

Light vector mesons (\$) from dAu in PHENIX



Richard Seto University of California, Riverside for the PHENIX Collaboration Quark Matter 2004 January 13, 2004

- The QCD Lagrangian ~ chiral symmetry (Is it true?)
 - → all masses ~0
- Doesn't match the world we know
- What do we do?
 - Assume the vacuum is not empty it full of stuff (the "condensate")
 - The interaction with the vacuum gives rise to mass
 - Condensate is Temperature dependent
 - I.e. at high T all masses ~ 0
- Crazy!? Can we test this idea?
- Heat up the vacuum in RHIC collisions

 we boil it and see if masses change
 go to zero ultimately
- Chiral phase transition
- Any connection to deconfinement??



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Nothingness

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Looking for Chiral symmetry restoration ¹⁰ Vector Meson mass shifts in the dilepton channel

- "Light" Vector mesons (□, *, ×)-ideal probes
 - Like putting a scale to measure mass inside the fireball
 - Short lifetime ~ few fm/c
 - Decay inside hot fireball
- Electrons are ideal messengers
 - Don't interact strongly (e.g. solar v's)
- e.g. In Medium \square , , ϕ
 - shows low mass tail -
 - With its good mass resolution PHENIX should be able to see this

R. Rapp (Nucl. Phys A661(1999) 238c





: Au-Au - function of centrality

What do we look for?

Chiral symmetry restored

- High temperature vacuum Au-Au Central
- High baryon density
 - even normal nuclear density.
- Look for
 - Mass shifts/broadening
 - A nice trick:
 - Q value of $\phi \rightarrow KK$ is small

 $\frac{BR(\phi \to ee)}{BR(\phi \to KK)}$

 Should be sensitive to mass changes in either φ or K

Lissauer and Shuryak, Phys. Lett. **B253**, 15 (1991).



T.Hatsuda and S.Lee

QCD sum rules for vector mesons in the nuclear medium

(Phys.Rev.C46-R34-38, 1992)

Has anyone seen such effects?¹³ e⁺e⁻ invariant mass spectra

- CERES Pb-Au
 - High T vacuum



- KEK E325 proton Nucleus
 - "high" baryon density



K.Ozawa et al.

Observation of ρ/ϖ Meson Modification in Nuclear Matter (Phys.Rev.Lett 86-22)

Let's Look at RHIC (PHENIX) Outline

- Compare BR (normal nuclear density)
 - ∎ dAu φ→ee
- Mass shifts/broadening
 - - Guess: cannot see this to hadronic decays (only see stuff which decays outside fireball) - or the kaons which do decay and make it out rescatter

• Centrality dependence of ϕ/N_{part}

Note: I will not talk about ϕ R_{CP} - see talk by D. Kochetkov: Friday parallel session 2

$BR(\phi \rightarrow ee)$ $BR(\phi \rightarrow KK)$ at normal nuclear density in PHENIX @ RHIC

dAu Collisions: comparing the

PHENIX- designed for such measurements

- Superb (and redundant) electron PID
 - EMC(PBSc, PbGI)
 - RICH
- PID (for kaons)
 - Via TOF to 2GeV
 - Via EMC to 1 GeV
- Good momentum resolution
- High rate capability
- Triggering capability on electron at Level-1
 - EMC-RICH-Trigger (ERT)
 - Require energy in EMC+RICH firing in coincidence

Need everything working in concert to get a di-electron low mass vector Meson measurement!



Data sample, electron cuts

- Analyzed 31M of EMC-RICH-Trigger triggered Events.
 - Corresponds to 1.9G minimum bias
 - 50% of total data taken during run3
 - Threshold > 600 MeV
- Electron PID cuts
 - $N_{\text{RICH PMT}} \ge 2$
 - 0.5<E/p<1.5
 - E from EMC
 - P from tracking



Conversion cuts, mixed background



- Zero mass pairs→PhiV~0
- Reject conversion pairs if
 - If M_{ee}<100
 - If 100<M_{ee}<400 and phiV<100 mrad



ee Invariant Mass Spectra 200 GeV dAu- all $m_{\rm T}$

- N₀~120
- Fit is to relativistic B-W convoluted with Gaussian
 - M=1.0177 \pm 0.0023 GeV
 - Γ=0.00446 GeV(fixed)
 - σ_{exp} =0.0081 ± 0.0021 GeV
 - χ²/DOF=13.6/13
- Consistent with PDG



- Now
 - break into 3 m_T bins
 - count signal by summing mass bins ±3σ around mass peak
 - Do corrections and

Poster: Electro 4 Yuji Tsuchimoto



dN/dm_T and yield



dN/dy=.056±.015(stat) ±50%(syst) T=326 ±94(stat) ± 53%(syst) MeV (PHENIX preliminary)

- major contributions to the systematic error
 - normalization of the background and signal extraction and the way the variations affect T and hence dN/dy
 - run-by run variation from the Electron-RICH-Trigger

200 GeV dAu - K⁺K⁻ invariant mass

- PID in TOF only (smaller acceptance) Yield
 - Higher pt
- Nevt = 62 M
- Min. bias
- Fit to Relativistic BW convoluted with a Gaussian
 - N = 207 + 16
 - S/B ~ 5/1
 - m= $1.0193 \pm 0.0003 \ GeV/c^2$
 - Momentum scale error ~1%
 - Γ = 4.750 ± 0.67 MeV/c²
 - σ=1.2 MeV (fixed)
 - PDG M=1.01946 GeV/c² Γ = 4.26 MeV/c²



Poster: Spectra 9 Dipali Pal

<u>Minimum-bias m_T distribution of ϕ </u>



 $\phi \rightarrow KK min bias$

dN/dy = 0.0468 +/- 0.0092(stat) (+0.0095,-0.0092) (syst.)

T (MeV) = 414 +/- 31 (stat) +/- 23 (syst)

(PHENIX preliminary)

 M_T (GeV/c²)

<u>Minimum-bias m_T distribution of ϕ </u>



 $\phi \rightarrow KK min bias$

dN/dy = 0.0468 +/- 0.0092(stat) (+0.0095,-0.0092) (syst.)

T (MeV) = 414 +/- 31 (stat) +/- 23 (syst)

(PHENIX preliminary)

Overall fit dN/dy~ .0485 T~408 χ^2 /DOF=6.7/7

Compare ee with KK results

KK channel dN/dy = 0.0468 + - 0.0092(stat)(+0.0095,-0.0092) (syst.)

ee channel

 $dN/dy = .056 \pm .015(stat) \pm 50\%(syst)$



KK channel T (MeV) = 414 + - 31 (stat)+/- 23 (syst)

ee

ee channel

600

500

400

300

200

100



PHENIX preliminary Au-Au collisions: \$\operatornow to KK mass and width dependence on centrality

Au-Au ϕ to KK



 study the mass and width as a function of centrality

- Fit to Relativistic Breit Wigner convoluted with a Gaussian experimental resolution
 - σ =1.2 MeV from MC

Poster: Strange 14 Charles Maguire



more standard fare: Yields and slopes in dAu and AuAu

AuAu $\phi \rightarrow K^+K^-$

Yields and slopes:

Centrality dependence

Min bias dN/dy=1.34±0.09(stat) ±0.20(syst) T=366 ±11(stat) ±18(syst) MeV



N_{part} dependence of T



T indep of centrality

dN/dy per N_{part} (N_{part}~9)



dN/dy rises than seems to saturate

N_{part}

Add kaons

AuAu K – published (<u>nucl-ex/0307022</u>) Au-Au phi to KK– PHENIX FINAL dAu – PHENIX prelim



Conclusion

- Summary:
 - A first measurement has been made of the ϕ to ee channel in dAu collisions at 200 GeV. Within error bars it agrees with the KK result.
 - For overall shapes in Au-Au φ to KK, mass and width stay consistent with PDG as a function of centrality

Outlook to the future

Note: early in the story of Imvm ee physics at RHIC

- Near term : this data
 - Use rest of statistics (ert threshold>800 MeV, min bias)
 - Better control of systematics
 - Centrality, pt dependence (dAu-KK, ee?)
 - omega
- run 4
 - \$\overline\$ flow (poster Flow 7: Debsankar Mukhopadhyay)
 - ee in Au-Au 50x run-2
- The far future
 - Upgrades- the Hadron Blind Detector (Cerenkov)
 DHTC TT
 - RHIC II

Full data sample - the future

All-Arm 600+800MeV all

80 60 40 20 -20 -40 0.5 0.6 0.7 0.8 0.9 1 1.1 1.2 1.3 1.4 1.5 e⁺e⁻ invariant mass [GeV/c²]

Behavior of K,p,pi

- Pion yellow
- Proton green
- Kaon lightblue
- Phi-Black+red+blue

