Study of $e^+e^- \to \phi\eta$ at energy point from1.84 to 1.97 GeV

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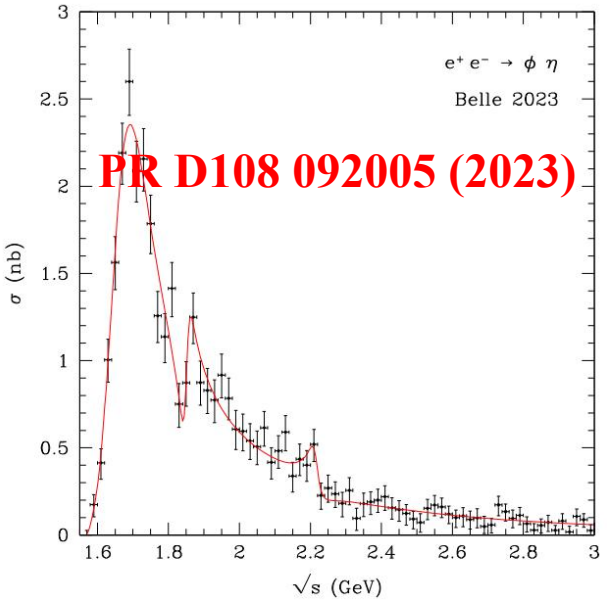
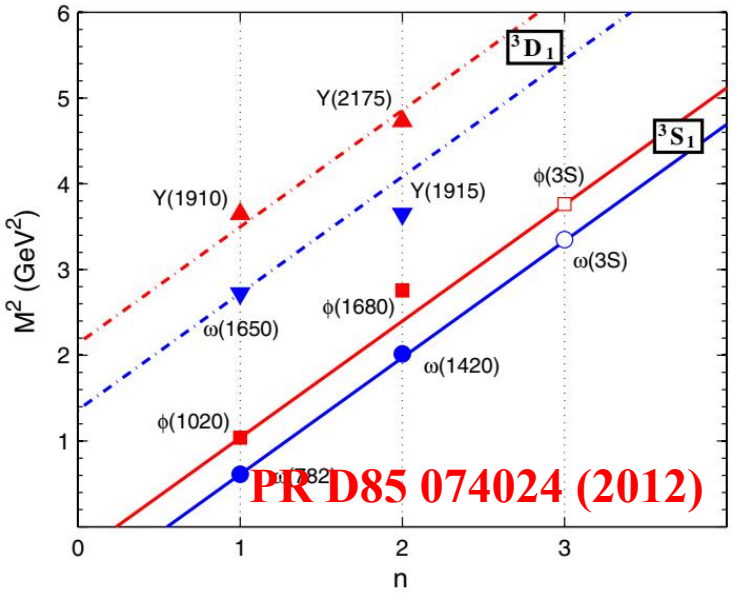
Introduction

- Predicted f(1D) state around 1.8 GeV, with large width ~ 400 MeV.
- Refit Belle $e^+e^- \to \phi\eta$ data, very narrow structure around 1.85 GeV.



PR D108 092005 (2023)



PR D85 074024 (2012)

	ϕ(1D)	X(2175) as ϕ(2D)	ϕ(3D)
Channel	Value	Value	Value
Total	442	186	229
KK_1	318	70.7	61.4
K^*K^*	11.5	33.4	40.5
KK	40.8	25.4	17.4
KK^*	57.8	18.7	12.6
$\eta\phi$	13.6	0.879	0.3
$\eta'\phi$	···	0.0887	0.087
$KK^*(1410)$	···	19.6	5.76
$KK_2^*(1430)$	···	14.5	12.1
KK_1'	···	2.56	0.59
$K^*K^*(1410)$	···	···	45.6
K^*K_1	···	···	26.8
$KK_3^*(1780)$	···	···	3.27
$f_1(1426)\phi$	···	···	2.16
K^*K_1'	···	···	0.454

PR D99 074015 (2019)

	1 resonance	2 resonances	3 resonances
r_1	0.3761(94)	0.291(29)	0.360(14)
M_1 (MeV)	1650.5 ± 4.1	1661.8 ± 6.0	1656.8 ± 4.9
Γ_1 (MeV)	158.7 ± 5.3	125 ± 12	150.8 ± 7.0
Σ_1	40σ	10σ	25σ
r_2		0.050(32)	0.0077(43)
M_2 (MeV)		1921 ± 86	1850.7 ± 5.3
Γ_2 (MeV)		290 ± 230	25 ± 35
δ_2		0.8 ± 1.2	5.59(44)
Σ_2		1.5σ	1.7σ
r_3			0.0044(22)
M_3 (MeV)			2215.7 ± 8.3
Γ_3 (MeV)			35 ± 23
δ_3			2.59(39)
Σ_3			2.0σ
χ^2/NDF	83.6/69	58.5/65	47.1/61
CL (%)	11.1	70.2	90.4

Data Sample

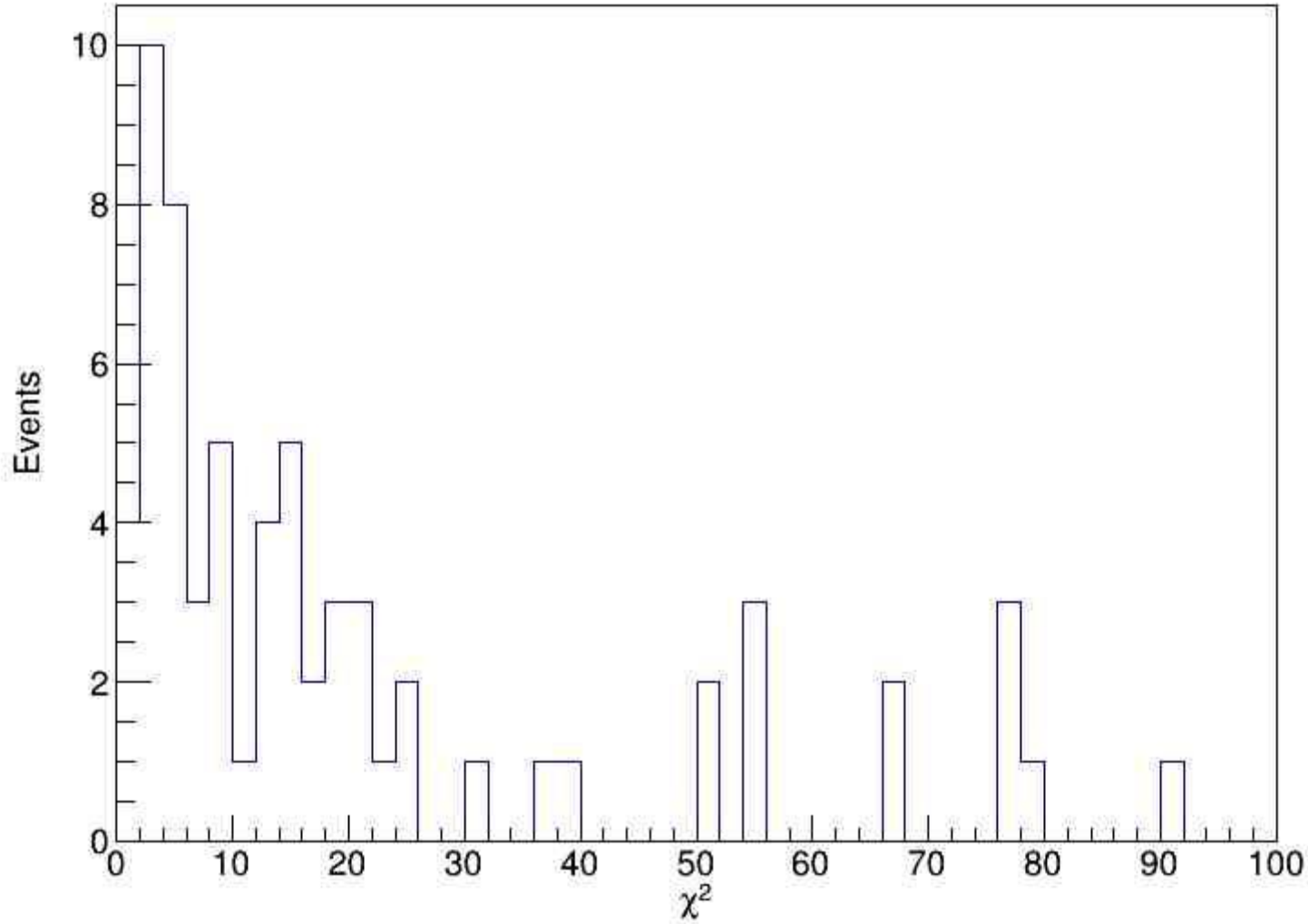
- BOSS version :711
- Data sets: new R scan data
- MC samples(ConExc):
  - 0.1M events per energy point

BESIII(GeV)	L(pb^{-1})
1.84	1.501
1.87	2.003
1.872	2.014
1.874	2.018
1.875	1.485
1.876	2.035
1.877	1.341
1.878	2.021
1.882	2.033
1.886	2.031
1.900	2.022
1.940	2.040
1.970	2.229

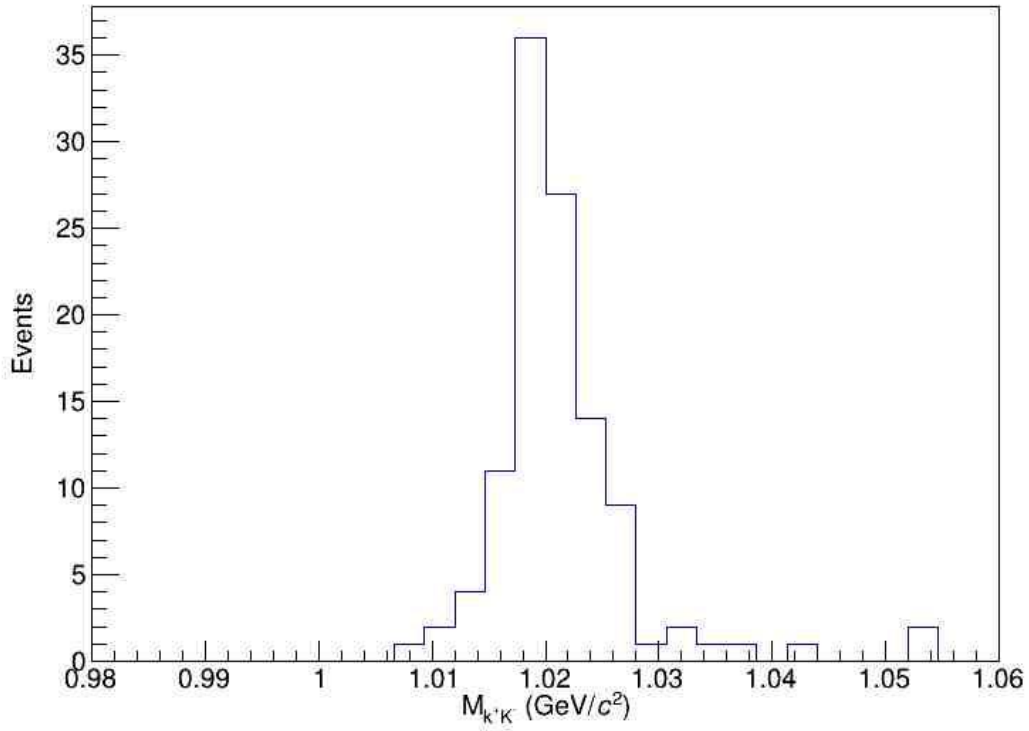
Event selection

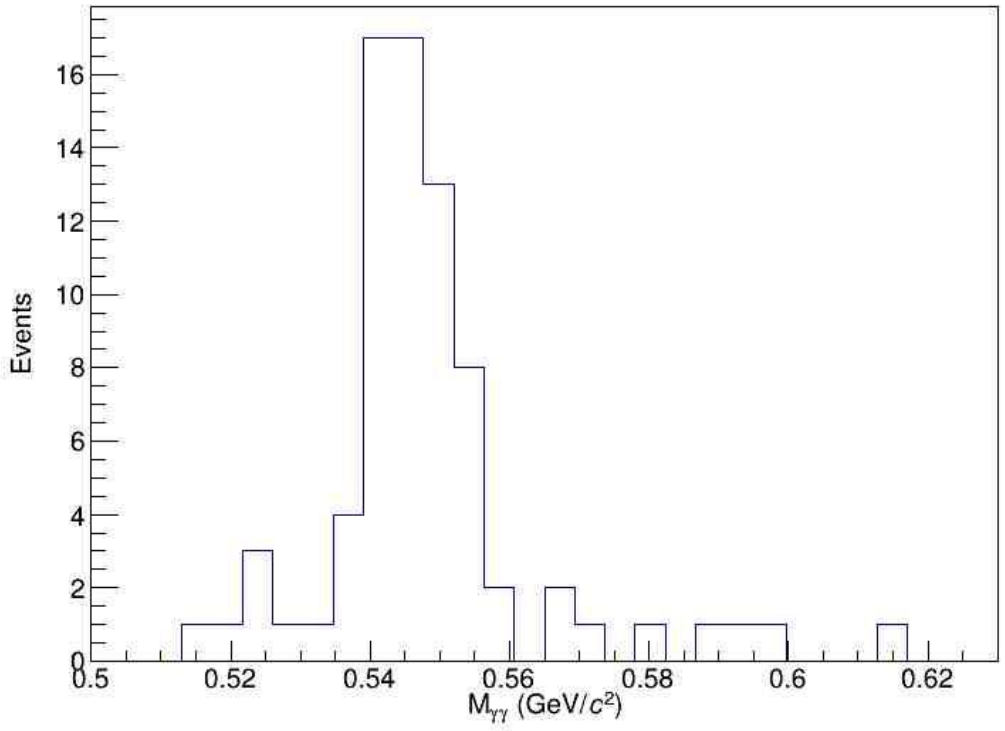
- Good Charged Track
  - $|V_r| < 1\text{cm}$
  - $|V_z| < 10\text{cm}$
  - $|\cos\theta| < 0.93$
  - $\mathrm{N_{good}} = 2$
  - $\mathrm{N_p} = \mathrm{N_m}$
- Good Photon Track
  - $\mathrm{E_{endcap}} > 40$ MeV
  - $\mathrm{E_{barrel}} > 20$ MeV
  - 0<TDC<700 ns
  - $\mathrm{N_{photon}} >= 2$
- PID
  - prob(K)>prob(pi),prob(K)>0.001
  - $\mathrm{N_{K+}} = \mathrm{N_{K-}} = 1$
- 4C Kinematic Fit
  - $\chi^2 < 100$
- Signal region
  - $0.98 < \mathrm{M}(\phi) < 1.05$ GeV
  - $0.48 < \mathrm{M}(\eta) < 0.62$ GeV

1.874GeV Event selection

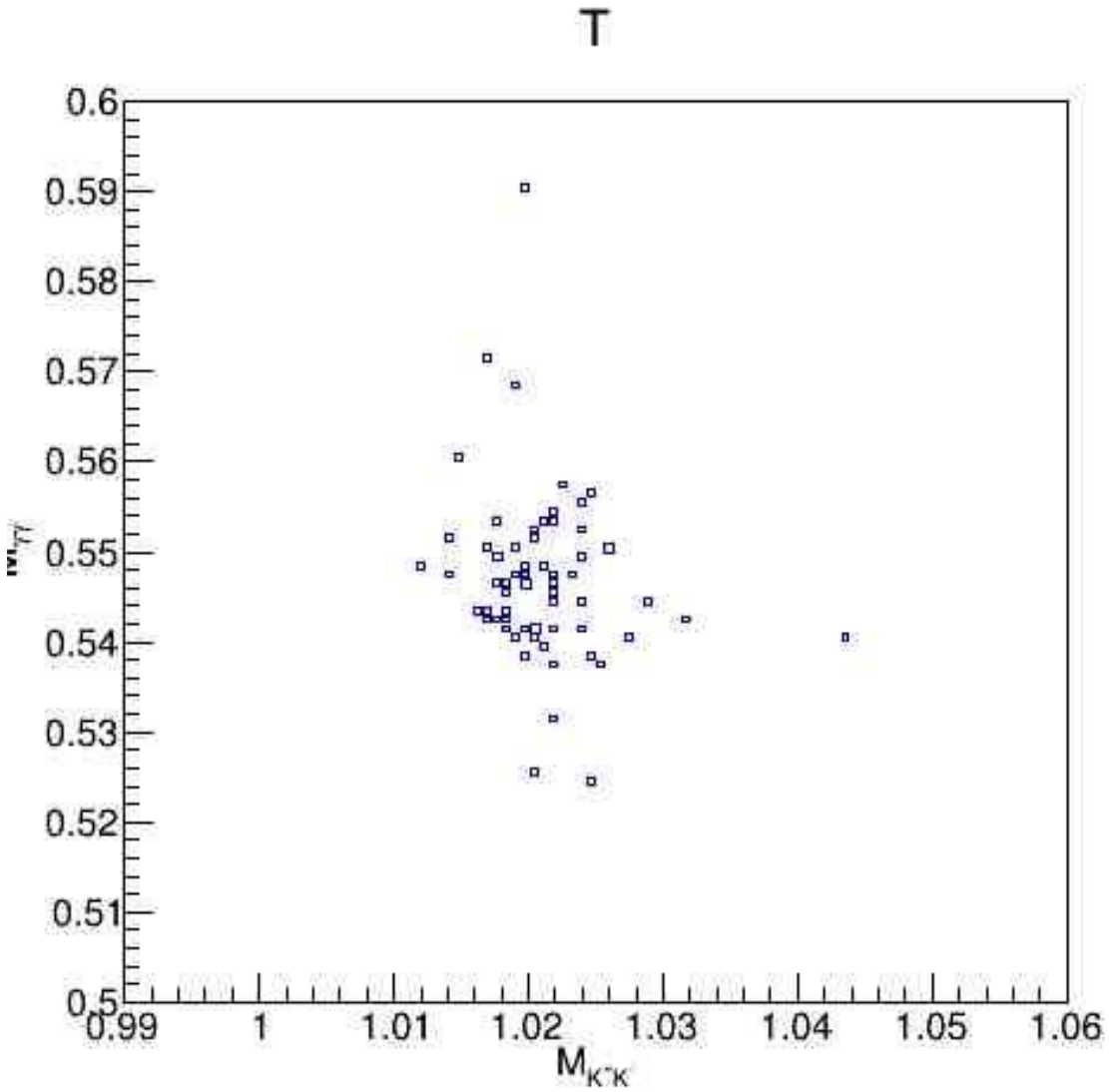


1.874GeV signal distribution

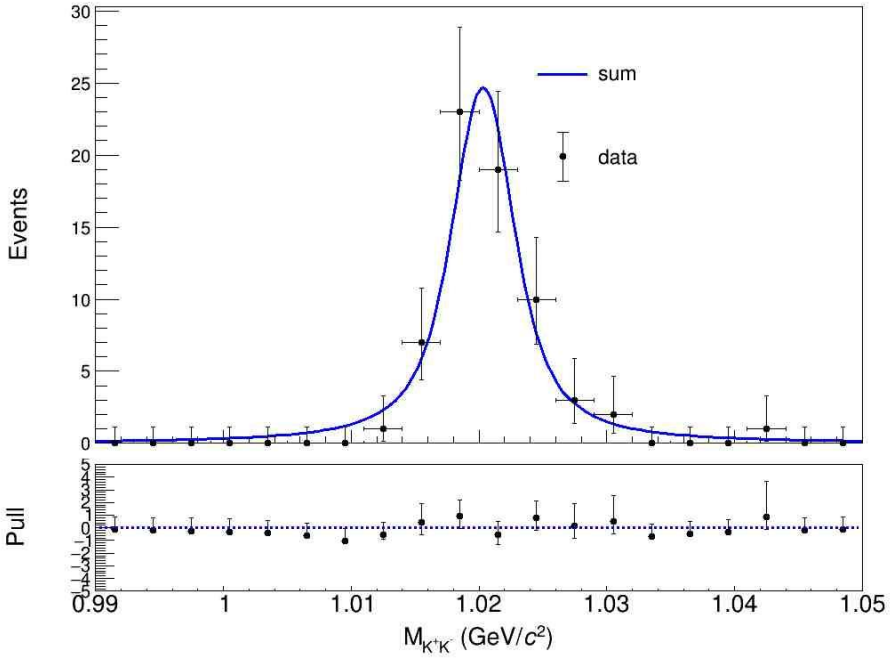


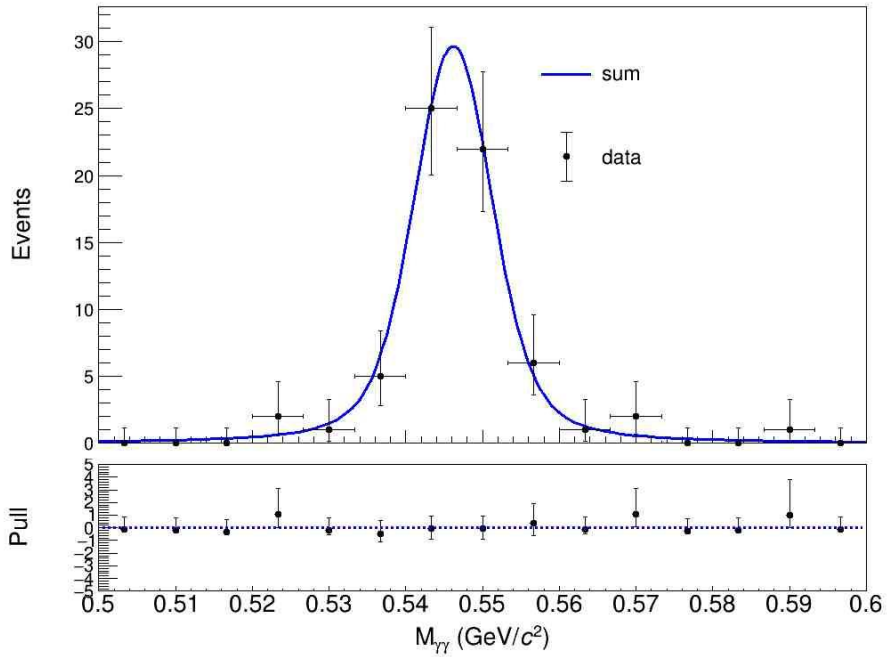


1.874GeV signal distribution



Data fit Gauss⊗Breit-Wigner

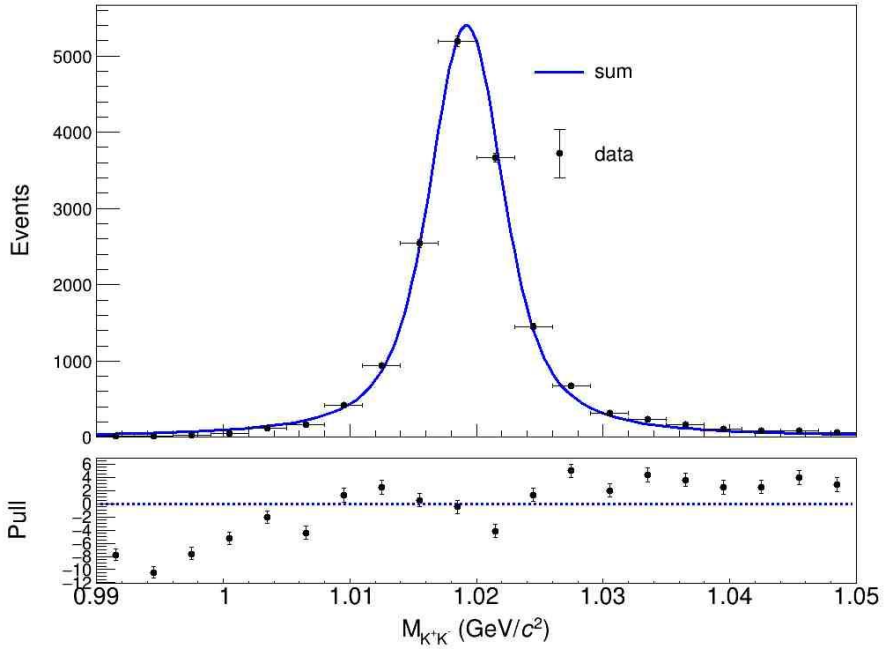


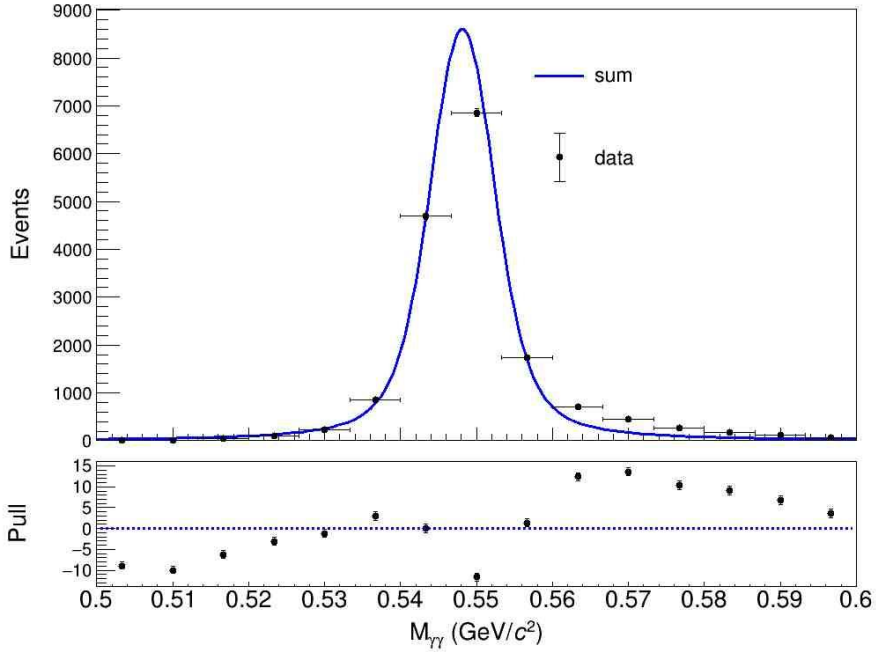


EXT NO.	PARAMETER NAME	VALUE	ERROR
1	mean0	9.01906e-04	1.39584e-03
2	nsig	6.60278e+01	8.12654e+00
3	sigma0	1.30840e-03	6.75255e-04

EXT NO.	PARAMETER NAME	VALUE	ERROR
1	mean0	-7.67885e-04	7.84281e-04
2	nsig	6.49931e+01	8.06155e+00
3	sigma0	4.16476e-03	7.45021e-04

MC fit Gauss⊗Breit-Wigner

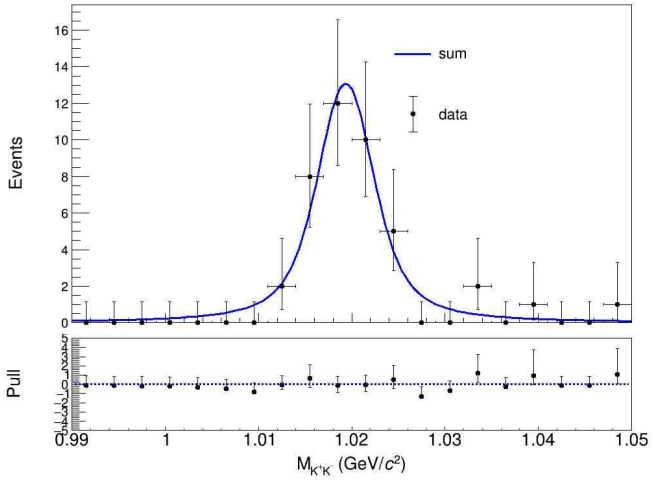




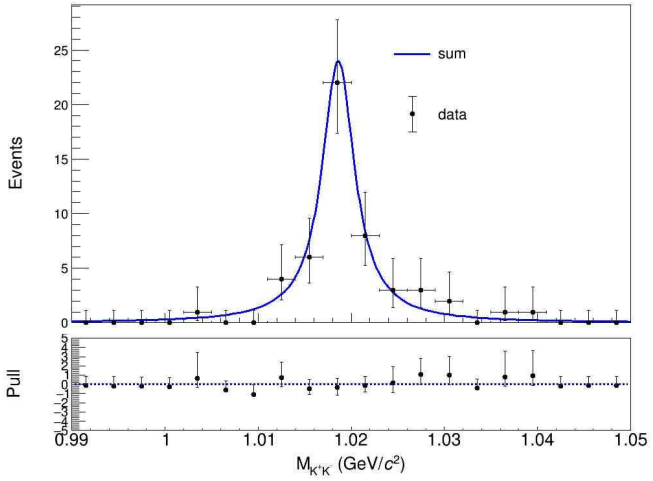
EXT	PARAMETER		
NO.	NAME	VALUE	ERROR
1	mean0	-2.23619e-04	3.20363e-05
2	nsig	1.63499e+04	1.27860e+02
3	sigma0	1.82901e-03	4.71660e-05

EXT	PARAMETER		
NO.	NAME	VALUE	ERROR
1	mean0	1.20309e-03	4.51427e-05
2	nsig	1.62981e+04	1.27659e+02
3	sigma0	3.32184e-03	5.81128e-05

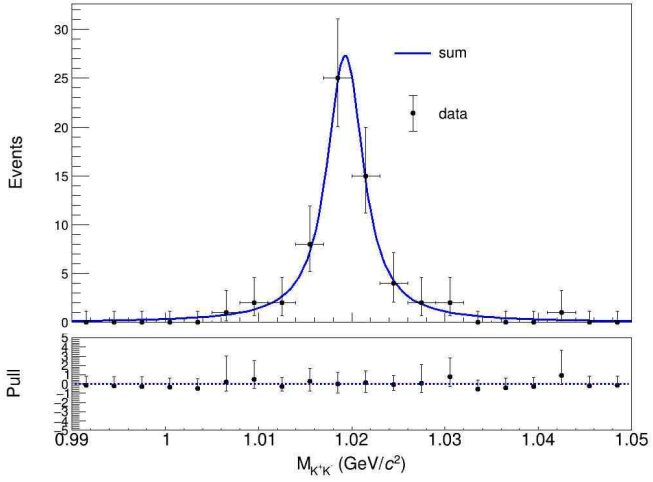
其他能量点$m_{k^+k^-}$



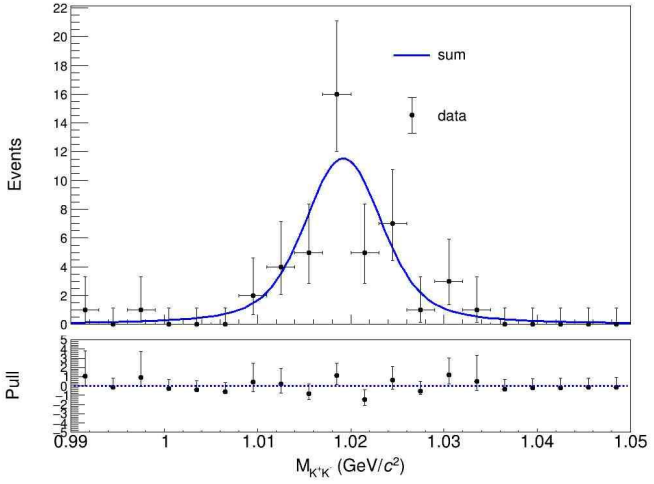
1.840GeV



1.870GeV

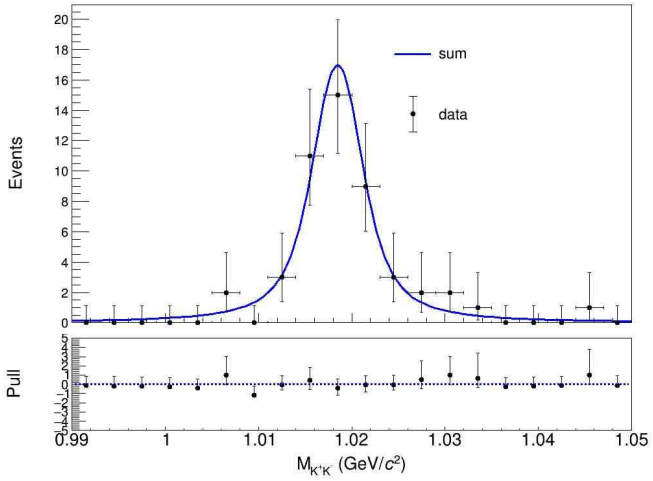


1.872GeV

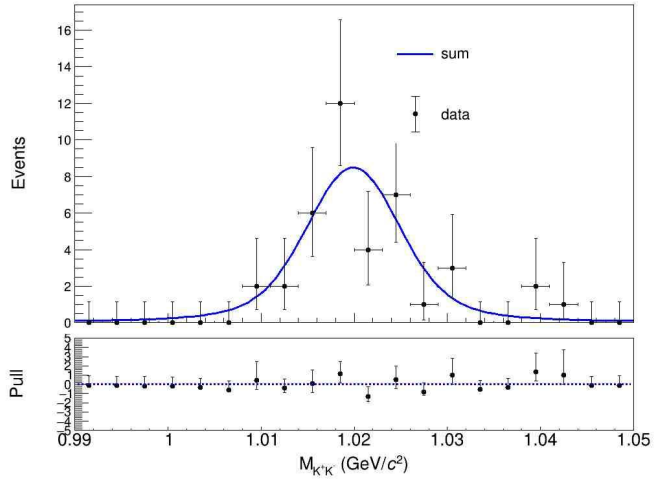


1.875GeV

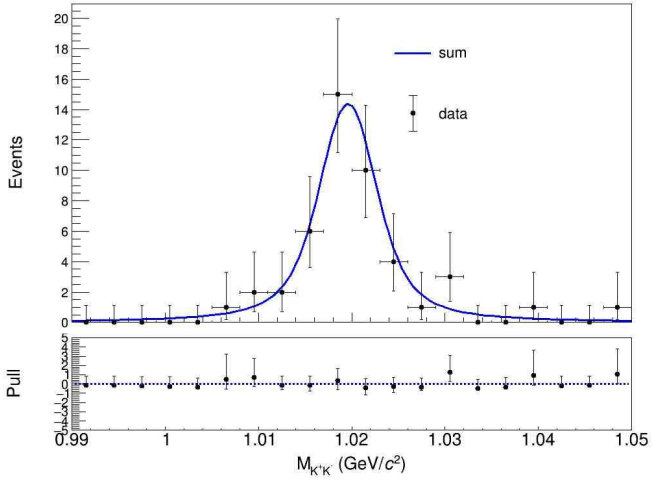
其他能量点$m_{k^+k^-}$



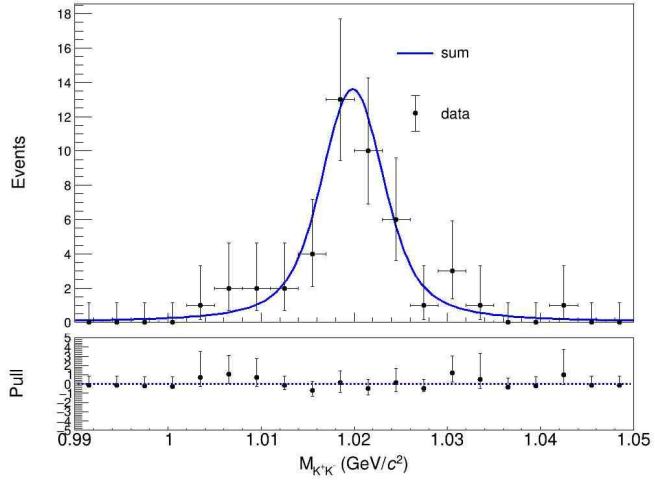
1.876GeV



1.877GeV

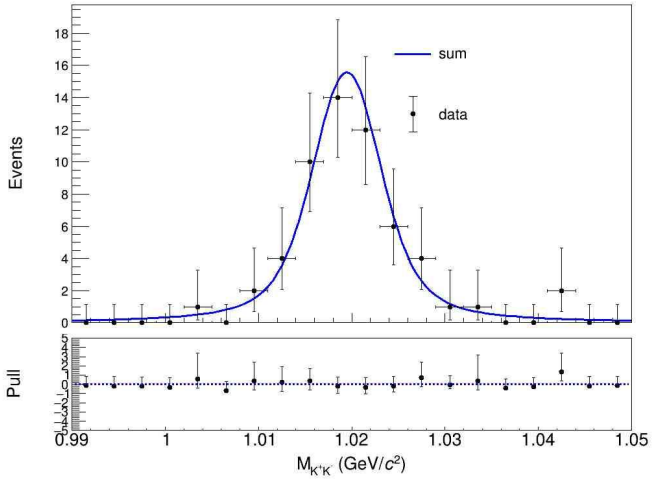


1.878GeV

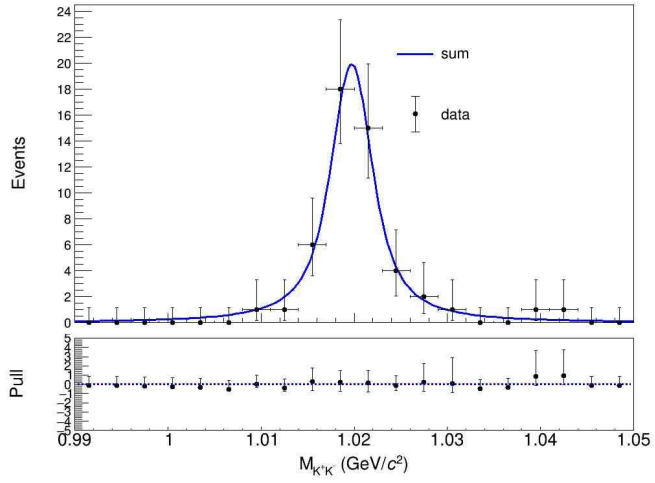


1.882GeV

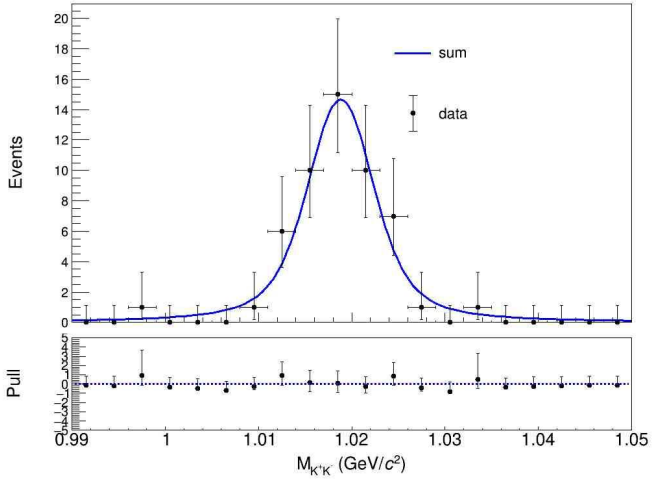
其他能量点$m_{k^+k^-}$



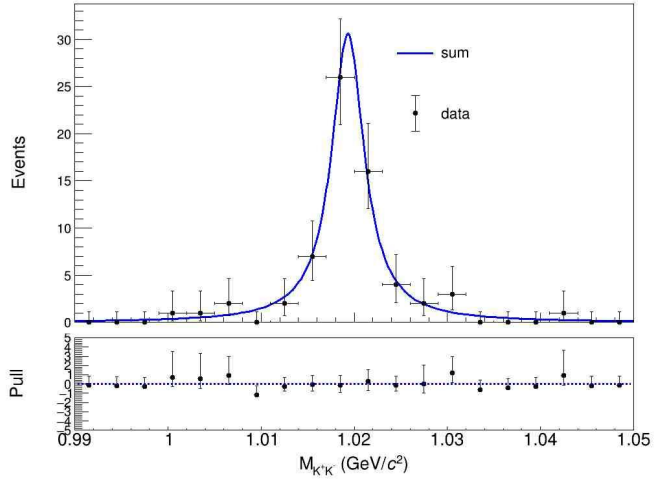
1.886GeV



1.900GeV



1.940GeV



1.970GeV

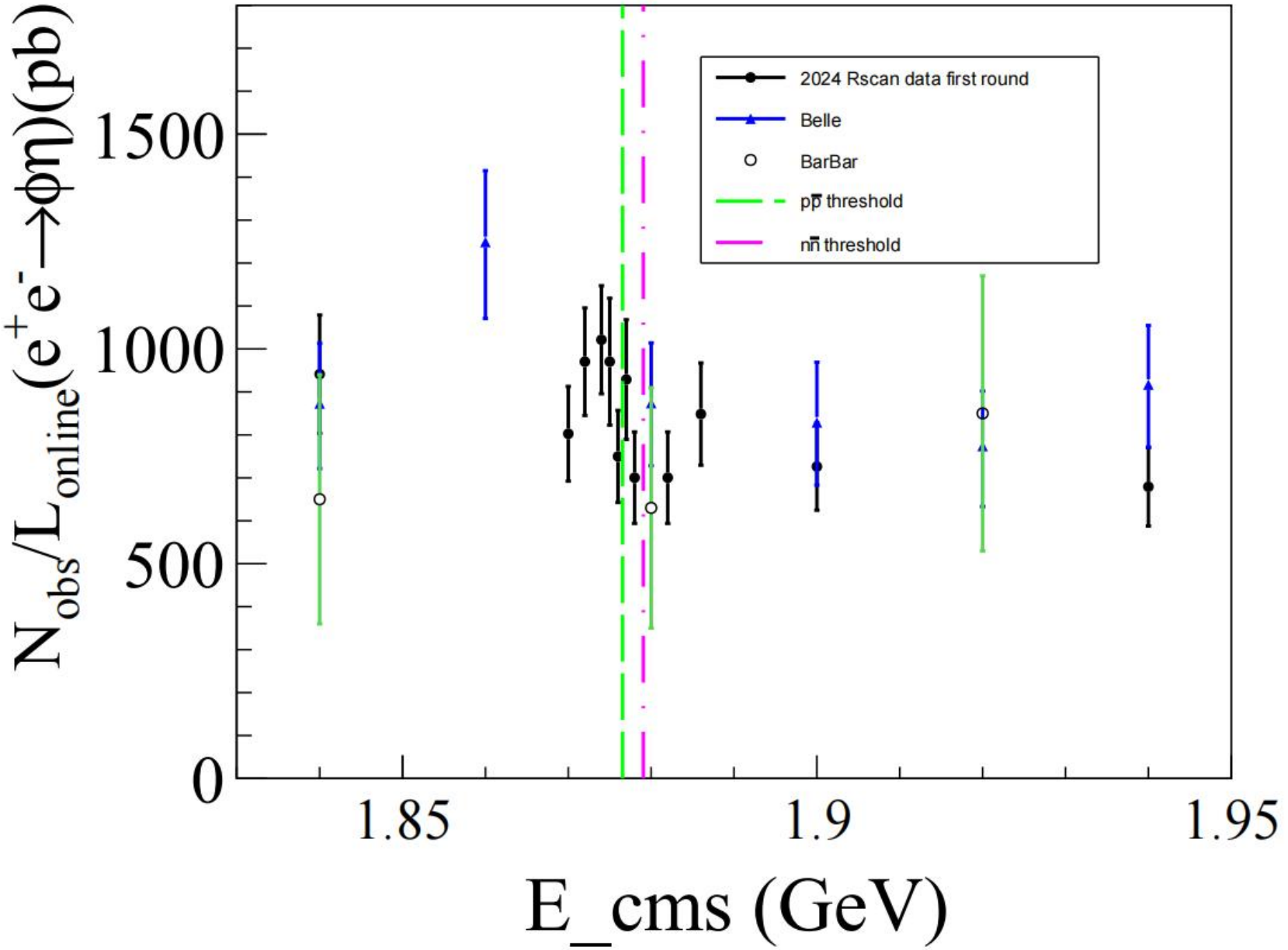
截面计算：

$$\sigma = \frac{n_{observed\ events}}{L \cdot \epsilon_{MC} \cdot BR(\eta \to \gamma\gamma) \cdot BR(\phi \to K^{+}K^{-})}$$

截面

BESIII(GeV)	observed events	$L(pb^{-1})$	ε(%)	N/(Lε)(pb)
1.84	41±6	1.501	15.0	941.31±137.75
1.87	51±7	2.003	16.4	802.54±110.15
1.872	62±8	2.014	16.4	970.31±125.2
1.874	65±8	2.018	16.3	1021.47±125.72
1.875	46±7	1.485	16.5	970.44±147.68
1.876	49±7	2.035	16.6	749.8±107.11
1.877	40±6	1.341	16.6	928.85±139.33
1.878	46±7	2.021	16.8	700.33±106.57
1.882	46±7	2.033	16.7	700.37±106.58
1.886	57±8	2.031	17.1	848.38±119.07
1.900	50±7	2.022	17.6	726.27±101.68
1.940	52±7	2.040	19.4	679.19±91.43
1.970	65±8	2.229	20.3	742.56±91.39

截面

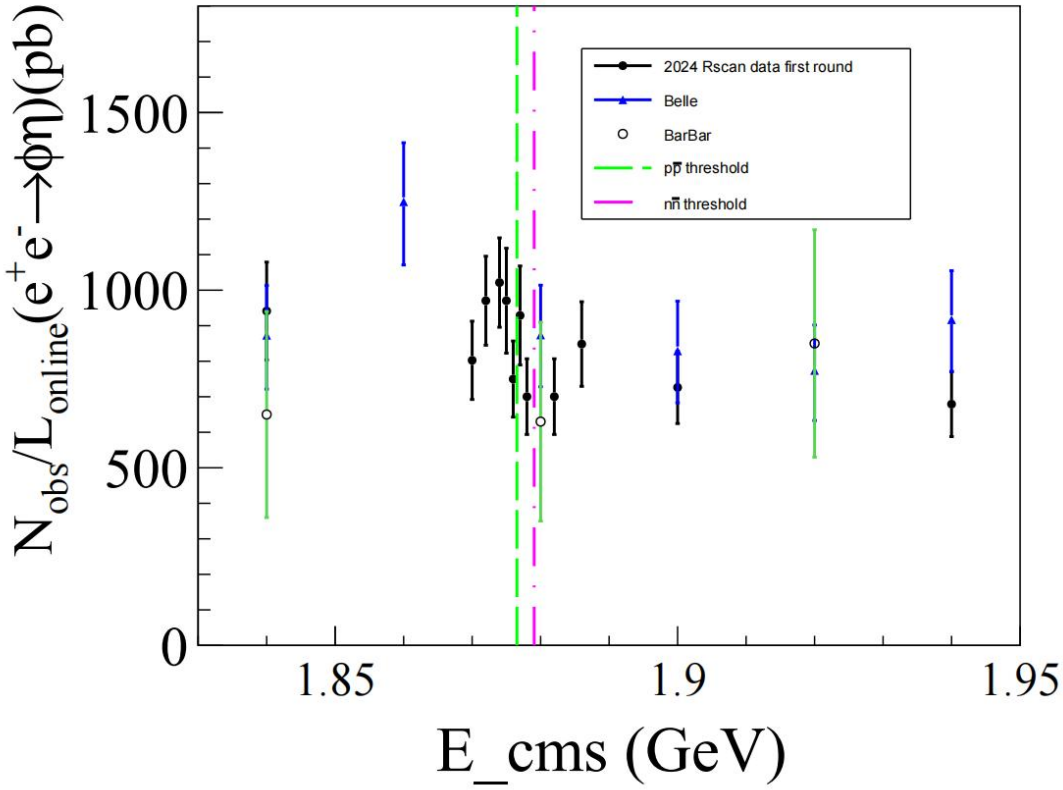

2024 Rscan data first round
Belle
BarBar
p$\bar{p}$ threshold
n$\bar{n}$ threshold
$N_{obs}/L_{online}(e^+e^-\to\phi\eta)(pb)$
1500
1000
500
0
1.85
1.9
1.95
E_cms (GeV)

Summary

- We use K+K- to reconstruct ϕ and $\gamma\ \gamma$ for η

- After dealing with the data and MC samples, we obtained the distribution of the cross section as a function of energy

- Next to do
  - Involving more decay channels of ϕ and η to achieve a larger statistical sample
  - Imposing stricter restrictions on event selection criteria



Backup cross check

BESIII(GeV)	observed events	L(pb^{-1})	ε(%)	N/(Lε)(pb)	N/(Lε)(pb)
1.84	41±6	1.501	15.1	935.08±136.84	941.31±137.75
1.87	51±7	2.003	16.5	797.68±109.49	802.54±110.15
1.872	62±8	2.014	16.5	964.43±124.44	970.31±125.2
1.874	64±8	2.018	16.5	993.57±124.2	1021.47±125.72
1.875	46±7	1.485	16.6	964.6±146.79	970.44±147.68
1.876	50±7	2.035	16.7	760.52±106.47	749.8±107.11
1.877	39±6	1.341	16.7	900.21±138.49	928.85±139.33
1.878	46±7	2.021	17	692.09±105.32	700.33±106.57
1.882	46±7	2.033	16.9	692.08±105.32	700.37±106.58
1.886	56±7	2.031	17.3	823.86±102.98	848.38±119.07
1.900	51±7	2.022	17.8	732.47±100.54	726.27±101.68
1.940	51±7	2.040	19.5	662.72±90.961	679.19±91.43
1.970	64±8	2.229	20	742.1±92.762	742.56±91.39