ϕ Dalitz decays

The high luminosity sample we are acquiring opens up the possibility to move from radiative to Dalitz ϕ decays: $\mathbf{N_\phi(2fb^{-1}) \approx 7\times10^9}$

Conversion decays of low mass vector mesons ($\rho/\omega/\phi \to \pi^0(\eta)\, e^+e^-(\mu^+\mu^-)$) are relevant since the spectra of the di-lepton invariant mass determines the transition form factor *vs* q^2 and, together with the BR, test predictions of various theoretical models (VMD, lattice)

Decay	BR (PDG04)
$\phi \to \pi^0 e^+e^-$	$(1.12 \pm 0.28) \times 10^{-5}$
$\phi \to \eta\, e^+e^-$	$(1.15 \pm 0.10) \times 10^{-4}$
$\phi \to \eta\, \mu^+\mu^-$	$< 9.4 \times 10^{-6}$

Theoretical expectations for BR($\phi \to \eta\, \mu^+\mu^-$) : $(5.3–6.8)\times10^{-6}$

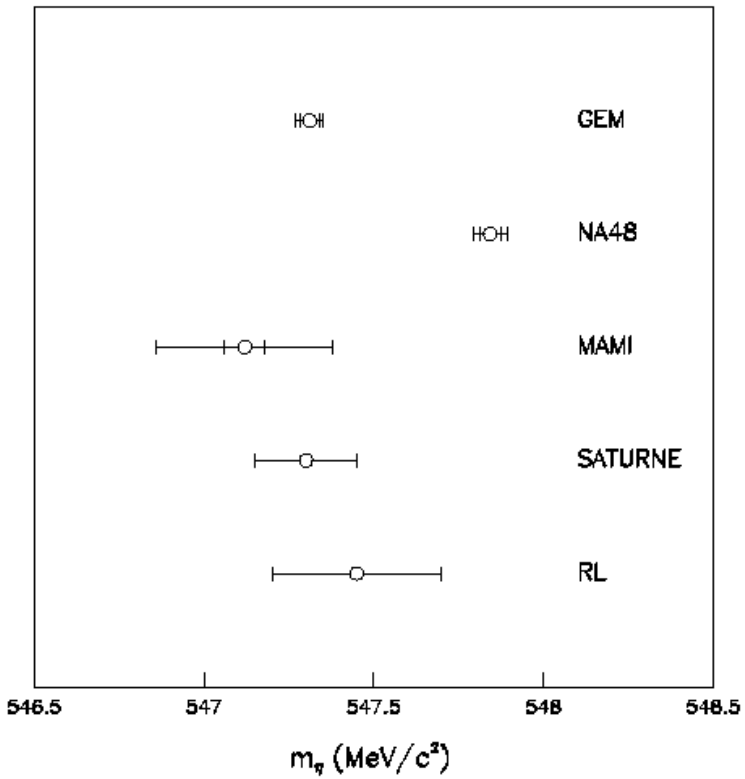
[Phys. Rev. C 61 (2000) 035206 , Phys. Rev. D 54 (1996) 5611]

ϕ Dalitz decays: precise η mass measurement?

4 May 2005:
The GEM Collaboration, hep-ex/0505006 [COSY, Julich]

Reaction used: $p+d \rightarrow {}^3He + \eta$

$M_\eta = (547.311 \pm 0.028 \pm 0.032)\ MeV/c^2$



High discrepancy with NA48!
[A, Lai et al., Phys. Lett. B 533 (2002) 196]

We can use $\phi \rightarrow \eta e^+ e^-$ to measure the η mass:

- $N_{\phi\eta ee} = N_\phi\ BR\ \varepsilon_{ana} = 7\times10^9 \times 1.15\times10^{-4} \times 0.3 \approx$ **240,000**
- Search: $M_{\gamma\gamma}=M_\eta + M_{ee}=373$ MeV
- By using the missing mass and the $\sqrt{s}$ constraint, $\delta M \approx O(10$ keV$)$

η decays: already studied @ KLOE

$\sigma_\phi = 3.3\ \mu b$
$BR(\phi \to \eta\gamma) = (1.295 \pm 0.025)\%$

$\Big\}$ **$N_\eta(2\ fb^{-1}) \approx 8.6 \times 10^7$**

Decay	BR	ε_{ana}	N_{exp}
$\eta \to \gamma\gamma$	(39.43 ± 0.26) %	70%	2.4×10^7
$\eta \to \pi^0\pi^0\pi^0$	(32.51 ± 0.29) %	45%	1.3×10^7
$\eta \to \pi^+\pi^-\pi^0$	(22.6 ± 0.4) %	36.5%	0.7×10^7
$\eta \to \pi^+\pi^-\gamma$	(4.68 ± 0.11) %	46%	1.8×10^6
$\eta \to \pi^0\gamma\gamma$	**(8.0 ± 2.7) × 10^{-5}**	**4.63%**	**330**
$\eta \to \pi^+\pi^-\gamma$	**< 1.3×10^{-5}**		
$\eta \to \gamma\gamma\gamma$	**< 1.6×10^{-5}**		

PDG04

KLOE preliminary

KLOE published

- Main BRs known with *O*(%) precision. Improvement requires a complete measurement of all main decay channels. $\eta \to \pi^+\pi^-\gamma$ analysis to be completed
- **For $BR(\eta\to\pi^0\gamma\gamma)$ a factor two improvement is expected**
- **Upper limits on $\pi^+\pi^-/\gamma\gamma\gamma$ background limited?**

η decays: Dalitz and double Dalitz

Dalitz and double Dalitz decay can be reached with 2 fb^{-1}

Decay	BR (PDG04)
$\eta \to e^+e^-\gamma$	$(6.0\pm0.8)\times10^{-3}$
$\eta \to \mu^+\mu^-\gamma$	$(3.1\pm0.4)\times10^{-4}$
$\eta \to e^+e^-e^+e^-$	6.9×10^{-5}
$\eta \to \pi^+\pi^-e^+e^-$	$(4.0^{+14.0}_{-2.7})\times10^{-4}$

All this measurements can be significantly improved and a first observation of $e^+e^-e^+e^-$ can be achieved (theoretical expectations: BR($\eta \to e^+e^-e^+e^-$) = 6.5×10^{-5} [PR 98 (1955) 1355]

Example of measurement for $e^+e^-\gamma$:

$N = 8.6\times10^7 \times 6\times10^{-3} \approx 5\times10^5$

$\varepsilon_{ana} = 50\%$

δBR/BR ~ 0.2 % (stat)

η' decays: main BRs

$\sigma_\phi = 3.3\ \mu b$
$BR(\phi \to \eta'\gamma) = (6.2 \pm 0.7)\times 10^{-5}$

$\Big\}$ **$N_\eta(2\ fb^{-1}) \approx 410{,}000$**

Decay	BR (PDG04)
$\eta' \to \pi^+\pi^-\eta$	(44.3±1.5)%
$\eta' \to \pi^+\pi^-\gamma$	(29.5±1.0)%
$\eta' \to \pi^0\pi^0\eta$	(20.0 ±1.2)%
$\eta' \to \omega\gamma$	(3.03±0.31)%
$\eta' \to \gamma\gamma$	(2.12±0.14)%

We can try to improve the η' main BRs, which are known with errors of the order of 5–10%. This will reduce the systematics in the measurement of $R = BR(\phi \to \eta'\gamma)/BR(\phi \to \eta\gamma)$ which dominate the total error

η' decays: Dalitz and double Dalitz

In principle Dalitz and double Dalitz decay can be reached with 2 fb^{-1}

Decay	BR (PDG04)
$\eta' \to \mu^+\mu^-\gamma$	$(1.04\pm0.26) \times 10^{-4}$
$\eta' \to e^+e^-\gamma$	$< 9\times10^{-4}$
$\eta' \to \pi^+\pi^-e^+e^-$	$< 6\times10^{-3}$

- More difficult search w.r.t. the η case because of the low energy of the recoil photon (60 MeV *vs* 373 MeV)

- Large background from not–resonant processes
  ($e^+e^- \to e^+e^-(\gamma)$ / $\mu^+\mu^-\gamma$ / $\pi^+\pi^-\gamma$)

Scalar mesons: $\pi\pi/\eta\pi$ final states

- **$f_0(980) \to \pi^0\pi^0$** Statistics collected in 2001+2002: **≈ 70 kevts** integrating all $\sqrt{s}$ values, after analysis cuts. Experimental issues like photon pairing and energy resolution and knowledge/interference of the VDM background limit further improvements

- **$f_0(980) \to \pi^+\pi^-$** ???

- **$a_0(980) \to \eta\pi^0$** Much cleaner situation with bckg/interf. The $\pi^+\pi^-\pi^0$ channel (background free) will reach statistical precision better than % on the BR

  Using 2001+2002 data , with analysis cuts:

$\eta \to \gamma\gamma$	(BR = 39.43%)	**1.2×10^4 events**
$\eta \to \pi^+\pi^-\pi^0$	(BR = 22.6%)	**4180 events**

Scalar mesons: the KK final state

Using the 2000 data fit results for $f_0 \to \pi^0\pi^0\gamma$, it is possible to evaluate the number of events expected for the KK final state by using the M_K mass for the phase space and substituting $g_{f\pi\pi}$ with g_{fKK}

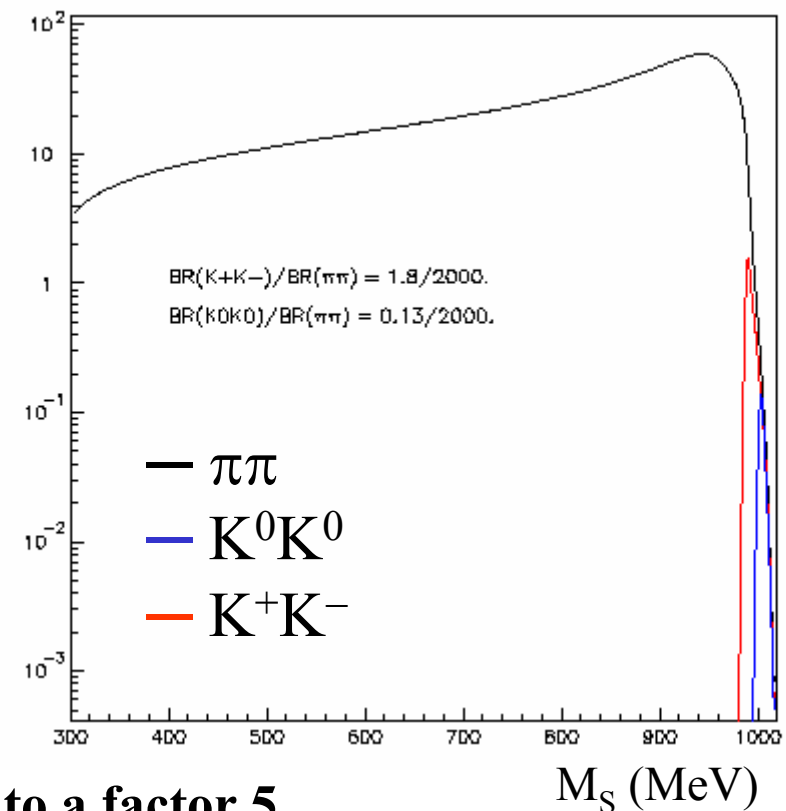
$BR(K^+K^-) / BR(\pi^0\pi^0) = 1.8/2000$

$BR(K^0K^0) / BR(\pi^0\pi^0) = 0.13/2000$

With 2.5 fb^{-1} (and ε_{ana}=100%)

$N(K^+K^-\gamma) \approx 1500$

$N(K^0K^0\gamma) \approx 100$



WARNING: these values can change up to a factor 5

BR ≈ *O*(10^{-8}) and a very soft photon… a real challenging measurement!!!

Rare ω decays

The not resonant process $e^+e^- \rightarrow \omega\pi^0$ reach a visible cross section of ~ 8 nb @ M_ϕ. We expect to collect **1.6×10^7 ω mesons**

This opens up the possibility to search for rare/medium-rare ω decays with good precision

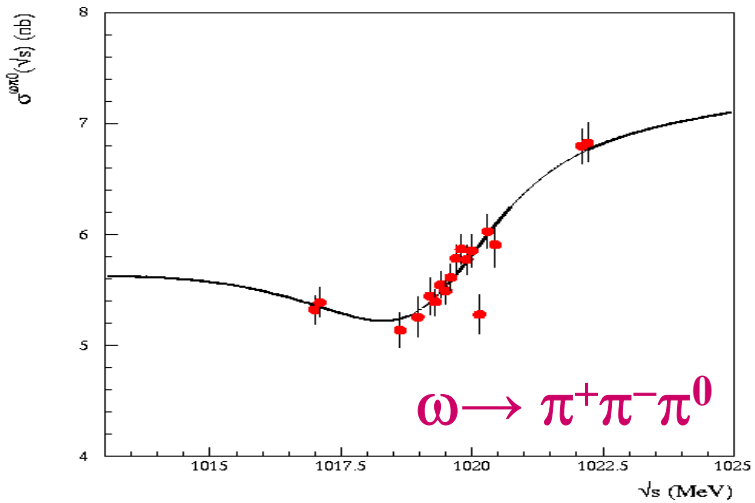
Decay	BR (PDG04)
$\omega \rightarrow \eta\gamma$	$(4.9 \pm 0.5) \times 10^{-4}$
$\omega \rightarrow \pi^0 e^+ e^-$	$(5.9 \pm 1.9) \times 10^{-4}$
$\omega \rightarrow \pi^0 \mu^+ \mu^-$	$(9.6 \pm 2.3) \times 10^{-4}$

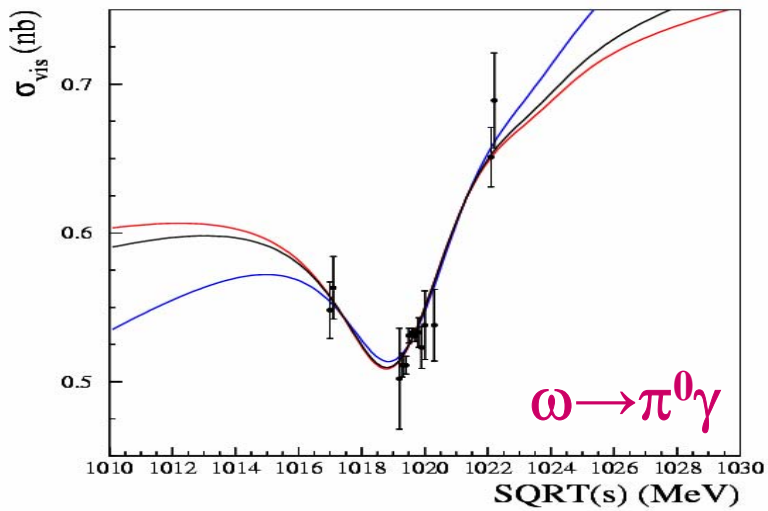
The last two process belongs to the same categories of Dalitz decay for the vector mesons discussed for the ϕ

ϕ scan : BR($\phi \to \omega\pi^0$)

BR($\phi \to \omega\pi^0$) from $\sigma(e^+e^- \to \omega\pi^0)$ *vs* $\sqrt{s}$

2001+2002 data





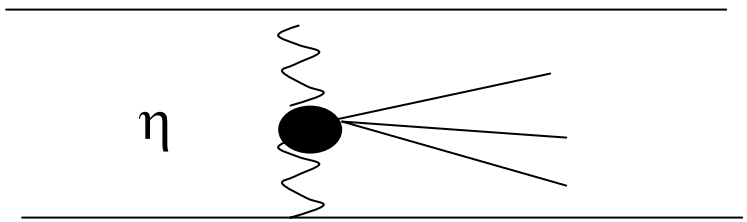
Preliminary result with $\pi^+\pi^-\pi^0$ (factor 3 improvements w.r.t. SND)

$$BR(\phi \to \omega\pi^0) = (4.0 \pm 0.5_{stat} \pm 0.3_{syst}) \times 10^{-5}$$

- ✓ Conclude the measurement with higher statistics from ϕ scan (if available)
- ✓ Data @ $\sqrt{s} = M_\phi \pm 30$ MeV values will allow to determine the slope from our data

ϕ scan: η width

η production from $\gamma\gamma$:



- Total width of η poorly known (10%)
- From DAΦNE Physics Handbook: expect $\gamma\gamma$ production rates of eta mesons at $O(5\times10^5)$/y @ 5 fb^{-1}/y luminosity
- One could look for final state $\eta\rightarrow\pi^+\pi^-\pi^0$ without detecting e^+e^-
- If we run below ϕ peak, we have no background from $\phi\rightarrow\pi^+\pi^-\pi^0$

Assegno di ricerca @ LNF per eta network

Scalar mesons: the KK final state

The observation of $\phi \to (a0, f0)\gamma \to KK\gamma$ would add an important piece in the understanding of the light scalars

- **A very interesting process for studying the scalars would be $\phi \to (a_0, f_0)\gamma \to KK\gamma$**

With L=2 fb^{-1} and assuming (Achasov-Gubin PRD64(2001)):

$$Br(\phi \to (a_0, f_0)\gamma \to K^+K^-\gamma) \sim 1\text{-}\ 2 \times 10^{-6}$$

$$\text{and } Br(\phi \to (a_0, f_0)\gamma \to K^0K^0\gamma) \sim 1\text{-}\ 4 \times 10^{-8}$$

$\Rightarrow$ N($\phi \to (a_0, f_0)\gamma \to K^+K^-\gamma$)= 6000-12000 evts

$\Rightarrow$ N($\phi \to (a_0, f_0)\gamma \to K^0K^0\gamma$)= 70-300 evts

$\Rightarrow$ golden channel: $K_SK_S\gamma$ $\to$ 10 – 100 evts