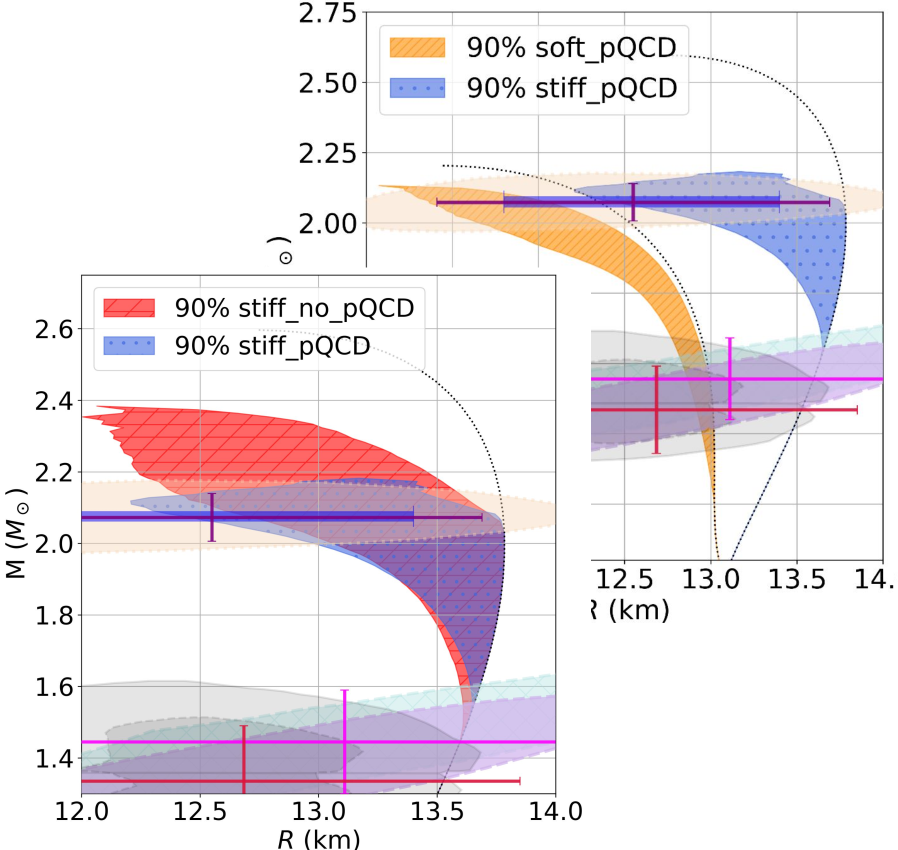
Hybrid Stars: Bayesian Approach with NJL

Milena Albino, Constança Providência, Tuhin Malik, Márcio Ferreira

- **Aims:**
  - investigate quark matter inside neutron stars using Bayesian inference;
  - analyze effects of pQCD calculation in neutron stars.
- **Model:**
  - **quark phase:** Nambu-Jona-Lasinio (NJL) with 5 different interaction terms;
  - **hadron phase:** Relativistic Mean Field (RMF);
  - **phase transition:** Maxwell transition.



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FCT Fundação para a Ciência e a Tecnologia
MINISTÉRIO DA CIÊNCIA, TECNOLOGIA E ENSINO SUPERIOR

Introduction to Berry Phase and Pair Production

Levon Asatryan
Student of

"Quantum and mesoscopic physics" in the master's degree program at the International Scientific-Educational Center Institution 'Pan-Armenian Center for Excellence”

Armenia Yerevan

Supervisor
David Blaschke
Colaboration with
Biplab Mahato

BAYESIAN ANALYSIS OF THE DENSE MATTER EQUATION OF STATE

Alexander Ayriyan

Institute of Theoretical Physics, University of Wrocław

Bayes' theorem:

$$\underbrace{p(H_1 \mid D, I)}_{\text{Posterior}} = \frac{\overbrace{p(D \mid H_1, I)}^{\text{Likelihood}}\,\overbrace{p(H_1 \mid I)}^{\text{Prior}}}{\underbrace{p(D \mid I)}_{\text{Evidence}}}$$

Hypothesis (H1 = EoS parameter set 1)

Prior: knowledge before experiment (logically)
Likelihood: Probability for data if the hypothesis was true
Posterior: Probability that the hypothesis is true given the data
Evidence: normalization; important for model comparison

Prior

EoS parameters
- Coupling constants
- CEP location
- Onset density
- etc.

→

Likelihood

Simulation of HIC and Astro phenomena

Comparison results with available data

→

Bayes theorem

→

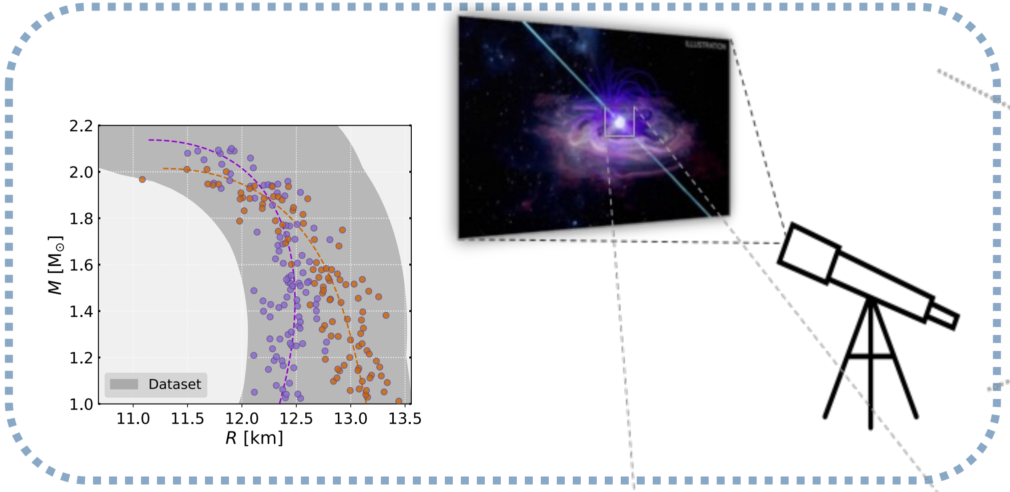
Posterior

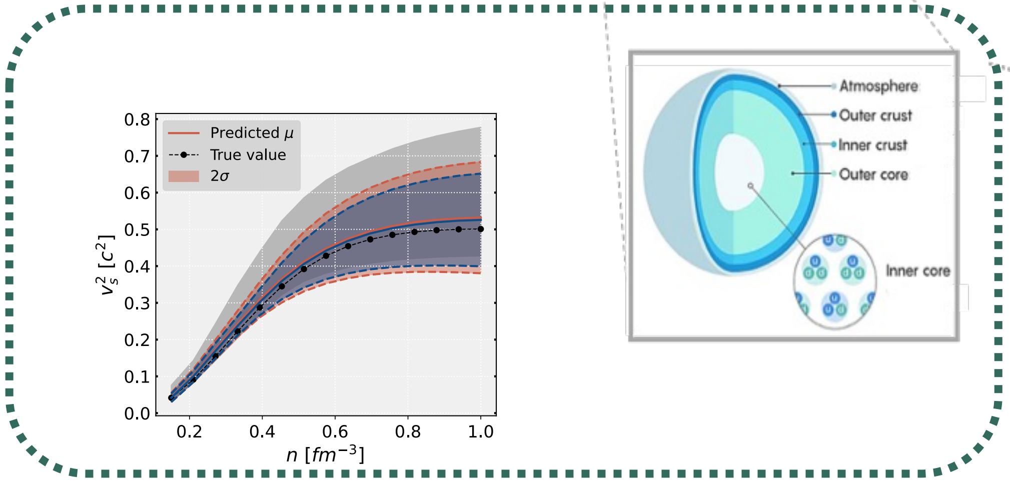
Refinement of EoS: measure effects on QCD phase diagram phenomenology

Do Neutron Stars give us nuclear matter properties?

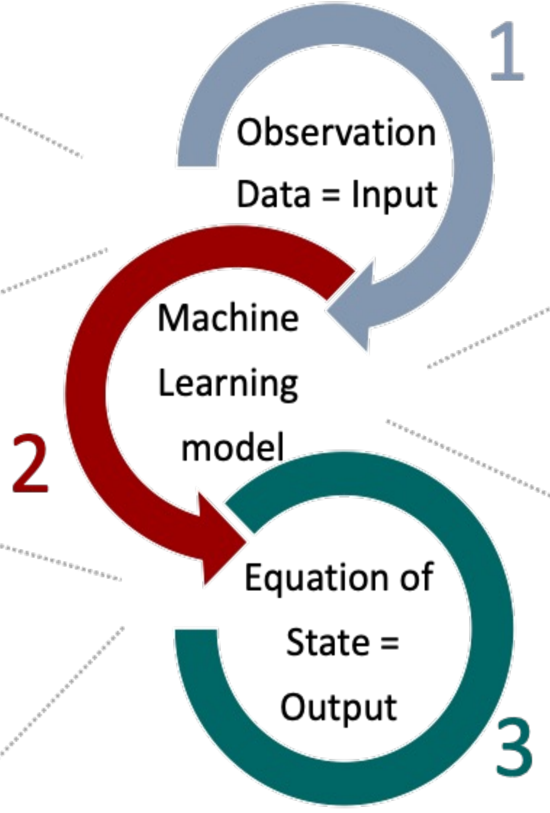
Karpacz School 2024

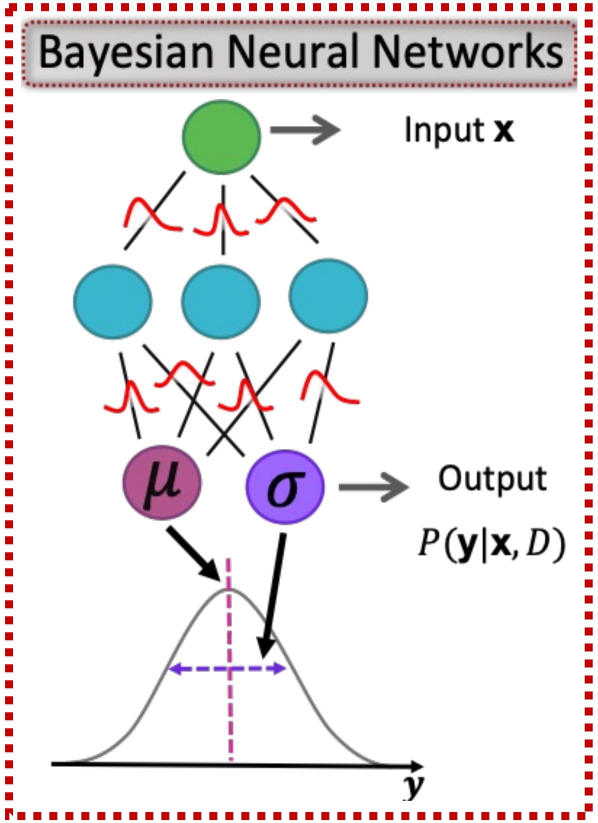
Machine Learning answers





PRD 108, 043031 (2023)





Valéria Carvalho, Márcio Ferreira, Constança Providência

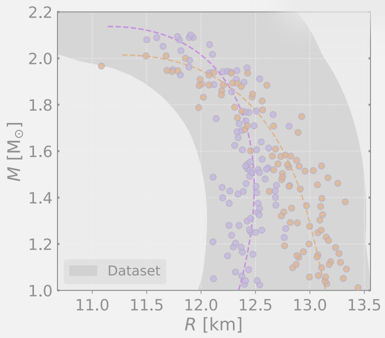
Do Neutron Stars give us nuclear matter properties?

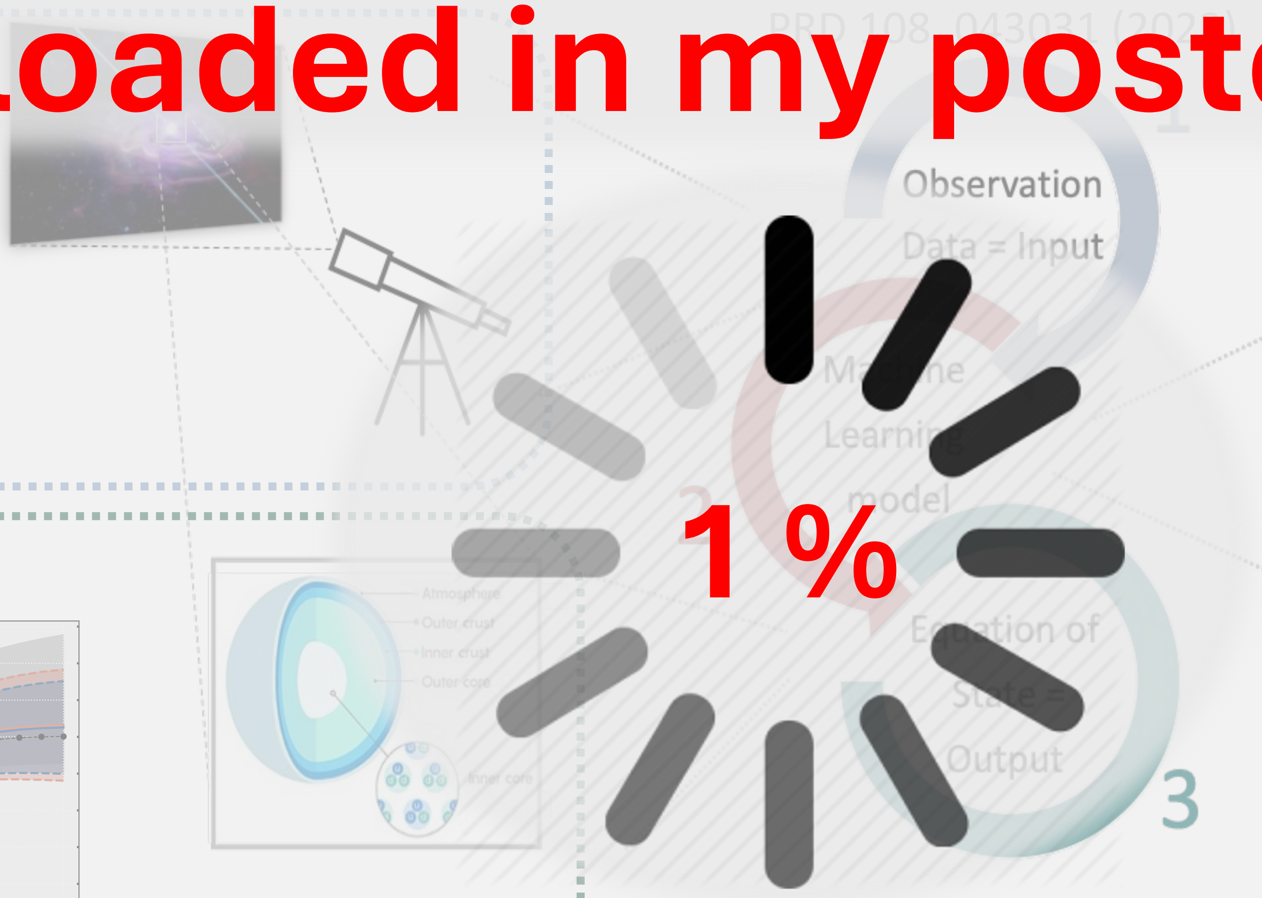
Karpacz School 2024

Machine Learning answers

PRD 108, 043031 (2023)

More information can be loaded in my poster ...





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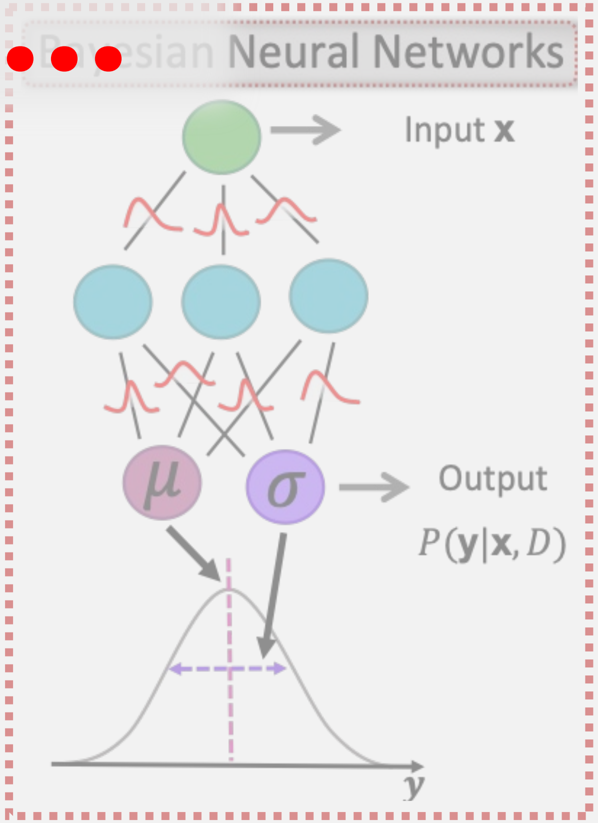

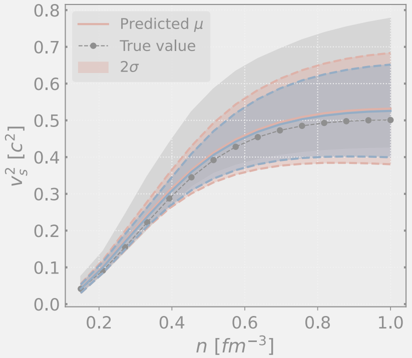

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Light Nuclei in hot stellar matter:
calibrating their nuclear couplings using heavy-ion collisions data

- **Tiago Custódio**, 2nd year PhD student

⇒ University of Coimbra, Portugal

⇒ LPC, Caen, France

- **Poster**

⇒ New calibration of **nuclear couplings** using experimentally measured **particle abundances** (INDRA collaboration)

⇒ Consequences on light nuclei **abundances** for **larger temperatures**

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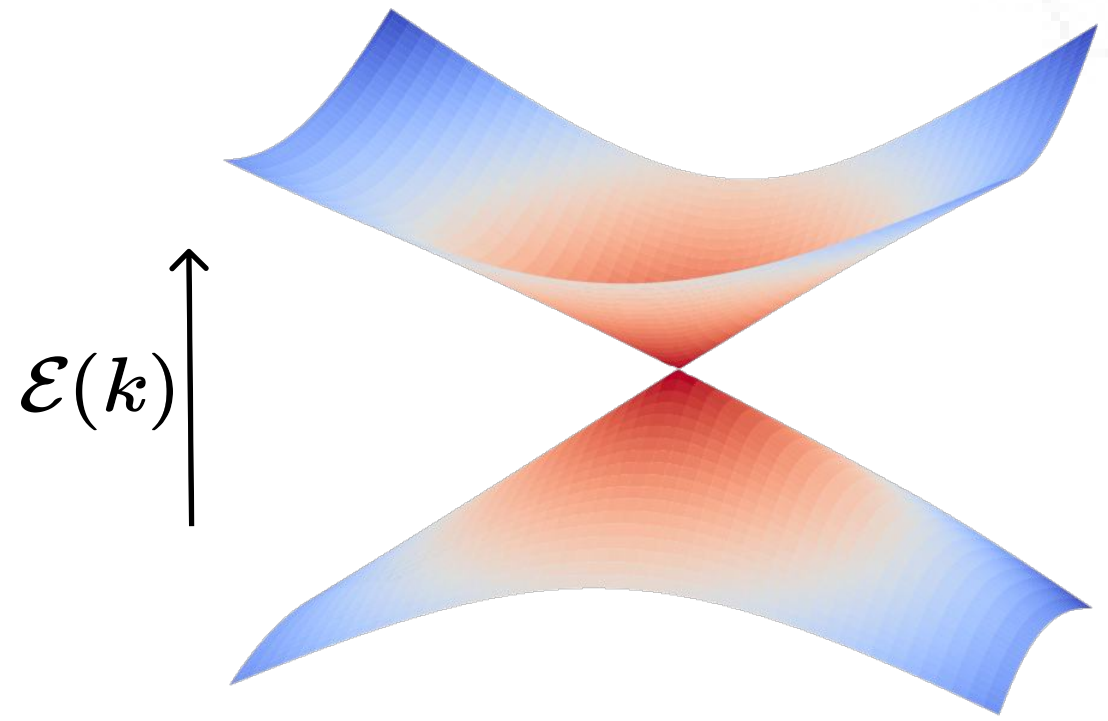
lpc caen Laboratoire de physique corpusculaire

Graphene Motivated 2+1 Dimensional Generalised Gross-Neveu Model

Biplab Mahato



- Graphene is a two dimensional material with hexagonal lattice structure.
- Near Dirac points, the theory can be described by massless Dirac fields.
- In analogy with NJL model and plausible interaction in graphene we generalise the Gross-Neveu model in 2+1 dimension.
- Mean Field Approximation
- Beyond MFA via Beth-Uhlenbeck approach.
- Applications.?

The effect of late-time heating in hybrid millisecond pulsars

Pavlo Panasiuk, Violetta Sagun[1], Oleksii Ivanytskyi[2], Koichi Hamaguchi[3], Natsumi Nagata[3]

[1]University of Coimbra, [2]University of Wroclaw, [3]Tokyo University

- NS cooling is an EoS observable
  - Descriptions has been successful
- Old MSPs do not fit the classical cooling
  - Heating mechanism must cancel photon contribution
- Rotochemical heating term may explain
  - Rotational rate decreases -> star contracts -> local perturbation of the chemical equilibrium
- We simulated RH with **realistic hybrid** EoS
  - *Reasonably distinct cooling lines between hadron vs hadron-quark composition*
  - *Rotochemical heating presents a viable mechanism for late-time heating*

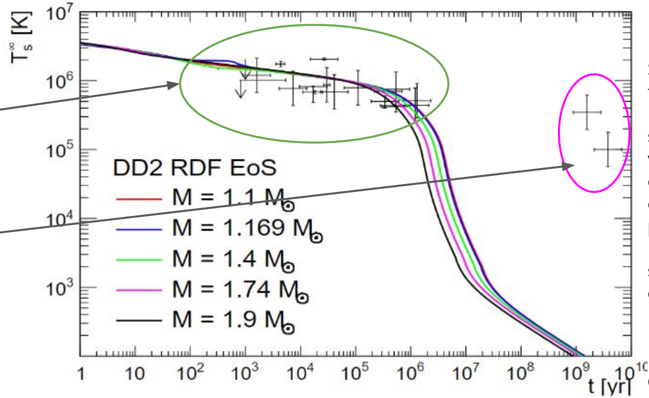
Time evolution of red-shifted temperature

$$C_V \frac{dT^\infty}{dt} = -L_\nu^\infty - L_\gamma^\infty +^? L_H^\infty$$

C_V - total heat capacity of the NS

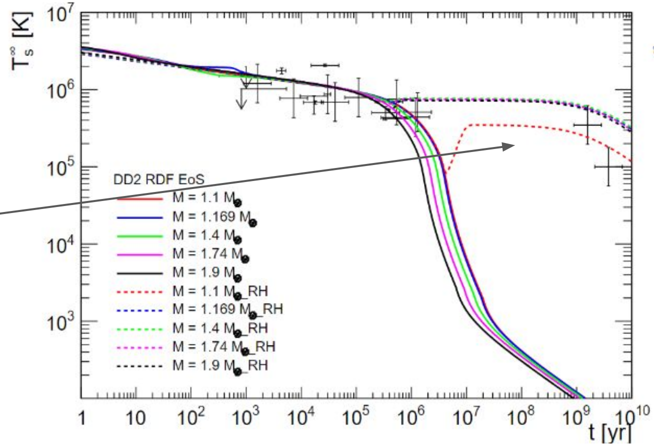
L_ν^∞ - neutrino red-shifted luminosity

L_γ^∞ - photon red-shifted luminosity.



Surface temperature of PSR objects superimposed with the classical cooling, prescribed by DD2-RDF EoS suppressed quarks.

Onset mass: 1.13 Solar



Same, with rotochemical heating enabled with MSP settings.

> *Pavlo Panasiuk et al (2024). Rotochemical heating in hybrid compact objects (IN PREPARATION)*

Exploring Neutron Star's Potential to Constrain the Mass of Bosonic Dark Matter

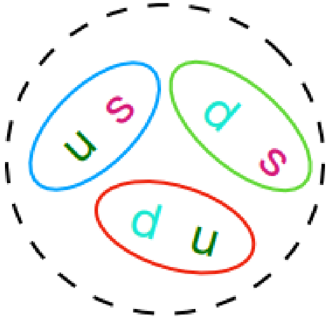
Mahboubeh Shahrbaf

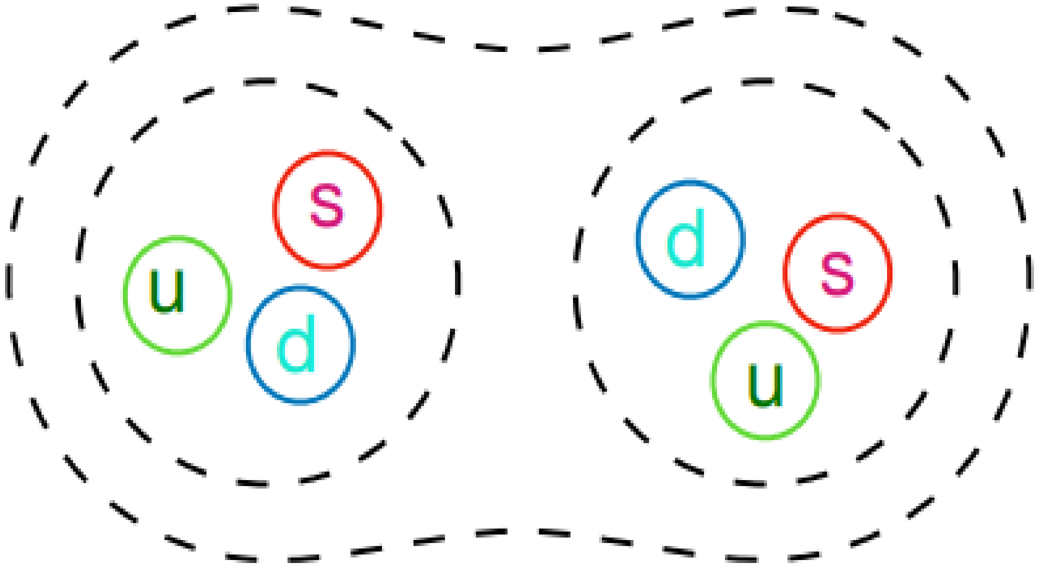
Institute of Theoretical Physics, University of Wroclaw

60th Karpacz Winter School on Theoretical Physics & WE-Heraeus Physics School

21 May 2024

Sexaquark vs H-Dibaryon





How would it behave under extreme conditions of Neutron Stars?
What would be the possible mass range as a Dark Matter Candidate?

Violation of Bell Inequalities on Quantum Computers

IBM Quantum System 1

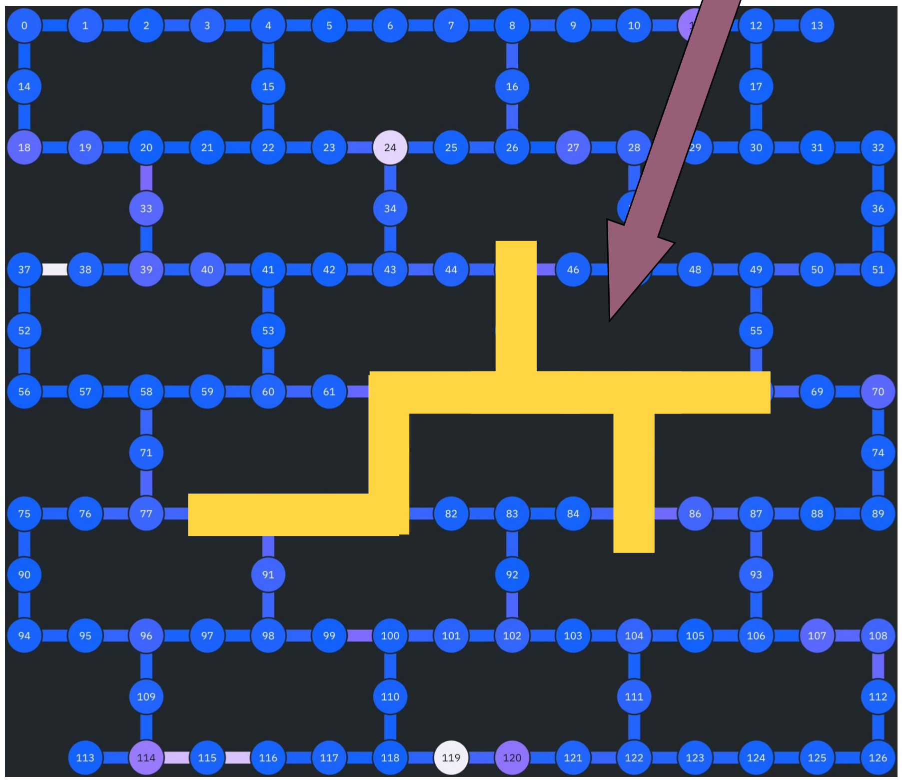
https://www.ibm.com/quantum/technology

Graph state

Graph inequality

Test it on a quantum computer

Graph



Example of a qubit layout

https://quantum.ibm.com/services/resources?system=ibm_brisbane

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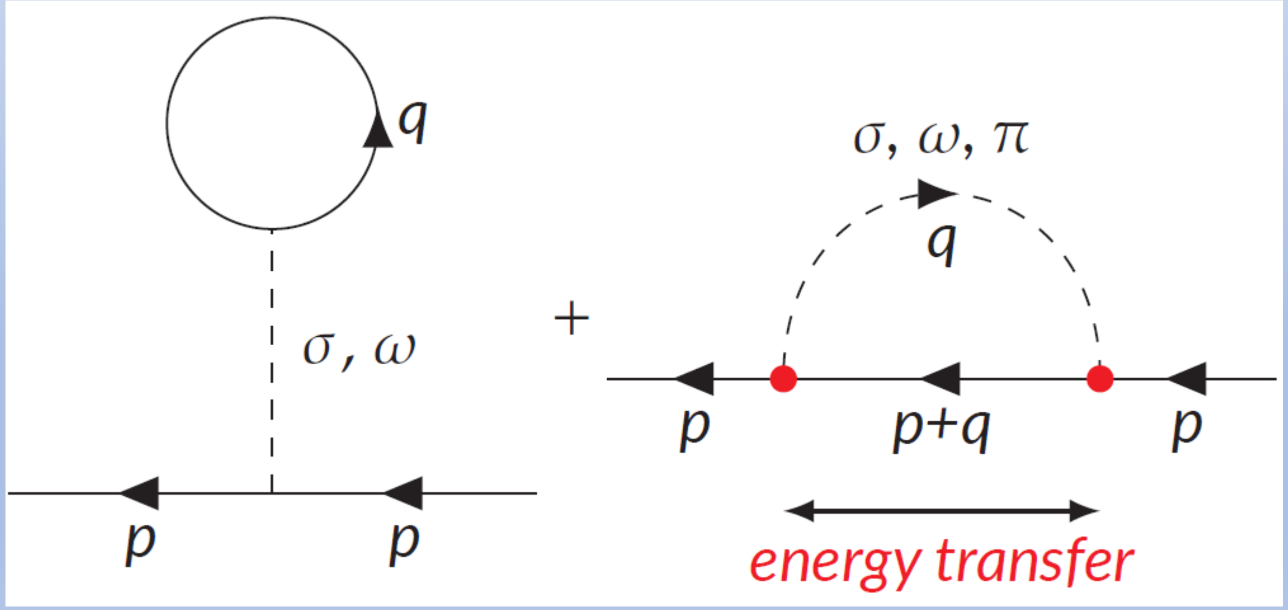
Infinite nuclear matter within the relativistic Hartree-Fock (HF) approximation

Role of pions and retardation

Kamil Sokołowski, Tobias Fischer

University of Wroclaw



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Zubarev Meets Bayes: Non-Equilibrium Pion Distribution Function in Heavy-Ion Collisions

Oleksandr Vitiuk[1], David Blaschke[1,2,3], Benjamin Dönigus[4], Gerd Röpke[5]

[1]University of Wroclaw, [2]HZDR, [3]CASUS, [4]University of Frankfurt, [5]University of Rostock

Motivation

The data provided by the ALICE Collaboration show an enhancement of the the low-p_T part of pion transverse momentum spectra with respect to the predictions of various models.

Model for Pions in Ultrarelativistic Heavy-Ion Collisions

- A state overpopulated by soft pions is formed at $\tau < \tau_\pi^{CFO}$
- For $\tau_\pi^{CFO} < \tau < \tau_\pi^{FO}$ the total pion number is dynamically fixed
- Zubarev approach + pion number as a good relevant observable

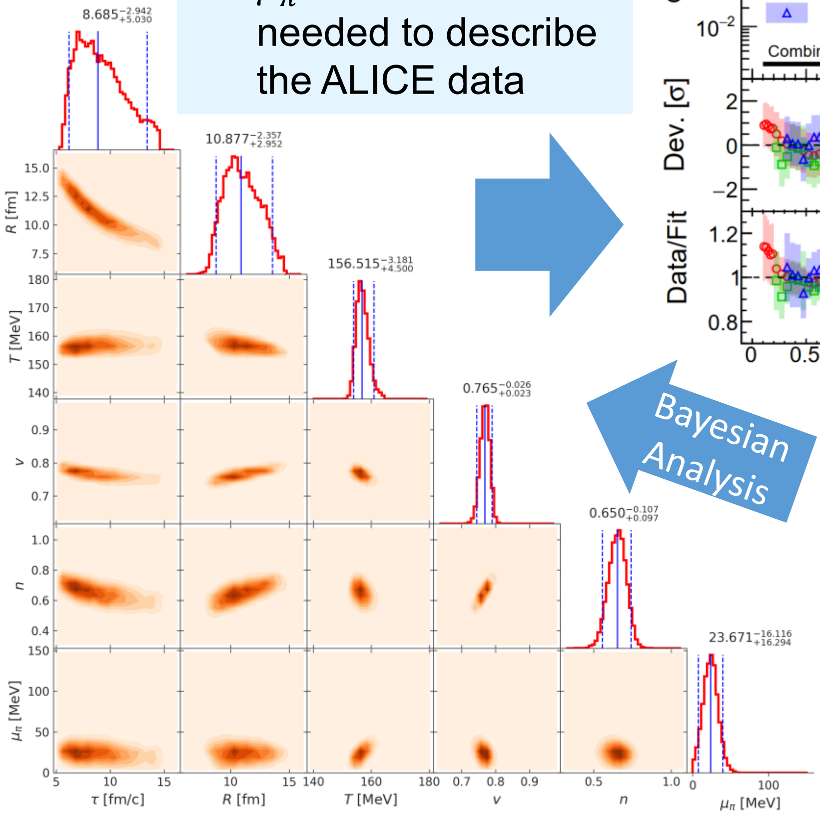
$$f_\pi = \left(\exp\left[\frac{E}{T}\right] - 1\right)^{-1} \Rightarrow f_\pi = \left(\exp\left[\frac{E-\mu_\pi}{T}\right] - 1\right)^{-1}$$

Blast-Wave Model of Particle Freeze-Out

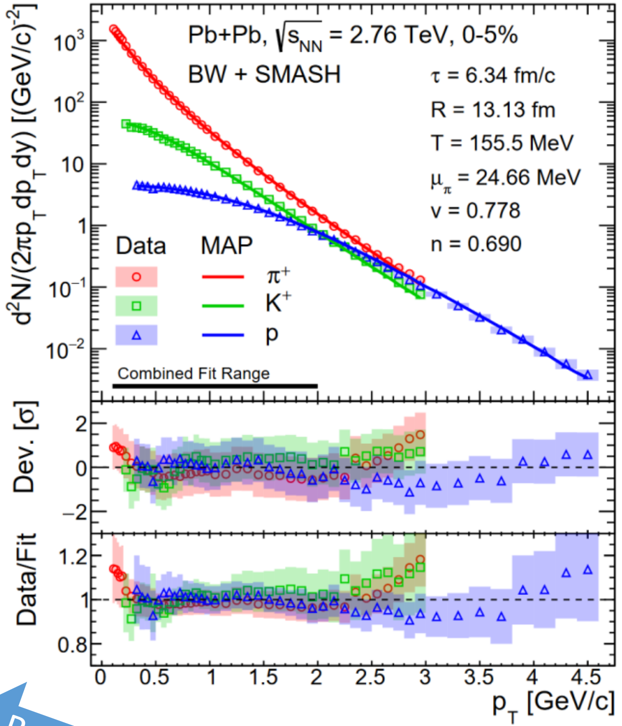
Freeze-out on the cylindrical boost-invariant hypersurface with boost invariant longitudinal expansion and the radial flow $\beta_T = v(r/R)^n$.

$$\frac{d^6 N_i}{dp_T dy d\psi dr d\eta d\varphi} \propto \tau r p_T m_T \cosh(y-\eta) \times \left(\exp\left[\frac{m_T \cosh\rho \cosh(y-\eta) - p_T \sinh\rho \cos(\varphi-\psi) - \mu_i}{T}\right] \pm 1\right)^{-1}$$

- The non-equilibrium pion production leads to the appearance of a non-equilibrium μ_π within the Zubarev approach
- $\mu_\pi \simeq 24$ MeV is needed to describe the ALICE data



Bayesian Analysis



BW based thermal particle generator + smash

oleksandr.vitiuk@uwr.edu.pl