

A generalized Glauber-Velasco model for LHC focussing on the low- t region

T. Csörgő¹ , R. J. Glauber² and F. Nemes^{1,3}

1 Wigner Research Center for Physics, Budapest

2 Harvard University, Cambridge, MA

3 CERN

Intro to Diffraction

Glauber-Velasco model

Non-exponential behaviour at low- t

Analysis of TOTEM/LHC p+p @ 7 TeV

New results, generalized Glauber & Velasco

Summary

[arxiv:1306.4217](#)

[arxiv:1311.2308](#)

Diffraction - Hofstadter, Nobel (1961)

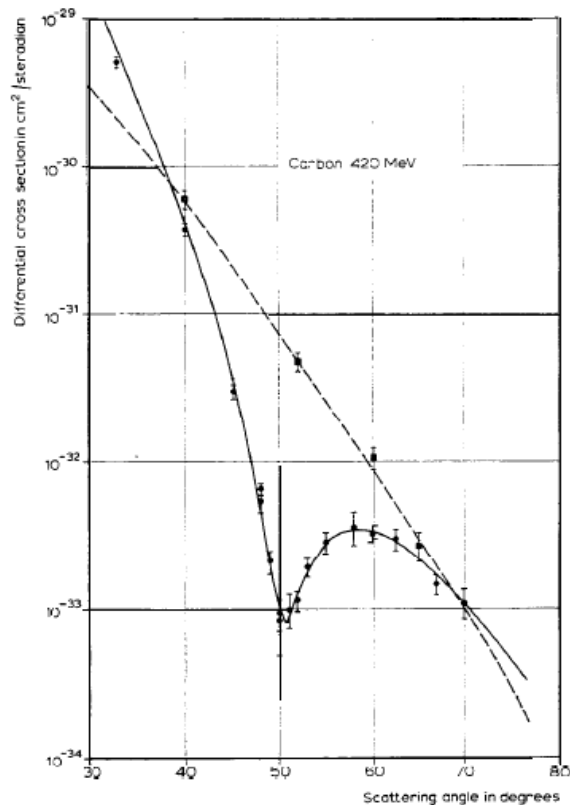
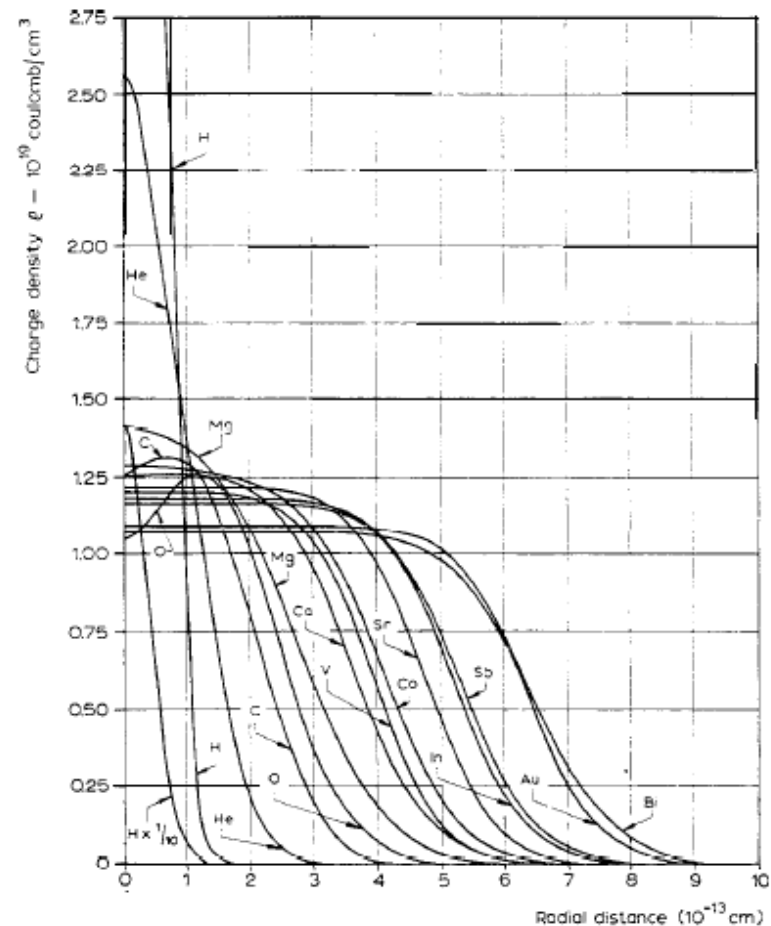


Fig. 5. This figure shows the elastic and inelastic curves corresponding to the scattering of 420-MeV electrons by ^{12}C . The *solid circles*, representing experimental points, show the elastic-scattering behavior while the *solid squares* show the inelastic-scattering curve for the 4.43-MeV level in carbon. The *solid line* through the elastic data shows the type of fit that can be calculated by phase-shift theory for the model of carbon shown in Fig. 8.

570

1961 R. HOFSTADTER

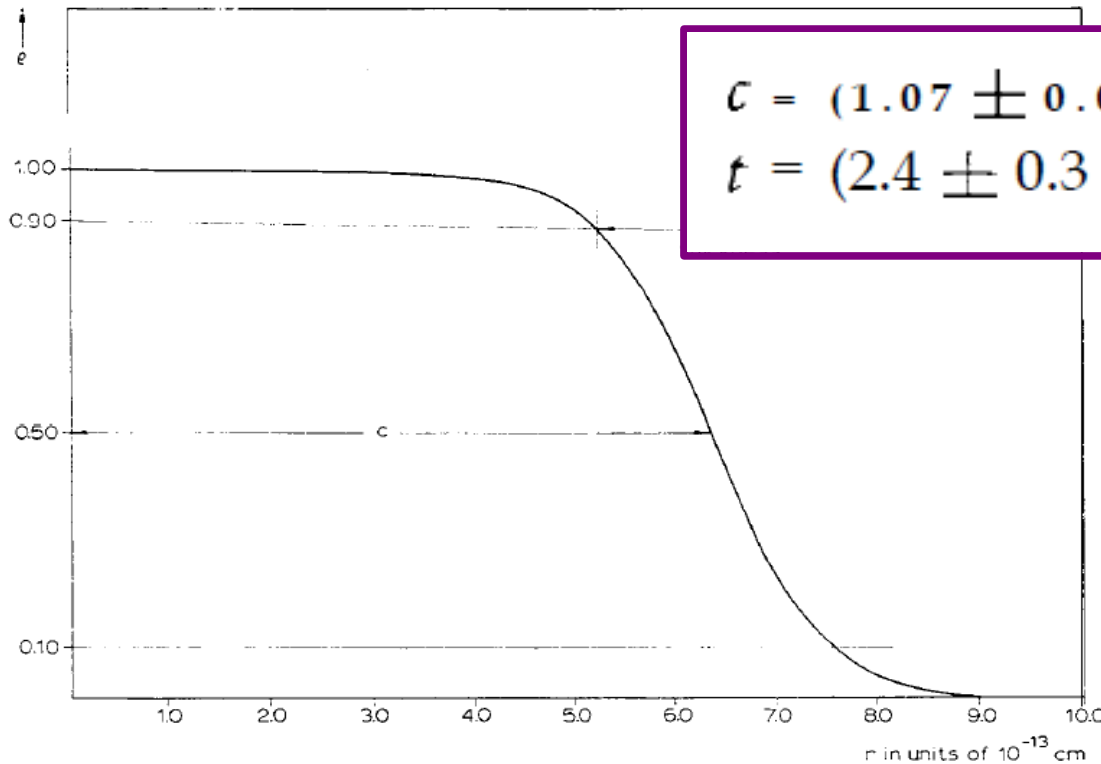


Diffraction electron scattering on nuclei and the resulting charge density distributions, images of spherical nuclei

Diffraction - What have we learned?

ELECTRON-SCATTERING METHOD

569

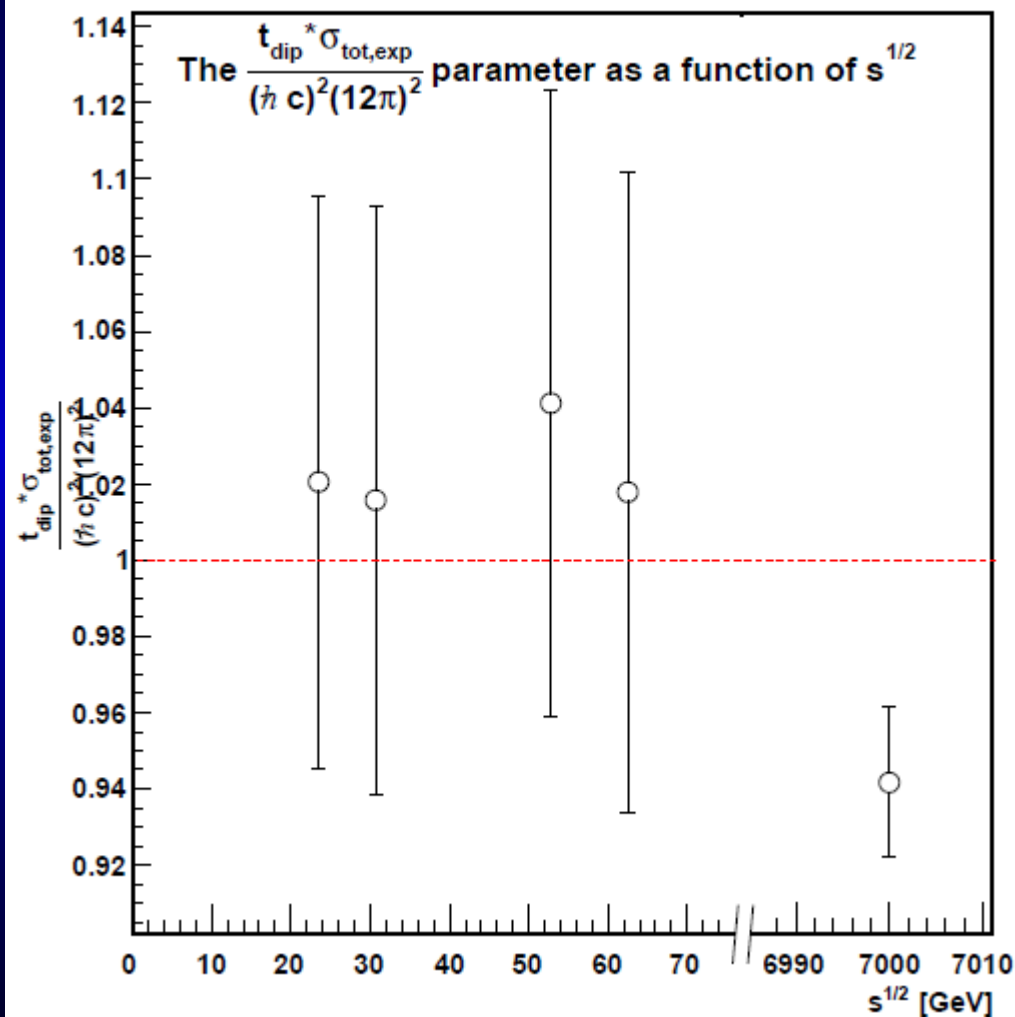


$$c = (1.07 \pm 0.02) \cdot 10^{-13} \text{ A}^{\frac{1}{3}} \text{ cm}$$

$$t = (2.4 \pm 0.3) \cdot 10^{-13} \text{ cm} = \text{constant}$$

- 1) The volume of spherical nuclei is proportional to A
 - 2) The surface thickness is constant, independent of A
- Central charge density of large nuclei is approx constant
R. Hofstadter, Nobel Lecture (1961)

What have we learned since LowX'13?



$$t_{\text{dip}} \sigma_{\text{tot}} \sim C$$

geometric scaling
at LHC

$$C = 54.8 \pm 0.7 \text{ mbGeV}^2 \text{ (data)}$$

$$C \neq 35.9 \text{ mbGeV}^2 \text{ (black disc)}$$

NOT black disk limit

[arxiv:1311.2308](https://arxiv.org/abs/1311.2308)

saturation, BEL = ?

Glauber - Velasco model summary

$$F(t) = i \int_0^\infty J_0(b\sqrt{-t}) \{1 - \exp[-\Omega(b)]\} b db$$

$F(t)$: f. sc. amplitude
 $\Omega(b)$: opacity, complex

$$\Omega(b) = \frac{\kappa}{4\pi} (1 - i\alpha) \int_0^\infty J_0(qb) G_{p,E}^2(-t) \frac{f(t)}{f(0)} q dq$$

$f(t)$: cluster averaged parton-parton scattering amplitude

$$\frac{f(t)}{f(0)} = \frac{e^{i(b_1|t| + b_2 t^2)}}{\sqrt{1 + a|t|}}$$

$-t = q^2$: momentum transfer
 b : impact parameter

$$G_{p,E}(q^2) = \sum_{i=1}^n \frac{a_i^E (m_i^E)^2}{(m_i^E)^2 + q^2}, \quad \sum_{i=1}^n a_i^E = 1, \quad G_{p,E}(0) = 1$$

$$d\sigma_{el}/d|t| = \pi |F(t)|^2$$

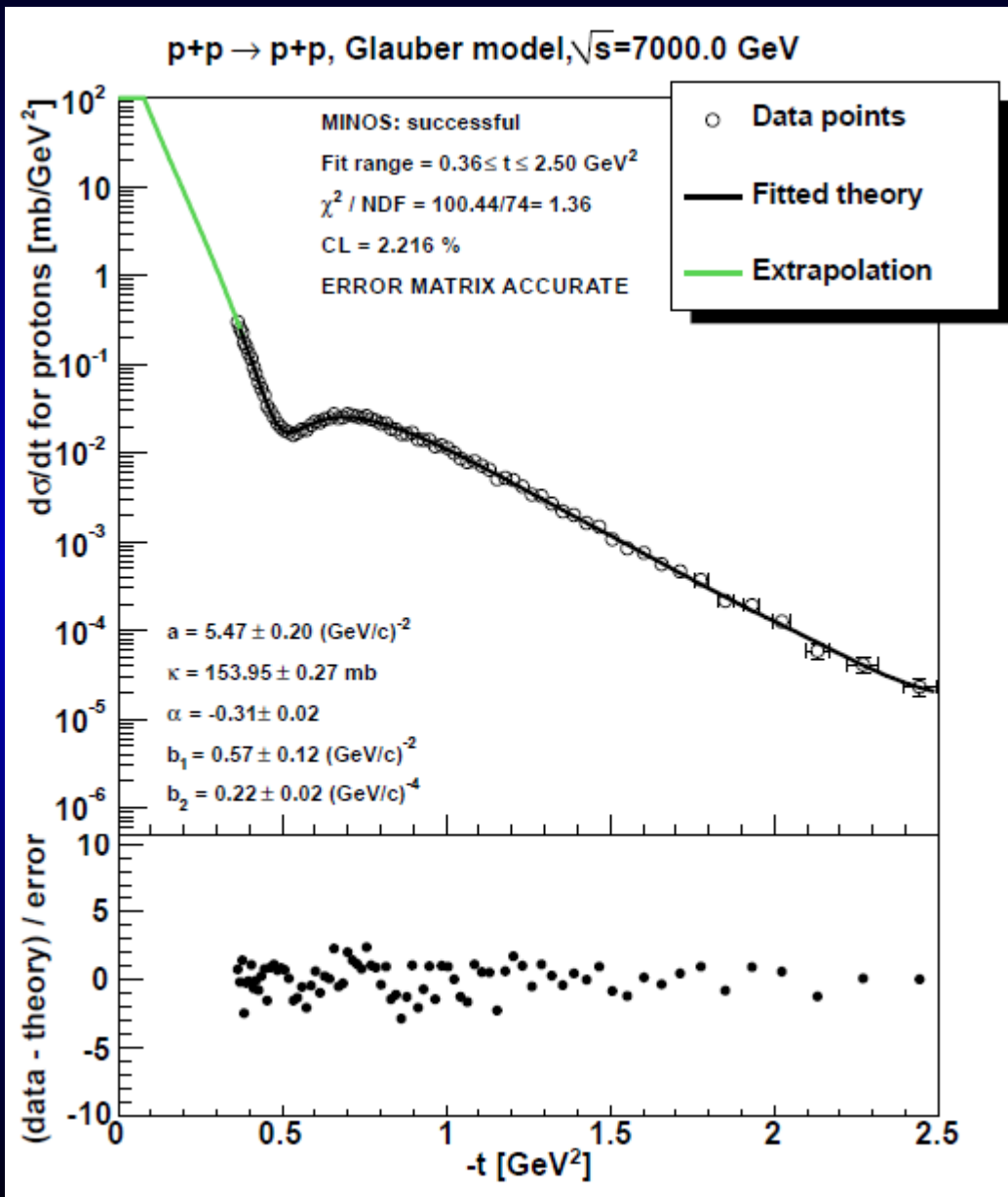
$d\sigma/dt$: diff. cross-section
 elastic pp scattering

a_i^E	$(m_i^E)^2 \text{ (fm}^{-2}\text{)}$
0.219	3.53
1.371	15.02
-0.634	44.08
0.044	154.20

R.J. Glauber and J.Velasco
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BSWW EM form factors GE

@ Low-X 2013: GV results, dip region



Glauber-Velasco
(unmodified version)

describes $d\sigma/dt$ data
Both at ISR and
TOTEM@LHC
in the dip region

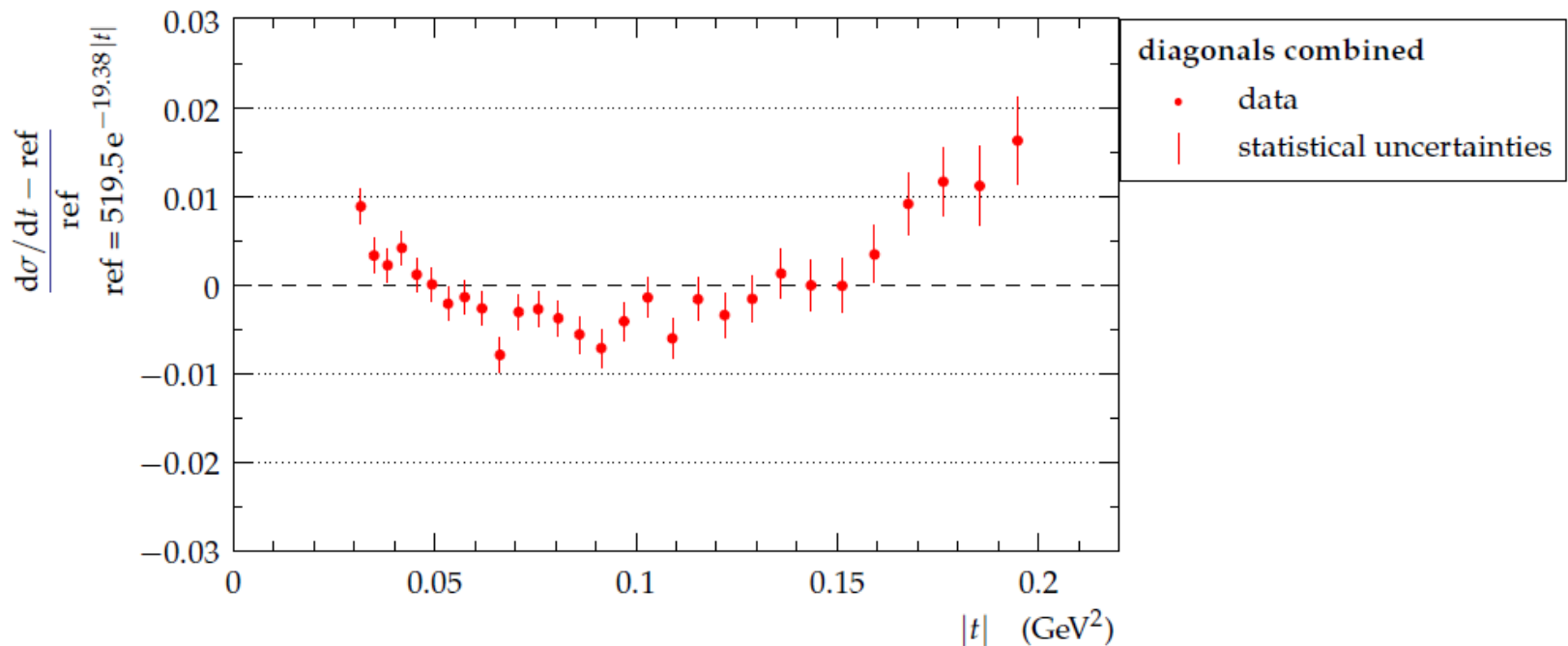
[arxiv:1311.2308](https://arxiv.org/abs/1311.2308)

Note: at low- t
model is exponential

News: non-exponential shape at low- t

Elastic Scattering : *Phase studies at larger $|t|$*

- $\beta^* = 90$ m data
- small statistical uncertainties allow for tight shape constraint:

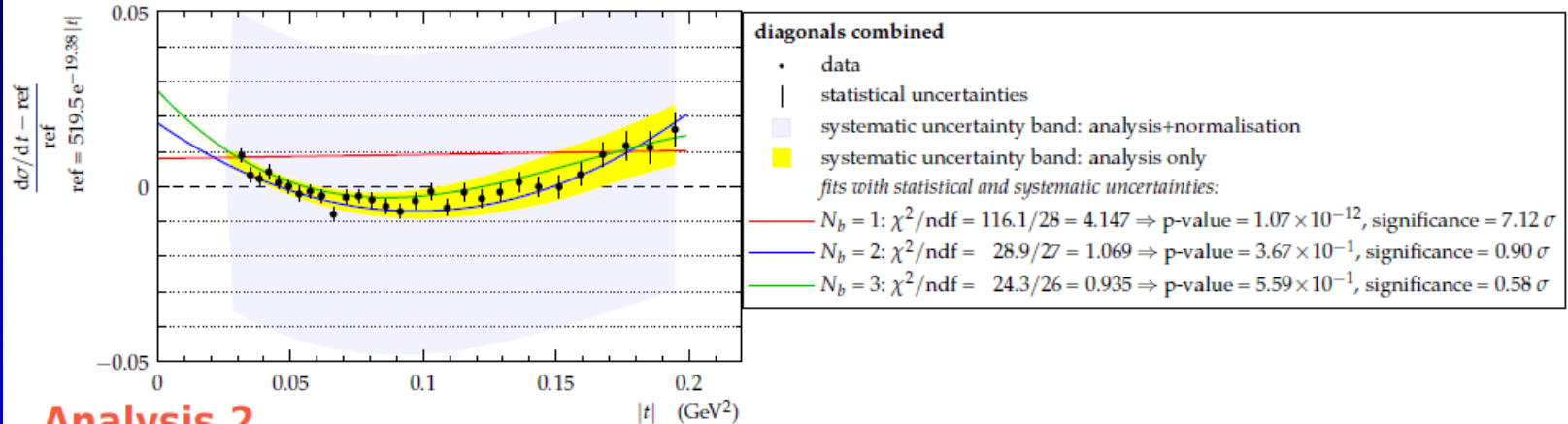


TOTEM preliminary
see F. Ferro's talk

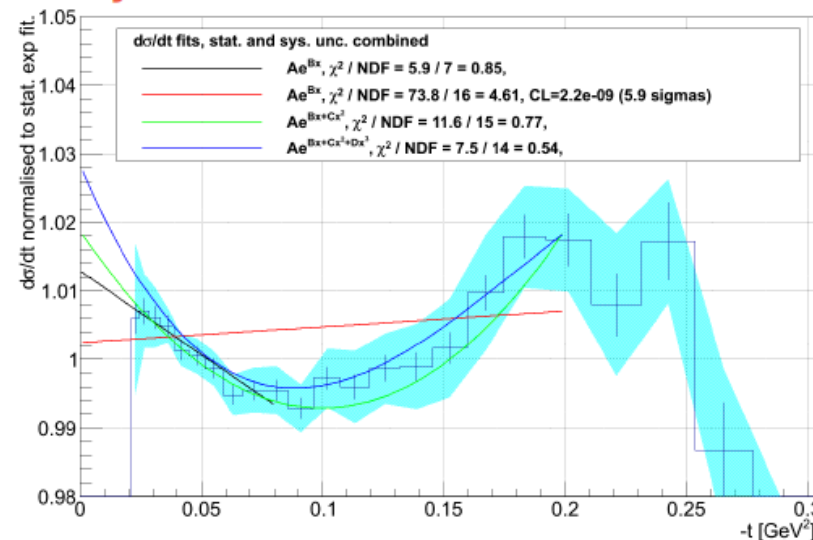
Non-exponential at low-t, details

Elastic Scattering : Cross-section fits at 90 m

Analysis 1: fits $A \exp(b_1 t + b_2 t^2 + \dots)$, N_b parameters in exponent



Analysis 2

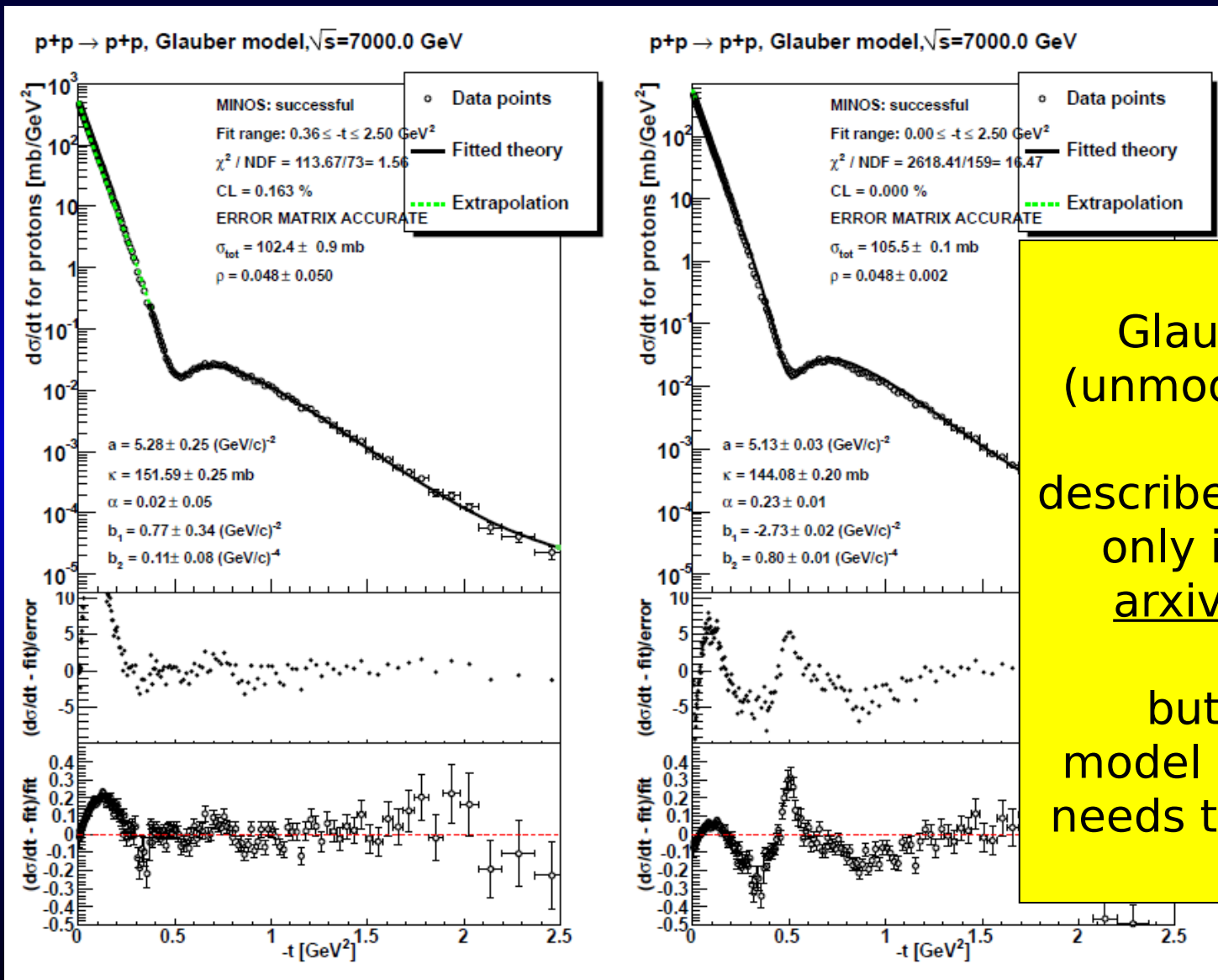


↓
purely exponential fit excluded
at 6 to 7σ significance

new determination
 $\sigma_{\text{tot}} = (101.4 \pm 2.0) \text{ mb}$

TOTEM preliminary
see F. Ferro's talk

GV: dip fits vs small t + dip fits



Glauber-Velasco
(unmodified version)

describes TOTEM $d\sigma/dt$
only in dip region
[arxiv:1311.2308](https://arxiv.org/abs/1311.2308)

but at small t
model is exponential
needs to be extended

Test: due to dataset normalization?

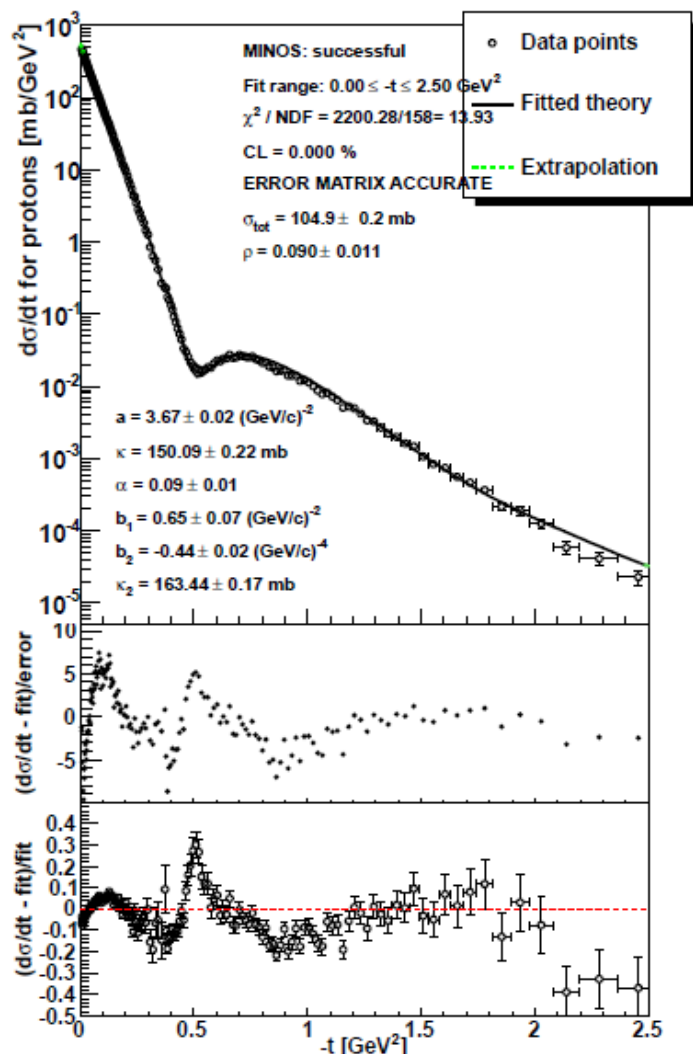
Glauber-Velasco

but fitted with different normalizations at low- t and dip- t

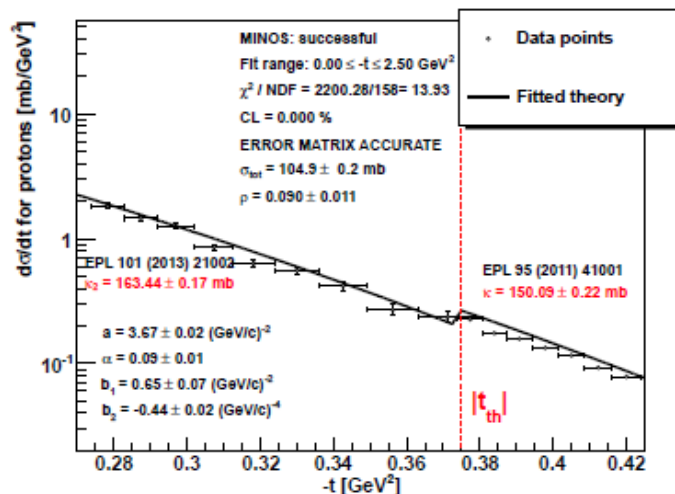
NOT due to normalization

Confirmed by further tests

p+p → p+p, Glauber model, $\sqrt{s}=7000.0$ GeV



p+p → p+p, Glauber model, $\sqrt{s}=7000.0$ GeV



Extension of Glauber-Velasco

$$\frac{f(t)}{f(0)} = \frac{e^{i(b_1|t|+b_2|t|^2)}}{\sqrt{1+a|t|}}$$



$$\frac{f(t)}{f(0)} = \frac{e^{i(b_1|t|+b_2|t|^2)}}{\sqrt{1+a|t|+d|t|^2}}$$

In principle,
similar
to TOTEM method

but expansion
on the parton amplitude level

several other extensions
e.g. Lévy generalizations tested

d: most effective, so far

original GV model: low-t fits

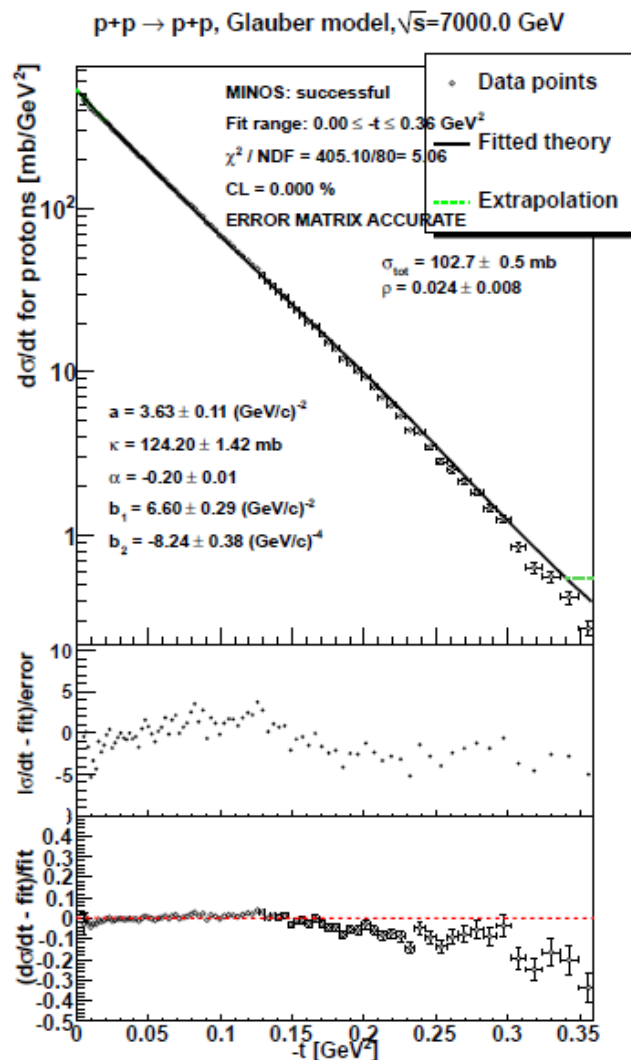


Figure 7: Glauber-Velasco fit, $d = 0$, to the TOTEM low- $-t$ data set.

GV model as it is
deviates from TOTEM data
in the low- t region

but

how about its
generalization?

generalized GV model: low-t fits

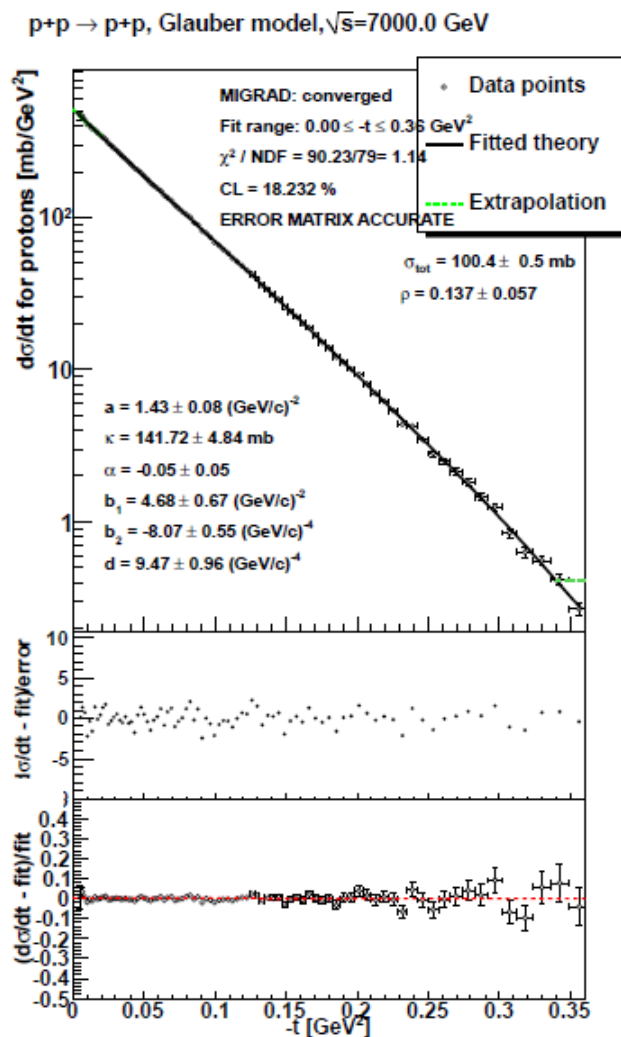


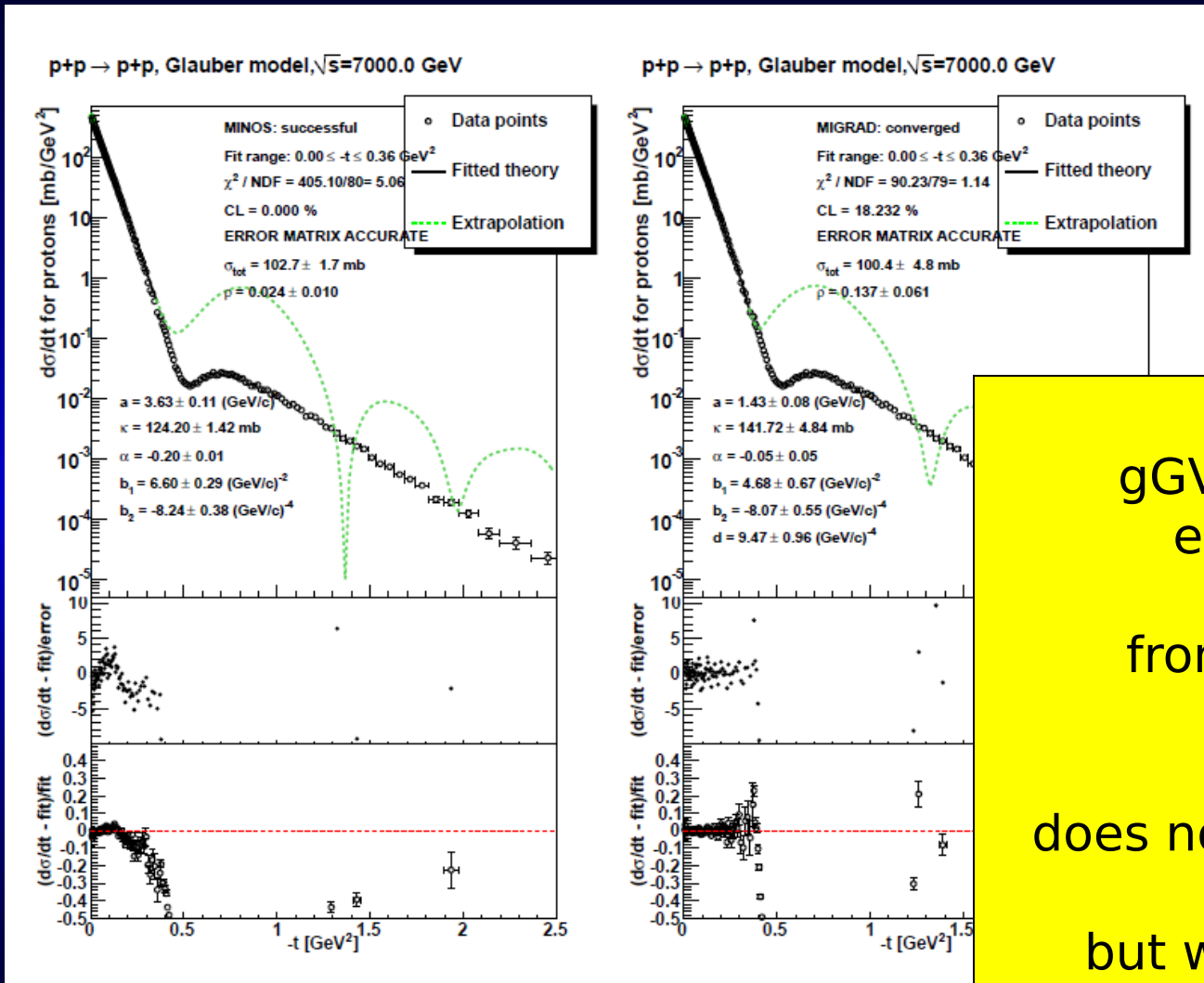
Figure 8: Generalized Glauber-Velasco fit, $d \neq 0$, to the TOTEM low- $-t$ data set.

generalized
GV model with $d \neq 0$
describes well TOTEM data
in the low- t region

but

how about its
extrapolation to the dip?

gGV model extrapolations from low- t



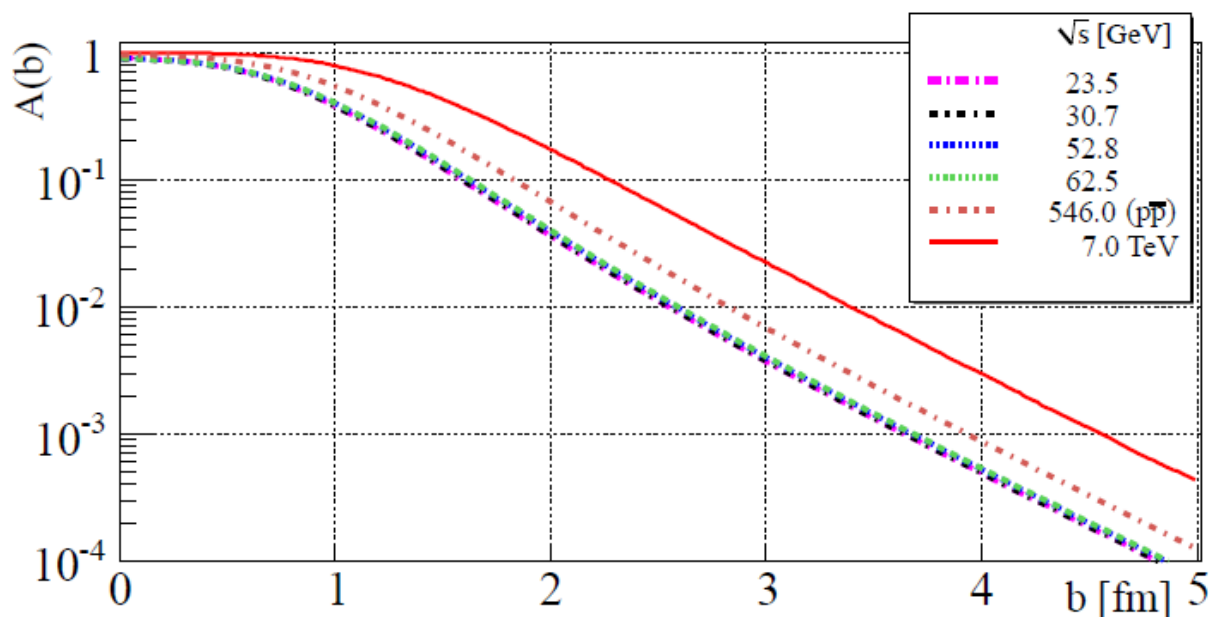
gGV model with d
extrapolated

from low- t region
to dip- t

does not extrapolate well

but work in progress
on low $|t|$ +dip $|t|$ fit

Saturation from shadow profiles



at 7 TeV
proton becomes

Blacker,
NOT Edgier,
and Larger

BEL → BL effect

$$A(b) = 1 - |e^{-\Omega(b)}|^2$$

ISR and SppS:

R.J. Glauber and J.Velasco
Phys. Lett. B147 (1987) 380
b1, b2 fixed

apparent saturation:
proton is ~ black at LHC
up to
 $r \sim 0.7$ fm

see also Lipari and Lusignoli,
[arXiv:1305.7216](https://arxiv.org/abs/1305.7216)

Summary

Investigation of Glauber-Velasco model

works well in the dip region at LHC
but needs extension in low- t

TOTEM: non-exponential behaviour

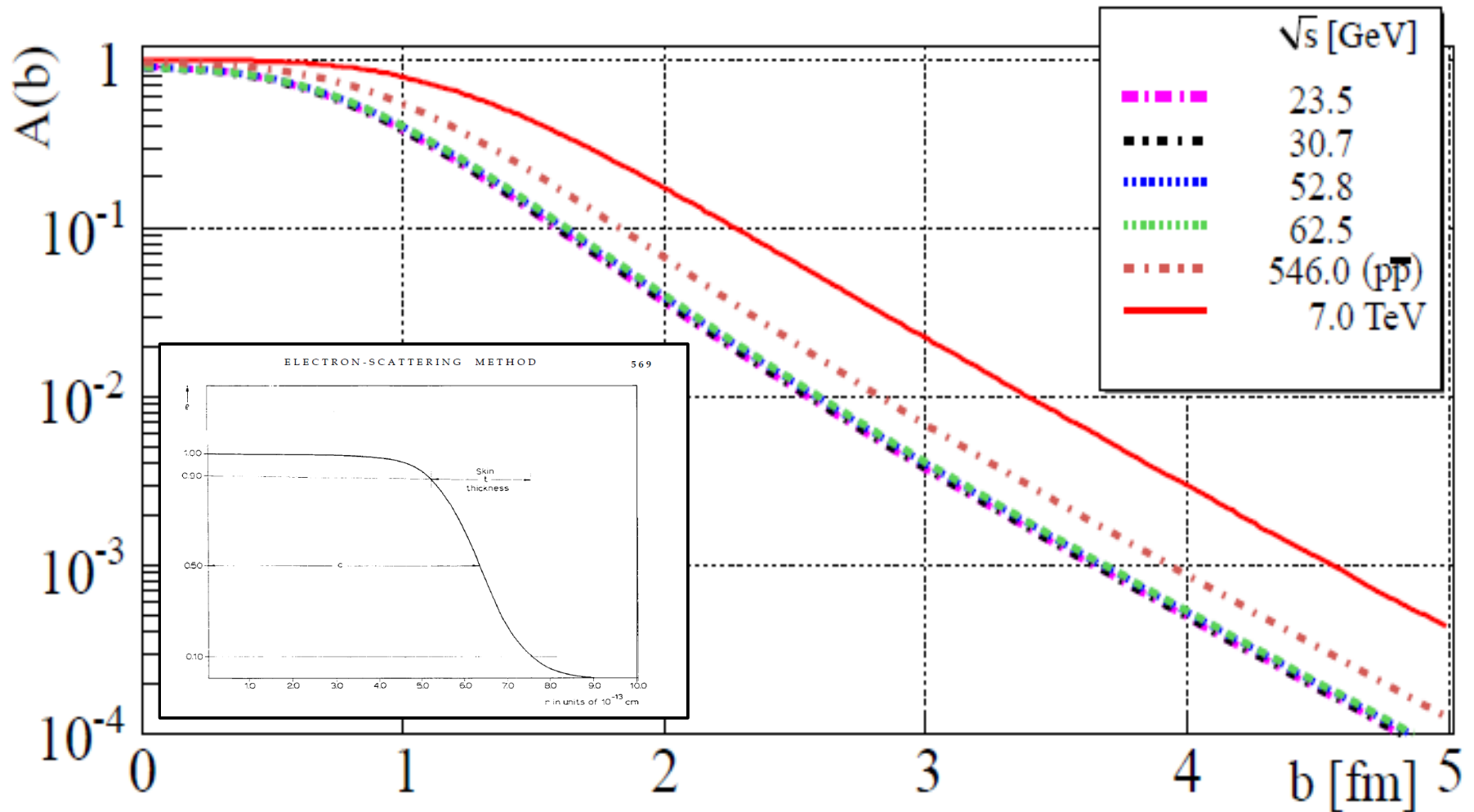
geometric scaling
but not in the Black Disc limit

generalized Glauber-Velasco
works well at low- t
also at dip- t , but ...

from BEL to BL effect

Saturation up to $r \sim 0.7$ fm

Saturation in p+p at LHC



Thank you!

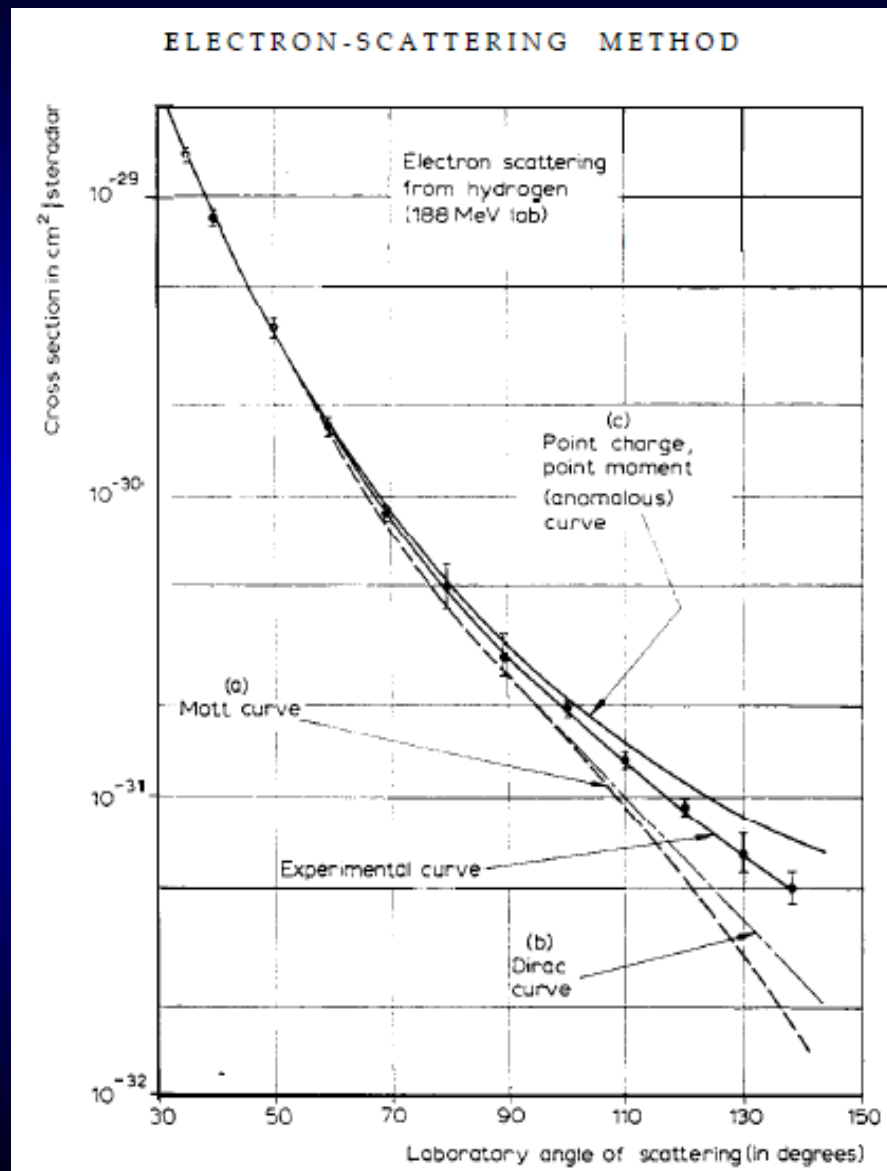
Acknowledgments

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Thank you!

Backup slides - Questions?

1954: first evidence for finite size of p



Curve (a):
spinless, structureless proton.

Curve (b):
Pointlike proton, Dirac moment

Curve (c):
Point charge, point moment

Deviations from (a,b,c):
→ first: proton has a finite size

R. Hofstadter & R. W. McAllister,
Phys. Rev. 98 (1955) 217

R. Hofstadter, Nobel lecture '61