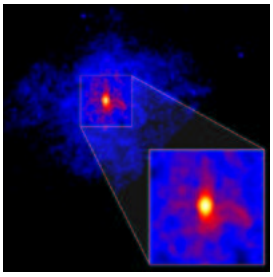
What you know that isn't (quite) so: E_T, energy density and HBT

David Morrison
Brookhaven National Laboratory

Global variables … anywhere

- Geometry
- Energy density
- Bulk properties
- Initial conditions



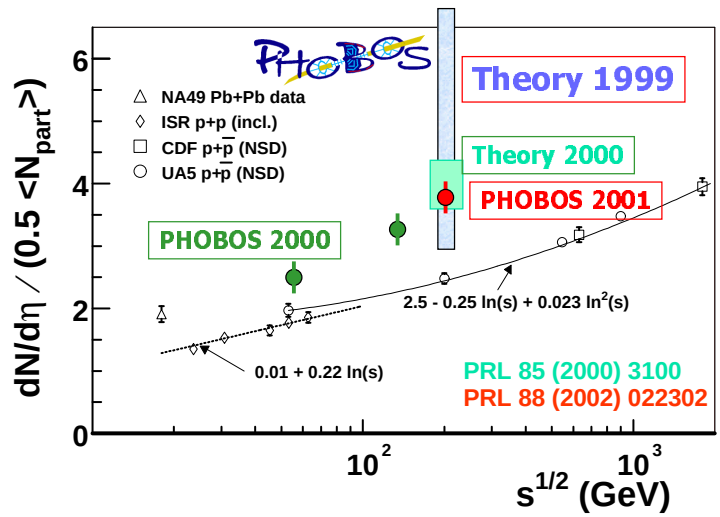
pulsar 3C58

RHIC global variables

- $dN_{ch}/d\eta$, flow, fluctuations
  - entropy, stopping, EOS, correlations
- transverse energy
  - energy density
- HBT radii
  - source size, collision development
- mid-rapidity baryons
  - "environmental" conditions of particle production

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 3



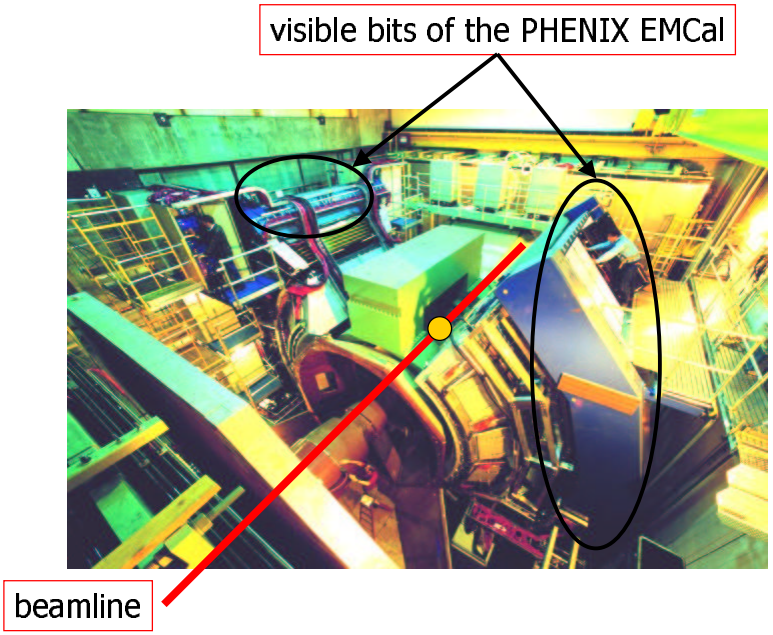
M. Baker, BNL seminar

Measuring E

- PHENIX (PbSc) EMCal: designed to be a superb calorimeter for measuring EM energy
  - finely segmented: 5.5cm x 5.5cm @ 5.1m
  - good resolution: $8.2\%/E^{1/2} \oplus 1.9\%$ for e^-
  - good EM containment: 18 X_0
- but that's for EM energy … only 0.85 λ

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 5



Determining E_T

- model particle composition (e.g. use HIJING)
- tune simulation to reproduce response
- choose definition of E_T

$E_T = \sum E_i \sin\Theta$ just kinetic energy for antinucleons, or include mass?

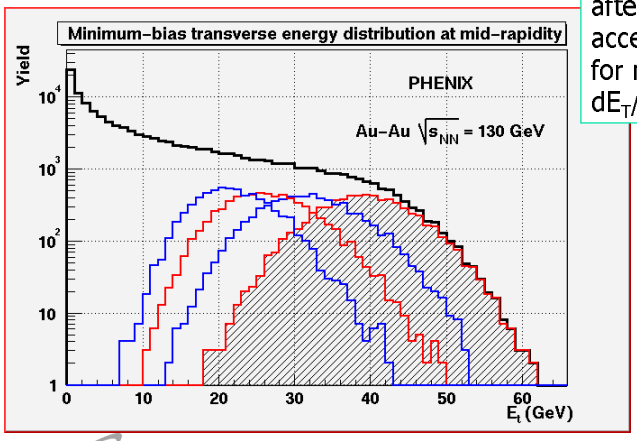
- PHENIX just KE, WA98 mass too
- accumulate total E minus initial nucleons

- calibrate coefficient relating detected E_T^{EMC} to primordial E_T

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 7

E_T for 130 GeV Au+Au



after corrections for acceptance, response for most central 5%: $dE_T/d\eta$ = 503±2±22 GeV

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 8

Energy density

The usual, with the usual caveats …

$$\varepsilon = \frac{1}{\pi R^2 \tau}\frac{dE_T}{dy}$$

Jacobian to convert dη to dy per particle, use original model to calculate complete factor converting to dE_T/dy: 1.19±0.01

for top 2% of distribution:
$dE_T/d\eta = 578^{+26}_{-39}$ GeV
ε = 4.6 GeV/fm^3 (τ = 1 fm/c)

cf. 405 GeV, 3.2 GeV/fm^3 in NA49 PRL 75, 3814, (1995)

ε = 15 GeV/fm^3 (τ = 0.3 fm/c)

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 9

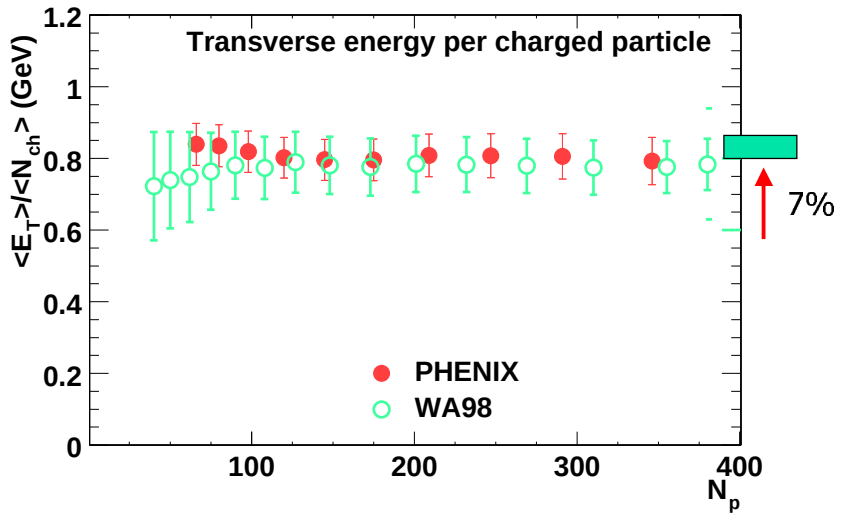
Adjust E_T definition

- p-bar/p=0.64±0.04±0.06 (PRL 87, (2001) 112305) so anti-baryon yields are not small
- p-bar yield at y=0 in top 5%: 20.1±1, uncorrected for feed-down (PRL, nucl-ex/0112006)
- add in like number of n-bar and E_T rises ~7%
- no measurement yet of n-bar, n
  - unpublished NA49 data on d+p suggesting p-bar, n-bar yield in n+p 1.5 times yield in p+p (CERN/SPSC/P264 Add. 10)

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 10

E_T per N_{ch}



Net/total baryon density

- EMCal based n-bar analysis is maturing but very tricky to extract yields
- "coffee talk": would it be possible to put small patch of hadronic calorimeter behind existing EMCal
  - FNAL E683, BNL E864, CERN WA98 retired calorimeters - various pros and cons

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 12

Segue to HBT

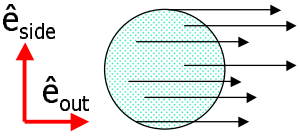
- Also a global observable, contains information about event configuration, dynamics
- In PHENIX, pions for HBT identified using time-of-flight to EMCal
  - ID pions up to ~1 GeV/c

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 13

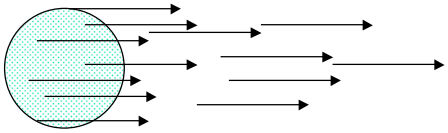
Early expectations

static, transparent source, with short emission duration …



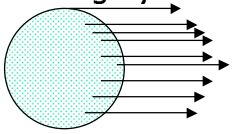
$R_{out}/R_{side} = 1$

with longer emission duration …



$R_{out}/R_{side} > 1$

with strong dynamical correlations …

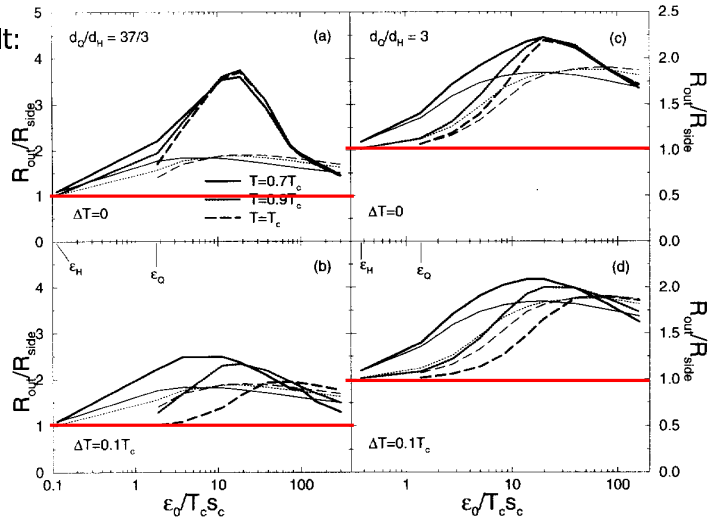


$R_{out}/R_{side} < 1$

Quantitative calculations

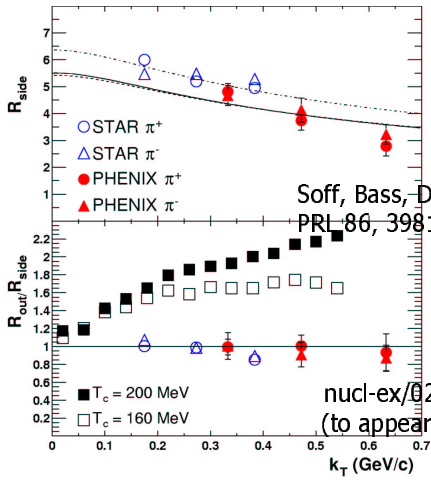
D.H. Rischke, M. Gyulassy/Nuclear Physics A 608 (1996) 479–512

consistent result: expect $R_{out}/R_{side} > 1$



$R_{out,side}$ vs k_T

Data show quote different trends than seen in quantitative calculations



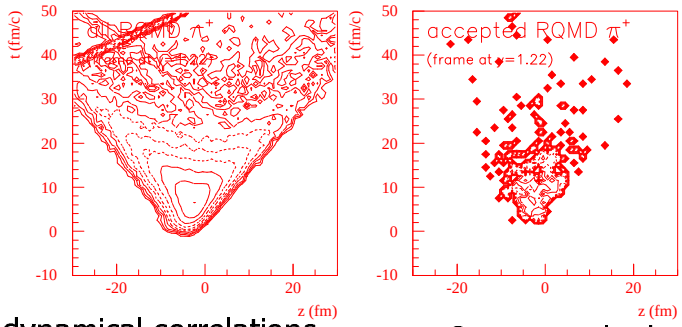
Soff, Bass, Dumitru PRL 86, 3981 (2001)

nucl-ex/0201008 (to appear in PRL)

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 16

Previous example: AGS



strong dynamical correlations

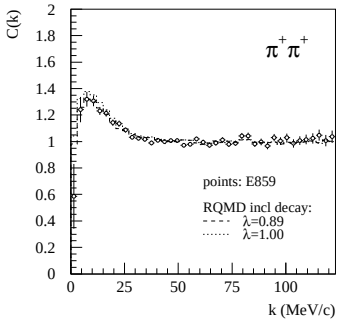
O. Vossnack Ph.D. thesis Columbia Univ.

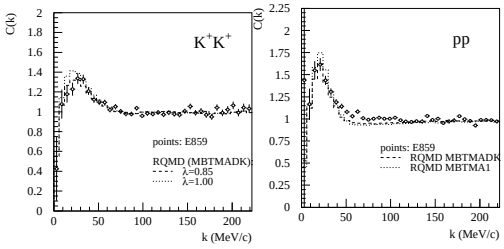
show Zajc, Nucleus-Nucleus'97

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 17

No easy solution





Have to amass significant collection of like, unlike correlations, compare quantitatively to microscopic models

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 18

Prospects

- extend k_T reach of $\pi\pi$ HBT in PHENIX
  - selected 0.5M events out of 5M for 130 GeV analysis
  - 90M minimum bias events for 200 GeV Au+Au
  - timing resolution of calorimeter ~500ps
  - k_T for pions out to ~1.3 GeV/c
- kaon, proton, unlike particles

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 19

A global view

- high energy density ... seemingly very high
  - 5 GeV/fm^3 very conservative; 10-15 GeV/fm^3 "Wit's N_{ch} times $\langle E_T \rangle$" to $dE_T/d\eta$ plus Bjorken using $\tau \ll 1$ fm/c
- interesting question regarding baryon density which is conceivably addressable
- pion HBT k_T systematics clear; implications not

BROOKHAVEN NATIONAL LABORATORY

QCD in the RHIC Era 20