Analytic Calculations In Multiperipheral Model

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Introduction

A new calculation method developed in [1] for hadron-hadron scattering cross-section .

This method based on so-called *"constraint maximum point"* [1] of scattering amplitude considering restrictions imposed by energy-momentum conservation law.

Furthermore, derived that the contribution of longitudinal momenta into the virtualities is vital and results in the new mechanism of cross-section growth, not considered in Regge-based approaches [2].

The new term "Mechanism of virtuality decrease" coined for it.

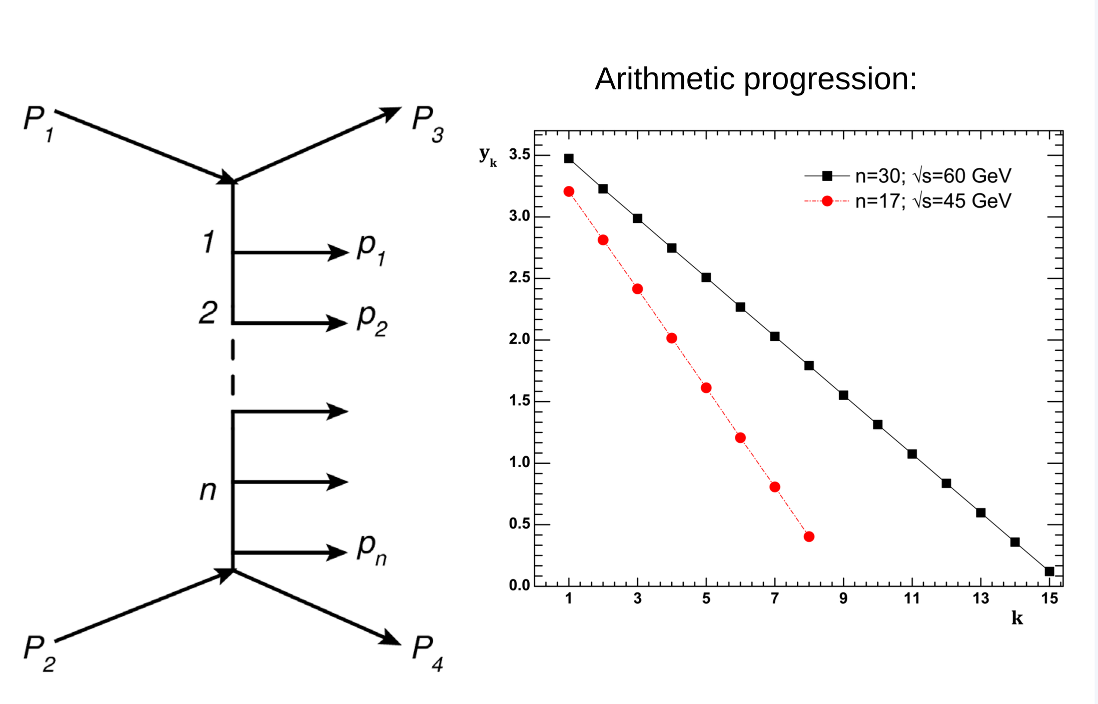
Objective

First, obtain analytic expression for scattering amplitude at the point of constrained maximum.

Second, develop analytic approach considering the interference contributions at high multiplicity of final-state particles.

Constrained maximum point of scattering amplitude

At the point of constraind maximum rapidies of final state particles form an arithmetic progression [1]:



Representation of proton-proton scattering amplitude as a "comb" Feynman diagram

Y : particle rapidity
X : position on the "comb"

Scattering amplitude at the point of constrained maximum can represented analytically [1]:

$$A^{(0),n}=\left(1+a\left(\sqrt{s},n\right)\right)^{-1}\left(1+b\left(\sqrt{s},n\right)\right)^{-(n-1)}\exp\left(c\left(\sqrt{s},n\right)\right)$$

$$a\left(\sqrt{s},n\right)=\left(\frac{1}{\left(\sqrt{s}/M\right)^{\frac{2}{n+1}}-1}\right)^2$$

$$b\left(\sqrt{s},n\right)=\left(\frac{\left(\sqrt{s}/M\right)^{\frac{1}{n+1}}}{\left(\sqrt{s}/M\right)^{\frac{2}{n+1}}-1}\right)^2$$

$$c\left(\sqrt{s},n\right)=2\left(1-(n-1)\left(\sqrt{s}/M\right)^{-\frac{n}{n+1}}\left(a\left(\sqrt{s},n\right)\right)^{-\frac{1}{2}}\right)$$

$$\times\left(\left(a\left(\sqrt{s},n\right)\right)^{-1}+\left(\sqrt{s}/M\right)^{\frac{2}{n+1}}\right)^{-1}$$

S : squared energy of colliding particles; M : proton mass

The four-momentum's scalar square (in Minkowsky space) for each virtual particle on the "comb" satisfies [1]:

$$\left(\frac{1}{\left(\sqrt{S}/M\right)^{\frac{2}{n+1}}-1}\right)^2\le\left|(p_i-p_{i+1})^2\right|\le\left(\frac{\left(\sqrt{S}/M\right)^{\frac{1}{n+1}}}{\left(\sqrt{S}/M\right)^{\frac{2}{n+1}}-1}\right)^2$$

$(p_i-p_{i+1})^2$ - "virtuality"

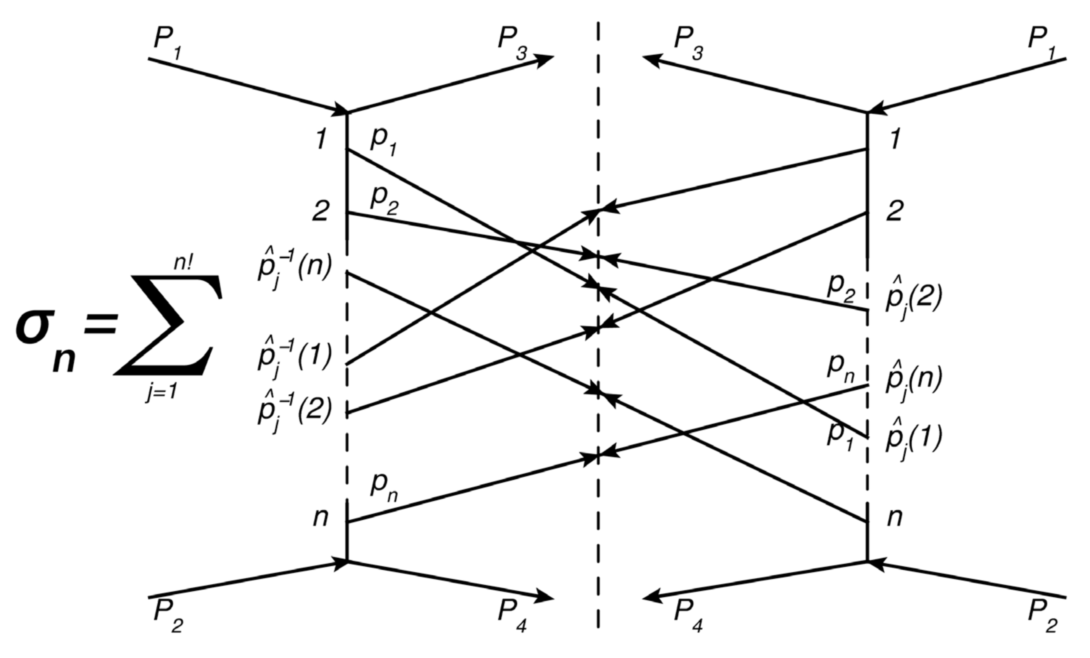
Mechanism of Virtuality Decrease

The increasing of $\left(\sqrt{s}/M\right)^{\frac{2}{n+1}}$ results in the growth of scattering amplitude maximum and therefore the growth of cross-section with the growth of energy $\sqrt{s}$.

If not too small n, the value of $\left(\sqrt{s}/M\right)^{\frac{2}{n+1}}$ is close to 1 even at high energiy ($\sqrt{s}>>M$). Thus, the virtuality can't be reduced to transverse momentum squared, as is usually supposed in Regge-based approaches.

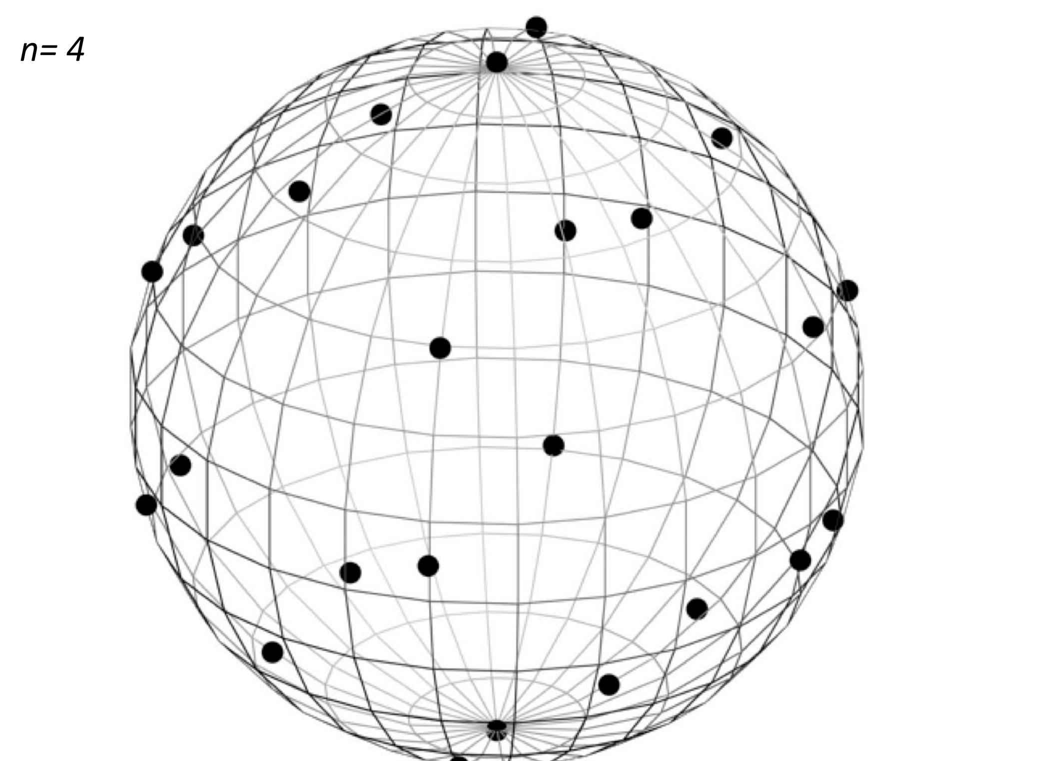
Interference contributions

Partial cross-section is a sum of n! interference contributions:



Cross-section of pp inelastic process with formation of n secondary particles. Represented as a sum of "cut" diagrams.

Each interference contribution corresponds to a point on *n-1* -dimensional sphere [1]:



Each point corresponds to one of interference "cut" diagrams for "2→4" scattering process

Interference contribution points are uniformly distributed on the sphere. That evolves the sum of interference contributions to the integral:

$$\sigma_n=\int_{-1}^{1}\sigma'_n(z)\rho(z)dz$$

$z=\cos(\theta)$, θ : angle between the vector, directed to "interference contribution point" on the sphere and the vector directed to the north pole of the sphere

$\sigma'_n(z)$: magnitude of interference contribution as a function of z

$\rho(z)$: density function for interference contributions

The relevance of this approach has been proved in [1] for *n=8-10*. For that case of *n* the interference contributions can be evaluated directly.

References

1. I.Sharf et al. "Mechanisms of hadron inelastic scattering cross-section growth in multiperipheral model within the framework of perturbation theory", *Accepted to Journal Of Modern Physics*, arXiv:0711.3690[hep-ph], arXiv:0605110[hep-ph], arXiv:0912.2598[hep-ph]

2. E.A Kuraev, L.N Lipatov, and V.S Fadin, "Multi Reggeon processes in the Yang-Mills theory", *Sov. Phys. JETP*, 44:443-450, 1976

Conclusions

The analytic expression obtained for scattering amplitude in the point of constrained maximum.

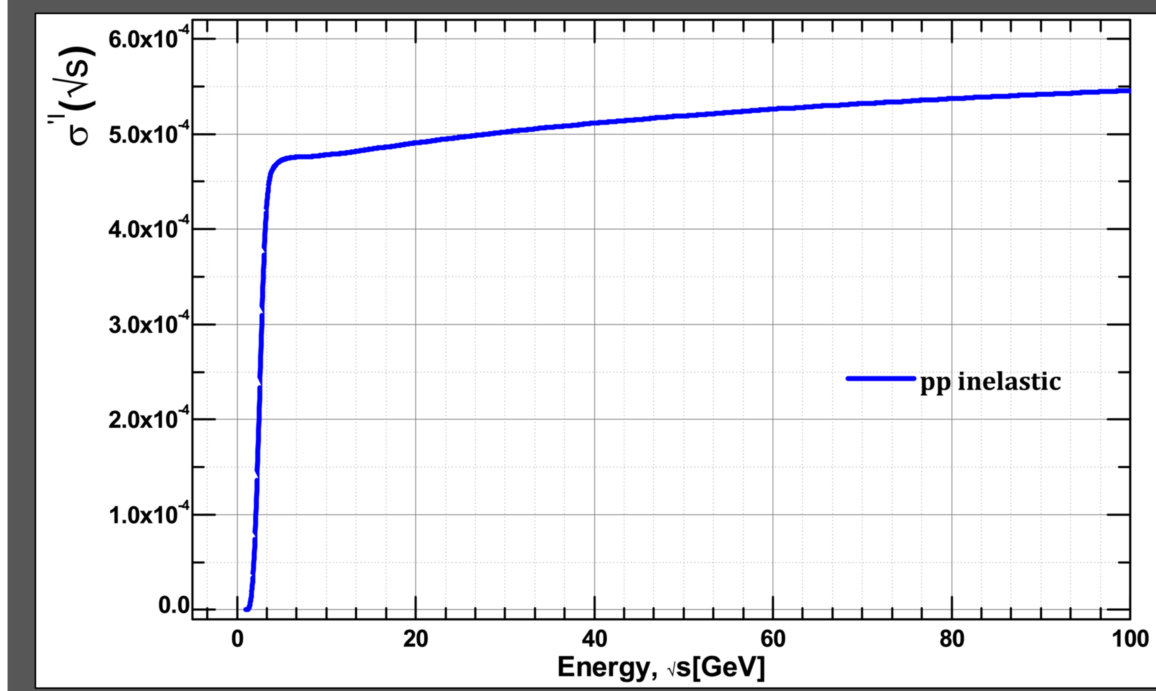
The result shows difference in multiperipheral model from that based on multi-Regge kinematics.

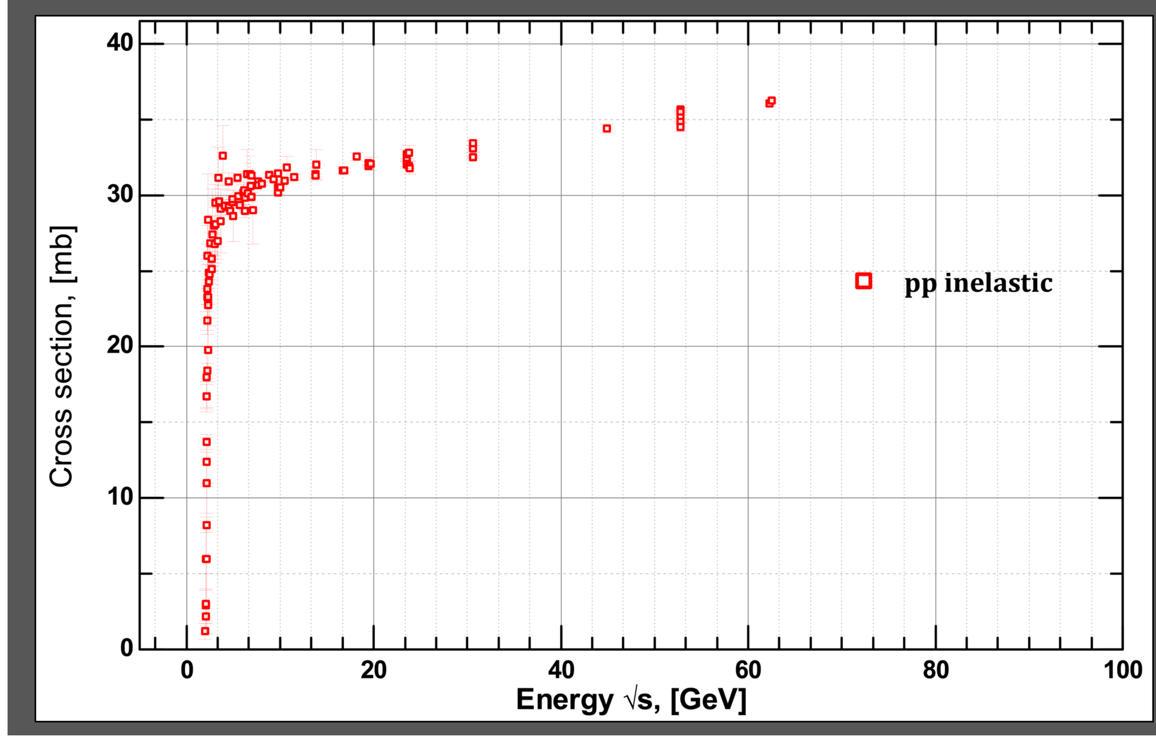
Quasi-analytic calculation approach provided for interference contributions.

The inelastic and total scattering cross-section as a function of energy of colliding particles (observed experimentally) can be qualitatively represented due to variation single parameter – coupling constant of considered φ^3 model.

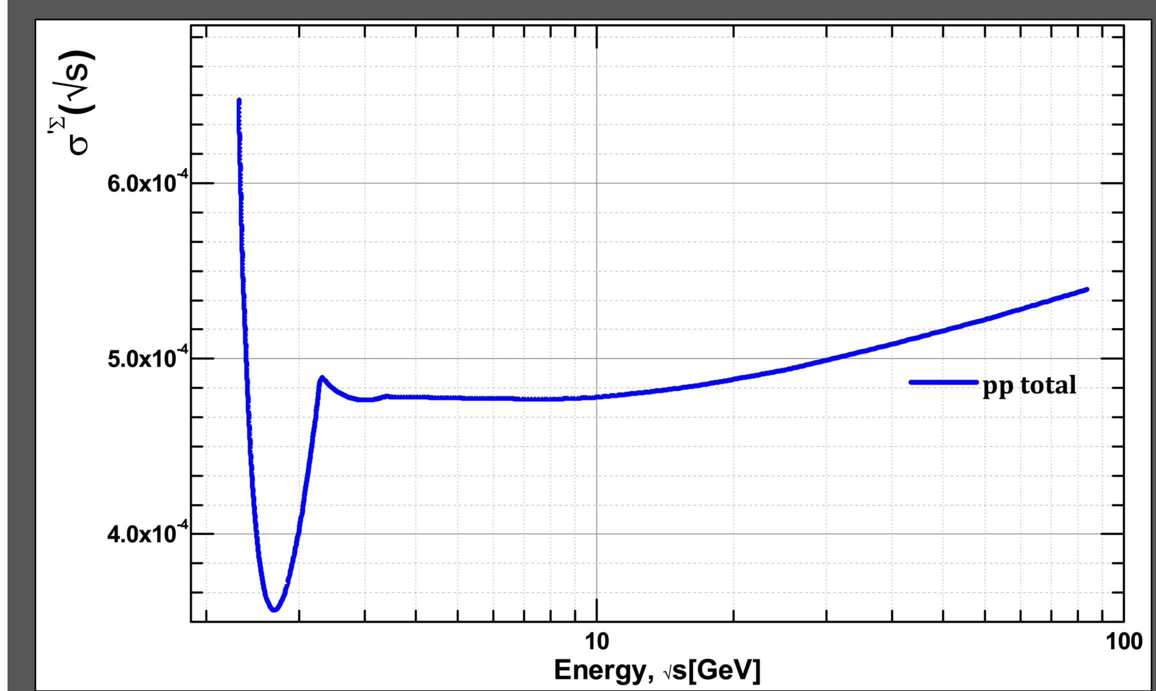
The more accurate quantitative presentation of empirical data requires the utilization of more realistic model (QCD). This is a subject of further investigation.

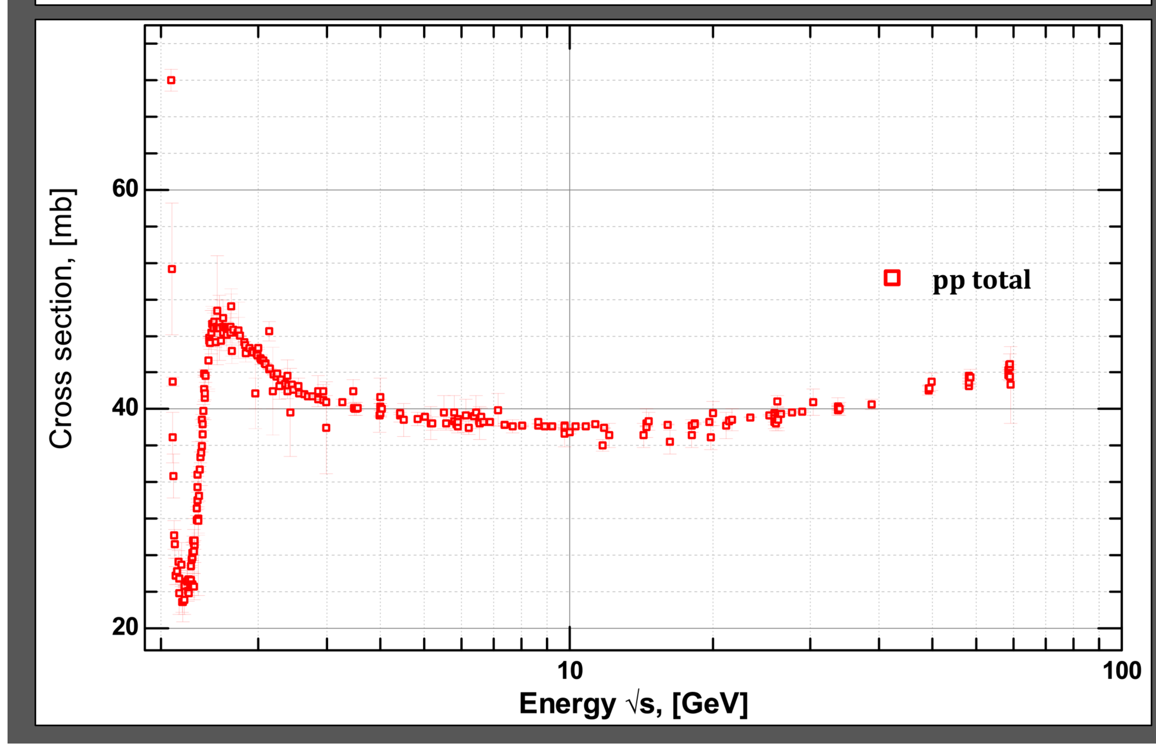
Proton-proton **inelastic** scattering cross-section as a function of energy of colliding particles in c.m.s. frame.
Theory (blue line) VS Experiment (red squares)





Proton-proton **total** scattering cross-section as a function of energy of colliding particles in c.m.s. frame.
Theory (blue line) VS Experiment (red squares)





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