Can Baryon Stopping be understood within the String Model?

Justin Mohs[1,2], Sangwook Ryu[1,2] and Hannah Petersen[1,2,3]

[1] *Frankfurt Institute for Advanced Studies, Frankfurt am Main, Germany*

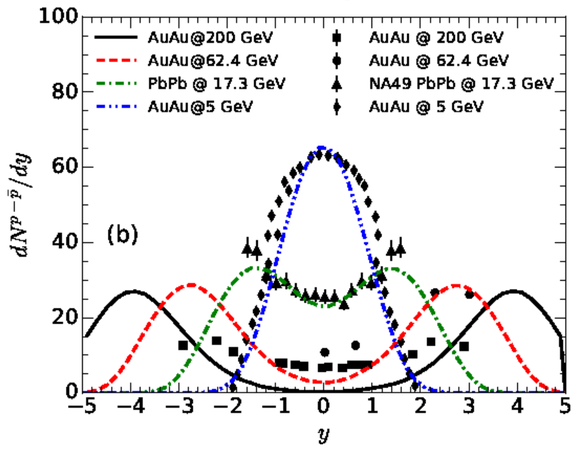
[2] *Institute for Theoretical Physics, Goethe University, Frankfurt am Main, Germany*

[3] *GSI Helmholtzzentrum für Schwerionenforschung, Darmstadt, Germany*

Motivation

- Investiage reagion in QCD phase diagram, where phase transition and critical point might exist
- Understand how much the protons from initial nuclei are stopped
- Full non-equilibrium dynamical description of colliding hadrons in transport model
- Correct fluctuations in participant number → necessary for finding possible critical point

3D MC-Glauber with simplified string model + Hydro



C. Shen, B. Schenke, 10.1103/PhysRevC.97.024907

Transport Model SMASH

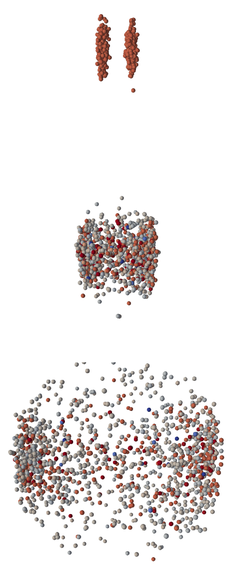
- Hadronic degrees of freedom
- Geometric collision criterion:

$$d_{\text{trans}} \leq \sqrt{\frac{\sigma}{\pi}}$$

- Well established hadrons from PDG
- Inelastic processes via resonances, soft strings or Pythia directly, depending on energy
- Photons and leptons treated perturbatively

  J.Staudenmaier et al. arXiv:1711.10297 [nucl-th]
- Effectively solving relativistic Boltzmann equation

  J.Tindall et al. 10.1016/j.physletb.2017.04.080



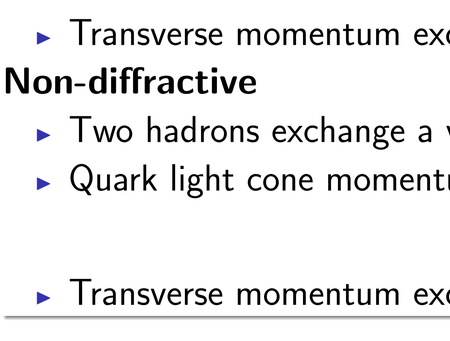
Au+Au @ $\sqrt{s_{NN}} = 10\,\text{GeV}$

J.Weil et al. 10.1103/PhysRevC.94.054905

String Model

- Describe particle production from excited quark antiquark or quark diquark pair
- Massless (di)quarks with momentum p_1, p_2 and position x_1, x_2

$$H = |p_1| + |p_2| + \kappa|x_1 - x_2|$$



- String tension κ
- New $q\bar{q}$ or $qq\bar{q}\bar{q}$ pairs are produced
- Hadrons are formed around constant proper time

B. Anderson et al. 10.1016/0370-1573(83)90080-7

Soft String Excitation

Single diffractive $A + B \to A + X$ or $A + B \to X + B$

- Hadrons collide, exchange momentum and one of them is excited to a string
- String mass M_X and transverse momentum exchange p_T are sampled from

$$\frac{d^3N}{dM_X^2 d^2\mathbf{p_T}} \propto \frac{1}{M_X^2} \exp\left(-\frac{p_T^2}{\sigma_T^2}\right)$$

G. Ingelman and P. E. Schlein 10.1016/0370-2693(85)91181-5

Double diffractive $A + B \to X + X$

- Hadrons exchange gluons and are both excited to a string
- Gluon light cone momentum fraction x sampled from PDF for gluons

$$\text{PDF}_g \propto \frac{1}{x}(1-x)^{\beta+1}$$

- Transverse momentum exchange also sampled from Gaussian

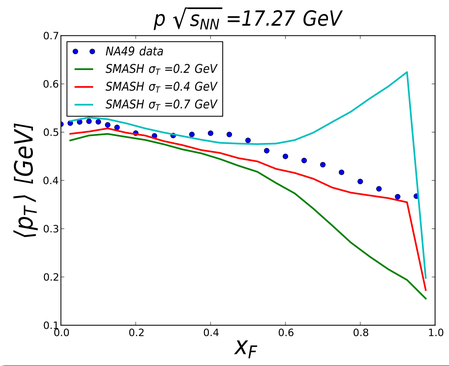
Non-diffractive

- Two hadrons exchange a valence quark and are both excited to a string
- Quark light cone momentum fraction x sampled from PDF for quarks

$$\text{PDF}_q \propto x^{\alpha-1}(1-x)^{\beta-1}$$

- Transverse momentum exchange again sampled from Gaussian

Transverse Momentum Transfer



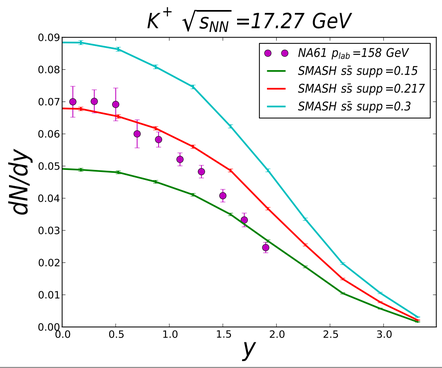
- Varying σ_T in order to reproduce p+p data at SPS energies
- Larger values of σ_T lead to more $\langle p_T \rangle$
- If more energy is transformed into p_T, protons are decelerated more
- Increasing σ_T tightens rapidity distribution

Strangeness Suppression

- Strangeness suppression factor

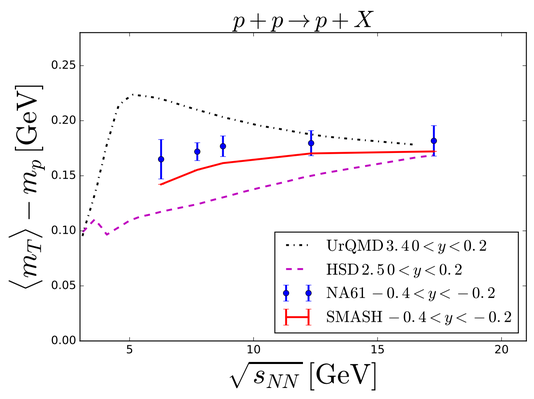
$$\lambda = \frac{P(s\bar{s})}{P(u\bar{u})} = \frac{P(s\bar{s})}{P(d\bar{d})}$$

- Can be used to tune strange hadron multiplicities
- Only slightly varies non strange hadron multiplicities



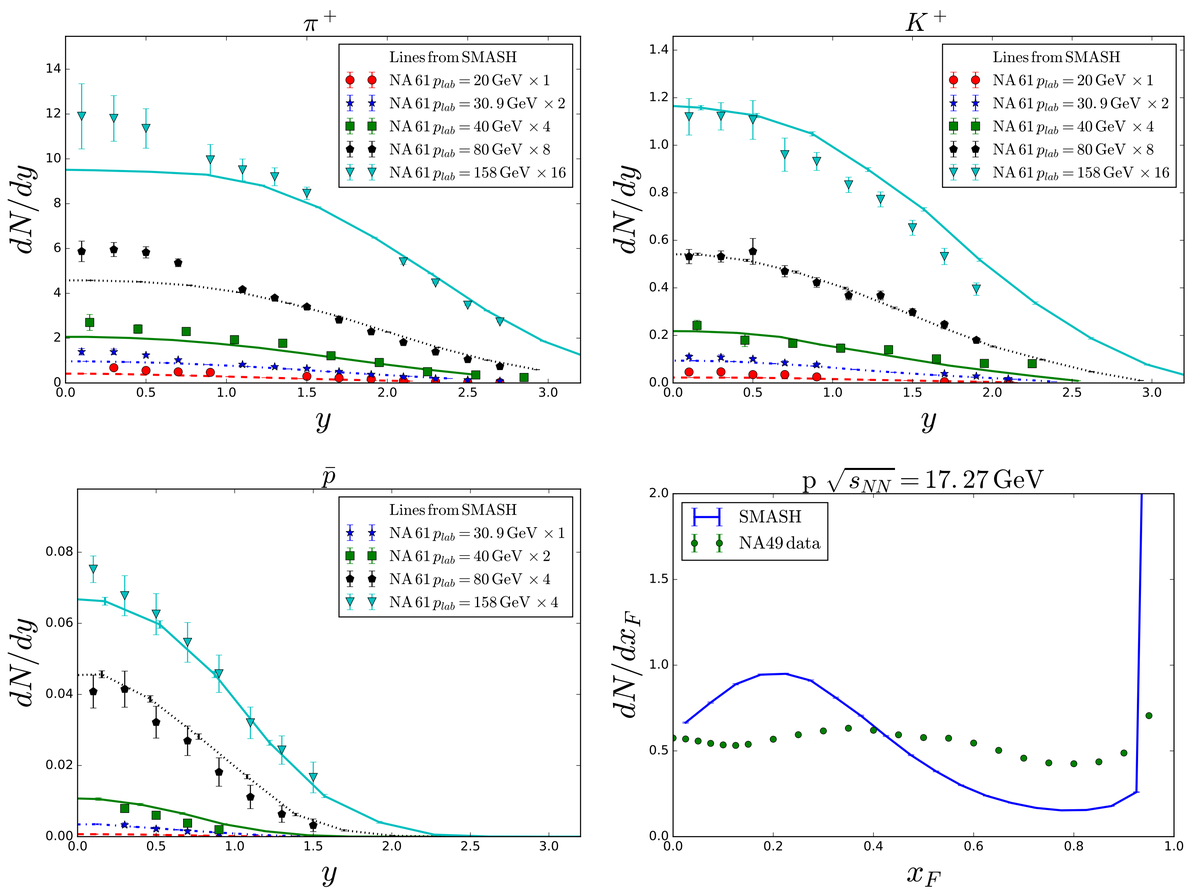
Proton Mean Transverse Mass

- Mean transverse mass of protons agrees with data for $8\,\text{GeV} < \sqrt{s} < 20\,\text{GeV}$
- New measurement by NA61 provides constraints on transport approaches



Particle Spectra in p+p

- Reasonable agreement for rapidity spectra of produced hadrons



NA61 10.1140/epjc/s10052-017-5260-4, NA49 10.1140/epjc/s10052-009-1172-2

- Proton x_F distribution still needs improvements

Outlook

- Find a set of parameters to reproduce p+p data at SPS energies
- Investigate baryon stopping in heavy ion collisions
- Understand how the interaction between string fragments affects stopping (formation times, cross section scaling factors etc.)

Acknowledgements

- Computational resources have been provided by the Center for Scientific Computing (CSC) at the Goethe-University of Frankfurt.
- This work was supported by the DFG through the grant CRC-TR 211.
- the authors acknowledge funding of a Helmholtz Young Investigator Group VH-NG-822 from the Helmholtz Association and GSI.