The study of the conversion decay of omega meson to π^0 meson and e^+e^- pair with the CMD-3 detector.

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Introduction

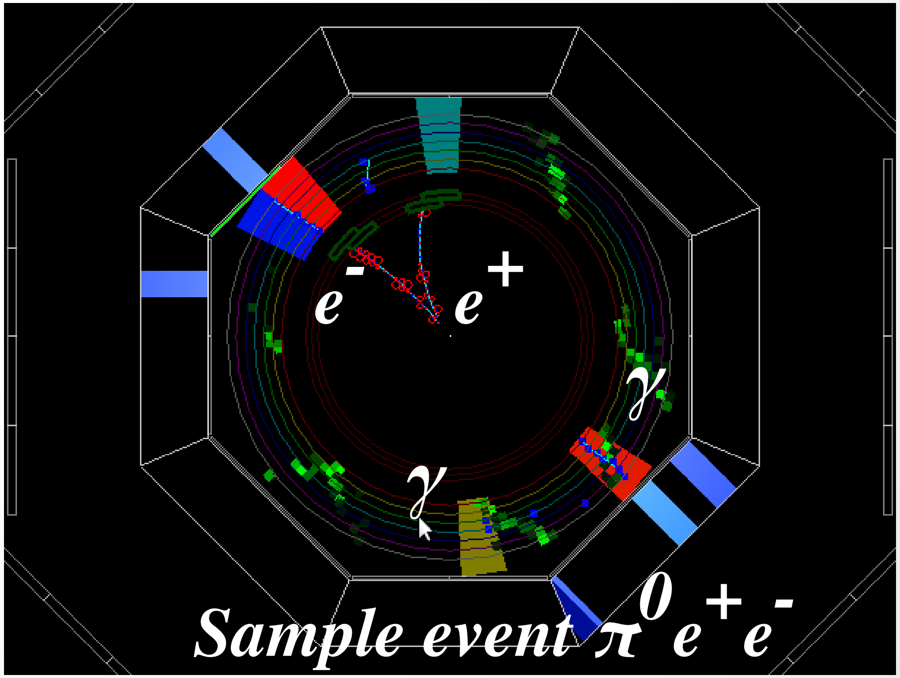
- Most recent previous experiments: CMD-2, SND and earlier.
- $Br(\omega \to \pi^0 e^+ e^-) = (7.7 \pm 0.6) \cdot 10^{-4}$ (PDG 2016).

- Motivation: study of the internal structure of the vector mesons (transition form factor).
- $\pi^0 \to \gamma\gamma$.

- Main background:

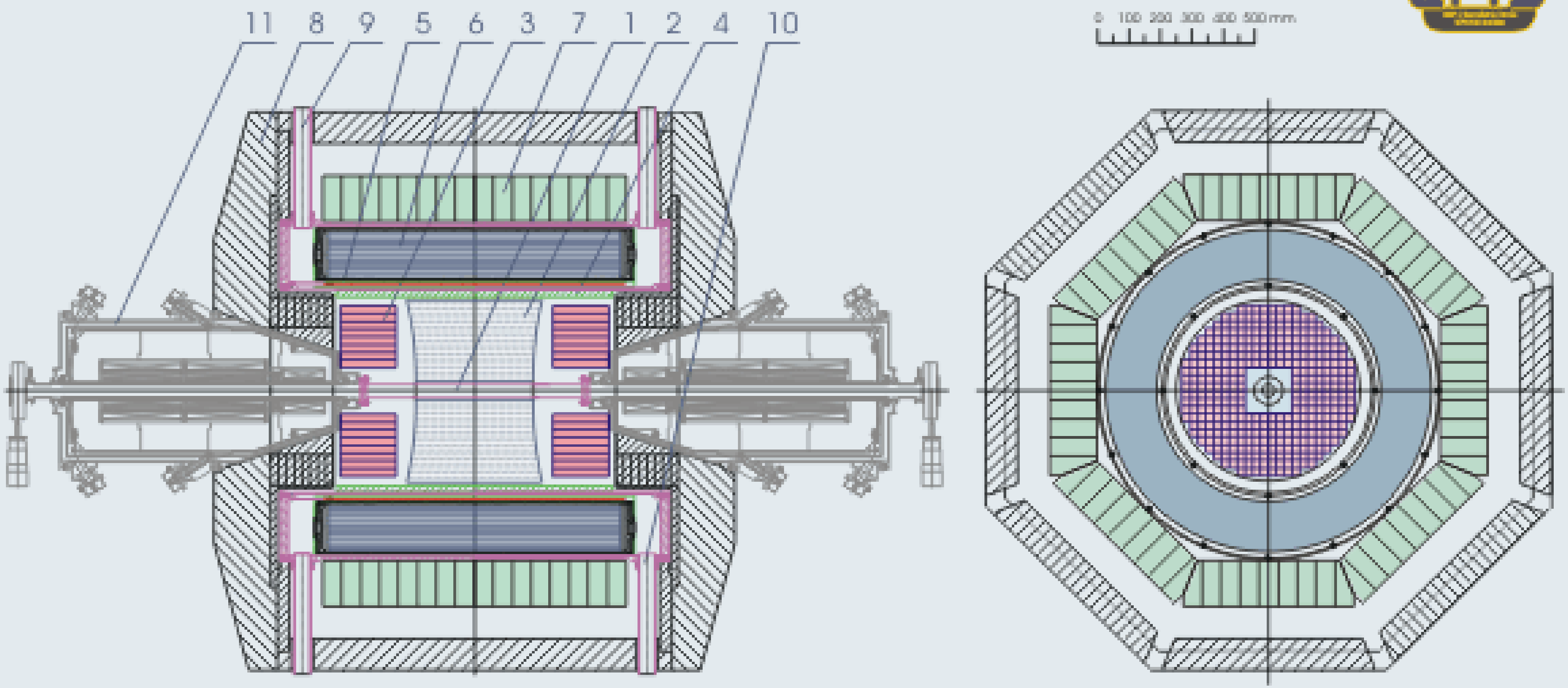
✓ $Br(\omega \to \pi^+ \pi^- \pi^0) = (89.2 \pm 0.7)$ %;
✓ $Br(\omega \to \pi^0 \gamma) = (8.28 \pm 0.28)$ %;
✓ events of Quantum Electrodynamics (QED);
✓ events from cosmic rays.

- We are using about 8 1/pb of data (energy near the ω - meson mass) recently collected with the CMD-3.



CMD-3 DETECTOR

HTTP://CMD.INP.NSK.SU

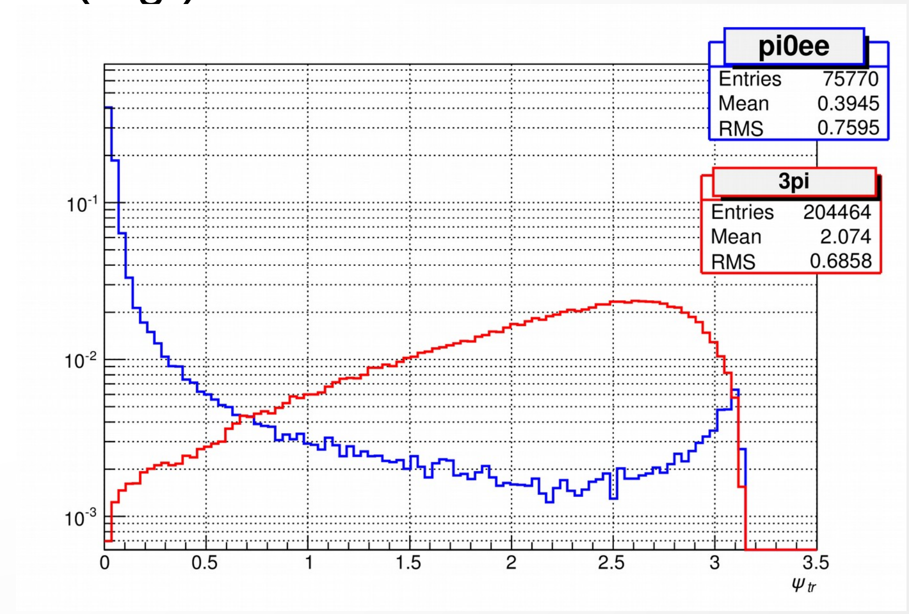


1 - Vacuum pipe
2 - Drift chamber
3 - BGO endcap calorimeter
4 - Z-chamber
5 - Superconducting solenoid
6 - LXe calorimeter
7 - CsI barrel calorimeter
8 - Yoke
9 - LHe supply
10 - Vacuum pumpdown
11 - VEPP2000 superconducting magnetic lenses

Selection criteria

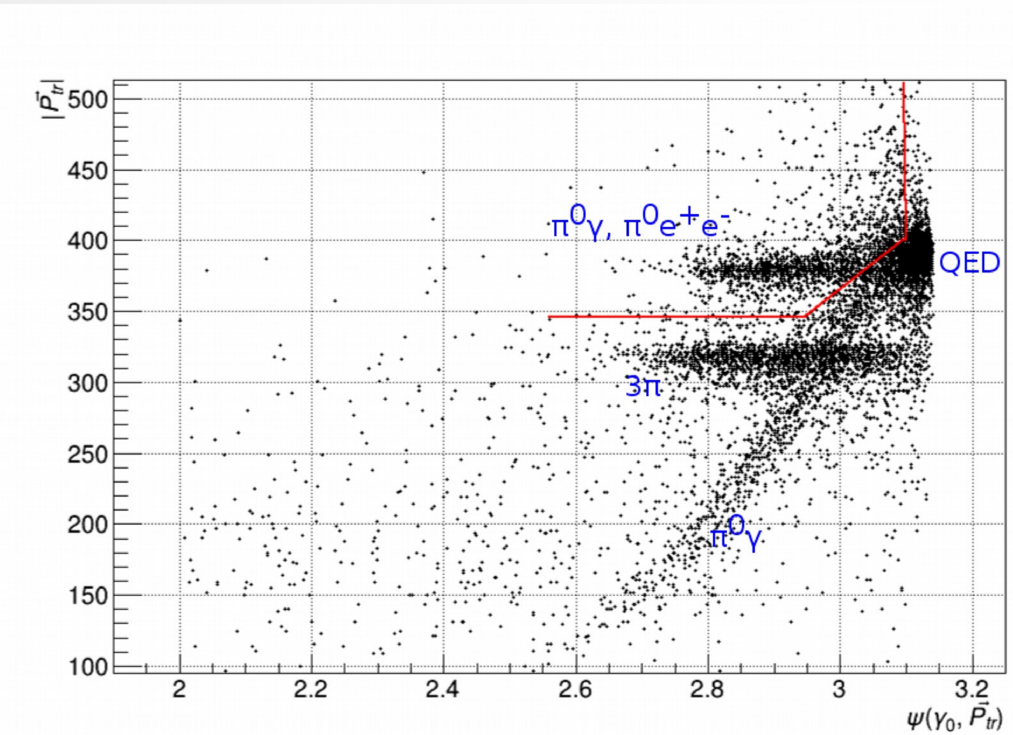
- $N_\gamma \geq 2$:
  - 20 MeV < $E_{\gamma\ max0,1} < 2E_{beam}$;
  - the angle between the photon and the point of track of entry into the calorimeter > 0.4 rad;
- $|Z_{vert}| < 8$ cm;
- the angle between the photons < 1.6 rad;
- the angle between the total momentum of the tracks and each photon is larger than 1.5 rad;
- $M(e^+e^-\gamma) < 1.9 \cdot E_{beam}$
- the uncollinear tracks in the R-φ projection $|\pi - |\varphi_1 - \varphi_2|| > 0.15$;
- $Q_1 + Q_2 = 0$;

- 2 «good» tracks in the drift chamber:
  - a track produces more than 10(15) hits in the DC;
  - transverse moment > 40 MeV/c;
  - polar angle $0.9 < \theta < \pi - 0.9$;
- Opening angle of the tracks $\Delta\Psi_{track} < 1$ rad (Fig.).



The space angle between the tracks for MC simulation of $\pi^0e^+e^-$ (blue color) and $\pi^+\pi^-\pi^0$(red color).

Selection criteria

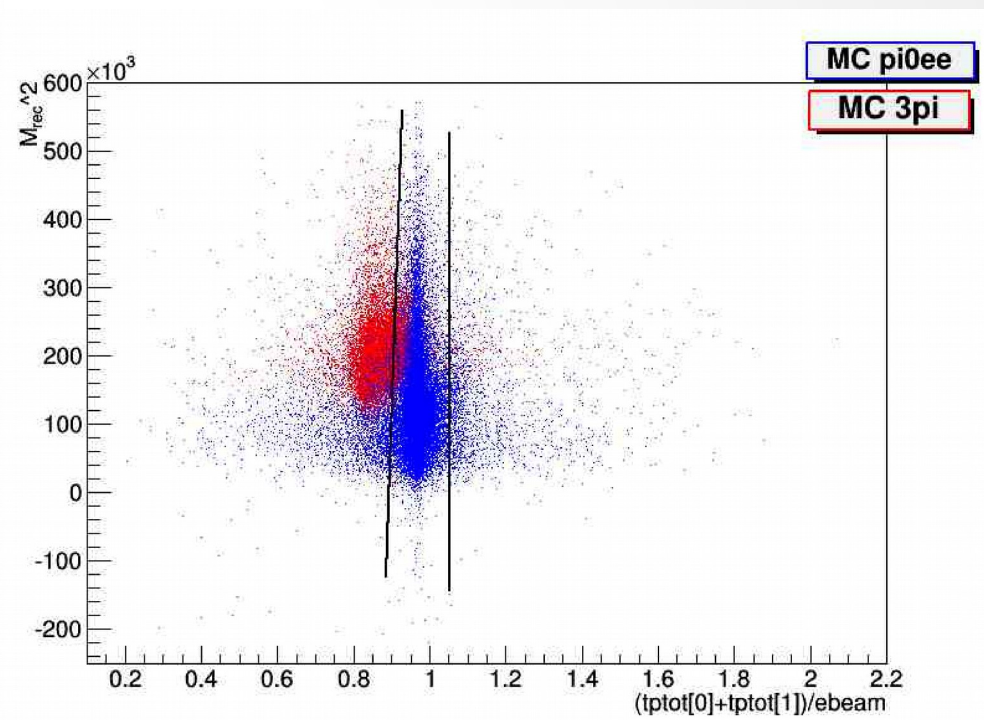


The total momentum of charged particles P_{tr} vs angle between the most energetic photon and P_{tr}. The red line presents the selection cut.

Recoil mass of photon pairs:

$$M_{rec}^2 = (2 \cdot E_0)^2 - 4 E_0 E_{\pi^0} + m_{\pi^0}^2$$

where $E_{\pi^0} = E_{\gamma,1} + E_{\gamma,2}$



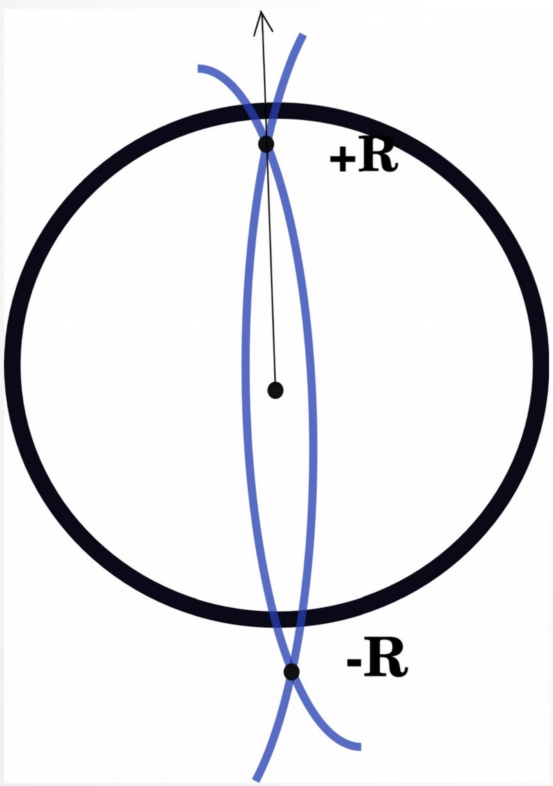
The recoil mass of photon pairs vs the total energy of electron-positron pairs, normalized to the beam energy for MC simulation of $\pi^0e^+e^-$ (blue dots) and $\pi^+\pi^{-5}$ π^0(red dots). The black line shows the selection cut.

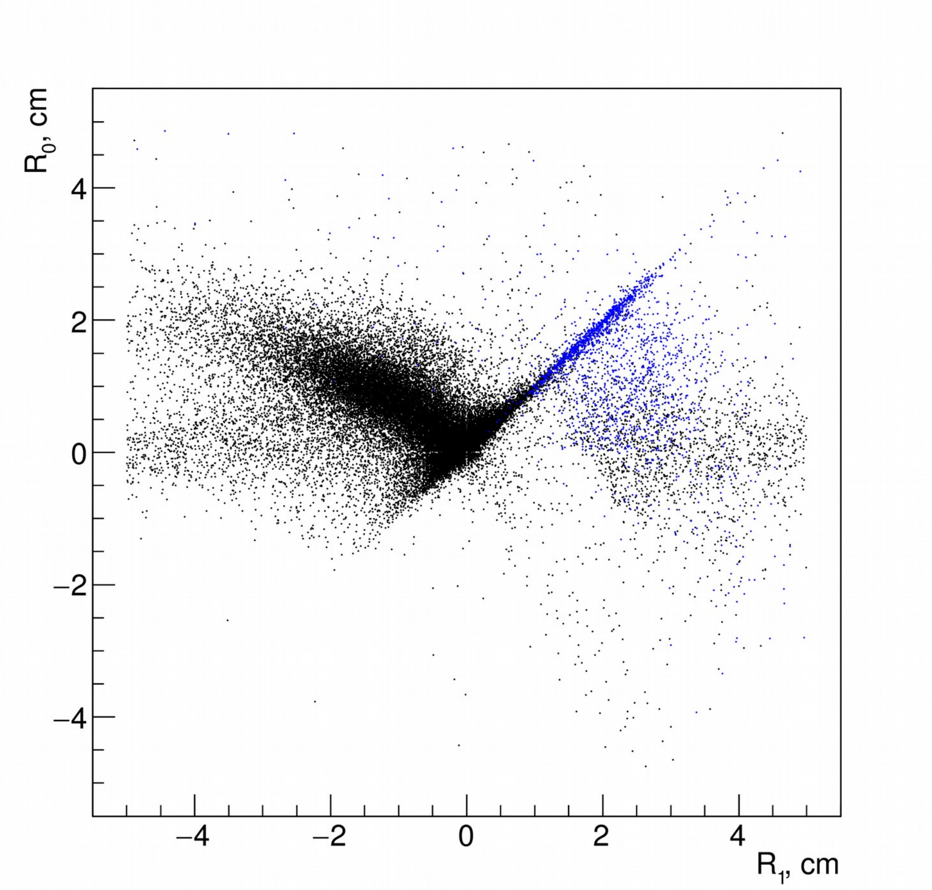
Separation of $\pi^0 e^+ e^-$ and $\pi^0\gamma$ (with conversion γ on the detector material)

- $\pi^0\gamma$:
  - Dalitz decay of π^0;
  - γ convert in e^+e^- pair on the detector material;
- We use a neural network;
- Input parameters:
  - the angle between the tracks;
  - the total momentum normalized to beam energy;
  - the track momentum normalized to beam energy;
  - the distance from the vertex to the center of the beam.

Separation of $\pi^0 e^+ e^-$ and $\pi^0 \gamma$ (with conversion γ on the detector material)

- The sign of the distance is "+" in case of the angle between the beam point direction to a cross-point and average momentum of tracks is sharp and "-" otherwise.
- In the transverse plane circles from tracks have two cross-points: the first one is the vertex and the second is additional.



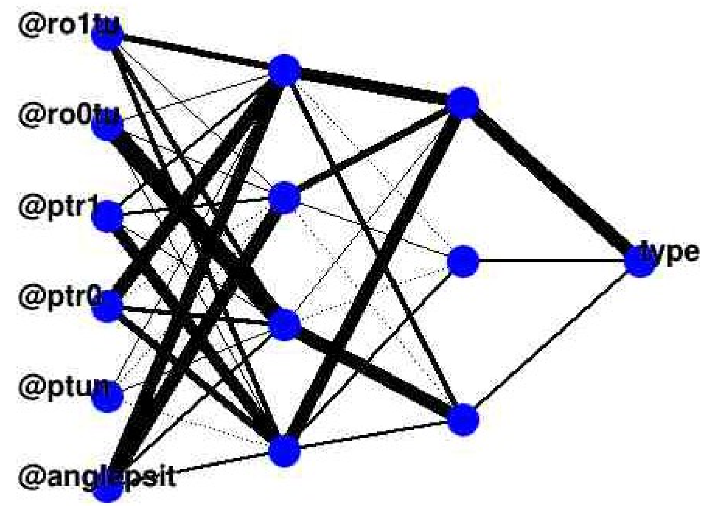


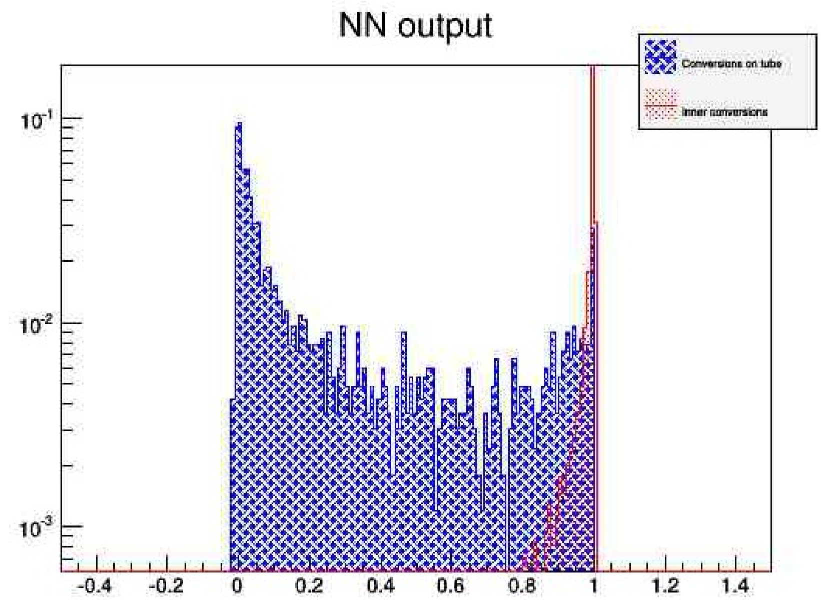
The distance from the beam point to the first cross-point vs distance to the second cross point is shown for MC simulation of $\pi^0 e^+ e^-$ (black dots) and $\gamma\gamma$ with photon conversion on material (blue dots).

Separation of $\pi^0 e^+ e^-$ and $\pi^0 \gamma$ (with conversion γ on the detector material)

- Output parameter of the neural network determines the event type (signal ($\pi^0 e^+ e^-$) or background ($\pi^0 \gamma$ and $\gamma\gamma$)).
- Training data: MC simulation of $\pi^0 e^+ e^-$ and of $\gamma\gamma$.
- The efficiency of suppression:

  $\pi^0\gamma$ – 84 % ($\gamma\gamma$ – 90 %), while we lose 2 % of signal events ($\pi^0 e^+ e^-$).



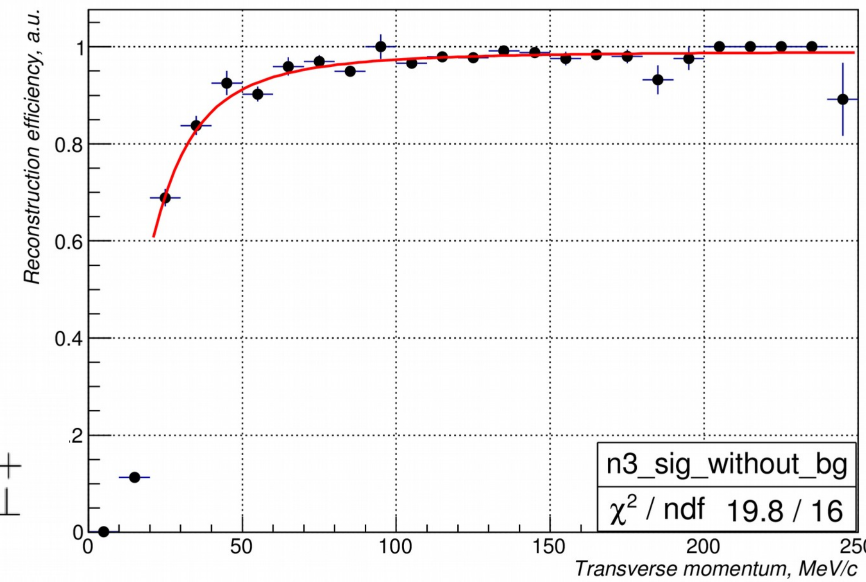


Reconstruction efficiency of close tracks

- Since Monte-Carlo simulation does not completely describe the experiment, a correction $\varepsilon_{\Delta\psi}$ for a difference between the reconstruction efficiencies of close tracks in simulation and experiment was included.
- $\omega \to \pi^+ \pi^- \pi^0$ where $\pi^0 \to e^+e^-\gamma$.
- $\varepsilon_{\Delta\psi}$ is calculated by averaging the integral in the formula for simulation events

$$\varepsilon_{\Delta\psi} = \int \frac{\varepsilon^{-}_{\Delta\psi,exp}(P^{-}_{\perp})}{\varepsilon^{-}_{\Delta\psi,sim}(P^{-}_{\perp})} \cdot \frac{\varepsilon^{+}_{\Delta\psi,exp}(P^{+}_{\perp})}{\varepsilon^{+}_{\Delta\psi,sim}(P^{+}_{\perp})} f(P^{-}_{\perp}) f(P^{+}_{\perp}) dP^{-}_{\perp} dP^{+}_{\perp}$$

- where $\varepsilon_{\Delta\psi,\ exp}(P_{\perp}^{-})$ - efficiency of tracks reconstruction depending on the transverse momentum (for e^- or e^+, and for simulation or experiment).
- $\varepsilon_{\Delta\psi} = 0.970 \pm 0.008 \pm 0.020$

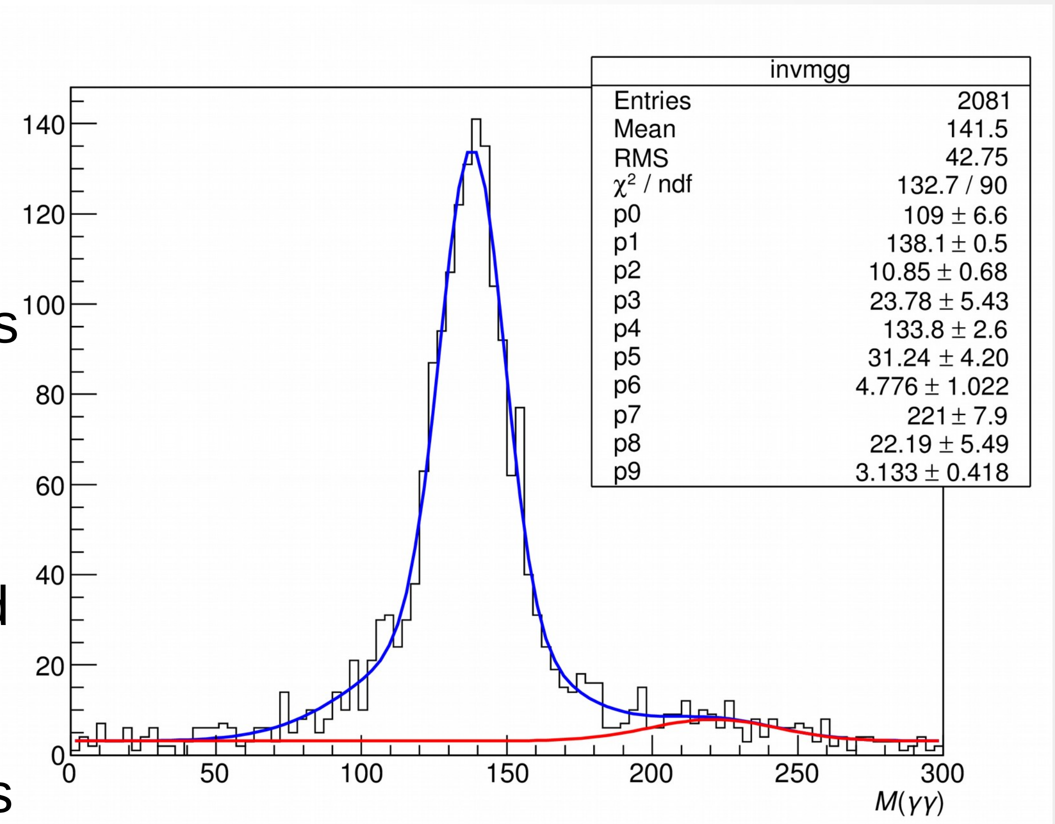


Efficiency of tracks reconstruction vs transverse momentum for e^- for experiment.

Determination of the number of background and signal events

- The detection efficiency $\varepsilon_{det}(\omega \rightarrow \pi^0 e^+ e^-)$ = 23 %, was determined using Monte-Carlo simulation.

- The number of signal and background events obtained from a fit of the γγ invariant mass distribution at each energy point.
- The signal was described by a 2 Gauss function, the shape of background was described by a Gauss function and constant;
- The shape of signal and of background curve were fixed from the fit of all experimental data in the energy range 760 — 820 MeV, so floated parameters at each energy point were the number of signal and background events;



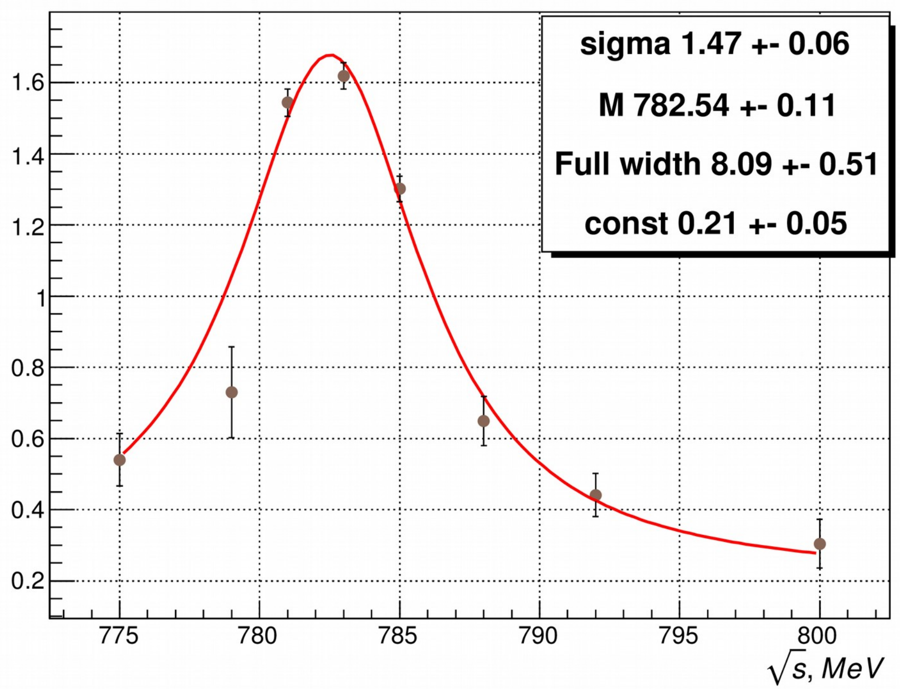
Invariant mass of γγ for all experimental data in the energy range 760 — 840 MeV.

Cross section

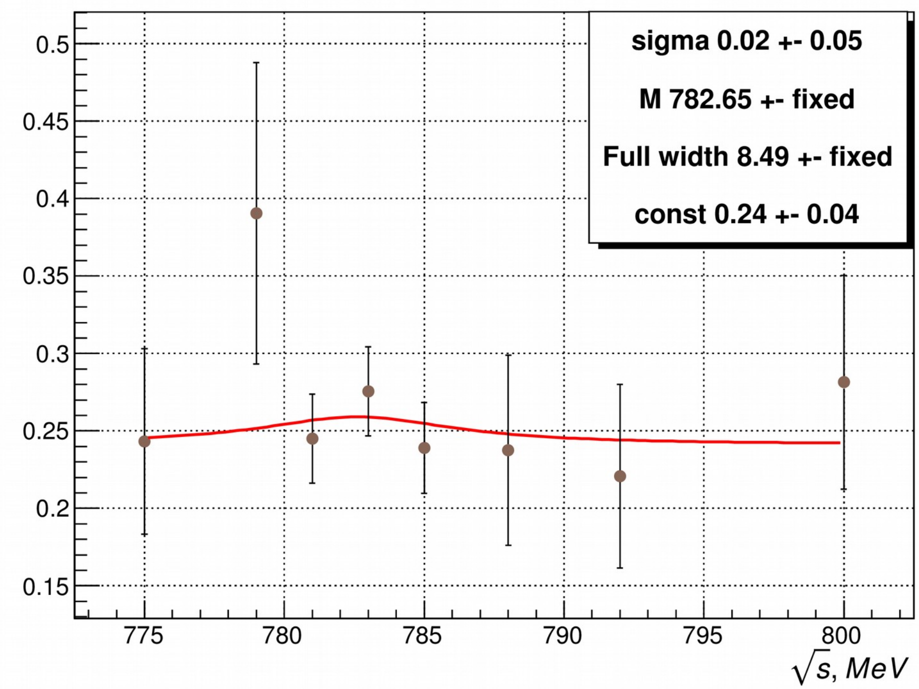
The numbers of background and signal events at each energy point were used to determine the visible cross section of signal and background events.

$$\sigma_{vis} = \frac{N_{sig,i}}{L_i(1+\delta_i)\cdot\varepsilon_{dec}\cdot\varepsilon_{\Delta\psi}\cdot Br(\pi^0\to\gamma\gamma)}$$

$$\sigma_{vis,bg} = \frac{N_{bg,i}}{L_i\cdot\varepsilon_{dec}}$$



Visible cross section of the signal process is fitted with a Breit–Wigner distribution.



Visible cross section of the background events is fitted with a Breit–Wigner distribution.

Cross section

experiments	$Br(\omega \to \pi^0 e^+ e^-)$	events	The amount of statistics, 1/pb
ND	$(5.9 \pm 1.9) \cdot 10^{-4}$	43	
CMD-2	$(8.19 \pm 0.71 \pm 0.62) \cdot 10^{-4}$	230	3.3
SND	$(7.61 \pm 0.53 \pm 0.64) \cdot 10^{-4}$	613	9.8
CMD-3*	**$(8.81 \pm 0.35) \cdot 10^{-4}$ (stat.)**	**1380**	**8**

*Future plans:

- To determine the contributions of the $\omega \to \pi^+ \pi^- \pi^0$ and $\omega \to \pi^0 \gamma$.
- Test of the method of $\pi^0\gamma/\pi^0 e^+ e^-$ separation on QED events;
- The study of the trigger efficiency;
- Systematics.

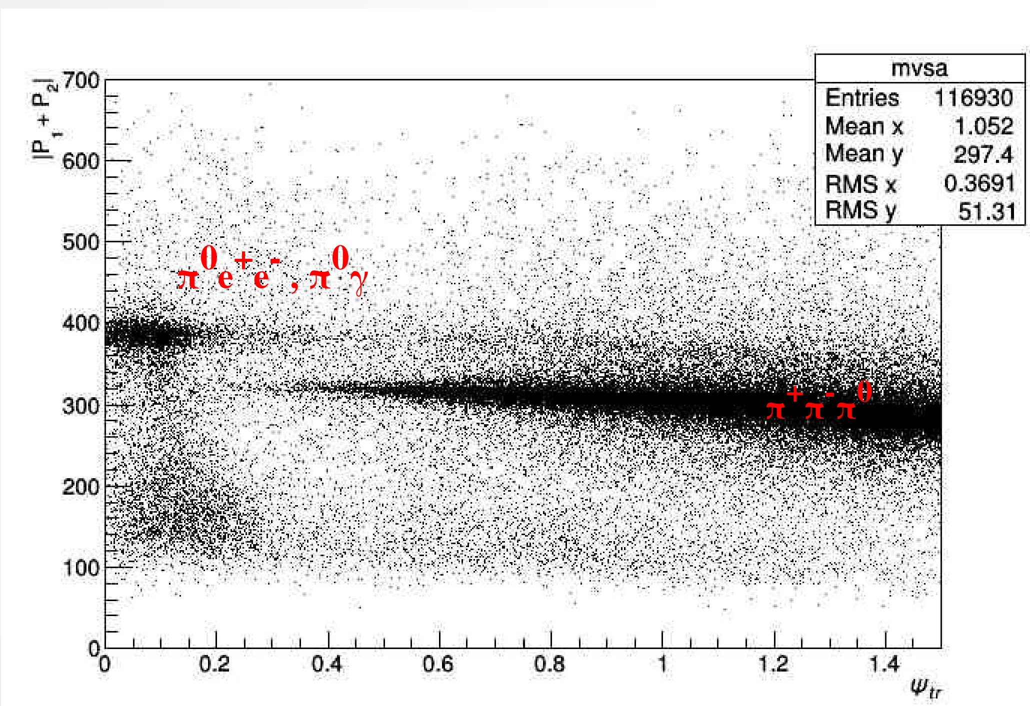
This analysis is useful in the study of data from the super c - tau factory, in particular the developed method for the separation of vertex conversion.

Thanks for attention!

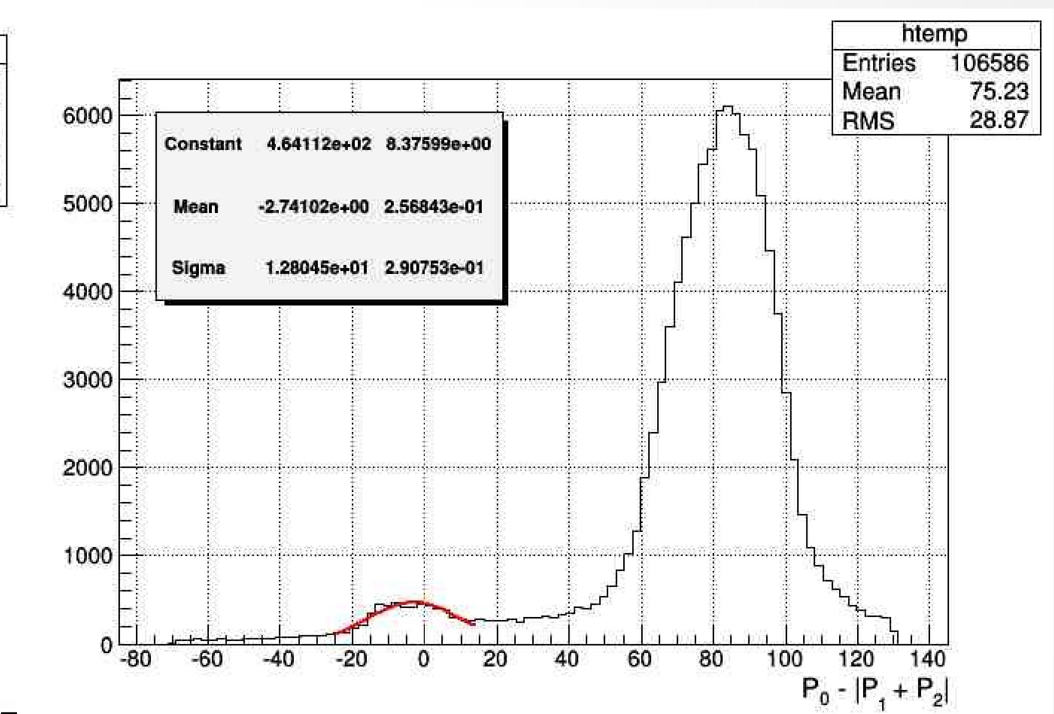
kinematic of the decay

The difference between the total momentum of the pair of charged particles $|P_1+P_2|$ and the value $P_0 = E_{beam} — (M_\pi^2/4E_{beam})$ in decay $\omega \to \pi^0\gamma$

$|P_0 - |P_1+P_2|| < 35$ MeV/c;

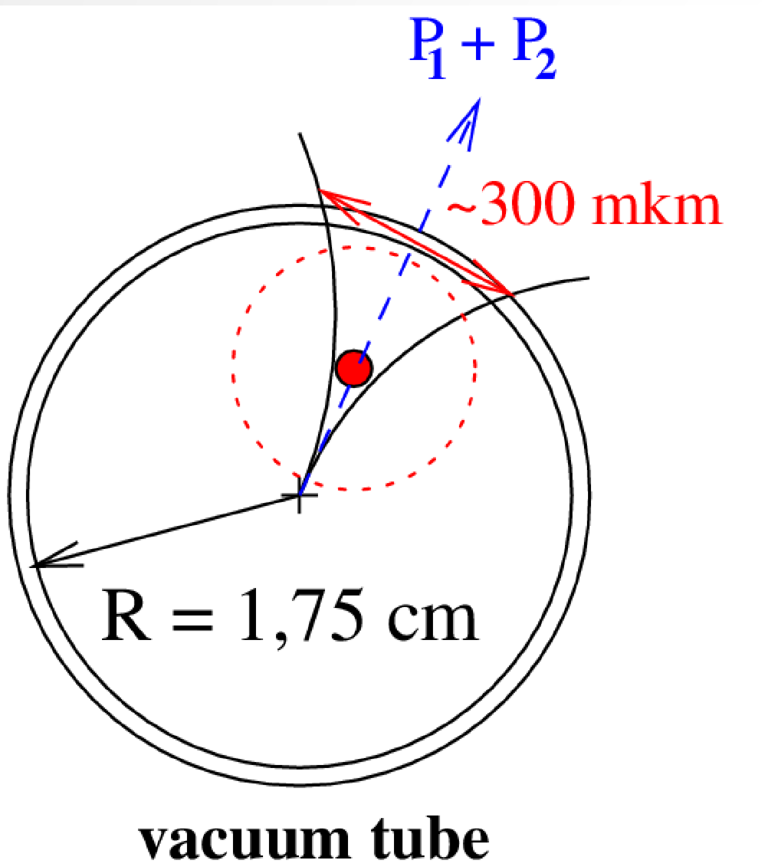


The dependence of the total momentum of the pair of charged particles | P1 + P2 | and the angle between the tracks for the experimental data .



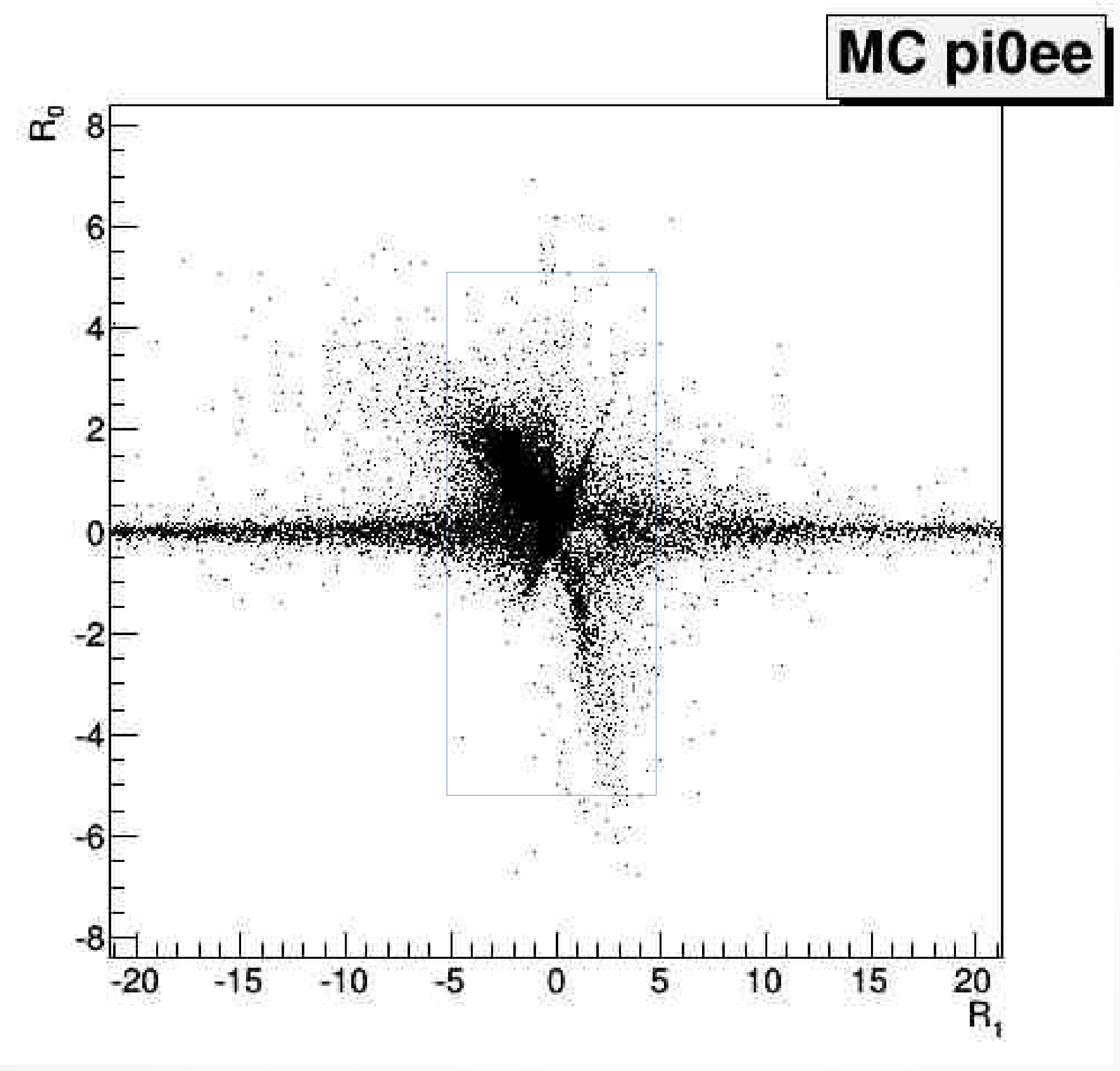
The dependence of the total momentum of the pair of charged particles P0 - | P1 + P2 | for experimental data .

The distance from the beam point to the first cross-point vs distance to the second cross point

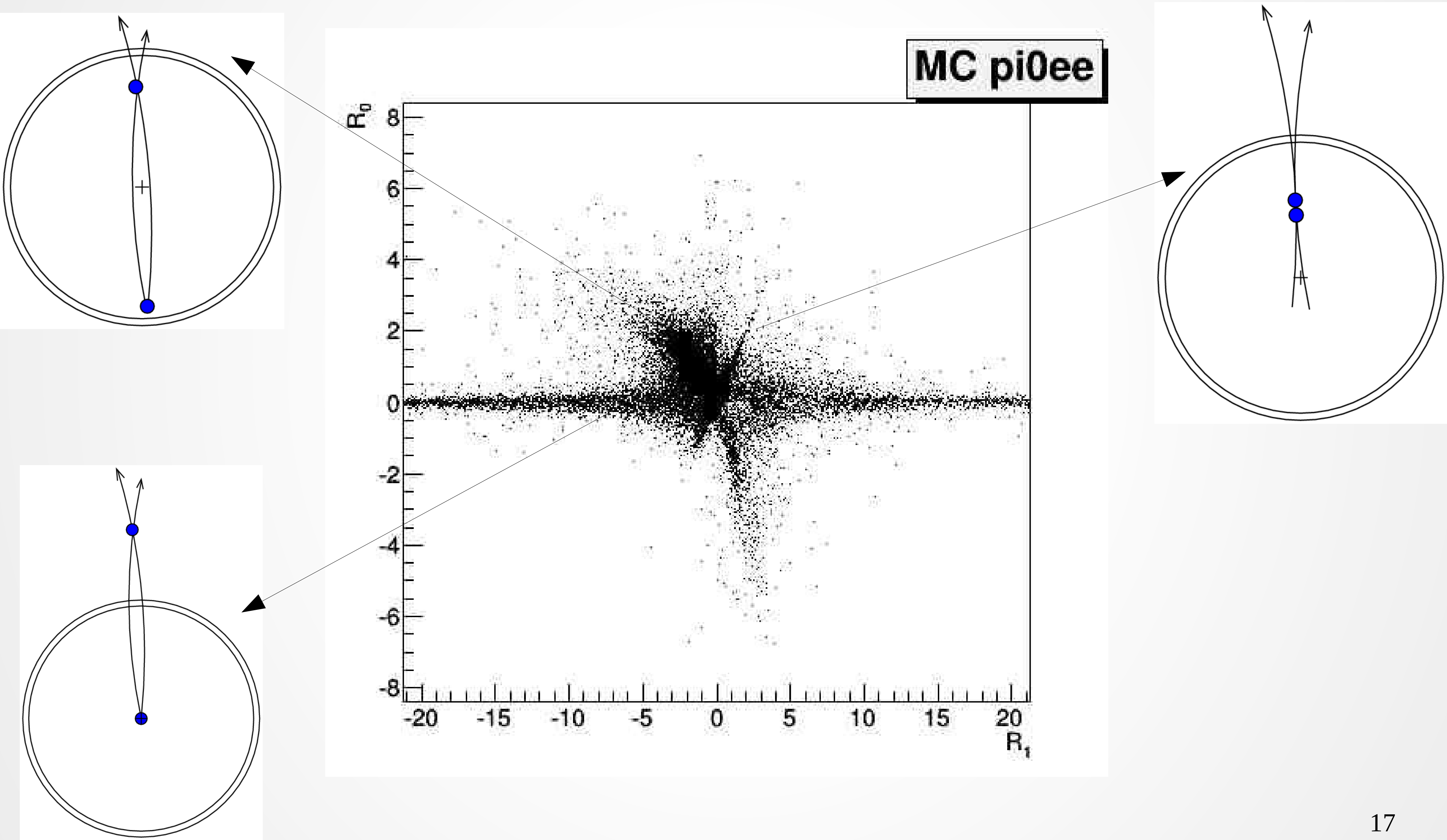


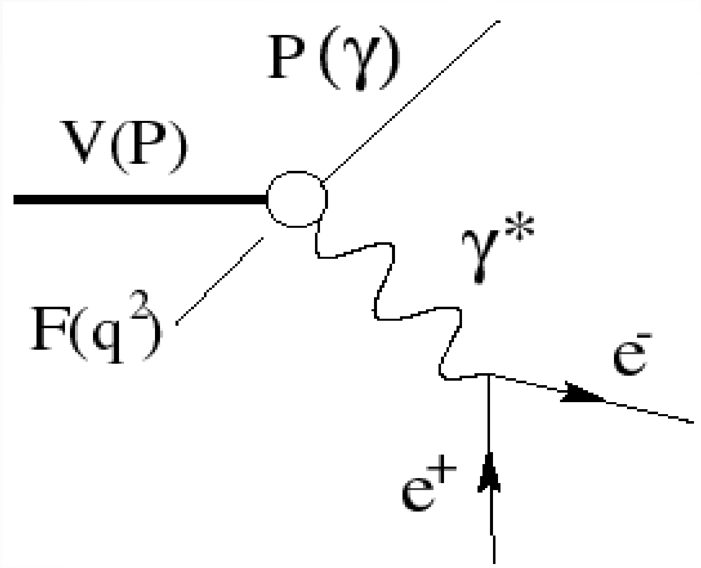
- **To calculate the parameters of the circles that describe the tracks, using data from fitvertex;**
- **Fitvertex function with input parameters (tracks, coordinates of the vertices and its error), there are always two intersections;**
- **The second intersection point is calculated.**

The distance from the beam point to the first cross-point vs distance to the second cross point



The distance from the beam point to the first cross-point vs distance to the second cross point





V — vector meson ω, P — pseudoscalar meson π^0