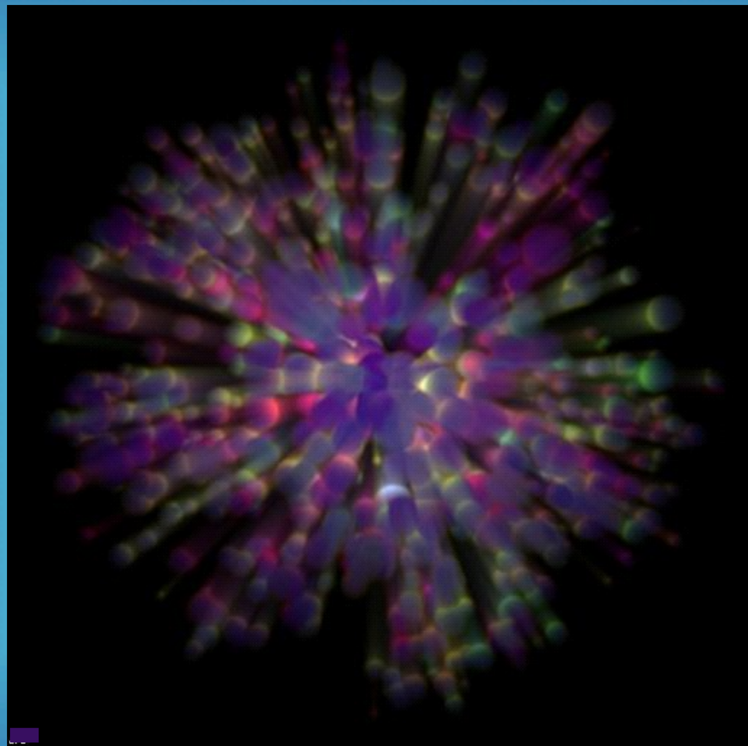
O comportamento de seções de choque hadrônicas com a energia no regime de saturação de gluons



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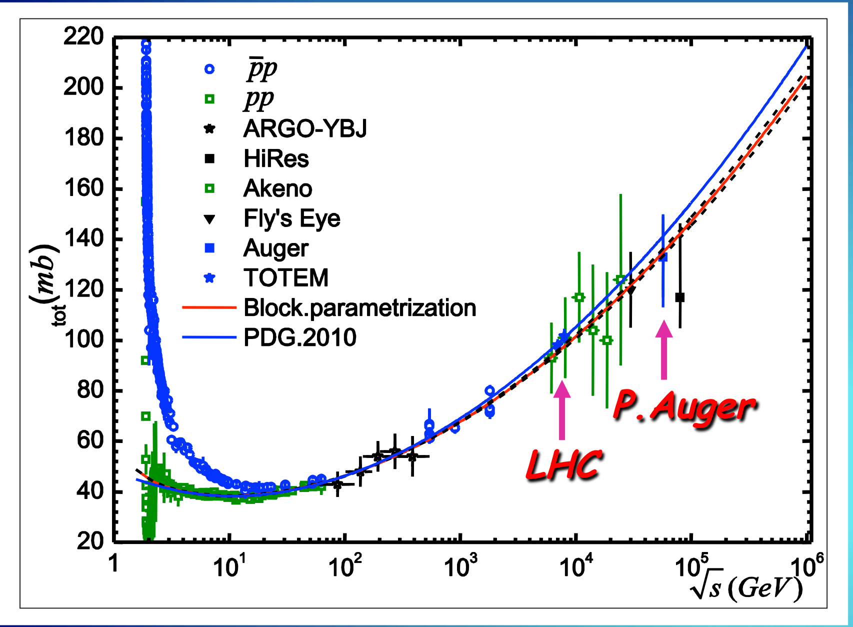
motivação: como crescem as seções de choque hadrônicas com a energia qdo um sistema de alta densidade de partons é formado ?

→ os dados do LHC e do P. Auger ditam esse comportamento ! (?)



$$\sigma^{\mp}_{\rm PDG}(s) = a_0 + a_1 A_1^{\,b_1} \mp a_2 A_1^{\,b_2} + \underline{a_3}\ln^{b_3}(A_2)$$

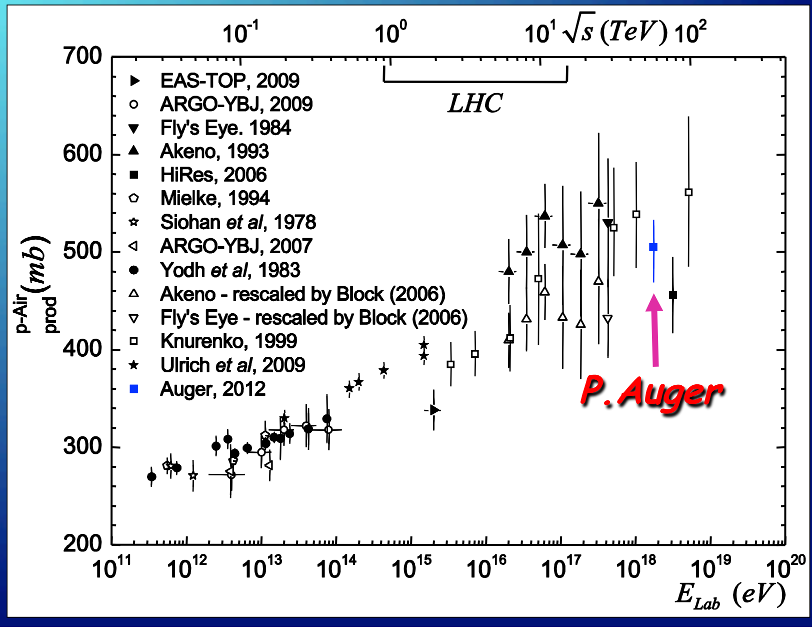
$$\sigma^{\pm}_{\rm BH}(\nu) = c_0 + c_1 C^{d_1} \pm c_2 C^{d_2} + \underline{c_3}\ln(C) + \underline{c_4}\ln^{d_3}(C)$$

PDG	PRD 86, 010001 (2012)	BH	PRD 86, 014006 (2012)
$a_0(mb)$	35.35 ± 0.48	$c_0(mb)$	37.32
$a_1(mb)$	42.53 ± 1.35	$c_1(mb)$	37.10
$a_2(mb)$	33.34 ± 1.04	$c_2(mb)$	−28.56
$a_3(mb)$	0.308 ± 0.010	$c_3(mb)$	-1.440 ± 0.070
b_1	-0.458 ± 0.017	$c_4(mb)$	0.2817 ± 0.0064
b_2	-0.545 ± 0.007	d_1	−0.5
b_3	2	d_2	−0.585
$s_l(\mathrm{GeV}^2)$	1.0	d_3	2
$s_h(\mathrm{GeV}^2)$	28.9 ± 5.4		

the upper (lower) sign is for pp ($\bar{p}p$) scattering, $A_1 \equiv s/s_l$, $A_2 \equiv \underline{s/s_h}$, $C \equiv \underline{\nu/m}$ [$\approx s/2m^2$, ν and m represent, respectively, the laboratory energy of the incoming proton (antiproton) and the proton mass

the Froissart bound states that total hadronic cross sections cannot grow faster than $\ln^2(s)$ as $s \to \infty$!

o que se discute hoje ?
elas crescem com a energia segundo um "Froissart-type behavior" ?



Eikonalized Minijet Model

L. Durand and H. Pi, Phys. Rev. Lett. 58, 303 (1987)
X.-N. Wang, Phys. Rev. D 43, 104 (1991)

$$\sigma_{tot}^{pp(\bar{p})}(s) = 2\int d^2\vec{b}\{1 - e^{-\mathrm{Im}\chi(b,s)}\cos[\mathrm{Re}\chi(b,s)]\},$$

$$\sigma_{el}^{pp(\bar{p})}(s) = \int d^2\vec{b}|1 - e^{i\chi(b,s)}|^2,$$

$$\sigma_{inel}^{pp(\bar{p})}(s) = \int d^2\vec{b}[1 - e^{-2\,\mathrm{Im}\chi(b,s)}].$$

$$\chi(b,s) = \mathrm{Re}[\chi(b,s)] + i\,\mathrm{Im}[\chi(b,s)]$$

$= 0$ (!)

$$n(b,s) \equiv 2\,\mathrm{Im}\chi(b,s) = n_{soft}(b,s) + n_{hard}(b,s)$$

$$n(b,s) = W(b,\mu_{soft})\sigma^{soft}(s) + \sum_{k,l} W(b,\mu_{hard})\sigma_{kl}^{hard}(s)$$

$$W(b,\mu_{soft}) = \frac{\mu_{soft}^2}{96\pi}(\mu_{soft}b)^3K_3(\mu_{soft}b),$$

$$\begin{cases} \sigma_{soft}^{pp}(E_{lab}) = 47 + \dfrac{46}{E_{lab}^{1.39}}, \\ \sigma_{soft}^{p\bar{p}}(E_{lab}) = 47 + \dfrac{129}{E_{lab}^{0.661}} + \dfrac{357}{E_{lab}^{2.7}}, \end{cases}$$

PRD 72, 076001 (2005)

$$\int W(b,\mu)d^2\vec{b} = 1$$

$$gg \to gg\,,\, gq(\bar{q}) \to gq(\bar{q}),\, gg \to q\bar{q}$$

$$q \equiv u,d,s \;;\; \kappa = 1$$

$$W(b,\mu_{gg}), W(b,\mu_{qq}), W(b,\mu_{gq} \equiv \sqrt{\mu_{gg}\,\mu_{qq}})$$

$$p_T \geq p_{T_{min}}$$

$$x_{1,2} = p_T/\sqrt{s}(e^{\pm y} + e^{\pm y_2})$$

$$f_{i,j/h_{1,2}}(x_{1,2}, Q^2)$$

parton densities: linear × nonlinear !!!

$$\frac{d\sigma_{kl}^{mj}}{dy}(s) = \kappa\int dp_T^2 dy_2 \sum_{i,j} x_1 f_{i/h_1}(x_1,Q^2)x_2 f_{j/h_2}(x_2,Q^2) \times \frac{1}{1+\delta_{kl}}\left[\delta_{fk}\frac{d\hat{\sigma}^{ij\to kl}}{d\hat{t}}(\hat{t},\hat{u}) + \delta_{fl}\frac{d\hat{\sigma}^{ij\to kl}}{d\hat{t}}(\hat{u},\hat{t})\right],$$

ZPC 75, 515 (1997)

~1980

DIS Cern/Fermilab:

<u>Violações de Scaling para altos Q^2 !</u> → $t = ln(Q^2/\Lambda^2)$

$$\alpha_s(Q^2) = \frac{12\pi}{(33-2f)\,t}$$

$$F_2(x) \rightarrow F_2(x, Q^2)$$

$\alpha_s(Q^2) << 1$

⇓

pQCD

F_2 cresce com Q^2 em x peq.

F_2 decresce com Q^2 em x gde. → emissão de gluons!

$$x^{-1}F_2(x,Q^2) = \sum_q e_q^2\, q(x,Q^2) = \sum_q e_q^2\,[q(x) + \delta q(x,Q^2)]$$

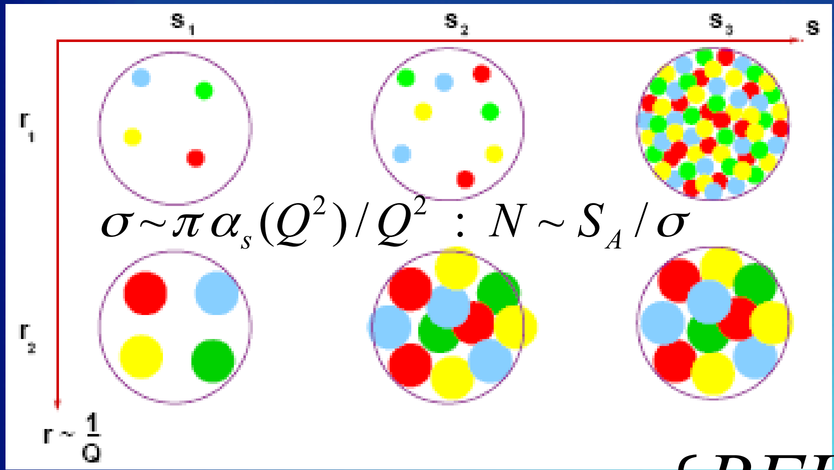
$$\delta q(x,Q^2) = \frac{\alpha_s(Q^2)}{2\pi}\, ln\left(\frac{Q^2}{\mu^2}\right)\int_x^1 \frac{dx'}{x'}\, q(x')\, P_{qq}\left(\frac{x}{x'}\right)$$

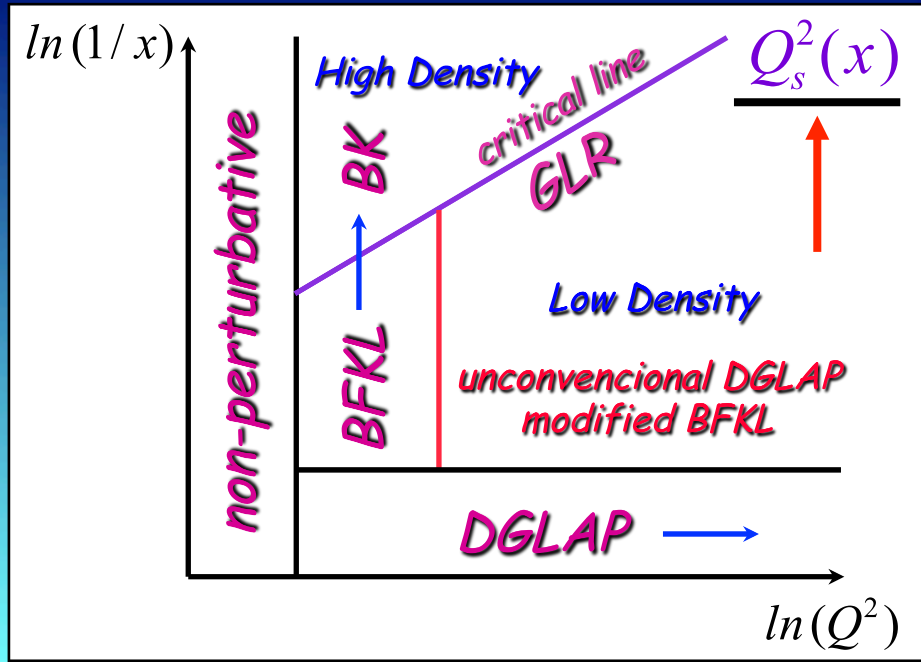
<u>DGLAP</u> → evolução linear

$$\frac{dq_i(x,Q^2)}{dln\,(Q^2)} = \frac{\alpha_s(Q^2)}{2\pi}\int_x^1 \frac{dx'}{x'}\left[q_i(x',Q^2)\,P_{qq}\left(\frac{x}{x'}\right) + g(x',Q^2)\,P_{qg}\left(\frac{x}{x'}\right)\right]$$

$$\frac{dg(x,Q^2)}{dln\,(Q^2)} = \frac{\alpha_s(Q^2)}{2\pi}\int_x^1 \frac{dx'}{x'}\left[\sum_i q_i(x',Q^2)\,P_{gq}\left(\frac{x}{x'}\right) + g(x',Q^2)\,P_{gg}\left(\frac{x}{x'}\right)\right]$$

Regimes da QCD





$$\sqrt{s} \uparrow + Q^2 \downarrow \;\Rightarrow \begin{cases} BFKL \\ BK \end{cases}$$

alta densidade de gluons :
a recombinação é importante !

GLR → evolução não-linear

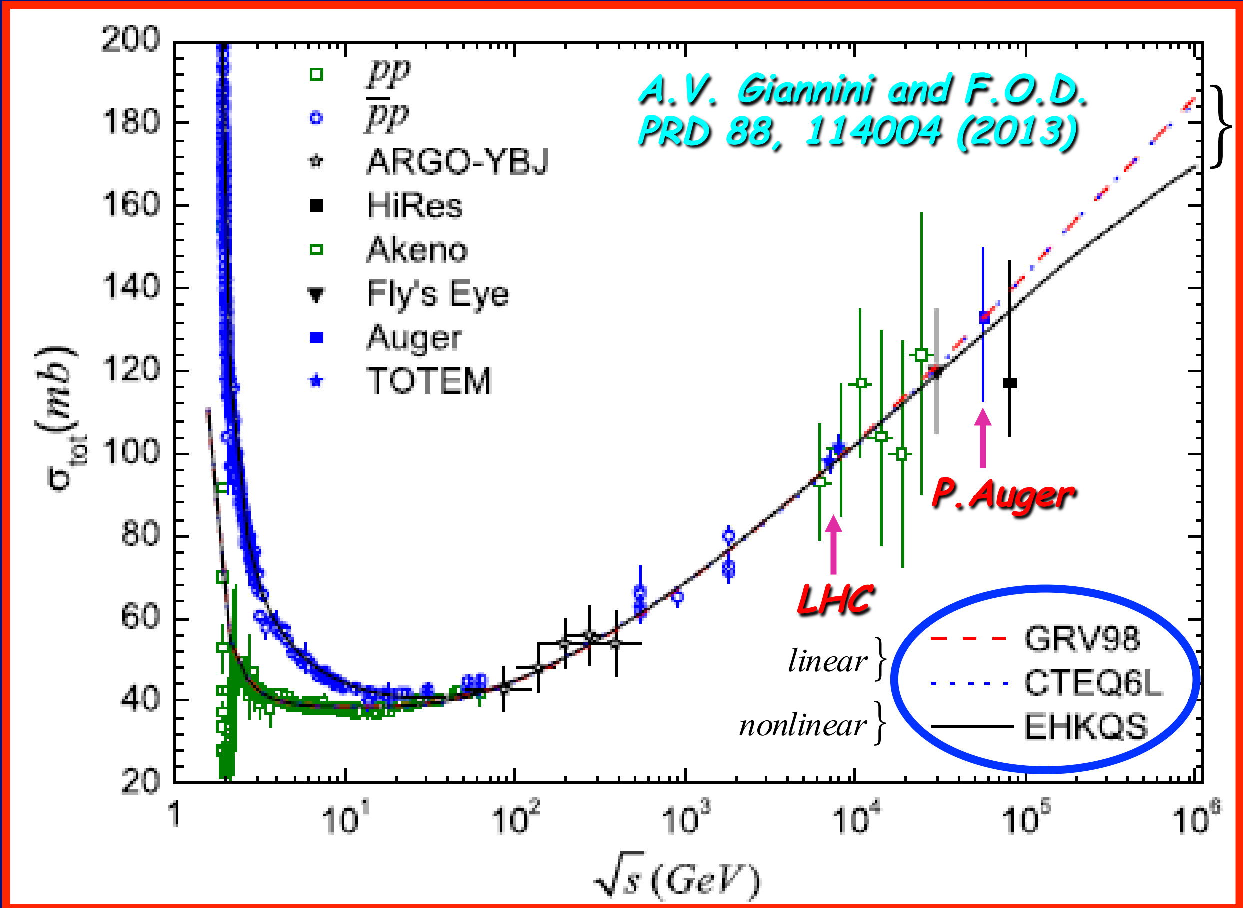
$$Q^2 \frac{\partial^2 x\, g(x,Q^2)}{\partial ln(1/x)\, \partial Q^2} = \frac{\alpha_s(Q^2) N_c}{\pi} x\, g(x,Q^2) - \frac{4\alpha_s^2 N_c}{3 C_F R^2 Q^2} [x\, g(x,Q^2)]^2$$

↳ $x\, g(x,Q^2) \sim \pi R^2 Q^2 / \alpha_s(Q^2)$

essa evolução atenua o
crescimento da densidade
de gluons com baixos momentos !

$Q_s^2(x) = Q_0^2 (x_0/x)^\lambda$ → define o regime !

↳ SATURAÇÃO !



linear × *nonlinear*

$$\mu_{soft}^2 = 0.70\, GeV^2$$

$$\mu_{gg}, \mu_{q\bar{q}} = \begin{cases} 1.88\, GeV, 1.00\, GeV \\ 2.03\, GeV, 0.73\, GeV \\ 2.00\, GeV, 0.70\, GeV \end{cases}$$

$$p_{T_{\min}}^2 = \begin{cases} 1.32\, GeV^2 \\ 2.10\, GeV^2 \\ 1.51\, GeV^2 \end{cases}$$

$$\tilde{\sigma}^{\rm GRV98}_{\rm CTEQ6L}(s) = (27.9 \pm 0.3) + a_1 s^{b_1} - a_2 s^{b_2} + (0.2152 \pm 0.0015)\ln^2(s),$$

à la PDG $\sigma^{\mp}_{\rm PDG}(s) = a_0 + a_1 A_1^{b_1} \mp a_2 A_1^{b_2} + a_3 \ln^{b_3}(A_2)$

$$\tilde{\sigma}^{\rm EHKQS}(s) = (30.5 \pm 0.8) + a_1 s^{b_1} - a_2 s^{b_2} + (0.2014 \pm 0.0035)\ln^2(s),$$

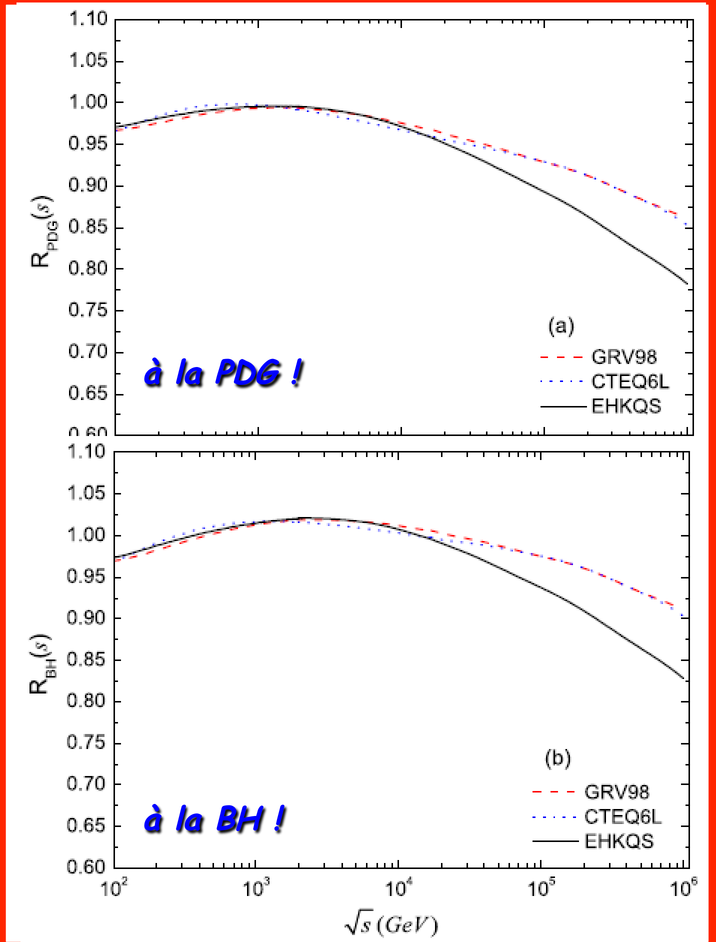
$$A_1 = s/s_l;\, A_2 = s/s_h;\, C \approx s/(2m^2)$$

$$s_l = s_h = 1\, GeV^2$$

$$\tilde{\sigma}^{\rm GRV98}_{\rm CTEQ6L}(s) = (29.74 \pm 0.11) + 49.2143 s^{d_1} - 39.7501 s^{d_2} - (0.252 \pm 0.004)\ln(s) + (0.2230 \pm 0.0004)\ln^2(s),$$

à la BH $\sigma^{\pm}_{\rm BH}(\nu) = c_0 + c_1 C^{d_1} \pm c_2 C^{d_2} + c_3 \ln(C) + c_4 \ln^{d_3}(C)$

$$\tilde{\sigma}^{\rm EHKQS}(s) = (18.2 \pm 0.5) + 49.2143 s^{d_1} - 39.7501 s^{d_2} + (1.80 \pm 0.08)\ln(s) + (0.1445 \pm 0.0026)\ln^2(s),$$



$$\sigma_{tot}^{pp(\bar{p})}(s) = 2\int d^2\vec{b}\{1 - e^{-\mathrm{Im}\chi(b,s)}\cos[\mathrm{Re}\chi(b,s)]\},$$

$= 0$ (!)

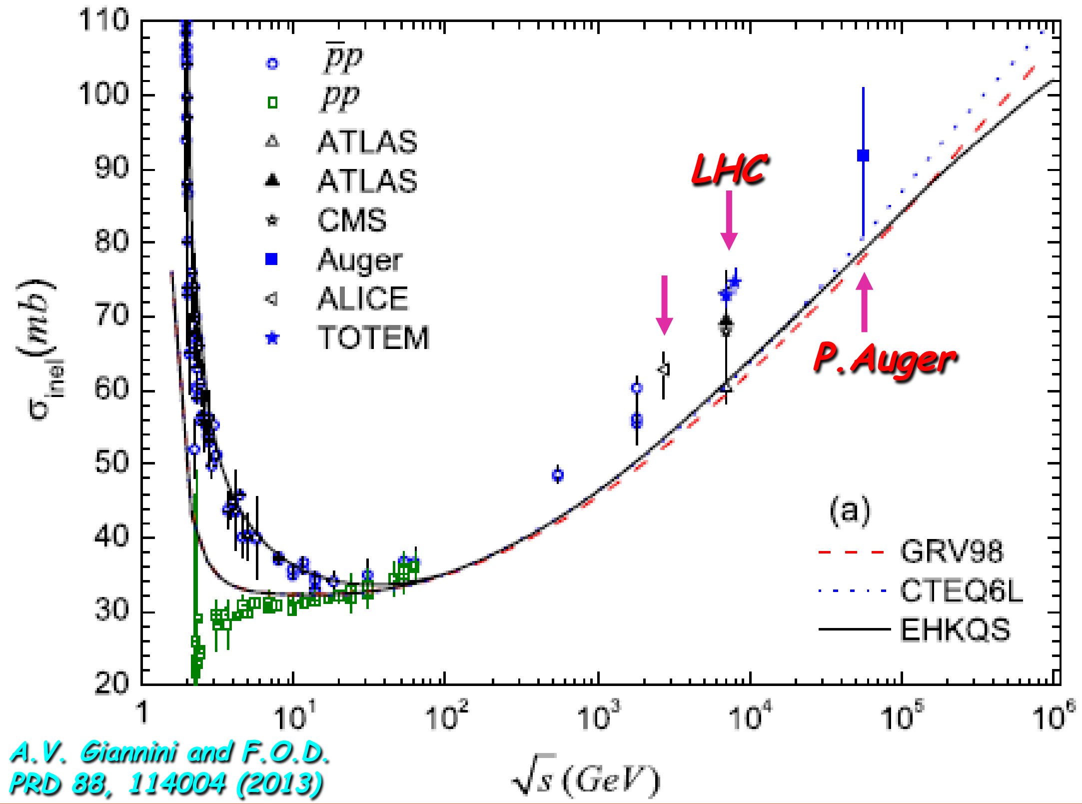
$$\sigma_{el}^{pp(\bar{p})}(s) = \int d^2\vec{b}|1 - e^{i\chi(b,s)}|^2,$$

$$\sigma_{inel}^{pp(\bar{p})}(s) = \int d^2\vec{b}[1 - e^{-2\,\mathrm{Im}\chi(b,s)}].$$

fixação de parâmetros !

$$2\,\mathrm{Im}\chi(b,s) = n_{soft}(b,s) + n_{hard}(b,s)$$

ρ, B, difração ... ? (!)



crescimento + modesto com a energia !

a saturação atenua + fortemente esse comportamento !

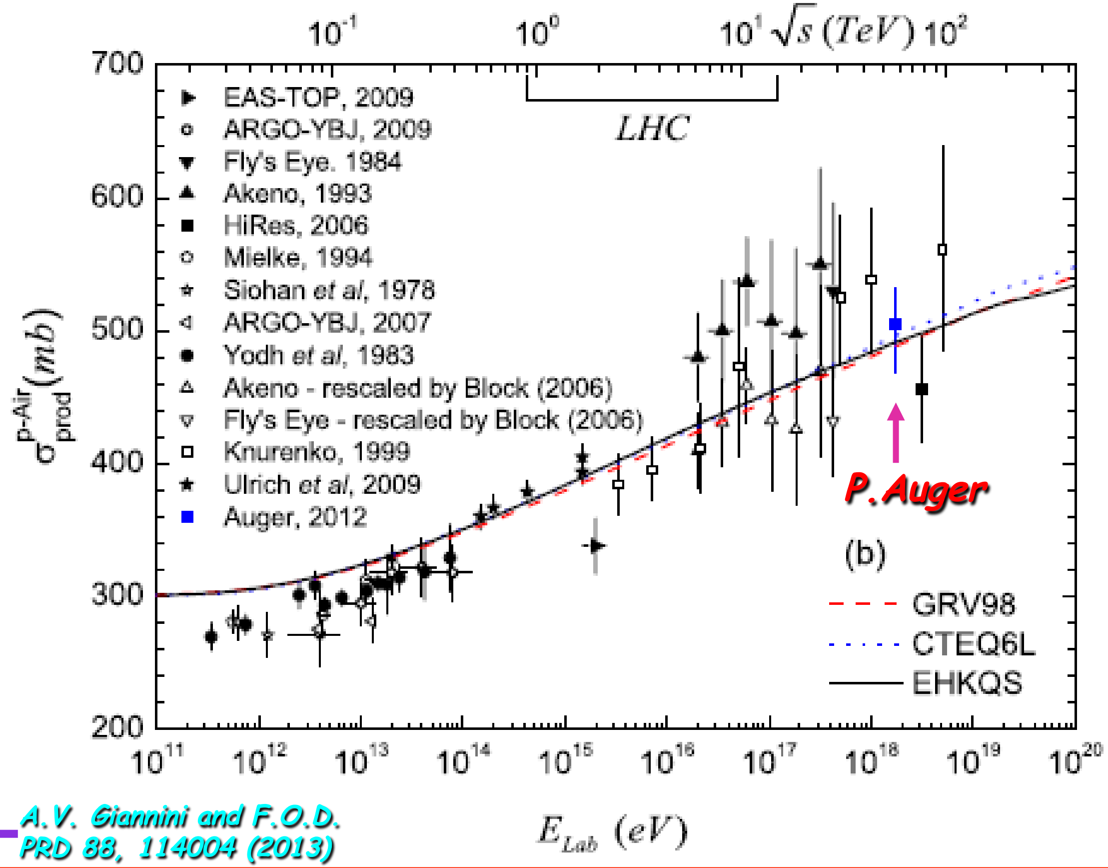
Glauber multiple collision model
NPB 21, 135 (1970)

$$\sigma_{\rm inel}^{pA}(s) = \int d^2\vec{b}\left[1 - e^{-\sigma_{\rm inel}^{NN}(s)T_A(b)}\right].$$

$$T_A(b) = \int dz\, \rho_A(b,z)\ ;\ \int d^2b\, T_A(b) = A$$

$$\rho_A(b,z) = \rho_0\{1 + \exp[(r - R_A)/a_0]\}^{-1},$$

$$r = \sqrt{b^2 + z^2},\quad R_A = 1.19A^{1/3} - 1.61A^{-1/3}$$



A.V. Giannini and F.O.D.
PRD 88, 114004 (2013)

vector meson dominance
+
additive quark model

$\Rightarrow$ $\sigma_{tot}^{\gamma p}(s)$ e $\sigma_{tot}^{\gamma\gamma}(s)$

mesmos parâmetros !

resultados e conclusões semelhantes !

fim


É isso aí! ...
Sinistro !!!