SHINE - SPS Heavy Ions and Neutrino Experiment

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for the NA61/SHINE collaboration

134 physicists from 27 institutes and 15 countries
NA61/SHINE physics program:
- Critical Point and Onset of Deconfinement,
- Neutrino physics,
- Cosmic-ray physics
TPC read-out - an increase of the data rate by a factor of 10 compared to the NA49 rate

TOF-F detector - acceptance X 2

Projectile Spectator Detector - with a resolution of 1 nucleon

He beam pipe - reduction of the δ-electron background by a factor of 10

Particle identification:
Combined energy loss and Time of Flight measurements
Physics 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 $\mu_B$ 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

[Graph showing phase boundaries and freeze-out points]
Evidence for the onset of deconfinement

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

M.Gazdzicki et al.,arXiv:1006.1765

the kink
pion yield per participant

\[ \langle \pi \rangle = 1.5 \cdot (\langle \pi^+ \rangle + \langle \pi^- \rangle) \]

central PbPb/AuAu

the horn
ratio of strange particle to pion yield

\[ E_s = \frac{\langle K \rangle + \langle \Lambda \rangle}{\langle \pi \rangle} \]

the step
shape of transverse mass spectra

Hydro+PT

\[ F \left( \text{GeV}^{1/2} \right) \approx S_{NN}^{1/4} \]

NA49,C.Alt et al.,PRC77,024903(2008)
Verification of the NA49 results by STAR and ALICE

• The RHIC results confirm the NA49 measurements at the onset of deconfinement

• The LHC data demonstrate that the energy dependence of hadron production properties shows rapid changes only at low SPS energies
Results of critical point search from NA49

First hint of the hill of fluctuations?

System size at 158 GeV

Energy for central Pb + Pb

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

- search for hill of fluctuation measures as signature of critical point
- study onset of deconfinement: e.g. disappearance of horn etc.
Progress and plans in data taking for CP&OD

**NA61 ion program**

- **Pb+Pb**
  - NA49 (1996-2002)
  - 2015

- **Au+Au**
  - STAR (2008-11)
  - 2014
  - 2010/11/12
  - 2009/10/11
  - 2012/14

- **Xe+La**
- **Ar+Ca**
- **Be+Be**
  - **T** - test of secondary ion beams
  - **P** - pilot data taken

- **p+p**
  - 13 20 30 40 80 158
  - energy (A GeV)

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NA61 preliminary results on p+C collisions

Pion spectra at 31 GeV/c (arXiv:1101.3250 and (A. Aduszkiewicz and T. Palczewski, Thu. P153)

Comparison between p+C (NA61) and central Pb+Pb (NA49) at 30A GeV

- Mean pion multiplicity is approximately proportional to the mean number of wounded nucleons in the projectile nucleus
- Precise data on p+A add significant constraints for models
NA61 preliminary results on p+C collisions

Pion spectra at 31 GeV/c (arXiv:1101.3250 and (A. Aduszkiewicz and T. Palczewski, Thu. P153)

Comparison between p+C (NA61) and central Pb+Pb (NA49) at 30A GeV

- p + C - convex form (with respect to the corresponding exponential fit) of the transverse mass spectrum
- Pb + Pb –concave spectrum
- significant colective flow in Pb + Pb collisions
 verification of NA49 results on the onset of deconfinement by STAR and ALICE

 search for critical point of strongly interacting matter presently inconclusive

 2D scan of fluctuations in $\mu_B$, T phase diagram was started by NA61/SHINE with p+p interactions at six momenta (13-158 GeV/c)

 first results are being released

 energy scan with secondary Be beam will start this year
Additional slides
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

2007 beam test

2007 beam test data simulation

\[ \sigma(E)/E = 56%/\sqrt{E(\text{GeV})} + 2\% \]
Fluctuation measures studied by NA49

- scaled variance $\omega$ of the multiplicity distribution $P(N)$

$$\omega = \frac{\text{Var}(N)}{\langle N \rangle} = \frac{\langle N^2 \rangle - \langle N \rangle^2}{\langle N \rangle}$$

superposition model: $\omega(A+A) = \omega(N+N) + \langle N \rangle \omega_{\text{part}}$

independent particle emission: $\omega = 1$

$\omega$ affected by participant fluctuations

- $\Phi_x$ measure of fluctuations of observable $x$ ($<p_{T}>$, $<\Phi>$, $Q$, identity, ...)

$$\Phi_x = \sqrt{\frac{\langle Z^2 \rangle}{\langle N \rangle}} - \sqrt{\langle Z^2 \rangle} ; \; Z = x - \langle x \rangle \; , \; Z = \sum_{i=1}^{N} (x_i - \langle x \rangle)$$

superposition model: $\Phi_x(A+A) = \Phi_x(N+N)$

independent particle emission: $\Phi_x = 0$

$\Phi_x$ strongly intensive fluctuation measure

- $\sigma_{\text{dyn}}$ measure of particle ratio fluctuations ( $K/\pi$, $p/\pi$, $K/p$ )

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

E-by-E fit of particle multiplicities required

mixed events used as reference

intensive fluctuation measure
Secondary Be beam: basic idea

primary Pb beam from the SPS

fragmentation target

Pb fragments

fragment separator

Test of secondary ion beams
The beam line is a double spectrometer with 0.04% resolution that helps to separate the ion fragments corresponding to a selected magnetic rigidity: $B_\rho$.

- Target length optimized to fragment production, degrader with variable length – optimization to be determined from the tests.
Ion beams for NA61

Primary Ar, Xe and Pb beams

ECR ion source
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

Strong points of BNL/STAR:
• full uniform azimuthal acceptance
• excellent TOF identification
• low track density

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