Correlations in p-p Collisions

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Outline

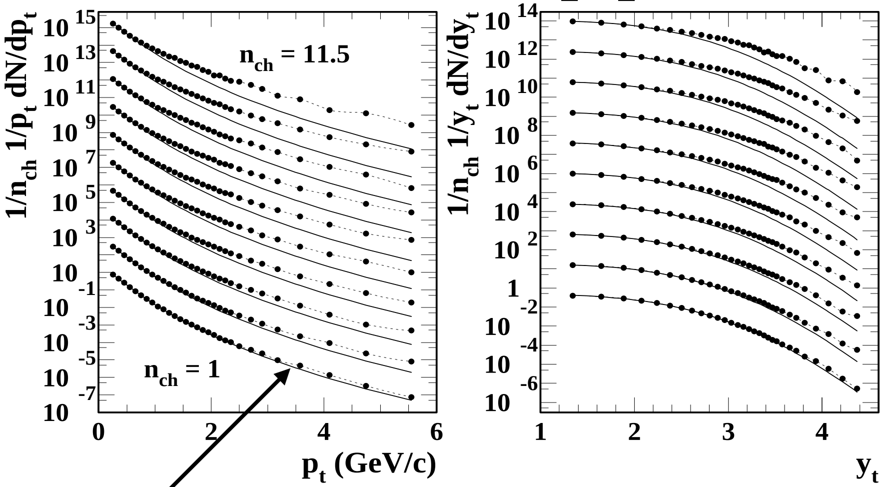
low-Q^2 partons in p-p collisions

- Parton fragments in single-particle spectra
- Two-particle fragment distributions on rapidity
- Jet angular autocorrelations at low Q^2
- Low-Q^2 physics phenomenology and LPHD
- 1D – 2D quantitative correspondence

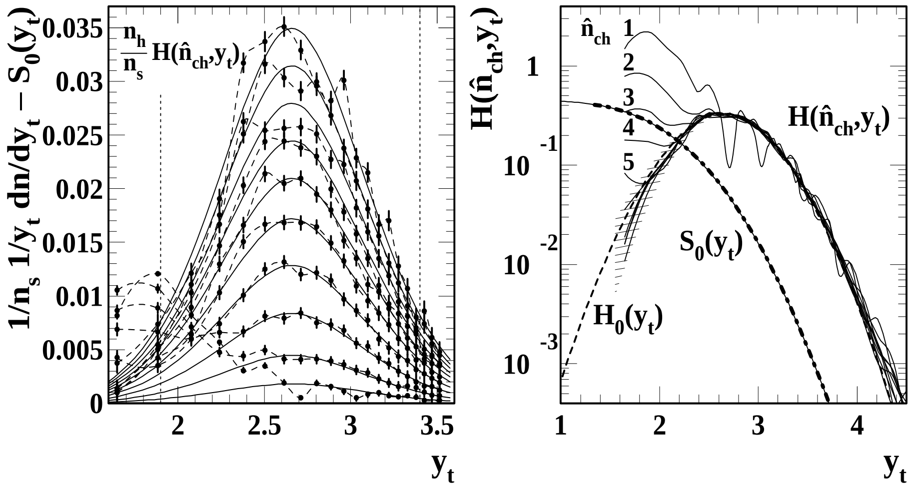
before we try to understand QCD in A-A collisions
we should understand it in elementary collisions

Two-component Analysis – p_t Spectra

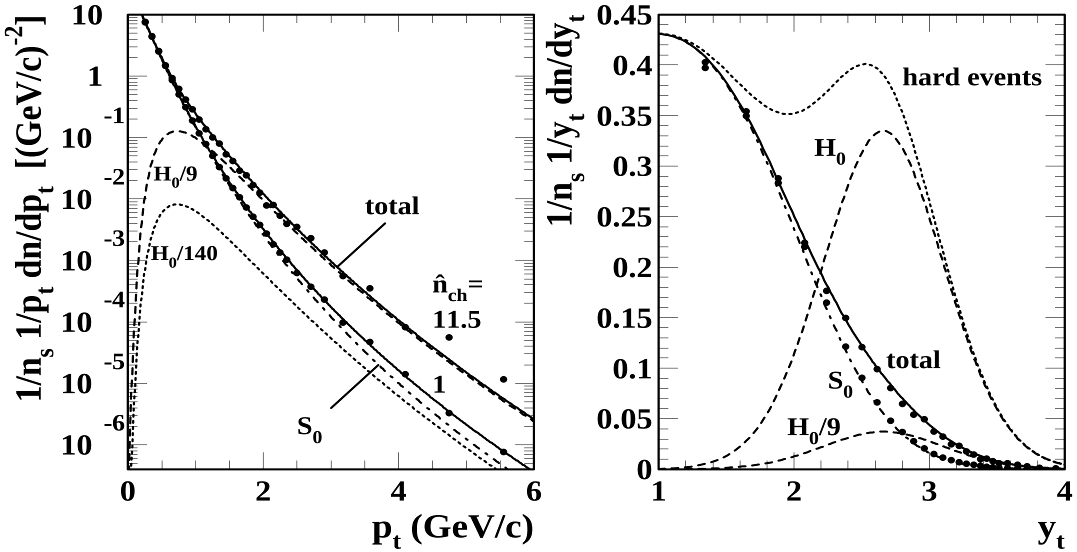
200 GeV p-p



H = data - S_0 – hard component



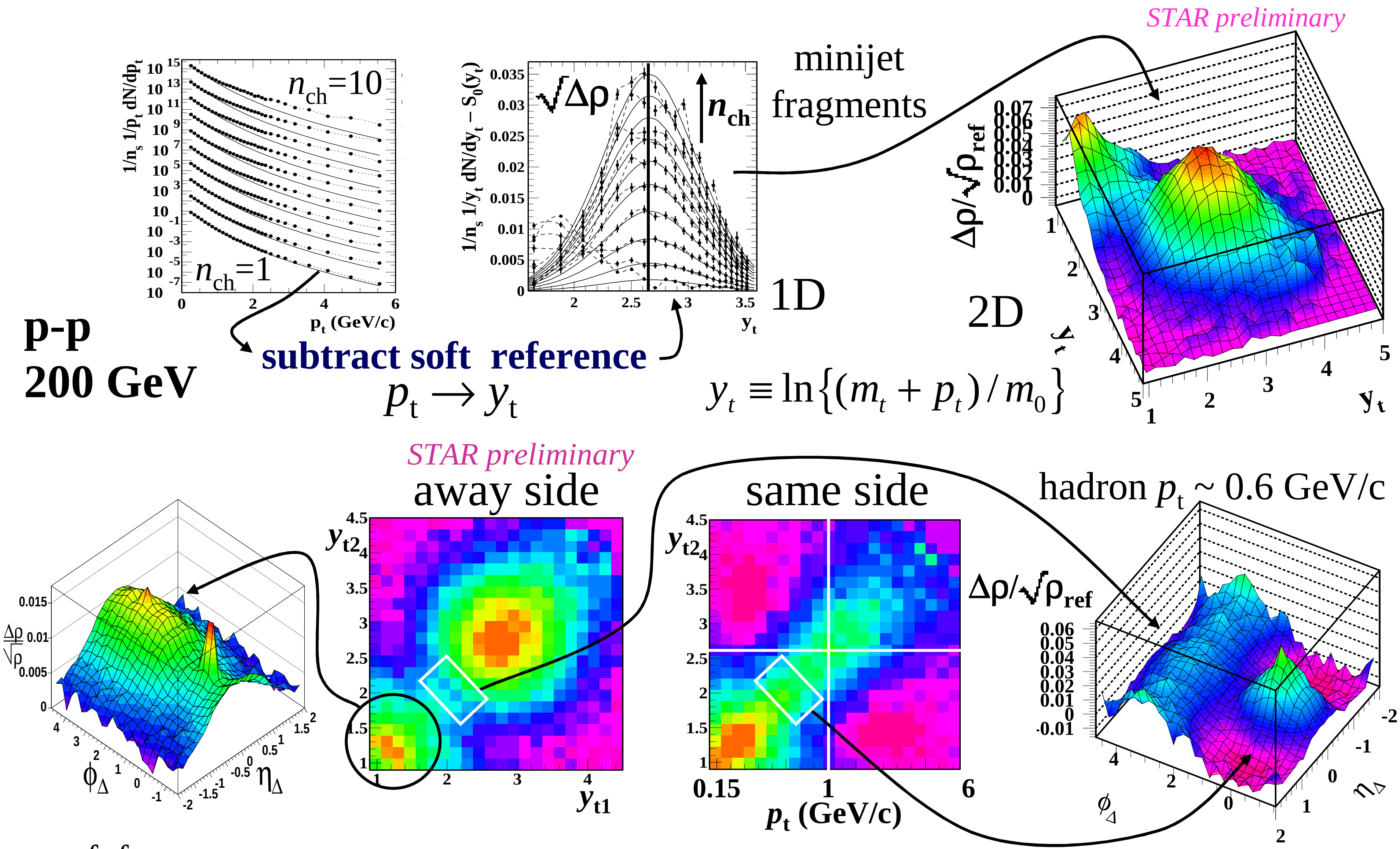
S_0 – soft component fixed reference



separated components based on n_{ch} dependence

what is the 'hard' component?

Low-Q^2 Partons in p-p Collisions



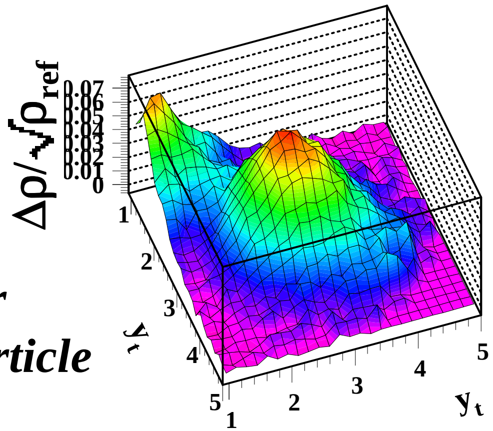
minimum-bias: no trigger condition

Correlation Analysis Methods

(y_{t1},y_{t2}) correlations

$(\eta_1,\eta_2,\phi_1,\phi_2)$ correlations

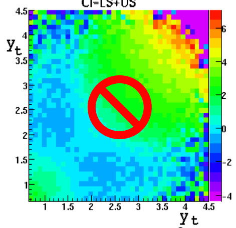
$(y_t,\eta,\phi)_1 \otimes (y_t,\eta,\phi)_2$



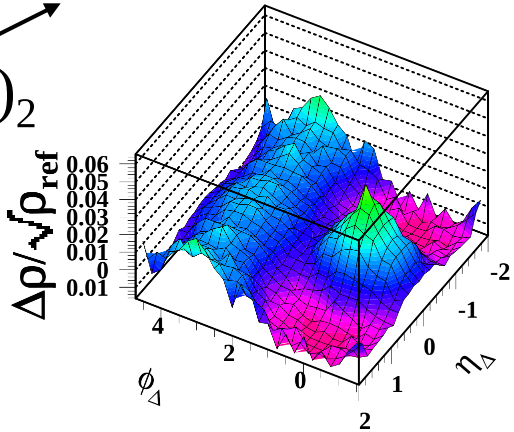
per particle

not an autocorrelation

$\Delta\rho / \rho_{ref}$



per pair



$\eta_\Delta = \eta_1 - \eta_2$

$\phi_\Delta = \phi_1 - \phi_2$

$\tau = t_1 - t_2$ ***'lag'***

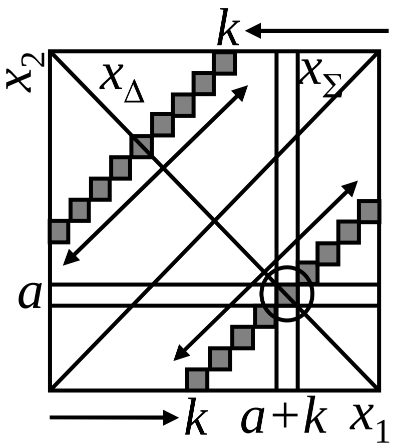
angular autocorrelation

in each 2D bin:

$$\Delta\rho / \sqrt{\rho_{ref}}\ |_{ab} \equiv \frac{\overline{(n-\bar{n})_a (n-\bar{n})_b}}{\varepsilon\sqrt{\bar{n}_a \bar{n}_b}}$$

ε = bin size

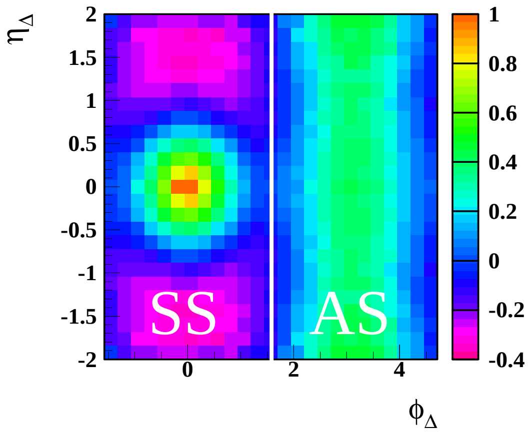
modified Pearson's coefficient:
normalized covariance density



$$\frac{\Delta n_k(n)}{\sqrt{n_{k,ref}(n)}} \equiv \left\{ \frac{\overline{(n-\bar{n})_a (n-\bar{n})_{a+k}}}{\sqrt{\bar{n}_a \bar{n}_{a+k}}} \right\}_{\bar{a}}$$

average over k^{th} diagonal

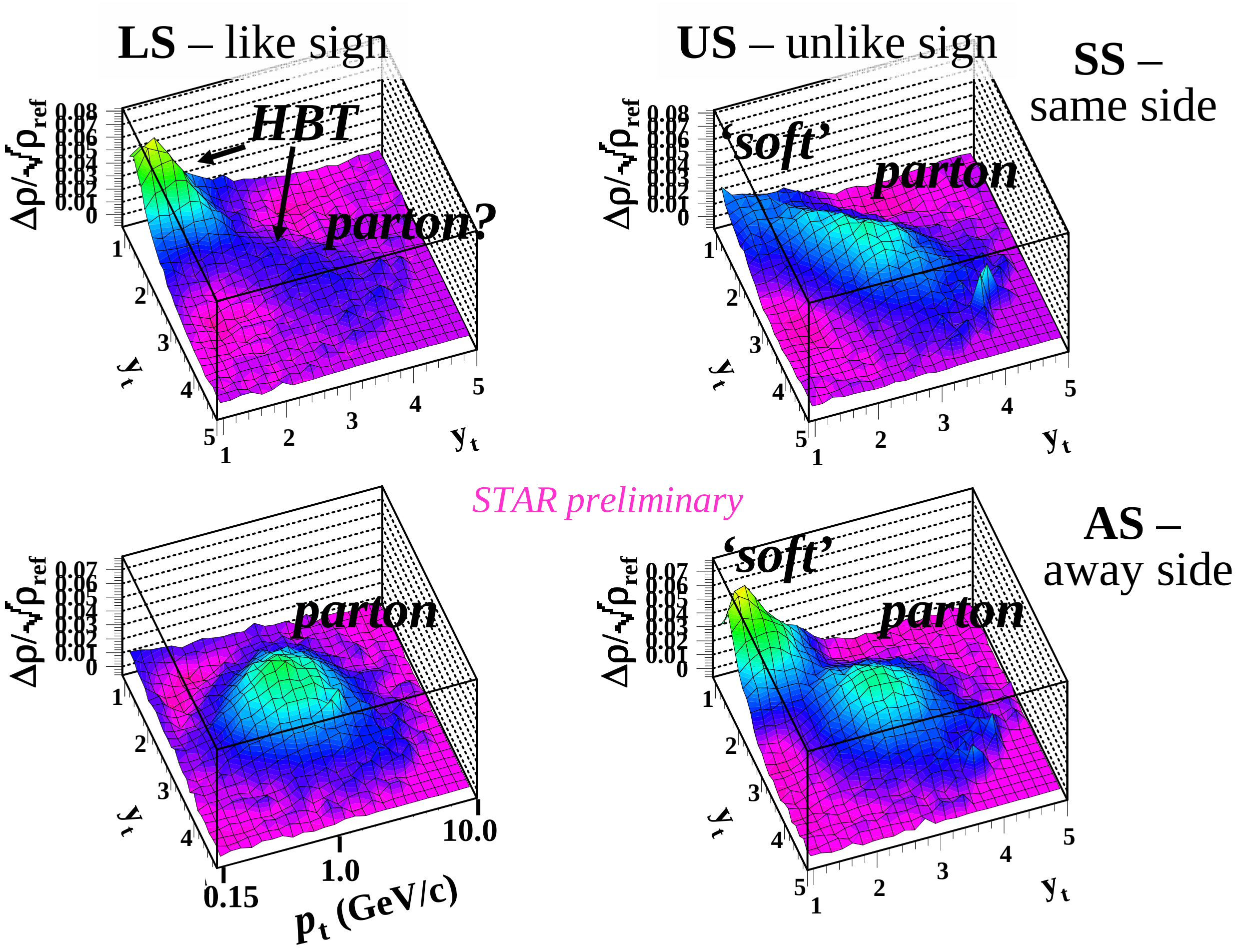
$$\frac{\Delta\rho(n;k\varepsilon_{x_\Delta})}{\sqrt{\rho_{ref}(n;k\varepsilon_{x_\Delta})}} \equiv \frac{\Delta n_k(n)}{\varepsilon_{x_\Delta}\sqrt{n_{k,ref}(n)}}$$



p-p Correlations on (y_{t1},y_{t2})

'string' and parton fragmentation: first two-particle *fragment distributions*

(except OPAL on ξ)



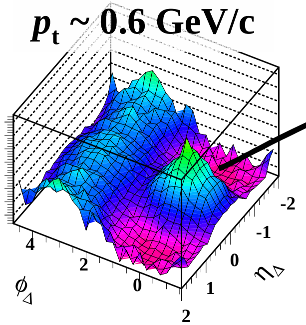
same-side parton fragmentation is restricted to US pairs

away-side parton fragmentation is independent of charge combination

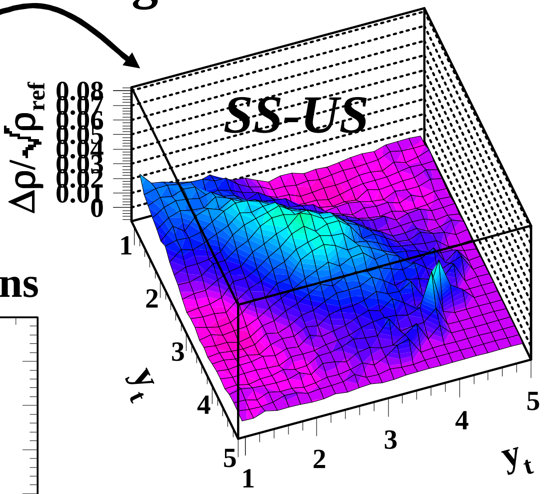
Low-Q^2 Parton Fragment Distributions

p-p 200 GeV $y_t \equiv \ln\{(m_t + p_t)/m_\pi\}$

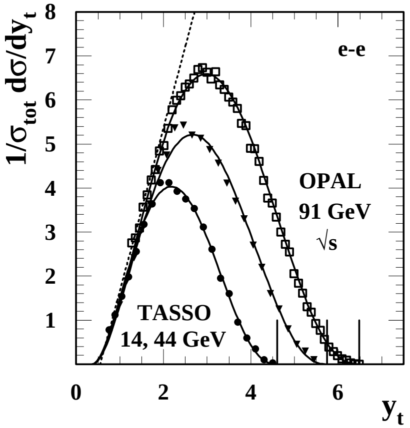
STAR preliminary



p-p *intrajet* two-particle fragment distribution



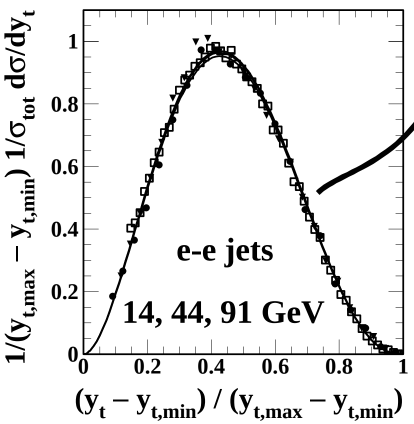
non-PID hadrons



e-e fragmentation functions on y_t

transformation

universal form



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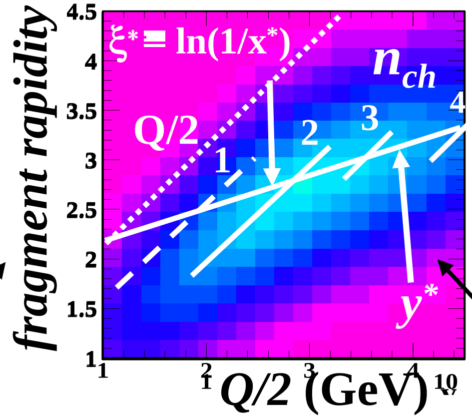
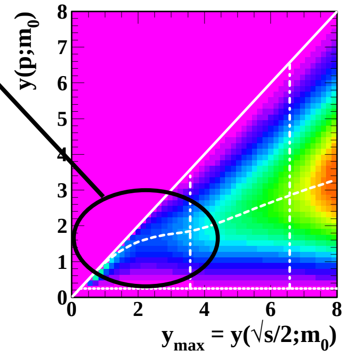
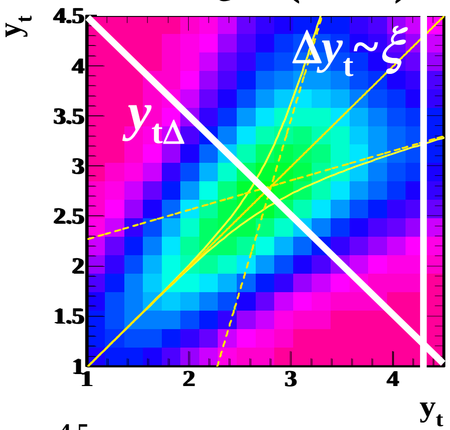
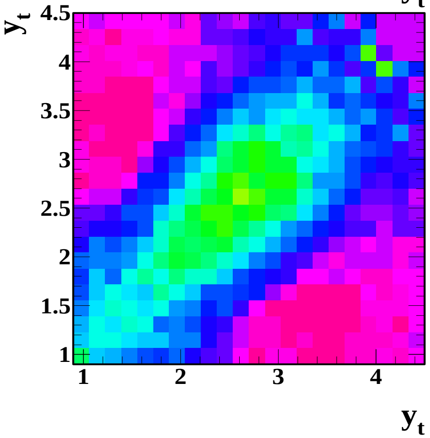


fragment-parton joint distribution on $(y_t, y_{t,max}) \sim (x_p, Q^2)$





symmetrize to fragment-fragment distribution on (y_t, y_t)

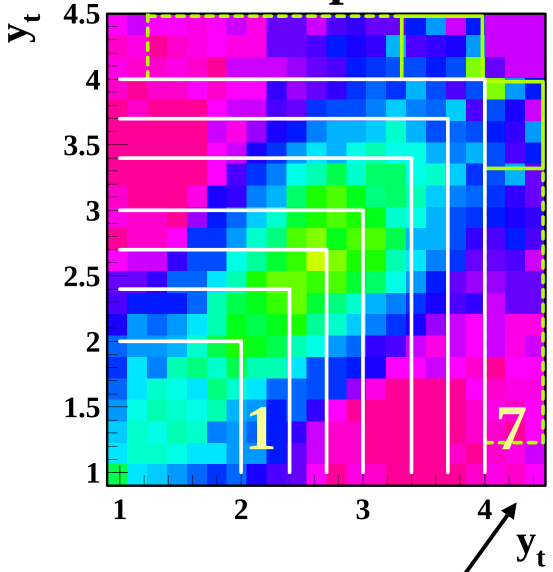


compare with data

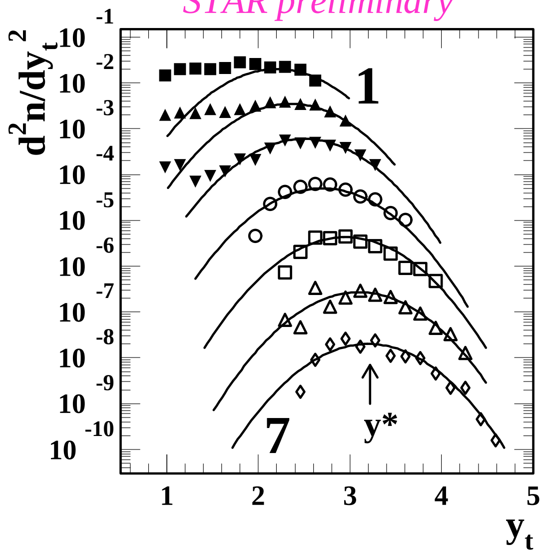
hacking QCD

$y_t \times y_t$ Analysis and Trigger Particles

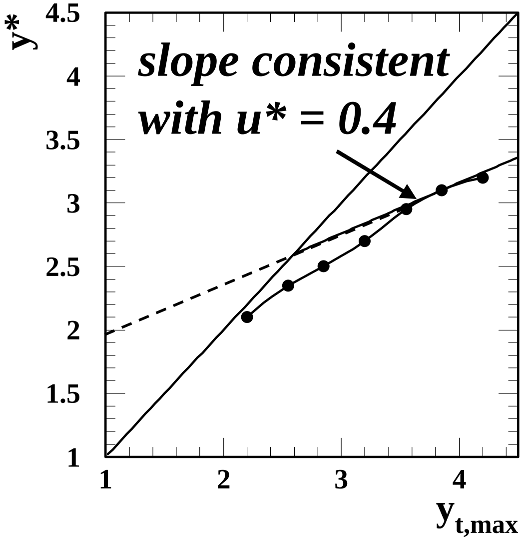
cut space



conventional trigger-particle condition



conditional distributions
***aka* trigger-particle analysis**



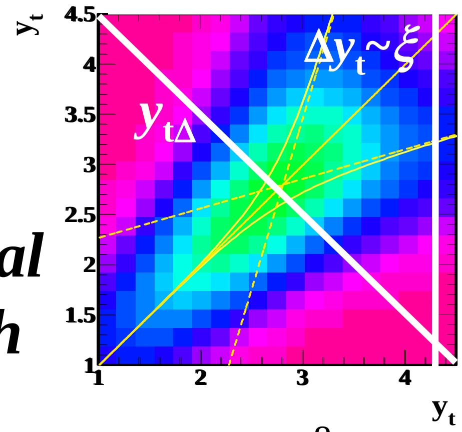
locus of modes

gaussian curves – width same as hard component in y_t spectrum

$\sigma_{y_t} = 0.46$

'fragmentation functions' extracted via analog to trigger-particle analysis

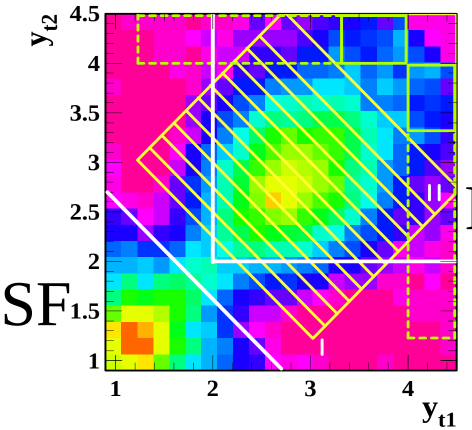
original sketch

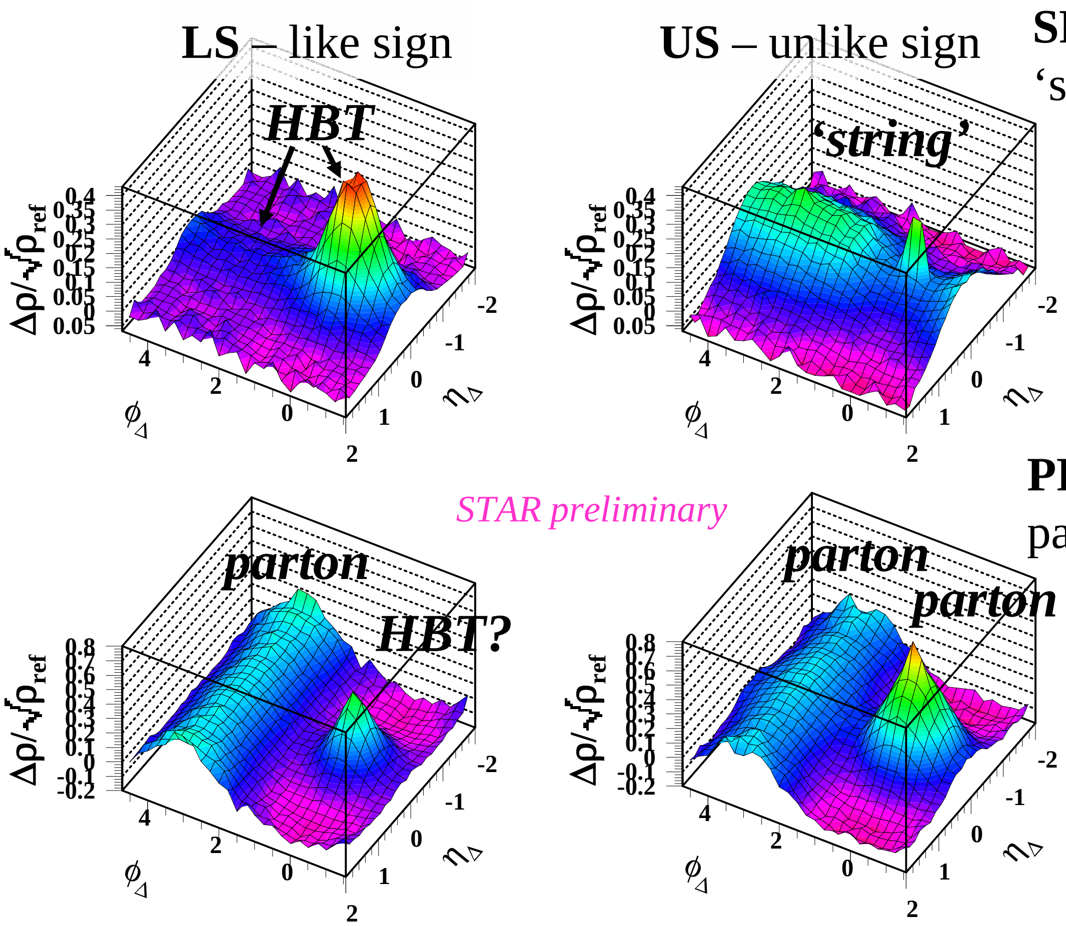


p-p Correlations on $(\eta_\Delta,\phi_\Delta)$

local charge and momentum conservation

joint autocorrelation on two difference variables





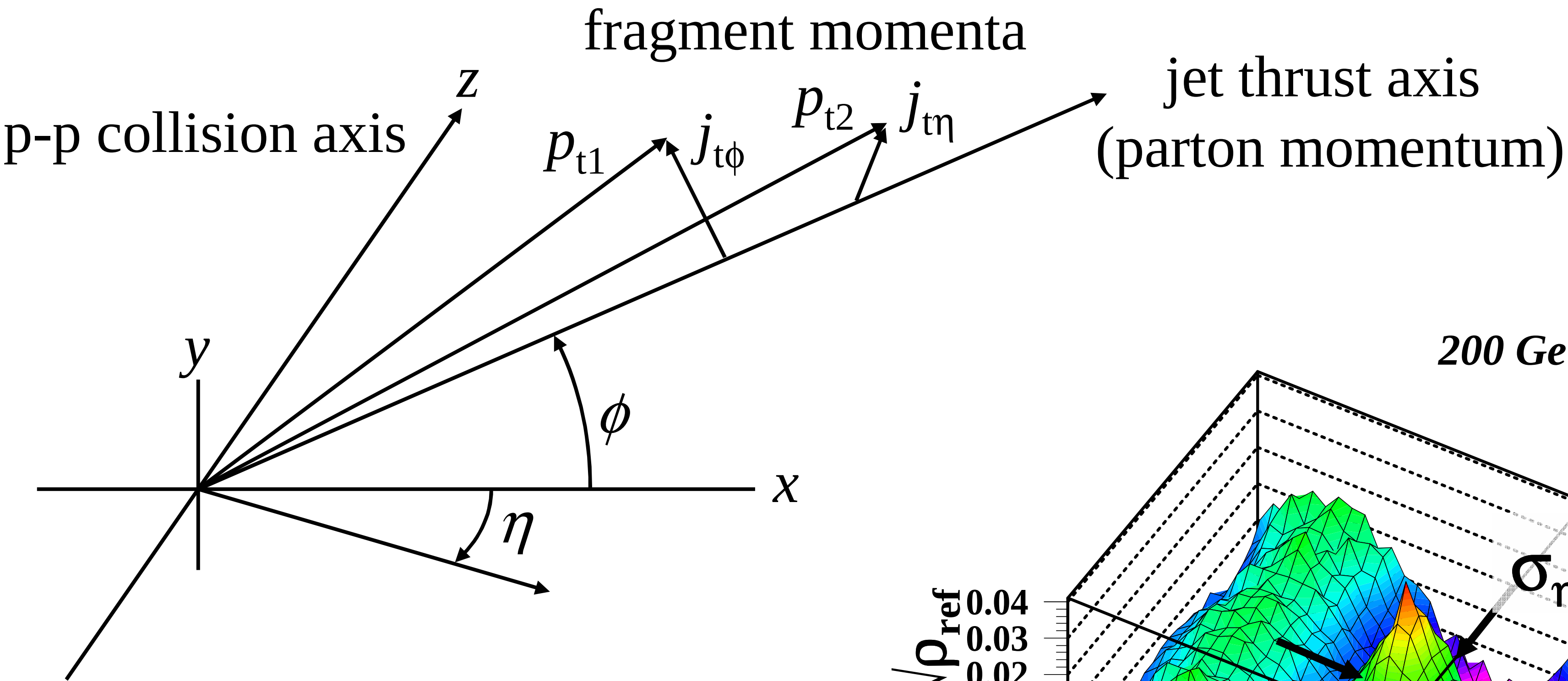
SF –
'string' or soft fragments

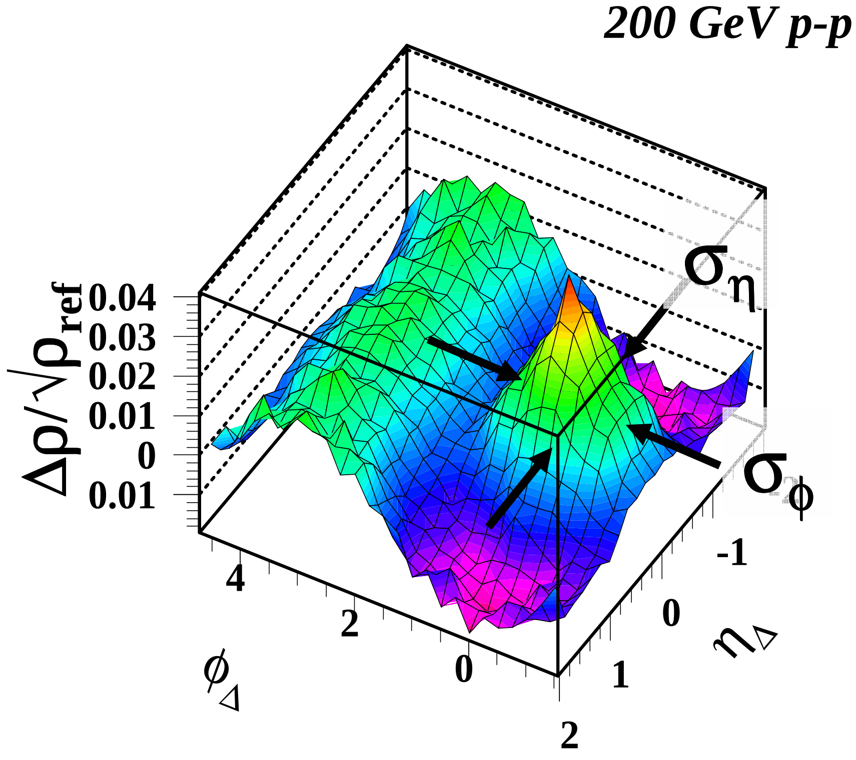
'string' fragmentation reflects local measure conservation

PF –
parton or hard fragments

away-side parton fragmentation is ~ independent of charge combination

Jet Morphology Relative to Thrust

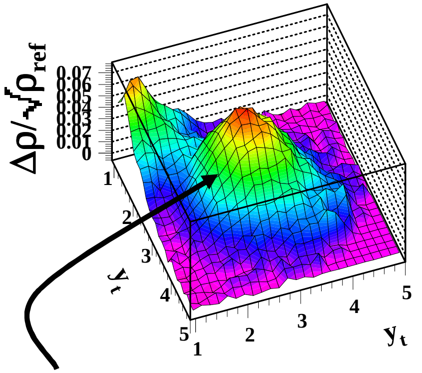




the most probable parton momentum for the distribution at right is 1 GeV/c

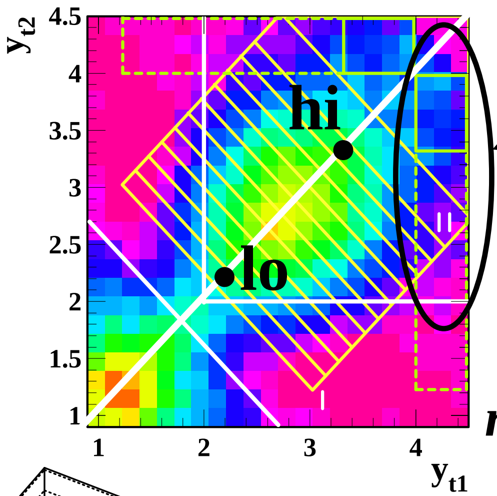
→ ***minijets***

Low-Q^2 Parton Angular Correlations



low-Q^2 partons – non-pQCD

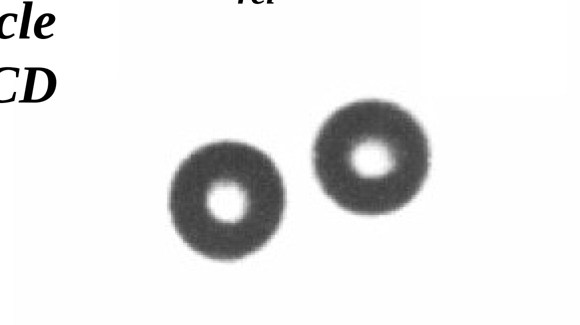
p-p 200 GeV



conventional high-p_t leading-particle analysis: pQCD

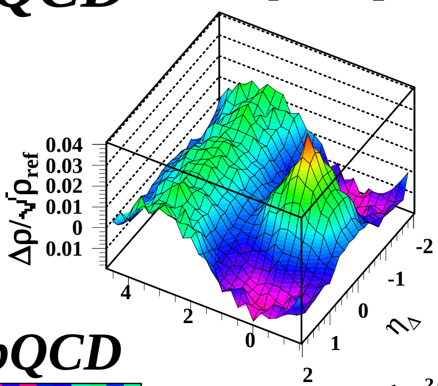
no trigger particle

water drops
v_{rel} = 6 m/s

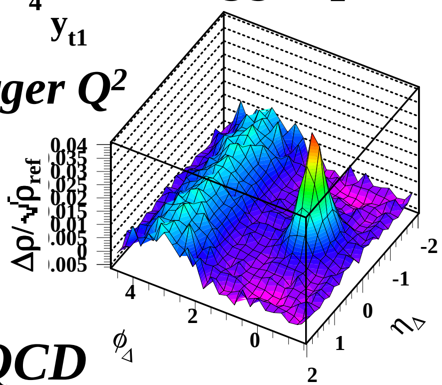


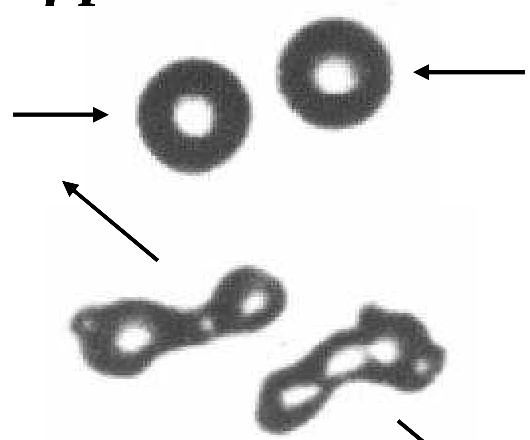
hydrodynamics of parton collisions?

small Q^2



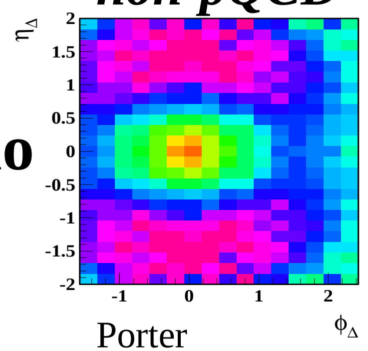
larger Q^2





non-pQCD

lo

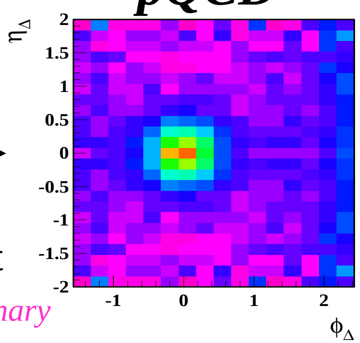


Q^2 →

1:1 aspect

STAR preliminary

pQCD



hi

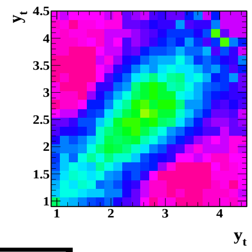
softest jets ever!
big non-perturbative effects

Porter

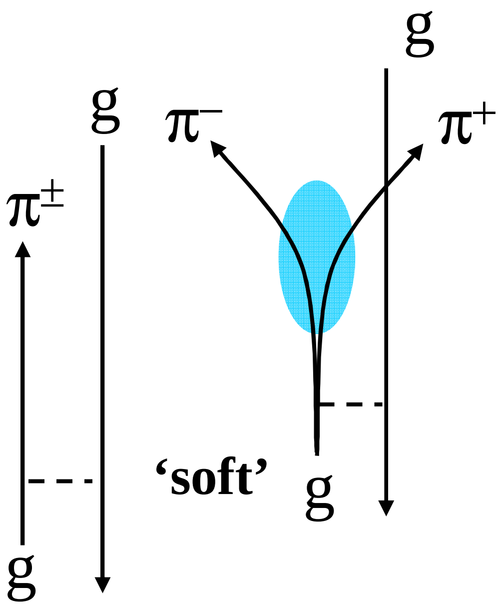
y_t, y_x Correlations

the softest detectable parton collisions → LPHD

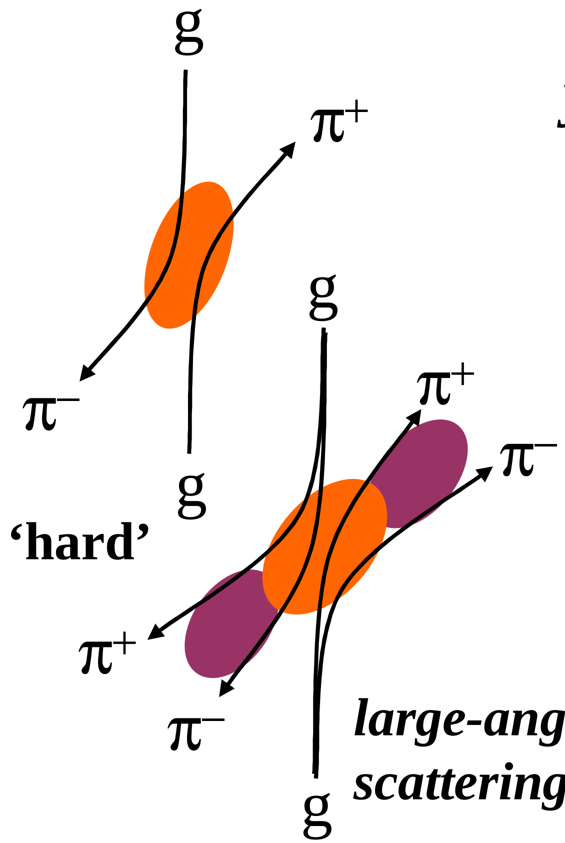
SS-US



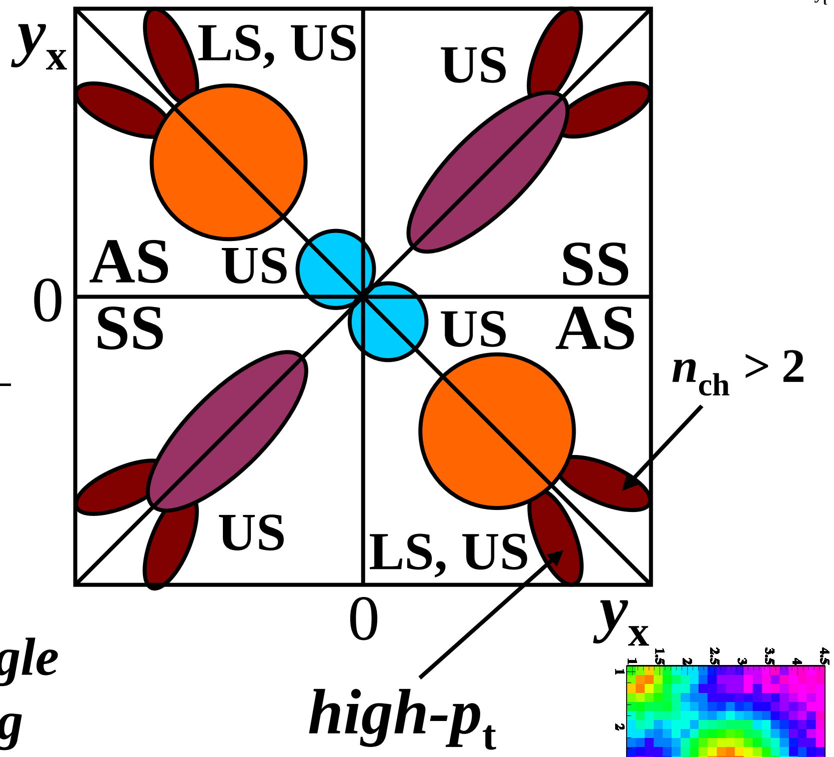
low-x gluons

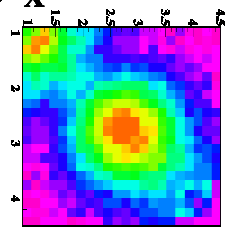


small-angle scattering



large-angle scattering





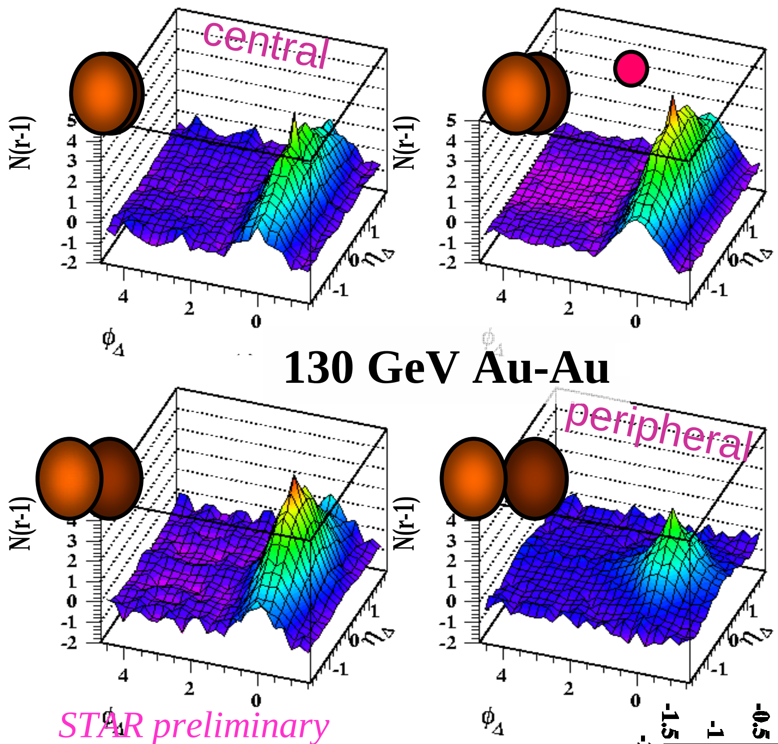
AS-CI

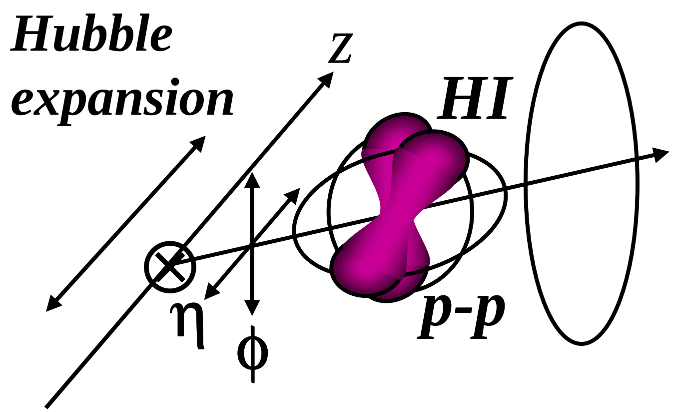
local parton-hadron duality: partons ‘blanche’ to become hadrons

LPHD: Ya. I. Azimov et al., Z. Phys. C 27, 65 **(1985)**

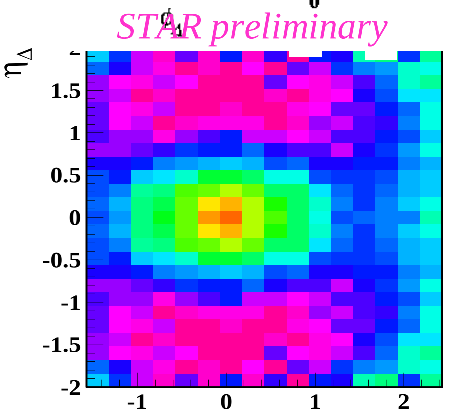
Minijet Deformation on (η,ϕ) in Au-Au

fragmentation asymmetry reverses: p-p → Au-Au



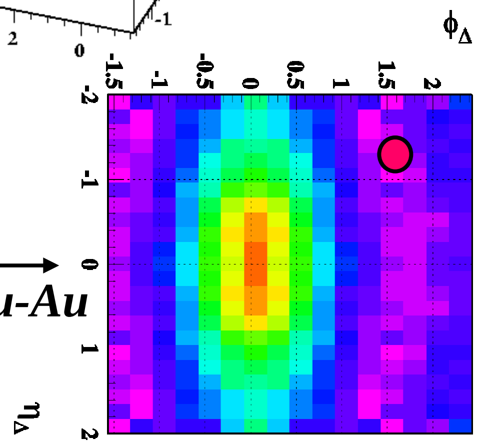


dramatic evolution with centrality

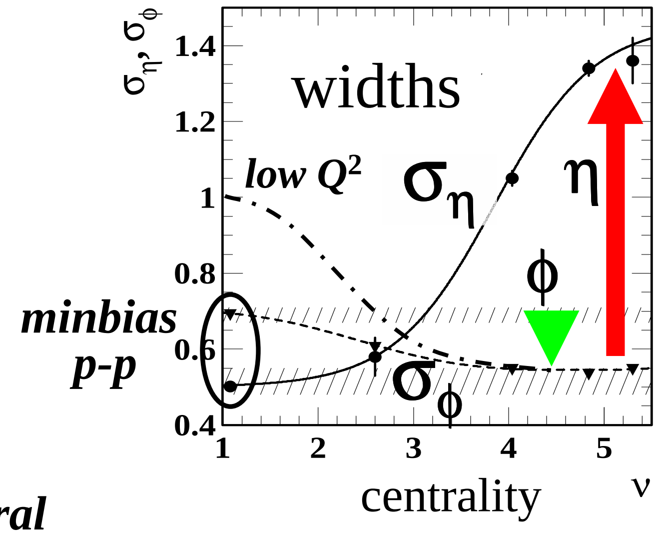


low Q² p-p

p-p → *Au-Au*

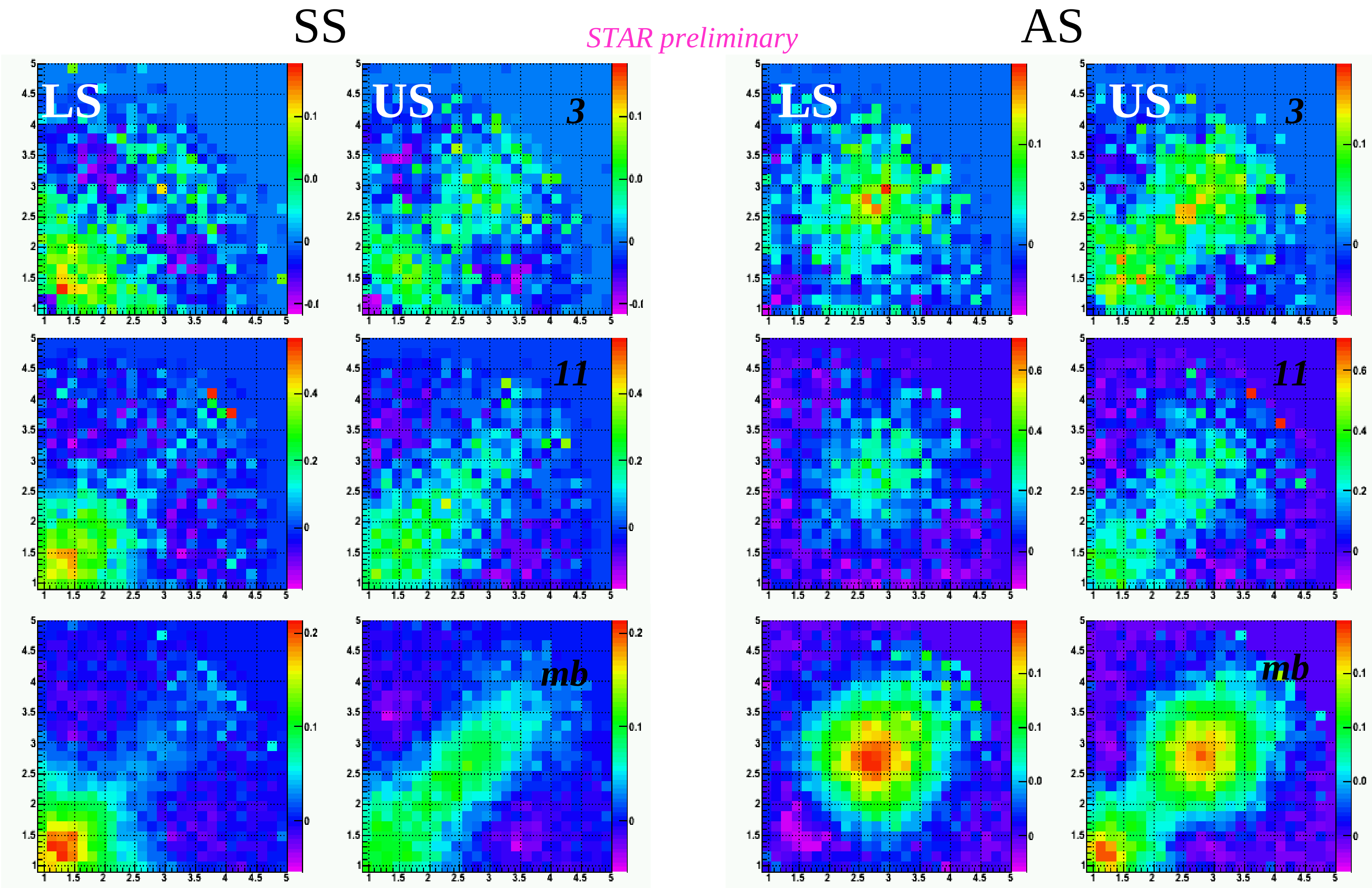


130 GeV Au-Au mid-central



Pearson: pair density ratios

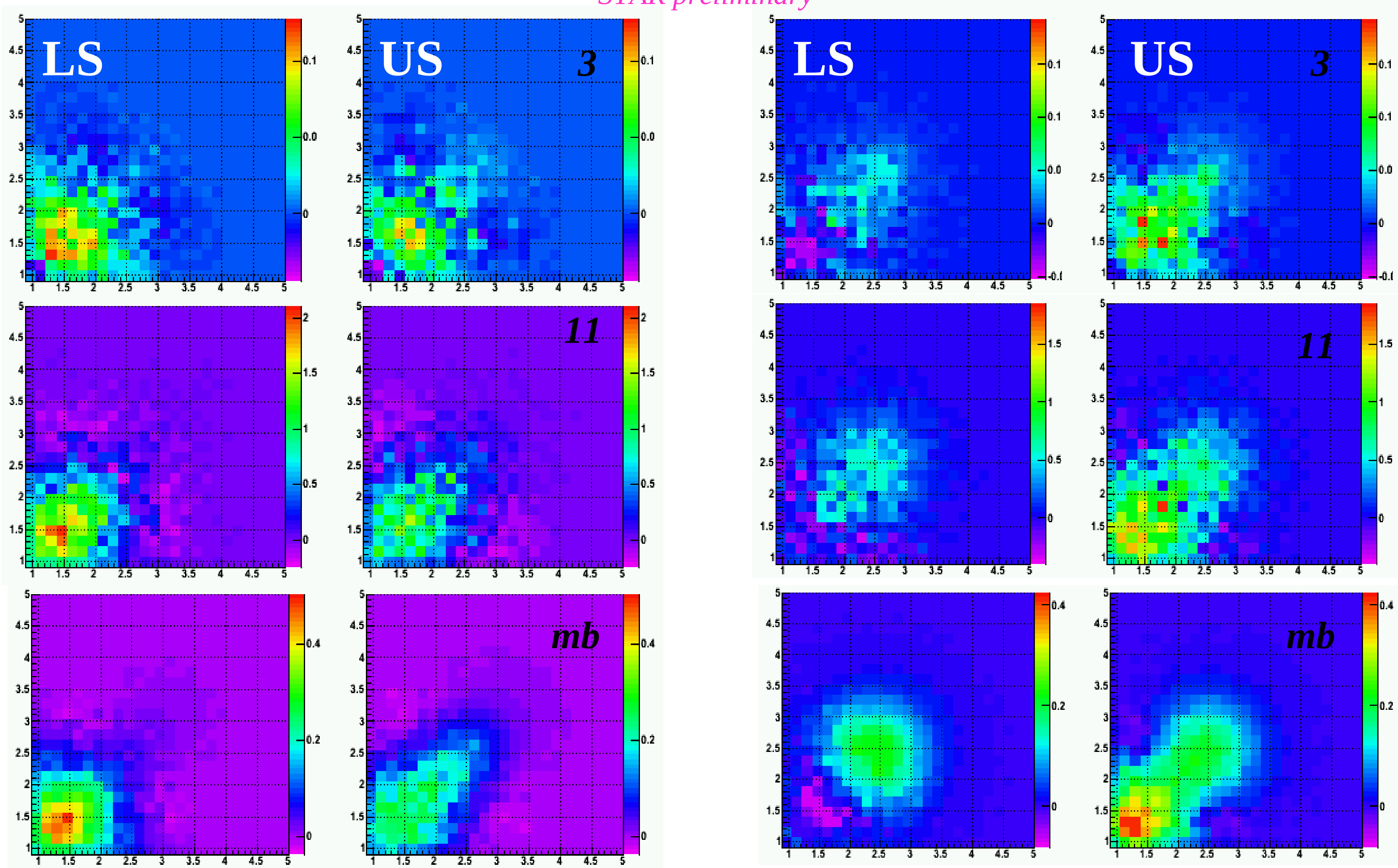
$\Delta\rho/\sqrt{\rho_{ref}}$ in hemi-cylinders

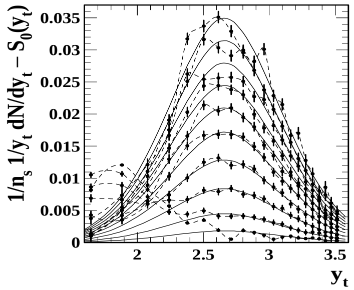


absolute correlated pair densities

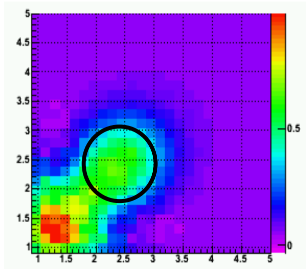
Δρ in hemi-cylinders

SS STAR preliminary AS





? $\leftrightarrow$



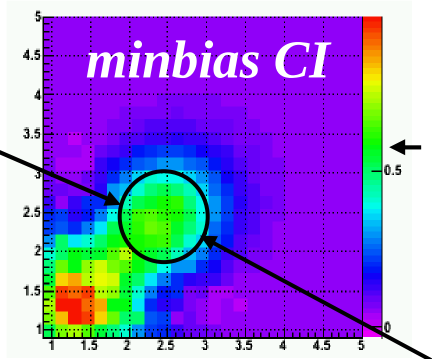
$\Delta\rho$ in 2π *with eta weighting*

provides absolute pair yields

STAR preliminary

unit-area circle

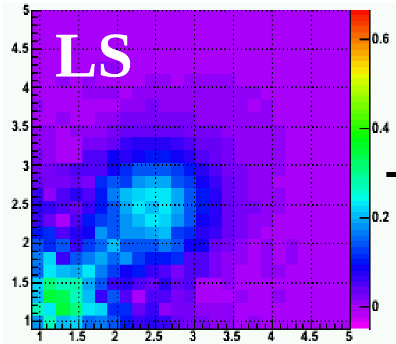
$\bar{n}_{ch} = 5.75$



← 0.6

all pairs

=



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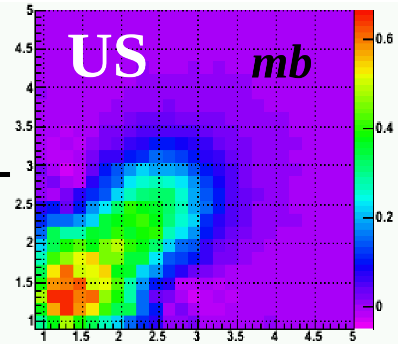


assume uniform distribution in circle with diameter = 1.13 on y_t consistent with spectra hard component

$\Delta\rho_{\max} = 0.6$ for minbias hard pairs

$\Delta n_{hard} = \text{unit area} \times \Delta\rho_{\max} = 0.6$ pairs/event in hard peak at $\bar{n}_{ch} = 5.75$

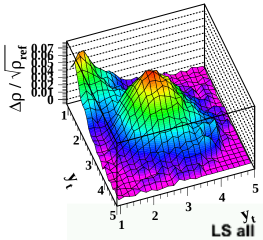
however, divide by ≈ 4 for symmetrization and eta weighting

$\Delta n_{hard} \rightarrow 0.15$ pairs per event in hard peak

from two-component spectra paper:

$\mathrm{n}_{\mathrm{hard}} = \bar{n}_{ch}^2 0.01/2 = 0.17$ particles per event in hard peak

absolute comparison within 2×



1D *vs* 2D Correspondence

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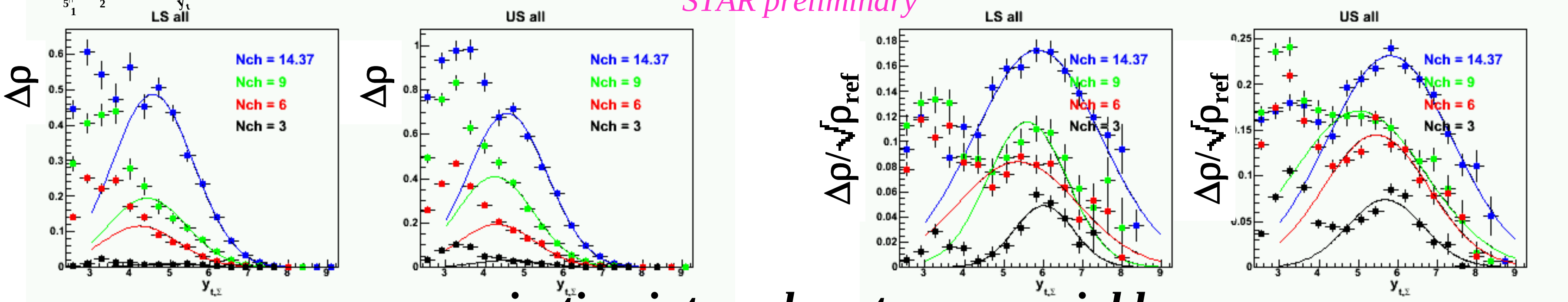
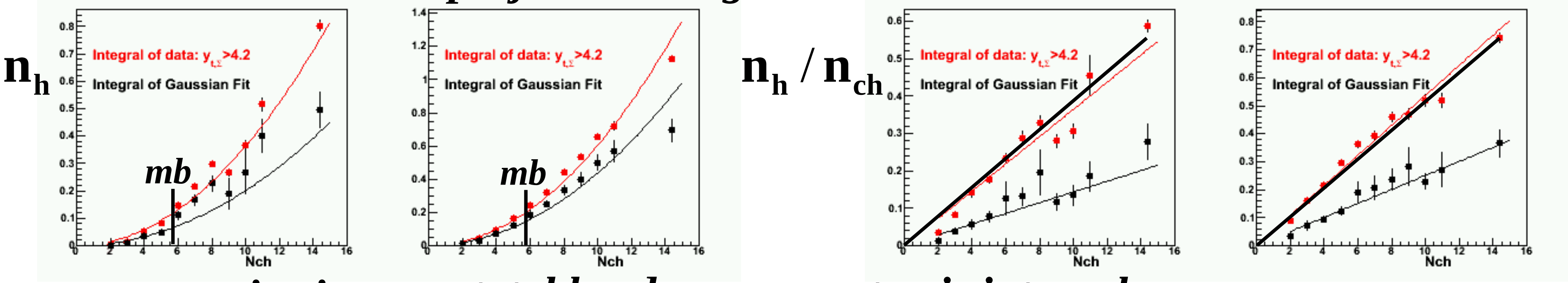


projection integrals onto sum variable



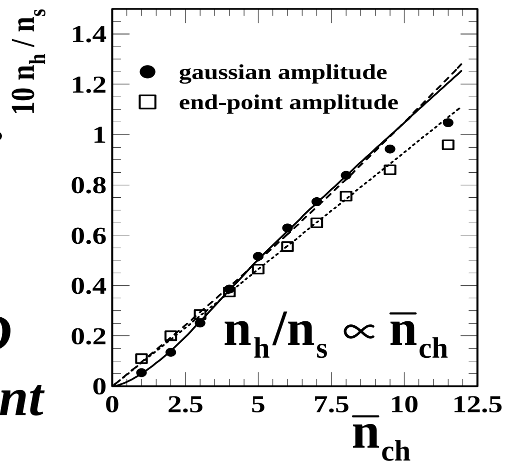
no symmetrization ***total hard-component pair integrals***

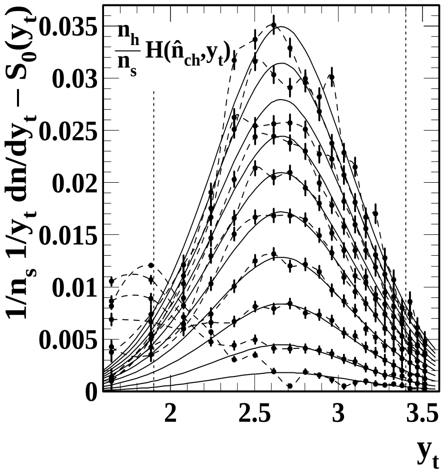
1D spectra:

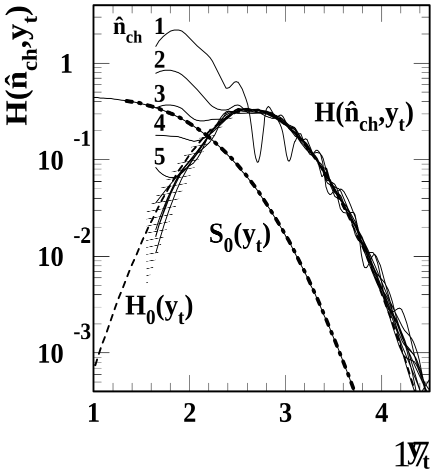
$\mathbf{n_h \propto \overline{n}_{ch}^2}$

1D and 2D are consistent

Porter







Summary

- Low-Q^2 parton fragmentation in p-p is precisely accessible down to hadron $p_t \cong 0.35$ GeV/c
- Jet morphology requires new treatment of fragment y_t distributions, angular correlations
- Low-Q^2 fragment distributions exhibit interesting systematic behavior → the physics of LPHD
- Jet angular correlations show strong asymmetry at low Q^2, 'remember' parton collision details
- Moving toward a quantitative relation between fragment pairs and y_t spectrum hard component