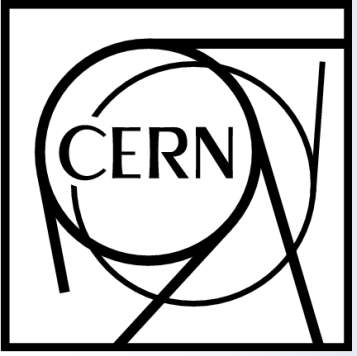



Geant 4

# Testing & improvement of inelastic πA, KA & anti-pA cross-sections

Mikhail Kosov, 14th Geant4 Users and Collaboration Workshop, 2009

# Introduction

- The inelastic cross-sections are improved for the new one-model CHIPS physics list
  - The pA and nA cross-sections are already improved 2 years ago
  - CHIPS πA cross-sections are competitive with Barashenkov XS
  - The existing GEISHA $K^+A$ cross-sections are bad for CHIPS
  - CHIPS improvement of anti-pA cross-sections is significant
- The main points of the improvement
  - Coulomb barrier for positive hadrons (p, $\pi^+$, $K^+$)
  - Melting of resonances at intermediate energies
  - Evolution of the cross-section minimum because of PPP vertex
  - Glauber calculation using CHIPS hA cross-sections (dashed)
  - Total to Inelastic Glauber reduction ($\sigma_{in}/\sigma_{tot}$ coefficient)

# CHIPS parameterization of $\sigma_{in}$ ($\pi$A, K$^-$A)

Parameterization of $\pi^-$A and $\pi^+$A inelastic cross-sections:

$$\sigma_{\pi D} = \sum_{i=1}^{3} \frac{V_i}{(\ln p - B_i)^2 + C_i^2} + \frac{D \cdot (\ln p - E)^2 + F + G/\sqrt{p}}{1. + H/p^4}$$

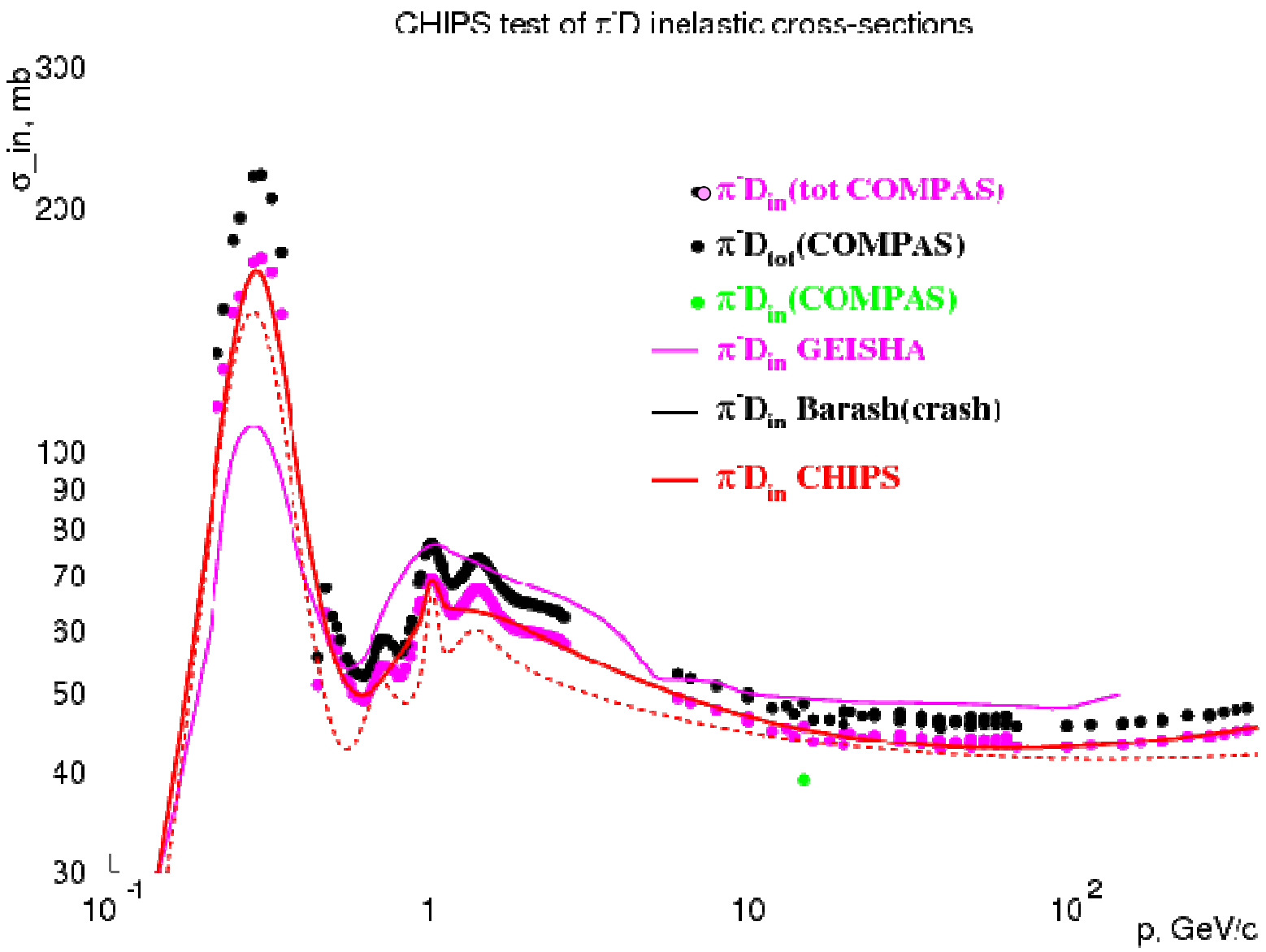
$$\sigma_{\pi^- A} = \frac{V(A)}{(\ln p - B(A))^2 + C(A)^2} + \frac{(\ln p - 4.2)^2 + F(A)}{1 + H(A)/p^4}$$

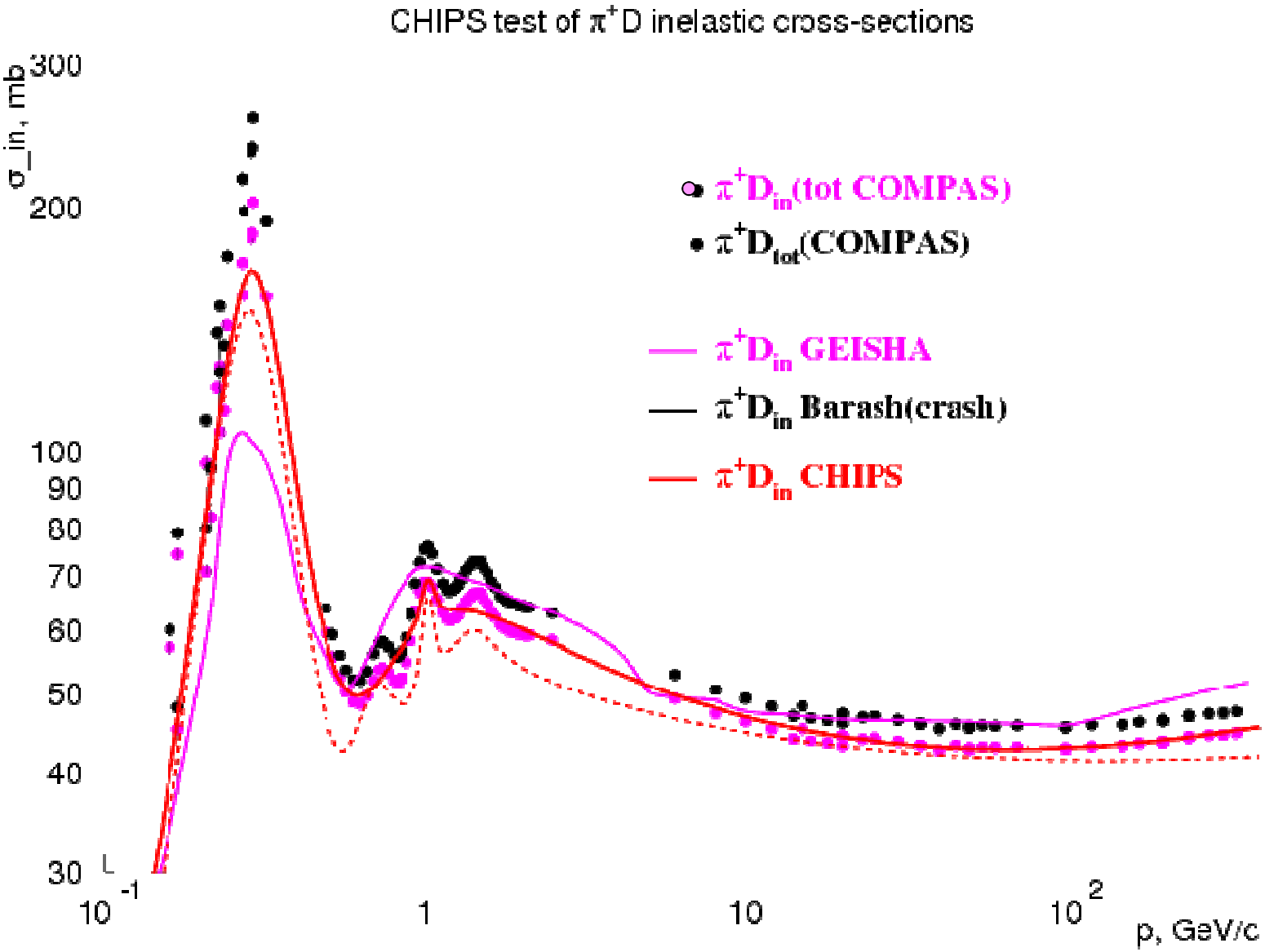
$$\sigma_{\pi^- A} = \frac{V(A)}{[(\ln p - B(A))^2 + C(A)^2][1 + D(A)/p^2]} + \frac{(\ln p - 4.2)^2 + F(A)}{1 + H(A)/p^4}$$

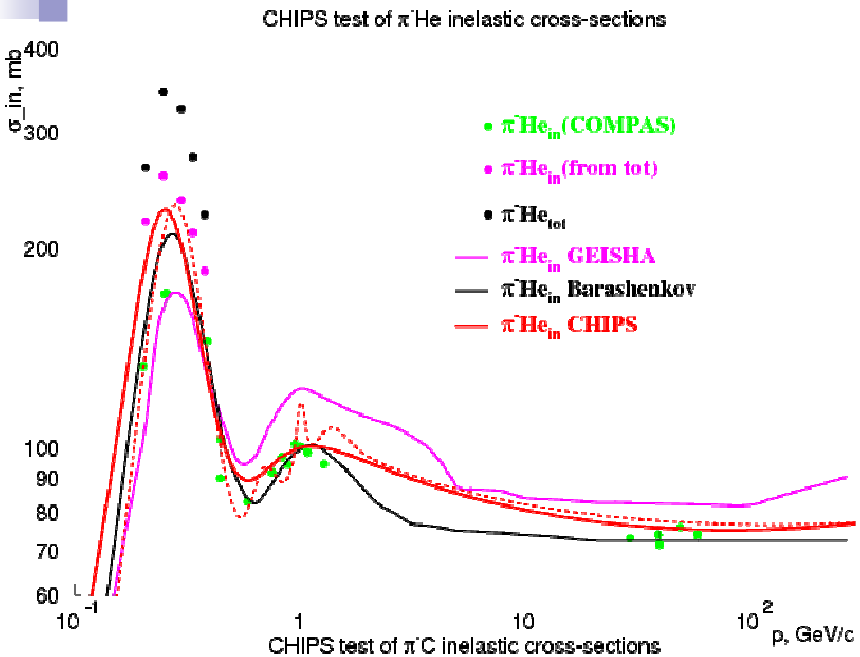
Parameterization of K$^-$A inelastic cross-sections:

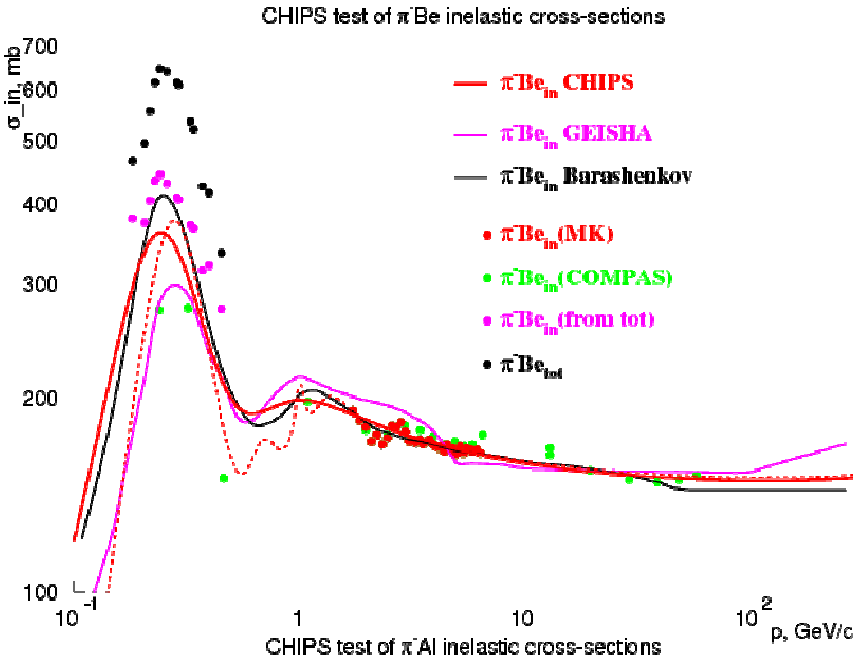
$$\sigma_{K^- D} = \frac{W}{p\sqrt{p}} + \sum_{i=1}^{2} \frac{V_i}{(p - B_i)^2 + C_i^2} + \frac{D \cdot (\ln p - E)^2 + F}{1. + G/\sqrt{p} + H/p^4}$$

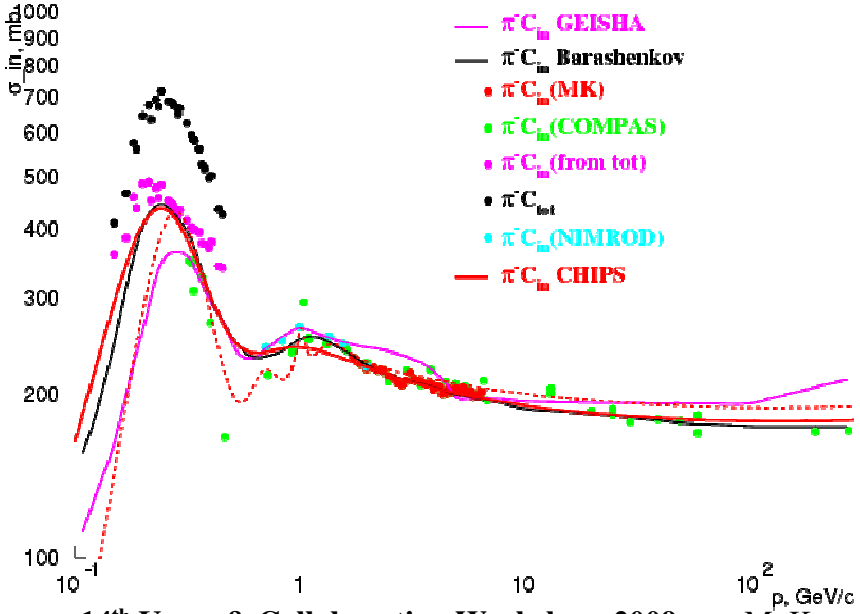
$$\sigma_{K^- A} = \frac{W(A)}{p\sqrt{p}} + \frac{V(A)}{(p - 1.)^2 + C(A)^2} + \frac{(\ln p - 4.2)^2 + F(A)}{1 + G(A)/\sqrt{p} + H(A)/p^4}$$

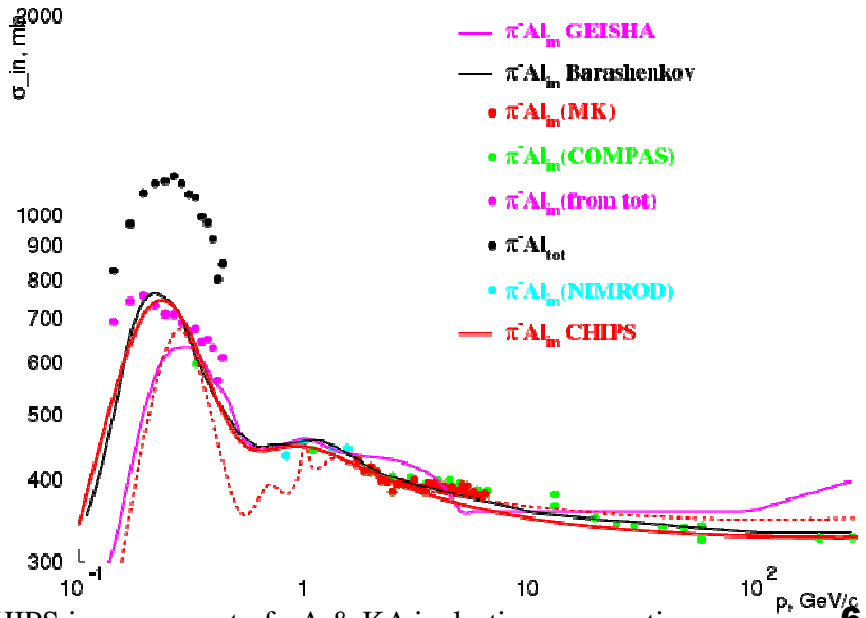

CHIPS test of π⁻D inelastic cross-sections
σ_in, mb
300
200
100
90
80
70
60
50
40
30
10⁻¹
1
10
10²
p, GeV/c
π⁻D_in(tot COMPAS)
π⁻D_tot(COMPAS)
π⁻D_in(COMPAS)
π⁻D_in GEISHA
π⁻D_in Barash(crash)
π⁻D_in CHIPS

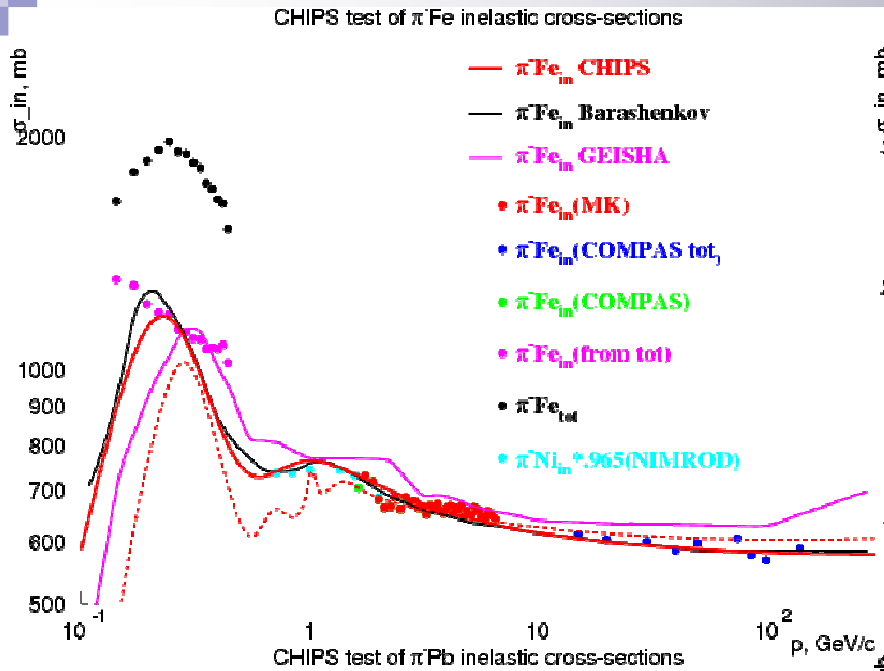

CHIPS test of π+D inelastic cross-sections
σ_in, mb
300
200
100
90
80
70
60
50
40
30
10-1
1
10
102
p, GeV/c
π+Din(tot COMPAS)
π+Dtot(COMPAS)
π+Din GEISHA
π+Din Barash(crash)
π+Din CHIPS

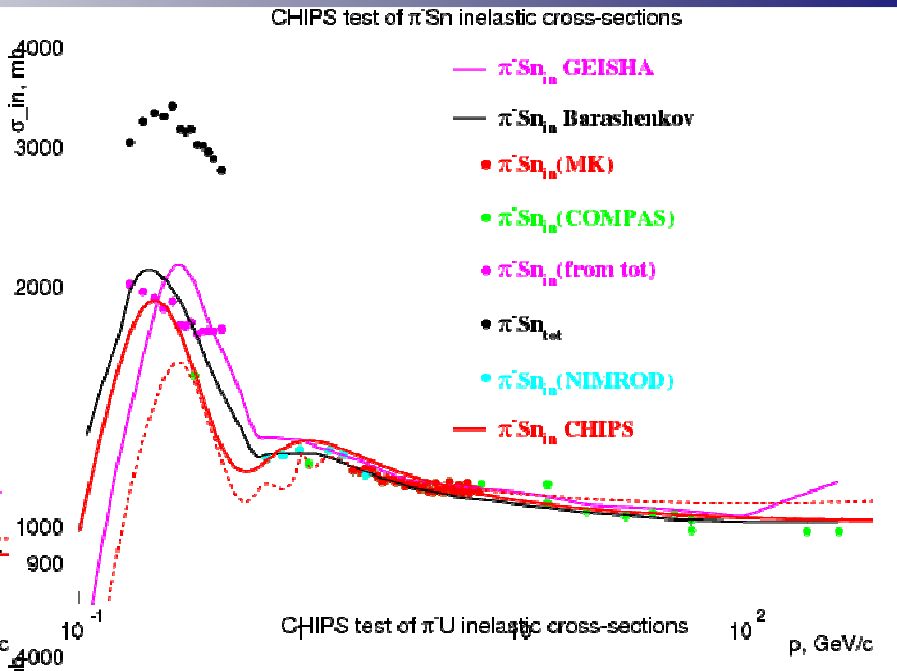

CHIPS test of π⁻He inelastic cross-sections
σ_in, mb
p, GeV/c
π⁻He_in (COMPAS)
π⁻He_in (from tot)
π⁻He_tot
π⁻He_in GEISHA
π⁻He_in Barashenkov
π⁻He_in CHIPS


CHIPS test of π⁻Be inelastic cross-sections
σ_in, mb
p, GeV/c
π⁻Be_in CHIPS
π⁻Be_in GEISHA
π⁻Be_in Barashenkov
π⁻Be_in (MK)
π⁻Be_in (COMPAS)
π⁻Be_in (from tot)
π⁻Be_tot


CHIPS test of π⁻C inelastic cross-sections
σ_in, mb
p, GeV/c
π⁻C_in GEISHA
π⁻C_in Barashenkov
π⁻C_in (MK)
π⁻C_in (COMPAS)
π⁻C_in (from tot)
π⁻C_tot
π⁻C_in (NIMROD)
π⁻C_in CHIPS


CHIPS test of π⁻Al inelastic cross-sections
σ_in, mb
p, GeV/c
π⁻Al_in GEISHA
π⁻Al_in Barashenkov
π⁻Al_in (MK)
π⁻Al_in (COMPAS)
π⁻Al_in (from tot)
π⁻Al_tot
π⁻Al_in (NIMROD)
π⁻Al_in CHIPS


CHIPS test of π⁻Fe inelastic cross-sections
σ_in, mb
p, GeV/c
π⁻Fe_in CHIPS
π⁻Fe_in Barashenkov
π⁻Fe_in GEISHA
π⁻Fe_in(MK)
π⁻Fe_in(COMPAS tot)
π⁻Fe_in(COMPAS)
π⁻Fe_in(from tot)
π⁻Fe_tot
π⁻Ni_in*.965(NIMROD)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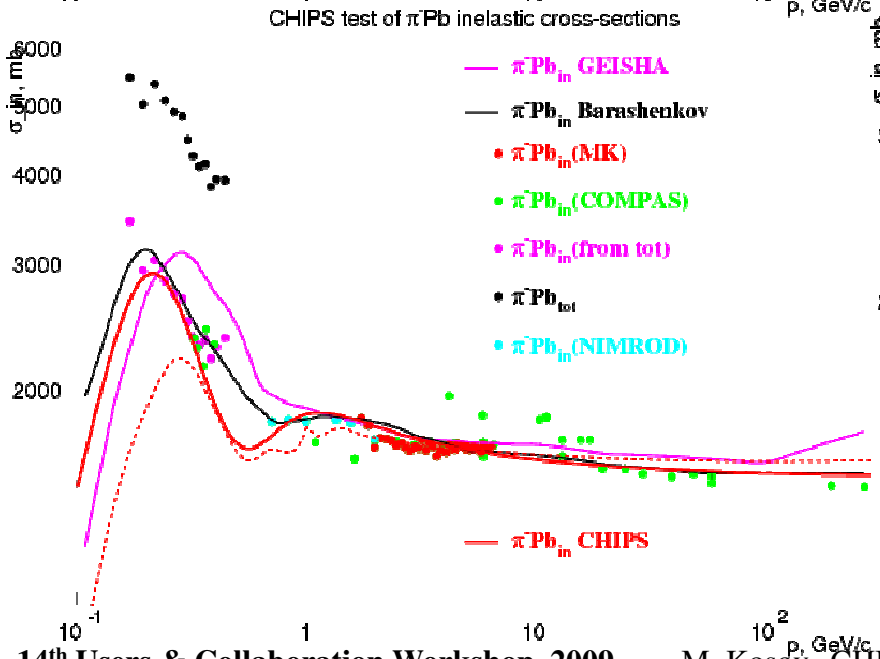
σ_in, mb
p, GeV/c
π⁻Sn_in GEISHA
π⁻Sn_in Barashenkov
π⁻Sn_in(MK)
π⁻Sn_in(COMPAS)
π⁻Sn_in(from tot)
π⁻Sn_tot
π⁻Sn_in(NIMROD)
π⁻Sn_in CHIPS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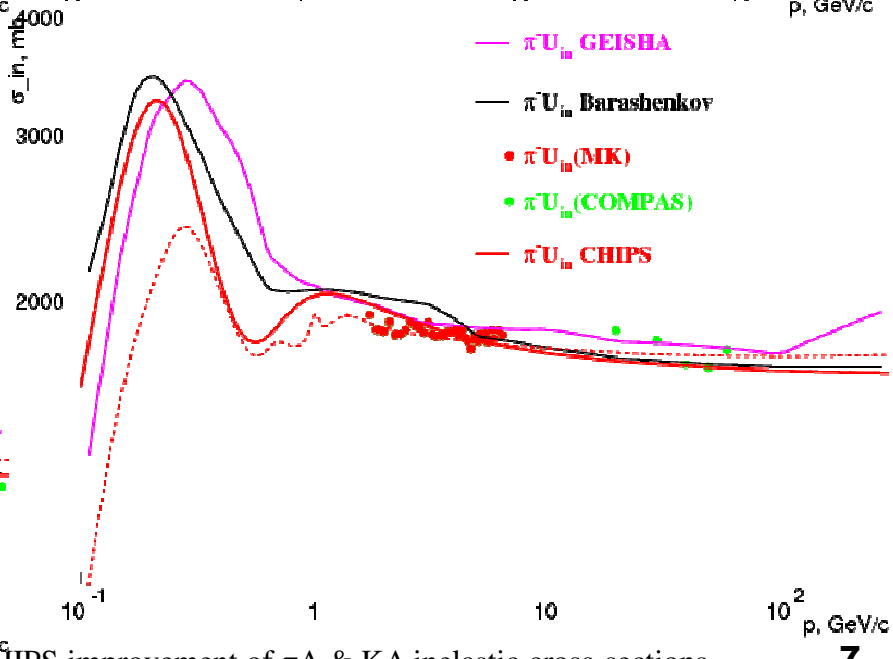
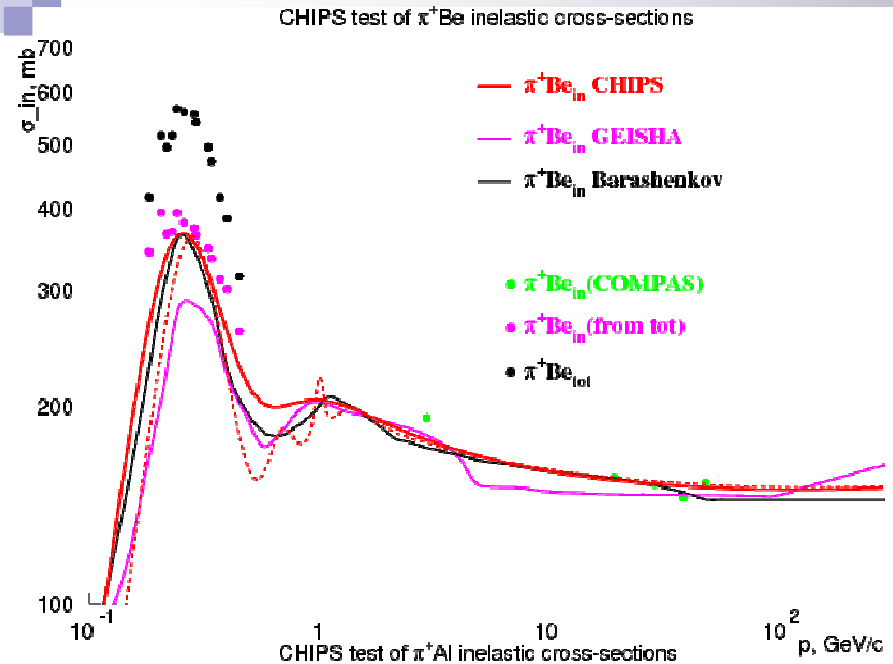
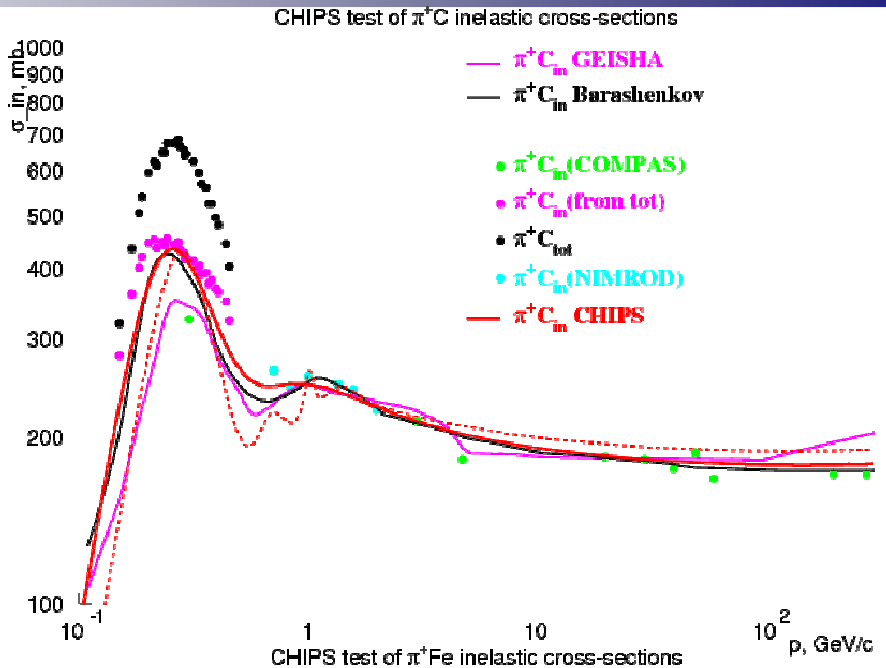
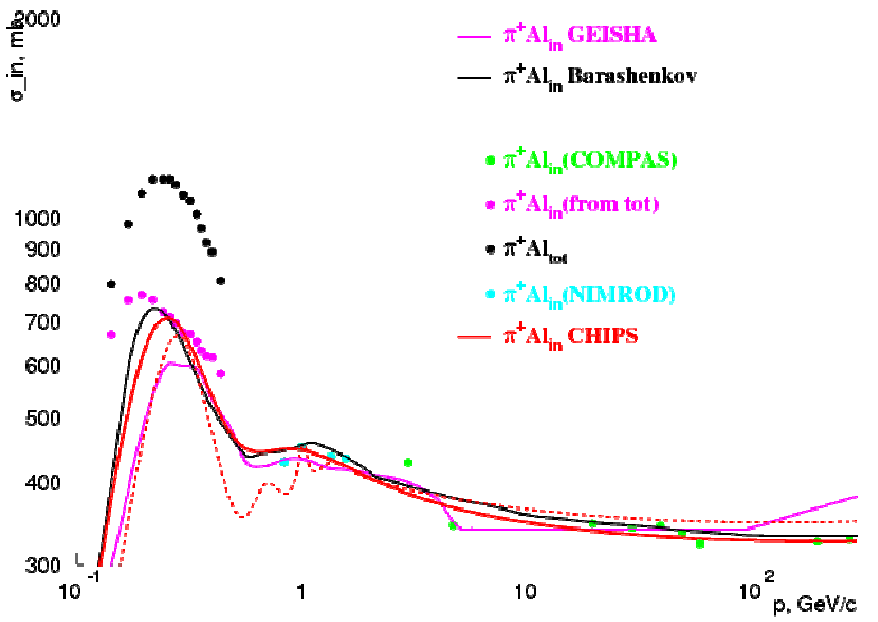
σ_in, mb
p, GeV/c
π⁻Pb_in GEISHA
π⁻Pb_in Barashenkov
π⁻Pb_in(MK)
π⁻Pb_in(COMPAS)
π⁻Pb_in(from tot)
π⁻Pb_tot
π⁻Pb_in(NIMROD)
π⁻Pb_in CHIPS


CHIPS test of π⁻U inelastic cross-sections
σ_in, mb
p, GeV/c
π⁻U_in GEISHA
π⁻U_in Barashenkov
π⁻U_in(MK)
π⁻U_in(COMPAS)
π⁻U_in CHIPS


CHIPS test of π+Be inelastic cross-sections
σ_in, mb
p, GeV/c
π+Be_in CHIPS
π+Be_in GEISHA
π+Be_in Barashenkov
π+Be_in(COMPAS)
π+Be_in(from tot)
π+Be_tot


CHIPS test of π+C inelastic cross-sections
σ_in, mb
p, GeV/c
π+C_in GEISHA
π+C_in Barashenkov
π+C_in(COMPAS)
π+C_in(from tot)
π+C_tot
π+C_in(NIMROD)
π+C_in CHIPS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σ_in, mb
p, GeV/c
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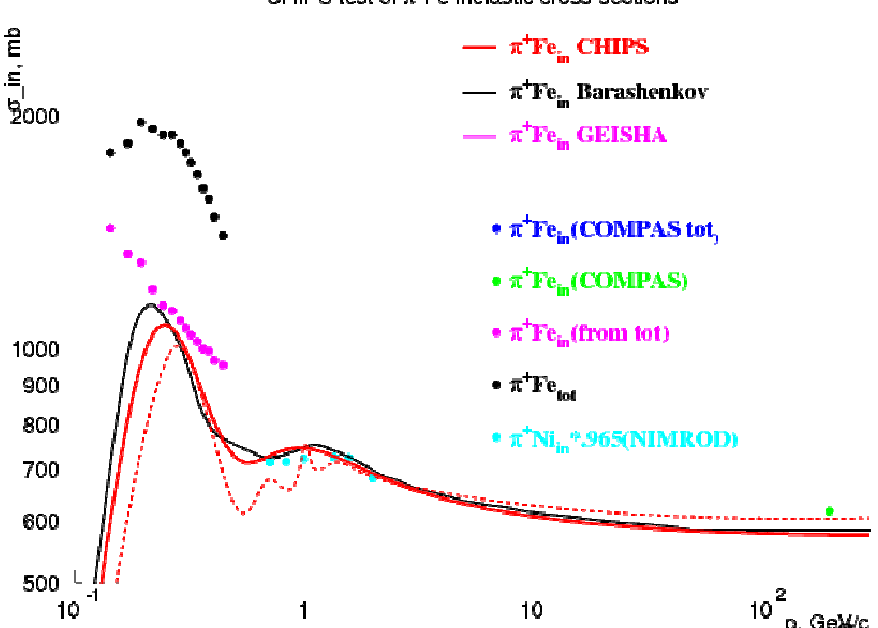
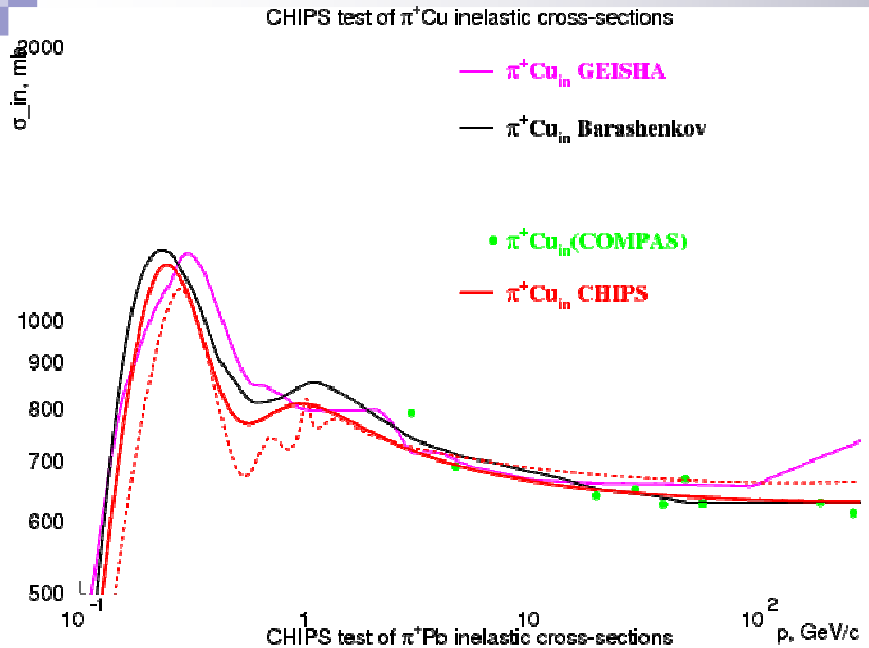
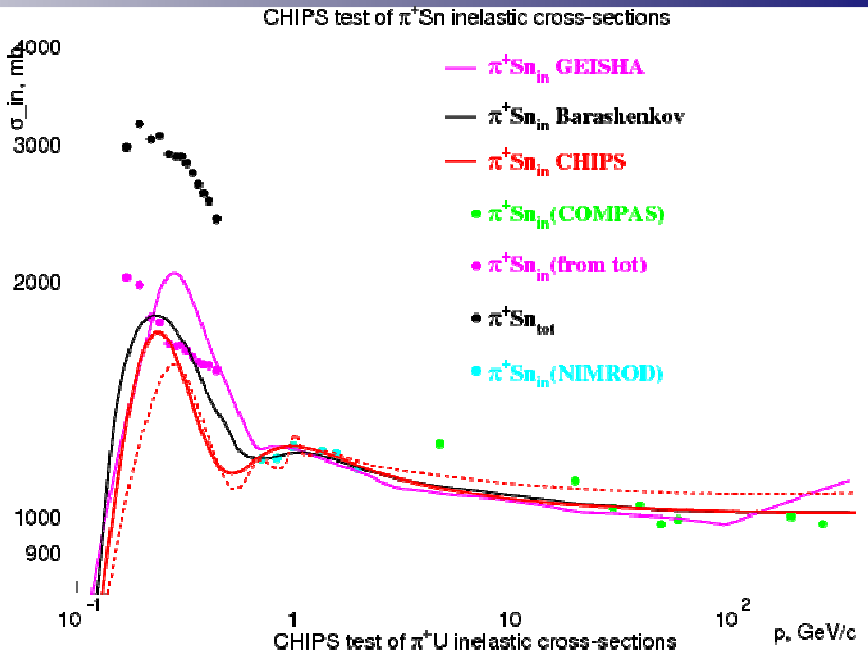
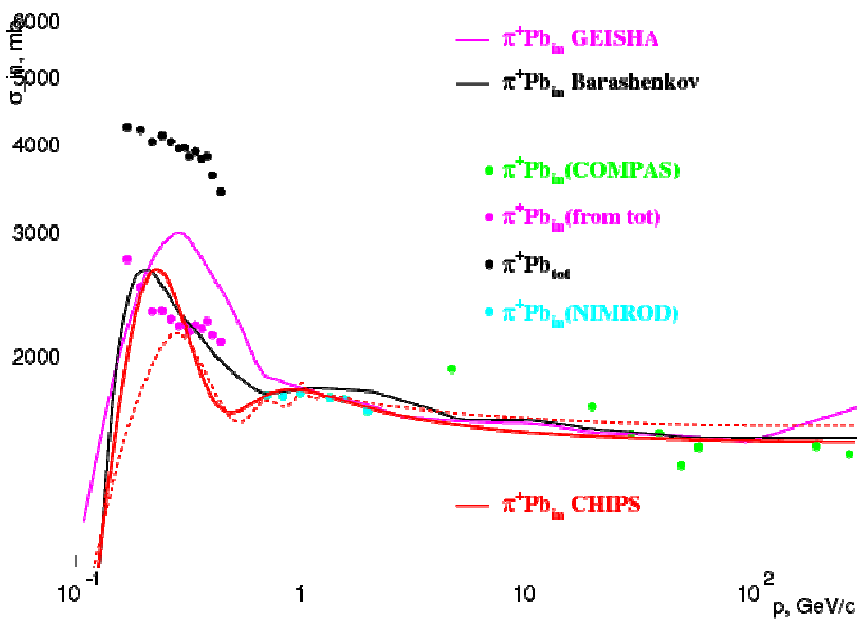
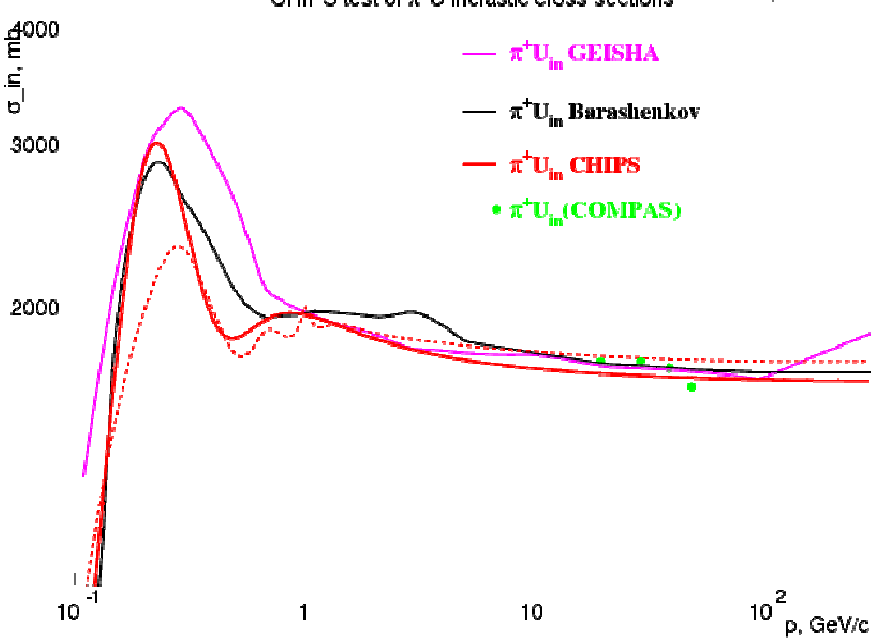
π+Al_in Barashenkov
π+Al_in(COMPAS)
π+Al_in(from tot)
π+Al_tot
π+Al_in(NIMROD)
π+Al_in CHIPS

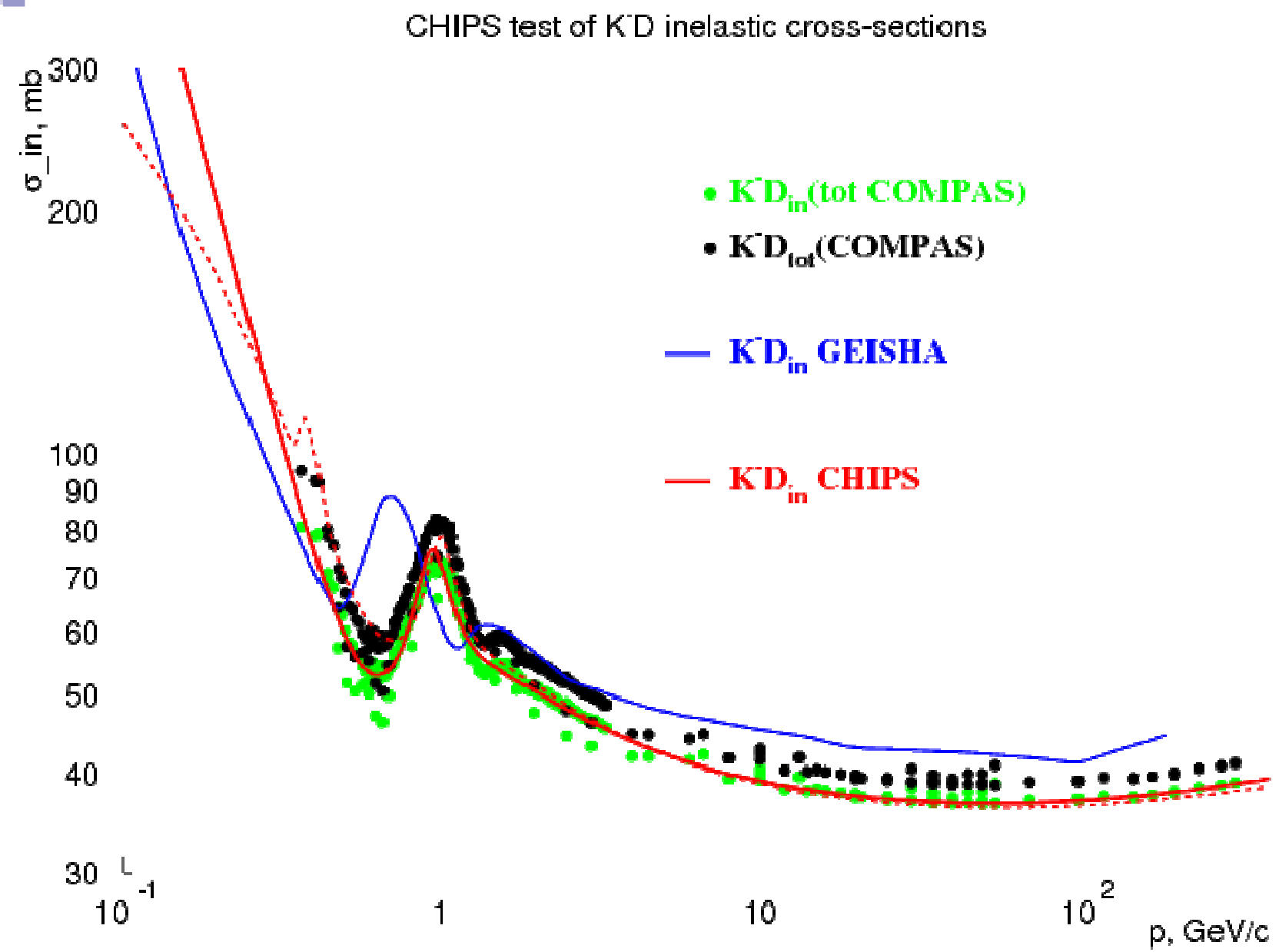

CHIPS test of π+Fe inelastic cross-sections
σ_in, mb
p, GeV/c
π+Fe_in CHIPS
π+Fe_in Barashenkov
π+Fe_in GEISHA
π+Fe_in(COMPAS tot)
π+Fe_in(COMPAS)
π+Fe_in(from tot)
π+Fe_tot
π+Ni_in*.965(NIMROD)

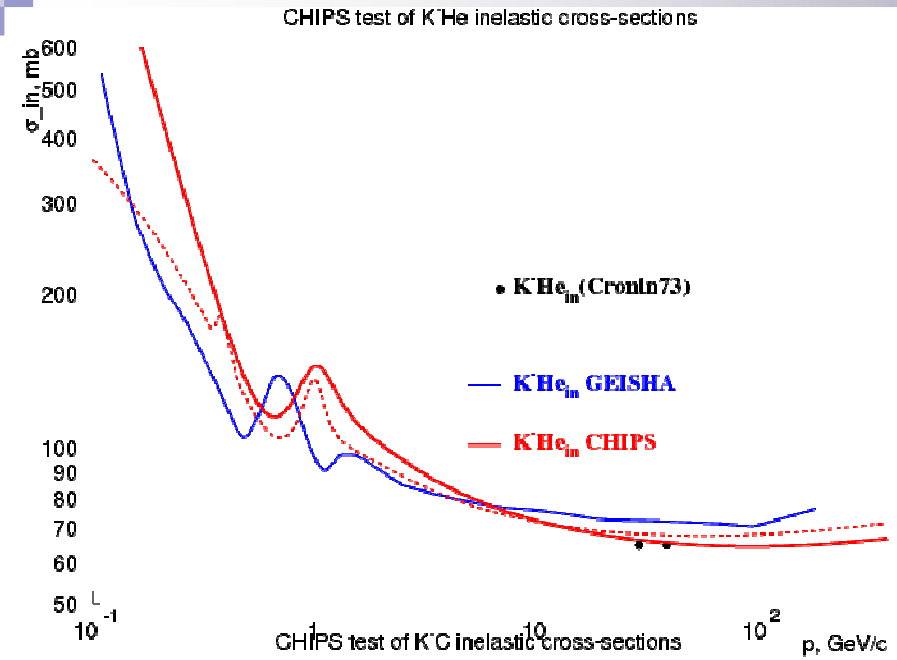

CHIPS test of π+Cu inelastic cross-sections
σ_in, mb
p, GeV/c
π+Cu_in GEISHA
π+Cu_in Barashenkov
π+Cu_in(COMPAS)
π+Cu_in CHIPS

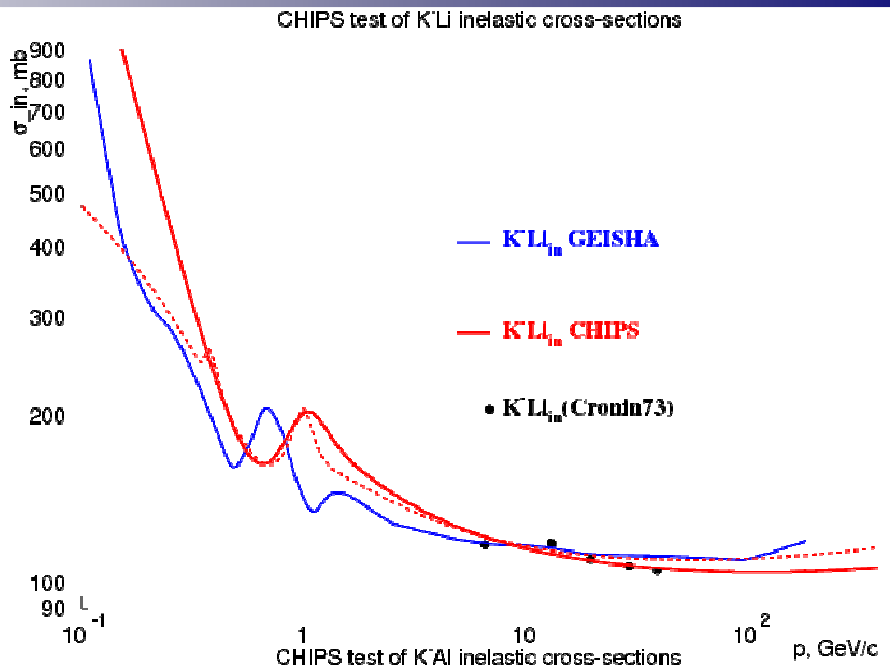

CHIPS test of π+Sn inelastic cross-sections
σ_in, mb
p, GeV/c
π+Sn_in GEISHA
π+Sn_in Barashenkov
π+Sn_in CHIPS
π+Sn_in(COMPAS)
π+Sn_in(from tot)
π+Sn_tot
π+Sn_in(NIMROD)

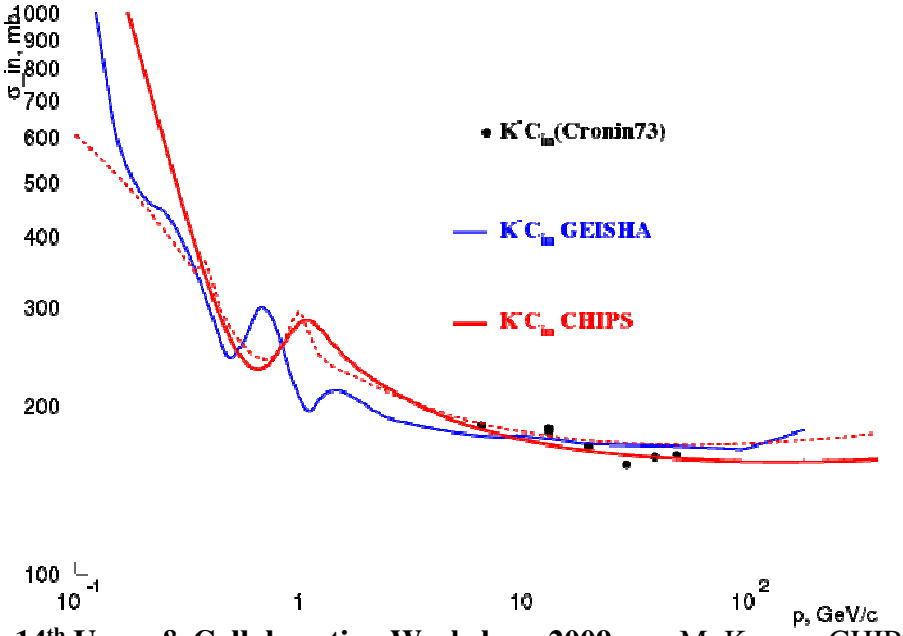

CHIPS test of π+Pb inelastic cross-sections
σ_in, mb
p, GeV/c
π+Pb_in GEISHA
π+Pb_in Barashenkov
π+Pb_in(COMPAS)
π+Pb_in(from tot)
π+Pb_tot
π+Pb_in(NIMROD)
π+Pb_in CHIPS

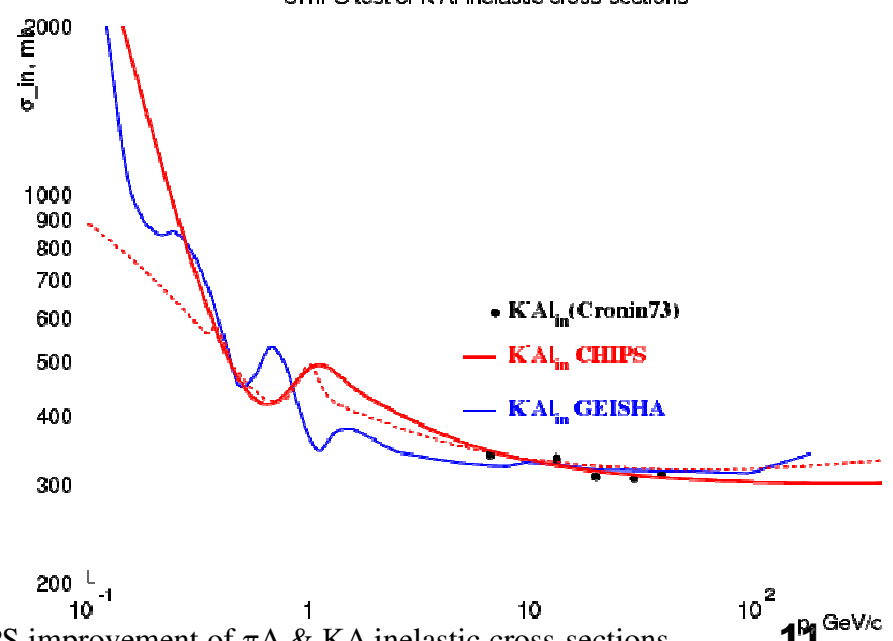

CHIPS test of π+U inelastic cross-sections
σ_in, mb
p, GeV/c
π+U_in GEISHA
π+U_in Barashenkov
π+U_in CHIPS
π+U_in(COMPAS)


CHIPS test of K⁻D inelastic cross-sections
σ_in, mb
300
200
100
90
80
70
60
50
40
30
10⁻¹
1
10
10²
p, GeV/c
K⁻D_in(tot COMPAS)
K⁻D_tot(COMPAS)
K⁻D_in GEISHA
K⁻D_in CHIPS


CHIPS test of K⁻He inelastic cross-sections
σ_in, mb
K⁻He_in(Cronin73)
K⁻He_in GEISHA
K⁻He_in CHIPS
p, GeV/c


CHIPS test of K⁻Li inelastic cross-sections
σ_in, mb
K⁻Li_in GEISHA
K⁻Li_in CHIPS
K⁻Li_in(Cronin73)
p, GeV/c


CHIPS test of K⁻C inelastic cross-sections
σ_in, mb
K⁻C_in(Cronin73)
K⁻C_in GEISHA
K⁻C_in CHIPS
p, GeV/c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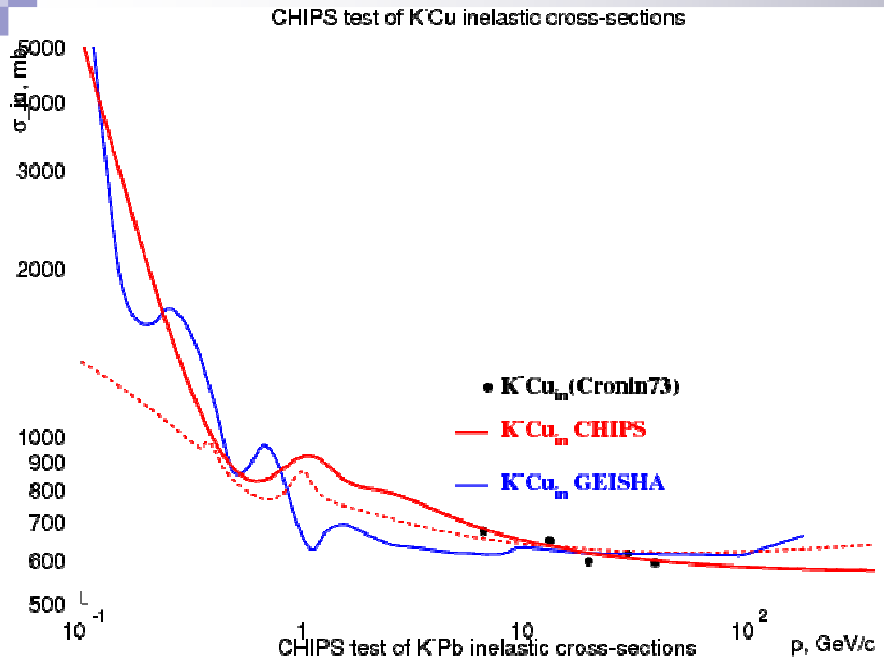
K⁻Al_in(Cronin73)
K⁻Al_in CHIPS
K⁻Al_in GEISHA
p, GeV/c


CHIPS test of K⁻Cu inelastic cross-sections
σ_in, mb
p, GeV/c
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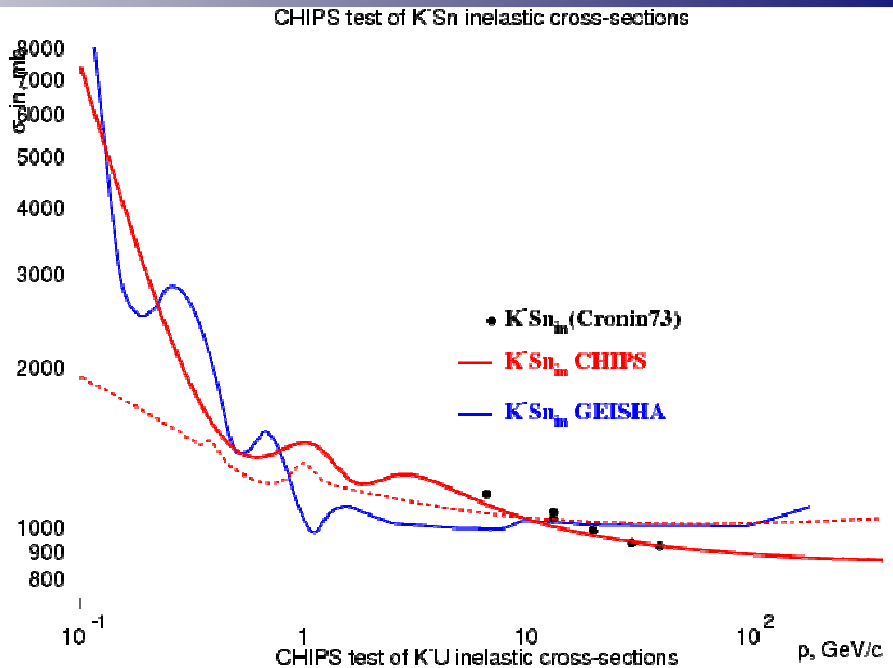
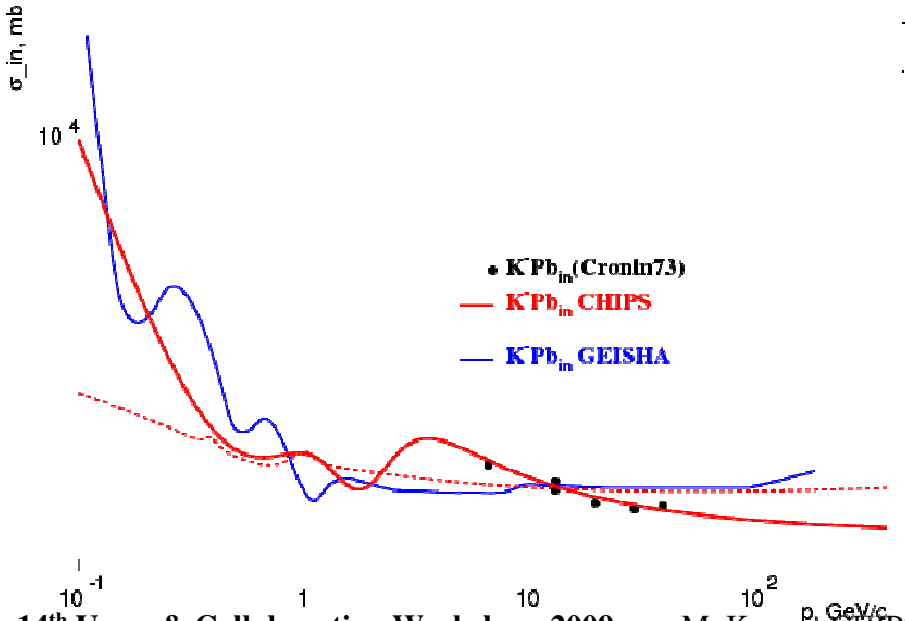
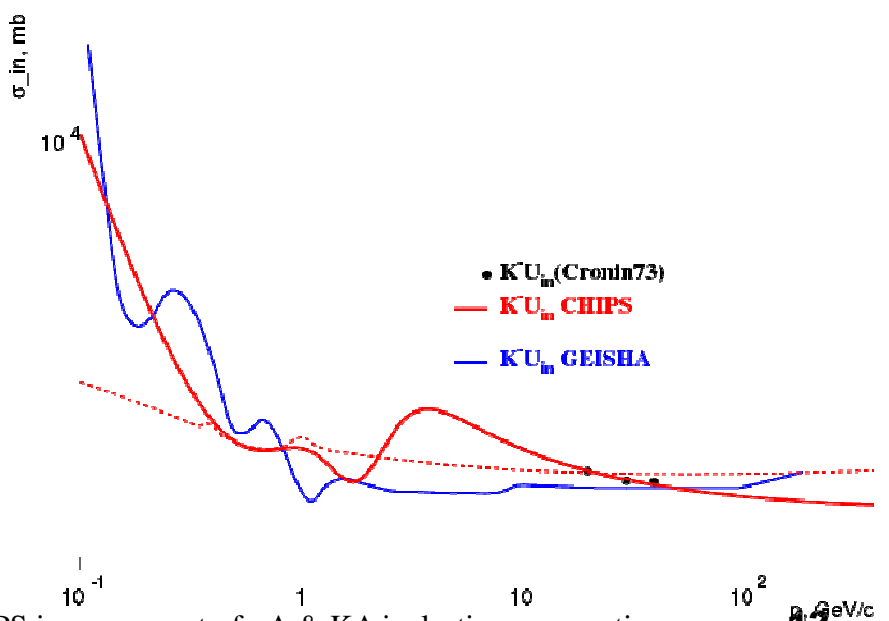
K⁻Cu_in CHIPS
K⁻Cu_in GEISHA


CHIPS test of K⁻Sn inelastic cross-sections
σ_in, mb
p, GeV/c
• K⁻Sn_in(Cronin73)
K⁻Sn_in CHIPS
K⁻Sn_in GEISHA


CHIPS test of K⁻Pb inelastic cross-sections
σ_in, mb
p, GeV/c
• K⁻Pb_in(Cronin73)
K⁻Pb_in CHIPS
K⁻Pb_in GEISHA


CHIPS test of K⁻U inelastic cross-sections
σ_in, mb
p, GeV/c
• K⁻U_in(Cronin73)
K⁻U_in CHIPS
K⁻U_in GEISHA

# Preliminary CHIPS fit for $\sigma_{in}$ ($K^+A$,anti-pA)

Parameterization of $K^+A$ inelastic cross-section:

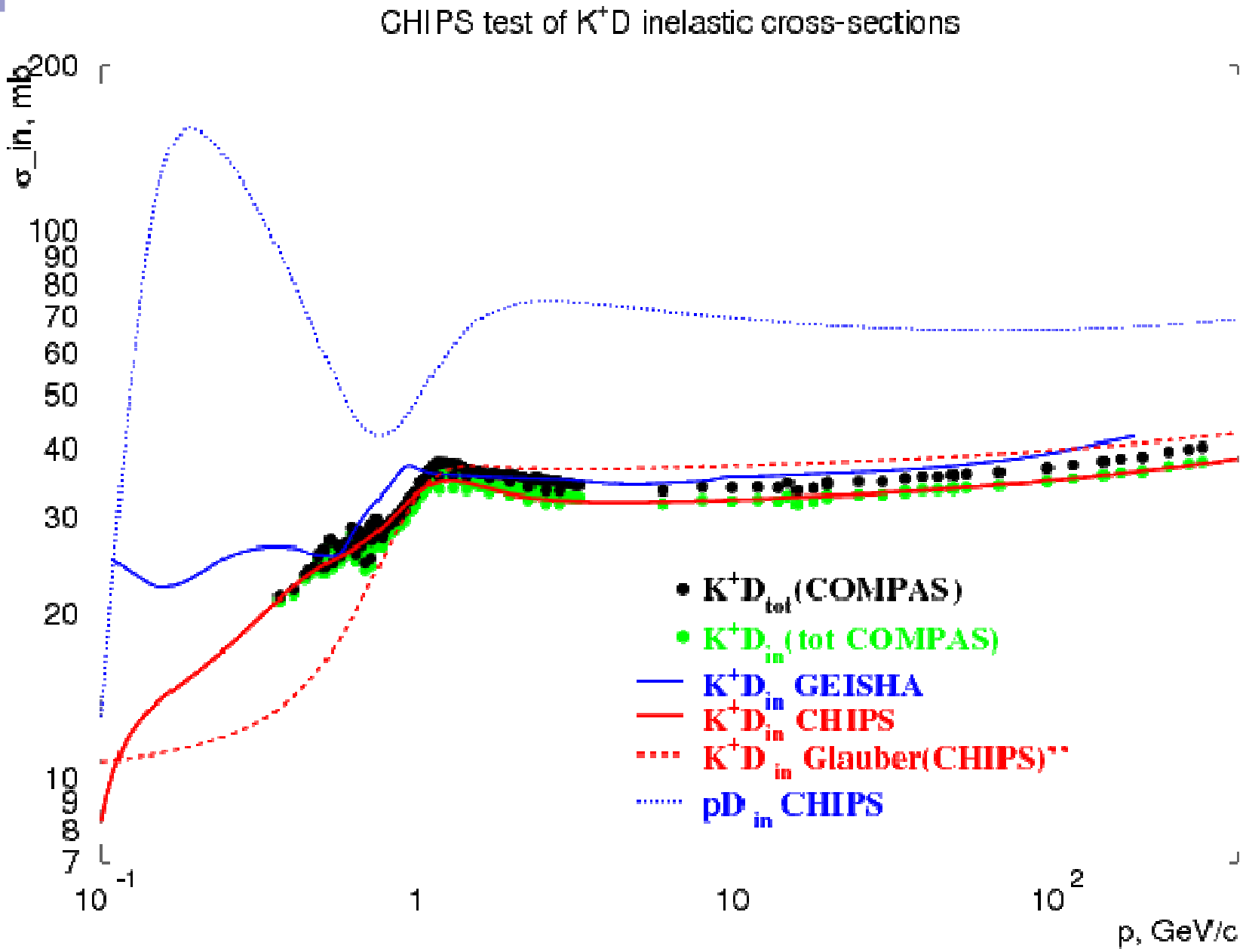
$$\sigma_{K^+D} = \frac{V}{(p-B)^2 + C^2} + \frac{D \cdot (\ln p - E)^2 + F}{1 + G/\sqrt{p} + H/p^4}$$

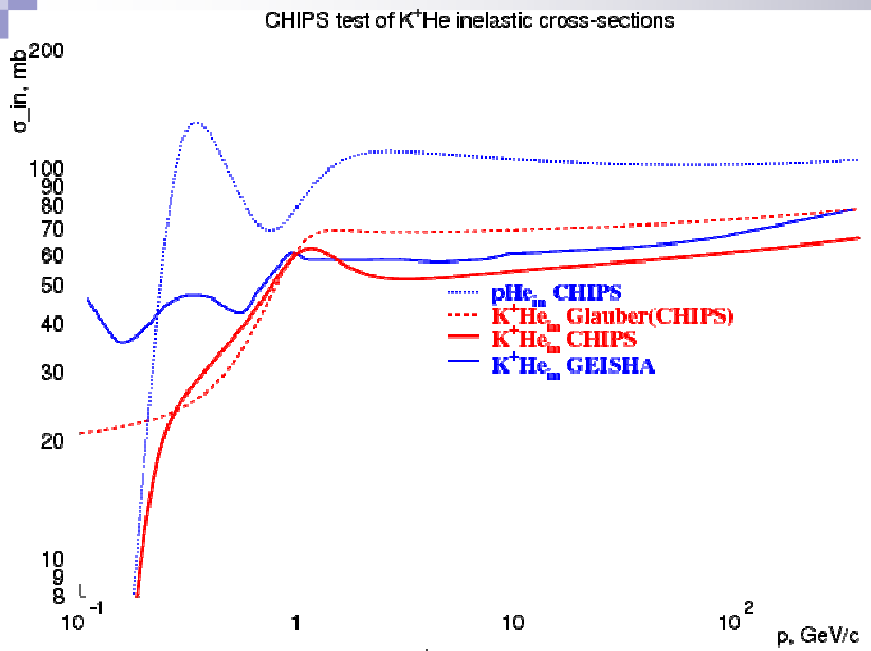
$$\sigma_{K^+A} = \left(\sum_{i=1}^{2} \frac{V(A)}{(p-B(A))^2 + C(A)^2}\right) / \left(1 + \frac{p^{12}}{A^8}\right) + \frac{(\ln p - 4.2)^2 + F(A)}{1 + G(A)/\sqrt{p} + H(A)/p^4}$$

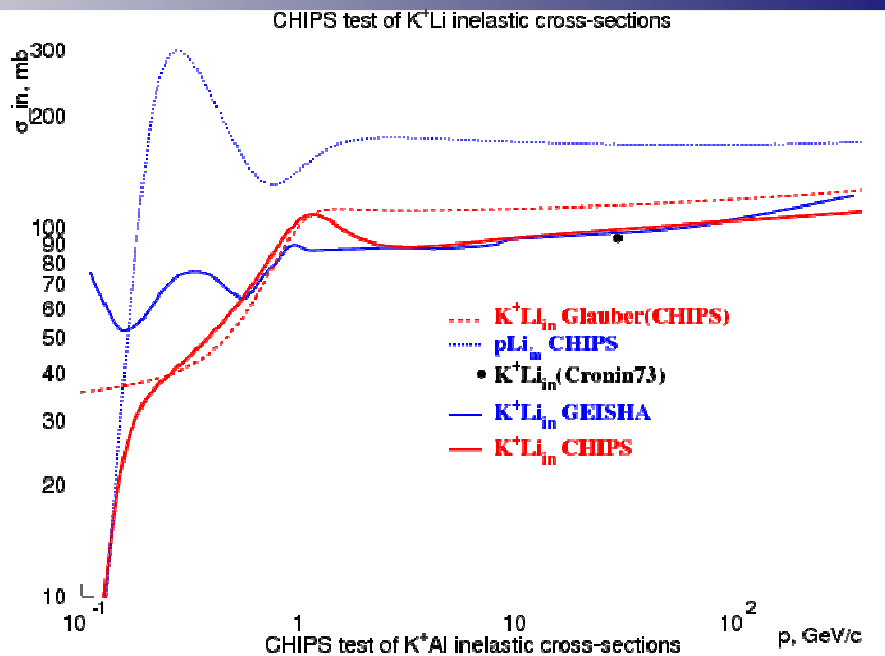
Parameterization of anti-pA inelastic cross-section:

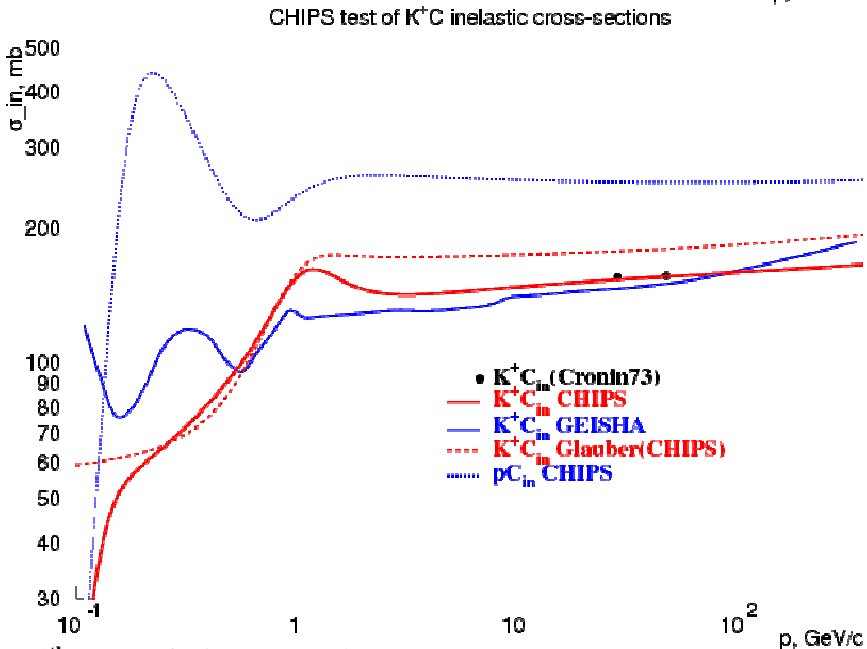
$$\sigma_{anti-pD} = G \cdot p^{-2/3} + H \cdot p^{-1/3} + D \cdot (\ln p - E)^2 + F$$

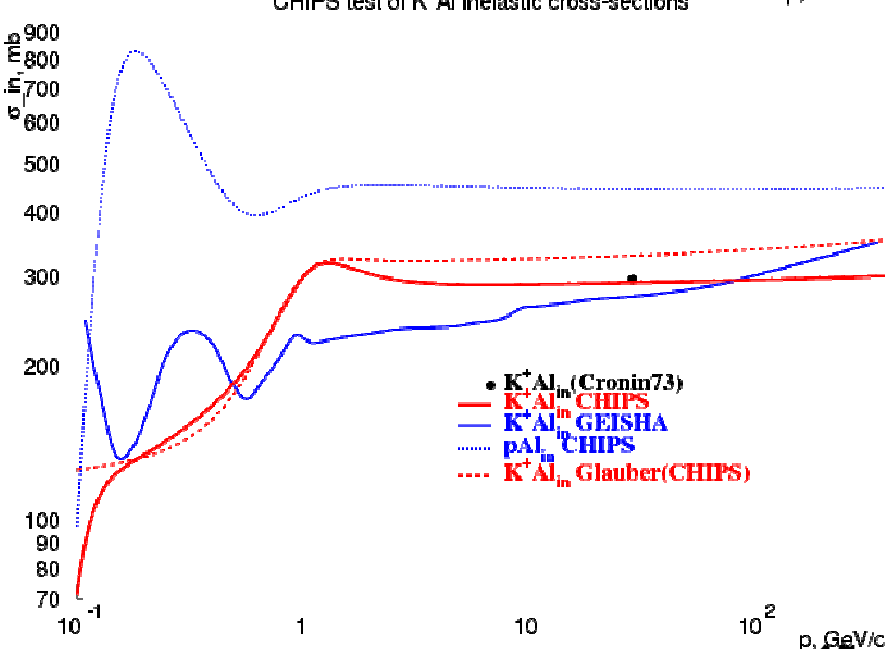
$$\sigma_{anti-pA} = D(A) + (\ln p - 4.2)^2 + F(A)/\sqrt{p}$$

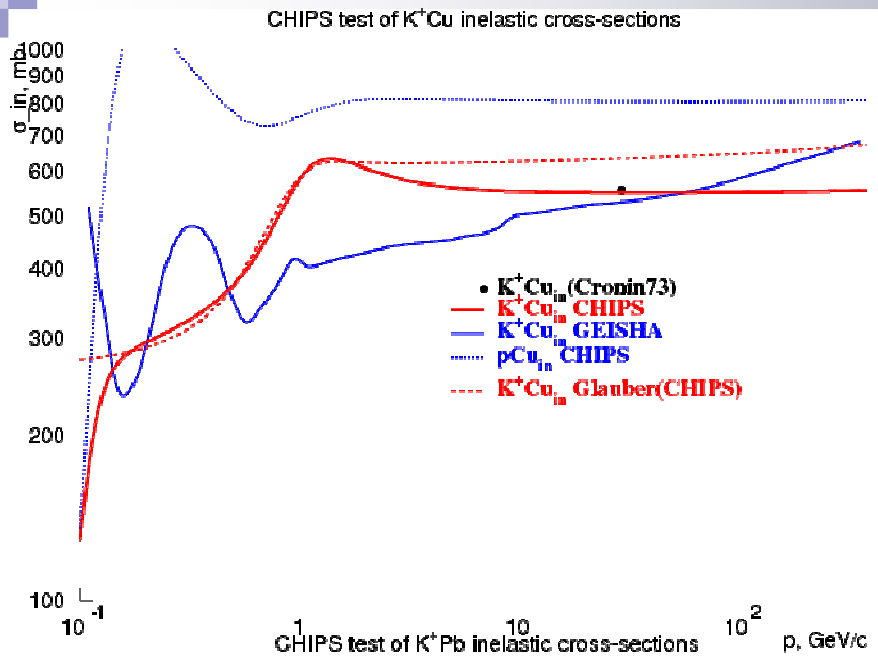

CHIPS test of K+D inelastic cross-sections
σ_in, mb
200
100
90
80
70
60
50
40
30
20
10
9
8
7
10^-1
1
10
10^2
p, GeV/c
K+Dtot(COMPAS)
K+Din(tot COMPAS)
K+Din GEISHA
K+Din CHIPS
K+Din Glauber(CHIPS)''
pDin CHIPS

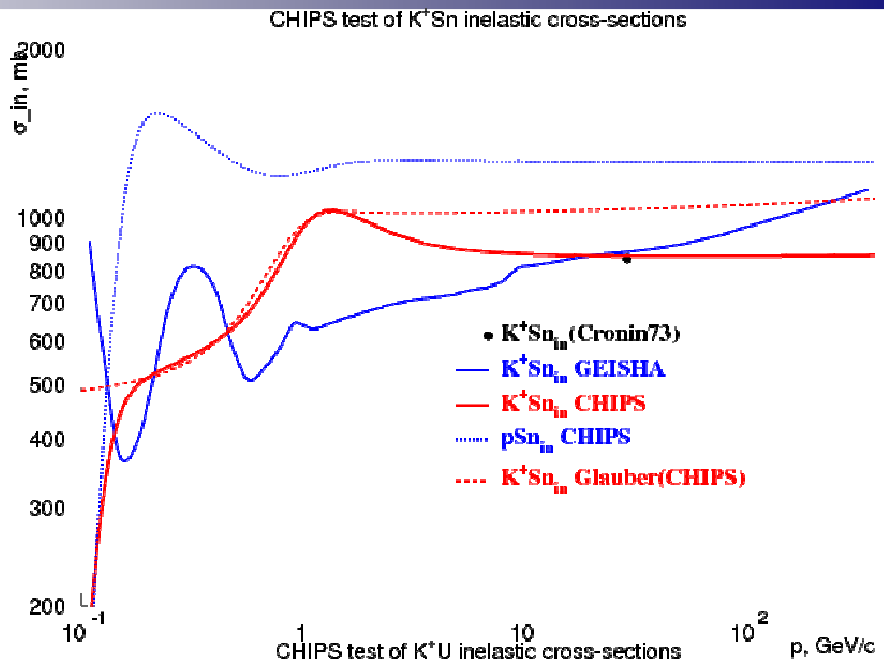

CHIPS test of K+He inelastic cross-sections
σ_in, mb
p, GeV/c
pHe_in CHIPS
K+He_in Glauber(CHIPS)
K+He_in CHIPS
K+He_in GEISHA

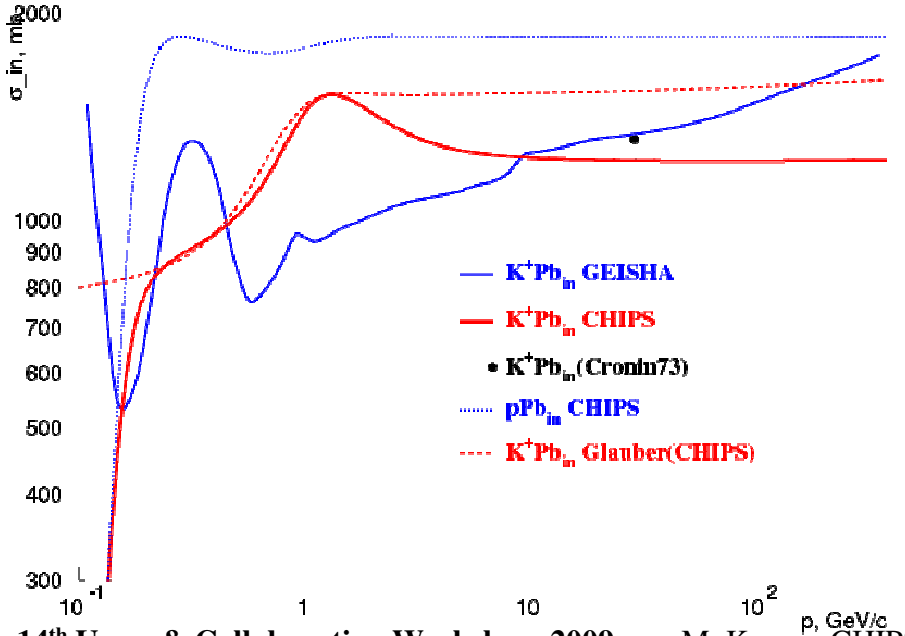

CHIPS test of K+Li inelastic cross-sections
σ_in, mb
p, GeV/c
K+Li_in Glauber(CHIPS)
pLi_in CHIPS
K+Li_in(Cronin73)
K+Li_in GEISHA
K+Li_in CHIPS

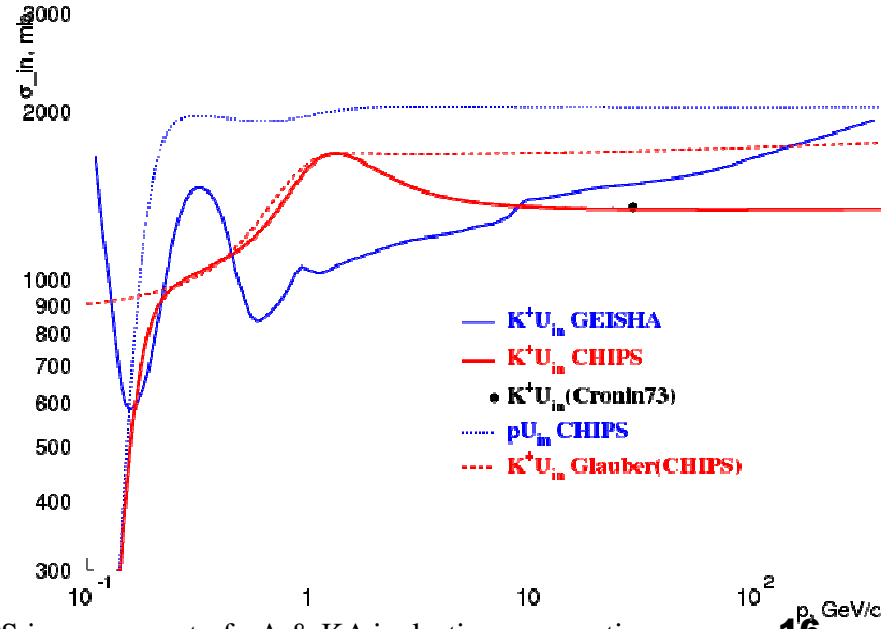

CHIPS test of K+C inelastic cross-sections
σ_in, mb
p, GeV/c
K+C_in(Cronin73)
K+C_in CHIPS
K+C_in GEISHA
K+C_in Glauber(CHIPS)
pC_in CHIPS

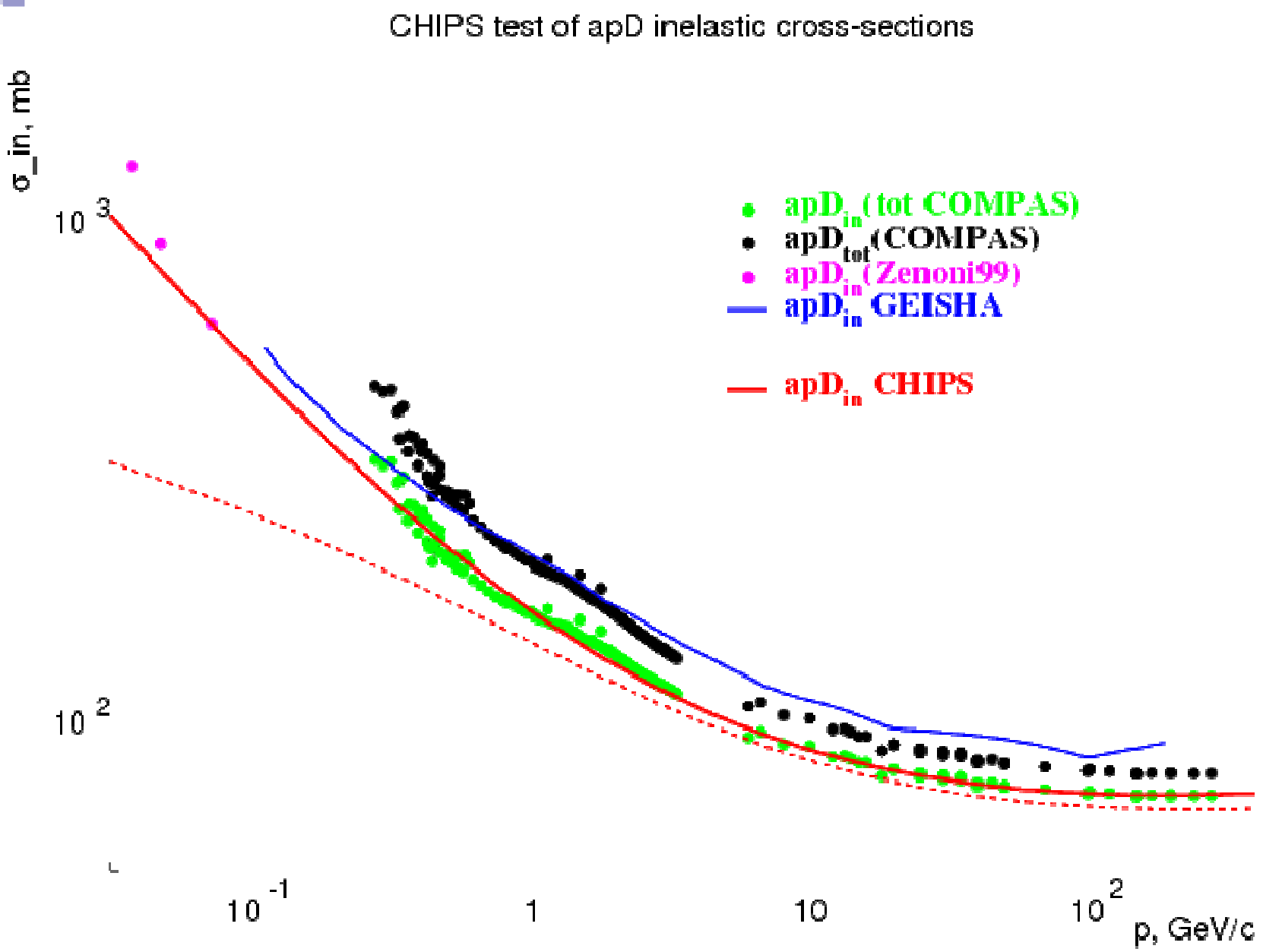

CHIPS test of K+Al inelastic cross-sections
σ_in, mb
p, GeV/c
K+Al_in(Cronin73)
K+Al_in CHIPS
K+Al_in GEISHA
pAl_in CHIPS
K+Al_in Glauber(CHIPS)

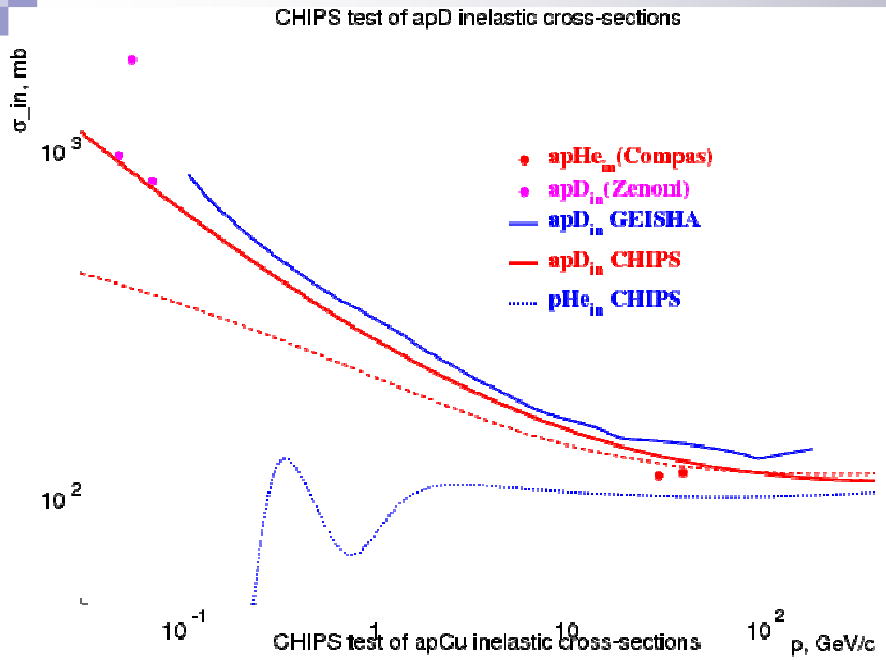

CHIPS test of K+Cu inelastic cross-sections
σ_in, mb
p, GeV/c
K+Cu_in (Cronin73)
K+Cu_in CHIPS
K+Cu_in GEISHA
pCu_in CHIPS
K+Cu_in Glauber(CHIPS)

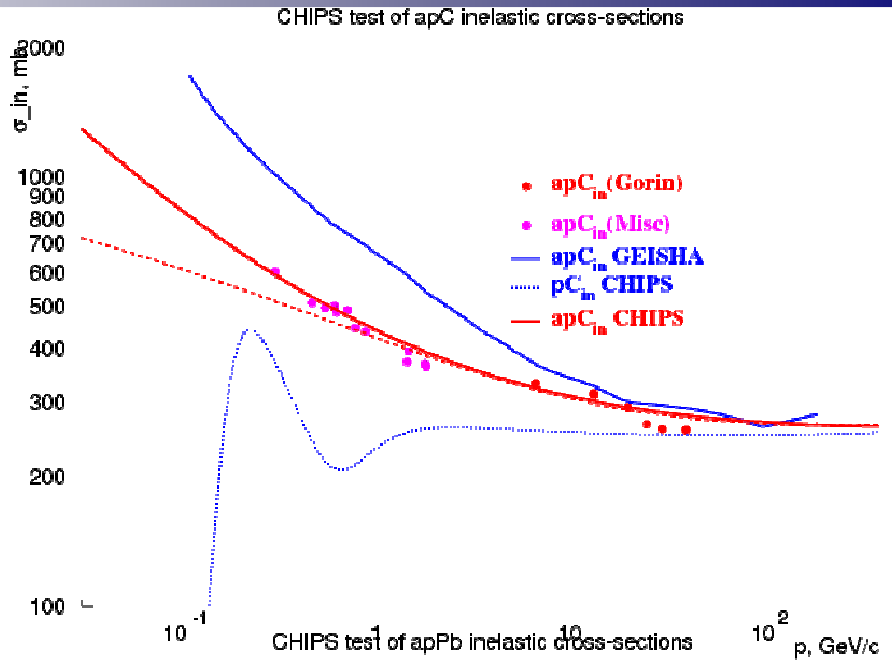

CHIPS test of K+Sn inelastic cross-sections
σ_in, mb
p, GeV/c
K+Sn_in (Cronin73)
K+Sn_in GEISHA
K+Sn_in CHIPS
pSn_in CHIPS
K+Sn_in Glauber(CHIPS)

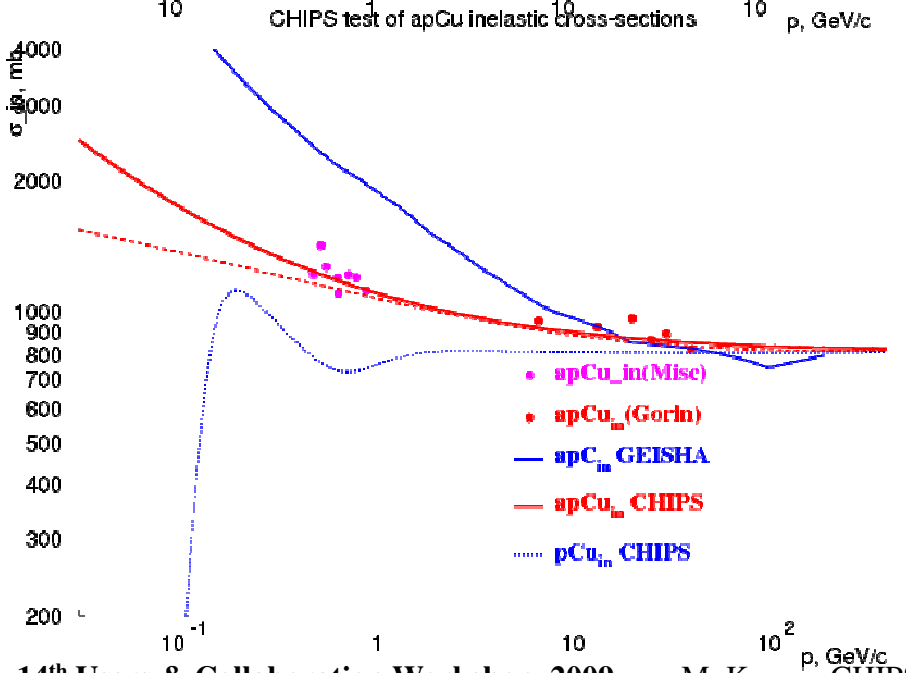

CHIPS test of K+Pb inelastic cross-sections
σ_in, mb
p, GeV/c
K+Pb_in GEISHA
K+Pb_in CHIPS
K+Pb_in (Cronin73)
pPb_in CHIPS
K+Pb_in Glauber(CHIPS)

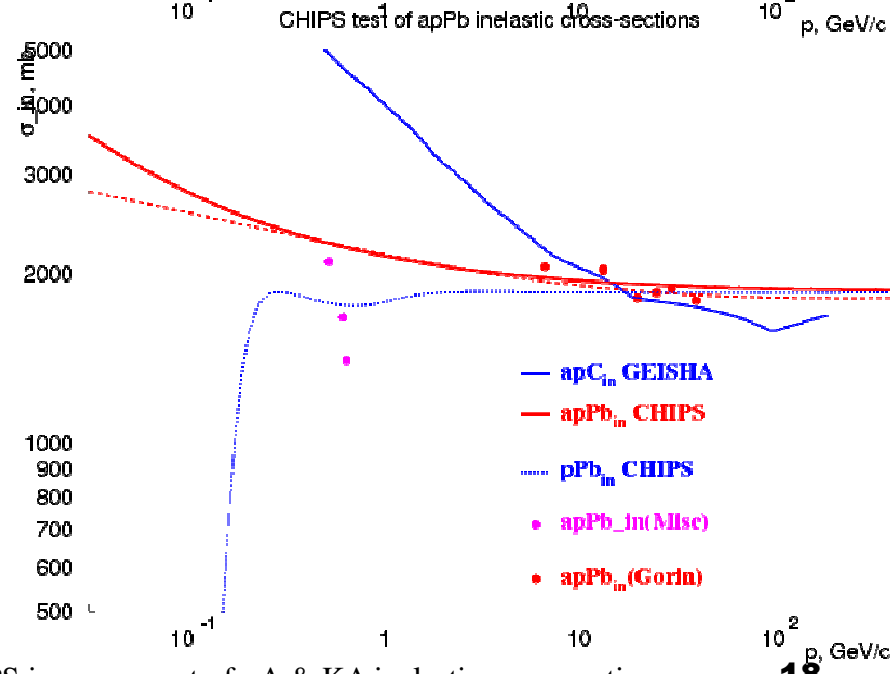

CHIPS test of K+U inelastic cross-sections
σ_in, mb
p, GeV/c
K+U_in GEISHA
K+U_in CHIPS
K+U_in (Cronin73)
pU_in CHIPS
K+U_in Glauber(CHIPS)


CHIPS test of apD inelastic cross-sections
σ_in, mb
10 3
10 2
10 -1
1
10
10 2
p, GeV/c
apD_in (tot COMPAS)
apD_tot (COMPAS)
apD_in (Zenoni99)
apD_in GEISHA
apD_in CHIPS


CHIPS test of apD inelastic cross-sections
σ_in, mb
apHe_in(Compas)
apD_in(Zenoni)
apD_in GEISHA
apD_in CHIPS
pHe_in CHIPS
p, GeV/c


CHIPS test of apC inelastic cross-sections
σ_in, mb
apC_in(Gorin)
apC_in(Misc)
apC_in GEISHA
pC_in CHIPS
apC_in CHIPS
p, GeV/c


CHIPS test of apCu inelastic cross-sections
σ_in, mb
apCu_in(Misc)
apCu_in(Gorin)
apC_in GEISHA
apCu_in CHIPS
pCu_in CHIPS
p, GeV/c


CHIPS test of apPb inelastic cross-sections
σ_in, mb
apC_in GEISHA
apPb_in CHIPS
pPb_in CHIPS
apPb_in(Misc)
apPb_in(Gorin)
p, GeV/c

# Conclusion

- Now the updated CHIPS inelastic cross-section update is almost ready for the CHIPS Phys. List
- The only scope to be covered is Hyperon-nuclear reactions for which there is no data: do similar to NA inelastic cross-sections with CHIPS Glauber
- A lot should be done for elastic cross-sections fit, but now the strategy is different (w.r.t.``` NA): use $\sigma_{el}$("ex")=$\sigma_{tot}$(ex)-$\sigma_{in}$(CHIPS)
- In November 2009 the first one-model CHIPS physics list can be implemented for testing; the inelastic cross-sections is the first thing to test
- Other G4 models can use CHIPS cross-sections

# Thank you

# Backup slides following