Cross Section measurements of process $e^+e^- \to \phi\pi^0$

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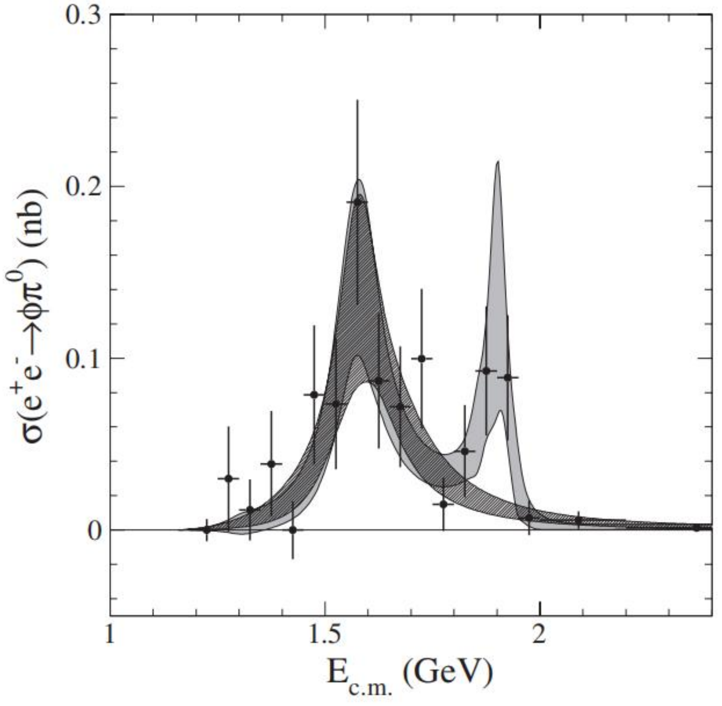
Contents

Motivation

- The $\phi\pi^0$ process is significant in the search for ρ-like excited states. Even though they are OZI-suppressed, its observation indicate that such excited states may exist, therefore it is considered a candidate for ρ-like excited state.
- Motivated by a narrow peak near $E_{cm} \approx$ 1900 MeV reported by the BaBar experiment, we perform a search for this structure.



BOSS Version & Data sets

- **Process :**
  - $e^+e^- \to \phi\pi$
- **BOSS Version :**
  - 713,6.6.5.p01
- **Signal MC :**
  - 1.8400GeV -2.3960 GeV
- **Data samples :**
  - listed in the right table

E_{cm}(GeV)	Run No.	Lumi.(1/pb)	E_{cm}(GeV)	Run No.	Lumi.(1/pb)
1840	81849-81970	1.501	1970	82463-82530	2.229
1870	81971-82104	2.002	2000	41729-41909	10.1
1872	82543-82656	2.014	2050	41911-41958	3.34
1874	82657-82783	2.019	2100	41588-41728	12.2
1875	82835-82909	1.485	2125	42004-43253	108
1876	82105-82203	2.035	2150	41533-41570	2.84
1877	82784-82834	1.341	2175	41416-41532	10.6
1878	82204-82261	2.021	2200	40989-41121	13.7
1882	82262-82310	2.033	22324	41240-41239	11.9
1886	82311-82358	2.031	23094	41240-41411	21.1
1900	82359-82404	2.022	23864	40806-40951	22.5
1940	82405-82462	2.040	23960	40459-40769	66.9

Event selection

- **The charged tracks**
  - $|cos\theta| < 0.93$
  - $|V_{\mathrm{r}}| < 1cm, |V_z| < 10cm$
  - $N_{charge}^{good} = 2 \ \sum Q = 0$
- **PID**
  - $Prob_{PID}(K) > Prob_{PID}(p)$
  - $Prob_{PID}(K) > Prob_{PID}(\pi)$
- **Neutral Tracks**
  - $0 \leq TDC \leq 700ns$
  - Barrel: $E > 25\mathrm{MeV}$, End cap: $E > 50\mathrm{MeV}$
  - Angle>10°
  - $N_{\gamma}^{good} \geq 2$
- **Vertex fit**
  - **A successful vertex fit for the particles with k and π is necessary for each candidate event.**

@2.125Gev

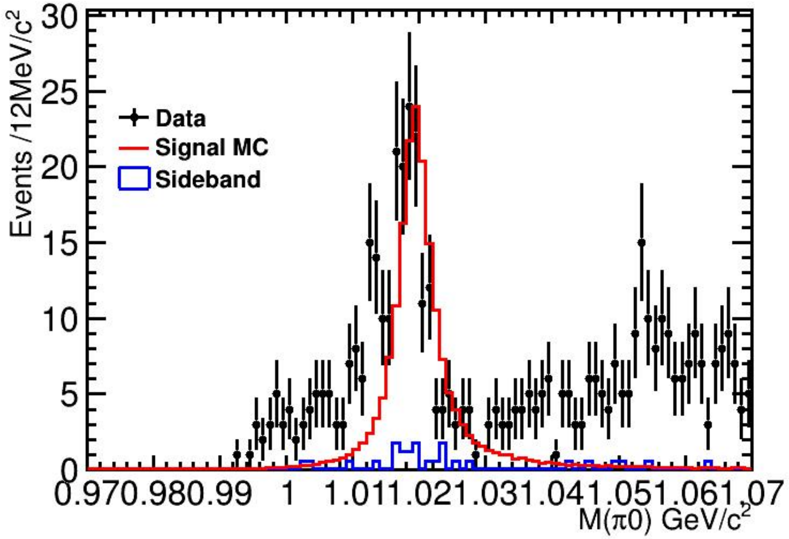
Background analysis

Table 1: Decay trees and their respective final states.

rowNo	decay tree	decay final state	iDcyTr	nEtr	nCEtr
1	$e^+e^- \to \pi^0\phi, \phi \to K^+K^-$	$\pi^0K^+K^-$	1	492	492
2	$e^+e^- \to \pi^0K^+K^-$	$\pi^0K^+K^-$	3	263	755
3	$e^+e^- \to vgam\gamma^I, vgam \to \pi^0\phi, \phi \to K^+K^-$	$\pi^0K^+K^-\gamma^I$	5	189	944
4	$e^+e^- \to vgam\gamma^I, vgam \to \pi^0K^+K^-$	$\pi^0K^+K^-\gamma^I$	0	130	1074
5	$e^+e^- \to \pi^0a_0^0, a_0^0 \to K^+K^-$	$\pi^0K^+K^-$	4	112	1186
6	$e^+e^- \to \pi^0a_0^0\gamma^f, a_0^0 \to K^+K^-$	$\pi^0K^+K^-\gamma^f$	2	78	1264
7	$e^+e^- \to \pi^0f_0', f_0' \to K^+K^-$	$\pi^0K^+K^-$	6	64	1328
8	$e^+e^- \to \pi^0f_0'\gamma^f, f_0' \to K^+K^-$	$\pi^0K^+K^-\gamma^f$	8	45	1373
9	$e^+e^- \to K^+K^-\gamma^I\gamma^I$	$K^+K^-\gamma^I\gamma^I$	7	44	1417
10	$e^+e^- \to K^+K^-\gamma^I$	$K^+K^-\gamma^I$	9	7	1424
11	$e^+e^- \to \pi^0\pi^0K^+K^-$	$\pi^0\pi^0K^+K^-$	11	2	1426
12	$e^+e^- \to vgam\gamma^I, vgam \to \pi^0K^+K^{*-}, K^{*-} \to \pi^0K^-$	$\pi^0\pi^0K^+K^-\gamma^I$	10	1	1427
13	$e^+e^- \to \pi^0K^-K^{*+}, K^{*+} \to \pi^0K^+$	$\pi^0\pi^0K^+K^-$	12	1	1428
14	$e^+e^- \to \pi^0K^+K^{*-}, K^{*-} \to \pi^0K^-$	$\pi^0\pi^0K^+K^-$	13	1	1429
15	$e^+e^- \to \pi^0\pi^0\phi, \phi \to K^+K^-$	$\pi^0\pi^0K^+K^-$	14	1	1430

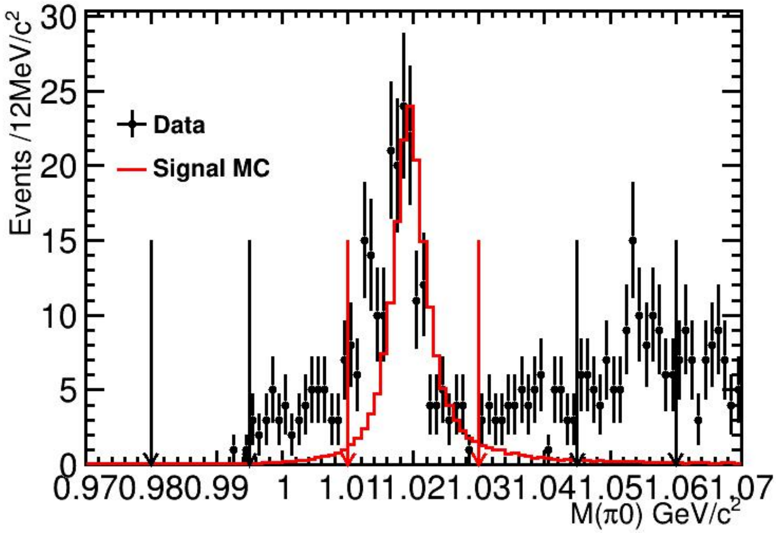
- No picking background
- Dominating background: $e^+e^- \to K^+K^-\pi^0$

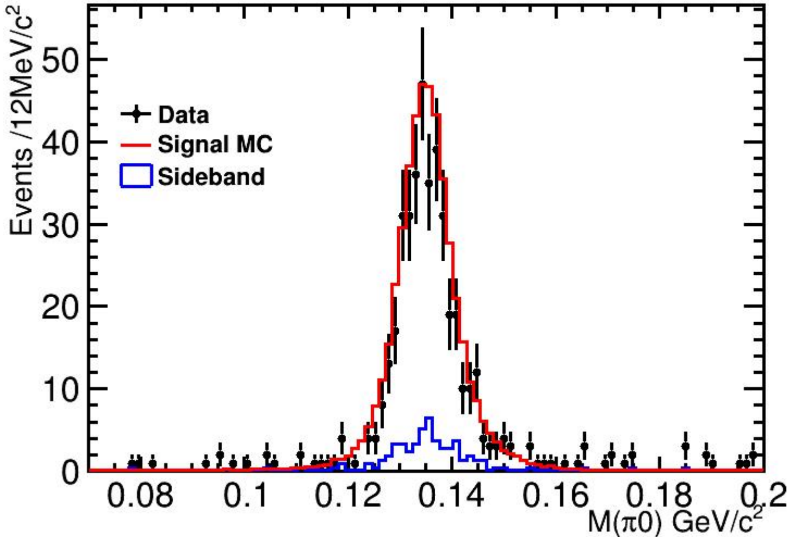
Background analysis



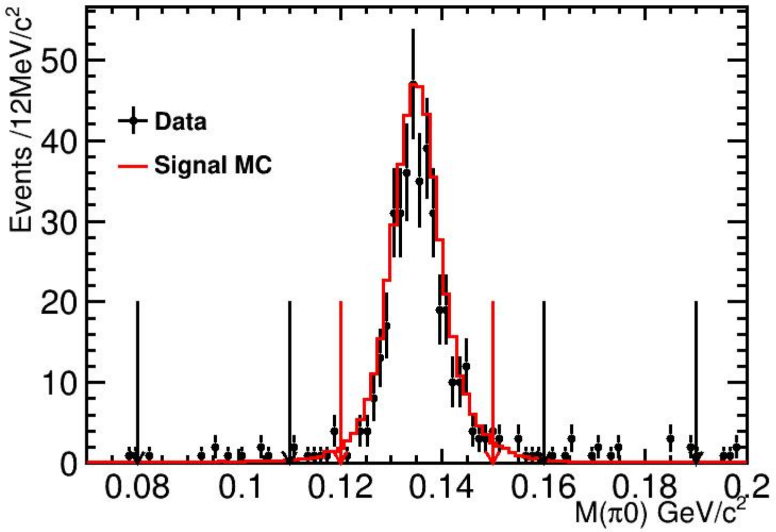
Condition:
chisq(γγKK) < chisq(γKK)

Φ
signal:[1.01,1.03]
Left sideband:[0.98,0.995]
Right sideband:[1.045,1.06]





π^0
signal:[0.12,0.15]
Left sideband:[0.08,0.11]
Right sideband:[0.16,0.19]



E_{cm} <2.0Gev

Signal yields

Due to the insufficient statistical data, We adopt the method of counting.

Calculation:

$$N_{obs} = N_{red} - \frac{1}{2} N_{blue} * f_{\phi} - \frac{1}{2} N_{green} * f_{\pi^0} + \frac{1}{4} N_{pink} * f_{\pi^0} * f_{\phi}$$

Represent:

N_{red} :ϕ,π^0 events

N_{blue} :π^0,non-ϕ events

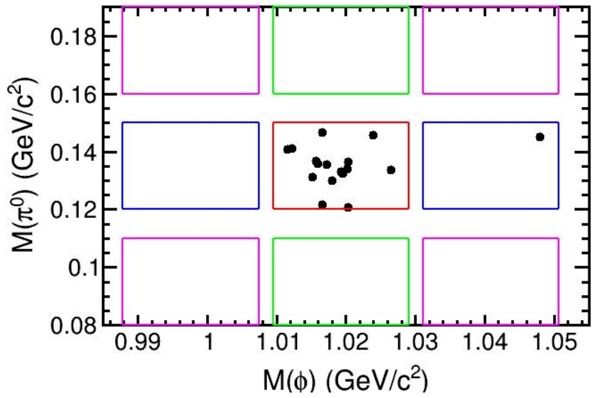
N_{green}: ϕ, non-π^0 events

N_{pink} :non-π^0,non-ϕ events

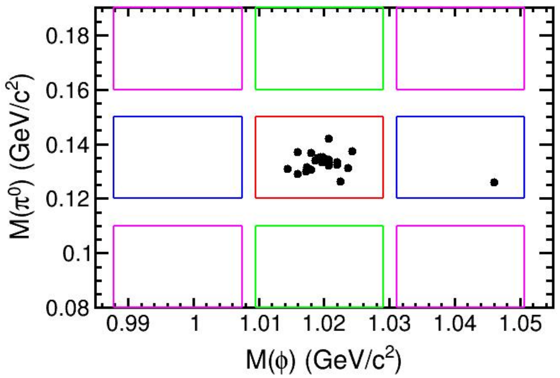
f_{ϕ}:$Normalizatio\ Factor\ for\ \phi$

f_{π^0}:$Normalizatio\ Factor\ for\ \pi^0$

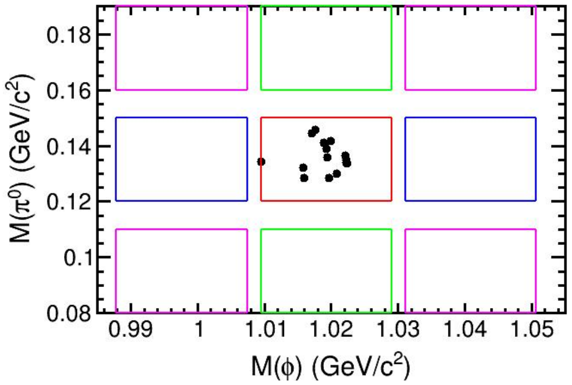
@1.840Gev



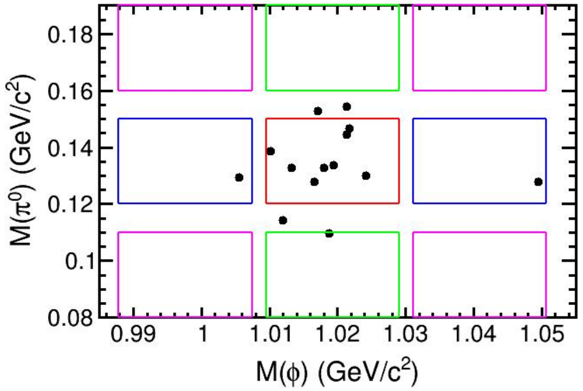
@1.870Gev



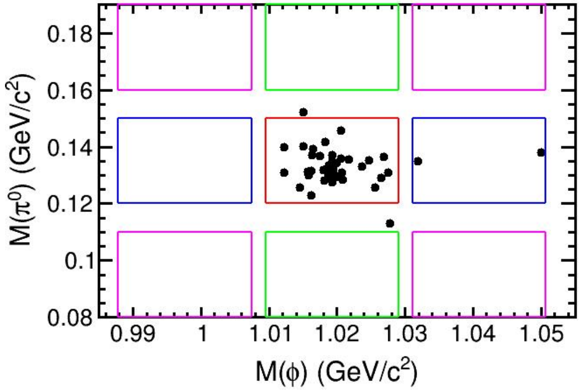
@1.872Gev



@1.874Gev



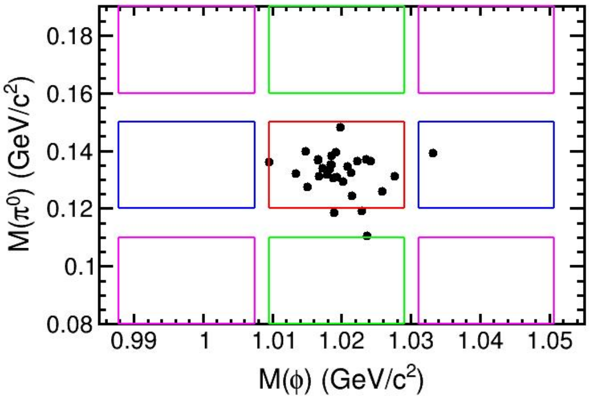
@1.875Gev



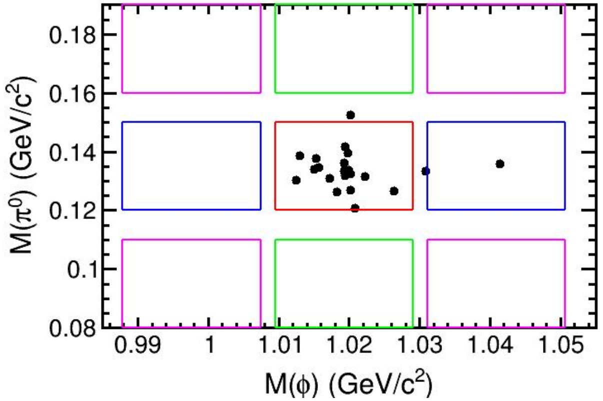
Signal yields

E_{cm} <2.0Gev

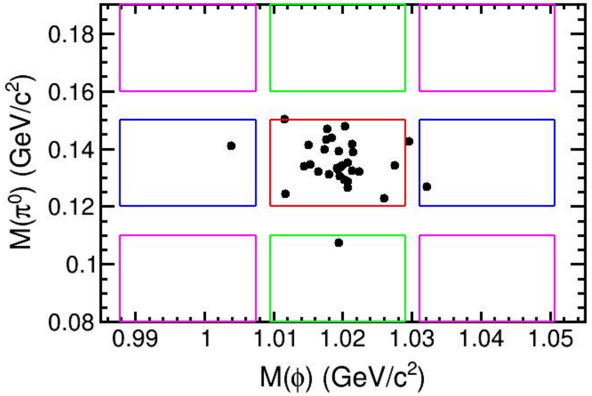
@1.876Gev



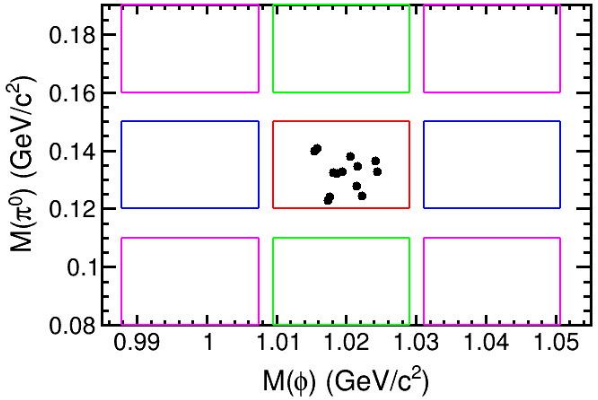
@1.877Gev



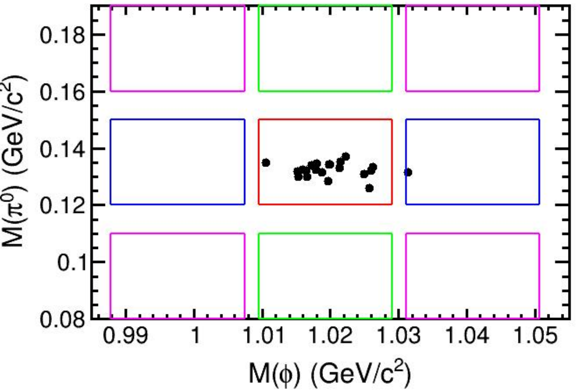
@1.878Gev



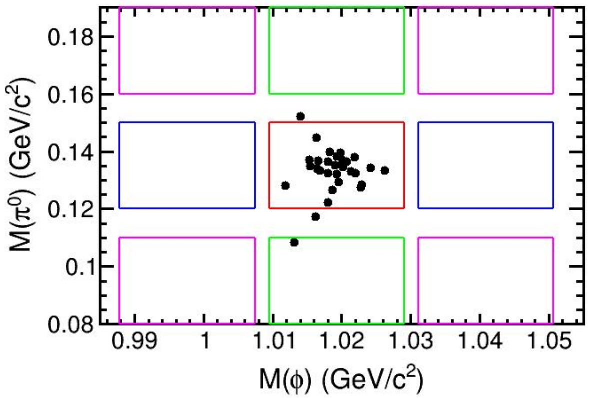
@1.882Gev



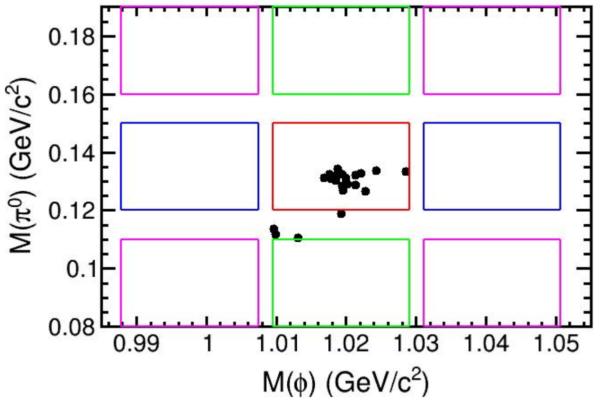
@1.886Gev



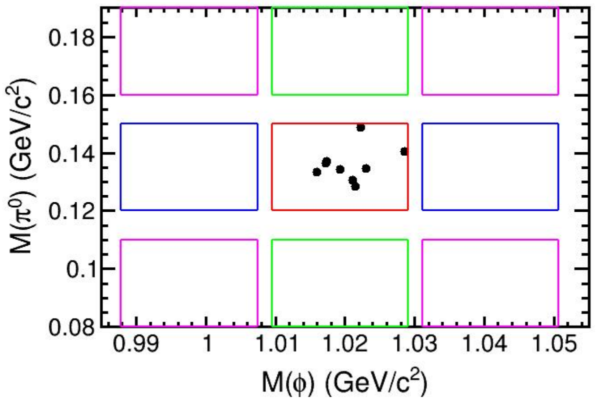
@1.900Gev



@1.940Gev



@1.970Gev



Signal yields

E_{cm} >2.0Gev

The data samples are sufficiently numerous, we fit the invariant mass spectrum.

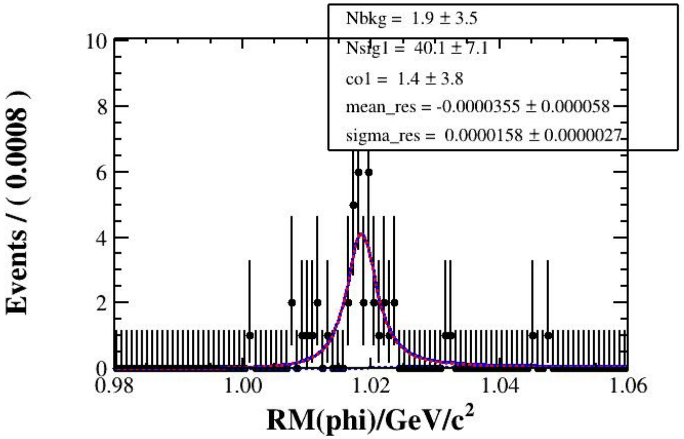
The fit are performed to the distribution of $RM(\Phi)$.

Signal is described by

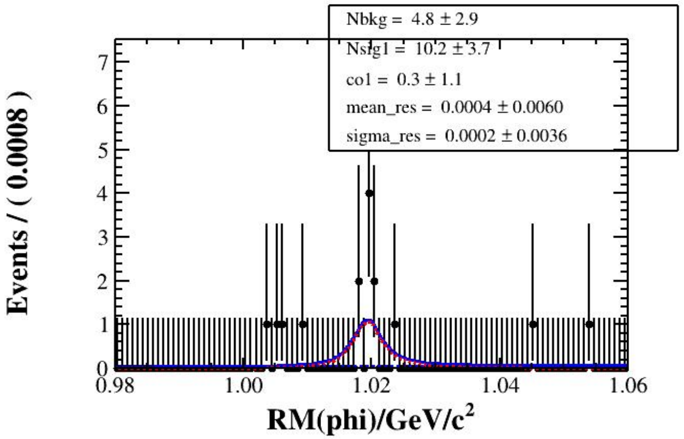
MC shape $\otimes$ Gauss

Background is described with a first-order polynomial function.

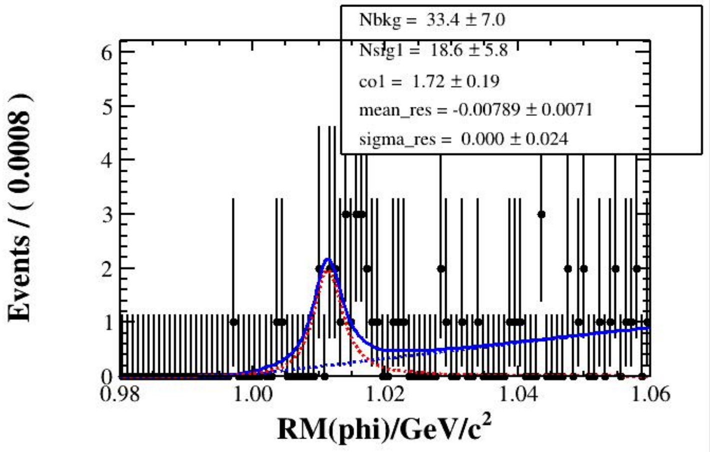
@2.000Gev



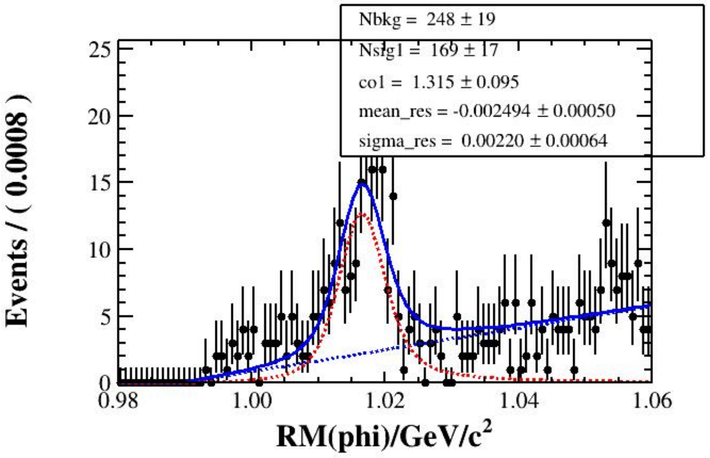
@2.050Gev



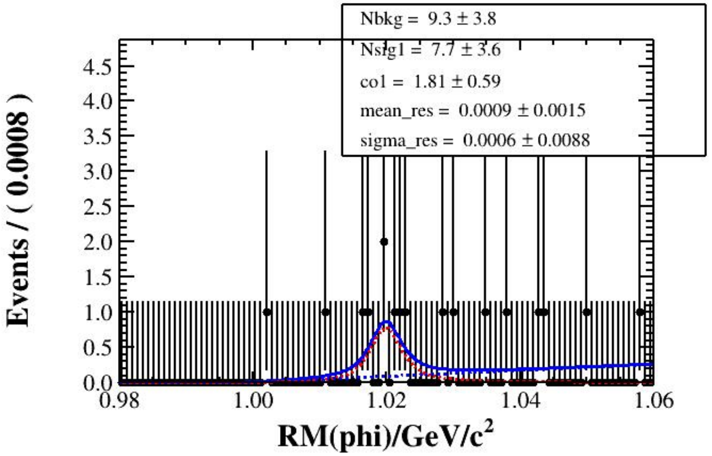
@2.100Gev



@2.125Gev



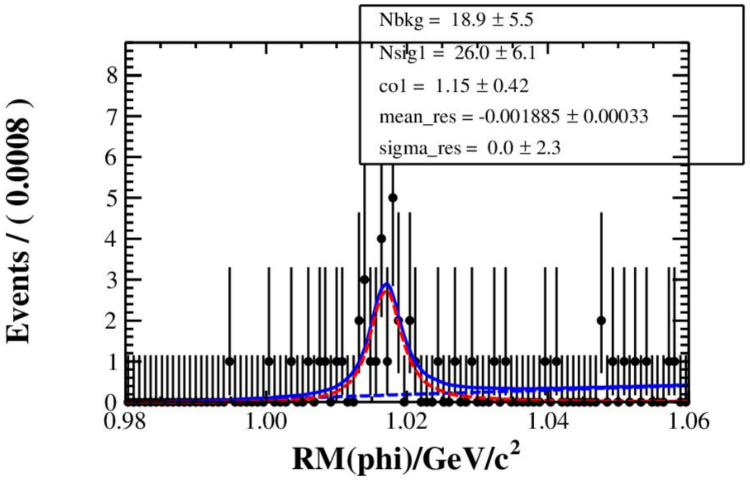
@2.150Gev



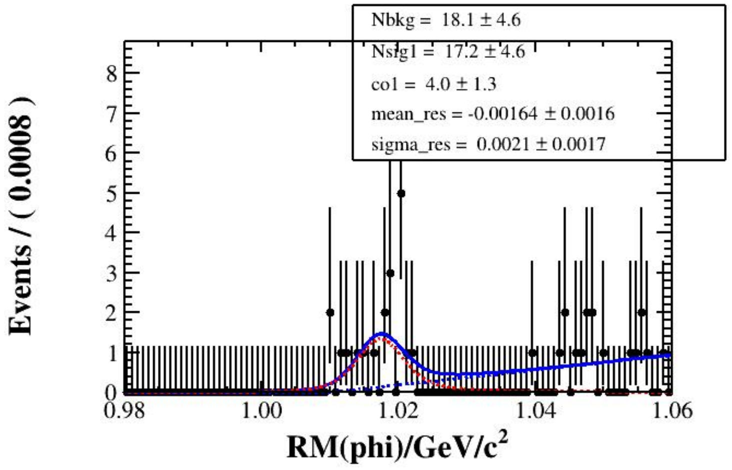
E_{cm} >2.0Gev

Signal yields

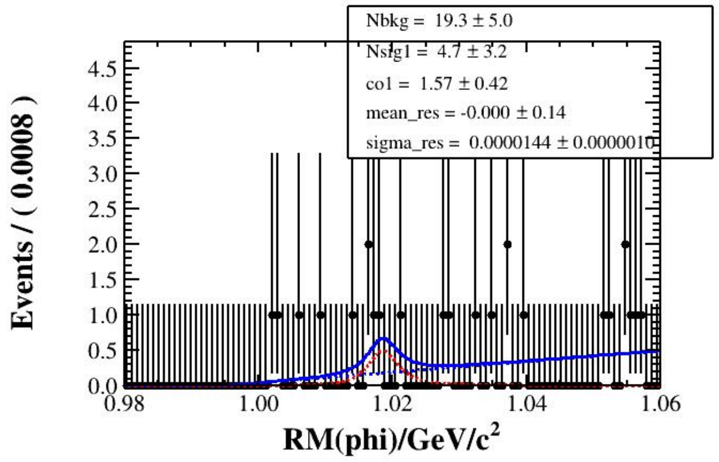
@2.175Gev



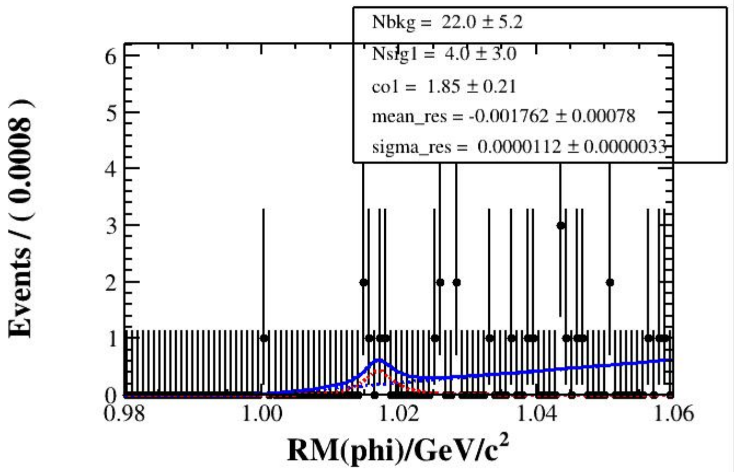
@2.200Gev



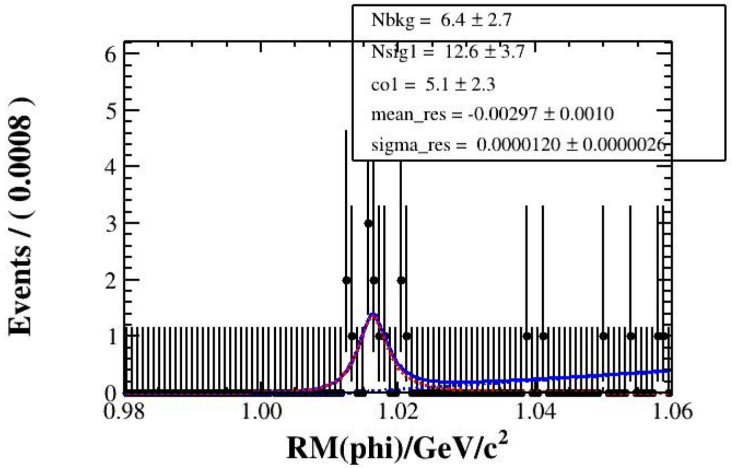
@2.2324Gev



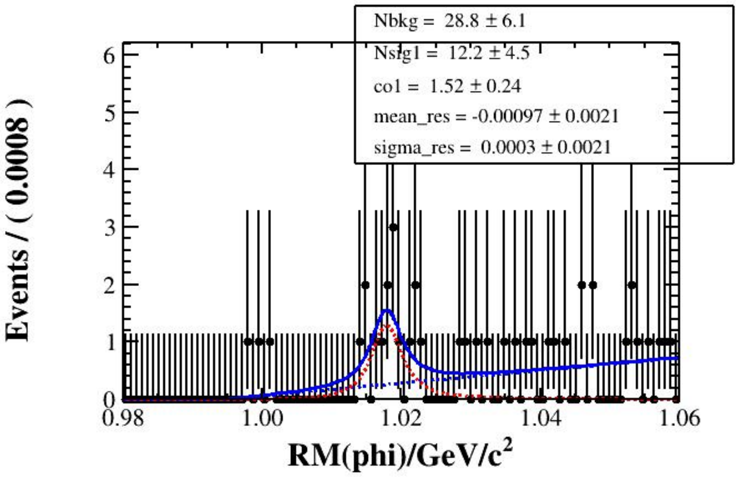
@2.3094Gev



@2.3864Gev



@2.3960Gev

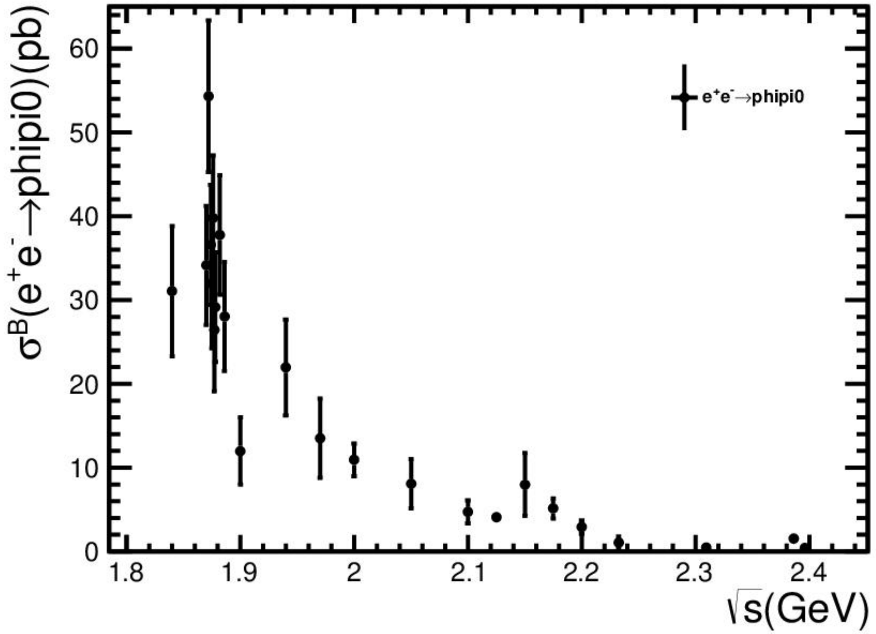


Cross section

Cross section calculation:

$$\sigma(e^+e^- \to phipi0) = \frac{N_{obs}}{\epsilon \cdot \mathcal{L} \cdot (1+\delta) \cdot \frac{1}{|1-\prod|^2}}$$

N_{obs}: signal yields



$\sqrt{s}$(Gev)	$\mathcal{L}$(1/pb)	N^{obs}	ϵ	$(1+\delta)\cdot\frac{1}{\lvert 1-\prod\rvert^2}$	σ^B(pb)
1840	1.501	16±4.0	0.30929	1.0236772	31.052±7.763
1870	2.002	23±4.8	0.23826	1.0243653	34.123±7.121
1872	2.014	36±6.0	0.32228	1.0243725	54.294±9.049
1874	2.019	26±5.1	0.32099	1.0243773	36.574±7.174
1875	1.485	17±4.2	0.32142	1.0243780	31.960±7.708
1876	2.035	29±5.4	0.31878	1.0244025	39.807±7.412
1877	1.341	13±3.7	0.32137	1.0244017	26.442±7.322
1878	2.021	20±4.5	0.31278	1.0243997	29.145±6.558
1882	2.033	28±5.3	0.31697	1.0243975	37.759±7.147
1886	2.031	19±4.4	0.30308	1.0244248	28.019±6.489

Cross section

$\sqrt{s}$(Gev)	$\mathcal{L}$(1/pb)	N^{obs}	ϵ	$(1+\delta)\cdot\frac{1}{\lvert 1-\prod\rvert^2}$	σ^B(pb)	$\sqrt{s}$(Gev)	$\mathcal{L}$(1/pb)	N^{obs}	ϵ	$(1+\delta)\cdot\frac{1}{\lvert 1-\prod\rvert^2}$	σ^B(pb)
1900	2.022	9±4.4	0.31189	1.0244973	11.995±3.998	**2150**	2.84	7.7±3.6	0.36551	1.0309417	8.007±3.743
1940	2.040	15±3.9	0.32802	1.0253173	21.945±5.706	**2175**	10.6	26.0±6.1	0.37561	1.0316347	5.141±1.206
1970	2.229	8±2.9	0.33205	1.0256117	13.516±4.731	**2200**	13.7	17.2±4.6	0.37720	1.0322960	2.927±0.783
2000	10.1	40.1±7.1	0.34482	1.0257275	10.943±1.937	**22324**	11.9	4.7±3.2	0.38148	1.0331155	1.069±0.728
2050	3.34	10.2±3.7	0.35489	1.0272650	8.084±2.932	**23094**	21.1	4.0±3.0	0.38415	1.0346510	0.509±0.382
2100	12.2	18.6±5.8	0.36073	1.0293558	4.732±1.376	**23864**	22.5	12.6±2.3	0.38063	1.0356943	1.530±0.279
2125	108	169±17	0.36210	1.0301695	4.076±0.410	**23960**	66.9	12.2±4.5	0.39097	1.0358138	0.448±0.165

Cross section fit

Model Fitting:

$$\sigma^{Dressed}(\sqrt{s}) = \left|\frac{a}{s^n}\sqrt{PS(\sqrt{s})} + Componet(\rho(1900)) + Componet(\rho(2170))\right|^2$$

$$PS(\sqrt{s}) = \frac{\sqrt{(s-(M_\phi - M_{\pi^0})^2)(s-(M_\phi + M_{\pi^0})^2)}}{2\sqrt{s}}$$

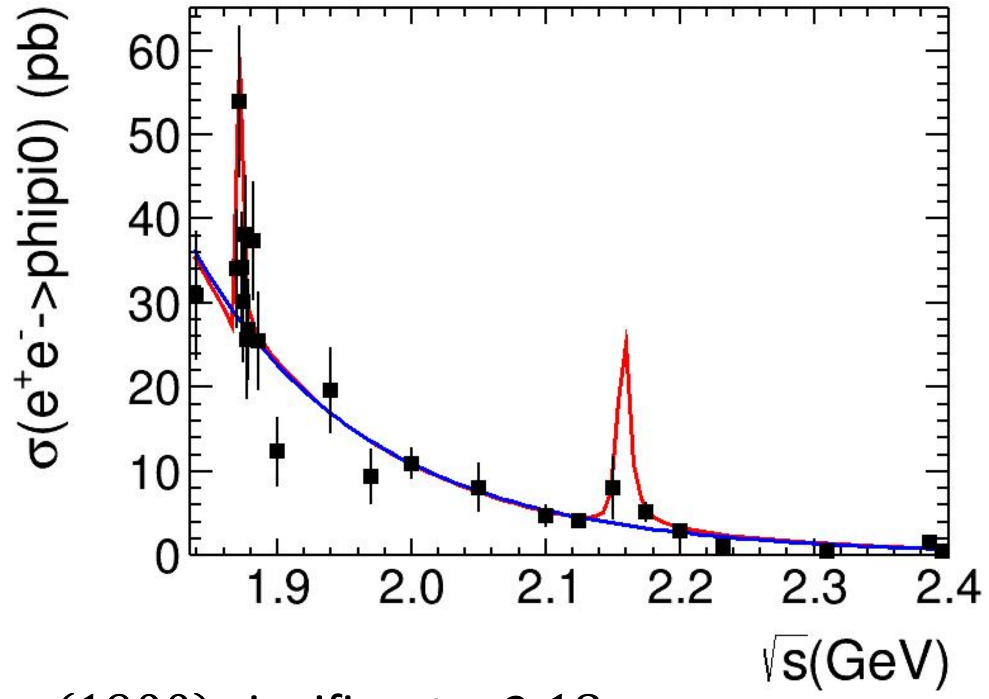
$$PS(M) = \frac{\sqrt{(M^2-(M_\phi - M_{\pi^0})^2)(M^2-(M_\phi + M_{\pi^0})^2)}}{2M}$$

$$Componet(\phi(1900)) = \frac{M}{\sqrt{s}}\frac{\sqrt{12\pi\Gamma_{ee}B_R\Gamma_{tot}}}{s-M^2+iM\Gamma_{tot}}\sqrt{\frac{PS(\sqrt{s})}{PS(M)}}e^{i\phi(1900)}$$

$$Componet(\phi(2170)) = \frac{M}{\sqrt{s}}\frac{\sqrt{12\pi\Gamma_{ee}B_R\Gamma_{tot}}}{s-M^2+iM\Gamma_{tot}}\sqrt{\frac{PS(\sqrt{s})}{PS(M)}}e^{i\phi(2170)}$$

Iterative MC generation method:

To evaluate the efficiency and ISR correction factor ,re-generate the MC events with ISR effect, with the CONEXC taking the new line shape as input.



$\rho(1900)$ significant ≈ 2.18$\boldsymbol{\sigma}$
$\rho(2170)$ significant ≈ 0.07$\boldsymbol{\sigma}$

Systematic Uncertainty

Luminosity	1.0%
Tracking	2.0%
PID	2.0%
Signal shape	11.59%
Background shape	9.76%
Fitting range	7.32%
Sum	17.1%

Summary

- Based on the data samples accumulated by the Beijing Spectrometer III (BESIII) detector when the center-of-mass energy is between 1.840 and 2.396 GeV, we conducted a precise measurement of the cross section for the process $e^+e^-\to\phi\pi^0$.
- The systematic uncertainties have been completed.
- By fitting cross section , We found that the significance of ρ(1900) is 2.29σ, and the significance of ρ(2170) is 0.08σ.No significant signal was found for this process.However, we observed a significant jump at 1900.

Next to do:

- *Prepare the memo.*