Global Description of Heavy Ion Collisions

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Part I: The Model

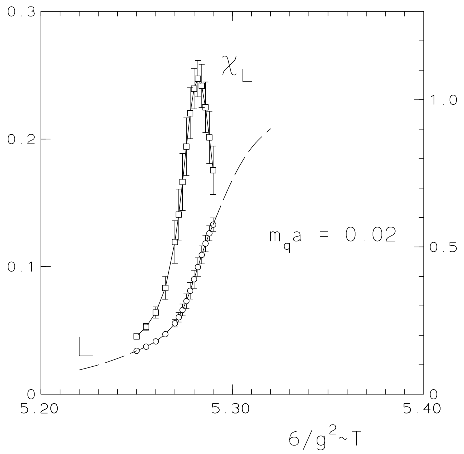
- Introduction
- Essential Scales
- Modelbuilding

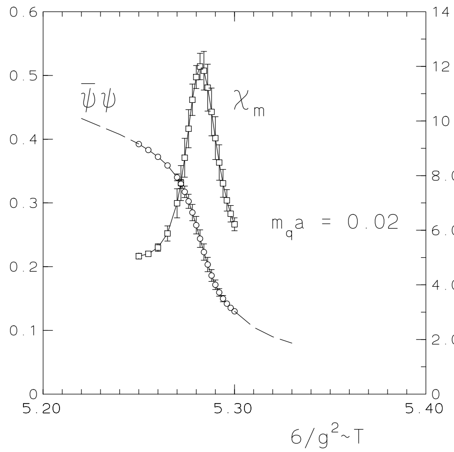
Part II: Observables

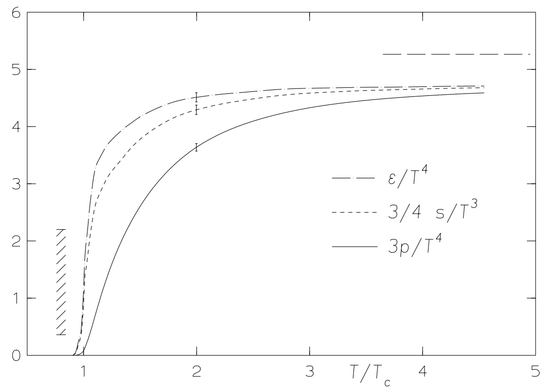
- m_t-spectra and HBT
- Photons and dileptons
- J/Ψ suppression

Summary

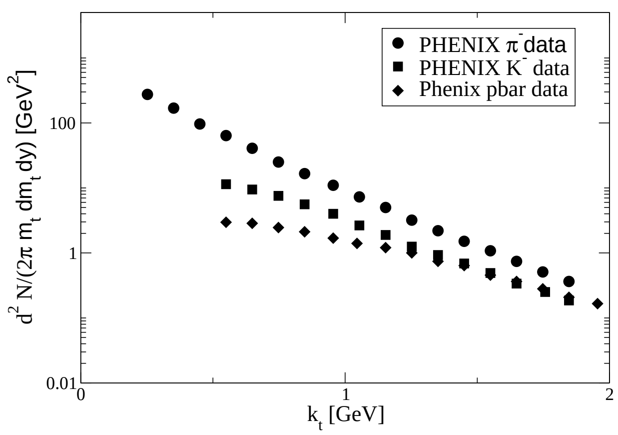
Properties of the QGP

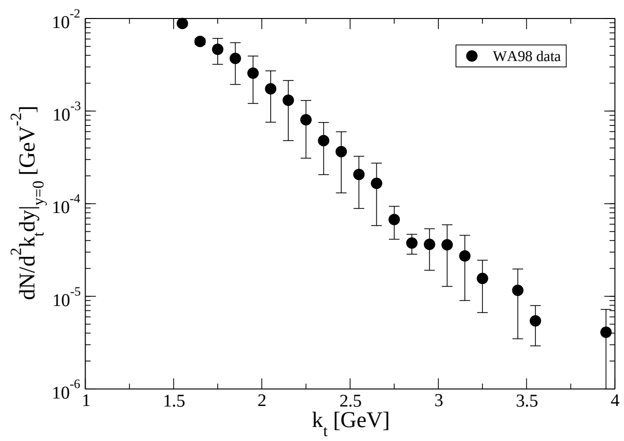






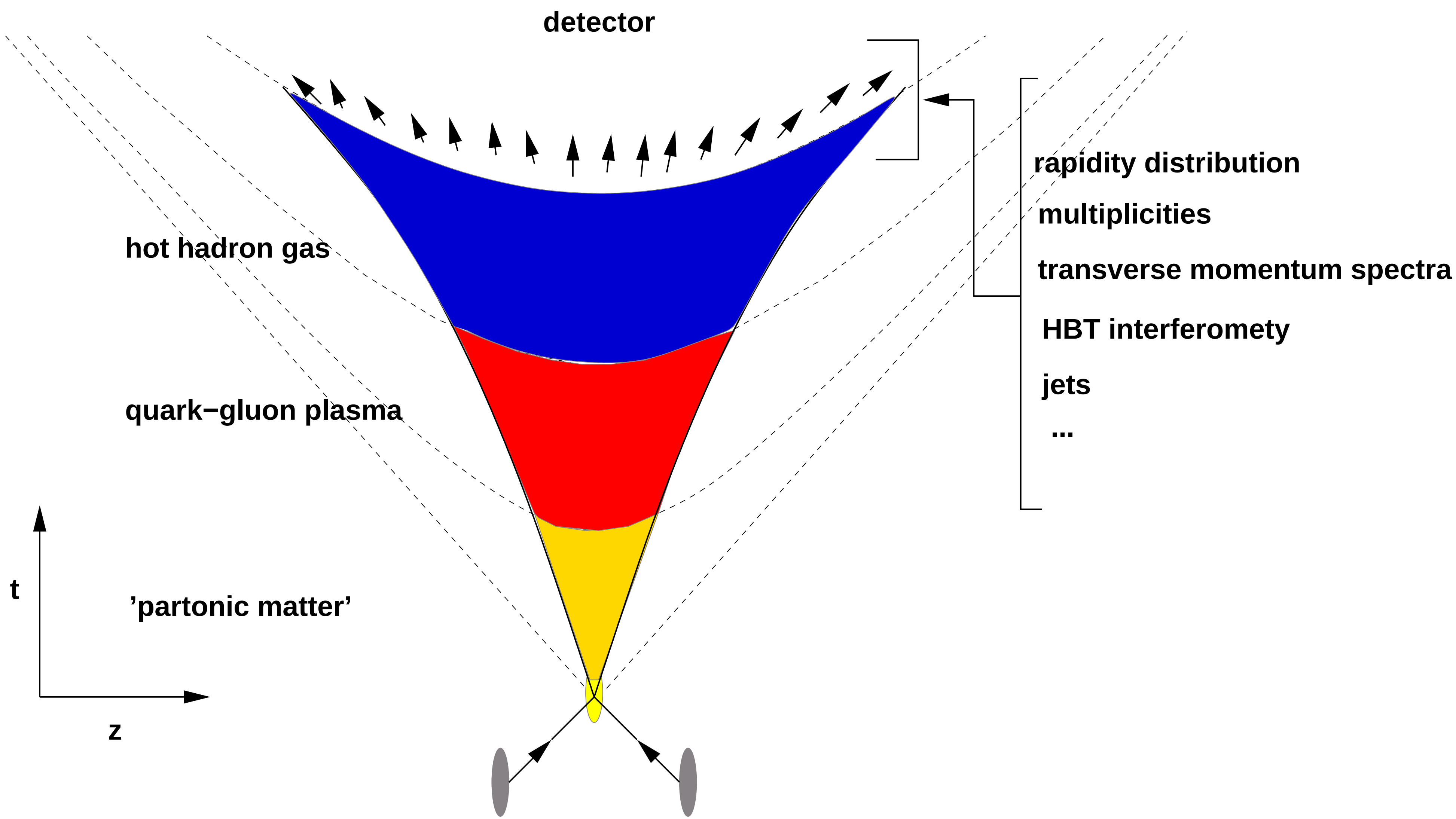
Lattice QCD $\Leftrightarrow$ Experiments at SPS and RHIC



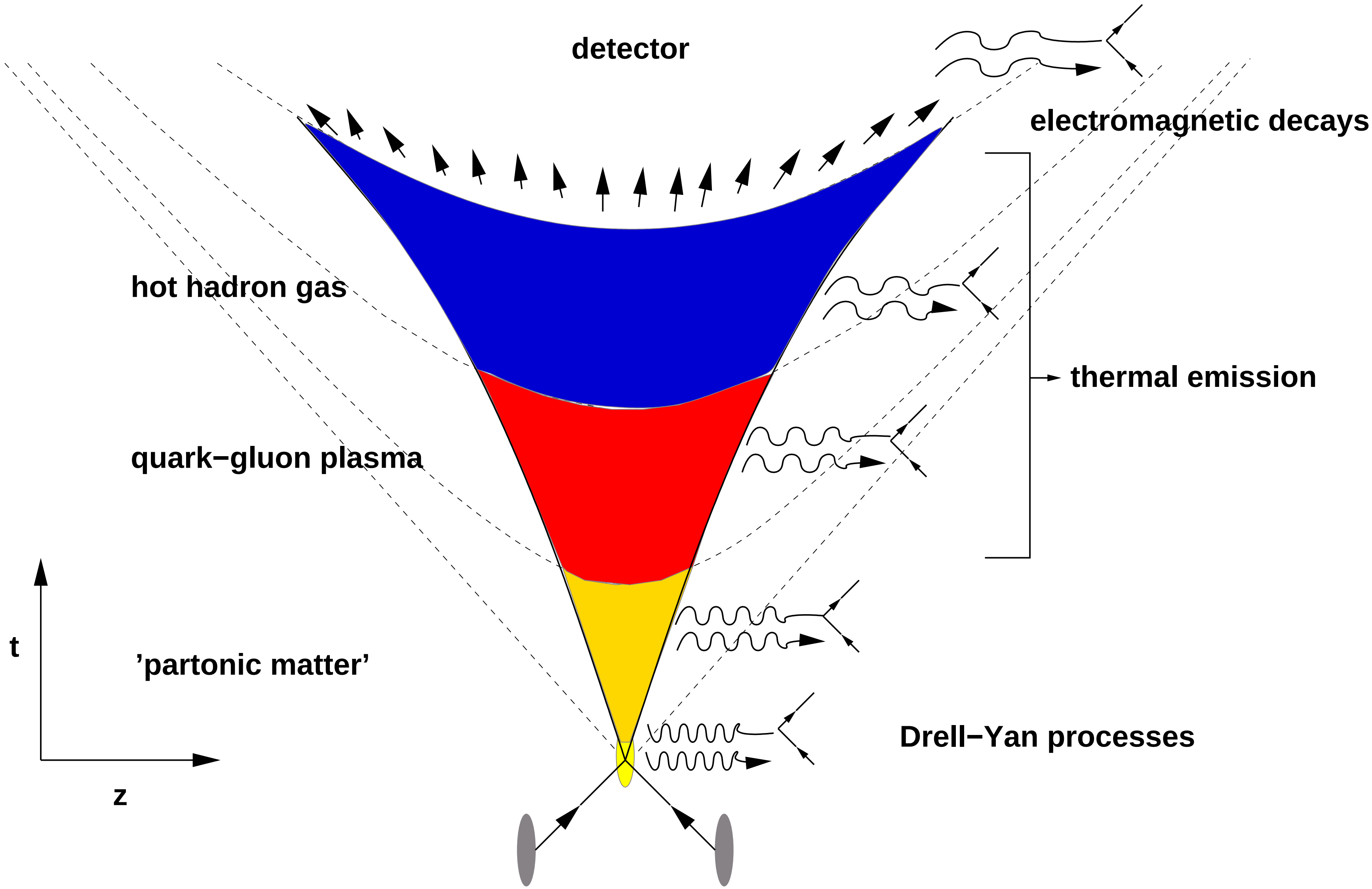


Same underlying physics? $\Rightarrow$ test thermalized scenario

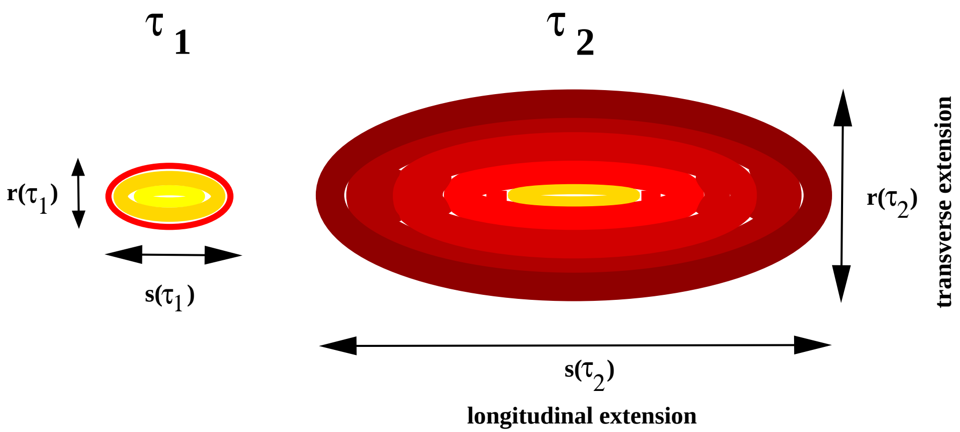
Properties of the QGP: Hadronic Observables



Properties of the QGP: Electromagnetic Observables



Essential scales



Do we know the relevant scales $R(\tau)$, $z(\tau)$, $v_\perp(\tau)$, $\eta(\tau)$ as functions of τ?

$\Rightarrow$ HBT correlations, m_t-spectra
$\Rightarrow$ Thermodynamics
$\Rightarrow$ Dilepton and photon emission
$\Rightarrow$ Jet and Charmonium suppression

Does it all fit together? $\Rightarrow$ Parametrize the scales!

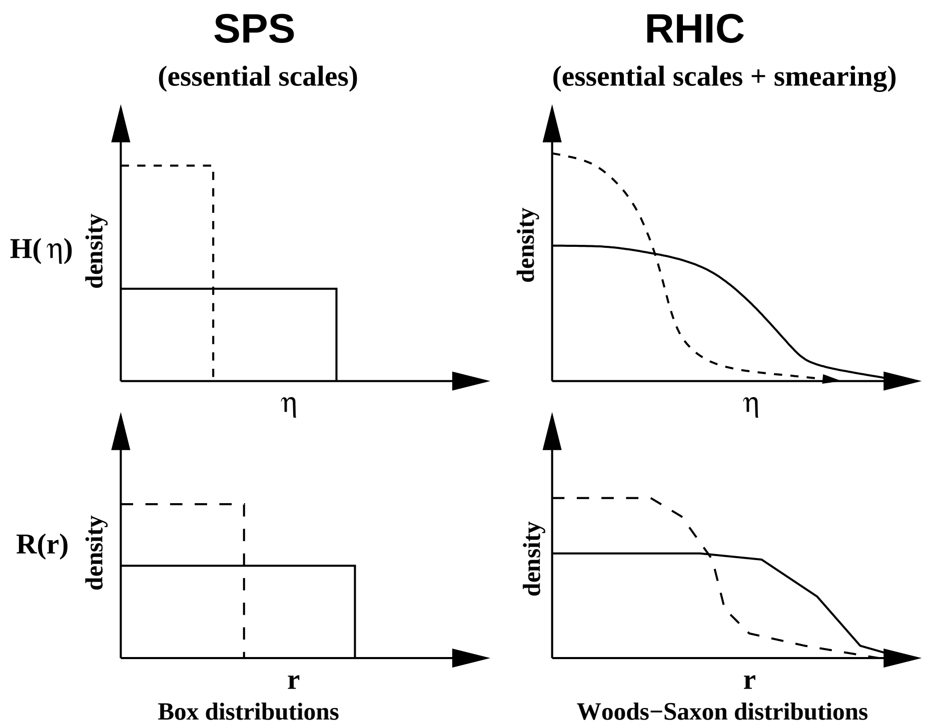
The model: Entropy density

Central collisions: radial symmetry

$$S = \int d^3x N R(r,\tau) H(\eta_s,\tau)$$

$R(r,\tau)$ and $H(\eta_s,\tau)$ encode scale expansion and smearing

$\eta_s \neq \eta$ for accelerated longitudinal expansion!



Complete evolution: Radius expansion and flow are correlated

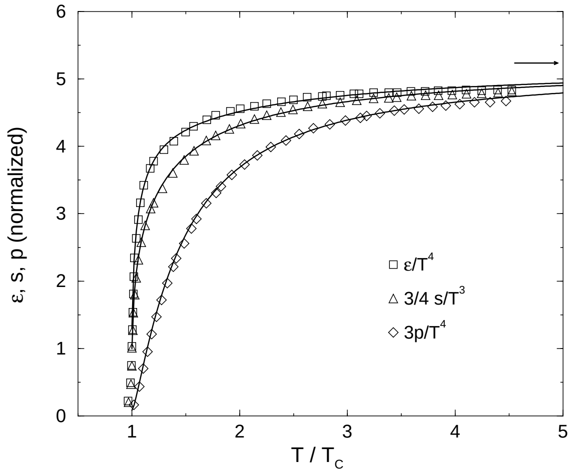
The model: Thermodynamics

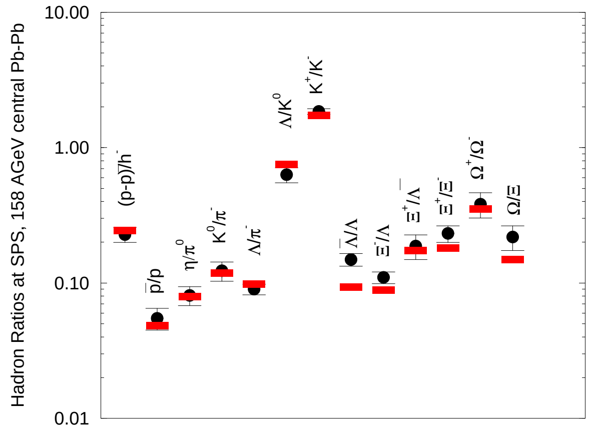
QGP phase:

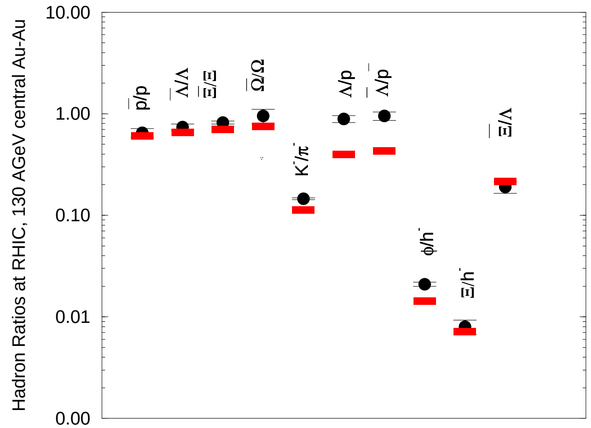
lattice QCD, physical quark masses via quasiparticle description

Hadronic phase:

statistical hadronization, account for resonance decay π's







$\Rightarrow$ Equation of State $s(\eta_s, r, \tau) \Rightarrow T(\eta_s, r, \tau)$

The model: Strategy

- Fit scale parameters to hadronic observables
- Test model using other observables

Hadron Emission: Cooper Frye

$$E\frac{d^3N}{d^3p} = \frac{g}{(2\pi)^3}\int d\sigma_\mu p^\mu \exp\left[\frac{p^\mu u_\mu - \mu_i}{T_f}\right] = d^4xS(x,p)$$

HBT

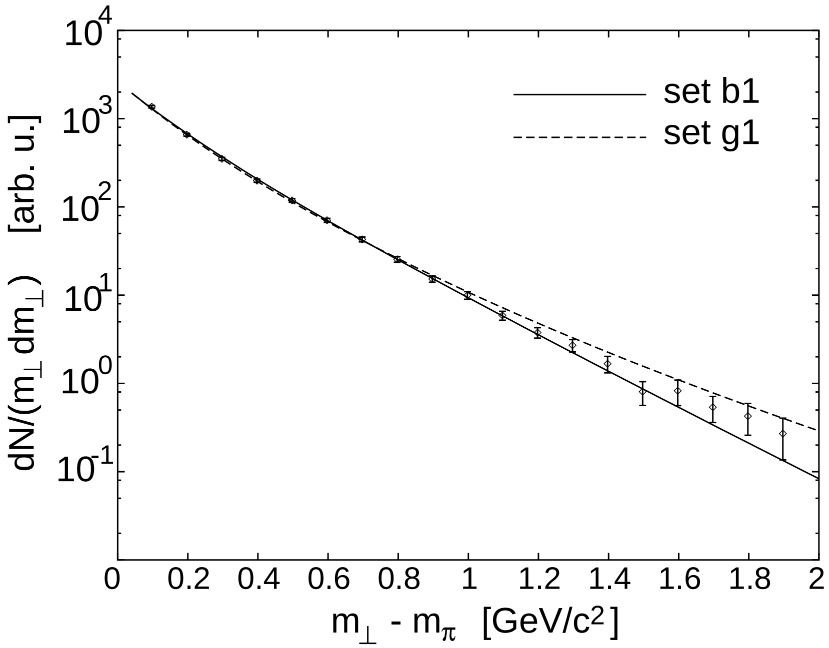
$$R^2_{\text{side}} = \langle \tilde{y}^2 \rangle \quad R^2_{\text{out}} = \langle (\tilde{x} - \beta_\perp \tilde{t})^2 \rangle \quad R_{\text{long}} = \langle \tilde{z}^2 \rangle$$

with $\tilde{x}_\mu = x_\mu - \langle x_\mu \rangle$ and

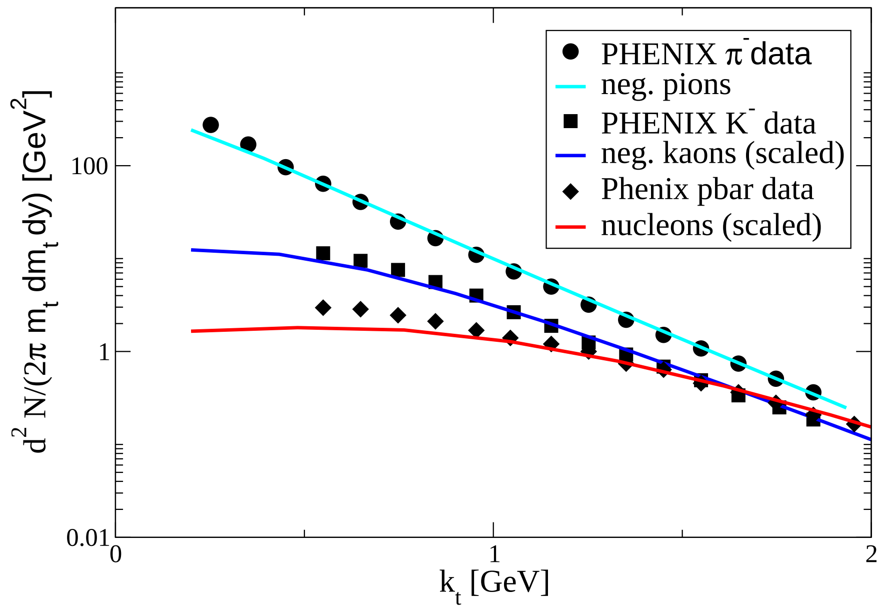
$$\langle f(x) \rangle (K) = \frac{\int d^4x f(x) S(x,K)}{\int d^4x S(x,K)}$$

m_t-SPECTRA

SPS



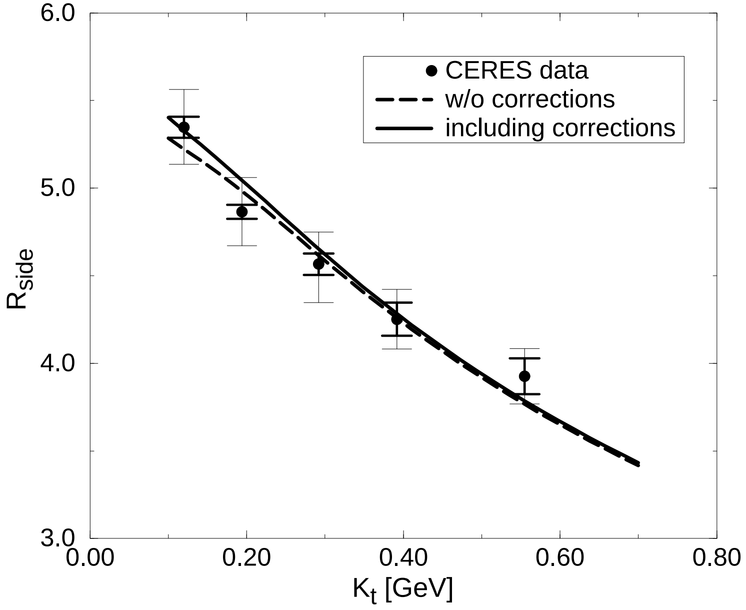
RHIC



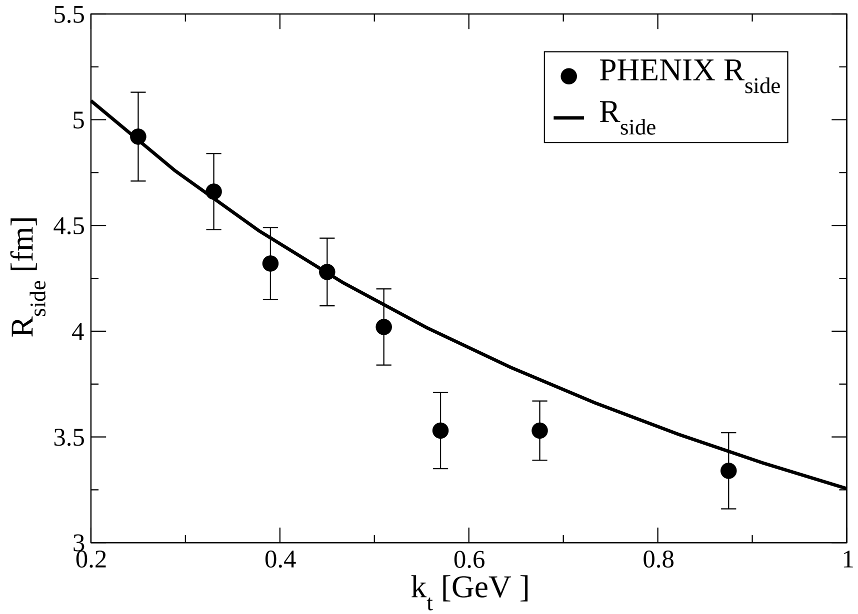
B. Tomasik, U. A. Wiedemann and U. W. Heinz, Acta Phys. Hung. New Ser. Heavy Ion Phys. **17** (2003) 105; T. Renk, hep-ph/0404140

HBT PARAMETERS — R_{side}

SPS



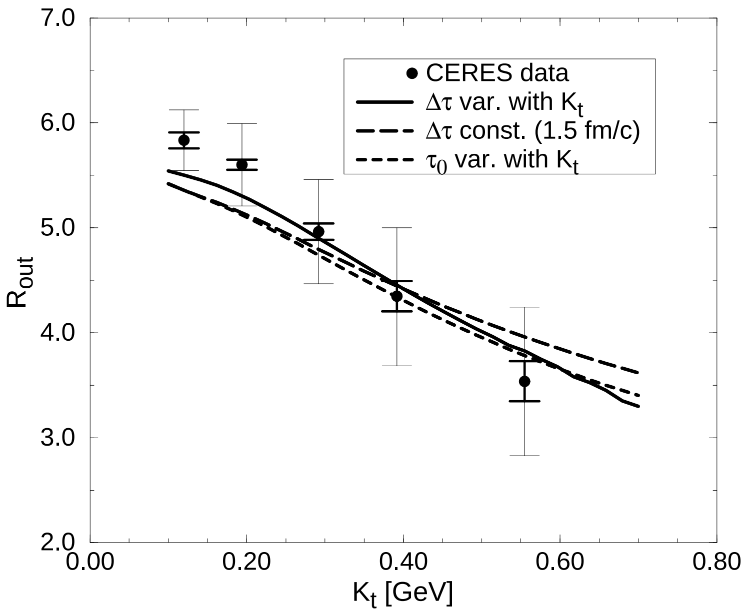
RHIC



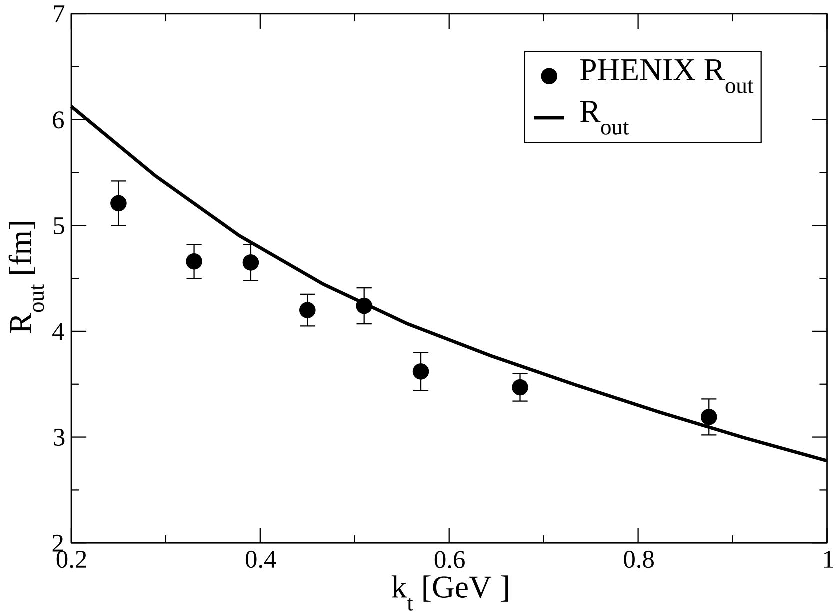
T. Renk, Phys. Rev. C **69**, 044902 (2004), hep-ph/0403239, hep-ph/0404140

HBT PARAMETERS — R_{out}

SPS



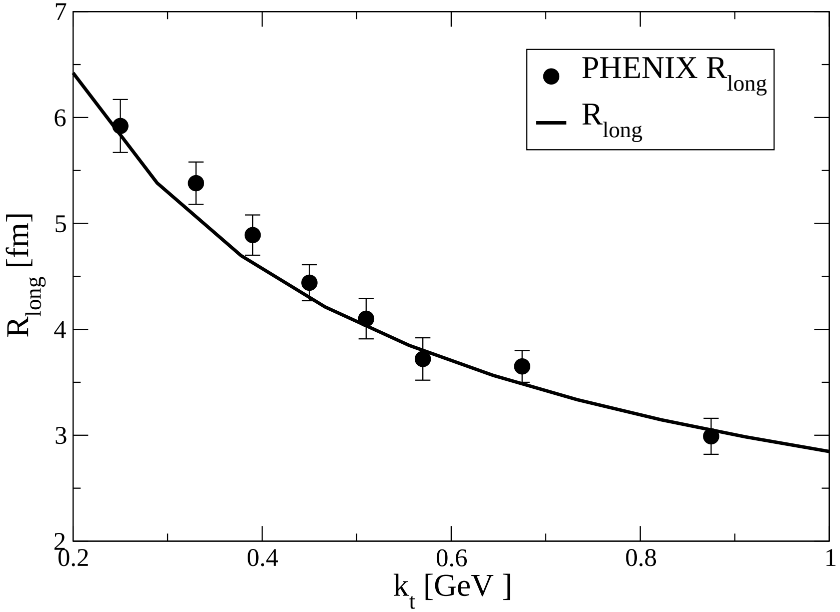
RHIC

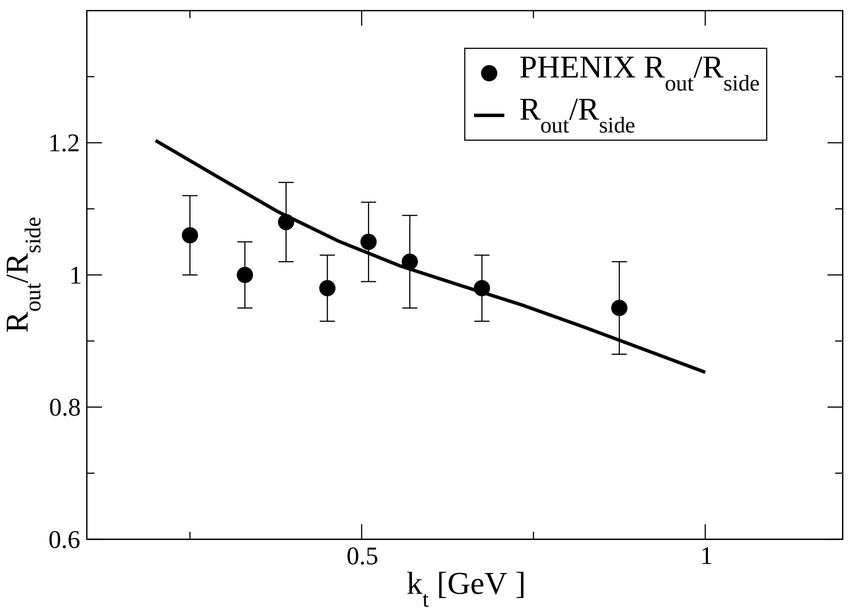


T. Renk, Phys. Rev. C **69**, 044902 (2004), hep-ph/0403239, hep-ph/0404140

HBT PARAMETERS — R_{long}, R_{out}/R_{side}

RHIC





T. Renk, hep-ph/0404140

The evolution

Initial long. compression and re-expansion is required for both SPS and RHIC

SPS	RHIC
Transverse flow:	
moderate, $v_\perp^f = 0.53c$	strong, $v_\perp^f = 0.65c$
Longitudinal dynamics:	
$\eta_0 = 0.55$, $\eta_f = 1.5$	$\eta_0 = 1.8$, $\eta_f = 3.6$
Initial temperature:	
$T_i = 300$ MeV (τ_0 =1 fm/c)	$T_i = 350$ MeV (τ_0 =0.6 fm/c)
Duration of QGP phase:	
≈ 7 fm/c	≈ 7.5 fm/c

Expressions and estimates based on boost-invariant expansions do not work

Electromagnetic Observables

Strategy

spectrum $=$ emission rate $\otimes$ fireball evolution $\otimes$ acceptance

Low mass (< 1.2 GeV) dileptons

in-medium vector meson masses
space-time volume of radiating matter

$\Rightarrow$ **hadronic matter**

Intermediate mass ($2 - 4$ GeV) photons

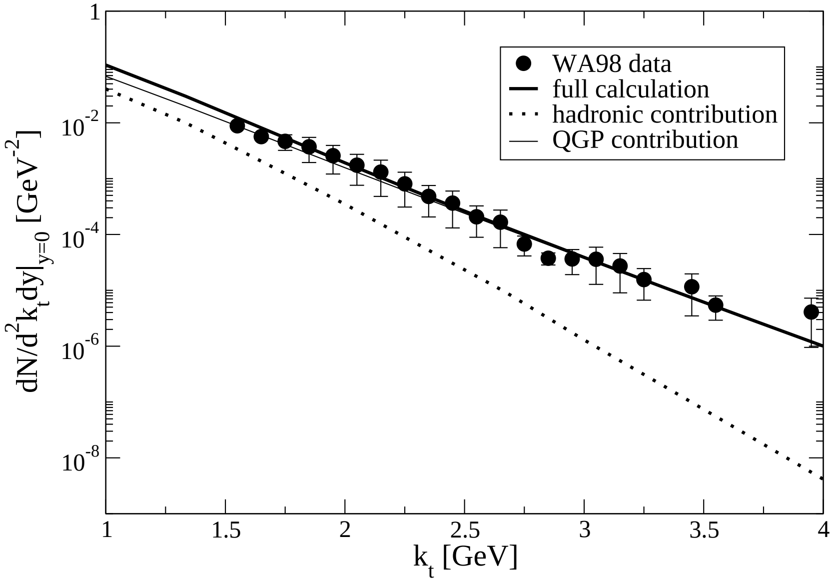
initial temperature
equilibration time

$\Rightarrow$ **partonic matter**

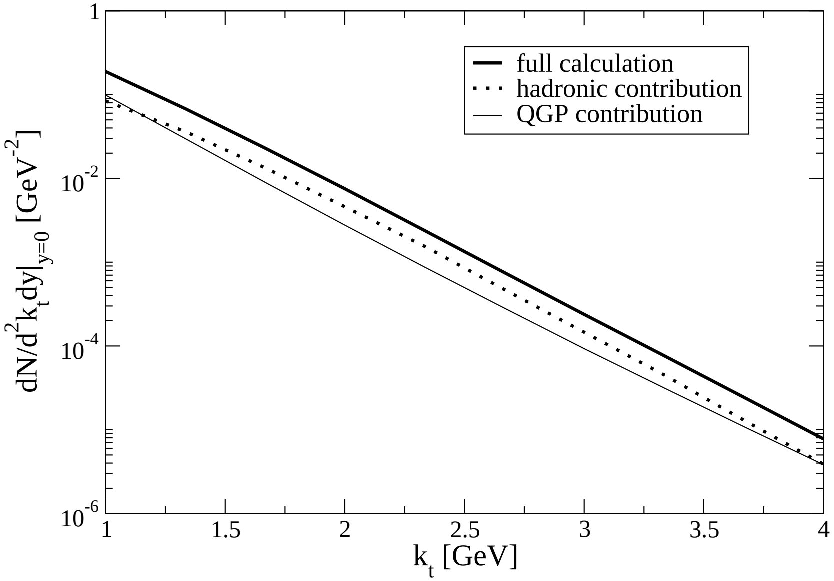
Selecting a momentum window selects a time interval

Photon Emission

SPS



RHIC



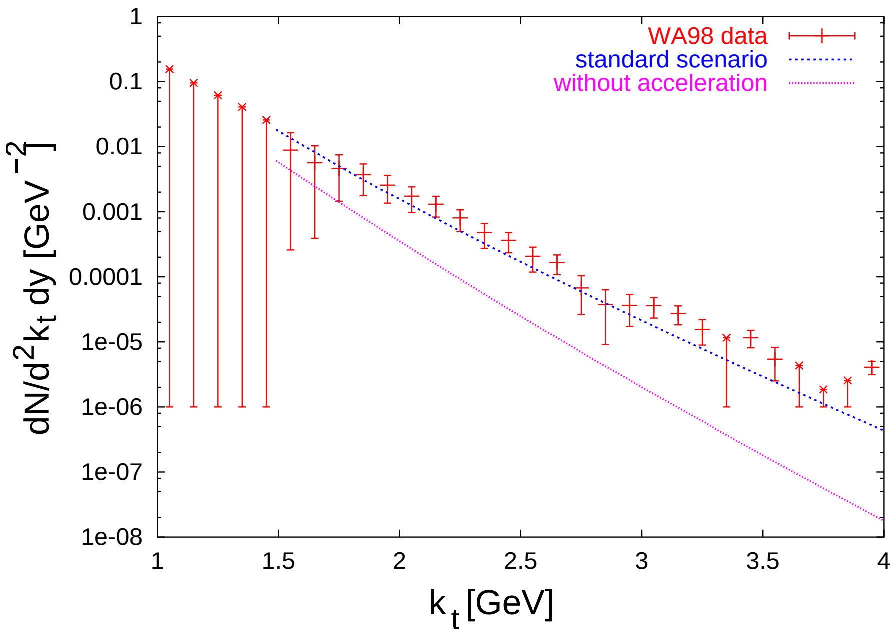
Long-lasting hadronic phase and strong flow at RHIC

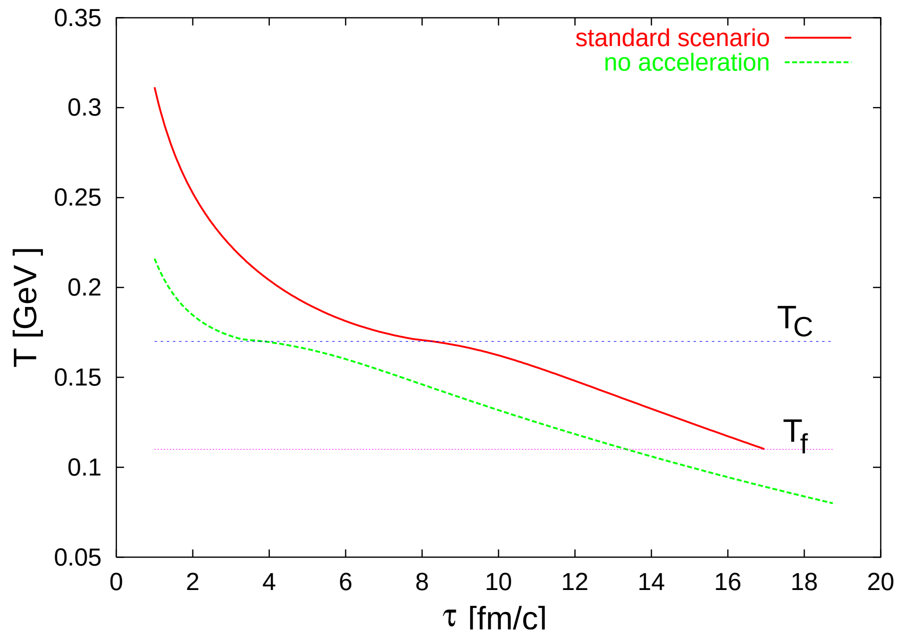
$\Rightarrow$ about equal QGP and hadronic gas contribution

T. Renk, Phys.Rev.C67:064901,2003

Boost-invariant free flow expansion?

Hadronic observables require initial long. compression





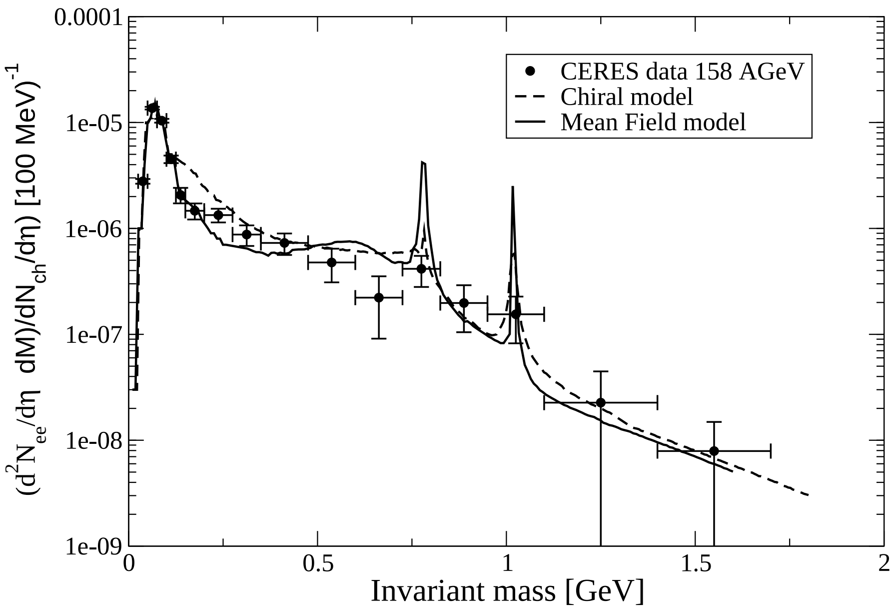
⇒ Photon emission confirms this

T. Renk, hep-ph/0403239

Dilepton Emission

SPS

RHIC



in progress

ρ mass-shift/collisional broadening, normalization correct

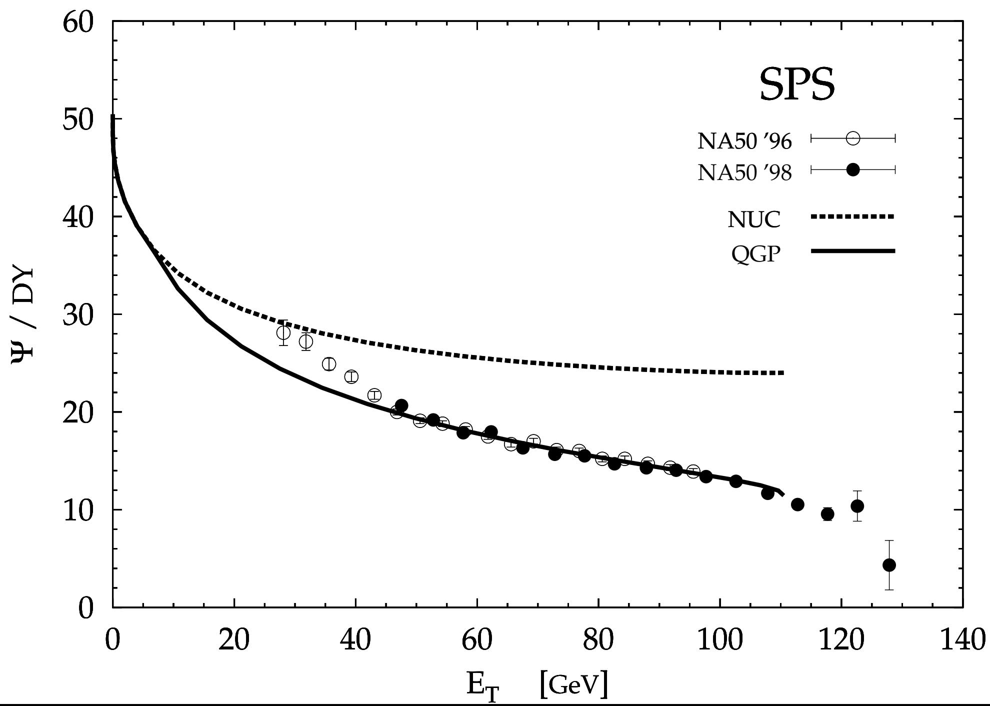
$\Rightarrow$ Hadron gas *not* weakly interacting, radiating 4-volume makes sense

T. Renk, hep-ph/0403239; T. Renk and A. Mishra, nucl-th/0312039

J/Ψ-Suppression at SPS

Rate equation for interaction with the medium (SPS: dissociation dominates):

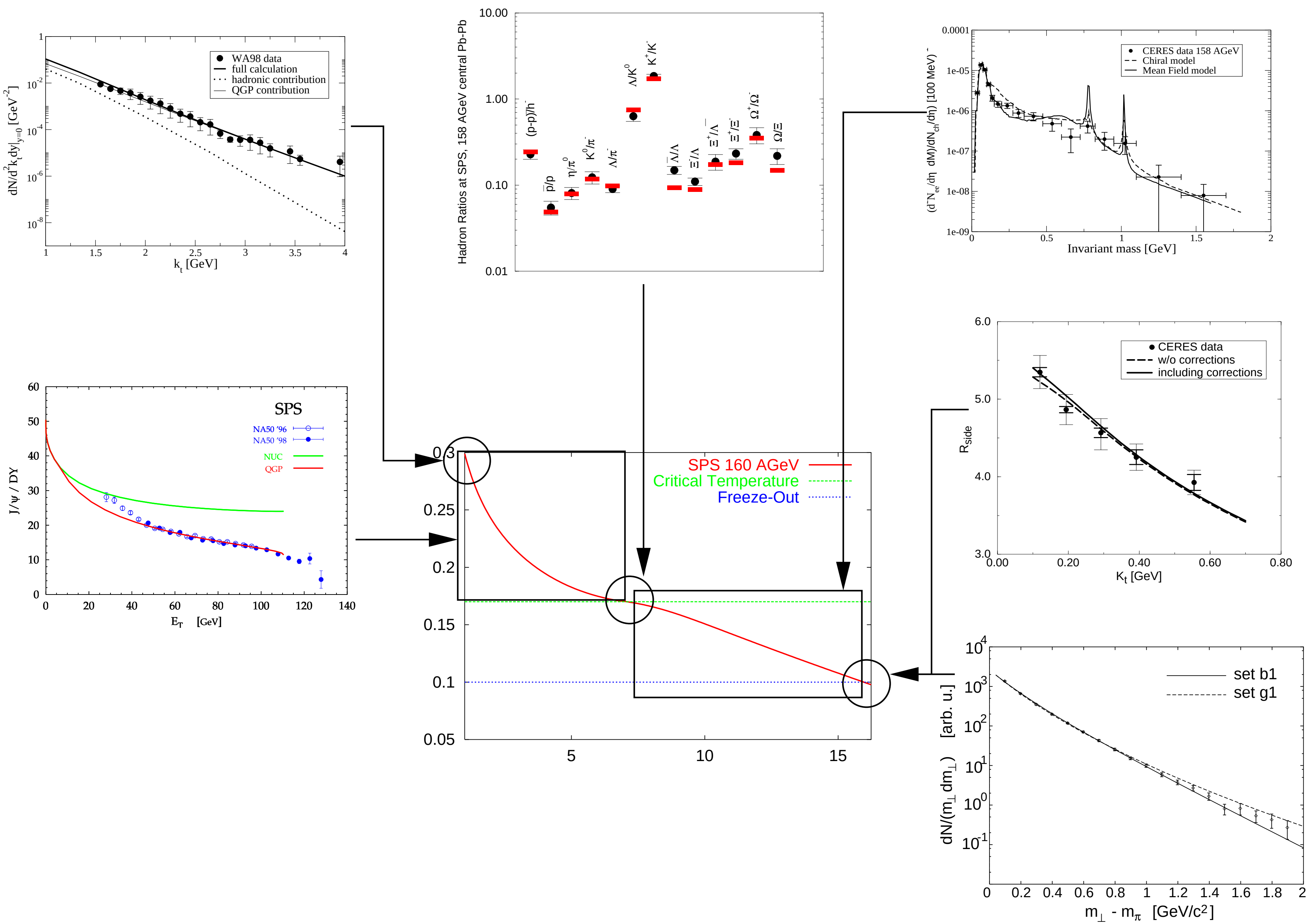
$$\frac{d}{d\tau}N^y_\Psi(\tau) = -\lambda_D(\tau)\,N^y_\Psi(\tau) + \lambda_F(\tau)\,, \quad \lambda_D(\tau) = \sum_n \langle\langle\,\sigma^n_D\,v_{rel}\,\rangle\rangle(\tau)\;\rho_n(\tau)$$



⇒ Reasonable matter density in the early evolution

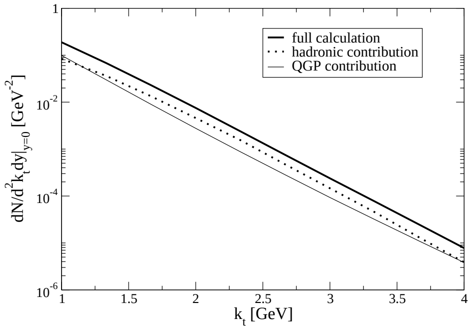
T. Renk, hep-ph/0403239; A. Polleri, T. Renk, R. Schneider and W. Weise, nucl-th/0306025

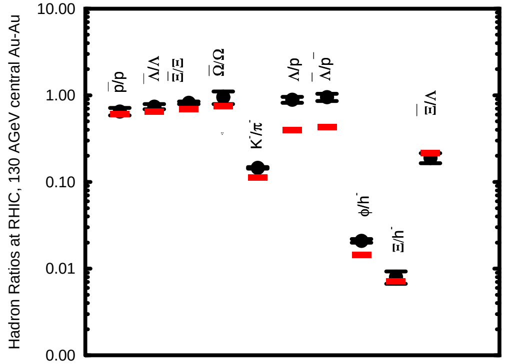
Summary — SPS



WA98 data
full calculation
hadronic contribution
QGP contribution
k_t [GeV]
Hadron Ratios at SPS, 158 AGeV central Pb-Pb
CERES data 158 AGeV
Chiral model
Mean Field model
Invariant mass [GeV]
SPS
NA50 '96
NA50 '98
NUC
QGP
J/ψ / DY
E_T [GeV]
SPS 160 AGeV
Critical Temperature
Freeze-Out
CERES data
w/o corrections
including corrections
R_side
K_t [GeV]
set b1
set g1
dN/(m_⊥ dm_⊥) [arb. u.]
m_⊥ - m_π [GeV/c²]

Summary — RHIC





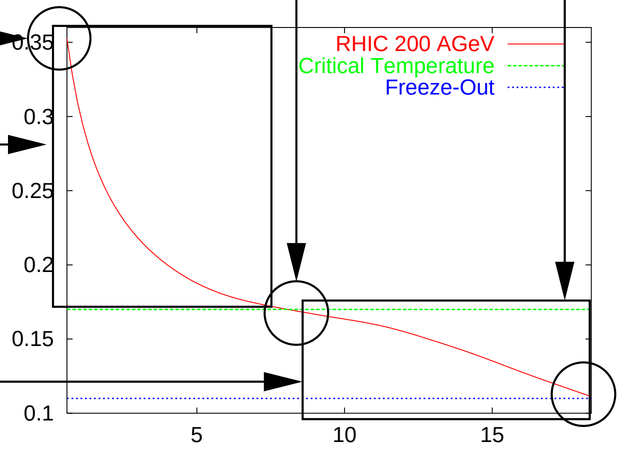
Low Mass

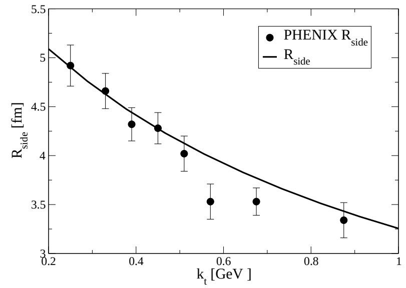
Dilepton Spectrum

? ?

Charmonium

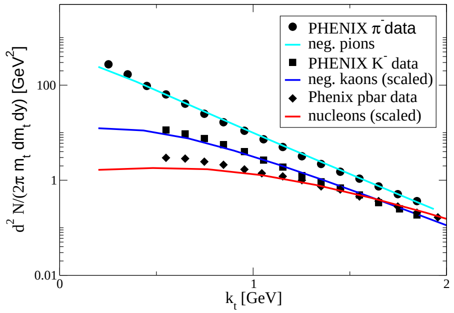
Suppression/Enhancement





Jet

Quenching



SUMMARY

SPS

Thermalized system: describes different observables in all expansion phases
⇒ highly consistent description, link between lattice and experiment

⇒ not proof, but: evidence for a QGP

RHIC

Simultaneous description of 1-particle spectra and 2-particle correlations

To come:

∗ photon HBT ∗ jet suppression ∗ dilepton emission ∗ charm suppression ∗ . . .

⇒ this should verify if this is the right scenario

Check also in microscopic calculations!