pp Elastic Scattering at LHC

Proton Structure

Outer Cloud – Inner Shell – Gluon Core

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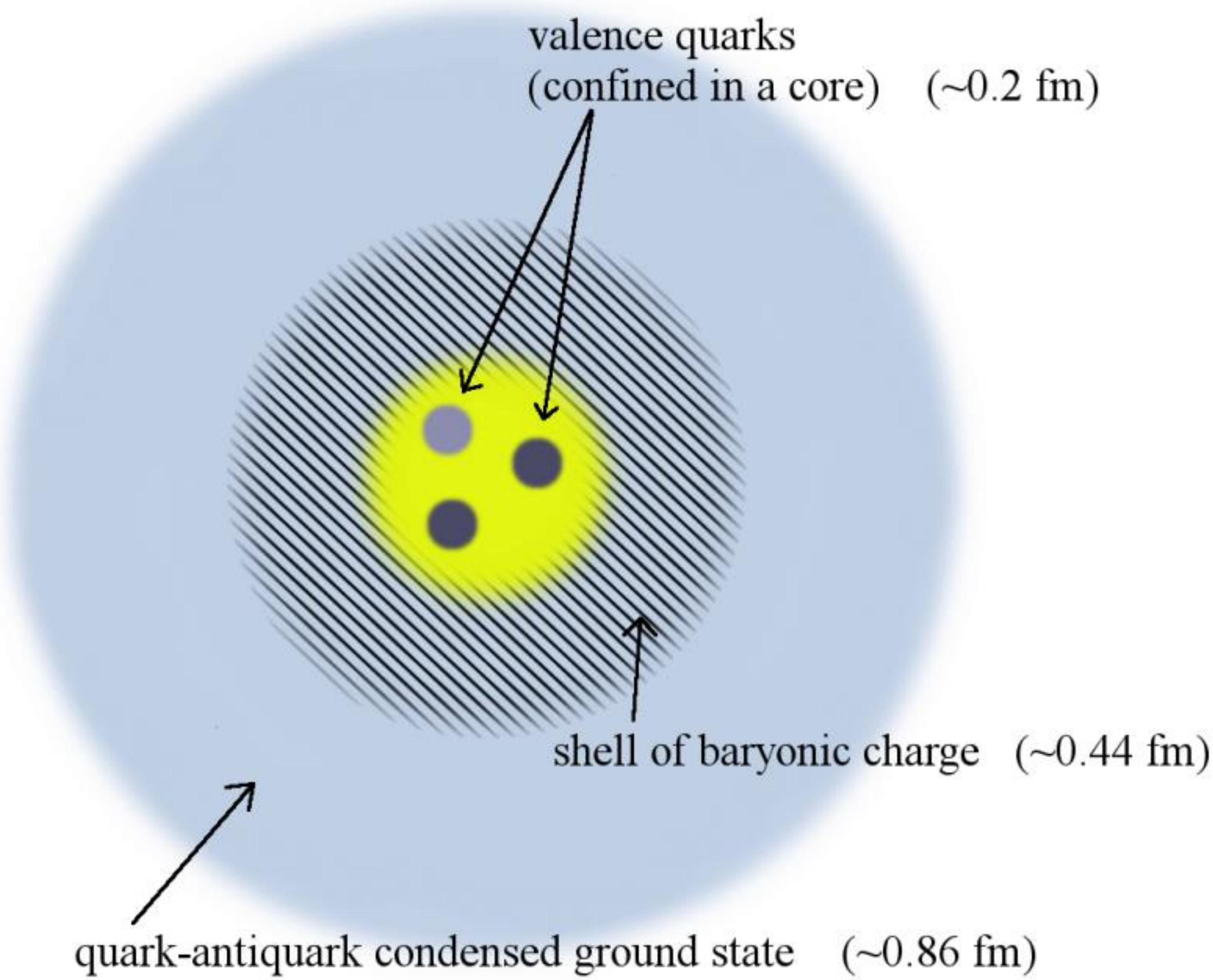
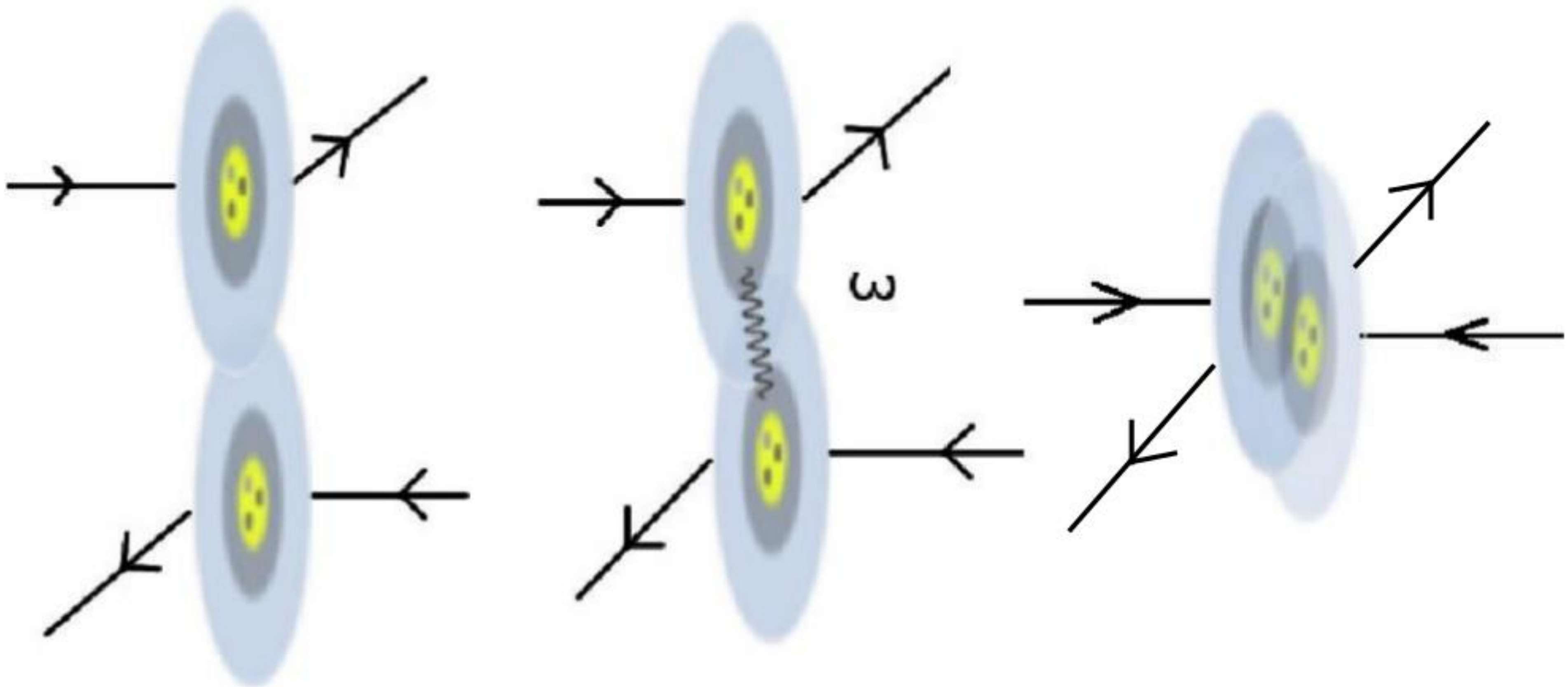
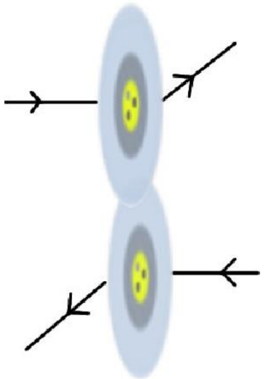

valence quarks
(confined in a core) (~0.2 fm)
shell of baryonic charge (~0.44 fm)
quark-antiquark condensed ground state (~0.86 fm)

This proton structure leads to three main processes in elastic scattering





The **first** process occurs in the small $|t|$ region. The outer cloud of $q\bar{q}$ condensed ground state of one proton interacts with that of the other.

Diffraction Amplitude

$$T_D(s,t) = i\,p\,W \int_0^\infty b\,db\;J_0(b,q)\;\Gamma_D(s,b)$$

Profile Function

$$\Gamma_D(s,b) = g(s)\left[\frac{1}{1+e^{(b-R)/a}} + \frac{1}{1+e^{-(b+R)/a}} - 1\right]$$

where $R = R_0 + R_1\left(\ln s - \frac{i\,\pi}{2}\right), \quad a = a_0 + a_1\left(\ln s - \frac{i\,\pi}{2}\right)$

and $g(s)$ is a complex crossing even function.

Our Diffraction Amplitude - Asymptotic Properties

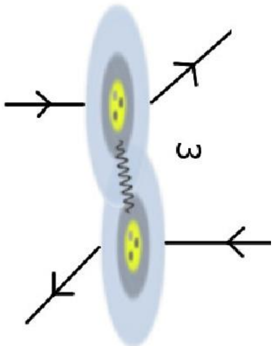
$\sigma_{tot}(s) \sim (a_0 + a_1 \ln s)^2$ ✓ (Froissart – Martin bound)

$\rho(s) \simeq \frac{\pi\, a_1}{a_0 + a_1 \ln s}$ ✓ (derivative dispersion relation)

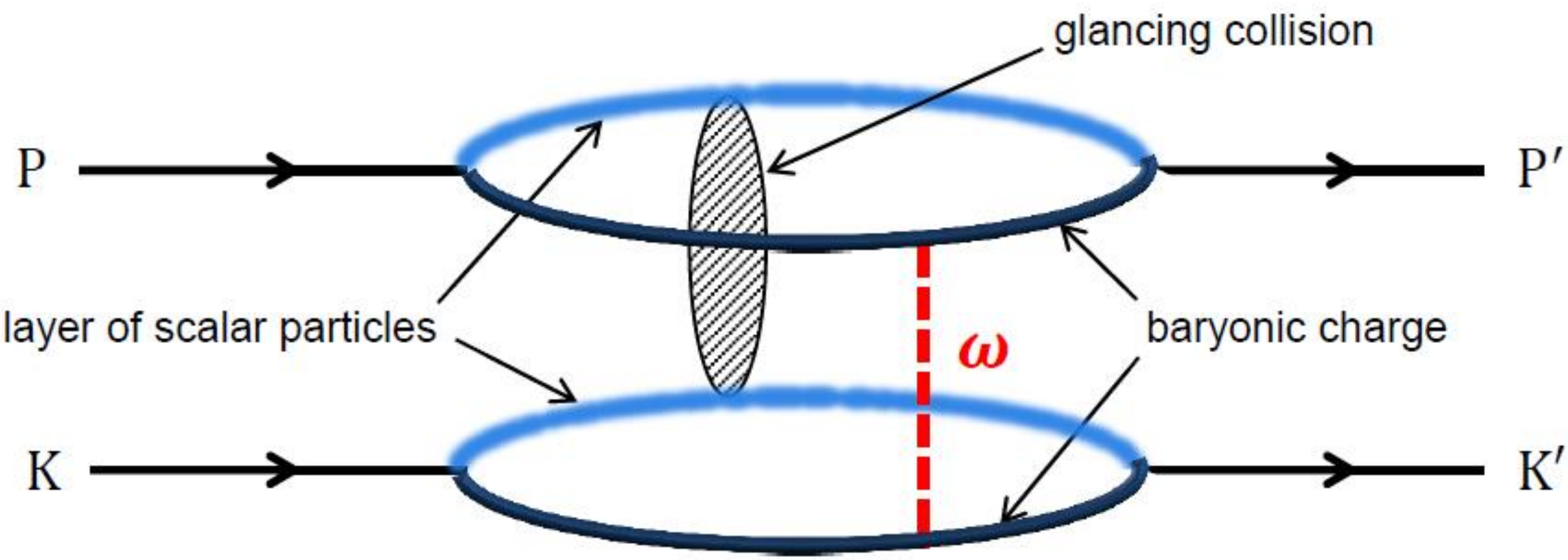
$T_D(s,t) \sim i\, s \ln^2 s \;\; f(|t|\, \ln^2 s)$ ✓ (Auberson-Kinoshita-Martin scaling)

$T_D^{\bar{\mathrm{p}}\mathrm{p}}(s,t) = T_D^{\mathrm{pp}}(s,t)$ ✓ (crossing even)

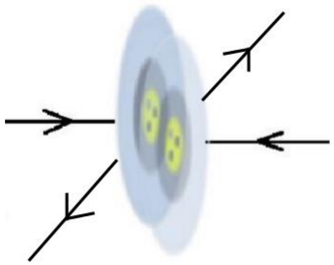
Beyond diffraction scattering –



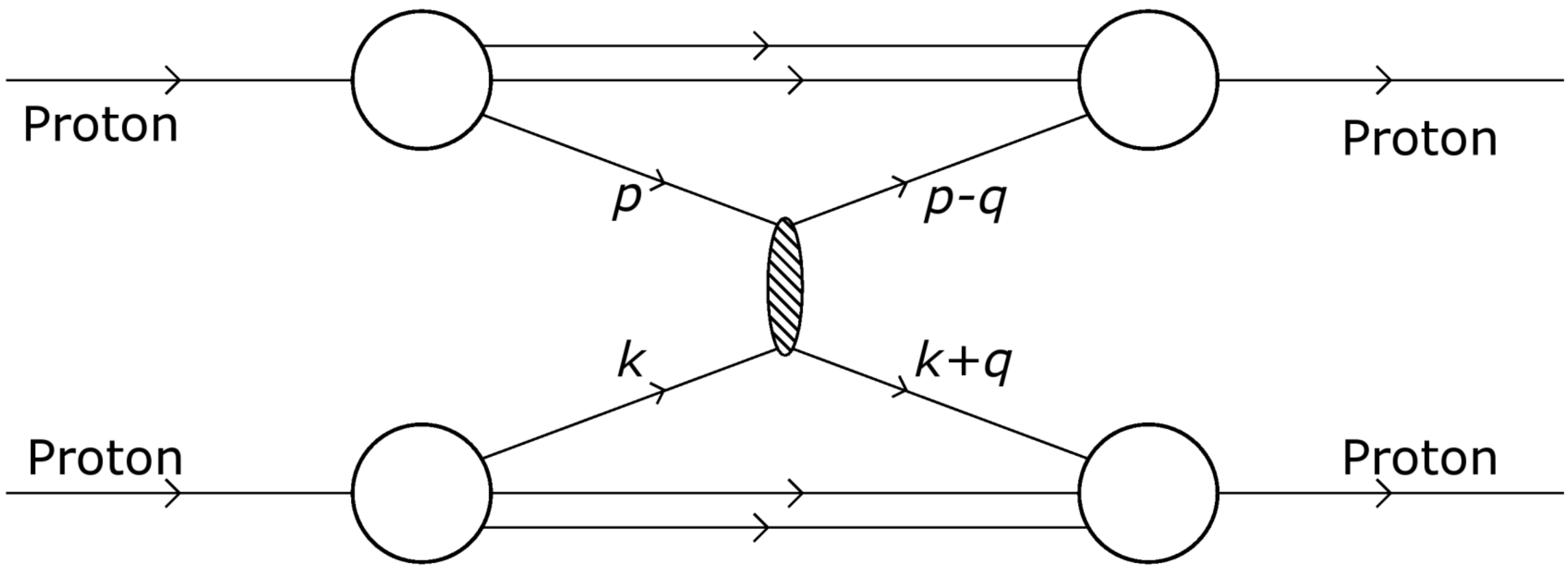
The **second** process becomes important at $|t| \gtrsim 0.5\ GeV^2$, when the baryonic charge core of one proton probes that of the other via multiple vector meson ω-exchanges.



Multiple $\boldsymbol{\omega}$-exchanges accompanied by the cloud-cloud interaction



The **third** process also begins at $|t| \gtrsim 0.5\ GeV^2$ (impact parameter $b \lesssim 0.3\ fm$) with gluon exchanges between valence quarks.



The **third** process viewed in momentum space.

We combine our multiple ω-exchange amplitude with our low-x gluon-gluon interaction amplitude by using a joint eikonal:

$$\chi_\omega(s,b) + \chi_{gg}(s,b).$$

Our combined hard scattering amplitude is then

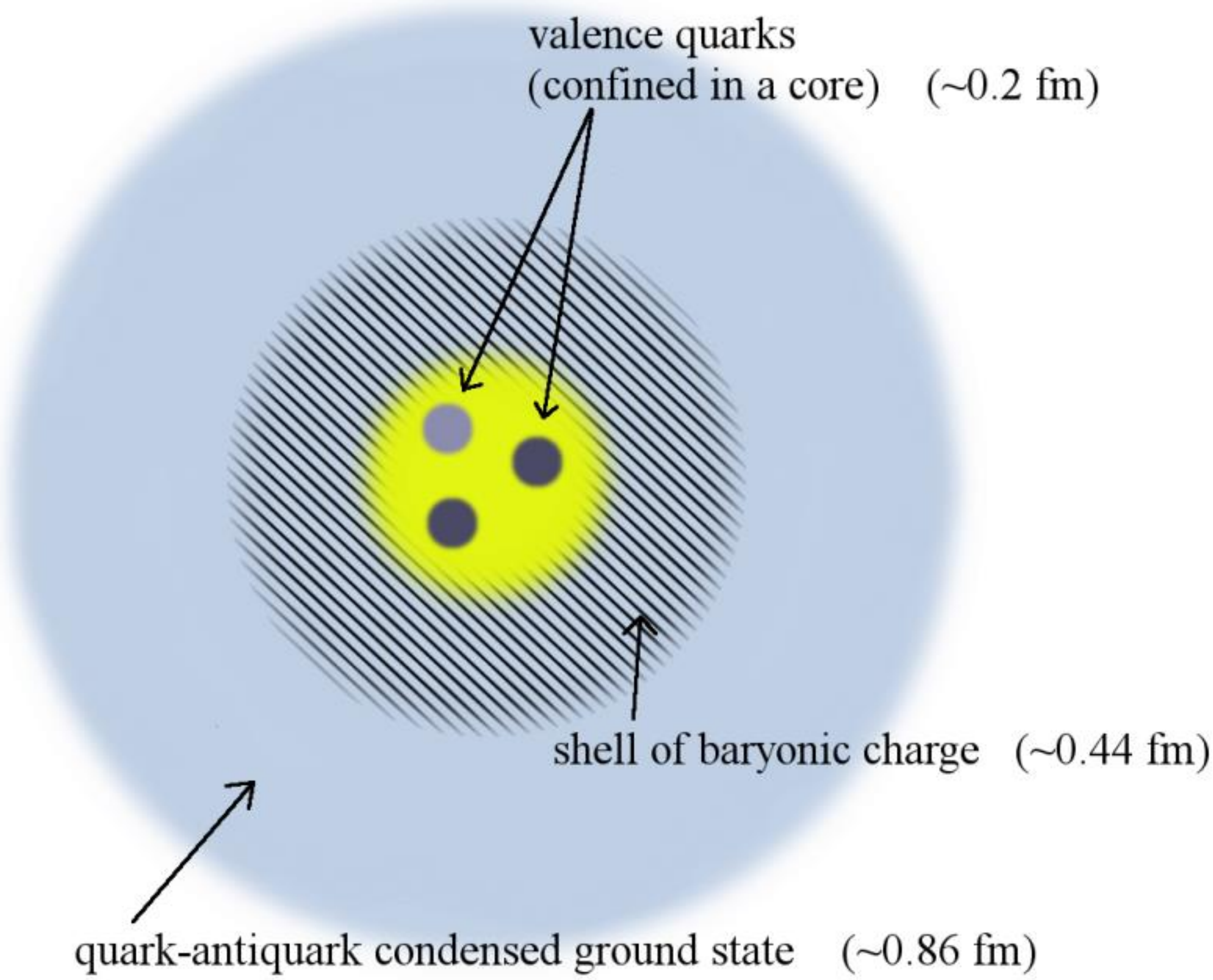
$$T_{\omega+gg}(s,t) \simeq$$

$$\left[\left(\eta_0 + \frac{c_0}{\left(s\, e^{i\frac{\pi}{2}}\right)^{\sigma}}\right) + i\left(\lambda_0 - \frac{d_0}{s^2}\right)\right]\left[T_\omega(s,t) + e^{i\,\chi_\omega(s,\tilde{b})}\, T_{gg}(s,t)\right].$$

$T_\omega(s,t)$: scattering amplitude due to multiple ω-exchanges

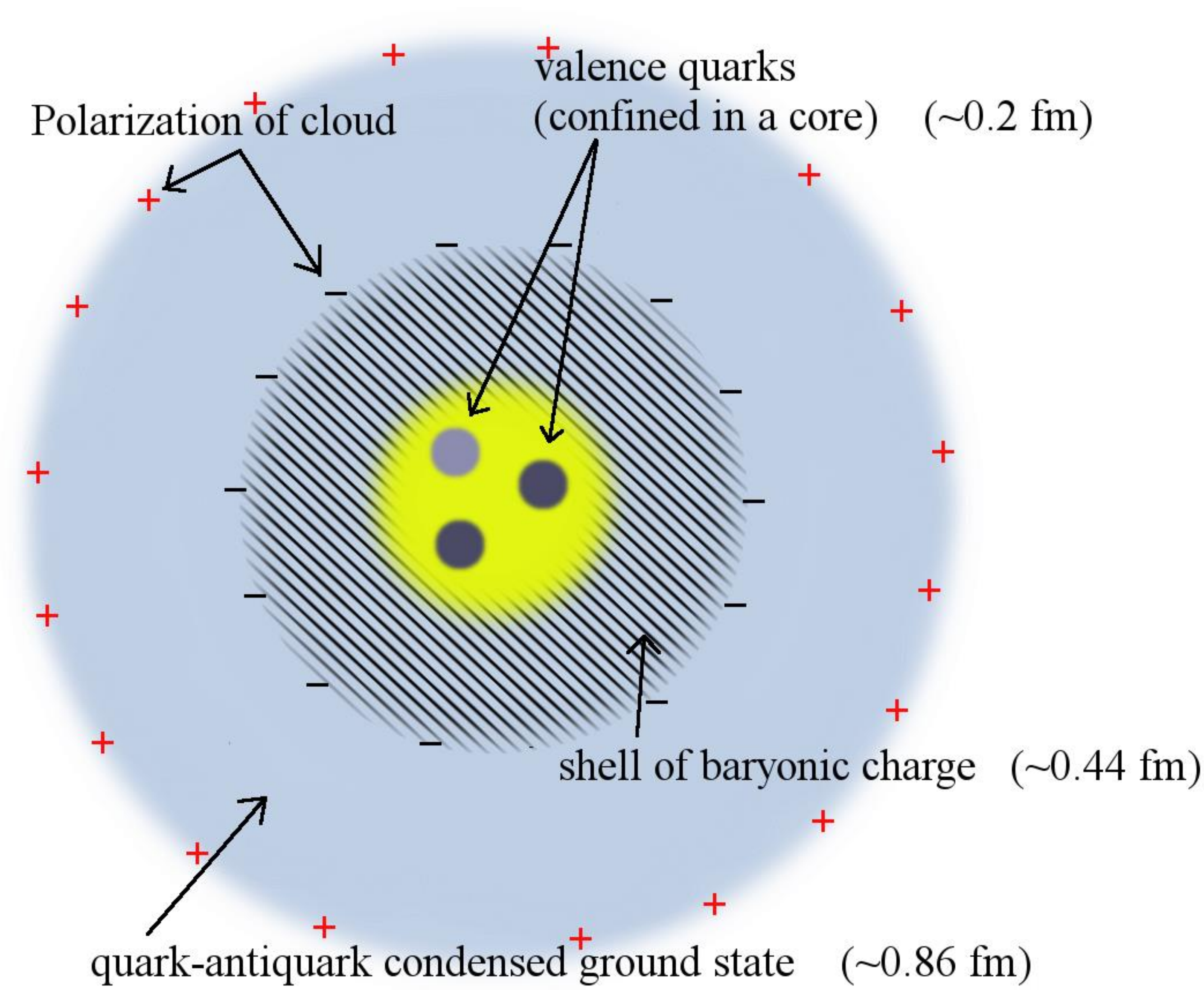
$T_{gg}(s,t)$: gluon-gluon scattering amplitude

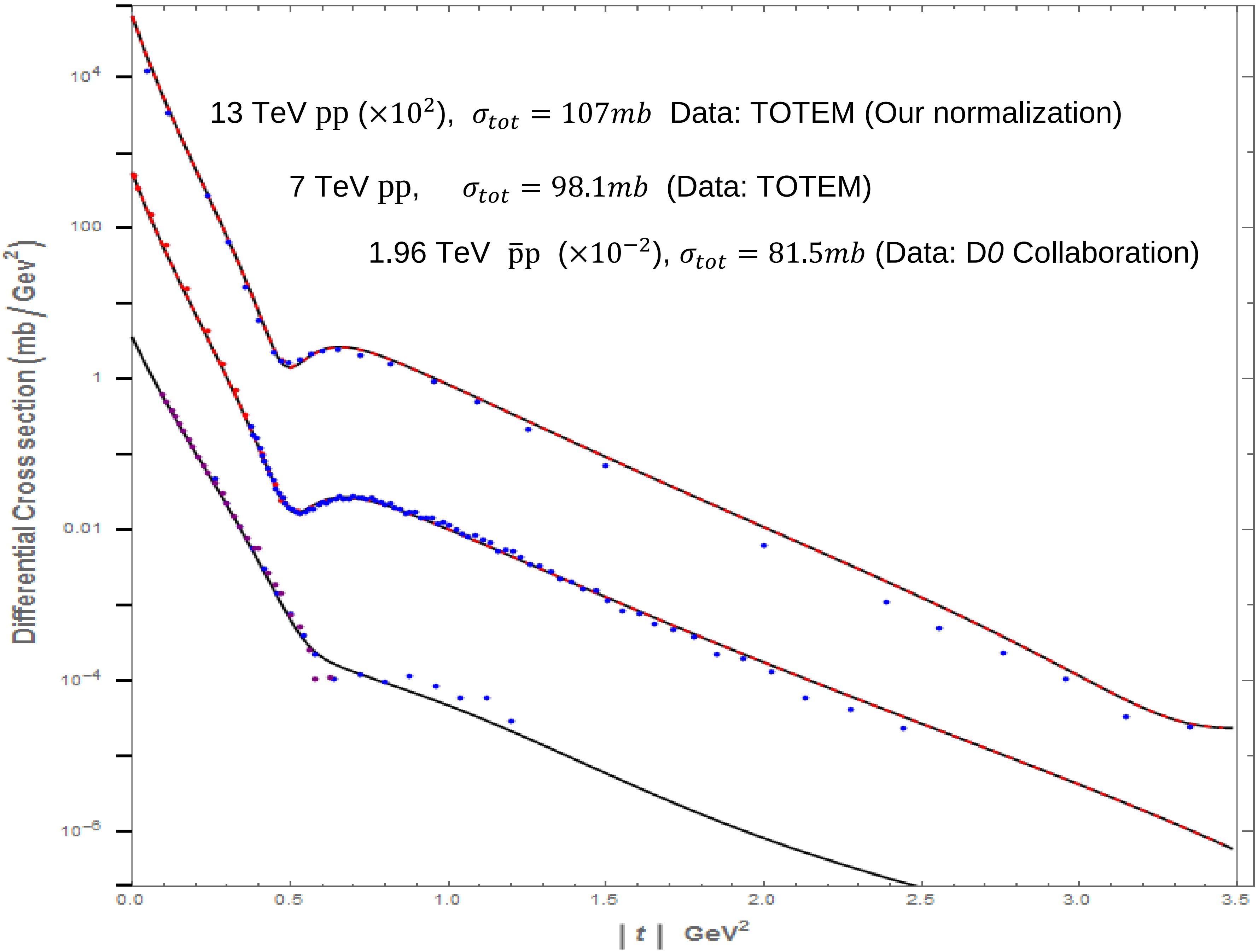
$e^{i\,\chi_\omega(s,\tilde{b})}$: additional screening of $T_{gg}(s,t)$ by the baryonic-charge shell.



Something was missing in our low-$|t|$ $\frac{d\sigma}{dt}$ calculation…

Polarization of the Quark-Antiquark Cloud





13 TeV pp ($\times 10^2$), $\sigma_{tot} = 107mb$ Data: TOTEM (Our normalization)
7 TeV pp, $\sigma_{tot} = 98.1mb$ (Data: TOTEM)
1.96 TeV $\bar{p}p$ ($\times 10^{-2}$), $\sigma_{tot} = 81.5mb$ (Data: D0 Collaboration)
Differential Cross section (mb / Gev^2)
10^4
100
1
0.01
10^{-4}
10^{-6}
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
| t | GeV^2

Conclusions

Over four decades of collider experience by many groups…

CERN ISR 23 – 62 GeV (pp)

Fermilab 27.4 GeV (pp)

CERN SPS 546, 630 GeV (p̄p)

Tevatron 1.8 TeV (p̄p)

Tevatron 1.96 TeV (p̄p)

CERN LHC 7, 8, 13…TeV (pp)

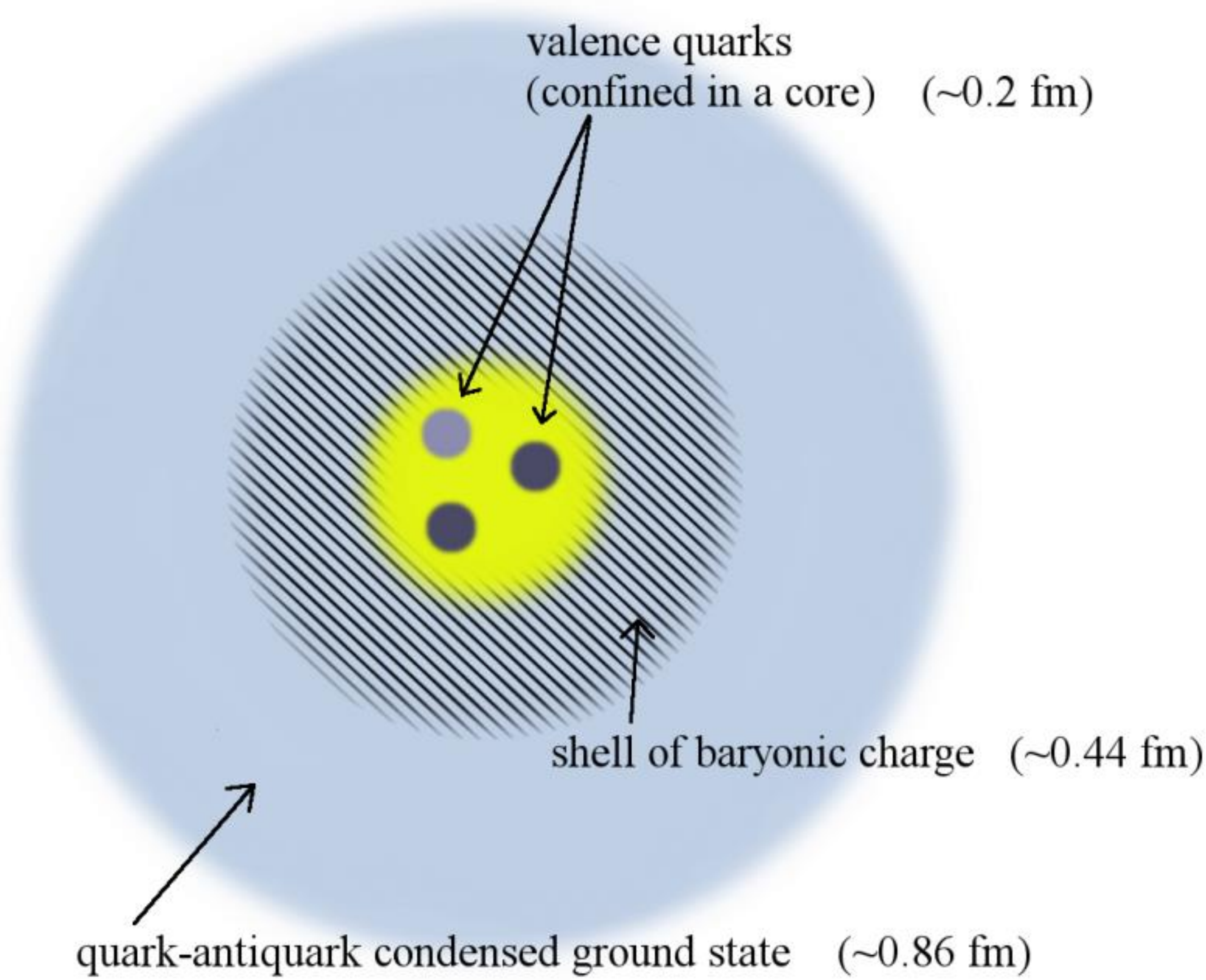
and more…

and much **theoretical development**…

have led us envision the **Structure of the Proton**.

The End…

Structure of the **Proton**



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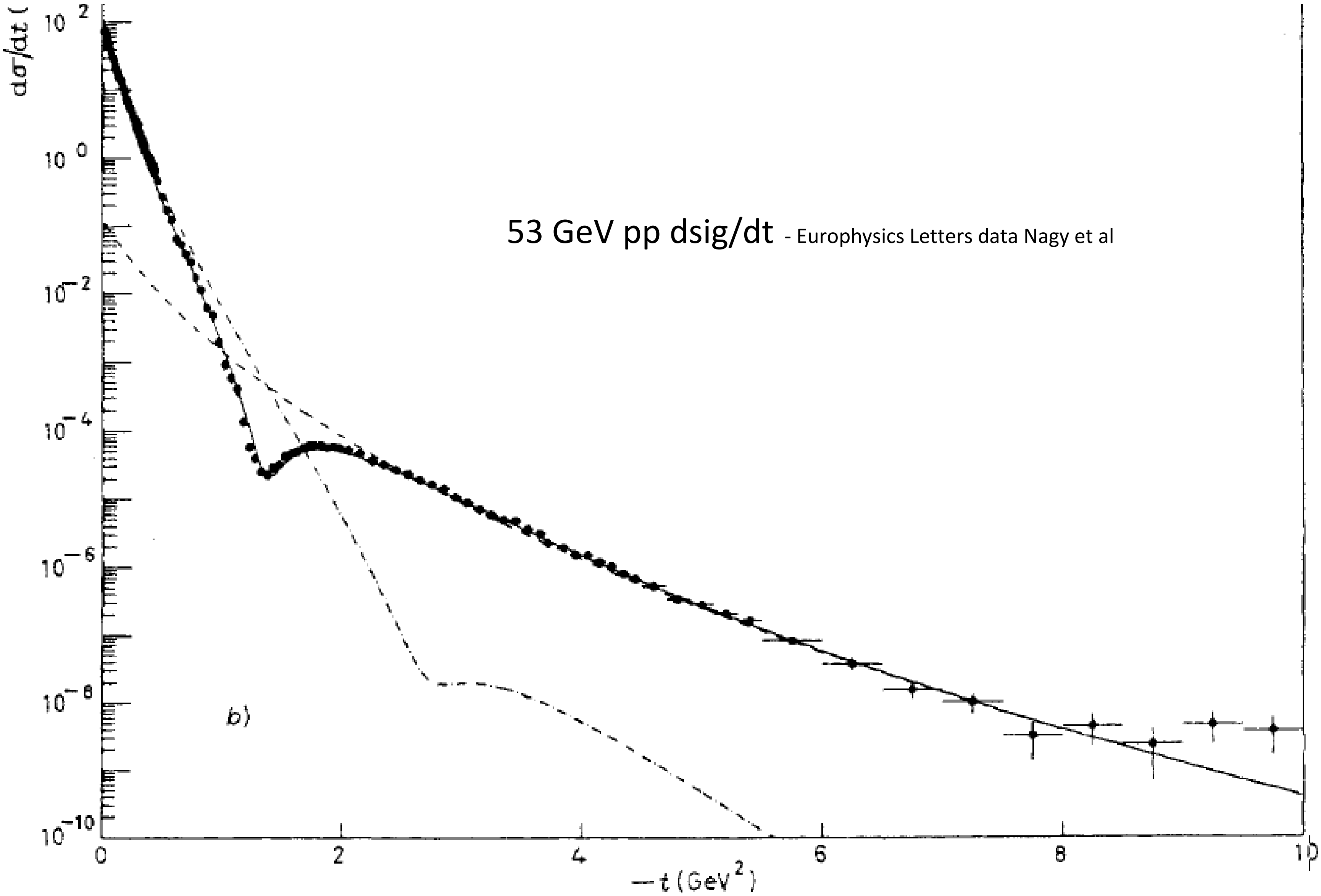
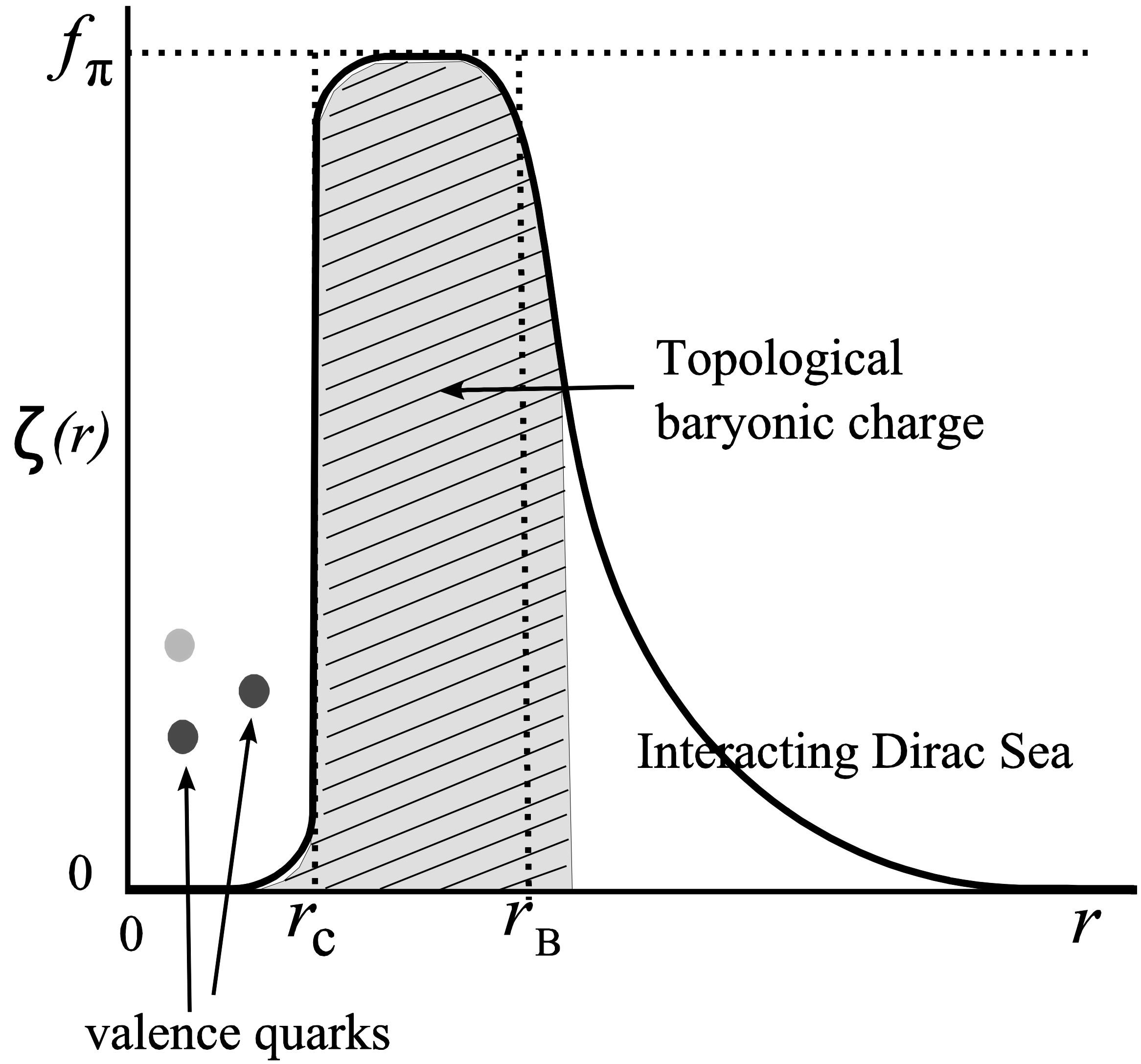


53 GeV pp dsig/dt - Europhysics Letters data Nagy et al



The scalar field $\zeta(r)$ as a function of r.

r_C: radius of the core, r_B: radius of the baryonic charge density.