

# Verification and CHIPS upgrade of Geant4 inelastic cross-sections.

Mikhail Kosov, Physics Validation Meeting

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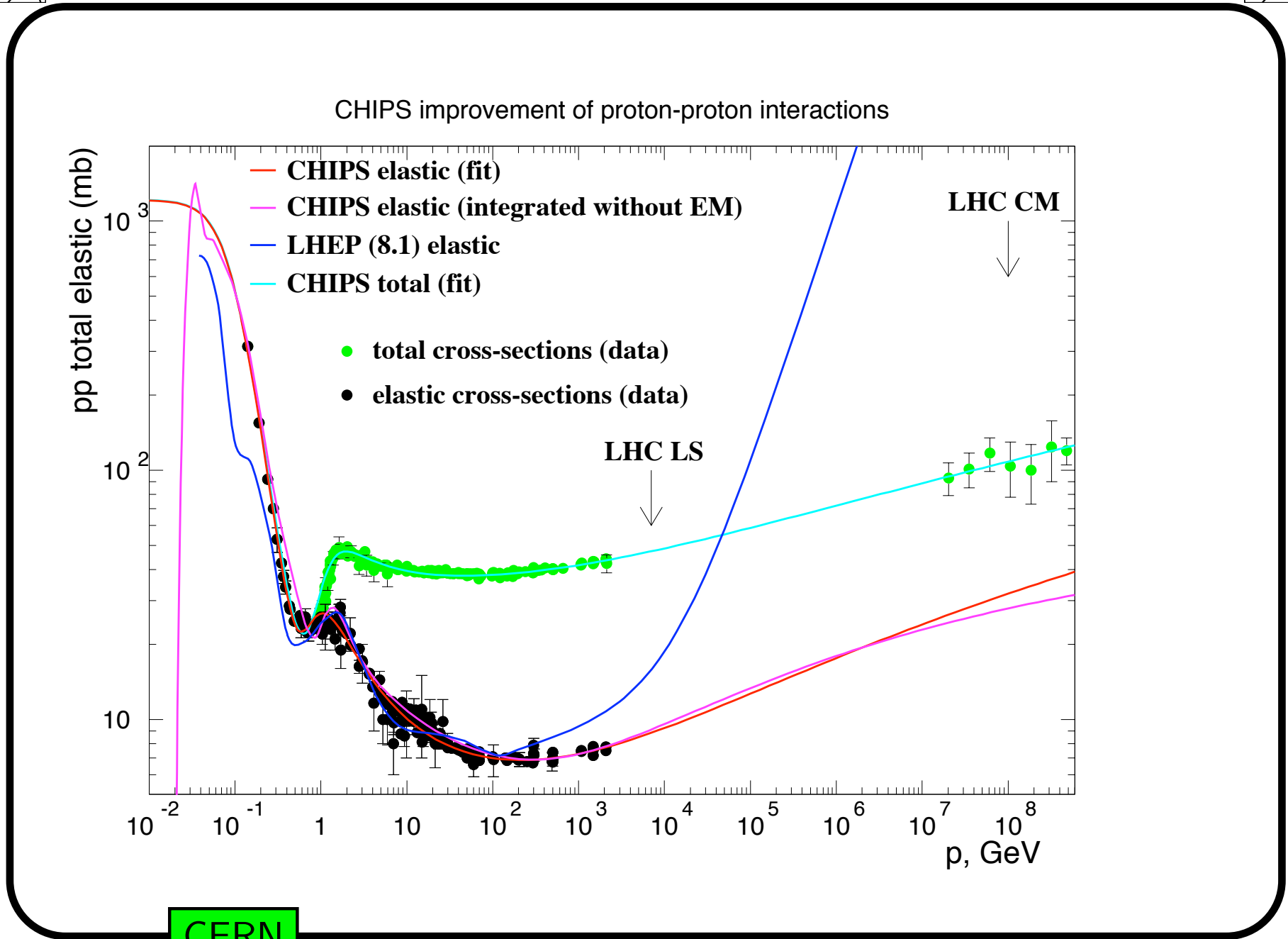


1. CHIPS approximation formula.
2. Verification and CHIPS upgrade at high energies.
3. Verification and CHIPS upgrade at low energies.

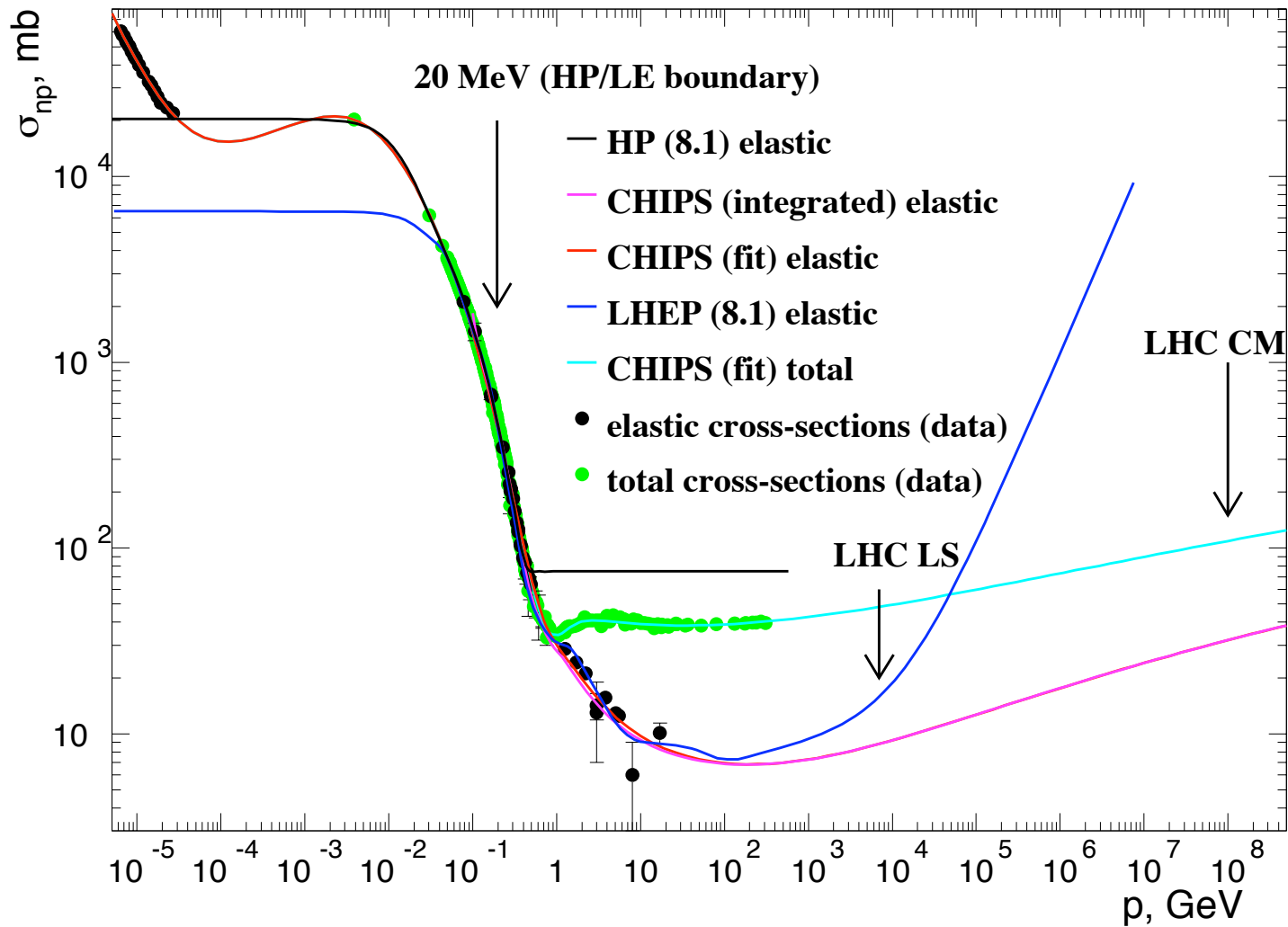


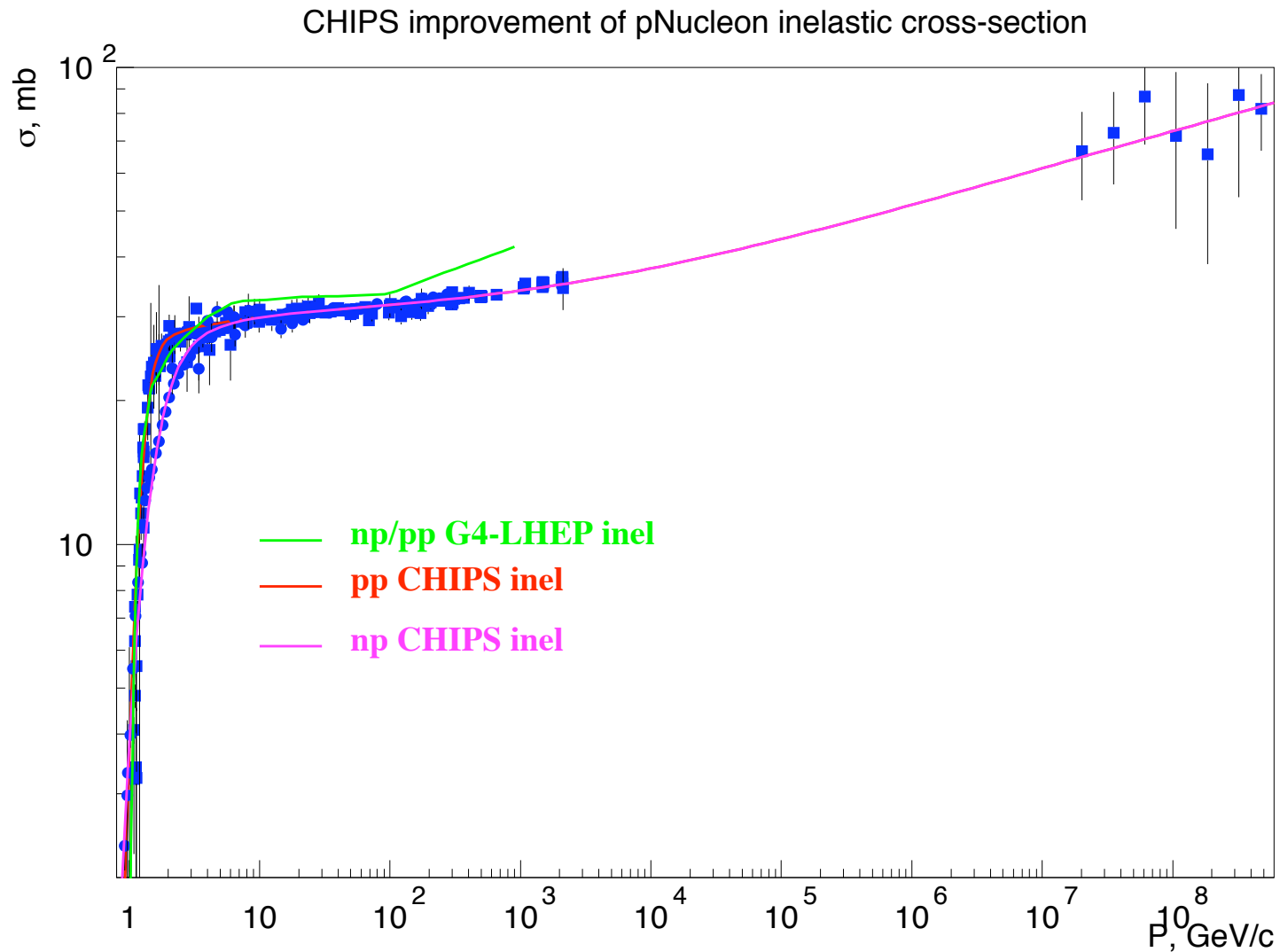
## Inelastic cross-sections in Geant4 simulation

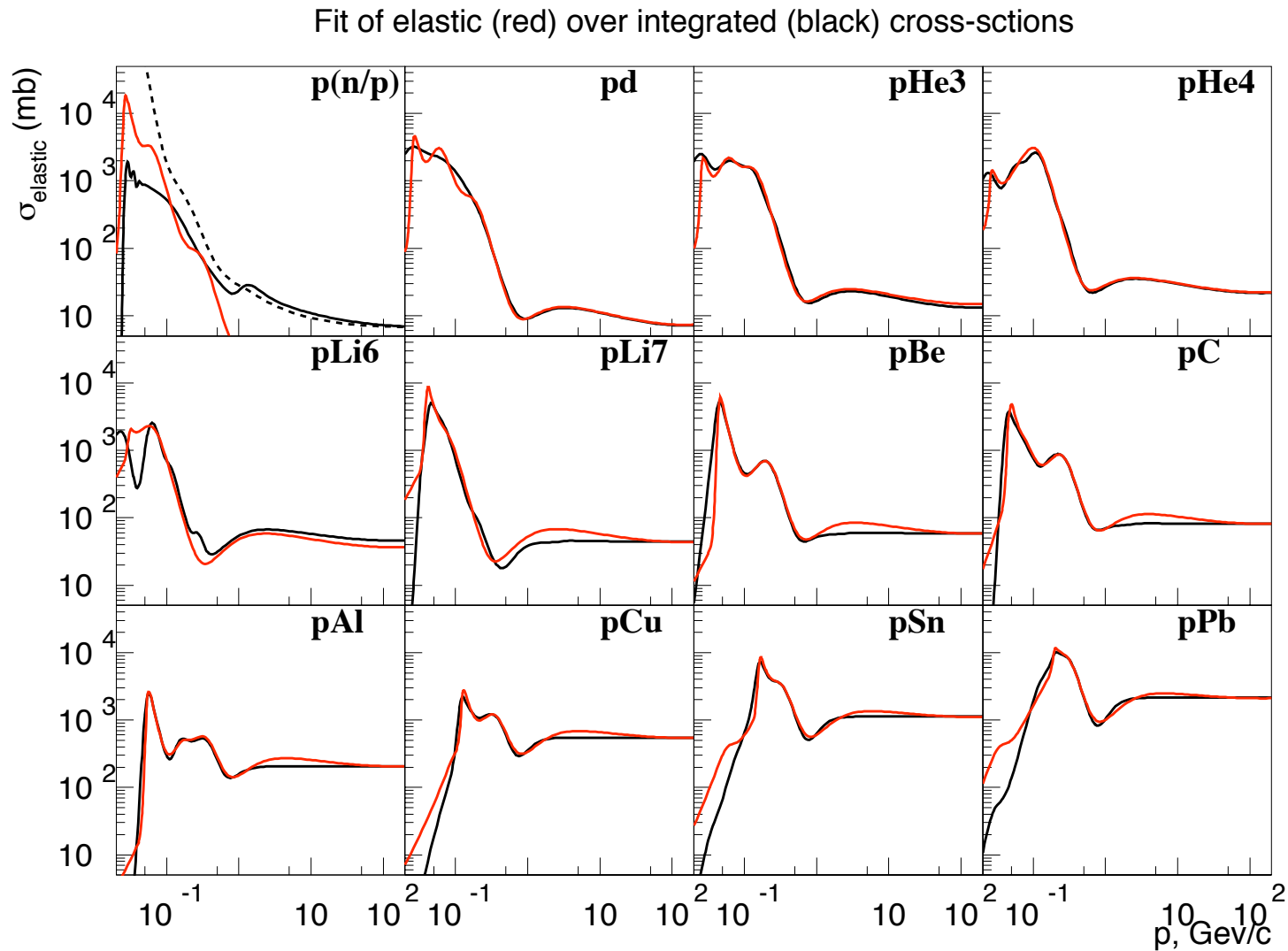
1. It has a lot of names: inelastic, incoherent, nonelastic, absorption, production, deep inelastic, and reaction cross-section.
2. As measured it includes coherent charge exchange, while it should not include coherent reactions (like coherent elastic). The coherent charge exchange exists only at low energies, where inelastic cross-sections are big. The coherent charge exchange part is practically within systematic errors of the CHIPS approximation.
3. Quasi-elastic cross section is included in the inelastic cross-section. The cross-section without quasi-elastic is usually called “production” or “deep inelastic” cross-section.
4. Total cross-section is a sum of elastic and inelastic. As CHIPS parameterization of elastic cross-sections already exists, one can use total cross-section measurements for inelastic cross-sections fit.



### CHIPS improvement of neutron-proton interaction





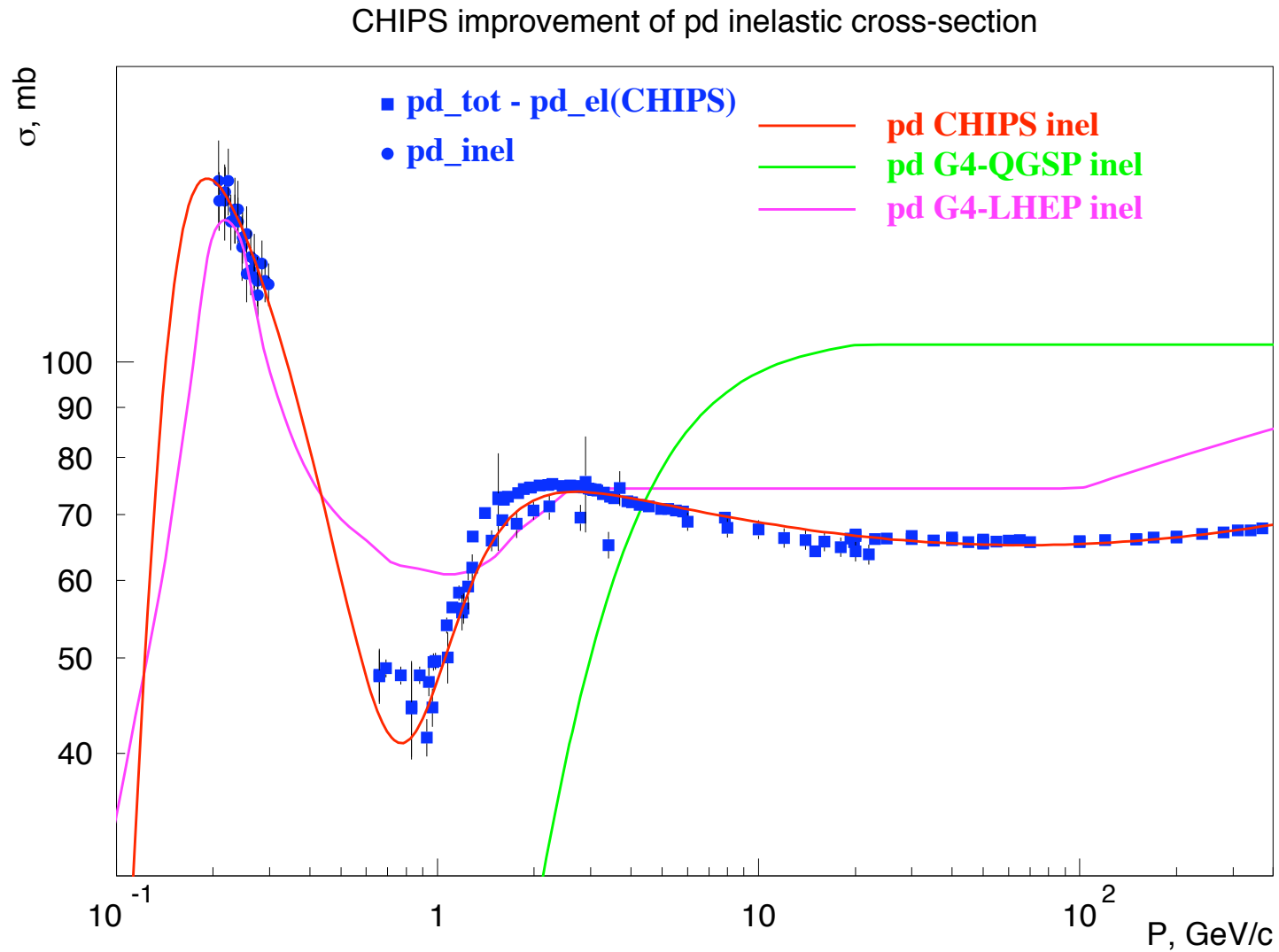


## CHIPS approximation formula for inelastic cross-sections

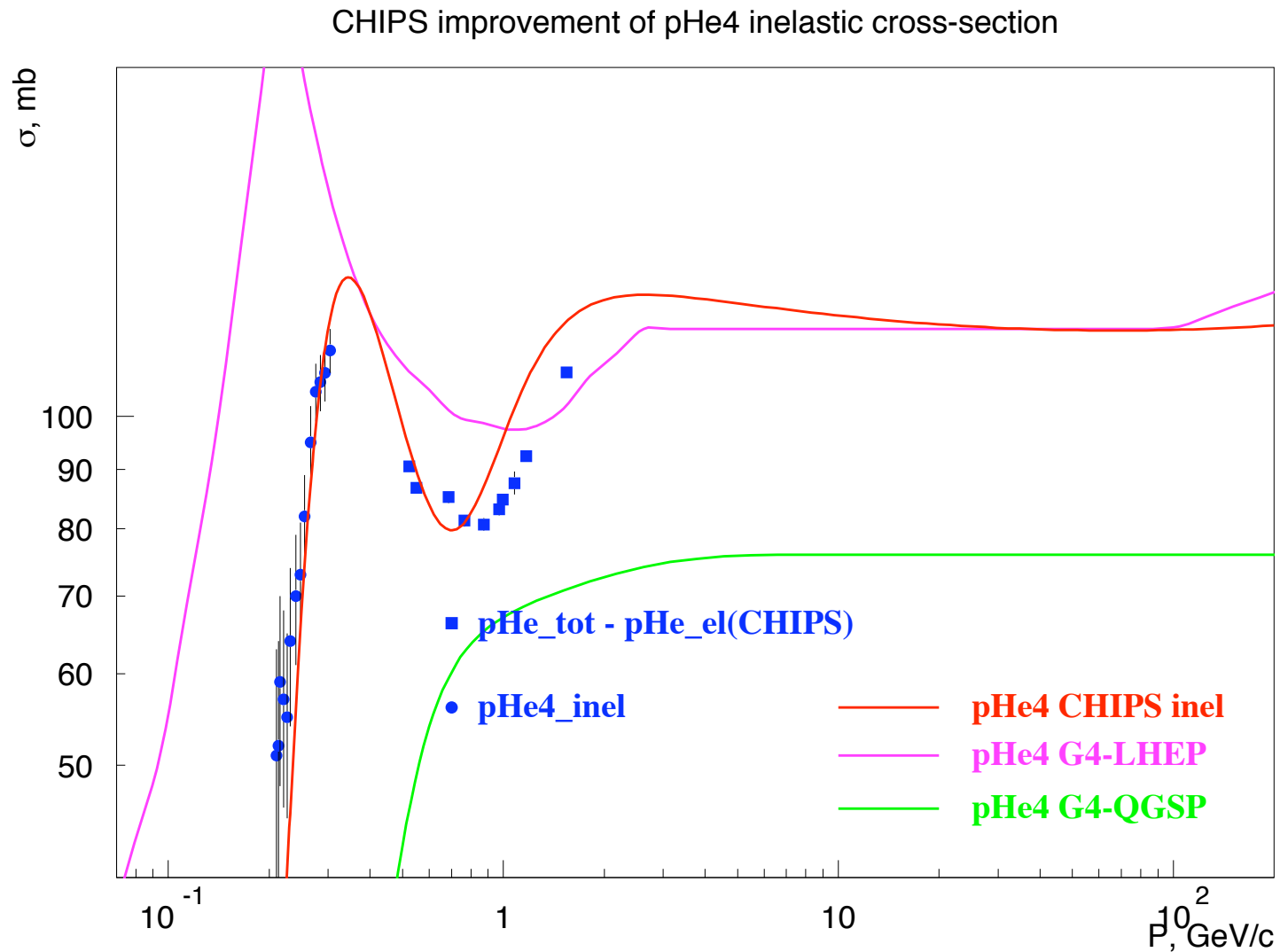
$$\sigma_{\text{in}} = \frac{A_1 + A_2(\ln(p) - A_3)^2}{1 + A_4/p^4} + \frac{A_5 + A_6e^{-A_7p}}{1 + A_8/p^8} + A_9e^{-(p-A_{10})^2/A_{11}}$$

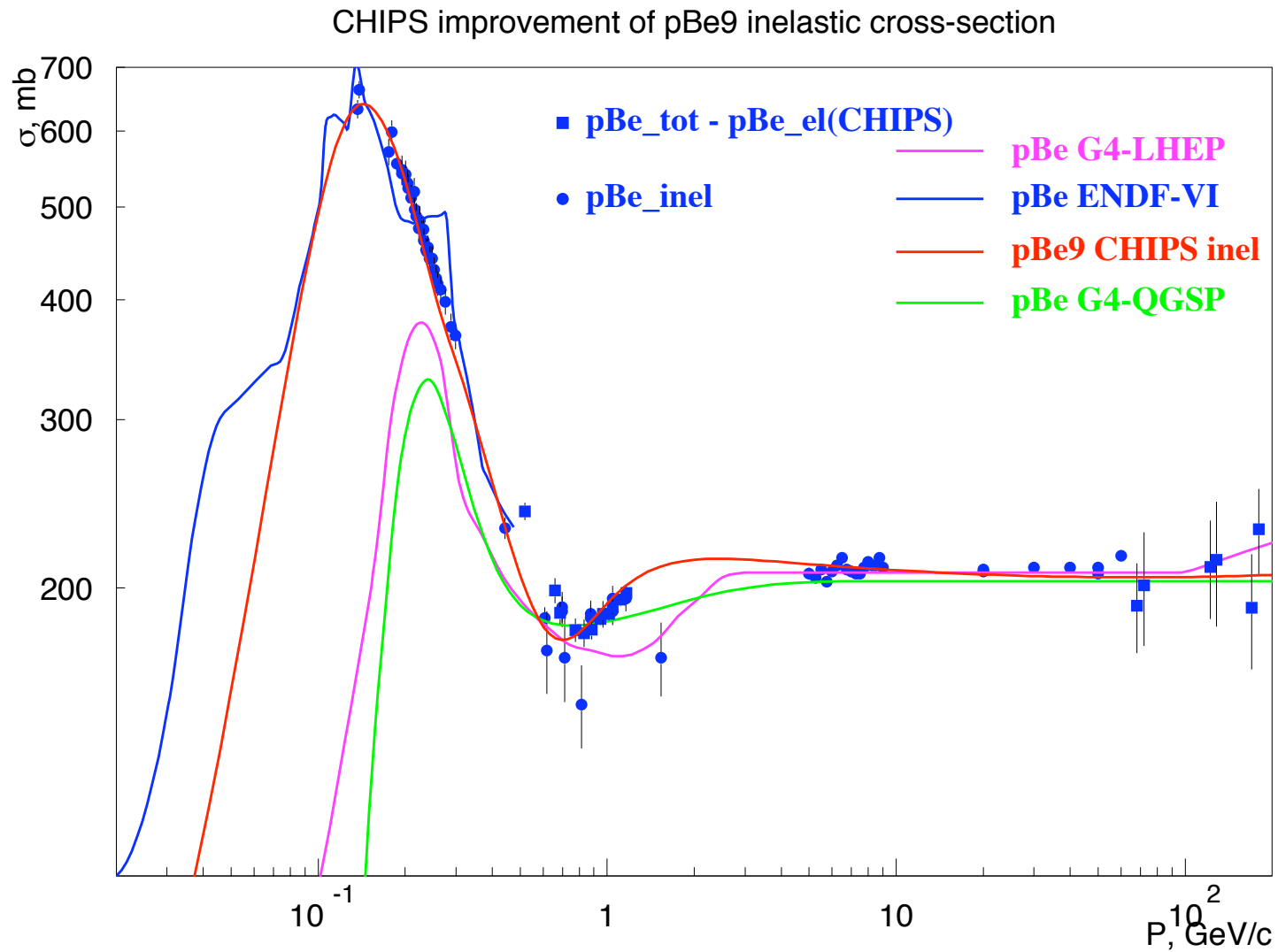
- 1. The logarithmic parameters are fixed:  $A_2 = 1$ ,  $A_3 = 4.2$ .*
- 2. The  $A_5$  parameter has meaning of “dark disc area”.*
- 3. The  $A_1$  has meaning of “transparent periphery contribution”.*
- 4. The  $A_4$  is a pion production threshold parameter.*
- 5. The  $A_6$ ,  $A_7$ ,  $A_8$  are elastic cascade parameters (low energy).*
- 6. The  $A_9$ ,  $A_{10}$ ,  $A_{11}$  are gaussian parameters (small  $A$ ).*

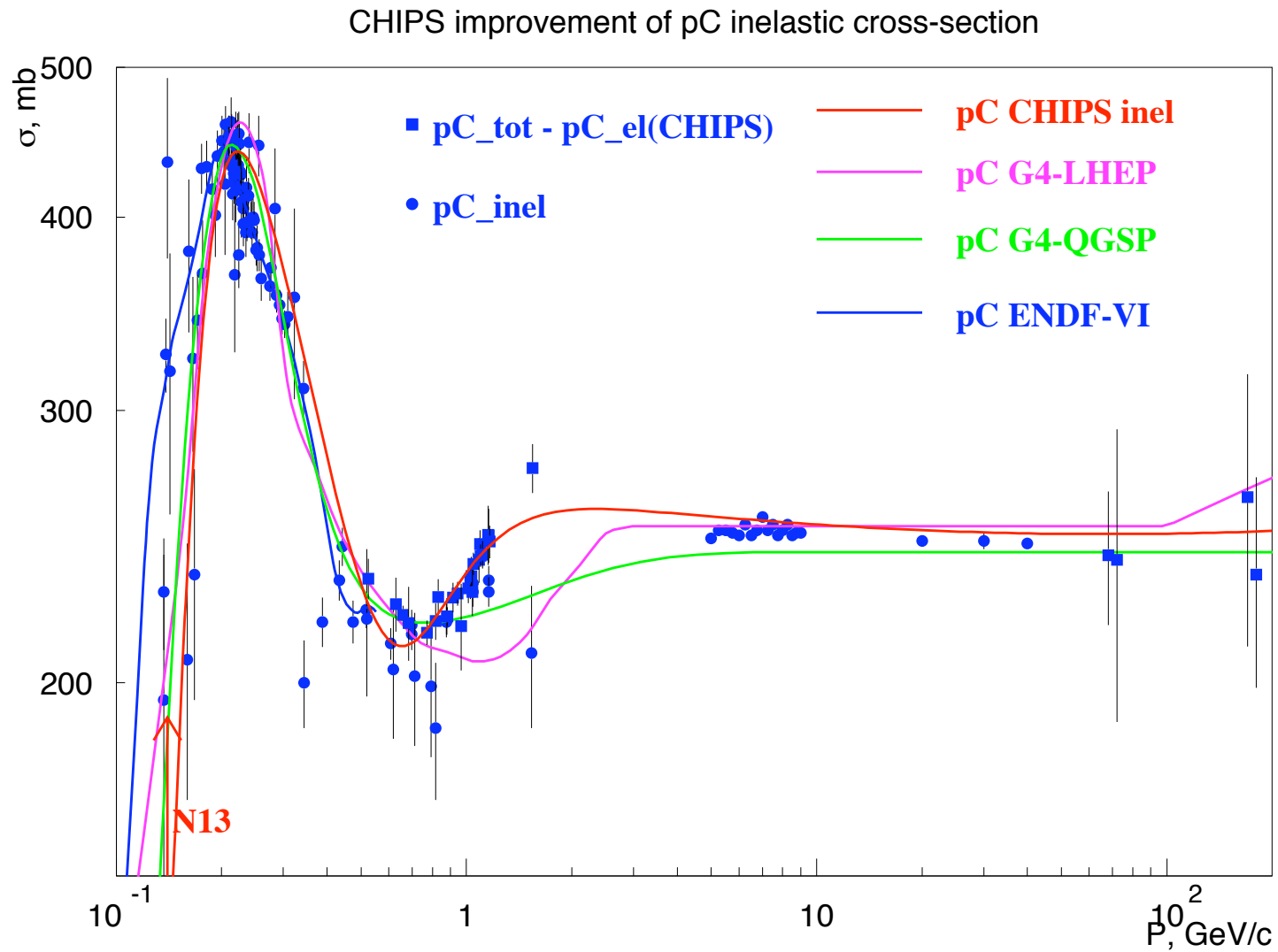
GREEN - cross-sections used in QGSP physics list, PINK - cross-sections used in LHEP physics list, BLUE - ENDF-VI approximation, RED - new (preliminary) CHIPS approximation.

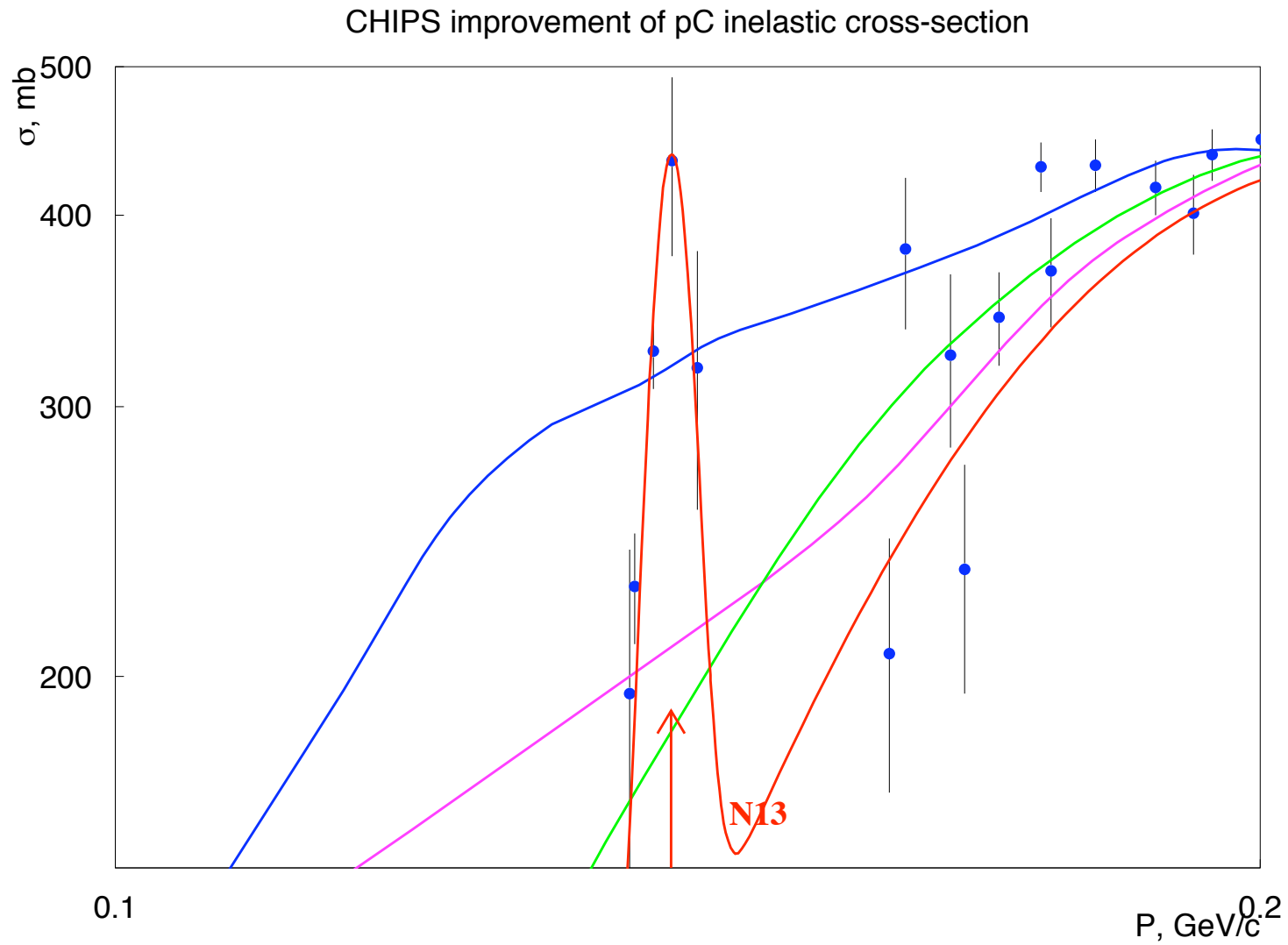


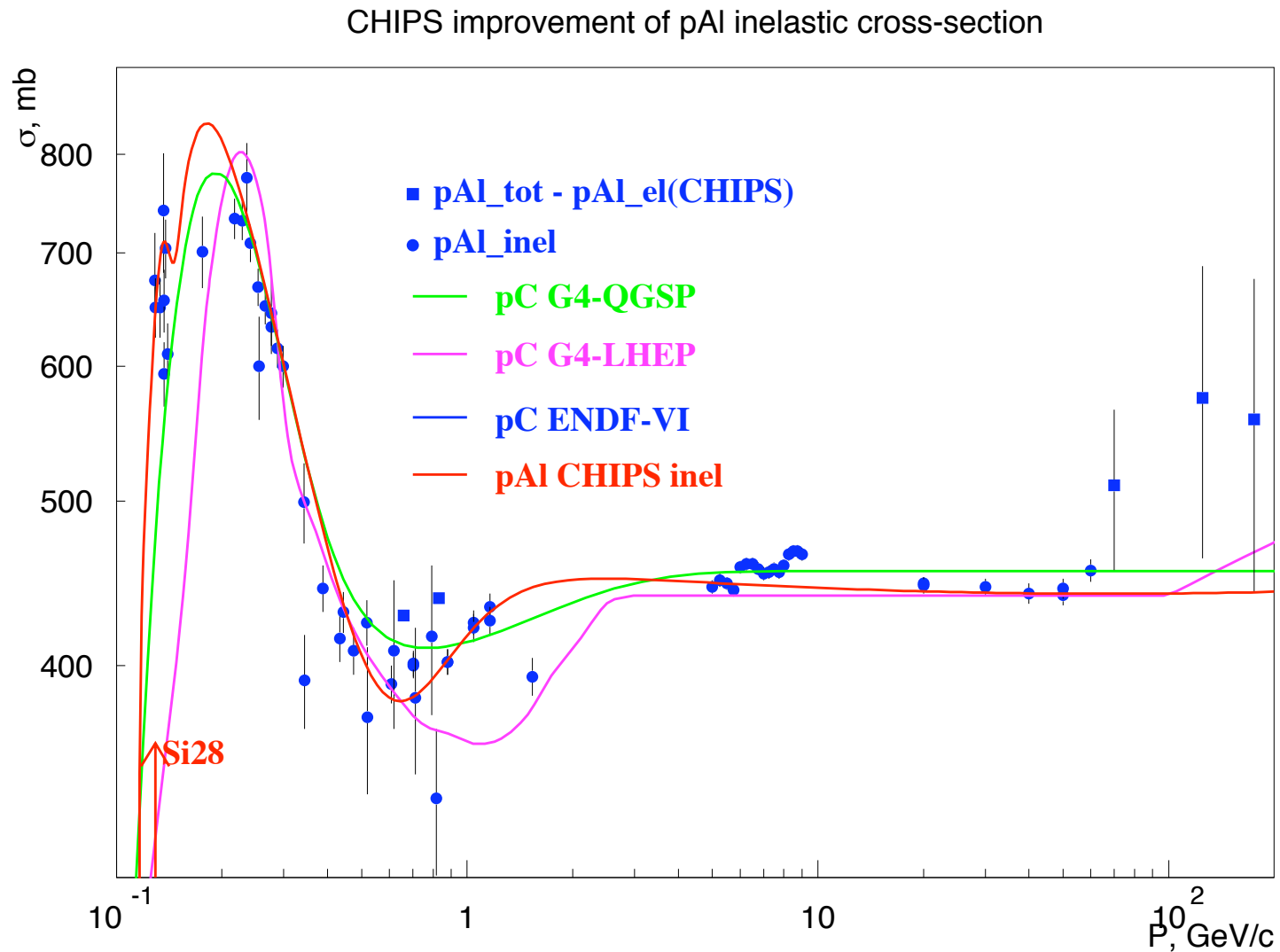


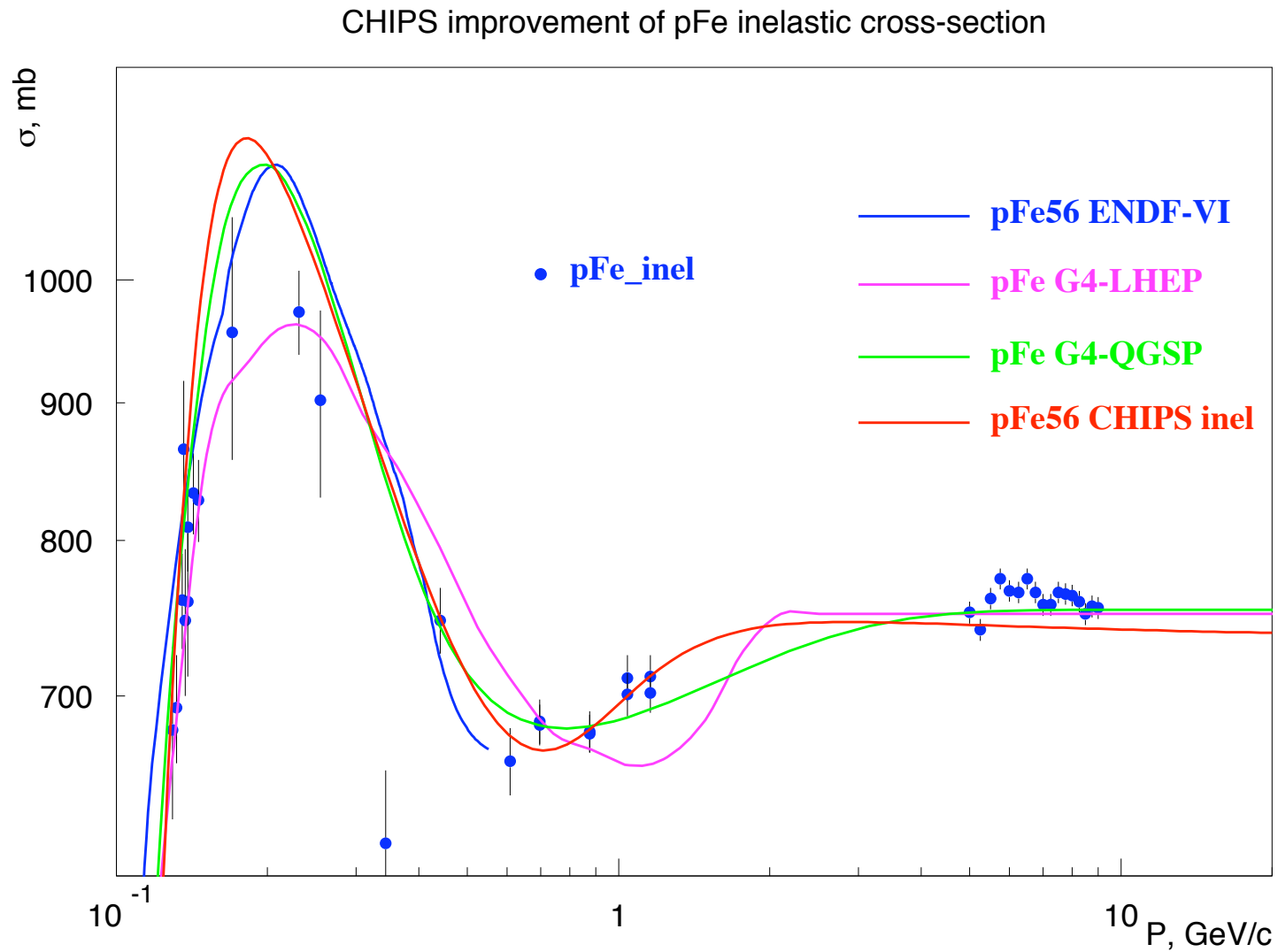


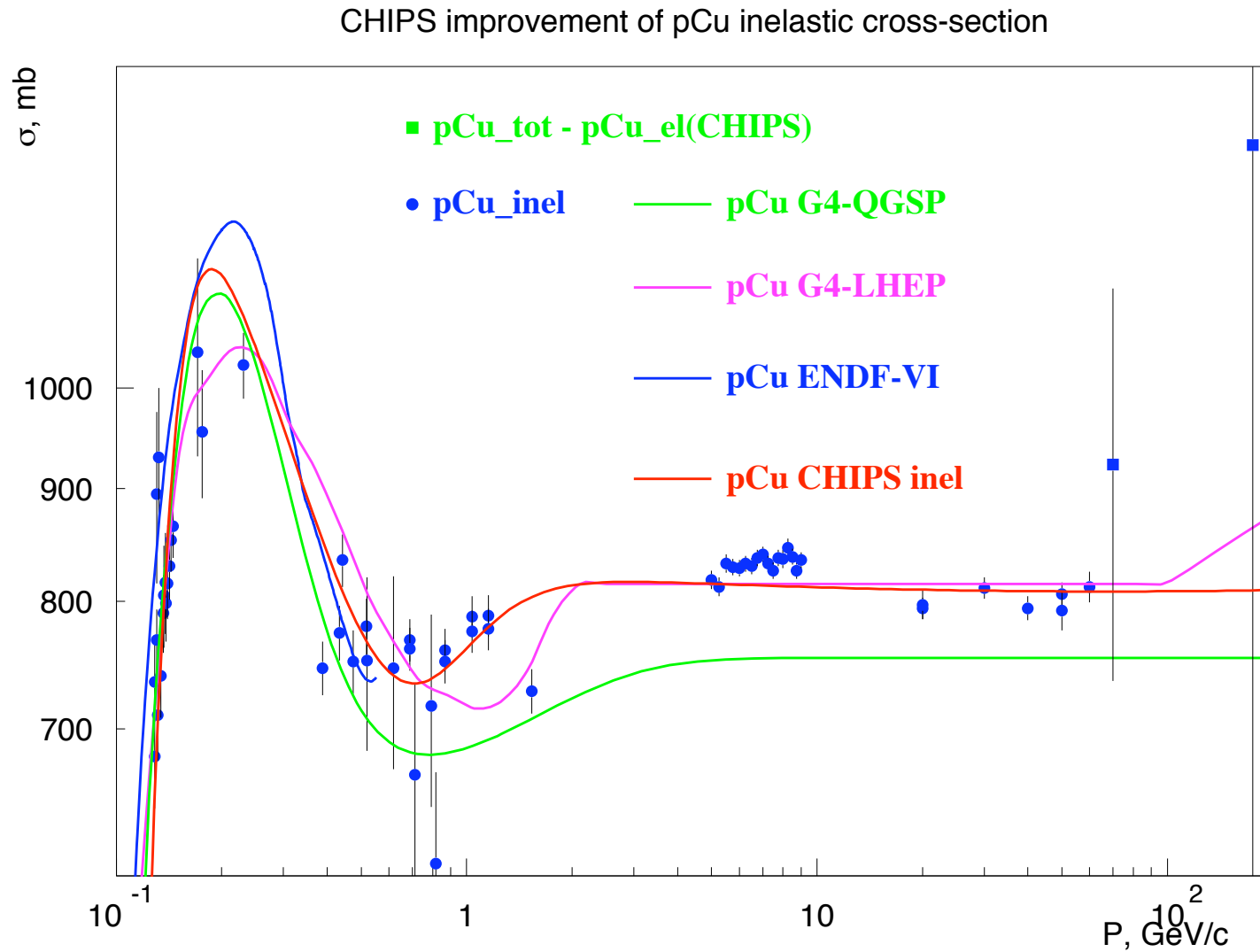


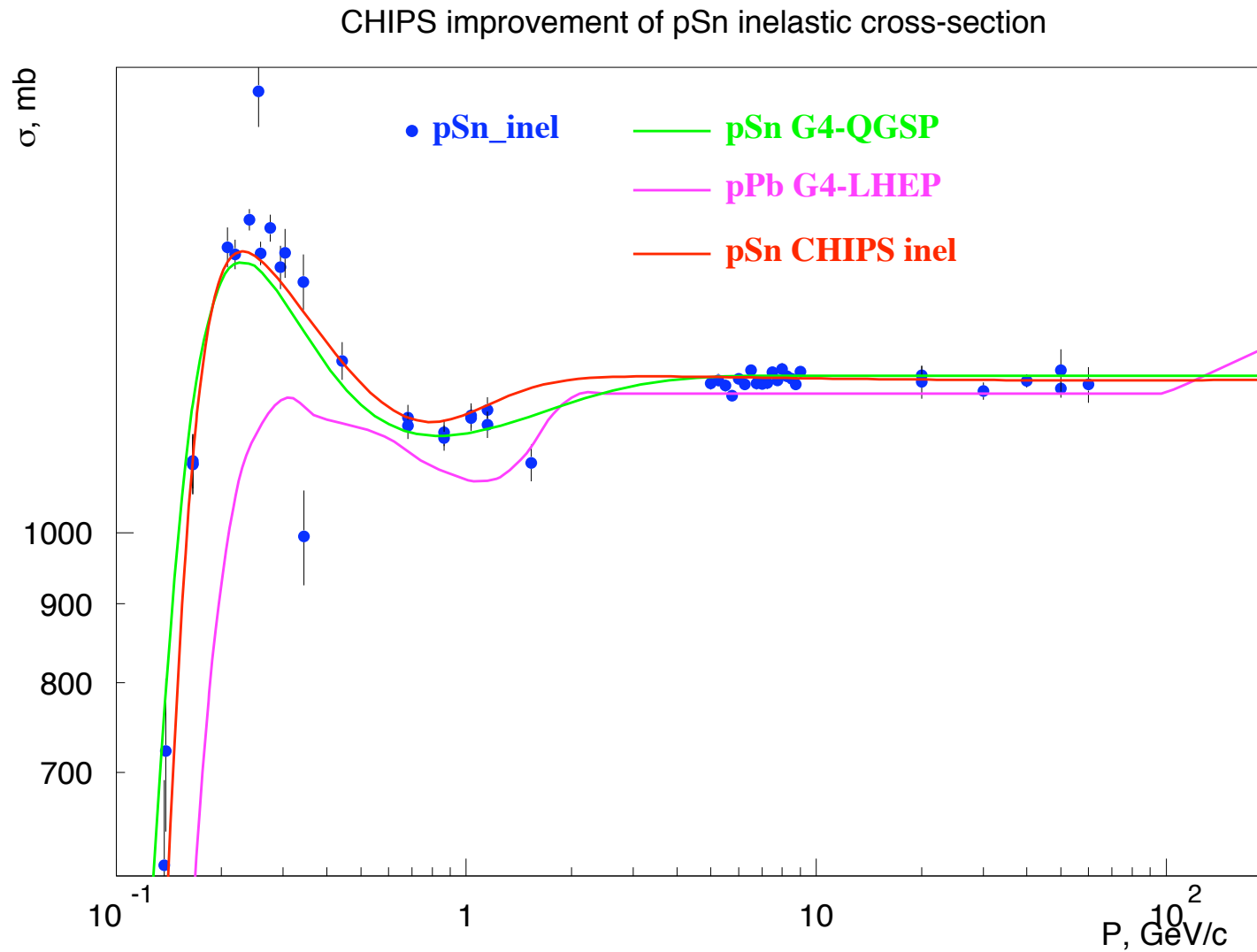




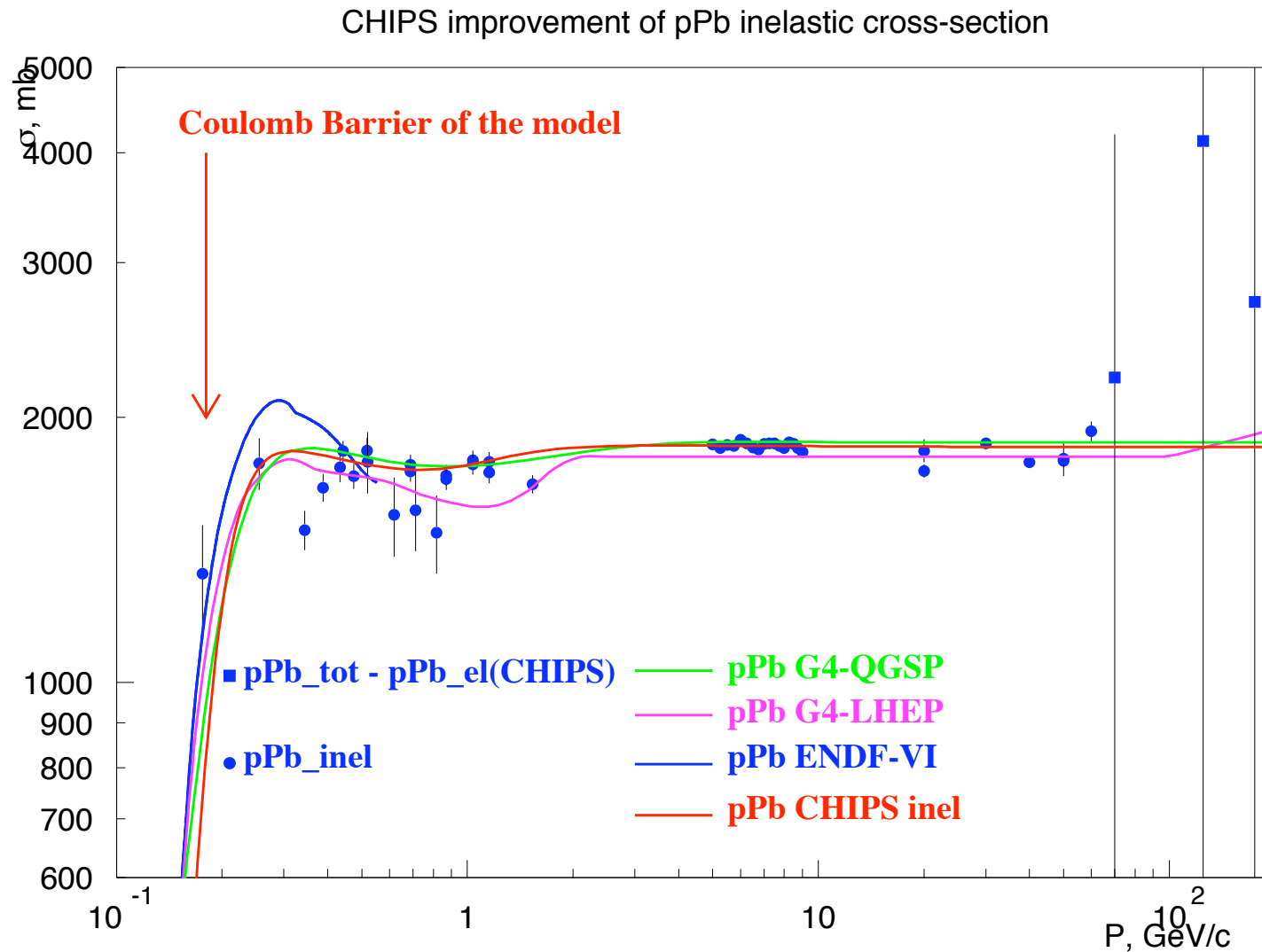


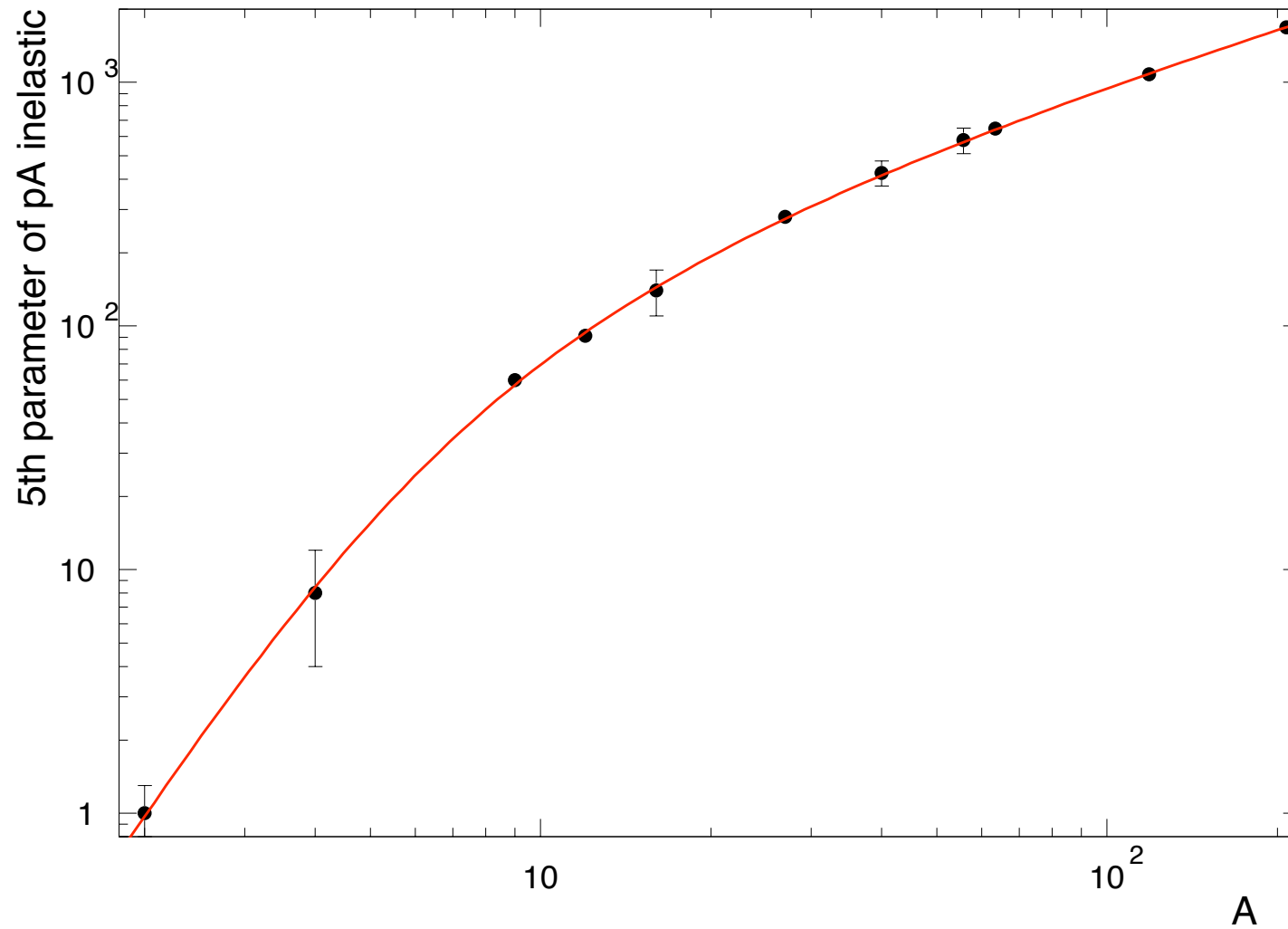


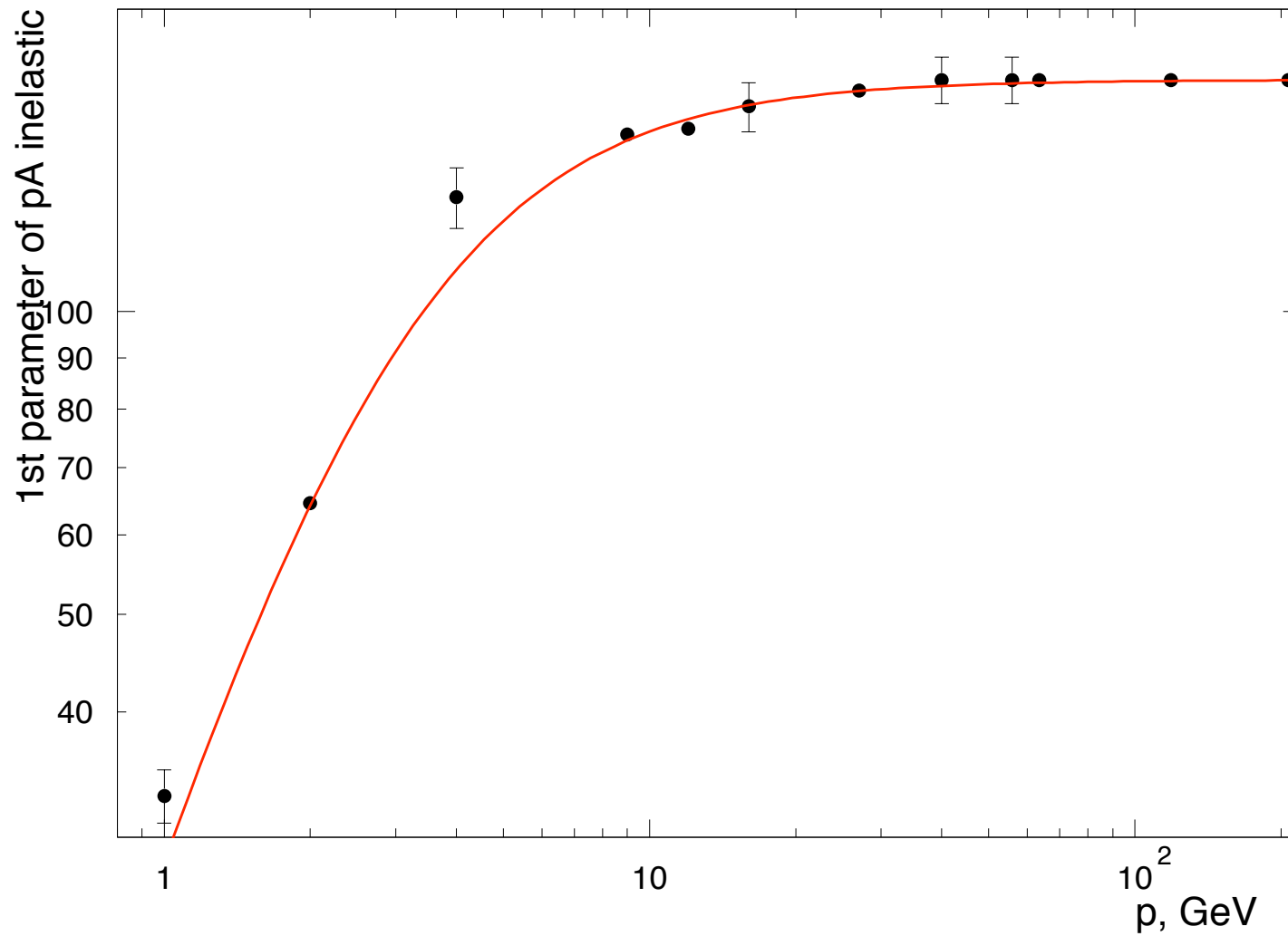


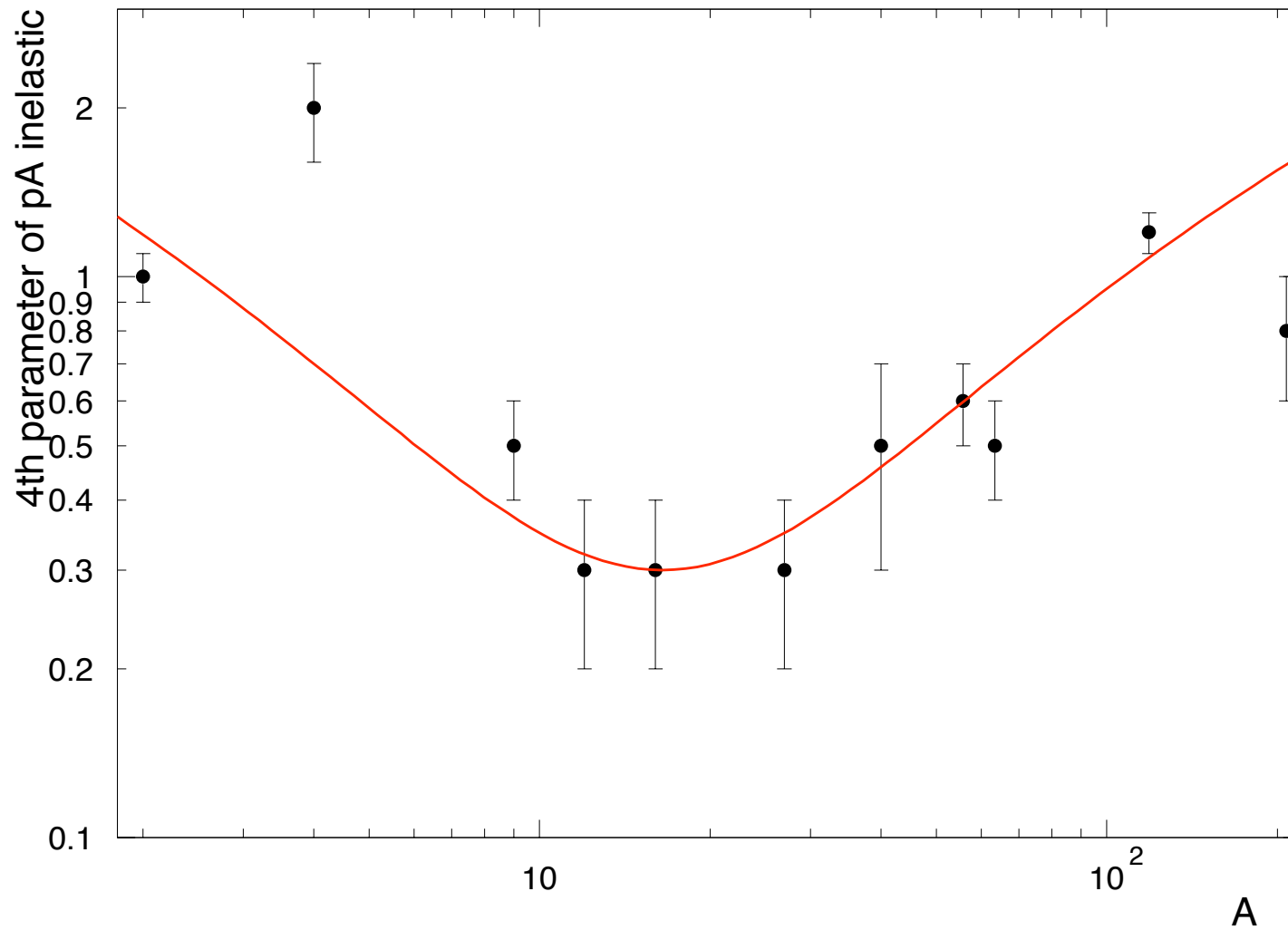








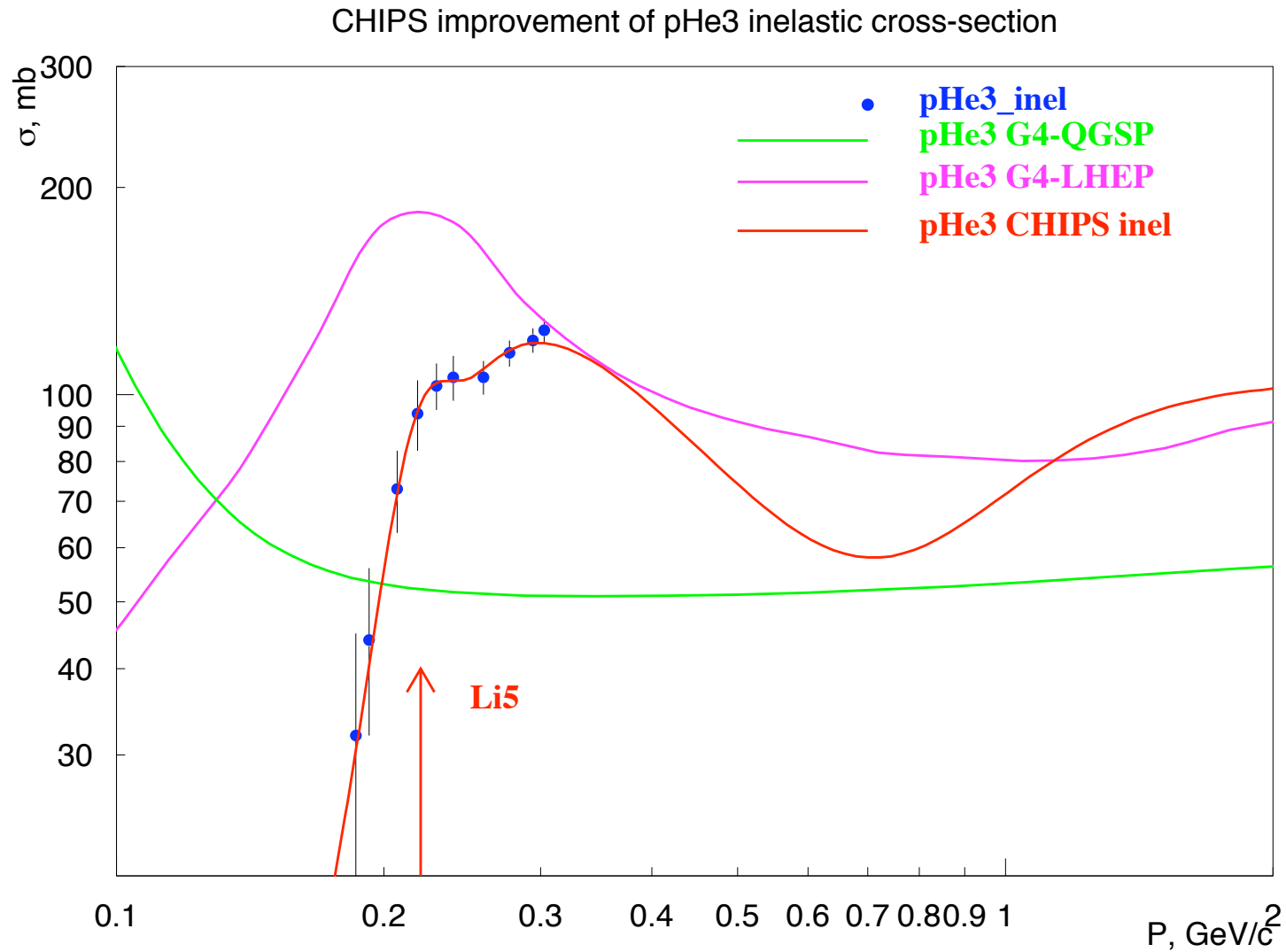


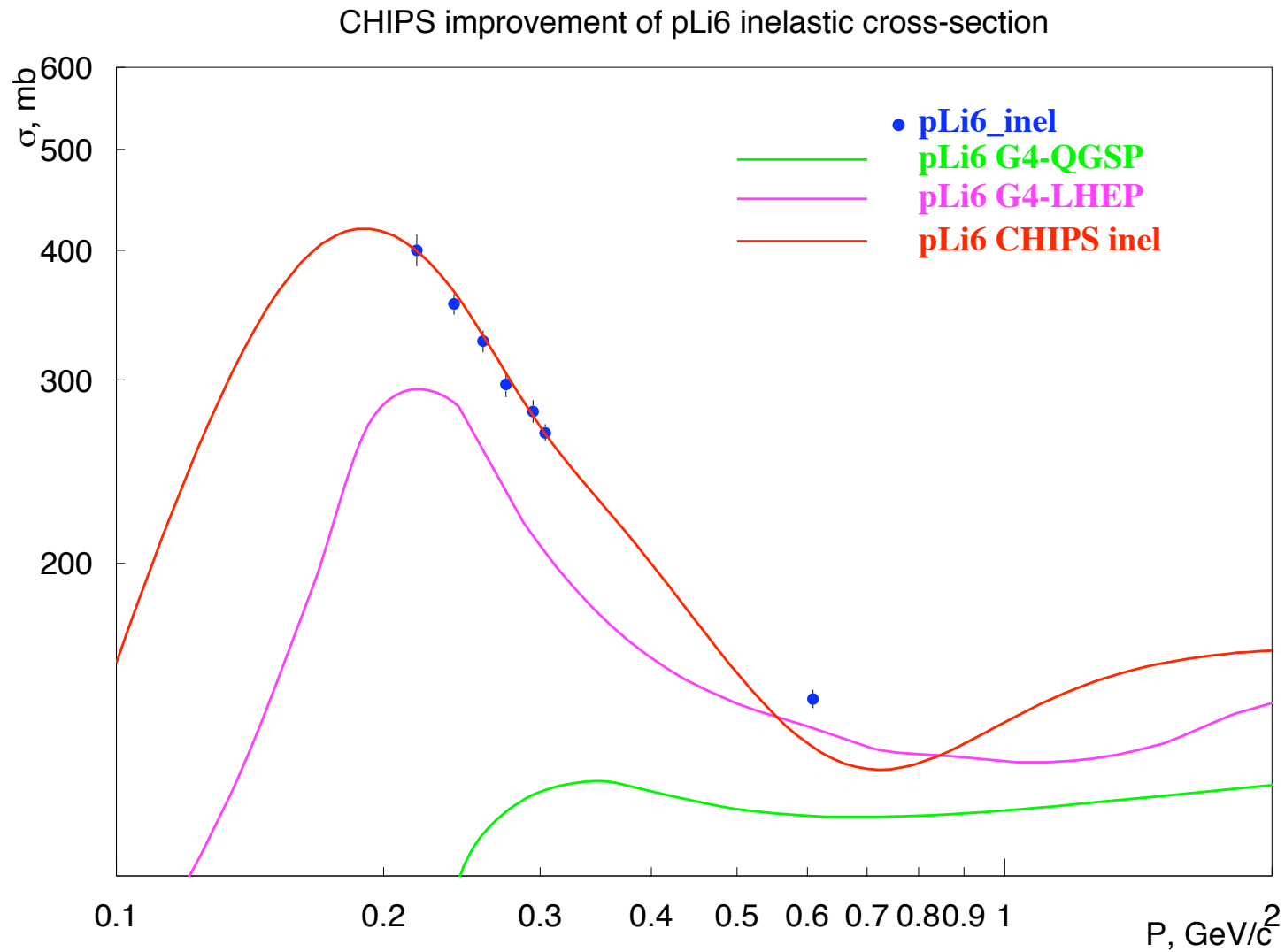


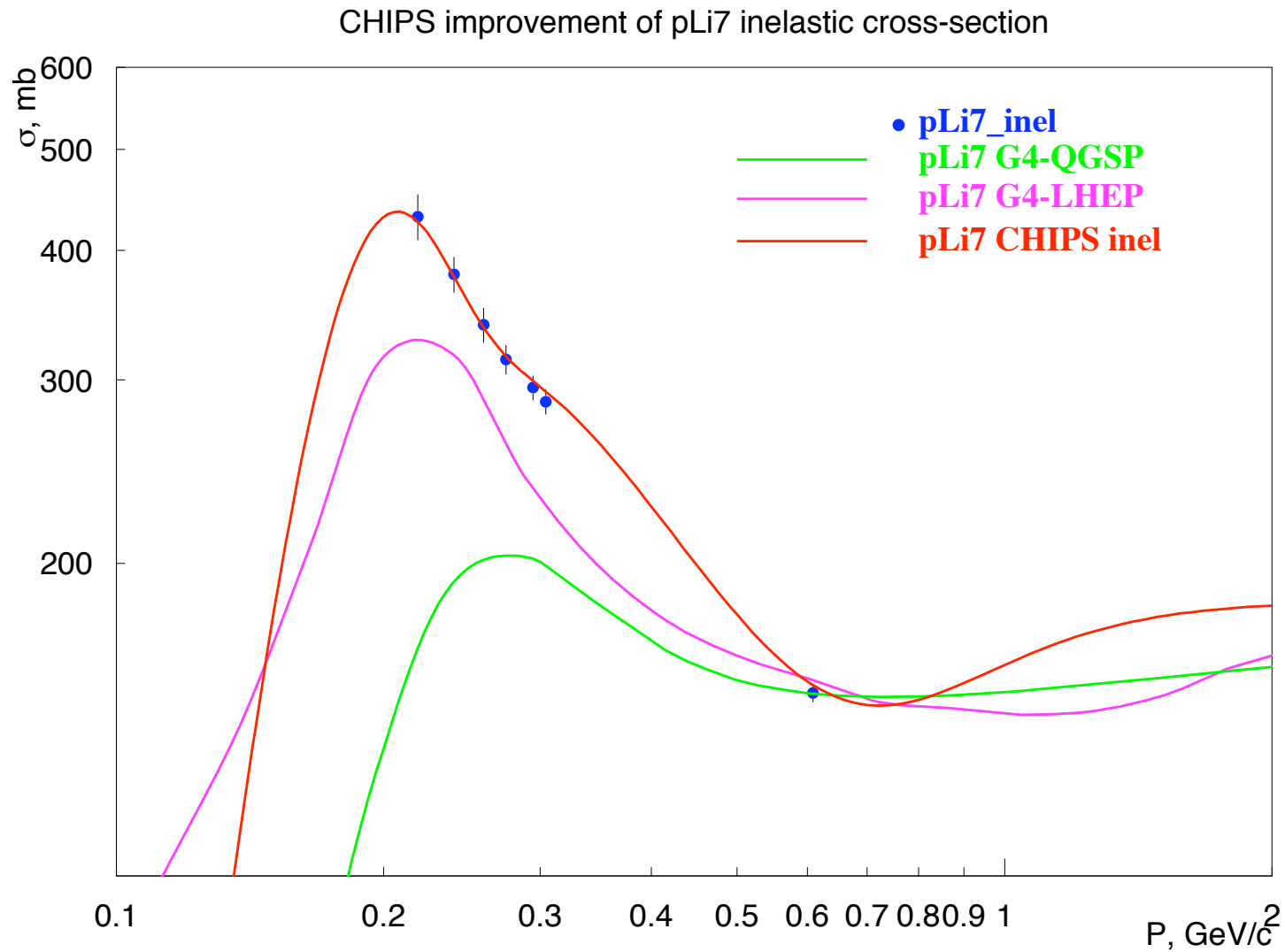


## Overall impression for high energies

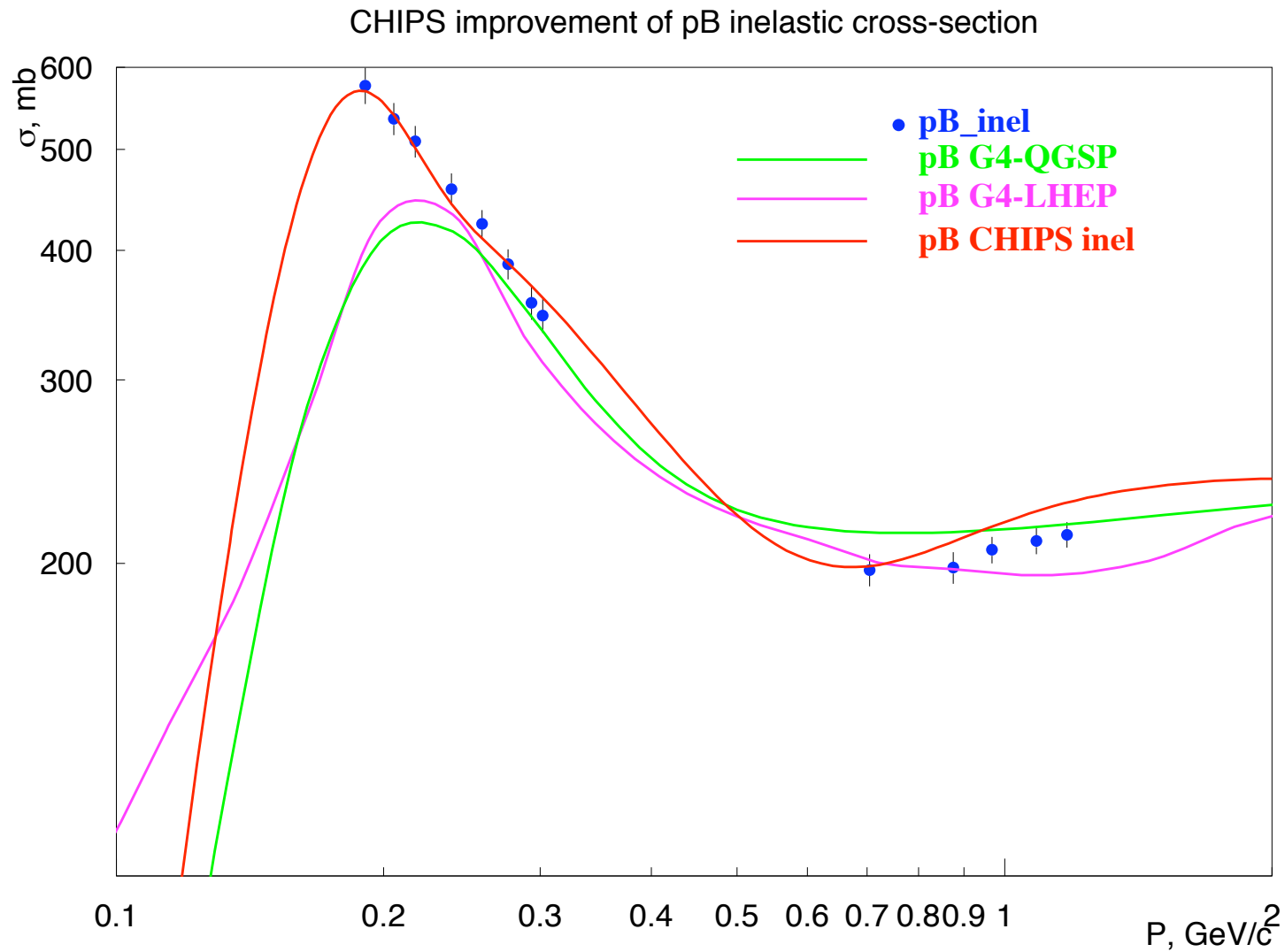
- The QGSP cross-sections are better than LHEP cross-sections for nuclei heavier than beryllium, while approximation for light nuclei is bad for both.
- The QGSP cross-sections are not applicable for D and Helium.
- The QGSP cross-sections are probably deliberately reduced by about 10%, which can lead to different shower shape results for different calorimeters.
- The LHEP makes unrealistic growing of cross-sections at high energies, while the QGSP cross-sections do not have any growing at all
- The A-dependent pion production threshold can be improved.

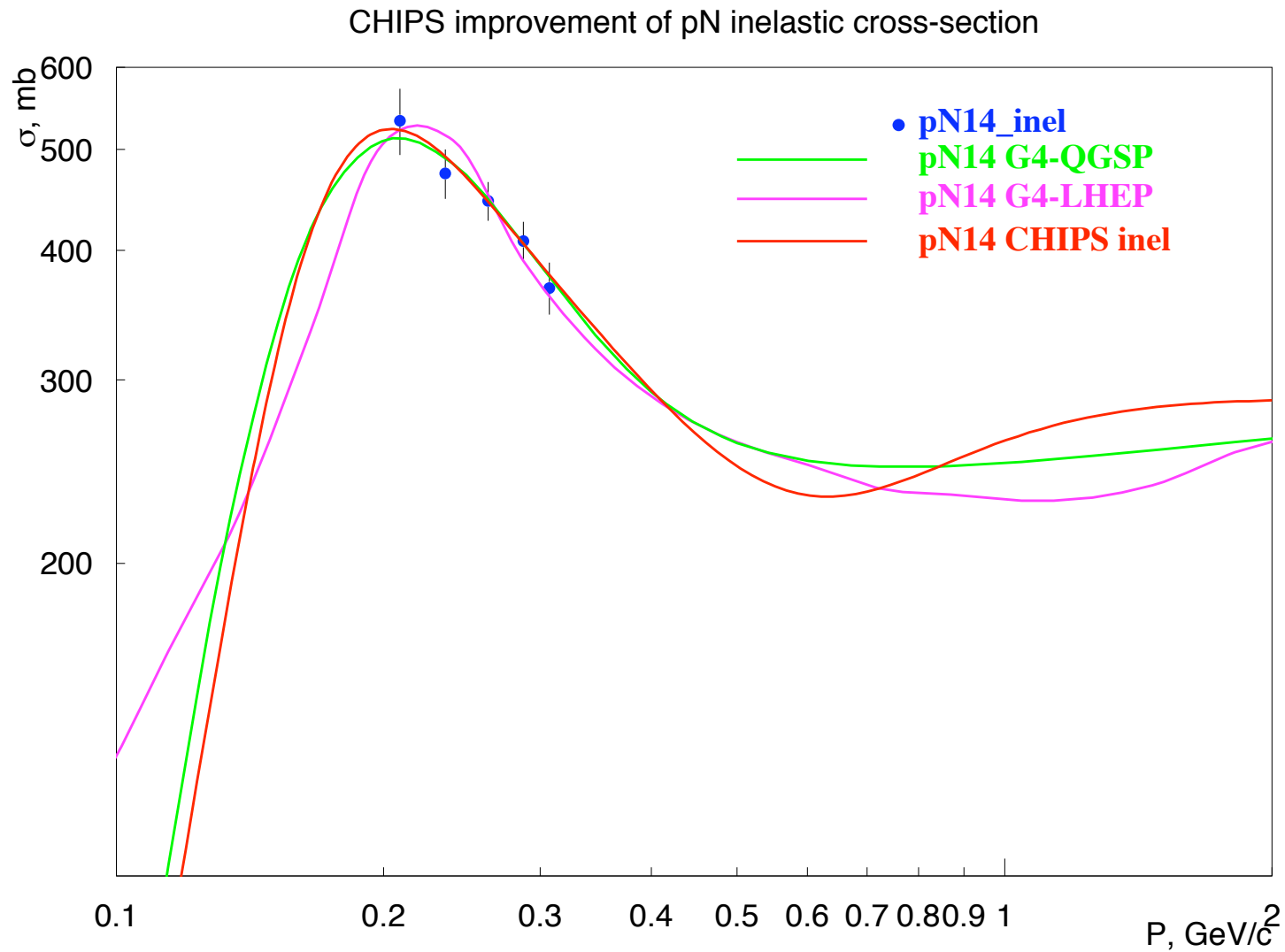


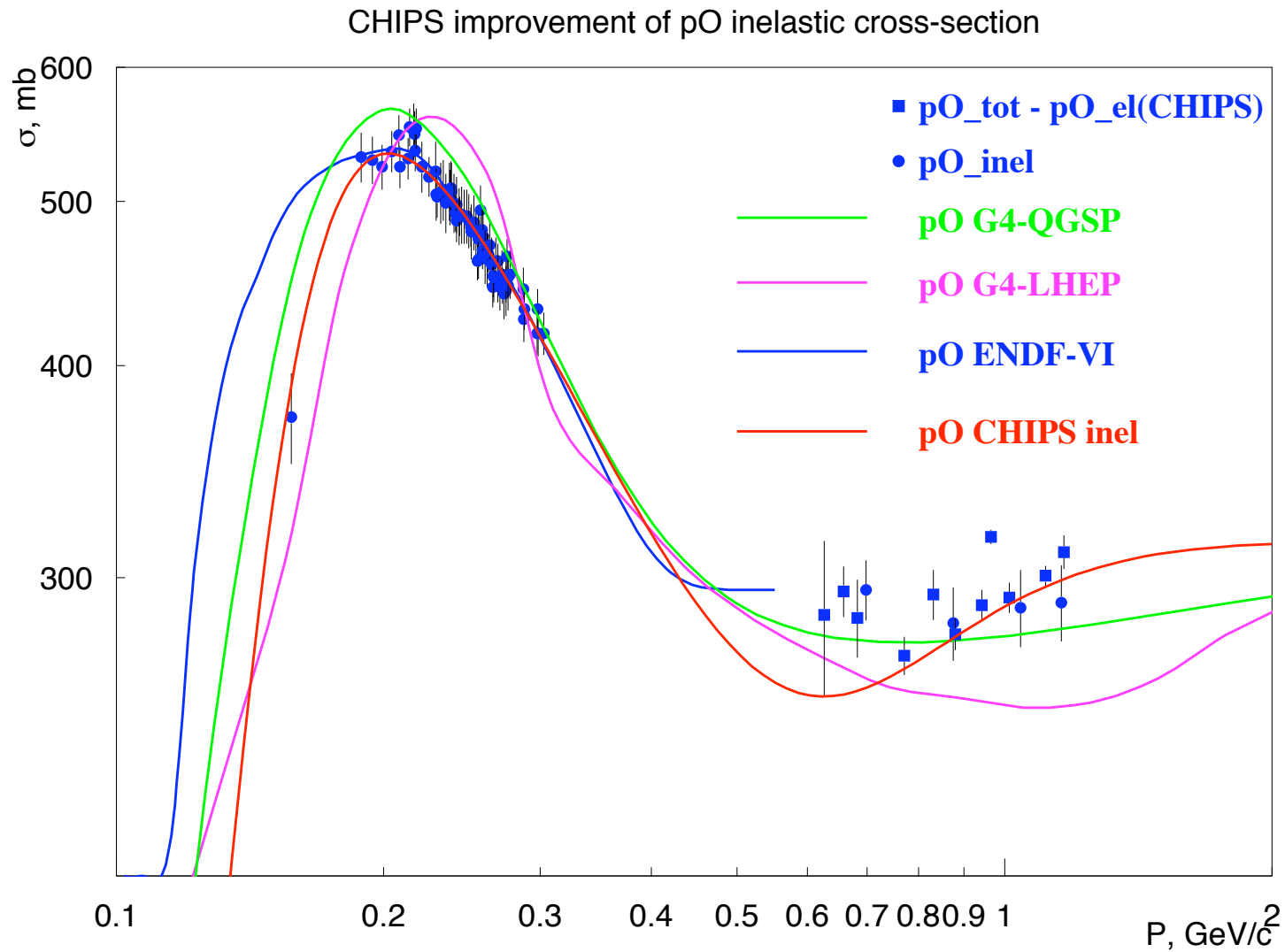


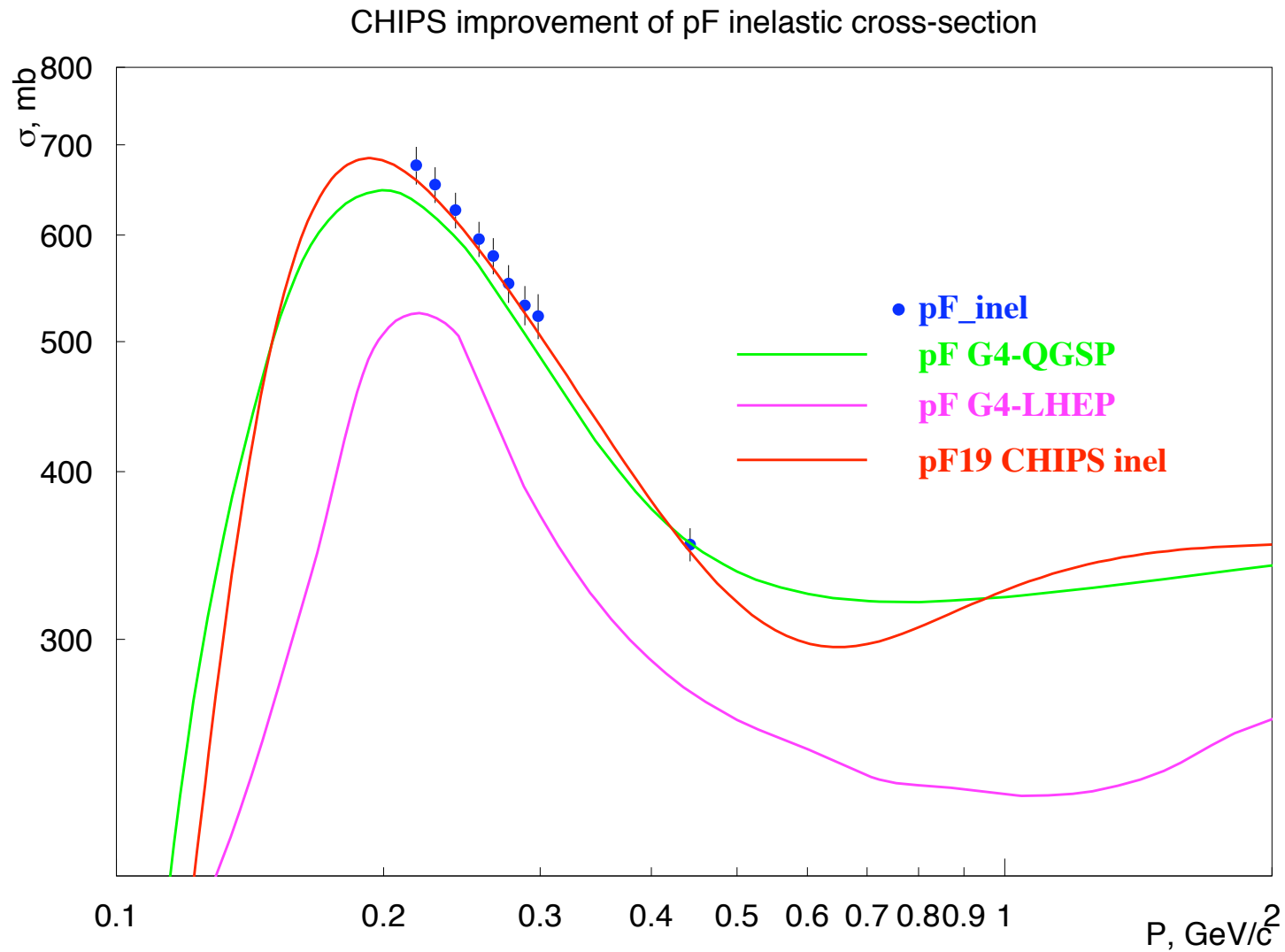


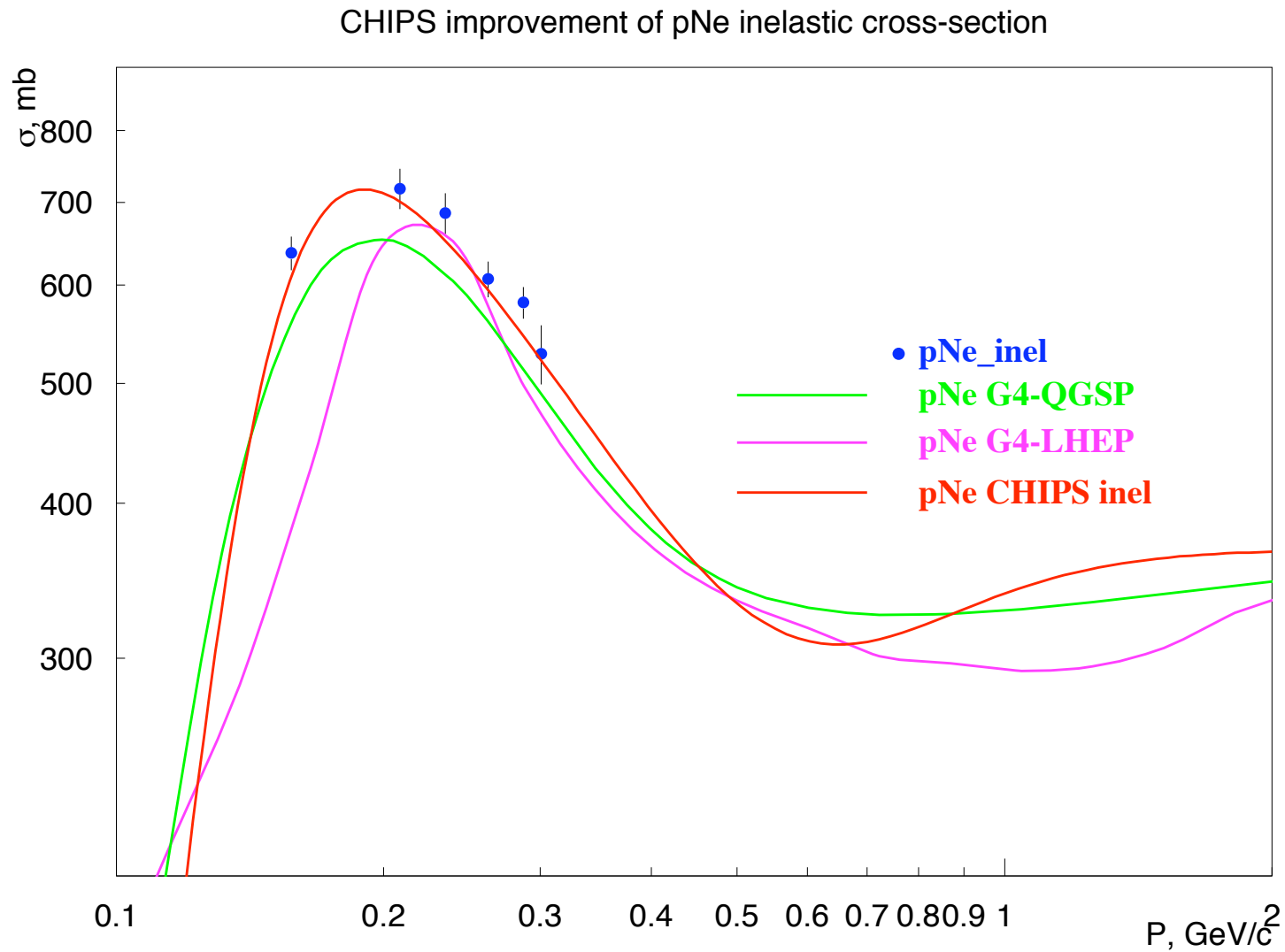


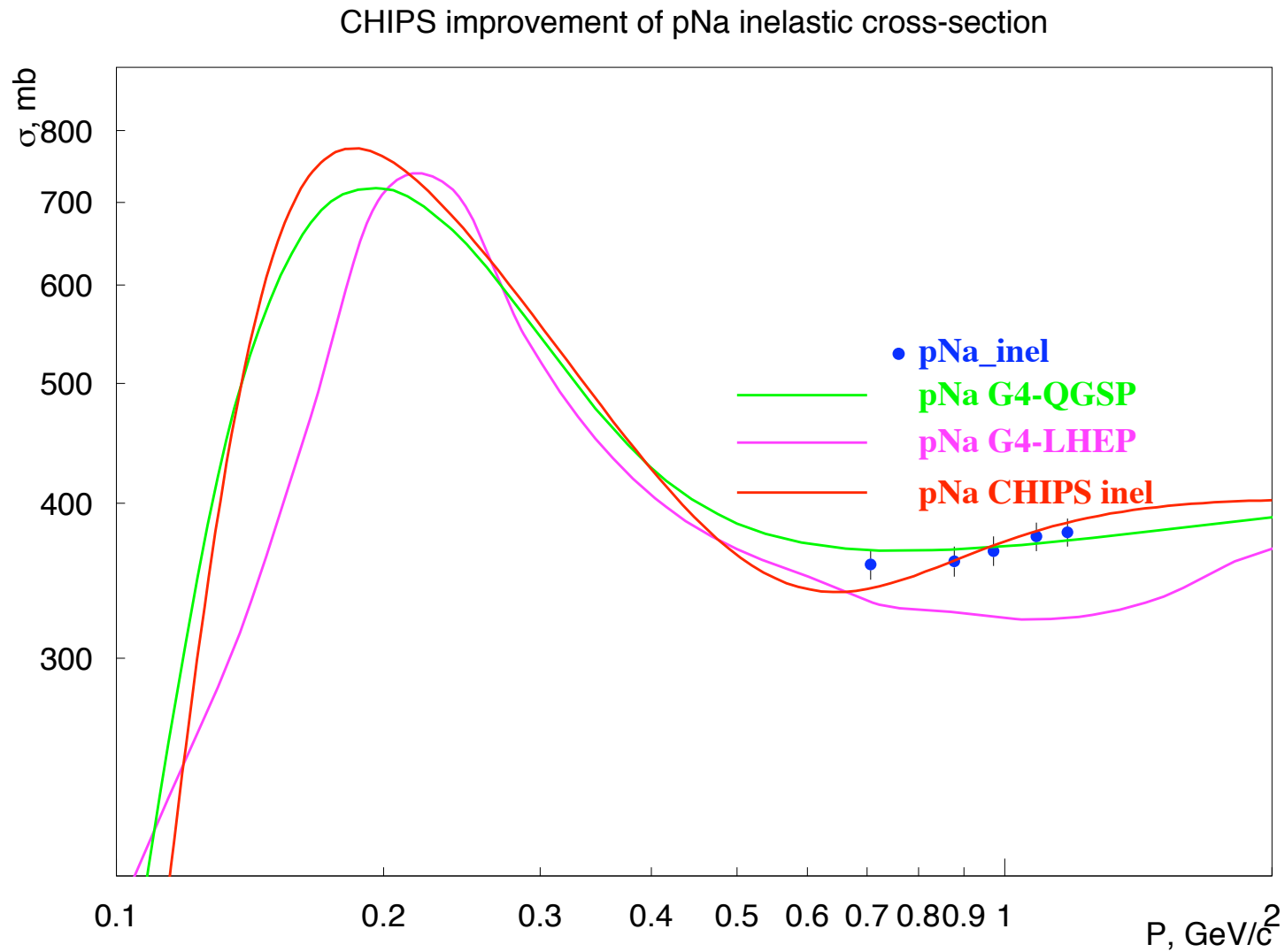


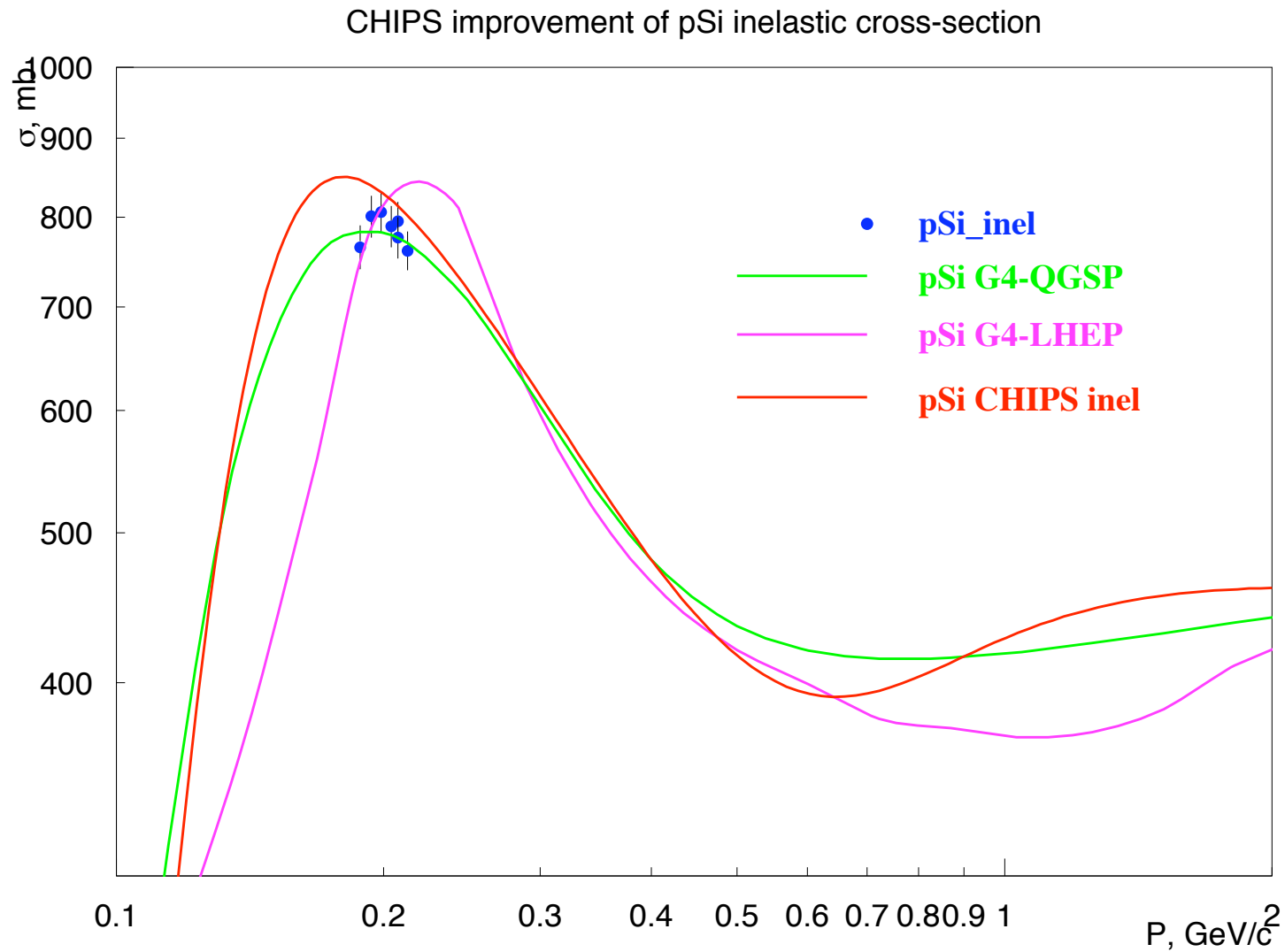


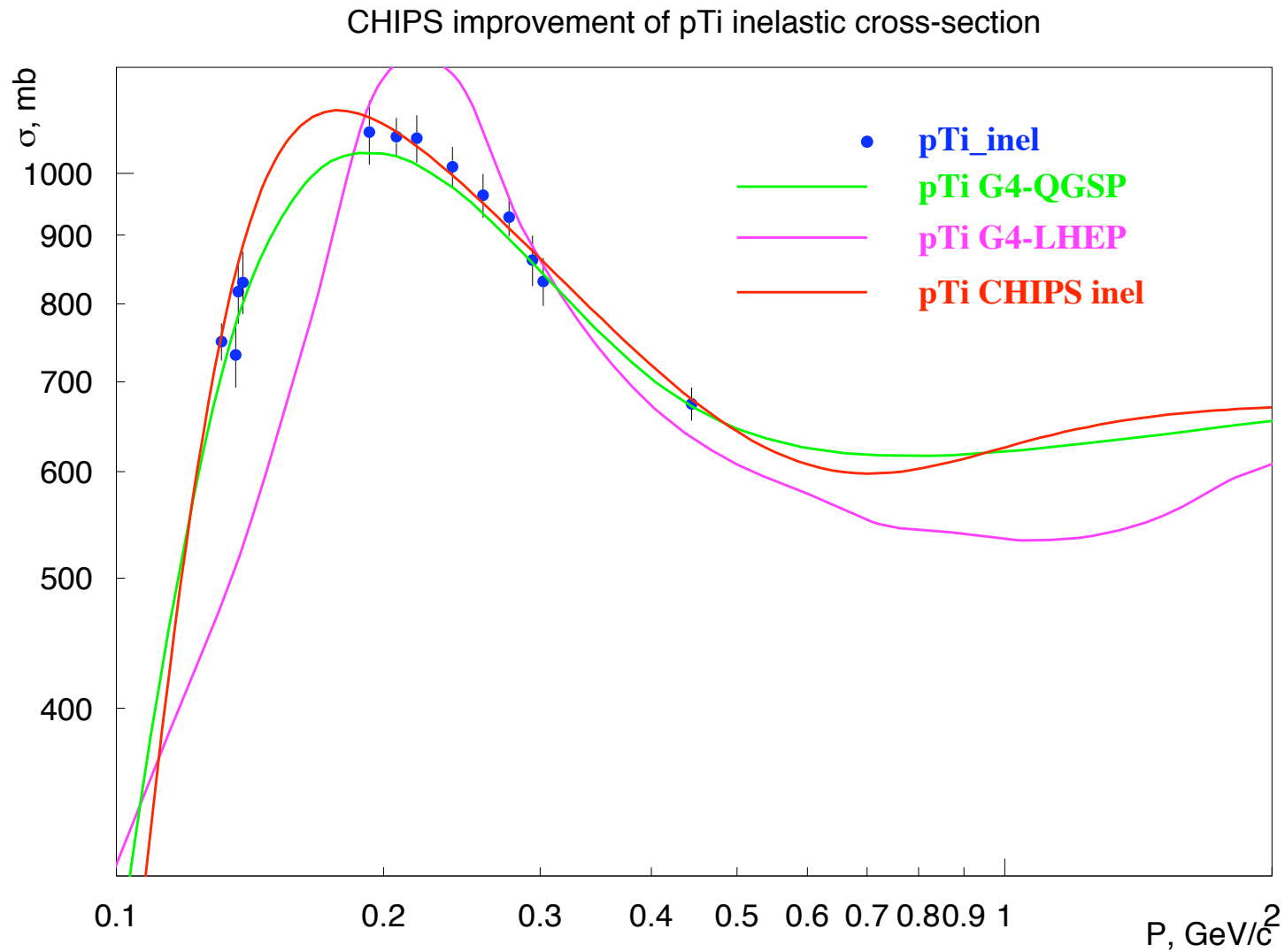




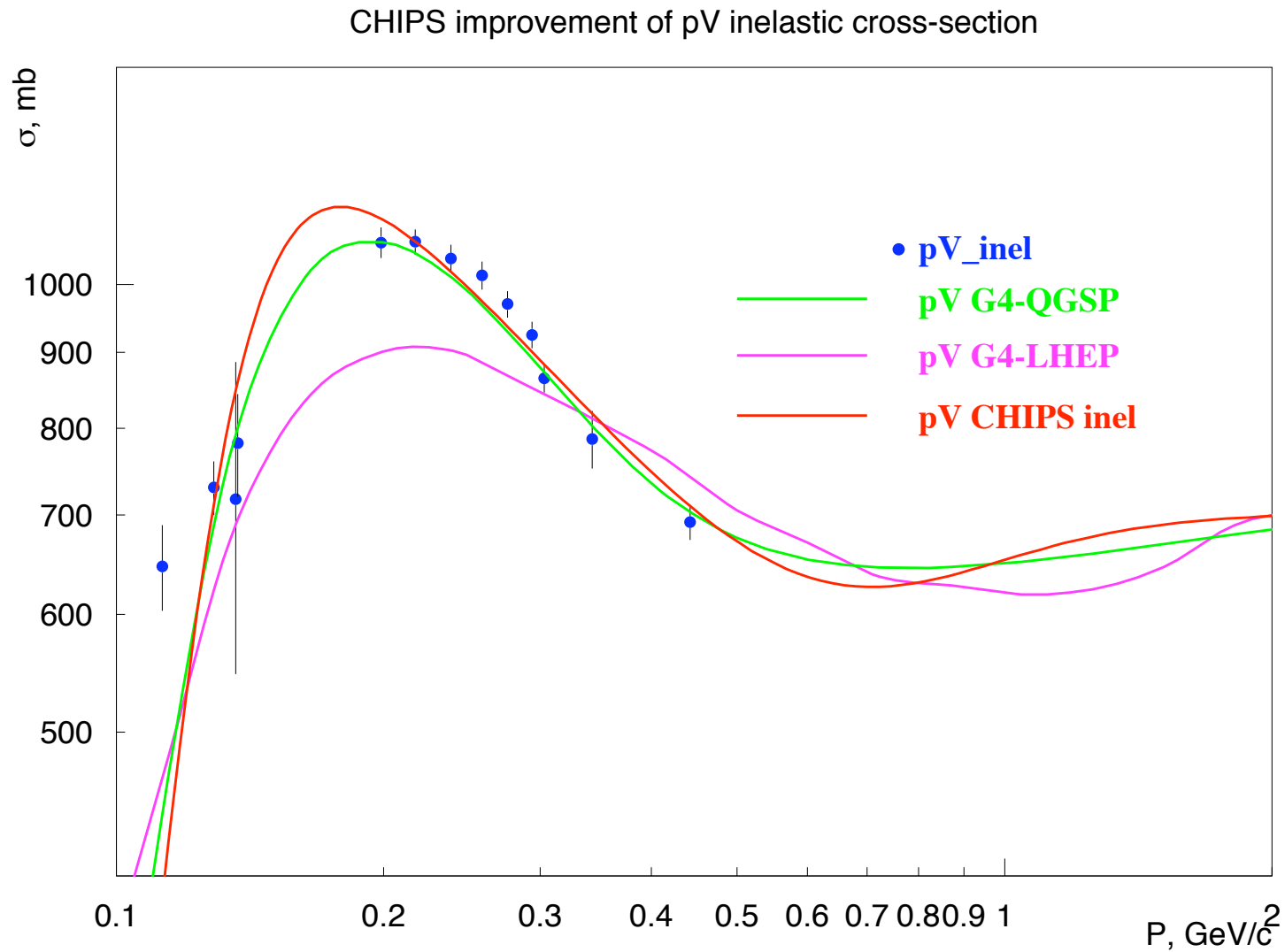


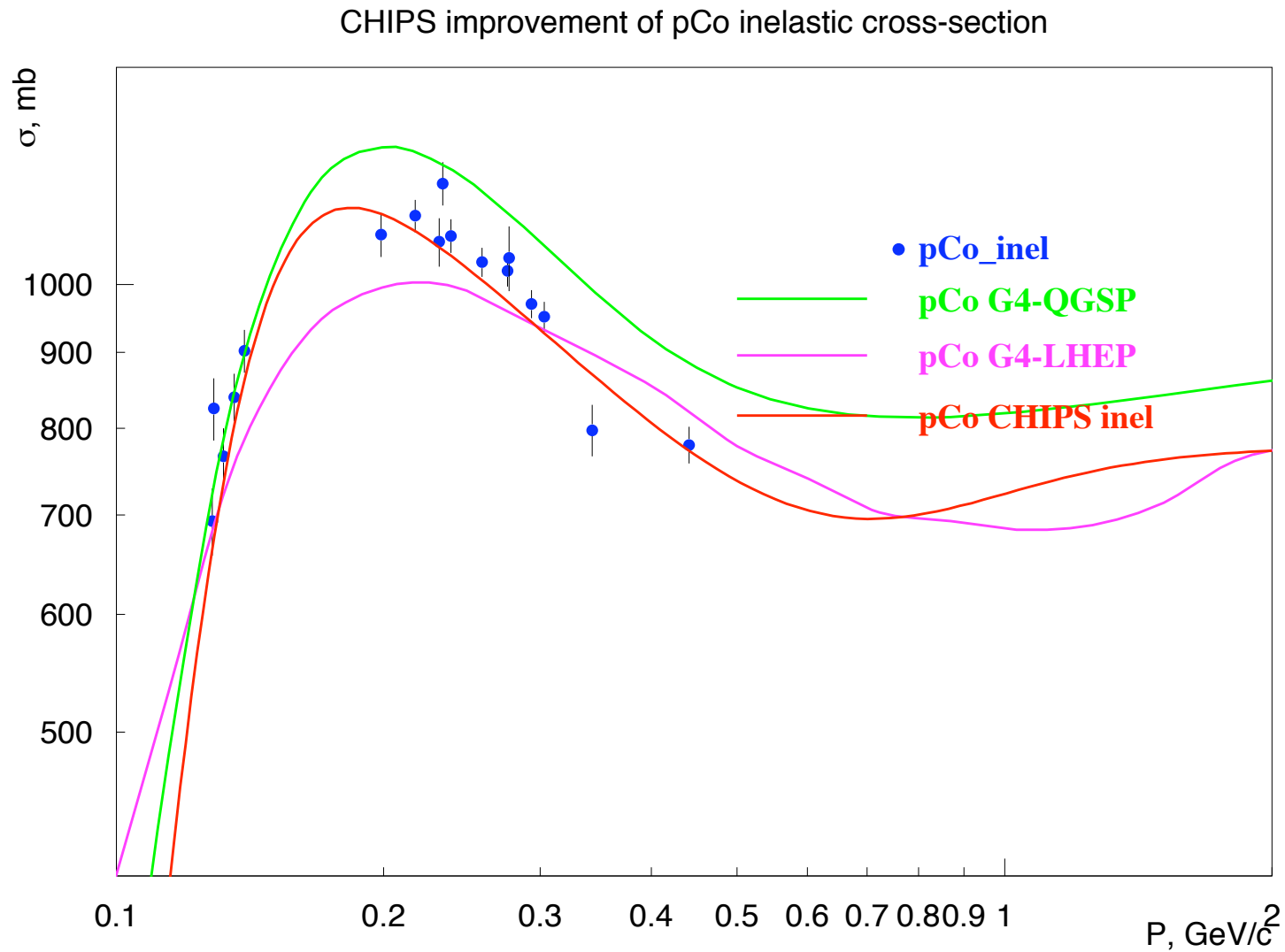


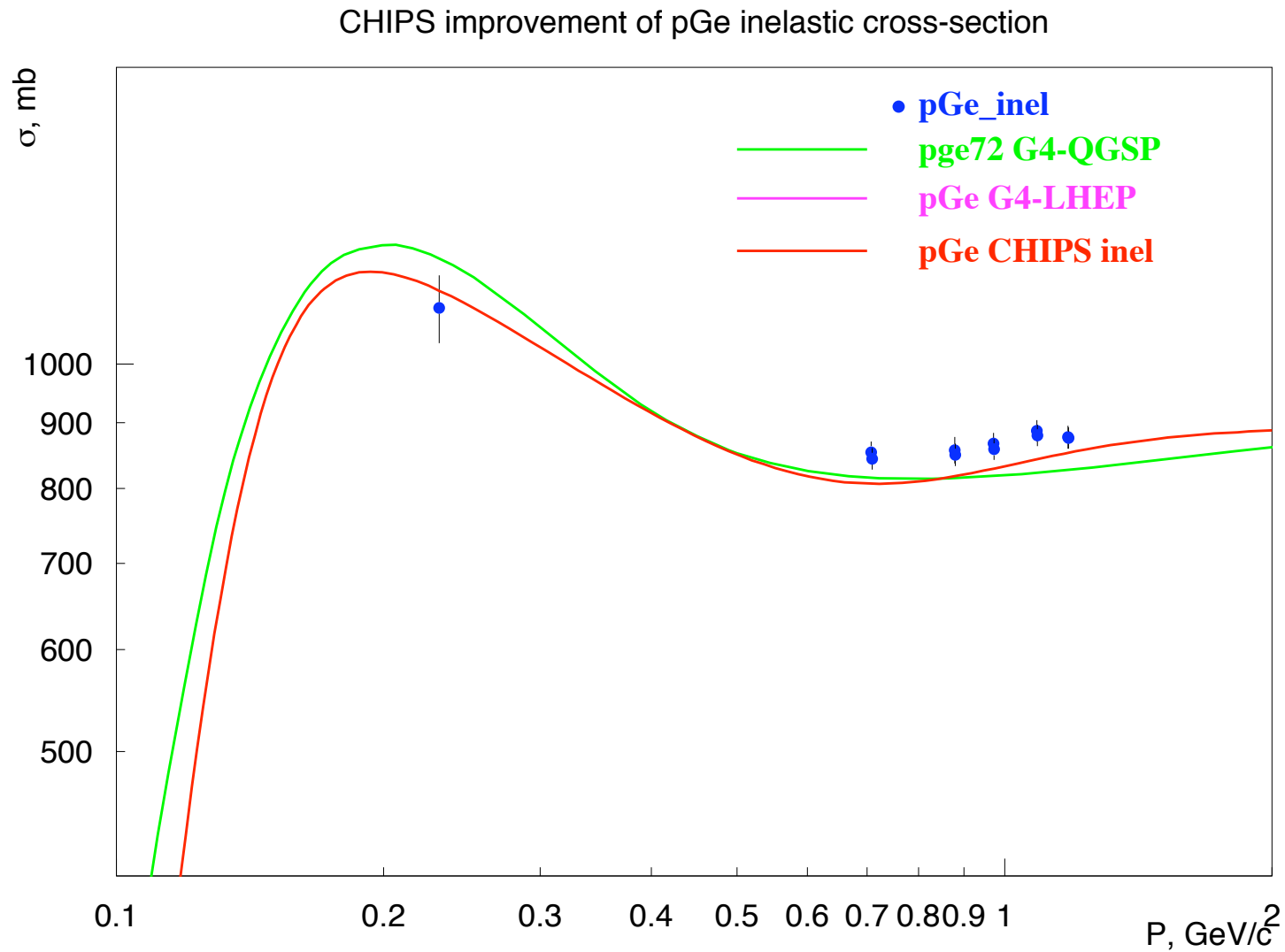


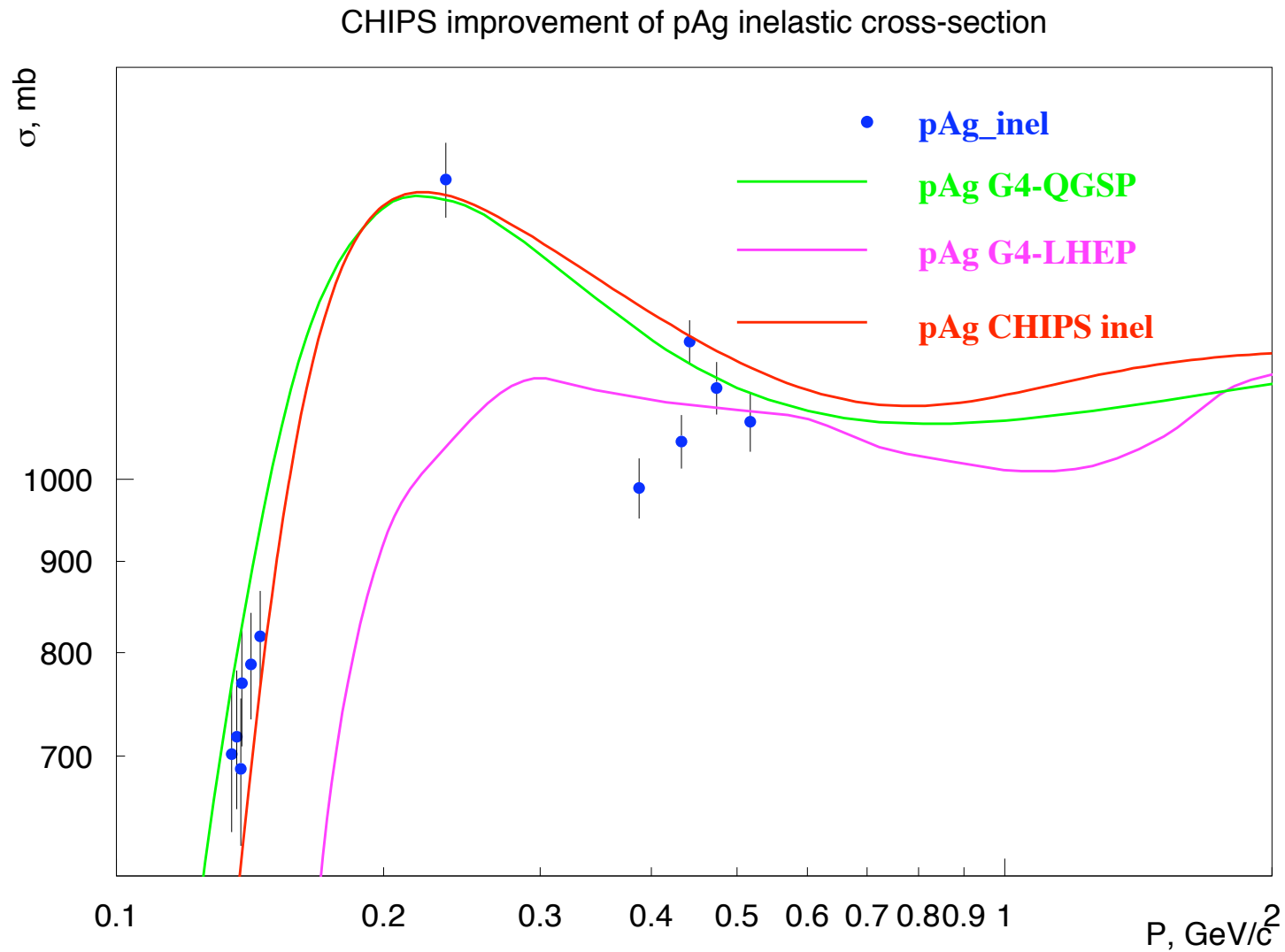


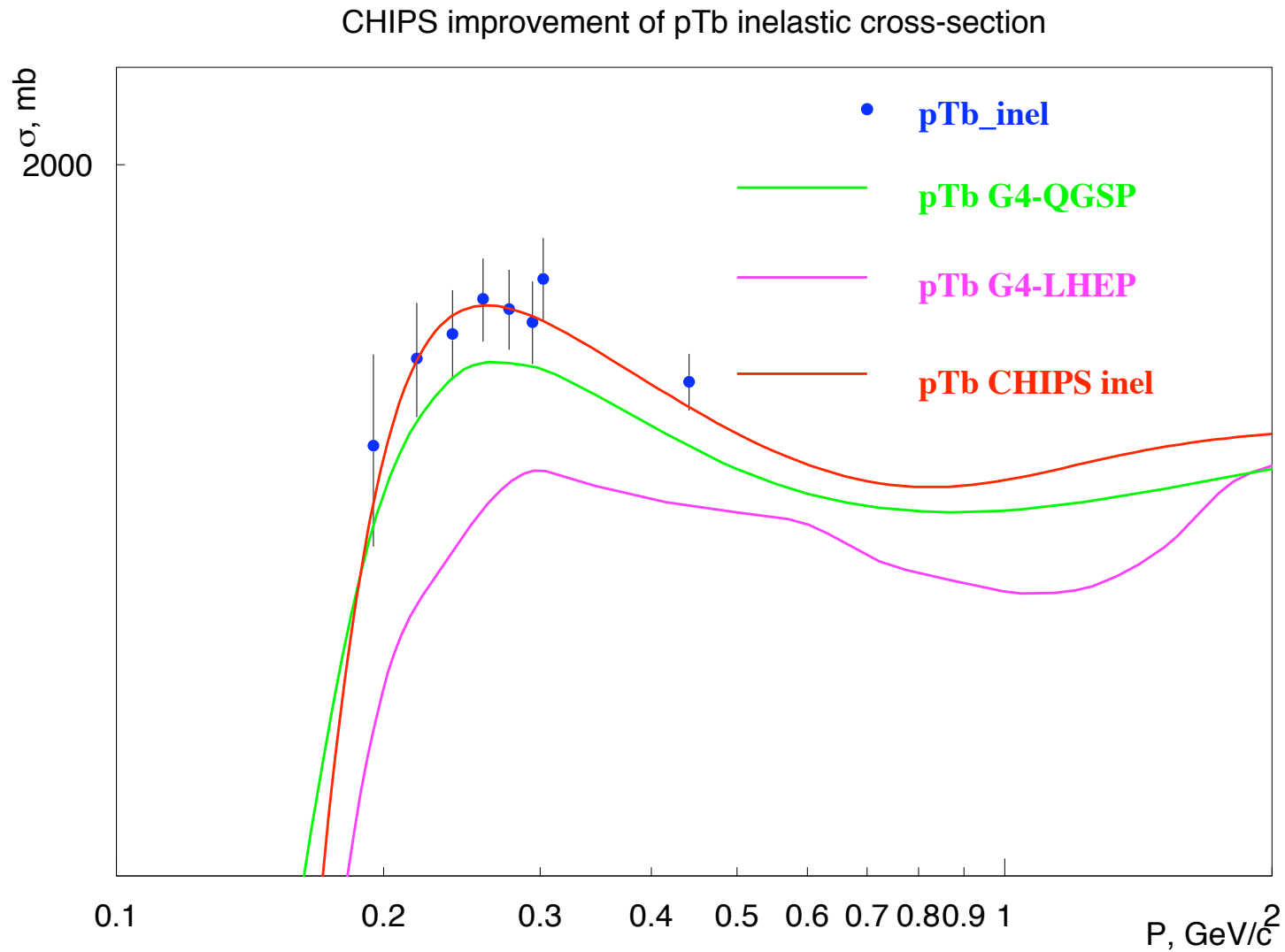


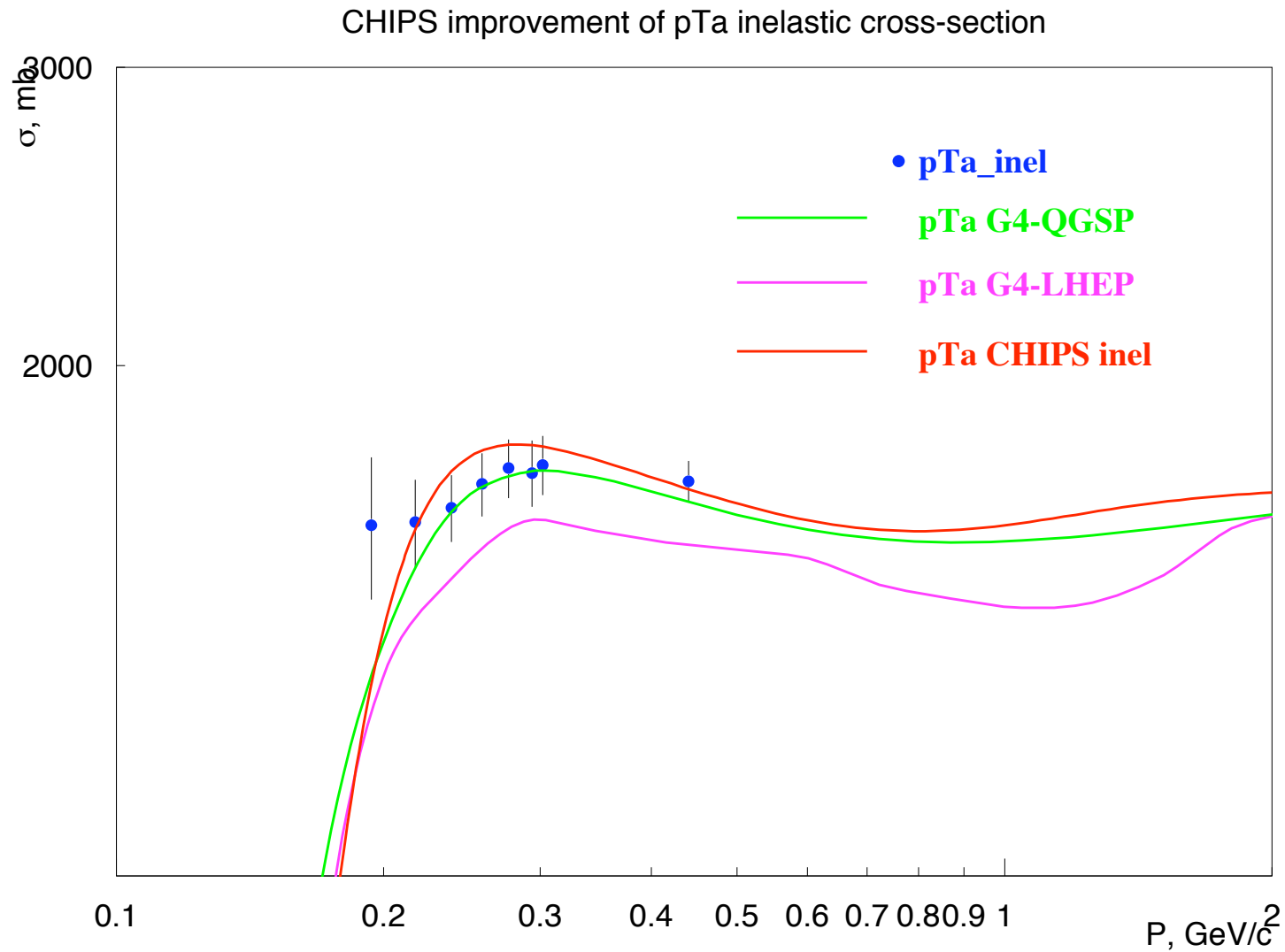


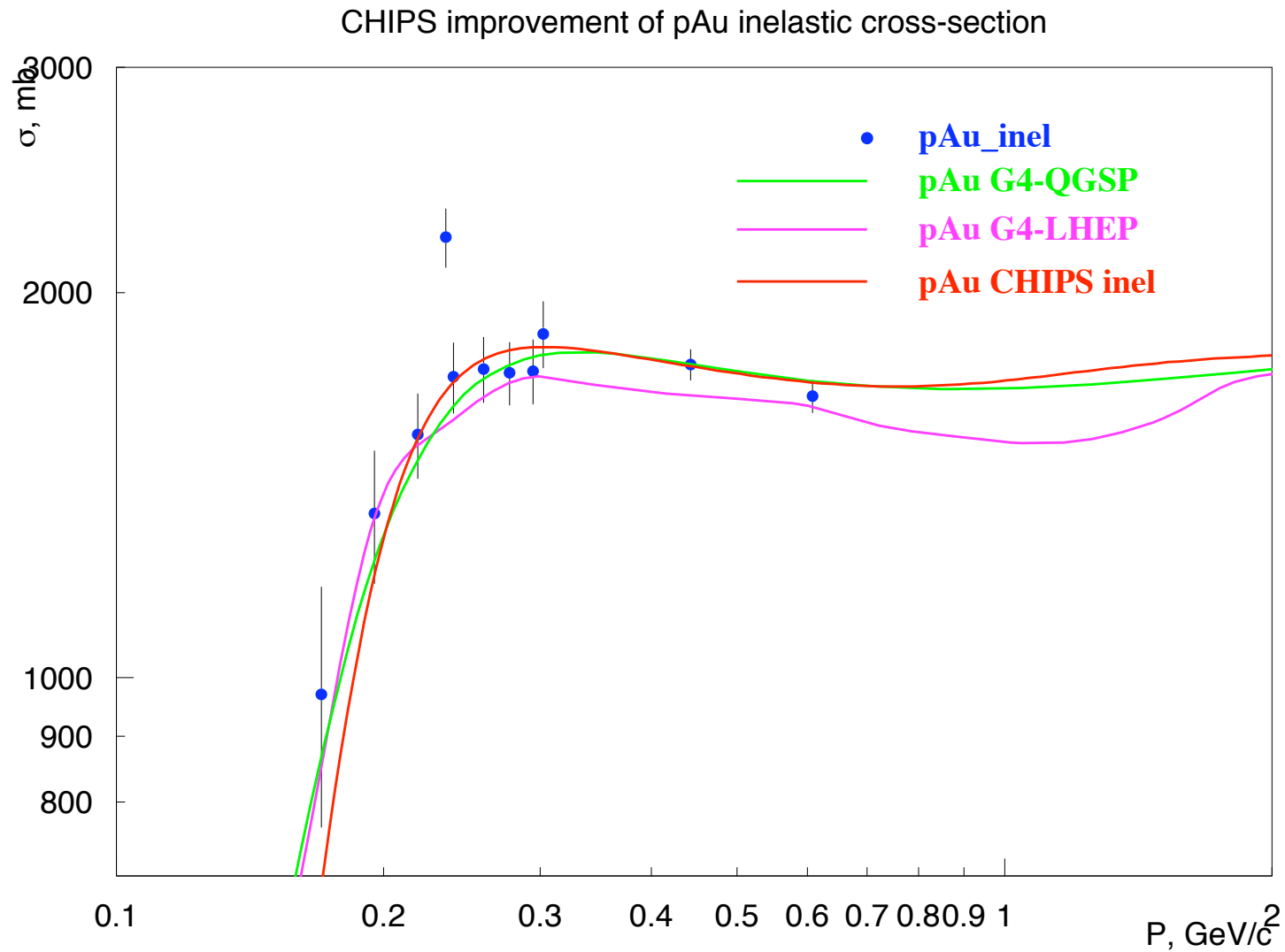


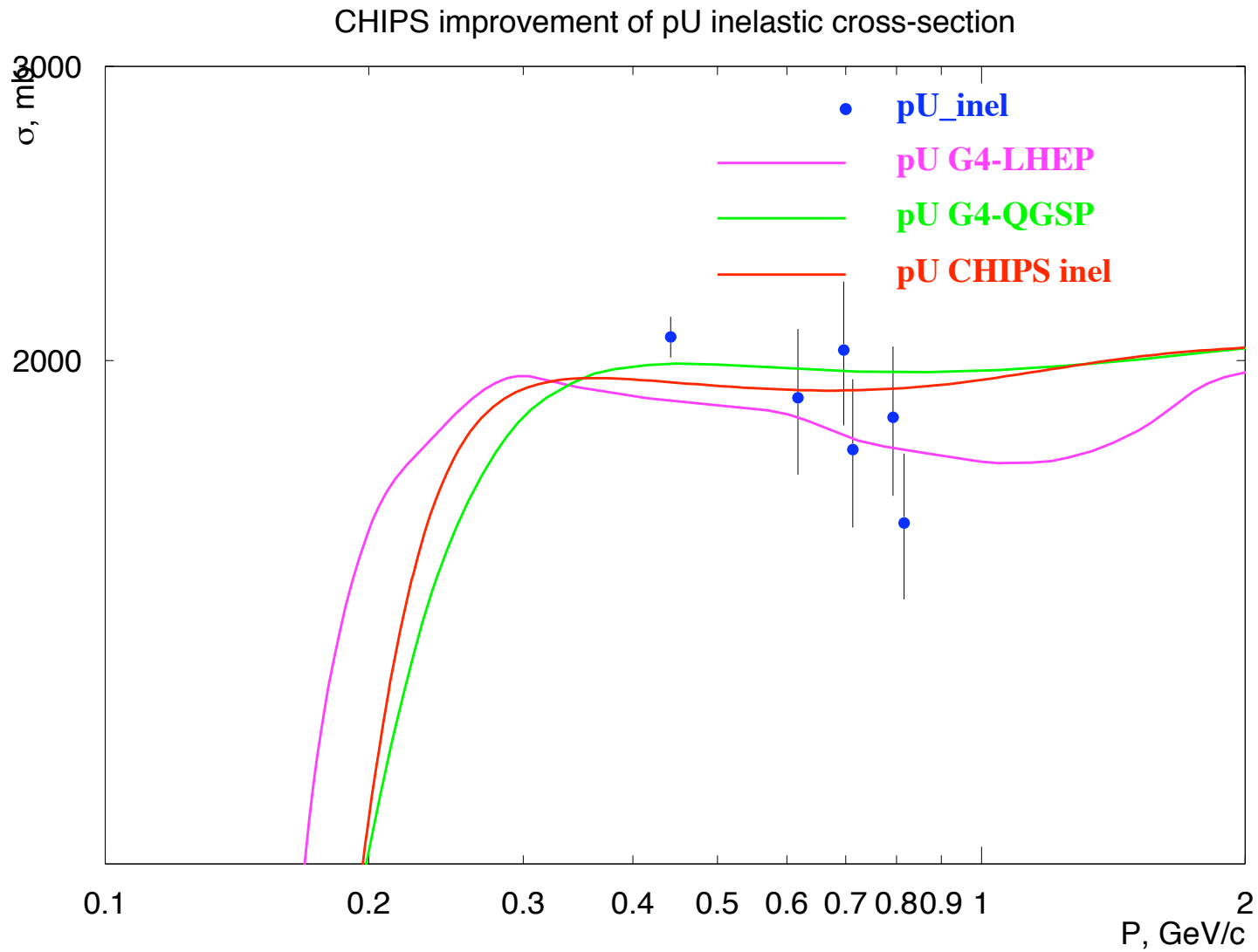




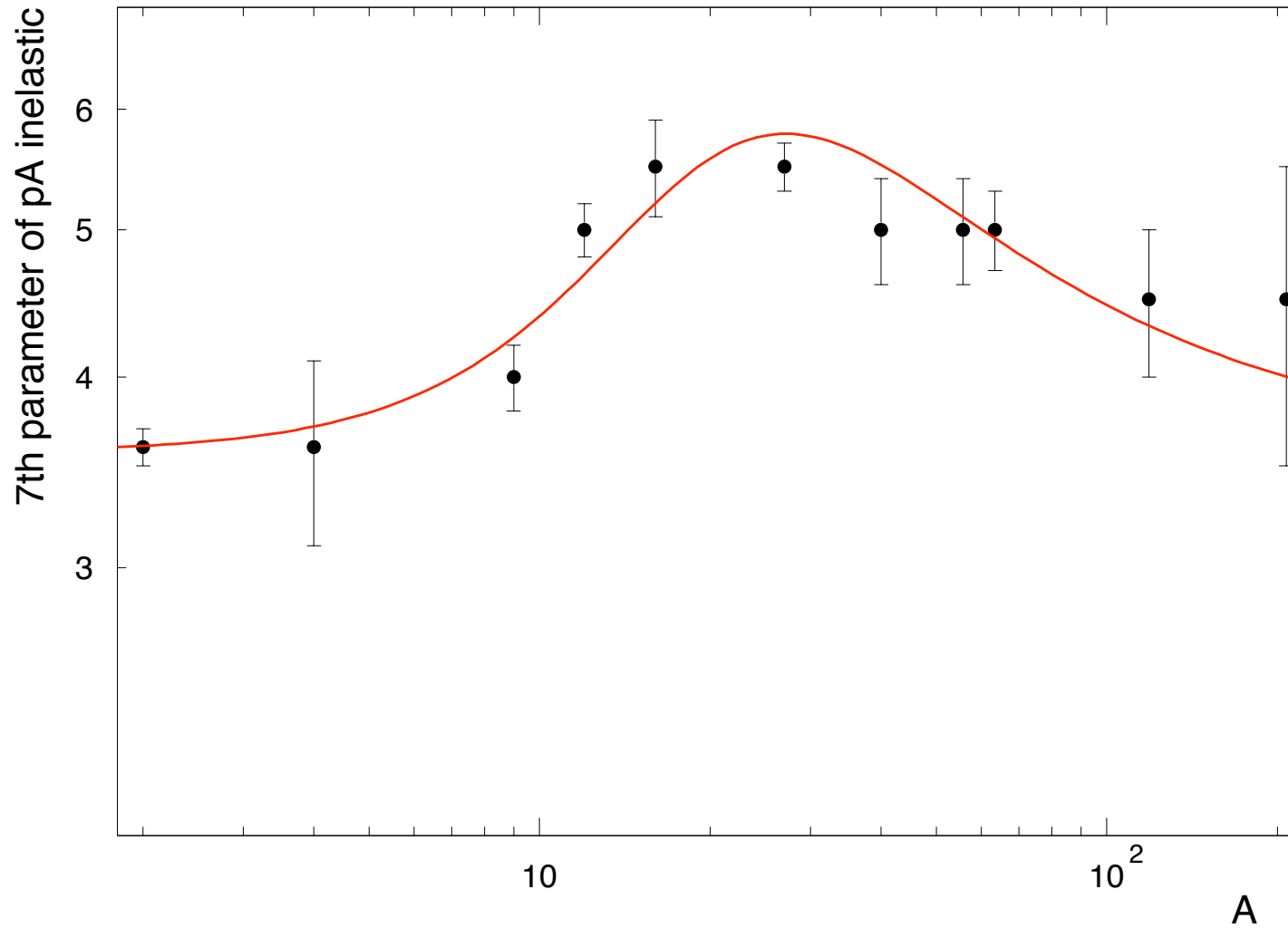




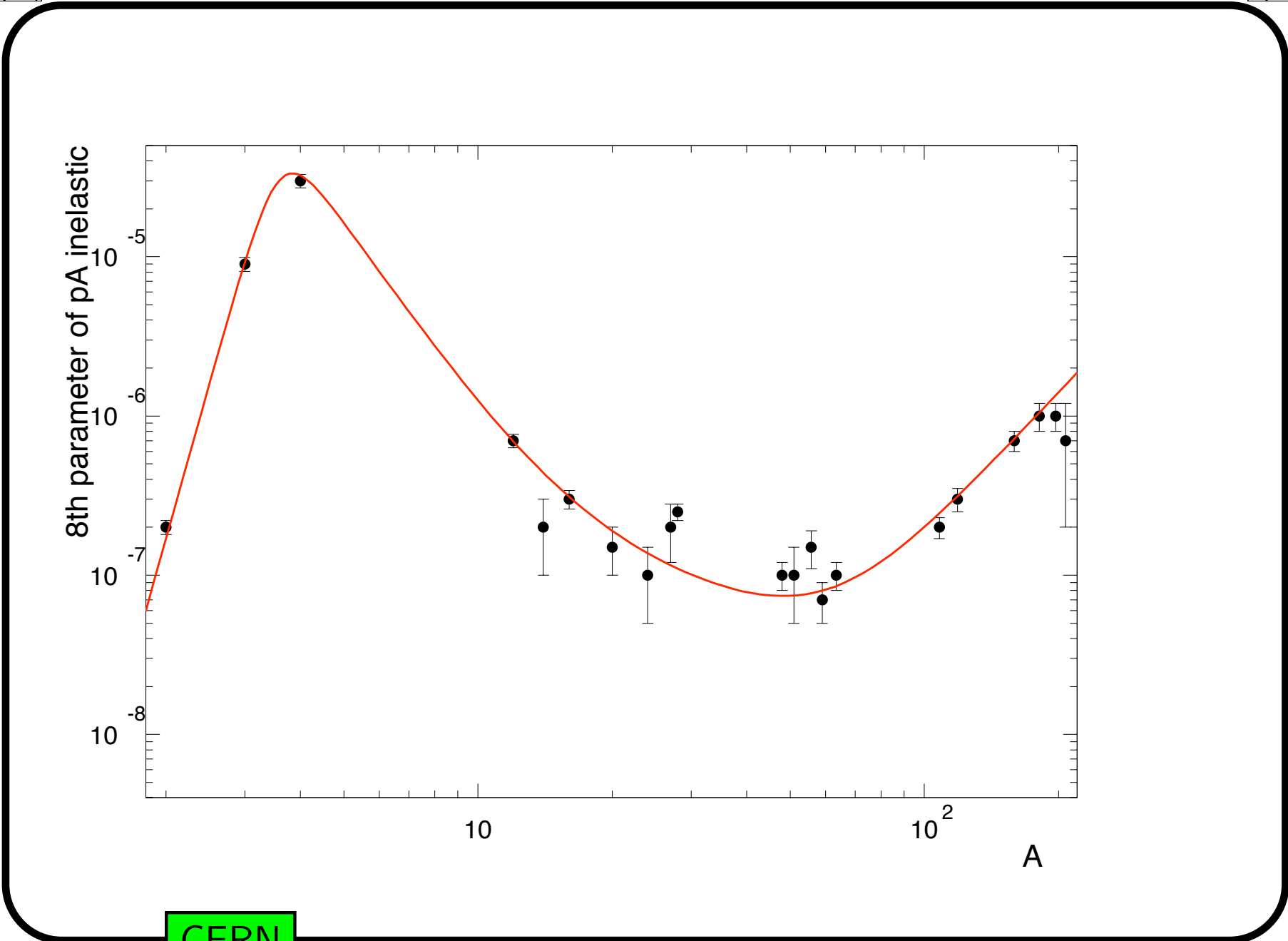














## Conclusion

- The QGSP inelastic cross-sections are good enough except for light nuclei and for copper.
- The LHEP inelastic cross-sections need improvement for all nuclei and can not be applied above 300 GeV
- CHIPS parameterizes inelastic cross-sections with 10 but at high energies ( above 300 GeV) may need further improvement.
- At least smooth A-dependence of inelastic cross-sections must be recovered in both LHEP and QGSP to avoid different shower shape conclusions on different calorimeters.
- It is recommended to use CHIPS inelastic cross-sections, if light nuclei (e.g. D-targets, Beryllium beam pipes) are used in the simulated detector.