The GiBUU transport model

Janus Weil, Ulrich Mosel

(for the GiBUU group)

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JUSTUS-LIEBIG-
UNIVERSITÄT
GIESSEN

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Outline

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4. propagation, potentials
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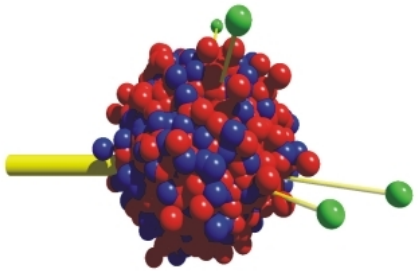
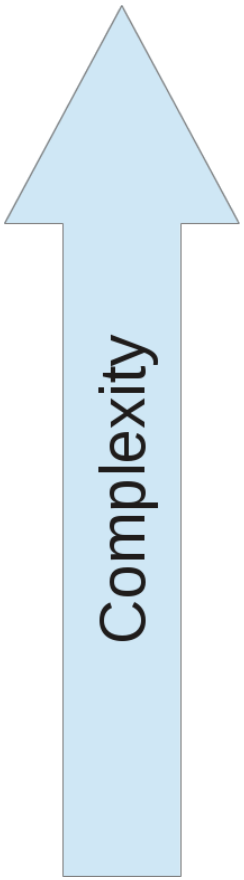


GiBUU

Introduction

- GiBUU: "The Giessen BUU transport model"
- coupled-channel hadronic transport model, based on the Boltzmann-Uehling-Uhlenbeck equation (BUU)
- unified framework for various types of reactions over a wide energy range
  - electroweak: γA, eA, νA
  - hadronic: pA, πA, KA
  - heavy-ion collisions: AA
- typical energies: $\sqrt{s} \approx 100$ MeV to 100 GeV
- review article: O. Buss et al., Phys. Rept. 512 (2012) (with all the details about physics contents)
- similar models: UrQMD, HSD, IQMD, BRoBUU, RQMD, ...

Theoretical Basis



- Kadanoff-Baym (KB) equation (1960s)
  - full equation can not be solved
  - not yet feasible for real-world problems
- Boltzmann-Uehling-Uhlenbeck (BUU) models (1980s)
  - gradient expansion of KB, quasi-particle limit
- Cascade models
  - no mean fields!

The BUU Equation

- BUU equ.: space-time evolution of phase space density F_i

$$\left[\left(1-\frac{\partial H}{\partial p_0}\right)\frac{\partial}{\partial t}+\frac{\partial H}{\partial \vec{p}}\frac{\partial}{\partial \vec{x}}-\frac{\partial H}{\partial \vec{x}}\frac{\partial}{\partial \vec{p}}+\frac{\partial H}{\partial t}\frac{\partial}{\partial p^0}\right]F_i(x,p)=C[F_i,F_j,...]$$

- i,j: particle species (N, Δ, π, ρ, ...)
- Hamiltonian H:
  - hadronic mean fields, Coulomb, "off-shell potential"
- collision term C:
  - decays and scattering processes (2- and 3-body)
- solve numerically via test-particle method:
  $F(x,p) \propto \sum_i \delta^{(3)}(\vec{x}-\vec{x}_i(t))\delta^{(4)}(p-p_i(t))$
- time evolution: collisions at discrete time steps,
  in between: propagation through mean fields

Degrees of Freedom

included hadronic states:

- 61 baryons
  - non-strange: N, Δ, 16 N^*, 13 Δ^* states
  - single-strange: Λ, Σ, 12 Λ^*, 7 Σ^* states
  - multi-strange/charmed: Ξ, Ω, Λ_c, Σ_c, Ξ_c, Ω_c
- 21 mesons
  - non-strange pseudo-scalars: π, σ, η, η', η_c
  - non-strange vectors: ρ, ω, ϕ, J/Ψ
  - strange: K, K^*
  - charmed: D, D^*, D_s, D_s^*
- 2- and 3-body decay modes, BRs taken from Manley PWA of $\pi N \to \pi N, 2\pi N$ (PRD 45, 1992) or PDG
- electromagnetic couplings from MAID (isobar model for photo- and electroproduction of pions)
- $\Rightarrow$ full consistency with hadron phenomenology

POTENTIALS AND PROPAGATION

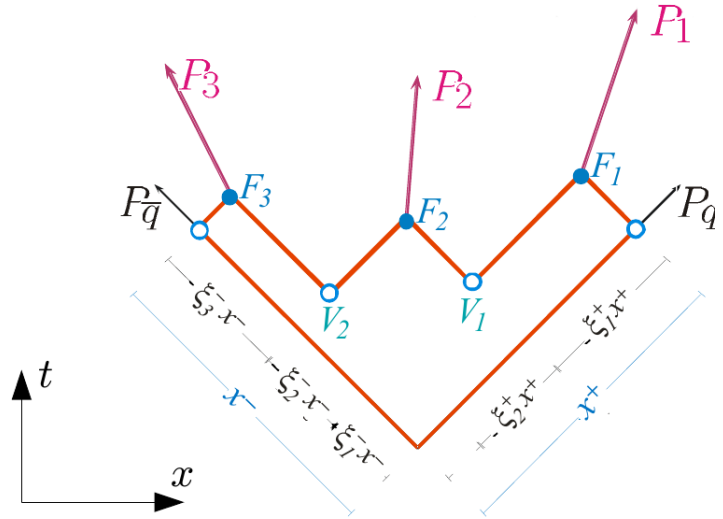
- hadronic mean fields:
  - either: non-rel. Skyrme-like potentials
  - or: relativistic mean fields (RMF)
- Coulomb potential
- "off-shell potential" (to handle density-dependent spectral functions, etc)
- dynamical density evolution (according to test particle distribution)
- mean-field propagation performed with predictor-corrector algorithm

low energies: resonance model ($\sqrt{s} \lesssim 3GeV$)

- assumption: cross sections dominated by resonance production and decay

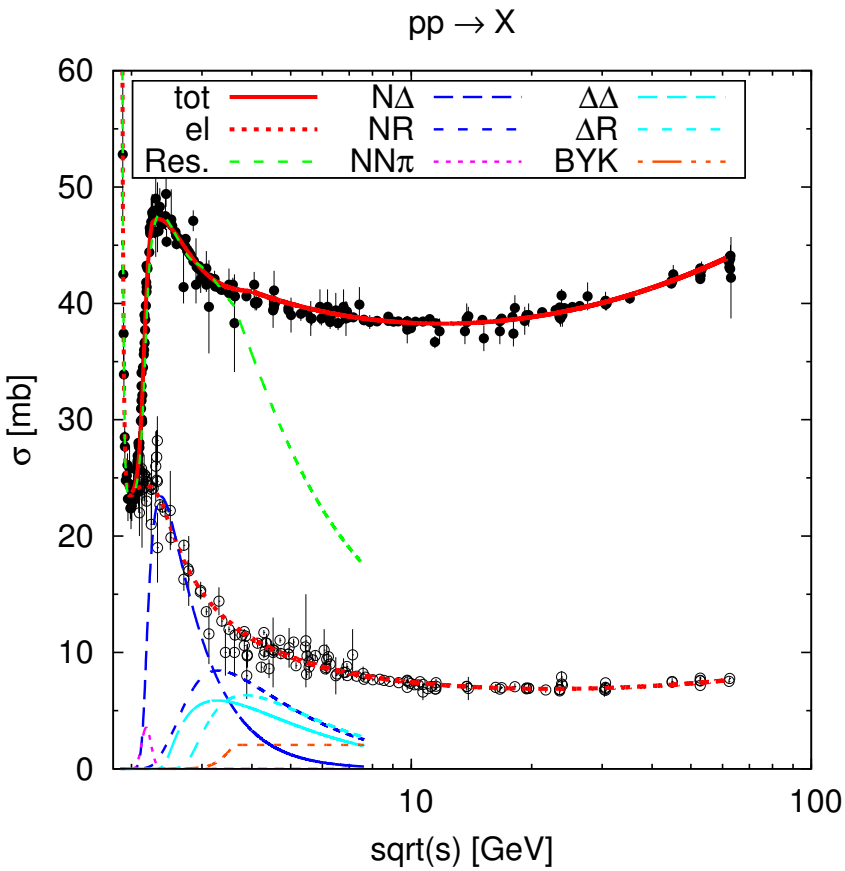
high energies: Lund string model

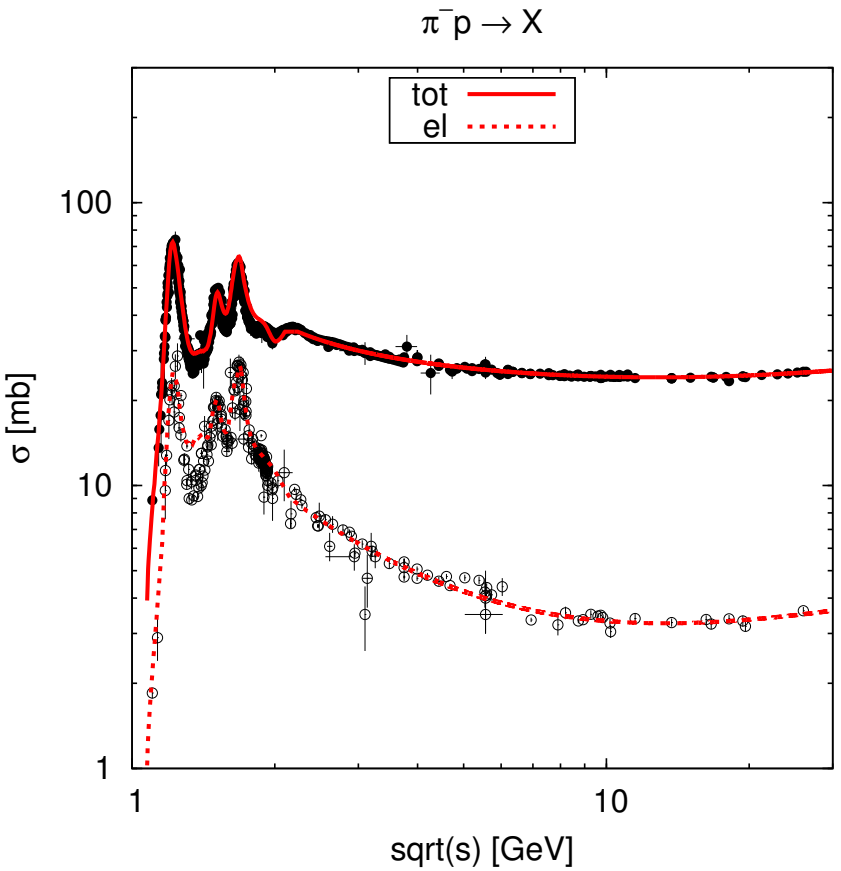
- PYTHIA 6.4
- hard pQCD interactions
- plus string fragmentation
- no N^*, Δ^*



in between: small transition region with mixed events from both models

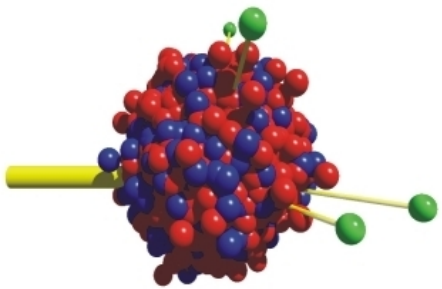
ELEMENTARY CROSS SECTIONS





Code

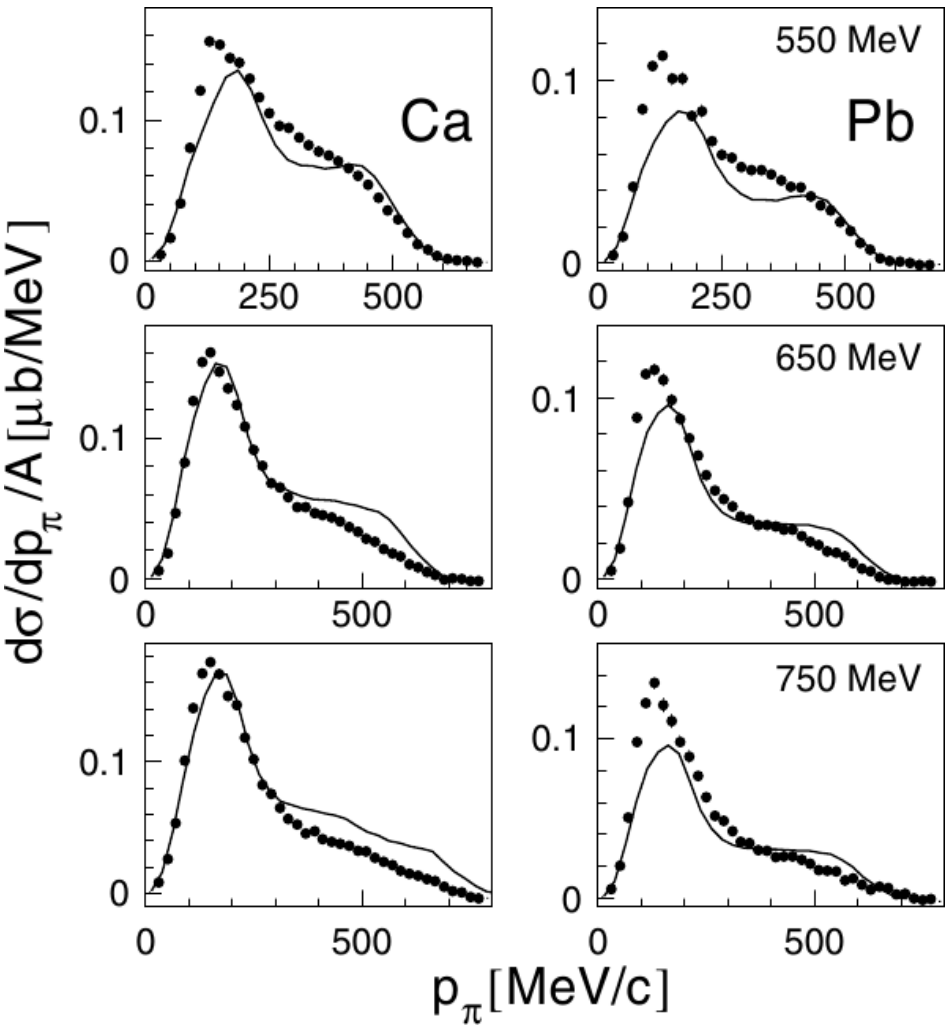
- modular and flexible Fortran code base (F95/2003)
- version control (svn): collaboration & reproducibility
- well documented (RoboDoc)
- publicly available releases (open source)
- website: http://gibuu.physik.uni-giessen.de

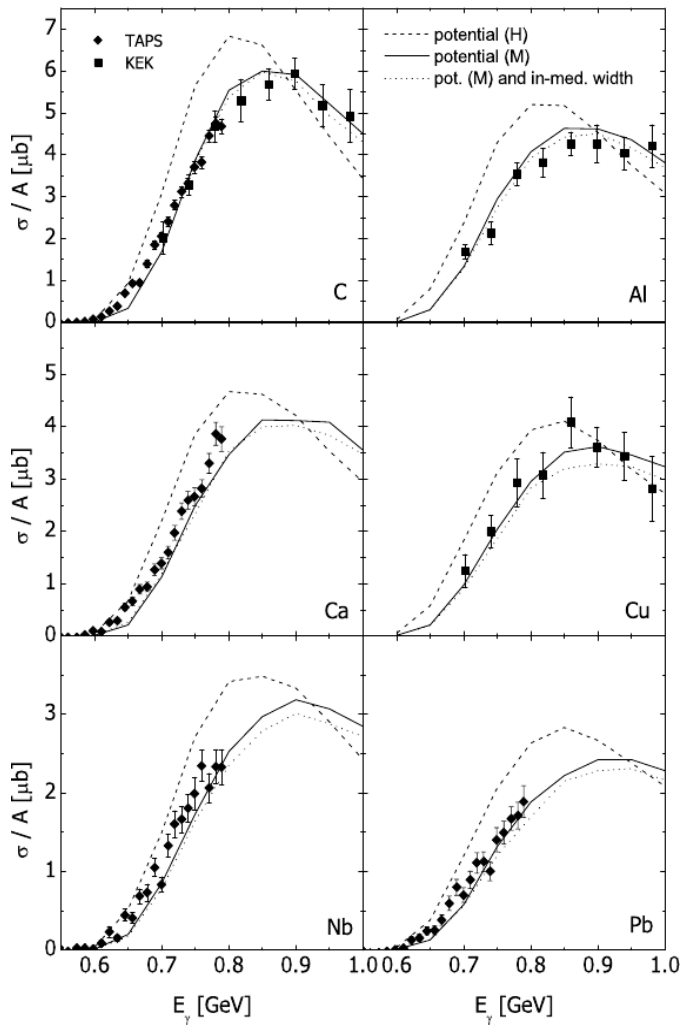


GiBUU

The Giessen Boltzmann-Uehling-Uhlenbeck Project

Applications (1): $\gamma A \to \pi^0 X,\ \eta X$

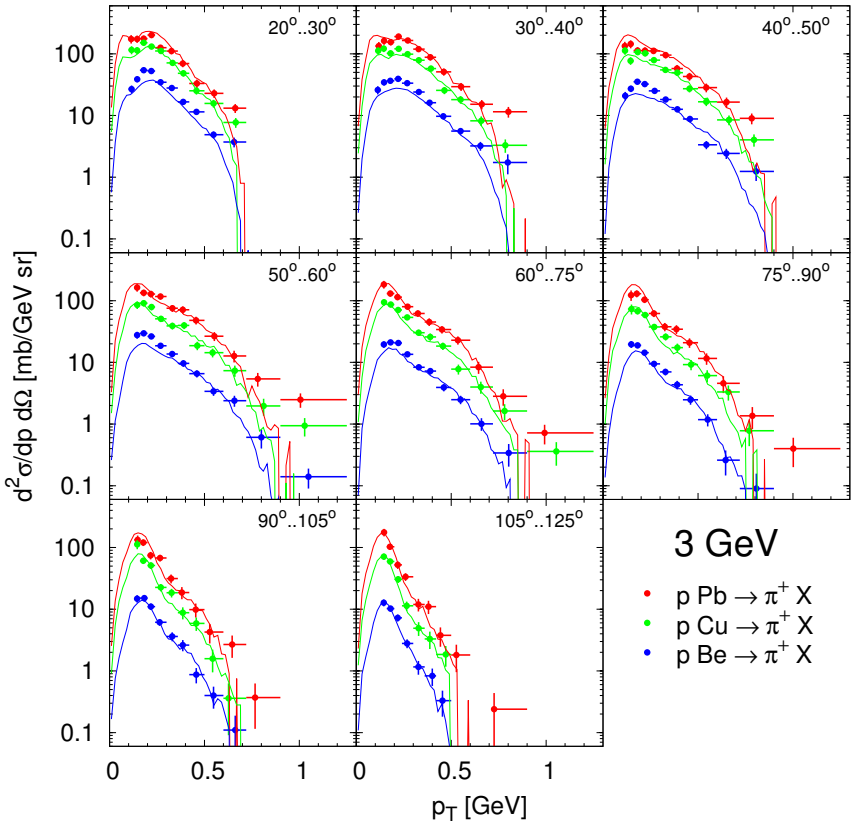


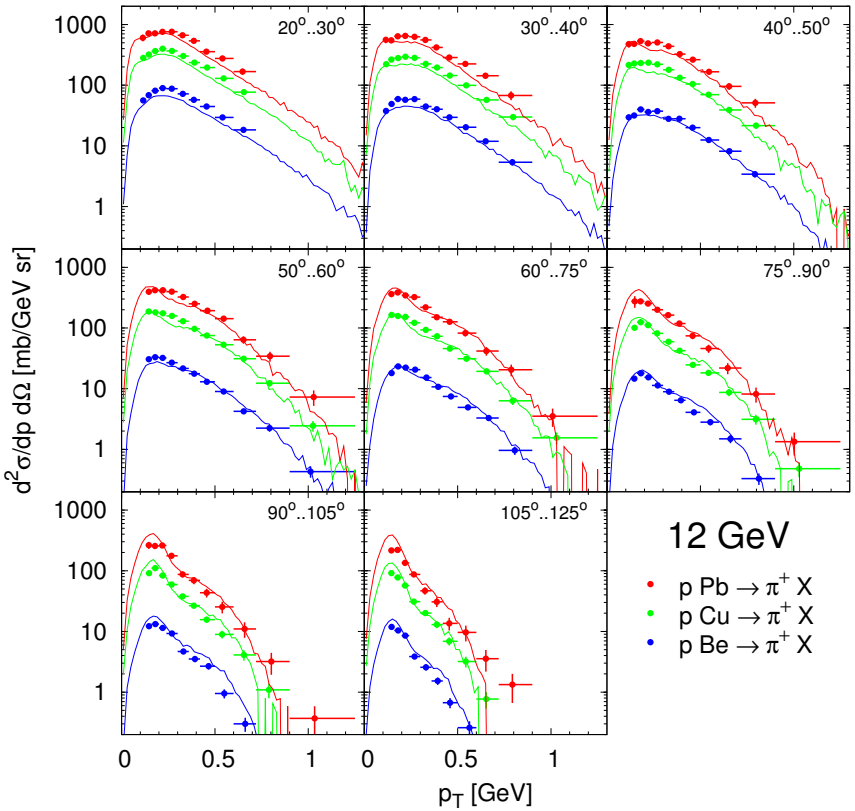


Lehr et al., EPJA 22 (2004), PRC 68 (2003)

Applications (2): $pA \to \pi X$

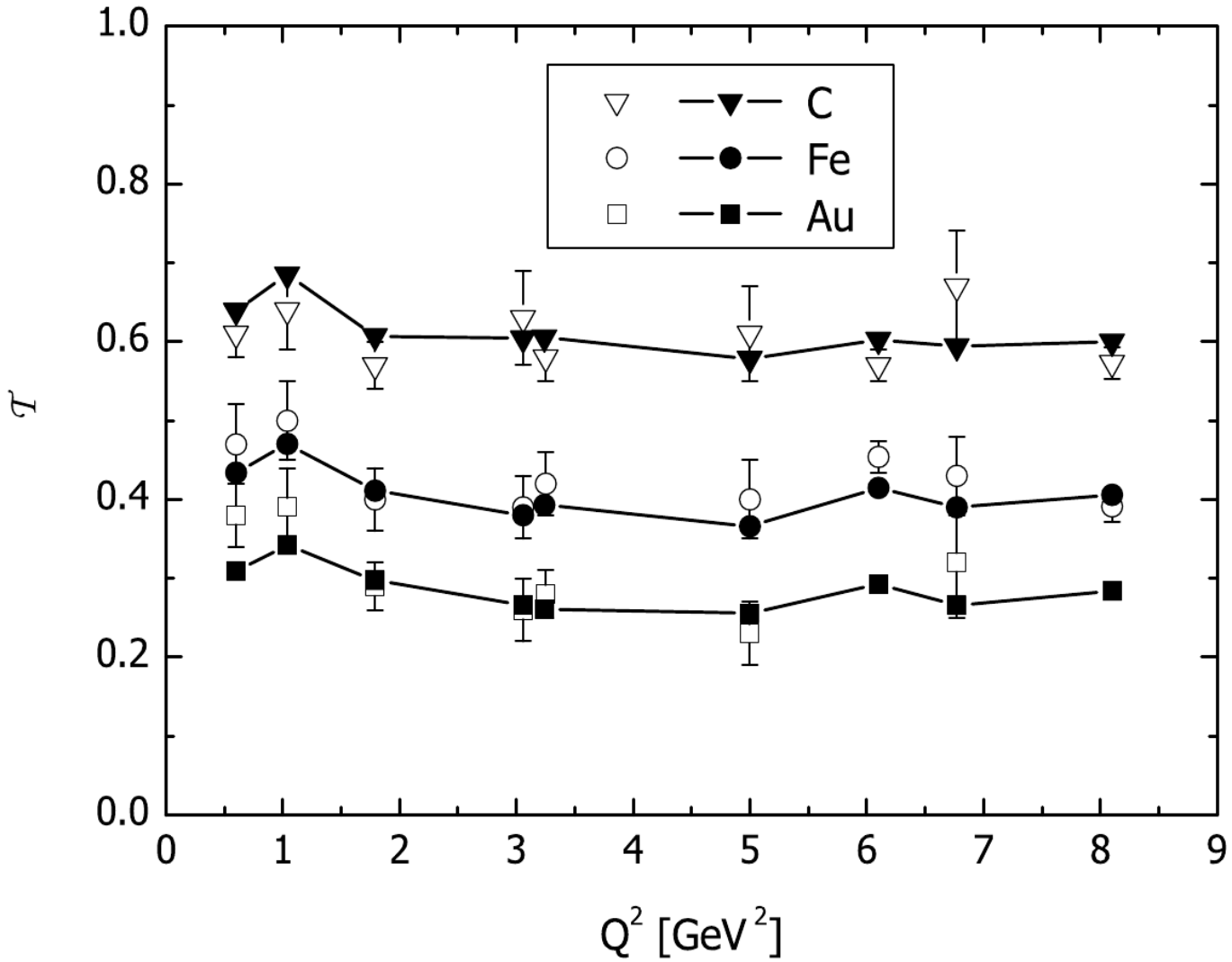
- GiBUU nicely describes inclusive pion production data by the HARP collaboration (Gallmeister et al., NPA 826, 2009)





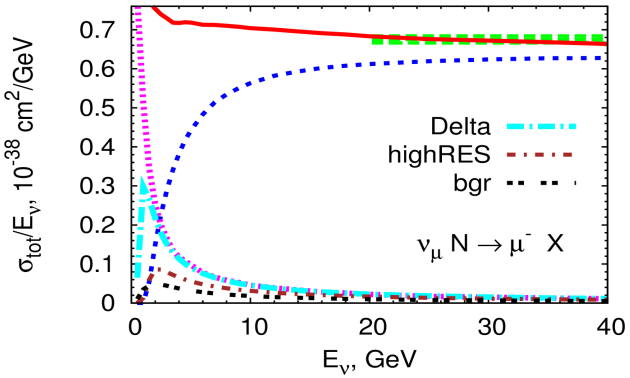
Applications (3): Proton Transparency

$eA \to pX$, Lehr NPA 699 (2002), data from JLab/SLAC

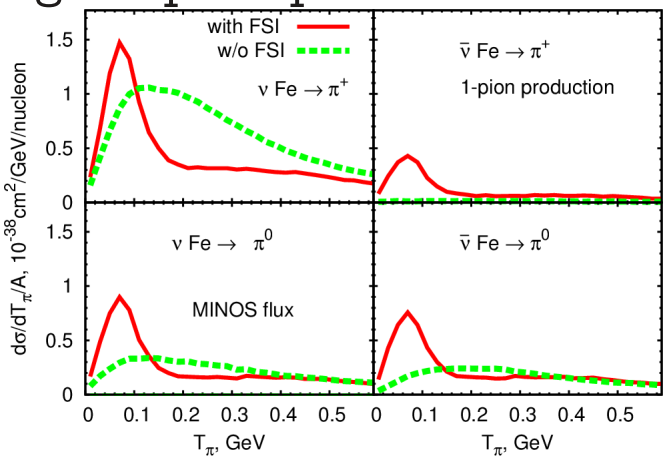


Neutrinos in GiBUU

$\nu A \rightarrow \ell X$



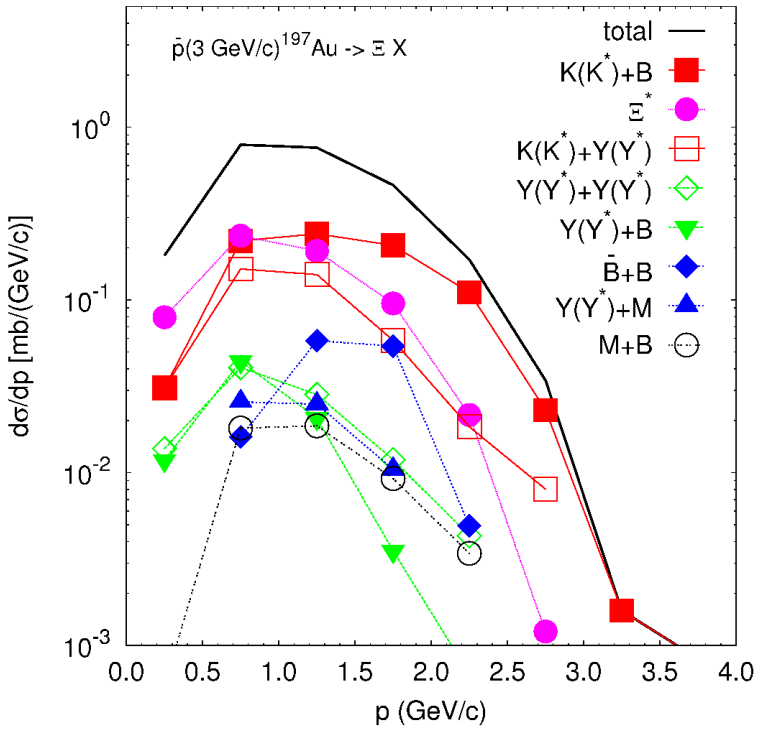
e.g. 1-pion production on Fe



Lalakulich et al., PRC 86 (2012)

Strangeness production in $\bar{p}$A reactions

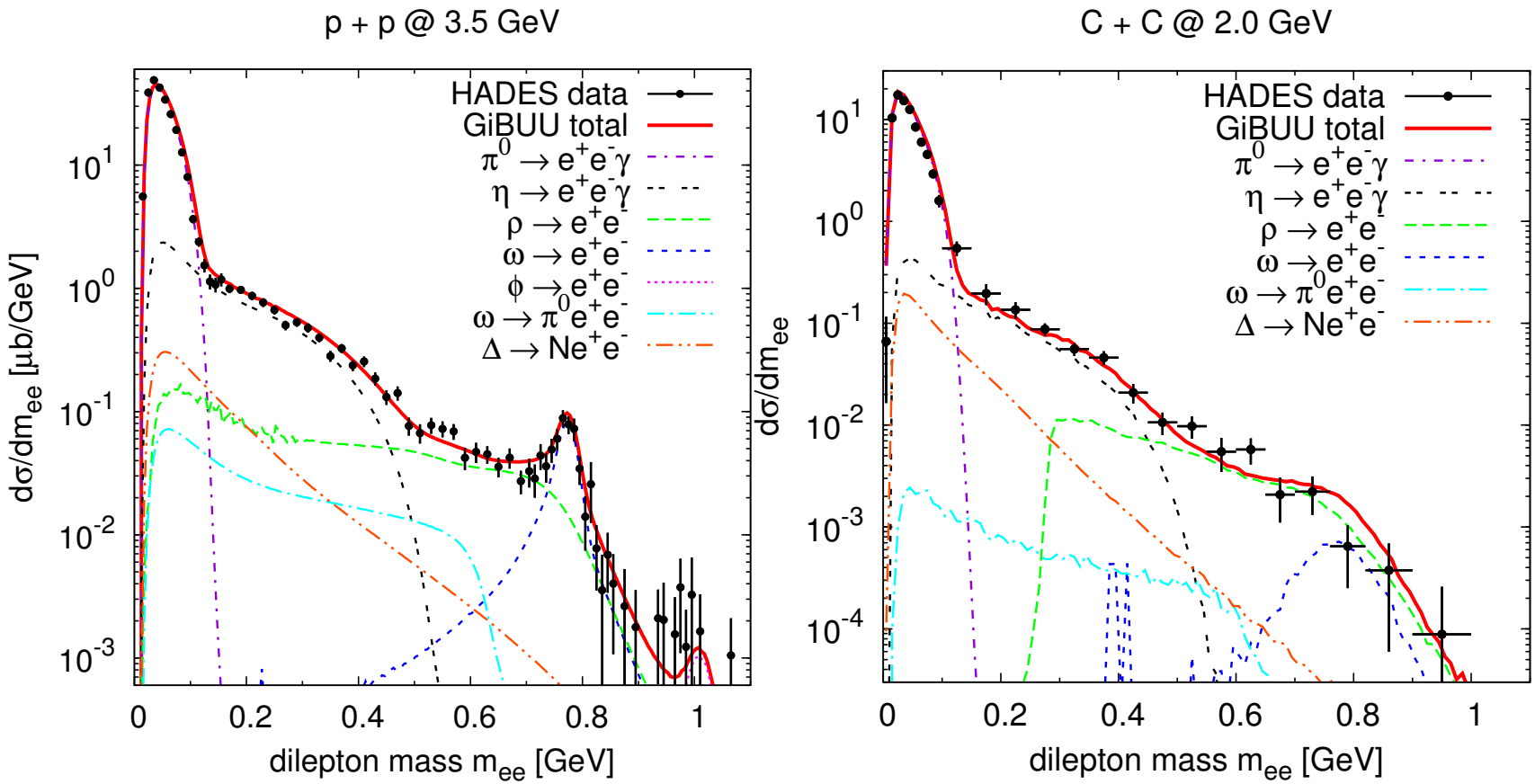
Predictions for PANDA@FAIR



Larionov et al., PRC 85 (2012)

Applications (5): Dileptons

- good description of dilepton data measured by HADES @ GSI (Weil et al., arXiv:1203.3557)



Applications (5)

- color transparency
- hypernuclei
- hadron attenuation
- fragment formation
- in-medium properties of hadrons
- ...

Conclusions

1. GiBUU is a versatile simulation tool
2. covers many different reaction types
3. over a wide range of energies
4. well-tested in various areas
5. source code available

$\Rightarrow$ http://gibuu.physik.uni-giessen.de