Search for Massive Squark Hadrons as NLSP and QCD phenomenology in Quark Gluon String Model.

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Outline

- Introduction
  - Definitions and astrophysical constraints
  - Scale for the life times
  - 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 for LHC
- Summary

Introduction: definitions of stable massive new particles

New heavy quark =
heavy exotic quark =
SMP= SIMP
R-hadron= mesino =
mesonino = CHAMP = ?

What is known from astrophysics:

The detection of strongly interacting massive particles will conflict with BBN scenario, if the lifetime of new quark > 1 sec;

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

Scale of the life times:

stop < 10^{-13} sec – we can not see this new particle

stop < 10^{-7} sec it is seen in LHC detectors

stop >1 sec it brings the macro structure to CMB

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)

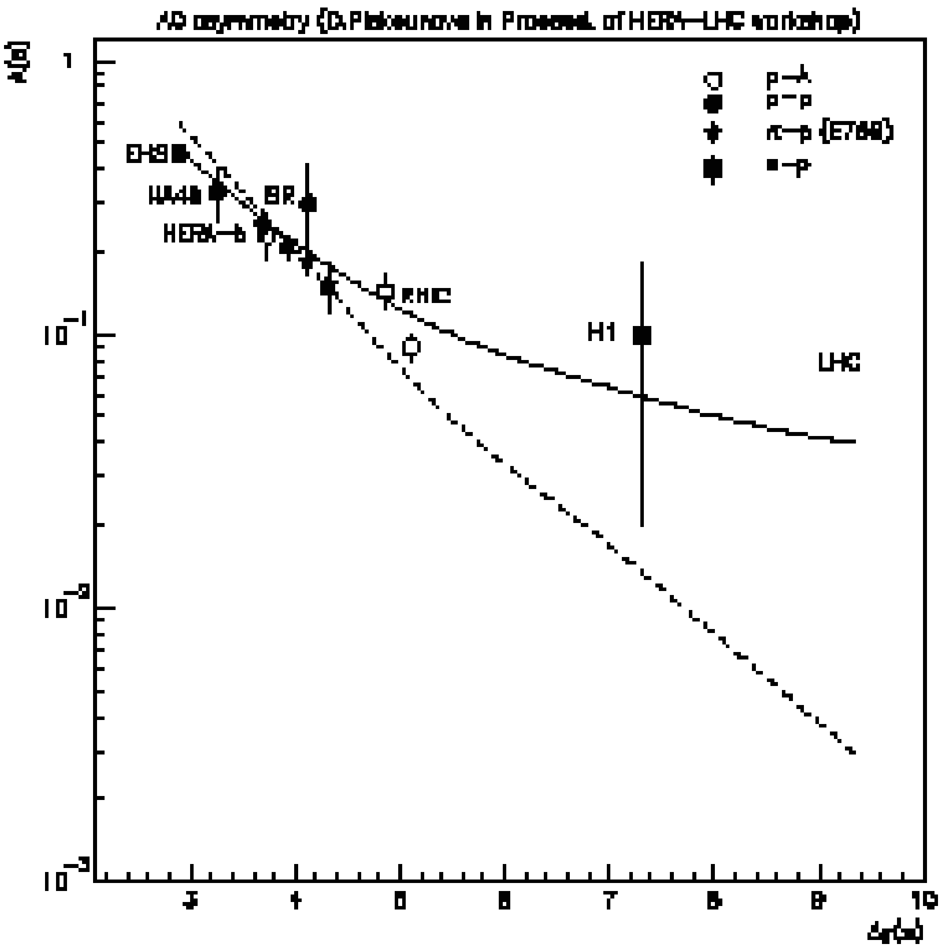
- Compressed SUSY model predicts NLSP stop quark with low mass ~ 200 GeV

- Sugra:

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

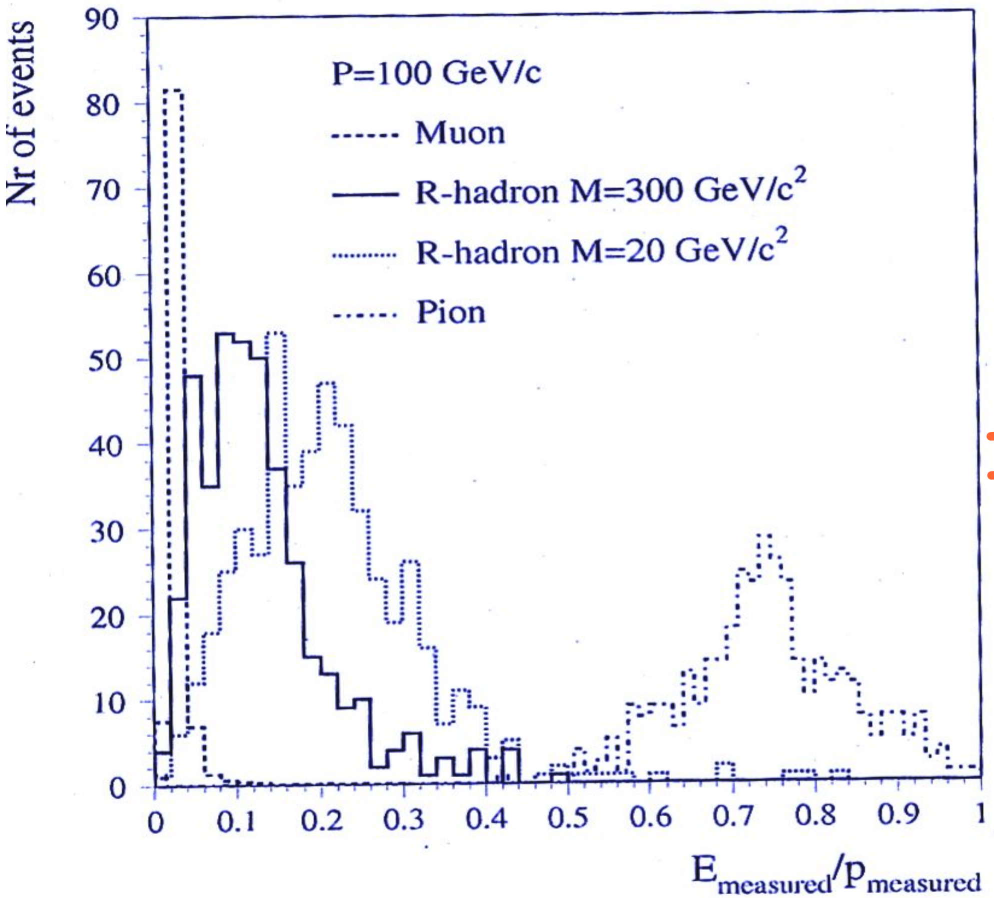
Introduction: advantages of QGSM

Quark Gluon String Model is good instrument for phenomenology of 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

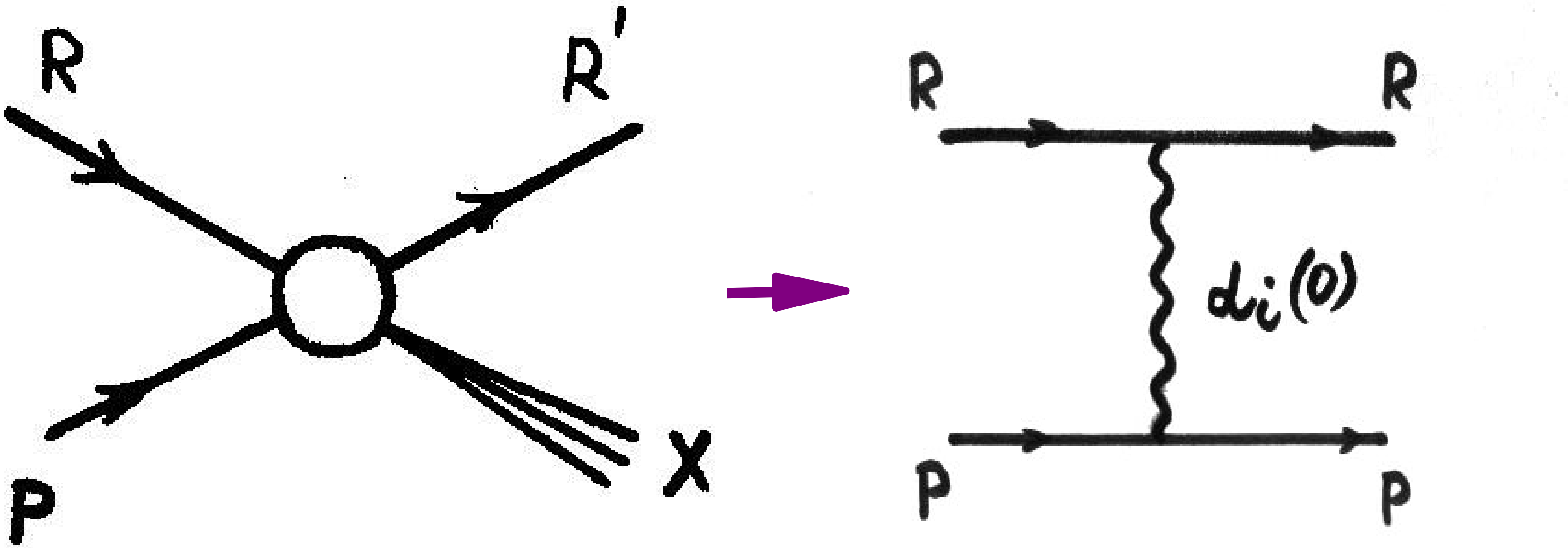


I. Stop hadrons are passing hadron calorimeter with little energy losses

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

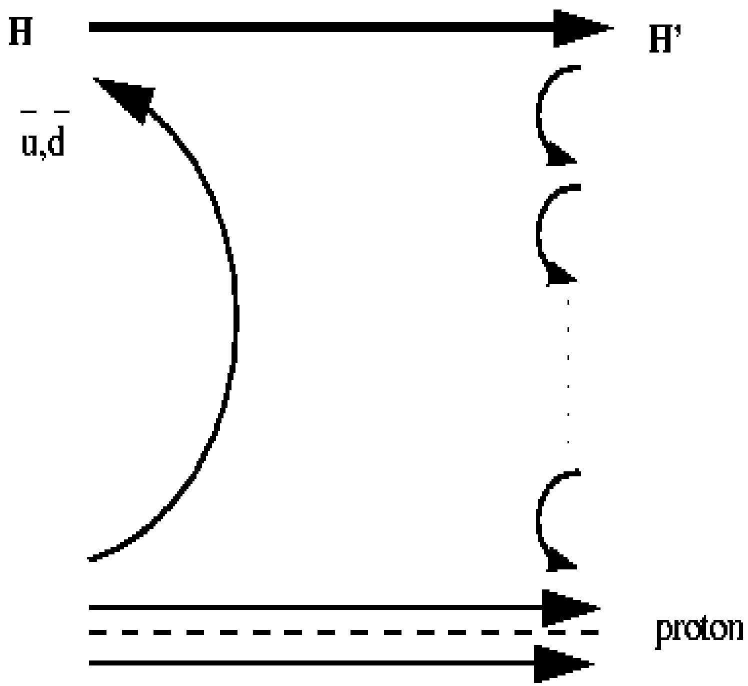
III. Charge asymmetry is to be kept in hadron calorimeter: charged mesino can be converted into neutral one and back due to hadronic interactions, but can not change the charge from + to -

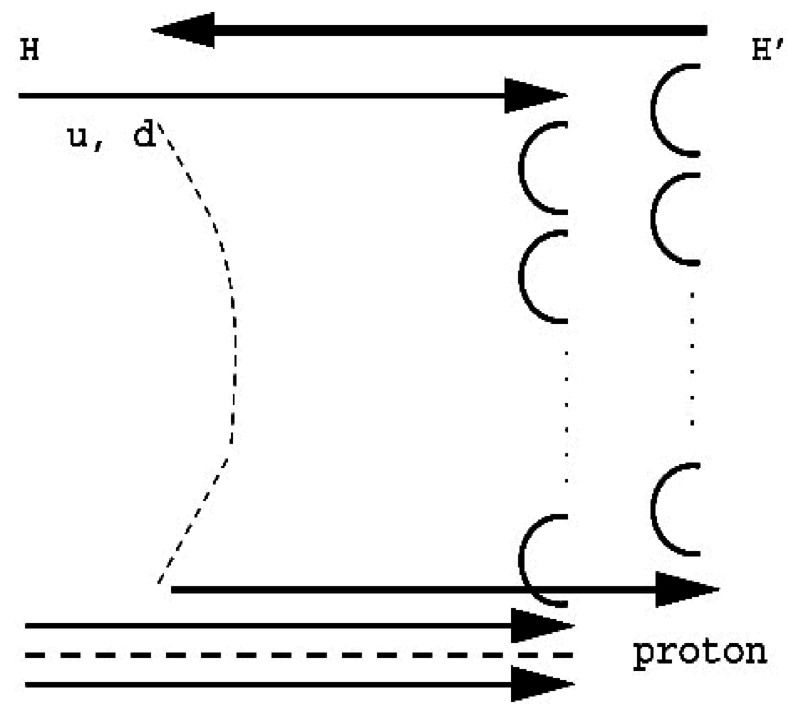
Interaction in particle representation



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

Interactions in quark representation

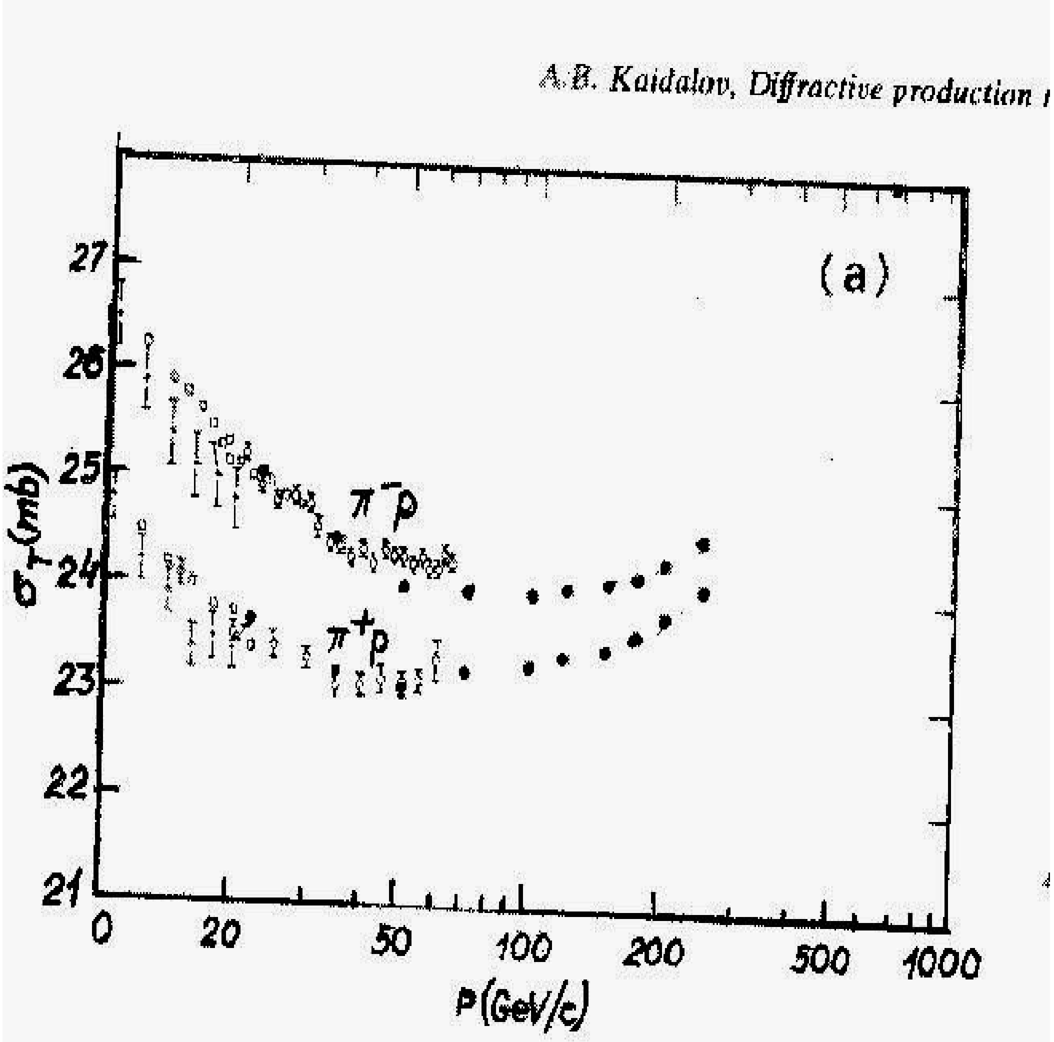


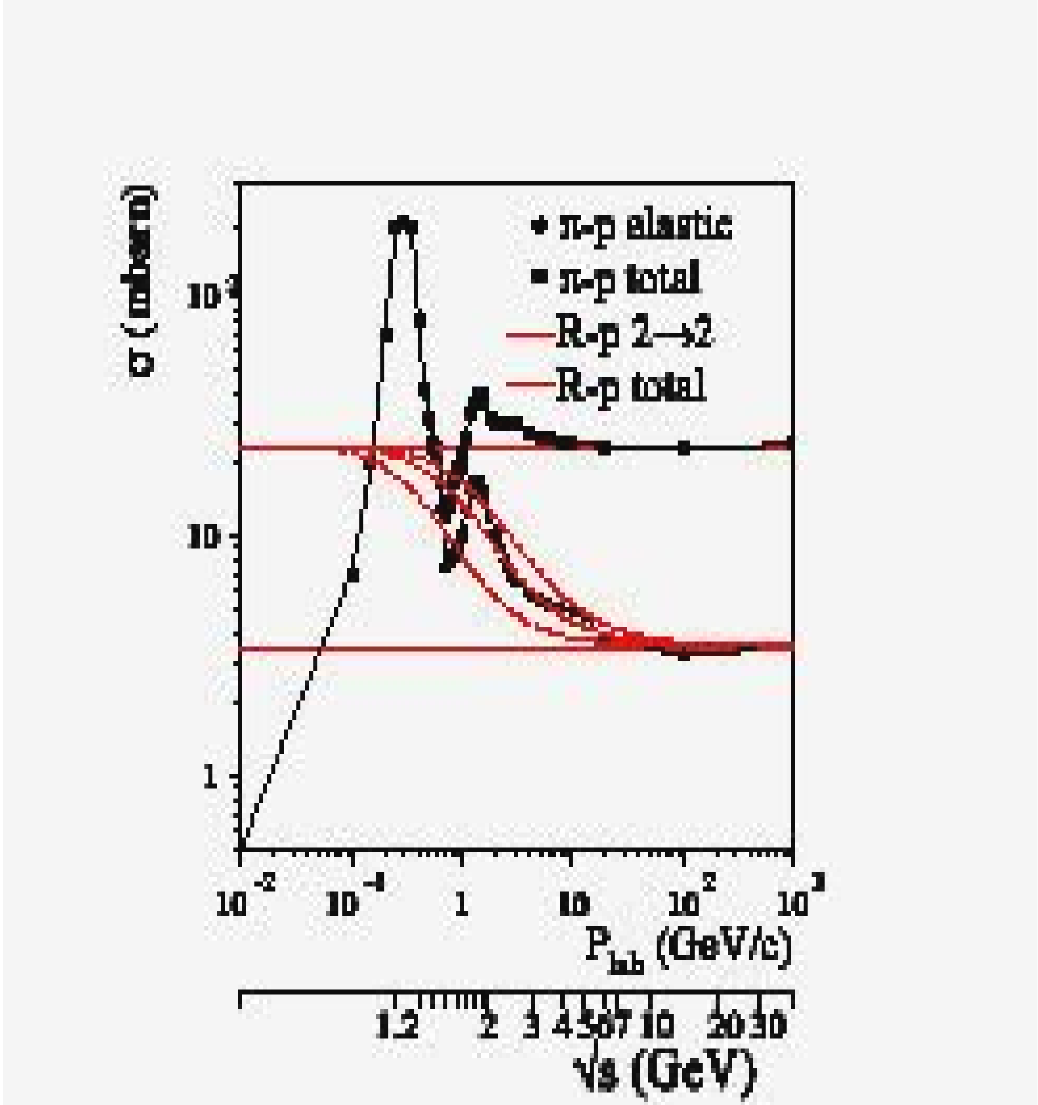


Planar diagram for reggeon exchange

Cylinder diagram for pomeron exchange

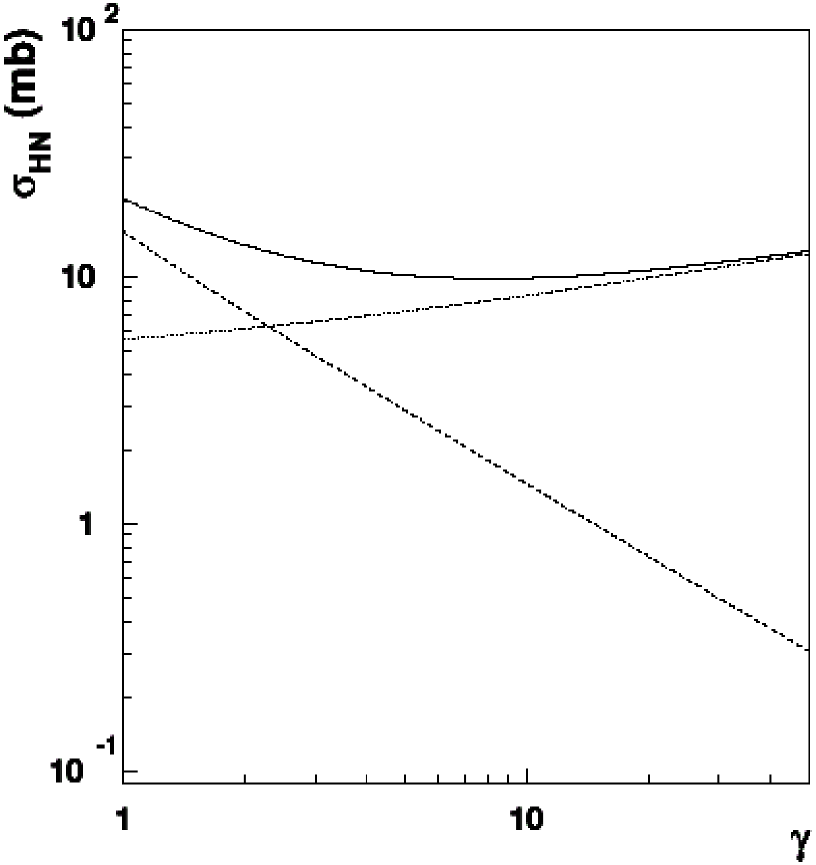
Cross sections





the X-section is not a constant and regeon contribution is much smaller

Cross sections in QGSM



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

$\gamma = E/M_H$

Pomeron cross section corresponds to:

$$\sigma_P(\gamma) \sim (2\gamma m_q)^{(\alpha_P(0)-1)}$$

Reggeon cross section can be expressed with the formula:

$$\sigma_R(\gamma) = g_R (2\gamma m_q / E_0)^{(\alpha_R(0)-1)}$$

Path length

- path length in the matter of detector :

$$\lambda = A/(N\rho\sigma)$$

atomic weight:

A_{Fe}=56 $gmol^{-1}$

- λ = 47cm!

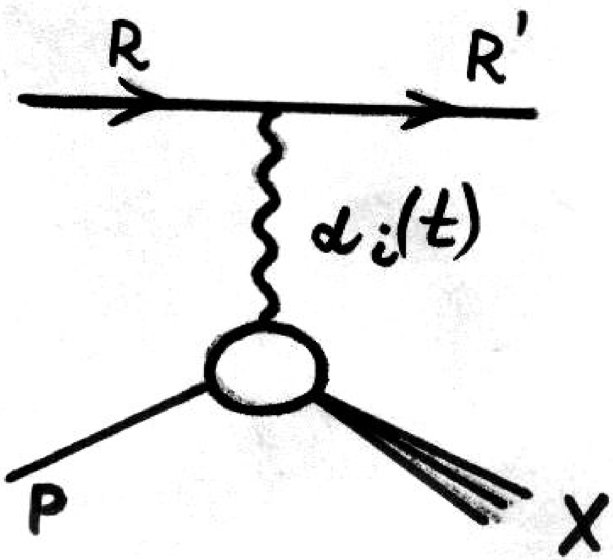
density:

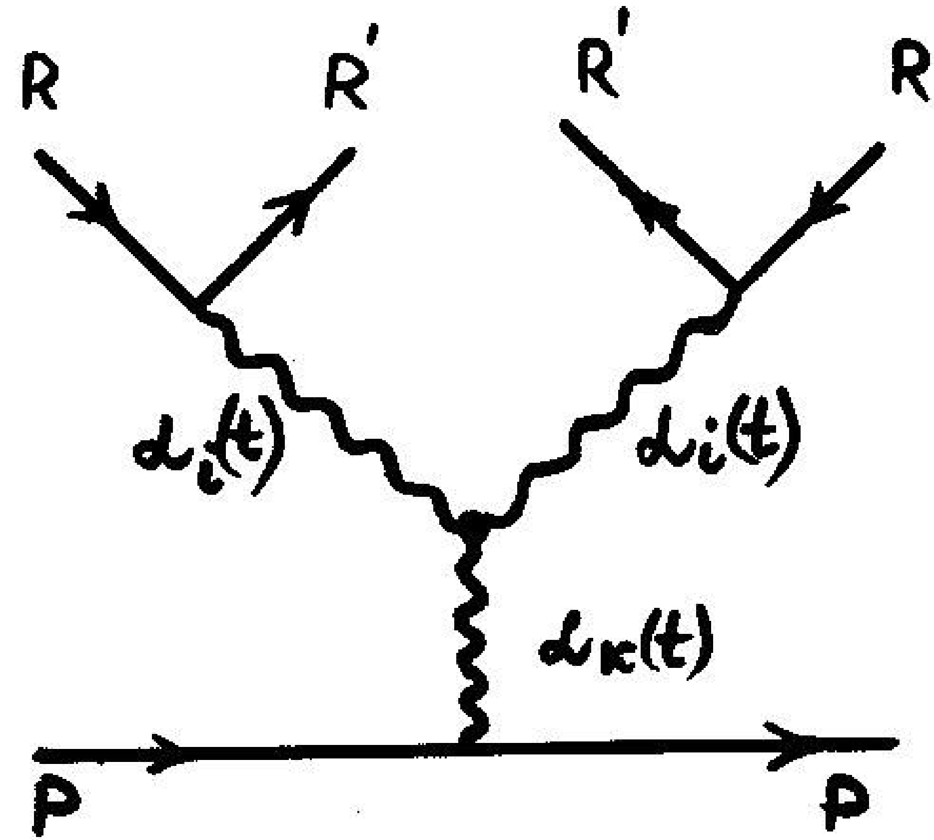
ρ=7,86gcm^{-3}

cross section:

σ_A=10mb$A^{0.8}$; 1mb=10^{-27}cm

Distributions after scattering



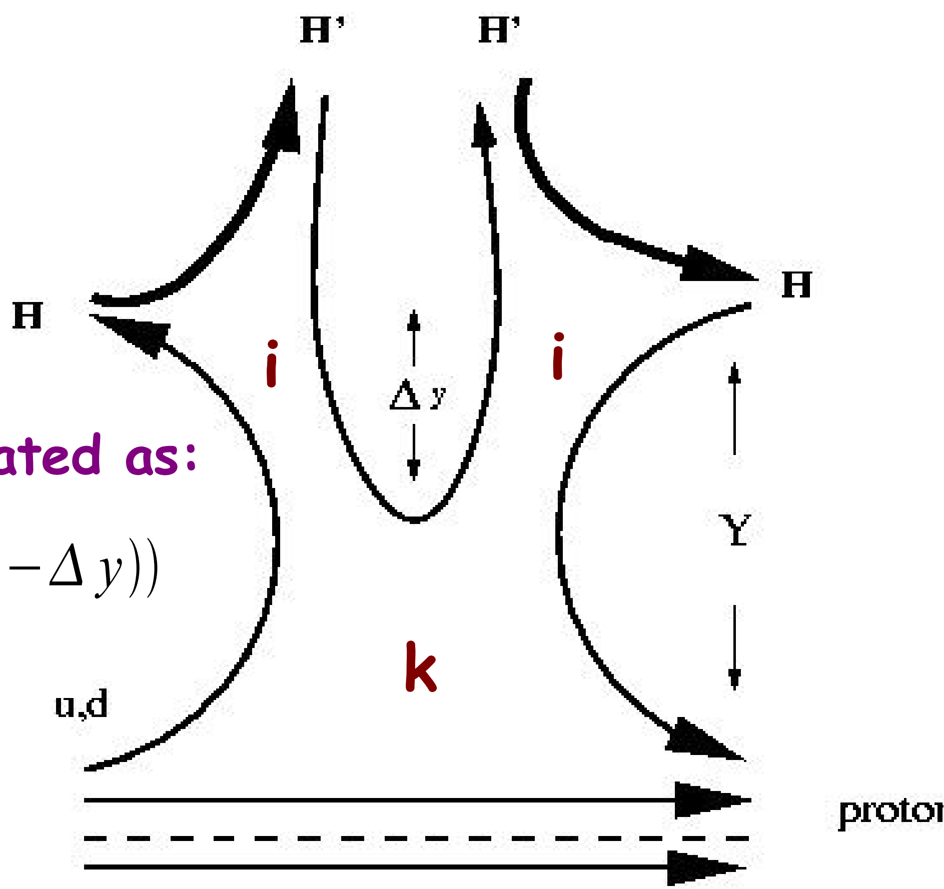


- Differential cross sections are derived from x_F close to 1 three reggeon asymptotics like RRR, RRP, PPR, PPP.

Rapidity distributions in R-hadron scattering

$$Y = \ln(2E/M_H) = \ln(2\gamma)$$

$$\Delta y = \ln(2\gamma M_0^2 / M_X^2)$$



The possibility of this process can be calculated as:

$$d^2\sigma/dtdy = \exp(-2(1-\alpha_i(t)\Delta y))\exp(-(1-\alpha_k(0))(Y-\Delta y))$$

where iik means triple-regge terms like RRR, RRP, PPR or PPP contributions

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:

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

The average energy loss can thus be calculated:

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

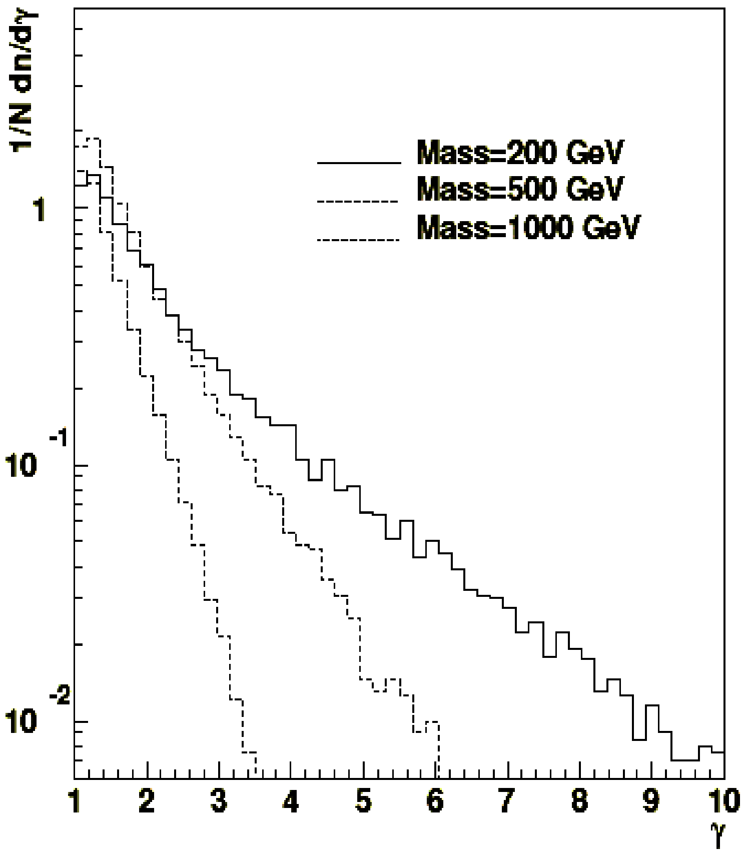
Here, m_N and m_π were taken as the mass of the proton and a charge pion, respectively. The upper limit on M_X is taken to be the lower of the following two limits: $M_{X max} = (2\gamma M_0^2)^{\frac{1}{2}}$, which represents the condition $\Delta y = 0$ or $M_{X max} = \sqrt{s} - m_H$ from energy-momentum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

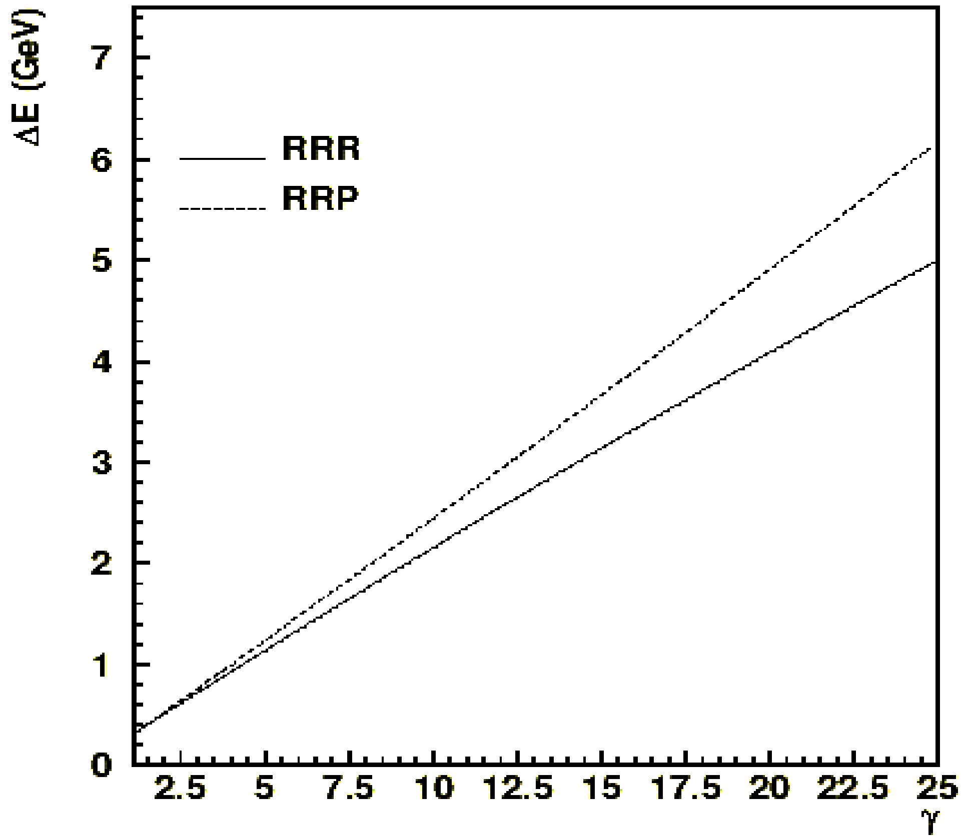
The limits on t are given by

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

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 $\lambda(a,b,c) = a^2 + b^2 + c^2 - 2(ab + ac + bc)$.

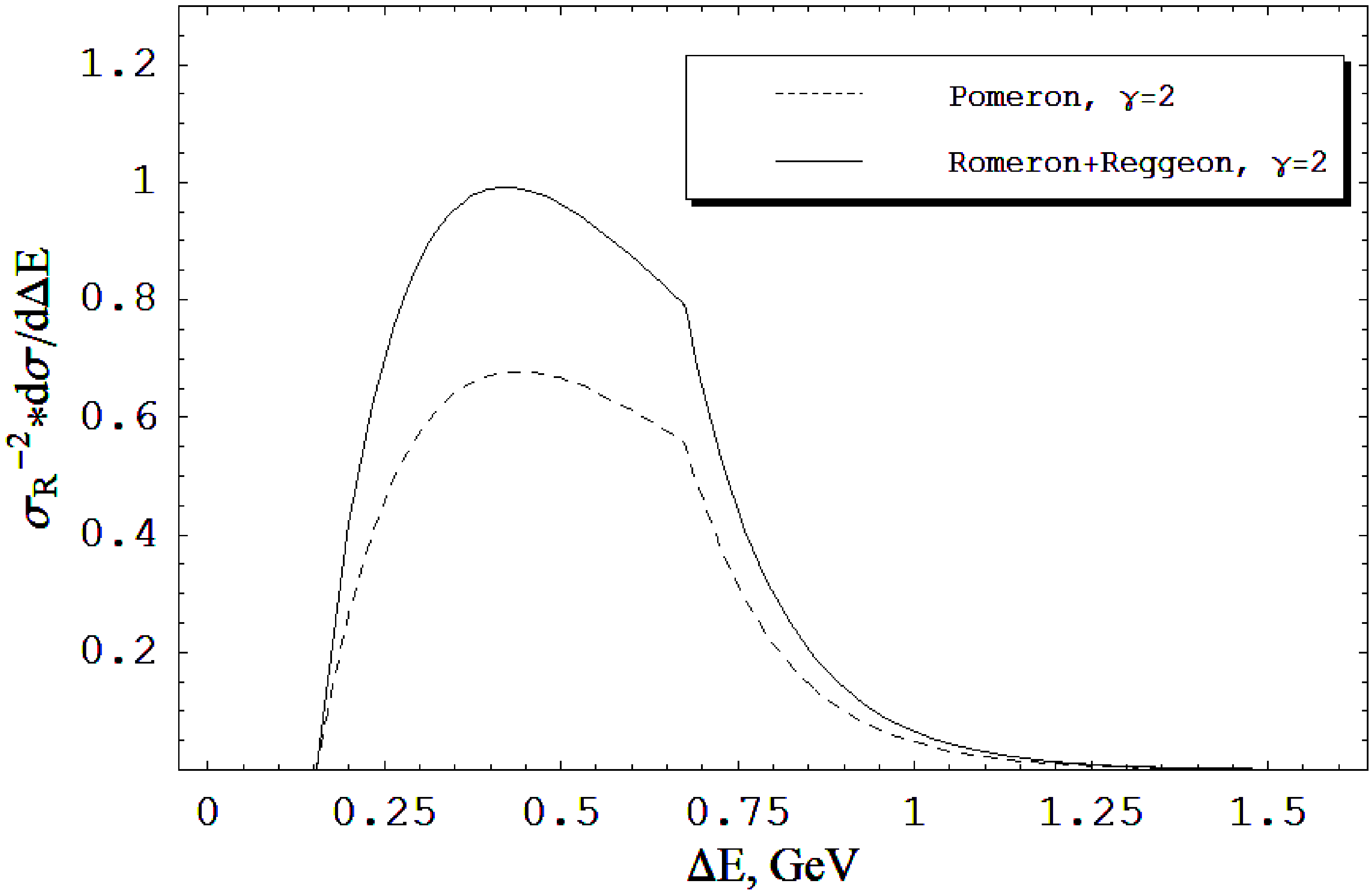
Comparison of energy losses





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

Energy losses per interaction



MC simulation of interactions in detector

the difference between the energy losses of heavy quark hadrons and heavy antiquark hadrons is due to different number of interactions in the calorimeter

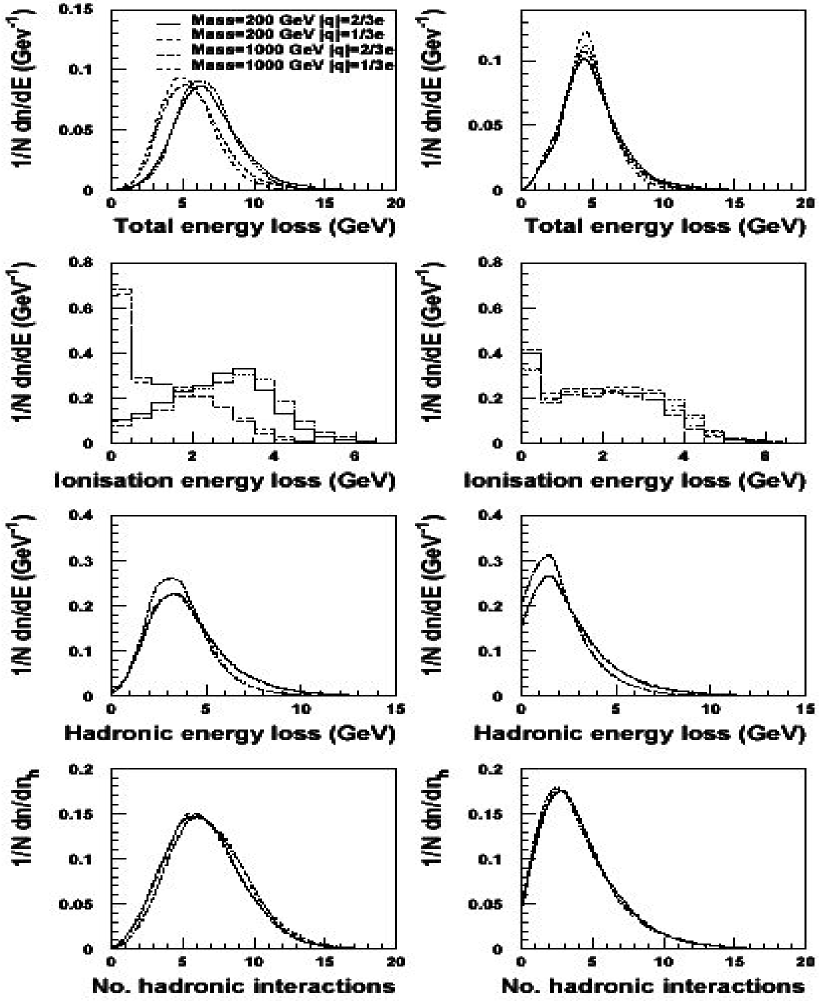
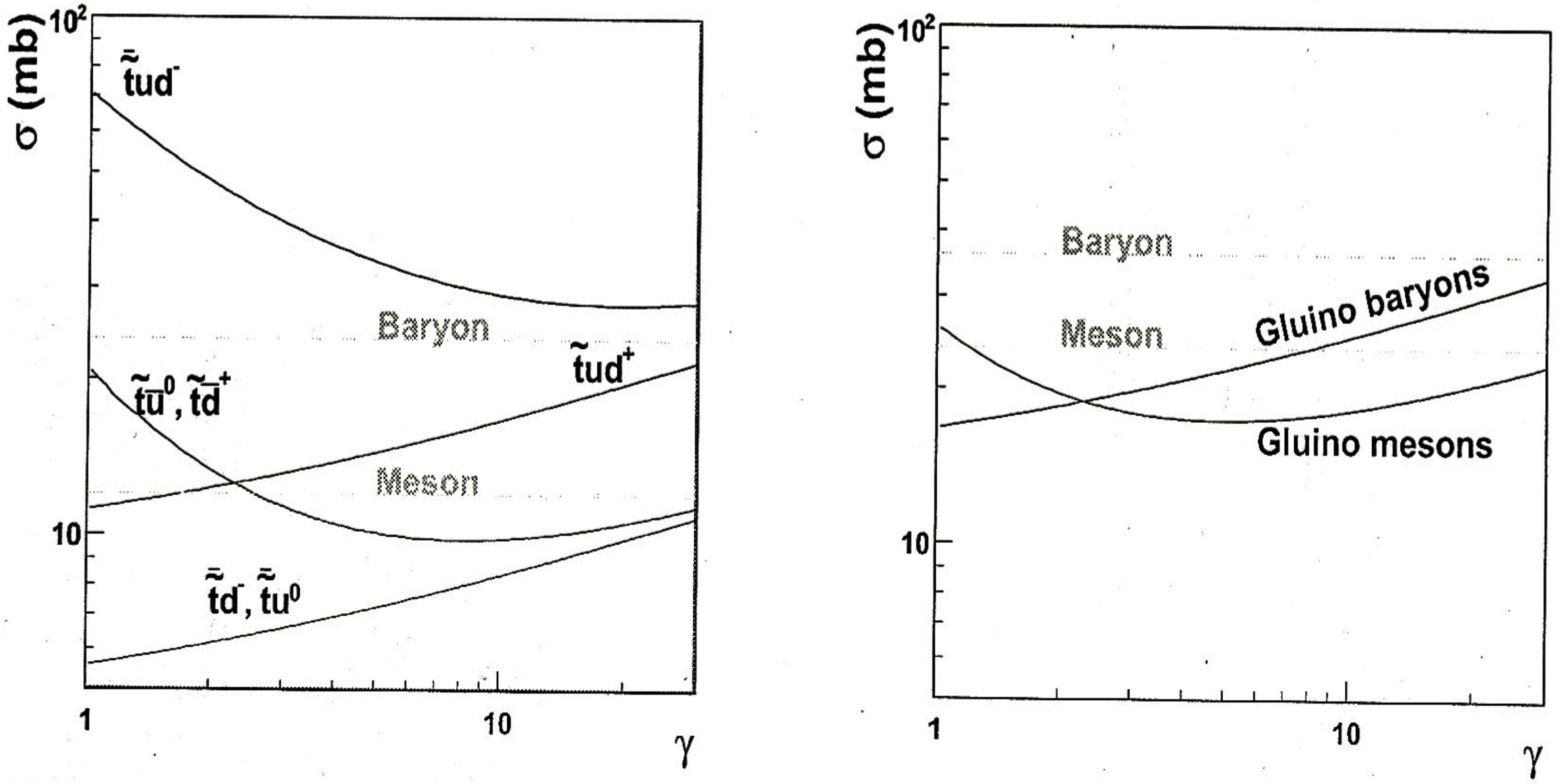


Figure 7: Distributions of energy loss and hadronic scattering for H-hadrons of masses 200 and 1000 GeV and for exotic quarks of charges $\pm\frac{1}{3}e$ and $\pm\frac{2}{3}e$. The left (right) column represents H-hadrons containing an exotic quark (anti-quark). Distributions of the total, ionisation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

Geant 4. simulations

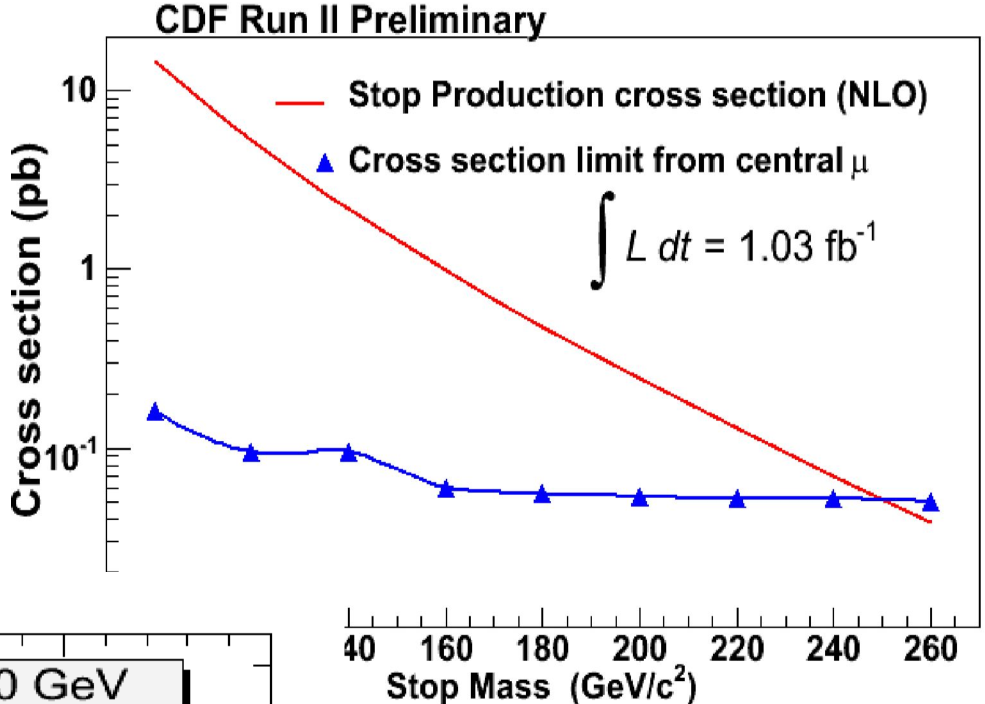


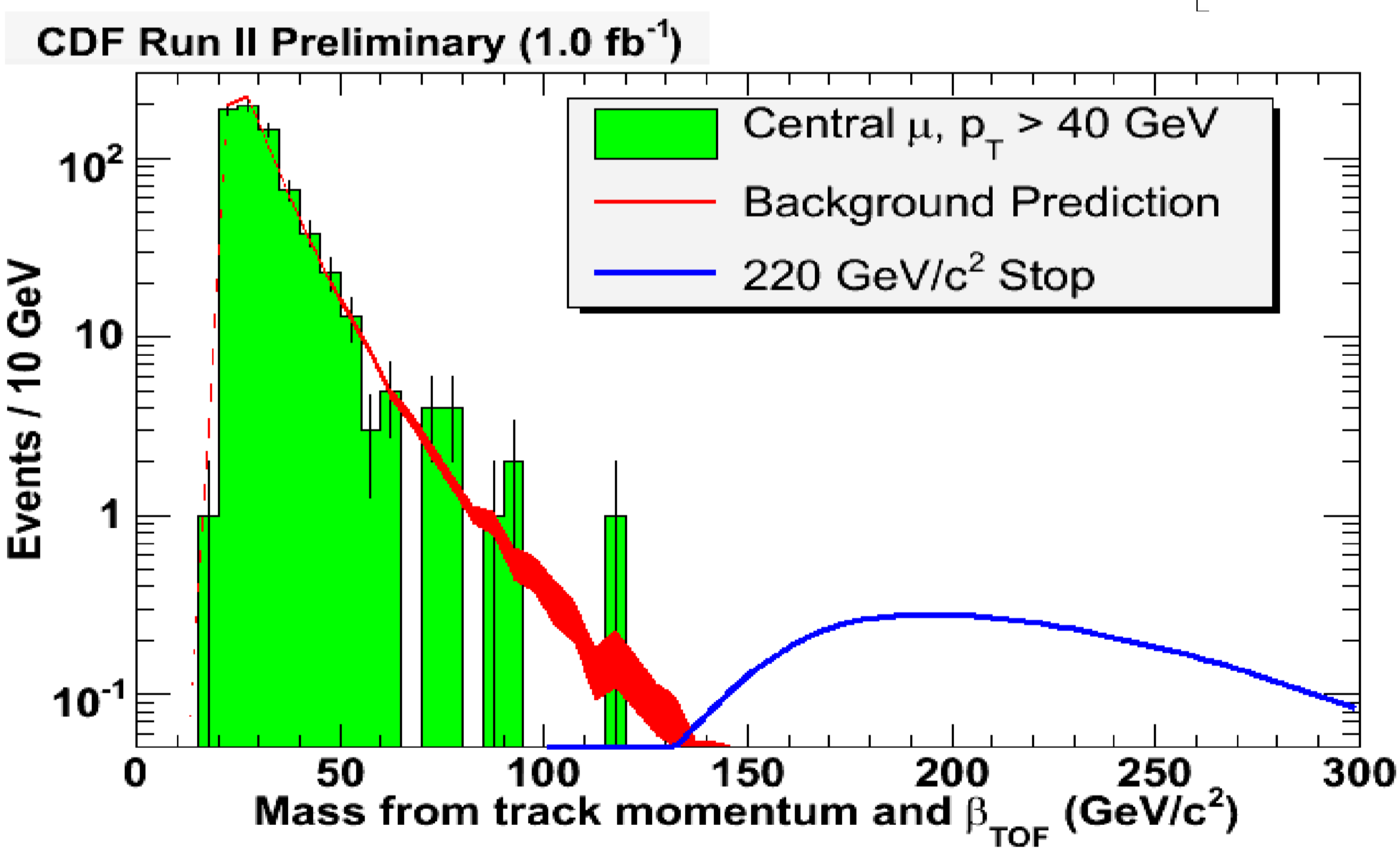
The simulations with Geant 4 were done recently on the basis of our calculations: D.Milstead,R.Mackeprang 0908.1868hep-ph

CDF results

m_{stop}>249 GeV at 95% C.L.

hep-ex/0902.1266





Summary

While we continue to study hadron systems with one exotic (supersymmetric) quark we have concluded that:

this system interacts very rare with cross section equal approximately ~10mb and can pass the hadronic calorimeter without valuable energy losses;

in the case of baryon the cross section is about 3 times higher;

after hadronic calorimeters R-hadrons behave like heavy muons with charge asymmetry because of some difference between scattering cross sections of positive and negative hadrons;

if heavy exotic quarks are NLSP, the discovery of them would have strong impact on the dark matter problem as well as on the structure of CMB.