The search for collective phenomena in hadron interactions

E. Kokoulina, A. Kutov, V. Nikitin,
Yu.Petukhov, V. Popov and V. Riadovikov.
For the SVD Collaboration

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Introduction

pp (pA) –> n, n = n_{ch} + n_0

Experiment at U-70, IHEP, Protvino

E_{lab} = 50 - 70 GeV

mean multiplicity: $\langle n_{ch} \rangle \sim 5$, $\langle n_0 \rangle \sim 2$

extreme (high) multiplicity (EM): $n \gg \langle n \rangle$

EM is formed in dense medium?

Introduction

We expect:

the collective behavior of secondary can be manifested at EM region. Since in this region can be formed the high density system.

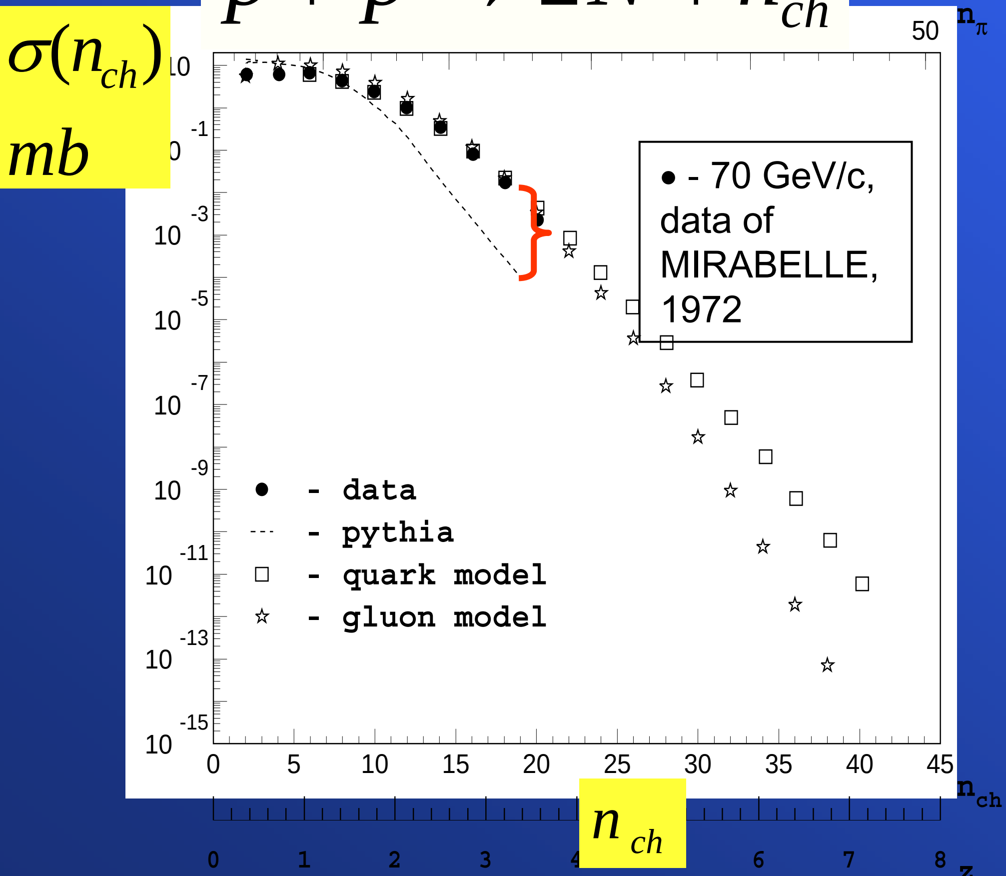
Outline

- The extreme multiplicity puzzles
- SVD-2 setup and data processing
- Collective phenomena search
- Gluon Dominance Model
- Outlook

The extreme multiplicity puzzles

The extreme multiplicity puzzles

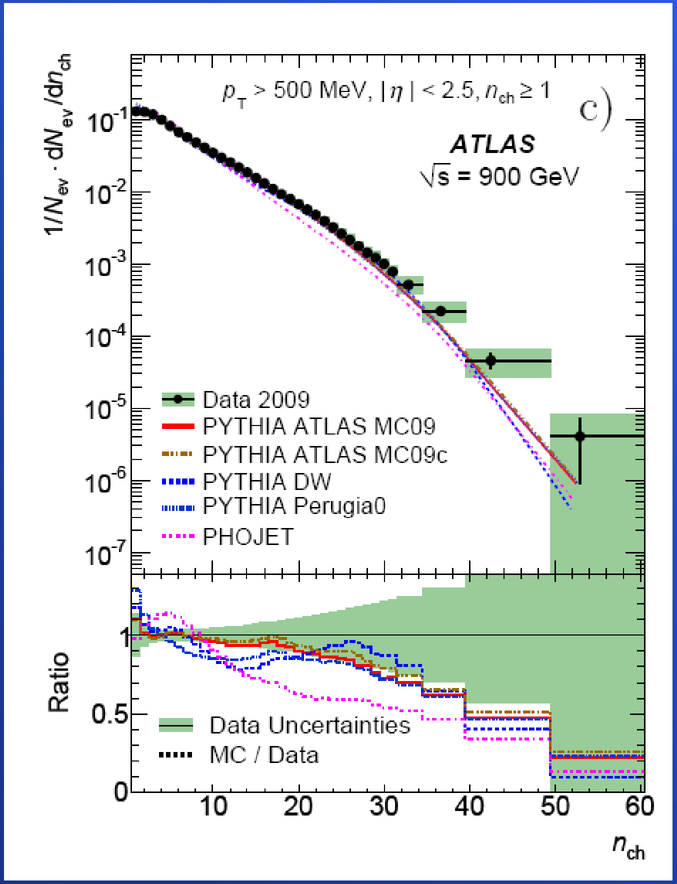
$$p + p \rightarrow 2N + n_{ch}$$



MC PHYPIA code has shown that standard generator predicts a value of the cross section at 70 GeV/c which is reasonably good agreement with data at small multiplicity, $n_{ch}<10$, but it underestimates the value $\sigma(n_{ch})$ by 2 orders of the magnitude at $n_{ch} > 18$.

At 70 (50) GeV/c up to n_{ch}= 18 (16).

The extreme multiplicity puzzles

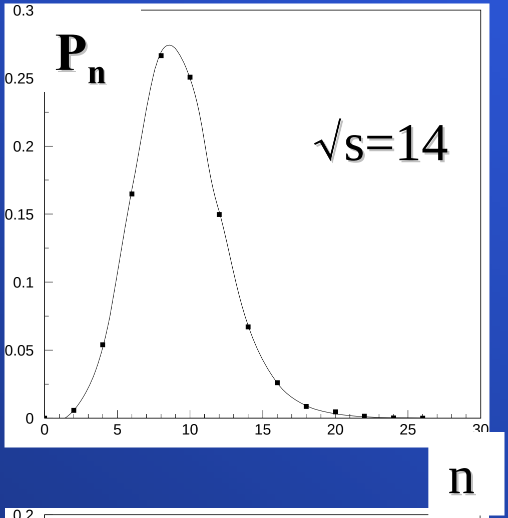


The present-day models are very much sensitive in the EM region for the multiplicity distributions (MD)

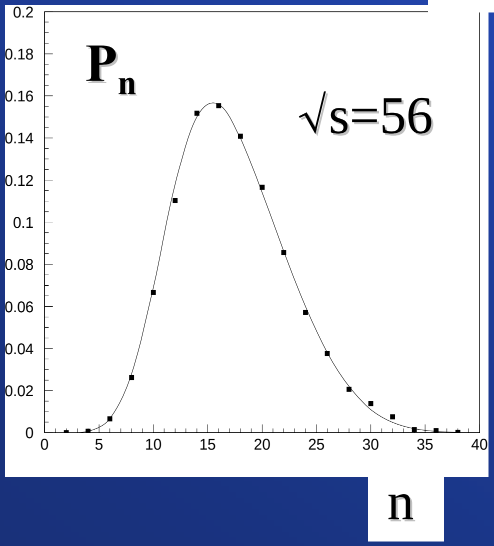
CERN-PH-EP/2010-004
March 15, 2010

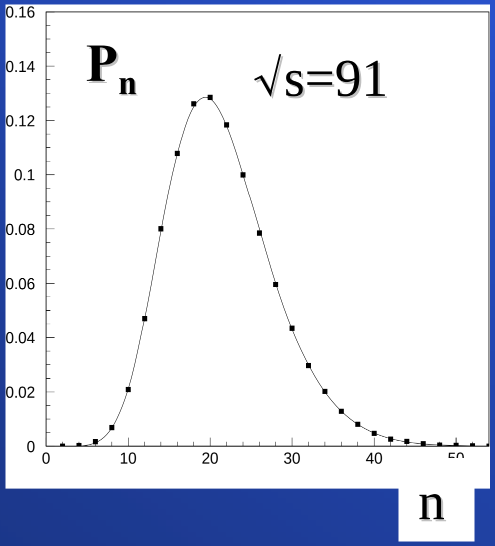
Charged-particle multiplicities in pp interactions at $\sqrt{s} = 900$ GeV measured with the ATLAS detector at the LHC

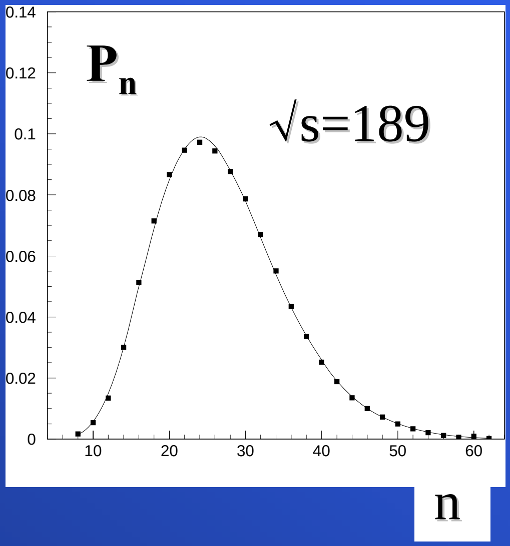
The extreme multiplicity puzzles



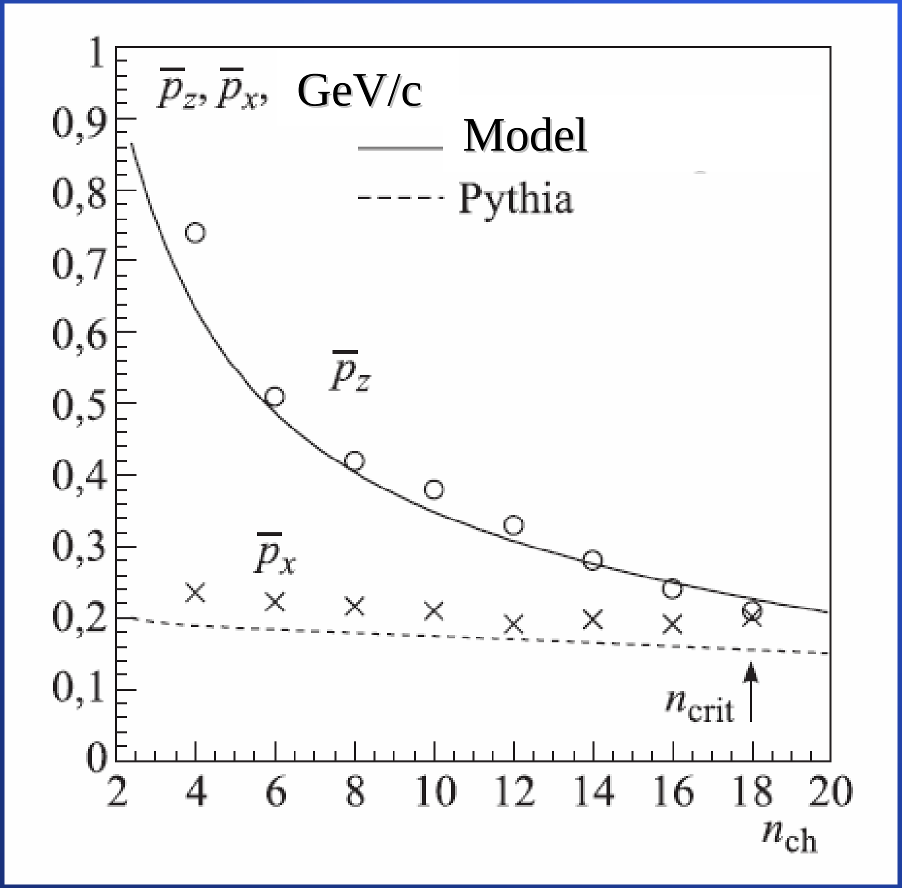
MD in e^+e^- -annihilation at $\sqrt{s}$=14, 56, 91 and 189 GeV: data and GDM (based on QCD-cascade and hadronization model).







The extreme multiplicity puzzles



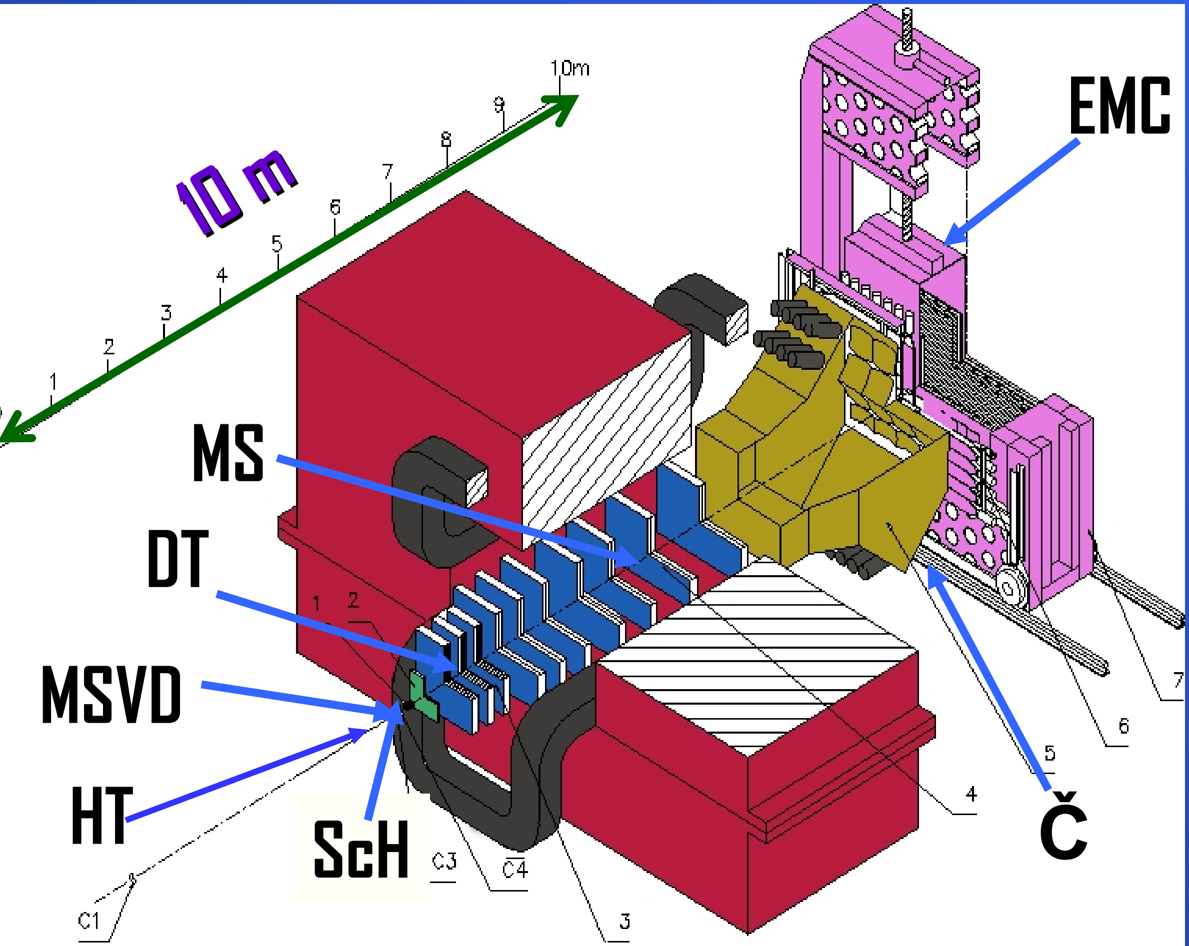
3 possible scenarios for $<p_{||}>$ and $<p_T>$ at EM:

(?)

- $<p_{||}> = <p_T>$
- $<p_{||}> > <p_T>$
- $<p_{||}> < <p_T>$

SVD-2 setup and data processing

SVD-2 setup



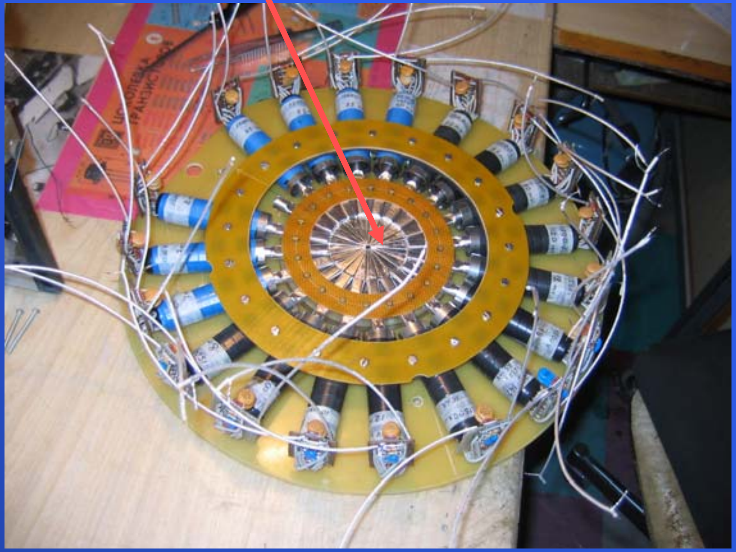
- Hydrogen Target (HT)
- MicroStrip Vertex Detector (MSVD)
- Scintillator Hodoscope (ScH or HMTr)
- Drift Tube Tracker (DT)
- Magnetic Spectrometer (MS) with PC
- Cherenkov counter (Č)
- Electromagnetic Calorimeter (EMC)

U-70 at IHEP, Protvino, E= 50 GeV. The ScH selects the rare events with the EM. The suppression factor of events with lower multiplicity amounts about 10^4. HT is a 7cm - thick, 25mm -diameter vessel.

SVD-2 setup

Scintillator hodoscope (camomile) for the EM event registration

20 petals: 18mm-altitude, 1.8-mm thick coupled with PMT FEU-137-3.



The liquid-hydrogen target

Software development

- MC event generator is designed for the setup element simulation;
- Data processing software;
- Alignment procedure;
- Track and vertex reconstruction...

Software development

Kalman Filter as Track Fitter for SVD

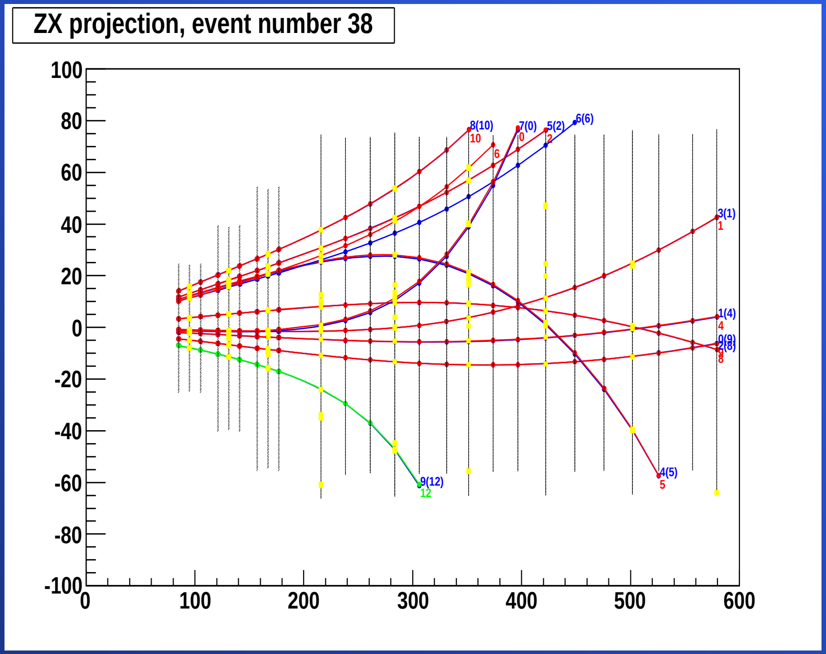
1. Drift tubes calibration - from raw TDC time to drift distance.
2. Recognize track candidates – find track-like groups of hits: pattern recognition.
3. Taking into account REALITY: alignment.
4. From track candidates to real track parameters: track fitting.
5. From tracks to vertexes: vertex fitting.

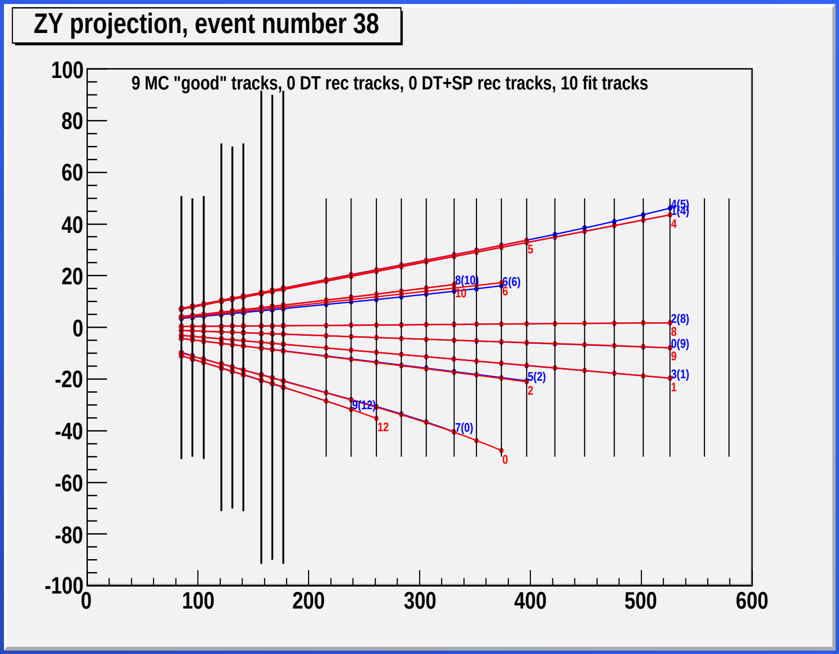
Software development

Analysis sequence (some detailes)

1. VD + MS reconstruction: track parameter determination; using of MS data for momentum estimation and vertex finding.
2. DT track candidate finding separately in U, Y and V planes, then build 3D tracks.
3. DT + MS track fitting: track parameters from 1 as initial values, hit list from 2, then Kalman Filtering procedure.
4. During fit taking into account non-uniform magnetic field, multiple scattering, energy losses.
5. Re-fit vertexes, if it is necessary.
6. Kinematical fit.

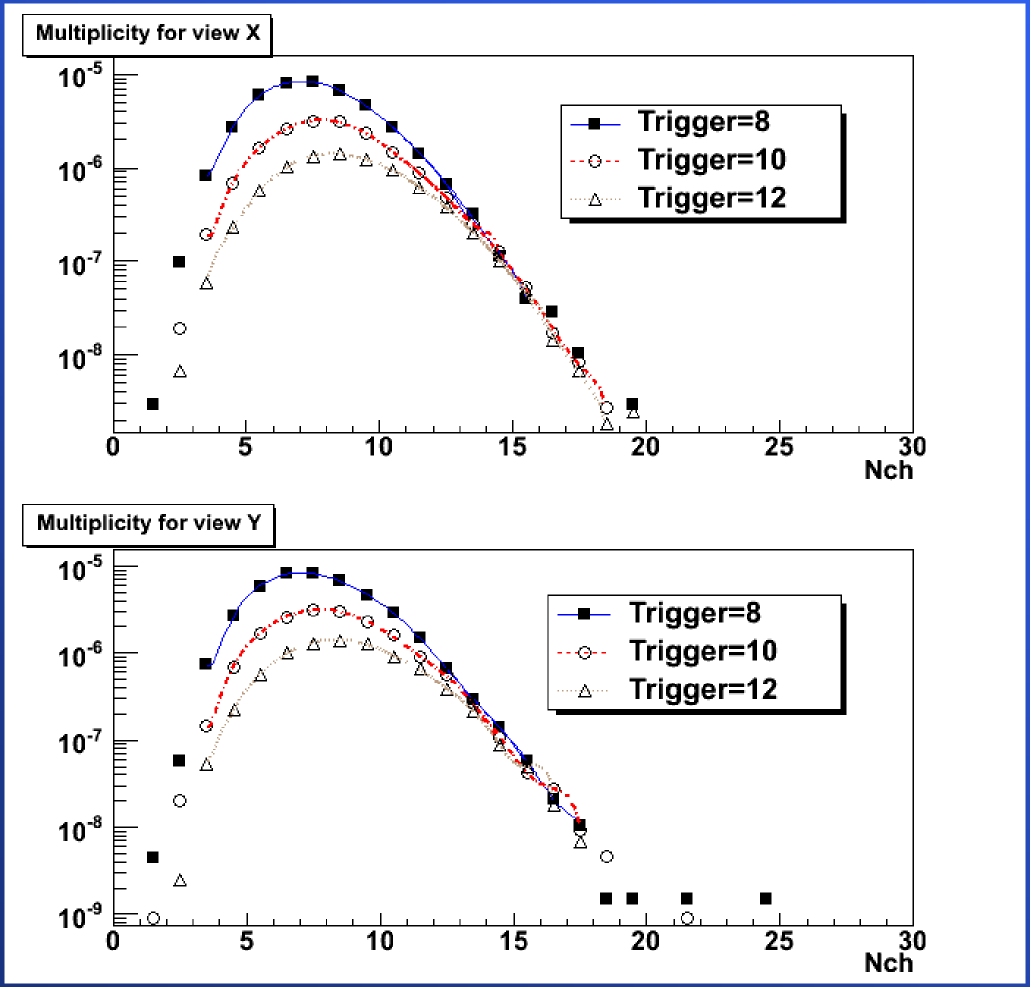
Software development





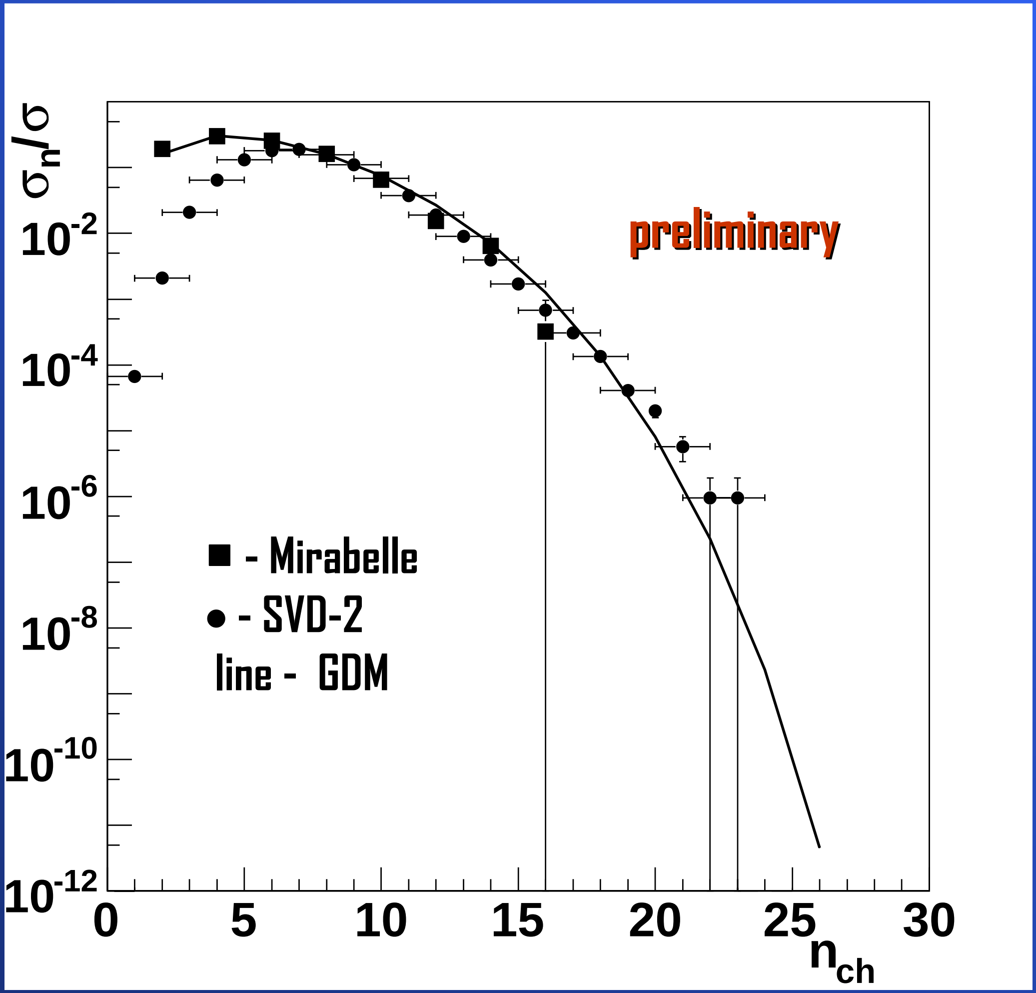
MC simulation and reconstruction in DT and MS detectors

Data from MSVD



Multiplicity Distributions (MD) in pp interactions at the different trigger levels: 8, 10, 12.
run 2008,PVD.

Data (MSVD) and GDM



Run 2008,
50 GeV/c, MD in pp-interactions

8^{th} trigger-level
(8 x MIP)

Collective phenomena search

Collective phenomena search

1. Bose-Einstein Condensation (BEC);

2. Cherenkov gluon emission;

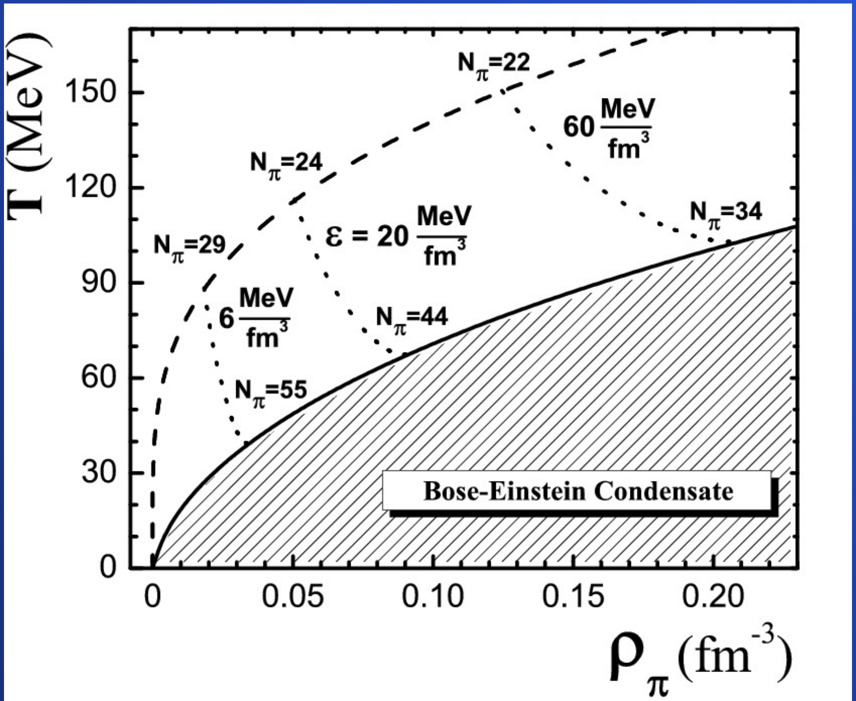
3. Gluon Dominance Model (GDM);

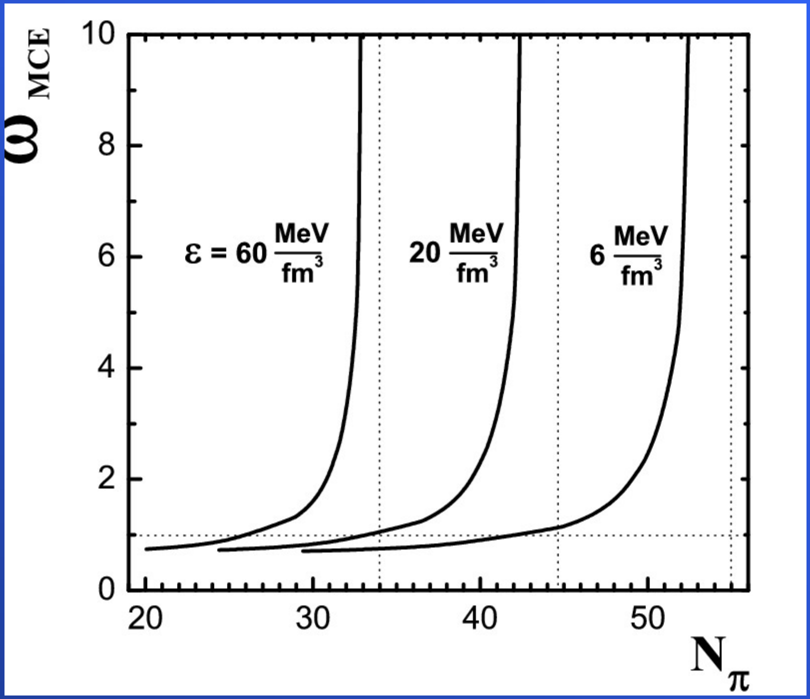
4. Excess of soft photon (SP) yield;

5. Clusterization; turbulence phenomena …

Collective phenomena search

M. Gorenstein and V. Begun had predicted an abrupt and anomalous increase of the scaled variance ω^0 of neutral and charged pion number fluctuations in the vicinity of the BEC line [Phys.Lett.B651:114 (2007)] .



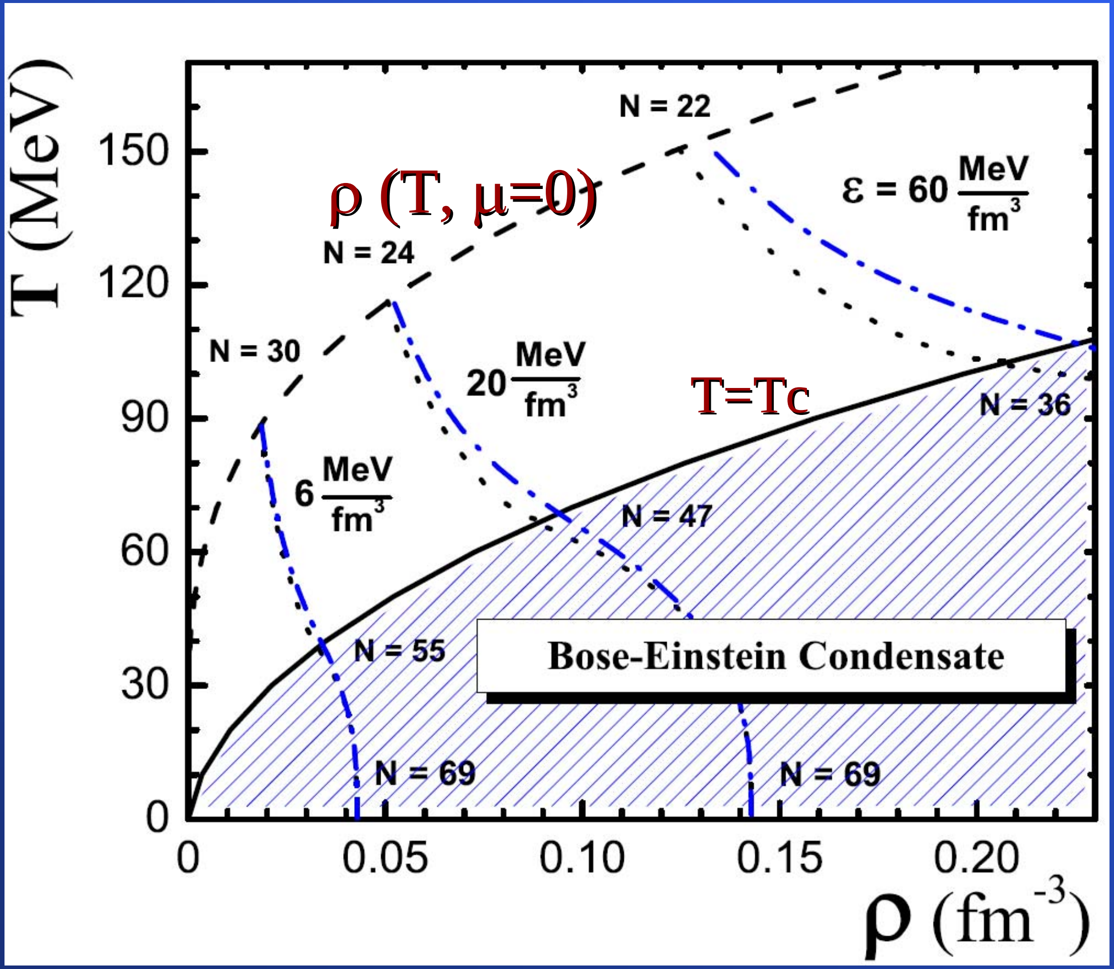


Collective phenomena search

ω^0 - scaled variance

$$\boxed{\begin{gathered}\omega^0 = \langle \Delta n_0{}^2 \rangle / \langle n_0 \rangle \\ \Delta n_0{}^2 = (n_0 - \langle n_0 \rangle)^2\end{gathered}}$$

Collective phenomena search



The phase diagram of the ideal pion gas with zero net electric charge.

The dashed-dotted lines present the trajectories in ρ-T plane with fixed energy density at 9.7GeV.
V.Begun and M.Gorenstein
Phys.Rev.C77:064903,2008

Collective phenomena search

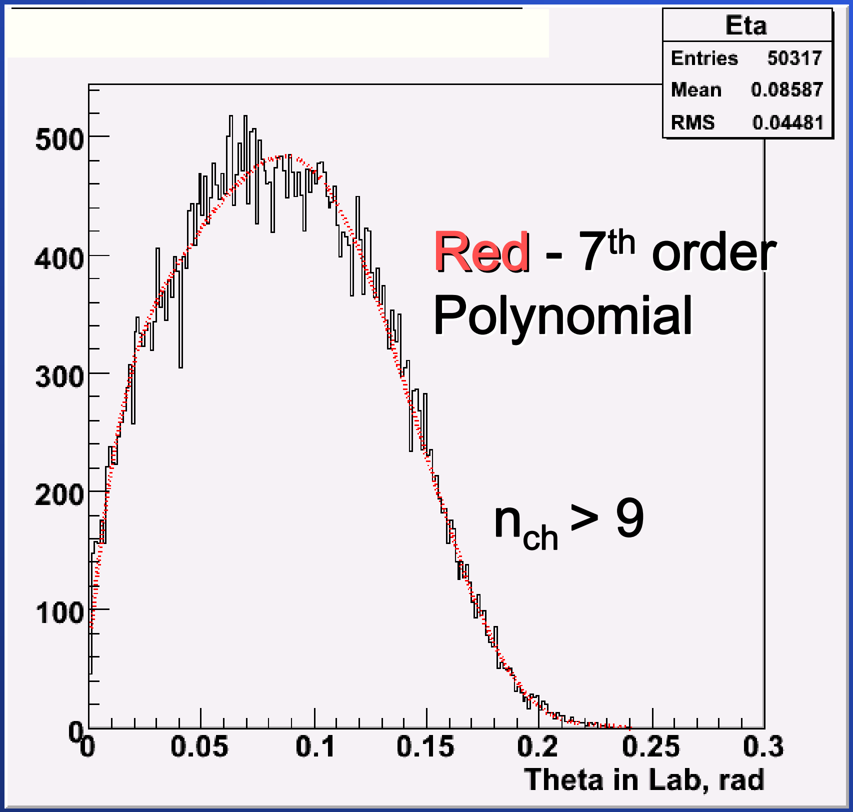
n	n_{ch}= 2	4	6	8	10	12	14	16	18	19	20	21	$<n_0>$
3	1*8												1.00
4	2*8	+0*198											0.08
5	3*8	+1*381											1.04
6	4*2	+2*425	+0*310										1.16
7	5*1	+3*285	+1*568										1.67
8	6*1	+4*191	+2*583	+0*751									1.27
9	7*1	+5*120	+3*443	+1*1369									1.71
10		6*56	+4*309	+2*1491	+ 0*434								1.99
11		7*24	+5*184	+3*1222	+ 1*835								2.47
12		8*10	+6*78	+4*836	+ 2*928	+0*157							2.86
13		9*2	+7*43	+5*472	+ 3*688	+1*305							3.34
14		10*2	+8*10	+6*231	+ 4*469	+2*371	+0*84						3.52
15		11*2	+9*9	+7*107	+ 5*265	+3*312	+1*157						3.83
16		12*1	+10*2	+ 8*64	+ 6*127	+4*188	+2*159	+0*74					3.86
17		13*1		+ 9*19	+ 7*49	+5*109	+3*127	+1*123					3.68
18				10*8	+ 8*39	+6*51	+4*79	+2*160	+0*8				3.87
19				11*5	+ 9*18	+7*28	+5*48	+3*109	+1*20	+0*3			4.33
20				12*3	+10*6	+8*16	+6*22	+4*70	+2*30	+1*11	+0*1		4.45
21					11*4	+9*8	+7*13	+5*53	+3*24	+2*8	+1*2	+0*2	4.93
22					12*1	+10*8	+8*7	+6*40	+4*16	+3*8	+2*7	+1*1	5.59
23						11*3	+9*3	+7*16	+5*11	+4*4	+3*1		6.47
24					14*1	+12*2	+10*3	+8*8	+6*6	+5*2	+4*3	+3*1	7.42
25							11*1	+9*8	+7*2	+6*2	+5*1		8.14
26					16*1	+14*1		+10*2	+8*3	+7*1		+5*2	9.1
27								11*5	+9*3	+8*1	+7*1		9.7
28								12*2	+10*3		+8*1		10.33
29								13*1					13.
30									12*1		+10*1		11.
ΣN_{ev}	29	1698	2539	6578	3865	1559	703	671	127	40	18	6	

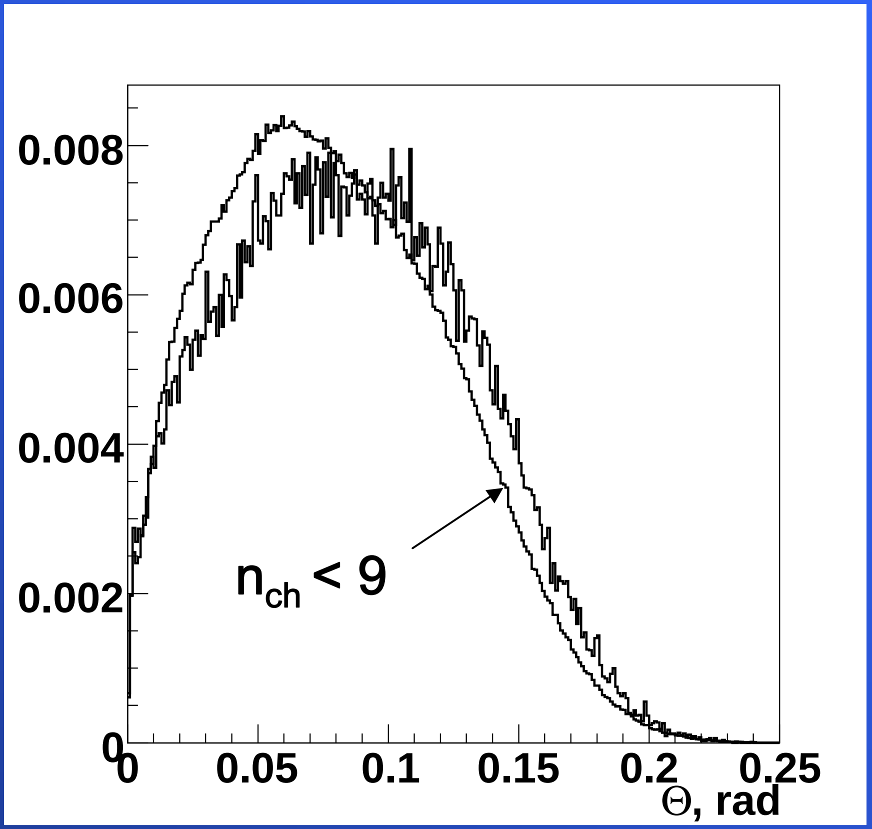
Preliminary, work in progress

data will be add

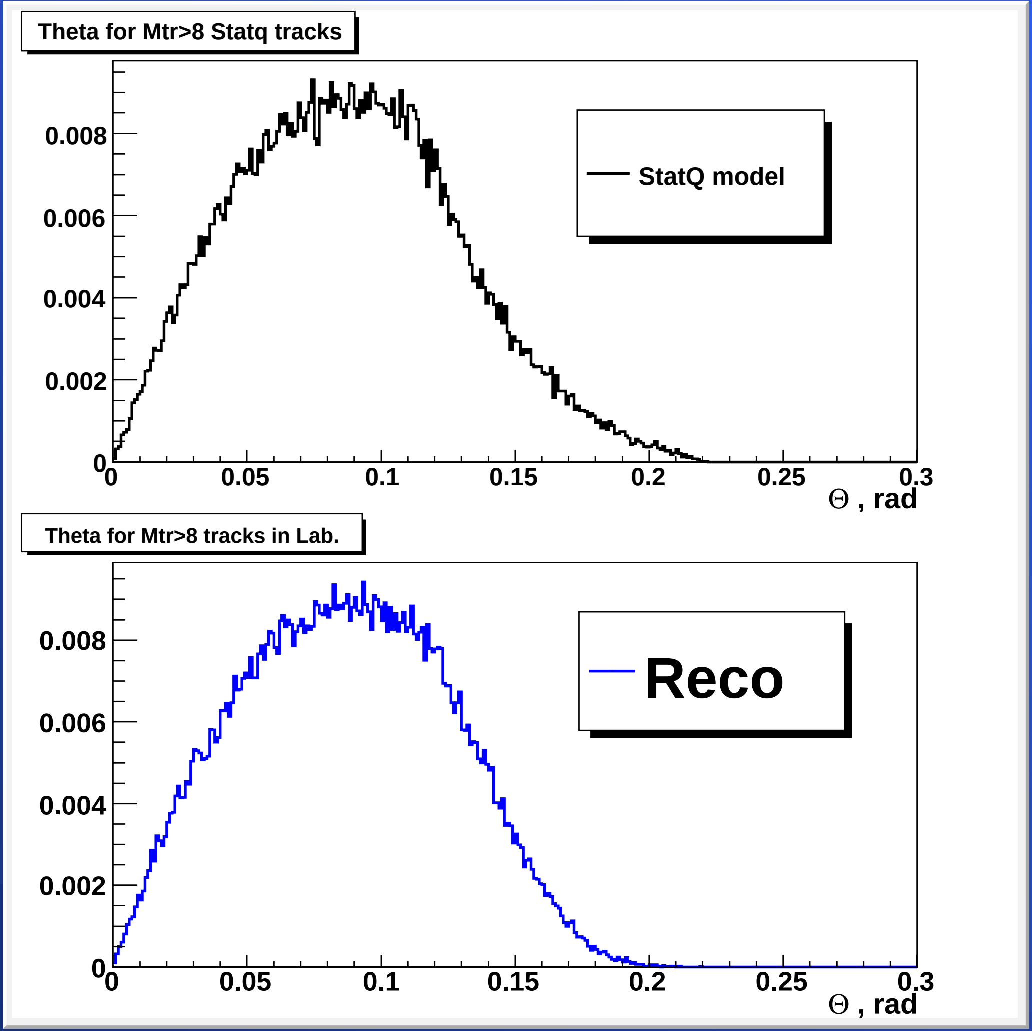
Collective phenomena search

Two-hump structure in pp at n_ch >9 (2008) run



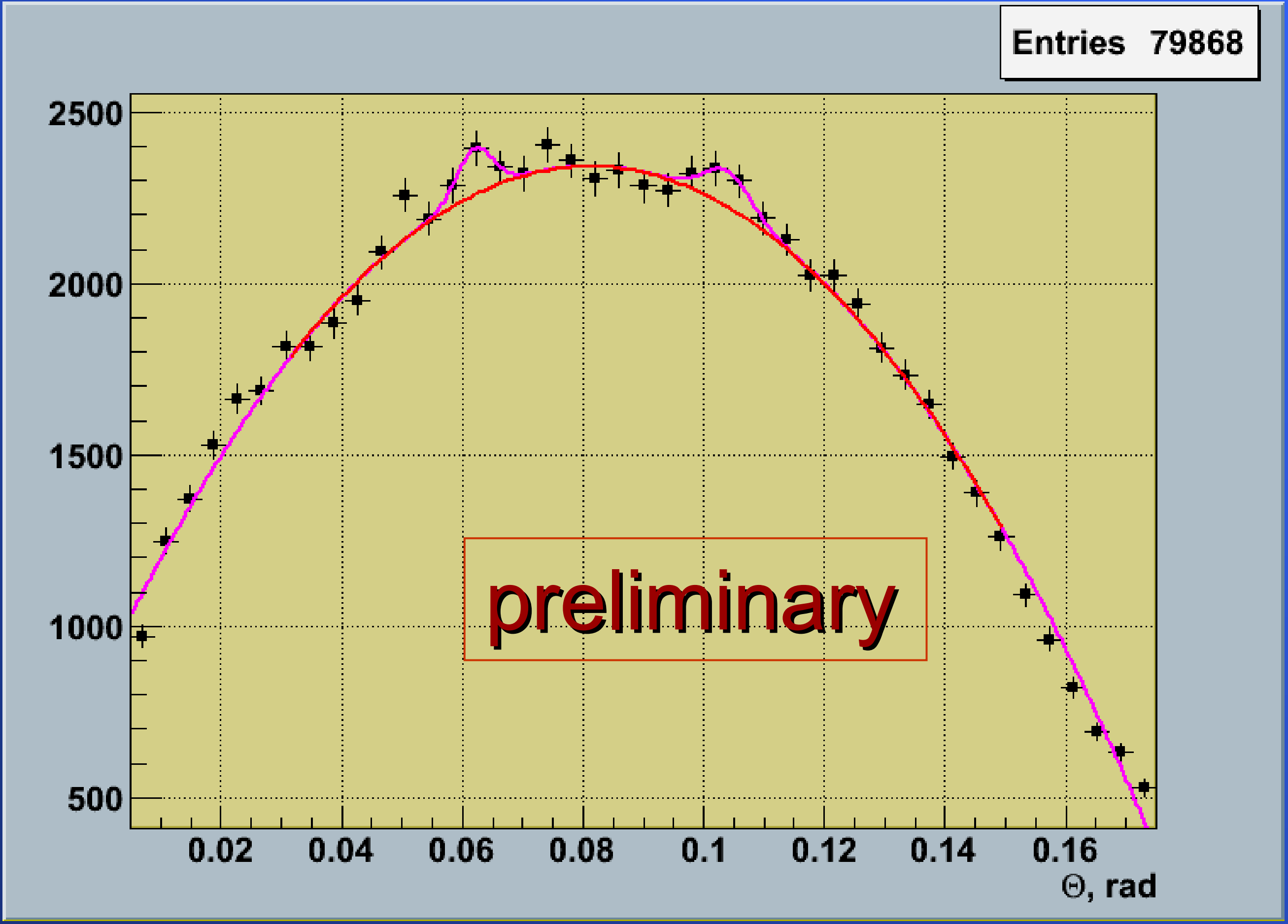


Collective phenomena search



Monte-Carlo simulation & track reconstruction ($n_{ch} \geq 9$)

Collective phenomena search



CI ~ 4 σ

3th order polynomial of background and two Gausses of peaks

Collective phenomena search

Ring Events (?) $$\cos\Theta_{Ch} = 1/\beta n,\ \ \beta = p/E,$$

Our experiment:

n - the index of the refraction,

$\theta_{Ch} = 0.065 \pm 0.005$, $\mathbf{n = 1.0023 \pm 0.0003}$

Dremin theory:

$n\,(p) = 1+\Delta n\,(p) = 1+3m_{pr}^{3}\,\sigma(p)\,\nu_h\,\rho(p)\,/\,8\pi p_{pr}$,

ν_h – the number of scatters, $\rho = \mathrm{Re}\,F/\,\mathrm{Im}\,F$,

$\Delta n\,(p) = 3\,m_p^{3}\,\mathrm{Re}\,F\,/\,2p^{2} = 0.0005 * \mathrm{Re}\,F$,

at Re F =4.6 GeV (0.92 fm)

Collective phenomena search

Dremin stresses (arXiv:0910.0099 [hep-ph]) that RHIC and cosmic rays data were fitted with different values of the refraction index close to 3 and 1, correspondingly. He explains this distinction via the difference in values x and Q^2:

✓ The large x and Q^2 are related to the dilute parton system (our case)

✓The low x and Q^2 correspondents to a more dense system (RHIC).

Gluon Dominance Model

Gluon Dominance Model

$$e^+e^- \to \gamma(Z^0) \to q\bar{q} \to (q,g) \to ? \to hadrons$$

First stage (cascade):
a) gluon fission; b) quark bremsstrahlung; c) quark pair creation; NBD.

Second stage (hadronization): BD

$$Q_p^H = \left[1 + \frac{\bar{n}_p^h}{N_p}(z-1)\right]^{N_P}.$$

$$P_m = \frac{k_p(k_p+1)\dots(k_p+m-1)}{m!}\left(\frac{\bar{m}}{\bar{m}+k_p}\right)^m\left(\frac{k_p}{\bar{m}+k_p}\right)^{k_p}.$$

A.Giovannini. NP, B161 (1979).

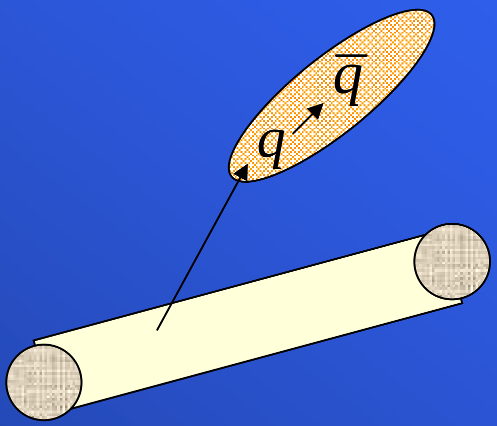
Convolution of two stages.

Gluon Dominance Model

GDM for e^+e^-: the mean hadron multiplicity formed from gluon, $\langle n^h_g \rangle$, while its passing through the hadronization stage is remained constant $\langle n^h_g \rangle \sim 1$ (14 -189 GeV).

Fragmentation mechanism: 1 parton $\rightarrow$ 1 hadron.

$$\frac{Baryon}{Meson} << 1$$



B.Muller [nucl-th/0404015]

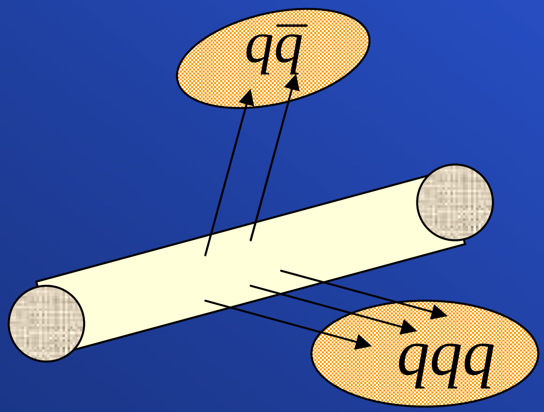
Gluon Dominance Model

GDM had shown: quarks of initial protons are staying in leading particles (from U-70 up to ISR). Multiparticle production is realized by active gluons.

Two schemes: with/without gluon branch. Convolution gluon (Poisson/Farry) & hadron (PBD) MDs.

Gluon Dominance Model

The recombination mechanism of hadronization: the increase of $<n^h_g>$ from 1.6 at 70 GeV (U-70) up to 3.3 at 60 GeV (ISR) in pp-interactions.



B.Muller [nucl-th/0404015]

RHIC, in central AA–interactions:

$$\frac{Baryon}{Meson} \approx 1$$

Gluon Dominance Model

Soft Photons (SP)

$$p_t \leq 0.1 GeV/c,\ x \leq 0.01$$

σ(SP) are 5-8 times more in the comparison with the QED predictions.

Assumption:

Parton system or excited new formed hadrons set in almost equilibrium state during a short period (we use the black body emission spectrum):

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

Estimations of SP emission region: <~ 4 fm.

Outlook

- ✓ The continuation of the search for the collective phenomena in pp (pA) interactions at the EM region: BEC, ring events (dense groups in angle distributions), clusterization, turbulence phenomena.
- ✓ Soft photon studies at the EM
- ✓ Preparation to autumn (2010) carbon-nucleus interaction program, ~34 GeV/N at U-70 on SVD-2 setup .