DAΦNE-2004

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

Epifanov D A
(BINP,Novosibirsk)

Outline:

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

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

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

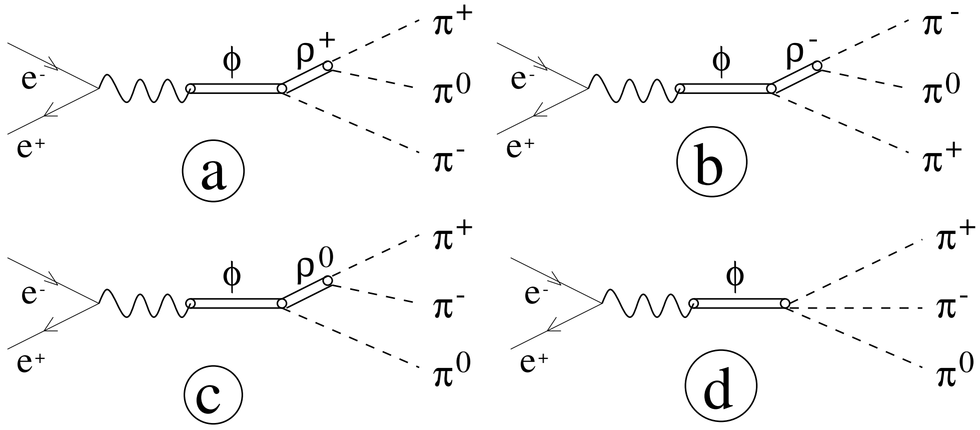
- $\phi \to K^+K^-$, $Br(K^+K^-) = 49.2 \pm 0.7\%$
- $\phi \to K_S K_L$, $Br(K_S K_L) = 33.7 \pm 0.5\%$
- $\phi \to \pi^+\pi^-\pi^0$, $Br(\pi^+\pi^-\pi^0) = 15.5 \pm 0.5\%$

We are interested in:

Cross section measurement of $e^+e^- \to \pi^+\pi^-\pi^0$

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

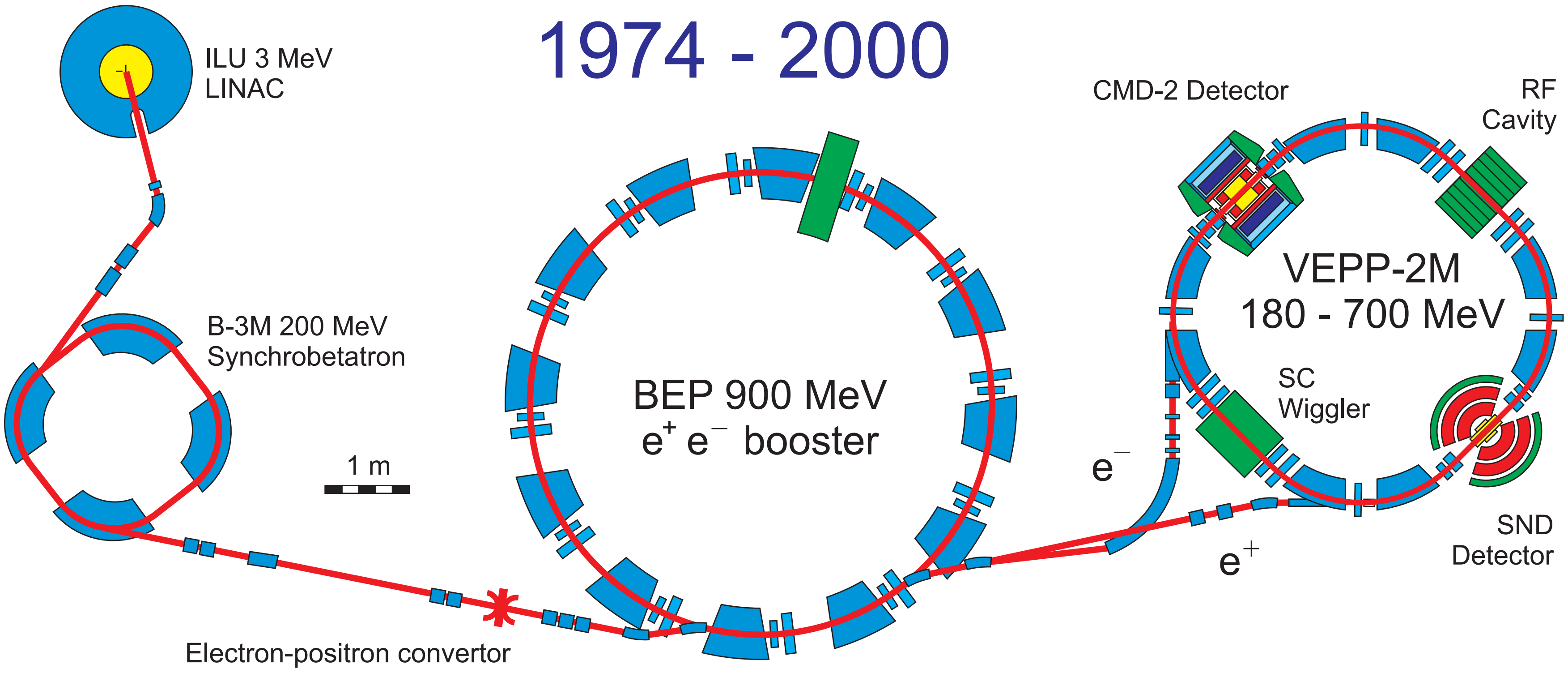
M.Gell-Mann, D.Sharp, W.G.Wagner, Decay rates of neutral mesons
Phys.Rev.Lett,1962,v.8,p.261



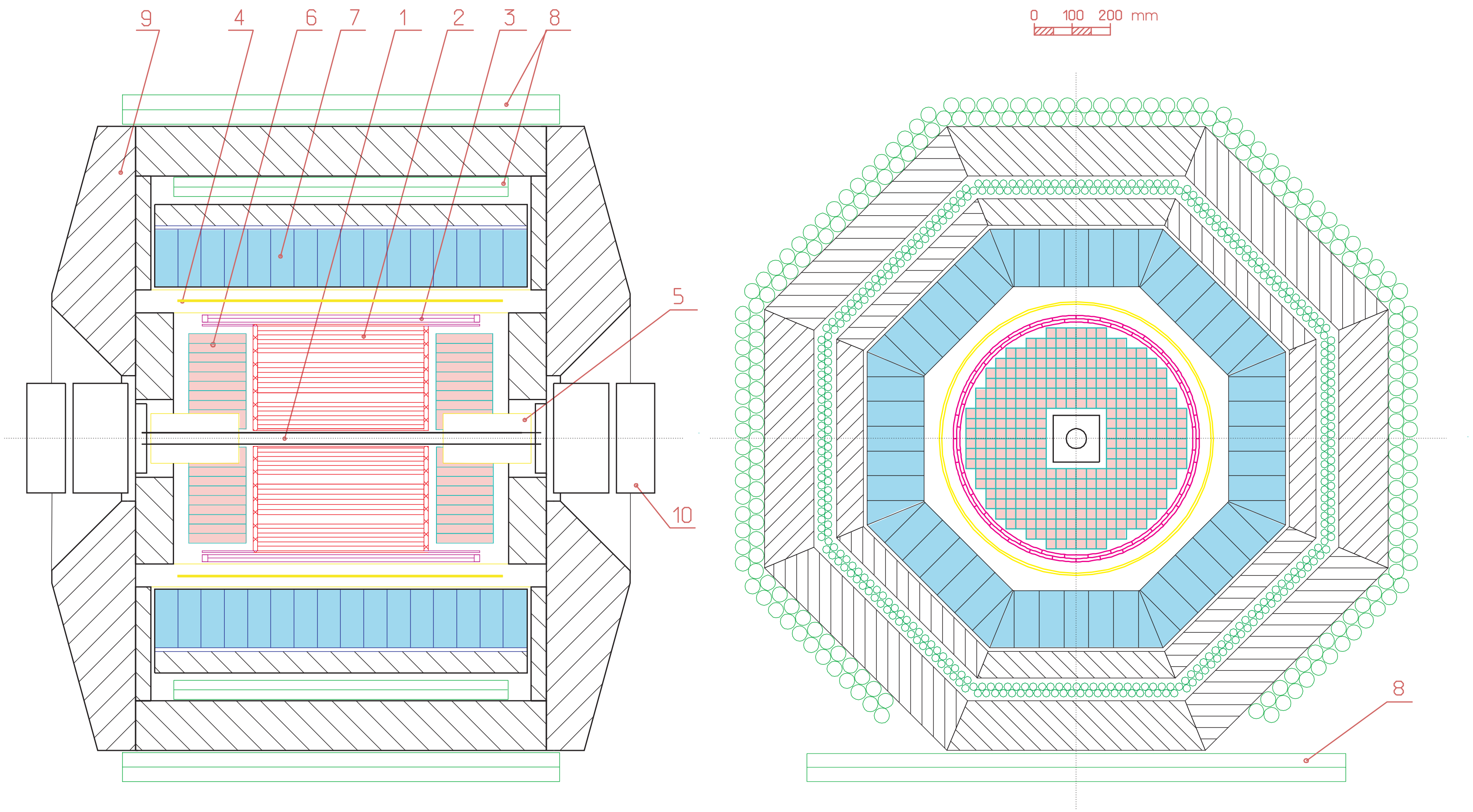
- G.Parrour, G.Cosme,A.Courau et al.,Evidence for $\rho\pi$ dominance in $\Phi \to 3\pi$ decay.,Phys.Lett.,1976,v.63B,p.362
- CMD-2 (1998)
- SND (2002)
- KLOE (2003)

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

Layout of experiment



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

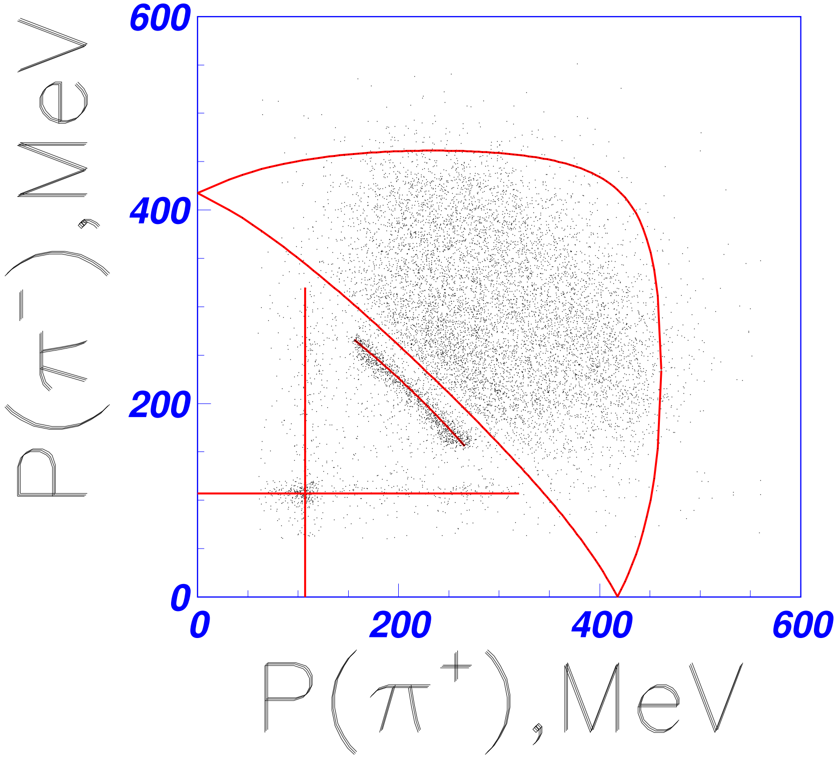


1 - vacuum chamber
2 - drift chamber
3 - **Z**-chamber
4 - main solenoid

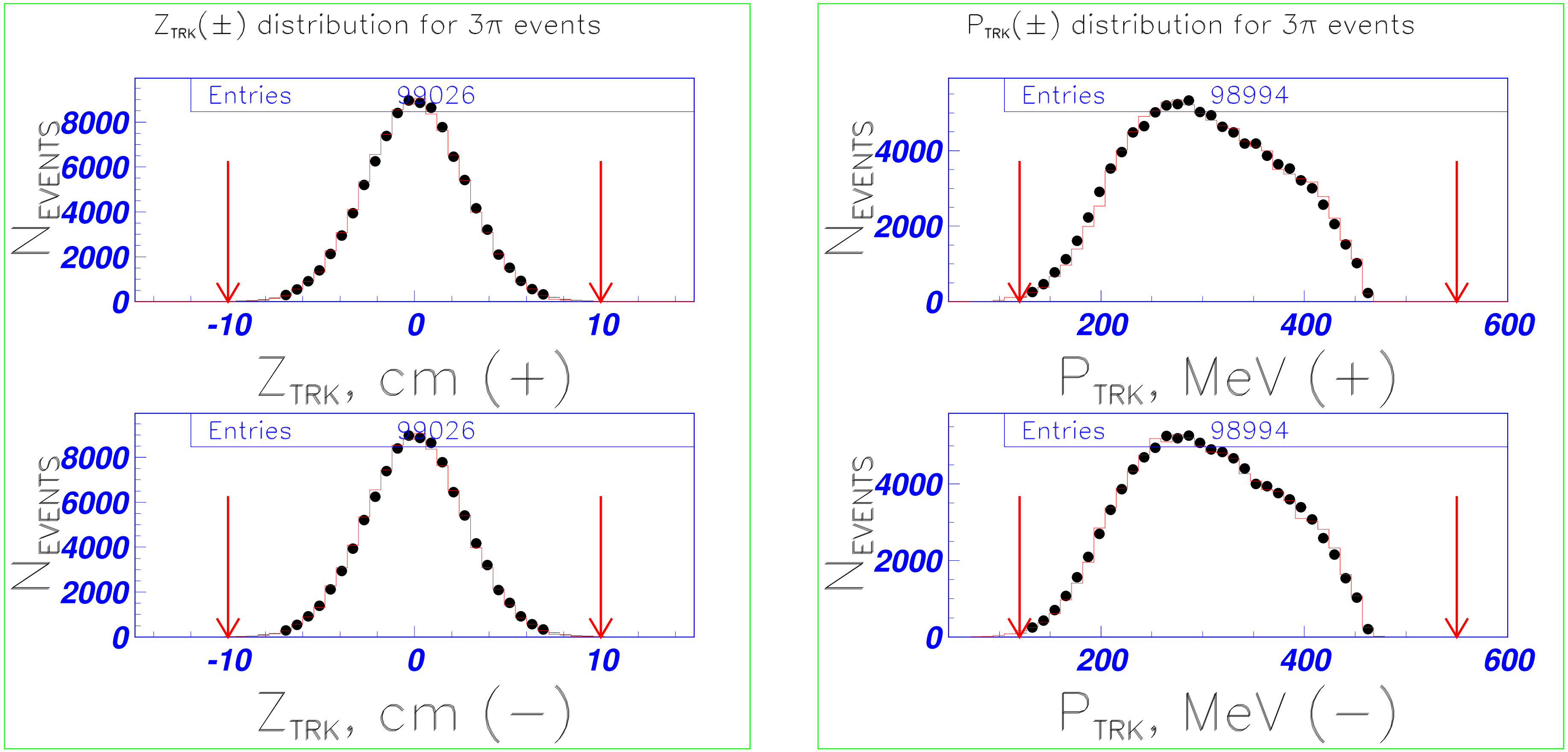
5 - compensating magnet
6 - **BGO** endcap calorimeter
7 - **CsI** barrel calorimeter
8 - muon range system

9 - iron yoke
10 - storage ring lenses

Selection of 3π events



- $N_{GOOD} = 2$
- $|Z_{TRK}| \leq 10\ cm$
- $|R_{min}| \leq 0.2\ cm$
- $52^o < \theta_{TRK} < 128^o$
- $P_{TRK} \geq 120\ MeV/c$
- $dE/dx < 2 \cdot dE/dx(mip)$
- $|180^o - |\varphi_2 - \varphi_1|| > 6^o$
- $N_{\pi^0} = 1$
  - $E_\gamma > 30\ MeV$
  - $80 < M_{\gamma\gamma} < 170\ MeV/c^2$



Red arrows show our cuts

Measurement of Born cross section

$\simeq 120000\ 3\pi$ events were selected at 17 energy points

$$2E = 984 \div 1060\ MeV$$

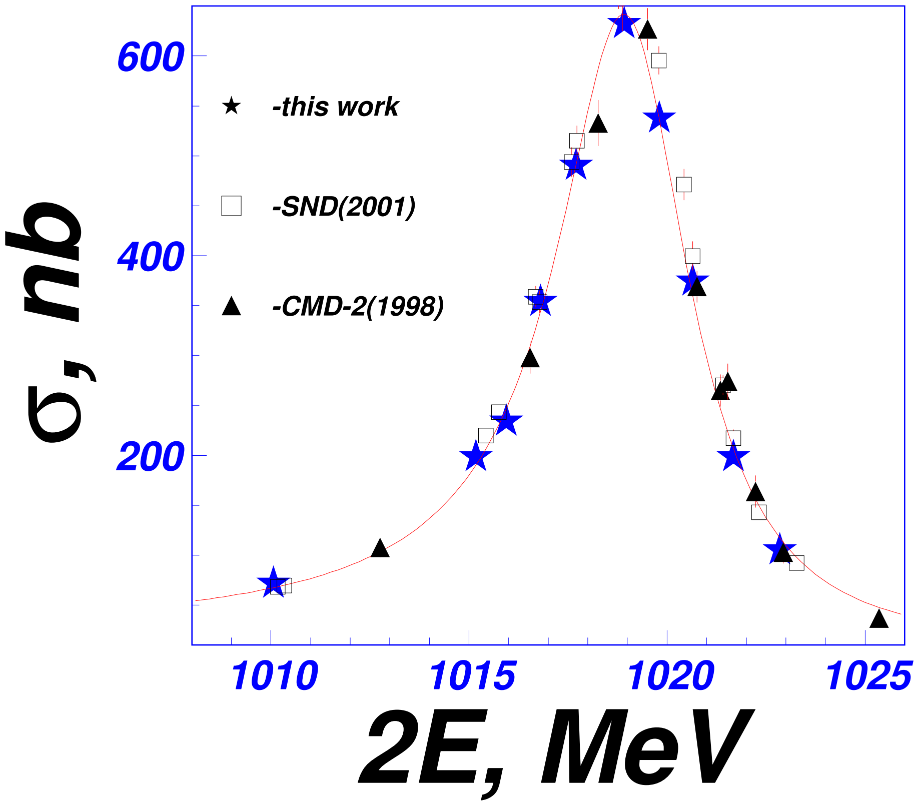
$$\varepsilon_{det} = 5.22 \pm 0.02\%$$

$$\sigma_B = \frac{N_{sel} - N_{bg}}{L \cdot \varepsilon_{det} \cdot \varepsilon_{trig} \cdot (1 + \delta_{wid}) \cdot (1 + \delta_{rad}) \cdot (1 - \delta_{MC})}$$

$$\sigma_{vis} = \sigma_B(1+\delta_{rad}) = \int_0^1 \int_0^1 D(x_1, s)D(x_2, s)\sigma_B(s(1-x_1)(1-x_2))\varepsilon(x_1, x_2)dx_1 dx_2$$

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

Born 3π cross section



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

$$\varphi_{\phi-\omega} = 160 \pm 17^o$$

$$M_\phi = 1019.3 \pm 0.1\ MeV$$

$$\Gamma_\phi = 4.14 \pm 0.13\ MeV$$

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

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

Data in 10 energy points were approximated

Preliminary result

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

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

Dalitz analysis

$\simeq 80000$ experimental 3π events were selected for Dalitz analysis

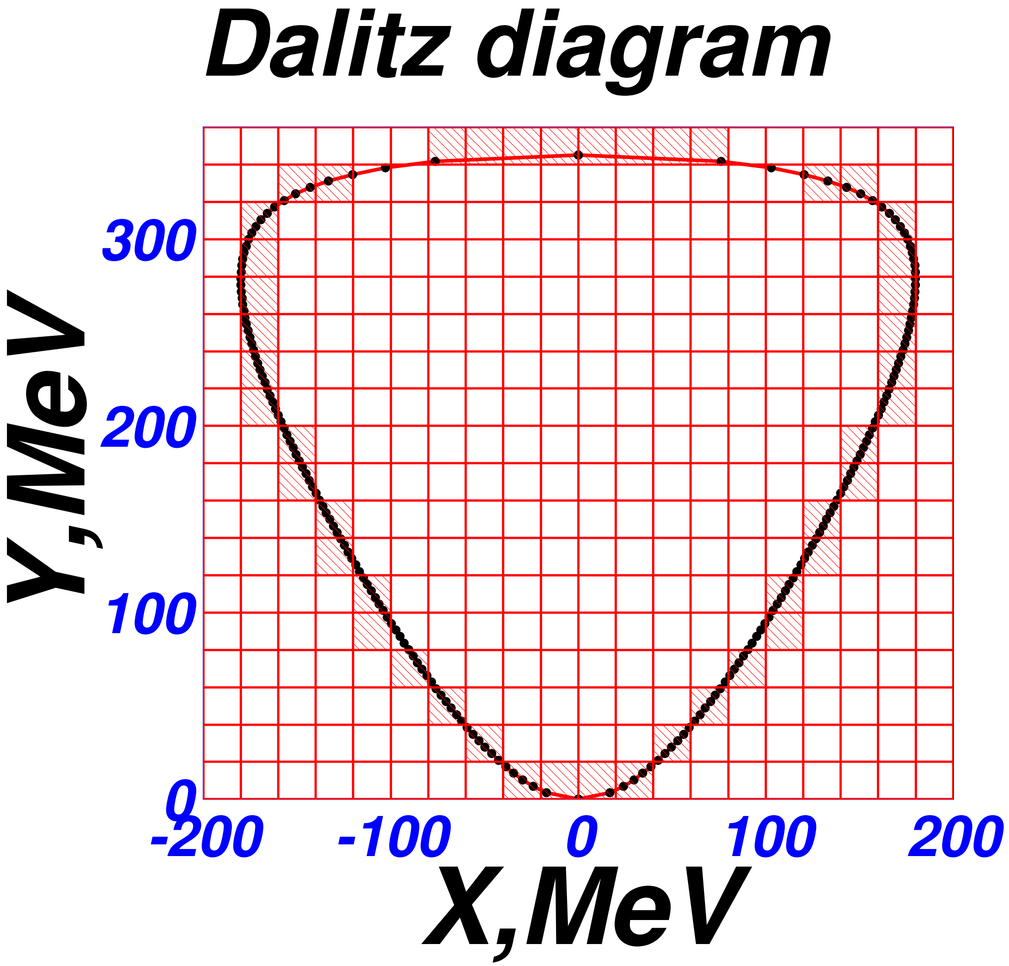
$$X = \frac{E_{\pi^-} - E_{\pi^+}}{\sqrt{3}}$$

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

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

$$N_{BINS} = 198$$

$$(20 \times 20\ MeV)$$



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

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

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

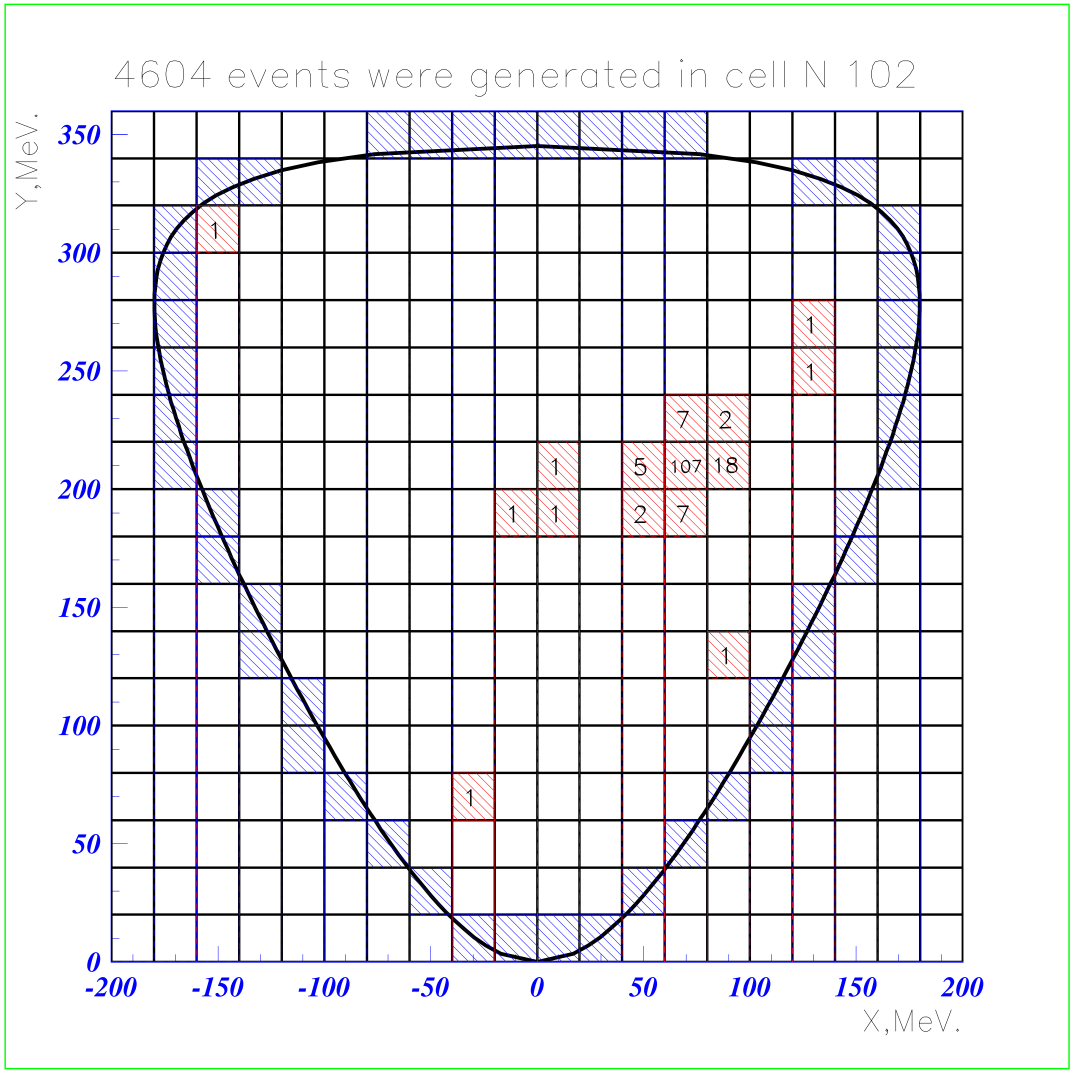
$A_{\rho\pi}$ — $\rho\pi$ contribution to amplitude

$A_n = 7.52$ — normalization coefficient

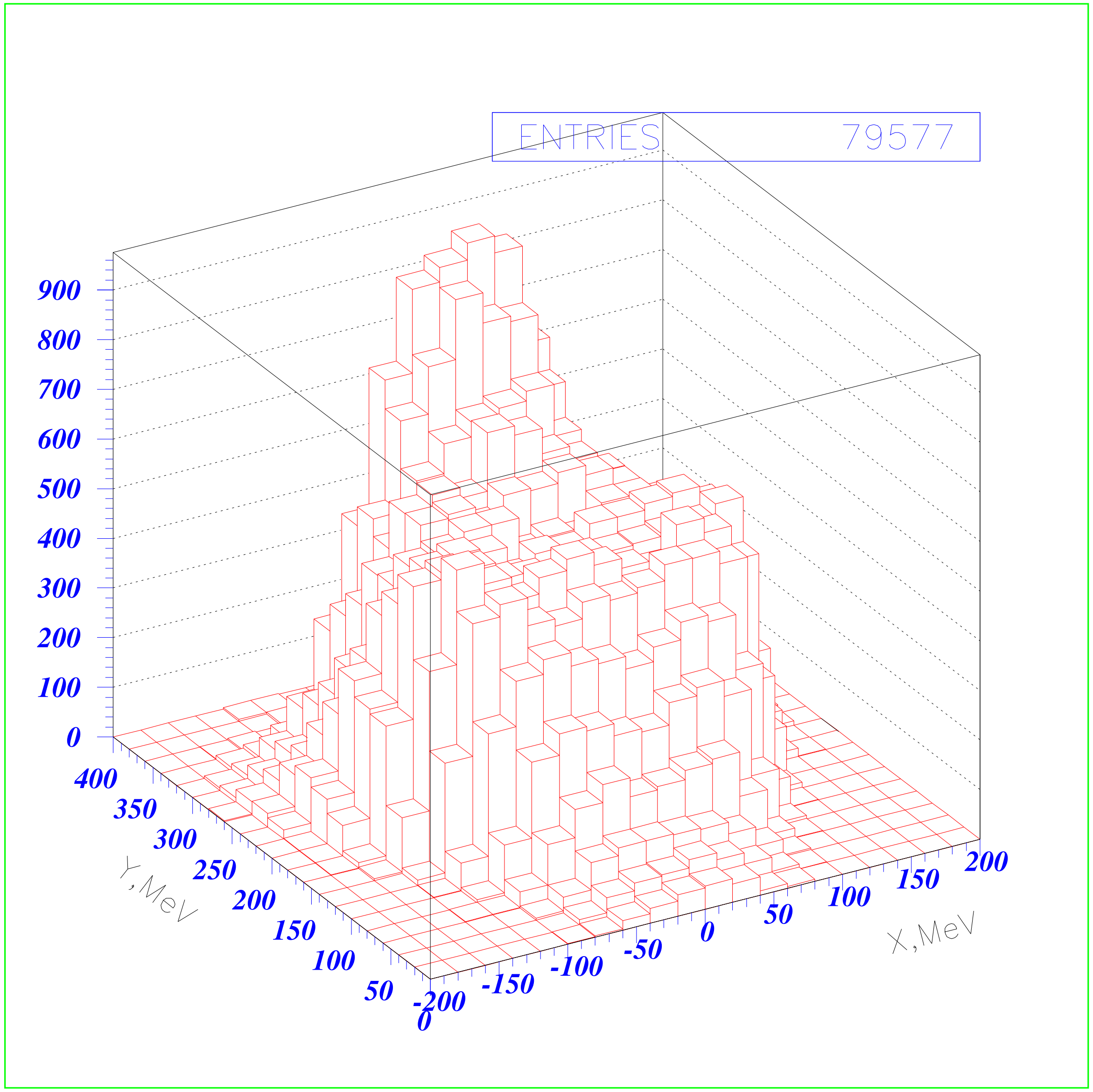
a, φ, N_0 — free parameters in approximation

$$N_{calc} = \varepsilon_{ij} \varepsilon_{jk}^{rad} N_k^{theory}$$

Efficiency matrix $\varepsilon_{ij}(198 \times 198)$



Experimental Dalitz distribution



Optimized functional

$$\chi^2 = \sum_{i=1}^{198} \frac{(N_i^{exp} - \varepsilon_{ij}\varepsilon_{jk}^{rad} N_k^{theory})^2}{N_i^{exp} + \sigma_{\varepsilon_i}^2}$$

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

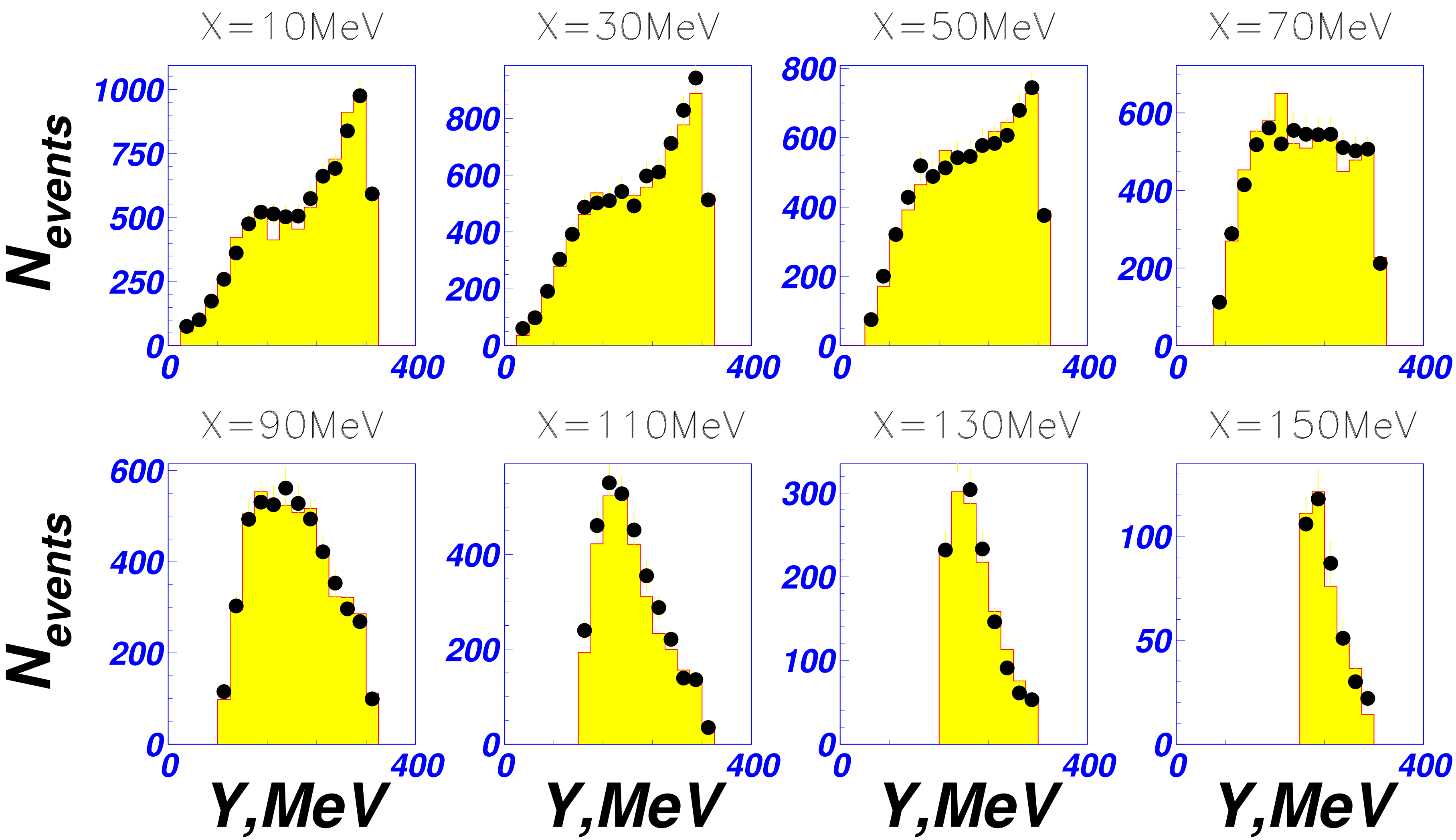
N_k^{theory} — theoretical number of 3π events in the k-th cell

ε_{ij} — efficiency matrix

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

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

Experimental distribution



Result of Dalitz analysis

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

Summary

- Born cross section of $e^+e^- \to \pi^+\pi^-\pi^0$ 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)

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

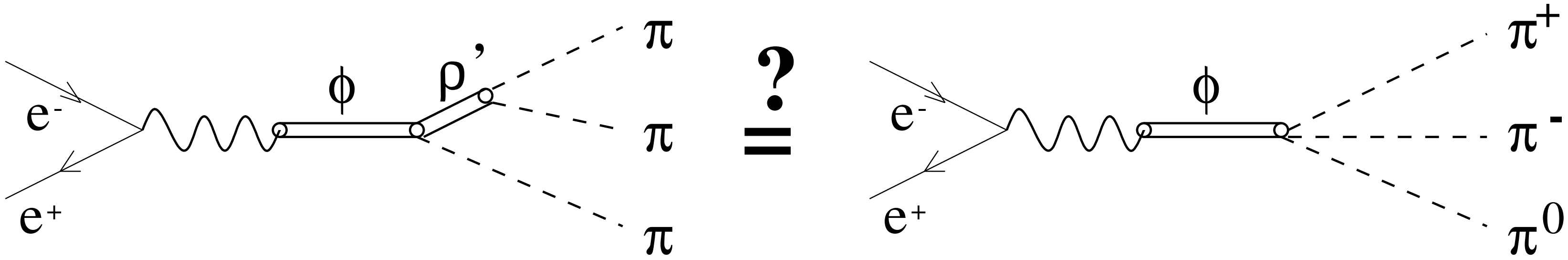
(preliminary)

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

$$a = 0.103 \pm 0.028$$
$$\varphi = -2.0 \pm 0.3$$

(preliminary)

ρ' contribution

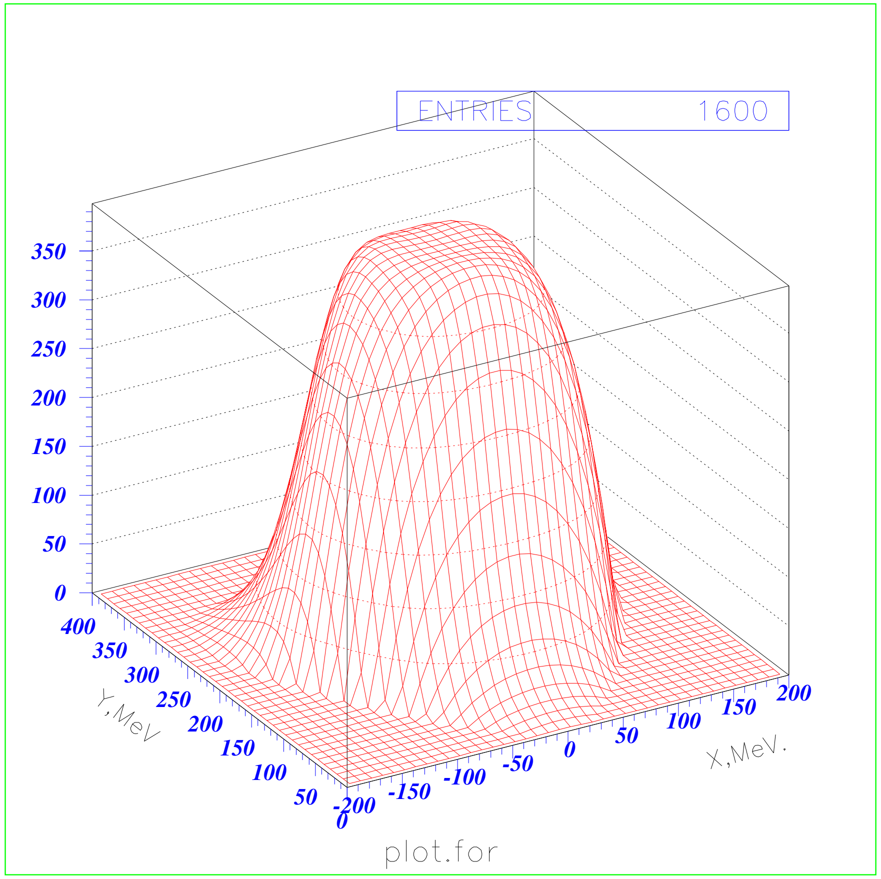


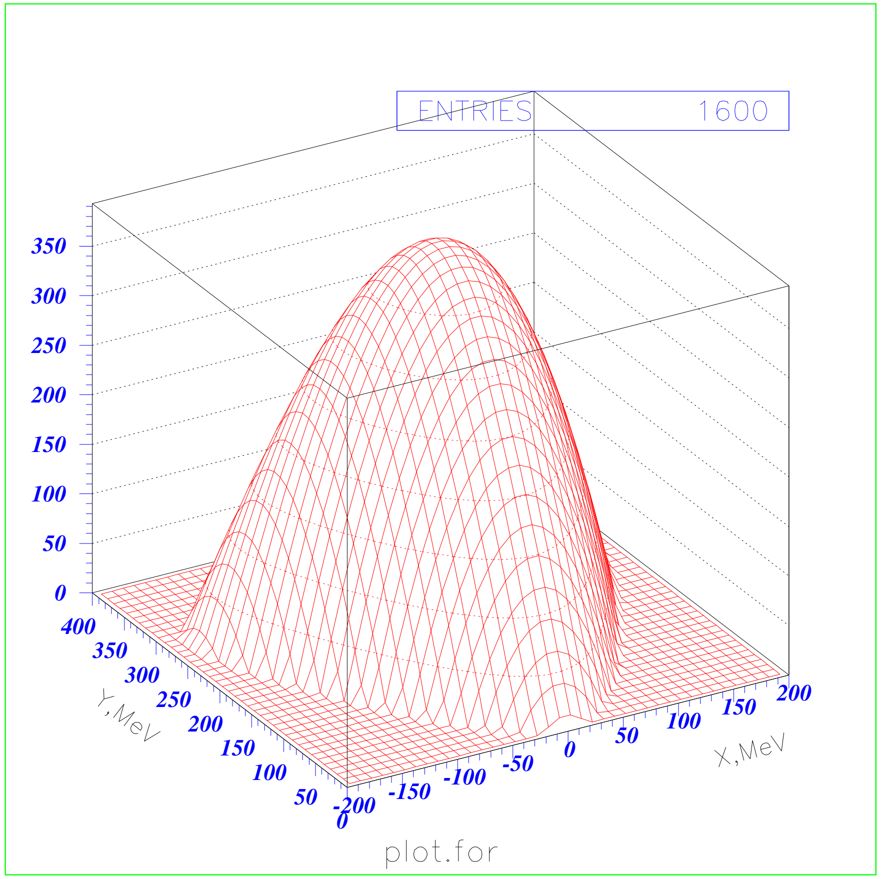
$$N_k^{th} = \frac{N_0}{Z}\int_k dXdY|\vec{P_+}\times\vec{P_-}|^2|A_{\rho'\pi}ae^{i\varphi}+A_{\rho\pi}|^2$$

a, φ, N_0 — fit parameters

$$a = \frac{g_{\phi\rho'\pi} \cdot g_{\rho'\pi\pi}}{g_{\phi\rho\pi} \cdot g_{\rho\pi\pi}}$$

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


ENTRIES 1600
0
50
100
150
200
250
300
350
400
Y,MeV
-200
-150
-100
-50
0
50
100
150
200
X,MeV.
plot.for


ENTRIES 1600
0
50
100
150
200
250
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Y,MeV
-200
-150
-100
-50
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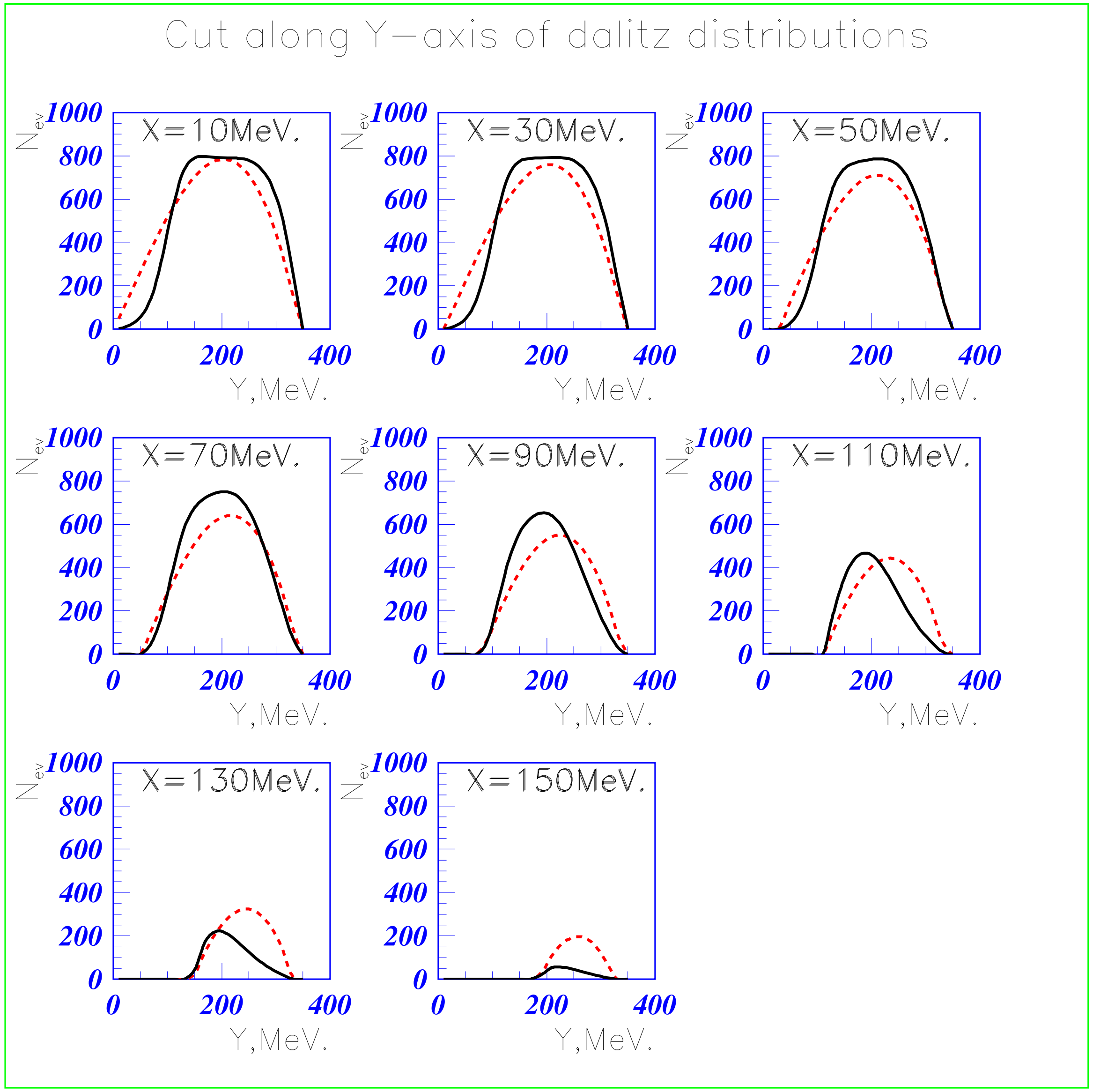
50
100
150
200
X,MeV
plot.for


Cut along Y–axis of dalitz distributions
X=10MeV.
X=30MeV.
X=50MeV.
X=70MeV.
X=90MeV.
X=110MeV.
X=130MeV.
X=150MeV.
N_ev
Y,MeV.
0
200
400
600
800
1000