Joint Institute for Nuclear Research
International Intergovernmental Organization

Status and progress of the NICA White Paper

A.S. Sorin

Round Table 5 “Physics at NICA”
JINR, Dubna, August 28, 2010

Round Table Discussions on NICA@JINR

Round Table Discussion I
Searching for the mixed phase of strongly interacting matter at the JINR Nuclotron
July 7 - 9, 2005
http://theor.jinr.ru/meetings/2005/roundtable/

Round Table Discussion II
Searching for the mixed phase of strongly interacting matter at the JINR Nuclotron: Nuclotron facility development
JINR, Dubna, October 6 - 7, 2006
http://theor.jinr.ru/meetings/2006/roundtable/

Round Table Discussion III
Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA
JINR (Dubna), November 5 - 6, 2008
http://theor.jinr.ru/meetings/2008/roundtable/

Round Table Discussion IV
Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA (White Paper)
JINR (Dubna), September 9 - 12, 2009
http://theor.jinr.ru/meetings/2009/roundtable/

Round Table Discussion V

Searching for the mixed phase of strongly interacting QCD matter at the NICA: Physics at NICA

JINR (Dubna), August 28, 2010

http://theor.jinr.ru/~cpod/program.html

TOPICS:

I: Fixed target experiments at Nuclotron-N

II: Status and progress of the NICA White Paper

NICA White Paper

SEARCHING for a QCD MIXED PHASE at the NUCLOTRON-BASED ION COLLIDER FACILITY

The final goal of the NICA White Paper is to address the following key topics:

- Phases of dense QCD matter and conditions for their possible realization
- Characteristic processes as indicators of phase transformations
- Estimates of various observables for events
- Comparison to other experiments

http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome

Editorial board:

D. Blaschke
D. Kharzeev
A. Sissakian
A. Sorin
O. Teryaev
V. Toneev
I. Tserruya

NICA

Draft v 3.01
June 17, 2010

SEARCHING for a QCD MIXED PHASE at the NUCLOTRON-BASED ION COLLIDER FACILITY (NICA White Paper)

http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome

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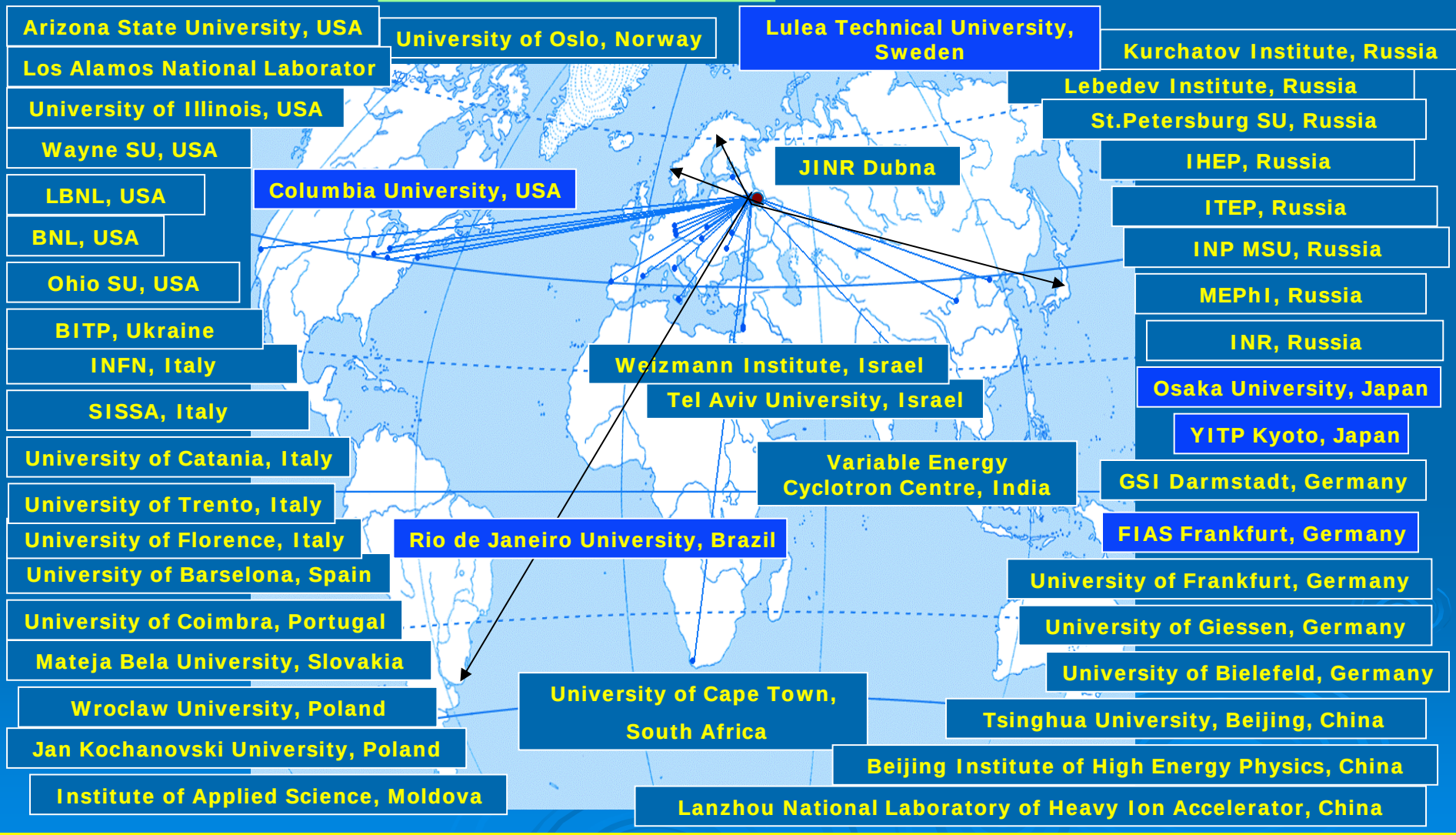
The NICA White Paper

114 authors *from* **46 scientific centers** *in* **19 Countries (8 JINR members)**



http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome

List of authors (114)

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Almost all experts in the field of heavy ion collisions have contributed to the NICA White Paper

Contents
(55 contributions = 44 + 11, additional 25%)

New Contributions to the NICA White Paper Draft v 3.03 (last update: June 20, 2010) http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome

1) Peter Senger (GSI): Nuclear matter physics at NICA
2) S.M. Troshin (Protvino): Directed flow as signal of liquid state of transient matter
3) Kenji Fukushima (YITP Kyoto): Transitional change to baryon-rich QCD matter at NICA energy
4) Masayuki Asakawa (U Osaka): Importance of third moments of conserved charges
5) Yuri Ivanov (Kurchatov I Moscow and GSI): Baryon stopping in Heavy-Ion Collisions at E=2...160 GeV/nucleon
6) Giorgio Torrieri (FIAS & Columbia U): Statistical hadronization phenomenology in a low-energy collider
7) Giorgio Torrieri (FIAS & Columbia U): Flow scaling in a low-energy collider: when does the perfect fluid turn on?
8) Takeshi Kodama (U Rio de Janeiro): Fluctuations and non-equilibrium processes in collective flow
9) Marcus Bleicher & Jan Steinheimer (FIAS): MEMO production at high baryon densities
10) Oleg Rogachevsky, A.S. & Oleg Teryaev (JINR): Chiral vortaic effect and neutron asymmetries at NICA
11) D.E. Donets et al. (JINR): Development of highly charged ion sources for NICA injector and its possible application for nanofabrication and in medicine

New contributions in preparation:

1. L. McLerran (BNL), K. Redlich (U Wroclaw), et al.
"Triple point and quarkyonic phase in the QCD phase diagram"

2. L.Turko (Wroclaw University, Poland), "TBA"

3. F.Karsch and Ch.Schmidt (BNL, Uni. Bielefeld, GSI Darmstadt)
"Lattice results on QCD at finite temperature and baryon density"

4. Joerg Aichelin (Universit´e de Nantes), "TBA"

5. Hans Georg Ritter (BNL), "TBA"

http://nica.jinr.ru/

http://theor.jinr.ru/twiki-cgi/view/NICA/WebHome

NICA

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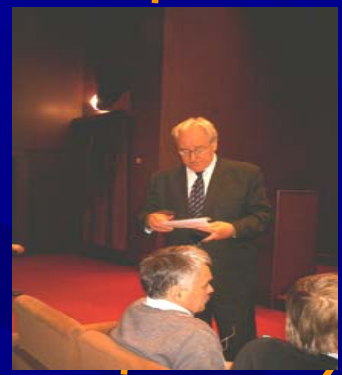
FOR NUCLEAR RESEARCH

Thank you for attention!



IHEP-JINR seminar at Protvino, 14.02.08

MEMORANDUM

МЕМОРАНДУМ
Совместного семинара ИТЭФ-ОИЯИ
Институт теоретической и экспериментальной физики
27 мая 2009 года, г. Москва

Участники семинара заслушали доклады:
А.Н. Сисакян "Ускорительный комплекс NICA: статус и перспективы".
Б.Ю. Шарков "Новые возможности ускорителей для исследования вещества экстремальных условиях".
И.Н. Мешков "Коллайдеры тяжёлых ионов RHIC и NICA: статус и перспективы".
В.Д. Тонеев "Физика тяжёлых ионов на ускорительном комплексе NICA".

Отмечены:
1) актуальность и возрастающая привлекательность исследований тяжелоионных столкновений в диапазоне энергий $\sqrt{s}NN \sim 4 - 11$ ГэВ для фундаментальных проблем поиска новых состояний ядерной материи и изучения процессов экстремально высоких плотностей;
2) прогресс в развитии проекта NICA, получившего широкую международную известность и высокую оценку авторитетных экспертов мирового уровня;
3) заинтересованность специалистов ИТЭФ в активном участии в совместных с ОИЯИ работах по проекту NICA;
4) необходимость более тесной кооперации в решении проблем, представляющих взаимный интерес, включая организацию ассоциации (консорциума, сообщества) по исследованию экстремальных состояний вещества и фазовых превращений в ионных столкновениях.

Соруководители семинара:
А.Н.Сисакян — **академик РАН**; **В.И.Захаров** — **профессор**
Участники семинара:
Б.Ю.Шарков — **член-корреспондент РАН**; **И.Н.Мешков** — **член-корреспондент РАН**; **А.Б.Кайдалов** — **член-корреспондент РАН**
А.С.Сорин — **профессор**; **В.Д.Тонеев** — **профессор**; **А.Д.Коваленко** — **профессор**; **Г.В.Трубников** — **кфмн**

ITEP-JINR seminar at ITEP, 27.05.09

Round Table Discussions I, II, III, IV…
JINR, Dubna, 2005, 2006, 2008, 2009…

Решение
Общемосковского семинара по релятивистской ядерной физике

27 марта 2008 года
Институт Ядерных Исследований РАН

Участники семинара "Проект NICA (тяжелоионный коллайдер: концепции, планы реализации и перспективы совместных работ)" заслушав доклады, представленные разработчиками Проекта NICA/MPD (ОИЯИ):
1. А.Н. Сисакян "Статус проекта NICA/MPD".
2. А.Н. Сисакян, А.С. Сорин "Программа физических исследований на ускорительном комплексе NICA".
3. И.Н. Мешков "Концептуальный проект ускорительного комплекса NICA".
4. В.Д. Кекелидзе "Концептуальный проект многоцелевого детектора MPD".
и обсудив цели и содержание проекта, а также перспективы его осуществления, пришли к следующему заключению.

1. Физическая проблема, инициировавшая разработку Проекта, является одной из наиболее важных среди фундаментальных проблем физики микромира и начальных этапов эволюции Вселенной.

2. Представленные на семинаре концептуальные проекты NICA и MPD выполнены на современном уровне с привлечением передовых технологий и использованием оригинальных идей, предложенных и развитых в России.

3. Осуществление Проекта на базе лабораторий ОИЯИ представляется вполне реальным, а представленные планы работ - выполнимыми.

4. Для успешного и быстрого выполнения Проекта целесообразно создание широкой Всероссийской и международной коллаборации.

5. Институты России располагают необходимым научным и инженерно-техническим потенциалом.

6. Успешная реализация Проекта позволит всем участникам Проекта занять лидирующие позиции в физике высоких энергий и войти в число самых передовых исследовательских центров мира.

В.А.Матвеев, Директор ИЯИ РАН, академик РАН
А.Н.Тавхелидзе, академик РАН
Б.Ю.Шарков, Директор ИТЭФ, чл.-корр. РАН
А.Н.Лебедев, чл.-корр. РАН
В.А.Рубаков, академик РАН

All Moscow-JINR seminar at INR, 27.03.08

Nuclear matter physics at NICA

Peter Senger
Helmholtzzentrum Heavy Ion Research, GSI Darmstadt, Germany

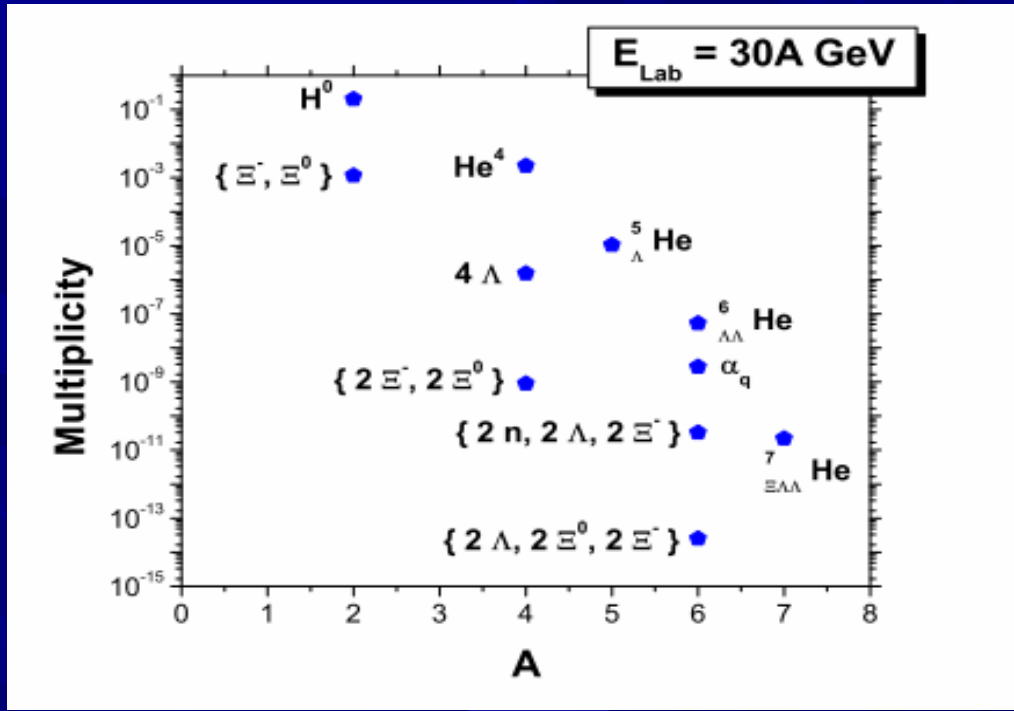
Physics case	Observables	Detectors
nuclear EOS at high densities	proton flow, Λ, Ξ, Ω	Silicon tracker, TPC, TOF
deconfinement phase transition, phase coexistence	excit. funct. of yield and flow of K, Λ, Ξ, Ω. e-by-e fluctuations	Silicon tracker, TPC, TOF
strange matter	multi-strange short-lived objects (decay into Λ, Ξ, Ω)	Silicon tracker, TPC, TOF
chiral phase transition, hadrons in dense matter	dileptons (e+e-)	HBD, RICH, TPC, TOF, ECAL, (TRD ?)

- Most interesting scientific questions with a basic version of the MPD: magnet, TPC, Silicon tracker and TOF detector; upgrade: electron detectors
- NICA/MPD part of worldwide program exploring the QCD phase diagram at high densities: AGS, SPS, NA61/SHINE, GSI/SIS18 --> RHIC, FAIR, NICA
- Problem for STAR @ RHIC: low luminosity, limited beamtime
- Virtues of NICA:
  - high luminosity at high baryon density-->multidifferential observables
  - collider exp. with uniform acceptance, almost independent of energy
- MPD @ NICA and CBM @ FAIR: complementary measurements, joint R&D

MEMO production at high baryon densities

Marcus Bleicher & Jan Steinheimer
FIAS & J.W.Goethe University Frankfurt (Main), Germany

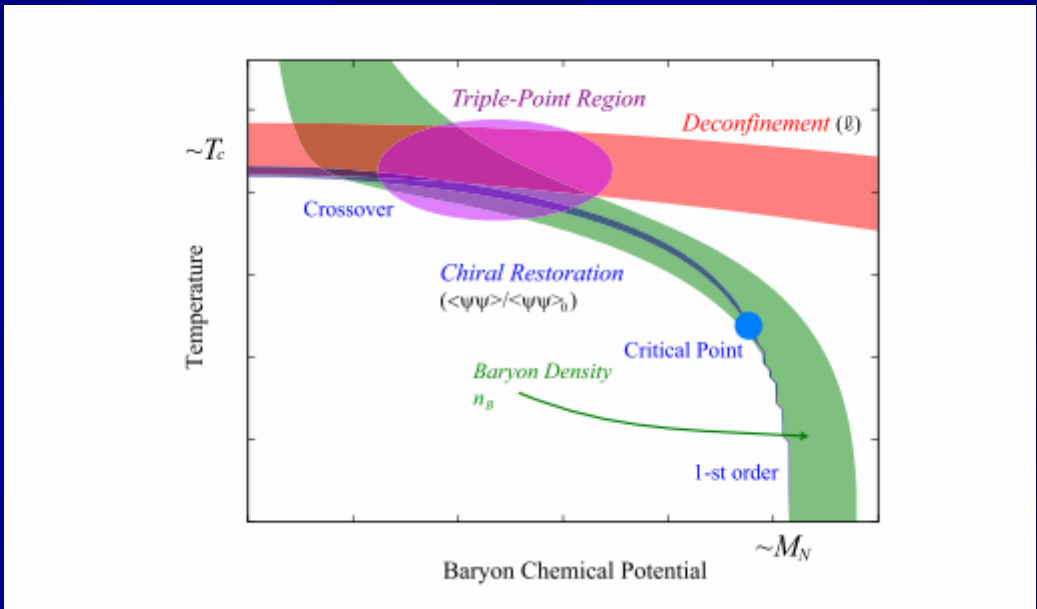
Cluster	Mass [GeV]	Quark content
He^4	3.750	$12q$
H^0	2.020	$4q+2s$
α_q	6.060	$12q+6s$
$\{\Xi^-,\Xi^0\}$	2.634	$2q+4s$
$\{4\Lambda\}$	4.464	$8q+4s$
$\{2\Xi^-,2\Xi^0\}$	5.268	$4q+8s$
${}^{5}_{\Lambda}He$	4.866	$14q+1s$
${}^{6}_{\Lambda\Lambda}He$	5.982	$16q+2s$
${}^{7}_{\Xi^0\Lambda\Lambda}He$	7.297	$16q+2s$
$\{2n,2\Lambda,2\Xi^-\}$	6.742	$12q+6s$
$\{2\Lambda,2\Xi^0,2\Xi^-\}$	7.500	$8q+10s$
$\{d,\Xi^-,\Xi^0\}$	4.508	$8q+4s$
$\{2\Lambda,2\Xi^-\}$	4.866	$6q+6s$
$\{2\Lambda,2\Sigma^-\}$	4.610	$8q+4s$



- Production of multi-strange metastable objects (MEMOs) explored in Pb+Pb reactions at 30 AGeV within coupled transport-hydrodynamics model
- Predictions for yields & particle-dependent rapidity and momentum distributions
- Excitation functions show clear maximum in the energy range of NICA and FAIR which are therefore the ideal place to study the production of these MEMOs

Transitional change to baryon-rich QCD matter at NICA energy

Kenji Fukushima
Yukawa Institute for Theoretical Physics,
Kyoto University, Japan



See also arxiv:1006.2596

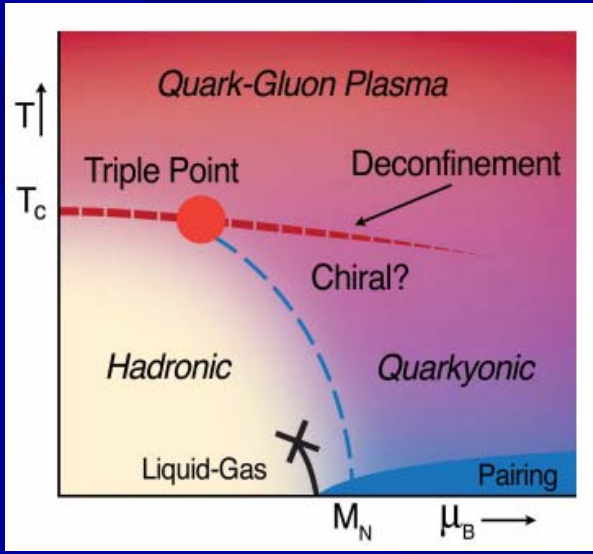
„Phase diagram of hot and dense QCD constrained by the statistical model“

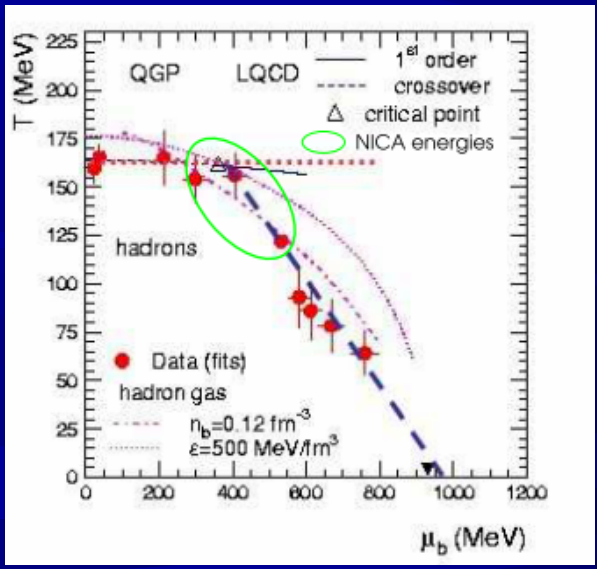
(Polyakov-loop NJL model)

“… the collision energy √s_NN ≈ 8 GeV is a threshold below which abundant baryons can emerge. Such baryon dominant matter yet below deconfinement could be identified with so-called **Quarkyonic Matter**. NICA would be an ideal facility to probe such an onset to enter the baryon-rich regime of QCD matter.“

Triple point and quarkyonic matter in the QCD phase diagram

Larry McLerran, Krzysztof Redlich and David Blaschke,
BNL Upton, USA; U Wroclaw, Poland; JINR Dubna, Russia





Based on A. Andronic et al.
Nucl. Phys. A 837. 65 (2010)
[arxiv:0911.4806]

In preparation

The NICA (and CBM) energy range (green ellipse) covers chemical freeze-out parameters in the QCD phase diagram from the fit of hadron production with the statistical model which lie in the transition from meson-dominated to baryon-dominated freeze-out.

Here we expect the suggested transition from a hadronization out of the Quark-Gluon Plasma to a hadronization out of the „Quarkyonic Phase“, i.e., where three phases meet in a „Triple Point“: QGP, Hadronic and Quarkyonic Phase!

Importance of third moments of conserved charges in HICs

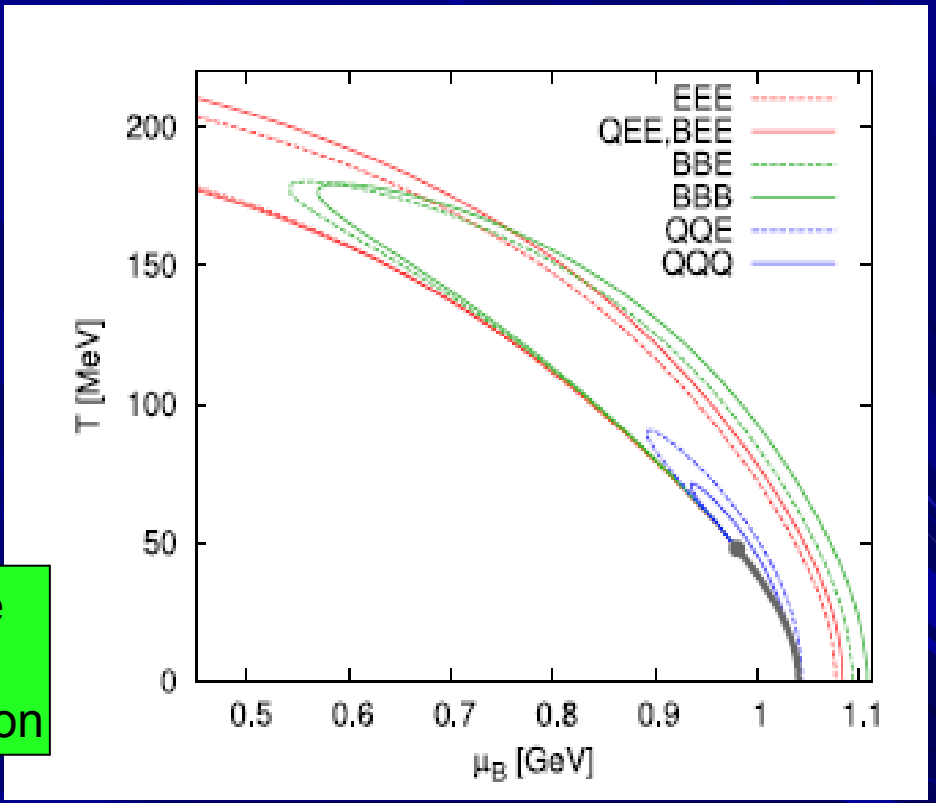
Masayuki Asakawa
Osaka University, Japan

Third moments of conserved charges (derivatives of susceptibilities)

$$m_3(ccc) \equiv \frac{\langle (\delta N_c)^3 \rangle}{VT^2}, \quad m_3(\mathrm{EEE}) \equiv \frac{\langle (\delta E)^3 \rangle}{VT^5}$$

where Nc with c=B,Q are net baryon and electric charge numbers in a volume V.
E denotes the total energy, dNc=Nc- <Nc>, dE=E - <E>. Mixed moments accordingly.

Regions where third moments take negative values in the T- mu_B plane are strongly correlated with the suspected phase transition



Establishing negativeness of third moments in experiment is evidence for:
(1) existence of peak structure of susceptibilities in the QCD phase diagram
(2) realization of hot matter beyond the peak, i.e. the QGP, in heavy-ion collisions

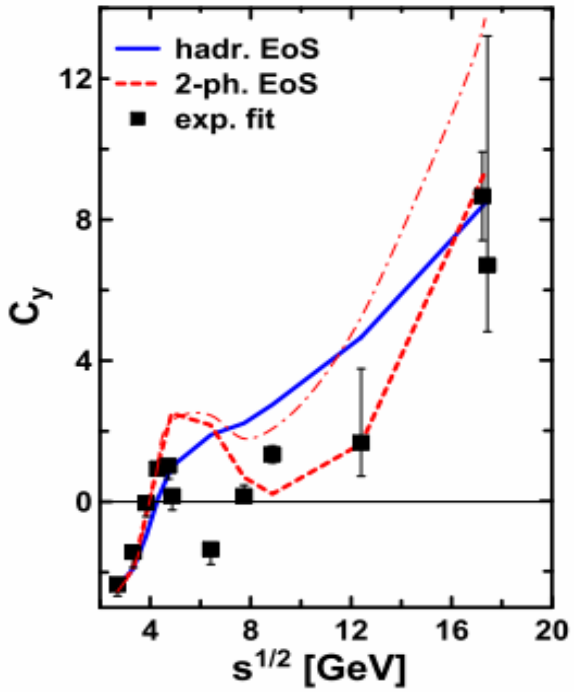
Baryon stopping in heavy-ion collisions at E=2-160 GeV/nucl.

Yuri B. Ivanov

Kurchatov Institute Moscow, Russia & GSI Darmstadt, Germany

Irregularity in the energy dependence of the curvature Cy of the proton spectrum as a function of the (dimensionless) rapidity (y-y_cm)/y_cm

$$C_y \equiv \left(y_{cm}^3 \frac{d^3N}{dy^3}\right)_{y=y_{cm}} \Big/ \left(y_{cm} \frac{dN}{dy}\right)_{y=y_{cm}} = (y_{cm}/w_s)^2 \left(\sinh^2 y_s - w_s \cosh y_s\right).$$



The „wiggle“ in Cy(s) is the characteristics of a first order phase transition in the EoS

- **The „wiggle“ in energy dependence of the curvature Cy of the proton spectrum occurs between AGS and low SPS energies**
- **It is characetristic for a 1st order phase transition („mixed phase“) behaviour !**
- **NICA @ JINR and CBM @ FAIR will cover the relevant energies to confirm or reject this observed trend in the experimental data**

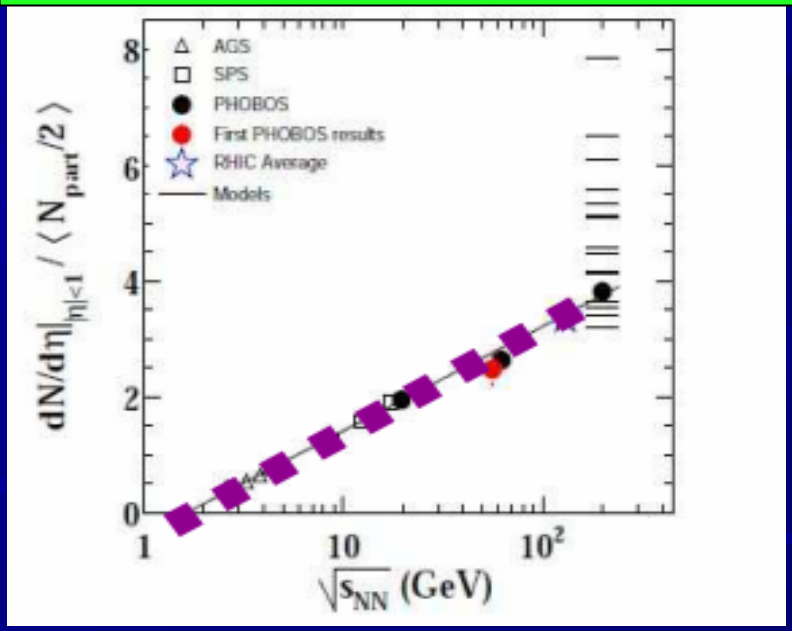
Flow scaling in a low-energy collider: When does the perfect fluid turn on?

Giorgio Torreri

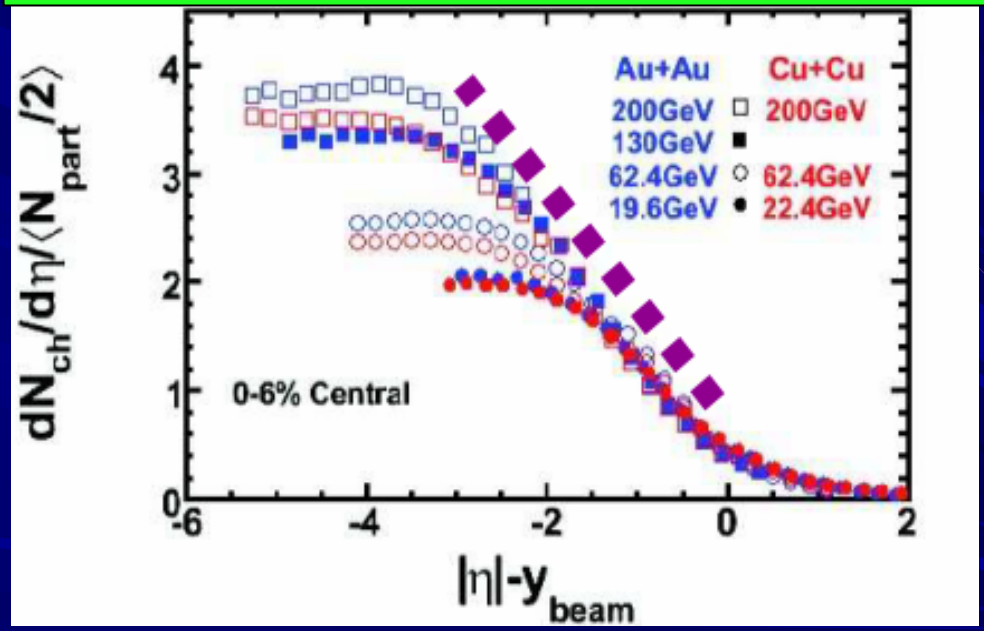
FIAS and University Frankfurt, Germany; Columbia Univ., USA

RHIC found remarkable scaling laws indicating „perfect fluid“ - minimal viscosity!

mid-rapidity dN/dy vs. energy



dN/dy away from y_beam - limiting fragmentation

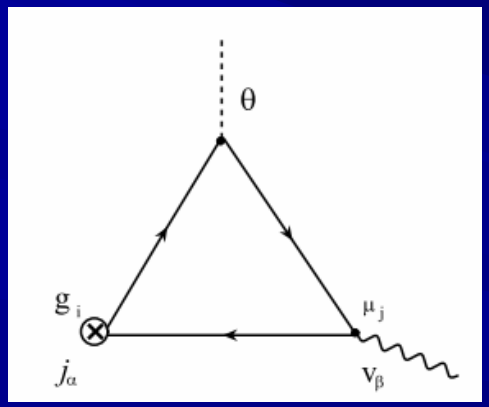


- Establish a lower limit for the onset of the hydro scaling in HIC experiments!
- Collider for scanning energy and rapidity below RHIC energies: NICA optimal!

Chiral vortaic effect and neutron asymmetries at NICA

Oleg Rogachevsky, Alexander Sorin and Oleg Teryaev
JINR Dubna, Russia

Both, chiral magnetic effect (CME) and chiral vortaic effect (CVE) belong to the class of effects based on the triangle anomaly in QFT. CVE is a generalization to conserved charges other than the electric one. In case of baryon charge and chemical potential, it should manifest itself by neutron asymmetries, observable at NICA/MPD !



$$e_j A_\alpha J^\alpha \Rightarrow \mu_j V_\alpha J^\alpha$$

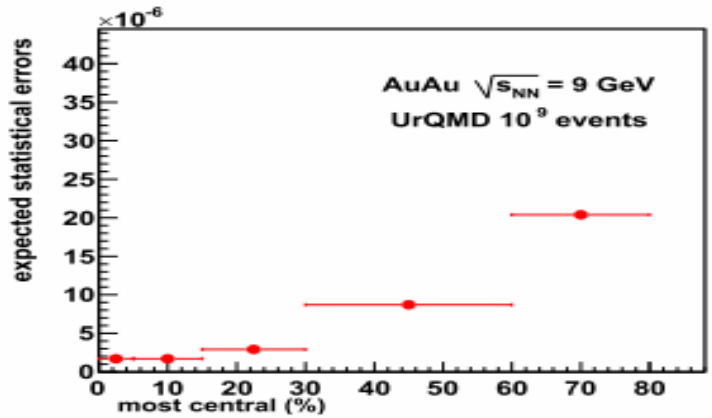
$$e_j \vec{H} \rightarrow \mu_j \vec{\nabla} \times \vec{V}$$

$$J_e^\gamma = \frac{N_c}{4\pi^2 N_f} \varepsilon^{\gamma\beta\alpha\rho} \partial_\alpha V_\rho \partial_\beta (\theta \sum_j e_j \mu_j)$$

$$J_i^\nu = \frac{\sum_j g_{i(j)} \mu_j}{\sum_j e_j \mu_j} J_e^\nu$$

$$J_i^0 = \frac{|\vec{\nabla} \sum_j g_{i(j)} \mu_j|}{|\vec{\nabla} \sum_j e_j \mu_j|} J_e^0$$

Observable: three-particle correlator: $\langle cos(\phi_\alpha + \phi_\beta - 2\phi_c) \rangle$



In CME case at RHIC: 15 M events were sufficient to establish the effect
For demonstrating the CVE, we need 1000 M events, which can be collected at NICA/MPD within a few months of running time!

Development of highly charged ion sources for NICA injector & possible applications for nanofabrication and in medicine

D.E. Donets, E.D. Donets, E.E. Donets, V. Salnikov, V. Shutov
Kurchatov Institute Moscow, Russia & GSI Darmstadt, Germany

Novel type of highly charged ions sources – Electron String Ion Sources (ESIS) is under development in JINR in framework of NICA project. This ion sources produce intense beams of highly charged ions of heavy elements, up to gold. Two major applications of this ion sources: for nanofabrication and for cancer therapy are briefly discussed.

1 Production of nanostructures by slow highly charged ions for information storage and processing at nanometer range

2 Resonant combination cancer therapy – newly proposed method with use of highly charged ion source of highest intensity

Basic and applied researches with highly charged intense ion beams of heavy elements, produced with ESIS-type ion sources have a very wide area for applications in nano-sceiences and medicine. Ion source development program in framework of the NICA project has a great potential for various nonaccelerator applications as well.