Onset of deconfinement and search for the critical point of strongly interacting matter at CERN SPS energies

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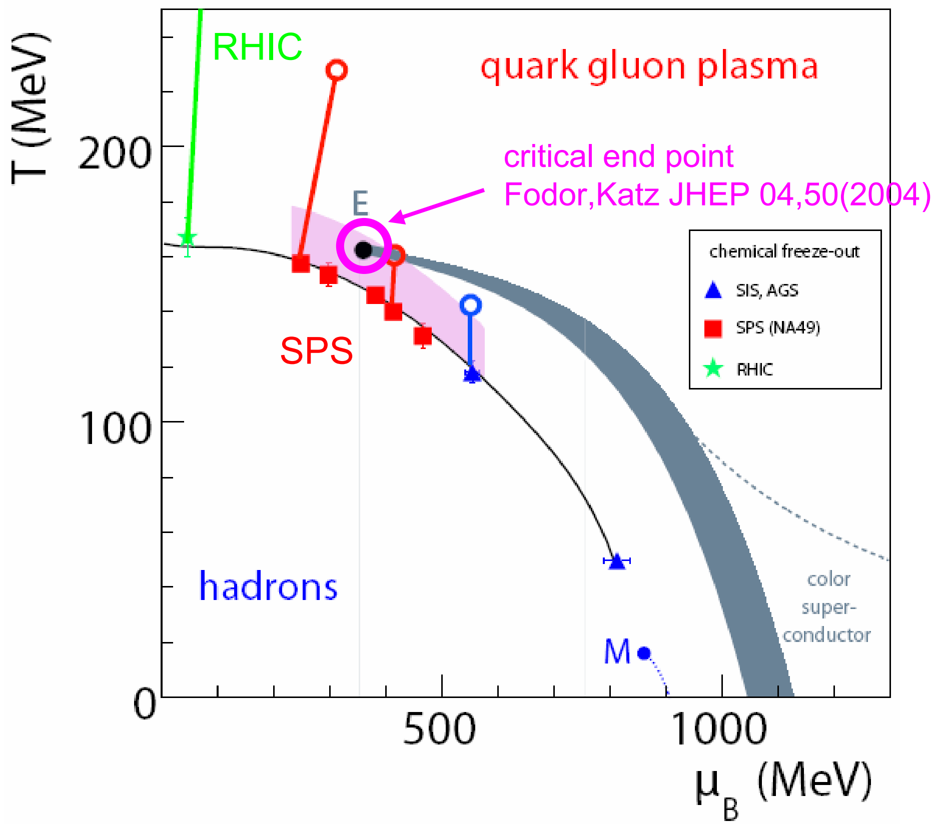
For the NA49 and NA61/SHINE collaborations

Exploration of phase diagram of strongly interacting matter



- QCD considerations suggest a 1st order phase boundary ending in a critical point

- hadro-chemical freeze-out points are obtained from statistical model fits to measured particle yields
- T and μ_B approach phase boundary and estimated critical point at SPS

- evidence of onset of deconfinement from rapid changes of hadron production properties
- search for indications of the critical point as a maximum in fluctuations

evidence for the onset of deconfinement (1)

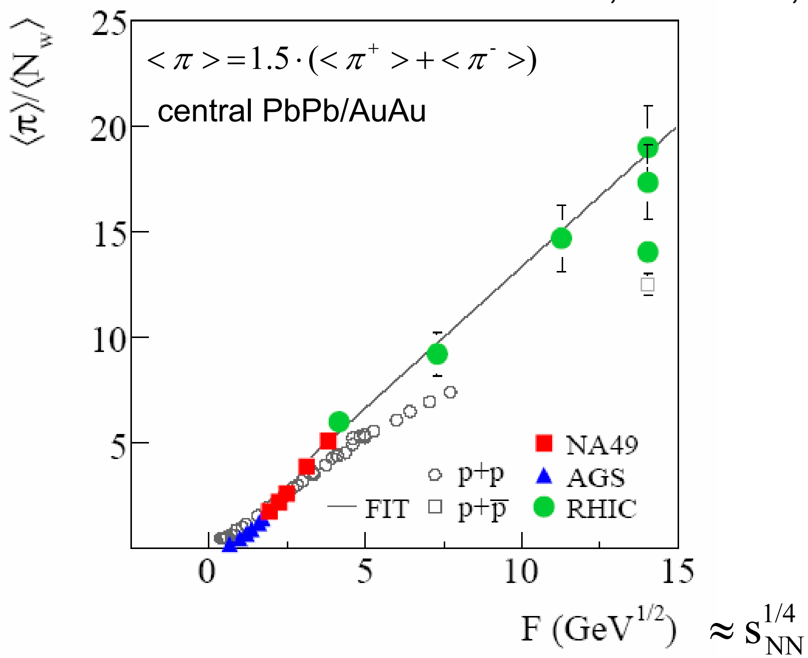
the kink

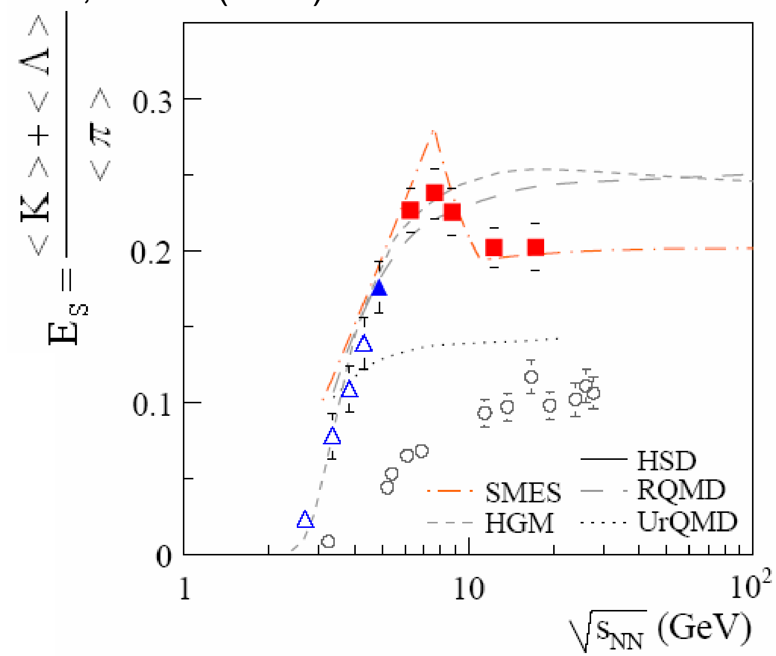
pion yield per participant

the horn

ratio of strange particle to pion yield

NA49,C.Alt et al.,PRC77,024903(2008)





- π yield related to entropy production
- steeper increase in A+A suggests 3-fold increase of initial d.o.f

- E_s related to strangeness/entropy ratio
- plateau consistent with prediction for deconfinement

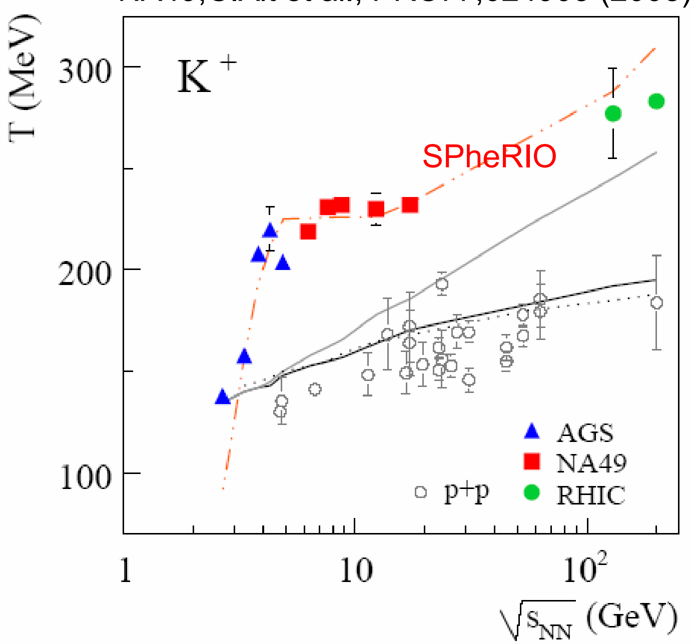
(SMES model, M.Gazdzicki and M.Gorenstein, Acta Phys. Pol.30,2705(1999))

evidence for the onset of deconfinement (2)

the step

shape of transverse mass spectra

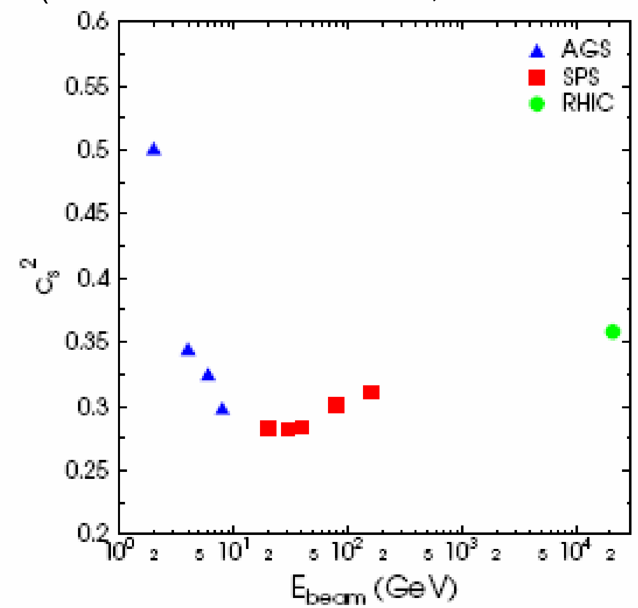
NA49,C.Alt et al., PRC77,024903 (2008)



the dale

estimate of sound velocicty

(H.Petersen and M.Bleicher, nucl-th/0611001)

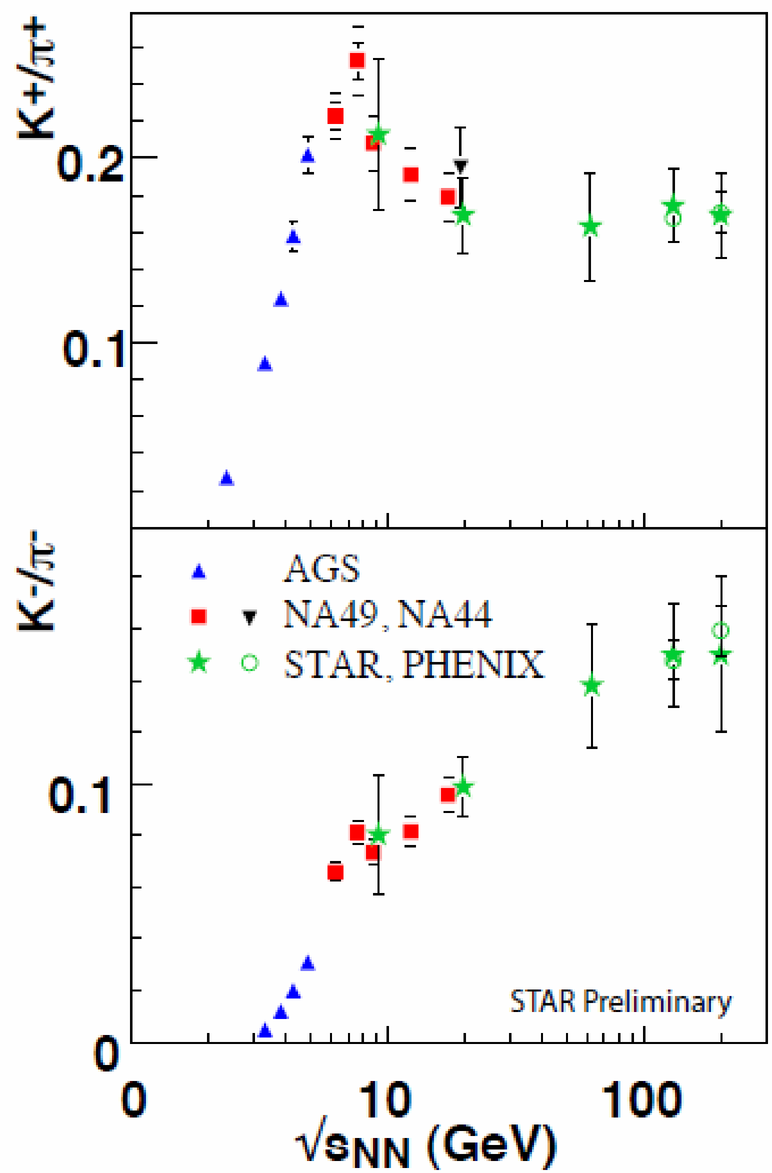


softening of transverse (step) and longitudinal (minimum of c_s) features of EoS due to mixed phase (soft point of EoS)

rapid changes of hadron production properties at low SPS energy most naturally explained by onset of deconfinement

NA49,C.Alt et al.,PRC77,024903(2008); M.Gazdzicki et al.,arXiv:1006.1765

Verification of the NA49 results by STAR in progress

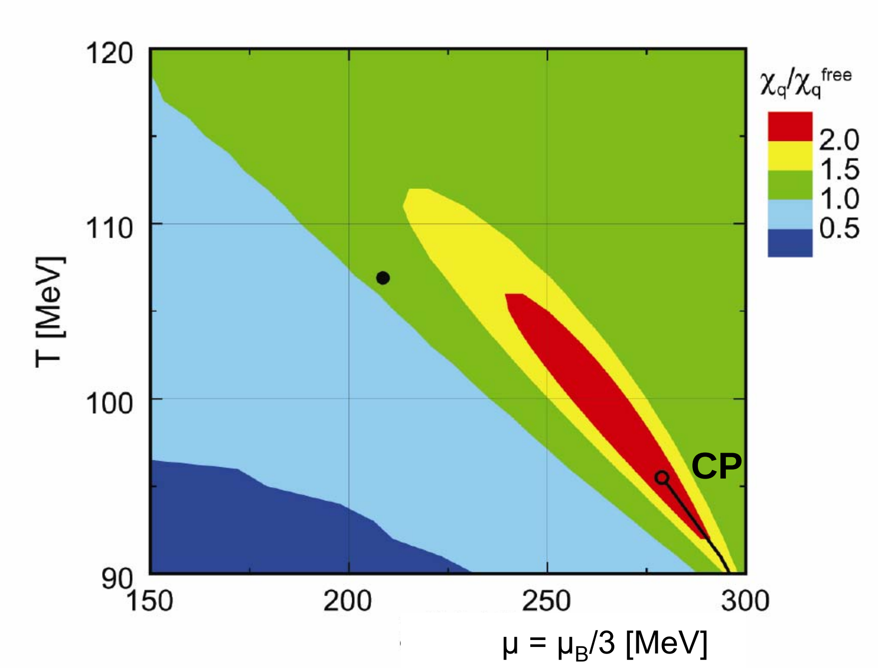


- presently available low statistics results from STAR compatible with NA49
- precise results from 2010 low energy run soon

Search for the critical point at the SPS

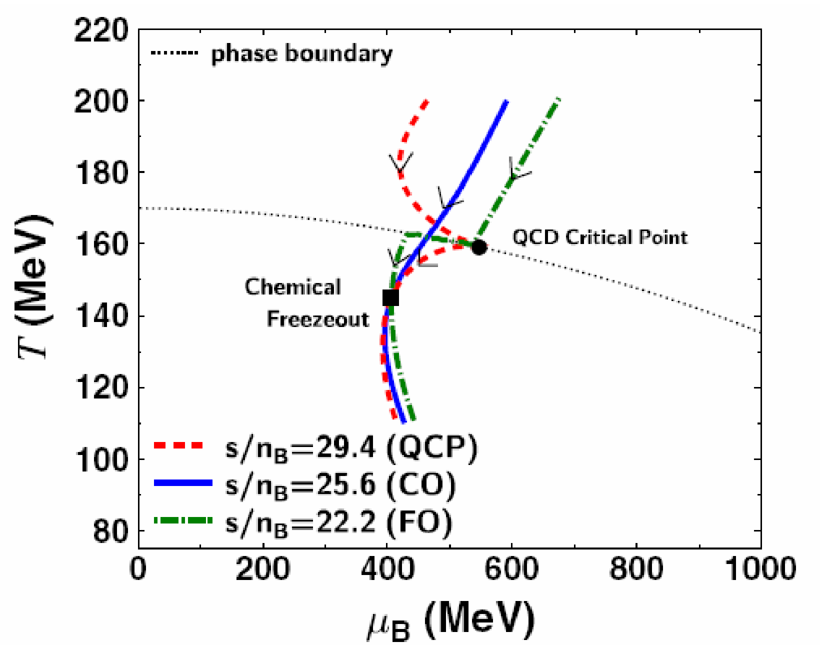
signature: enhanced fluctuations of multiplicity, p_T, …

effects of critical point are expected over a range of T,μ_B



Y.Hatta and T.Ikeda, PRD67,014028 (2003)

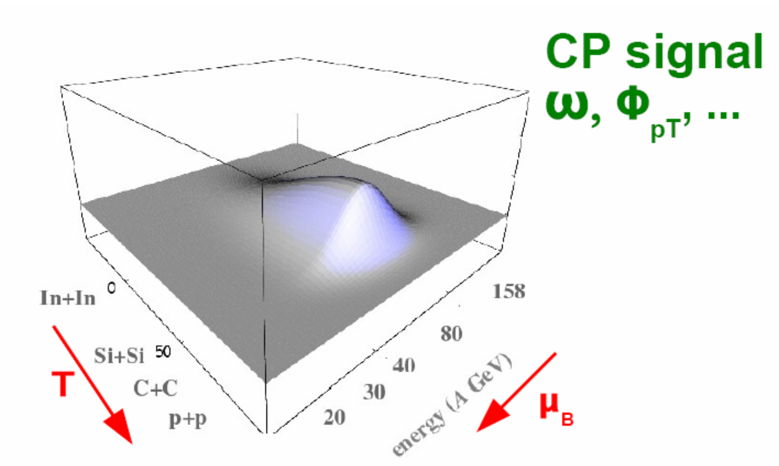
hydro predicts that evolution of the system is attracted to critical point

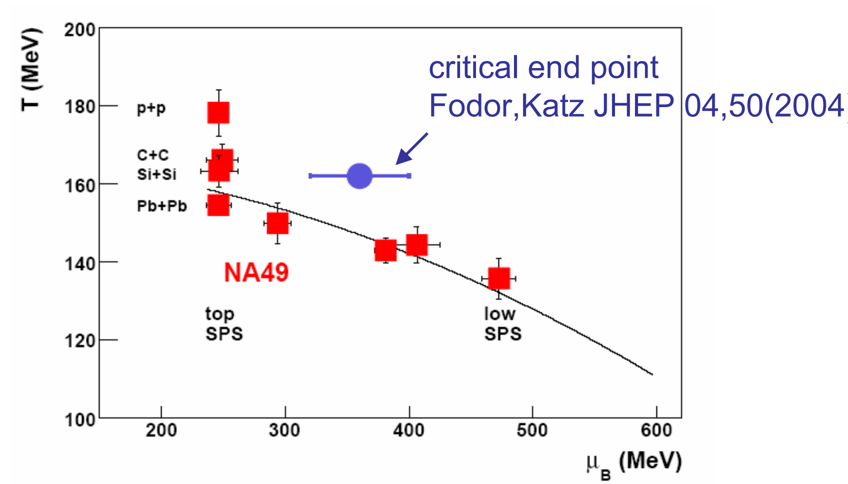


M.Asakawa et al., PRL 101,122302 (2008)

Search strategy of NA49 and NA61

search for "hill" in fluctuation signals in 2d scan (T,μ_B) of phase diagram





- deconfinement necessary for observing CP effect (above 30A GeV)
- freeze-out occurs close to the critical point
- expected size of fluctuation signals limited by short lifetime and size of collision system (correlation lengths ~ 3 – 6 fm)

(M.Stephanov, K.Rajagopal,E.Shuryak, PRD60,114028(1999))

Estimates of effects due to the critical point

correlation length ξ at the critical point is limited by finite size and lifetime of the fireball and was parameterized as:

$$\xi = \min(\underbrace{c_1 A^{1/3}}_{\text{size}},\ \underbrace{c_2 A^{1/9}}_{\text{lifetime}})$$

suggesting $\xi(\text{Pb+Pb}) = 3 \rightarrow 6$ fm for $c_1 = 2 \rightarrow 1$

$\xi(\text{p+p}) = 1 \rightarrow 2$ fm $c_2 = 3.32 \rightarrow 1.66$

(M.Stephanov, private comm.)

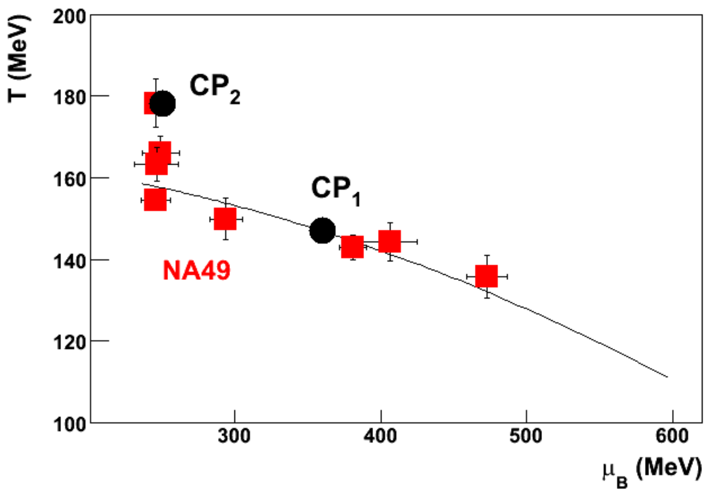
range of correlation effect estimated from QCD calculations:

$\sigma(\mu_B) = 30$ MeV, $\sigma(T) = 10$ MeV

(Hatta,Ikeda,PRD67,014028(2003)

considered examples:

- $\mu_B = 360$ MeV (lattice QCD), $T = 147$ MeV (chem. freeze-out line)
- $\mu_B = 250$ MeV (data 158A GeV) $T = 178$ MeV (fit of p+p data)



Fluctuation measures studied by NA49

- scaled variance ω of the multiplicity distribution P(n)

$$\omega = \frac{Var(n)}{<n>} = \frac{<n^2> - <n>^2}{<n>}$$

- intensive fluctuation measure
- independent particle emission: ω = 1
- superposition model: $\omega(A+A)=\omega(N+N)+<N>\omega_{part}$
- ω affected by participant (N_{part}) fluctuations

- Φ_x measure of fluctuations of observable x ($<p_T>$, $<\Phi>$, Q, identity, …)

$$\Phi_x = \sqrt{\frac{<Z^2>}{<N>}} - \sqrt{<z^2>} ;$$

$$z = x - <x> ,$$

$$Z = \sum_{i=1}^{N} (x_i - <x>)$$

M.Gazdzicki and S.Mrowczyski, Z.Phys.C54,127(1992)

- superposition model: $\Phi_x(A+A) = \Phi_x(N+N)$
- independent particle emission: $\Phi_x = 0$
- Φ_x strongly intensive fluctuation measure independent of N_{part} and its fluctuations

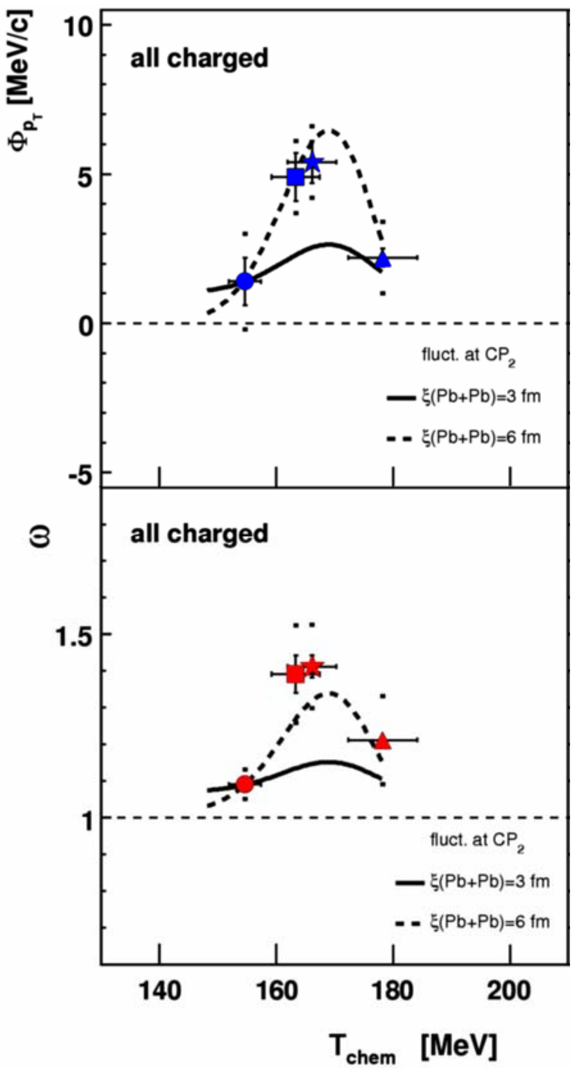
- σ_{dyn} measure of particle ratio fluctuations (K/π, p/π, K/p)

$$\sigma_{dyn} = \mathrm{sign}(\sigma^2_{data} - \sigma^2_{mix})\sqrt{\left|\sigma^2_{data} - \sigma^2_{mix}\right|} \quad ; \quad \sigma^2_{dyn} = \left|\nu_{dyn}\right|$$

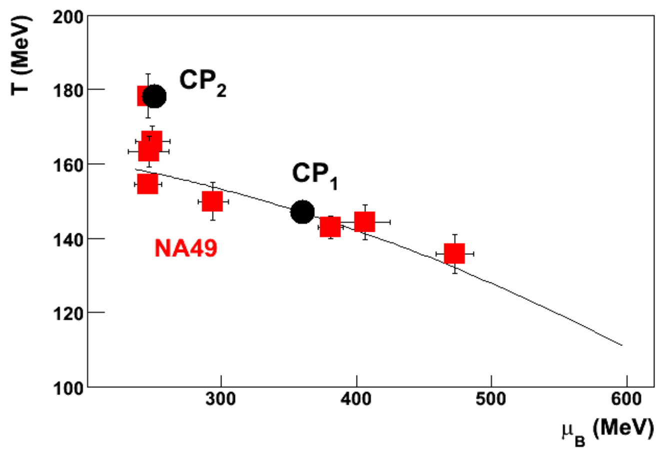
- E-by-E fit of particle multiplicities required
- mixed events used as reference
- $1/N_{part}$ dependence, sensitive to fluctuations

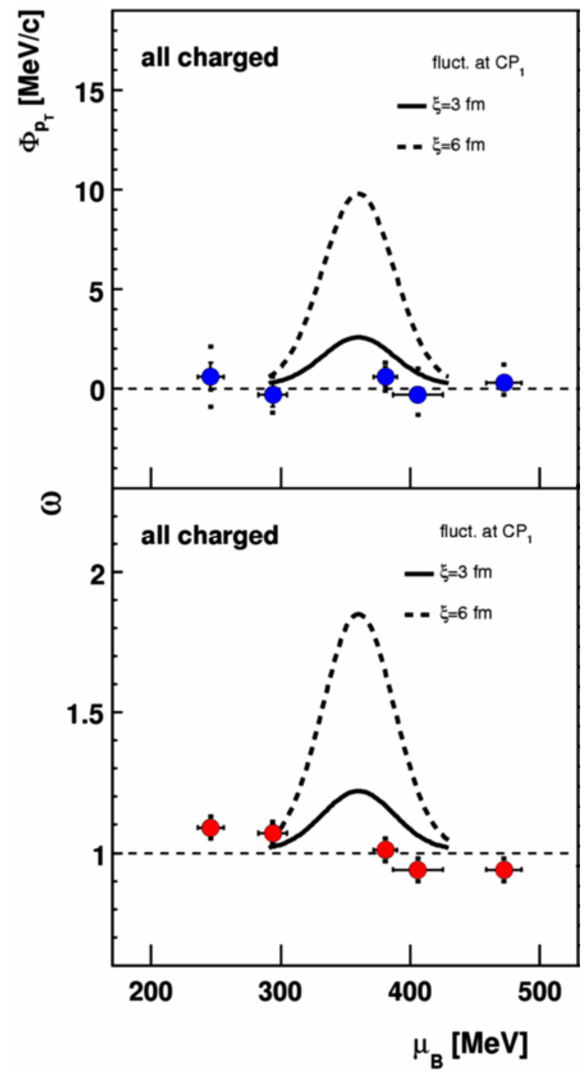
- F_2 factorial moments of low mass $\pi^+\pi^-$ pair density fluctuations in p_T space

results of critical point search from NA49



T.Anticic et al., PRC70, 034902 (2004)
C.Alt et al., PRC75, 064904 (2007)
C.Alt et al,. PRC78, 034914 (2008)
T.Anticic et al., PRC79, 044904 (2009)
B.Lungwitz, NA49 thesis (2008)





first hint of the
hill of fluctuations?

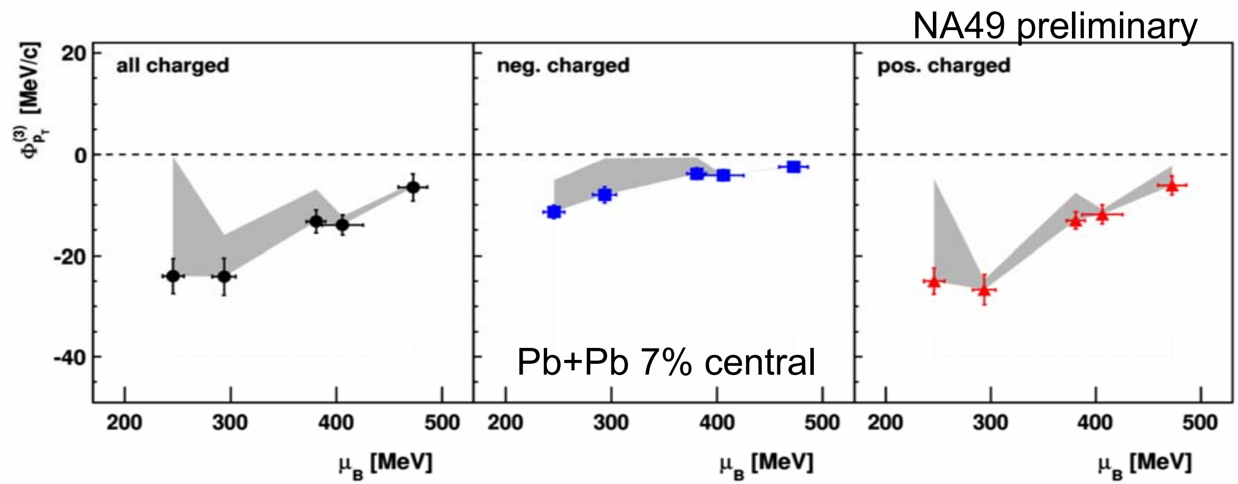
$\Phi_{p_T}^{(3)}$: 3rd moment of <p_T> fluctuations

K.Grebieszkow and M.Bogusz, NA49 preliminary

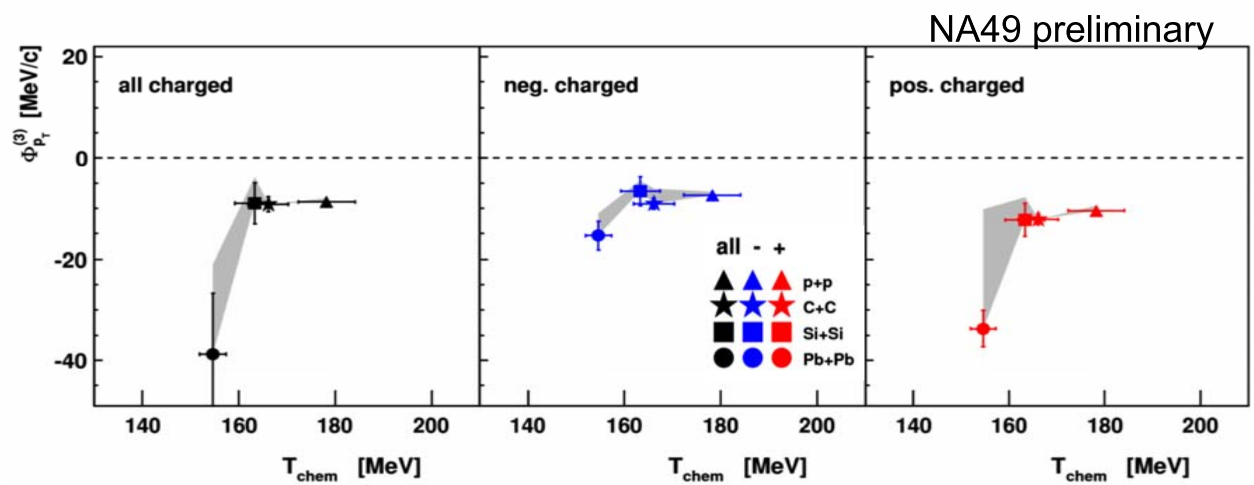
$$\Phi_{p_T}^{(n)} = \left(\frac{\langle Z_{p_T}^{2}\rangle}{\langle N\rangle}\right)^{1/n} - \left(\overline{z_{p_T}^{n}}\right)^{1/n}$$

$\Phi_{p_T}^{(3)}$ has strongly intensive property like Φ_{p_T}

(S.Mrowczynski,Phys.Lett.B465,8(1999))



higher moments are expected to be more sensitive to fluctuations



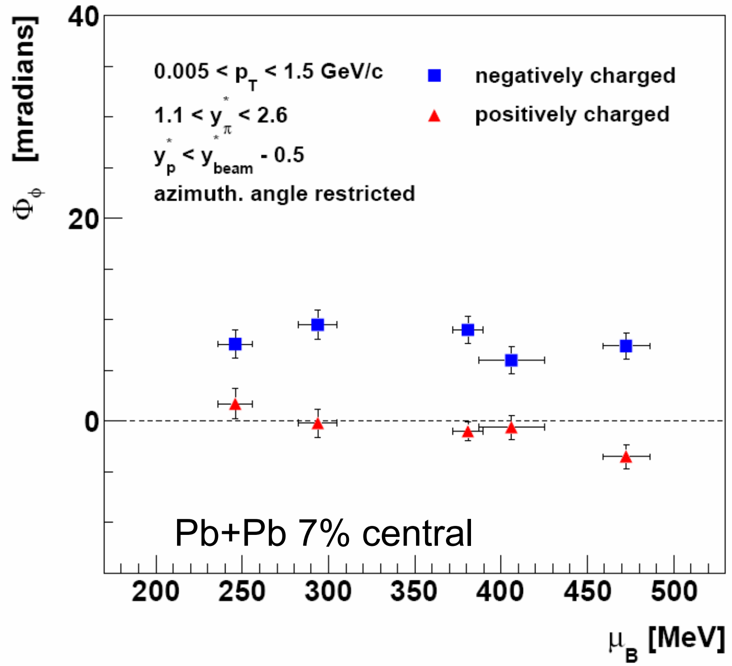
systematic errors are large

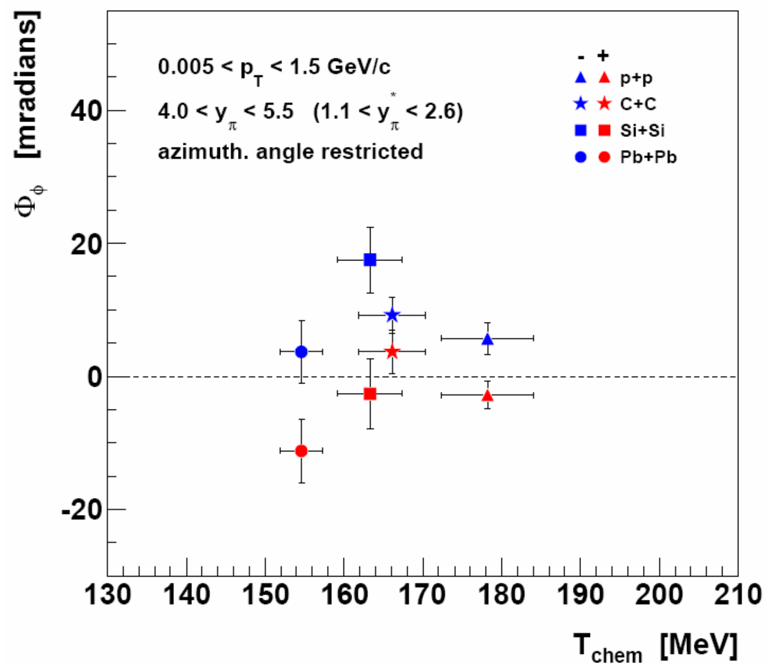
no indication of CP fluctuations

Φ_Φ : fluctuations of average azimuthal angle

K.Grebieszkow, NA49 preliminary

- plasma instabilities (S.Mrowczynski, Phys.Lett. B314,118(1993))
- flow fluctuations (S.Mrowczynski,E.Suryak,Act.Phys.Pol.B34,4241(2003)
- onset of deconfinement, critical point





- no significant energy (μ_B) dependence in central Pb+Pb collisions
- perhaps hint of maximum in nuclear size (T) dependence

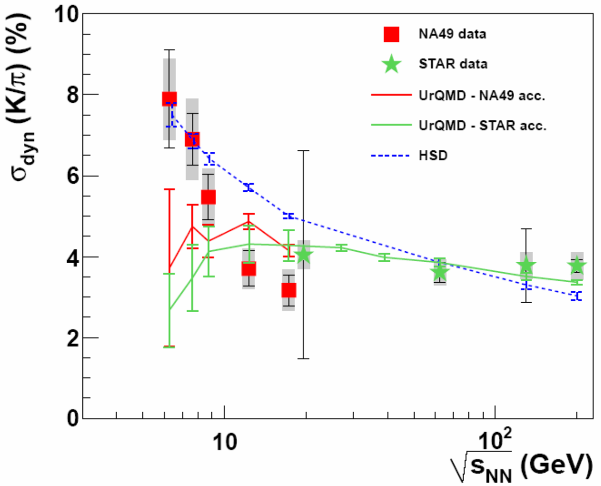
Event-by-event particle ratio fluctuations

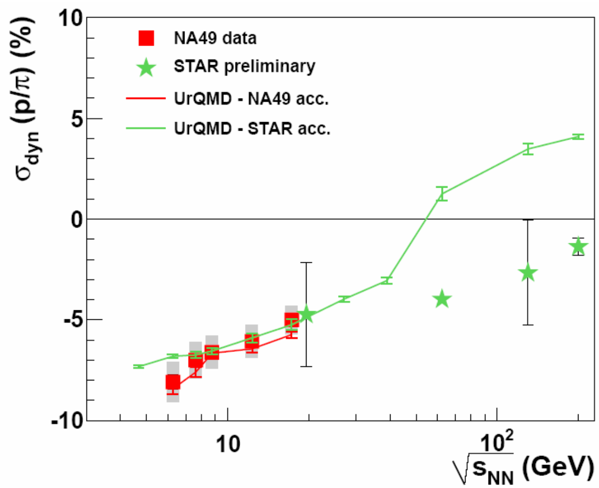
E-by-E fit of particle ratios to dE/dx spectra in real and mixed events

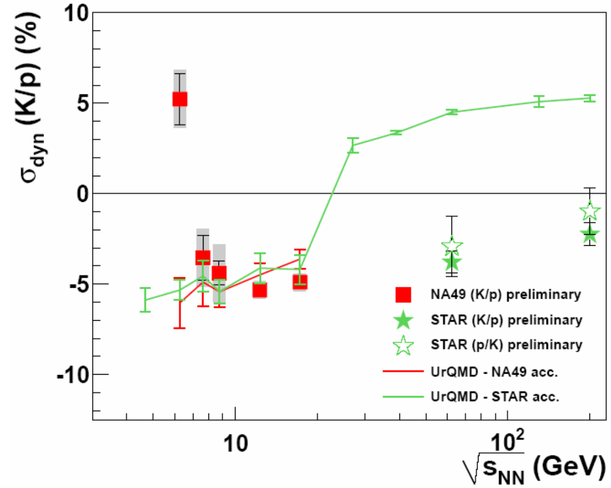
$$\sigma_{dyn} = \text{sign}(\sigma^2_{data} - \sigma^2_{mix})\sqrt{\left|\sigma^2_{data} - \sigma^2_{mix}\right|} \quad ; \quad \sigma^2_{dyn} = \left|\nu_{dyn}\right|$$

NA49 data: PRC79,044910(2009)

T.Schuster, NA49 prel.







rise towards low √s
low multiplicity effect ?
deconfinement ?

negative values
effect of nucleon
resonances (UrQMD)

sign change at low √s
related to C_{BS}
deconfinement ?

Gorenstein et al.,PLB585,237

New measure Ψ of particle ratio fluctuations

M.Gazdzicki, M.Mackowiak, S.Mrowczynski (more detail in talk at CPOD2010)

Ψ generalizes the Φ_x measure to the situation of imperfect identification,
retains advantages of Φ_x: strongly intensive measure, no $1/N_{part}$ dilution
not required: e-by-e fits of particle ratios
mixed event reference: $\Psi_{mix} = 0$

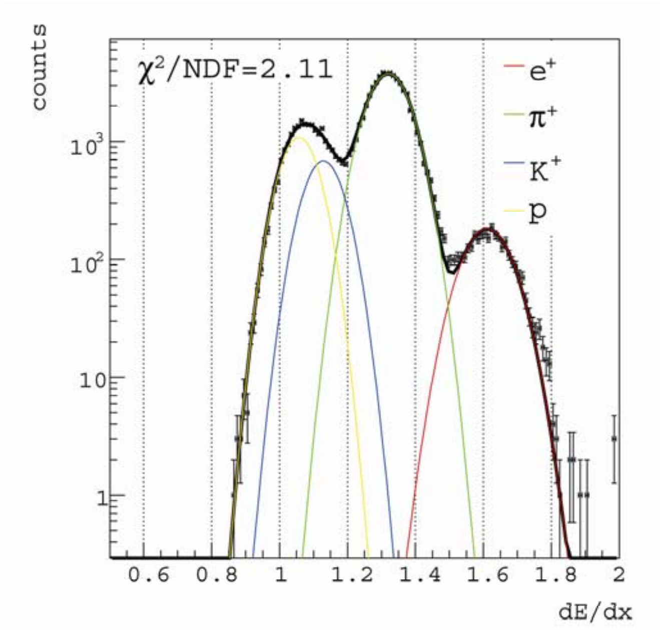
Identity method:

- obtain inclusive probability distribution ρ_h of particle type h from fit to inclusive dE/dx distribution
  $\int \rho_h(m)dm = N_h \quad ; \quad \int \rho(m)dm = N$
- $w_{h,i} = \rho_h(dE/dx_i) / \rho(dE/dx_i)$ probablity for particle i having identity h

$$\Psi_{w_h} = \frac{\langle Z^2 \rangle}{\langle N \rangle} - \overline{z^2}$$

$$z = w_{h,i} - \overline{w_h} \qquad \text{single-particle variable}$$

$$Z = \sum_{i=1}^{n} (w_{h,i} - \overline{w_h}) \qquad \text{event variable}$$



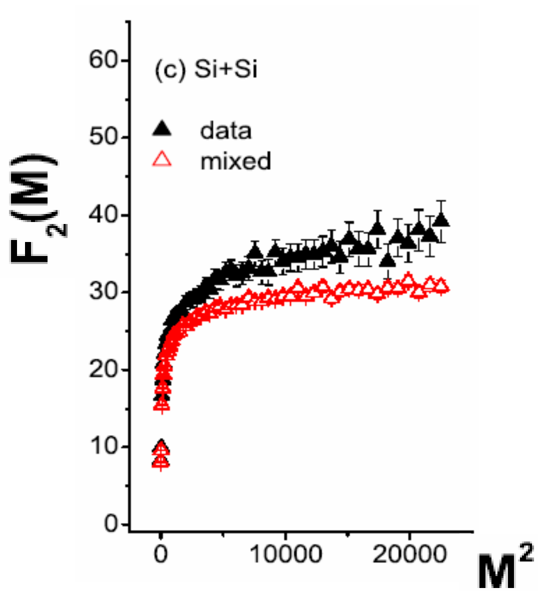
- effect of limited resolution can be corrected in a model independent way

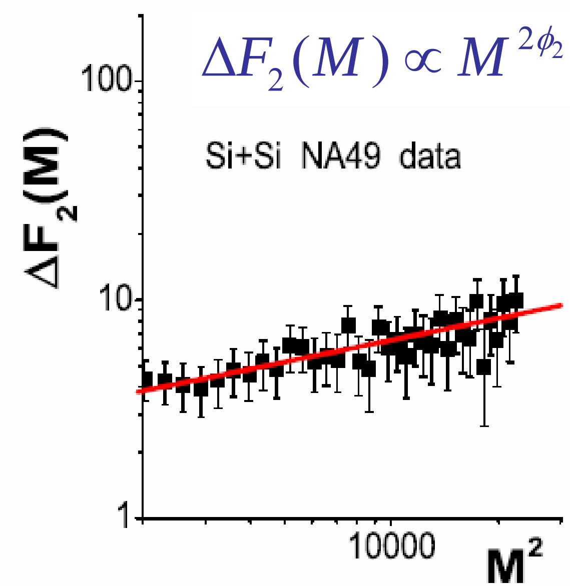
low mass $\pi^+\pi^-$ pair density: 2d intermittency in p_T space

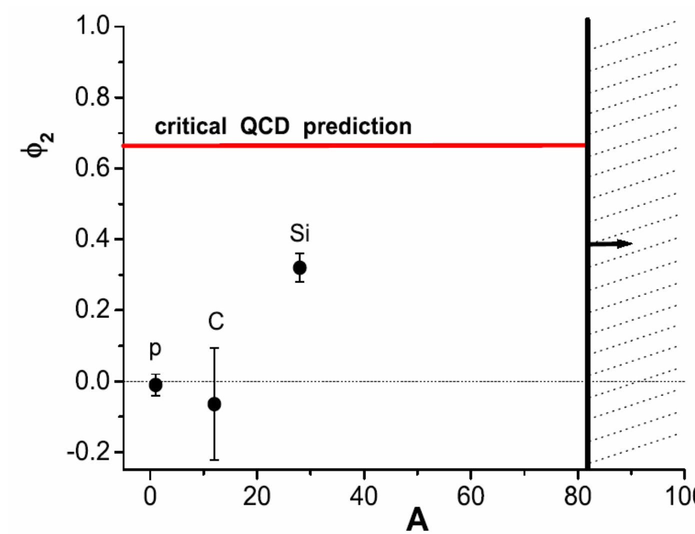
N.Antoniou et al.,Nucl.Phys.A693,799(2001);A761,149(2005)

- critical point predicted to lead to power-law density fluctuations of σ field
- observation via density fluctuations of low mass $\pi^+\pi^-$ pairs in p_T space
- power law behavior of $F_2(M)$ factorial moment expected (intermittency)
- use $\pi^+\pi^-$ pairs near threshold to reduce combinatorial background
- estimate combinatorial background by mixed events and subtract

NA49 data indicate intermittency for Si+Si (T.Anticic et al.,PRC81,064907(2010))



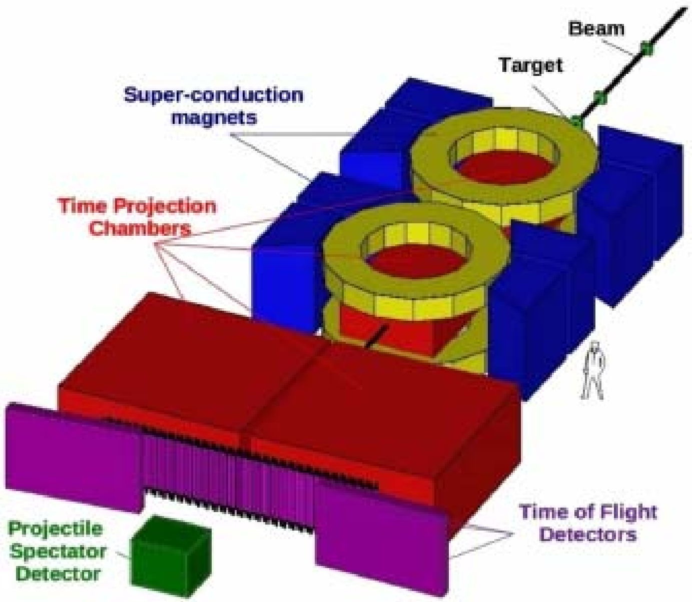




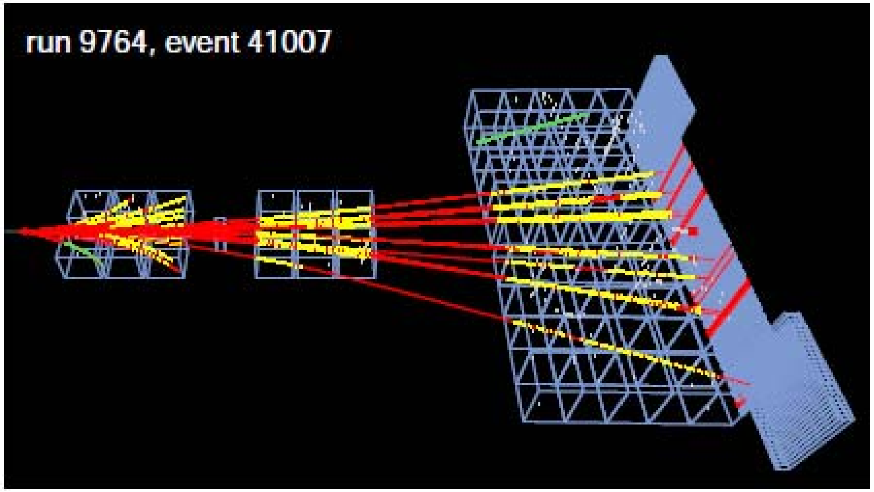
critical point close to freeze-out point of Si+Si system ?

NA61/SHINE – successor and extension of NA49

(**SHINE – S**PS **H**eavy **I**on and **N**eutrino **E**xperiment)



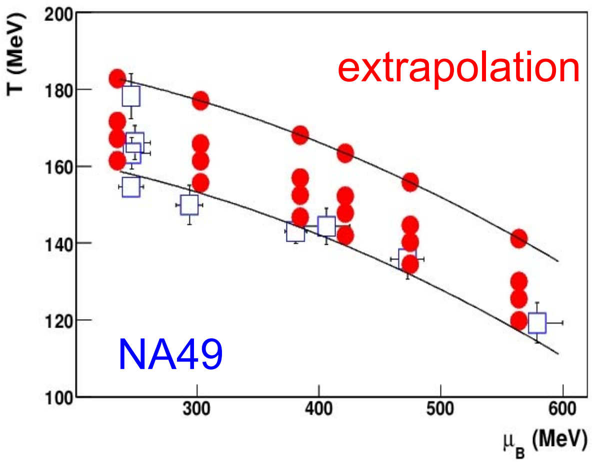
π^--C interaction at 350 GeV/c

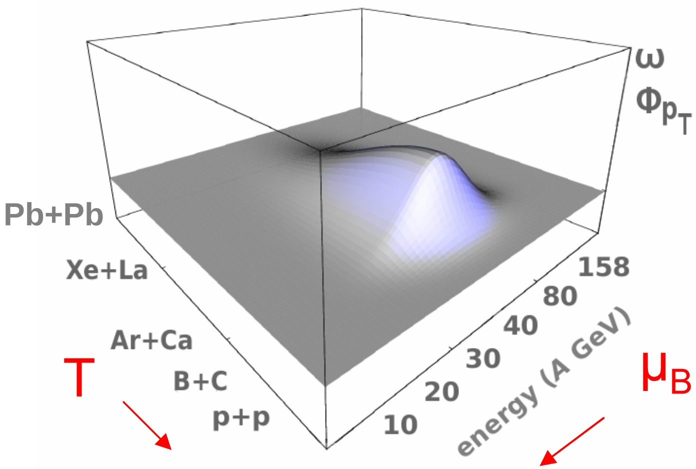


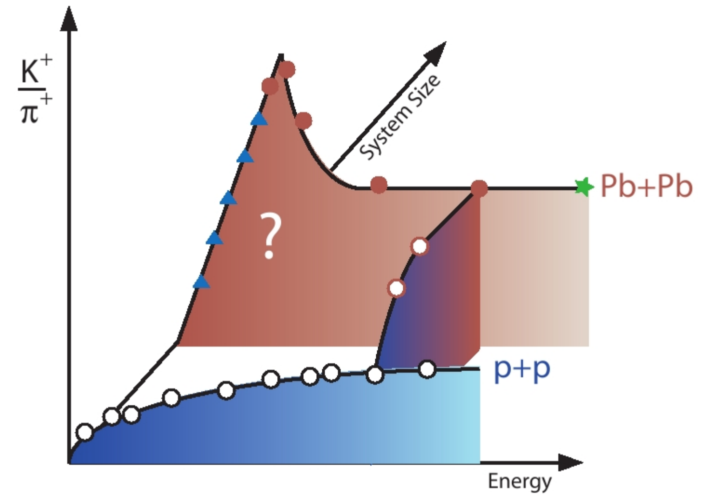
- study of the onset of deconfinement and search for the critical point
- precision particle production measurement for improving calculations of T2K neutrino beam and air shower (P.Auger,KASKADE) properties
- study of nuclear modification factor and Cronin effect using p+p and p+Pb interactions with extended range in p_T

Ion physics program of NA61/SHINE: scan in energy and system size A

search for hill of fluctuations as signature of critical point

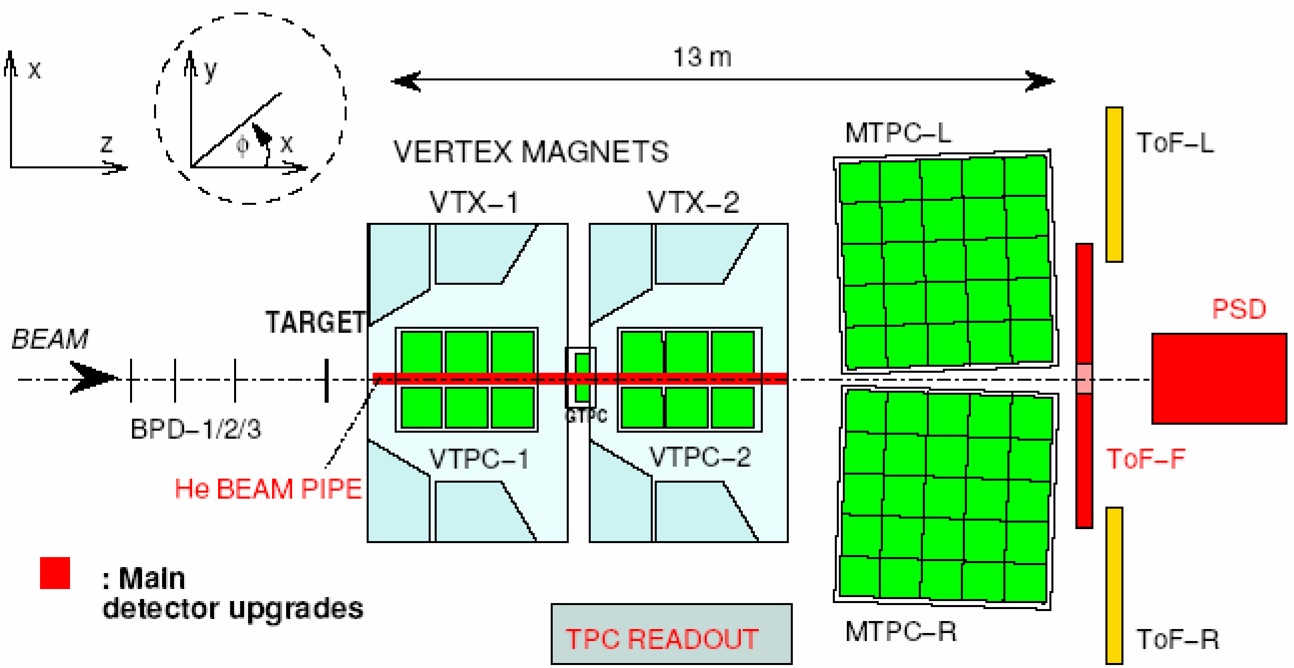






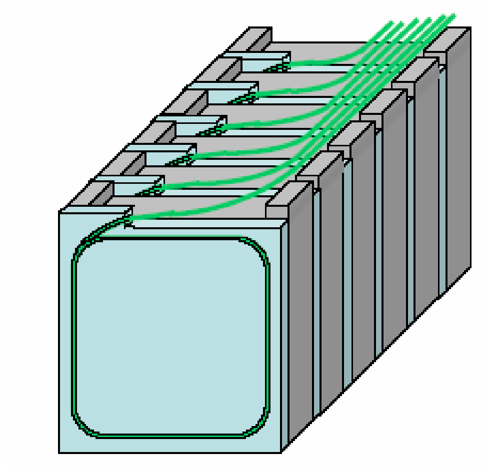
study onset of deconfinement: disappearance of horn etc.

NA61/SHINE uses the upgraded NA49 detector

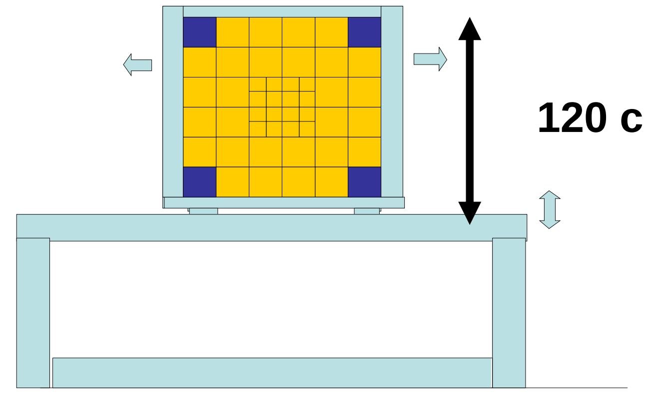


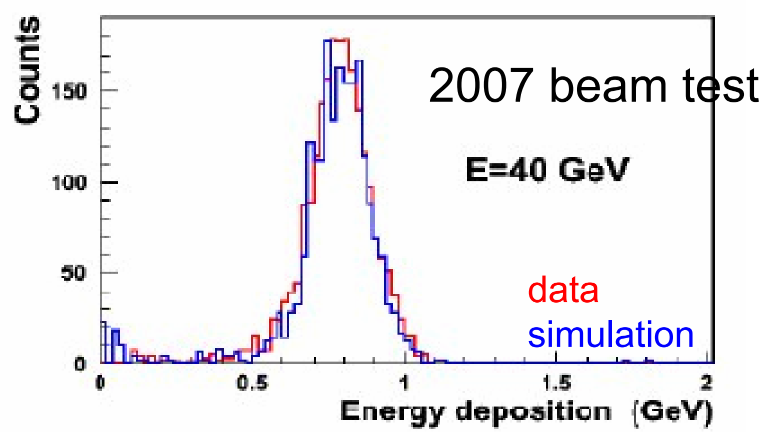
- forward TOF system for low momentum tracks in p+p, p+A collisions
- new TPC readout and DAQ → data taking rate increase x 10 (80 Hz)
- new zero degree calorimeter PSD with single nucleon resolution
- He-filled beam pipe through VTPCs to reduce δ-ray background

PSD – Projectile Spectator Detector (completion for 2012)

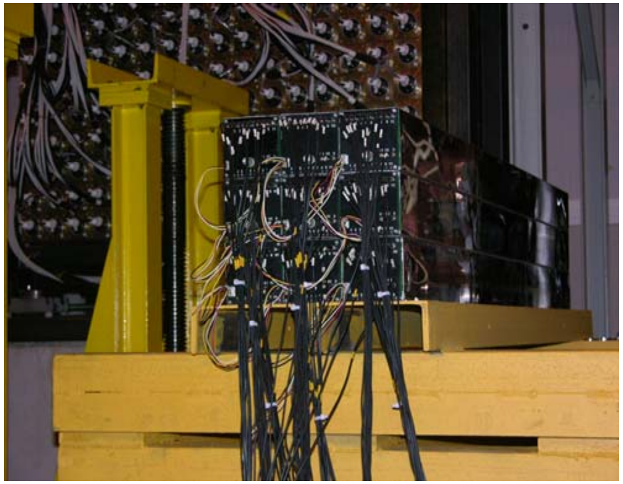


- 60 lead/scintillator sandwiches
- 10 longitudinal sections
- 6 WLS-fiber/MAPD
- 10 MAPDs/module
- 10 Amplifiers with gain~40

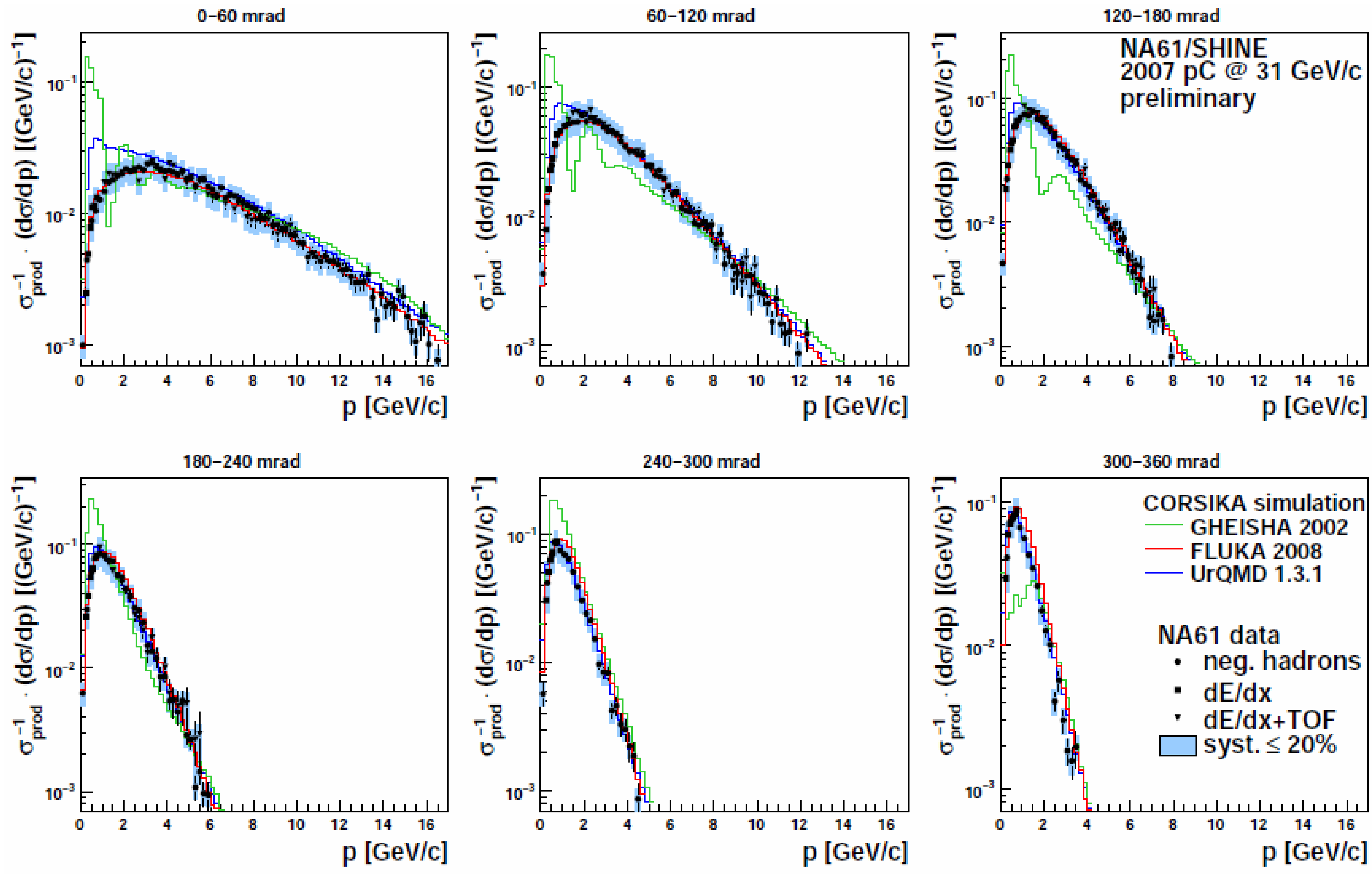




$\sigma(E)/E = 36\%/\sqrt{E(GeV)} + 0.2\%$

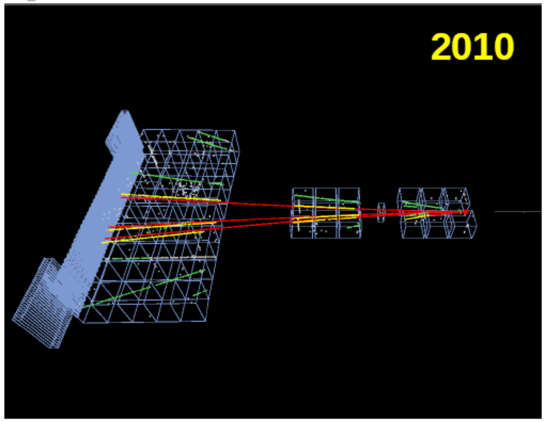


first physics results from p+C collisions at 31 GeV (2007 pilot run)

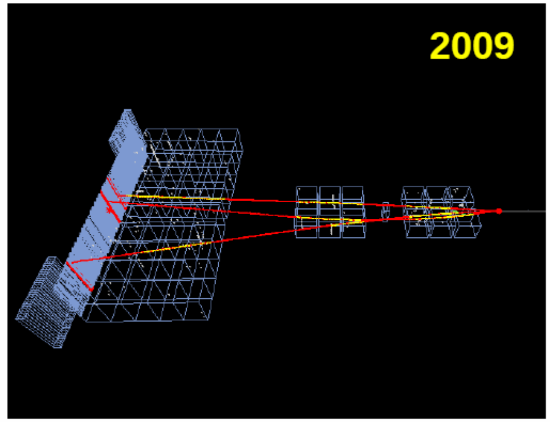


already low statistics pilot data provide significant constraints

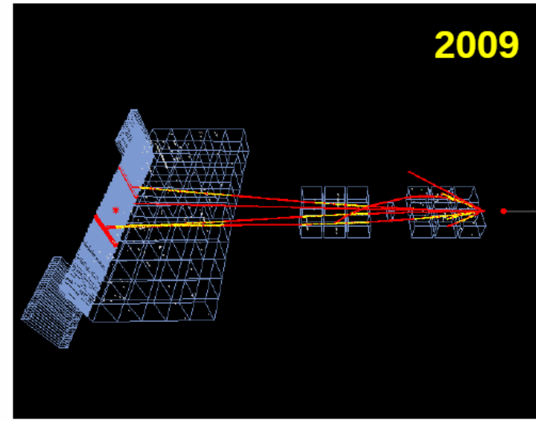
present status of the ion program



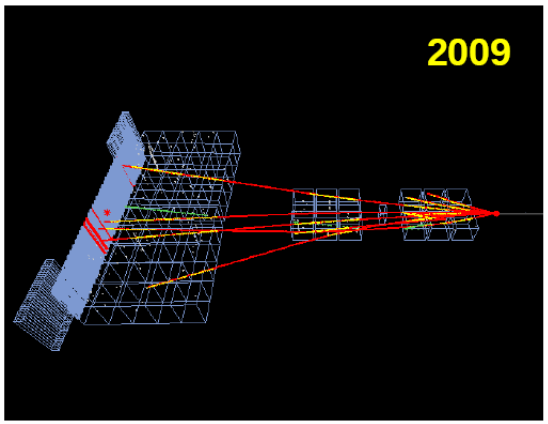
p+p at 13 GeV/c,
~700k events



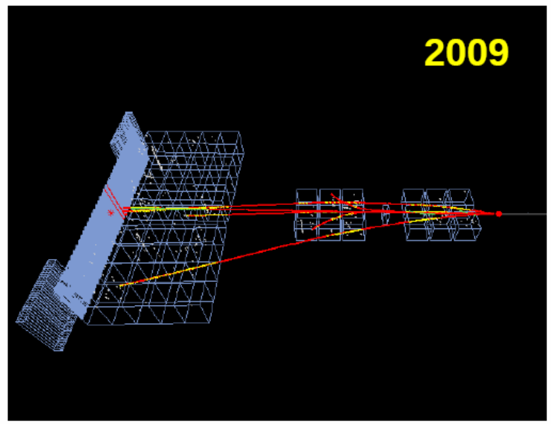
p+p at 20 GeV/c,
2M events



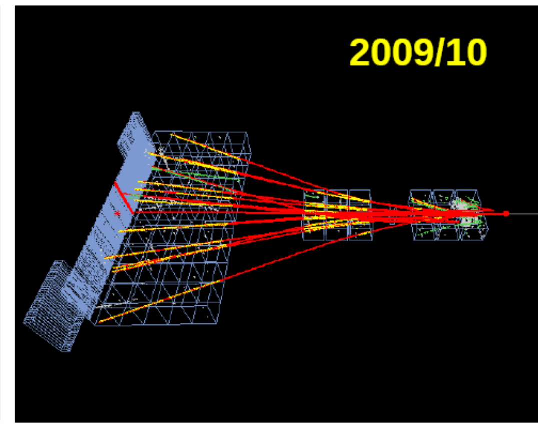
p+p at 31 GeV/c,
3M events



p+p at 40 GeV/c,
6M events



p+p at 80 GeV/c,
4M events

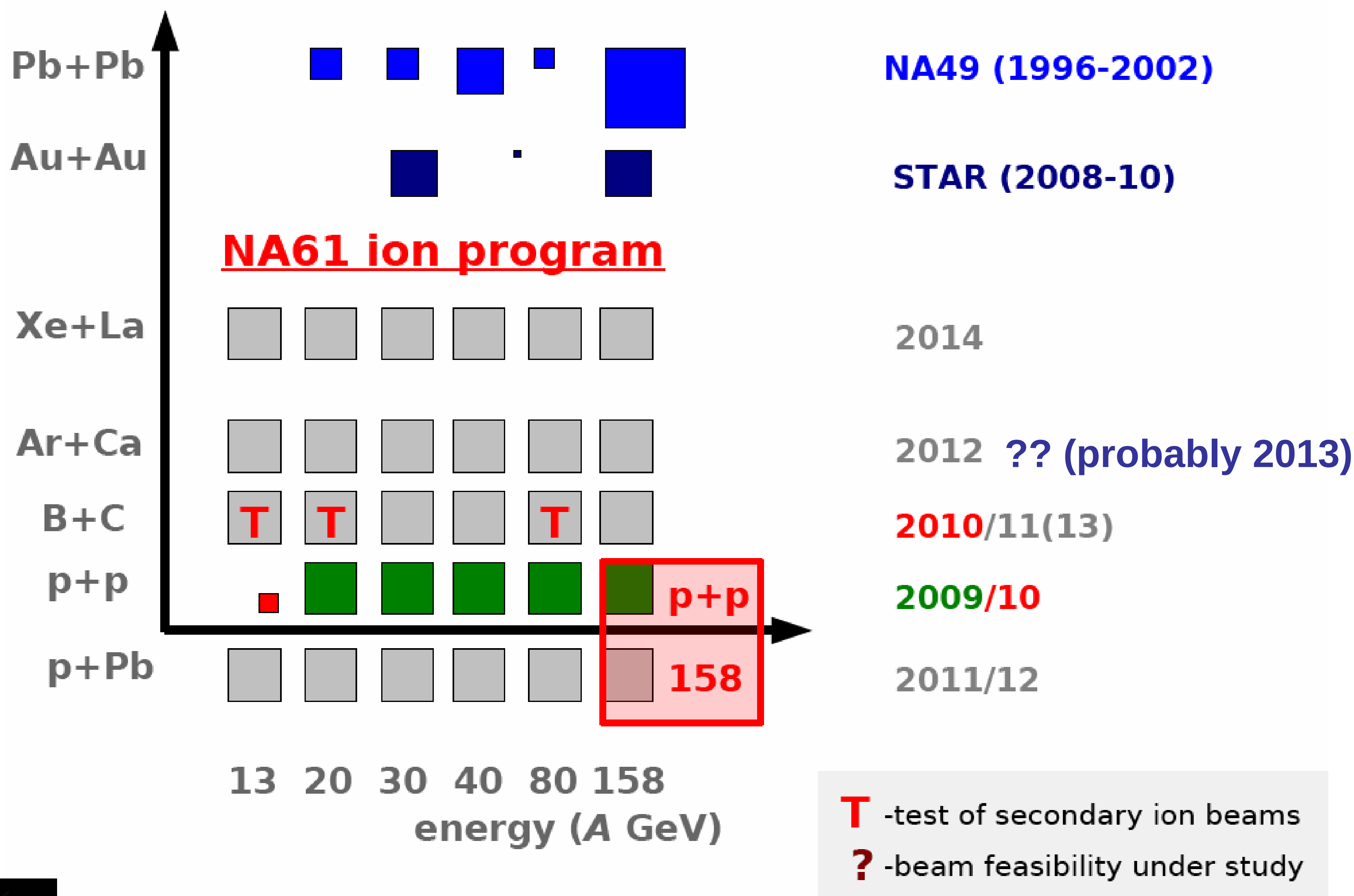


p+p at 158 GeV/c,
4M events

10

p+p energy scan data recorded, data analysis in progress

Status and plans for ion collisions at SPS energies

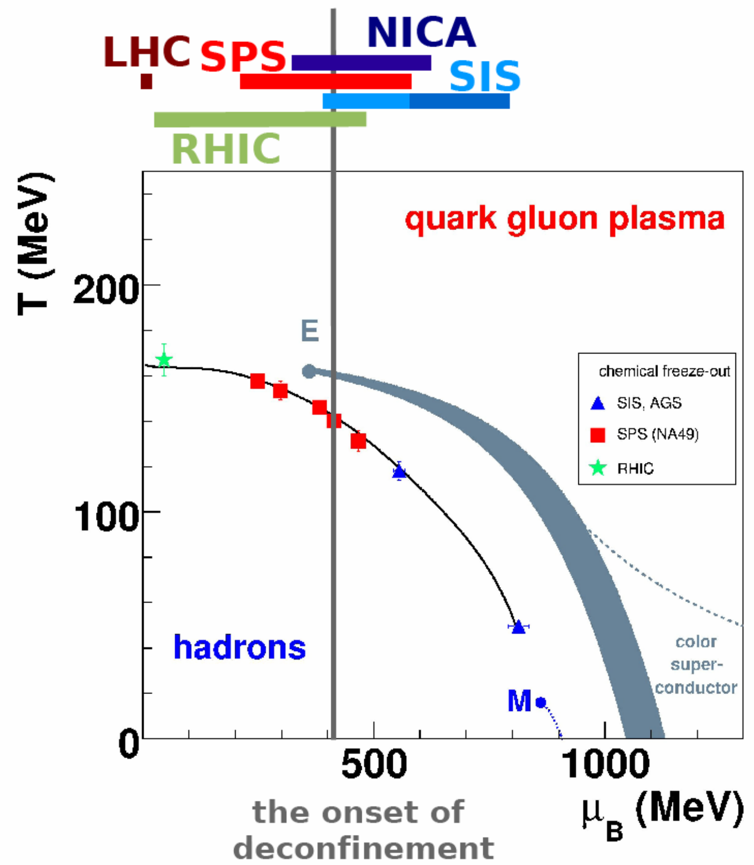


Experimental landscape of complementary programs of nucleus-nucleus collisions around the SPS energies

Facility:	**SPS**	**RHIC**	**NICA**	**SIS-100 (SIS-300)**
Exp.:	**NA61**	**STAR PHENIX**	**MPD**	**CBM**
Start:	**2011(2)**	**2010**	**2015**	**2017 (2019)**
Pb Energy: (GeV/(N+N))	**4.9-17.3**	**7.7-50**	**≤11**	**≤5 (<8.5)**
Event rate: (at 8 GeV)	**100 Hz**	**3-30 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

QCD critical point searches – future experimental landscape



partly complementary programs
planned at CERN SPS 2011
BNL RHIC 2010
DUBNA NICA 2015 ?
GSI SIS-CBM 2017 ?

strong points of NA61:

- tight constraint on spectators
- high event rate at all SPS energies
- flexibility to change A and energy
- overlap with AGS energy

Strong points of BNL/STAR:

- full uniform azimuthal acceptance
- excellent TOF identification
- low track density

Conclusion

- verification of NA49 results on the onset of deconfinement by STAR low energy scan at RHIC in progress
- search for critical point of strongly interacting matter presently inconclusive
- 2D scan of fluctuations in μ_B,T phase diagram was started by NA61/SHINE
- future programs at NICA and CBM/FAIR plan to continue and augment these studies

NA49 collaboration

T. Anticic[23], B. Baatar[8],D. Barna[4], J. Bartke[6], H. Beck[9], L. Betev[10], H. Białkowska[20], C. Blume[9], B. Boimska[20], W. Borowski[22], J. Book[9],M. Botje[1], J. Bracinik[3], P. Bunčić[10], V. Cerny[3], P. Christakoglou[1], P. Chung[19], O. Chvala[14], J.G. Cramer[16], P. Csató[4], P. Dinkelaker[9], V. Eckardt[13], Z. Fodor[4], P. Foka[7], V. Friese[7], J. Gál[4], M. Gaździcki[9,11], V. Genchev[18], K. Grebieszkow[22], S. Hegyi[4], C. Höhne[7], K. Kadija[23], A. Karev[13], V.I. Kolesnikov[8], M. Kowalski[6], M. Kreps[3], A. Laszlo[4], R. Lacey[19], M. van Leeuwen[1], P. Lévai[4], L. Litov[17], B. Lungwitz[9], M. Makariev[17], A.I. Malakhov[8], M. Mateev[17], G.L. Melkumov[8], M. Mitrovski[9], J. Molnár[4], St. Mrówczyński[11], V. Nicolic[23], G. Pálla[4], A.D. Panagiotou[2], D. Panayotov[17], A. Petridis[2,†], W. Peryt[22], M. Pikna[3], J. Pluta[22], D. Prindle[16], F. Pühlhofer[12], R. Renfordt[9], C. Roland[5], G. Roland[5], M. Rybczyński[11], A. Rybicki[6], A. Sandoval[7], N. Schmitz[13], T. Schuster[9], P. Seyboth[13], F. Siklér[4], B. Sitar[3], E. Skrzypczak[21], M. Slodkowski[22], G. Stefanek[11], R. Stock[9], H. Ströbele[9], T. Susa[23], I. Szentpétery[4], J. Sziklai[4], M. Szuba[22], P. Szymanski[10,20], V. Trubnikov[20], M. Utvić[9], D. Varga[4,10], M. Vassiliou[2], G.I. Veres[4,5], G. Vesztergombi[4], D. Vranić[7], A. Wetzler[9], Z. Włodarczyk[11], A. Wojtaszek[11], I.K. Yoo[15]

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The NA61/SHINE Collaboration

NA61: 130 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
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
Universidad Tecnica Federico Santa Maria, Valparaiso, Chile
Rudjer Boskovic Institute, Zagreb, Croatia
ETH Zurich, Zurich, Switzerland

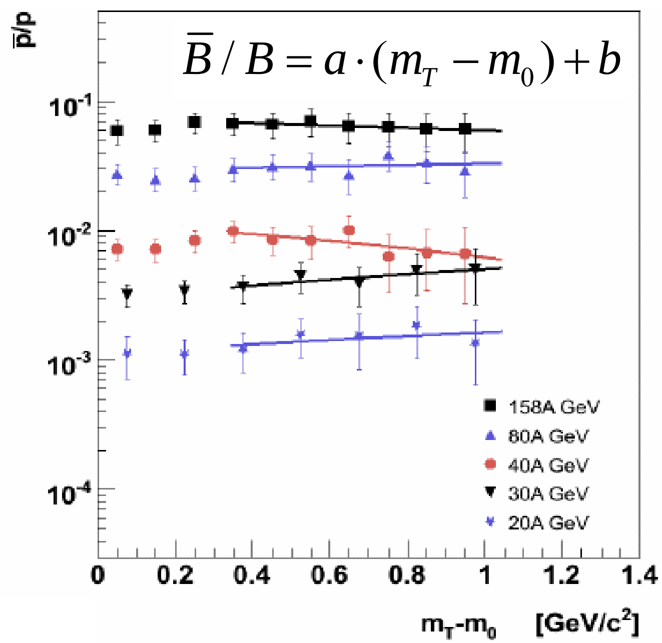
additional / backup slides

transverse mass spectra of baryons and antibaryons

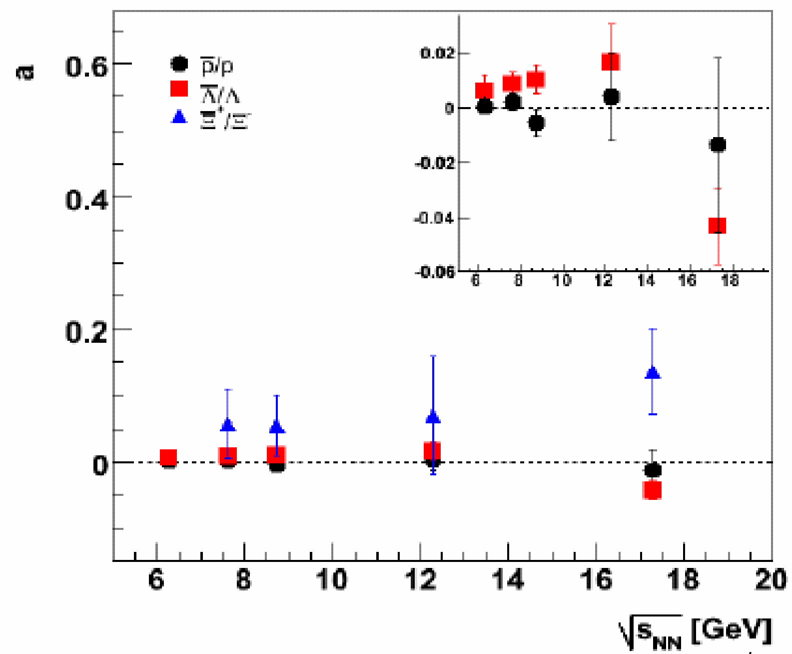
presence of critical point predicted to attract fireball evolution trajectory altering average freeze-out time → β_T dependence of pbar/p ratio

critical point: pbar/p increases with m_T M.Asakawa et al.,PRL101,122302(2008)

annihilation: decreases



similar data for Λ and Ξ



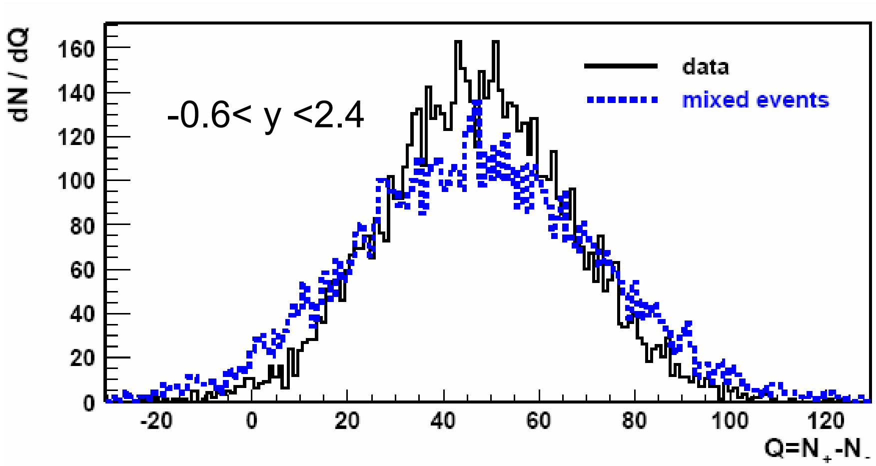
no significant change with √s of slope parameter a

no evidence for critical point effect

Electric charge fluctuations

- Smaller in a QGP than in a hadron gas
  (Jeon,Koch,Asakawa,Heinz,Müller)

Central Pb+Pb collisions 158A GeV



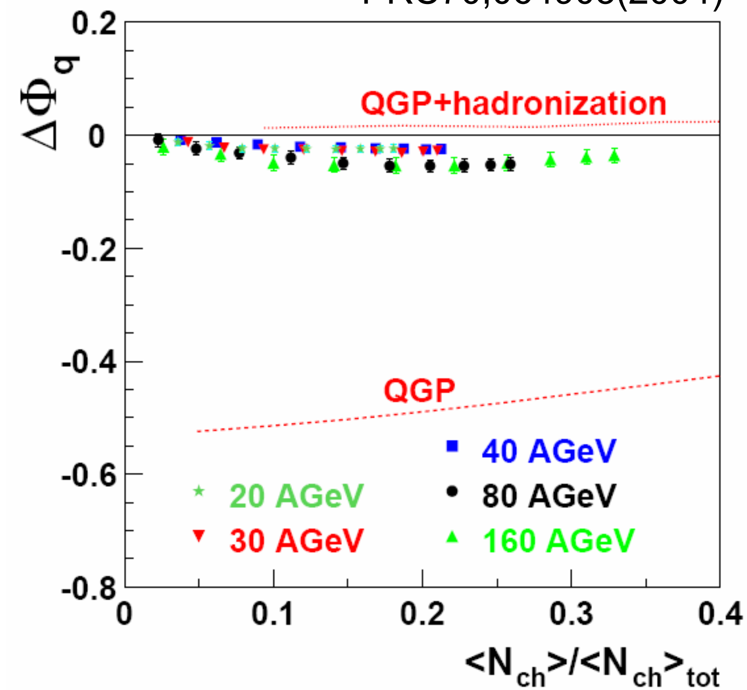
Global charge conservation

$$\Phi_q = \sqrt{\frac{< Z^2 >}{< N >}} - \sqrt{\overline{z^2}}$$

$$z = q - \overline{q} \qquad Z = \sum_{i=1}^{N} (q_i - \overline{q})$$

$$\Delta\Phi_q = \Phi_q - \Phi_{q,gcc}$$

PRC70,064903(2004)



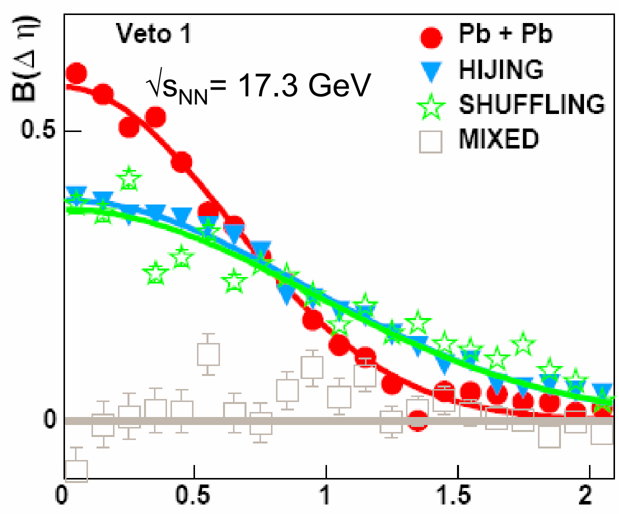
QGP signature probably erased by hadronisation (Bialas) or the effect of resonance decays (Zaranek)

Balance Function: charge correlations in pseudo-rapidity

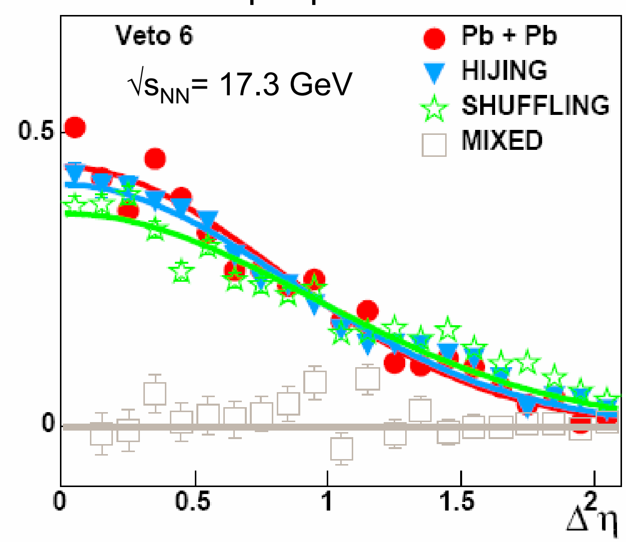
$$B(\delta\eta) = \frac{1}{2}\left(\frac{N_{(+-)}(\delta\eta) - N_{(--)}(\delta\eta)}{N_{-}} + \frac{N_{(-+)}(\delta\eta) - N_{(++)}(\delta\eta)}{N_{+}} \right)$$

narrowing of the balance function proposed as QGP signature (delayed hadronisation due to phase coexistence)

central



peripheral

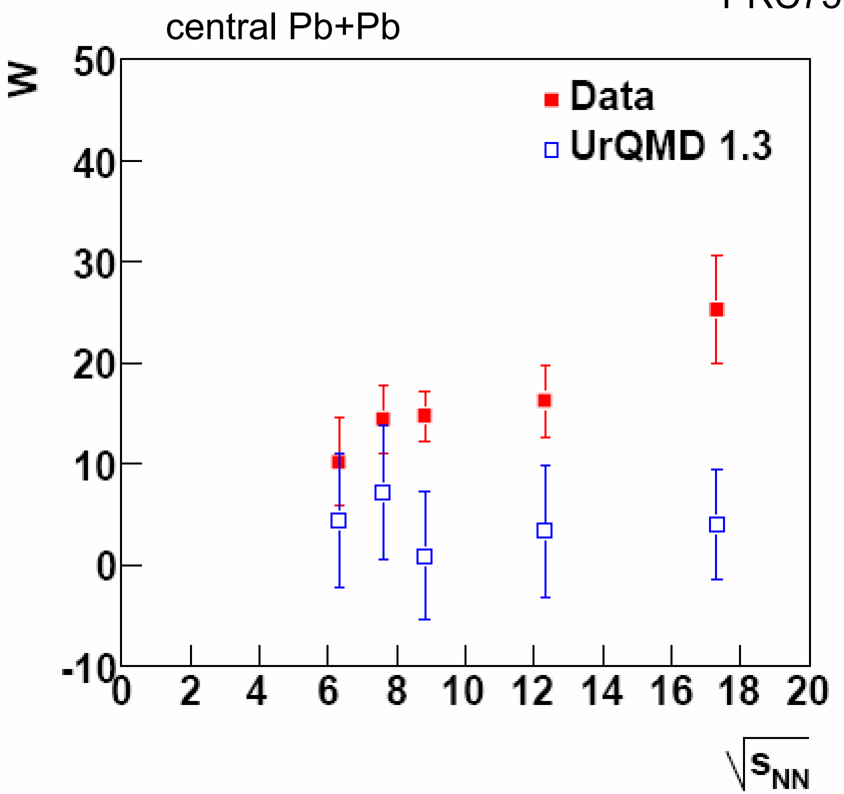


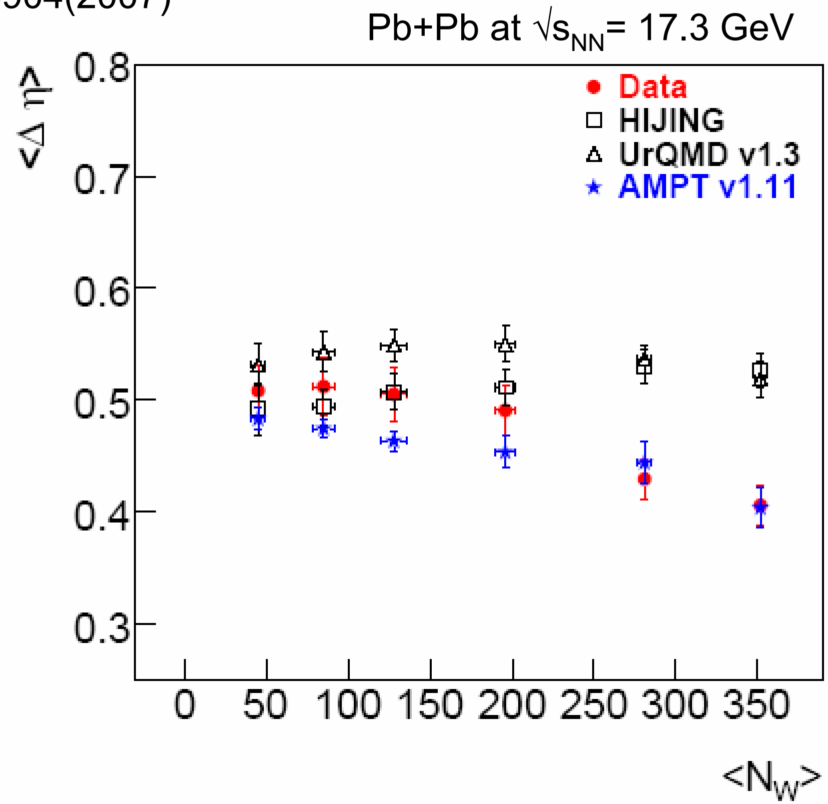
data compared to shuffled events: $W = (\langle\Delta\eta\rangle_{shuff} - \langle\Delta\eta\rangle_{data}) / \langle\Delta\eta\rangle_{shuff} \cdot 100$

(scrambling of rapidities, retention of global charge conservation)

BF: model comparisons at mid-rapidity

PRC75,064904(2007)





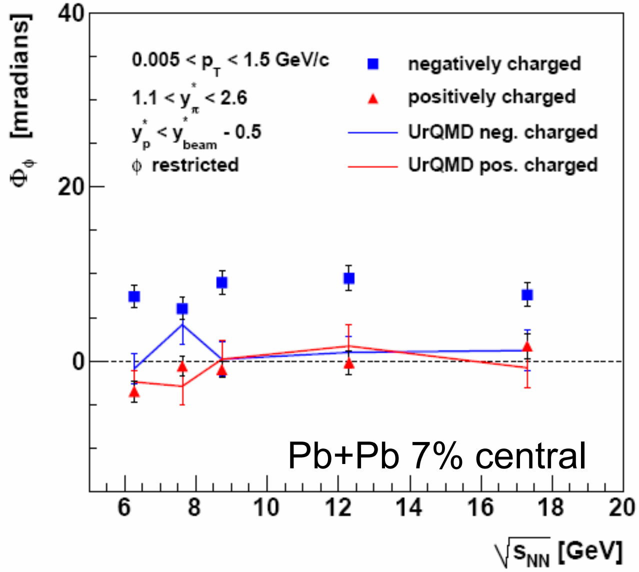
- no anomaly at SPS energy: effects due to local charge conservation and radial flow may dominate (Pratt, Bialas)
- microscopic model AMPT with deconfined phase reproduces BF narrowing

Φ_ϕ : fluctuations of average azimuthal angle

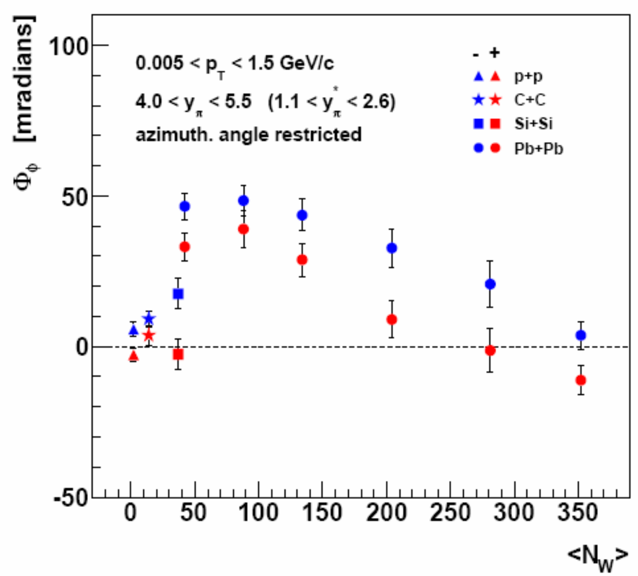
K.Grebieszkow, NA49 preliminary

- plasma instabilities (S.Mrowczynski, Phys.Lett. B314,118(1993))
- flow fluctuations (S.Mrowczynski,E.Suryak,Act.Phys.Pol.B34,4241(2003)
- onset of deconfinement, critical point

energy dependence



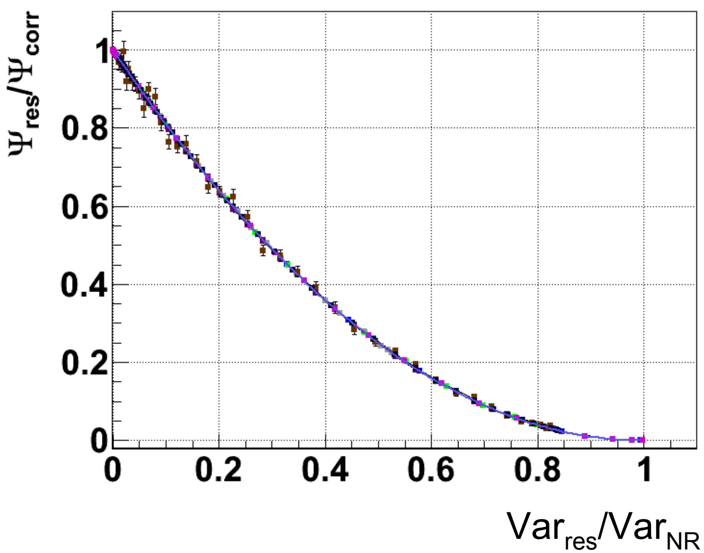
system size dependence



- no significant energy or A dependence in central collisions
- increase for peripheral Pb+Pb collision as for ω, Φ_{pT}; not understood

- experimental resolution of identification reduces the value of Ψ
- a correction was found which was proven (S.Mrowczynski) to work for all types of correlations, resolution and particle yields

various model calculations



Ψ_{res} value evaluated for data

Ψ_{corr} correct value for ideal resolution

variances of ρ(m) for experimental and no resolution cases provide correction

$$Var_{res} = \frac{1}{M}\sum_{i-1}^{M} w_{h_i}(dE/dx_i)\cdot(1-w_{h_i}(dE/dx_i))$$

$$Var_{NR} = w_{h_i}\cdot(1-w_{h_i})$$

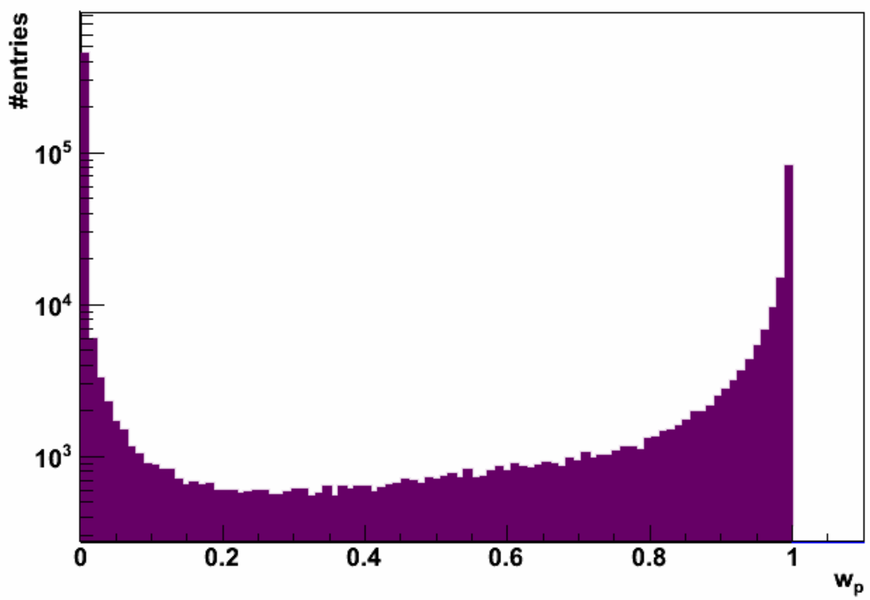
$$\boxed{\frac{\Psi_{res}}{\Psi_{corr}} = (1-Var_{res}/Var_{NR})^2}$$

first look at NA49 data (preliminary)

proton number fluctuations in central Pb+Pb collisions at 40A GeV

Ranges of kinetic variables:
- q: neg. and pos. charge
- p_{tot}: 0-40 GeV/c
- p_T: 0-2 GeV/c
- φ from 0 to 2π

sample of 4k events



M = 661581

N = 165.40

N_p = 42.16 – value calculated from dE/dx fit

Var_B = 0.1899

Var_{res} = 0.0223

$\Psi_{res} \cdot 1000 = -17.3823 \pm 3.44916$

correction $\Psi_{corr} / \Psi_{res} = 1.2832$

$\boldsymbol{\Psi_{corr} \cdot 1000 = -22.3048 \pm 4.4259}$

Event-by-event transverse momentum and multiplicity fluctuations

Φ_{PT} - measures transverse momentum fluctuations on event-by-event basis

single-particle variable $z_{p_T} = p_T - \bar{p}_T$

$\bar{p}_T$ - inclusive average

event variable $Z_{p_T} = \sum_{i=1}^{N} (p_{T_i} - \bar{p}_T)$

(summation runs over particles in a given event)

$$\Phi_{p_T} = \sqrt{\frac{\langle Z_{p_T}^2 \rangle}{\langle N \rangle}} - \sqrt{\overline{z_{p_T}^2}}$$

$\langle \ldots \rangle$ - averaging over events

ω - measures multiplicity fluctuations on event-by-event basis

Scaled variance of multiplicity distribution

$$\omega = \frac{V(N)}{\langle N \rangle}$$

where variance $V(N) = \langle N^2 \rangle - \langle N \rangle^2$

If A+A is a **superposition** of independent N+N

Φ_{PT} (A+A) = Φ_{PT} (N+N)

Φ_{PT} is independent of N_{part} fluctuations

ω (A+A) = ω (N+N) + < n > ω_{part}

< n > - mean multiplicity of hadrons from a single N+N

ω_{part} - fluctuations in N_{part}

ω is strongly dependent on N_{part} fluctuations

For a system of **independently emitted particles** (no inter-particle correlations)

$\Phi_{PT} = 0$

For **Poissonian multiplicity distribution**

ω=1

7

Critical point predictions for multiplicity and transverse moment. fluctuations

Magnitude of fluctuations at CP from Stephanov, Rajagopal, Shuryak PRD**60**, 114028 (1999)
with correlation length $\xi = \min(c_1 A^{1/3}, c_2 A^{1/9}) =$

min (limit due to finite system size, limit due to finite life time)

(M. Stephanov, private communication)
where c_1 and c_2 are fixed such that

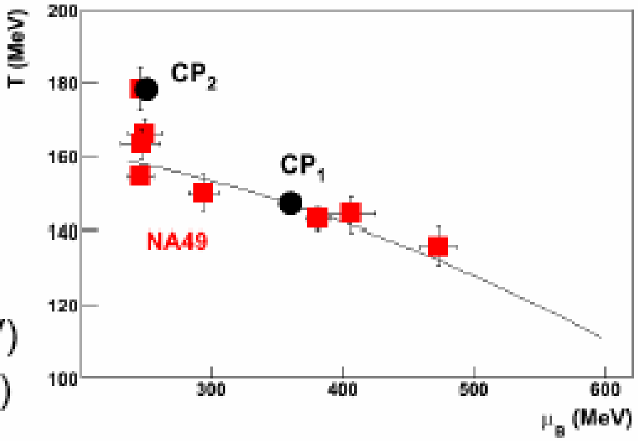
- ξ(Pb+Pb) = 6 fm and ξ(p+p) = 2 fm ($c_1 = 2$, $c_2 = 3.32$)
- ξ(Pb+Pb) = 3 fm and ξ(p+p) = 1 fm ($c_1 = 1$, $c_2 = 1.66$)

Width of CP region in (T, μ_B) plane based on Hatta, Ikeda PRD**67**, 014028 (2003)
$\sigma(\mu_B) \approx 30$ MeV and $\sigma(T) \approx 10$ MeV

Chemical freeze-out parameters, $T(A,\sqrt{s_{NN}})$ and $\mu_B(A,\sqrt{s_{NN}})$ from Beccatini, Manninen, Gaździcki PRC**73**, 044905 (2006)

Location of the Critical Point:
two examples considered

- $\mu_B(CP_1) = 360$ MeV (Fodor, Katz JHEP **0404**, 050 (2004))
  $T(CP_1) \approx 147$ (chemical freeze-out temperature T_{chem} for central Pb+Pb at $\mu_B = 360$ MeV)
- $\mu_B(CP_2) \simeq 250$ MeV (μ_B for A+A collisions at 158A GeV)
  $T(CP_2) = 178$ MeV (T_{chem} for p+p collisions at 158 GeV)



NA61/SHINE data taking plan

	Beam Primary	Beam Secondary	Target	Energy (A GeV)	Year	Duration days/MDs	Physics	Status
	p	p	p	400 158	2010	77 d	High p_T	*recommended*
FR test-1	Pb	^{11}B	none	20,80 20,80	2010	10 MDs	FS test-1	*to be discussed*
	p	p	Pb	400 158	2011	77 d	High p_T	*recommended*
secondary (FR test-2)	Pb	^{11}B	C	10,20,30,40,80,158 10,20,30,40,80,158	2011	20 d	FS test-2	*to be discussed*
	p	p	Pb	400 10,20,30,40,80,158	2012	6x8 d	CP,OD	*recommended*
primary	Ar		Ca	10,20,30,40,80,158	2012	6x8 d	CP,OD	*recommended*
(secondary)	Pb	^{11}B	C	10,20,30,40,80,158 10,20,30,40,80,158	2013	6x10 d	CP,OD	*to be discussed*
primary	Xe		La	10,20,30,40,80,158	2014	6x8 d	CP,OD	*to be discussed*