

New study of $\phi \rightarrow \pi^+\pi^-\pi^0$ decay with CMD-2 detector

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Outline:

- Physics interests in $\phi \rightarrow 3\pi$ reaction
- Layout of experiment
- Selection of 3π events
- Measurement of cross section
- Dalitz analysis
- Summary

Physics interests in $\phi \rightarrow 3\pi$ reaction

$$M_\phi = 1019.456 \pm 0.020 \text{ MeV}, \Gamma_\phi = 4.26 \pm 0.05 \text{ MeV}$$

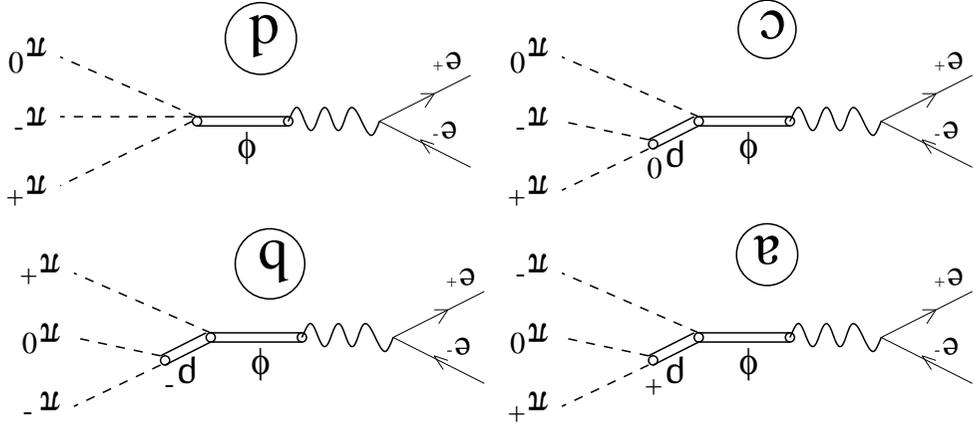
- $\phi \rightarrow K^+K^-, Br(K^+K^-) = 49.2 \pm 0.7\%$
- $\phi \rightarrow K_S K_L, Br(K_S K_L) = 33.7 \pm 0.5\%$
- $\phi \rightarrow \pi^+ \pi^- \pi_0, Br(\pi^+ \pi^- \pi_0) = 15.5 \pm 0.5\%$

We are interested in:

Cross section measurement of $e^+e^- \rightarrow \pi^+ \pi^- \pi_0$

Investigation of $\phi \rightarrow 3\pi$ dynamics

M.Gell-Mann, D.Sharp, W.G.Wagner, DECAY RATES OF NEUTRAL MESONS
 Phys.Rev.Lett,1962,v.8,p.261

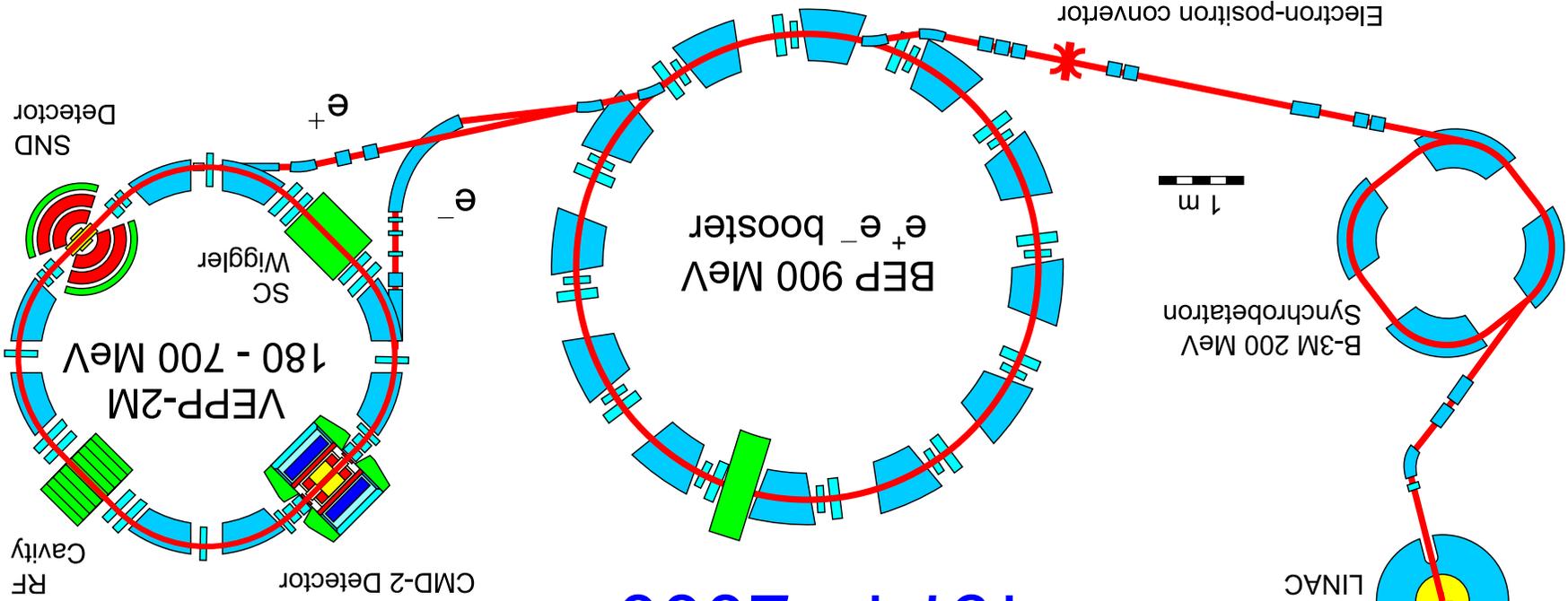


- G.Parrou, G.Cosme, A.Courau et al., Evidence for $\rho\pi$ dominance in $\Phi \rightarrow 3\pi$ decay., Phys.Lett., 1976, v.63B, p.362
- CMD-2 (1998)
- SND (2002)
- KLOE (2003)

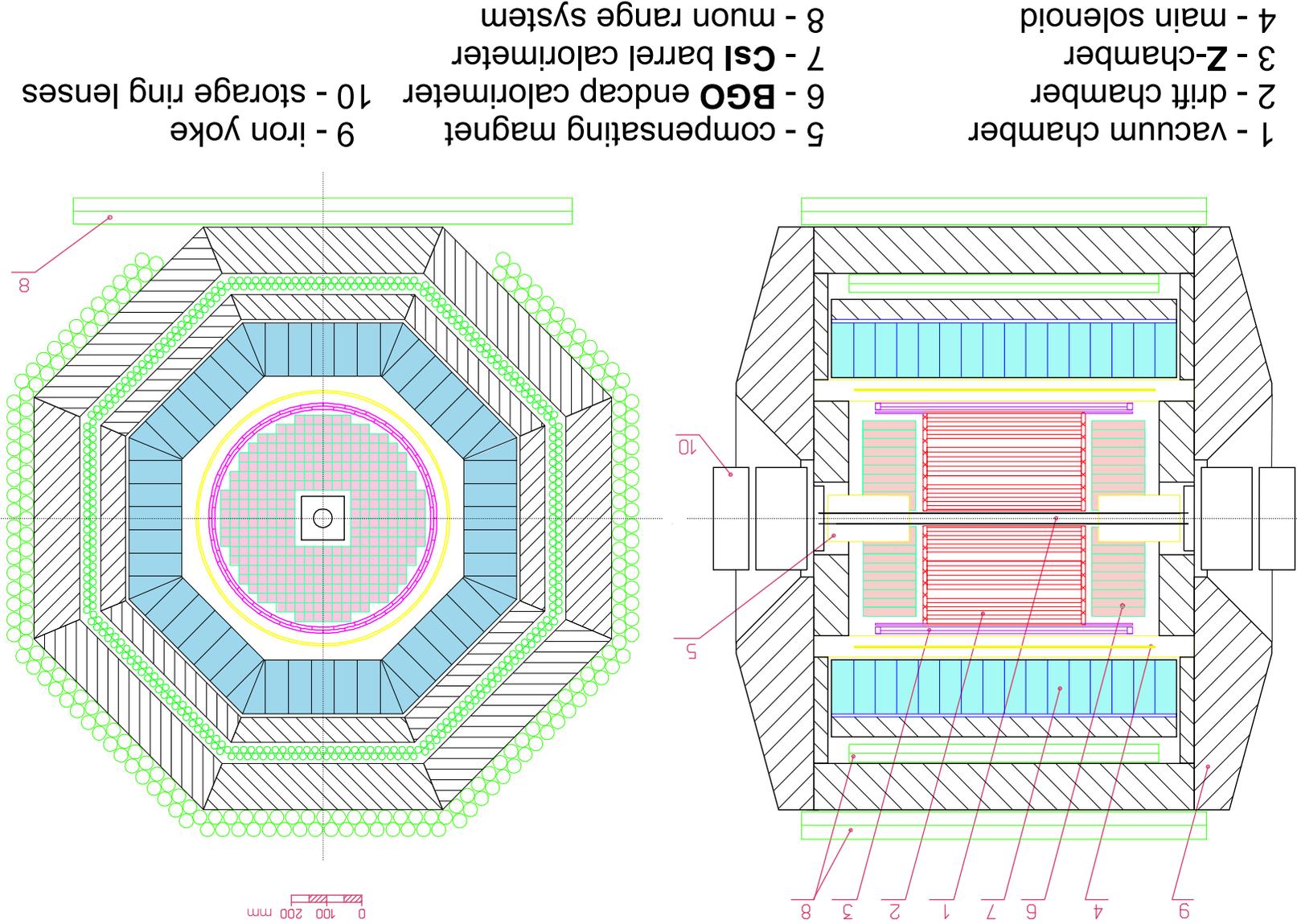
This work is based on the statistics of $L \approx 12 \text{ pb}^{-1}$ collected by CMD-2 at the period of 1997 ÷ 1998

Layout of experiment

1974 - 2000



- c.m. energy range: $360 < 2E_{\text{beam}} < 1400 \text{ MeV}$;
- peak luminosity: $L_{\text{peak}} = 3 \cdot 10^{30} \text{ cm}^{-2} \text{ s}^{-1}$;
- physics dates: 1974 - 2000.

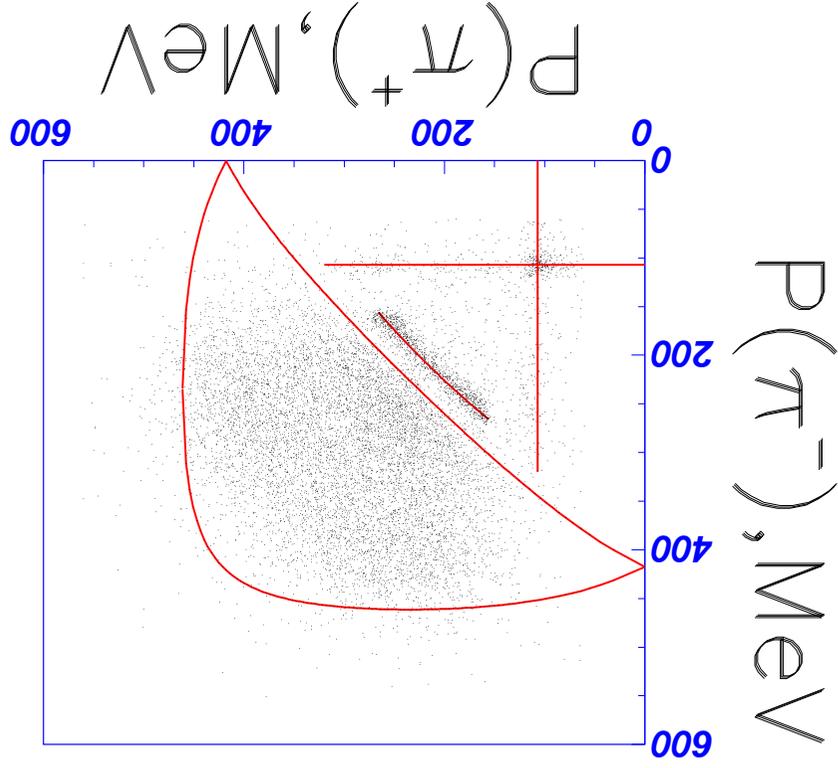


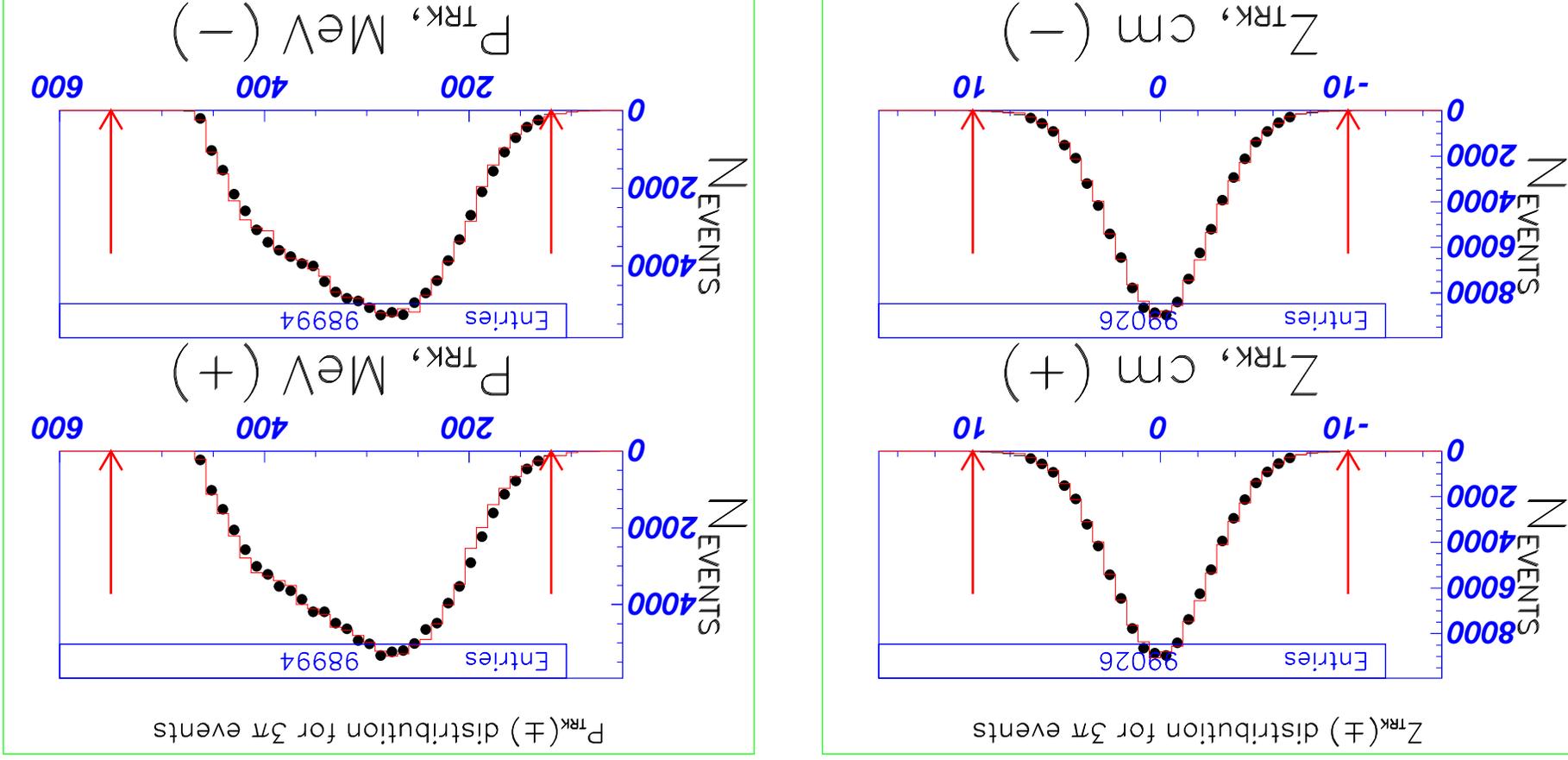
- 1 - vacuum chamber
- 2 - drift chamber
- 3 - Z-chamber
- 4 - main solenoid

- 5 - compensating magnet
- 6 - **BGO** endcap calorimeter
- 7 - **CsI** barrel calorimeter
- 8 - muon range system
- 9 - iron yoke
- 10 - storage ring lenses

Selection of 3π events

- $N^{GOOD} = 2$
- $|Z_{TRK}| \leq 10 \text{ cm}$
- $|R_{min}| \leq 0.2 \text{ cm}$
- $52^\circ < \theta_{TRK} < 128^\circ$
- $P_{TRK} \geq 120 \text{ MeV}/c$
- $dE/dx < 2 \cdot dE/dx(mip)$
- $|180^\circ - |\varphi_2 - \varphi_1|| > 6^\circ$
- $N^{\pi_0} = 1$
- $-E_\gamma > 30 \text{ MeV}$
- $-80 < M_{\gamma\gamma} < 170 \text{ MeV}/c^2$





Red arrows show our cuts

Measurement of Born cross section

≈ 120000 3π events were selected at 17 energy points

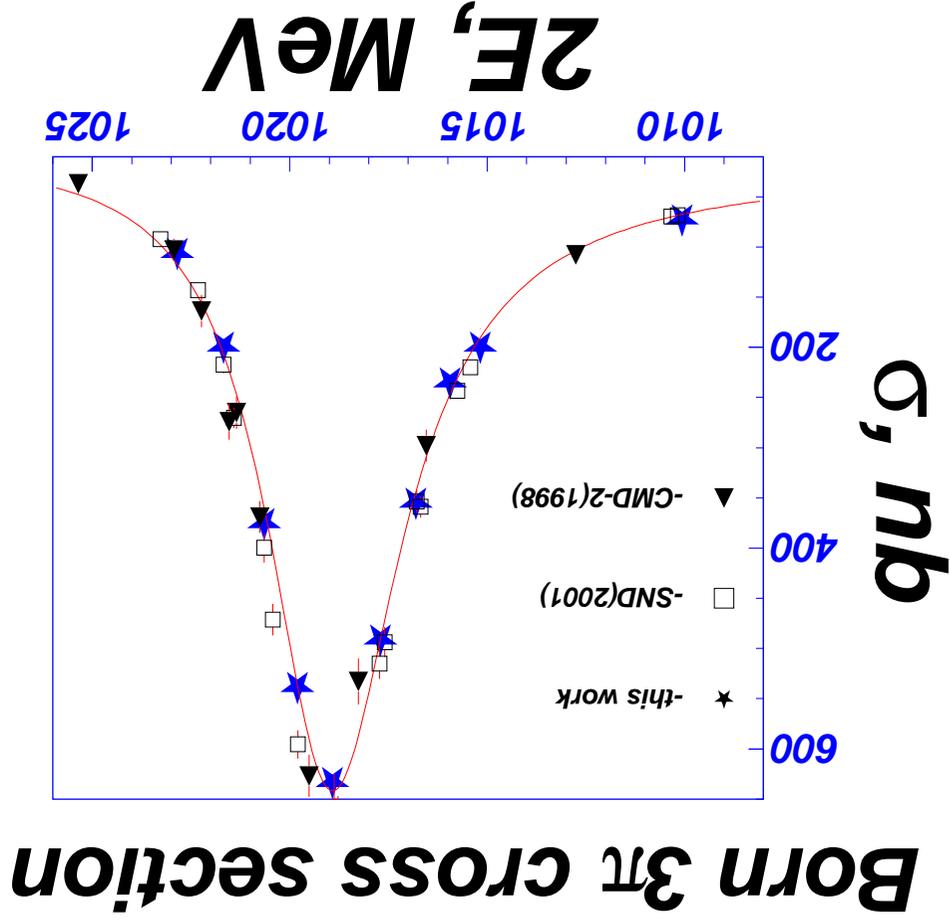
$$2E = 984 \div 1060 \text{ MeV}$$

$$\epsilon^{det} = 5.22 \pm 0.02\%$$

$$\sigma_B = \frac{L \cdot \epsilon^{det} \cdot \epsilon^{trig} \cdot (1 + \delta^{wtd}) \cdot (1 + \delta^{rad}) \cdot (1 - \delta^{MC})}{N^{sel} - N^{bg}}$$

$$\sigma_{vis} = \sigma_B (1 + \delta^{rad}) = \int_1^0 \int_1^0 D(x_1, s) D(x_2, s) \sigma_B(s) (1 - x_1) (1 - x_2) \epsilon(x_1, x_2) dx_1 dx_2$$

The $\delta^{MC} \approx 10\%$ correction takes into account the difference of experimental and simulated reconstruction efficiencies for π^+ , π^- and π^0 .



Data in 10 energy points were approximated

$$\sigma_{3\pi} = 624 \pm 33 \text{ nb}$$

$$\phi_{\phi-\omega} = 160 \pm 17^\circ$$

$$M_\phi = 1019.3 \pm 0.1 \text{ MeV}$$

$$\Gamma_\phi = 4.14 \pm 0.13 \text{ MeV}$$

$$\sigma_{bg} = 12 \pm 6 \text{ nb}$$

$$\chi^2/N = 8.6/5$$

Preliminary result

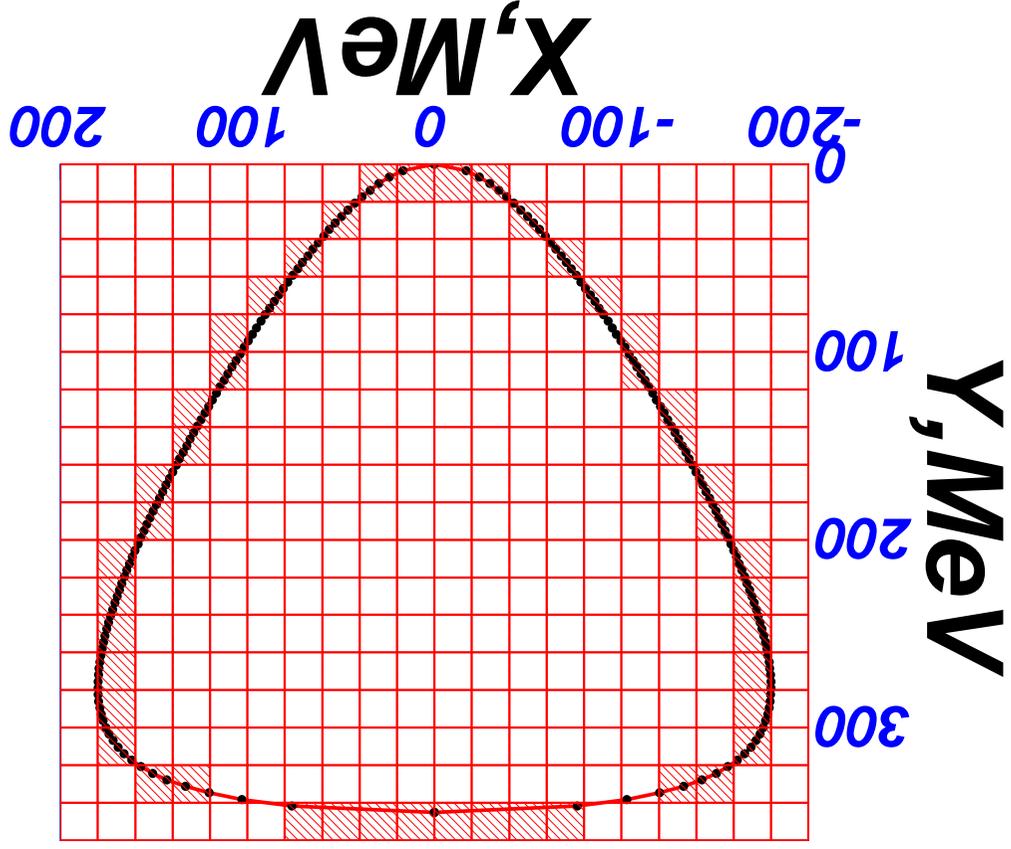
$$\sigma_{3\pi} = \frac{12\pi}{m_\phi^2} Br(\phi \rightarrow e^+ e^-) Br(\phi \rightarrow 3\pi)$$

Experiment	CMD-2 (preliminary) SND (2001) CMD-2 (1998)
$Br(\phi \rightarrow e^+ e^-) Br(\phi \rightarrow 3\pi)$ (units 10^{-5})	4.42 ± 0.23 $4.665 \pm 0.042 \pm 0.261$ $4.35 \pm 0.27 \pm 0.08$

Dalitz analysis

≈ 80000 experimental 3π events were selected for Dalitz analysis

Dalitz diagram



$$X = \frac{E_{\pi^-} - E_{\pi^+}}{\sqrt{3}}$$

$$Y = E_{\pi^0} - m_{\pi^0}$$

$$E_{\pi^0} = 2E - E_{\pi^-} - E_{\pi^+}$$

$$N_{BINS} = 198$$

$$(20 \times 20 \text{ MeV})$$

$$N_k^{th} = \frac{N_0}{N_0} \int^k dX dY |P_+^+ \times P_-^-|^2 |A_n a e^{i\varphi} + A_{\rho\pi}|^2$$

$$Z = \sum_{198}^{k=1} \int^k dX dY |P_+^+ \times P_-^-|^2 |A_n a e^{i\varphi} + A_{\rho\pi}|^2$$

$$\int^{Dalitz} dX dY |P_+^+ \times P_-^-|^2 |A_{\rho\pi}|^2 = |A_n|^2 \int^{Dalitz} dX dY |P_+^+ \times P_-^-|^2$$

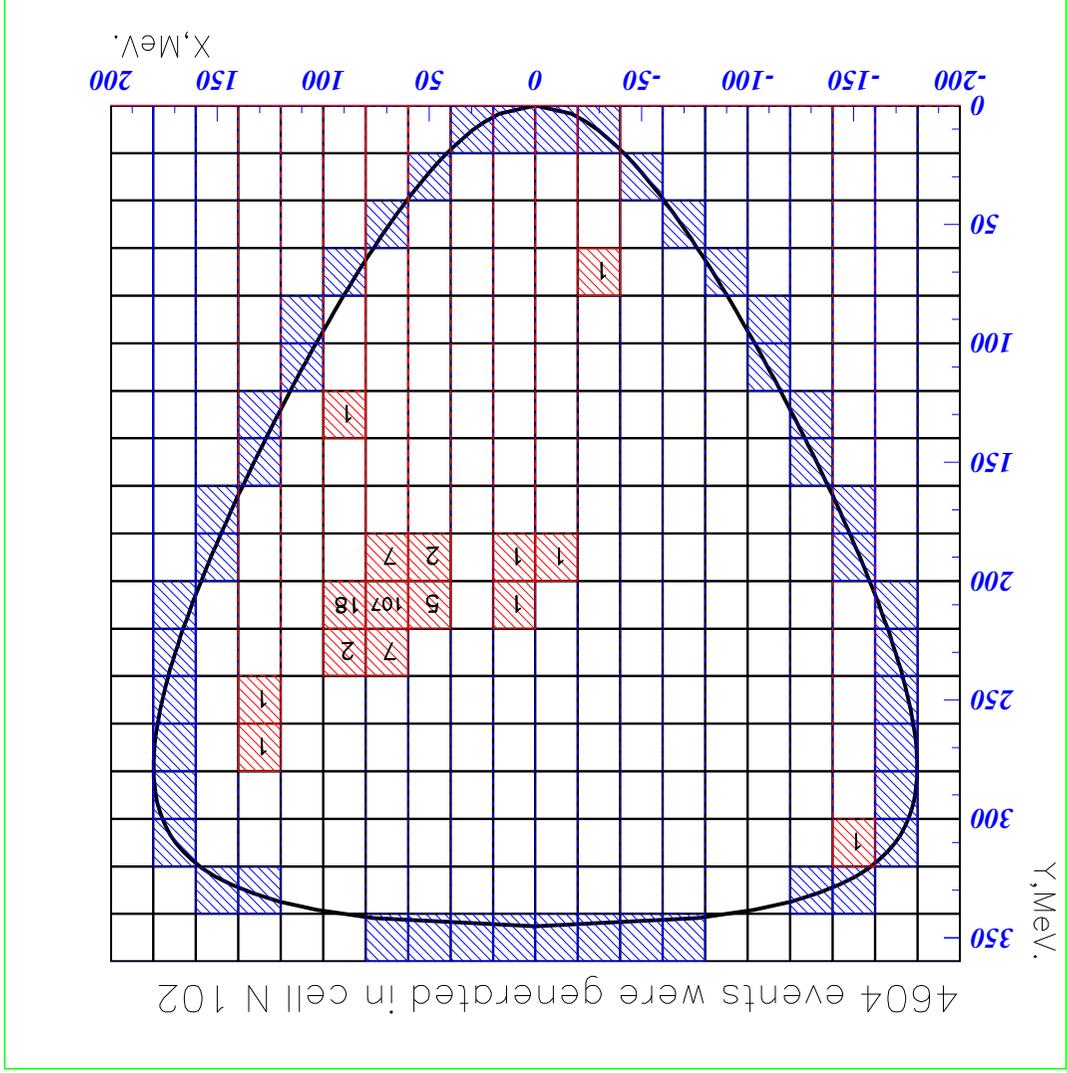
$A_{\rho\pi}$ — $\rho\pi$ contribution to amplitude

$A_n = 7.52$ — normalization coefficient

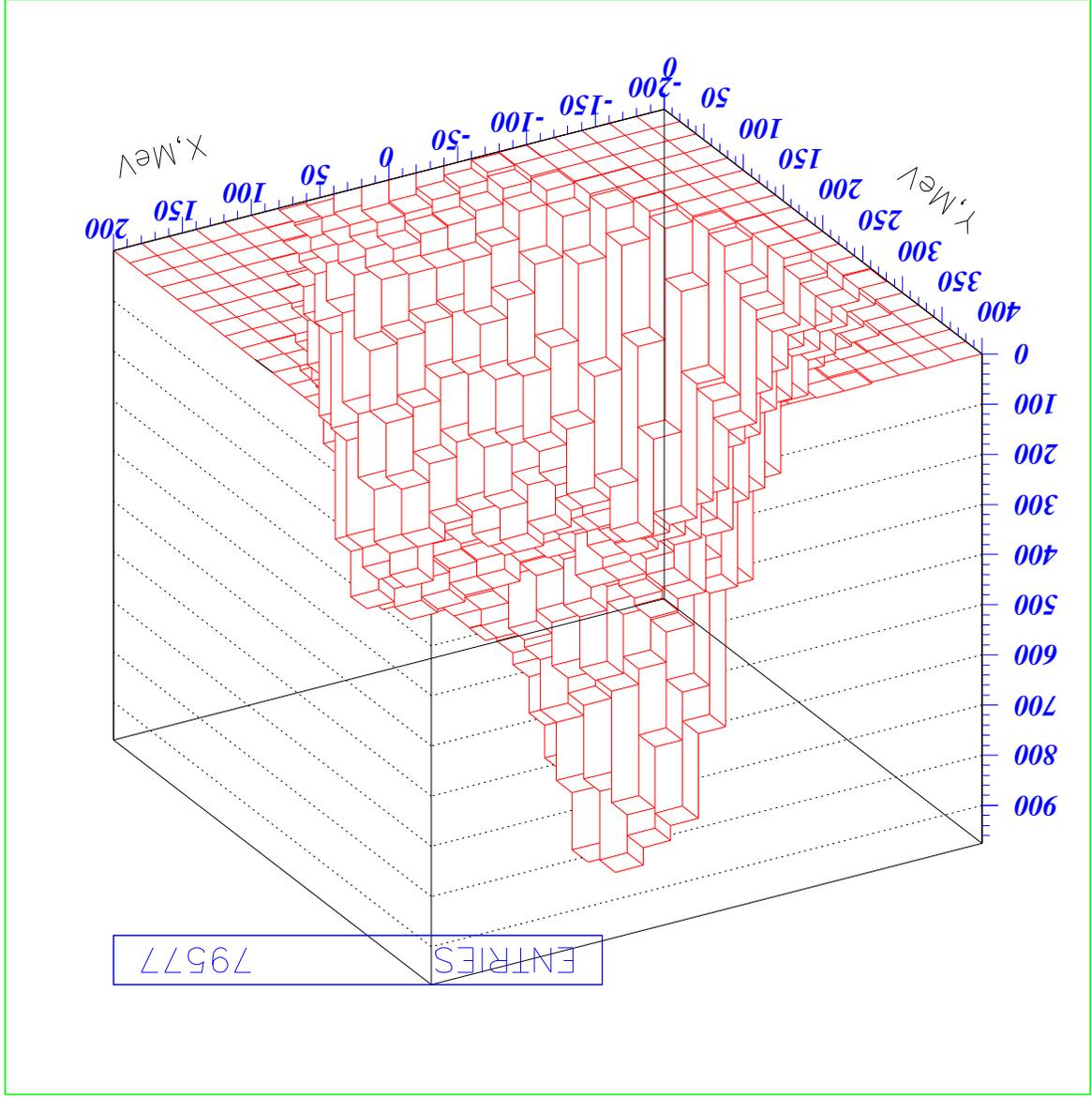
a, φ, N_0 — free parameters in approximation

$$N^{calc} = \epsilon_{ij} \epsilon_{jk} N_{theory}^{rad}$$

Efficiency matrix ϵ_{ij} (198 × 198)



Experimental Dalitz distribution



Optimized functional

$$\chi^2 = \sum_{i=1}^{198} \frac{(N_{exp}^i - \epsilon_{ij} \epsilon_{rad}^{jk} N_{theory}^k)^2}{N_{exp}^i + \sigma_{\epsilon_i}^2}$$

N_{exp}^i — experimental number in the i -th cell

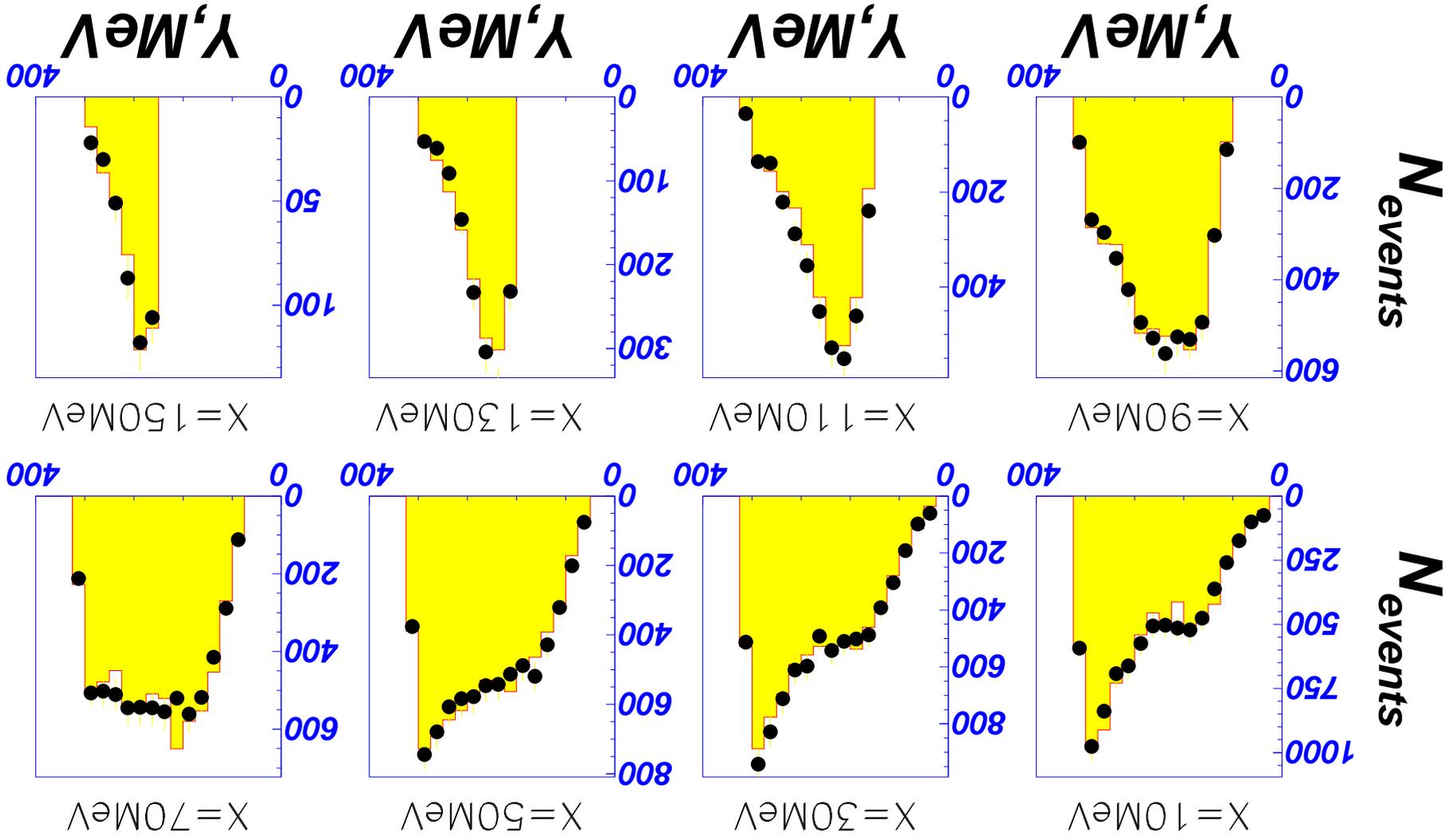
N_{theory}^k — theoretical number of 3π events in the k -th cell

ϵ_{ij} — efficiency matrix

$\sigma_{\epsilon_i}^2$ — error of corrected theoretical number in the i -th cell

ϵ_{rad}^{jk} — distortion matrix due to emission of radiation photon

Experimental distribution



Result of Dalitz analysis

CMD-2 (preliminary)	$a = 0.103 \pm 0.028$ $\phi = -2.0 \pm 0.3$ $P(\chi^2) = 81\%$
KLOE (2003)	$a = 0.104 \pm 0.01 \pm 0.02$ $\phi = 2.47 \pm 0.08 \pm 0.08$ $P(\chi^2) = 12\%$
SND (2002)	$-0.06 < a < 0.06$ $\phi = 0\text{-fixed}$ 90% CL
CMD-2 (1998)	$-0.15 < a < 0.10$ $\phi = 0\text{-fixed}$ 90% CL

Summary

- Born cross section of $e^+e^- \rightarrow \pi^+\pi^-\pi^0$ reaction was measured on the statistics of $\simeq 120000$ 3π events at energy range $2E = 984 \div 1060$ MeV
- The values of cross section are in good agreement with previous measurements (SND, CMD-2)

$$\sigma_{3\pi} = 624 \pm 33 \text{ nb}$$

(preliminary)

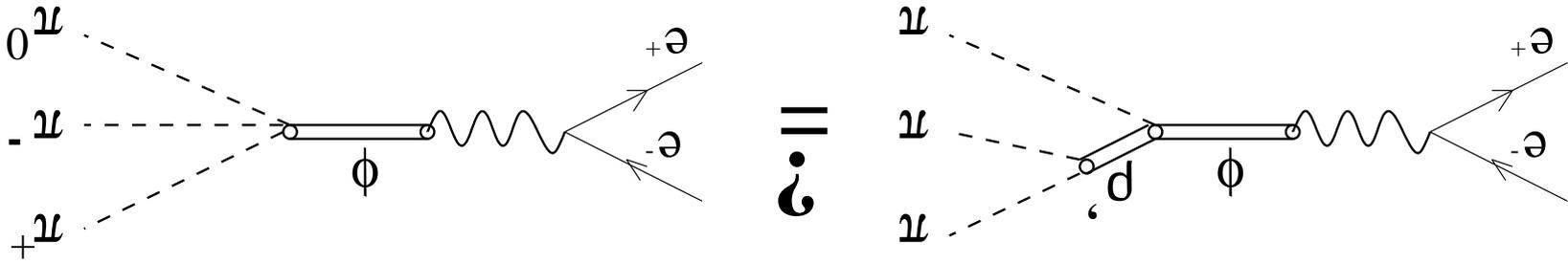
- Dalitz analysis was based on 80000 of experimental 3π events

$$a = 0.103 \pm 0.028$$

$$\phi = -2.0 \pm 0.3$$

(preliminary)

ρ' contribution



$$N_k^{th} = \frac{Z}{N_0} \int dX dY |P_+^+ \times P_-^-|^2 |A_{\rho,\pi} a e^{i\varphi} + A_{\rho\pi}|^2$$

a, φ, N_0 — fit parameters

$$a = \frac{g_{\phi p, \pi} \cdot g_{p, \pi \pi}}{g_{\phi p \pi} \cdot g_{p \pi \pi}}$$

$a = 0.21 \pm 0.06$	$a = -0.35 \pm 0.03$
$\phi = 1.1 \pm 0.3$	$\phi = 0$ -fixed
$P(\chi^2) = 79\%$	$P(\chi^2) = 23\%$

