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

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# Outline

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  - Quark Gluon String Model
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# Introduction

- 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 quasystable stop quark with low mass > 200 GeV

# Introduction

## Previous works:

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**

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*The Ohio State University*
*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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hep-ex/0511014 v2 7 Nov 2005

**Discovery potential**
**of R–hadrons**
**with the ATLAS detector**

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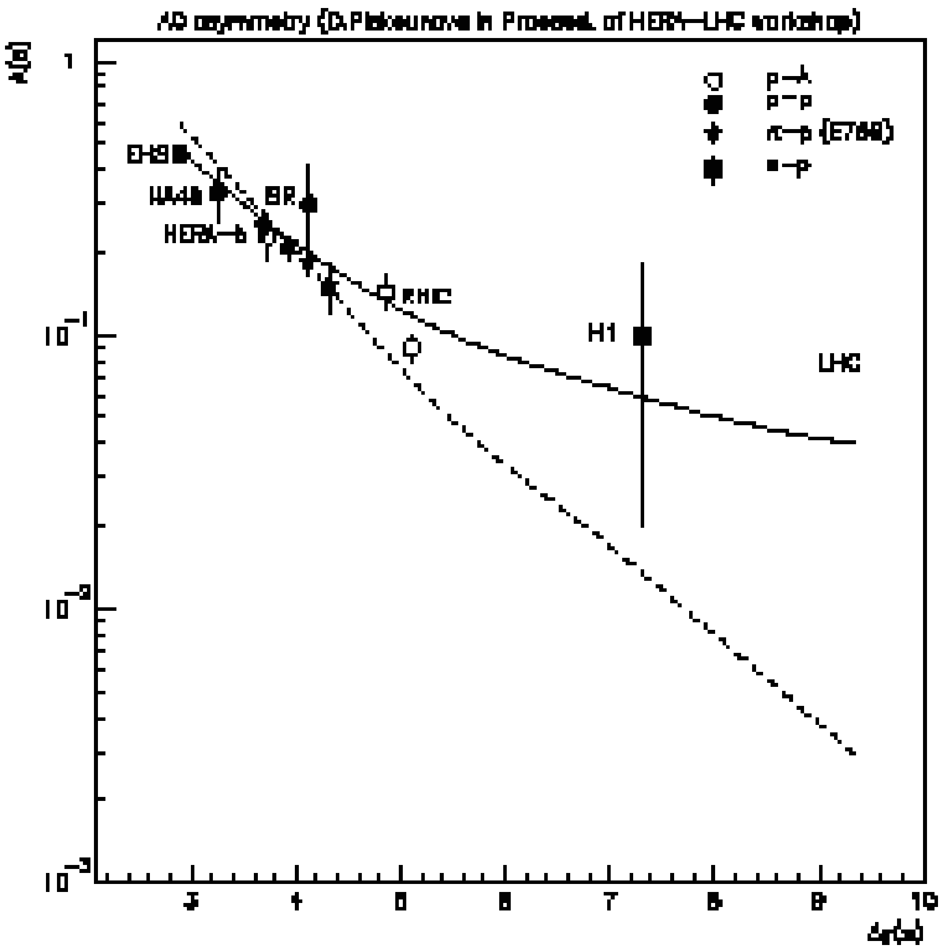
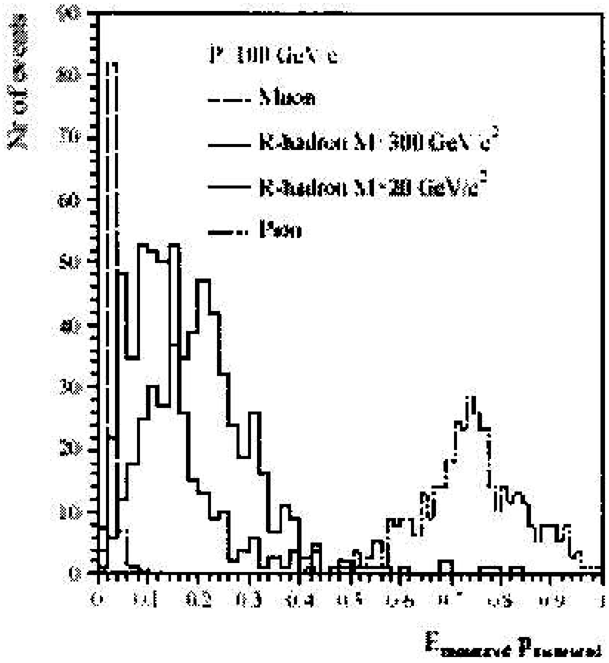
# Introduction

## 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

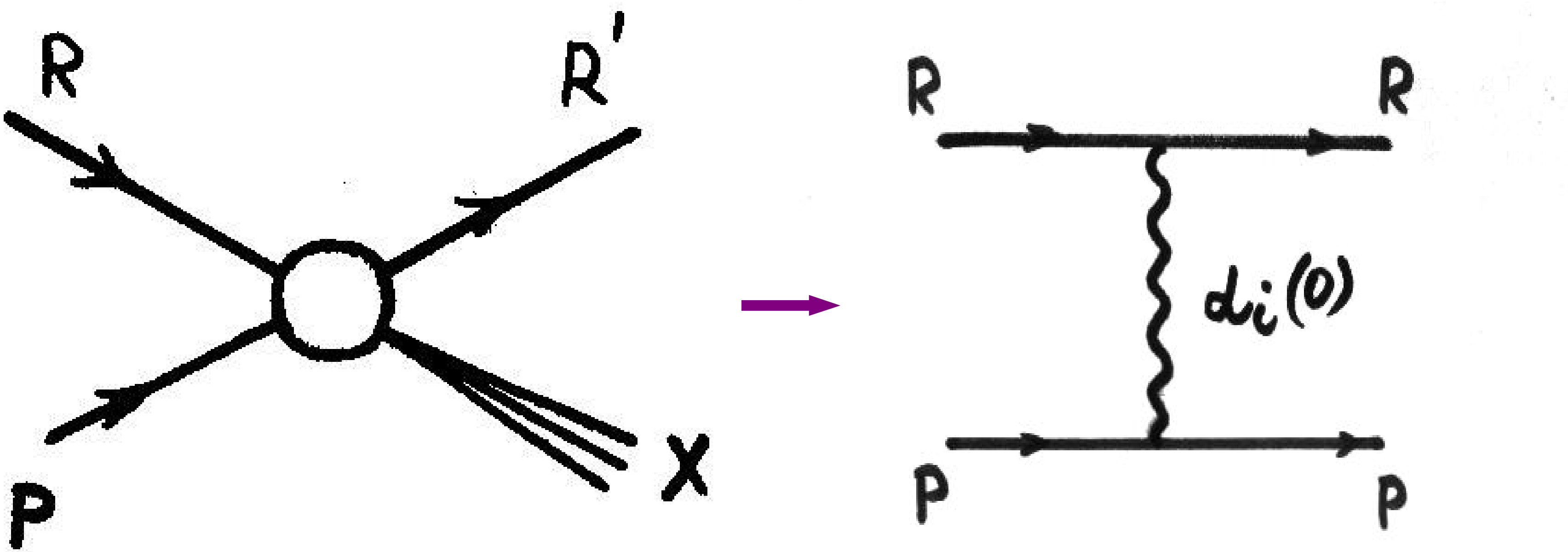
# Conditions of experiment




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

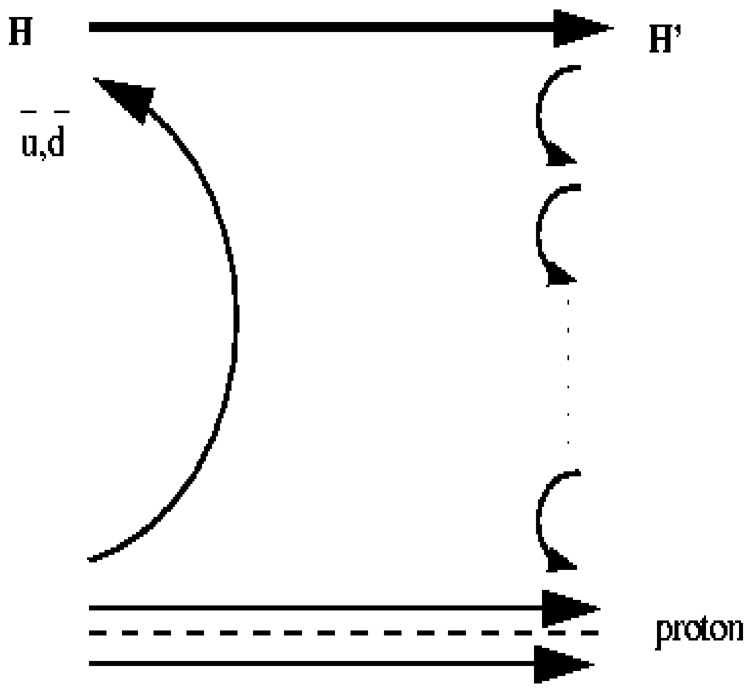
II. Charge changing interactions: charged particle can anyhow pass into neutral one and back due to hadronic interactions, but can not change the charge from + to -

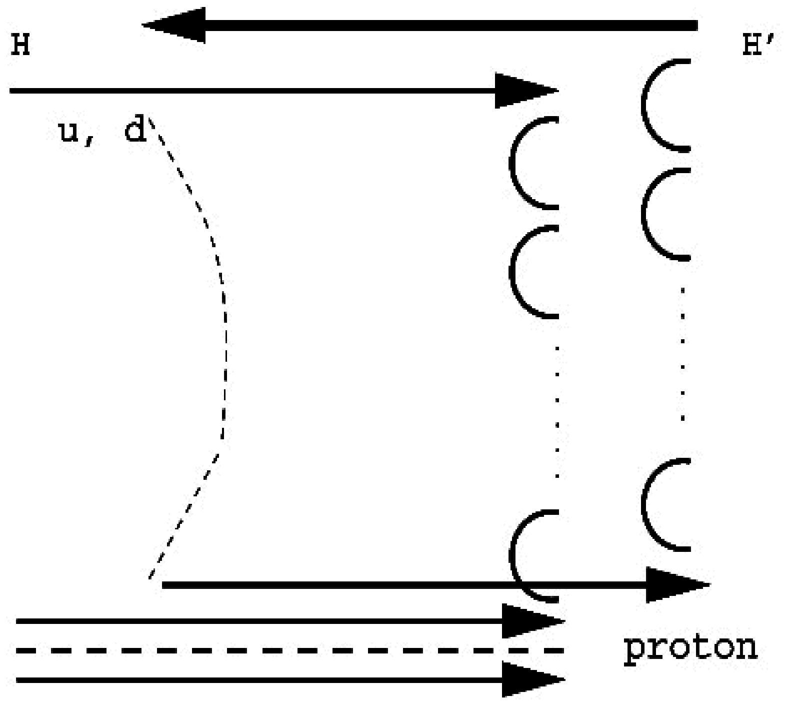
# Interaction in particle presentation




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

# Interactions in quark presentation

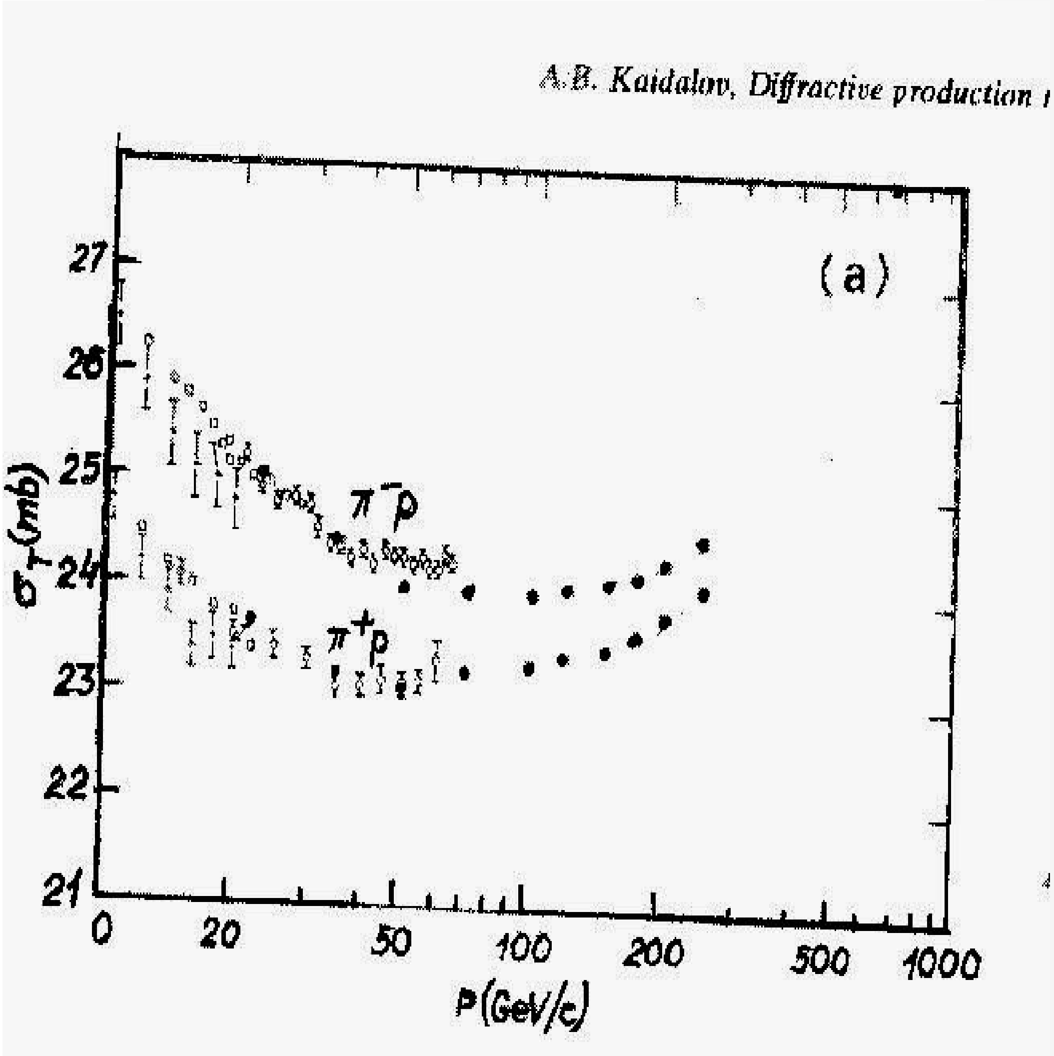


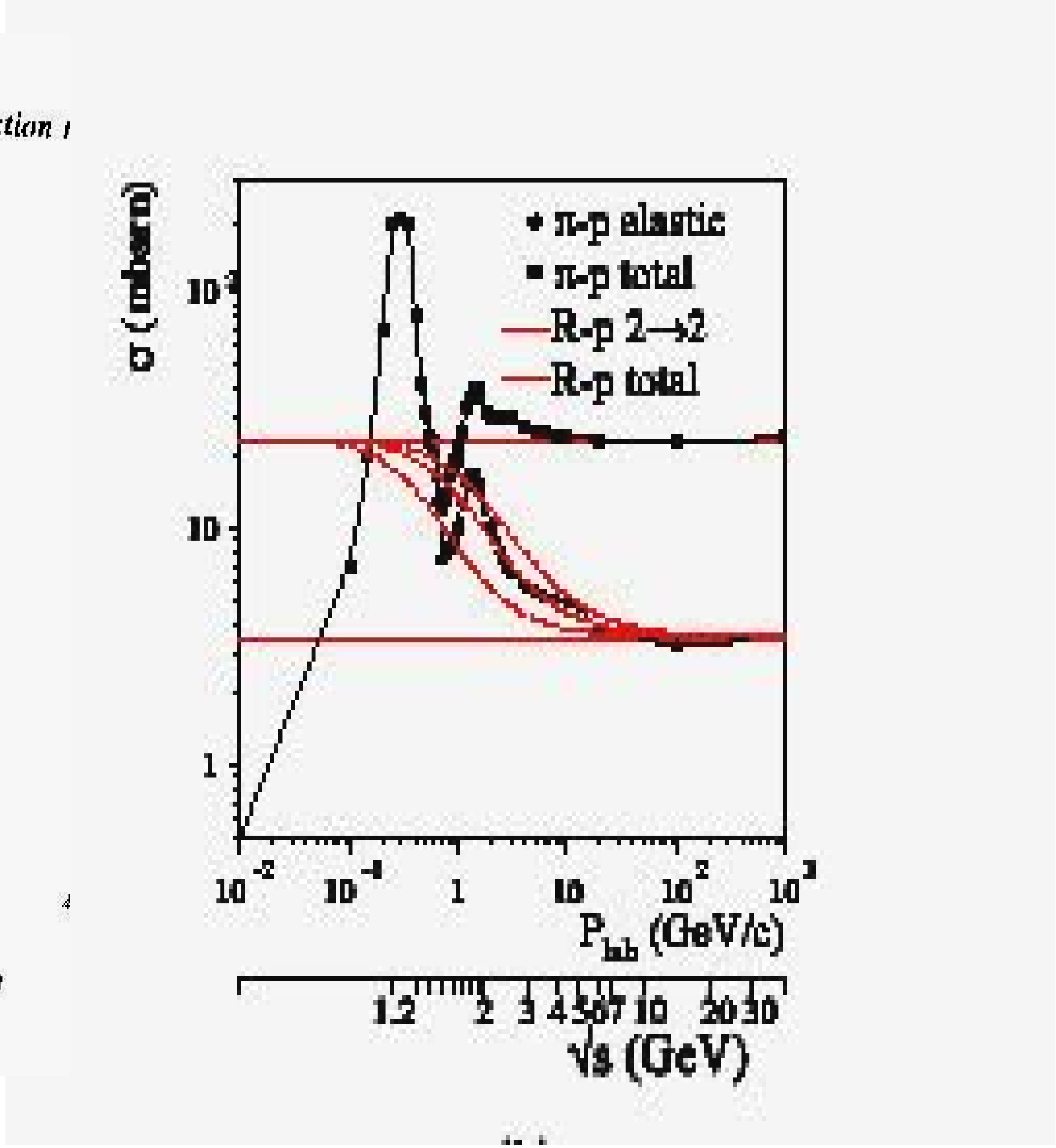




Planar diagram for reggeon exchange.

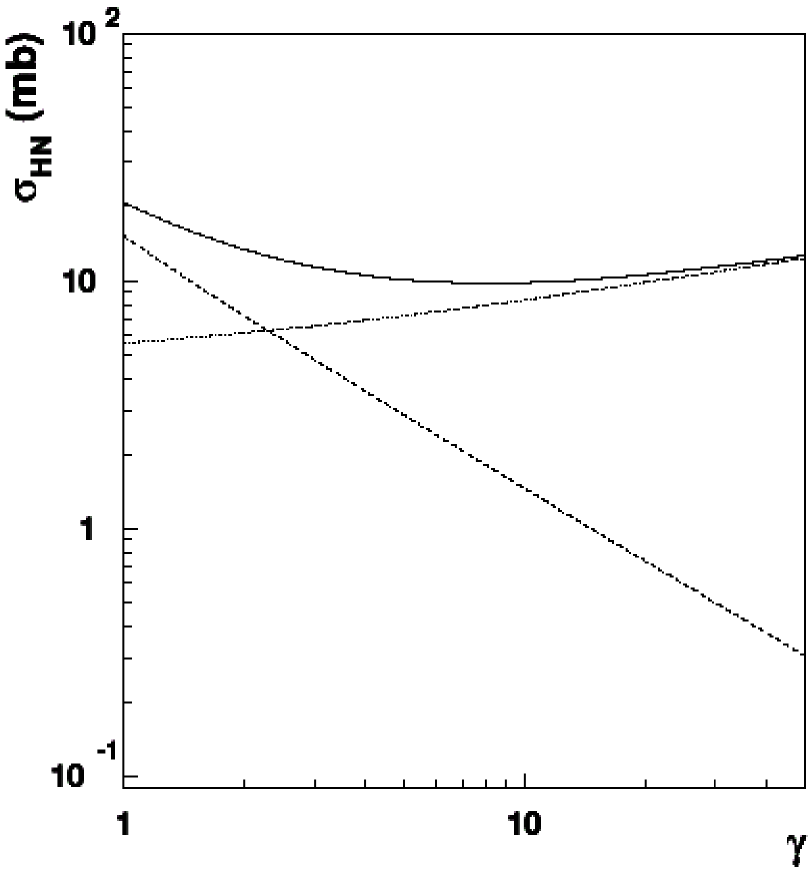
Cylinder diagram for pomeron exchanges

# Cross sections



# Cross sections in QGSM



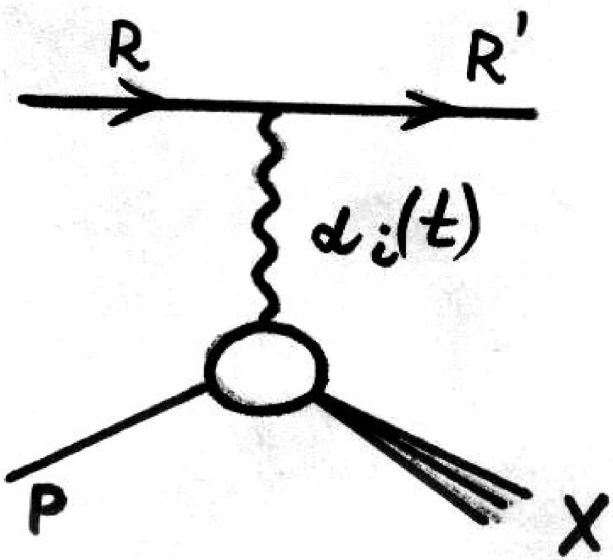

$\gamma = E/M_H$

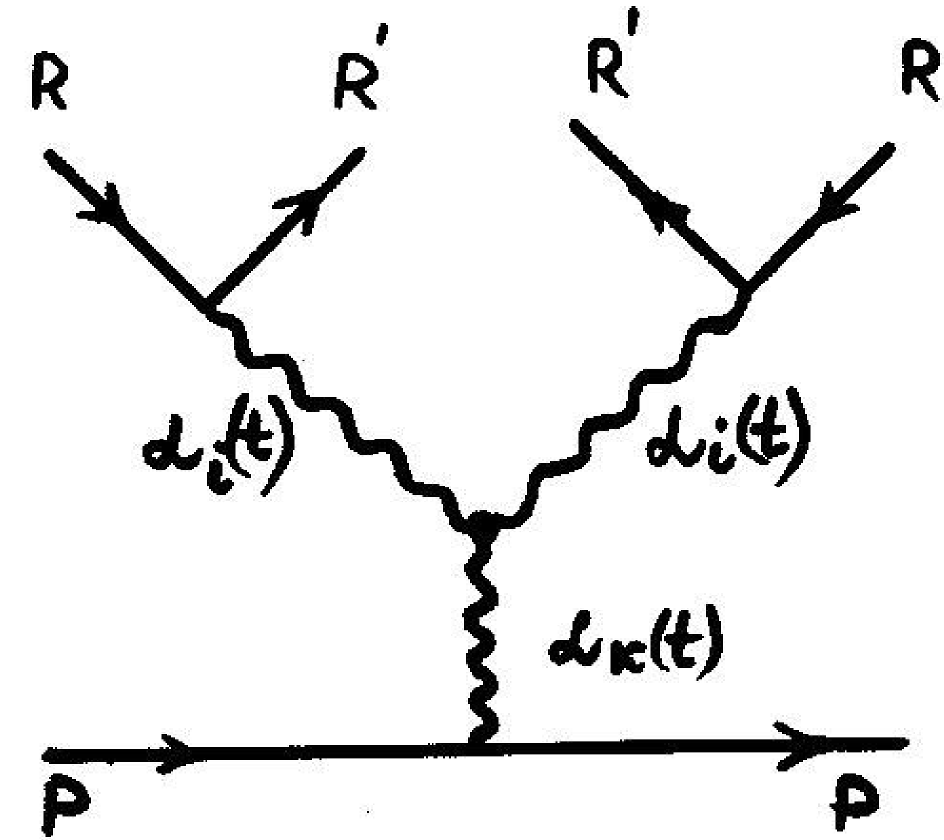
Pomeron cross section corresponds to $\gamma^{\Delta}$, where $\Delta_P = \alpha_P(0) - 1 = 0.12$

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

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:

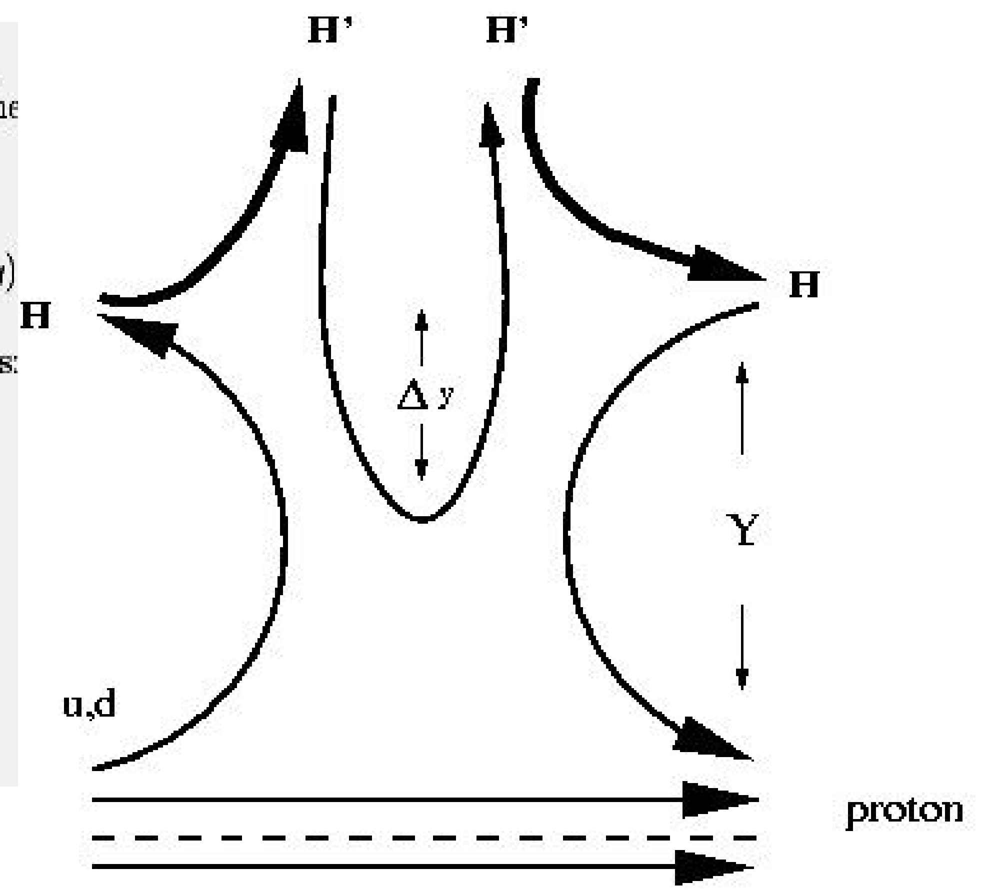
$$\frac{d^2\sigma}{dt dy} = \frac{(1-x)d^2\sigma}{dtd(1-x)} \sim exp(-2(1-\alpha_i(t))\Delta y)exp(-(1-\alpha_j(0))(Y-\Delta y)$$

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



# RRR, RRP, PPR and PPP contributions

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

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

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

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

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:

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

The average energy loss can thus be calculated:

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

Here, $m_N$ and $m_\pi$ were taken as the mass of the proton and a charge pion, respectively.

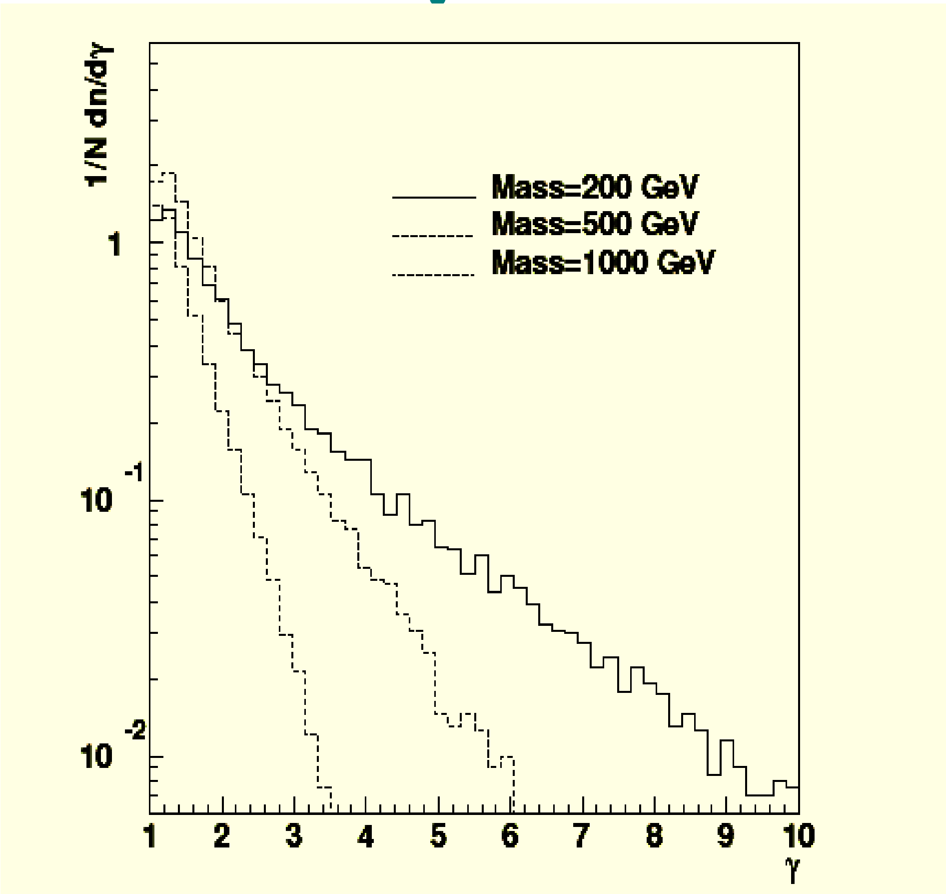
The upper limit on $M_X$ is taken to be the lower of the following two limits: $M_{X_{max}} = (2\gamma M_0^2)^{\frac{1}{2}}$, which represents the condition $\Delta y = 0$ or $M_{X_{max}} = \sqrt{s} - m_H$ from energy-momentum conservation and where $m_H$ is the mass of the interacting $H$-hadron.

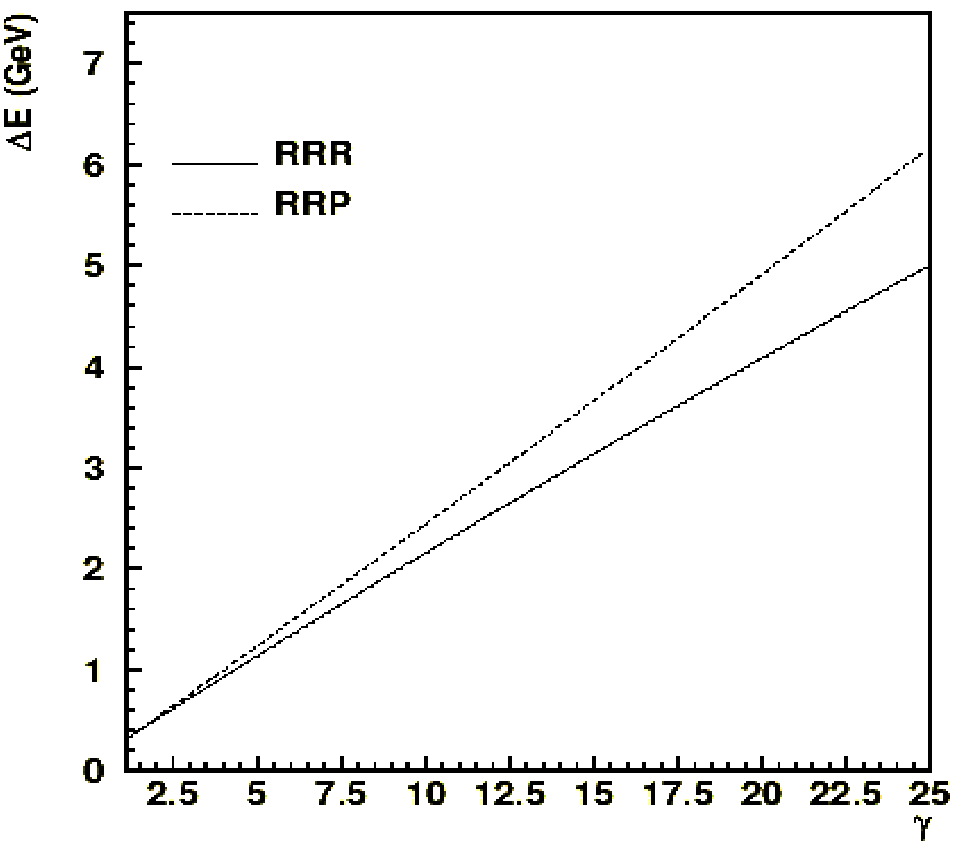
The limits on $t$ are given by

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

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 $\gamma$'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

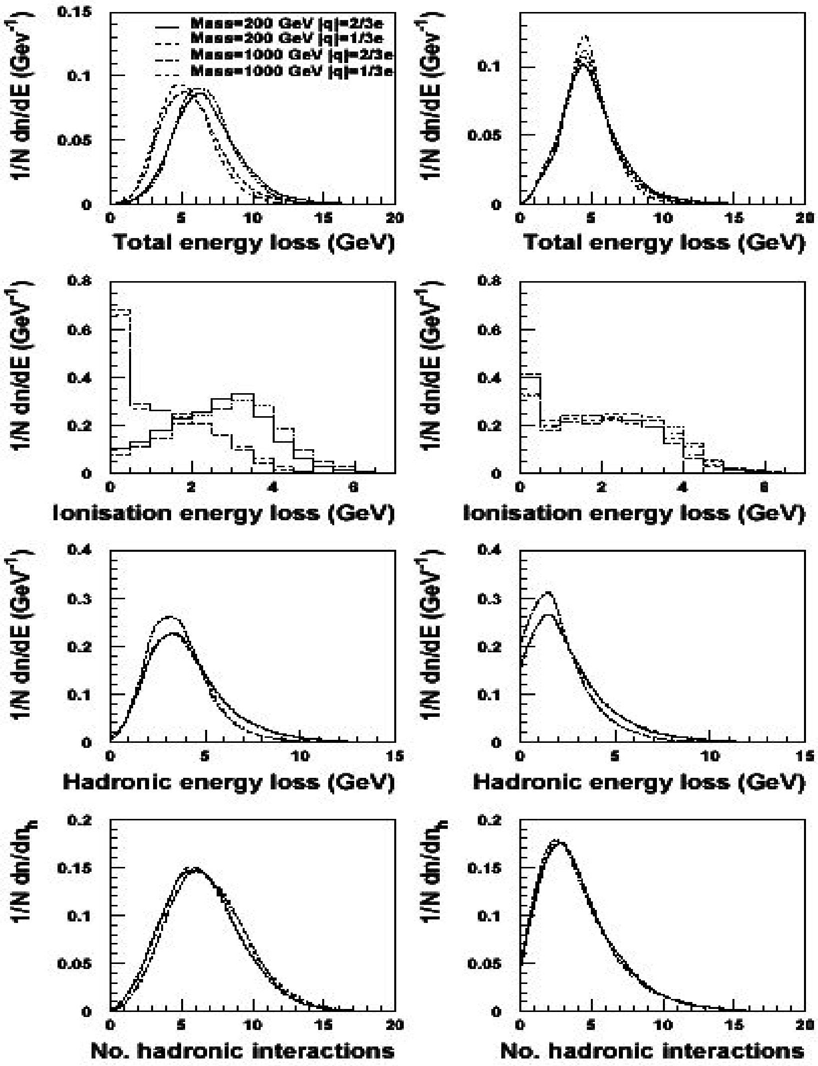



Figure 7: Distributions of energy loss and hadronic scattering for $H$-hadrons of masses 200 and 1000 GeV and for exotic quarks of charges $\pm\frac{1}{3}e$ and $\pm\frac{2}{3}e$. The left (right) column represents $H$-hadrons containing an exotic quark (anti-quark). Distributions of the total, ionisation 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 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 antimater 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

# 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.