EVENT TEXTURE SEARCH FOR CRITICAL FLUCTUATIONS IN PB+PB COLLISIONS AT THE CERN SPS

Mikhail Kopytine (SUNY at Stony Brook) for the NA44 Collaboration

I.Bearden[a], H.Bøggild[a], J.Boissevan[b], L.Conin[d], J.Dodd[c], B.Erazmus[d], S.Esumi[e], C.W.Fabjan[f], D.Ferenc[g], D.E.Fields[b], A.Franz[f], J.J.Gaardhøje[a], A.G.Hansen[a], O.Hansen[a], D.Hardtke[i], H. van Hecke[b], E.B.Holzer[f], T.J.Humanic[i], P.Hummel[f], B.V.Jacak[j], R.Jayanti[i], K.Kaimi[e], M.Kaneta[e], T.Kohama[e], M.L.Kopytine[j], M.Leitchouk[c], A.Ljubicic, Jr[g], B. Lörstad[k], N.Maeda[e], L.Martin[d], A.Medvedev[c], M.Murray[h], H.Ohnishi[e], G.Paic[f], S.U.Pandey[i], F.Piuz[f], J.Pluta[d], V.Polychronakos[l], M.Potekhin[c], G.Poulard[f], D.Reichhold[i], A.Sakaguchi[e], J.Schmidt-Sørensen[k], J.Simon-Gillo[b], W.Sondheim[b], T.Sugitate[e], J.P.Sullivan[b], Y.Sumi[e], W.J.Willis[c], K.L.Wolf[h], N.Xu[b], D.S.Zachary[i].

[a] Niels Bohr Institute, Denmark; [b] Los Alamos National Laboratory, USA; [c] Columbia University, USA; [d] Nuclear Physics Laboratory of Nantes, France; [e] Hiroshima University, Japan; [f] CERN, Switzerland; [g] Rudjer Boscovic Institute, Croatia; [h] Texas A&M University, USA; [i] Ohio State University, USA; [j] SUNY at Stony Brook, USA; [k] University of Lund, Sweden; [l] Brookhaven National Laboratory, USA.

- introduction to the EbyE Discrete Wavelet Transform power spectrum analysis of local fluctuations

- experimental technique

- results and conclusions
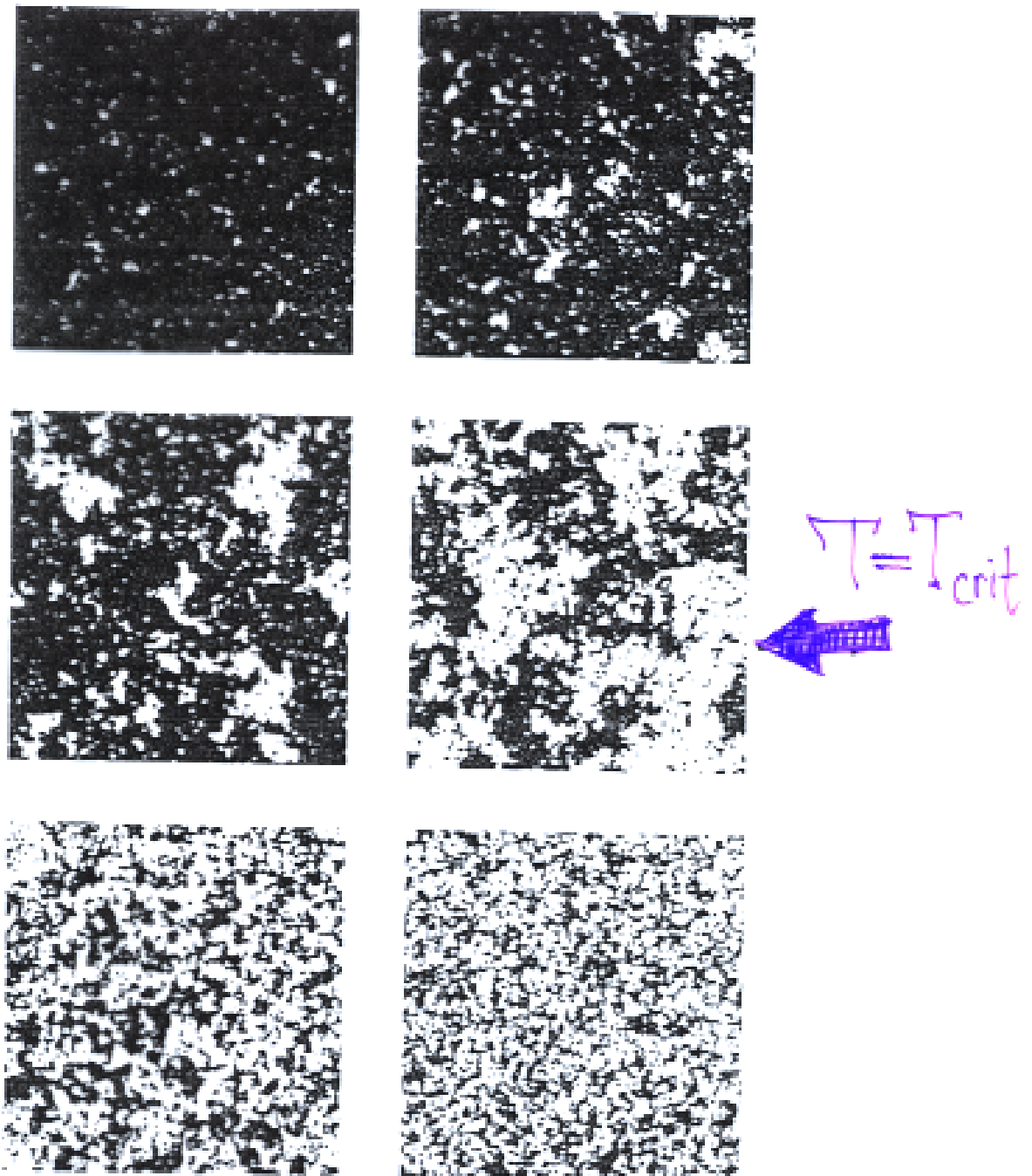
Texture: universe vs gift wrapper.
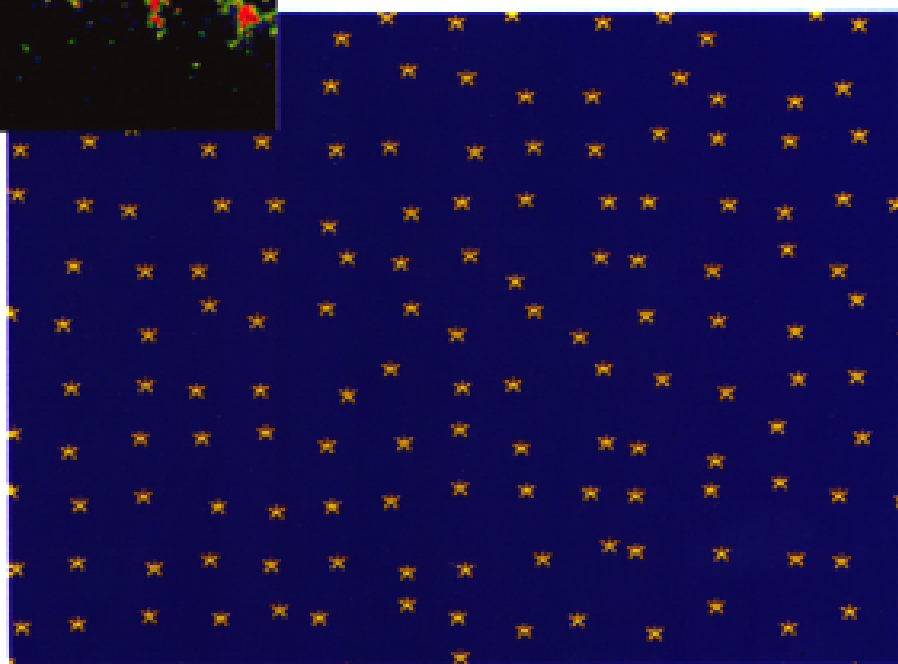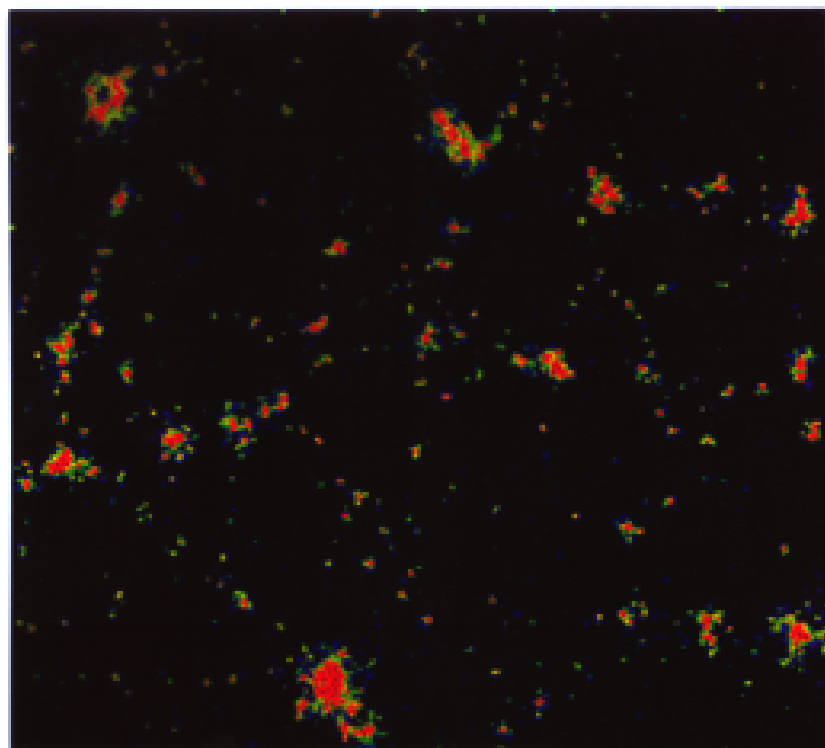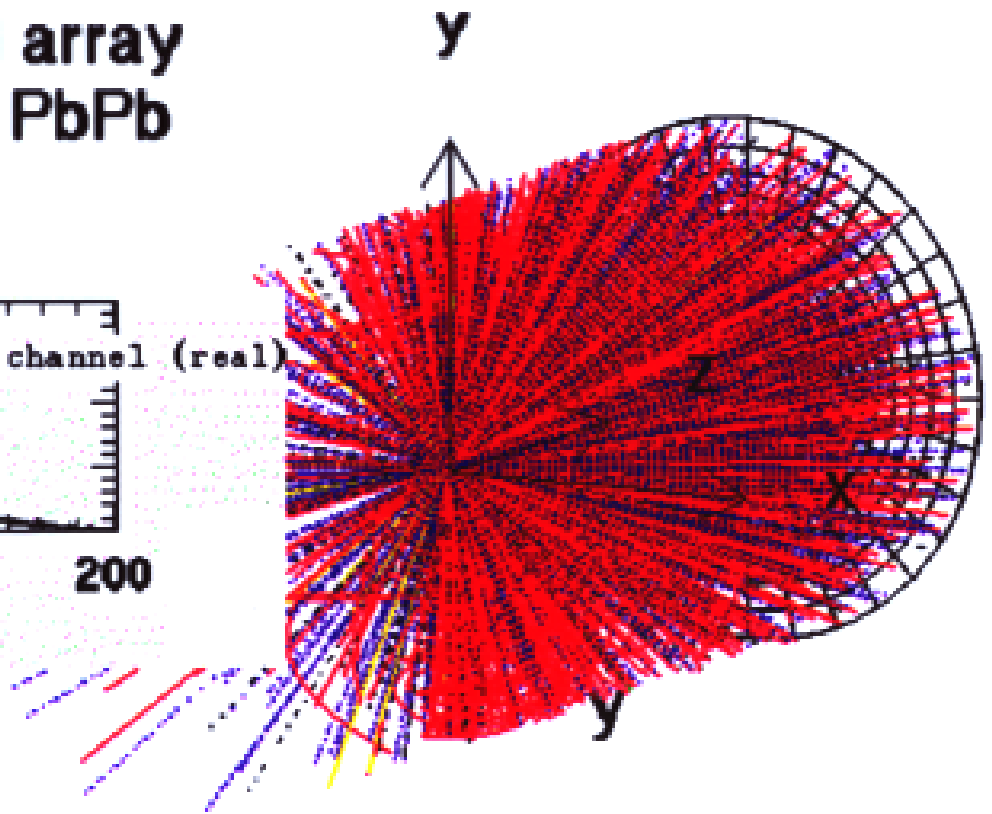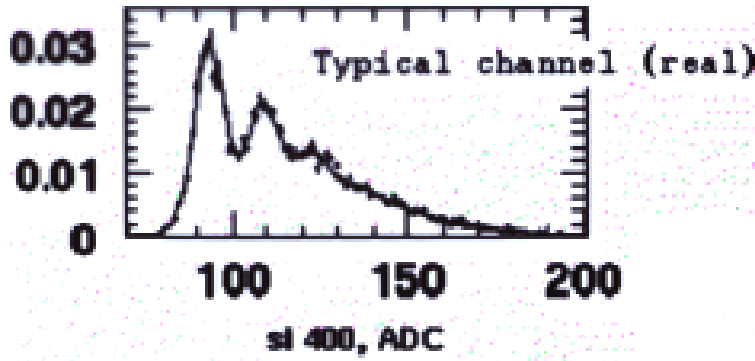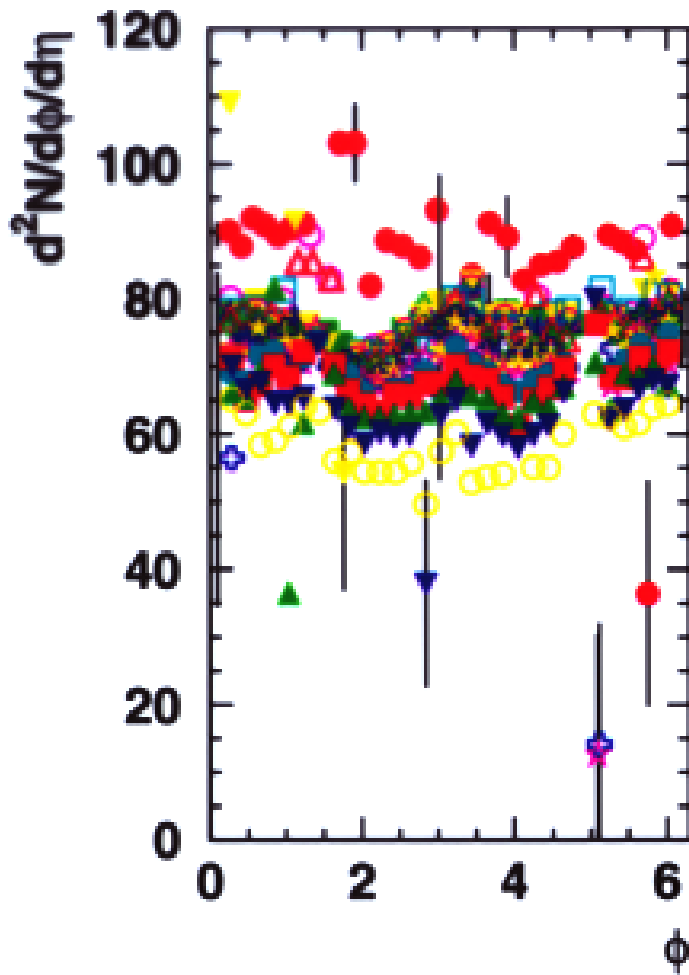
$T = T_{crit}$

Fig. 29. Clusters of spin-up and spin-down in the 2-dimensional Ising model. From top left to bottom $T/T_{crit} = 0.97, 0.99, 1, 1.01, 1.06, 1.15$; $T = T_{crit}$ at middle right. Figure taken from Ref. [21].

From Binney, Dowrick, Fisher, Newman,
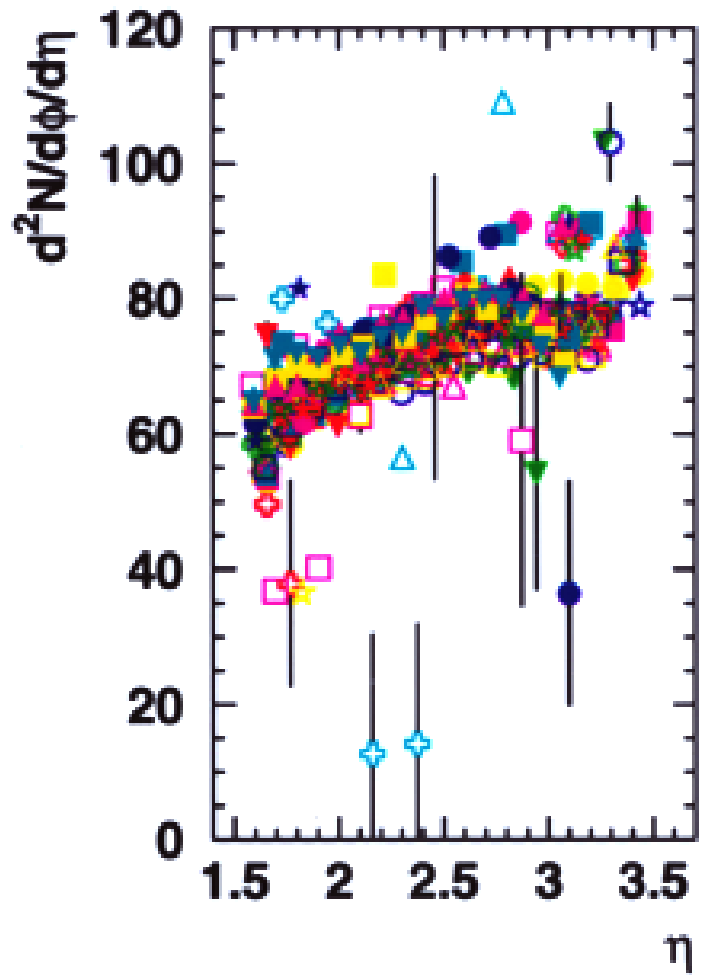The Theory of Critical Phenomena

NA44 Si pad array
158 AGeV/c PbPb

Typical channel (real)
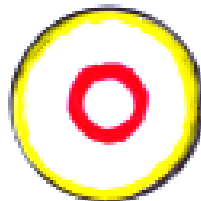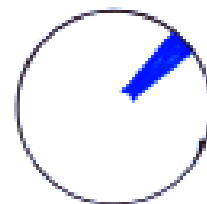
0.03
0.02
0.01
0

100   150   200

sl 400, ADC

y

y

y

z

1 cm

x

x

14.4

86
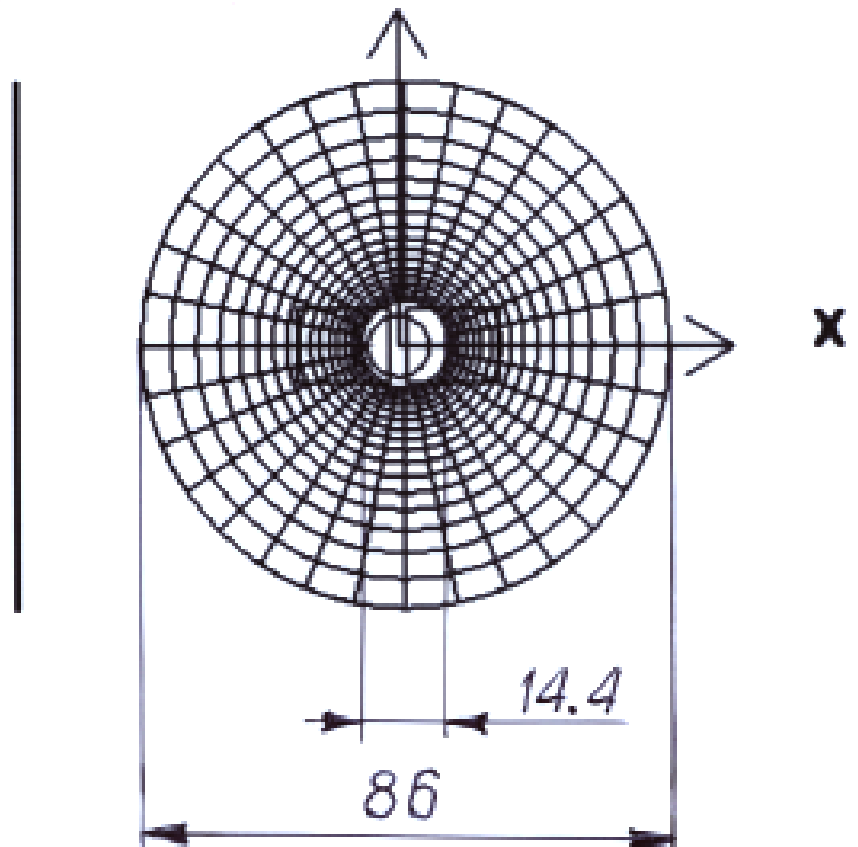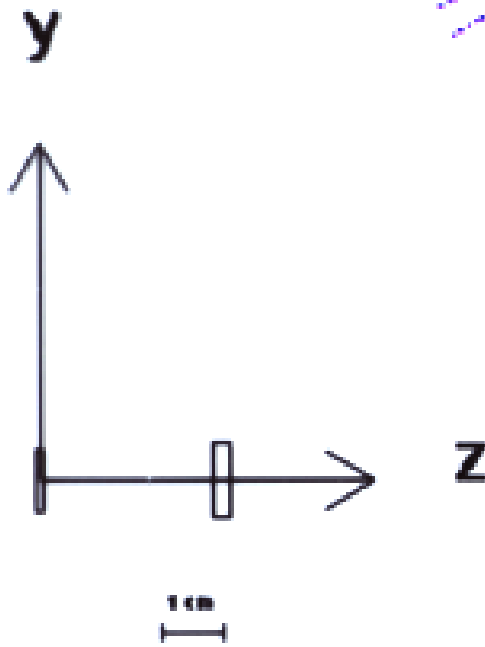
NA44 Si pad preliminary

color = ring   color = sector

DWT power spectra : intuition training
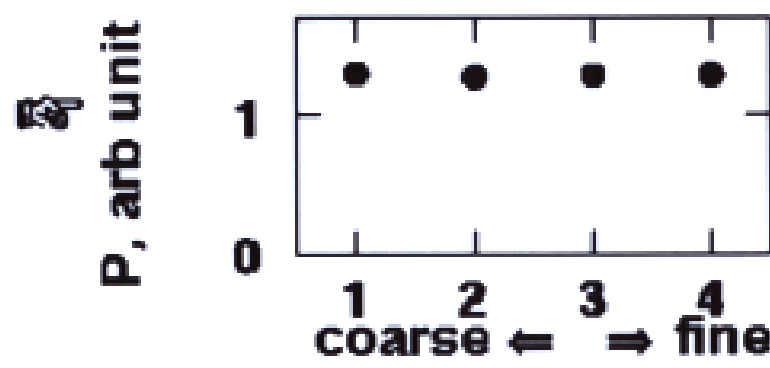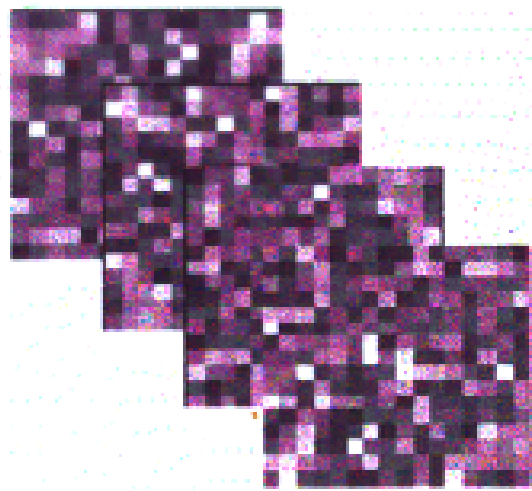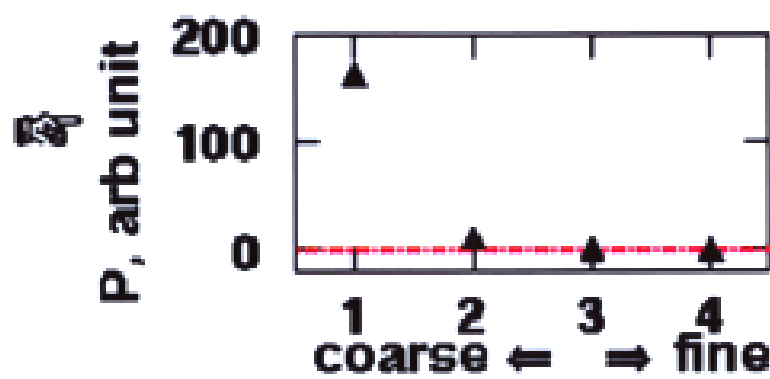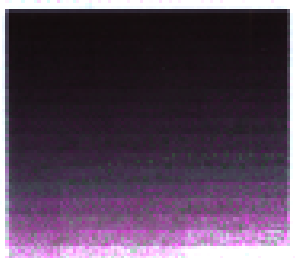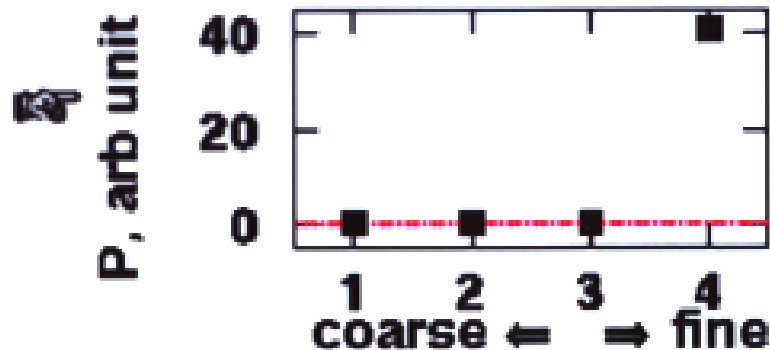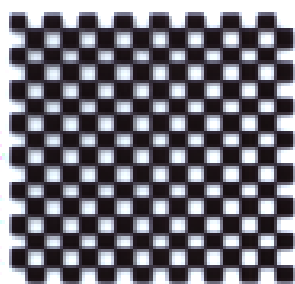
Multiresolution analysis
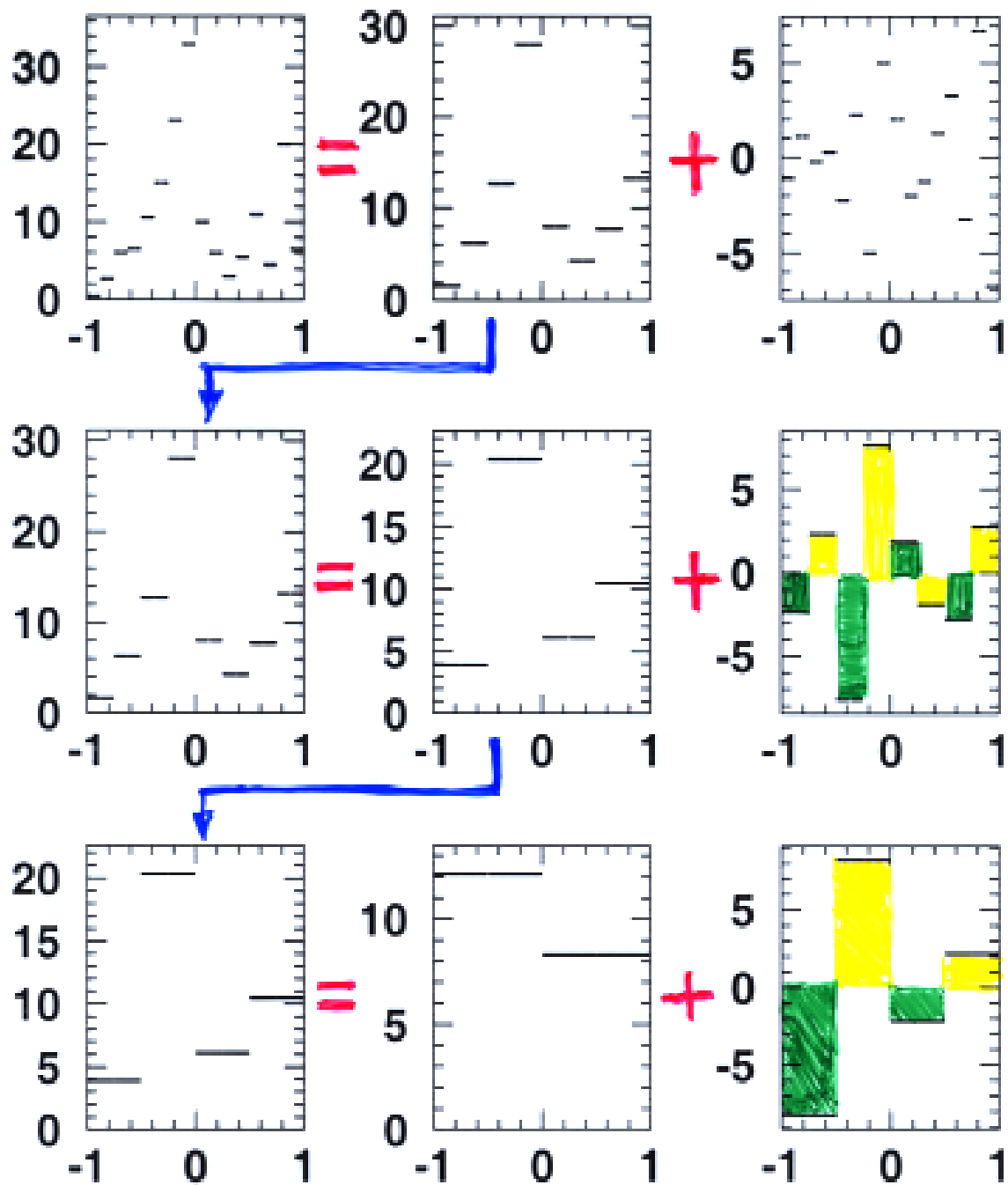
Basic functions of Haar wavelet basis in 2D

$$\Psi^{\lambda}_{m,i,j}(x,y) = 2^{m}\Psi^{\lambda}(2^{m}x-i, 2^{m}y-j)$$

λ - hor/vert/diag

$$\Psi\ hor = \psi(x)\phi(y)$$
$$\Psi\ vert = \phi(x)\psi(y)$$
$$\Psi\ diag = \psi(x)\psi(y)$$
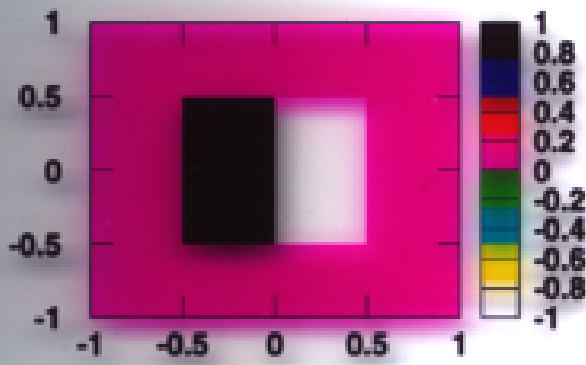
Ψ horizontal
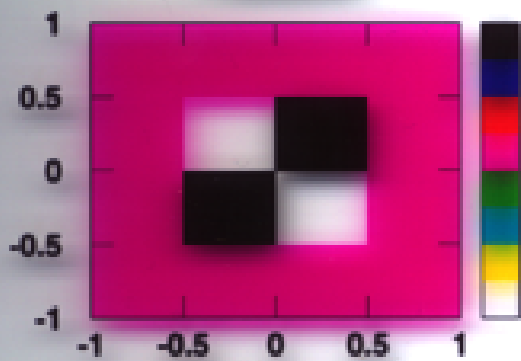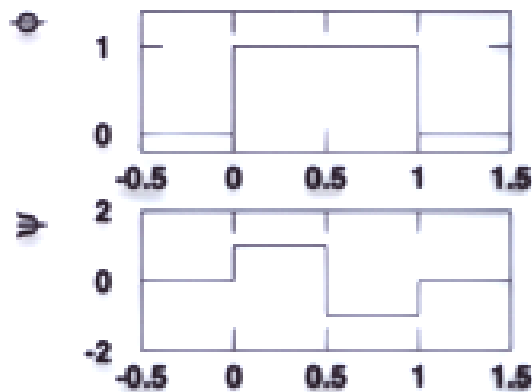
Ψ diagonal
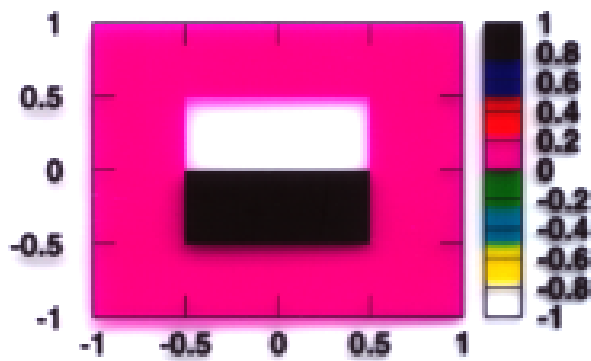
Ψ vertical

$$P^{\lambda}_{m} = 2^{-2m}\sum_{i,j}\langle \rho, \Psi^{\lambda}_{m,i,j}\rangle^{2} \quad \text{power spectrum component of scale } m$$
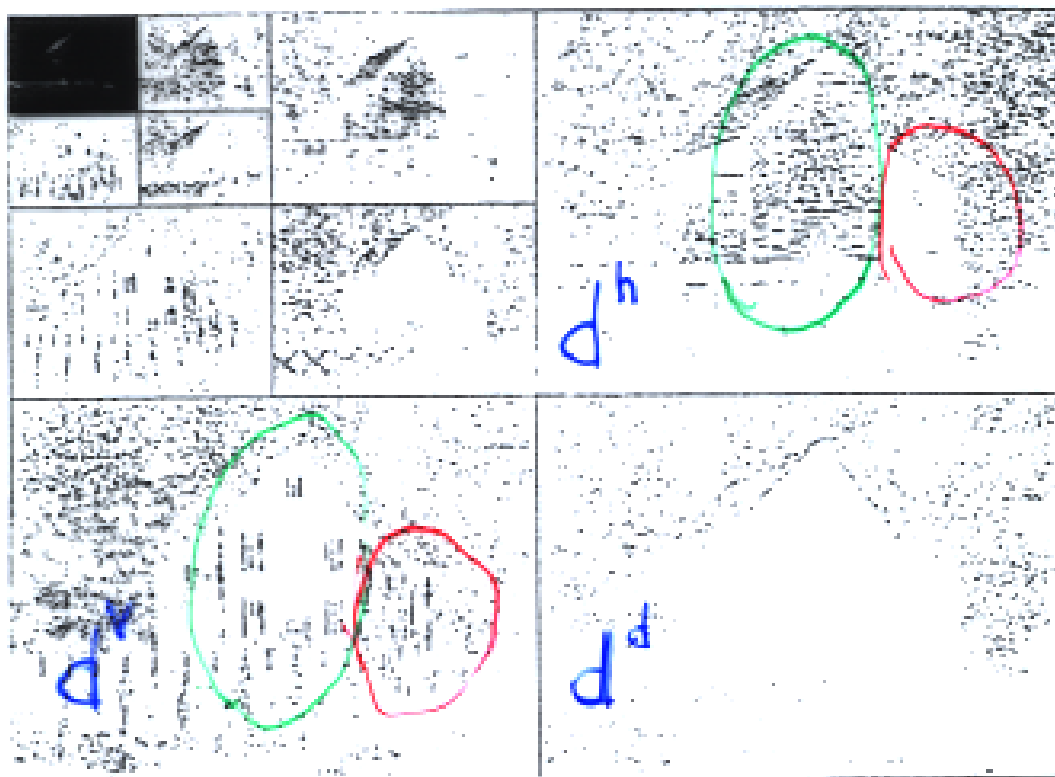
FIG. 10.3. A real image, and its wavelet decomposition into three multiresolution layers. On the wavelet components one clearly sees that the $d^{j,v}$, $d^{j,h}$, $d^{j,d}$ emphasize, respectively, vertical, horizontal, and diagonal edges. In this figure, the bottom picture has been overexposed to make details in the $d^{j,h}$ more apparent. I would like to thank M. Barlaud for providing this figure.

from "Ten lectures on Wavelets" by I. Daubechies

NA44 Si 2D DWT power spectra. PbPb 158AGeV

PRELIMINARY

P_m, σ^2/(dE MIP)^2

10

1

10^{-1}

10^{-2}

0   2   4
$\phi\eta$ fineness

0   2   4
ϕ fineness

0   2   4
η fineness
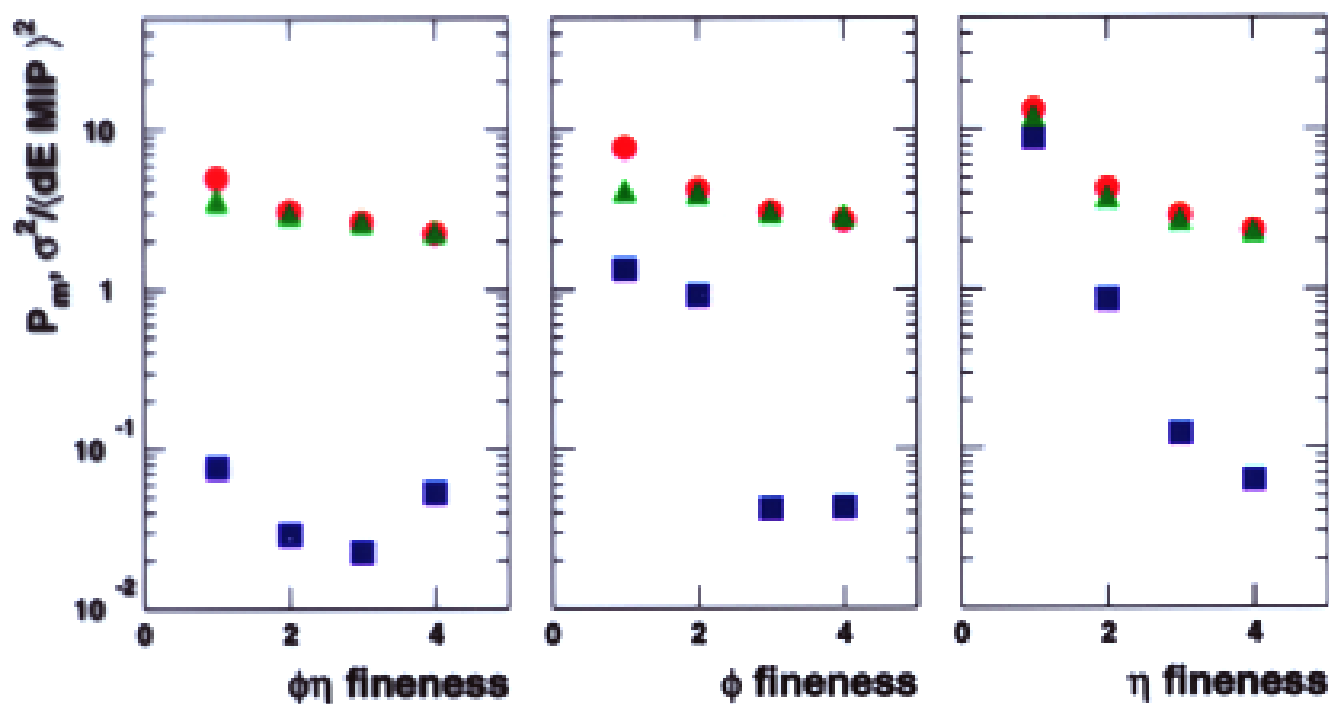
■ averaged

▲ mixed

● true

$379 < dN/d\eta < 463$

Treatment of static texture :

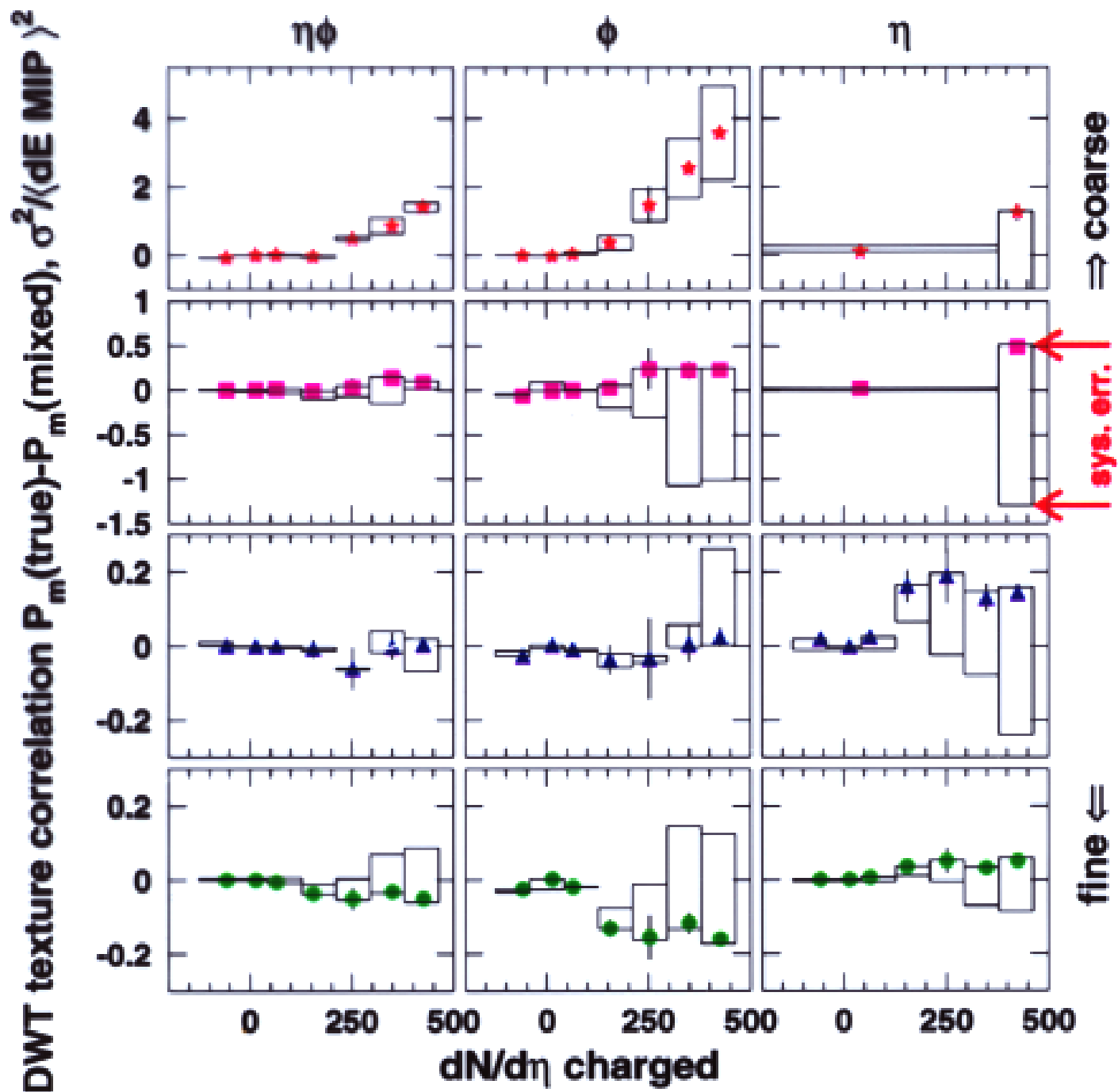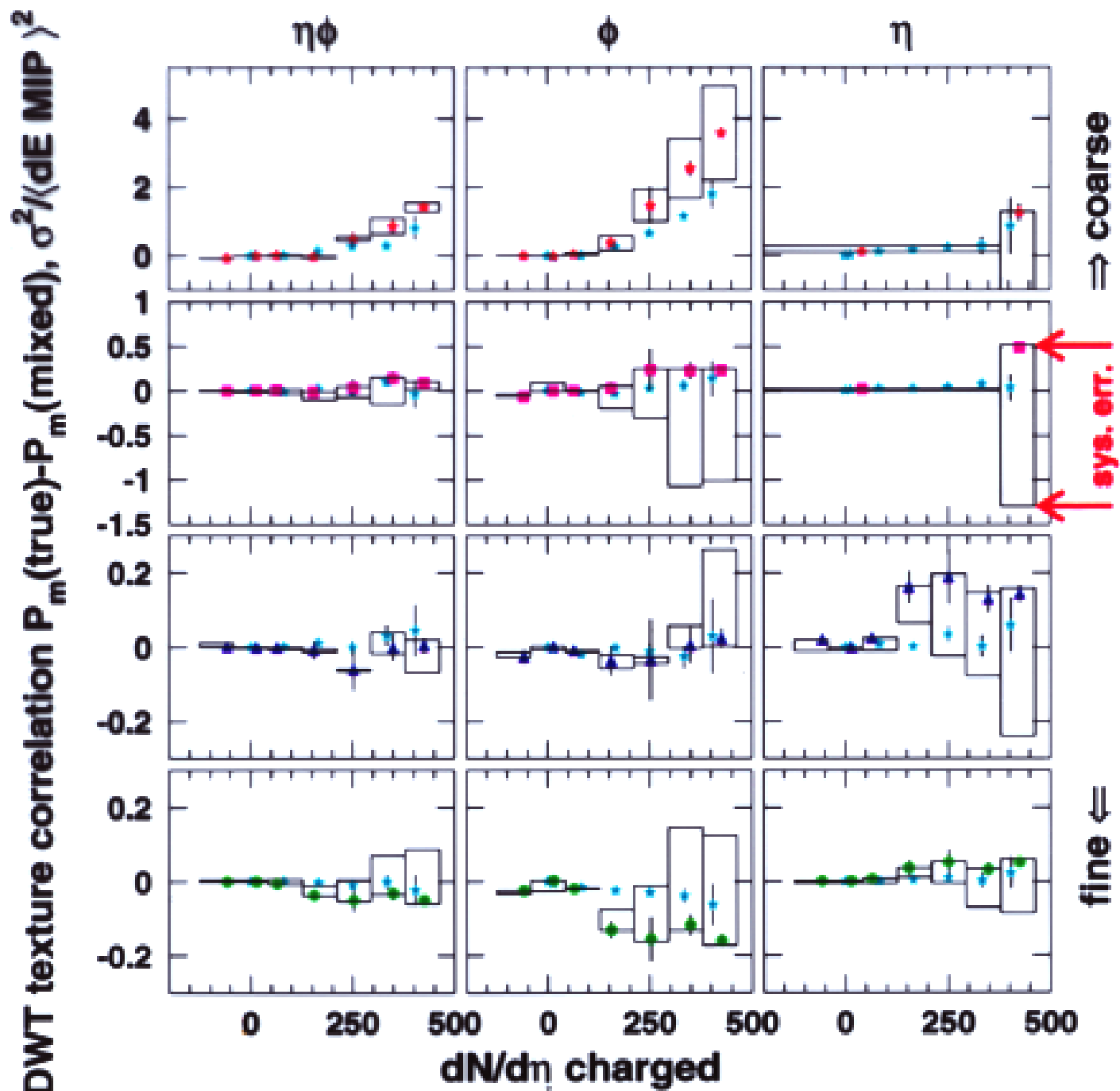| Source | Treatment | | | | Irreducible remainder estimate** (quoted for diagonal texture correlation in the $379 < dN/d\eta < 463$ bin), $\sigma^2/\langle dE\ MIP \rangle^2$ |
| | subtract empty target | event mixing * | | MC | |
		subtract mixed events	preserve sectors		
finite beam Xsection: 1X2mm	irrelevant	no	irrelevant	yes !	0.14 for the coarsest scale, negligible otherwise
detector offset dx=1.1mm, dy=0.3mm	irrelevant	yes !	irrelevant	yes !	
$dN/d\eta$ shape	irrelevant	yes !	irrelevant	yes !	
dead pads	irrelevant	yes !	irrelevant	yes !	
background hits	yes !	yes !	yes !	no	< 0.15, generally decreases with scale fineness
channel Xtalk 7% for neighbours; negligible otherwise	irrelevant	yes !	yes !	no	
statistical fluctuations	irrelevant	yes !	irrelevant	yes !	0.

* event mixing = event NUMBER scrambling, NOT channel scrambling
** info for orientation only, see the data plots for details and all cases

SPS PbPb 158AGeV/c NA44 preliminary

SPS PbPb 158AGeV/c NA44 preliminary

Vertical axis: DWT texture correlation P_m(true)$-P_m$(mixed), $\sigma^2/\langle dE\ MIP\rangle^2$

Horizontal axis: dN/dη charged

Column headers: $\eta\phi$ ϕ η

Right side: $\Rightarrow$ coarse,   sys. err.,   fine $\Leftarrow$

* RQMD

measured limit on the local fluctuations :

NA44 preliminary

confidence coeff. α

6 to 10 % central

$\eta\phi$

ϕ

η
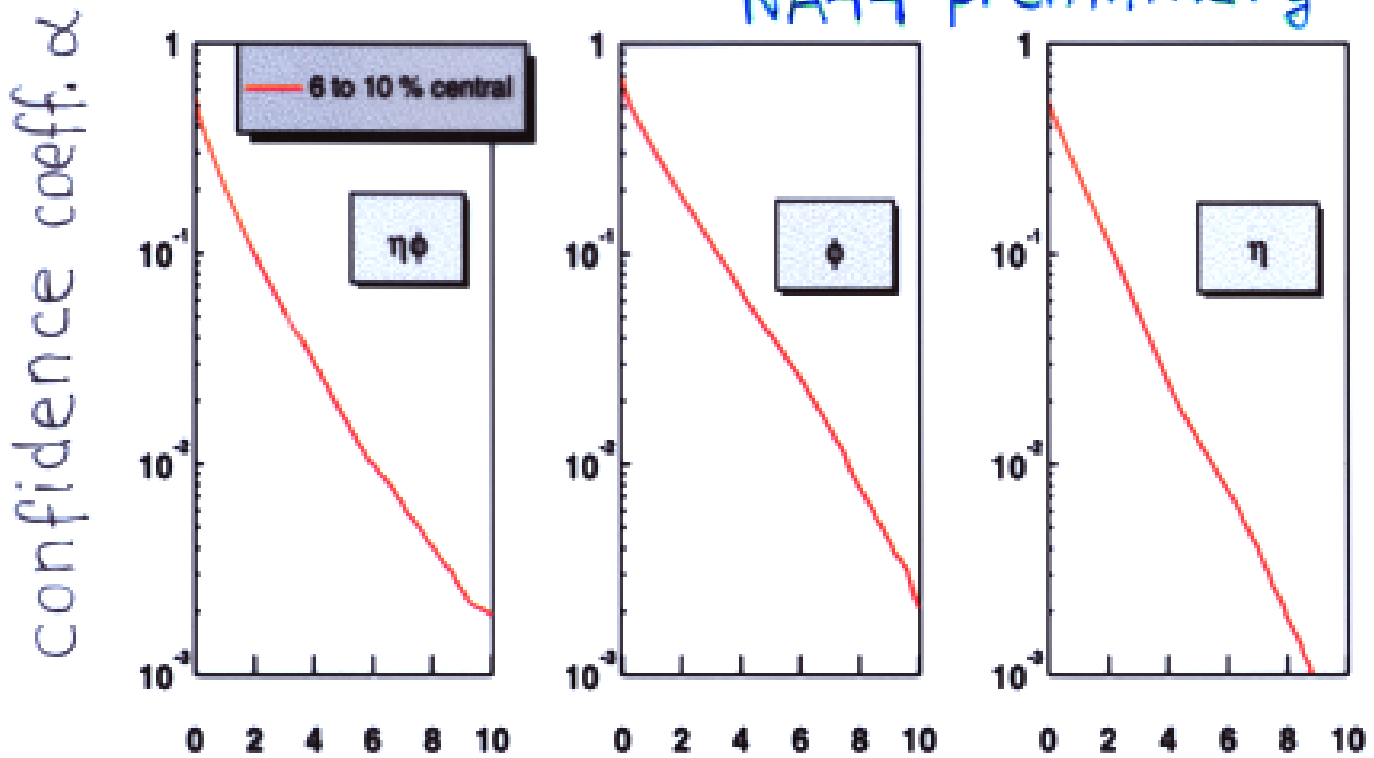
$$\left(P_{true} - P_{mix}\right)/RMS_{mix}$$

Smooth $\Rightarrow$ no abnormal subsample visible.

Fluctuations of $> 3RMS_{mix}$ are excluded to 90%$C.L.$ in ϕ; 95%$C.L.$ in η.
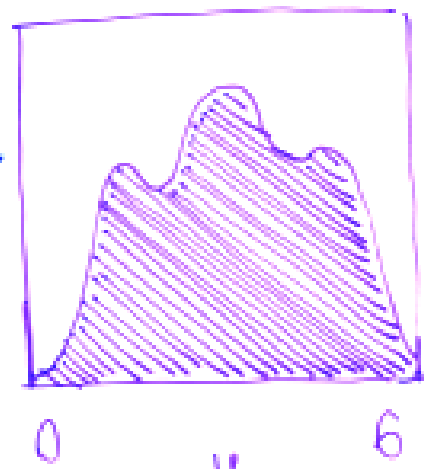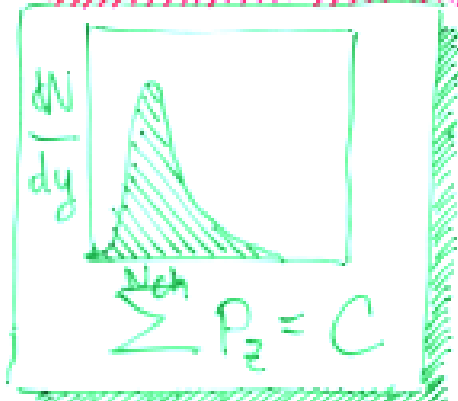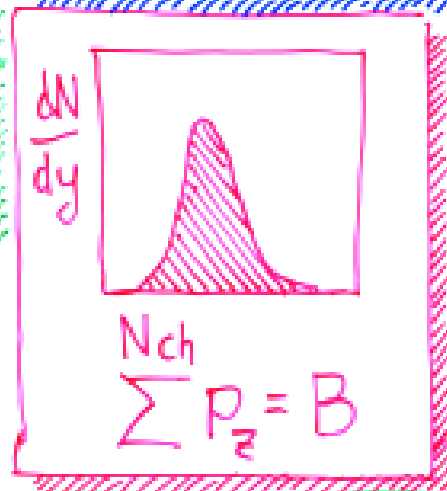
$$C.L. = 1 - \alpha$$

Multifireball event generator:

● what is it?

make isotropic fireballs:

$$\frac{dN}{dy}$$

$$N_{ch}; \quad \sum \vec{P} = 0$$

boost them ⇒ long. flow

$$\frac{dN}{dy}$$

$$\sum_{N_{ch}} P_z = A$$

$$\frac{dN}{dy}$$

$$\sum_{N_{ch}} P_z = B$$

$$\frac{dN}{dy}$$

$$\sum_{N_{ch}} P_z = C$$

$$A + B + C = 0$$

get event with texture
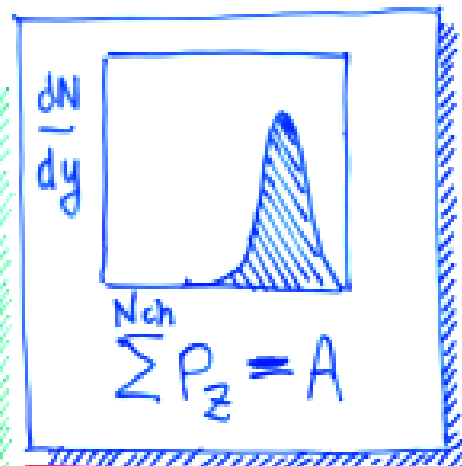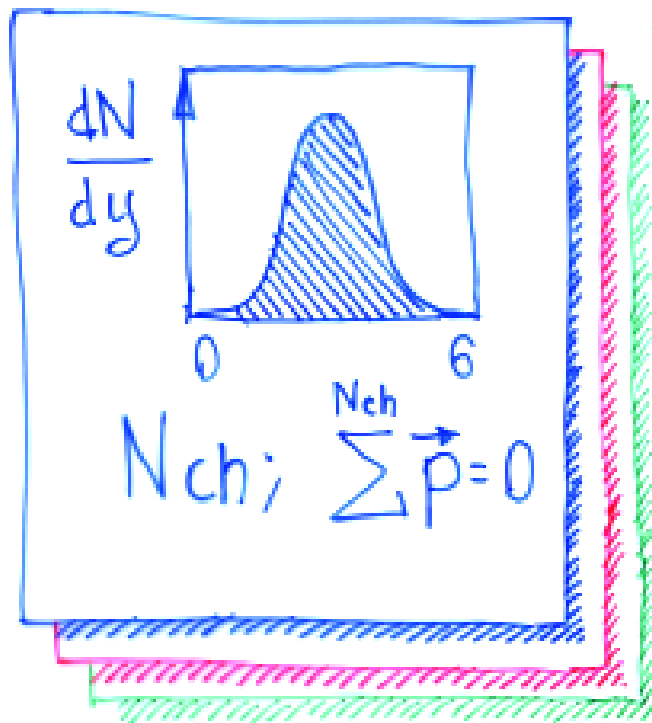
$$\sum \vec{P} = 0$$

● why useful?
study response of the method to the data with controlled (Nch/fireball ↕) local fluctuations

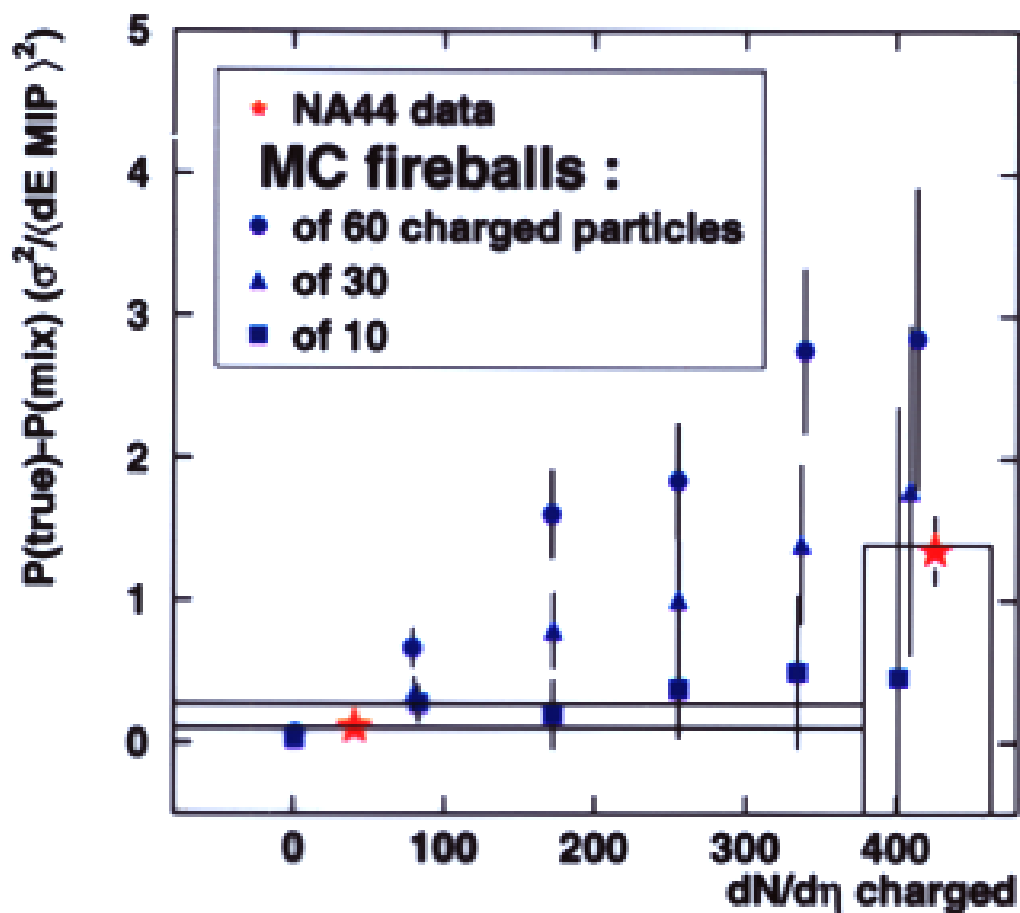How big a fluctuation can we see ? Method
sensitivity calibrated with a very simple multi-
fireball event generator :

Conclusion:

- a novel method of EbyE analysis has been applied to the SPS Pb+Pb data; DWT-estimated power spectra of *local* fluctuations in the hadron distribution in 2D (η, ϕ) are obtained in a wide range of multiplicities

- the power spectra are corrected for static texture contributions using a mixed event technique, thereby introducing a scale localized *texture correlation* observable

- the texture correlation is compared with that of RQMD events, folded with the detector response MC simulation

- multifireball event generator "calibrates" sensitivity of the method to a cluster size; data consistent with clustering of $N_{ch}/fireball < 30$

- see no evidence of critical phenomena