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

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Outline

- Introduction
  - Definitions and astrophysical constraints
  - Squarks as NLSP in SUSY and Sugra
  - Quark Gluon String Model
- Conditions of experiment
  - Interactions with proton
- Cross sections from QGSM
  - Distributions after scattering
  - RRR, RRP, PPR and PPP contributions
  - Average energy losses
  - Results of MC simulations
- Summary

Introduction I

New heavy quark =
heavy exotic quark = SMP
= SIMP = NLSP

Introduction II

- about SUSY models :

- conventional SUSY models (neutralino LSP, masses ~ 1TeV, 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)

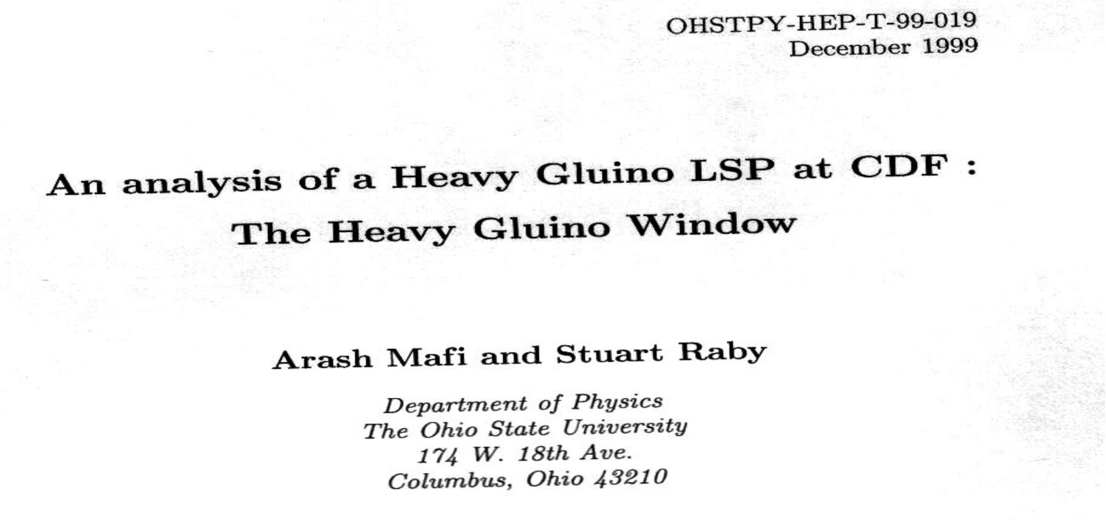
- Compressed SUSY model (S.Martin) predicts NLSP stop quark with low mass > 200 GeV

in Sugra :

in the models with gravitino LSP, squarks as NLSP would be almost stable because gravitino is practically not connected to the matter

Introduction III

Previous publications:



OHSTPY-HEP-T-99-019
December 1999

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

Arash Mafi and Stuart Raby

Department of Physics
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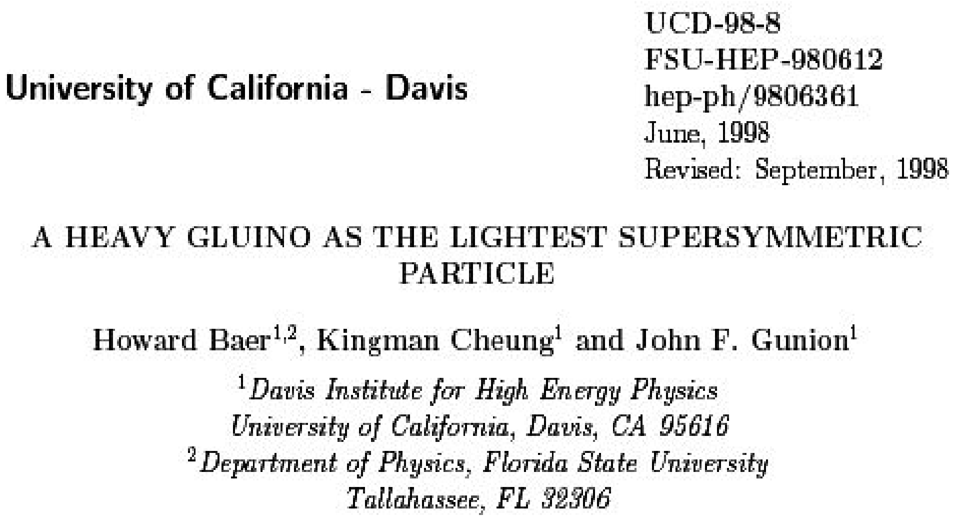
174 W. 18th Ave.
Columbus, Ohio 43210



University of California - Davis

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

A HEAVY GLUINO AS THE LIGHTEST SUPERSYMMETRIC PARTICLE

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University of California, Davis, CA 95616
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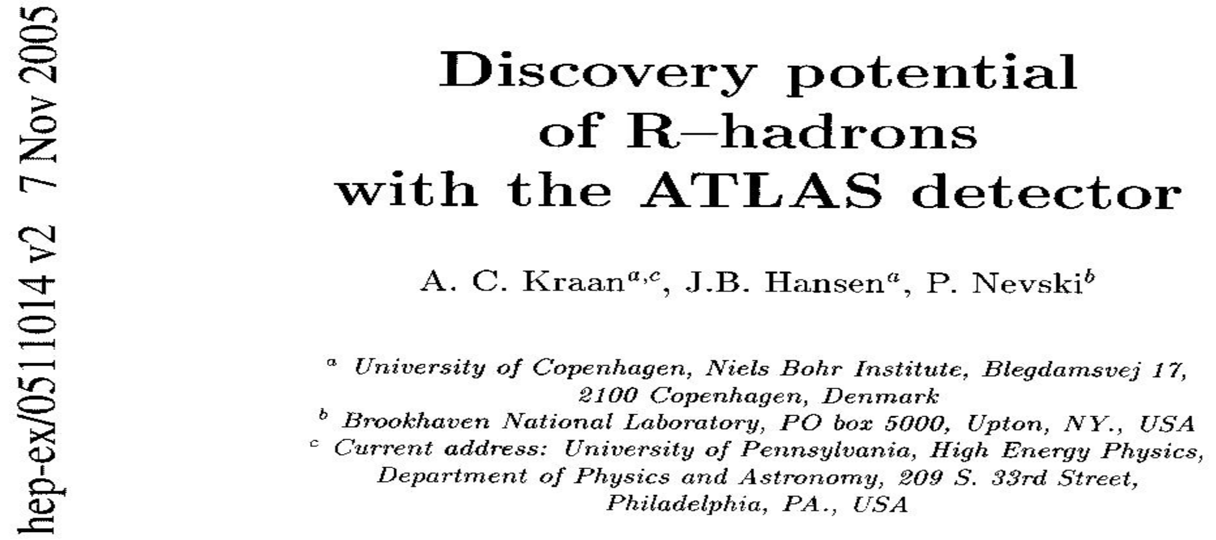

hep-ex/0511014 v2 7 Nov 2005

Discovery potential of R–hadrons with the ATLAS detector

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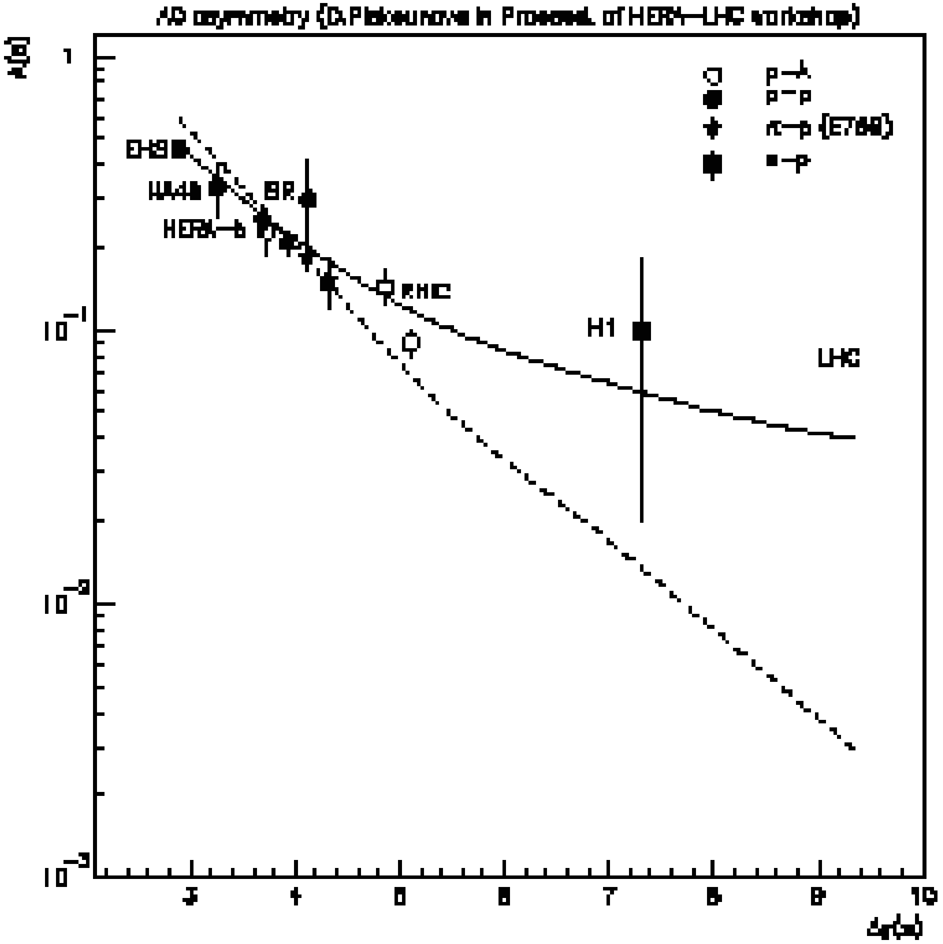
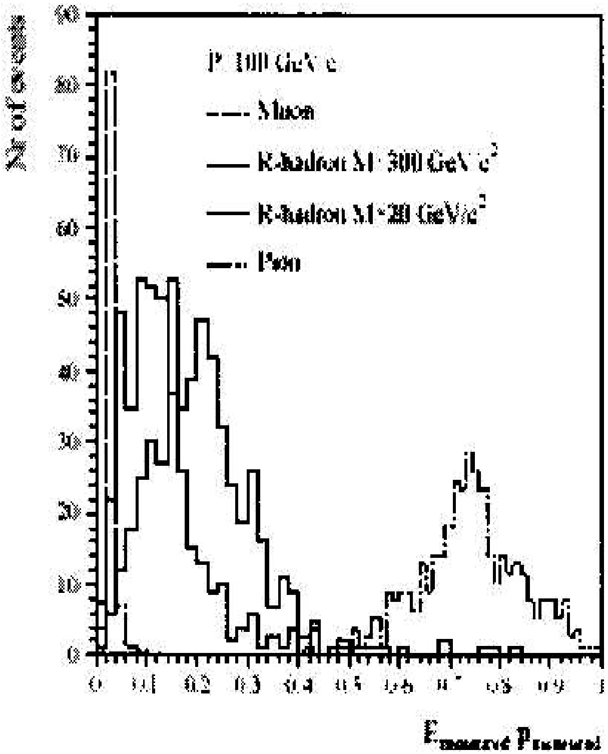
Introduction

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

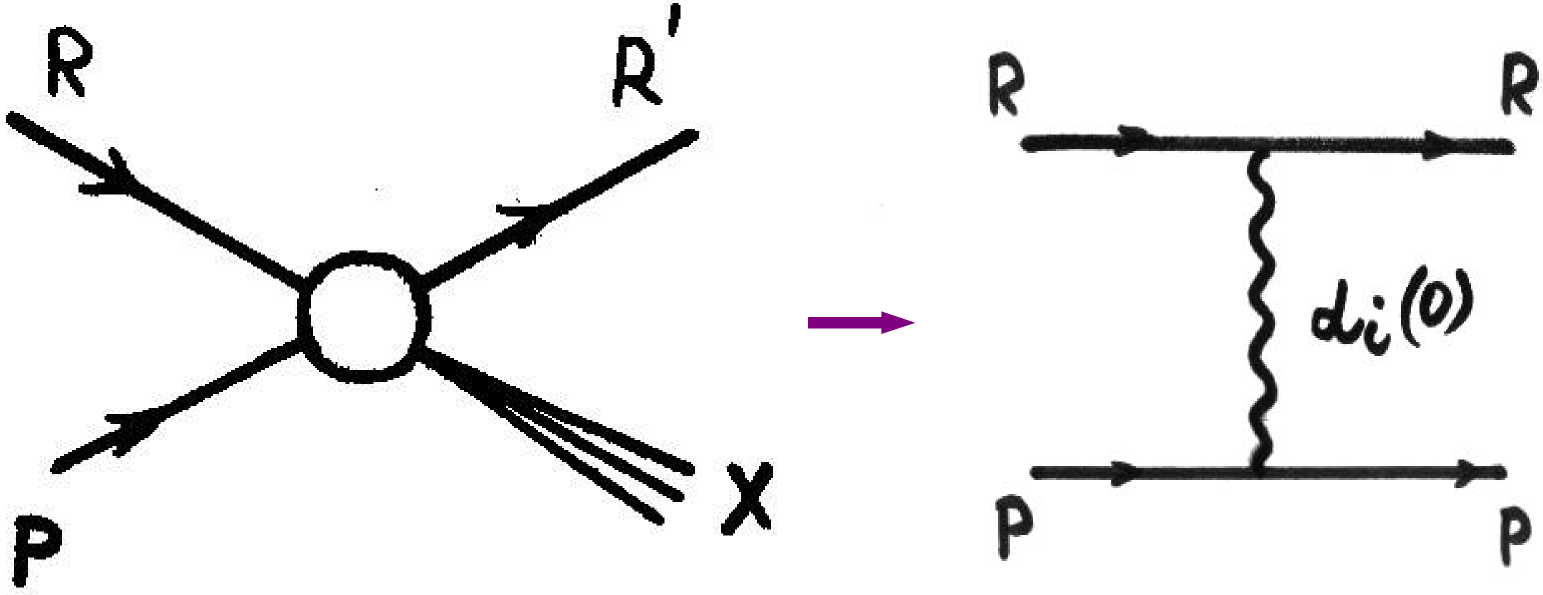


I. Stop hadrons are passing hadron calorimeter with little energy losses

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

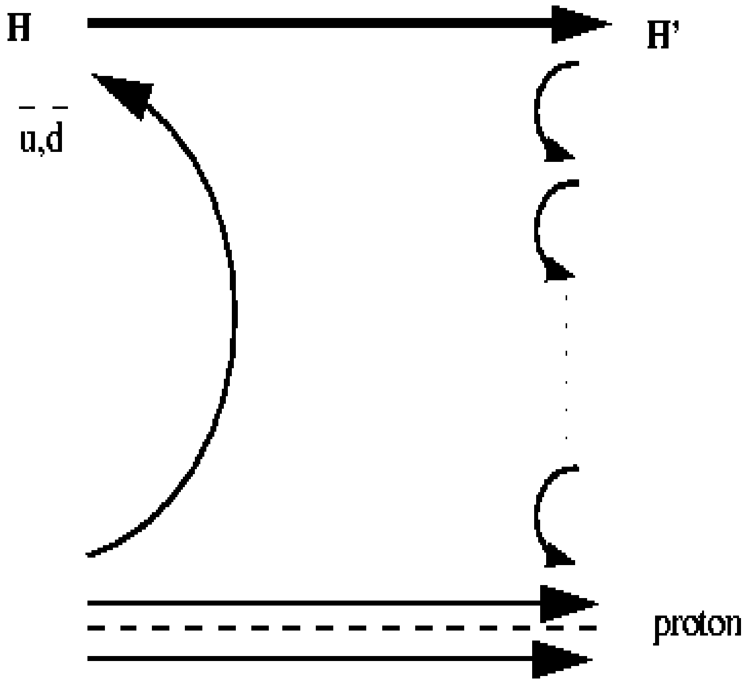
III. Charge changing interactions: charged particle can anyhow pass into neutral one and back
due to hadronic interactions,
but can not change the charge from + to -

Interaction in particle representation

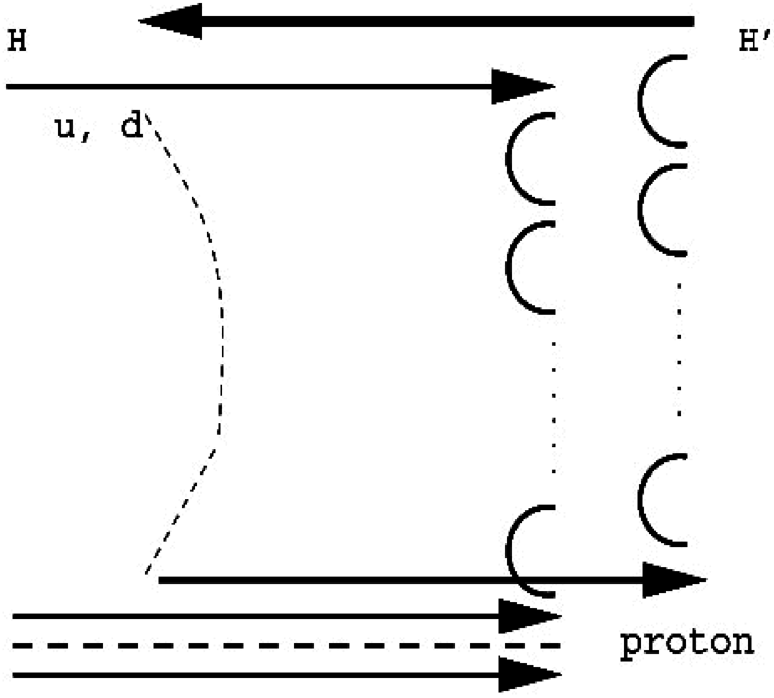


Two particle interactions can be presented as the exchange with Regge trajectory with angle momenta $\alpha_i(t)$

Interactions in quark representation

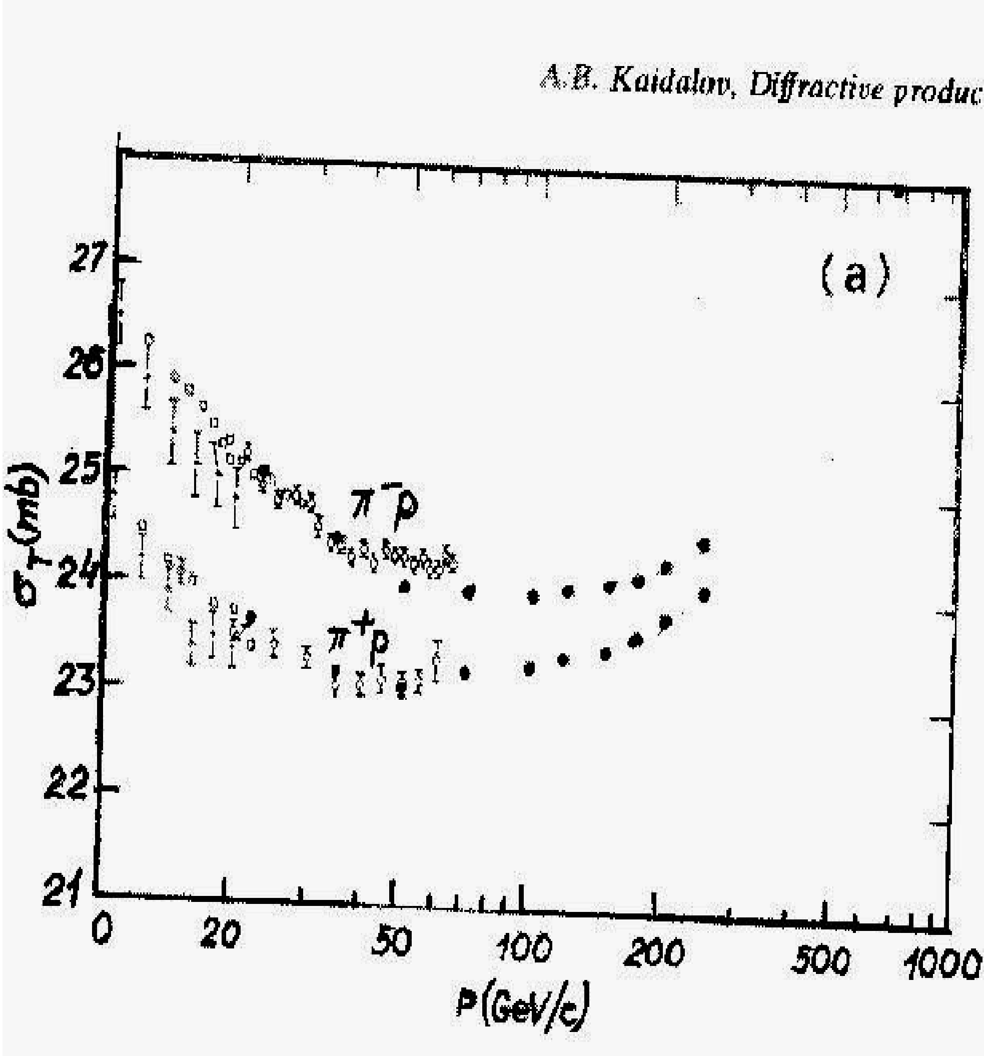


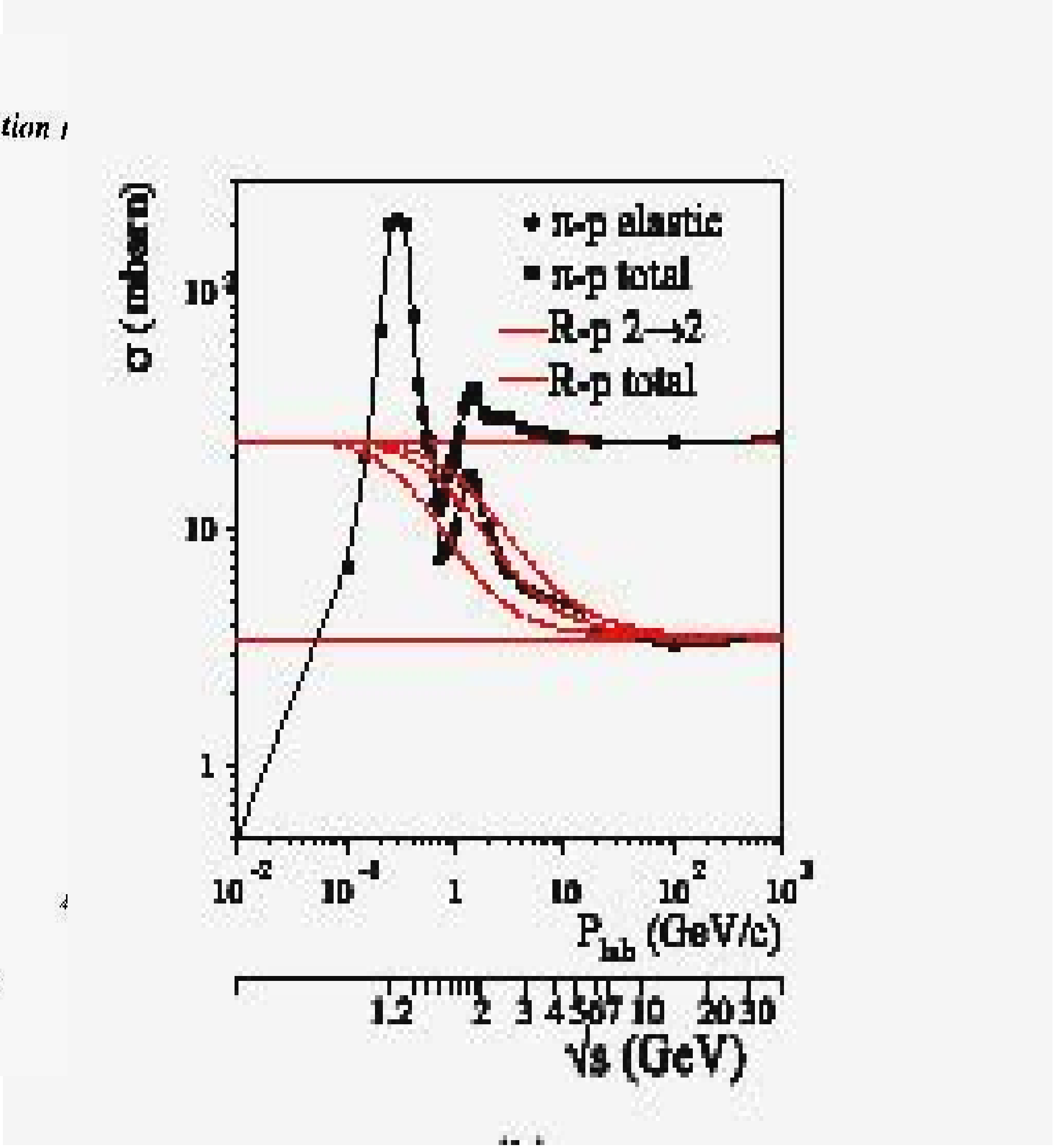
Planar diagram for reggeon exchange.



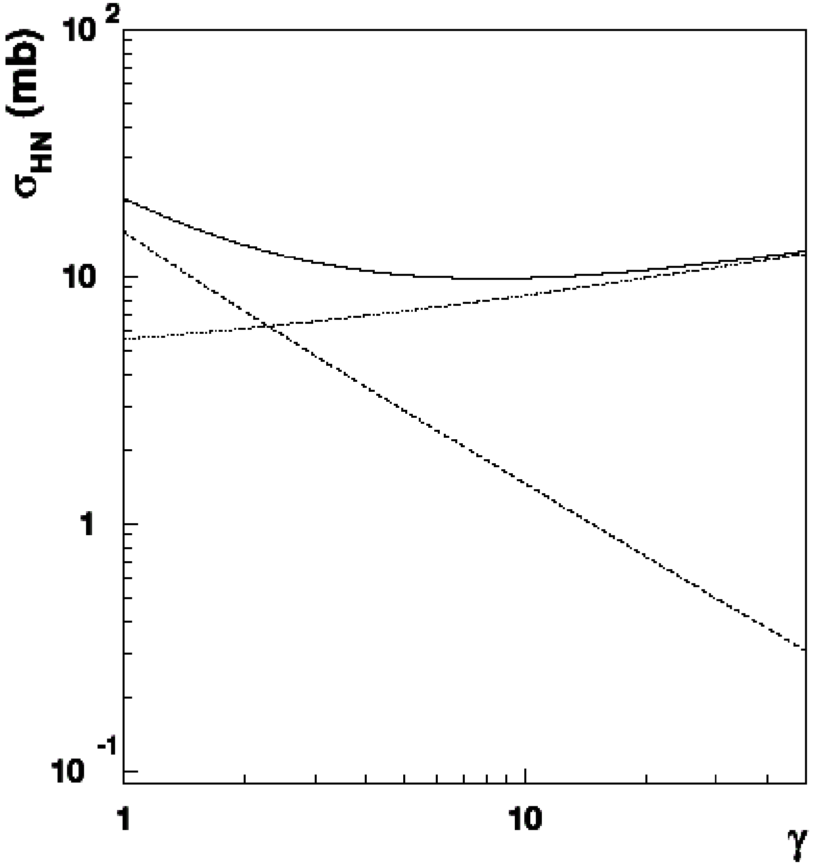
Cylinder diagram for pomeron exchanges

Cross sections





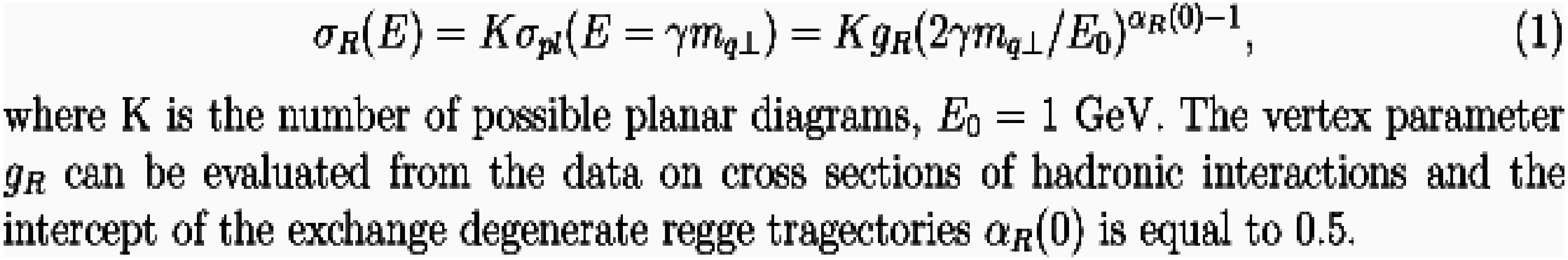
Cross sections in QGSM



γ = E/M$_H$

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

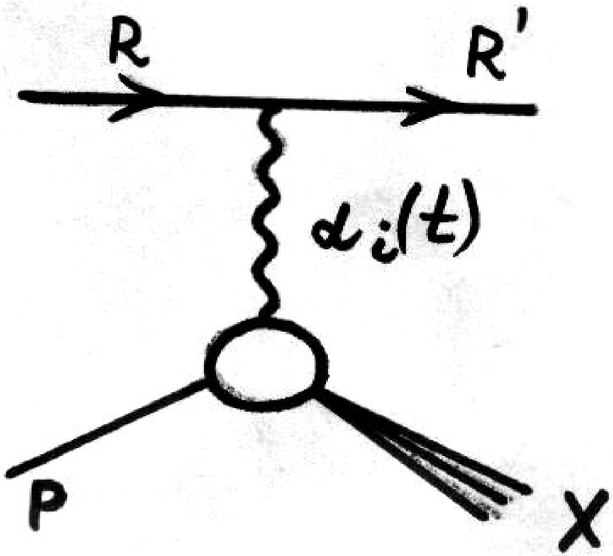
Pomeron cross section corresponds to γ^{Δ}, where $\Delta_P = \alpha_P(0) - 1 = 0.12$

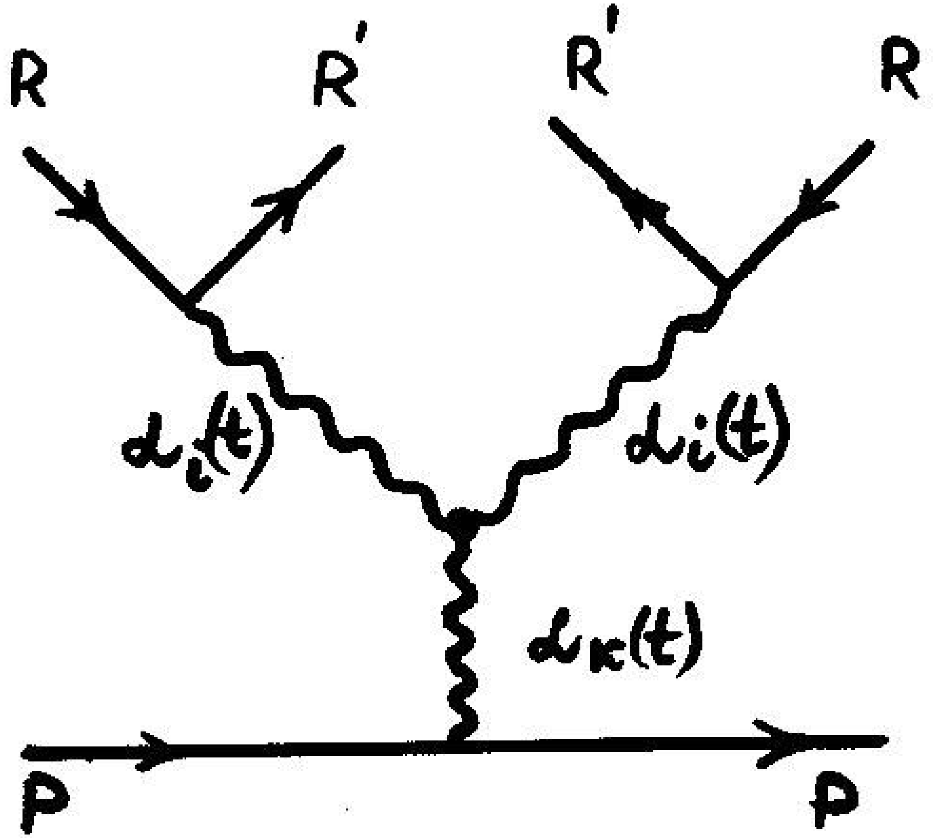


$$\sigma_R(E) = K\sigma_{pl}(E = \gamma m_{q\perp}) = K g_R (2\gamma m_{q\perp}/E_0)^{\alpha_R(0)-1}, \qquad (1)$$

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 tragectories $\alpha_R(0)$ is equal to 0.5.

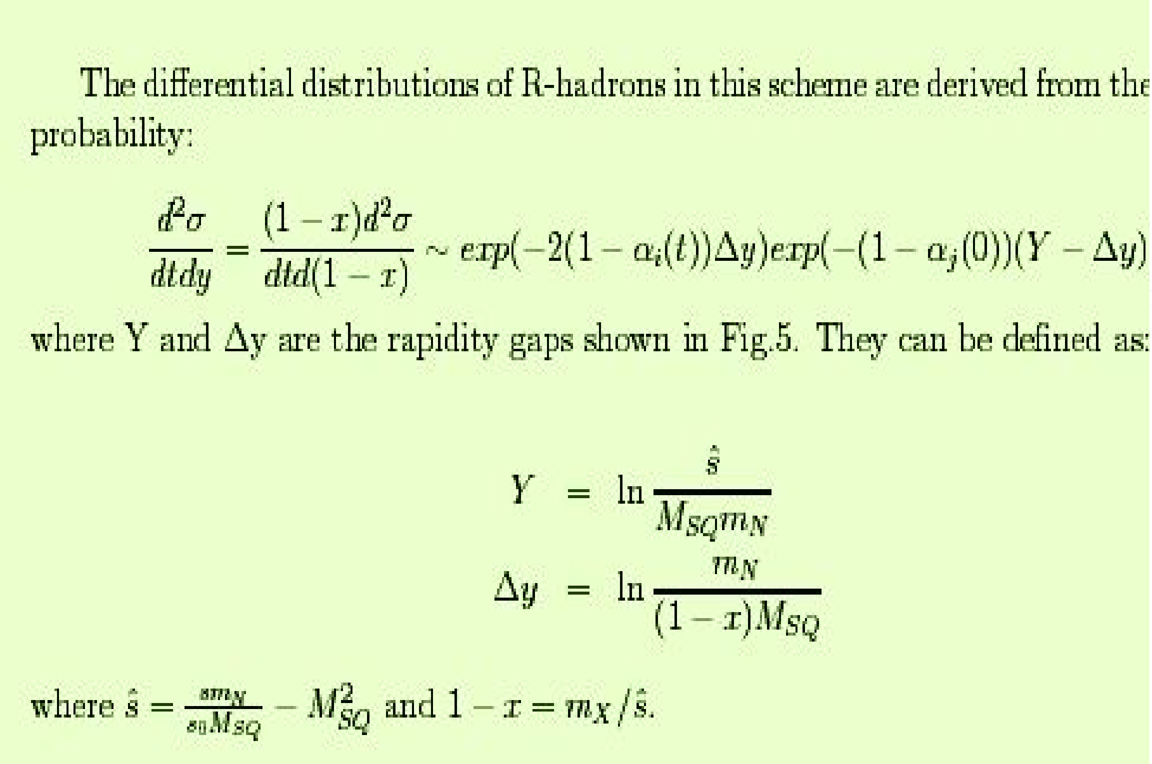
Distributions after scattering





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:

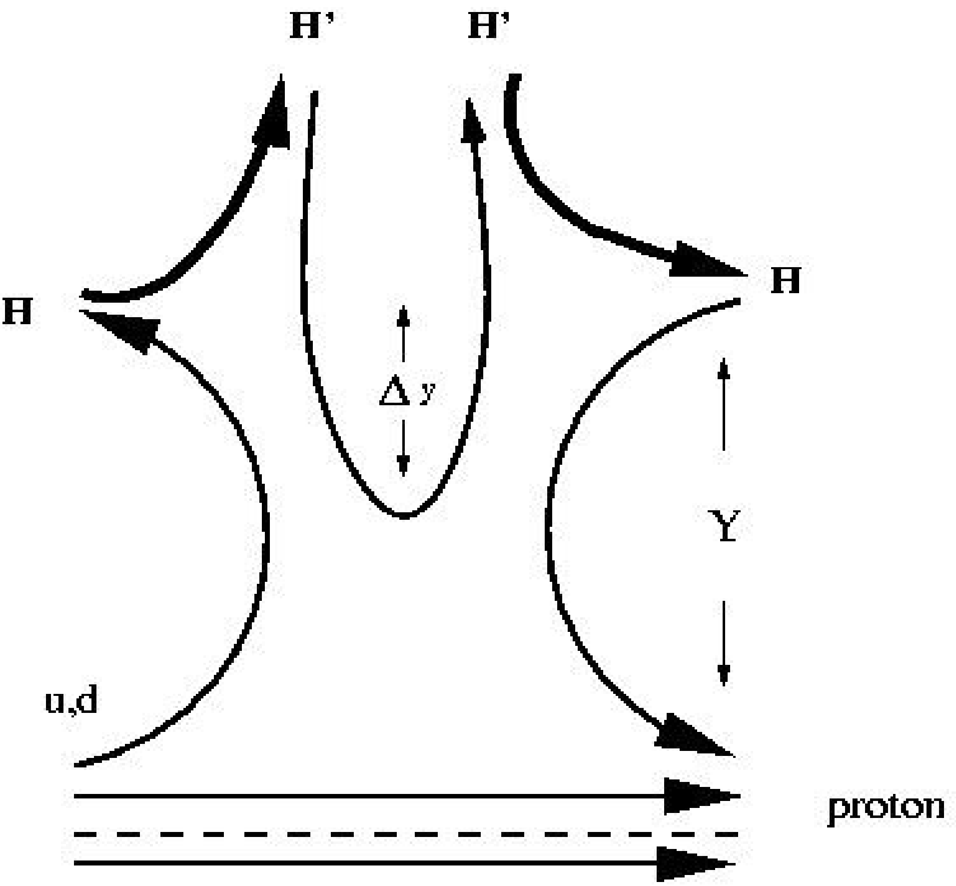
$$\frac{d^2\sigma}{dtdy} = \frac{(1-x)d^2\sigma}{dtd(1-x)} \sim exp(-2(1-\alpha_i(t))\Delta y)exp(-(1-\alpha_j(0))(Y-\Delta y)$$

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

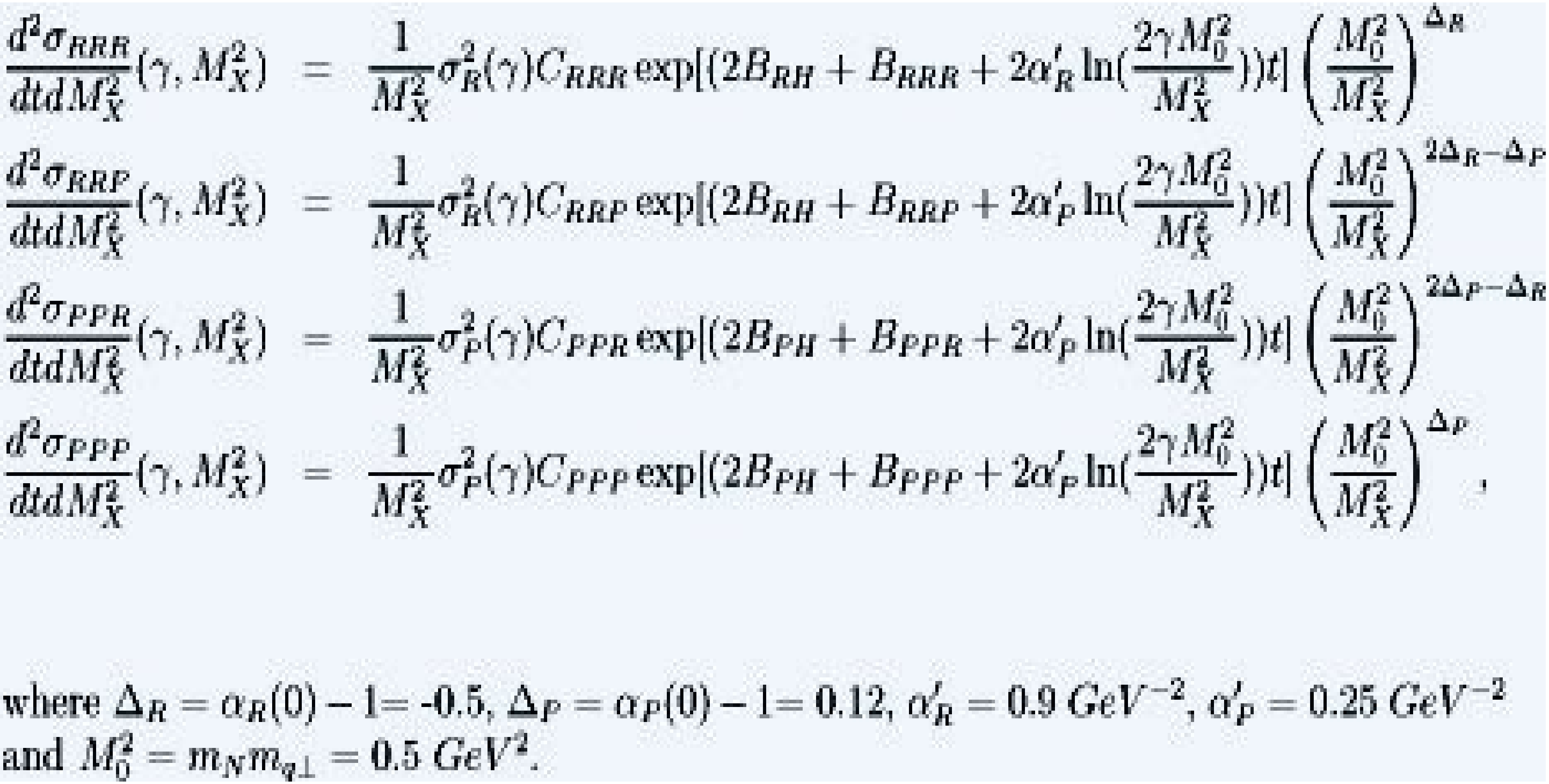
$$Y = \ln\frac{\hat{s}}{M_{SQ}m_N}$$

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

where $\hat{s} = \frac{sm_N}{s_0M_{SQ}} - M_{SQ}^2$ and $1-x = m_X/\hat{s}$.



RRR, RRP, PPR and PPP contributions



$$\frac{d^2\sigma_{RRR}}{dtdM_X^2}(\gamma, M_X^2) = \frac{1}{M_X^2}\sigma_R^2(\gamma)C_{RRR}\exp[(2B_{RH} + B_{RRR} + 2\alpha'_R\ln(\frac{2\gamma M_0^2}{M_X^2}))t]\left(\frac{M_0^2}{M_X^2}\right)^{\Delta_R}$$

$$\frac{d^2\sigma_{RRP}}{dtdM_X^2}(\gamma, M_X^2) = \frac{1}{M_X^2}\sigma_R^2(\gamma)C_{RRP}\exp[(2B_{RH} + B_{RRP} + 2\alpha'_P\ln(\frac{2\gamma M_0^2}{M_X^2}))t]\left(\frac{M_0^2}{M_X^2}\right)^{2\Delta_R-\Delta_P}$$

$$\frac{d^2\sigma_{PPR}}{dtdM_X^2}(\gamma, M_X^2) = \frac{1}{M_X^2}\sigma_P^2(\gamma)C_{PPR}\exp[(2B_{PH} + B_{PPR} + 2\alpha'_P\ln(\frac{2\gamma M_0^2}{M_X^2}))t]\left(\frac{M_0^2}{M_X^2}\right)^{2\Delta_P-\Delta_R}$$

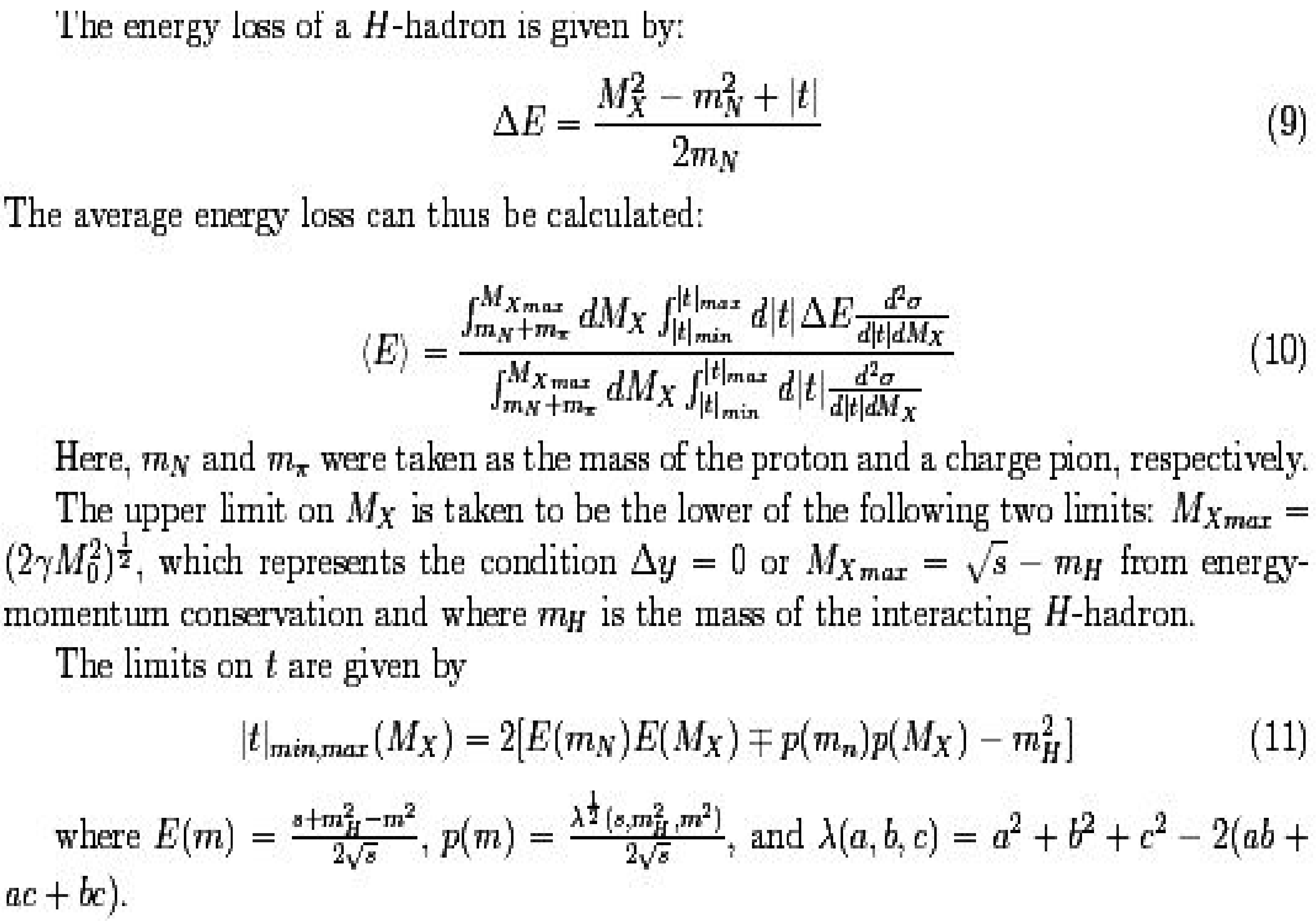
$$\frac{d^2\sigma_{PPP}}{dtdM_X^2}(\gamma, M_X^2) = \frac{1}{M_X^2}\sigma_P^2(\gamma)C_{PPP}\exp[(2B_{PH} + B_{PPP} + 2\alpha'_P\ln(\frac{2\gamma M_0^2}{M_X^2}))t]\left(\frac{M_0^2}{M_X^2}\right)^{\Delta_P},$$

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

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:

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

The average energy loss can thus be calculated:

$$\langle E \rangle = \frac{\int_{m_N+m_\pi}^{M_{X\,max}} dM_X \int_{|t|_{min}}^{|t|_{max}} d|t|\,\Delta E \frac{d^2\sigma}{d|t|dM_X}}{\int_{m_N+m_\pi}^{M_{X\,max}} dM_X \int_{|t|_{min}}^{|t|_{max}} d|t| \frac{d^2\sigma}{d|t|dM_X}} \tag{10}$$

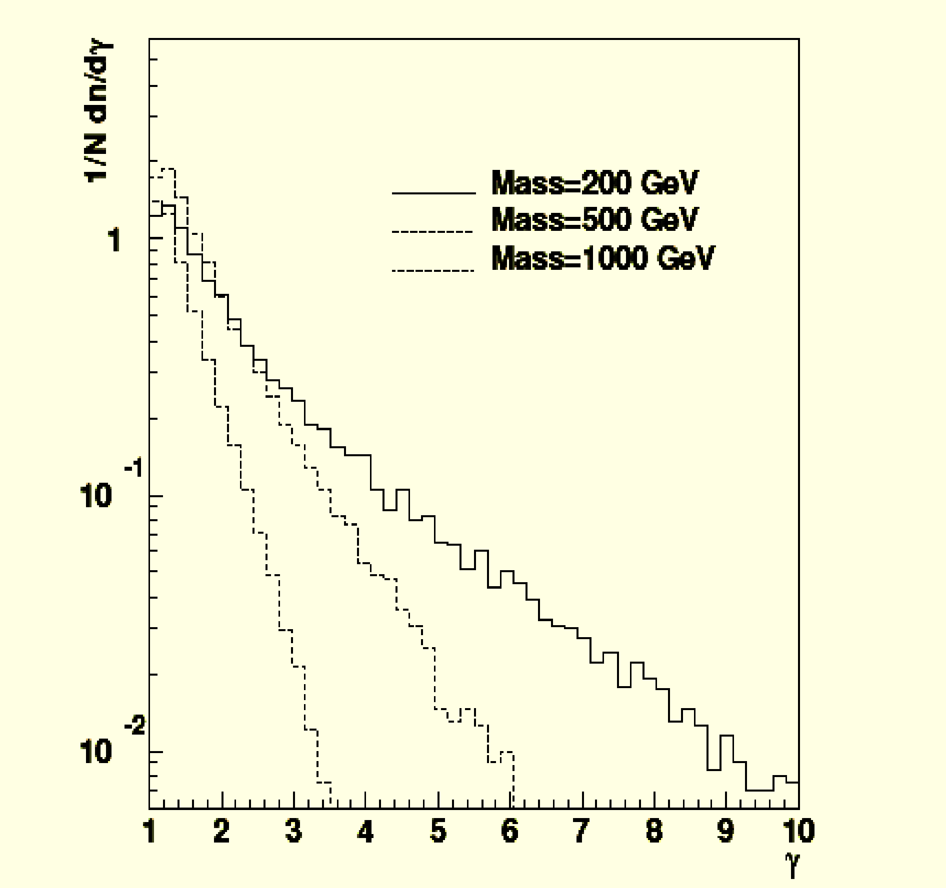
Here, m_N and m_π were taken as the mass of the proton and a charge pion, respectively. The upper limit on M_X is taken to be the lower of the following two limits: $M_{X\,max} = (2\gamma M_0^2)^{\frac{1}{2}}$, which represents the condition $\Delta y = 0$ or $M_{X\,max} = \sqrt{s} - m_H$ from energy-momentum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

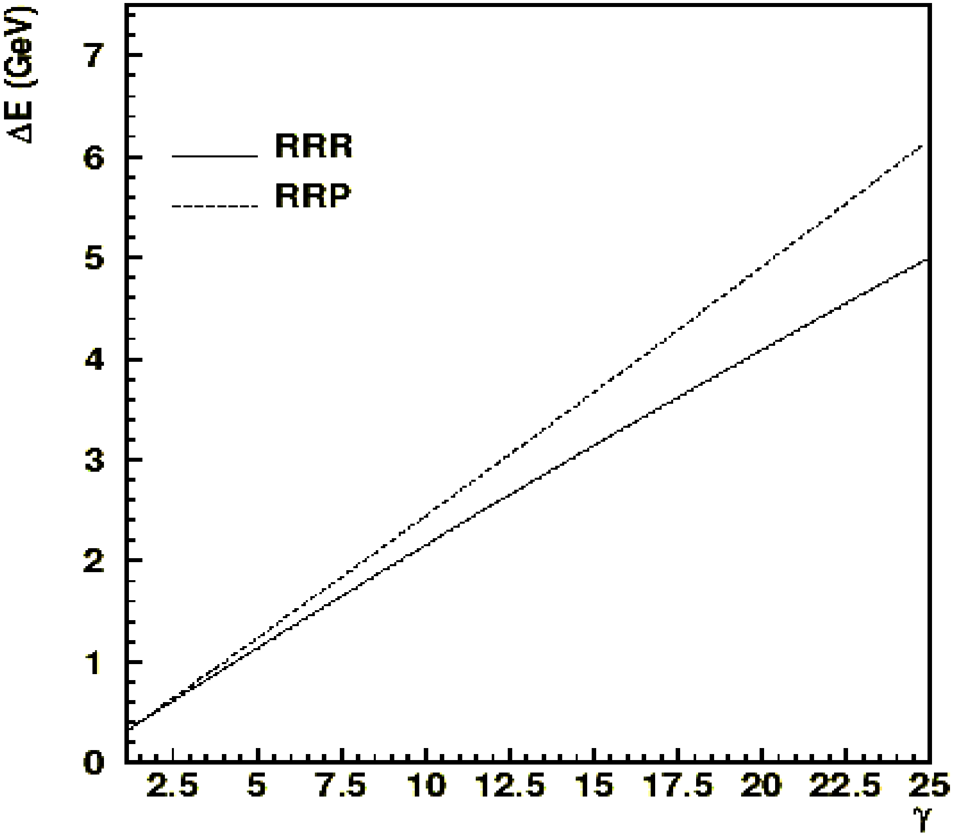
The limits on t are given by

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

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

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

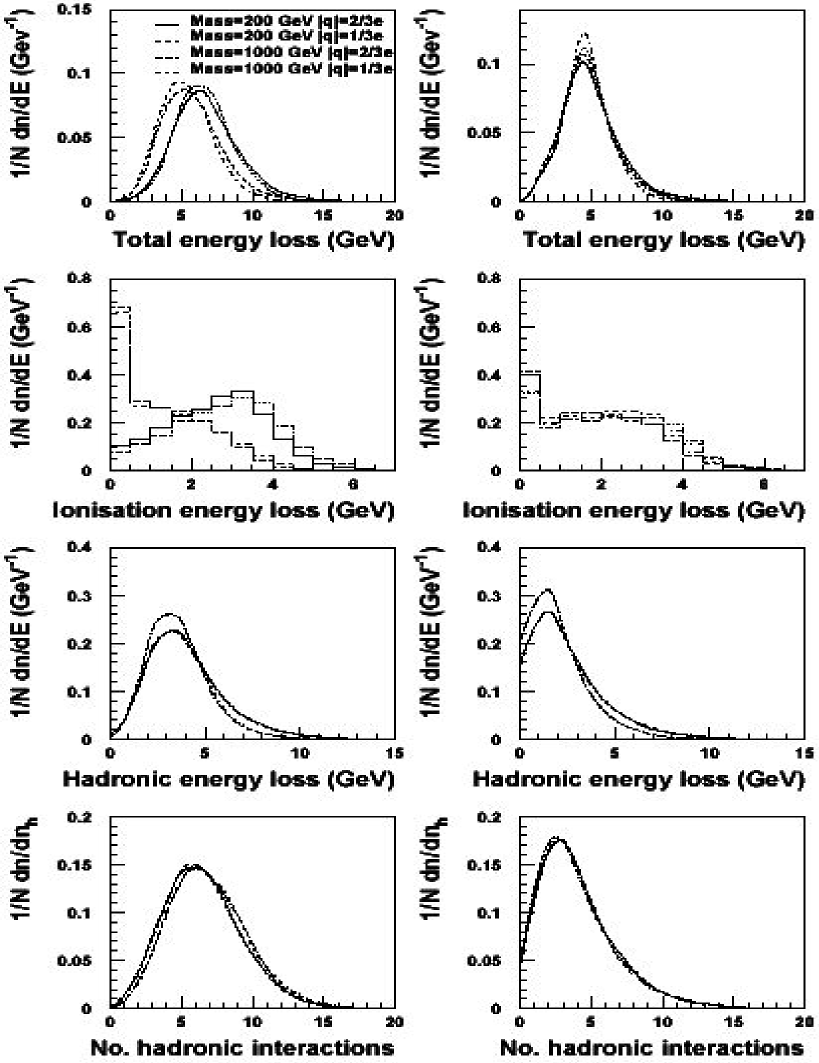


Figure 7: Distributions of energy loss and hadronic scattering for H-hadrons of masses 200 and 1000 GeV and for exotic quarks of charges $\pm\frac{1}{3}e$ and $\pm\frac{2}{3}e$. The left (right) column represents H-hadrons containing an exotic quark (anti-quark). Distributions of the total, ionisation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

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 interact twice on one meter of iron and lose 1% of energy in an interaction;

Summary

the number of interactions of heavy quark hadron in hadron calorimeter is much larger than of antiquark hadron, that allows to separate antimater from matter;

- 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

What is known from astrophysics:

The detection of strongly interacting massive particles will conflict with BBN scenario;

The abundance of very long living hadronic NLSP lead to the visible structure of CMB ;

Observation of stop quark hadrons will have strong impact on the calculations of nuclear balance in Universe and dark energy estimation

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.