LOW MASS VECTOR MESON MEASUREMENTS VIA DI-ELECTRONS AT RHIC BY THE PHENIX EXPERIMENT

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For the PHENIX collaboration.

10th November, 2008
1 Motivation

2 The PHENIX Detector

3 Results
   - $\phi$, $\omega$ in $p + p$ and $d + Au$
   - Nuclear modification factors in $d + Au$
   - Spectras

4 Summary
Motivation

Low mass vector mesons (\(\rho, \omega, \phi\)) are important to understand several aspects of HIC.

- Systematic measurements of different particles is needed to understand the medium properties:
  - by comparisons of \(p_T/m_T\) spectra of \(\phi\) and \(\omega\) in several decay modes.
  - Nuclear modification factors, \(R_{AA}\).
    - comparison of several mesons allows to disentangle if suppression is mass or quark number or flavor dependent.

- as probes to chiral symmetry restoration. This can be manifested as:
  - a modification of line shape parameters (mass or width) inside the nuclear medium.
  - a difference in the yields between the hadronic and leptonic decay channels. e.g. branching ratio of the \(\phi\) decay through \(e^+e^-\) and \(K^+K^-\) may be sensitive to mass modification. Since \(m_\phi \sim 2M_K\) \(\Rightarrow\), small changes in \(\phi\) or \(K\) can induce significant change in yields of the two decay modes.

Topics covered in this talk

- Spectra measurement of \(\phi \rightarrow e^+e^-/K^+K^-; \omega \rightarrow e^+e^-/\pi^+\pi^-\pi^0/\pi^0\gamma\).
- Comparison between different decay modes.
- Nuclear modification factors.

The results covered in this talk correspond to data \(\sqrt{s_{NN}} = 200\,\text{GeV}\).
OUTLINE

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The PHENIX Detector

PHENIX Central arms Acceptance: $-0.35 < \eta < 0.35$, $2 \times 90^\circ$ in $\varphi$

- Vertex: BBC
- Tracking: DC/PC1
- Trigger:
  - Min. bias: BBC
  - e: RICH, EmCal
- h ID: Time-of-flight
  - TOF $d\tau \sim 100$ ns
  - EmCal $d\tau \sim 500$ ns
- Aerogel $d\tau \sim 500$ ns
- e ID:
  - RICH ($e/\pi$ rejection $>1000$)
  - E-p matching EmCal ($e/\pi$ rejection $\sim 10$)

$\phi \rightarrow K^+ K^-$ (No Kaon ID): All charged tracks are assumed to be Kaons.
PHENIX Central arms Acceptance: $-0.35 < \eta < 0.35$, $2 \times 90^\circ$ in $\varphi$

- Vertex: **BBC**
- Tracking: **DC/PC1**
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$\phi \rightarrow K^+ K^-$ (One Kaon ID): One of the two tracks is identified as Kaon using the TOF.
**THE PHENIX DETECTOR**

**PHENIX Central arms Acceptance:** $-0.35 < \eta < 0.35$, $2 \times 90^\circ$ in $\varphi$

- **Vertex:** BBC
- **Tracking:** DC/PC1
- **Trigger:**
  - Min. bias: BBC
  - e: RICH, EmCal
- **h ID:** Time-of-flight
  - TOF $d\tau \sim 100$ ns
  - EmCal $d\tau \sim 500$ ns
  - Aerogel $d\tau \sim 500$ ns
- **e ID:**
  - RICH ($e/\pi$ rejection $>1000$)
  - E-p matching EmCal ($e/\pi$ rejection~10)

$\phi \rightarrow K^+K^-$ (Both Kaon ID): Both tracks are identified as Kaons in the TOF or EmCal (*For details, see poster by Yuri Ryabov*)

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**The PHENIX Detector**

**PHENIX Central arms Acceptance:** $-0.35 < \eta < 0.35$, $2 \times 90^\circ$ in $\phi$

- **Vertex:** BBC
- **Tracking:** DC/PC1
- **Trigger:**
  - Min. bias: BBC
  - $e$: RICH, EmCal
- **h ID:** Time-of-flight
  - TOF $d\tau \sim 100$ ns
  - EmCal $d\tau \sim 500$ ns
  - Aerogel $d\tau \sim 500$ ns
- **e ID:**
  - RICH ($e/\pi$ rejection $>1000$)
  - E-p matching EmCal ($e/\pi$ rejection $\sim 10$)

$\phi/\omega \rightarrow e^+e^-$
**THE PHENIX DETECTOR**

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- Vertex: **BBC**
- Tracking: **DC/PC1**
- Trigger:
  - **Min. bias:** BBC
  - **e:** RICH, EmCal
- **h ID:** Time-of-flight
  - **TOF** $d\tau \sim 100$ ns
  - **EmCal** $d\tau \sim 500$ ns
  - **Aerogel** $d\tau \sim 500$ ns
- **e ID:**
  - **RICH** ($e/\pi$ rejection $>1000$)
  - E-p matching **EmCal** ($e/\pi$ rejection $\sim 10$)

$\omega \rightarrow \pi^+\pi^-\pi^0, \pi^0\gamma$
$\phi -$ MASS SPECTRA EXAMPLES

$p + p$

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

$d + Au$

$Au + Au$

$\phi \rightarrow e^+ e^-$
\[ \omega \rightarrow \pi^+ \pi^- \pi^0 \]

\[ \omega \rightarrow \pi^+ \pi^- \pi^0 \]

\[ \omega \rightarrow \gamma \pi^0 \]

\[ \phi \rightarrow e^+ e^- \]

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The different analysis techniques used to measure $\phi \rightarrow K^+ K^-$ yield the same results in both systems. The measurements using $K^+ K^-$ cover a $p_T$ range up to 7 GeV/c in $p + p$ and 5 GeV/c in $d + Au$.

There is a reasonable agreement between the spectras for $e^+ e^-$ and $K^+ K^-$. 
ω- SPECTRA IN p + p AND d + Au

- ω has been measured using several decay channels in both p + p and d + Au (a $p_T$ coverage of 0-12 GeV/c in p + p and 0-9 GeV/c in d + Au).
- Good agreement among spectra from various decay channels.
Nuclear Modification Factors in $d + Au @ 200 GeV$

$\phi$


$\omega$


$\phi$ and $\omega$ are not suppressed in $d + Au$

Similar $R_{dA}$ of $\omega$, $\eta$ and $\pi_0 \sim 1$

Large error bars in $\phi$ for 0-20% leave some room for Cronin enhancement

$R_{AA} = \frac{dN_{dA}}{dp_T} / \frac{dN_{p+p}}{dp_T}$

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**Nuclear Modification Factors in \( d + Au \) @ 200 GeV**

- **\( \phi \) and \( \omega \) are not suppressed in \( d + Au \)**
- **Similar \( R_{dA} \) of \( \omega, \eta \) and \( \pi^0 \sim 1 \)**
- **Large error bars in \( \phi \) for 0-20\% leave some room for Cronin enhancement**
Two independent analyses in $\phi \rightarrow K^+ K^-$ yield same results.

With no Kaon ID method, $Au + Au$ has been measured up to $p_T$ of 7 GeV/c.
The spectra and yields for $e^+e^-$ and $K^+K^-$ can undergo modification inside hot and dense matter formed. The present results for $e^+e^-$ in $\text{Au} + \text{Au}$ suffer from large uncertainties because of the small S/B ratio and hence do not allow to make a definitive statement. The results are expected to improve significantly in the future with the newly built Hadron Blind Detector in PHENIX.
The spectra and yields for $e^+e^-$ and $K^+K^-$ can undergo modification inside hot and dense matter formed. The present results for $e^+e^-$ in $Au + Au$ suffer from large uncertainties because of the small S/B ratio and hence do not allow to make a definitive statement.

The results are expected to improve significantly in the future with the newly built Hadron Blind Detector in PHENIX.
$\omega \rightarrow \pi^0 \gamma, e^+ e^- \text{ IN } Au + Au \ 200 \text{ GeV}$
The solid curve represents a fit to $p + p$ data and the dashed curves are obtained from $p + p$ fits scaled by the corresponding number of binary collisions.
Nuclear Modification Factor $R_{AA}$ in Au + Au 200 GeV

In Central Collisions

arXiv:0809.3557 [nucl-ex]
So far we believe that Hadron suppression patterns do not depend on the mass of the particles, but are sensitive to the number of valence quarks.
\[ R_{AA} \]

**PHENIX Preliminary**

\[ \text{Au+Au, } \sqrt{s_{NN}} = 200 \text{ GeV} \]

- direct \( \gamma \) 0-10%
- \( \eta \) 0-10%
- \( \pi^0 \) 0-10% (arXiv:0801.4020)
- \( (p+\bar{p})/2 \) 0-10%
- \( \phi \) 0-10%
- \( (K^++K^-)/2 \) 0-10%
- \( \omega \) 0-20%

**\( \phi \) meson does not fit into this picture…**

At intermediate \( p_T \): It is more suppressed than protons but less than \( \pi^0 \) and \( \eta \).

At high \( p_T \): the \( \phi \)-suppression level is similar to that of \( \pi^0 \) and \( \eta \).

Does suppression depend on quark flavor composition?

The \( \omega \) points are not conclusive.

*More details in the talk by V.Ryabov*
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PHENIX has measured $\phi$-meson in $p + p$, $d + Au$ and $Au + Au$ collisions @ $\sqrt{s_{NN}} = 200$GeV by $K^+K^-$ and $e^+e^-$ decay modes.

The measurements using $K^+K^-$ decay channels are complete in all systems. Different analysis techniques, yield same results in all the systems. Measurements cover wide $p_T$ coverage.

The leptonic channel measurements suffer from the combinatorial background and statistics in $Au + Au$ and $d + Au$. The preliminary results from $p + p$ are shown.

In $d + Au$, no suppression is seen for both $\phi$ and $\omega$, but large error bars in case of $\phi$ make room for Cronin enhancement.

The $R_{AA}$ of $\omega$ is inconclusive due to large error bars.

The $R_{AA}$ of $\phi$-meson in $Au + Au$ shows similar suppression pattern to that of $\pi^0$ and $\eta$ at high $p_T$, but at intermediate $p_T$, the suppression pattern is different.

This is not understood, but could be a hint to quark flavour dependence.
OUTLOOK TO THE FUTURE

$p + p$
Final results of $\phi$ and $\omega$ measurements via $e^+e^-$ in $p + p$ decay channel will be available soon.

$d + Au$
The high statistics run8 $d + Au$ data is available now for analysis and we hope to get better results in $e^+e^-$ channel soon, with this new data set.

$Au + Au$
The current measurements in $Au + Au$ suffer due to small S/B ratio. The newly installed Hadron Blind Detector will improve the quality of measurements by at least one order of magnitude in the near future. *for details refer to talk by Z.Citron.*
COMPARISON WITH STAR

PHENIX Preliminary
φ - meson at $\sqrt{s_{NN}}=200$GeV

$(1/2\pi m_{\phi}) \frac{d^2N}{dmd_{T}} ((\text{GeV}/c^2)^2)$

$d+Au$
0-20%

$d+Au$
MinBias

$p+p$

no PID
one leg PID
two legs PID (run3)
$e^+e^-$
STAR

Au+Au
0-10%

MinBias
60-92%

$p+p$

no PID
one leg PID
two legs PID
STAR
The measurements in $e^+e^-$ channel suffer due to huge combinatorial background, arising mostly due to uncorrelated pairs from $\gamma$- conversions and $\pi^0$ Dalitz decays.

- HBD identifies and vetoes $e^+e^-$ from these sources via opening angle.

**HBD concept**
- Windowless Cherenkov: Radiator Gas = Avalanche Gas, $CF_4$ ($n \approx 1.000620$), radiator length = 50 cm.
- Cherenkov light collected as blobs on an image plane.
- triple GEM stack.
- $\sim 300$ nm CsI photocathode on top GEM that used for electron amplification.
- To preserve the pair opening angle, the magnetic field is turned off (compensated) in the detector.