IPN
INSTITUT DE PHYSIQUE NUCLÉAIRE
ORSAY

Aspects of Nucleon form factors measurements:

- Phenomenological study of proton anti-proton annihilation into light meson pairs
- Contribution to ALPOM2 experiment

École Doctorale
PHENIICS
Doctoral School

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Nucleon Form Factors (FFs)

The electromagnetic FFs: GE and GM

- Inside structure of nucleon

Spatial distributions of charge and magnetization current inside the nucleon.

How to measure?

Can be approached from two sides

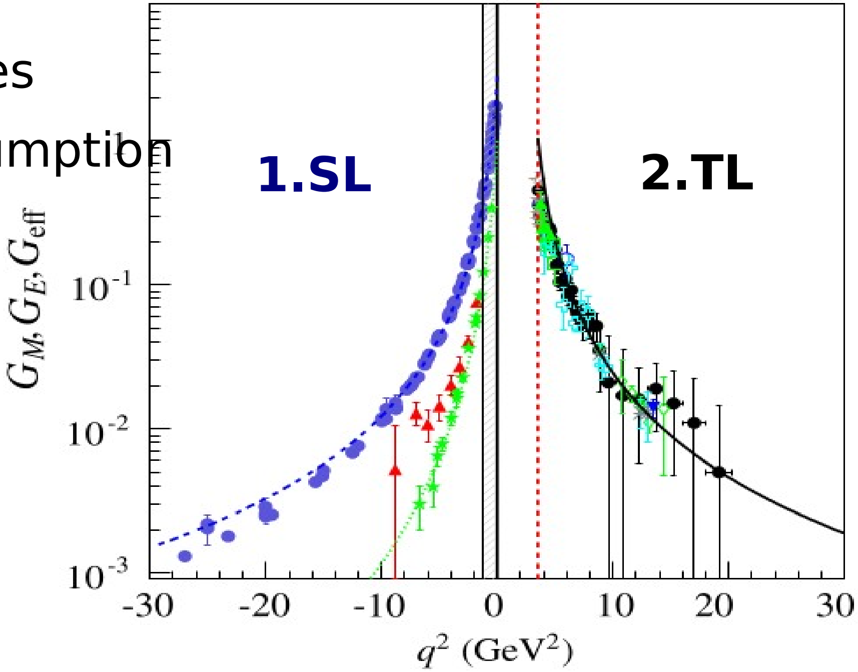
within one photon exchange assumption

1. Space-like region (SL)

ep → ep

2. Time-like region (TL)

pbar p → e+ e-
e+ e- → pbar p



S. Pacetti et al. / Physics Reports 550–551 (2015) 1–103

Content

Time-like region ($\bar{p}$ p → e+ e-)

PANDA experiment

- Neutral particles

pbar p → $\pi^0\pi^0$, η η, ηπ^0

Space-like region (e- p → e-p)

Experiment preparation ALPOM2

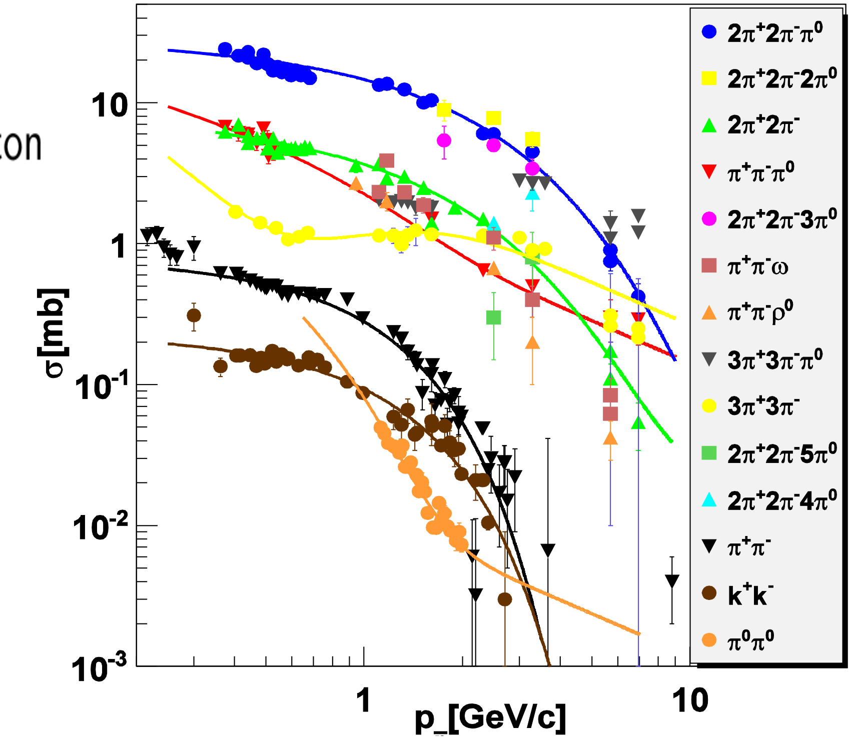
- Experimental prediction for np → np (pn)

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

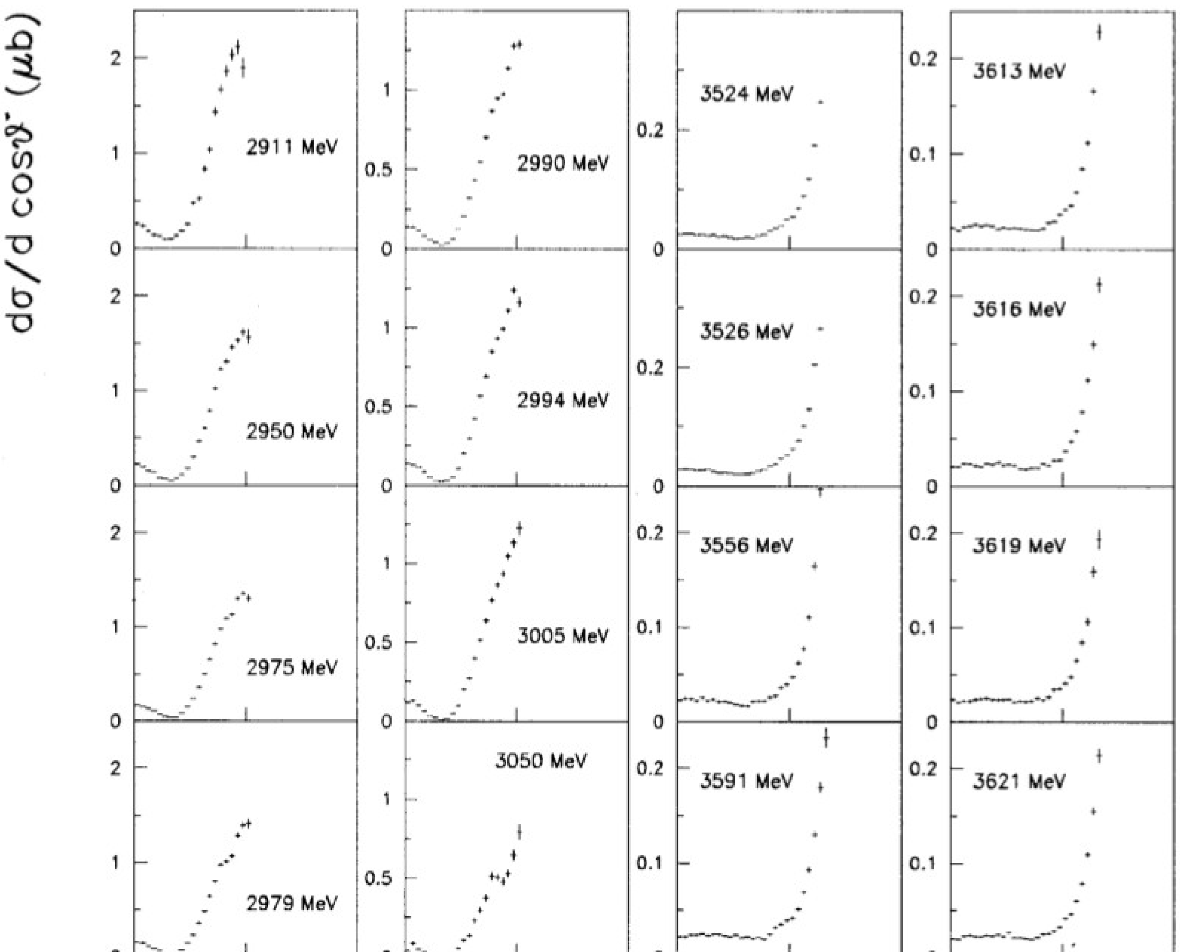
PHYSICAL REVIEW D VOLUME 56, NUMBER 5 1 SEPTEMBER 1997

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

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



Energy under 2.911 GeV

Sum of resonances:

$$T_{L,J} = \sum_{i=1} \frac{G_i B_L(p) B_J(q) \exp(i\phi_i)}{M_i^2 - s - iM_i\Gamma_i}$$

We develop effective Lagrangian model based on s,t, u channel Feynman diagrams.

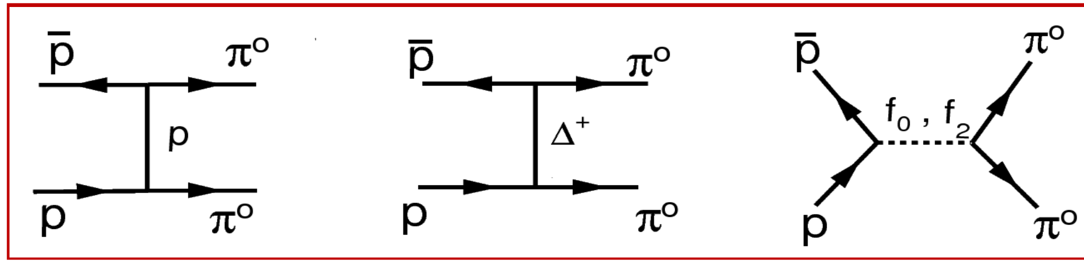
The aim is to reproduce all available data and make reliable predictions at higher energies.

Our model should work in Panda energy region

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

➢ <u>Differential cross section</u>

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



✓ <u>(e.g.)Nucleon exchange</u>

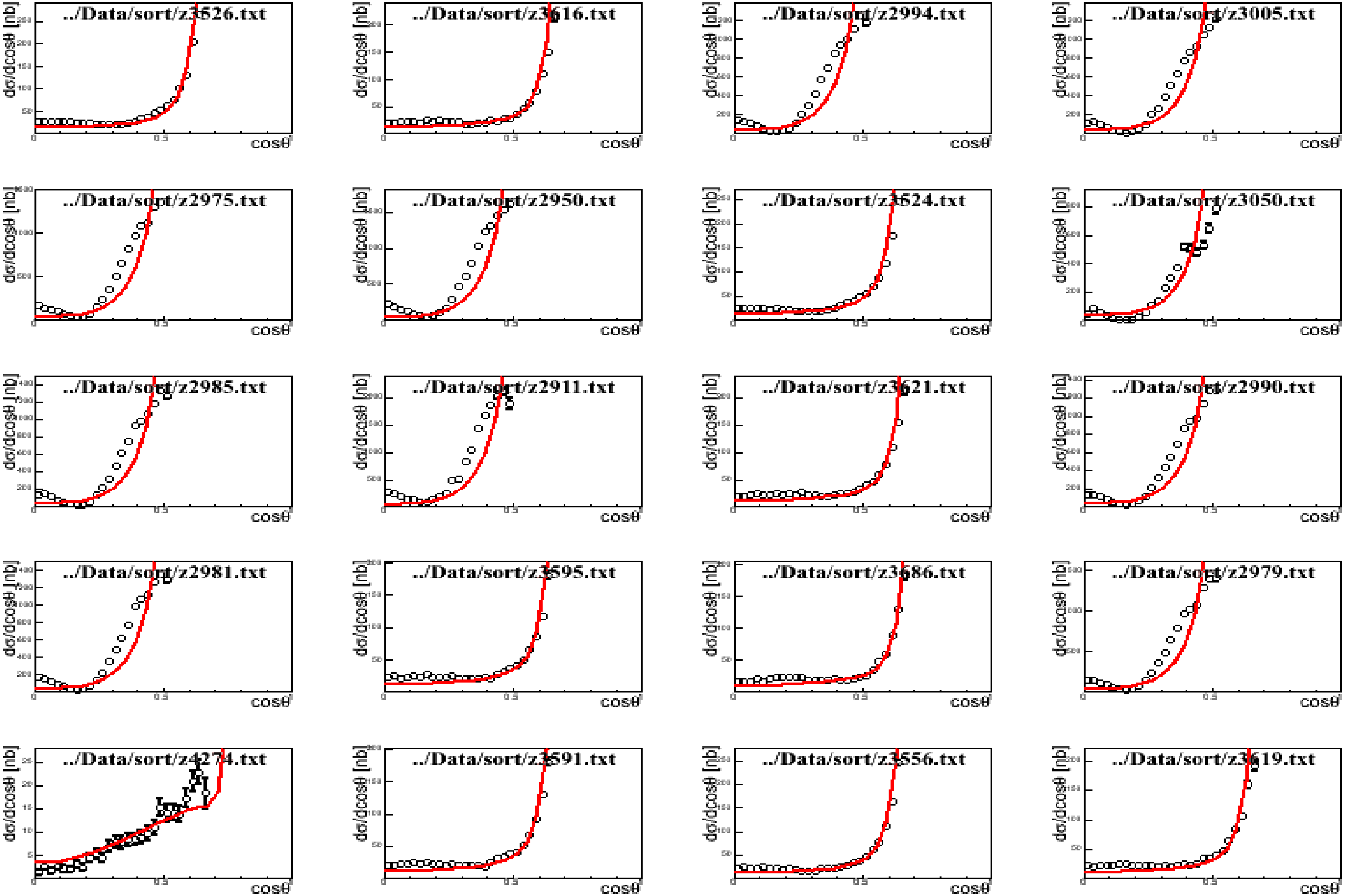
- Vertex: $-ig_{\pi NN}(i\gamma_5)(2\pi)^4$
- Propagator: $\frac{i}{(2\pi)^4}\frac{\hat{q}_t + M_p}{q_t^2 - M_p^2}$

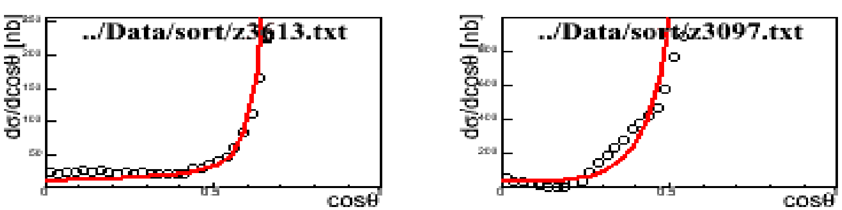
$$|\overline{\mathcal{M}_n}|^2 = \mathcal{M}_n A^*(a) = \frac{g_{\pi NN}^4}{(q^2 - M_p)^2} Tr\left[(\hat{p}_1 - M_p)(\hat{q} + M_p)^2(\hat{p}_2 + M_p)\right]$$

Add Regge factors and form factors
(compositeness of particles, absorption, ISI, FSI…)

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

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





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

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

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.

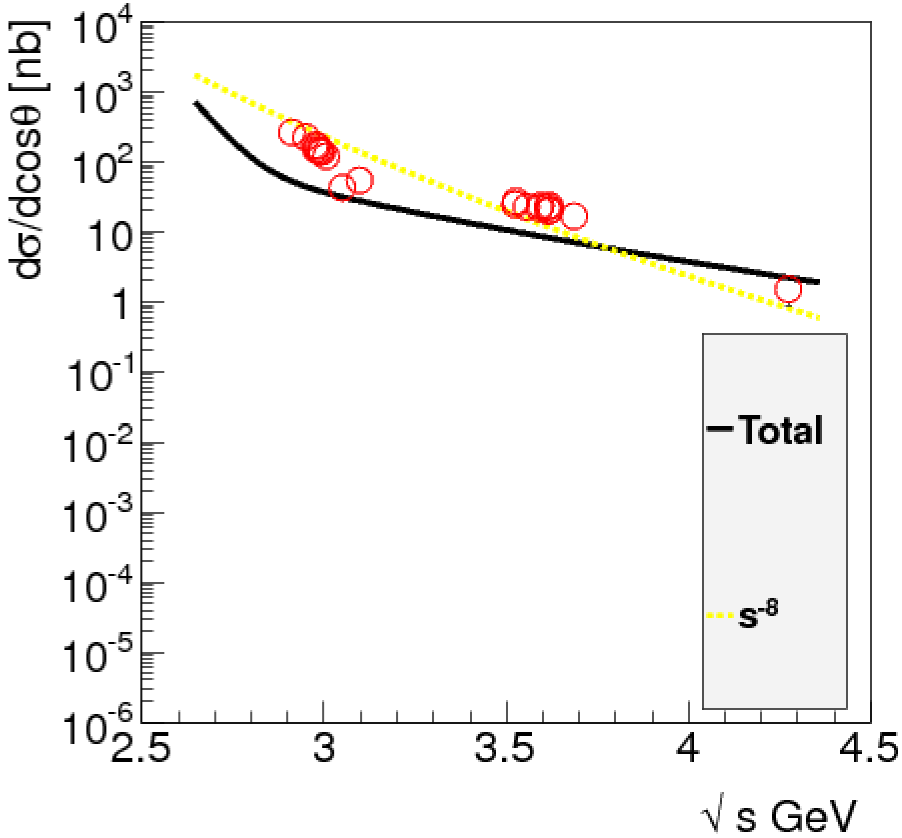
$d\sigma/dt \sim s^{2-n} f(t/s)$

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

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



From pion to eta through SU(3)

Physics Letters B 471 (1999) 271–279

Π and η mesons are pseudoscalar mesons.
The decay to ηη can be described from $\pi^0\pi^0$ using the well-known decomposition of singlet and octet states,
where the mixing angle is Θ ≈ 40°

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

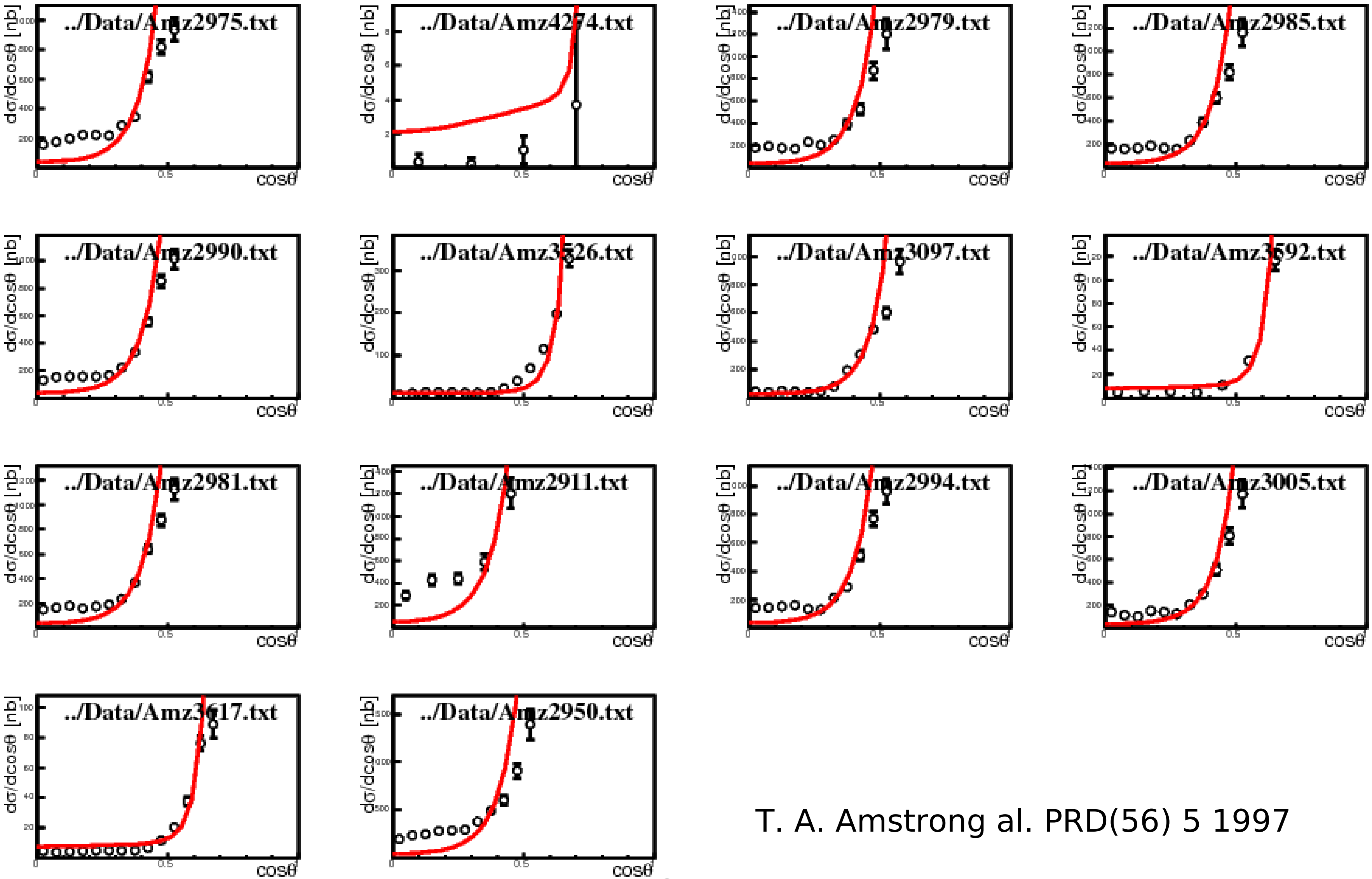
$$(u\bar{u} + d\bar{d})\sqrt{2}$$

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

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

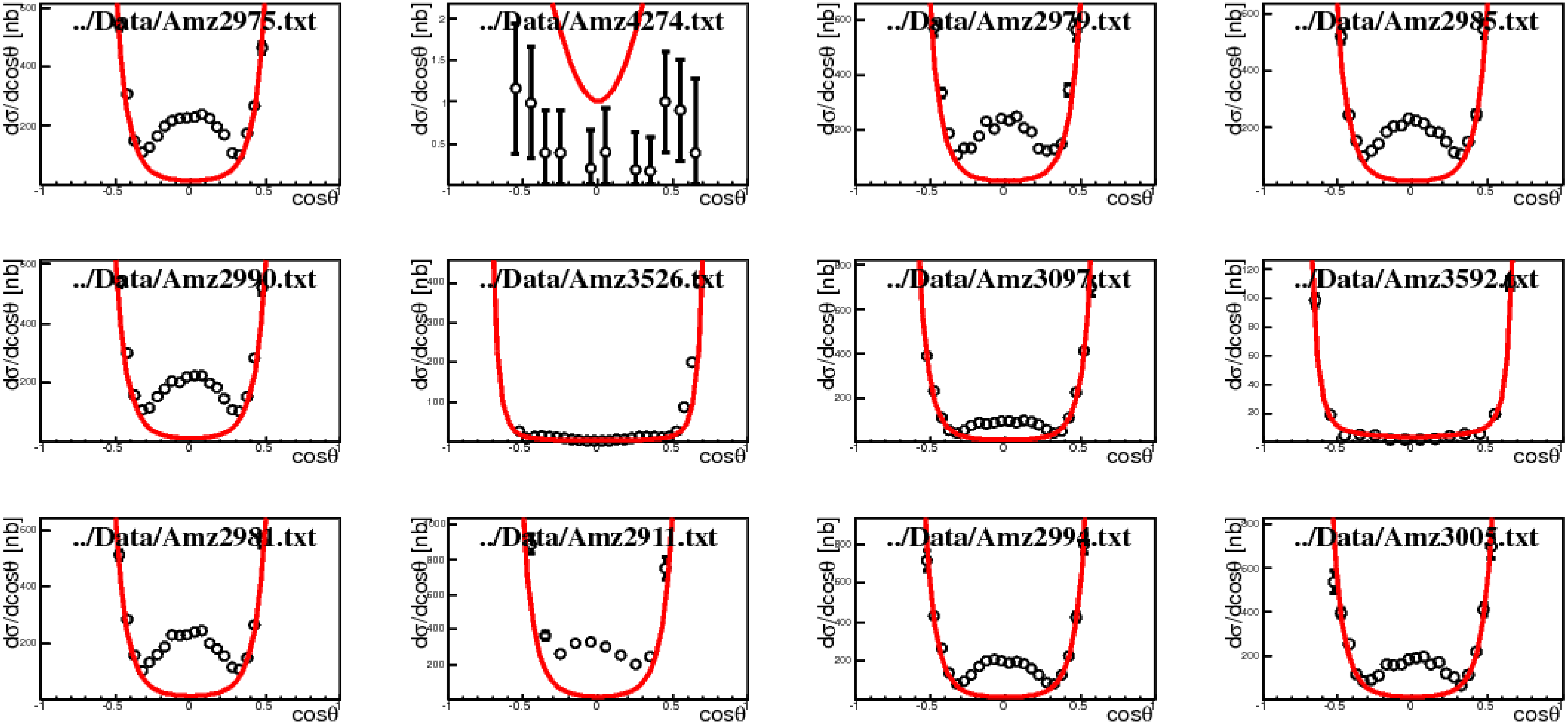
$$f(\eta\eta) = f(\pi^0\pi^0)\cos^2\Theta$$

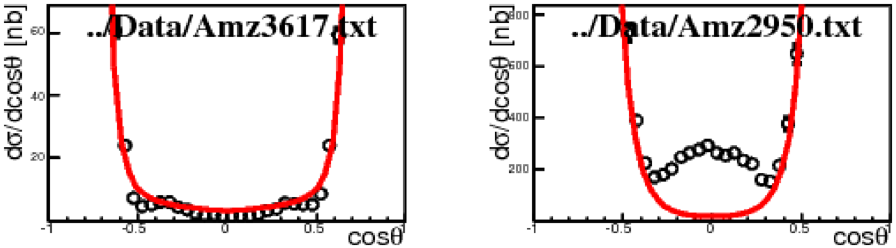
$\bar{p}\, p \rightarrow \eta\, \eta$



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

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





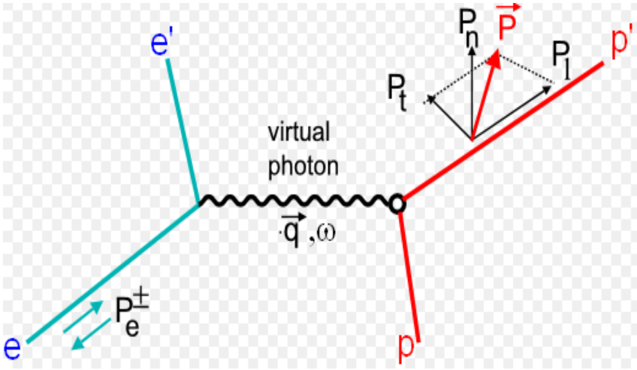
T. A. Amstrong al. PRD(56) 5 1997

II part
ALPOM2 experiment

Hadron form factor measurement

Polarized ep elastic scattering

$$\frac{G_E}{G_M} = -\frac{P_t}{P_\ell}\frac{(E_e + E'_e)}{2M_p}\tan(\frac{\theta_e}{2})$$



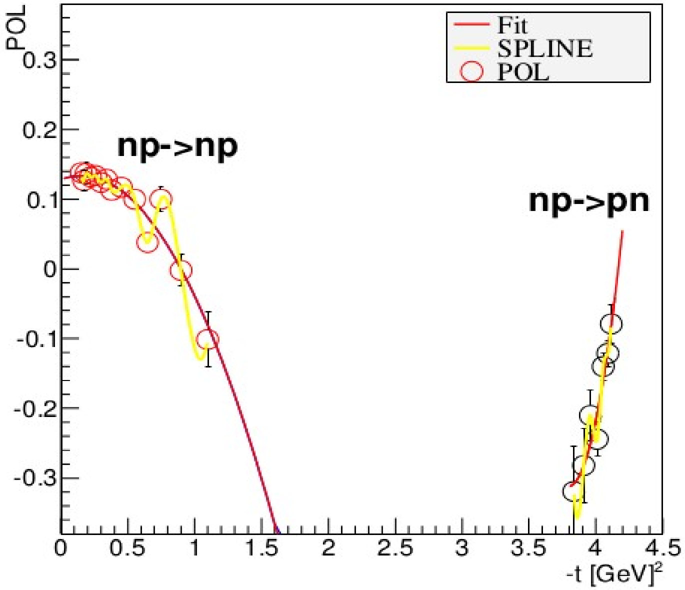
1st step: measure the proton analyzing powers (Ay) in GeV region

(Analyzing power is the Polarization of the beam)

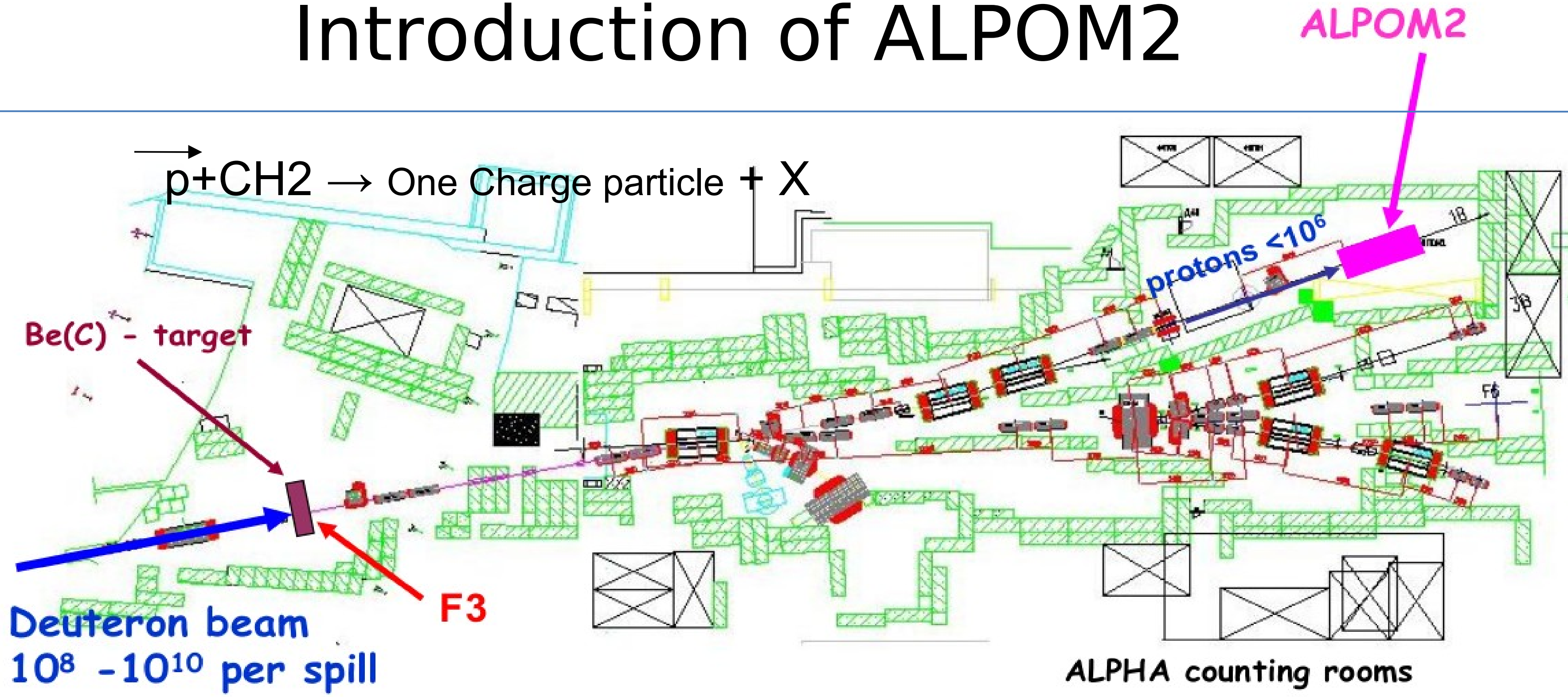
ALPOM2 (JINR- Dubna):

p+CH2 → One Charge particle + X

n p → p n (np)

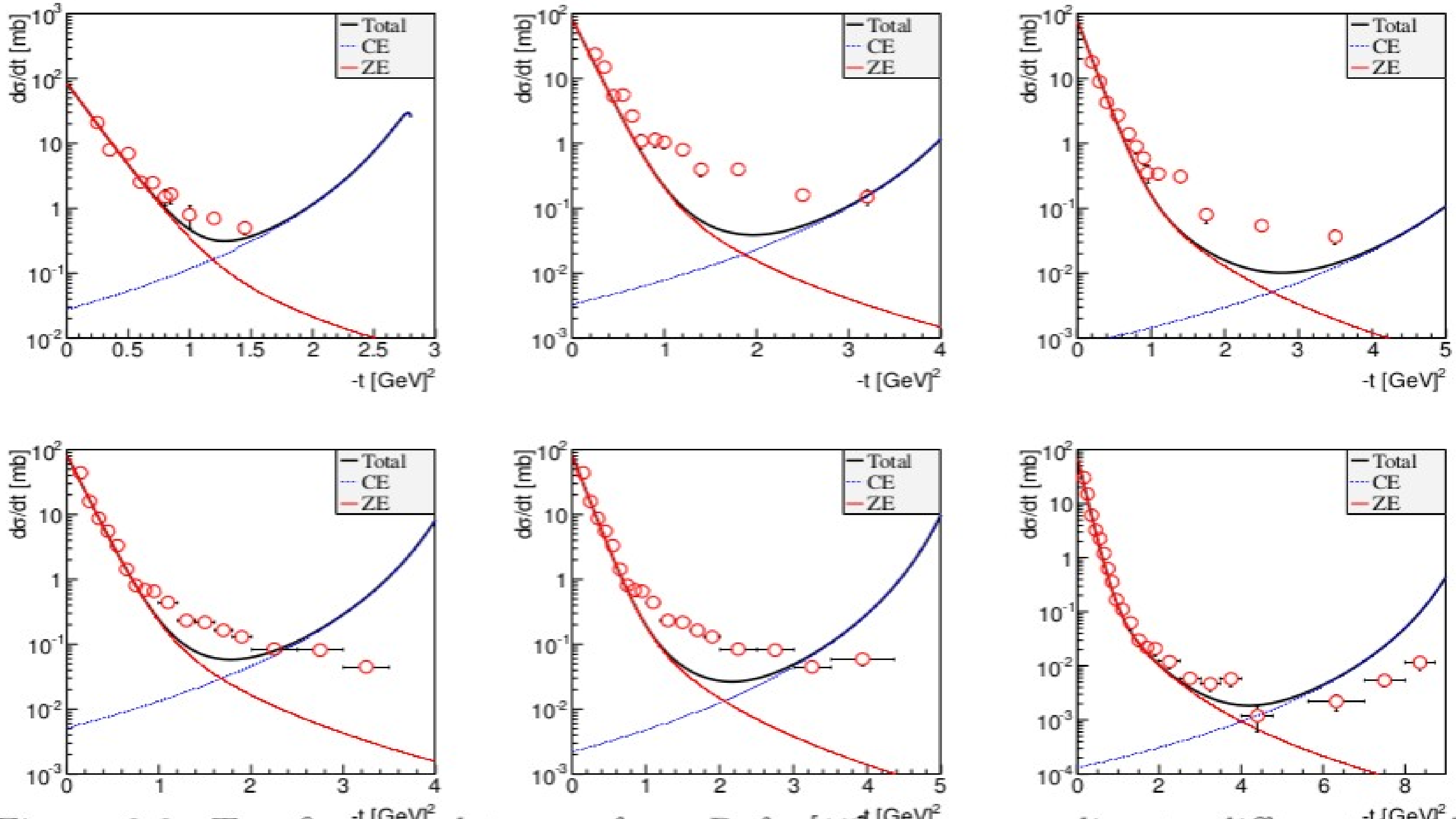


Introduction of ALPOM2



-Polarized protons will be produced by the fragmentation of the polarized deutron beam
-Protons interact with actived target CH2
-Through the drift chambers to reconstruct the trajectories
-Finally the particles will be detected by the hadron calorimeter

Differential cross section of np → np(pn)



Red circles are from experiment, and the red line reprents Zero-exchange (ZE) and the blue line is Charge-exchange (CE).

$$\frac{d\sigma}{dt} = \frac{1}{64\pi s q^2}(|T_\pi(u) + T_\rho(u)|^2 + \frac{1}{4}|T_\pi(t) + T_\rho(t)|^2 + |T_P(t)|^2)$$

Analyzing power and Figure of Merit

$$\mathcal{F}^2(\cos\theta) = A_y^2(\cos\theta) \cdot \frac{d\sigma/d\cos\theta}{\sigma_{tot}}.$$

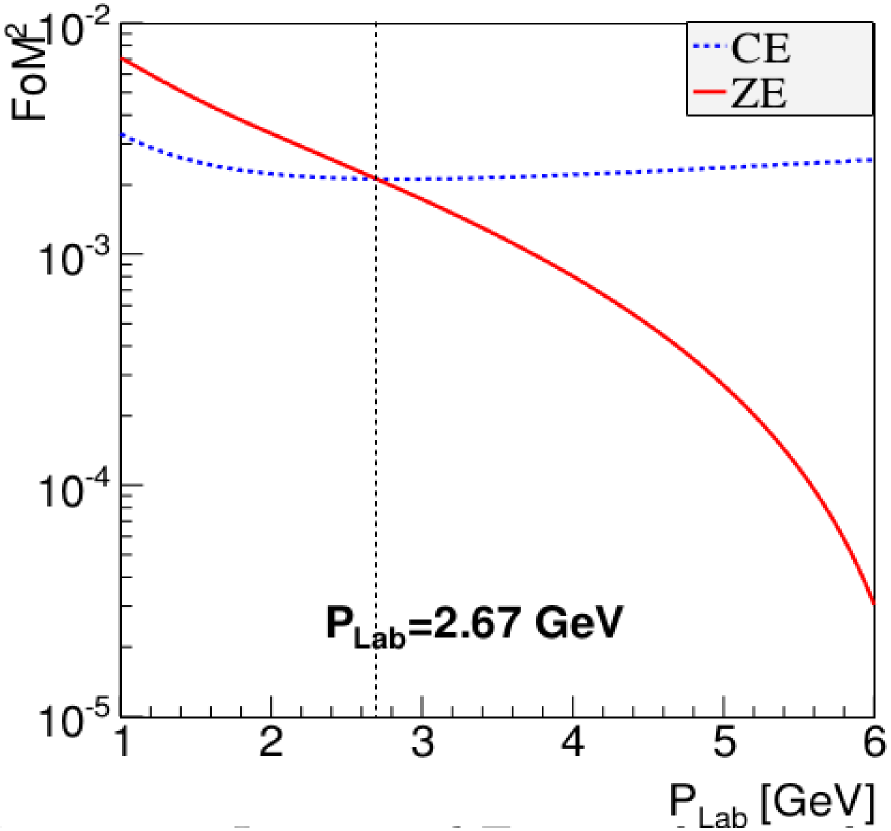
The statistical error

$$\Delta P = \sqrt{\frac{2}{N_{inc}\mathcal{F}^2}}$$

Figure of Merit considered both cross section and the analyzing power.

It can predict the statistical error when you know the experiment condition.

Also it can help to decide which energy which reaction to have better expected data.



Summary

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

- Parameters fixed on $\pi^0\pi^0$

- neutral channel obtained from SU3 symmetry: $\eta\ \eta$, $\eta\ \pi^0$

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

II) Calculation of Figure of Merit for proton and neutron polarimetry at 7.5 GeV/c momentum and comparison of the elastic and charge exchange reactions np->np(pn) for JLAB experiments.

Perspectives

Optimize the parameters to improve charged pion description at small angles

Apply similar formalism to other channels:

$\gamma\gamma$, $\gamma\pi^0$, KK

Goal:

To build a generator based on our model

Thank you!