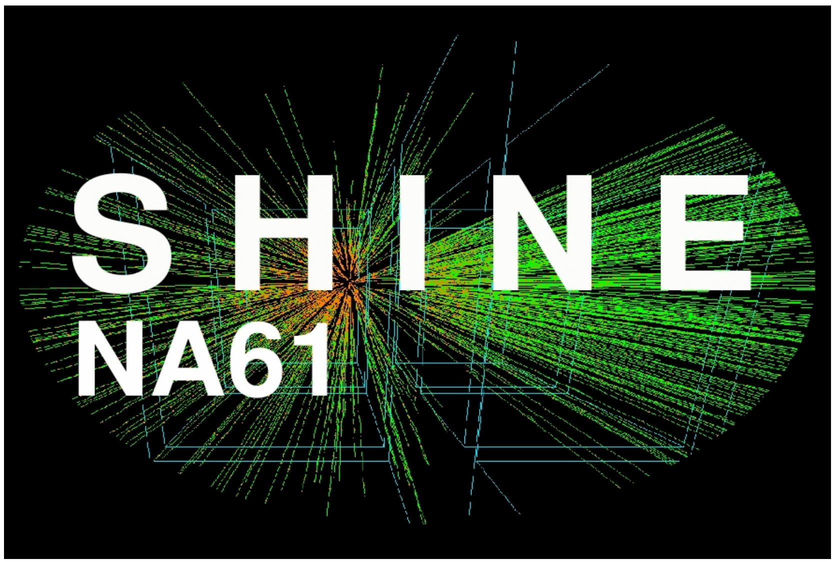
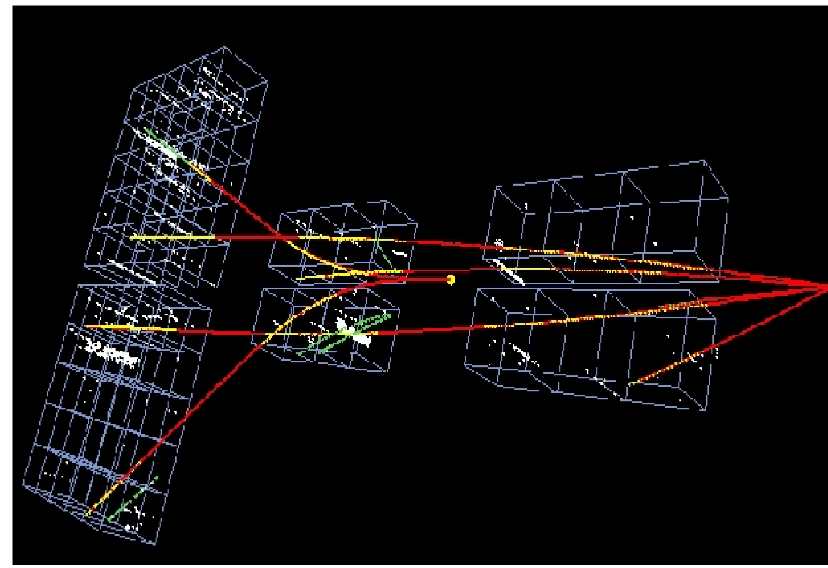
Fluctuations and correlations in NA61

(SHINE – SPS Heavy Ion and Neutrino Experiment)





Proposal: *CERN-SPSC-2006-034, SPSC-P-330 (November 3, 2006)*

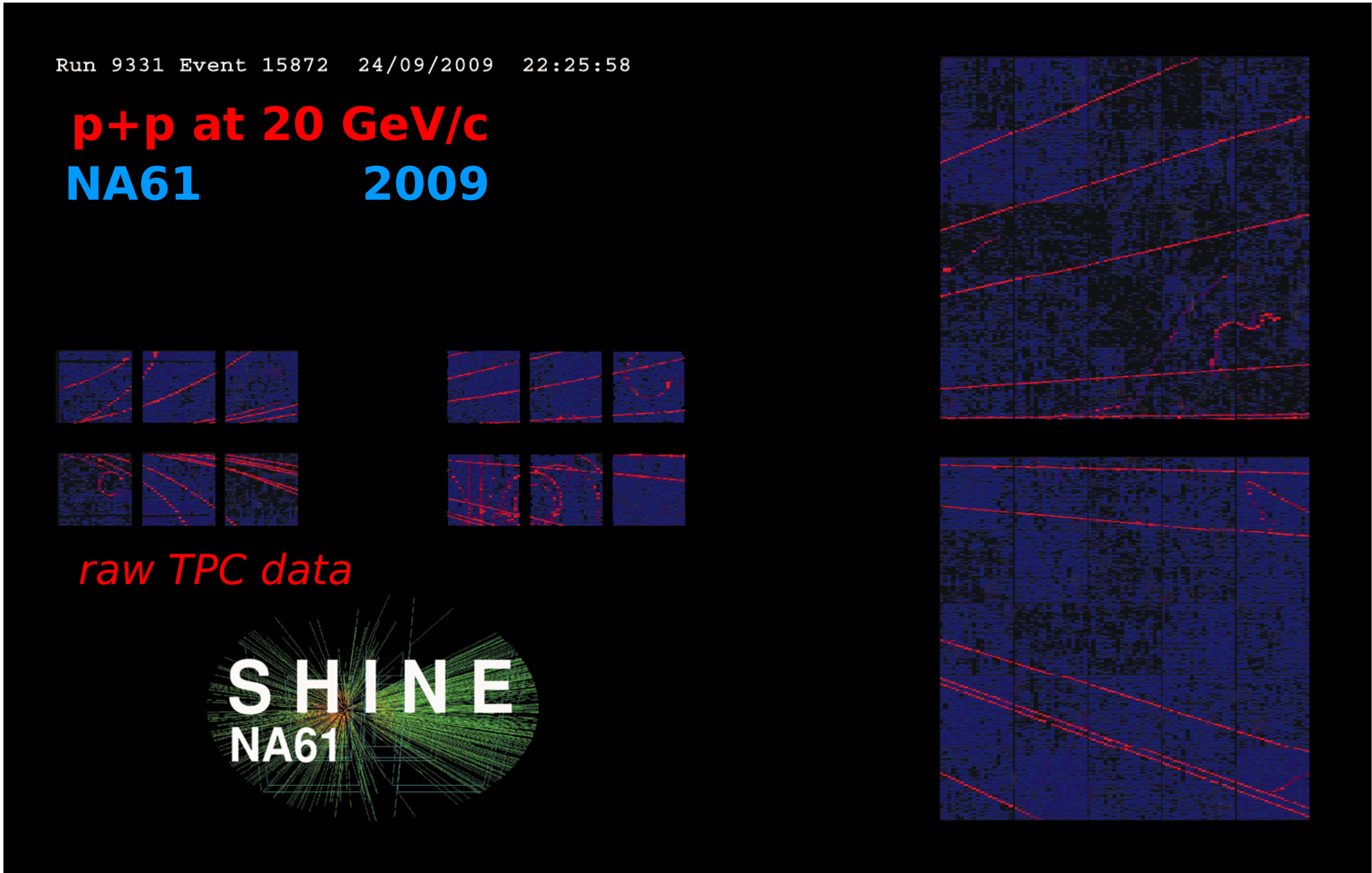
M. Gazdzicki, Frankfurt, Kielce
for the NA61 Collaboration

NA61 fundamentals

Participant number fluctuations

Fluctuations and search for the critical point

Correlations and onset of deconfinement



NA61 fundamentals

Physics goals (I):

Physics of strongly interacting matter

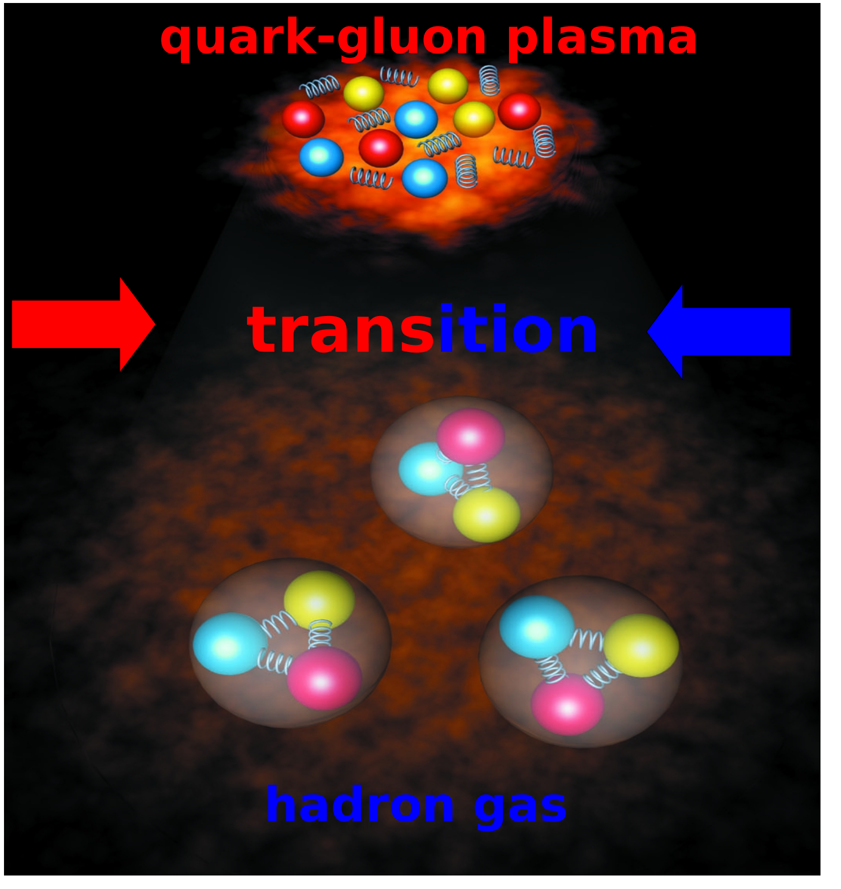
Discovery potential:

Search for the critical point of strongly interacting matter

Precision measurements:

Study the properties of the onset of deconfinement in nucleus-nucleus collisions

Measure hadron production at high transverse momenta in p+p and p+Pb collisions as reference for Pb+Pb results



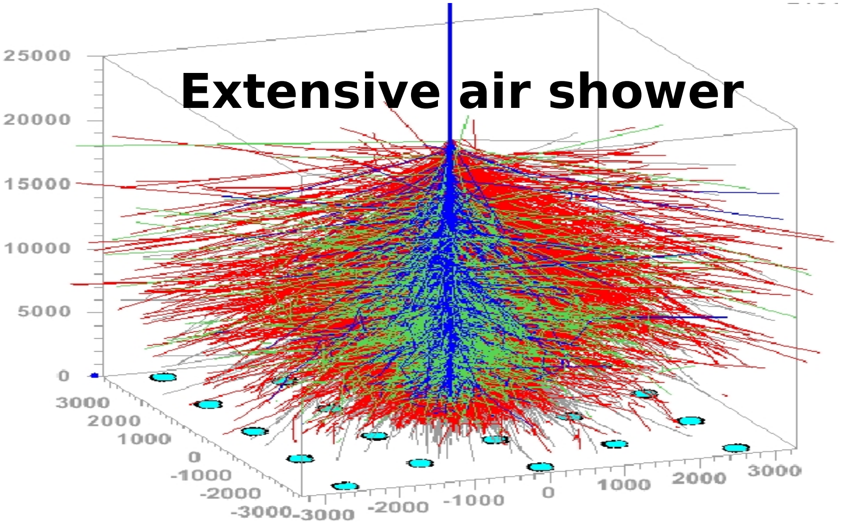
Physics goals (II):

Data for neutrino and cosmic ray experiments

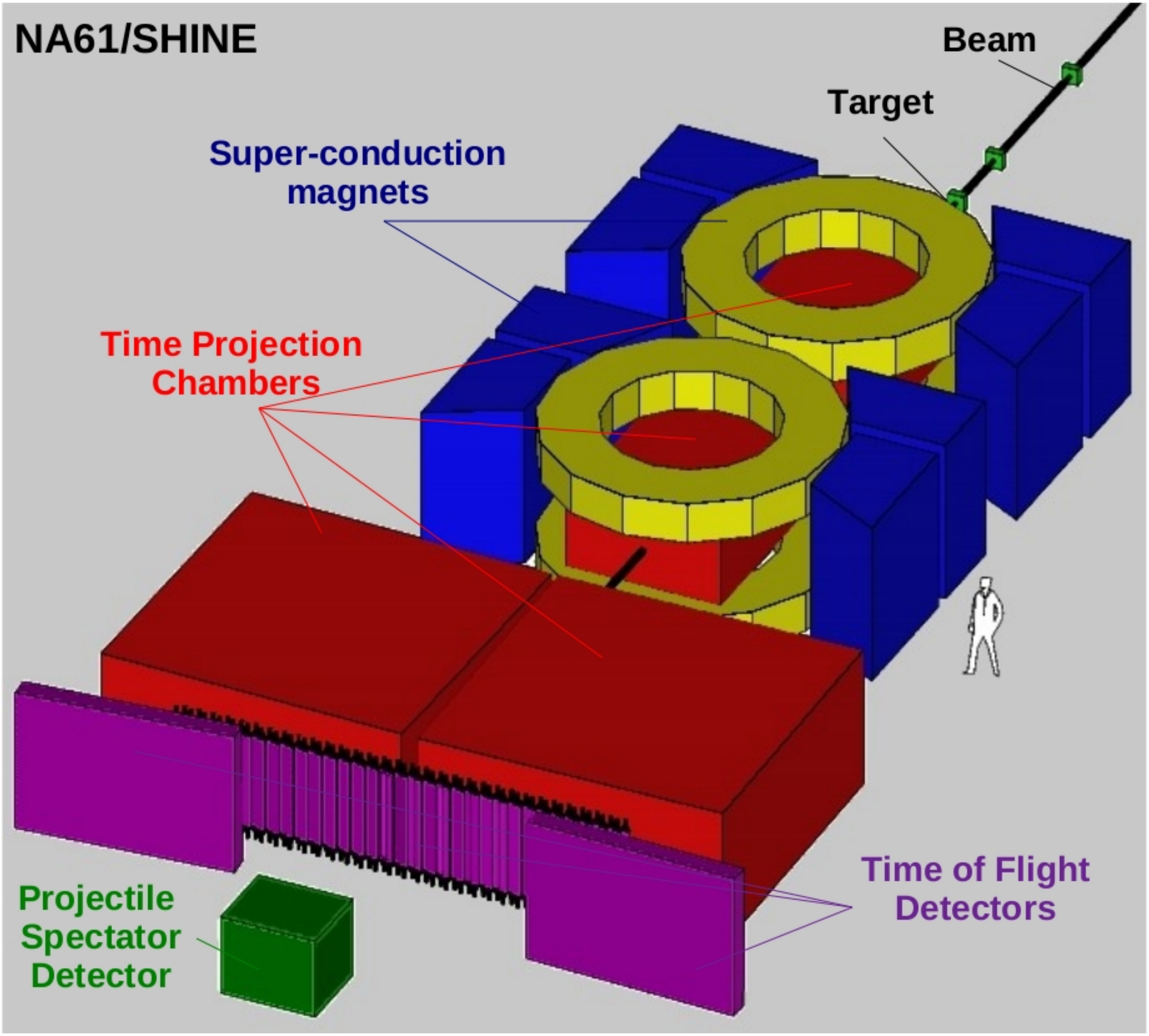
Precision measurements:

Measure hadron production in p+C interactions needed for T2K and cosmic-ray, Pierre Auger Observatory and KASCADE, experiments

Measure hadron production in the T2K target needed for the T2K (neutrino) physics



Detector

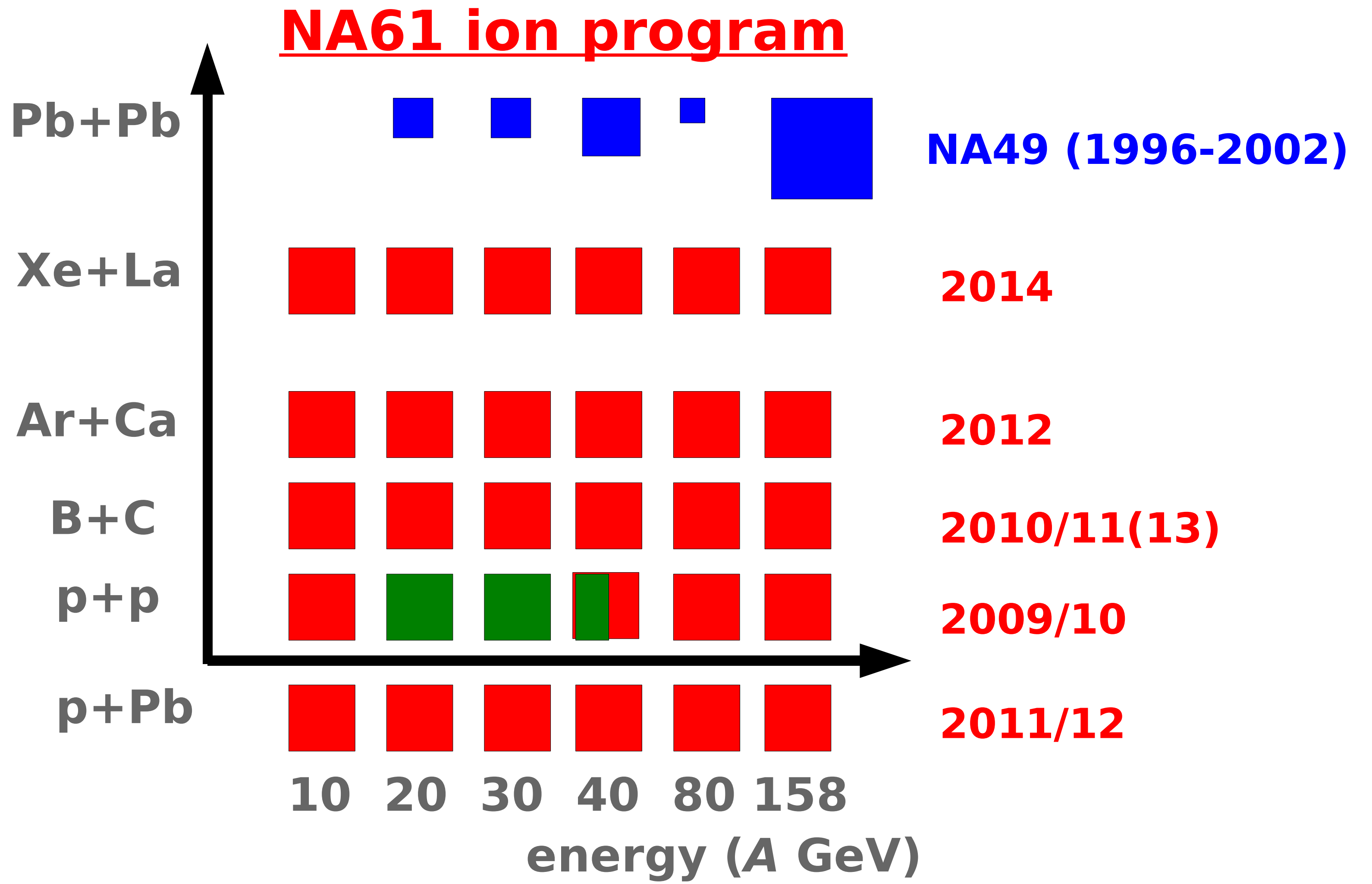


NA49 facility +

TPC read-out (x10)
ToF (x2)
PSD (x10)
Beam pipe (x10)

NA49: Nucl. Instrum. Meth. A430, 210 (1999)
NA61 upgrades: CERN-SPSC-2006-034, SPSC-P-330

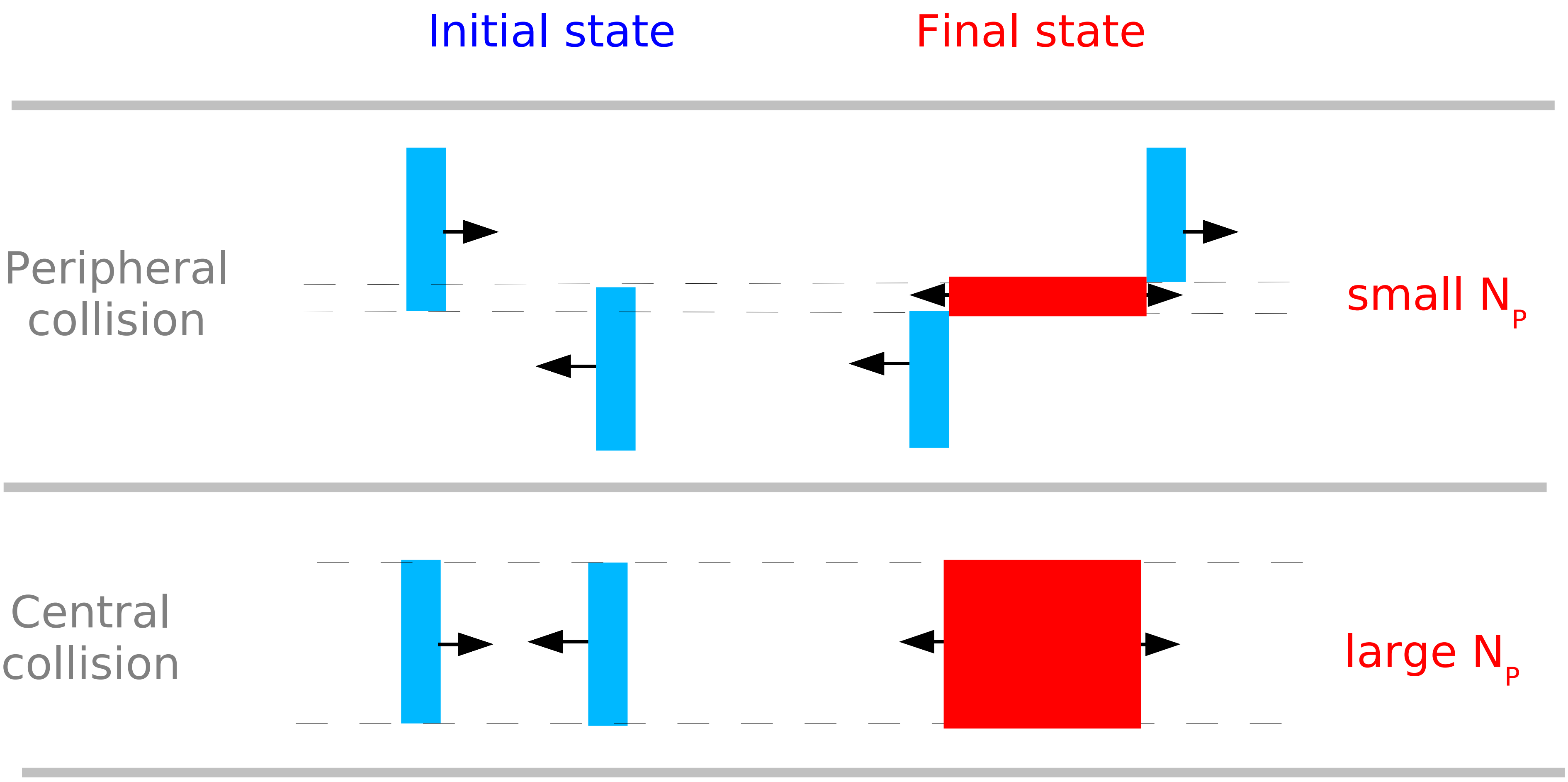
Ion data taking status and plans



The first 2D scan in history of A+A collisions

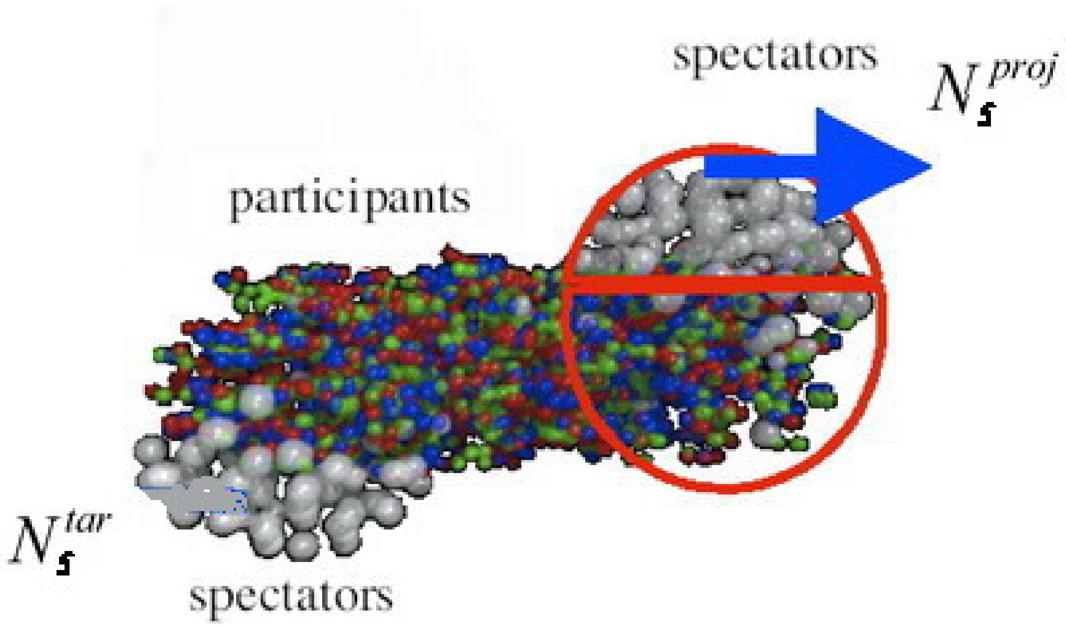
= $2\cdot10^6$ registered collisions

Participant number fluctuations



Fluctuations in the collision geometry lead to large fluctuations in the number of participants and are a dominant source of fluctuations in nucleus-nucleus collisions

NA61 event selection

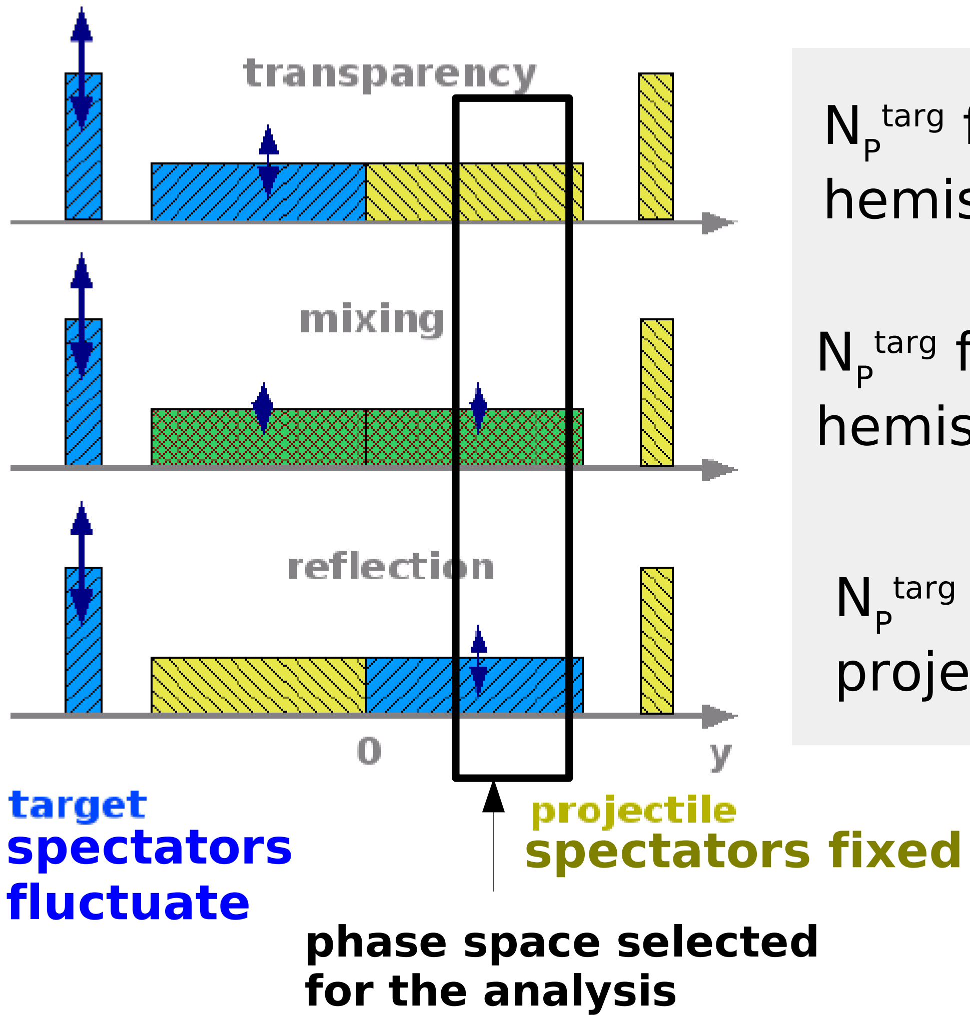


projectile spectators are measured by PSD

$$N_P^{proj} = A^{proj} - N_S^{proj}$$

collisions with fixed (±1) number of the projectile participants can be selected

Impact of target participant fluctuations



N_P^{targ} fluctuations contribute in target hemisphere (most string-hadronic models)

N_P^{targ} fluctuations contribute in both hemispheres (early stage thermalization)

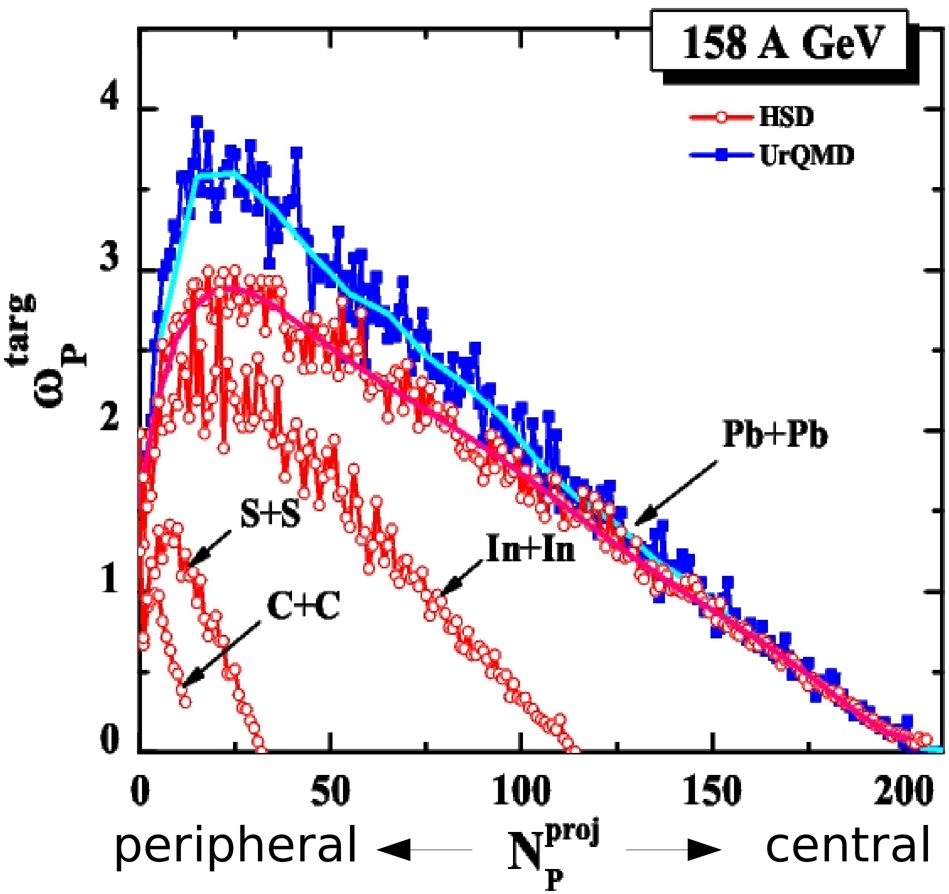
N_P^{targ} fluctuations contribute in projectile hemisphere

Target participant fluctuations allow to study properties of the early stage of collisions,
but may shadow study of other fluctuation sources (e.g. fluctuations due to the critical point)

M.G., Gorenstein, PL B640:155

Fixing target participant fluctuations

Fluctuations of target participants



Number of projectile participants

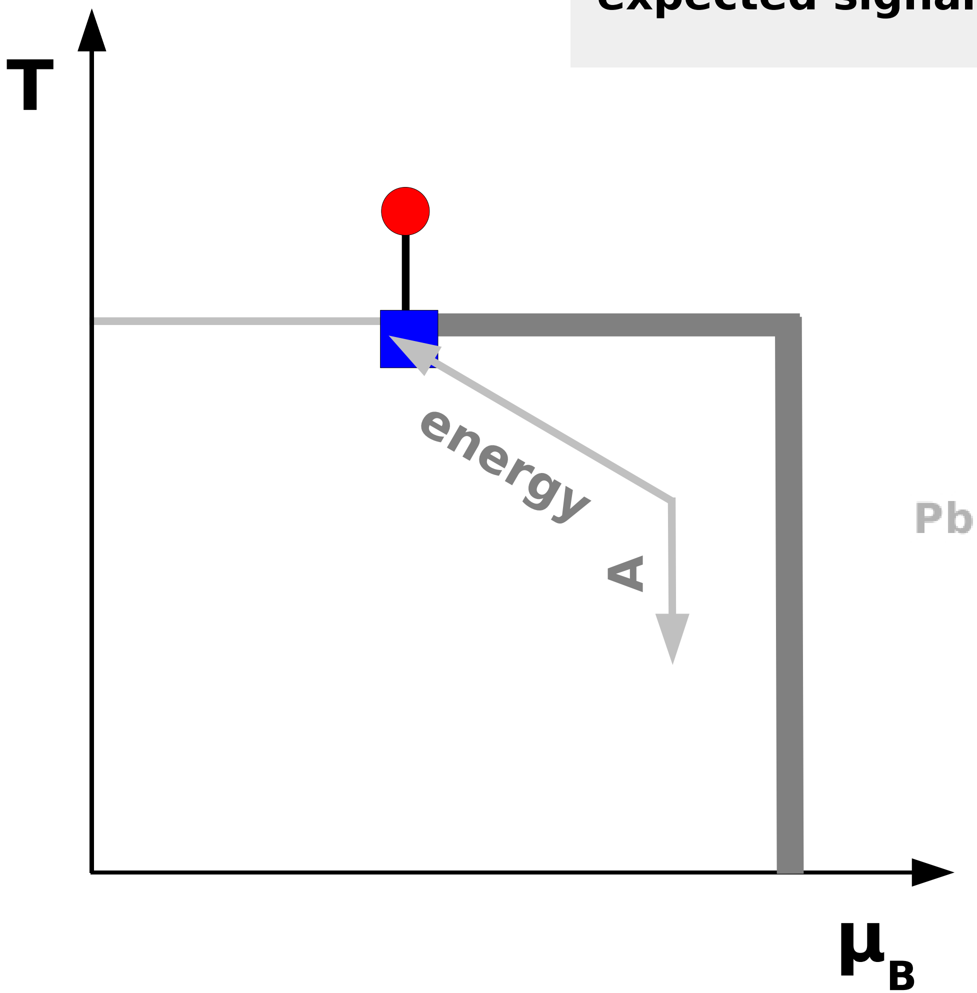
Strategy

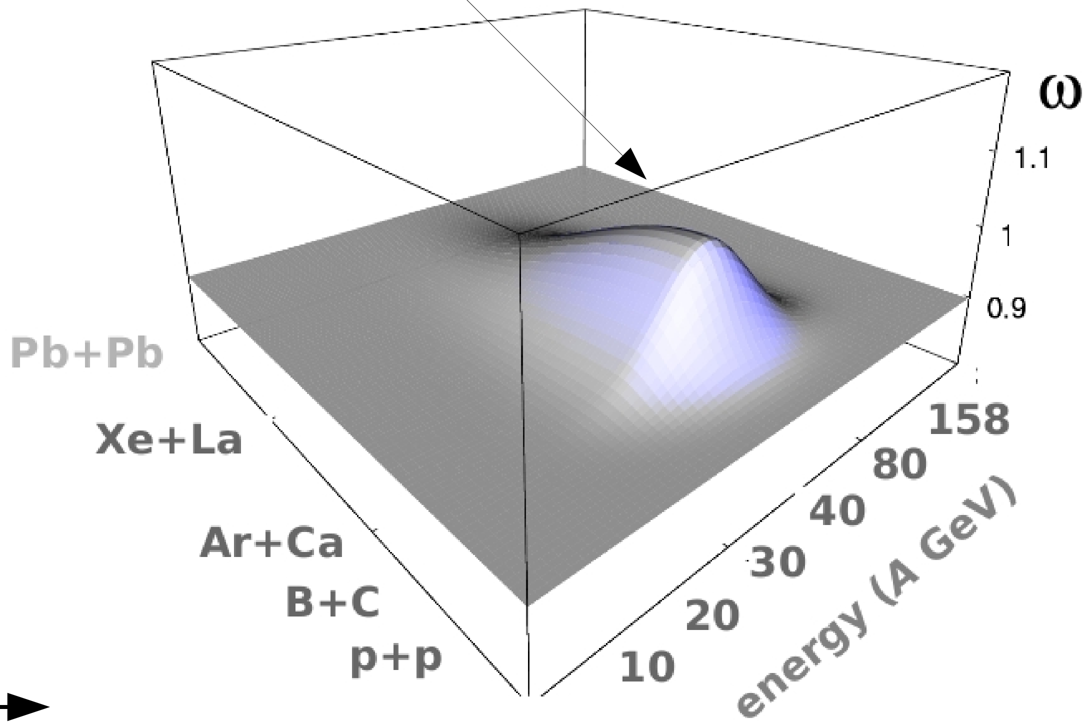
Target participant fluctuations are removed for collisions with the maximum number of spectator participants

Konchakovski et al., Phys. Rev. C 73, 034902

Fluctuations and search for the critical point

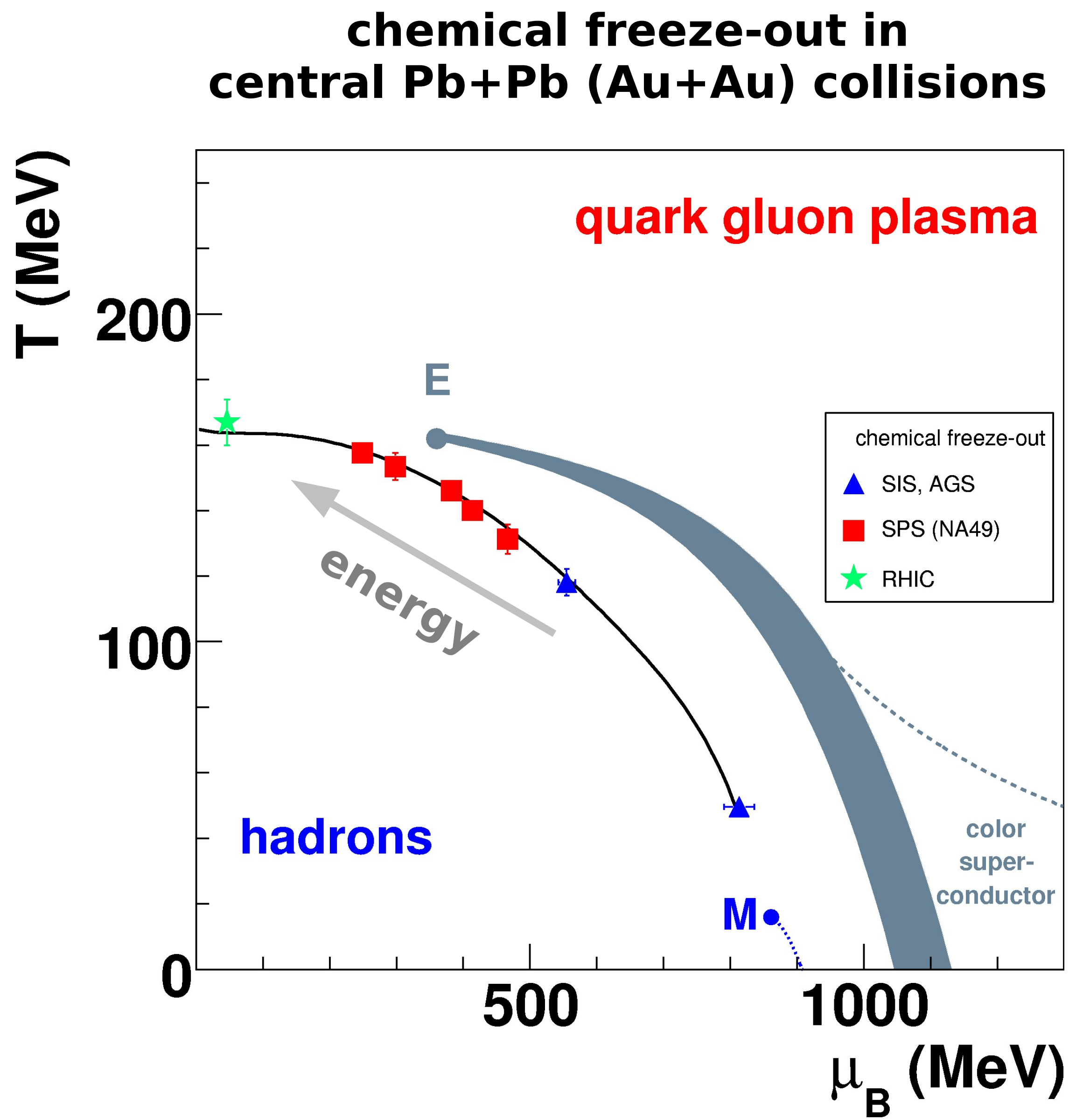
Critical Point:
freeze-out close to critical point,
and system large enough,
expected signal: a hill in fluctuations





Stephanov et al., PRD60:114028
NA61 (M.G.), PoS CPOD2006:016

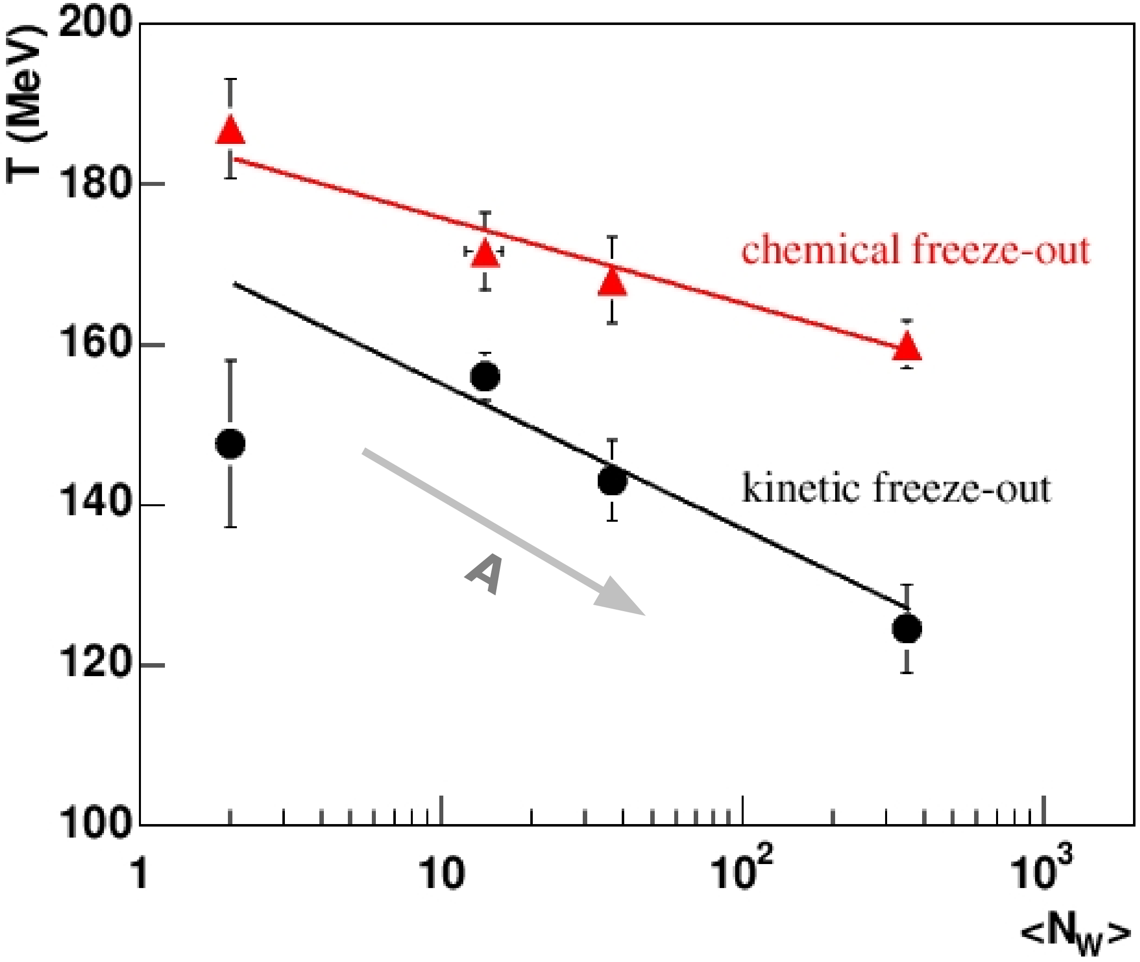
Scanning the T - μ_B plane



Becattini et al., PRC73:044905

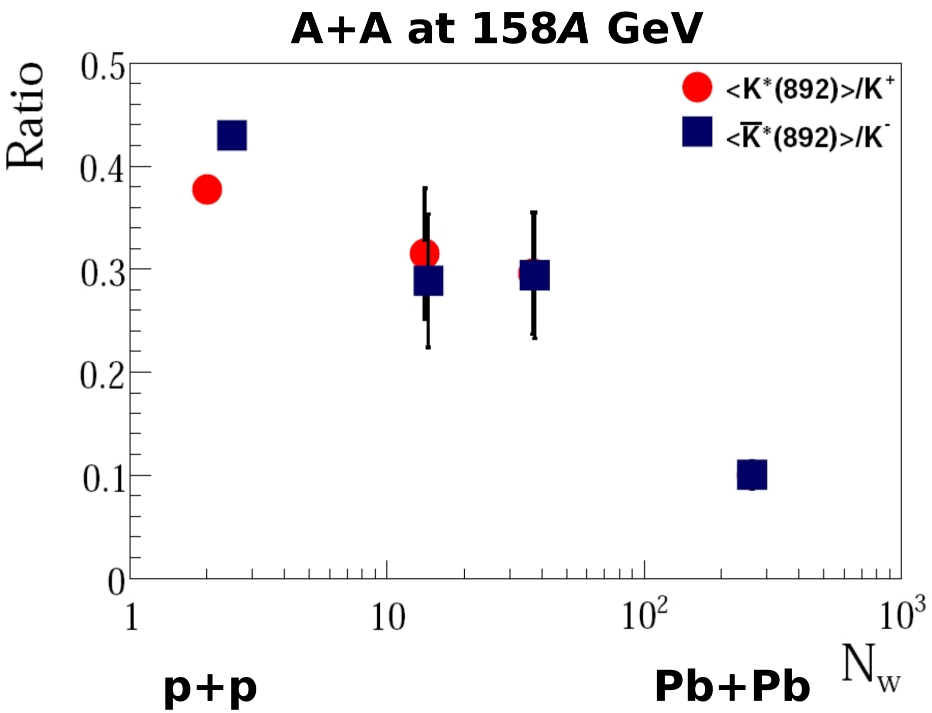
Scanning the T - μ_B plane

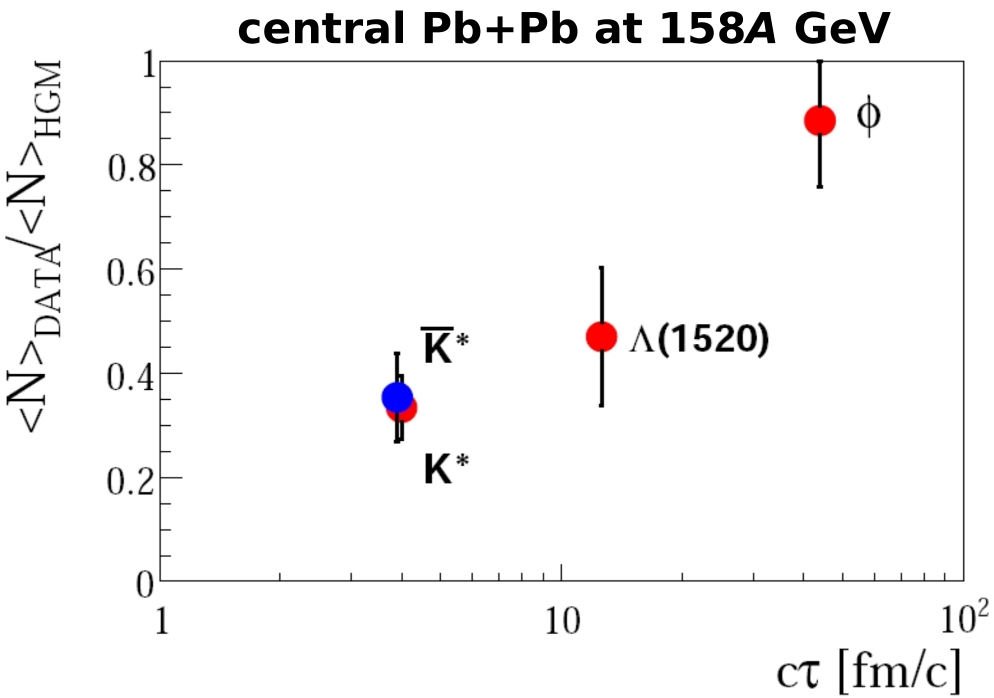
freeze-out in
A+A collisions at 158*A* GeV



Becattini et al., PRC73:044905

Scanning the T - μ_B plane





strong suppression of the resonance yield in central Pb+Pb collisions

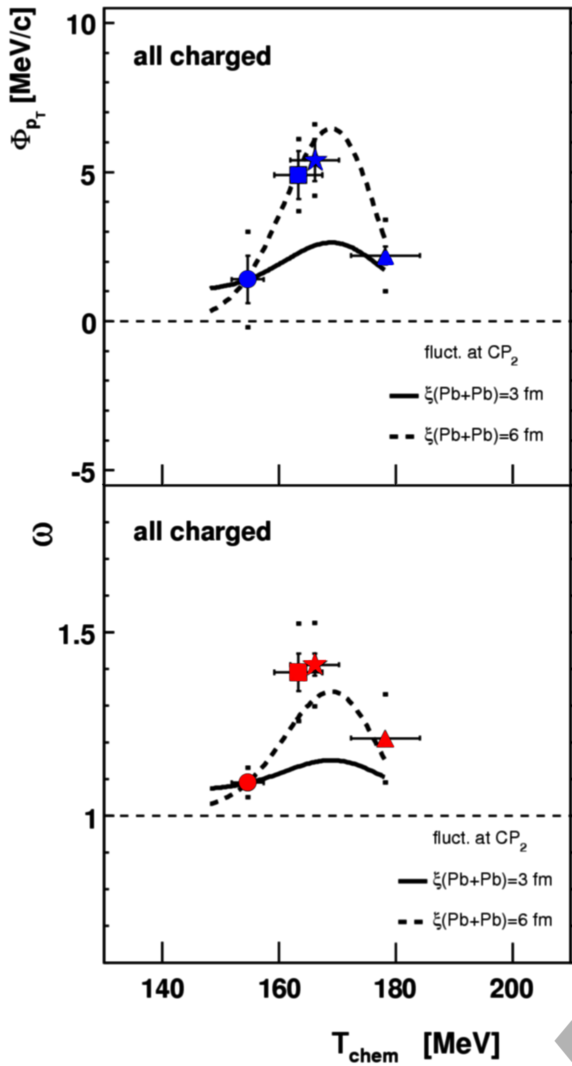
The suppression increases with decreasing resonance life-time

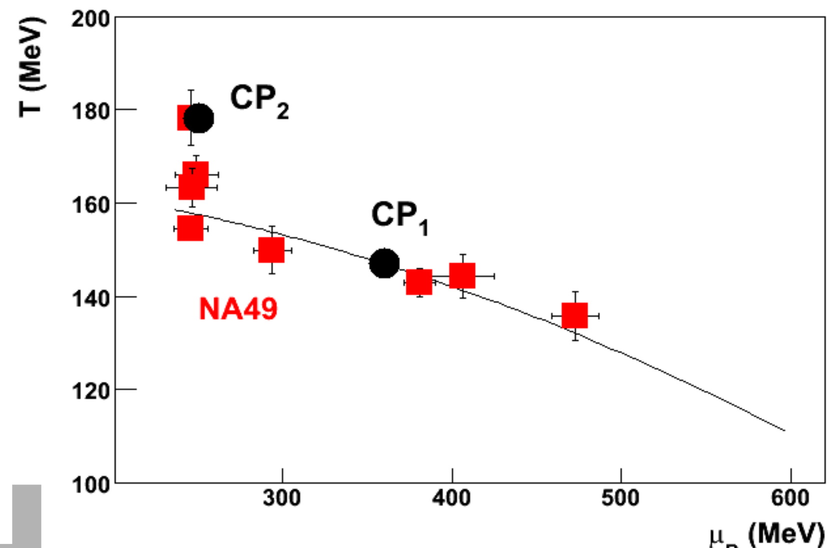
Rescattering of decay products in the long lasting hadronic phase

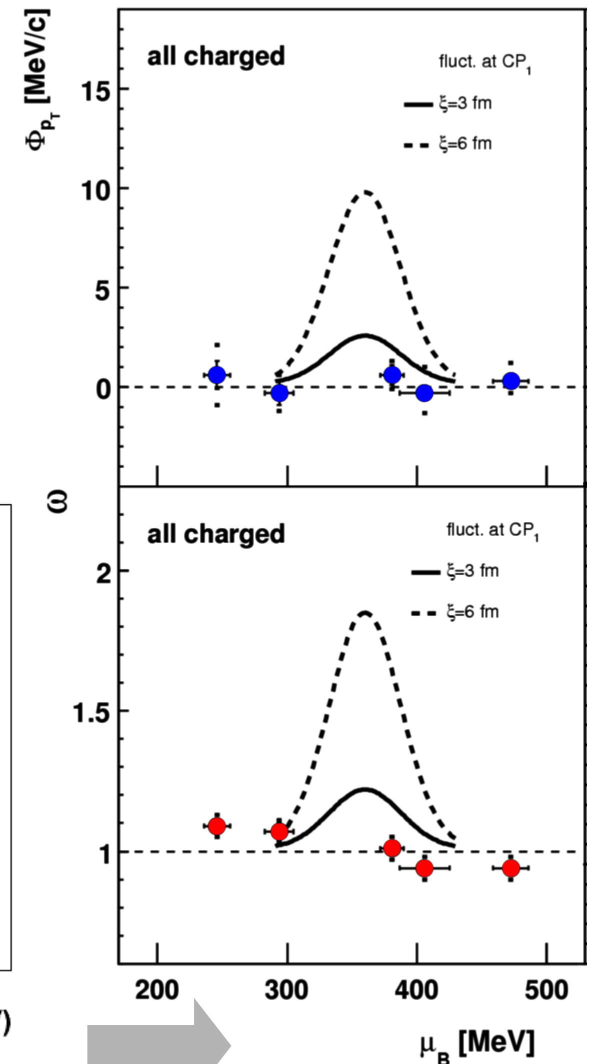
The K* freeze-out temperature decreases with increasing system size

NA49: M. Slodkowski

NA49 search for the critical point



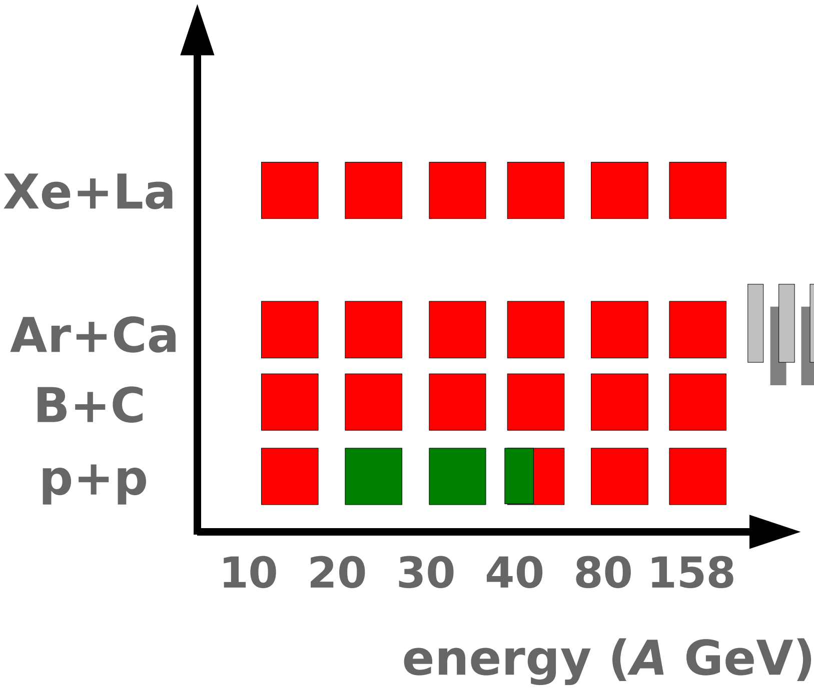


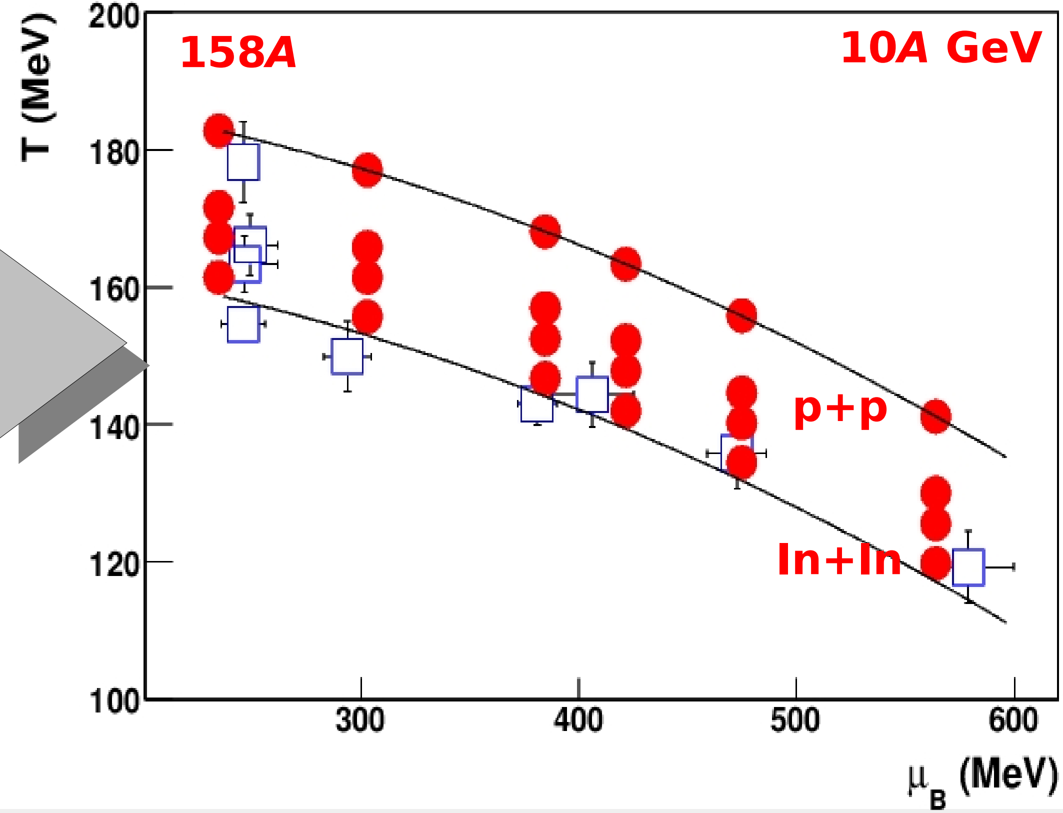


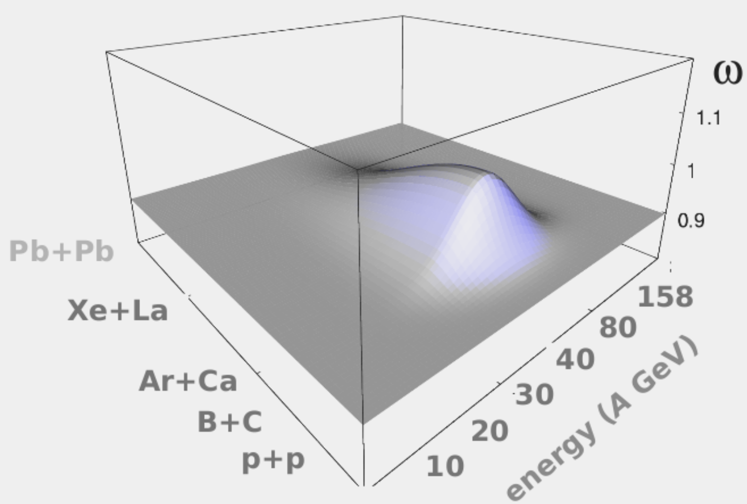
First hint of the fluctuation hill?

NA49 (Grebieszkow),0907.4101

Search for the critical point





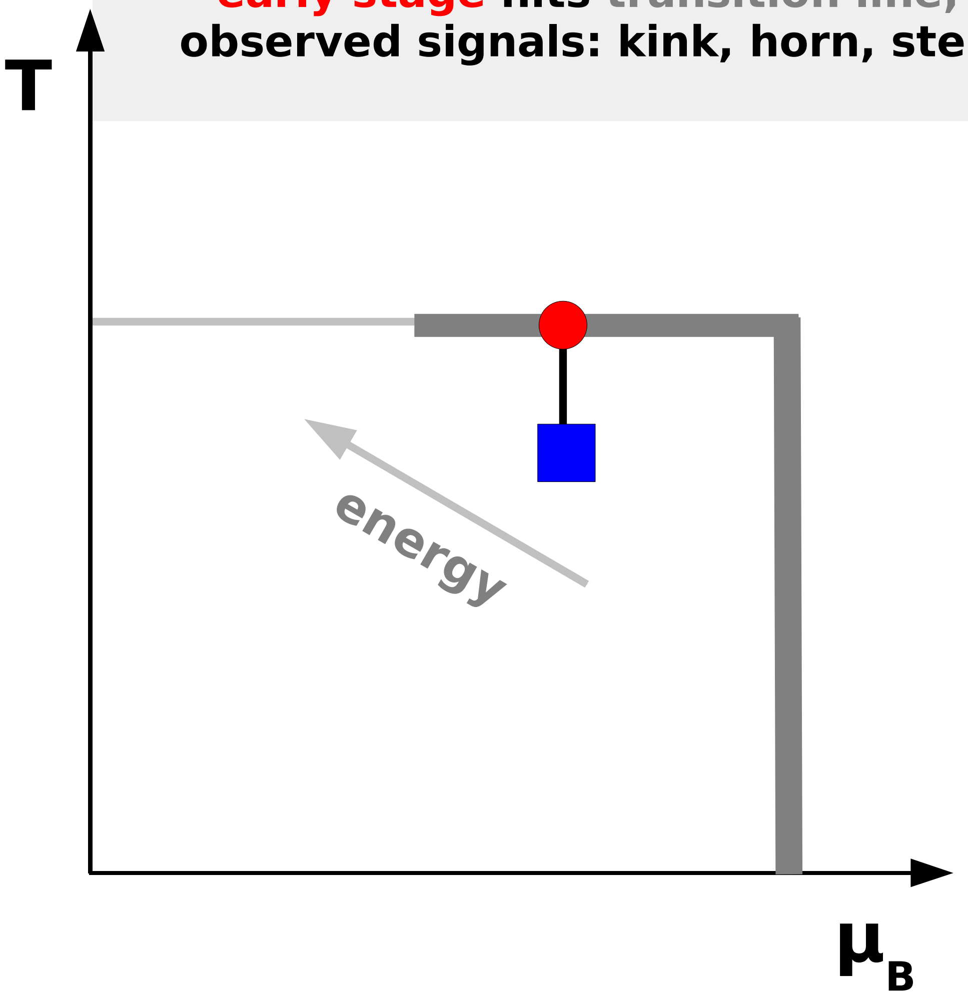


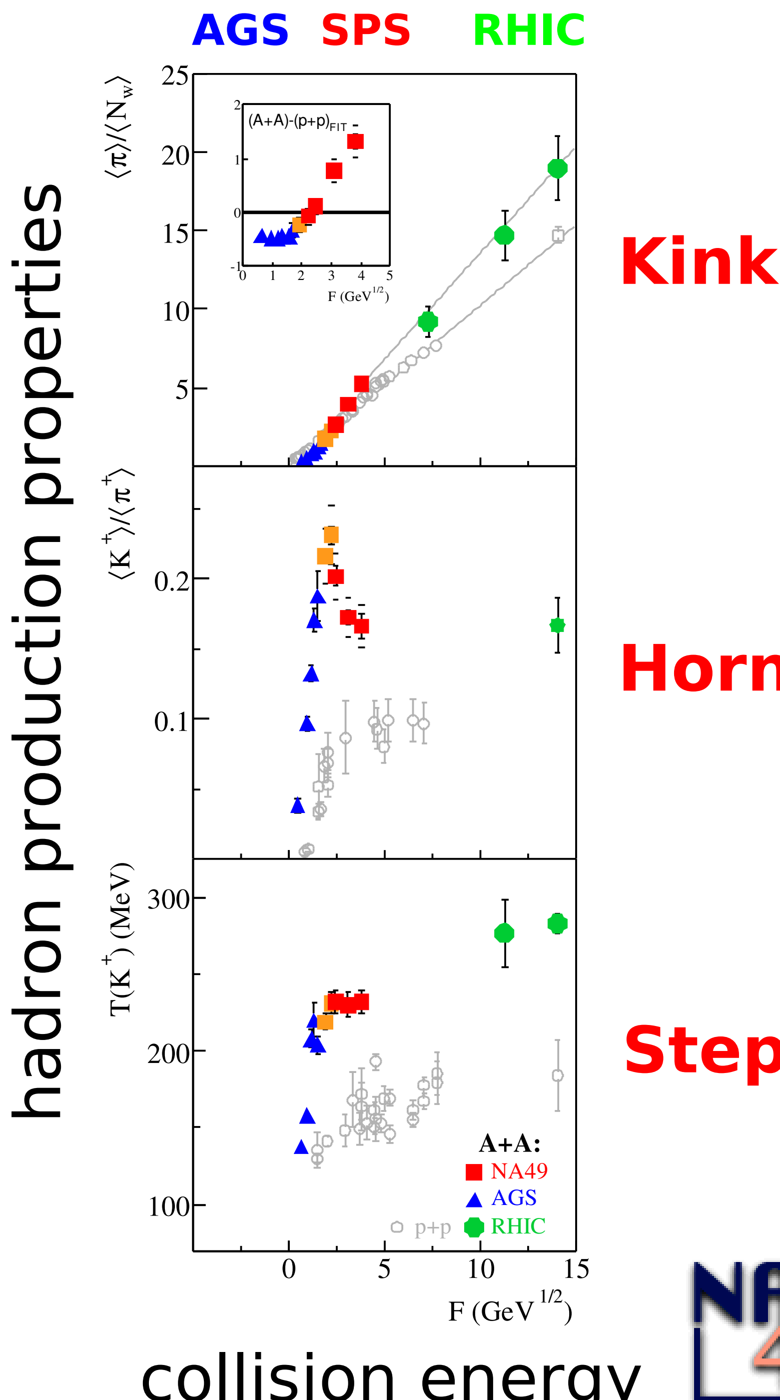
Search for the hill of fluctuations

Discovery potential

Correlations and the onset of deconfinement

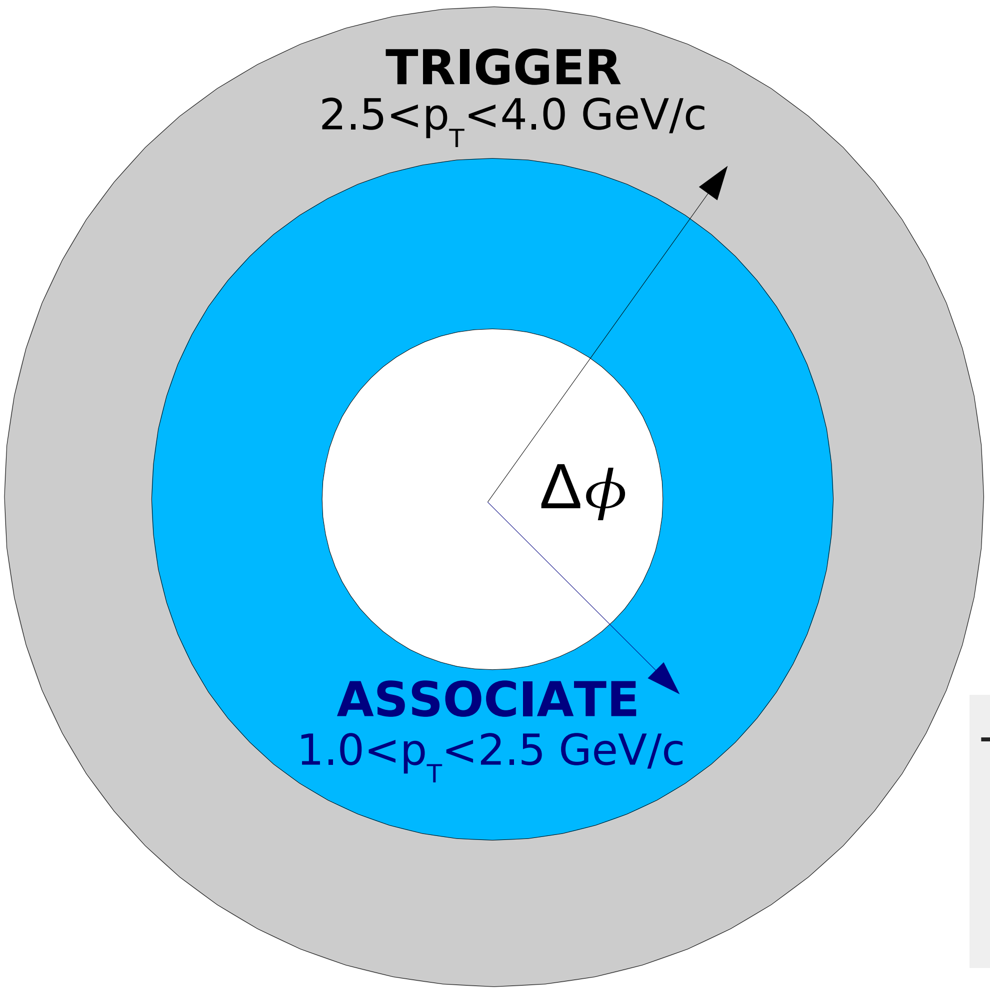
Onset of Deconfinement:
early stage hits transition line,
observed signals: kink, horn, step





M.G., M. Gorenstein, APPB30:2705
NA49, PRC77:024903

Energy dependence of azimuthal correlations

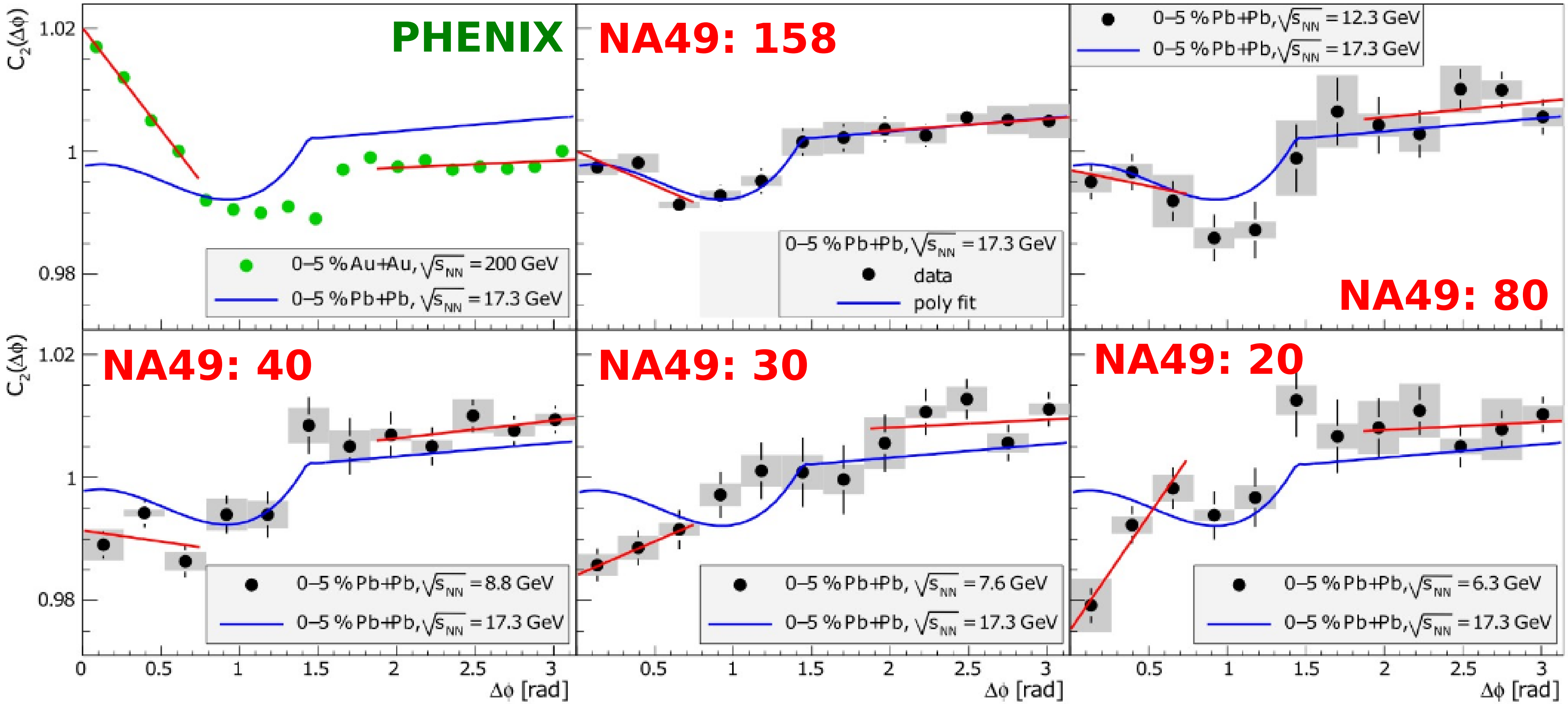


Plane transverse to the collision axis

The azimuthal correlation function:

$$C_2(\Delta\phi) = \frac{N_{corr}(\Delta\phi)}{N_{mix}(\Delta\phi)} \frac{\int N_{mix}(\Delta\phi')\, d(\Delta\phi')}{\int N_{corr}(\Delta\phi')\, d(\Delta\phi')}$$

Energy dependence of azimuthal correlations

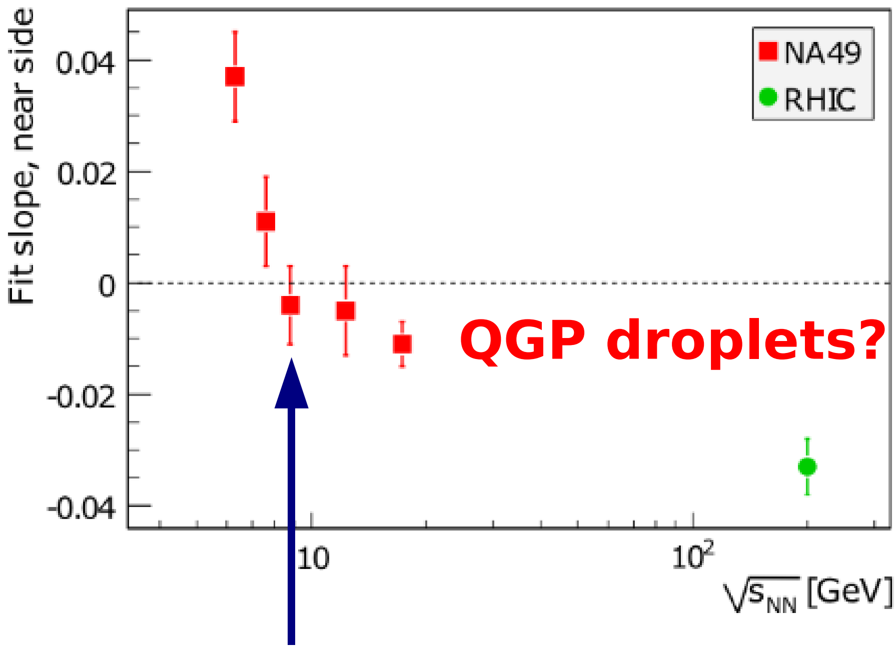


The jet-hole transition at the low SPS energies

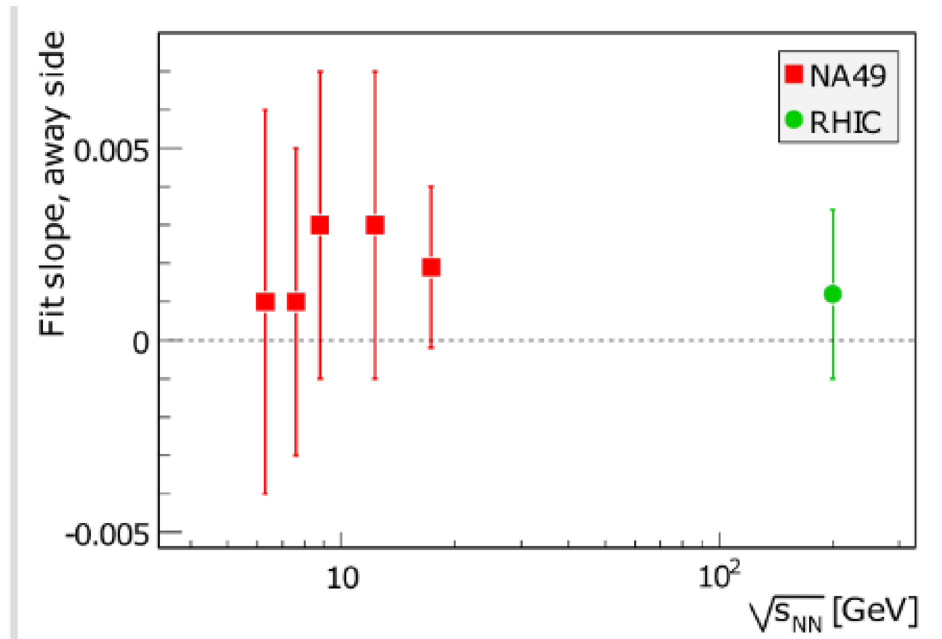
NA49 (Szuba),0908.2155

Energy dependence of azimuthal correlations

momentum conservation?



momentum conservation?

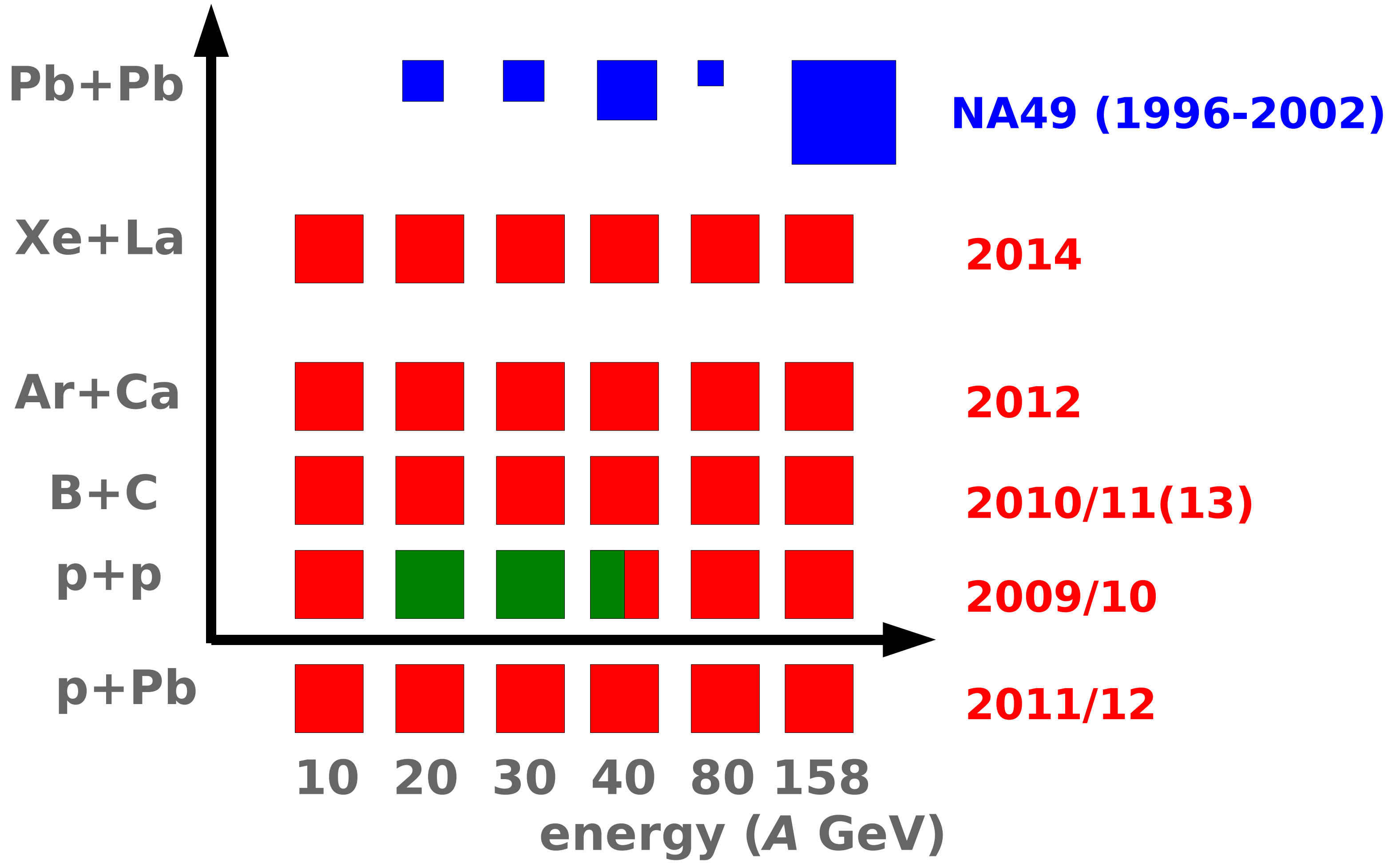


Horn
Kink **+**
Step

The jet-hole transition at the low SPS energies

NA49 (Szuba),0908.2155

Study the onset of deconfinement



Precision measurements following the NA49 discovery

Conclusions:

Study of fluctuations and correlations within NA61 will play crucial role in:

-search for the critical point and

-study of properties of the onset of deconfinement

Additional slides

The NA61/SHINE Collaboration:

122 physicists from 24 institutes and 13 countries:

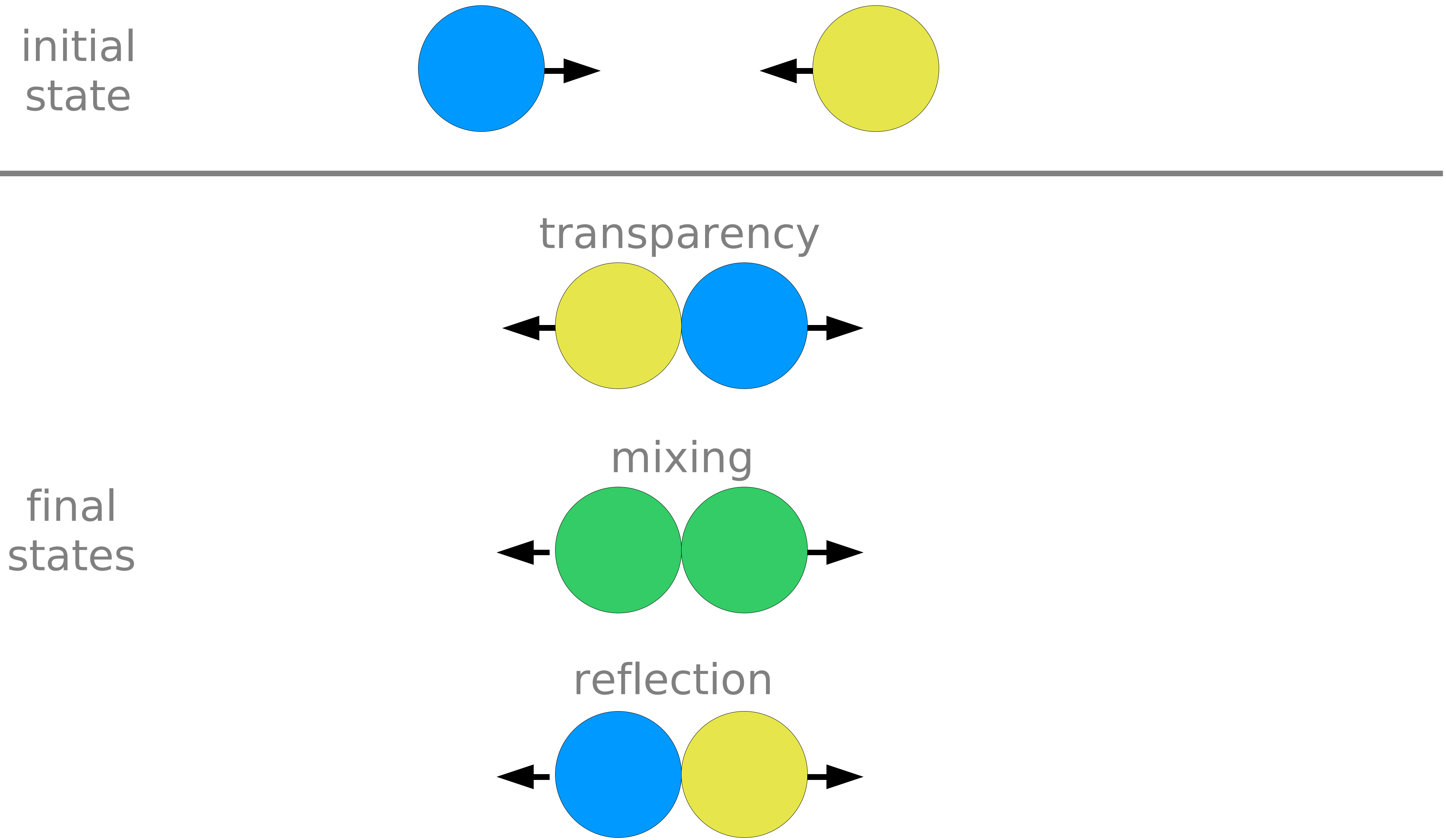
University of Athens, Athens, Greece
University of Bergen, Bergen, Norway
University of Bern, Bern, Switzerland
KFKI IPNP, Budapest, Hungary
Cape Town University, Cape Town, South Africa
Jagiellonian University, Cracow, Poland
Joint Institute for Nuclear Research, Dubna, Russia
Fachhochschule Frankfurt, Frankfurt, Germany
University of Frankfurt, Frankfurt, Germany
University of Geneva, Geneva, Switzerland
Forschungszentrum Karlsruhe, Karlsruhe, Germany
Institute of Physics, University of Silesia, Katowice, Poland
Jan Kochanowski Univeristy, Kielce, Poland
Institute for Nuclear Research, Moscow, Russia
LPNHE, Universites de Paris VI et VII, Paris, France
Faculty of Physics, University of Sofia, Sofia, Bulgaria
St. Petersburg State University, St. Petersburg, Russia
State University of New York, Stony Brook, USA
KEK, Tsukuba, Japan
Soltan Institute for Nuclear Studies, Warsaw, Poland
Warsaw University of Technology, Warsaw, Poland
University of Warsaw, Warsaw, Poland
Rudjer Boskovic Institute, Zagreb, Croatia
ETH Zurich, Zurich, Switzerland

Experimental landscape of complementary programs of nucleus-nucleus collisions around the SPS energies

Facility:	**SPS**	**RHIC**	**NICA**	**SIS-100 (SIS-300)**
Exp.:	**NA61**	**STAR PHENIX**	**MPD**	**CBM**
Start:	**2011(2)**	**2011**	**2015**	**2017 (2019)**
Pb Energy: (GeV/(N+N))	**4.9-17.3**	**4.9-50**	**≤9**	**≤5 (<8.5)**
Event rate: (at 8 GeV)	**100 Hz**	**1 Hz(?)**	**≤10 kHz**	**≤10 MHz**
Physics:	**CP&OD**	**CP&OD**	**OD&HDM**	**HDM (OD)**

CP – critical point
OD – onset of deconfinement, mixed phase, 1st order PT
HDM – hadrons in dense matter

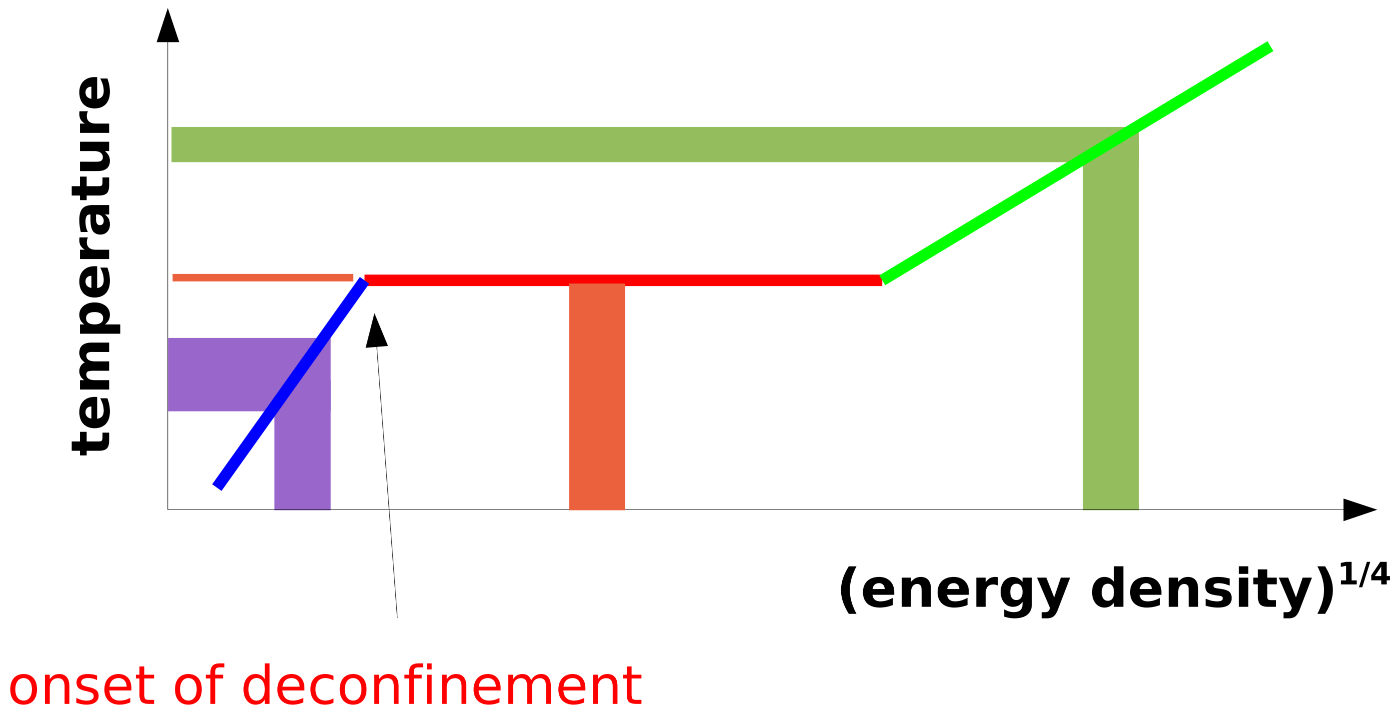
Fluctuations and the early stage thermalization



Strangeness fluctuations

The basic idea as for multiplicity fluctuations

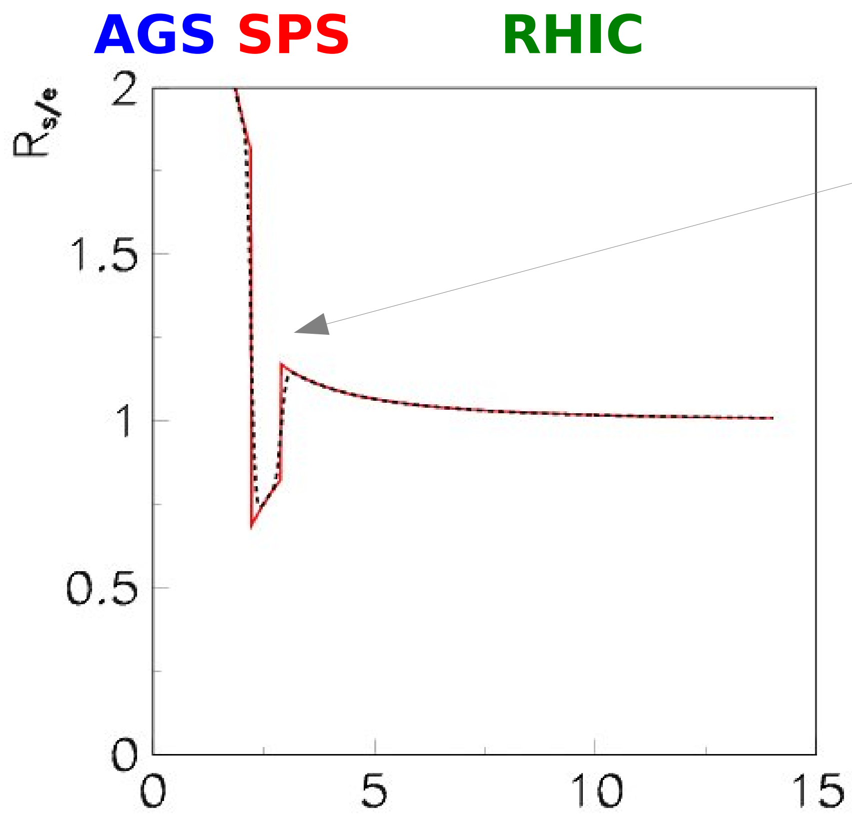
Response to the initial energy density fluctuations depends on the Equation of State at the early stage of the collisions



Gorenstein, M.G., Zozulya, PL B585:237, 2004

... and the energy dependence of dynamical strangeness fluctuations

dynamical strangeness fluctuations



$$F \approx \sqrt{\sqrt{s_{NN}}}$$

collision energy

The onset of deconfinement is signaled by a ''tooth'' -like structure

The proposed measure

Model: $$R_{s/e} \equiv \frac{(\delta N_s)^2 / N_s^2}{(\delta S)^2 / S^2}$$

Experiment: $$\frac{\delta N_s}{N_s} \approx \frac{\delta \bar{n}_K}{\bar{n}_K} \qquad \frac{\delta S}{S} \approx \frac{\delta \bar{n}}{\bar{n}}$$

The $R_{s/e}$ measure is:

+ sensitive to the EoS,
+ insensitive to the initial energy density fluctuations,
- sensitive to the geometrical fluctuations,
- sensitive to global conservation laws

The NA49 measure

$$R^2_{NA49} \equiv \overline{(\delta n_K/n)^2} / \langle n_K/n \rangle^2$$

$$\left(\quad R_{s/e} \equiv \overline{(\delta n_K)^2}/\bar{n}_K^2 \ / \ \overline{(\delta n)^2}/\bar{n}^2 \quad \right)$$

The R_{NA49} measure is:

+sensitive to the EoS,

- sensitive to the initial energy density fluctuations,

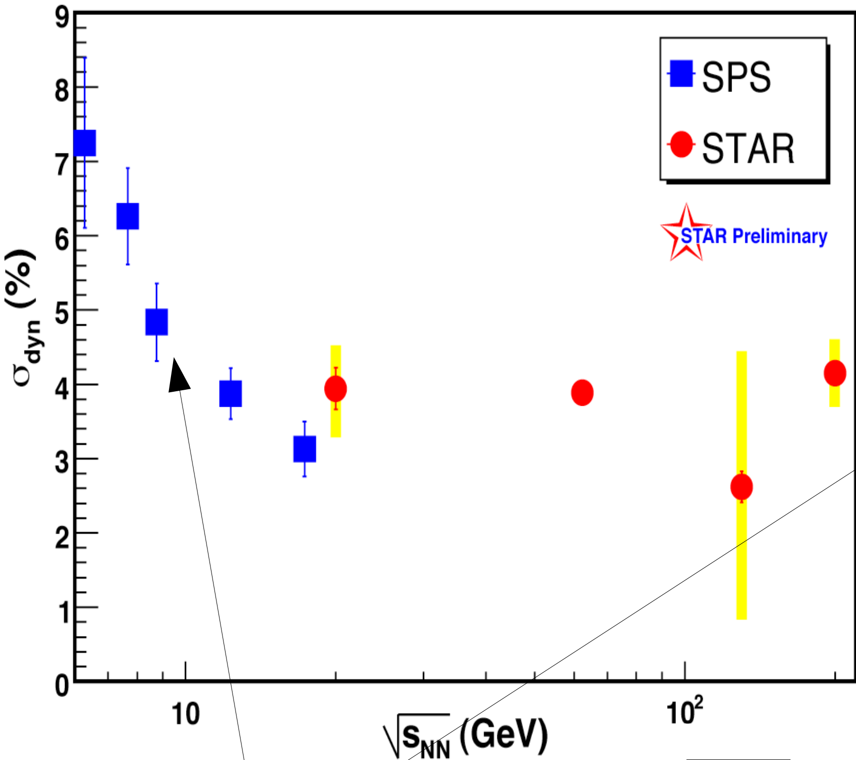
+insensitive to the geometrical fluctuations,

- sensitive to global conservation laws

Difficult, further work is needed!

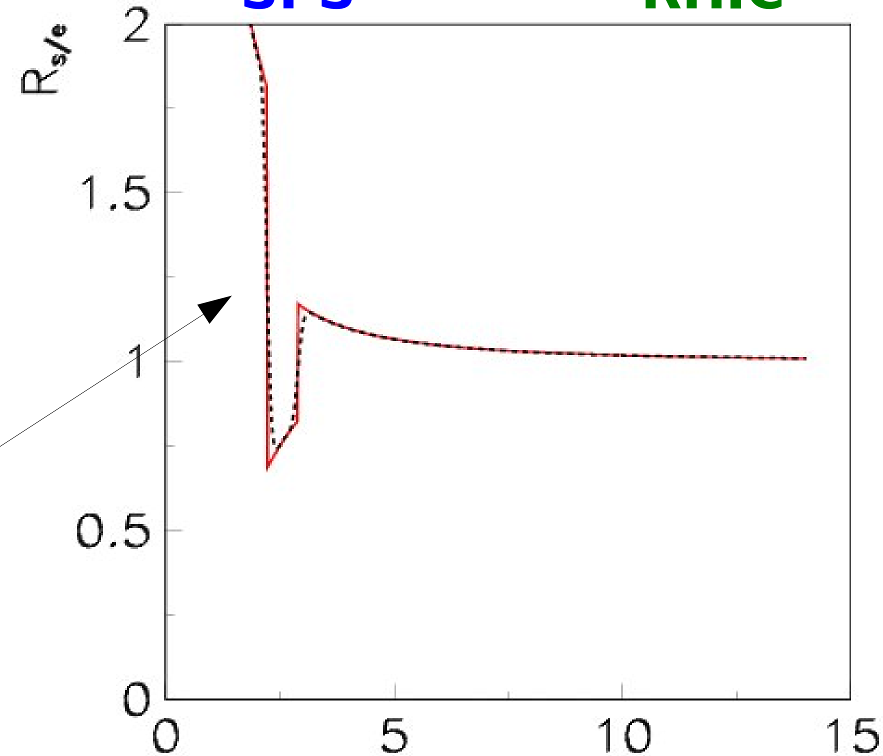
The NA49+STAR data

NA49 **STAR**



$\sqrt{s_{NN}}$

SPS **RHIC**



$F \approx \sqrt{\sqrt{s_{NN}}}$

Is the increase of fluctuations due to the onset of deconfinement?

Model calculations needed!!!

ϕ_x - **strongly intensive measure of fluctuations**

independent of volume

independent of volume fluctuations

$$\phi_x \equiv \sqrt{\frac{\langle Z^2 \rangle}{\langle N \rangle}} - \sqrt{\overline{z^2}}; \quad z \equiv x - \bar{x}; \quad Z \equiv \sum_{i=1}^{N} z$$

ϕ_x is independent of:

-volume and volume fluctuations in thermodynamical models,

-number of wounded nucleons and their fluctuations in WNM,

-acceptance in rapidity in a boost invariant hydro-model,

...