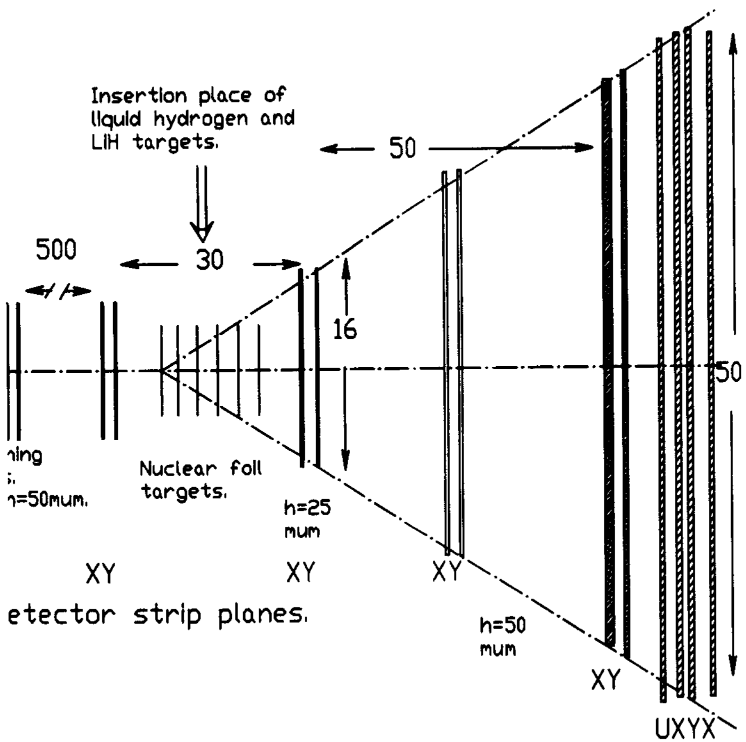
Setup components

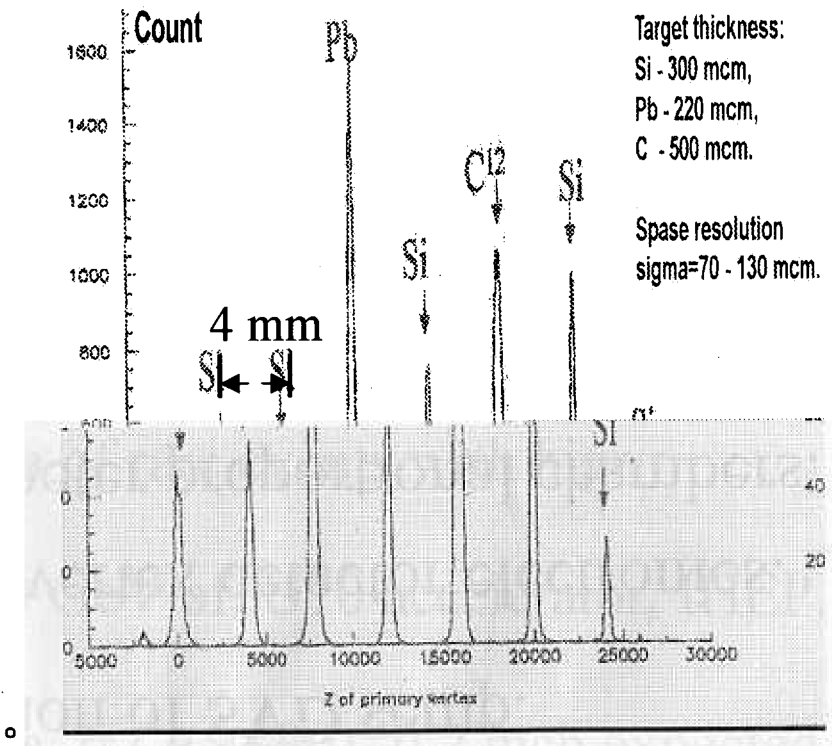
- Spectrometer with Vertex Detector includes the following components.
- Silicon vertex detector (6 beam planes and 10 tracker planes, 10 000 ch.).
- Drift tubes trekker (9 planes, 2300 channels).
- Magnetic spectrometer (18 proportional chambers).
- Liquid hydrogen target (∅ 25 mm, l= 70 mm).
- Threshold Cherenkov detector (32 PMT).
- Electromagnetic calorimeter (1540 channels).
- Trigger system for registration of rare events with high multiplicity.
- Extracted proton beam E = 70 GeV of U70 accelerator, IHEP.
- Beam intensity $\sim 10^7 s^{-1}$.
- Assuming partial cross section $\sigma (n_\pi = 30) = 0.2$ mcb expected counting rate is 100 events per hour.

Modernization of SVD setup.

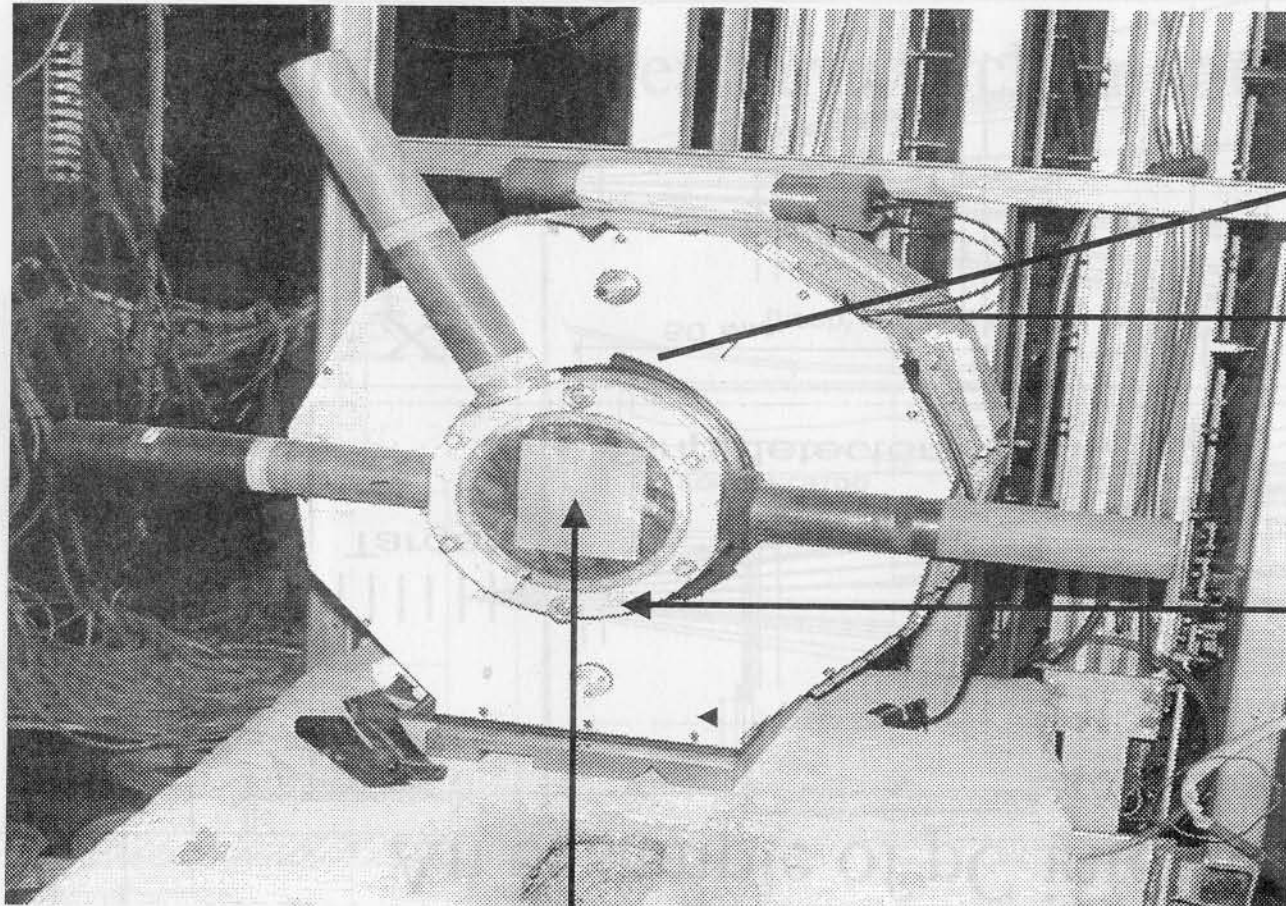
- Renew and repair silicon vertex detector electronics.
- Repair magnetic spectrometer proportional chambers.
- Design and create drift tubes trekker.
- Design and create Liquid hydrogen target.
- Renew and repair Cherenkov detector electronics.
- Renew and repair electromagnetic calorimeter electronics.
- Design and create trigger system for registration of rare events with high multiplicity.

Silicon micro strip vertex detector. An exsample of foil targets imaging.

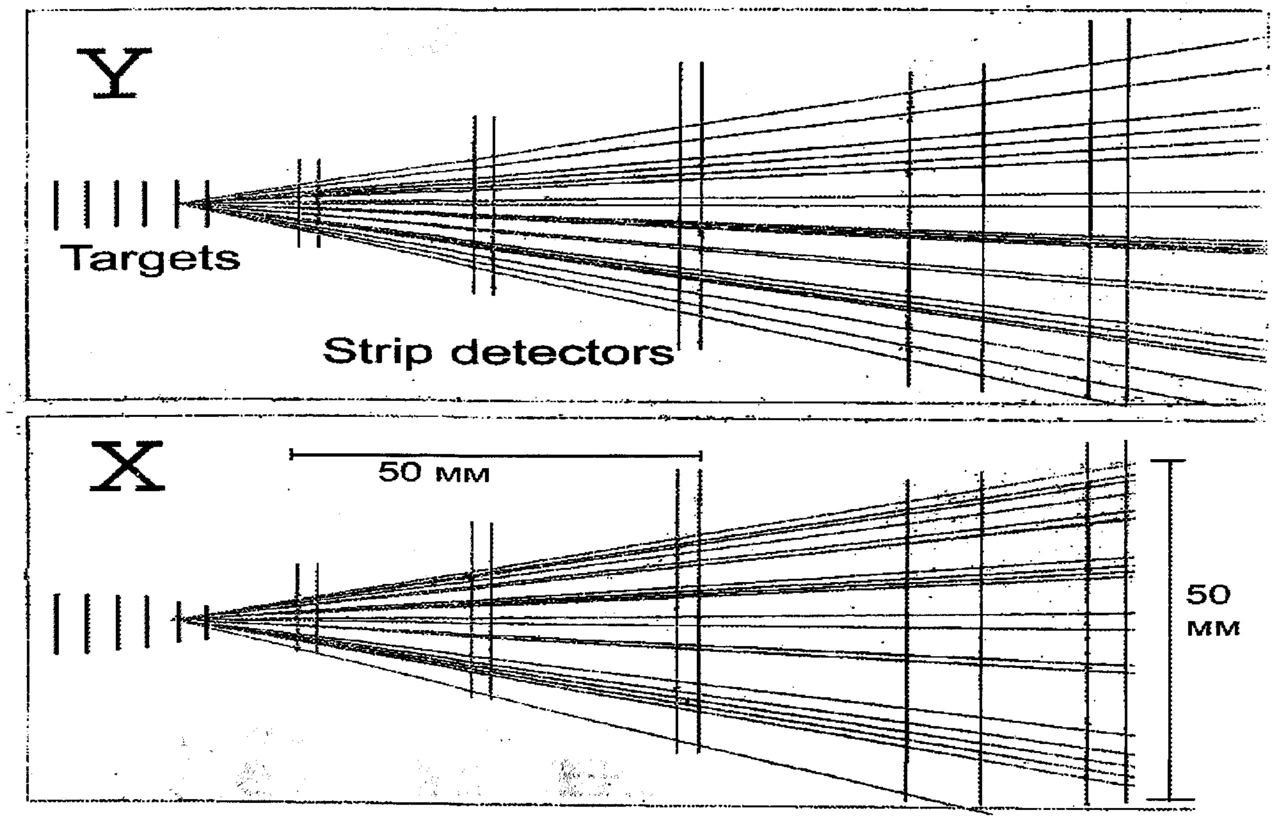




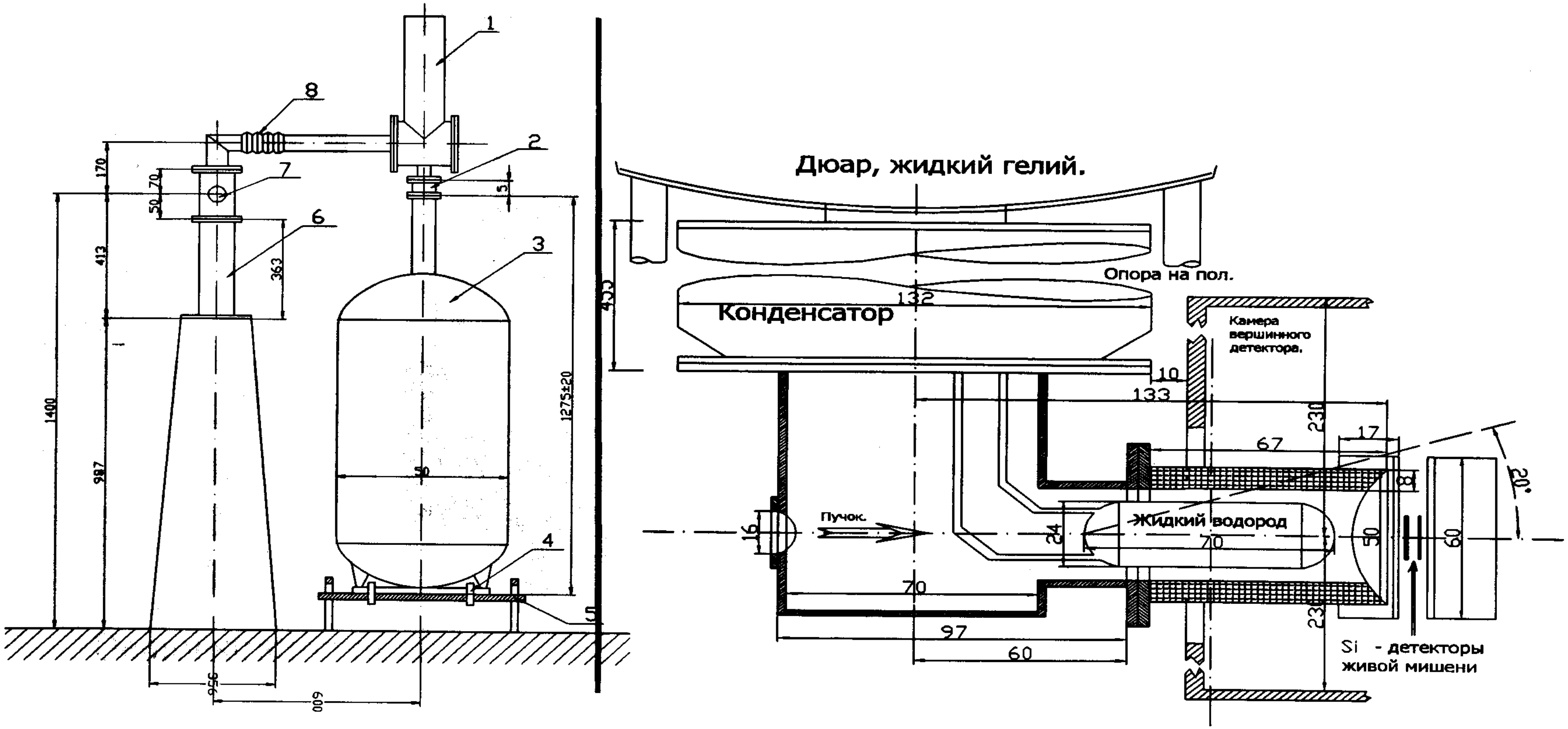
Box of vertex detector.



Silicon micro strip vertex detector.
An exsample of pC interaction event.



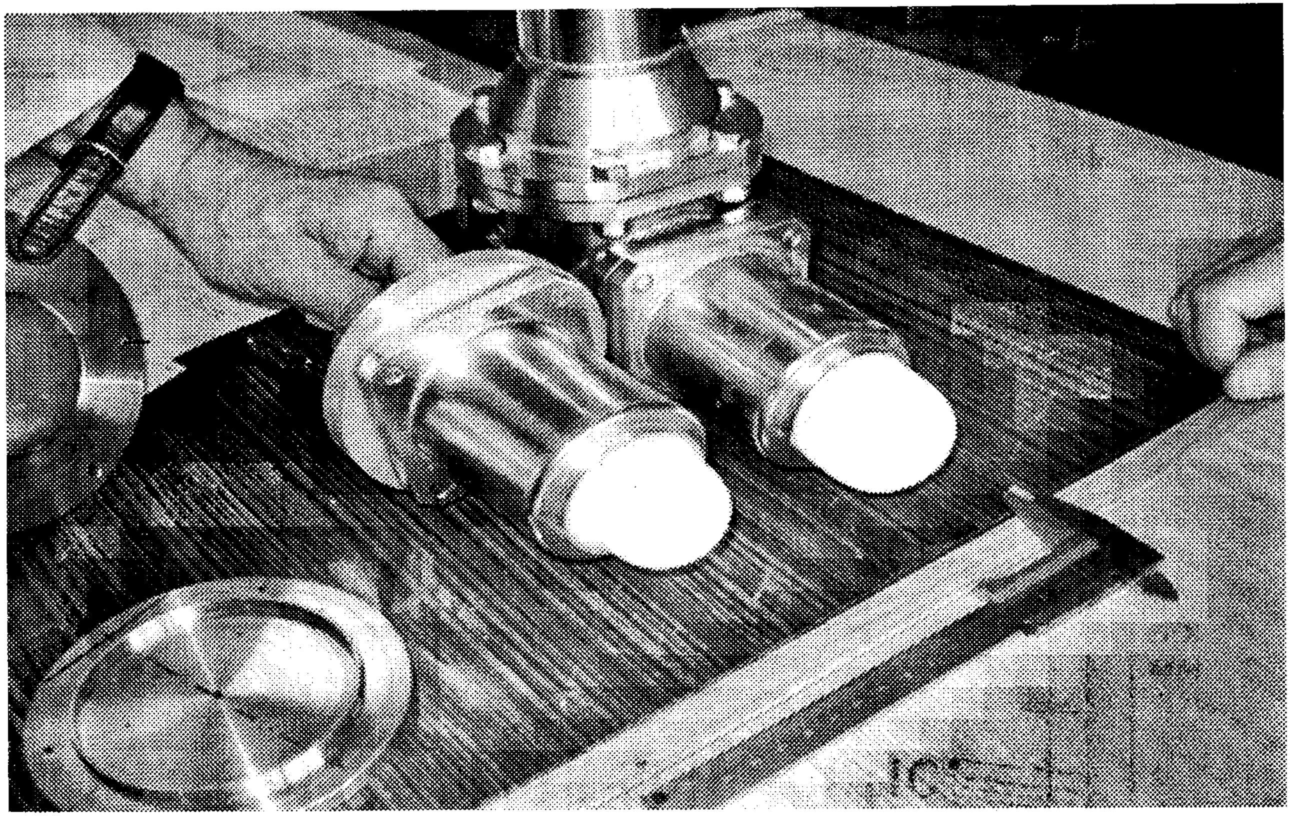
Liquid hydrogen target schematic.



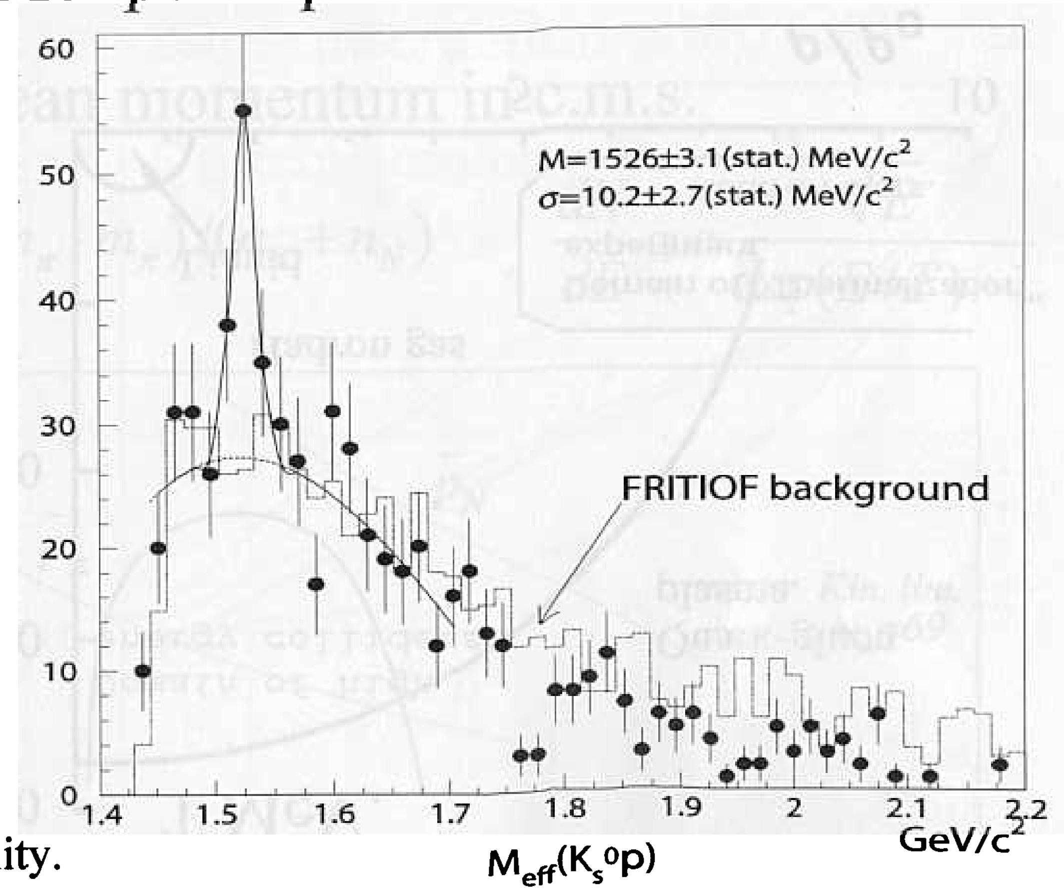
1.Конденсатор Н2. 2. Ввод указателя уровня. 3. Дюар Не 100 л. 4, 5. Узел крепления и юстировки положения дюара. 6. Система юстировки мишени. 7. Н2-мишень. 8. Сильфон.

Пучок перпендикулярен к плоскости чертежа.

Liquid hydrogen target.



Search for pentaquark θ+.



Demonstration of setup capability.

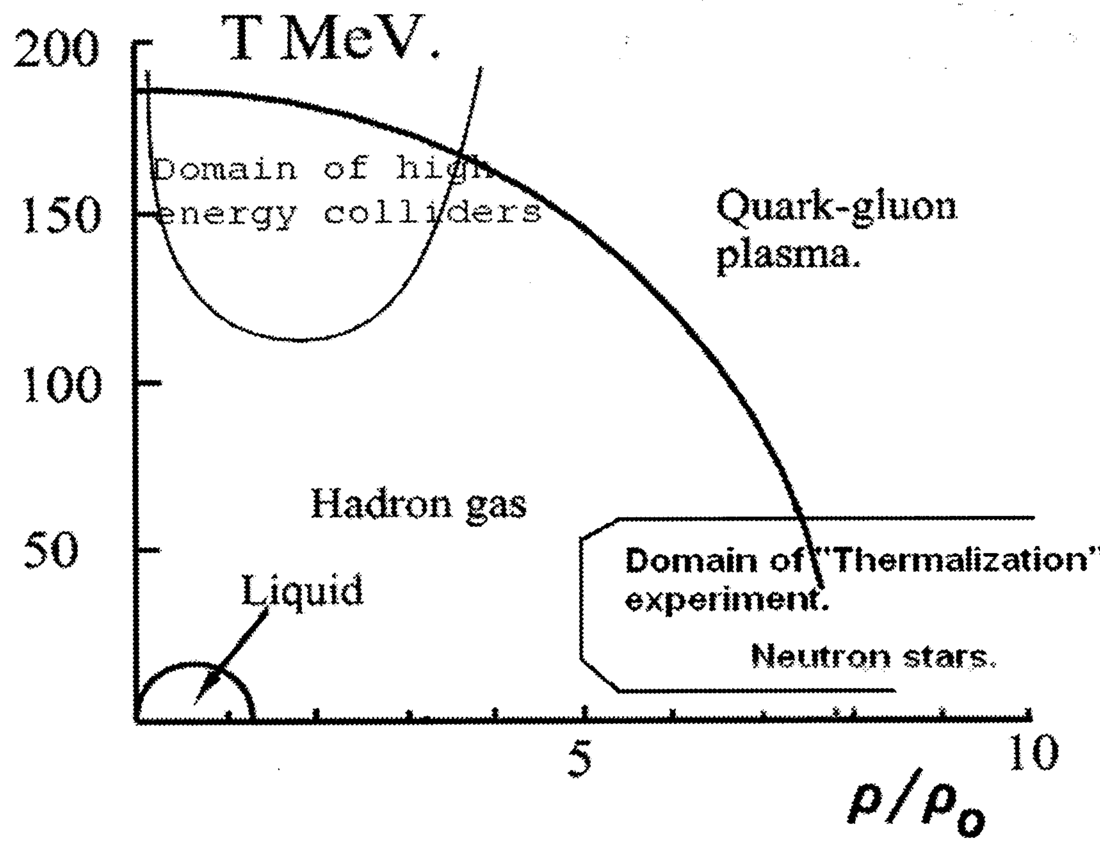
Effective mass spectrum of (ππ), (πp) and (Kp) systems:

M(K) = 497.6 MeV, σ=4.4 MeV;

M(Λ) = 1115.0 MeV, σ=1.6 MeV

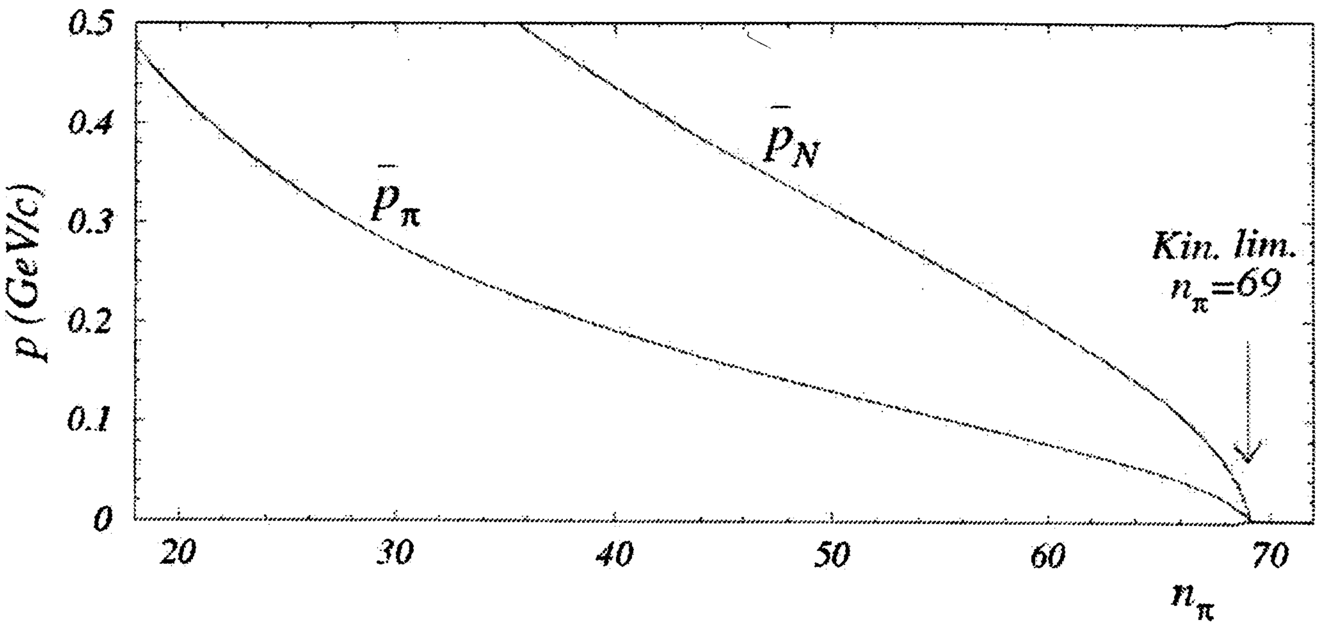
M(θ+) = 1526.0 ± 3.1 MeV, σ =10.2 MeV

Phase diagram of hadronic matter

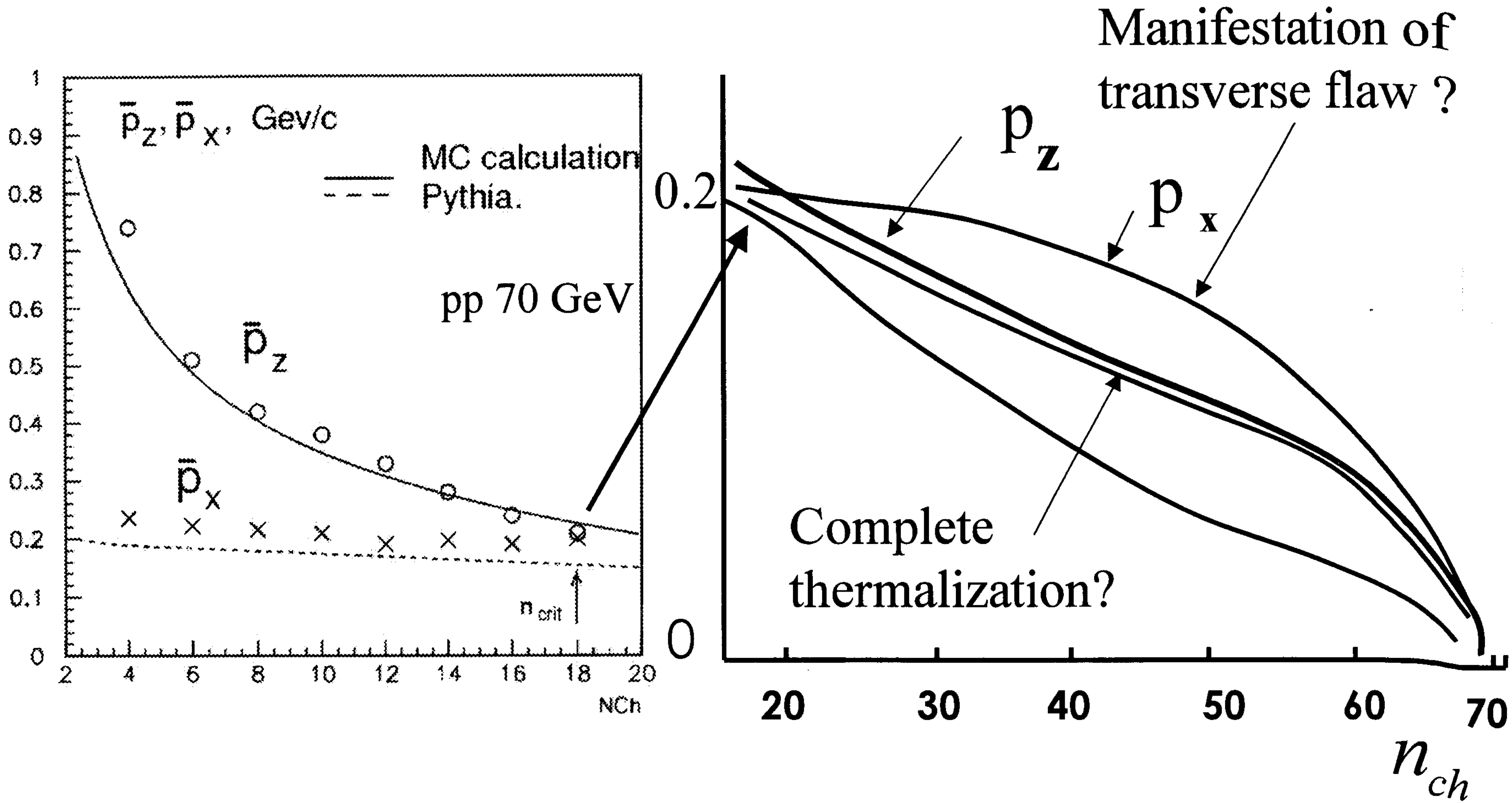


Mean momentum in c.m.s.

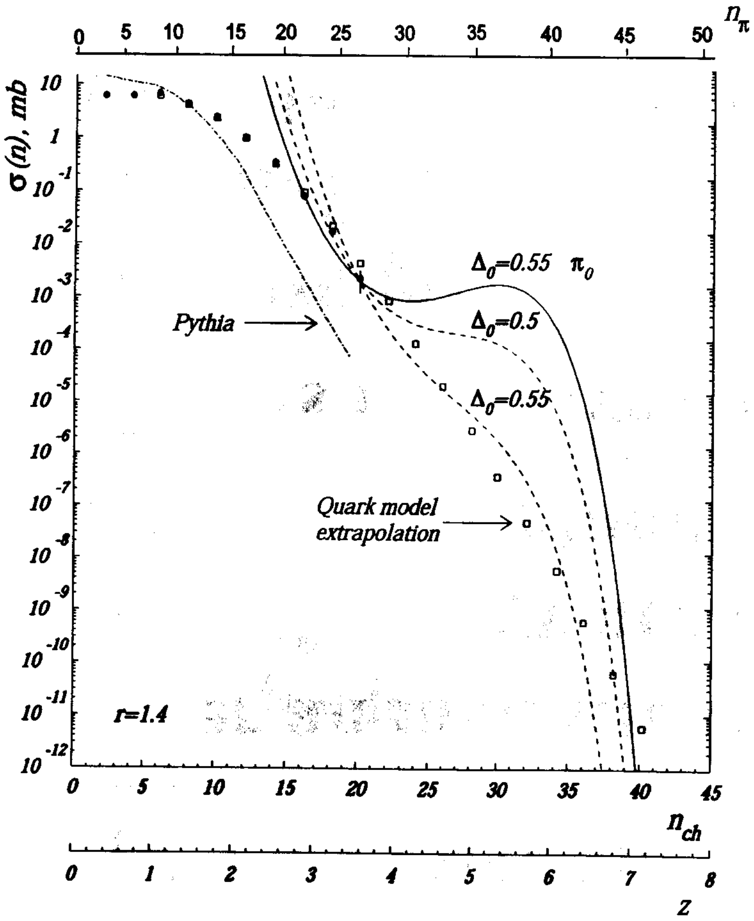
$$E_{kin} = (\sqrt{s} - 2m_N - n_\pi \cdot m_\pi)/(n_\pi + n_N) \qquad \frac{dN}{dE} = c\frac{\sqrt{E}}{\exp(E/T)-1}$$

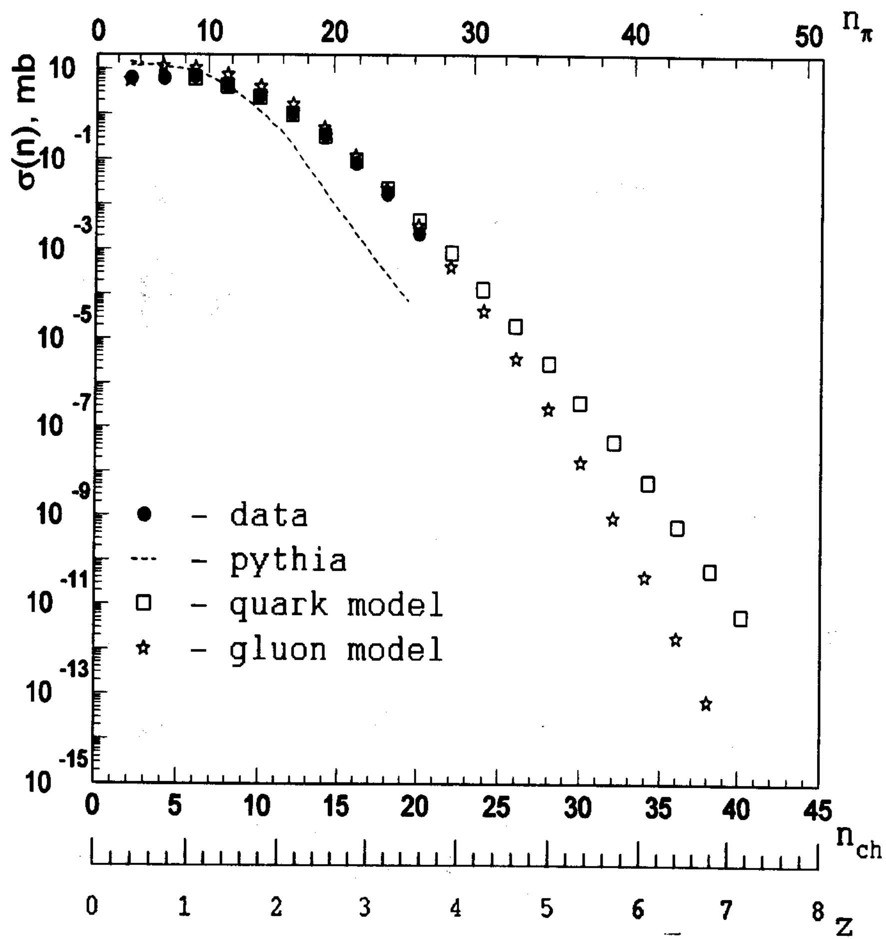


Comparison
of longitudinal p_z and transverse p_x momenta behavior in c.m.s.



Multiplicity distribution in pp interaction at 70 GeV.





Two Stage Gluon model

- **After an inelastic collision of two protons the part of energy are converted into the thermal one and few gluons become free**
- **Gluons may give cascade – I stage**
- **Some of gluons (not of all) leave Quark-Gluon System (are evaporated) and convert to hadrons – II stage**

Model formulation

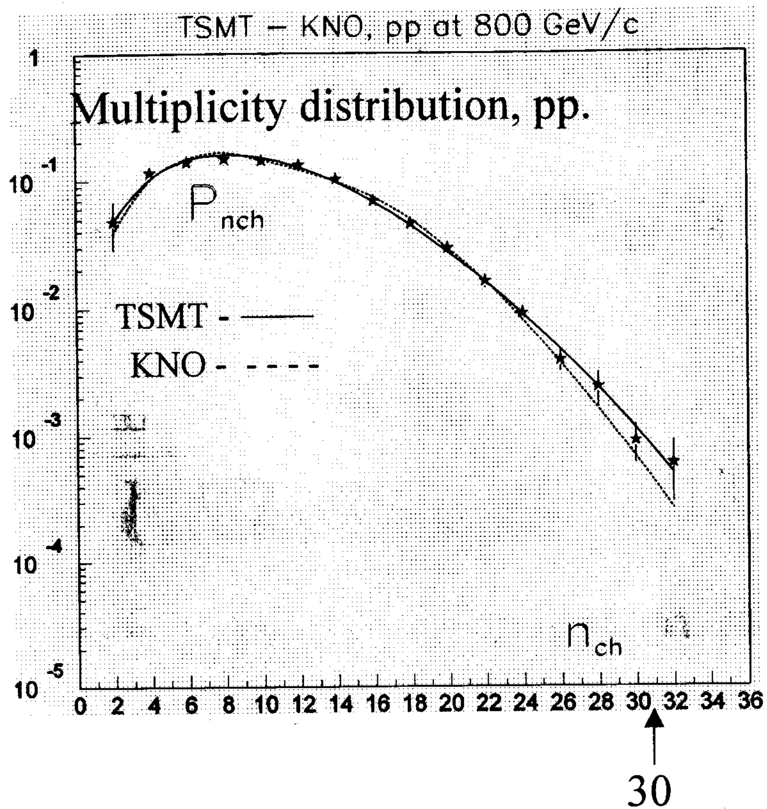
- **MD for active gluons at the moment of impact – Poisson** $e^{-\bar{k}}\bar{k}^{k}/k!$
- **MD for branch of gluons – Farry**

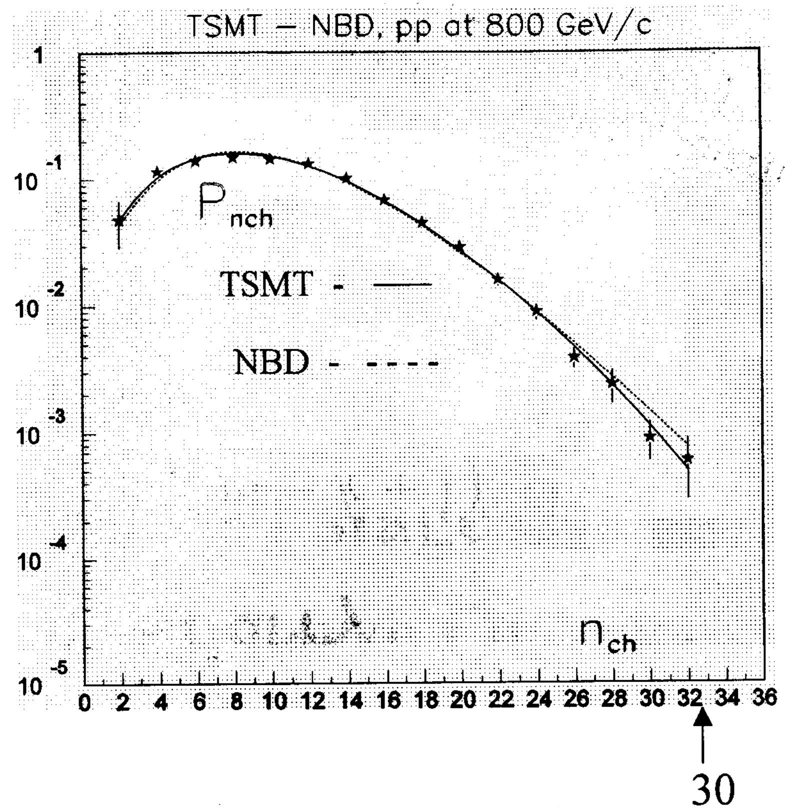
$$\frac{1}{\bar{m}^{k}}\left(1-\frac{1}{\bar{m}}\right)^{m-k}\frac{(m-1)(m-2)\ldots(m-k+1)}{(k-1)!}$$

- **MD for hadronization stage – Binomial**

$$C_{\alpha mN}^{n-2}\left(\frac{\bar{n}_h}{N}\right)^{n-2}\left(1-\frac{\bar{n}_h}{N}\right)^{\alpha mN-(n-2)}$$

E.Kokoulina. Minsk, Belarus (2002)[hep-ph/0209334]





$$\psi(\nu) = (0.1/\nu^2 + 18.85\,\nu^4 + 9.39\,\nu^{10}) \cdot \exp(-8.25\,\nu - 1.35/\nu + 6.628)$$

$$\nu = n/\bar{n}$$

Semenov S. et al. Sov.J. Nucl Phys.22(1975) 792

A.Giovannini, R.Ugocioni [hep-ph/0405251]

Low energy direct photons.

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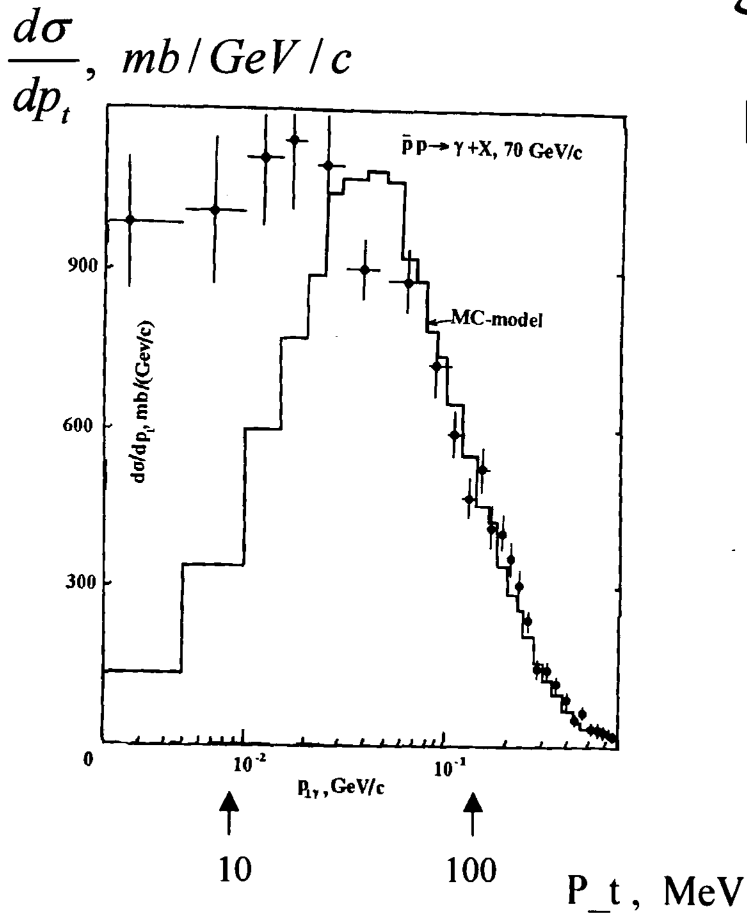
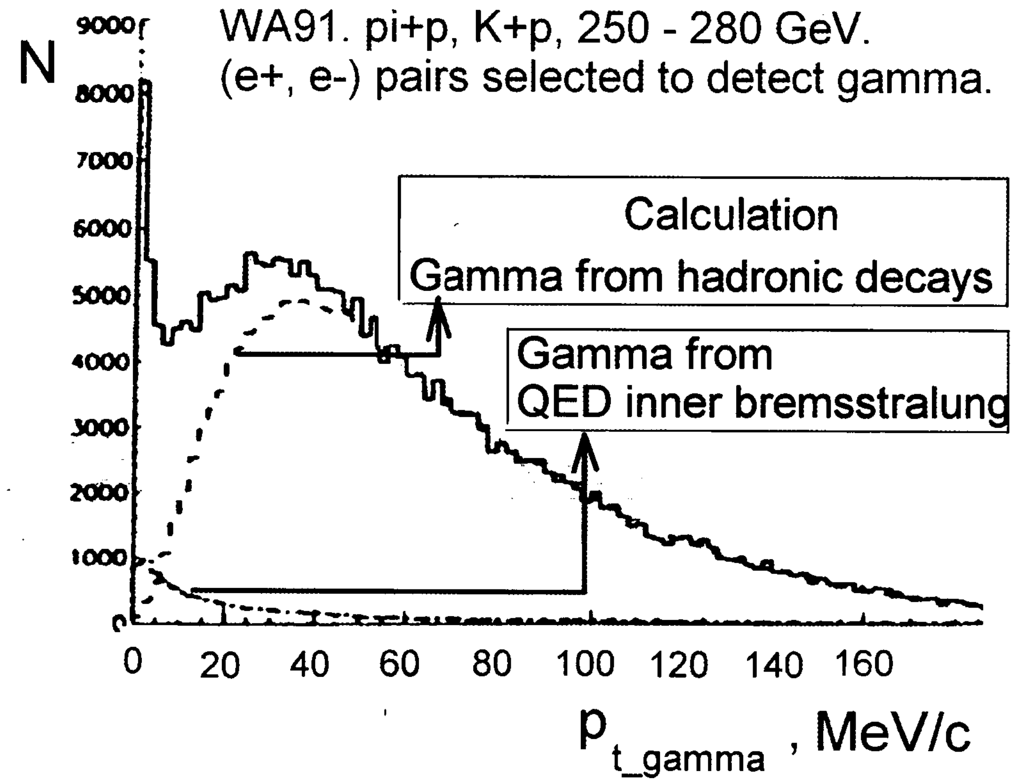


Anti-p + p = γ + X, 70 GeV



Tentative mechanisms of anomalous low energy photon generation.

- Quasistable cold spot in hadron gas or QGP (P.Lichard, L.Van Hove, E.Shuryak).

- Relic emission of fireball

(M.Volkov, E.Kokoulina, E.Kuraev).

- Formation of multipion bound state.

Soft photons as relic emission of the fireball.

$$\sigma_\gamma \approx 4mb,\ \sigma_{in} \approx 40mb,\ \sigma_\gamma \approx n_\gamma(T)\cdot\sigma_{in} \to n_\gamma \approx 0.1$$

The black body emission spectrum:

$$\frac{dn_\gamma}{d\nu} = \frac{8\pi}{c^3}\frac{\nu^3}{e^{\frac{h\nu}{T}}-1}$$

$$n_\gamma(T) = 0.244\cdot V\left(\frac{2\pi kT}{hc}\right)^3,$$

Excess of soft photons:

$$T = p \approx p_t\cdot\sqrt{2}$$

$$L^3\cdot\rho(T) \approx n_\gamma \to L(T)$$

<u>Our result</u>: L - the size of hadronization region

	L(fm)		L(fm)
p_t 10	11.	p_t 30	3.5
15	6.9	40	2.6
25	4.1	50	2.0

M.Volkov,E.Kokoulina, E.Kuraev. Ukr. Jour. of Phys., 48(2003) 1252, [hep-ph/0402163]

Conclusion.

The goal of the proposed experiment "Hadronization" is to investigate the collective behavior of particles in the process of multiple hadron production in pp and pA interaction. Near the threshold of reaction all particles get small relative momenta. As a consequence of multiboson interference a number of collective effects may show up.

The processes of the deep energy dissipation at hadron interaction and the thermalization of the formed system are far from full understanding. The further experimental and theoretical studies in this direction are called to throw light on fundamental grounds of the particle physics: confinement mechanism, nature of the vacuum, the equation of state of hadronic matter etc.

Conclusion

The physics objectives of the experiment are as follows.

1. Search for new phenomena.

a) Drastic variation of the multiplicity distribution is expected comparing with the behavior obtained by means of conventional extrapolations. The BEC may manifest itself by formation of narrow jets of identical particles or "cold spots" in the fireball of the secondary particles. The other notions for this effect are pion laser, classical boson field, boson condensate.

b)The measurement of the multiparticle correlation function. Search for identical particles jets.

c) Search for large variation of charged and neutral particles multiplicity. This may also manifest the classical pionic field production or onset of chiral condensate.

Conclusion

The systematic and precision study of known phenomena.

a) Study of anomalous low energy photons.

b) The study of stochastic intermittency is an instrument for phase transition search.

c) Search of events with regular intermittency, so called ring events. This effect is referred as a gluonic Cherenkov radiation. If it exists, it will be a genuine probe of the hadronic matter properties.

d) Simultaneous analysis of the differential cross section and BE correlation functions makes it possible to disentangle the hadronic system size, temperature and expansion rate. All parameters are measured as function of particle multiplicity.

Conclusion

Experimental setup.

The experiment is being carried out at 70 GeV extracted proton beam of IHEP U70 accelerator.

The apparatus design is essentially based on the fact that at high multiplicity all the secondary particles have good forward collimation. In spite of the modest setup size (and cost) it is expected that at least 70% of all particles drop into the apparatus aperture and will be detected.

The apparatus includes a liquid hydrogen target, a micro strip silicon vertex detector, Threshold Cherenkov counter, magnetic spectrometer and electromagnetic calorimeter.

The two level trigger system is designed to select the rare events with high charged and neutral multiplicity.

The counting rate of the events with total multiplicity 35 is expected to be 10 events per hour. If scenario of BEC is realized then counting rate will be essentially igher.

The modernization of the setup is in progress.

<u>Our model investigations had shown</u> :
quarks of initial protons are staying
in leading particles (from 70 to 800 GeV/c).
Multiparticle production (MP) is realized
by gluons. We name them active.

P.Carruthers about a passive role quarks: "...labels and sources of colour perturbation in the vacuum: meanwhile the gluons dominates in collisions and MP." (1984)

The domination of gluons was first proposed by S.Pokorski and L.Van Hove (1975).

The Multiplicity Distributions (MD) analysis are used to study MP-processes.

Model with the gluon branch in QGS - **branch model** (TSMB)

or

Model without the gluon branch - **Thermodynamic model** (TSMT)

E.Kokoulina, V.Nikitin. 7th Int. school-seminar The actual problems of Microworld Physics, Gomel, Belarus [hep-ph/0308139]

α - **ratio of evaporated gluons to all active ones**

$\overline{n}_h$, N – **parameters of hadronization for gluon**

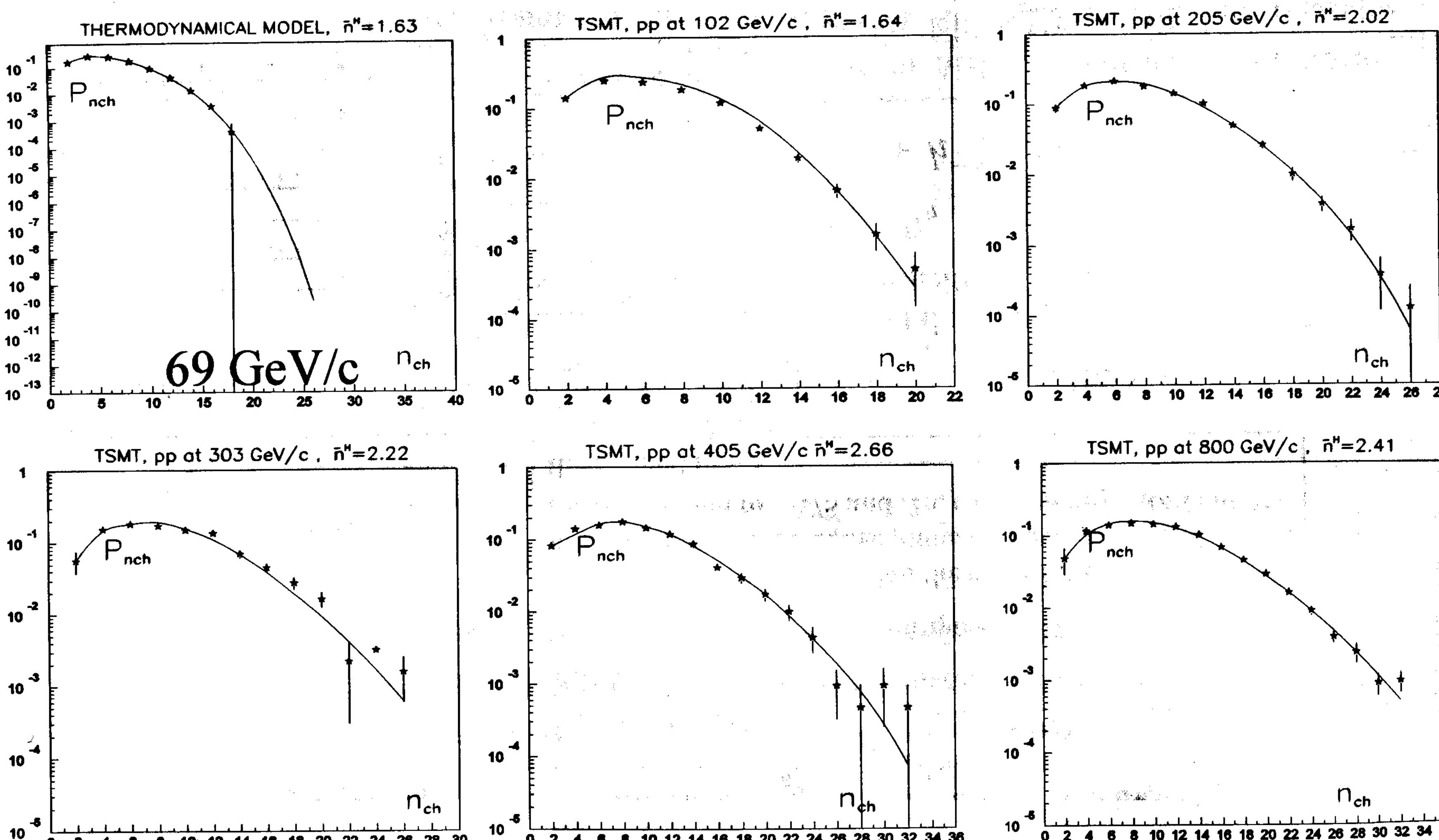
$(\alpha < 1)$ Some of active gluons (from 50 to 1 %) are staying inside QGS and don't give hadron jets. New formed hadrons catching up them, are excited and throw down excess of energy by soft photons.

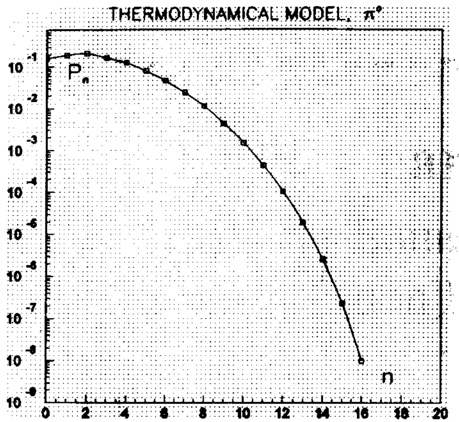
We found weak branching of active gluons.

TSMT - gluons leave QGS and fragment to hadrons without branch:
MD = Poisson & Binomial

M - max number of evaporated gluons is rising (from 6 to 10)
max number of hadrons is limited by M*N
(~ 24-26 for charged particles at 69 GeV/c)

Kokoulina E. Acta Phys.Polon. B35(2004)295


THERMODYNAMICAL MODEL, n̄ᴴ=1.63
69 GeV/c
TSMT, pp at 102 GeV/c , n̄ᴴ=1.64
TSMT, pp at 205 GeV/c , n̄ᴴ=2.02
TSMT, pp at 303 GeV/c , n̄ᴴ=2.22
TSMT, pp at 405 GeV/c n̄ᴴ=2.66
TSMT, pp at 800 GeV/c , n̄ᴴ=2.41
P_{nch}
n_{ch}



MD of neutral mesons at 69 GeV/c

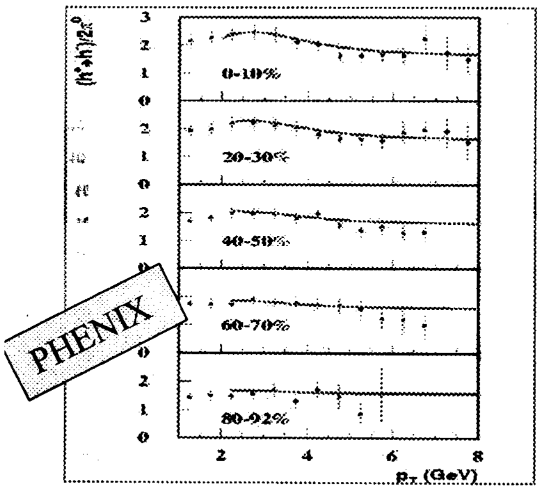
The simplification on the second stage of TSM:

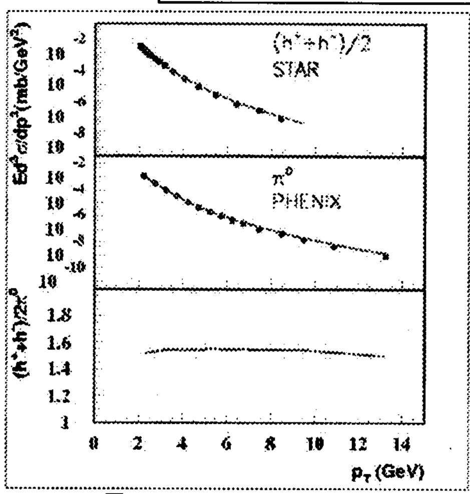
$$\frac{\overline{n}_{hch}}{N_{ch}} \approx \frac{\overline{n}_{h0}}{N_0} \approx \frac{\overline{n}_{htot}}{N_{tot}}$$

<u>Our results</u>: max of neutral mesons = 16

max of total multiplicity =42

on the stage of hadronization the probabilities of production from the active gluon charged or neutral particles equal to ~ .75 and .25, consequently. Ratio of them equal to ~ 3.





$\sqrt{s} = 200 GeV/c$

pp

X.Zhang, G.Fai.[hep-ph/0306227]

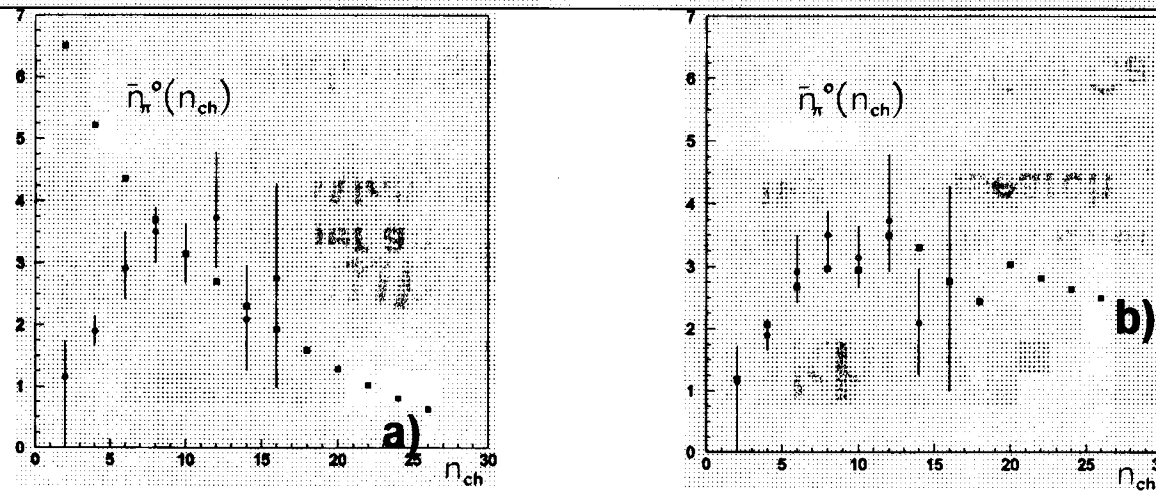
For total mean (charged or neutral) multiplicity in TSM:

$$\overline{m}_{gl} \cdot \overline{n}_h$$

$$(h^+ + h^-)/2\pi^0 \approx (\overline{n}_{h+} + \overline{n}_{h-})2\overline{n}_{h0}$$

Binom. MD – ratio probabilities =ratio multiplicities. <u>Our result:</u> 3/2

Mean multiplicity of neutral mesons versus the number of charged particles



$$\overline{n}_0(n_{ch}) = \sum_{n_{tot}=n_1}^{n_2} P_{n_{tot}} \cdot (n_{tot} - n_{ch}) \,/ \sum_{n_{tot}=n_1}^{n_2} P_{n_{tot}}$$

In the case a) top and bottom limits are determinated: $n_{ch} + n_0 = 42$

The noticeable improvement is reached if we decrease the top limit at low multiplicities (n<10) to $n_2 = 2n_{ch}$ **(the case b)).**

<u>Our result</u>: Centaur events may be realized in the region of high multiplicity. AntiCentaur events must be absent.