Evaluation of systematics for the analysis of the $\pi^0\pi^0\gamma$ final state

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- ✓ Introduction and analysis scheme
- ✓ Acceptance issues
- ✓ Photon pairing
- ✓ Kinematic fitting and ISR
- ✓ Evaluation of the background
- ✓ Fit procedure
- ✓ Prospects and plans

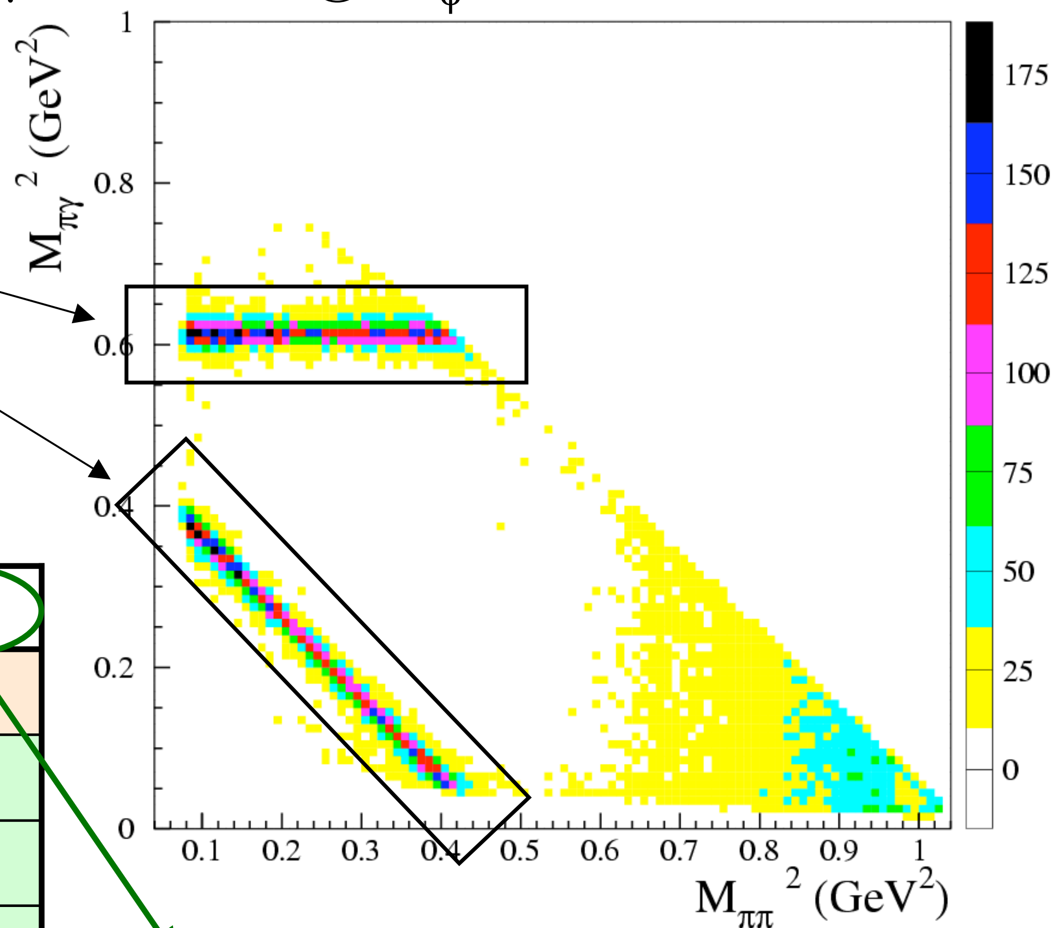
ϕ decays meeting – 9 May 2005

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

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

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

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



Backgrounds:

Process	S/B
$\phi \rightarrow a_0\gamma \rightarrow \eta\pi^0\gamma \rightarrow \gamma\gamma\pi^0\gamma$	8.51
$\phi \rightarrow \eta\gamma \rightarrow \pi^0\pi^0\pi^0\gamma$	0.06
$\phi \rightarrow \eta\gamma \rightarrow \gamma\gamma\gamma$	0.05
$\phi \rightarrow \pi^0\gamma$	0.21
$e^+e^- \rightarrow \gamma\gamma(\gamma)$	0.002

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

Data and Monte Carlo samples

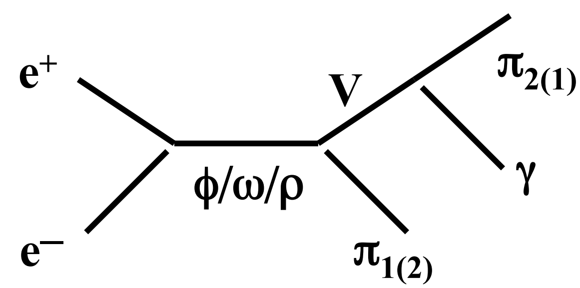
DATA

2001+2002 data : **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 $\sqrt{s}$**
Today we will discuss only about the 145 pb^{-1} at 1019.6 MeV

MC

RAD04 MC production: **5 × L_{int}**
GG04 MC production: **1 × 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: $|T_{cl} - R_{cl}/c| < \mathrm{MIN}(5\sigma_T, 2\ \mathrm{ns})$]

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 γγ pairs

Study on Trigger, FILFO and ECL

1. Trigger and Cosmic Veto efficiency

Calorimeter trigger fully efficient on the signal. Cosmic Veto losses evaluated with prescaled events.

$$\varepsilon_{CV} = (99.54 \pm 0.08)\ \%$$

2. MC evaluation of FILFO and ECL losses

$\varepsilon_{FLF} = (99.95 \pm 0.01)\ \%$ $\varepsilon_{ECL} = (96.5 \pm 0.1)\ \%$

3. DATA evaluation of FILFO and ECL losses

The minimum bias sample streamed by C.DiDonato was used to evaluate with data ε_{FLF} and ε_{ECL} Only data with $\sqrt{s}$ =1019.6 used.

$\varepsilon_{FLF} = (99.90 \pm 0.05)\ \%$ $\varepsilon_{ECL} = (99.2 \pm 0.1)\ \%$ **!!**

The large difference on ε_{ECL} mainly due to the a wrong parametrization of time res in neurad code! An overall correction R=1.02±0.01 applied to ε(MC)

Study on the acceptance (I)

1. Effect of the wrong energy scale in MC

As for other analyses, the MC energy scale is shifted of ~ 1.4 %. We have corrected the MC energy of this amount and counted again the number of prompt photons.

The **related systematics is ~ 0.3 of the statistical error** on the efficiency.

2. Systematics on cluster efficiency

We have varied the data-MC efficiency curve following the 3 search cones used in the calibration with $\phi \rightarrow \pi^+\pi^-\pi^0$.

The **related systematics is ~0.5 of the statistical error** on the efficiency .

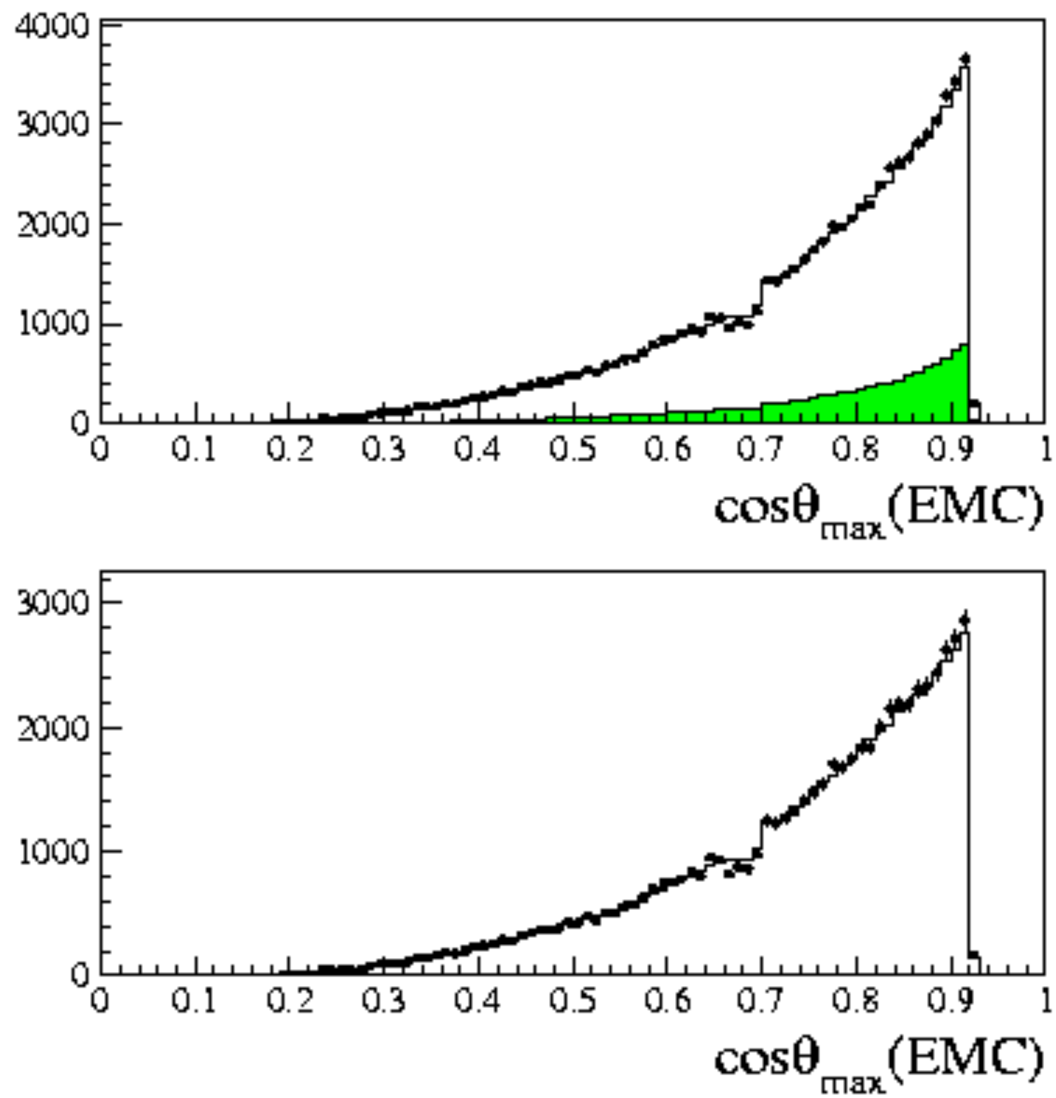
WARNING:

The new "softer" data/MC efficiency curves obtained by Tommaso and Matteo may have some impact in the spectrum at low energy (below 70 MeV). We are planning to evaluate the systematics applying these new curves!

Study on the acceptance (II)

3. Angular acceptance

Calorimeter resolution on angular position has very high precision.
To see how well we define our acceptance we compare data and MC.

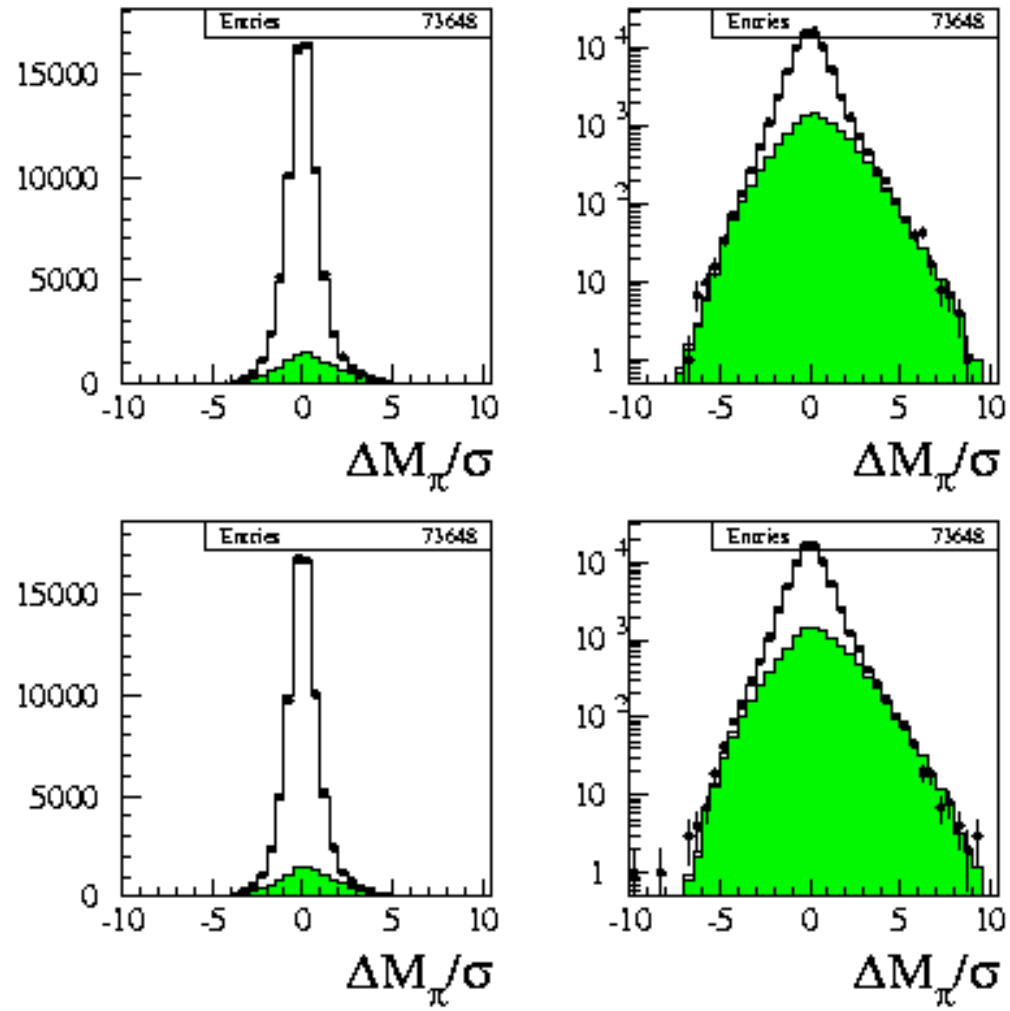


Agreement is excellent.

Photon pairing efficiency (I)

After the first kinematic fit we pair photons into π^0 depending upon the expected energy resolution and minimizing a χ^2_{SEL} estimator. Good agreement is observed between data and MC in $\Delta M/\sigma$

$\Delta M/s = (M\gamma\gamma - M\pi^0)/\sigma$



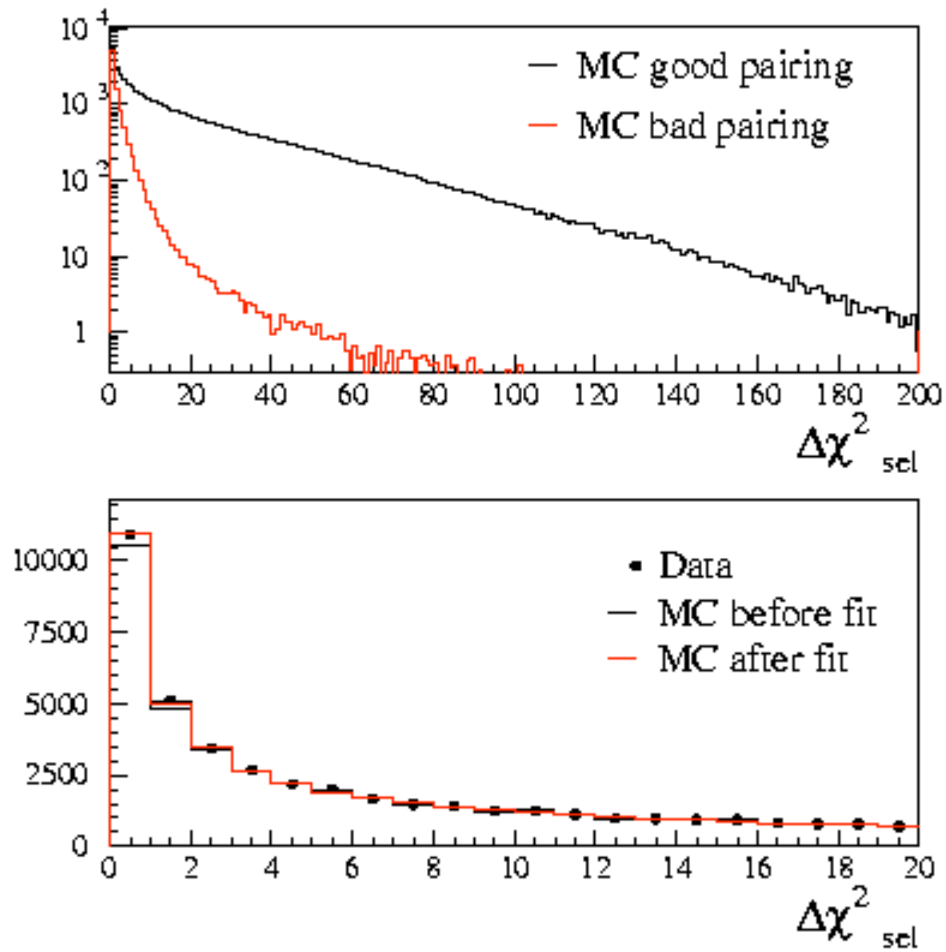
Resolution is evaluated with same parametrization of energy resolution (after first kinematic Fit) used in pairing procedure.

We keep only events with $|\Delta M/\sigma| < 5$

Photon pairing efficiency (II)

- ✓ To assign a systematics to the pairing procedure we studied the difference between χ^2_{SEL} for the best and second best choise of photons: $\Delta\chi^2_{SEL} = \chi^2_{SEL}$ (Best)- χ^2_{SEL} (SecondBest)

- ✓ We then fit the $\Delta\chi^2_{SEL}$ distribution in data with a linear combination of MC spectra for the right and wrong choise of paired photons (by MC truth).



$R_{pair} = 1.08 \pm 0.02$

Second Kinematic fit and related problems ….

- ✓ After pairing photons **a second kinematic fit is performed constraining on M_{π} (11C).**
- ✓ The data-MC comparison of the χ^2 distribution is excellent (cumulative distributions differ less than 1% at the analysis-cut value) … but …..

we have problems in fitting the Dalitz when applying a tight χ^2 cut

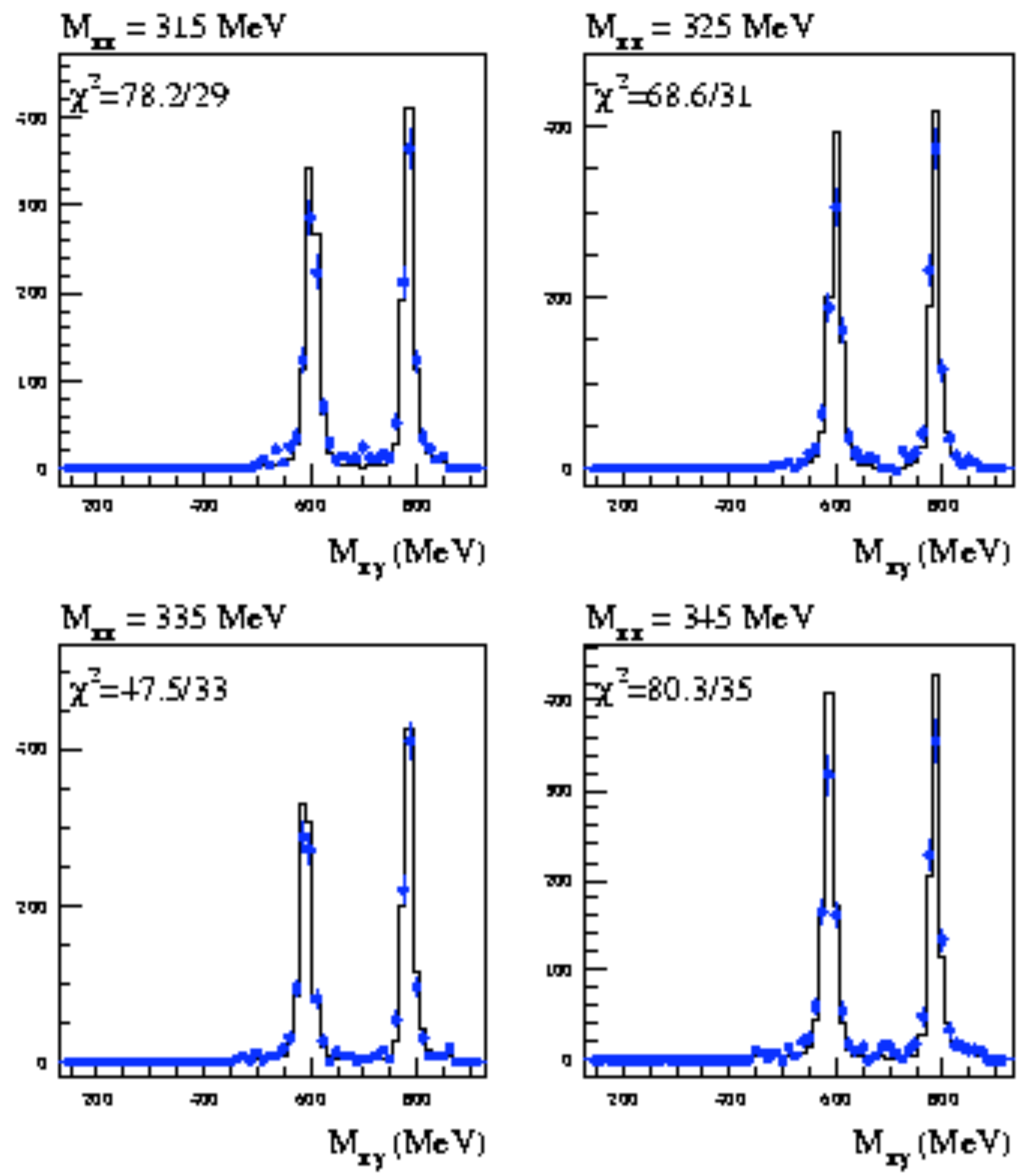
⬇

Indeed, while testing the fit on the Dalitz we realized that :

- when leaving free Γ_{ω} and VDM couplings the width tends to grow with a correlated increase of the couplings.
- The χ^2 of the fit nicely improves!

The fit problem: a growing Γ_ω ??

A flavour of the Dalitz regions where the fit fails and the χ^2 jumps up.



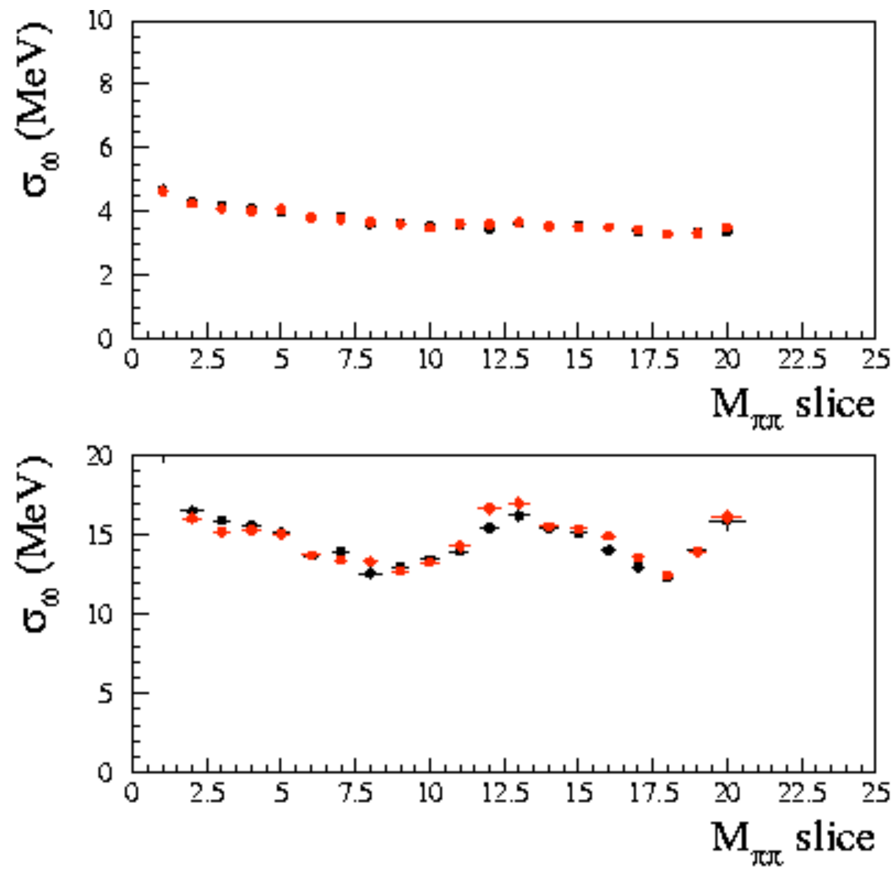
A too large Γ_ω cannot be a realistic origin/solution of the problem:

- Γ_ω is well known
- our own measurement of $\omega \to \pi\pi\pi$ agrees with PDG.
- even inserting in the propagator a Γ_ω (s) does not help.

The fit problem: different data-MC resolution??

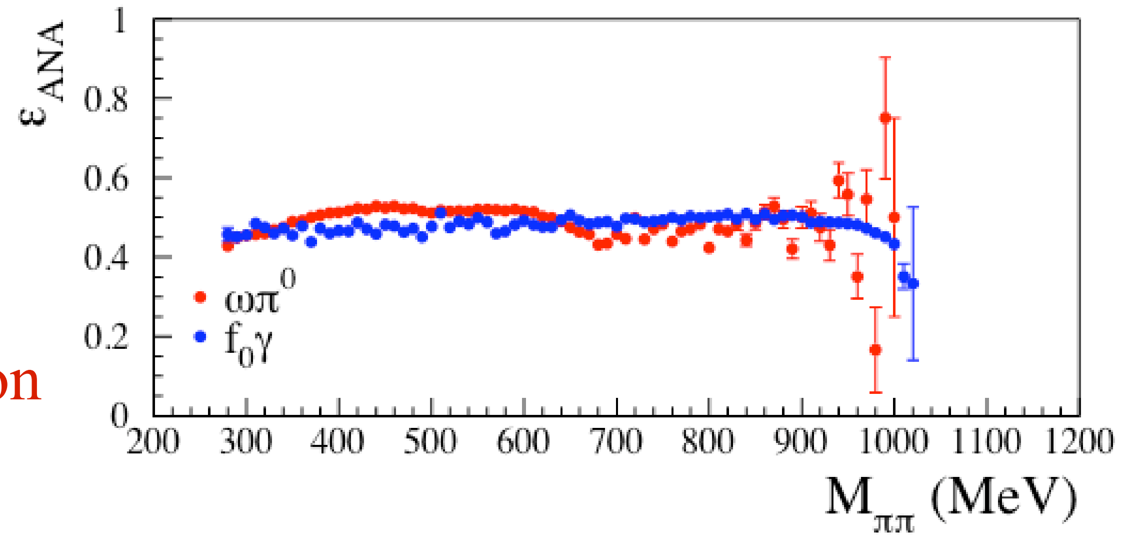
The mass resolution after the second kinematic fit cannot be the origin of such an apparent enlargment on Γ_ω. To simulate the effect of Γ_ω = 11 MeV we should add in the MC an additional source of resolution able to contribute for ≈ 7 MeV. The MC resolution on $M\pi\gamma$ shows a core of 3-4 MeV (F=0.66) and tails of 12-15 MeV (F=0.33).

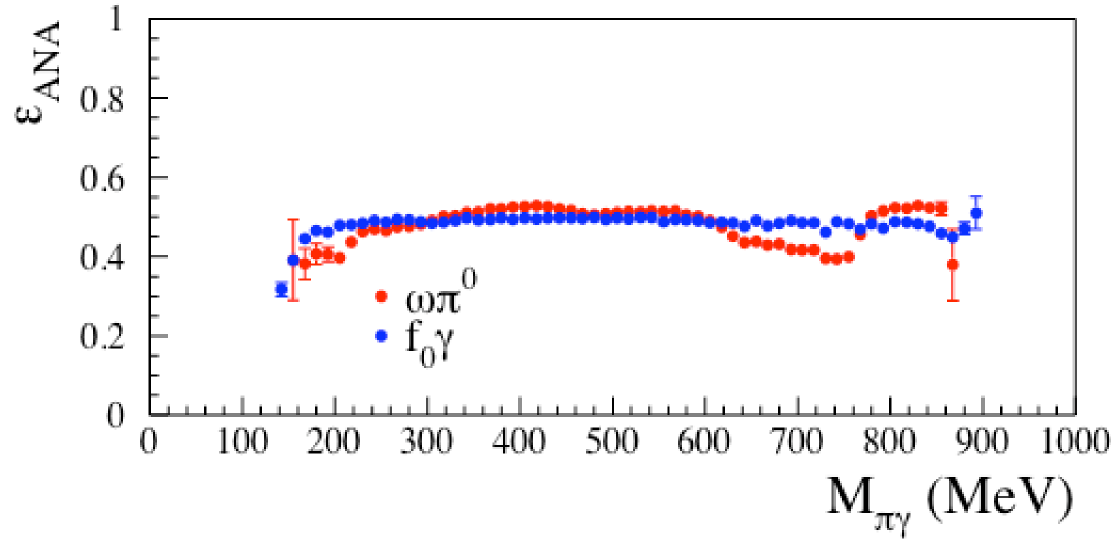
From the agreement on ΔM
we consider this effect negligible



The fit problem: dependence of ε_{ana} on the dalitz

- By looking at the behaviour of ε_{ana} in the Dalitz we recall that:
  - The dependence of ε_{ana} for the $S\gamma$ process is flat
  - ε_{ana} for the VDM process shows instead fast variation along the plane.





Relation between ISR and ε_{ana} (I)

We searched for the origin of the difference on ε_{ana} dependence

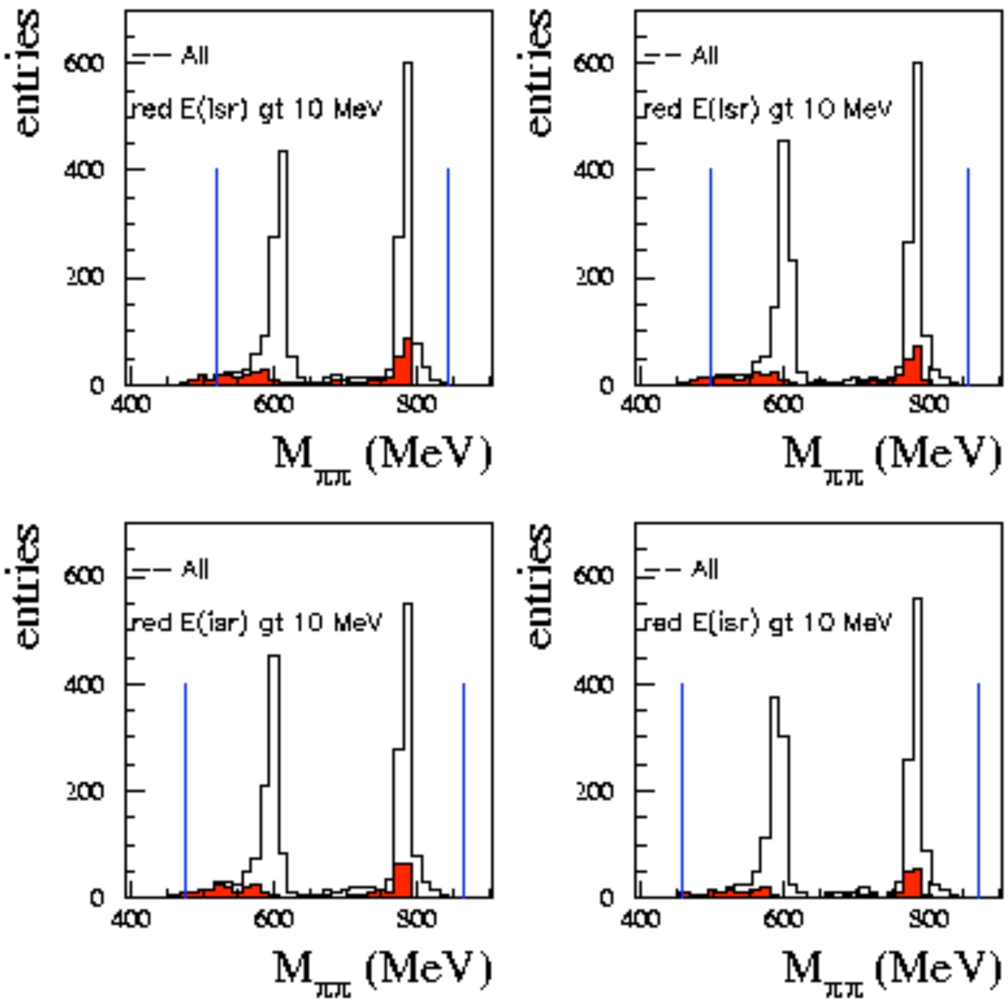
- We found that this is due to the different spectrum of ISR photons betweem the Sγ and VDM processes.
- The resonant behaviour of Sγ originates large (25%) radiative corrections with an ISR energy spectrum constrained by Γφ to be below 10 MeV.
- The not-resonant behaviour of VDM makes small the radiative correction while the ISR energy spectrum shows large tails.

Our kinematic fit constrains the energy sum to the beam energy with an error of 300 keV (BES).

Require a tight χ^2_{FIT} cut implies rejection of the VDM events with large ISR tails.

Relation between ISR and ε_{ana} (II)

The MC distribution of VDM events with an ISR photon >10 MeV is concentrated on the low-$M_{\pi\gamma}$ tails of the omega peaks.



Trying to handle the ISR problem ….

Two different roads to attack / understand this point :

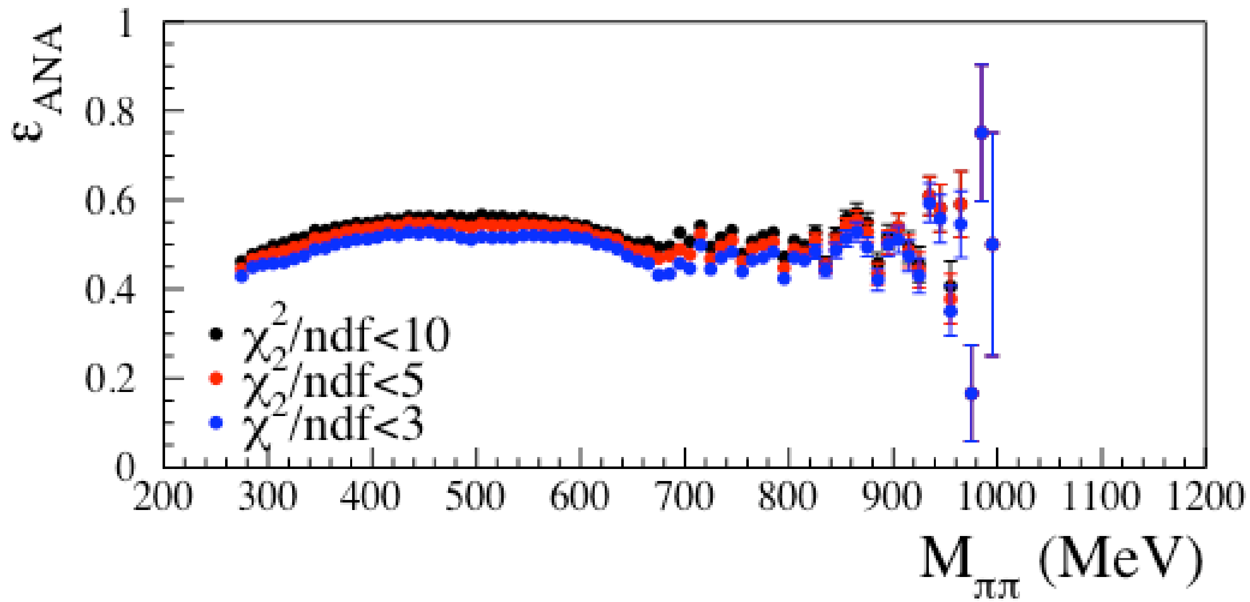
1) Relax the cut on χ^2_{FIT}/ndof. Moving it from 3 to 5, 10

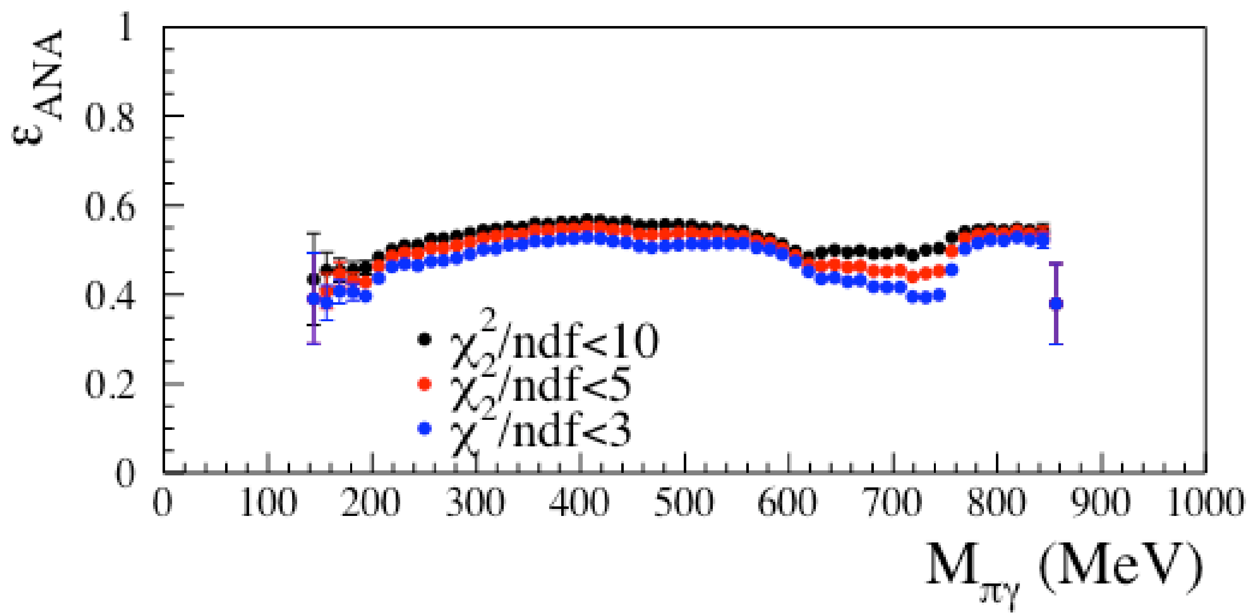
the efficiency gets flatter but the background goes up

Process	ε_{ana} ($\chi^2 < 3$)	**S/B** ($\chi^2 < 3$)	**S/B** ($\chi^2 < 5$)	**S/B** ($\chi^2 < 10$)
$e^+e^- \to \omega\pi^0 \to \pi^0\pi^0\gamma$	50.2 %			–
$\phi \to S\gamma \to \pi^0\pi^0\gamma$	48.7 %			–
$\phi \to a_0\gamma \to \eta\pi^0\gamma \to \gamma\gamma\pi^0\gamma$	18.7 %	22.6	18.9	16.5
$\phi \to \eta\gamma \to \pi^0\pi^0\pi^0\gamma$	3.6×10^{-3}	**8.7**	**3.9**	**2.0**
$\phi \to \eta\gamma \to \gamma\gamma\gamma$	6.0×10^{-3}	43.4	32.3	30.9
$\phi \to \pi^0\gamma$	0.2×10^{-3}	448.0	346.1	324.6
$e^+e^- \to \gamma\gamma(\gamma)$	0.9×10^{-6}	804.2	407.5	267.9

2) Study/check ISR in MC and learn how to assign a syst. error to it

ε_{ana} vs χ^2 cut for VDM processes





Background composition vs $\chi 2$ cut

The systematic study on BKG repeated for the different $\chi 2$ cuts.

In this table we report the data-MC weight factors found by fitting a set of Background-enriched distributions.

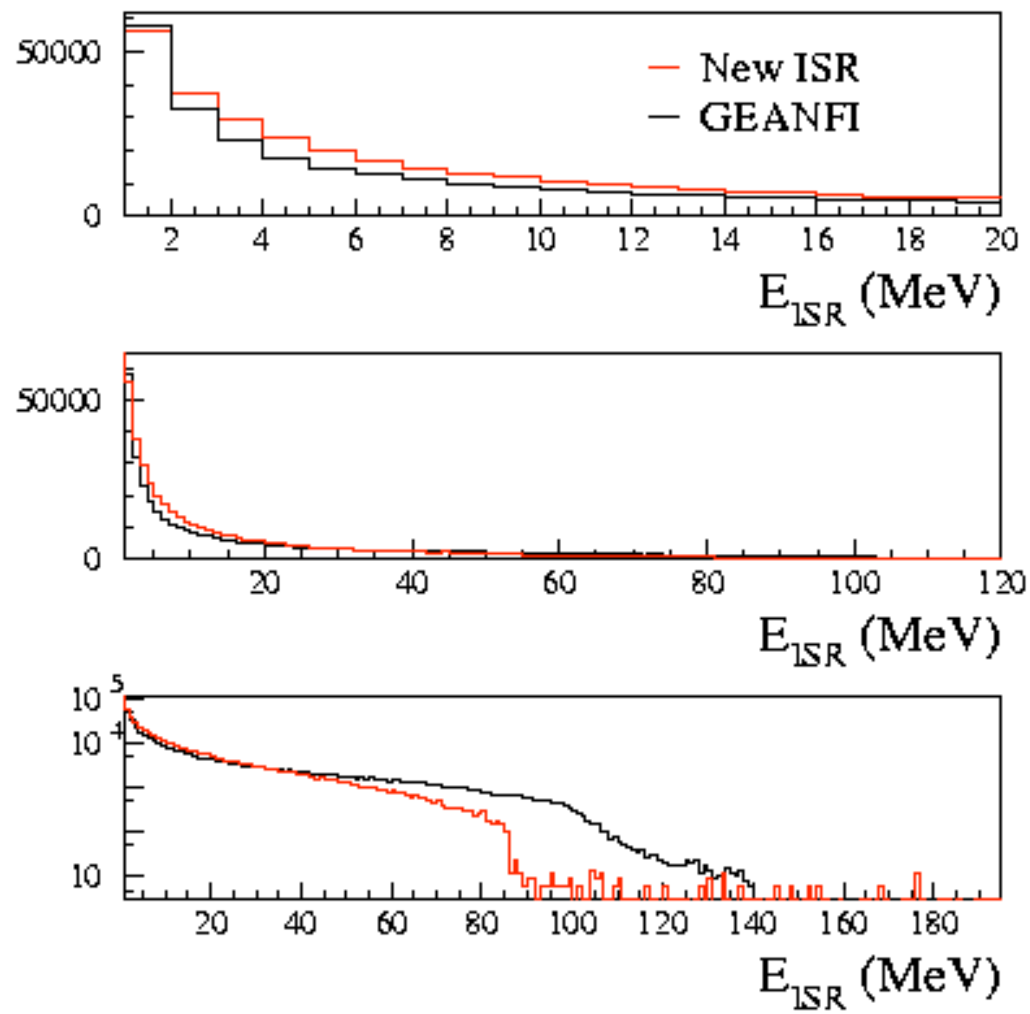
Process	**Wb ($\chi^2 < 3$)**	**Wb ($\chi^2 < 5$)**	**Wb ($\chi^2 < 10$)**
$\phi \to a_0\gamma \to \eta\pi^0\gamma \to \gamma\gamma\pi^0\gamma$	0.787 ± 0.003	0.787 ± 0.005	0.760 ± 0.020
$\phi \to \eta\gamma \to \pi^0\pi^0\pi^0\gamma$	**1.064 ± 0.002**	**1.064 ± 0.002**	**1.064 ± 0.002**
$\phi \to \eta\gamma \to \gamma\gamma\gamma$	0.892 ± 0.005	0.820 ± 0.040	0.802 ± 0.003
$\phi \to \pi^0\gamma$	1.78 ± 0.33	1.70 ± 0.24	1.61 ± 0.03
$e^+e^- \to \gamma\gamma(\gamma)$	1.85 ± 0.03	1.85 ± 0.03	1.85 ± 0.03

Situation is under control. For the main $\eta \to 3\pi^0$ background the related systematics have been checked with a $\chi 2$ region between 4-20

ISR in Geanfi vs fast generator

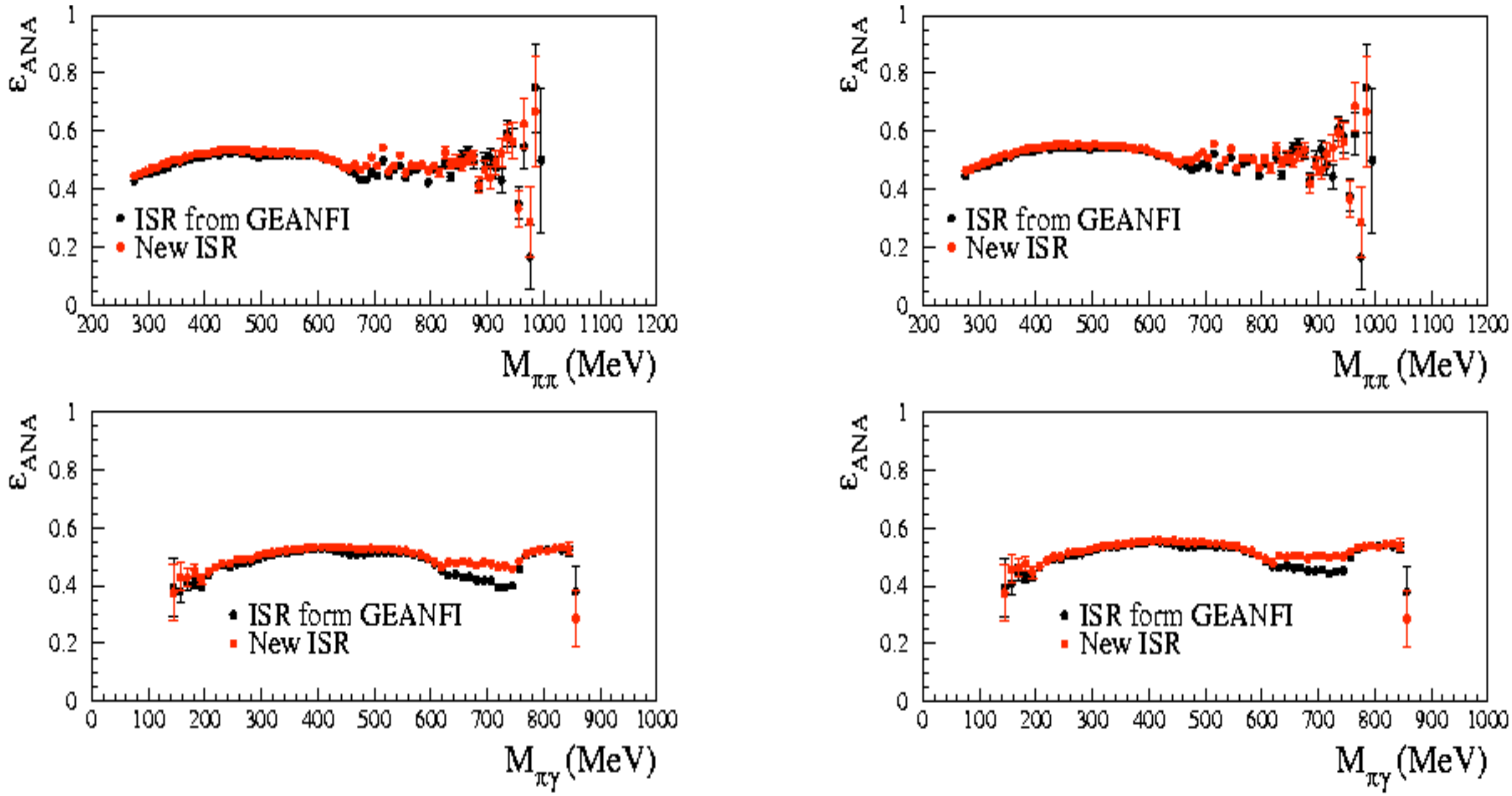
Another way is to test if the ISR in GEANFI is correct.

- We applied the Greco-Nicrosini ISR to our standalone VDM generator
- we apply a threshold cutoff at $4M\pi^2$
- a correct $\sqrt{s}$ dependence on the xsec with a threshold behaviour around $M\omega+M\pi$



ε_{ana} (VDM) vs simulation of ISR

$\chi 2 < 3$ $\chi 2 < 10$



Fit function: the Achasov parametrization

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

} $f_0\gamma$ — Model dependent term

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

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

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

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

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

It was modified in + cos ϕ (???)

NO MORE

$$\frac{1}{\sqrt2}Re\left[g(m)e^{i\delta_B(m)}\frac{g_{f_0K^+K^-}g_{f_0\pi^0\pi^0}}{D_{f_0}(m)}\frac{g_{\phi\gamma}}{D_\phi(s)}\right.\Bigg($$

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

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

} $f_0\gamma$/VP interf

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

VDM parametrization: C_{VP} fixed – K_{VDM} (norm factor), $\delta_{b\rho}$, M_V , G_V free

Fit function: the Isidori-Maiani parametrization

- 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]

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

In the interference term, a global phase due to the $\pi\pi$ re-scattering is included. No other free phases used.

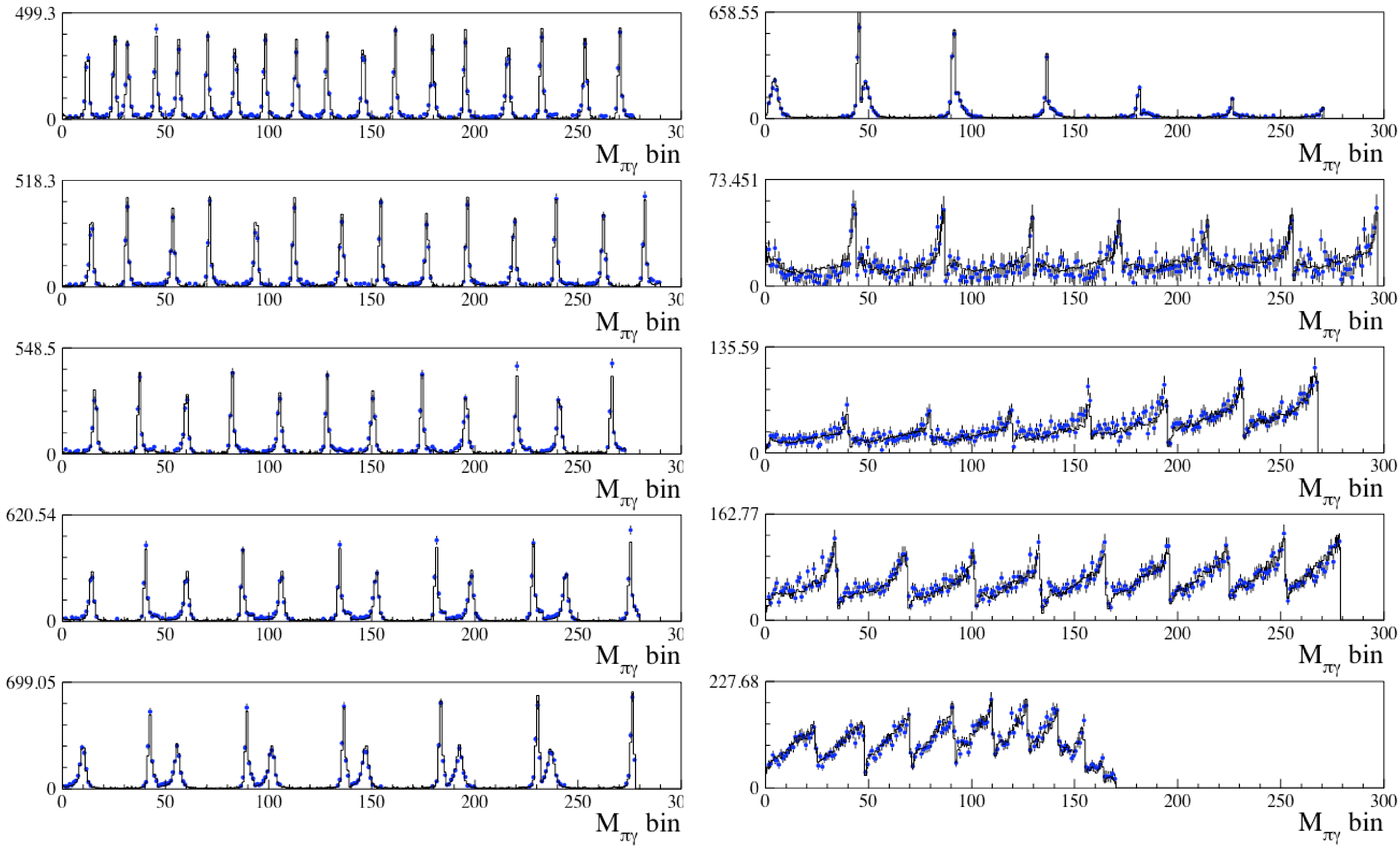
A more refined parametrization received today:
- Propagator with correct threshold behaviour (Flatte-like)
- Different $\pi\pi$ re-scattering phases for the a_0 and a_1 terms in order to reproduced behaviour of δ^0_0 at low $m_{\pi\pi}$ values

Stability of Fit results for ACH vs $\chi 2$ (new/old ISR)

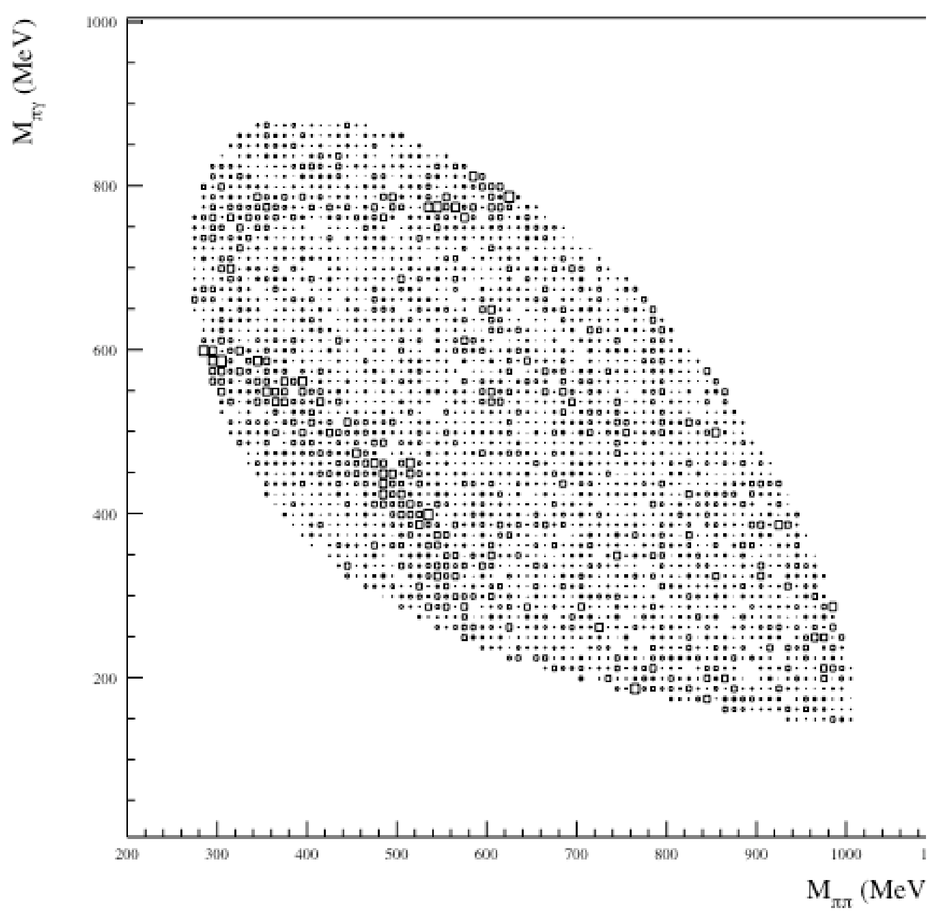
ISR χ^2 (KineFit) cut	NEW 3	 5	 10	OLD 5
M_{f0} (MeV)	959.0 . 2.5	959.0 ± 1.0	959.5 2.0	961.4 0.8
g (f K^+K^-)(GeV)	4.75 0.12	4.83 ± 0.06	4.84 ± 0.11	5.00 ± 0.06
g (f $\pi^+\pi^-$)(GeV)	1.64 0.09	1.62 ± 0.05	1.66 ± 0.09	1.71 ± 0.03
g (σ $\pi^+\pi^-$)(GeV)	4.56 0.09	4.5 ± 0.1	4.2 ± 0.1	4.5 ± 0.1
Cf0s(GeV $^{-2}$)	0.107 0.020	0.111± 0.008	0.119± 0.020	0.130± 0.008
Pf0s	0.74 0.05	0.79± 0.02	0.83± 0.06	0.73± 0.04
K_{VDM}	0.848 0.005	0.857 ± 0.005	0.847 ± 0.005	0.862 ± 0.005
M_ω (MeV)	782.4 0.1	782.6 ± 0.1	783.3 ± 0.1	777.0 ± 0.2
δ_{b_ρ} (degree)	100.5 1.4	102.7 ± 1.2	102.5 ± 1.7	102.4 ± 1.3
χ^2/ndf	**3310.4/2675**	**3051.2/2675**	**2684.0/2675**	**3061.5/2675**
Prob(χ^2)	**0.3x10-15**	**0.4x10-6**	**0.442**	**0.2x10-6**

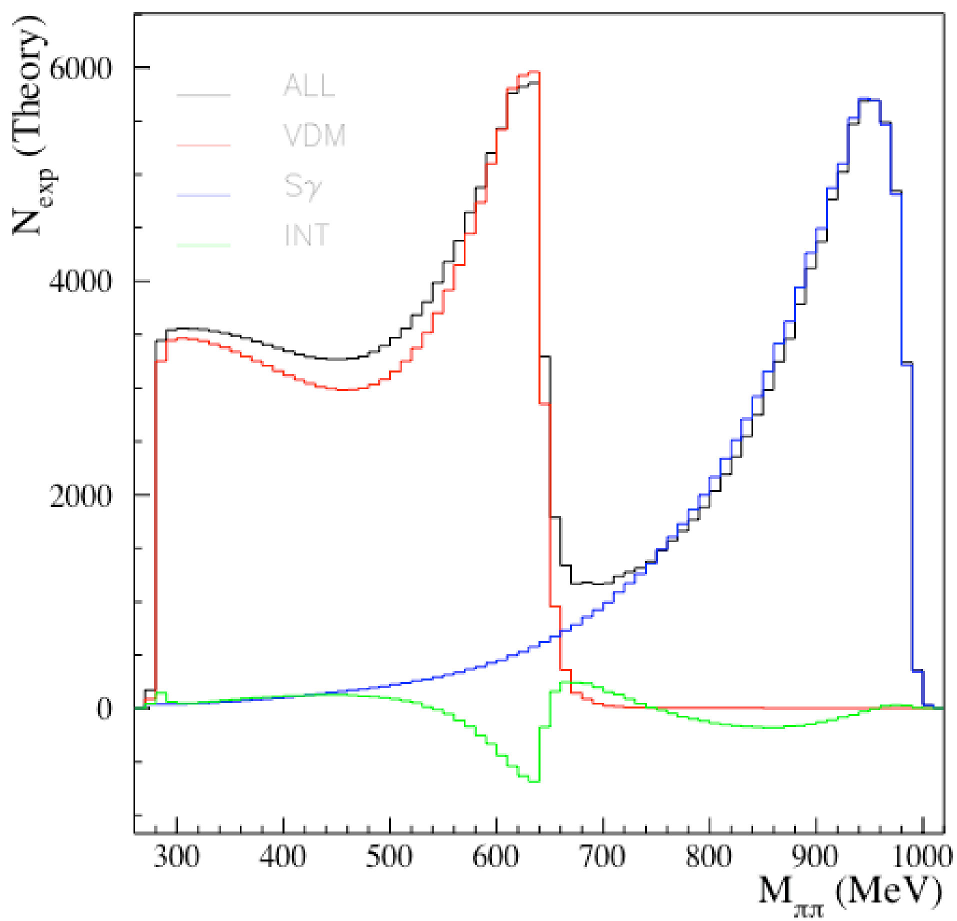
VDM-Scalar interference +, M(Sigma) = 540 MeV (Bes)

Dalitz-fit with ACH for χ2(KineFit) < 5: projections



Dalitz-fit with ACH for $\chi 2$(KineFit) < 5: contributions



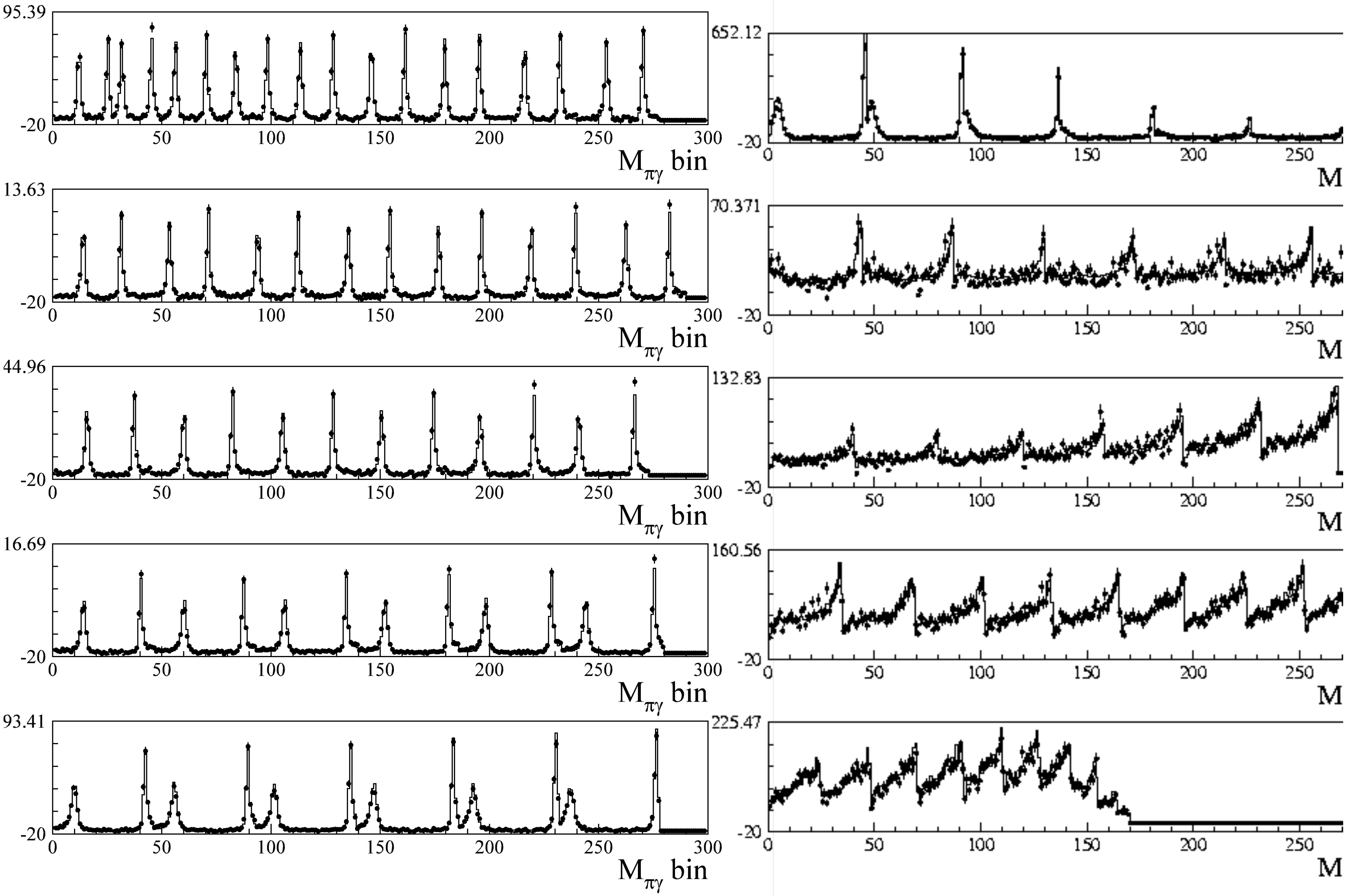


Stability of Fit results for IM vs χ2 cut (new/old ISR)

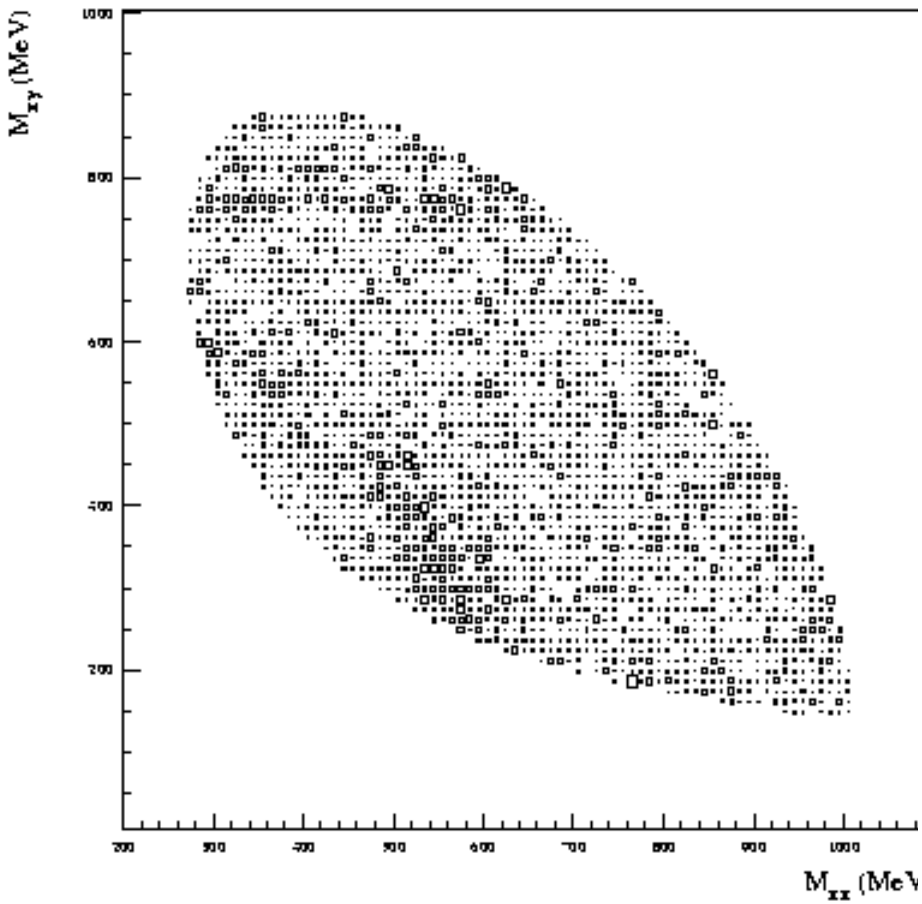
ISR χ^2 (KineFit) cut	NEW 3	 5	 10	OLD 5
M_{f0} (MeV)	981.7 ± 0.6	983.0 ± 0.7	982.8 ± 0.6	982.7 ± 0.2
Γ_{f0} (MeV)	43.3 ± 0.7	43.9 ± 0.6	43.9 ± 0.7	43.8 ± 0.6
$g_{\phi f\gamma} \times g_{f\pi\pi}$	2.02 ± 0.02	2.10 ± 0.03	2.11 ± 0.02	2.08 ± 0.01
a_0	3.42 ± 0.07	3.74 ± 0.07	3.80 ± 0.09	3.64 ± 0.05
a_1	0.79 ± 0.07	1.08 ± 0.06	1.11 ± 0.10	1.03 ± 0.06
K_{VDM}	0.683 ± 0.004	0.683 ± 0.004	0.675 ± 0.004	0.686 ± 0.004
M_ω (MeV)	782.03 ± 0.07	782.09 ± 0.07	782.85 ± 0.07	782.13 ± 0.05
δ_{b_ρ} (degree)	2.4 ± 1.3	2.2 ± 1.3	0.0 ± 2.0	1.7 ± 1.2
χ^2/ndf	**3020.8/2675**	**2766.2/2675**	**2380.4/2675**	**2776.0/2675**
Prob(χ^2)	**0.27×10^{-3}**	**0.107**	**1.00**	**0.085**

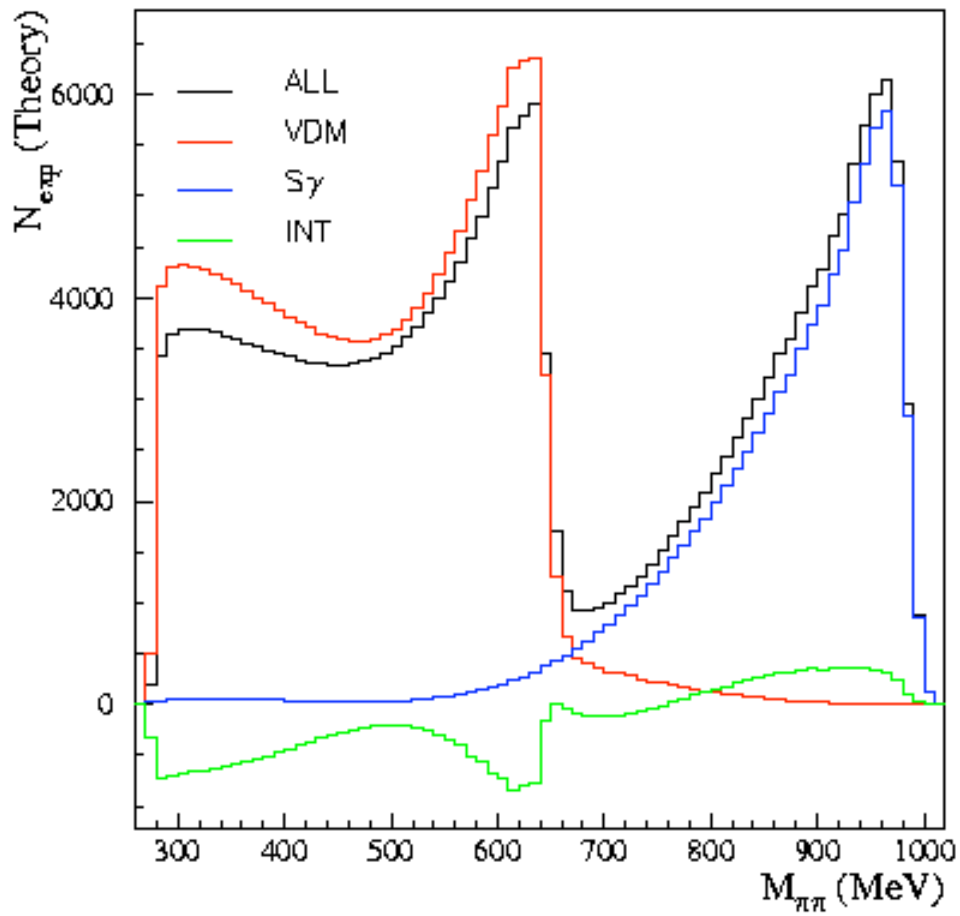
To be tried with the new parametrization and fixing
δbrho to grant a correct VDM dip vs sqrt(s)

Dalitz-fit with IM for χ2(KineFit) < 5: projections



DALITZ-fit with IM for χ2(KineFit)<5 : contributions





Summary of Fit results (I)

- We have ≈ finished to look for systematic effects ..we will incorporate their error on the $\chi 2$ evaluation for the Dalitz-fit.

  No large improvements foreseen.

- The ISR for VDM processes introduces a variation of the analysis efficiency along the plane. Easy to overcome enlarging the cut … but the background increases of a large factor.

  Intermediate case chosen: $\chi 2 < 5$.

- Due to the large statistics the prob($\chi 2$) reaches very low values also for this case (much better values obtained for the adjacent bins in sqrt(s) …)

Summary of Fit results (II)

- HOWEVER … we have stable results for a “given” parametrization!

- We are unable to fit the dalitz with the ach-f0 parametrization without including the SIGMA meson.

- The inclusion of sigma seems to be fine but different results are obtained if leaving free or not the value of the mass.

- For both models we are not yet convinced of the proper δ^0_0 behaviour of the found solution.

This is still work in progress.

Conclusions/prospects

The two positive sides of the story:

1) above 700 MeV the situation is stable at 5-10 % level for whatever parametrization we use. Also at low masses we have similar shapes.
2) We are not anymore in disagreement with the $\pi^+\pi^-$ case

IF/WHEN we use an identical parametrization.

The two negative sides of the story:

1) We have to complete the description of δ^0_0 to be sure these fits make any sense!
2) although many efforts done on this item and we consider the EXPERIMENTAL SIDE "CONCLUDED" we have not yet come to a solid conclusion.

PLAN is however to start writing a note, incorporate latest changes of IM and go for a paper even with large prob(χ2) …

Spare Slides
Old Slides

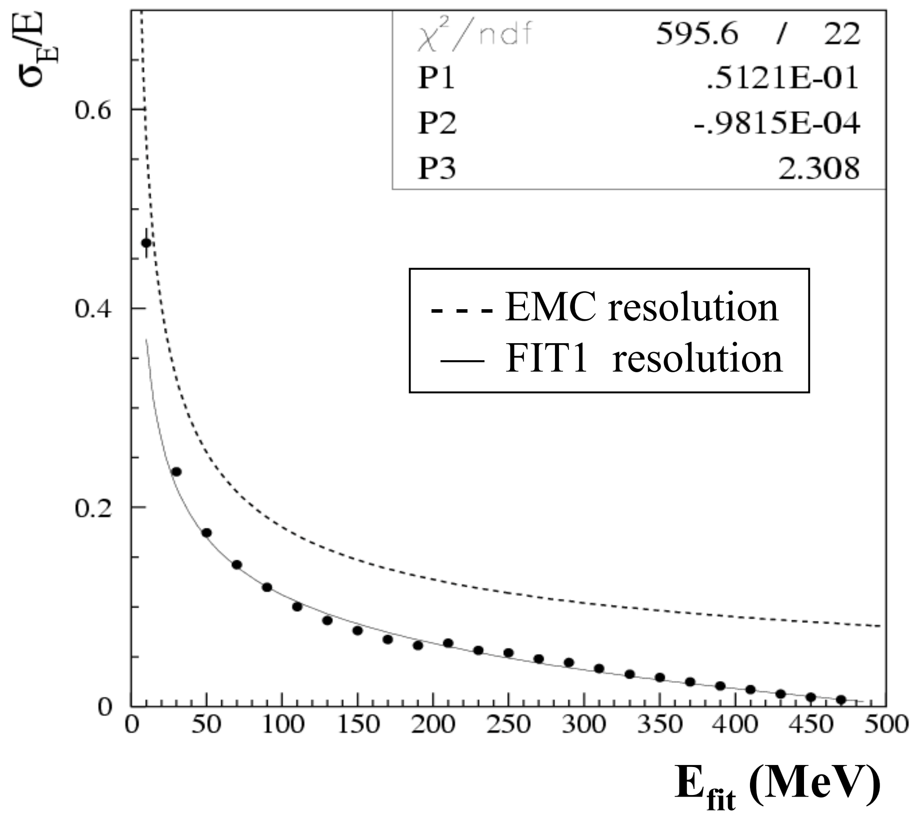
γ's pairing

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:

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



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

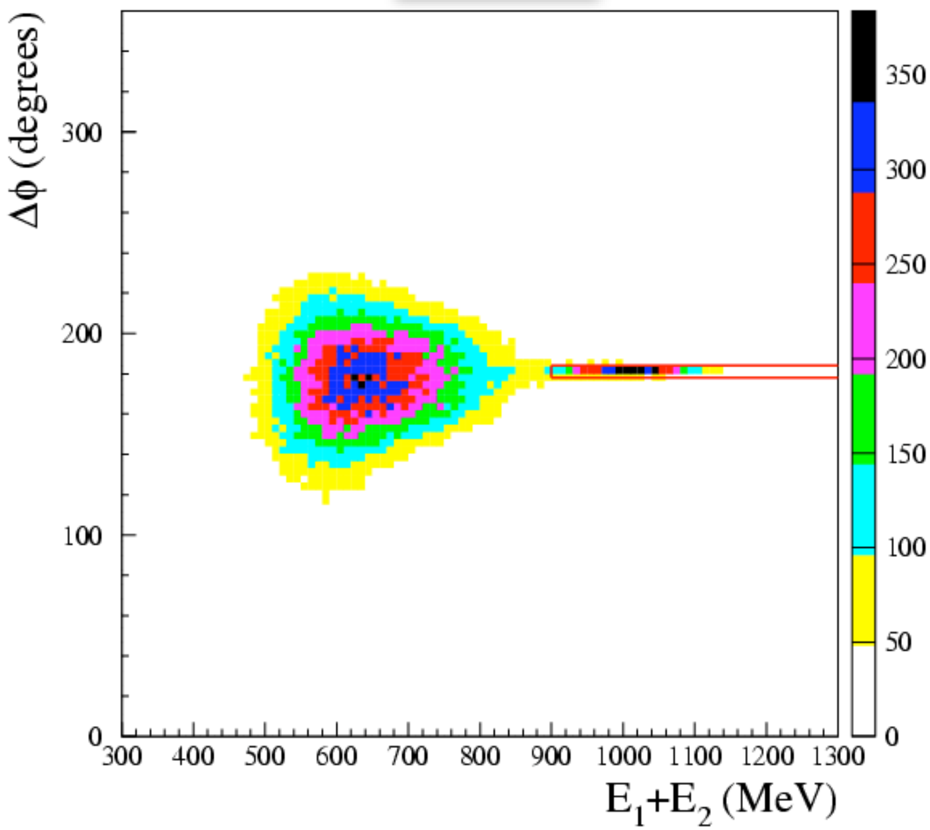
$$\chi^2 = (M_{\gamma_i\gamma_j} - M_\pi)/\sigma_{M_{ij}} + (M_{\gamma_k\gamma_l} - M_\pi)/\sigma_{M_{kl}}$$

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

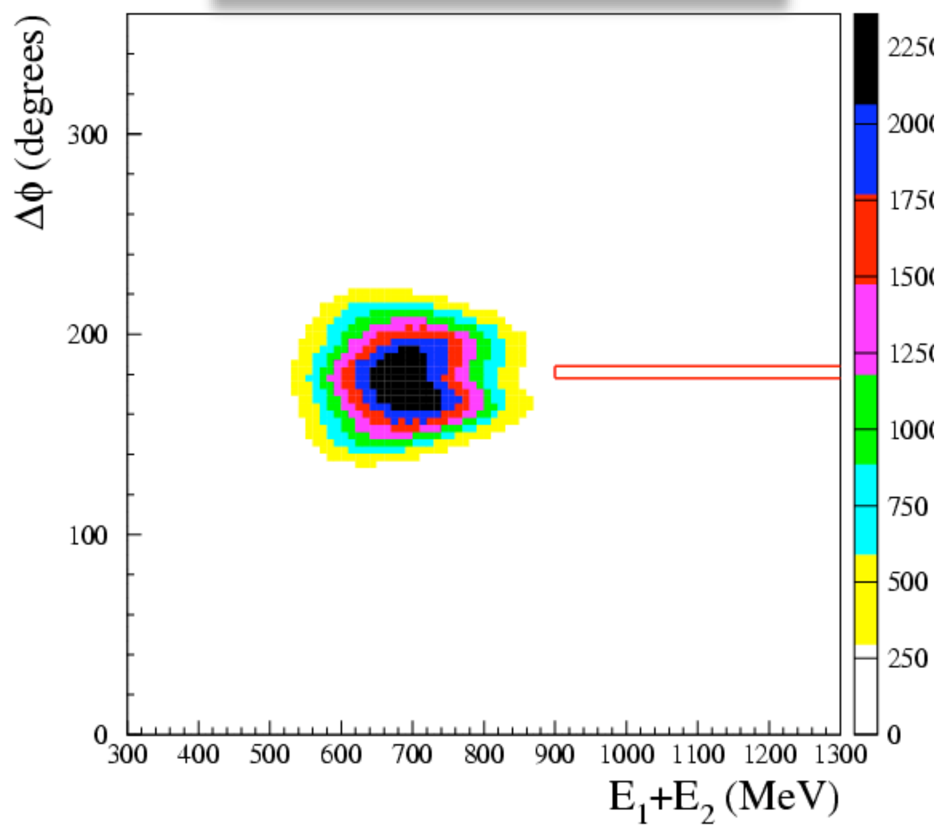
$e^+e^- \rightarrow \gamma\gamma$ rejection done using the two most energetic clusters of the event:

$E_1+E_2 > 900$ MeV

Data

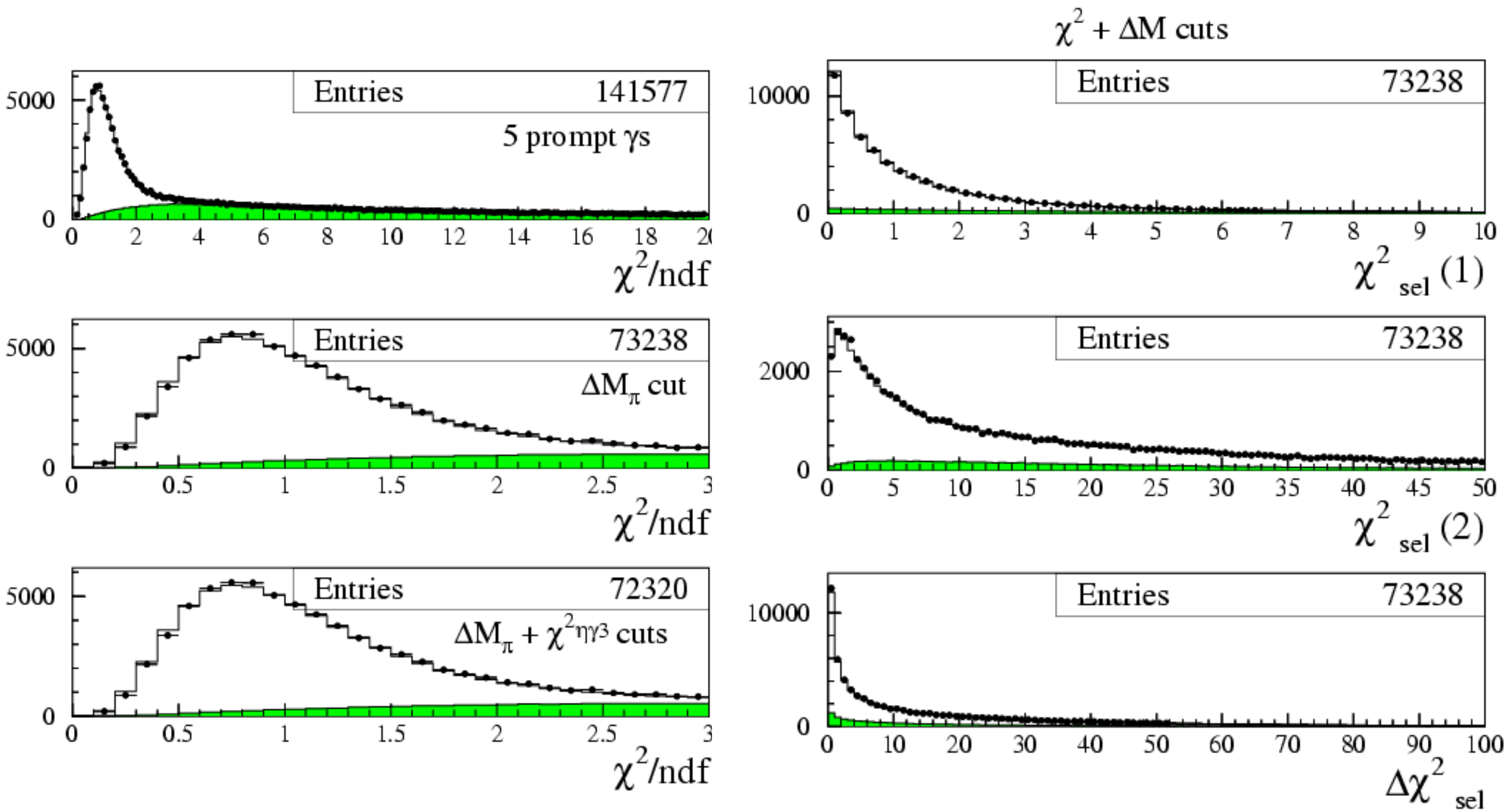


MC $\pi^0\pi^0\gamma$ events



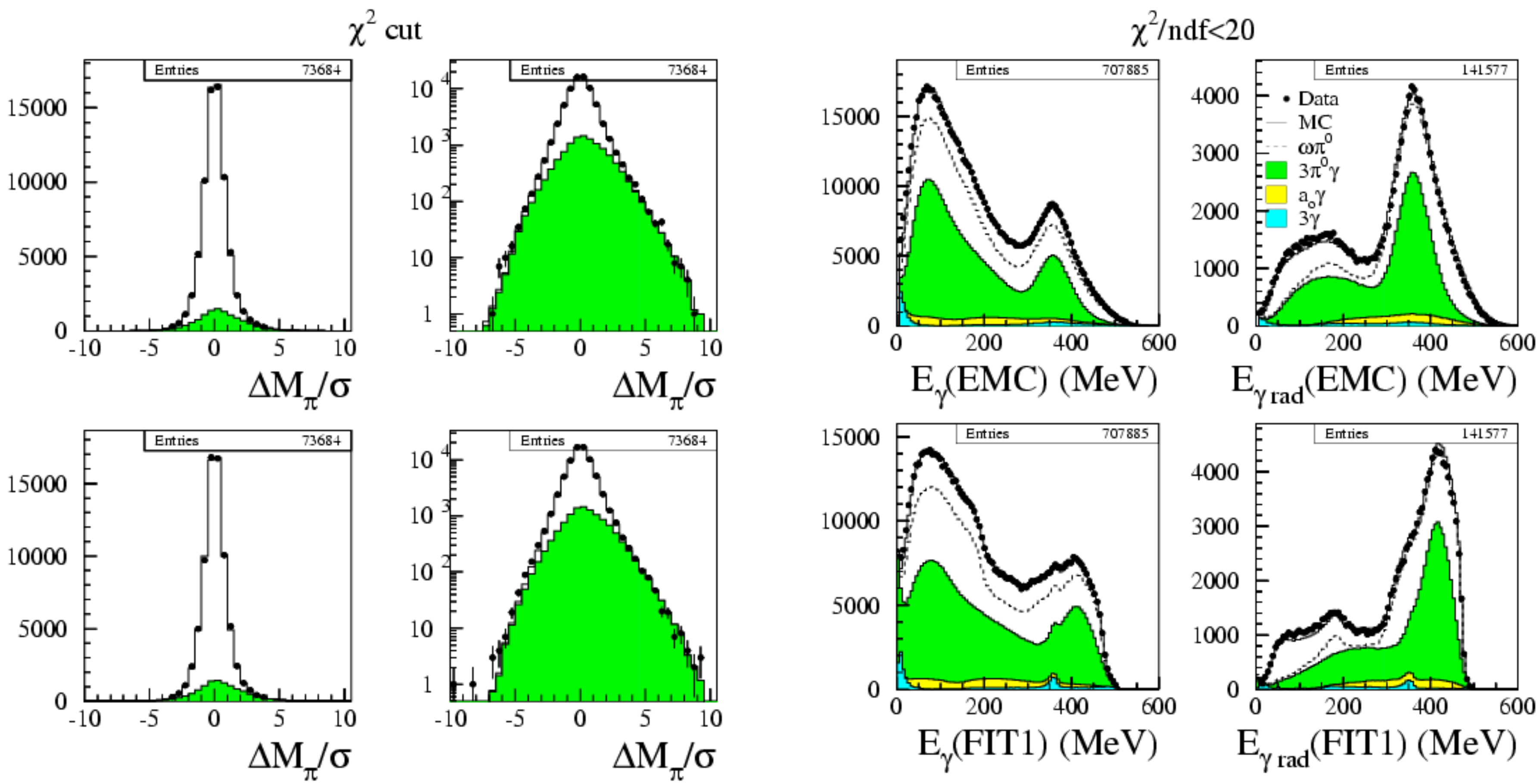
Dalitz plot analysis: data-MC comparison (I)

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



Dalitz plot analysis: data-MC comparison (II)

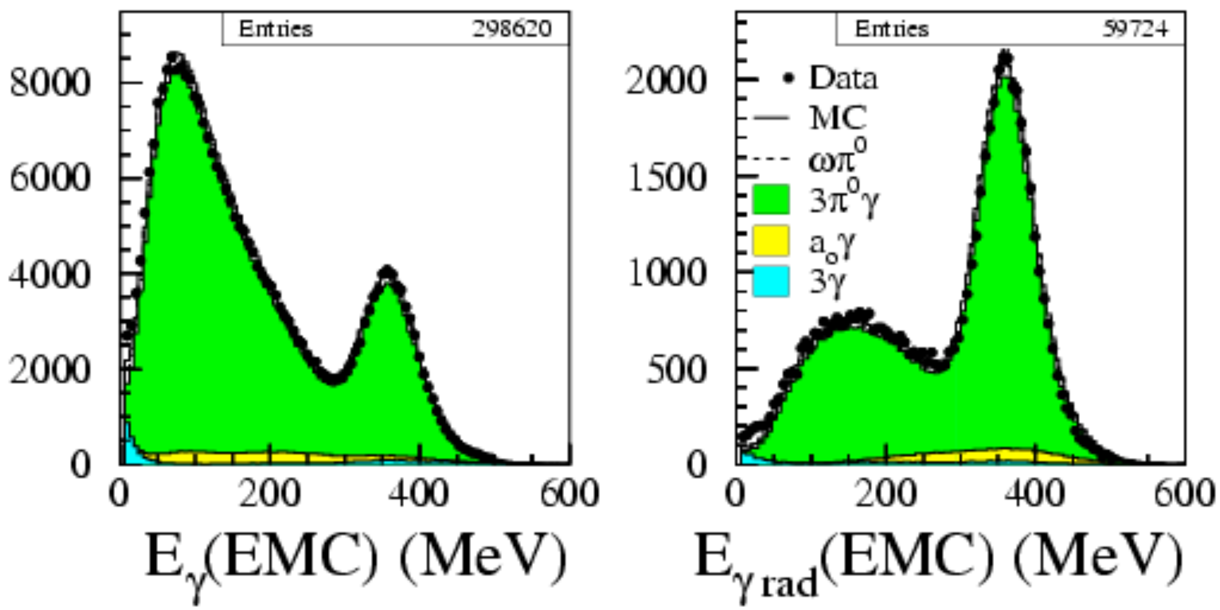
Analysis @ $\sqrt{s}$ = 1019.6 MeV (L_{int} = 145 pb^{-1})



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

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

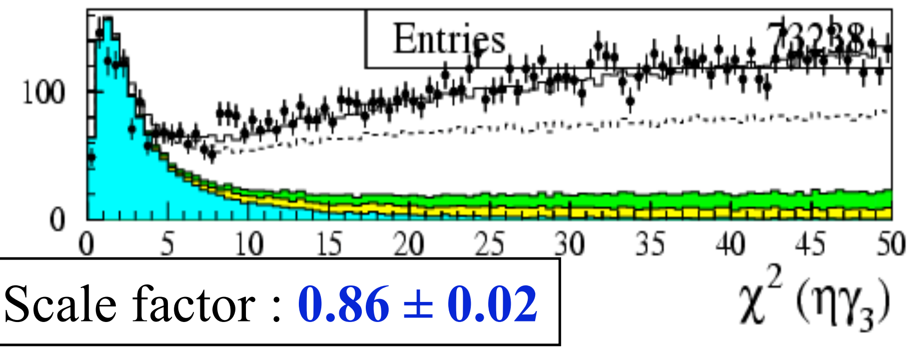


Scale factor :
1.0156 ±0.0002

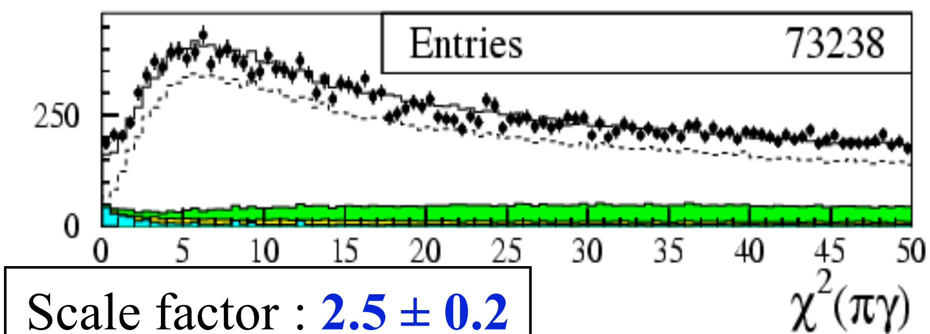
All of this fit results are used to evaluate the systematics on the background counting : half of the difference (1 – scale factor) is used

Background study for Dalitz plot analysis (II)

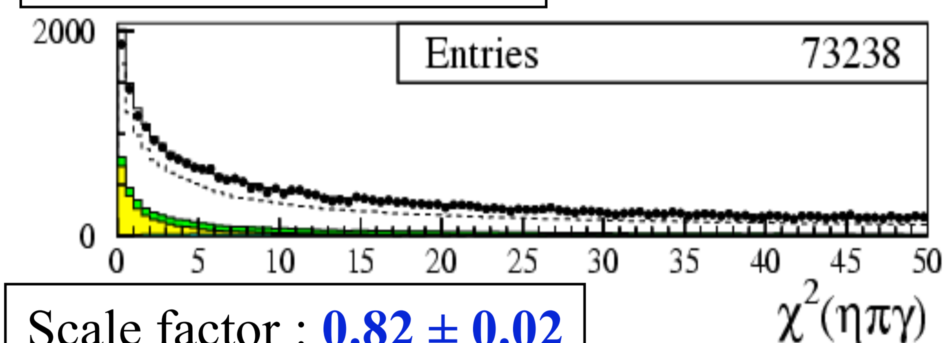
For $\phi \to \eta\gamma \to \gamma\gamma\gamma$, $\phi \to \pi^0\gamma$, $\phi \to a_0\gamma$ we calculate a χ^2 in the mass hypothesis



Scale factor : **0.86 ± 0.02**

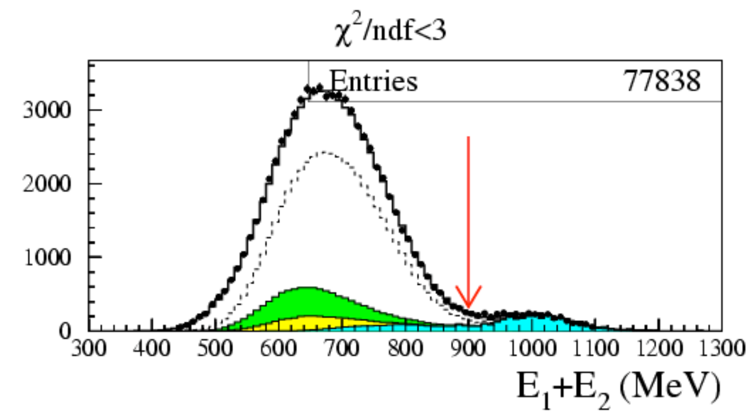


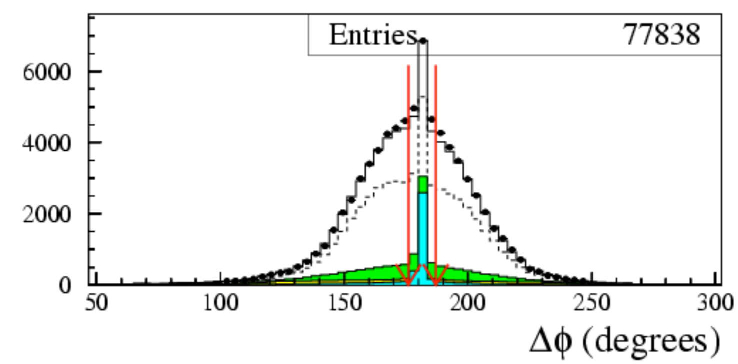
Scale factor : **2.5 ± 0.2**



Scale factor : **0.82 ± 0.02**

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





Scale factor : **1.85 ± 0.03**

Dalitz plot @ $\sqrt{s}$=1019.6 MeV

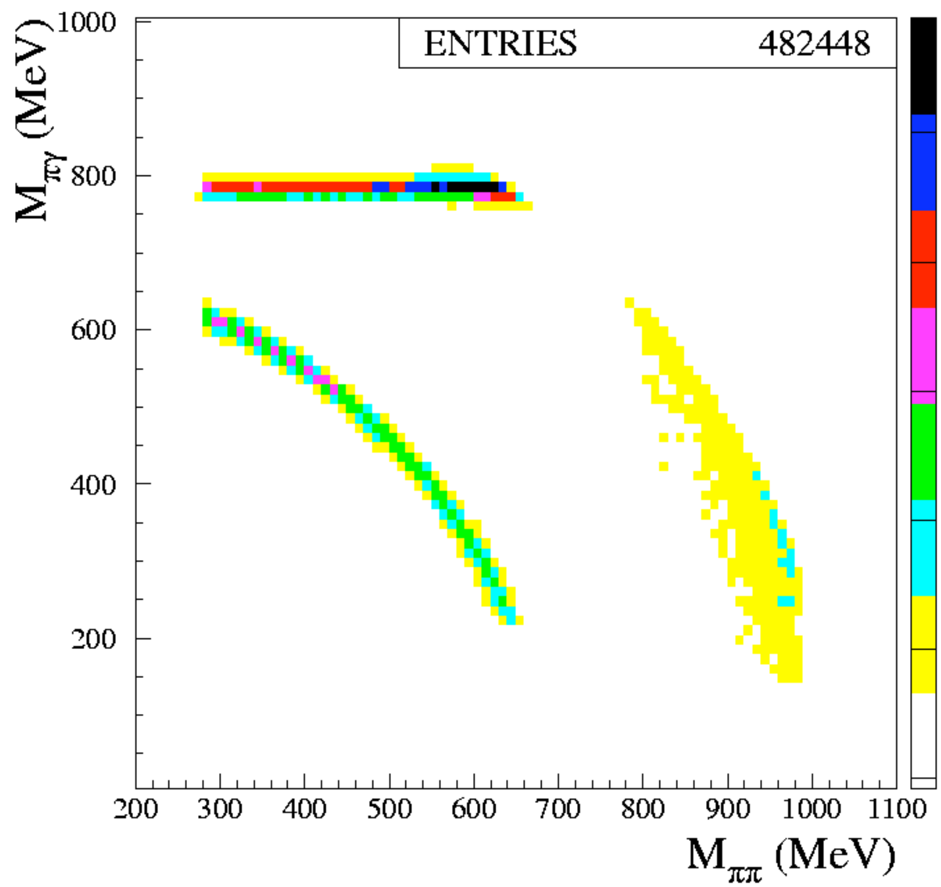
Fit to the Dalitz plot with the VDM and scalar term, including also interference

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

What is needed:

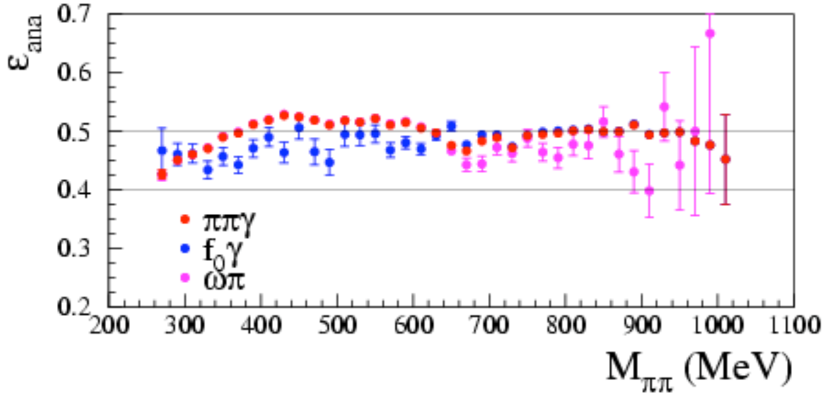
- Analysis efficiency
- Smearing matrix
- Theoretical functions
- ISR

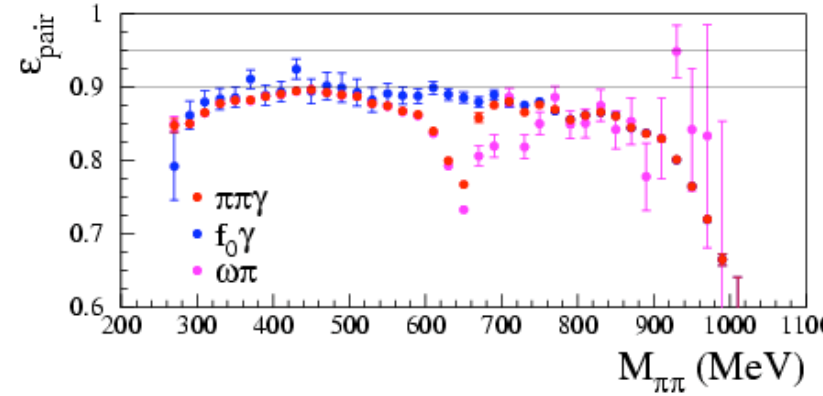
Only statistical error and systematics on background considered for the moment

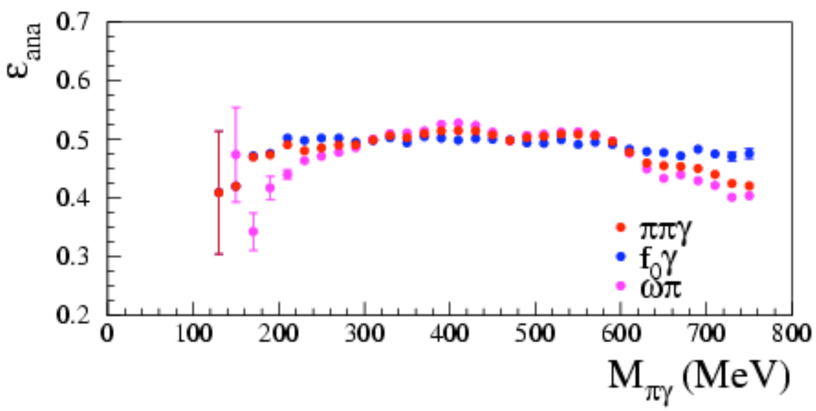


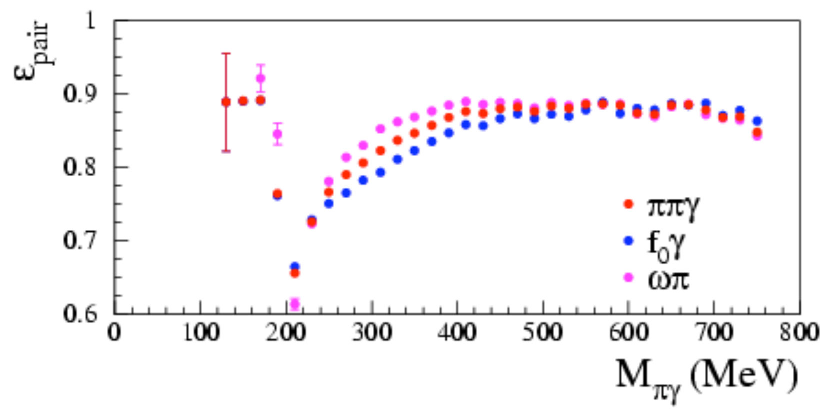
Analysis and pairing efficiencies *vs* $M_{\pi\pi}$, $M_{\pi\gamma}$

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







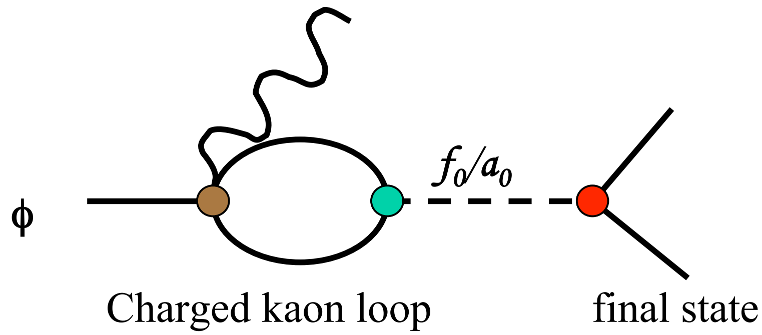


Different for the two processes!

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)

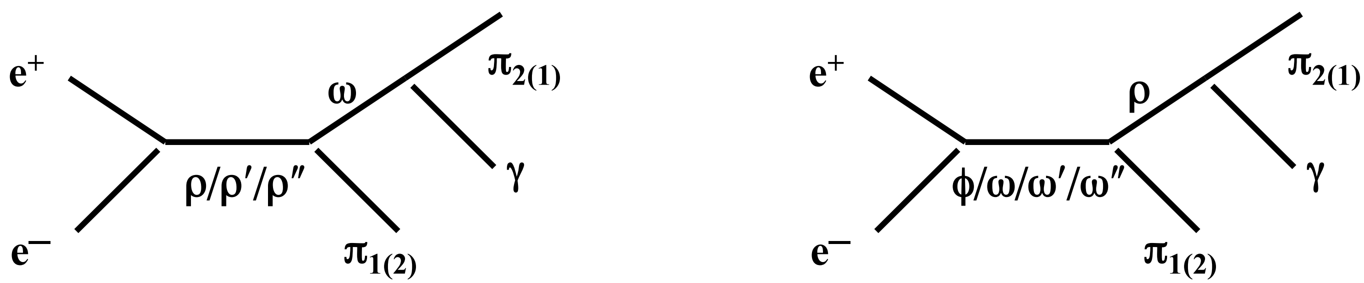
- **Scalar produced through a kaon loop**



- (brown) g(φ*KK*) from Γ(φ → K^+K^-)
- (green) g(f_0*KK*) g(a_0*KK*)
- (red) g(f_0ππ) g(a_0ηπ)

} fit output

- **VDM contribution from the following diagrams :**



- **All interferences considered**

Calculation of the radiative corrections

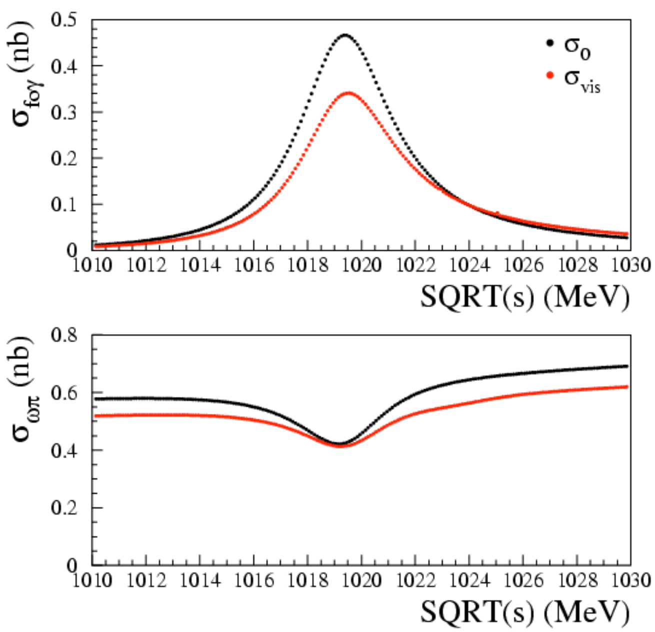
ISR evaluated starting from the following σ_0 :

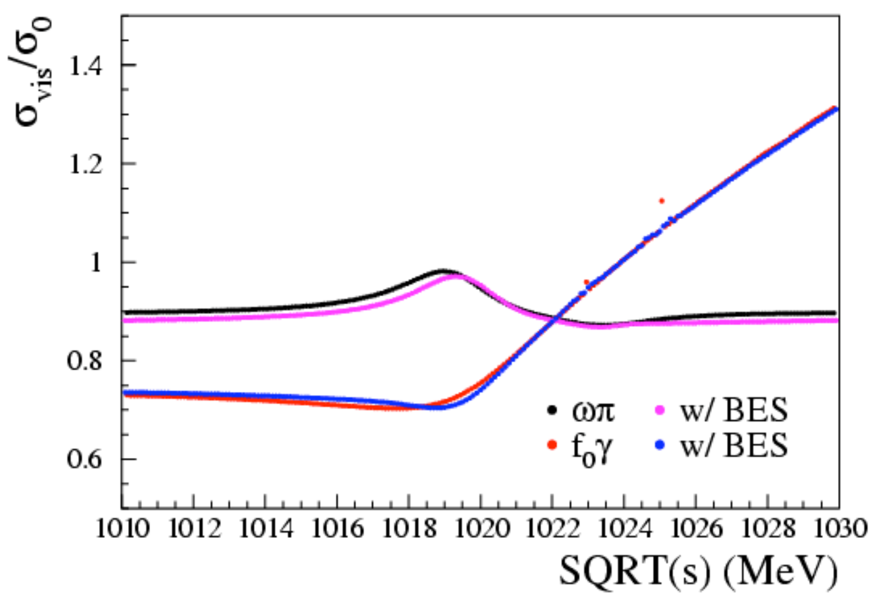
f_0 = "simple" BW (by integrating the Achasov scalar term)

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

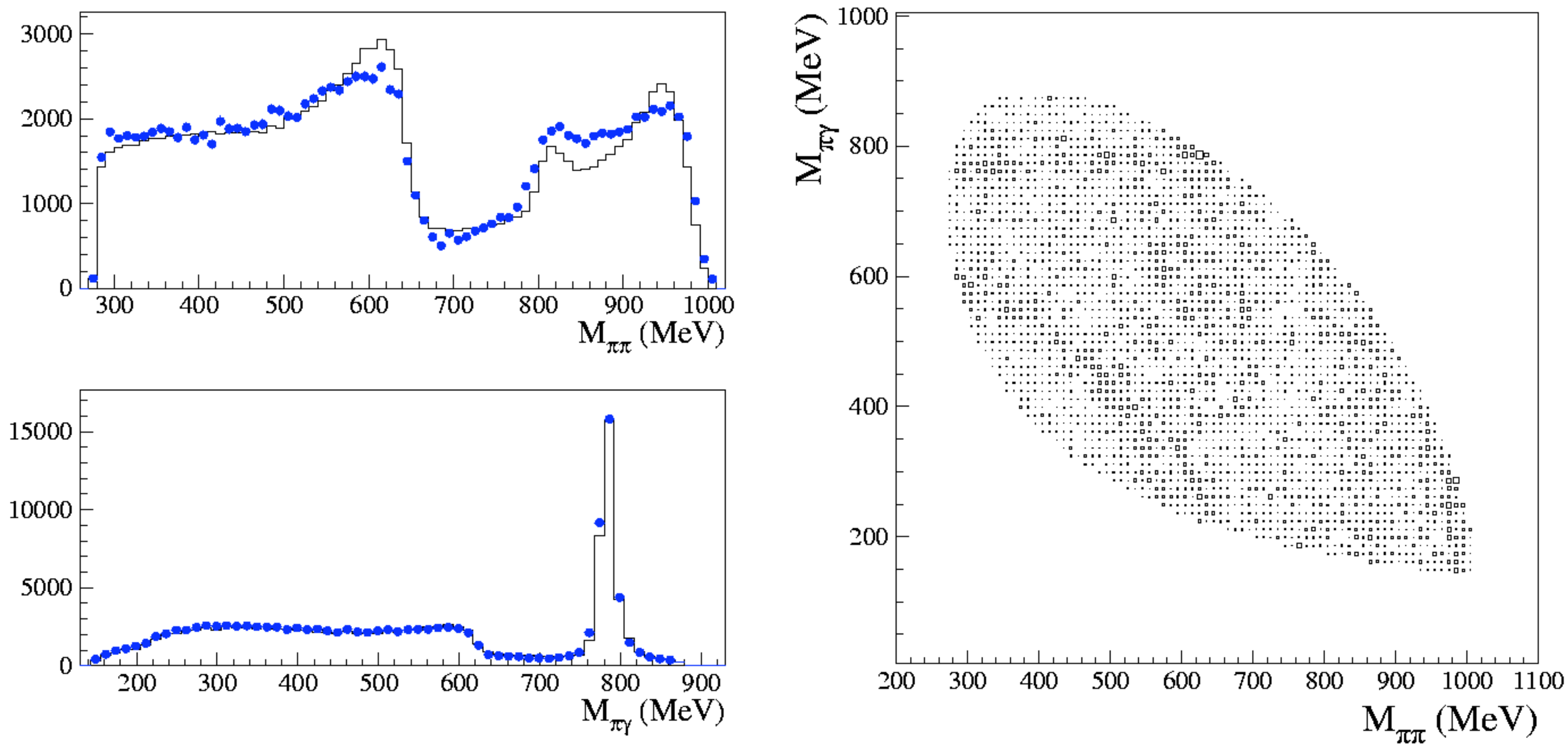
$$\sigma_{vis} = \int_0^{4m_\pi^2} \sigma_0[(1-x)s]H(s,x)$$

H(s,x) from Antonelli, Dreucci





Fit results: the Achasov parametrization



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

$$\frac{g_{f_0K^+K^-}\, g_{f_0\pi^+\pi^-}}{D_{f_0}(M_{\pi\pi})} \longrightarrow \sum g_{R_1 kk}\, G_{RR}^{-1}\, g_{R_2\pi\pi}$$

Where

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

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

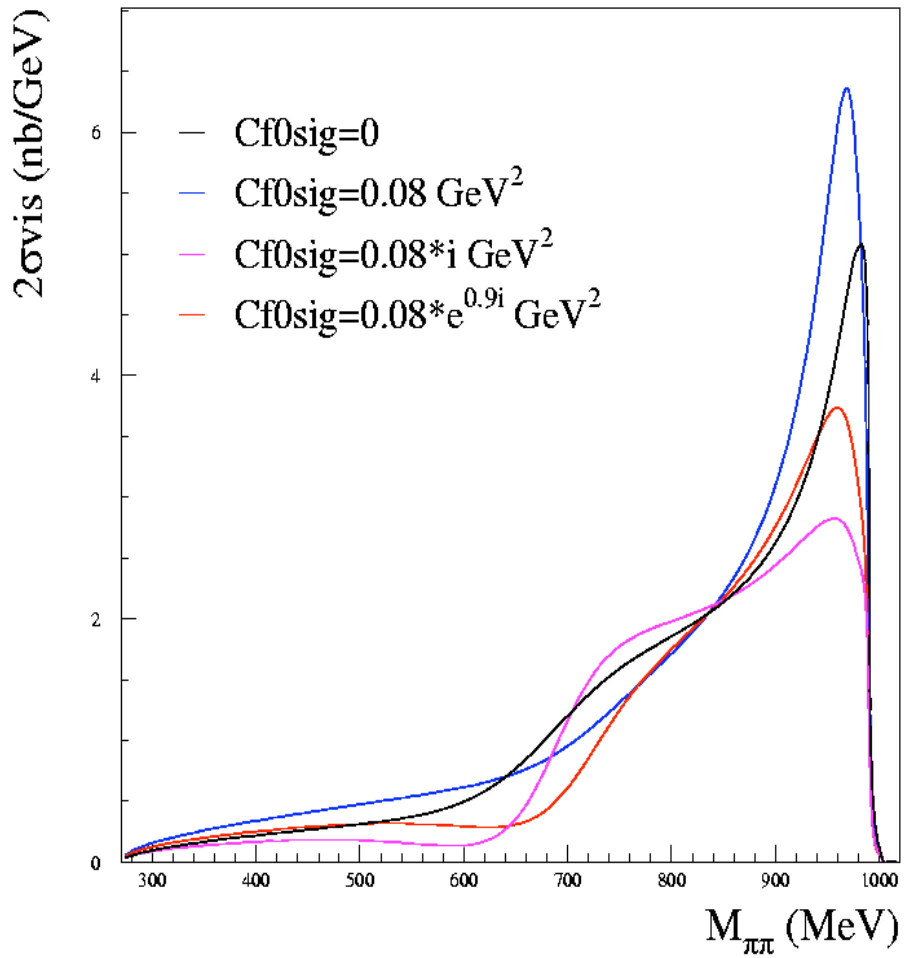
$C_{R1R2} = C_{f0\sigma}$ takes into account the contributions of VV, 4 pseudoscalar mesons and other intermediate states. In the 4q,2q models there are free parameters

The parametrization with the σ meson (II)

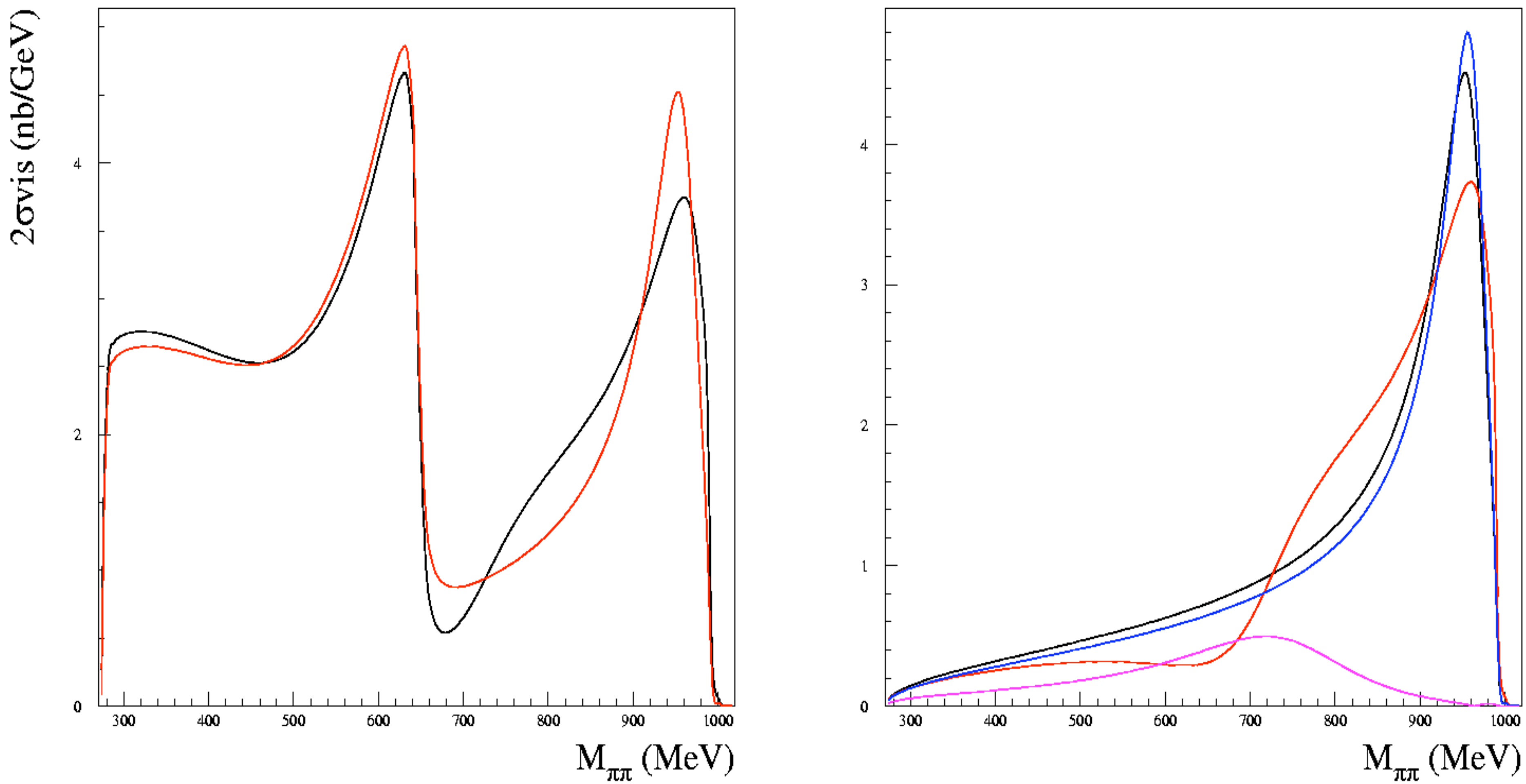
Extensive tests have been done on the formula used.

- 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

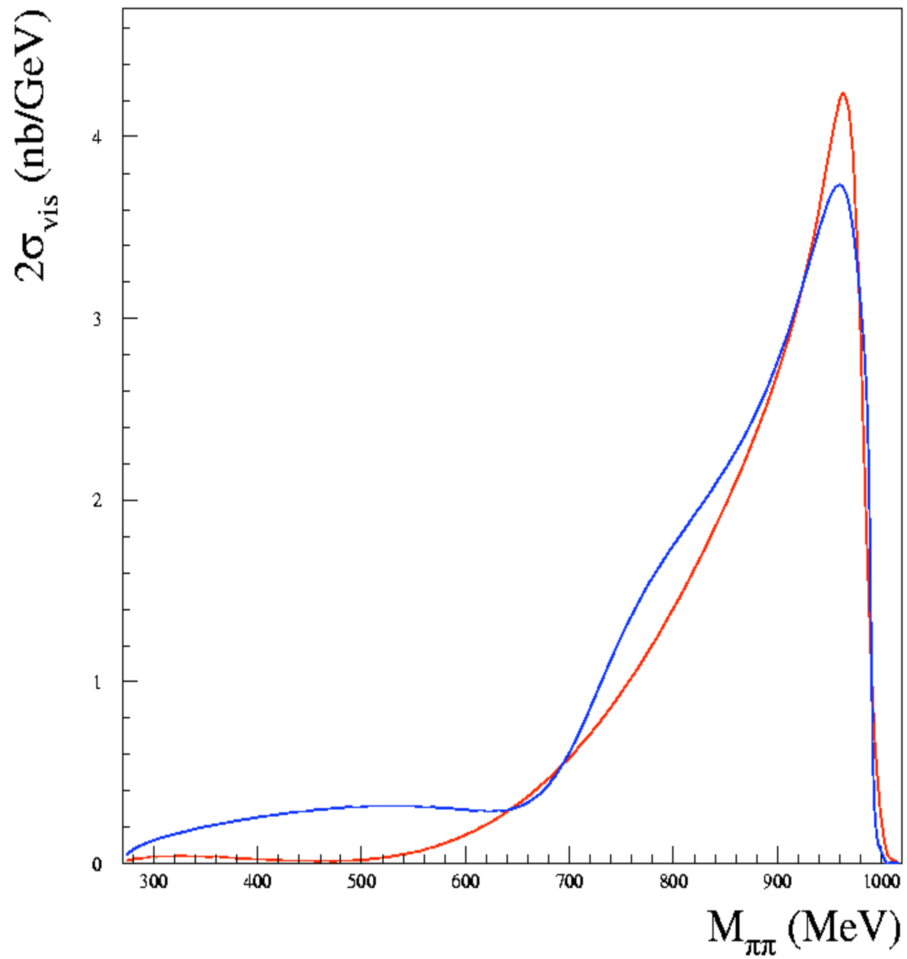


Fit results: the Achasov parametrization with σ (II)



- 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!