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Enhanced Pomeron diagrams and hadronic diffraction

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Enhanced Pomeron diagrams and hadronic diffraction

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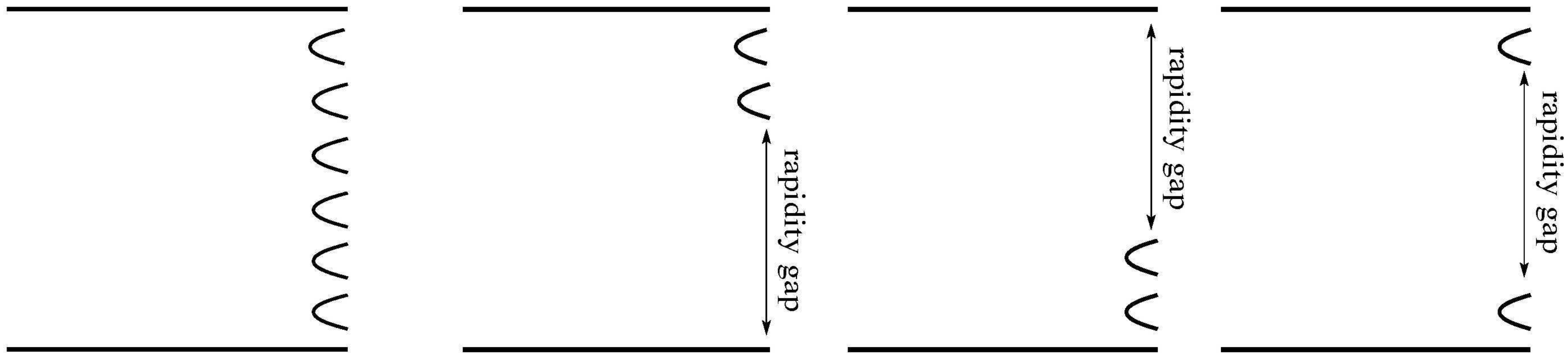
Outline

- Diffraction at colliders and in cosmic rays
- RFT: quasi-eikonal approach
- Enhanced Pomeron graphs: elastic amplitude
- AGK cuts: diffractive final states
- Multi-Pomeron vertices

Diffraction - production of secondaries in narrow rapidity windows

multiple production projectile diffr. target diffr. double diffr.



- diffraction in collider physics:

  valuable information about interaction dynamics

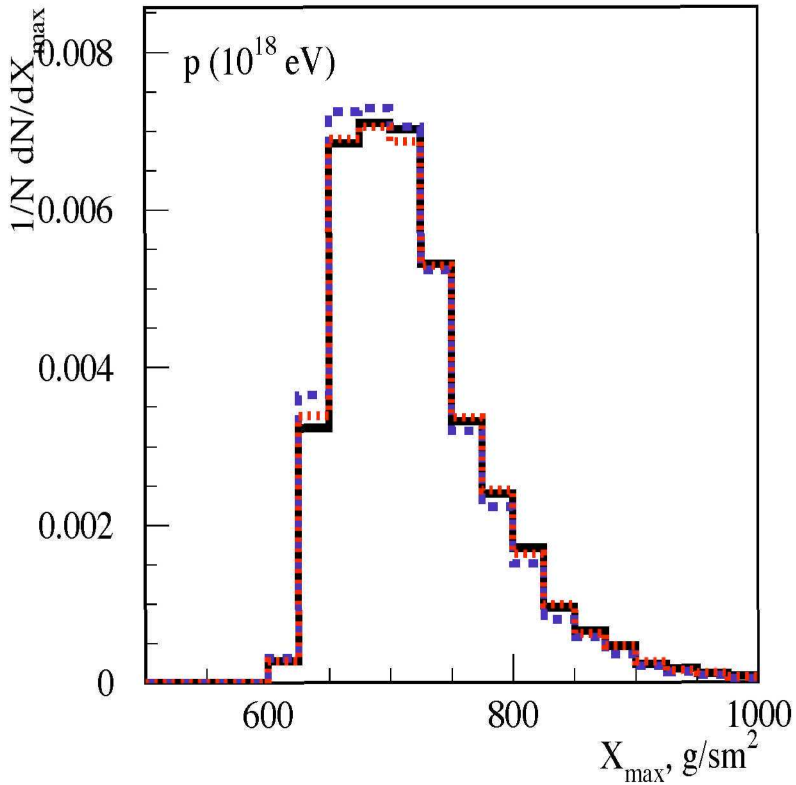
  clean experimental environment for new physics (e.g. production of Higgs)

- diffraction in cosmic ray physics:

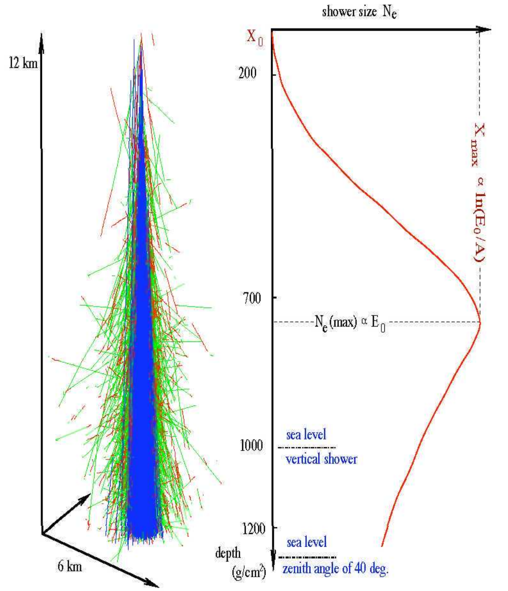
  direct impact on air shower maximum

Strictly speaking, EAS physics is sensitive to non-diffractive interactions only

Example: remove all events with less than 10% energy loss in the 1st interaction and use the rescaled cross section:



Detection: extensive air showers (EAS)

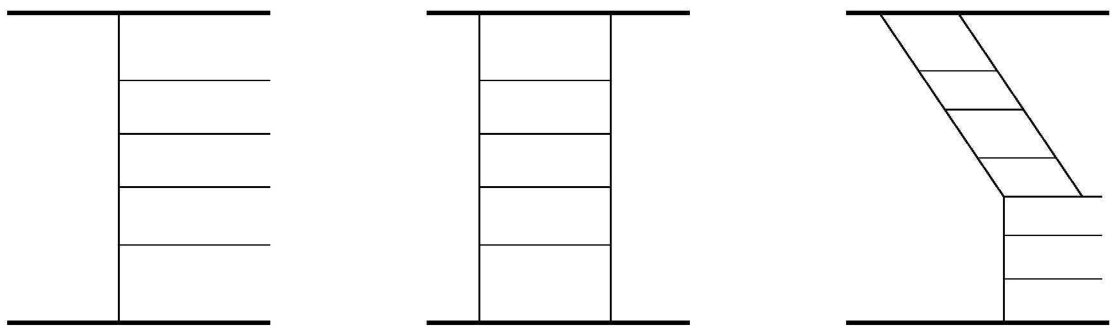


(Pryke, Auger Project)

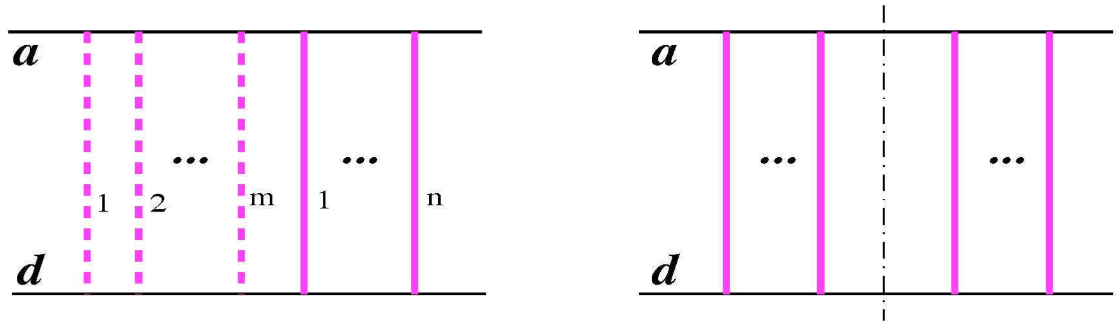
- particles: γ, e and μ
- about $7 \cdot 10^{10}$ charged particles at X_{max} in EAS with $E_0 = 10^{20}$ eV

Diffraction - microscopic picture

non-diffr. production virtual rescattering diffraction



- Reggeon Field Theory (schematic):



elementary parton cascades - Pomeron exchanges

intermediate states between Pomeron exchanges include inelastic excitations: $\sum_i |X_i\rangle\langle X_i| = |p\rangle\langle p| + \sum_{i\neq p} |X_i\rangle\langle X_i|$

Things get simplier in the multi-component (Good-Walker-like) scheme - use elastic scattering eigenstates: $|X_i\rangle \to |j\rangle$

- e.g., using eikonal vertices for Pomeron emission:

$$\sigma_{ad}^{\rm inel}(s) = \sum_{i,j} C_{i/a} C_{j/d} \int d^2b \left[1 - e^{-2\lambda_{i/a}\lambda_{j/d}\,\chi_{ad}^{\mathbb{P}}(s,b)}\right]$$

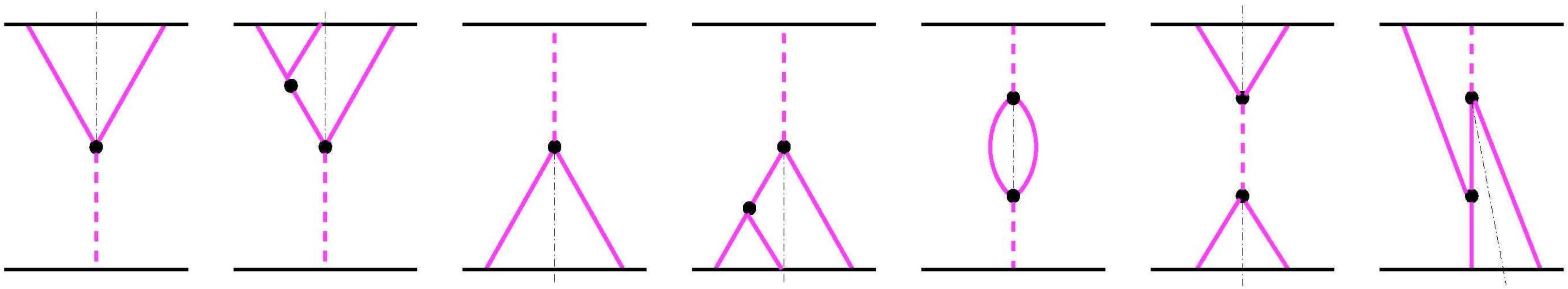
$$\sigma_{ad}^{\rm diffr-proj}(s) = \sum_{i,j,k,l} \left(C_{i/a}\delta_{ik} - C_{i/a}C_{k/a}\right) C_{j/d} C_{l/d} \times \int d^2b \left[1 - e^{-\lambda_{i/a}\lambda_{j/d}\,\chi_{ad}^{\mathbb{P}}(s,b)}\right] \left[1 - e^{-\lambda_{k/a}\lambda_{l/d}\,\chi_{ad}^{\mathbb{P}}(s,b)}\right]$$

$\chi_{ad}^{\mathbb{P}}$ - Pomeron exchange eikonal
$C_{i/a}, \lambda_{i/a}$ - relative weights & strengths of the eigenstates

- important: for low mass excitations ($M_X^2 \ll s$): $C_{i/a}, \lambda_{i/a}$ - independent of s
- M_X^2-dependence for LMD - usually $\mathbb{PPR}$-asymptotics:

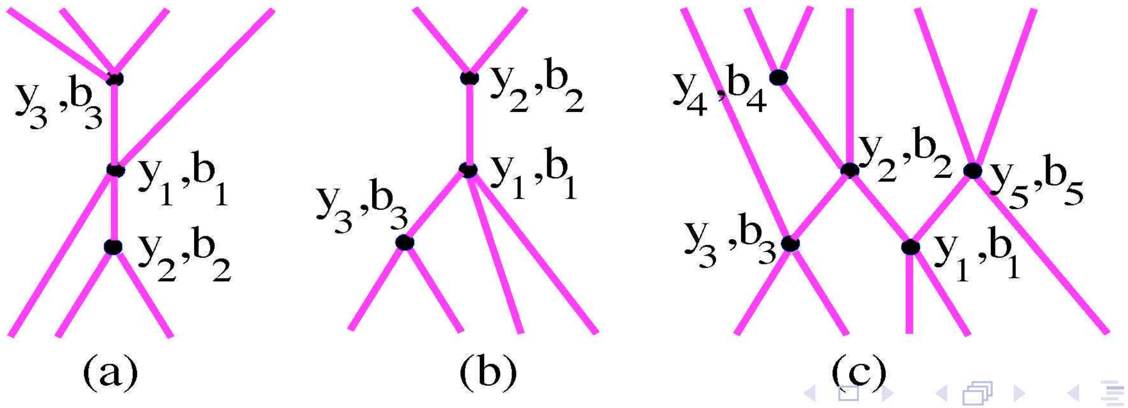
$$f(M_X^2) \sim (M_X^2)^{\alpha_{\mathbb{R}}(0)-2+2(\alpha_{\mathbb{P}}(0)-1)} \sim (M_X^2)^{-3/2}$$

High mass diffraction - Pomeron asymptotics ⇒ enhanced diagrams

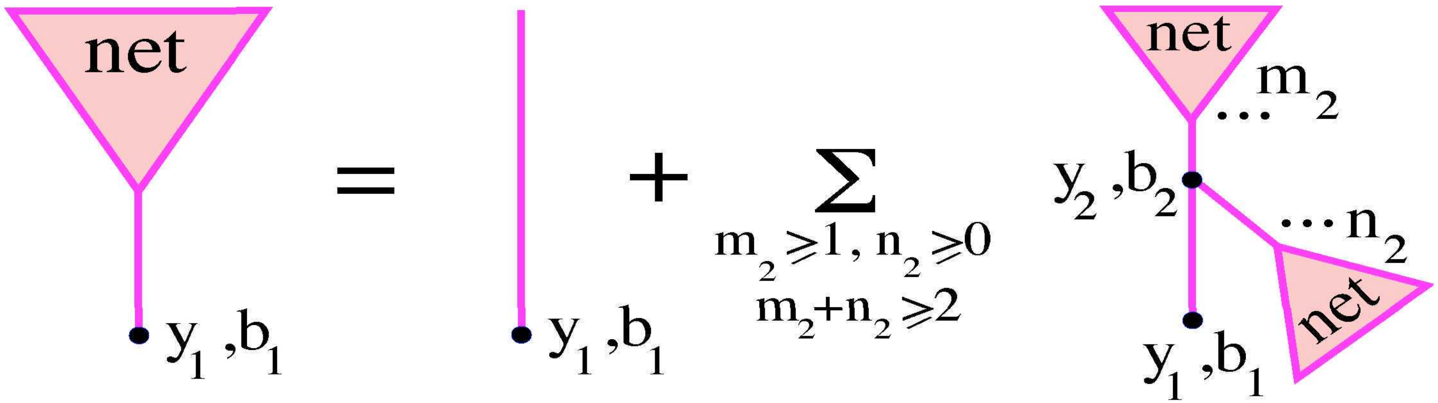


- sign-indefinite contributions
- higher orders - increasingly important with energy
- ⇒ all order resummation needed

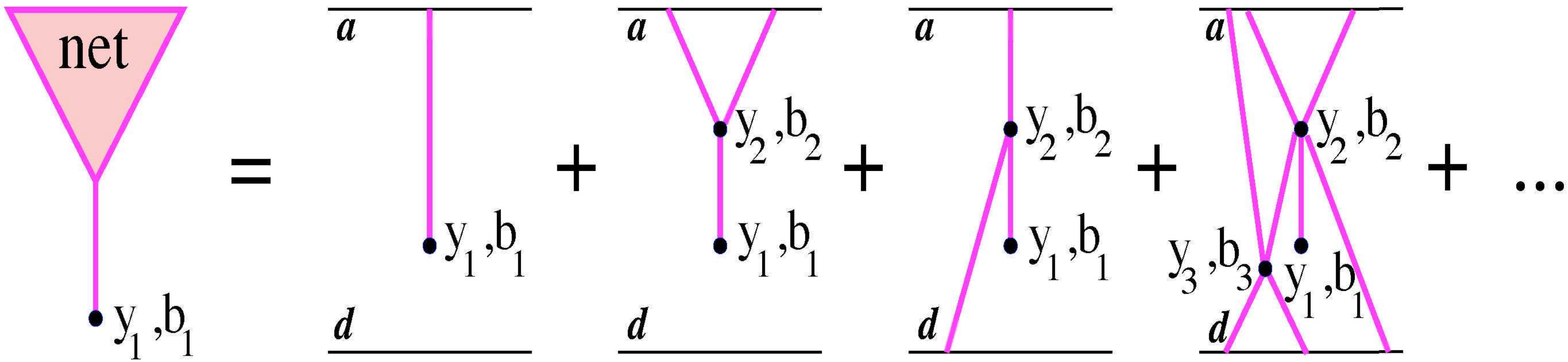
Let us start with the resummation of 'net'-like graphs (anything except Pomeron 'loops'):



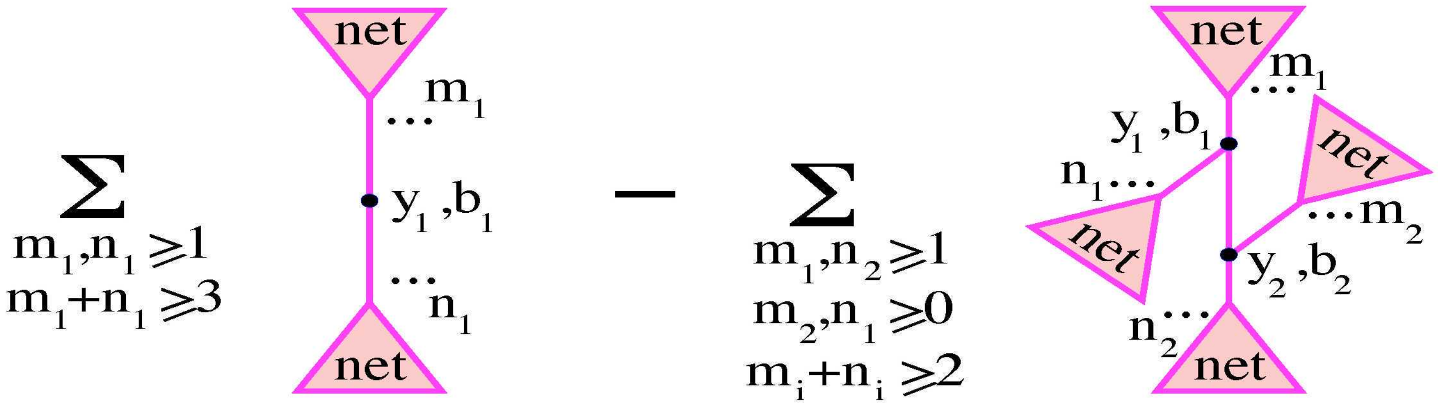
Introduce 'net fan' contributions via Schwinger-Dyson equation:



- correspond to arbitrary Pomeron 'nets' coupled to given vertex

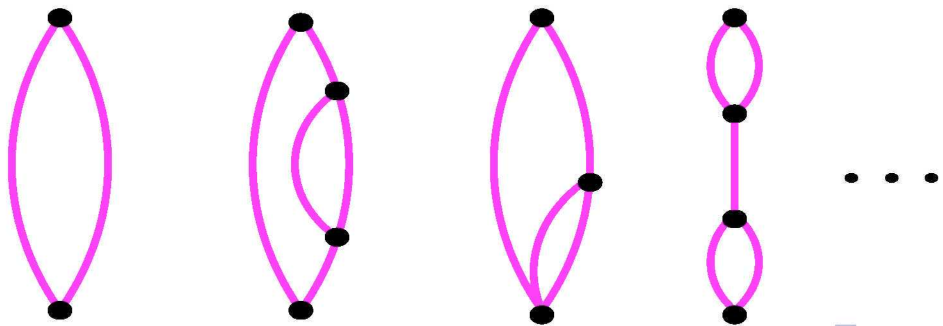


Sum of all irredicible contributions of non-loop enhanced diagrams to elastic scattering amplitude:

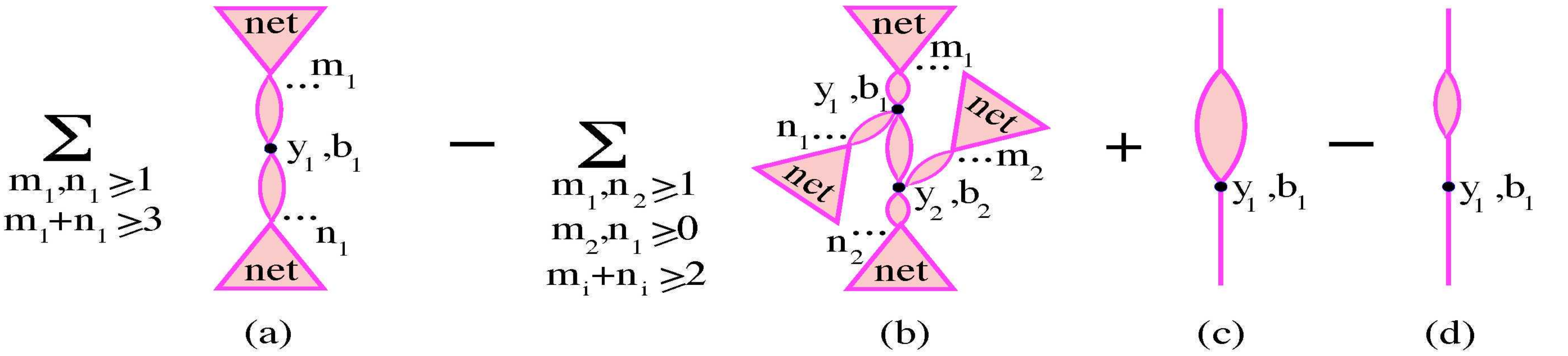


any diagram with n multi-Pomeron vertices is generated n times by the 1st term and $(n-1)$ times - by the 2nd

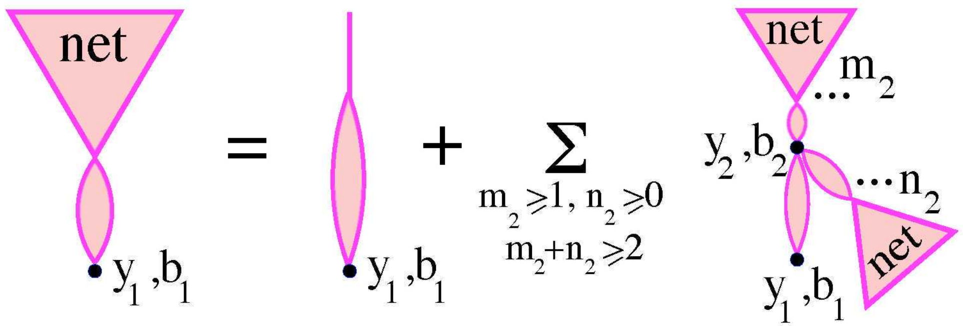
- generalization: replace single Pomerons by 2-point sequences of Pomerons and Pomeron loops, e.g.



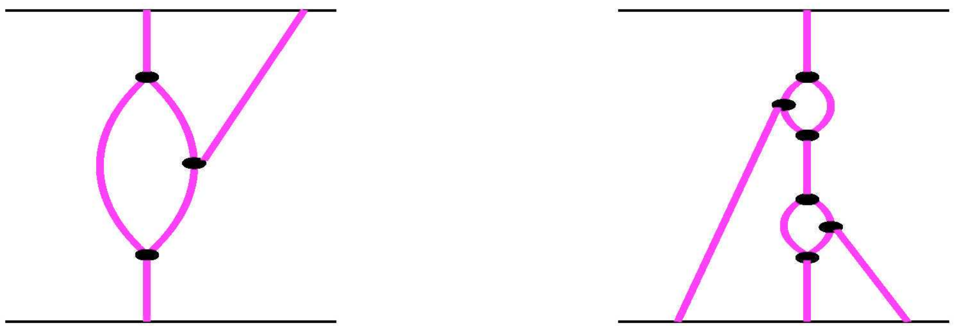
Final result:



- with



- examples of graphs which can not be included in this scheme:



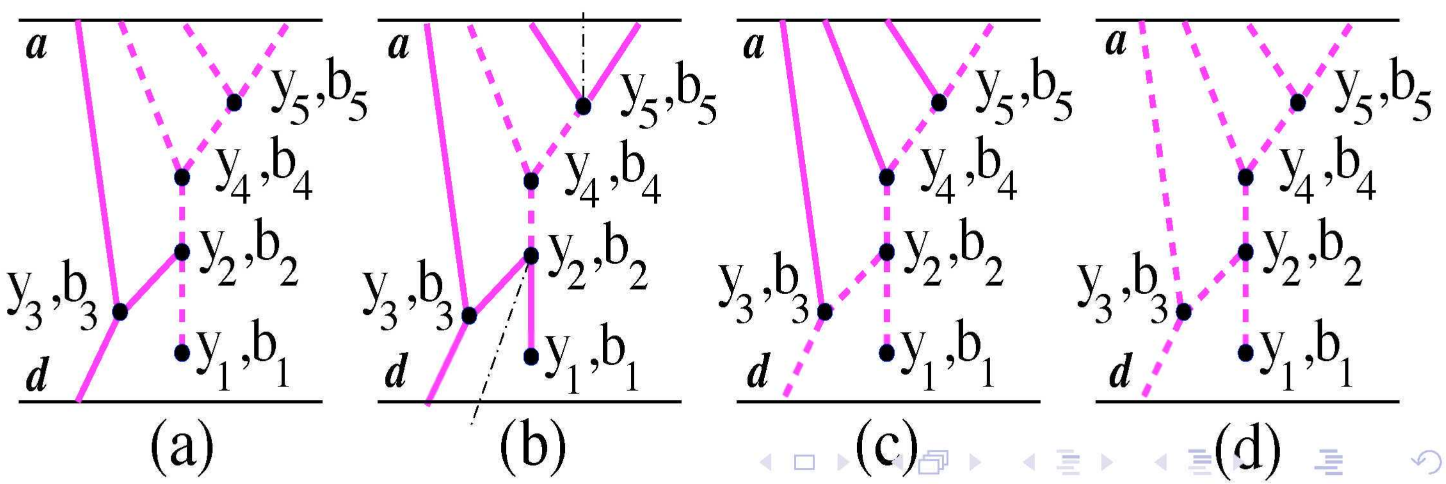
One has to be more specific about the Pomeron eikonal and about multi-Pomeron vertices

to judge the importance of neglected graphs
to verify the very convegence of the series

However, let us first discuss the structure of final states in general

- let us assume the validity of AGK cutting rules
- we start from AGK-cuts of 'net fans'; there are 2 kinds of cuts:

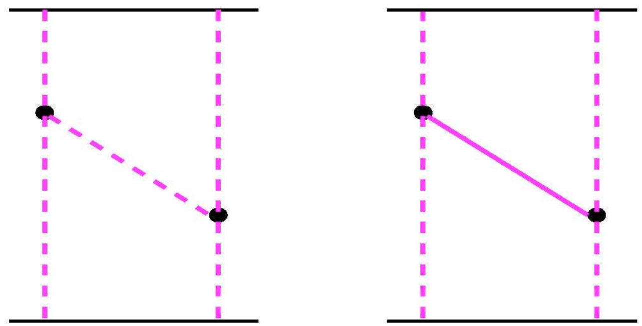
with 'fan'-like structure of cut Pomerons
with 'zigzag'-like structure of cut Pomerons



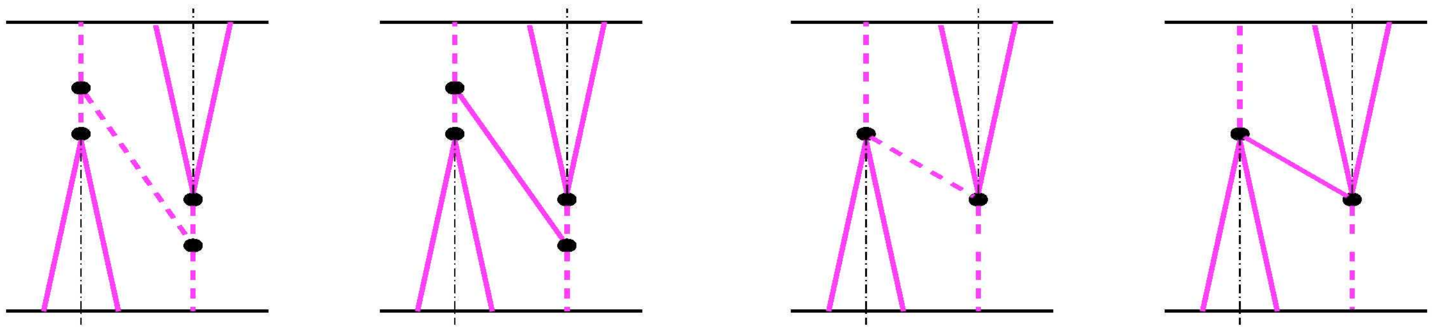
Important observations:

- summary contribution of 'zigzag' cuts of 'net fans' $\equiv 0$
- $\Rightarrow$ only 'tree'-like final states contribute to $\sigma_{\rm tot}$
- 'zigzag'-like final states have minor influence on the rap-gap structure of the events

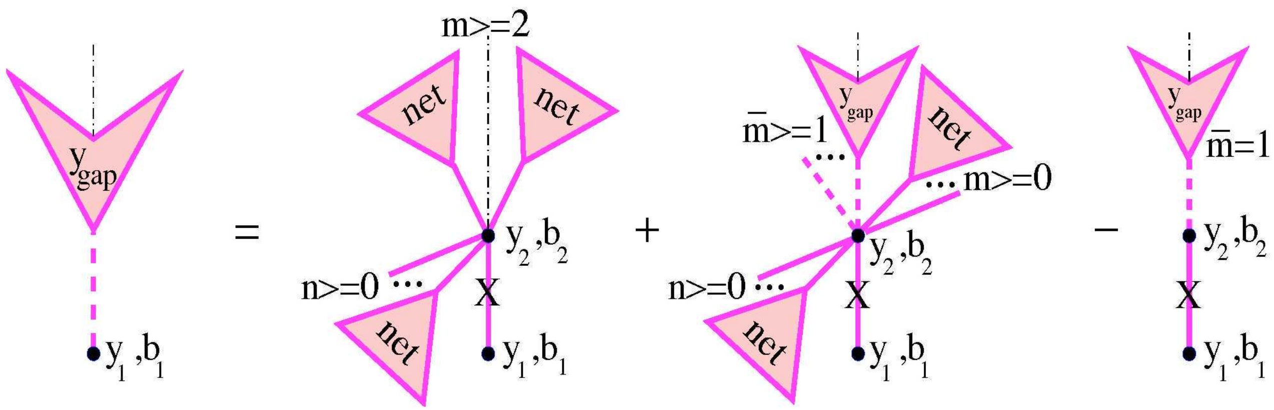
e.g., simpliest contributions do not generate rap-gaps:



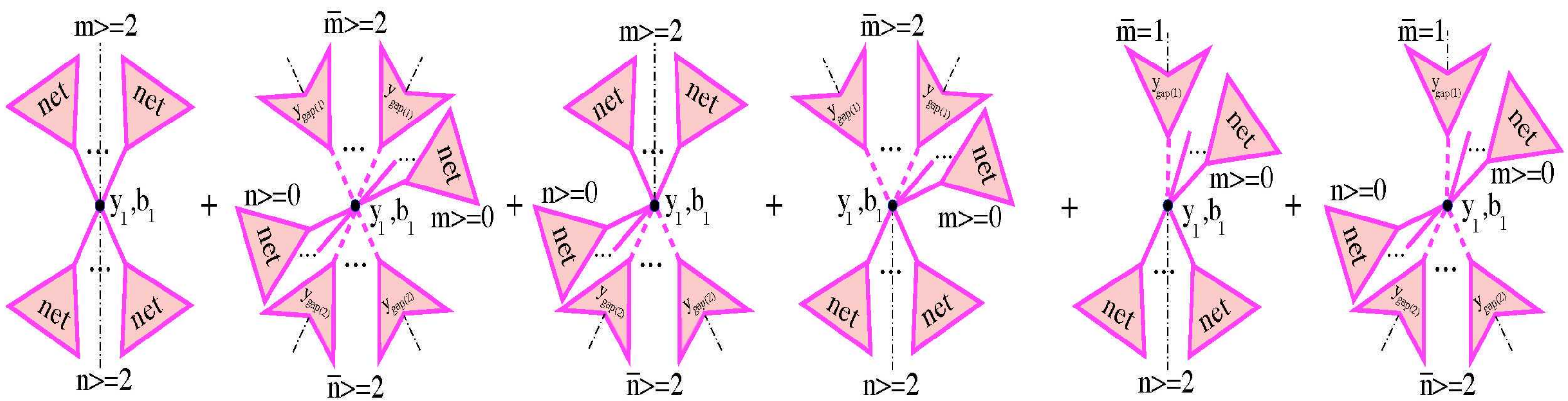
higher order contributions - small in peripheral collisions:



Difffractive cuts of 'net fans' (incomplete):



- ⇒ central diffraction (DPE) contributions (incomplete):



- to calculate DPE cross section:

  choose elastic channel in the cut plane

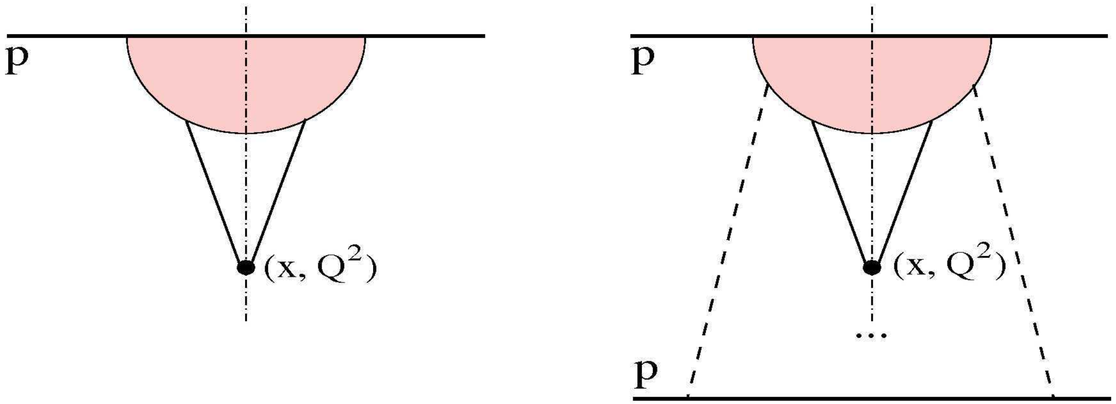
  include rap-gap suppression factors (left & right from the cut)

What is the meaning on 'net fan' contributions?

- compare inclusive and exclusive (certain structure of final states) jet production:

'fan' diagrams - low-x PDFs as 'seen' in DIS & inclusive cross sections

'net fans' - 'reaction-dependent PDFs' (without 'soft' production in parallel to the hard process):



Diffractive cuts of 'net fans' - low-x diffractive PDFs

- rapidity gap survival factor includes:

  elastic form factor - to suppress additional multiple production processes ('eikonal' suppression)

  absorptive corrections due to rescattering on the target - to suppress soft production in the same process

  large hard scale (e.g., Higgs production) $\Rightarrow$ smaller corrections of the 2nd kind (reduced phase space)

When the approach is self-consistent?

- let us consider simple Pomeron pole amplitude:

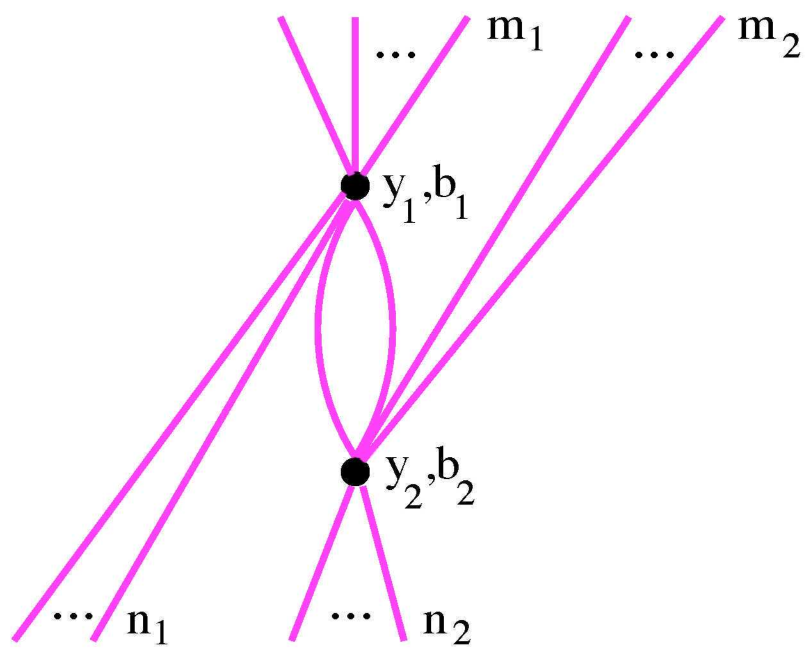
$$\chi^{\mathbb{P}}(\hat{s},b)=\mathrm{Im}f^{\mathbb{P}}(\hat{s},b)\sim\frac{\hat{s}^{\alpha_{\mathbb{P}}(0)-1}}{\lambda_{\mathbb{P}}}\,e^{-\frac{b^2}{4\lambda_{\mathbb{P}}}}$$

- clearly, no problem arises at moderate s and large b: enhanced graphs provide small corrections
- $\Rightarrow$ we have to investigate the 'dense' limit: $s\rightarrow\infty$, $b\rightarrow 0$
- well-behaving scheme proposed by Cardi / Kaidalov:

$$G^{(m,n)}=G\,\gamma^{m+n-3}$$

'Loop' graphs - dissapear in the dense limit
(suppressed by exponential factors):

$$\sum_{n_1=0}^{\infty} \frac{(-\chi^{\mathbb{P}}_{d\mathbb{P}}(s_0 e^{y_1}, b_1))^{n_1}}{n_1!} = e^{-\chi^{\mathbb{P}}_{d\mathbb{P}}(s_0 e^{y_1}, b_1)}$$

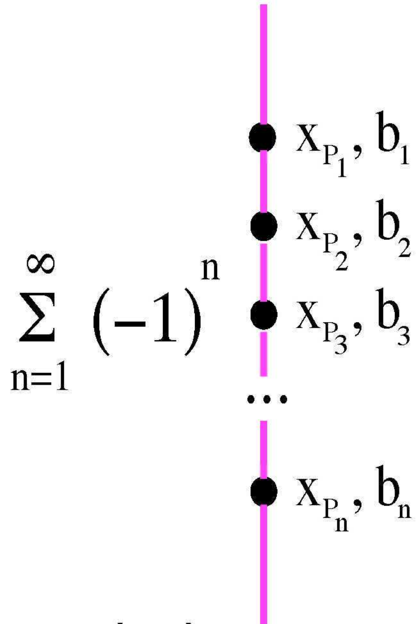


- ⇒ one is left with 'net'-like graphs

Both 'net fan' contributions and elastic scattering amplitude approach at $s \to \infty$, $b \to 0$ the Kaidalov's limit: renormalization of the Pomeron intercept:

$$\tilde{\chi}^{\mathbb{P}}(\hat{s}, b) =\sim \frac{\hat{s}^{\tilde{\alpha}_{\mathbb{P}}(0)-1}}{\lambda_{\mathbb{P}}} \, e^{-\frac{b^2}{4\lambda_{\mathbb{P}}}}$$

$$\tilde{\alpha}_{\mathbb{P}}(0) = \alpha_{\mathbb{P}}(0) - 4\pi G/\gamma^2$$



- valid only for $\tilde{\alpha}_{\mathbb{P}}(0) > 1$!
- for $\tilde{\alpha}_{\mathbb{P}}(0) < 1$ - saturation solution; $\sigma_{tot}(s) \to const$ at $s \to \infty$
- in particular, this is the case if one restricts himself with triple-Pomeron vertex only!

Durham group:

$$G^{(m,n)} = m\, n\, G\, \gamma^{m+n-3}$$

- same 'dense' limit (renormalization of the Pomeron intercept)
- one Pomeron is 'more equal' than others
- $\Rightarrow$ analysis of unitarity cuts - difficult
- diffraction cross sections - inconsistent with AGK rules