Multi-resolution dynamic texture analysis of Au+Au events at RHIC

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for the STAR Collaboration

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Outline:

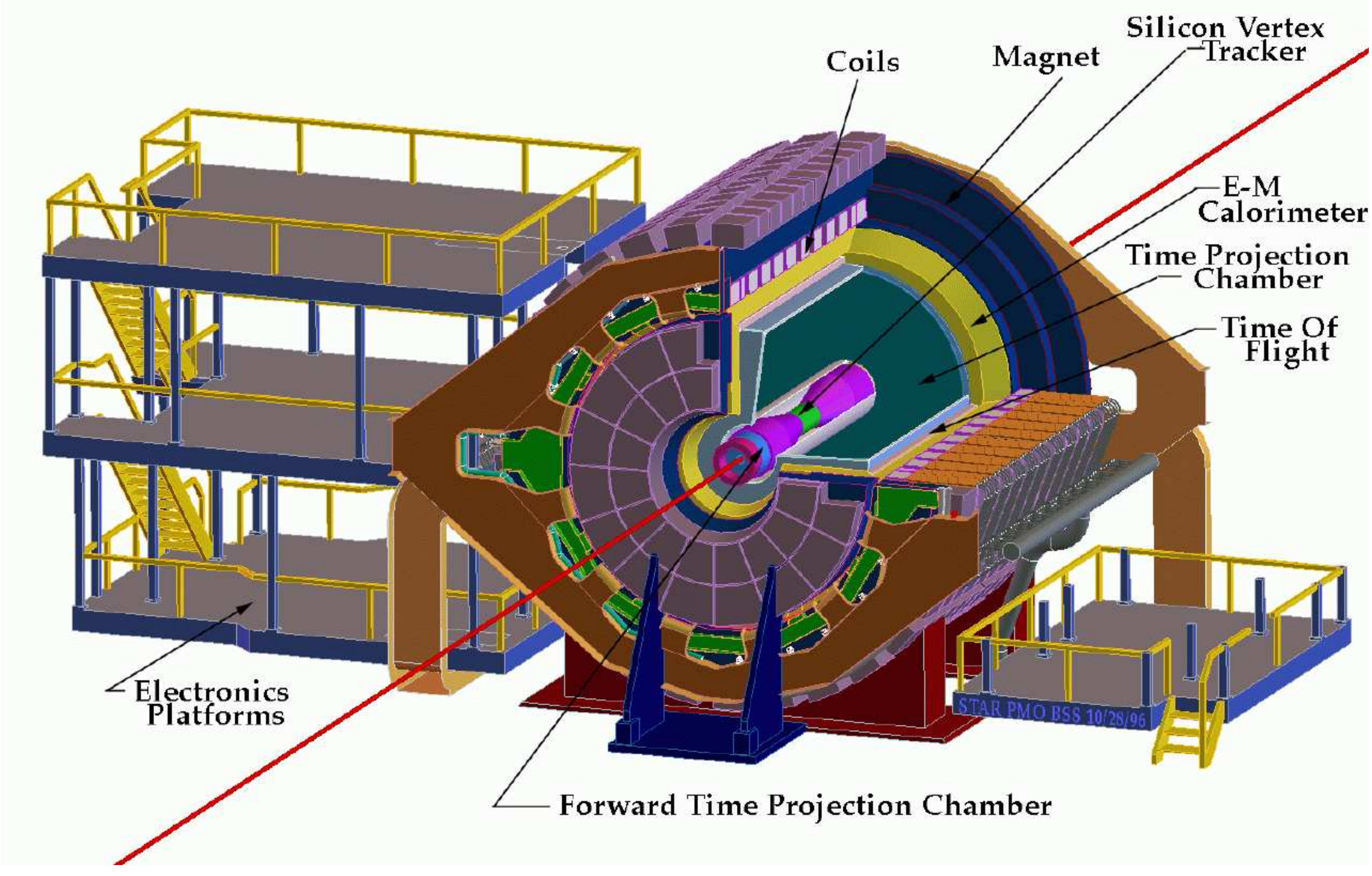
- Discrete Wavelet Transform and power spectra of local fluctuations

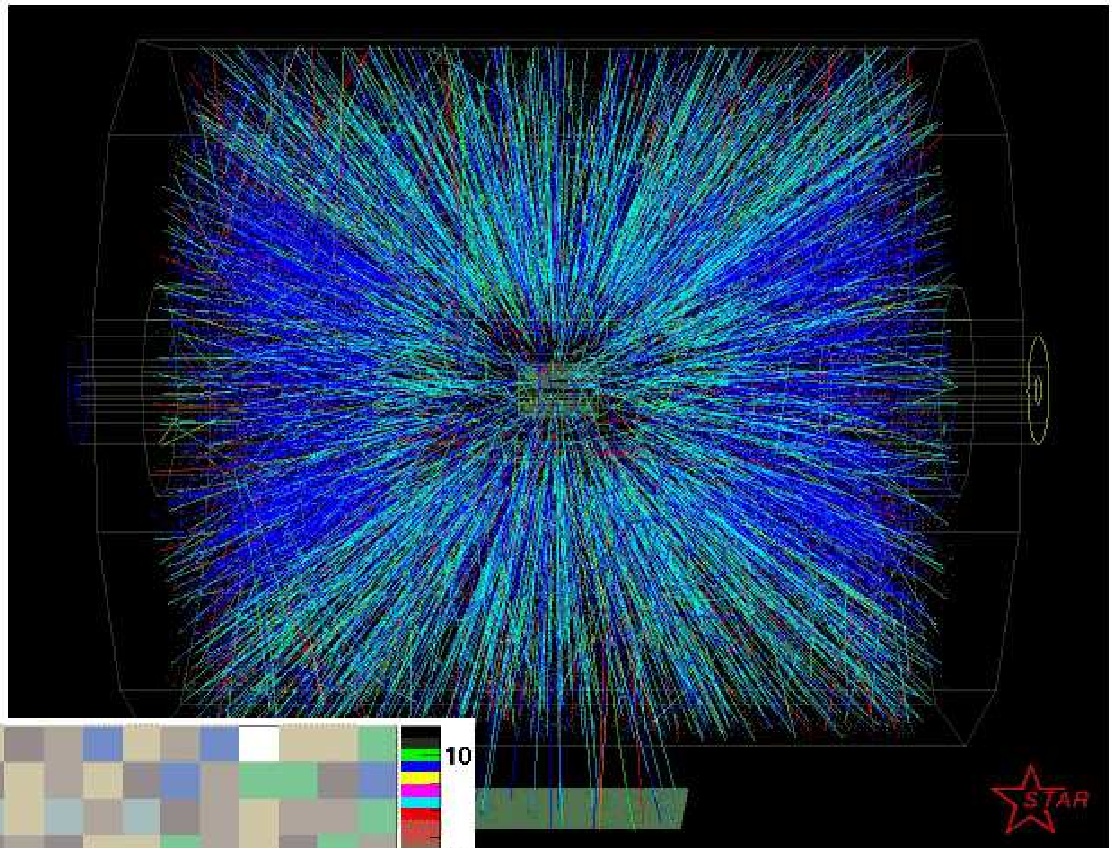
- Physics models: HIJING, Critical MC

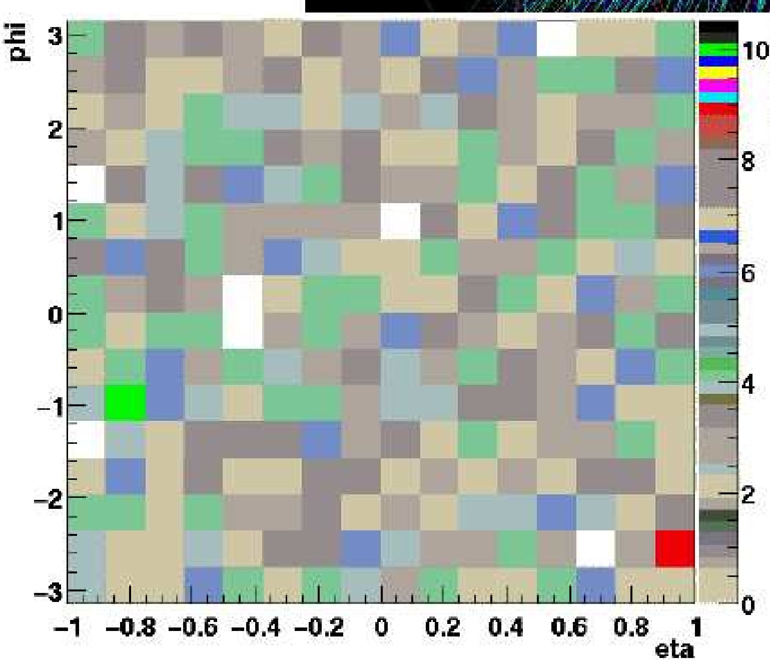
- STAR vs models

- conclusions

STAR Detector




STAR


phi
3
2
1
0
−1
−2
−3
−1
−0.8
−0.6
−0.4
−0.2
0
0.2
0.4
0.6
0.8
1
eta
10
8
6
4
2
0

Q: What is **dynamic texture ?**

A: Any systematically reproducible non-statistical and non-static local density correlation/fluctuation.

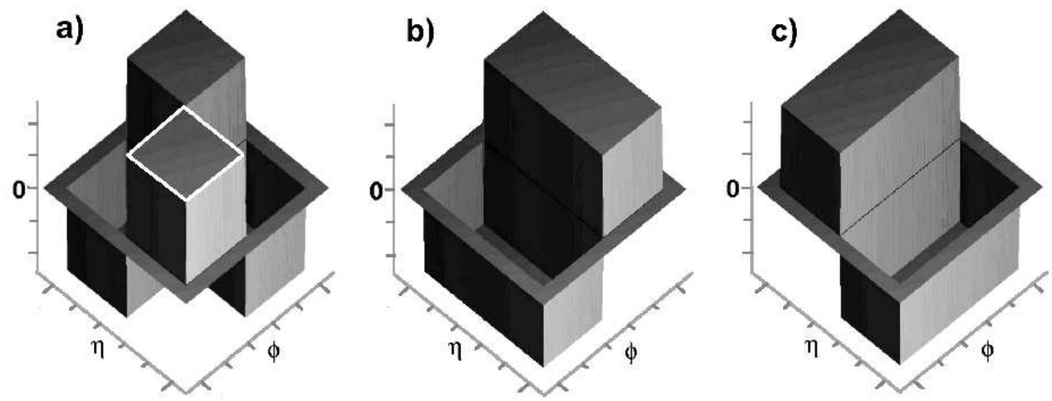
Examples:

– reaction plane effects (elliptic flow and directed flow)

– rapidity clustering

– jets

$F^{\lambda}_{m,i,j}(\phi,\eta)$–Haar wavelet basis in 2D:



scale fineness (m), directional modes of sensitivity (λ), track density $\rho(\eta,\phi,p_T)$.

Basic observables:

Power of local fluctuations, mode λ:

$$P^{\lambda}(m) = \frac{1}{2^{2m}} \sum_{i,j} \langle \rho, F^{\lambda}_{m,i,j} \rangle^2, \tag{1}$$

Dynamic texture:

$$P^{\lambda}(m)_{true} - P^{\lambda}(m)_{mix} \tag{2}$$

"incoherently" normalized :

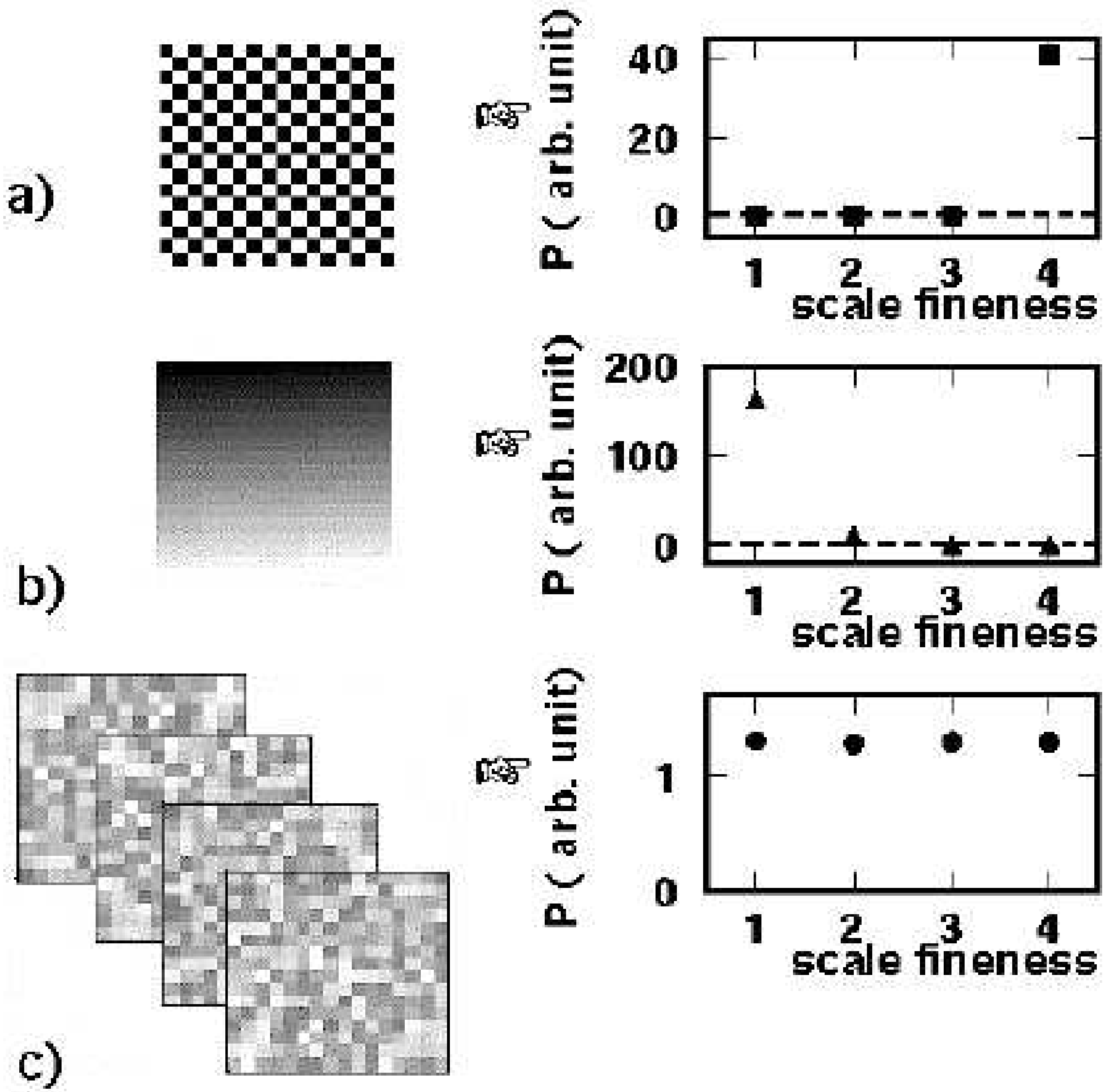
$$(P^{\lambda}(m)_{true} - P^{\lambda}(m)_{mix})/P^{\lambda}(m)_{mix} \tag{3}$$

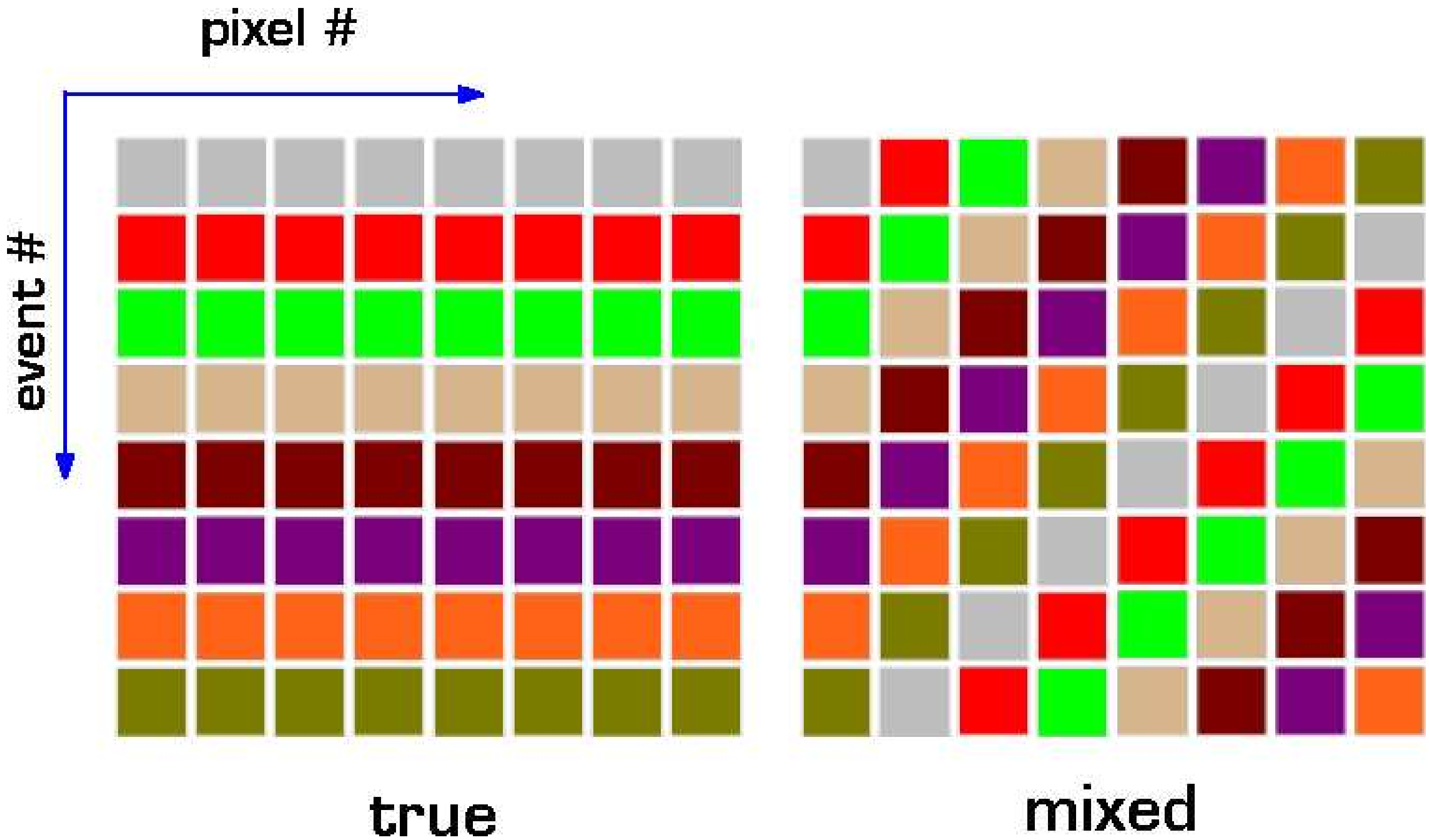
"coherently" normalized :

$$(P^{\lambda}(m)_{true} - P^{\lambda}(m)_{mix})/P^{\lambda}(m)_{mix}/N, \tag{4}$$

where N is (sub)event (p_T bin) multiplicity

Scale is localized:





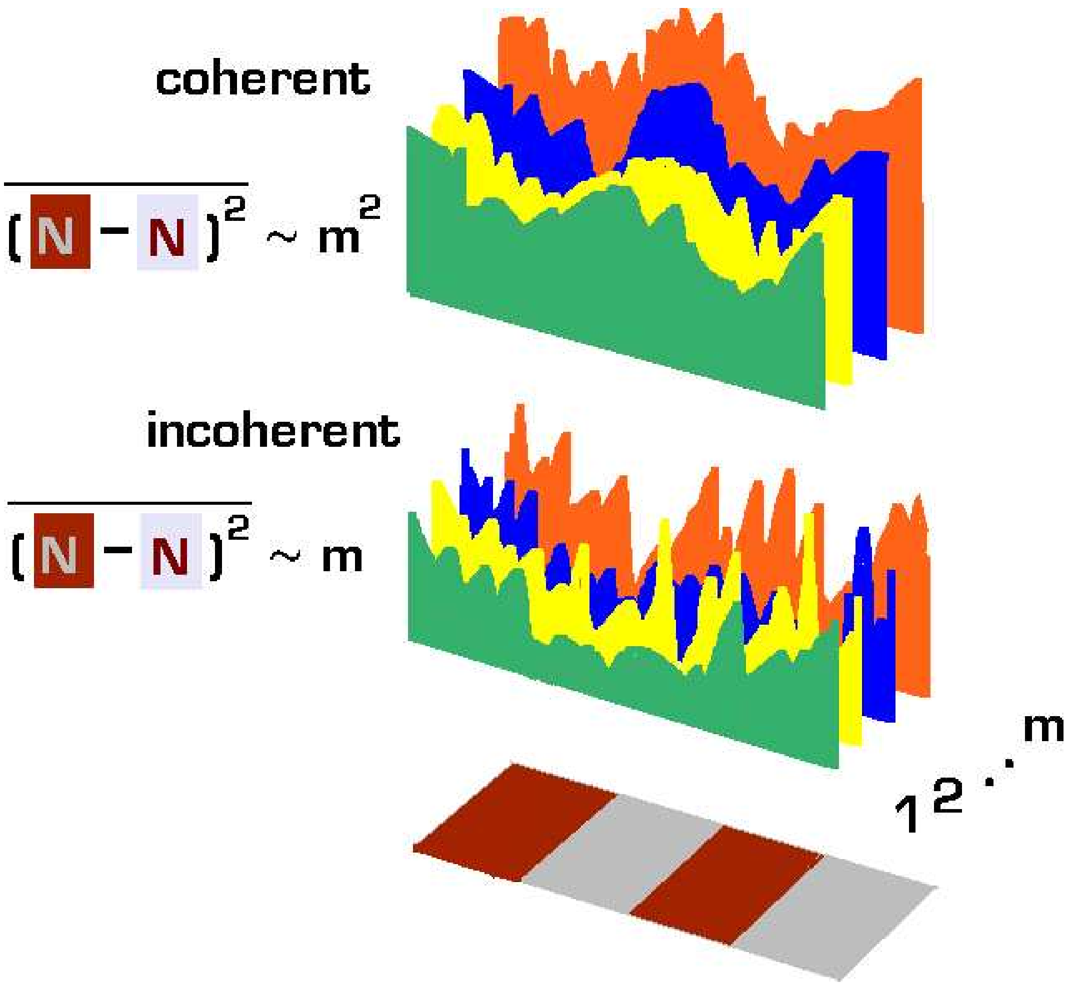
Event mixing scheme:

– no pixel is used twice

– not more than one pixel from any given true event per mixed event

– no mixing of “different” events: multiplicity, vertex

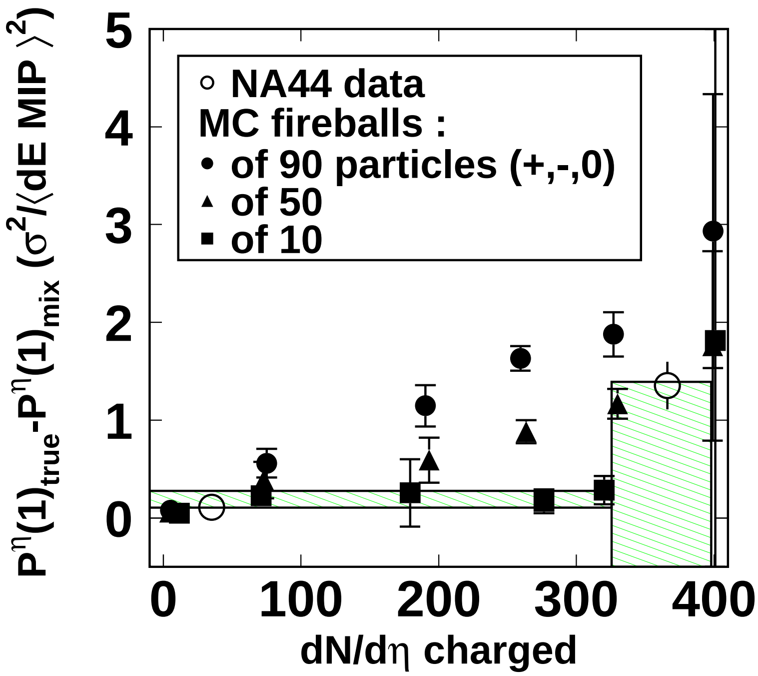
With n pixels, need $\geq n^2$ events per event class.



Proper normalization ⇒ results independent of bin size or subevent multiplicity.

Coherent: $(P^{\lambda}(m)_{true} - P^{\lambda}(m)_{mix})/P^{\lambda}(m)_{mix}/N$,

Incoherent: $(P^{\lambda}(m)_{true} - P^{\lambda}(m)_{mix})/P^{\lambda}(m)_{mix}$



Sensitivity to clustering in η.

A multi-fireball generator: $dN/d\eta \propto \#$ independent fireballs $\Rightarrow$ incoherence, $P \propto dN/d\eta$. [Phys. Rev. C 65 (2002) 044903]

Inspired by van Hove's (1st order P.T.) signature.

Ising model: coarse scale texture enhanced at transition

H. Kröger / Physics Reports 323 (2000) 81–181 153

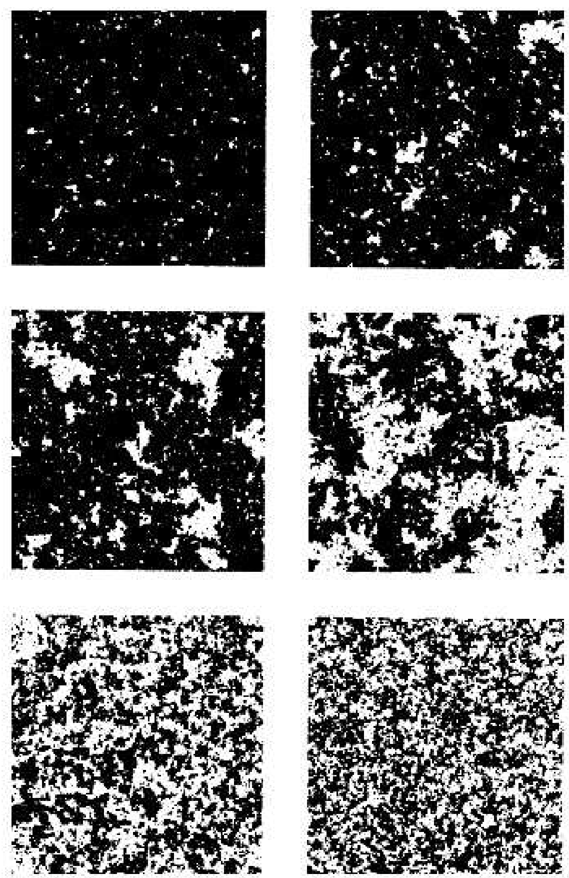
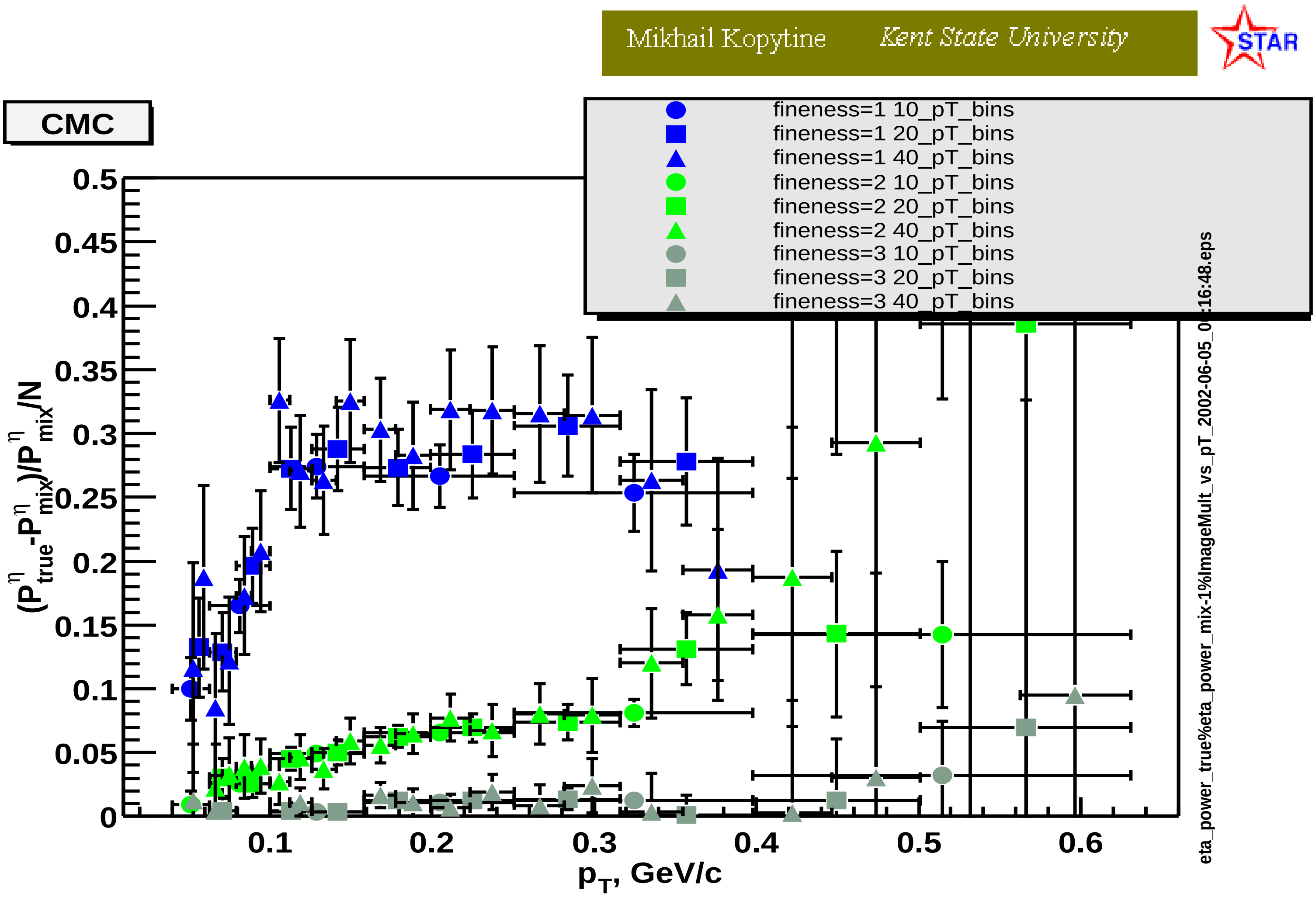


Fig. 29. Clusters of spin-up and spin-down in the 2-dimensional Ising model. From top left to bottom right $T/T_{crit} = 0.97, 0.99, 1, 1.01, 1.06, 1.15$; $T = T_{crit}$ at middle right. Figure taken from Ref. [21].

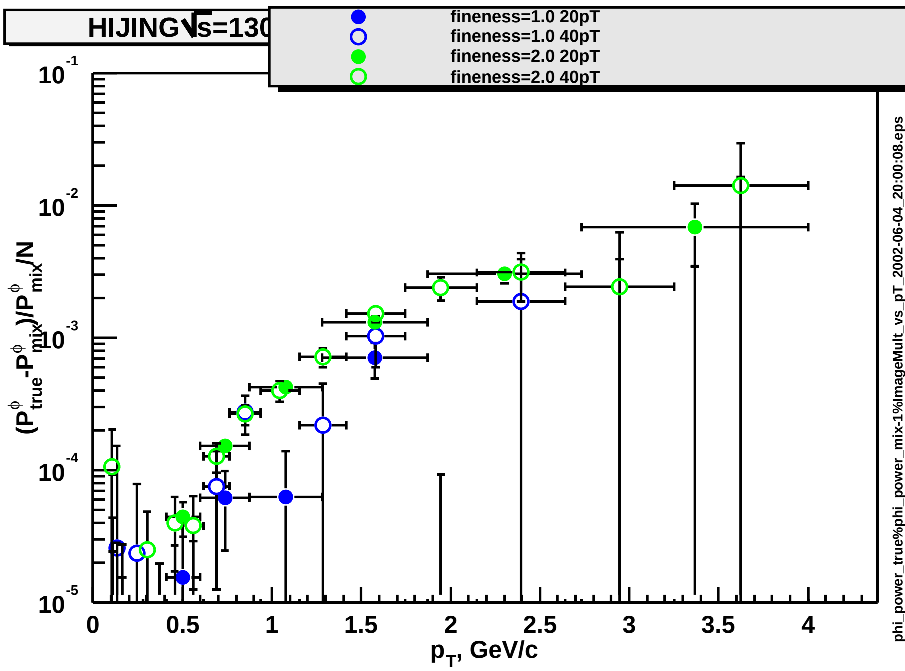
[J.J.Binney, N.J.Dowrick, A.J.Fisher, M.E.J.Newman,

The Theory of Critical Phenomena,

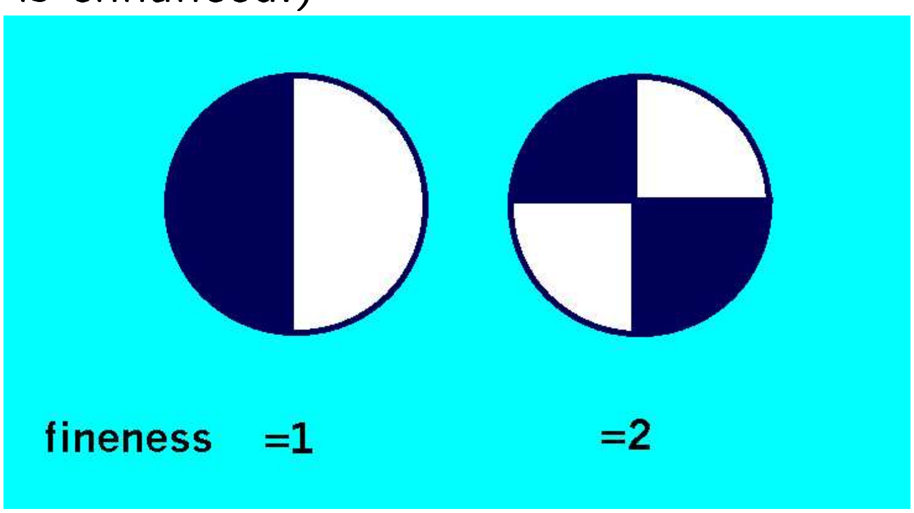
Oxford University Press, Oxford, 1992]

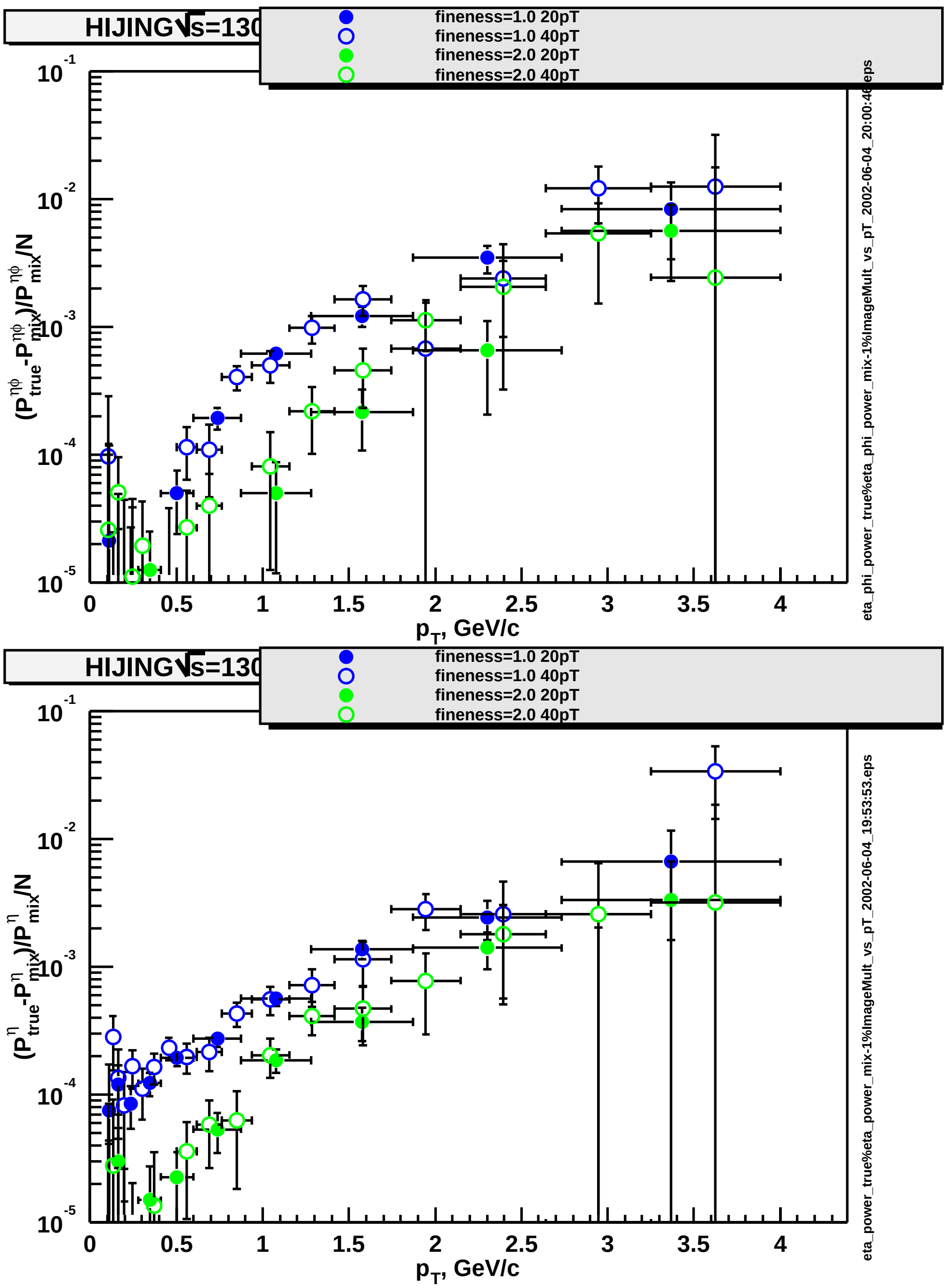


Critical Monte Carlo (N.Antoniou et al.): Ising model (2nd order P.T.), 1000 events, coherent fluctuations on the coarse scale, go down with scale

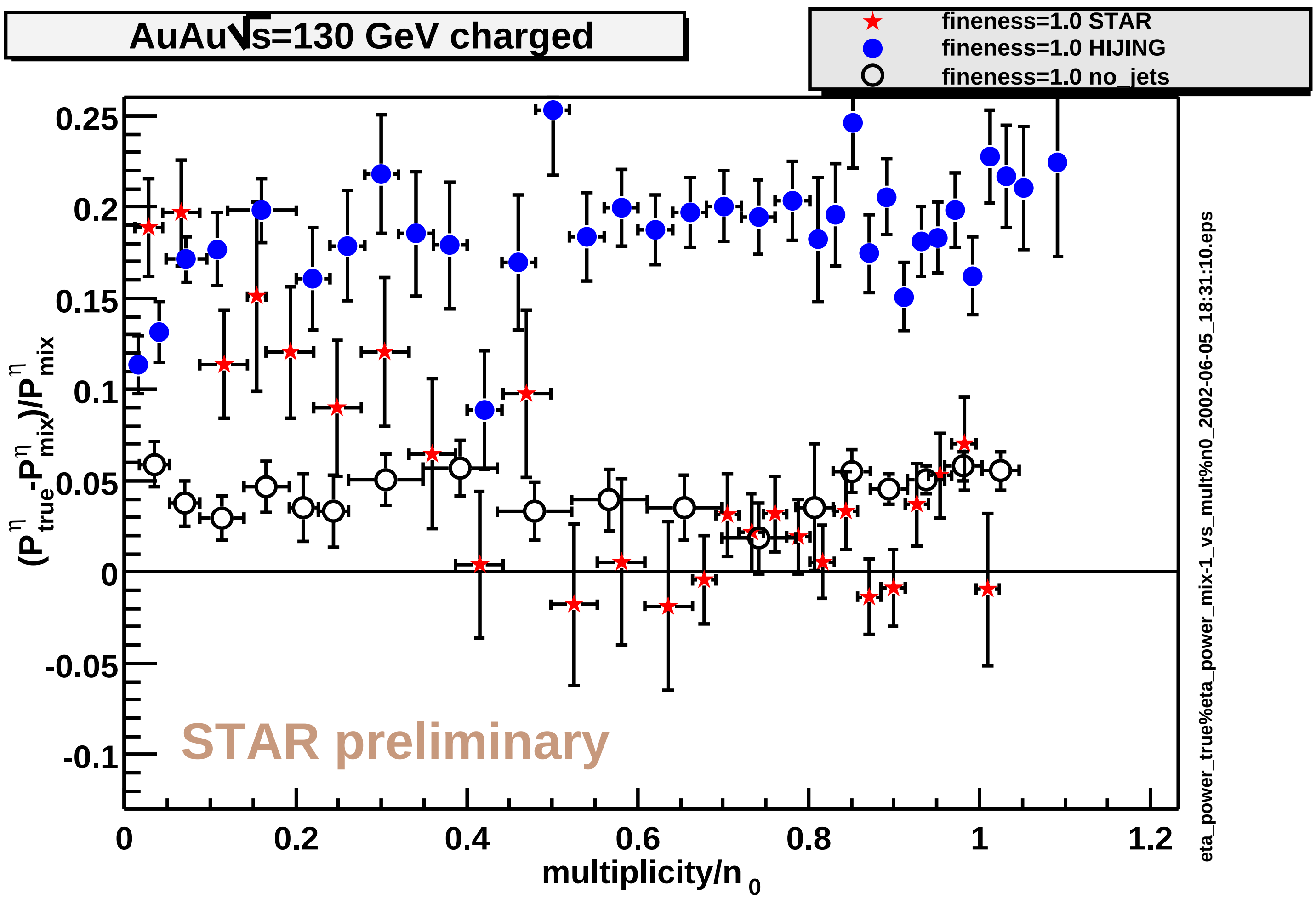


HIJING – azimuthal back to back correlations (fineness=2 is enhanced!)





HIJING shows coherent scaling with p_T bin width



⋆ – STAR; • – regular HIJING; ∘ – HIJING without jets.

The HIJING texture is mostly jets. STAR data: a change of regime with centrality.

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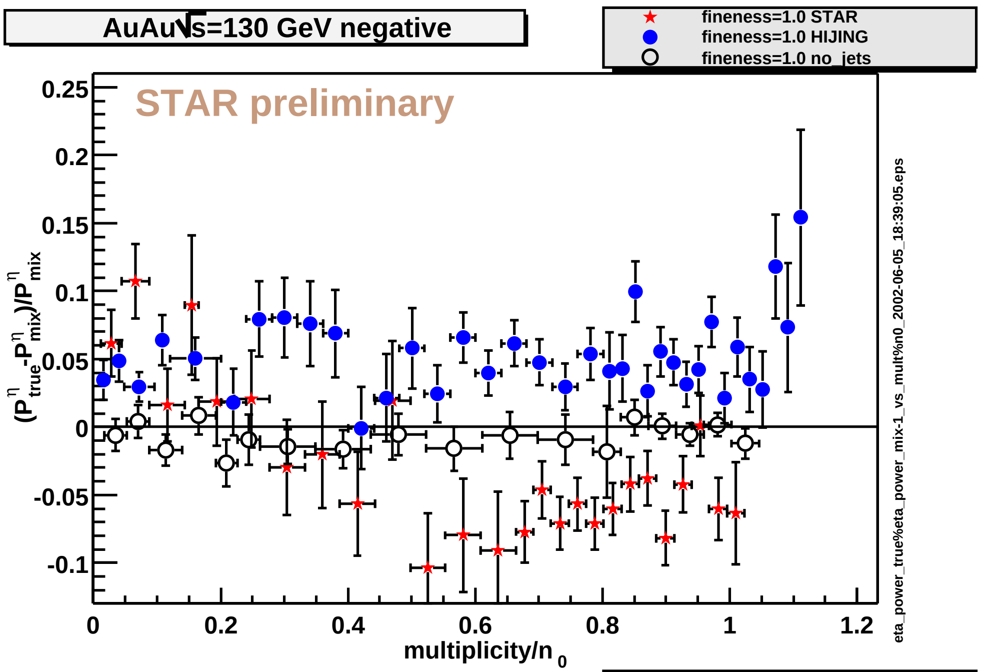
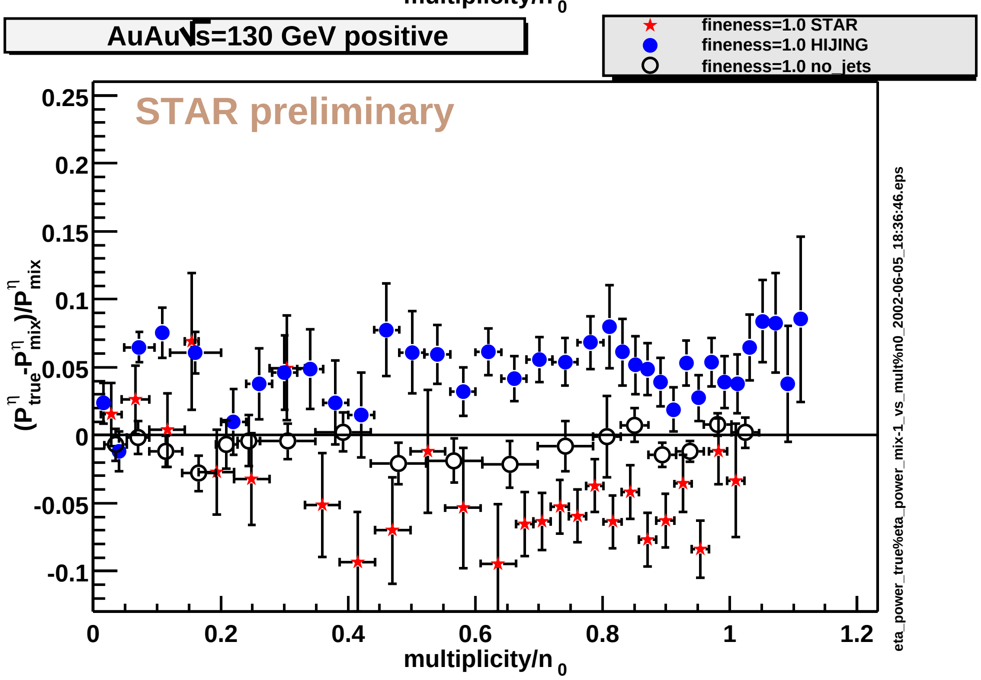




$P_{true} < P_{mix} \Rightarrow$ long range correlation

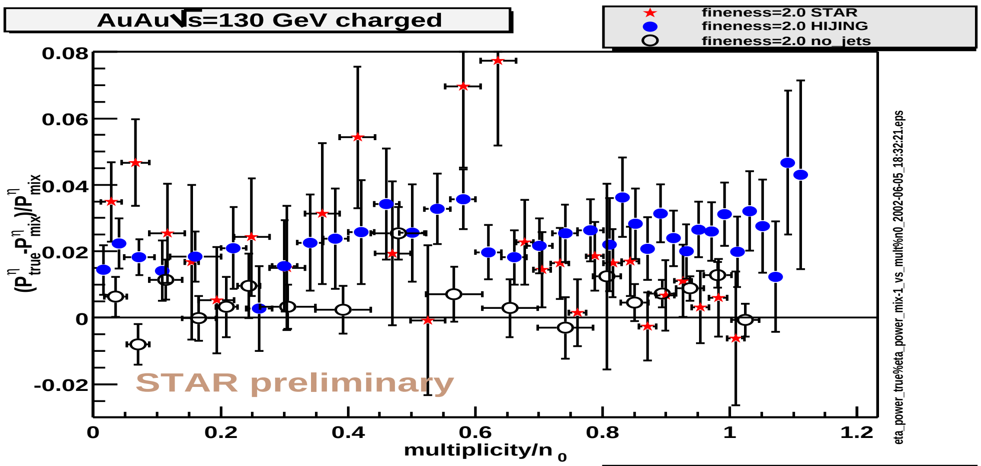
Conclusions so far:

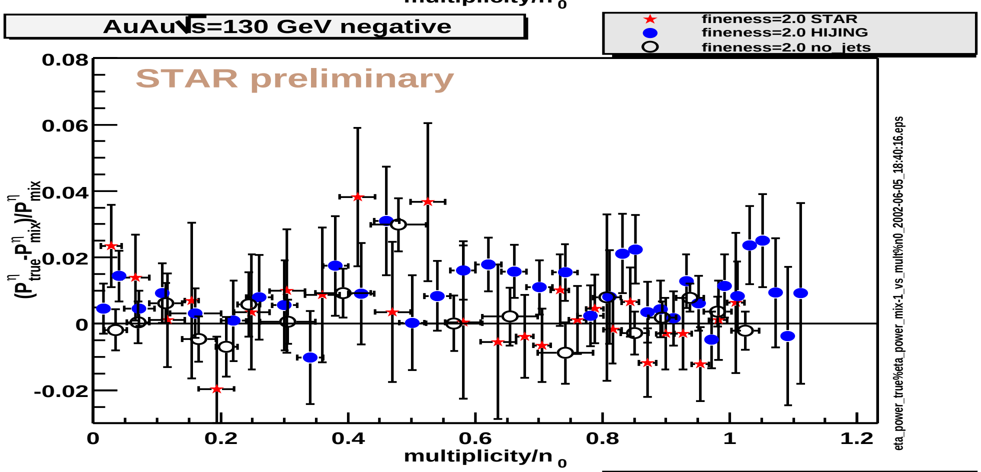
– the HIJING texture is mostly jets

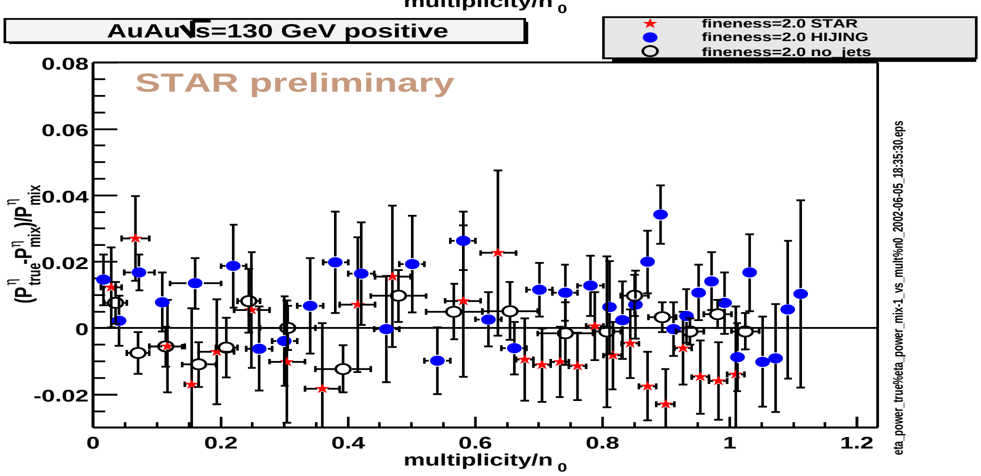
– the signal like in HIJING is seen in peripheral STAR data

– a change of regime with centrality: long range correlation (or suppressed fluctuation vis-á-vis mixed events) is seen in same charge data!

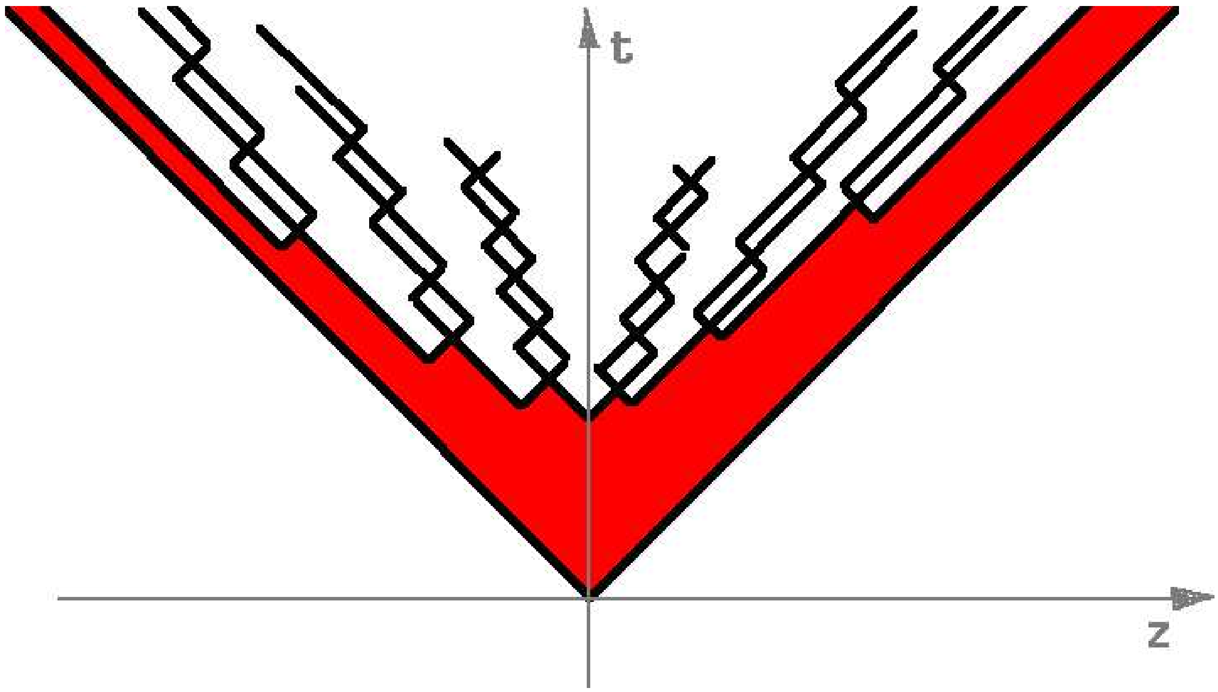
– with jets off see a hint of a similar long range correlation in HIJING – much weaker than in the data – string dynamics ?



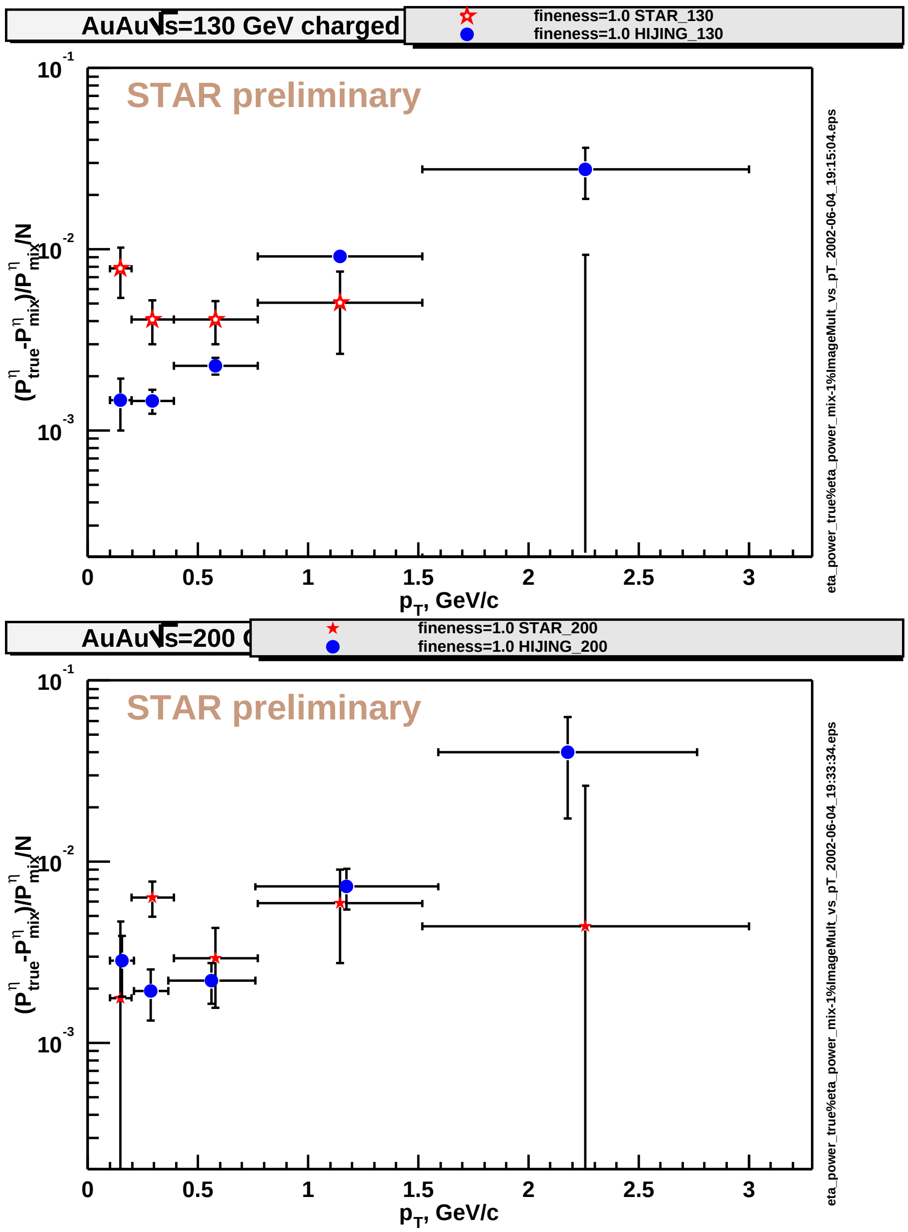




fineness=1 was more informative ⇒ large acceptance is good !

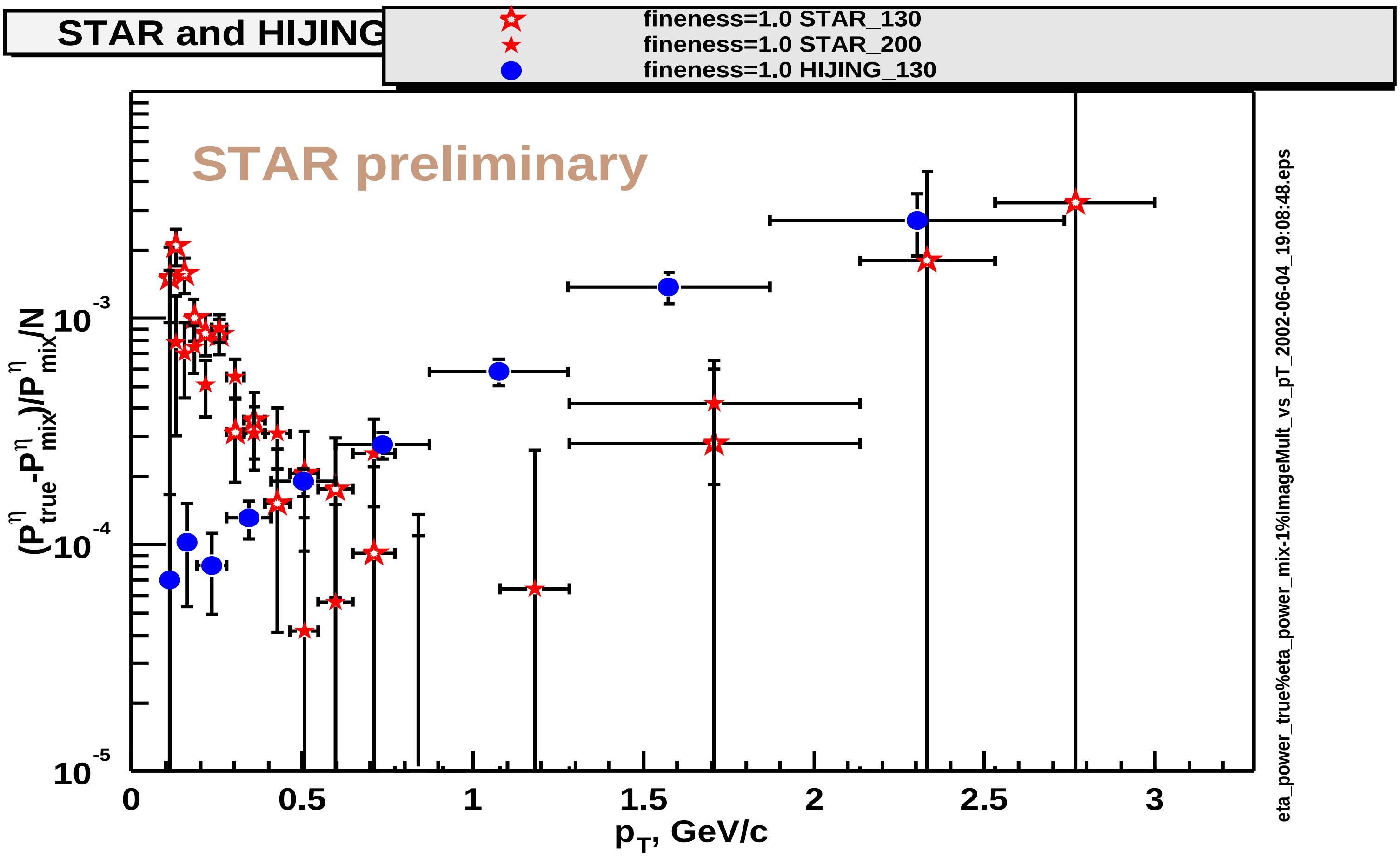


What is the origin of the long range η correlation = suppressed fluctuation ? Need common memory/communication over $\Delta\eta \approx 1$. Different break-up points **causally disjoint.** Hadron rescattering can not increase order. Strings $\Rightarrow$ forward-backward correlation.

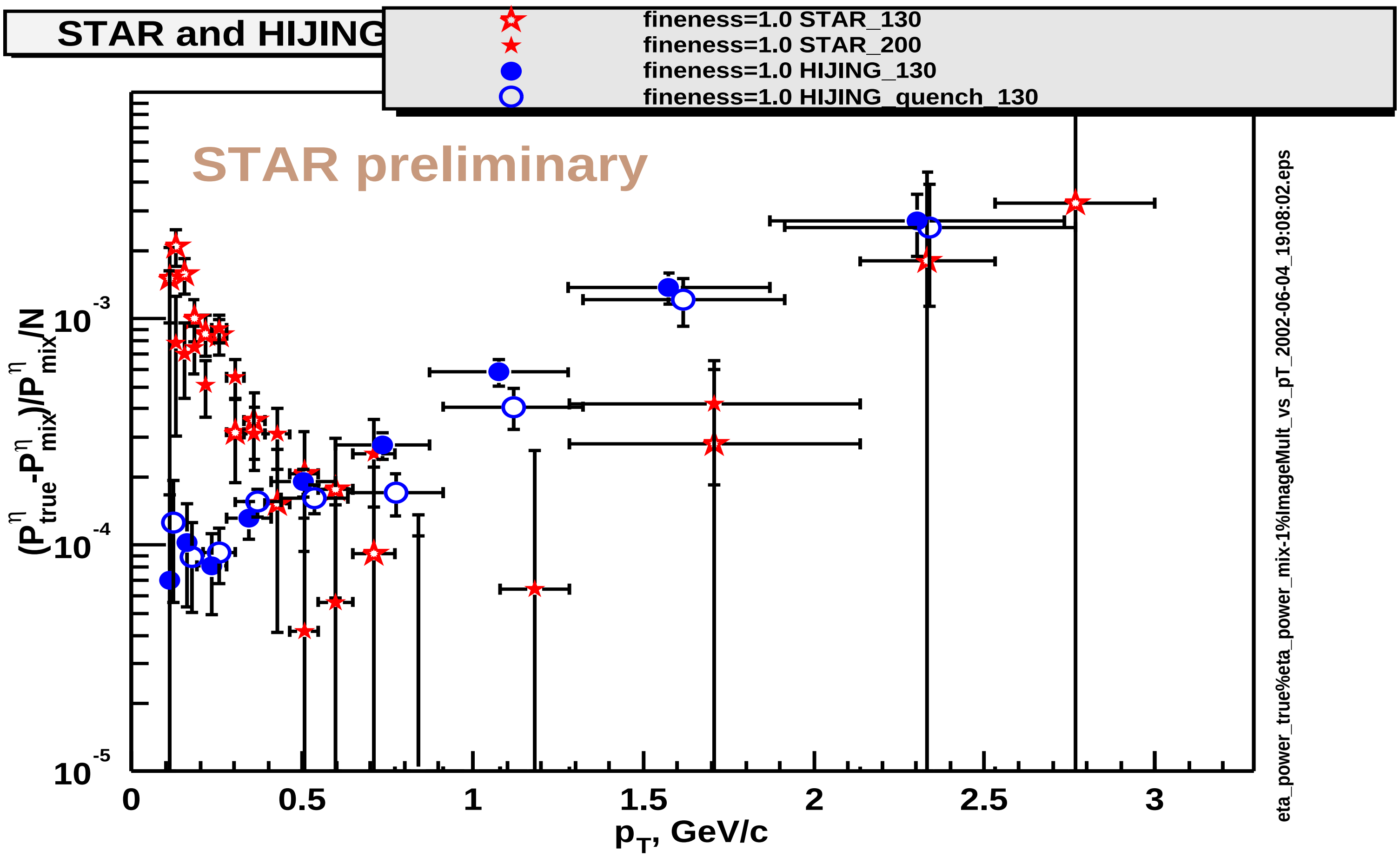


Peripheral ($mult/n_0 < 0.1$) events: p_T "break-down" of event texture. Charged particles. $1/N$ assumes "coherence".

STAR $\sqrt{s_{NN}} = 130$ and 200 GeV, HIJING 130 GeV.



Central $(0.7 < mult/n_0 < 1)$ events: HIJING does not reproduce the low p_T fluctuations. High $p_T \rightarrow$ low p_T energy dissipation ? Jet quenching ?



HIJING model of jet quenching does not predict the low p_T fluctuations. Alternative hypotheses: Bose-Einstein correlation+Coulomb? – but long range ! Critical phenomena ?

Conclusions:

– studies with event generators $\Rightarrow$ sensitivity to η clustering, jets, critical fluctuations

– peripheral ($mult/n_0 < 0.1$) data agree with HIJING well except for elliptic flow and details of p_T behaviour

– long range correlations (suppression of fluctuations) in η emerge in central events

– low p_T ($< 0.4GeV$) fluctuations in η and ϕ in peripheral and central (not reproduced by HIJING !) events