R&D of CHIPS ion-ion physics: elastic & fast low energy inelastic

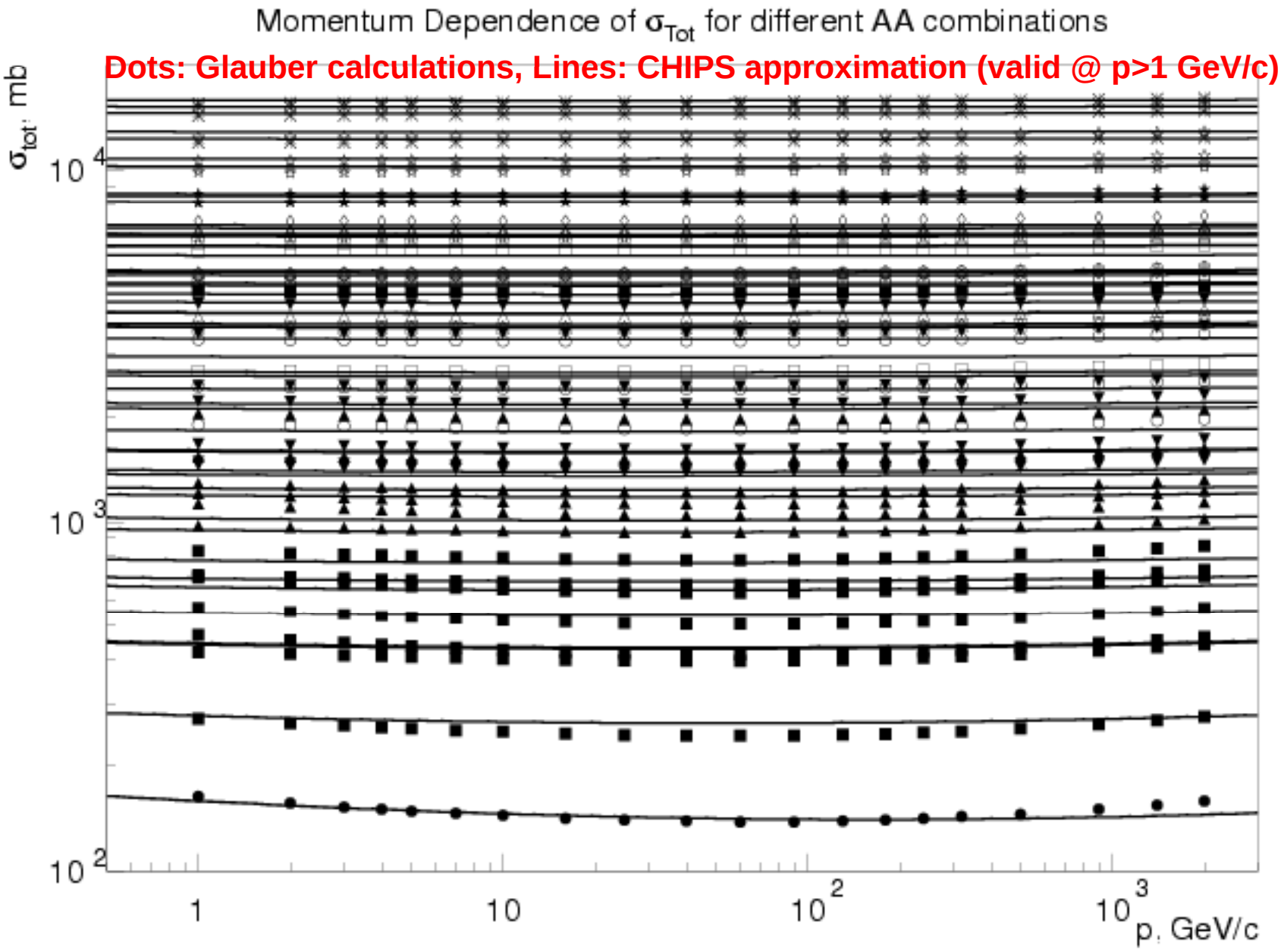
Mikhail Kosov, Physics Validation, CERN, Nov.2007.

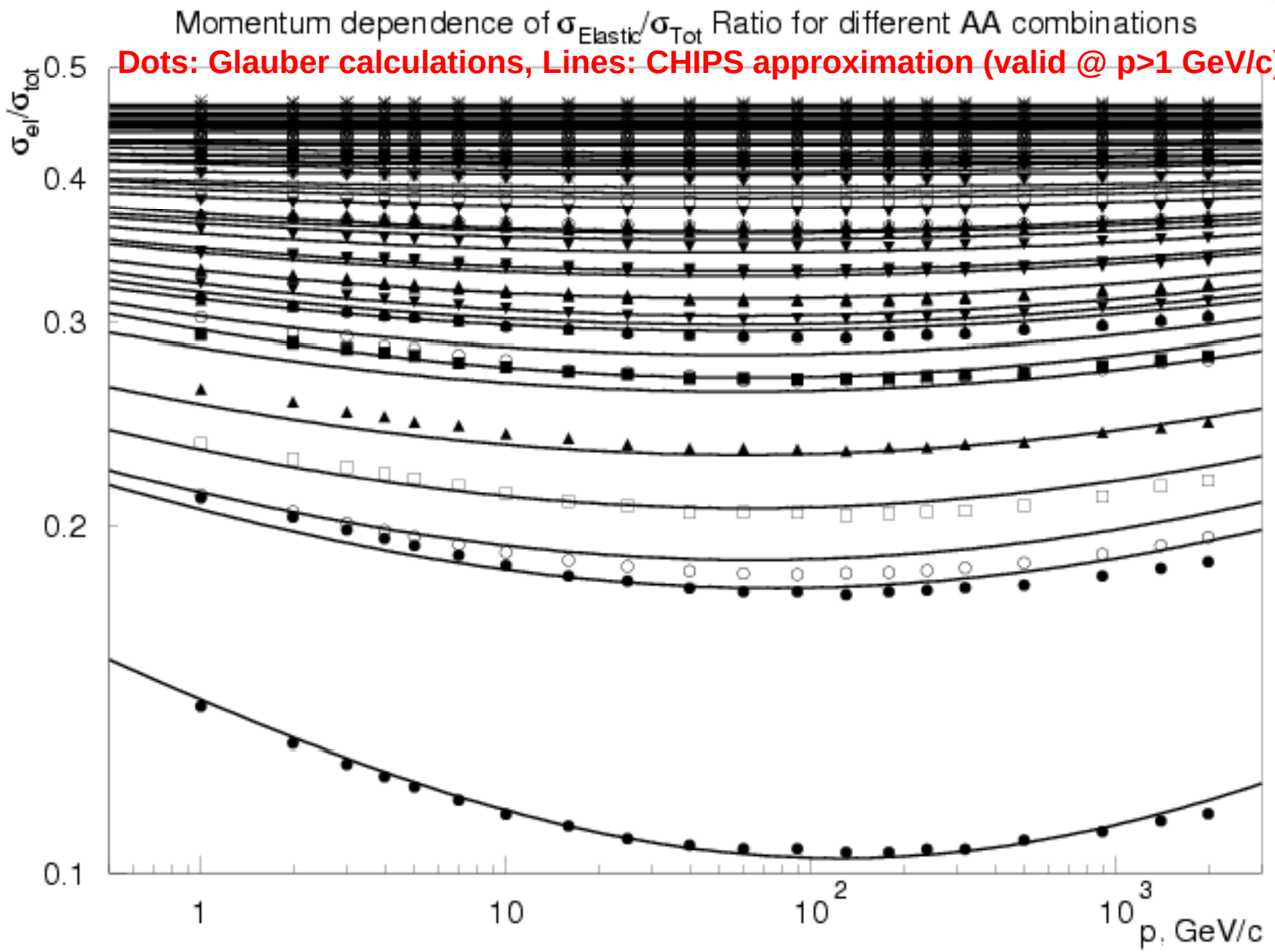
First CHIPS R&D for Ion-Ion interactions

- To make the nuclear/hypernuclear transport
  - G4QIonIonCrossSection can be used for nuclear fragments and hyperfragments:(Z,N,L)=(Z,N+L,0).
  - G4QLowEnergy for inelastic ion-ion interactions.
- For heavy ions the elastic part reaches 45%
  - G4QIonIonCrossSection provides σ_{el}/σ_{tot} ratio.
  - … and **t-distribution** for AA elastic scattering
- High energy inelastic interactions are needed
  - Fast G4QHighEnergy class (to be implemented)

Preliminary solution for Ion-Ion XS

- Glauber calculations have been done for AA elastic and total cross-sectioins
  - Nuclei: D, He, Li, Be, C, Al, Cu, Sn, Pb, U
- Calculated cross-sections have been fitted
  - Parameterization of $\sigma_{tot}(A_1,A_2,P)$ cross-sections
  - Parameterization of $\sigma_{el}/\sigma_{tot}(A_1,A_2,P)$ ratios
- In future the AA measurements should be collected and the parameterization formulas should be tuned to the data.
  - Elastic scattering t-distribution (low energies)
  - Inelastic interactions (spectra of secondaries)

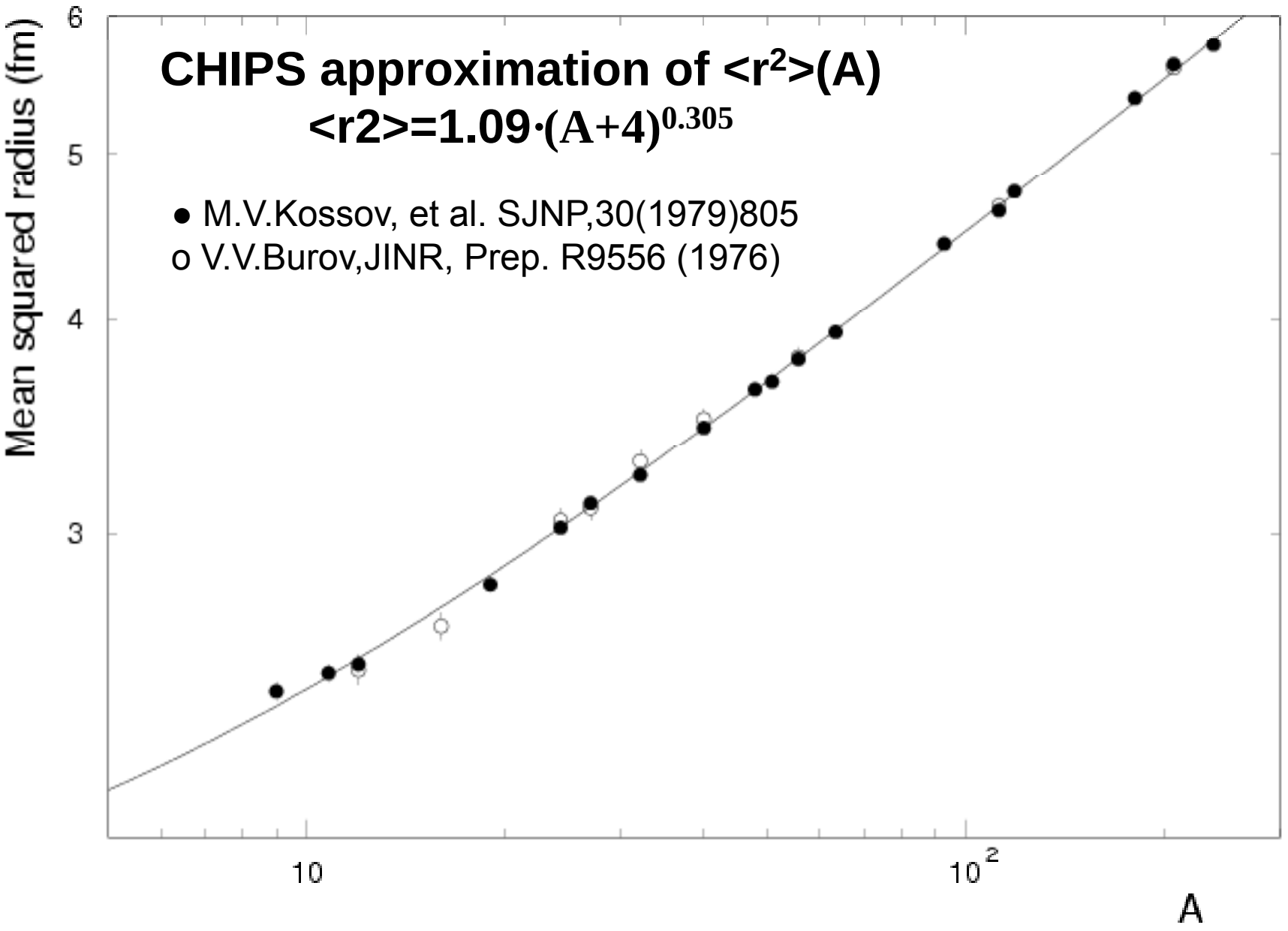

Momentum Dependence of σTot for different AA combinations
Dots: Glauber calculations, Lines: CHIPS approximation (valid @ p>1 GeV/c)
σtot, mb
10 4
10 3
10 2
1
10
10 2
10 3
p, GeV/c


Momentum dependence of $\sigma_{Elastic}/\sigma_{Tot}$ Ratio for different AA combinations
Dots: Glauber calculations, Lines: CHIPS approximation (valid @ p>1 GeV/c)
σ_{el}/σ_{tot}
0.5
0.4
0.3
0.2
0.1
1
10
10^2
10^3
p, GeV/c

Simulation of elastic ion-ion cross-section

- Ion-Ion elastic cross-section is very forward, but it can produce recoil nuclei (medical applications, damaging of electronic devices, detector's aging).
- CHIPS approximation for <R2>:SJNP,30(1979)805
- At high energies (E >1 GeV) with good accuracy the **t-distribution** is energy independent
  - For mean squared radius $<R^2>$ the nuclear form-factor can be calculated as $F_A(t)=e^{<R2>t/6}$
  - The diffraction cone parameter B is energy dependent, but B **<<** $<\mathbf{R}^2>/3+<\mathbf{r}^2>/3$, where **r** and **R** are radii of target and projectile. Thus the solution is

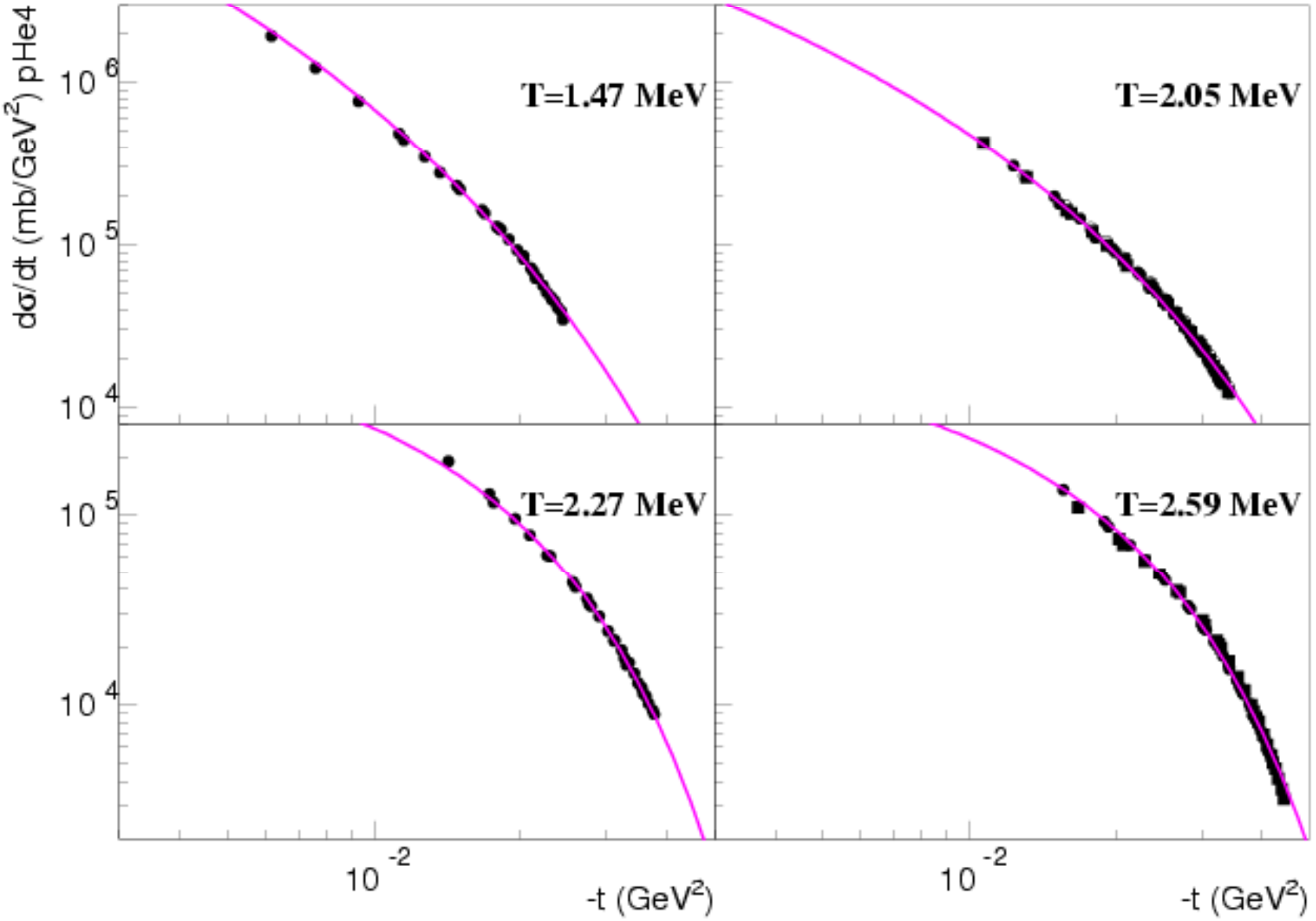
$$d\sigma/dt=C\cdot e^{(B+<R2>/3+<r2>/3)t}$$


CHIPS approximation of <r²>(A)
<r2>=1.09·(A+4)^0.305
● M.V.Kossov, et al. SJNP,30(1979)805
o V.V.Burov,JINR, Prep. R9556 (1976)
Mean squared radius (fm)
6
5
4
3
10
10²
A

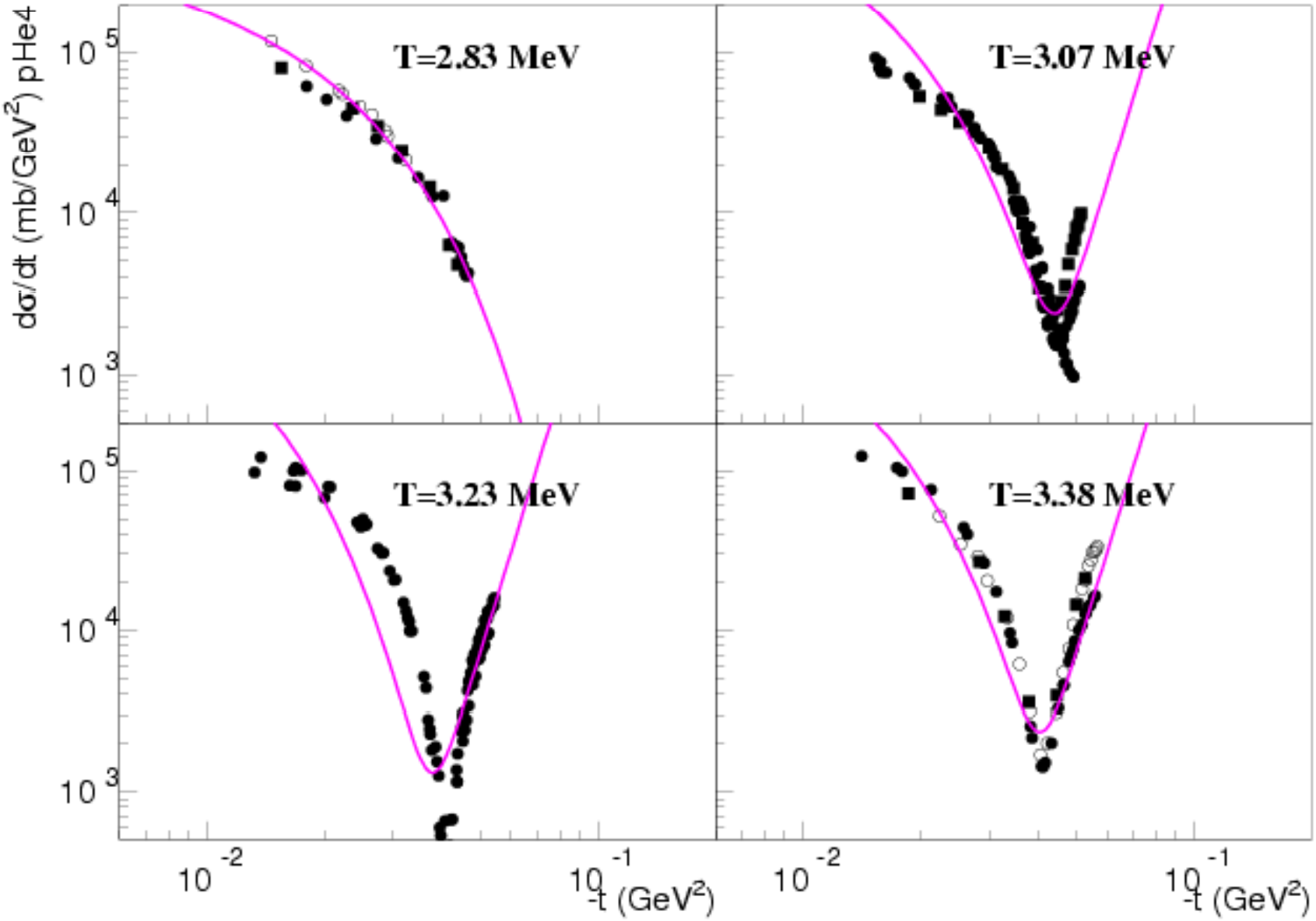
Low energy elastic t-distributions

- As the hadronic ion-ion elastic distributions are very forward, they strongly interfere with electromagnetic elastic scattering (M.S.?!)
- At very low energies ($E < Z \cdot z/10$ MeV) the electromagnetic elastic is dominating
- At higher energies a big backward scattering appear and the hadronic/electromagnetic interference should be taken into account
- CHIPS ion-ion elastic database includes AA elastic differential cross-sections for E<1.5GeV. The $\alpha^{12}C$ is an example.

CHIPS improvement of αC12 elastic scattering



CHIPS improvement of αC12 elastic scattering



Conclusion

- CHIPS is developed to be prepared for the ion-ion transport.
- It is very important for medical applications and for the simulation of radiation damage of electronics, probably, detectors aging too.
- As an SU(3) package CHIPS supports both ions and hyper-ions.
- At high energies the total and elastic cross-sections are provided by CHIPS for ion-ion interactions, but at low energies it needs tuning.
- Ion-Ion elastic scattering is already supported for high energies, providing a narrow diffractive scattering, but at low energies its interference with electromagnetic should be taken into account.
- Multiple scattering for ions cannot be properly implemented without proper implementation of hadron elastic scattering/
- Low energy inelastic interactions for all nuclear fragments are supported by the fast G4QLowEnergy, but it should be tuned.
- In future high energy inelastic interactions must be implemented in the CHIPS SU(3) form.