Latest news and perspectives on the $\phi \rightarrow f_0(980)\gamma$ analysis

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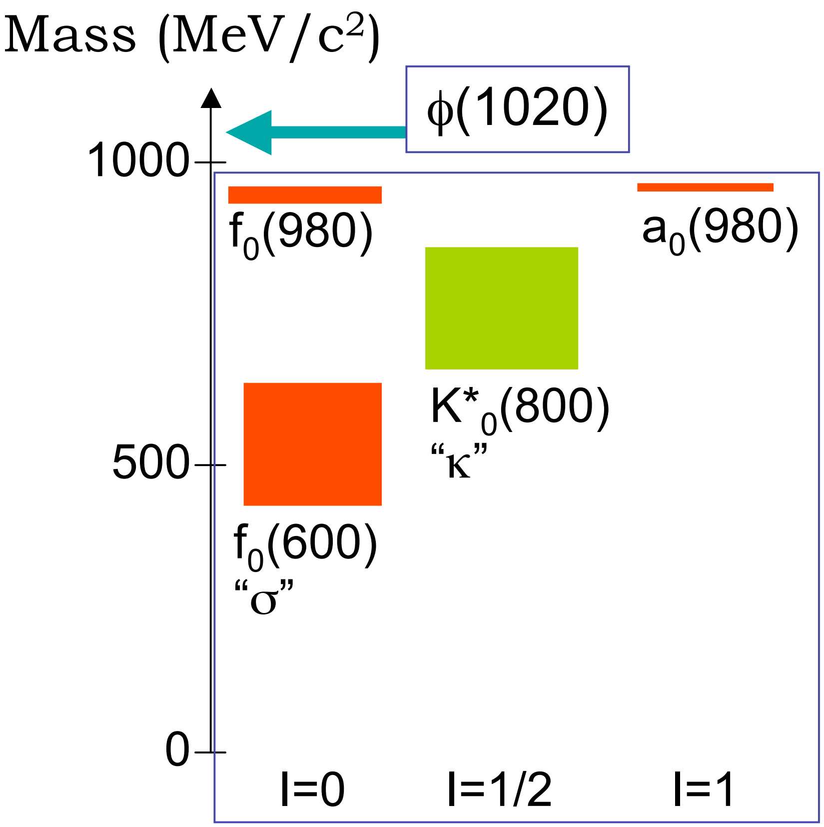
For the scalar phidec wg

- Short report on $\pi^+\pi^-\gamma$ final results
- perspectives on $\pi^+\pi^-\gamma$ final state
- situation of the $\pi^0\pi^0\gamma$ final state:
  - fits to the $\sqrt{s}$-dependence of cross sections
  - status of KLOE memos …
  - latest results on the Dalitz-plot fit

KLOE General Meeting
LNF 14-dec-2005

Scalar Mesons at a ϕ - factory

How a ϕ-factory can contribute to the understanding of the scalar mesons



Scalar Mesons Spectroscopy:

f_0(980), f_0(600) and **a_0(980)** are accessible (κ not accessible) through $\phi \rightarrow$ **S**γ;

Questions:

1. Is f_0(600) needed to describe the mass spectra ?

2. "couplings"of f_0(980) and a_0(980) to $\phi \cong |s\bar{s}\rangle$ and to KK, $\pi\pi$ and $\eta\pi$.

➔ *4-quark* vs. *2-quark* states

How to detect these radiative decays

$\phi \to$ **f_0(980)**γ $\to \pi^+\pi^-\gamma$
$\to \pi^0\pi^0\gamma$
$\to K^+K^-\gamma$ [$2m(K) \sim m(f_0) \sim m(\phi)$] ➔ expected BR $\sim 10^{-6}$
$\to K^0K^0\gamma$ " " $\sim 10^{-8}$

$\phi \to$ **a_0(980)**γ $\to \eta\pi^0\gamma$
$\to K^+K^-\gamma$ ➔ expected BR $\sim 10^{-6}$
$\to K^0K^0\gamma$ ➔ " $\sim 10^{-8}$

$\phi \to$ **f_0(600)**γ $\to \pi^+\pi^-\gamma$
$\to \pi^0\pi^0\gamma$

General Comments:

→ fits of mass spectra needed to extract the ***signals***: this requires a *parametrization* for the signal shape;

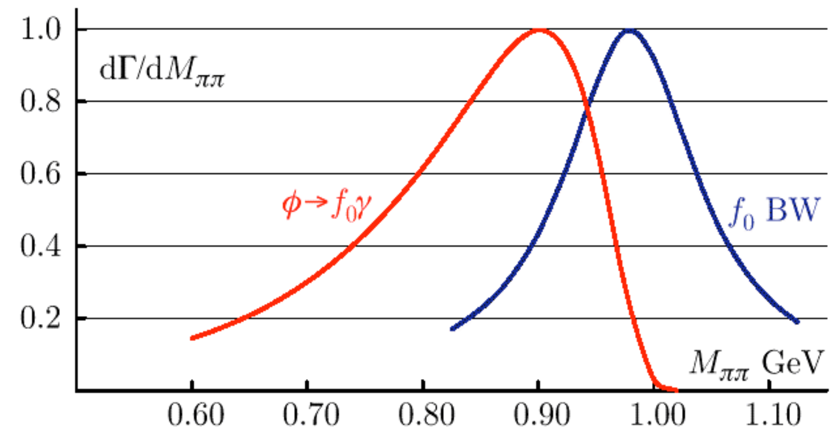
→ the unreducible ***background*** is not fully known: a *parametrization* is required and some parameters have to be determined from the data themselves;

→ sizeable interferences between ***signal*** and ***background***

How to extract the signal:

1. Electric Dipole Transitions:
   ➔ $\Gamma(E1) \propto \mathbf{E_\gamma^3} \times \mathbf{|M_{if}(E_\gamma)|^2}$

2. Distortions due to KK thresholds (Flatte'-like).



Kaon-loop (*by N.N.Achasov*): for each scalar meson S: $(\mathbf{g_{S\pi\pi}}, \mathbf{g_{SKK}}, \mathbf{M_S})$

No-Structure (*by G.Isidori and L.Maiani*): a modified BW + a *polynomial continuum*: $(\mathbf{g_{\phi S\gamma}}, \mathbf{g_{S\pi\pi}}, \mathbf{g_{SKK}}, \mathbf{M_S}$ + pol. cont. parameter)

Scattering Amplitudes (*by M.E.Boglione and M.R.Pennington*)

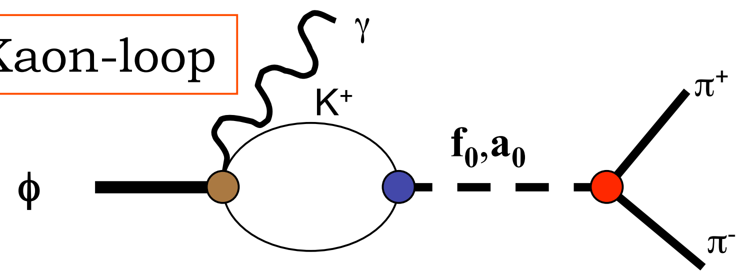
$A \propto (a_1+b_1m^2+c_1m^4)\ T(\pi\pi\rightarrow\pi\pi) + (a_1+b_1m^2+c_1m^4)\ T(\pi\pi\rightarrow KK)$

➔ pole residual $\mathbf{g_\phi}$

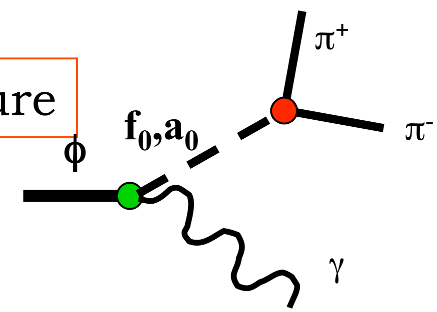
Definition of the relevant couplings (S=f_0 or a_0):

S to ϕ	$g_{\phi S\gamma}$	(GeV^{-1})
S to kaons	$g_{SKK}=g_{SK^+K^-}=g_{SK^0K^0}$	(GeV)
f_0 to $\pi\pi$ (I=0)	$g_{f0\pi\pi}=\sqrt{3/2}\, g_{f0\pi^+\pi^-}=\sqrt{3}\, g_{f0\pi^0\pi^0}$	(GeV)
a_0 to $\eta\pi$ (I=1)	$g_{a0\eta\pi}$	(GeV)
Coupling ratio	$R_{f0}=(g_{f0K^+K^-}/\, g_{f0\pi^+\pi^-})^2$	
	$R_{a0}=(g_{a0K^+K^-}/\, g_{a0\eta\pi})^2$	

Kaon-loop



No-structure



$$A_{KL} = g(m^2)e^{i\delta(m)}\frac{g_{f_0K^+K^+}g_{f_0\pi^+\pi^-}}{(s-m^2)D'_{f_0}(m)},$$

$$A_{NS} = \frac{g_{\phi f_0\gamma}g_{f_0\pi^+\pi^-}}{D_{f_0}(m)} + \frac{a_0}{m_\phi^2}e^{ib_0p_\pi(m)} + a_1\frac{m^2-m_{f_0}^2}{m_\phi^4}e^{ib_1p_\pi(m)}$$

$$D_{f_0}(m) = m^2 - m_{f_0}^2 + i\left(\frac{g_{f_0\pi\pi}^2}{16\pi}\sqrt{1-\frac{4m_\pi^2}{m^2}} + \frac{g_{f_0KK}^2}{16\pi}\left(\sqrt{1-\frac{4m_{K^\pm}^2}{m^2}} + \sqrt{1-\frac{4m_{K^0}^2}{m^2}}\right)\right)$$

The unreducible backgrounds

($\pi^+\pi^-$): *huge* backgrounds:

Initial + Final state radiation (ISR+FSR)

$\phi \rightarrow \rho^\pm\pi^\pm$ with $\rho^\pm \rightarrow \pi^\pm\gamma$

($\pi^0\pi^0$): *large* backgrounds:

$e^+e^- \rightarrow \omega\pi^0$ with $\omega \rightarrow \pi^0\gamma$

$\phi \rightarrow \rho^0\pi^0$ with $\rho^0 \rightarrow \pi^0\gamma$

HOWEVER, practically background free for $M_{\pi\pi}$ above 700 MeV

($\eta\pi^0$): *small* backgrounds:

$e^+e^- \rightarrow \omega\pi^0$ with $\omega \rightarrow \eta\gamma$

$\phi \rightarrow \rho^0\pi^0$ with $\rho^0 \rightarrow \eta\gamma$

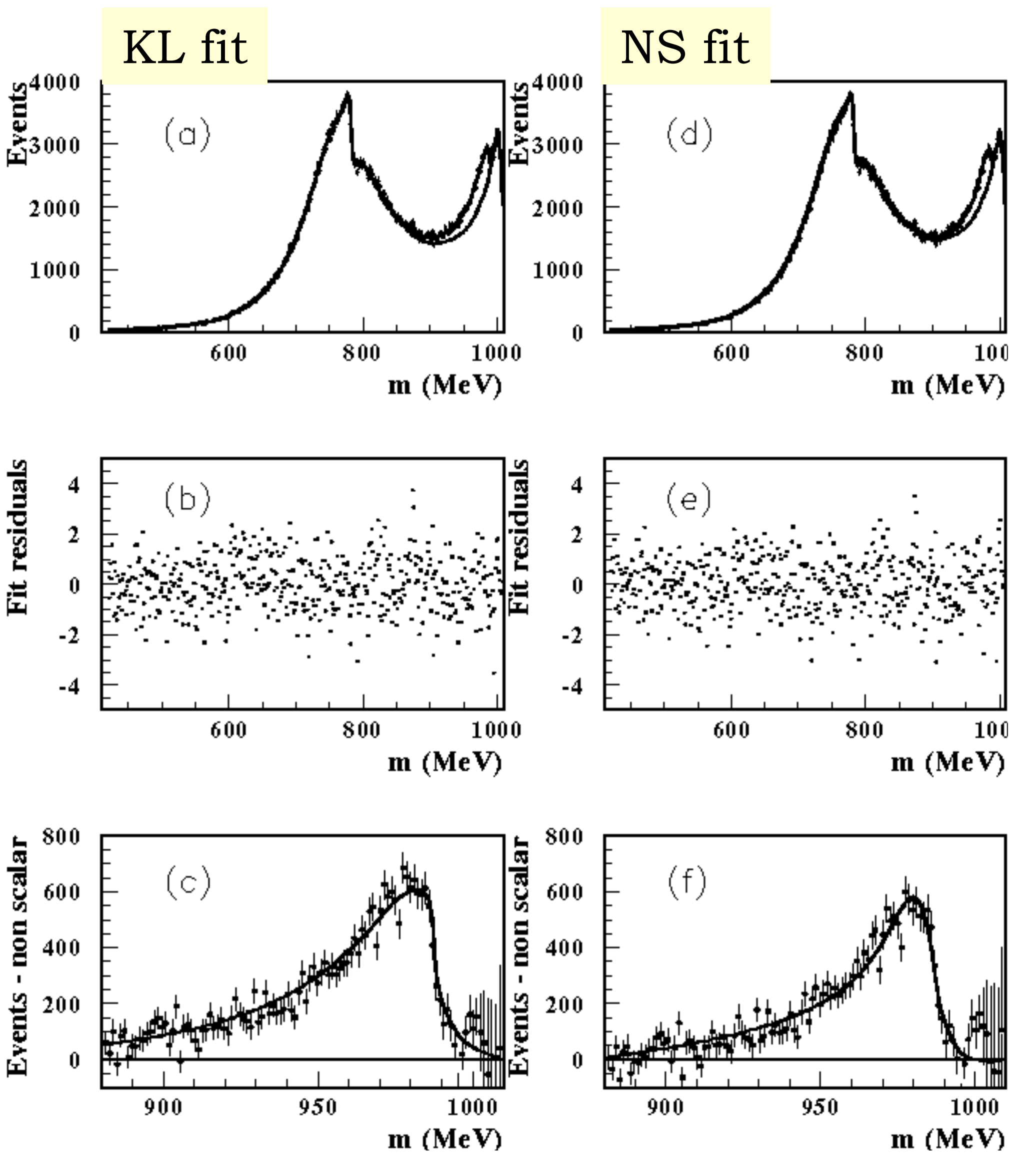
($\pi^+\pi^-$) vs. ($\pi^0\pi^0$): "same amplitude" with different background !

($\eta\pi^0$) is the "cleanest" sample:

Not discussed today .. no news since Capri 05

Fit to the m(π⁺π⁻) spectrum

F= ISR + FSR + ρπ + scalar ± interference



KL and NS fits:
→Good description in both cases of **signal** and **background** (KS);
→ “negative” interference;
→f_0(600) doesn’t help.

	KL	NS
χ^2 (p(χ^2))	538/483 (4.2%)	533/479 (4.4%)
m_{f_0} (MeV)	983.0±0.6	977.3±0.9
$g_{\phi f_0 \gamma}$ (GeV^{-1})	–	1.48±0.06
$g_{f_0 K^+K^-}$ (GeV)	5.89±0.14	1.73±0.12
$g_{f_0 \pi^+\pi^-}$ (GeV)	(3.6)	0.99±0.02
$R = g^2_{f_0 K^+K^-}/g^2_{f_0\pi^+\pi^-}$	2.66±0.10	(3.1)
a_0	–	6.00±0.02
a_1	–	4.10±0.04
b_1(rad/GeV)	–	3.13±0.05
m_{ρ^0} (MeV)	773.1±0.2	773.0±0.1
Γ_{ρ^0} (MeV)	144.0±0.3	145.1±0.1
α ($\times 10^{-3}$)	1.65±0.05	1.64±0.04
β ($\times 10^{-3}$)	-123±1	-137±1
$a_{\rho\pi}$	0.0±0.6	1.5±1.4

Parameter uncertainties are dominated by the systematic errors:

parameter	KL	NS
m_{f_0} (MeV)	980–987	973–981
$g_{f_0 K^+K^-}$ (GeV)	5.0 – 6.3	1.6– 2.3
$g_{f_0 \pi^+\pi^-}$ (GeV)	3.0– 4.2	0.9–1.1
$R = g^2_{f_0 K^+K^-}/g^2_{f_0 \pi^+\pi^-}$	2.2– 2.8	2.6– 4.4
$g_{\phi f_0 \gamma}$ (GeV^{-1})	–	1.2– 2.0

Comments:

→Mass value OK [PDG 980 ± 10 MeV]

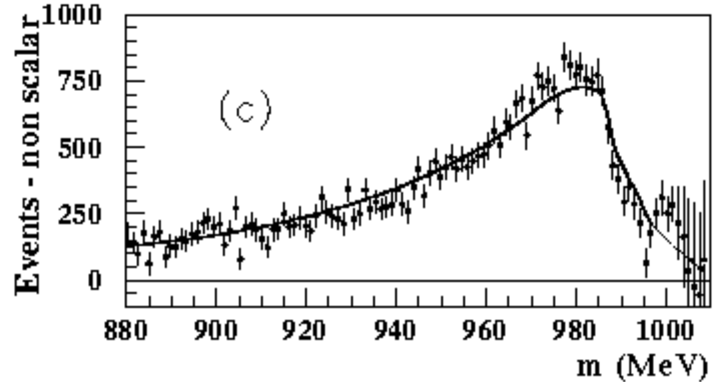
→R > 1 in both fits (in agreement with published values $\pi^0\pi^0\gamma$)

→KL couplings >> NS couplings: effect of polynomial continuum

→NS suggests "large" coupling to the ϕ (see following)

Scattering Amplitude Fit

χ^2 $(p(\chi^2))$	577/477 (0.1%)				
a_1	11.9	a_2	-14.7	m_{ρ^0} (MeV)	774.4±0.2
b_1	3.3	b_2	-15.3	Γ_{ρ^0} (MeV)	142.8±0.3
c_1	-15.1	c_2	35.8	α $(\times 10^{-3})$	1.74±0.05
m_0	0.	λ	-1.63	β $(\times 10^{-3})$	-100±18
				$a_{\rho\pi}$	0±2



$$\Gamma(\phi \to \gamma f_0(980)) = \frac{\pi^2}{2} g_\phi^2 \frac{m_\phi^2 - m_{f_0}^2}{m_\phi^3}$$

$g_\phi = 6.6 \times 10^{-4}$ ➔ BR($\phi \to f_0(980)\gamma$) × BR($f_0(980) \to \pi^+\pi^-$) ~ 3×10^{-5}
[similar conclusion from BP analysis of $\pi^0\pi^0\gamma$ data (KLOE + SND)]

Summarizing:

The peak at ~980 MeV is interpreted in both KL /NS as due to the decay $\phi \to f_0(980)\gamma$ with a neg. interference with FSR.

The couplings suggest the $f_0(980)$ to be strongly coupled to kaons and to the ϕ. No space for $f_0(600)$.

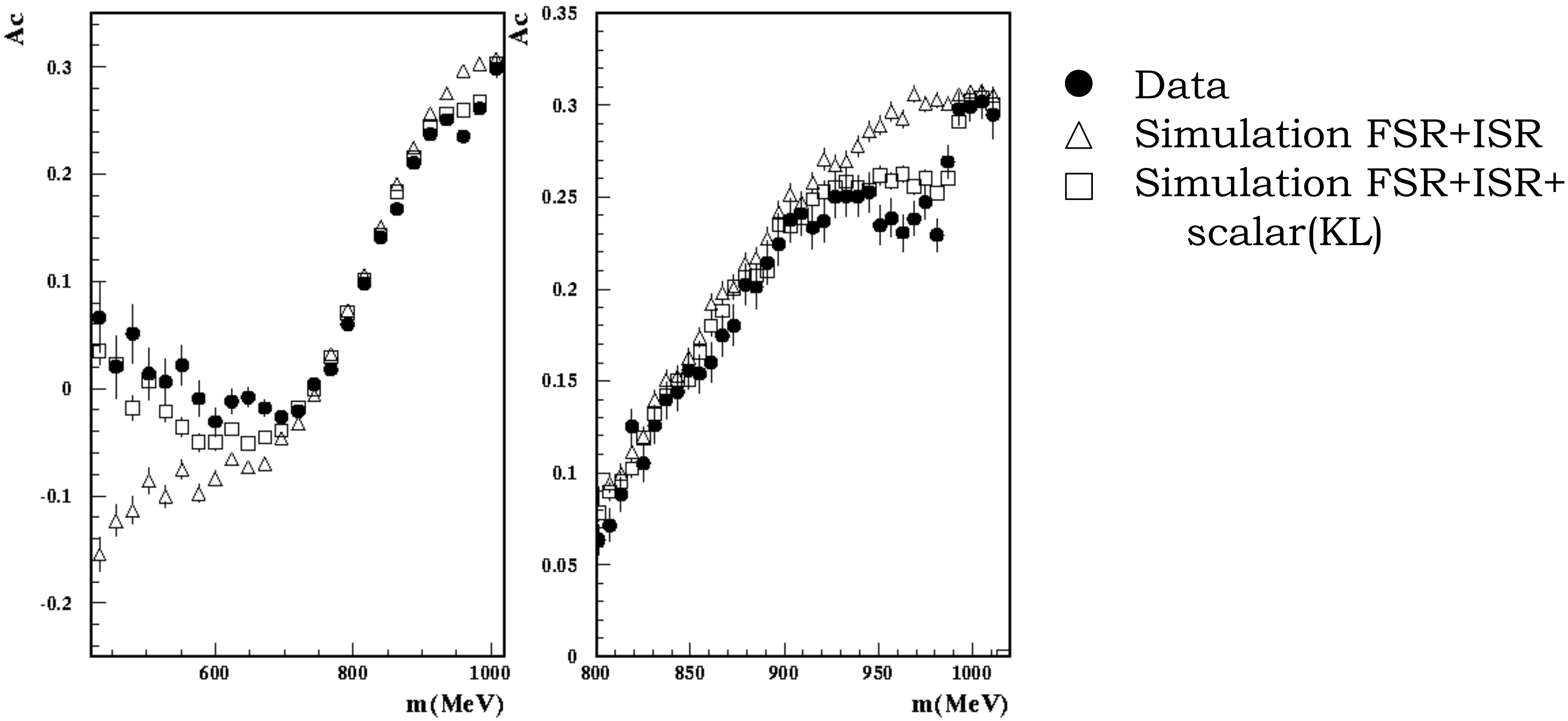
Scattering Amplitude gives a marginal agreement.

Submitted to PLB (HEP-EX 0511031)

FB asymmetry vs. m(ππ):

→ Clear signal ~ 980 MeV

→ Interesting comparison with simulation:



The simulation provides a "qualitative" description of:

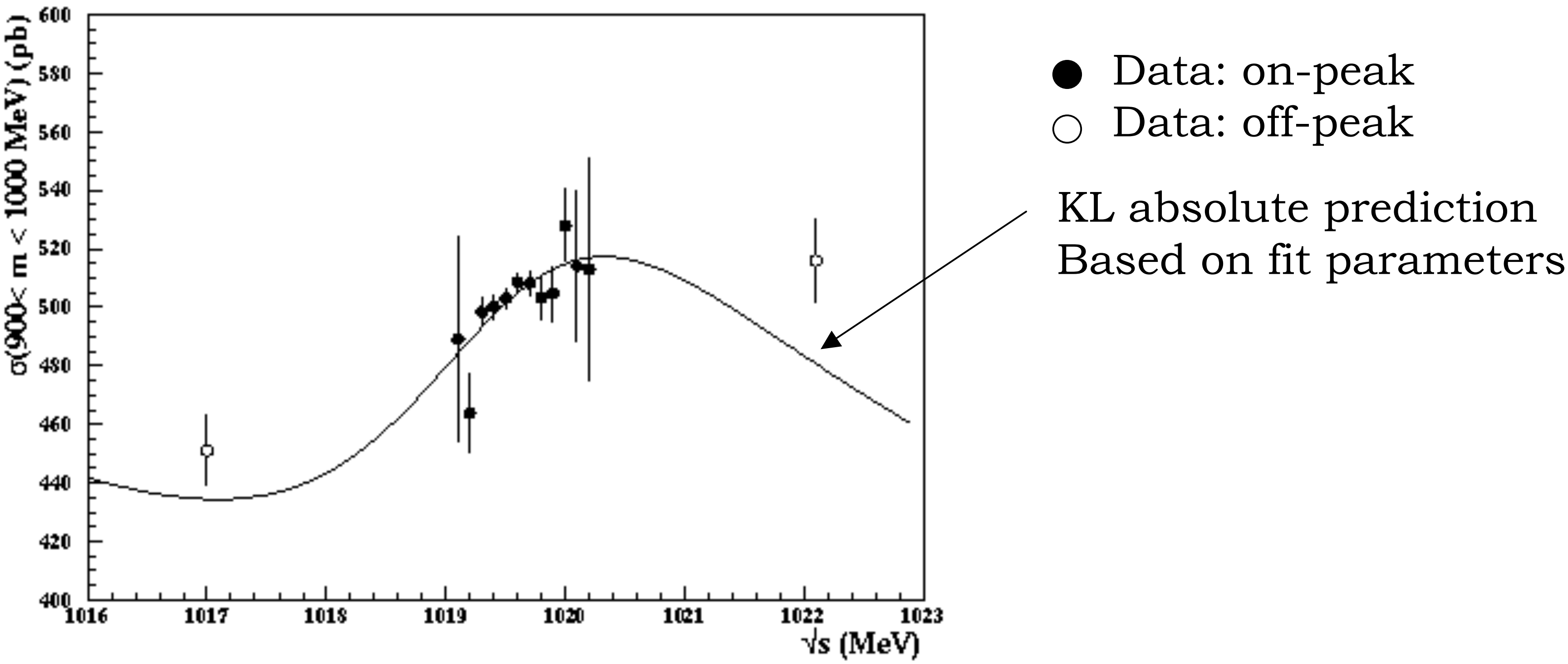
→f_0(980) region behaviour (the signal is reproduced);

→Low mass behaviour (low mass tail of the signal.

Remarkable result: not a fit but an **absolute prediction**

Cross section dependence on √s:

Absolute prediction based on KL fit parameters



Concluding remark: $\pi^+\pi^-\gamma$ is a powerful tool to test scalar production: mass spectrum, FB asym. and √s dependence

the now collected 2 fb^{-1} at ϕ ➔ factor 6 more of what already published + the finer energy scan around the ϕ will allow us to test deeply this model

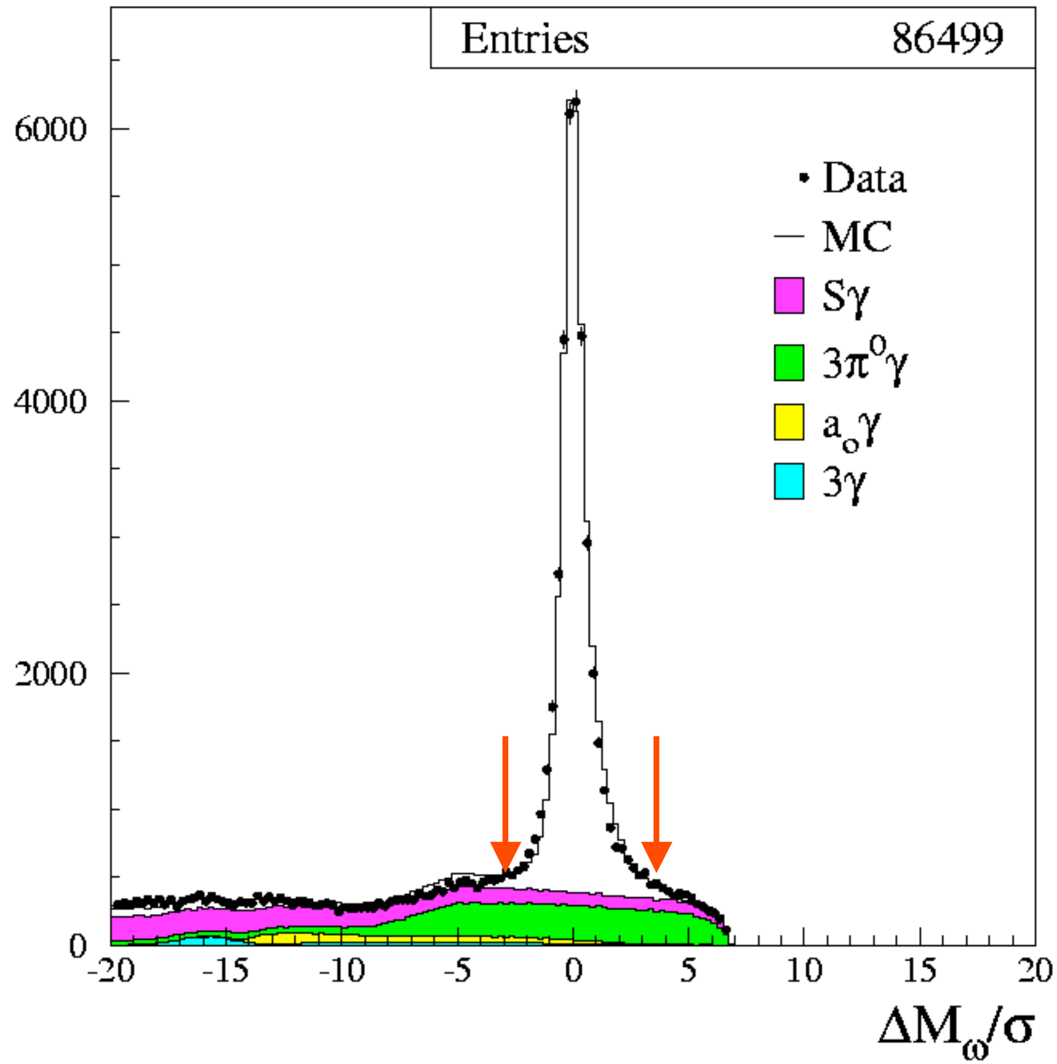
Status of $\pi^0\pi^0\gamma$ final state

- As shown at Capri, we have reached a stable conclusive result on the data analysis while we are completing the fit on the dalitz-plot.
- Today we show the results of the fits to the $\pi\pi\gamma$ visible cross section obtained by repeating, with our new process independent photon pairing procedure, the analysis "as for 2000 data" i.e. **neglecting any interference between VDM and scalar terms .**
- From these fits we will extract the parameters describing the $e^+e^- \to \omega\pi^0$ and the BR($\phi \to \pi\pi\gamma$).
- To understand how well we do all of this (+ for checking the normalization of our main background) we have also analized a large sample of $\phi \to \eta\gamma$ decays in 7 photons (prescaling 1/50 while running our 5-photon selection).

$\omega\pi$ vs Sγ events (Masses)

- With our new, process independent, photon pairing procedure, we build the invariant mass $\pi^0\gamma$ and select the one closest to Mω

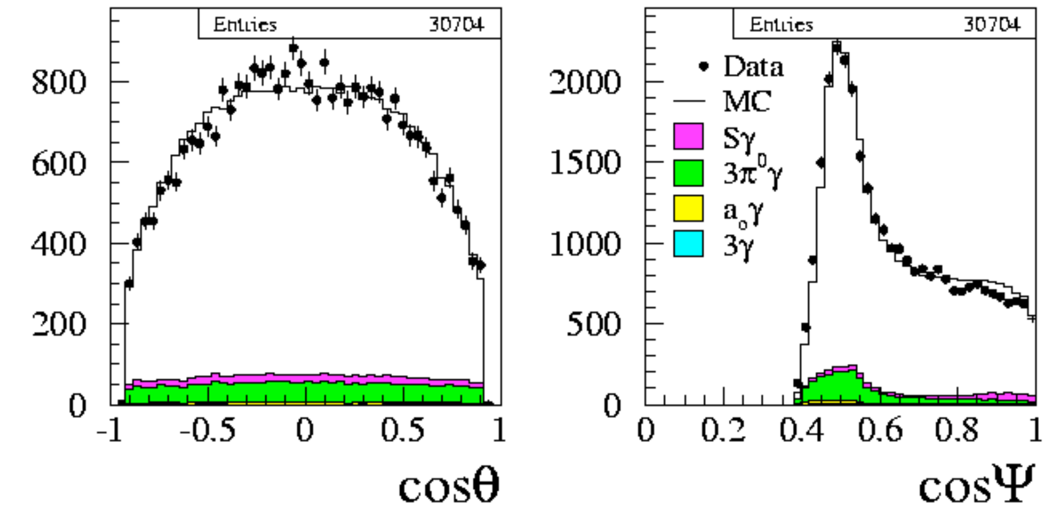
- As for 2000 data, we then count as :
  - $\omega\pi$ events the ones in within 3 sigma from Mω
  - Sγ all the others



ωπ vs Sγ events (Angular distributions)

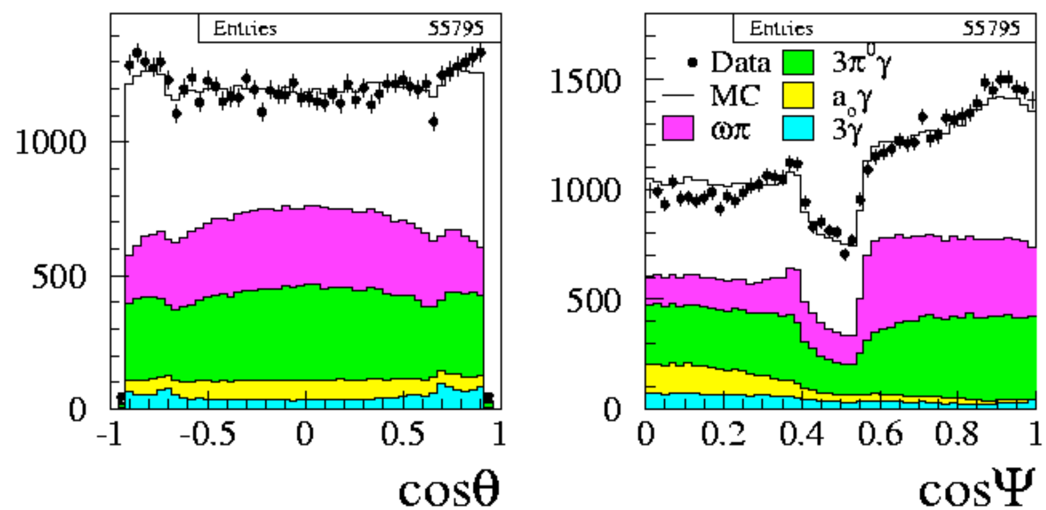
ωπ events

Clear S=1
angular dependence



Sγ events

Clear S=0
angular dependence



ωπ: energy dependence of the xsec

$$\sigma^{\omega\pi}(\sqrt{s}) = \sigma_0^{\omega\pi}(\sqrt{s}) \left| 1 - Z\frac{M_\phi \Gamma_\phi}{D_\phi} \right|^2 , \qquad (11)$$

where $\sigma_0^{\omega\pi}(\sqrt{s})$ represents the nude cross section for the not-resonant process, Z is the complex interference parameter (i.e. the ratio between the ϕ decay amplitude and the not-resonant process), while M_ϕ, Γ_ϕ and $D_\phi = M_\phi^2 - s - i\sqrt{s}\Gamma_\phi$ are respectively the mass, the width and the inverse propagator of the ϕ meson.

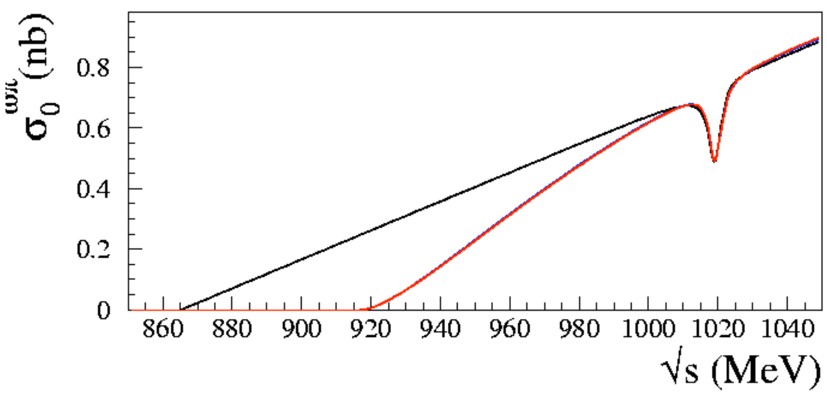
A) Linear dependence

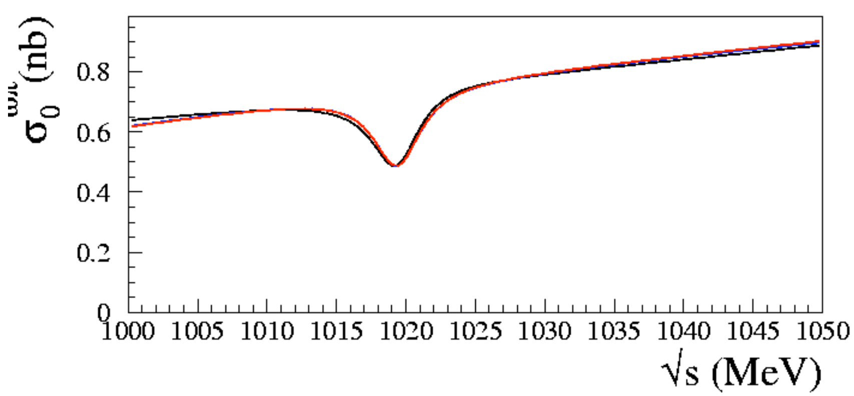
- $\sigma = \sigma_0 \times (1+\alpha\,(\sigma' - M_\phi))$

B) Model ρ/ρ' mesons

$$\sigma_0^{\omega\pi}(\sqrt{s}) = \frac{K}{s^{3/2}} \left| \frac{M_\rho^2}{D(\rho)} + \frac{A_1 M_{\rho'}^2}{D(\rho')} \right|^2 P_f(\sqrt{s}) ,$$

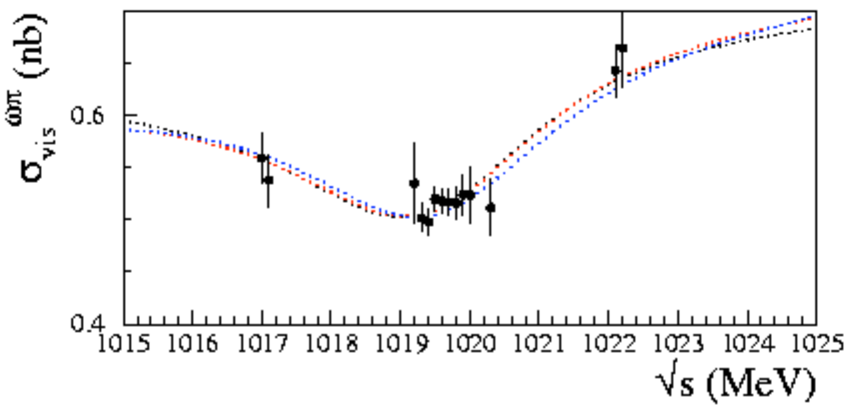
2 different parametrizations of ρ ρ' used



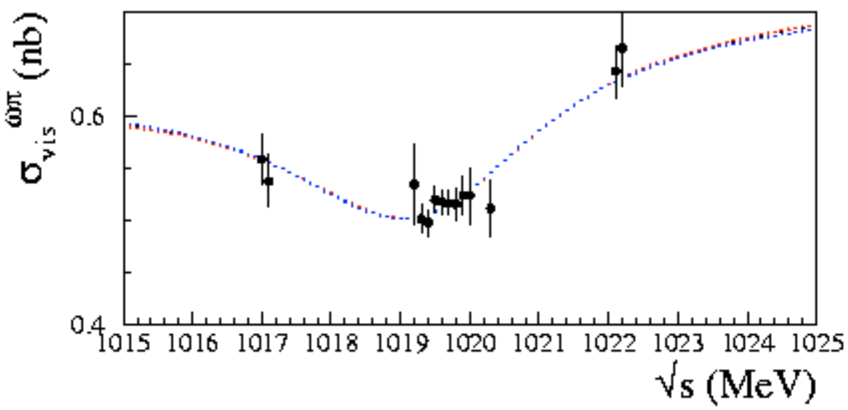


ωπ: Fit to the visible xsec

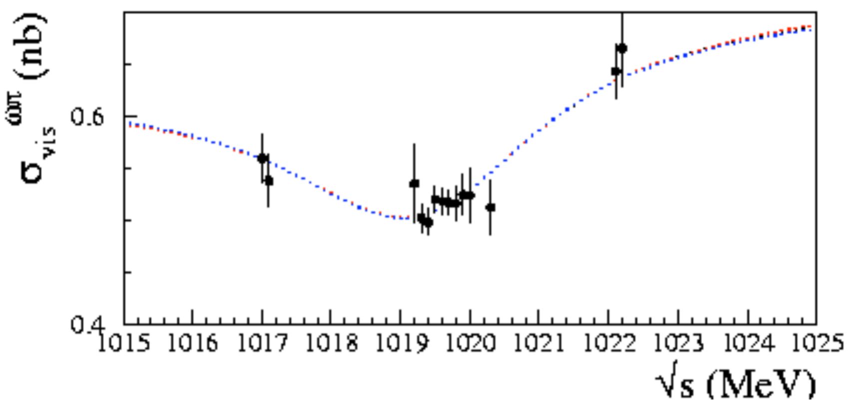
Fit A



Fit B



Fit C



$\varphi \rightarrow \eta\gamma$: energy dependence of the cross sections

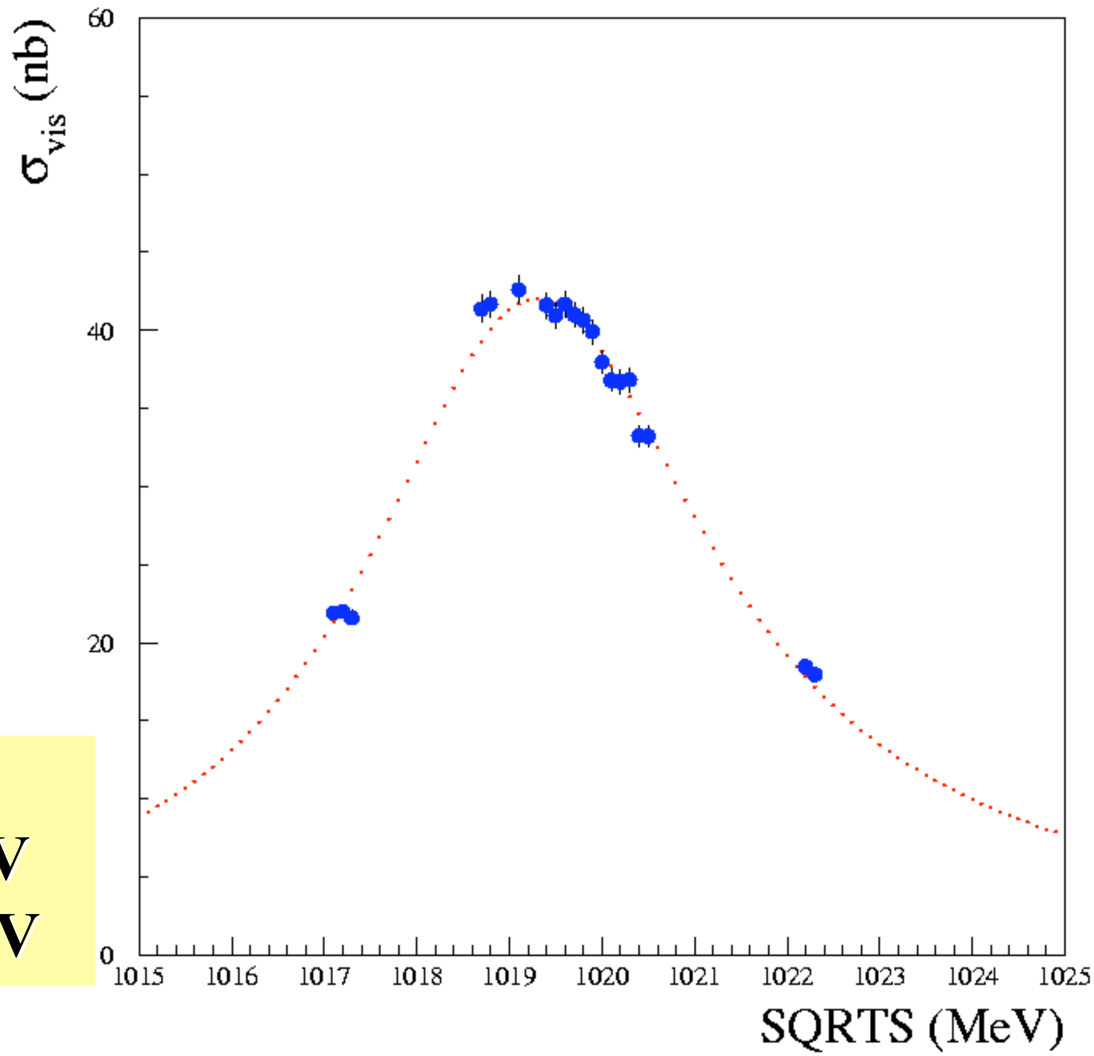
$$12\pi\,\Gamma_{\phi}^{e^+e^-}\,\Gamma_{\phi}^{\eta\gamma}\left|\frac{e^{i\pi}}{D_\phi}+\frac{R_\rho}{D_\rho}+\frac{R_\omega}{D_\omega}\right|^2\left(\frac{M_\phi}{\sqrt{s}}\right)^3\left(\frac{Q_\eta(\sqrt{s})}{Q_\eta(M_\phi)}\right)^3 \quad (3)$$

3 Fit parameters :
- α normalization
- M_ϕ , Γ_ϕ

We use Γ_ϕ^{ll}(KLOE) = 1.320 ±0.017 ±0.015 keV

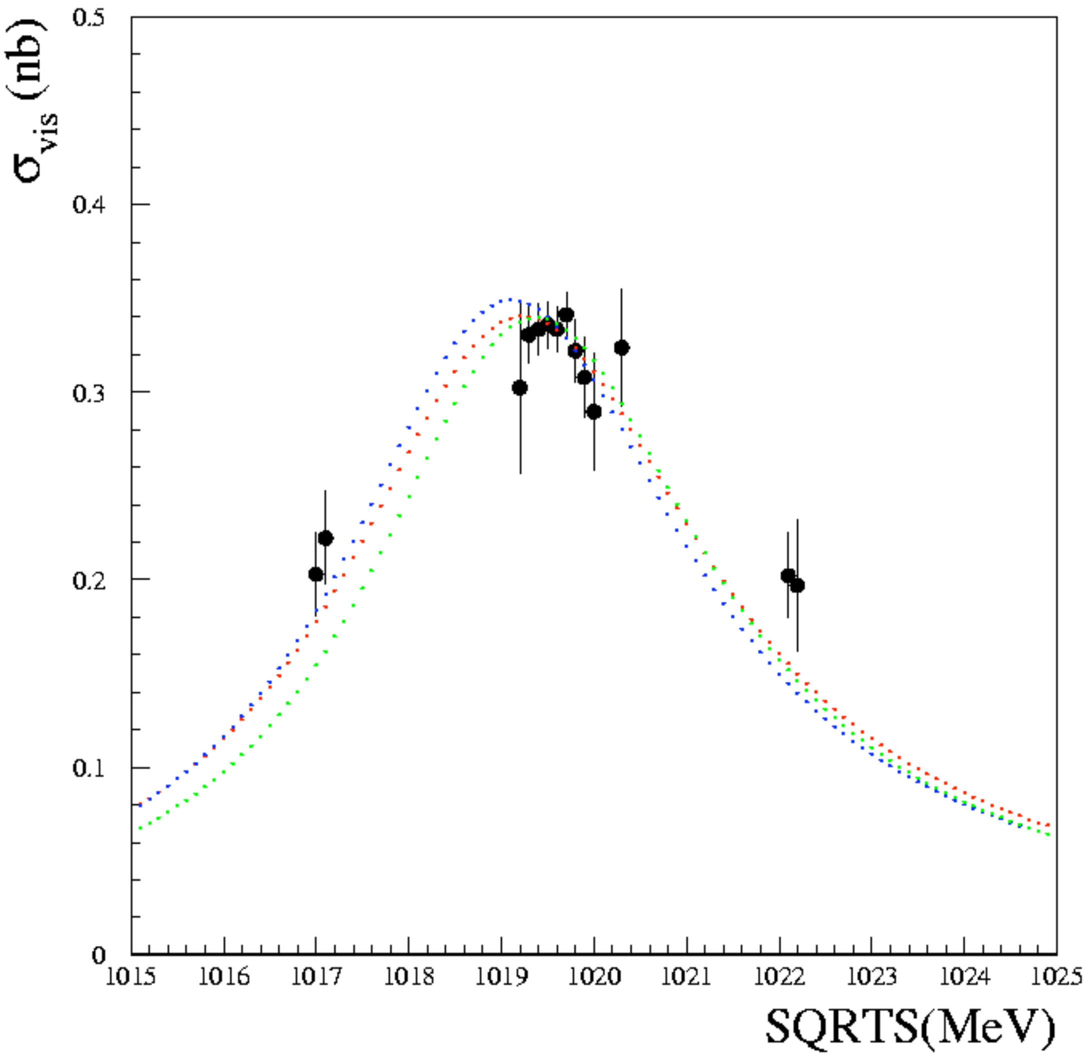
$\chi^2 = 16.8/17$

α = 1.014 ± 0.010
Mϕ = 1019.40 ± 0.01 MeV
$\Gamma\phi$ = 4.36 ± 0.09 MeV



$\varphi \to f_0 \gamma$: energy dependence of the xsec

$$\sigma_0^{S\gamma}(s) = 12\pi\Gamma_\phi^{e^+e^-}\Gamma_\phi^{S\gamma}\left|\frac{1}{D_\phi(s)}\right|^2\left(\frac{M_\phi}{\sqrt{s}}\right)^3 R_\Gamma(s)$$



$f_0\gamma$: Determination of BR ($\phi \to f_0\gamma \to \pi^0\pi^0\gamma$)

FIT	α	M_ϕ (MeV)	Γ_ϕ (MeV)	χ^2/ Ndof
(A) All free	1.319 ± 0.012	1019.34 ± 0.01	4.60 ± 0.09	13.9/11
(B) Γ_ϕ fixed	1.285 ± 0.001	1019.21 ± 0.35	4.358	17.2/12
(C) M_ϕ, Γ_ϕ fixed	1.223 ± 0.001	1019.46	4.26	21.8/12

From the valus of α we determine the value of $\Gamma(\phi \to f_0\gamma)$ at M_ϕ which is proportional to $\left(g_{f_0}^{K^+K^-} g_{f_0}^{\pi^+\pi^-}\right)^2$. **We get $\Gamma(\phi \to \pi^0\pi^0\gamma) = (0.498 \pm 0.005 \pm 0.022)$ keV**. The systematic error is dominated by the variation of the three fits. When dividing by $\Gamma_\phi(M_\phi)$ we determine the $BR(\phi \to f_0\gamma)$ to be:

$$\mathbf{BR(\phi \to \pi^0\pi^0\gamma) = (1.057 \pm 0.046_{fit} \pm 0.017_{norm}) \cdot 10^{-4}}$$

where the normalization error reflects our knowledge of Γ_ϕ^{ll}. The result is in pretty good agreement with our old measurement.

First conclusions on $\pi^0\pi^0\gamma$ final state

- When neglecting the interference between $\omega\pi$ and $S\gamma$ we are able to distinguish the most relevant features of the **$\pi\pi\gamma$** events:

- There is a clear resonant – not resonant component

- The not resonant component is dominated by $e^+e^- \rightarrow \omega\pi \rightarrow \pi\pi\gamma$ events with a well defined spin 1 angular dependence.
- The resonant component is a scalar

- If we fit the not-resonant component we find the parameters describing the interference with the ϕ meson to be in reasonable agreement with SND.
- If we fit the resonant component we find that the two points far away the ϕ peak are not perfectly described by our model. However **we extract the BR ($\phi \rightarrow \pi\pi\gamma$)**
- All of this work has been summarized in a KLOE Memo 319

Improved KL parametrization for the $\pi^0\pi^0\gamma$

N.N.Achasov, private communication
NOW PUBLISHED HEP-PH 0512047

- Insertion of a KK phase:

$$\tan\delta_B^{K\bar{K}} = \sqrt{m^2 - 4m_{K+}^2}\, f_K(m^2) = \frac{\sqrt{m^2 - 4m_{K+}^2}}{\Lambda_K}\mathrm{atan}\frac{m_2^2 - m^2}{m_0^2}$$

Beyond to its contribution in the interference term,
IT CHANGES THE SCALAR TERM AMPLITUDE
IN THE $M_{\pi\pi}<2M_{K^+}$ REGION

$$M_{sig} = \sqrt{\frac{1 - f_K(m^2)\sqrt{4m_{K+}^2 - m^2}}{1 + f_K(m^2)\sqrt{4m_{K+}^2 - m^2}}}\, g(m) e^{i\delta_B^{\pi\pi}} \left((\phi\epsilon) - \frac{(\phi q)(\epsilon p)}{(pq)} \right) \sum_{R,R'} g_{RK^+K^-} G^{-1}_{RR'} g_{R'\pi^0\pi^0}$$

- New parametrization of the $\pi\pi$ phase:

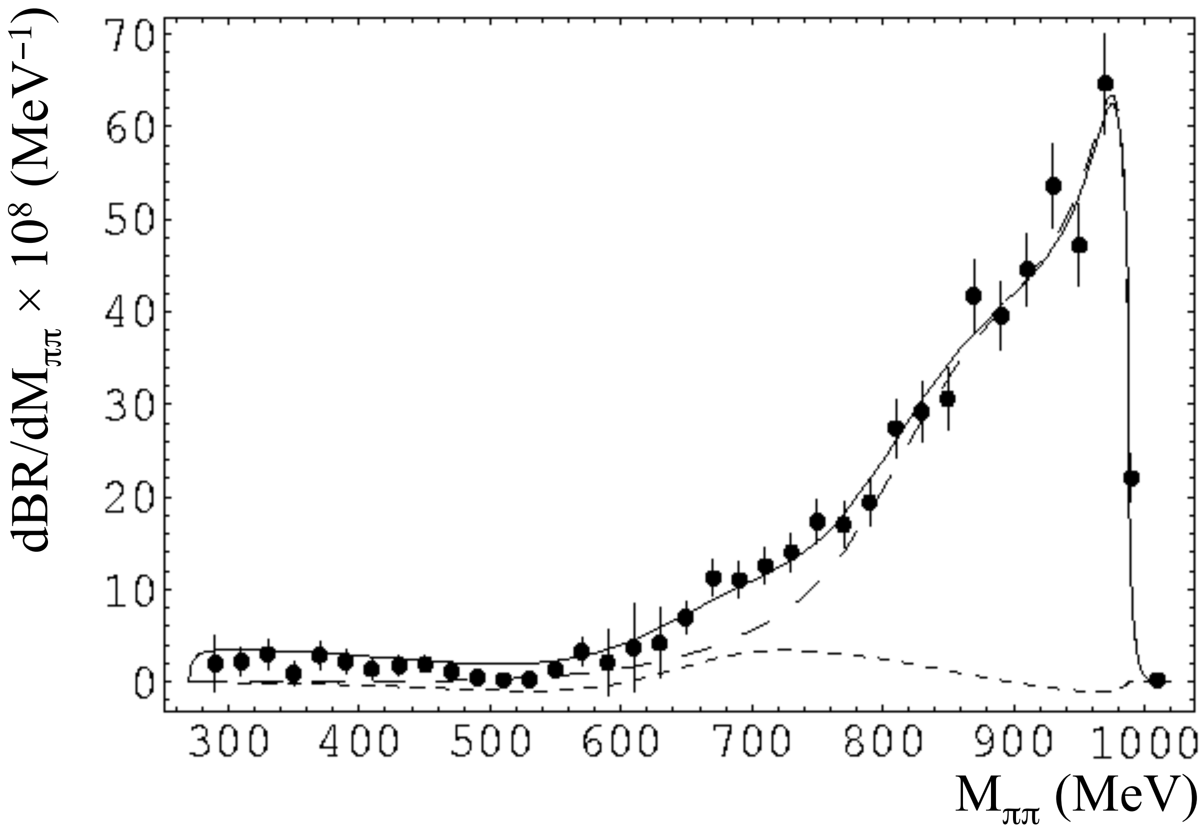
$$\tan(\delta_B^{\pi\pi}) = -\frac{p_\pi}{2m_\pi}\left(b_0 - b_1\frac{p_\pi^2}{(2m_\pi)^2} + b_2\frac{p_\pi^4}{(2m_\pi)^4}\right)\frac{1}{1 + p_\pi^2/\Lambda^2}$$

$$p_\pi = \sqrt{m^2 - 4m_{\pi+}^2}$$

new KL parametrization on old KLOE data (I)

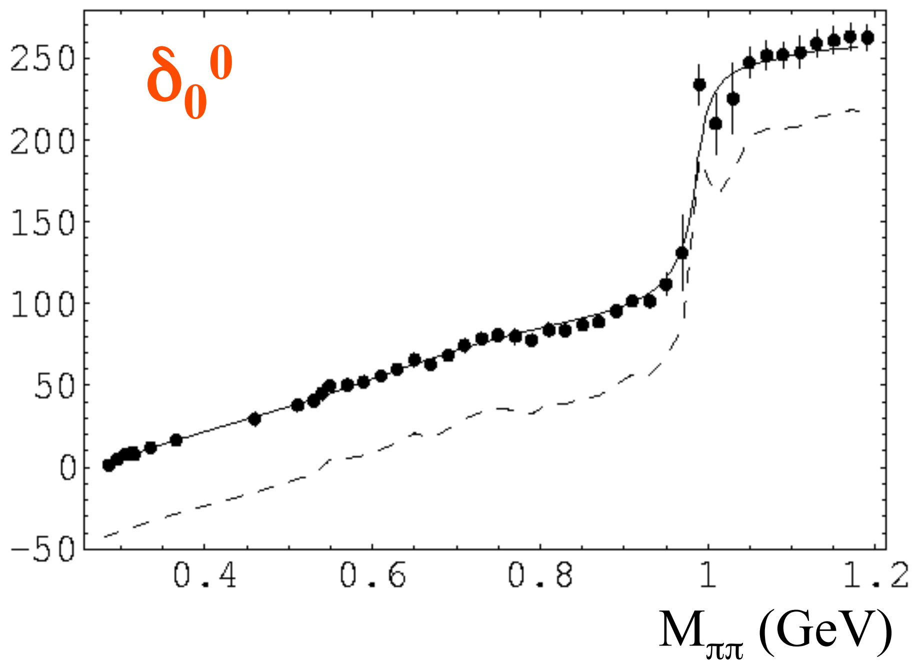
Achasov-Kiselev: combined fit to KLOE 2000 + ππ scattering data

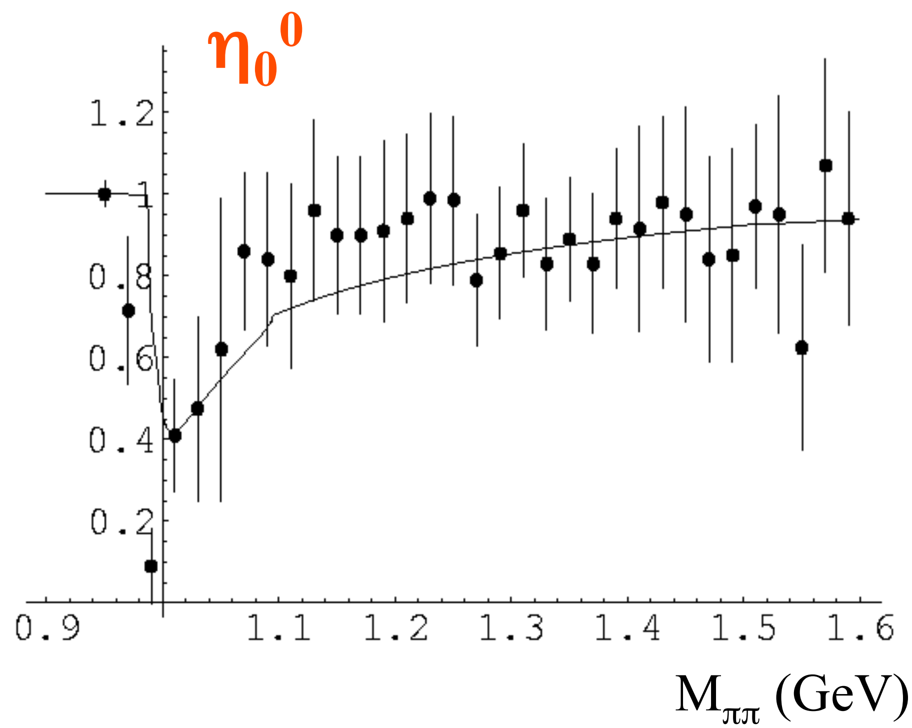
$dBR/dM_{\pi\pi}$ (KLOE 2000 data)



new KL parametrization on old KLOE data (II)

Achasov-Kiselev: combined fit to KLOE 2000 + ππ scattering data





Paper published:
Hep-ph 0512047

Theory advantages of the new parametrization

✓Able to reproduce Mass-spectrum, δ^0_0 and inelasticity
✓ Sum of overlapping resonances with the correct propagator matrix

✓ A lot of theory restrictions applied:

- The $\pi\pi$ scattering length a^0_0 fixed to the recent calculation of Colangelo
- In the $\pi\pi$ scattering amplitude the "famous?" Adler zero is granted in the region below the threshold ($0 < m^2_{\pi\pi} < 4M^2_{\pi}$)
- It needs a $\sigma(600)$ meson to obtain a good fit.

K-loop fit results: $f_0 + \sigma$

- Discussing with Achasov we realized that the parameters of σ and the KK, $\pi\pi$ phases are very much related.

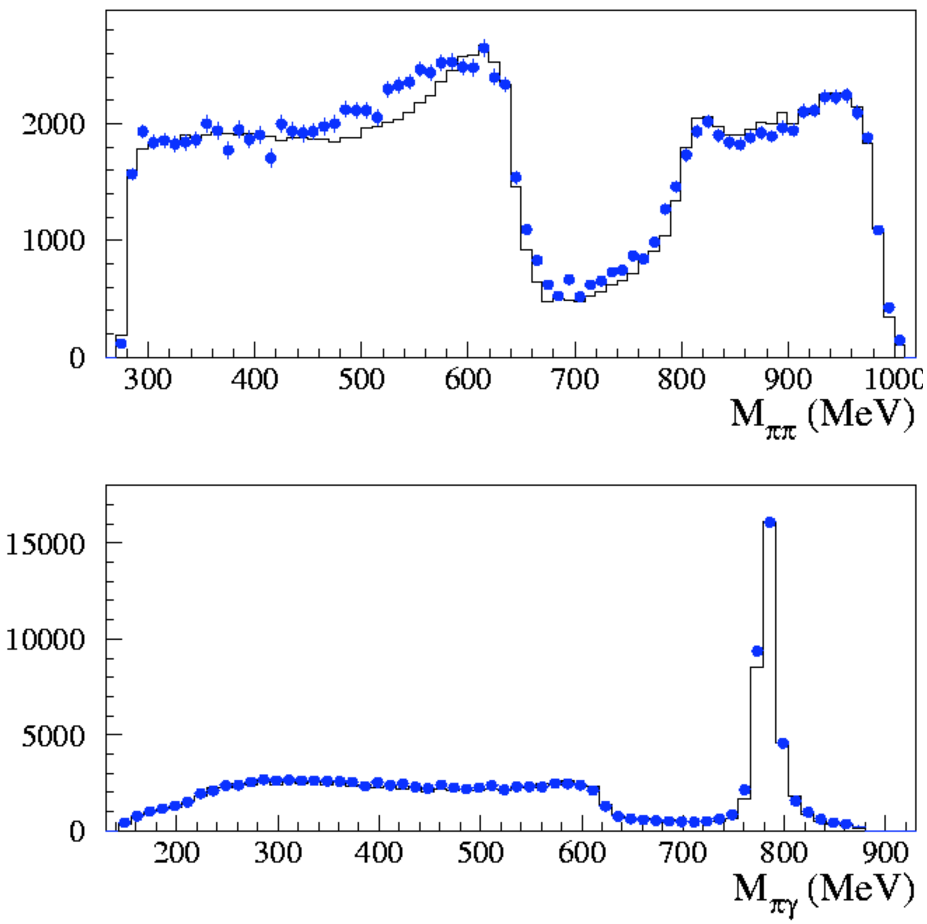
- To let them vary freely we should either fit also the data on δ^0_0 or impose the theory restrictions explained before which are not easy to implement in our fitting function.

- We therefore followed a much more simple approach:

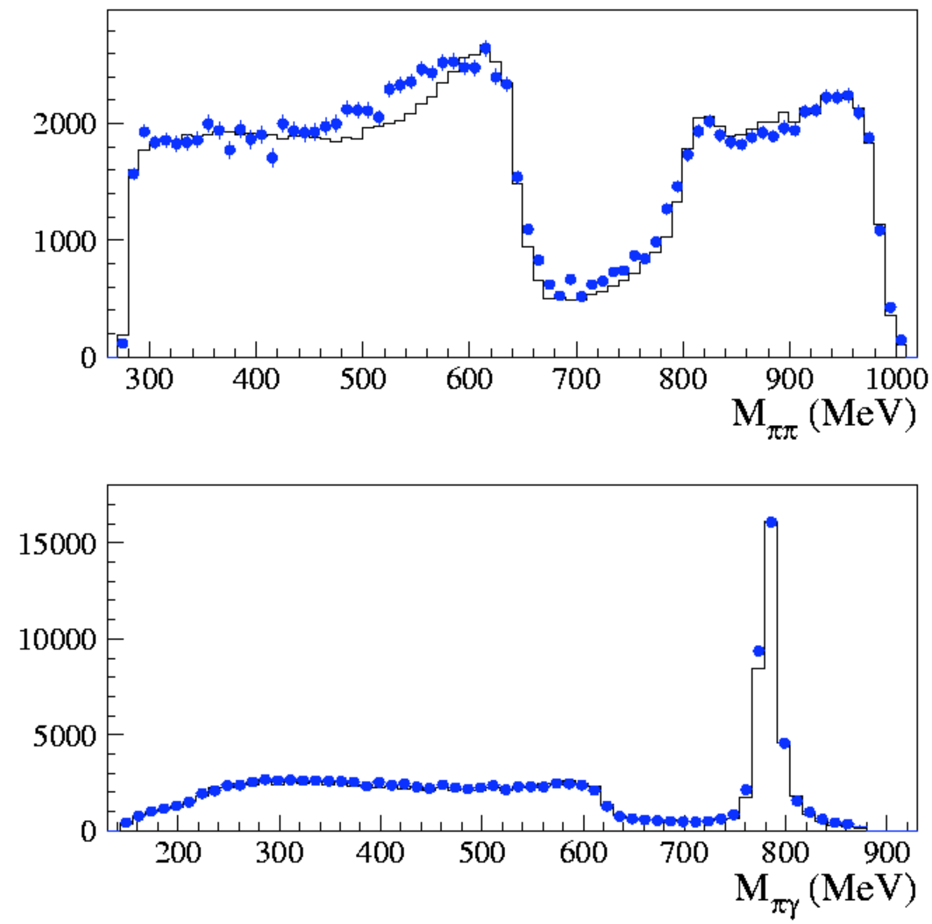
- (Fit A) we left free only the f_0 parameters + VDM

- (Fit B) as (Fit A) leaving the sigma mass to vary

K-loop fit results: $f_0 + \sigma$ (MASSES) $\sqrt{s}$=1019.6 MeV

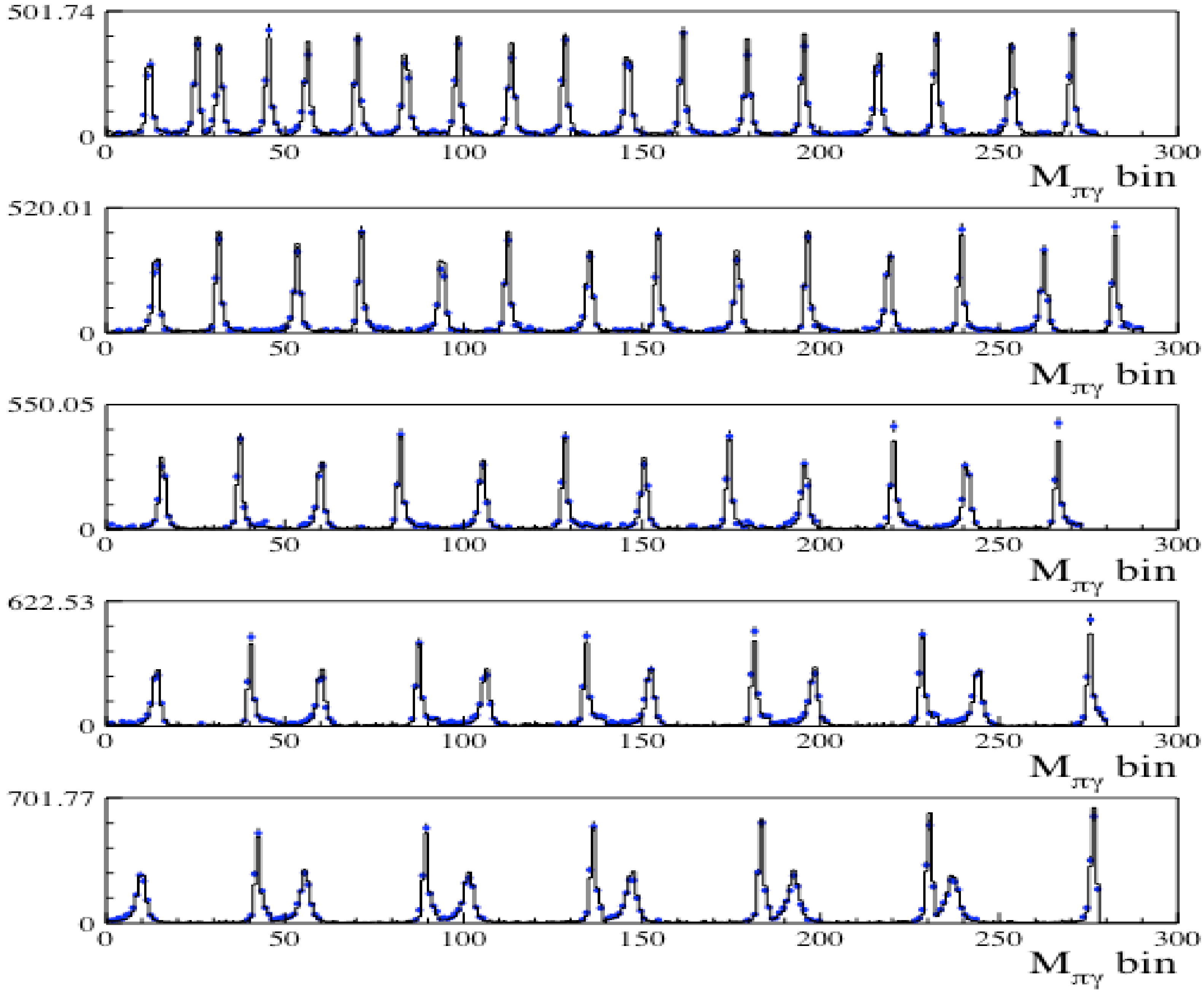


f_0 + VDM + Mσ FIXED

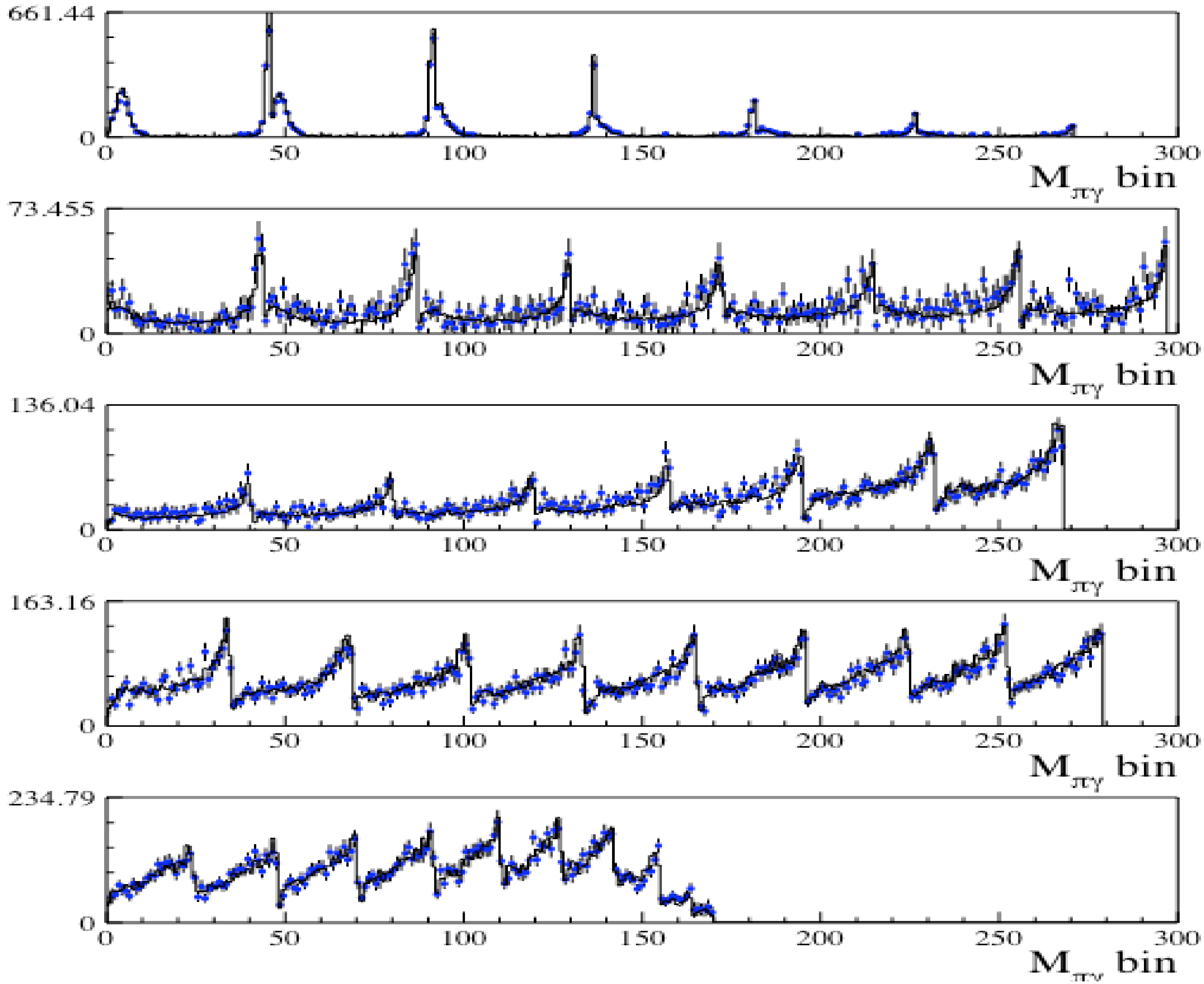


f_0 + VDM + Mσ Free

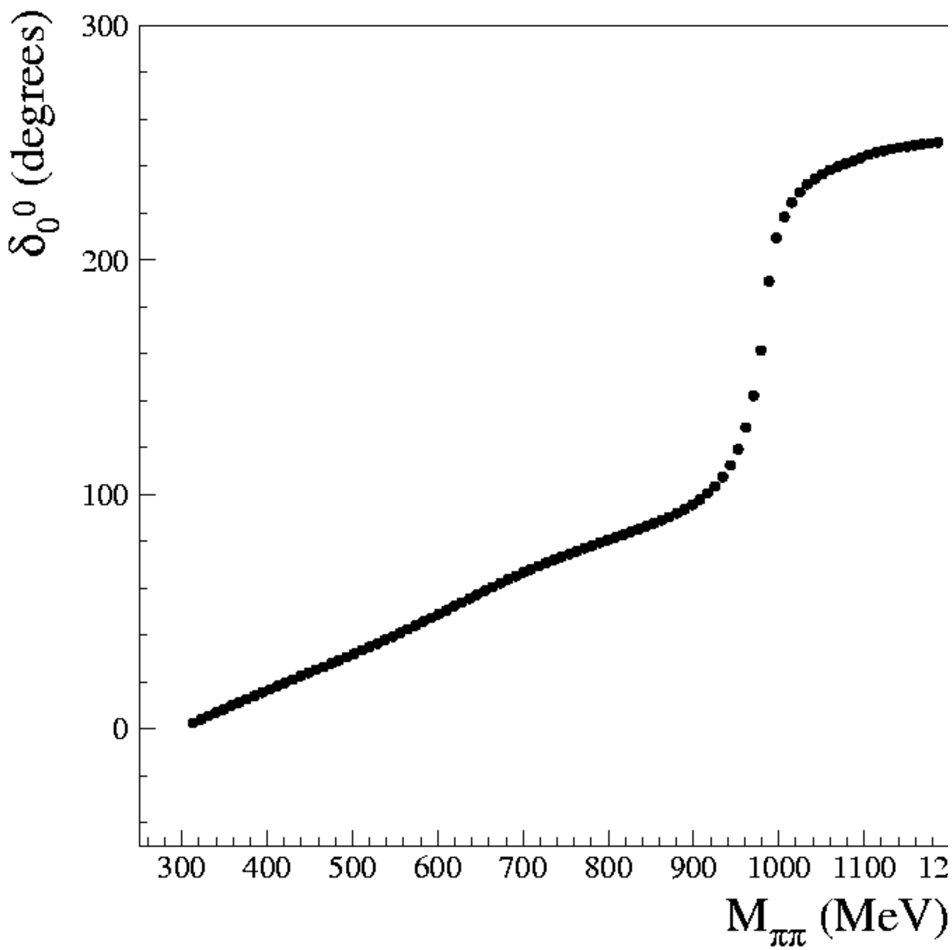
K-loop fit results: $f_0 + \sigma$ (dalitz-slices) $\sqrt{s}$=1019.6 MeV

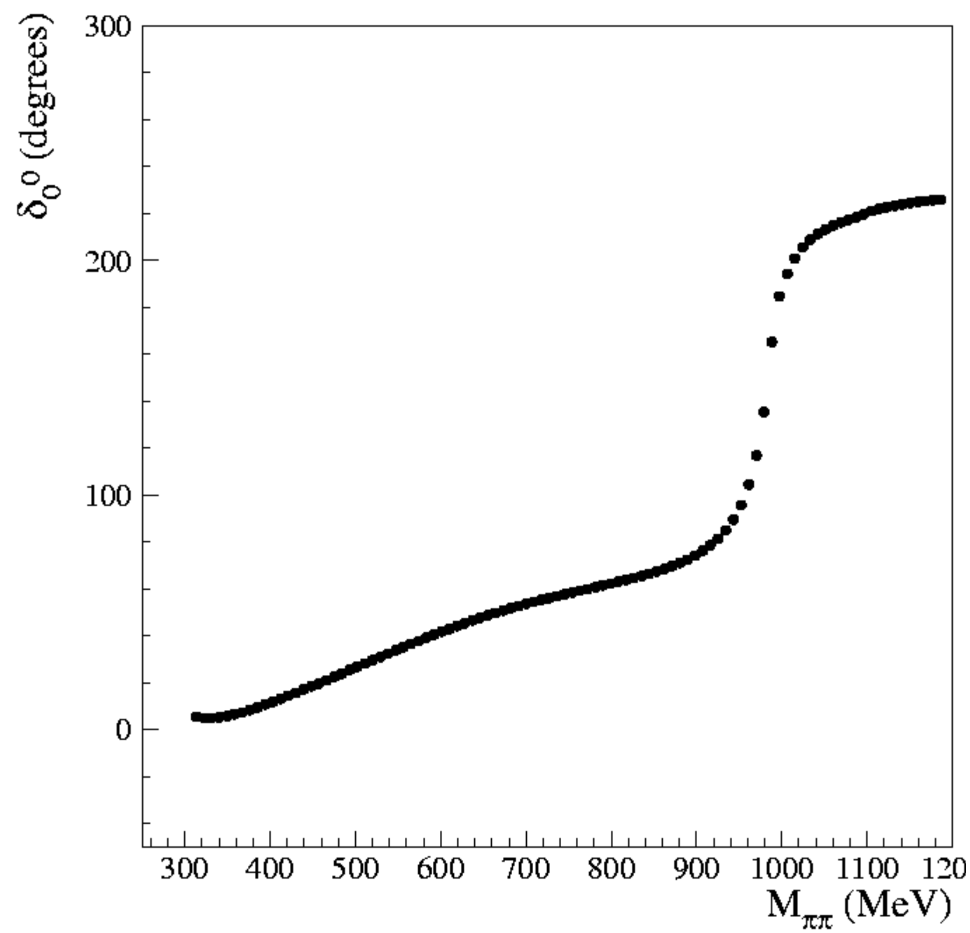


K-loop fit results: $f_0 + \sigma$ (dalitz-slices) $\sqrt{s}$=1019.6 MeV



K-loop fit results: $f_0 + \sigma$ (phases)

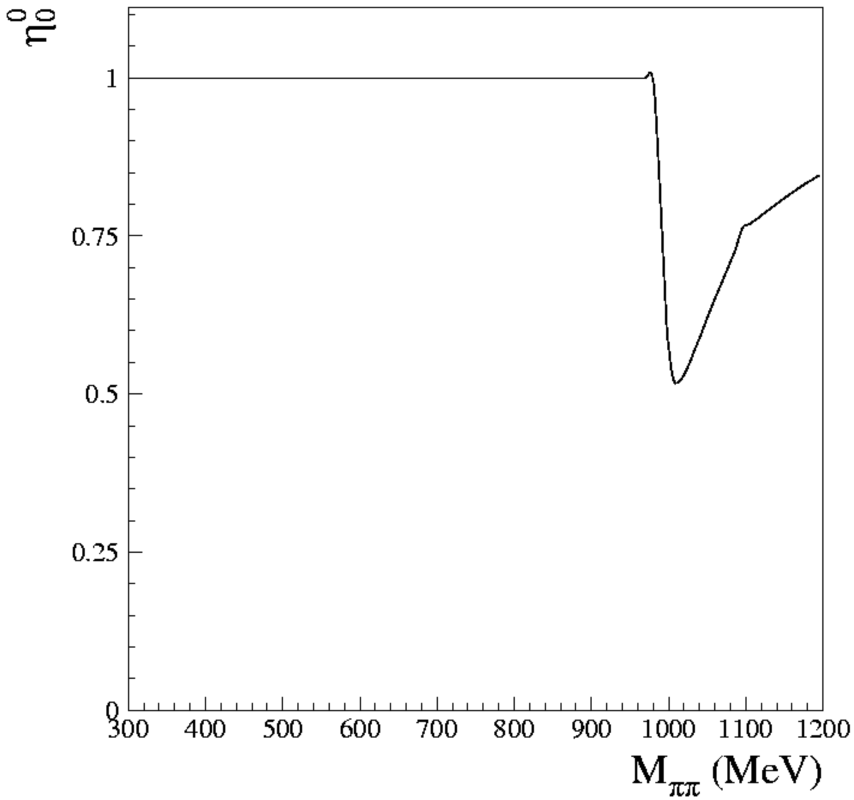


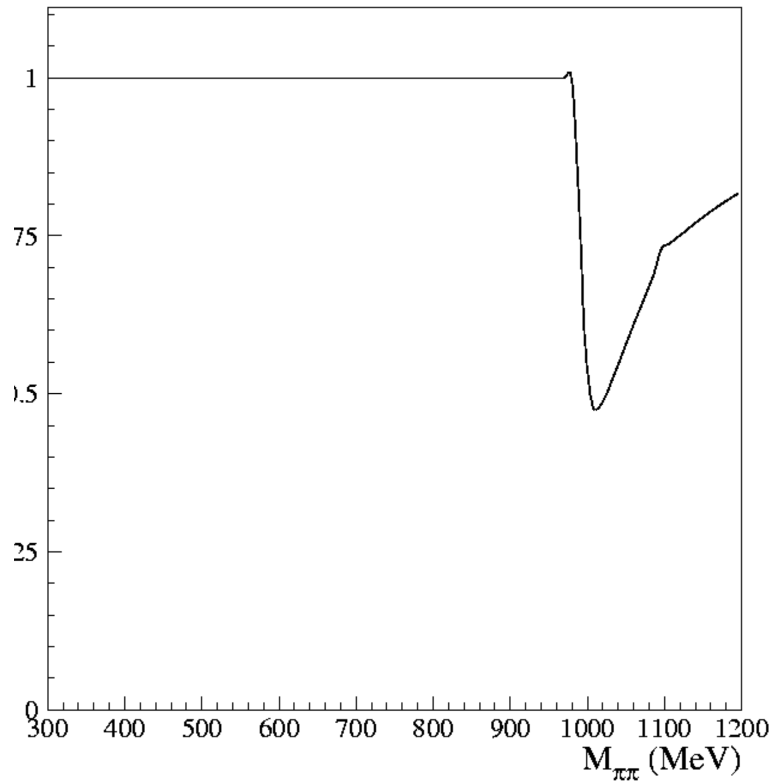


f_0 + VDM + Mσ FIXED

f_0 + VDM + Mσ Free

K-loop fit results: $f_0 + \sigma$ (phases)

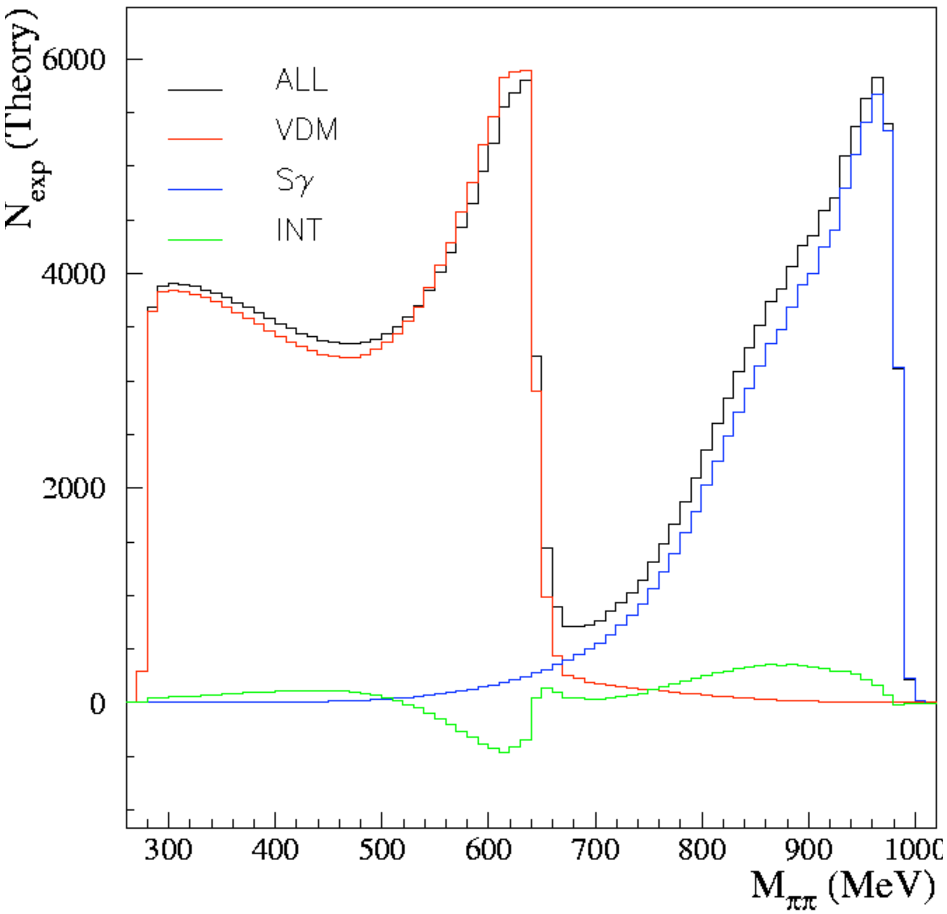




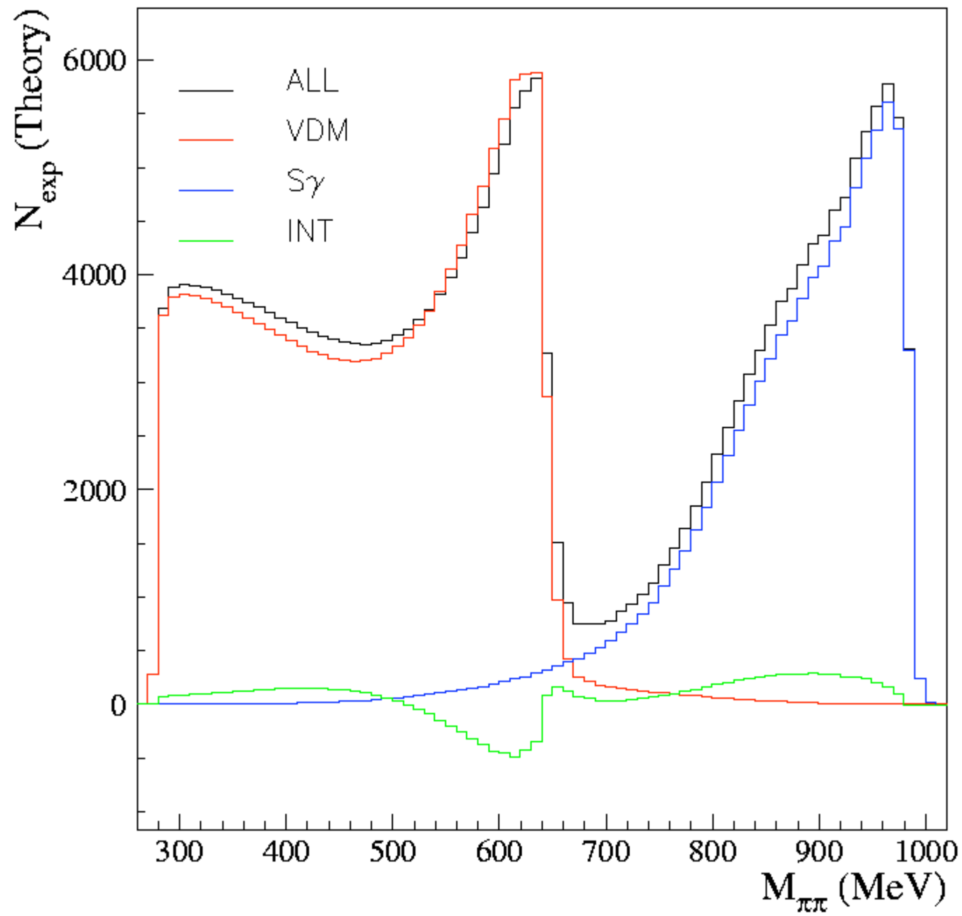
f_0 + VDM + Mσ FIXED

f_0 + VDM + Mσ Free

K-loop fit results: $f_0 + \sigma$ (compositions)



f_0 + VDM + Mσ FIXED

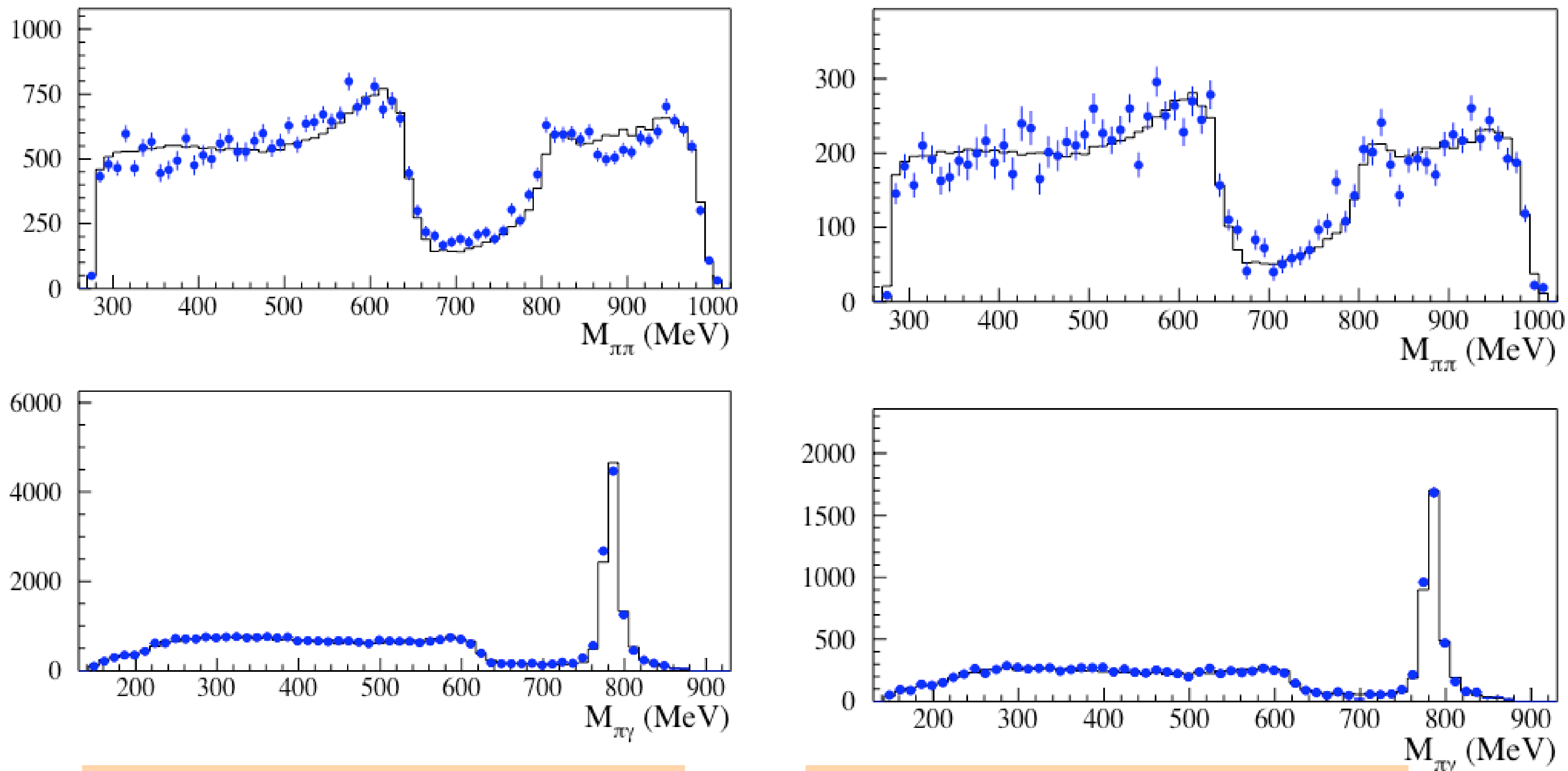


f_0 + VDM + Mσ Free

Fit results at $\sqrt{s}$ = 1019.6 MeV:

	$f_0 + \sigma$ (M_σ fixed)	$f_0 + \sigma$ (M_σ free)	$f_0 \to \pi^+\pi^-$
M_{f0} (MeV)	**987.1 ± 0.1**	**987.2 ± 0.1**	**980 – 987**
$g_{fK^+K^-}$ (GeV)	**3.53 ± 0.04**	**3.80 ± 0.07**	**3.9 – 6.5**
$g_{f\pi^+\pi^-}$ (GeV)	**–1.95 ± 0.01**	**–2.03 ± 0.01**	**2.8 – 3.8**
M_σ (MeV)	**541**	**484.6 ± 21.9**	
$\alpha_{\rho\pi}(\phi)$	0.76±0.18	0.69 ± 0.05	
$C_{\omega\pi}$ (GeV^{-2})	0.826 ±0.003	0.827 ± 0.001	
$\phi_{\omega\pi}$	0.21 ±0.03	0.47 ± 0.05	
$C_{\rho\pi}$ (GeV^{-2})	0.198 ±0.045	0.62 ± 0.23	
$\phi_{\rho\pi}$	3.14 ± 1.98	3.14 ±2.45	
M_ω (MeV)	**782.1 ± 0.3**	**782.2 ± 0.2**	
δ_{b_ρ} (degree)	7.5 ± 3.2	31.0 ± 4.0	
χ^2/ndf	2862/ 2676	2845 / 2675	
$P(\chi^2)$	**0.6 %**	**1.1 %**	

Extrapolating at √ s = 1019.4-1019.8 MeV:



√ s = 1019.4 MeV

√ s = 1019.8 MeV

Not too bad … by keeping the results of the fit at 1019.6 MeV.
This is an absolute normalization!

No Structure parametrization

G.Isidori, L.Maiani, S.Pacetti, private communication

- Flatte-like propagator: $\Gamma_{f_0}(s) = (g_{12}^{f_0})^2 \frac{v_\pi(s)}{8\pi s} + (g_{KK}^{f_0})^2 \frac{v_K(s) + v_{K^0}(s)}{8\pi s}$

  Now **we can extract the $g_{S\pi\pi}$, g_{SKK} couplings** $v_\alpha(s) = \sqrt{\frac{s}{4} - M_\alpha^2}$.

- New phases related to the particle velocity

- Parametrization with the σ(600) **[M_σ and $g_{\sigma\pi\pi}$ fixed to BES values]**

$$F^{\text{scal}}_{\text{Flatté}}(s) = \frac{g_{12}^{f_0} g_{f_0\gamma}^{\phi}}{s - M_{f_0}^2 + i\sqrt{s}\,\Gamma_{f_0}(s)} + \frac{a_0 e^{\frac{i b_0 v_\pi(s)}{M_\phi}}}{M_\phi^2} + \frac{a_1 e^{\frac{i b_1 v_\pi(s)}{M_\phi}}}{M_\phi^4}(s - M_{f_0}^2)$$

$$F_S^\sigma(s) = \frac{g_{12}^{f_0} g_{f_0\gamma}^{\phi}}{s - M_{f_0}^2 + i\Gamma_{f_0}(s)\sqrt{s}} + \frac{a_0 e^{\frac{i b_0 v_\pi(s)}{M_\phi}}}{M_\phi^2} + \frac{g_{12}^{\sigma} g_{\sigma\gamma}^{\phi}}{s - M_\sigma^2 + i\Gamma_\sigma(s)\sqrt{s}}.$$

b_0 fixed to ensure the proper behaviour of δ_0^0 near the $M_{\pi\pi}$ threshold

Fit results: new No Structure parametrization

	f_0 only	$f_0 + \sigma$	$f_0 \to \pi^+\pi^-$
M_{f0} (MeV)	**987.5 ± 0.4**	**979.8 ± 0.4**	**968 – 979**
$G_{\phi f \gamma}$ (GeV^{-1})	**2.83 ± 0.03**	**2.33 ± 0.02**	**1.2 – 1.8**
$G_{\phi \sigma \gamma}$ (GeV^{-1})	—	**(0.0 ± 0.1) × 10^{-6}**	
$g_{fK^+K^-}$ (GeV)	**0.6 ± 0.1**	**0.0 ± 5.8**	**1.2 – 2.8**
$g_{f\pi^+\pi^-}$ (GeV)	**1.360 ± 0.006**	**1.209 ± 0.017**	**0.9 – 1.2**
a_0	5.38 ± 0.02	2.81 ± 0.05	6.00 ±0.02
a_1	2.56 ± 0.02	—	4.10 ± 0.04
b_1 (rad/GeV)	–0.72 ± 0.02	—	3.13 ± 0.05
$\alpha_{\rho\pi}(\phi)$	1.32 ± 0.02	0.92 ± 0.09	
$C_{\omega\pi}$ (GeV^{-2})	0.952 ± 0.001	0.940 ± 0.007	
$\phi_{\omega\pi}$	0.036 ± 0.009	0.000 ± 0.007	
$C_{\rho\pi}$ (GeV^{-2})	0.21 ± 0.02	0.29 ± 0.22	
$\phi_{\rho\pi}$	0.65 ± 0.09	2.7 ± 0.3	
M_{ω} (MeV)	781.70 ± 0.08	782.3 ± 0.2	
δ_{b_ρ} (degree)	87.1 ± 0.5	70 ± 7	
χ^2/ndf	2784.1 / 2672	2981.2 / 2673	
$P(\chi^2)$	6.4%	0.2 × 10^{-4}	

Summary for the ppg final state

- S-dependence of $\pi^0 \pi^0 \gamma$ x-sec done!
  KLOE memo submitted. For a PLB paper waiting for the new scan data + analysis of $\pi^+\pi^-\pi^0\pi^0$

- Fit results to the Dalitz at 1019.6 with new KL parametrization is reasonable !
  + It has a good ππ phase behaviour and other theoretical advantages.

KLOE memo on the fit to the dalitz-plot in writing.

PLB paper planned for the KL + NS fit around Mϕ.
Final blessing expected for Jan 06.

Summary and Perspectives on $f_0(980)$

1. **$f_0(600)$:** required in the $\pi^0\pi^0$ channel not in the $\pi^+\pi^-$one: no clear answer by now … although the large S/B difference in the spectrum should be considered.

2. **Couplings:**

   with the KL parametrization the $\pi^+\pi^-$ / $\pi^0\pi^0$ final state give results in good agreement:

   $R_{f0} = (g_{f0K+K-} / g_{f0\pi+\pi-})^2 = 2 - 4$ vs 3.5-3.8

   Mf_0 = 980-987 MeV vs (987.1 ± 0.1) MeV

   with the NS analysis contradictory results obtained:

   $gf_0K^+K^-$(GeV) = 1.6 - 2.3 vs 0.6

   $gf_0\,\pi^+\pi^-$ (GeV) = 0.9 - 1.1 vs 1.36

   $g\phi f_0\gamma$ (GeV-1) = 1.2 - 2.0 vs 2.8

   Mf_0(MeV) = 973-981 vs 987.5

suggesting: too much freedom of the parametrization?

KLOE perspectives on scalar mesons

1. Conclude analysis on 2001-2002 data sample for **$f_0(980)$** (neutral final states) and **$a_0(980)$**.

2. With **2000 pb^{-1} @ ϕ peak**:
   improvement expected for $f_0 \rightarrow \pi^+\pi^-$
   combined fit $\pi^+\pi^-$ AND $\pi^0\pi^0$
   search for f_0, $a_0 \rightarrow KK$

3. With new forthcoming **energy scan data**
   improved study of the $\sqrt{s}$-dependence of the cross-section;
   Off-peak: "test run" of $\gamma\gamma \rightarrow \pi^0\pi^0$

Fit function: the Achasov parametrization

$$\frac{d\sigma(e^+e^- \to \pi^0\pi^0\gamma)}{dm\,dm_{\pi\gamma}} = \frac{\alpha m_{\pi\gamma} m}{3(4\pi)^2 s^3}\Bigg\{ |A_{scalar}|^2 +$$

$f_0\gamma$

Model dependent term

$\alpha_{\rho\pi}(\phi)$

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

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

$\omega\pi/\rho\pi$

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

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

Set to +1

$$\frac{1}{\sqrt{2}} Re\Big[A_{scalar} \Big($$

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

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

$f_0\gamma$/VP interf

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

- ✓ **VDM free parameters: C_{VP} , $\delta_{b\rho}$, $\alpha_{\rho\pi}(\phi)$, M_ω**
- ✓ **M_σ free or fixed to BES value** (541 MeV)

IV - The Forward-Backward asymmetry:

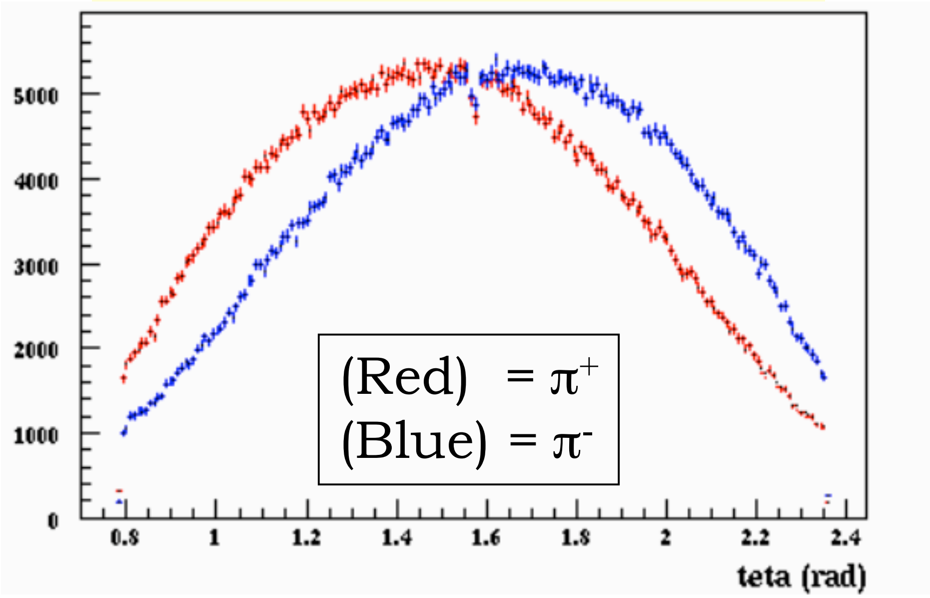
$$A = (N(\theta^+>90^o) - N(\theta^+<90^o)) / sum$$

$\pi^+\pi^-$ system: A(ISR) C-odd

A(FSR) & A(**scalar**) C-even

Cross-section: $|A(tot)|^2 = |A(ISR)|^2 + |A(FSR)|^2 + |A(\mathbf{scalar})|^2$
$+ 2Re[A(ISR)\ A(FSR)] + 2Re[A(ISR)\ A(\mathbf{scalar})]$
$+ 2Re[A(FSR)\ A(\mathbf{scalar})]$

Pion polar angle distributions

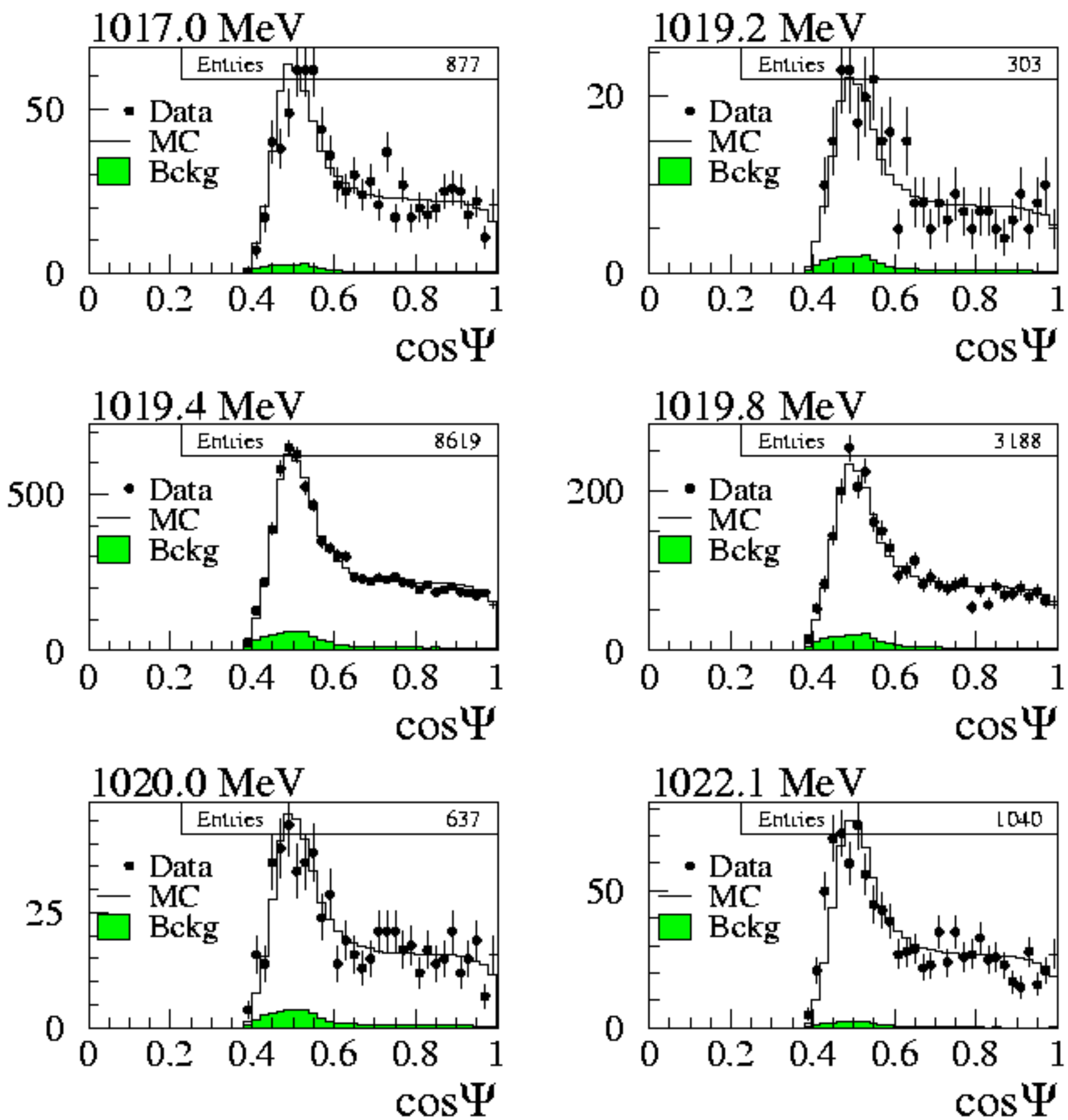


Effect of the scalar amplitude on the FB asymmetry:

Plot of **A** in slices of **m(ππ)**;

Comparison with simulation *with* and *without* the scalar amplitude.

$\omega\pi$ events vs $\sqrt{s}$ (angular distributions)



$\omega\pi$: FIT RESULTS to the visible xsec

FIT	σ_0 (nb)	$\Re$ (Z)	$\Im$ (Z)	σ'(nb/MeV)	χ^2/ Ndof
(A) σ' fixed	0.731 ± 0.035	0.060 ± 0.020	-0.157 ± 0.030	0.0048	5.0/11
(A) σ' fixed	0.748 ± 0.010	0.049 ± 0.016	-0.152 ± 0.007	0.0073	4.8/11
(A) All free	0.756 ± 0.245	0.041 ± 0.040	-0.148 ± 0.124	0.0098 ± 0.0114	4.5/10
FIT	σ_0 (nb)	$\Re$ (Z)	$\Im$ (Z)	A_1	χ^2/ Ndof
(B) A_1 fixed	0.745 ± 0.014	0.051 ± 0.012	-0.153 ± 0.007	-0.114	5.0/11
(B) A_1 fixed	0.746 ± 0.028	0.050 ± 0.020	-0.153 ± 0.022	-0.150	4.9/11
(B) All free	0.743 ± 0.016	0.054 ± 0.019	-0.154 ± 0.012	-0.005 ± 0.001	5.1/10
FIT	σ_0 (nb)	$\Re$ (Z)	$\Im$ (Z)	A_1	χ^2/ Ndof
(C) A_1 fixed	0.745 ± 0.011	0.052 ± 0.020	-0.154 ± 0.012	-0.114	5.0/11
(C) A_1 fixed	0.746 ± 0.007	0.051 ± 0.001	-0.154 ± 0.001	-0.150	5.0/11
(C) All free	0.743 ± 0.009	0.055 ± 0.016	-0.154 ± 0.006	-0.012 ± 0.002	5.1/10

$$\sigma_0^{\omega\pi} = (0.75 \pm 0.03_{stat}\,^{+0.01}_{-0.02})\ \mathrm{nb} \quad (14)$$

$$\Re(Z) = 0.05 \pm 0.02_{stat} \pm 0.01 \quad (15)$$

$$\Im(Z) = -0.15 \pm 0.02_{stat} - 0.01 \quad (16)$$

in good agreement and with similar accuracy with respect to SND results [26]: $\sigma_0^{\omega\pi} = (0.74 \pm 0.02_{stat} \pm 0.04_{syst})$ nb, $\Re(Z) = 0.025 \pm 0.035$, $\Im(Z) = -0.19 \pm 0.05$.