NEUTRAL PION NUMBER FLUCTUATIONS

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On behalf of SVD Collaboration
(JINR, IHEP, SINP MSU)

MIYAJIMA, September, ISMD2011,

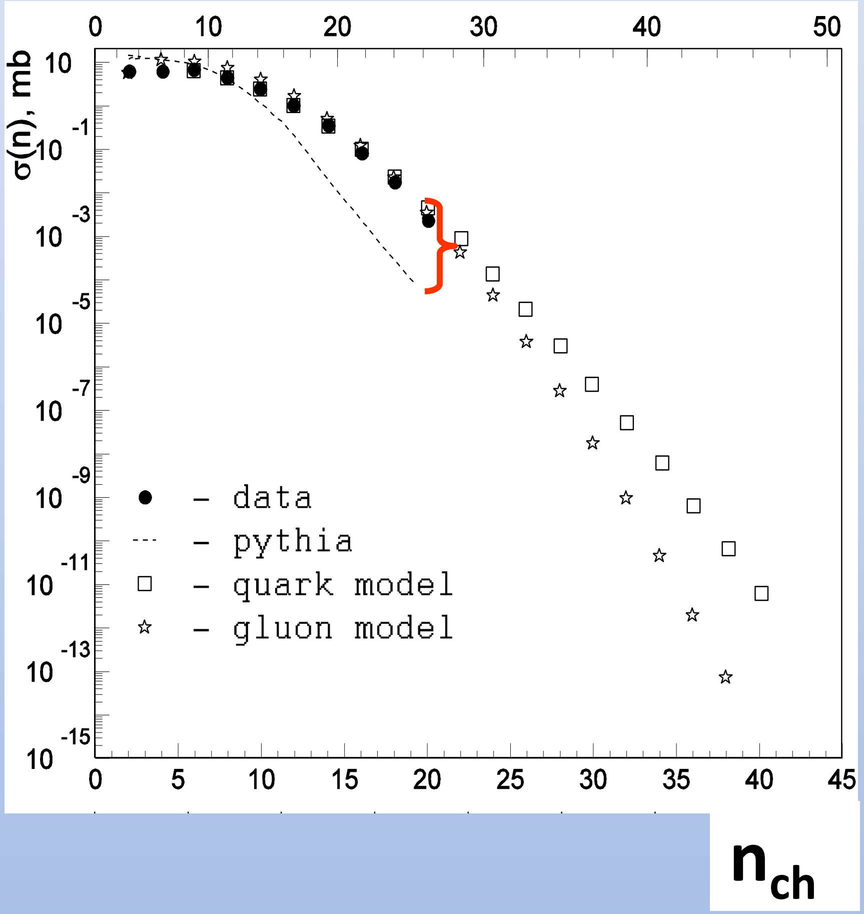
Task of the Thermalization project:

Studies of *pp* and *pA* collisions at accelerator U-70 in IHEP (Protvino, Russia)

$$p + p(A) \rightarrow 2N + n_{\pi}$$

Multiplicities: n_{ch}, n_0 or $n_{tot} = n_{ch} + n_0$, much more than their mean values, High Multiplicity (**HM**) region: $n >> \bar{n}.$

HM description difficulties



- MC underestimates topological cross section: $E_p = 70$ GeV;
- model predictions are differed at HM region;
- MC discrepancies with first LHC data.

We have measured topological cross sections in pp interactions at 50 GeV/c up to $n_{ch} = 24$. Data Mirabelle (70^{th}) were up to $n_{ch}=16$.

PROGRAMME:
SEARCH FOR COLLECTIVE PHENOMENA

- Bose-Einstein Condensation (BEC);
- Cherenkov radiation, shock waves or ?;
- Anomaly soft photon yield;
- Fluctuations, correlations, turbulence …

1. It has been revealed:

Sharp increasing of neutral pion number fluctuations with total multiplicity growth, $n_{tot} > 22$.

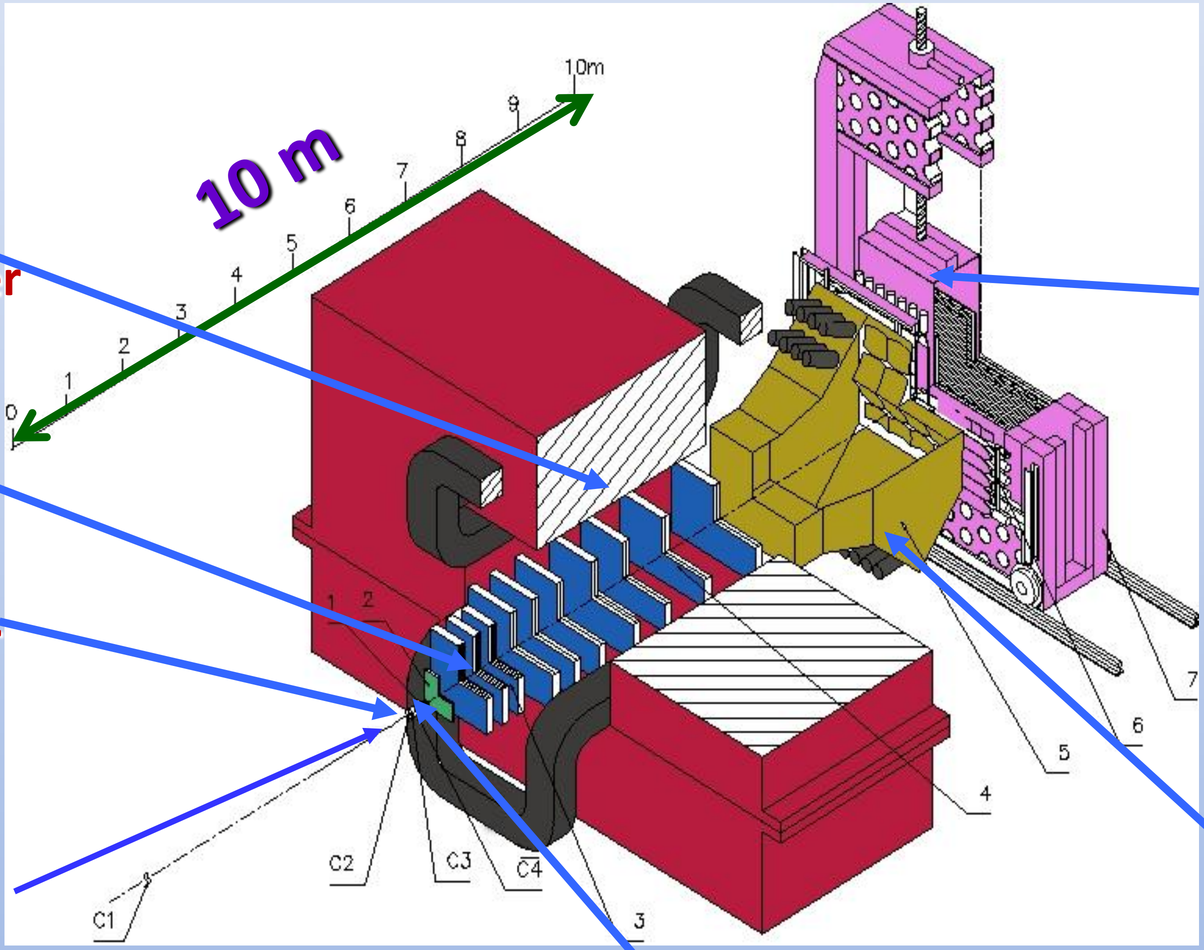
2. The indications to:

The peak structure in angular distribution at HM have been obtained.

3. It is carried out:

The simulation and manufactured of EMCal prototype for anomaly soft photon yield study.

SVD-2 setup



Magnetic Spectrometer

Drift Tubes

Vertex Detector

Hydrogen Target

Electromagnetic calorimeter (DeGa)

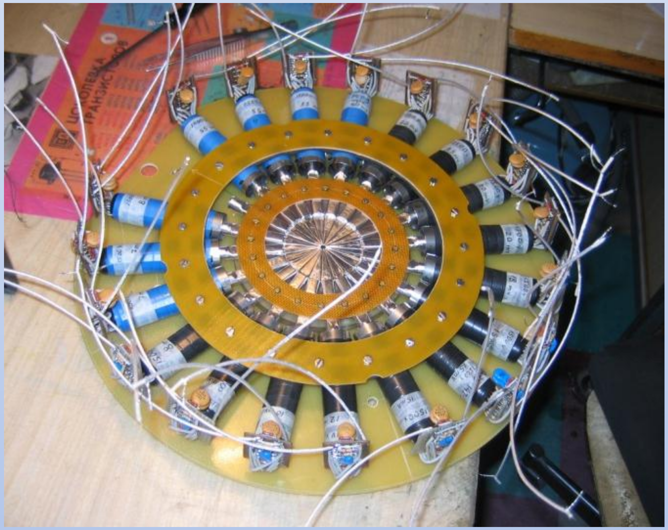
Čerenkov counter

HM Trigger

SVD (Spectrometer with Vertex Detector)

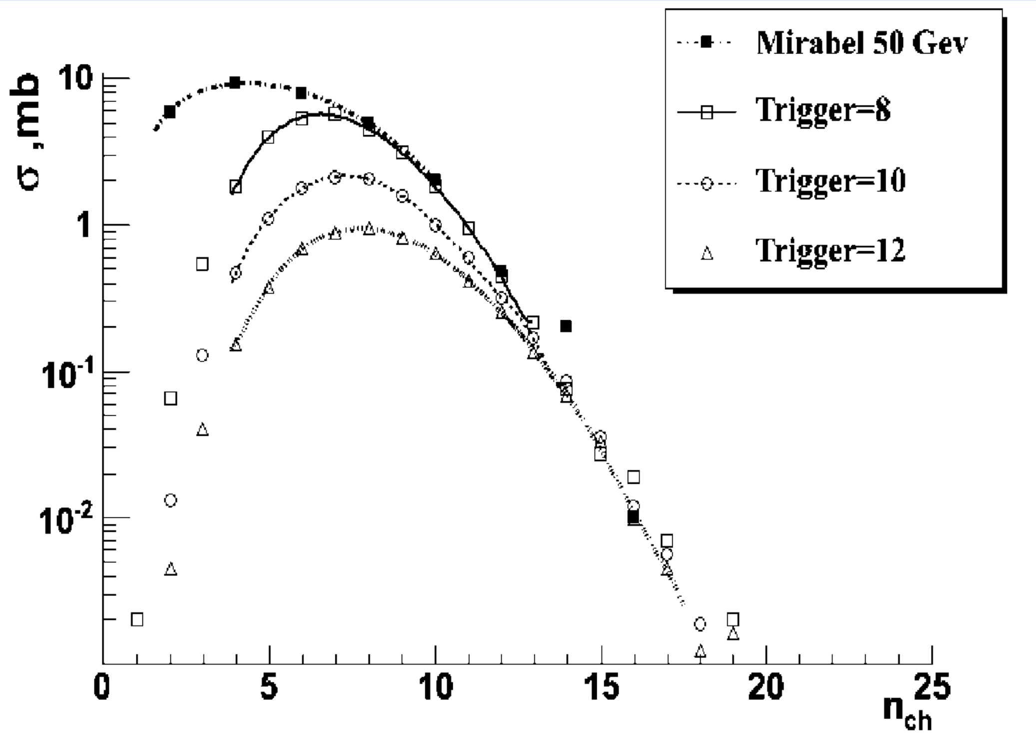
SCINTILLATOR HODOSCOPE
(HIGH MULTIPLICITY TRIGGER, HMT)

HMT suppresses low multiplicity events in 100 times!



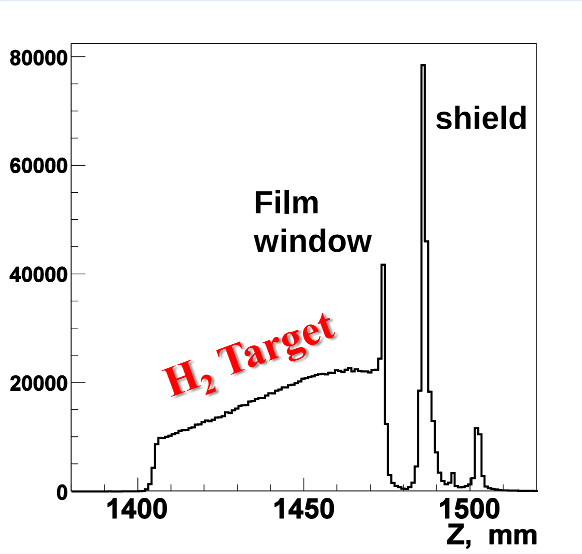
HMT

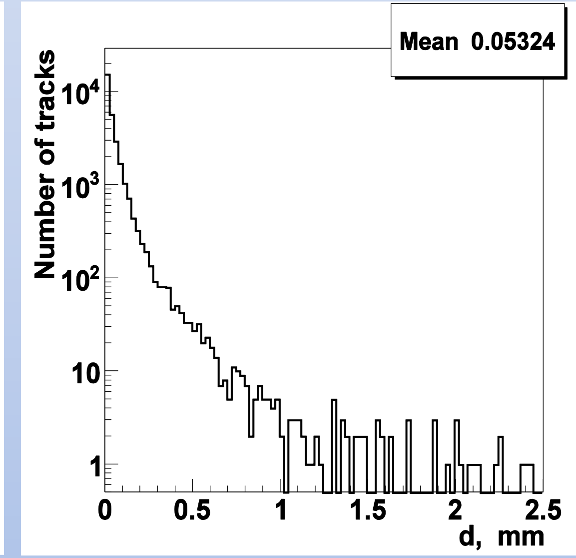
Trigger level = n x MIP

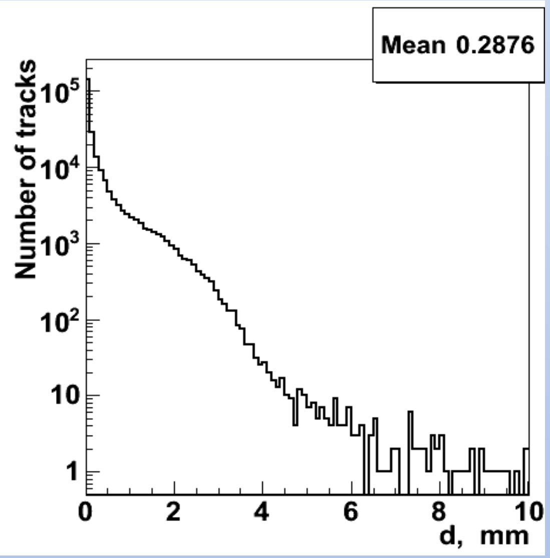


Event selection, track reconstruction

Data from Run 2008, 5 mln events. For analysis ~ 1 mln.
Selection criterions: the primary beam number, the restricted value of discrepancy for Z - coordinate on X and Y planes.







Z-coordinate vertex distribution

MC impact and experimental impact distributions

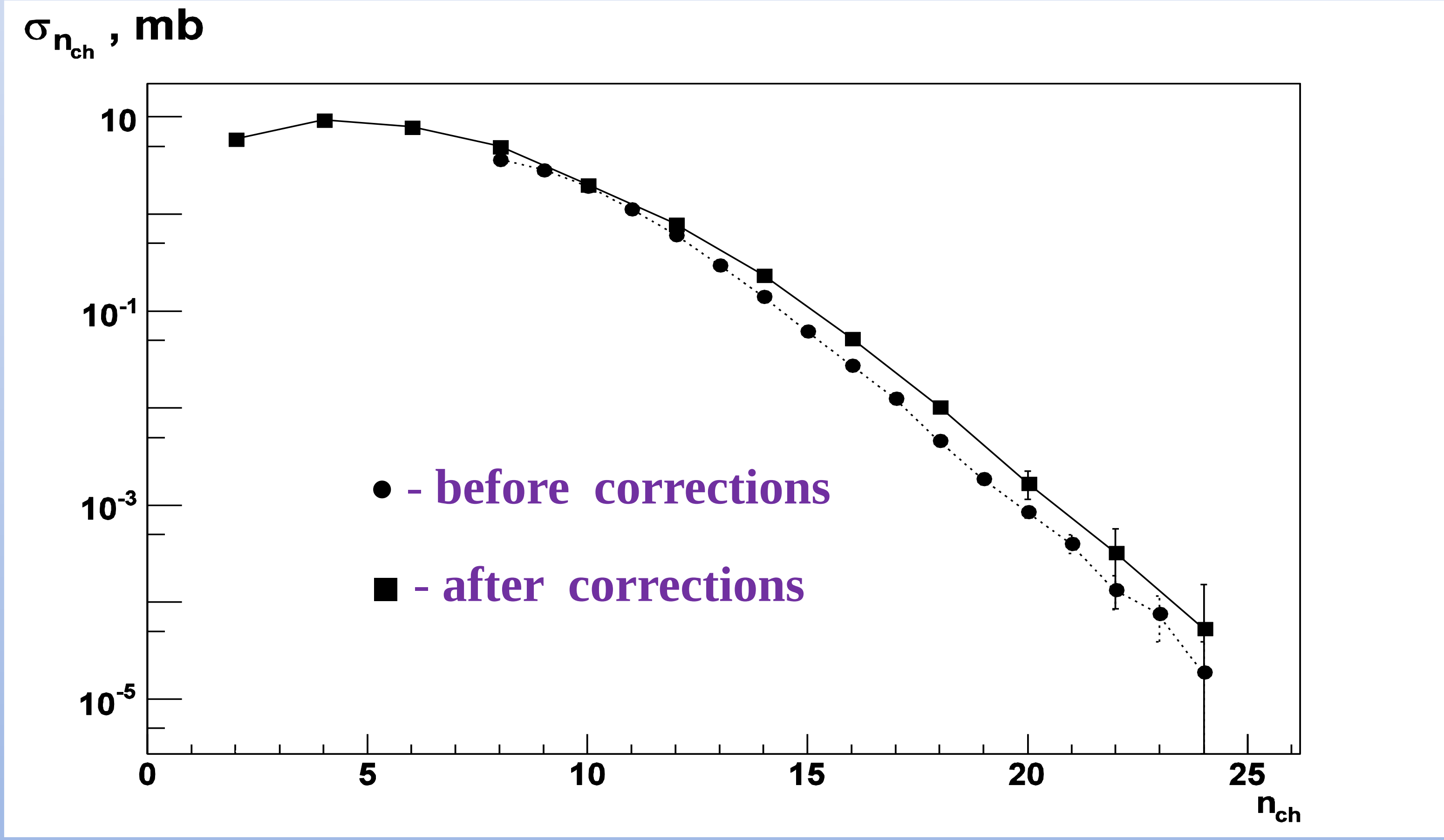
Table 1. **Topological cross sections for *pp* – interactions at 50 GeV, SVD Collaboration.** [hep-ex 1104.0101]

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

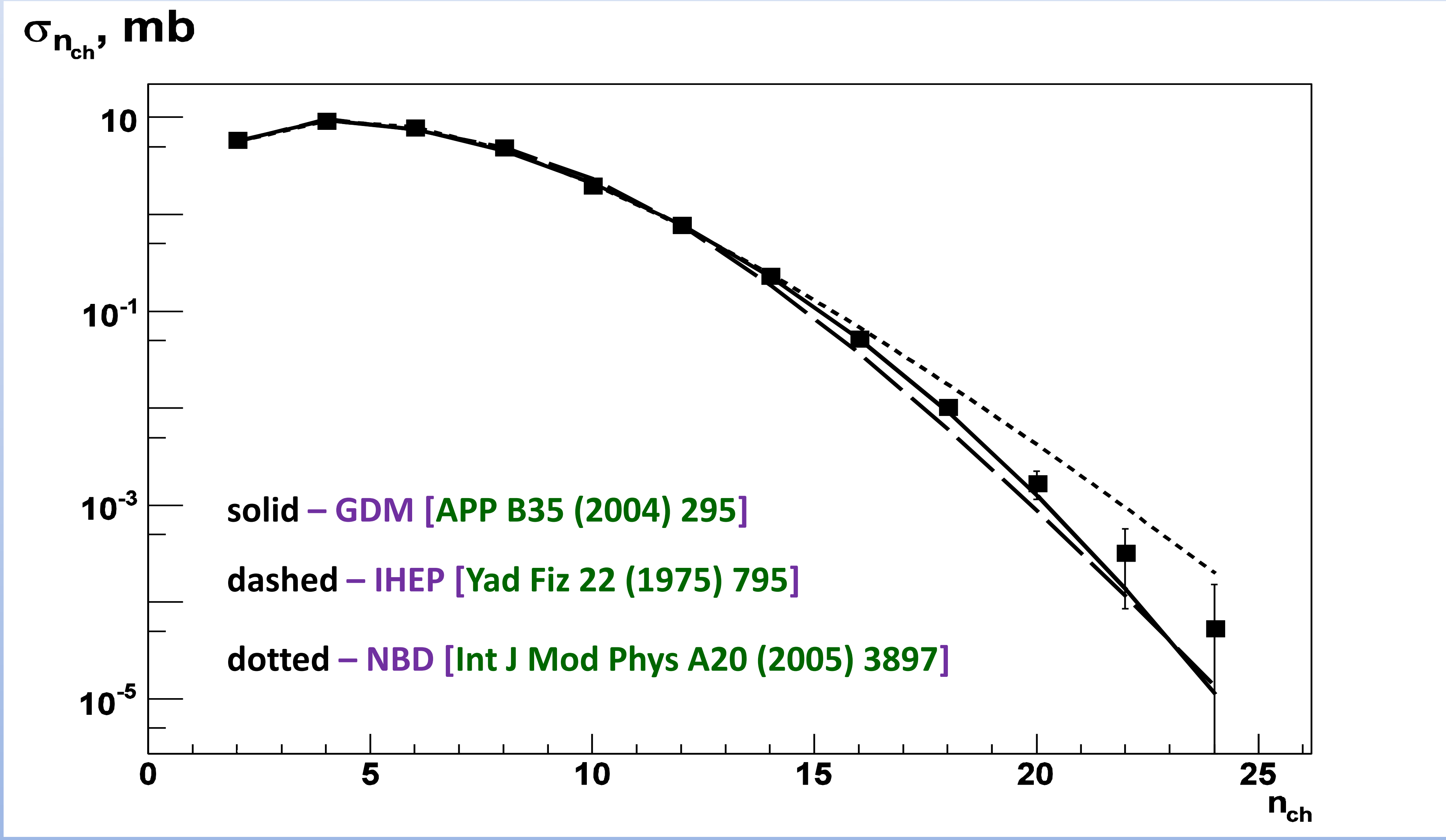
Table 2. The same, Mirabelle data [*PL, 42B (1972) 519*].

N_{ch}	2	4	6	8	10	12	14	16
σ, mb	5.97	9.40	7.99	5.02	2.03	0.48	0,20	0,01
Δσ, mb	0.88	0.47	0.43	0.33	0.20	0.10	0.06	0.02

Topological cross sections before and after correction procedure

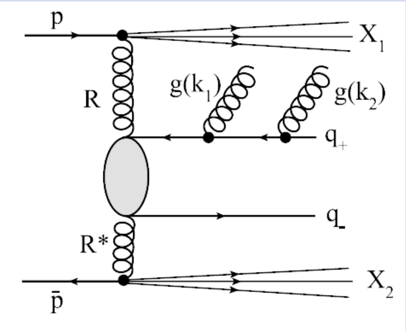


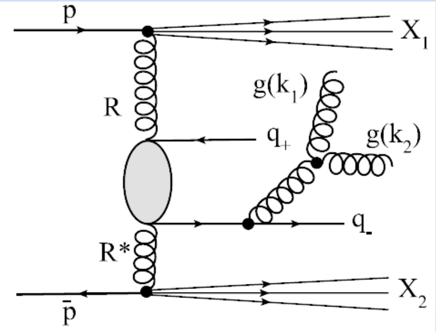
Comparison with models

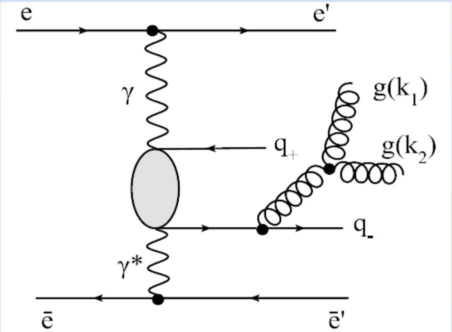


Gluon branching in pp, p$\bar{\text{p}}$ & e^+e^-

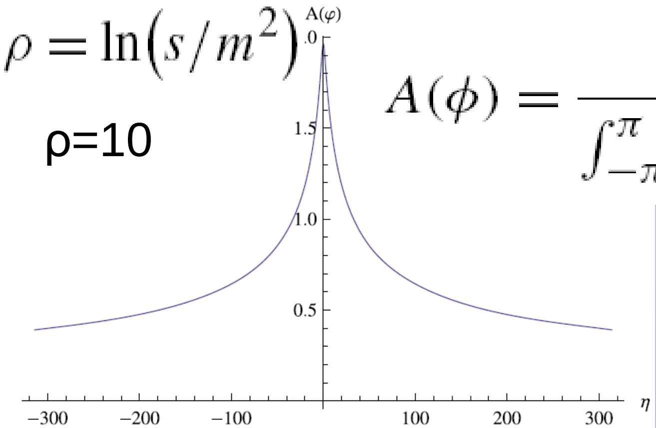
$$p(p_1)+\bar{p}(p_2)\to V(q)\to q(q_-)+\bar{q}(q_+)+g(k_1)+g(k_2)$$







$$\rho=\ln\left(s/m^2\right)$$



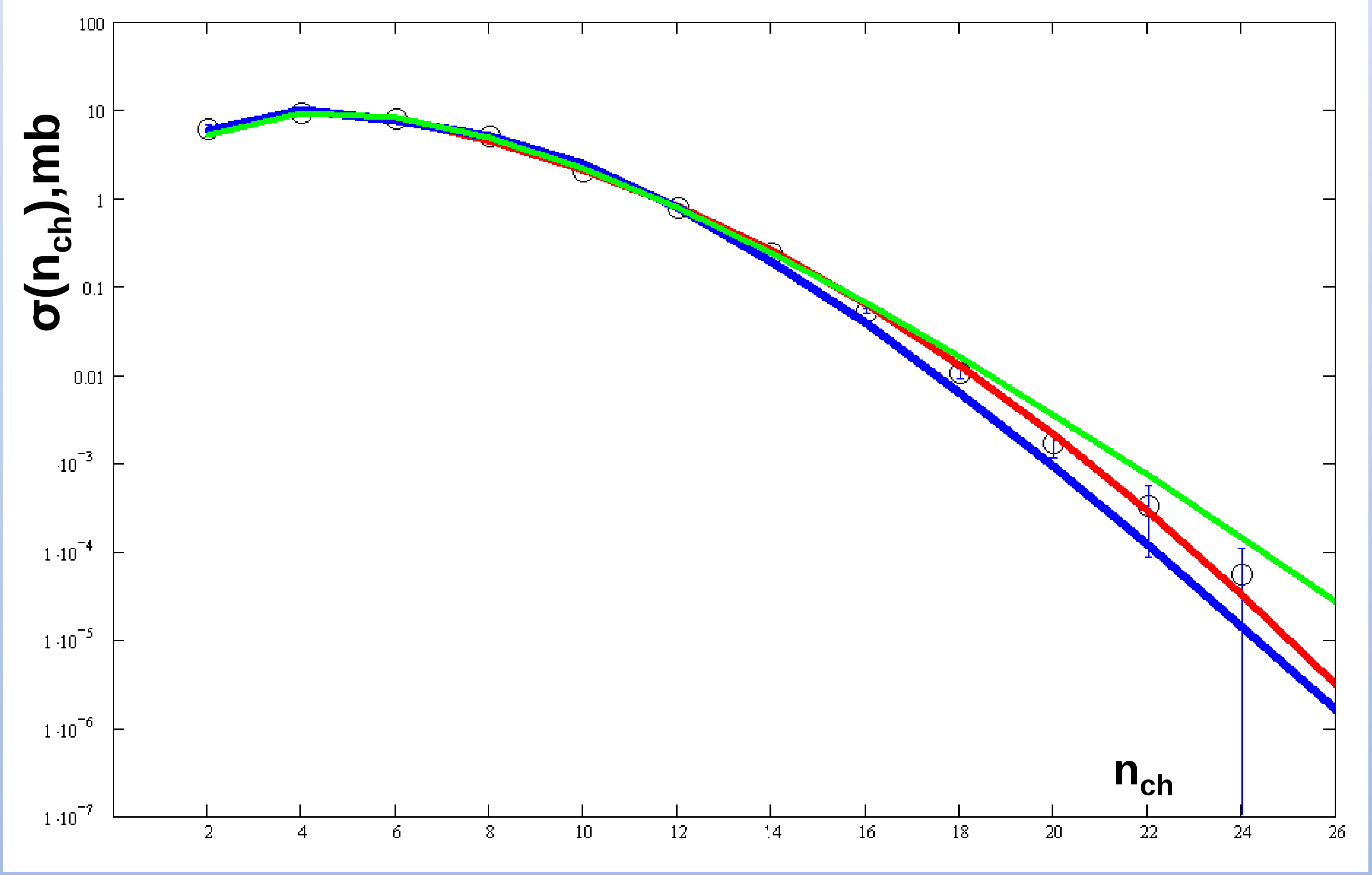
$$A(\phi)=\frac{\frac{d\sigma^{(2)}}{d\phi}}{\int_{-\pi}^{\pi}\frac{d\sigma^{(2)}}{d\phi}\,d\phi}=\frac{c_F^2+8c_Fc_V\pi\frac{Z(\rho,\phi)}{\rho^4}}{2\pi(c_F^2+\frac{1}{6}c_Fc_V)}=\frac{4+72\pi\frac{Z(\rho,\phi)}{\rho^4}}{11\pi}.$$

$$Z(\rho,\phi)=\frac{1}{4}\int_0^\rho(\rho-y)^2\frac{1}{\sqrt{\phi^2+e^{-y}}}\,dy$$

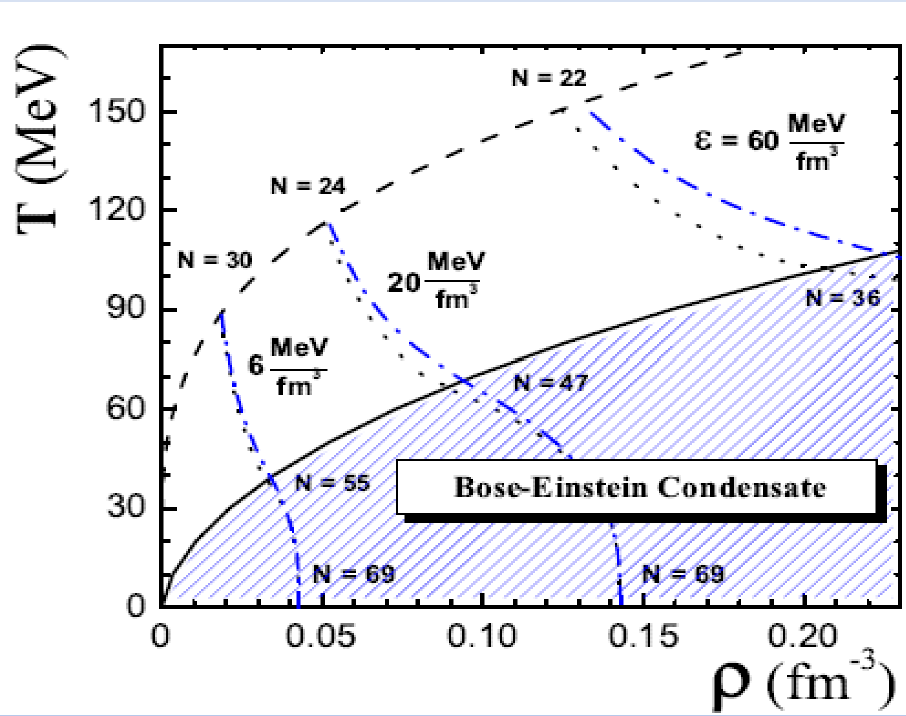
$$+\frac{1}{|\phi|}\int_0^\rho(\rho-y)\ln\left(|\phi|e^{y/2}+\sqrt{1+\phi^2e^y}\right)dy+O(\rho^2).$$

[E.Kuraev, S.Bakmaev, E.K. NP B851 (2011) 551]

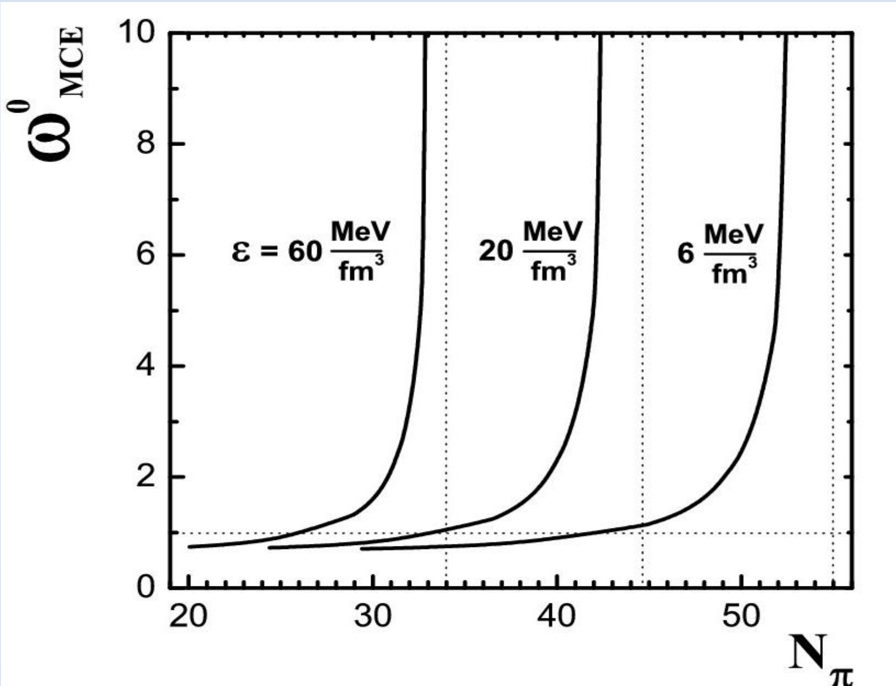
The g-fission inclusion improves essentially description of σ(n_{ch}) at the HM area



NEUTRAL PION NUMBER FLUCTUATIONS at HM region in pp at 50 GeV/c



The phase diagram of the ideal pion gas. The dashed line corresponds to μ=0, the solid – BEC at $T=T_C$ (TL), the dotted lines present the trajectories in the (ρ – T) plane with fixed energy densities: ε = 6, 20 and 60 MeV/fm³ . N_π – number of pions (μ=0, T_C, T=0).



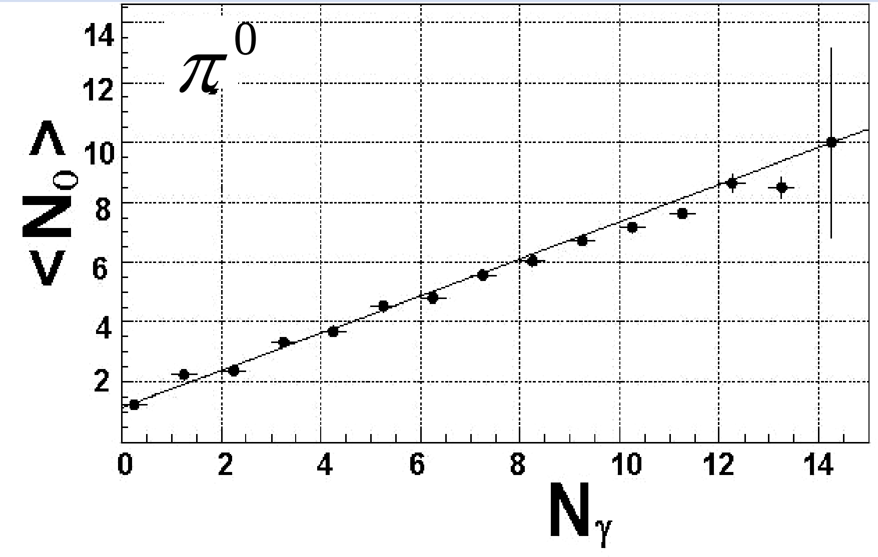
The scaled variance of neutral pions as function of the total number of pions (N_π),

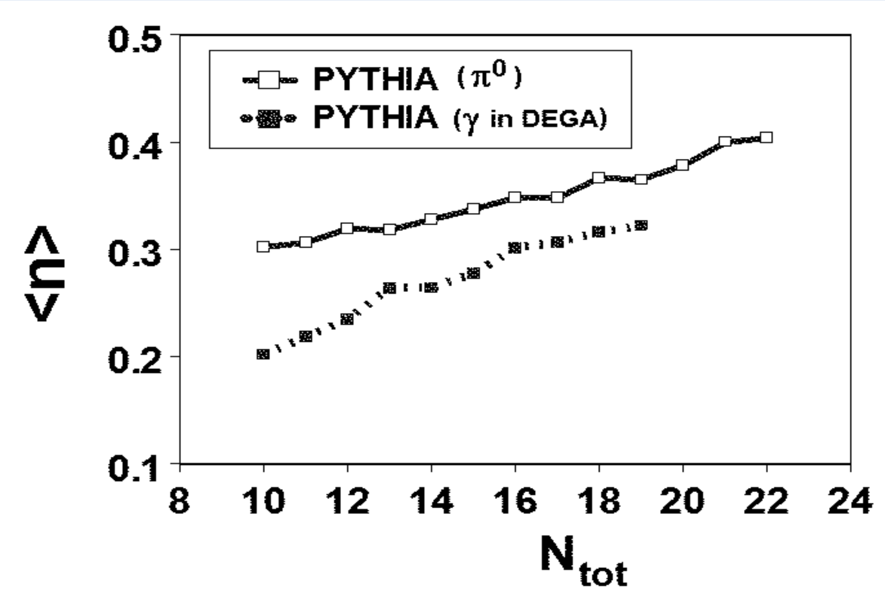
$$\omega^0 = D / < N_0 >$$

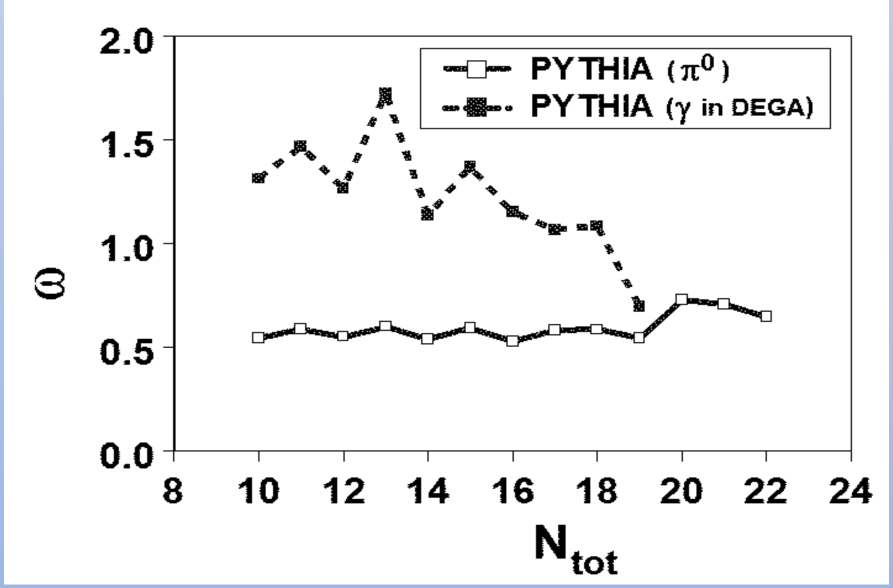
[V.V. Begun and M.I. Gorenstein, Phys. Lett. B 653, 190 (2007); Phys. Rev. C 77, 064903 (2008)]

SIMULATION of NEUTRAL PION DETECTION

$$N_\gamma < 12,\ N_0 < 16$$







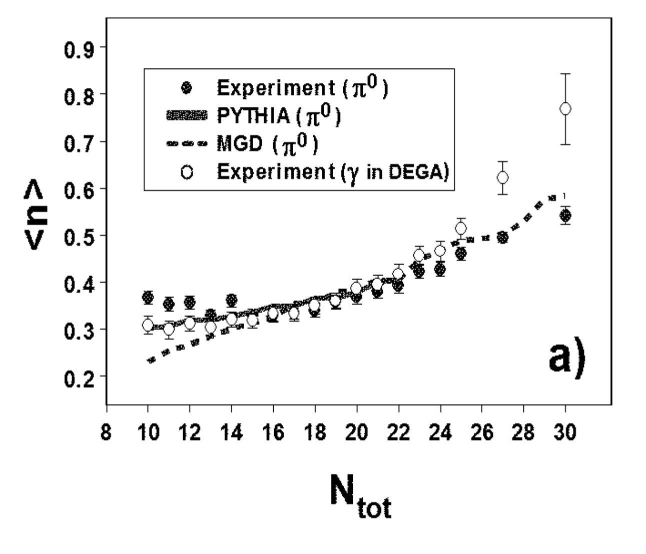
$n = N_0/N_{tot}$, $n \subset [0,1]$,

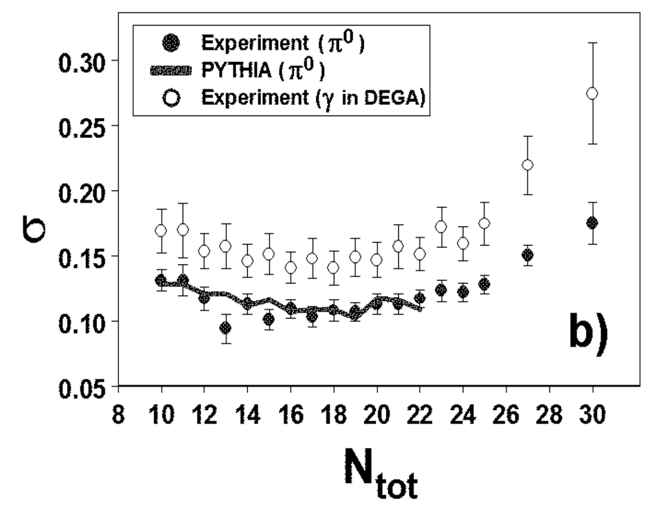
Scaled multiplicities;

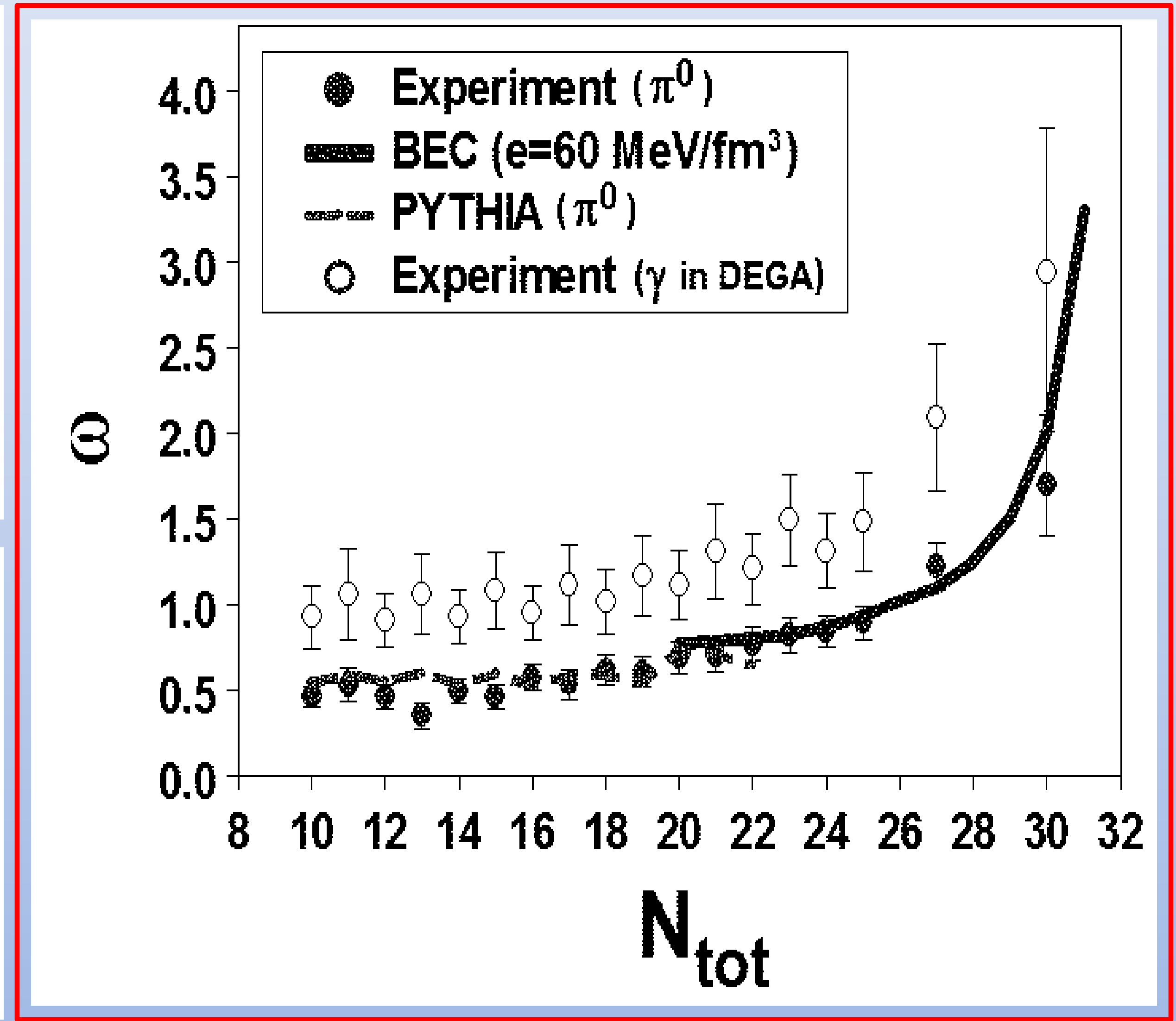
$r(N_0, N_{tot}) = N_{ev}(N_0, N_{tot})/N_{ev}(N_{tot})$,

probabilities at fix n_{ch}.

The main results







BEC FORMATION CONDITIONS

Estimation of the mean energy of pion:

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

$E_{p,\ beam} = 50\ GeV$, $n_\pi = 30$ -> $E_\pi = 0.12\ GeV$.

Critical energy of condensation (Landau L.):

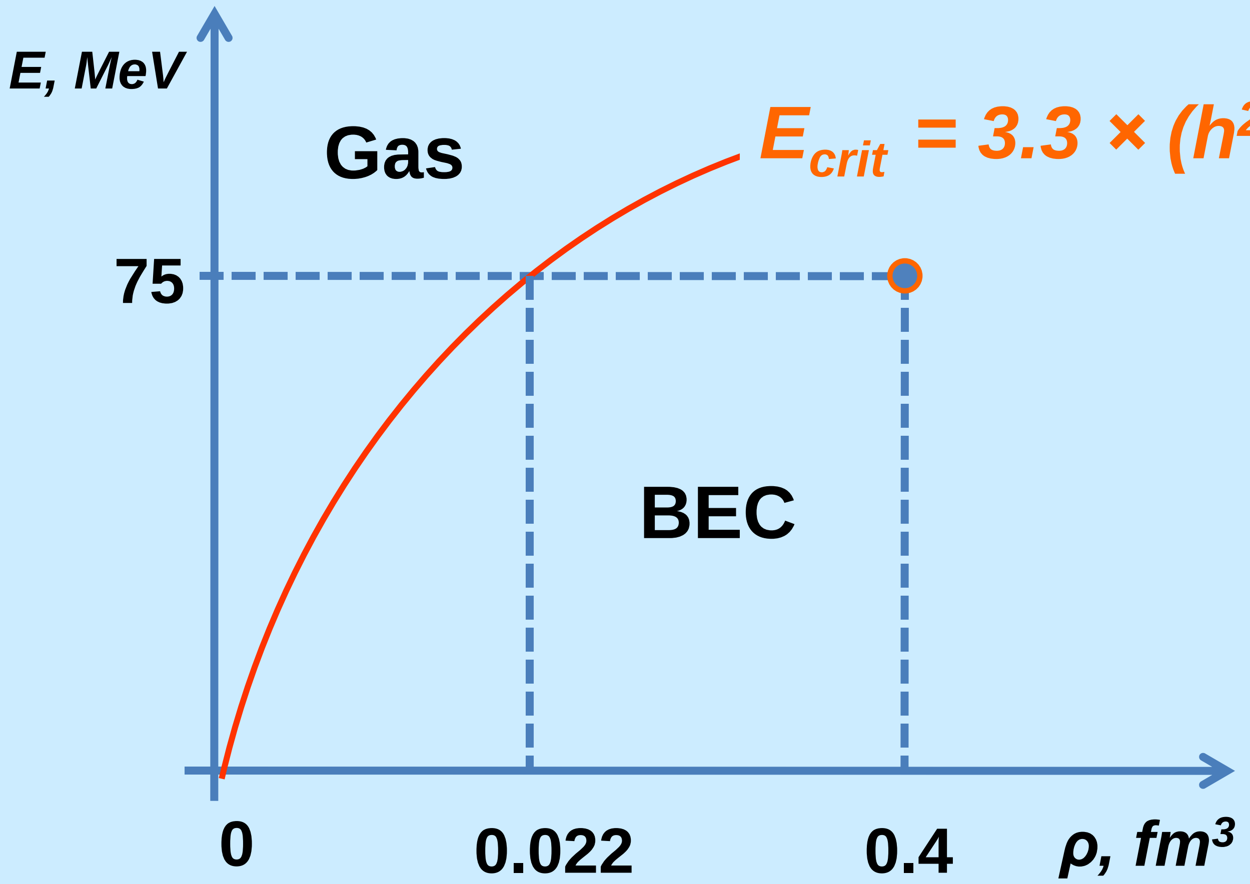
$$E_{crit} = (3{,}3/g^{2/3})(h^2/m_\pi)\rho^{2/3}. \qquad (2)$$

If fireball radius, r≈ 3 fm -> ρ, pion gas density:

$\rho = 0{,}2\ ф^{-3}$, $E_{crit} = 0{,}1$ ГэВ, $E_\pi \approx E_{crit}$

The max observable π-multiplicity at 50 GeV $N_{tot}=36$ ($N_{ch}=12$&&$N_0=24$). BEC has chance be formed in HM region!

Critical energy & density of pions

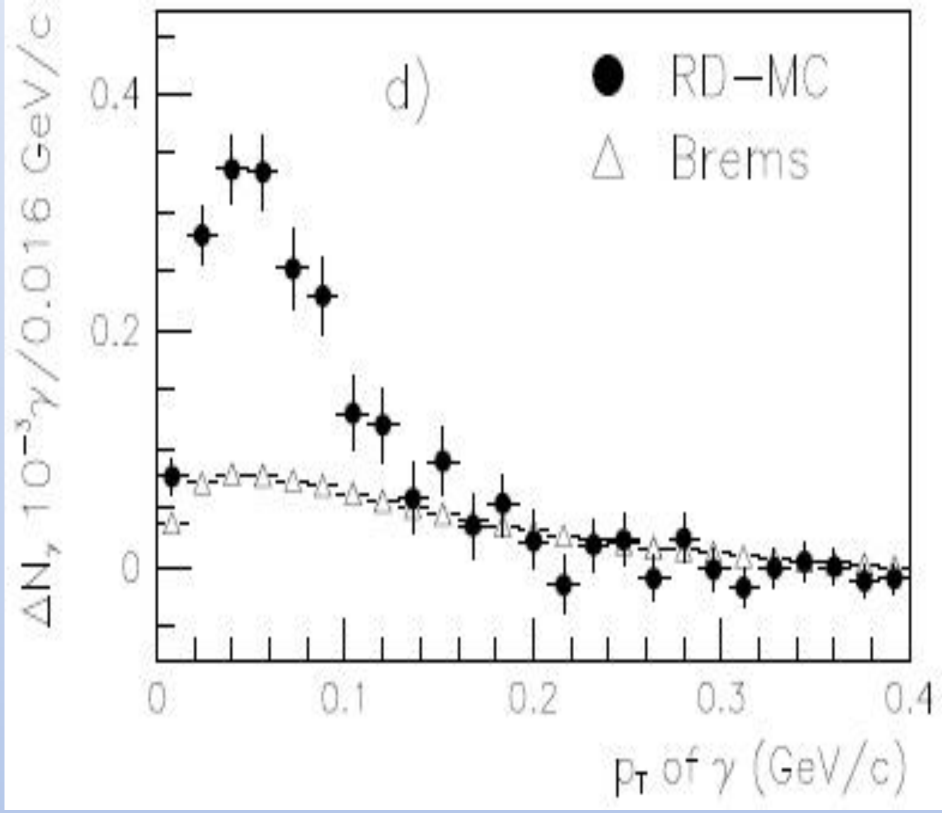


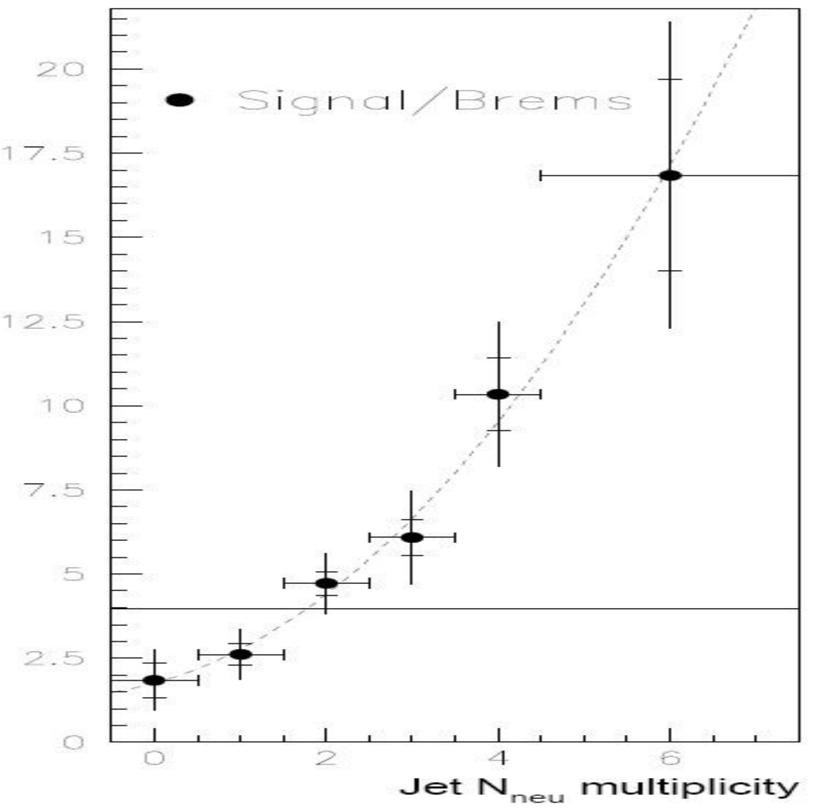
$E_{crit} = 3.3 \times (h^2/m_\pi) \times \rho^{2/3}$

CONCLUSIONS

1. The mean number of π^0 's in the event is proportional to the number of photons detected in ECal.
2. It is useful to present data in the scaled form: $n_0 = N_0/N_{tot}$ and $r_0 = N_{ev}(N_0, N_{tot})/N_{ev}(N_{tot})$, N_{ch}=fix, where $n_0 \subset [0 \div 1]$.
3. The corrections for VD acceptance, HMT action and data processing efficiency have been taken into account.
4. $r_0(n_0)$ is fitted with Gaussian and $\langle n_0 \rangle$, σ and $\omega = D/\langle N_0 \rangle$ are derived. These values are agreed with values received for PYTHIA5.6 code at $N_{tot} < 22$.
5. ω increases at $N_{tot} > 22$, that can indicate to the BEC approaching for the HM pion system in accordance with Gorenstein and Begun predictions.
6. This effect have been observed for the first time.
7. S. Barshay: Anomaly soft photon yield is stipulated of BEC.

Anomaly soft photon yield





Photon spectrum in hadron jet

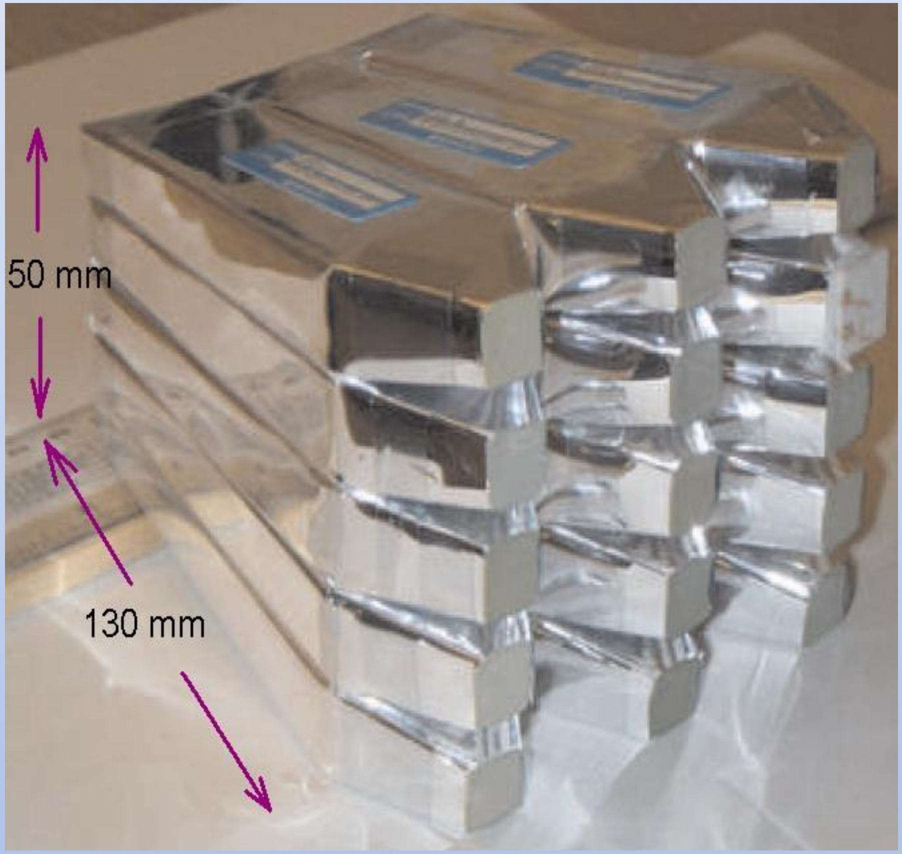
$e^+e^- \to Z^0 \to jet \to \gamma + X$.

(RD – MC) –photon spectrum without of known particle decay contribution calculated by MC.

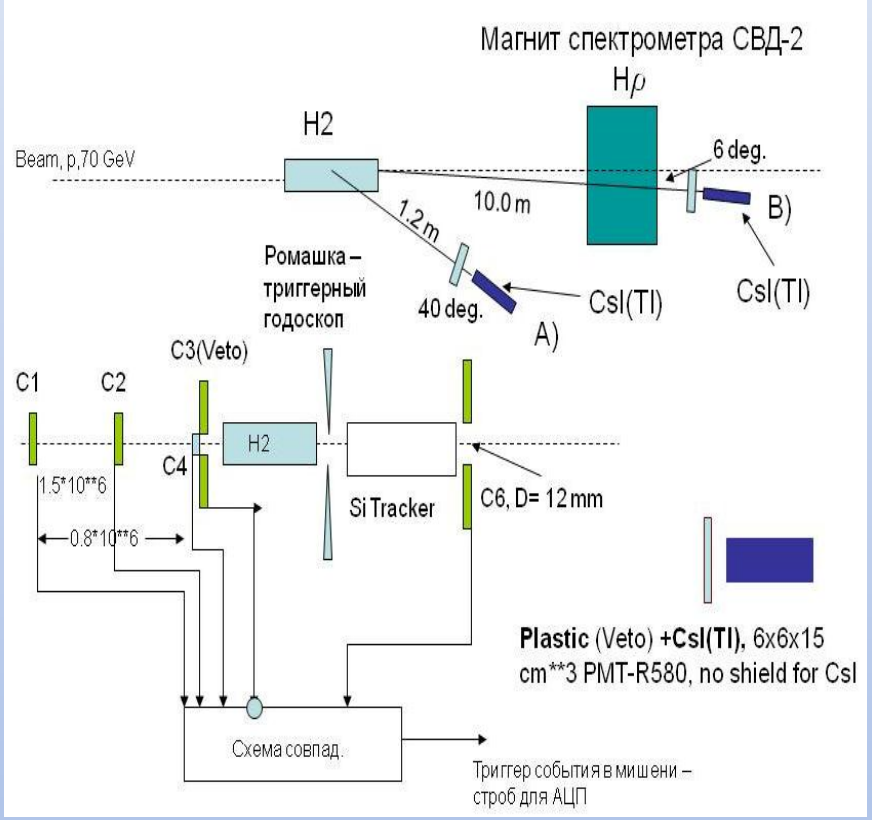
The ratio: the intensity of low energy photons to calculated value according to neutral particle number in jet.

[Eur.Phys. J. C47 (2006) 273]

Test of EMCal



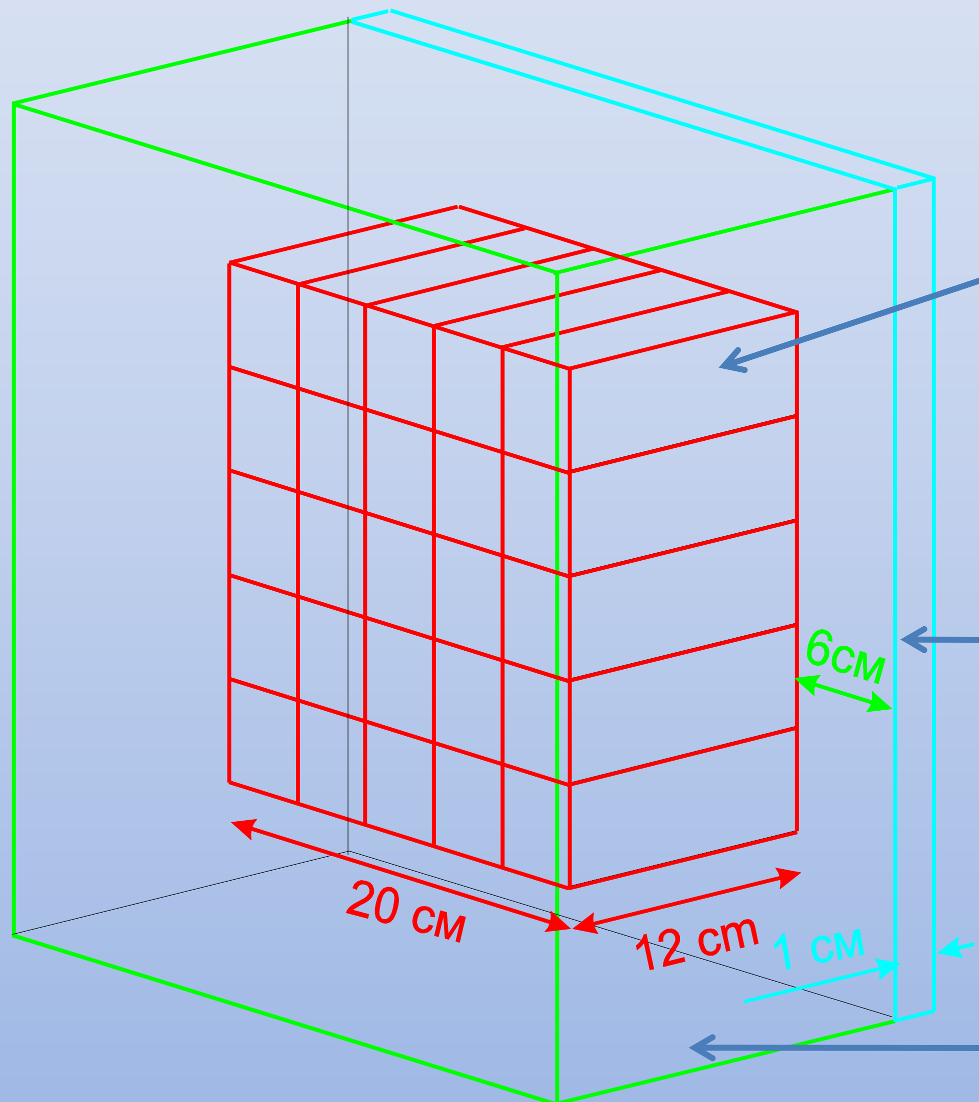
Prototype of soft photon EMCal on CsI(Tl) crystals.



Disposition scheme of counter CsI(Tl) on its test at SVD-2.

1. **We have obtained:** the dependence of the angle of emission in c.m.s. from the angle in lab.s.;
dependence momentum in lab s. from the angle in lab.s.;
2. **Conclusion:** background loading is high. It is necessary to manufacture calorimeter with passive and active protection (anti-coincidence counter environment).
3. **Barshay S.:** Connection with BEC.

Preparation for soft photon study

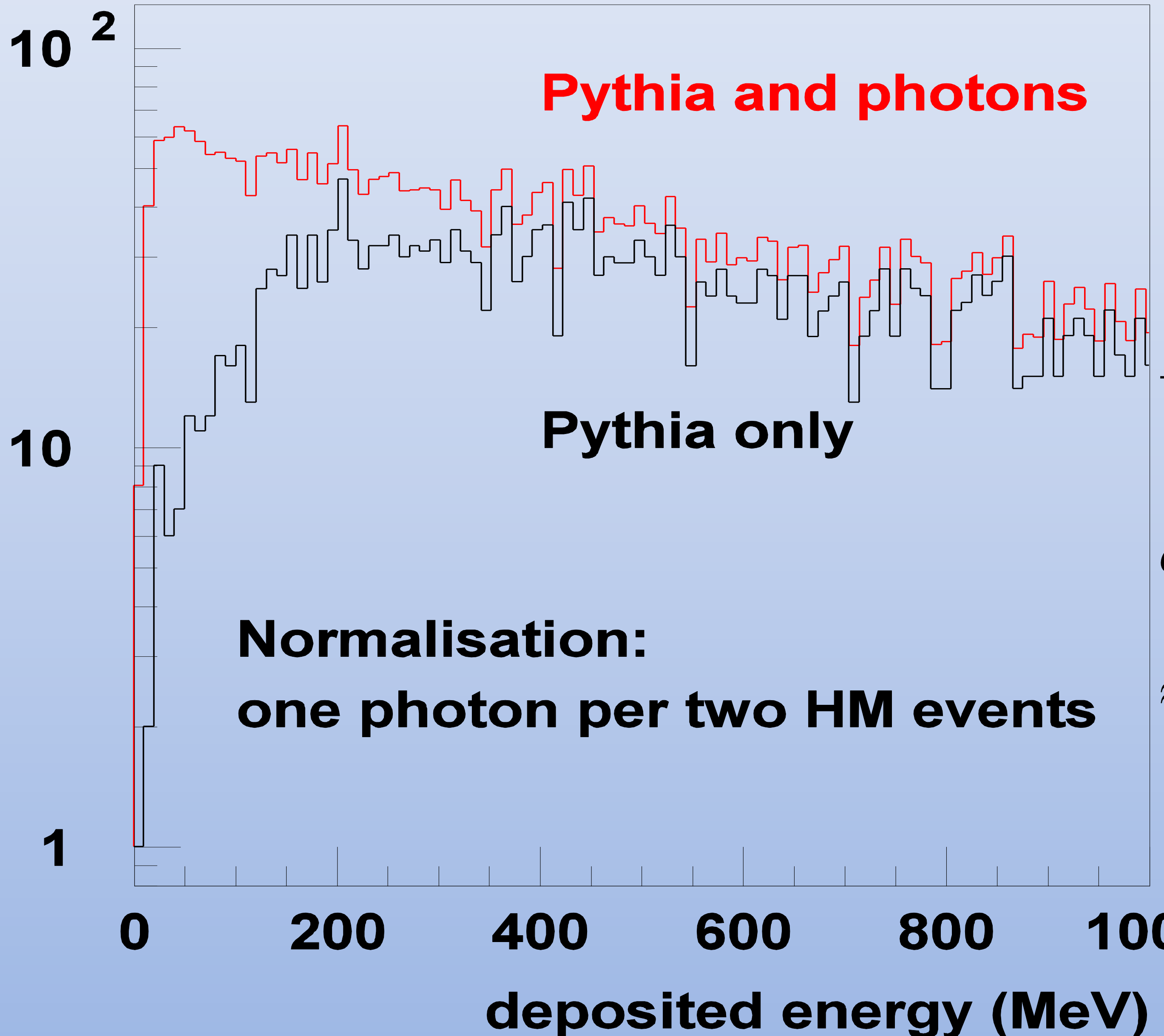


EMCalorimeter (red)

Forward counter of anti coincidencies (blue). Plastic, 1cm

Flank and back veto, 6 cm width, BGO or $PbWO_4$. (green).

EMCal simulation



Anomaly photon spectrum described by Low formula:

$$\frac{d\sigma}{dp} = \frac{C}{p};$$

$$\sigma_{SP} = \int_{10}^{30\,MeV/c} \frac{d\sigma}{dp} dp = $$

$$\approx 4\,mb.$$

Thank you for attention