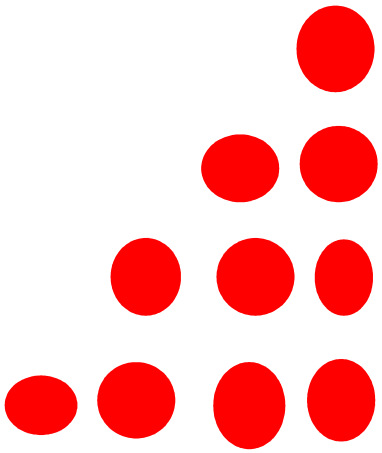
SHINE/NA61 at the CERN SPS



Physics goals

Detector

Ion Physics Program and Performance

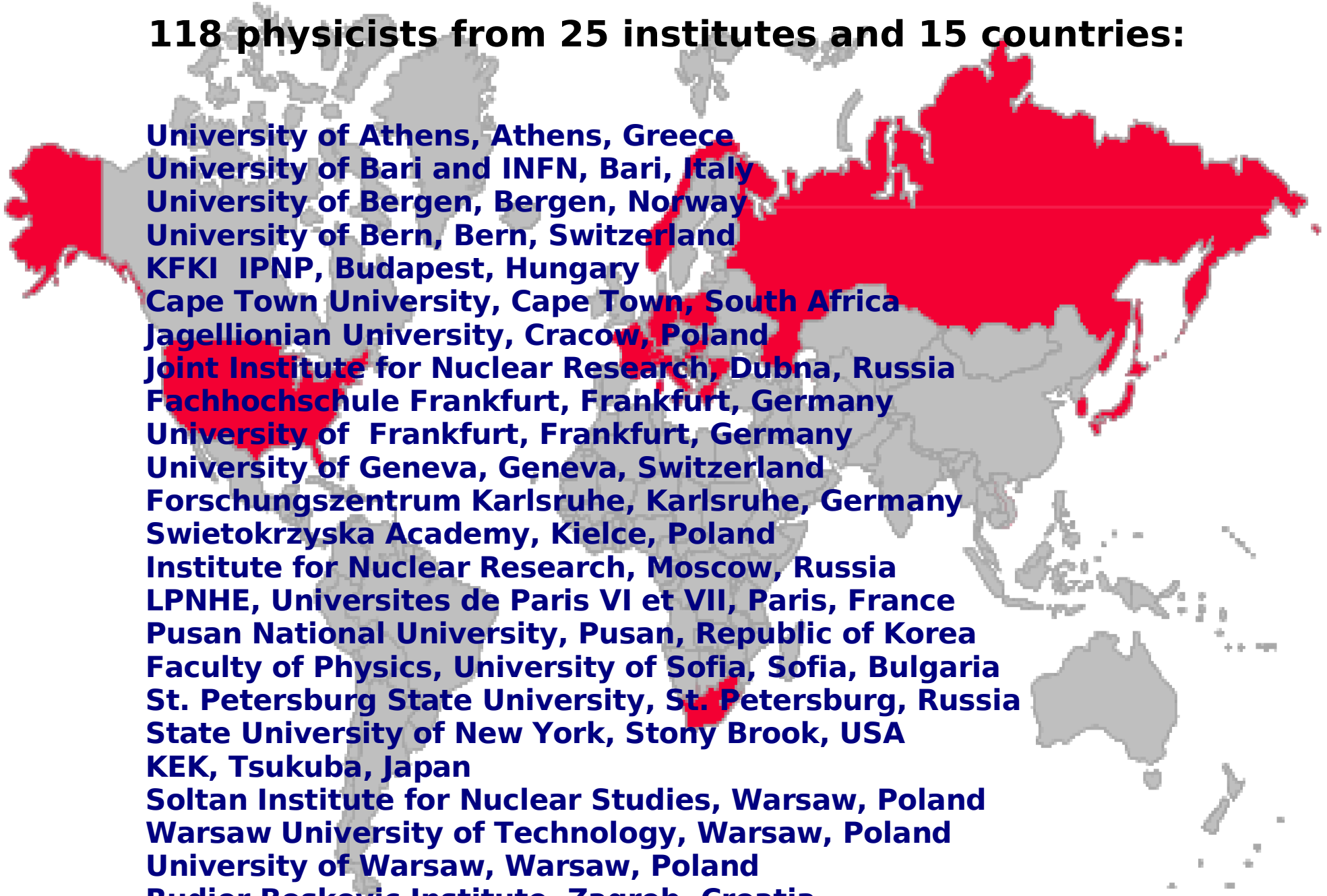
Beam request and status

Addendum-2:	*CERN-SPSC-2007-019, SPSC-P-330 (June 15, 2007)*
Addendum-1:	*CERN-SPSC-2007-004, SPSC-P-330 (January 25, 2007)*
Proposal:	*CERN-SPSC-2006-034, SPSC-P-330 (November 3, 2006)*
Status Report:	*CERN-SPSC-2006-023, SPSC-SR-010 (September 5, 2006)*
LoI:	*CERN-SPSC-2006-001, SPSC-I-235 (January 6, 2006)*
EoI:	*CERN-SPSC-2003-031, SPSC-EOI-001 (November 21, 2003)*

M. Gazdzicki, Frankfurt, Kielce
for the NA61 Collaboration

The NA61/SHINE Collaboration:

118 physicists from 25 institutes and 15 countries:



University of Athens, Athens, Greece
University of Bari and INFN, Bari, Italy
University of Bergen, Bergen, Norway
University of Bern, Bern, Switzerland
KFKI IPNP, Budapest, Hungary
Cape Town University, Cape Town, South Africa
Jagellionian 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
Swietokrzyska Academy, Kielce, Poland
Institute for Nuclear Research, Moscow, Russia
LPNHE, Universites de Paris VI et VII, Paris, France
Pusan National University, Pusan, Republic of Korea
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

Physics goals (I):

Physics of strongly interacting matter

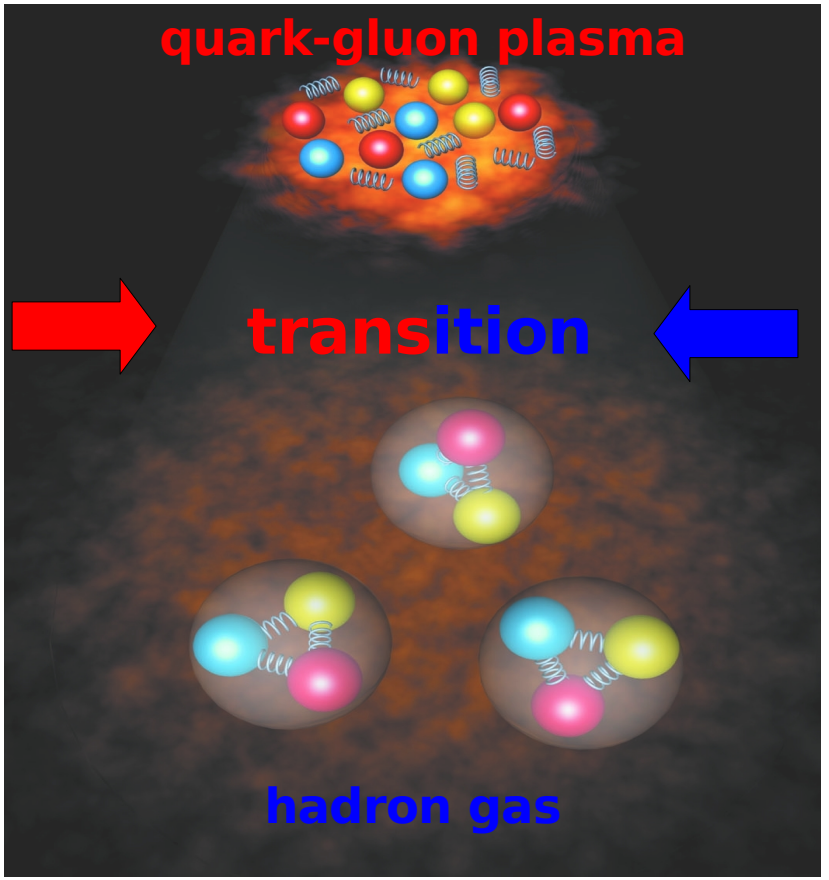
Discovery potential:

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



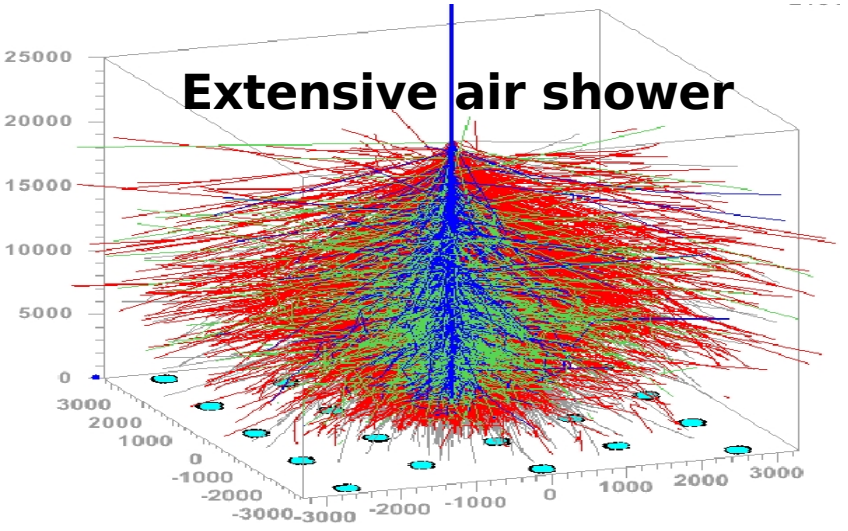
Physics goals (II):

Data for neutrino and cosmic ray experiments

Precision measurements:

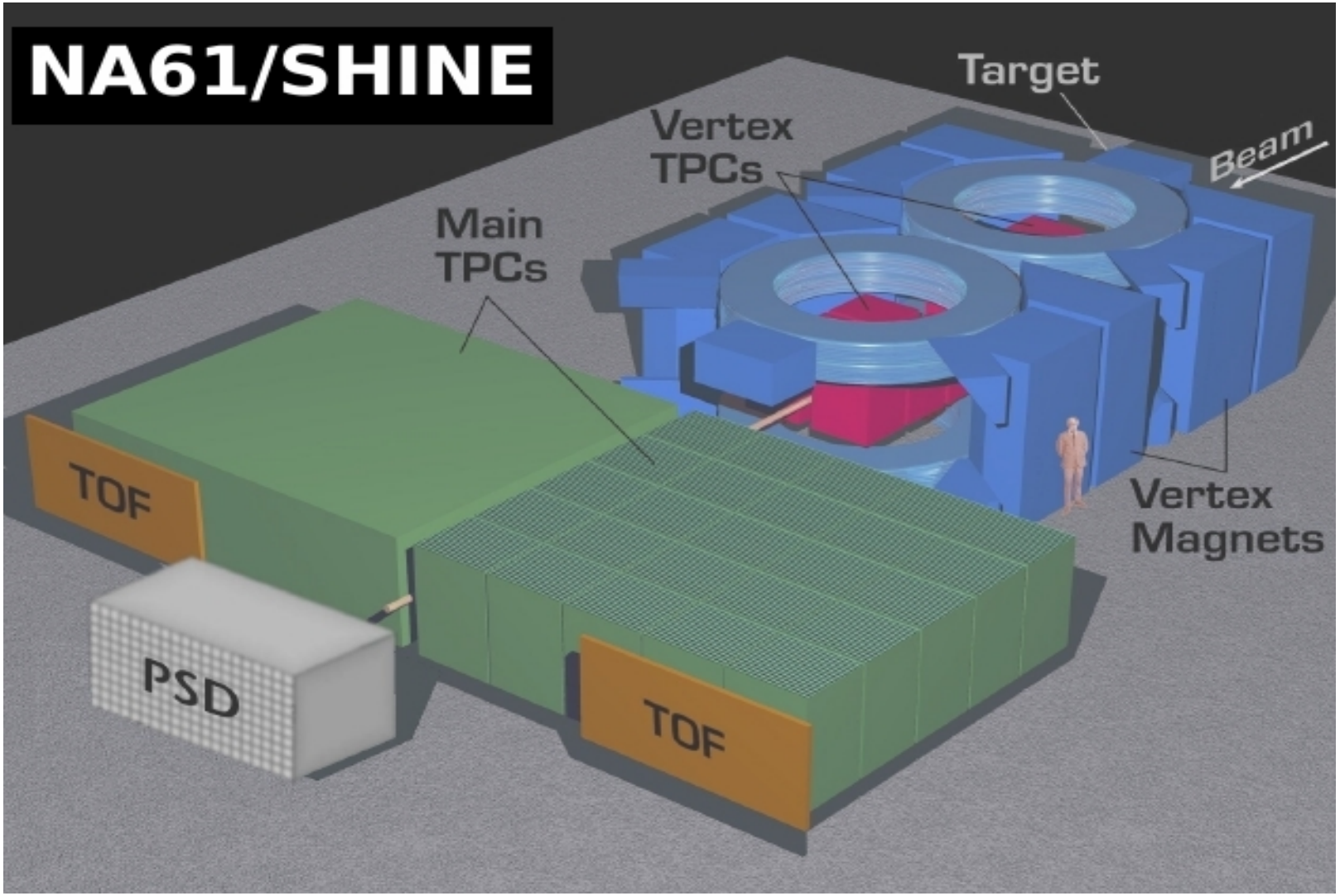
Measure hadron production in the T2K target needed for the T2K (neutrino) physics

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



Detector

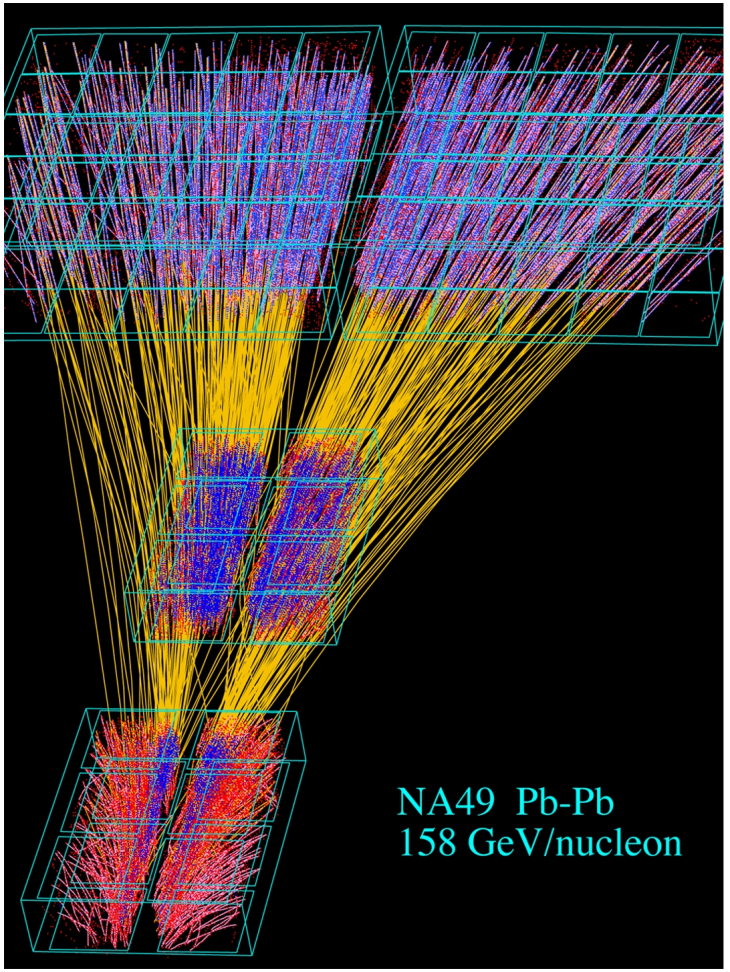
Upgraded NA49 apparatus



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

SHINE/NA61 at the CERN SPS

Existing NA49 facility:



- **Large acceptance: ≈50%**
- **High momentum resolution:**
  $\sigma(p)/p^2 \approx 10^{-4} \quad ((GeV/c)^{-1})$
- **Good particle identification:**
  $\sigma(TOF) \approx 60\,ps,$
  $\sigma(dE/dx)/\langle dE/dx \rangle \approx 0.04,$
  $\sigma(m_{inv}) \approx 5\,MeV$
- **High detector efficiency:**
  > 95%
- **Precise and rich physics results:**
  37 publications with final data

Tested in a one week long run in August 2006:

- No degradation of the performance since the beginning of operation
- Reconstruction, calibration, simulation and analysis software works
- All necessary experts are in the collaboration

Report from the test run: CERN-SPSC-2006-023, SPSC-SR-010 (September 5, 2006)

Planned basic upgrades:

2007: Modification and replacement of the obsolete equipment

→ **reestablish the full functionality of NA49**

(2007 total cost 300k CHF)

2008: Replacement of the TPC digital read-out and DAQ (by an ALICE-like system):

→ **an expected event rate ≈ *100 Hz***

(2008 total cost 440k CHF)

2009: Replacement of the VETO Calorimeter by a Projectile Spectator Detector:

→ **an increase of the resolution in the measurement of the number of projectile spectators by a factor ≈5 to $\Delta E/E \approx 50\%/E$,**

→ ***a* possible determination of the reaction plane**

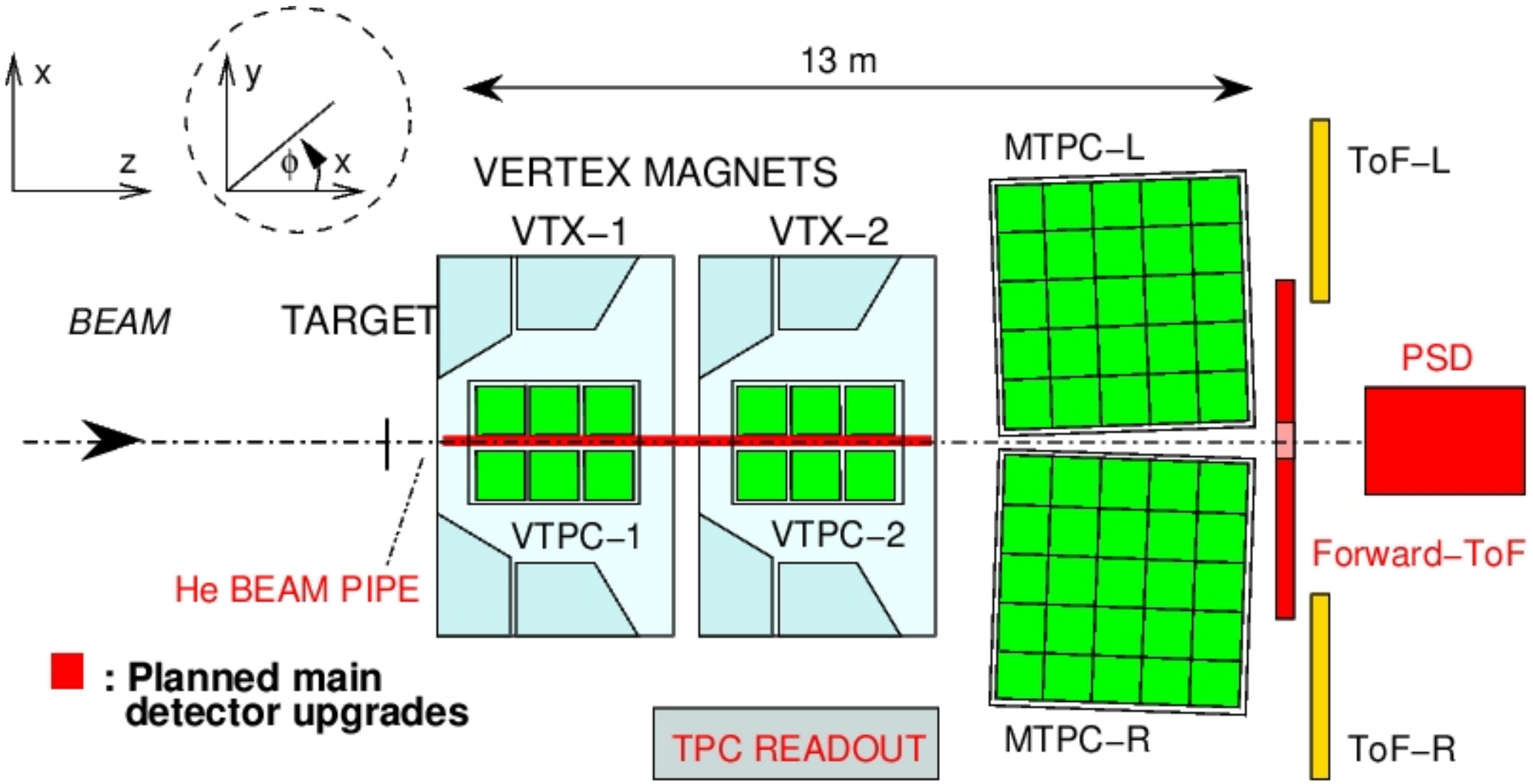
Installation of the Helium beam pipe in the VTPC gas cage

→ **a reduction of the delta-electron background by a factor of 10**

(2009 total cost 700k CHF)

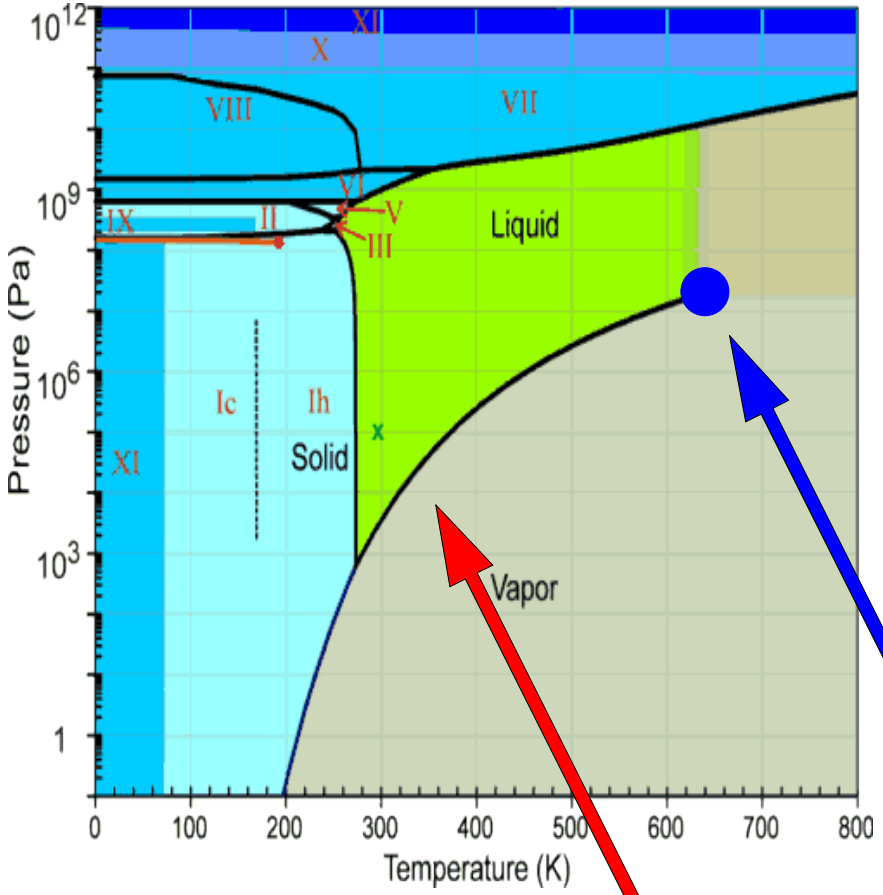
covered by the participating institutes

NA61 and planned basic upgrades:

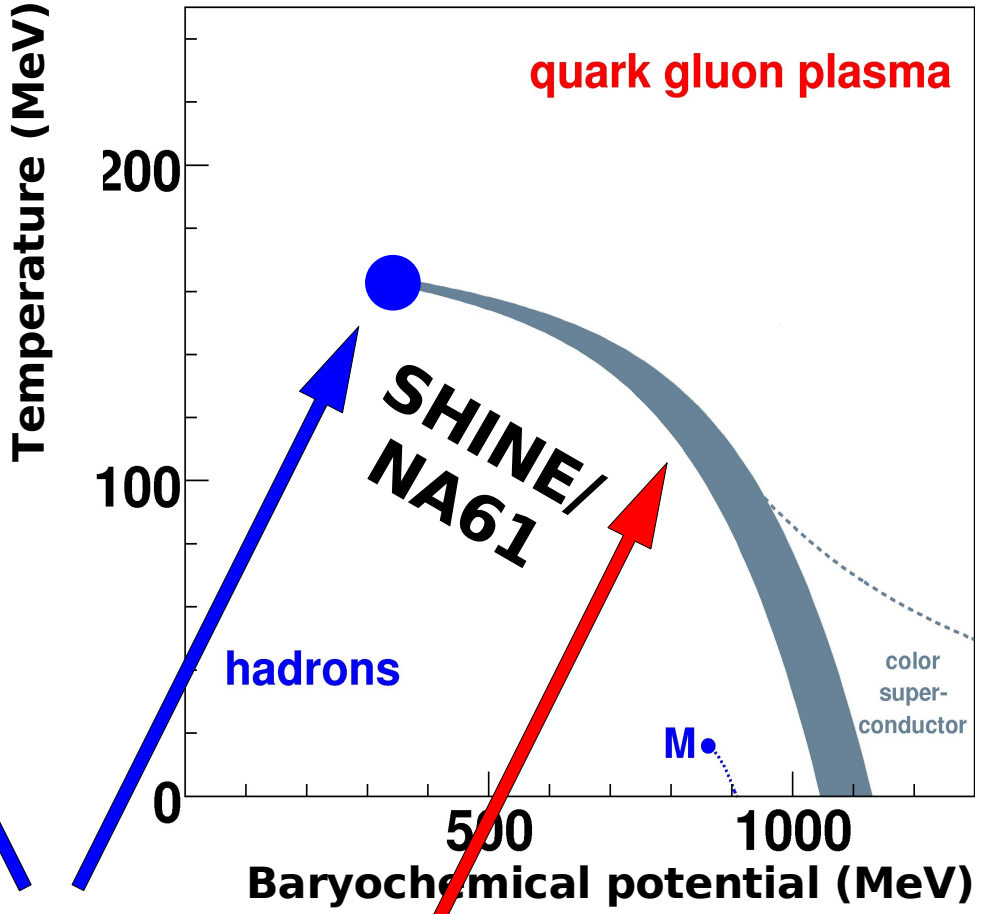


Ion Physics Program and Performance

water



strongly interacting matter

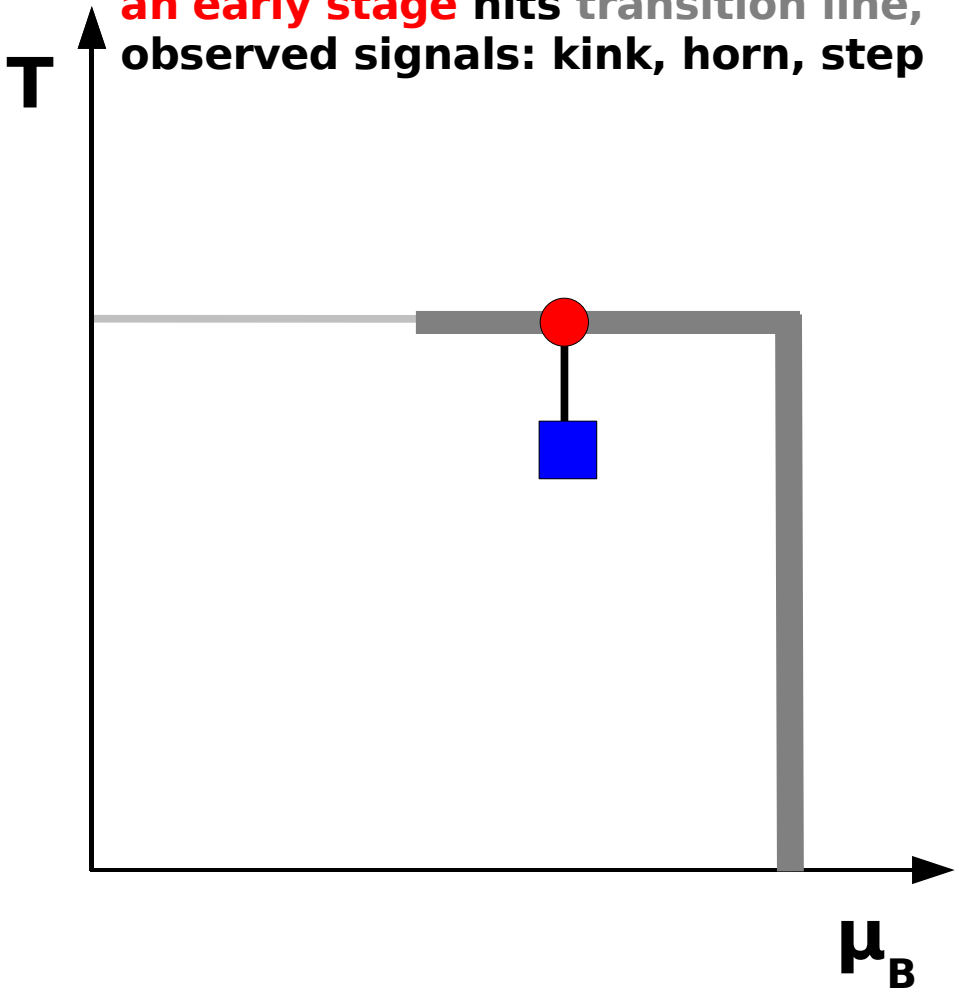


critical point

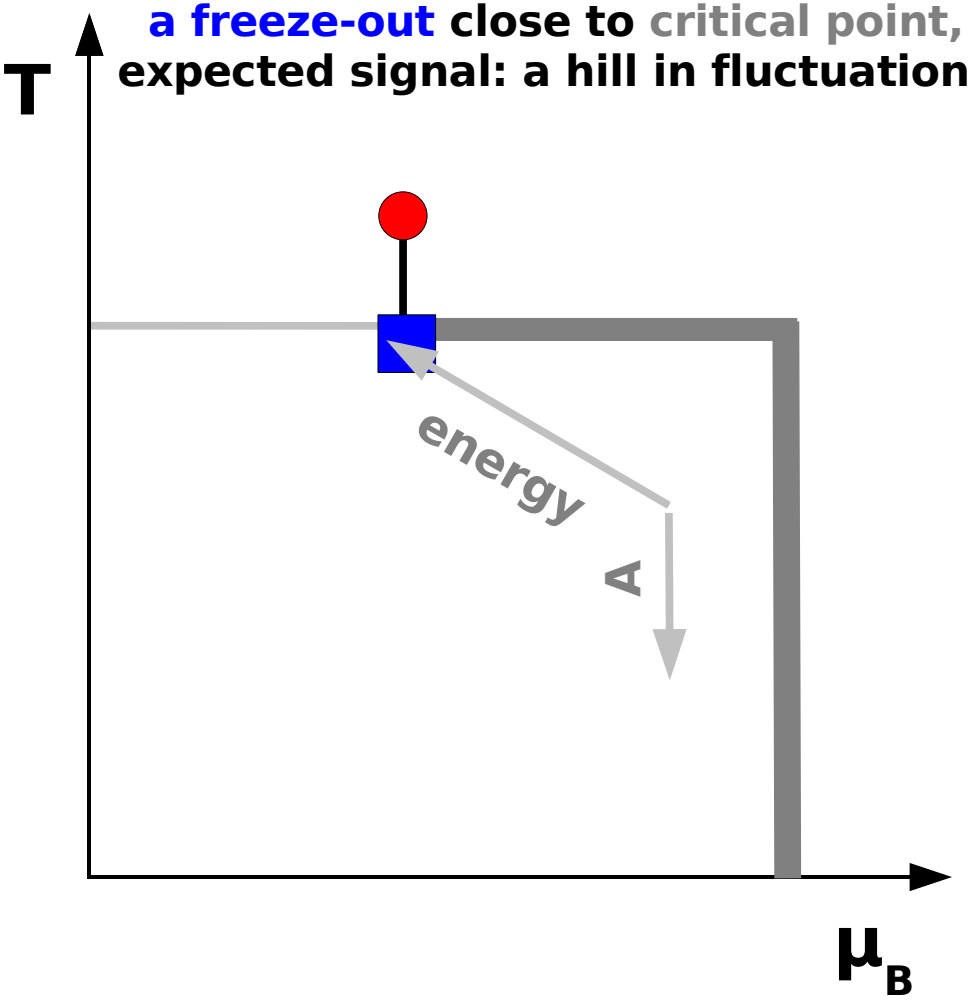
1st order phase transition

Two main events in nucleus-nucleus collisions

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

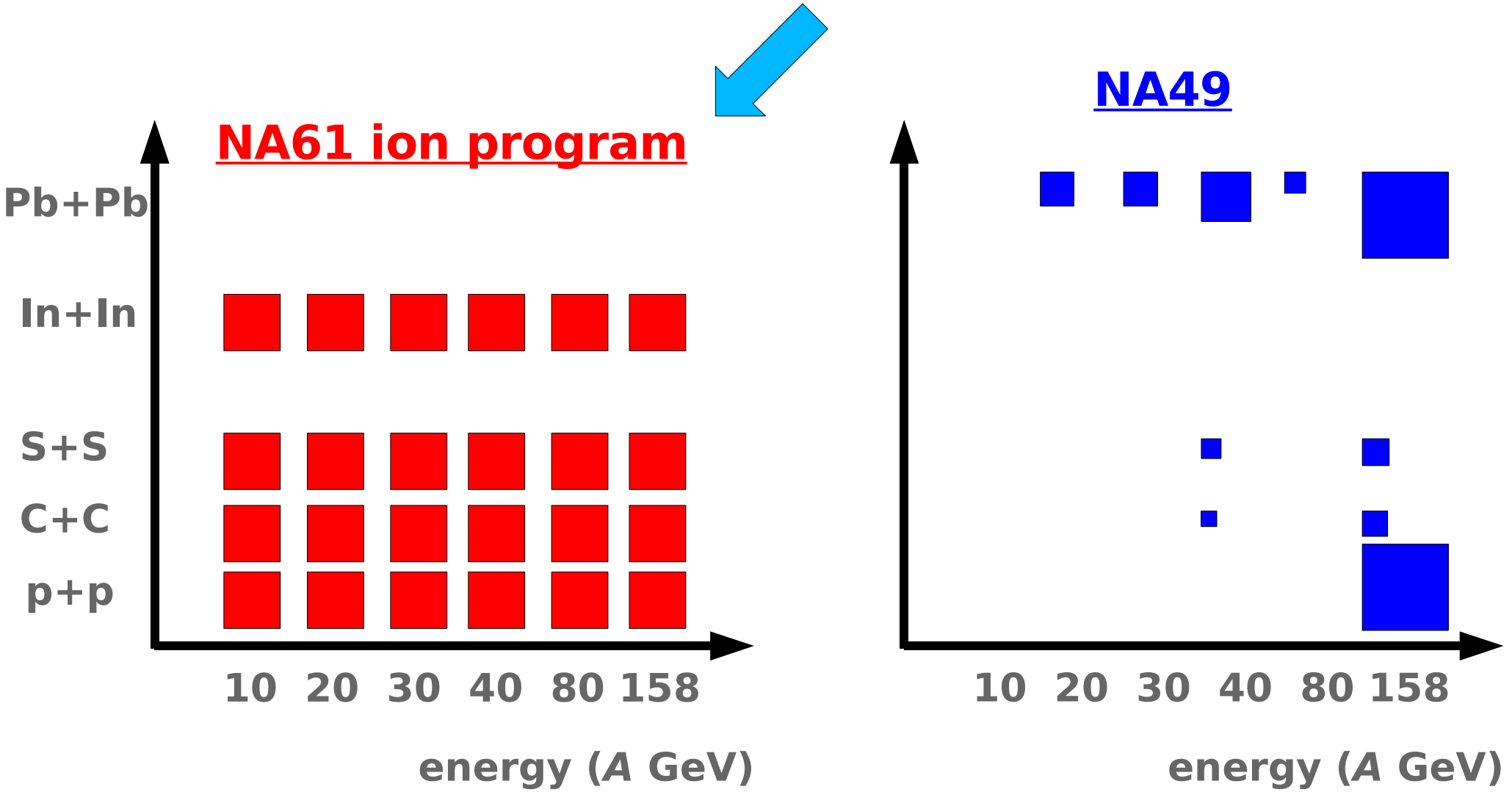


Critical Point:
a freeze-out close to critical point,
expected signal: a hill in fluctuations



E(OoD) ≈ 30*A* GeV ≤ E(OoC)

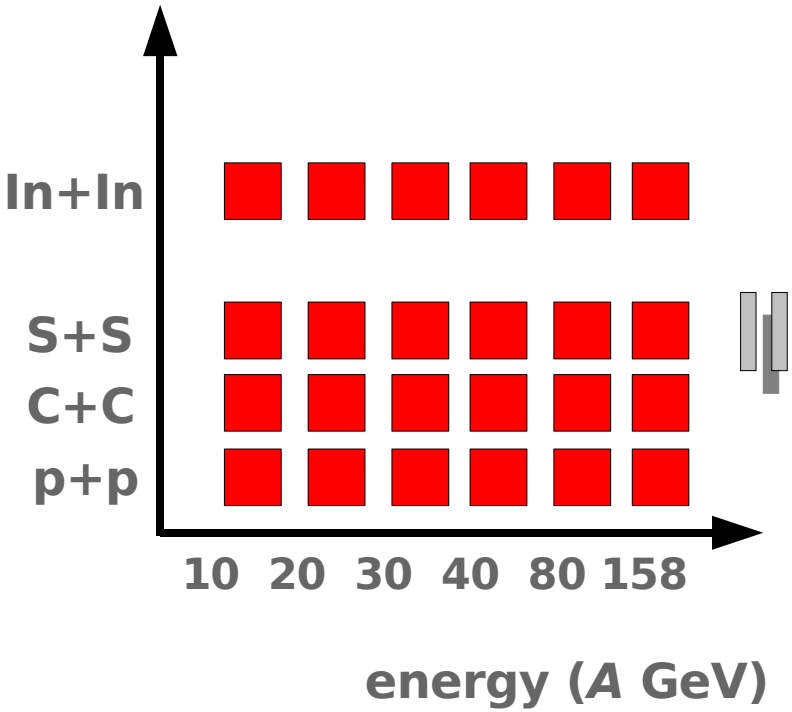
NA61 plans a comprehensive scan in the two dimensional plane (energy)-(system size) in the CERN SPS energy domain

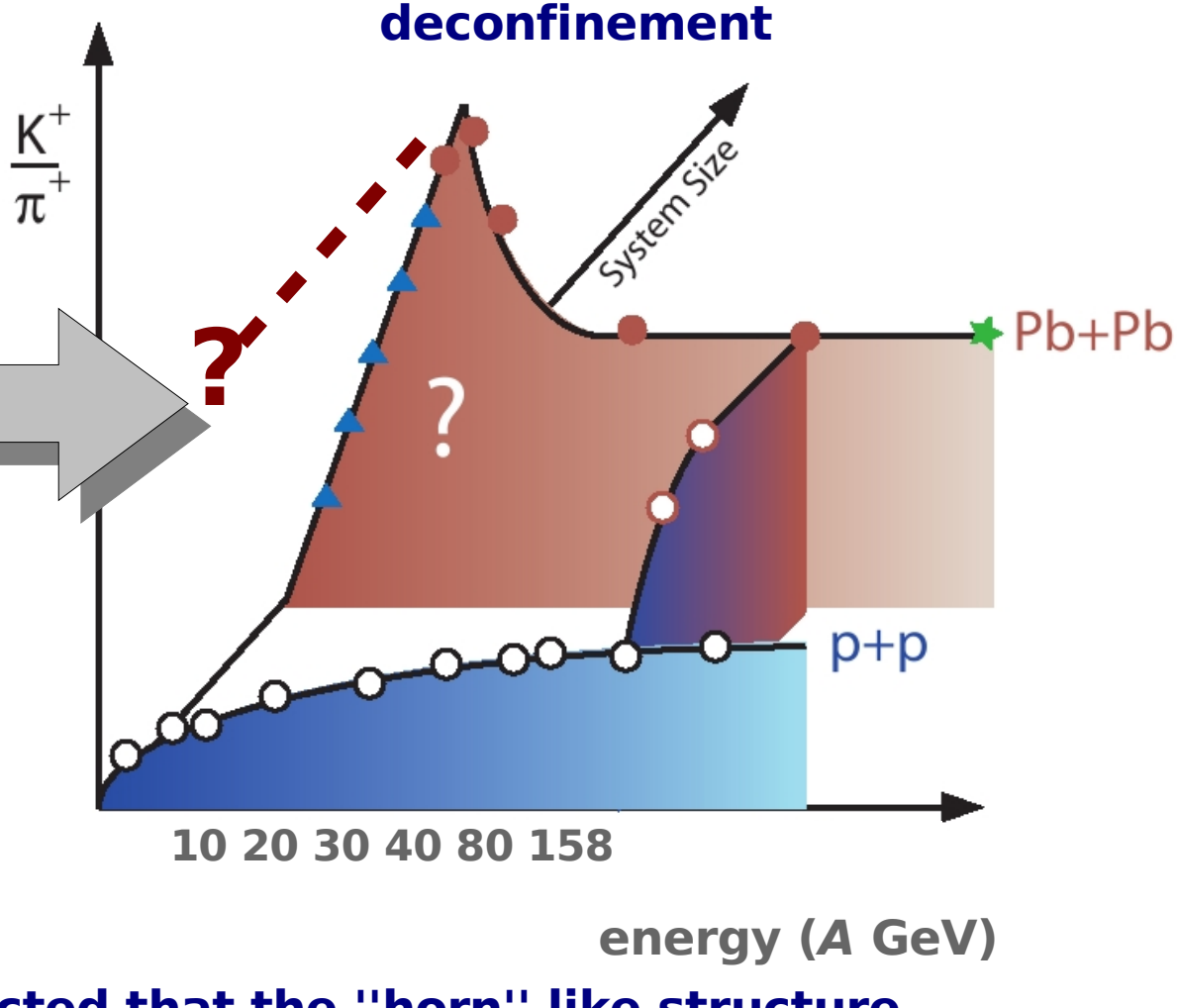


= $2 \cdot 10^6$ registered collisions

New data registered by NA61

will allow to establish the system size dependence of the anomalies observed in Pb+Pb collisions and thus further test their interpretation as due to the onset of deconfinement



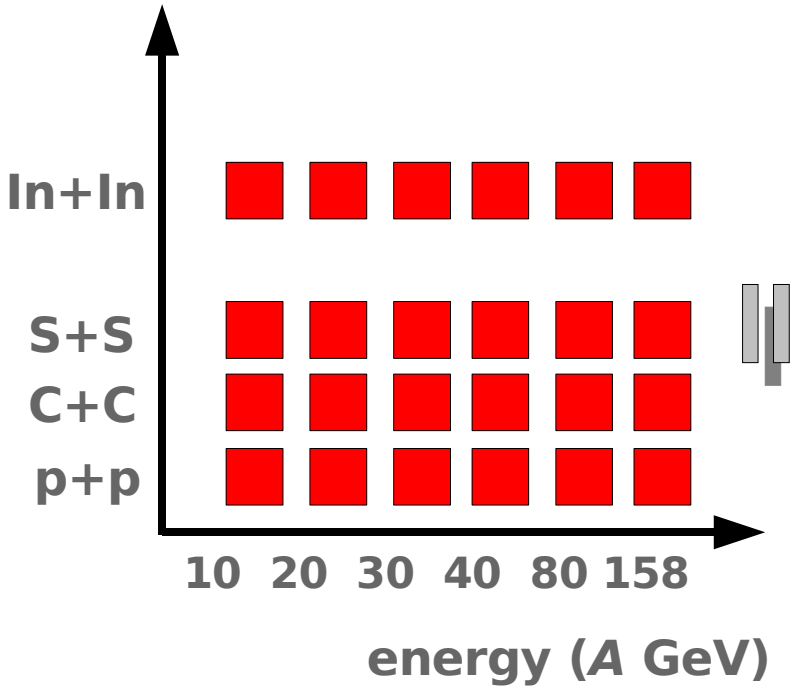


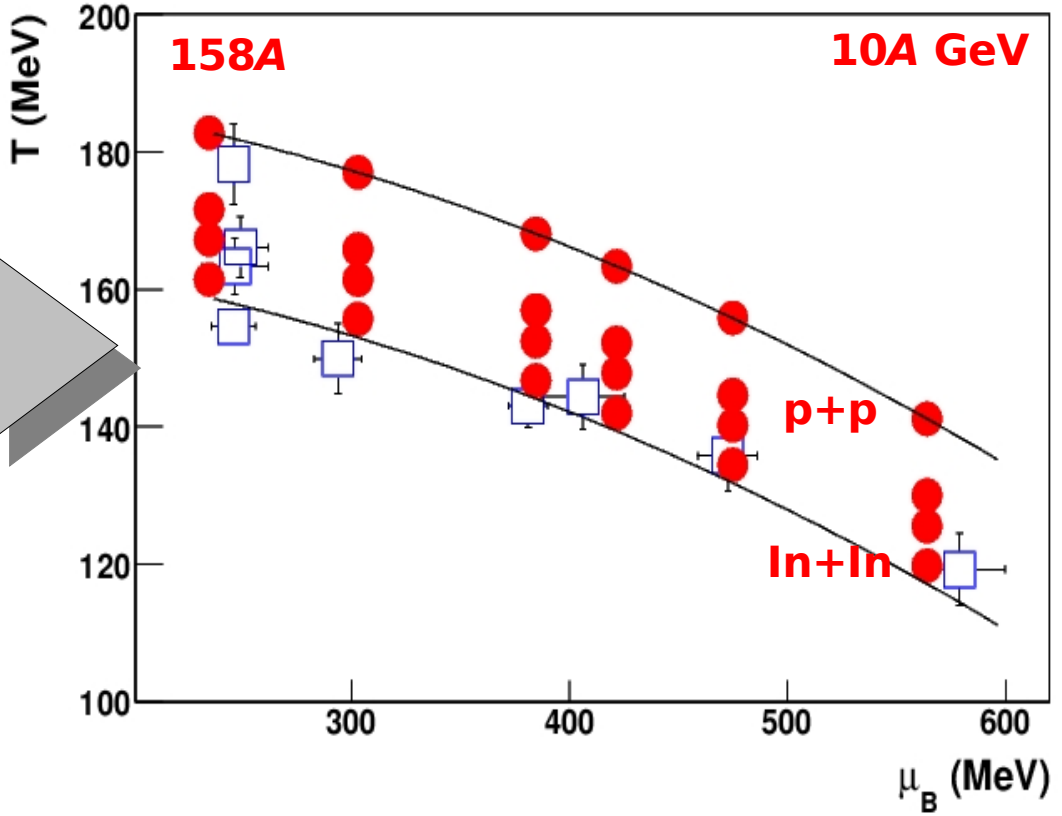
In particular, it is expected that the ''horn'' like structure should be the same for S+S and Pb+Pb collisions and then rapidly disappear for smaller systems

M.G., Gorenstein

New data registered by NA61

may lead to discovery of the critical point of strongly interacting matter by an observation of a hill of fluctuations in two dimensional plane (energy)-(system size) or equivalently (temperature)-(baryo-chemical potential)

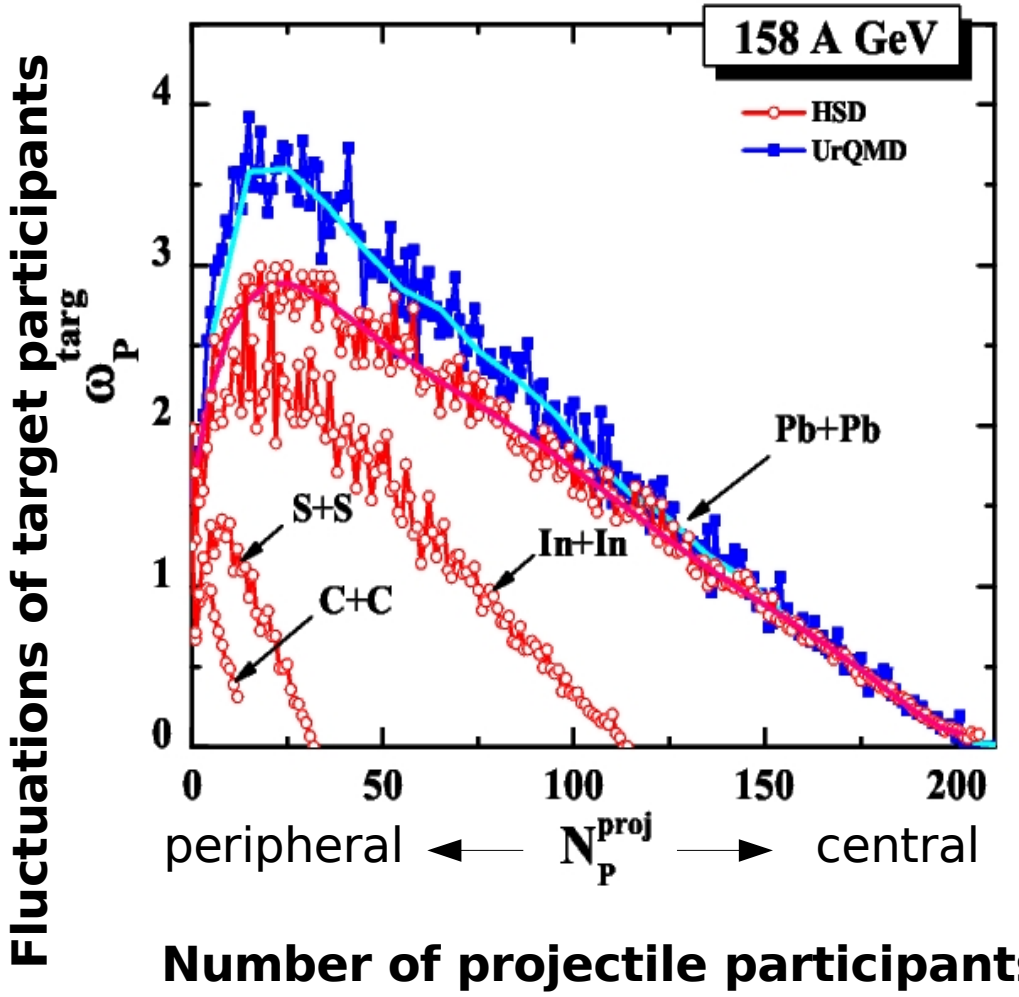




In particular the critical point should lead to an increase of multiplicity and transverse momentum fluctuations

Fluctuations and CP: Stephanov, Rajagopal, Shuryak, Phys. Rev. D 60, 114028
Freeze-out points: Becattini et al., Phys. Rev. C 73, 044905

Central collisions of light and medium size nuclei are required for the proposed fluctuation studies



Event-by-event fluctuations in the number of interacting (participant) nucleons are the main source of the background in the fluctuation studies

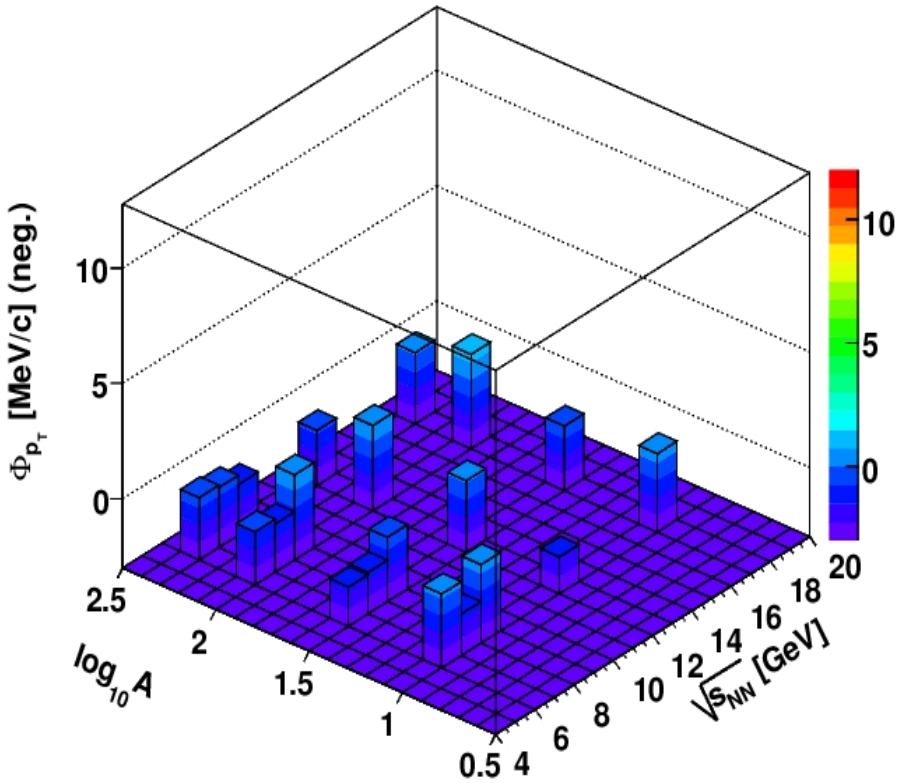
The fluctuations of the number of projectile participants are suppressed by selecting collisions with fixed number of projectile spectators (in NA49-future measured by PSD)

The fluctuations of the number of target participants can be suppressed only by selection of very central collisions

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

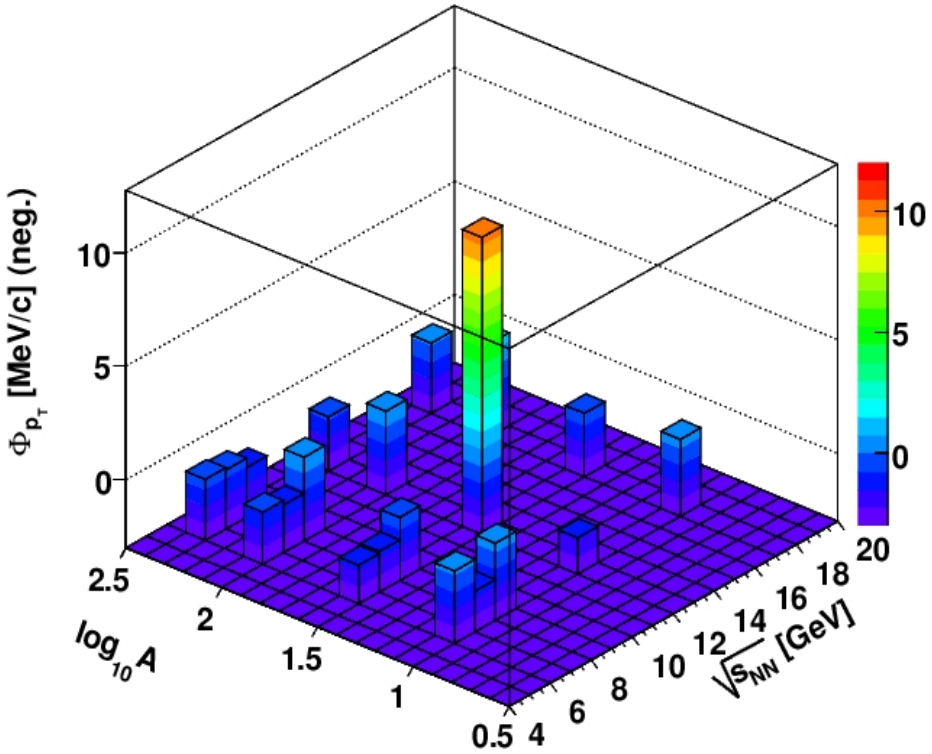
Test of the performance in the search for the critical point by simulating events in the NA49 detector

Transverse momentum fluctuations in the NA61 acceptance within the UrQMD model



Smooth dependence on energy and system size

… + an enhancement due to CP added to S+S collisions at 80*A* GeV



Clearly visible maximum (+10 MeV/c) over a smooth background

results from K. Grebieszkow

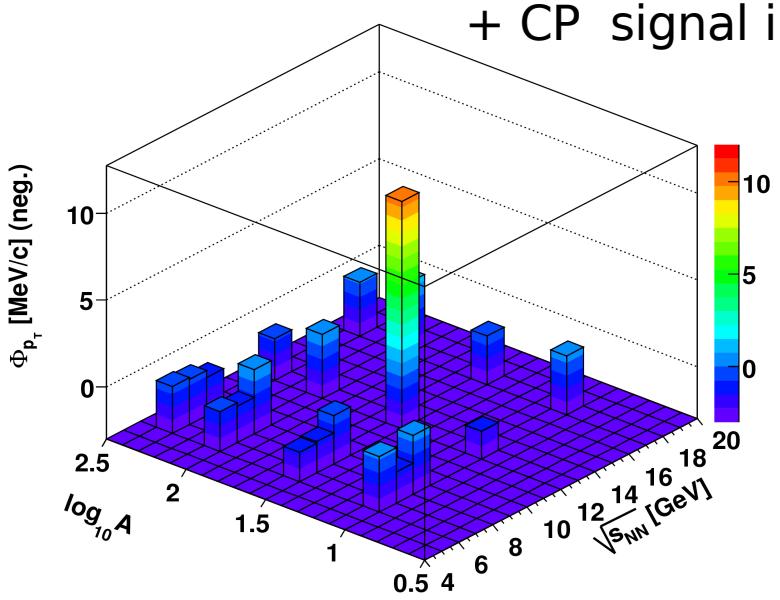
experimental uncertainties in the search for the critical point

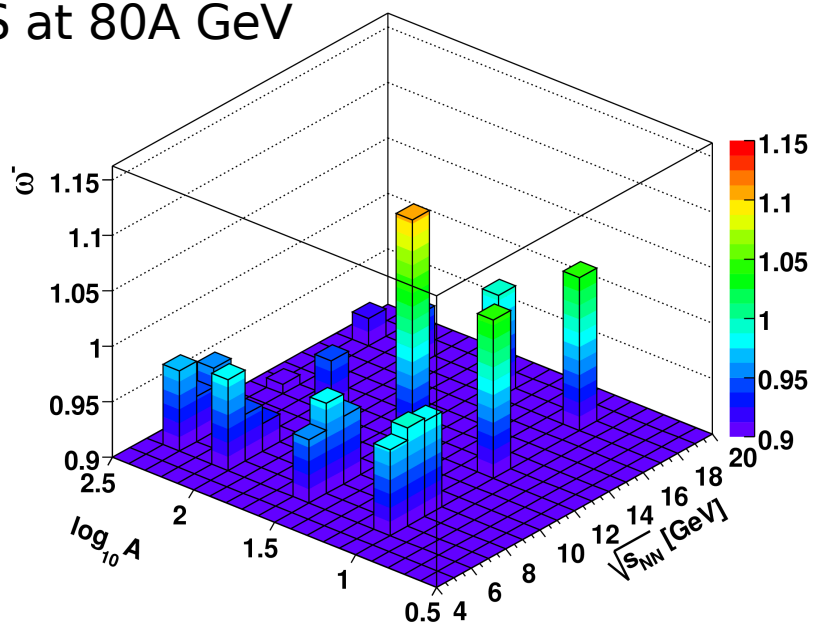
The multiplicity and transverse momentum fluctuations are predicted (*Phys. Rev. D60, 114028 (1999)*) to increase ($\Delta\omega \cong 0.1$ and $\Delta\phi_{PT} \cong 10$ MeV/c) in the vicinity of the critical point. This prediction is used to study the experimental resolution of NA61 in the search for the critical point.

The following uncertainties were quantified (simulations and/or NA49 data):

- **statistical errors,**
- **systematic error due to variation of the background fluctuations,**
- **systematic error due to the uncertainty in the measurement of the number of projectile spectators,**
- **systematic error due to reconstruction efficiency and the small contribution of non-vertex tracks.**

An example: ''background'' fluctuations in the UrQMD model + CP signal in S+S at 80A GeV





experimental uncertainties in the search for the critical point

Multiplicity fluctuations, ω

	NA49	NA61
Statistical error	≤ 0.05	≈ 0.005 MeV/c
Systematic error	≈ 0.05 (VETO CALO.)	≤ 0.003 (PSD)
Systematic error	≤ 0.025 (bkg,1D)	≤ 0.01 (bkg,2D) ($\leq$ *0.025 (bkg,1D)*)
Systematic error	≤ 0.02 (reco/non-vertex)	≤ 0.02 (reco/non-vertex)
Signal significance	$2 \cdot \Delta_{stat}$ and $2 \cdot \Delta_{sys}$	$20 \cdot \Delta_{stat}$ and $\geq 5 \cdot \Delta_{sys}$

Transverse momentum fluctuations, Φ_{P_T}

	NA49	NA61
Statistical error	≤ 1 MeV/c	≈ 0.1 MeV/c
Systematic error	≤ 1 MeV/c	≤ 1 MeV/c
Signal significance	$10 \cdot \Delta_{stat}$ and $10 \cdot \Delta_{sys}$	$100 \cdot \Delta_{stat}$ and $10 \cdot \Delta_{sys}$

strategy of data taking with ions

Conclusions:

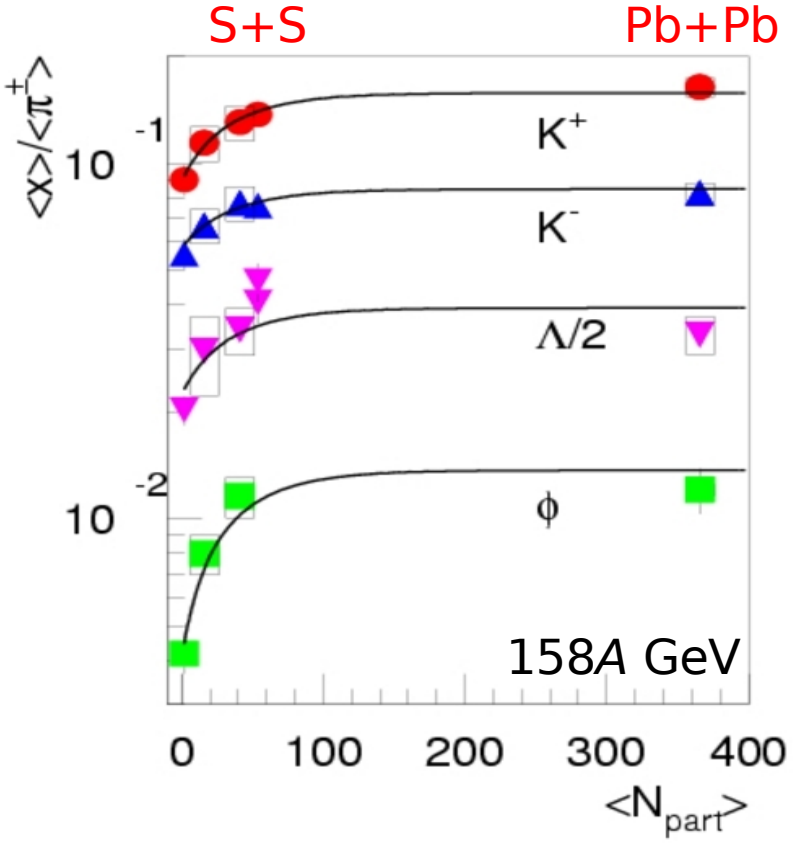
The proposed (collision energy)-(system size) scan with ion beams is necessary for a conclusive and comprehensive results on the critical point and onset of deconfinement.

The original suggested sequence of data taking is optimized in order to increase the probability to observe indications of the new physics in the shortest time.

Taking this into account we propose to start ion data taking in 2009 with S+S interactions and continue with In+In (2010) and C+C (2011)

strategy of data taking with ions

Arguments:



Relative yield of strange hadrons is independent of the system size starting from central S+S collisions

↓

Simple thermodynamical models can be used already for central S+S collisions

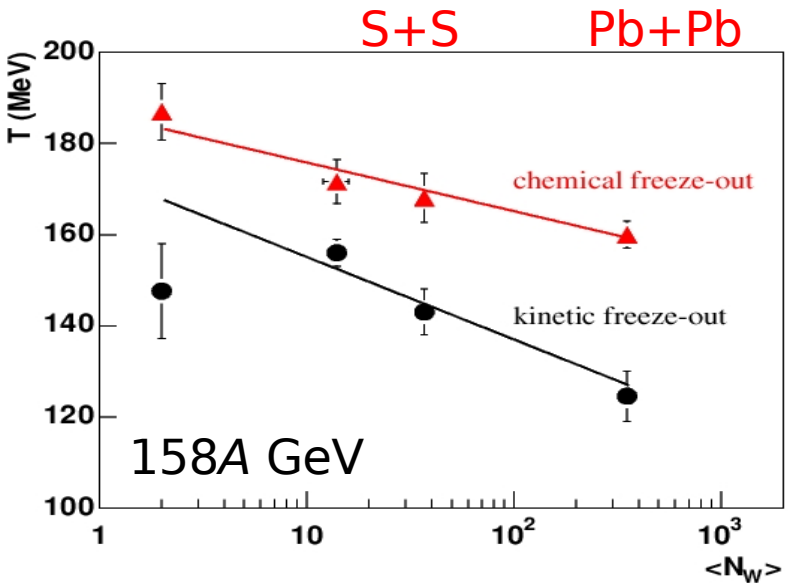
Large systems (A > 30) are preferred

Freeze-out temperature decreases with increasing system size.

↓

Small systems freeze-out close to the transition line

Small systems are preferred



S+S collisions are optimal

Beam request and status

SHINE/NA61 beam request

Beam	Energy (A GeV)	Year	Days	Physics
p	30, 40, 50	2008	14	Data for T2K, C-R
π^-	158, 350	2008	3	Data for C-R
p	158	2008	28	High p_T
S	10, 20, 30, 40, 80, 158	2009	30	CP&OoD
p	10, 20, 30, 40, 80, 158	2009	30	CP&OoD
In	10, 20, 30, 40, 80, 158	2010	30	CP&OoD
p	158	2010	30	High p_T
C	10, 20, 30, 40, 80, 158	2011	30	CP&OoD
p	10, 20, 30, 40, 80, 158	2011	30	CP&OoD

SHINE/NA61 status:

-approved experiment at the CERN SPS

-two test runs were successfully performed

-the first physics run (32 days) is approved and it will start in two weeks

-the 2008 run (45 days) is fully recommended

-the 2009 run (60 days) are fully recommended contingent to successful run 2007 and progress in data analysis

-the door for continuation of the ion program at the CERN SPS is clearly opened

Summary

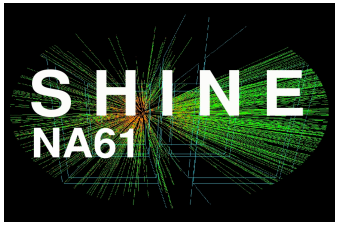
The SHINE/NA61 program gives the unique opportunity to reach exciting physics goals in a very efficient and cost effective way

It has the potential to discover the critical point of strongly interacting matter and guarantees a broad set of important precision measurements

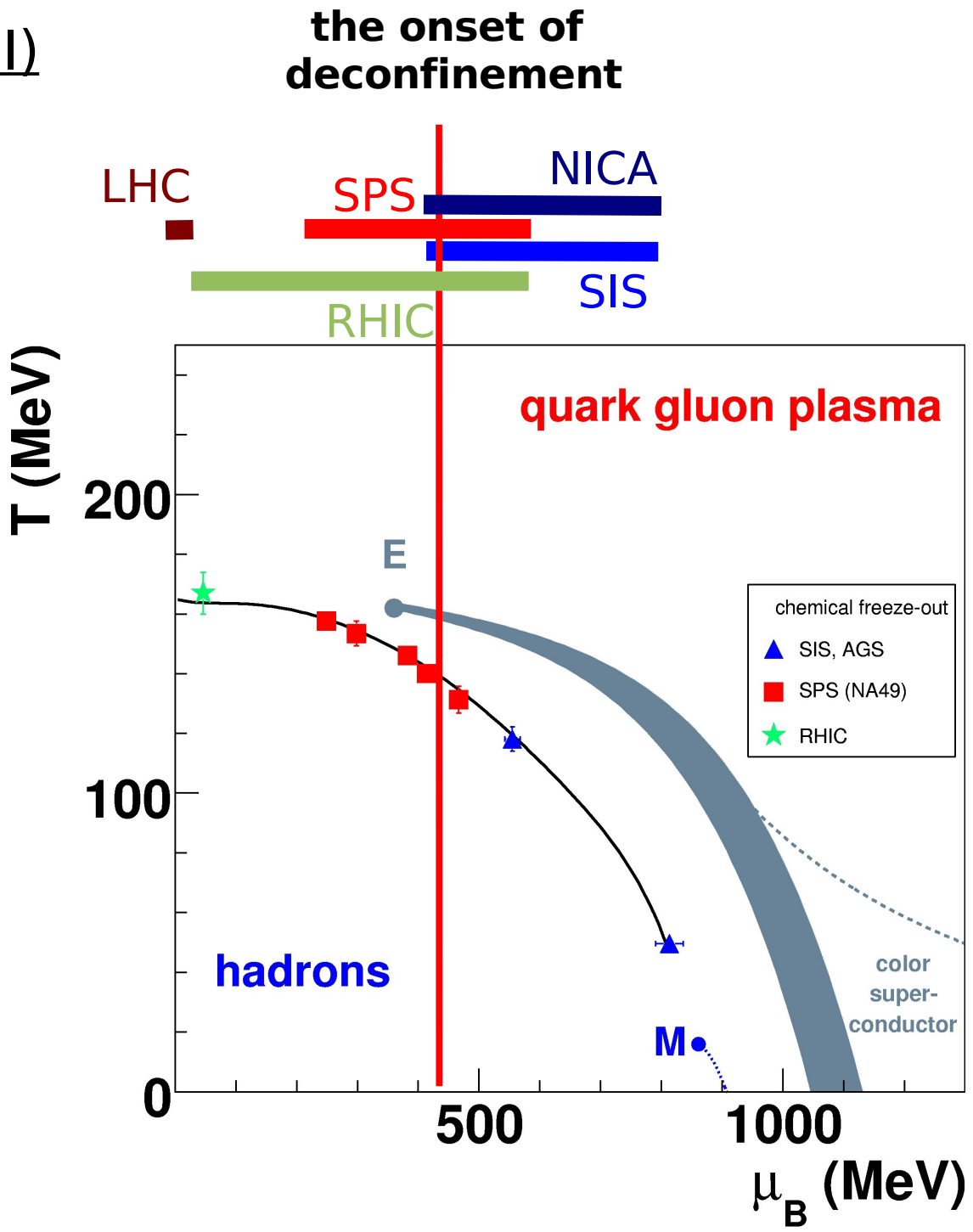
It is well recognized by the world community, see e.g. the supporting letters by Frank Wilczek and T2K, Pierre Auger Observatory and KASCADE collaborations as well as an annual workshop on Critical Point and Onset of Deconfinement

It is complementary to the efforts of other international and national laboratories, FAIR, JINR, KEK and RHIC and to the heavy ion program at the CERN LHC

It is of common interest for different physics communities, heavy ions, neutrino and cosmic-rays



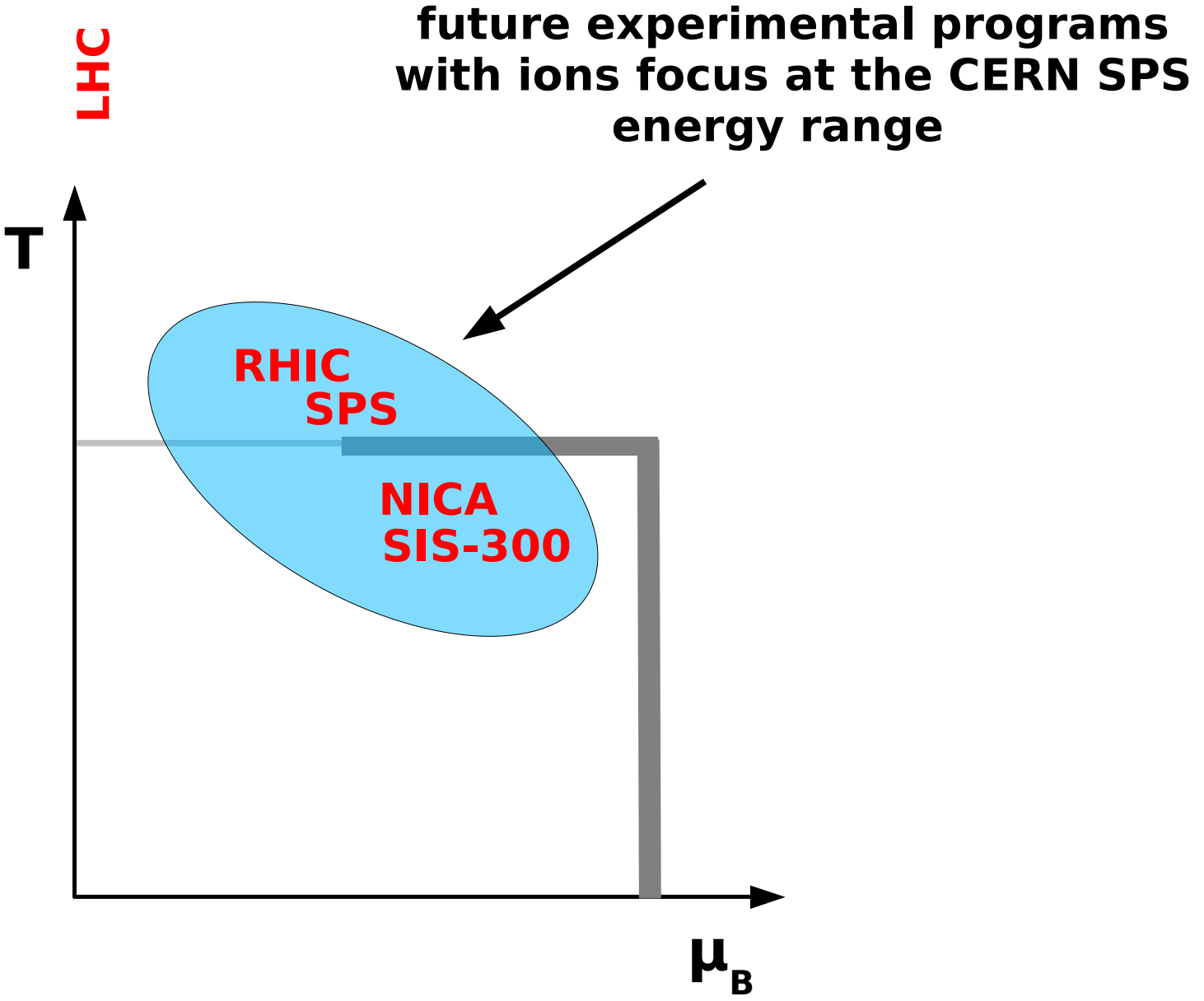
Overview (I)


the onset of deconfinement
LHC
SPS
NICA
SIS
RHIC
quark gluon plasma
T (MeV)
200
100
0
E
chemical freeze-out
SIS, AGS
SPS (NA49)
RHIC
hadrons
color super-conductor
M
500
1000
μB (MeV)

Overview (II)

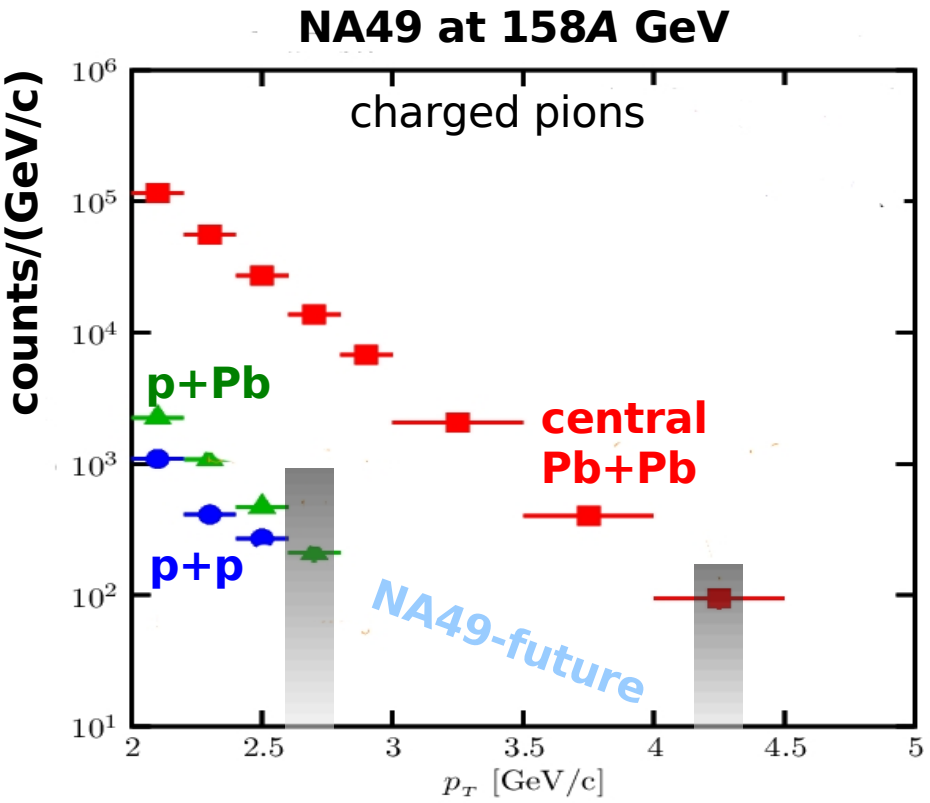
Facility:	**SPS**	**RHIC**	**NICA**	**SIS-300**
Exp.:	**NA61**	**STAR** **PHENIX**	**MPD**	**CBM**
Start:	**2009**	**2010**	**2013**	**2015**
Pb Energy: **(GeV/(N+N))**	**4.9-17.3**	**4.9-50**	**≤9**	**≤8.5**
Event rate: **(at 8 GeV)**	**100 Hz**	**1 Hz(?)**	**≤10 kHz**	**≤10 MHz**
Physics:	**CP&OD**	**CP&OD**	**OD&HDM**	**OD&HDM**

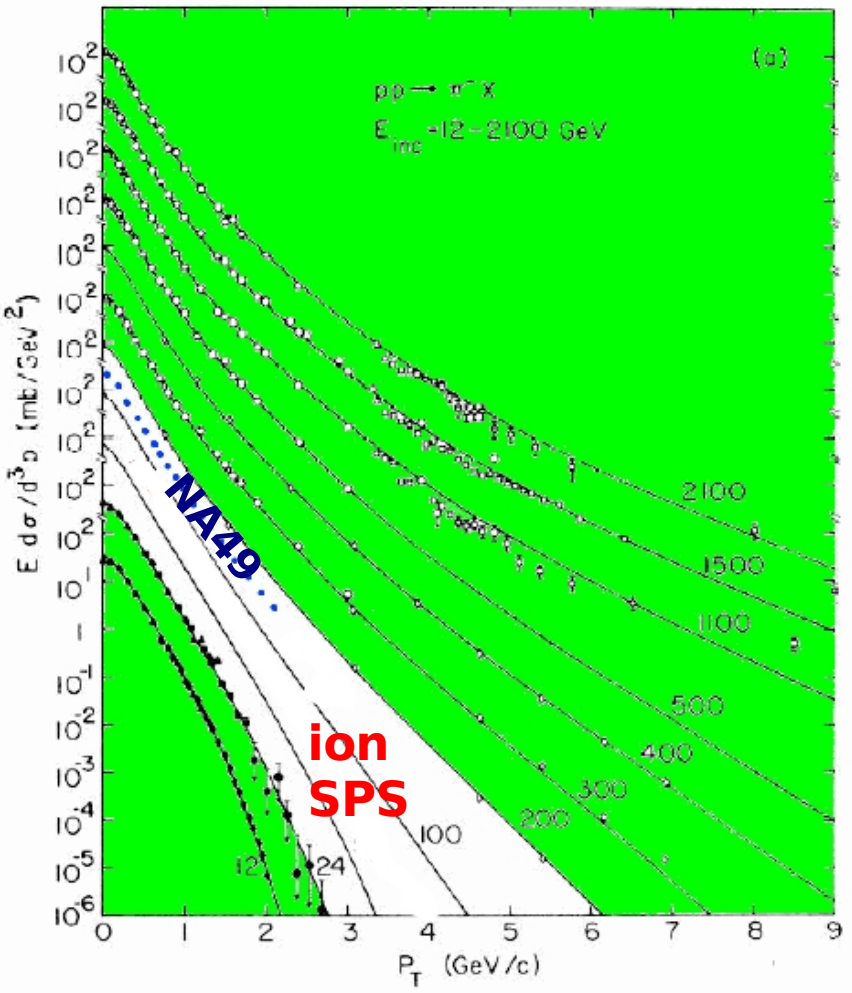
CP – critical point
OD – onset of deconfinement, mixed phase, 1st order PT
HDM – hadrons in dense matter


future experimental programs
with ions focus at the CERN SPS
energy range
LHC
T
RHIC
SPS
NICA
SIS-300
μB

Additional slides

NA49 and other CERN SPS experiments measured high pT spectra in central Pb+Pb collisions up to 4.5 GeV/c





E. Beier et al., Phys. Rev. D18, 2235 (1978)

The p_T spectra in p+p and p+Pb interactions at the ion SPS energies are measured only up to 2.5 GeV/c

NA49-future intends to measure the missing high p_T spectra in p+p and p+Pb interactions. Study of the high p_T correlations and centrality dependence will be also possible.