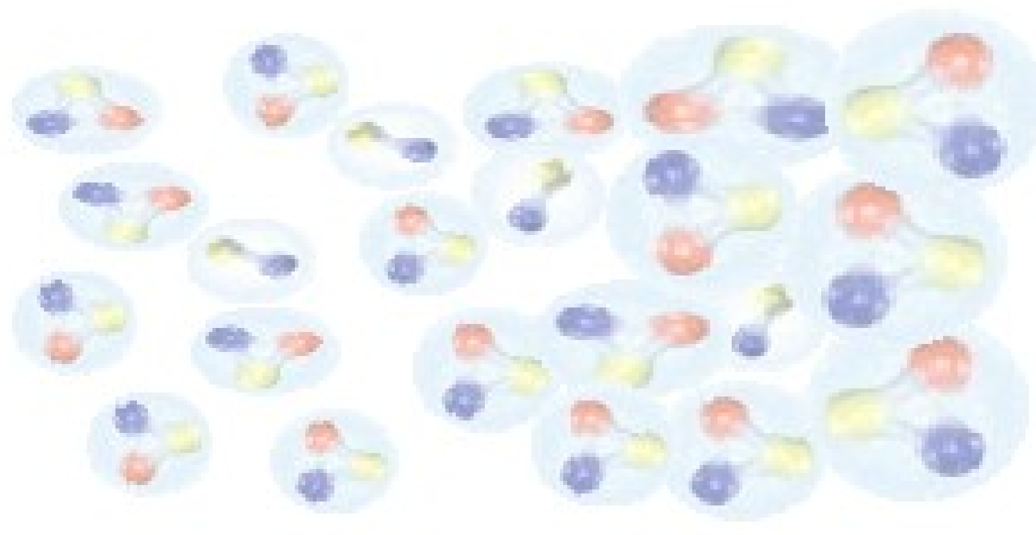
Quantum flavor kinetics and chemical freeze-out
(Hadronization as Mott-Anderson localization)

David Blaschke
University of Wroclaw, Poland & JINR Dubna, Russia



Dense Matter Seminar, BLTP, JINR Dubna, January 21, 2015

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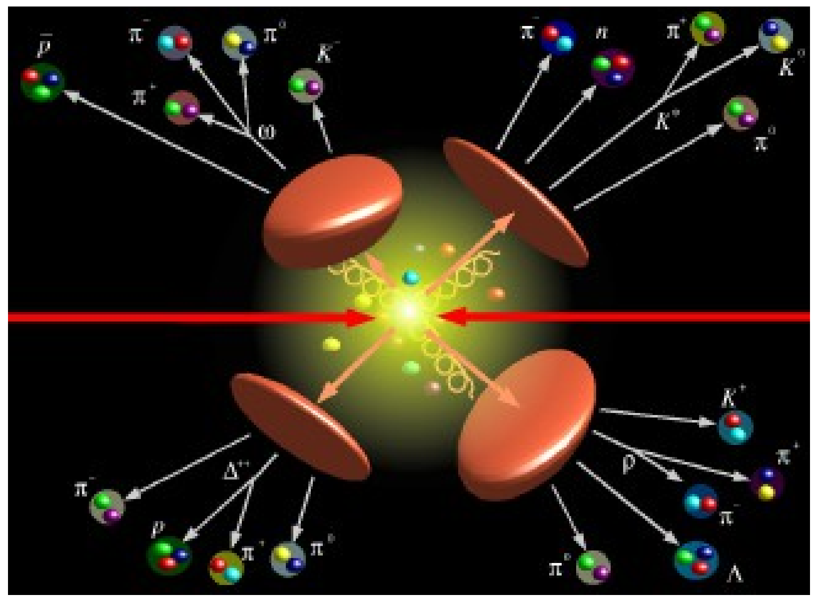
M. Srednicki,
"Chaos and Quantum Thermalization",
PRE 50 (1994) 888



F. Becattini @ ECT* 2014

11th Polish Workshop on Heavy Ion Collisions, Warsaw, January 17, 2015

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Quantum flavor kinetics and chemical freeze-out
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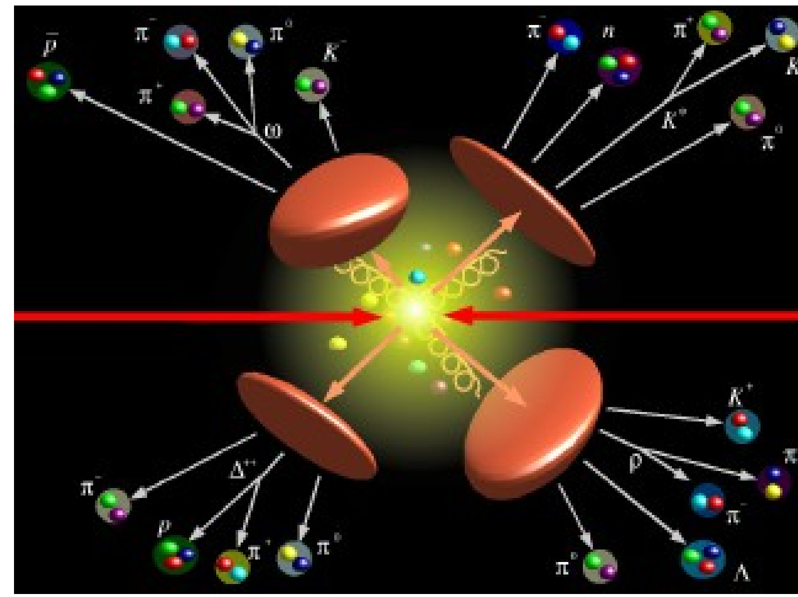
Dictionary:

Quantum: hadrons = bound states of quarks

Flavor kinetics: quark exchange between hadrons

Freeze-out: localization of bound states in expanding, cooling system
(inverse of delocalization by compression: Mott effect)



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Quantum flavor kinetics and chemical freeze-out
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1. **Mott-Anderson localization model for chemical freeze-out**
   - idea
   - inputs
   - results
2. **Chiral QM for hadron Mott transition**
3. **Thermodynamics of Mott-HRG and lattice QCD data**

11th Polish Workshop on Heavy Ion Collisions, Warsaw, January 17, 2015

Mott-Anderson localization model for chemical freeze-out

DB, J. Berdermann, J. Cleymans, K. Redlich, Phys. Part. Nucl. Lett. 8 (2011) 811

The basic idea: Localization of (certain) multiquark states ("cluster") = hadronization;
Reverse process = delocalization by quark exchange between hadrons

Freeze-out criterion:

$$\tau_{\exp}(T,\mu) = \tau_{\rm coll}(T,\mu)$$

$$\tau_{\rm coll}^{-1}(T,\mu) = \sum_{i,j}\sigma_{ij}n_j$$

Povh-Huefner law, PRC 46 (1992) 990

$$\sigma_{ij} = \lambda\langle r_i^2\rangle\langle r_j^2\rangle$$

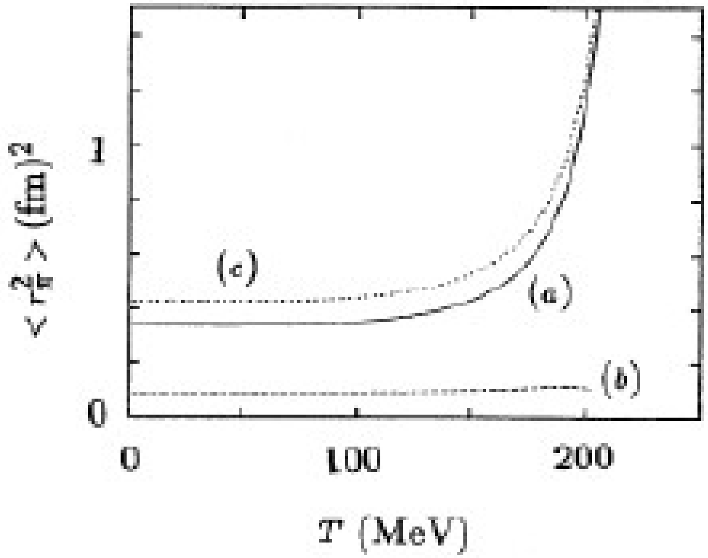
$$r_\pi^2(T,\mu) = \frac{3}{4\pi^2}f_\pi^{-2}(T,\mu)$$

$$f_\pi^2(T,\mu) = -m_0\langle\bar{q}q\rangle_{T,\mu}/M_\pi^2$$

$$r_\pi^2(T,\mu) = \frac{3M_\pi^2}{4\pi^2 m_q}\left|\langle\bar{q}q\rangle_{T,\mu}\right|^{-1}$$

$$\langle\bar{q}q\rangle = \langle\bar{q}q\rangle_{\rm MF}\left[1-\frac{T^2}{8f_\pi^2(T,\mu)}-\frac{\sigma_N n_{s,N}(T,\mu)}{M_\pi^2 f_\pi^2(T,\mu)}\right]$$

Hippe & Klevansky, PRC 52 (1995) 2172



Mott-Anderson localization model for chemical freeze-out

DB, J. Berdermann, J. Cleymans, K. Redlich, Phys. Part. Nucl. Lett. 8 (2011) 811

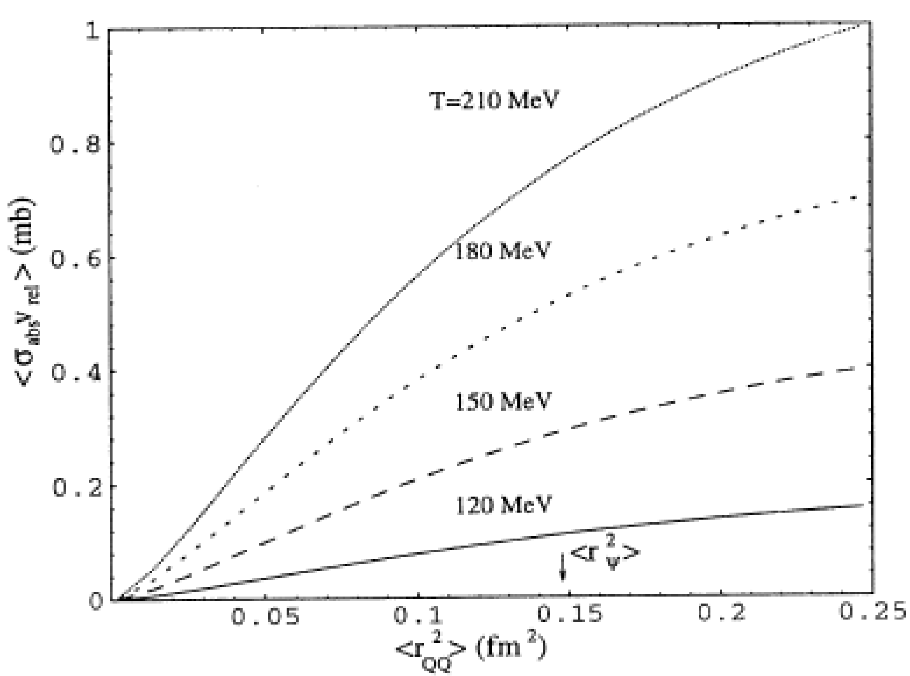
Povh-Huefner law behaviour for quark exchange between hadrons

PHYSICAL REVIEW C VOLUME 51, NUMBER 5 MAY 1995

Quark exchange model for charmonium dissociation in hot hadronic matter

K. Martins* and D. Blaschke†
Max-Planck-Gesellschaft AG "Theoretische Vielteilchenphysik," Universität Rostock, D-18051 Rostock, Germany

E. Quack‡
Gesellschaft für Schwerionenforschung mbH, Postfach 11 05 52, D-64220 Darmstadt, Germany
(Received 15 November 1994)



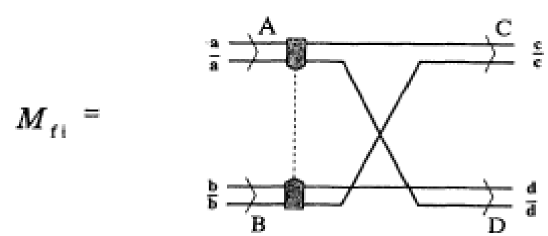
$$\langle \sigma_{\rm abs} v_{\rm rel} \rangle \propto \langle r^2 \rangle_{Q\bar{Q}} \langle r^2 \rangle_{q\bar{q}}$$

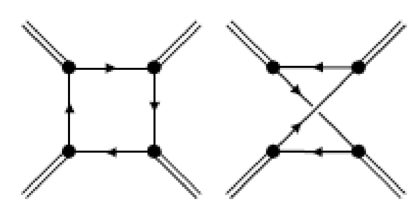
Flavor exchange processes

$$\phi + \pi \to K + \bar{K},$$

$$K^- + p \to \Lambda + X,$$
$$K^+ + p \to \Lambda + X,$$

Nonrelativistic → rel. quark loop integrals





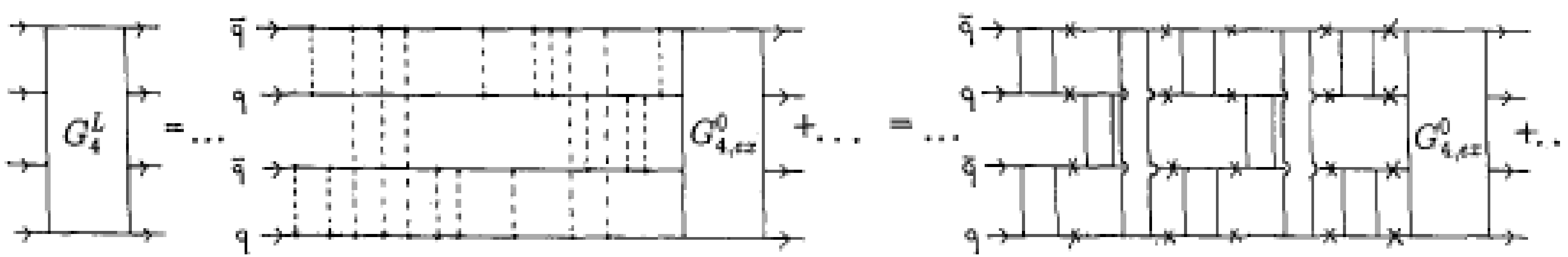
Quark exchange in meson-meson scattering

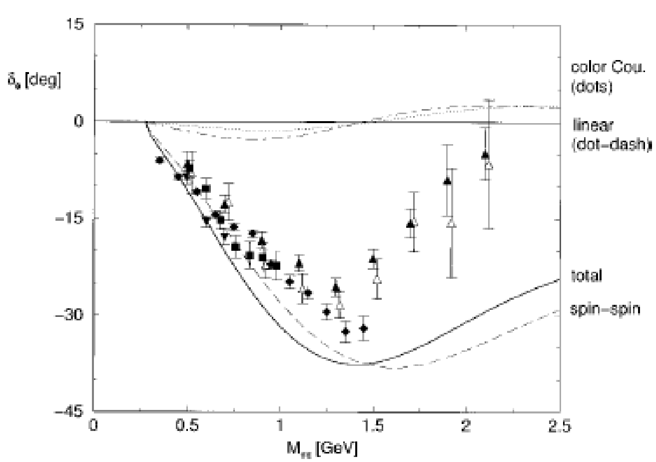
DB, G. Roepke, Phys. Lett. B 299 (1993) 332; T. Barnes et al., PRC 63 (2001) 025204

Povh-Huefner law behaviour for quark exchange between hadrons ?

$$\sigma_{ij} = \lambda \langle r_i^2 \rangle \langle r_j^2 \rangle \qquad r_\pi^2(T,\mu) = \frac{3 M_\pi^2}{4\pi^2 m_q} \left| \langle \bar{q} q \rangle_{T,\mu} \right|^{-1}$$

$$\mathscr{V}^{ss}(12, 1'2') = \frac{16}{3\sqrt{3}} C_{SFC}(12, 1'2') \frac{(2\pi)^3}{\Omega_0} \frac{\alpha_s}{3\pi^2 m_q^2} \exp\left(-\frac{1}{4b^2} (k'^2 + \tfrac{1}{3} k^2) \right) \delta_{K,K'}$$

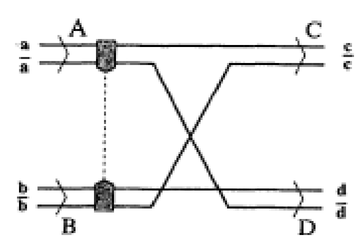


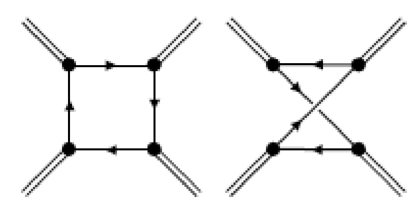


Quark exchange process in M-M scattering

Nonrelativistic → rel. quark loop integrals

$M_{fi} =$





Mott-Anderson localization model for chemical freeze-out

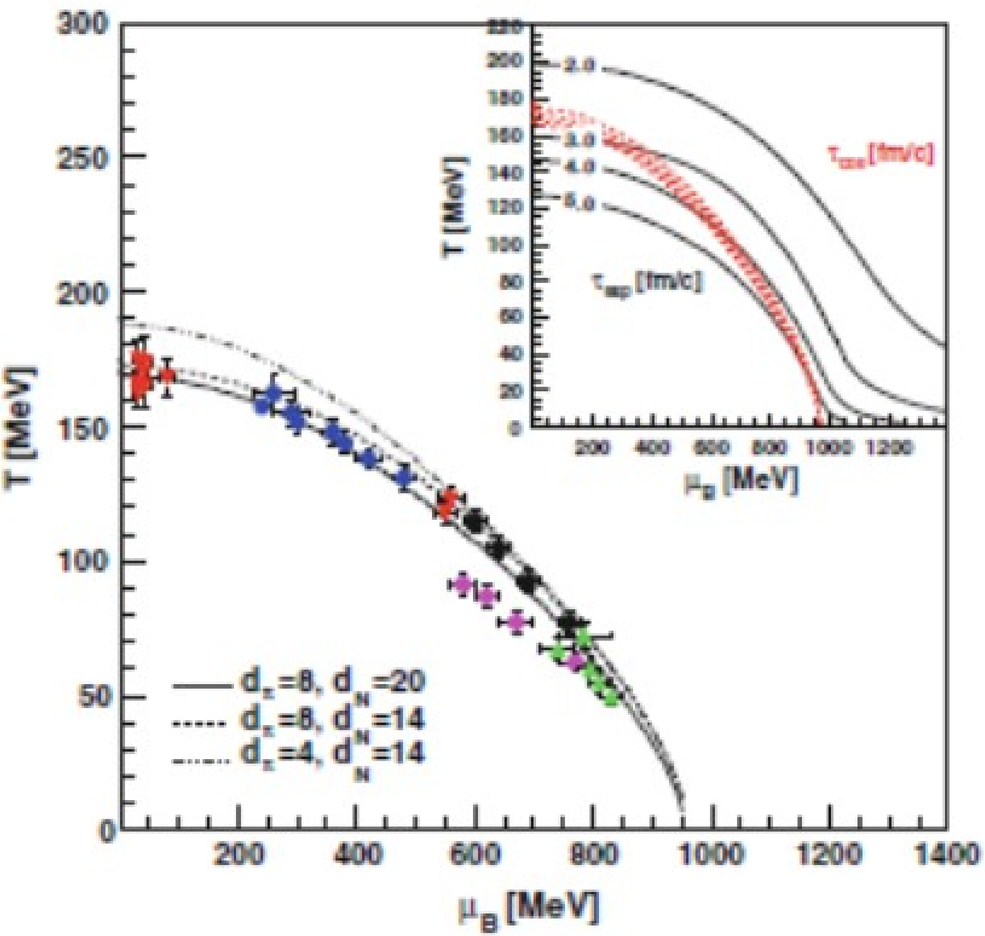
DB, J. Berdermann, J. Cleymans, K. Redlich, Phys. Part. Nucl. Lett. 8 (2011) 811

<u>**Model results:**</u>

$$\tau_{exp}(T, \mu) = \tau_{coll}(T, \mu)$$

Collision time strongly T, mu dependent !

Schematic resonance gas: dp pions, dN nucleons

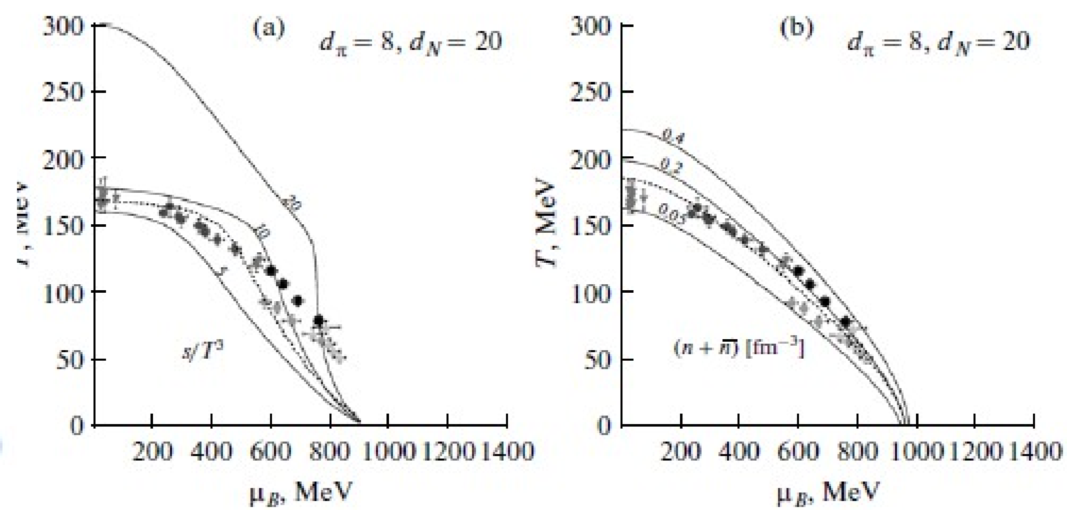


Expansion time scale from entropy conservation:

$$s(T, \mu)\, V(\tau_{exp}) = \text{const}$$

$$\tau_{exp}(T, \mu) = a s^{-1/3}(T, \mu),$$

Thermodynamics consistent with phenomenological Freeze-out rules:



Mott-Anderson localization model for chemical freeze-out

DB, J. Berdermann, J. Cleymans, K. Redlich, Few Body Syst. 53 (2012) 99

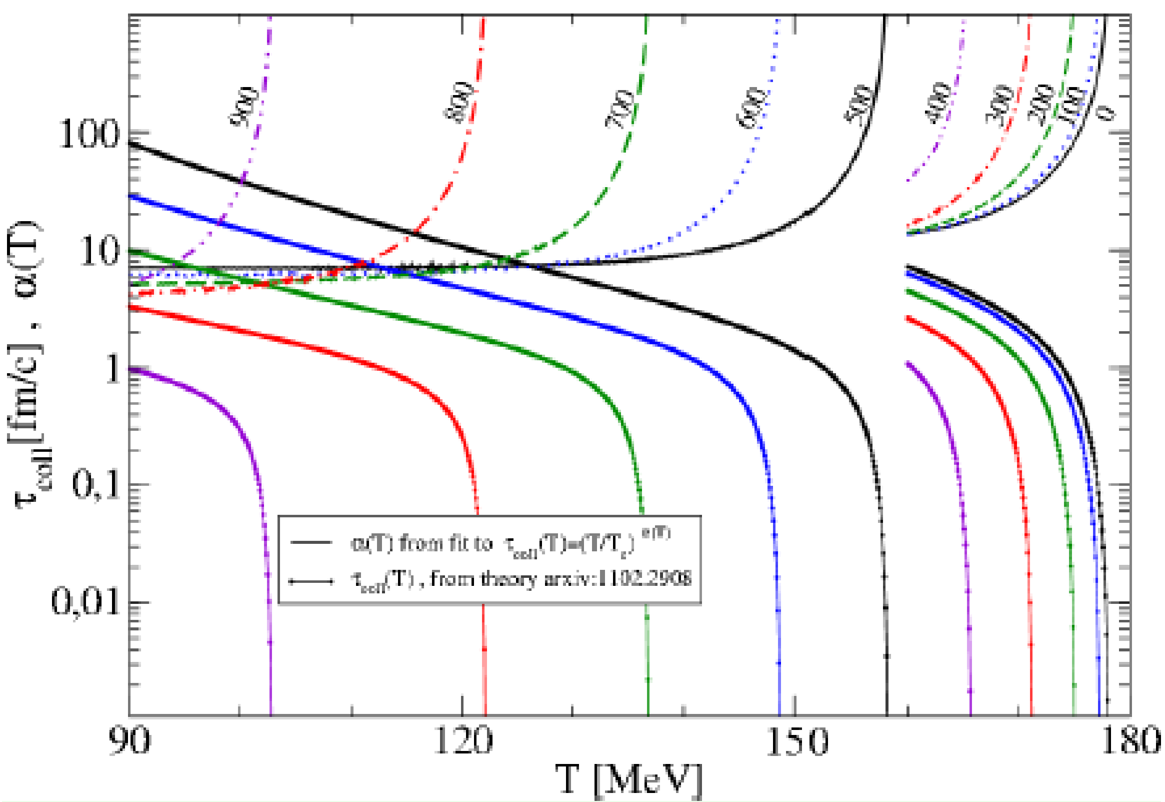
Model results:
Full hadron resonance gas model

$$\sigma_{ij} = \lambda \langle r_i^2 \rangle \langle r_j^2 \rangle \;;$$

$$r_\pi^2(T,\mu) = \frac{3 M_\pi^2}{4\pi^2 m_q} \left| \langle \bar{q} q \rangle_{T,\mu} \right|^{-1}$$

$$r_N^2(T,\mu) = r_0^2 + r_\pi^2(T,\mu)$$

$$\begin{aligned}\frac{\langle \bar{q}q\rangle}{\langle \bar{q}q\rangle_{\rm vac}} = 1 - \frac{m_0}{F_\pi^2 m_\pi^2}\Bigg\{ & 4N_c \int \frac{dp\, p^2}{2\pi^2}\frac{m}{\varepsilon_p}\left[f_\Phi^+ + f_\Phi^-\right] \\ & + \sum_{M=f_0,\omega,\dots} d_M(2-N_s)\int \frac{dp\, p^2}{2\pi^2}\frac{m_M}{E_M(p)} f_M(E_M(p)) \\ & + \sum_{B=N,\Lambda,\dots} d_B(3-N_s)\int \frac{dp\, p^2}{2\pi^2}\frac{m_B}{E_B(p)}\left[f_B^+(E_B(p)) + f_B^-(E_B(p))\right]\Bigg\} \\ & - \sum_{G=\pi,K,\eta,\eta'} \frac{d_G r_G}{4\pi^2 F_G^2}\int dp\, \frac{p^2}{E_G(p)} f_G(E_G(p)).\end{aligned}$$



Collision time follows a power law
t_coll ~ (T/Tc)^a
with a large exponent a ~ 20

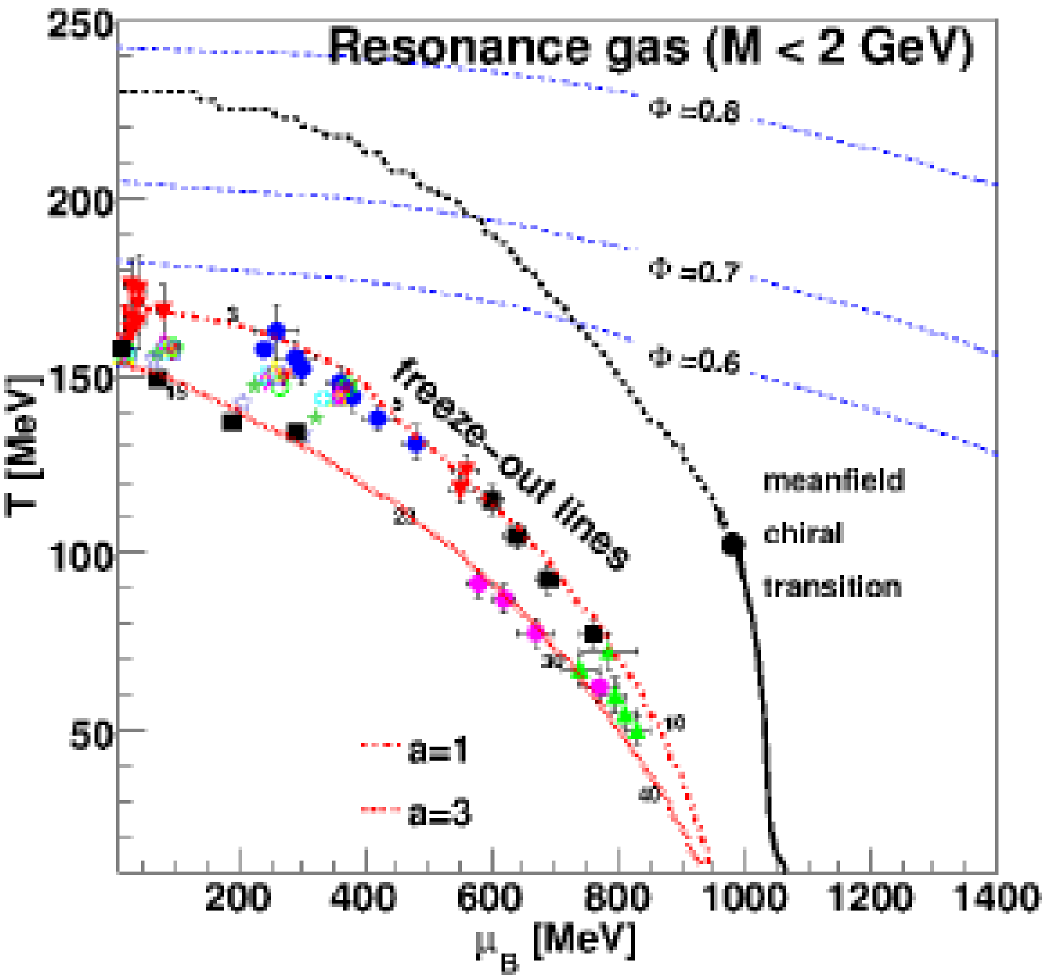
See also: P. Braun-Munzinger, J. Stachel, C. Wetterich, PLB (2004)

Mott-Anderson localization model for chemical freeze-out

DB, J. Berdermann, J. Cleymans, K. Redlich, Few Body Syst. 53 (2012) 99

<u>**Model results:**</u>
Full hadron resonance gas model

See also: S. Leupold, J. Phys. G (2006)



$$\frac{\langle\bar{q}q\rangle}{\langle\bar{q}q\rangle_{\rm vac}} = 1 - \frac{m_0}{F_\pi^2 m_\pi^2}\Bigg\{4N_c\int\frac{dp\,p^2}{2\pi^2}\frac{m}{\varepsilon_p}\left[f_\Phi^+ + f_\Phi^-\right]$$
$$+ \sum_{M=f_0,\omega,\ldots} d_M(2-N_s)\int\frac{dp\,p^2}{2\pi^2}\frac{m_M}{E_M(p)}f_M(E_M(p))$$
$$+ \sum_{B=N,\Lambda,\ldots} d_B(3-N_s)\int\frac{dp\,p^2}{2\pi^2}\frac{m_B}{E_B(p)}\left[f_B^+(E_B(p)) + f_B^-(E_B(p))\right]\Bigg\}$$
$$- \sum_{G=\pi,K,\eta,\eta'}\frac{d_G r_G}{4\pi^2 F_G^2}\int dp\,\frac{p^2}{E_G(p)}f_G(E_G(p)).$$

$$\sigma_{ij} = \lambda\langle r_i^2\rangle\langle r_j^2\rangle \quad ; \quad r_N^2(T,\mu) = r_0^2 + r_\pi^2(T,\mu)$$

$$r_\pi^2(T,\mu) = \frac{3M_\pi^2}{4\pi^2 m_q}\left|\langle\bar{q}q\rangle_{T,\mu}\right|^{-1}$$

The factor a stands for the inverse system size in the formula

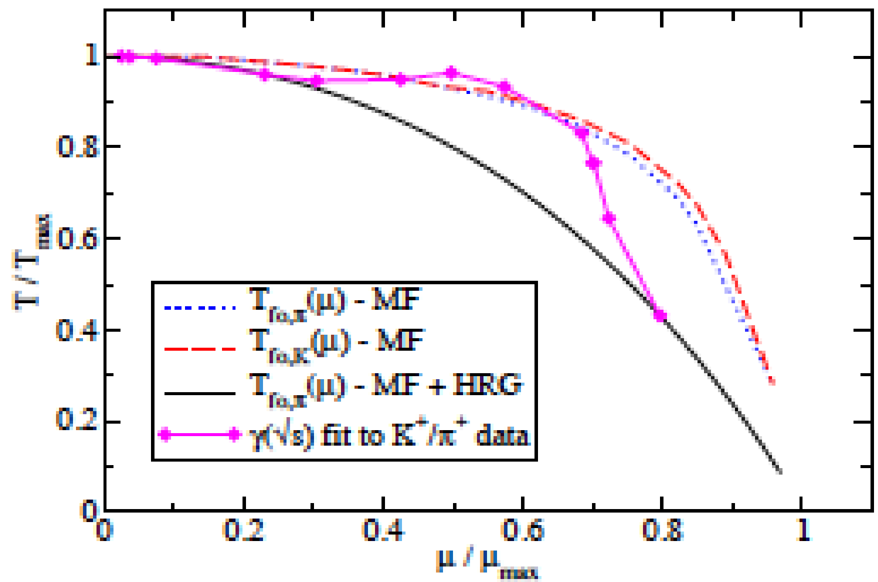
$$\tau_{\rm exp}(T,\mu) = \tau_{\rm coll}(T,\mu)$$

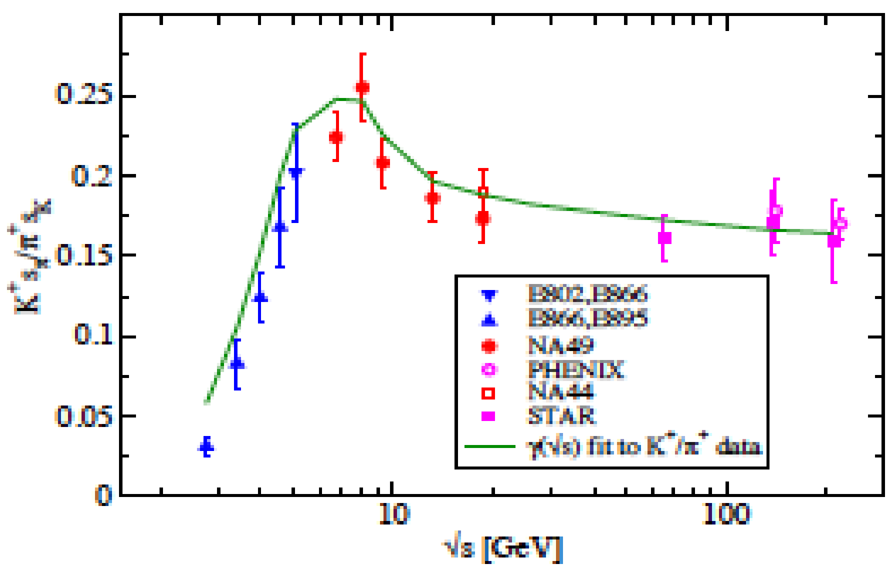
for the 3D expansion time scale assuming entropy conservation

Mott-Anderson localization model for K+/π+ “horn”

M. Naskret, DB, A. Dubinin, arxiv:1501.01599; Pis'ma EchAYa 12 (2015) accepted.

Full hadron resonance gas model; J. Jankowski et al., Phys. Rev. D (2013)





$$\langle\bar{q}q\rangle_{T,\mu} = \langle\bar{q}q\rangle^{MF}_{T,\mu} + \sum_{h=M,B} \frac{\sigma_q^h}{m_q} n_h(T,\mu) \ ,$$

$$n_h(T,\mu) = \frac{d_h}{2\pi^2} \int_0^\infty dk k^2 \frac{m_h}{E_h} \frac{1}{e^{(E_h-\mu_h)/T} \mp 1} \ .$$

$$\tau^{-1}_{coll}(T,\mu) = \sum_{i,j} \sigma_{ij} n_j \ ; \ \sigma_{ij} = \lambda \langle r_i^2\rangle \langle r_j^2\rangle$$

$$\langle r_\pi^2\rangle_{T,\mu} \simeq \frac{3}{4\pi^2} f_\pi^{-2}(T,\mu) = \frac{3M_\pi^2}{4\pi^2 m_q} \left|\langle\bar{q}q\rangle_{T,\mu}\right|^{-1}$$

$$\langle r_K^2\rangle_{T,\mu} \simeq \frac{3M_K^2}{\pi^2(m_q+m_s)} \left|\langle\bar{q}q\rangle_{T,\mu} + \langle\bar{s}s\rangle_{T,\mu}\right|^{-1}$$

The factor a stands for the inverse system size in the formula

$$\tau_{exp}(T,\mu) = \tau_{coll}(T,\mu)$$

for the 3D expansion time scale assuming entropy conservation

Mott Dissociation of Hadrons in Hadron Matter

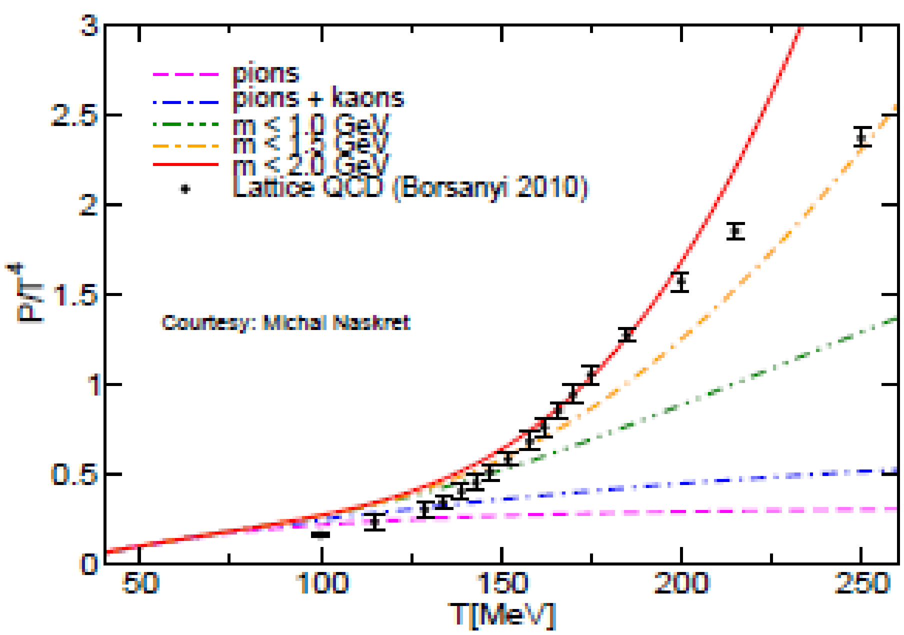
- Partition function as a Path Integral (imaginary time $\tau = i\,t$, $0 \le \tau \le \beta = 1/T$)

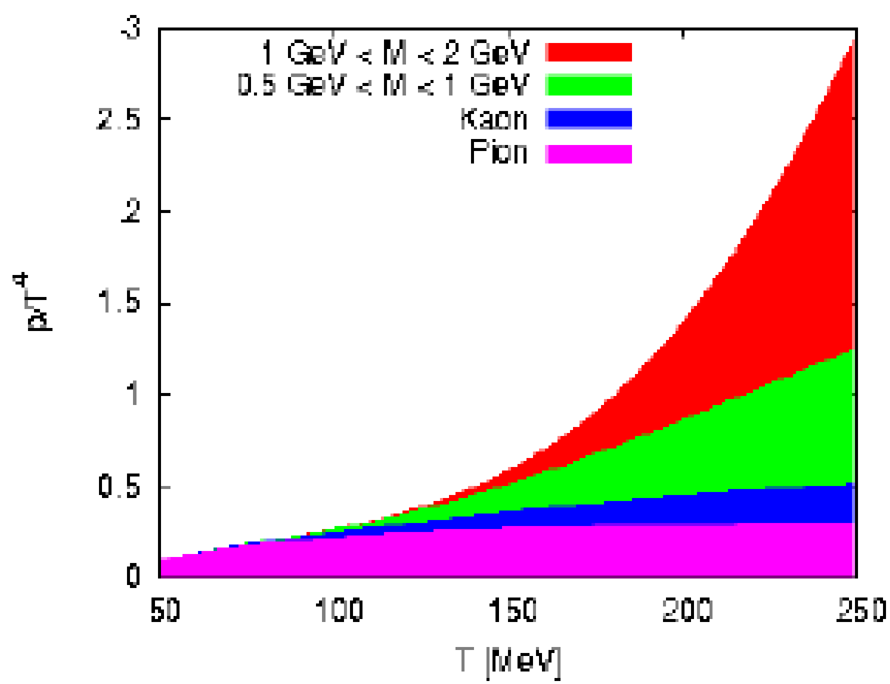
$$Z[T,V,\mu] = \int \mathcal{D}\bar{\psi}\mathcal{D}\psi\mathcal{D}A \exp\left\{-\int_0^\beta d\tau \int_V d^3x\, \mathcal{L}_{QCD}(\psi,\bar{\psi},A)\right\}$$

- QCD Lagrangian, non-Abelian gluon field strength: $F^a_{\mu\nu}(A) = \partial_\mu A^a \nu - \partial_\nu A^a_\mu + g\, f^{abc}[A^b_\mu, A^c_\nu]$

$$\mathcal{L}_{QCD}(\psi,\bar{\psi},A) = \bar{\psi}[i\gamma^\mu(\partial_\mu - igA_\mu) - m - \gamma^0\mu]\psi - \frac{1}{4}F^a_{\mu\nu}(A)F^{a,\mu\nu}(A)$$

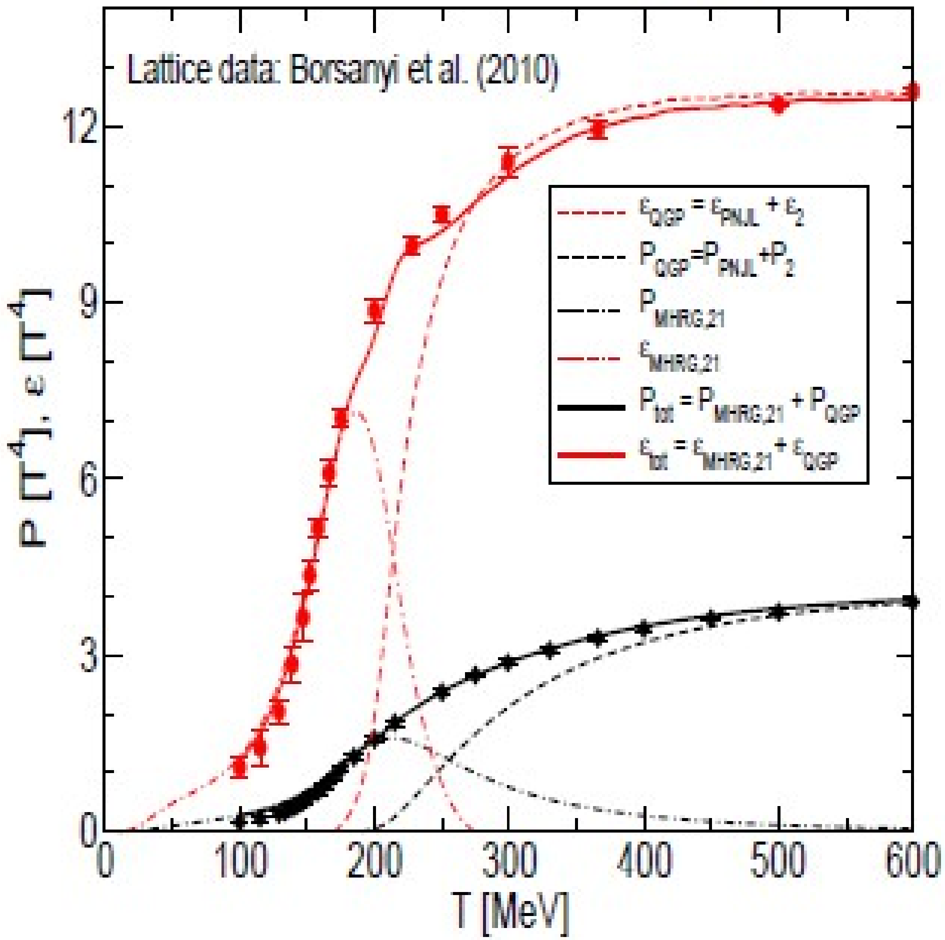
- Numerical evaluation: Lattice gauge theory simulations (hotQCD, Wuppertal-Budapest)





Mott Dissociation of Hadrons in Hadron Matter

$$P_{\rm tot}(T,\{\mu_j\}) = P_{\rm PNJL}(T,\{\mu_i\}) + \sum_{r=M,B} \delta_r g_r \int ds\, A_r(s,m_r;T) \int \frac{d^3p}{(2\pi)^3} T \ln\left\{1+\delta_r \exp\left(\frac{\sqrt{p^2+s}-\mu_r}{T}\right)\right\}$$



Spectral function for hadronic resonances:

$$A_r(s,m;T) = N_s \frac{m\Gamma_r(T)}{(s-m^2)^2 + m^2\Gamma_r^2(T)}$$

Ansatz motivated by chemical freeze-out model:

$$\Gamma_r(T) = \tau_r^{-1}(T) = \sum_h \lambda < r_r^2 >_T < r_h^2 >_T n_h(T)$$

Apparent phase transition at $T_c \sim 165$ MeV

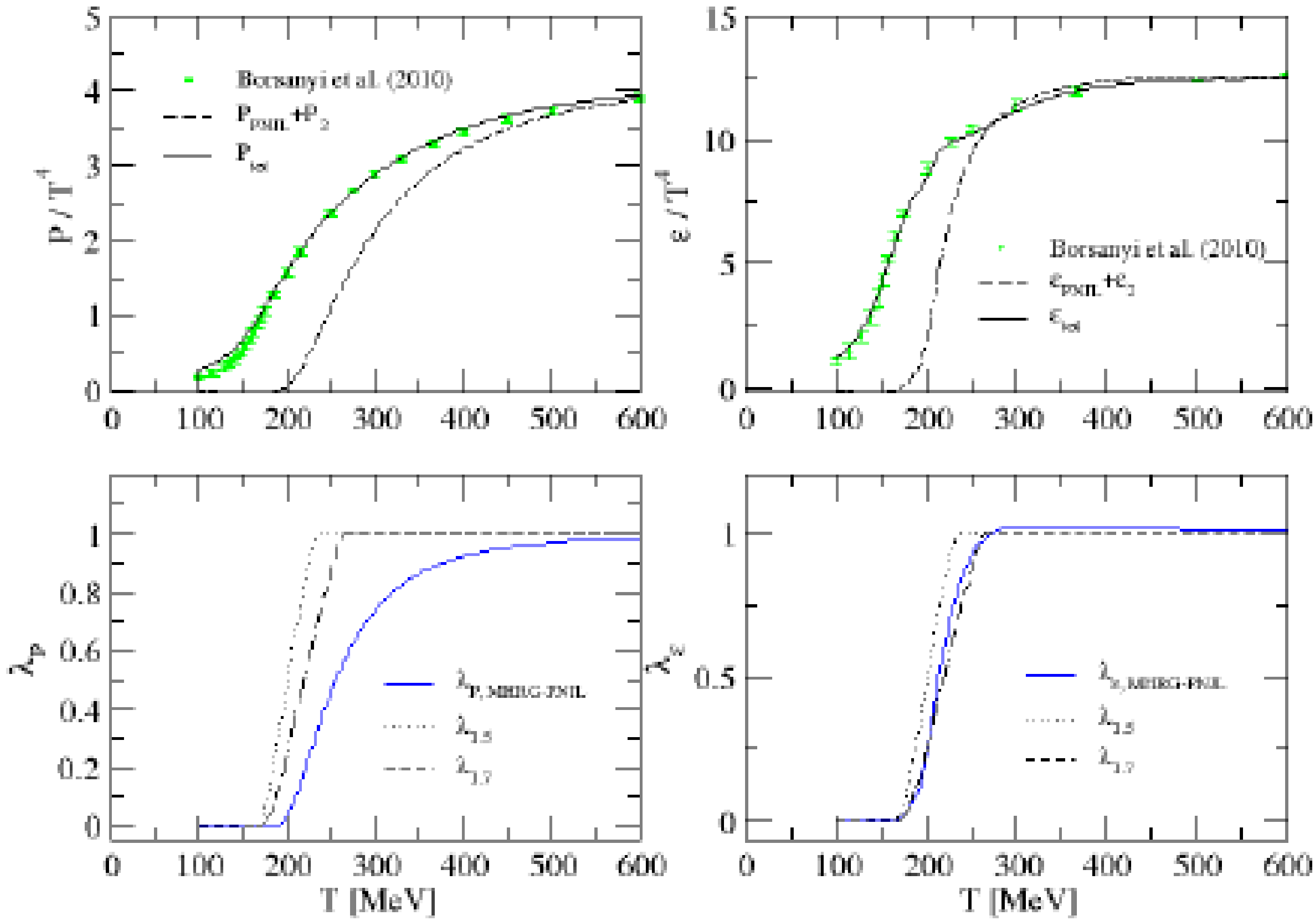
Hadron resonances present up to $T_{\rm max} \sim 250$ MeV

Blaschke & Bugaev, Fizika B13, 491 (2004)
Prog. Part. Nucl. Phys. 53, 197 (2004)
Turko, Blaschke, Prorok & Berdermann,
APPS 5, 485 (2012); J. Phys. Conf. Ser. 455, 012056 (2013)

Hadronic states above T_c ! See also: Ratti, Bellwied et al., arXiv:1109.6243 [hep-ph]

Mott Dissociation of Hadrons in Hadron Matter

Possible application: parton fraction in the EoS at the hadronization transition



L. Turko et al. "Effective degrees of freedom in QCD …", EPJ Web Conf. 71 (2014) 00134
Compare:
M. Nahrgang et al. "Influence of hadronicbound states above Tc …", PRC 89 (2014) 014004

Mott Dissociation of Mesons in Quark Matter

DB, M. Buballa, A. Dubinin, G. Roepke, D. Zablocki, Ann. Phys. (2014)

- Partition function as a Path Integral (imaginary time $\tau = i\,t$)

$$Z[T,V,\mu] = \int \mathcal{D}\bar{q}\mathcal{D}q \exp\left\{-\int^{\beta} d\tau \int_V d^3x[\bar{q}(i\gamma^\mu\partial_\mu - m_0 - \gamma^0\mu)q + \sum_{M=\pi,\sigma} G_M(\bar{q}\Gamma_M q)^2]\right\}$$

- Couplings: $G_\pi = G_\sigma = G_S$ (chiral symmetry)
- Vertices: $\Gamma_\sigma = \mathbf{1}_D \otimes \mathbf{1}_f \otimes \mathbf{1}_c$; $\Gamma_\pi = i\gamma_5 \otimes \vec{\tau} \otimes \mathbf{1}_c$
- Bosonization (Hubbard-Stratonovich Transformation)

$$\exp\left[G_S(\bar{q}\Gamma_\sigma q)^2\right] = \text{const.} \int \mathcal{D}\sigma \exp\left[\frac{\sigma^2}{4G_S} + \bar{q}\Gamma_\sigma q\sigma\right]$$

- Integrate out quark fields $\longrightarrow$ bosonized partition function

$$Z[T,V,\mu] = \int \mathcal{D}\sigma\mathcal{D}\pi \exp\left\{-\frac{\sigma^2+\pi^2}{4G_S} + \frac{1}{2}\mathrm{Tr}\,\ln S^{-1}[\sigma,\pi]\right\}$$

- Systematic evaluation: Mean fields + Fluctuations
  - Mean-field approximation: order parameters for phase transitions (gap equations)
  - Lowest order fluctuations: hadronic correlations (bound & scattering states)

Mott Dissociation of Mesons in Quark Matter

- Separate the mean-field part of the quark determinant

$$\mathrm{Tr}\,\ln S^{-1}[\sigma,\pi] = \mathrm{Tr}\,\ln S^{-1}_{\mathrm{MF}}[m] + \mathrm{Tr}\,\ln[1 + (\sigma + i\gamma_5\vec{\tau}\vec{\pi})S_{\mathrm{MF}}[m]]$$

- Mean-field quark propagator

$$S_{\mathrm{MF}}(\vec{p}, i\omega_n; m) = \frac{\gamma_0(i\omega_n + \mu) - \vec{\gamma}\cdot\vec{p} + m}{(i\omega_n + \mu)^2 - E_p^2}$$

- Expand the logarithm: $\ln(1+x) = -\sum_{n=1}^{\infty}(-1)^n x^n/n = x - x^2/2 + \ldots$
- Thermodynamic potential in Gaussian approximation

$$\Omega(T,\mu) \;=\; -T\ln Z(T,\mu) = \Omega_{\mathrm{MF}}(T,\mu) + \sum_M \Omega^{(2)}_{\mathrm{M}}(T,\mu) + \mathcal{O}[\phi^3_M]$$

$$\Omega^{(2)}_{\mathrm{M}}(T,\mu) \;=\; \frac{N_M}{2}\int\frac{d^2p}{(2\pi)^3}\frac{1}{\beta}\sum_n e^{i\nu_n\eta}\ln S^{-1}_M(\vec{p}, i\nu_n)\;,\quad N_\sigma = 1,\; N_\pi = 3$$

- Meson propagator $S_M(\vec{p}, i\nu_n) = 1/\left[1/(2G_S) - \Pi_M(\vec{p}, i\nu_n)\right]$
- Mesonic polarization loop

$$\Pi_M(\vec{p}, i\nu_n) = -\frac{1}{\beta}\sum_{n'} e^{i\nu_{n'}\eta}\int\frac{d^2k}{(2\pi)^3}\mathrm{Tr}\left[\Gamma_M S_{\mathrm{MF}}(-\vec{k}, -i\omega_{n'})\Gamma_M S_{\mathrm{MF}}(\vec{k}+\vec{p}, i\omega_{n'} + i\nu_n)\right]$$

Mott Dissociation of Mesons in Quark Matter

- Polar representation of the analytically continued quark propagator

$$S_{\rm M} = |S_{\rm M}| e^{i\delta_{\rm M}} = S_R + i S_I \ ,$$

- Phase shift $\delta_{\rm M}(\omega, \mathbf{q}) = -{\rm Im} \ln S_{\rm M}^{-1}(\omega - \mu_M + i\eta, \mathbf{q})$
- Thermodynamic potential for mesonic modes

$$\begin{aligned}\Omega_{\rm M}(T,\mu) &= {\rm Tr} \ln S_{\rm M}^{-1}(iz_n, \mathbf{q}) = d_{\rm M} T \sum_n \int \frac{{\rm d}^3 q}{(2\pi)^3} \ln S_{\rm M}^{-1}(iz_n, \mathbf{q}) \ , \\ &= -d_{\rm M} T \sum_n \int \frac{{\rm d}^3 q}{(2\pi)^3} \int_{-\infty}^{\infty} \frac{{\rm d}\omega}{2\pi} \frac{1}{iz_n - \omega} {\rm Im} \ln S_{\rm M}^{-1}(\omega + i\eta, \mathbf{q})\end{aligned}$$

- Perform Matsubara summation $\Omega_{\rm M}(T,\mu) = d_{\rm M} \int \frac{{\rm d}^3 q}{(2\pi)^3} \int_{-\infty}^{\infty} \frac{{\rm d}\omega}{2\pi} n_M^-(\omega) \delta_M(\omega, \mathbf{q})$
- Using symmetries of Bose function $n_M^-(-\omega) = -[1 + n_M^+(\omega)]$ and polarization loop

$$\Omega_{\rm M}(T,\mu) = d_{\rm M} \int \frac{{\rm d}^3 q}{(2\pi)^3} \int_0^{\infty} \frac{{\rm d}\omega}{2\pi} [1 + n_M^-(\omega) + n_M^+(\omega)] \delta_{\rm M}(\omega, \mathbf{q})$$

- Partial integration gives field theoretic Beth-Uhlenbeck formula

$$\Omega_{\rm M} = -d_{\rm M} \int \frac{{\rm d}^3 q}{(2\pi)^3} \int_0^{\infty} \frac{{\rm d}\omega}{2\pi} \left[\omega + T \ln\left(1 - {\rm e}^{-(\omega - \mu_{\rm M})/T}\right) + T \ln\left(1 - {\rm e}^{-(\omega + \mu_{\rm M})/T}\right)\right] \frac{d\delta_{\rm M}(\omega, \mathbf{q})}{d\omega}$$

Mott Dissociation of Mesons in Quark Matter

- When polarization loop integral can be expressed in the form

$$\Pi_{\rm M}(z,\mathbf{q}) = \Pi_{M,0} + \Pi_{M,2}(z,\mathbf{q})$$

- Factorization of two-particle propagator possible with $R_M(z,\mathbf{q}) = \frac{1-G_{\rm M}\Pi_{M,0}}{G_{\rm M}\Pi_{M,2}(z,\mathbf{q})}$

$$S_{\rm M}(z,\mathbf{q}) = \frac{1}{G_{\rm M}^{-1} - \Pi_{M,0} - \Pi_{M,2}(z,\mathbf{q})} = \frac{1}{\Pi_{M,2}(z,\mathbf{q})}\frac{1}{R_M(z,\mathbf{q})-1}$$

- This entails $\ln S_{\rm M}(z,\mathbf{q})^{-1} = \ln \Pi_{M,2}(z,\mathbf{q}) + \ln[R_M(z,\mathbf{q})-1]$
  and thus a separation of the phase shift in two contributions

$$\delta_{\rm M}(\omega,\mathbf{q}) = \delta_{X,c}(\omega,\mathbf{q}) + \delta_{X,R}(\omega,\mathbf{q})$$

- They correspond to continuum (state independent) and resonant phases

$$\delta_{M,c}(\omega,\mathbf{q}) = -\arctan\left(\frac{{\rm Im}\Pi_{M,2}(\omega-\mu_M+i\eta,\mathbf{q})}{{\rm Re}\Pi_{M,2}(\omega-\mu_M+i\eta,\mathbf{q})}\right)$$

$$\delta_{M,R}(\omega,\mathbf{q}) = \arctan\left(\frac{{\rm Im}R_M(\omega-\mu_M+i\eta,\mathbf{q})}{1-{\rm Re}R_M(\omega-\mu_M+i\eta,\mathbf{q})}\right)$$

Mott Dissociation of Mesons in Quark Matter

- Suppose $\delta_{X,R}(\omega, \mathbf{q})$ corresponds to a resonance at $\omega = \omega_M = \sqrt{\mathbf{q}^2 + M_{\rm M}^2}$, then the propagator shall have the representation with a complex pole at $z = z_M = \omega_M + i\Gamma_M/2$, where $\Gamma_{\rm M}$ is the width of the resonance.
- The position of the pole is found from the condition ${\rm Re}R_M(z_M, \mathbf{q}) = 1$, where $\delta_{M,R}(\omega \to \omega_M) \to \pi/2$ since $\tan \delta_{M,R}(\omega \to \omega_M) \to \infty$
- Expanding $R_M(z, \mathbf{q})$ at the complex pole z_M for small width, one obtains

$$1 - {\rm Re}R_M(z_M, \mathbf{q}) = -(\omega^2 - \omega_M^2)\frac{dR_M(z, \mathbf{q})}{d\omega^2}\Big|_{z=z_M} \quad , \quad {\rm Im}R_M(z_M, \mathbf{q}) = \omega_M \Gamma_M \frac{dR_M(z, \mathbf{q})}{d\omega^2}\Big|_{z=z_M} \quad (1)$$

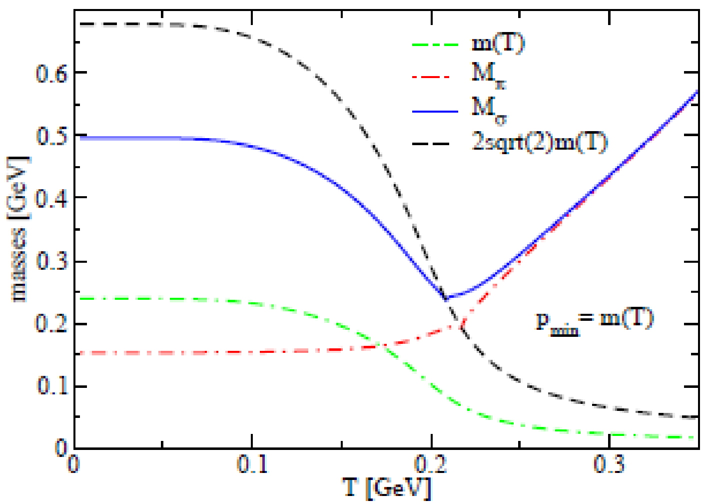
- The resonant shift becomes $\delta_{M,R}(\omega, \mathbf{q}) = -\arctan\left(\frac{\omega_{\rm M}\Gamma_{\rm M}}{\omega^2 - \omega_{\rm M}^2}\right)$ corresponding to a Breit-Wigner form of the spectral density in the Beth-Uhlenbeck EoS

$$\frac{{\rm d}\delta_{M,R}}{{\rm d}\omega} = \frac{2\omega\omega_{\rm M}\Gamma_{\rm M}}{(\omega^2 - \omega_M^2)^2 + \omega_{\rm M}^2\Gamma_{\rm M}^2} \, .$$

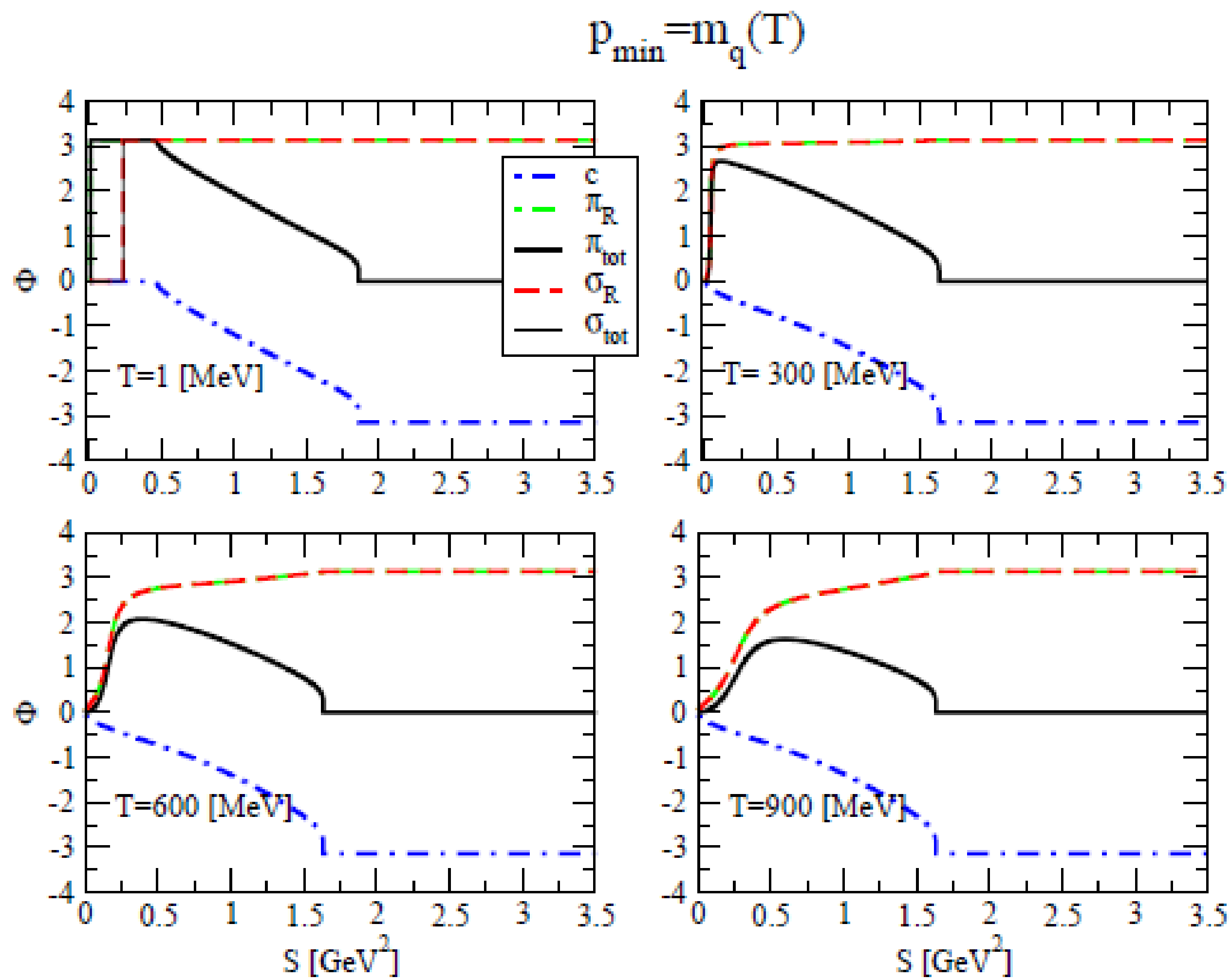
- This takes the form of a bound state spectral density for $\Gamma_M \to 0$

$$\lim_{\Gamma_{\rm M}\to 0} \delta'_{M,R}(\omega) = \pi\left[\delta(\omega - \omega_M) + \delta(\omega + \omega_M)\right]$$

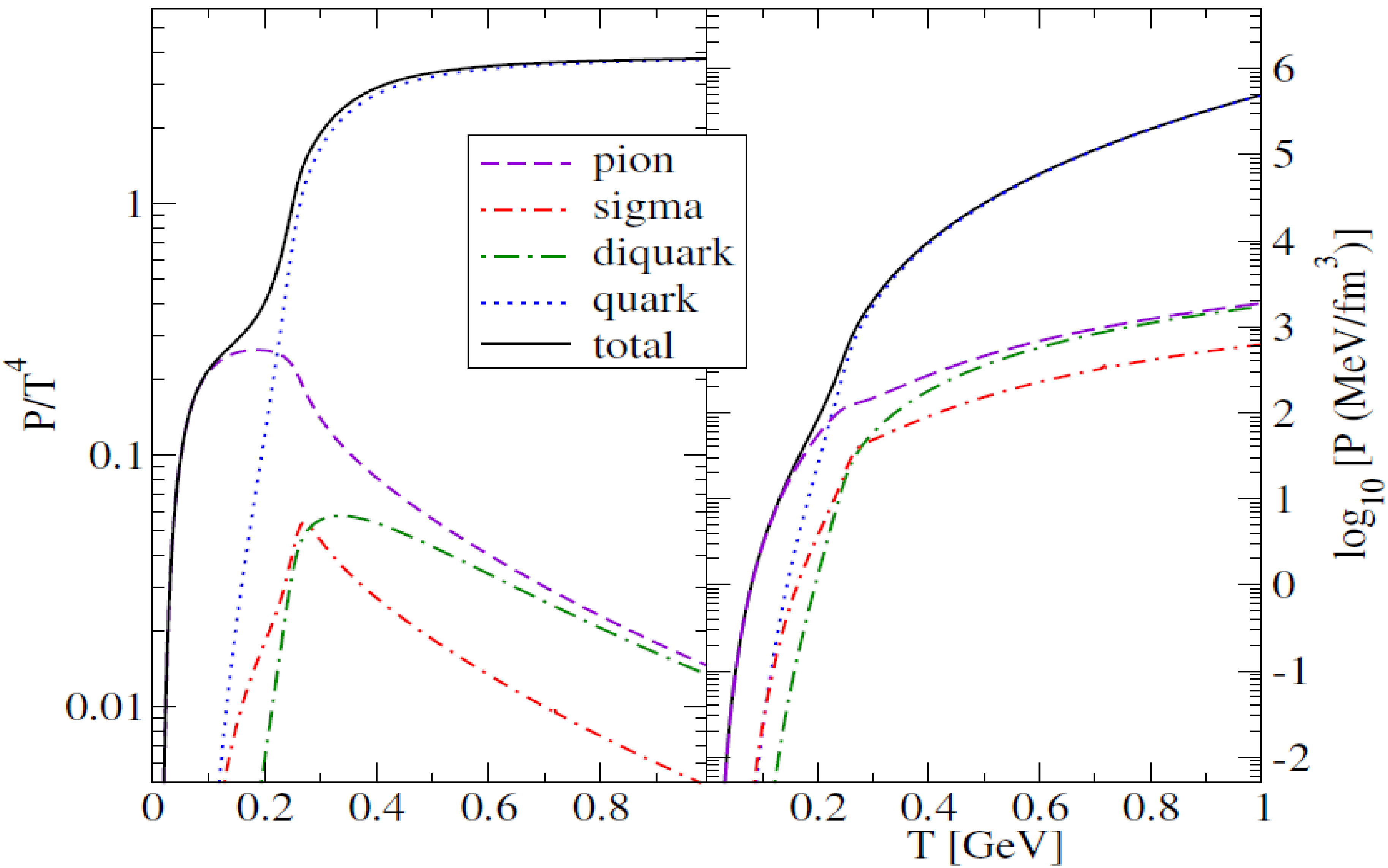
Mott Dissociation of Mesons in Quark Matter



DB, A. Dubinin, Yu. Kalinovsky, Acta Phys. Pol. Suppl. 7 (2014)



Mott Dissociation of Mesons and Diquarks in Quark Matter



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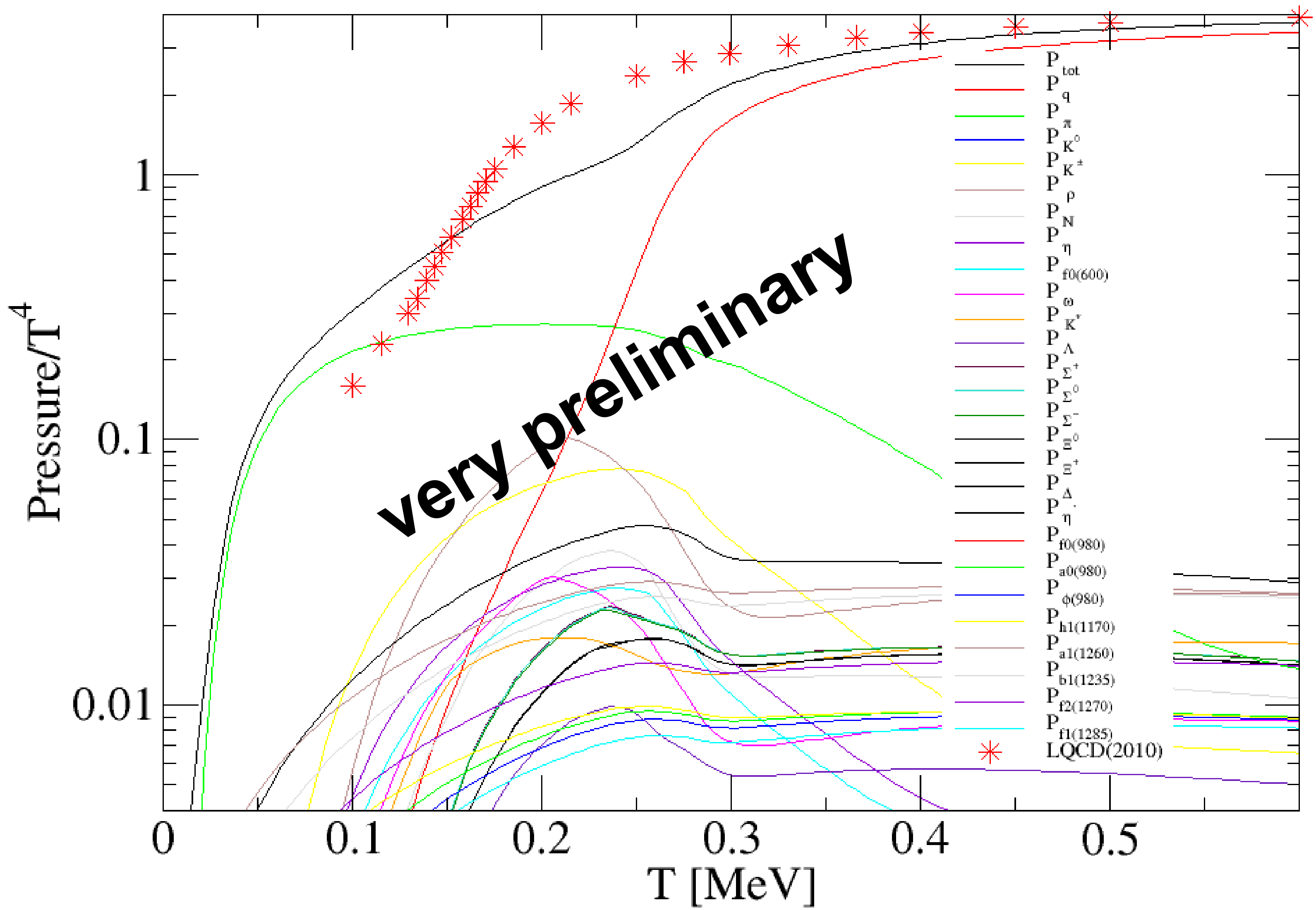
Mott Dissociation of Hadrons in Hadron Matter in a cQM

DB, A. Dubinin, in preparation (2014): Schematic Beth-Uhlenbeck model with generic phase shifts



Summary

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- Benchmark: pion and sigma Mott effect within NJL model, revised within nonlocal PNJL model
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Outlook

- RMF (Walecka) model as limit of the PNJL model: chiral transition effects in nuclear EoS
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TOPICS

STRANGENESS and heavy QUARK production in nuclear collisions
Hadronic INTERACTIONS
Bulk MATTER PHENOMENA associated with strange and HEAVY quarks
Strangeness in astrophysics
OPEN questions and NEW developments

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Solving the Puzzles of Compact Star Interiors

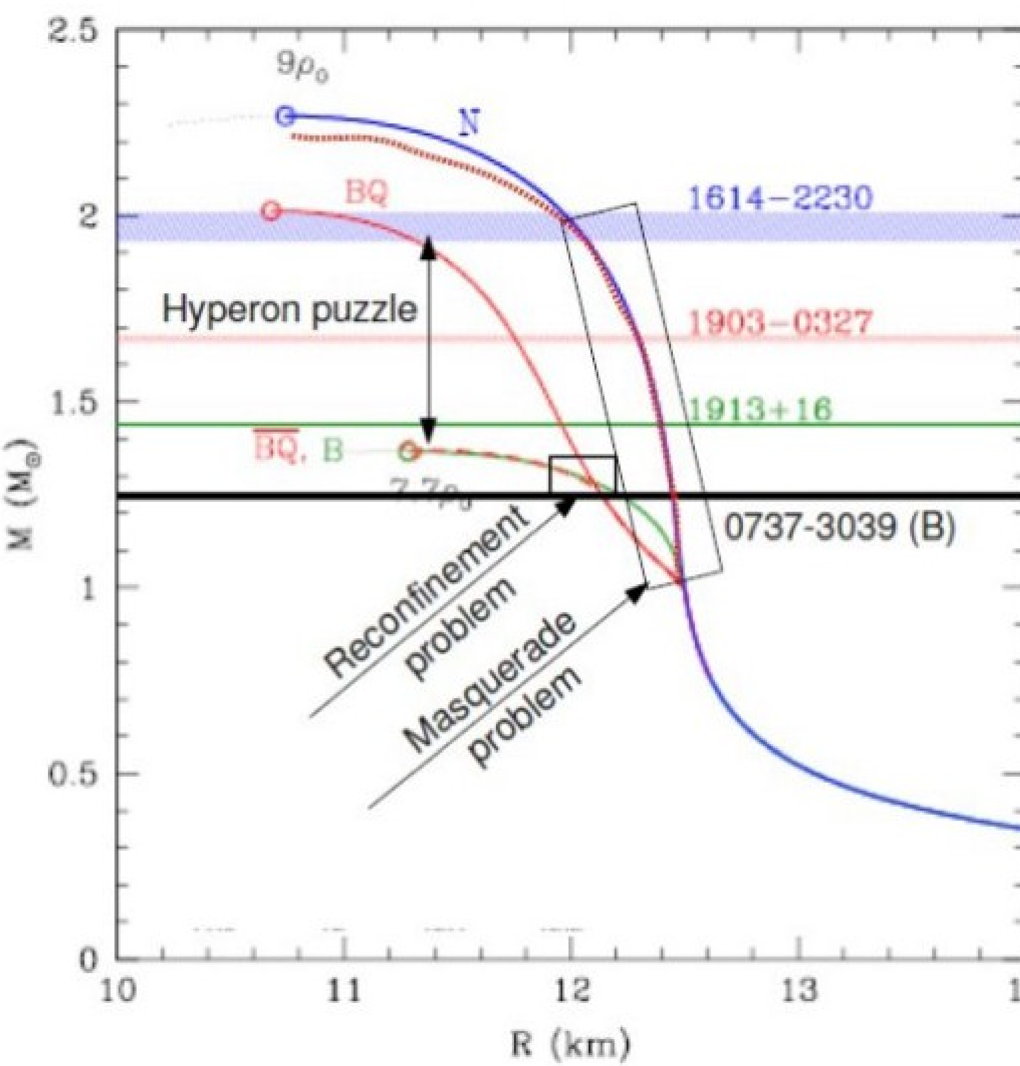
David Blaschke (University of Wroclaw, Poland & JINR Dubna, Russia)

1. The Puzzles:
- Hyperon puzzle
- Reconfinement
- Masquerade

2. The Solution:
Baryon finite size (compositenes
→ Excluded volume Appr. (EVA)

3. The Mechanism:
Quark Pauli Blocking

4. Outlook:
- High-Mass Twins (next talk)
- Supernova explosion mechanis



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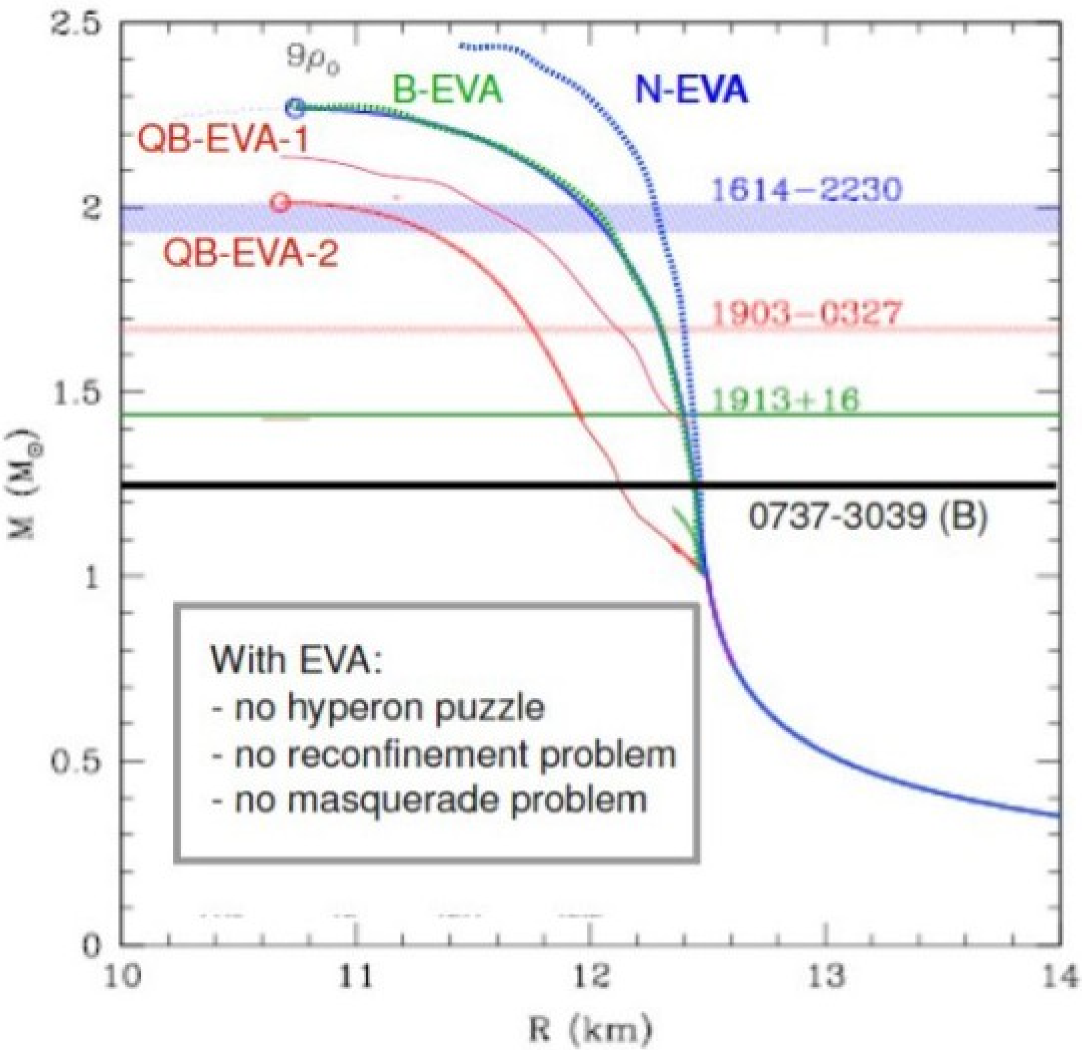

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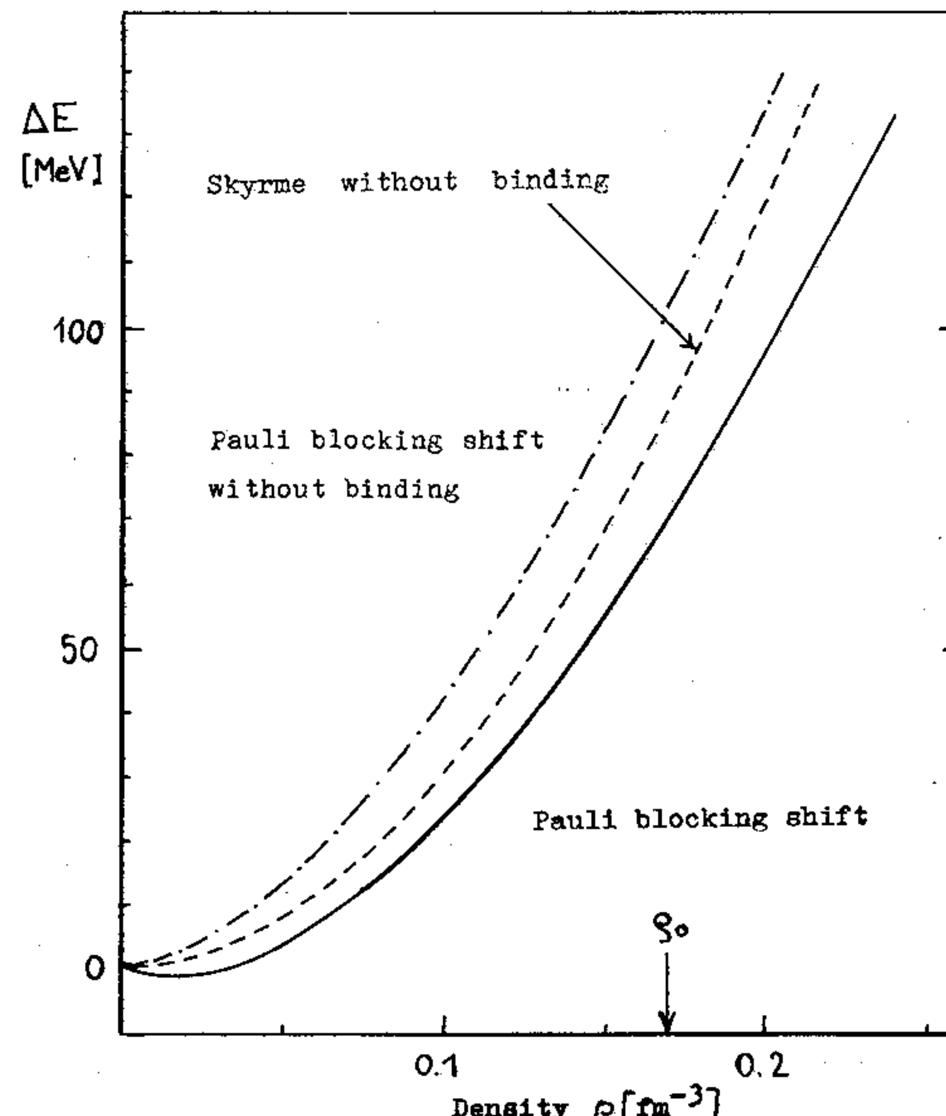

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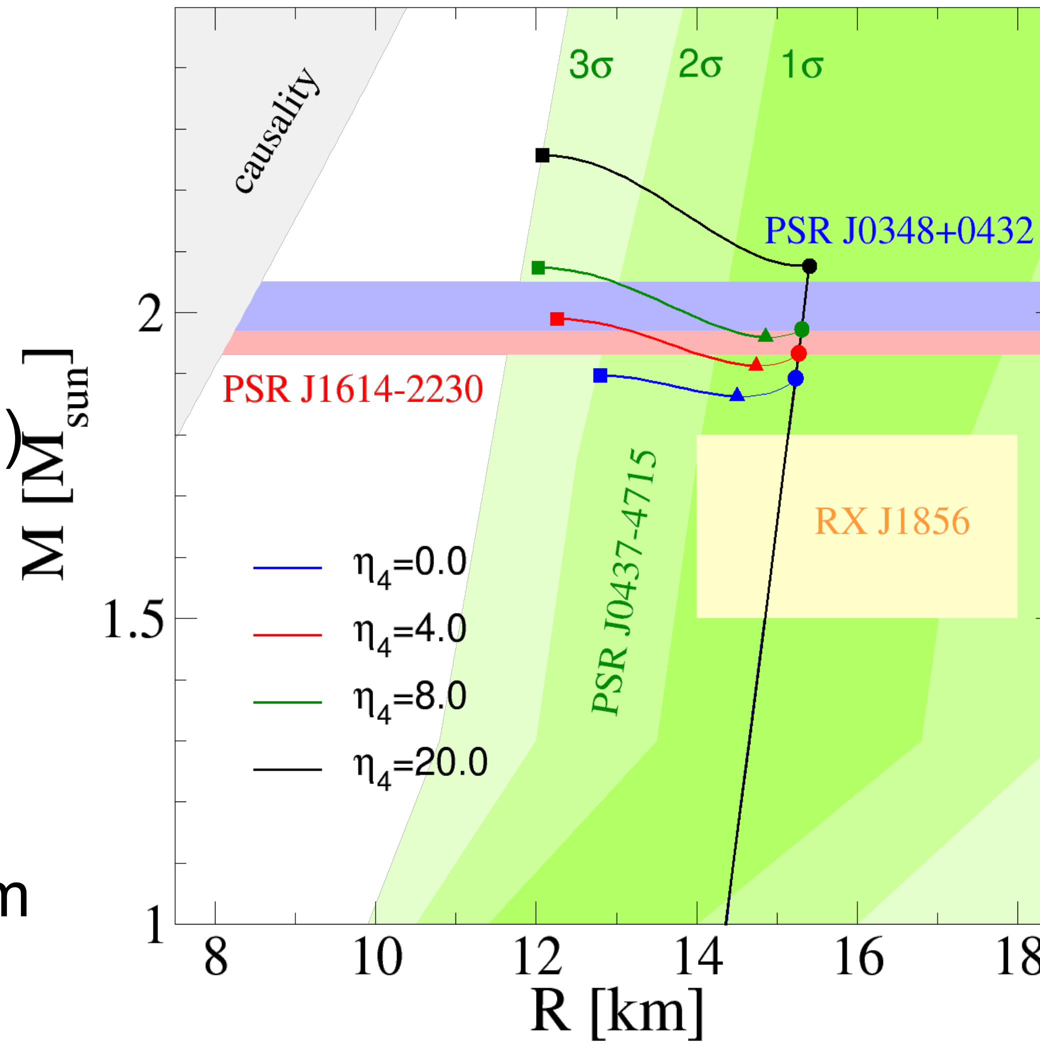

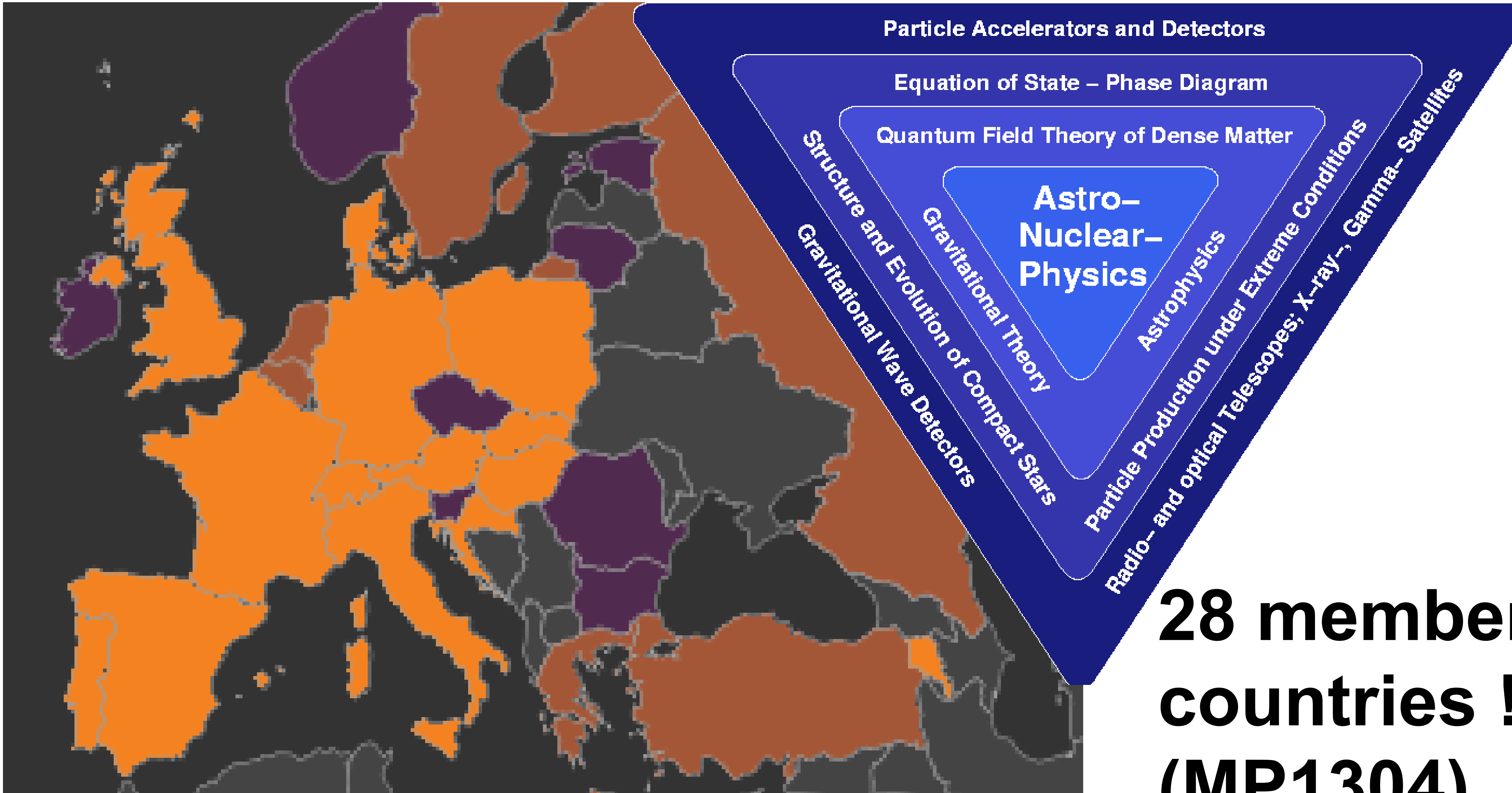

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