IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

First results of a global analysis of pion pair production in proton and antiproton annihilation

Supervisors: Egle Tomasi-Gustafsson

Dominique Marchand

Collaborator: Yury Bystritskiy

Content

Introduction

- Physics with antiproton
- The Panda experiment
- pbar p annihilation into mesons

Effective meson theory

Results

- Neutral particles

  pbar p → $\pi^0\pi^0$, $\eta\,\eta$

- Charged particles
- Crossing symmetry

Summary

Introduction

PANDA will be one of four key experiments at FAIR (Facility for Antiproton and Ion Research)

Main questions in QCD

Quark confinement

Can't separate quark-antiquark without creating new pair of quarks.

Origin of Hadron Masses

Three valence quarks only provide less than 2% of the mass of Nucleon.

How to understand the other more than 98% mass ?

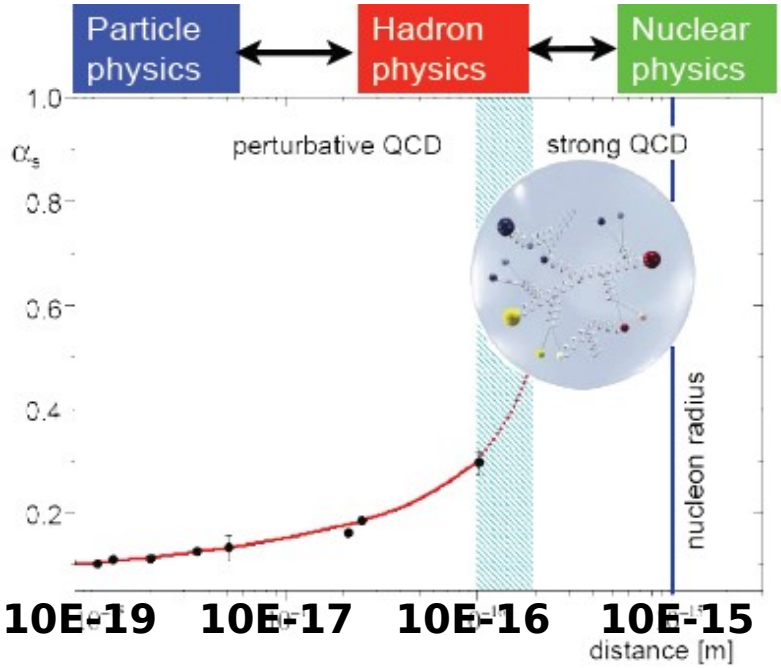
Study kinetic and interaction (confinement) energy in the nucleon (gluon rich environment).

Panda Physics

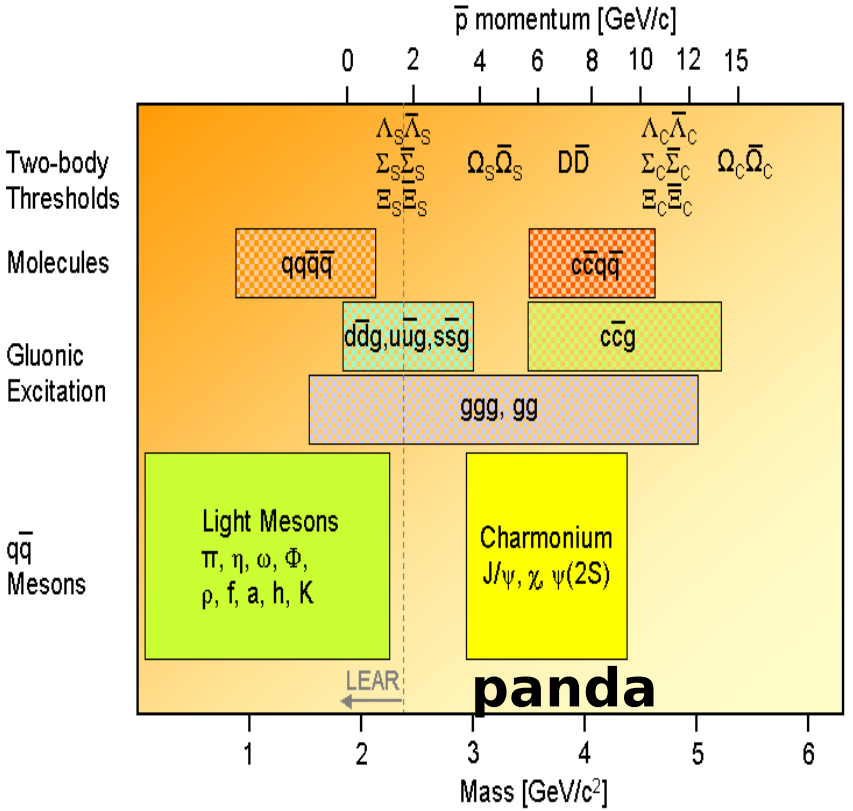
PANDA region: 1.5 GeV/c < Ppbar < 15 GeV/c, 5 GeV^2 < s < 30 GeV^2

Physic topics

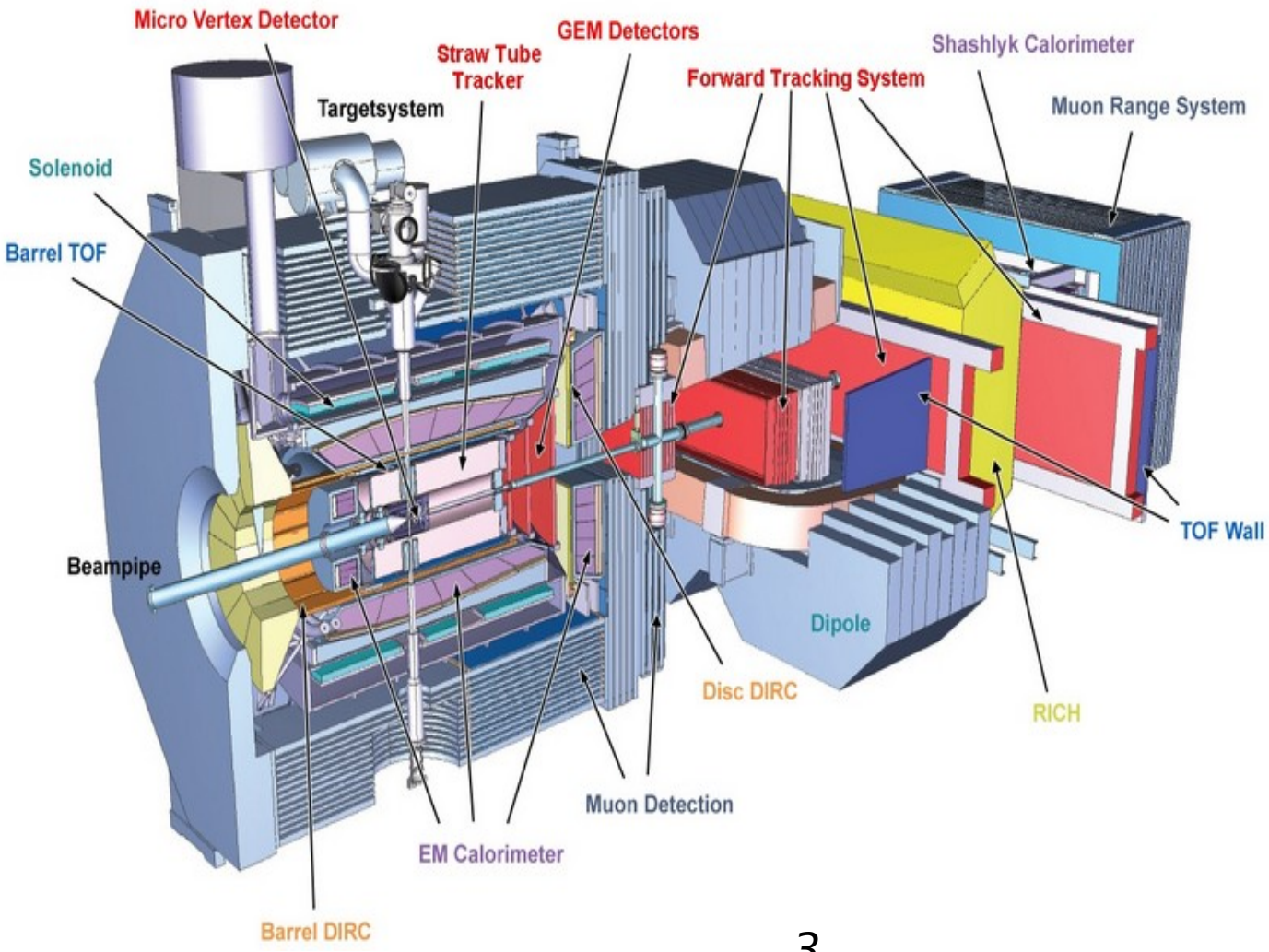
- *QCD bound states,*
- *hybrids, glueballs*
- *Hadrons in nuclear matter*
- *Electroweak physics*
- *Electromagnetic processes*
- *Hypernuclear Physics*



Gluon rich environment



Panda Detector



4π acceptance

Tracking momentum resolution 1%

Interaction rate 20MHz

PID
Charge and neutral particles
π , K, e, p, μ

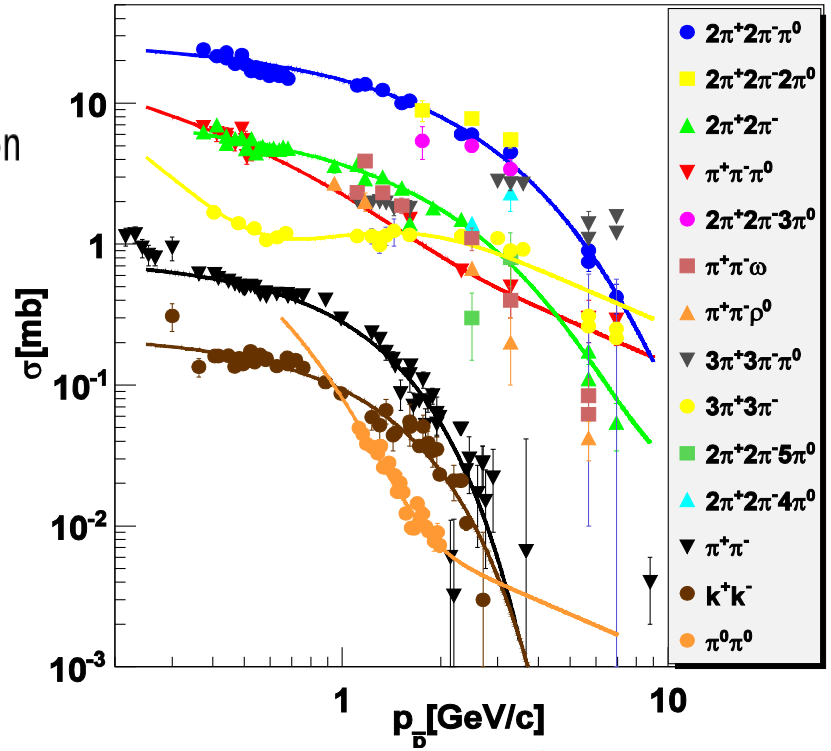
γ detection from 3 MeV - 10 GeV

Motivation of my work

- The reaction $\bar{p}p \rightarrow e^+e^-$ allows to measure electromagnetic proton form factors.
- Important simulation work is under way.
- The reaction $\bar{p}p \rightarrow \pi^+\pi^-$ is the main background :
  - has a large cross section,
  - contains information on the quark content of the proton
  - allow to test different QCD models

Largest cross sections come from multi-pions

(5 > 4> 2)



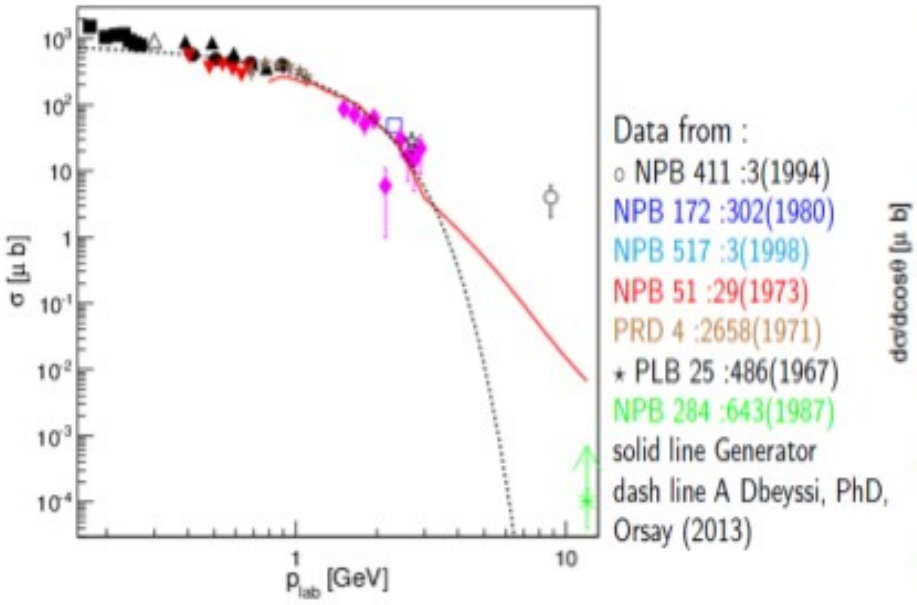
It is necessary to fully understand the process $\bar{p}p \rightarrow \pi^+\pi^-$

Motivation of my work

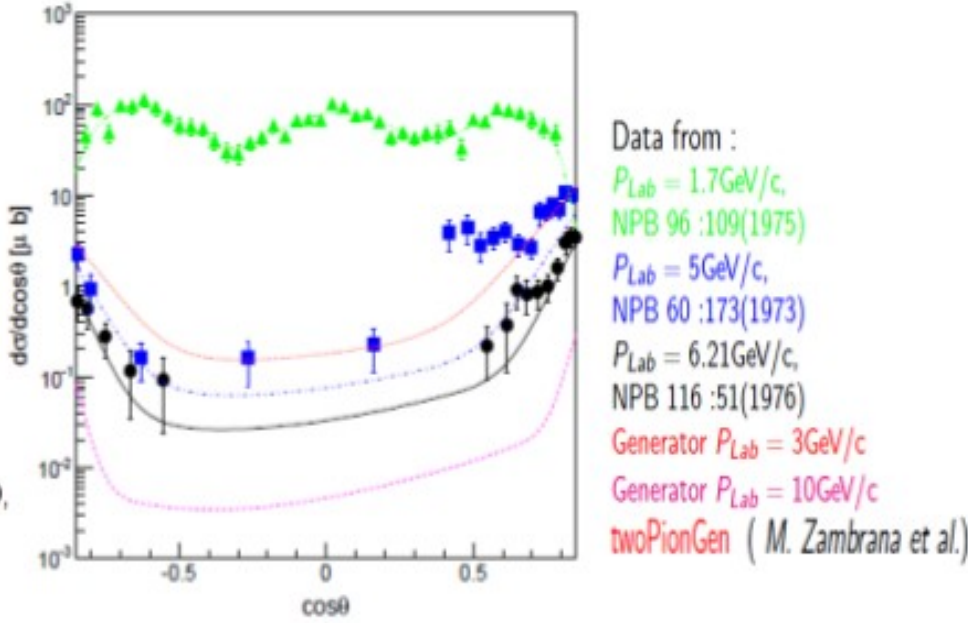
Few experimental data at the PANDA energies to constrain the models

$\bar{p}p \rightarrow \pi^+\pi^-$

Total cross section



Differential cross section



Few and incomplete angular distributions data of annihilation

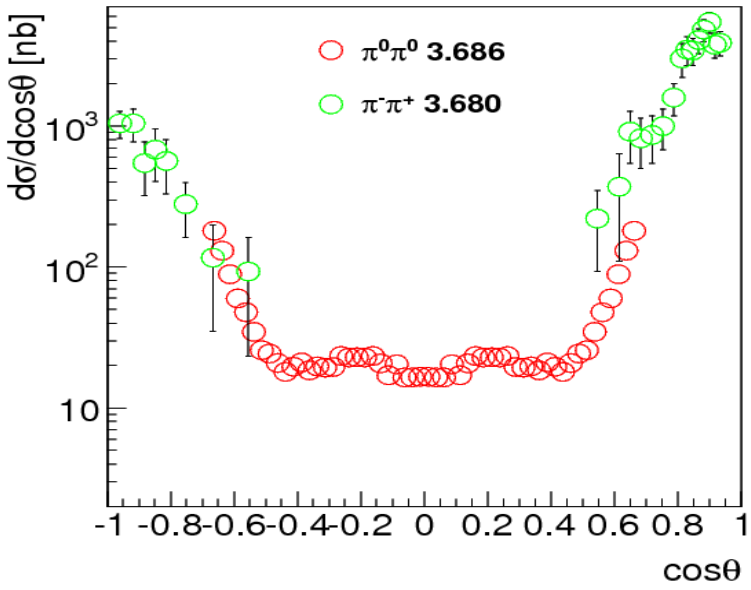
(6 sets of $\pi^+\pi^-$ in panda energy region)

Motivation of this model

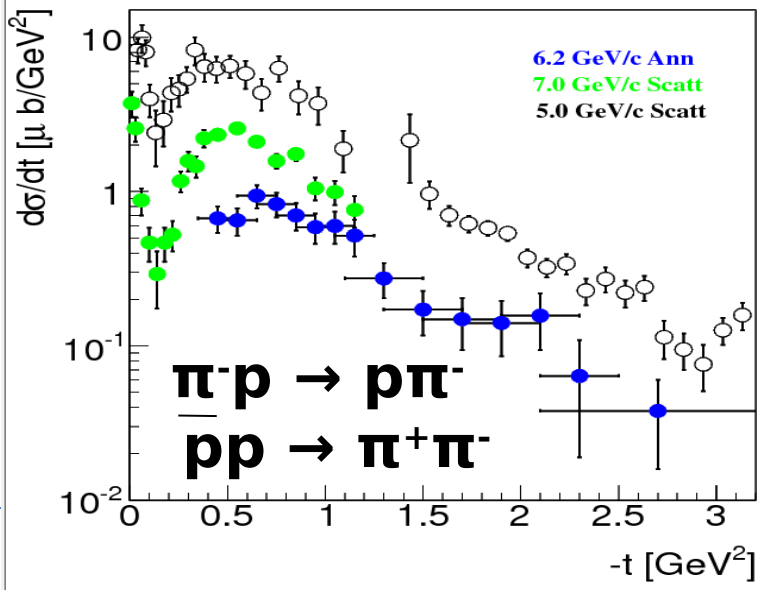
Global description in Panda energy range

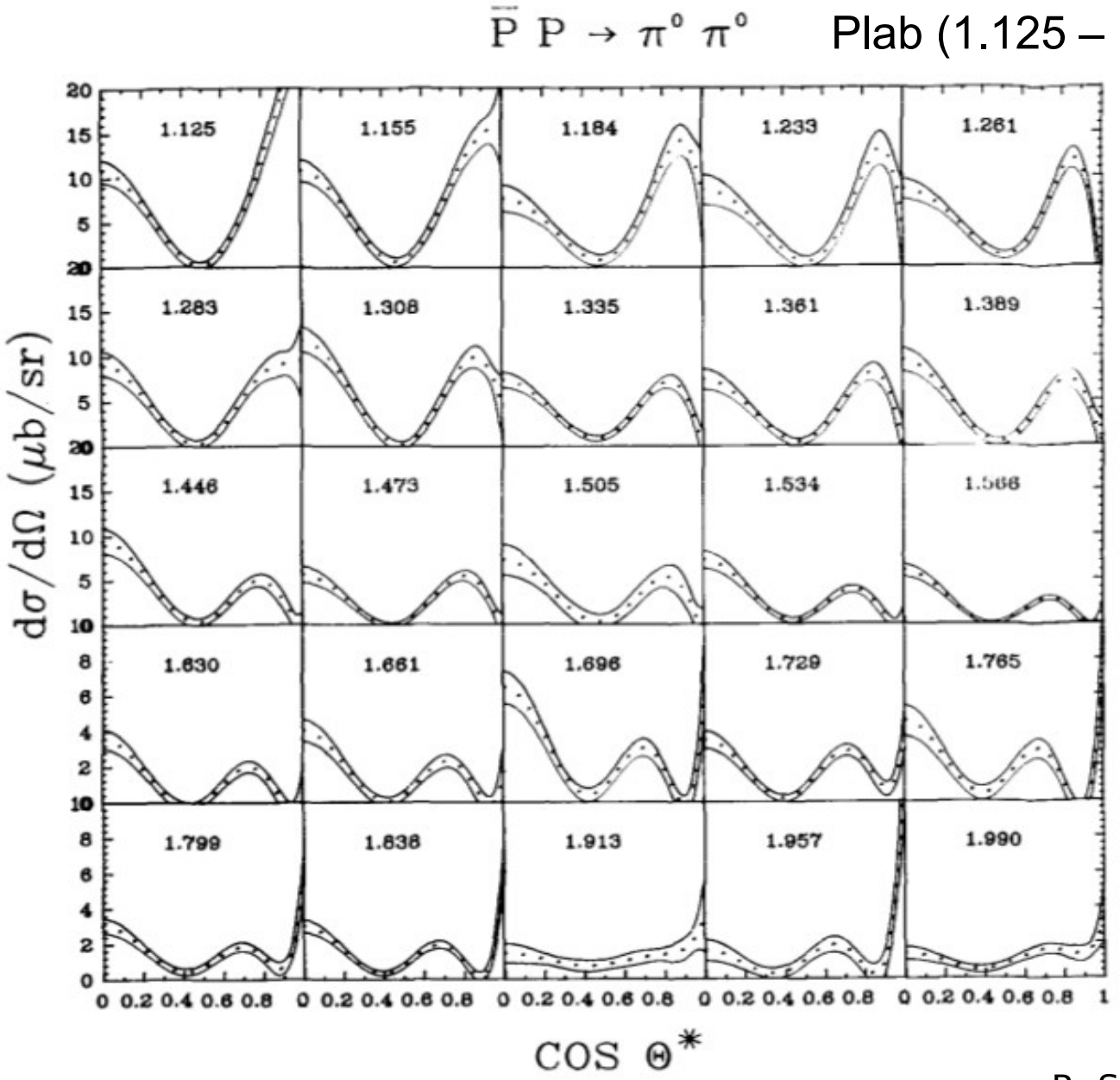
Developing an effective Lagrangian model based on Feynman diagrams to describe binary annihilation reactions induced by antiprotons in Panda energy region.

Describe the similar production $\pi^+\pi^-$, $\pi^o\pi^o$ in a coherent way



- using crossing symmetry from $p\pi^-$ elastic to get more experiment data
- Getting a reliable s dependence to predict the panda region where there are very few data



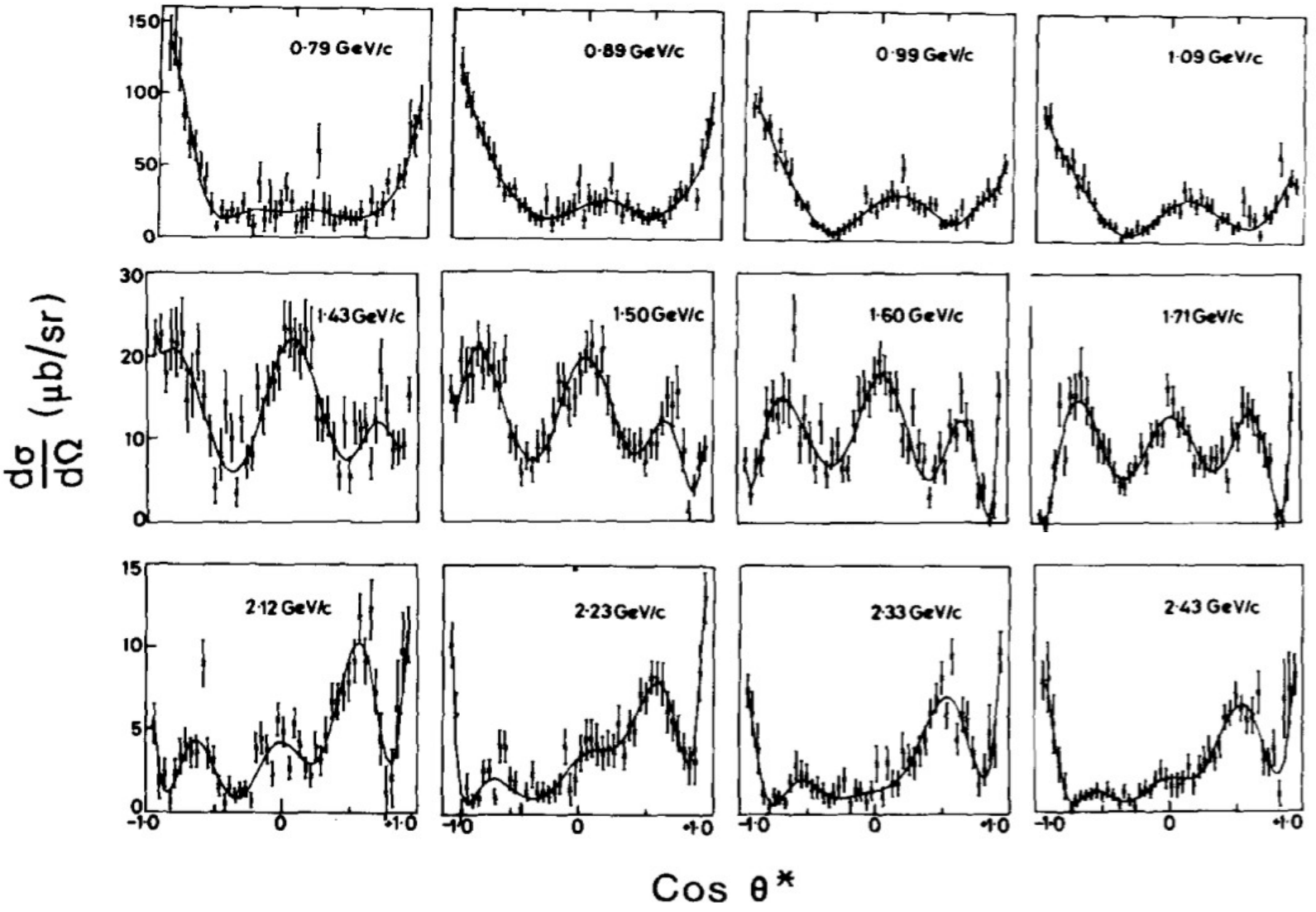


Low energy oscillatory behavior, few partial waves curves from Legendre polynomes

R. S. Dulude al. PLB(79) 3 1978

Evolution of oscillatory behavior : Sum of resonances

Plab (0.79 – 2.43 GeV/c)



$\bar{p}p \rightarrow \pi^+\pi^-$

E. Eisenhandler, et al., Nucl. Phys. B 98 (1975) 109

Physics Letters B 471 (1999) 271–279

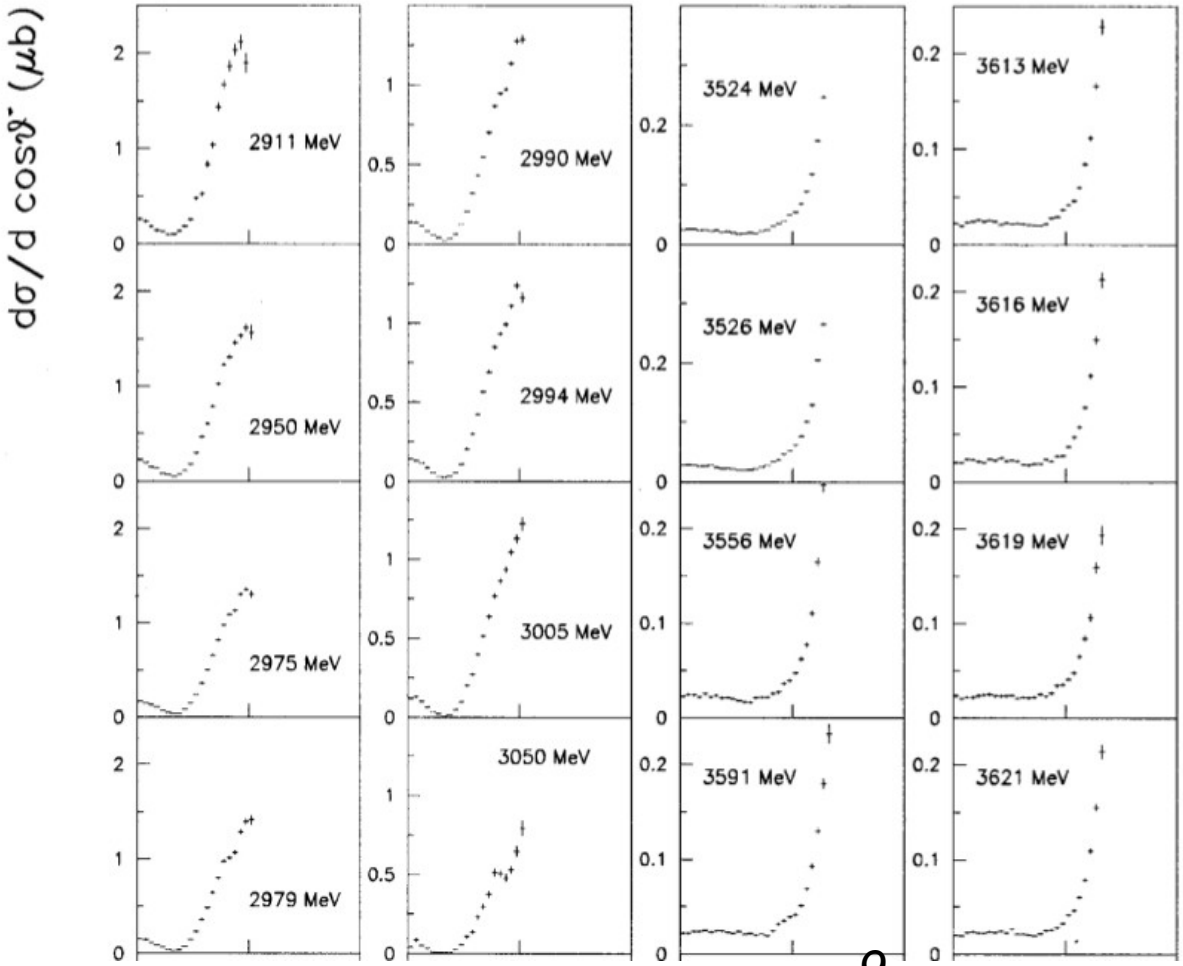
PHYSICAL REVIEW D VOLUME 56, NUMBER 5 1 SEPTEMBER 1997

ARTICLES

T. A. Amstrong, al

Two-body neutral final states produced in antiproton-proton annihilations at $2.911 \leqslant \sqrt{s} \leqslant 3.686$ GeV

$$p + \bar{p} \rightarrow \pi^0 + \pi^0,\ \eta + \pi^0,\ \eta + \eta,\ \pi^0 + \gamma,\ \gamma + \gamma$$



We are using effective

Lagrangian method with

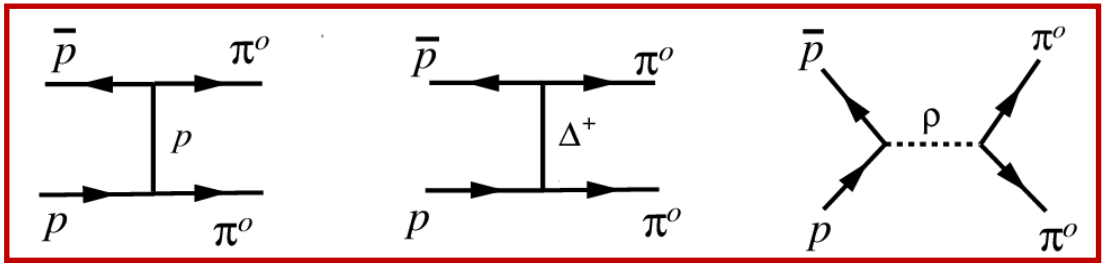
Feynman diagram to study

these data, our model should work in Panda energy region

Calculation $\bar{p}p \rightarrow \pi^o\pi^o$

- Differential cross section

$$\frac{d\sigma}{d\cos\theta} = \frac{1}{2^7\pi}\frac{1}{s}\frac{\beta_\pi}{\beta_p}|\overline{\mathcal{M}}|^2$$



- ✓ (e.g.)Nucleon exchange
  - Vertex: $-ig_{\pi NN}(i\gamma_5)(2\pi)^4$
  - Propagator: $\frac{i}{(2\pi)^4}\frac{\hat{q}_t + M_p}{q_t^2 - M_p^2}$

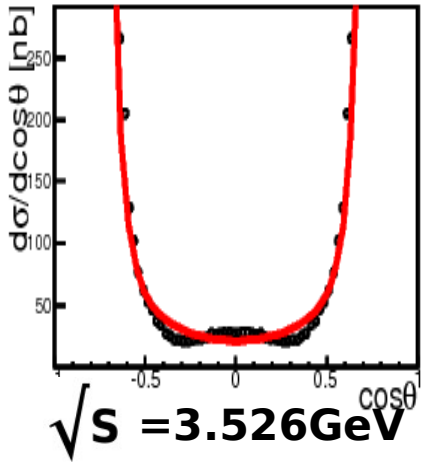
$$|\overline{\mathcal{M}_n}|^2 = \mathcal{M}_n A^*(a) = \frac{g_{\pi NN}^4}{(q^2 - M_p)^2} Tr\left[(\hat{p}_1 - M_p)(\hat{q} + M_p)^2(\hat{p}_2 + M_p)\right]$$

About 10^8 differences

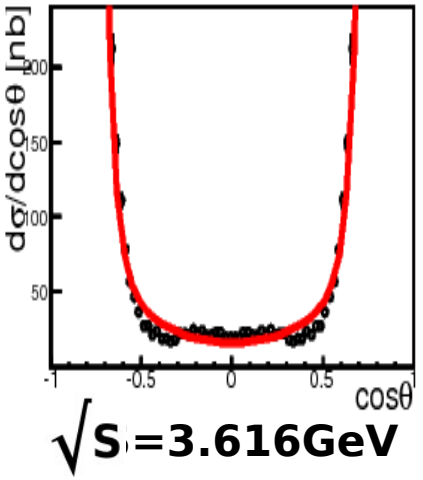
add Regge factors and form factors

$$R_N(t) = \left(\frac{s}{p_3}\right)^{\frac{1}{2}+p_2\left(\frac{t-M_p^2}{M_p^2}\right)} \quad F_N(t) = (t - p_0^2)^2$$

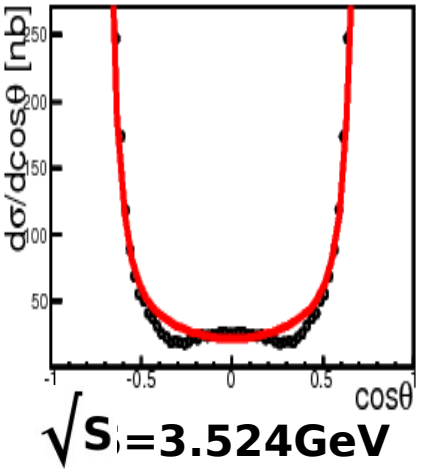
$$R_\Delta(u) = \left(\frac{s}{p_3}\right)^{\frac{3}{2}+p_4\left(\frac{t-M_\Delta^2}{M_\Delta^2}\right)} \quad F_\Delta(u) = (u - p_1^2)^2$$



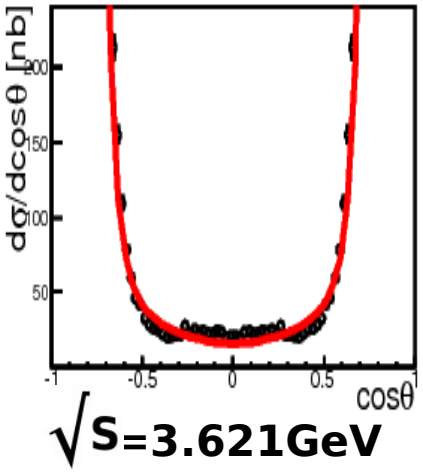
$\sqrt{S}$ =3.526GeV



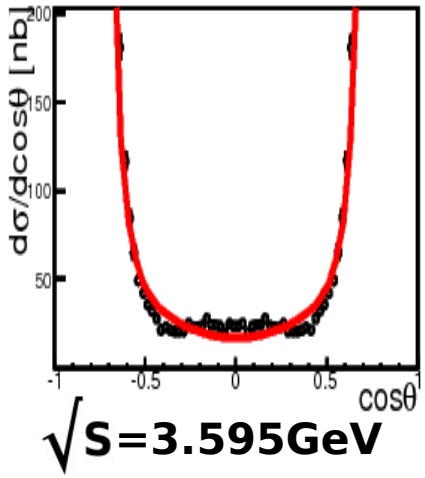
$\sqrt{S}$=3.616GeV



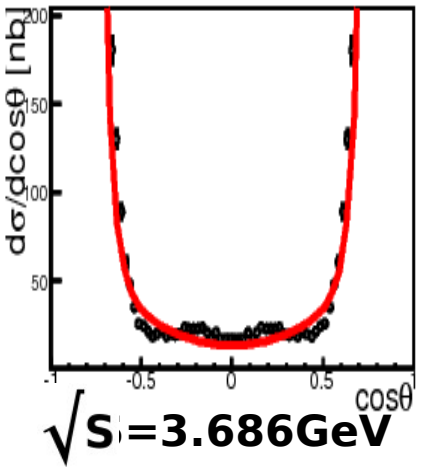
$\sqrt{S}$=3.524GeV



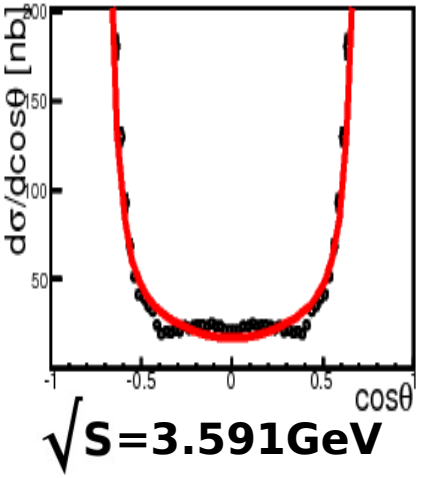
$\sqrt{S}$=3.621GeV



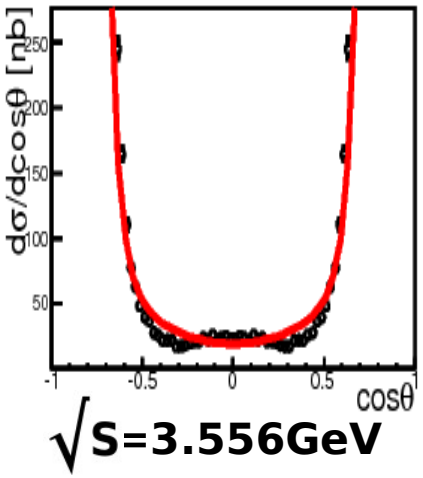
$\sqrt{S}$=3.595GeV



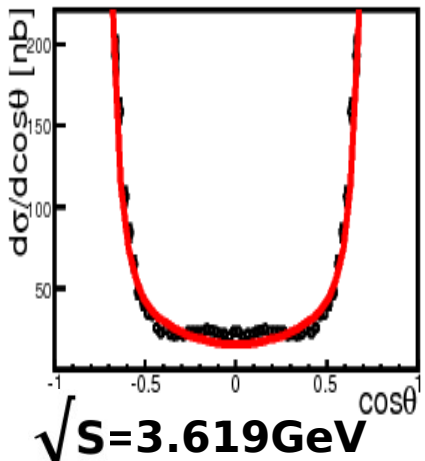
$\sqrt{S}$=3.686GeV



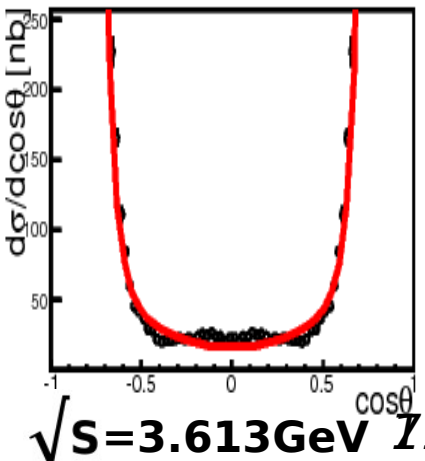
$\sqrt{S}$=3.591GeV



$\sqrt{S}$=3.556GeV



$\sqrt{S}$=3.619GeV

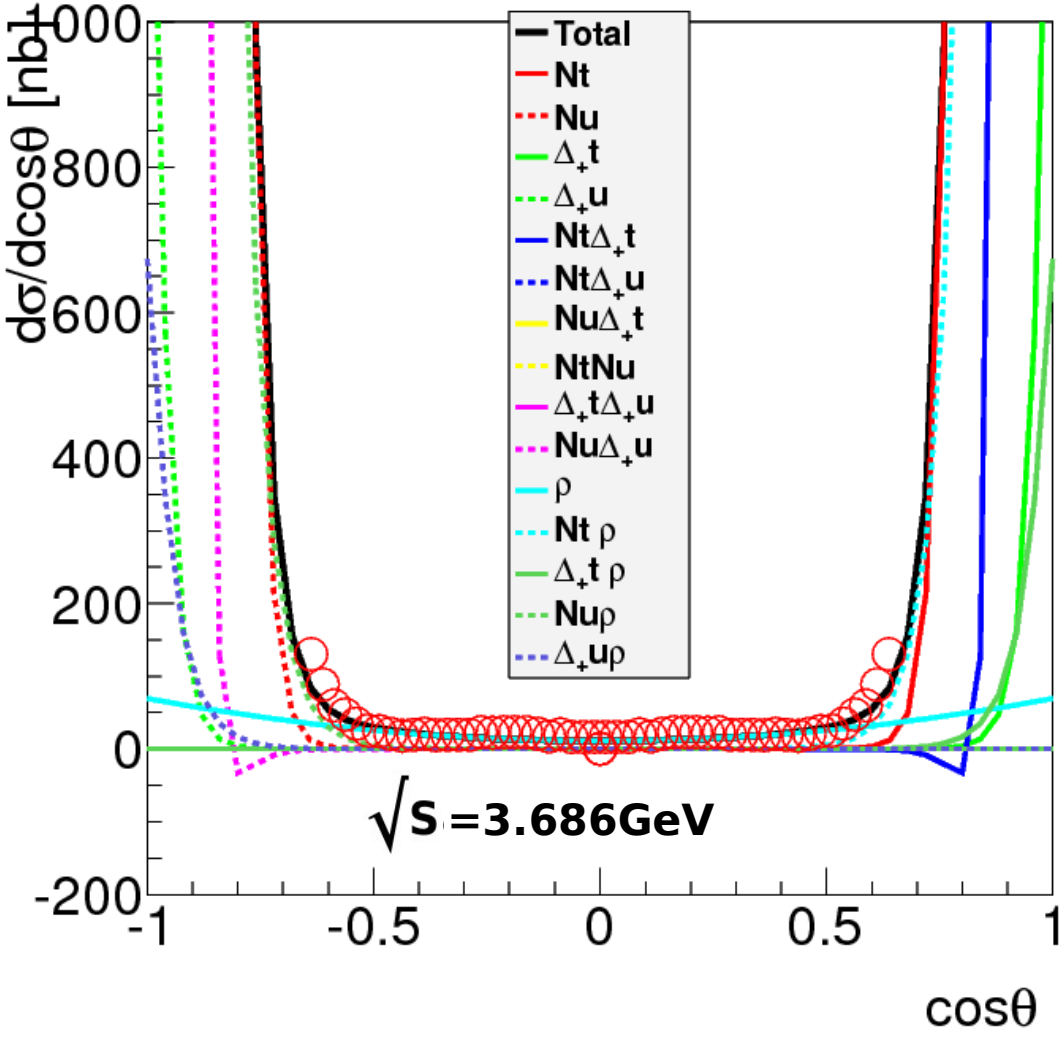


$\sqrt{S}$=3.613GeV

our fit of $\pi^o\pi^o$

Data from T. A. Amstrong al. PRD(56) 5 1997

First results for $\bar{p}p \rightarrow \pi^o\pi^o$



- angular dependence

- fully symmetrized components forward and backward

ρ Exchange mainly contributes to central angules (s channel)

- N and Δ mainly contribute forward and backward

S-dependence $\bar{p}p \rightarrow \pi^o\pi^o$

Test of quark counting

PRL (1973) 31. 18.
S. J. Brodsky, G. R. Farrar
Scaling Laws at Large Transverse Momentum

LETTERE AL NUOVO CIMENTO (1973) 5 14
V. A. Matveev et al.
Automodelity in Strong Interactions.

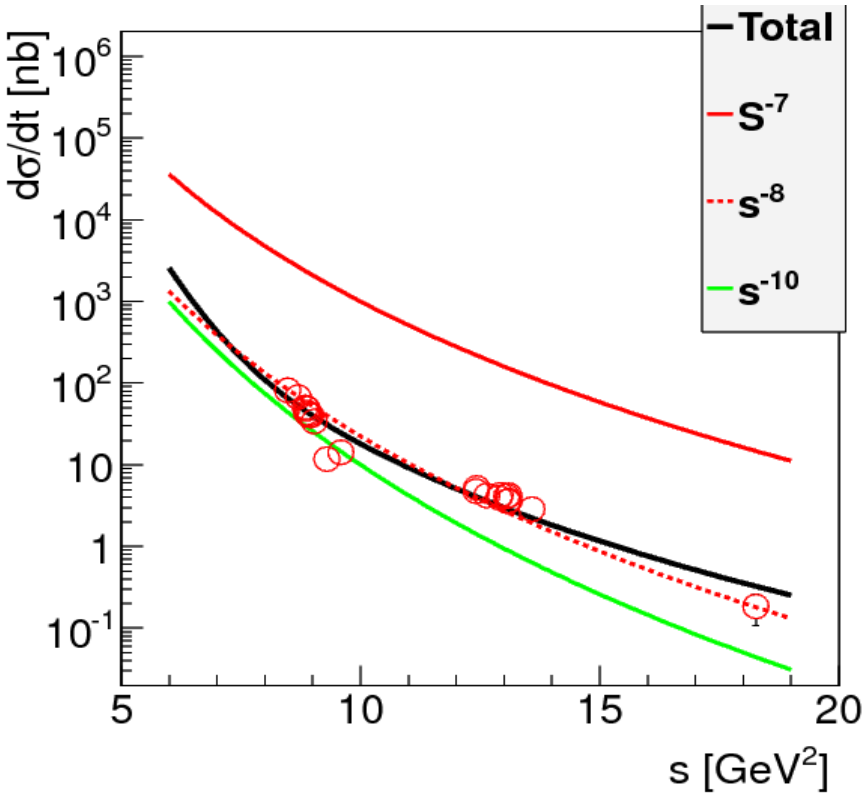
$d\sigma/dt \sim s^{2-n} f(t/s)$

n total number of leptons, photons and quark components

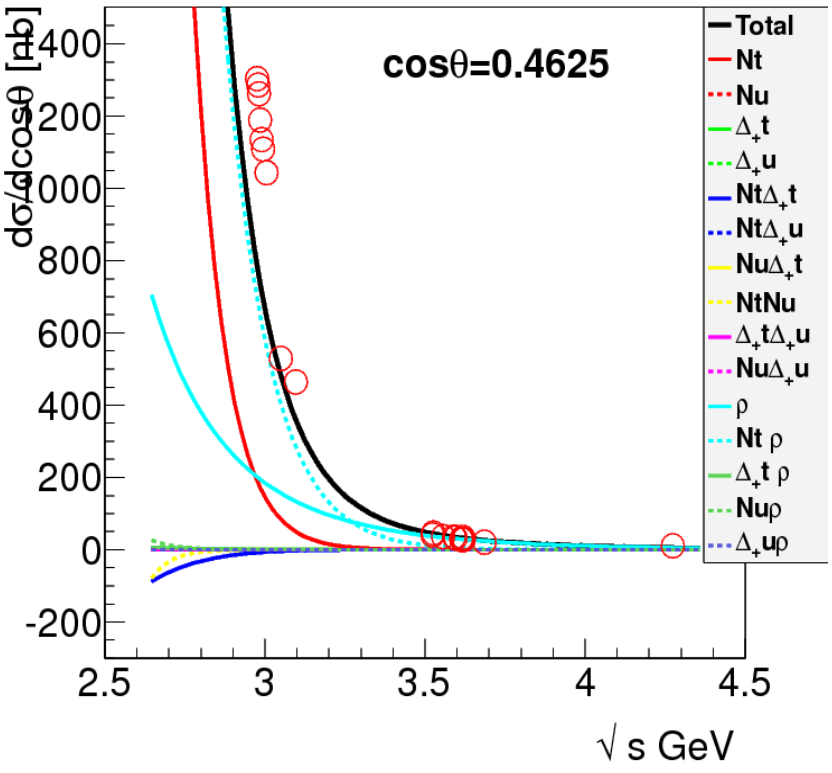
Reaction $\bar{p}p \rightarrow \pi^o\pi^o$

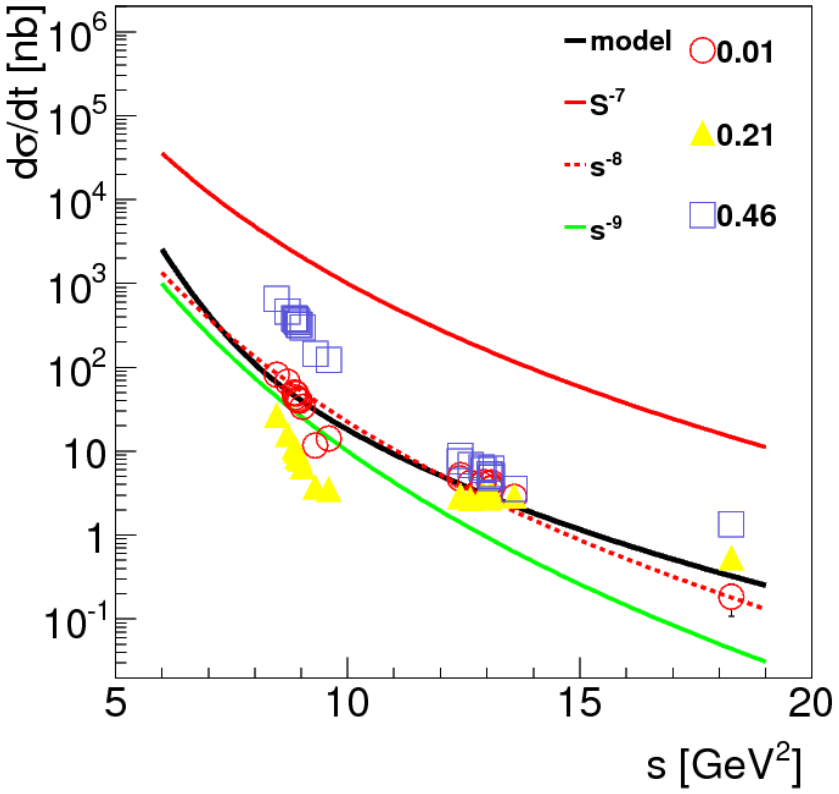
n=ni+nf=2x(3+2)=10
2-n=-8

$d\sigma/dt \sim s^{-8} f(t/s)$



S-dependence $\bar{p}p \to \pi^o\pi^o$





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Physics Letters B 471 (1999) 271–279

Π and η mesons are pseudoscalar mesons, and the decay to ηη allows us to use well-known composition of singlet and octet states, and mixing angle Θ ≈ 40°

$$\eta \approx (u\bar{u} + d\bar{d})/\sqrt{2} + s\bar{s}$$

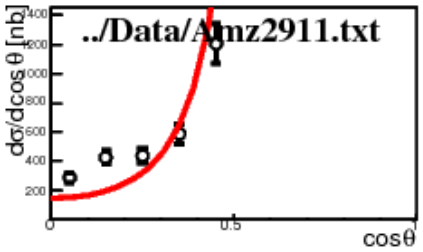
$$(u\bar{u} + d\bar{d})\sqrt{2}$$

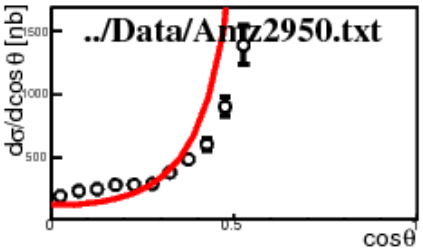
$$|q\bar{q}> = \cos\Theta|\eta> + \sin\Theta|\eta'>$$

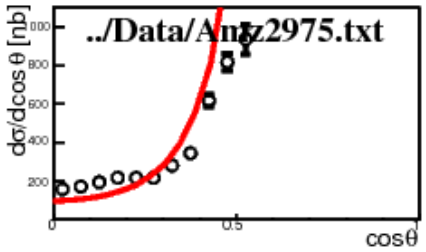
$$|s\bar{s}> = -\sin\Theta|\eta> + \cos\Theta|\eta'>$$

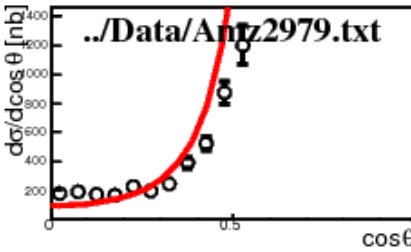
$$f(\eta\eta) = f(\pi^0\pi^0)\cos^2\Theta$$

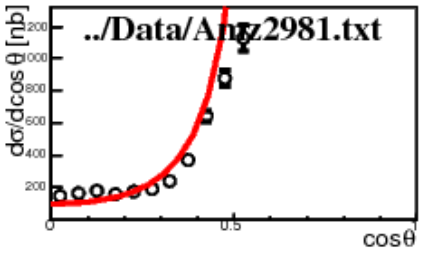
$\bar{p}\,p \rightarrow \eta\,\eta$

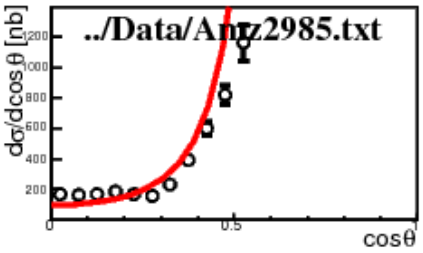


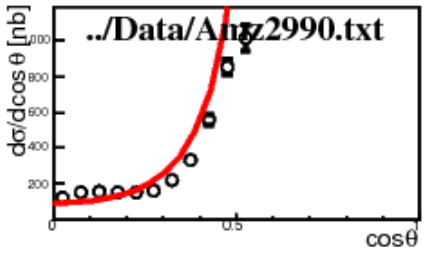


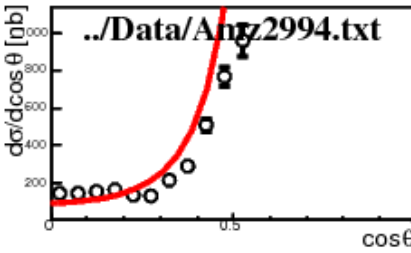


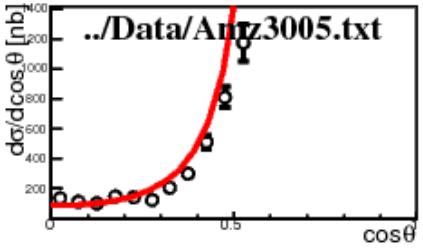


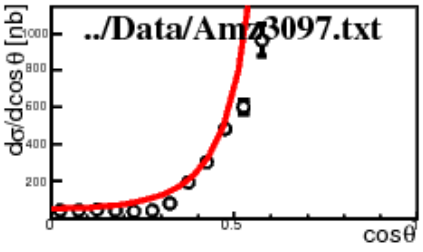


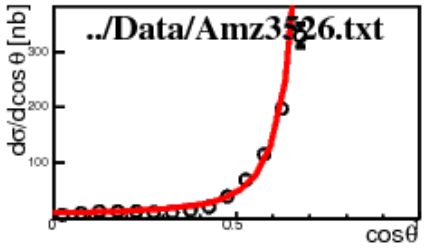


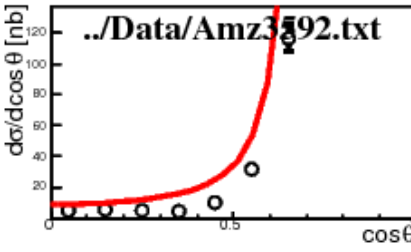


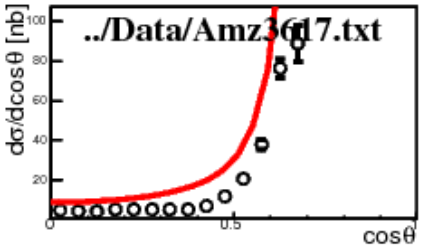


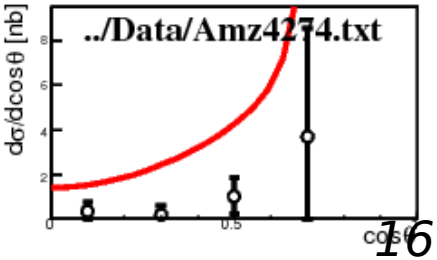










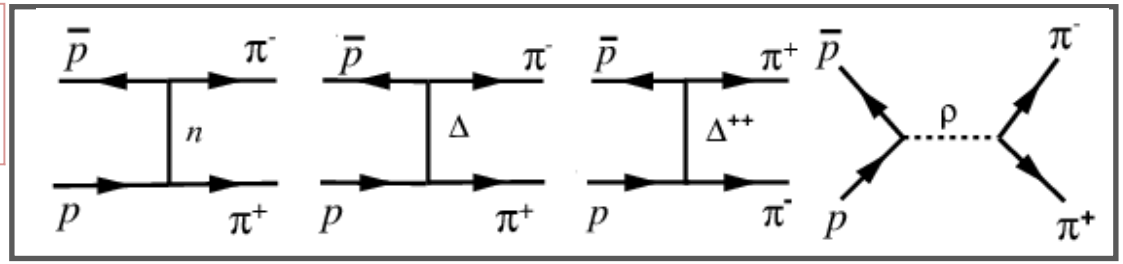


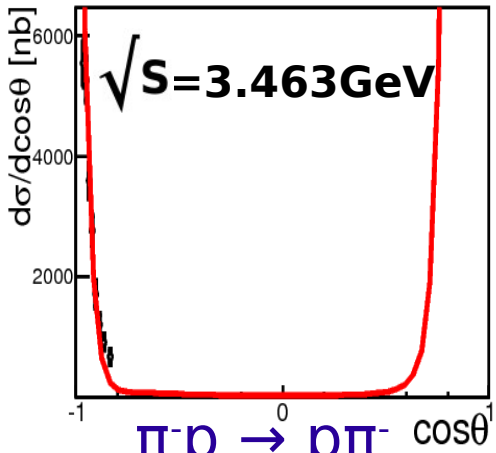
T. A. Amstrong al. PRD(56) 5 1997

Calculation $\bar{p}p \rightarrow \pi^+\pi^-$

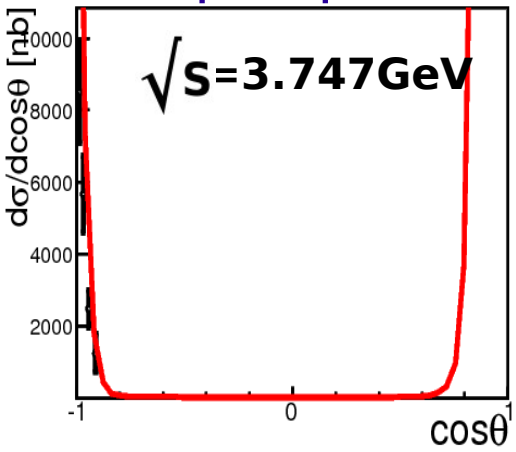
Add u-channel Δ^{++}

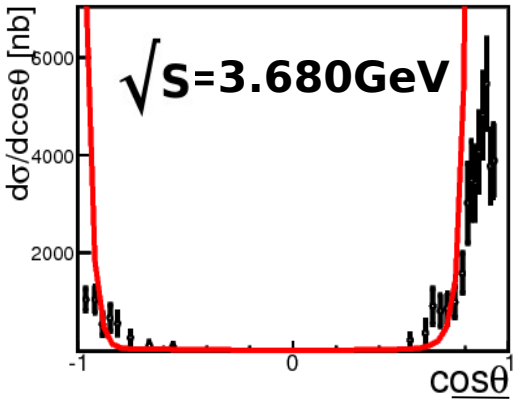
keep same parameters as π^0

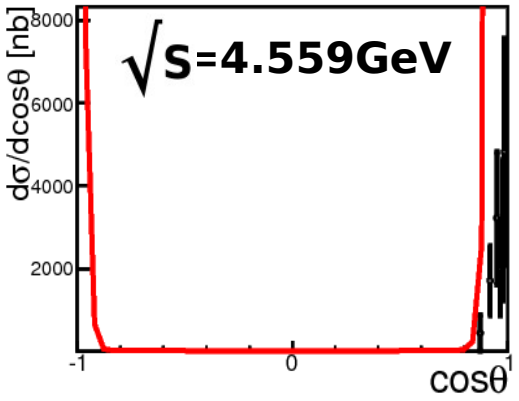




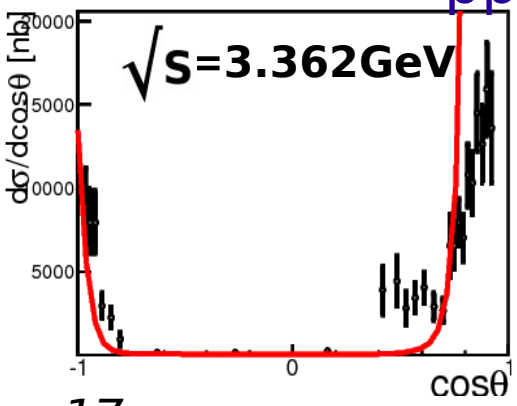
$\pi^-p \rightarrow p\pi^-$

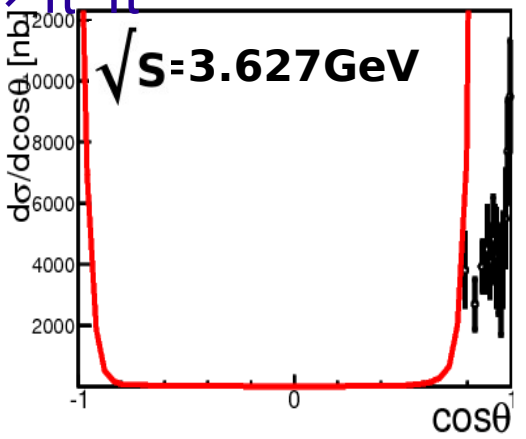






$pp \rightarrow \pi^+\pi^-$





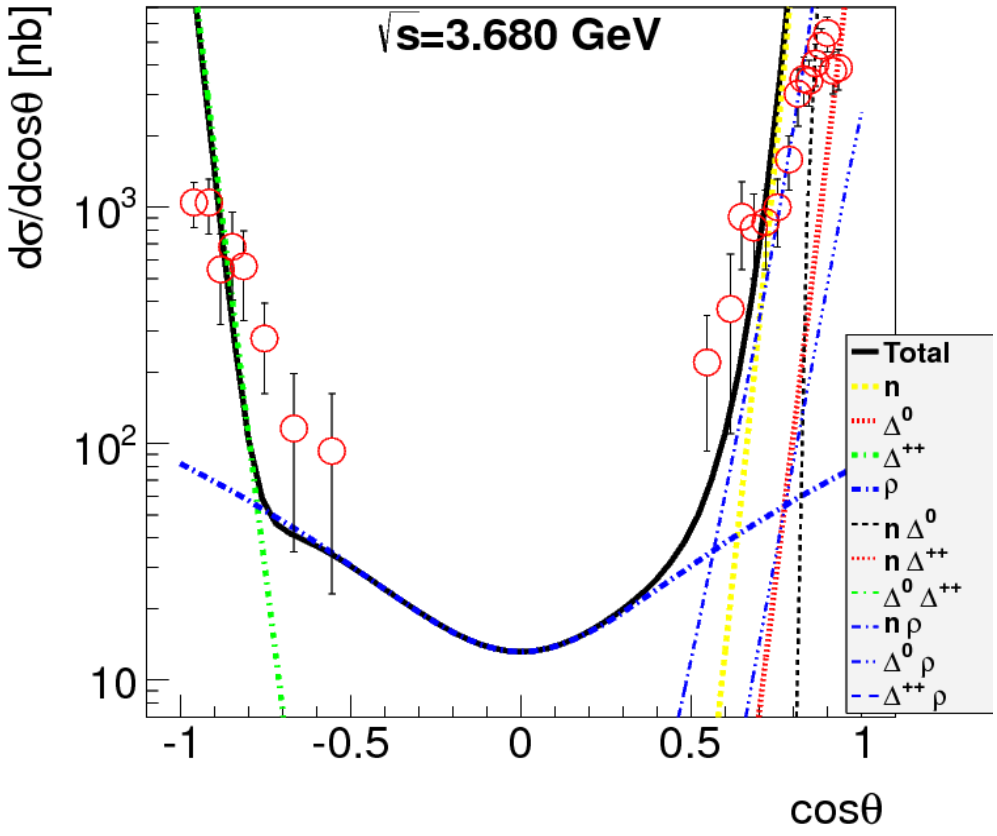
Calculation $\bar{p}p \to \pi^+\pi^-$

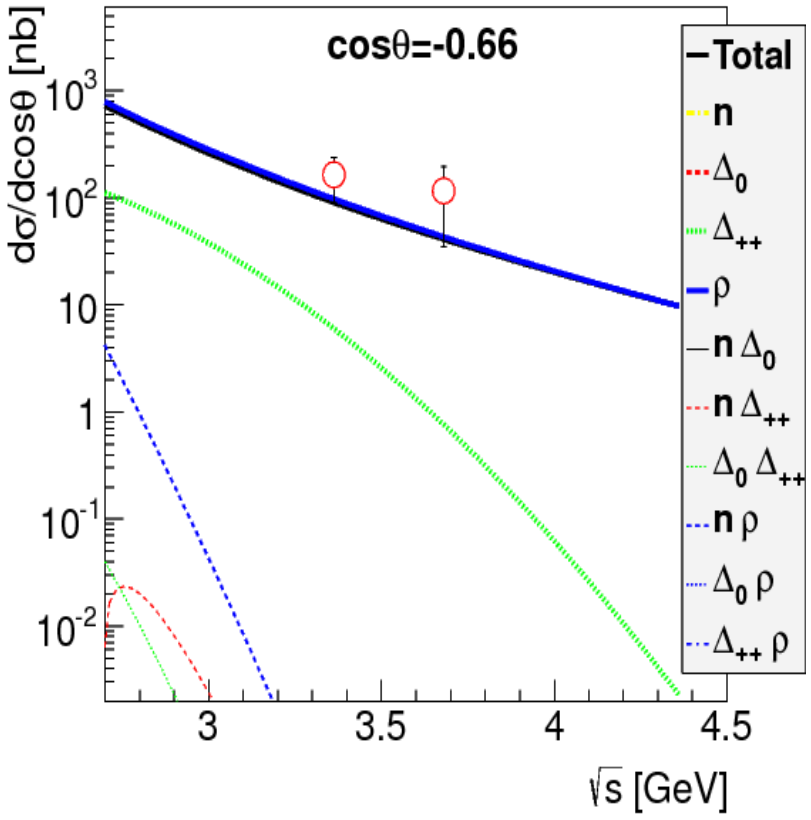
- Angular distribution

Add u-channel Δ^{++}

keep same parameters as π^0

- s-dependence





Summary and perspectives

- We have built a promising model based on effective lagrangian to describe 2 meson production in pbar p annihilation

- Parameters fixed on pi0pi0

- We reproduced pi^+pi^-

- We reproduced pi^+p, pi^-p using the crossing symmetry

- Encouraging results on angular distributions and expected s dependence have been obtained

Next:

- Optimize the parameters to improve charged pion description at small angles

- Apply similar formalism to other channels: $\gamma\gamma$, $\gamma\pi^0$, $\eta\pi^0$, KK

Thank you!

Test of quark counting

Hadron-hadron collision at high energies (CMS)

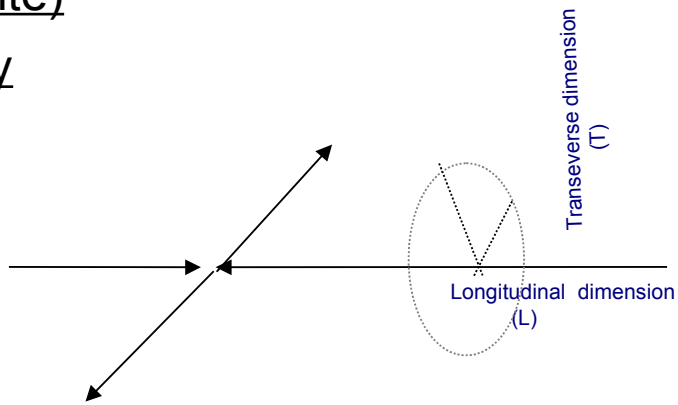
2 experimental rules in the reaction

LETTERE AL NUOVO CIMENTO (1973) 5 14
V. A. Matveev et al.
Automodelity in Strong Interactions.

limited T momenta with s increasing (L can be infinite)

average number of particles produced grows slowly when s increases

↓ kinematics is defined by dimensions T and L



- Strong dynamical difference between T-L

- Essential constants purely related to T

↓

Asymptotically, the average number of particles(mutiplicity), and the average transverse momentum are constant as function of s.