DYNAMICS of the $\pi^- p \to \pi^0 \pi^0 n$ REACTION for $p_{\pi^-} < 750$ MeV/c

J. R. Comfort

for the

N* 2002

OUTLINE

I. Interest of $\pi^0\pi^0$ Production

II. Possible Mechanisms

III. Total Cross Sections

IV. Dalitz Distributions
- A. $\pi^0\pi^0$ Projections
- B. $\pi^0 n$ Projections

V. Multipole Analysis

VI. Summary and Conclusions

Takamatsu et al Hadron '99 (Beijing)

$\pi^- p \to \pi^0 \pi^0 n$ 9 GeV

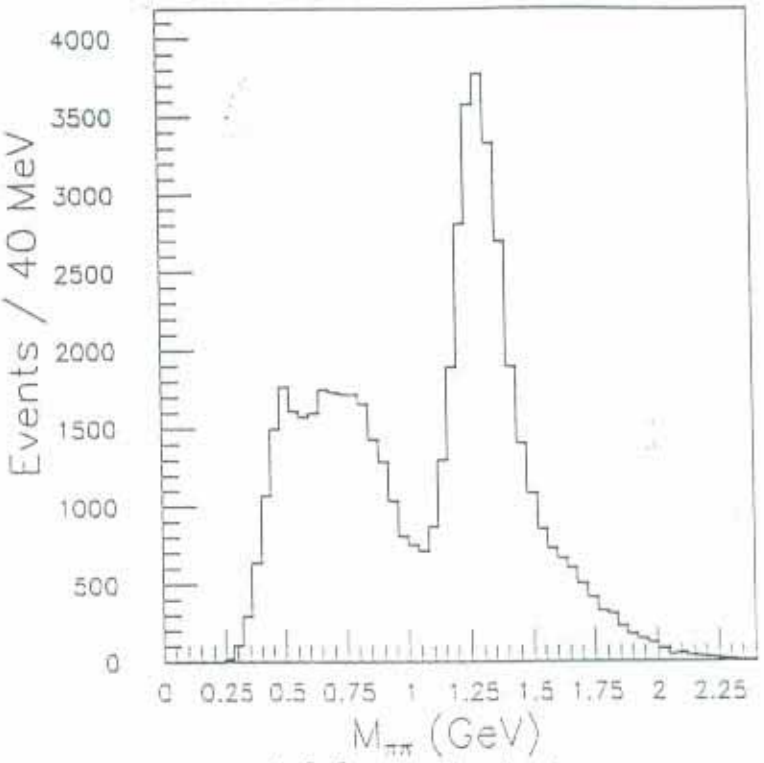


Figure 1. Acceptance corrected $\pi^0\pi^0$ mass distribution

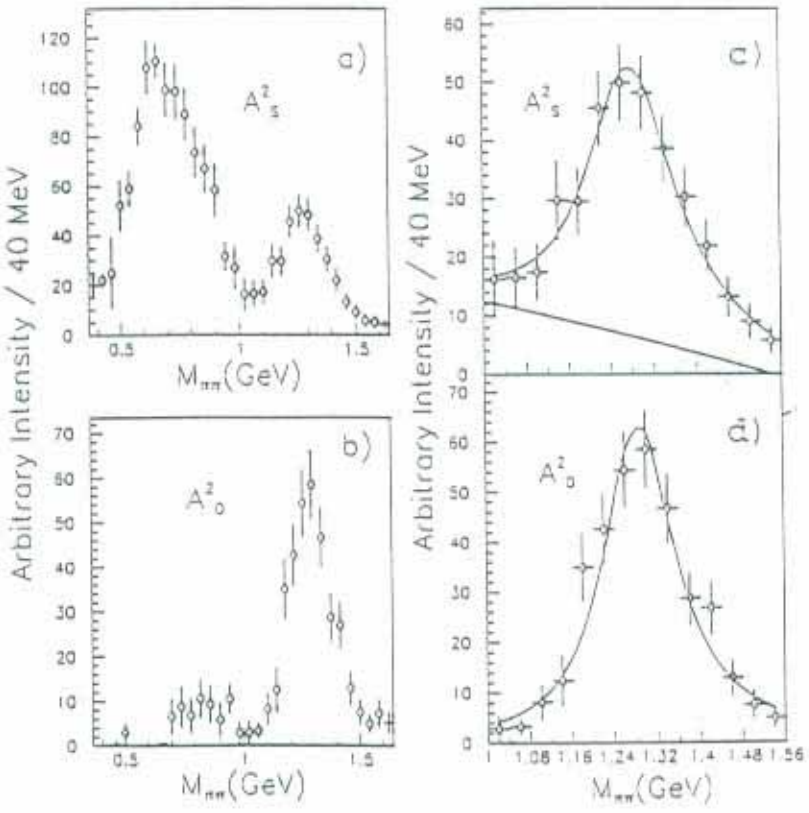
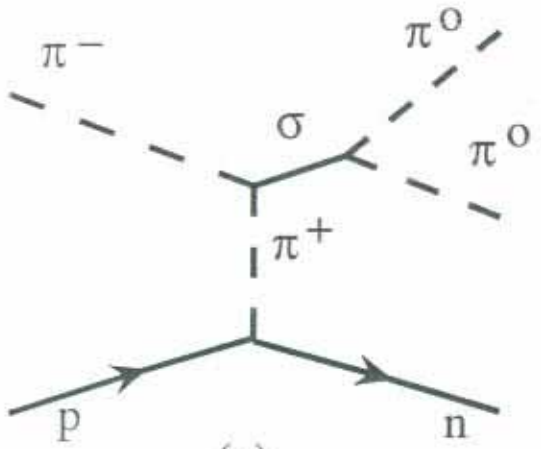
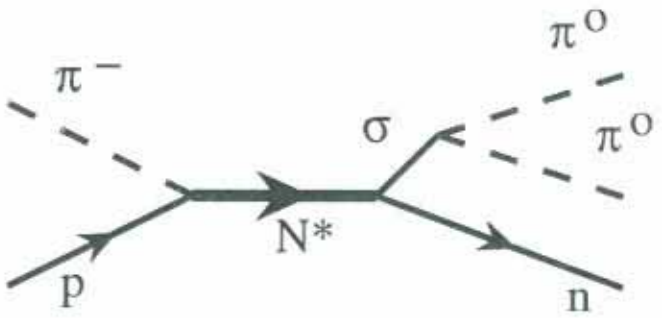


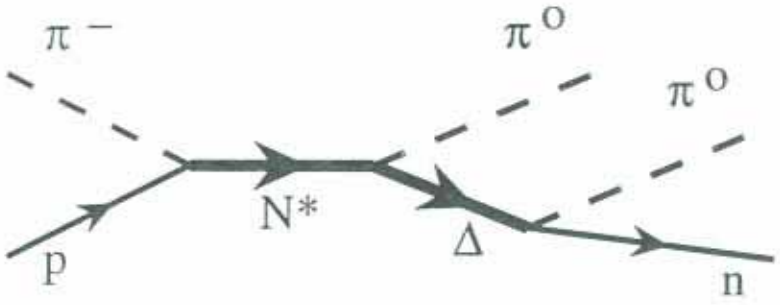
Figure 3. Results of the partial wave analysis. a) for S wave, b) for D wave. c), d)



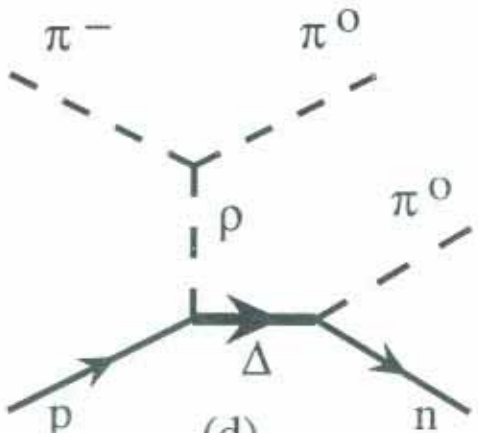
(a)



(b)

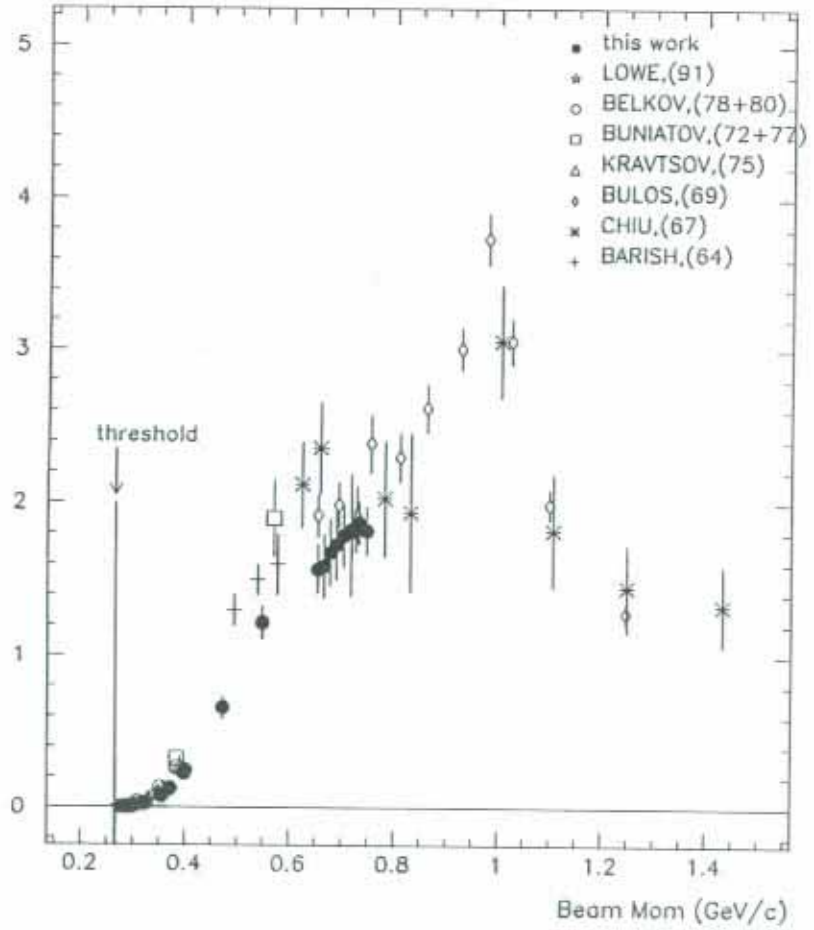


(c)

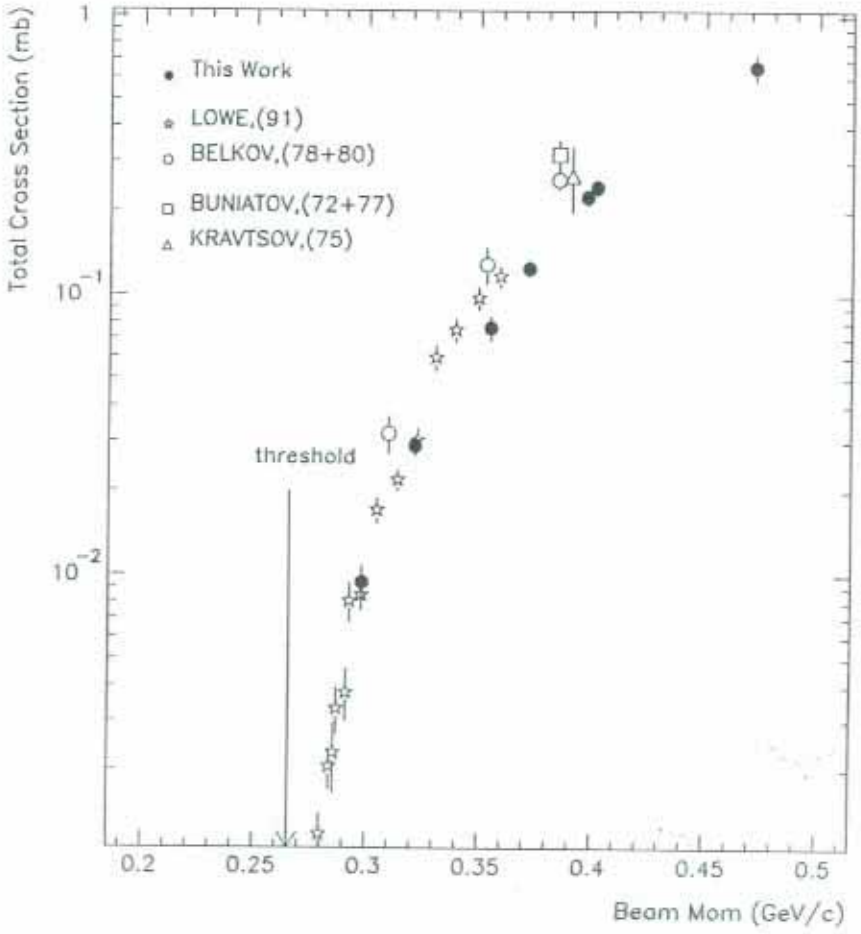


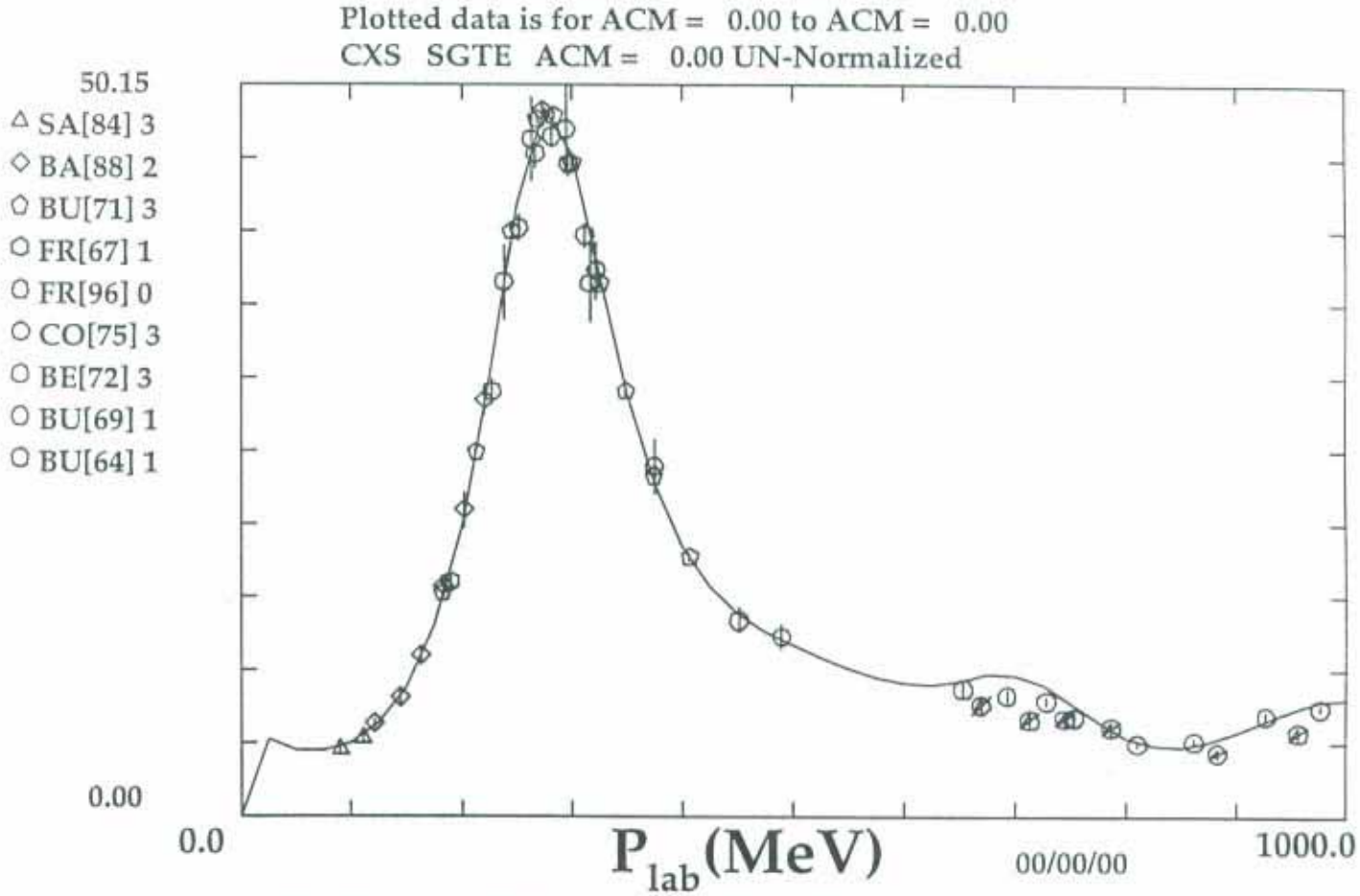
(d)

Total Cross Section for $\pi^- p \to 2\pi^0 n$

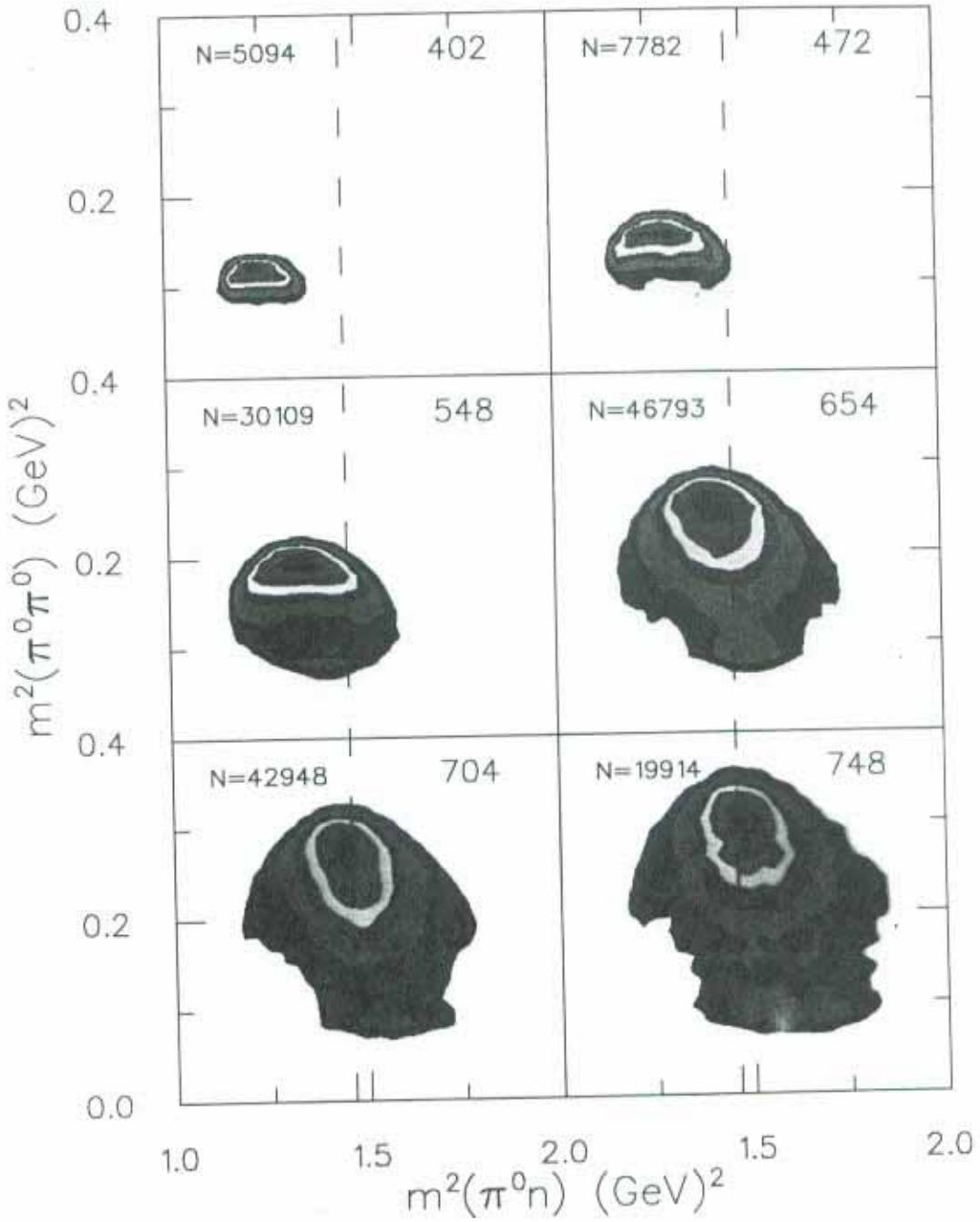


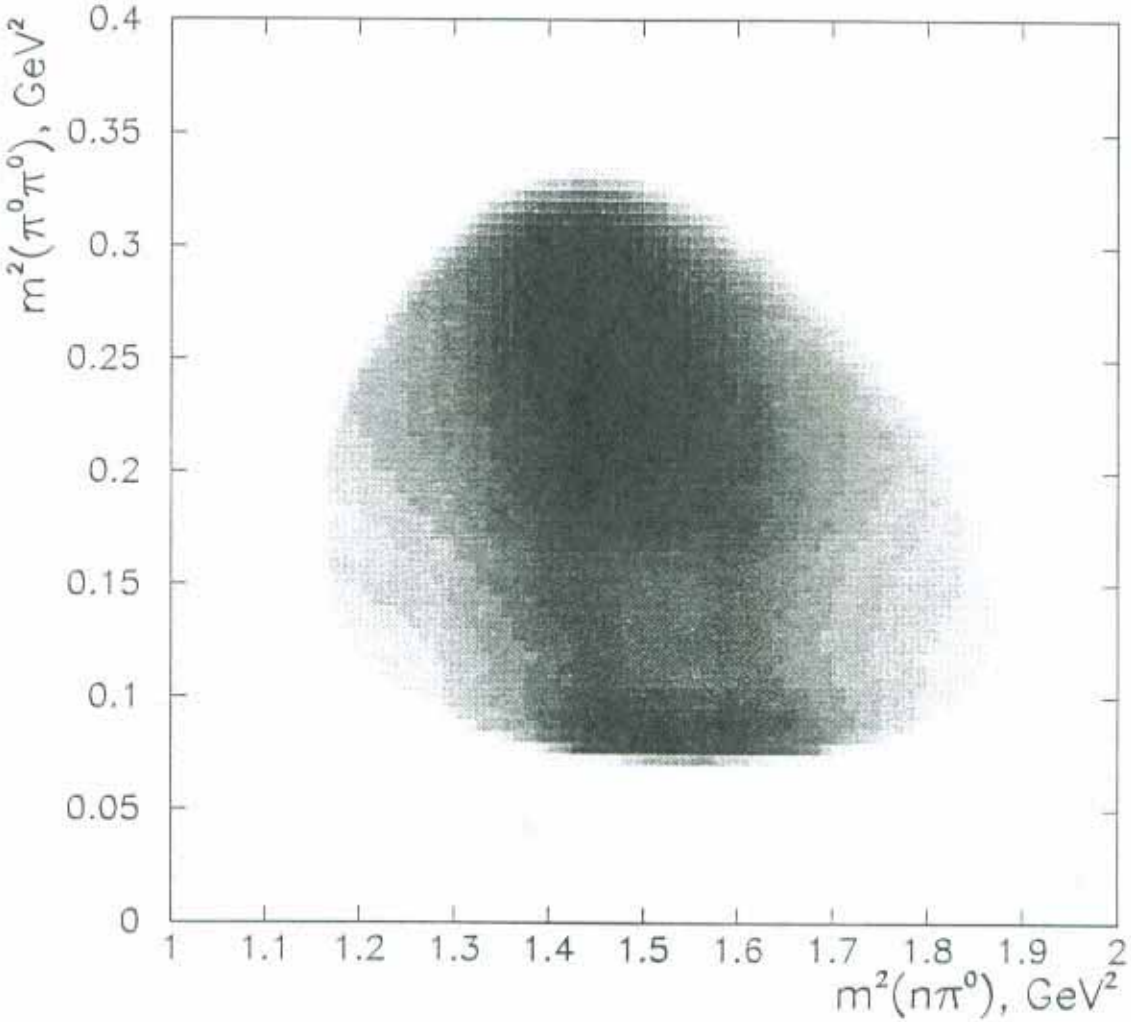
Total Cross Section for $\pi^- p \to 2\pi^0 n$

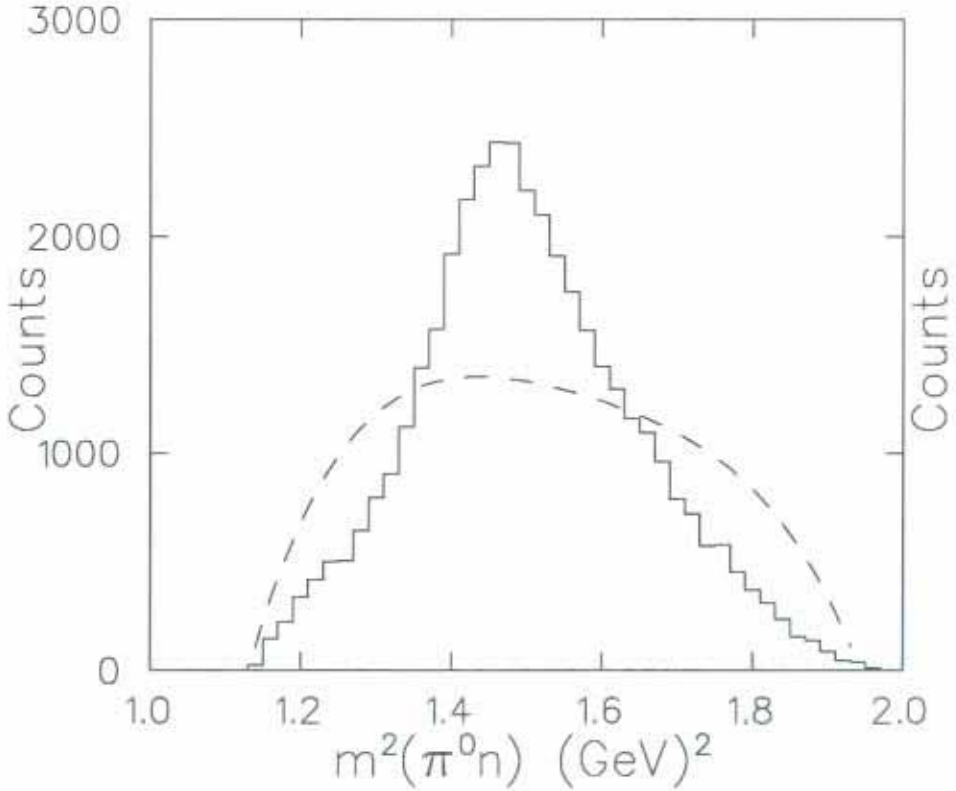


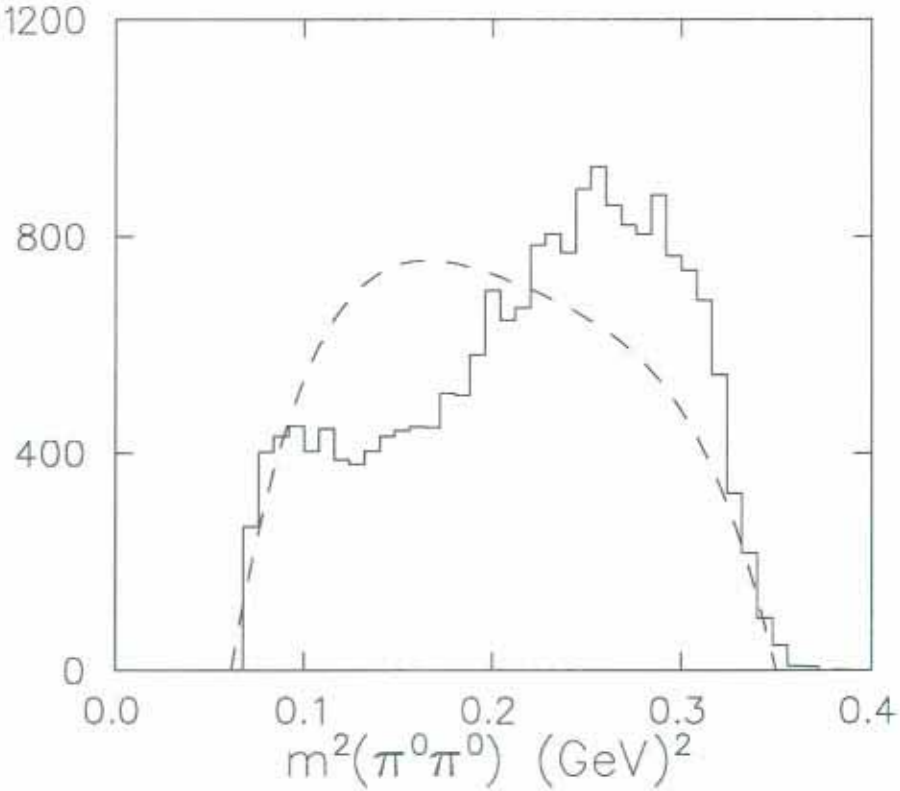


SM02 706276 46278/23860 P+=22021/10446 P-=18932/ 9553 CX=
PN012f PI-N data VPI&SU 11/01 Arndt 11/29/ 1

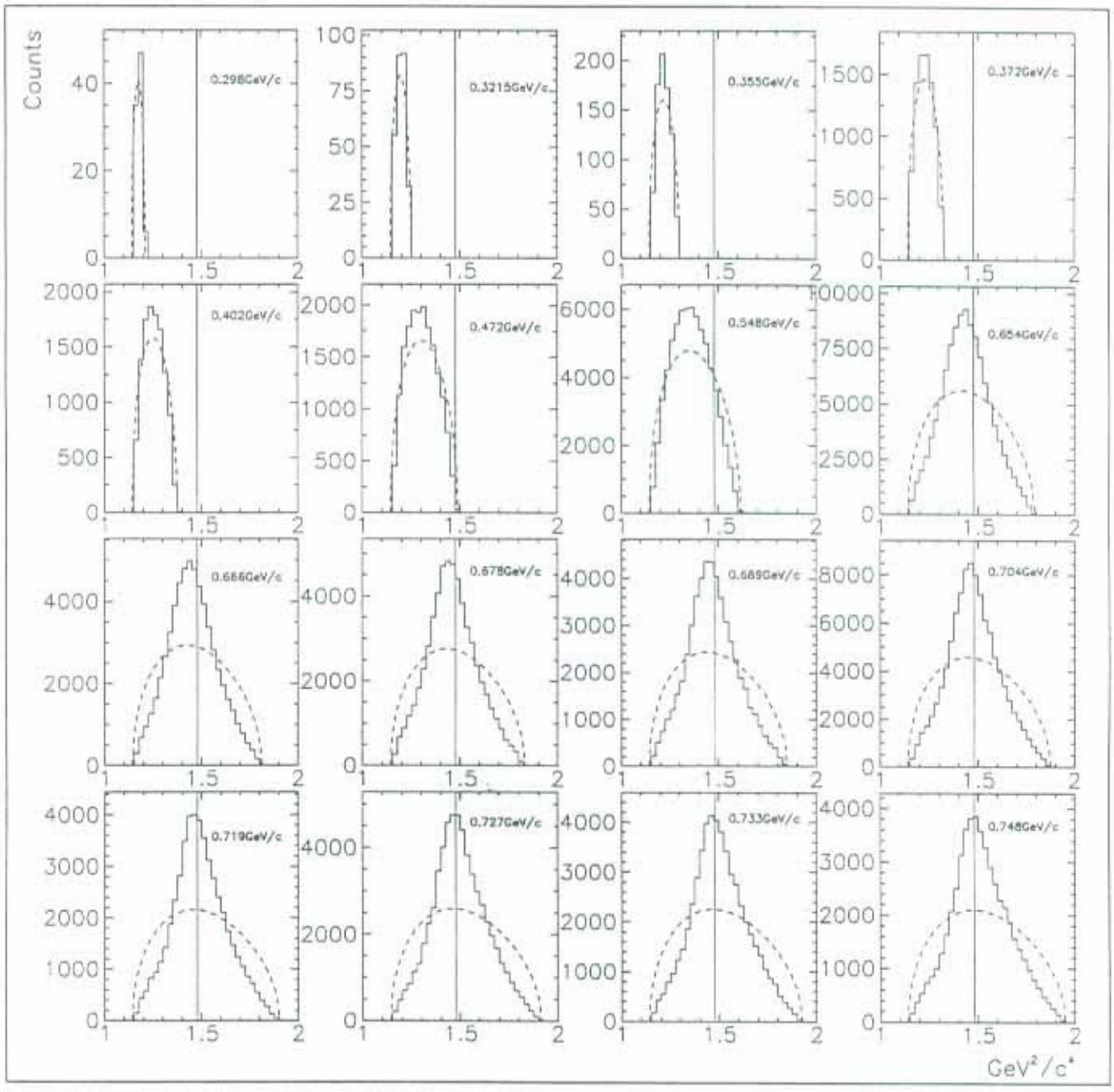

N=5094
402
N=7782
472
N=30109
548
N=46793
654
N=42948
704
N=19914
748
0.4
0.2
0.4
0.2
0.4
0.2
0.0
1.0
1.5
2.0
1.5
2.0
$m^2(\pi^0\pi^0)$ (GeV)^2
$m^2(\pi^0 n)$ (GeV)^2


$m^2(\pi^0\pi^0)$, GeV^2
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
1.1
1.2
1.3
1.4
1.5
1.6
1.7
1.8
1.9
2
$m^2(n\pi^0)$, GeV^2

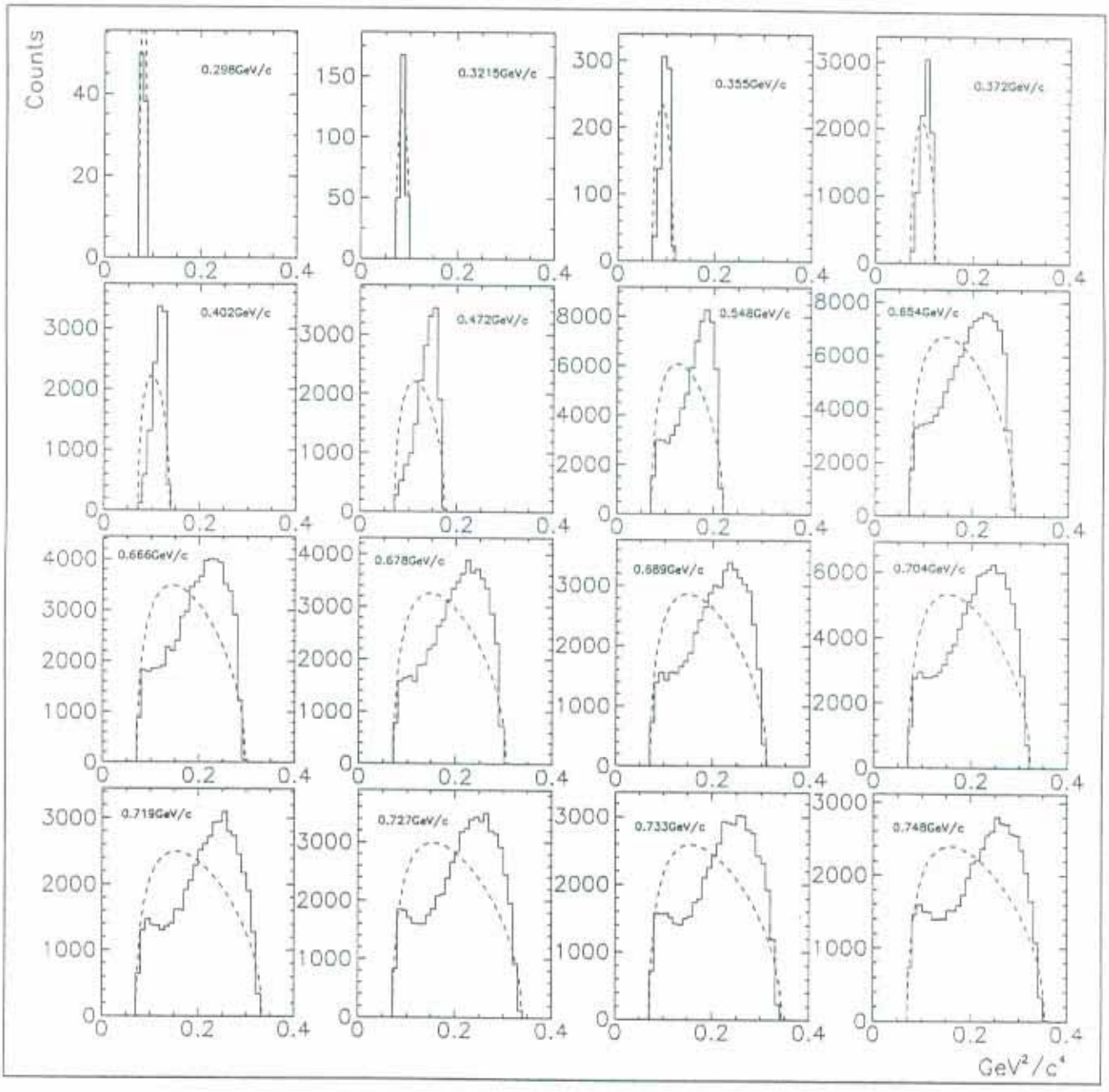

3000
2000
1000
0
Counts
1.0
1.2
1.4
1.6
1.8
2.0
$m^2(\pi^0 n)$ $(GeV)^2$


1200
800
400
0
Counts
0.0
0.1
0.2
0.3
0.4
$m^2(\pi^0\pi^0)$ $(GeV)^2$

p_π Dependence of $M^2_{\pi^0 n}$



p_π Dependence of $M^2_{2\pi^0}$



One-Pion-Exchange Tests

Cross Section

$$\left(\frac{d\sigma}{dt}\right) = \frac{\text{const.}}{(t - m_\pi^2)^2}\left(\frac{-t}{m_\pi^2}\right)$$

The distribution peaks at $-t = 1 \cdot m_\pi^2$.

Decay ϕ Dependence

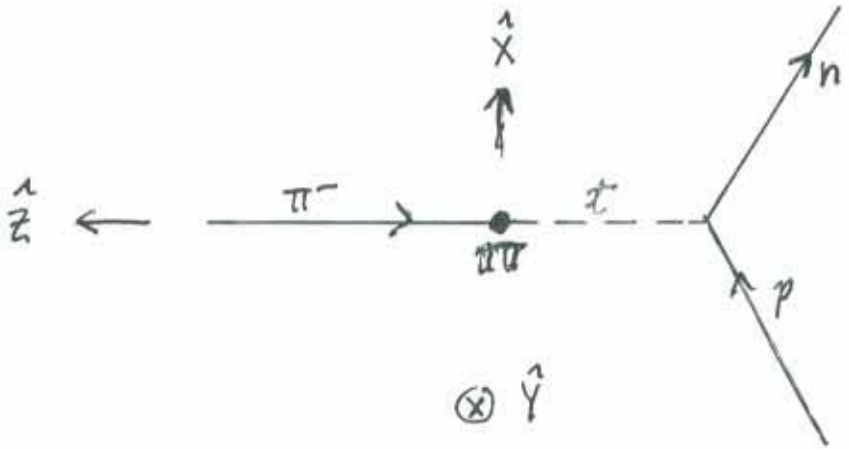
Pure OPE is independent of azimuthal decay angle ϕ in the t-channel dipion rest frame.

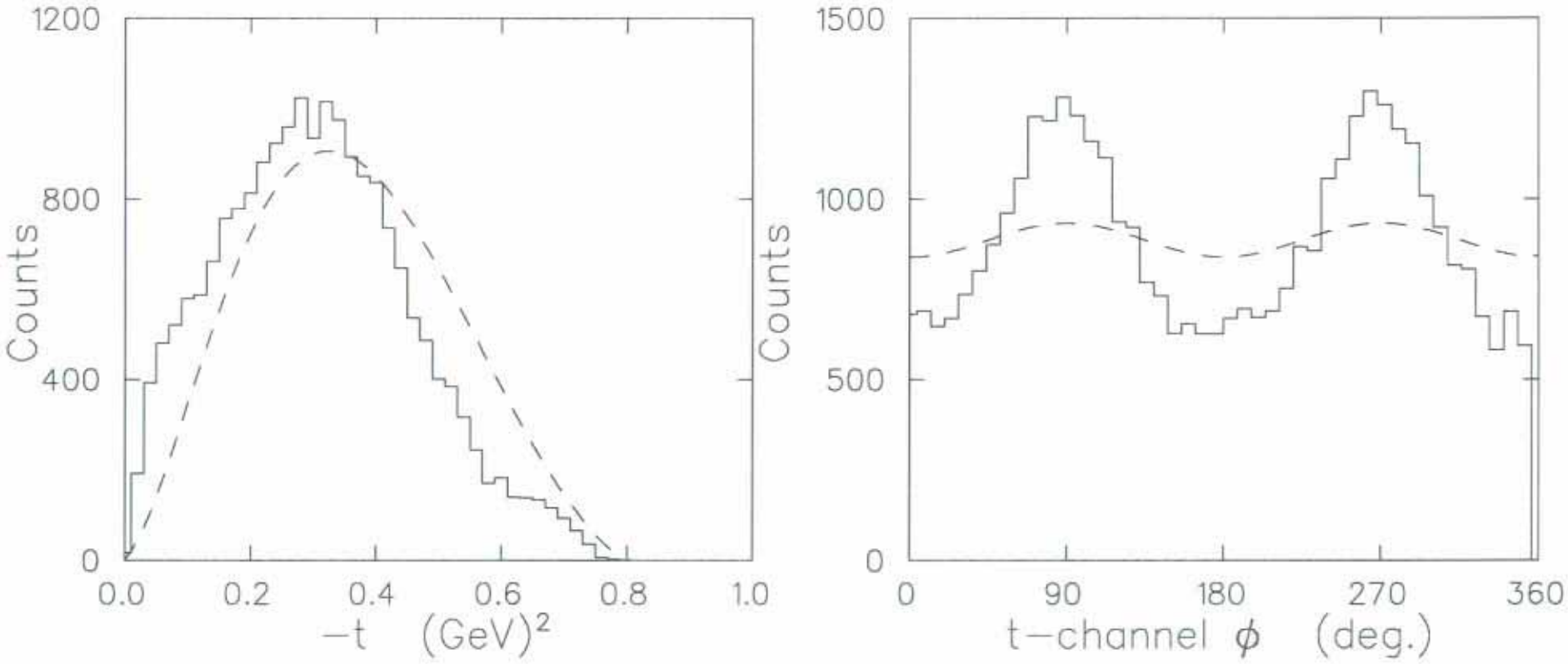
The t-channel frame is characterized by:

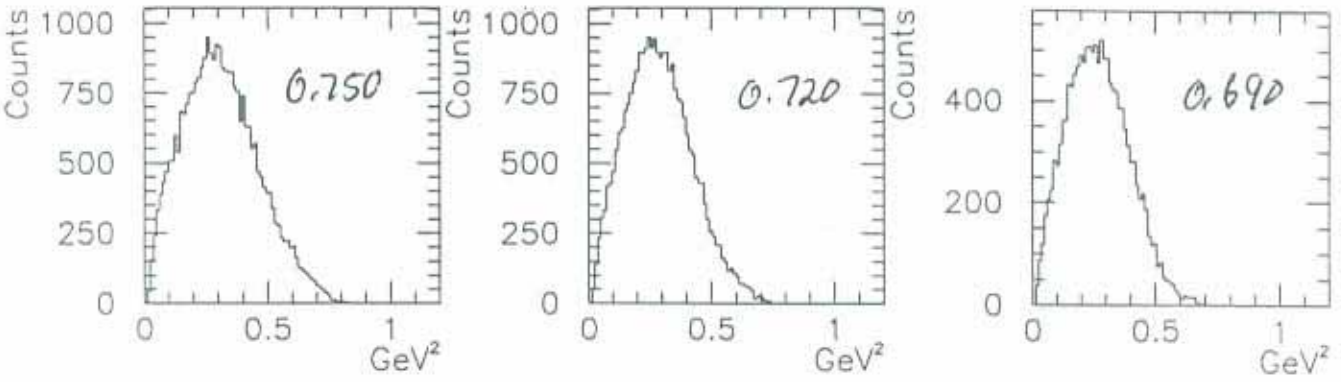
Y axis – $\vec{p}_{\pi^-} \times \vec{p}_{\pi\pi}$ (lab or CM)

Z axis – opposite to $\vec{p}_{\pi^-}$ (dipion rest frame)

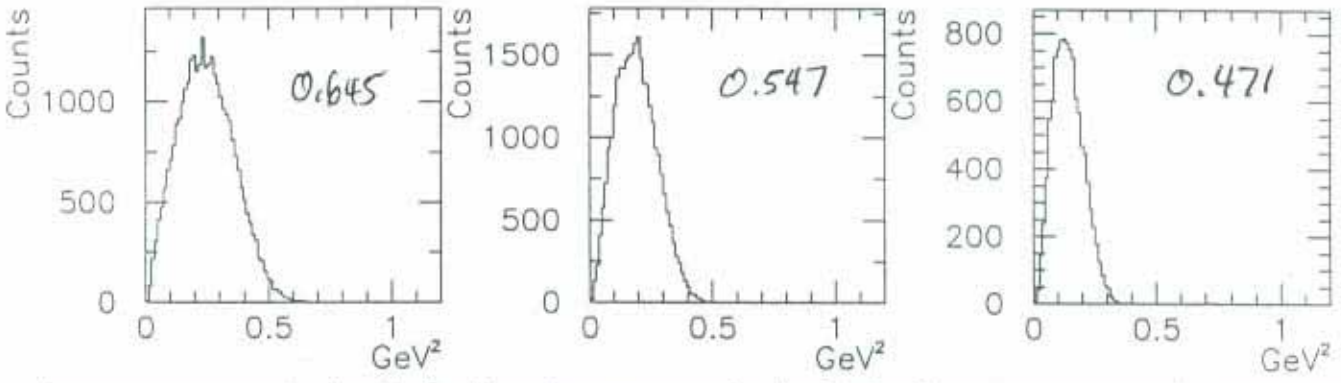
X axis – $\hat{Y} \times \hat{Z}$



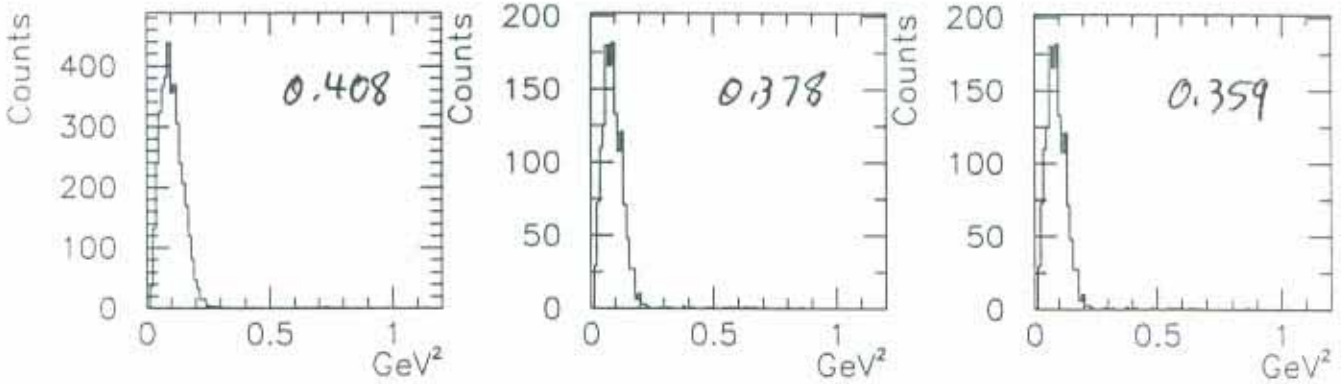

1200
800
400
0
Counts
0.0
0.2
0.4
0.6
0.8
1.0
−t (GeV)²
1500
1000
500
0
Counts
0
90
180
270
360
t−channel φ (deg.)



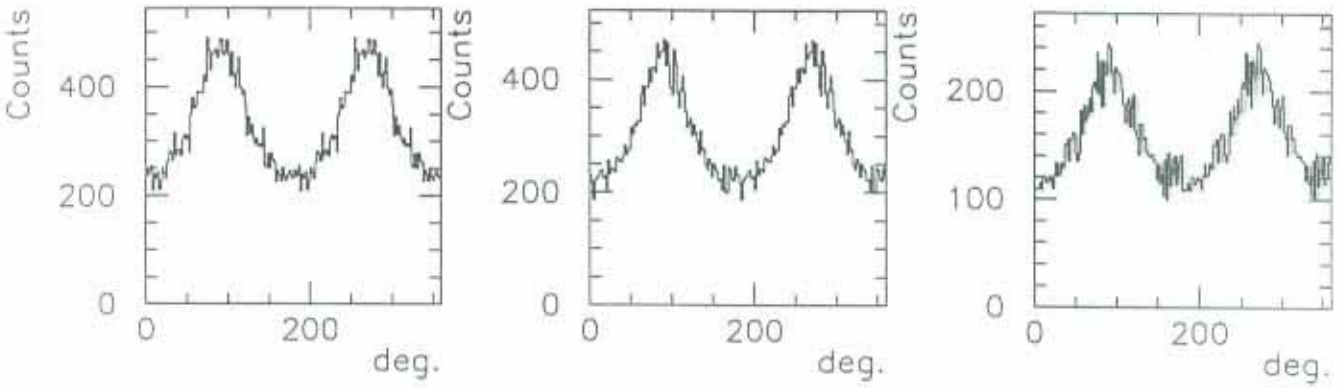
4-momentum transfer (anal.) (both_test) *4-momentum transfer (anal.) (both_test)* *4-momentum transfer (anal.) (both_test)*



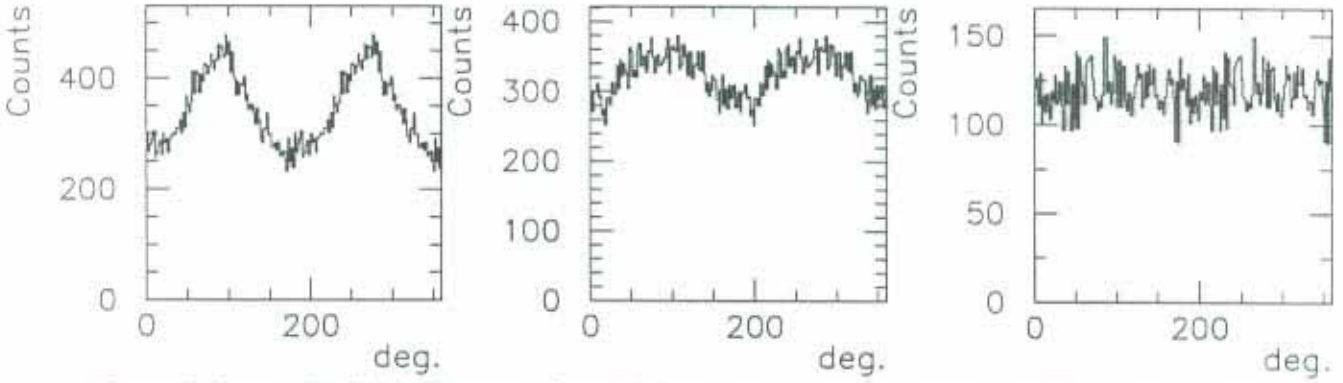
4-momentum transfer (anal.) (both_test) *4-momentum transfer (anal.) (both_test)* *4-momentum transfer (anal.) (both_test)*



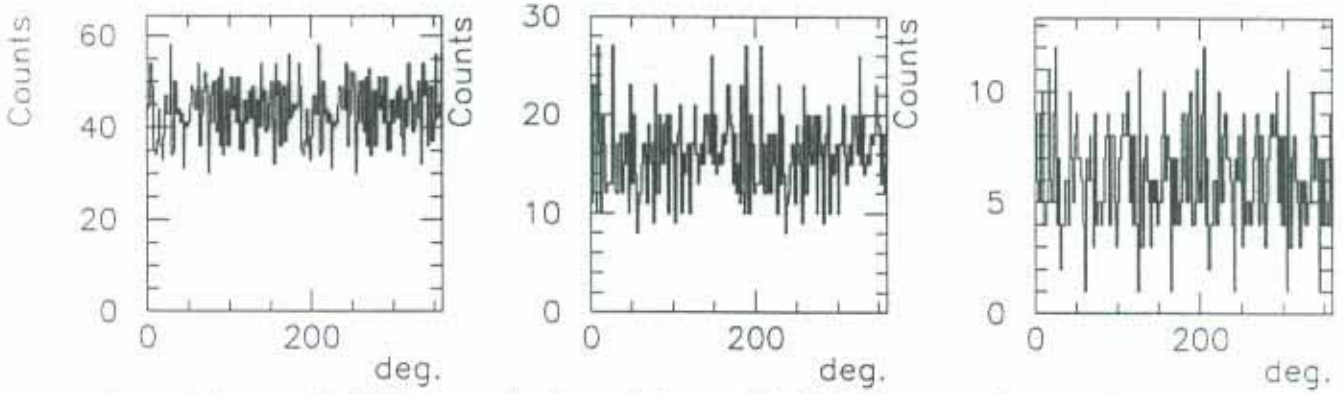
4-momentum transfer (anal.) (both_test) *4-momentum transfer (anal.) (both_test)* *4-momentum transfer (anal.) (both_test)*



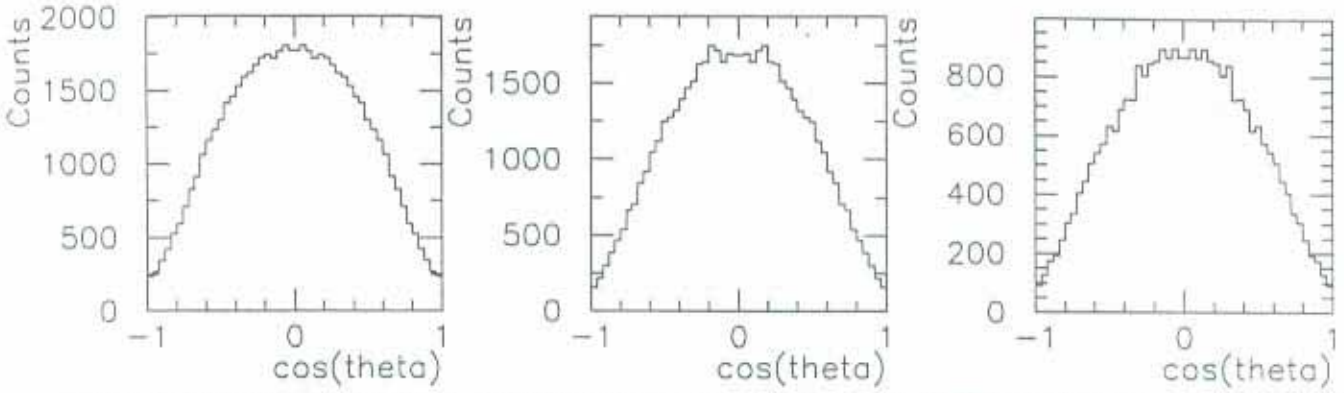
t-channel decay pi0 phi (both_test) *t-channel decay pi0 phi (both_test)* *t-channel decay pi0 phi (both_test)*



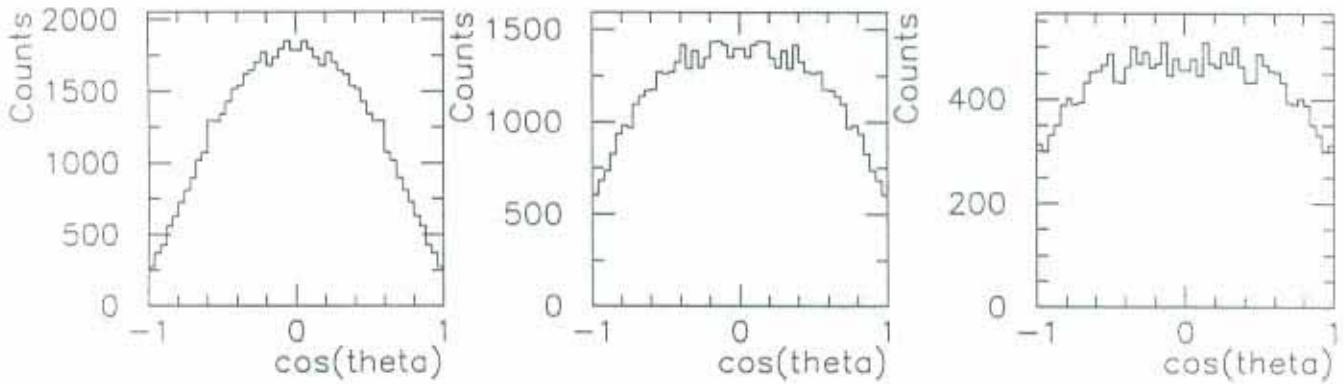
t-channel decay pi0 phi (both_test) *t-channel decay pi0 phi (both_test)* *t-channel decay pi0 phi (both_test)*



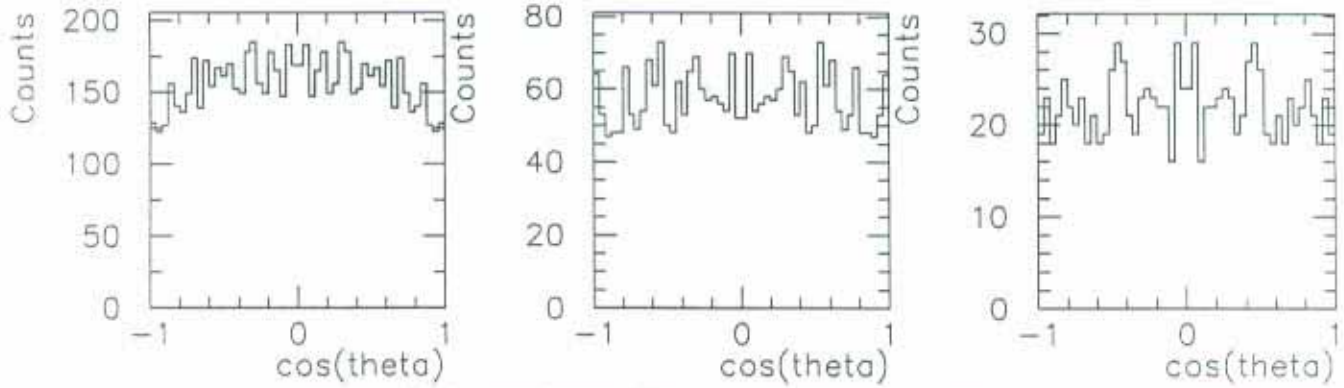
t-channel decay pi0 phi (both_test) *t-channel decay pi0 phi (both_test)* *t-channel decay pi0 phi (both_test)*



t-channel decay pi0 theta (both_test) *t-channel decay pi0 theta (both_test)* *t-channel decay pi0 theta (both_test)*



t-channel decay pi0 theta (both_test) *t-channel decay pi0 theta (both_test)* *t-channel decay pi0 theta (both_test)*



t-channel decay pi0 theta (both_test) *t-channel decay pi0 theta (both_test)* *t-channel decay pi0 theta (both_test)*

Multipole Analysis

Amplitude

$$A = \sum_{\ell=0}^{\infty} \sum_{m=-\ell}^{\ell} \alpha_{\ell m} Y_\ell^m(\theta, \phi)$$

Intensity

$$\begin{aligned} I(s, t, M, \theta, \phi) &\equiv \frac{\partial^4 \sigma}{\partial t \, \partial M \, \partial(\cos\theta) \, \partial\phi} \\ N &\equiv 4\pi \langle I \rangle = \frac{\partial^2 \sigma}{\partial t \, \partial M} \\ W(\theta, \phi) &\equiv \frac{1}{N} I(\theta, \phi) \\ &= \sum_{L=0}^{\infty} \sum_{M=-L}^{L} a_{LM} \, \Re \, Y_L^M(\theta, \phi) \end{aligned}$$

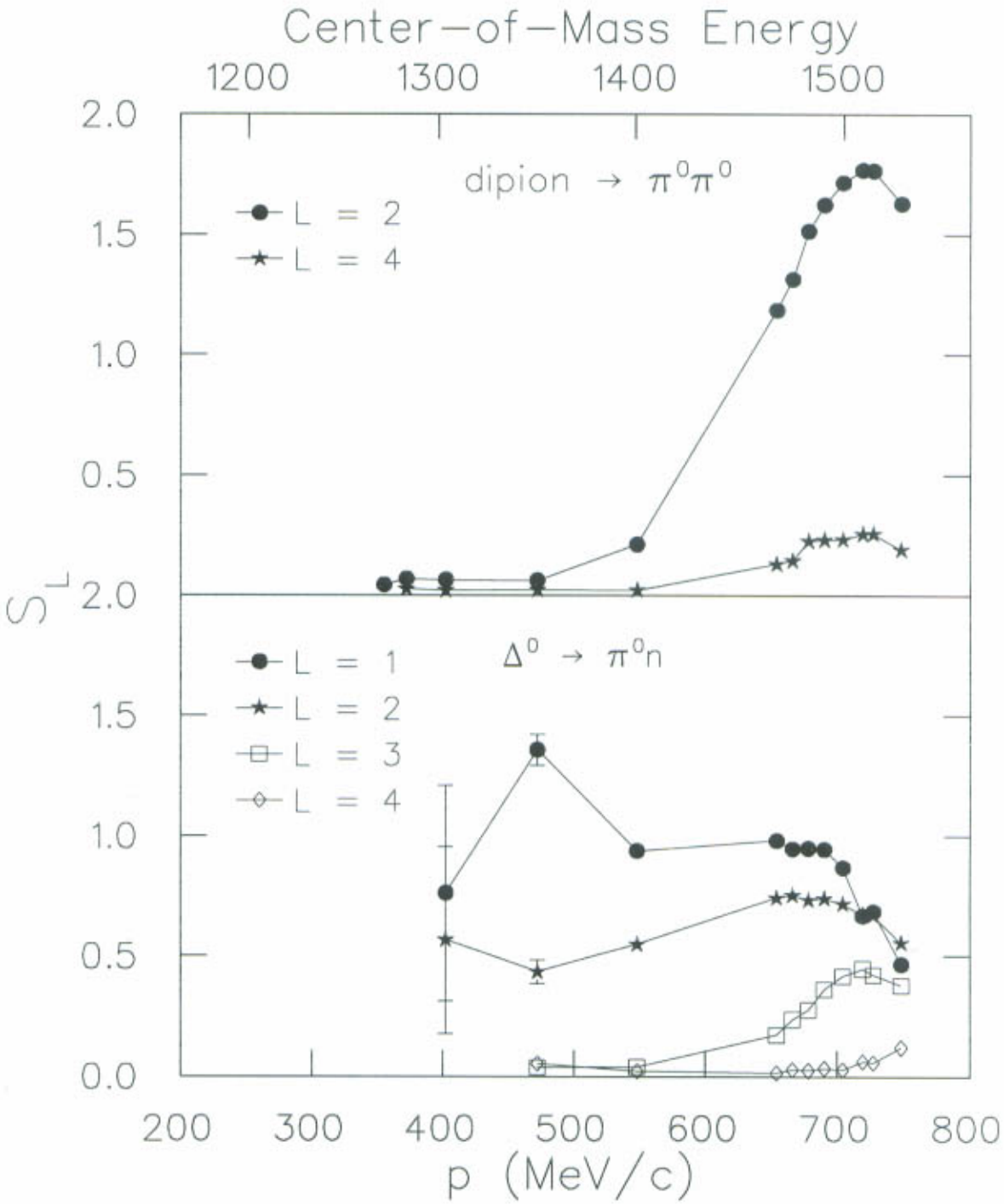
where $a_{00} = (4\pi)^{-\frac{1}{2}}$.

$L_{\max} = 2\,\ell_{\max}$

L =even only for decay of $\pi^0\pi^0$.

A measure of multipole strength:

$$S_L = (2L+1) \sum_{M=-L}^{L} \left(\frac{a_{LM}}{a_{00}} \right)^2$$


Center–of–Mass Energy
1200
1300
1400
1500
2.0
1.5
1.0
0.5
S^L
dipion → $\pi^0\pi^0$
L = 2
L = 4
2.0
1.5
1.0
0.5
0.0
Δ^0 → π^0n
L = 1
L = 2
L = 3
L = 4
200
300
400
500
600
700
800
p (MeV/c)

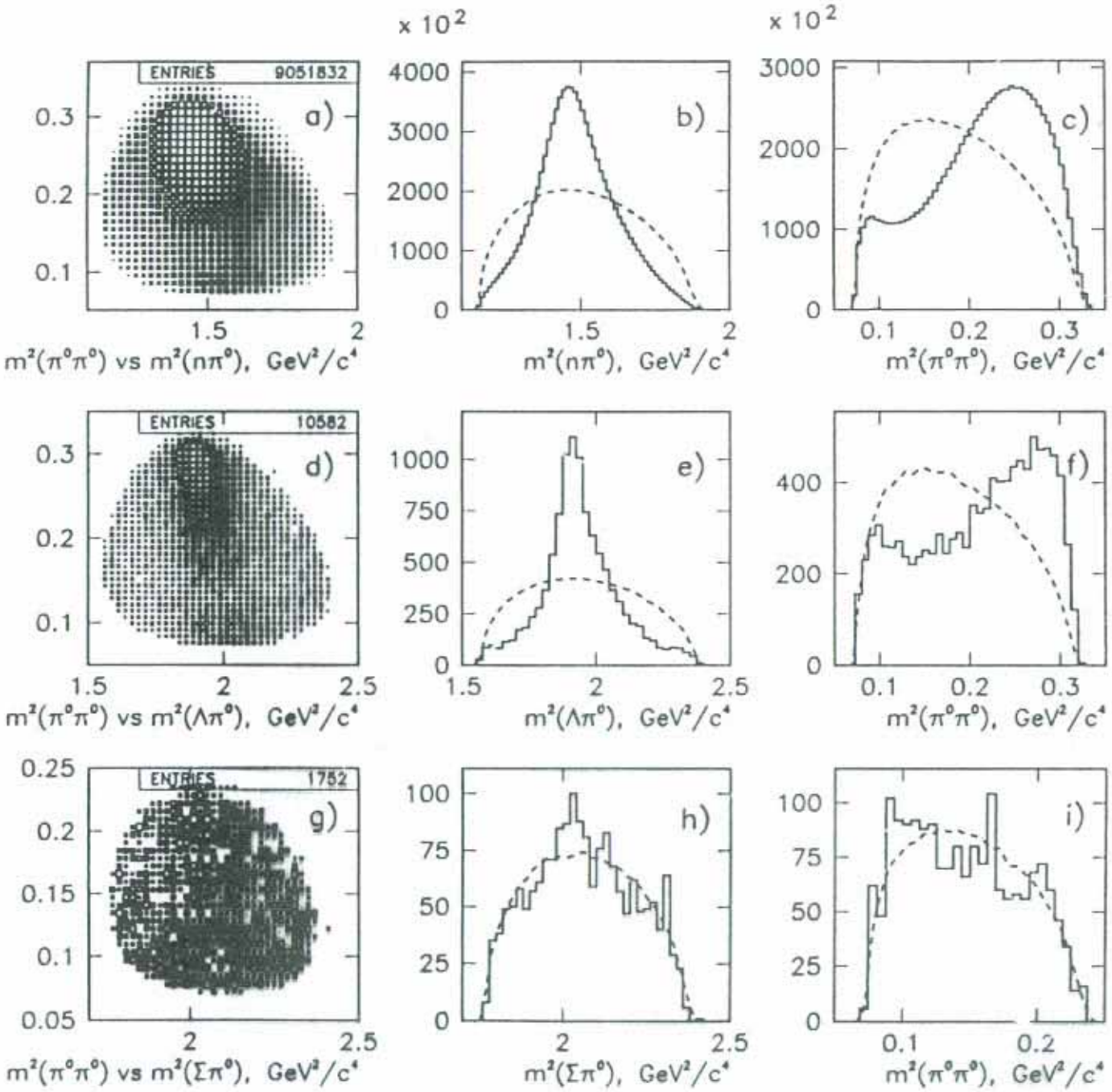
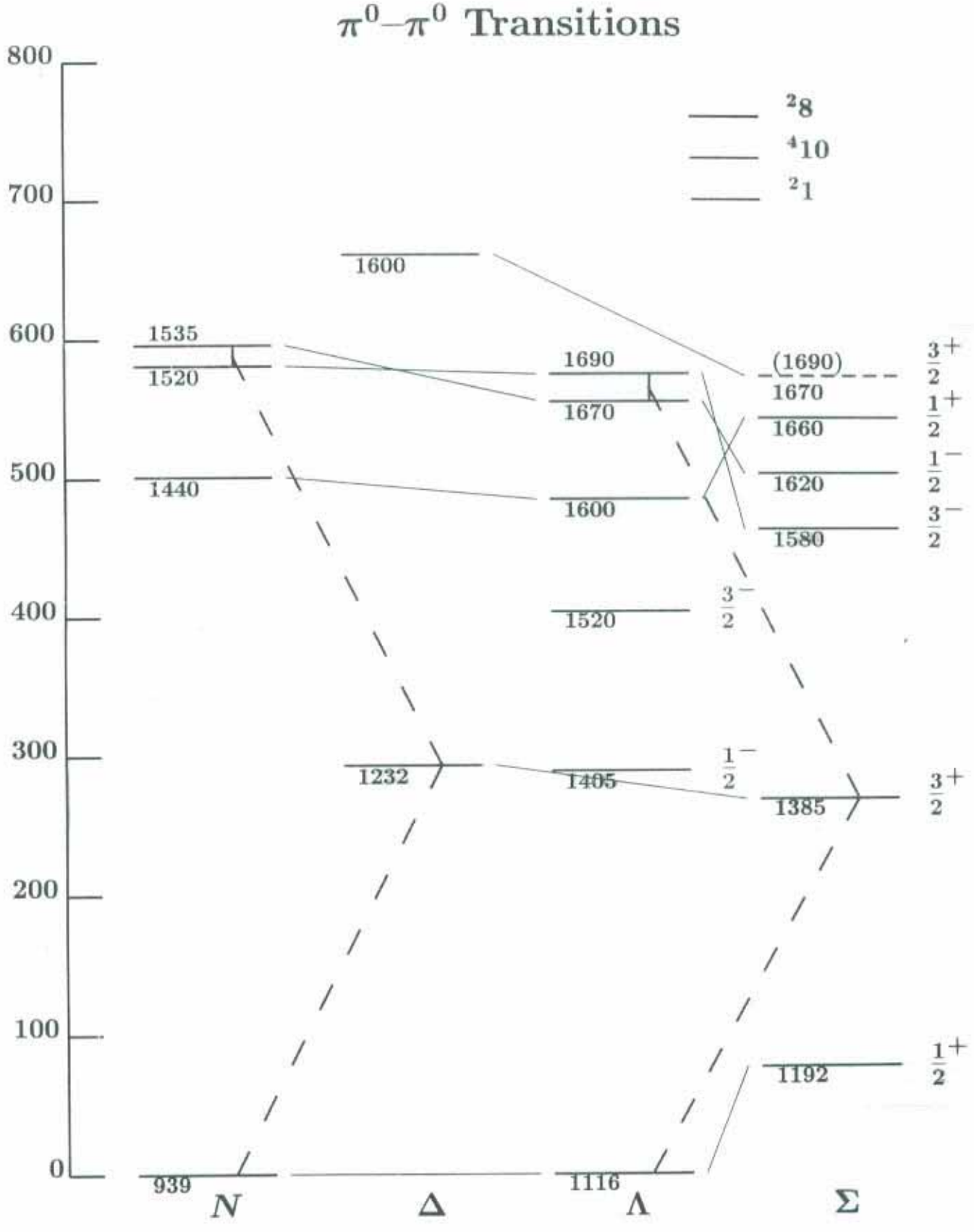
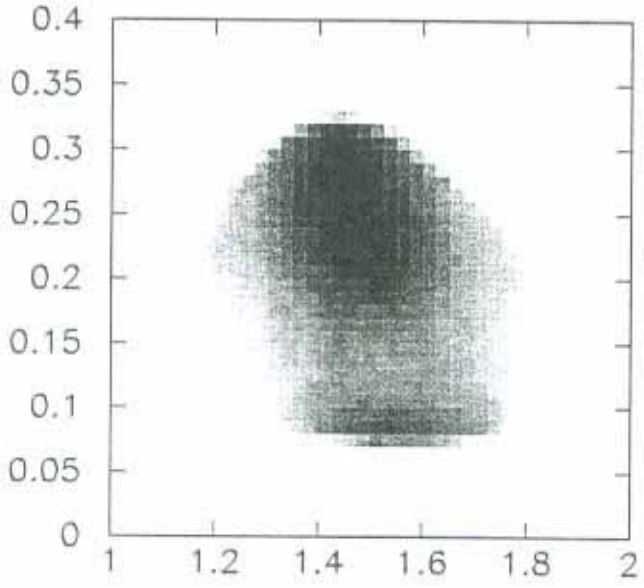


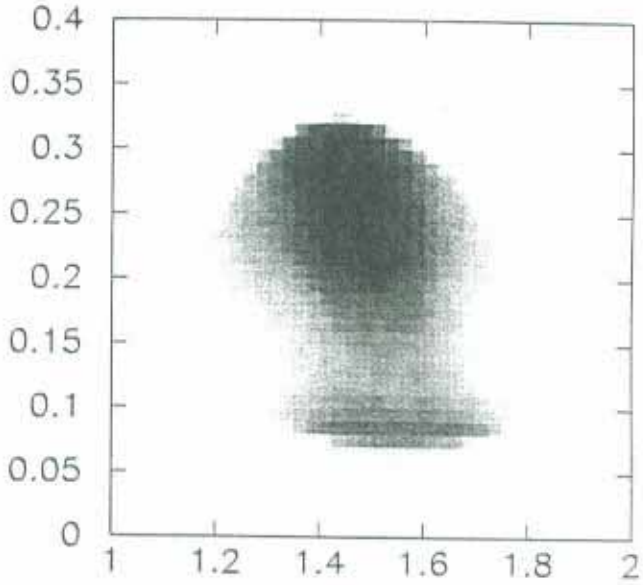
Figure 5. Figures a–c: $\pi^- p \to \pi^0\pi^0 n$ at $p_{\pi^-} = 720$ MeV/c; d–f: $K^- p \to \pi^0\pi^0\Lambda$ at $p_{K^-} = 750$ MeV/c; g–i: $K^- p \to \pi^0\pi^0\Sigma^0$ at $p_{K^-} = 750$ MeV/c. Preliminary data. The dashed lines show the phase space.


π^0–π^0 Transitions
800
700
600
500
400
300
200
100
0
^{2}8
^{4}10
^{2}1
1600
1535
1520
1440
1690
1670
1600
1520
(1690)
1670
1660
1620
1580
1232
1405
1385
1192
939
1116
$\frac{3}{2}^+$
$\frac{1}{2}^+$
$\frac{1}{2}^-$
$\frac{3}{2}^-$
$\frac{3}{2}^-$
$\frac{1}{2}^-$
$\frac{3}{2}^+$
$\frac{1}{2}^+$
N
Δ
Λ
Σ

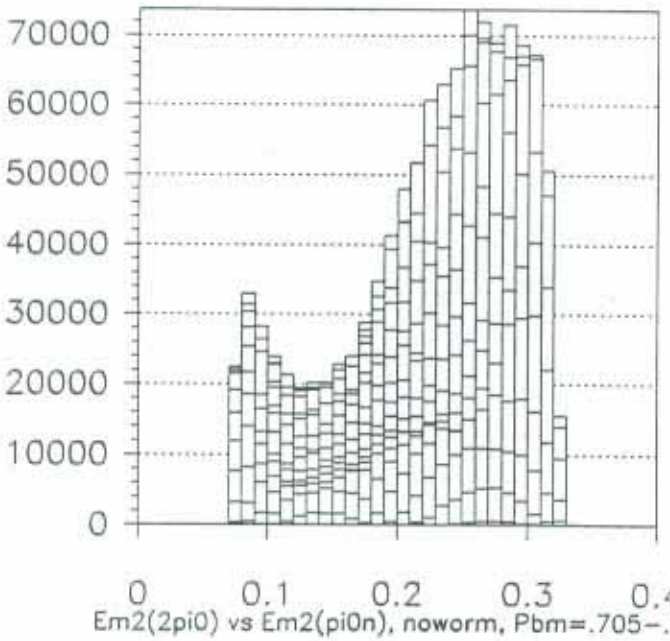
z0/04/18 12.25



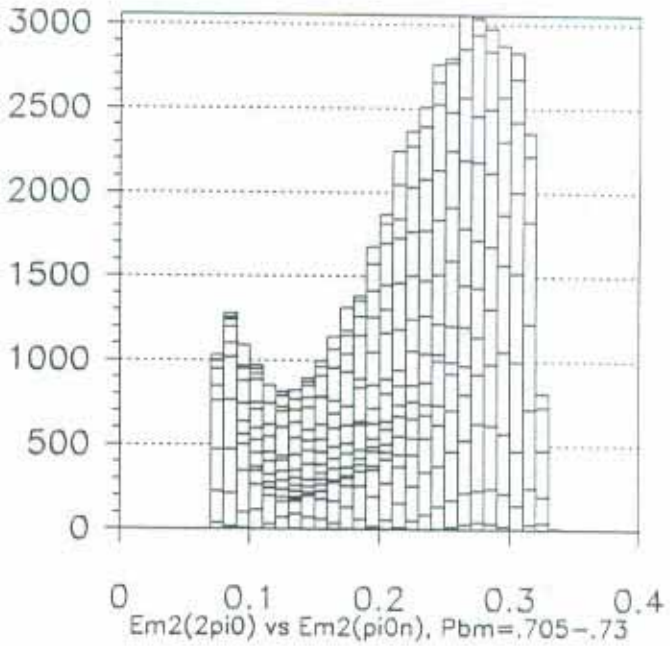
Em2(2pi0) vs Em2(pi0n), noworm, Pbm=.705−.73



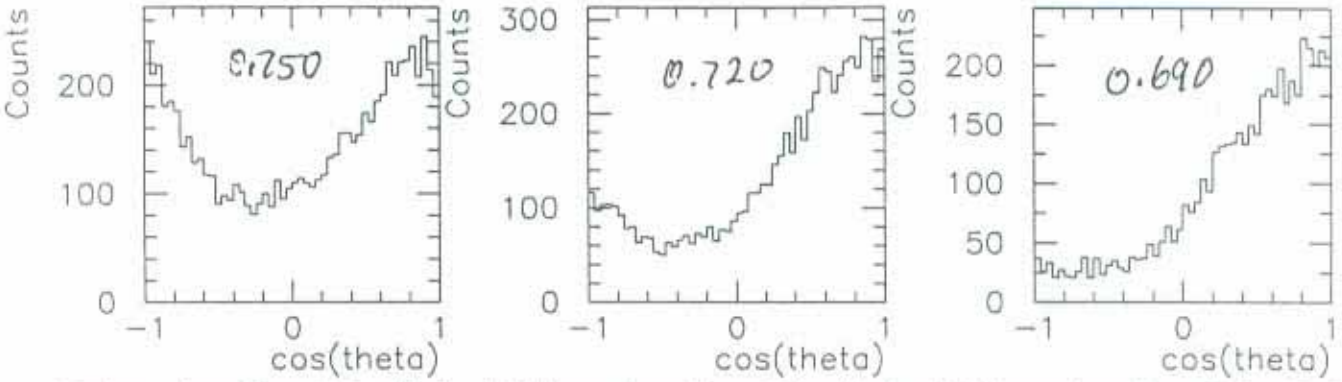
Em2(2pi0) vs Em2(pi0n), Pbm=.705−.73



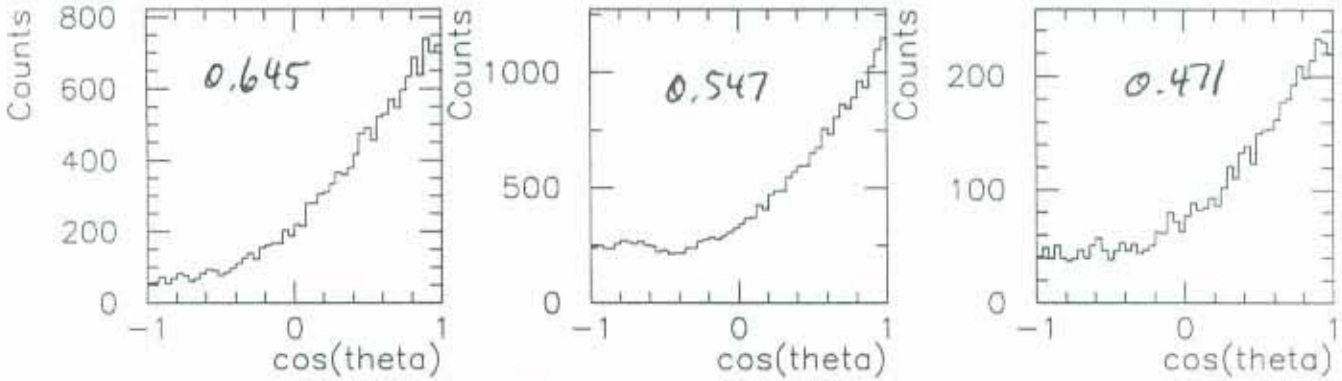
Em2(2pi0) vs Em2(pi0n), noworm, Pbm=.705−.73



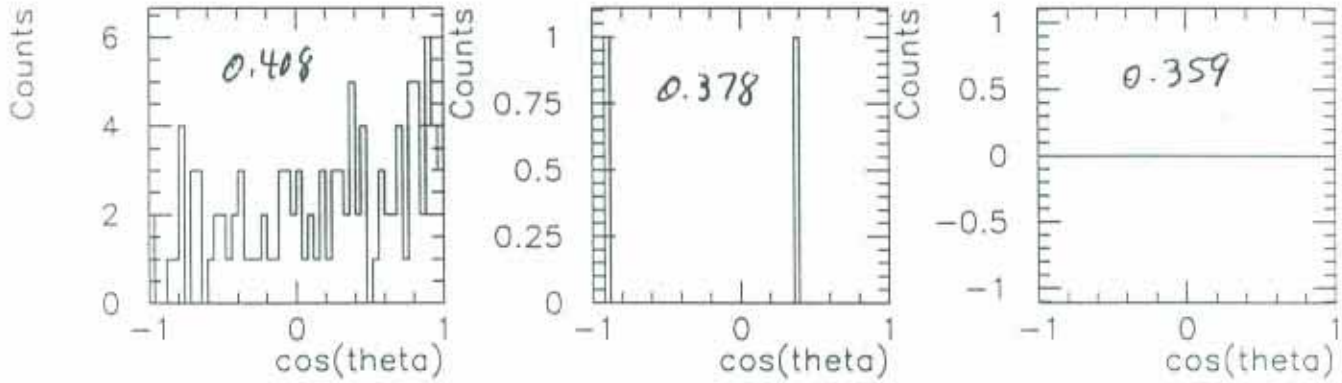
Em2(2pi0) vs Em2(pi0n), Pbm=.705−.73



pi0 decay theta from Delta (both_pi0p) pi0 decay theta from Delta (both_pi0n) pi0 decay theta from Delta (both_pi0n)



pi0 decay theta from Delta (both_pi0p) pi0 decay theta from Delta (both_pi0n) pi0 decay theta from Delta (both_pi0n)



pi0 decay theta from Delta (both_pi0p) pi0 decay theta from Delta (both_pi0n) pi0 decay theta from Delta (both_pi0n)

CONCLUSIONS

- The Crystal Ball Program has produced an extensive set of high-quality data for $\pi^0\pi^0$ production.

- For $p_{\pi^-} > 500$ MeV/c,
  - $\pi^- p \to \pi^0\Delta^0$ is strongly favored;
  - the signatures are inconsistent with OPE;
  - decay multipoles have large $L > 0$ components;
  - there is little or no evidence for σ mesons.

- For low momenta,
  - the $\pi^0\Delta^0$ channel is not open;
  - the $2\pi^0$ invariant mass is in the tail of the presumed σ mass distribution.