# Measurement of $\Gamma(\phi \to l^+l^-)$

## from $e^+e^- \to e^+e^-$, $\mu^+\mu^-$ processes

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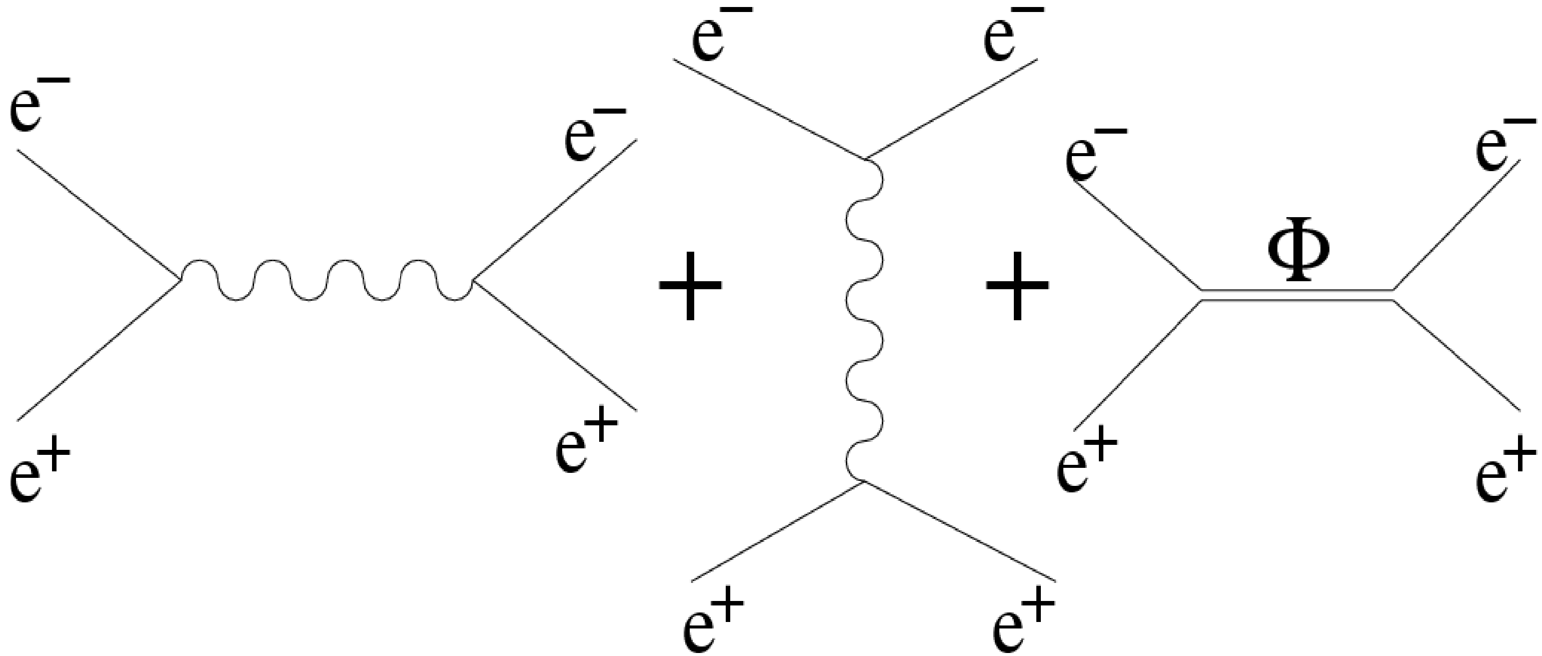
# Cross section




$$A = A_{s/t} + A_{\Phi}$$

$$\sigma = \sigma_{s/t} + \sigma_{\Phi} + \sigma_{int}$$

# The interference term $\sigma_{int}$

$$\sigma_{\text{int}} = \frac{3\alpha\Gamma_{ll}}{M_\Phi} \frac{s - M_\Phi{}^2}{(s - M_\Phi{}^2)^2 + s\Gamma_\Phi{}^2} \int_{\cos\theta_1}^{\cos\theta_2} f_{ll}(\theta) d\cos\theta$$

**Bhabha**

$$f_{ee}(\theta) = 2(1 + \cos^2\theta - \frac{(1+\cos\theta)^2}{1-\cos\theta})$$

$$\Gamma_{ll} = \Gamma_{ee}$$

**muons**

$$f_{\mu\mu}(\theta) = \beta_\mu(1 + \cos^2\theta + (1-\beta_\mu{}^2)\sin^2\theta)$$

$$\Gamma_{ll} = \sqrt{\Gamma_{ee}\Gamma_{\mu\mu}}$$

- W below and above $M_\Phi$ affects in opposite way $\sigma_{int}$ . This difference is linear in $\Gamma_{LL}$. For this reason our analysis uses only 3 energy points

- For muons we fit directly cross section

- For Bhabha, in order to increase sensitivity, we fit the forward-backward asymmetry $A_{FB}$

# Experimental advantages

- $\Gamma_{LL}$ in first approsimation depends only on absolute difference in $A_{FB}$ (bhabha) and $\sigma_{\mu\mu}$ (muons)

- In addition we have some experimental advantages in both cases :

**Bhabha**

- Luminosity not nedeed
- Partial cancellation in eff, bkg

**muons**

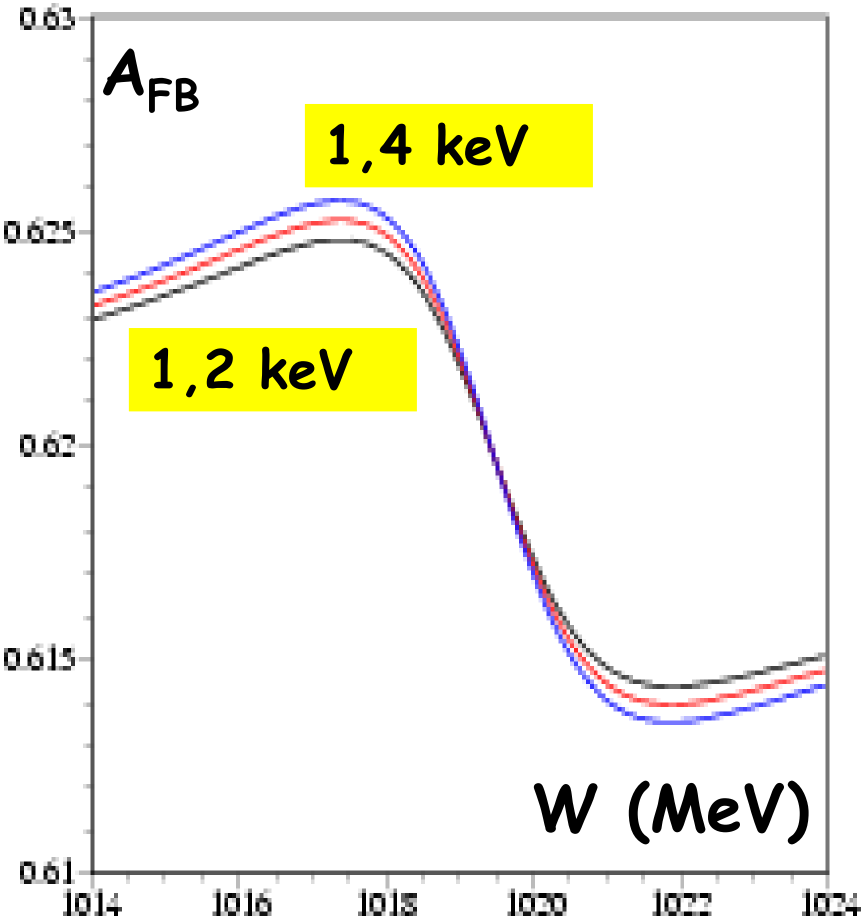
- fully energy-correlated systematics needed only to evaluate $\sigma_{\mu\mu}$
- These systematics cancel out in $\Gamma_{\mu\mu}$ evaluation

# Sensitivity

## Bhabha

$\delta\Gamma_{ee}/\Gamma_{ee} \sim 0.03$ translates

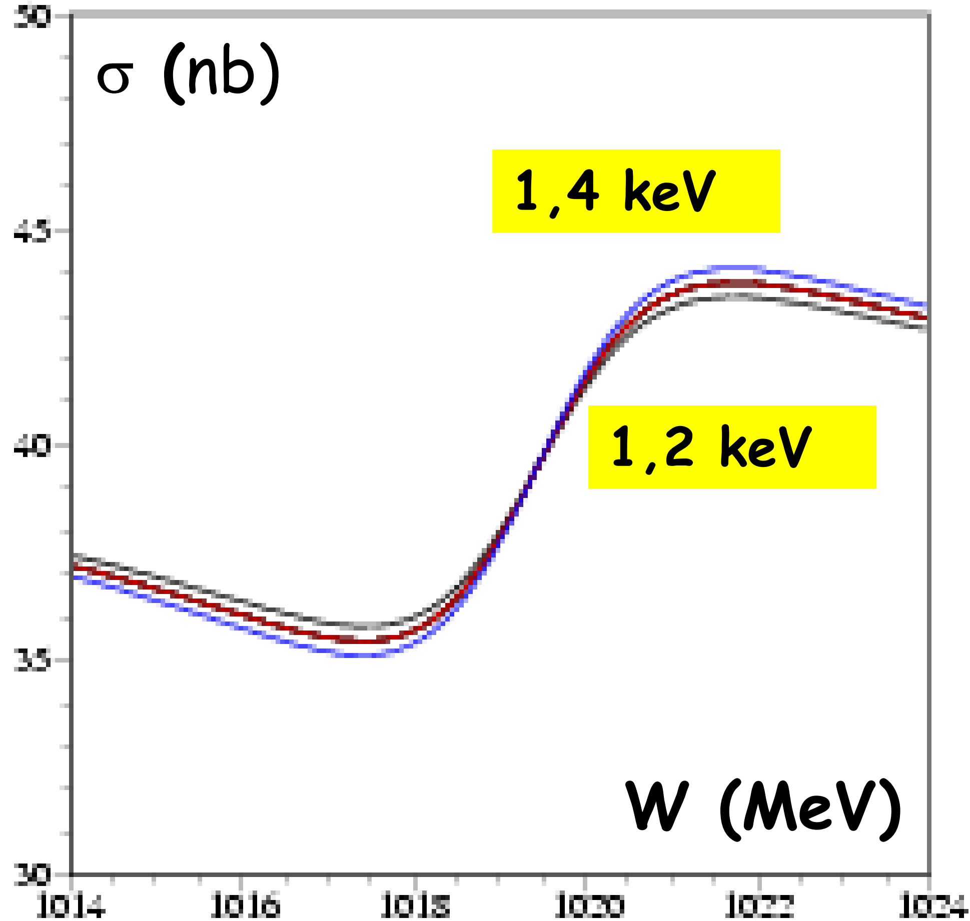
in $\delta A_{FB}/A_{FB} \sim 0.0003$




## Muons

$\delta\Gamma_{\mu\mu}/\Gamma_{\mu\mu} \sim 0.03$ translates

in $\delta\sigma/\sigma \sim 0.004$



# Selection

## W'/W reconstruction

We use a lower cut on W'/W. If we boost back in $\phi$ rest frame, assuming a single beam collinear ISR photon and collinear FSR, then :

$$\frac{W'}{W} = \frac{\sin\theta_1 + \sin\theta_2 - \left|\sin(\theta_1 + \theta_2)\right|}{\sin\theta_1 + \sin\theta_2 + \left|\sin(\theta_1 + \theta_2)\right|}$$

## $\theta_{eff}$ reconstruction

To define our geometrical acceptance we define the polar angle in the effective c.o.m., $\theta_{eff}$ , by using ISR photon mementum (average angle)

# Data sample

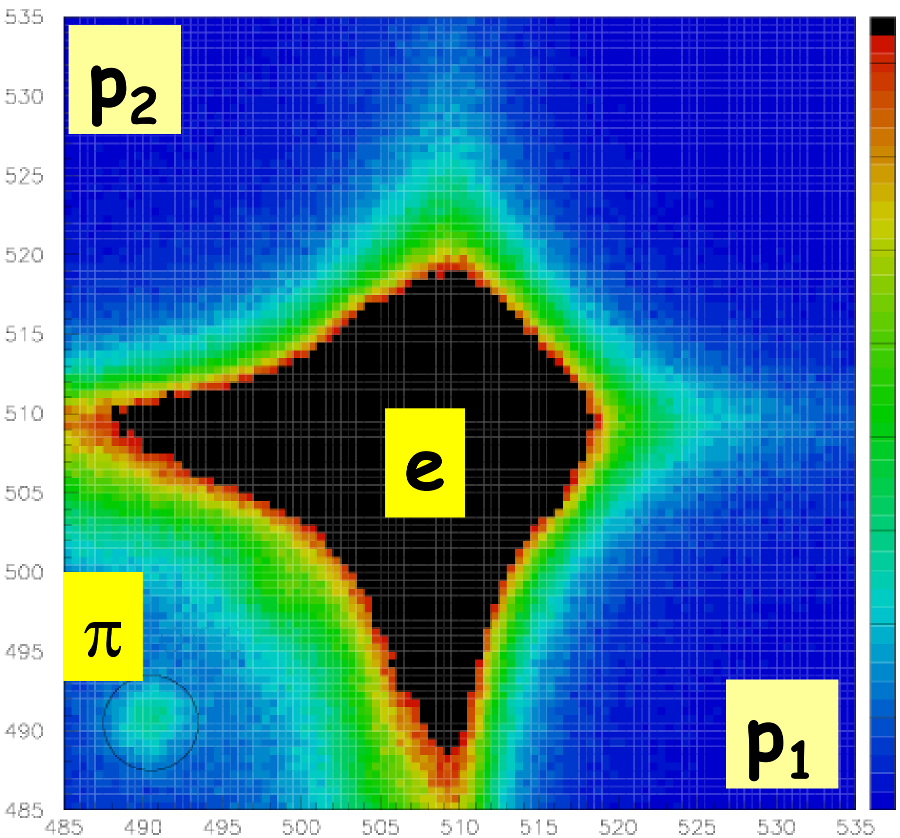
- 3 energy points of 2002 scan
- BHABHA stream : basically only $ee \to ee$ events
- CLB stream : $ee \to \mu\mu$ and $ee \to \pi\pi$ events

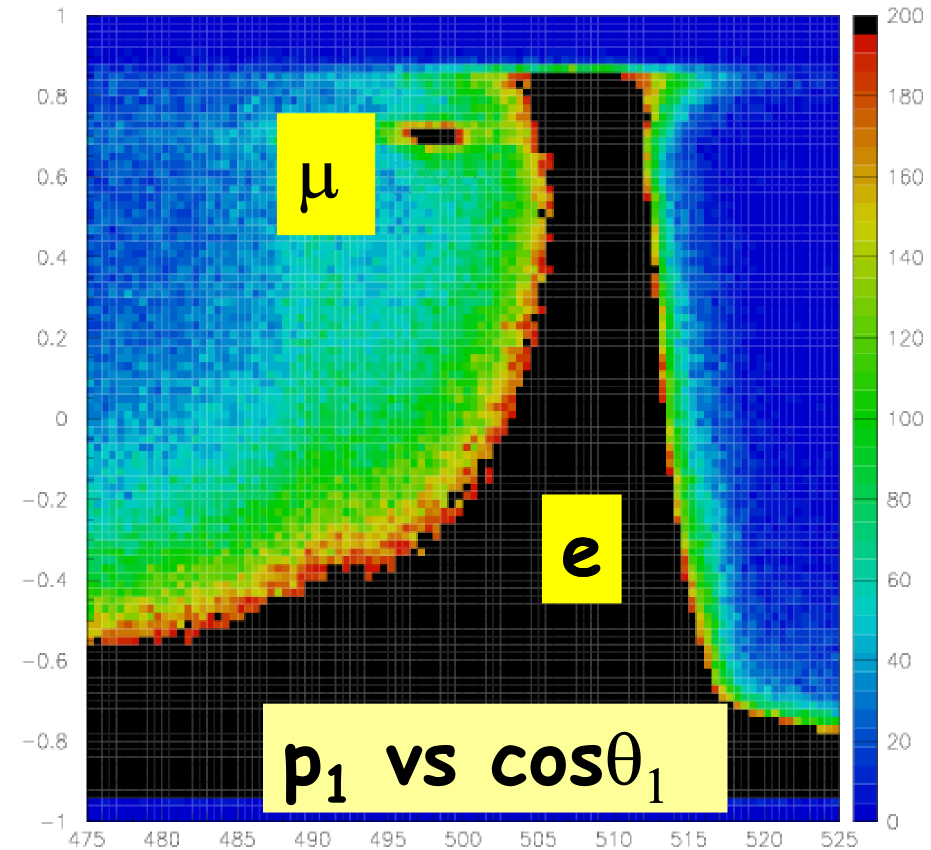
| Energy, MeV | Luminosity, $nb^{-1}$ |
|---|---|
| $1017.17 \pm 0.01_{stat} \pm 0.03_{syst}$ | $6966 \pm 4_{stat} \pm 42_{syst}$ |
| $1019.72 \pm 0.02_{stat} \pm 0.03_{syst}$ | $4533 \pm 3_{stat} \pm 27_{syst}$ |
| $1022.17 \pm 0.01_{stat} \pm 0.03_{syst}$ | $5912 \pm 3_{stat} \pm 35_{syst}$ |

# $e^+e^- \rightarrow e^+e^-$ analysys

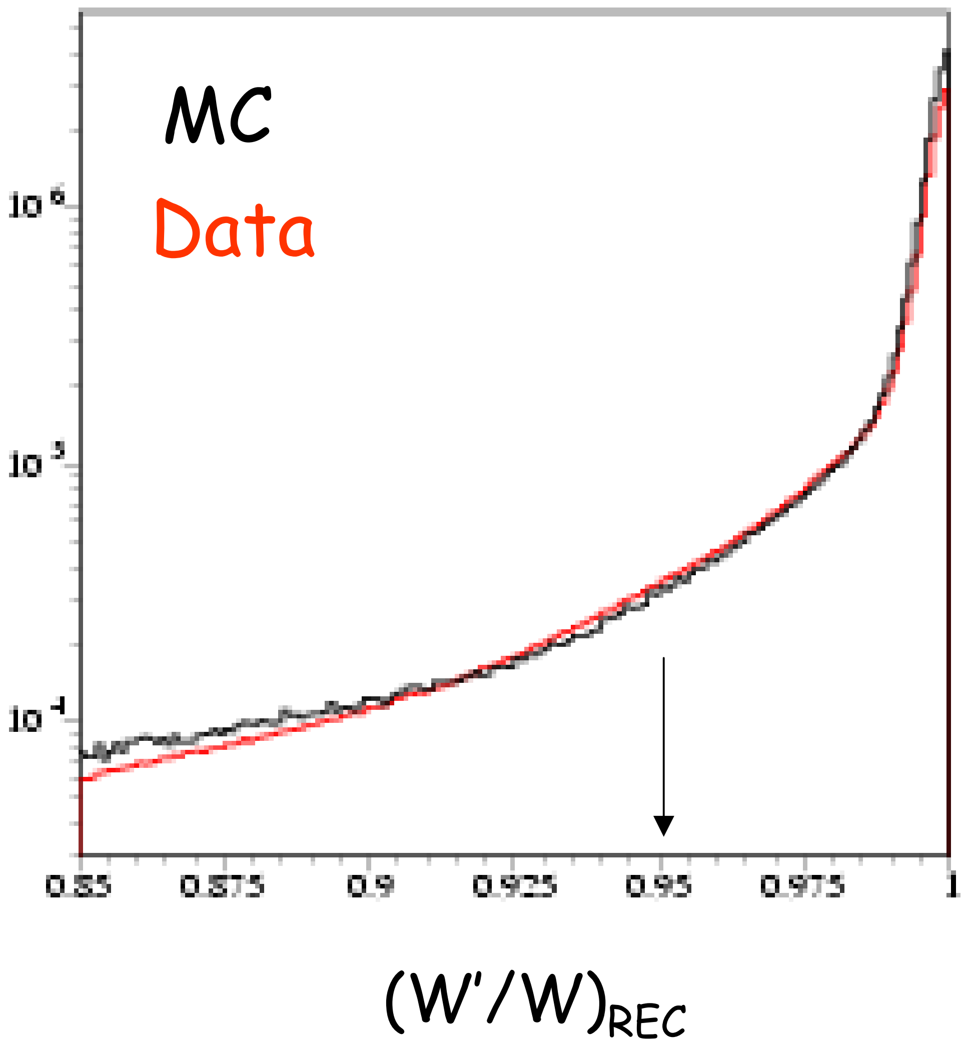
ACCEPTANCE

$(W'/W)_{REC} = 0.95$ $53 < \theta_{eff} < 127$

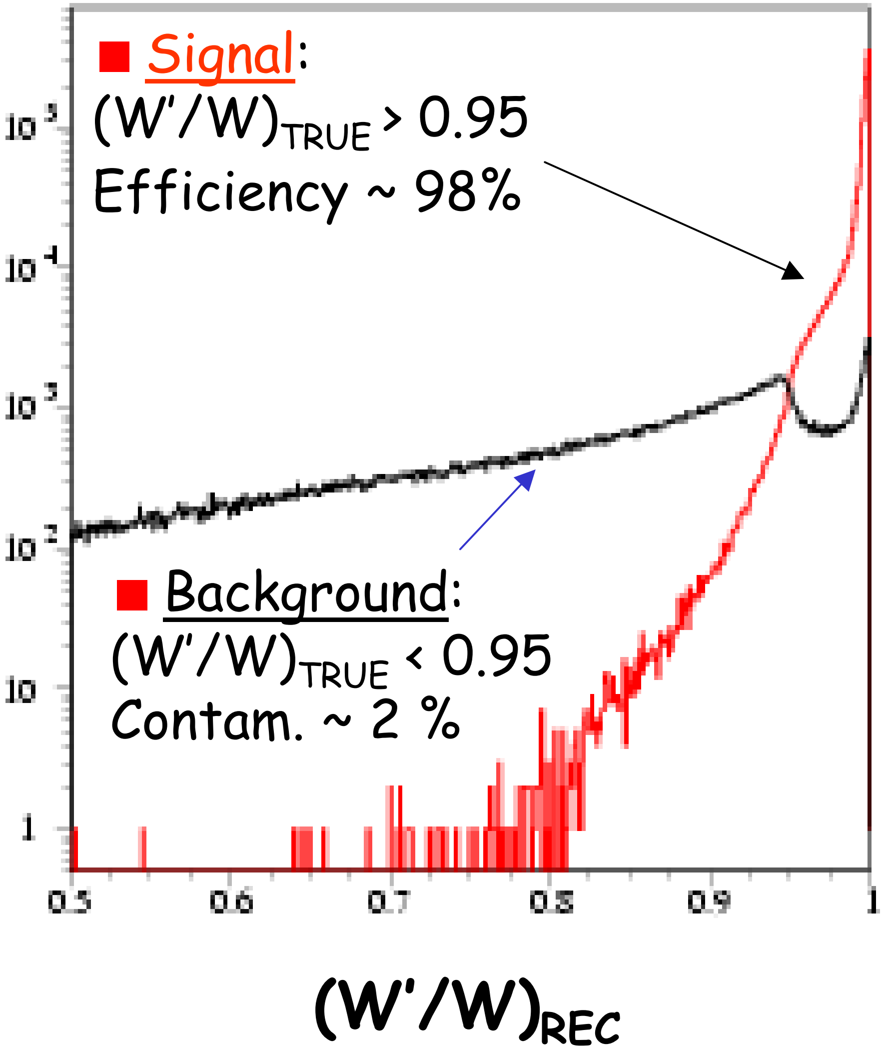


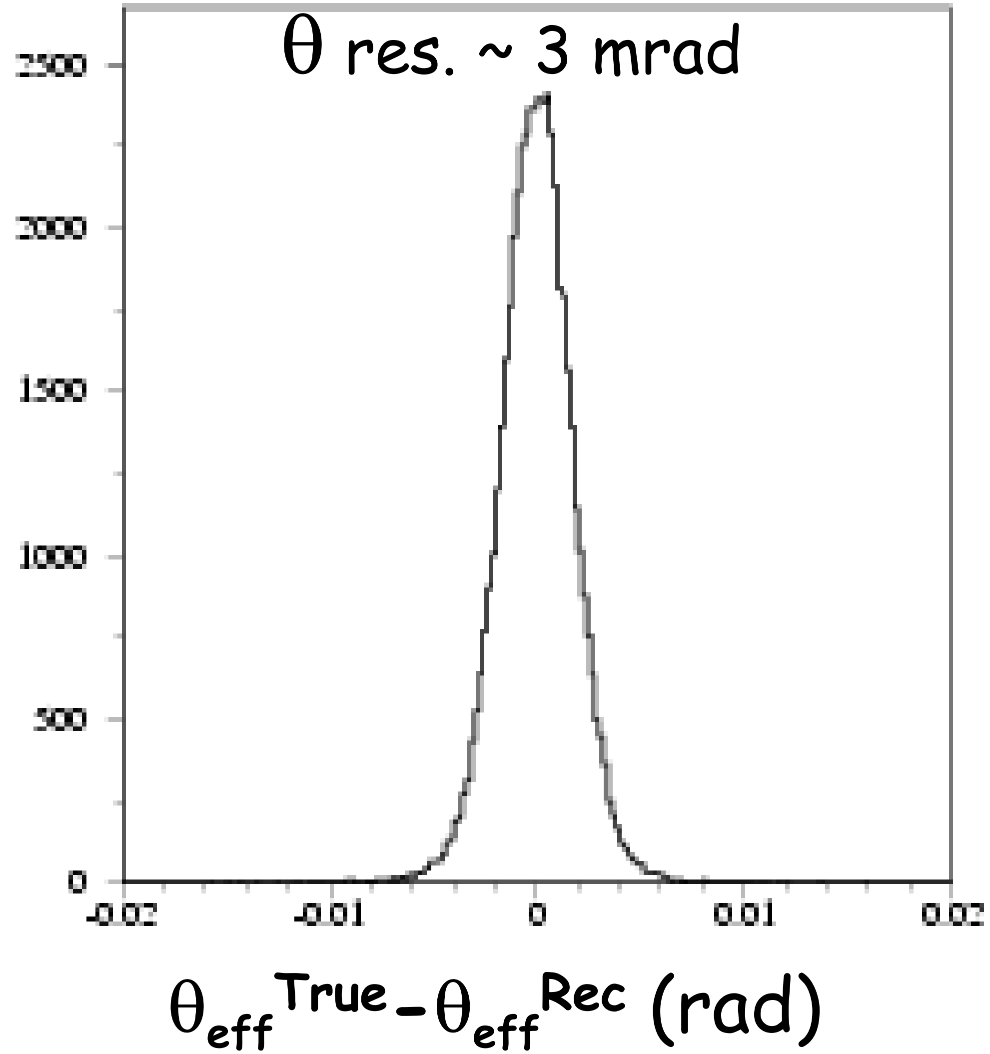



# Monte Carlo



# Monte Carlo


Signal:
(W'/W)TRUE > 0.95
Efficiency ~ 98%
Background:
(W'/W)TRUE < 0.95
Contam. ~ 2 %
10^5
10^4
10^3
10^2
10
1
0.5
0.6
0.7
0.8
0.9
1
(W'/W)REC


θ res. ~ 3 mrad
2500
2000
1500
1000
500
0
-0.02
-0.01
0
0.01
0.02
θeff True - θeff Rec (rad)

# Systematics

Uncorr. syst. dominated by acceptance cuts

efficiency ,bkg uncertainties

method: cuts variation

| $\delta A_{FB}$ | 1017.17 MeV | 1019.72 MeV | 1022.17 MeV |
|---|---|---|---|
| $(W'/W)_{rec}$ cut (0.90 − 0.98) | 0.00008 | 0.00003 | 0.00011 |
| $\theta_{\rm eff}$ cut (50° − 70°) | 0.00010 | 0.00010 | 0.00010 |
| Total | 0.00013 | 0.00010 | 0.00015 |

Table 2: Summary of uncorrelated systematic uncertainties on $A_{FB}$

The correl. syst. amount to about ~ 0.2% ($\theta_{eff}$ res., FSR)

# Experimental data

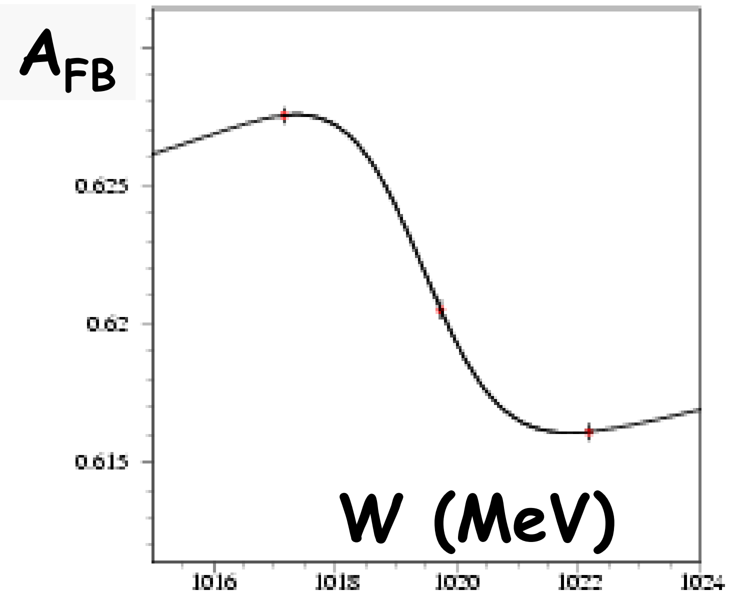
| W, MeV | Forw-Back Asymmetry $A_{FB}$ |
|---|---|
| 1017.17 | $0.6275 \pm 0.0003_{stat} \pm 0.0001_{un.syst}$ |
| 1019.72 | $0.6205 \pm 0.0003_{stat} \pm 0.0001_{un.syst}$ |
| 1022.17 | $0.6161 \pm 0.0003_{stat} \pm 0.0002_{un.syst}$ |

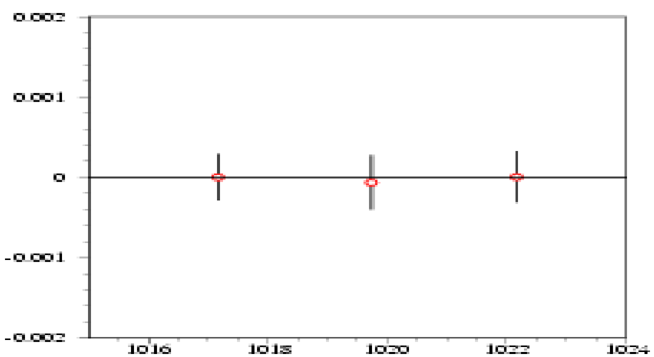
The correl. syst. amount to about ~ 0.2% ($\theta_{eff}$ res., FSR)

# Fit function to data

- We use a B.W. cross section, corrected for ISR, FSR and BES.
- The fit parameters are : $\Gamma_{LL}$, $M_{\Phi}$ and $A_{FB}(M_{\Phi})$

## Fit result




$\Gamma_{ee}$= 1.32 ± 0.05 keV

$M_\Phi$= 1019.50 ±0.08 MeV

## Systematics

- W'/W cut ~ $1.9\cdot10^{-2}$ keV
- $\theta_{eff}$ cut ~ $2.0\cdot10^{-2}$ keV
- $\delta\Gamma_\Phi$ ~ $1.3\cdot10^{-2}$ keV
- $\omega$ exchange ~ $10^{-3}$ keV
- $\pi$ and $\mu$ cont. ~ 0

Tot → 0.03 keV

result : 1.32 ± 0.05 ± 0.03

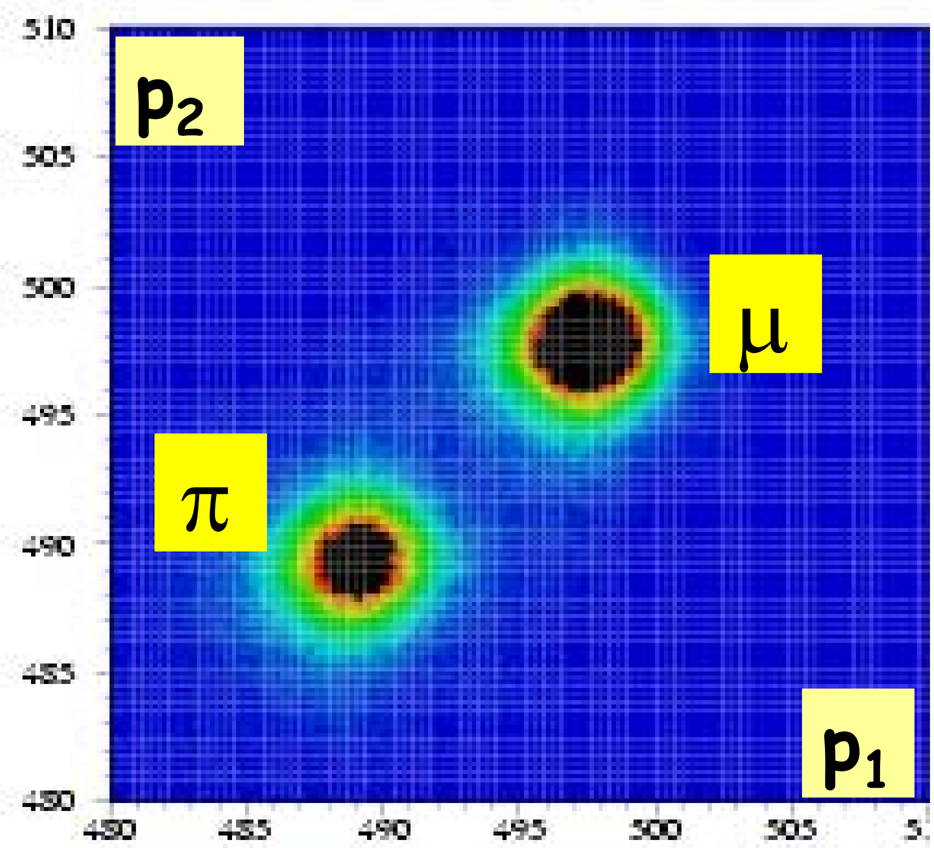
$A_{FB}(M_\Phi)$= 0.6212 ± 0.0002 ± 0.001

$A_{FB}(M_\Phi)_{th}$= 0.6214 ± 0.001(FSR)

# $\mu^+\mu^- \to \mu^+\mu^-$ analysys

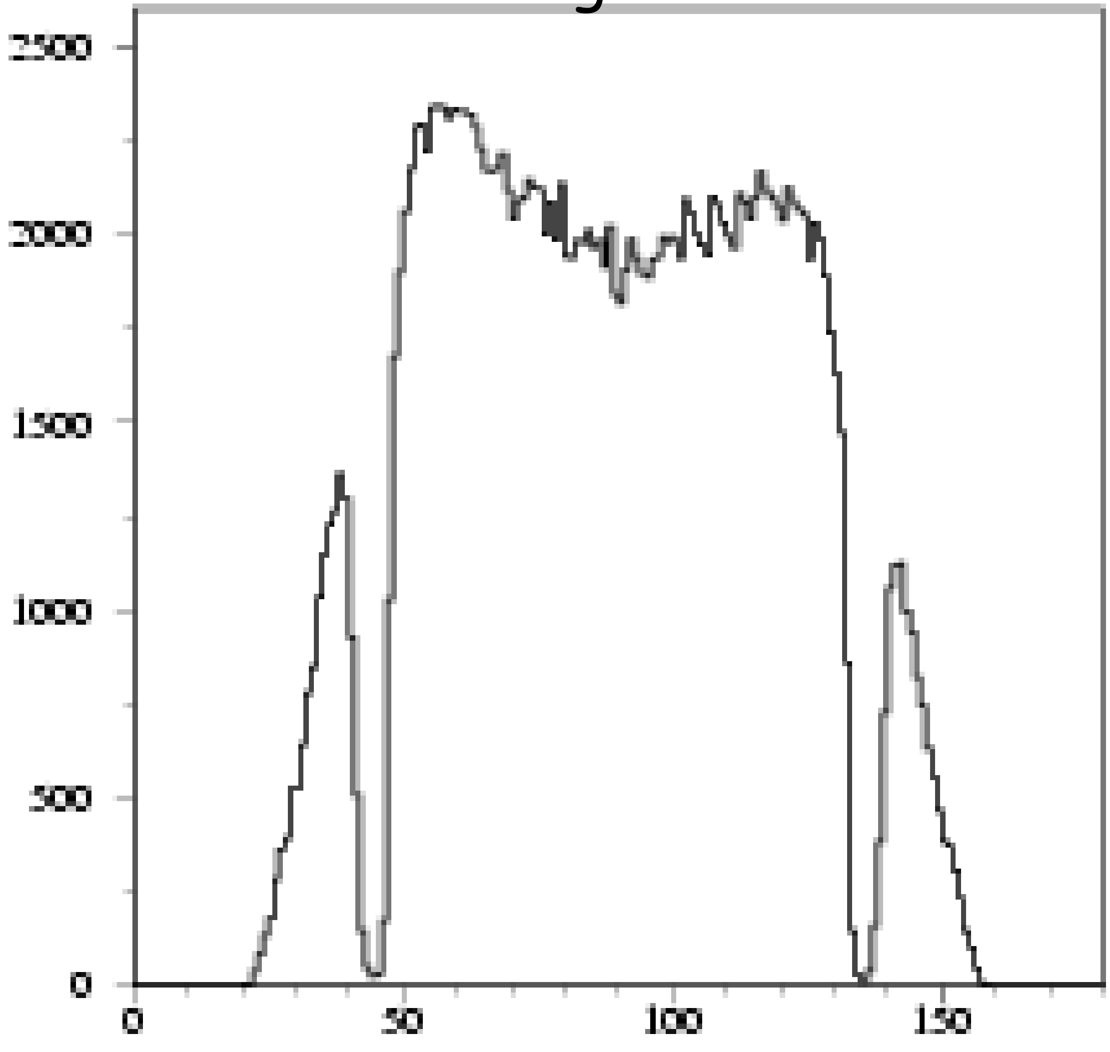
ACCEPTANCE

$(W'/W)_{REC} = .985$ $\quad$ $50 < \theta_{eff} < 130$



# Streaming data

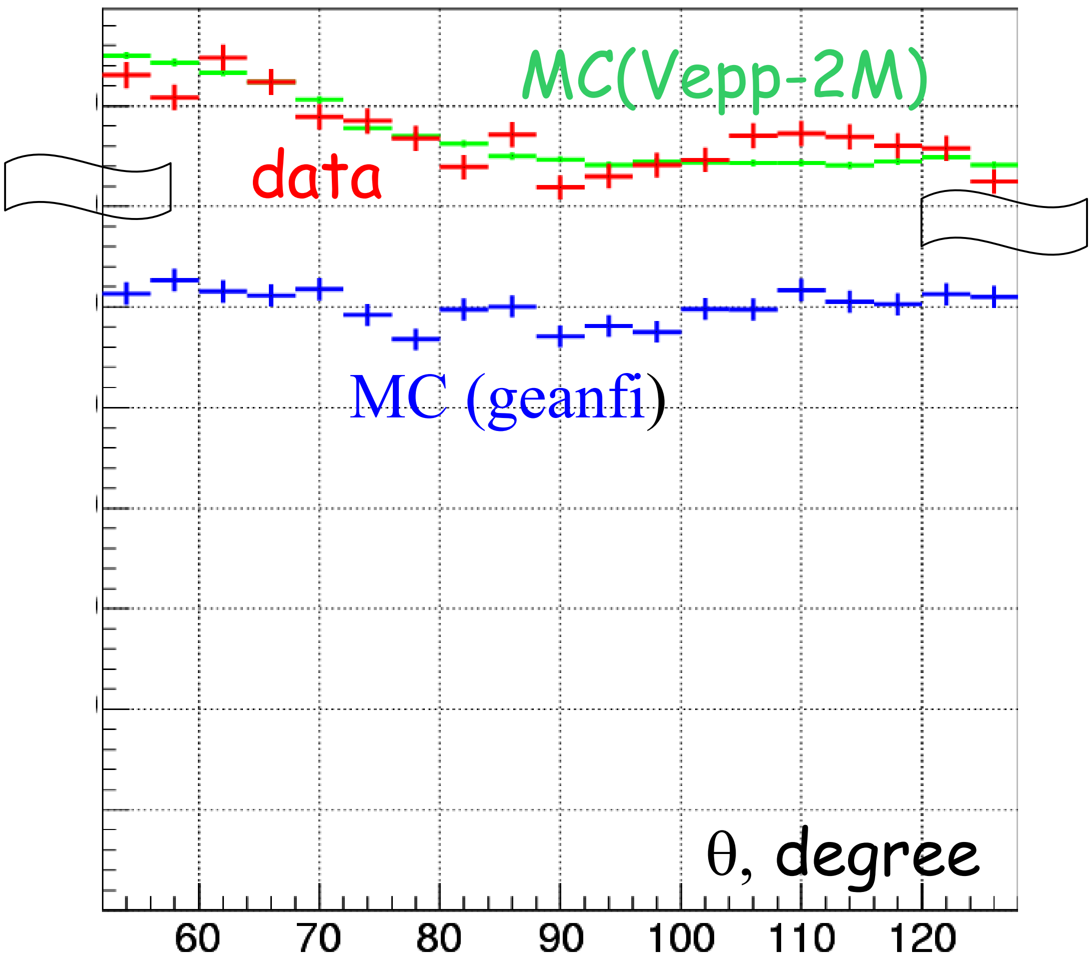
Data: muon angular distribution




θ, degree

# Monte Carlo

- We have tested a MC in which radiative corrections in the 1º order are taken into account exactly and leading logarithmic contributions are computed in all orders using the structure-function method (***A.B.Arbuzov** et al., hep-ph/9702262*)



# Monte Carlo

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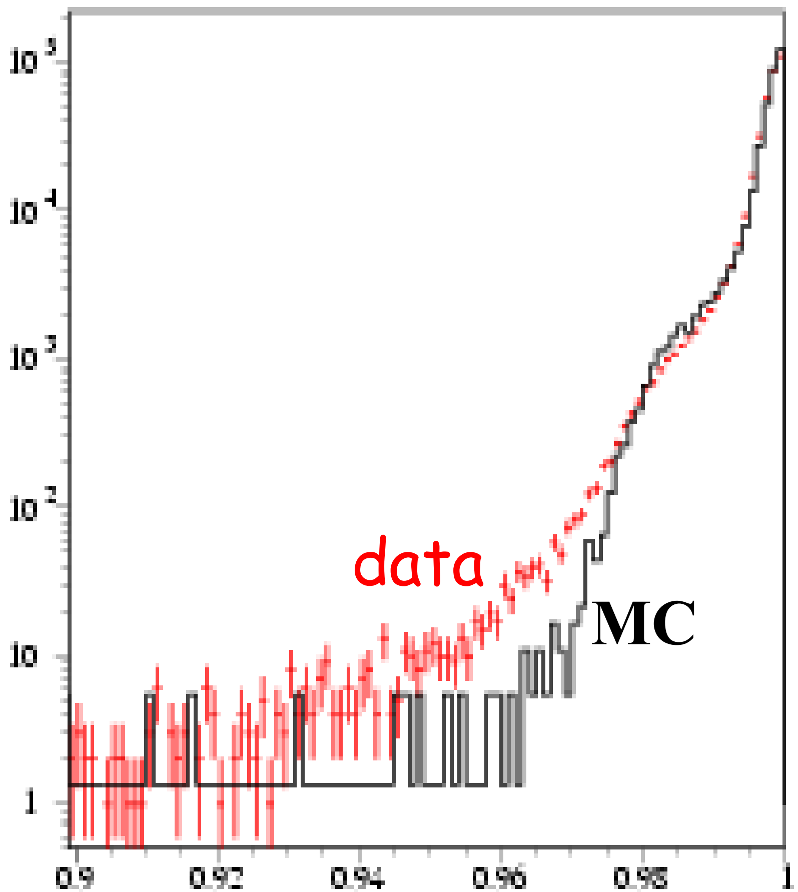
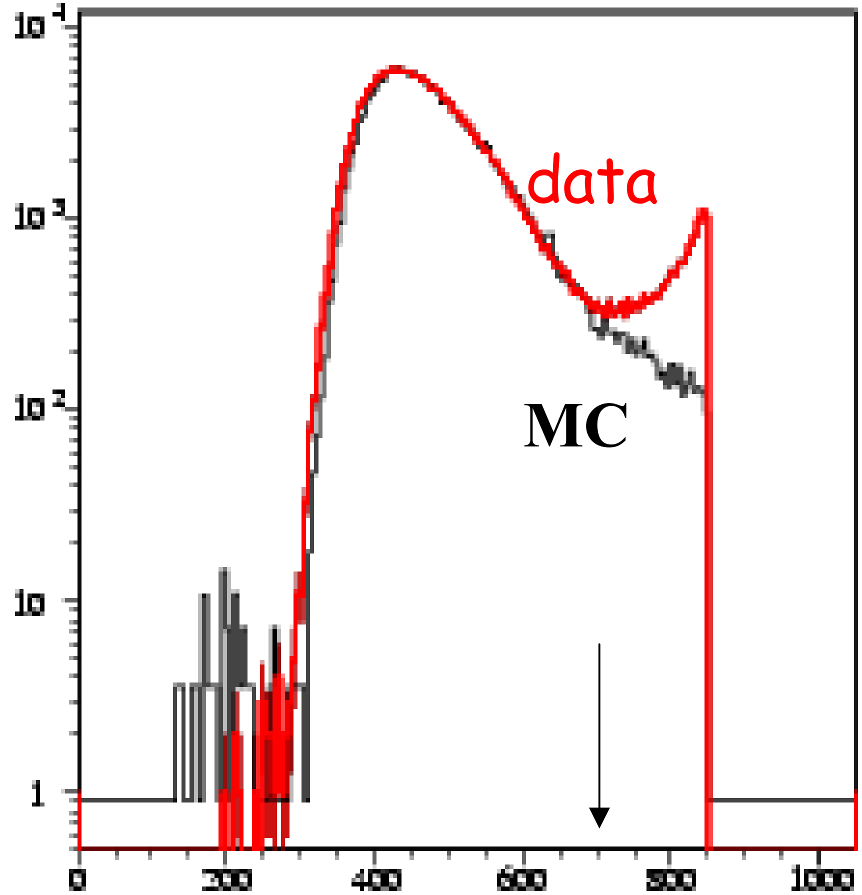


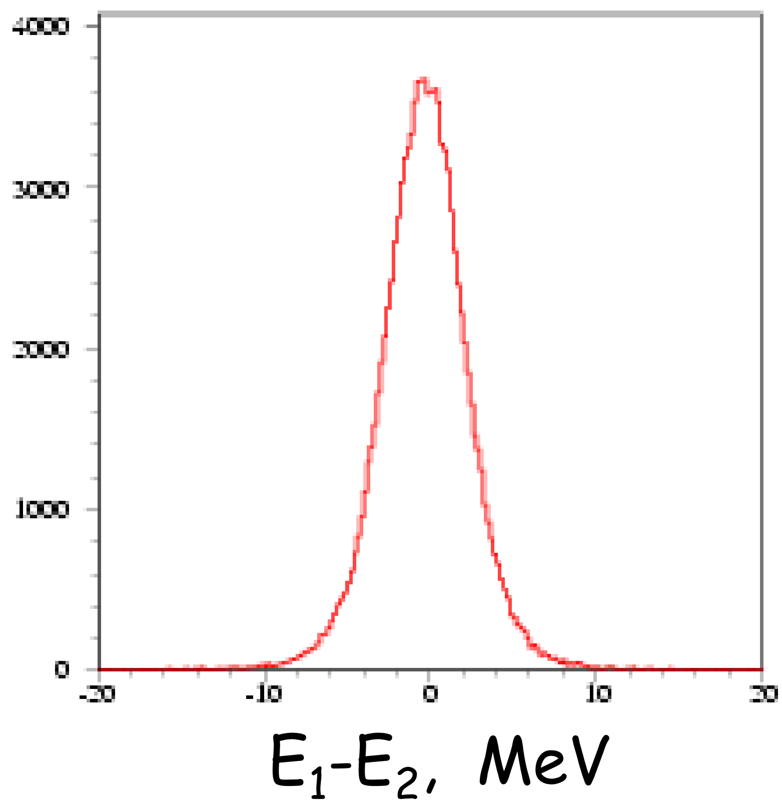

$(W'/W)_{REC}$

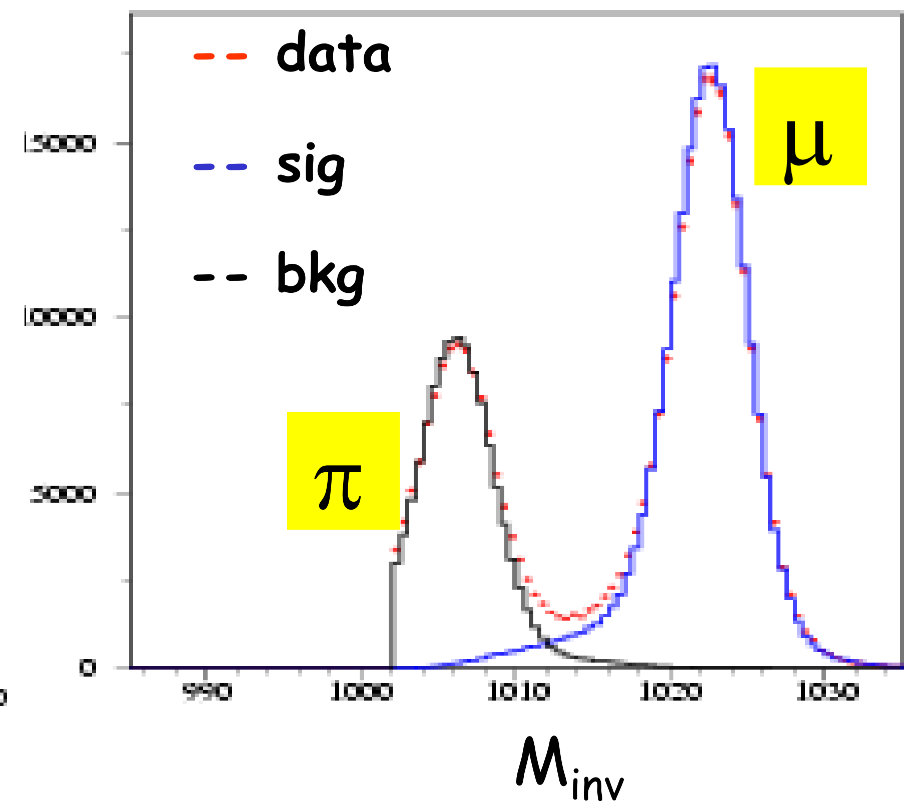



$E_{ECAL}$, MeV

# counting

- Muons and pions counting comes from a fit to the invariant mass distribution.
- To fit signal ($ee \to \mu\mu$) and background ($ee \to \pi\pi$) we use a MC with ISR and FSR generator convoluted with $M_{inv}$ resolution (from data) and BES.



# $\sigma_{\mu\mu}$ systematics

Uncorr. syst. dominated by acceptance cuts

efficiency ,bkg uncertainties

0.01 nb (W'/W), 0.002 nb($\theta$), 0.0045nb(counting)

* Fully energy-correlated → don't affect $\Gamma_{\mu\mu}$ measurement

| | |
|---|---|
| Trigger * | $3 \cdot 10^{-3}$ |
| Filfo * | $3 \cdot 10^{-3}$ |
| CLB stream * | $6 \cdot 10^{-3}$ |
| Tracking * | $5 \cdot 10^{-3}$ |
| $E_{ECAL}$ cut * | $5 \cdot 10^{-3}$ |
| Tot → | $10^{-2}$ |

Relative err.

# cross section

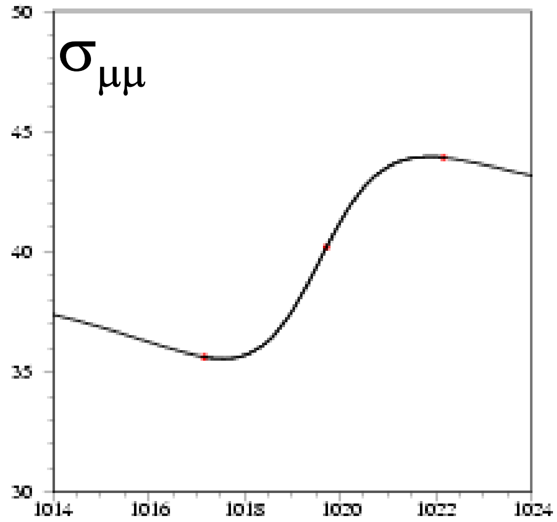
| W, MeV | $\sigma_{\mu\mu}$, nb |
|---|---|
| 1017.17 | $35.66 \pm 0.08_{stat} \pm 0.02_{syst}$ |
| 1019.72 | $40.19 \pm 0.14_{stat} \pm 0.02_{syst}$ |
| 1022.17 | $43.92 \pm 0.09_{stat} \pm 0.02_{syst}$ |

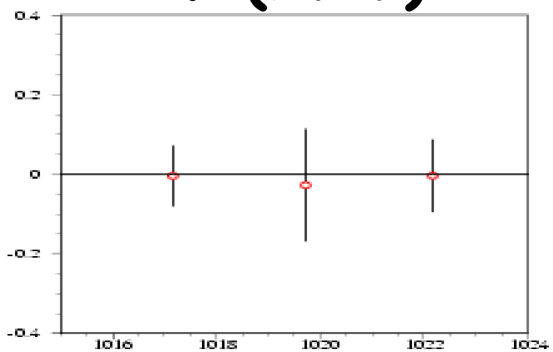
# Fit function to data

- We use a B.W. cross section, corrected for ISR, FSR and BES.

- The fit parameters are : $\Gamma_{\mu\mu}$, $M_{\Phi}$ and $\sigma^{\circ}$.

# Fit result




$\Gamma_{ee}$= 1.320 ± 0.018 keV

$M_{\Phi}$= 1019.63 ±0.04 MeV

# Systematics

| | |
|---|---|
| - W'/W cut | ~ $0.9 \cdot 10^{-2}$ keV |
| - $\theta_{eff}$ cut | ~ $0.2 \cdot 10^{-2}$ keV |
| - $\delta\Gamma_{\Phi}$ | ~ $1.0 \cdot 10^{-2}$ keV |
| - $\omega$ exhange | ~ $10^{-3}$ keV |
| - counting | ~ $0.4 \cdot 10^{-2}$ keV |
| Tot → | 0.017 |

Result: 1.320 ± 0.018 ± 0.017

$\sigma°(M_{\Phi})$=39.20 ± 0.04 ± 0.4

$\sigma°(M_{\Phi})_{th}$=39.2

# Conclusion

| bhabha | Muons |
|---|---|
| $\Gamma_{ee} = 1.32 \pm 0.05 \pm 0.03$ | $\sqrt{\Gamma_{ee}\Gamma_{\mu\mu}} = 1.320 \pm 0.018 \pm 0.017$ |

$$\Gamma_{LL} = \mathbf{1.320 \pm 0.017 \pm 0.015}$$

CMD-2 (1999) 1.32 ± 0.02 ± 0.04 (indirect)

More details on KLOE memo 289