Status of the $\pi^0\pi^0\gamma$ analysis

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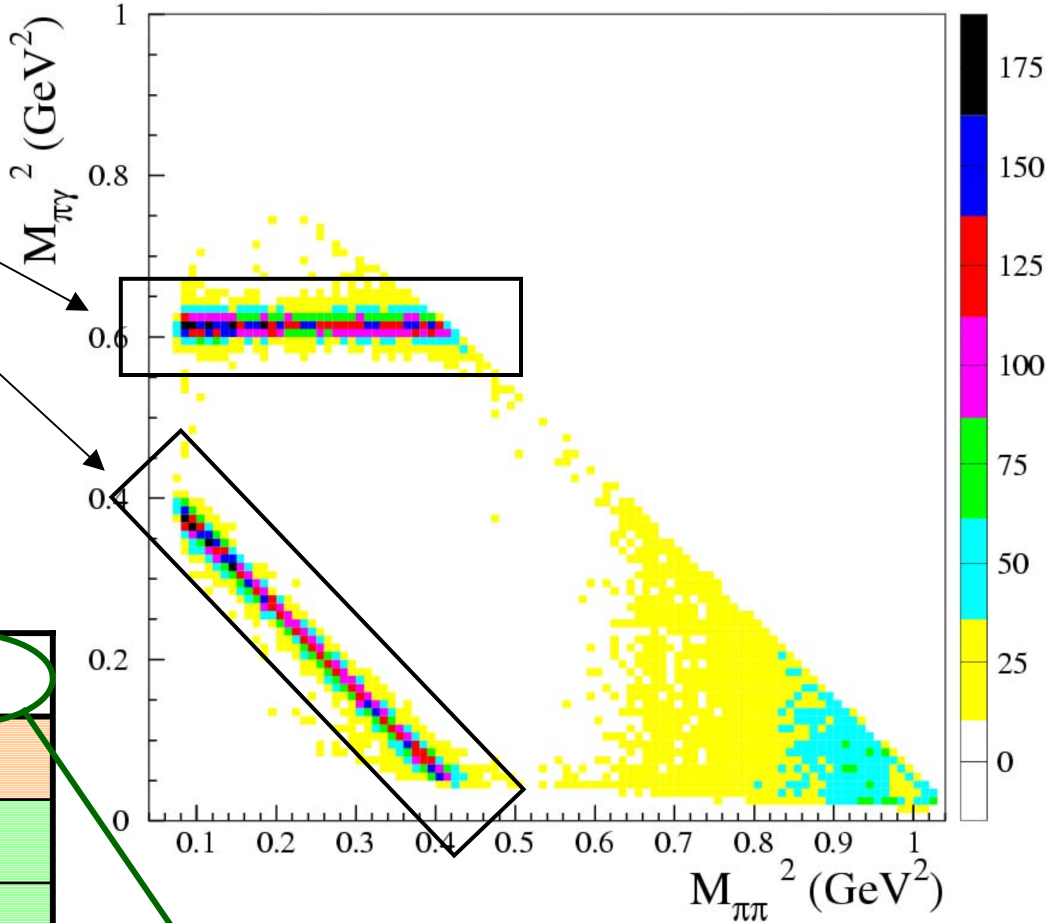
ϕ decays meeting – 22 Feb 2005

Composition of the $\pi^0\pi^0\gamma$ final state

Two main contributions to $\pi^0\pi^0\gamma$ final state @ M_ϕ:

1. $e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$
   $\sigma_{vis}(M_\phi) \sim 0.5$ nb

2. $\phi \to S\gamma \to \pi^0\pi^0\gamma$
   $\sigma_{vis}(M_\phi) \sim 0.3$ nb



Backgrounds:

Process	S/B
$\phi \to a_0\gamma \to \eta\pi^0\gamma \to \gamma\gamma\pi^0\gamma$	8.51
$\phi \to \eta\gamma \to \pi^0\pi^0\pi^0\gamma$	0.06
$\phi \to \eta\gamma \to \gamma\gamma\gamma$	0.06
$\phi \to \pi^0\gamma$	0.21
$e^+e^- \to \gamma\gamma(\gamma)$	0.002

S= $\omega\pi$ + $S\gamma$

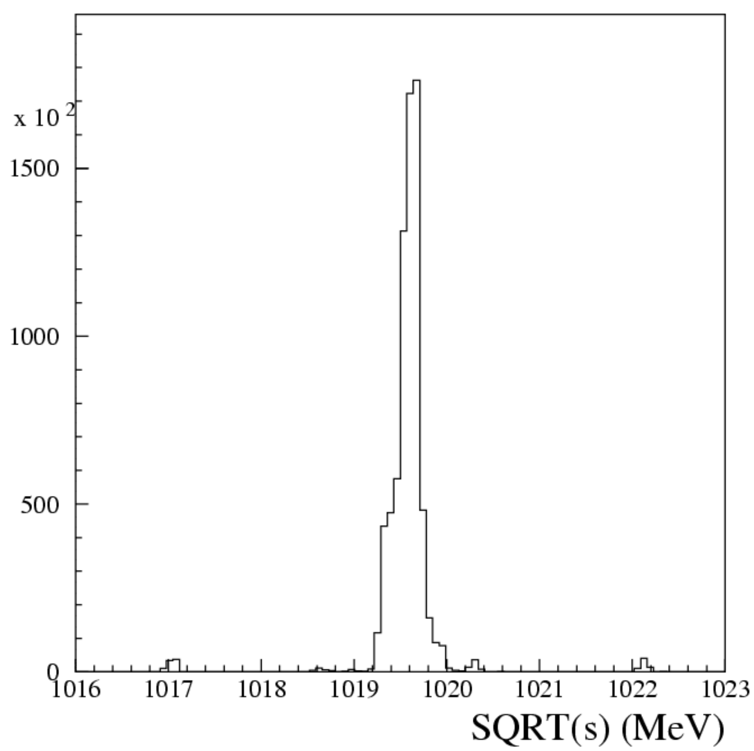
Data and Montecarlo samples

DATA

2001+2002 data : $\mathbf{L_{int} = 450\ pb^{-1}}$

Data have some spread aroud the ϕ peak + two dedicated off-peak runs @ 1017 and 1022 MeV $\Rightarrow$

Data divided in 100 keV bins of $\sqrt{s}$



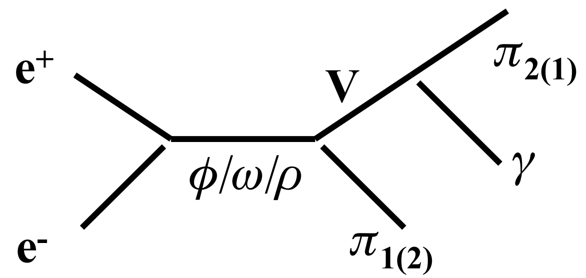
MC

RAD04 MC production: $\mathbf{5 \times L_{int}}$

GG04 MC production: $\mathbf{1 \times L_{int}}$

Improved $e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$ generator

Three body phase space according to VDM from NPB 569 (2000), 158



Sample preselection and kinematic fit

1. **Acceptance** cut:
   5 neutral clusters in TW with $E > 7$ MeV and $|\cos\theta|<0.92$
   [TW: $|T_{cl}-R_{cl}/c| < MIN(5\sigma_T, 2 \text{ ns})$]

2. **Kinematic fit** requiring 4-momentum conservation
   and the "promptness" of γ's ($T_{cl}-R_{cl}/c = 0$)

3. **Pairing**: best γ's comb. for the $\pi^0\pi^0\gamma$ hypothesis

4. **Kinematic fit** for both γ's pairing, requiring also
   constraints on π masses of the assigned $\gamma\gamma$ pairs

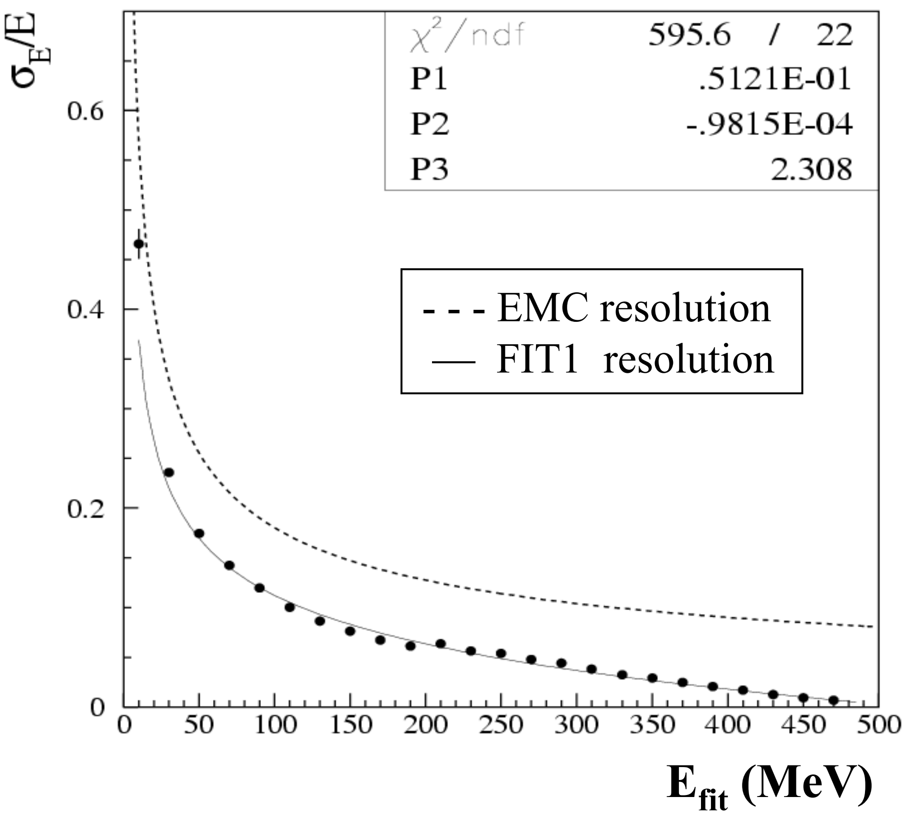
γ's pairing

π^0 mass resolution parametrized as a function of the γ's energy resolution after kinematic fit:

$$\sigma_M/M = 0.5\ (\ \sigma_{E_1}/E_1 \oplus \sigma_{E_2}/E_2\ )$$

Fit function for energy resolution:

$$\sigma_E/E = (\ P_1 + P_2\ E\ )\ /\ E[GeV]^{P_3}$$



The photon combination that minimize the following χ^2 is chosen:

$$\chi^2 = (M_{\gamma_i\gamma_j} - M_\pi)/\sigma_{M_{ij}} + (M_{\gamma_k\gamma_l} - M_\pi)/\sigma_{M_{kl}}$$

Analysis cuts

1. e^+e^- ? $\gamma\gamma$ rejection using the two most energetic clusters of the event: $\mathbf{E_1+E_2 > 900}$ **MeV**

2. $\gamma\gamma\gamma$+accidentals background rejection: $\mathbf{E_\gamma}$**(Fit2) > 7 MeV**

3. Cut on 2nd kinematic fit: $\chi^2_{\mathrm{Fit2}}/\mathrm{ndf} < 3$

4. Cut on π masses of the assigned $\gamma\gamma$ pairs: $|M_{\gamma\gamma} - M_\pi| < 5\sigma_M$

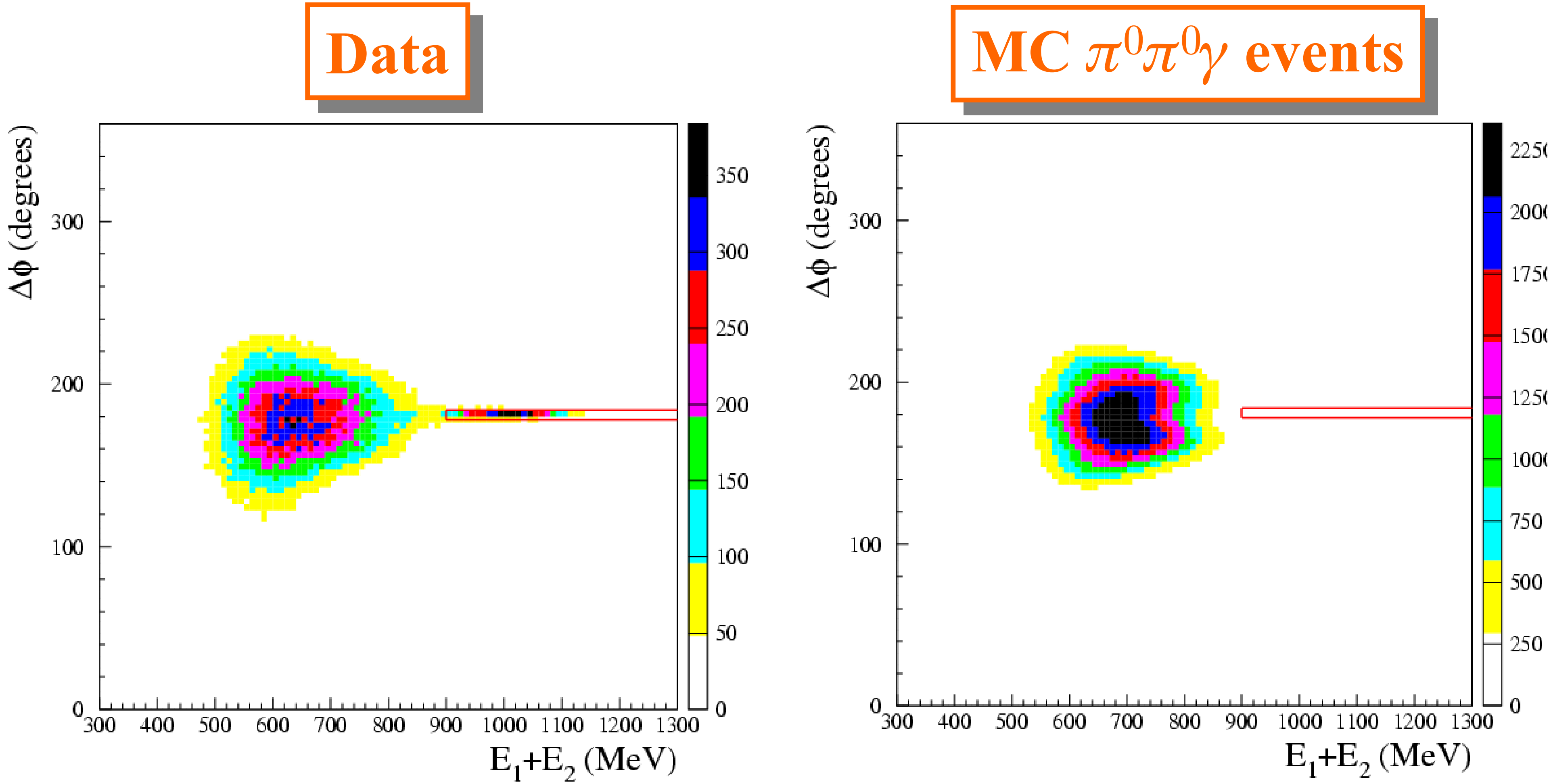
Process	$\varepsilon_{\mathrm{ana}}$	S/B
$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$	50.1 %	-
$\phi \to S\gamma \to \pi^0\pi^0\gamma$	36.8 %	-
$\phi \to a_0\gamma \to \eta\pi^0\gamma \to \gamma\gamma\pi^0\gamma$	7.0 %	22.9
$\phi \to \eta\gamma \to \pi^0\pi^0\pi^0\gamma$	0.3 %	**8.9**
$\phi \to \eta\gamma \to \gamma\gamma\gamma$	5.4×10^{-4}	50.0
$\phi \to \pi^0\gamma$	1.5×10^{-4}	606.2
$e^+e^- \to \gamma\gamma(\gamma)$	0.7×10^{-4}	1048.2

- ✓ S= $\omega\pi + S\gamma$
- ✓ $\varepsilon_{\mathrm{ana}}(S\gamma)$ obtained using the 2000 data $M_{\pi\pi}$ shape

$e^+e^- \to \gamma\gamma$ rejection

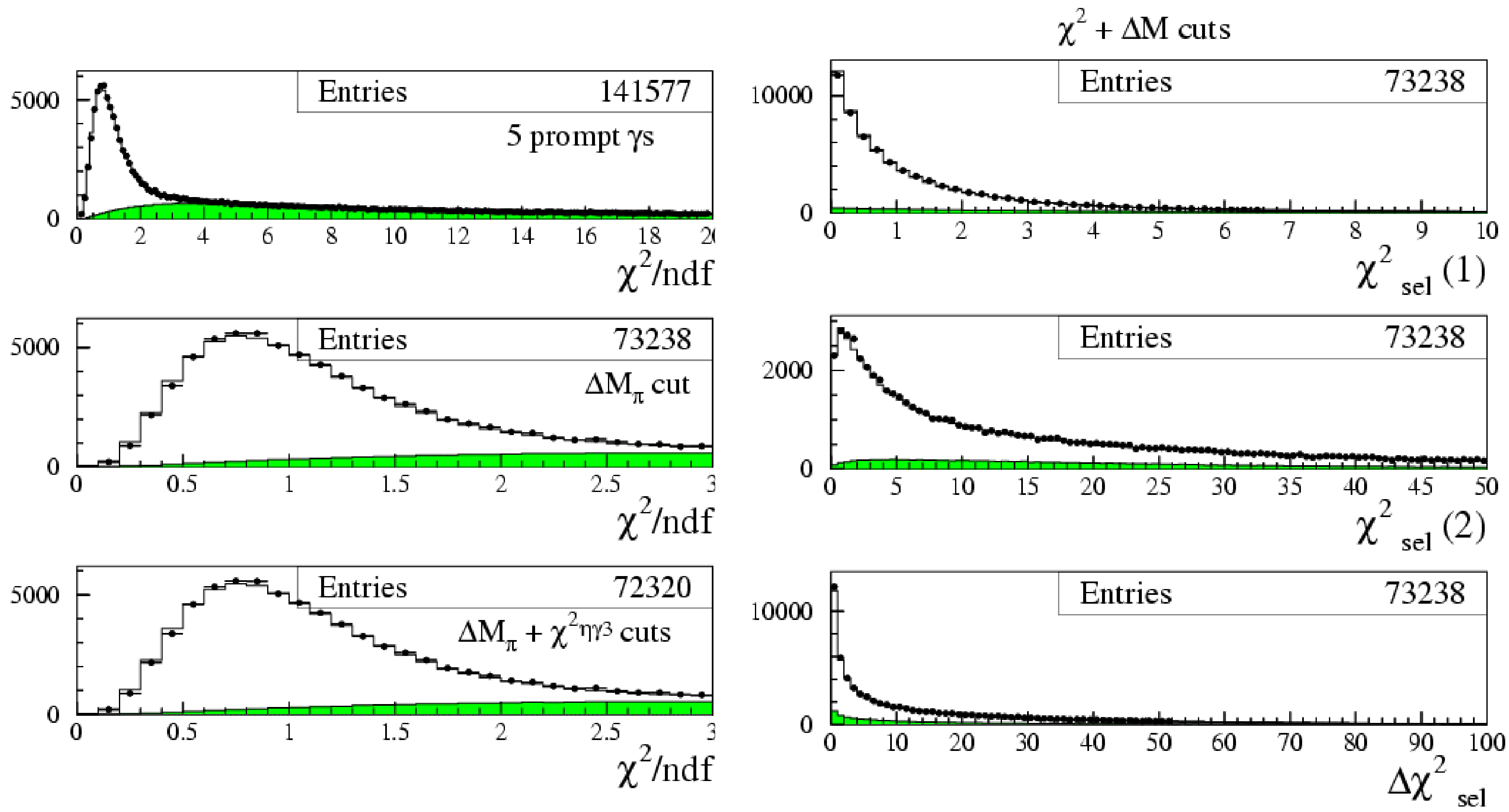
$e^+e^- \to \gamma\gamma$ rejection done using the two most energetic clusters of the event:

$E_1+E_2 > 900$ MeV



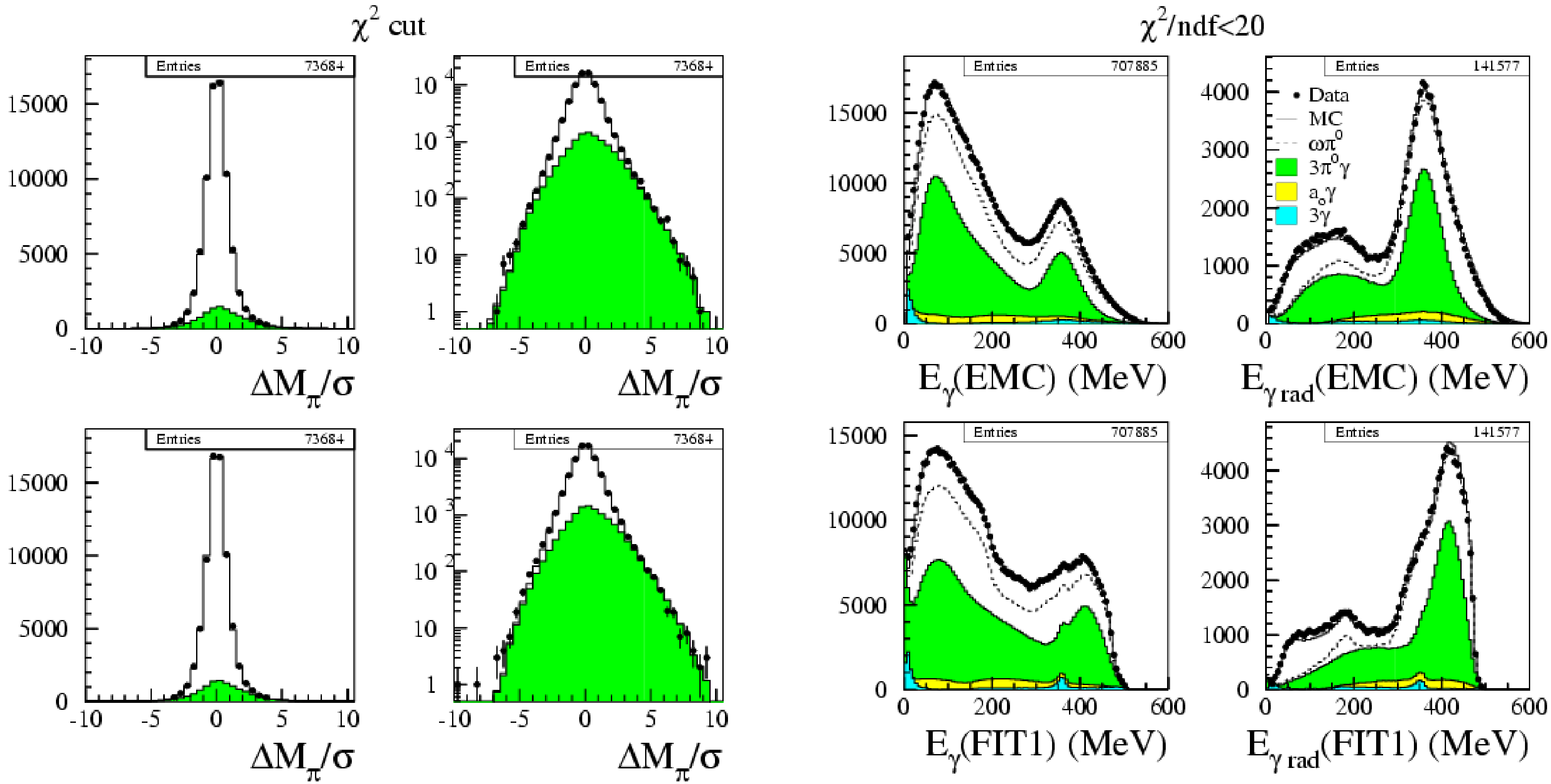
Dalitz plot analysis: data-MC comparison (I)

Analysis @ $\sqrt{s}$ = 1019.6 MeV (L_{int} = 145 pb^{-1})



Dalitz plot analysis: data-MC comparison (II)

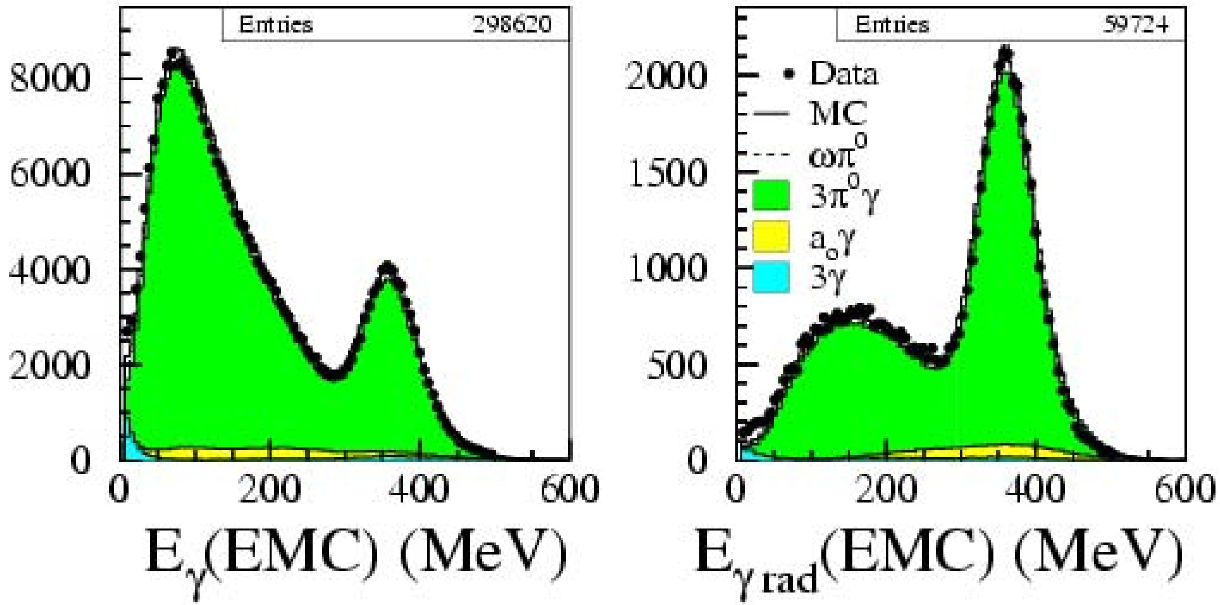
Analysis @ "s = 1019.6 MeV (L_{int} = 145 pb^{-1})



Background study for Dalitz plot analysis (I)

In order to study the systematics connected to the background subtraction we found for each category a distribution "background dominated" to be fitted

- $\phi \rightarrow \eta\gamma \rightarrow \pi^0\pi^0\pi^0\gamma$ (most relevant bckg contribution)
  - Background enriched sample : $4 < \chi^2/\text{ndf} < 20$

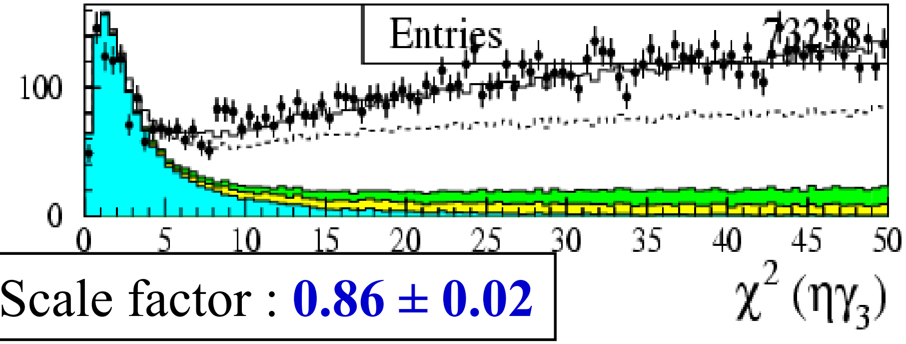


Scale factor :
1.0156 ±0.0002

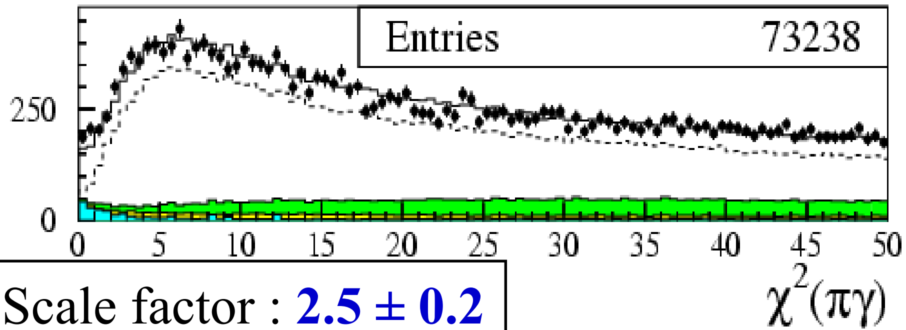
All of this fit results are used to evaluate the systematics on the background counting : half of the difference (1 – scale factor) is used

Background study for Dalitz plot analysis (II)

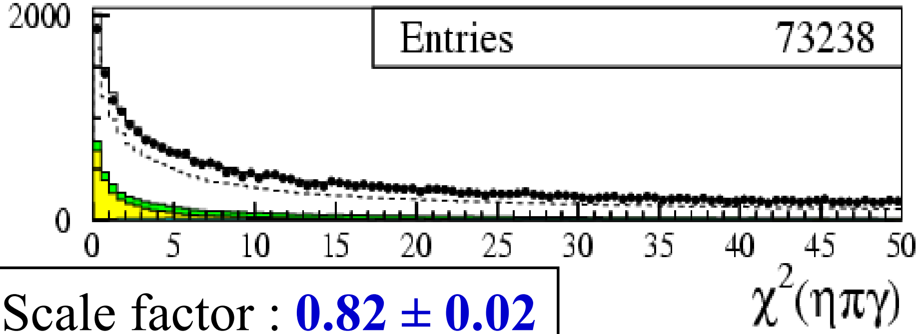
For $\phi \to \eta\gamma \to \gamma\gamma\gamma$, $\phi \to \pi^0\gamma$, $\phi \to a_0\gamma$
we calculate a χ^2 in the mass hypothesis



Scale factor : **0.86 ± 0.02**

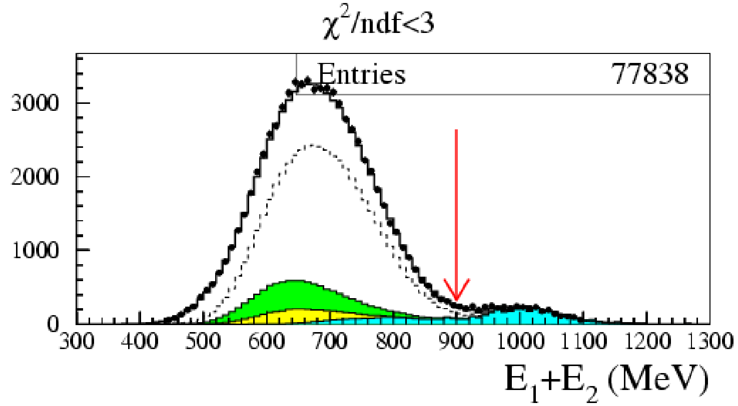


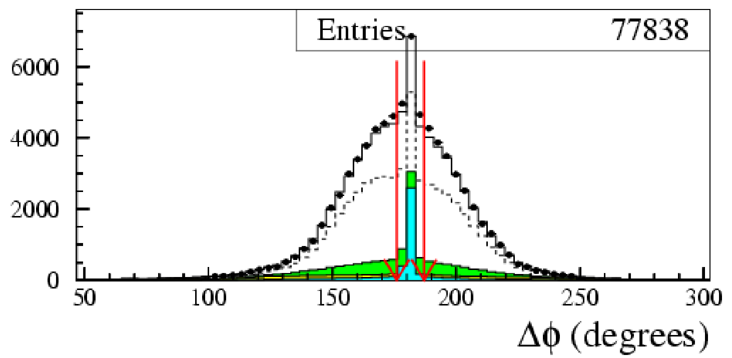
Scale factor : **2.5 ± 0.2**



Scale factor : **0.82 ± 0.02**

For $e^+e^- \to \gamma\gamma$, we fit the $\Delta\phi$ distribution for χ^2/ndf < 3 (and no $\gamma\gamma$ rejection cut)





Scale factor : **1.85 ± 0.03**

Dalitz plot @ √s=1019.6 MeV

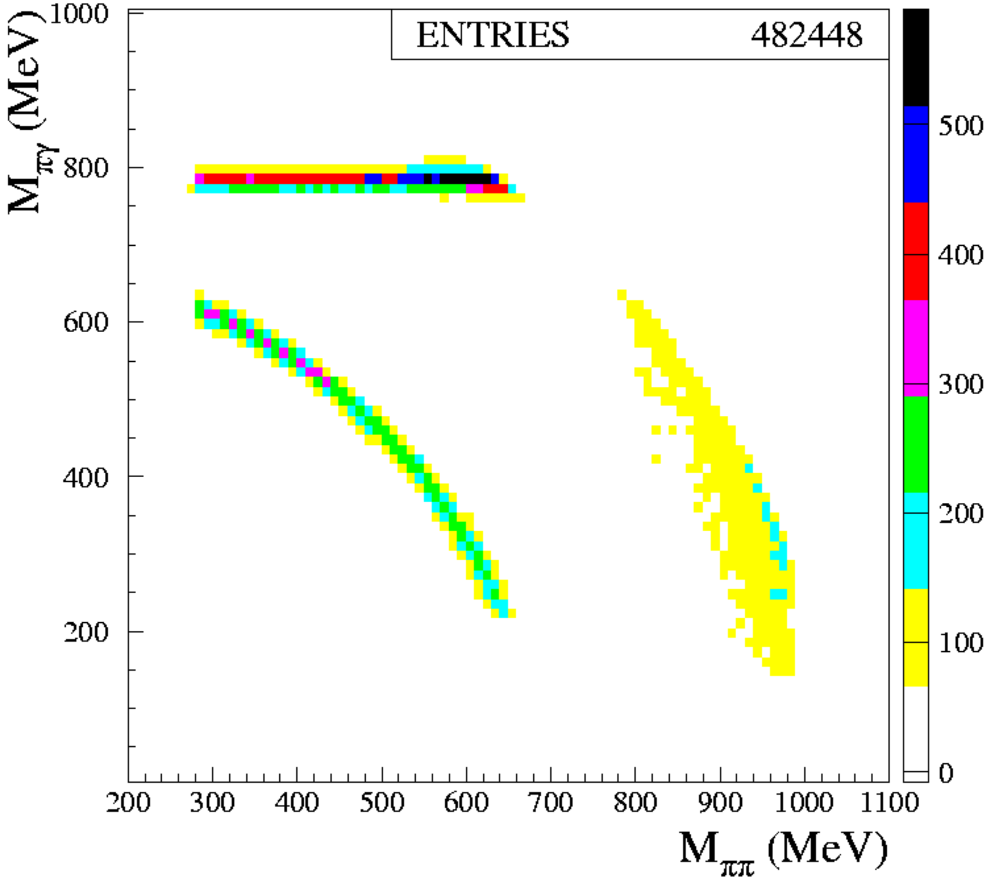
Fit to the Dalitz plot with the VDM and scalar term, including also interference

Binning: 10 MeV in $M_{\pi\pi}$, 12.5 MeV in $M_{\pi\gamma}$

What is needed:

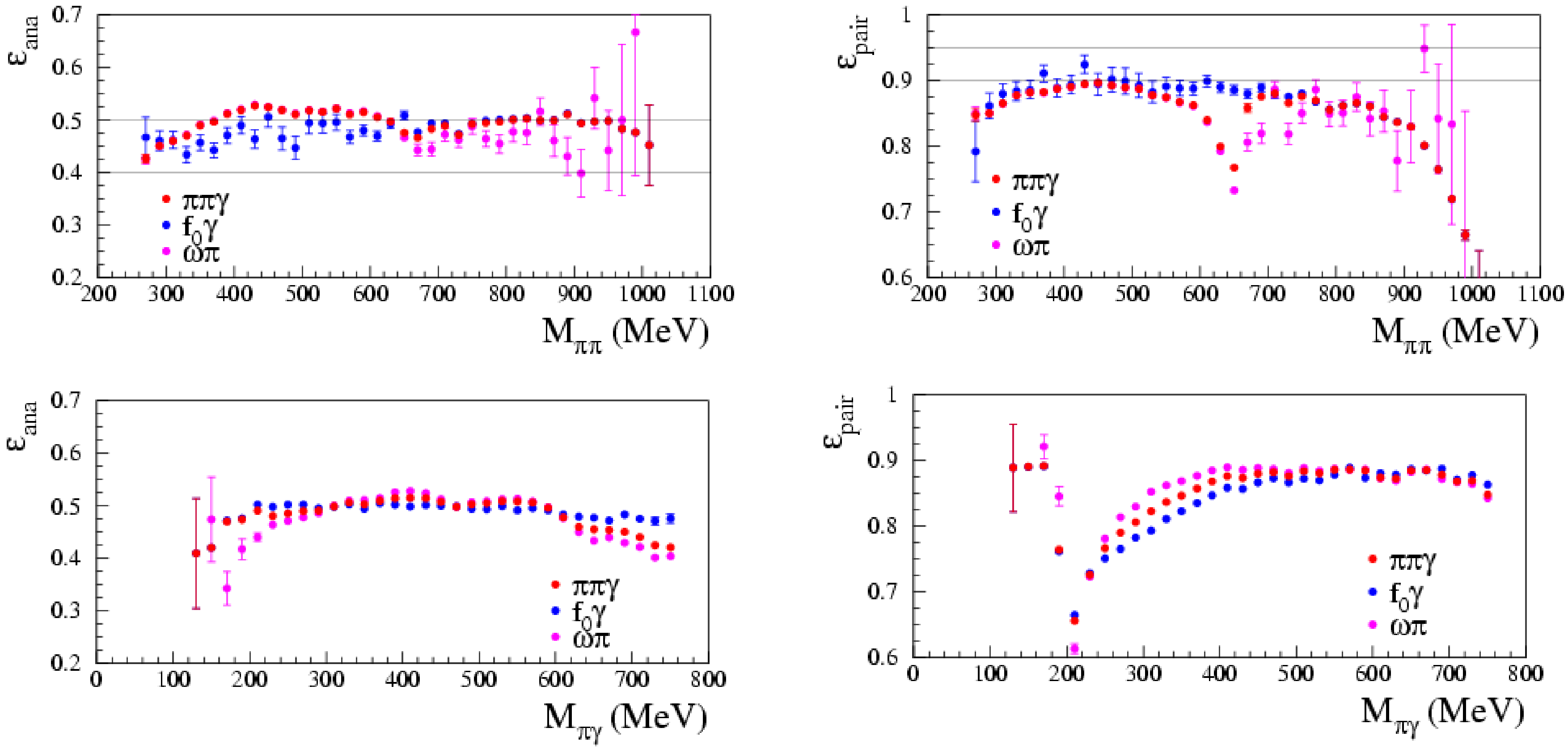
- ➢ Analysis efficiency
- ➢ Smearing matrix
- ➢ Theoretical functions
- ➢ ISR

Only statistical error and systematics on background considered for the moment



Analysis and pairing efficiencies *vs* $M_{\pi\pi}$, $M_{\pi\gamma}$

Analysis efficiency and smearing matrix evaluated from MC for each bin of the $M_{\pi\pi} - M_{\pi\gamma}$ plane

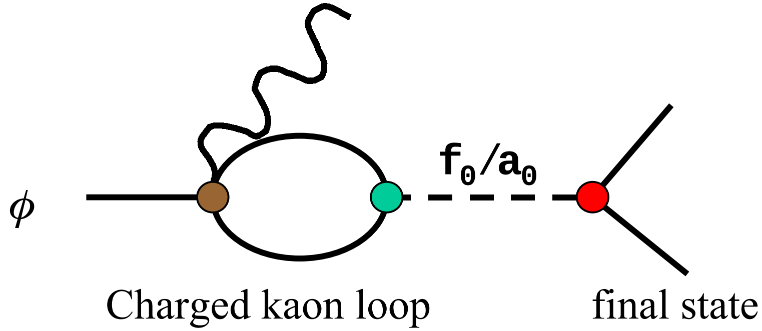


Different for the two processes!

In the fit of the Dalitz different ε_{ana} and smearing used for the VDM and scalar contributions. For the moment the VDM results are used also for the interference term

Fit function: the Achasov parametrization (I)

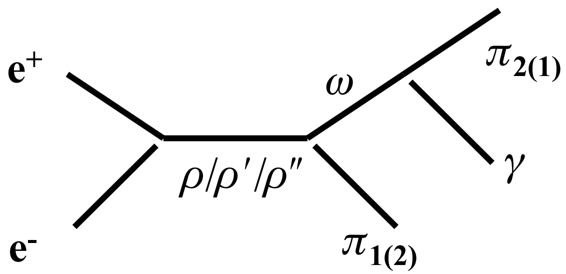
➢ Scalar produced through a kaon loop

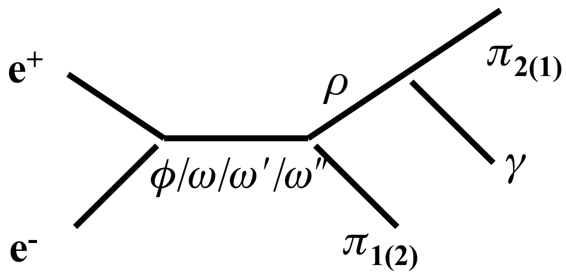


- ● $g(\phi KK)$ from $\Gamma(\phi \to K^+K^-)$
- ● $g(f_0 KK)$ $g(a_0 KK)$
- ● $g(f_0 \pi\pi)$ $g(a_0 \eta\pi)$

} fit output

➢ VDM contribution from the following diagrams :





➢ All interferences considered

Fit function: the Achasov parametrization (II)

$$
\frac{d\sigma(e^+e^-\to\pi^0\pi^0\gamma)}{dm\,dm_{\pi\gamma}} = \frac{\alpha m_{\pi\gamma} m}{3(4\pi)^2 s^3}\Bigg\{\frac{2g_{\phi\gamma}^2}{|D_\phi(s)|^2}|g(m)|^2\left|\frac{g_{f_0K^+K^-}g_{f_0\pi^0\pi^0}}{D_{f_0}(m)}\right|^2 +
$$

} $f_0\gamma$

Model dependent term

$$
\frac{1}{16}F_1(m^2,m_{\pi\gamma}^2)\left|\left(\frac{e^{i\phi_{\omega\phi}(m_\phi^2)}g_{\phi\gamma}g_{\phi\rho\pi}g_{\rho\pi\gamma}}{D_\phi(s)}+C_{\rho\pi}\right)\frac{e^{i\delta_{b_\rho}}}{D_\rho(m_{\pi\gamma}^2)}+\frac{C_{\omega\pi^0}}{D_\omega(m_{\pi\gamma}^2)}\right|^2+
$$

$$
\frac{1}{16}F_1(m^2,\tilde m_{\pi\gamma}^2)\left|\left(\frac{e^{i\phi_{\omega\phi}(m_\phi^2)}g_{\phi\gamma}g_{\phi\rho\pi}g_{\rho\pi\gamma}}{D_\phi(s)}+C_{\rho\pi}\right)\frac{e^{i\delta_{b_\rho}}}{D_\rho(\tilde m_{\pi\gamma}^2)}+\frac{C_{\omega\pi^0}}{D_\omega(\tilde m_{\pi\gamma}^2)}\right|^2+
$$

$$
\frac{1}{8}F_2(m^2,m_{\pi\gamma}^2)Re\Bigg[\left(\left(\frac{e^{i\phi_{\omega\phi}(m_\phi^2)}g_{\phi\gamma}g_{\phi\rho\pi}g_{\rho\pi\gamma}}{D_\phi(s)}+C_{\rho\pi}\right)\frac{e^{i\delta_{b_\rho}}}{D_\rho(m_{\pi\gamma}^2)}+\frac{C_{\omega\pi^0}}{D_\omega(m_{\pi\gamma}^2)}\right)\times
$$

$$
\left(\left(\frac{e^{i\phi_{\omega\phi}(m_\phi^2)}g_{\phi\gamma}g_{\phi\rho\pi}g_{\rho\pi\gamma}}{D_\phi(s)}+C_{\rho\pi}\right)\frac{e^{i\delta_{b_\rho}}}{D_\rho(\tilde m_{\pi\gamma}^2)}+\frac{C_{\omega\pi^0}}{D_\omega(\tilde m_{\pi\gamma}^2)}\right)^*\Bigg]\mp
$$

} $\omega\pi/\rho\pi$

Modified in + cos ϕ (???)

$$
\frac{1}{\sqrt{2}}Re\Bigg[g(m)e^{i\delta_B(m)}\frac{g_{f_0K^+K^-}g_{f_0\pi^0\pi^0}}{D_{f_0}(m)}\frac{g_{\phi\gamma}}{D_\phi(s)}\Bigg(
$$

$$
F_3(m^2,m_{\pi\gamma}^2)\left(\left(\frac{e^{i\phi_{\omega\phi}(m_\phi^2)}g_{\phi\gamma}g_{\phi\rho\pi}g_{\rho\pi\gamma}}{D_\phi(s)}+C_{\rho\pi}\right)\frac{e^{i\delta_{b_\rho}}}{D_\rho(m_{\pi\gamma}^2)}+\frac{C_{\omega\pi^0}}{D_\omega(m_{\pi\gamma}^2)}\right)^*+
$$

$$
F_3(m^2,\tilde m_{\pi\gamma}^2)\left(\left(\frac{e^{i\phi_{\omega\phi}(m_\phi^2)}g_{\phi\gamma}g_{\phi\rho\pi}g_{\rho\pi\gamma}}{D_\phi(s)}+C_{\rho\pi}\right)\frac{e^{i\delta_{b_\rho}}}{D_\rho(\tilde m_{\pi\gamma}^2)}+\frac{C_{\omega\pi^0}}{D_\omega(\tilde m_{\pi\gamma}^2)}\right)^*\Bigg)\Bigg]\Bigg\},
$$

} $f_0\gamma$/VP interf

[N.N.Achasov, A.V.Kiselev, private communication]

VDM parametrization: C_{VP} fixed − K_{VDM} (norm factor), δ_{b_ρ} , M_V , G_V free

Fit function: different parametrization for the scalar term

1. Point-like $\phi S\gamma$ coupling. Corrections to a "standard" BW-like f_0 (fixed Γ_S) described by the a_0 , a_1 parameters
   [Isidori-Maiani, private communication]

$$A_1^{\rm scal} = \frac{e}{4F_\Phi}\frac{sM_\Phi^2}{D_\Phi(s)}\left[\frac{g_{12}^f g_{f\gamma}^\Phi}{D_S[(1-x)s]} + \frac{a_0}{M_\Phi^2} + a_1\frac{(1-x)s - M_S^2}{M_\Phi^4}\right]$$

2. Fit based on the hadronic scattering amplitudes $\pi\pi?\ \ \pi\pi$, $\pi\pi?\ \ KK$ in the $\pi^0\pi^0\gamma$ production mechanism
   [Boglione-Pennington, Eur. Phys. J. C 30 (2003) 503]
   This is implemented in our fit function with the replacement:

$$\frac{g(M_{\pi\pi})g_{f_0K^+K^-}g_{f_0\pi^+\pi^-}e^{i\delta_B(M_{\pi\pi})}}{D_{f_0}(M_{\pi\pi})} \longrightarrow$$

$$(M_{\pi\pi}^2 - m_0^2)[(a_1 + b_1 M_{\pi\pi}^2 + c_1 M_{\pi\pi}^4)T(\pi\pi\to\pi\pi) + (a_2 + b_2 M_{\pi\pi}^2 + c_2 M_{\pi\pi}^4)T(KK\to\pi\pi)]$$

Calculation of the radiative corrections

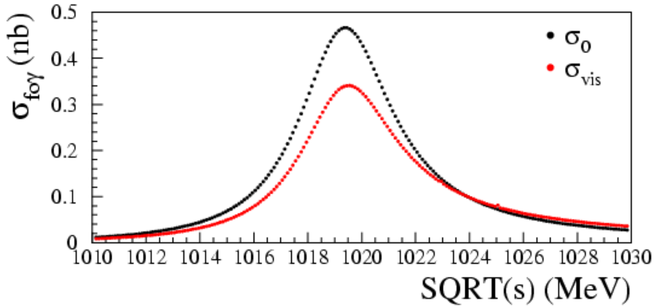
ISR evaluated starting from the following σ_0 :

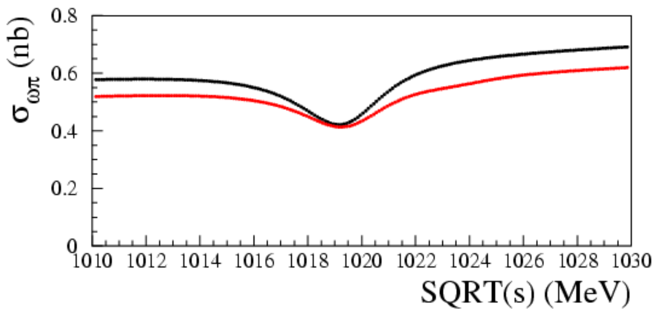
f_0 = "simple" BW (by integrating the Achasov scalar term)

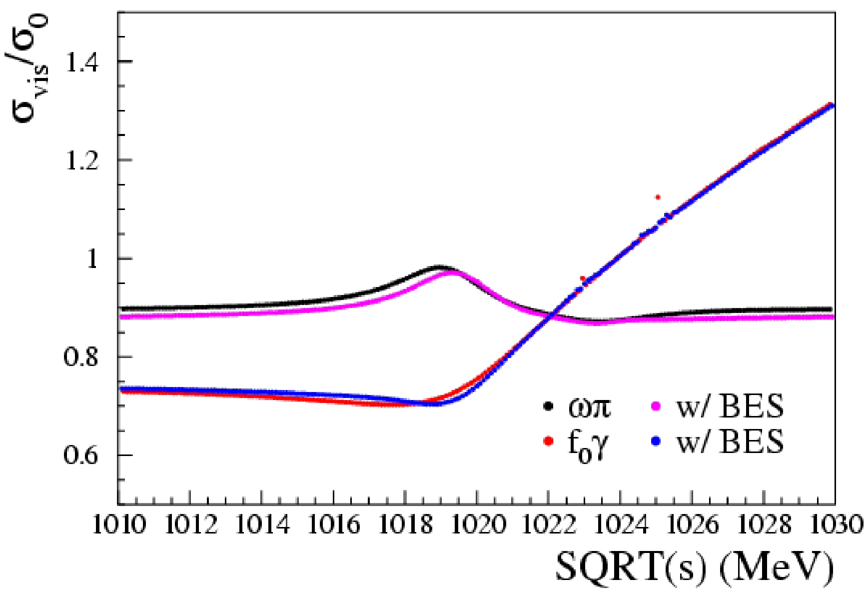
$\omega\pi$ = SND parametrization from JETP-90 6 (2000) 927, obtained by fitting over a large $\sqrt{s}$ range ... Proper threshold behaviour

$$\sigma_{vis} = \int_0^{4m_\pi^2} \sigma_0[(1-x)s]H(s,x)$$

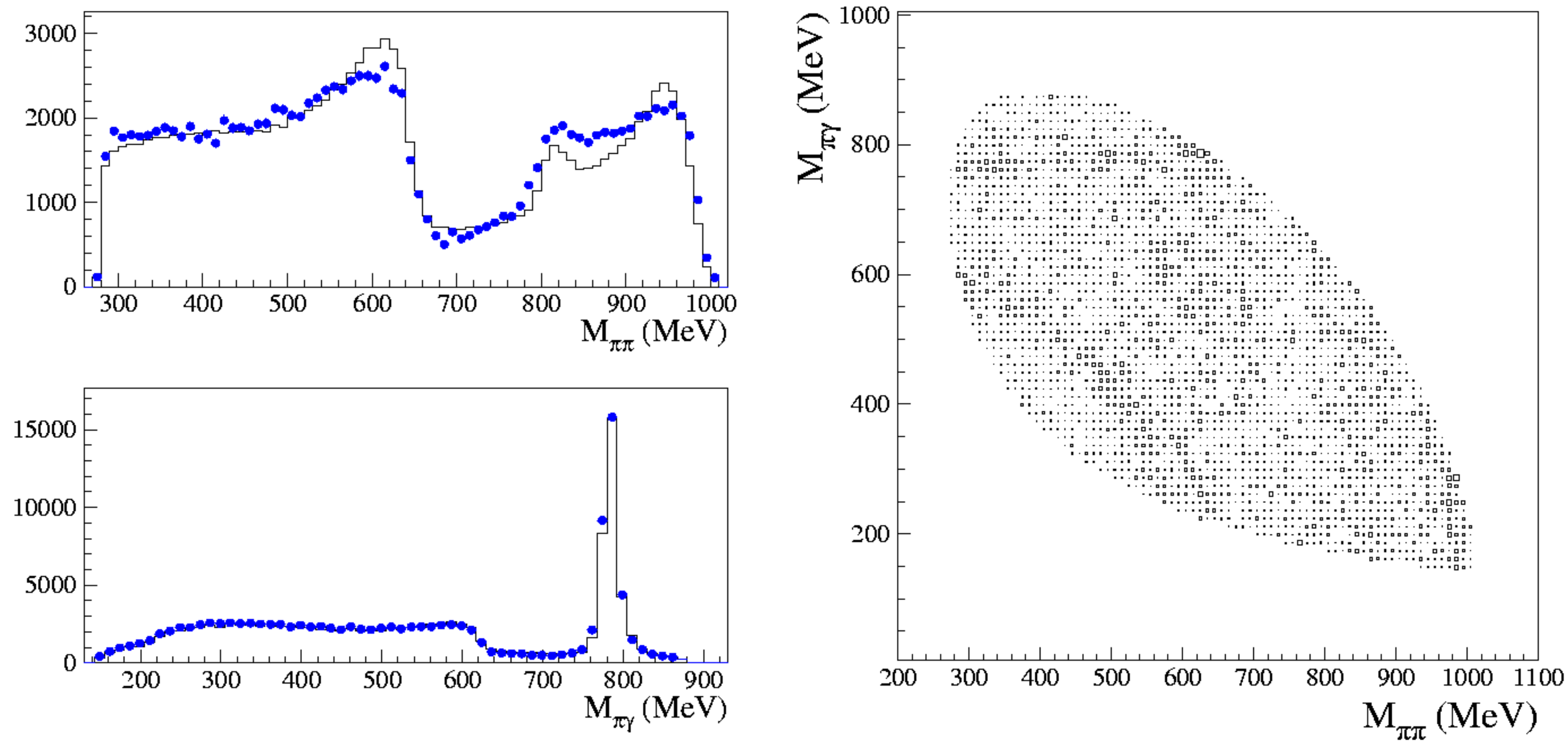
H(s,x) from Antonelli, Dreucci







Fit results: the Achasov parametrization



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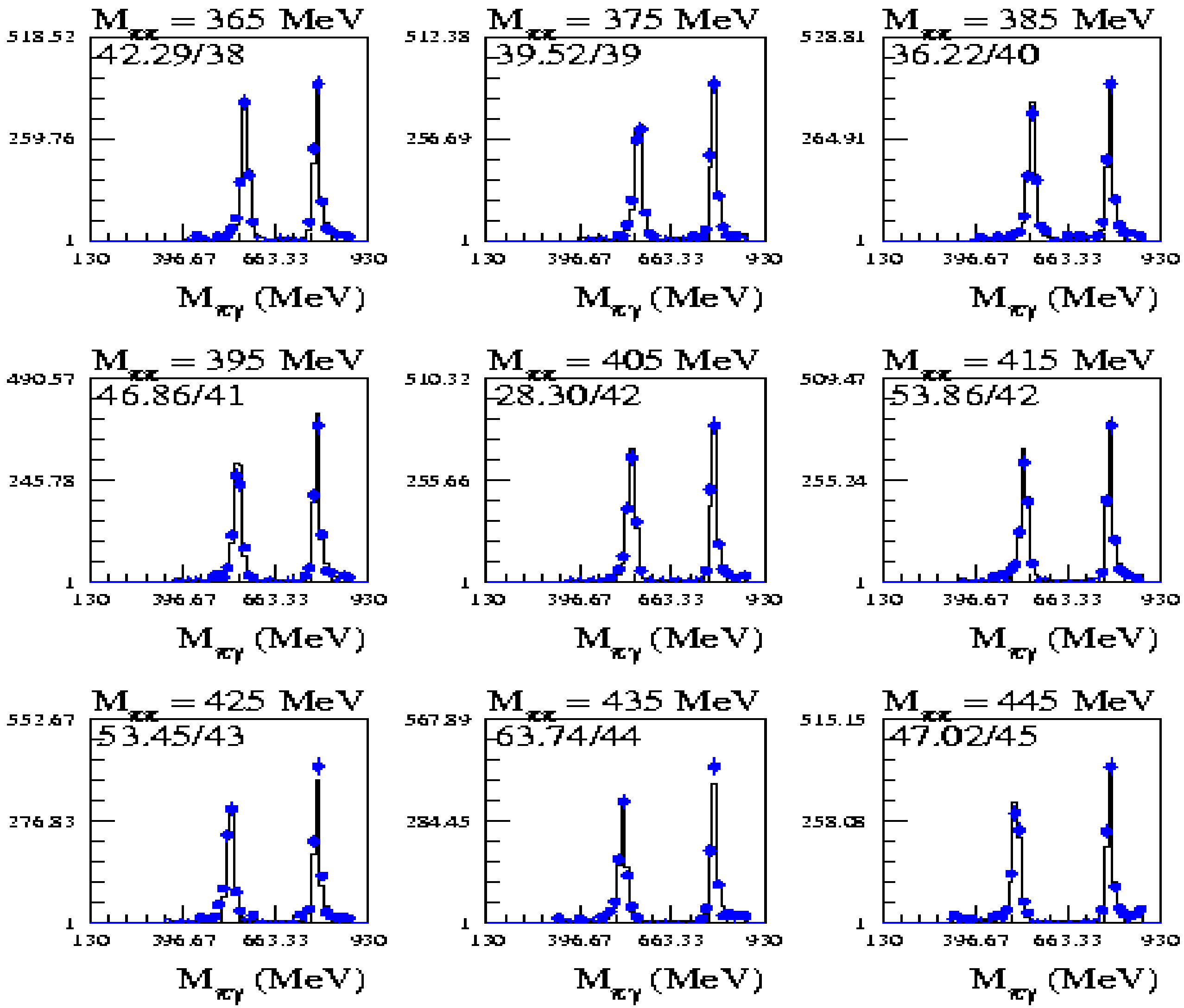

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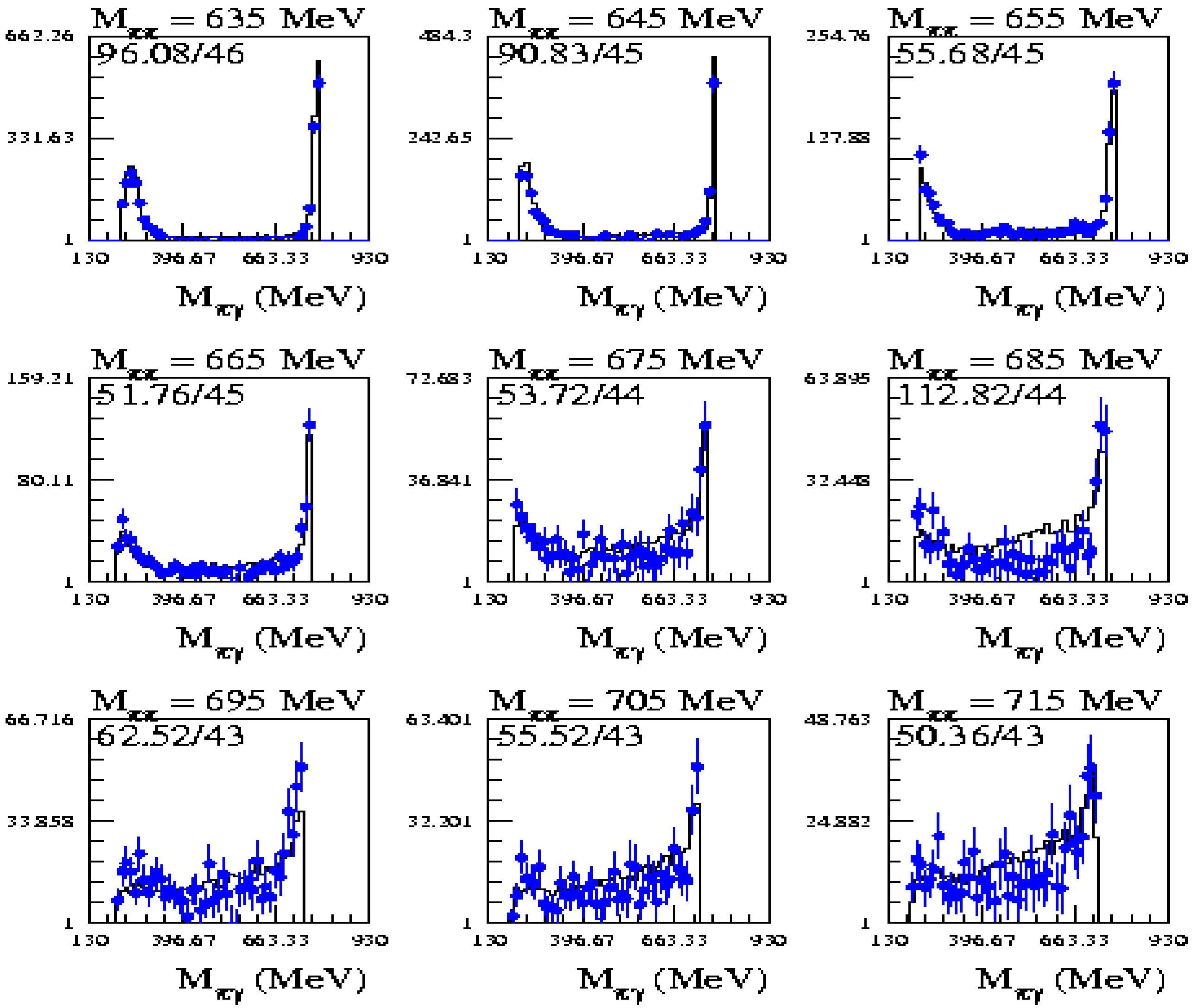

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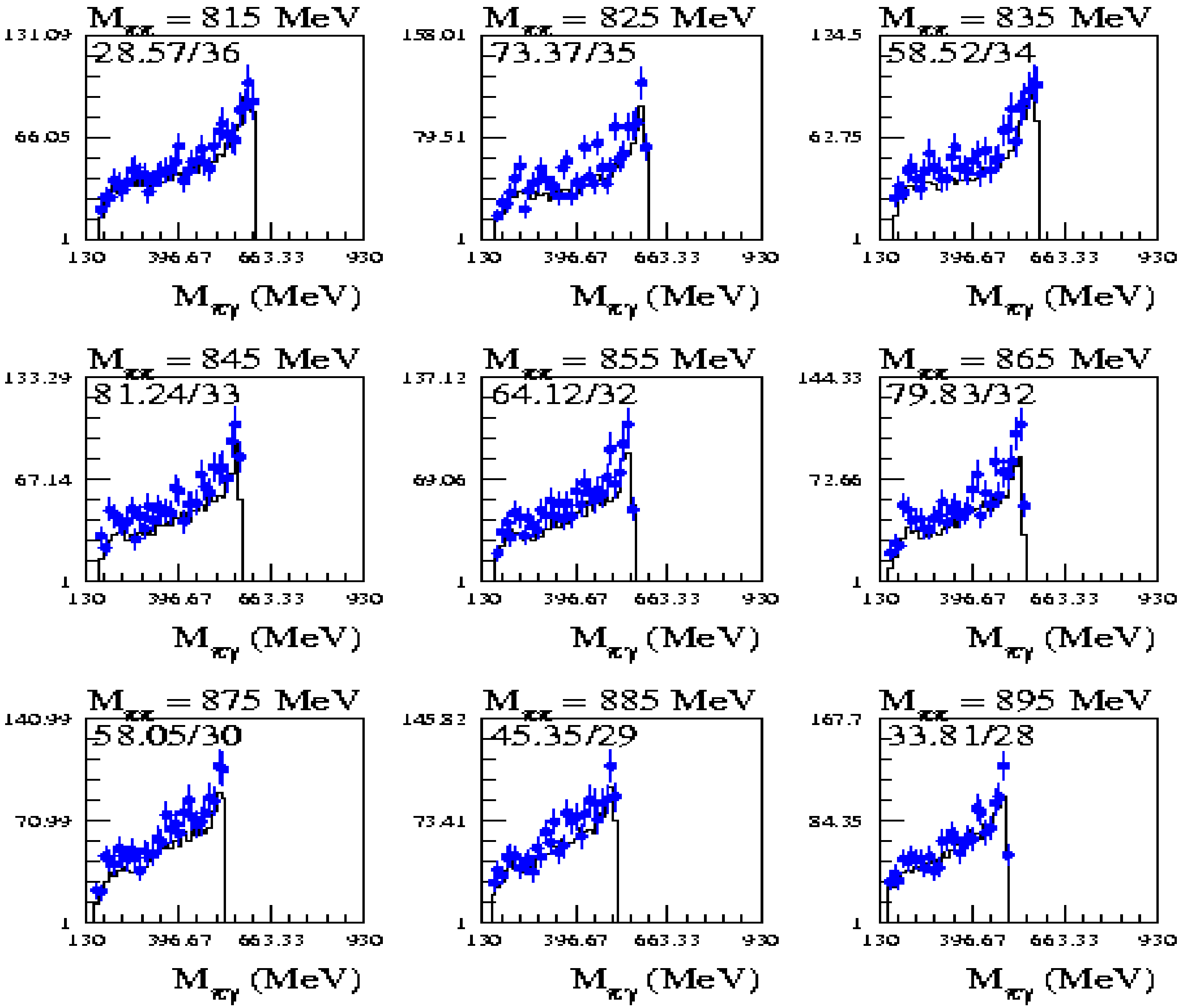
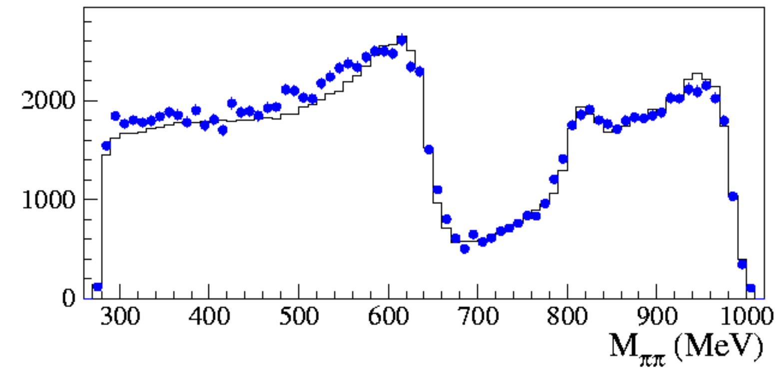
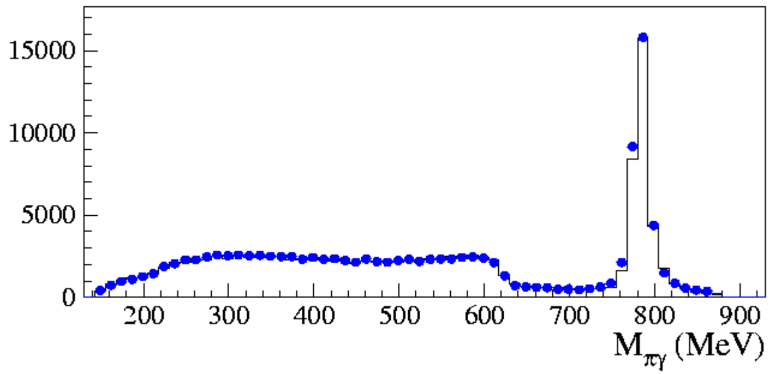
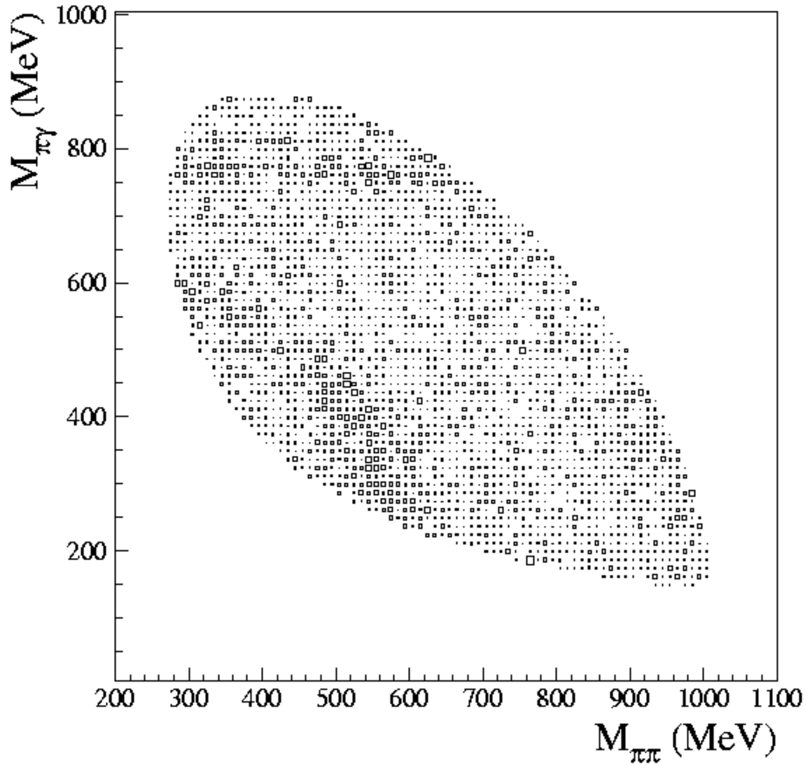


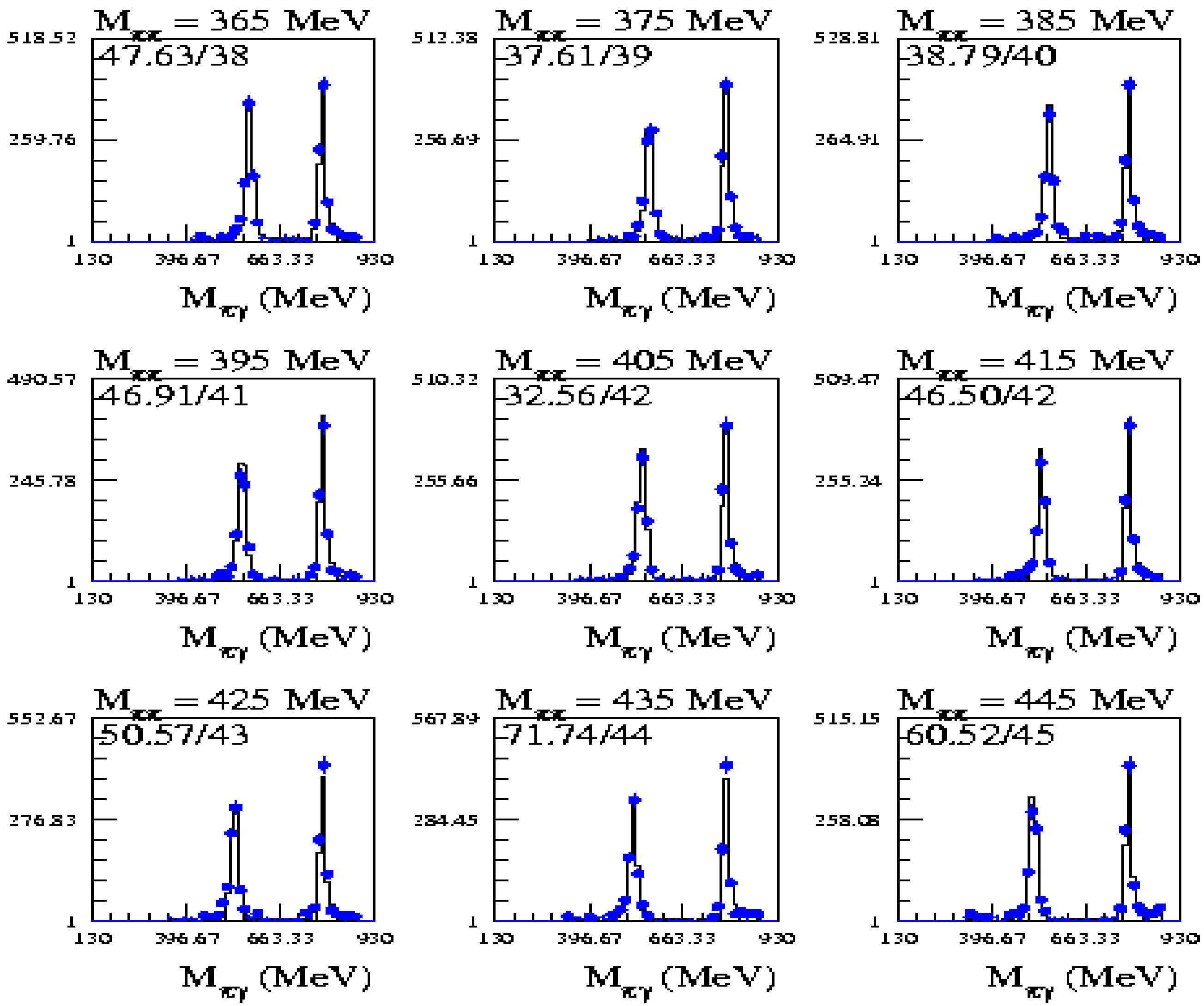
Fit results: the Isidori-Maiani parametrization



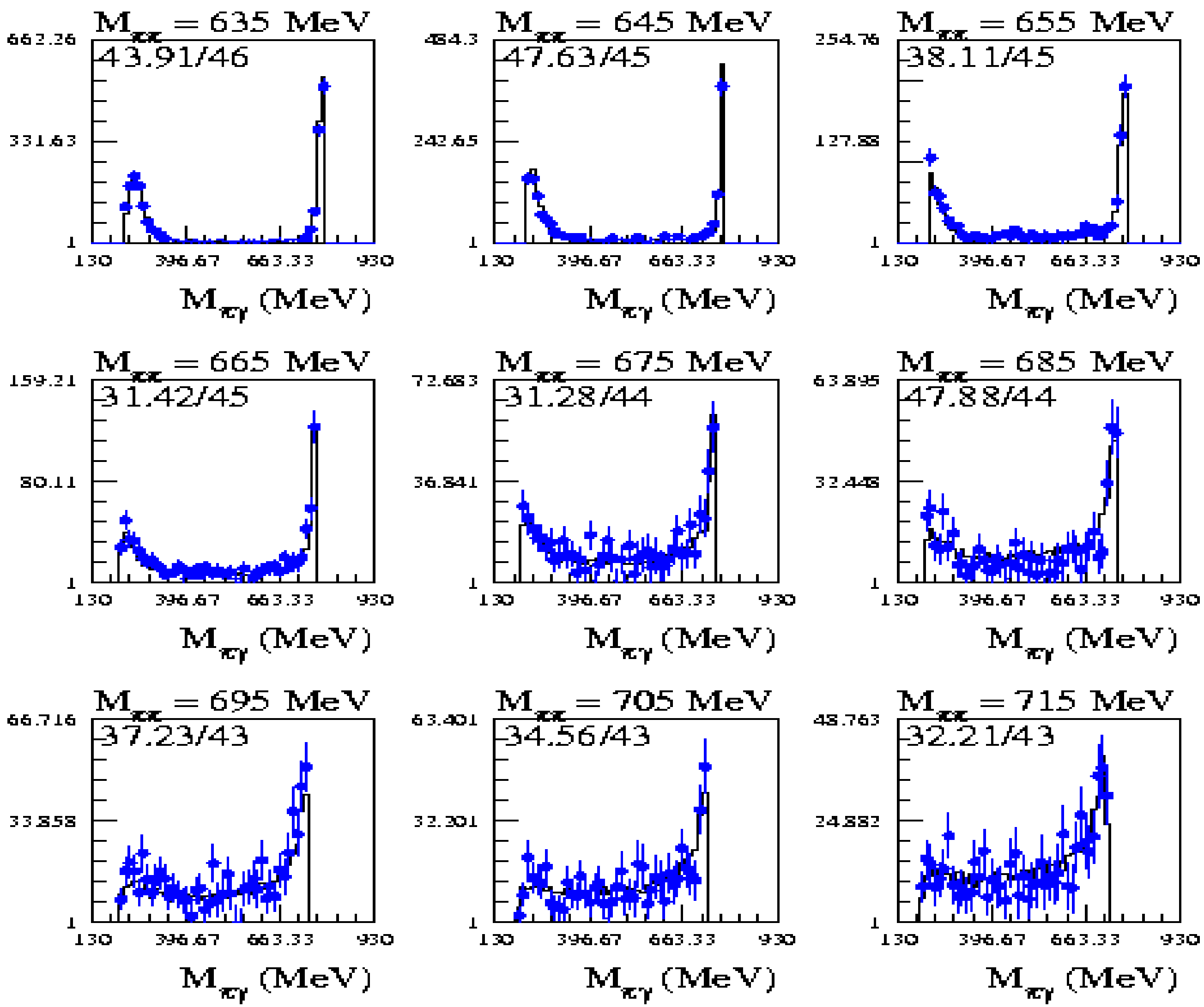




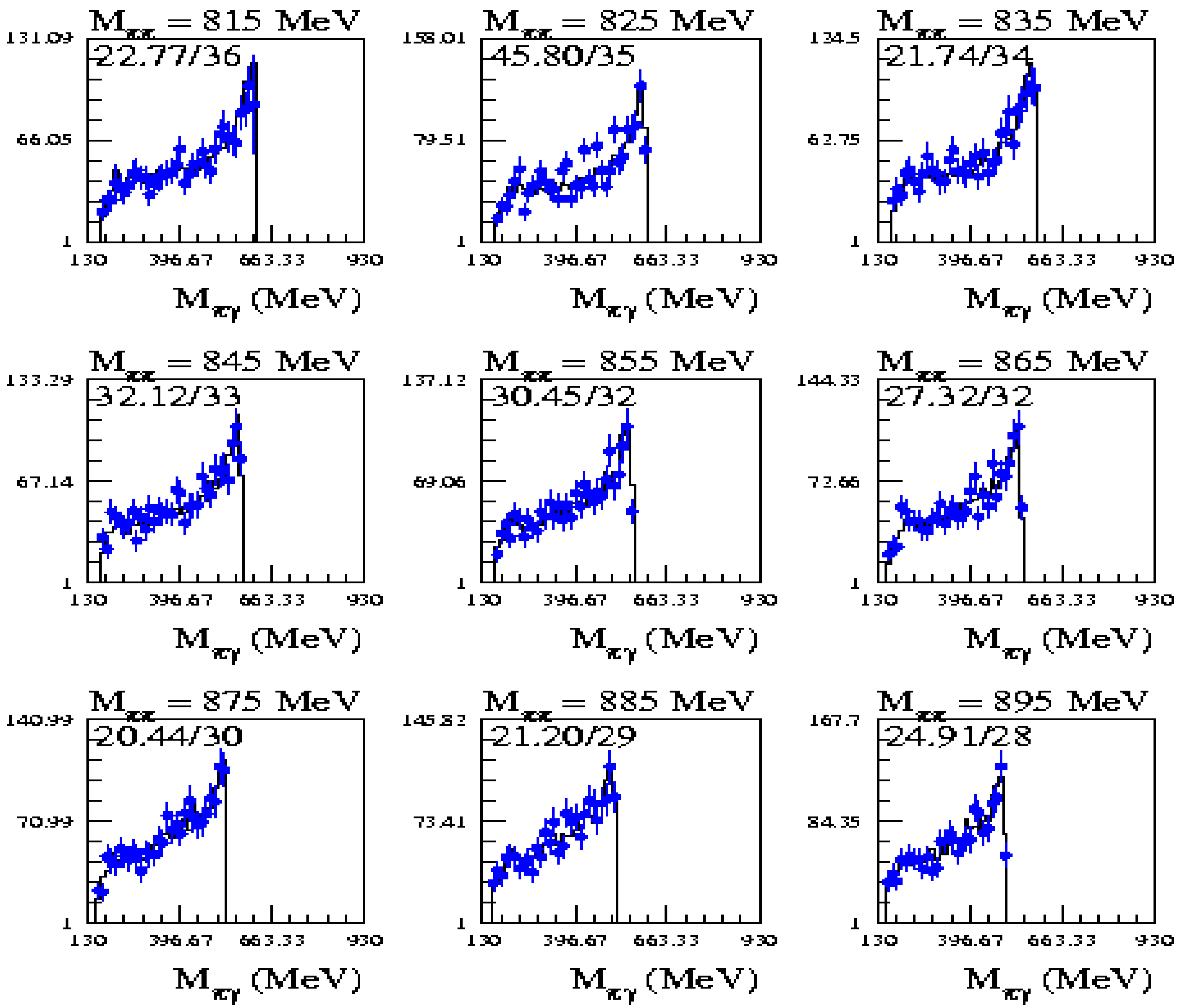
Fit results: the Isidori-Maiani parametrization



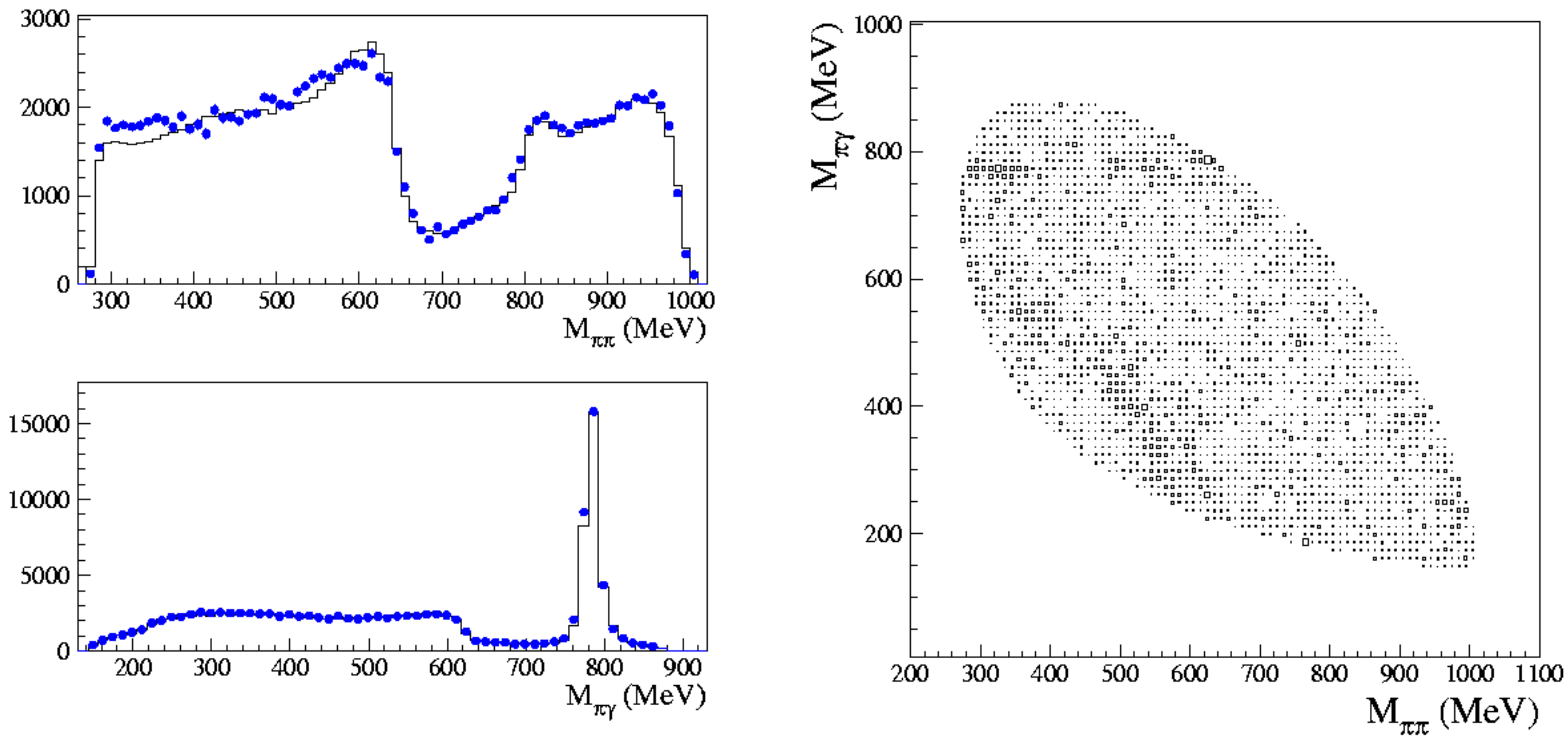
Fit results: the Isidori-Maiani parametrization



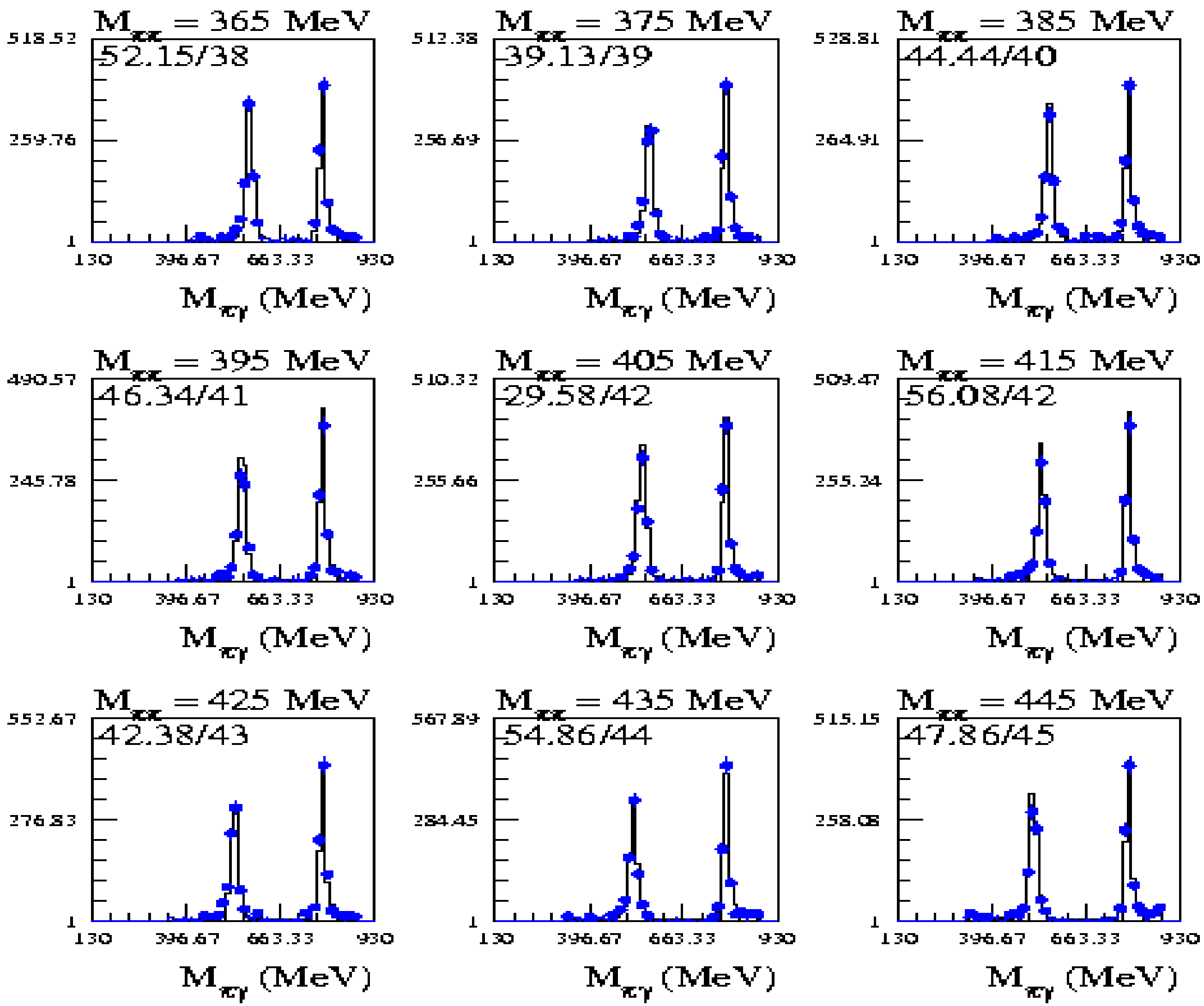
Fit results: the Isidori-Maiani parametrization



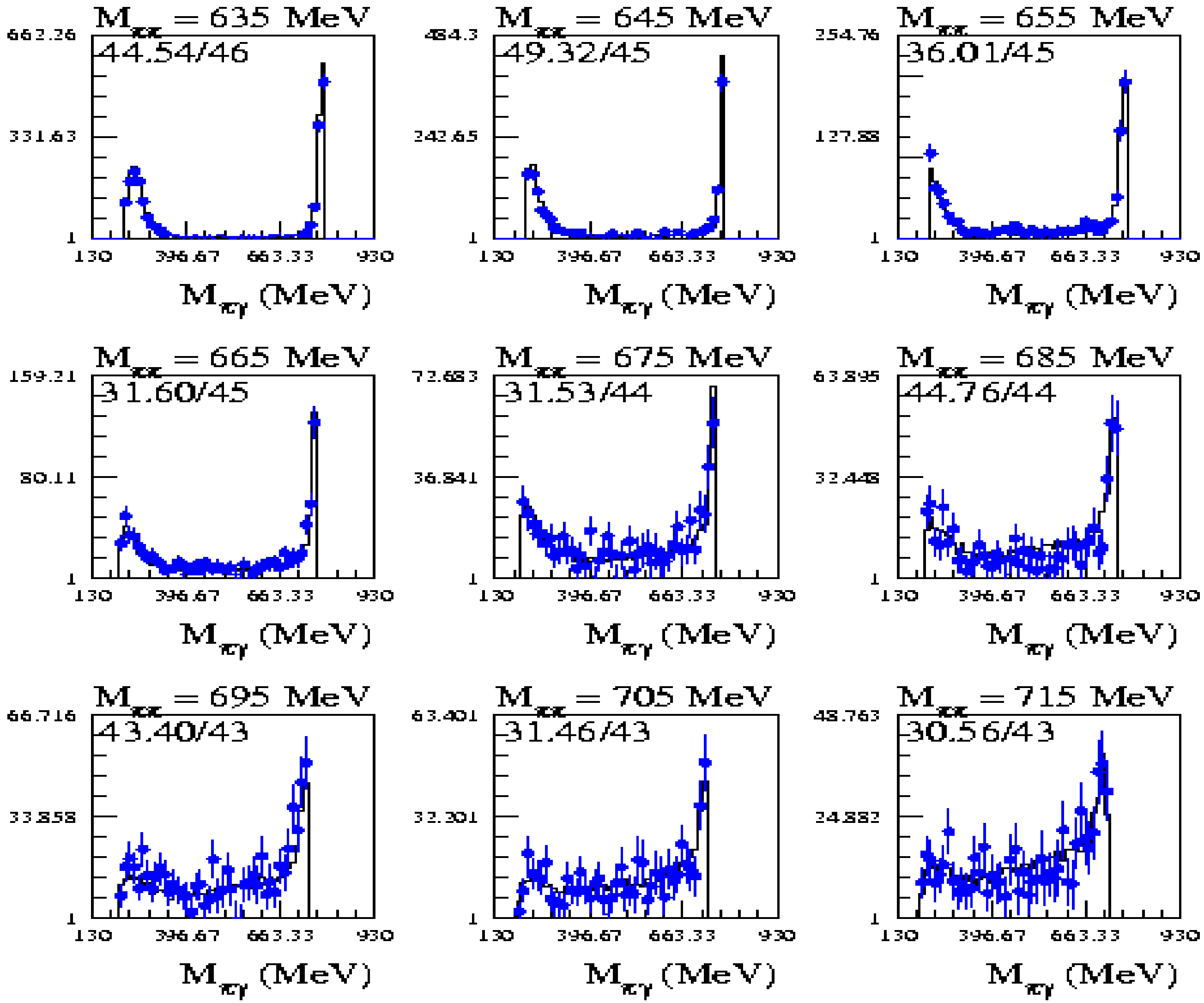
Fit results: the Boglione-Pennington parametrization



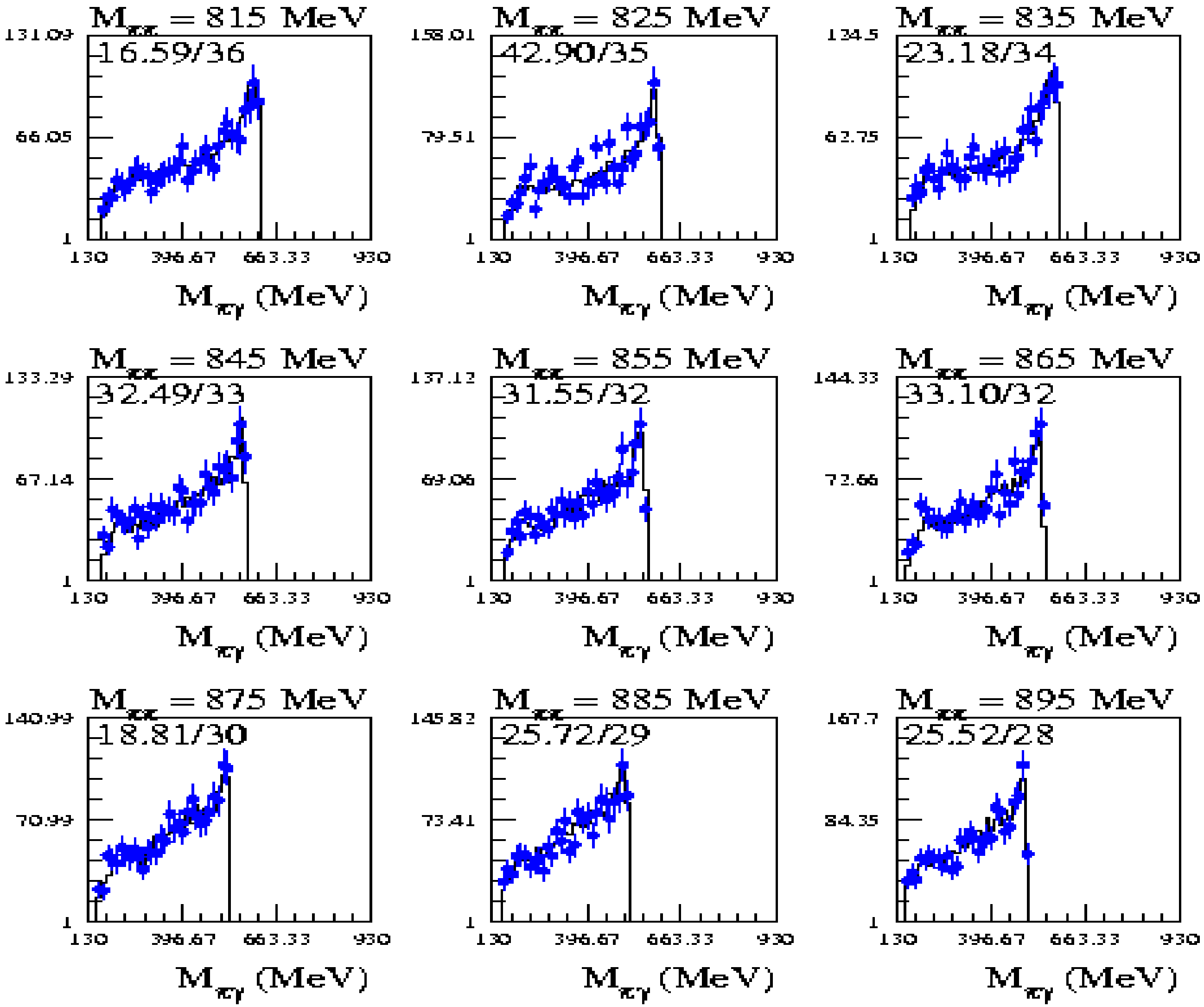
Fit results: the Boglione-Pennington parametrization



Fit results: the Boglione-Pennington parametrization



Fit results: the Boglione-Pennington parametrization



Fit results: the Achasov parametrization

	All free			Γ_ω = 8.49 MeV Γ_ρ = 146.4 MeV
$\sqrt{s}$ (MeV) L_{int} (pb^{-1})	1019.5 77.5	1019.6 145.0	1019.7 110.4	**1019.6** **145.0**
M_{f0} (MeV)	962.6 ± 0.4	962.2 ± 0.2	964.0 ± 0.2	**962.3 ± 0.6**
$g_{fK^+K^-}$ (GeV)	4.33 ± 0.04	4.42 ± 0.03	4.59 ± 0.02	**4.44 ± 0.05**
$g_{f\pi^+\pi^-}$ (GeV)	2.23 ± 0.01	2.28 ± 0.01	2.31 ± 0.01	**2.29 ± 0.01**
$\cos\phi$	−0.06 ± 0.04	0.16 ± 0.04	0.02 ± 0.04	**0.16 ± 0.04**
M_ρ (MeV)	780.0 ± 0.7	780.0 ± 0.2	780.0 ± 0.4	**780.0 ± 0.2**
Γ_ρ (MeV)	150.0 ± 3.3	150.0 ± 1.1	150.0 ± 1.1	**-**
M_ω (MeV)	781.9 ± 0.1	782.25 ± 0.07	781.95 ± 0.05	**782.2 ± 0.1**
Γ_ω (MeV)	9.00 ± 0.01	9.000 ± 0.008	9.000 ± 0.006	**-**
$\delta_{b\rho}$ (degree)	78 ± 6	95 ± 2	94 ± 2	**95 ± 3**
K_{VDM}	0.84 ± 0.02	0.870 ± 0.005	0.861 ± 0.005	**0.806 ± 0.006**
χ^2/ndf	3529.3/2677 = 1.32	4188.1/2676 = 1.57	3688.6/2675 = 1.38	**4282.2/2678 = 1.60**

Fit results: the Isidori-Maiani parametrization

	All free			Γ_ω = 8.49 MeV Γ_ρ = 146.4 MeV
√s (MeV)	1019.5	1019.6	1019.7	**1019.6**
M_{f0} (MeV)	983.5 ± 1.2	981.3 ± 0.8	980.8 ± 0.7	**981.3 ± 0.5**
Γ_{f0} (MeV)	43.1 ± 1.2	42.8 ± 0.7	40.5 ± 0.7	**42.8 ± 0.6**
$g_{\phi f\gamma} g_{f\pi\pi}$	2.11 ± 0.07	1.99 ± 0.04	1.91 ± 0.03	**2.00 ± 0.02**
a_0	3.7 ± 0.3	3.2 ± 0.1	2.8 ± 0.1	**3.22 ± 0.05**
a_1	1.0 ± 0.3	0.6 ± 0.1	0.1 ± 0.1	**0.60 ± 0.06**
$\cos\phi$	−0.85 ± 0.08	−0.99 ± 0.02	−0.88 ± 0.05	**−0.96 ± 0.05**
M_ρ (MeV)	780.0 ± 0.4	780.0 ± 0.2	780.00 ± 0.07	**780.0 ± 0.2**
Γ_ρ (MeV)	145.0 ± 3.4	145.0 ± 0.9	145.0 ± 0.7	**-**
M_ω (MeV)	782.2 ± 0.1	782.03 ± 0.08	781.99 ± 0.07	**782.05 ± 0.06**
Γ_ω (MeV)	9.000 ± 0.006	9.000 ± 0.004	9.000 ± 0.003	**-**
δ_{b_ρ} (degree)	2 ± 2	8 ± 2	5 ± 1	**7 ± 1**
K_{VDM}	0.720 ± 0.006	0.737 ± 0.004	0.729 ± 0.004	**0.688 ± 0.004**
χ^2/ndf	2613.2/2675 = 0.98	3081.3/2674 = 1.15	2917.5/2673 = 1.09	**3355.7/2675 = 1.25**

Fit results: the Boglione-Pennington parametrization

	All free			Γ_ω = 8.49 MeV Γ_ρ = 146.4 MeV
√s (MeV)	1019.5	1019.6	1019.7	**1019.6**
m_0 (MeV)	580.2 ± 5.1	345.5 ± 0.6	471.6 ± 3.2	**547.4 ± 3.2**
a_1	11.44 ± 0.03	9.345 ± 0.001	6.934 ± 0.005	**19.49 ± 0.05**
b_1	2.08 ± 0.01	−2.736 ± 0.001	−18.55 ± 0.01	**−20.4 ± 0.2**
c_1	−11.75 ± 0.03	−4.809 ± 0.002	9.72 ± 0.02	**2.4 ± 0.1**
a_2	−15.03 ± 0.04	−10.623 ± 0.001	−10.148 ± 0.007	**−26.51 ± 0.08**
b_2	−11.85 ± 0.01	−8.866 ± 0.002	28.16 ± 0.02	21.2 ± **0.3**
c_2	32.09 ± 0.02	23.060 ± 0.002	−14.39 ± 0.01	**10.0 ± 0.2**
$\cos\phi$	0.30 ± 0.07	0.47 ± 0.01	0.03 ± 0.05	**0.41 ± 0.04**
M_ρ (MeV)	770.0 ± 1.3	779.89 ± 0.04	770.0 ± 0.6	**770.0 ± 0.2**
Γ_ρ (MeV)	150.0 ± 3.5	149.71 ± 0.05	150.0 ± 0.7	**-**
M_ω (MeV)	783.0 ± 0.01	782.78 ± 0.07	782.72 ± 0.09	**783.00 ± 0.02**
Γ_ω (MeV)	9.000 ± 0.006	9.000 ± 0.001	9.000 ± 0.003	**-**
δ_{b_ρ} (degree)	111 ± 2	109 ± 1	108 ± 2	**113 ± 1**
K_{VDM}	0.900 ± 0.006	0.904 ± 0.001	0.904 ± 0.004	**0.826 ± 0.003**
χ^2/ndf	3056.4/2673 = 1.14	3211.3/2672 = 1.20	3483.9/2671 = 1.30	**3984.6/2673 = 1.49**

The parametrization with the σ meson (I)

The σ is introduced in the scalar term as in ref. PRD 56 (1997) 4084.

- The two resonances are not described by the sum of two BW but wth the matrix of the inverse propagators G_{R1R2}.
- Non diagonal terms on G_{R1R2} are the transitions caused by the resonance mixing due to the final state interaction which occured in the same decay channels R1 ? ab ? R2

$$\frac{g_{f_0 K^+K^-} g_{f_0 \pi^+\pi^-}}{D_{f_0}(M_{\pi\pi})} \longrightarrow \sum g_{R_1 kk} G_{RR}^{-1} g_{R_2 \pi\pi}$$

Where

$$G_{R1R2} = \begin{pmatrix} D_{f0} & -\Pi_{f\sigma} \\ -\Pi_{\sigma f0} & D_{\sigma} \end{pmatrix}$$

$$\Pi_{R1R2} = \Sigma_{ab}\, g_{R2ab}\, P_{R1}^{ab}(m) + C_{R1R2}$$

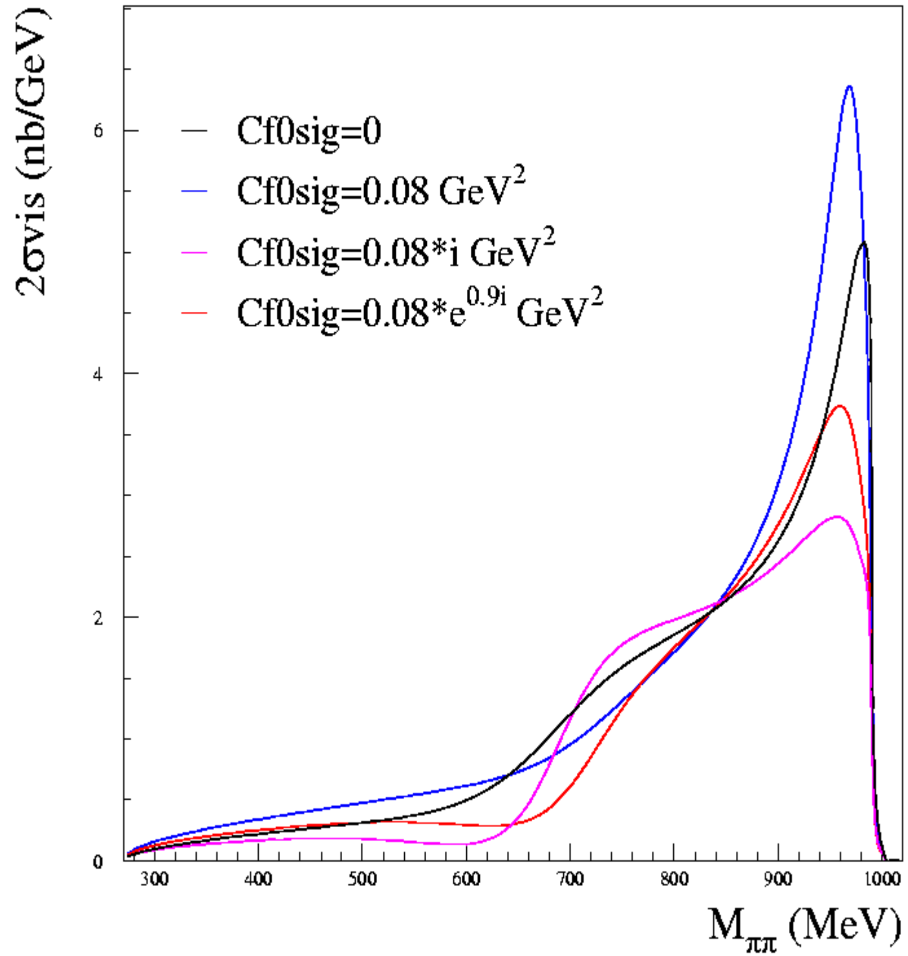
$C_{R1R2} = C_{f0\sigma}$ takes into account the contributions of VV, 4 pseudoscalar mesons and other intermediate states. In the 4q,2q models there are free parameters

The parametrization with the σ meson (II)

Extensive tests have been done on the formula used.

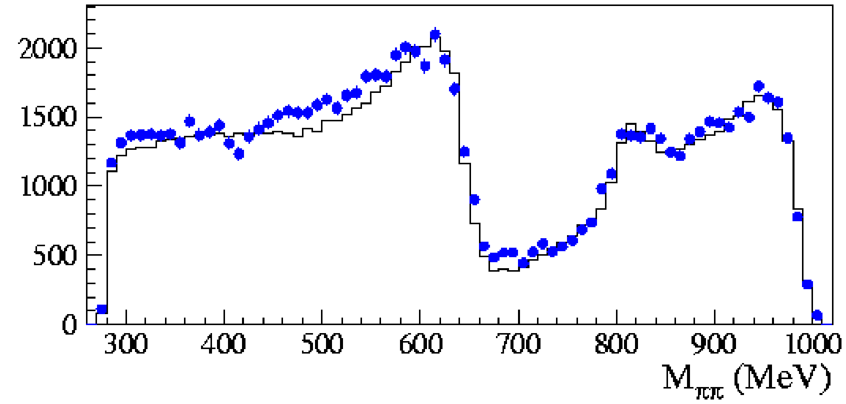
- Good agreement found between our coding and the one of Cesare we agreed that there is a mistype in the PRD
- We have asked also the help of G.Isidori-S.Pacetti to check this

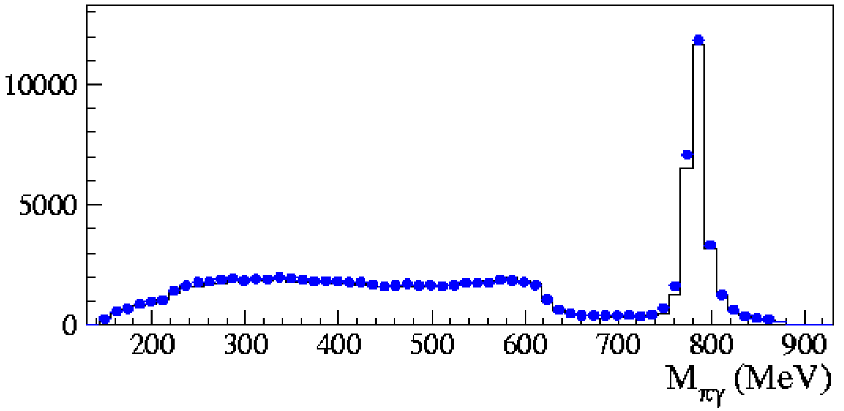
The effect of the free term $C_{f0\sigma}$ and of its phase is large



Fit results: the Achasov parametrization with σ (I)

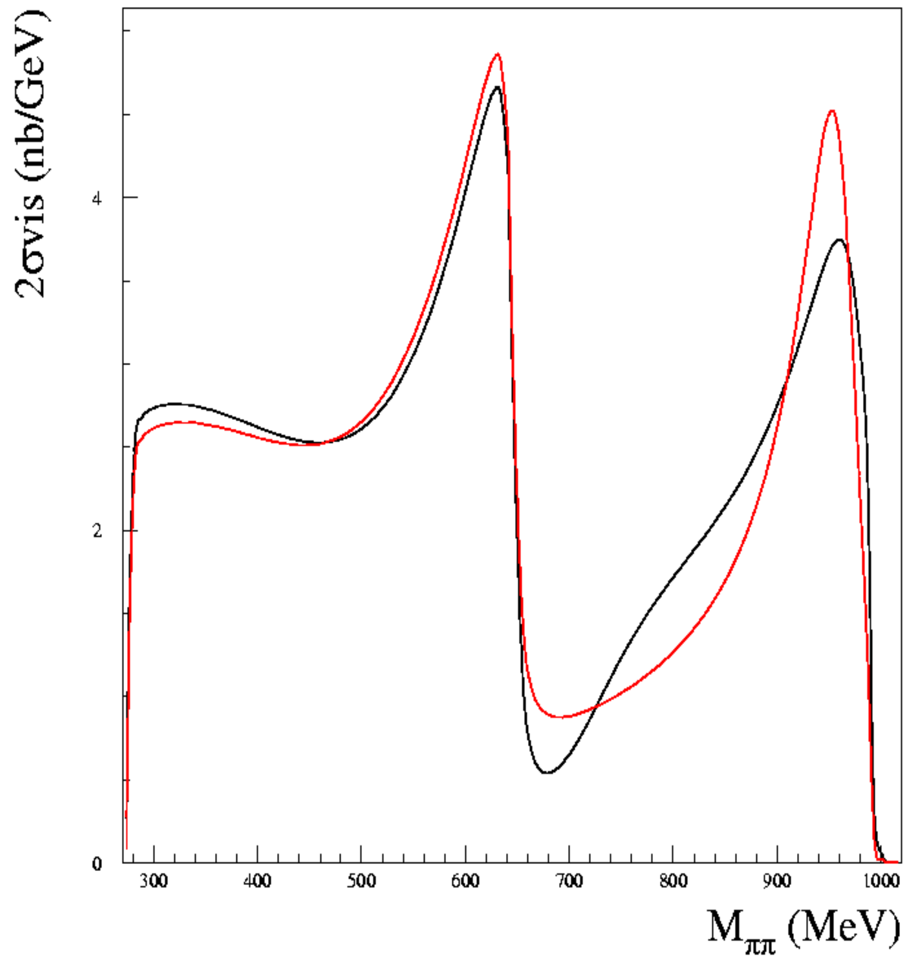
Fit @ 1019.7 MeV
SIMPLEX only

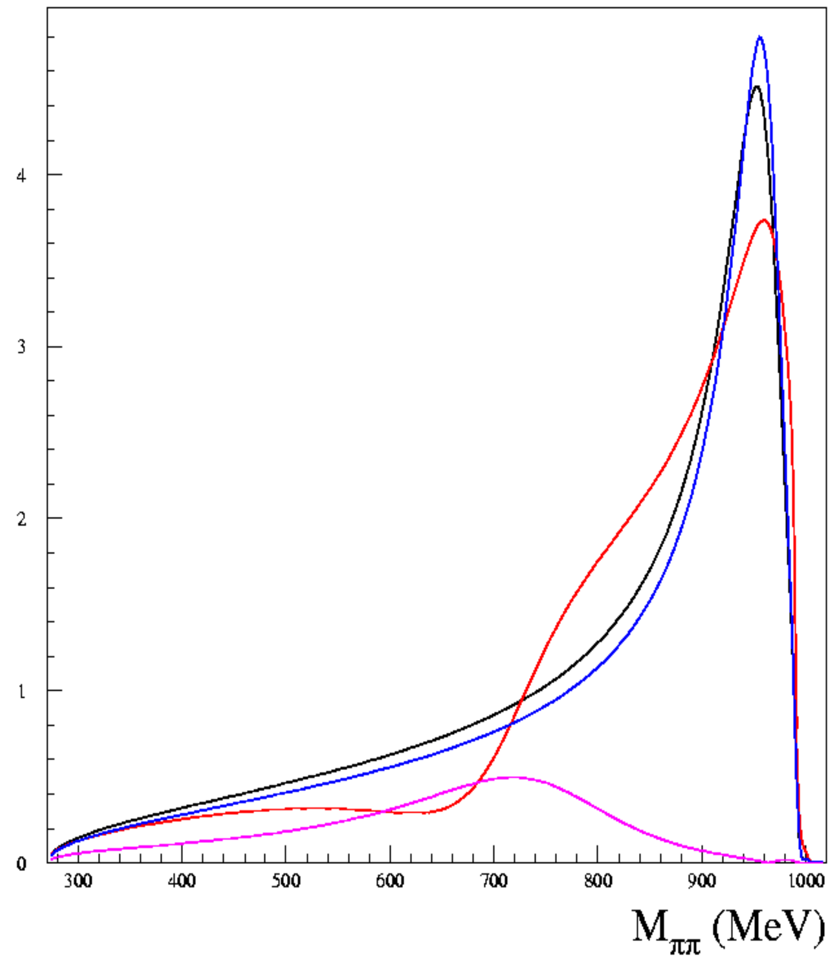




	$f_0+\sigma$	f_0 only
M_{f0} (MeV)	963.7	964.0 ± 0.2
$g_{fK^+K^-}$ (GeV)	4.41	4.59 ± 0.02
$g_{f\pi^+\pi^-}$ (GeV)	2.18	2.31 ± 0.01
M_{σ} (MeV)	741.2	-
$G_{\sigma\pi\pi}$ (GeV)	2.35	-
$\lvert C_{f0\sigma}\rvert$(GeV)	81.1	-
$\phi_{f0\sigma}$	0.68	-
$\cos\phi$	0.28	0.02 ± 0.04
M_{ρ} (MeV)	780.0	780.0 ± 0.4
Γ_{ρ} (MeV)	150.0	150.0 ± 1.1
M_{ω} (MeV)	781.91	781.95 ± 0.05
Γ_{ω} (MeV)	8.91	9.000 ± 0.006
$\delta_{b\rho}$ (degree)	98	94 ± 2
K_{VDM}	0.848	0.861 ± 0.005
χ^2/ndf	3072.1/2679 = 1.15	3688.6/2675 = 1.38

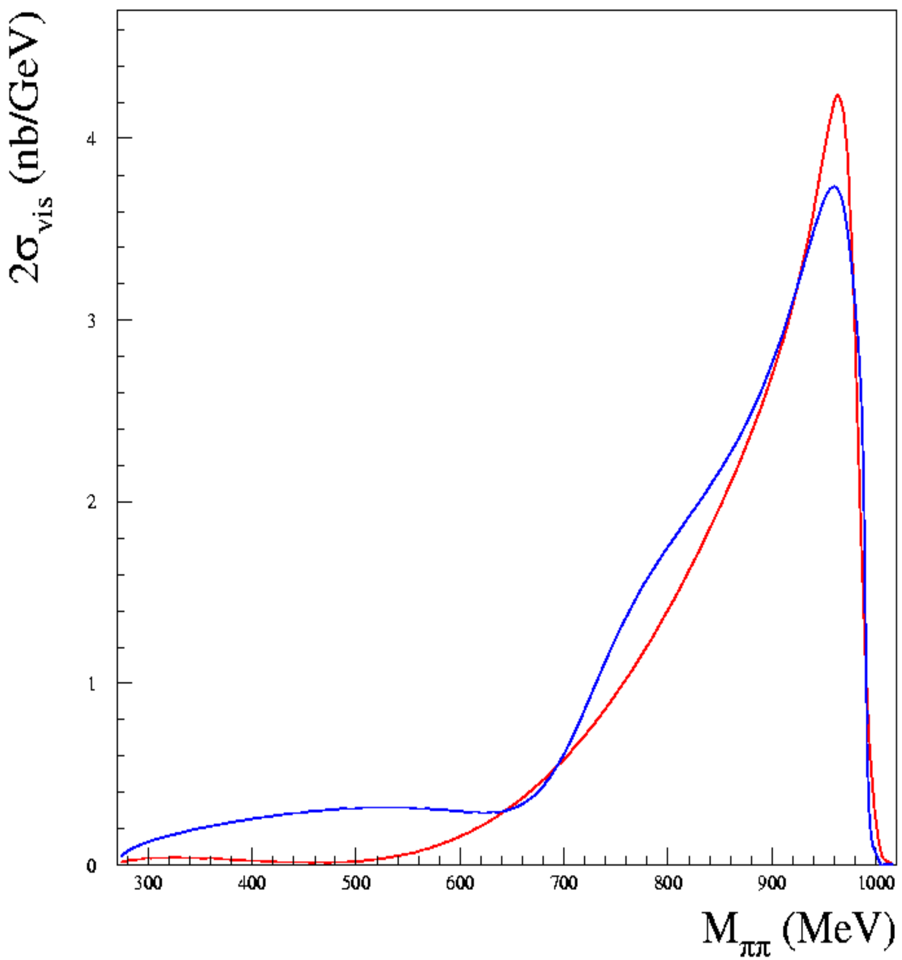
Fit results: the Achasov parametrization with σ (II)





- Black (red) curve are ACH model with (without) the inclusion of the σ meson
- Blue (purple) curve are the contribution due to the f0 (σ) meson only with the ACH model when including the σ meson

Comparison between ACH-IM for the scalar term



Without the inclusion of the σ meson the agreement between ACH model and IM is not excellent although the integrals do not differ more than 20% above 700 MeV . Including the σ the agreement is better!

Conclusions

- ❖ Fit results start giving reasonable results. Improvement due to: better binning, reduced free VDM parameters (overall scale factor + ρ, ω masses). Is the interference phase added in the right way?

- ❖ Systematics still to be included in the fit

- ❖ Achasov model without sigma does not provide a good fit to data
  Parameters in agreement with our old analysis

- ❖ The Isidori-Maiani function better describes the data
  Still some doubts in the use of the $\pi\pi$ scattering phase

- ❖ The Boglione-Pennington parametrization provide a very unstable fit, with very different parameters for different v*s*

- ❖ A preliminary test including σ in the kaon loop model shows an improvement of the fit