Variable Formation Zone with Virtual Photons

The Experimental Problem

Multi-particle production on nuclei doesn't seem to 'cascade' or 'shower up'.

SLOW growth of multiplicity with A

$A = nuclear\ number$

See review Busza [1].

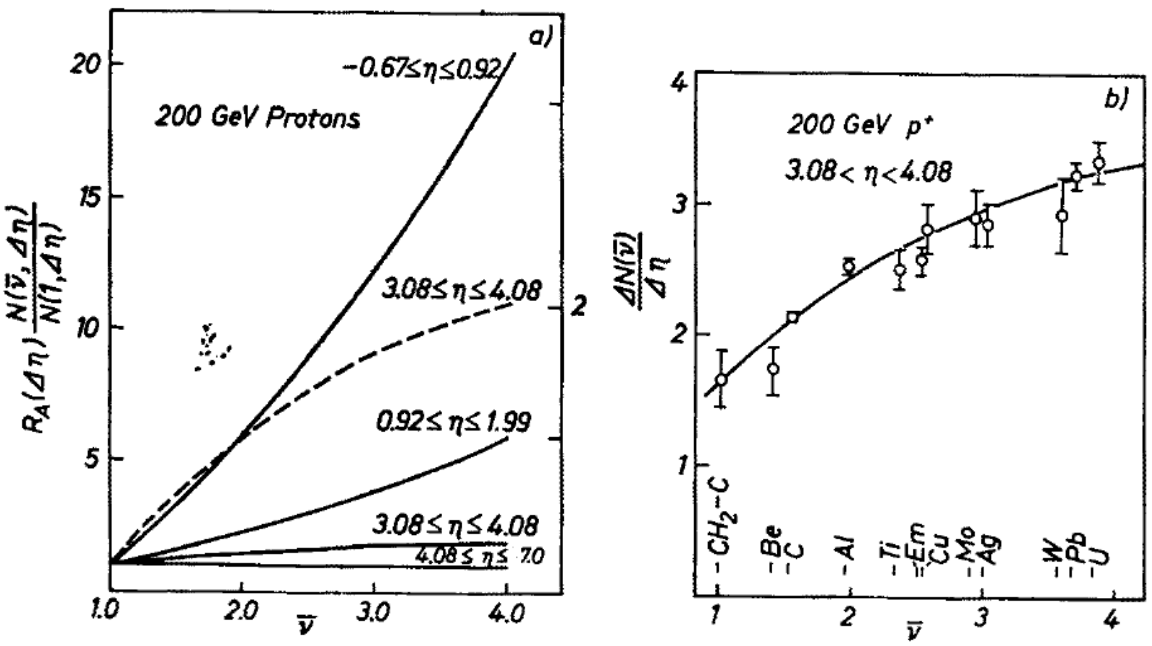


Fig. 4a). For various regions of the pseudorapidity distribution, the variation of $\Delta N/\Delta\eta$ as a function of $\bar{\nu}$. The scale for the broken curve is on the right. Data are from Busza et al. [35] These results show how little, if any, cascading occurs in the nucleus. b) Example of data which were used in obtaining Fig. 4a

$\bar{\nu}$ = average thickness of nucleus

EXPLANATION (according to L.S.[2])

The FORMATION ZONE

Nice idea, but never really thoroughly tested experimentally (in hadron physics)

Could have a simple and dramatic test with hi-E e-A machine.

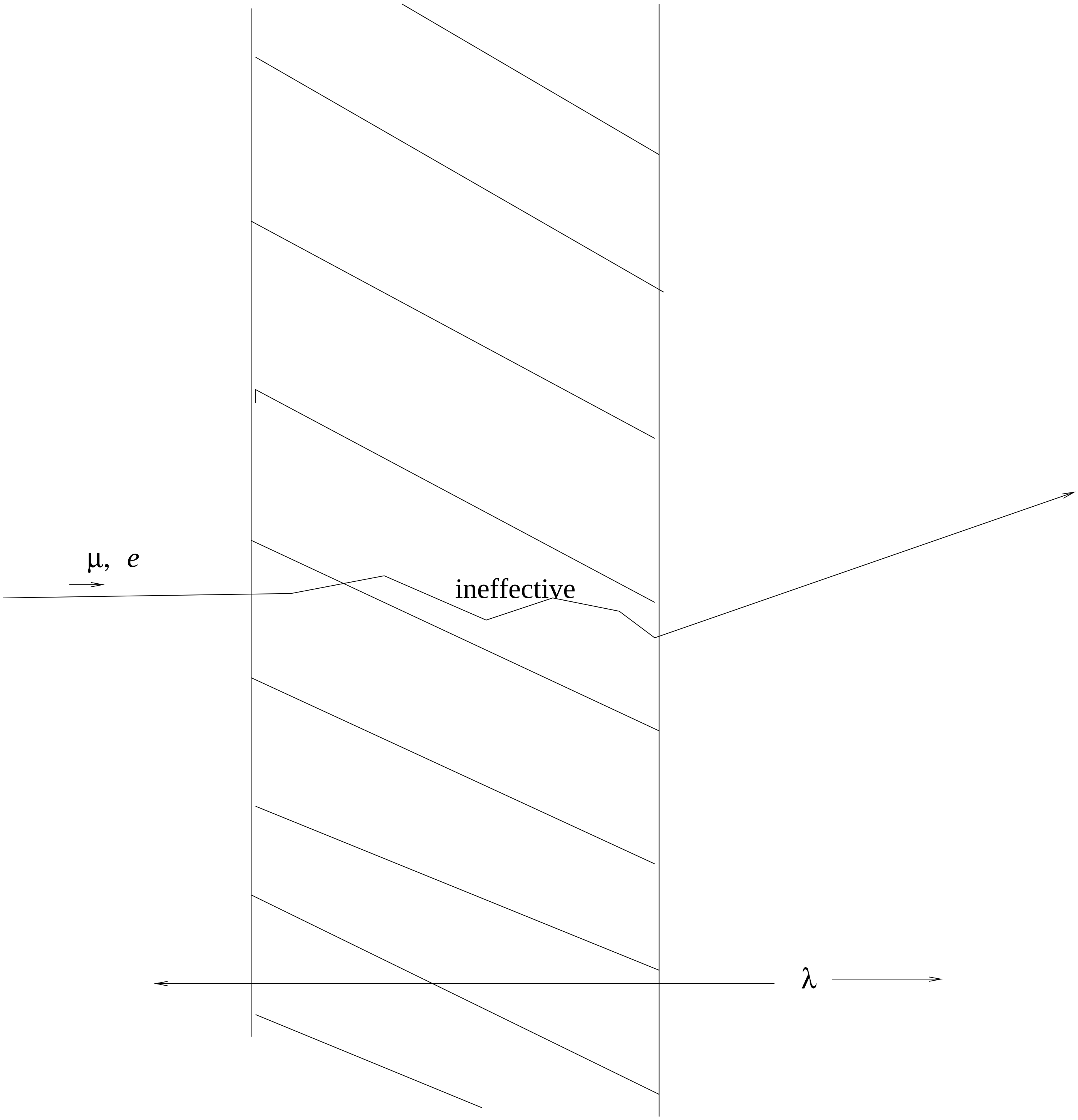
Turn 'cascading' ON and OFF by varying q^2

FORMATION ZONE

It takes a certain time, or for relativistic particles a certain space, for a particle to be created

First proposed by Landau and Pomeranchuk [3] as leading to a suppression of soft bremsstrahlung from hi-E cosmic rays in matter. Verified in detail by a SLAC experiment[4]

Idea Can be understood even classically: for long wavelengths intermediate scatterings are ineffective. Or extra kicks during the time a photon is being “born” don’t lead to more radiation.



For a short scattering region soft photons are produced ‘outside’ the target.

Suggested application to hadron physics [2]

'Birth time' of a pion, or maybe soft gluon should be $\mathcal{O} \sim (few\, 100MeV)^{-1} \sim 1 fermi$ in rest frame of incident beam.

Boosted to lab with large gamma factor, Formation Zone is bigger than any nucleus. zB For 100 GeV beam, FZ is $\sim$ 23 f [2].

Nuclear target is 'thin' , most production is 'outside'.

Explains lack of 'cascading'.

Qualitative TEST in hi-E e-A

Hard to do detailed calculations, but in hi-E e-A
can vary the FZ!

Simple and dramatic TEST:

FZ $>>$ size of nucleus, no cascading

FZ $<<$ size of nucleus, yes cascading

How to vary the FZ

In DIS we have two variables energy and q^2 to vary, as opposed to only (beam) energy

The coherence length l for producing a state of mass M^* in DIS is [5]

$$l \approx \frac{\nu}{q^2+(M^*)^2}$$

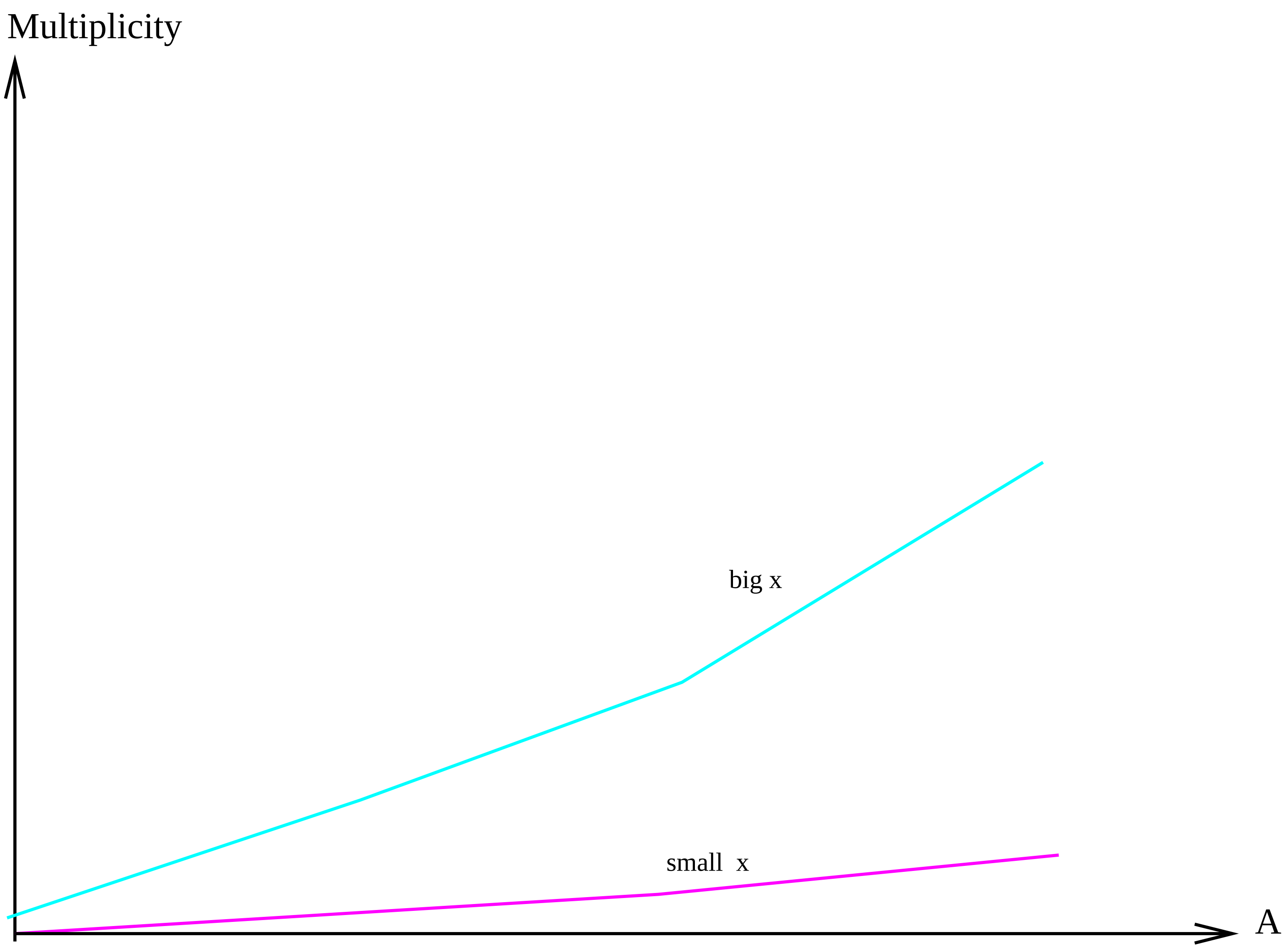
It is plausible this should scale [6] and this is verified by E665[7], where nuclear shadowing sets at about $x_{bj} = 0.02$

Asssociating $l \sim FZ$ suggests that

1) cascading starts for some definite low x_{bj}

2) the value of this x_{bj} is around 0.02

So expect



HOPE this can be done!

Experimental verification, determination of parameters, would be very valuable for understanding spacetime structure of DIS

References

[1] W. Busza, "Review of Experimental Data on Hadron-Nucleus Collisions at High-Energies," Acta Phys. Polon. B **8**, 333 (1977).

[2] L. Stodolsky, "Formation Zone Description in Multiproduction," VIIth International Colloquim on Multiparticle Reactions, Oxford. 1975; MPI-PAE-PTH-23/75.

[3] L. D. Landau and I. Pomeranchuk, "Limits of applicability of the theory of bremsstrahlung electrons and pair production at high-energies," Dokl. Akad. Nauk Ser. Fiz. **92**, 535 (1953) and **92**, 735 (1953). Translations RT-350 and RT-864. Further work was presented by Migdal: A. B. Migdal, "Bremsstrahlung and pair production in condensed media at high- energies," Phys. Rev. **103**, 1811 (1956). doi:10.1103/PhysRev.103.1811, so this is often refered to as the LPM effect.

[4] P. L. Anthony *et al.* [SLAC-E-146 Collaboration], "Bremsstrahlung suppression due to the LPM and dielectric effects in a variety of materials," Phys.

Rev. D **56**, 1373 (1997) doi:10.1103/PhysRevD.56.1373
[hep-ex/9703016]. Miesowicz

[5] L. Stodolsky, "The Inelastic Shielding Effect", in the Hercegnovi Lectures 1969: Methods in Subnuclear Physics, ed. M. Nikolic, Gordon and Breach; pg 165. The length l has of course nothing to do with the proton, the appearance of m_p when evaluating the expression is simply an artifact of the way x_{bj} is conventionally defined.

[6] L. Stodolsky, ''Rapidity gap' events and shadowing in deep inelastic scattering," Phys. Lett. B **325**, 505 (1994). doi:10.1016/0370-2693(94)90047-7

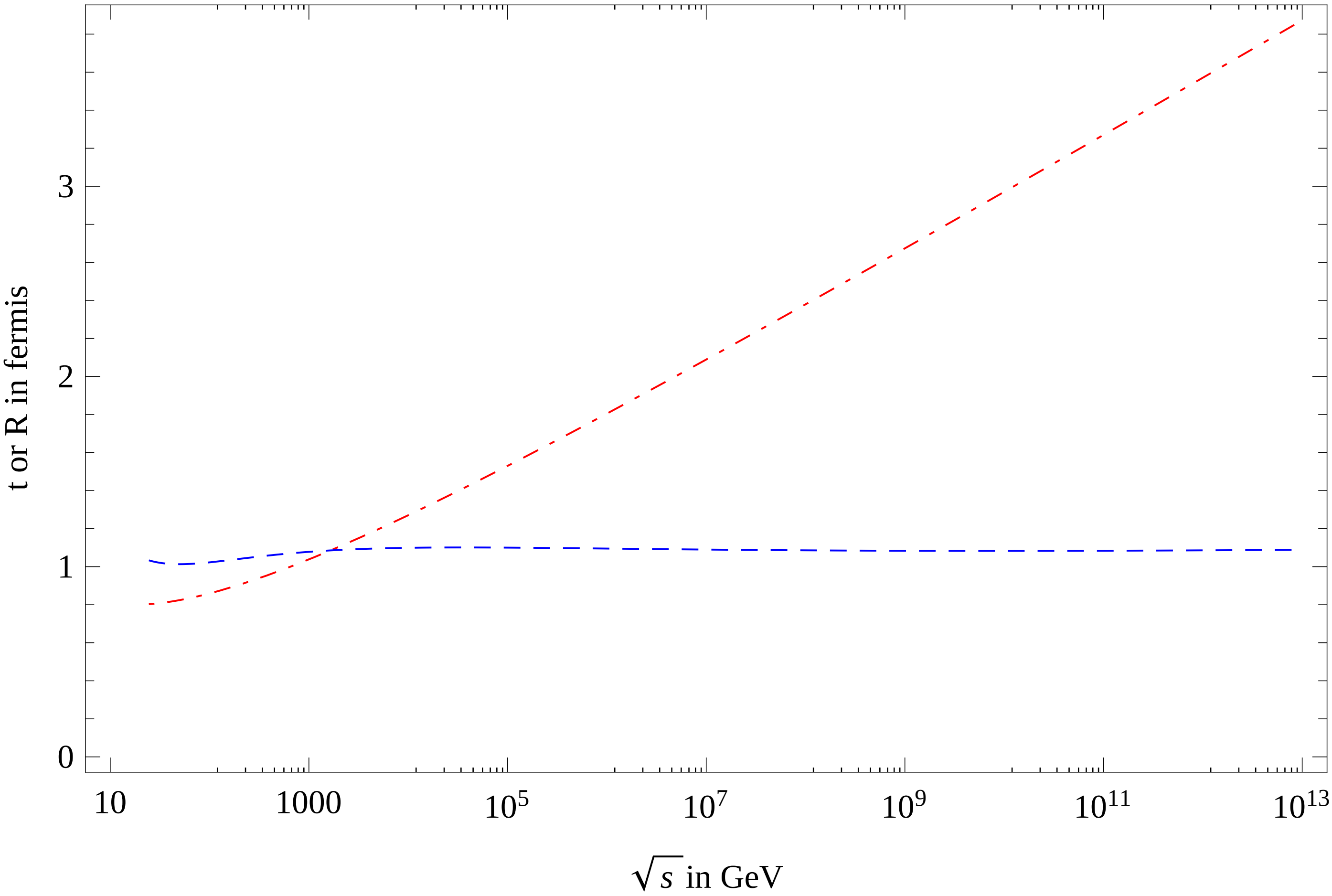
[7] M. R. Adams *et al.* [E665 Collaboration], "Saturation of shadowing at very low $x_{\rm BJ}$," Phys. Rev. Lett. **68**, 3266 (1992). doi:10.1103/PhysRevLett.68.32
M. R. Adams *et al.* [Fermilab E665 Collaboration], "Shadowing in the muon xenon inelastic scattering cross-section at 490-GeV," Phys. Lett. B **287**, 375 (1992). doi:10.1016/0370-2693(92)90999-K

Talk II —–The

"EDGE' in VHE

Scattering

There is an 'EDGE of the proton' in P-P scattering [1],[2]



Red= Radius for $\sigma^{TOT} = 4\pi R^2$

Blue=t=thickness of Edge

Note t constant with energy

To find t:

$$t \approx (\sigma^{TOT} - 2\sigma^{EL})/\sqrt{(\pi/2)\sigma^{TOT}}$$

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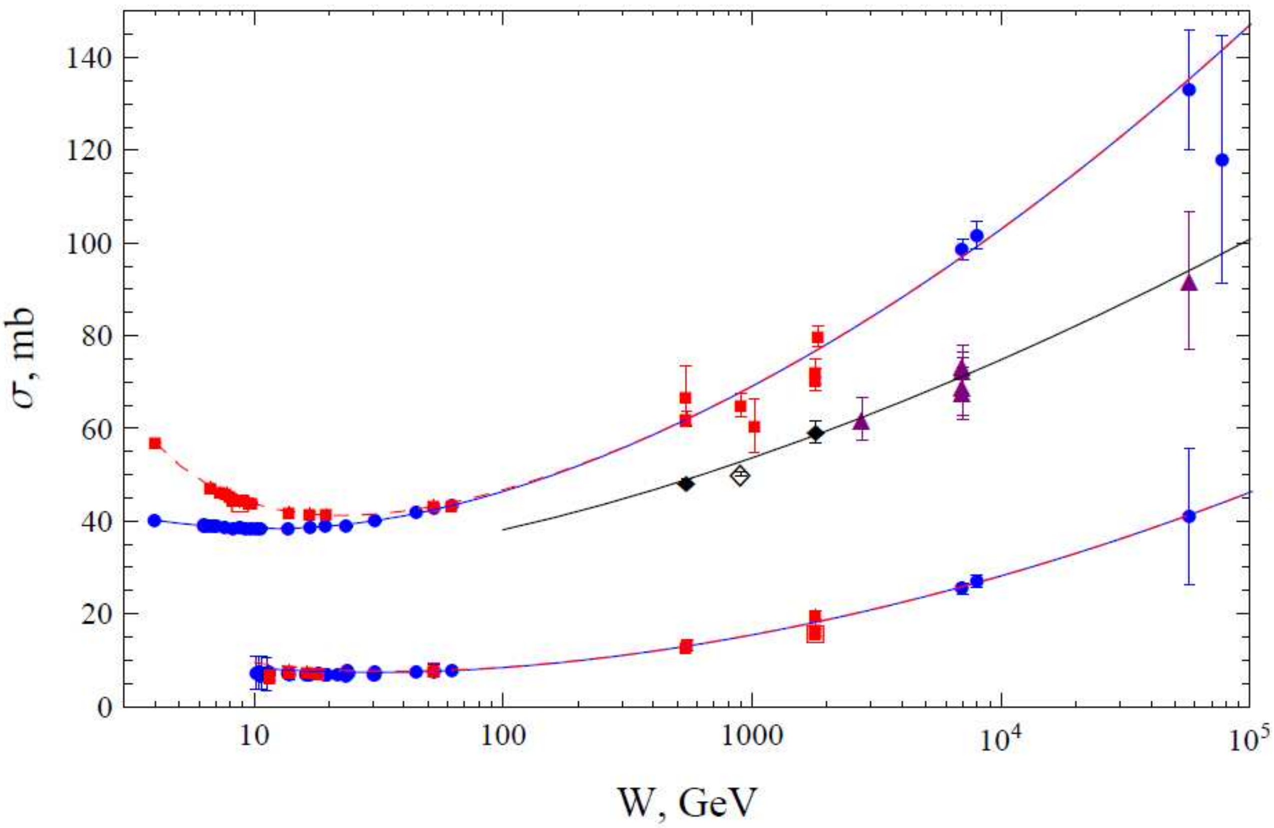

Exists an ‘Edge’ in DIS?

Need accurate σ^{EL}

Precise VDM parameters??

Maybe best via proton recoil definition.
$Q_{recoil} < 1 GeV$??

Or consider true ‘elastic’ $\gamma_{Virtual}P \rightarrow \gamma_{real}P$??

Would be very pretty !

My GUESS

An energy - indpendent ‘edge’ (as seen through t) will exist for low x_{bj}

Then disappears at high x_{bj}

Reason: The t formula is based [1] on having an imaginary amplitude, (strong absorbtion). While true at small x_{bj}, (VDM...) very probably not at large values

References

[1] M. M. Block, L. Durand, F. Halzen, L. Stodolsky and T. J. Weiler, "Evidence for an energy-invariant 'edge' in proton-proton scattering at very high energies," Phys. Rev. D **91**, no. 1, 011501 (2015) doi:10.1103/PhysRevD.91.011501

[2] L. Stodolsky, "Behavior Of Very High Energy Hadronic Cross Sections," arXiv:1703.05668 [hep-ph].