CompStar

WG2/TL2

Low energy QCD and Superdense Matter

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Lyon, France, 18th November 2014

WG2/TL2

Open Questions of the field by MoU:

1. What are the transport properties of hot/cold dense matter?
2. What is the role of the equation of state in core-collapse supernovae?
3. What is the role of the equation of state in binary neutron star mergers?
4. Are binary neutron star mergers behind short gamma-ray bursts (GRBs)?
5. How does the equation of state influence pulsar/magnetar dynamics?
6. How can observations of neutron stars (isolated or in binaries) constrain the EoS?
7. How do matter properties change under extremely strong electromagnetic fields?
8. How can neutron stars be used to test general relativity and other theories of gravity?

WG2/TL2

It is mainly about how EoS of the extreme matter works:

1. What are the transport properties of hot/cold dense matter?
2. What is the role of the equation of state in core-collapse supernovae?
3. What is the role of the equation of state in binary neutron star mergers?
4. Are binary neutron star mergers behind short gamma-ray bursts (GRBs)?
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8. How can neutron stars be used to test general relativity and other theories of gravity?

WG2/TL2

The Big Picture (WG2):

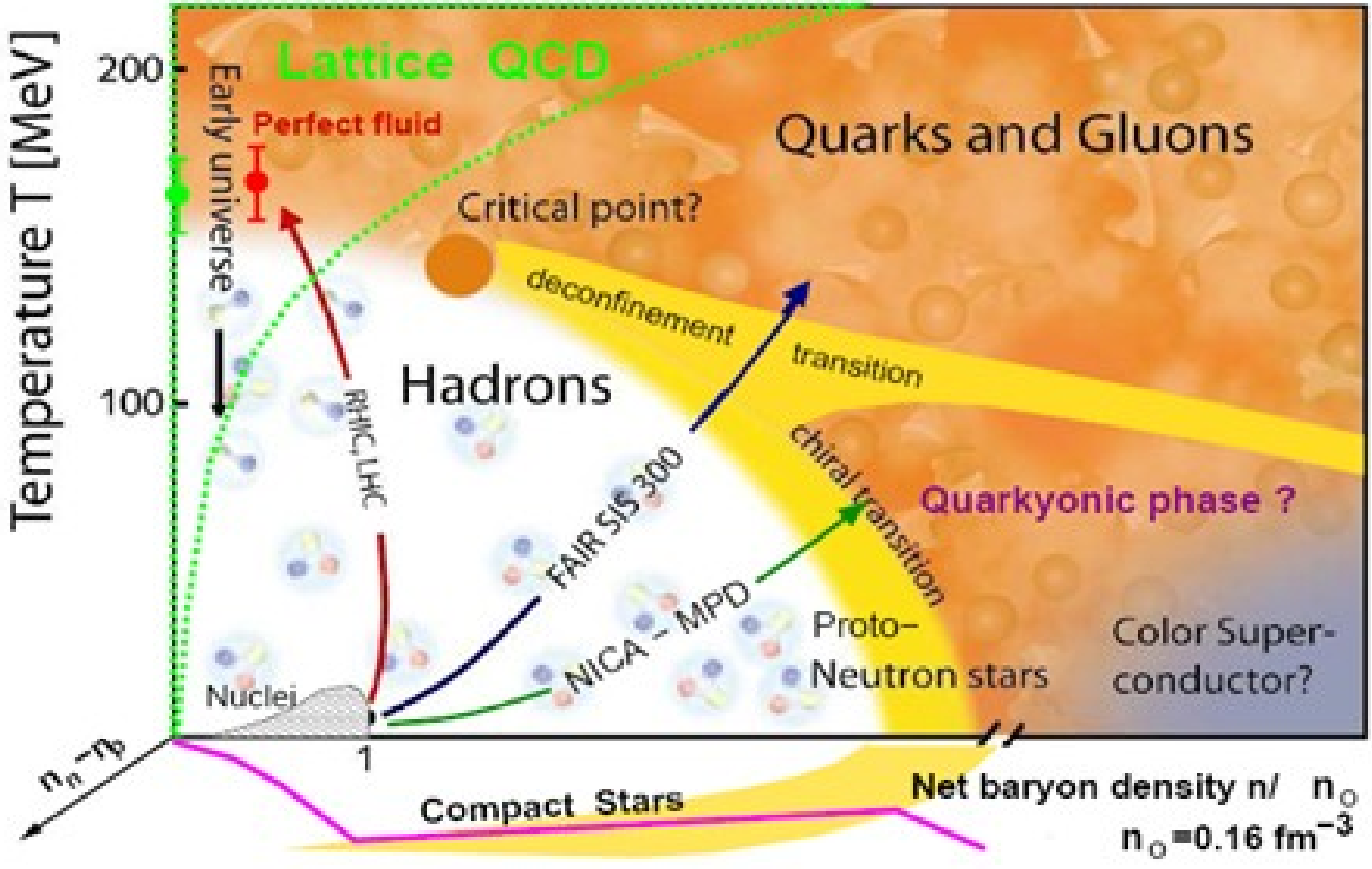
The physics of the strong interaction, theory and experiment

The Small Picture (TL2):

Investigate the predictions for the phase diagram of hot and dense matter, clarifying the role of phase transitions and exotic degrees of freedom predicted by nuclear physics and low-energy QCD.

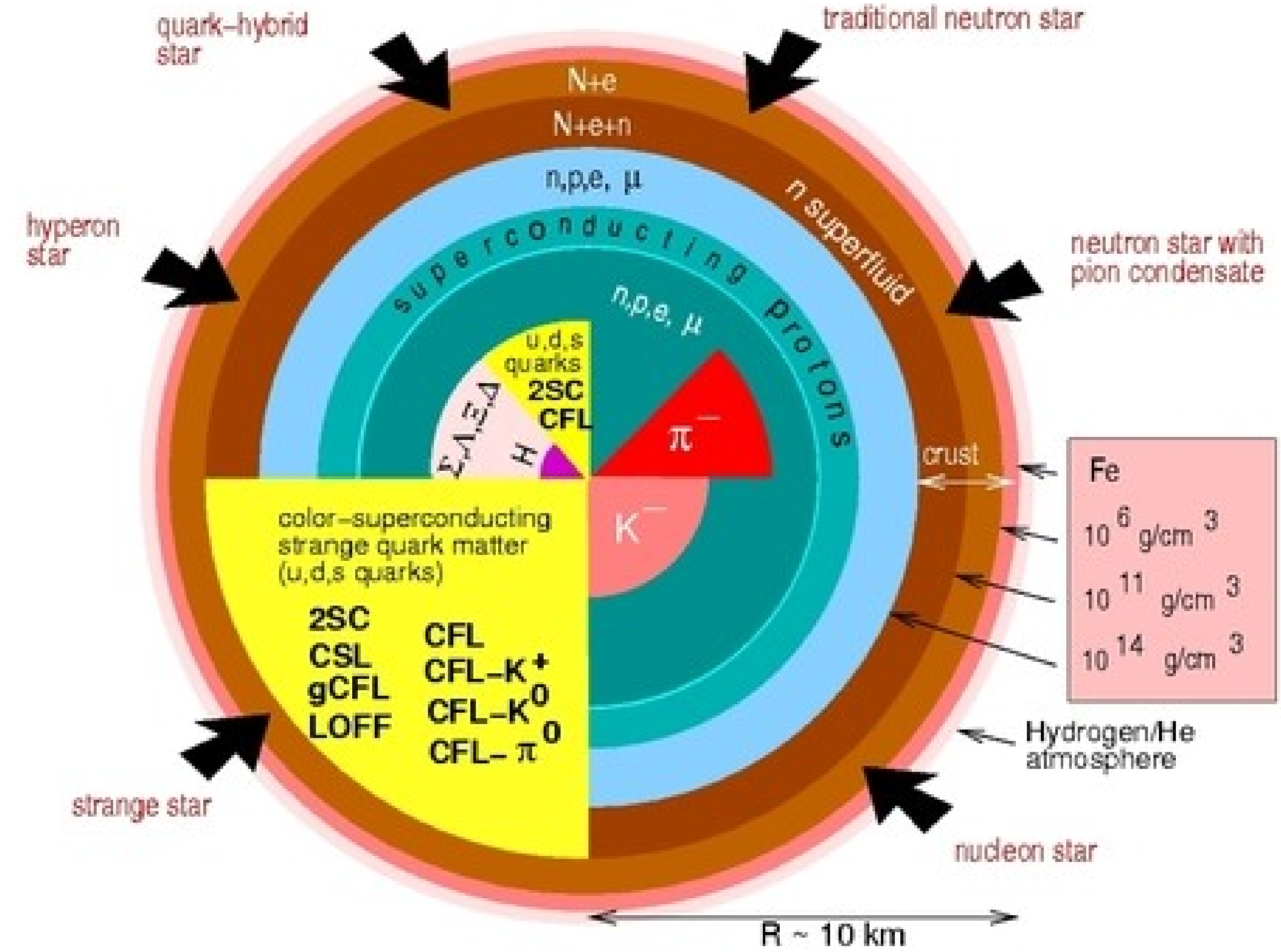
WG2/TL2

Which is generally all about this Big Picture…



WG2/TL2

Or how can we make the circle from the square...



OUTLINE

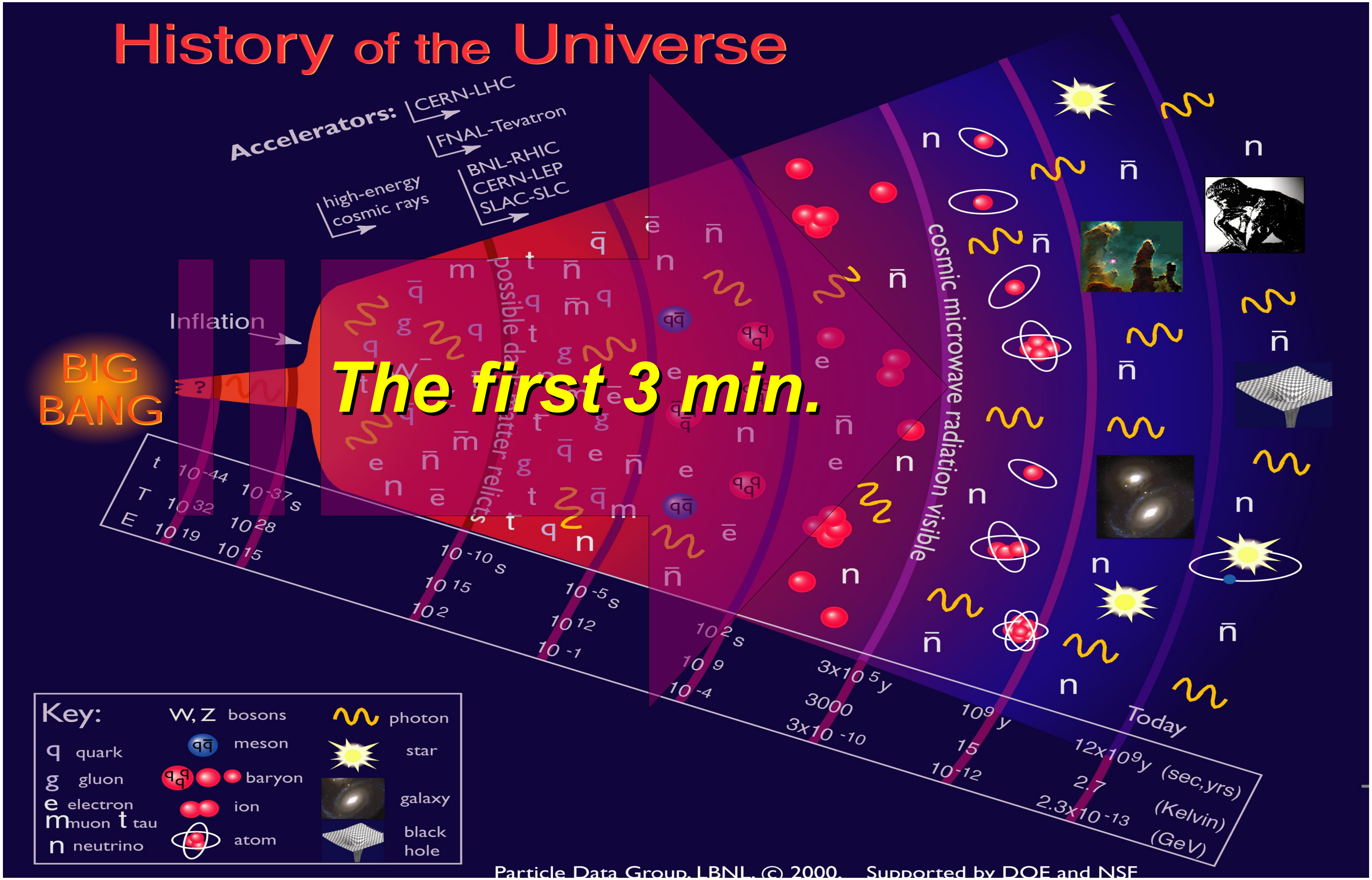
- Experimental observation of QCD phase diagram
  - Observation so far (SPS, RHIC, LHC)?
  - Facilities of the near/far future
  - Resources for future numerical calculations

- General trends in QCD theory
  - Investigations of the QCD phase diagram
  - Lattice QCD results
  - Future theoretical developments

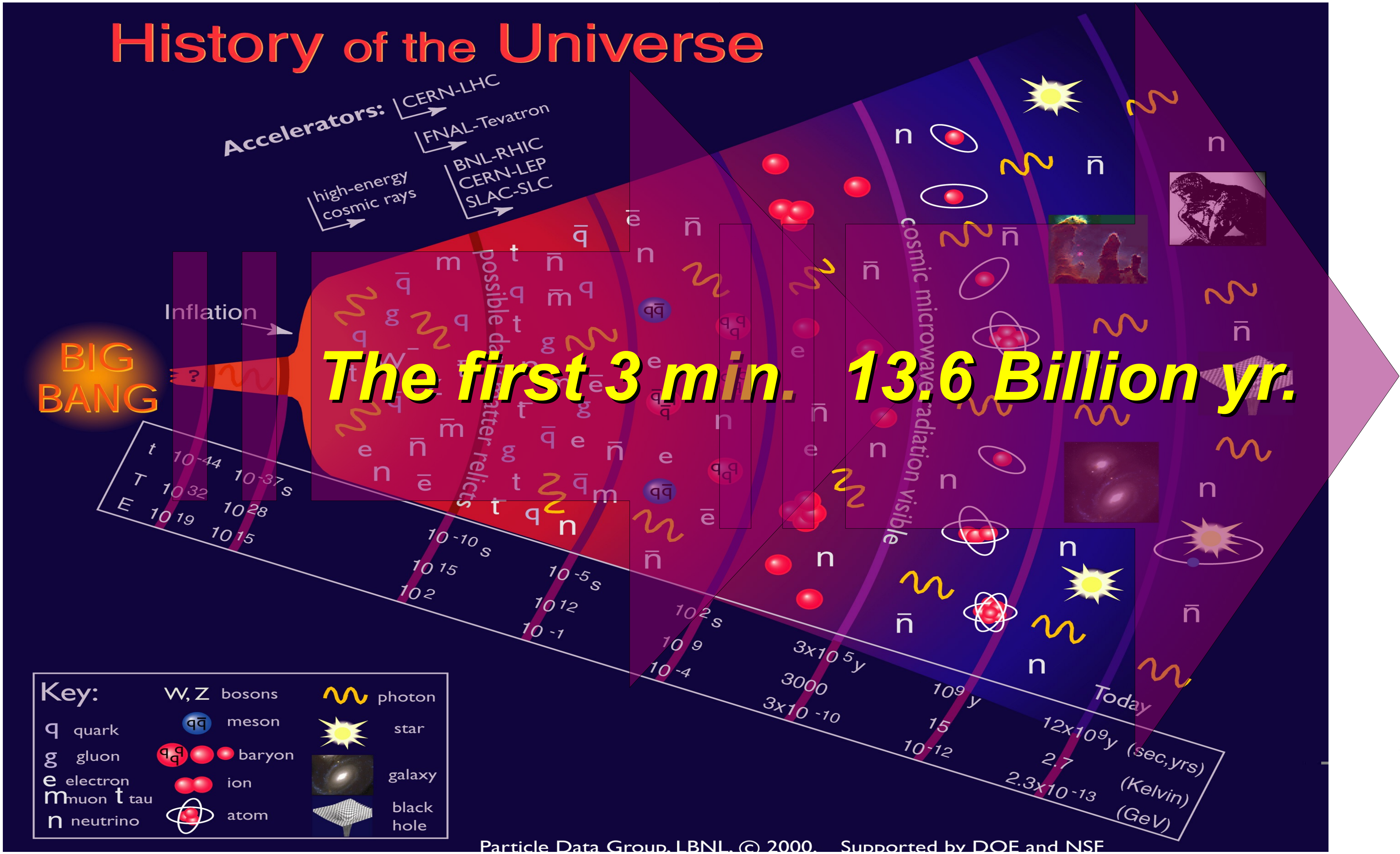
OUTLINED QUESTIONS

- Experimental observation of QCD phase diagram
  - Beam energy scans (playing with the temperature)
  - Variable size collisions (playing with energy density)
  - How can we make constraints from the high T and μ?
- General QUESTIONS in QCD theory
  - Lattice at finite chemical potential: can we calculate?
  - Hyperon puzzle: how to reconcile pulsar masses of 2M with the hyperon softening of the equation of state (EoS)?
  - Masquerade problem: modern EoS for cold, high density hadronic and quark matter are almost identical?
  - Reconfinement puzzle: what to do when after a deconfinement transition the hadronic EoS becomes favorable again?

HIC: Research of the early Universe



CompStar: Research of the late Universe



G.G. Barnaföldi: Wigner ALICE Group

Experimental observation of the QCD phase diagram

HOT Experimental Observations

- HOT, means that the aim is to measure the properties of the hot & dense color thermalized matter the Quark-Gluon Plasma (QGP)

- What to measure in AA:
  - Spectra → Temperature
  - Multiplicity fluctuation
  - Transport and hydrodynamical properties
  - Suppression via medium induced parton energy loss (jet quenching)
  - Search for critical point

COLD Experimental Observations

- COLD, means searching for the nuclear effects in the case when Quark-Gluon Plasma is not there. These are mainly initial state nuclear effects.

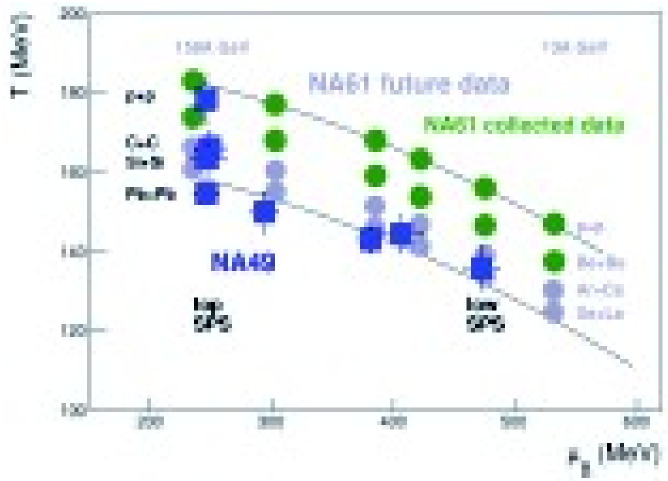
- What to measure in pp and in pA
  - Baseline for AA measurements
  - Spectra and fluctuations
  - Cold nuclear matter effects (Cronin, shadowing, CGC)
  - Jets and media including Underlying Event studies
  - Short and long range correlation

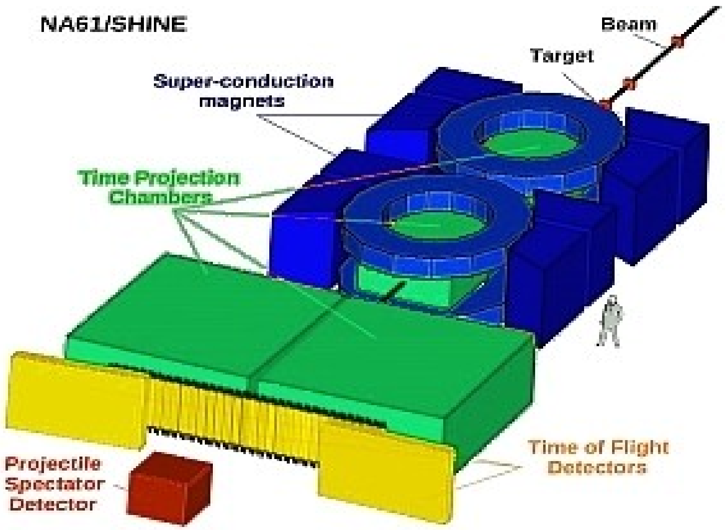
Existing and Working Detectors

- NA49, NA61/SHINE (< 20 GeV SPS energies)
- STAR/PHENIX (10-500 GeV RHIC energies)
- ALICE/CMS/ATLAS (0.2-14 TeV LHC energies)

Experimental Observation

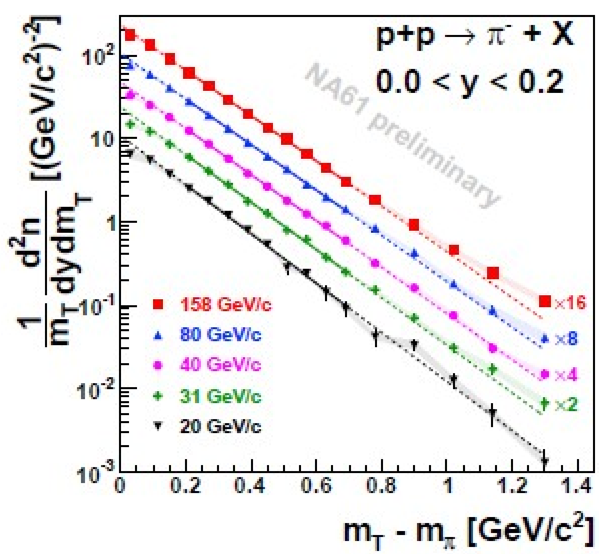
- NA49, NA61/SHINE (SPS energies)
  - NA61 is a large acceptance hadron spectrometer with excellent capabilities for momentum, charge and mass measurements.

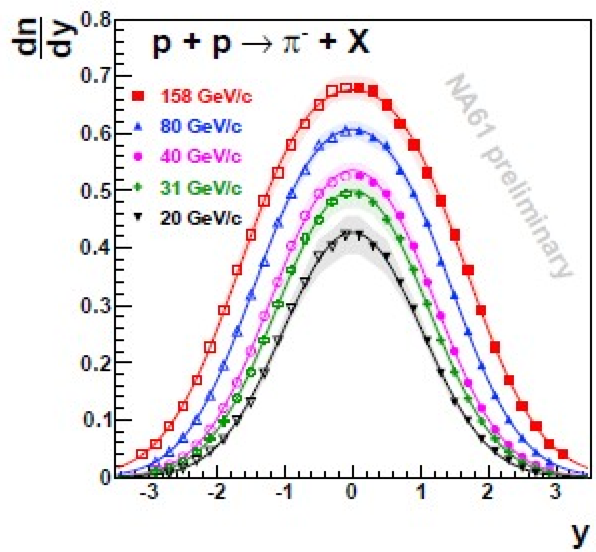




Experimental Observation

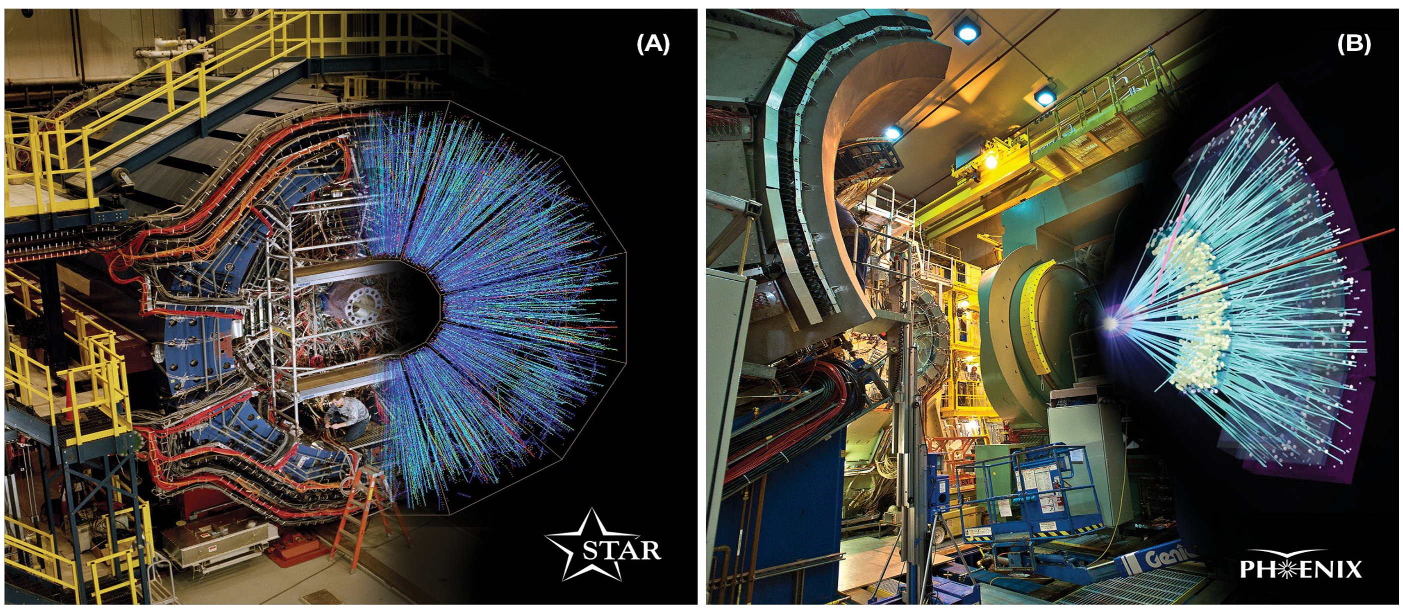
- NA49, NA61/SHINE (SPS energies)
  - Search for the critical point onset of deconfinement.
  - Hadron production reference measurements for neutrino (T2K) and cosmic-ray (Pierre Auger Observatory, KASCADE)
  - Study of high momentum spectra in pp and pA





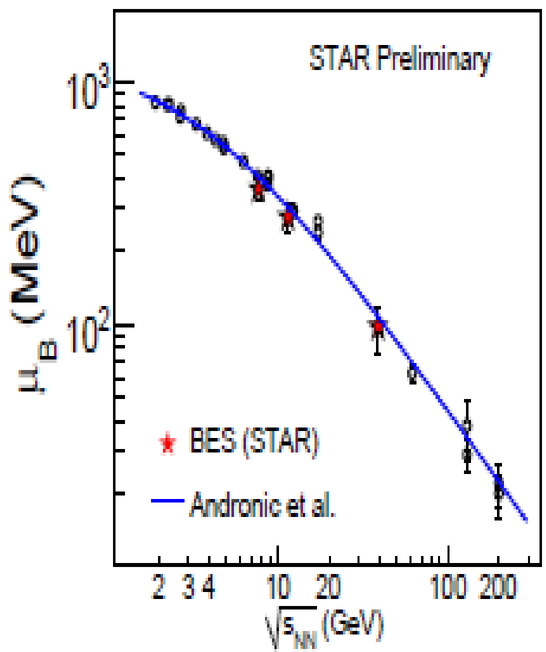
Experimental Observation

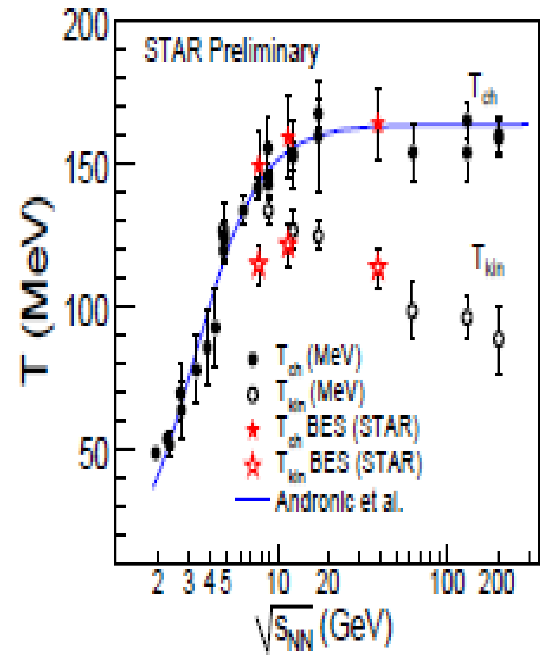
- STAR & PHENIX (RHIC energies)
  - RHIC c.m. energy can be easily vary 10-200 GeV
  - Various target: d, S, O, Cu, Au and Cu+Au, d+Au

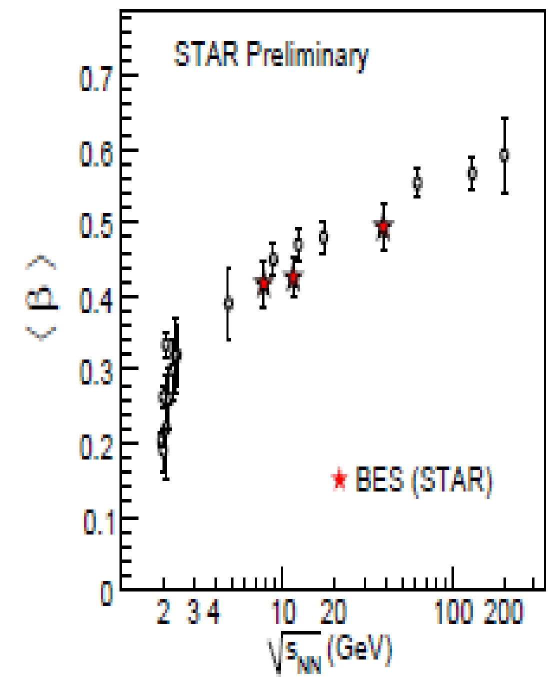


Experimental Observation

- STAR & PHENIX (RHIC energies)
  - Beam Energy Scan: Search for the critical point



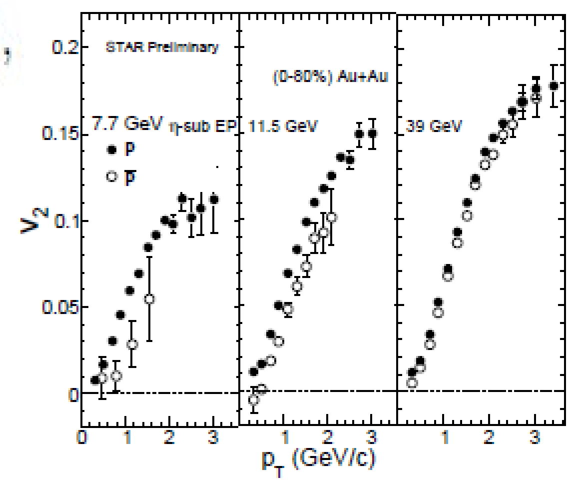


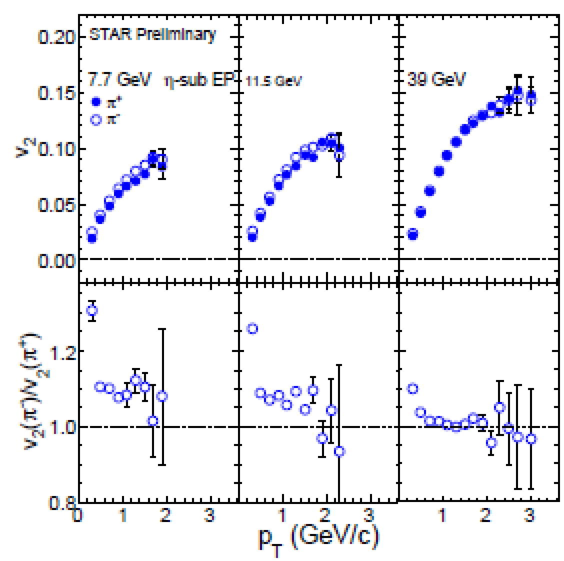


Experimental Observation

- STAR & PHENIX (RHIC energies)
  - Hard probes: Nuclear Modification Factor (see later)
  - Elliptic Flow: Fourier expansion of the of the azimuthal particle distribution on the transverse plane with respect to the symmetry plane of a semi-central collision:

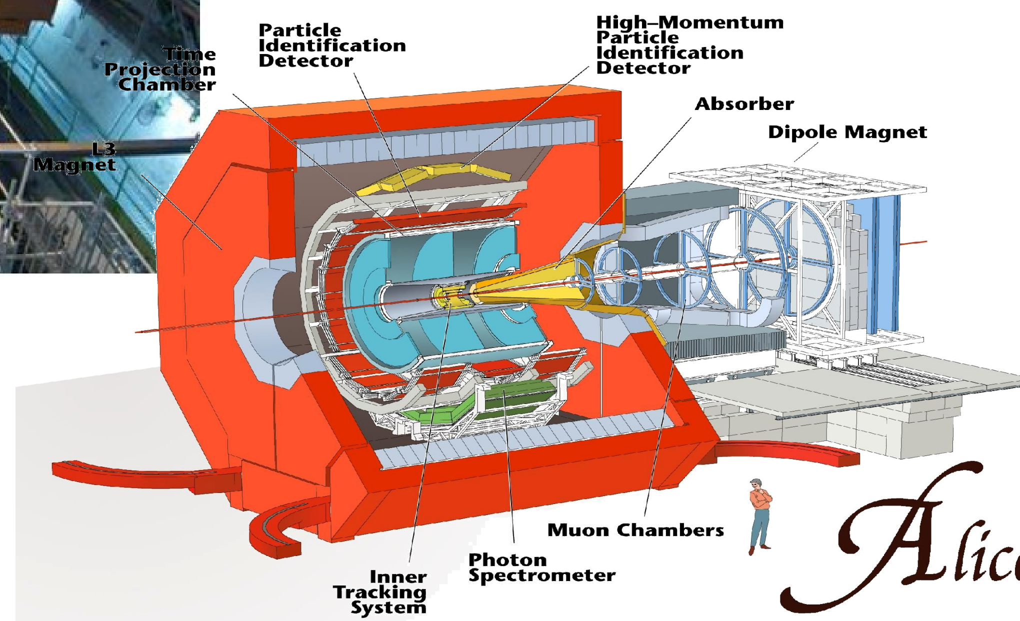
$$v_n = \langle \cos[n(\phi - \Psi_n)] \rangle,$$





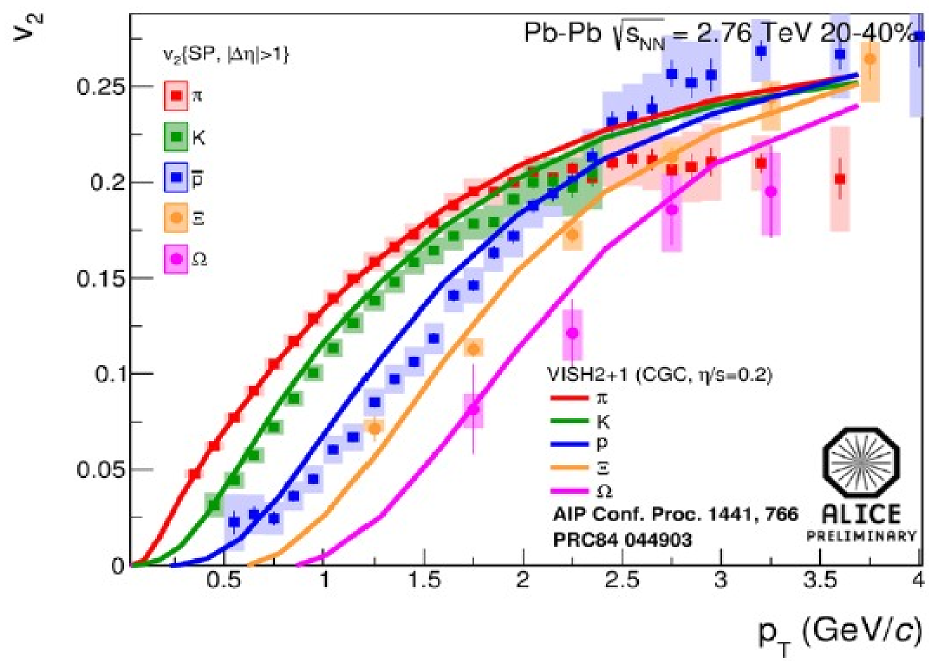
Recent Experimental Observations

- ALICE (CMS & ATLAS) LHC CERN



Recent Experimental Observations

- ALICE LHC CERN
  - The v2 measures the non-isotropic emission of particles on the azimuthal plane: $v_n = \langle \cos[n(\phi - \Psi_n)] \rangle,$
  - Results are in agreement with viscous hydrodynamic model calculations at low transverse momenta $p_T < 2$ GeV/c.
  - Collective effects
  - Constraint for hydro calculations, better IS parameters

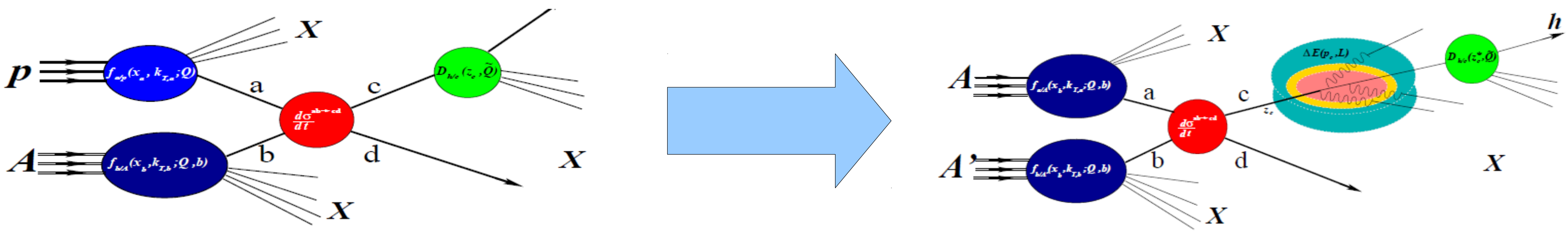


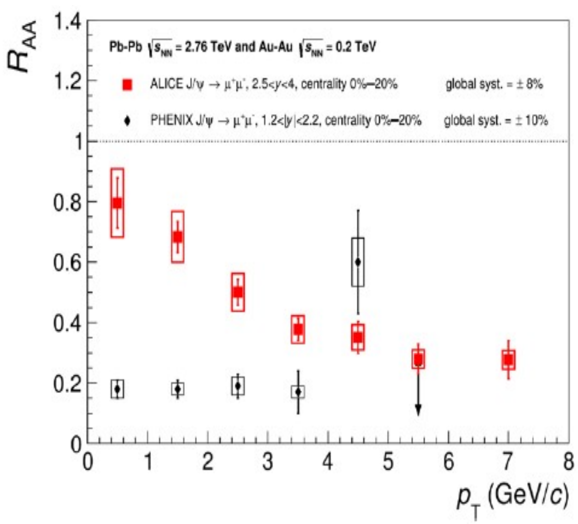
Recent Experimental Observations

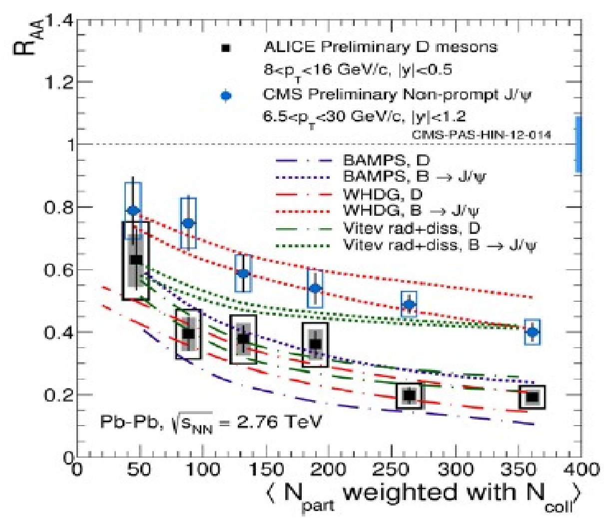
- ALICE LHC CERN

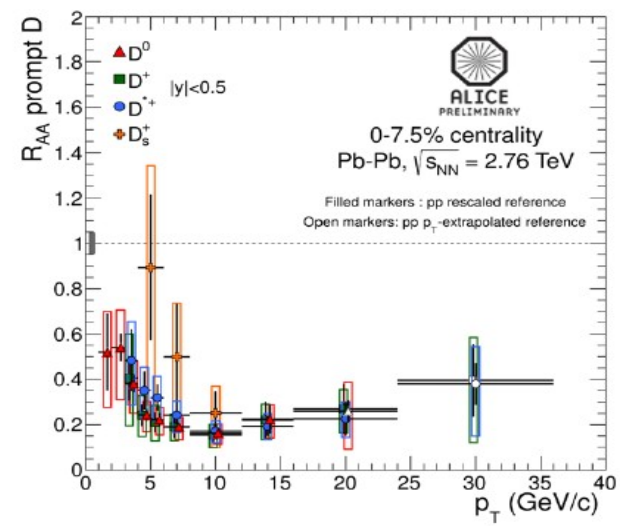
Nuclear Modification Factor: $R_{AA} = \frac{1}{N_{bin}} \frac{\mathrm{d}N_{AA}/\mathrm{d}y\ \mathrm{d}^2p_T}{\mathrm{d}Npp/\mathrm{d}y\ \mathrm{d}^2p_T}$

$$R^{\pi}_{AA'} := \frac{d\sigma^{AA'\to\pi}/d^3p\,(\text{"shadowing+multiscattering+ jet-quenching"})}{d\sigma^{AA'\to\pi}/d^3p\,(\text{"NO nuclear effect"})}$$







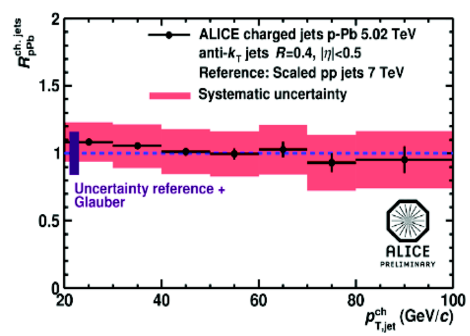


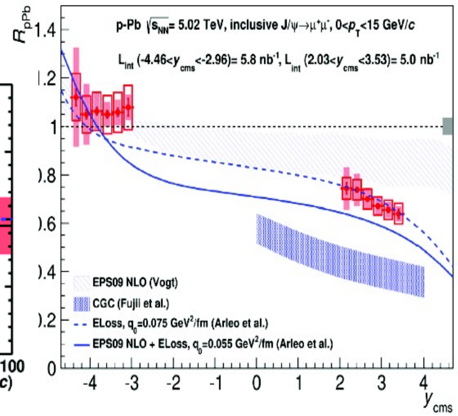
Recent Experimental Observations

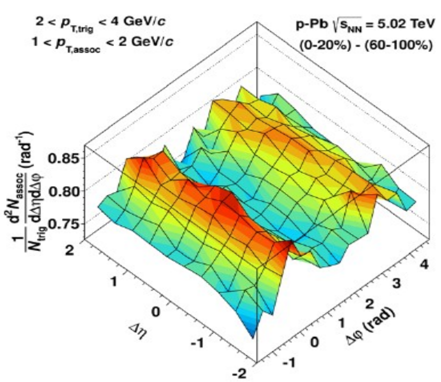
- ALICE LHC CERN

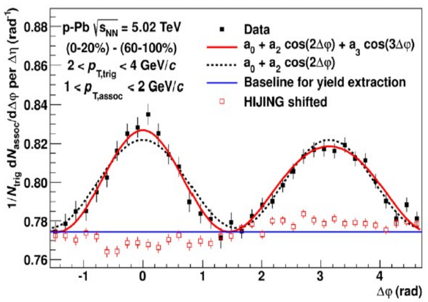
  TEST: p+Pb measurements

  - Initial state nuclear effects: Nuclear shadowing, Multiple scattering, CGC, Cronin?
  - Jet quenching is a final state effect (No effect in pp & pA)
  - Strongly-interacting media: long-range correlations



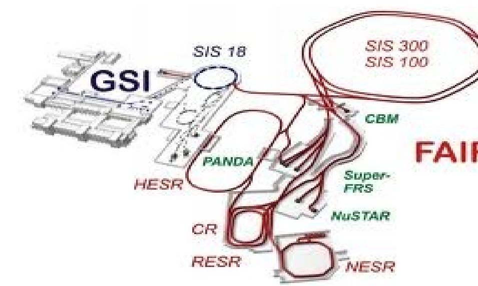




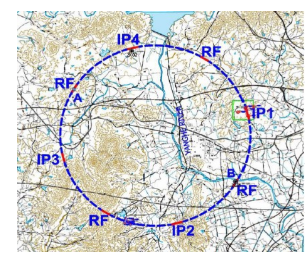


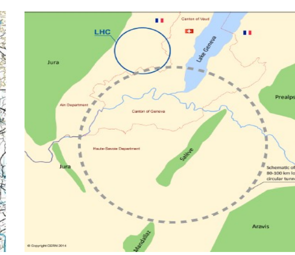
Future Experimental Facilities

- 2017: NICA (DUNBA)
  - In accordance with GSI, parallel & pre-studies
- 2016: FAIR (GSI)
  - PANDA and CBM probably in this order



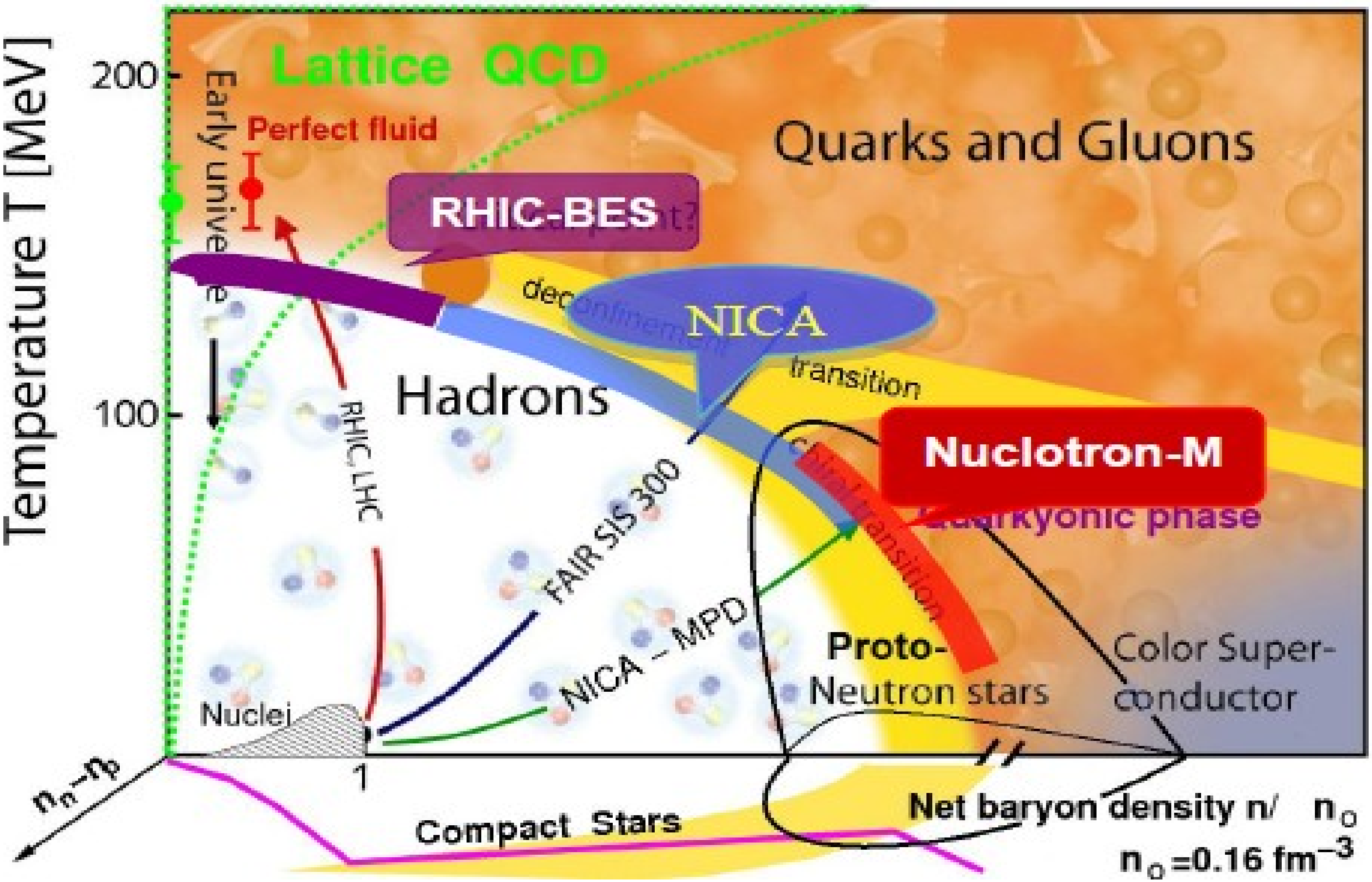
- 2020: HLLHC (CERN)
  - ATLAS, CMS, ALICE after upgrade
- 2025-2040 ILC, FCC (CERN, China)
  - US: Neutrino Physics
  - Japan: ILC, FCC:
  - FCC CERN and/or China





- Future computing technologies:
  - Rise of the parallel computing
  - Multi-core machines
  - GP/GPU technologies

Future Experimental Facilities



General trends in QCD theory

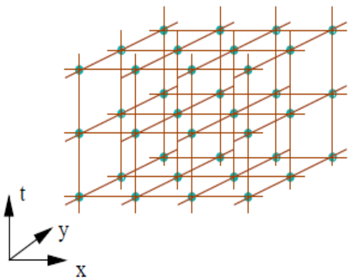
Theories in low energy QCD

- Lattice QCD
- Effective theories
- New Directions:

Lattice QCD

- General aims, questions from the field:
  - Investigation of confinement mechanism(s). What are the relevant degrees of freedom at the QCD phase transition?
  - Spectral properties of hadrons (masses, decay widths) as bound states of quarks and gluons, their modification at the chiral and deconfinement phase transition, Mott effect. Quark and gluon substructure effects in hadron-hadron interactions. Lattice QCD investigations of light and heavy quark bound states.
  - Properties of hadrons in different media: dense hadronic phase, deconfined light quark matter, deconfined light and strange quark matter, heavy quarkonia. QCD sum rules (role of various condensates). Role of resonances, gluons and exotic degrees of freedom.
  - Development of off-shell transport approaches to describe the formation and evolution of dense hadronic/quark-gluon matter. In-medium cross sections and spectral functions determined earlier will be used as inputs. Simultaneous description of heavy-ion and elementary nuclear reactions (photon-nucleus, pion-nucleus) with the same methods to obtain cross checks/constraints on the developed models. Algorithmic realization of an off-shell transport in order to model the nucleus-nucleus collision process.
  - Investigation of QCD phase transition signals: open and hidden charm production, fluctuations, kaon inverse slopes, etc. Are there differences in the deconfinement of light and strange flavors?

Lattice QCD



- Methods & tools

Systematic non-perturbative approach (numerical solution):

- quantum fields on the lattice
- quantum theory: path integral formulation with $S=E_{kin}-E_{pot}$
- quantum mechanics: for all possible paths add exp(iS)
- quantum fields: for all possible field configurations add exp(iS)
- Euclidean space-time (t=iτ): exp(-S) sum of Boltzmann factors

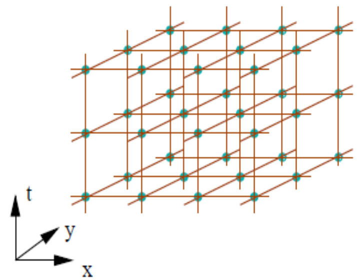
Since we do not have infinitely large computers) two consequences

a) put it on a space-time grid (proper approach: asymptotic freedom) formally: four-dimensional statistical system

b) finite size of the system (can be also controlled)

→ Stochastic approach, with reasonable spacing/size: solvable

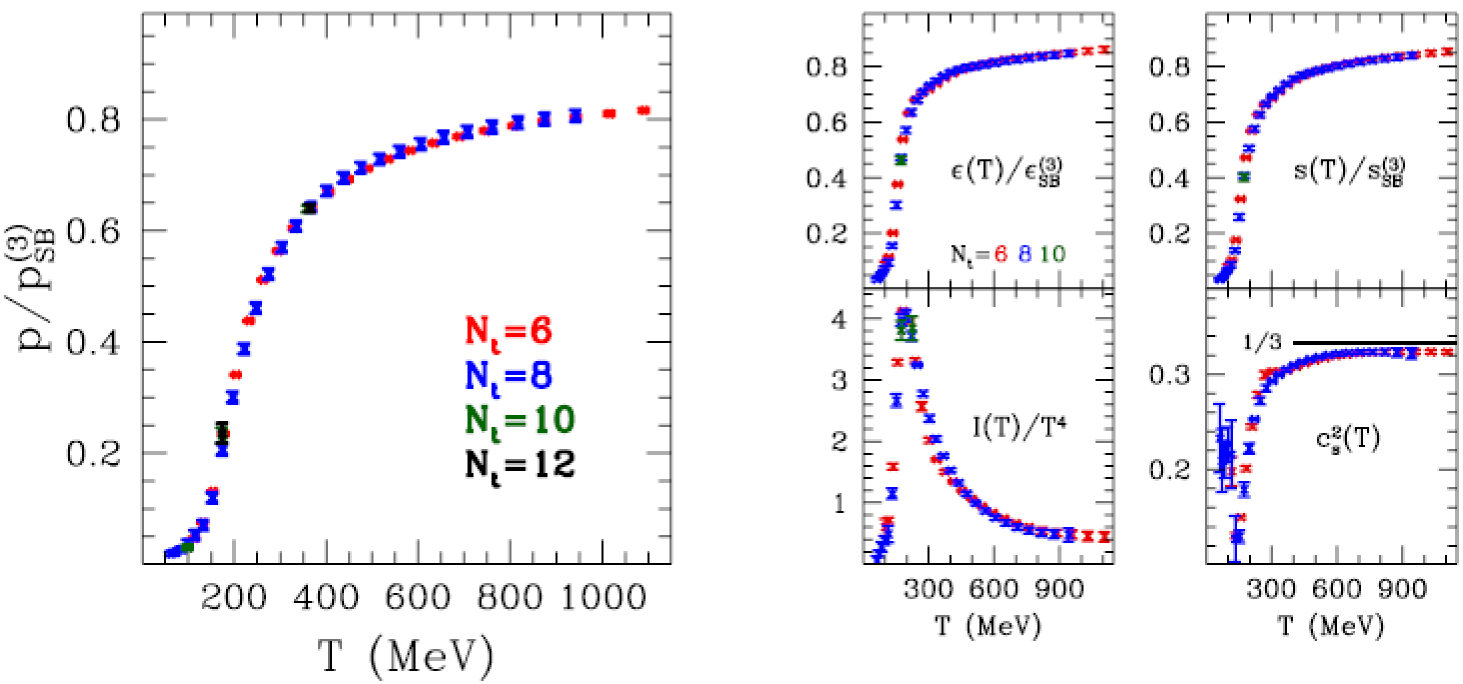
Lattice QCD



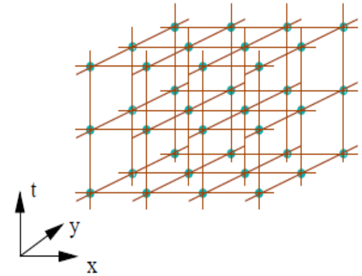
- Methods for high-T and μ=0:

Quantized Dirac operator

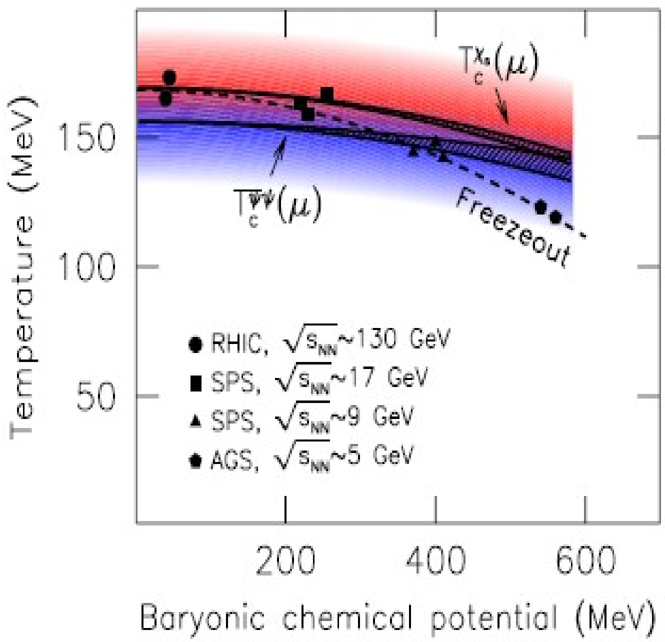
$$(D\Psi)_x = m_q\Psi_x + \frac{1}{2}\sum_{\mu=1..4}\alpha_{x\mu}\left(U_{x\mu}\Psi_{x+\hat{\mu}} - U^{\dagger}_{(x-\mu)\mu}\Psi_{x-\hat{\mu}}\right),$$



Lattice QCD



- Problem with Finite Chemical Potential



fermion determinant is complex

$$[\det M(\mu)]^* = \det M(-\mu^*) \in \mathbb{C}$$

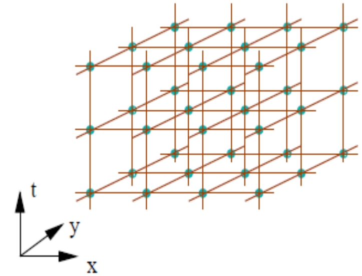
no positive weight in path integral

$$Z = \int DU\, e^{-S_{\rm YM}} \det M(\mu)$$

standard lattice methods based on importance sampling cannot be used

$\Rightarrow$ sign problem

Lattice QCD



- Problem with Finite Chemical Potential

Dirac eigenvalues and Silver Blaze

original formulation of Silver Blaze problem:

- weight and therefore configurations and eigenvalues of Dirac operator depend on μ
- this μ dependence should cancel: sensitive test
- commonly demonstrated using spectrum of Dirac operator   Cohen 04, Splittorff, Verbaarschot, Osborn 05

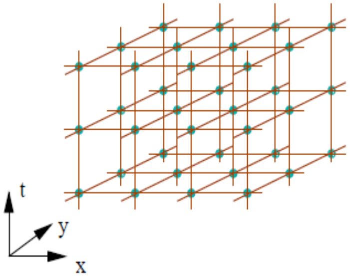
write $D + m$ with $D = \not{D} + \mu\gamma_4$

then $Z = \int DU \, \det(D+m) e^{-S_{\rm YM}} = \langle \det(D+m) \rangle_{\rm YM}$

write $\det(D+m) = \prod (\lambda_k + m)$ where $D\psi_k = \lambda_k \psi_k$

- since D is not γ_5 hermitian, eigenvalues not real or imaginary, instead $\lambda_k \in \mathbb{C}$

Lattice QCD



- Problem with Finite Chemical Potential

  - chiral condensate

$$\langle\bar\psi\psi\rangle = \frac{1}{\Omega}\frac{\partial \ln Z}{\partial m} = \left\langle \frac{1}{\Omega}\sum_k \frac{1}{\lambda_k + m}\prod_j(\lambda_j + m)\right\rangle_{\rm YM}$$

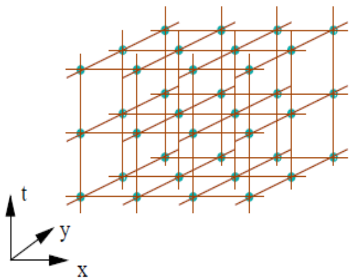
  - introduce density of eigenvalues

$$\rho(z;\mu) = \frac{1}{Z}\int DU\ \det(D+m)e^{-S_{\rm YM}}\frac{1}{\Omega}\sum_k \delta^2(z-\lambda_k)$$

$$= \left\langle \det(D+m)\frac{1}{\Omega}\sum_k \delta^2(z-\lambda_k)\right\rangle_{\rm YM}$$

  - then $\langle\bar\psi\psi\rangle = \int d^2z\,\frac{\rho(z;\mu)}{z+m}$

Lattice QCD



- Problem with Finite Chemical Potential

$\rho(z;\mu)$ depends on μ since $D+m$ does

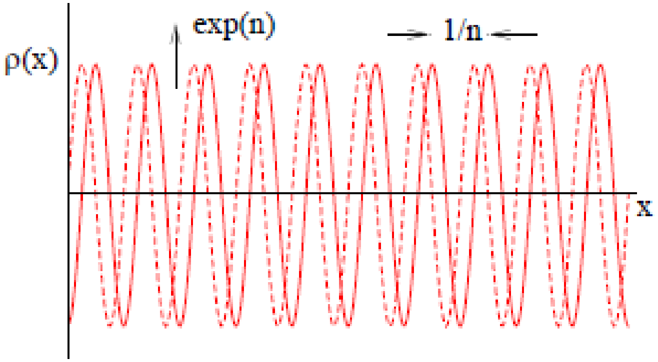
$$\langle\bar{\psi}\psi\rangle = \int d^2z \, \frac{\rho(z;\mu)}{z+m}$$

if $\mu \lesssim m_B/3$ (below onset), all μ dependence should cancel

achieved:

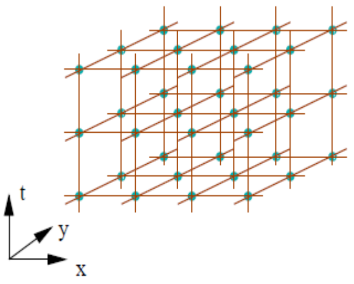
$\rho(z;\mu)$ is complex, oscillating with amplitude $e^{\Omega\mu}$ and period $1/\Omega$

only when all oscillations are correctly integrated, μ dependence will cancel



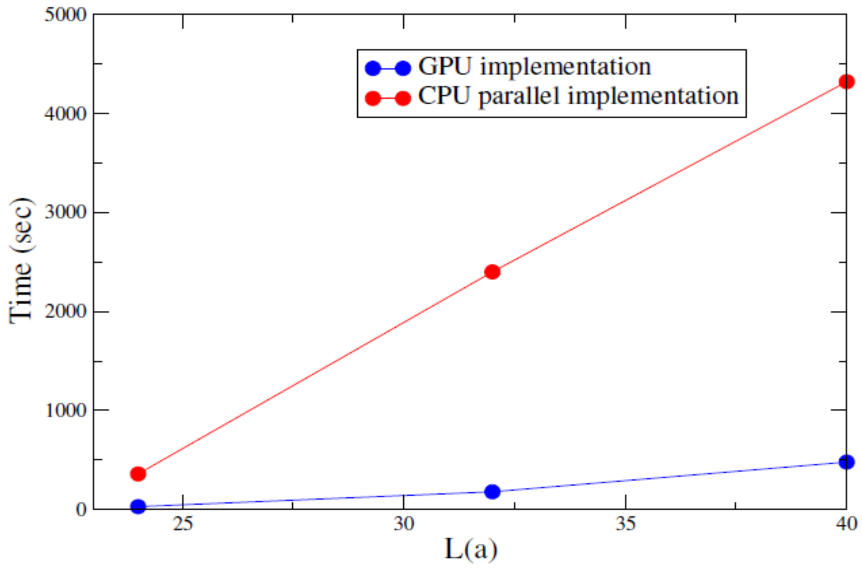
'solution to Silver Blaze problem'
from viewpoint of Dirac spectral density

Lattice QCD



- Groups
  - BNL
  - Ohio State University
  - Swansea University
  - GSI/Frankfurt
  - Budapest-Wuppertal Group

- Directions
  - From CPU to Many-Core
  - GPU technologies



Theories in low energy QCD

- 3-flavor NJL Model
  - Lagrangian: $\mathcal{L} = \mathcal{L}_0 + \mathcal{L}_{\bar{q}q} + \mathcal{L}_{qq}$
    - free part: $\mathcal{L}_0 = \bar{q}(i\partial\!\!\!/ - \hat{m})q \,, \qquad \hat{m} = diag_f(m_u, m_d, m_s)$
    - quark-antiquark interaction (as used earlier):

$$\mathcal{L}_{\bar{q}q} = G\left\{(\bar{q}\tau^a q)^2 + (\bar{q}i\gamma_5\tau^a q)^2\right\} - K\left\{\det_f\left(\bar{q}(1+\gamma_5)q\right) + \det_f\left(\bar{q}(1-\gamma_5)q\right)\right\}$$

    - quark-quark interaction:

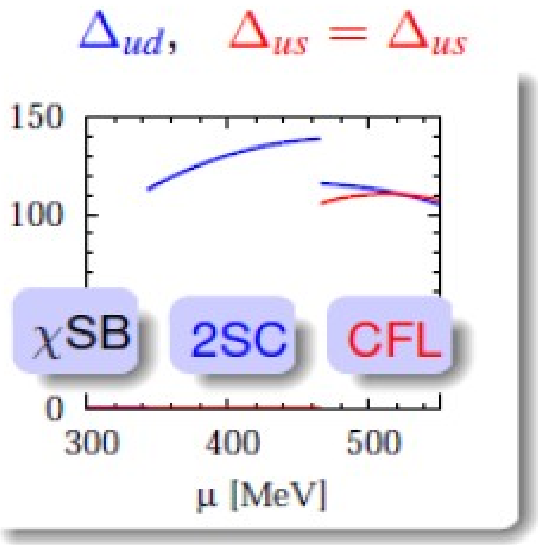
$$\mathcal{L}_{qq} = H\,(\bar{q}\,i\gamma_5\tau_A\lambda_{A'}\,C\bar{q}^T)(q^T C\,i\gamma_5\tau_A\lambda_{A'}\,q)$$

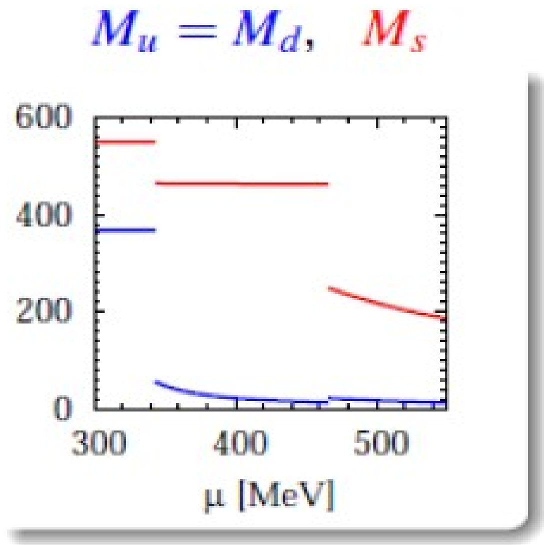
  - mean-field approximation:
    - $\bar{q}q$-condensates: $\langle\bar{u}u\rangle, \langle\bar{d}d\rangle, \langle\bar{s}s\rangle \leftrightarrow$ *dynamical masses*
    - qq-condensates: $\langle ud\rangle, \langle us\rangle, \langle ds\rangle \leftrightarrow$ *diquark gaps*

Theories in low energy QCD

- 3-flavor NJL Model at T=0

  - "realistic" parameters
  - isospin symmetry

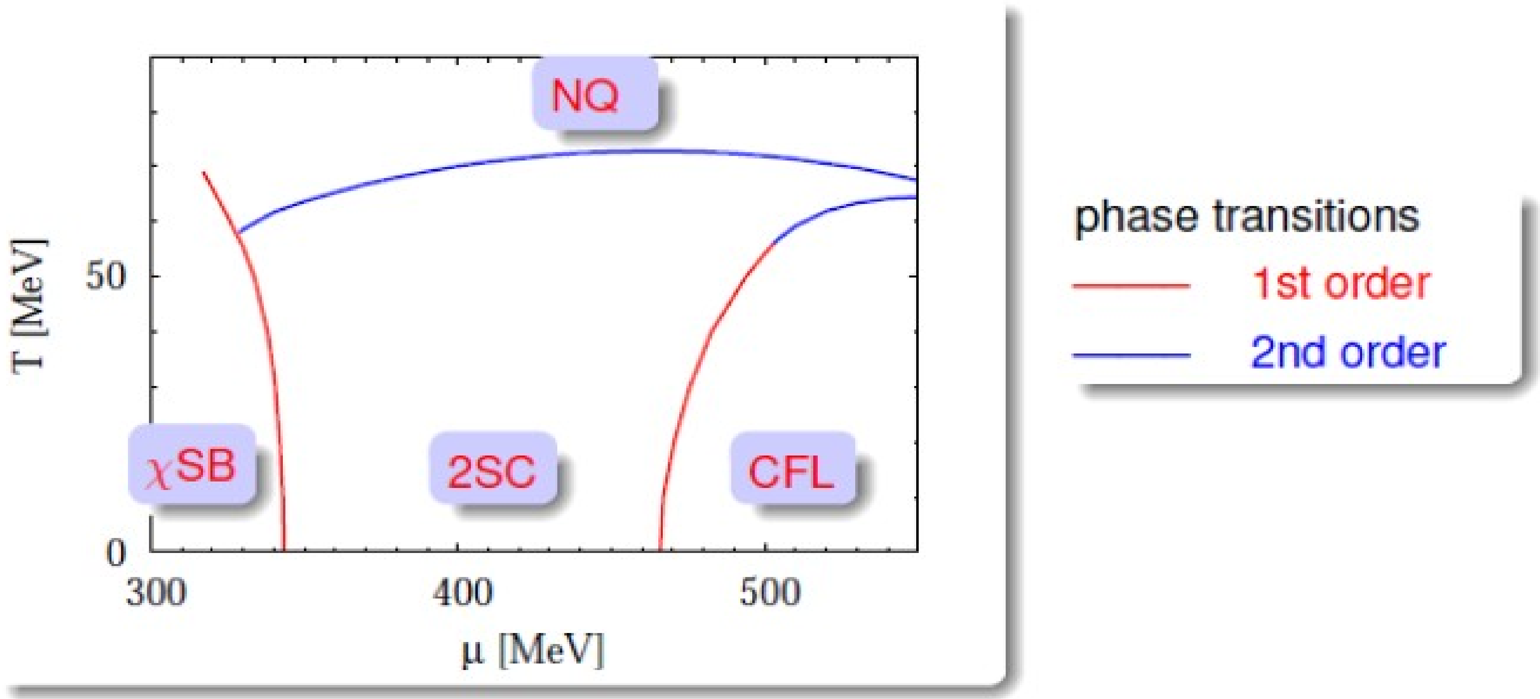




→ strong interdependencies between dynamical masses and diquark gaps

Theories in low energy QCD

- Phase diagram



S. Ruester et al. Phys. Rev. D 72 (2005) 034004
D. Blaschke et al. Phys. Rev. D 72 (2005) 065020

Theories in low energy QCD

- NLJ with multiqvark interaction

$$\mathcal{L} = \bar{q}(i\partial\!\!\!/ - m)q + \mu_q \bar{q}\gamma^0 q + \mathcal{L}_4 + \mathcal{L}_8\ ,\ \mathcal{L}_4 = \frac{g_{20}}{\Lambda^2}[(\bar{q}q)^2 + (\bar{q}i\gamma_5\tau q)^2] - \frac{g_{02}}{\Lambda^2}(\bar{q}\gamma_\mu q)^2\ ,$$

$$\mathcal{L}_8 = \frac{g_{40}}{\Lambda^8}[(\bar{q}q)^2 + (\bar{q}i\gamma_5\tau q)^2]^2 - \frac{g_{04}}{\Lambda^8}(\bar{q}\gamma_\mu q)^4 - \frac{g_{22}}{\Lambda^8}(\bar{q}\gamma_\mu q)^2[(\bar{q}q)^2 + (\bar{q}i\gamma_5\tau q)^2]$$

Meanfield approximation: $\mathcal{L}_{\mathrm{MF}} = \bar{q}(i\partial\!\!\!/ - M)q + \tilde{\mu}_q \bar{q}\gamma^0 q - U\ ,$

$$M = m + 2\frac{g_{20}}{\Lambda^2}\langle\bar{q}q\rangle + 4\frac{g_{40}}{\Lambda^8}\langle\bar{q}q\rangle^3 - 2\frac{g_{22}}{\Lambda^8}\langle\bar{q}q\rangle\langle q^\dagger q\rangle^2\ ,$$

$$\tilde{\mu}_q = \mu_q - 2\frac{g_{02}}{\Lambda^2}\langle q^\dagger q\rangle - 4\frac{g_{04}}{\Lambda^8}\langle q^\dagger q\rangle^3 - 2\frac{g_{22}}{\Lambda^8}\langle\bar{q}q\rangle^2\langle q^\dagger q\rangle\ ,$$

$$U = \frac{g_{20}}{\Lambda^2}\langle\bar{q}q\rangle^2 + 3\frac{g_{40}}{\Lambda^8}\langle\bar{q}q\rangle^4 - 3\frac{g_{22}}{\Lambda^8}\langle\bar{q}q\rangle^2\langle q^\dagger q\rangle^2 - \frac{g_{02}}{\Lambda^2}\langle q^\dagger q\rangle^2 - 3\frac{g_{04}}{\Lambda^8}\langle q^\dagger q\rangle^4\ .$$

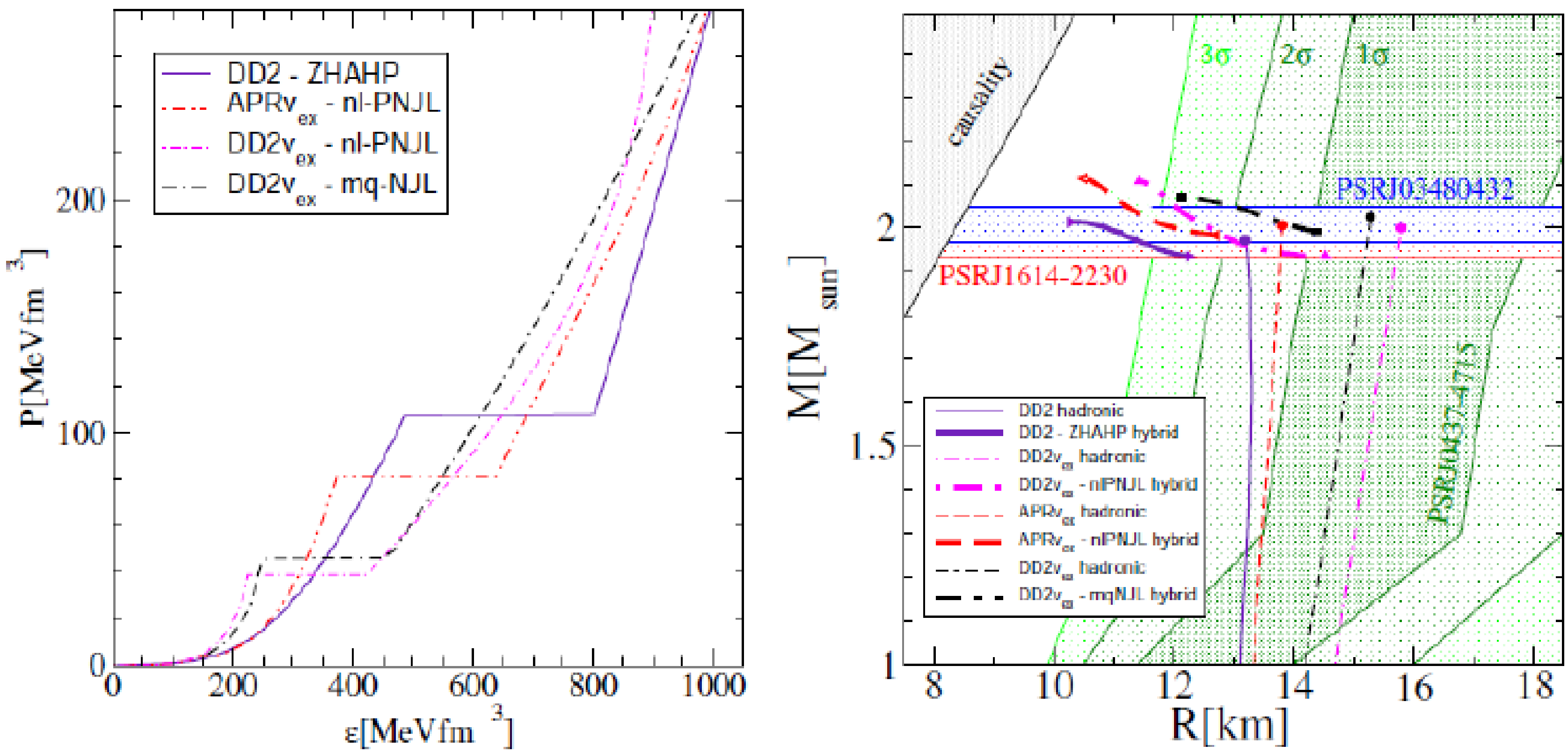
Thermodynamic Potential:

$$\Omega = U - 2N_f N_c \int \frac{d^3p}{(2\pi)^3}\left\{E + T\log[1 + e^{-\beta(E-\tilde{\mu}_q)}] + T\log[1 + e^{-\beta(E+\tilde{\mu}_q)}]\right\} + \Omega_0$$

Theories in low energy QCD

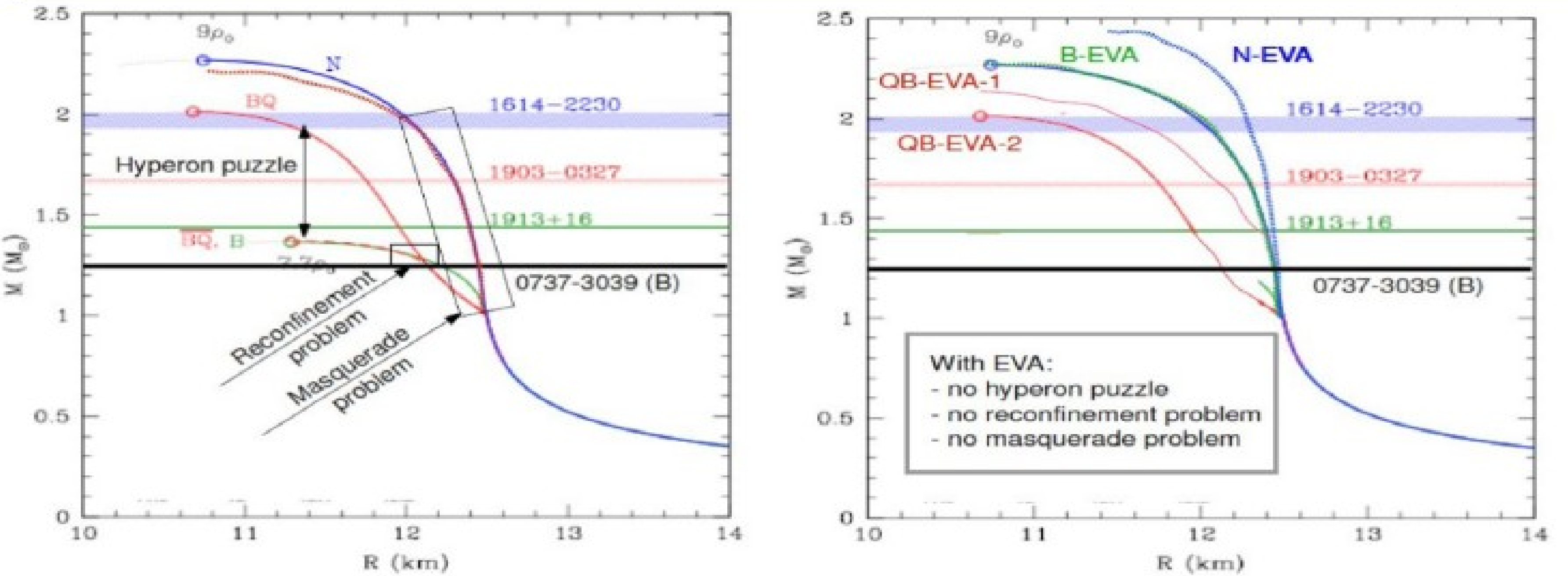
- NLJ with multiqvark interaction

S. Benic, D. Blaschke, D. Alvarez-Castillo, T. Fischer, in progress (2014)



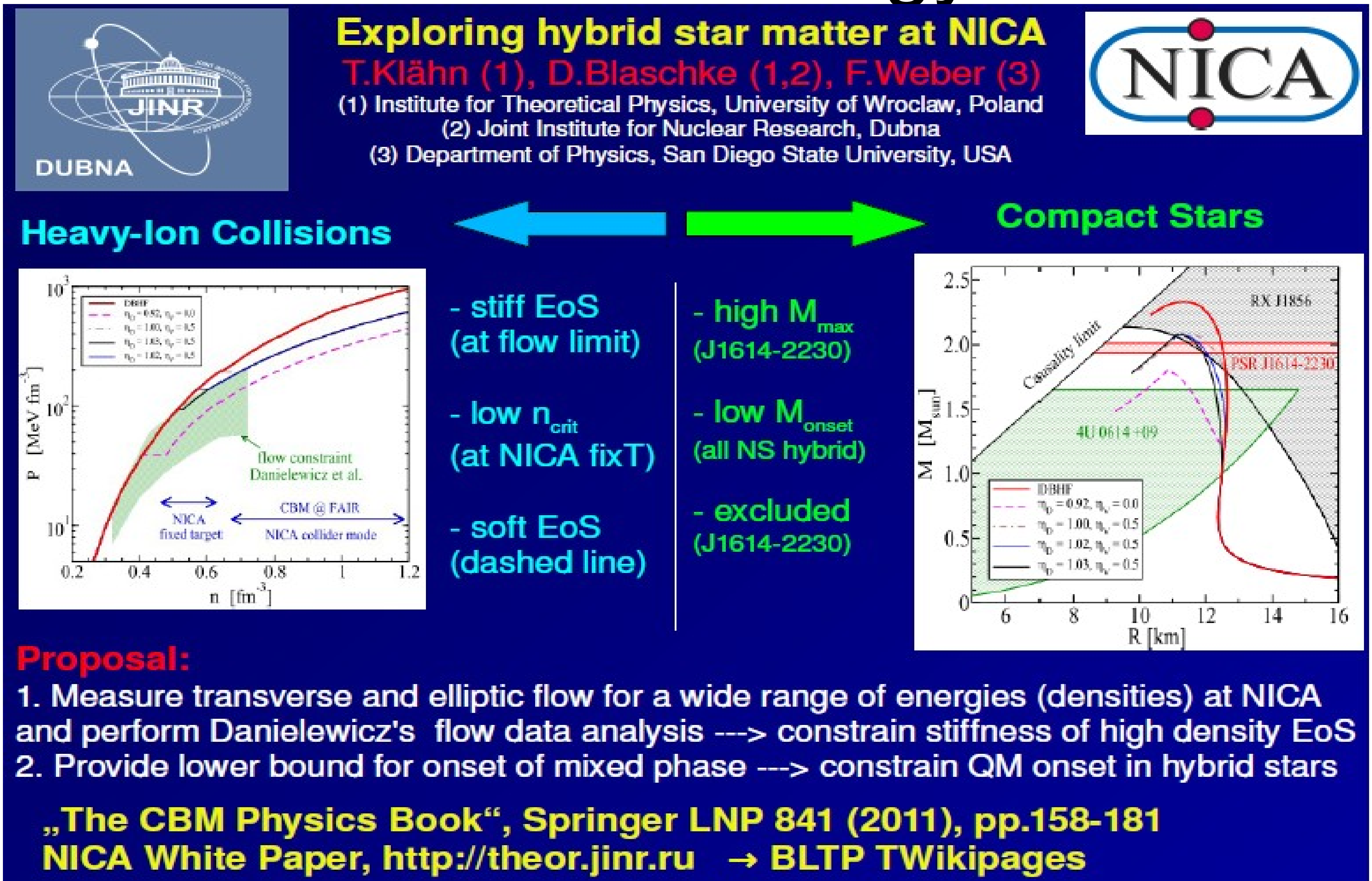
Theories in low energy QCD

Hyperon puzzle & quark matter



Mass-radius sequences for different model equations of state (EoS) illustrate how the **three major problems** in the theory of exotic matter in compact stars (left panel) can be solved (right panel) by taking into account the baryon size effect within a excluded volume approximation (EVA). Due to the EVA both, the nucleonic (N-EVA) and hyperonic (B-EVA) EoS get sufficiently stiffened to describe high-mass pulsars so that the hyperon puzzle gets solved which implies a removal of the reconfinement problem. Since the EVA does not apply to the quark matter EoS it shall be always sufficiently different from the hadronic one so that the masquerade problem is solved.

Theories in low energy QCD



New Theoretical directions

- Application of FRG in Nuclear EoS

  General idea to find an order parameter or scale using in dense matter EoS to evolve an characterize the equation via RG method.

  - Running Coupling Constant in Walceka model RG

    W. Zisheng et al: PRC55 55 (1997)
  - New application of RG Methods in Nuclear Applications

    R.J. Furnstahl, K. Hebeler: 1305.3800

    Chiral Nucleon-meson model + fluctuations
  - M. Drews et al: 1307.6973

New Theoretical directions

- Application of FRG in Nuclear EoS

  General idea to find an order parameter or scale using in dense matter EoS to evolve an characterize the equation via RG method.

Conjecture (for low baryon densities):
only multi-particle processes/collective effects can maintain chemical equilibrium

$$\Rightarrow \quad T_{\text{chemical freeze-out}} \simeq T_{\text{chiral crossover}}.$$

Braun-Munzinger, Stachel, Wetterich, Phys.Lett.B596, 2004

Question: What happens at large densities?
large μ is territory of nuclear physics $\rightarrow$ effective **nucleon-meson model** applicable

Floerchinger, Wetterich, arXiv:1202.1671

New Theoretical directions

- Application of FRG in Nuclear EoS

Study **neutron star matter**. Additional ingredients:

1. Different **chemical potentials** μ_p, μ_n for neutrons and protons.
2. **Electrons** with chemical potential μ_e.
3. ρ **degree of freedom**.

New Lagrangian:

$$\mathcal{L} = \bar{\psi}\Big(i\partial\!\!\!/ + g_\omega(\omega\!\!\!/ + \rho\!\!\!/ \cdot \tau) + g_\sigma(\sigma + i\gamma_5\pi \cdot \tau) + \begin{pmatrix} \mu_p & \\ & \mu_n \end{pmatrix}\gamma^0\Big)\psi +$$
$$+ \bar{\psi}_e(i\partial\!\!\!/ + \mu_e\gamma^0)\psi_e + \tfrac{1}{2}(\partial\sigma)^2 + \tfrac{1}{2}(\partial\pi)^2 + U(\rho,\sigma) +$$
$$+ \partial_{[\mu}\omega_{\nu]}\partial^{[\mu}\omega^{\nu]} + \partial_{[\mu}\rho_{\nu]}\partial^{[\mu}\rho^{\nu]} + \tfrac{1}{2}m_\omega^2\omega_\mu\omega^\mu + \tfrac{1}{2}m_\rho^2\rho_\mu\rho^\mu .$$

Now σ, ω_0 and ρ_0^3 get expecation values.
New **effective chemical potential**:

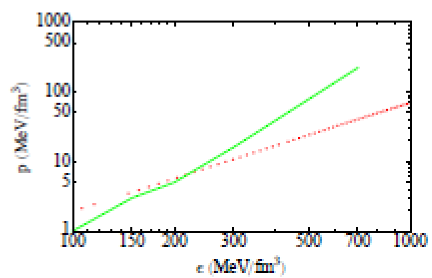
$$\mu_{\mathrm{eff},p} = \mu + g_\omega(\omega_0 + \rho_0^3),$$
$$\mu_{\mathrm{eff},n} = \mu + g_\omega(\omega_0 - \rho_0^3).$$

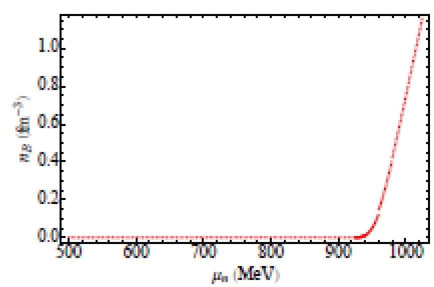
New Theoretical directions

- Application of FRG in Nuclear EoS

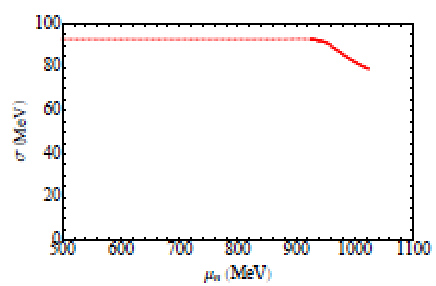
Red: Neutron Star Matter, Green: Akmal et al.

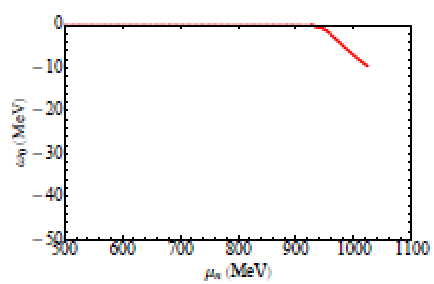
Akmal, Pandharipande, Ravenhall, Phys.Rev.C58, 1998





(a) Equation of state. (b) Baryon density.



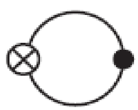


(c) Chiral order parameter. (d) ω_0-expectation value.

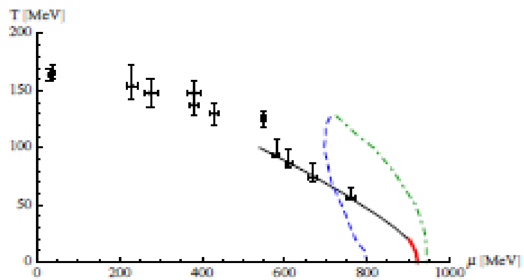
New Theoretical directions

- Application of FRG in Nuclear EoS

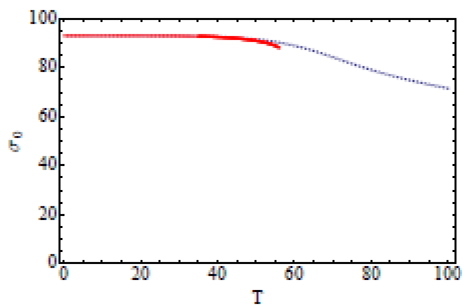
$$\partial_t \Gamma_k[\Phi_k] = \frac{1}{2}\,\mathrm{Tr}\,\partial_t R_k \left(\Gamma_k^{(2)}[\Phi_k] + R_k\right)^{-1} =$$

$$= \frac{1}{2}$$  .

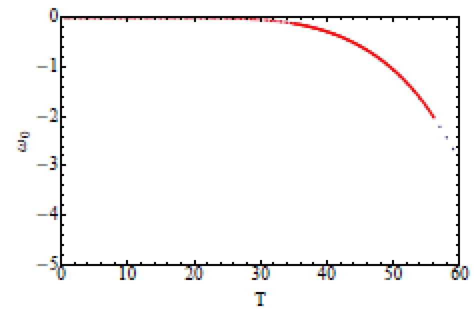
$$\partial_t \Gamma_k = \beta V \frac{k^5}{12\pi^2}\left[3\frac{1+2\frac{1}{e^{\beta E_\pi}-1}}{E_\pi} + \frac{1+2\frac{1}{e^{\beta E_\sigma}-1}}{E_\sigma} - \right.$$
$$\left. -\frac{4\cdot 2}{E_q}\left(1-\frac{1}{e^{\beta(E_q-\mu_{\mathrm{eff}})}+1}-\frac{1}{e^{\beta(E_q+\mu_{\mathrm{eff}})}+1}\right)\right].$$



(a) Chemical freeze-out.



(b) Chiral order parameter.



(c) ω_0 expectation value.

1. A **Nucleon-meson model** fitted to the liquid-gas phase transition shows **no** indication of **first order phase transition** at chemical freeze out.
2. Neutron star matter may be studied via implementing **beta equilibrium**.
3. Excitations beyond mean field: **Functional Renormalization Group**.

New Theoretical directions

- Non-extensive statistical methods

  In finite systems ~fm^3 or complex/fractal strucutres the temperature and thermodynamical variables cannot be handle in the standard form

  - New Generalized Entropy Formulas: $S \rightarrow L(S)$
  - In small or Fractal like systems Fini
  - Boltzmann Gibbs → Tsallis – Pareto, Rényi like entropy functions
  - Meaning of the Tsallis q and T parameters $q = 1\text{-}1/C+\Delta T^2/T^2$

    TS Biró, BGG, P. Van arxiv: 1404.1256
- Mass Gap method
  - The Mass Gap and its application
- Beyond the Standard Model & GUT like theories
  - Geometrical models, extra dimensions, etc.

Summary for OpenDiscussion

- Experimental observation of QCD phase diagram
  - Observation so far (SPS, RHIC, LHC)?
  - Facilities of the near/far future
  - Resources for future numerical calculations

- General trends in QCD theory
  - Investigations of the QCD phase diagram
  - Lattice QCD results
  - Effective models
  - Future theoretical developments

… and from the practical side

- I had a dream...

… and from the practical side

- I had a dream...

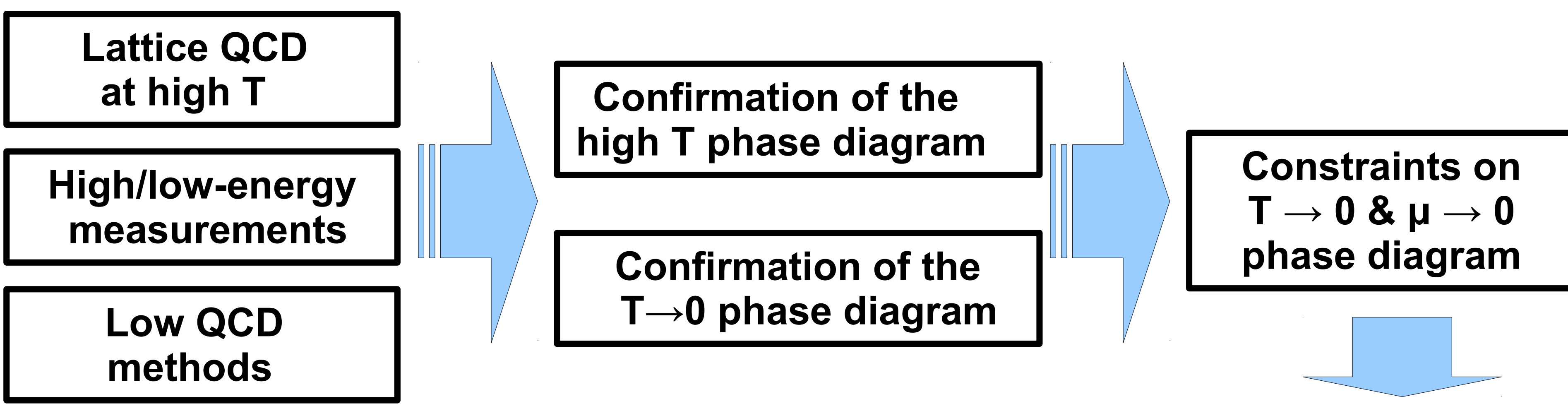
  A very bad one! Since there was no global picture in my mind, how CompStar can gain from all these.

… and from the practical side

- I had a dream...

  A very bad one! Since there was no global picture in my mind, how CompStar can gain from all these.

- Something what can be good for the white paper:



Finally: Apologize for those many who were not mentioned..