Critical Point and Onset of Deconfinement – Ion Program of NA61/SHINE at the CERN SPS

(SHINE – SPS Heavy Ion and Neutrino Experiment)

NA61/SHINE physics program:

- Critical Point and Onset of Deconfinement,
- High p_T physics
- Neutrino physics,
- Cosmic-ray physics

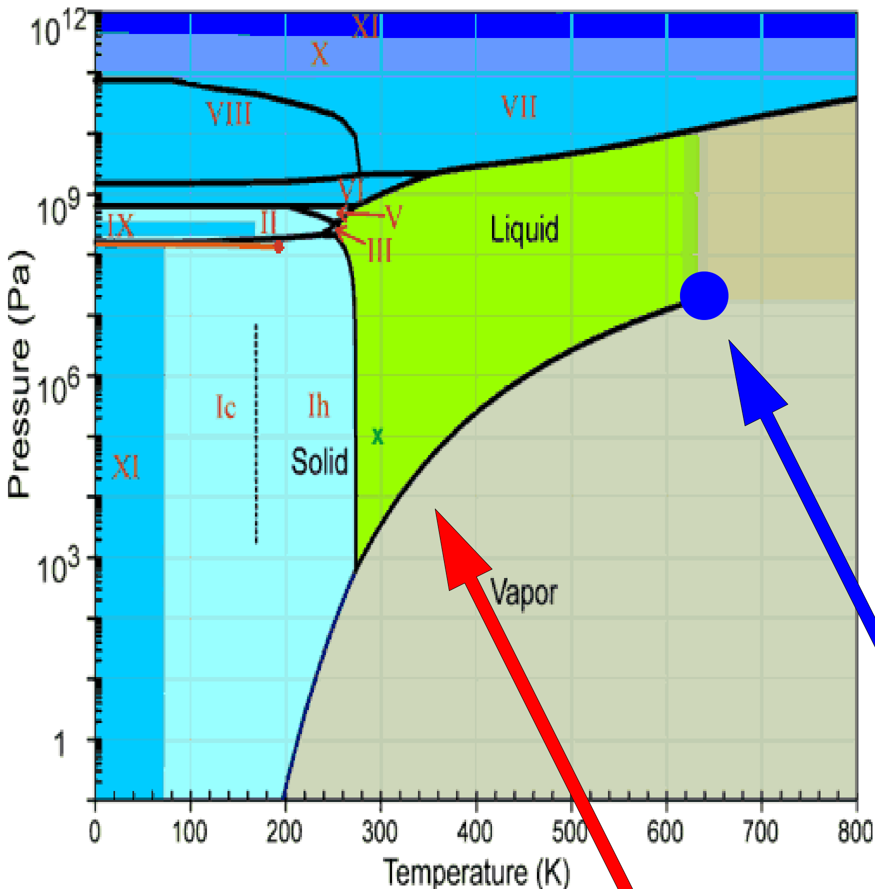
Proposal: CERN-SPSC-2006-034, SPSC-P-330 (November 3, 2006)
LoI: CERN-SPSC-2006-001, SPSC-I-235 (January 6, 2006)
EoI: CERN-SPSC-2003-031, SPSC-EOI-001 (November 21, 2003)

M. Gazdzicki, Frankfurt, Kielce
for the NA61 Collaboration

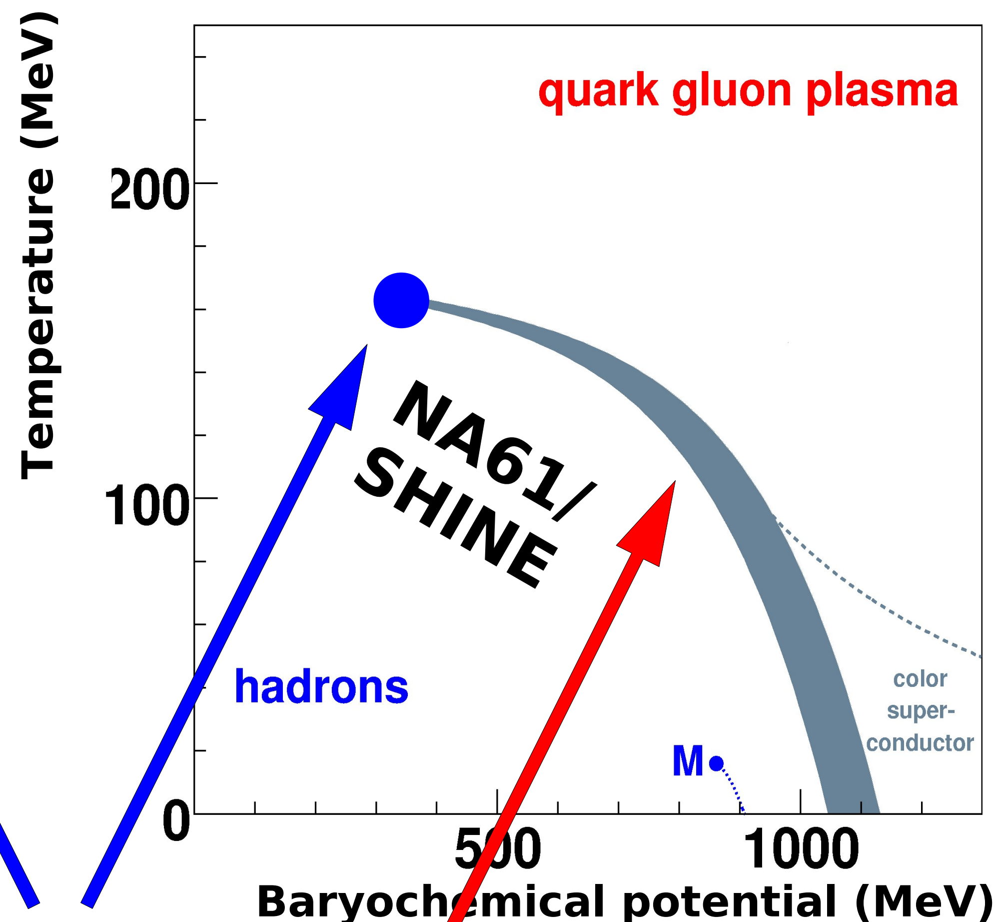
Onset of deconfinement and Critical Point:

Properties of the transition between confined and deconfined matter

water



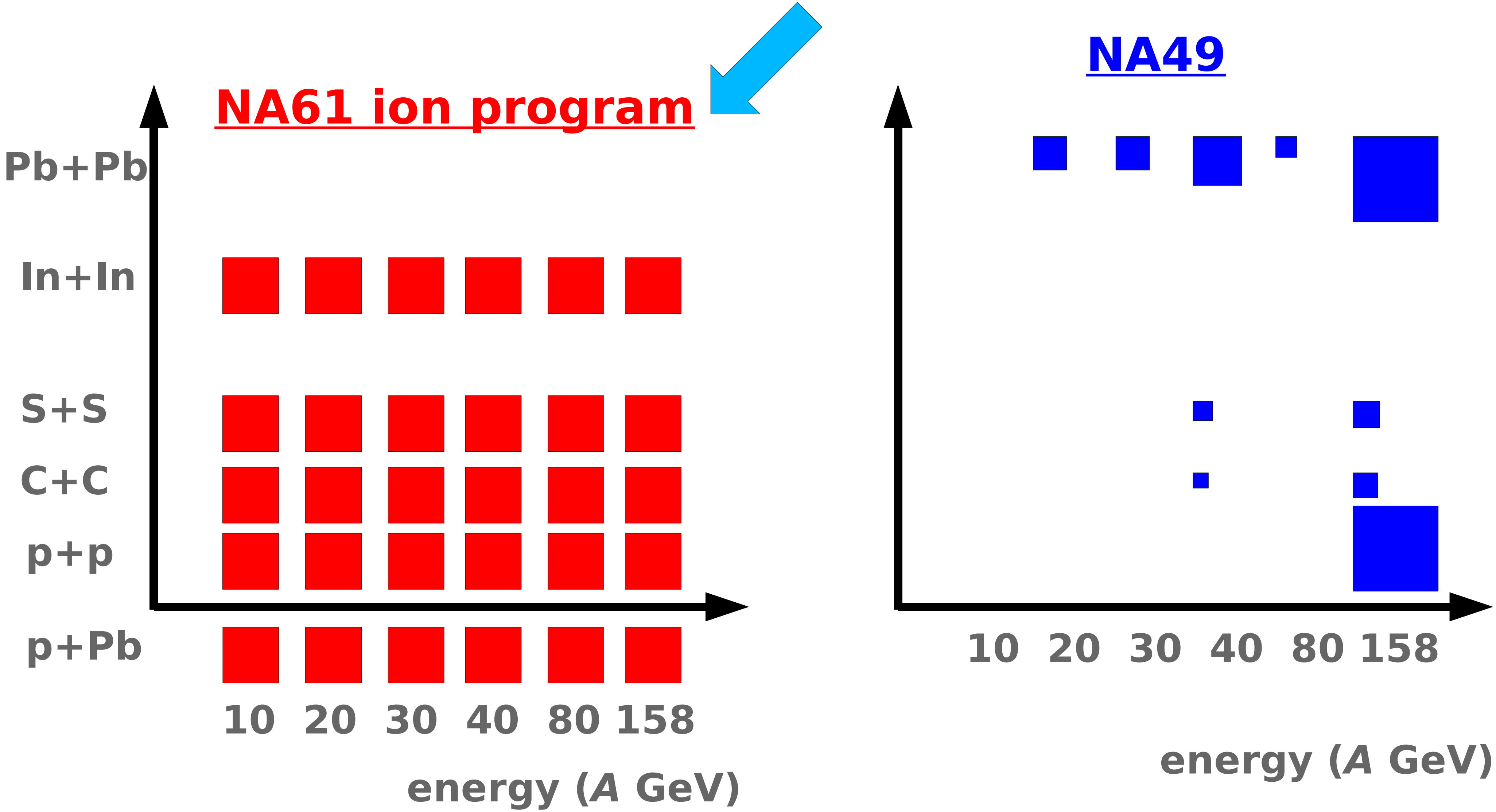
strongly interacting matter



critical point

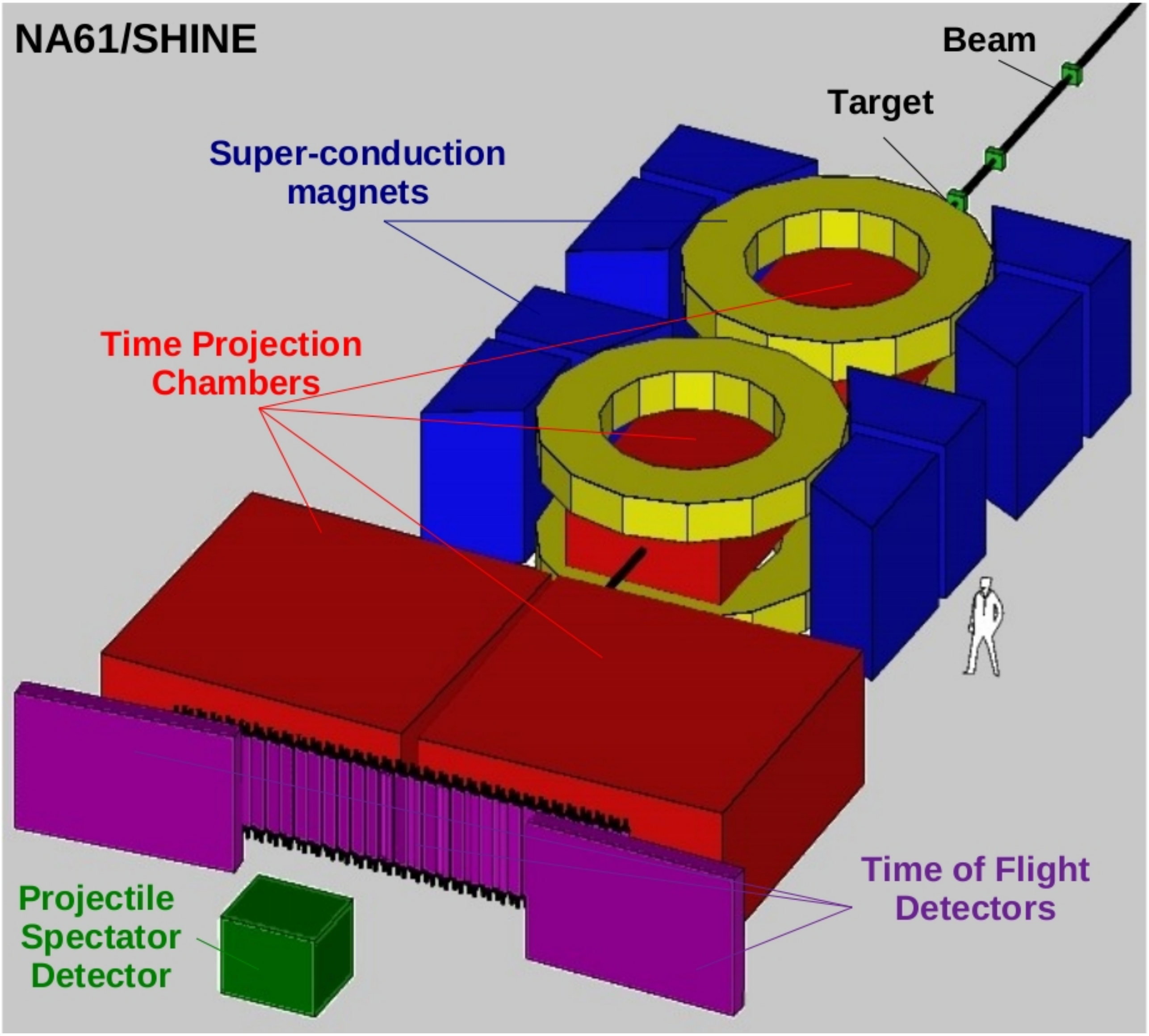
1^{st} order phase transition

NA61/SHINE energy-system size scan



= $2\cdot10^6$ registered collisions

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



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

NA61/SHINE ion related contributions to this workshop

This presentation on the NA61 ion program presented in the NA61 proposal and largely recommended by the SPSC in 2008. Approval by the RB is delayed due to undergoing study of the compatibility with I-LHC. *Expected data taking period: 2009-2013*

abstract 47 by M.G. for NA61/SHINE

The next presentation on a possible extension of the NA61 ion program by measurements of ''Rare probes of Quark-Gluon Matter: High p_T di-hadron correlations and open charm''.
Possible data taking period: 2014+...

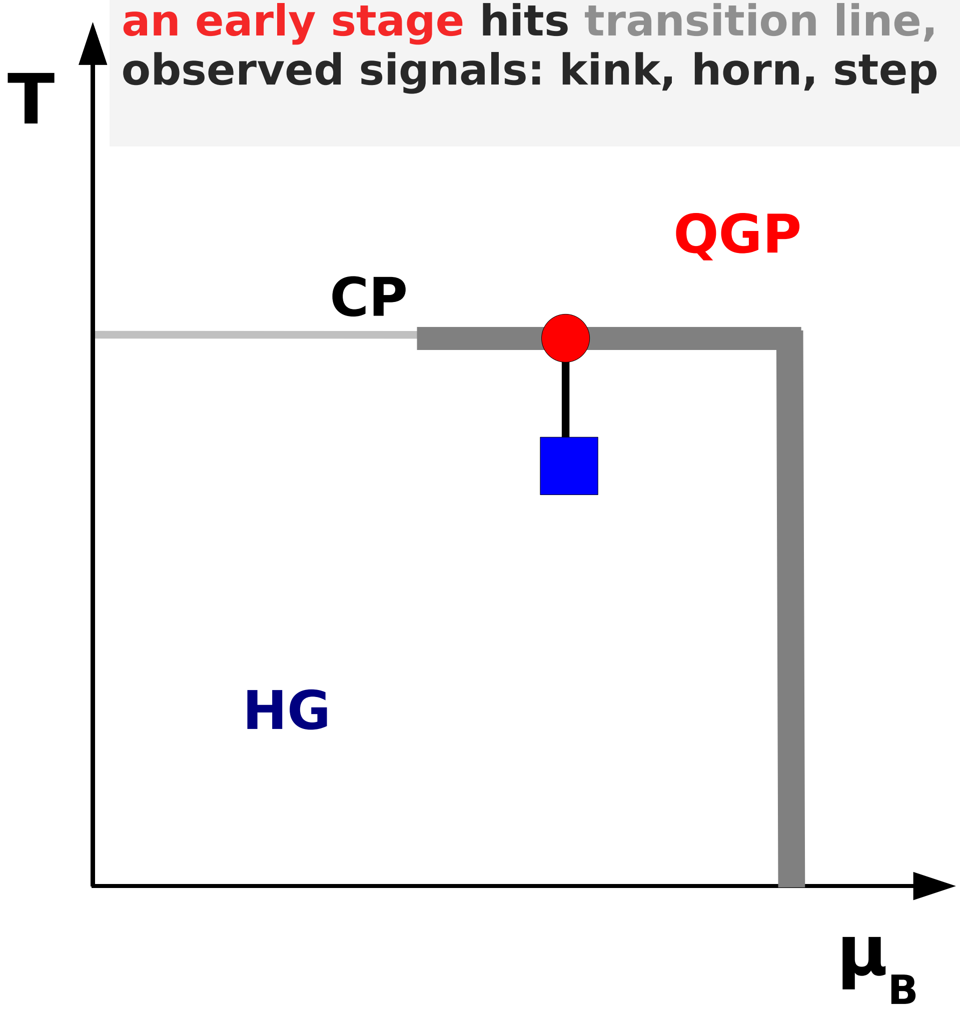
abstract 41 by M. van Leeuwen and NA61/SHINE

The contribution on ''Production of high energy secondary beams of ion fragments for experiments and instrument tests at CERN SPS''
Included in the review presentation in Test Beams session.

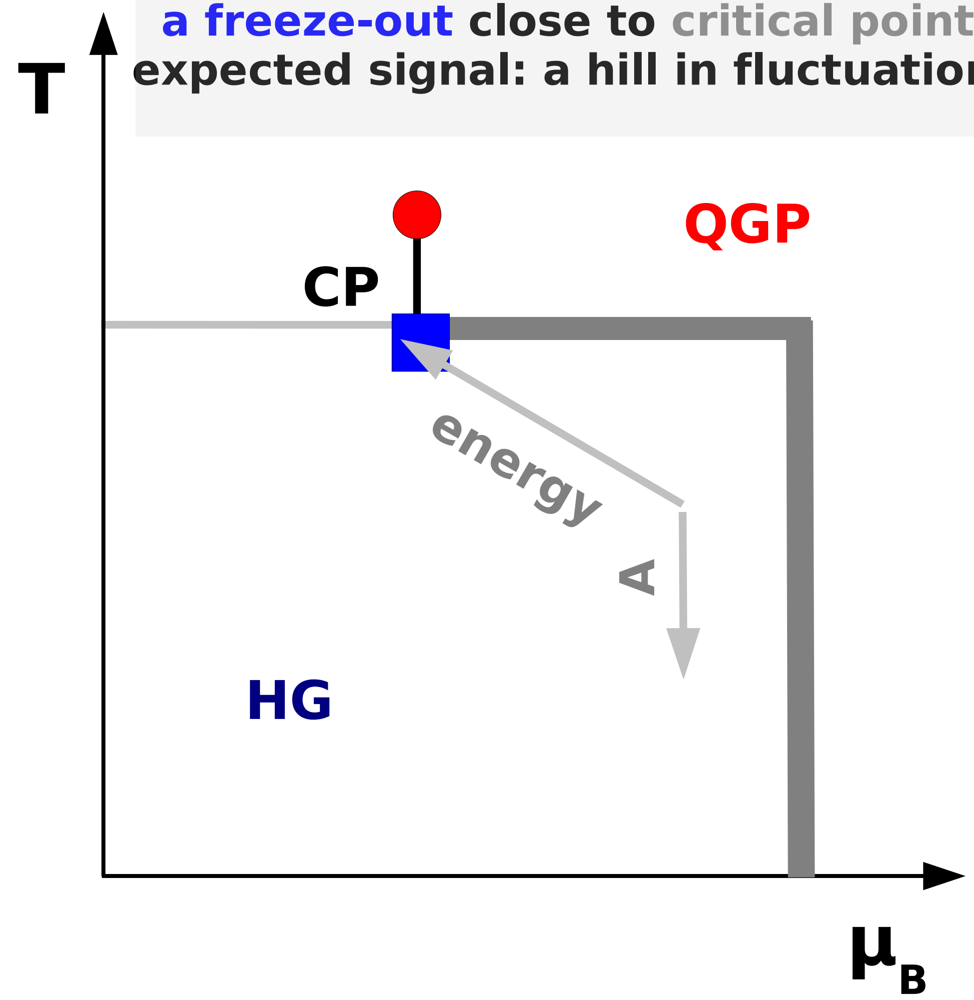
abstract 61 by I. Efthymiopoulos et al.

Two main events in nucleus-nucleus collisions

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



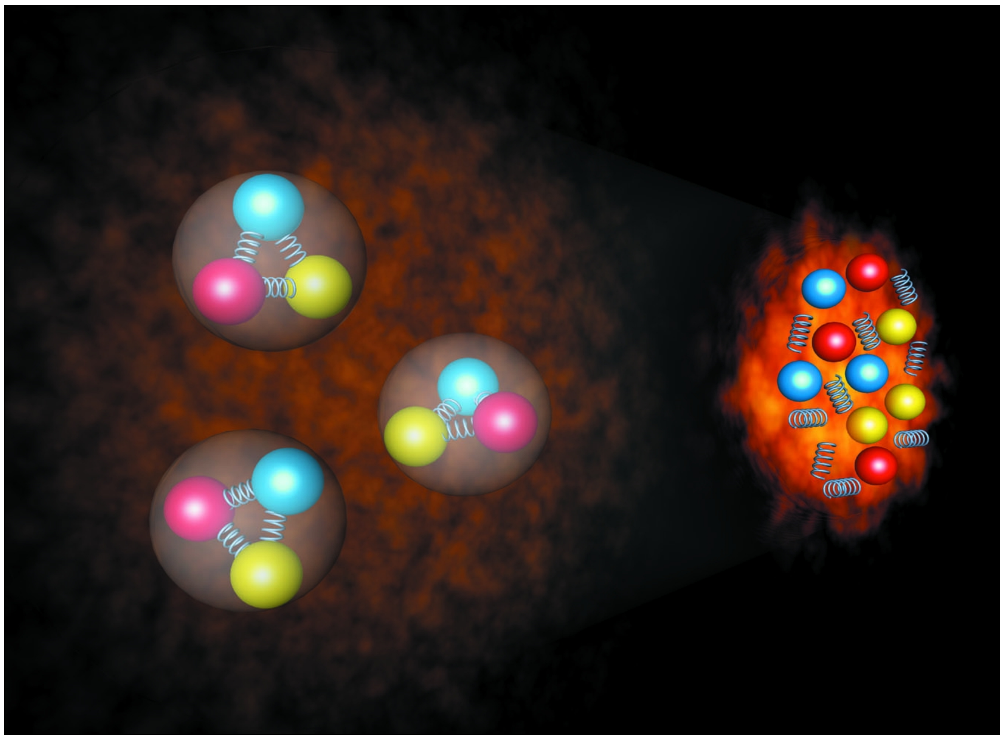
Critical Point:
a freeze-out close to critical point,
expected signal: a hill in fluctuations



E(OD) ≈ 30*A* GeV ≤ E(CP)

Onset of deconfinement

hadrons **mixed** **QGP**



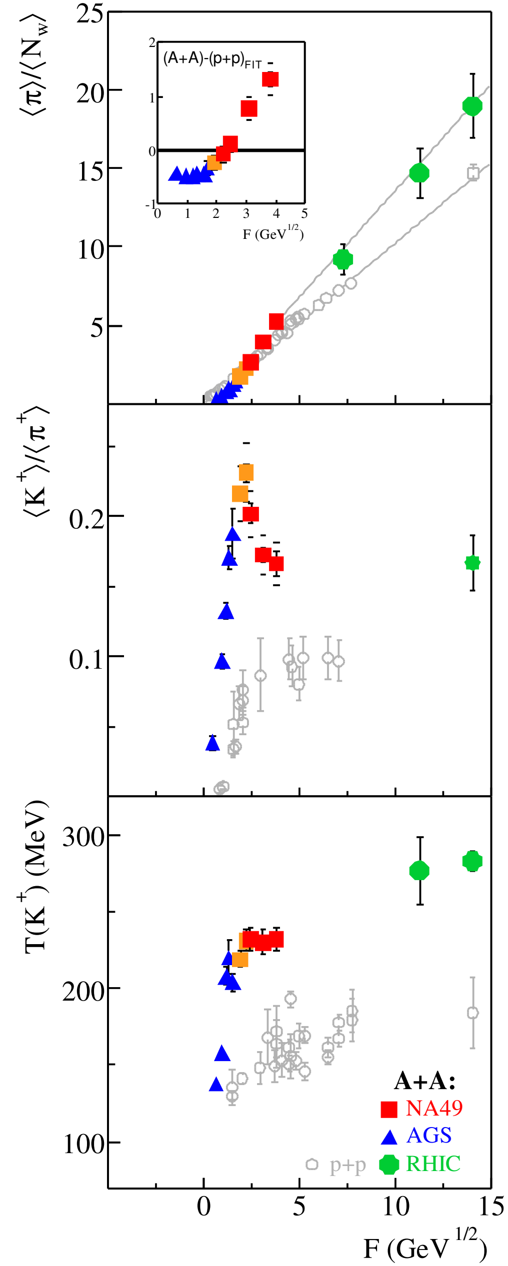
AGS **SPS** **RHIC**

collision energy

NA49 results (PRC77:024903): evidence for the onset of deconfinement at the low CERN SPS energies

AGS **SPS** **RHIC**

hadron production properties



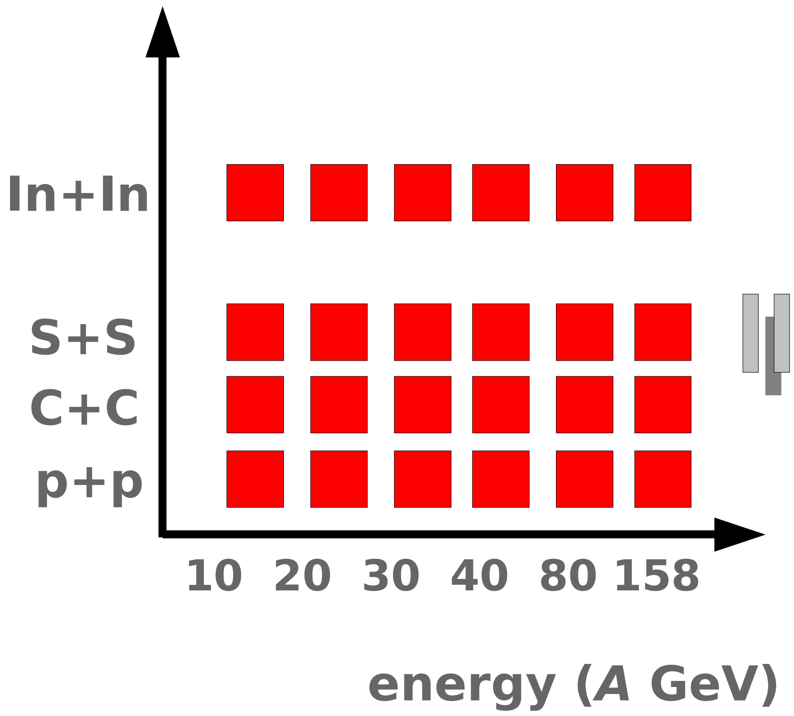
Kink

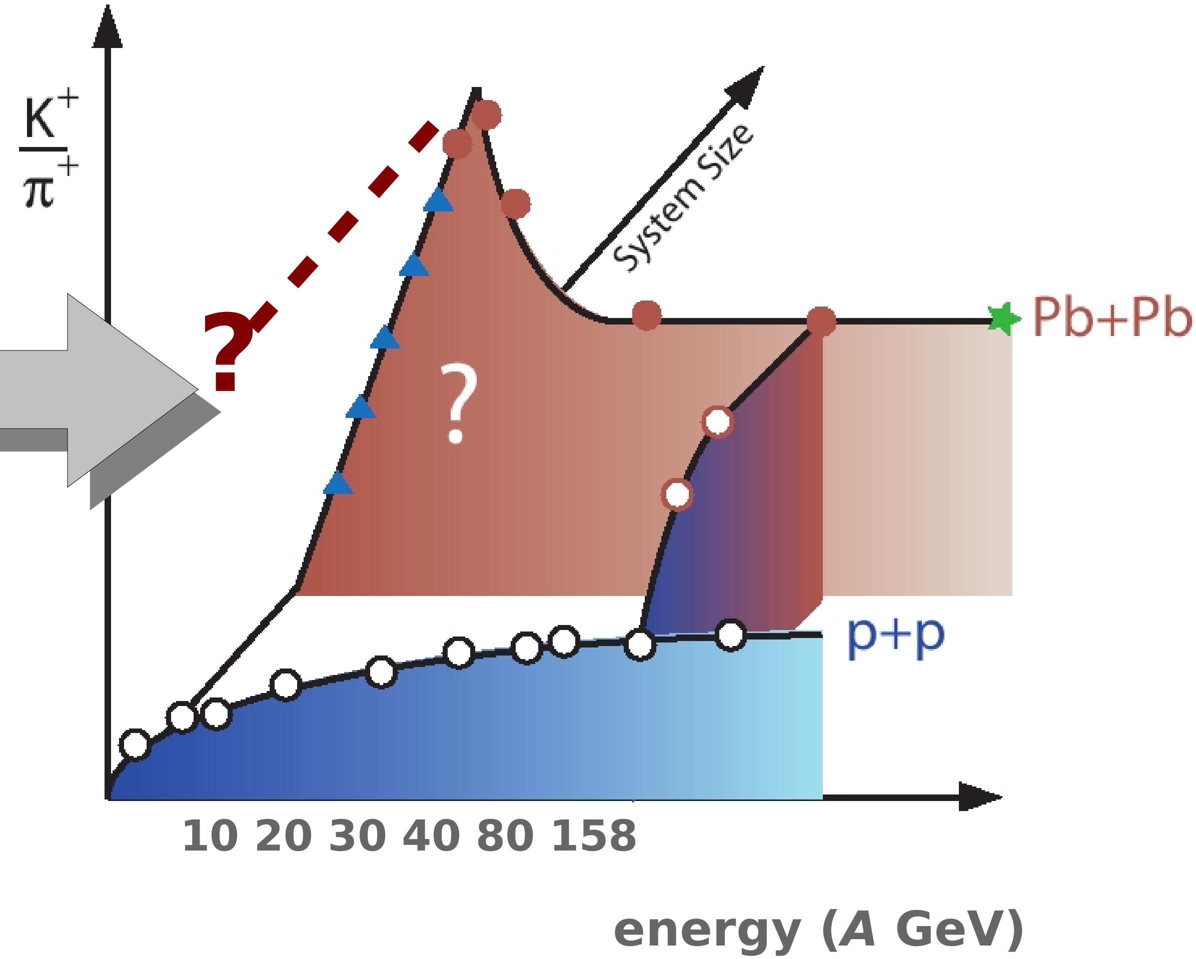
Horn

Step

collision energy

NA61/SHINE study the onset of deconfinement



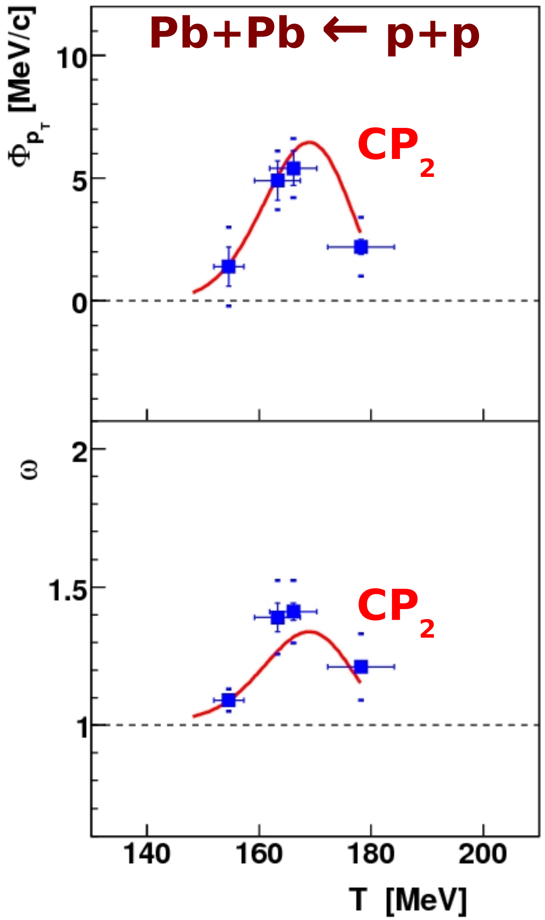


Search for the onset of the horn in collisions of light nuclei

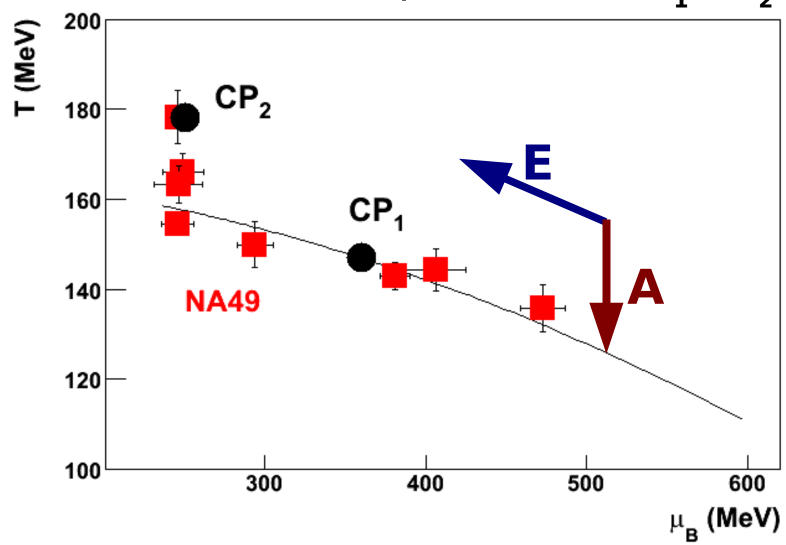
Precision measurements following the NA49 discovery

Critical point

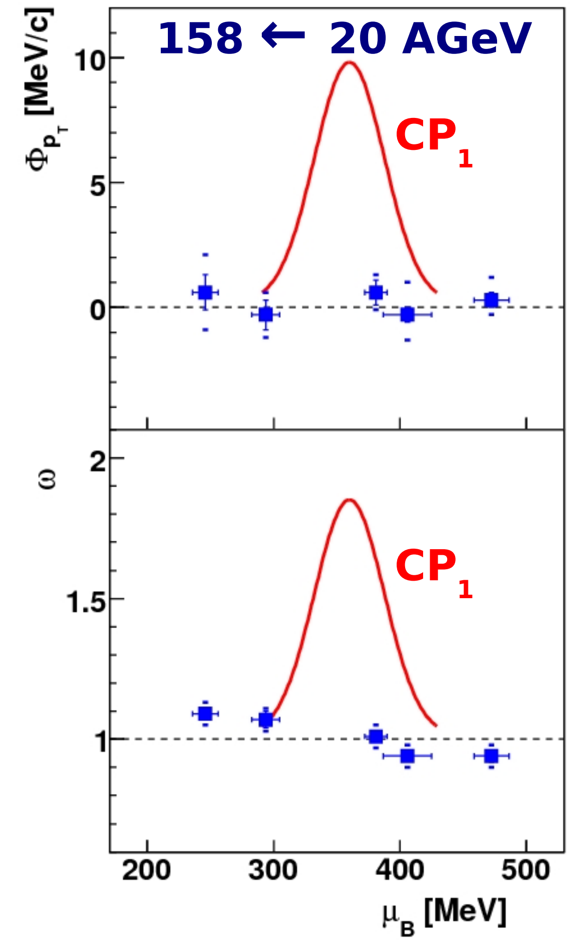
Fluctuations vs. system size at 158*A* GeV



Chemical freeze-out parameters and tested CP positions (**CP_1,CP_2**)



Fluctuations vs. energy in central Pb+Pb

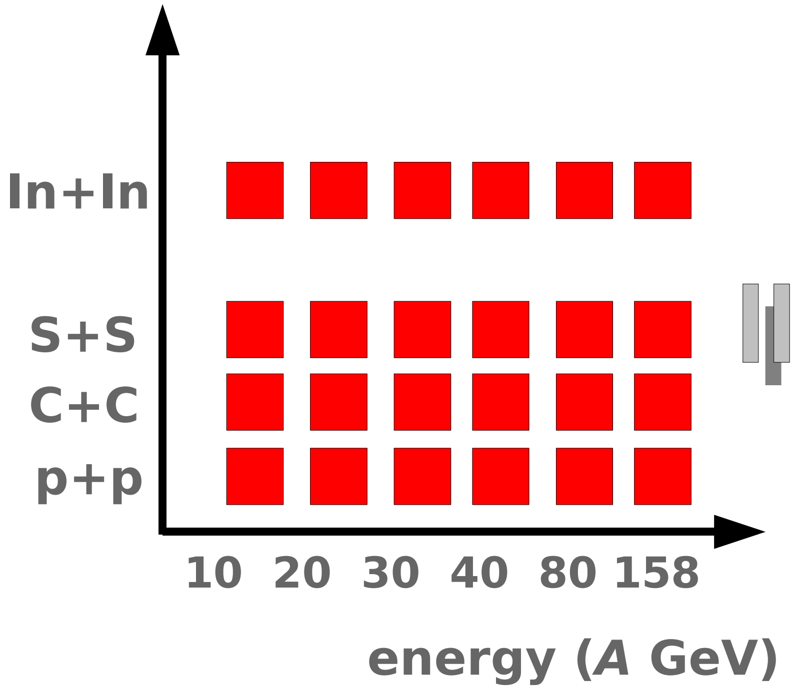


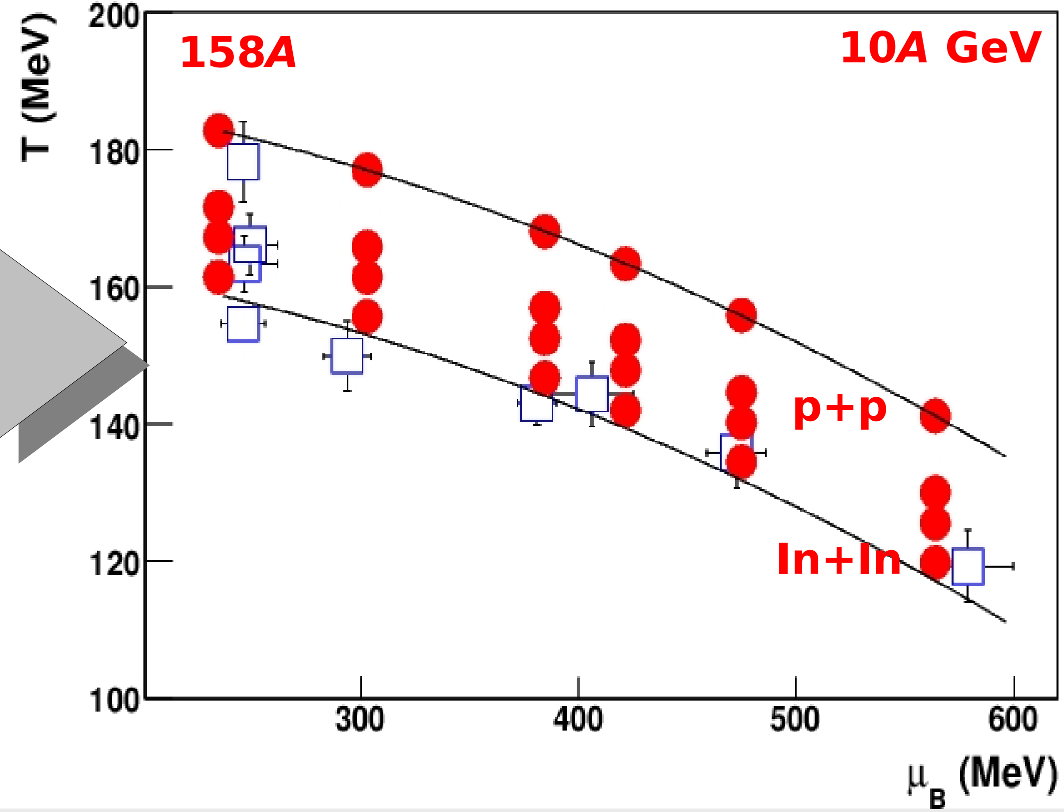
NA49 results on fluctuations (Grebieszkow, QM 2009) can be fitted assuming that the critical point is located close to CP_2

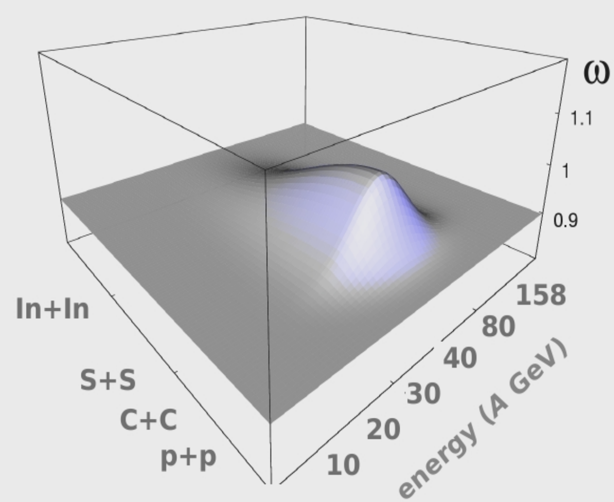
(Signal not visible in central Pb+Pb collisions possible due to re-scattering in hadronic phase)

But alternative explanations are possible!

NA61/SHINE search for the critical point







Search for the hill of fluctuations

Discovery potential

Experimental landscape

1st generation study: NA49
(1999-2002, used existing beam and detector)
-pioneering energy scan program,
-discovery of the onset of deconfinement

2nd generation studies: NA61/SHINE, STAR, PHENIX
(2009-2013, optimized beams and detectors)
-systematic study of the onset of deconfinement,
-search for the critical point

3rd generation studies: MPD, CBM
(2014-..., dedicated machines and detectors)
-precision study of the onset of deconfinement and
-dense hadronic matter

Experimental landscape

The advantages of the NA61/SHINE ion program over the RHIC (STAR, PHENIX) energy scan program:

- measurement of identified hadron spectra in a broad rapidity range, which in particular allows to obtain mean hadron multiplicities in full phase space,

- measurement of the total number of projectile spectators including free nucleons and nucleons in nuclear fragments, which allows for a proper control of collision centrality, crucial in study of fluctuations

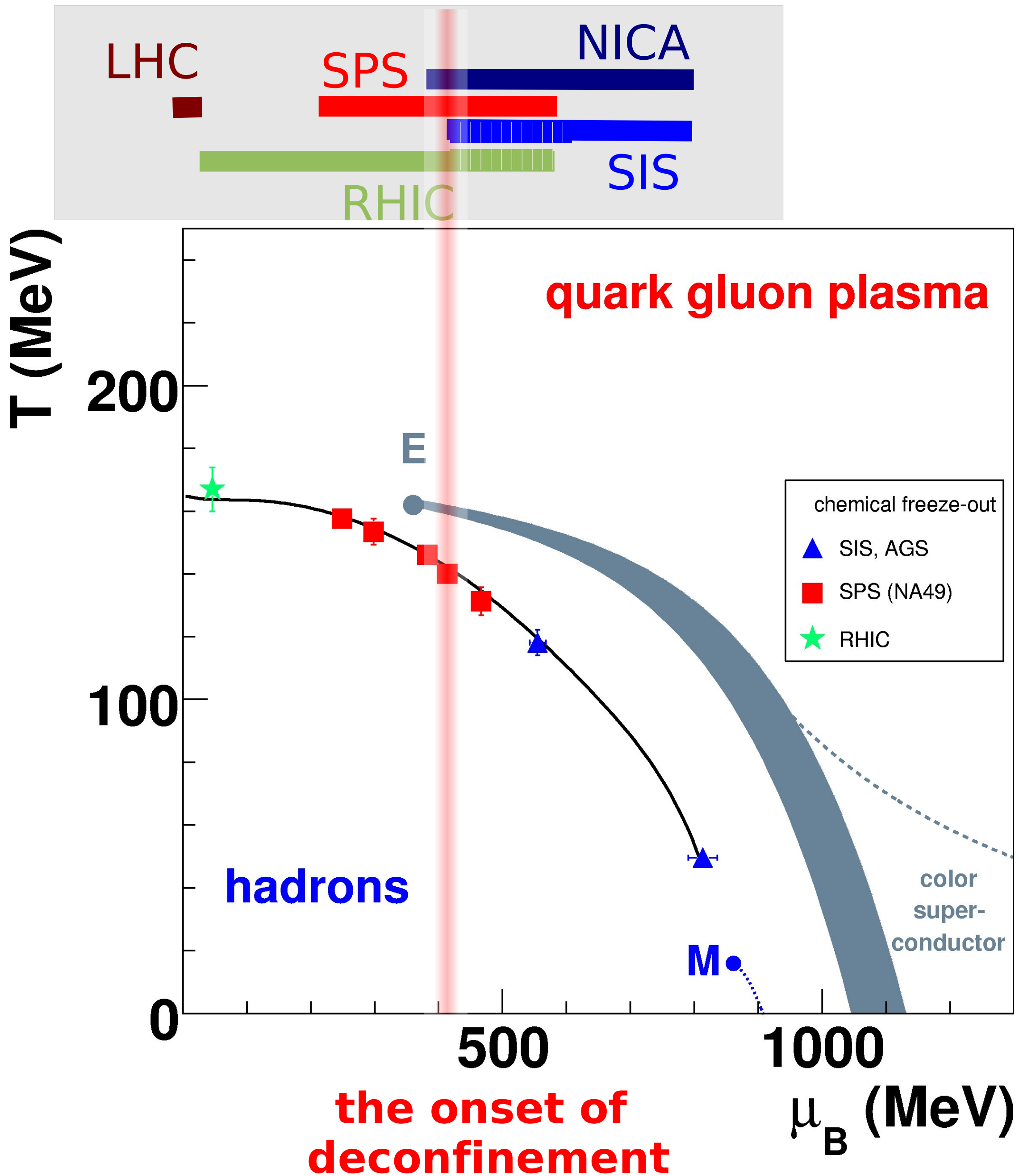
- high event rate in the full SPS energy range including the lowest energies, which allows for a uniform coverage of the whole SPS energy range

Experimental landscape

	2nd generation		3rd generation	
Facility:	**SPS**	**RHIC**	**NICA**	**SIS-100 (SIS-300)**
Exp.:	**NA61**	**STAR PHENIX**	**MPD**	**CBM**
Start:	**2009(11)**	**2011**	**2014**	**2015 (2017)**
Pb Energy: (GeV/(N+N))	**4.9-17.3**	**4.9-50**	**≤9**	**≤5 (<8.5)**
Event rate: (at 8 GeV)	**80 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

Experimental landscape



NA61/SHINE status and plans:

-NA61 was approved at CERN in June 2007,

-the pilot run was performed during October 2007,

-the 2008 run has been cut due to the LHC incident

-2009-2010: runs with proton beams,

-2011-2013: runs with ion (primary or secondary) and proton beams

Options for NA61 ion beams:

The challenge: compatibility with the I-LHC

Option 1 (strongly preferred): primary ion beams for NA61
 -should be reconsidered in view of the recent LHC schedule

Option 2 (back-up solution): secondary ion beams for NA61 resulting from fragmentation of the primary Pb beam
 -first simulation studies indicate that a minimal required performance can be reached for A ≈ 30,
 -final results should be ready by the September SPSC meeting

Summary

The NA61/SHINE ion 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 systematic data on the onset of deconfinement

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

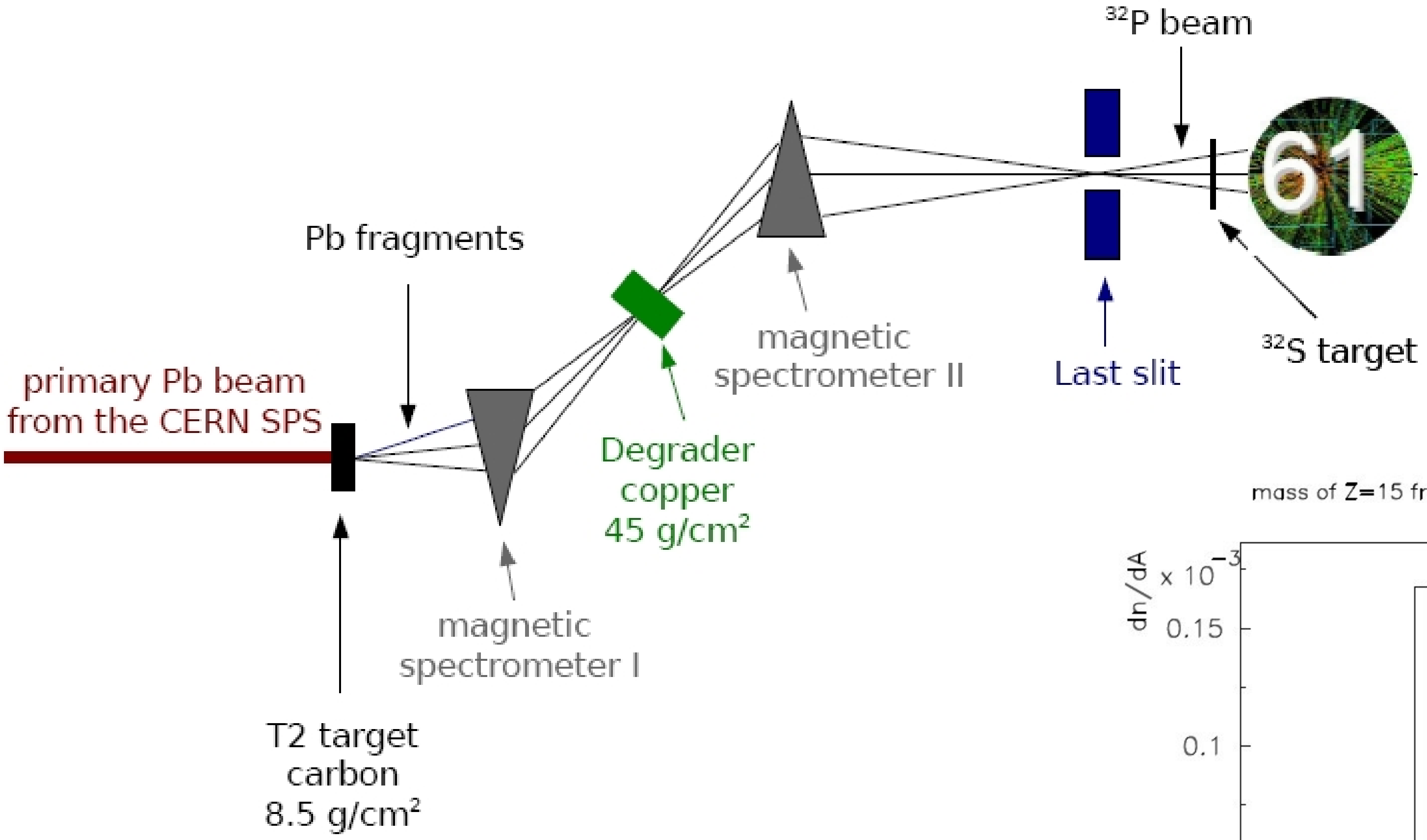
It profits from the synergy of different physics programs performed within NA61/SHINE on strongly interacting matter, neutrino and cosmic-rays physics

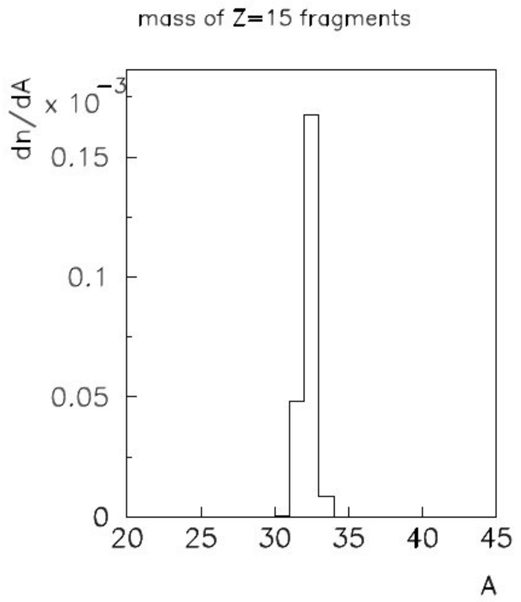
Additional slides

NA61/SHINE updated beam request

Beam Primary	Beam Secondary	Target	Energy (A GeV)	Year	Days	Physics	Status
p			400				
	p	C(T2K)	31	2009	21	T2K, C-R	*recommended*
p			400				
	π^-	C	158,350	2009	2x7	C-R	*recommended*
p			400				
	p	p	10,20,30,40,80,158	2009	6x7	CP&OD	*recommended*
p			400				
	p	p	158	2010	77	High p_T	*recommended*
Pb			10,20,30,40,80,158				
	$A \approx 30$	$A \approx 30$	10,20,30,40,80,158	2011	6x7	CP&OD	*recommended*
p			400				
	p	Pb	158	2011	6x7	High p_T	*recommended*
Pb			10,20,30,40,80,158				
	$A \approx 10$	$A \approx 10$	10,20,30,40,80,158	2012	6x7	CP&OD	*to be discussed*
p			400				
	p	Pb	10,20,30,40,80,158	2012	6x7	CP&OD	*recommended*
Pb			10,20,30,40,80,158				
	$A \approx 100$	$A \approx 100$	10,20,30,40,80,158	2013	6x7	CP&OD	*to be discussed*

Secondary Ion Beam Line for NA61:

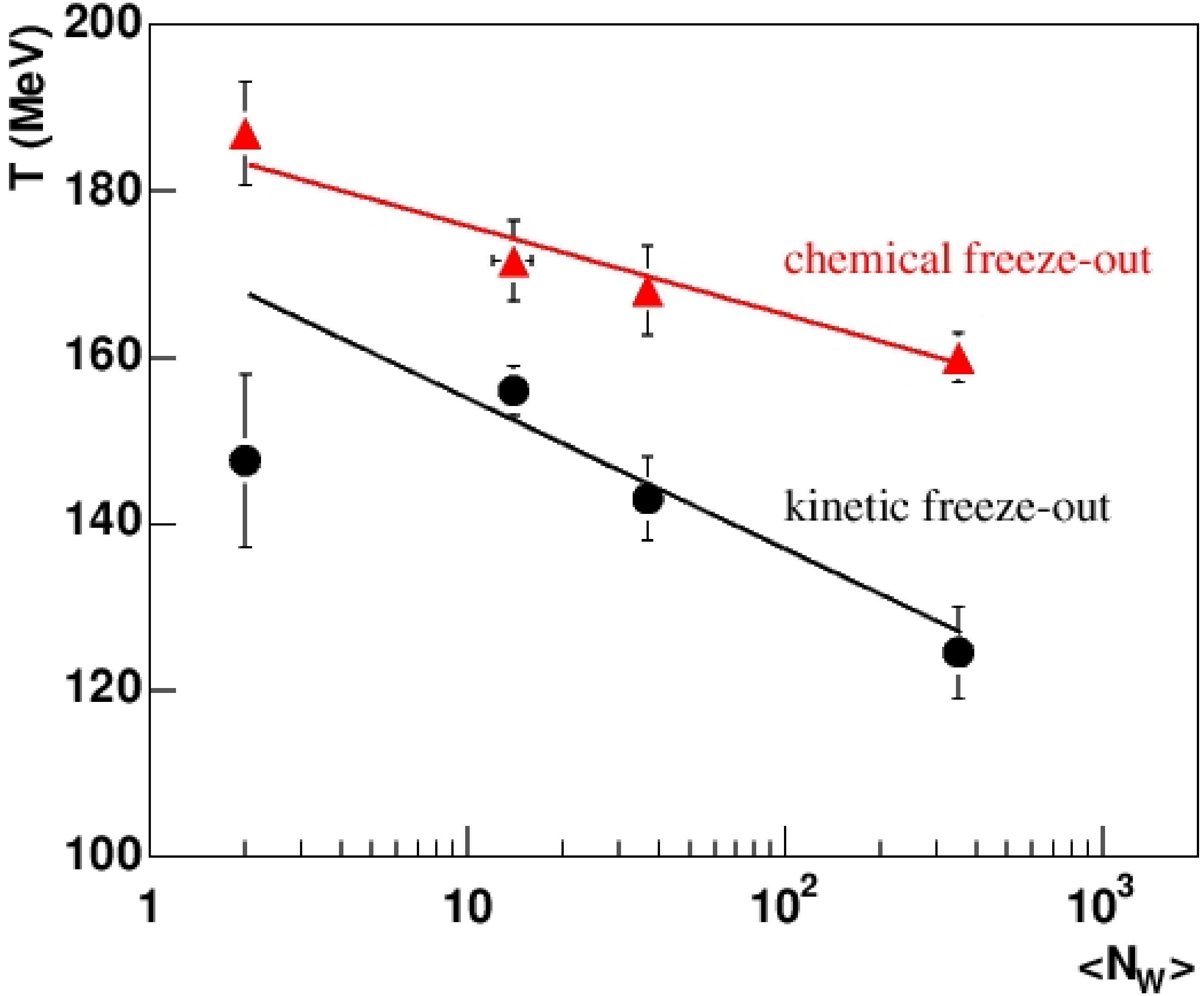




-selects beam of nuclei with close Z and A,
-further ion identification possible by Z (charge) measurements
-momentum per nucleon cannot be changed

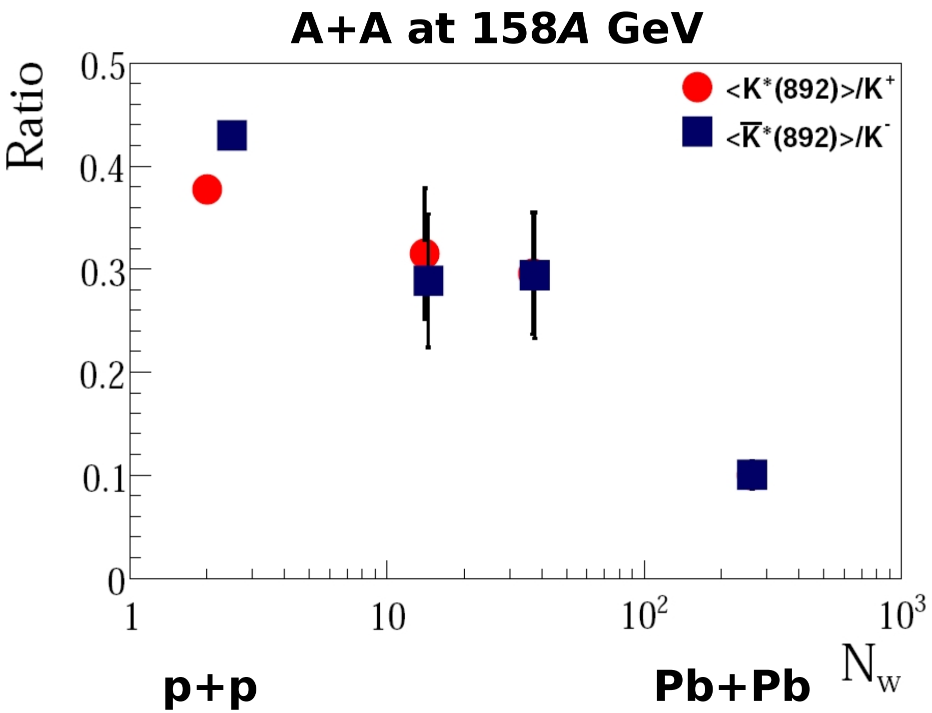
The freeze-out temperature decreases with an increasing system size

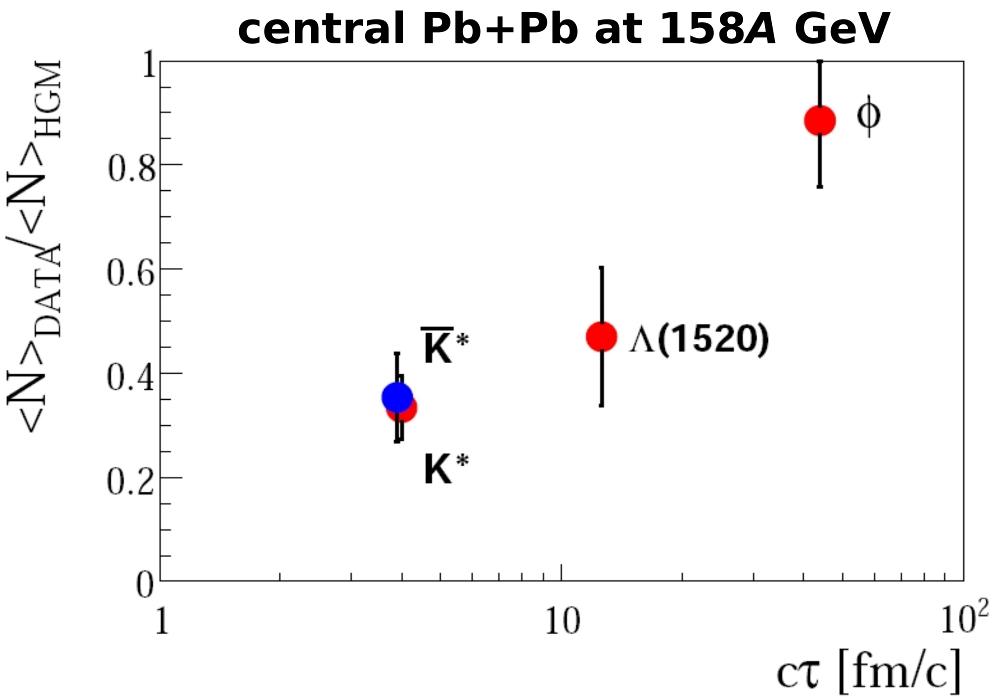
A+A at 158*A* GeV



p+p **Pb+Pb**

Resonances in central Pb+Pb collisions:
The long lasting hadronic phase





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

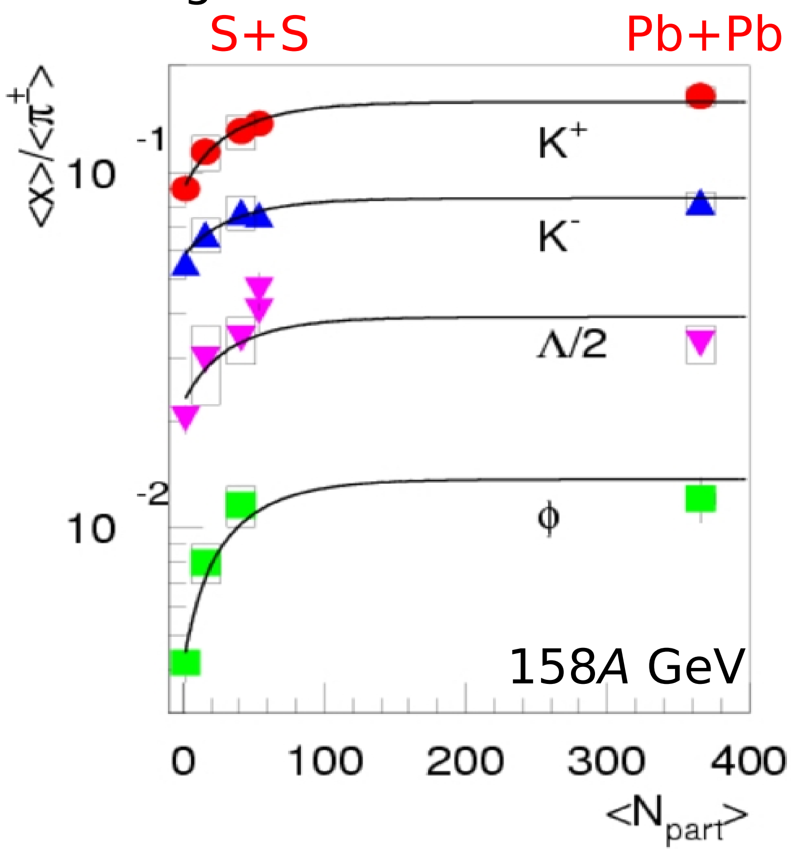
The suppression increases with decreasing resonance life-time

Rescattering of decay products in the long lasting hadronic phase

The freeze-out temperature decreases with an increasing system size

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

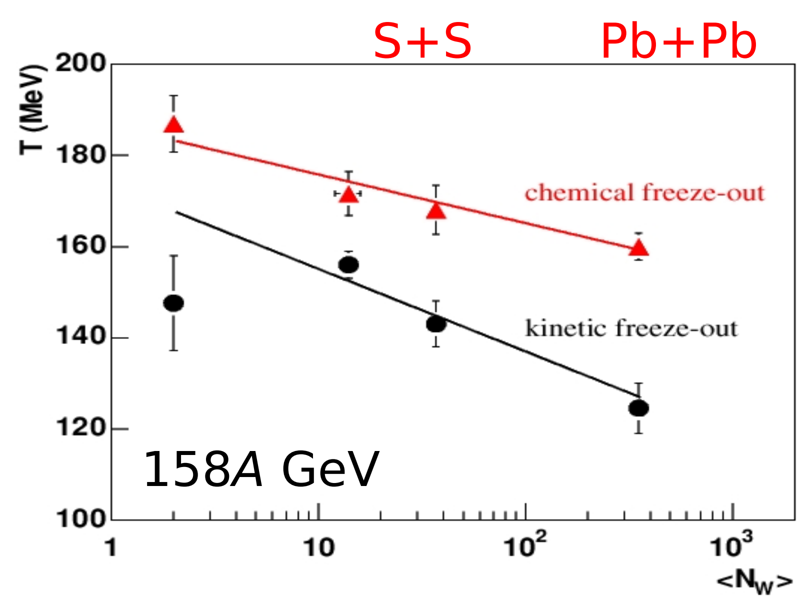
Large systems (A > 30) are preferred

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

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