Vector meson production with hot spot model

Radim Dvořák

September 2021

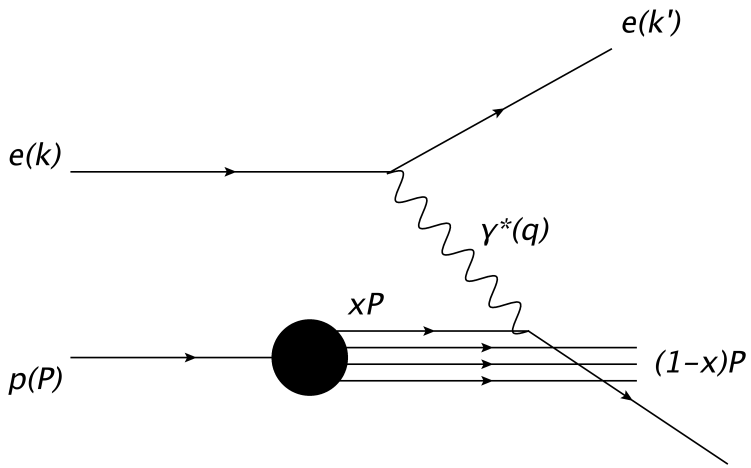
4. miniworkshop difrakce a ultraperiferiálních srážek

Content

- Structure of hadrons
- Parton model and evolution equations
- Production of vector mesons
- Hot spot model
- Differential cross-section
- Total cross-section
- Summary

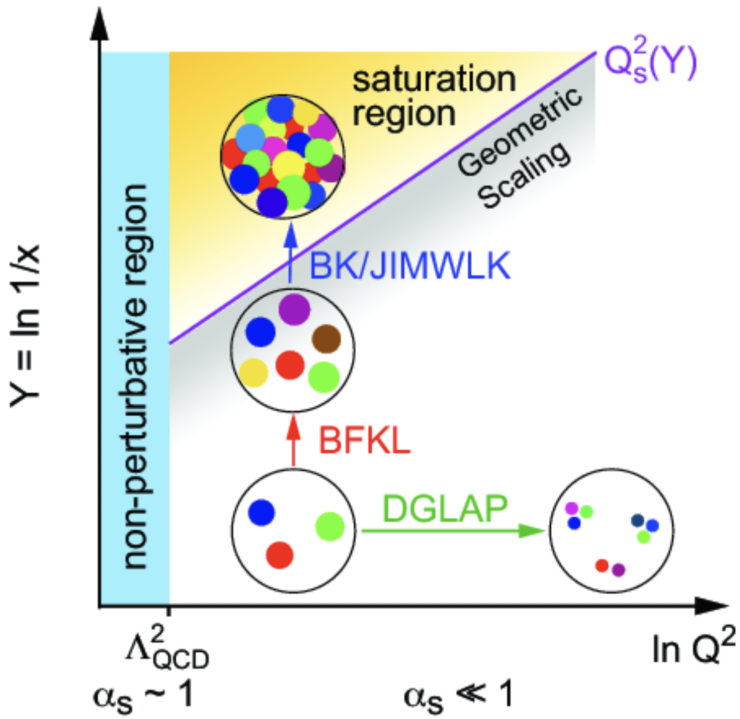
Structure of hadrons

- For studying structure of hadrons we can use deep inelastic scattering
- Interaction between electron and hadron
- Virtulatity $Q^2 = -(k - k')^2$
- Bjorken $x = \dfrac{Q^2}{2Pq}$
- For explanation of experimental results parton model was introduced
- Partons = quarks and gluons
- Parton has fraction of momentum xP



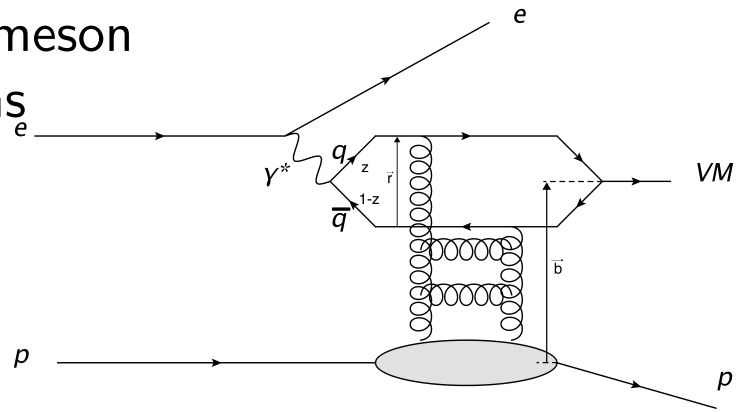
Evolution equations

- They describe development of structure of hadrons
- Higher virtuality $\rightarrow$ higher resolution $\rightarrow$ smaller partons
- Smaller Bjorken $x \rightarrow$ increasing number of partons
- For high energies (small x) $\rightarrow$ saturation
- Transition between saturated and non-saturated region is given by Q_s^2



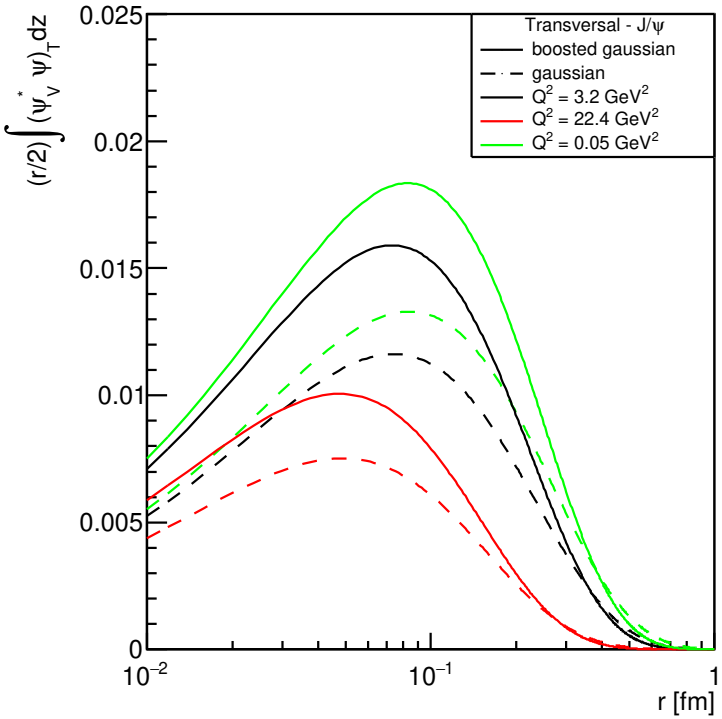
Production of vector mesons

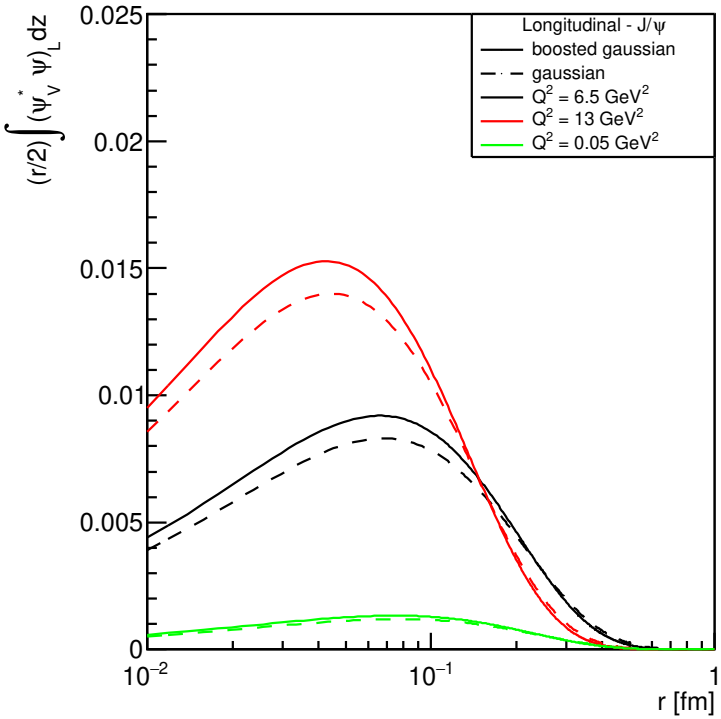
- Fundamental properties:
  - Content: $q\bar{q}$ ($J/\Psi \rightarrow c\bar{c}$)
  - Orbital angular momentum: 1, Parity: -1
- Production of vector mesons is sensitive to structure of hadrons
- Color dipole approach
- Amplitude of this process can be separated into:
  - Dipole cross-section
  - Overlap of wave function of virtual photon with wave function of vector meson
  - Corrections



Overlap of wave functions

- Overlap contains scalar part $\rightarrow$ models
  - Gaussian
  - Boosted Gaussian



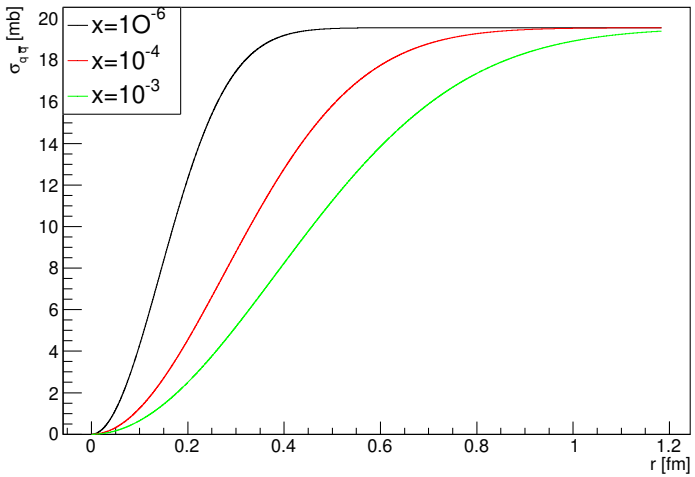


Dipole cross-section

- Dipole cross-section:

$$\frac{\mathrm{d}\sigma}{\mathrm{d}\vec{b}} = 2N(x, \vec{b}, \vec{r}) \rightarrow \sigma_0 N(x, \vec{r})\, T_p(\vec{b})$$

- $T_p(\vec{b})$ - profile function of proton $\rightarrow$ Gauss x Hot spot model
- σ_0 is from normalization of profile function
- Dipole amplitude can be taken from models $\rightarrow$ GBW model



Hot spot model

- Proton is modelled as cluster of areas with high color charge (hot spots) $\rightarrow$ variable structure
- Profile function:

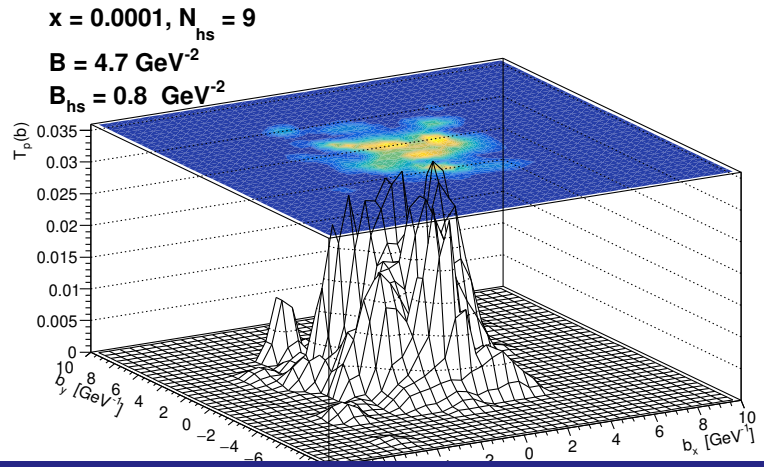
$$T(\vec{b}) = \frac{1}{N_{hs}} \sum_{i=1}^{N_{hs}} T_{hs}(\vec{b} - \vec{b_i}), \qquad T_{hs}(\vec{b} - \vec{b_i}) = \frac{1}{2\pi B_{hs}} e^{-\frac{(\vec{b}-\vec{b_i})^2}{2B_{hs}}}$$

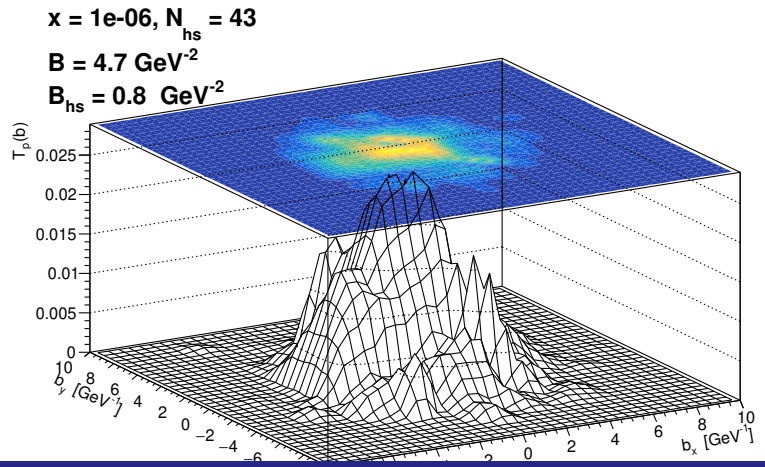
- T_{hs} profile function of hot spots, B_{hs} square radius of hot spots
- N_{hs} number of hot spots b_i $\rightarrow$ energy dependence of structure

$$\langle N_{hs} \rangle = p_0 x^{p_1} (1 + p_2 \sqrt{x})$$

Hot spot model - implementation

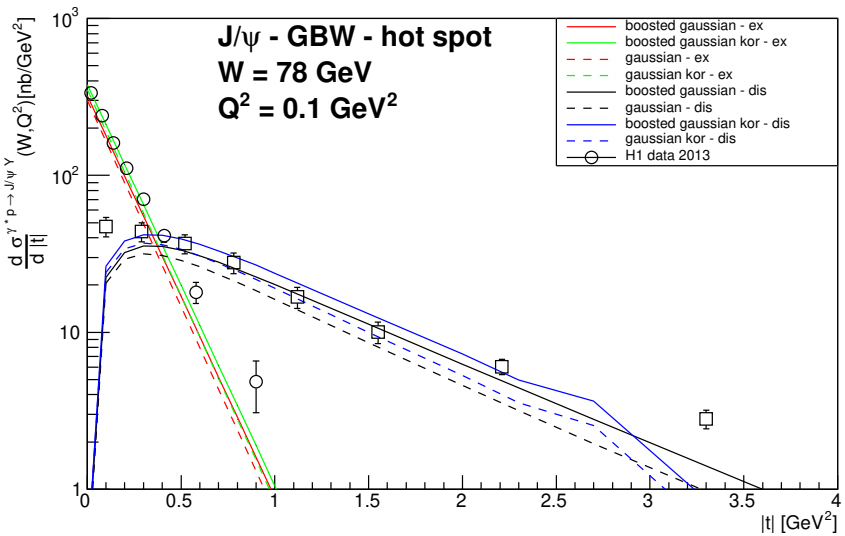
- In hot spot model amplitude is calculated for large number of events
- Calculation $\langle N_{hs} \rangle \rightarrow$ calculation N_{hs} from modified Poisson distribution $\rightarrow$ generation of $\vec{b_i} \rightarrow$ calculation of amplitude (cross-section)
- Middle value $\rightarrow$ exclusive production
- Variance $\rightarrow$ dissociative production
- Benefits: calculation of dissociative cross-section, integration over $\vec{b}$ can be done analytically





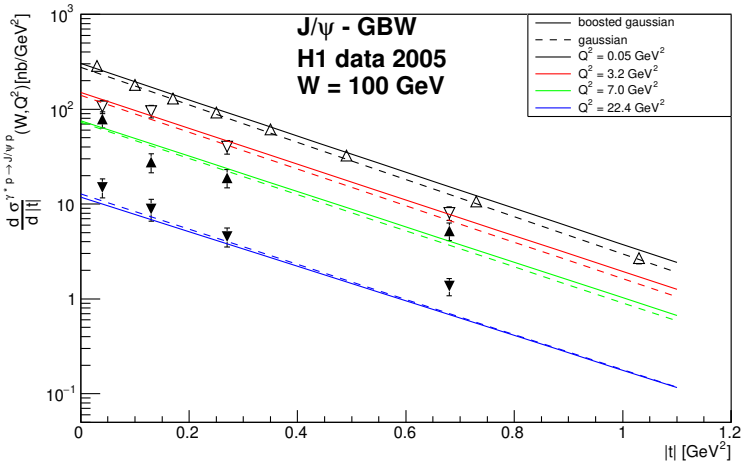
Differential cross-section

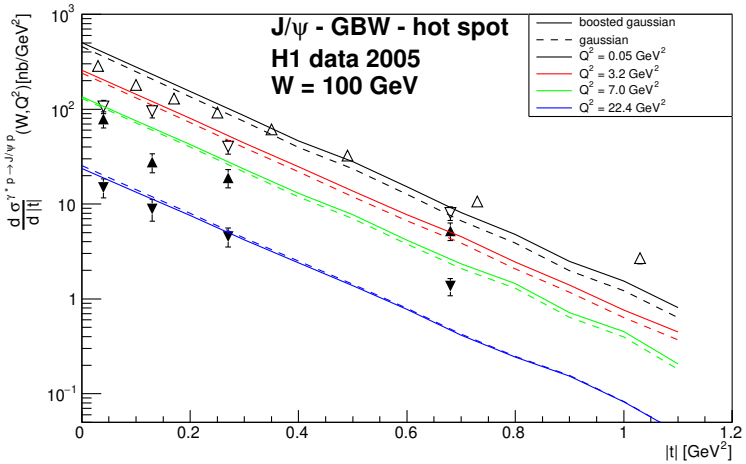
- Amplitude production VM $\rightarrow$ differential cross-section
- Correction has large impact
- In the graph there is photo production of J/Ψ
- Data are from HERA



Differential cross-section

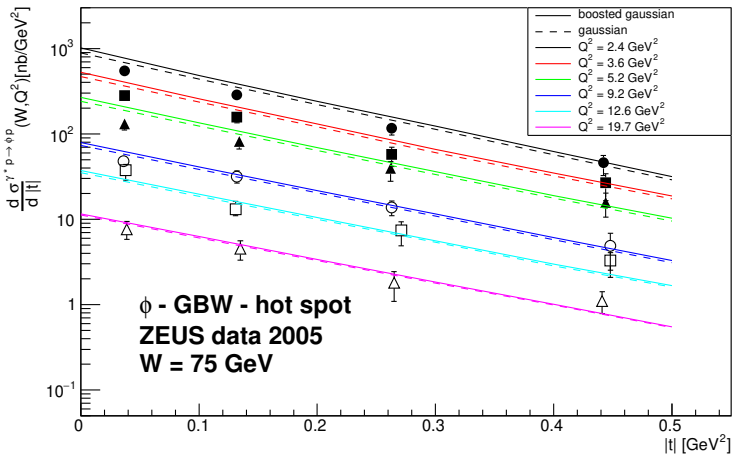
- Comparison between Gauss and hot spot model
- Gauss model has better results
- Hot spot model fluctuate for higher $|t|$

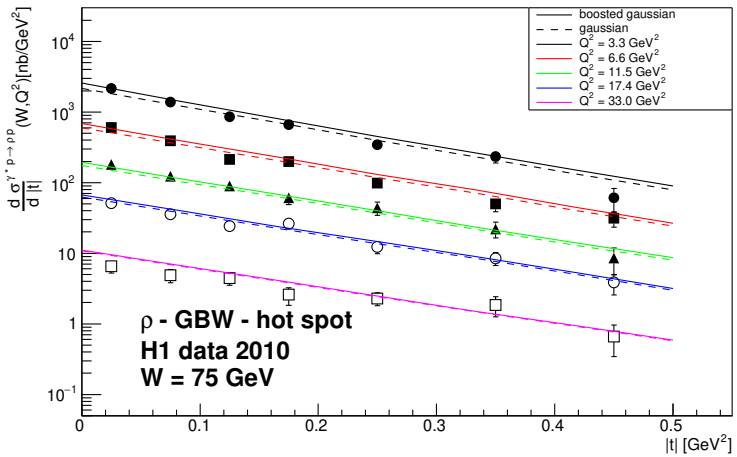




Differential cross-section

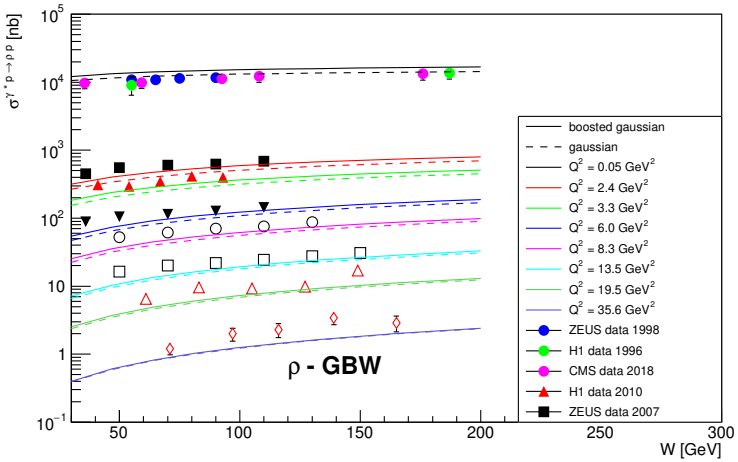
- Differential cross-section for meson ϕ and ρ
- Results are in good agreement with data

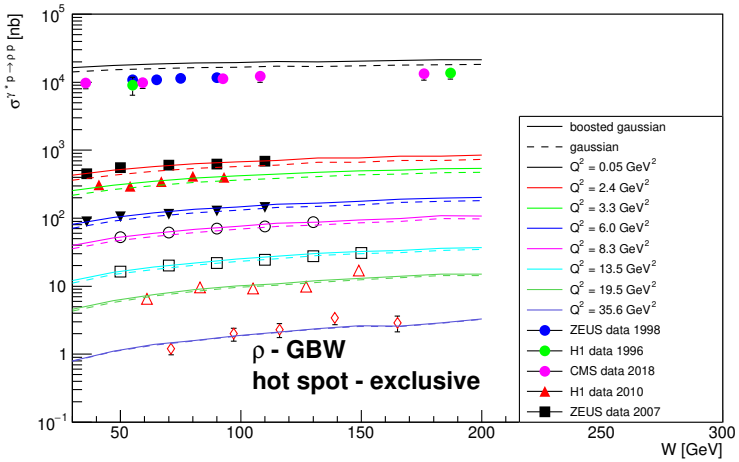




Total cross-section

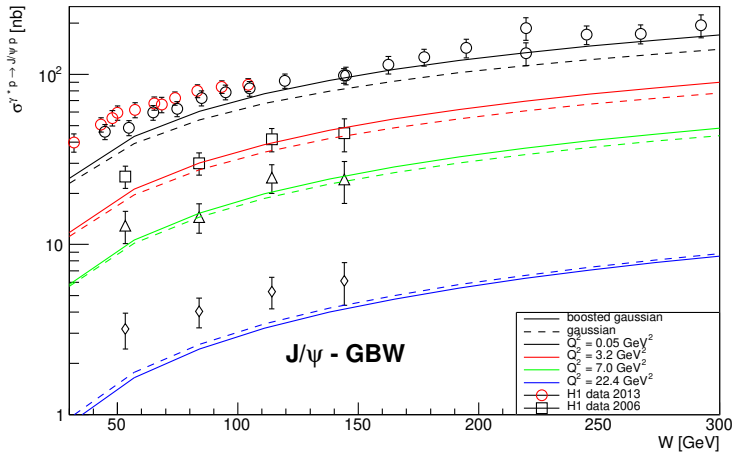
- Integration of differential cross-section $\rightarrow$ total cross-section
- Comparison between Gauss and hot spot for meson ρ
- Data are from HERA and LHC
- Hot spot model $\rightarrow$ better results for electro production

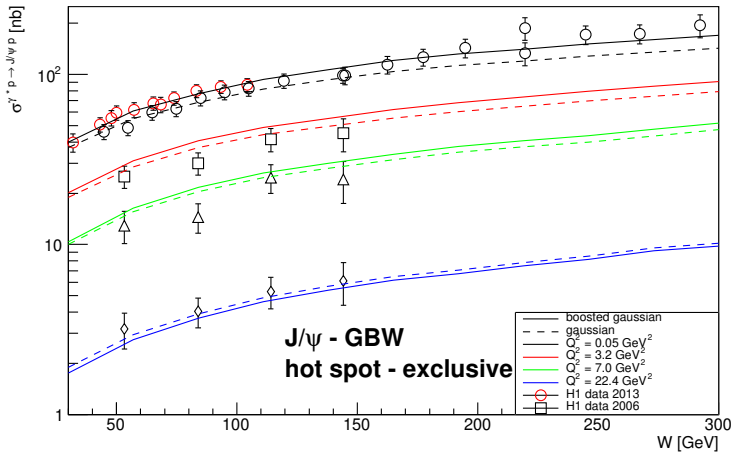




Total cross-section

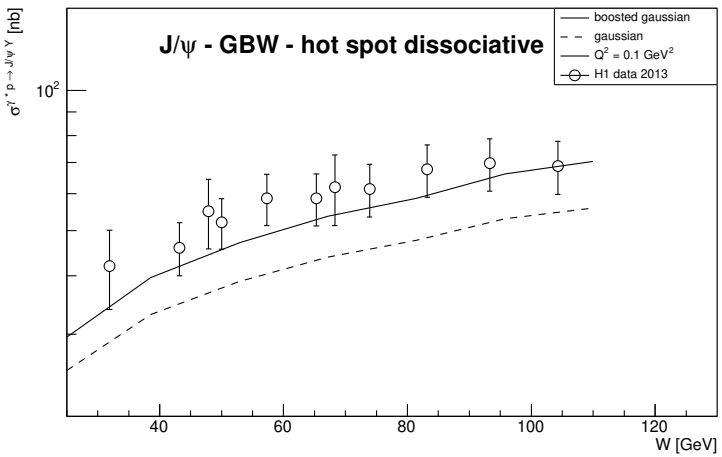
- Comparison between Gauss and hot spot for meson J/Ψ
- Hot spot model $\rightarrow$ better results
- Data are from HERA

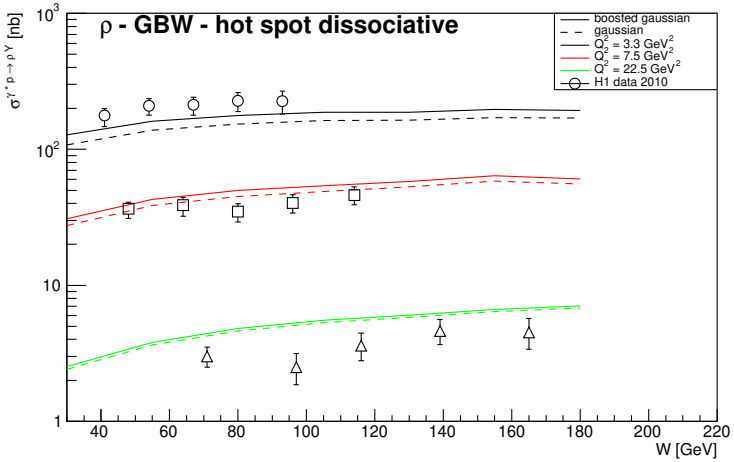




Dissociative cross-section

- Dissociative cross-section of mesons J/Ψ a ρ
- For meson J/Ψ good agreement with data
- ρ slightly worse results





Summary

- Results for vector mesons production in color dipole approach were shown
- GBW model for dipole cross-section and two models for overlap were used
- For structure of hadrons Gaussian and hot spot model were used
- Gauss model has better results for differential cross-section of J/Ψ
- Hot spot model has better results for total cross-section

Thank you for your attention