Total, inelastic and elastic cross-sections of high energy pp, pA and eA collisions in DIPSY

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Introduction
The Lund Dipole Cascade Model DIPSY
New: nuclei in DIPSY
Monte Carlo cross section results
Comparison with Glauber results

arXiv:1103.4320
arXiv:1103.4321
arXiv:1206.1733
+ manuscript in preparation

Introduction: Glauber theory++

$$p \propto \exp\left(-\sigma_{in}^{hN}\rho L\right)$$

$$T_A(b) = \int \rho(z,b)\,dz$$

$$\int d^2b\,T_A(b) = A$$

$$T_{AB}(b) = \int d^2s\,T_A(s)\,T_B(|s-b|)$$

Glauber, 1955, 1967, 1970
Glauber and Matthiae, 1970
Bialas, Bleszynski, Czyz, 1976, …

Optical model, high energy physics

Nuclear thickness function

Overlap function

$$\sigma_{AB} = \int d^2b \int d^2s_1^A \ldots d^2s_A^A d^2s_1^B \ldots d^2s_B^B \quad \times$$
$$T_A(s_1^A)\ldots T_A(s_A^A) T_B(s_1^B)\ldots T_B(s_B^B) \quad \times$$
$$\left\{1 - \prod_{j=1}^{B}\prod_{i=1}^{A}\left[1 - \sigma(b - s_i^A + s_j^B)\right]\right\}$$

Configuration space

Nuclear geometry (uncorrelated)

Elementary n-n interactions

Analytically ~ impossible. Nuclear short range correlations?
-> Monte-Carlo simulations

SR correlations, Gribov corrections

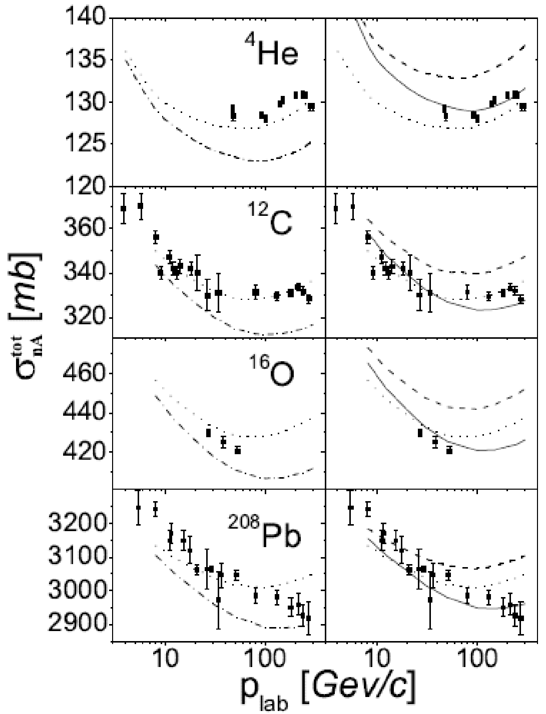
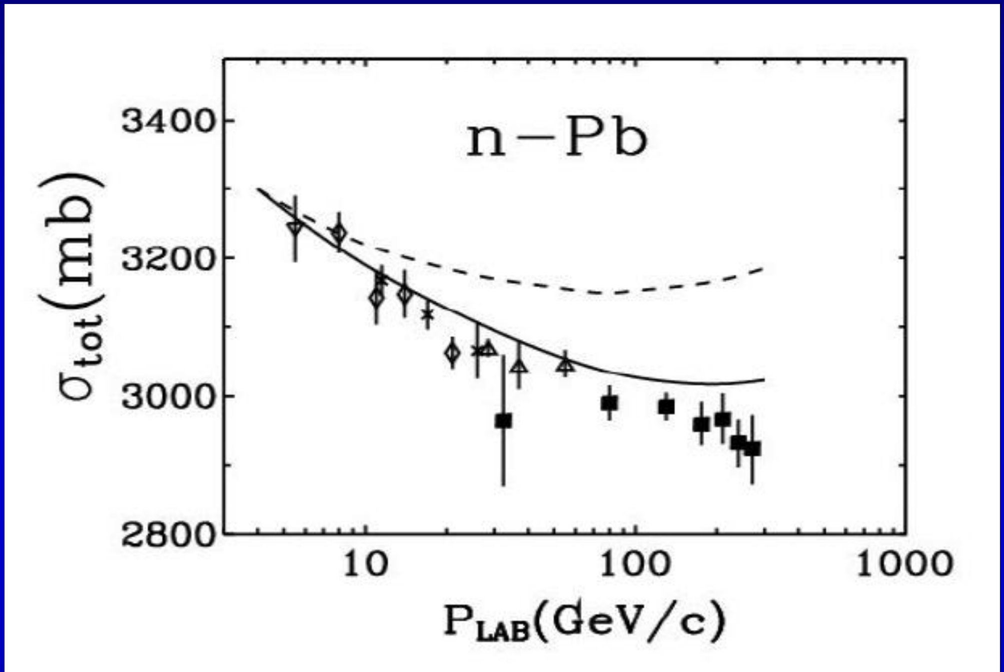


FIG. 2: σ^{nA}_{tot} *vs* p_{lab}. *Left panel*: Glauber single density approximation (σ_G; *dots*) and Glauber plus Gribov inelastic shadowing ($\sigma_G + \Delta\sigma_{IS}$; *dot-dash*). *Right panel*: Glauber (σ_G; *dots*); Glauber plus SRC ($\sigma_G + \sigma_{SRC}$; *dashes*); Glauber plus SRC plus Gribov inelastic shadowing ($\sigma_G + \sigma_{SRC} + \Delta\sigma_{IS}$; *full*). Experimental data from [6, 17].

<- Avioli et al, arXiv:0708.0873

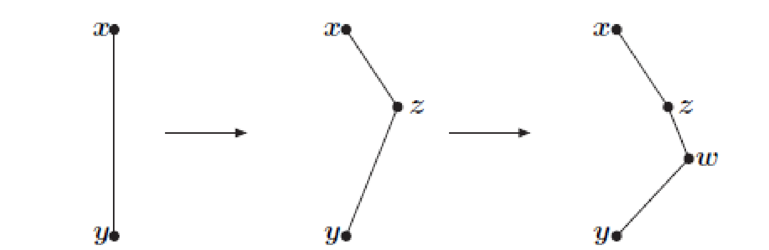


Gribov: fluctuations in the size of n decrease total nA cross-sections

Short range nucleon-nucleon correlations (SRC) + Gribov diffractive corrections are important for nA and pA collisions
→ DIPSY detailed MC study for future accelerators

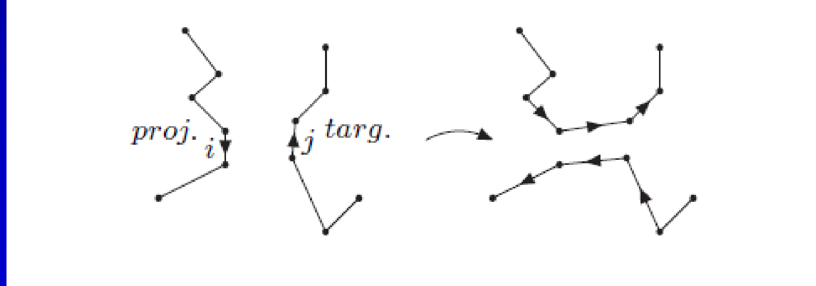
DIPSY: Lund Dipole Cascade Model

$$\frac{d\mathcal{P}}{dY} = \frac{\bar{\alpha}}{2\pi} d^2z \frac{(x-y)^2}{(x-z)^2(z-y)^2}, \quad \text{with } \bar{\alpha} = \frac{3\alpha_s}{\pi}.$$



The evolution of the dipole cascade in transverse coordinate space.

Based on: Mueller's dipole cascade
Formulation of BFKL evolution
in rapidity and trasverse coordinates



A dipole–dipole interaction implies exchange of colour and reconnection

2 dipoles interact (in Born approx.)
Multiple collisions:
in eikonal approx.(unitarity OK)
Forward amplitude and cross sections:

$$2f_{ij} = 2f(x_i, y_i | x_j, y_j) = \frac{\alpha_s^2}{4} \left[\log\left(\frac{(x_i - y_j)^2 (y_i - x_j)^2}{(x_i - x_j)^2 (y_i - y_j)^2} \right) \right]^2.$$

$$\text{Int. prob.} = 1 - e^{-2F}, \quad \text{with } F = \sum f_{ij}.$$

$$T = 1 - e^{-F},$$

$$\sigma_{\text{inel}} = \int d^2\boldsymbol{b} \langle 1 - e^{-2F(\boldsymbol{b})} \rangle = \int d^2\boldsymbol{b} \langle 1 - (1 - T(\boldsymbol{b}))^2 \rangle.$$

$$\sigma_{\text{el}} = \int d^2\boldsymbol{b} \langle T(\boldsymbol{b}) \rangle^2.$$

$$\sigma_{\text{diff}} = \int d^2\boldsymbol{b} \langle T(\boldsymbol{b})^2 \rangle.$$

$$\sigma_{\text{diff ex}} = \sigma_{\text{diff}} - \sigma_{\text{el}} = \int d^2\boldsymbol{b} \left(\langle T(\boldsymbol{b})^2 \rangle - \langle T(\boldsymbol{b}) \rangle^2 \right)$$

DIPSY: a graphical summary

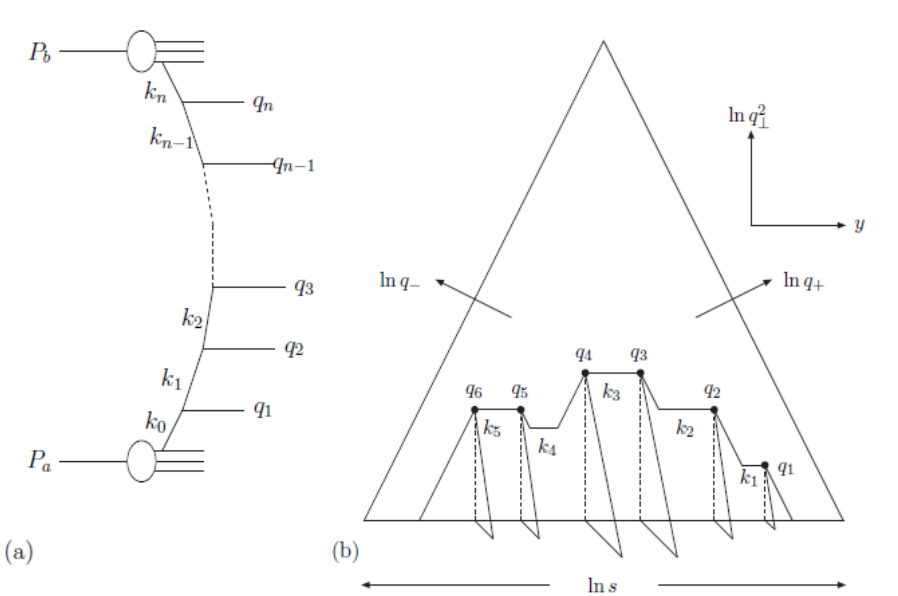


Figure 5: (a) A parton chain stretched between projectile and target. (b) A backbone of $k_\perp$-changing gluons in a $(y, \ln q_\perp^2)$ plane. The transverse momentum of the virtual links k_i are represented by horizontal lines.

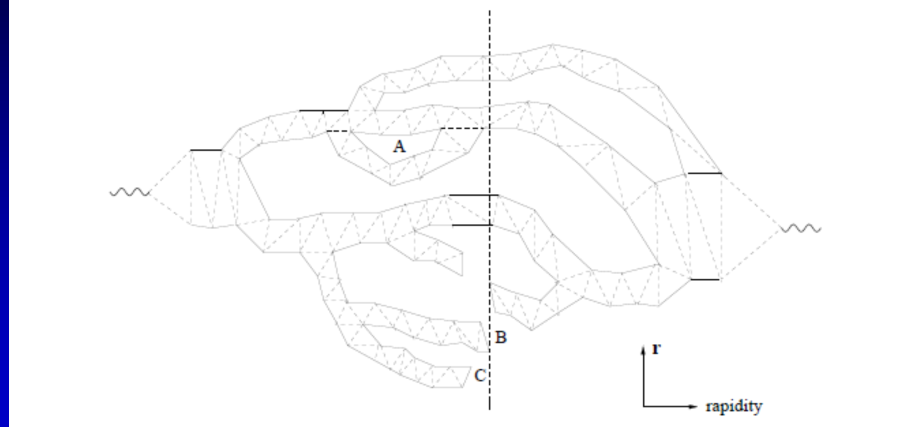


Figure 6: Collision of two dipole cascades in $\boldsymbol{r}$-rapidity space. The dashed vertical line symbolizes the Lorentz frame in which the collision is viewed. The dipole splitting vertex can result in the formation of different dipole branches, and loops are formed due to multiple sub-collisions. The loop denoted by A is an effect of saturation within the cascade evolution, which can be formed via a dipole swing. Branches which do not interact, like those denoted B and C are to be treated as virtual, and to be absorbed.

Dipole chain (top)

Chain split (bottom)

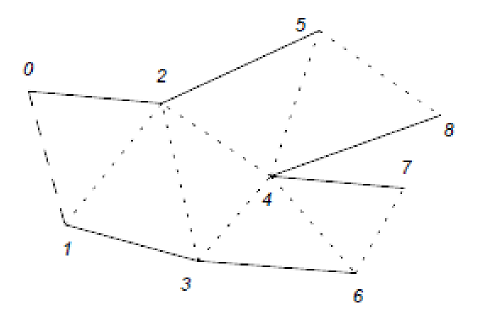


Figure 27: Two interactions makes a chain split in two. Dotted lines show parent structure, full lines show colour flow.

Saturation (top)

Swing: rearranged color flow (bottom)

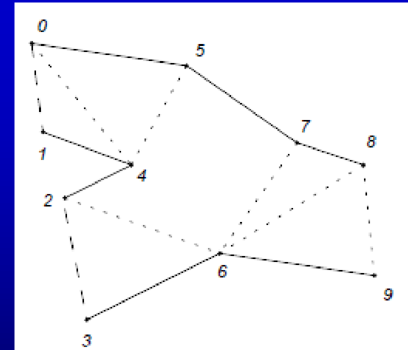
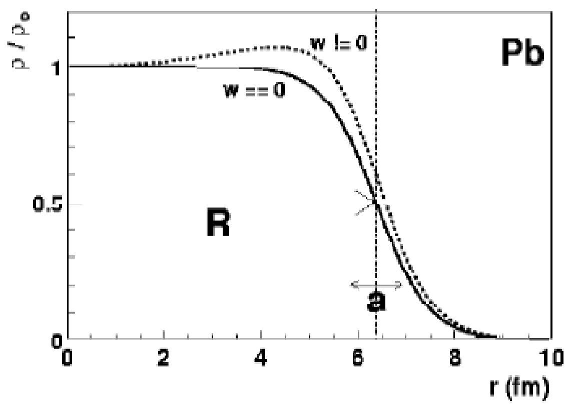


Figure 28: A swing between (45) and (26) causing two chains of backbone gluons to merge. Dotted lines show parent structure, full lines show colour flow. The picture is in impact-parameter space.

Treatement of nuclei in DIPSY

$$\rho(r) = \frac{\rho_0 \left(1 + wr^2 / R^2\right)}{1 + \exp\left((r - R)/a\right)}$$



Electron Scattering Measurements

Nucleus	A	R	a	w
C	12	2.47	0	0
O	16	2.608	0.513	-0.051
Al	27	3.07	0.519	0
S	32	3.458	0.61	0
Ca	40	3.76	0.586	-0.161
Ni	58	4.309	0.516	-0.1308
Cu	63	4.2	0.596	0
W	186	6.51	0.535	0
Au	**197**	**6.38**	**0.535**	**0**
Pb	208	6.68	0.546	0
U	238	6.68	0.6	0

H. DeVries, C.W. De Jager, C. DeVries, 1987

$$T_A(s) = \int_{-\infty}^{+\infty} \rho_A(\vec{s}, z)$$

Extended Woods-Saxon charge density

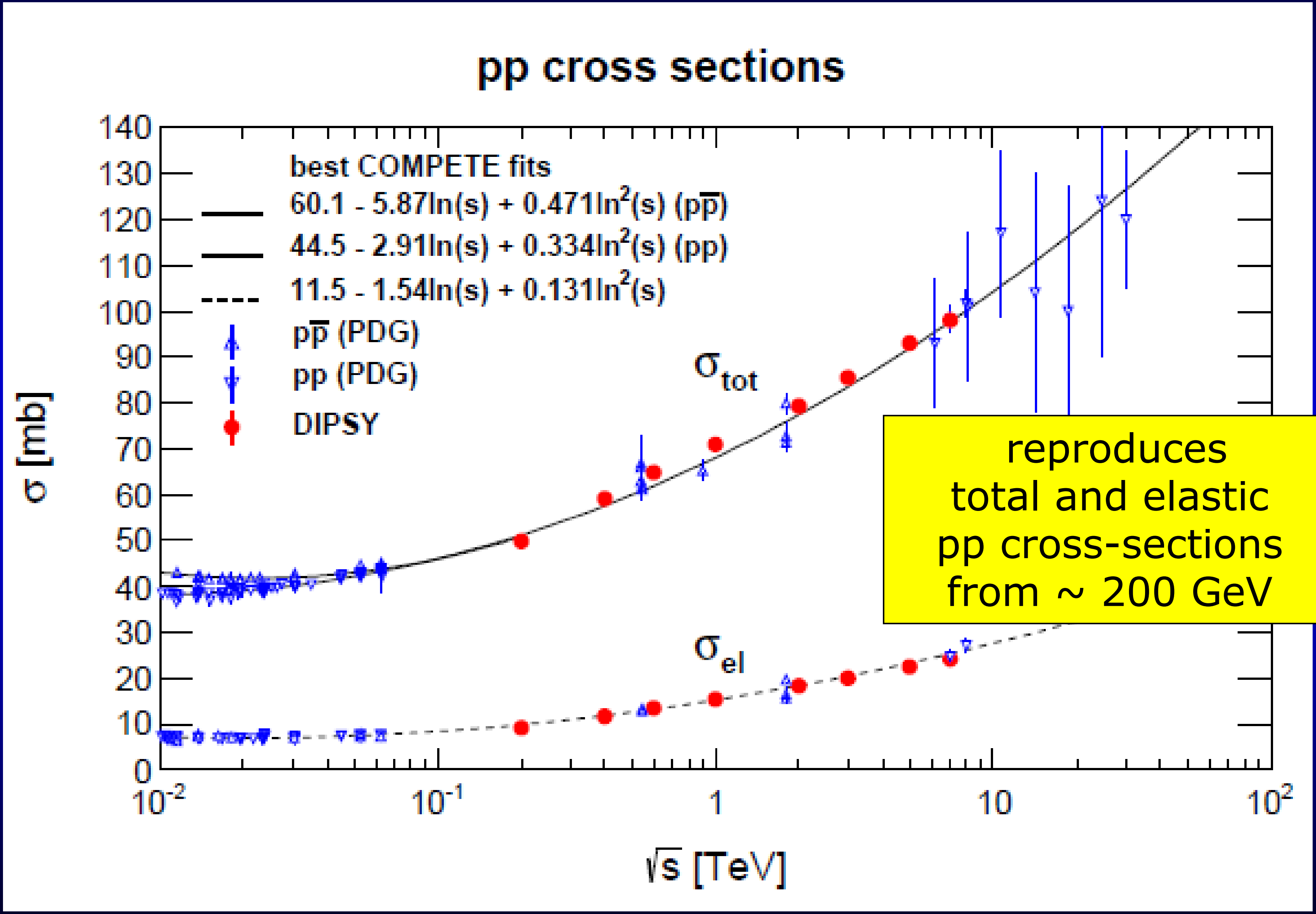
Currently in DIPSY for He, O, Cu, Au and Pb

GLISSANDRO: (Broniowski et al) corrections for nuclear center

R(Pb,NC) = 6.4 fm
R(Au, NC) = 6.2 fm
R(Cu,NC) = 4.2 fm
R(O,NC) = 2.5 fm

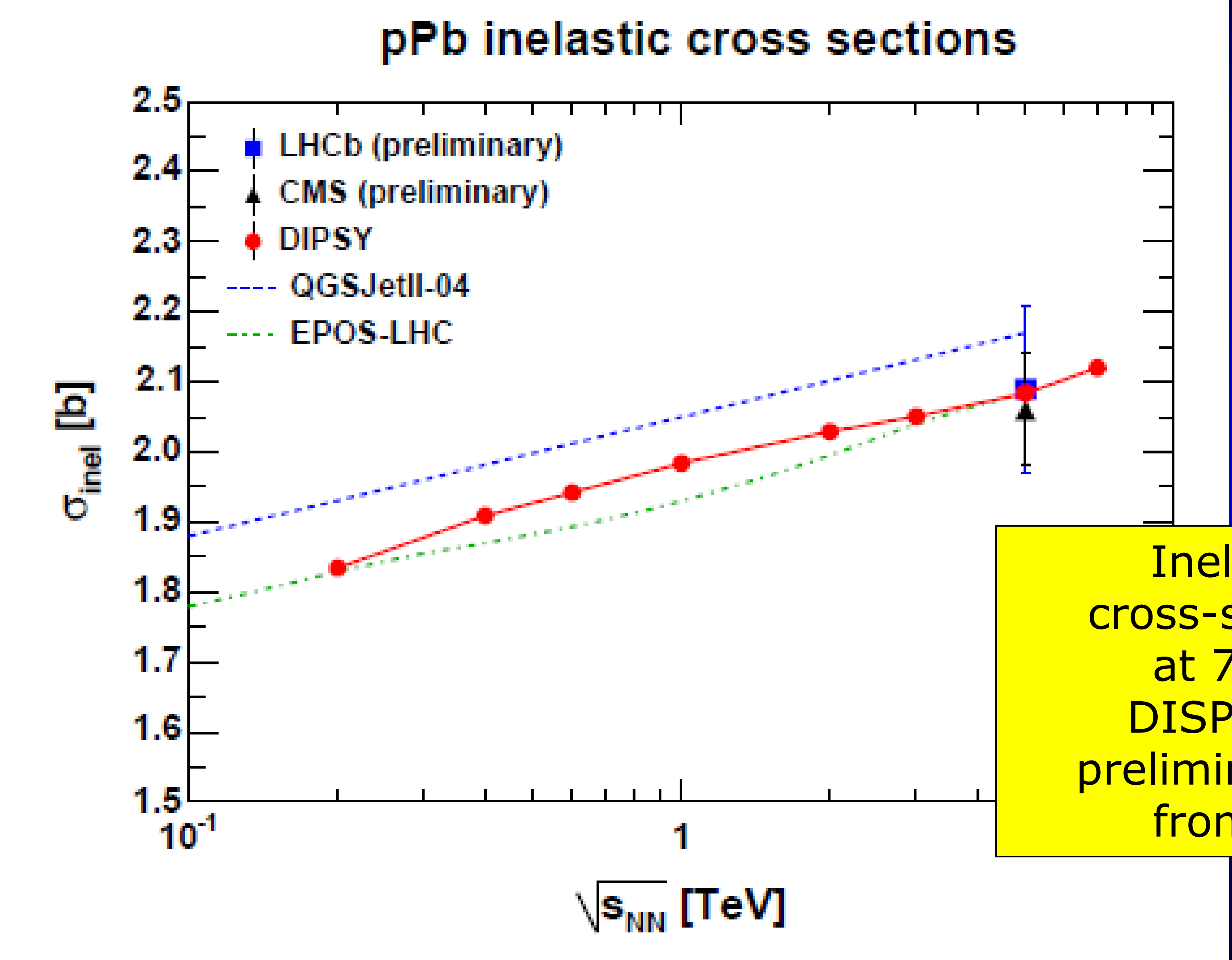
$(1.1A^{1/3} - 0.656A^{-1/3})$ fm

DIPSY test 1: pp cross sections



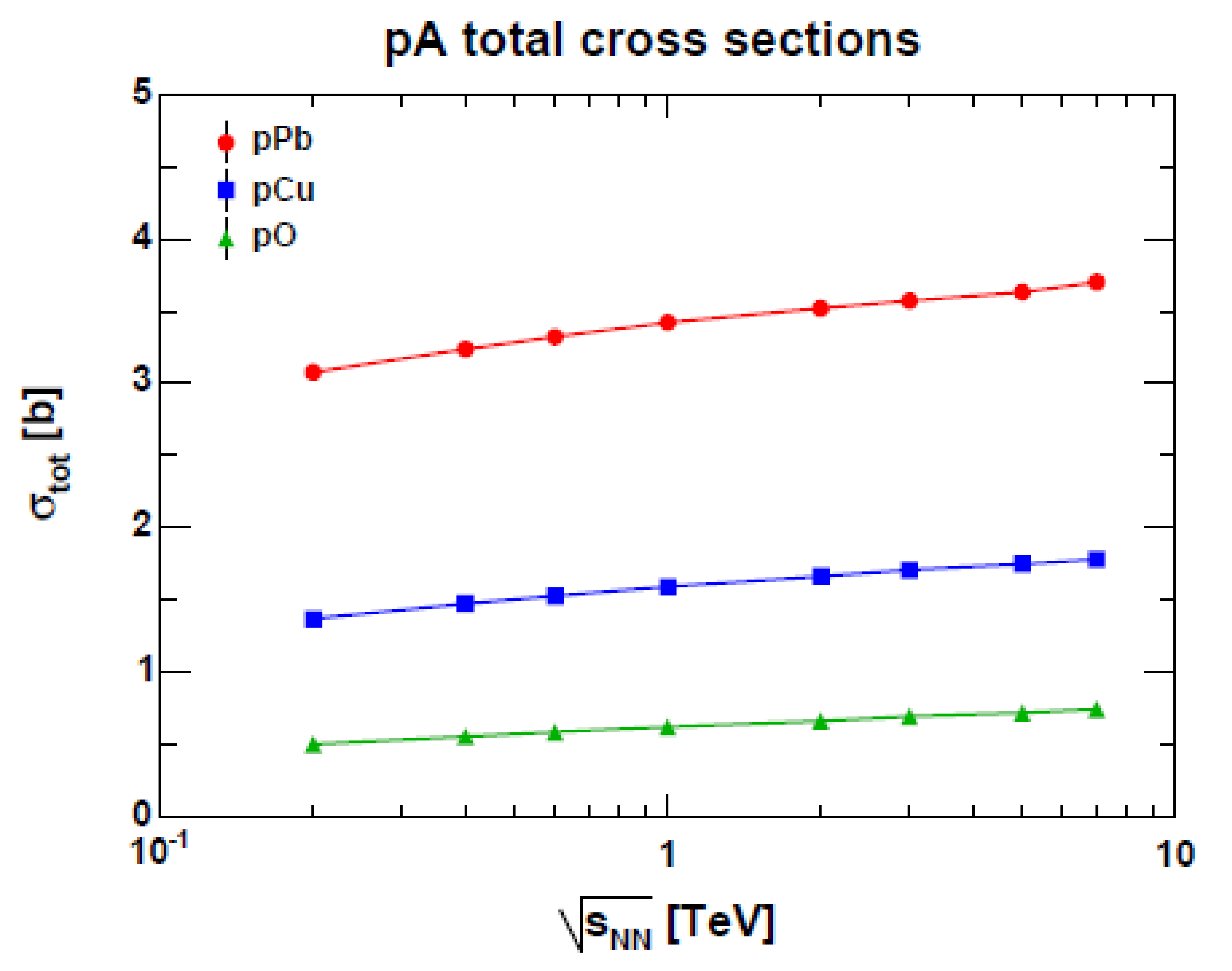
reproduces total and elastic pp cross-sections from ~ 200 GeV

DIPSY test 2: pPb cross sections

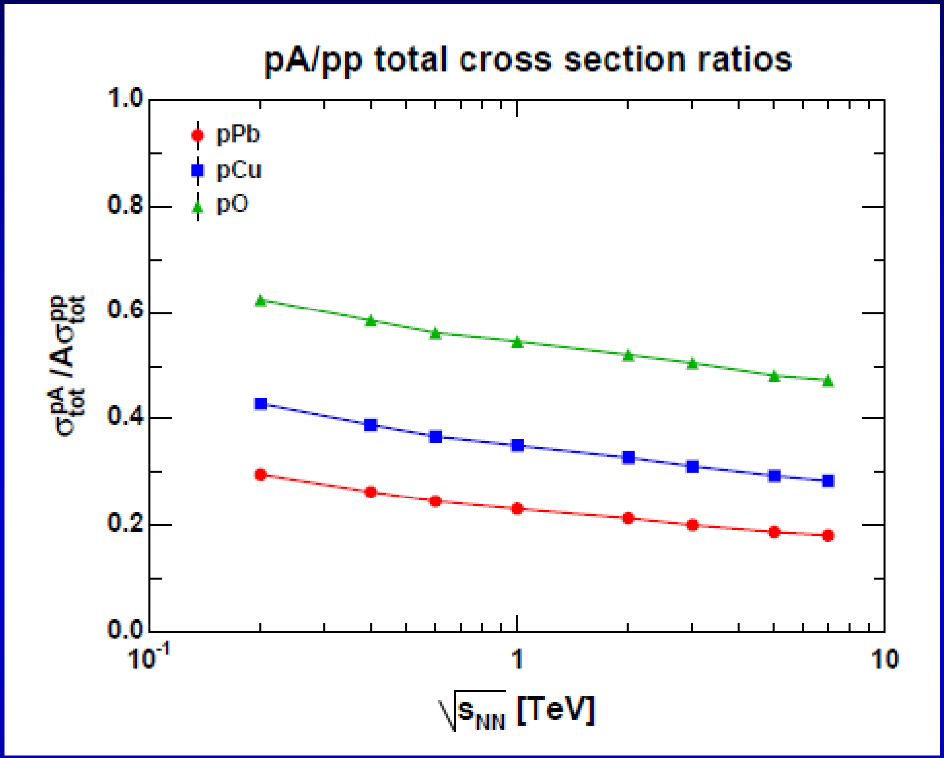


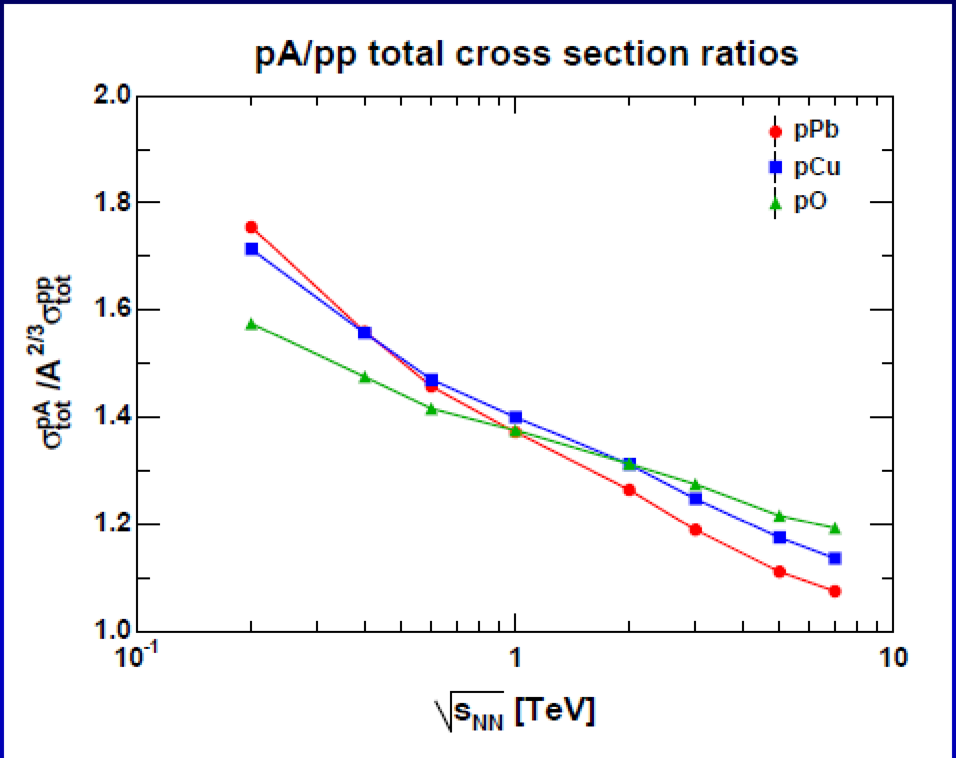
Inelastic cross-sections at 7 TeV DISPY and preliminary data from LHC

DIPSY predictions: pA



DIPSY pA/pp ratios

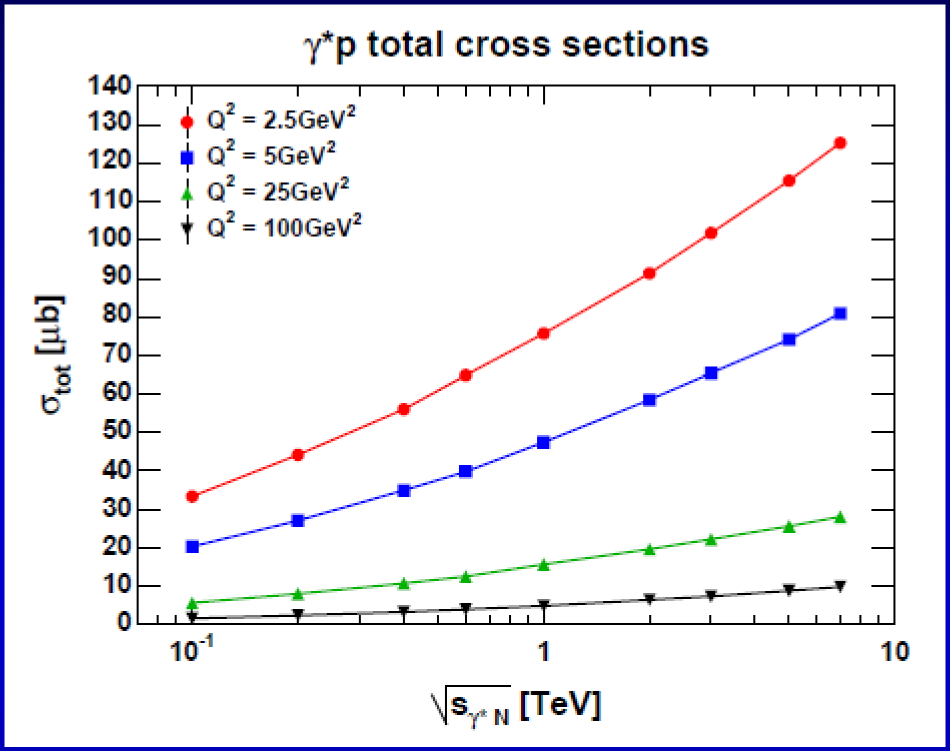


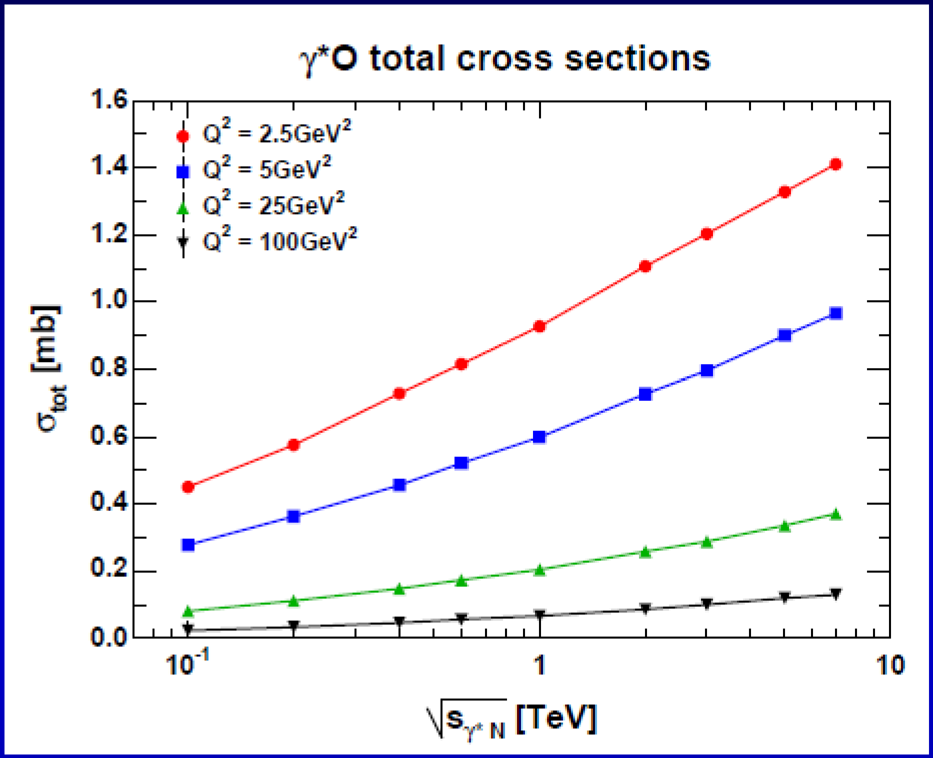


pA total cross section does not scale with A (fluctuations, swing)

DIPSY pA total asymptotically scales with $A^{2/3}$

DIPSY for a future ep and eA collider

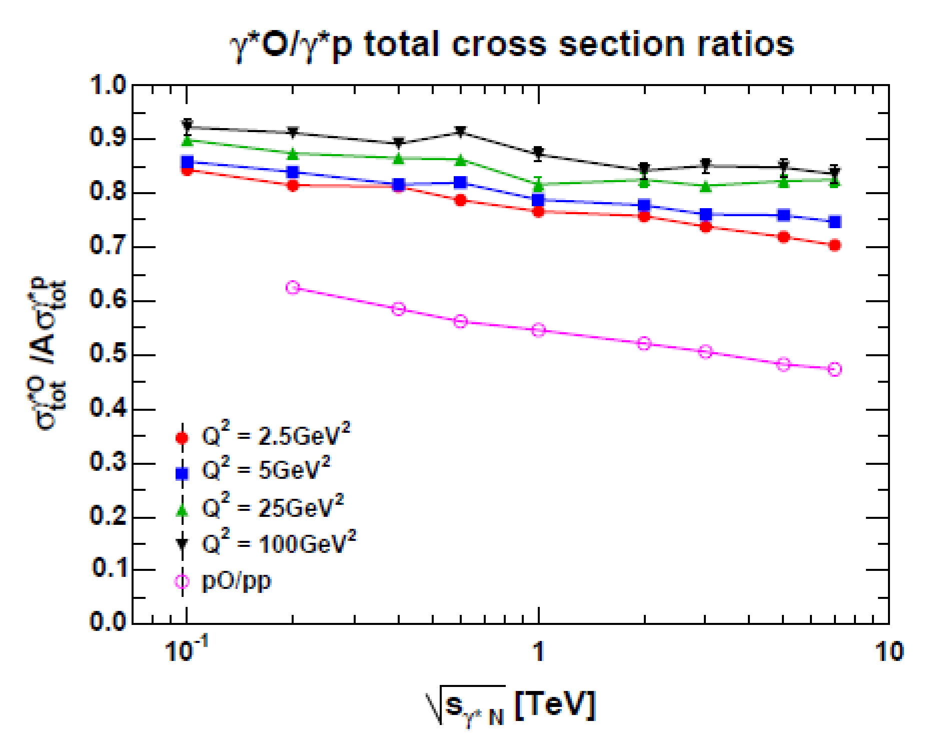


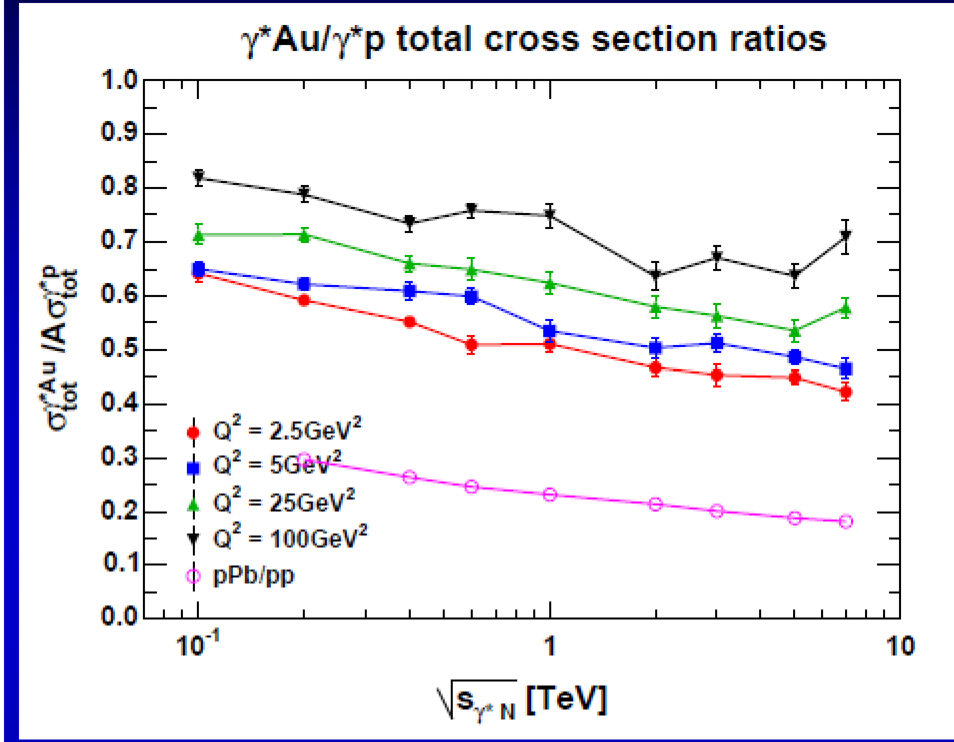


γ^*p
DIPSY predictions

γ^*A
DIPSY predictions

DIPSY predictions for eA collisions

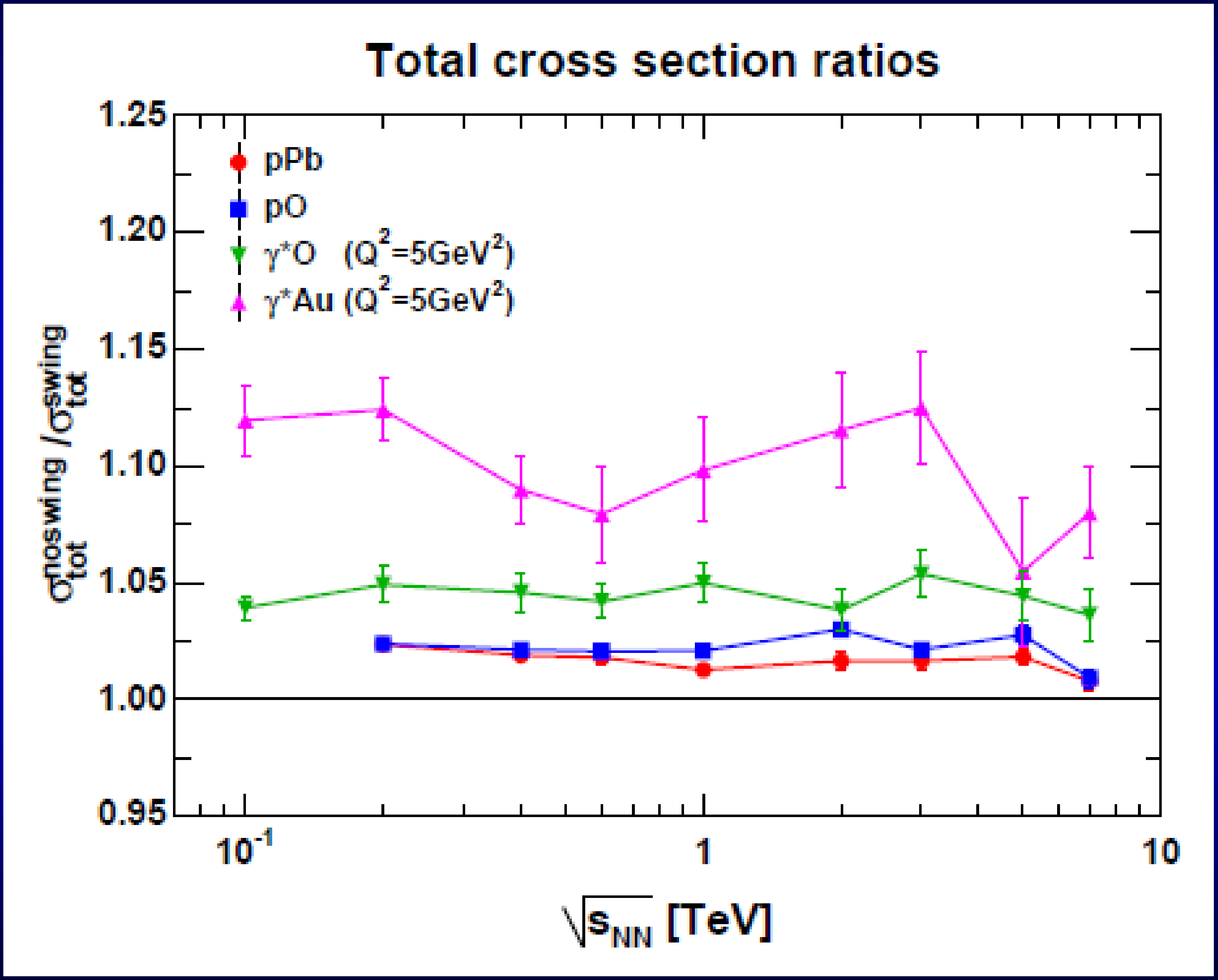




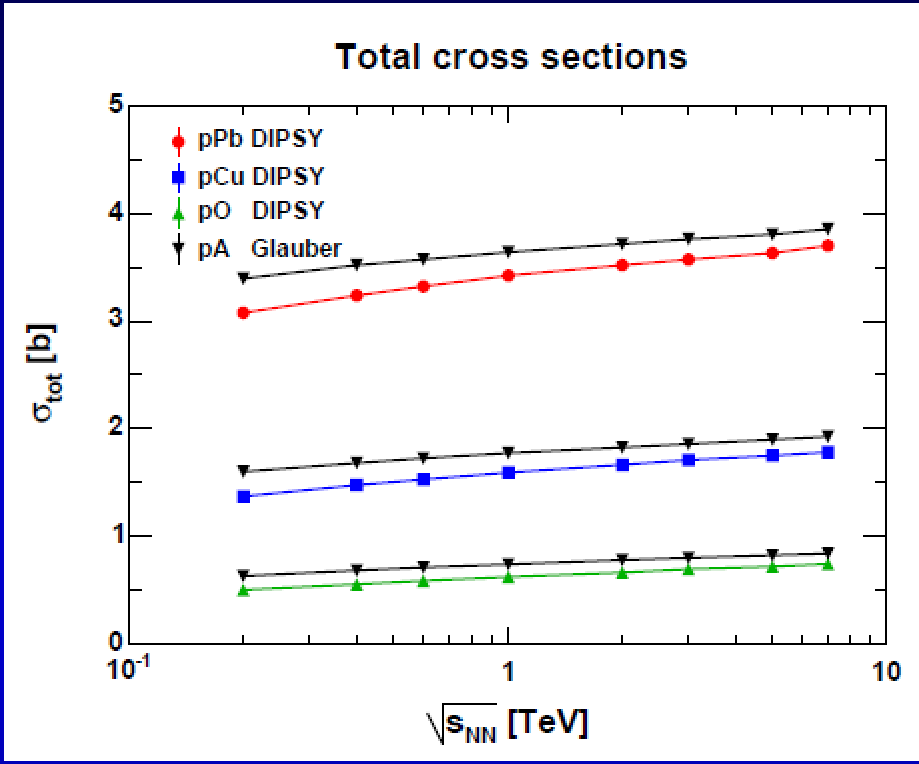
eO sigma(tot) approximately scales with A (fluctuations, swing)

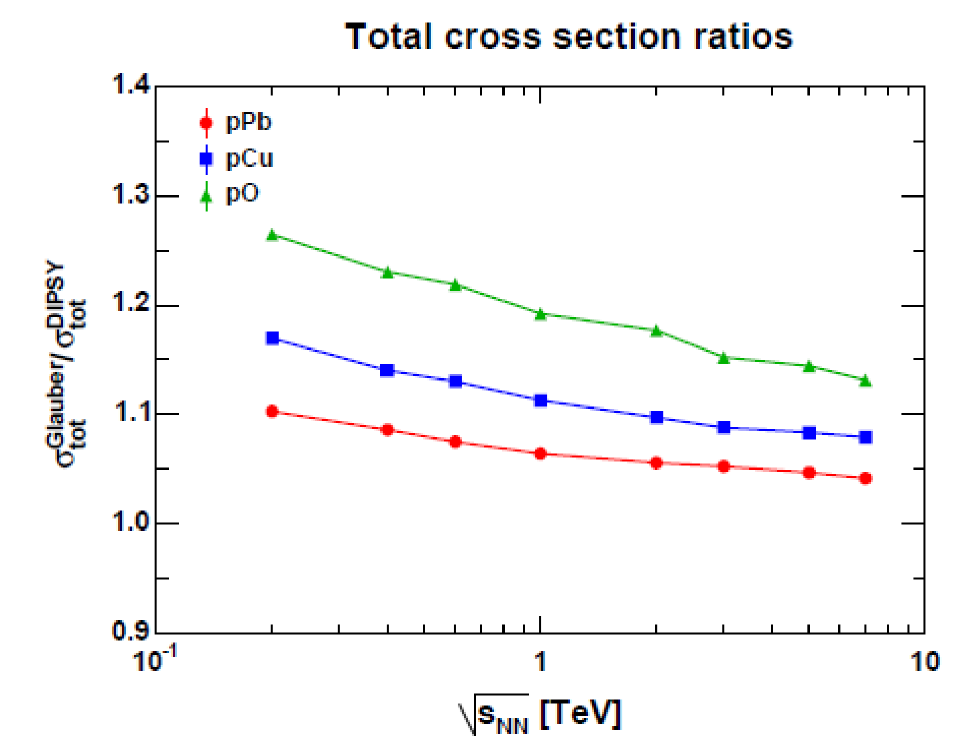
eAu sigma(tot) reduced as compared to eO: fluctuations, swing important

Swing effects in DIPSY



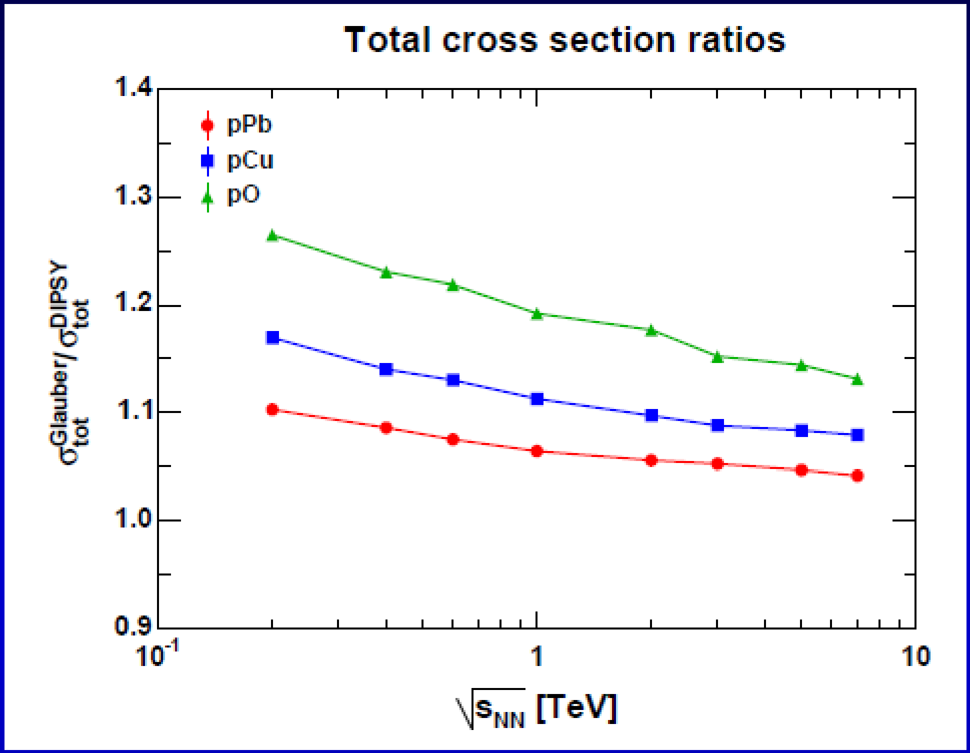
DIPSY predictions vs Glauber MC

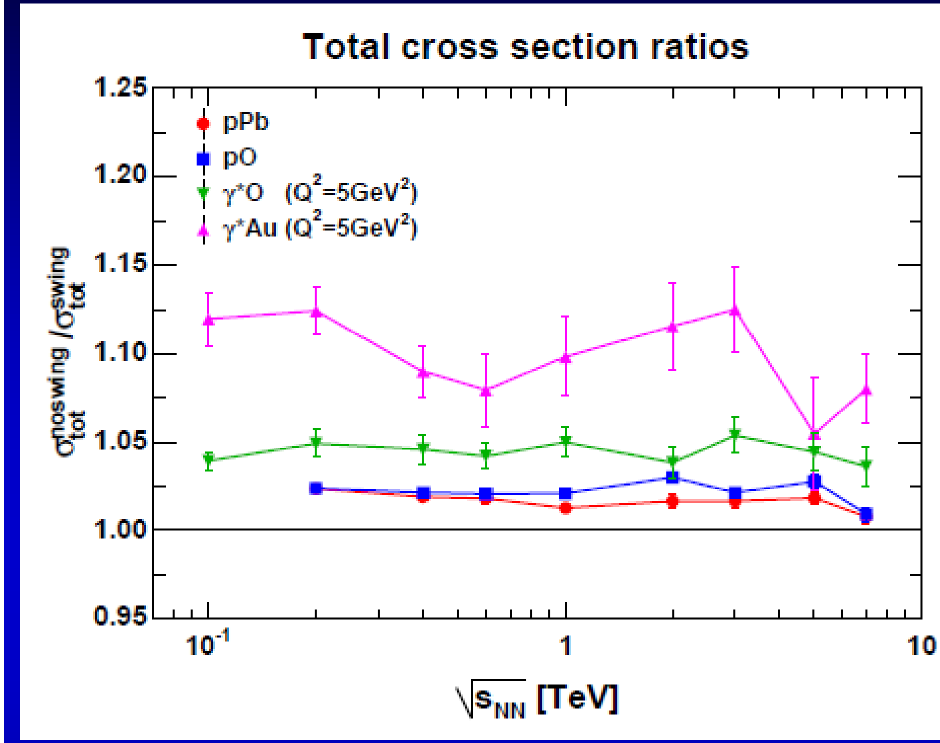




DIPSY with dipole fluctuations and swing effects reduce pA cross sections by cca 5 – 15 %. Effect bigger for smaller A.

What have we learned?





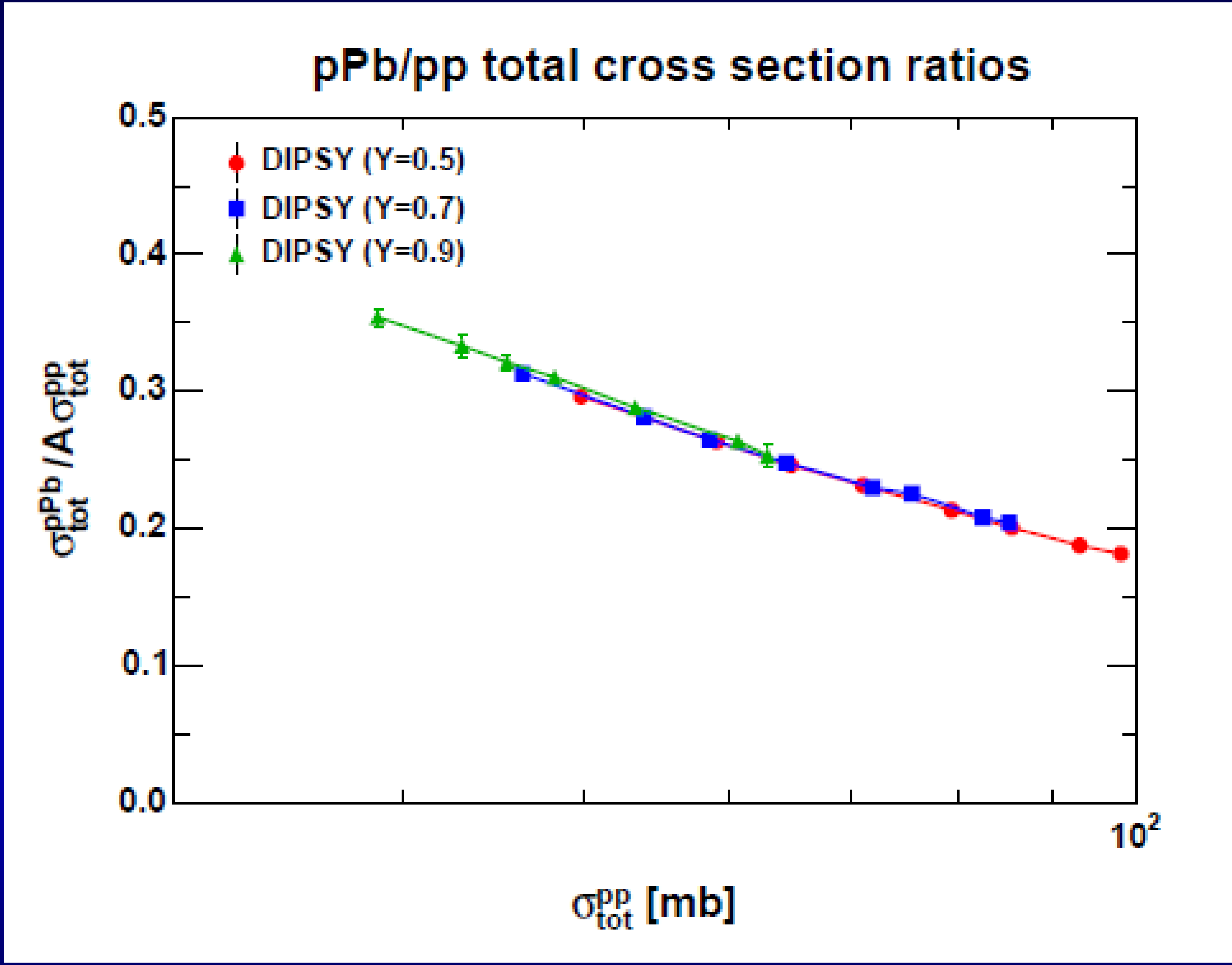
pA cross sections reduce by 10% due to dipole fluctuations + swing

Effect is larger in eA than in pA, decreases with increasing dipole size

DIPSY Monte Carlo is available from Lund for future eA collider simulations

Backup slides – Questions?

Frame dependence?



DIPSY pp cross sections need to be tuned in each frame, after this step the cross section ratios are frame independent.