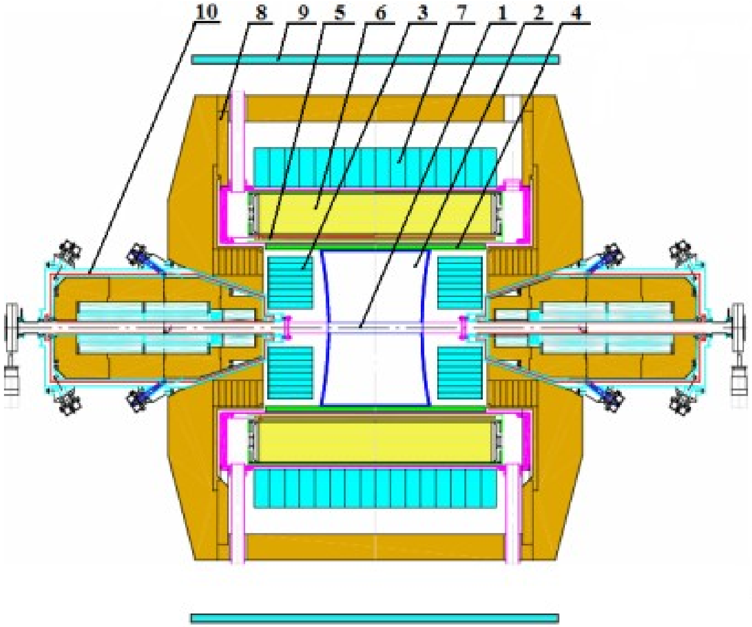
Study of the process $e^+e^- \to K_SK_L$ in the energy range above 1.0 GeV with the CMD-3 detector.

Nikita Petrov, BINP, NSU.
Scientific Advisor: Peter A. Lukin

Goal

- To measure the cross section of the process $e^+e^- \to K_S K_L$ in the 1.1 – 2.0 GeV center-of-mass energy range.

CMD-3 and VEPP-2000



The CMD-3 detector layout.

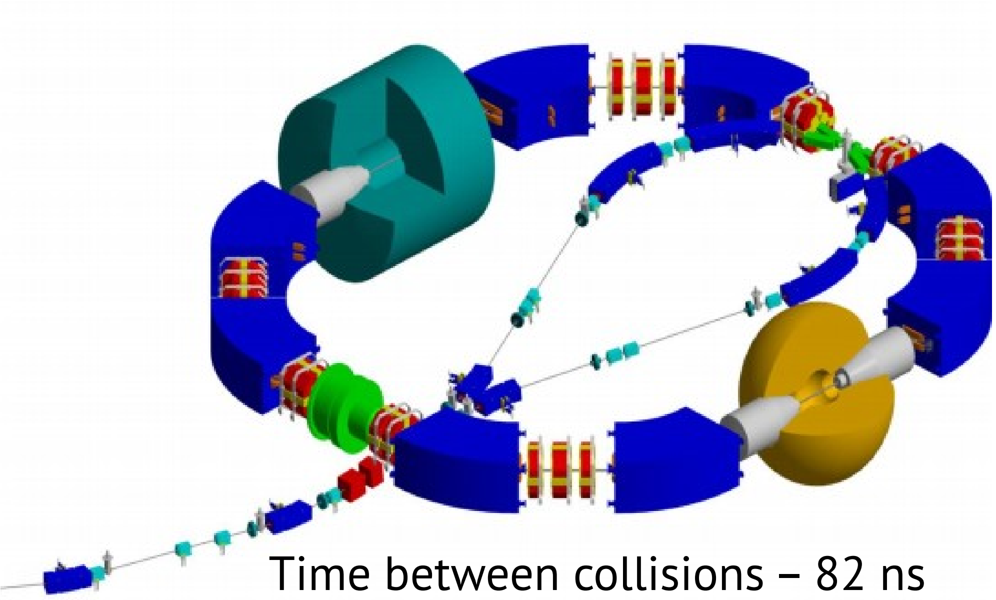
1 – beam pipe, 2 – drift chamber,

3 – BGO end cap calorimeter, 4 – Z-chamber,

5 – superconducting solenoid, 6 – LiXe calorimeter,

7 – CsI calorimeter, 8 – yoke,

9 – outer muon system, 10 – VEPP solenoids.



Time between collisions – 82 ns

Beam current – 200 mA

Collision length – 3.3 cm

Beam energy dispersion – 0.7 MeV

Perimeter – 24.4 m

L = 10^{32} cm^{-2}s^{-1} at 2.0 GeV

L = 10^{31} cm^{-2}s^{-1} at 1 GeV

Experiment and Monte Carlo simulation

We use 2011, 2012 and 2017 experimental data.

Year	Integrated Luminosity, pb^{-1}	Number of energy points	Energy range (center-of-mass), GeV
2011	18,9	38	1,1 – 2,0
2012	13,2	16	1,28 – 1,98
2017	39,6	28	1,45 – 2,007

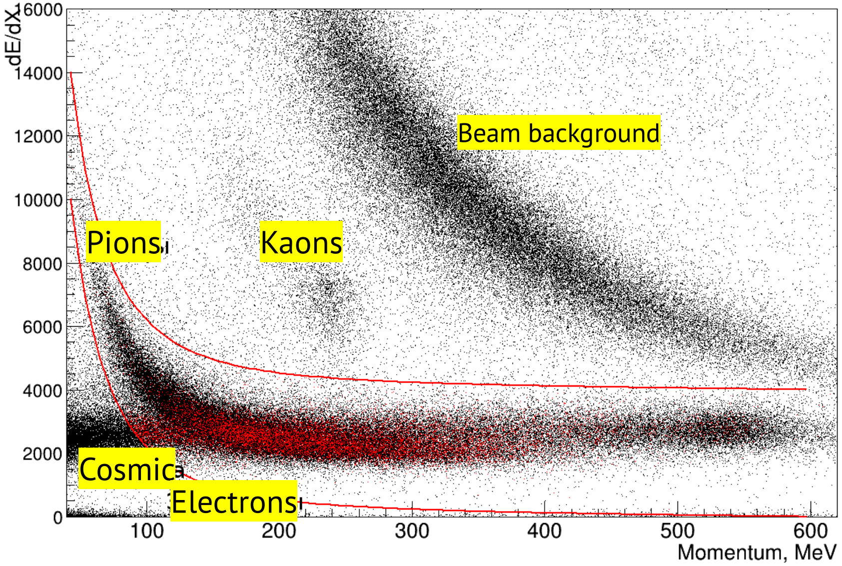
20 000 events of $e^+e^- \to K_S K_L(\gamma)$ were simulated for each of 51 energy points in the center-of-mass energy range 1.1 – 2.0 GeV

Selection criteria of $e^+e^- \to K_SK_L$

- Process is detected by the decay $K_S \to \pi^+\pi^-$, according to the special procedure.
- K_S-candidate has to be reconstructed by two «good» tracks.

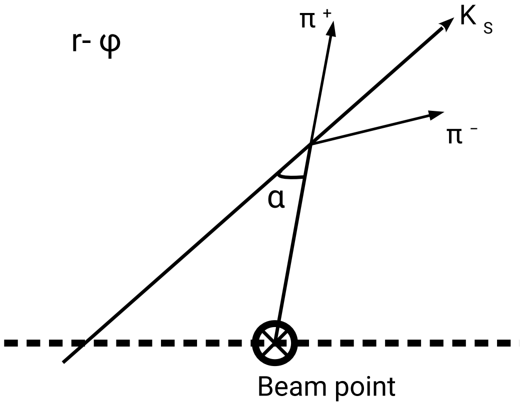
«Good» tracks selection criteria:

- $|z| < 15$ cm
- $0{,}9 < \theta < \pi-0{,}9$
- $|\rho| > 0{,}1$ cm
- $|p| > 40$ MeV
- $\chi_r^2 < 30$; $\chi_z^2 < 25$
- dE/dX of the tracks corresponds to pion ionization losses

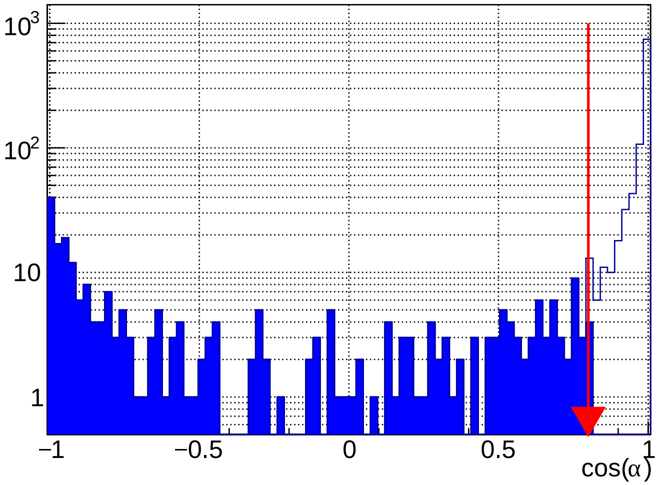


Ionization losses, red lines shows the selection criterion. ($\sqrt{s}$ = 1,1 GeV)

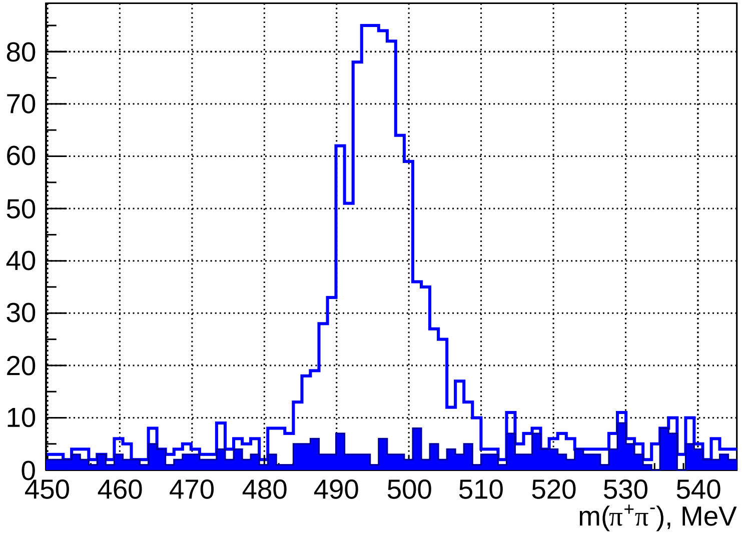
Selection criteria of $e^+e^- \to K_SK_L$



α – the angle between the vector directed from the beam point to the K_S decay point and the K_S momentum.



The cos α distribution and the selection criterion: cos α > 0.8



The invariant mass distribution with the α selection

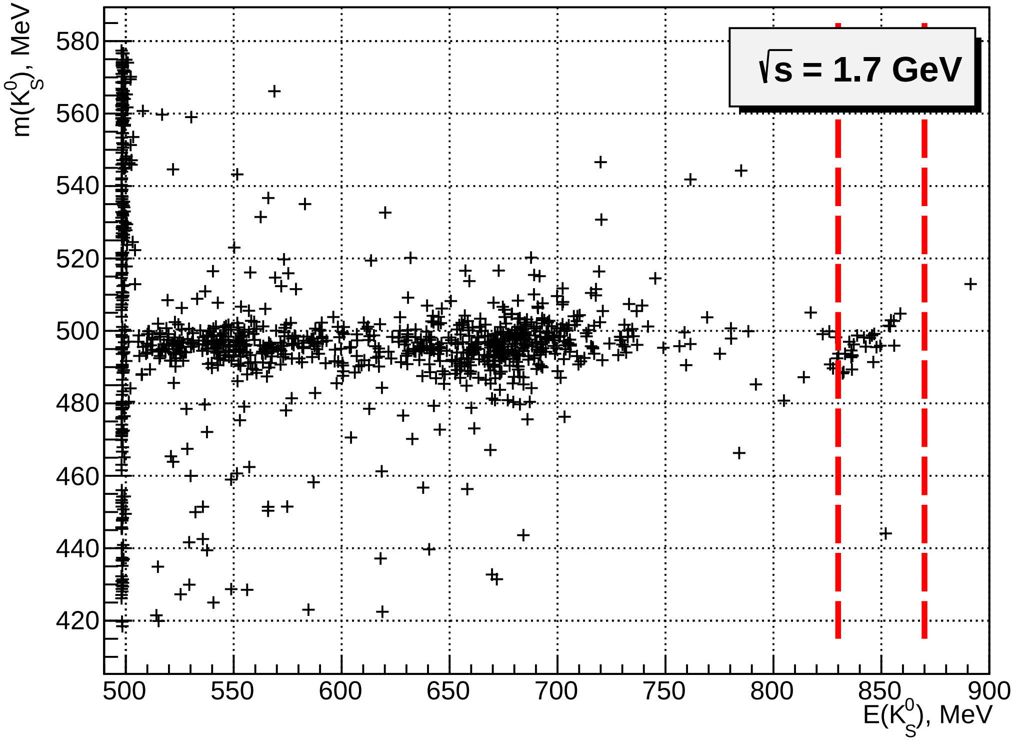
Selection criteria of $e^+e^- \to K_S K_L$

K_S energy is equal to beam energy

$$| E(K_S) - E_{beam} | < 20 \text{ MeV}$$

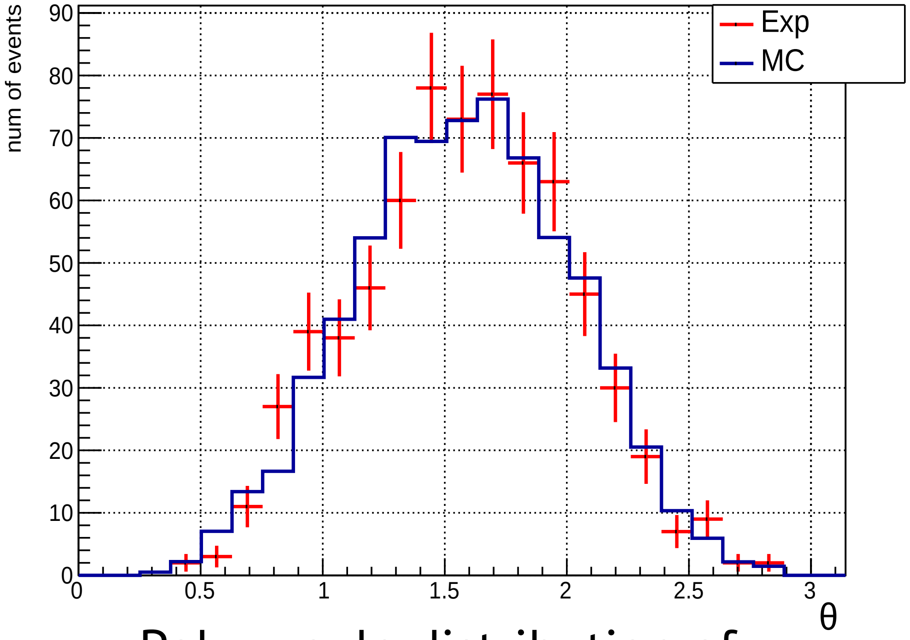
This selection excludes these background processes:

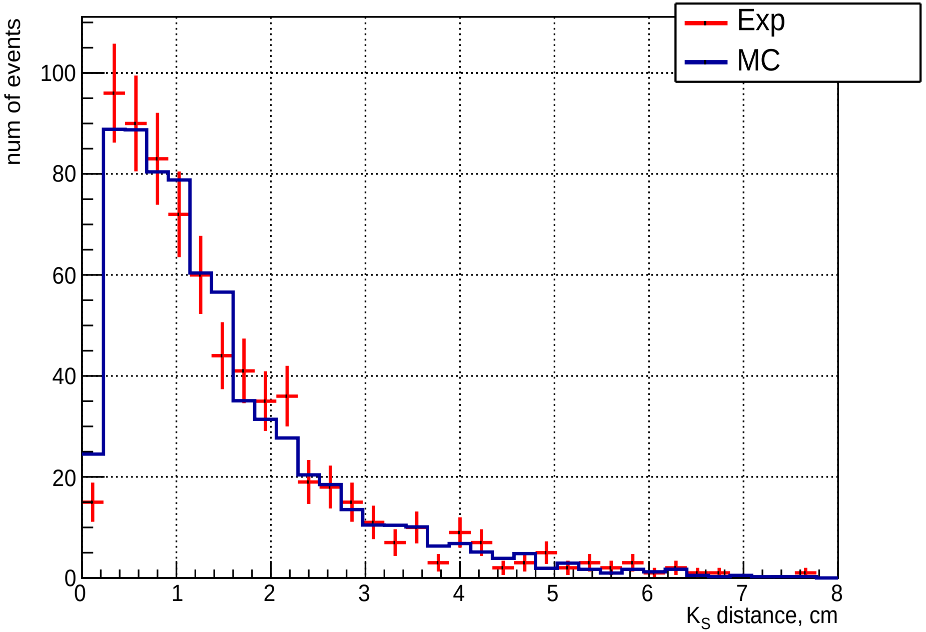
$e^+e^- \to K_S K_L \eta$; $e^+e^- \to K_S K_L \pi^0$



Invariant mass – energy distribution, red lines show the selection criterion. (√s = 1.7 GeV)

Polar angle distribution (left fig.) and flight length distribution (right fig.) for selected K_S.





Polar angle distribution of the selected K_S in the energy range 1.1 – 1.15 GeV

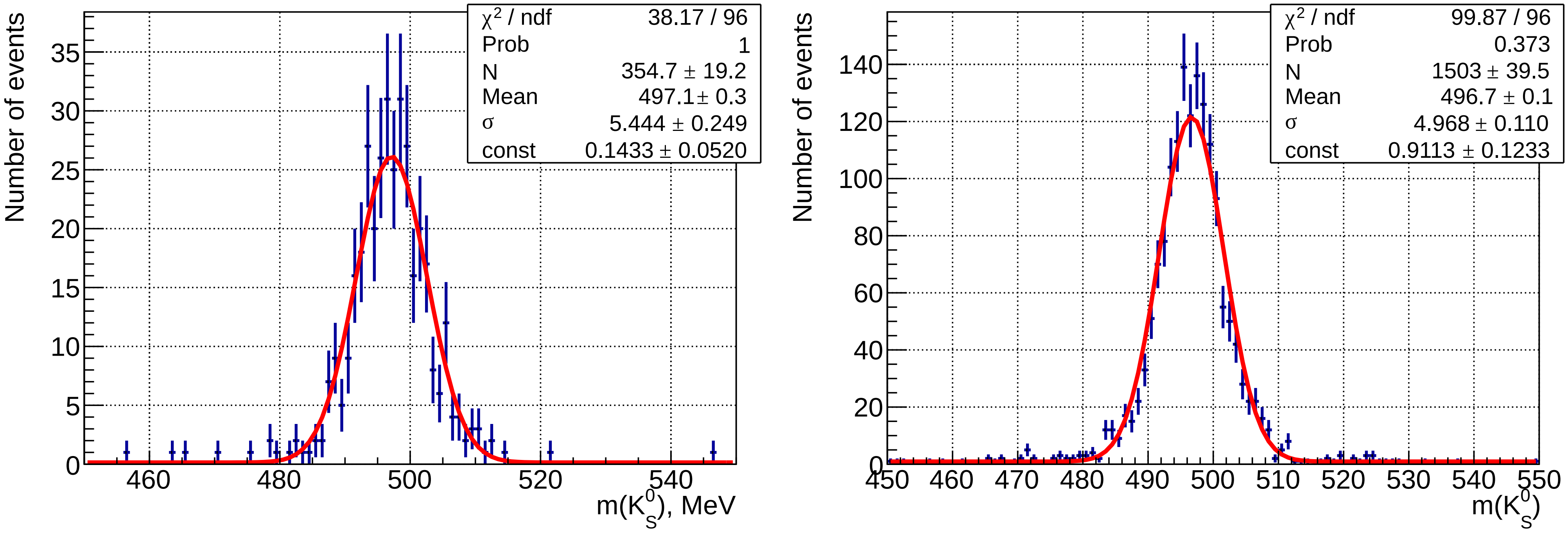
Flight length distribution of the selected K_S in the energy range 1.1 – 1.15 GeV

Determining of signal events

- Number of signal events is determined equally to both the experiment and Monte Carlo simulation
- **Approximation function: one Gauss function + constant**
- Data in table are represented by season
  - N_{sig} – number of signal events
  - N_{bkg} – number of background events

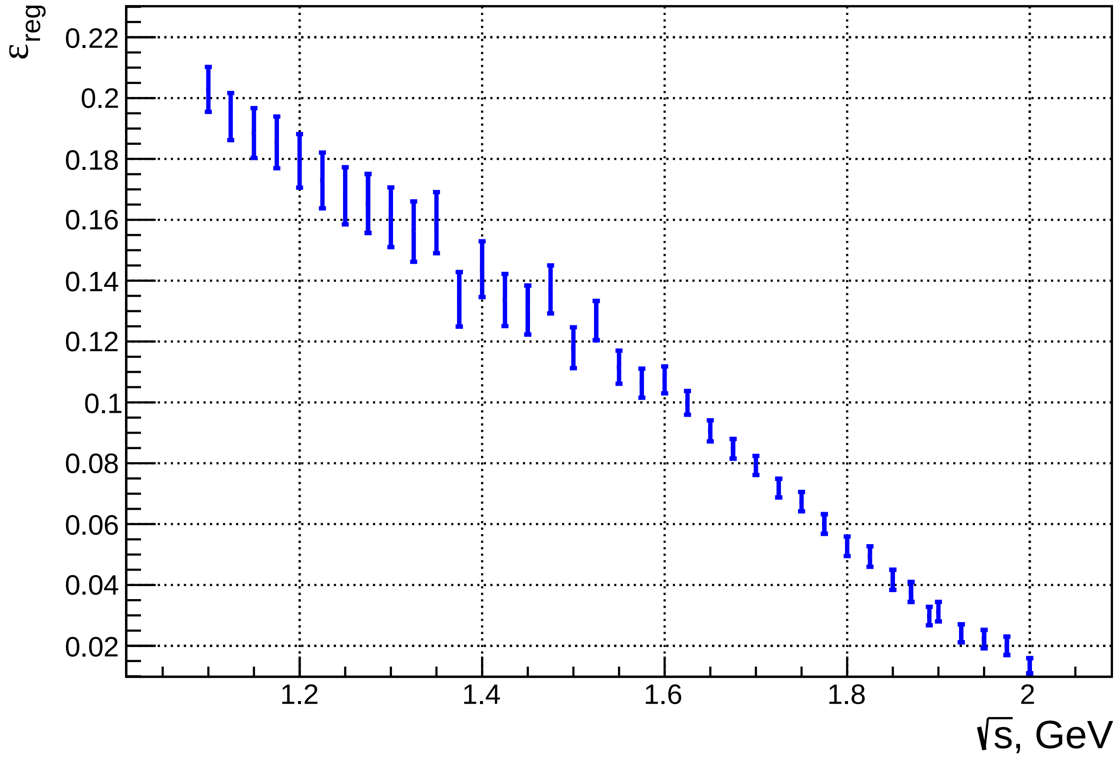
Year	N_{sig}	N_{bkg}
2011	1639	62
2012	364	16
2017	484	29

Determining of signal events



Number of events determining in the experiment (left fig.) and in the Monte Carlo simulation (right fig.) at the energy point 1.1 GeV

Registration efficiency



The dependence of the registration efficiency on the energy

$$\varepsilon_{reg} = \frac{N_{sig}}{N_{total}}$$

ε – registration efficiency

N_{sig} – number of signal events in MC simulation (determined from an approximation).

N_{total} – number of events in MC, satisfying this criterion $|E(K_S) - E_{beam}| < 20$ МэВ

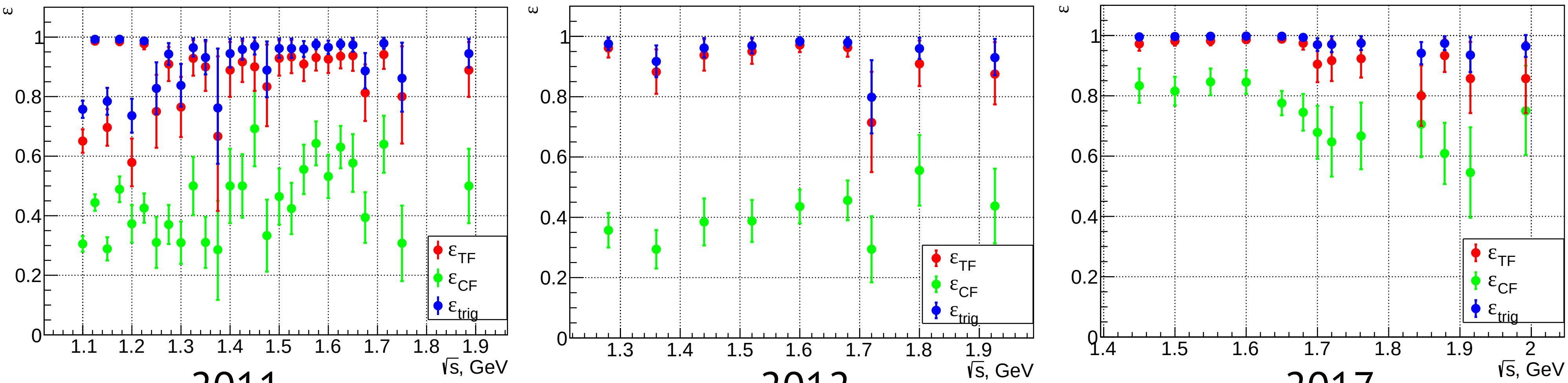
Trigger efficiency

- CMD-3 has two independent triggers: charged trigger (TF), neutral trigger (CF)

$$\varepsilon_{trig} = 1 - (1 - \varepsilon_{CF})(1 - \varepsilon_{TF})$$

$$\varepsilon_{TF} = \frac{N_{TF\&CF}}{N_{CF} + N_{TF\&CF}}$$

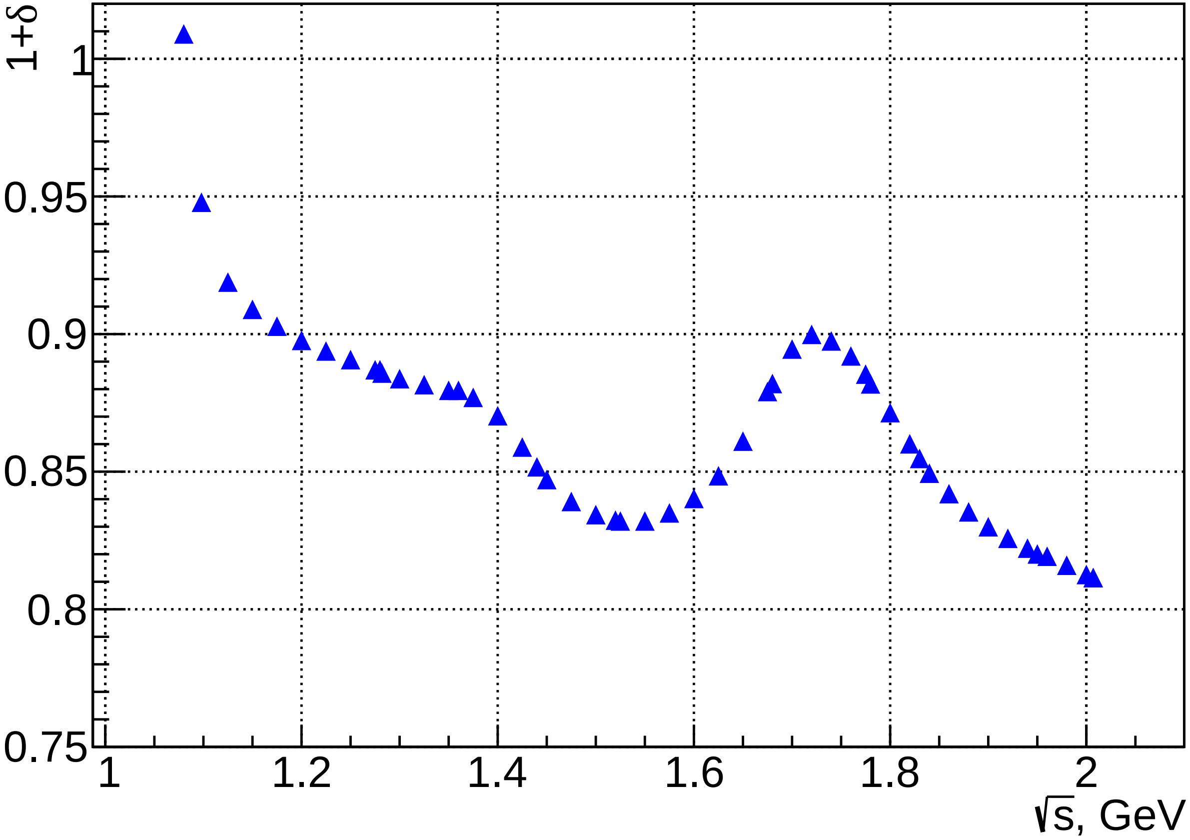
$$\varepsilon_{CF} = \frac{N_{CF\&CF}}{N_{TF} + N_{TF\&CF}}$$



2011 2012 2017

Trigger efficiency by year

Radiative corrections



The dependence of the radiative correction on the energy

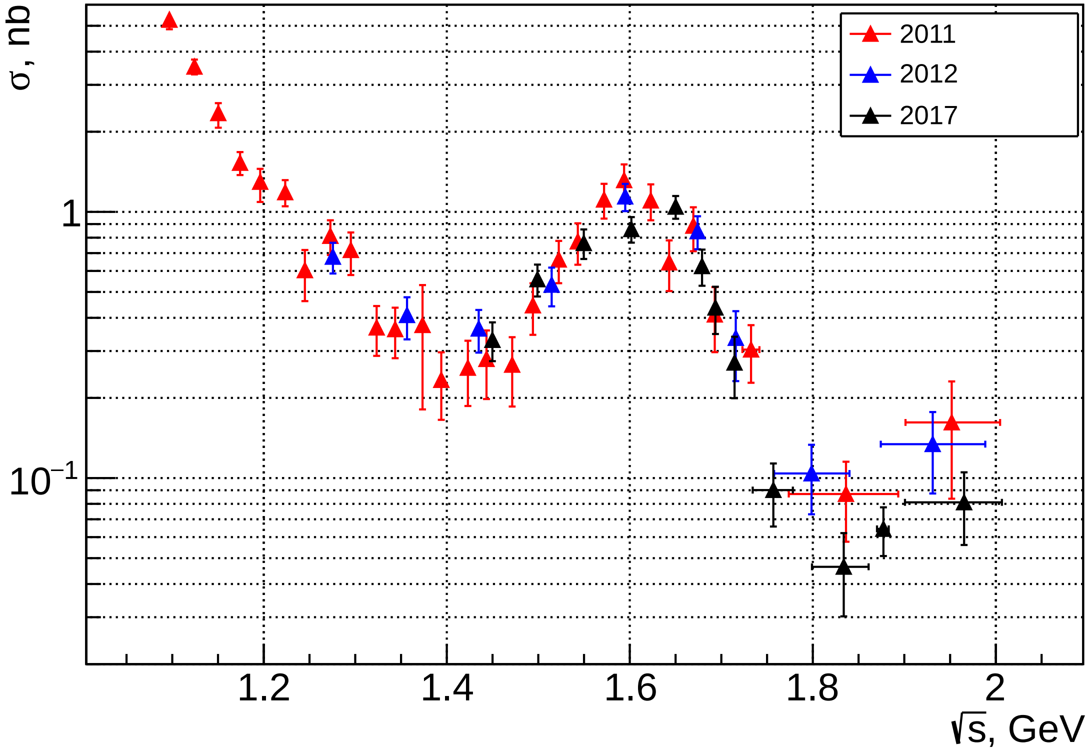
On Radiative Corrections to e+ e- Single Photon Annihilation at High-Energy.

E.A. Kuraev, Victor S. Fadin

Sov.J.Nucl.Phys. 41 (1985) 466-472

Cross section of $e^+e^- \to K_SK_L$

$$\sigma = \frac{N_{\mathrm{sig}}}{\varepsilon(1+\delta)\,L}$$

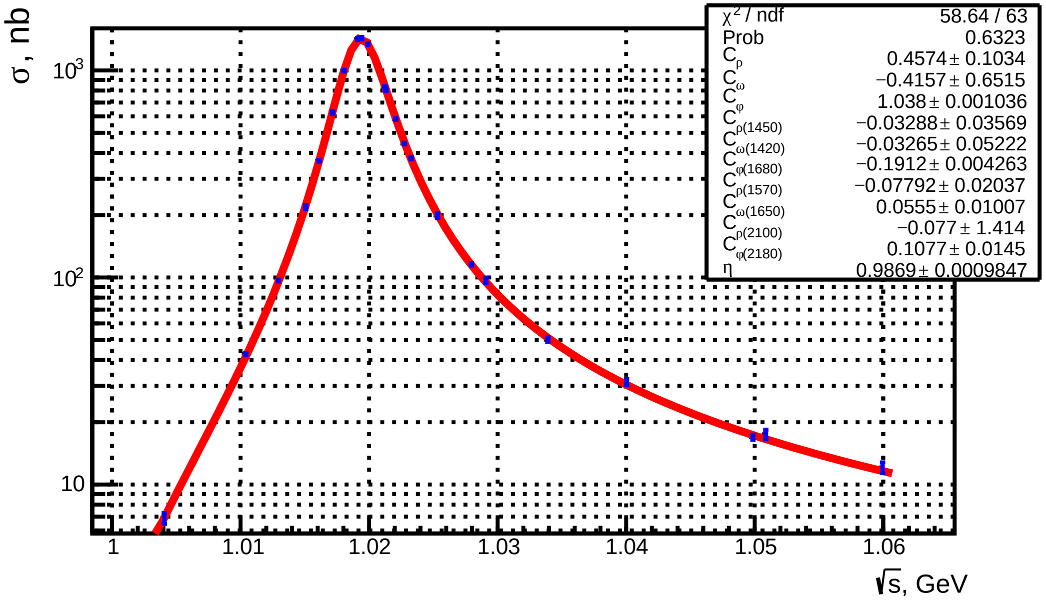


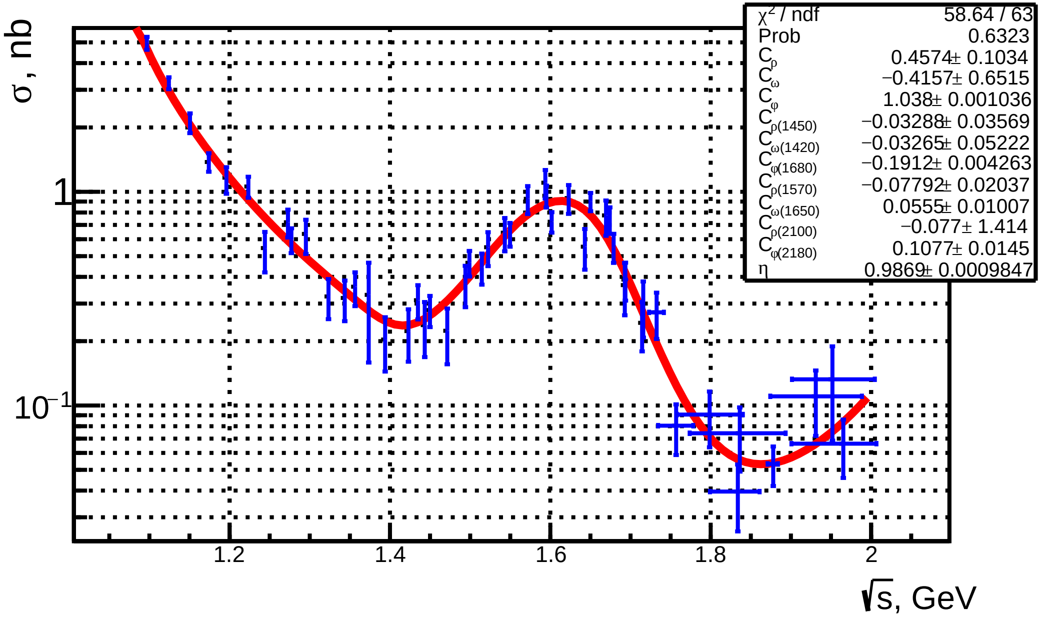
Conclusion

- Cross section of $e^+e^- \to K_S K_L$ has been measured for 2011, 2012 and 2017 data from the CMD-3 detector

Visible cross section

$$\sigma = \frac{N_{\mathrm{sig}}}{\varepsilon L}$$





CMD-3. $e^+e^- \to K_S K_L$

Kozyrev, E. A. et al. Phys. Lett. B760 (2016), p. 314-319

Cross section approximation

$$\sigma_{K_S K_L}(s) = \frac{\pi\alpha^2\beta^3}{3s}|F_{K^0}(s)|^2$$

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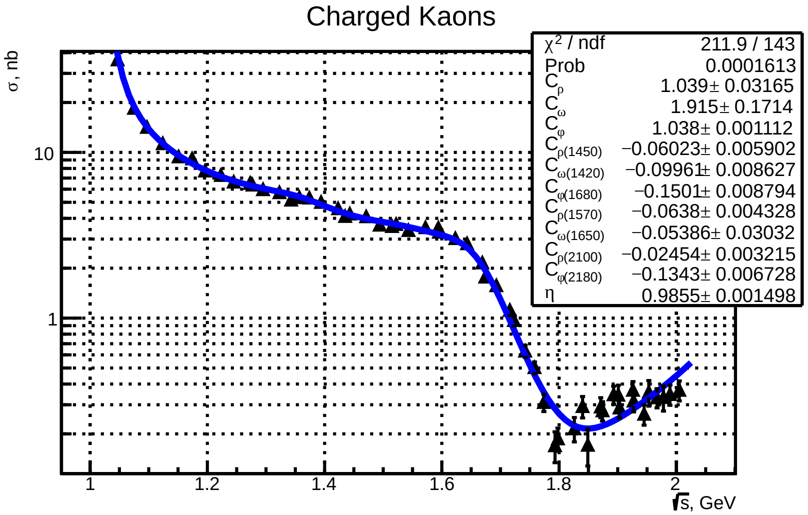
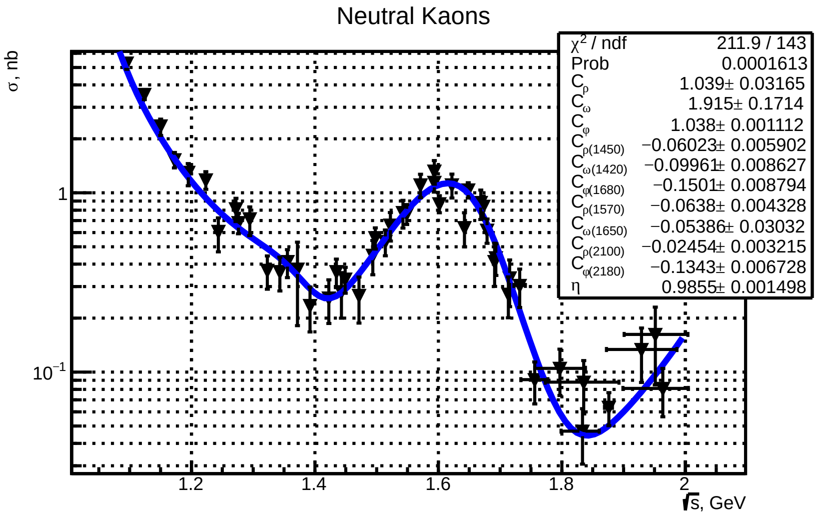
$$F_{K^+}(s) = \frac{1}{2}\sum_{V=\rho,\rho',\ldots} c_V BW_V + \frac{1}{6}\sum_{V=\omega,\omega',\ldots} c_V BW_V + \frac{1}{3}\sum_{V=\phi,\phi',\ldots} c_V BW_V,$$

$$F_{K^0}(s) = -\frac{1}{2}\sum_{V=\rho,\rho',\ldots} c_V BW_V + \frac{1}{6}\sum_{V=\omega,\omega',\ldots} c_V BW_V + \frac{1}{3}\sum_{V=\phi,\phi',\ldots} c_V BW_V,$$


Charged Kaons
σ, nb
10
1
1
1.2
1.4
1.6
1.8
2
√s, GeV
χ^2 / ndf 211.9 / 143
Prob 0.0001613
C_{ρ} 1.039± 0.03165
C_{ω} 1.915± 0.1714
C_{φ} 1.038± 0.001112
$C_{\rho(1450)}$ −0.06023± 0.005902
$C_{\omega(1420)}$ −0.09961± 0.008627
$C_{\varphi(1680)}$ −0.1501± 0.008794
$C_{\rho(1570)}$ −0.0638± 0.004328
$C_{\omega(1650)}$ −0.05386± 0.03032
$C_{\rho(2100)}$ −0.02454± 0.003215
$C_{\varphi(2180)}$ −0.1343± 0.006728
η 0.9855± 0.001498


Neutral Kaons
σ, nb
1
10^{-1}
1.2
1.4
1.6
1.8
2
√s, GeV
χ^2 / ndf 211.9 / 143
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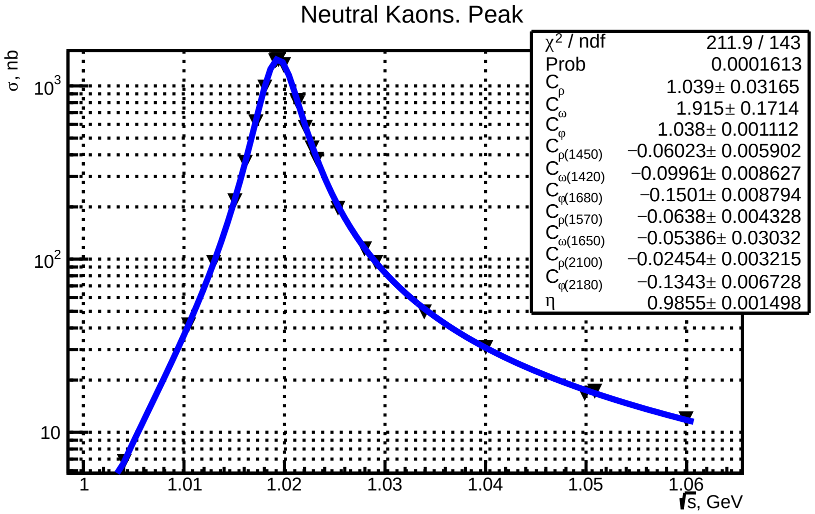
Neutral Kaons. Peak
σ, nb
10^3
10^2
10
1
1.01
1.02
1.03
1.04
1.05
1.06
√s, GeV
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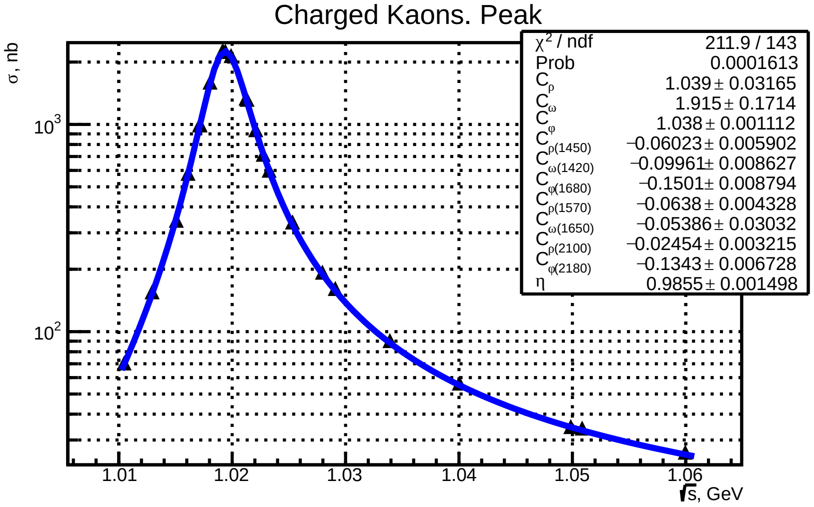
Charged Kaons. Peak
σ, nb
10^3
10^2
1.01
1.02
1.03
1.04
1.05
1.06
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