Analysis

of $\eta\pi^-$ and $\eta\pi^0$ systems

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Ludmila Malinina
Moscow State University

12 October 2004

E852 experiment

Search of mesons with unusual quantum numbers

$$\pi^- p \to \eta\pi^- p, \quad \pi^- p \to \pi^+\pi^-\pi^- p,$$

$$\pi^- p \to \eta\pi^0 n, \quad \pi^- p \to \eta'\pi^- p, \quad \pi^- p \to K^+K^-\pi^0\, n, \ \ldots$$

at 18 GeV/c, AGS (BNL)

E852 date:10.59•10^6 (1994-95), 8.79•10^6 (1997-98)-число событий

E852 collaboration: BNL, SINP MSU, IHEP

and 6 USA universities

62 physicists, **12** – from MSU

1995-2004

E852 author list of last publications

S.U. Chung, K. Danyo, R.W. Hackenburg, C. Olchanski, J.S. Suh, H.J. Willutzki (Brookhaven),

T. Adams, J.M. Bishop, N.M. Cason, E.I. Ivanov, J.M. LoSecco, J.J. Manak, W.D. Shephard, D.L. Stienike, S.A. Taegar (Notre Dame U.),

V.A. Bodyagin, A.I. Demianov, A.M. Gribushin, O.L. Kodolova, V.L. Korotkikh, M.A. Kostin, **L.V. Malinina**, A.I. Ostrovidov, L.I.Sarycheva, N.V. Sinev, I.N. Vardanyan, A.A. Yershov (Moscow State U.),

New E852 member !

S.P. Denisov, V. Dorofeev, V.V., I. Kachaev, V.V. Lipaev, A.V. Popov, D.I. Ryabchikov (Serpukhov, IHEP),

Z. Bar-Yam, J.P. Dowd, P. Eugenio, M. Hayek, W. Kern, E. King, N.Shenhav (Massachusetts U., North Dartmouth),

D.S. Brown, X.L. Fan, D. Joffe, T.K. Pedlar, K.K. Seth, A.Tomaradze (Northwestern U.),

G.S. Adams, J.P. Cummings, J. Hu, J. Kuhn, M. Lu, J. Napolitano, D.B. White, M. Witkowski (Rensselaer Poly.),

M. Nozar, X. Shen, D.P. Weygand (Jefferson Lab)

E852 statistics and Exotics $J^{PC}=1^{-+}$

Publications. Reaction	Final state	Main result
1. D.R.Thompson et al. $\pi^- p \to \eta\pi^- p$, Phys. Rev. Lett. 79(1997)1630, S.U. Chung et al, $\pi^- p \to \eta\pi^- p$, Phys. Rev. D60(1999)092001	$\eta\pi^-$ 47200	$\pi_1(1400)$
2. G.S. Adams et al. "Observation of a New $J^{PC}=1-+$ Exotic State in the Reaction $\pi^- p \to \pi^+\pi^-\pi^- p$ at 18 GeV/c", Phys. Rev. Lett. 81(1998)5760	$\pi^+\pi^-\pi^-$ 250000	$\pi_1(1600)$
3. E. Ivanov et al. $\pi^- p \to \eta\pi^+\pi^- p$, Phys. Rev. Lett. 86(2001)3977	$\eta'\pi^-$ 6040	$\pi_1(1600)$
4. J. Kuhn et al. $\pi^- p \to \eta\pi^+\pi^-\pi^- p$ Phys. Lett. B., 2003.	$f_1\pi^-$ 68900	$\pi_1(1600)$ $\pi_1(2000)$
5. M. Lu et al. $\pi^- p \to \omega\pi^0\pi^- p$. Phys. Rev. Lett. 2004. To be published	$b_1\pi^-$ 145148	$\pi_1(1600)$ $\pi_1(2000)$
6. V.L.Korotkikh et al. $\pi^- p \to \eta\pi^0 n$, $\eta \to \pi^+\pi^-\pi^0$ HADRON99, Nucl.Phys. A675(2000)413c	$\eta\pi^0$ 18712	$M=1280\pm 24$ $\Gamma=526\pm 81$

1^{-+} мезонная экзотика

π_1 (1400)

	M, МэВ	Г, МэВ	Распад
E852	1370	385	$\eta\pi^-$
CrBar	1400	310	$\eta\pi^-$
CrBar	1360	220	$\eta\pi^0$
GAMS	1370	300	$\eta\pi^0$
	1301	190	$\eta\pi^0$ $0.14<\|t\|<$ ГэВ^2
E852-IU	1268	670	$\eta\pi^0$ $0.14<\|t\|<0.31$
	1356	629	$\eta\pi^0$ $\|t\|>0.31$ ГэВ^2

E852 **1280** **526** $\eta\pi^0$, $\eta\to\pi^+\pi^-\pi^0$

Korotkikh HADRON2000

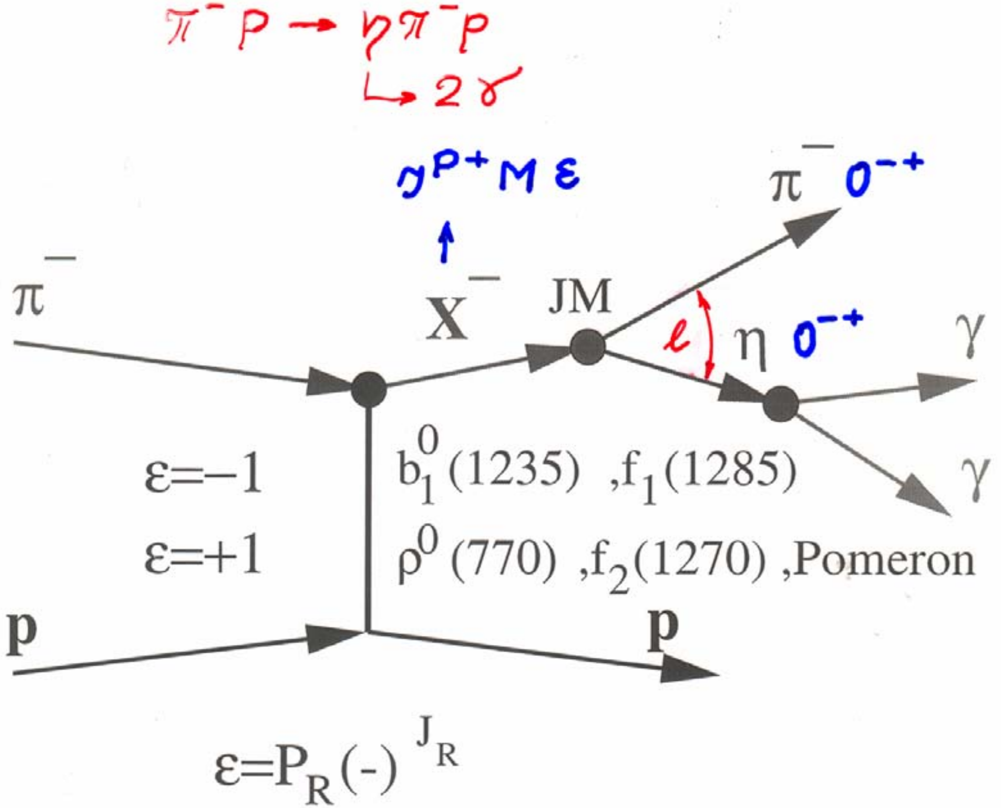
π_1 (1600)

	M, МэВ	Г, МэВ	Распад
E852	1593	168	$\rho\pi^-$
E852	1597	340	$\eta'\pi^-$
VES	1610	290	$\rho\pi^-$, $\eta'\pi^-$, $b_1\pi$
E852	1709	403	$f_1\pi^-$
E852	1664	185	$b_1\pi^-$

π_1 (2000)

E852	2001	333	$f_1\pi^-$
E852	2014	230	$b_1\pi^-$

$\eta\pi^-$



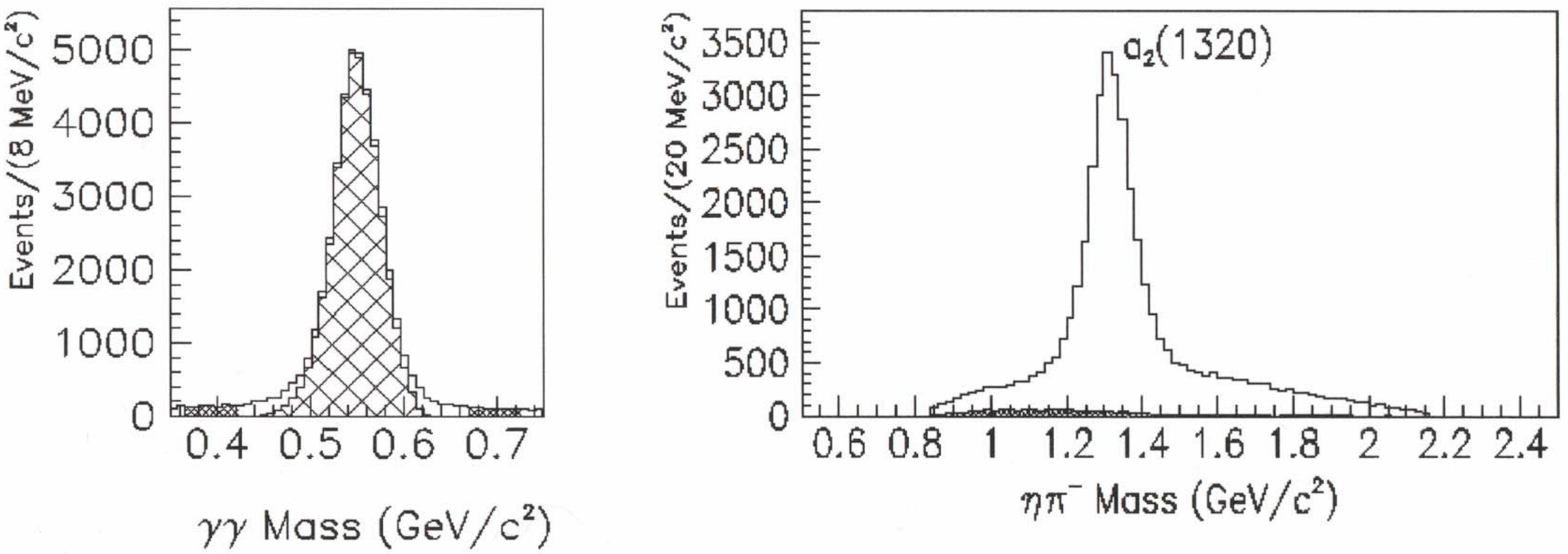
Allowed waves:

J^{PC}: (1^{-+} → P_+; 2^{++} → D_+); L → Notation

Notation	J	P	C	M	ε
S_0	0	+	+	0	-
P_0	1	-	+	0	-
P_-	1	-	+	1	-
D_0	2	+	+	0	-
D_-	2	+	+	1	-
P_+	1	-	+	1	+
D_+	2	+	+	1	+
G_+	4	+	+	1	+

$\pi^- p \to \eta\pi^- p,\ \eta \to 2\gamma$ при 18 ГэВ/c

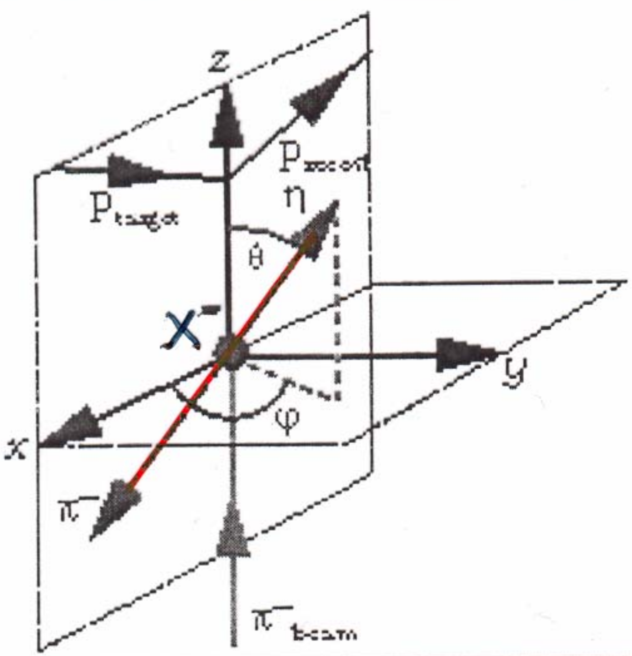
47 200 событий $\to \eta\pi^- p\ (\eta \to 2\gamma)$



a) η - meson signal and the side bands selected for background

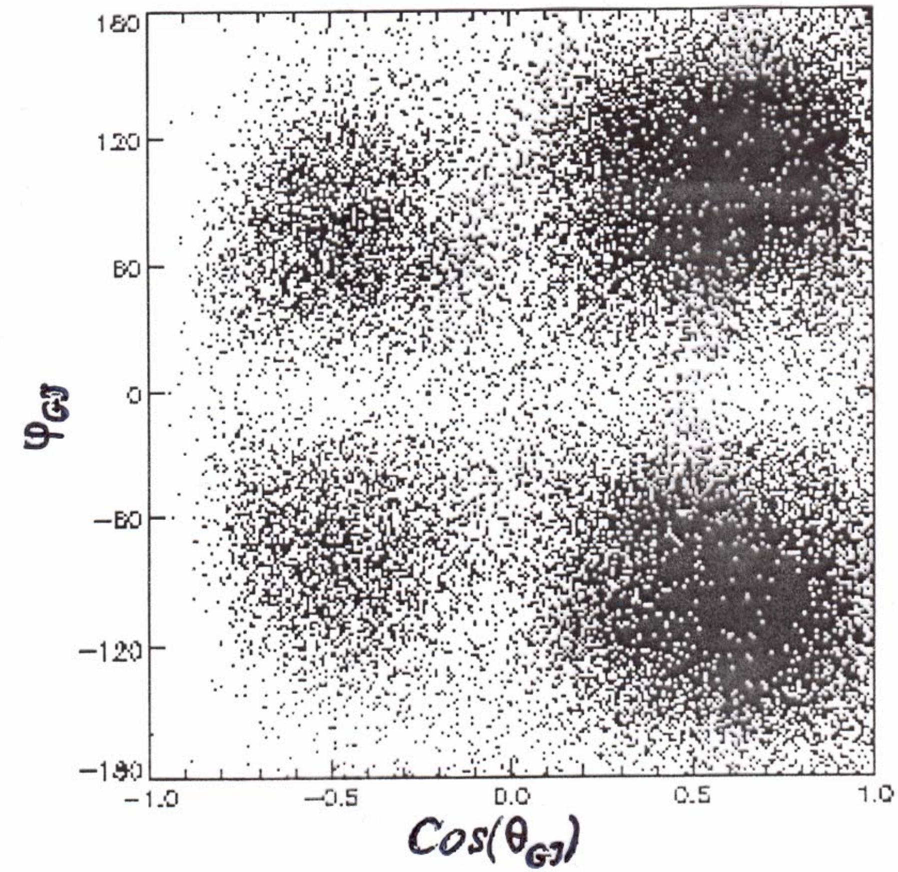
b) $\eta\pi^-$ - mass distribution in data sample, black region is background

$$\pi^- + p \rightarrow X^- + p$$
$$\hookrightarrow \eta\pi^-$$

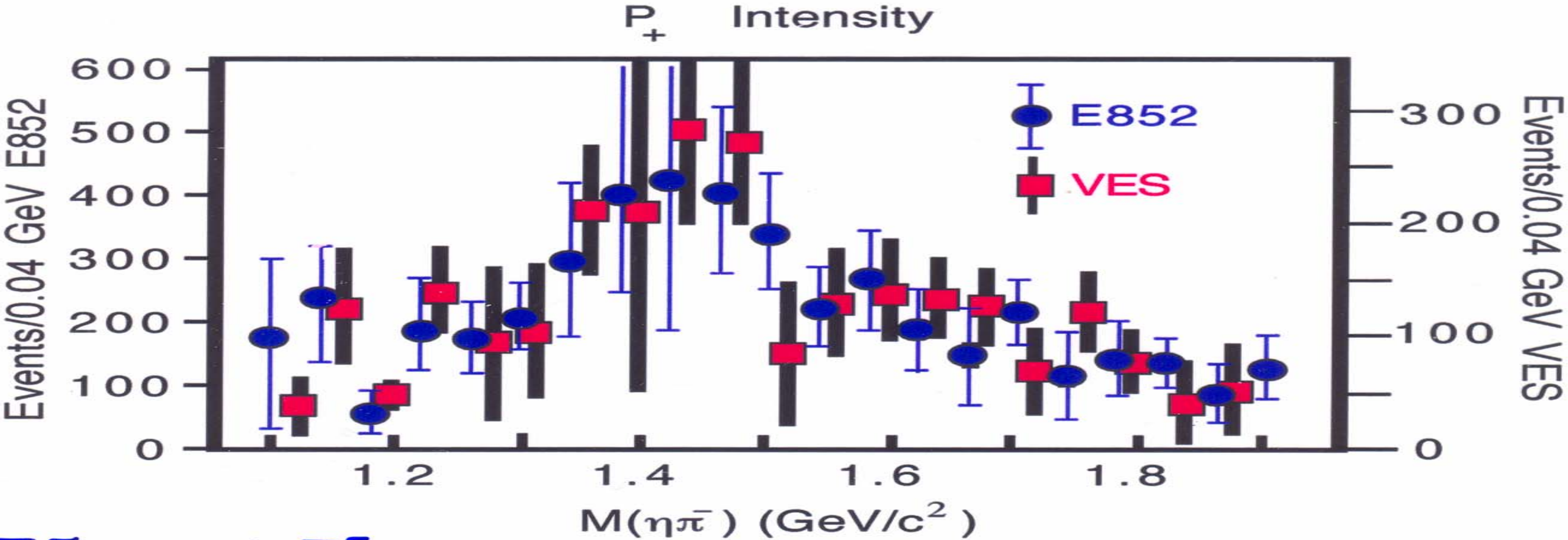


$X^- \rightarrow \eta$

Definition of the Gottfried-Jackson frame

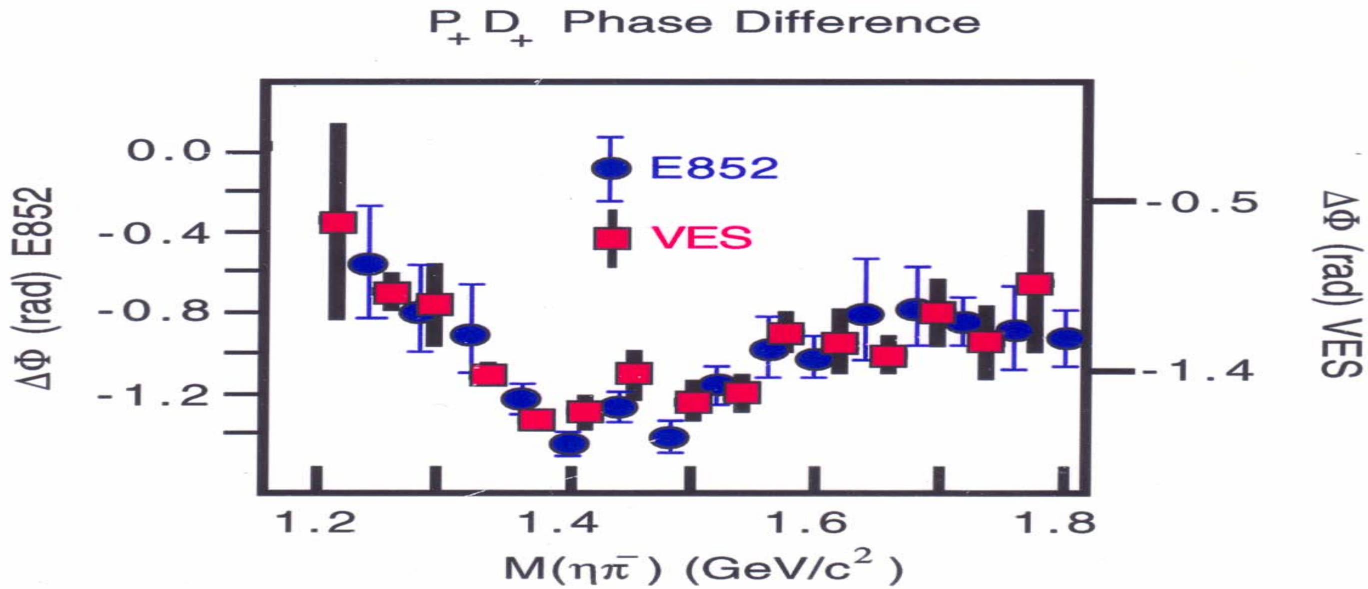


ηπ⁻ : E852 vs. VES (Protvino)

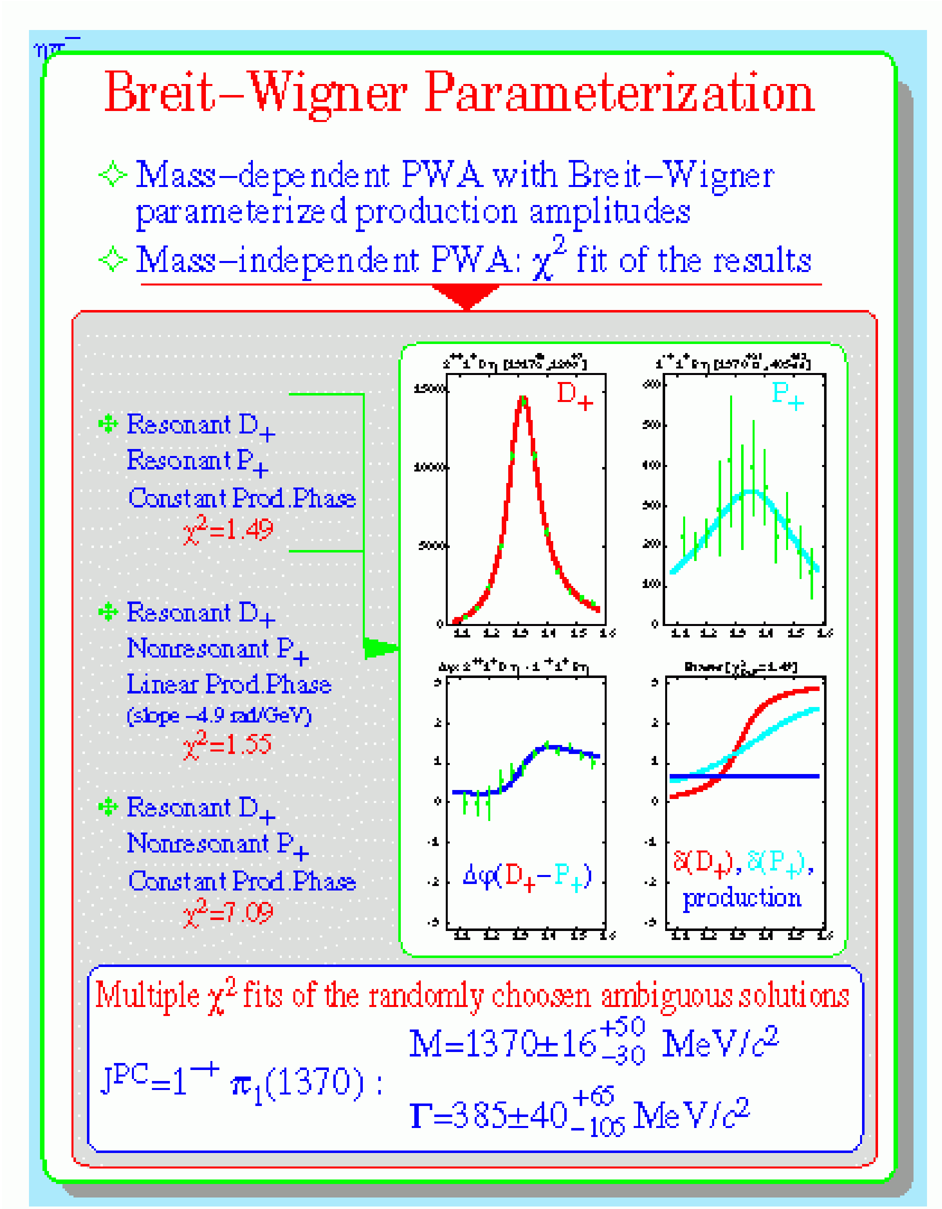


$\pi^- + p \rightarrow \eta\pi^- p$

$\pi^- + Be \rightarrow \eta\pi^- Be'$



$\pi^- p \rightarrow \eta\pi^- p$ at 18 GeV/c, $\pi_1(1400)$



The evidence of resonant nature of P_+ wave and the parameters

$\pi_1(1400)$,

$J^{PC}=1^{-+}$

Ambiguous solutions

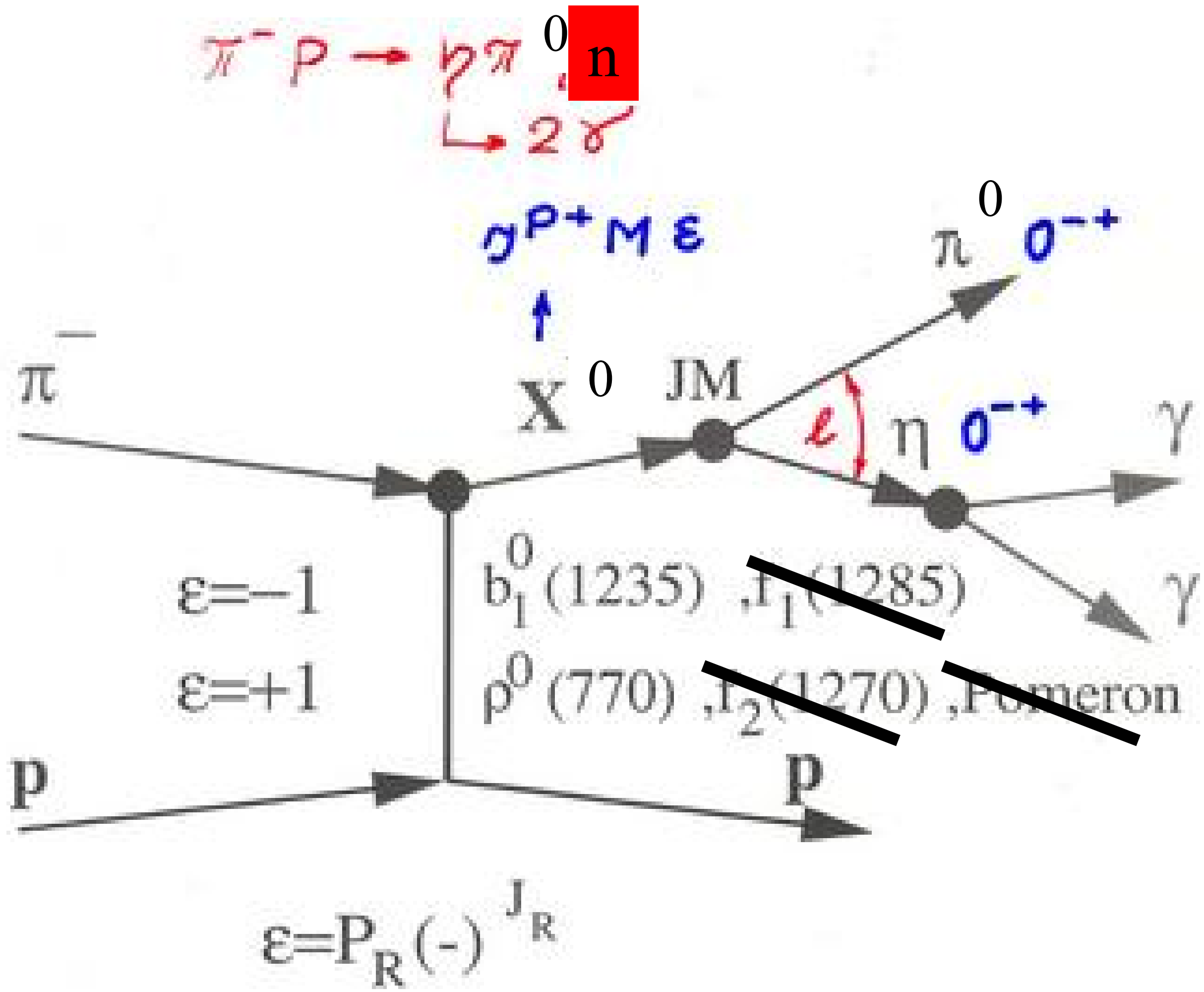
Three methods :

1. Average of eight solutions (E852)

2. Follow to BW of a_0 and a_2 famous resonances (E852_IU)

3. Selection of one solution according to Regge model prediction of the ratio $R=(D_0+D_-)/D_+$ (GAMS)

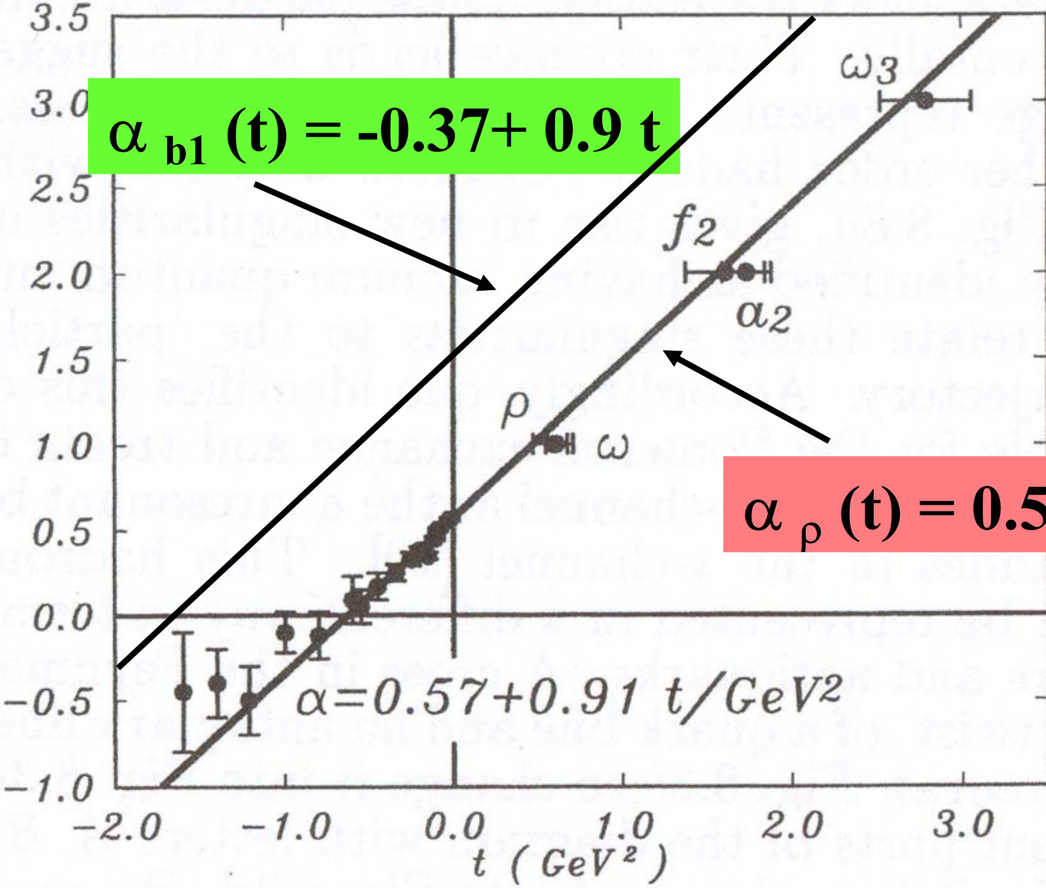
$\eta\pi^0$



$\pi^- p \to \eta\pi^0 n$
$\to 2\gamma$
η^{P+} M ε
π^0 0^{-+}
π^-
X^0
JM
η 0^{-+}
γ
γ
ε=−1
ε=+1
$b_1^0(1235)$,$f_1(1285)$
$\rho^0(770)$,$f_2(1270)$,Pomeron
p
p
$\varepsilon = P_R(-)^{J_R}$

D $_0$,D -

$\alpha_{b1}(t) = -0.37 + 0.9\,t$



$\alpha_{\rho}(t) = 0.57 + 0.91\,t$

D $_+$

For $a_2(1320)$

$D_+ \sim p^{-1}$,

$D_0, D_- \sim p^{-2}$

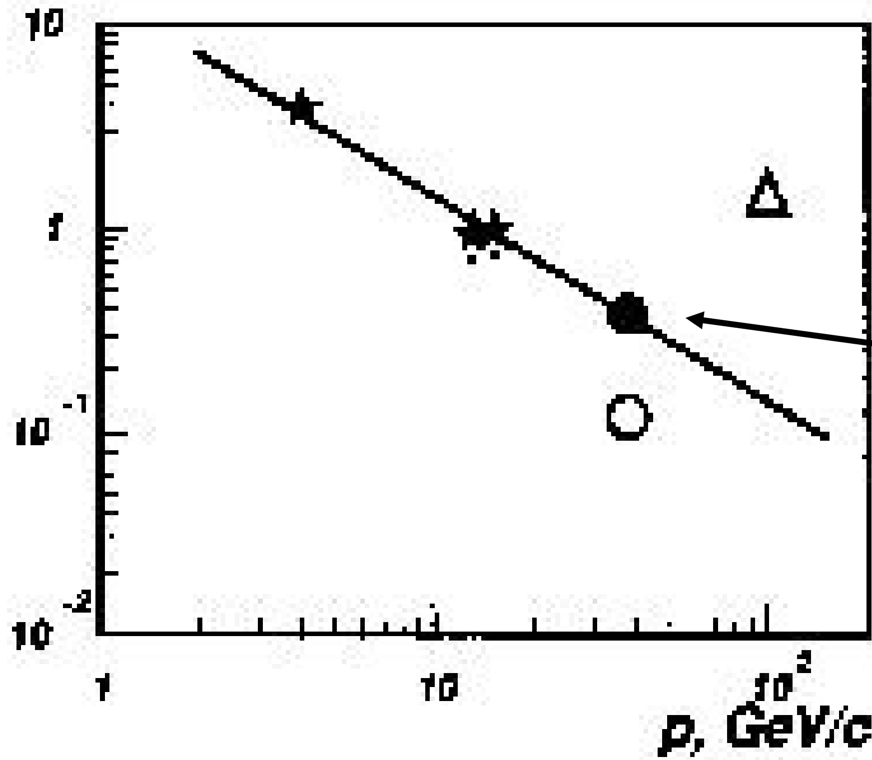
$R=(D_0+D_-)/D_+$, $R(p) \sim p^{-1}$

p, GeV/c	Regge model	GAMS $\eta\to 2\gamma$	E852-IU $\eta\to 2\gamma$	
38.	0.4	0.38 ±0.015		
18.	0.84		0.72 ± 0.12	

GAMS ,**S.A.Sadovsky, Nucl. Phys. A655(1999) 131c**

$\pi^- p \rightarrow \eta\pi^0 n$ at 38 GeV/c, GAMS

$R=(D_0+D_-)/D_+$



Regge model extrapolation

$R \sim p^{-1}$

At 38 GeV/c

$R \approx 0.4$

GAMS:

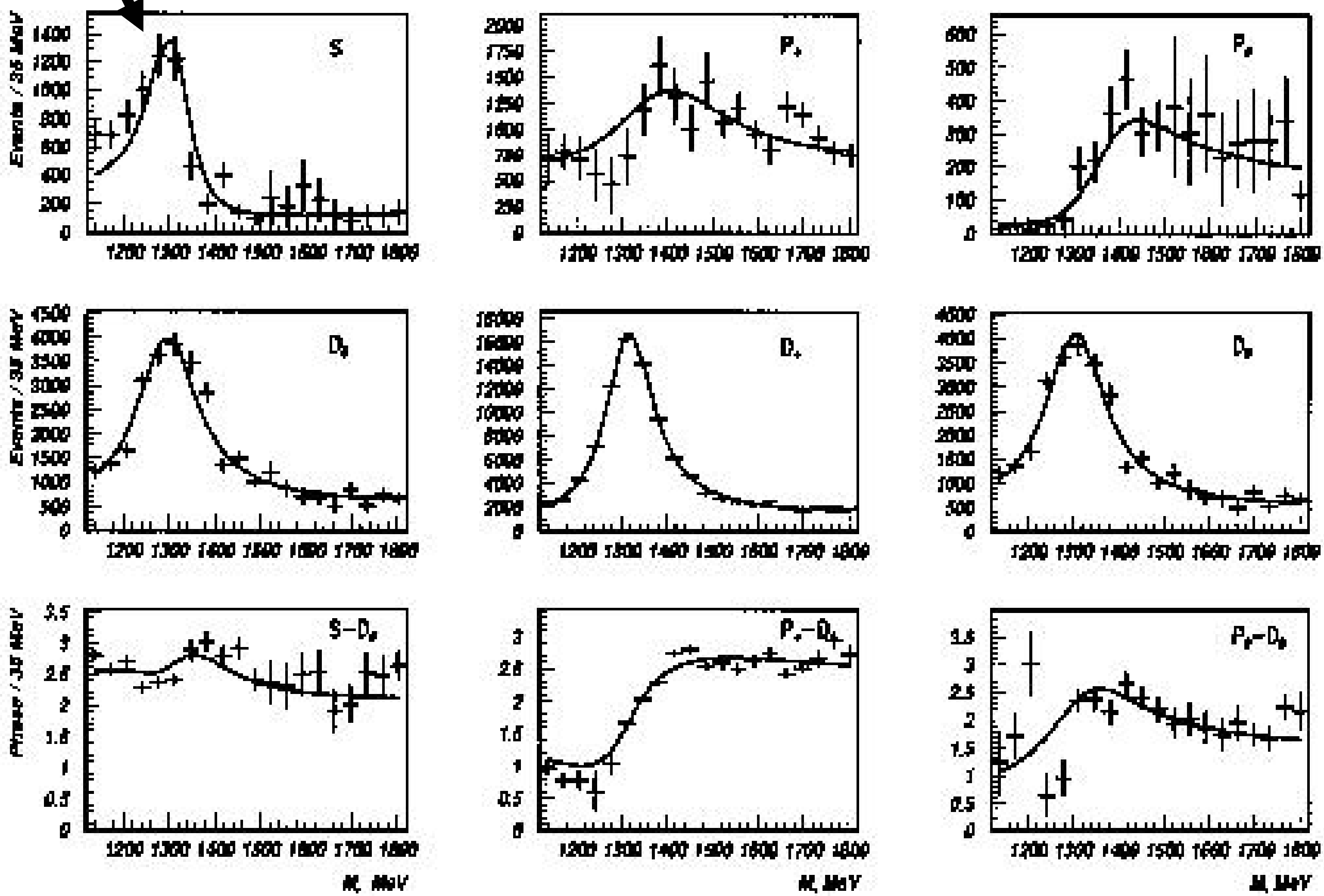
1. $R = 0.38 \pm 0.15$ for one solution among eight

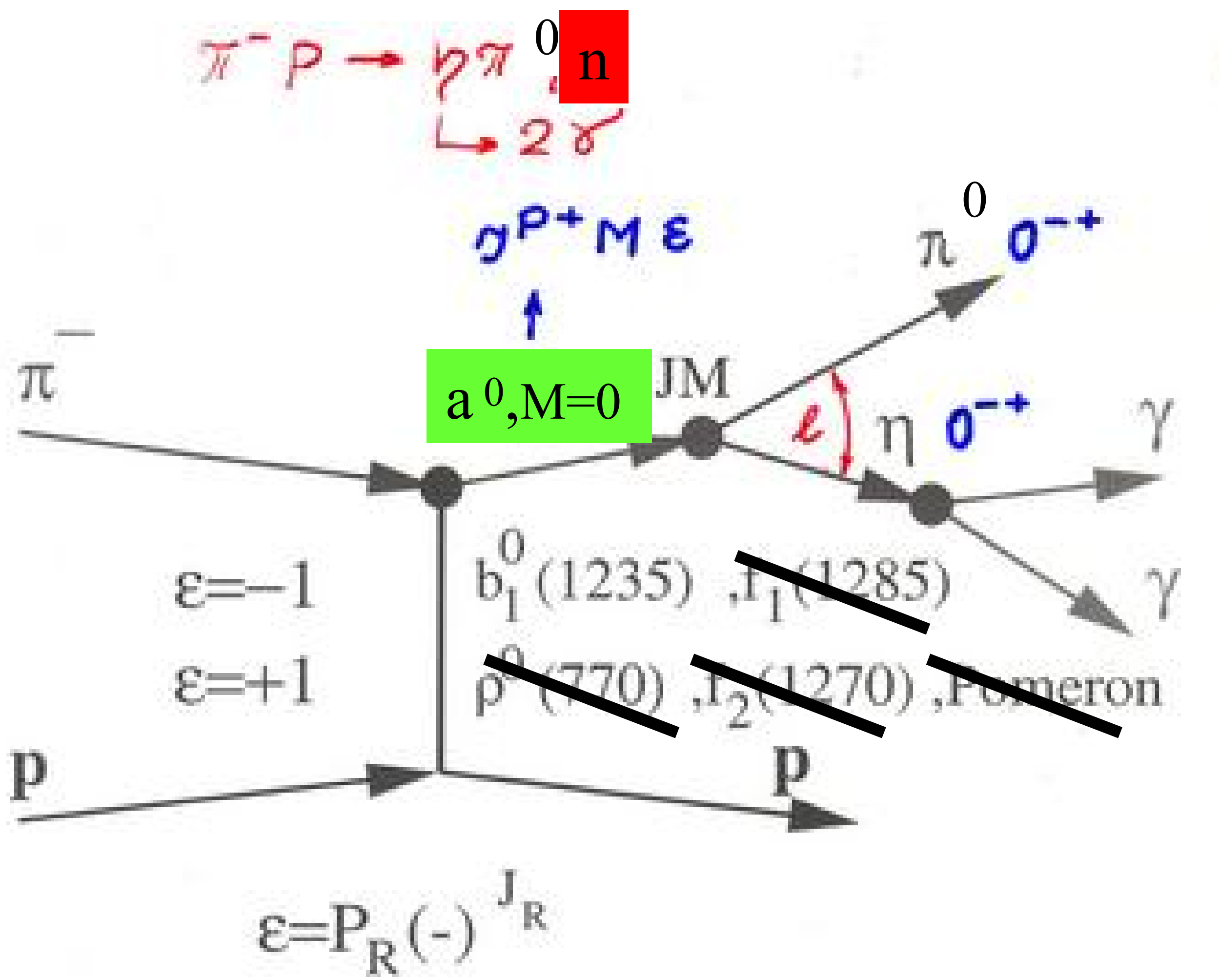
2. For this solution R is maximum !!! $\rightarrow$ Rule of selection

$a_0(1320)$? !

After selection of the physical solution:

$\pi^- p \rightarrow \eta\pi^0 n$ at 38 GeV/c, GAMS





If we see $a_0(980)$, why we don't see a_0 (1320) in E852 data?

GAMS ,

$\pi^- p \rightarrow \eta\pi^0 n$

π_1(1400), J^{PC}=1^{-+}

GAMS claims

M=1370 MeV (fixed from BNL data $\pi_1 \rightarrow \eta\pi^-$)

Γ =300±125 MeV

S.A.Sadovsky, Nucl. Phys. A655(1999) 131c

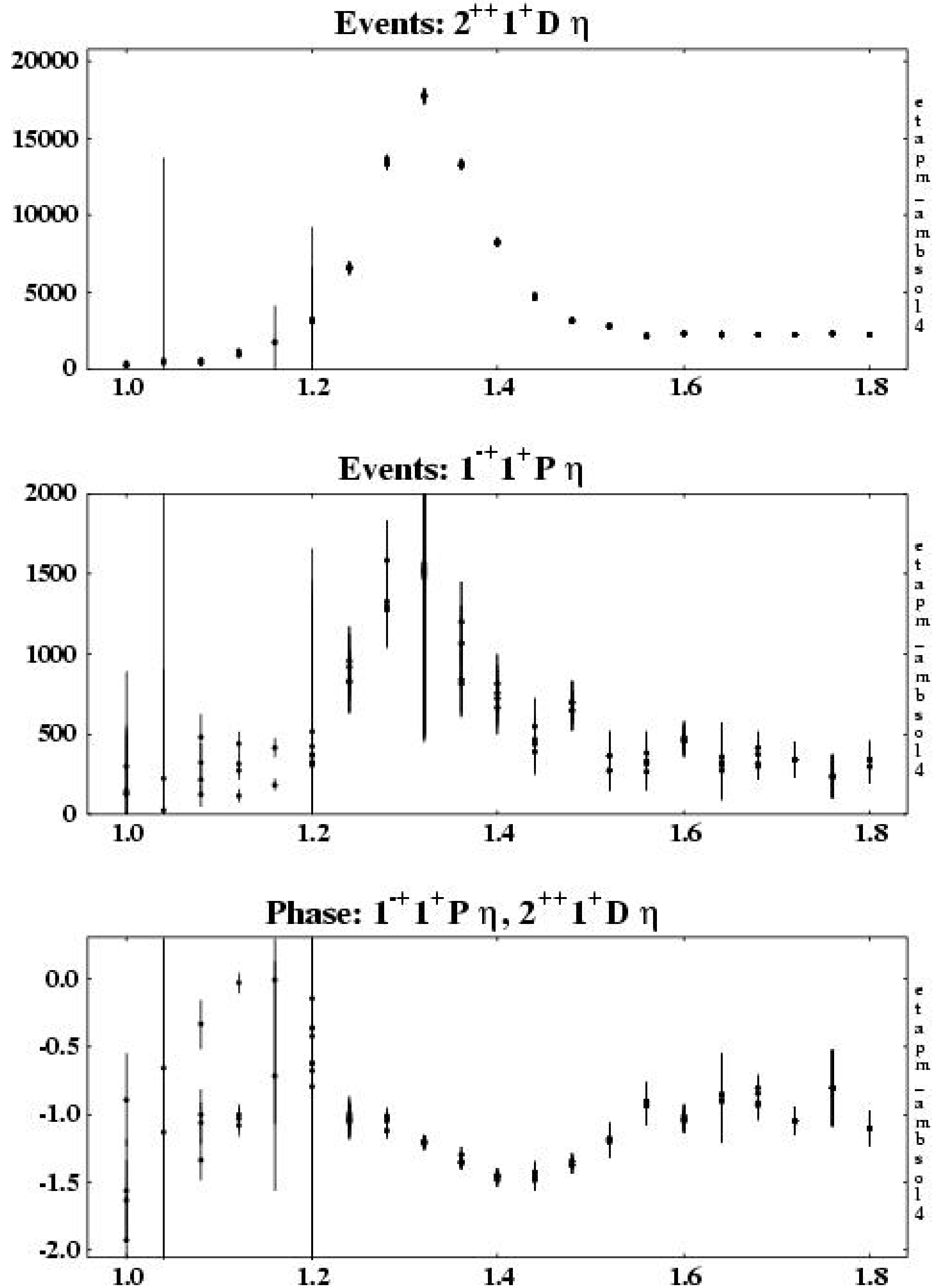
$\pi^- p \rightarrow \eta\pi^- p$ при 18 ГэВ/с

Experimental data and analysis are published in

S.U. Chung et al (E852), Phys. Rev. D60(2001)092001

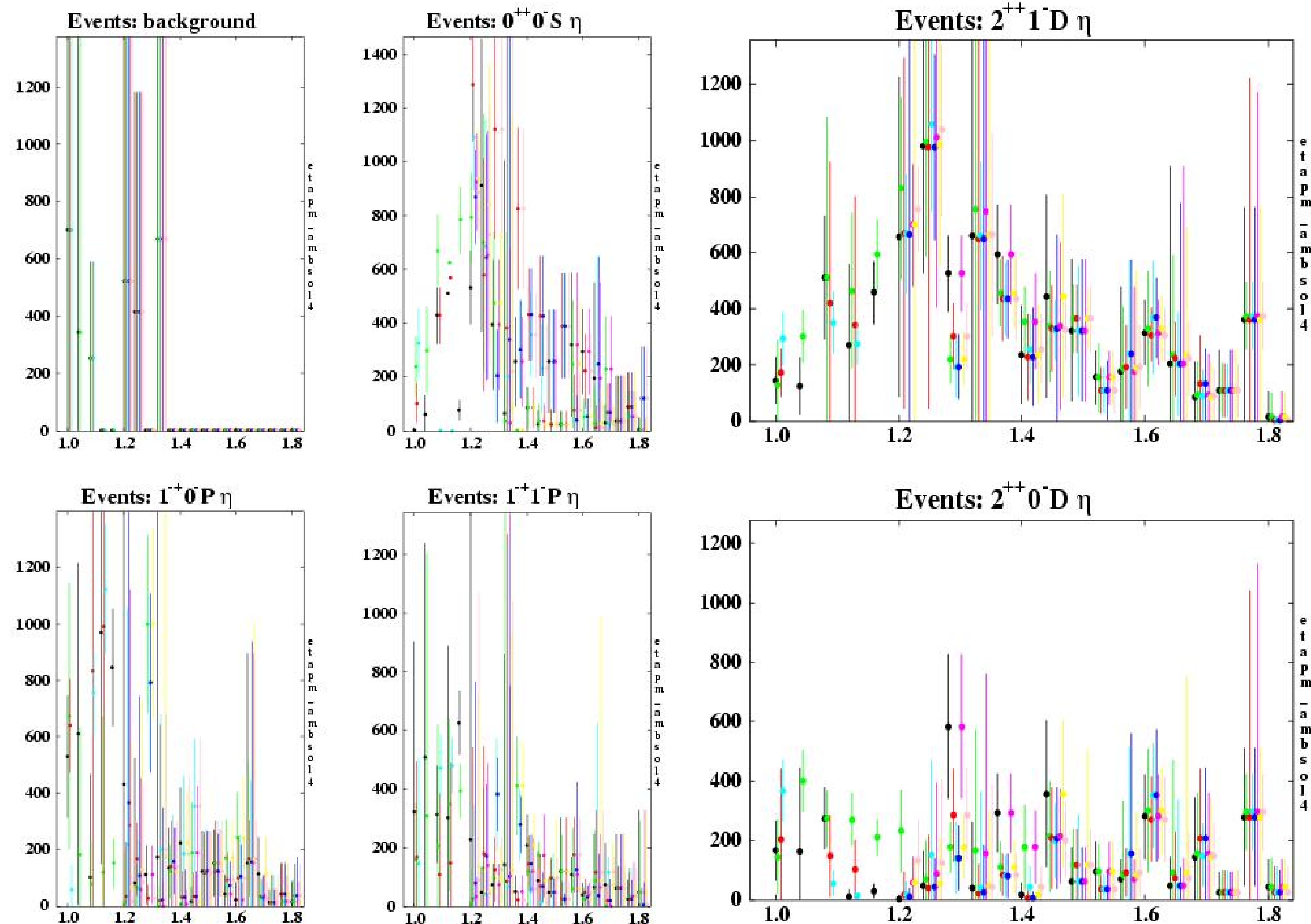
Lets calculate
$R=(D_0+D_-)/D_+$

NPE waves



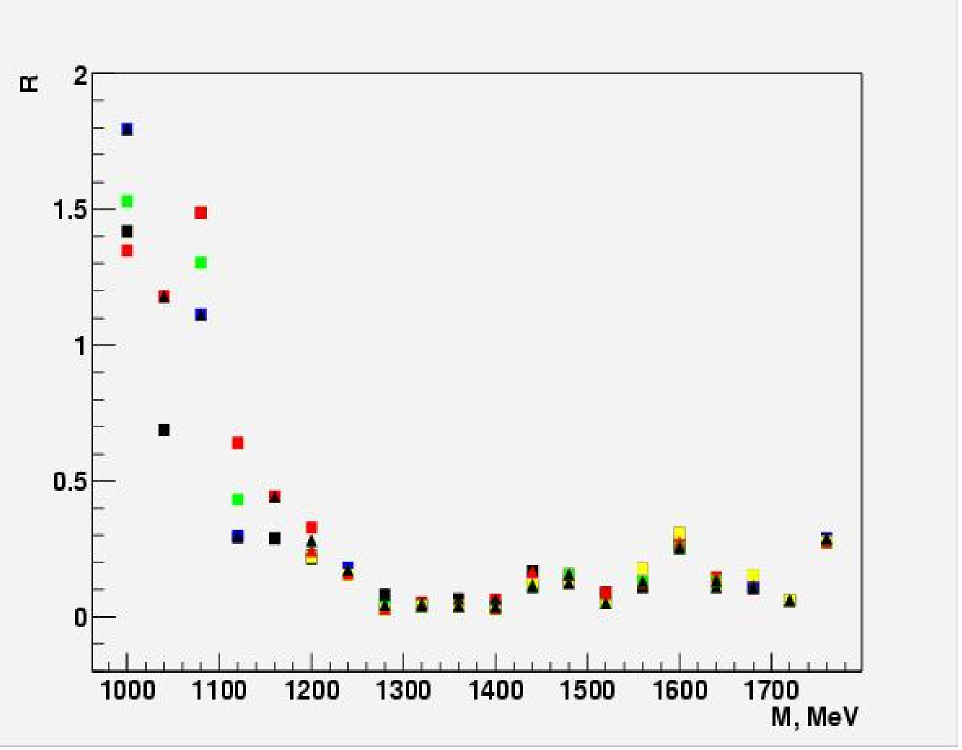
Events: 2++ 1+ D η
20000
15000
10000
5000
0
1.0
1.2
1.4
1.6
1.8
etapm_ambsol4
Events: 1-+ 1+ P η
2000
1500
1000
500
0
1.0
1.2
1.4
1.6
1.8
etapm_ambsol4
Phase: 1-+ 1+ P η, 2++ 1+ D η
0.0
-0.5
-1.0
-1.5
-2.0
1.0
1.2
1.4
1.6
1.8
etapm_ambsol4

UNPE waves

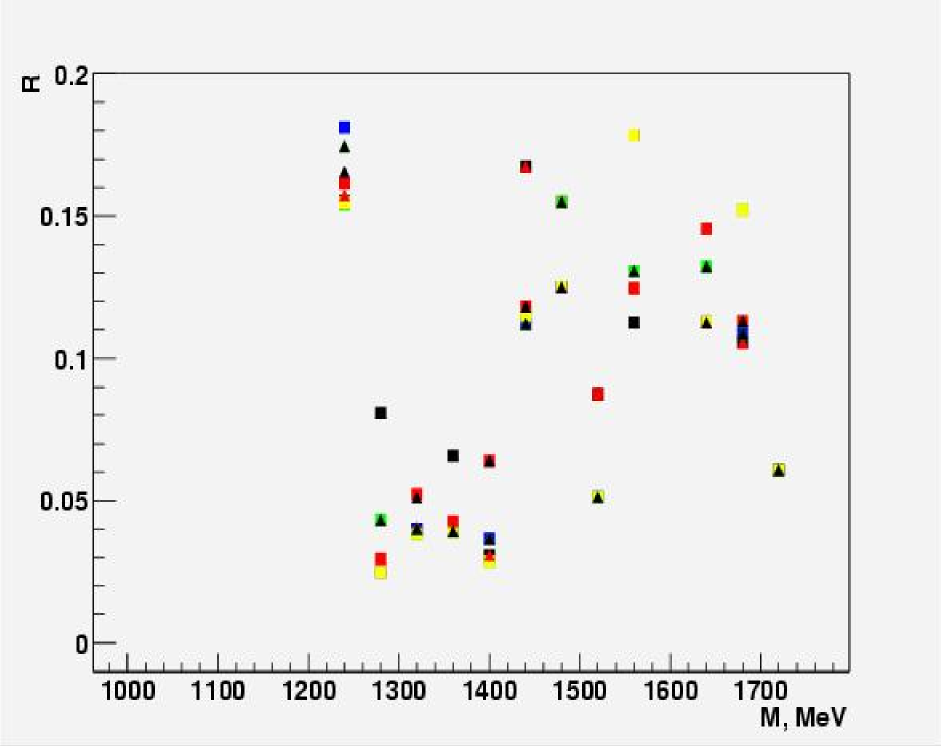

Events: background
Events: $0^{++}0^{-}S\ \eta$
Events: $2^{++}1^{-}D\ \eta$
Events: $1^{-+}0^{-}P\ \eta$
Events: $1^{-+}1^{-}P\ \eta$
Events: $2^{++}0^{-}D\ \eta$
etapm_ambsol4
etapm_ambsol4
etapm_ambsol4
etapm_ambsol4
etapm_ambsol4
etapm_ambsol4

$R=(D_0+D_-)/D_+$

Large scale



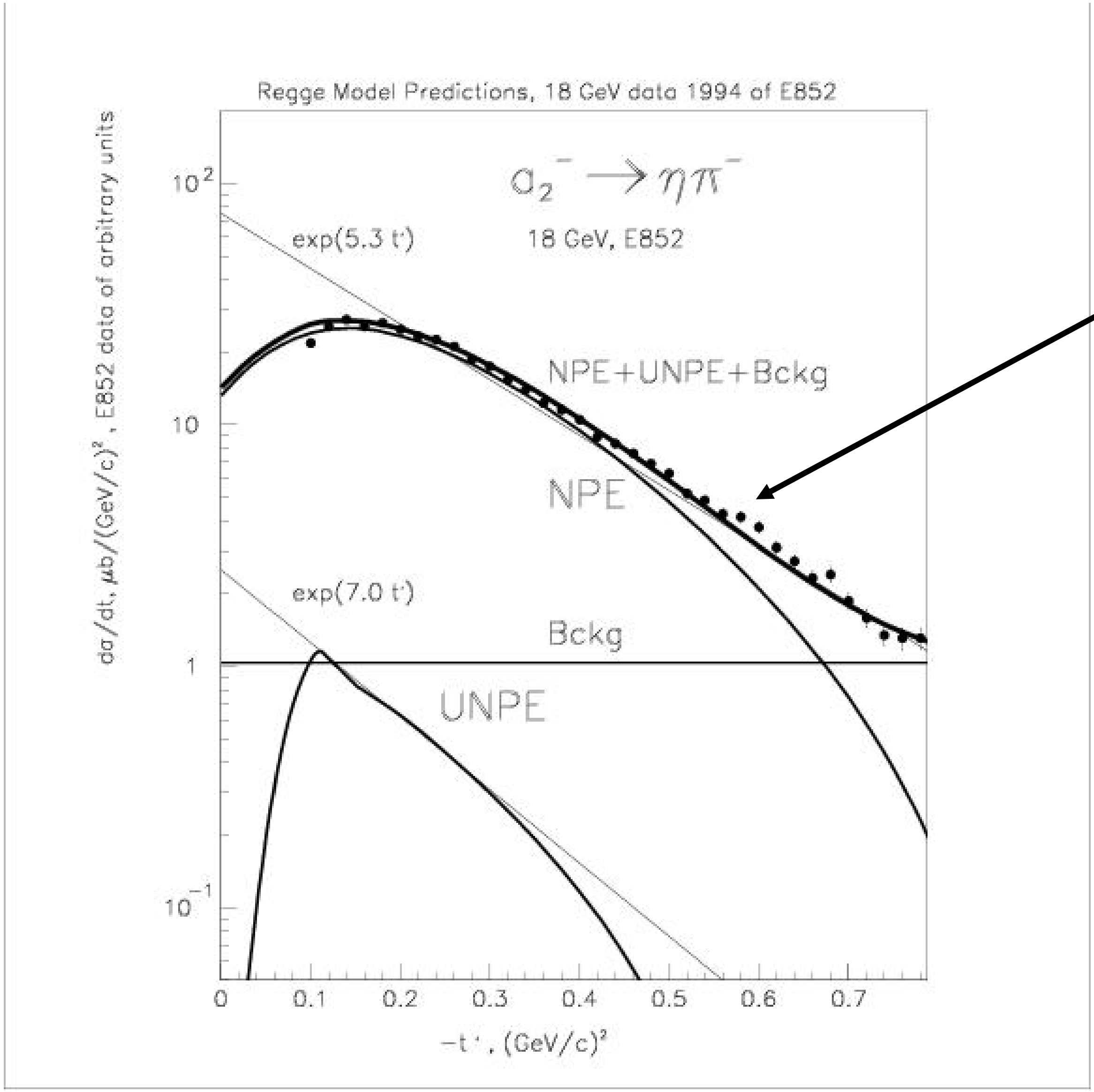
Small scale



For charge system $\eta\pi^-$ the ratio is **R** $\approx$ **0**

f_2 reggion exchange is dominated

V.L. Korotkikh, BNL note , 1998 "t-dependence of a_2 production …"



Points are E852 data for a2 region

Regge parameters from E.J. Sacharidis, Lett. Nuov.Cim. 24(1979)193

$\eta\pi^0$,

$\eta \rightarrow 2\gamma$

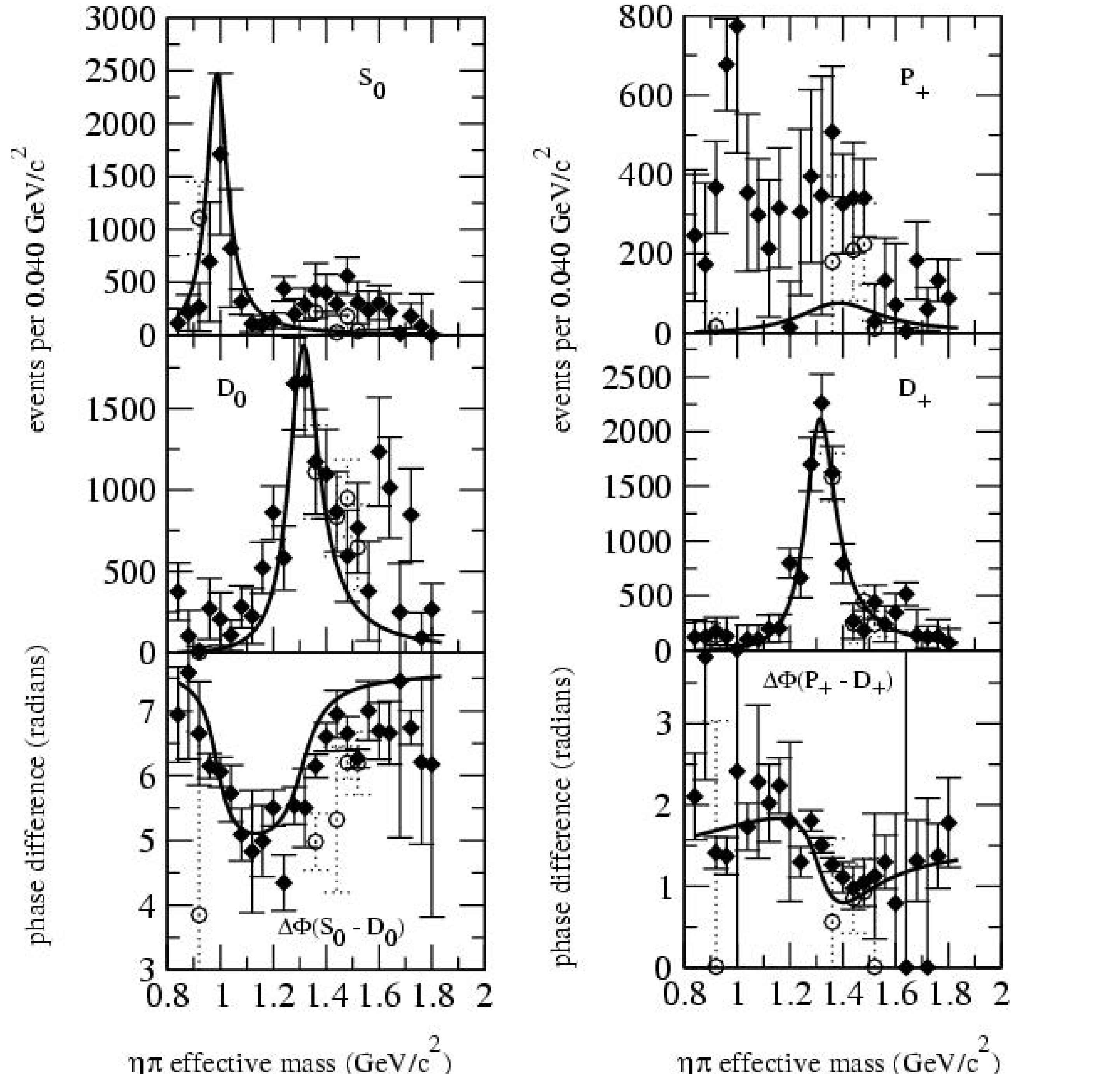
(39.4%)

A.R.Dzierba et al. $\pi^- p \rightarrow \eta\pi^0 n$, $\eta \rightarrow 2\gamma$, Phys. Rev. D67(2003))094015
45000 events

A.R.Dzierba et al. $\pi^- p \rightarrow \eta\pi^0 n$, $\eta \rightarrow 2\gamma$

PWA, low |t|

MDFit of H(LM)



A.R.Dzierba et al.
$\pi^- p \to \eta \pi^0 n$, $\eta \to 2\gamma$
PWA+MDFit

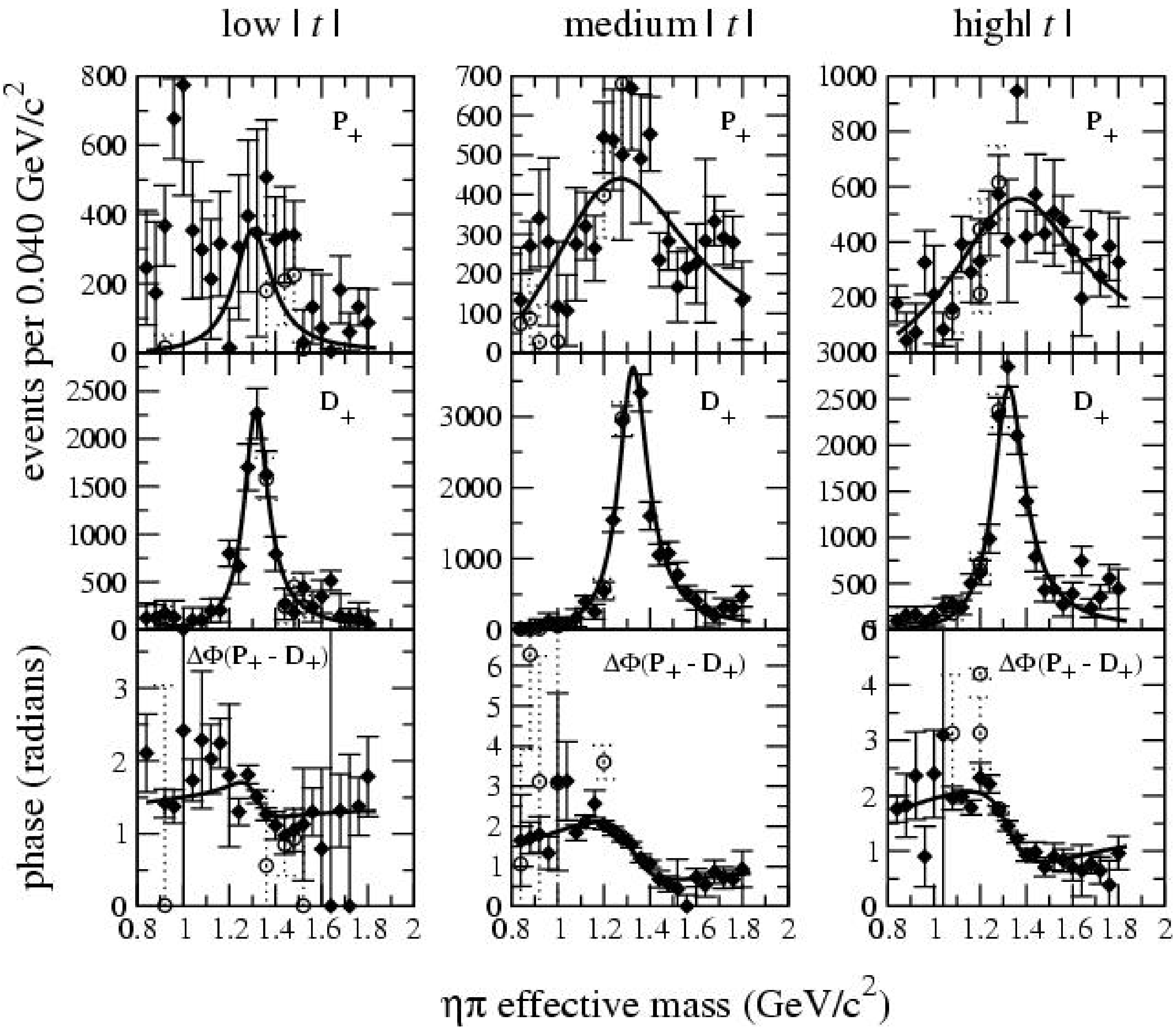


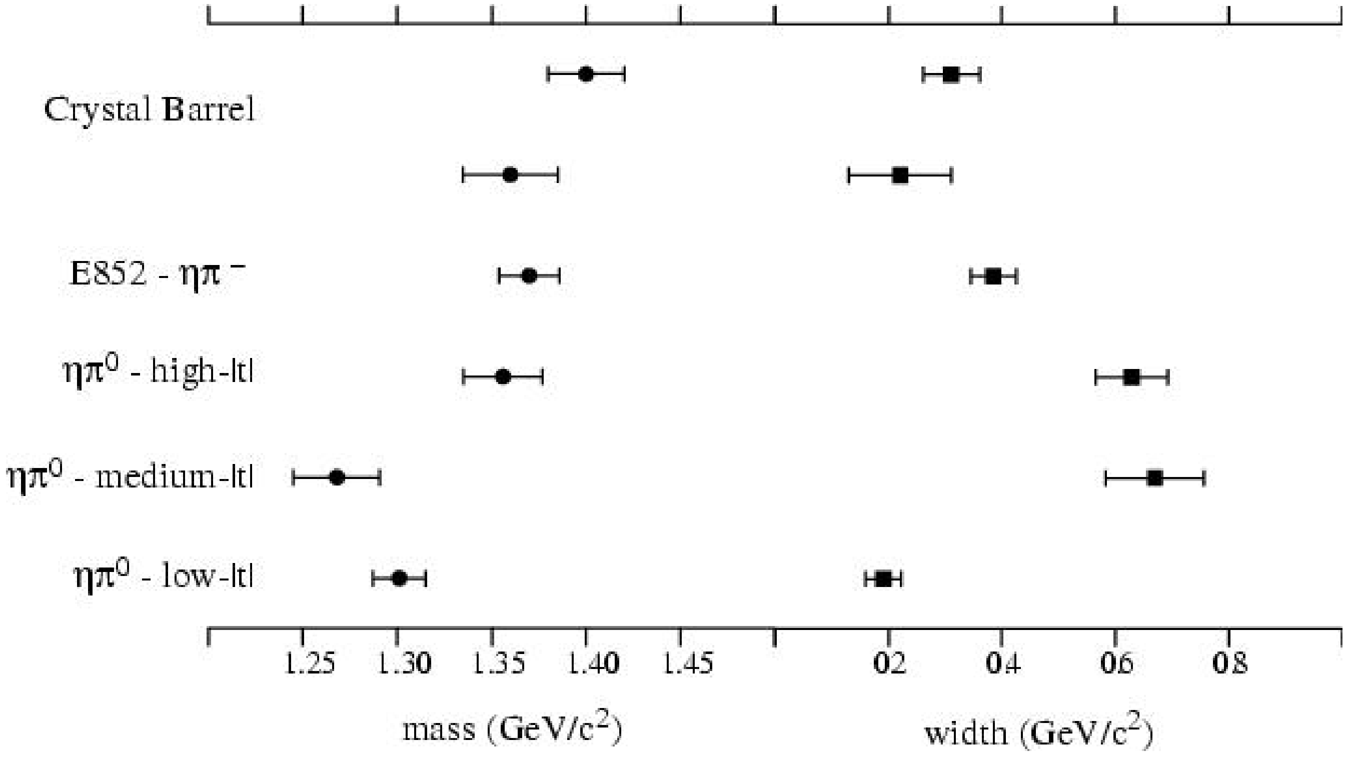
Table of the P+ bump parameters

A.R.Dzierba et al. $\pi^- p \rightarrow \eta\pi^0 n$, $\eta \rightarrow 2\gamma$, Phys.Rev. D67(2003))094015

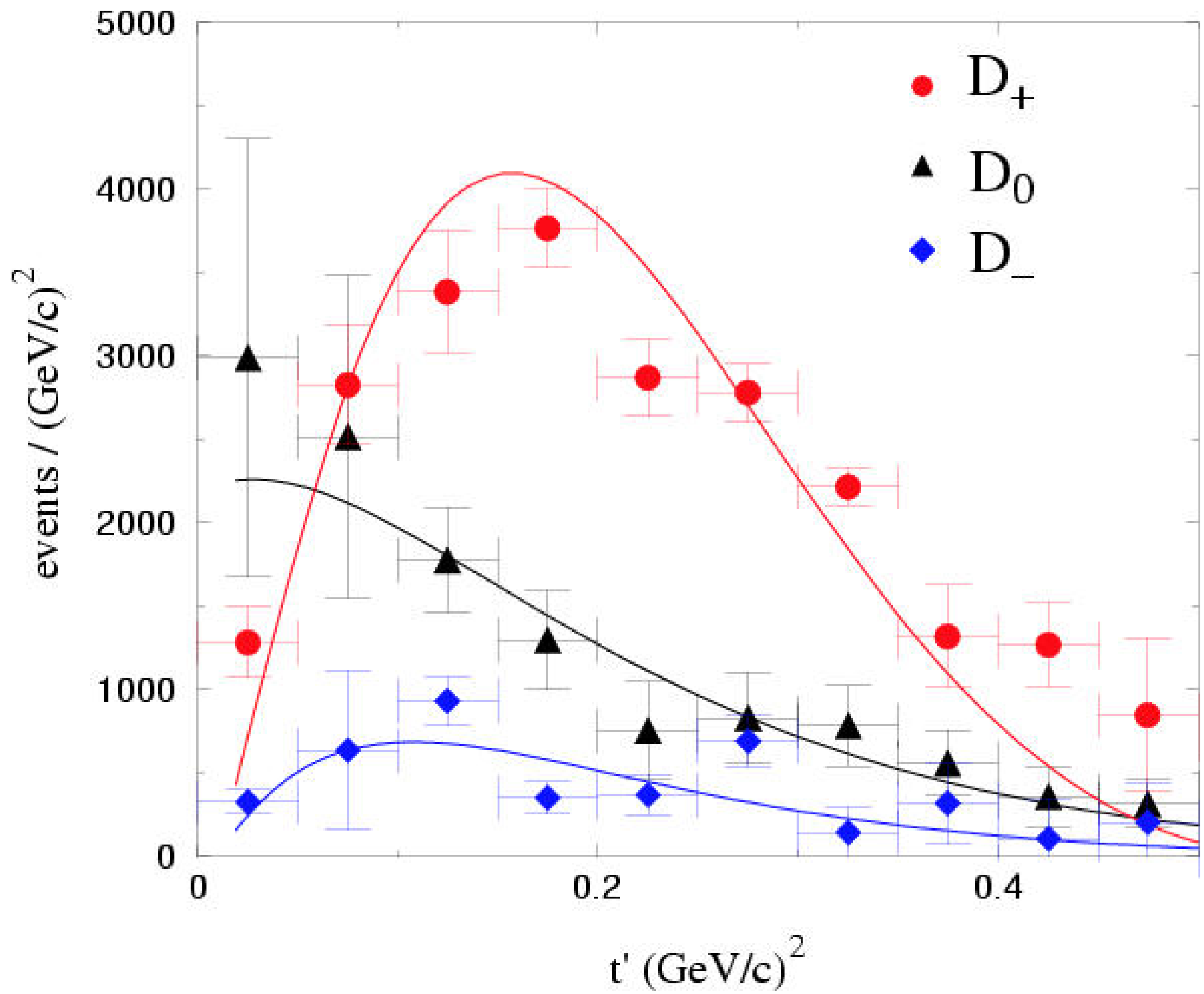
	all |t|	low-|t|	medium-|t|	high-|t|
M_{a2}	1.326	1.316	1.329	1.326
	±0.0023	±0.0049	±0.0029	±0.0036
a2	0.169	0.127	0.154	0.166
	±0.0069	±0.014	±0.0082	±0.01
M_X	1.272	1.301	1.268	1.356
	±0.017	±0.014	±0.023	±0.021
Γ_X	0.66	0.19	0.67	0.629
	±0.048	±0.032	±0.087	±0.064
$\chi 2$	3.23	2.13	1.51	1.60

π1(1400)

A.R.Dzierba et al.
$\pi^- p \to \eta\pi^0 n$,
$\eta \to 2\gamma$
Comparison



A.R.Dzierba et al.
π−p→ηπ0n,
η→2γ
t'-dependence



R = 0.72 ± 0.12

It is obvious that **$R=(D_0+D\_)/D_+$** depends on t' cuts by the acceptance

For $a_2(1320)$

$D_+ \sim p^{-1}$,

$D_0, D_- \sim p^{-2}$

$R=(D_0+D_-)/D_+$, $R(p) \sim p^{-1}$

p, GeV/c	Regge model	GAMS $\eta \to 2\gamma$	E852-IU $\eta \to 2\gamma$	
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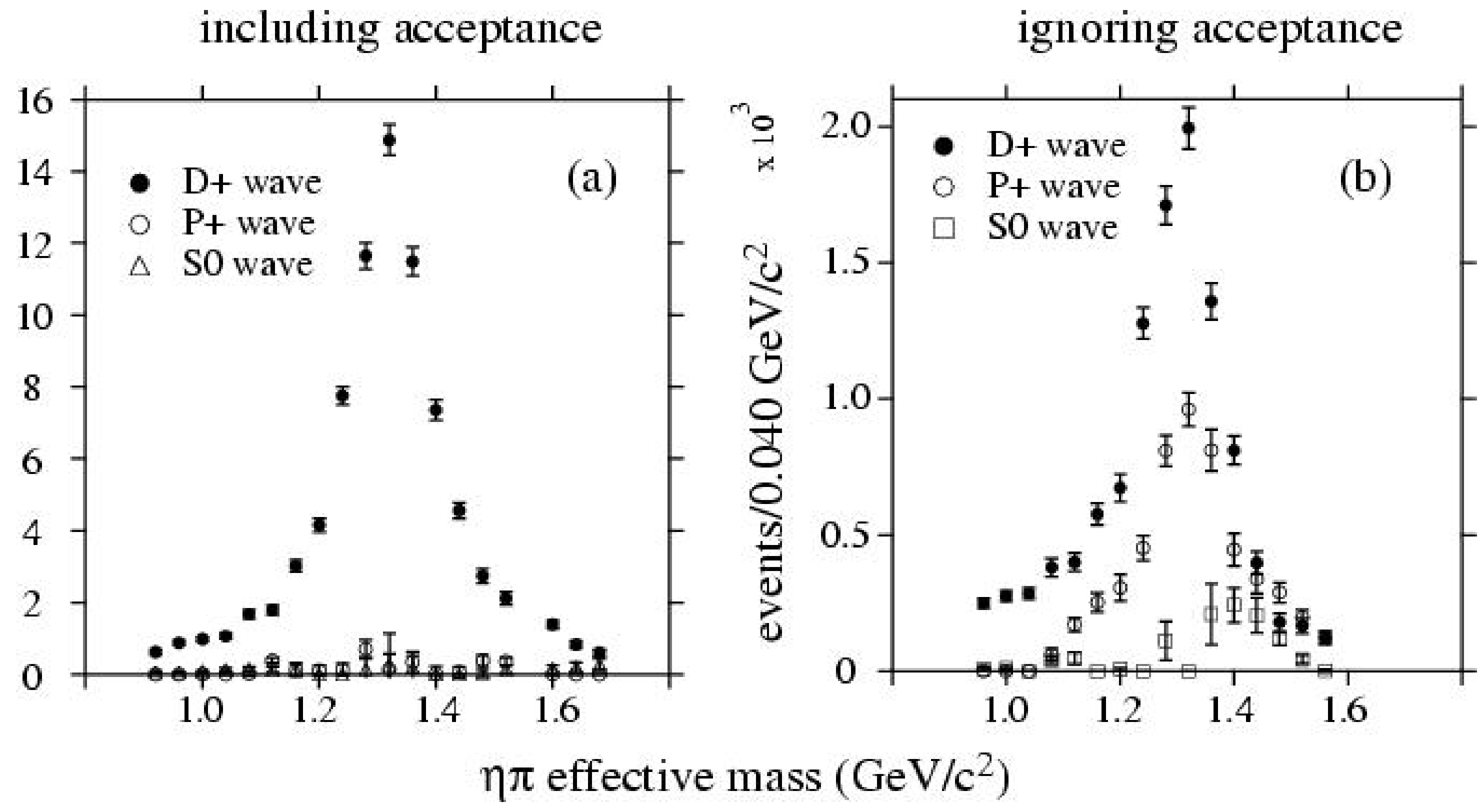
18.	0.84		0.72 ± 0.12	

A.R.Dzierba et al.

$\pi^- p \to \eta\pi^0 n$, $\eta \to 2\gamma$

Leakage study



Mine criticism on IU results of $\eta\pi^0$

1. There is not the point of interaction in analysis
2. Selection of physical solution is not complete
3. Leakage study is made without the beam smearing

Comment on the $\eta\pi^0$ Analysis

S. U. Chung
BNL

I want to comment on three aspects of the IU analysis.

First, a short comment on the production characteristics of exotic mesons seen in our data. We have seen from our $\pi^+\pi^-\pi^-$, $\eta\pi^-$ and $\eta'\pi^-$ analyses that an exotic meson can have very different production properties depending on the naturality of the exchanged Reggeon. Our $\pi_1(1600)$ is produced entirely through natural parity exchange. (It may, of course, be also produced by unnatural parity exchange but at a level too small to be detectable with our statistics.) In any event there is one inescapable fact: the 1^{-+} waves are very different in the two sectors.

□ Comment One:

I assume that the mass-dependent fit to the observed moments in the $\eta\pi^0$ analysis resulted from putting in a same resonance in the P-waves in both natural- and unnatural-parity exchange. As we have seen in our previous analyses, this may not be the case at all for exotic mesons.

Our $\eta\pi^-$ analysis relied only on the exotic waves produced in the natural-parity sector. If we assume that only S-, P- and D-waves are present below 1.6 GeV, then there are only three quantities in the natural-parity sector, $|D_+|^2$, $|P_+|^2$ and the phase difference. So our mass-dependent fit to $\eta\pi^-$ in this sector is complete—nothing left out.

Assume ρ exchange for the natural-parity sector in the $\eta\pi^0$ channel and $b_1(1235)$ exchange for the unnatural-parity sector. We know that $a_2(1320)$ is produced in both sectors, but this may not be so for $\pi_1(1400)$. It is possible, for instance, that $\pi_1(1400)$ does *not* couple to $b_1(1235)\pi$ at all.

- We need to quote two sets of M and Γ, obtained from fits to the partial wave amplitudes in each sector. Then the results from the natural-parity sector can be compared directly to those of $\eta\pi^-$.

□ Comment Two:

- In order to understand the results of the fit to the moments, we also need to see the plots of all the amplitudes (magnitudes and phase differences) as determined by the mass-dependent fit to the moments. We can then compare directly with the amplitudes determined from the PWA.

□ Comment Three:

Since Pomeron exchange can be present in one production mode only, the production characteristics could be quite different in the two channels $\eta\pi^0$ and $\eta\pi^-$. Our mass-dependent fit to $\eta\pi^-$ may not directly apply to $\eta\pi^0$. In particular, we may need a more elaborate mass-dependence in the formula used. It is quite possible that the 'Watson's phase' may no longer be mass-independent.

- A fit to $|D_+|^2$, $|P_+|^2$ and the phase difference in the $\eta\pi^0$ channel should be performed with the mass and the width fixed to those of the $\eta\pi^-$ channel *but* incorporating a more elaborate mass-dependence to the Watson's phase and the backgrounds under P- and D-waves.

E852 statistics and Exotics $J^{PC}=1^{-+}$

Publications. Reaction	Final state	Main result
1. D.R.Thompson et al. $\pi^- p \to \eta\pi^- p$, Phys. Rev. Lett. 79(1997)1630, S.U. Chung et al, $\pi^- p \to \eta\pi^- p$, Phys. Rev. D60(1999)092001	$\eta\pi^-$ 47200	$\pi_1(1400)$
2. G.S. Adams et al. “Observation of a New $J^{PC}=1^{-+}$ Exotic State in the Reaction $\pi^- p \to \pi^+\pi^-\pi^- p$ at 18 GeV/c”, Phys. Rev. Lett. 81(1998)5760	$\pi^+\pi^-\pi^-$ 250000	$\pi_1(1600)$
3. E. Ivanov et al. $\pi^- p \to \eta\pi^+\pi^- p$, Phys. Rev. Lett. 86(2001)3977	$\eta'\pi^-$ 6040	$\pi_1(1600)$
4. J. Kuhn et al. $\pi^- p \to \eta\pi^+\pi^-\pi^- p$ Phys. Lett. B., 2003.	$f_1\pi^-$ 68900	$\pi_1(1600)$ $\pi_1(2000)$
5. M. Lu et al. $\pi^- p \to \omega\pi^0\pi^- p$. Phys. Rev. Lett. 2004. To be published	$b_1\pi^-$ 145148	$\pi_1(1600)$ $\pi_1(2000)$
6. V.L.Korotkikh et al. $\pi^- p \to \eta\pi^0 n$, $\eta \to \pi^+\pi^-\pi^0$,HADRON99, Nucl.Phys. A675(2000)413c	$\eta\pi^0$ 18712	M=1280± 24 Γ=526± 81

7. A.R.Dzierba et al. $\pi^- p \to \eta\pi^0 n$, $\eta \to 2\gamma$, Phys.Rev. D67(2003))094015	$\eta\pi^0$ 45000	M=1272± 17 Γ=660±48 All |t|

$$\eta\pi^{0},$$

$$\eta \to \pi^{+}\pi^{-}\pi^{0}$$

(28 %)

V.L.Korotkikh et al.(E852) $\pi - p \to \eta\pi 0n$, $\eta \to \pi + \pi - \pi 0$
HADRON99, Nucl. Phys. A675(2000)413c

Onn-line selection

Trigger: 0-2-2-(4)
$\eta\pi^0$

* Interaction beam
* Two downstream tracks
* No recoil trac
* LGD trigger processor mass > π^0 mass

Off-line selection

* Reconstructed beam
* No recoil
* CsI < 160 MeV
* Two forward reconstructed tracks
* Vertex in target
* Exactly 4 photons
* Kinematical fit selecting events consistent with (n, η, π^0)

Statistics. Data cuts.

Trigger: 0-2-2-(4)

$\eta\pi^0$

Total 0-2-2-X triggers analyzed	108,000,000		
After skimming data 0-2-2-4Photons	6,000,000		
1.1. Hypothesis EtaPi0,(cl>0.01)	41,108 (36,475)		
1.1.1. Hypothesis EtaPi0,(ellips cut+cl>0.01)	26,871		
1.2. Hypothesis EtaPi0,(cl>0.10)	41,108 (20,674)		
1.2.1. Hypothesis EtaPi0,(ellips cut, cl>0.10)	18,712	→	PWA
1.1.MC. EtaPi0, Raw Monte Carlo Events	900,424	→	PWA
1.1.MC. EtaPi0, Acc MC Events,(after SQUAW)	265,972		
1.1.MC. EtaPi0, Acc MC Events,(ellips cut)	196,560		
1.1.1.MC. EtaPi0, Acc MC Events,(ellips cut, cl>0.01)	192,302		
1.2.1.MC. EtaPi0, Acc MC Events,(ellips cut, cl>0.10)	180,294	→	PWA

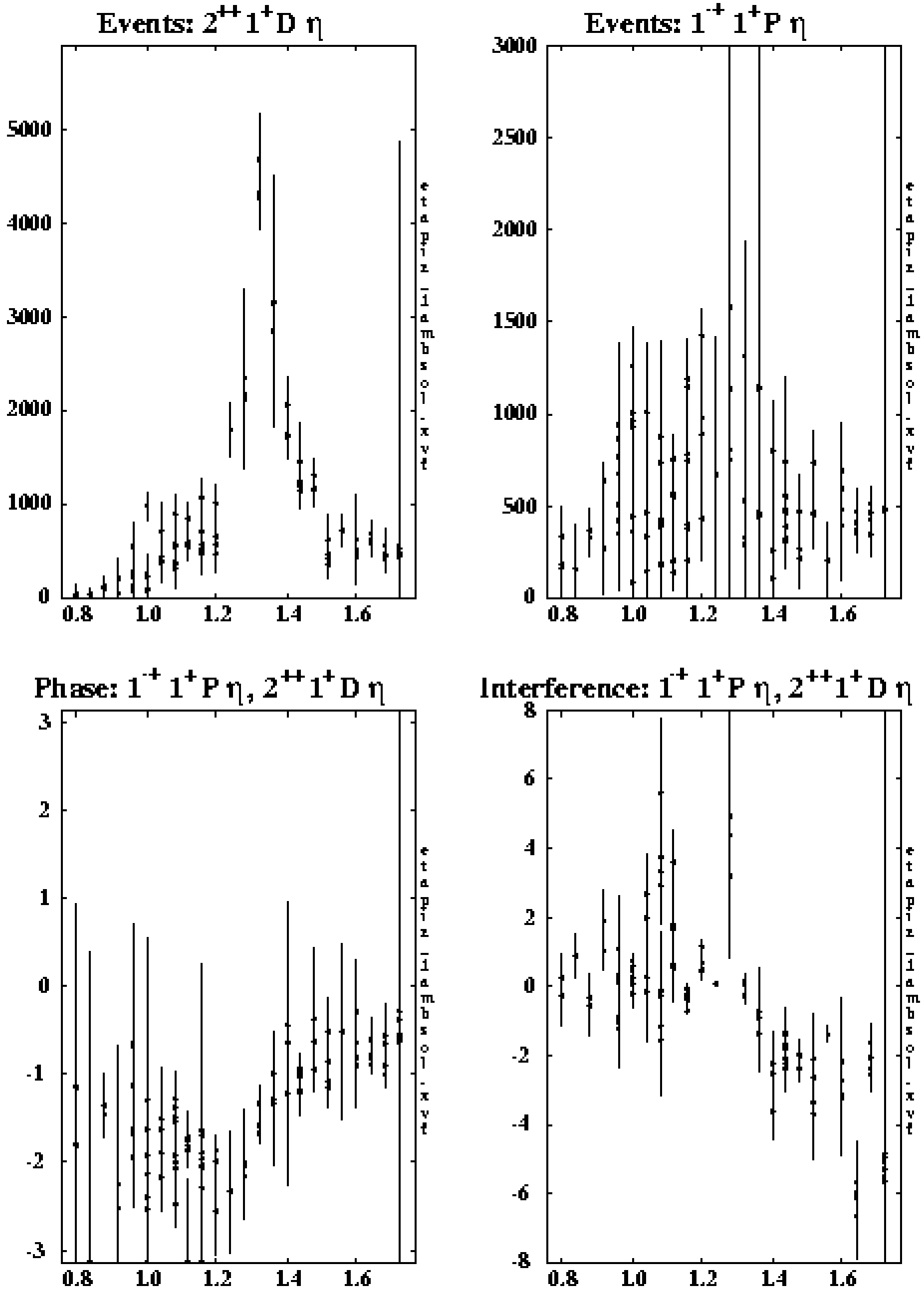
Set waves

Allowed waves:

	Notation (L)	J	P	C	M	ε
	S_0	0	+	+	0	-
	P_0	1	-	+	0	-
η^{PC}:	P_-	1	-	+	1	-
	D_0	2	+	+	0	-
	D_-	2	+	+	1	-
1^{-+} →	P_+	1	-	+	1	+
2^{++} →	D_+	2	+	+	1	+
	G_+	4	+	+	1	+

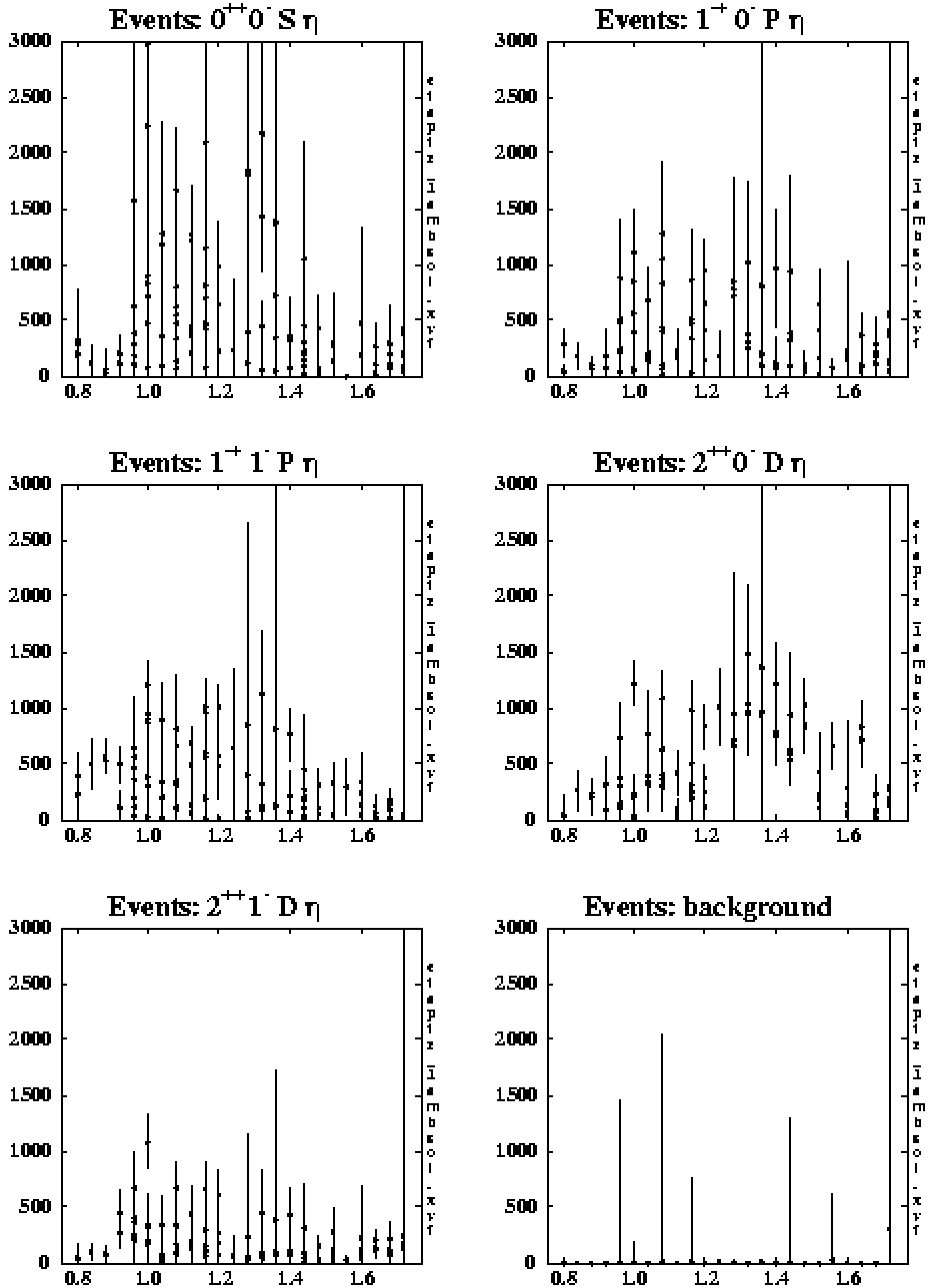
NPE waves

cl > 0.10
18712 data
180294 acc
900000 raw



PWA
mass bin=
40 MeV

UNPE waves

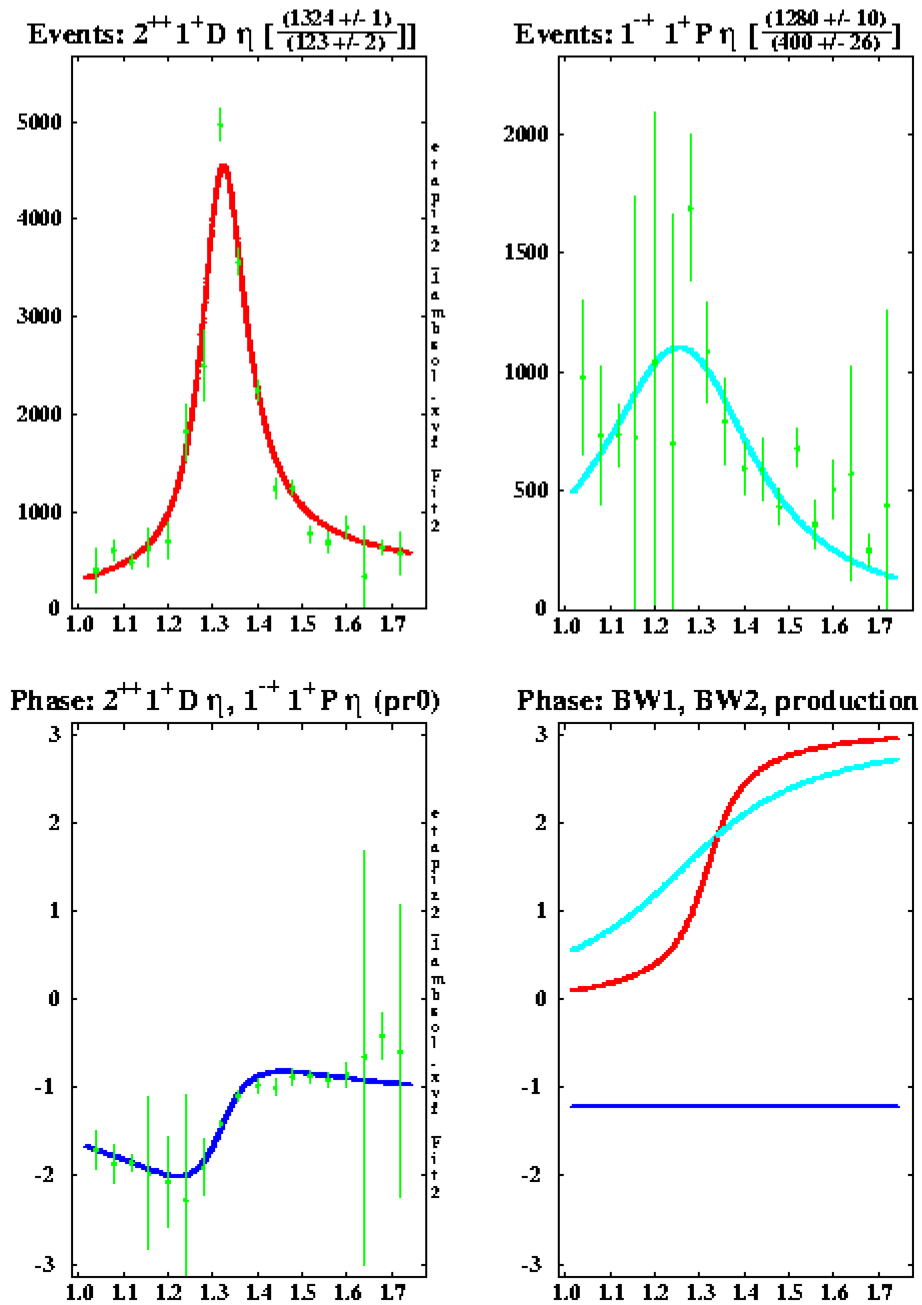


Events: $0^{++}0^{-}$ S η
Events: $1^{-+}0^{-}$ P η
Events: $1^{-+}1^{-}$ P η
Events: $2^{++}0^{-}$ D η
Events: $2^{++}1^{-}$ D η
Events: background
3000
2500
2000
1500
1000
500
0
0.8
1.0
1.2
1.4
1.6

Mass dependent fit of $\eta\pi^0$

1. Two BW
2. Average of amb. solutions

The same as in analysis of $\eta\pi^-$



Comparison of $\eta\pi^-$ and $\eta\pi^0$

$\eta\pi^-$ PWA + MDF

$$\text{Mass}(a_2) = (1317 \pm 1 \pm 2)$$

$$\text{Width}(a_2) = (127 \pm 2 \pm 2)$$

$$\text{Mass}(\pi_1) = (1370 \pm 16\ ^{+50}_{-30})$$

$$\text{Width}(\pi_1) = (385 \pm 40\ ^{+65}_{-105})$$

$\eta\pi^0$ PWA + MDF

$$\text{Mass}(a_2) = (1326 \pm 4\ ^{+19}_{-11},\ ^{+24}_{-56})$$

$$\text{Width}(a_2) = (119 \pm 5\ ^{+36}_{-19},\ ^{+140}_{-59})$$

$$\text{Mass}(\pi_1) = (1280 \pm 24\ ^{+30}_{-45},\ ^{+70}_{-50})$$

$$\text{Width}(\pi_1) = (526 \pm 81\ ^{0}_{-286},\ ^{34}_{-326})$$

———— min, max of amb solutions

V.L.Korotkikh et al.(E852) HADRON 99,

Nucl.Phys. A675(2000)413c

E852 statistics and Exotics $J^{PC}=1^{-+}$

Publications. Reaction	Final state	Main result
1. D.R.Thompson et al. $\pi^- p \to \eta\pi^- p$, Phys. Rev. Lett. 79(1997)1630, S.U. Chung et al, $\pi^- p \to \eta\pi^- p$, Phys. Rev. D60(1999)092001	$\eta\pi^-$ 47200	$\pi_1(1400)$
2. G.S. Adams et al. "Observation of a New $J^{PC}=1-+$ Exotic State in the Reaction $\pi^- p \to \pi^+\pi^-\pi^- p$ at 18 GeV/c", Phys. Rev. Lett. 81(1998)5760	$\pi^+\pi^-\pi^-$ 250000	$\pi_1(1600)$
3. E. Ivanov et al. $\pi^- p \to \eta\pi^+\pi^- p$, Phys. Rev. Lett. 86(2001)3977	$\eta'\pi^-$ 6040	$\pi_1(1600)$
4. J. Kuhn et al. $\pi^- p \to \eta\pi^+\pi^-\pi^- p$ Phys. Lett. B., 2003.	$f_1\pi^-$ 68900	$\pi_1(1600)$ $\pi_1(2000)$
5. M. Lu et al. $\pi^- p \to \omega\pi^0\pi^- p$. Phys. Rev. Lett. 2004. To be published	$b_1\pi^-$ 145148	$\pi_1(1600)$ $\pi_1(2000)$
6. V.L.Korotkikh et al. $\pi^- p \to \eta\pi^0 n$, $\eta \to \pi^+\pi^-\pi^0$,HADRON99, Nucl.Phys. A675(2000)413c	$\eta\pi^0$ 18712	M=1280± 24 Γ=526± 81

7. A.R.Dzierba et al. $\pi^- p \to \eta\pi^0 n$, $\eta \to 2\gamma$, Phys.Rev. D67(2003))094015	$\eta\pi^0$ 45000	M=1272± 17 Γ=660±48 All |t|

$\eta\pi^0$,

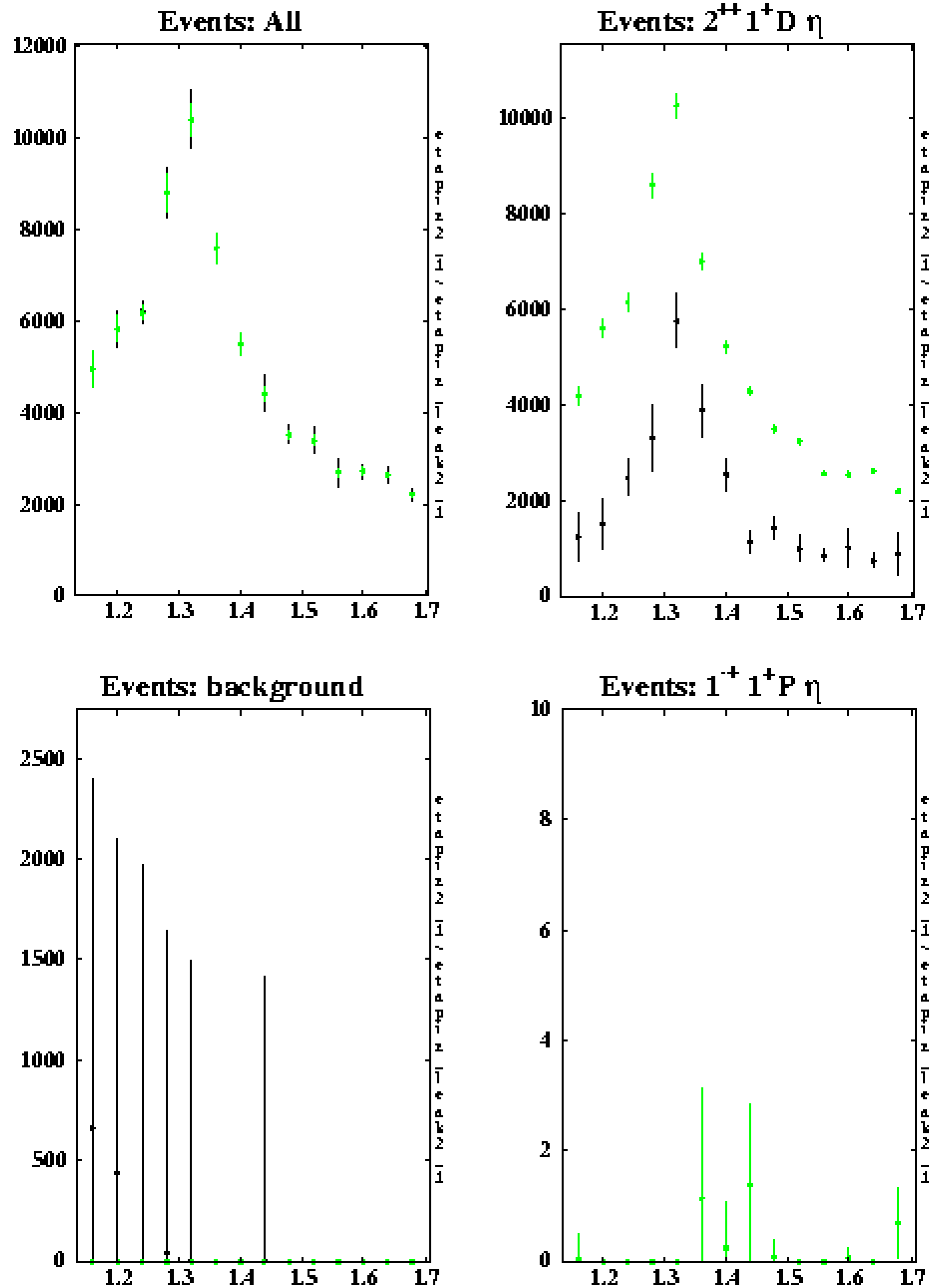
$\eta \rightarrow \pi^+\pi^- \pi^0$

Leakage study

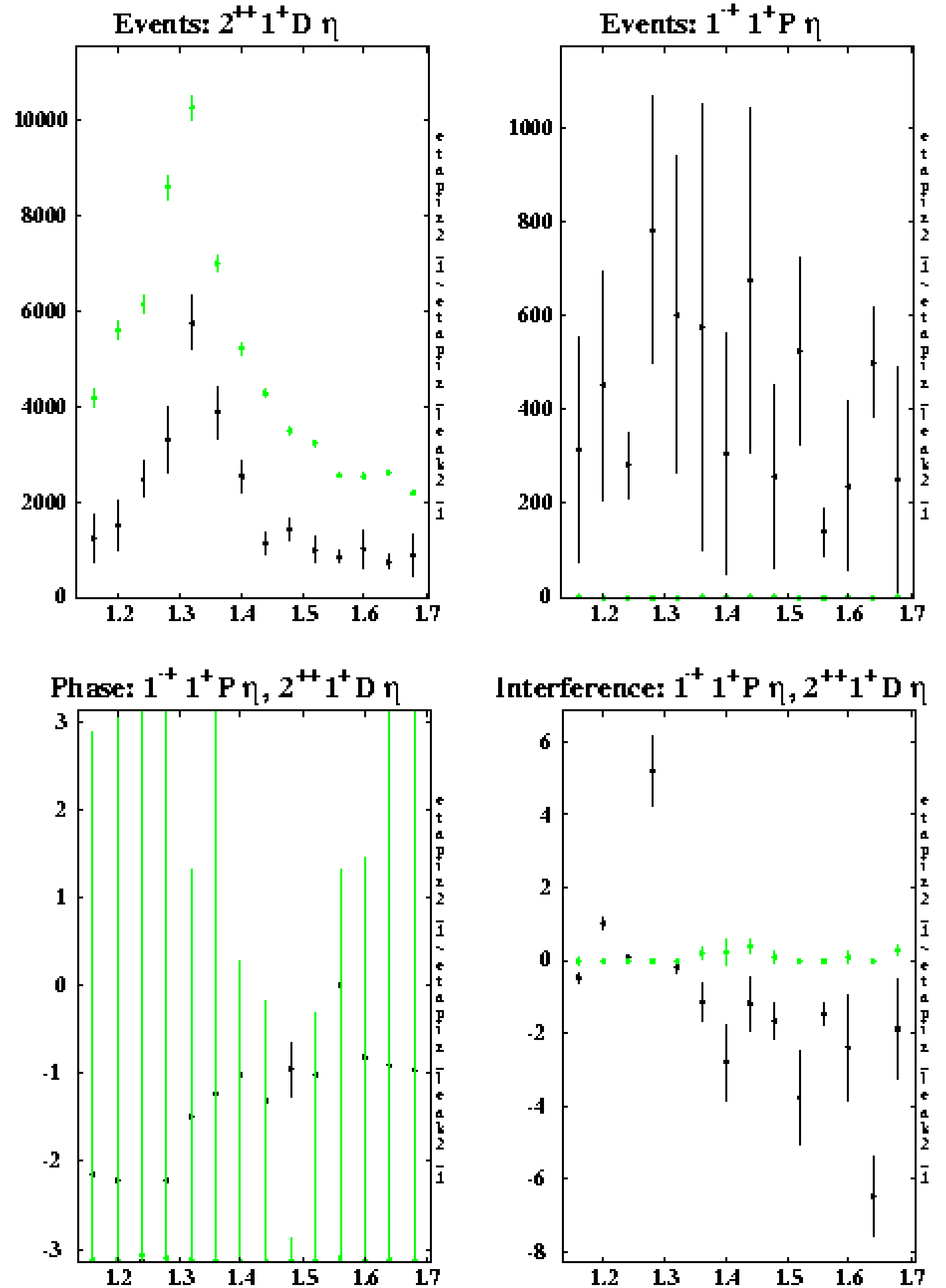
1. Only D+ wave
2. Whole chain to get acceptance events
3. PWA

green – input data
black – PWA results

There is no the beam smearing



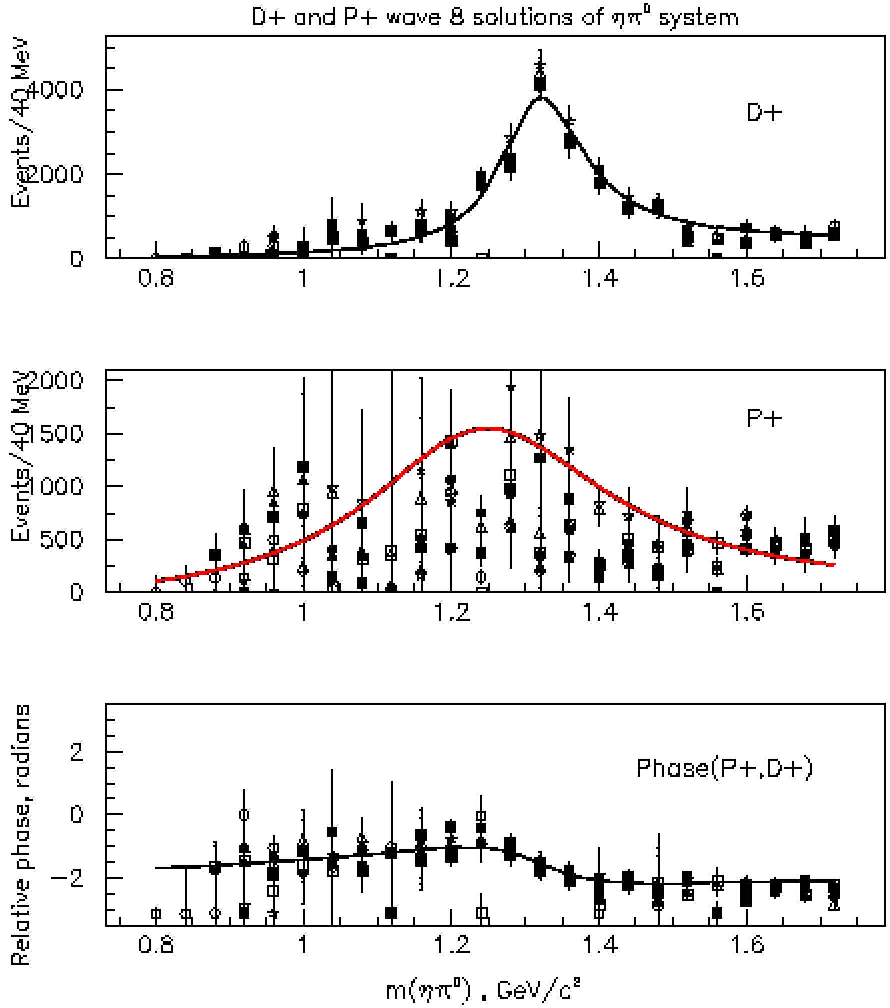
Leakage study



Mass dependent PWA of ηπ0

A) Leakage = 0 and fixed

1. Simultaneous fit of angular and mass distributions
2. Free BW parameters and leakage



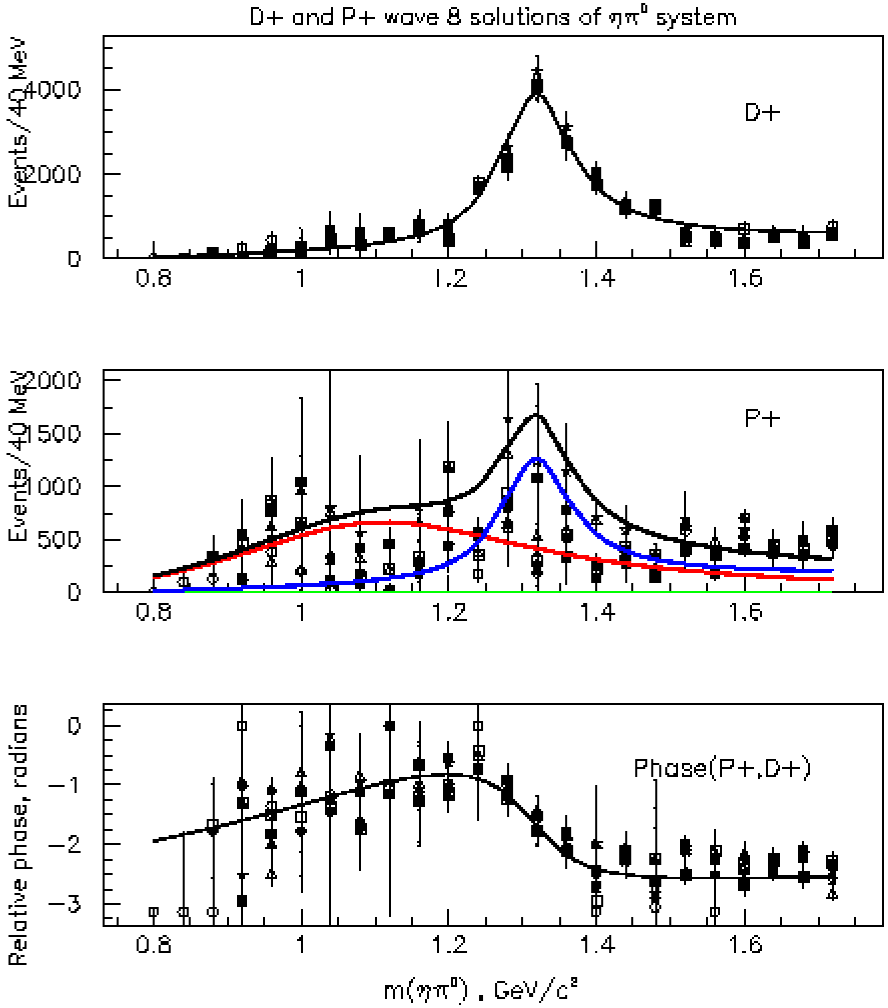
red – BW of P+ wave

M=1250 ± 7
Γ =386 ± 10

B) Leakage is free ??? !

Mass dependent PWA of ηπ0

1. Simultaneous fit of angular and mass distributions
2. Free BW parameters an leakage



M=1118 ± 21
Γ =477 ± 32

blue – leakage
red – BW contribution

We can't make the free leakage, but there is problem !!!

Lets calculate

$\mathbf{R=(D^{0}+D^{-})/D+}$

for

$\eta\pi^{0}$,

$\eta \rightarrow \pi+\pi- \pi^{0}$

The source of ambiguous solutions is UNP waves.

So we need to work with them in order to select the physical solution

For $a_2(1320)$

$D_+ \sim p^{-1}$,

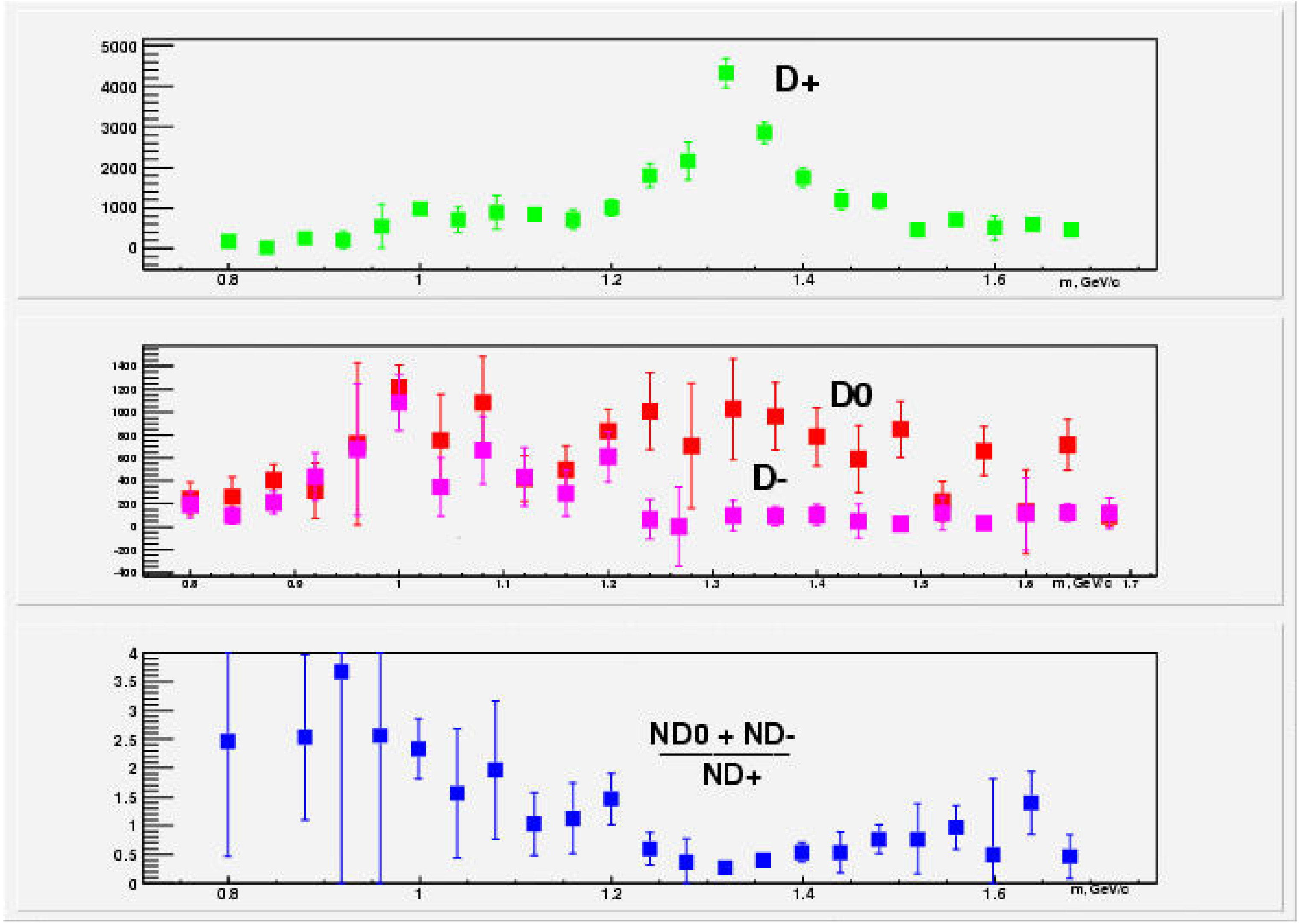
D_0, $D_- \sim p^{-2}$

$R=(D_0+D_-)/D_+$, $R(p) \sim p^{-1}$

p, GeV/c	Regge model	GAMS $\eta \to 2\gamma$	E852-IU $\eta \to 2\gamma$	E852 $\eta \to \pi^+\pi^-\pi^0$
38.	0.4	0.38 ±0.015		
18.	0.84		0.72 ± 0.12	**?**

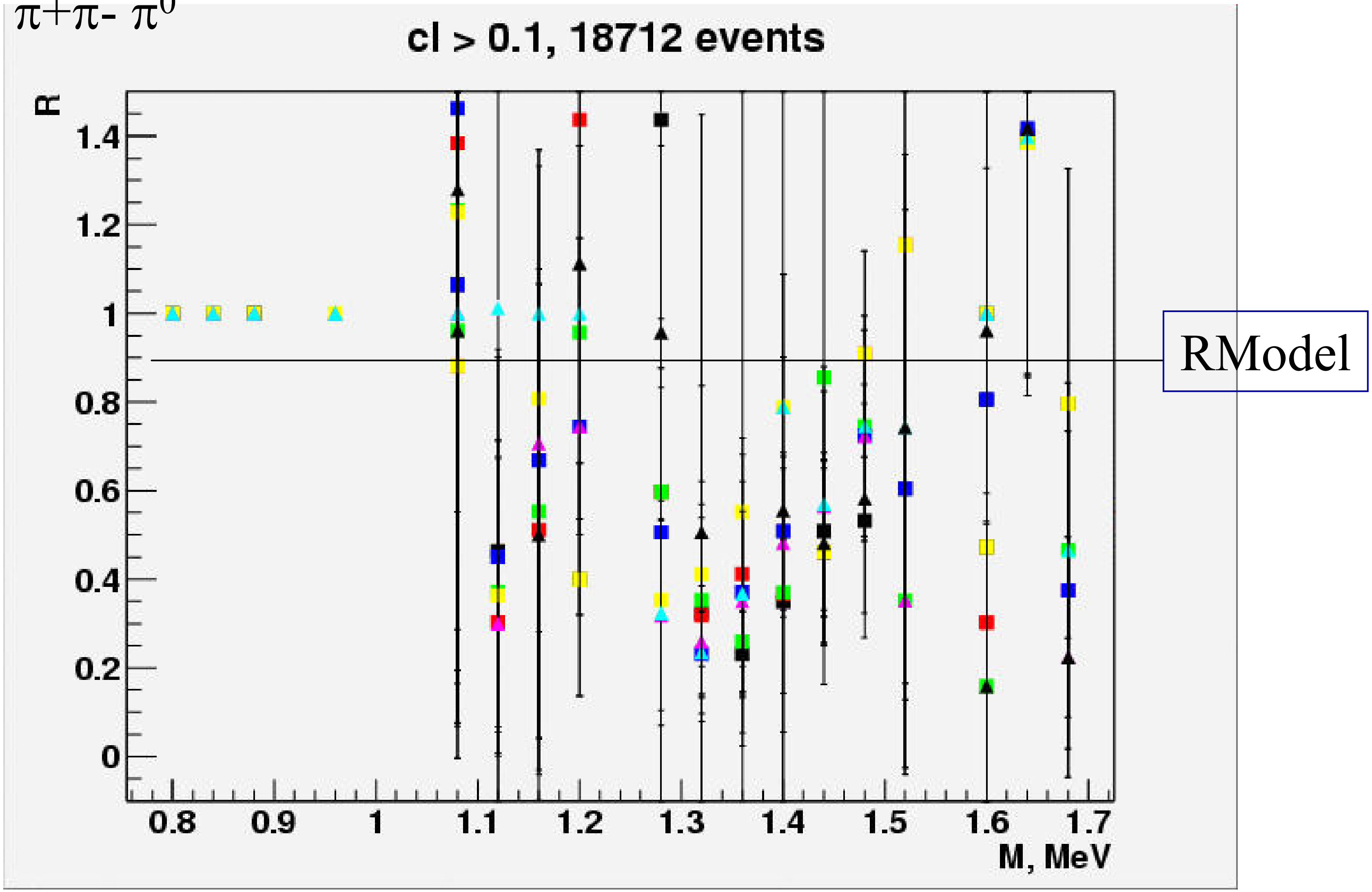
$\eta\pi^0$,
$\eta \to \pi^+\pi^- \pi^0$

One solution



$\eta\pi^0$,
$\eta \to \pi^+\pi^- \pi^0$

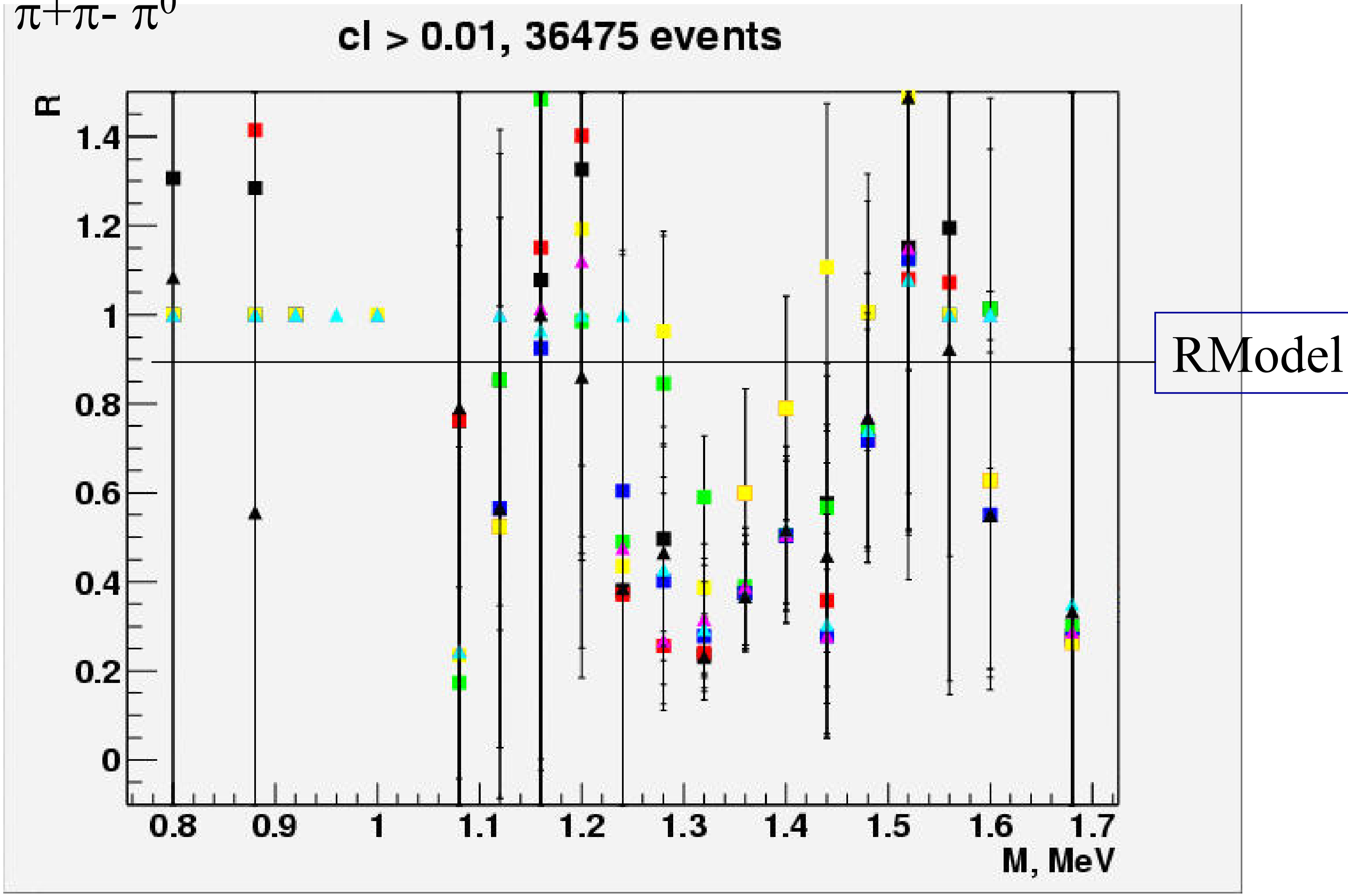
Ambiguous solution



$\eta\pi^0$,

$\eta \to \pi^+\pi^- \pi^0$

Ambiguous solution



Why

1. R is small ?
   → It depends on t– acceptance cut
2. R jumps up and down ?
   → Small statistic.

Why

π_1 (1400)$\rightarrow\eta\pi$ and not $\rightarrow \eta'\pi$

π_1 (1600)$\rightarrow\eta'\pi$ and not $\rightarrow \eta\pi$

S.U. Chung, E.Klempt, J.G.Korner, Eur.Phys.J.A15(2002)539

In the limit of flavor SU(3) conservation and by the requirement of Bose symmetrization

$$\pi, \eta \Rightarrow \{\text{Octet}\}_8$$

If $\{X\}_8 \rightarrow \{\eta\}_8 + \{\pi\}_8$, then $X = \eta\pi + \pi\eta$

$X=\pi_1\ (1400) \rightarrow [\eta\pi]_-$, $L=1$, $X = \eta\pi - \pi\eta$

So π_1 (1400) is not $\{\text{Octet}\}_8$, not Hybrid !!

$\pi_1(1600)$ may be $\{\text{Octet}\}_8$, $\{X\}_8 \rightarrow \{\eta'\}_1 + \{\pi\}_8$

Experimental results and interpretation

1^{-+}	$X \rightarrow \eta\pi$	$X \rightarrow \eta'\pi$	Interpretation
π_1 (1400)	+	–	Decuplet {4q}
π_1 (1600)	–	+	Hybrid

S.U. Chung, E.Klempt, J.G.Korner, Eur.Phys.J.A15(2002)539
S.U. Chung , E.Klempt, Phys.Lett. B563(2003)83

SU(3) Decomposition

$$8 \otimes 8 = 27 \otimes 10 \otimes 10 \otimes 8_1 \otimes 8_2 \otimes 1$$

Multiplet	J^{PC}	Composition
Singlet (1)	even $^{++}$	$\bar{q}q$, Hybrid, 4q
Symm.Octet(8_1) Antisym.Octet(8_2)	even $^{++}$ even $^{--}$	$\bar{q}q$, Hybrid, 4q $\bar{q}q$, Hybrid, 4q
Multiplet 17(10+ 10) Multiplet 17(10–10)	odd $^{-+}$ odd $^{--}$	4q, X(ζ=+1), X'(ζ=-1) 4q ,X(ζ=+1), X'(ζ=-1)
Multiplet 27	even $^{++}$	4q

S.U. Chung , E.Klempt, Phys.Lett. B563(2003)83

Nonstrange decays of multiplets X and X'

J^{PC}	[{a},{b}]	Decays	
1^{-+} 1^{-+}	$X(\zeta=+1) \rightarrow [\{a\},\{b\}]_+$ $X'(\zeta=-1) \rightarrow [\{a\},\{b\}]_-$	$[\eta]_8\pi$, $\rho[\omega]_8$ $\rho\pi$, $b_1\pi$	π_1 (1400) π_1'(1400)

If **1^{-+} bump ($\eta\pi^0$) is a true resonant state,**
then how to understand the different resonant masses in ($\eta\pi^-$) and **($\eta\pi 0$) systems ?**

J^{PC}	Production	Exchange by	Mass, MeV	Question
1^{-+} 1^{-+}	$\pi^- p \to \eta\pi^- p$ $\pi^- p \to \eta\pi^0 n$	f_2 ρ, b_1	1370 1280	Mass difference of X and X' ?

My comments on $\eta\pi^0$, $\eta \to \pi^+\pi^- \pi^0$

1. We have the good selection events
2. There is coincidence of IU and V.L. results for all t
3. There is the leakage problem
4. Selection of the physical solution
5. Watson phase for UNP wave and new PWA

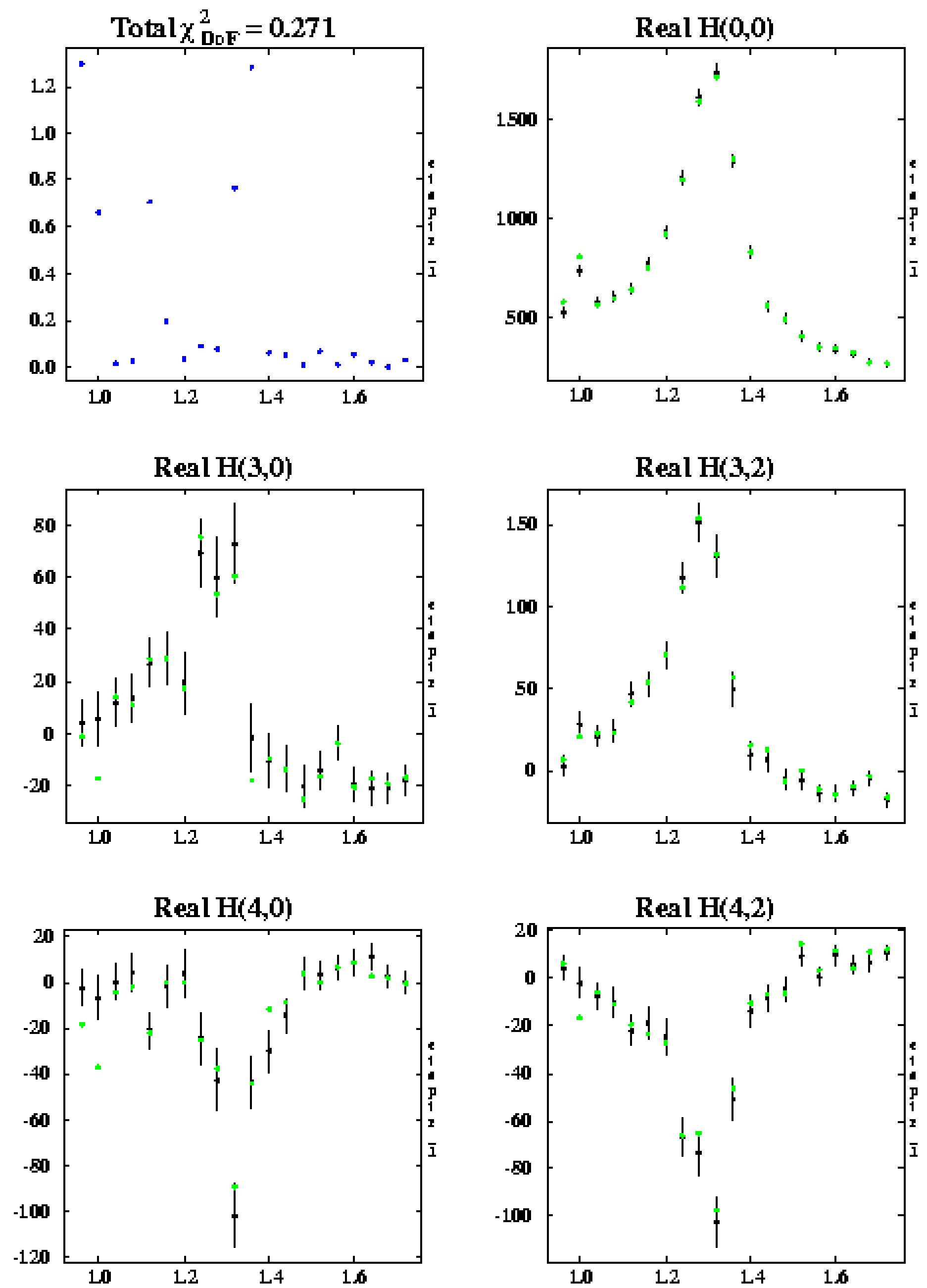
Comments

Continuation of $\eta\pi^0$ analysis

- Estimation of leakage with beam smearing
- Why don't we see $a_0(1320)$ in E852 as in GAMS
- Selection of the physical solution
- Exotic **$J^{PC}=1^{-+}$** in $\eta\pi^0$: **π_1(1400) or π_1'(1400)**

Outside slides

Goodness of fit $\eta\pi 0$



Goodness of fit