New CHIPS development

Mikhail Kosov, Lisbon, 2006

Plan

- CHIPS simulation of μ-nuclear reactions
  - Universal G4QCollision process
  - Comparison with G4MuNuclearInteraction
- Improvement of QGSC against QGSP
  - Compensation of lack of nuclear fragmentation
- CHIPS approach to A-A reactions
  - Algorithm for ion-ion total cross sections
  - Quark exchange (Regeon) and gluon exchange (Pomeron) algorithms of nuclear excitation

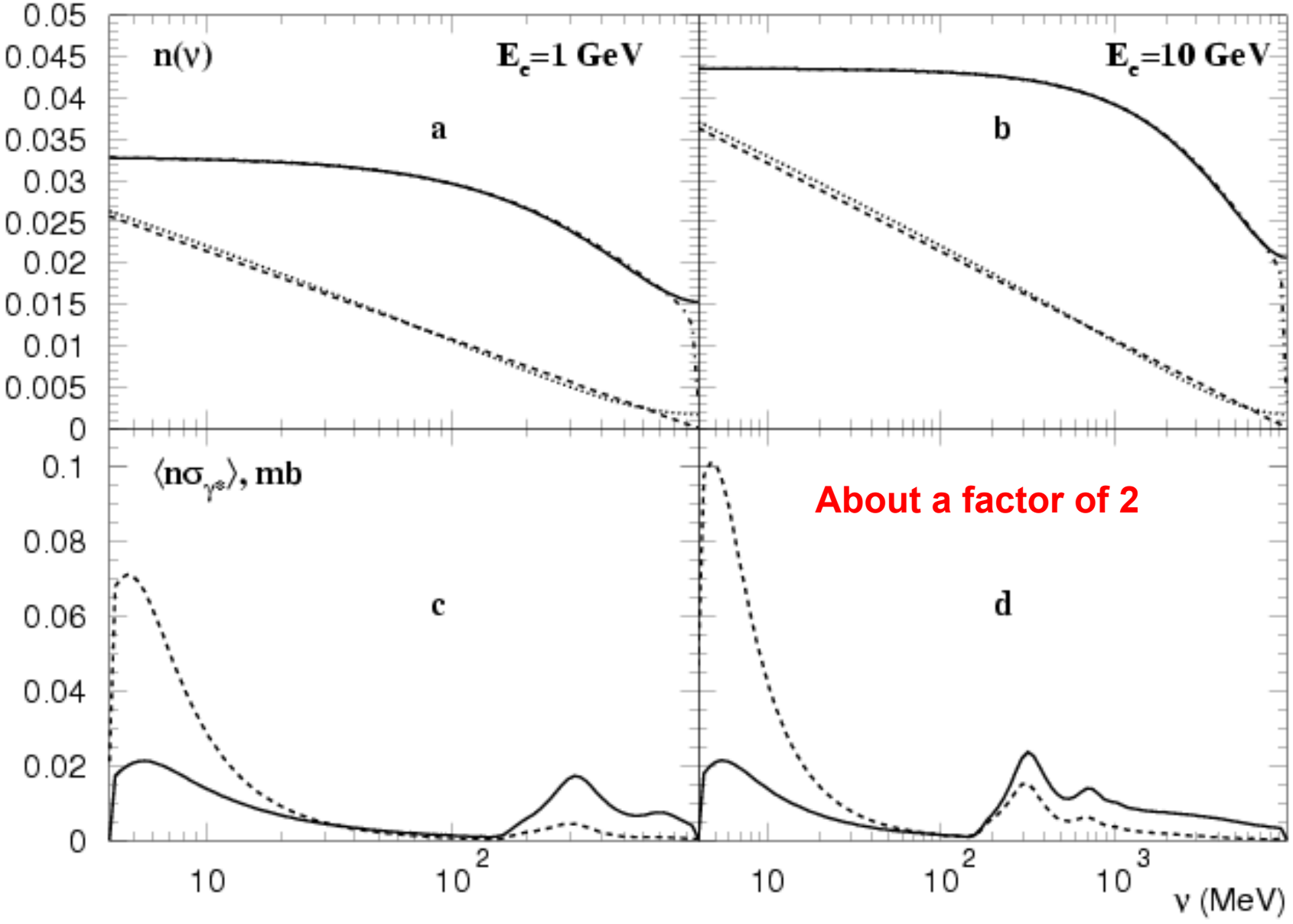
Importance of μ-nuclear reactions

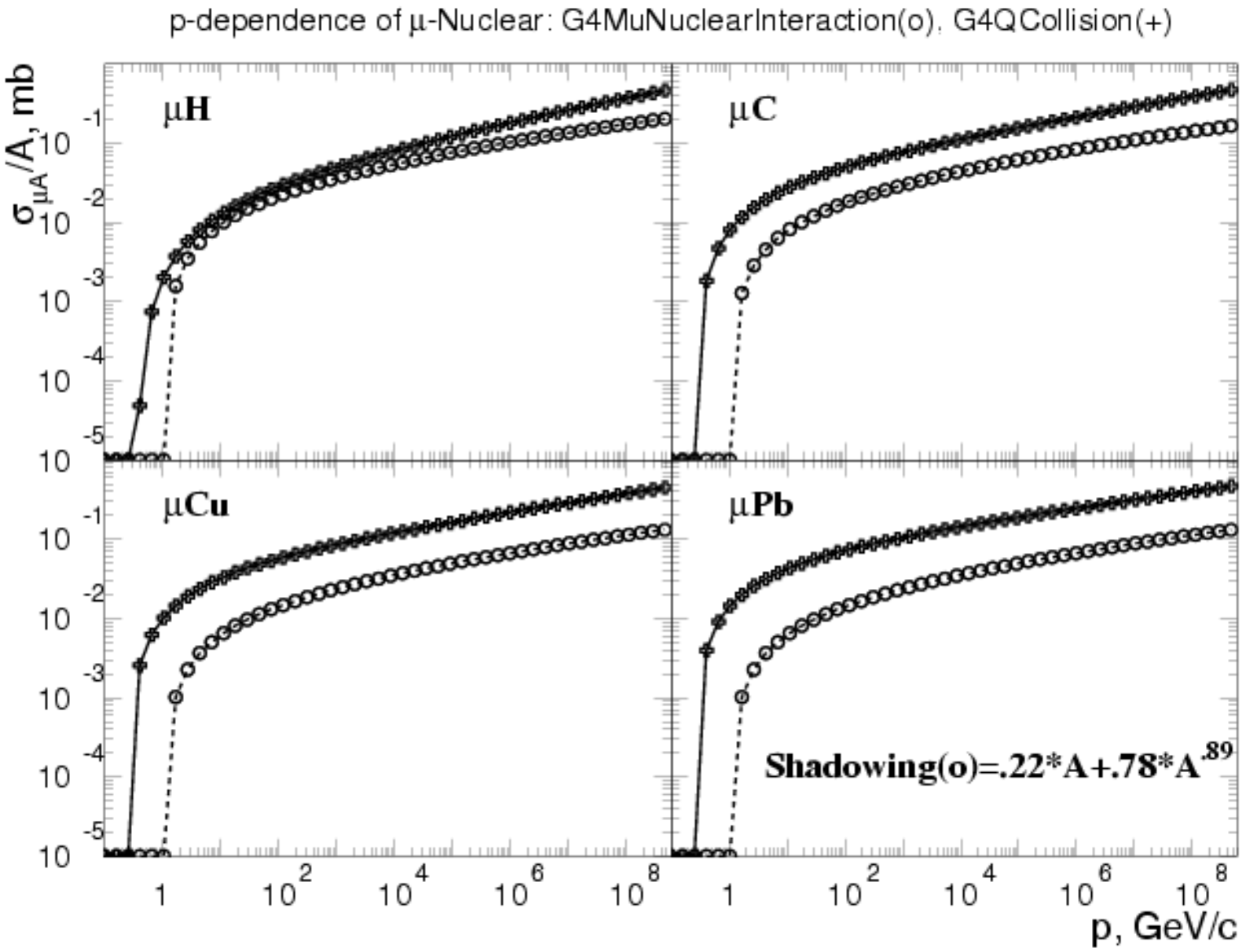
- Simulation of catastrophic μ energy loss and correlated μ BG in LHC experiments
  - Energy loss of μ reduces momentum resolution
  - High Q^2 interactions change direction of μ
  - Nuclear reactions produce punch through $\pi \rightarrow \mu$
- Interaction of high energy leptons of International Linear Collider with matter
  - Accelerator simulation, neutron production
- Simulation of scattering/absorption of atmospheric μ in cosmic experiments
  - Hadronic/electromagnetic attenuation ratio

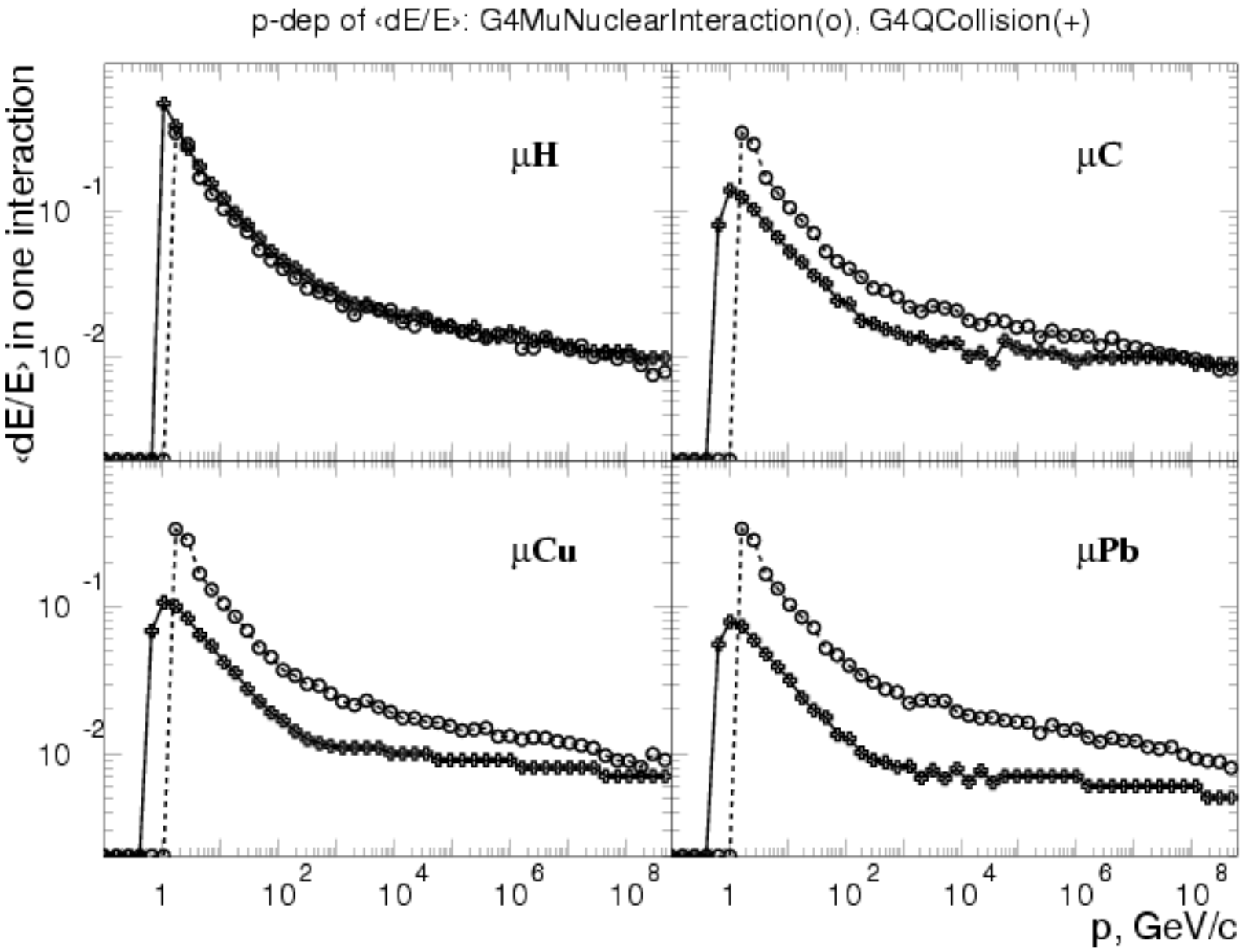
Development of α-version of μ-nuclear

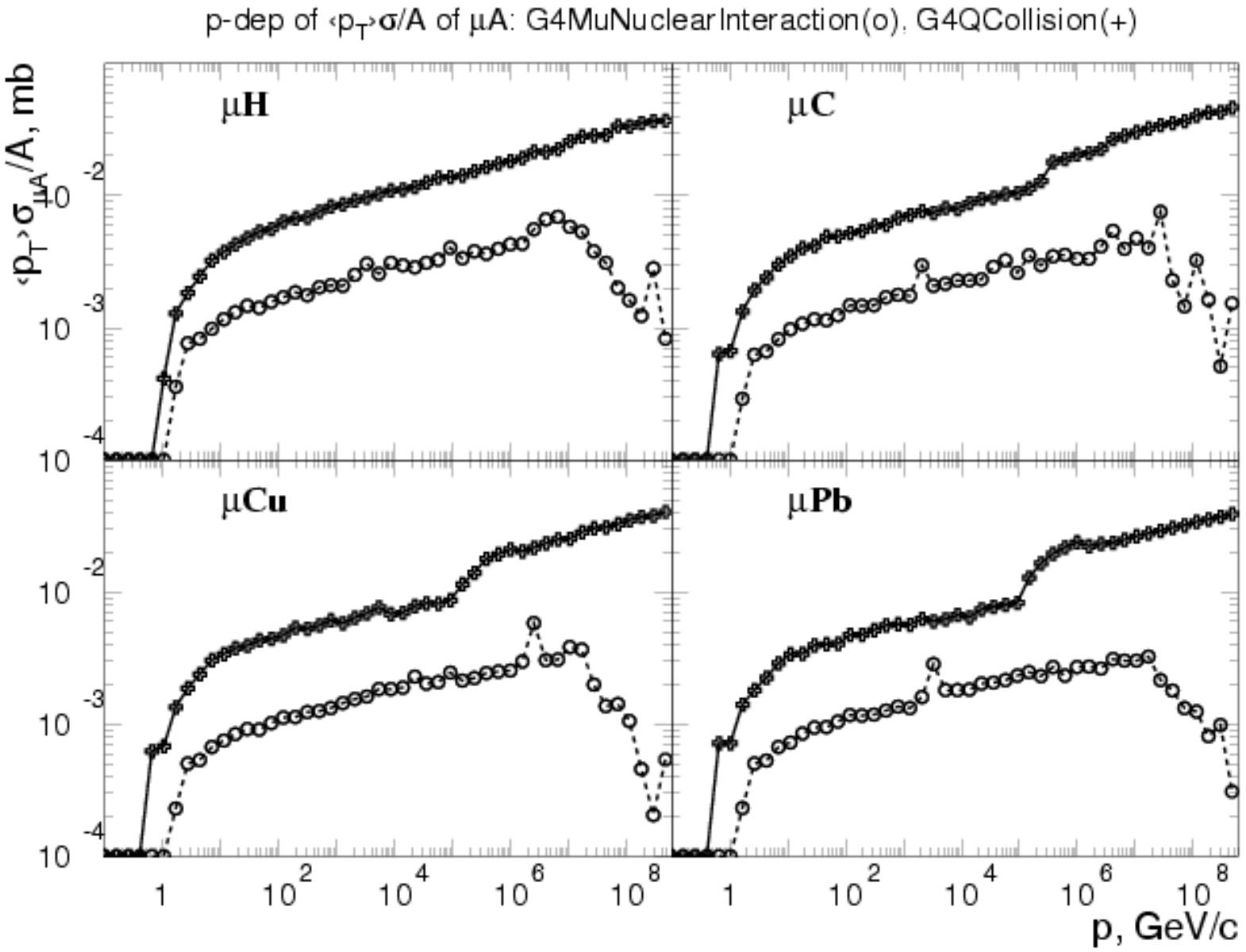
- Published CHIPS algorithm (**Eur.Phys.J.A14(2002)377**) for electron-nuclear reactions is generalized for μ and τ leptons.
- Universal **G4QCollision** process is made for e, μ, τ, and γ:
  - e with G4QElectroNuclearCrossSection
  - μ with G4QMuonNuclearCrossSection
  - τ with G4QTauNuclearCrossSection
  - γ with G4QPhotoNuclearCrossSection
- **G4QCollision** CHIPS process can be used instead of
  - e: G4ElectronNuclearProcess/G4PositronNuclearProcess
  - μ: G4MuNuclearInteraction (π^0 is used for nuclear reaction)
  - τ: *** **G4QCollision** is unique ***
  - γ: G4PhotoNuclearProcess(CHIPS for E<3GeV,QGSC for E>3GeV)
- **G4QCollision** process can be considered together with **G4QCaptureAtRest** process for μ^- and τ^- nuclear capture

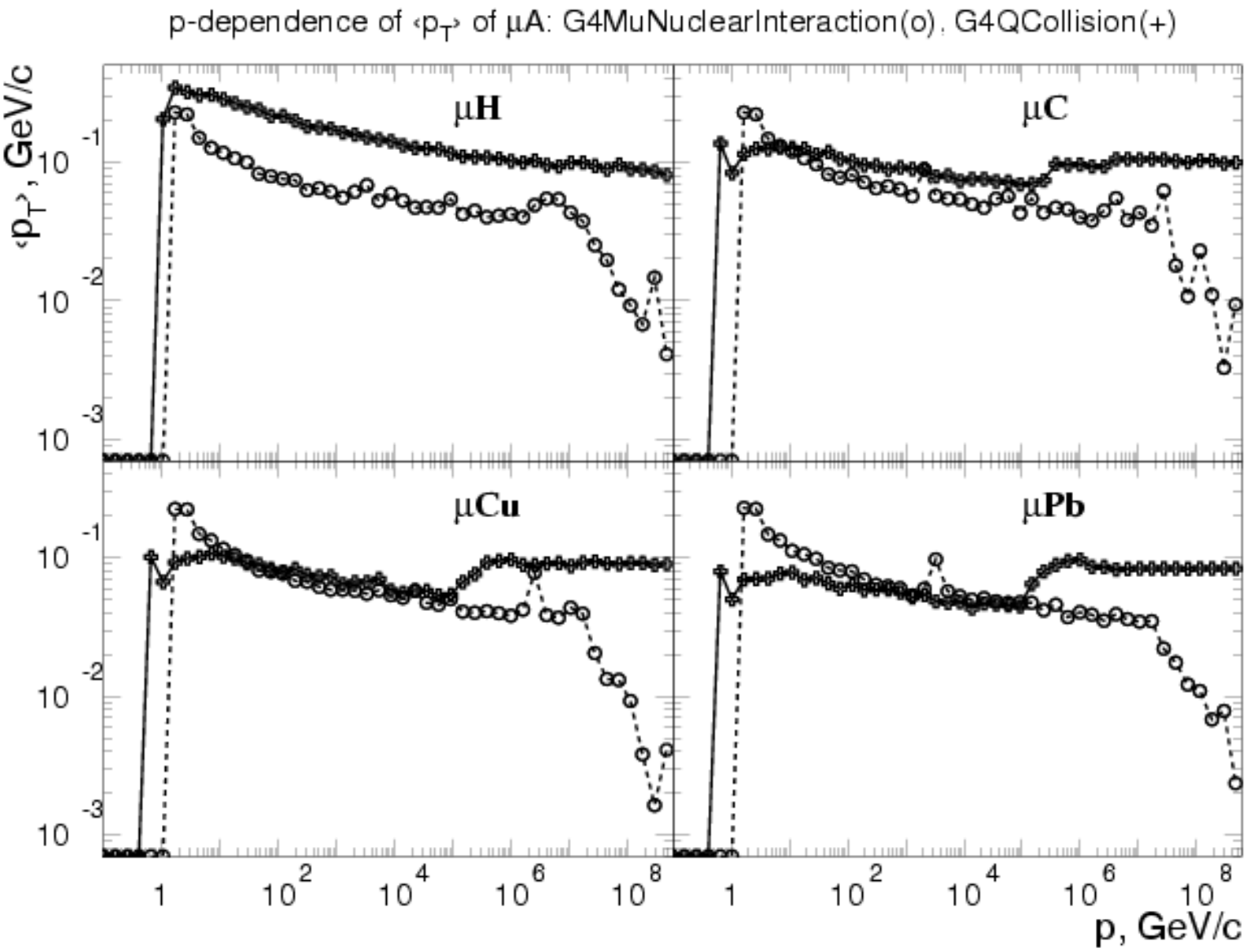
Quasi-real effective photons (dashed lines), all (a,b), high Q^2 (c,d) (solid lines)

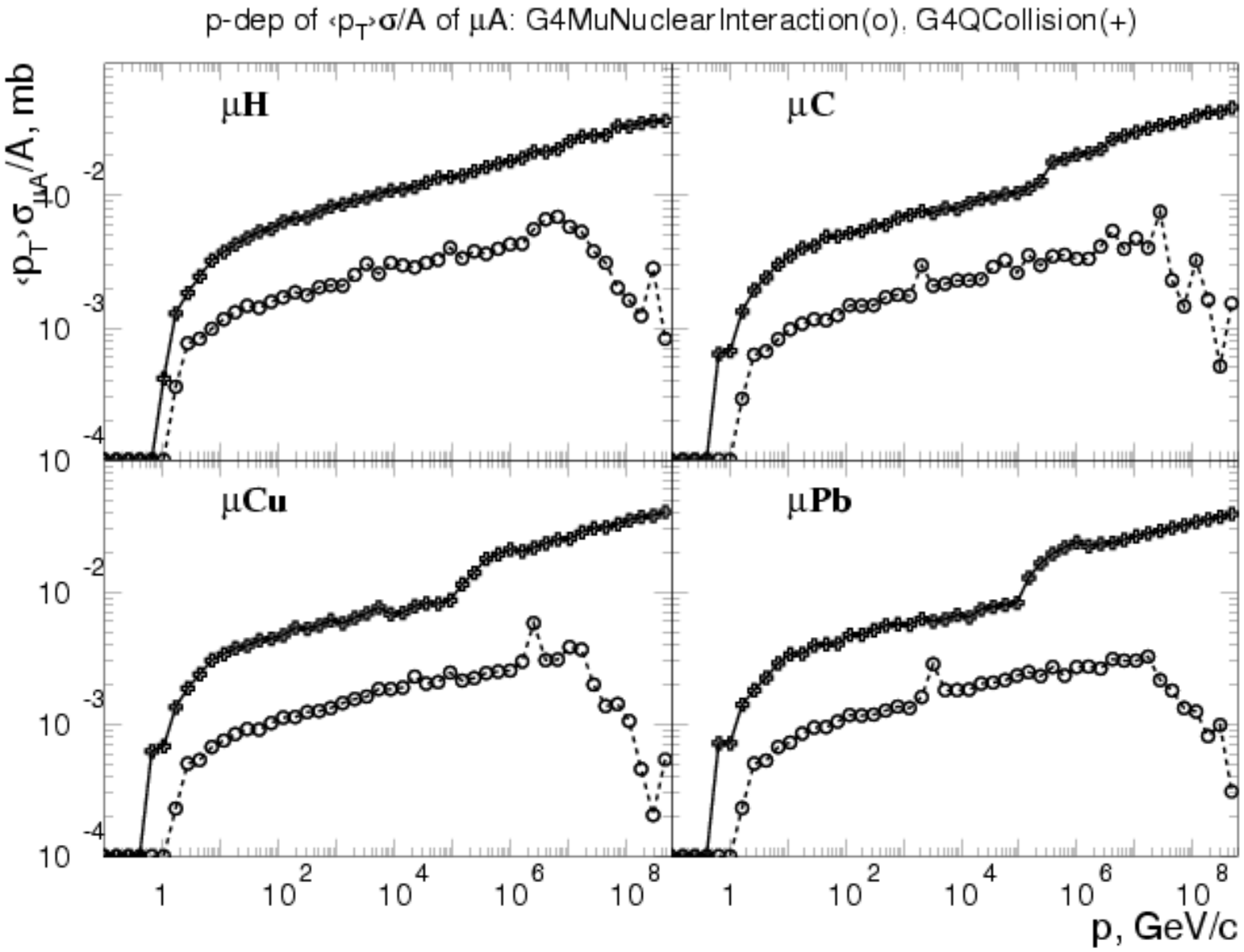



p-dependence of μ-Nuclear: G4MuNuclearInteraction(o), G4QCollision(+)
σμA/A, mb
μH
μC
μCu
μPb
Shadowing(o)=.22*A+.78*A^.89
p, GeV/c


p-dep of ‹dE/E›: G4MuNuclearInteraction(o), G4QCollision(+)
‹dE/E› in one interaction
μH
μC
μCu
μPb
p, GeV/c

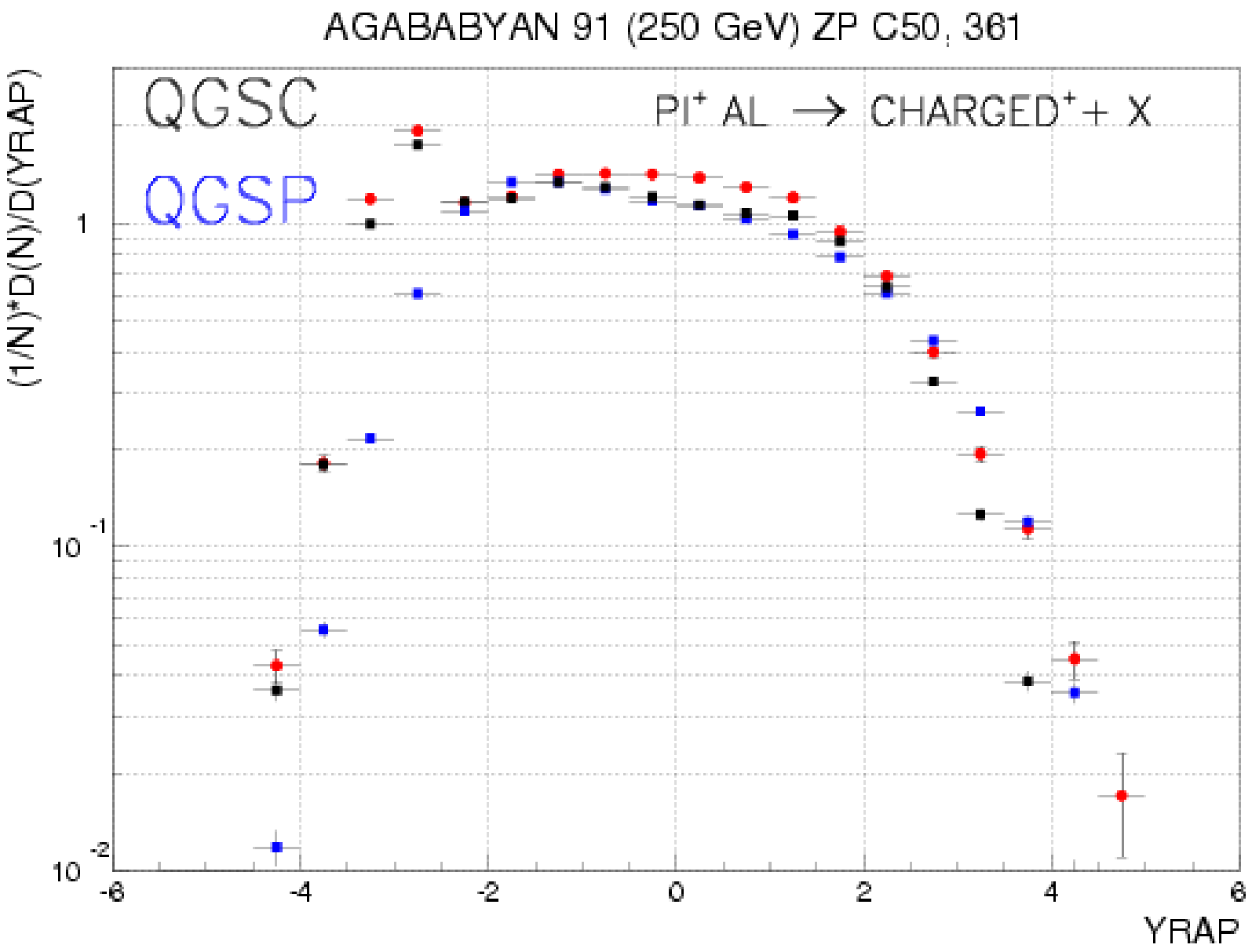

p-dep of ‹p_T›σ/A of μA: G4MuNuclearInteraction(o), G4QCollision(+)
‹p_T›σ_μA/A, mb
μH
μC
μCu
μPb
p, GeV/c

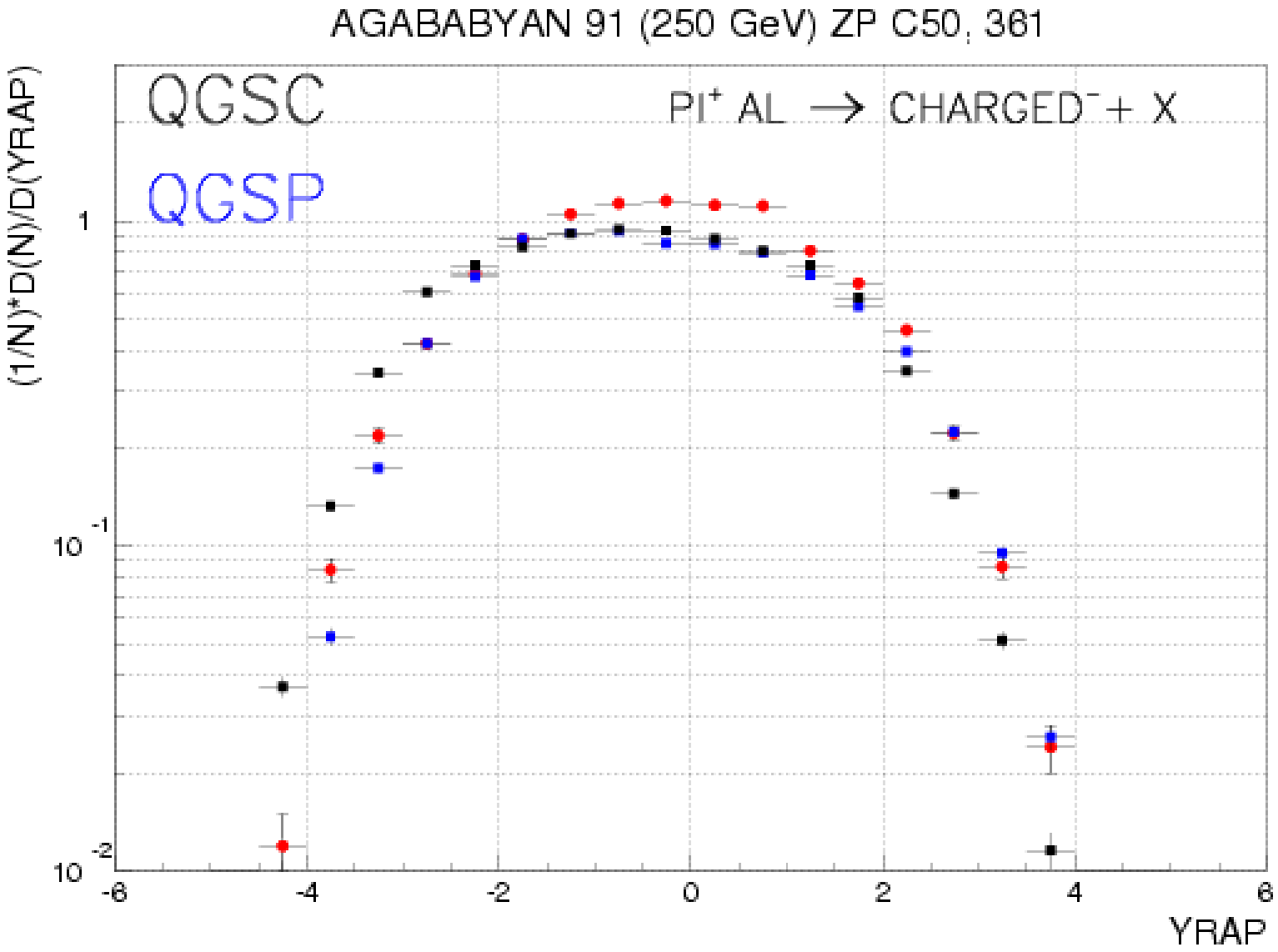

p-dependence of ‹p_T› of μA: G4MuNuclearInteraction(o), G4QCollision(+)
‹p_T›, GeV/c
μH
μC
μCu
μPb
p, GeV/c


p-dep of ‹p_T›σ/A of μA: G4MuNuclearInteraction(o), G4QCollision(+)
μH
μC
μCu
μPb
‹p_T›σ_μA/A, mb
p, GeV/c

Nuclear fragmentation in QGSC model

- QGS with CHIPS nuclear fragmentation is QGSC
  - Nuclear stopping power: 1 GeV/fm → 1.5 GeV/fm
  - Absorption radius (in % of max density): 50% →70%
  - 1 Quasmon for total energy flow instead of a separate Quasmons for each low rapidity QGS particle
- QGSP has only a small Particle-Hole nuclear excitation and practically makes only evaporation
  - NA22 experiment (Red) is blind for P_p< 0.2 GeV/c protons
- QGSC produces more nuclear protons but a soft part of them is cut off by the NA22 acceptance
- Important: NA22 experiment cuts off diffraction part, while QGS includes the diffraction (no special cuts!)


AGABABYAN 91 (250 GeV) ZP C50, 361
QGSC
QGSP
PI+ AL → CHARGED+ + X
(1/N)*D(N)/D(YRAP)
1
10-1
10-2
-6
-4
-2
0
2
4
6
YRAP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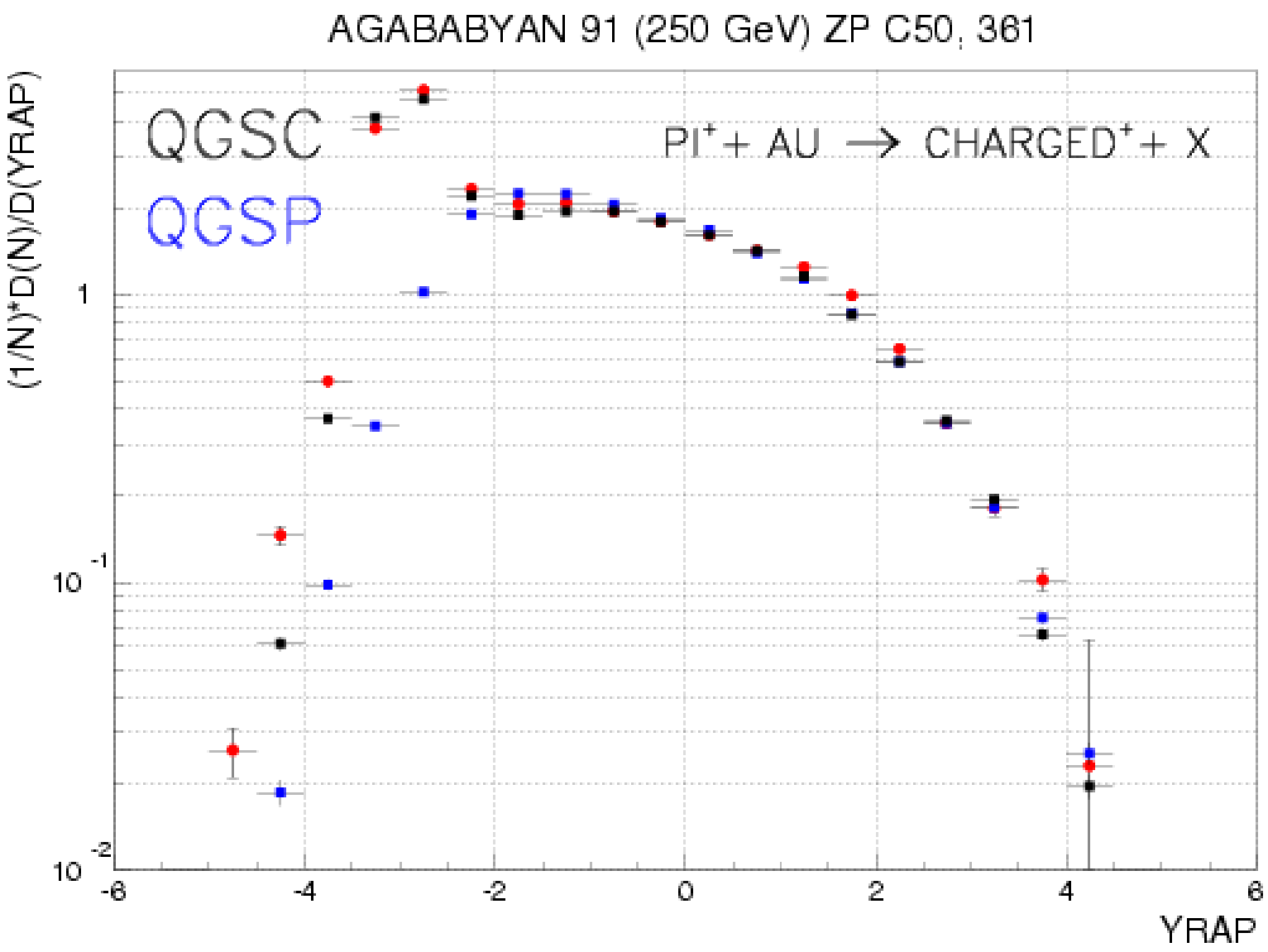
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QGSC
QGSP
PI+ + AU → CHARGED+ + X
(1/N)*D(N)/D(YRAP)
1
10-1
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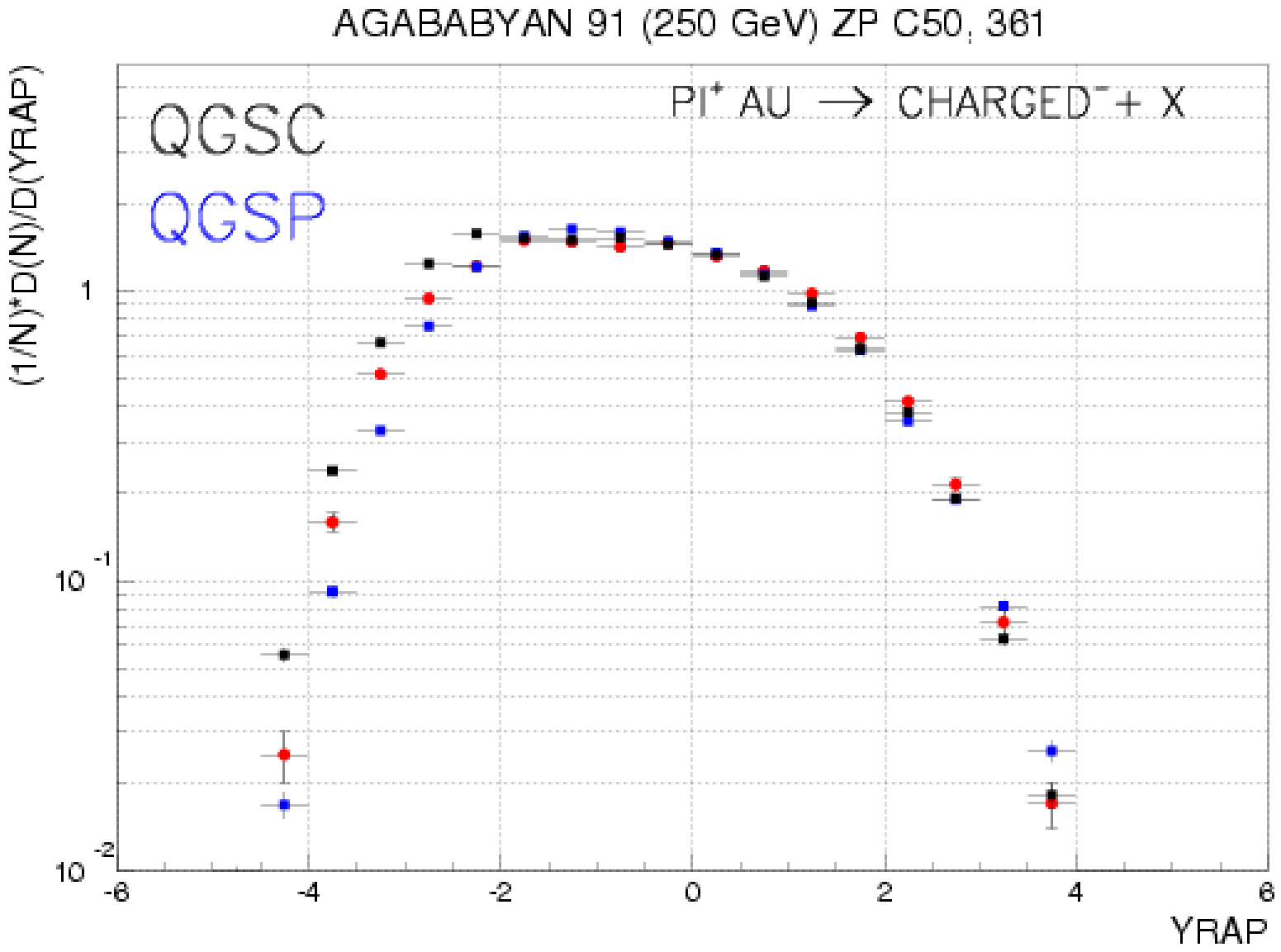
0
2
4
6
YRAP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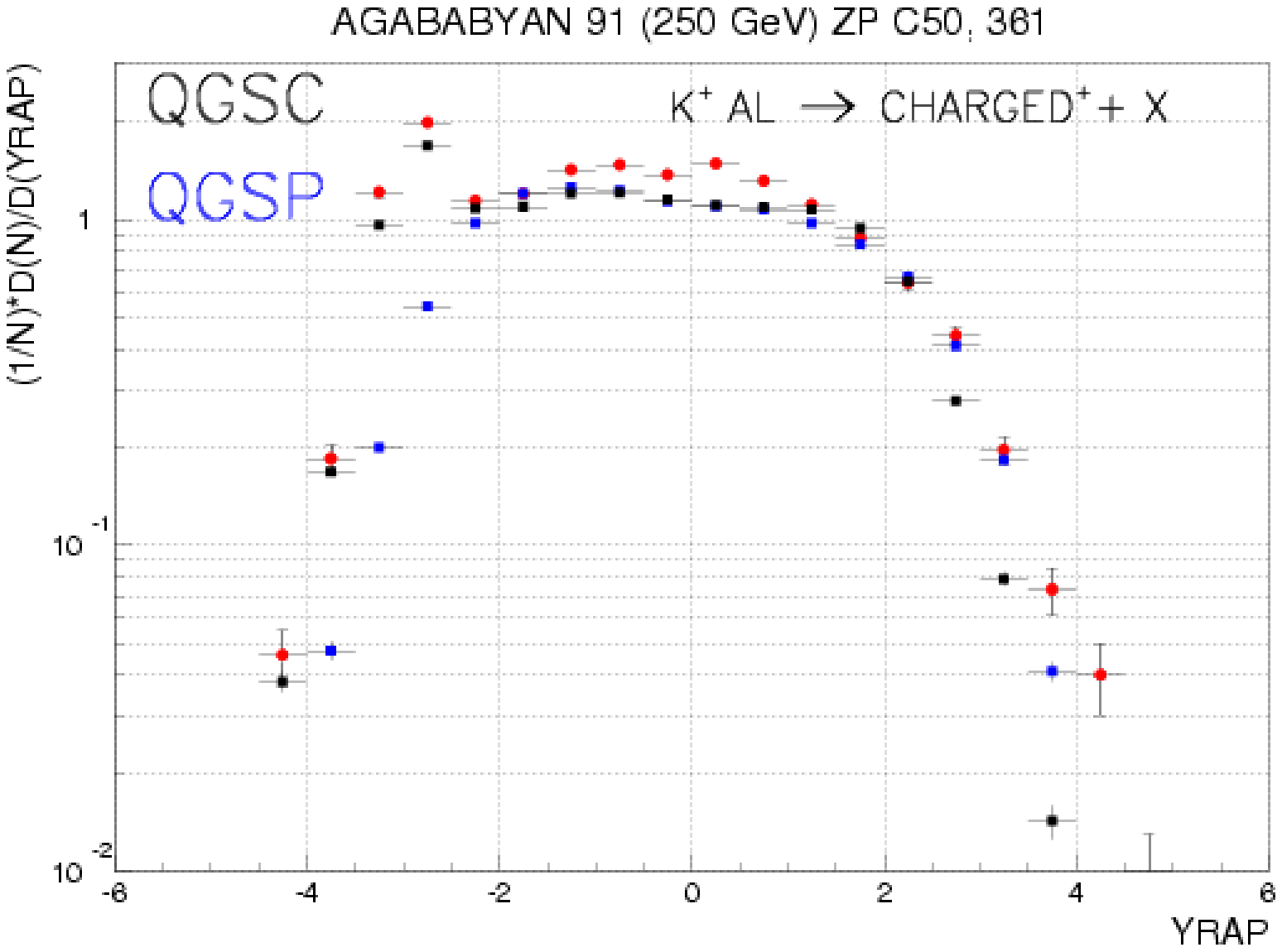
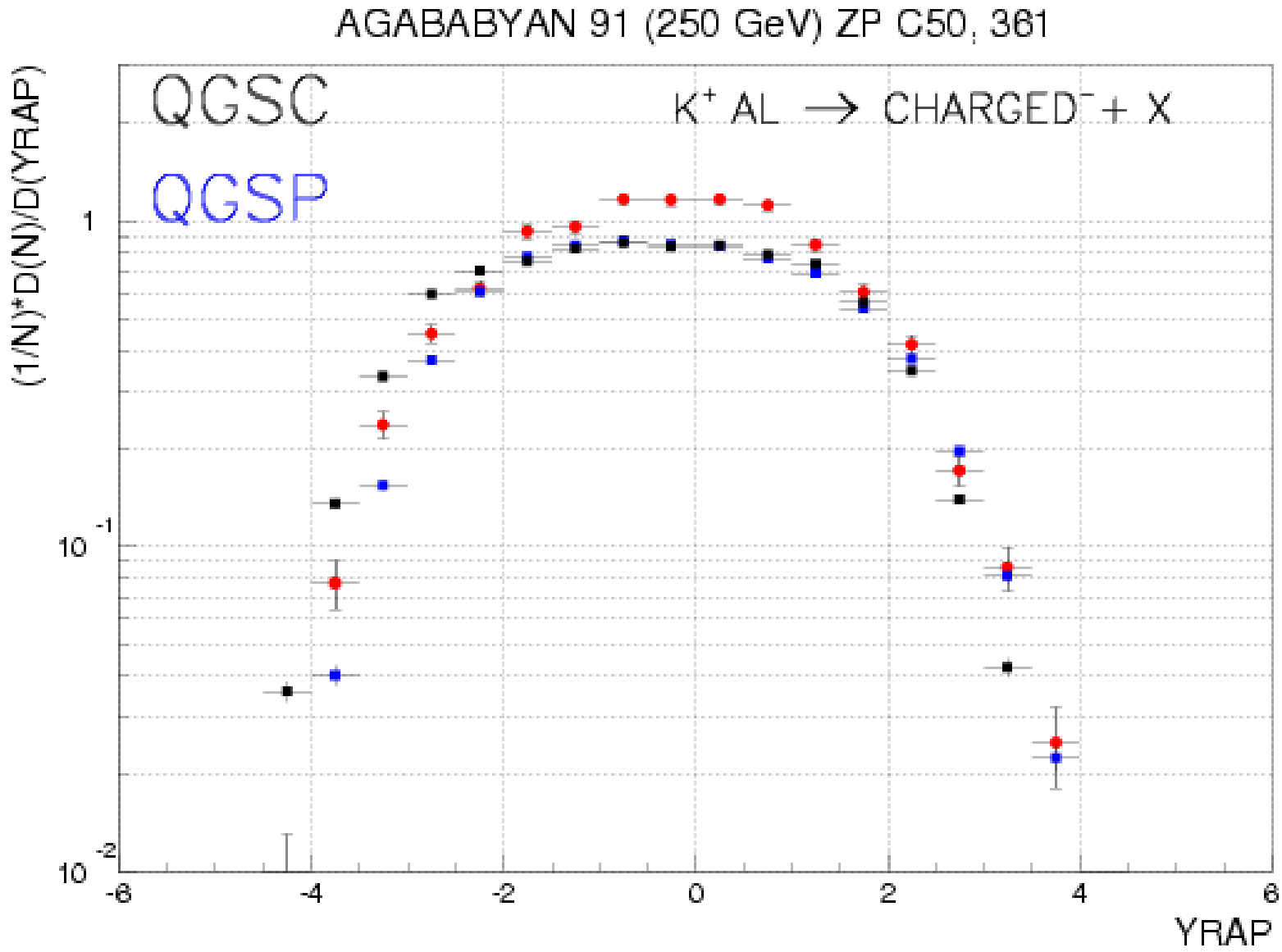

AGABABYAN 91 (250 GeV) ZP C50, 361
QGSC
QGSP
K+ AL → CHARGED+ + X
(1/N)*D(N)/D(YRAP)
1
10-1
10-2
-6
-4
-2
0
2
4
6
YRAP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QGSC
QGSP
K+ AL → CHARGED- + X
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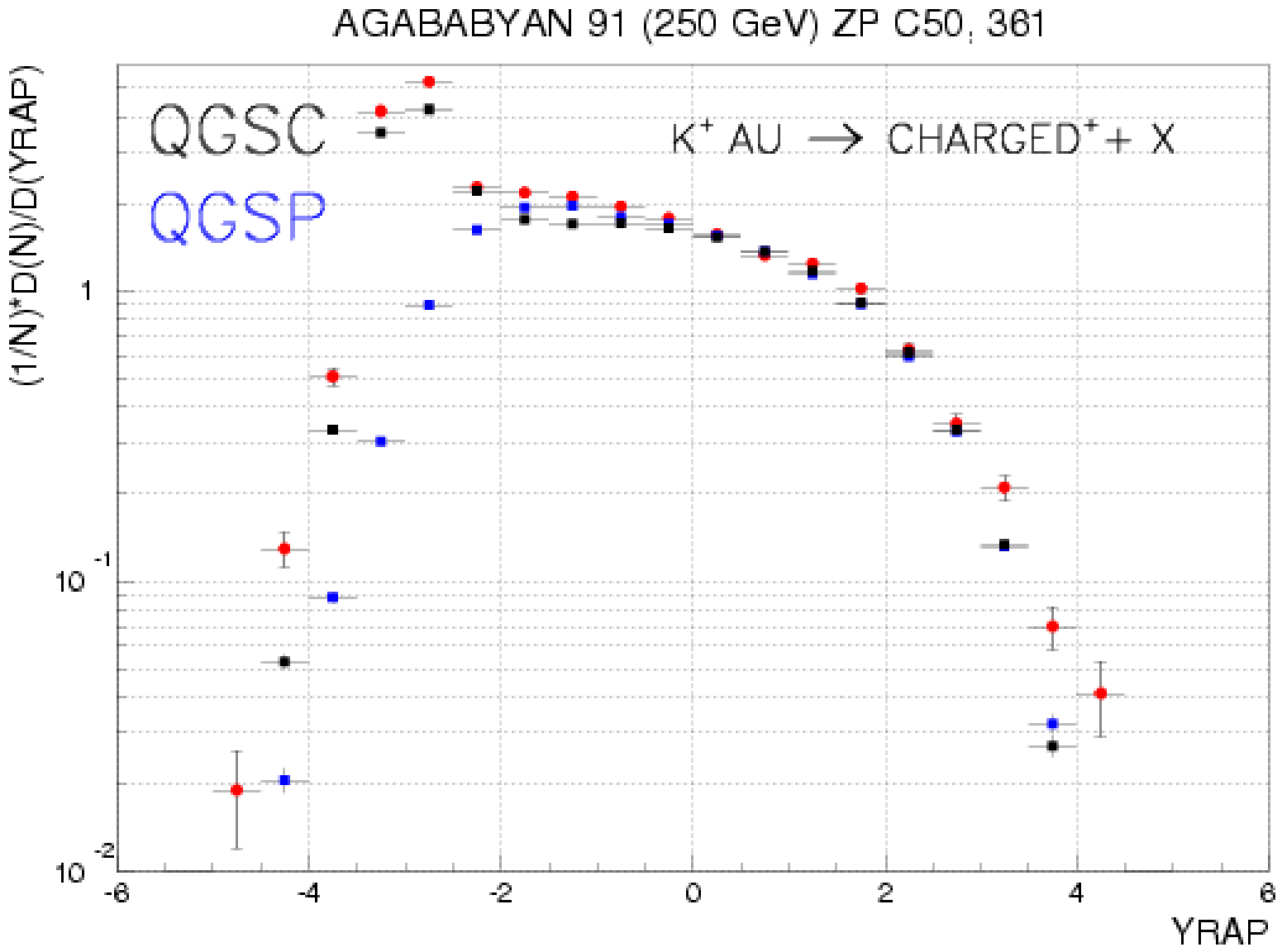
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K+ AU → CHARGED+ + X
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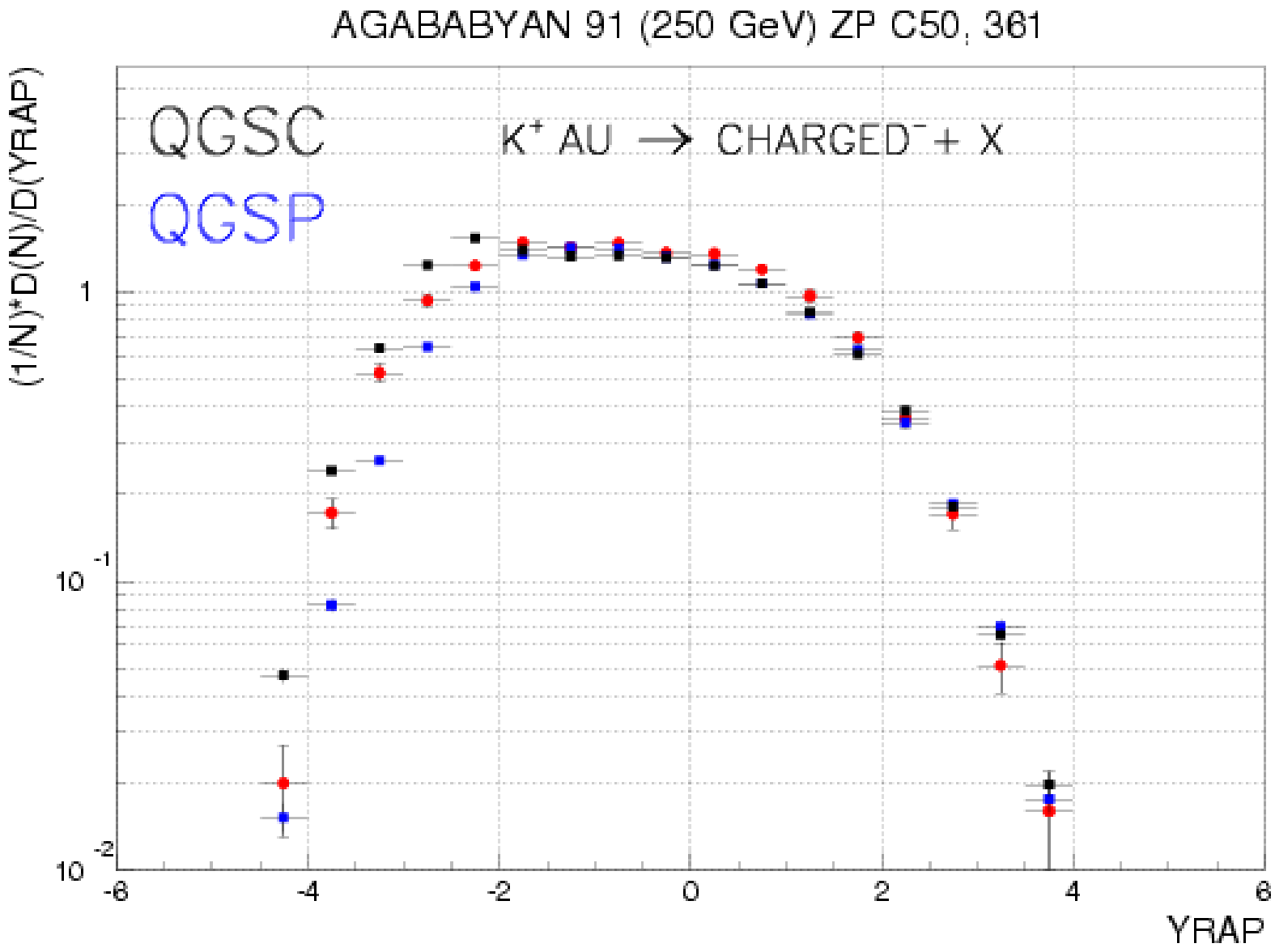
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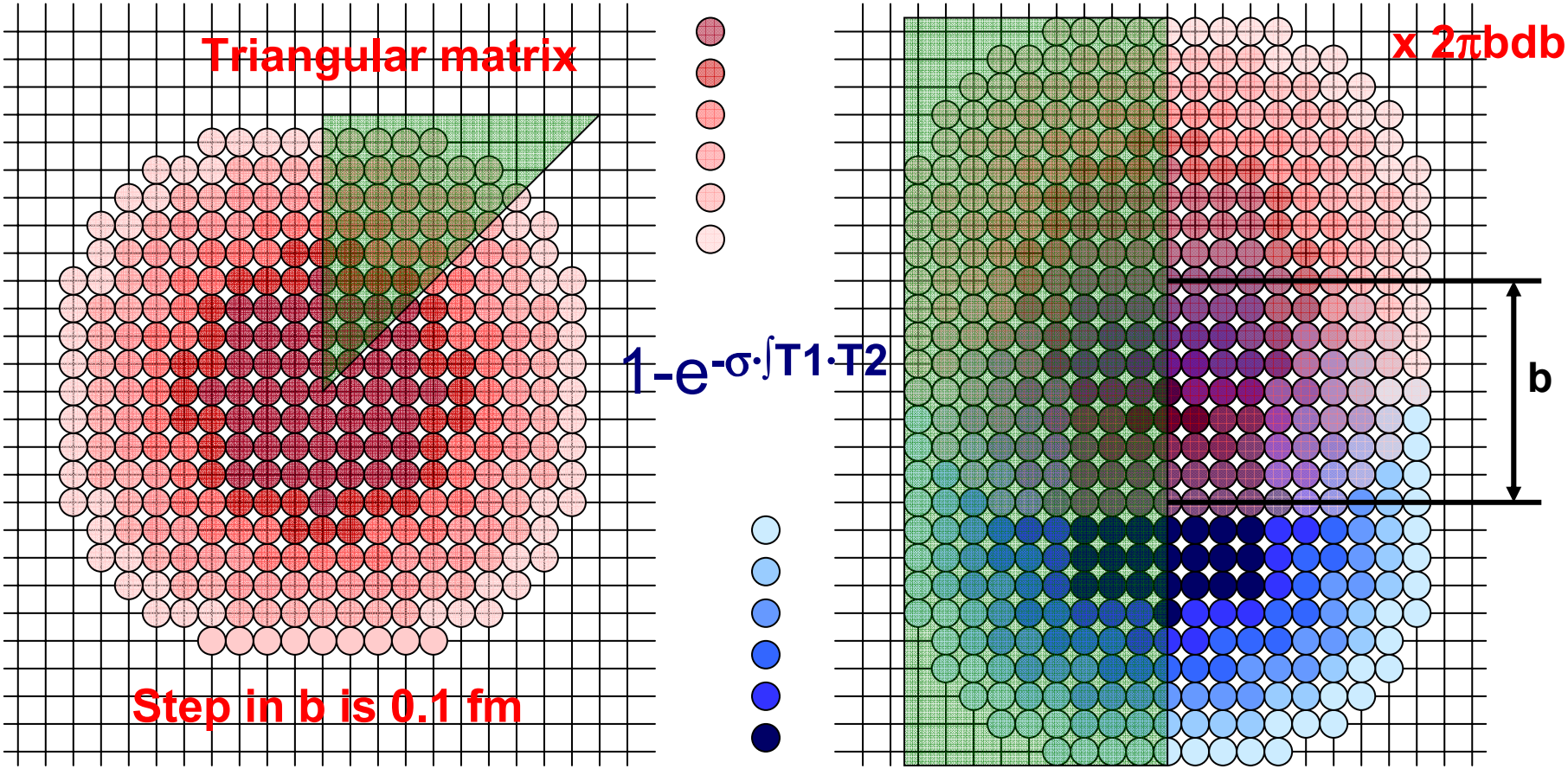
QGSP
K+ AU → CHARGED- + X
(1/N)*D(N)/D(YRAP)
1
10-1
10-2
-6
-4
-2
0
2
4
6
YRAP

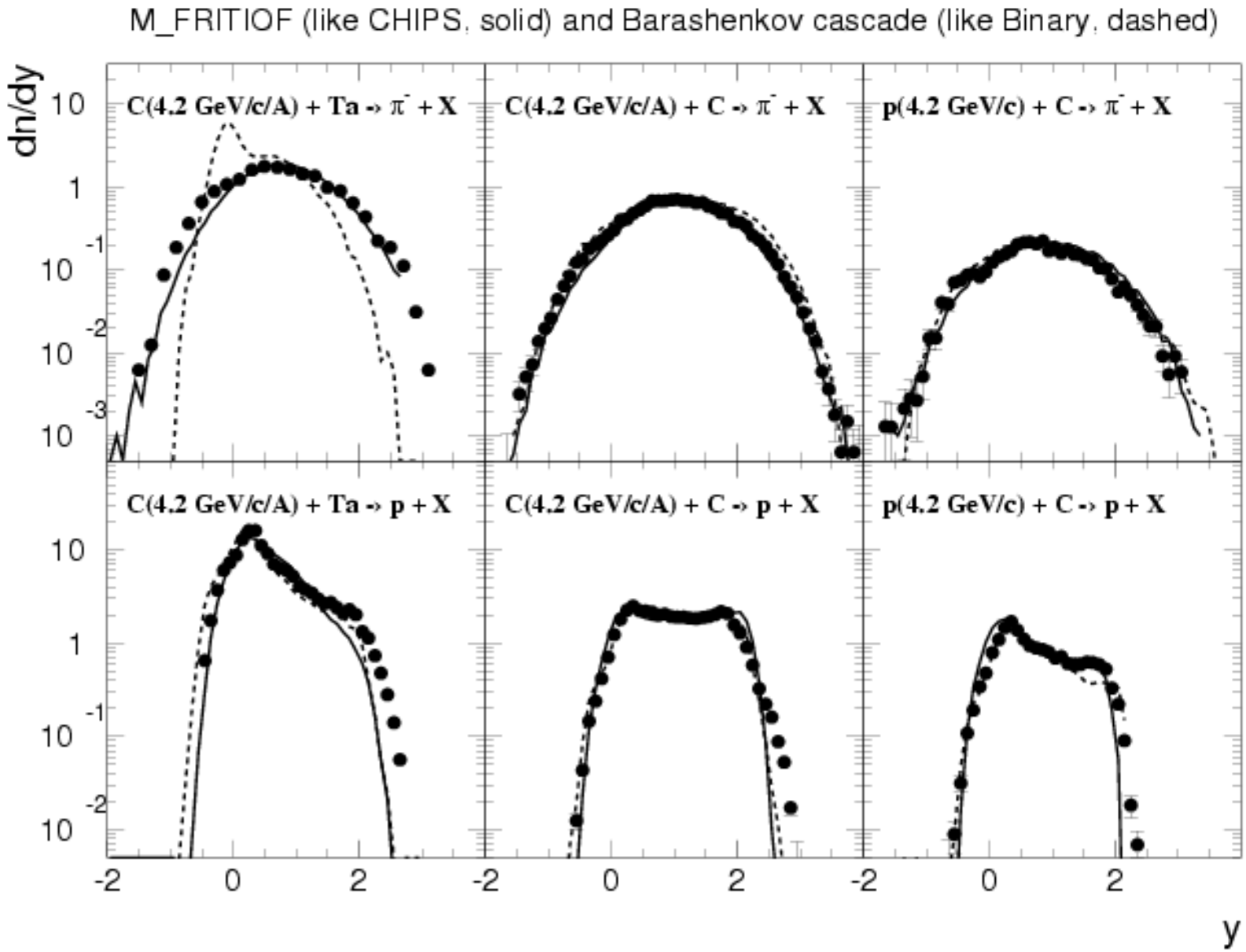
CHIPS algorithm of total AA interaction

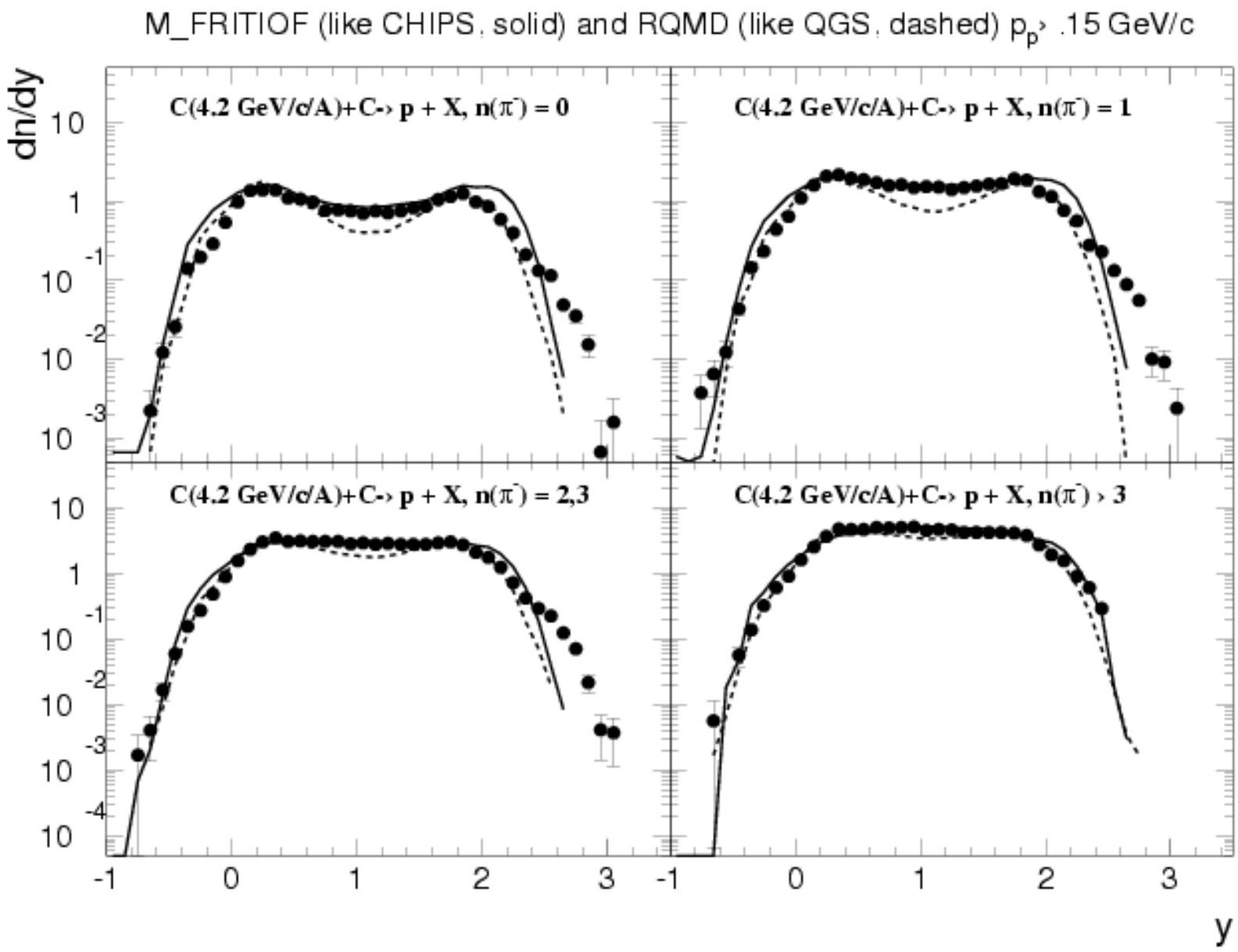
- Overlap of profile functions $T_1(b)$ and $T_2(b)$ defines the total interaction cross-section.

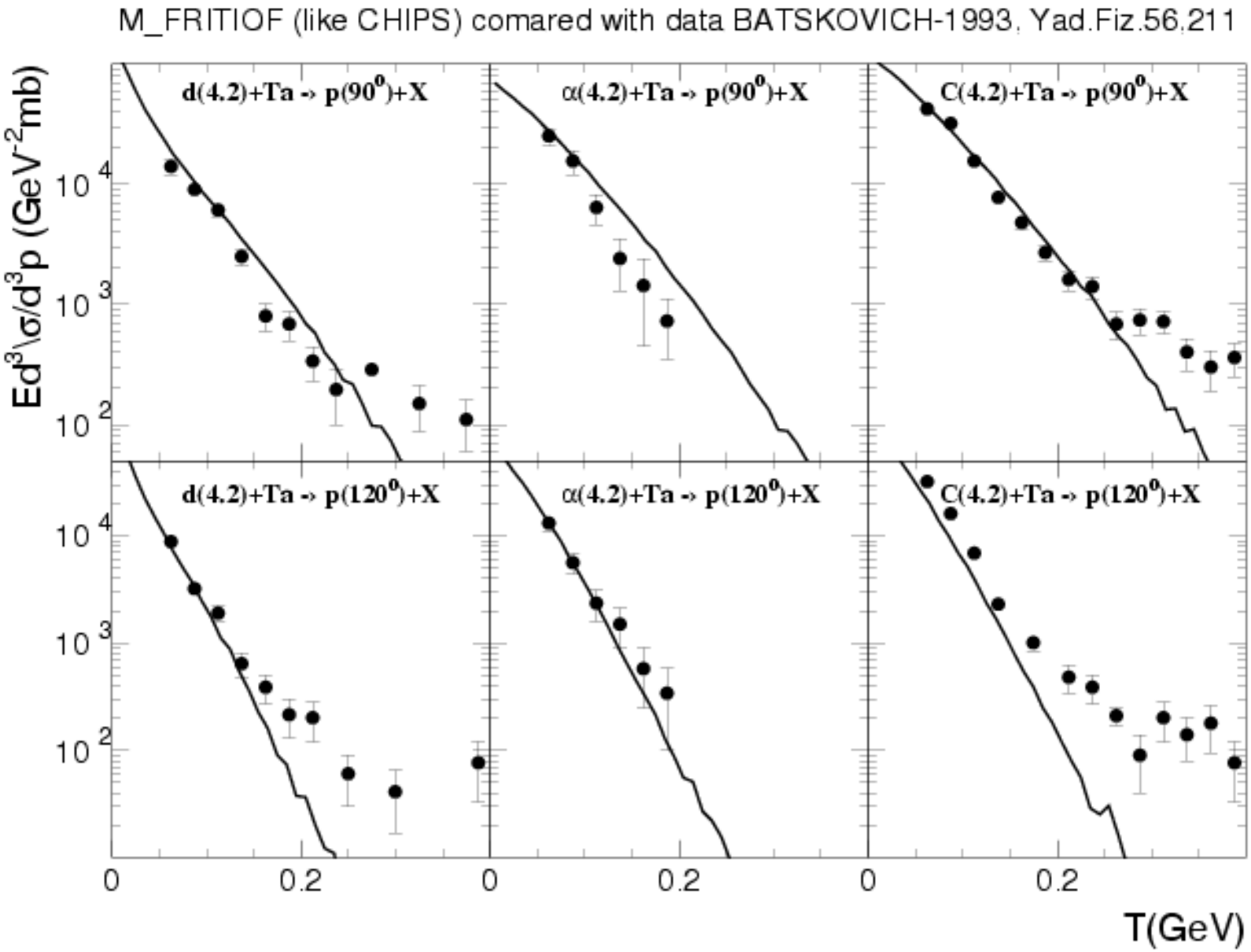


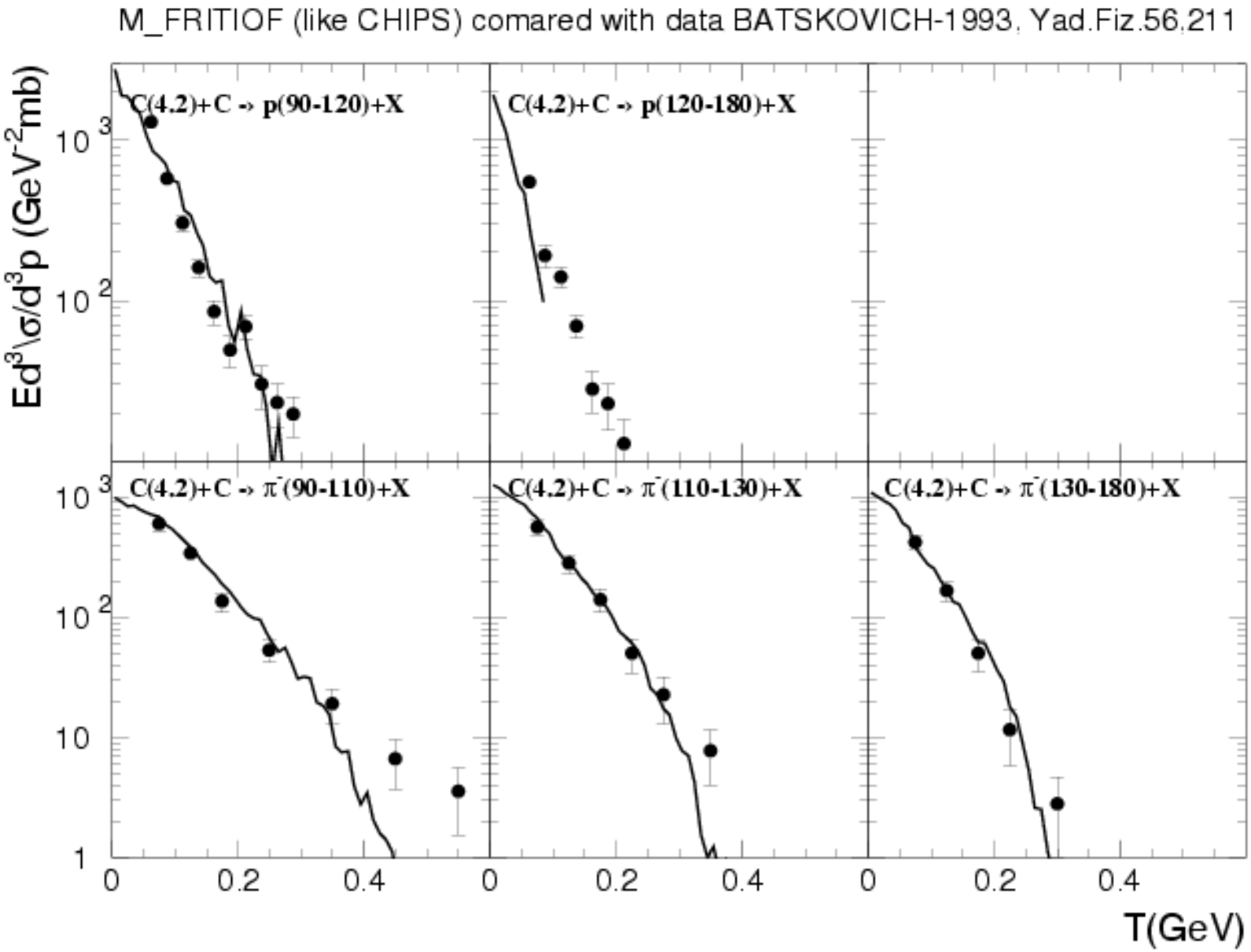
Ion-ion interactions (data of V.Uzhinsky)

- The cascading of nucleons of nucleus-projectile inside nucleus target (Barashenkov, G4 Binary)
  - Tries to take all possible resonances in NN interactions
  - Transports secondary mesons and resonances
  - Decays short-lived and glues nucleons in fragments
- The excitation models (FRITIOF, CHIPS) excite nucleons of both nuclei passing through each other
  - FRITIOF algorithm (only nucleons):
    - parameterizes p_t and ΔE excitation transfer for NN interactions
    - decays excited nucleons in vacuum using ISAJET algorithm
  - CHIPS algorithm (nucleons and nuclear Clusters = C):
    - Quark/gluon-exchange excitation for NN, NC, CC interactions
    - decay of created Quasmons in vacuum and in nuclear matter


M_FRITIOF (like CHIPS, solid) and Barashenkov cascade (like Binary, dashed)
dn/dy
C(4.2 GeV/c/A) + Ta -› π⁻ + X
C(4.2 GeV/c/A) + C -› π⁻ + X
p(4.2 GeV/c) + C -› π⁻ + X
C(4.2 GeV/c/A) + Ta -› p + X
C(4.2 GeV/c/A) + C -› p + X
p(4.2 GeV/c) + C -› p + X
y


M_FRITIOF (like CHIPS, solid) and RQMD (like QGS, dashed) p_p› .15 GeV/c
dn/dy
C(4.2 GeV/c/A)+C-› p + X, n(π⁻) = 0
C(4.2 GeV/c/A)+C-› p + X, n(π⁻) = 1
C(4.2 GeV/c/A)+C-› p + X, n(π⁻) = 2,3
C(4.2 GeV/c/A)+C-› p + X, n(π⁻) › 3
y


M_FRITIOF (like CHIPS) comared with data BATSKOVICH-1993, Yad.Fiz.56,211
d(4.2)+Ta -› p(90°)+X
α(4.2)+Ta -› p(90°)+X
C(4.2)+Ta -› p(90°)+X
d(4.2)+Ta -› p(120°)+X
α(4.2)+Ta -› p(120°)+X
C(4.2)+Ta -› p(120°)+X
Ed³\σ/d³p (GeV⁻²mb)
10⁴
10³
10²
0
0.2
T(GeV)


M_FRITIOF (like CHIPS) comared with data BATSKOVICH-1993, Yad.Fiz.56,211
C(4.2)+C -> p(90-120)+X
C(4.2)+C -> p(120-180)+X
C(4.2)+C -> π⁻(90-110)+X
C(4.2)+C -> π⁻(110-130)+X
C(4.2)+C -> π⁻(130-180)+X
Ed³\σ/d³p (GeV⁻²mb)
T(GeV)

Conclusion

- G4MuNuclearInteraction process gives nun's for cross-sections below T = 1 GeV. G4QCollision process does not produce nun's and doubles mean integrated deposited energy and mean p_T of μ's.
- QGSC (with respect to QGSP) fits the nuclear fragmentation region better, but it is much slower.
- Nuclear excitation models (M_FRITIOF,CHIPS) better describe spectra of heavy ion collisions at intermediate energies (Dubna, 4.2 GeV/c/A) then the cascade algorithm models (RQMD, QGSM).