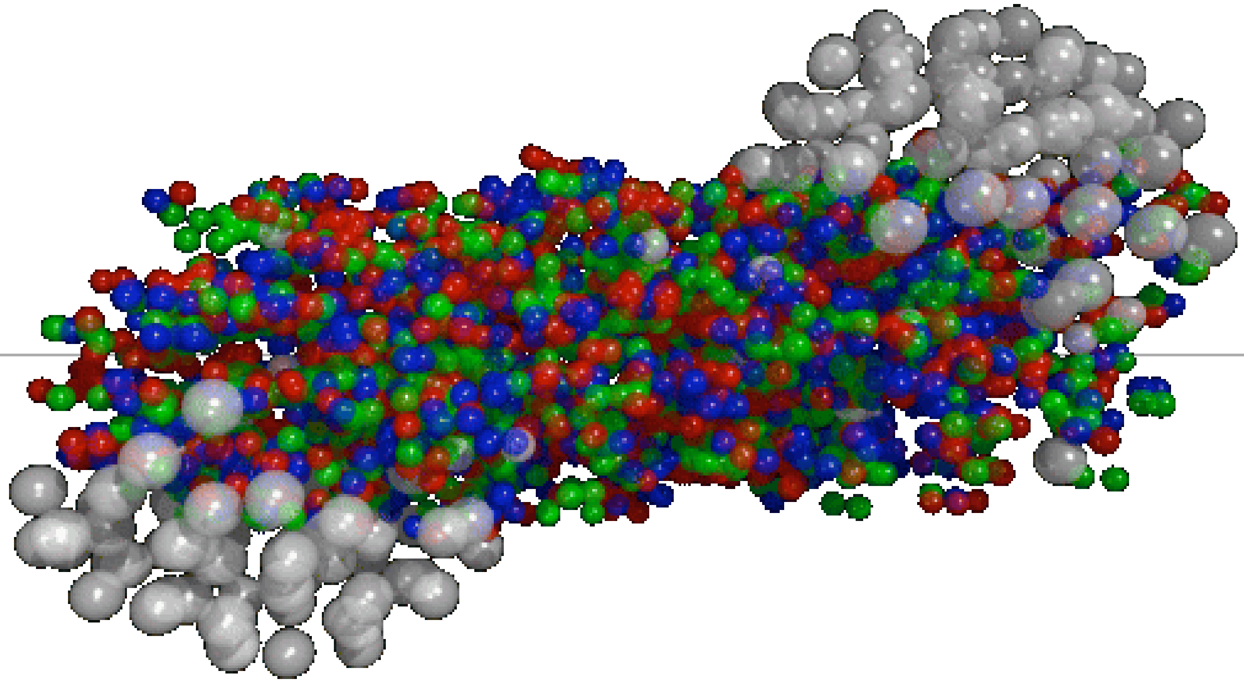
How robust are signals for chiral symmetry restoration?



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(in collaboration with Katharina Schmidt, Diana Schumacher and Marcus Bleicher)

TBS2007, 05/21/07, Berkeley

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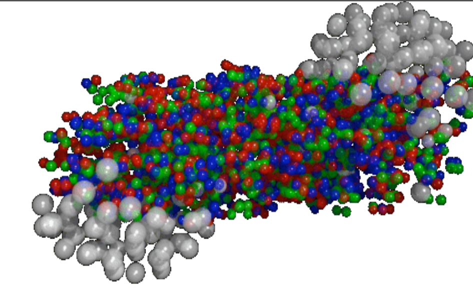
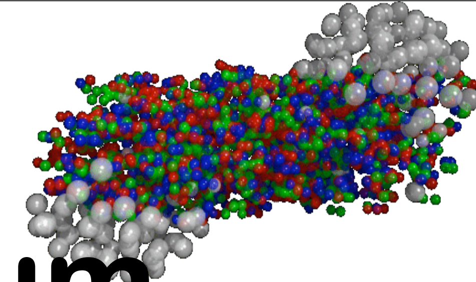
H-QM Helmholtz Research School
Quark Matter Studies



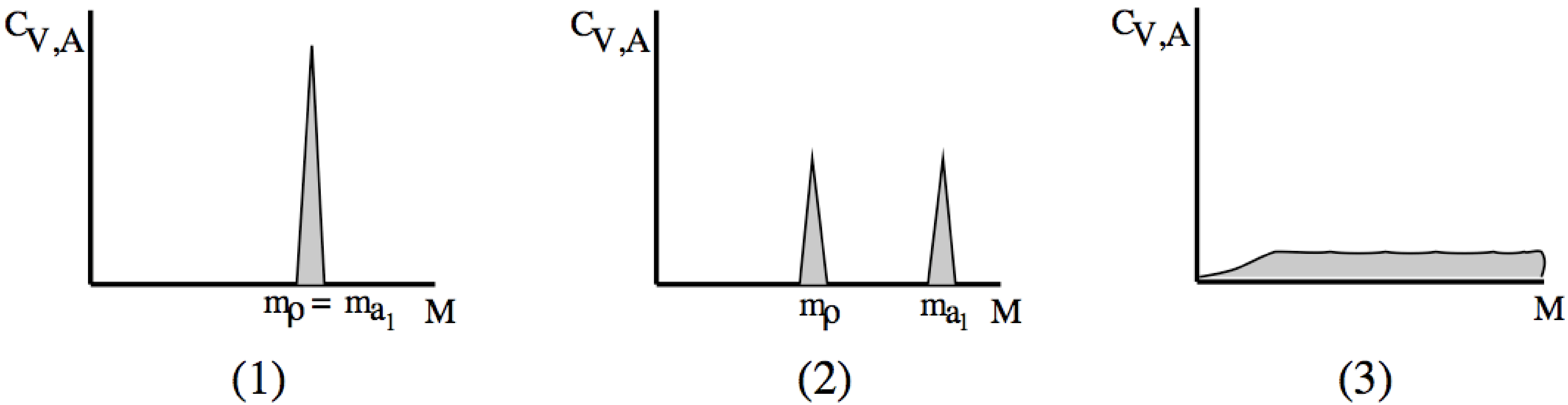
Outline

- (Short) Motivation
- Signals for chiral symmetry restoration and their analysis in UrQMD
    - Dilepton spectra
    - ρ meson
    - a_1 meson
- Summary

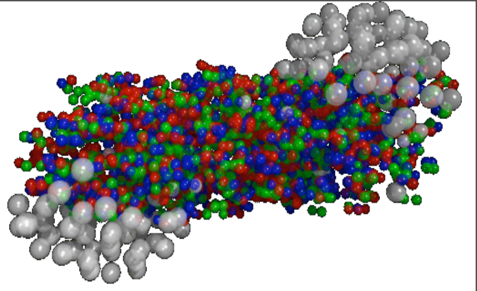


Chiral Symmetry and the medium

- **What happens within the medium? Can we observe a chirally restored phase? (and how?)**
- **What happens to the ρ meson in the medium? What happens to the a_1 meson?**
- **What can we learn from a reasonable hadronic dynamics (without a chirally restored phase)?**



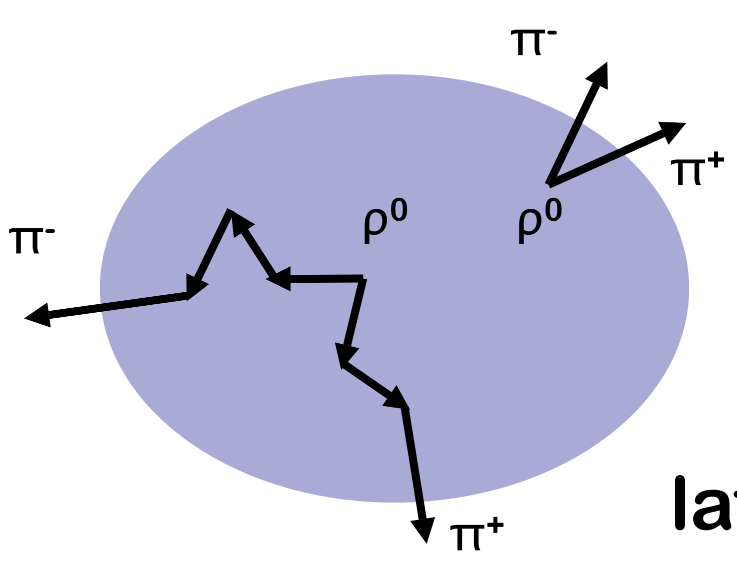
V. Koch, Int.J.Mod.Phys.E6:203-250,1997



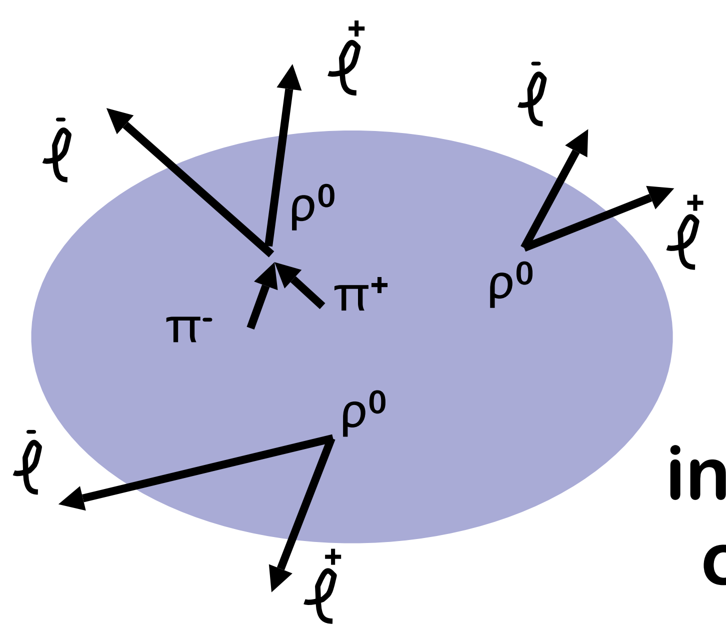
Why looking at dileptons?

Dileptons...

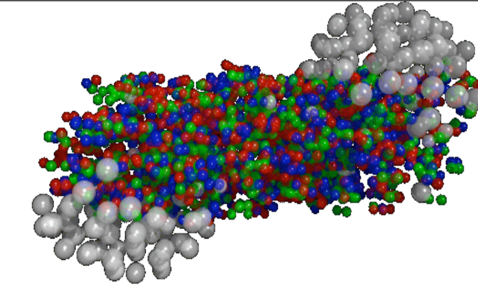
- do not interact strongly with the surrounding medium
- are expected to be the ideal probe for the early stage of a heavy ion collision
- originate from various sources
- Typical branching ratios on the order of 10^{-4} - 10^{-5}



late stage

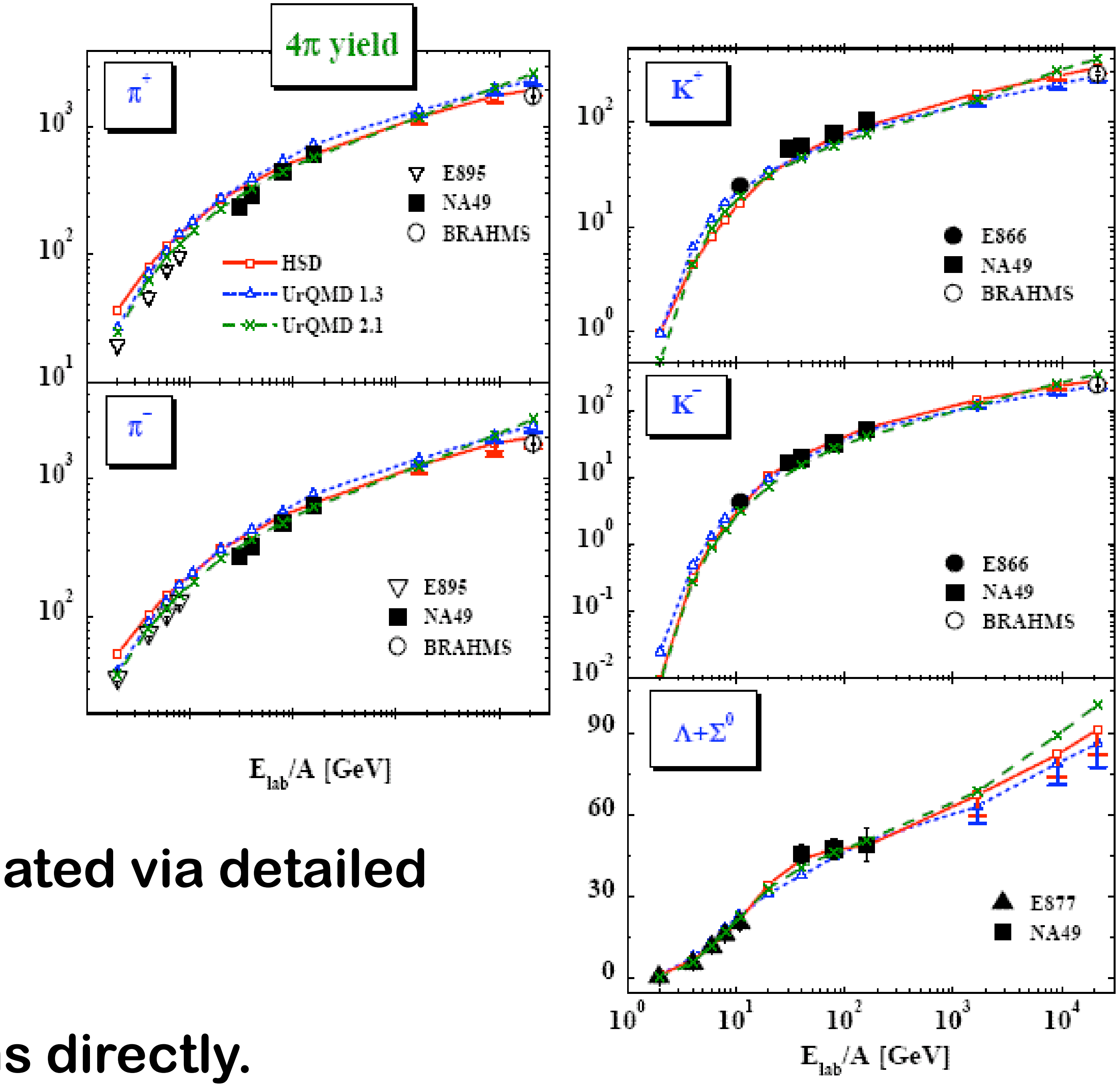


integrated collision



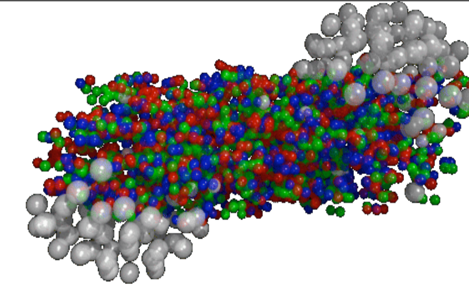
UrQMD

- Ultra Relativistic Quantum Molecular Dynamics.
- Non equilibrium transport model.
- All hadrons and resonances up to 2.2 GeV included.
- Particle production via string excitation and -fragmentation.
- Cross sections are fitted to available experimental data or calculated via detailed balance or the additive quark model.
- Does not handle decays into dileptons directly.



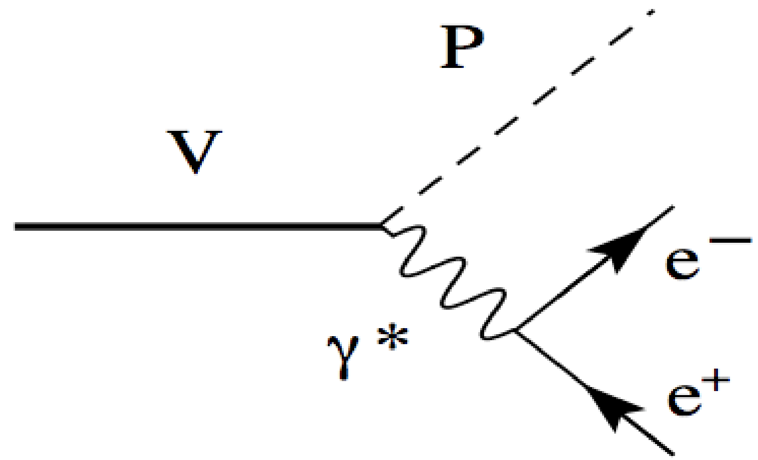
No explicit implementation of in-medium modifications!

Bratkovskaya, Bleicher et al., Phys.Rev.C69:054907,2004

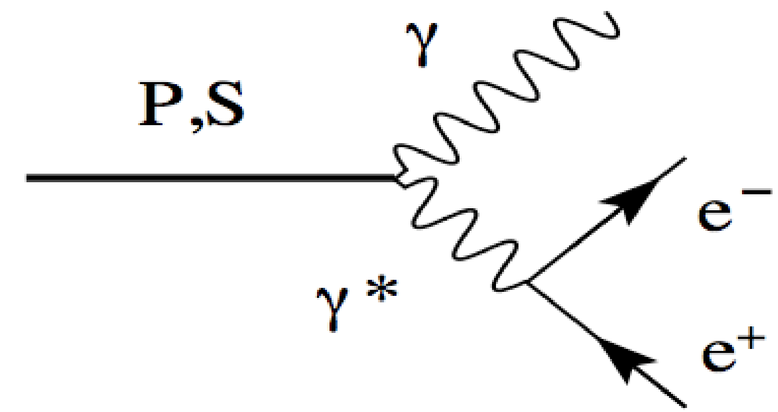


Dilepton sources

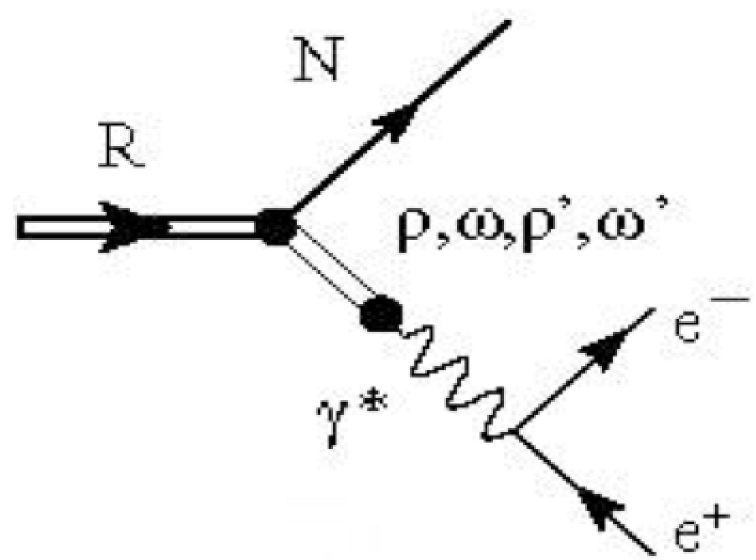
- **Dalitz decays**
  - **π^0, η, η', ω, Δ**
- **Direct decays**
  - **ρ, ω, ϕ**



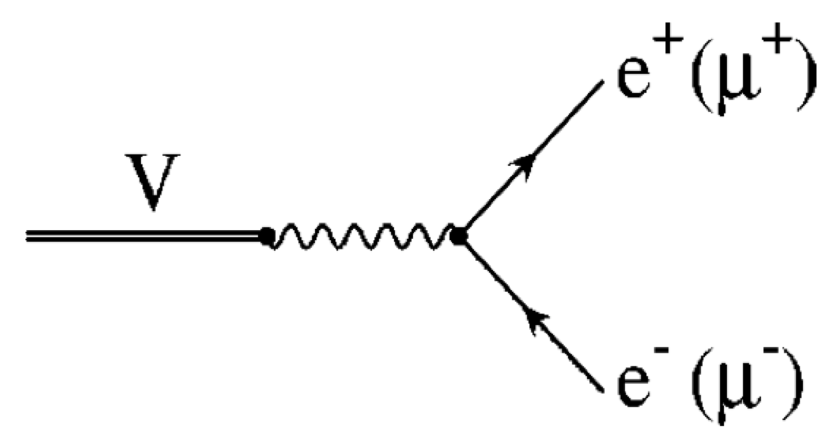
Dalitz decay (vector meson)



(pseudoscalar meson)



Dalitz decay (Δ)

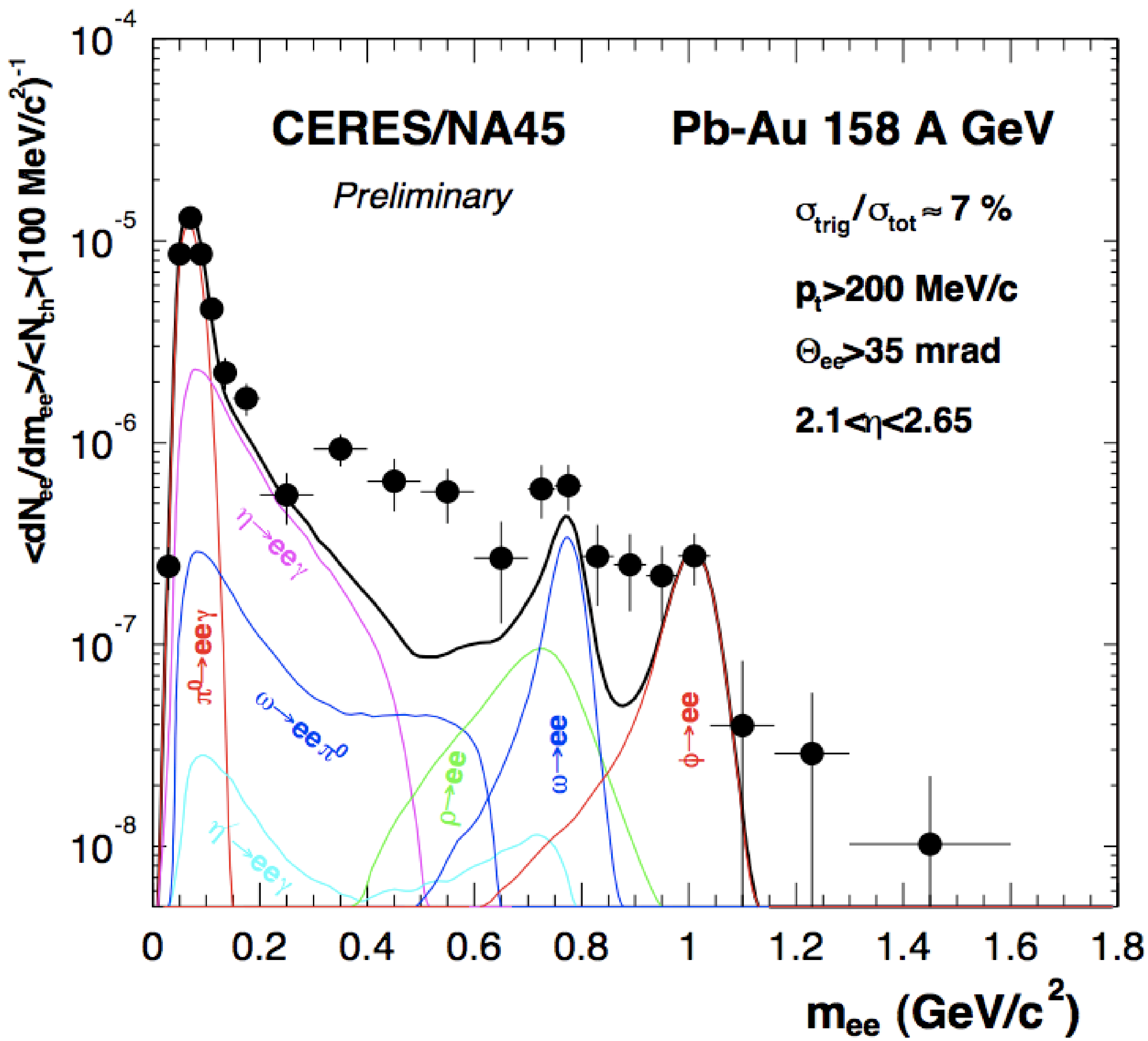


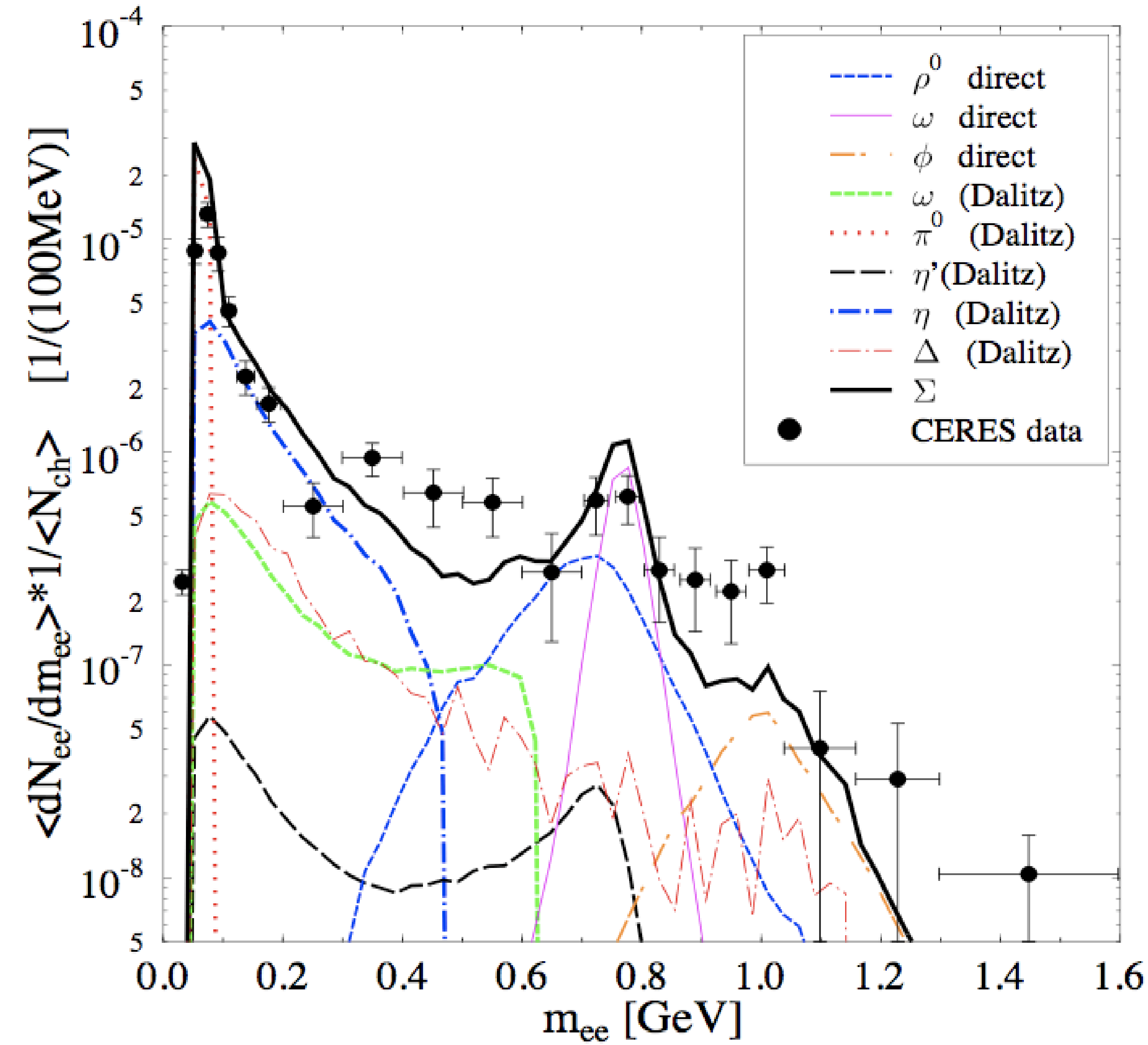
Direct decay

L.G. Landsberg, Phys.Rept.128:301-376,1985
P. Koch, Z. Phys. C57:283-304, 1993

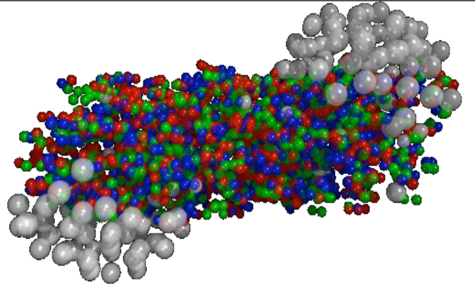
Dilepton spectra

Certainly not a perfect fit, yet doing better than the hadronic cocktail.



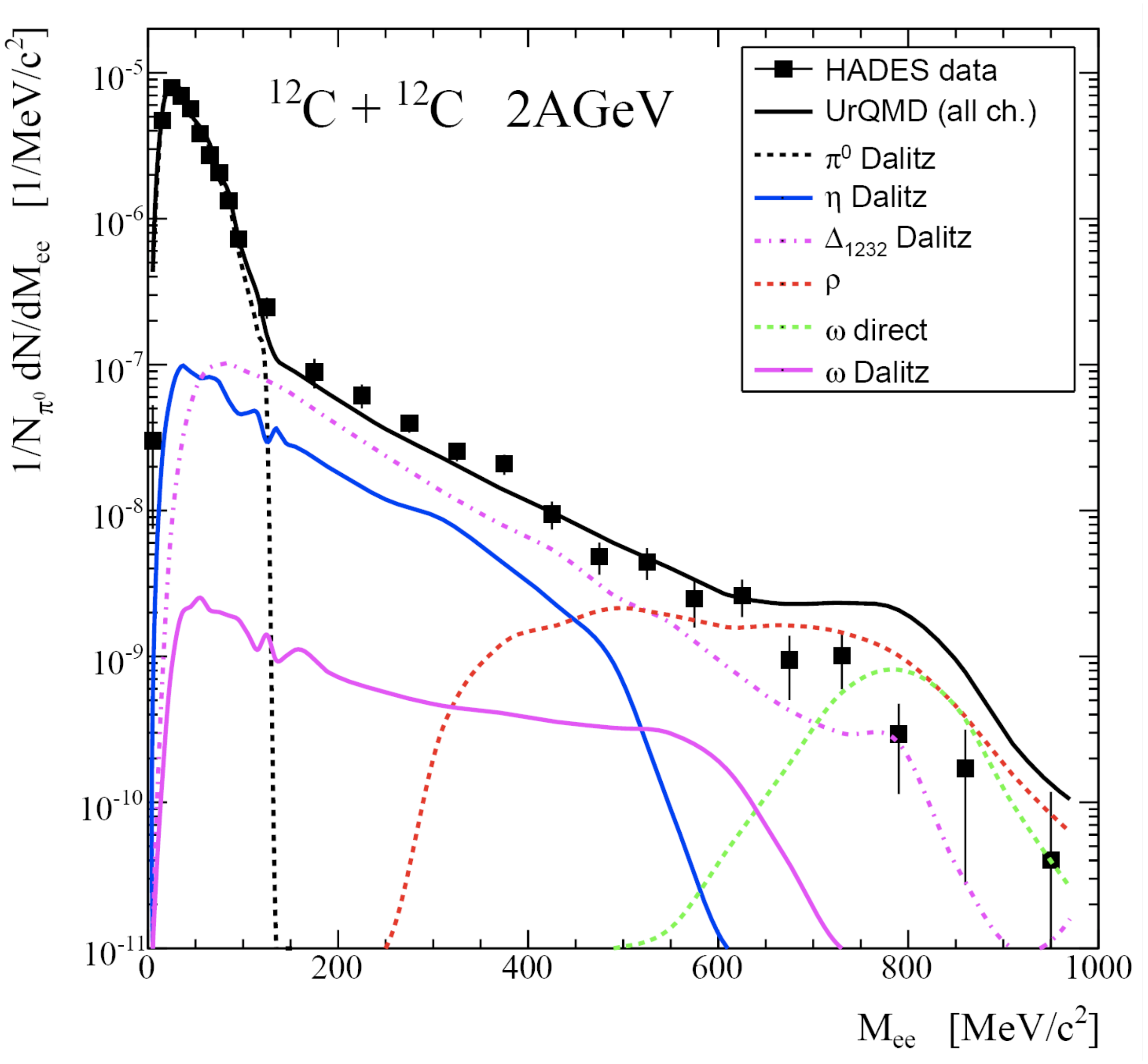


CERES Collaboration, Nucl. Phys A 774, 43, 2006
D. Schumacher, diploma thesis, 2006



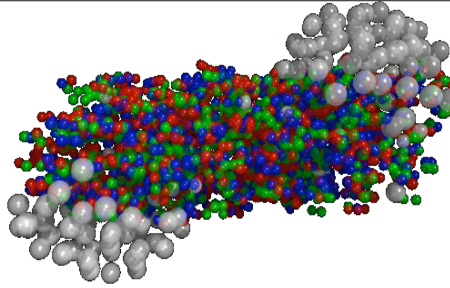
Dilepton spectra

The comparison to the data gives a reasonable explaination of the 400-600 MeV region.



Note: No explicit in-medium modifications have been implemented.

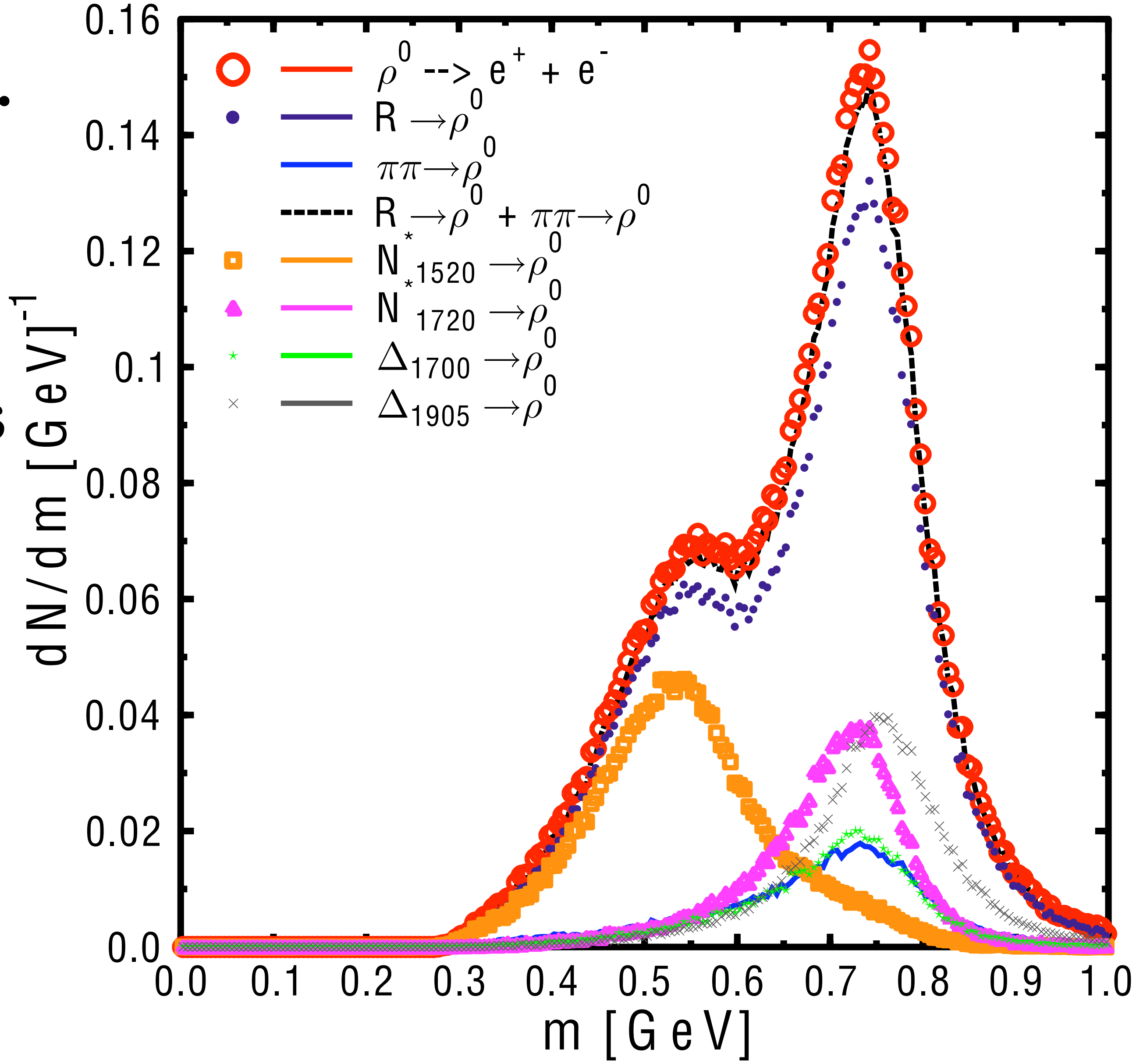
HADES collaborations, Phys. Rev. Lett.98, 052302, 2007
D. Schumacher, S.Vogel, M. Bleicher, submitted



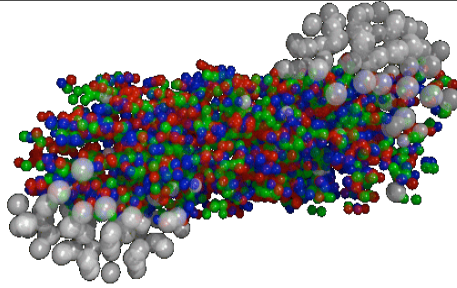
ρ meson in C+C @ 2AGeV

At low energies (~2 AGeV) contributions from baryon resonance decays are dominant.

Especially the N^*_{1520} contributes via the decay chain
$N^*_{1520} \rightarrow N + \rho$
$\rho \rightarrow \pi^+\pi^-$ or $\rho \rightarrow e^+e^-$
to the low mass part of the ρ meson mass spectrum.



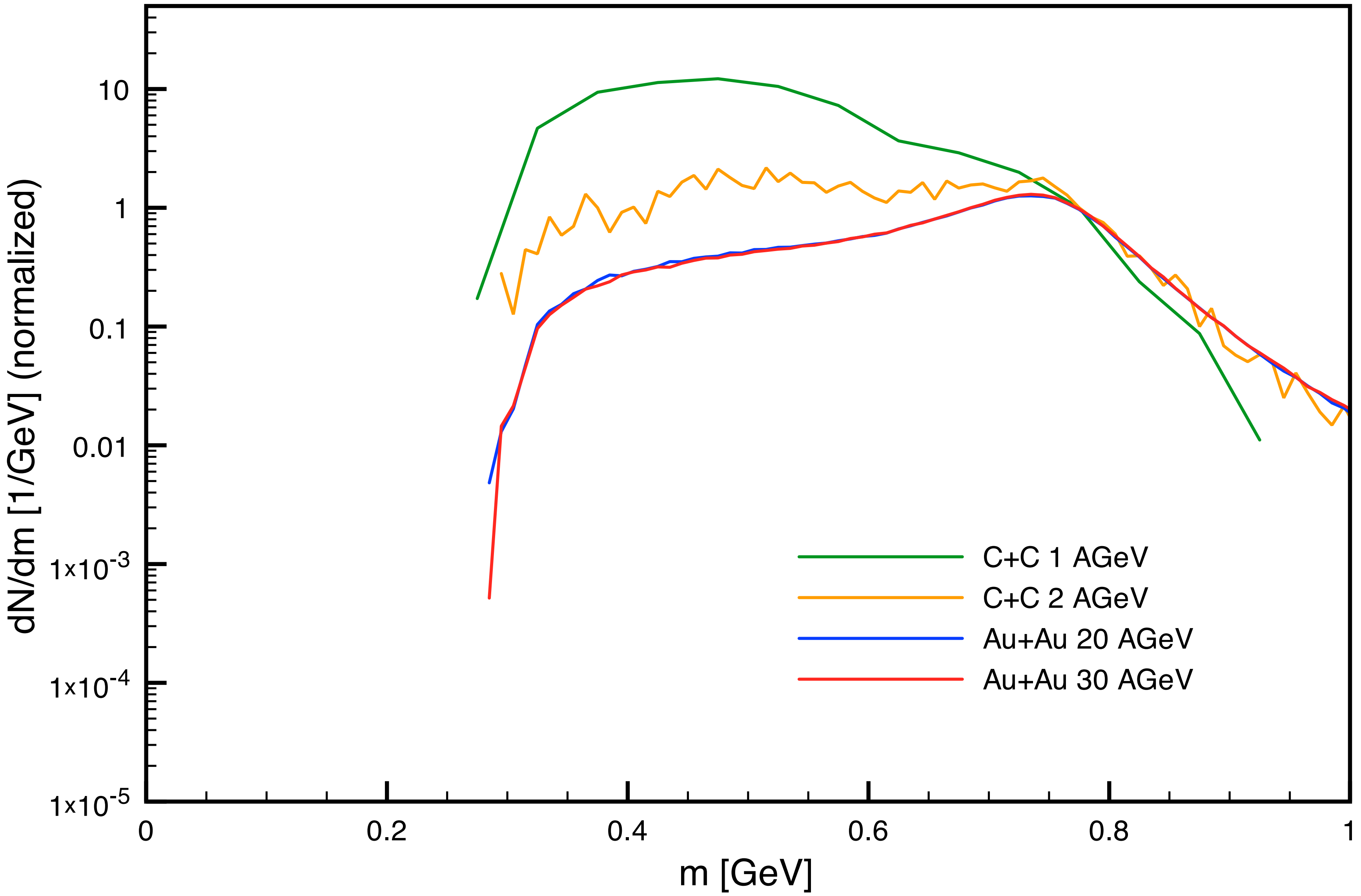
S. Vogel, M. Bleicher, Phys.Rev.C74:014902,2006

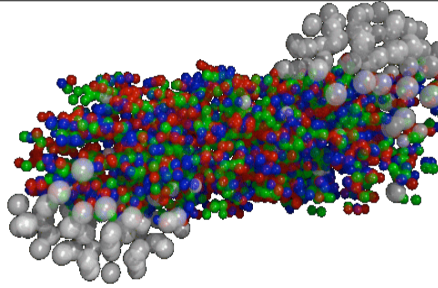


ρ meson at higher energies

At higher energies the contribution from baryonic resonance decays become less important.

Note: All curves normalized to the 770 MeV point.

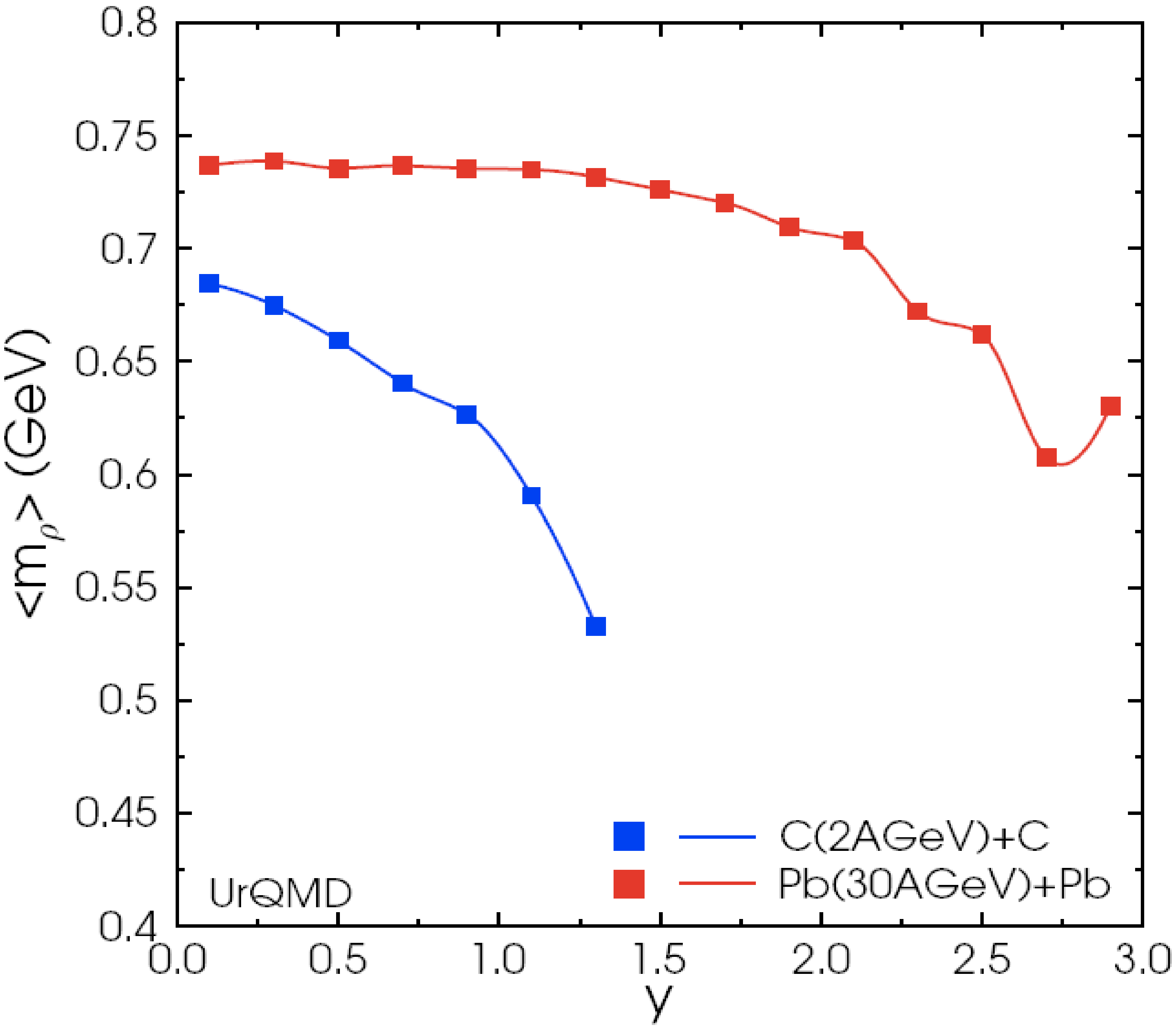




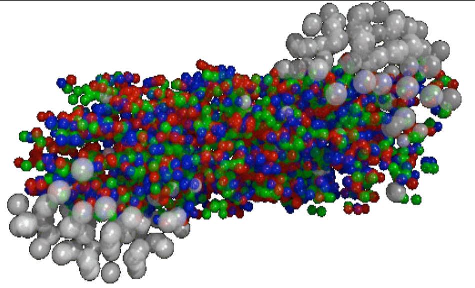
ρ meson at higher energies

Due to the dependence on the baryon density the mass of the ρ meson is rapidity dependent.

The ρ meson mass drops towards higher rapidity.



a_1 meson

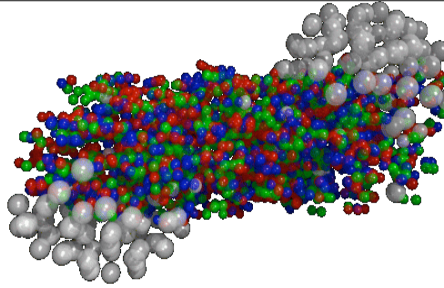


The a1 meson mass is expected to be equal to the mass of the ρ meson, in the case of chiral symmetry restoration.

Problem:
It is hard to measure.

$a_1(1260)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)
Γ_1	$\pi^+\pi^-\pi^0$	
Γ_2	$\pi^0\pi^0\pi^0$	
Γ_3	$(\rho\pi)_{S-\text{wave}}$	seen
Γ_4	$(\rho\pi)_{D-\text{wave}}$	seen
Γ_5	$(\rho(1450)\pi)_{S-\text{wave}}$	seen
Γ_6	$(\rho(1450)\pi)_{D-\text{wave}}$	seen
Γ_7	$\sigma\pi$	seen
Γ_8	$f_0(980)\pi$	not seen
Γ_9	$f_0(1370)\pi$	seen
Γ_{10}	$f_2(1270)\pi$	seen
Γ_{11}	$K\overline{K}^*(892)+$ c.c.	seen
Γ_{12}	$\pi\gamma$	seen



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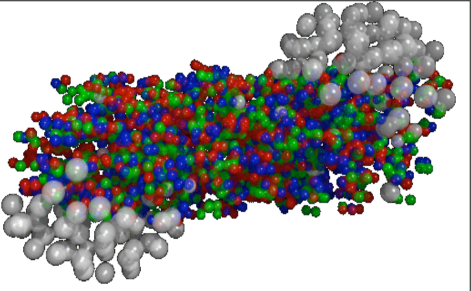
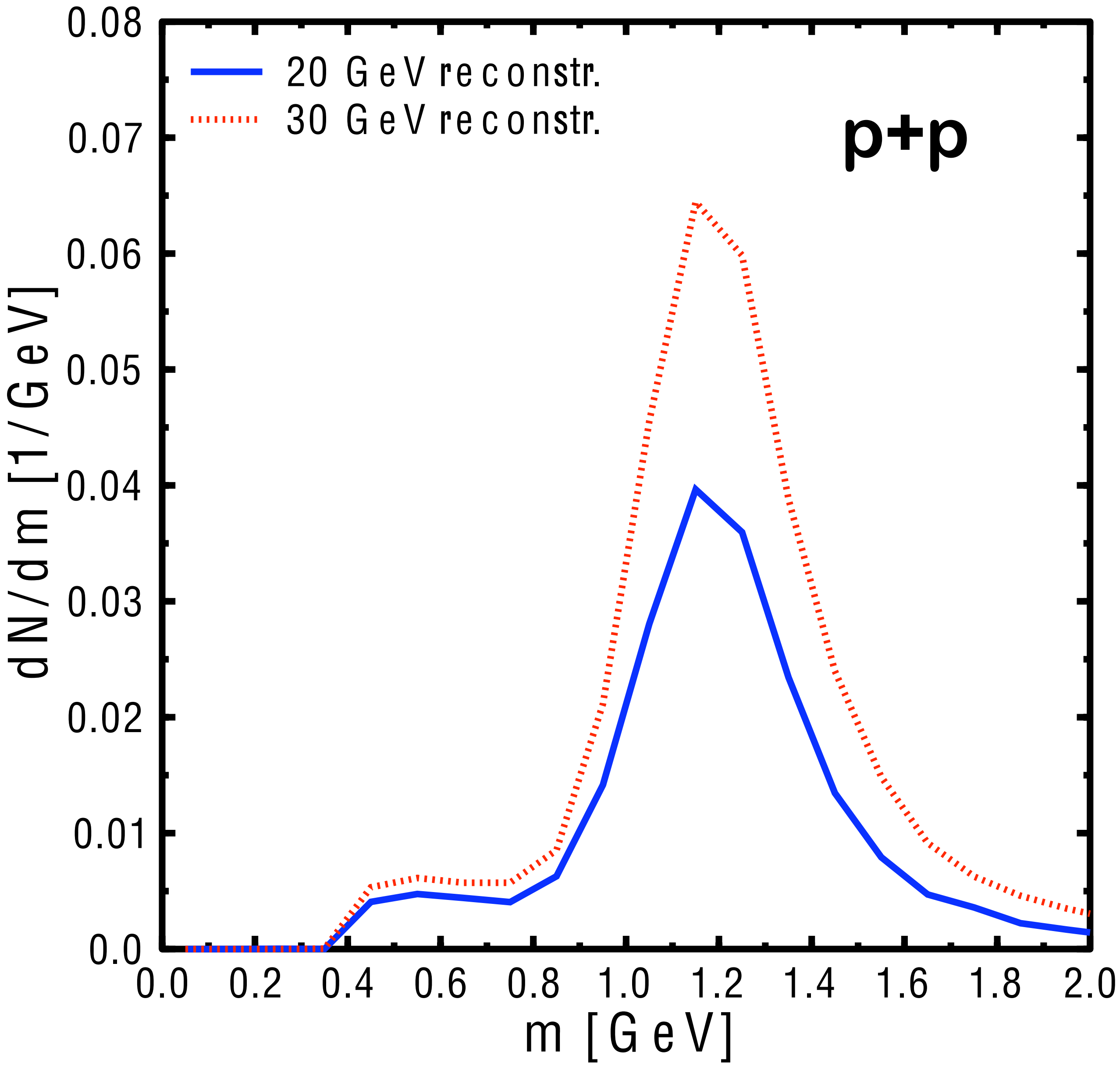
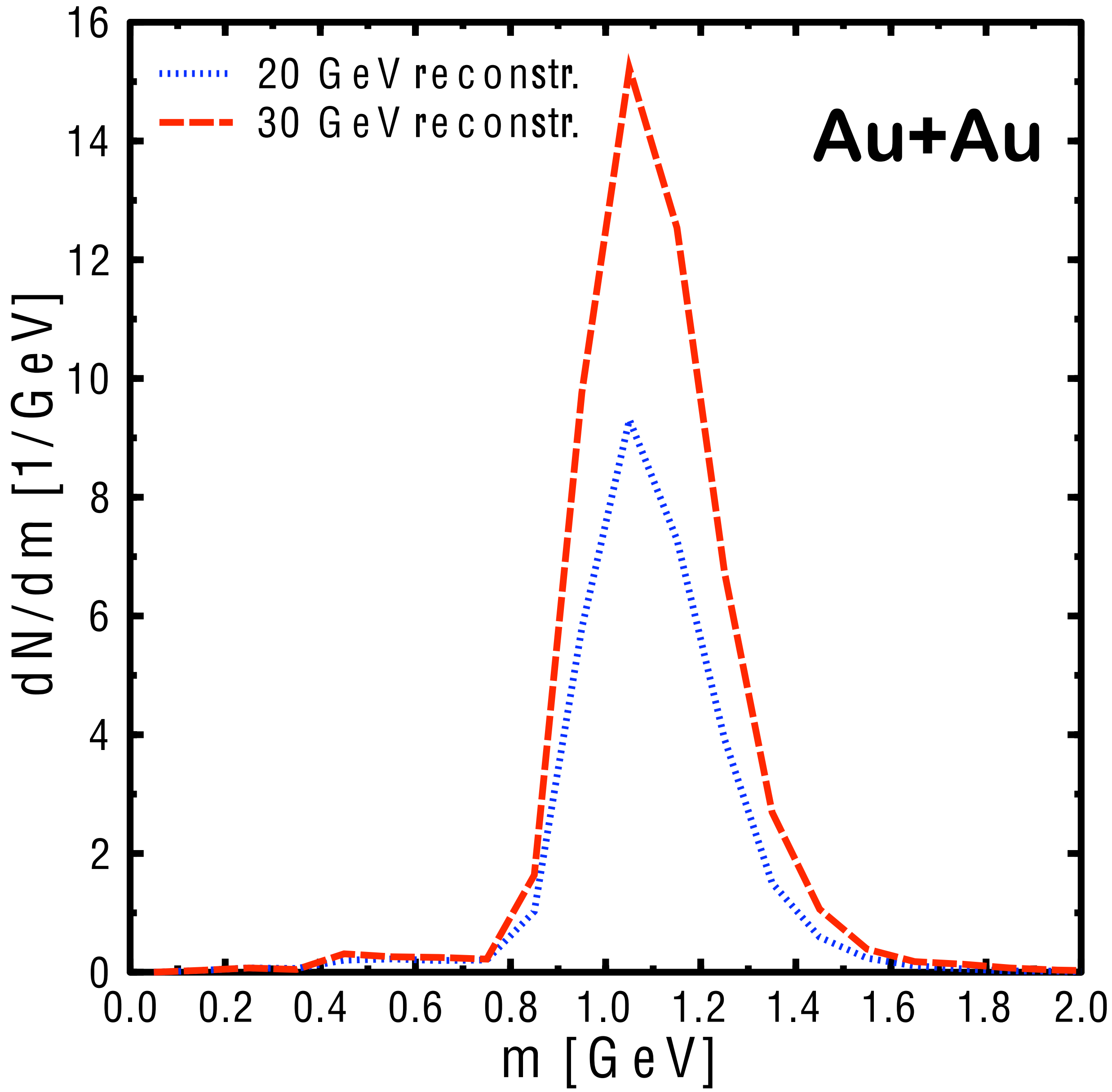
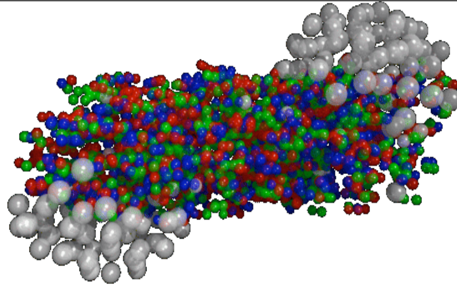
a_1 meson



Idea: Check the mass distribution from the transport code.

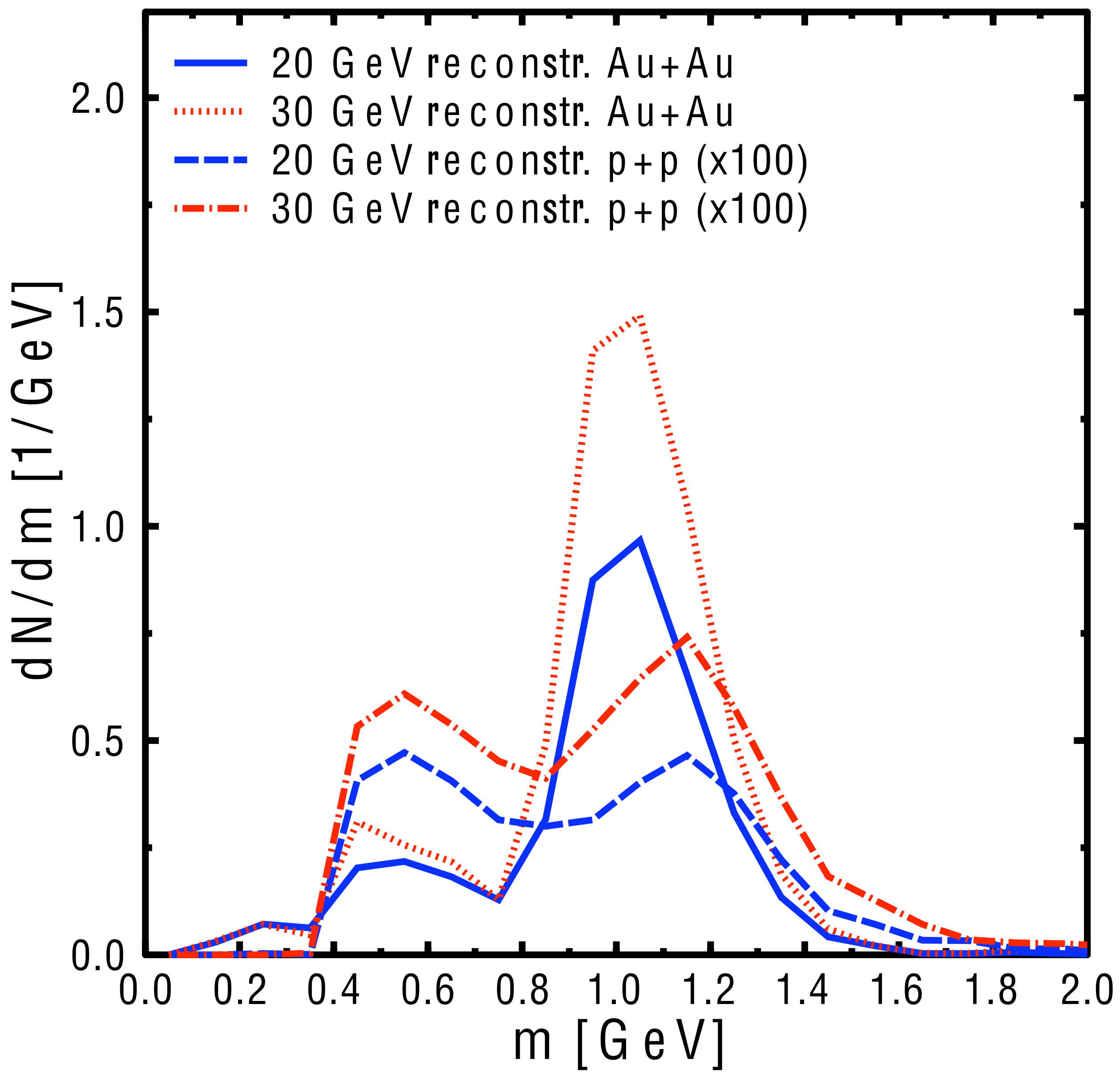


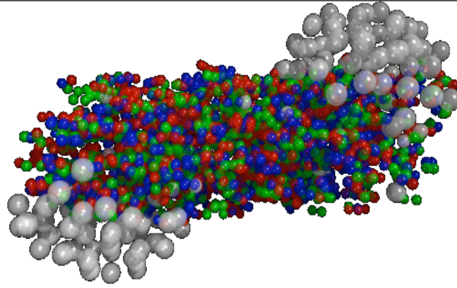




a_1 meson

Idea: Check the mass distribution from the transport code and trigger on the decay channel $a_1 \rightarrow \gamma\pi$. (assumed BR = 0.1)





a_1 meson

So, how does that come when the model does not know about chiral symmetry?

→ Mass dependent branching ratios

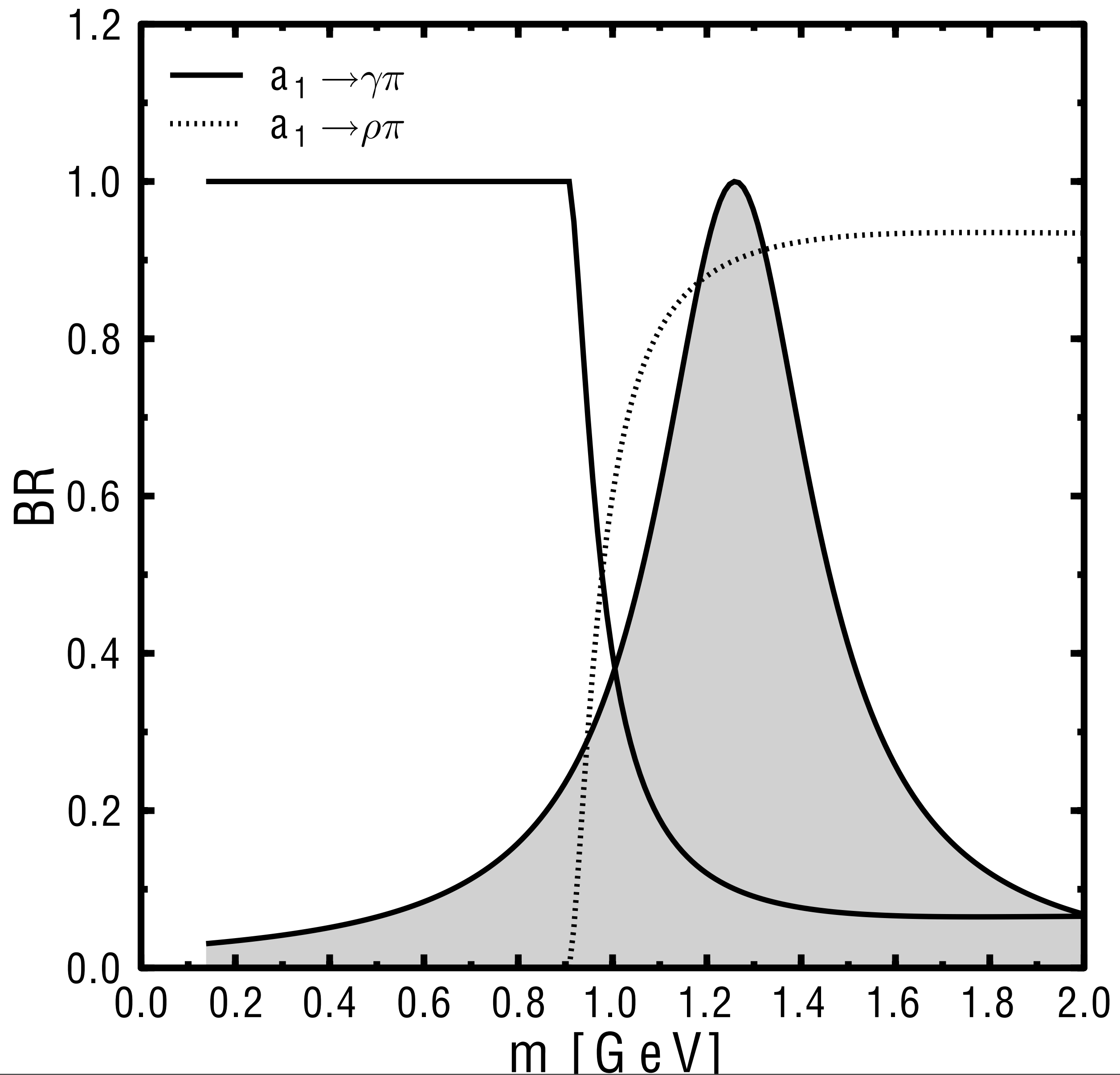
$$\Gamma_{i,j}(M) = \Gamma_R^{i,j} \frac{M_R}{M} \left(\frac{\langle p_{i,j}(M) \rangle}{\langle p_{i,j}(M_R) \rangle} \right)^{2l+1} \frac{1.2}{1 + 0.2 \left(\frac{\langle p_{i,j}(M) \rangle}{\langle p_{i,j}(M_R) \rangle} \right)^{2l}}$$

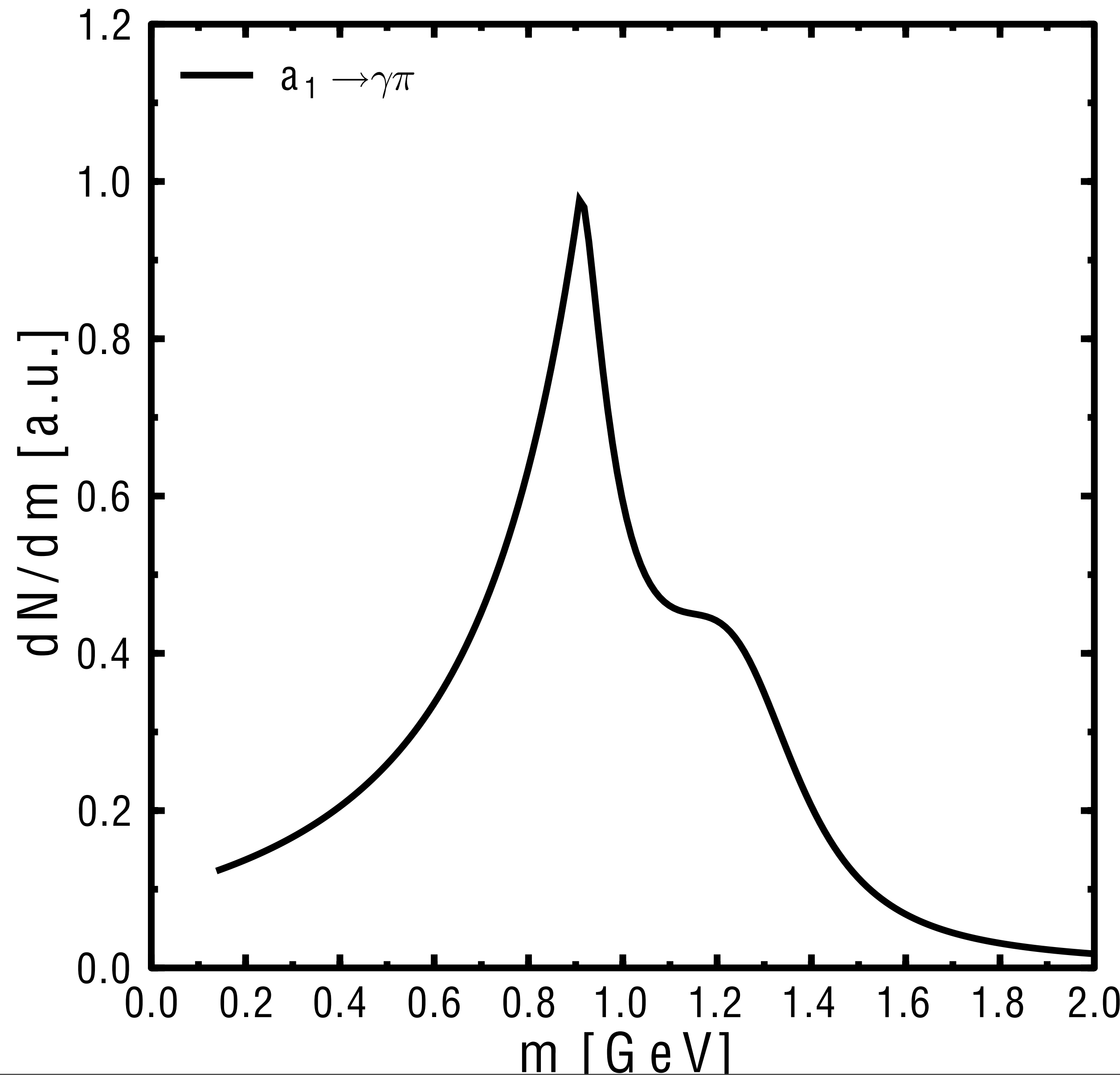
If you trigger on $a_1 \to \gamma\pi$, you automatically trigger on low mass a_1 mesons. A low mass a_1 has a high probability to decay into $\gamma\pi$, yet a low chance to decay into something else.

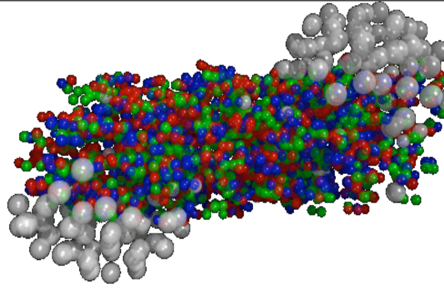
The branching ratio for $a_1 \to \gamma\pi$ is large (compared to the other decay channels) at low masses ⇒ enhancement of $a_1 \to \gamma\pi$ decay processes.

a_1 meson

(Left) At masses below 900 MeV the γπ channel is the only contributing channel, since the branching ratio of heavier decay products is kinematically suppressed.
(Right) Branching ratio folded with BW distribution

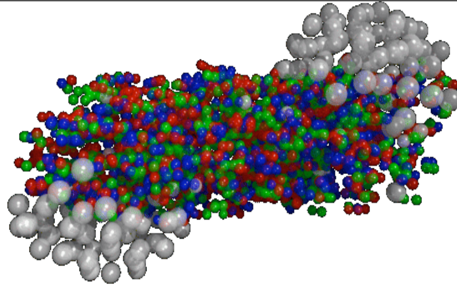






Summary

- The ρ meson might not be a feasible candidate for studies on the restoration of chiral symmetry, at least not at lower energies, where the system is baryon-dominated.
- The a_1 meson also might not be a feasible candidate for those studies (at least not in the $\gamma\pi$ exit channel) either, yet too few details are known about it and we need further experimental analyses.
- There is a need for more (direct?) experimental observables.



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Thanks!