What and idiot like myself would like to do

Write fortran for
A(input=4-vectors,param; output=cmplx number)

Fit in several different ways, moments, data,projections, Dalitz plots

Change amplitudes frequently

Compare an arbitrary projection of the data with theory

Do it fast and use only a combination of fortran + point and click

Amplitudes are complicated and may take a long time to compute

What Would Geoffrey Say

Computation of “normalization integrals” is a computer science problem which must have a solution

Convergence after O(10) iterations <-> physics is correct

Amplitude parametrization : beyond the isobar model

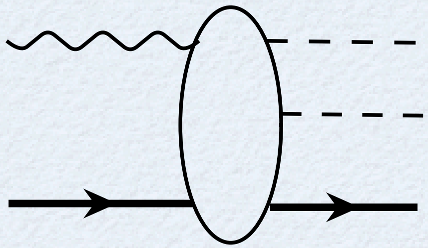
1. t-channel expansion

2. deficiencies of the isobar model

3. examples

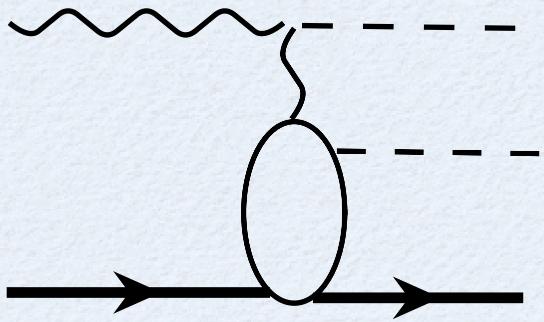
4. analysis plan

Amplitude factorization $\gamma p \to \pi^+ \pi^- p$

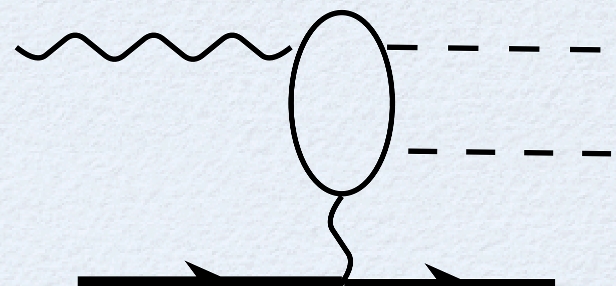


$s/t >> 1$

= sum of t-channel processes



exchange + reggions
(Delta production)

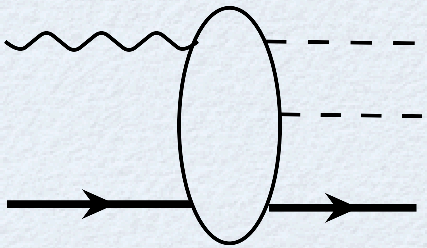


isobar model = particular approximation to this type of amplitudes

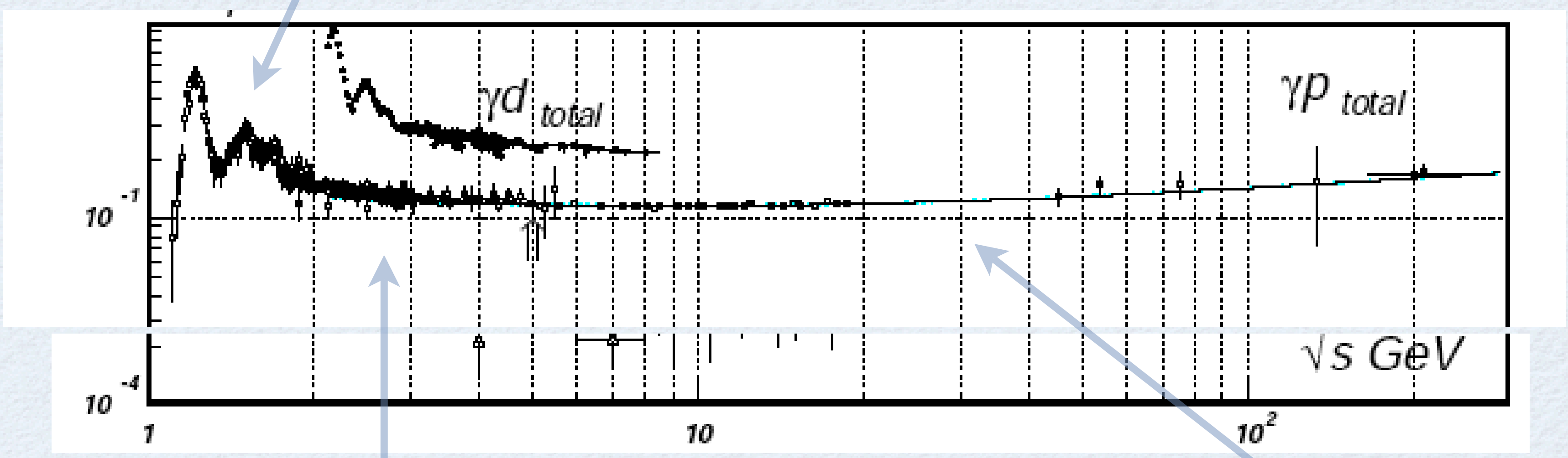
What characterizes t-channel amplitudes is that the s-dependence factorizes (unlike in baryon resonance production)

Justification for t-channel expansion

$$\gamma p \to \pi^+ \pi^- p$$



Resonance region

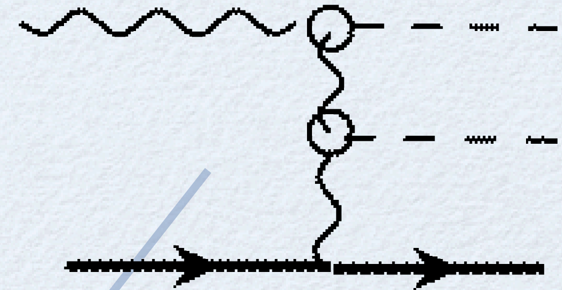


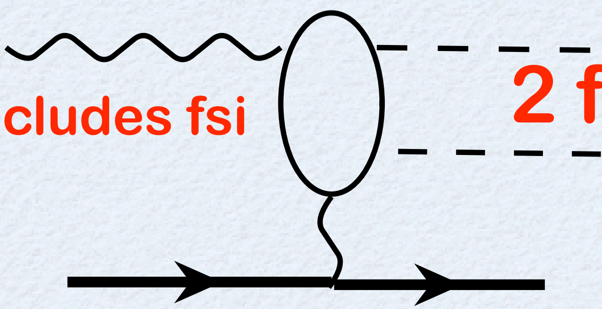
$$E_\gamma = 3 \text{ GeV} \to \sqrt{s} = 2.5 \text{ GeV}$$

Pomeron

Dual description, in terms of (t-channel) forces is appropriate outside the resonance region

What does isobar model miss

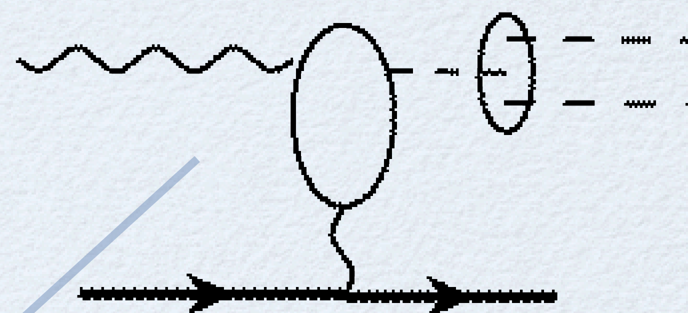




includes fsi

2 fast

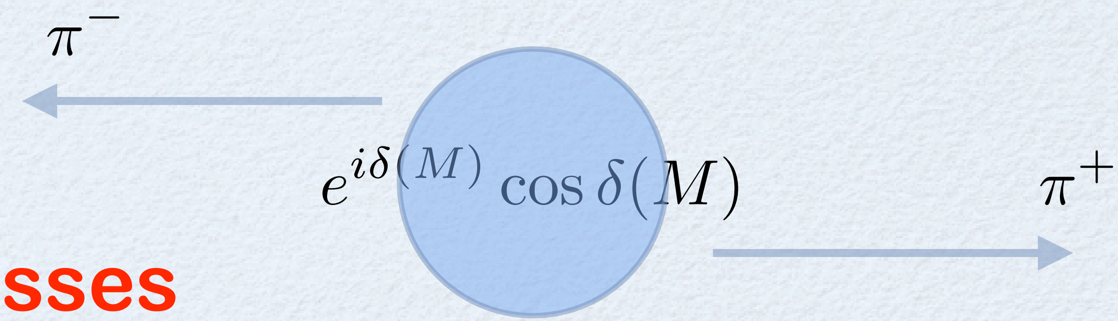
leading (Pomeron)



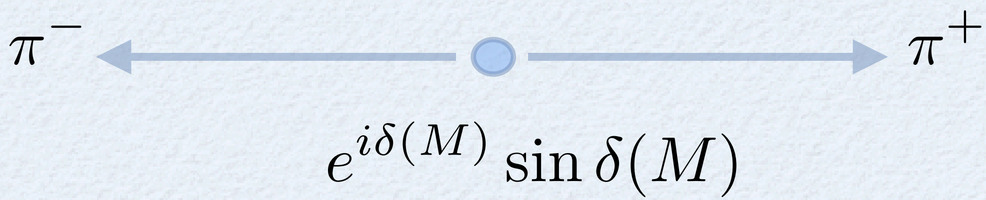
$$Ae^{i\delta}\cos\delta + Be^{i\delta}\sin\delta$$

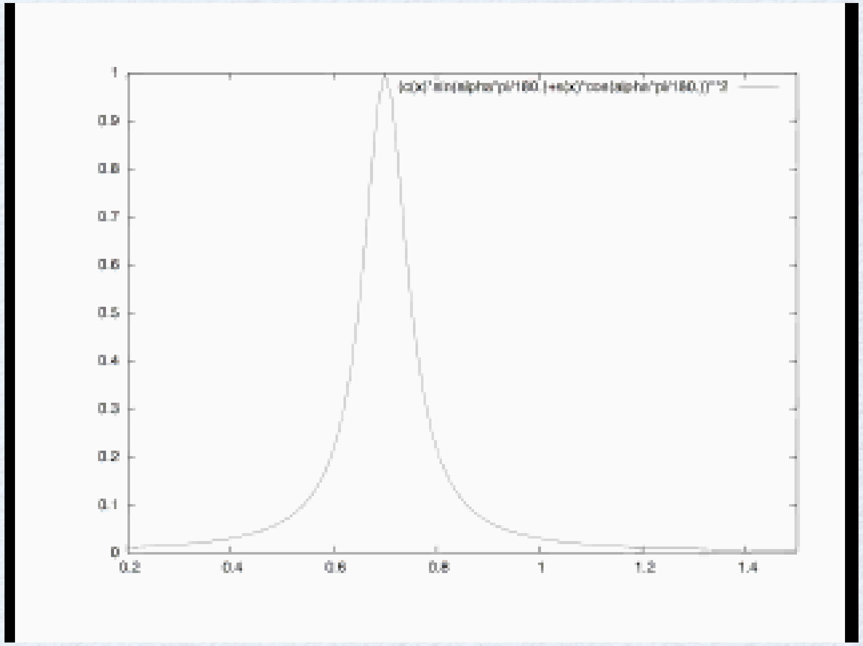
in a single partial wave

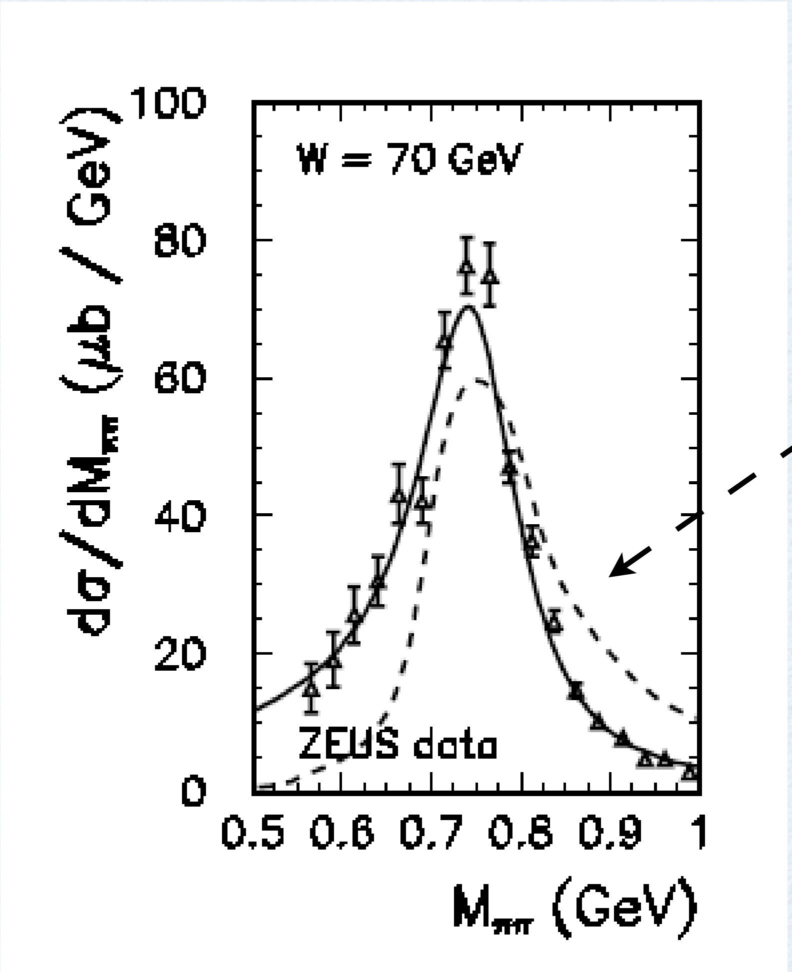
Inelastic processes can produce resonances directly !

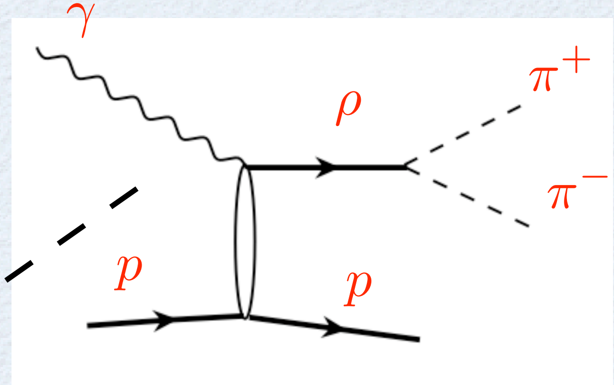


Diffuse source suppresses resonance production (Watson theorem)

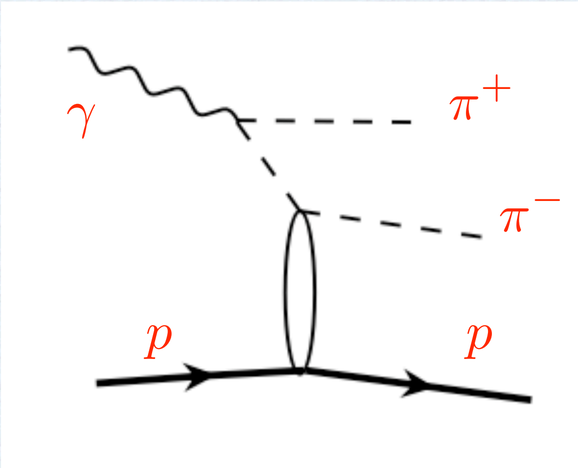








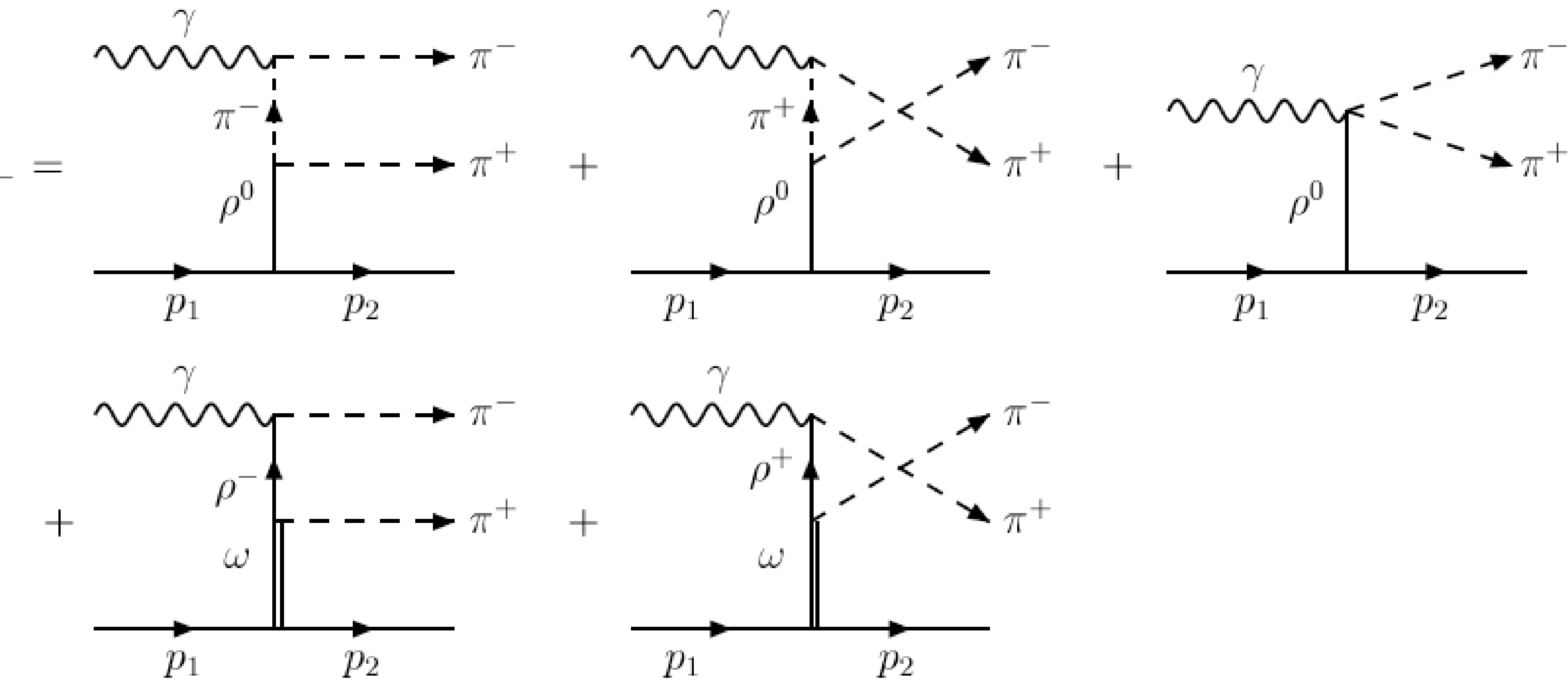
Inelastic diffraction, (W > 2 GeV)



$\sigma(\pi^+ p \to \pi^+ p) \neq \sigma(\pi^- p \to \pi^- p)$

A.Szczurek, AS.

Born diagrams of the $\pi^+\pi^-$ photoproduction in the S-wave



...when applied to KK photo-production

1. DESY (1978) $E_\gamma = 4.6 - 6.7$ GeV
   $|t| < 0.2$ GeV^2

   total photoproduction S-wave cross section

   $$\sigma_S = (2.7 \pm 1.5) nb$$

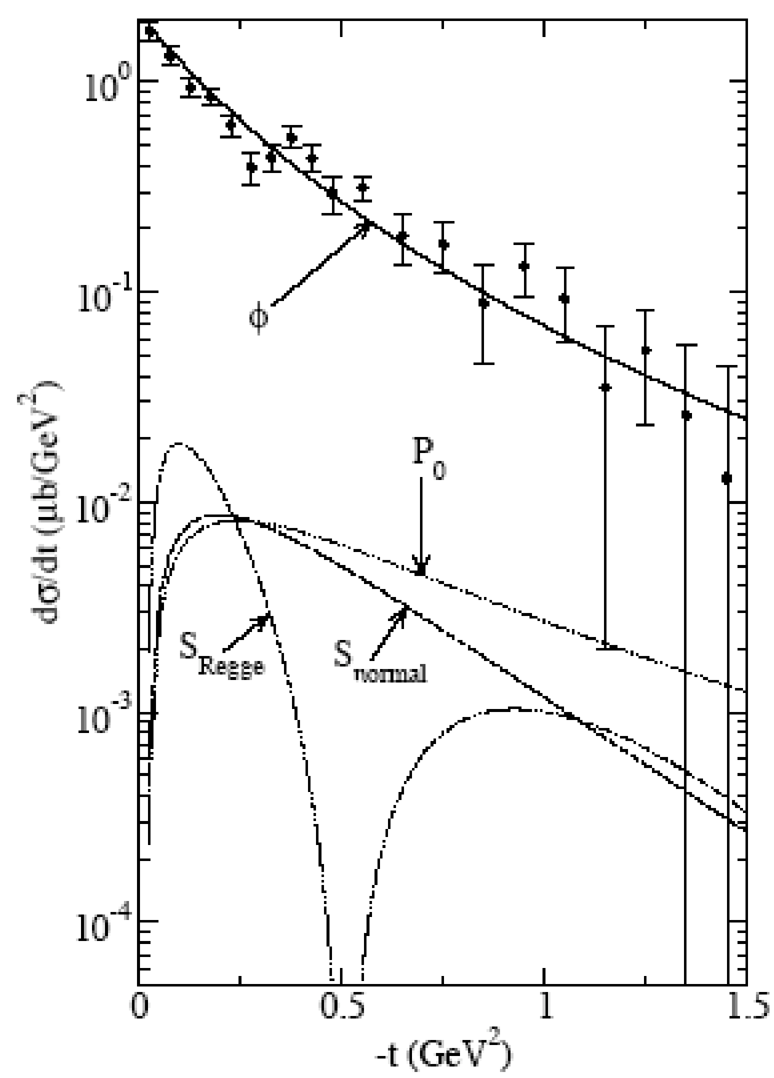
2. Daresbury (1982) $E_\gamma = 2.8 - 4.8$ GeV
   $|t| < 1.5$ GeV^2

   total photoproduction S-wave cross section

   $$\sigma_S = (96 \pm 20) nb$$

   for the resonant component

Differential cross section at 4 GeV



Partial Wave decomposition cont.

$$\mathrm{Ampl} = \sum_{LM} T^L_M(E_\gamma, t, M; \lambda, s_1, s_2) Y_{LM}(\Omega)$$

$$I(\Omega) = \sum_{\lambda=\pm, s_1, s_2=\pm\frac{1}{2}} |\mathrm{Ampl}(\lambda, s_1, s_2)|^2$$

e.g. with S and P waves only

$$\langle Y^0_0 \rangle = \frac{\mathcal{N}}{\sqrt{4\pi}} \left(|S|^2 + |P^2_+| + |P^2_-| + |P^2_0|\right),$$

$$\langle Y^1_0 \rangle = \frac{\mathcal{N}}{\sqrt{4\pi}} \left(SP^*_0 + S^* P_0\right), \quad \langle Y^1_1 \rangle = \frac{\mathcal{N}}{\sqrt{4\pi}} \left(P_+ S^* - SP^*_-\right),$$

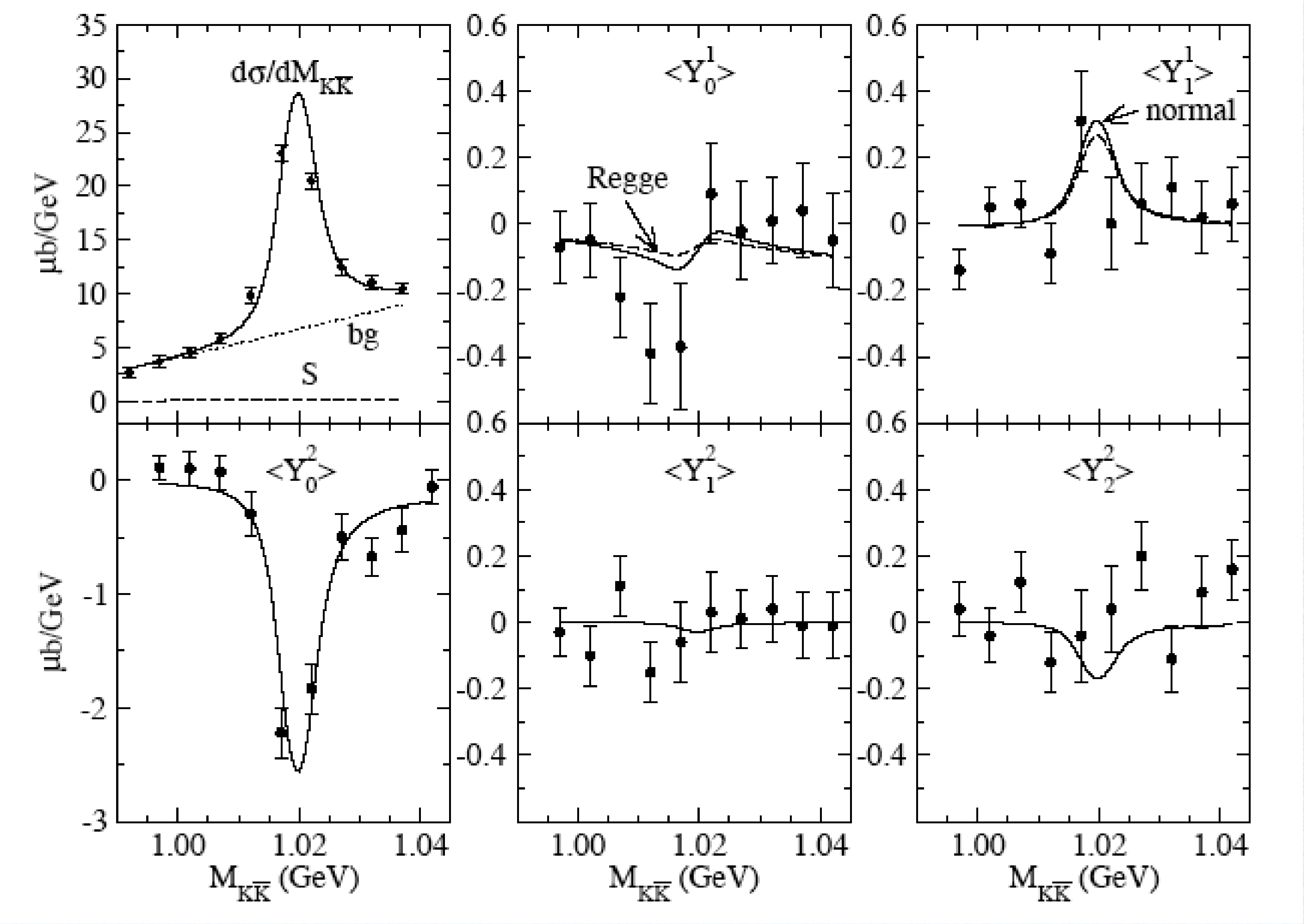
$$\langle Y^2_0 \rangle = \frac{\mathcal{N}}{\sqrt{4\pi}} \sqrt{\frac{1}{5}} \left(2P_0 P^*_0 - P_+ P^*_+ - P_- P^*_-\right),$$

$$\langle Y^2_1 \rangle = \frac{\mathcal{N}}{\sqrt{4\pi}} \sqrt{\frac{3}{5}} \left(P_+ P^*_0 - P_0 P^*_-\right), \quad \langle Y^2_2 \rangle = \frac{\mathcal{N}}{\sqrt{4\pi}} \sqrt{\frac{6}{5}} \left(-P_+ P^*_-\right).$$

Notation

$$SP^*_0 = \sum_{\lambda, s_1, s_2} T^0_0(\lambda, s_1, s_2) {T^1_0}^*(\lambda, s_1, s_2)$$

Fit to Daresbury, 4GeV data



Integrated cross sections in nb

photon energy	4 GeV		5.65 GeV	
S-wave propagator	normal	Regge	normal	Regge
sum of all P-waves	218.4 ± 39.5		120.5 ± 9.4	
P_0-wave	$6.4^{+5.5}_{-4.8}$	$4.7^{+5.7}_{-4.5}$	$13.8^{+5.3}_{-4.7}$	$14.0^{+5.3}_{-4.8}$
S-wave	$4.9^{+5.8}_{-3.6}$	$4.3^{+6.6}_{-3.6}$	$7.0^{+6.8}_{-4.4}$	$6.8^{+6.6}_{-4.3}$
background	$299.4^{+10.0}_{-10.4}$	$300.0^{+10.0}_{-10.7}$	$4.5^{+4.3}_{-6.1}$	$4.7^{+4.2}_{-5.8}$
$\|t\|_{max}$	1.5 GeV^2		0.2 GeV^2	
$M_{K\overline{K}}$ range	(0.997,1.042) GeV		(1.01,1.03) GeV	

Important result: 4 nb $< \sigma_S < 7$ nb for $4 < E_\gamma < 7$ GeV.

Recall: Daresbury estimation was $\sigma_S = 96$ nb.

3pi Deck

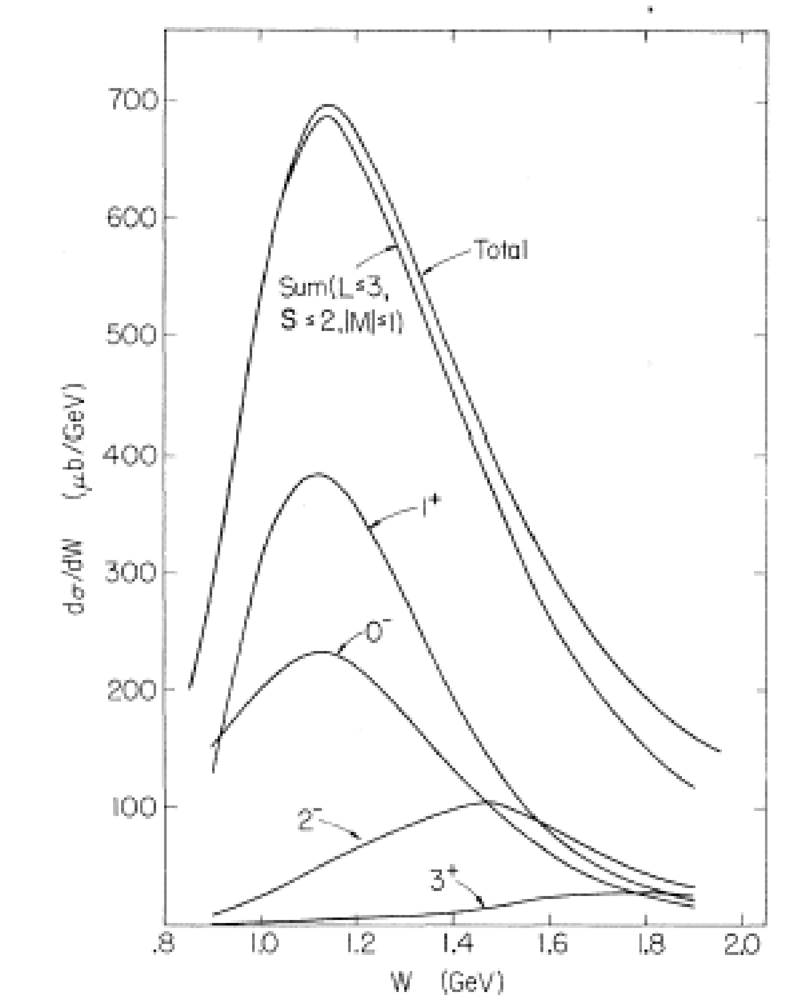
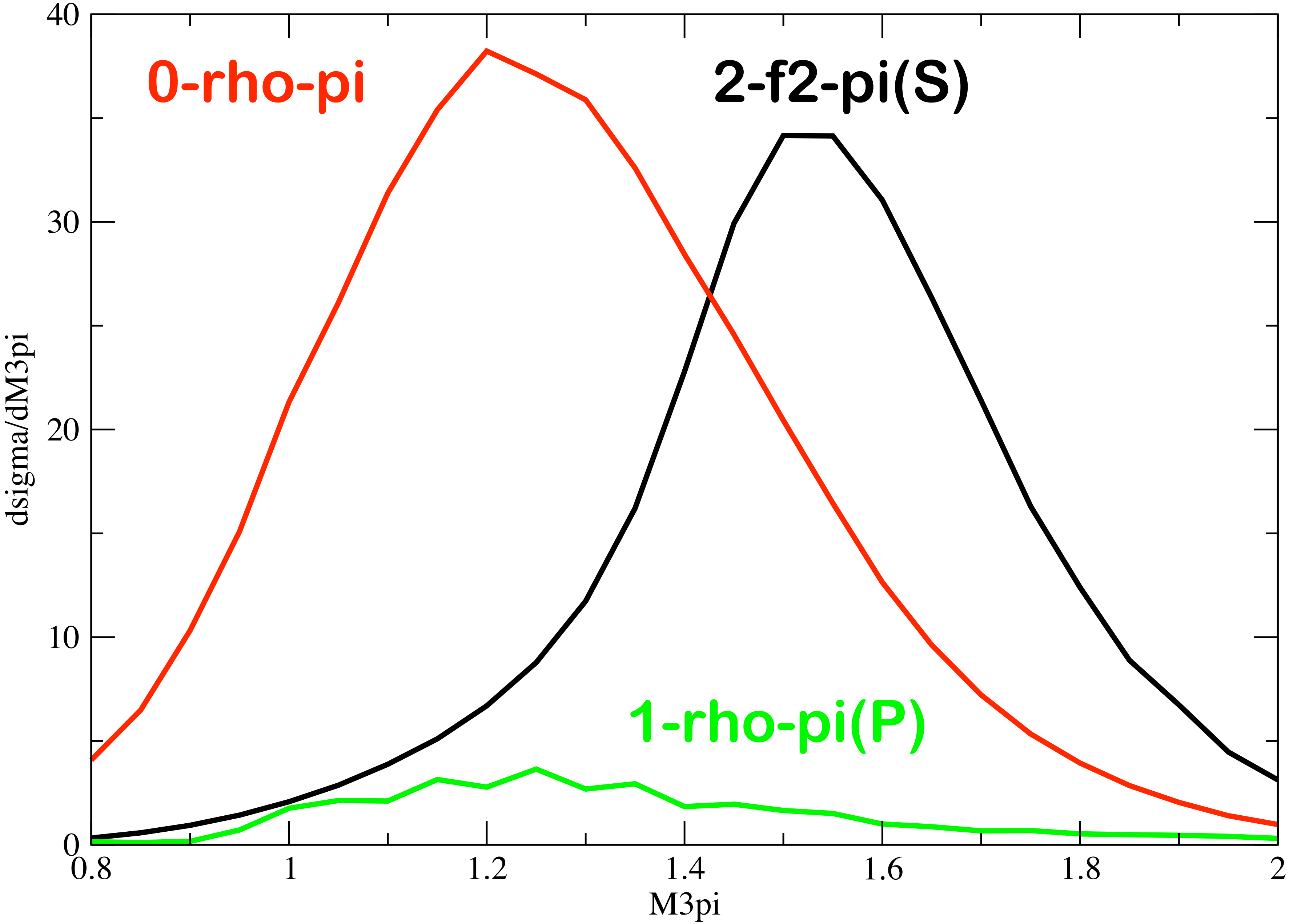


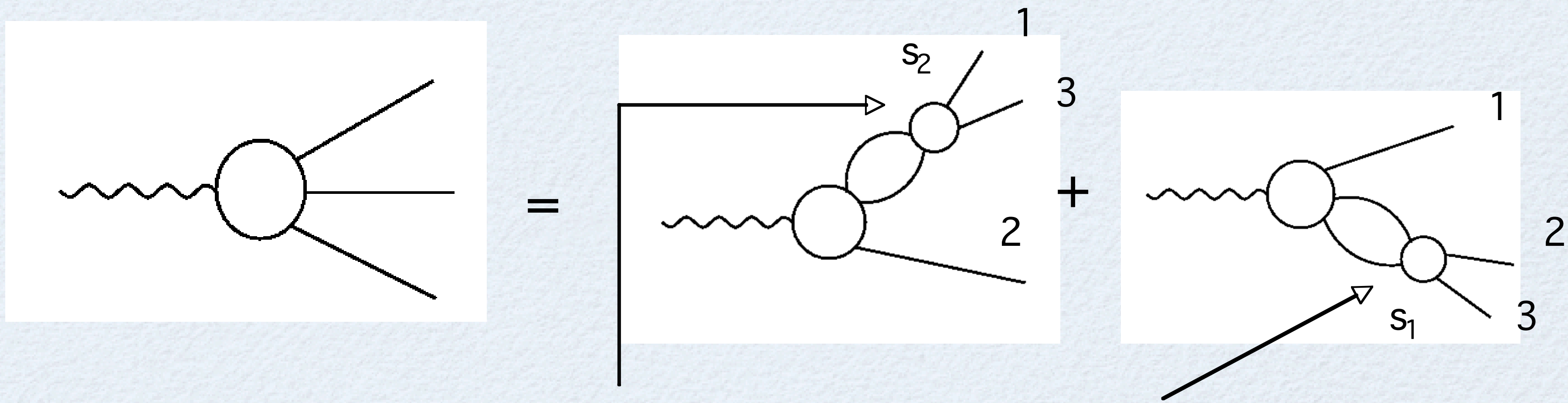
FIG. 7. Cross sections for the dominant J^P states, and the sum of cross section contributions for low L, S, and J are compared with the total cross section obtained by Monte Carlo summation. $P_{lab} = 16$ GeV/c. Only amplitudes with $M < 2$ and only the nucleon helicity combination $F_{++} + F_{--}$ are used in calculating the contributions of definite J.

Ascoli & Wyld

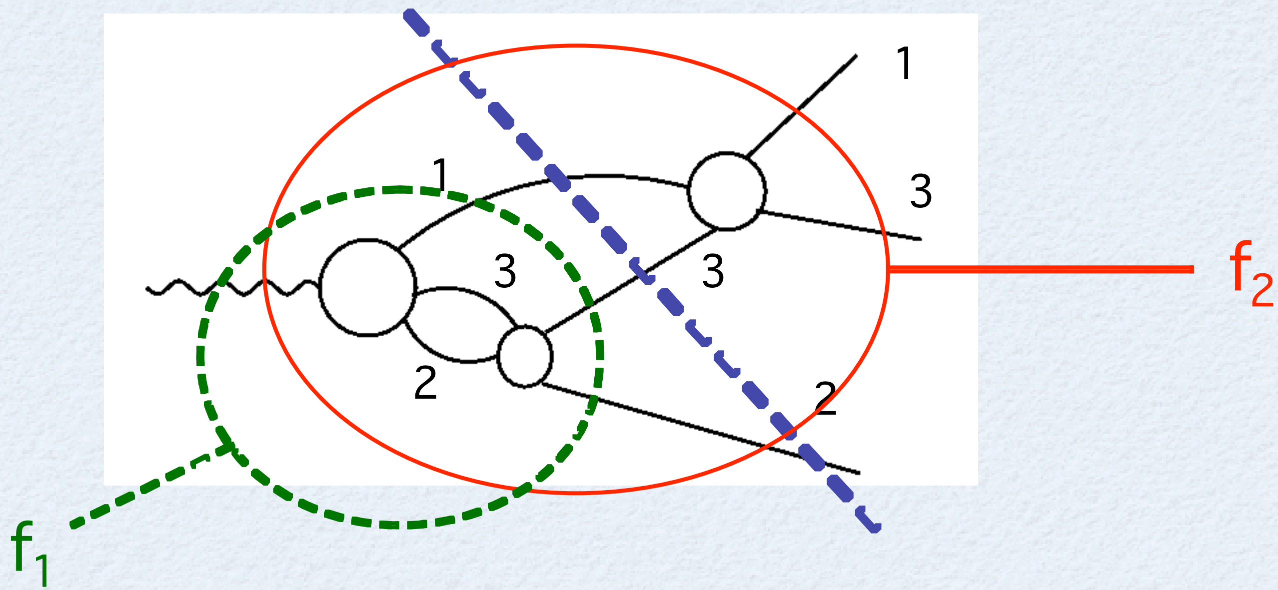
TABLE I. Partial-wave amplitudes at $P_{lab} = 16$ GeV/c ($s = 30.9$ GeV^2), $t'_{NN} = -0.05$ (GeV/c)^2, $W = 1.1$ GeV, $s_1^{1/2} = 0.820$ GeV.

Quantum numbers of partial waves					$\frac{1}{2}(F_{++}+F_{--})$		$\frac{1}{2}(F_{+-}-F_{-+})$		$\frac{1}{2i}(F_{++}-F_{--})$		$\frac{1}{2i}(F_{+-}+F_{-+})$	
J	P	M	L	S	Magnitude[a]	Phase	Magnitude	Phase	Magnitude	Phase	Magnitude	Phase
0	−	0	0	0	20.12	129°	1.36	66°	0		0	
1	+	0	1	0	4.70	46°	0.32	74°	0		0	
1	+	1	1	0	2.46	129°	0.11	6°	0.09	−163°	0.01	17°
2	−	0	2	0	0.82	76°	0.45	101°	0		0	
2	−	1	2	0	0.99	123°	0.19	− 69°	0.05	−174°	0.01	6°
1	+	0	0	1	34.07	129°	2.30	67°	0		0	
1	+	1	0	1	0.65	− 51°	0.03	178°	0.02	16°	0.00	−164°
0	−	0	1	1	7.18	170°	0.09	5°	0		0	
1	−	1	1	1	3.10	129°	0.14	− 8°	0.11	−164°	0.02	16°
2	−	0	1	1	8.11	76°	0.70	69°	0		0	


0-rho-pi
2-f2-pi(S)
1-rho-pi(P)
dsigma/dM3pi
M3pi
0
10
20
30
40
0.8
1
1.2
1.4
1.6
1.8
2



B-W : unitary in sub-channel energy



Has to depend on 2-particle energy

$f_i = f_i(s_i, M)$

$$f_2(s_{2+}) - f_2(s_{2-}) = 2i\rho(s_2)\ \mathrm{P.V.} \int f_1(s_1)/D_1(s_1)$$

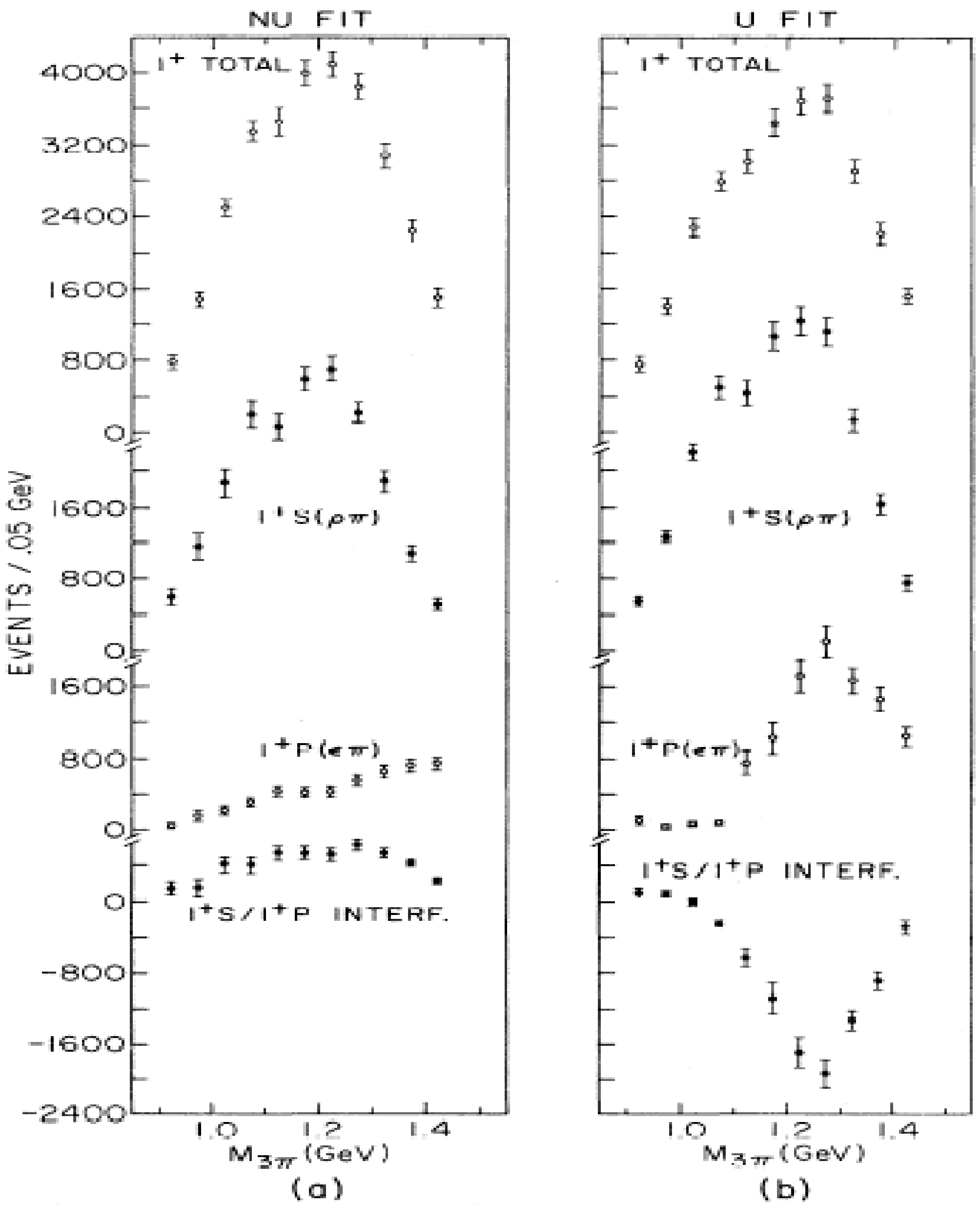


FIG. 9. Comparison of NU (nonunitarized) and U (unitarized fits to the Serpukhov data (Refs. 8 and 9). The number of events per 0.05 GeV is shown for total $J^P = 1^+$, $1^+S(\rho\pi)$, $1^+P(\epsilon\pi)$, and 1^+S-1^+P interference. (a) nonunitarized fits and (b) unitarized fits.

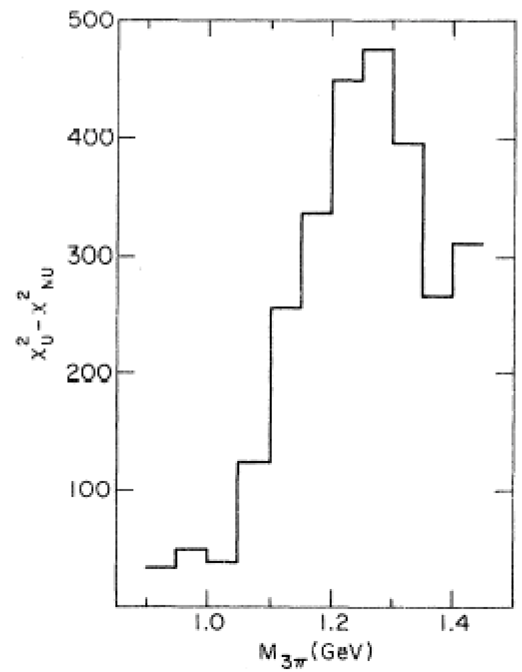


FIG. 7. χ^2 difference between U (unitarized) and NU (nonunitarized) fits to the Serpukhov data (Refs. 8 and 9).