

Detection of Hadrons with New Heavy Quark at LHC and Quark Gluon String Model.

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Outline

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SUSY definitions

Quark Gluon String Model

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Interactions with proton

Cross sections

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RRR, RRP, PPR and PPP contributions

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Introduction

- about SUSY models :
- conventional SUSY models (neutralino LSP, masses $\sim 1\text{TeV}$, dark matter > no color, no charge)
- Split SUSY (gluino LSP of **very small relic density**)
- models with universal extra dimensions (squarks and gluino are **effectively stable**, masses > 100GeV)
- Compressed SUSY model (S.Martin) predicts quasystable stop quark with low mass > 200 GeV

Introduction

Previous works:

OHSTPY-HEP-T-99-019
December 1999

University of California - Davis

UCD-98-8
FSU-HEP-980612
hep-ph/9806361
June, 1998
Revised: September, 1998

**An analysis of a Heavy Gluino LSP at CDF :
The Heavy Gluino Window**

Arash Mafi and Stuart Raby

*Department of Physics
The Ohio State University
174 W. 18th Ave.
Columbus, Ohio 43210*

**A HEAVY GLUINO AS THE LIGHTEST SUPERSYMMETRIC
PARTICLE**

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Discovery potential of R-hadrons with the ATLAS detector

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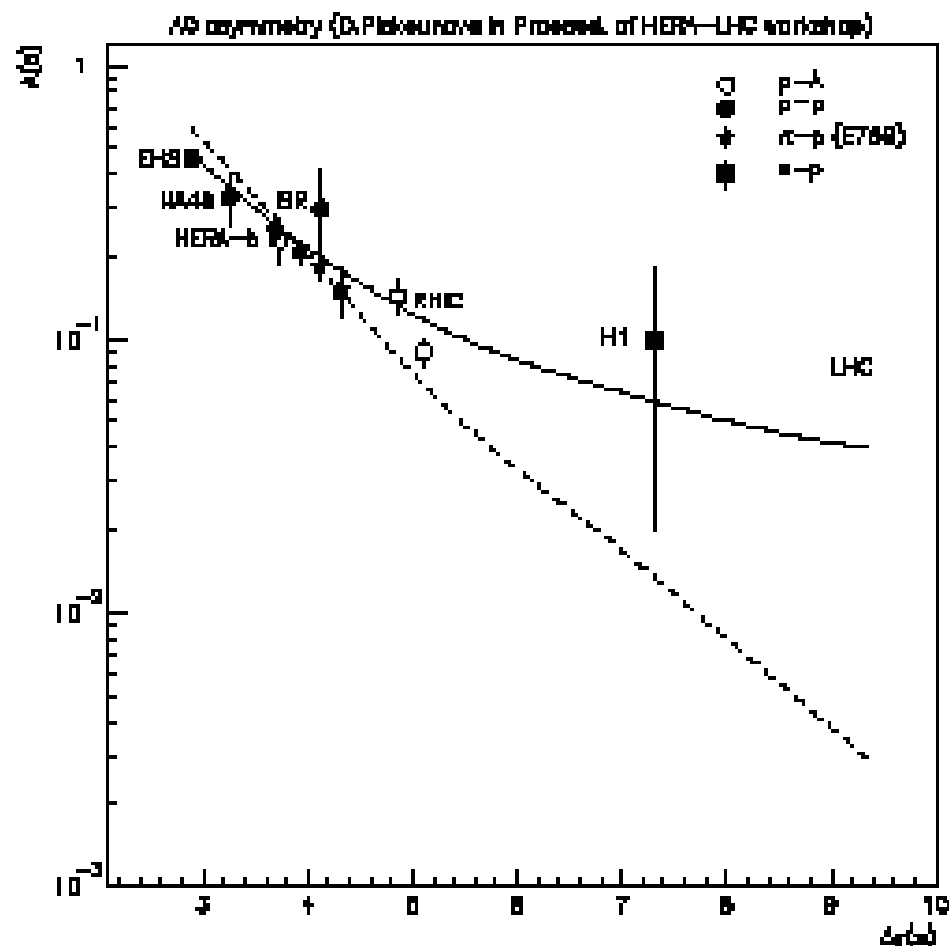
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Philadelphia, PA., USA*

hep-ex/0511014 v2 7 Nov 2005

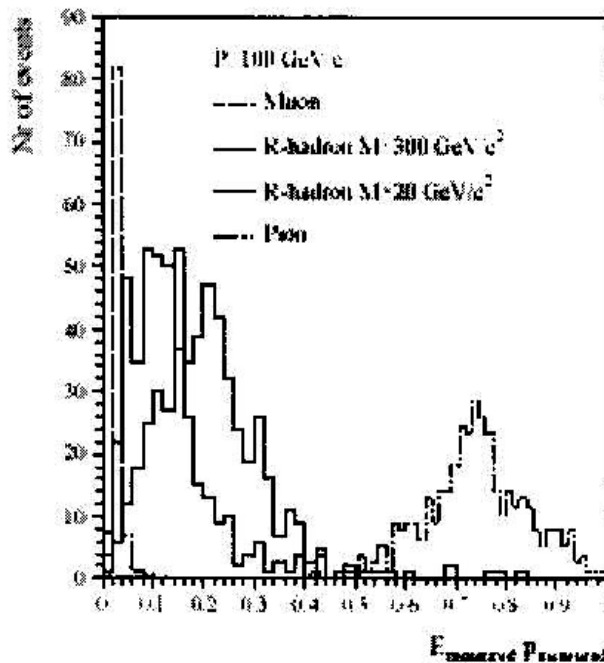
Introduction

Quark Gluon String Model knows everything about hadron interactions:



- it considers very high energies
- it gives cross section for the interactions of various quark (antiquark) systems
- it provides the calculations for differential distributions of particles after collision

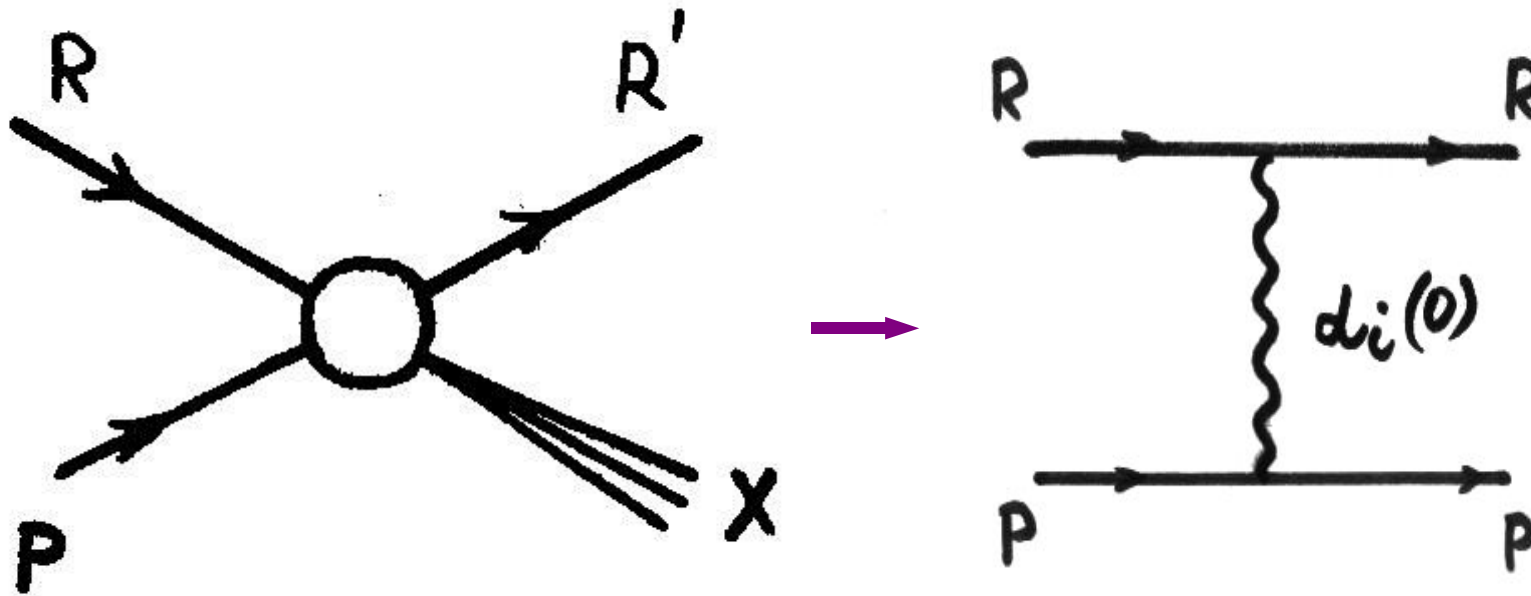
Conditions of experiment



I. Search strategy: to collect the time-of-flight in muon chambers information in order to isolate slow-moving-muon-like tracks

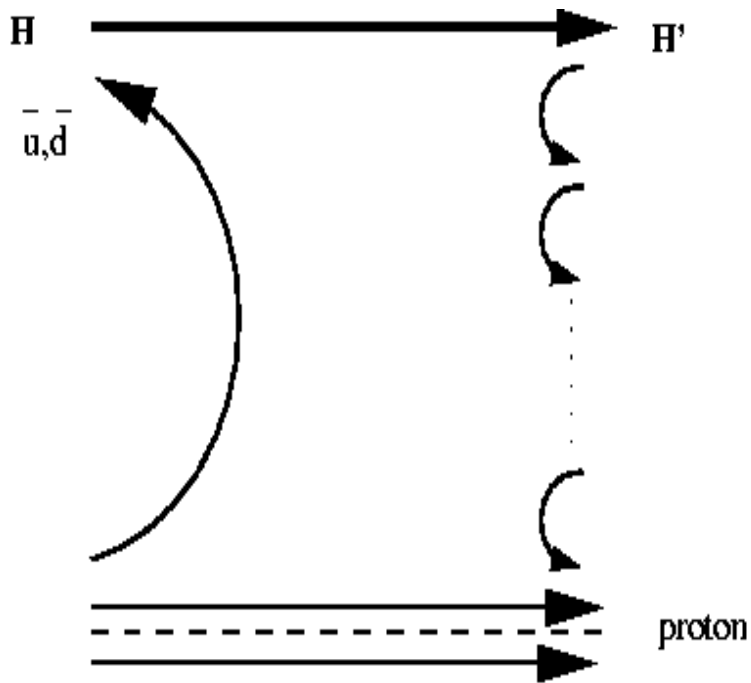
II. Charge changing interactions: charged particle can anyhow pass into neutral one and back due to hadronic interactions, but can not change the charge from + to -

Interaction in particle representation

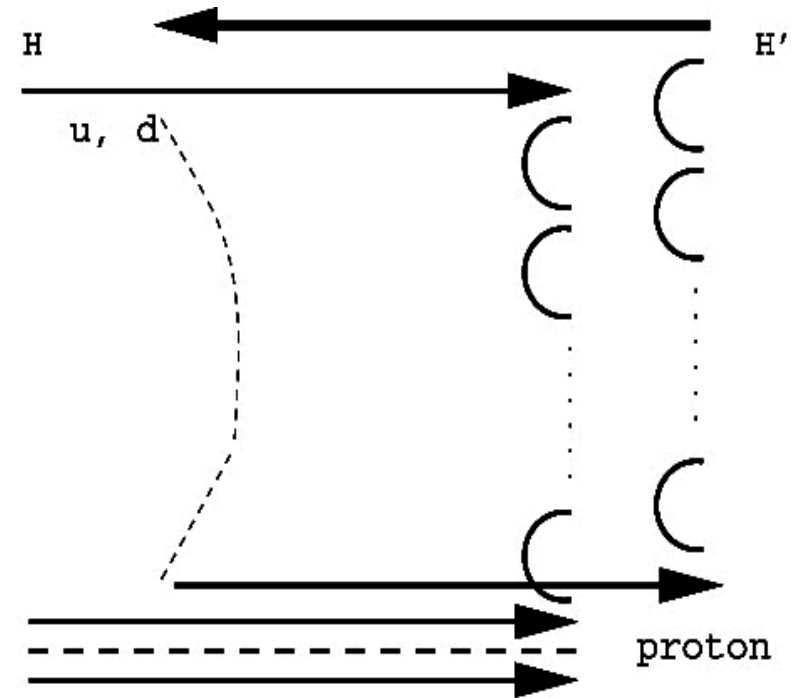


Two particle interactions can be presented as the exchange with Regge trajectory with angle momenta $\alpha_i(t)$

Interactions in quark representation



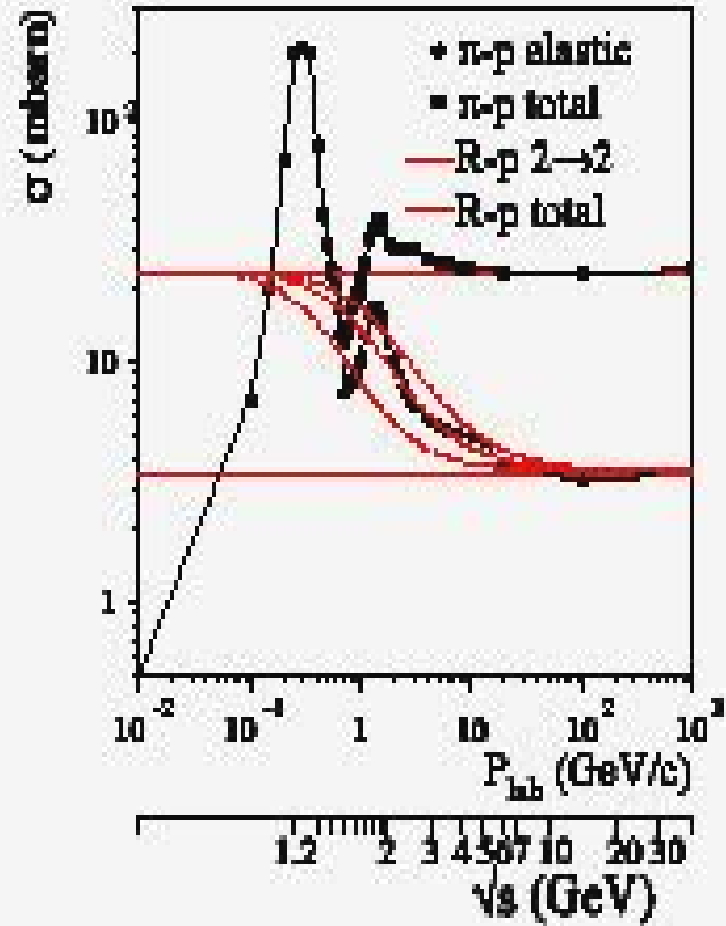
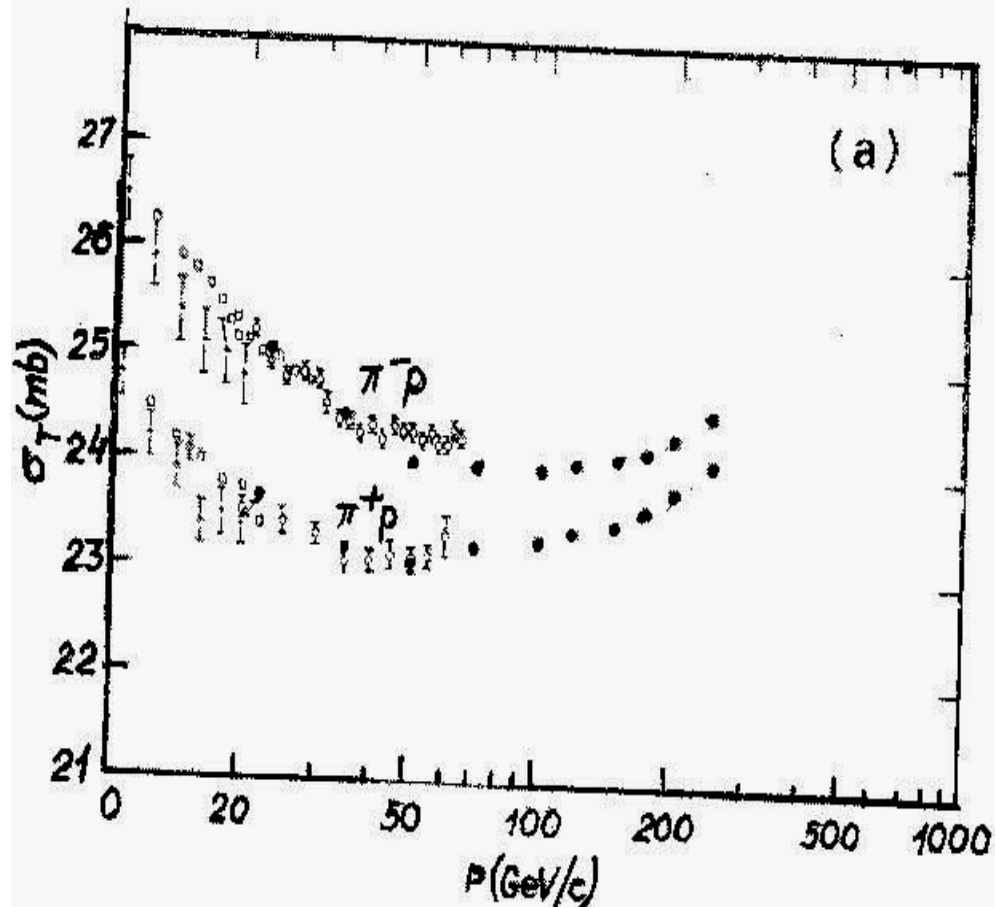
Planar diagram for
reggeon exchange.



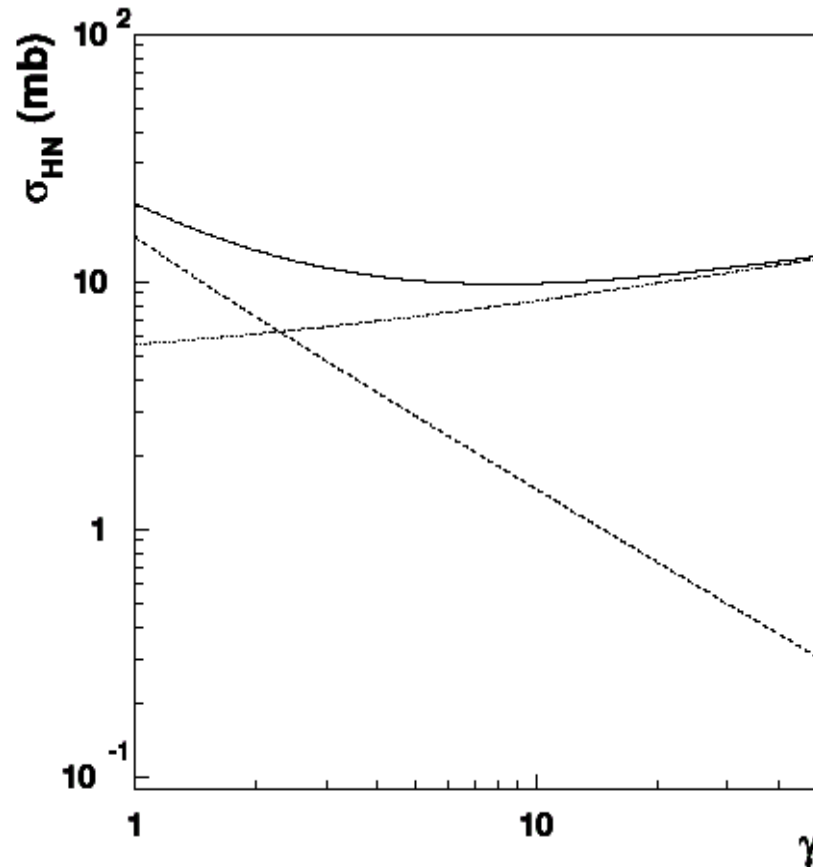
Cylinder diagram for
pomeron exchanges

Cross sections

A.B. Kaidalov, *Diffractive production*



Cross sections in QGSM



$$\gamma = E/M_H$$

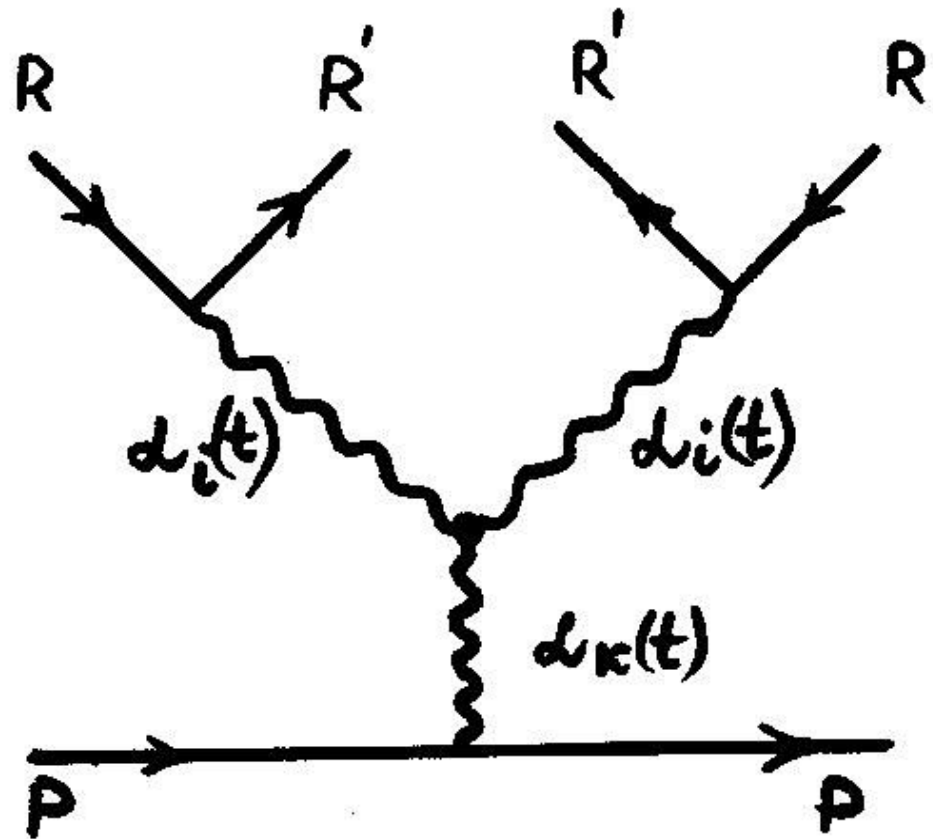
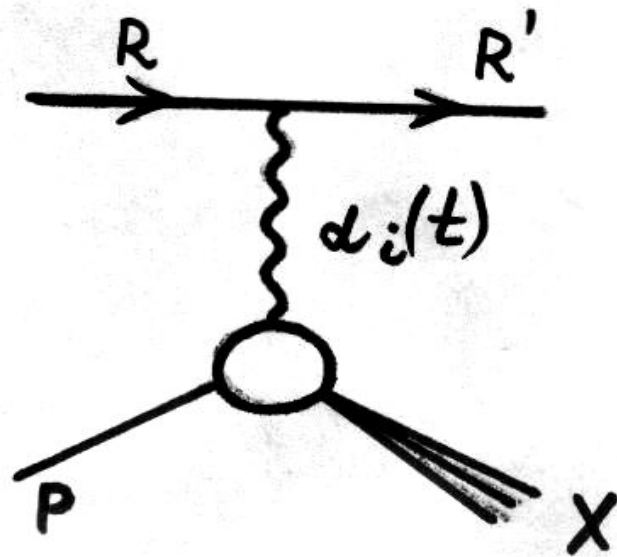
Cross section depends only on energy that is left for light quark

Pomeron cross section corresponds to γ^Δ , where $\Delta_P = \alpha_P(0) - 1 = 0.12$

$$\sigma_R(E) = K\sigma_{pl}(E = \gamma m_{q\perp}) = Kg_R(2\gamma m_{q\perp}/E_0)^{\alpha_R(0)-1}, \quad (1)$$

where K is the number of possible planar diagrams, $E_0 = 1$ GeV. The vertex parameter g_R can be evaluated from the data on cross sections of hadronic interactions and the intercept of the exchange degenerate regge trajectories $\alpha_R(0)$ is equal to 0.5.

Distributions after scattering



Differential cross sections are derived from x_F close to 1
three reggeon asymptotics like RRR , RRP , PPR , PPP .

Rapidity distributions in R-hadron scattering

The differential distributions of R-hadrons in this scheme are derived from the probability:

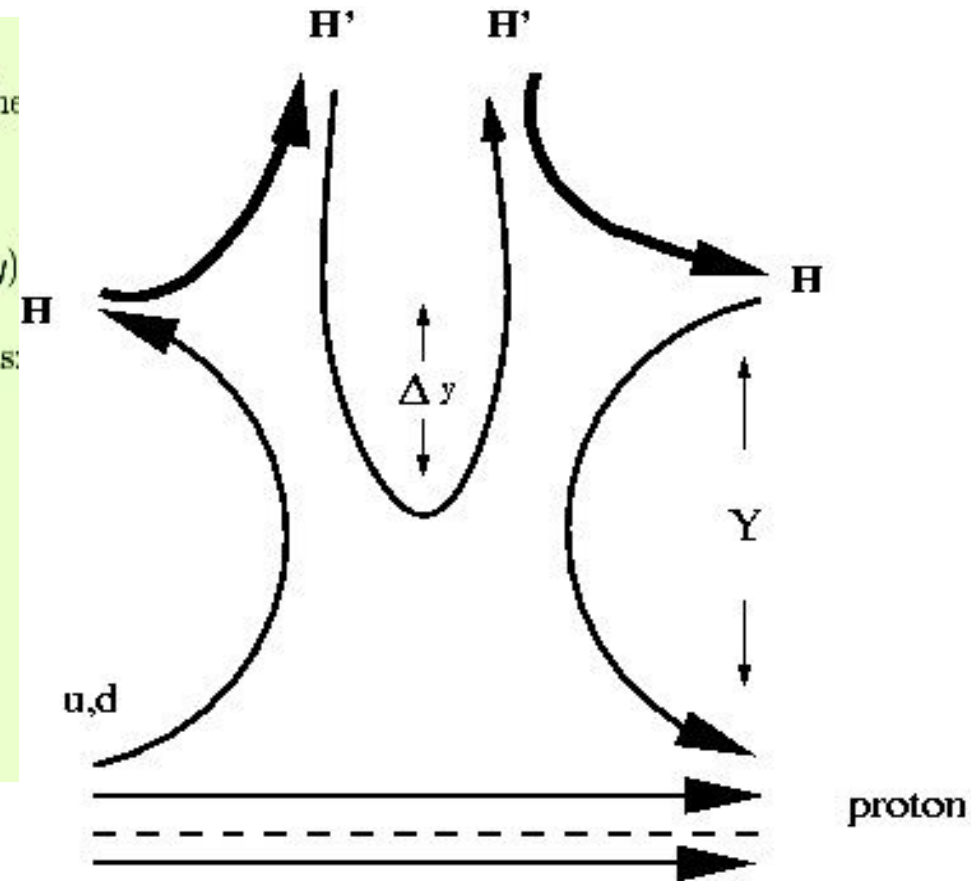
$$\frac{d^2\sigma}{dt dy} = \frac{(1-x)d^2\sigma}{dt d(1-x)} \sim \exp(-2(1-\alpha_i(t))\Delta y) \exp(-(1-\alpha_j(0))(Y-\Delta y))$$

where Y and Δy are the rapidity gaps shown in Fig.5. They can be defined as:

$$Y = \ln \frac{\hat{s}}{M_{SQ} m_N}$$

$$\Delta y = \ln \frac{m_N}{(1-x)M_{SQ}}$$

where $\hat{s} = \frac{s m_N}{s_0 M_{SQ}} - M_{SQ}^2$ and $1-x = m_X/\hat{s}$.



RRR, RRP, PPR and PPP contributions

$$\begin{aligned}
 \frac{d^2\sigma_{RRR}}{dtdM_X^2}(\gamma, M_X^2) &= \frac{1}{M_X^2} \sigma_R^2(\gamma) C_{RRR} \exp[(2B_{RH} + B_{RRR} + 2\alpha'_R \ln(\frac{2\gamma M_0^2}{M_X^2}))t] \left(\frac{M_0^2}{M_X^2}\right)^{\Delta_R} \\
 \frac{d^2\sigma_{RRP}}{dtdM_X^2}(\gamma, M_X^2) &= \frac{1}{M_X^2} \sigma_R^2(\gamma) C_{RRP} \exp[(2B_{RH} + B_{RRP} + 2\alpha'_P \ln(\frac{2\gamma M_0^2}{M_X^2}))t] \left(\frac{M_0^2}{M_X^2}\right)^{2\Delta_R - \Delta_P} \\
 \frac{d^2\sigma_{PPR}}{dtdM_X^2}(\gamma, M_X^2) &= \frac{1}{M_X^2} \sigma_P^2(\gamma) C_{PPR} \exp[(2B_{PH} + B_{PPR} + 2\alpha'_P \ln(\frac{2\gamma M_0^2}{M_X^2}))t] \left(\frac{M_0^2}{M_X^2}\right)^{2\Delta_P - \Delta_R} \\
 \frac{d^2\sigma_{PPP}}{dtdM_X^2}(\gamma, M_X^2) &= \frac{1}{M_X^2} \sigma_P^2(\gamma) C_{PPP} \exp[(2B_{PH} + B_{PPP} + 2\alpha'_P \ln(\frac{2\gamma M_0^2}{M_X^2}))t] \left(\frac{M_0^2}{M_X^2}\right)^{\Delta_P},
 \end{aligned}$$

where $\Delta_R = \alpha_R(0) - 1 = -0.5$, $\Delta_P = \alpha_P(0) - 1 = 0.12$, $\alpha'_R = 0.9 \text{ GeV}^{-2}$, $\alpha'_P = 0.25 \text{ GeV}^{-2}$ and $M_0^2 = m_N m_{q\perp} = 0.5 \text{ GeV}^2$.

only RRR and RRP terms are coming into energy losses because of small contributions from pomeron terms, PPP and PPR, that correspond to diffraction dissociation of proton.

Average energy losses

The energy loss in each hadronic collision with the single nucleon target:

The energy loss of a H -hadron is given by:

$$\Delta E = \frac{M_X^2 - m_N^2 + |t|}{2m_N} \quad (9)$$

The average energy loss can thus be calculated:

$$\langle E \rangle = \frac{\int_{m_N+m_\pi}^{M_{Xmax}} dM_X \int_{|t|_{min}}^{|t|_{max}} d|t| \Delta E \frac{d^2\sigma}{d|t|dM_X}}{\int_{m_N+m_\pi}^{M_{Xmax}} dM_X \int_{|t|_{min}}^{|t|_{max}} d|t| \frac{d^2\sigma}{d|t|dM_X}} \quad (10)$$

Here, m_N and m_π were taken as the mass of the proton and a charge pion, respectively.

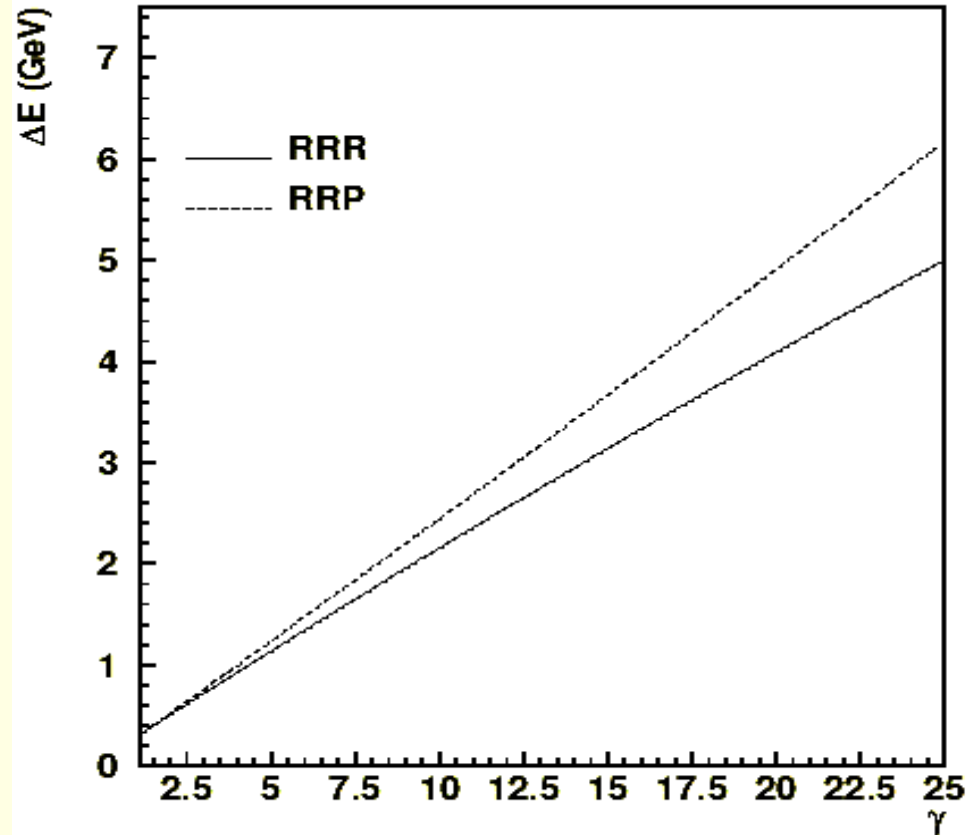
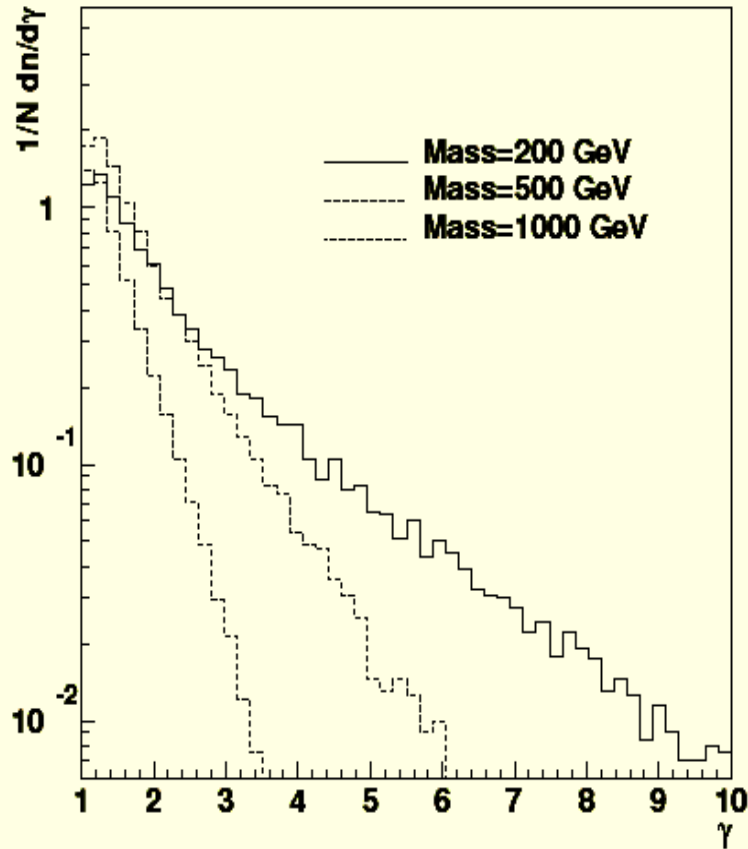
The upper limit on M_X is taken to be the lower of the following two limits: $M_{Xmax} = (2\gamma M_0^2)^{\frac{1}{2}}$, which represents the condition $\Delta y = 0$ or $M_{Xmax} = \sqrt{s} - m_H$ from energy-momentum conservation and where m_H is the mass of the interacting H -hadron.

The limits on t are given by

$$|t|_{min,max}(M_X) = 2[E(m_N)E(M_X) \mp p(m_N)p(M_X) - m_H^2] \quad (11)$$

where $E(m) = \frac{s+m_H^2-m^2}{2\sqrt{s}}$, $p(m) = \frac{\lambda^{\frac{1}{2}}(s,m_H^2,m^2)}{2\sqrt{s}}$, and $\lambda(a,b,c) = a^2 + b^2 + c^2 - 2(ab + ac + bc)$.

Comparison of energy losses



In the region of effective γ 's both contributions are similar. It gives the same energy losses for reggeon and pomeron types of contribution.

MC simulation of interactions

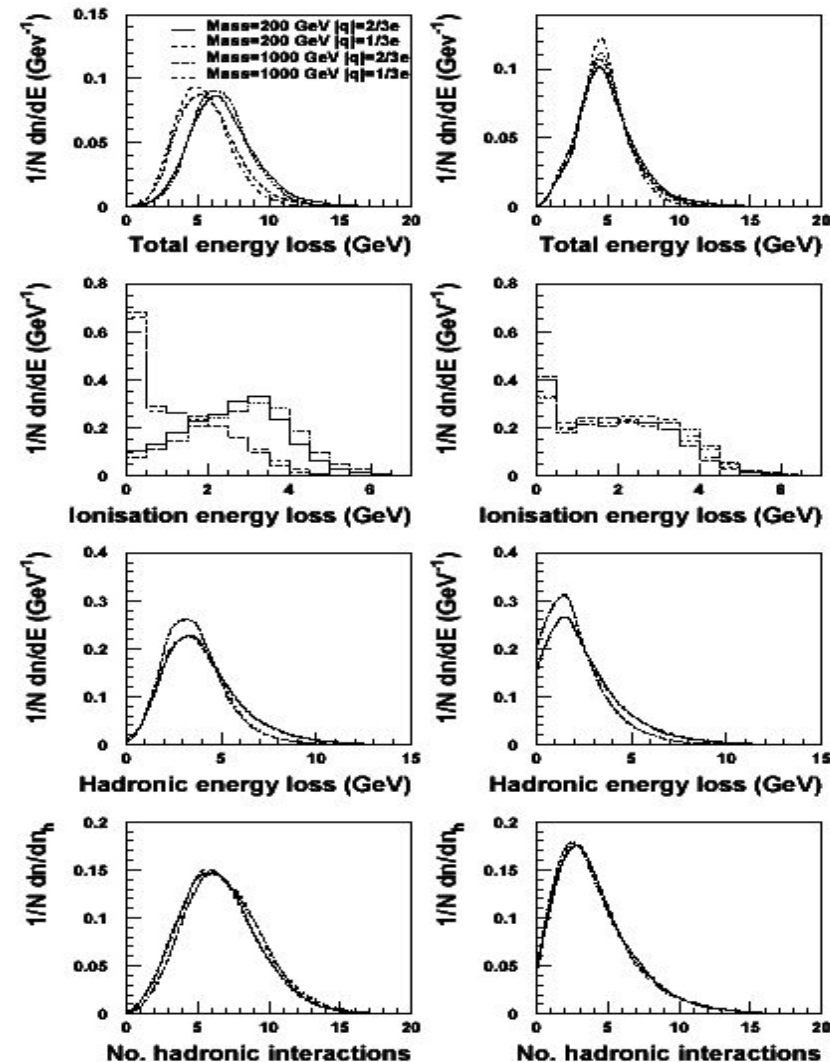


Figure 7: Distributions of energy loss and hadronic scattering for H -hadrons of masses 200 and 1000 GeV and for exotic quarks of charges $\pm\frac{1}{3}e$ and $\pm\frac{2}{3}e$. The left (right) column represents H -hadrons containing an exotic quark (anti-quark). Distributions of the total, ionisation and hadronic energy loss is shown along with the multiplicity of interactions. The distributions assume no mixing of neutral H -mesons.

the difference in the number of interactions of heavy quark hadrons and heavy antiquark hadrons is clearly seen

Summary

Hadronic systems with one exotic quark behave rather specifically. Their interactions with ordinary matter was considered in QGSM with the following conclusions:

- cross sections for the scattering of squark exotic hadrons (mesinos) on protons of matter is not large because of new quantum number that can not annihilate. It is bigger than X-section of antisquark mesino due to the valuable possibility of light antiquark to interact with quarks of proton;
- energy losses in matter in case of stop hadrons (RRR) differ not very much from antistop hadron losses (RRP). Hadrons lose 10% of energy in an interaction;
- the number of interactions of heavy quark hadron in hadron calorimeter is much larger than of antiquark hadron, that allows to separate antimatter from matter;

Summary

- recharge for stop hadrons is possible only by ± 1 in hadron interaction, such a way the valuable asymmetry between stop and antistop hadrons is retained though the hadronic calorimeter;
- in muon tracking system we could measure this asymmetry as well as the particular spectra of heavy exotic hadrons
- first publication => [arXiv:0710.3930](https://arxiv.org/abs/0710.3930)

Заключение

Адроны с тяжелым суперсимметричным кварком проявляют себя во взаимодействиях с веществом весьма специфически.

Моделирование с помощью МКГС прохождения такой частицы через вещество, привело к следующим выводам:

- в области эффективных сечения взаимодействия с протонами вещества различаются так, что адроны с кварком взаимодействуют чаще, чем адроны содержащие тяжелый антикварк;
- средние потери энергии в этих двух случаях различаются незначительно;

Заключение

- так как перезарядка адрона во взаимодействии возможна лишь на ± 1 , в адронном калориметре сохраняется асимметрия между спектрами скварковых и антискварковых адронов;
- мы можем предсказывать зарядовую асимметрию и спектры суперсимметричных адронов, измеряемые в мюонных детекторах.