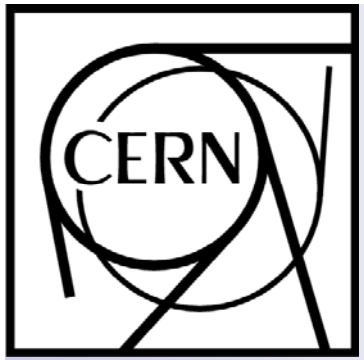


CHIPS approximation of proton-nuclear Coulomb scattering

Mikhail Kosov, 12th Geant4 Workshop (GB, Sept. 2007)

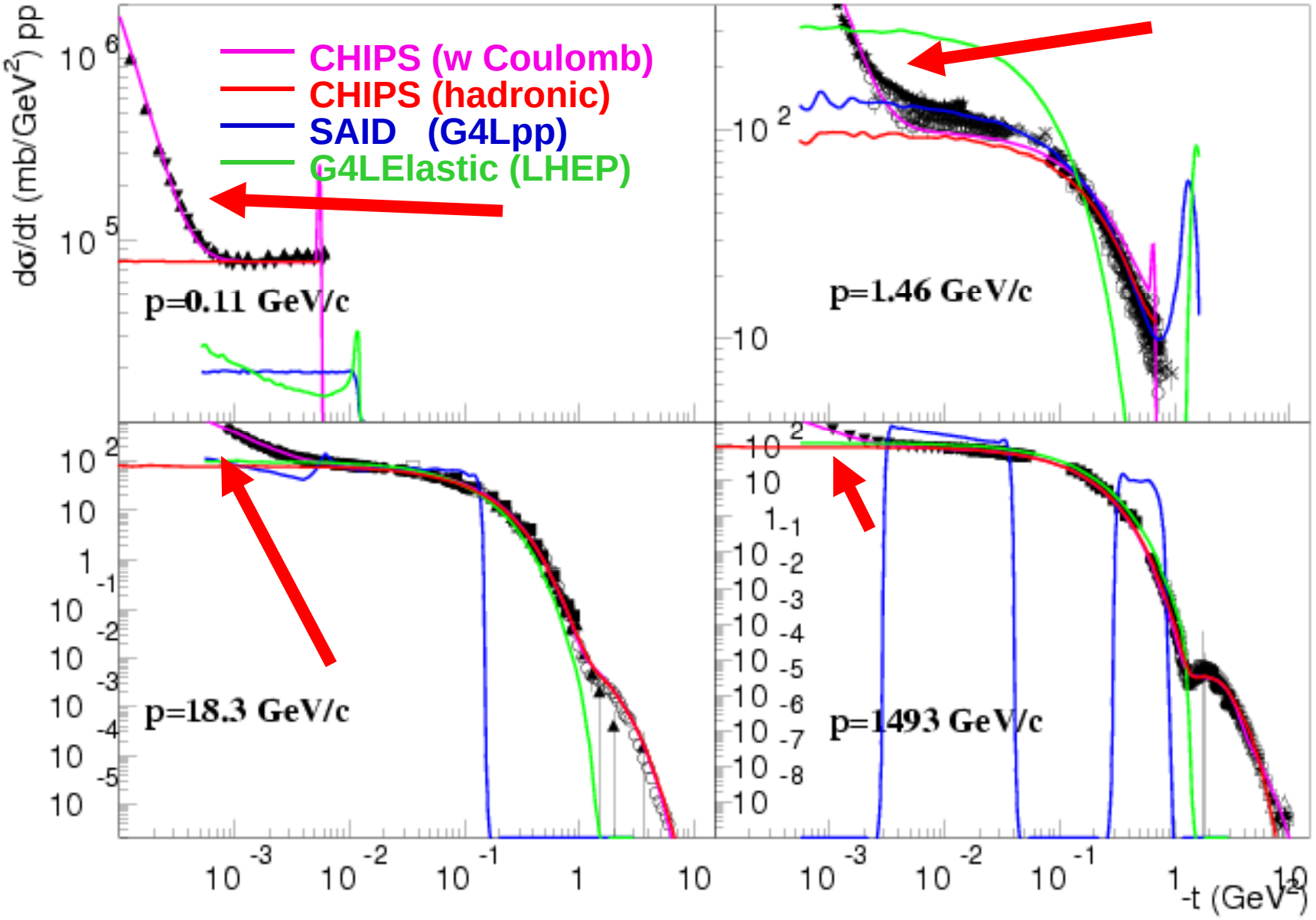
Typical features of Elastic scattering

- The final state for electromagnetic and hadronic scattering is the same, so they interfere on the amplitude level.
- Nobody can separate the ElectroMagnetic and Hadronic scattering, but the measured and disentangled differential EM part can be approximated and made in a form of an independent discrete process.
- The low t electromagnetic part (ee) can be still simulated by a continuous process

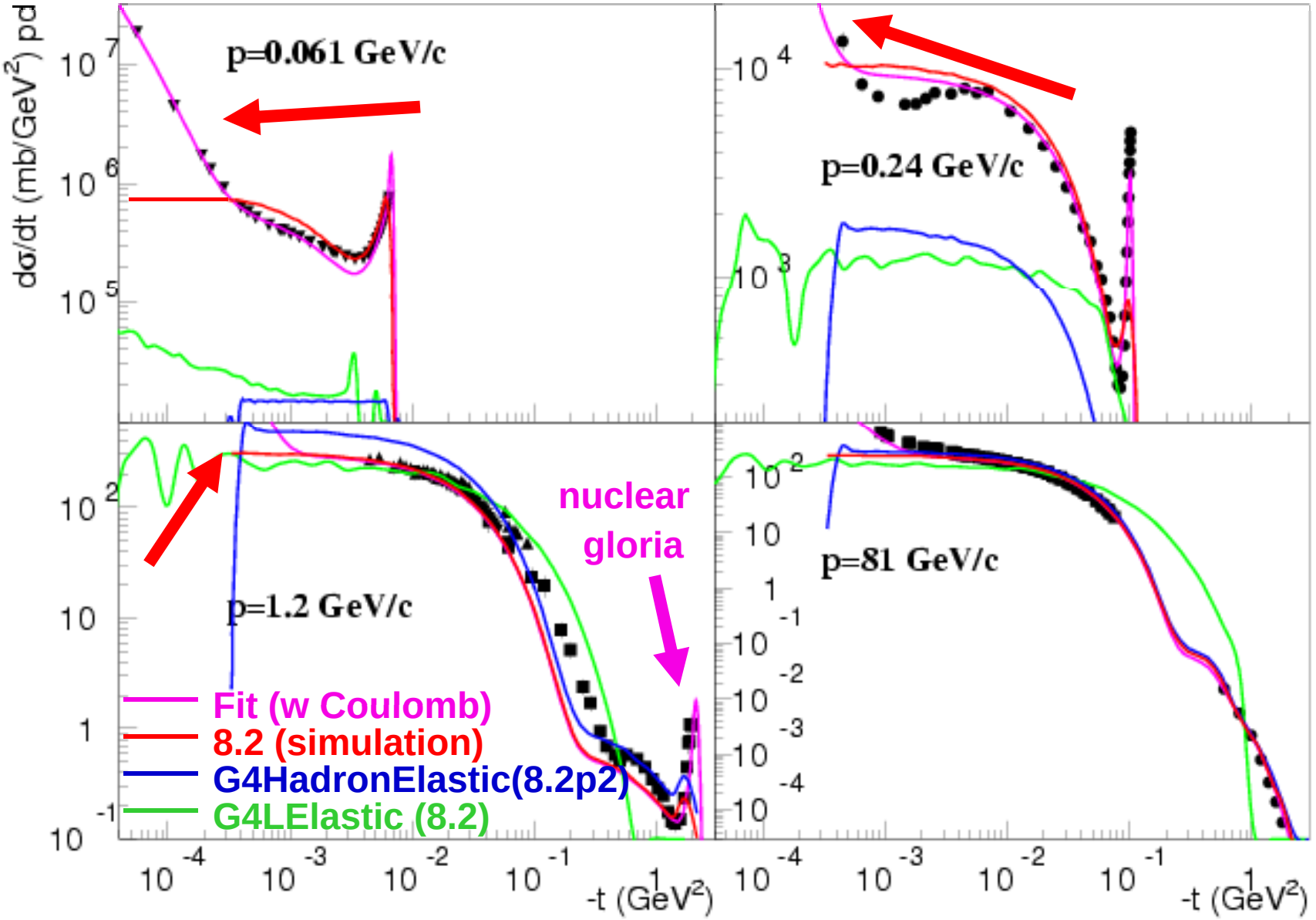
Definitions for the Mondelstam t variable

- Invariant Mondelstam variable: $s+t+u=2m^2+2M^2$
- General: $t=(\mathbf{p_i}-\mathbf{p_f})^2=2m^2-2E_iE_f+2p_ip_f\cdot\cos(\theta)$
- At high energy: $t \sim -2p^2(1-\cos(\theta))$
- Approximation: $-t=4p^2\sin^2(\theta/2)\sim p^2q^2$
- Transferred momentum: $q=p\sin(\theta)=p\theta$, $-t=q^2$
- Differential XS: $d\sigma/dt = d\sigma/2p^2d\cos(\theta)$
- $d\sigma/d\Omega=d\sigma/2\pi d\cos(\theta)=p^2d\sigma/\pi dt$

CHIPS improvement of pp elastic scattering



CHIPS improvement of pd elastic scattering



Approximation of “Coulomb scattering”

$$\frac{d\sigma}{dt} = \frac{e^{-b\sqrt{-t}}}{\sqrt{-t}} \xrightarrow{\text{-t = q}^2} \frac{d\sigma}{dq^2} = \frac{e^{-bq}}{q}$$

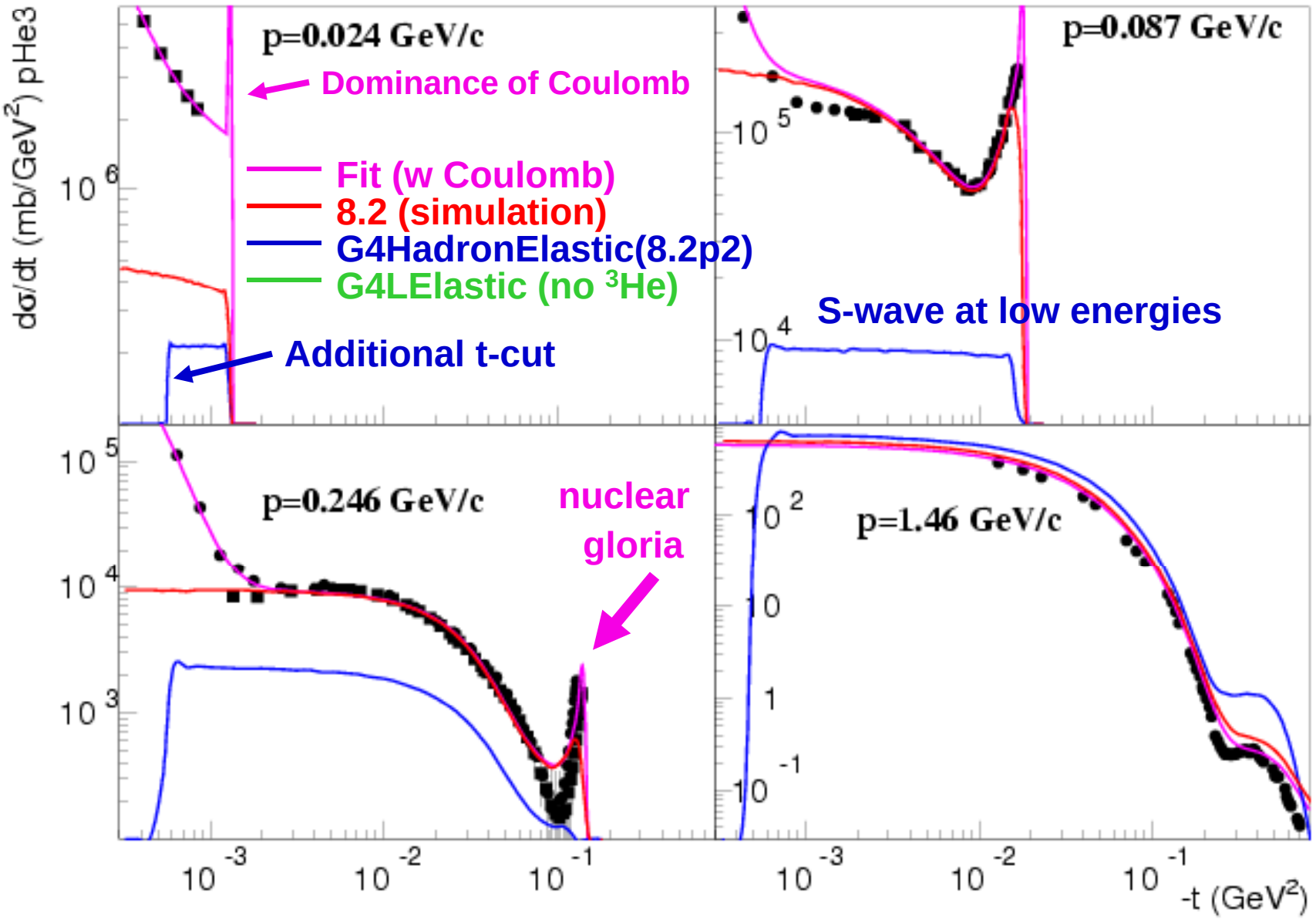
Infinite differential cross-section has a finite integral

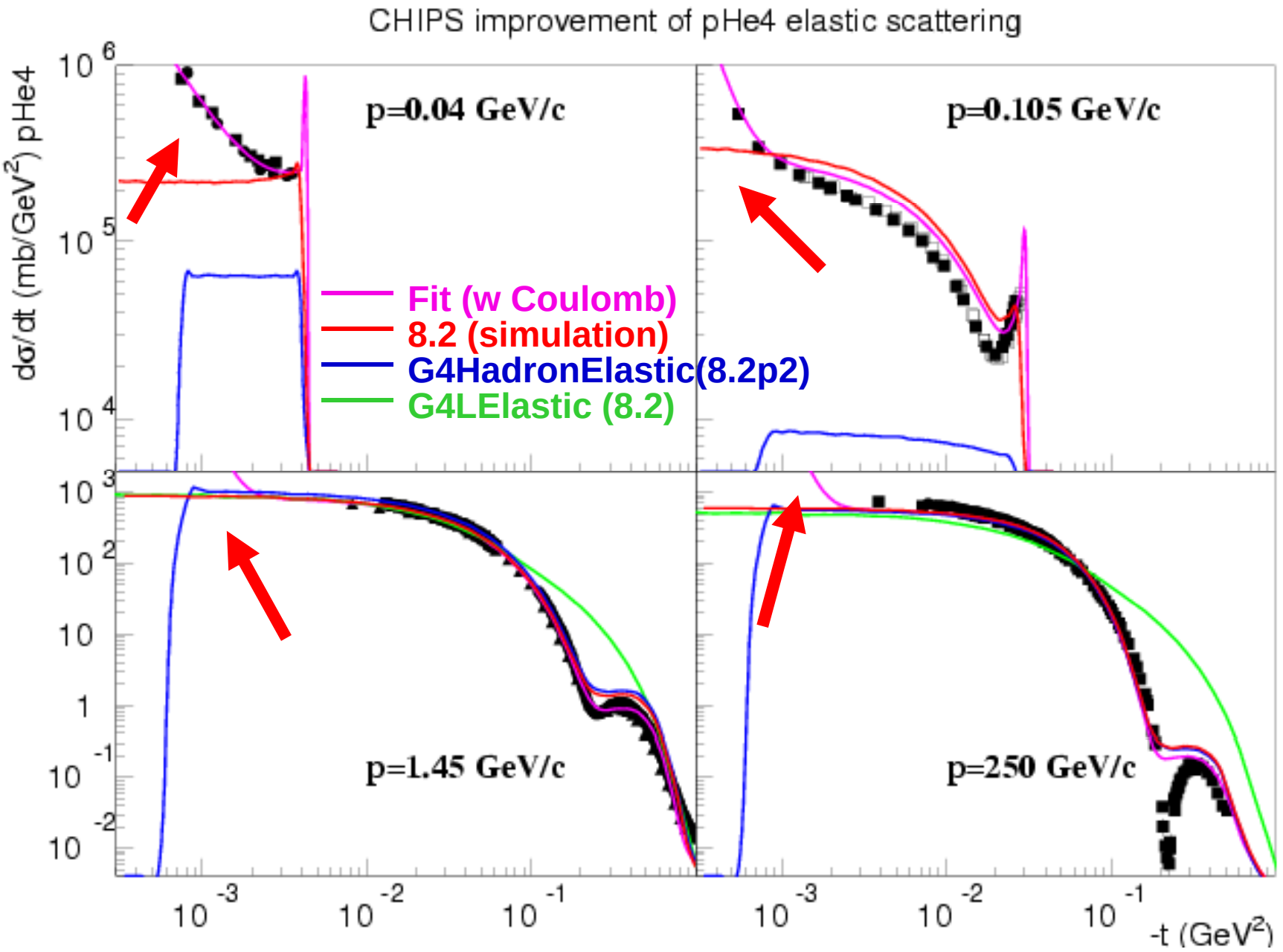
a) at high energy it is only a few mb

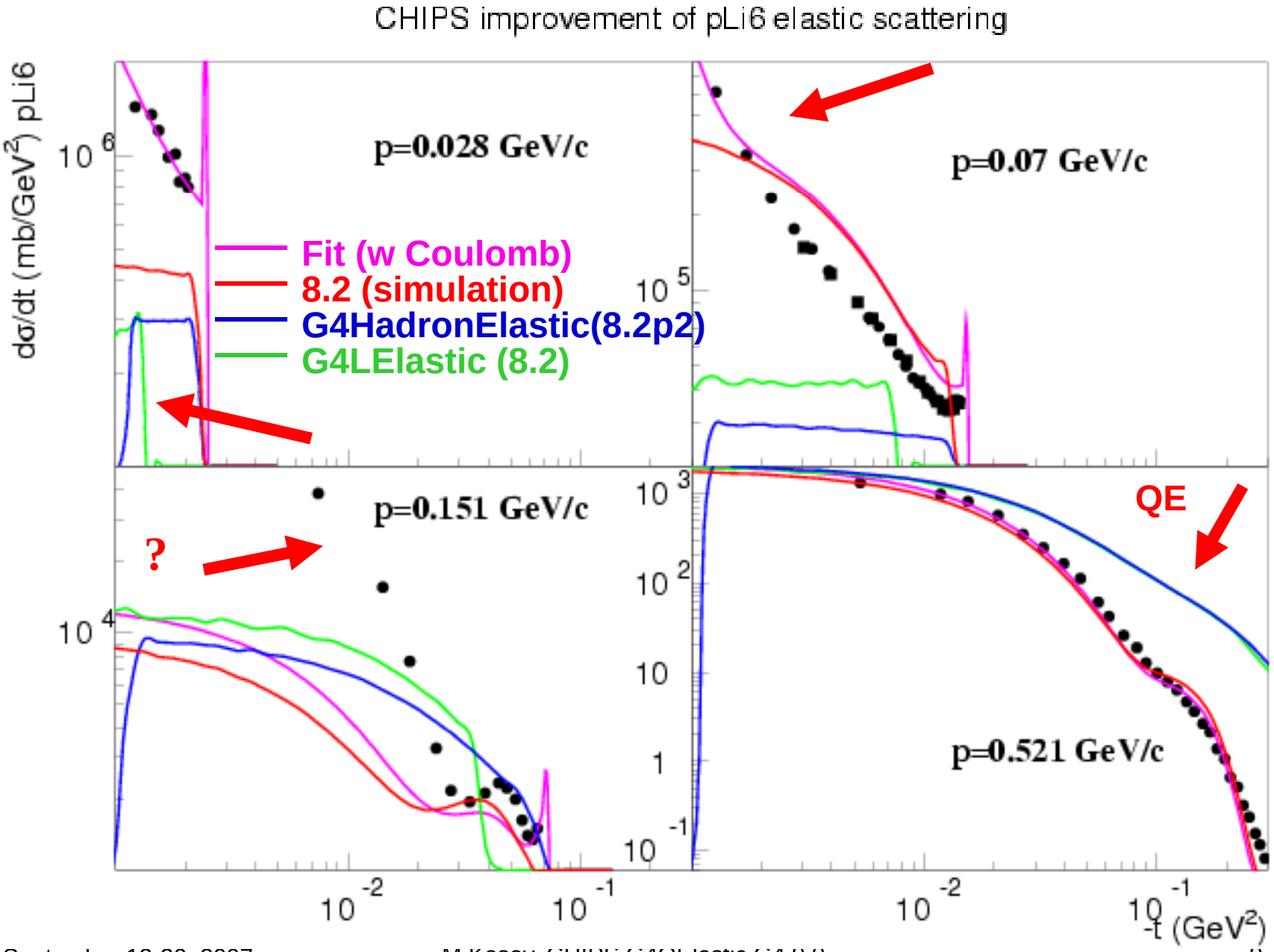
b) at low energy it can be barns

c) Below Coulomb threshold it is pure electromagnetic

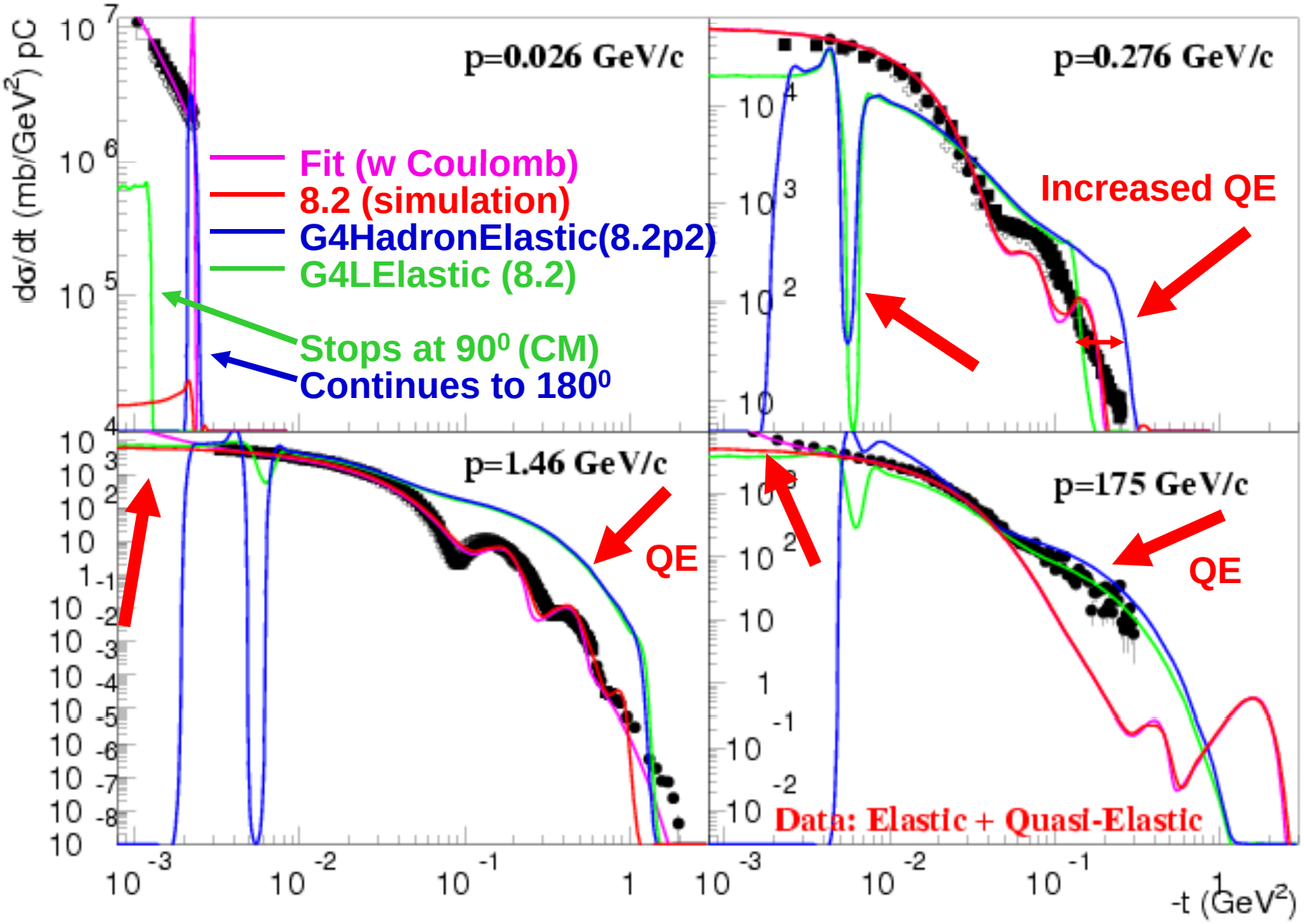
CHIPS improvement of pHe3 elastic scattering



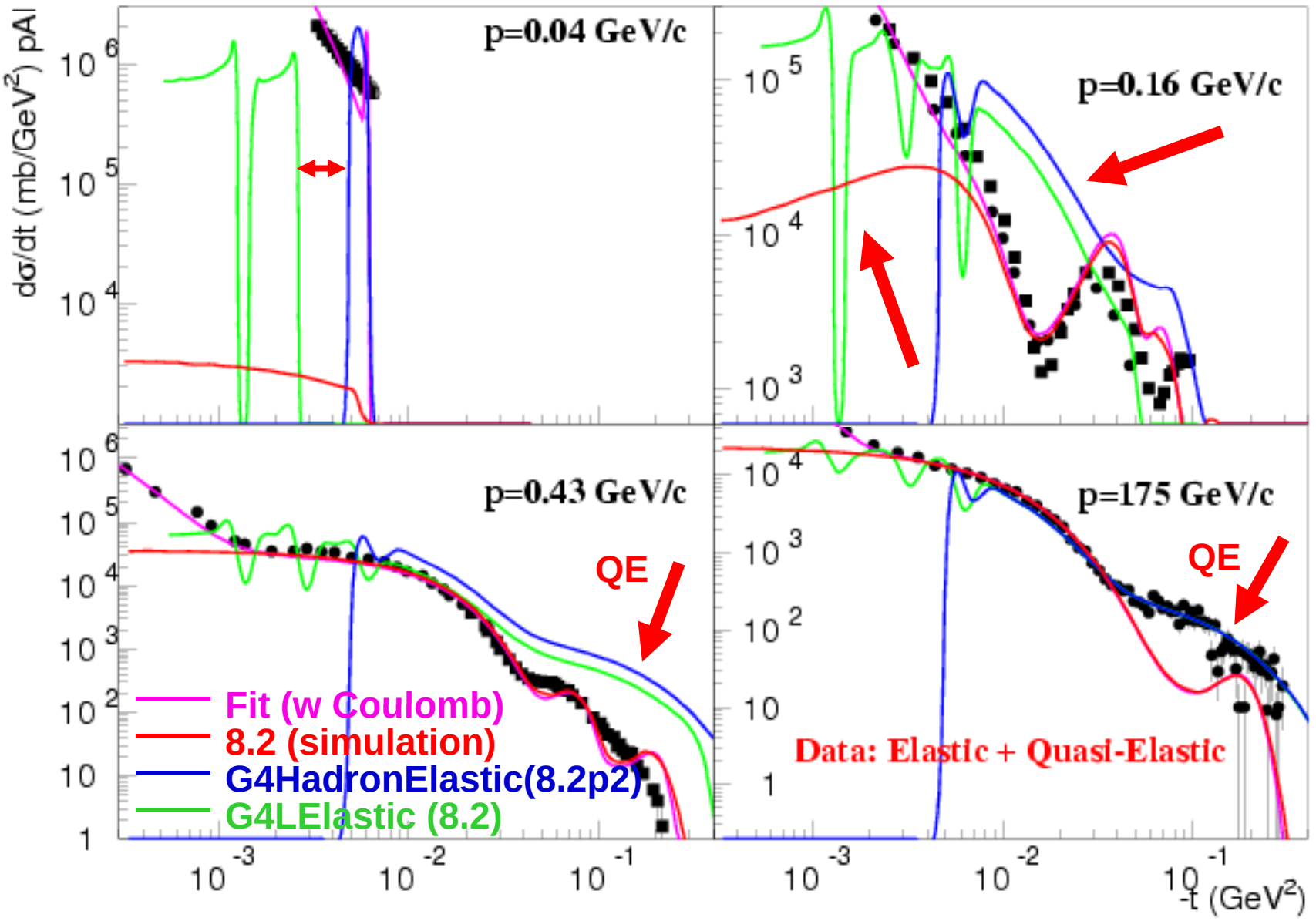

CHIPS improvement of pHe4 elastic scattering
dσ/dt (mb/GeV²) pHe4
p=0.04 GeV/c
p=0.105 GeV/c
p=1.45 GeV/c
p=250 GeV/c
Fit (w Coulomb)
8.2 (simulation)
G4HadronElastic(8.2p2)
G4LElastic (8.2)
-t (GeV²)

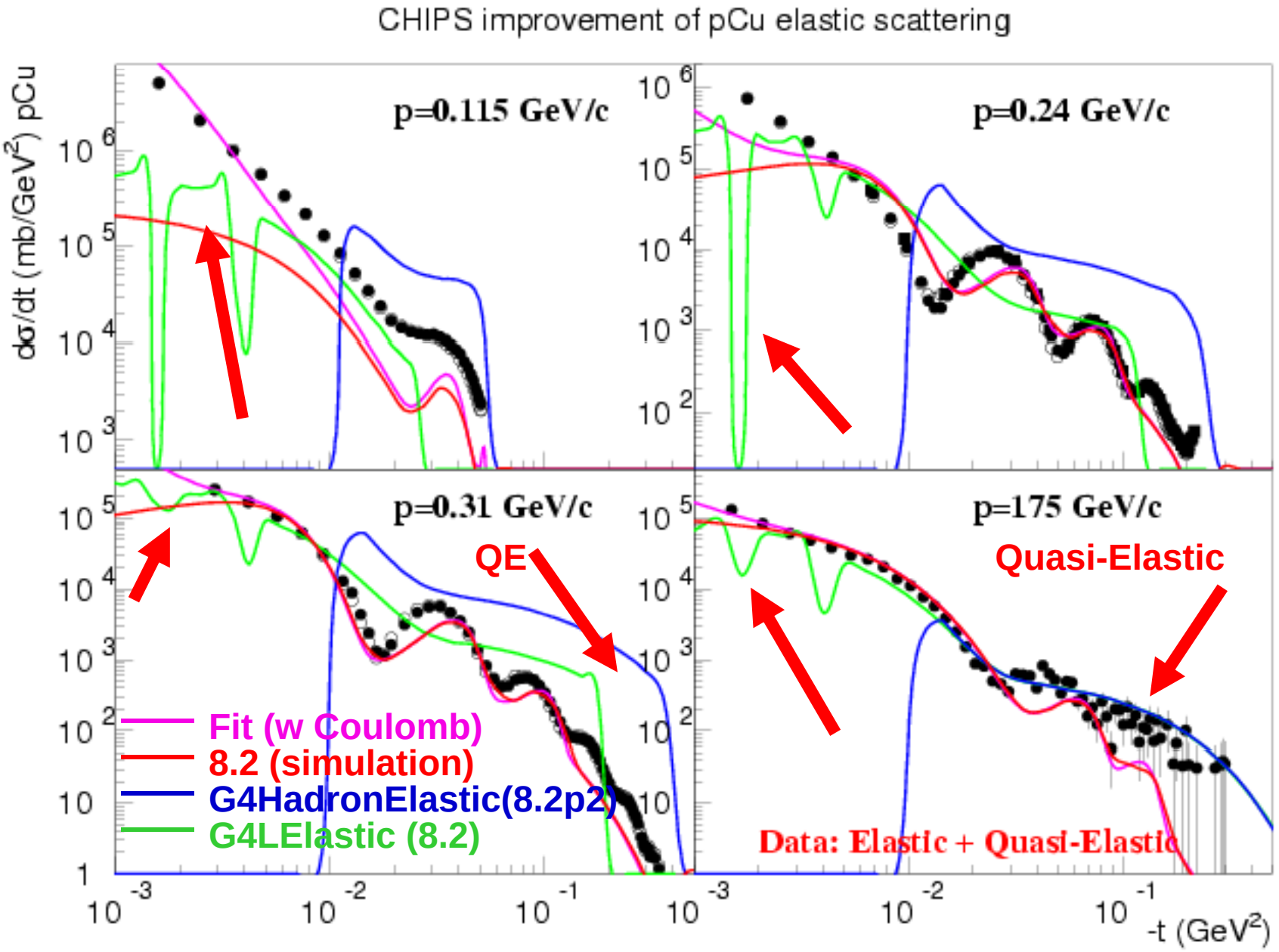

CHIPS improvement of pLi6 elastic scattering
dσ/dt (mb/GeV²) pLi6
p=0.028 GeV/c
p=0.07 GeV/c
p=0.151 GeV/c
p=0.521 GeV/c
Fit (w Coulomb)
8.2 (simulation)
G4HadronElastic(8.2p2)
G4LElastic (8.2)
?
QE
-t (GeV²)

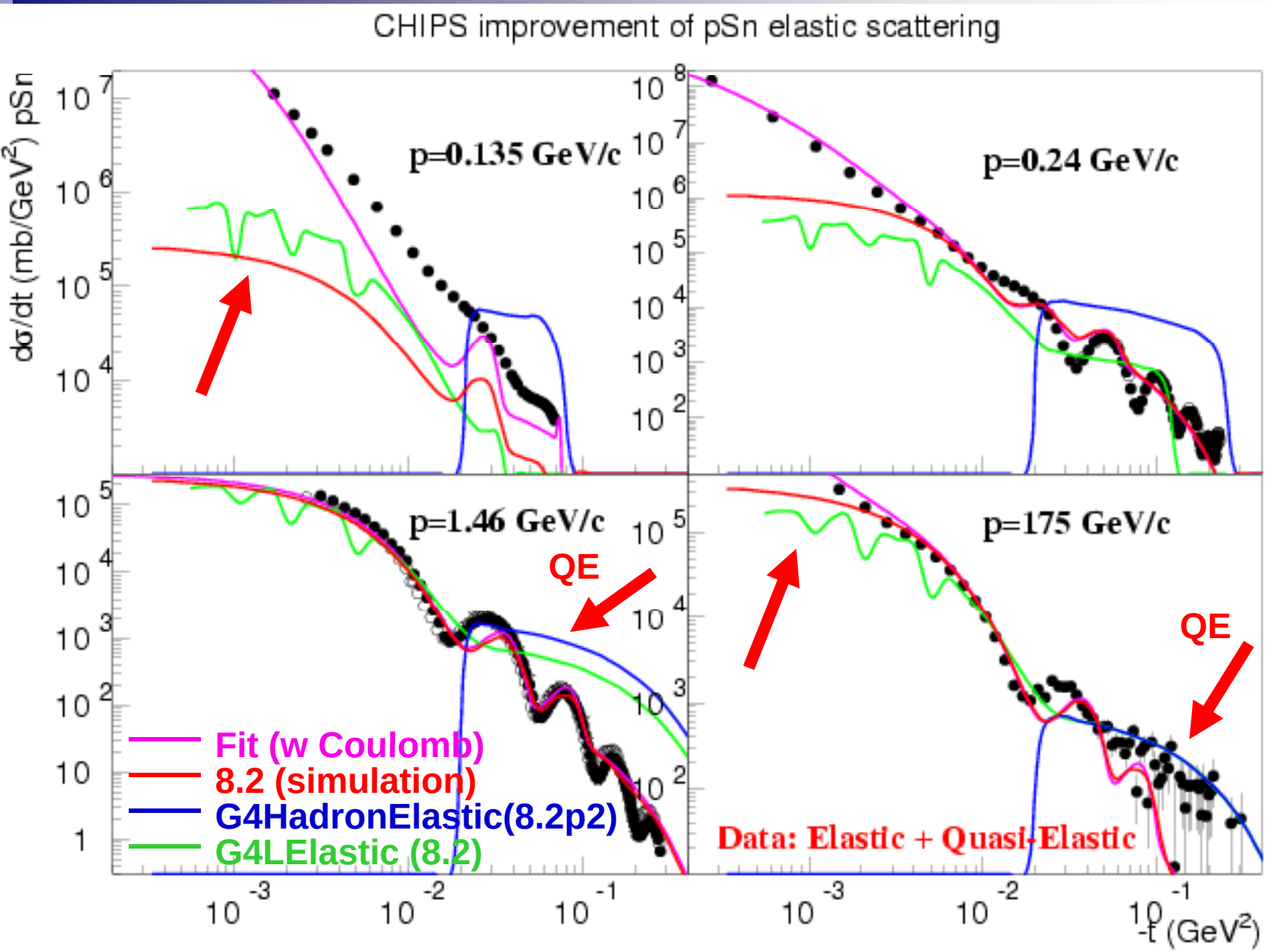
CHIPS improvement of pC elastic scattering



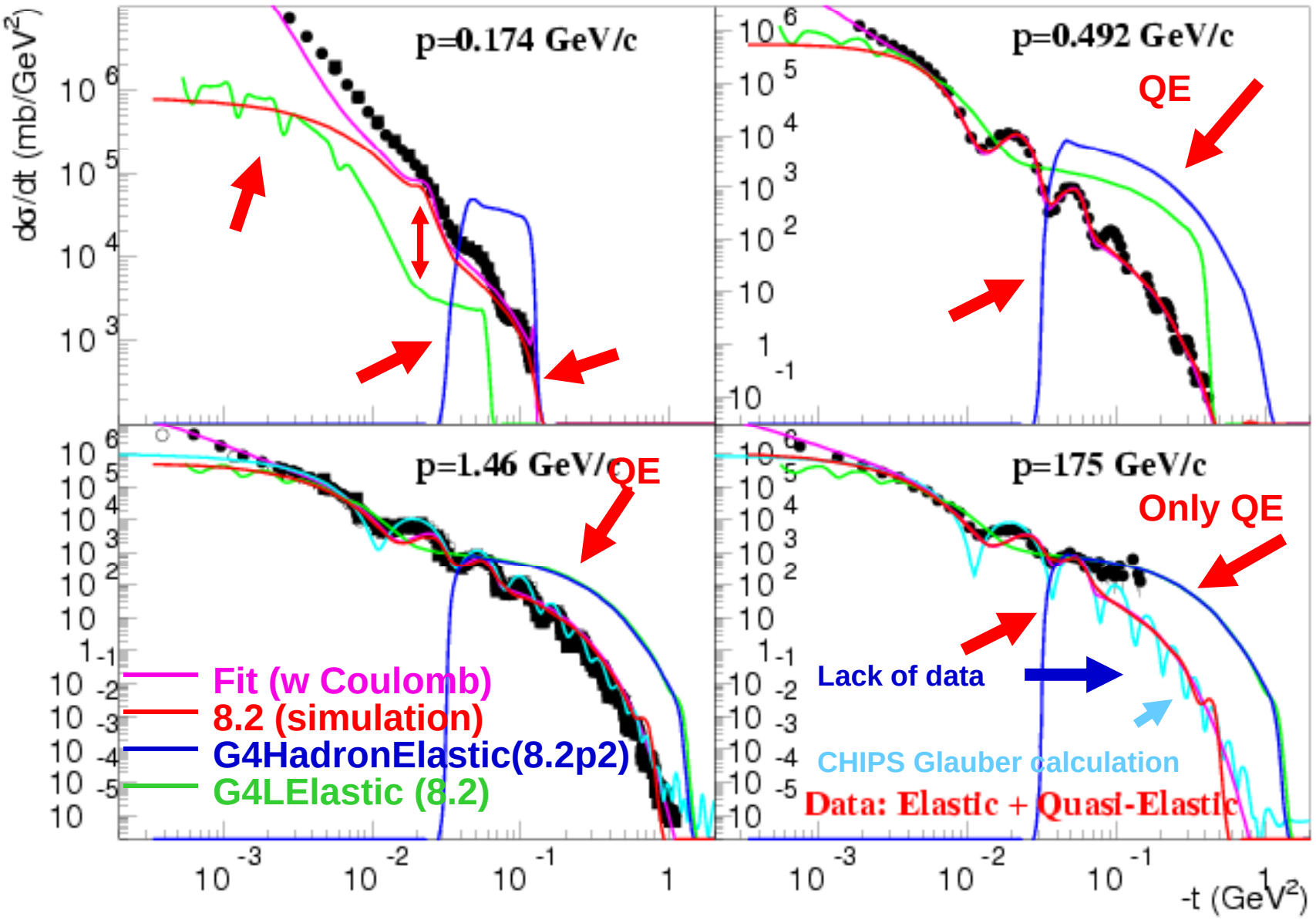
CHIPS improvement of pAl elastic scattering




CHIPS improvement of pCu elastic scattering
dσ/dt (mb/GeV²) pCu
p=0.115 GeV/c
p=0.24 GeV/c
p=0.31 GeV/c
p=175 GeV/c
QE
Quasi-Elastic
Fit (w Coulomb)
8.2 (simulation)
G4HadronElastic(8.2p2)
G4LElastic (8.2)
Data: Elastic + Quasi-Elastic
-t (GeV²)


CHIPS improvement of pSn elastic scattering
dσ/dt (mb/GeV²) pSn
p=0.135 GeV/c
p=0.24 GeV/c
p=1.46 GeV/c
p=175 GeV/c
QE
QE
Fit (w Coulomb)
8.2 (simulation)
G4HadronElastic(8.2p2)
G4LElastic (8.2)
Data: Elastic + Quasi-Elastic
-t (GeV²)

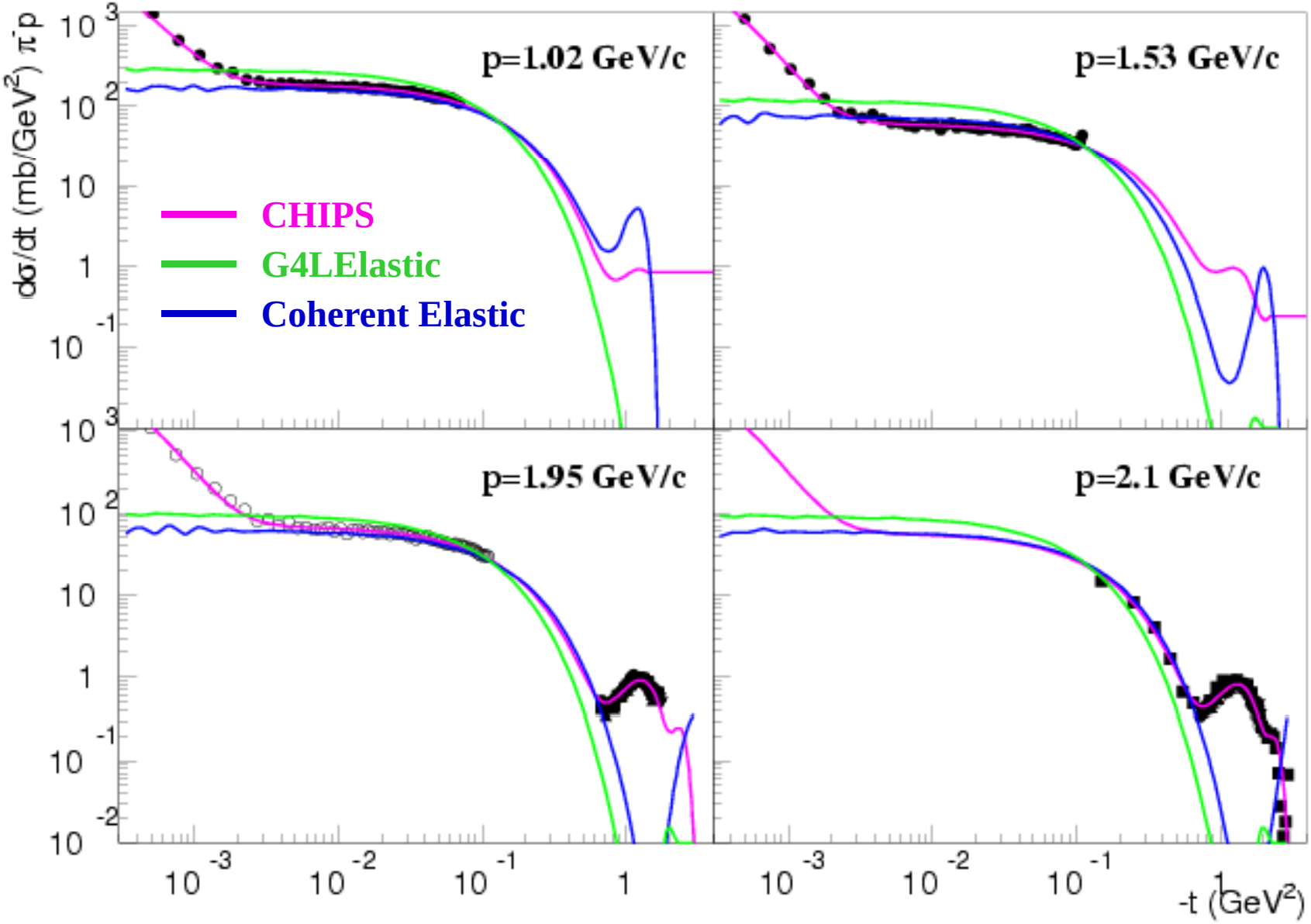
CHIPS improvement of pPb elastic scattering



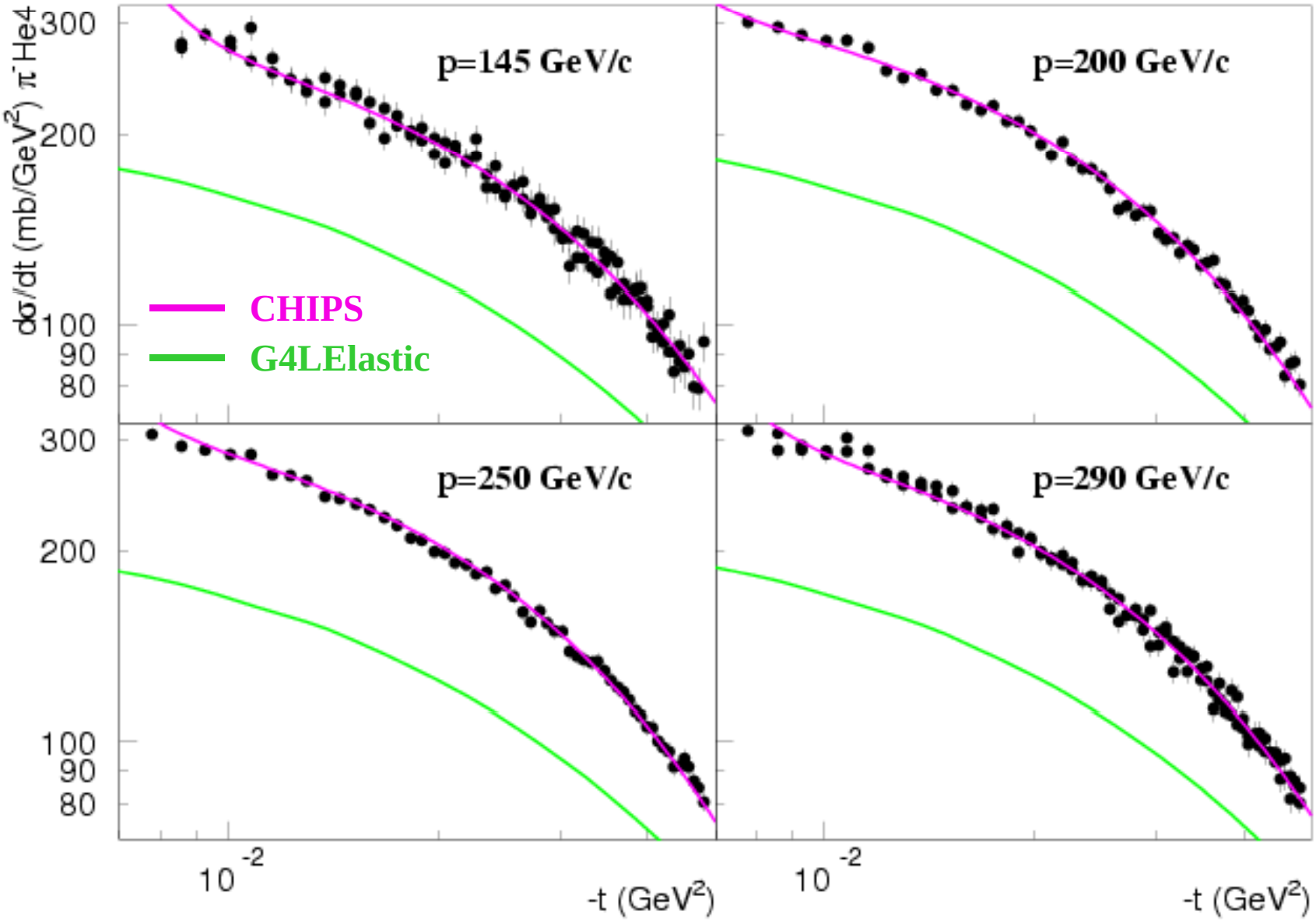
The same fit can be done for pions

- There is a fundamental difference between the pion and the muon elastic scattering
  - Muons do not have the hadronic scattering part
  - Muons do not have the EM/H interference part
  - Muons do not have screening in the interactions
- Data for the pion and for the muon Multiple Scattering should be found and compared
- The discrete and continuous processes must be consistent, otherwise the Stopping Ranges for hadrons can be spoiled

CHIPS improvement of π^-p elastic scattering



CHIPS improvement of π^-He4 elastic scattering



Conclusion

- If the Electromagnetic group is ready for the consistent improvement of the “Multiple Scattering”, CHIPS can provide a discrete process G4QEMElastic for pions & protons
- At high energies the cross-section is an order of magnitude smaller than the hadronic part
- At low energy the EM cross-section is huge, but the small stepping should be avoided.