

A Comparative Study of Baryon Stopping: SMASH and Angantyr



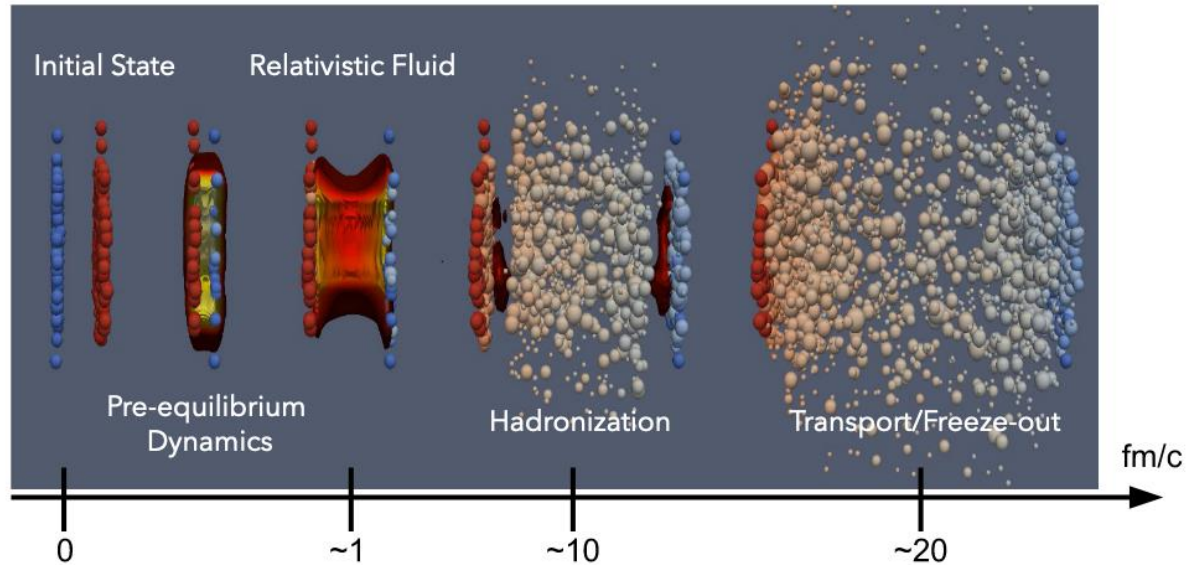
Presentation of a Bachelor Project

by Manou Engel

A Comparative Study of **Baryon Stopping**: SMASH and Angantyr



Heavy Ion Collision

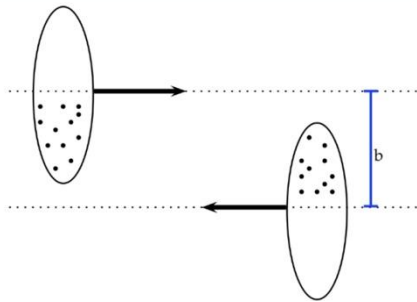


<https://doi.org/10.48550/ARXIV.2210.12056>



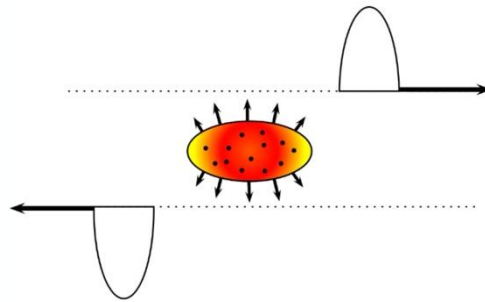
Baryon Stopping

How does the final distribution of the net number of nucleons behave?



Fermi-Landau-picture:

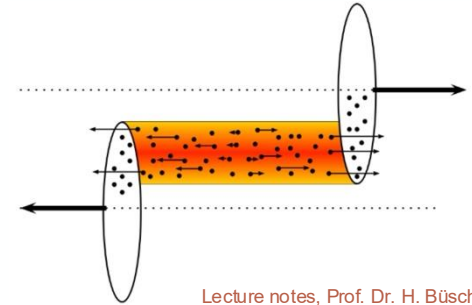
- Incoming nuclei are fully stopped
- Expansion of dense medium in all directions



low energies

Bjorken-McLerran-picture:

- Nuclei pass through each other transparently
- Interactions take place in the central region
- Plateau-like particle yield

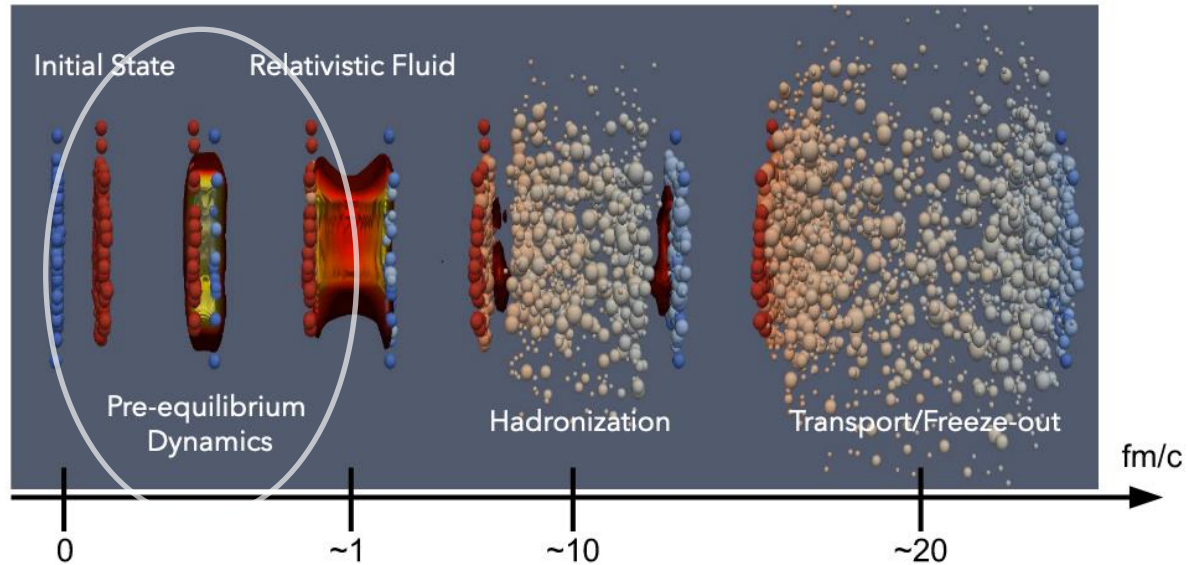


Lecture notes, Prof. Dr. H. Büsching

high energies



Baryon Stopping



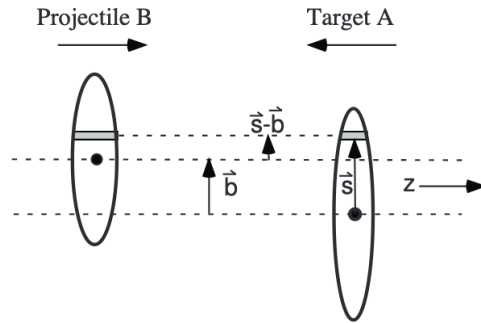
<https://doi.org/10.48550/ARXIV.2210.12056>

A Comparative Study of Baryon Stopping:
SMASH and Angantyr

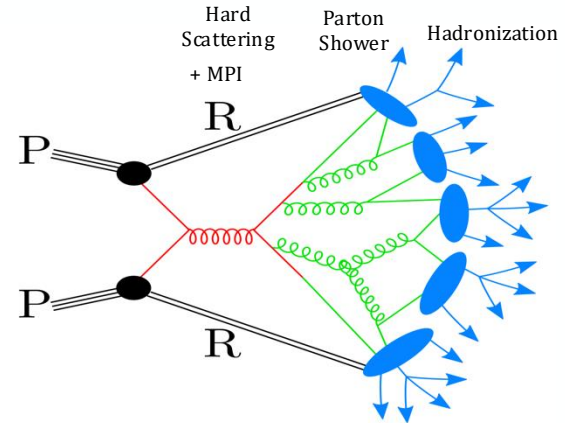


Angantyr & Pythia

- *Angantyr*: PYTHIA8's heavy ion extension
 - Glauber model
 - Nucleus-nucleus collision modelled as multiple nucleon-nucleon collisions
- *PYTHIA8*: event generator, e.g. proton-proton
 - Partonic interactions



Annu. Rev. Nucl. Part. Sci. **57**, 205–243 (2007).

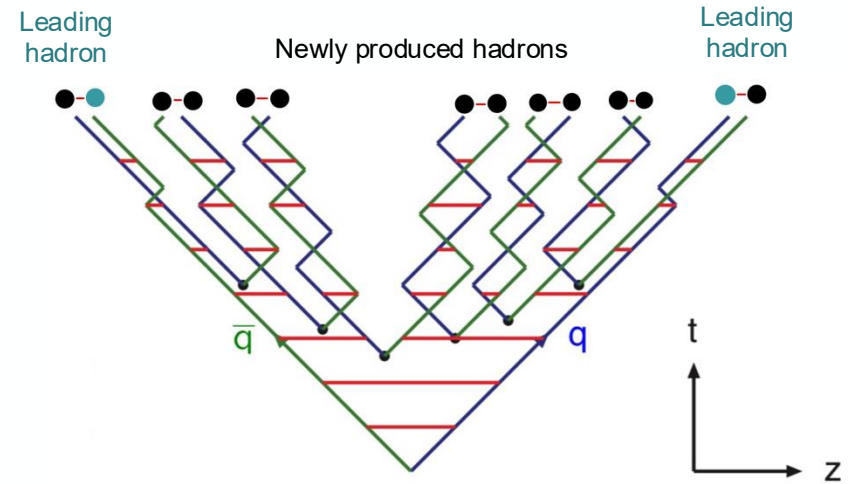


With permission, C.B. Rosenkvist



Angantyr & Pythia

- *Lund String Model*: describes hadronization
 - Assumes linearly potential between color charges with increasing distance
 - $V(r) = \kappa r$
 - String 'breaking' produces more quark-antiquark pairs



Physics Reports 504, 145–233 (2011).



SMASH

- *SMASH: hadronic transport model*

$$p^\mu \frac{\partial f_i}{\partial x^\mu} + m_i \frac{\partial (K^\mu f_i)}{\partial p^\mu} = C_i^{coll}$$

- Hadrons are propagated according to
 - their momenta
 - mean-field potential
 - collision with other hadrons



smash

Open source on [Github](#)

Phys. Rev. C **94**, 054905 (2016).

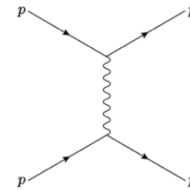


SMASH

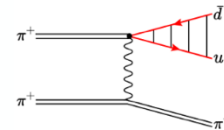
- Geometric collision criterium determined by total cross section

$$\pi d_{\perp}^2 \leq \sigma_{ab}$$

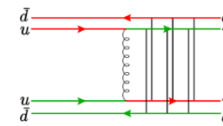
- Partial cross section determines which process takes place



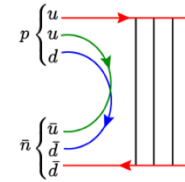
Elastic



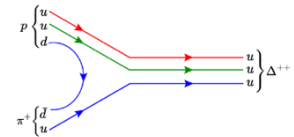
Diffractive



Non-diffractive



Annihilation



Resonant

Dr. M. Utheim, Prof. T.Sjöstrand

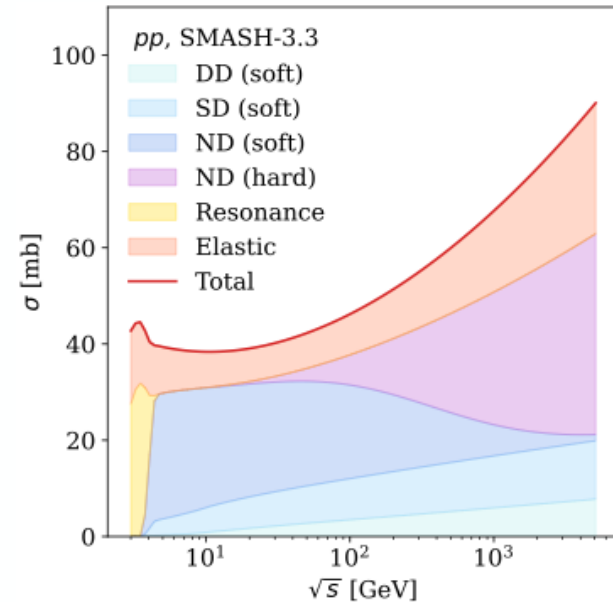


SMASH

- Geometric collision criterium determined by total cross section

$$\pi d_{\perp}^2 \leq \sigma_{ab}$$

- Partial cross section determines which subprocess takes place
 - Resonances
 - Soft processes: SMASH + PYTHIA8
 - Hard process: full PYTHIA8 event
 - Elastic

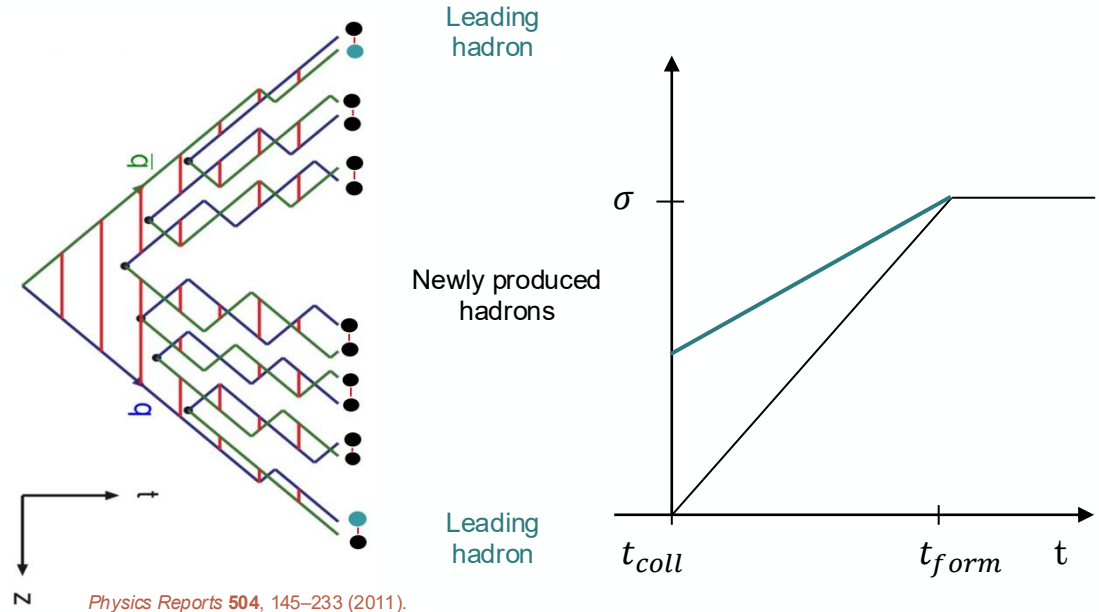


DD: double diffractive
SD: single diffractive
ND: non-diffractive



SMASH

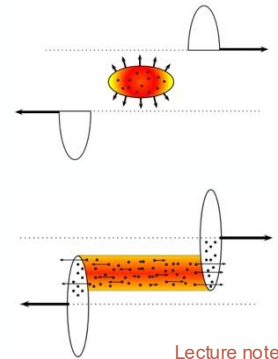
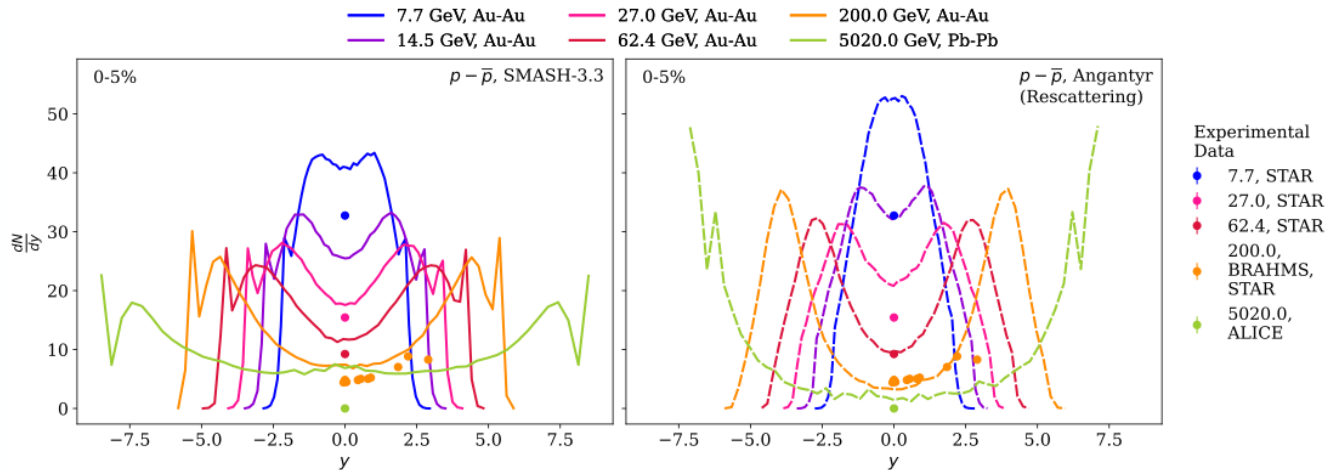
- SMASH adds outgoing hadrons at collision time and propagates them as unformed particles
- During this formation time, their cross section is reduced



A Comparative **Study** of Baryon Stopping: SMASH and Angantyr

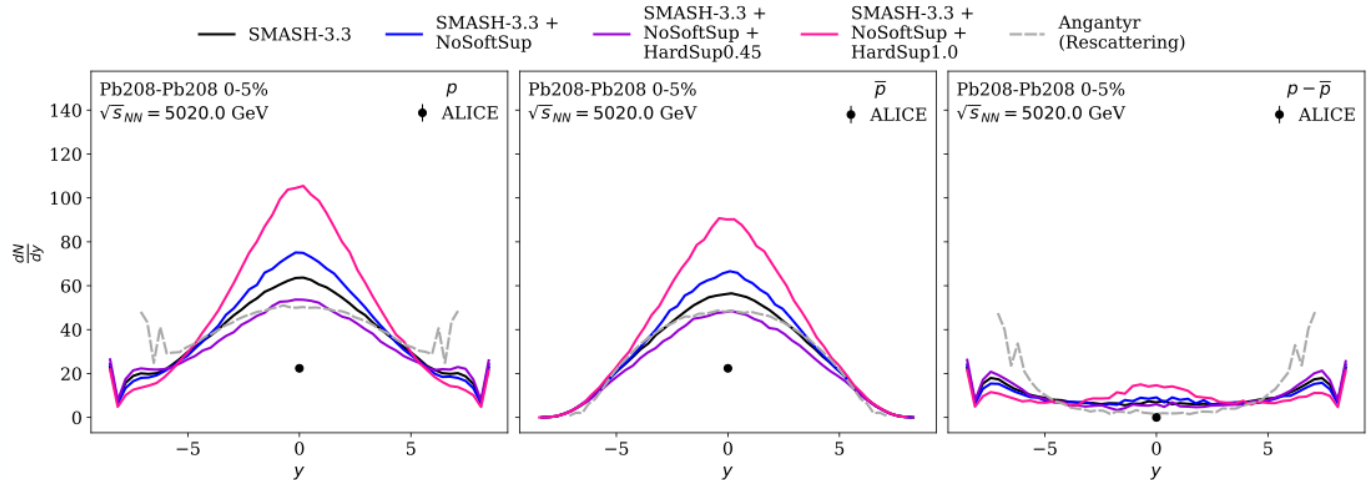
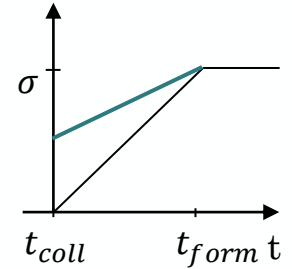
Current Description

- Low energy: high net proton yield at midrapidity
- High energy: characteristic low plateau-structure in central region
- SMASH performs better at low energies, while Angantyr describes high energies well



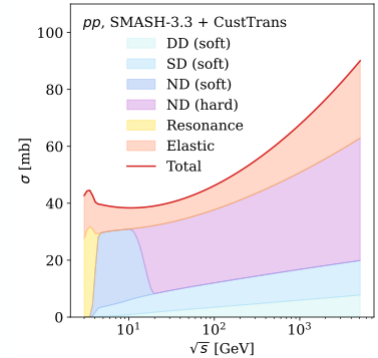
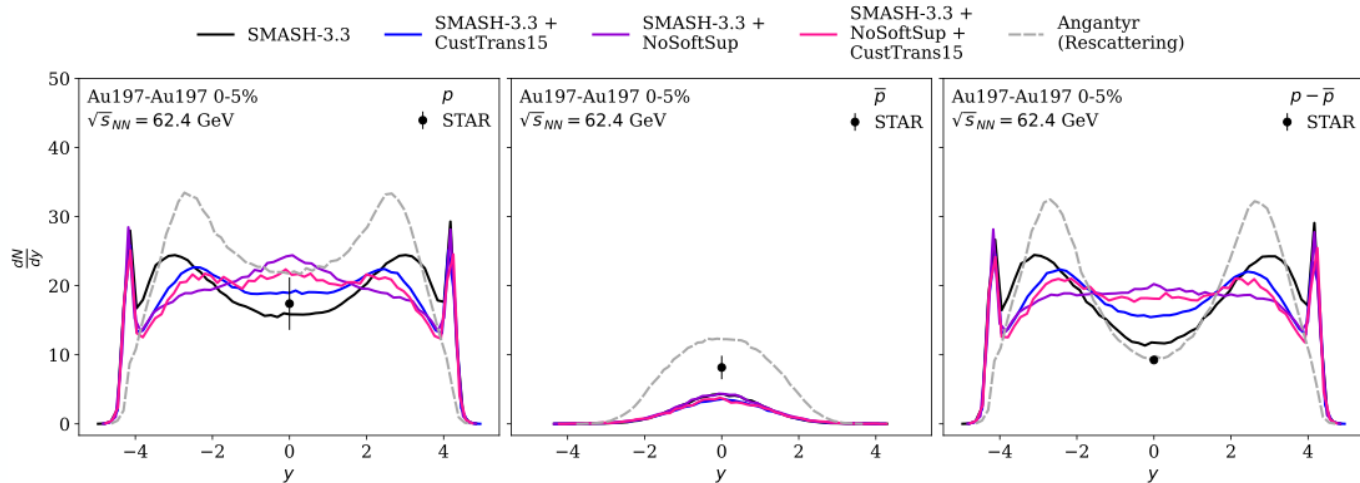
Suppression of Unformed Strings

- SMASH-3.3: suppression of unformed string processes by a factor of 0.7
 - Takes color coherence effects into account
- NoSoftSup: removing the suppression of soft string processes
- HardSup: investigating different suppression factors for string processes



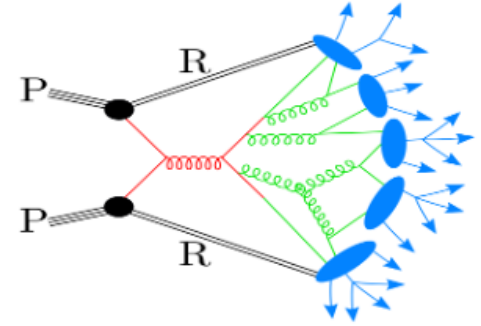
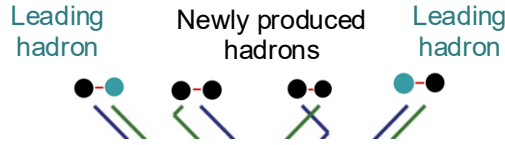
Transition between ND Processes

- SMASH-3.3: Continuous smooth transition between soft and hard processes
- **CustTrans15**: earlier and steeper transition around 15 GeV

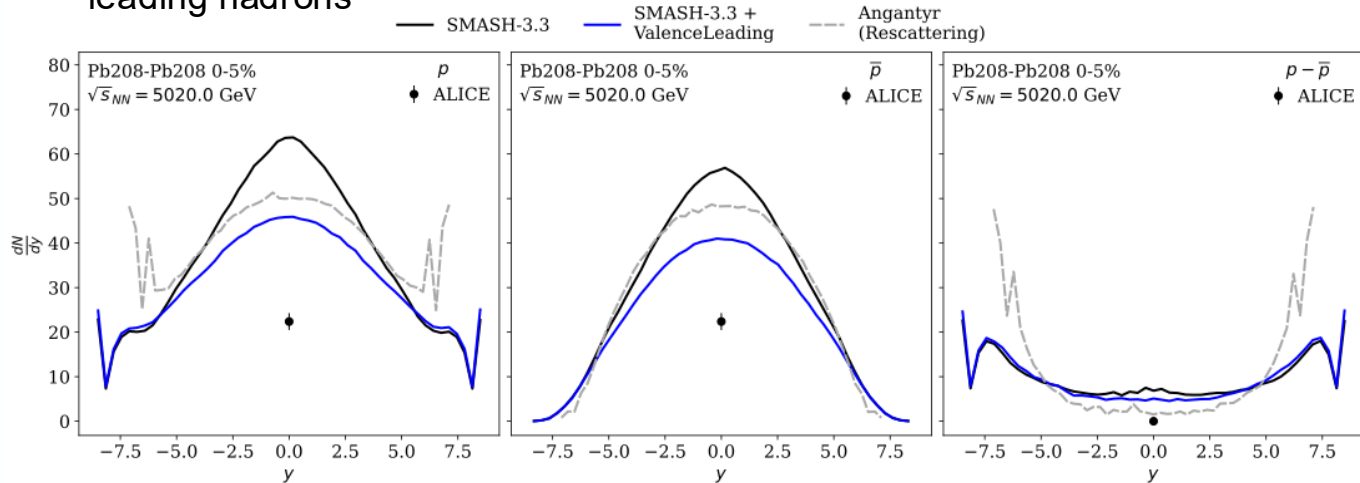


Assignment of Leading Hadrons

- SMASH-3.3: Each string is fragmented individually and assigned leading hadrons
- ValenceLeading**: Only strings with valence quarks are assigned leading hadrons



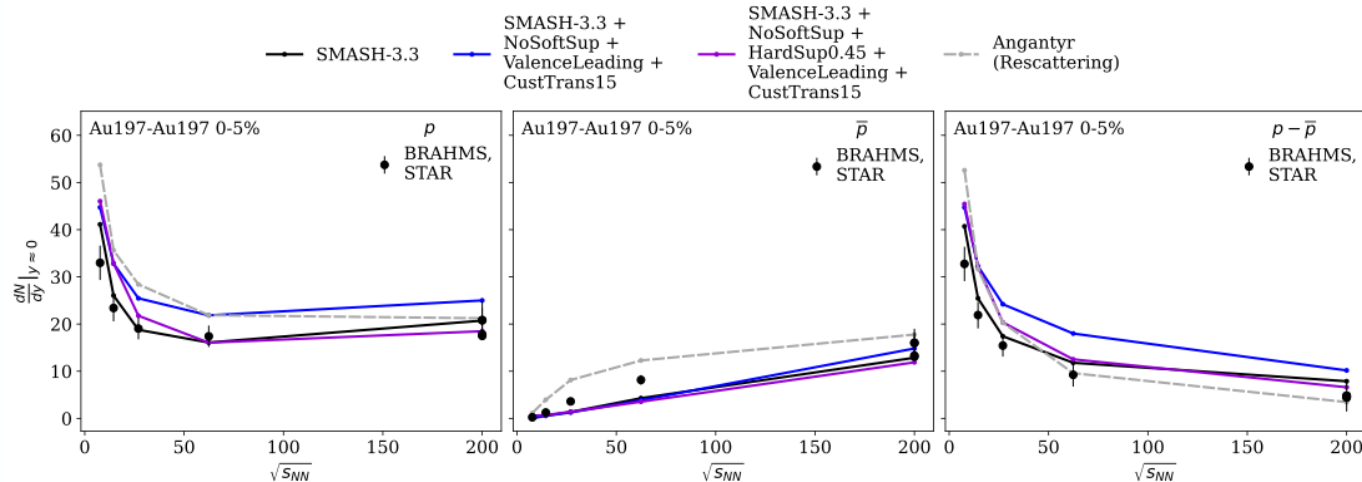
With permission, C.B. Rosenkvist



Combining Changes

Lower energies up to 200 GeV:

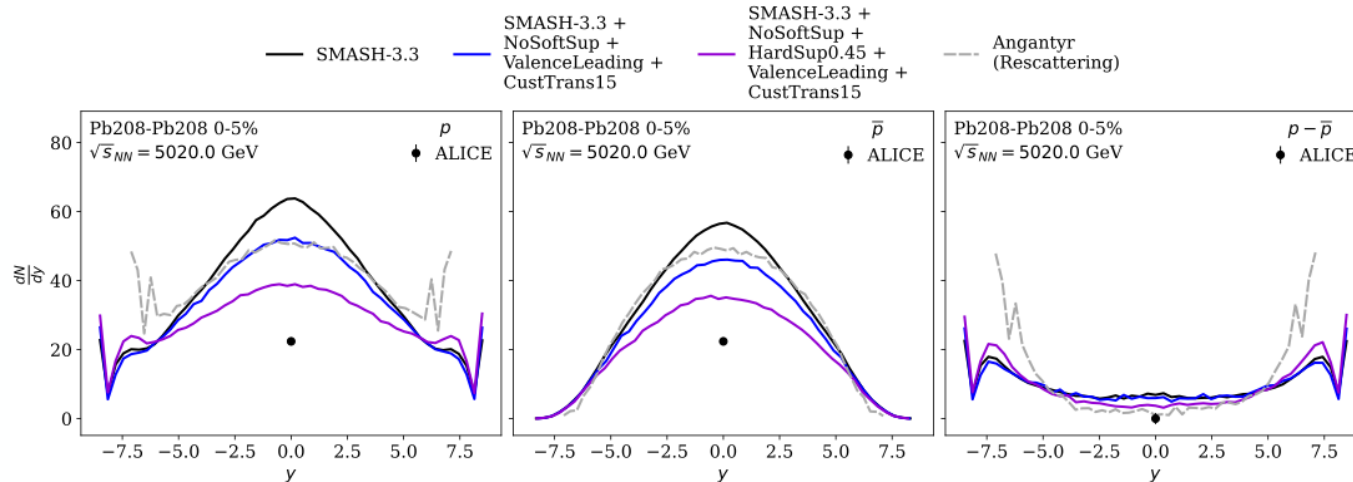
- Removing the suppression of unformed soft strings, transitioning between ND processes earlier and changing the assignment of leading hadrons overall increases baryon stopping
- Increasing the suppression of unformed hard strings partially decreases it



Combining Changes

At LHC energies

- Combined changes improve baryon stopping, although it is still high compared to data



Conclusion & Outlook

- Investigated baryon stopping in Angantyr and SMASH
- Several changes to SMASH's default behaviour were analysed to improve the underlying physical picture
- This results in an increase of baryon stopping at low, and a decrease of baryon stopping at high energies
- Additionally to the cross section, the formation time is a possible avenue to investigate baryon stopping

