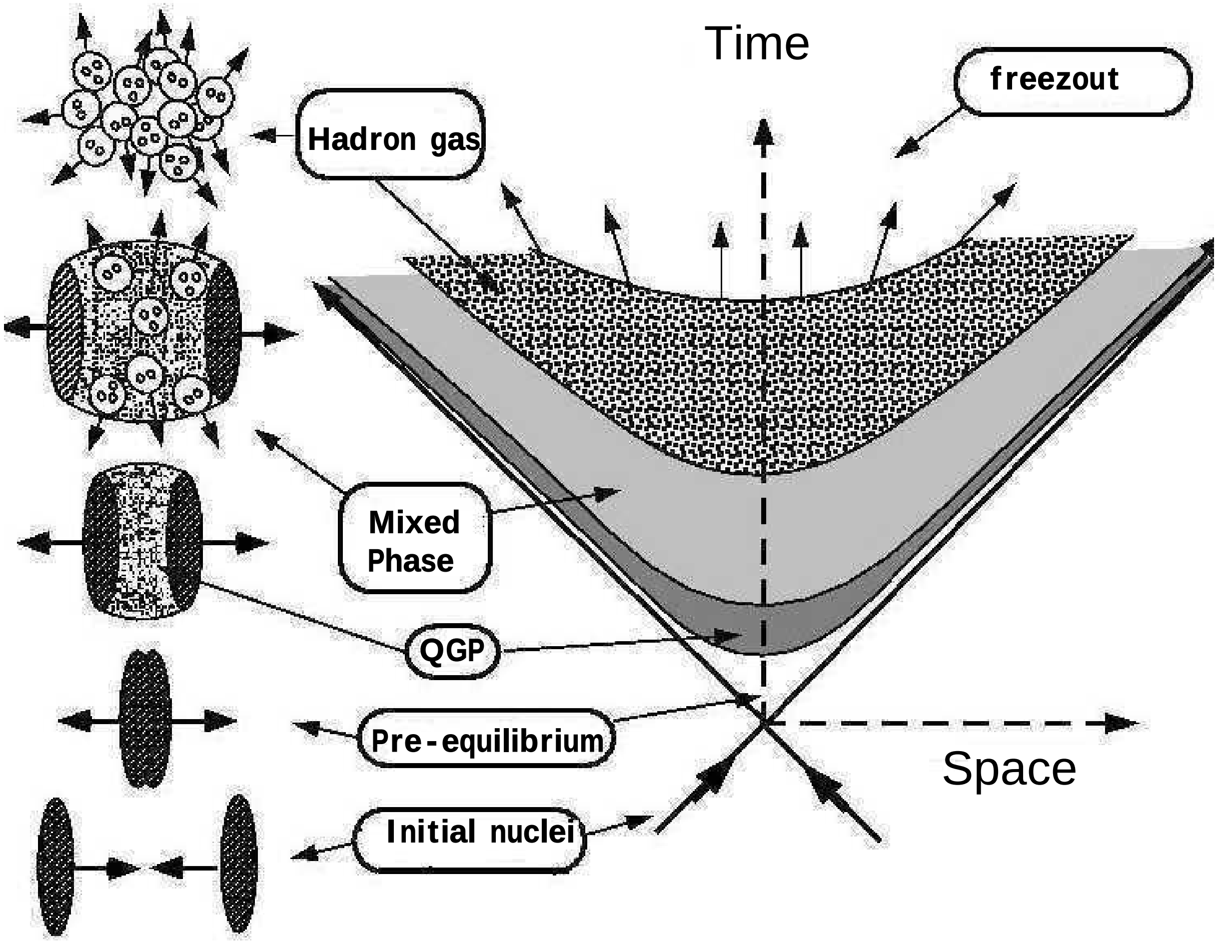
JINR Joint Institute for Nuclear Research

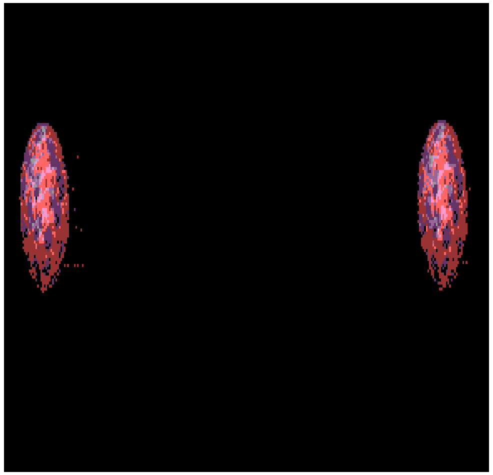
A research program on hadron properties in hot and dense baryonic matter in heavy ion collisions at the JINR Nuclotron

A.N. Sissakian and A.S. Sorin

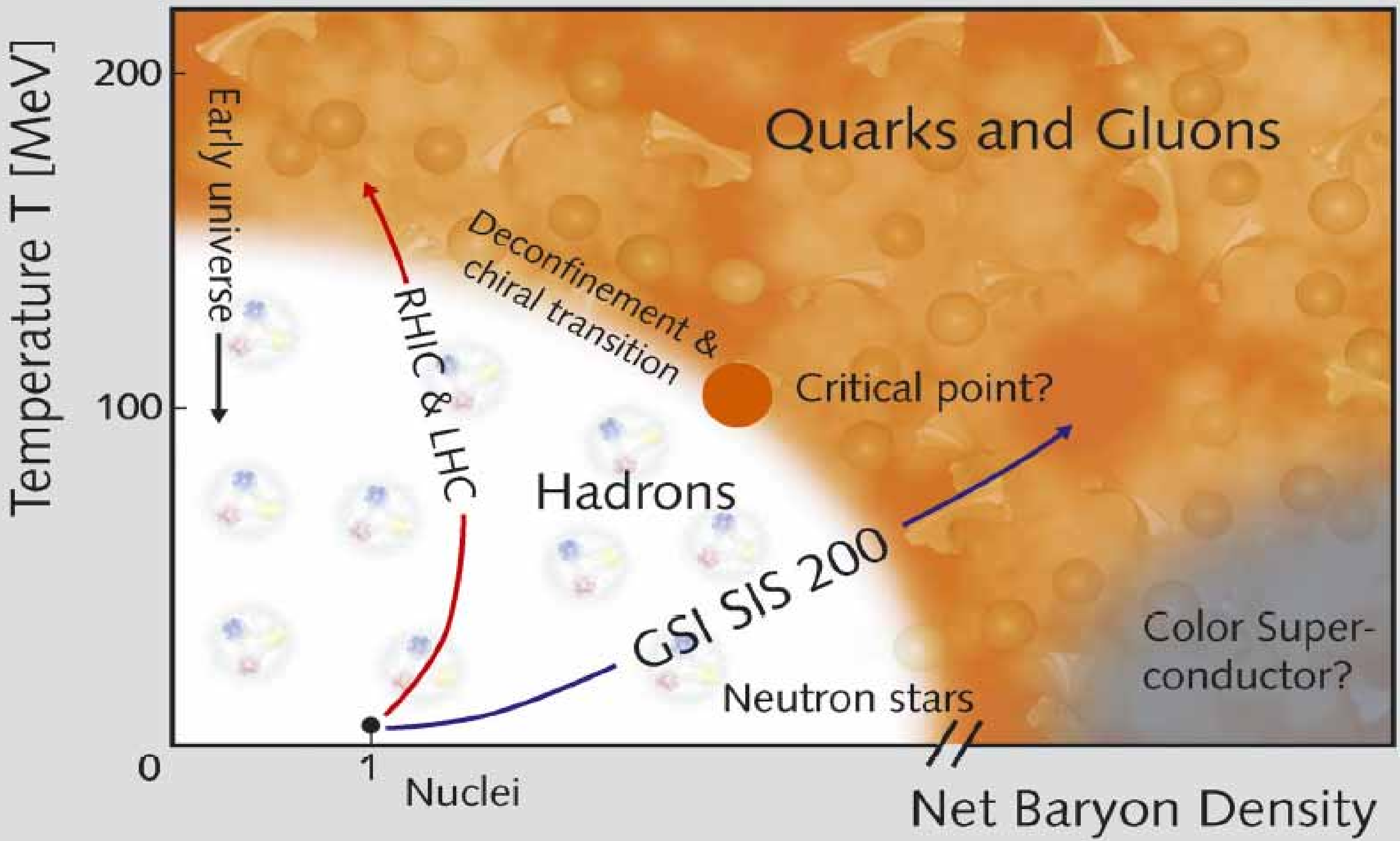
4-th WINTER SCHOOL on THEORETICAL PHYSICS
Dubna, January 29 -- February 7, 2006
Properties of Hadronic Matter under Extreme Conditions

Space-time evolution of heavy ion collision





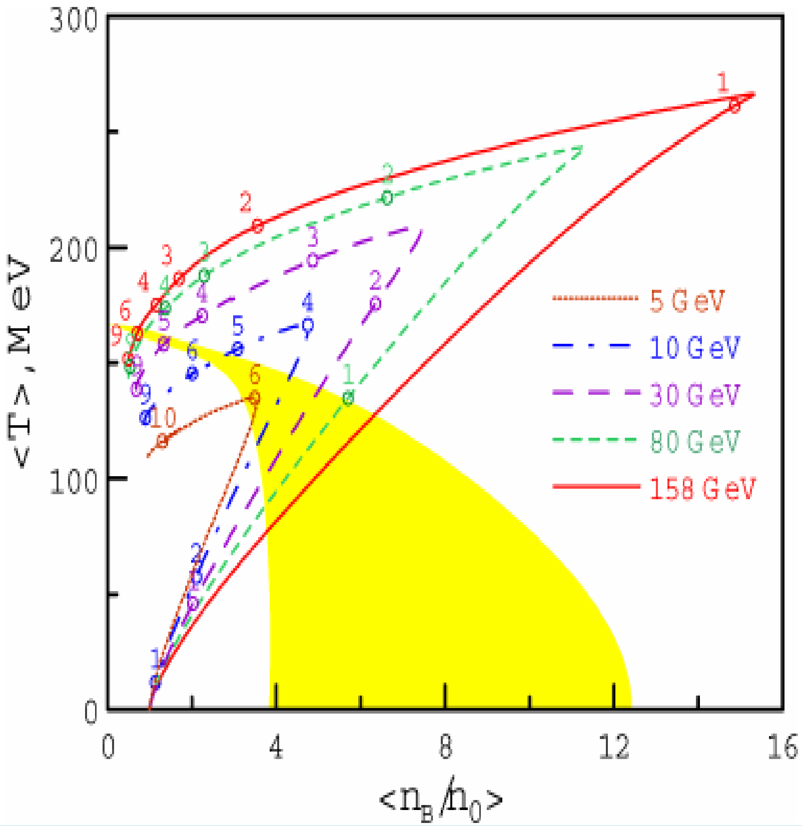
Phases of strongly interacting matter



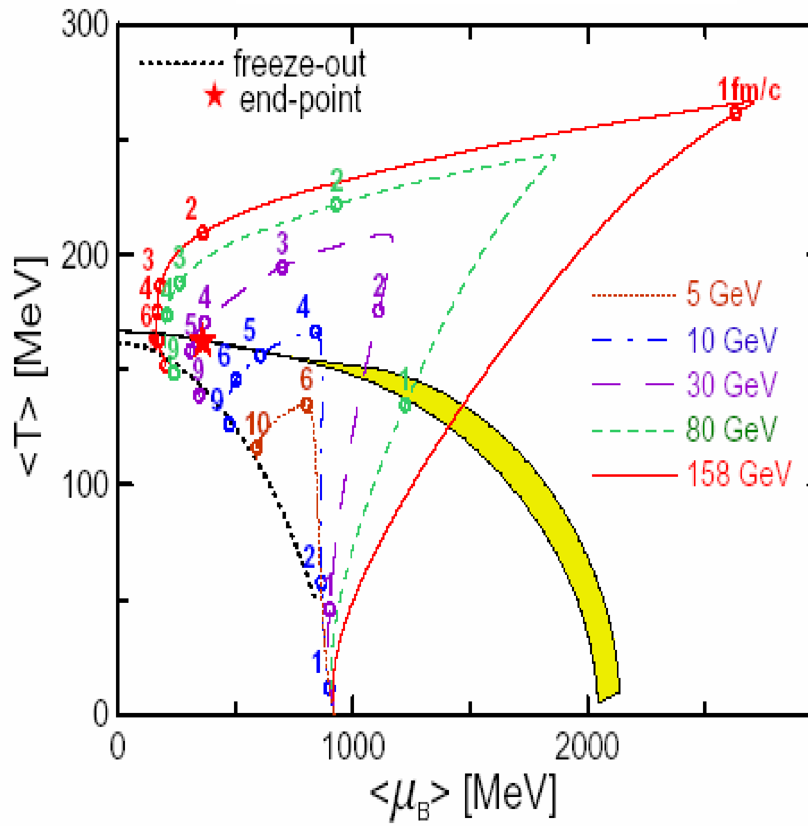
Proposal for an International Accelerator Facility for Research with Heavy Ions and Antiprotons, http://www.gsi.de/documents/DOC-2004-Mar-196-2.pdf

Dynamical trajectories for central (b=2fm) Au+Au collisions

With light quarks



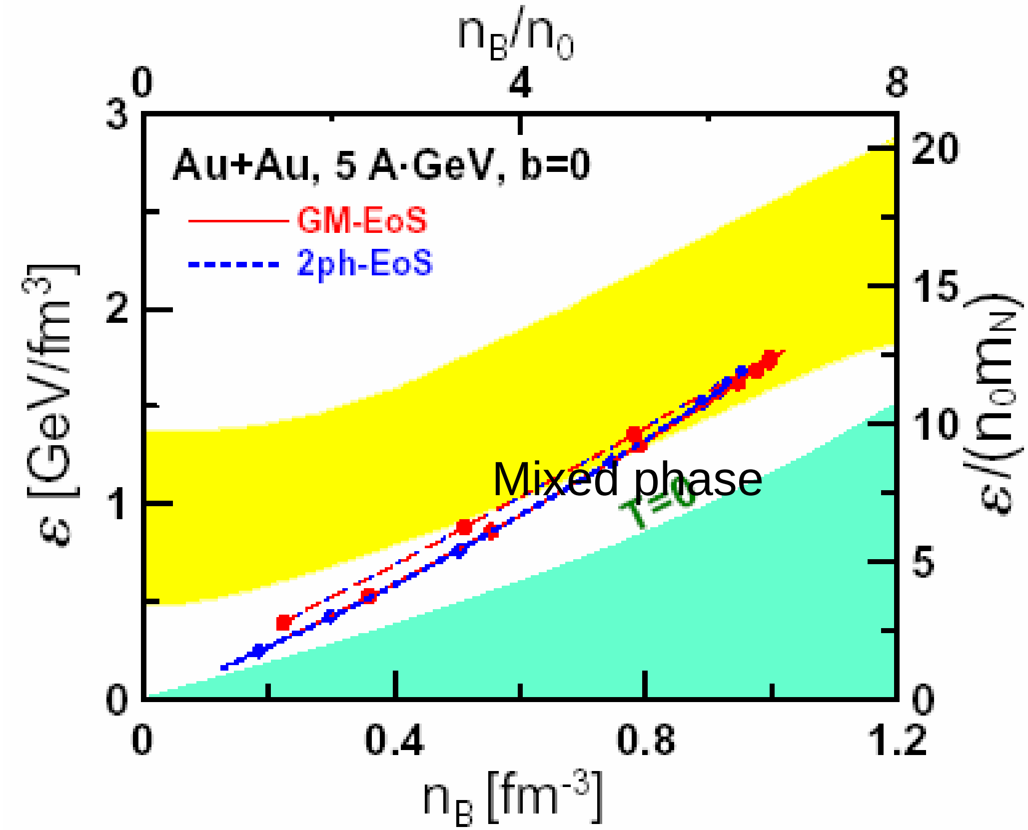
With heavy quarks



V.Toneev, Talk at the CBM Collaboration Meeting March 9-12, 2005, GSI,Darmstadt, http://www.gsi.de/documents/DOC-2005-Mar-87-12.1.pdf

Y.Ivanov,V.Russkikh,V.Toneev, nucl-th/0503088

A system formed in a high energy collision is fast heated and compressed and then starts to expand slowly reaching the freeze-out point which defines hadronic observables



Dynamical trajectory in the ε -n_B-plane for central Au+Au collisions calculated with two equations of state: pure hadronic (solid line) and with first order phase transition (dashed).

Yu.Ivanov, Multi-fluid hydrodynamics, Talk at the CBM Collaboration Meeting "FAIR, The physics of compressed baryonic matter", December 15-16, 2005, GSI,Darmstadt, http://www.gsi.de/documents/DOC-2005-Dec-87-112-1.pdf

At the maximal achievable Nuclotron energy E_lab=5 AGeV the system "looks" into the mixed phase for a short time

Hard to believe that some irregular structure can manifest itself at the Nuclotron energy

The global observables are expected to be quite smooth with energy (average multiplicities, rapidity, transverse spectra, and so on ...).

However it might be not the case for more delicate characteristics!

A permanent trend of leading world research centers

SIS

BEVALAC

(shut down)

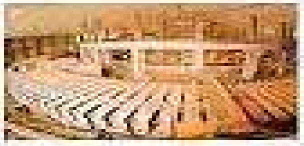
NUCLOTRON

SPS

RHIC

AGS

(shut down)



Synchrophasotron

(shut down)

Heavy ion collisions from Bevalac to SIS

The Day Before Yesterday

BEVALAC: 2 AGeV

The investigation of the properties of compressed hadronic matter

Yesterday

AGS: 11 AGeV

The study of hadronic matter at several times normal nuclear density.

Today

SPS: 20 – 160 AGeV   (NA49 experiments).

NUCLOTRON: 5 AGeV

Search for a mixed phase of strongly interacting matter.

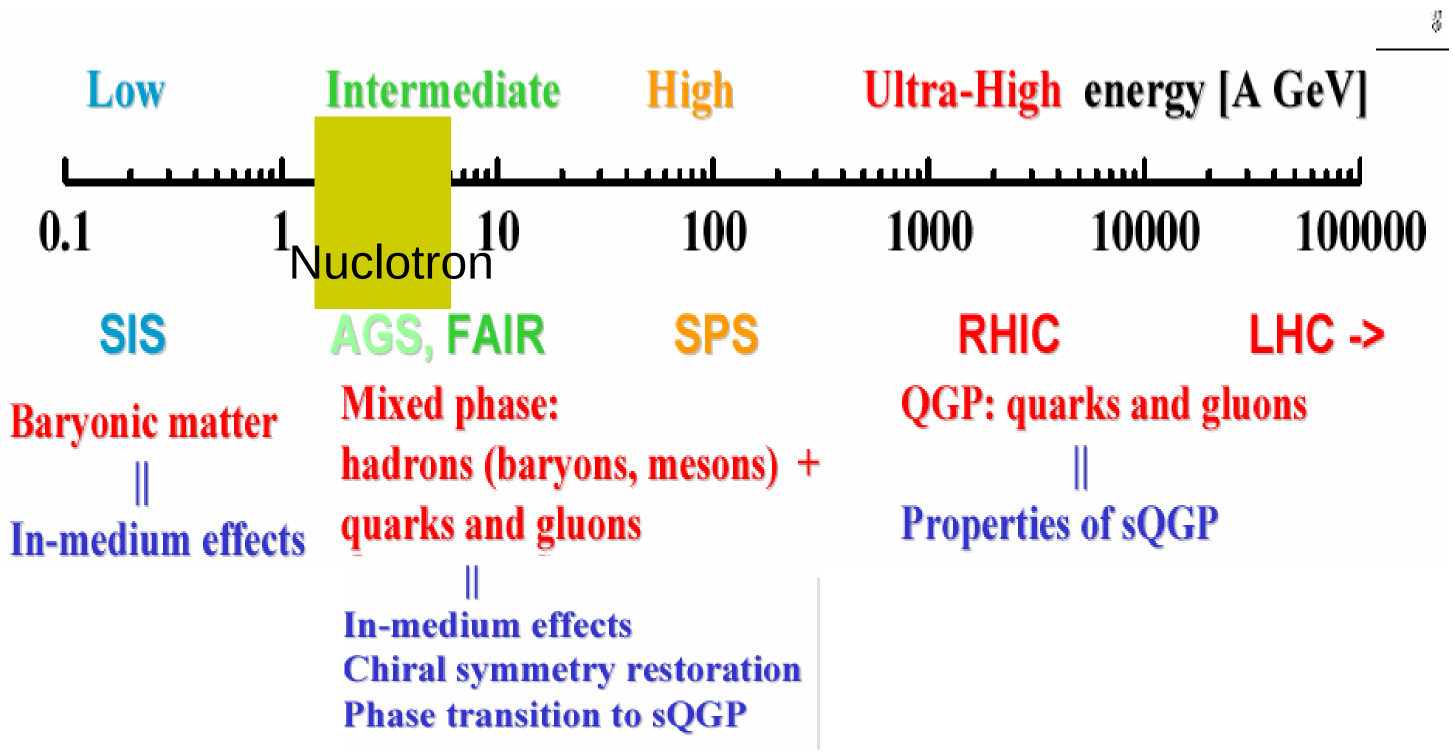
SIS: 1-2 AGeV

The study of electron-positron pair emission in relativistic heavy ion collisions (HADES)

Tomorrow

SIS (FAIR GSI): 10 – 30 GeV/nucl

Compressed Baryonic Matter (CBM)



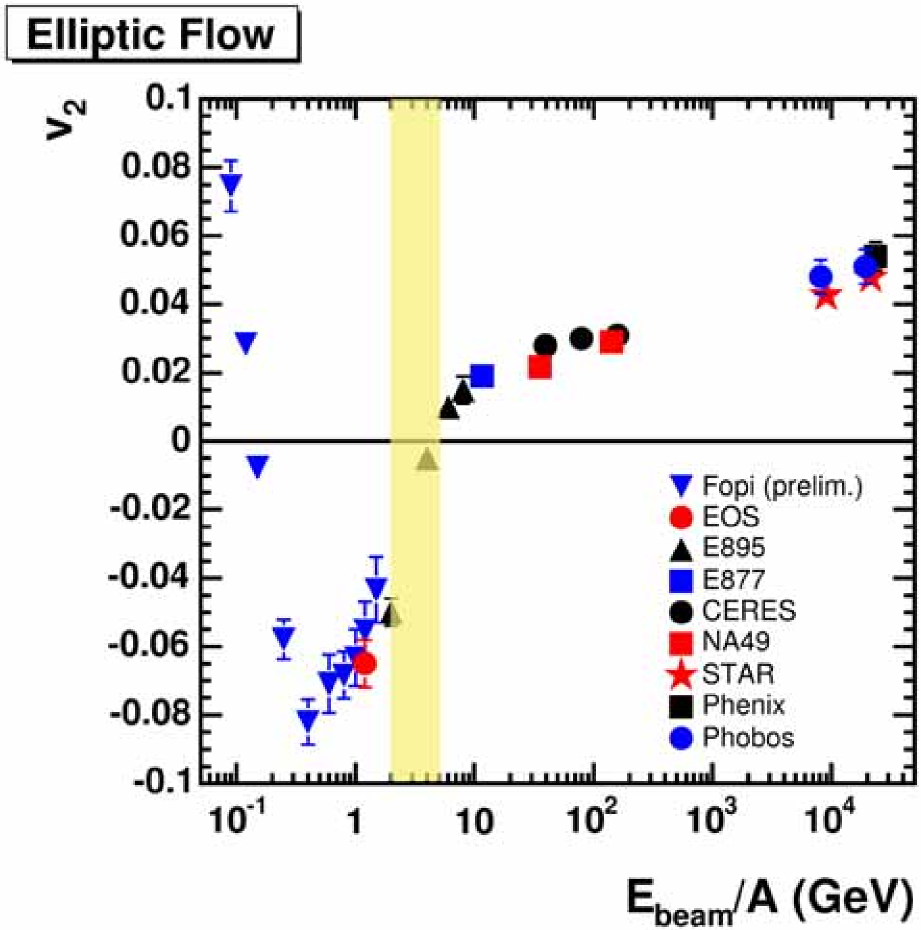
Low
Intermediate
High
Ultra-High
energy [A GeV]
0.1
1
10
100
1000
10000
100000
Nuclotron
SIS
AGS, FAIR
SPS
RHIC
LHC ->
Baryonic matter
||
In-medium effects
Mixed phase:
hadrons (baryons, mesons) +
quarks and gluons
||
In-medium effects
Chiral symmetry restoration
Phase transition to sQGP
QGP: quarks and gluons
||
Properties of sQGP

The expected behavior of global hadronic observables is smooth.

Peculiarities of delicate hadron characteristics may be found and their hints are available even now.

In particular, the excitation function of the elliptic flow (v_2-coefficient) exhibits some structure and changes the sign JUST at the Nuclotron energy of about 5 GeV/nucleon.

$$dN/d\phi \propto [1+2v_1 \cos(\phi)+2v_2 \cos(2\phi)]$$



Presently available data for the elliptic flow coefficient v2 (near midrapidity,integrated over p_T), for √s from SIS /Bevalac via AGS and SPS to RHIC. **R. Stock, nucl-ex/0405007**

At the Nuclotron energy range v_2 strongly depends on the collision energies. V_2 is sensitive to the EOS and space-time evolution. Its measurement at the Nuclotron energy will be extremely important!

Physically, it could be explained by some softening of an equation of state which can be considered as a precursor of a phase transition

Remarkable structure in v_2 versus centrality.

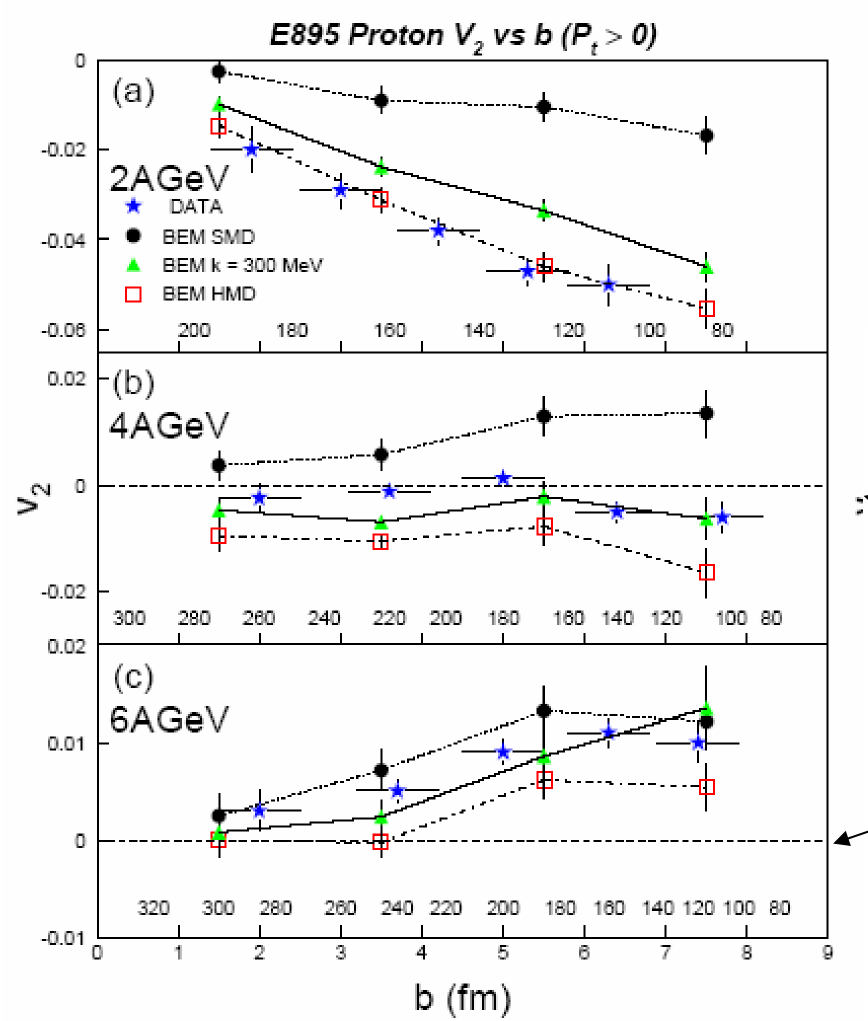


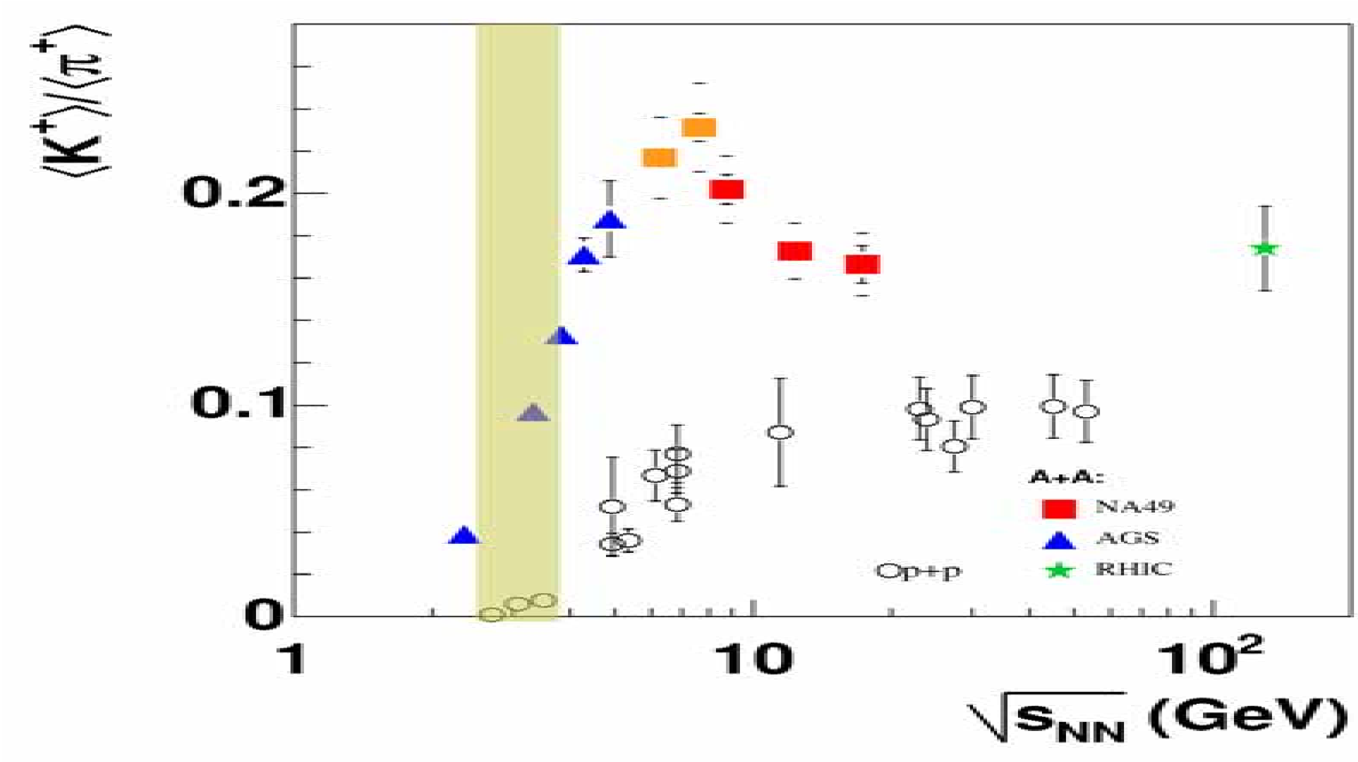
FIG. 2. v_2 as a function of b ($p_T > 0$) for 2 (a), 4 (b) and 6 (c) AGeV Au + Au collisions. Experimental values are indicated by the filled stars. The open squares, full circles and solid triangles represent v_2 values from BEM calculations with a stiff ($K = 380$ MeV), a soft ($K = 210$ MeV) and an intermediate ($K = 300$ MeV) momentum-dependent EOS respectively. The identified charged particle multiplicity M_{filt}, is also indicated for several values of b. The solid, dotted and dashed-dotted lines serve to guide the eye only.

Nuclotron

Boltzmann Equation Model BEM which assumes a soft (K = 210 MeV), a stiff (K = 380 MeV) and an intermediate (K = 300 MeV) EOS respectively (K is the nuclear matter compressibility).

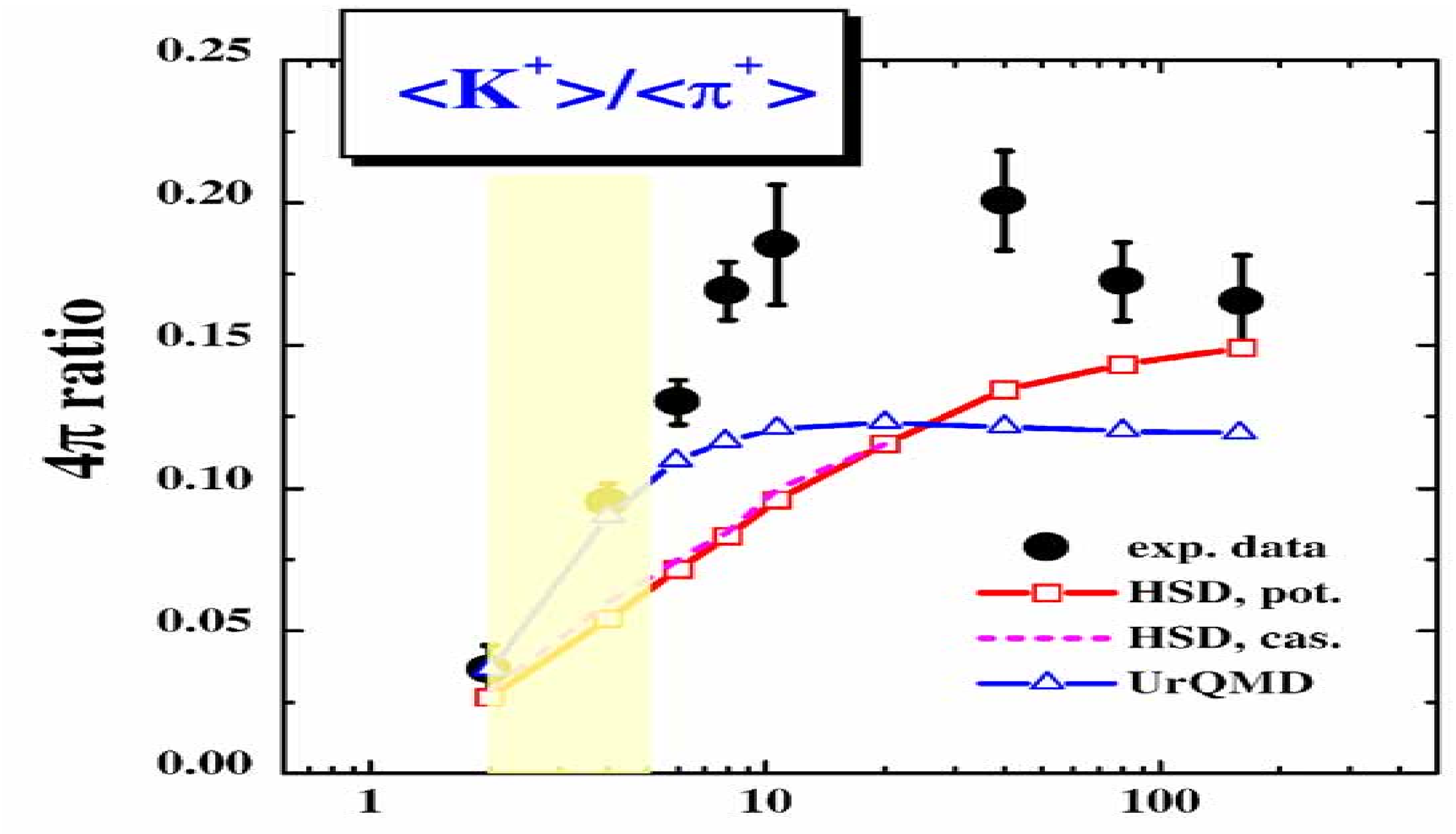
P. Chung et al. Differential Elliptic Flow in 2 - 6 AGeV Au + Au Collisions: A New Constraint for the Nuclear Equation of State, nucl- ex/ 0112002.

- Strangeness enhancement is an intriguing point of physics of heavy ion collisions, being one of the first proposed signals of quark-gluon plasma formation. An important experimental finding is the observation of some structure ("horn") in the energy dependence of reduced strangeness multiplicity at E_lab~30 GeV,as a signal that the formed excited system came into a deconfinement phase.



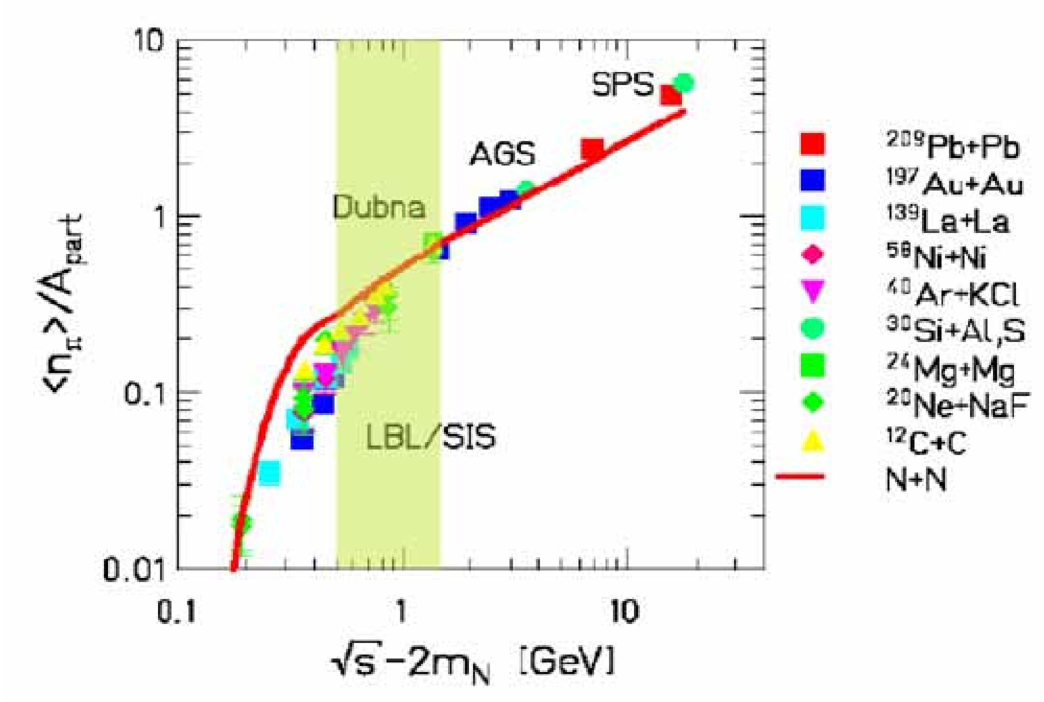
M.Gazdzicki (for the NA49 collaboration), J. Phys. G 30 (2004), S701

Moreover, even global characteristics are not completely explained by modern transport theory (UrQMD, HSD models). While average pion and kaon multiplicities are well reproduced at SIS and SPS energies, the above-mentioned models essentially underestimate kaon/pion ratio in the Nuclotron-AGS energy domain.



H. Weber, E. L. Bratkovskaya, W. Cassing, H. Stoecker, nucl-th/0209079

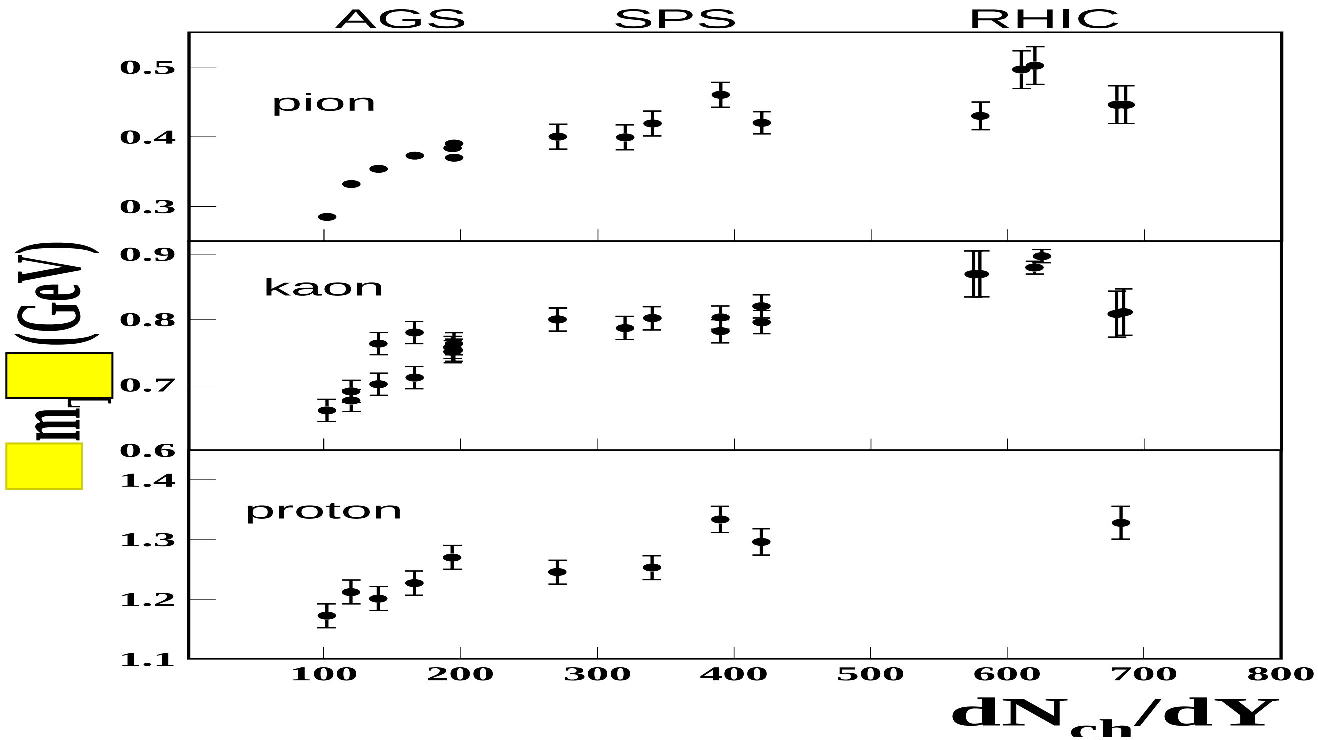
Peculiarities are observed in average pion number per nucleon-nucleon interaction



Pion multiplicity per participating nucleon for nucleus-nucleus (symbol) and nucleon-nucleon collisions (solid line) as a function of available energy in nucleon-nucleon collisions. The shaded band corresponds to the Nuclotron energy.

P.Senger and H.Strobele, J. Phys. G: Nucl. Part. Phys. 25 (1999) R59.

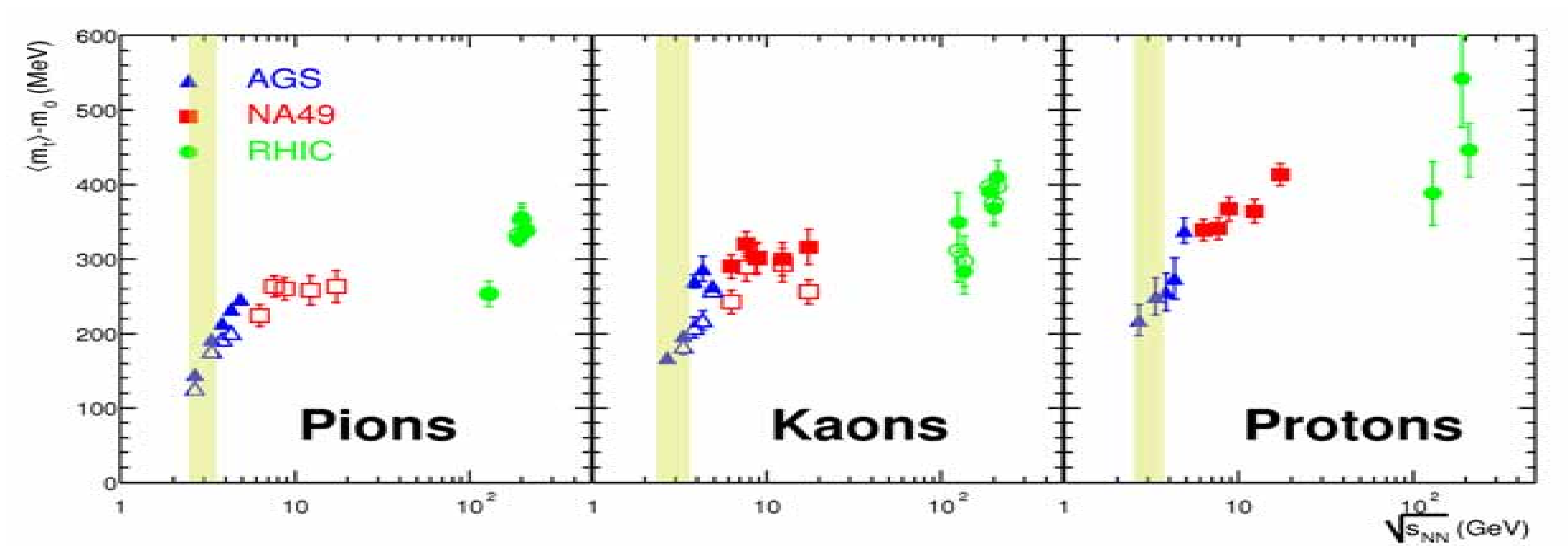
Among many signals of the formation of QGP, one of the earliest is based on the relation of the thermodynamical variables, temperature and entropy to the average transverse momentum and multiplicity, respectively, as was originally proposed by Van Hove. It was argued that a plateau in the transverse momentum beyond a certain value of multiplicity would indicate the onset of the formation of a mixed phase of QGP and hadrons, similar to the plateau observed in the variation of temperature with entropy in a first order phase transition scenario.



Variation of <m_T> with produced charged particles per unit rapidity at midrapidity for central collisions corresponding to the energy range from AGS to RHIC.

B.Mohanty, Jan-e~Alam, S.Sarkar, T.K.Nayak, B.K Nandi, Phys. Rev. C 68, 021901 (2003) [arXiv:nucl-th/0304023].

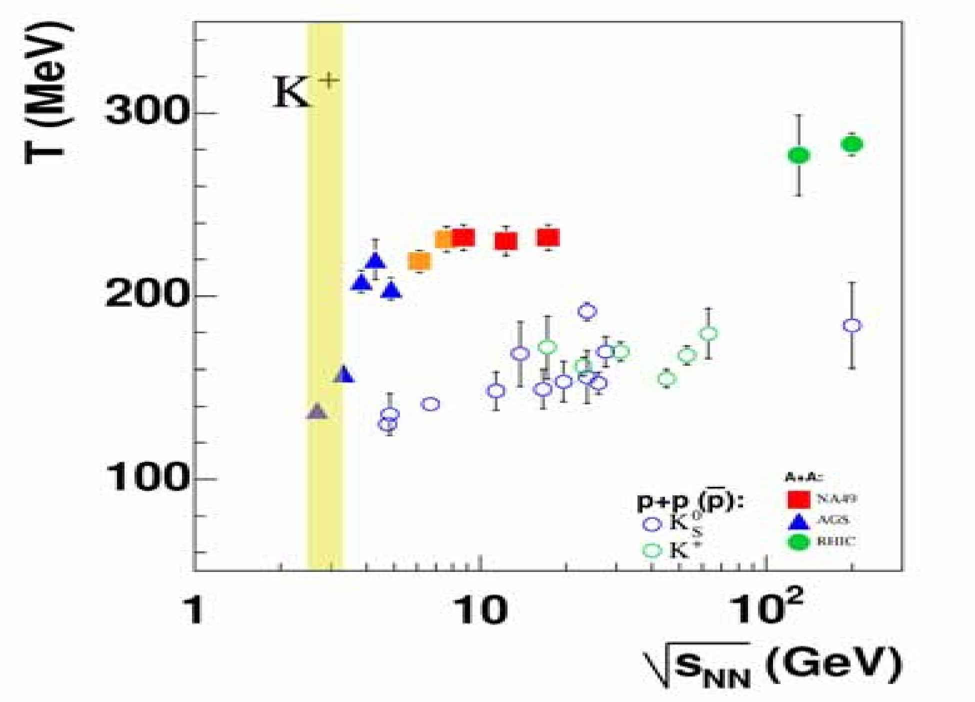
The behavior of the average transverse mass, <m_T> - m_0, versus colliding energy sqrt s_{NN}, is not trivial. A remarkable change in the energy dependence around a beam energy of ~30 AGeV is clearly visible for pions and kaons exhibiting some kind of plateau. While <m_T> -m_0 rises steeply in the AGS energy range, this rise is much weaker from low SPS energies until RHIC energies where it starts again to rise. To a lesser extent this change is also seen for protons. One should emphasize that the beginning of the plateau is well correlated with the "horn" position. Measurements at the Nucloron may specify a pre-plateau behavior, in particular, for kaons and protons.



The energy dependence of <m_T> - m_0 for pions, kaons,and protons at midrapidity for the most central Pb+Pb/Au+Au collisions. Shaded bands correspond to the Nuclotron energy.

M.Gazdzicki, arXiv:nucl-ex/0507017; C.Blume (NA49 Collaboration), [arXiv:hep-ph/0505137].

The inverse slope parameter of kaons increases in the AGS and RHIC energy domains but it stays constant at SPS energies in natural agreement with the particle ratio results.

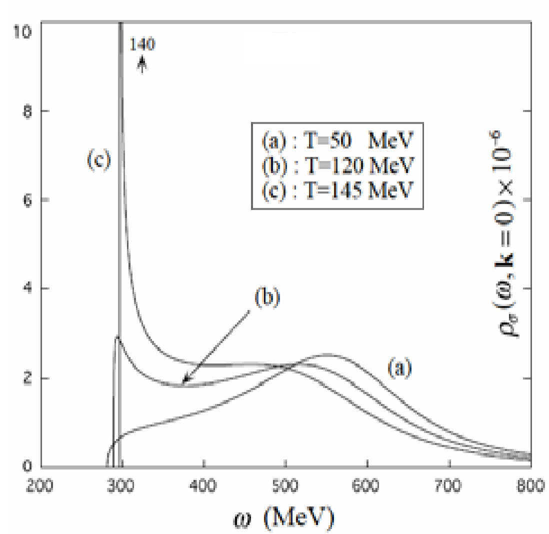


M.Gazdzicki, arXiv:nucl-ex/0507017; C.Blume (NA49 Collaboration), [arXiv:hep-ph/0505137]

Might be attributed to the latent heat of a phase transition (M.I.Gorenstein, M.Gazdzicki, K.A.Bugaev, PL B467 (2003) 175).

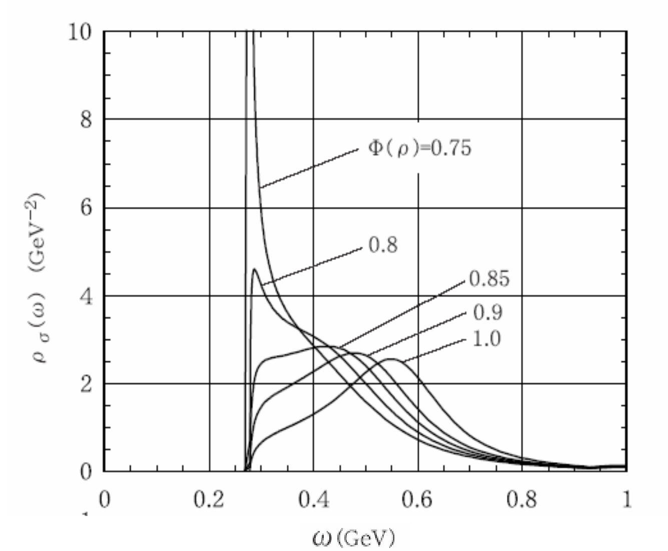
Chiral restoration and scalar meson $\langle \bar{q} q \rangle \to 0$

Finite temperature

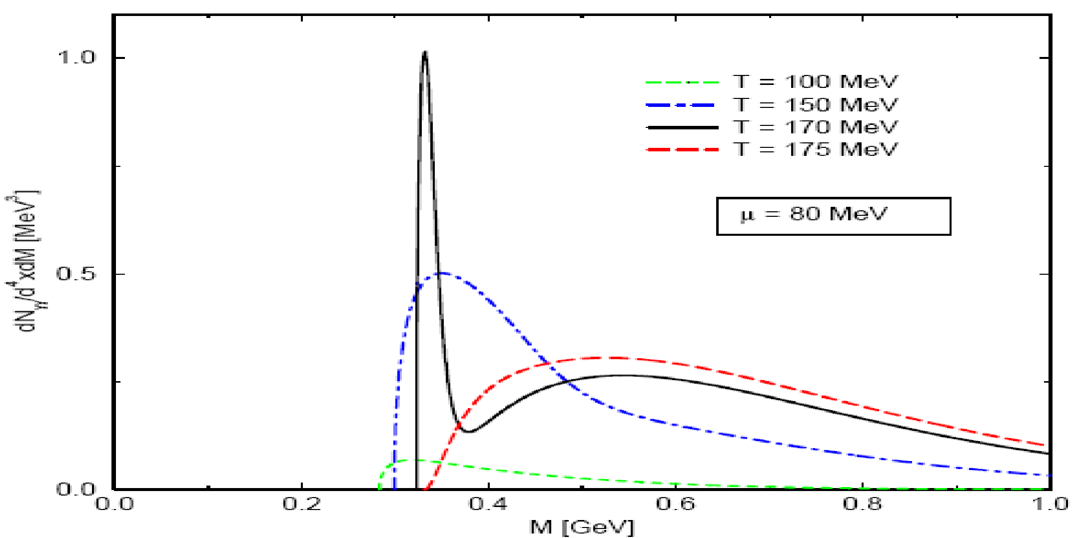


Chiku and Hatsuda, PRD58 ('98)
Volkov et al., PLB424 ('98)

Finite density



Hatsuda, Kunihiro and Shimizu, PRL82 ('99)



M.Volkov, E.Kuraev, D.Blaschke, G.R¨opke, S.Schmidt, PLB(1998)

$\sigma \to \pi\pi \quad \sigma \to \gamma\gamma$

$\Gamma_\sigma = 600 - 1000 MeV$

$M_\sigma = 400 - 1200 MeV$

Problems of SPS and RHIC:
huge background from neutral pion decays complicates identification of this signal.

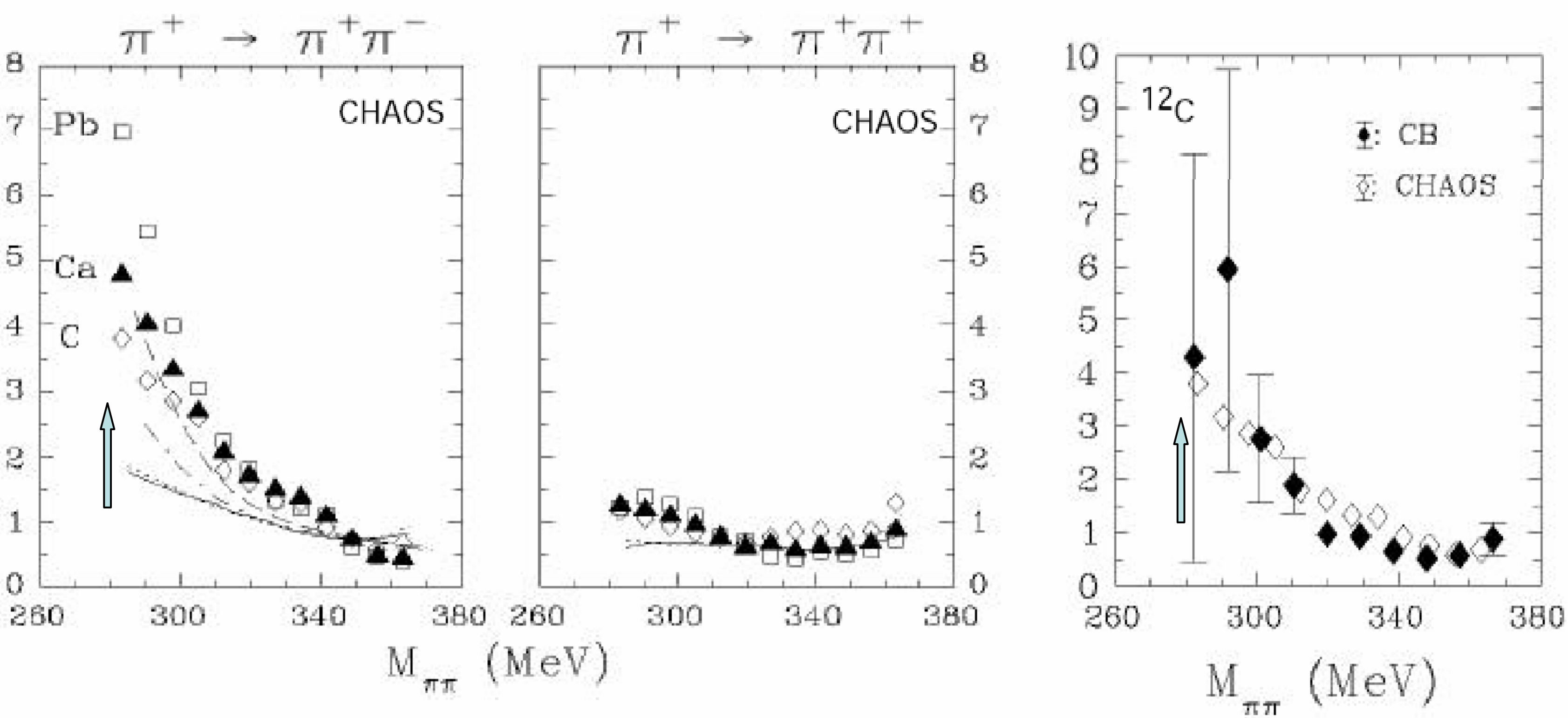
Privilege of the Nuclotron and FAIR:
higher densities entail lower critical temperatures → lower background!

π-production experiments

Composite ratio :

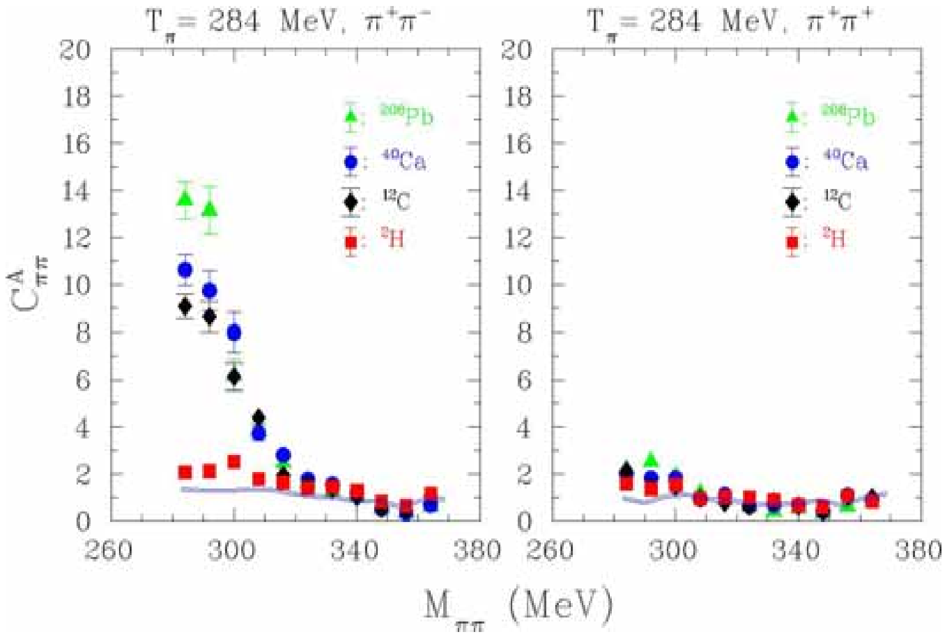
$$C^{A}_{\pi\pi} = \frac{\sigma^{A}(M_{\pi\pi})}{\sigma^{A}_{T}} \Big/ \frac{\sigma^{N}(M_{\pi\pi})}{\sigma^{N}_{T}}$$

- $\pi^{+}A \rightarrow \pi\pi A'$ $p_{\pi+}$=399 MeV/c
  CHAOS, PRL 77('96), Nucl. Phys. A677 ('00)
- $\pi^{-}A \rightarrow \pi\pi A'$ $p_{\pi-}$=408 MeV/c
  Crystal Ball, PRL 85 ('00)
- $\gamma A \rightarrow \pi\pi A'$ E_{γ}=400-460 MeV
  TAPS, PRL 89 ('02)



Camerini et al, Phys.Rev.C64 ('01)

CHAOS update

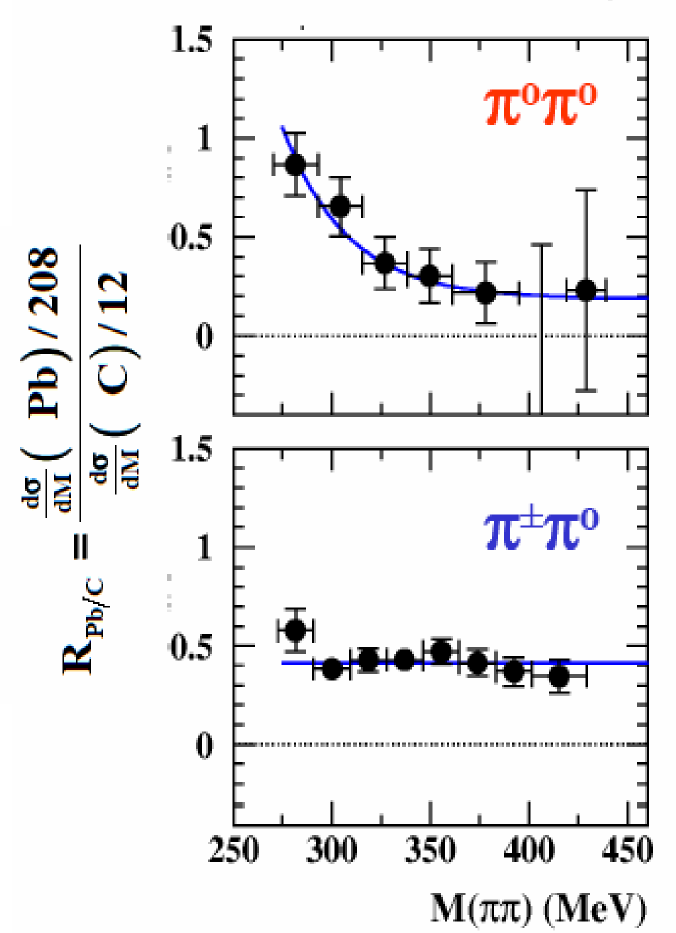


Chiral 05 workshop at RIKEN

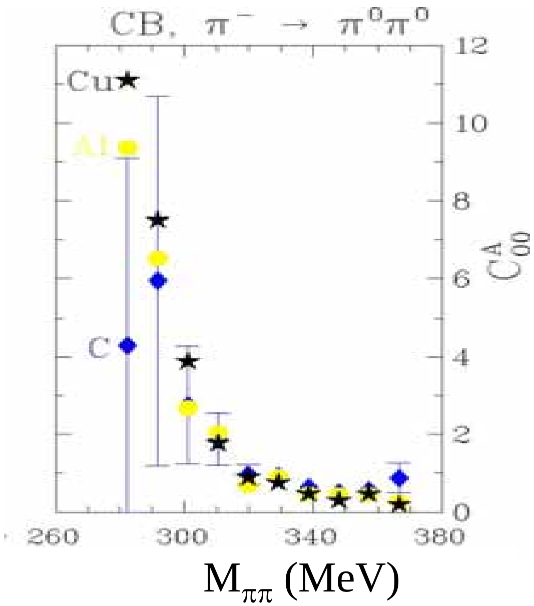
http://chiral05.riken.jp/

N. Grion (CHAOS), S. Shadmand (TAPS)

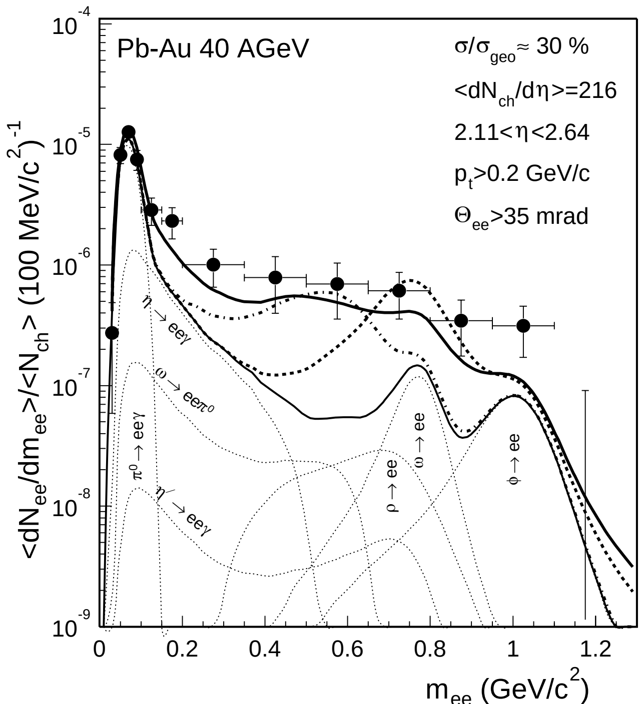
TAPS update

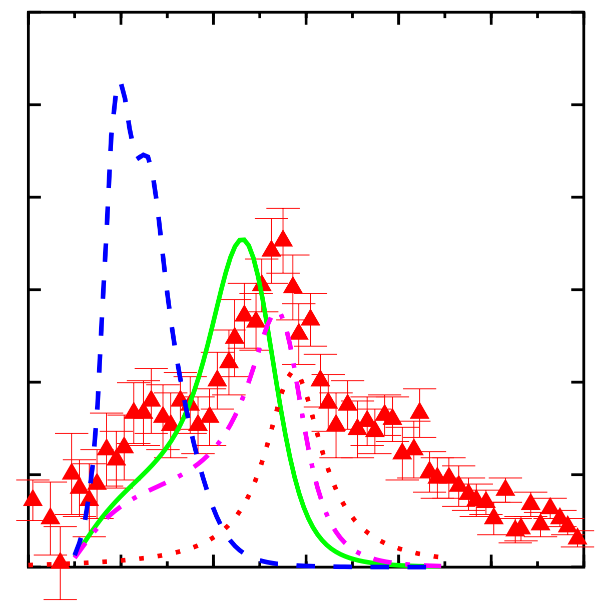


CB update



Properties of hadrons are expected to change in hot and/or dense baryon matter





Left panel: e^+e^- invariant spectra from central Pb+Au (40 GeV) a collisions(CERES). **D.Adamova et al., CERES/NA45 Collaboration, arXiv:nucl-ex/0209024**

Thin solid and dotted lines are hadronic cocktail and the calculated results for free ρ mesons, respectively. Appropriate thick solid and dash-dotted lines are calculated in the Rapp-Wambach (**R.Rapp and J.Wambach, Adv. Nucl. Phys. 25, (2000) 1.**) and Brown-Rho (**G.E.Brown and M.Rho, Phys. Rep. 269, (1996) 333**) scenarios.Contributions of different channels are shown as well.

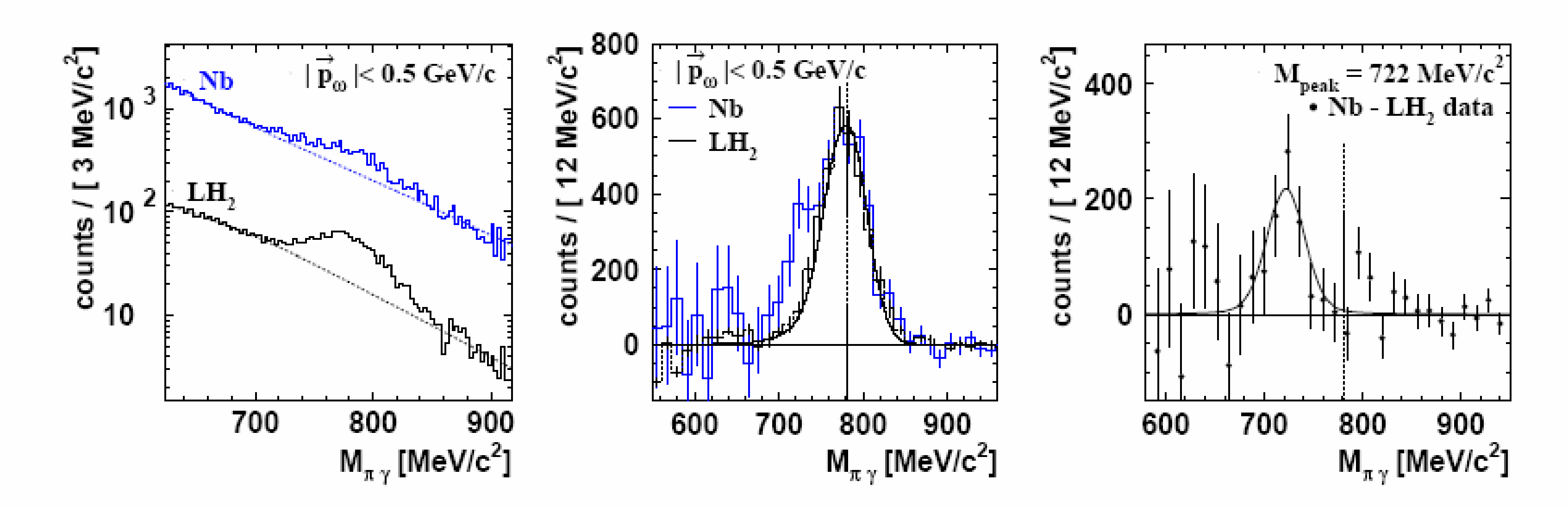
Right panel: Invariant mass distribution of dimuons from semi-central In+In collisions at the beam energy 158 AGeV. Experimental points are from (NA60, **S.Scomparin et al., QM 2005 Proceedings (2005); S.Damjanovic et al., QM 2005 Proceedings (2005) [arXiv: nucl-ex/ 0510044].).** Solid and dashed curves are calculated in the dropping mass (**V.V.Skokov and V.D. Toneev, arXiv:nucl-th/0509085**) scenario using the rho-mass modification factors as density and temperature-density dependent, respectively. Dash-dotted curve neglects any in-medium modification.Dotted line indicates the hydrodynamically calculated rho-meson decay at the freeze-out.

CBELSA/TAPS Collaboration,
"FIRST OBSERVATION OF IN-MEDIUM MODIFICATIONS OF THE OMEGA MESON", nucl-ex/0504010

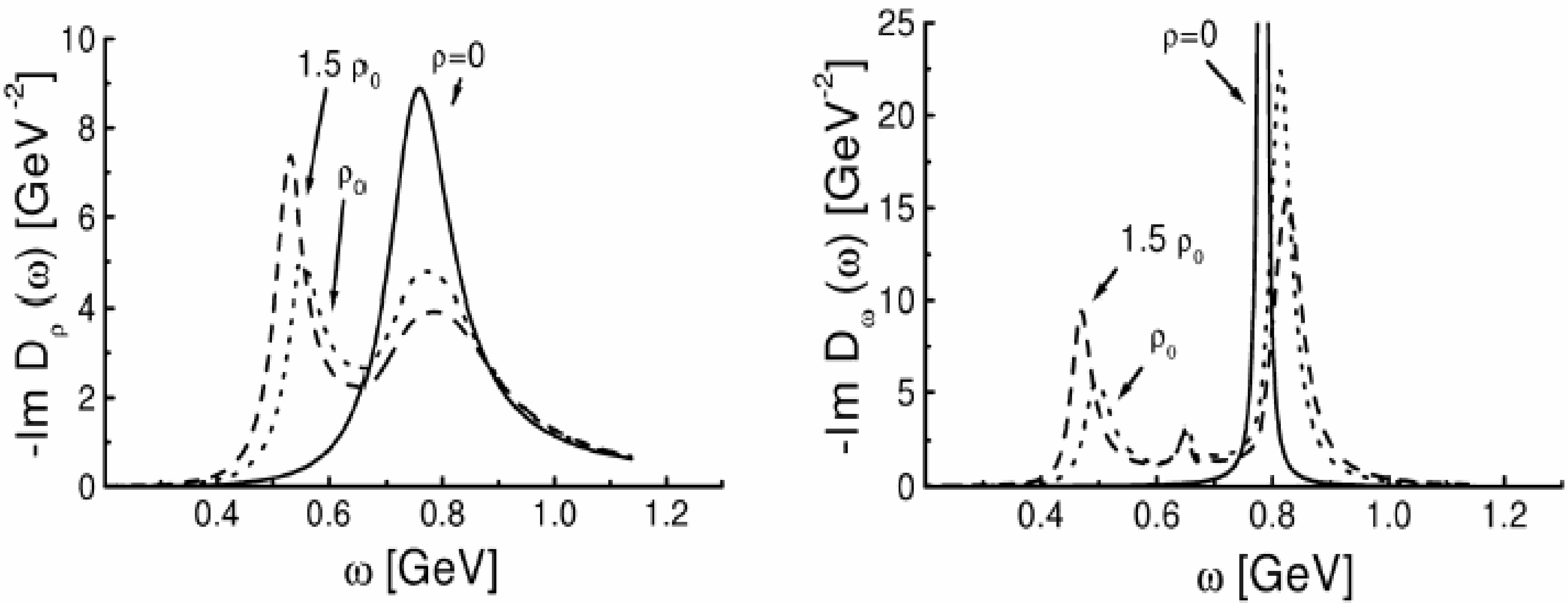
ELSA tagged photon facility in Bonn

$$\gamma + A \rightarrow \omega + X \rightarrow \pi^0\gamma + X'$$

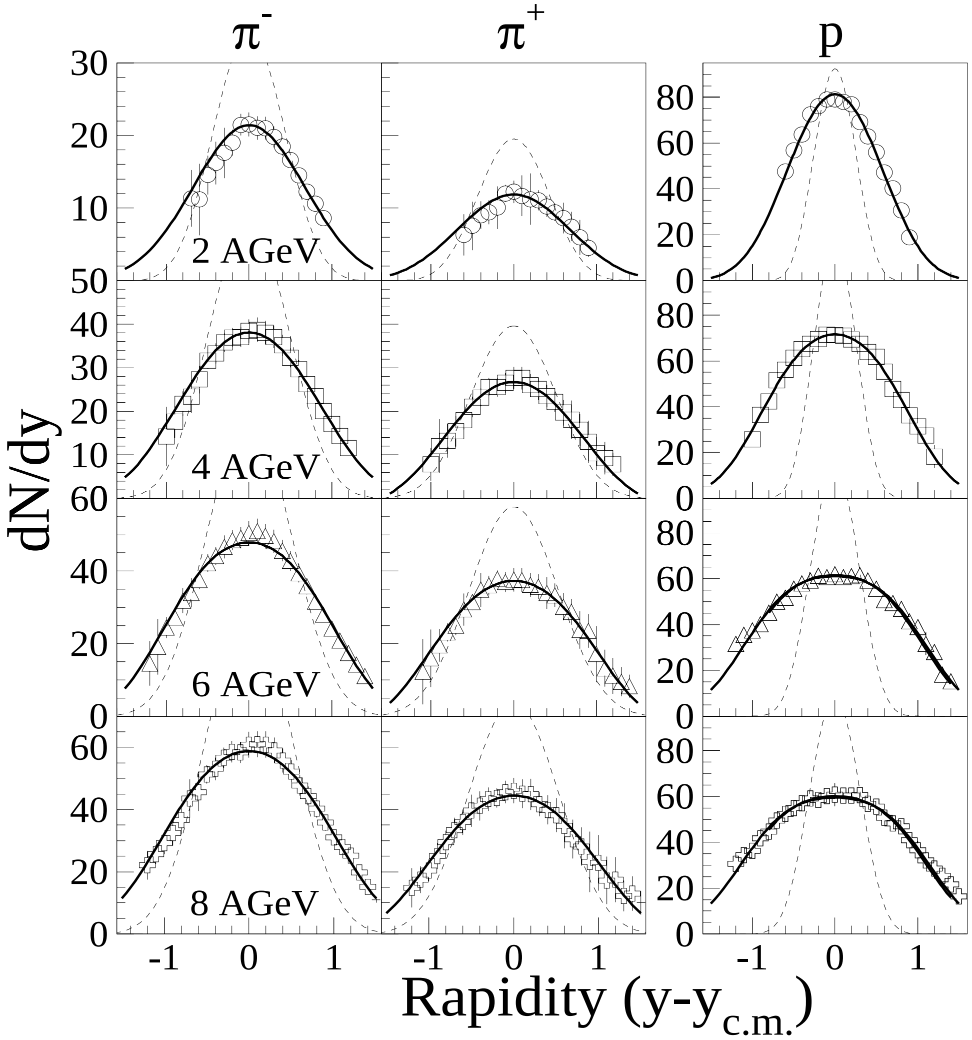
$E\gamma$=0.64-2.53 GeV



Left panel: Inclusive $\pi^0\gamma$ invariant mass spectra for ω momenta less than 500 MeV/c. Upper histogram: Nb data, lower histogram: LH_2 target reference measurement. The dashed lines indicate fits to the respective background.Center panel: $\pi^0\gamma$ invariant mass for the Nb data (solid histogram) and LH_2 data (dashed histogram) after background subtraction. The error bars show statistical uncertainties only. The solid curve represents the simulated lineshape for the LH_2 target. Right panel: In-medium decays of ω mesons along with a Voigt fit to the data. The vertical line indicates the vacuum ω mass of 782 MeV/c^2.



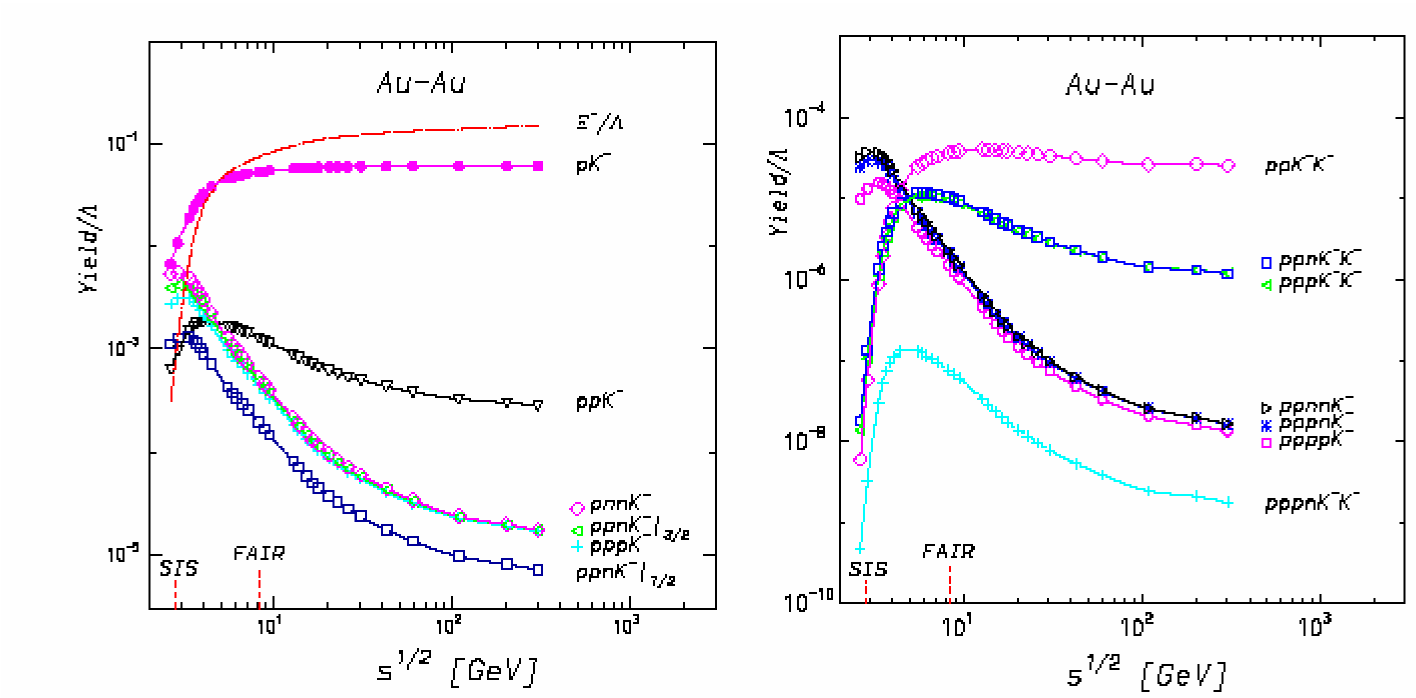
The ρ (left) and ω (right) spectral functions in vacuum and in nuclear matter at densities $\rho = \rho_0$ and $\rho_0 = 1.5\ \rho_0$, obtained in a model that describes meson-nucleon scattering data at energies near the vector meson threshold [B. Friman, M. Lutz and G. Wolf, In Proc. Int. Workshop on Gross Properties of Nuclei and Nuclear Excitations, Hirschegg, Austria, 2000, p. 161]



The shape of rapidity spectra for newly produced mesons is bell-like but cannot be described by a single Gaussian due to flow effects. Note that a number of pi^+ is not equal to that of pi^- though their difference essentially decreases with the bombarding energy. So the isotopic degree of freedom should properly be taken into account under theoretical consideration in the Nuclotron energy range.

J.L.Klay et al. Phys. Rev. C 68, 054905 (2003) [archive:nucl-ex/0306033]

A. Andronic, P. Braun-Munzinger, K. Redlich. arXiv: nucl-th/0506083



Excitation function of the yields of antikaon bound states relative to Λ yields. The calculations are done along the freezeout curve of fixed E/N = 1 GeV ***[J. Cleymans and K. Redlich, Phys. Rev. Lett. 81 (1998) 5284 and Phys. Rev. C60 (1999) 054908.].*** **For comparison, also show in the left panel is the Ξ^-/Λ yield ratio. The vertical lines indicate the upper energies accessible in experiments at SIS and FAIR.**

The yield of double K- clusters is maximal in the energy range of the Nuclotron and SIS accelerator.

As became clear at the last years, excited nuclear matter near the phase transition boundary line behaves like a liquid rather than a gas, both from hadron and quark sides, see, e.g. the following references:

1. E.V.Shuryak and I.Zahed, "Towards the theory of binary bound states in the quark-gluon plasma", hep-ph/0403127,
2. E.V.Shuryak and I.Zahed, "Rethinking on properties of the quark-gluon plasma at $T\sim T_c$", hep-ph/0307267,
3. G.E.Brown, Ch,-H.Lee and M.Rho, "A new state of matter at high temperature as "sticky molasses", hep-ph/0402207,
4. D.N. Voskresensky, Hadron Liquid with a Small Baryon Chemical Potential at Finite Temperature, Nucl.Phys. A744 (2004) 378 [hep-ph/0402020,
5. E.Shuryak, Why does the Quark-Gluon Plasma at RHIC behave as a nearly ideal fluid, Prog.Part.Nucl.Phys. 53 (2004) 273-303, hep-ph/0312227,
6. Masakiyo Kitazawa, Teiji Kunihiro, Yukio Nemoto, Non-Fermi Liquid Behavior Induced by Resonant Diquark-pair Scattering in Heated Quark Matter, hep-ph/0505070,
7. Masakiyo Kitazawa, Teiji Kunihiro, Yukio Nemoto, Quark Spectrum near Chiral Transition Points, hep-ph/0505106,
8. G.E. Brown, B.A. Gelman, M. Rho, What hath RHIC wrought? nucl-th/0505037.

It is hardly to say now that we understand properly physics in this energy range, both experimentally and theoretically. We hope that the JINR Nuclotron facilities could contribute into solving the related problems.

Due to the proximity of the phase diagram region under discussion to the confinement transition and chiral symmetry restoration, some precursory phenomena cannot be excluded at a bombarding energy of about 5 AGeV, which opens a new perspective for physical investigations at the JINR Nuclotron.

In this connection the following theoretical and experimental studies at JINR are considered as perspective:

1) research into the hadron properties in hot and/or dense baryonic matter. A spectral function change is expected, first of all for the sigma-meson as a chiral partner of pions, which characterizes a degree of chiral symmetry violation. The rare specific channels of rho-meson decays are also quite attractive.

Solving these issues assumes a proper understanding of reaction mechanisms of high-energy colliding ions, knowledge of properties of strongly interacting QCD matter and its equation of state. In this respect, more general researches are in order:

2) analyzing multiparticle hadron interactions, targeted to the development of a new statistical treatment as well as codes for space-time evolution of heavy nuclei collisions at high energies. Particular attention should be paid to signals of a new phase formation during this evolution;

3) studying the system size, lifetime, freeze-out duration, expansion time in the HBT analysis, scanning in atomic number and energy;

4) analyzing the energy and centrality dependencies of the pion, hadron resonance and strange particle multiplicities, and the ratio of their yields, together with the transverse momentum, including K^-, K^*- and phi-meson spectra as well as manifestation of baryon repulsion effects on hadron abundances;

5) studying dileptons (electron and muon pairs) production to see in-medium modification of hadron properties at high baryon densities;

6) studying angular correlations in the transverse plane as well as radial, directed and elliptic flows;

7) analyzing fluctuations of multiplicities, electric charge, and transverse momenta for secondary particles (their energy dependencies could give information on the phase transition range);

8) analyzing nuclear fragments characteristics versus centrality, universality of nuclear fragmentation;

9) energy and atomic number scanning for all characteristics of central heavy nuclei collisions (this might allow one to obtain information on the equation of state of strongly interacting QCD matter in the transition area), difference between central collisions of light nuclei and peripheral heavy ion collisions.

The JINR Nuclotron has a possibility to accelerate heavy ions (up to A> 200) to the maximal energy of 5 AGeV in about a year. This gives a chance to address experimentally many recent problems within the next several years before the FAIR GSI accelerator comes into operation. The proposed research program at the Nuclotron may be considered as a pilot study preparing for subsequent detailed investigations at SIS-100/300 and as an integral part of the world scientific cooperation to study the energy dependence of hadron production properties in nuclear collisions.

It seems that the JINR Nuclotron is a unique possibility to investigate statistical fluctuations in relativistic systems: we will create a statistical relativistic system and all its particles can be detected event-by-event!

For these investigations we will need a very high statistics. This can give us a possibility to observe the productions of very rare particles (for example, threshold and sub-threshold production of multistrange baryons with uss-, dss-, sss-quark content).

Measurements require tracking detectors of large acceptance and precise control of collision centrality on event-by-event basis. Up to now only results on very limited acceptance at high energies are available, thus new measurements at the Nuclotron energy are of particular importance.

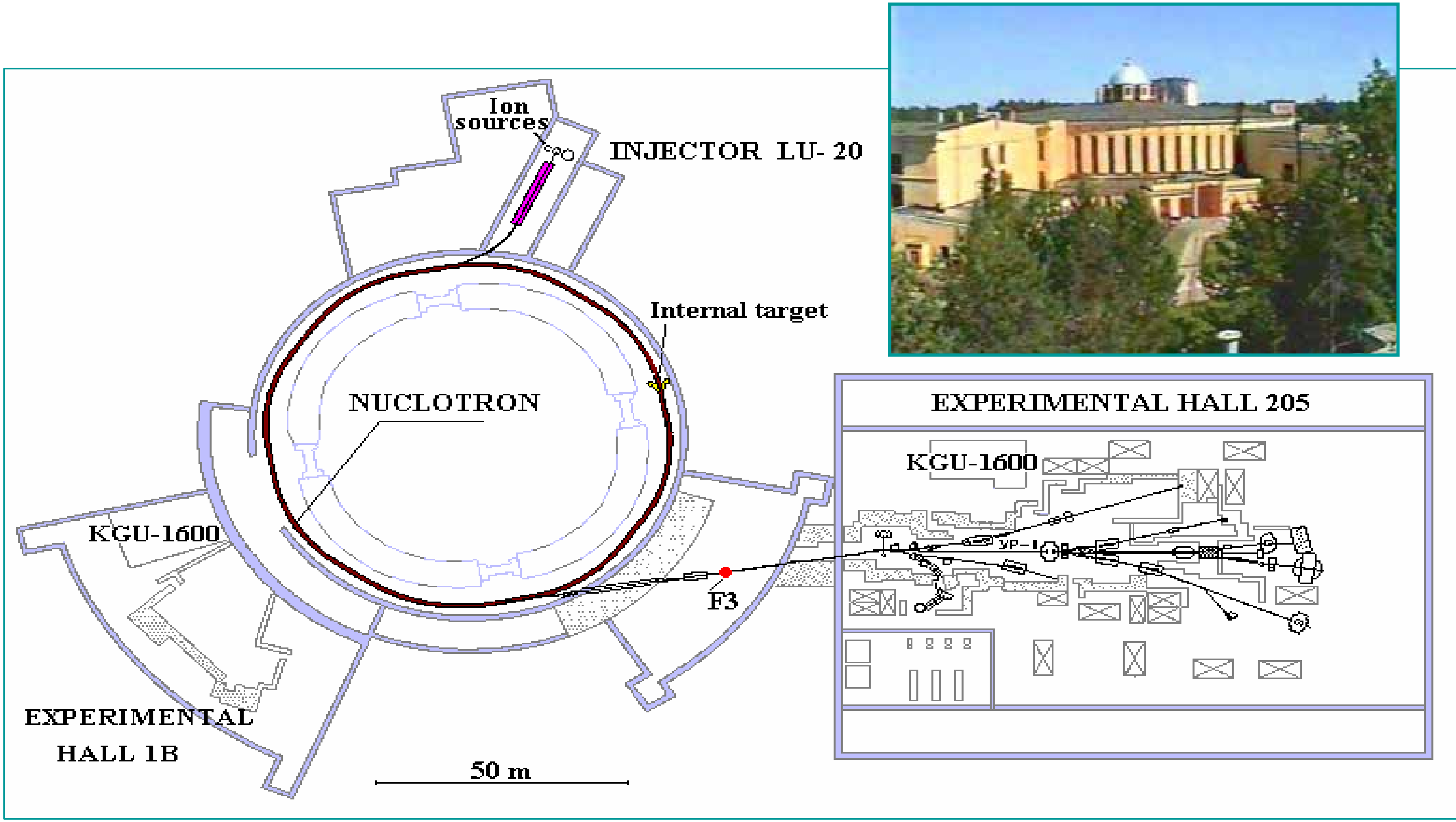
From the experimental point of view the Nuclotron energy range seems to be ideal for these measurements. This is because moderate particle multiplicity and their relatively broad angular distribution simplify an efficient detection of all produced charged particles.

All these investigations suppose that centrality of heavy-ion collisions is under control and centrality scanning of the characteristics under discussion is an indispensable condition.

Measurements of these quantities at the Nuclotron energies should be considered as a necessary continuation of global efforts to establish the energy dependence of properties of hadron productionand search for signals of a phase change in nuclear collisions.

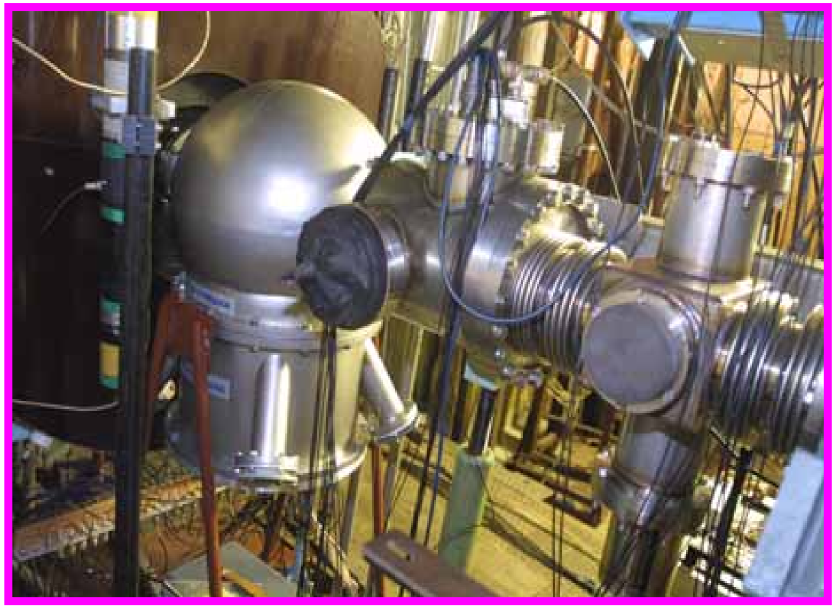
Modern superconducting accelerator

THE JINR NUCLOTRON ACCELERATOR FACILITY



THE JINR NUCLOTRON ELEMENTS

INTERNAL TARGET and the OTHER EQUIPMENT at the WARM STREIGHT SECTION



The main parameters of the Nuclotron

PARAMETER	DESIGN	AVAILABLE
• PARTICLES	1<Z<92	1<Z<36
• MAXIMUM ENERGY, GeV/u	6 (A/Z=2)	4.2
• MAXIMUM MAGNETIC FIELD, T	2.0	1.5
• INJECTION ENERGY, MEV/U	5	5
• SLOW EXTRACTION:		
• SPILL DURATION, s • ENERGY RANGE, GeV/u	to 10 — 6.0	10 0.2 — 2.3
• VACUUM, Torr	$1\cdot10^{-10}$	$1\cdot10^{-10}$
• PULSE REPETITION RATE, HZ	0.5	0.2
• MAGNETIC FIELD RAMP, T/s		
stand tests	4	4.1
in the ring	2	1.0

The beam intensities

	INTENSITY (Particles per cycle)		
BEAM	YEAR 2002	YEAR 2003	YEAR 2005
p	$3\cdot10^{10}$	$1\cdot10^{11}$	$2\cdot10^{11}$
d	$5\cdot10^{10}$	$5\cdot10^{10}$	$1\cdot10^{11}$
^{4}He	$8\cdot10^{8}$	$3\cdot10^{9}$	$2\cdot10^{10}$
^{7}Li	$8\cdot10^{8}$	$1\cdot10^{9}$	$2\cdot10^{9}$
^{10}B	$2.3\cdot10^{7}$	$2\cdot10^{8}$	$5\cdot10^{7}$
^{12}C	$1\cdot10^{9}$	$2\cdot10^{9}$	$1\cdot10^{10}$
^{14}N	-	$1\cdot10^{7}$	$5\cdot10^{7}$
^{16}O	$5\cdot10^{8}$	$7\cdot10^{8}$	$1\cdot10^{9}$
^{24}Mg	$2\cdot10^{7}$	$1\cdot10^{8}$	$3\cdot10^{8}$
^{40}Ar	$\sim1\cdot10^{6}$	$3\cdot10^{7}$	$2\cdot10^{8}$
^{56}Fe	-	$1.2\cdot10^{6}$	$5\cdot10^{7}$
^{84}Kr	$\sim1\cdot10^{3}$	-	$5\cdot10^{6}$
^{131}Xe	-	-	$1\cdot10^{6}$

The expected heavy ion beam progress

BEAMS	2003 г.	2005 г.	2009 г.
p	$1\cdot10^{11}$	$2\cdot10^{11}$	$1\cdot10^{13}$
d	$5\cdot10^{10}$	$1\cdot10^{11}$	$1\cdot10^{13}$
^{4}He	$3\cdot10^{9}$	$2\cdot10^{10}$	$2\cdot10^{12}$
^{7}Li	$1\cdot10^{9}$	$2\cdot10^{9}$	$5\cdot10^{12}$
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^{16}O	$7\cdot10^{8}$	$1\cdot10^{9}$	
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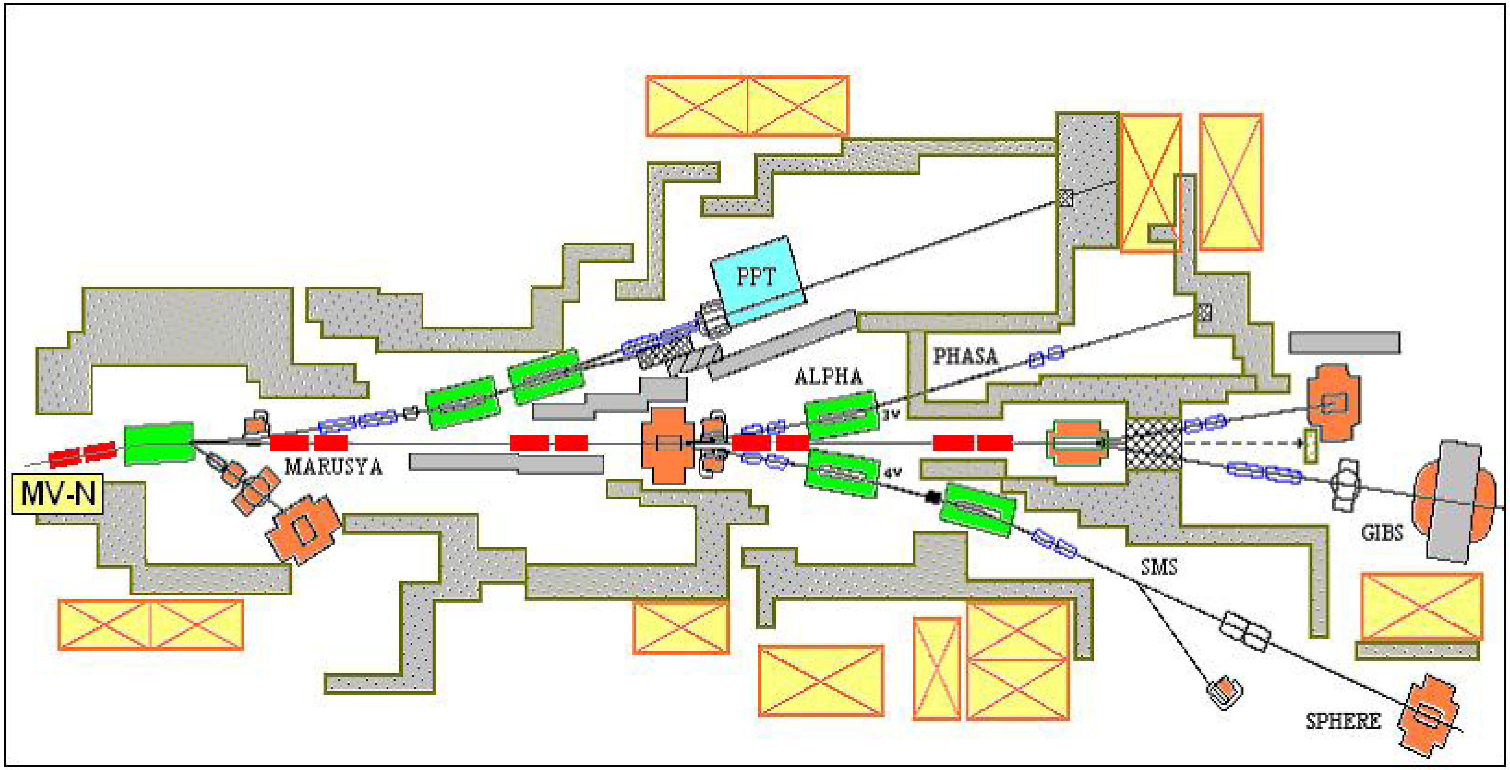
^{56}Fe	$1.2\cdot10^{6}$	$2\cdot10^{7}$	$1\cdot10^{11}$
^{84}Kr	-	$2\cdot10^{7}$	$5\cdot10^{8}$
^{131}Xe	-	$1\cdot10^{7}$	$2\cdot10^{8}$
^{181}Ta	-	-	$1\cdot10^{8}$
^{209}Bi	-	$3\cdot10^{6}$	$1\cdot10^{8}$
U			$3\cdot10^{6}$
↑d	$2\cdot10^{8}$	$3\cdot10^{10}$	$5\cdot10^{10}$

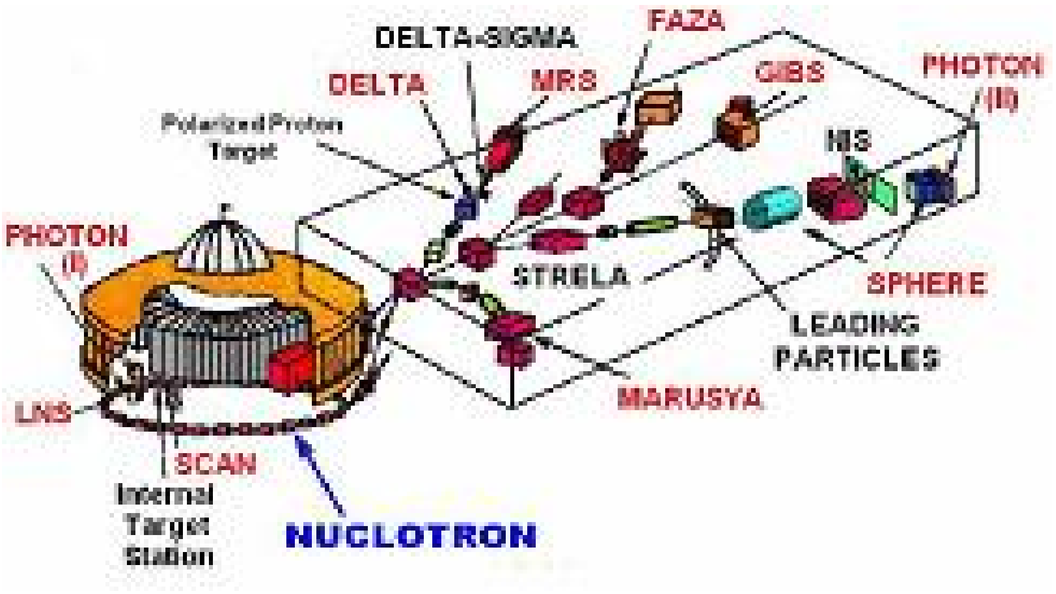
2007

JINR Round Table Discussion (Dubna, July 7 - 9, 2005) A.D. Kovalenko

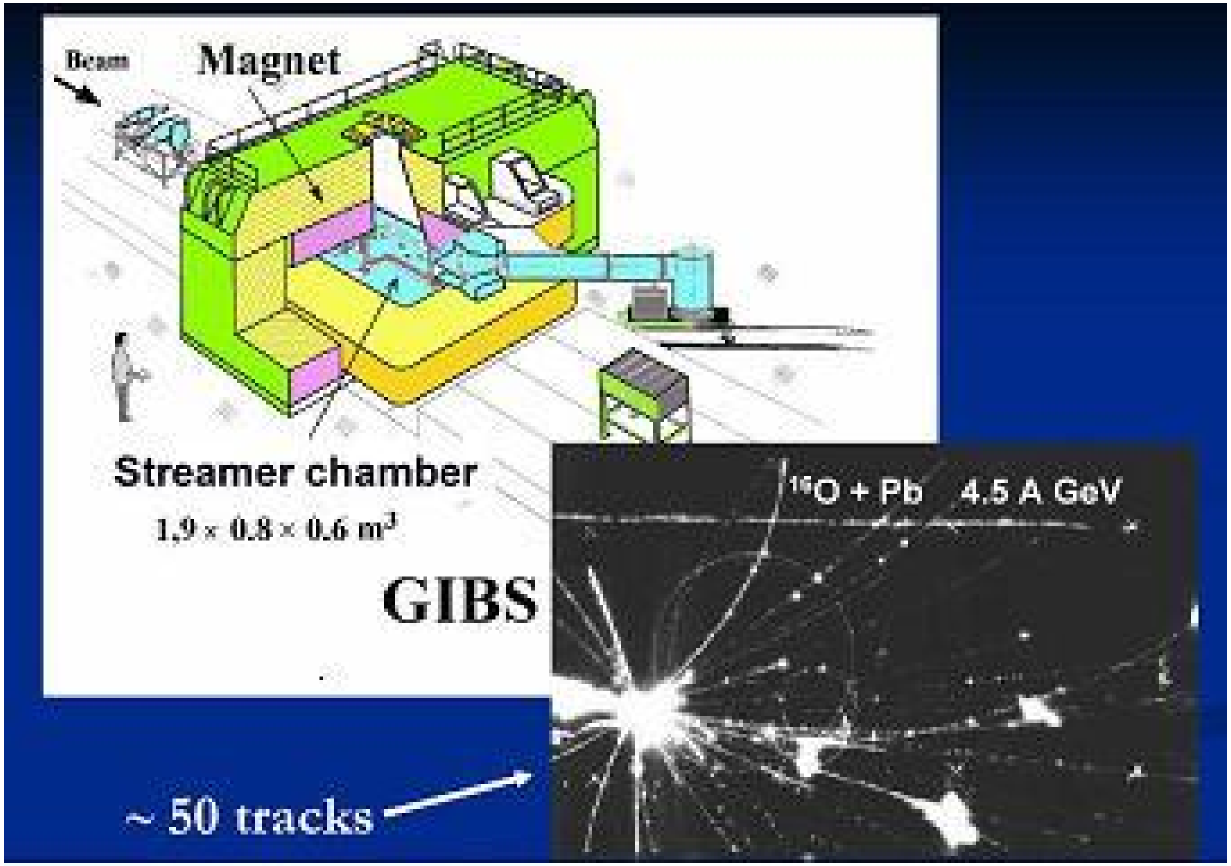
THE NUCLOTRON: EXISTING BEAM LINES



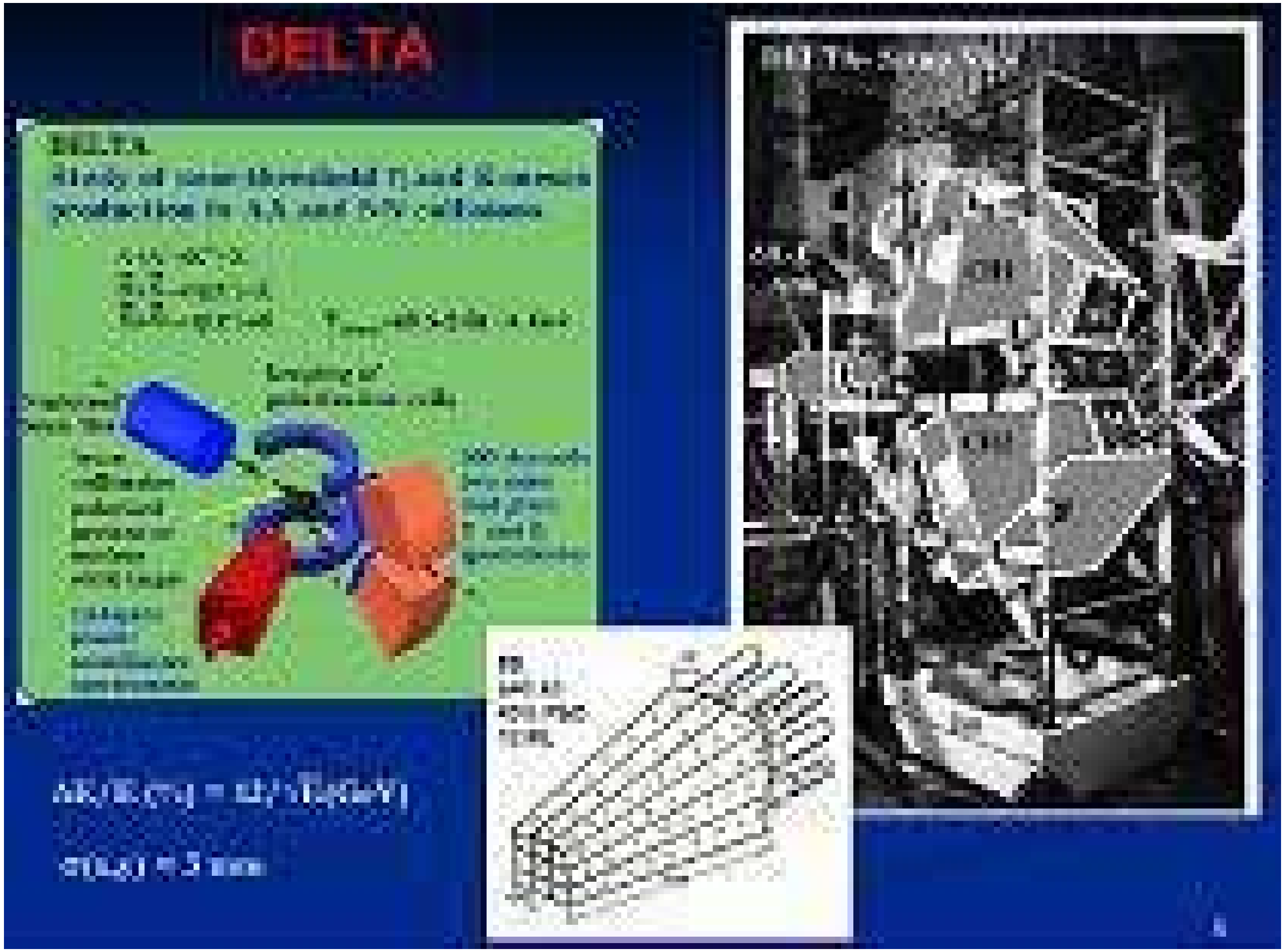
The JINR possibility to satisfaction the experimental requirements.



The scheme of placed of the JINR Detectors at Nuclotron



The scheme of placed of the JINR Detectors at Nuclotron



The setup DELTA

The setup Foton

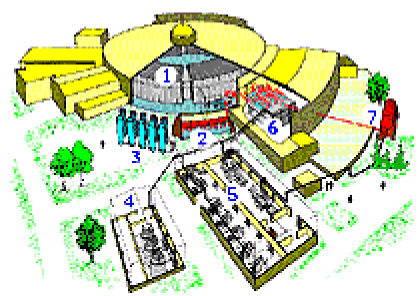
Round Table Discussion

Searching for the mixed phase of strongly interacting matter at the JINR Nuclotron

July 7 - 9, 2005

Program

Talks



Organizing Committee

Photographs

Research Program & Expert's Report

http://theor.jinr.ru/meetings/2005/roundtable/

V Workshop "Scientific Cooperation between German Research Centers and JINR " ***Dubna , Russia, January 17 - 19,***
http://www.jinr.ru/BMBF_05/index.html

Session of the Programme Advisory Committee for Particle Physics, April 14 - 15, Dubna

VI International Workshop on Very High Multiplicity Physics 16 - 17 April, Dubna
http://www.jinr.ru/~vhmp/

Relativistic Nuclear Physics: from Hundreds MeV to TeV
May 23 - 28 , Dubna
http://lhe.jinr.ru/rnp2005/index.html

Round Table Discussion
"Searching for the mixed phase of strongly interacting matter at the JINR Nuclotron"
JINR, Dubna, July 7 - 9, 2005
http://theor.jinr.ru/meetings/2005/roundtable/
E-print: nucl-ex/0511018

“Towards searching for a mixed phase of strongly interacting QCD matter at the JINR Nuclotron"
A.N.Sissakian, A.S.Sorin, M.K.Suleymanov, V.D.Toneev, G.M.Zinovjev
nucl-ex/0601034

Joint Institute for Nuclear Research

Bogoliubov Laboratory of Theoretical Physics

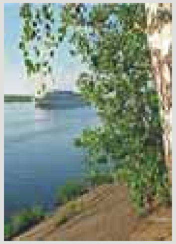
Dubna International Advanced School of Theoretical Physics

2006

January 29 – February 7
Forth Winter School on Theoretical Physics

April 1 – 30
Xth Research Workshop on Nucleation Theory and Applications

July 15 – 25
Helmholtz International School Calculations for Modern Future Colliders



August 7 – 17
International School on Few-Body Problems in Physics

August 21 – 30
Helmholtz International School Dense Matter in Heavy Ion Collisions and Astrophysics

September 3 – 13
Advanced Summer School on Modern Mathematical Physics

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