Oscillations in elastic high energy amplitude

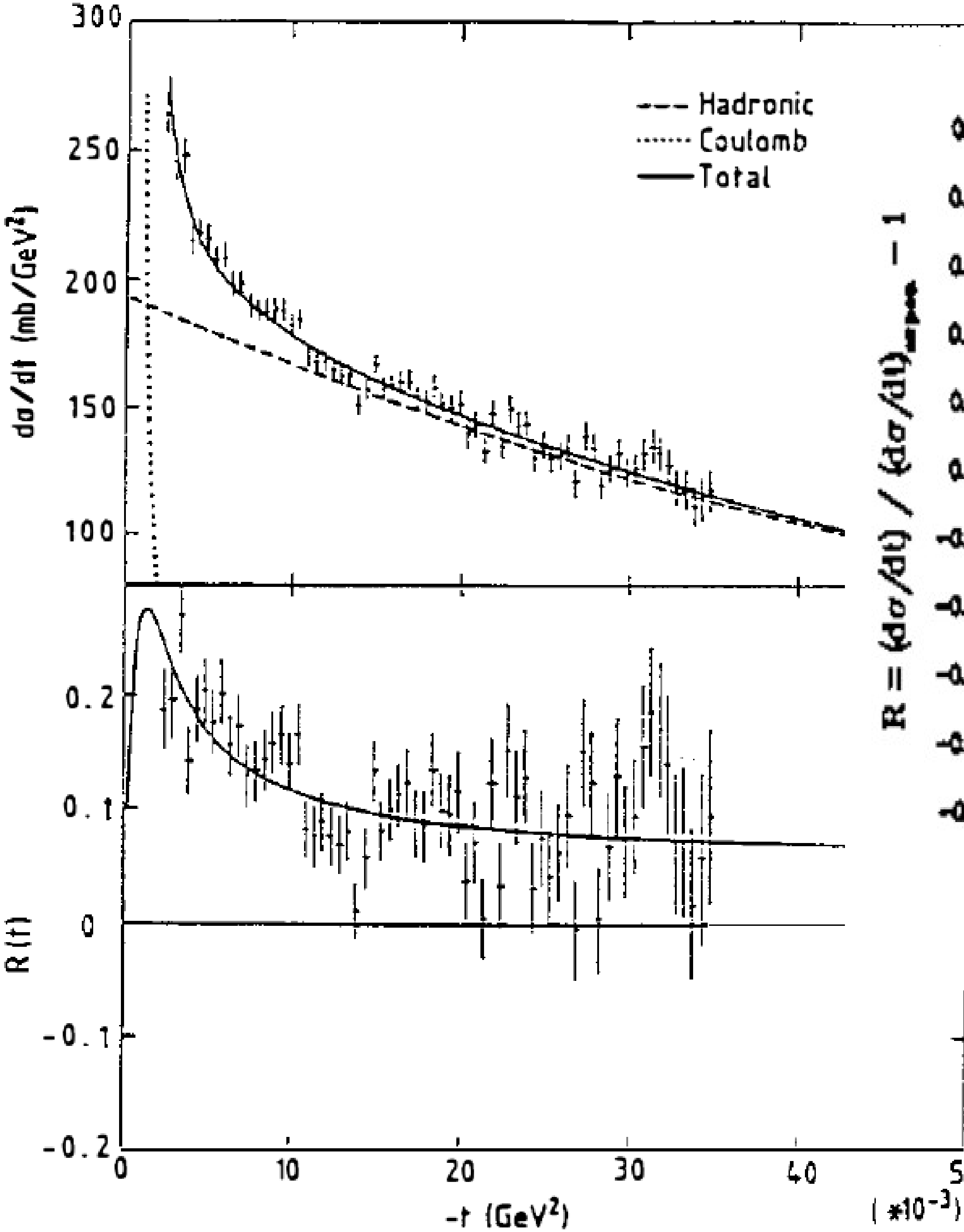
M.G. Ryskin (based on
Selyugin 230814459 and Grafstrom 2401.16115)

Oscillations due to multi-Pomeron exchange
–t representation
– impact parameter, b, representation

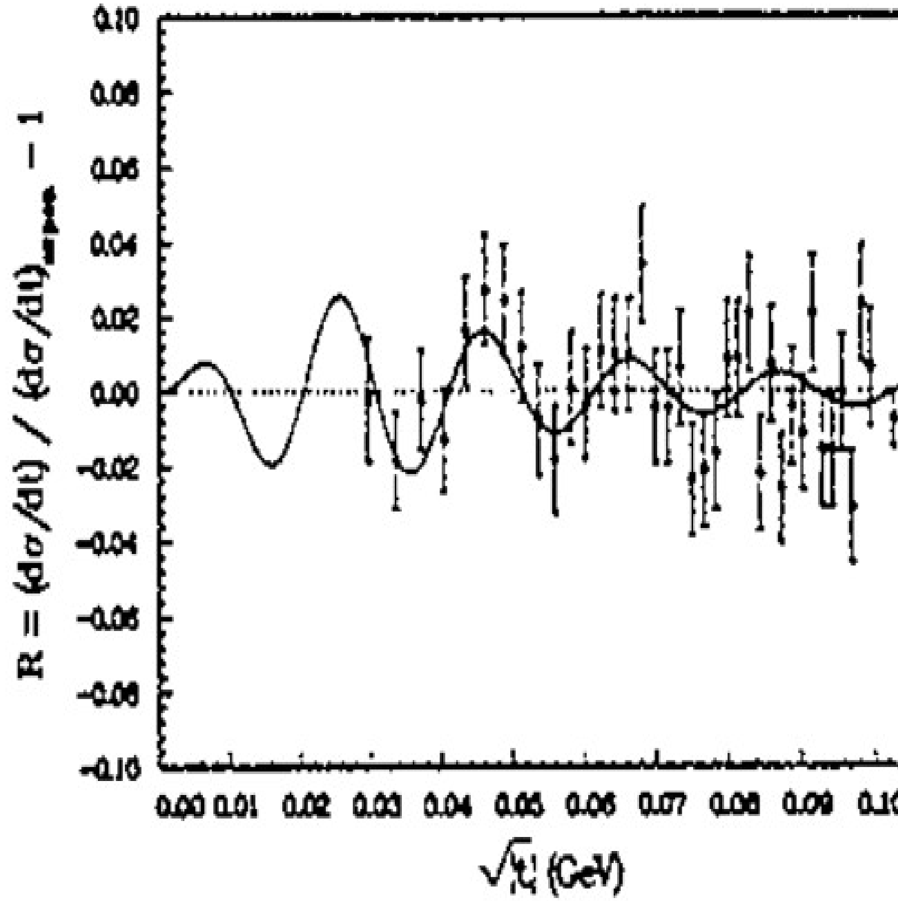
UA4 (541 GeV) and TOTEM (13 TeV)

Global analysis by Selyugin

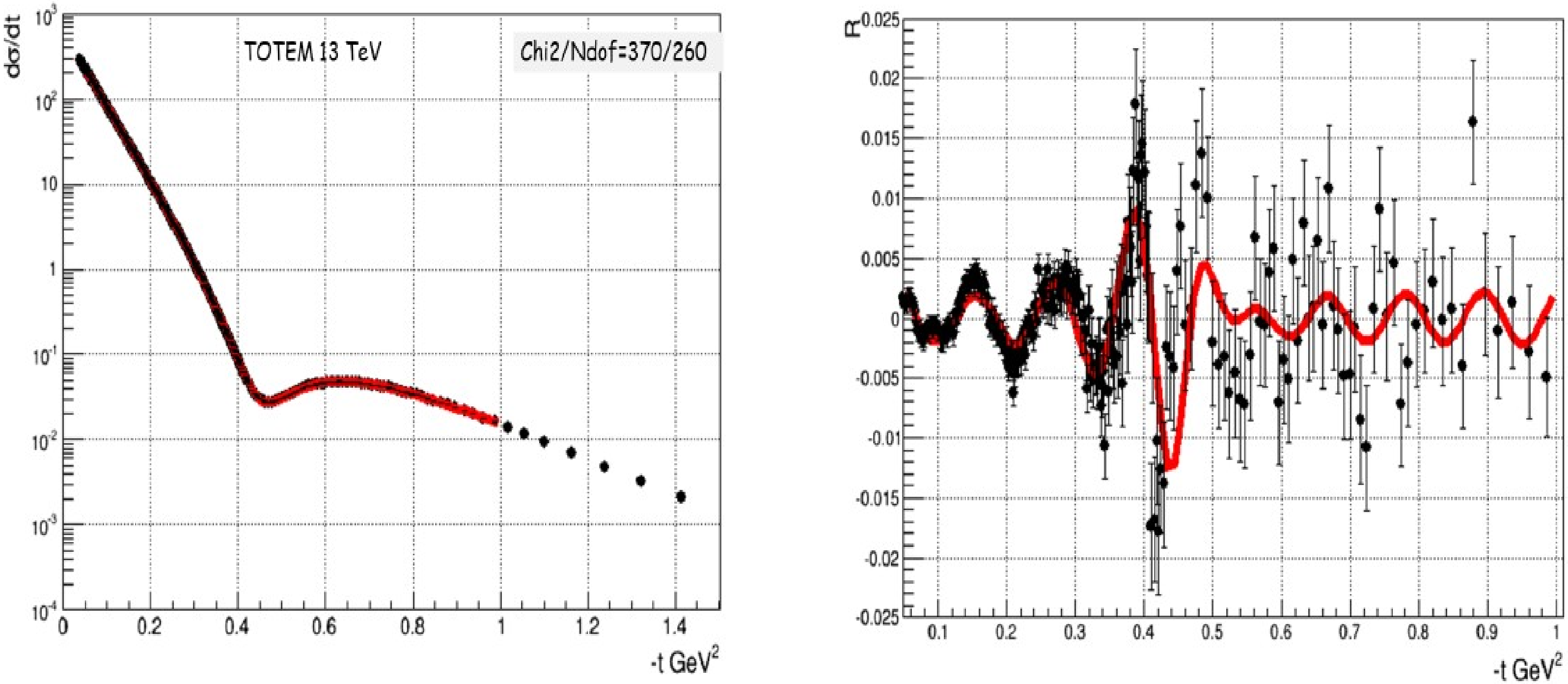
ATLAS did not confirm TOTEM oscillations (which at 13 TeV comes from $b \sim 7$ fm !)



Hadronic
Coulomb
Total
dσ/dt (mb/GeV²)
R(t)
-t (GeV²)
(*10⁻³)



R = (dσ/dt) / (dσ/dt) − 1
√|t| (GeV)



(a) (b)

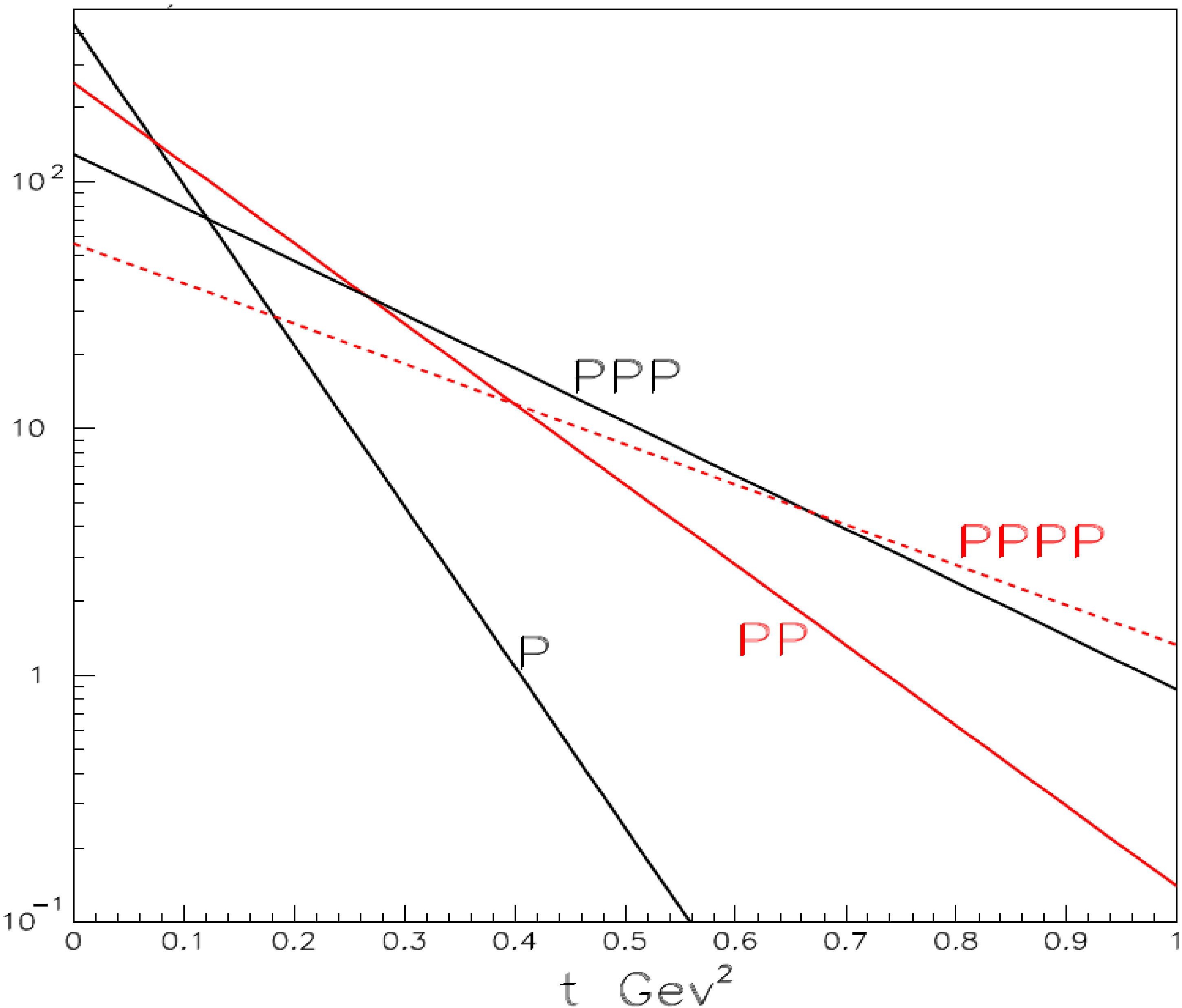
Figure 2: (a) TOTEM data at 13 TeV [18] as a function of $-t$. The data have been fitted with the Philipps-Barger model [16] using Eq. 1 and adding an oscillatory term as given by Eq. 2. (b) The ratio R defined in the text and in Eq. 4 as a function of $-t$. The red curve represents the oscillatory contribution found in the fit.

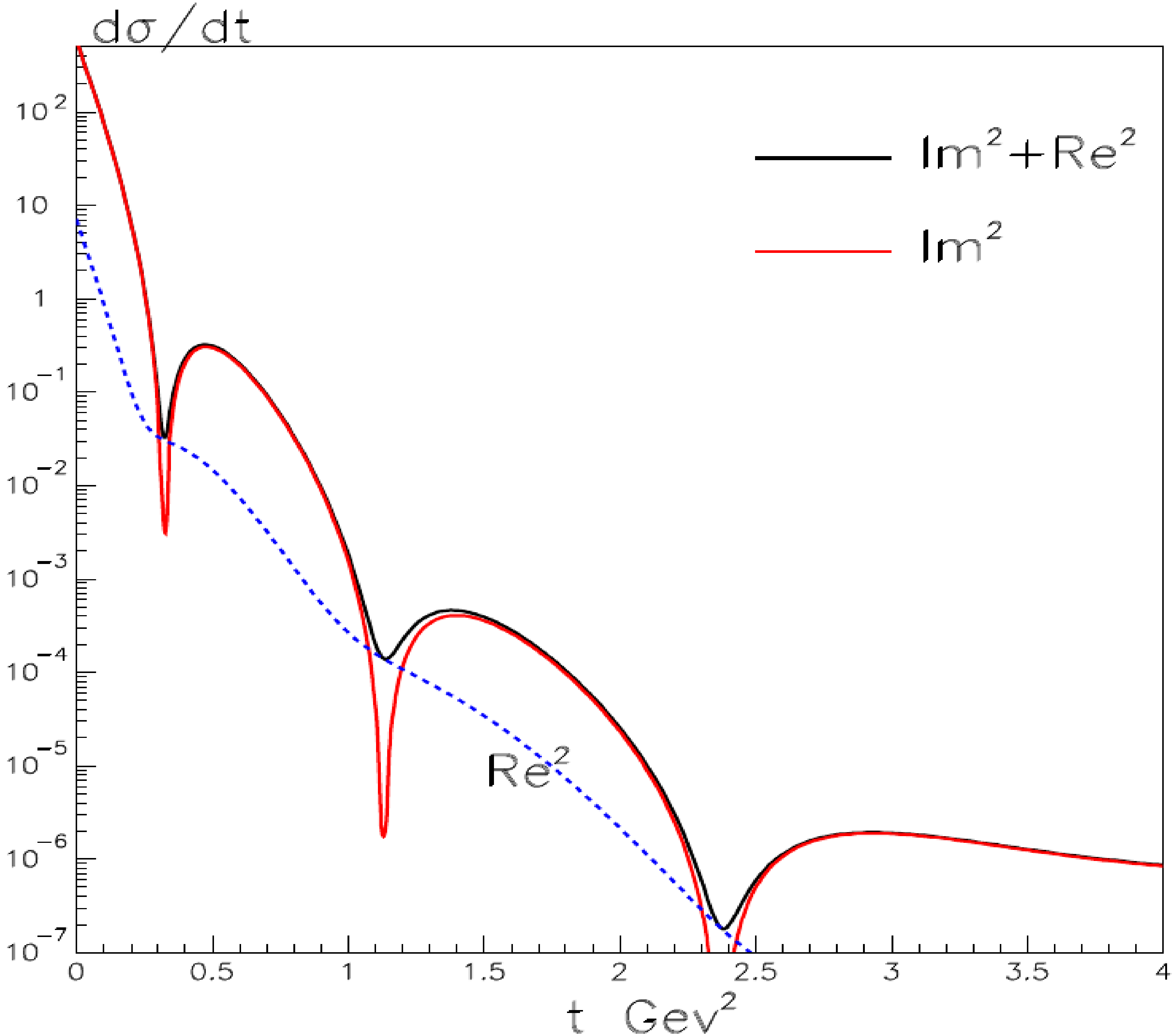
A.A. Anselm, I.T. Dyatlov
(Ph. Lett. B 24 (1967) 479)

An attempt is made to determine the behavior of the elastic cross section at high energy s and large momentum transfer t by considering the contribution of Mandelstam branch points in the complex angular momentum plane. Outside the diffraction cone, but for $|t| << s$ the cross section $d\sigma/dt$ decreases exponentially with $\sqrt{-t}$ (which is in qualitative agreement with Orear's formula) and also exhibits oscillations. The possibilities of experimental investigation of these oscillations is discussed.

G. Auberson, T. Kinoshita, A. Martin (1971)

$$A(t) = P - PP + PPP - PPPP + ...$$





dσ/dt
Im²+Re²
Im²
Re²
10²
10
1
10⁻¹
10⁻²
10⁻³
10⁻⁴
10⁻⁵
10⁻⁶
10⁻⁷
0
0.5
1
1.5
2
2.5
3
3.5
4
t Gev²

Pomeron==> $\Omega(b,s)$=opacity

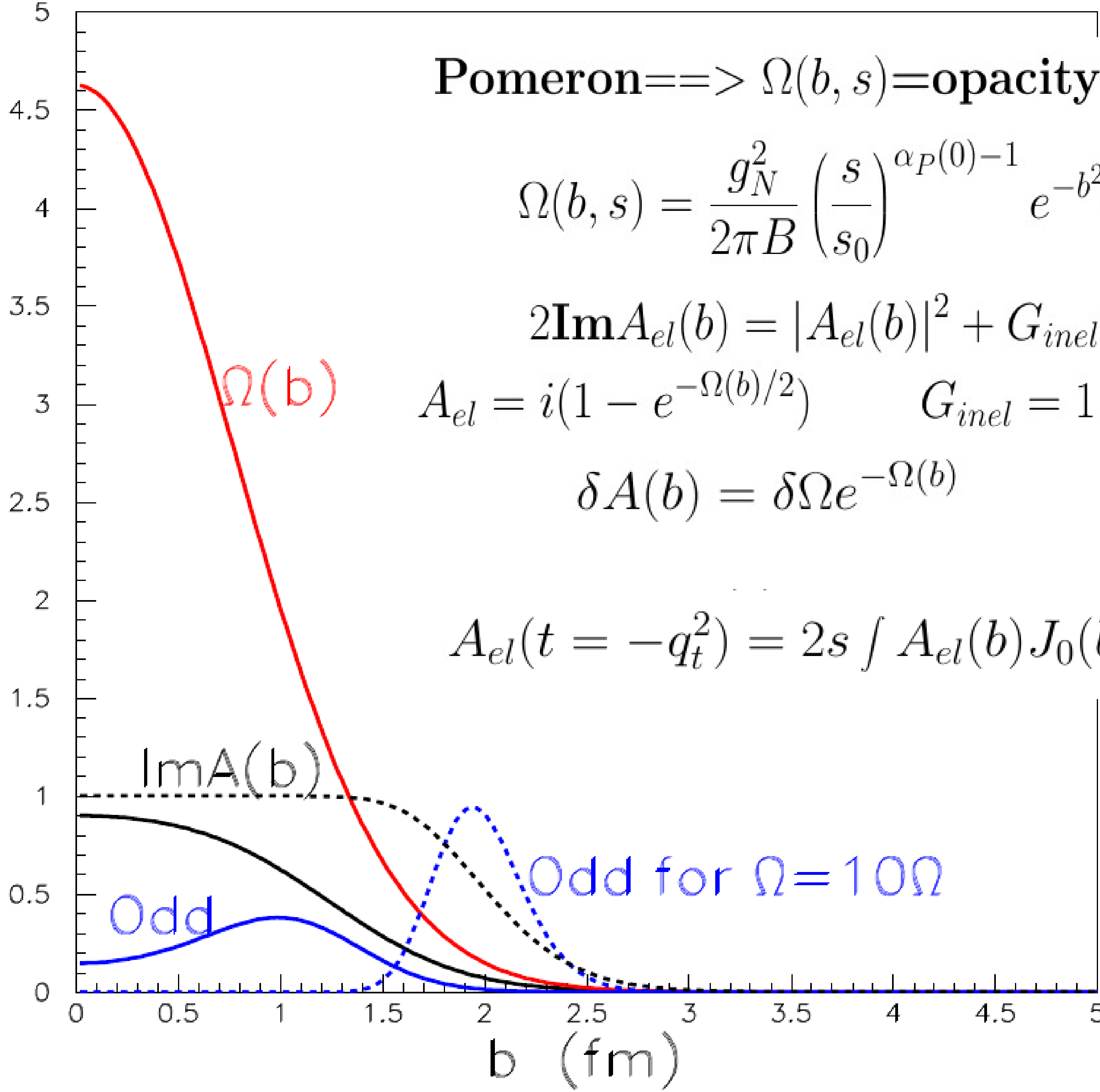
$$\Omega(b,s) = \frac{g_N^2}{2\pi B}\left(\frac{s}{s_0}\right)^{\alpha_P(0)-1} e^{-b^2/2B}$$

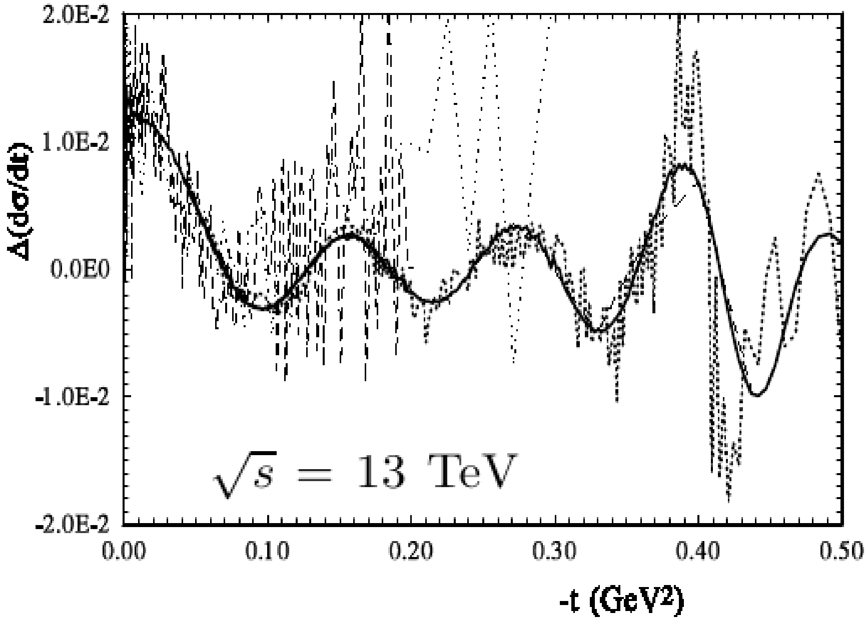
$$2\mathbf{Im}A_{el}(b) = |A_{el}(b)|^2 + G_{inel}(b)$$

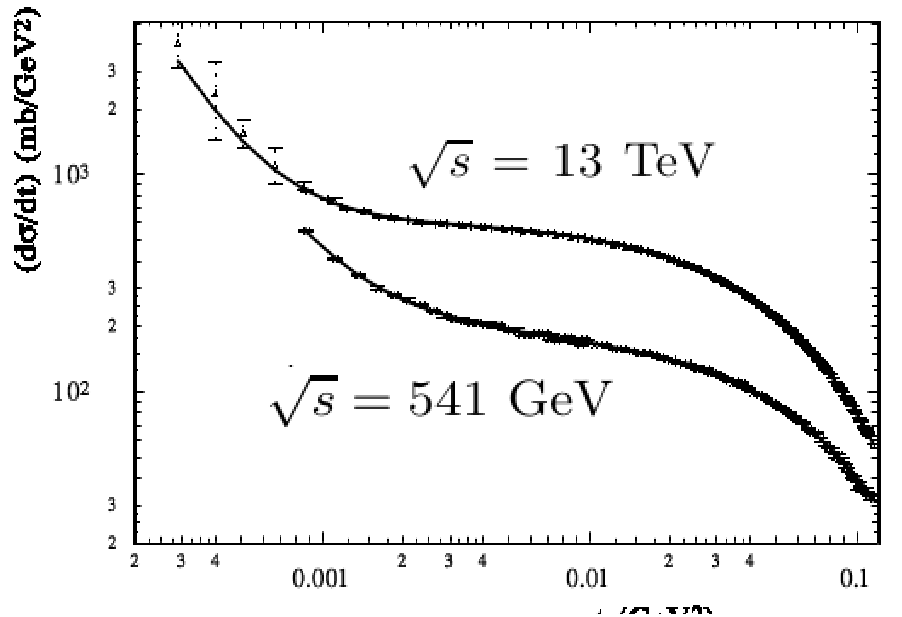
$$A_{el} = i(1 - e^{-\Omega(b)/2}) \qquad G_{inel} = 1 - e^{-\Omega(b)}$$

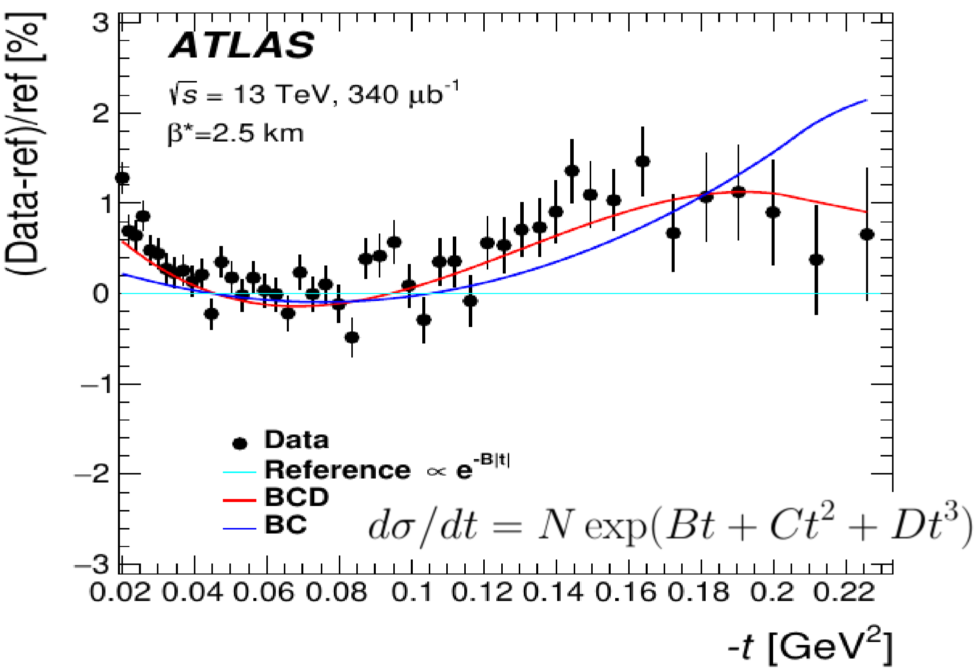
$$\delta A(b) = \delta\Omega e^{-\Omega(b)}$$

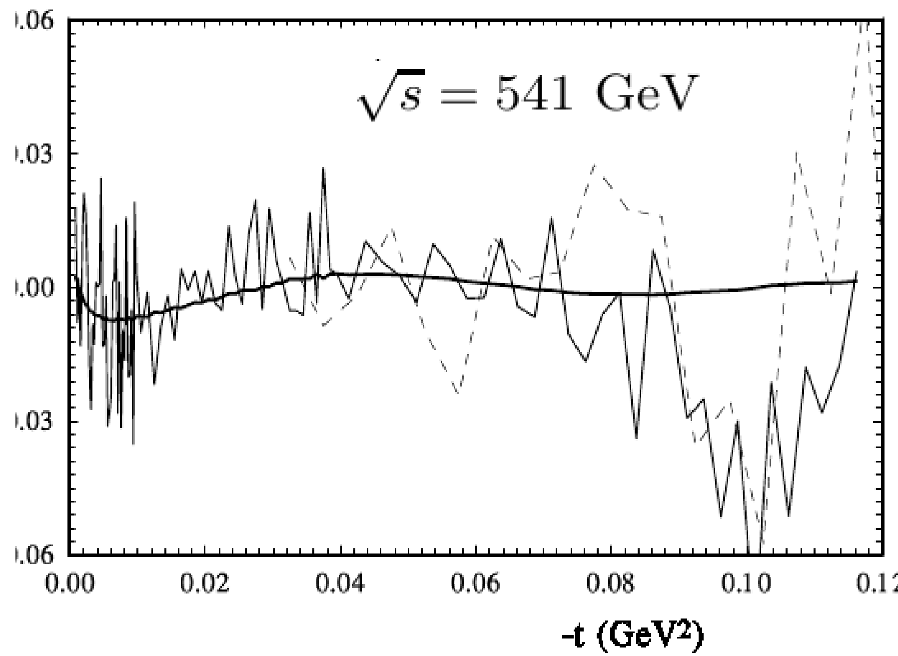
$$A_{el}(t = -q_t^2) = 2s \int A_{el}(b) J_0(b q_t) d^2 b$$




Δ(dσ/dt)
2.0E-2
1.0E-2
0.0E0
-1.0E-2
-2.0E-2
$\sqrt{s}$ = 13 TeV
0.00 0.10 0.20 0.30 0.40 0.50
-t (GeV2)


(dσ/dt) (mb/GeV2)
10³
10²
$\sqrt{s}$ = 13 TeV
$\sqrt{s}$ = 541 GeV
0.001
0.01
0.1


(Data-ref)/ref [%]
ATLAS
√s = 13 TeV, 340 μb⁻¹
β*=2.5 km
Data
Reference ∝ e^{-B|t|}
BCD
BC
$d\sigma/dt = N\exp(Bt + Ct^2 + Dt^3)$
0.02 0.04 0.06 0.08 0.1 0.12 0.14 0.16 0.18 0.2 0.22
-t [GeV²]


$\sqrt{s}$ = 541 GeV
0.00 0.02 0.04 0.06 0.08 0.10
-t (GeV2)

Selyugig - 1321 points $\sqrt{s} > 540$ GeV

$\chi^2 = 1620$ **with oscillations**

$\chi^2 = 2300$ **- No oscillations.**

For 13 TeV – 425 points (TOTEM) + 79 (ATLAS)

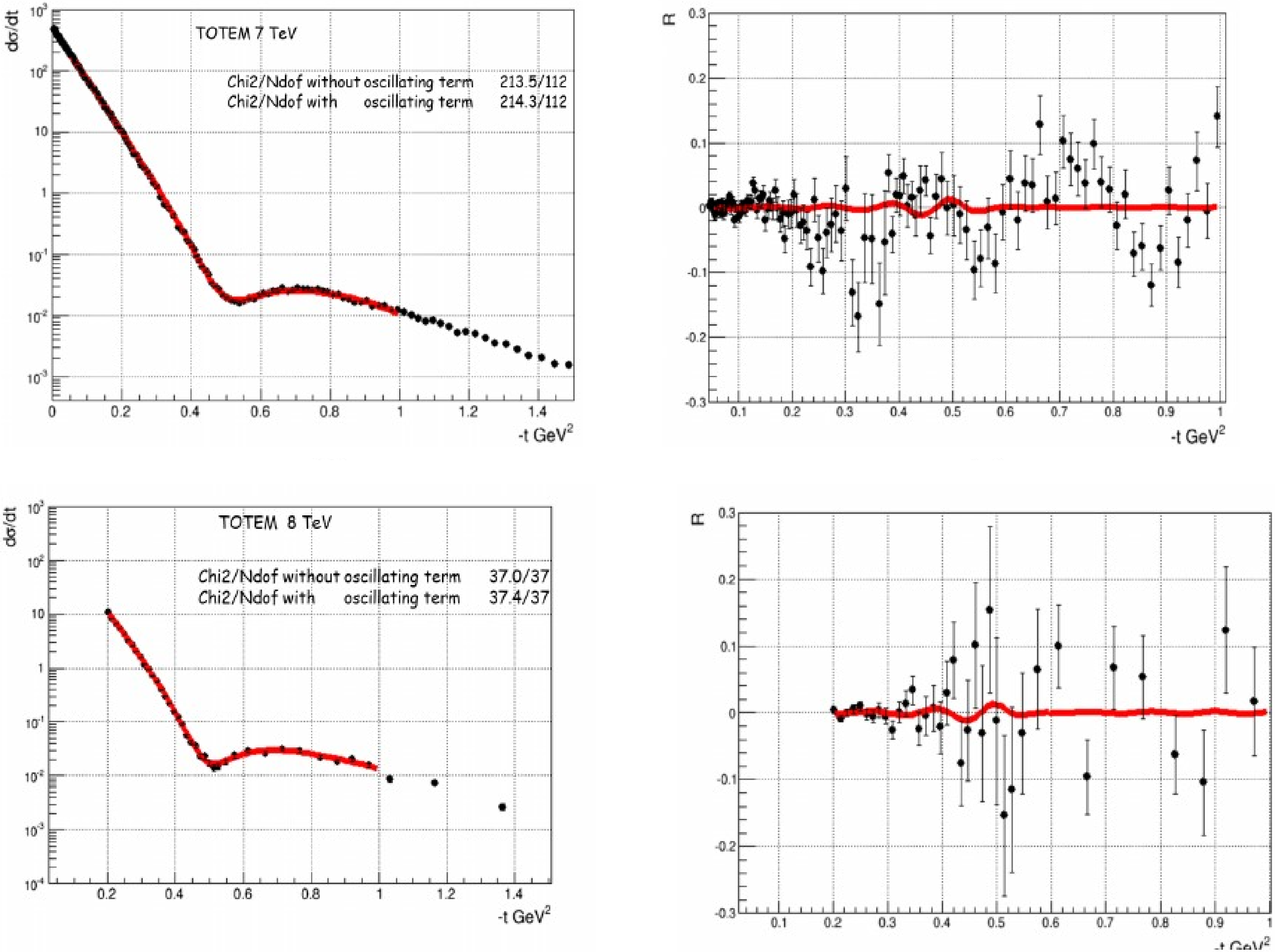
$\chi^2 = 515$ **with oscillations**

$\chi^2 = 1140$ **- No oscillations.**

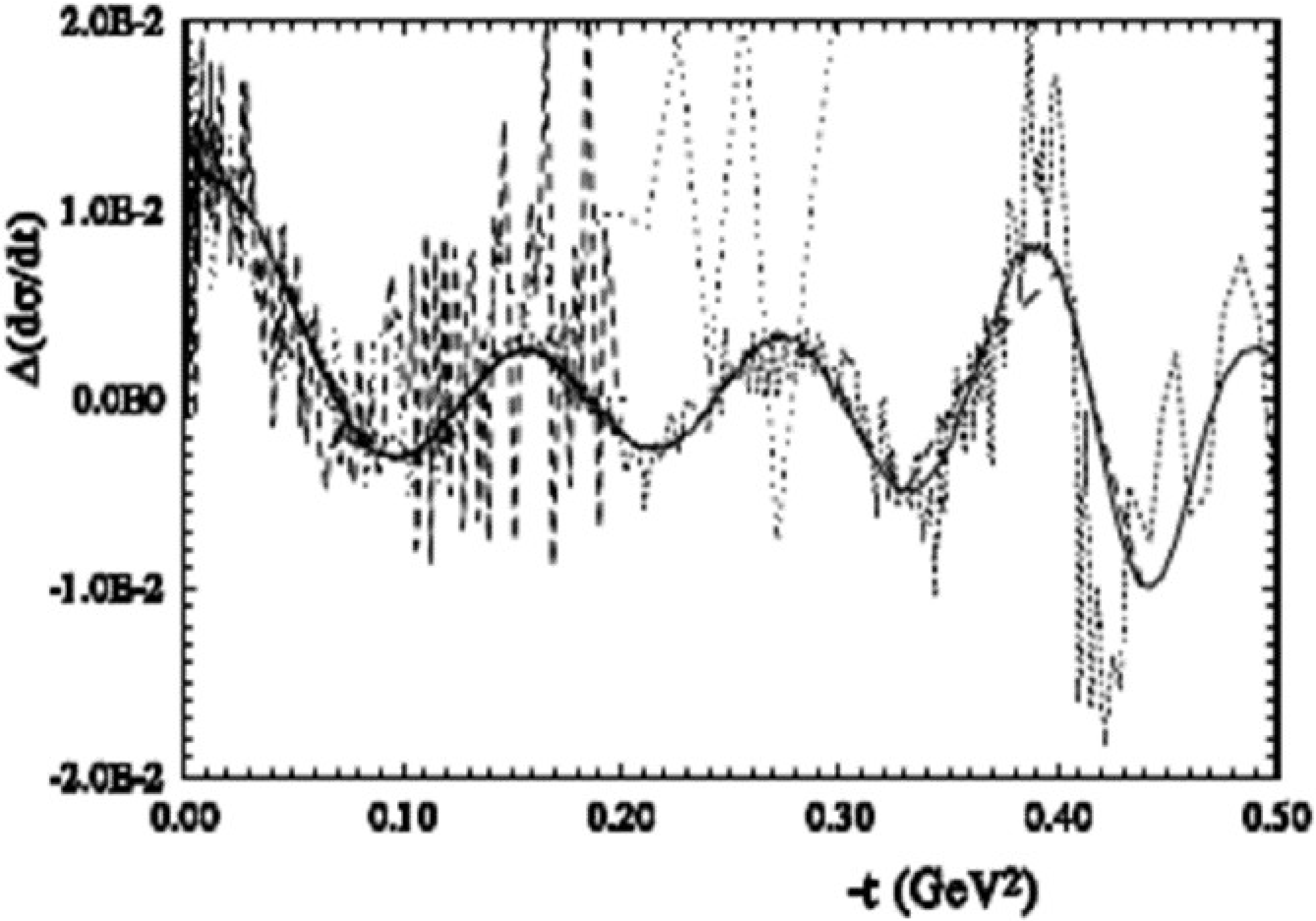
$$f_{osc}(t) = \quad \pm i h_{osc}(1+i)\ln(\hat{s}/s_0)/k \; J_1(\tau)/\tau, \qquad \tau = \pi a_p t \ln s$$

$$h_{osc} = 0.27 \quad k = \ln(13^2 TeV^2)$$

$$F_{main}(t=0) = 27$$


dσ/dt
TOTEM 7 TeV
Chi2/Ndof without oscillating term 213.5/112
Chi2/Ndof with oscillating term 214.3/112
-t GeV²
R
-t GeV²
dσ/dt
TOTEM 8 TeV
Chi2/Ndof without oscillating term 37.0/37
Chi2/Ndof with oscillating term 37.4/37
-t GeV²
R
-t GeV²

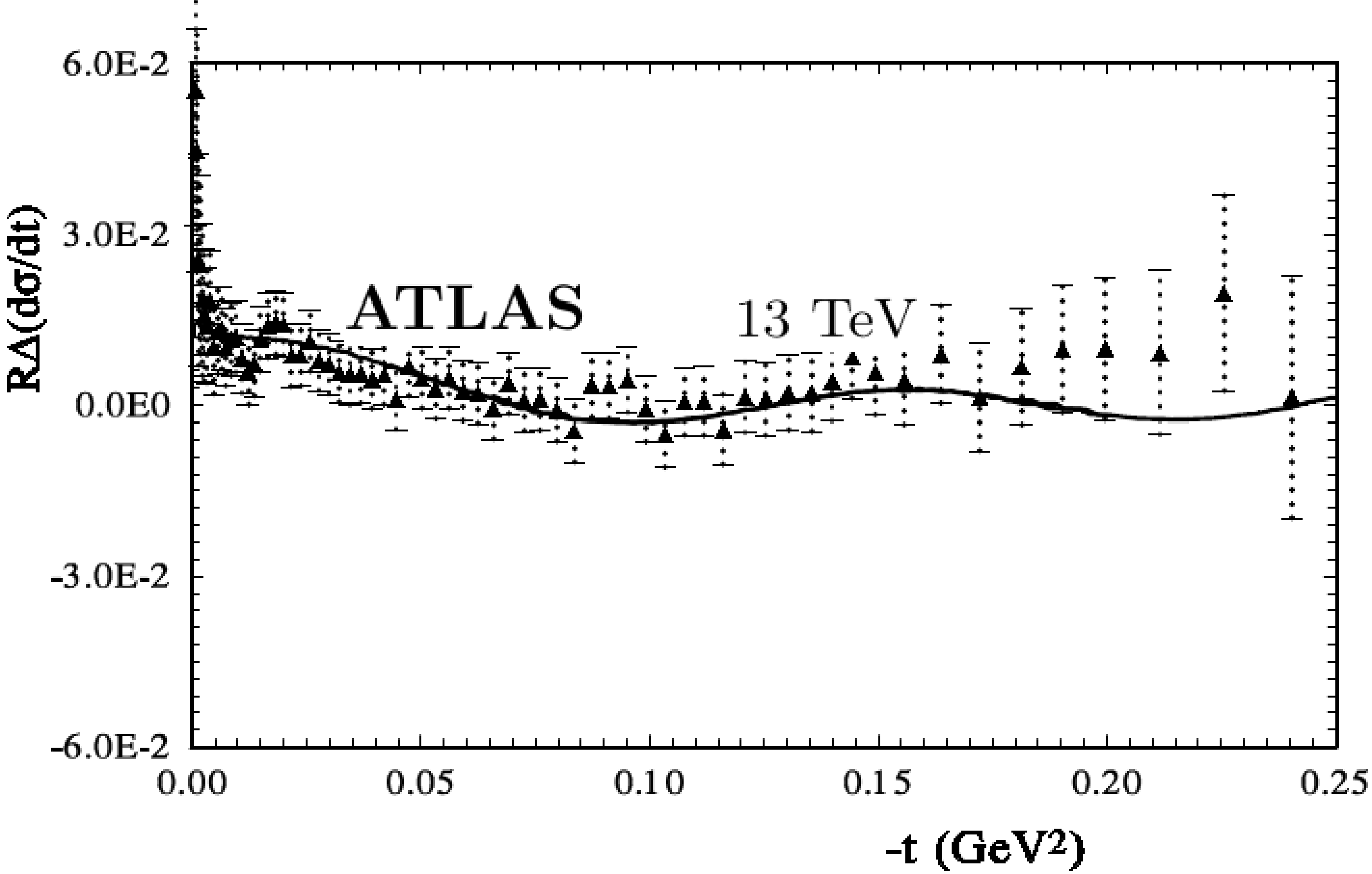
(a) (b)



4 periods up to $t = -0.5\,GeV^2$

$$A_{el}(t = -q_t^2) = 2s \int A_{el}(b) J_0(bq_t) d^2b$$

i.e. $b\sqrt{|t|} \simeq 8\pi = 25 \quad b = 7$ **fm**



$$\frac{d\sigma_{el}}{dt} = |f_{pb}|^2 = |\sqrt{A}e^{Bt/2} + \sqrt{C}e^{(Dt/2+i\Phi)}|^2$$

$$f_{osc}(t) = ih_{osc}(1+i)\cdot \ln \hat{s}\cdot J_1(\tau)/\tau. \qquad \tau = \pi(\phi_0 - t)/t_0,$$

Per Grafström

In this note we have shown that the high statistics differential elastic cross section as measured by the TOTEM experiment at 13 TeV has a clearly significant oscillating component. The χ^2/Ndof takes the value of 873/262 in a fit without an oscillating term and adding an oscillating term the χ^2/Ndof changes to 370/260. This clearly confirms the observation of Selyugin in Ref. [15]. However the data sets of TOTEM at the energies 2.76 TeV, 7 TeV and 8 TeV do not have enough statistics to confirm or reject the oscillating pattern found at 13 TeV.

the structure seen at 13 TeV has to be explained.

a subtle detector effect not understood or it can also be an artifact of the unfolding method

THANK YOU

André MARTIN

Auberson, Kinoshita and Martin [5] have shown that

$$\lim_{s \to \infty} \frac{F(s,t)}{F(s,0)} = f(\tau) \qquad \tau = t\,(\log s)^2$$

for finite arbitrarily large τ, that is for $|t| < c/\log^2 s$, where $f(\tau)$ is an entire function of order $\frac{1}{2}$. This function has an infinite number of zeros [5), 6)] close to the real axis which accumulate around $t = 0$ but which might not be close enough to the physical region to produce oscillations.

black disk $\quad f(\tau) = \dfrac{2 J_1(\sqrt{\tau})}{\sqrt{\tau}}$

AKM $\quad \tilde{\chi}(p) = \frac{1}{2}\exp\left[-\left(\dfrac{1}{1-p^2}\right)^n\right], \quad -1 \leqslant p \leqslant 1, \quad n \gg 1$

$$p = b/b_{max}$$

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(which at 13 TeV comes from $b \sim 8$ fm !)