Phenomenological approach to elastic scattering

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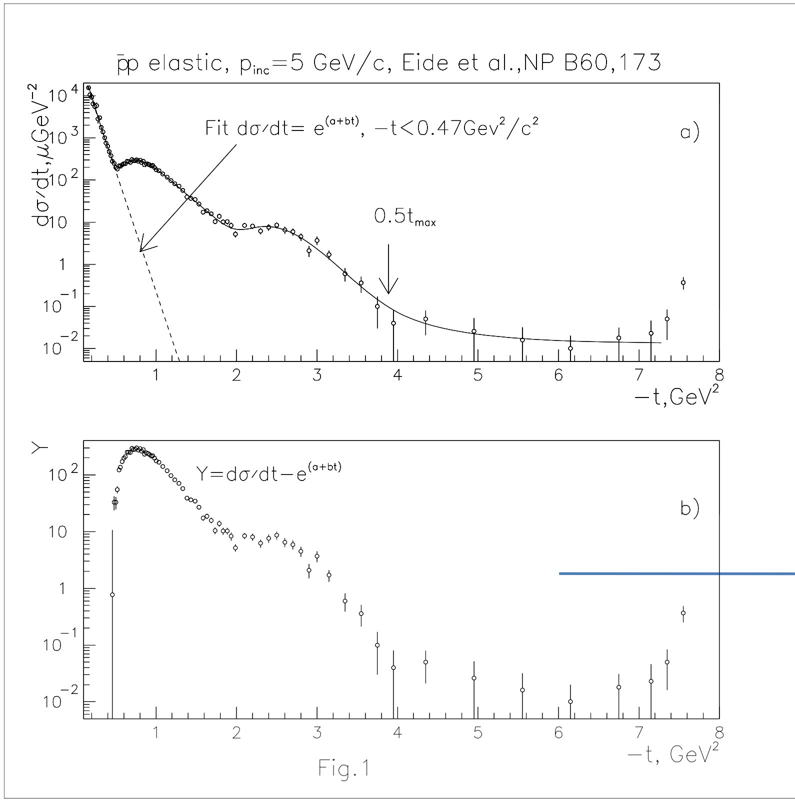
It is well know that the experimental data of $\bar{p}p$ elastic scattering at low energies show significant structure $\frac{d\sigma}{dt}$ as the function of the momentum transfer squared *t*.

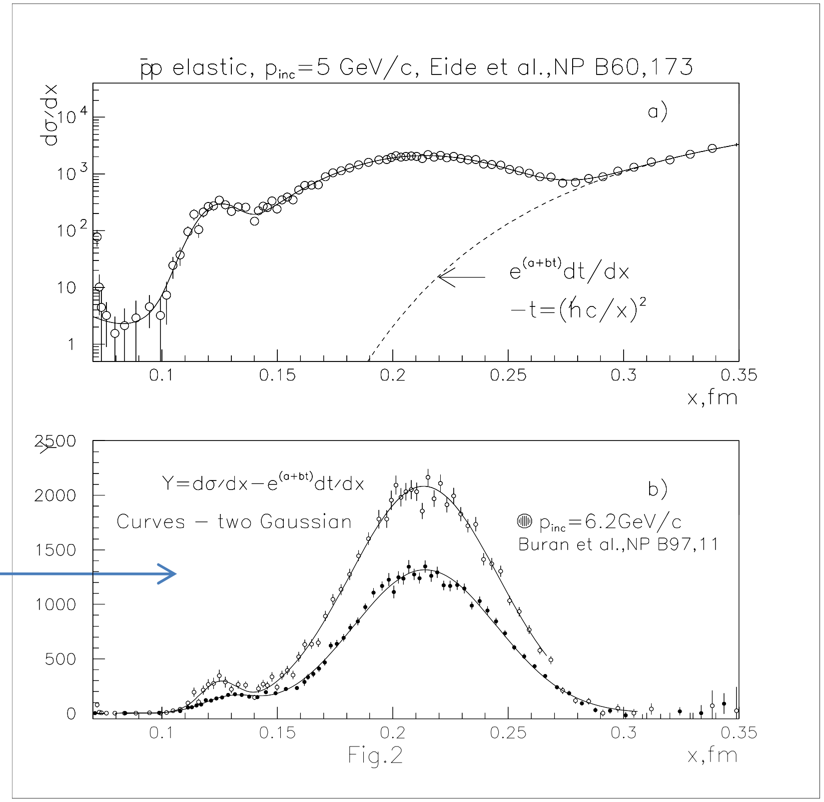
If we want to connect this structure in momentum variables with the space structure of nucleons it will be more natural to investigate elastic scattering in terms of spatial variables. Since we cannot measure small distances let us Introduce a quantity $x = \frac{\hbar c}{\sqrt{-t}}$ which has a space dimension of Fermi and corresponds to some mean size of the interaction region along the vector $\Delta\vec{p} = \vec{p}_{beam} - \vec{p}_{scet}$.

From the measured $\frac{d\sigma}{dt}$ one can define:

$$\frac{d\sigma}{dx} = \frac{d\sigma}{dt}\frac{dt}{dx} = \frac{d\sigma}{dt}\frac{2(\hbar c)^2}{x^3}$$

The advantage of the data presentation in terms of $\frac{d\sigma}{dx}$ versus x can be seen from the following pictures:





On Fig.2-b we can see a surprising transformation of the complicated distribution on Fig.1-b in the momentum variables to the very simple two Gaussian distribution in the spatial variables.

That is the main point of my talk

Now we can assume that the differential cross-section of the elastic $\bar{p}p$ scattering can be expressed in the spatial variables by the very simple form(for x less then 1.0*fm*, to be far from the electromagnetic effects):

$$\frac{d\sigma}{dx} = (e^{(a+bt)} + c)\frac{2(\hbar c)^2}{x^3} + w_1 G_1 + w_2 G_2 \qquad (1)$$

$$\frac{dt}{dx}$$

Here $G_i = \frac{1}{\sqrt{2\pi}\sigma_i} e^{-\frac{(x-x_i)^2}{2\sigma_i^2}}$

Or in the momentum variables:

$$\frac{dx}{dt}$$

$$\frac{d\sigma}{dt} = e^{(a+bt)} + c + (w_1 G_1 + w_2 G_2)\frac{\hbar c}{2\sqrt{-t^3}} \qquad (2)$$

The solid lines on Fig.1 and Fig.2 are the results of the fit by (2) and (1) respectively. The fit quality by (1) can be seen from the next picture.

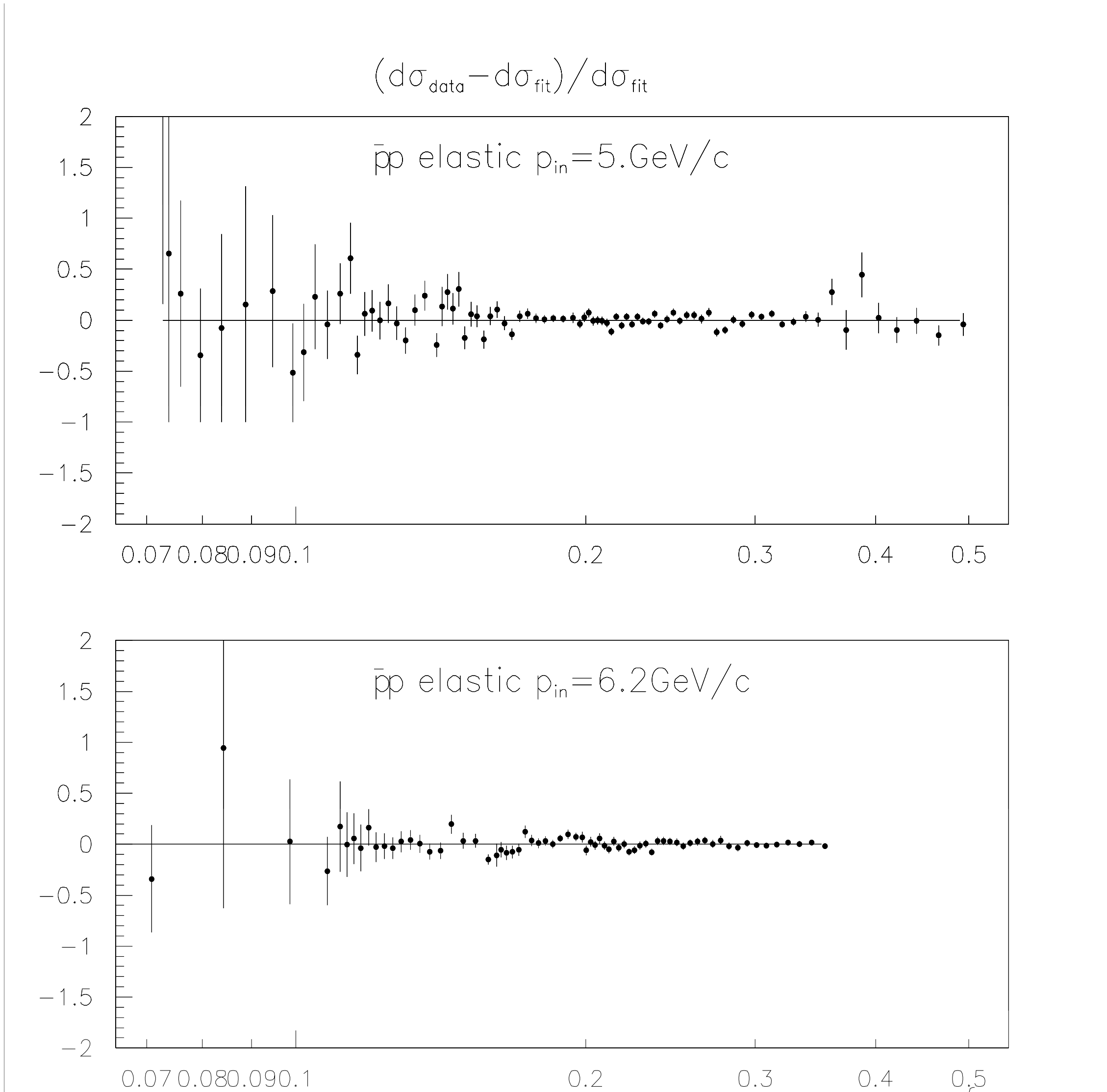
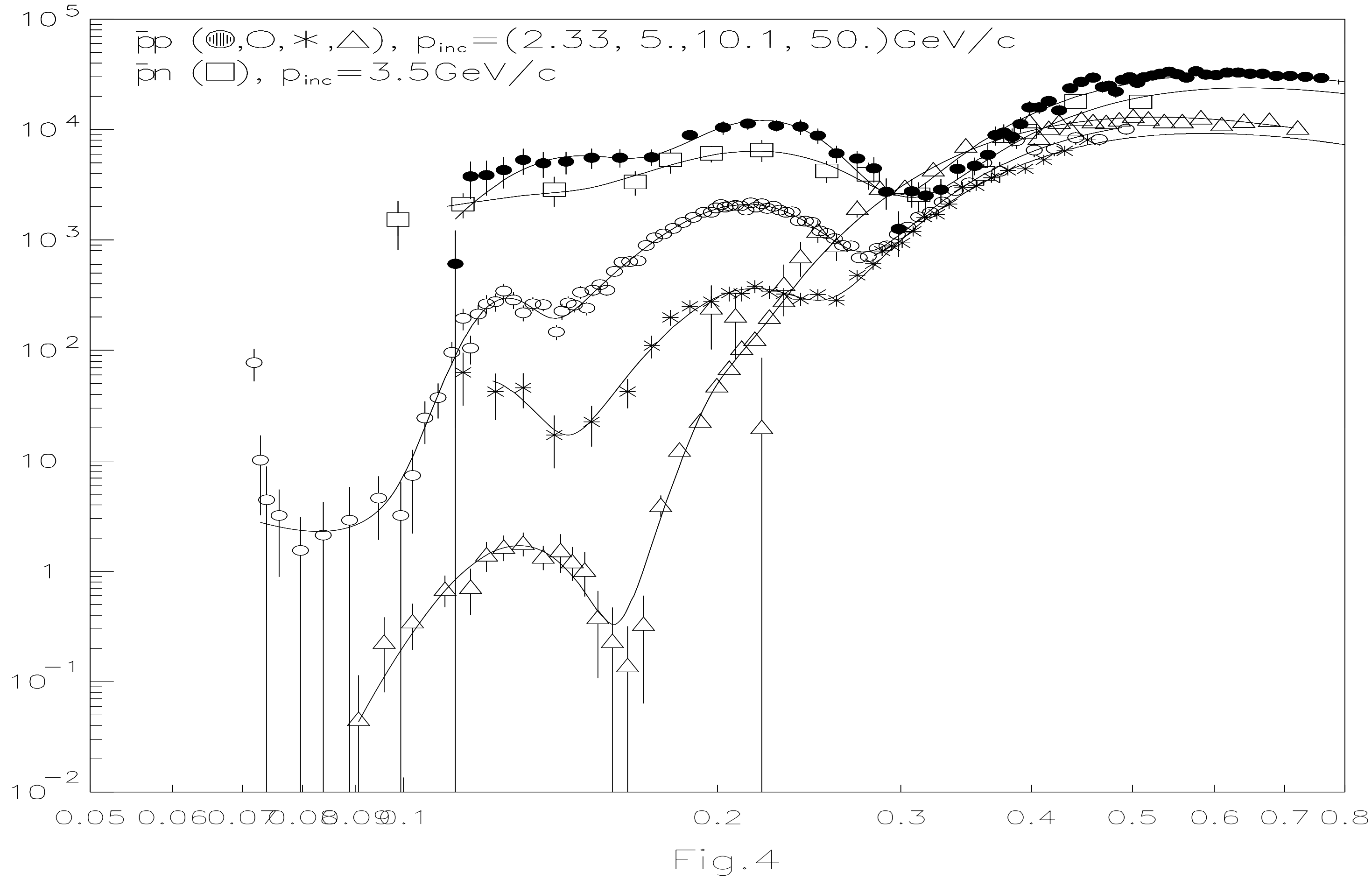


Fig.3

Differences between measured and fitted values of differential cross-sections normalized to the fitted ones.



$\bar{p}p$ and $\bar{p}n$ elastic at different energies. Solid lines – the results of the fits by (1). The significance of the first structure (x=0.21*fm*) decreases with energy while the second one (x=0.13*fm*) - increases.

Some speculations (not important)

The behaviour of the considered differential cross-sections can be qualitatively understood in the frame of constituent models of nucleons. The scenario may be as follows: at large x the scattering occurs on a nucleon as a whole, then at the *x* about 0.21 *fm* probably the valence quarks, as the constituents of the nucleons, are responsible for the interactions and at x about 0.13 *fm* more deep constituents, may be diquarks, start to contribute to the process. (For details of quark-diquark models of elastic scattering see for example A.Bialas and A.Bzdak, Act.Phys., B38, 159 and quoted ref.)

When the energy increases the number of sea quarks increases too, they screen the valence quarks and as a result the significance of the first structure decreases. The second structure becomes more evident probably because there are no corresponding objects to screen the effect (not to much sea diquarks, otherwise the yield of baryons would be large).

If the observed structure is really connected to the space structure of a nucleon then it should be seen in *pp* elastic also, may be not so evident at low energies where the cross-section of *pp* is notably less then $\bar{p}p$ cross-section.

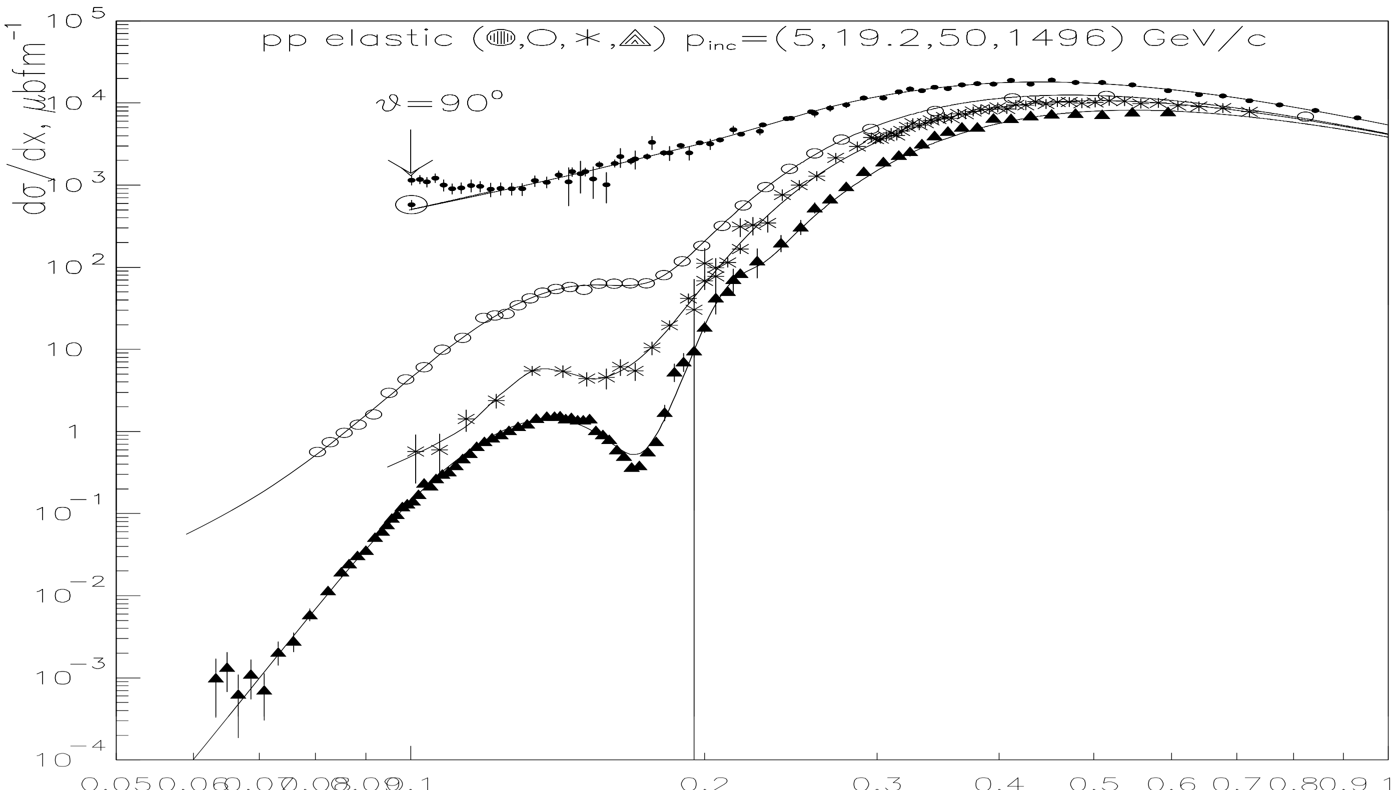
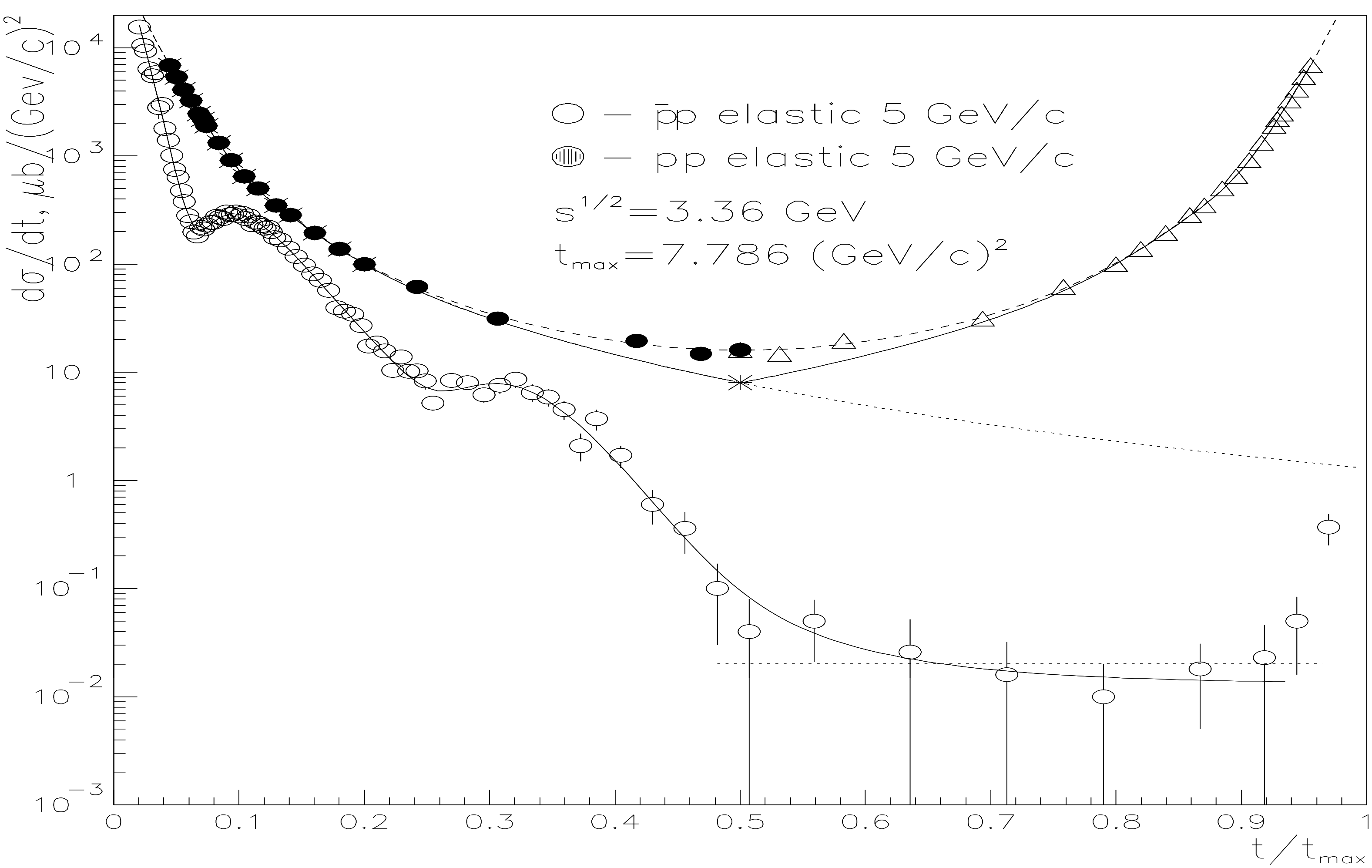
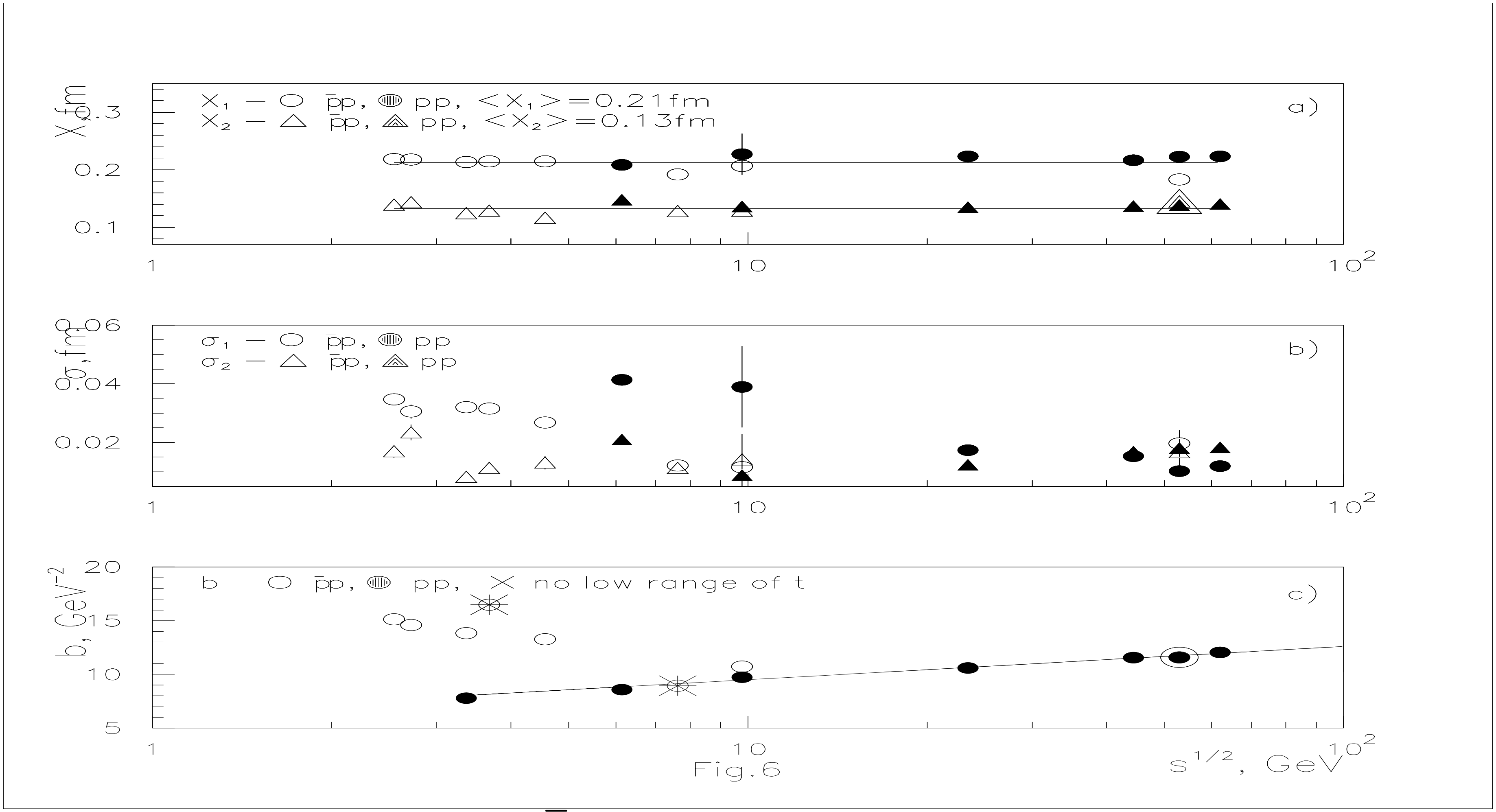


Fig.5

The solid lines – fits by (1). The structure at *x*=0.21*fm* although not seen by eye is still needed to have a reasonable fit. The rise of the cross-section of 5.0GeV/c at x less then 0.15 *fm* - because in this region one measures both the scatter-incident and the target one.



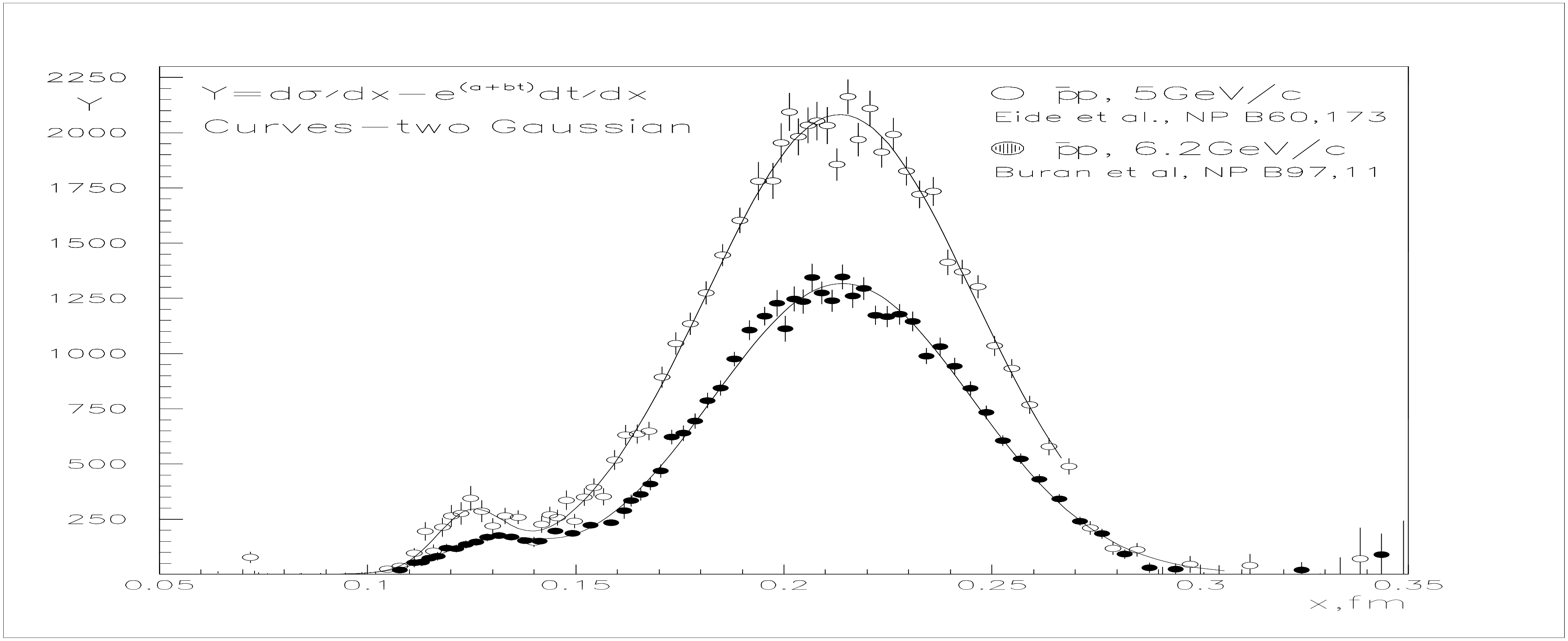
○ – p̄p elastic 5 GeV/c
◍ – pp elastic 5 GeV/c
$s^{1/2}$=3.36 GeV
t_{max}=7.786 $(GeV/c)^2$
dσ/dt, μb/(GeV/c)^2
t/t_{max}



Fitted parameters for $\bar{p}p$ and pp events at different energies.

1. The central positions of the maxima are more or less stable.
2. The slope parameters *b* show the know behaviour.
3. The fitted widths of Gaussians are not stable. In any case they do not equal to the true widths of the constituents exactly because relation $x = \frac{\hbar c}{\sqrt{-t}}$ corresponds to the true value of the space distance in average only.

Вместо заключения



Вернёмся к Рис.2-b. Означает ли он, что наблюдается пространственная структура нуклонов? Ответ может быть и ДА и НЕТ. Мне же кажется, что ответ должен быть ВОЗМОЖНО, но необходим новый целенаправленный эксперимент с большей статистикой в широком диапозоне *t* и с одинаковой систематикой при разных энергиях. И не только измерение упругого рассеяния, но и квази-упругого как например $\bar{p}p \to \bar{p}N^*$.

The buy product такого эксперимента будет обнаружение резонансов в $\bar{p}p$ системе(если есть таковые) с минимальным фоном при измерении рассеяния антипротонов назад при разных энергиях.