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Analysis of diffractive pion-proton scattering data

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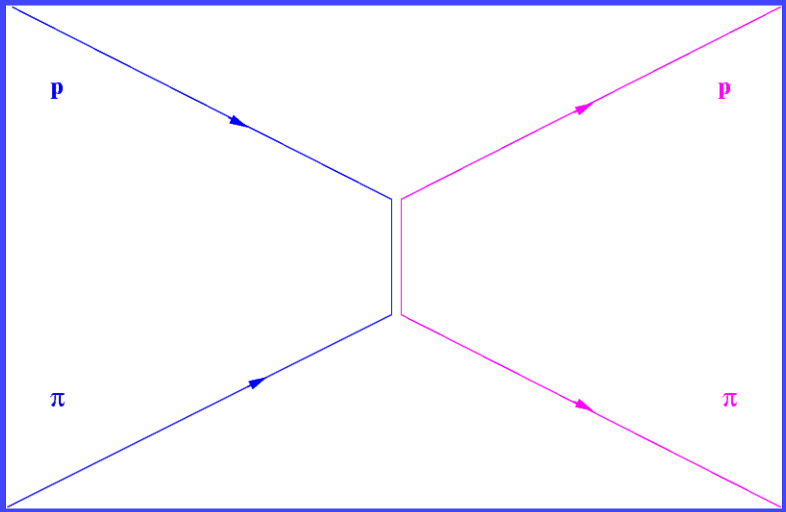
Elastic scattering in p-π collision

Elastic scattering: $|i\rangle = |f\rangle$ and the momentum is conserved. In the case of proton-π scattering



From unitarity the elastic amplitude[1]

$$t_{el}\left(b\right) = 1 - \sqrt{1 - \sigma\left(b\right)}\ ,$$

$\sigma\left(b\right)$ is the **inelastic** cross section. Momentum representation

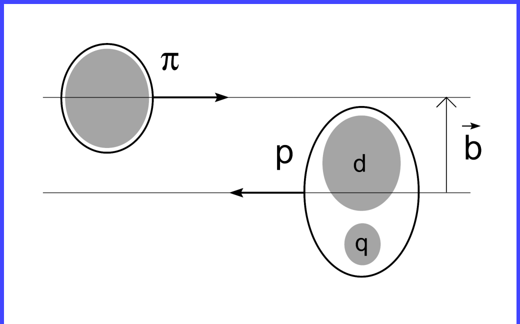
$$T\left(\Delta\right) = \int t_{el}\left(b\right) e^{i\vec{\Delta}\vec{b}} d^2 b$$

Elastic differential cross section[2]

$$\frac{d\sigma}{dt} = \frac{1}{4\pi}\left|T\left(\Delta\right)\right|^2$$

[1] A. Bzdak *The diquark and elastic pion-proton scattering at high energies.* arXiv:hep-ph/0701028v1; 2007
[2] M. M. Block *Hadronic forward scattering: Predictions for the Large Hadron Collider and cosmic rays.* arXiv:hep-ph/0606215v2; 2006

The results of A. Bzdak when the π is a single entity



According to the factorization theorem

$$\sigma(b) = \int d^2 s_q d^2 s_d D_p(s_q, s_d)\, \sigma(s_q, s_d; b)$$

and using the Glauber expansion[3]

$$1 - \sigma(s_q, s_d; b) = [1 - \sigma_{q\pi}(b - s_q)][1 - \sigma_{d\pi}(b - s_d)]$$

A quark-diquark distribution in the proton

$$D_p(s_q, s_d) = \tfrac{1+\lambda^2}{\pi R^2} e^{-\left(s_q^2+s_d^2\right)/R^2} \delta^2(s_d + \lambda s_q)$$

and parametrization of the inelastic cross sections

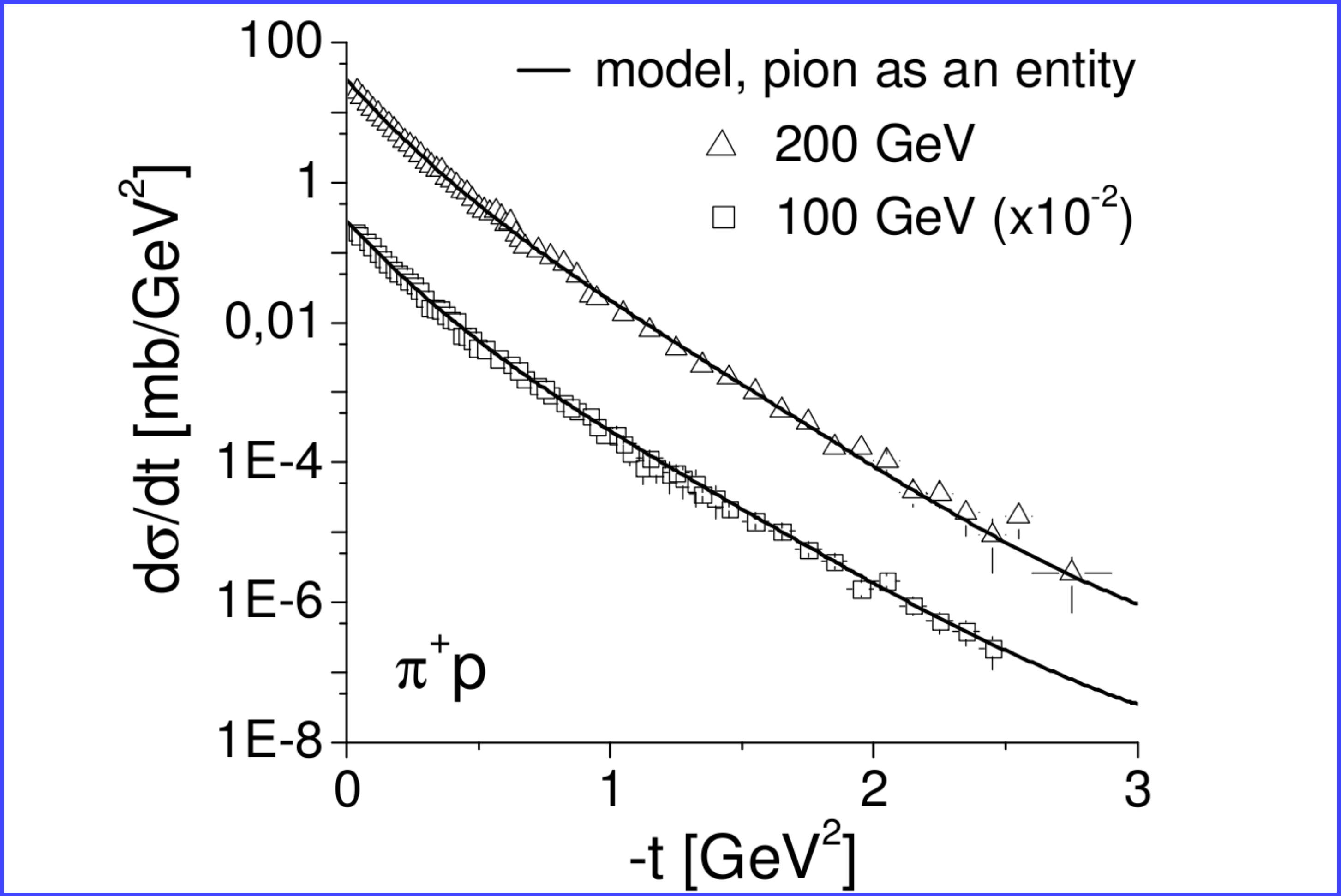
$$\sigma_{ab}(s) = A_{ab} e^{-s^2/R_{ab}^2}, \qquad R_{ab}^2 = R_a^2 + R_b^2$$

After evaluating the Gaussian integrals

$$\sigma(b) = -\frac{xyA_{\mathrm{d}\pi}A_{\mathrm{q}\pi}e^{-\frac{b^2\left(r(\lambda+1)^2+x+y\right)}{rx\lambda^2+ry+xy}}}{rx\lambda^2+ry+xy} + \frac{yA_{\mathrm{d}\pi}e^{-\frac{b^2}{r\lambda^2+y}}}{r\lambda^2+y} + \frac{xA_{\mathrm{q}\pi}e^{-\frac{b^2}{r+x}}}{r+x}$$

[3] Roy J.Glauber, *Quantum optics and Heavy Ion Physics.* arXiv:nucl-th/0604021v1 2006.

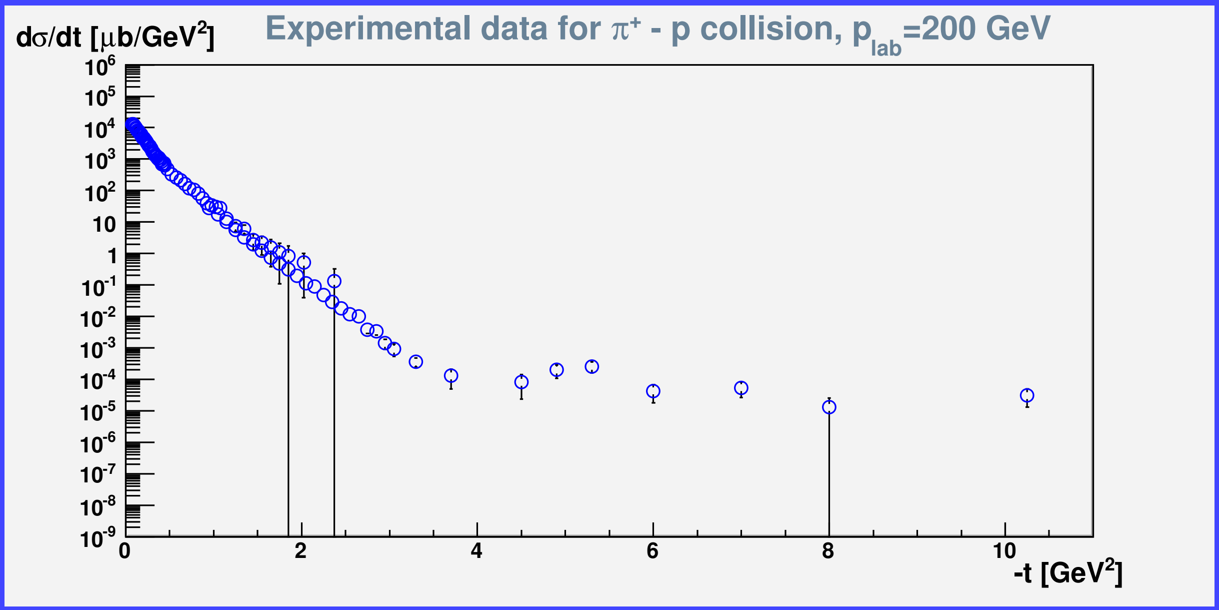
The results of A. Bzdak when the π is a single entity



$p_{lab}[GeV]$	R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$ [fm]
100	0.25	0.79	0.28	0.50	0.80
200	0.25	0.79	0.28	0.52	0.75

Not the full experimental data was used χ^2 **has not been specified !**

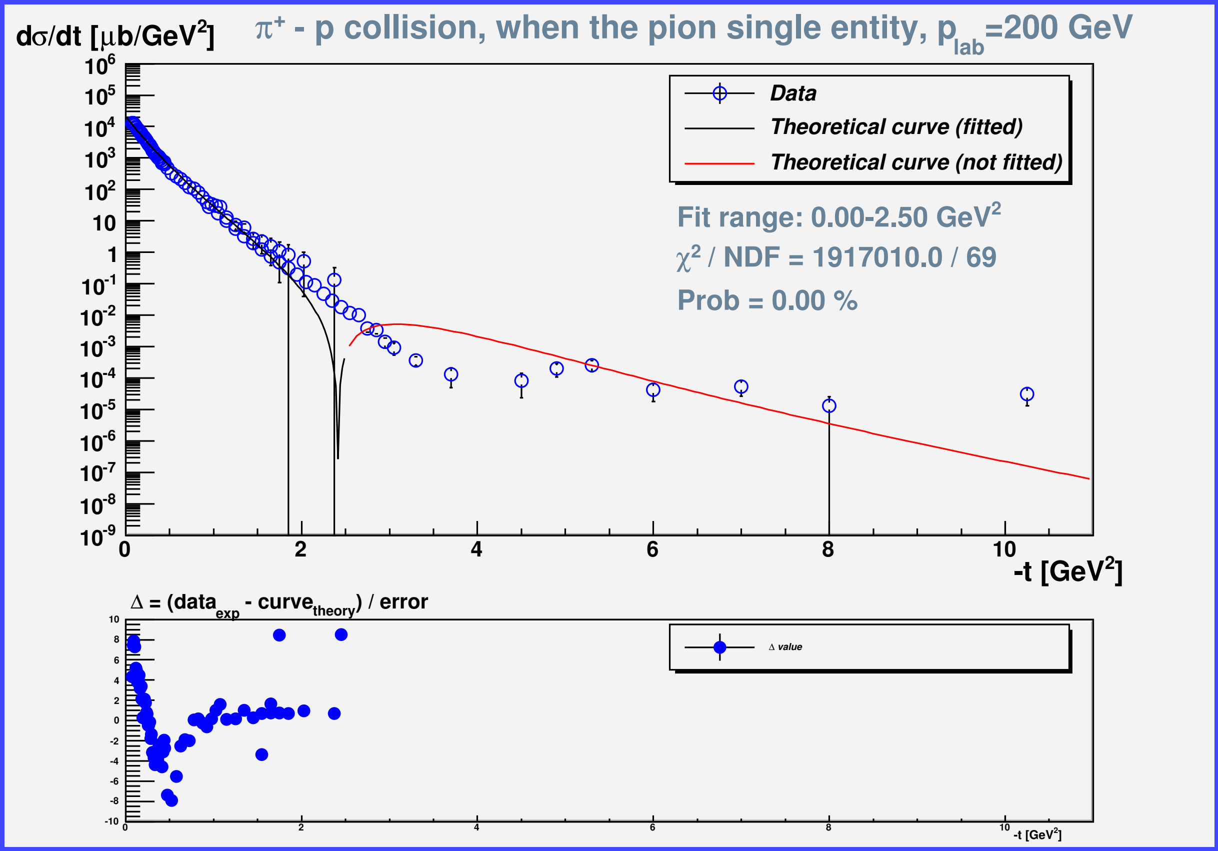
The whole experimental data referenced by A. Bzdak[1]



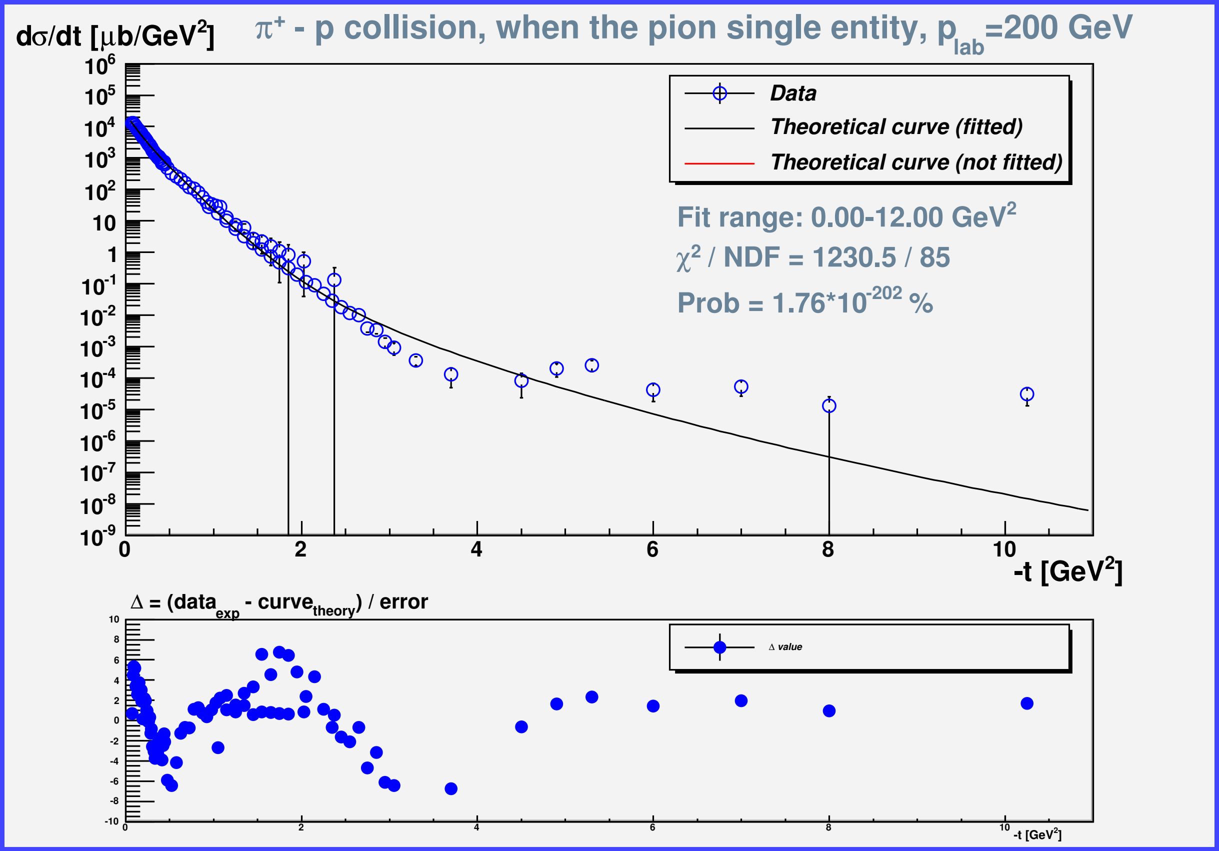
[1] C. W. Akerlof et al., Phys. Rev. D14 (1976) 2864

The results of A. Bzdak on the larger interval

The missing χ^2 value is provided

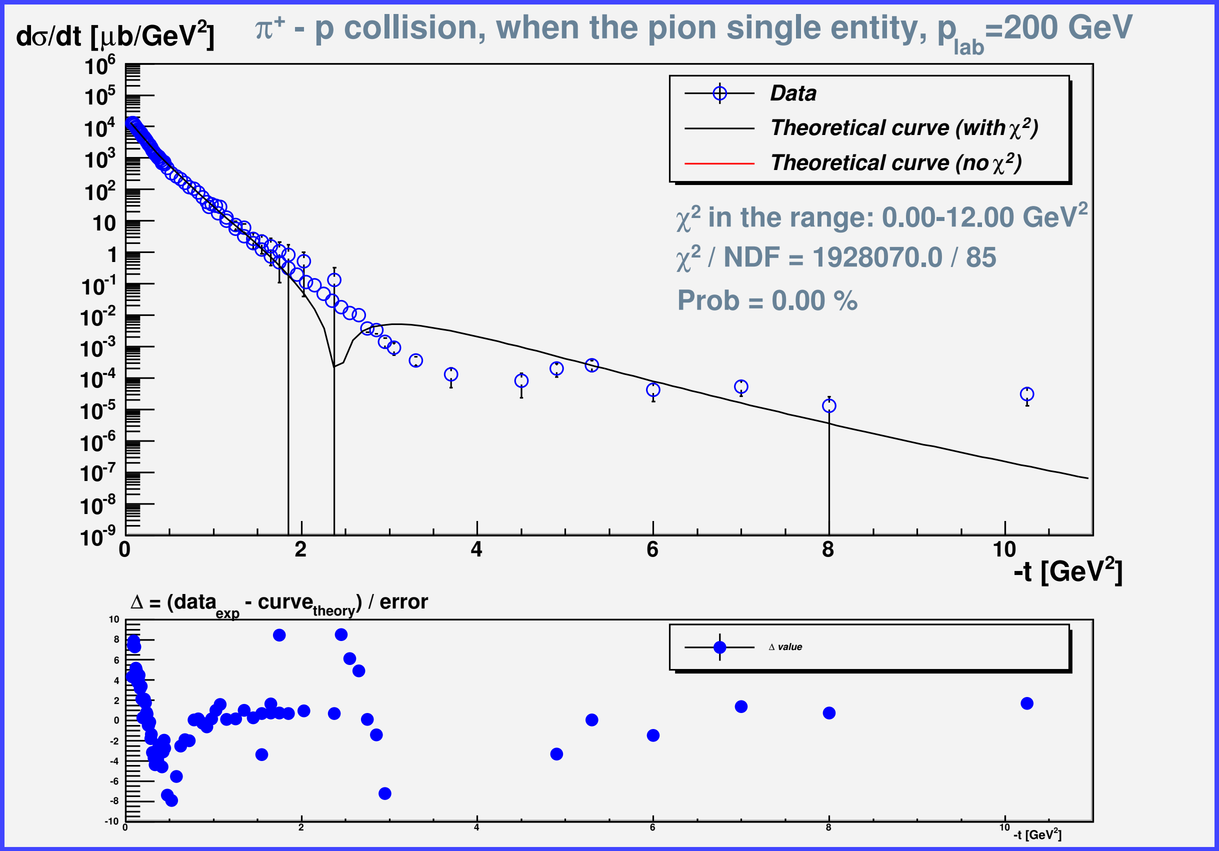


My results when the pion is a single entity 1

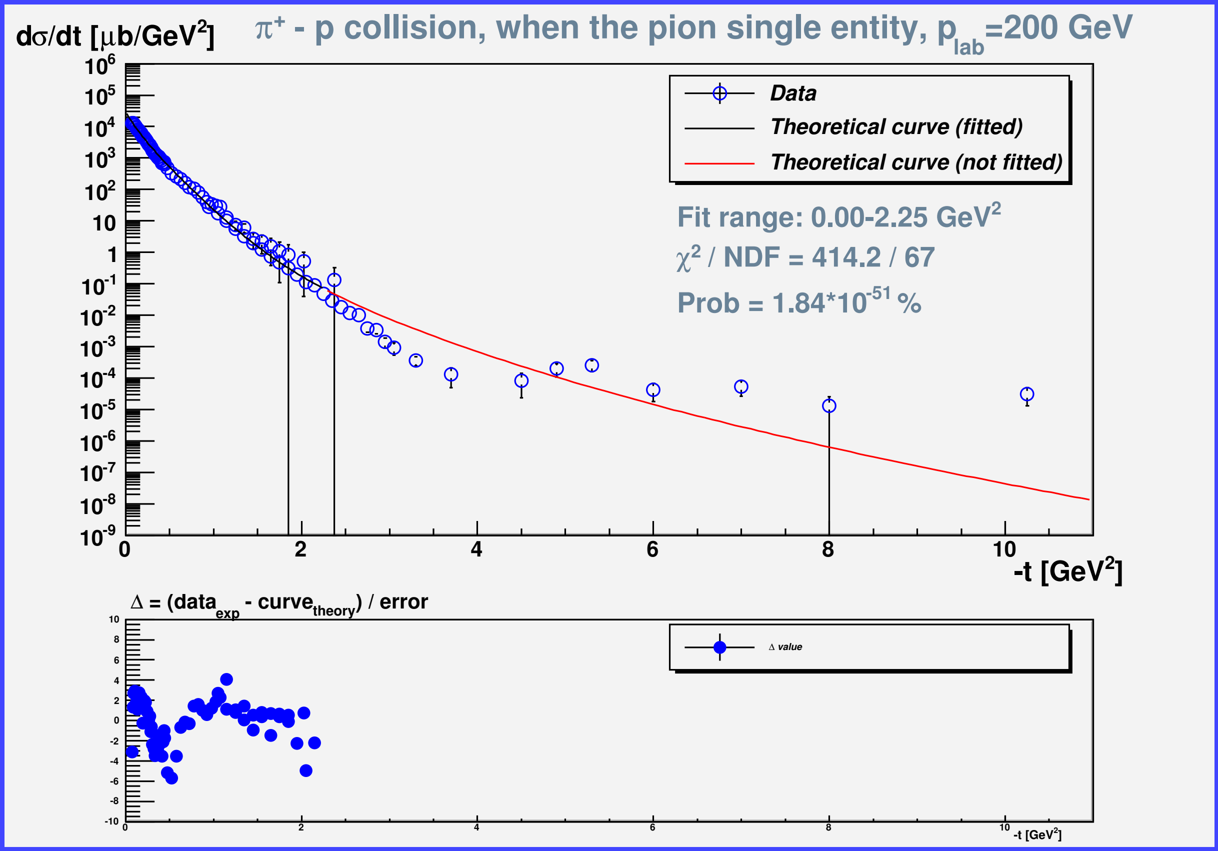


R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$	λ
0.787	0.346	0.673	0.526	0.1264	0.559

Comparison with A. Bzdak on the same range 1

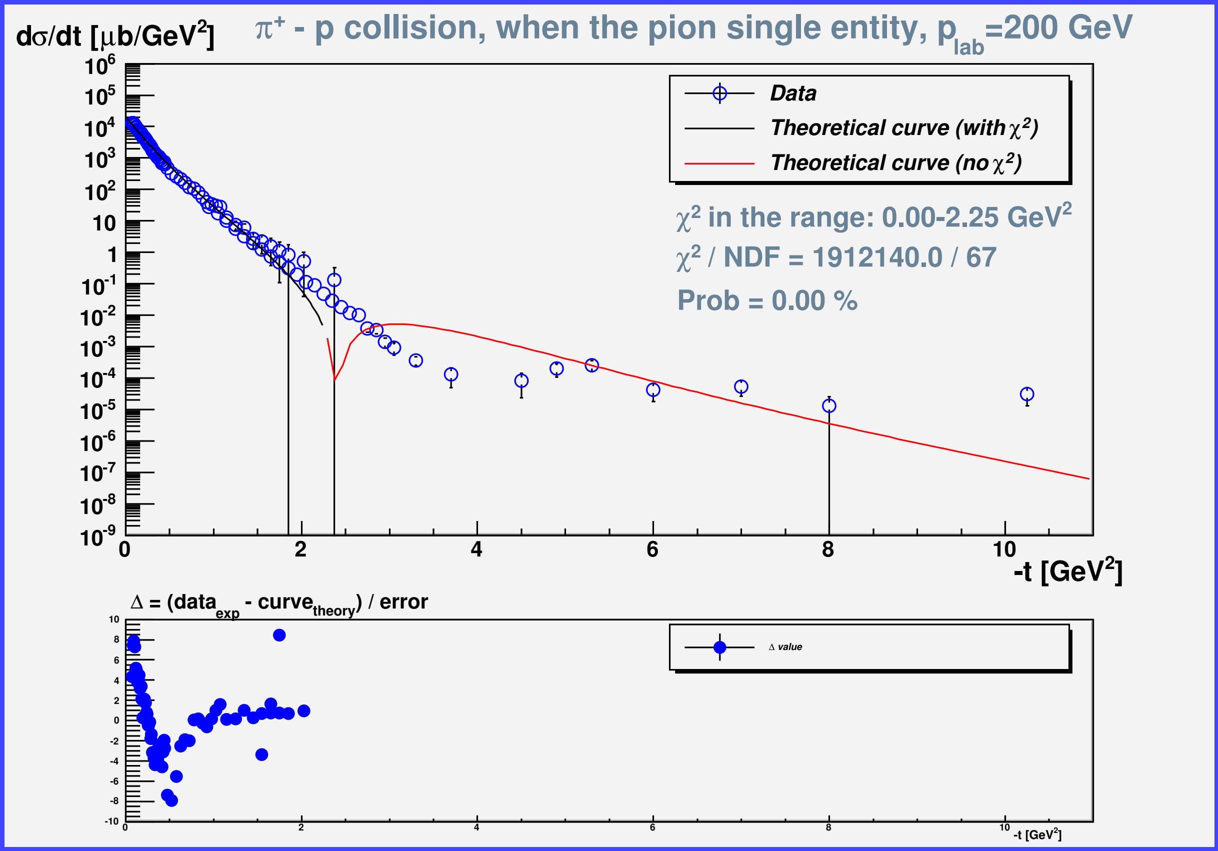


My results when the pion is a single entity 2

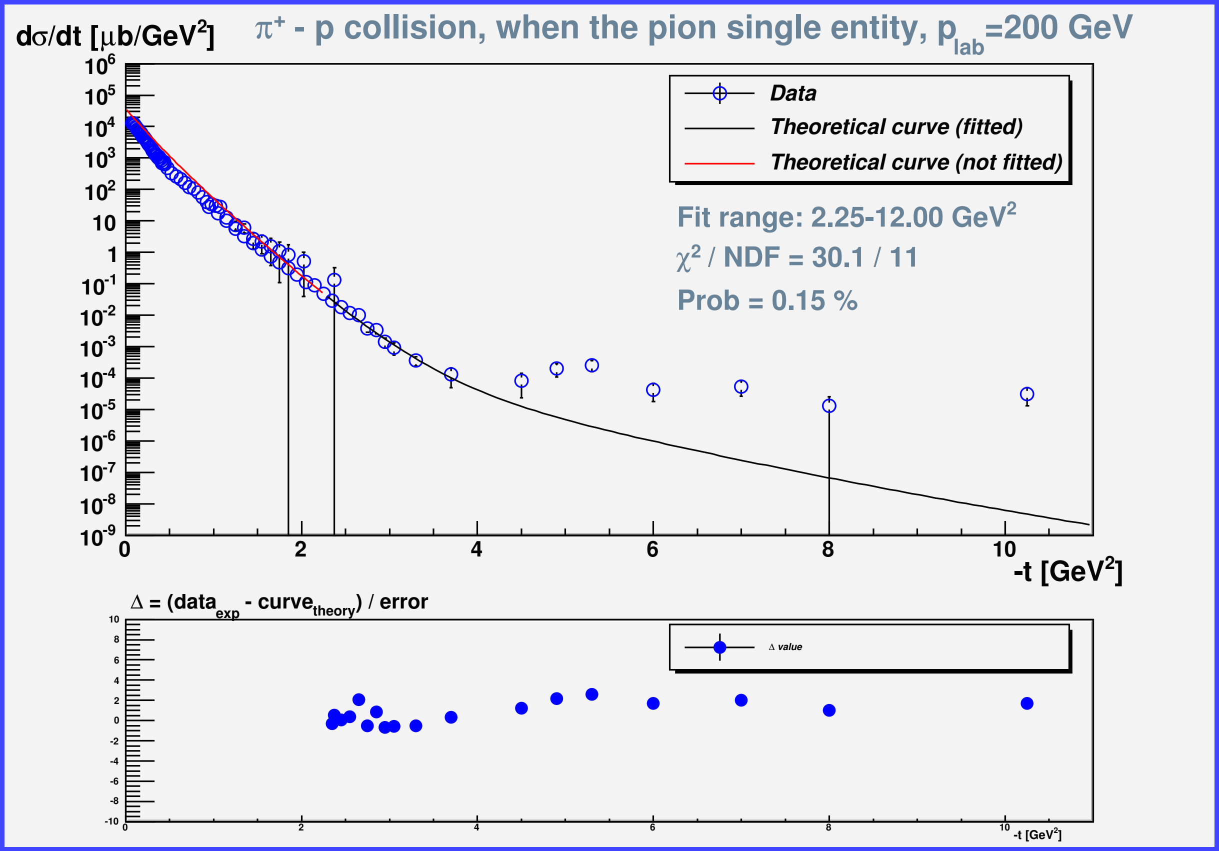


R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$	λ
0.993	0.366	0.411	0.605	0.0909	0.501

Comparison with A. Bzdak on the same range 2

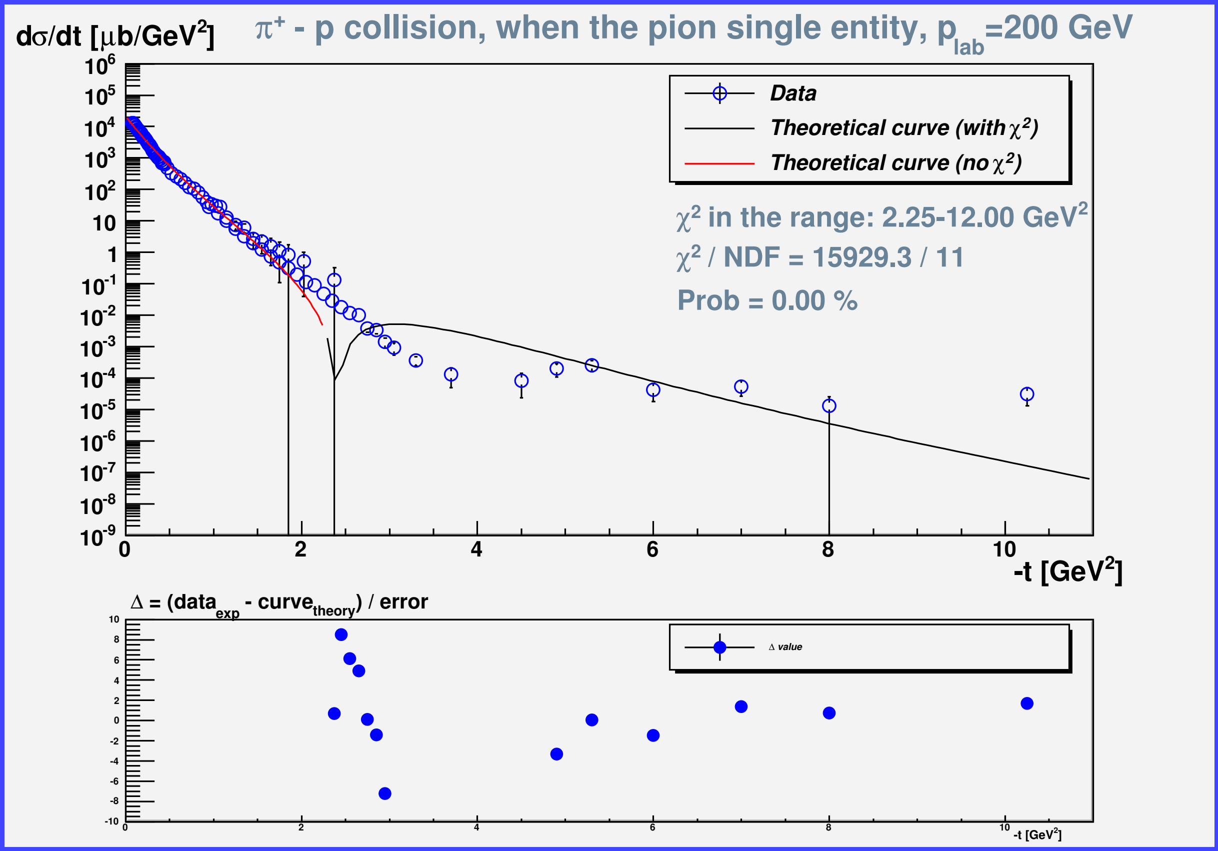


My results when the pion is a single entity 3

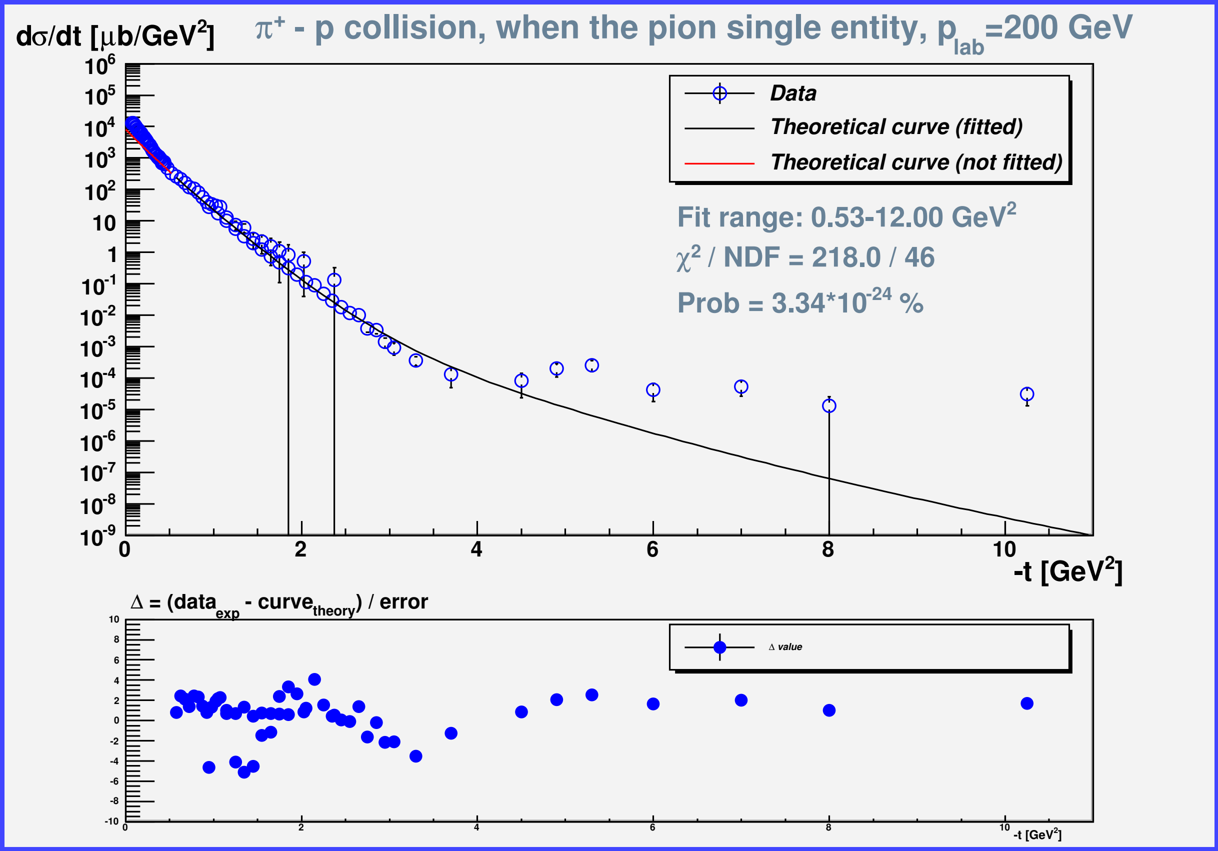


R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$	λ
0.583	0.319	0.581	0.509	0.228	0.713

Comparison with A. Bzdak on the same range 3

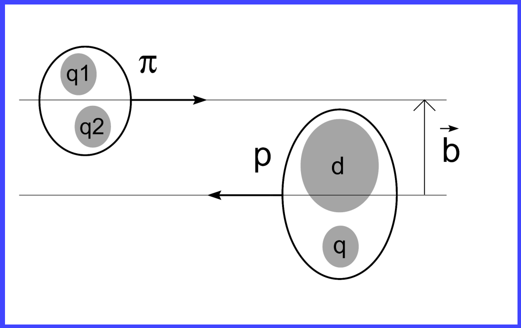


My results when the pion is a single entity 4



R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$	λ
0.561	0.349	0.424	0.502	0.116	0.56

The results of A. Bzdak when the π is a $q\bar{q}$ system



Assume that the pion has a structure

$$\sigma(b) = \int d^2 s_q d^2 s_d d^2_{q1} d^2_{q2} D_p(s_q, s_d) D_\pi(s_{q1}, s_{q2}) \sigma(s_q, s_d; s_{q1}, s_{q2}; b)$$

... with a pion-quark distribution function

$$D_\pi(s_{q1}, s_{q2}) = \frac{1}{\pi d^2} e^{-\left(s_{q1}^2 + s_{q2}^2\right)/2d^2} \delta^2(s_{q1} + s_{q2})$$

$$\begin{aligned} 1 - \sigma(s_q, s_d, s_{q1}, s_{q2}; b) &= [1 - \sigma_{qq}(b + s_{q1} - s_q)][1 - \sigma_{qq}(b + s_{q2} - s_q)][1 - \sigma_{qd}(b + s_{q1} - s_d)] \times \\ &\quad [1 - \sigma_{qd}(b + s_{q2} - s_d)] \end{aligned}$$

The structure of the integral

$$\frac{r_1 r_2}{\pi^2} \int d^2 s d^2 s' e^{-r_1 s^2} e^{-r_2 s'^2} e^{-y_1\left(b+\lambda s-s'\right)^2} e^{-y_2\left(b+\lambda s+s'\right)^2} e^{-x_1\left(b-s-s'\right)^2} e^{-x_1\left(b-s+s'\right)^2} = \frac{r_1 r_2}{\Omega} e^{-\frac{b^2 \Gamma}{\Omega}}$$

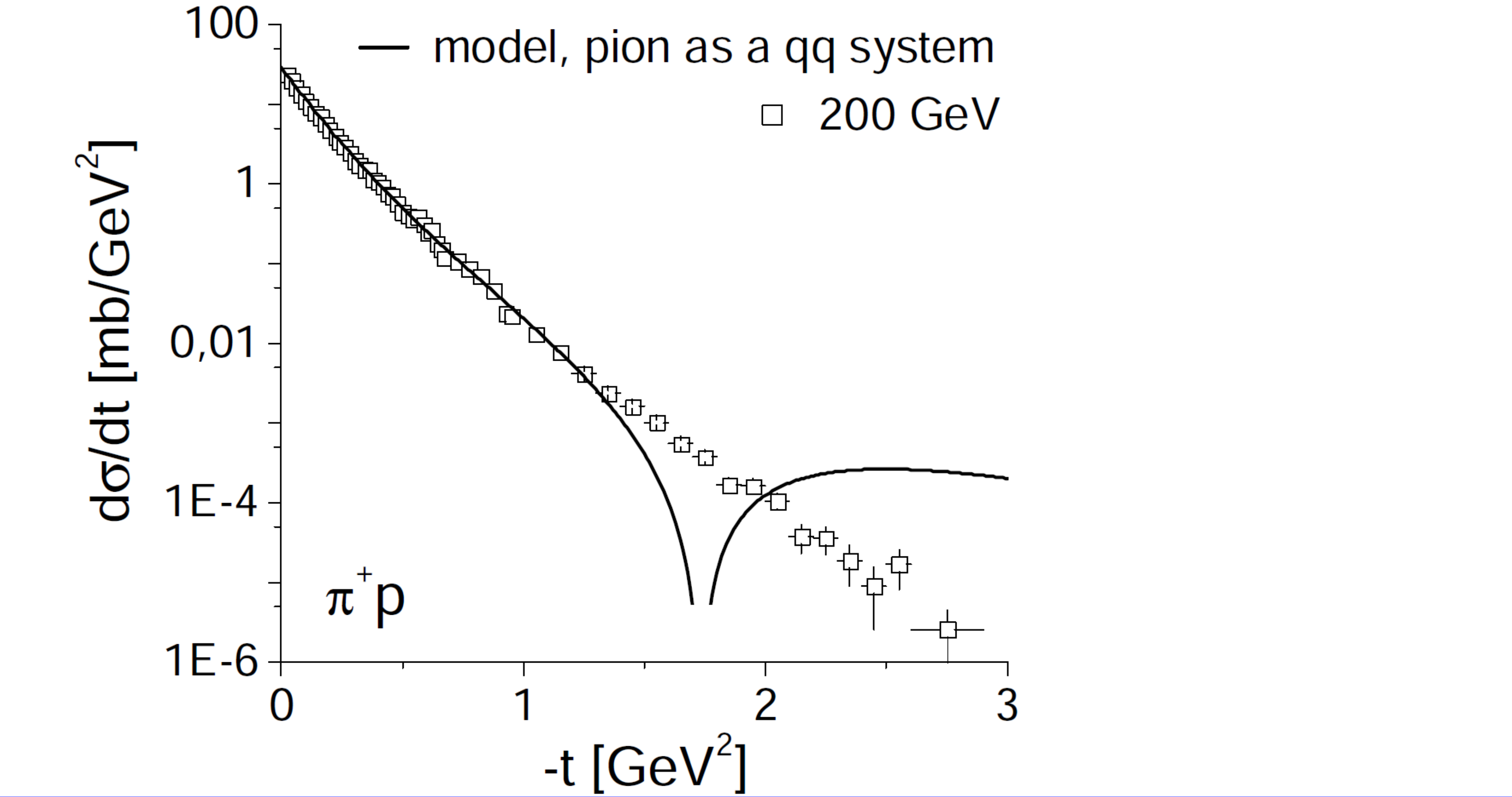
where

$$\Gamma = r_1 r_2 (x_1 + x_2 + y_1 + y_2) + 4 r_1 (x_1 + y_1)(x_2 + y_2) + (\lambda + 1)^2 (r_2 (x_1 + x_2)(y_1 + y_2) + 4 y_1 y_2 (x_1 + x_2) + 4 x_1 x_2 (y_1 + y_2))$$

$$\Omega = r_1 (r_2 + x_1 + x_2 + y_1 + y_2) + r_2 (x_1 + x_2) + \lambda^2 (r_2 (y_1 + y_2) + 4 y_1 y_2) + (1 - \lambda)^2 (x_1 y_2 + x_2 y_1) + (\lambda + 1)^2 (x_1 y_1 + x_2 y_2) + 4 x_1 x_2$$

The results of A. Bzdak when the π is a $q\bar{q}$ system

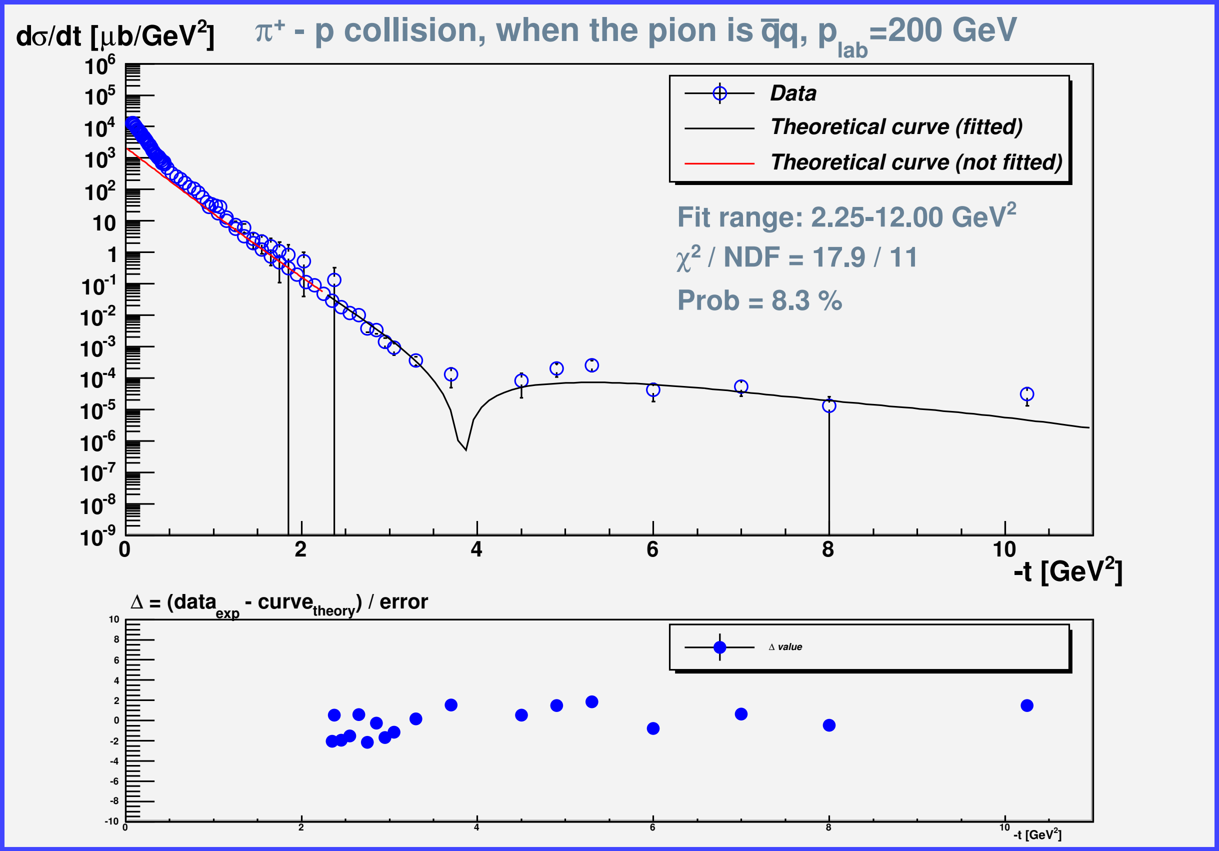
Not the full experimental data and χ^2 has not been specified !



Conclusion of A. Bzdak: the pion can be treated as a single entity !

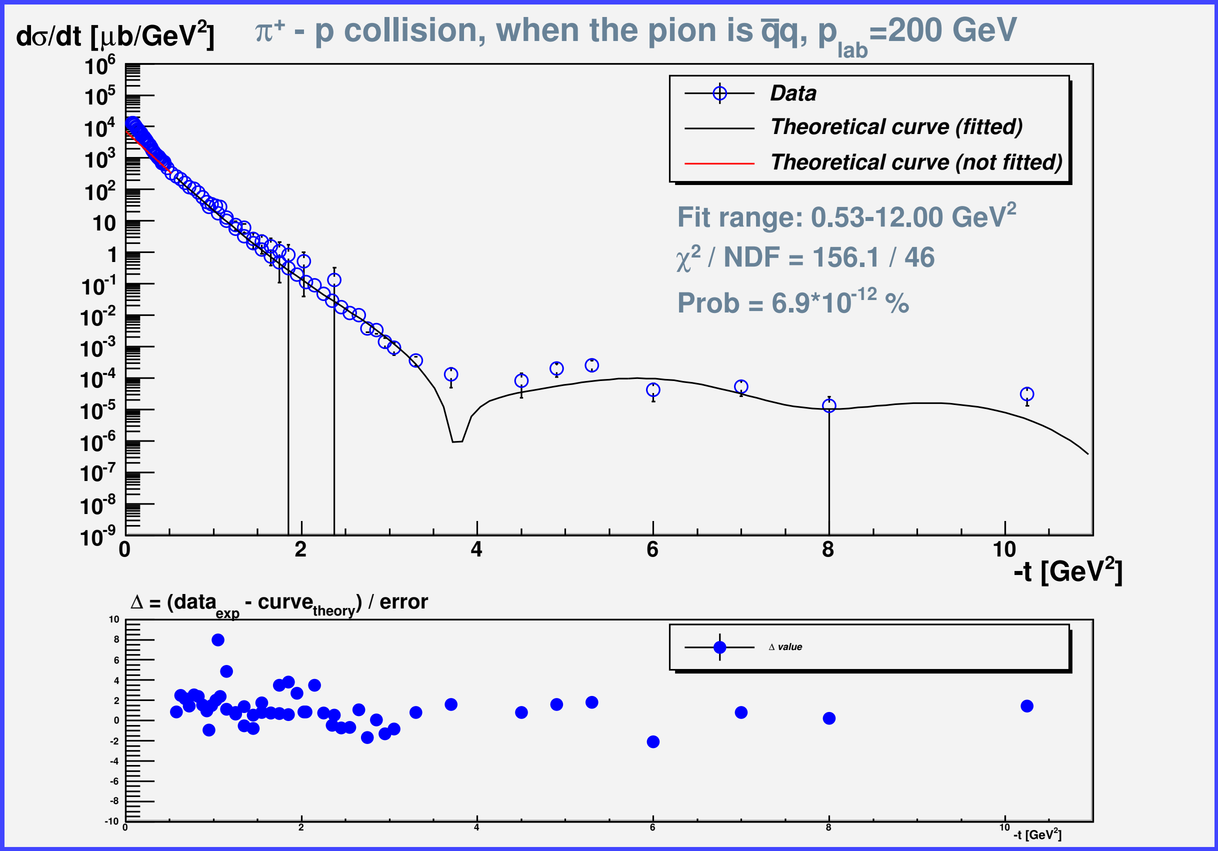
p_{lab} [GeV]	R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$
200	0.26	0.82	0.28	0.44	1

My results when pion is a $q\bar{q}$ system 1



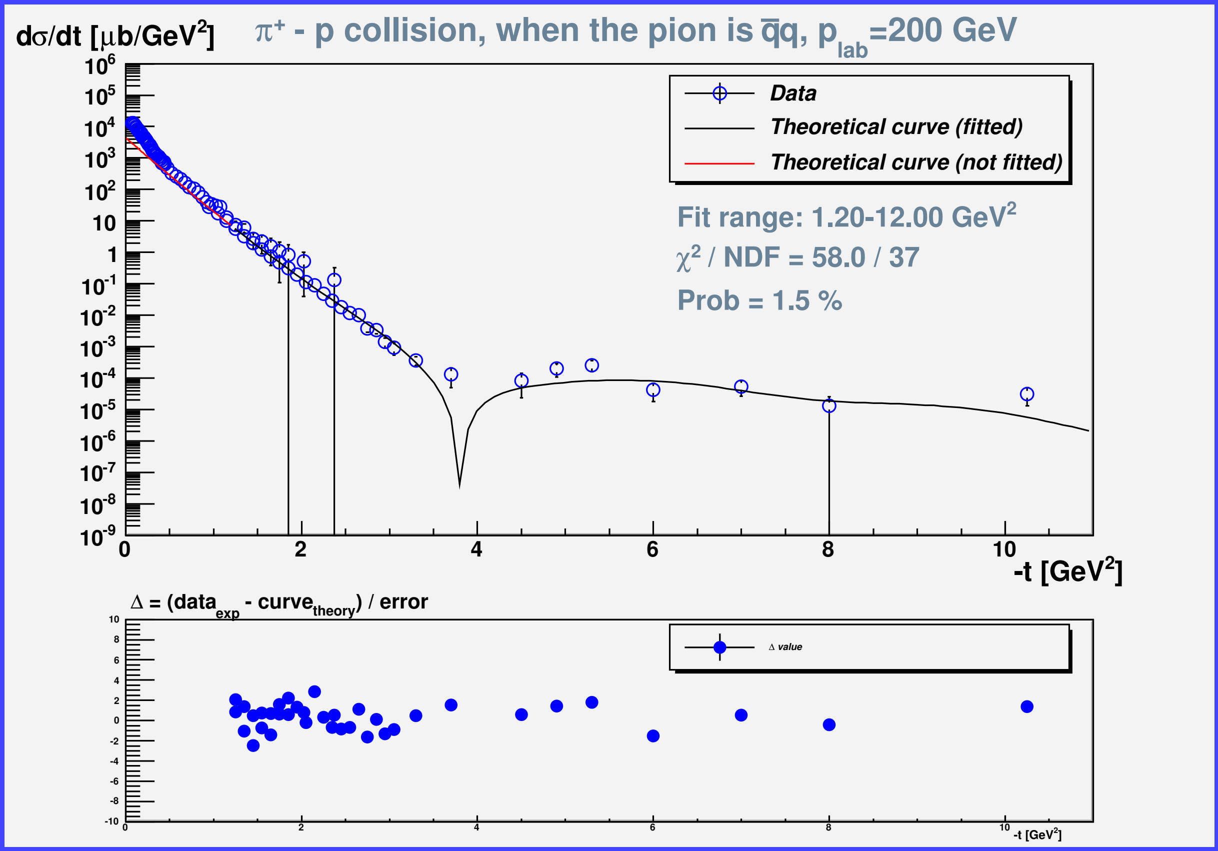
R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$	λ
0.0991	0.672	0.83	0.0511	1.22	0.899

My results when pion is a $q\bar{q}$ system 2



R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$	λ
0.093	0.719	0.912	0.0316	1.34	0.875

My results when pion is a $q\bar{q}$ system 3



R_q [fm]	R_d [fm]	R_p [fm]	R_π [fm]	$A_{q\pi}$	λ
0.091	0.678	0.88	0.0334	1.28	0.89

Conclusion

The single entity model is acceptable with 0.15% probability between 2.25-12.00 GeV^2.

Otherwise the single entity model of the π can be rejected.

The $q\bar{q}$ model can be accepted with 1.5% probability between 1.20-12.00 GeV^2.

Note: the "fit by eye method" is not reliable.