Resonance production with a quark coalescence type model

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Outlook

- Experimental data on resonances
- Quark coalescence models
- How to include resonances?
- Invariant mass spectrum
- Parity questions
- Results
- Expected yields
- Summary
Resonance measurements

- NA49
  - data on $K^*(892), \Lambda(1520), \phi(1020)$
  - resonance yields differ from thermal model predictions
    (difference increases with increasing widths)
  - P. Seyboth QM08, Monday

- RHIC
  - data on $\rho(770), K^*(892), \phi(1020), \Sigma^*(1385), \Xi^*(1530), \Lambda(1520), \ldots$
Hadronization – Quark coalescence

- Fast hadronization process
- $v_2$ scaling $\sim$ valence quark scaling $\sim$ quark coalescence
- ALCOR (Bíró, Lévai, Zimányi 1995)
  - describes hadron yields at SPS and RHIC
- MICOR (Csizmadia, Lévai 1999)
  - describes $p_T$ spectra for hadrons
- Recombination models
  - Hwa, Yang; Greco, Ko, Lévai; Fries, Müller, Bass ...
MICOR

• Microscopic rehadronization
• Quantum mechanics based:
  \[ g_{gh} = V_g \frac{-M_{h,Q'}}{2\pi} \int d^3\vec{x}_1 d^3\vec{x}_2 \cdot \bar{\Psi}^*(\vec{x}_1, \vec{x}_2) V(\vec{x}_1 - \vec{x}_2) \phi_1(\vec{x}_1) \phi_2(\vec{x}_2) \]

• Prehadron production rate:
  \[ \langle \sigma^{h} \nu \rangle = \frac{\int d^3\vec{p}_1 d^3\vec{p}_2 \cdot f_q(m_1, \vec{p}_1) f_q(m_2, \vec{p}_2)(\sigma(k)\nu_{12})}{\int d^3\vec{p}_1 d^3\vec{p}_2 \cdot f_q(m_1, \vec{p}_1) f_q(m_2, \vec{p}_2)} \]

• Need quasi-particle momentum distribution!
• Prehadron --> Hadron
• Makes only the meson octet and the baryon decuplet
• Protons, pions, ... came from the decays
Could we add resonances to MICOR?

• Resonance <---> higher mass

• MICOR hadron mass:
  \[ M_h = m_{q_1} + m_{q_2} \]

• Production rate will increase with the mass
  \[ M_h \sim g_{gh} \Rightarrow <\sigma v> \sim |g_{gh}|^2 \sim M_h^2 \]

• Production rate will increase with the mass
  \[ \Rightarrow \text{too sensitive to high energy resonances} \]
  (proper decays, mass, width; still unknown reson.)

• Solution: use the real relativistic kinematics!
  Thus we can obtain higher invariant masses
Invariant mass

- Massive quasi-particle collision: \( M_{qq} = \| p_1^\mu + p_2^\mu \| \)
- Need initial quark momentum distribution (Jüttner d.)
Binded (qq) momentum distributions
Binded (qq) momentum distributions
Binded (qq) momentum distributions
qs resonance masses
qs resonance mass spectrum (lin scale)

mass of (qs) resonances with their widths

probability

mass [MeV]

0 500 1000 1500 2000 2500 3000
qq resonance mass spectrum (lin scale)
qq resonance mass spectrum (log scale)
Selecting the proper resonances

- $q+q \rightarrow (qq)$ with: mass = invariant mass
- Which resonance could appear from a (qq) state?
  - Resonance width characterizes the decay
  - Use the same width for production channels
- Define the appearance of a resonance at mass $= m$
- Probability to produce hadron resonance “$H$” from (qq) invariant mass $m_{qq}$:

$$P(H|m_{qq}) = \frac{\exp\left(\frac{(m_H - m_{qq})^2}{2 s_H^2}\right)}{\sum_h \exp\left(\frac{(m_h - m_{qq})^2}{2 s_h^2}\right)}$$
Resonance appearance
Parity

- Experimental data: $f_0/\rho$ suppression
  - how to handle this?
    - Quantum mechanics: Zimányi '04, Müller '06
    - Should we consider +1 and -1 parity resonance cocktails with a parity suppression factor?
    - Imbalance in the decay chains
    - Quasi-quark mass has big influence on primer $f_0$ yield
Baryons and Strangeness production

- Baryons are made of a diquark and a quark
  - $qqq$ invariant mass spectrum is similar to $qq$
  - Baryon resonances, width, appearance, ...
- Insert strange quark into the system: mass: $m_s$
  - New mesons: $qs$, $ss$
  - New baryons: $qqs$, $qss$, $sss$
Mesonic invariant mass probabilities
Mesonic invariant mass probabilities
Baryonic invariant mass probability

![Graph showing the probability distribution of baryonic invariant mass in MeV. The x-axis represents the (qq) invariant mass in MeV, and the y-axis represents the probability per MeV. The graph shows a peak around 1500 MeV with a tail extending to higher masses.]
Predictions at RHIC

• Parity check
  - $\phi(1020) \leftrightarrow \phi(1680)$,
    without parity suppression $\phi(1680) / \phi(1020) = 0.22$
  - $\Sigma(1385) \leftrightarrow \Lambda(1520)$
    without parity suppression $\Lambda(1520)/ \Sigma(1385) = 0.91$

• Expected yields for resonances with small width
  - $\rho_3(1690) / \phi(1020) = 0.10$
  - $\Sigma(1660) / \Sigma(1385) = 0.55$
Conclusion

- Coalescence models can be extended for resonance productions
- Relativistic kinematics $\leftrightarrow$ prehadron mass spectrum
- Successful application for mesonic and baryonic resonances
- Predictions for measurable hadron resonance ratios