Analysis of φ(1020) production in the BM@N experiment

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Introduction

- Collisions of heavy relativistic ions allow us to study nuclear matter at extreme density and temperature.
- At sufficiently high temperature and energy density, the so-called Quark-Gluon Plasma (QGP) is formed [1]:
  - Formation of strange particles.
- Theoretical models offer different descriptions [2],[3]:
  - New experimental data is needed for clarification.

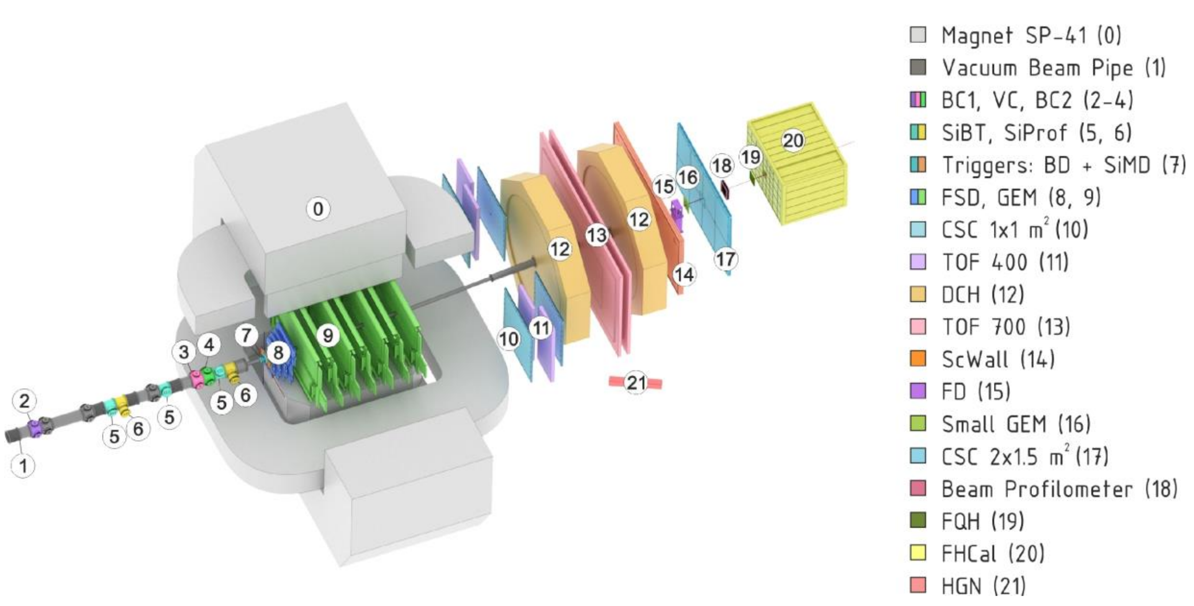
[1] Kapishin.M, “Studies of baryonic matter at the BM@N experiment (JINR).” Nuclear Physics A 982 (2019) 967–970.
[2] J. A. et al Nucl. Phys., vol. A 757, pp. 102–183, 2005.

[3] K. A. et al Nucl. Phys., vol. A 757, pp. 184–283, 2005.

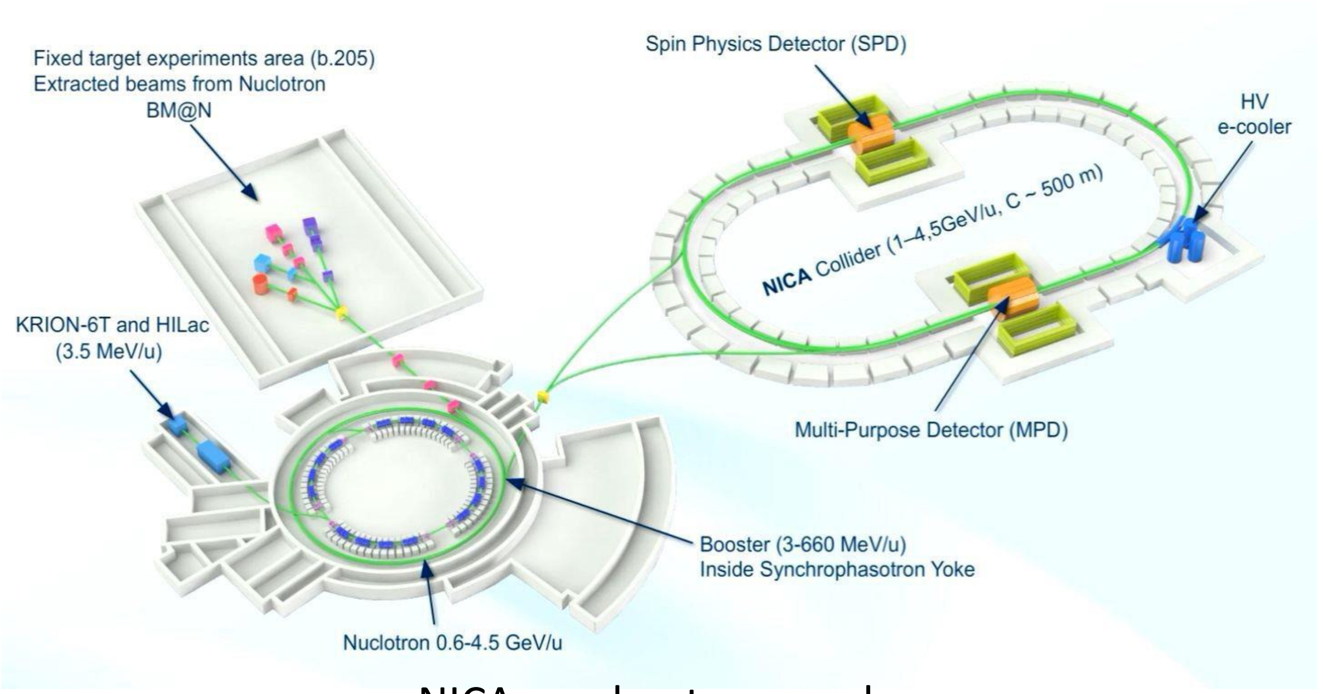
BM@N experiment at the NICA complex

- Collisions of elementary particles and ions with a stationary target at energies up to 4 GeV per nucleon.

- Studying the properties of dense baryonic matter, the formation of hypermatter, the equation of state of symmetric and asymmetric nuclear matter, collective phenomena...



Experimental setup of BM@N



NICA accelerator complex

Goal

- Observation of $\varphi(1020)$ signal in the MC and experimental data.

Data

- Experimental data obtained in the physical session at the beginning of 2023 with a beam energy of 3.8 AGeV, a CsI target and Xe beam.
- Dubna Cascade Model - Statistical Multifragmentation Model (DCM-SMM) and BOX Monte Carlo generators were used to model the data.
- About 0.8 million Monte Carlo and 22 million experimental events were analyzed.

Data processing procedure

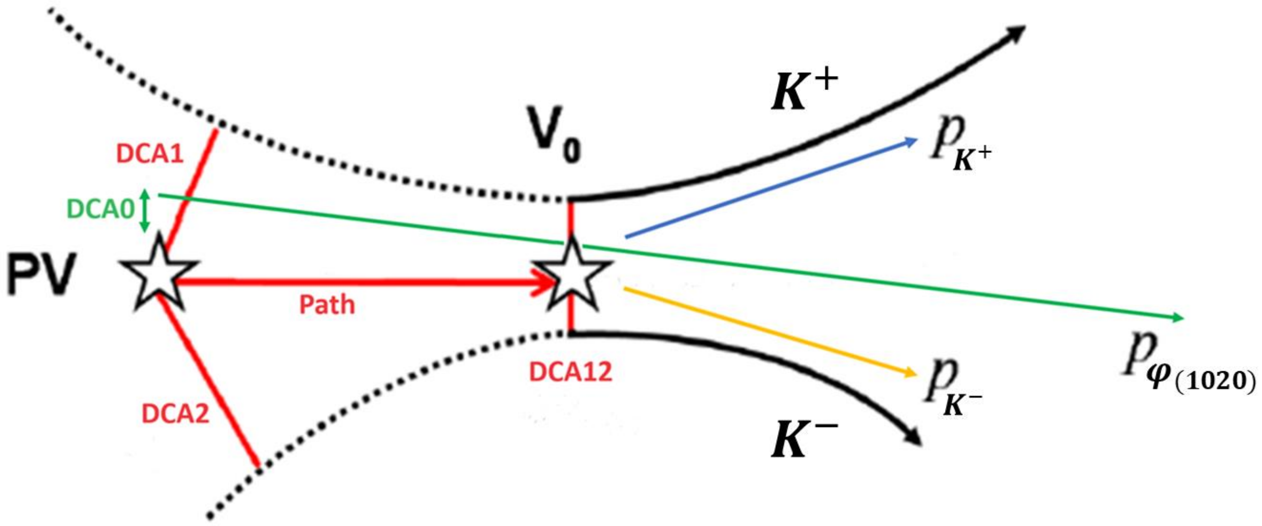
- Reconstruction of particle tracks was carried out.
- Mathematical algorithms were developed and implemented to search for the φ(1020) → $K^+ + K^-$ decay:
  - shuffling pairs of particles with different signs
  - calculation of invariant mass
  - imposing a number of geometric restrictions on the parameters of each pair

PV – primary vertex.
Path – the distance traveled by φ(1020) from the primary vertex to the point of its decay.
DCA0 – the distance between the primary vertex and the projection of momentum of φ(1020).

DCA1 – the shortest distance from K^+ to the vertex.

DCA2 – the shortest distance from K^- to the vertex.

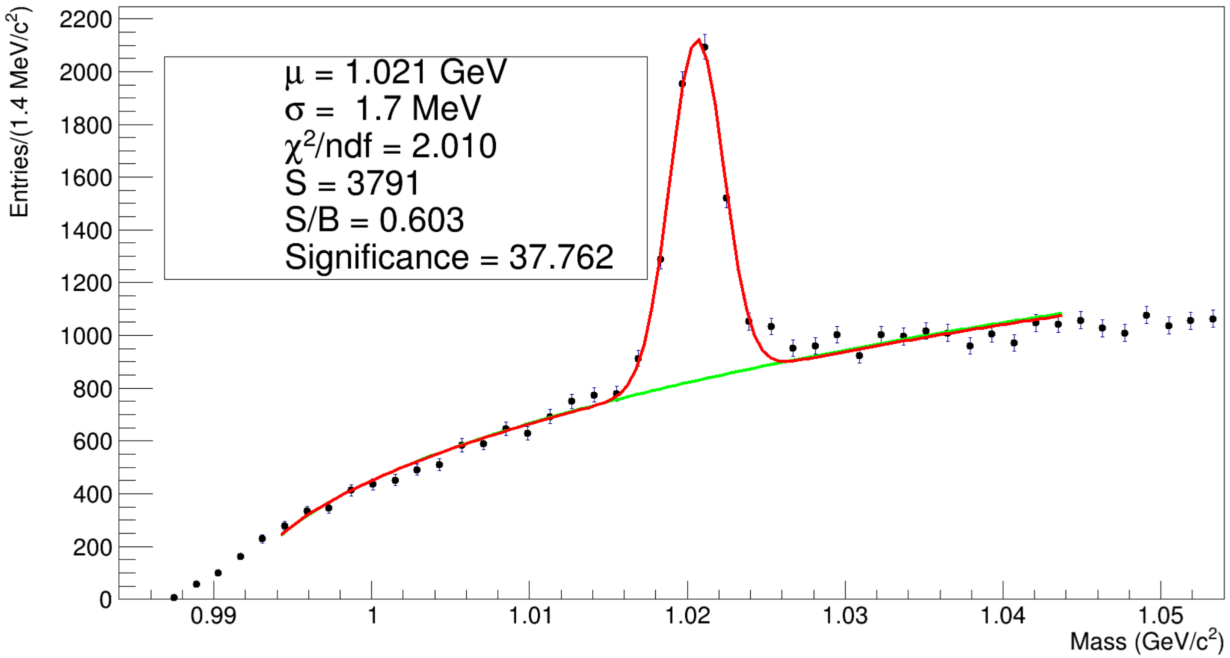
DCA12 – the distance between K^+ and K^- at the decay point of φ(1020).



Event topology

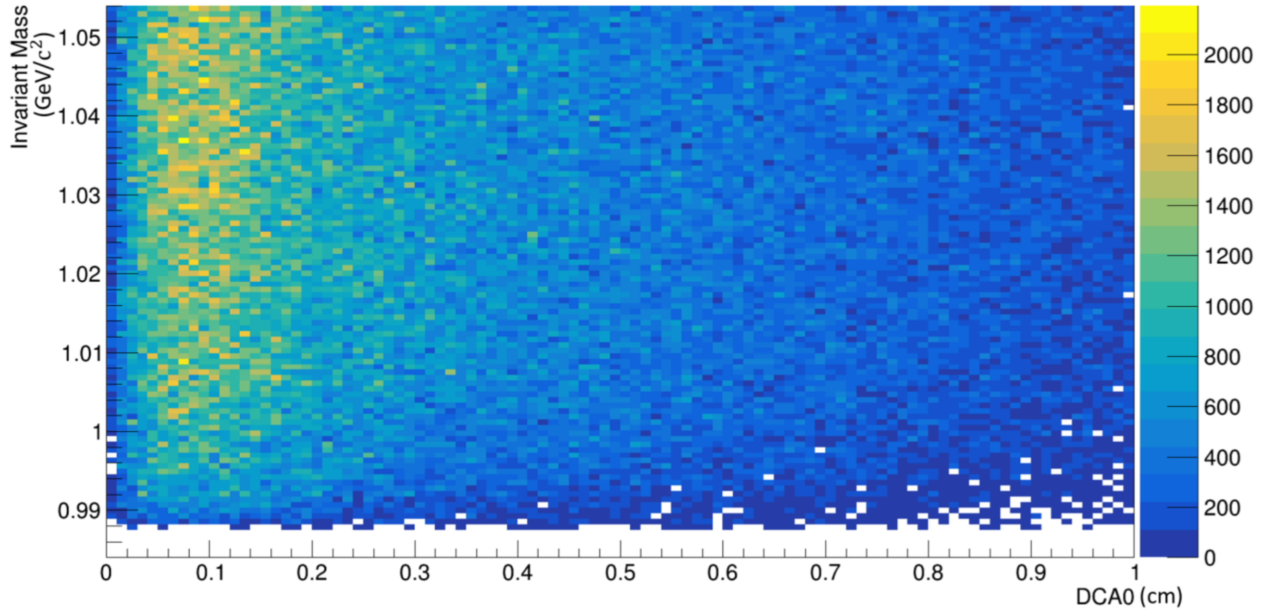
Results

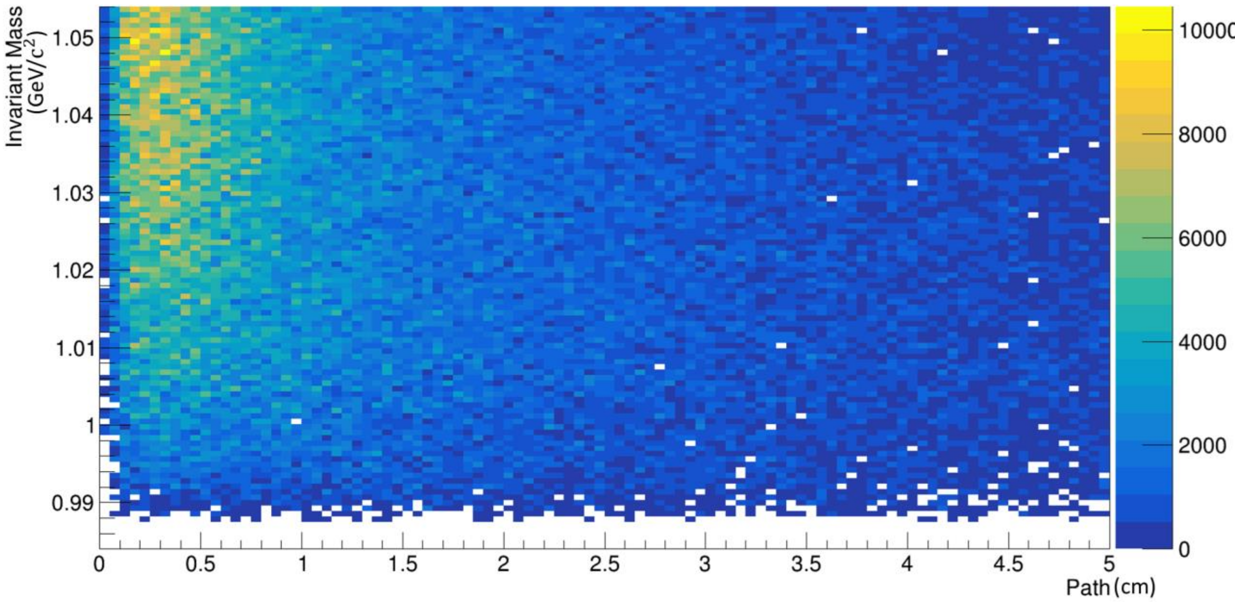
MC

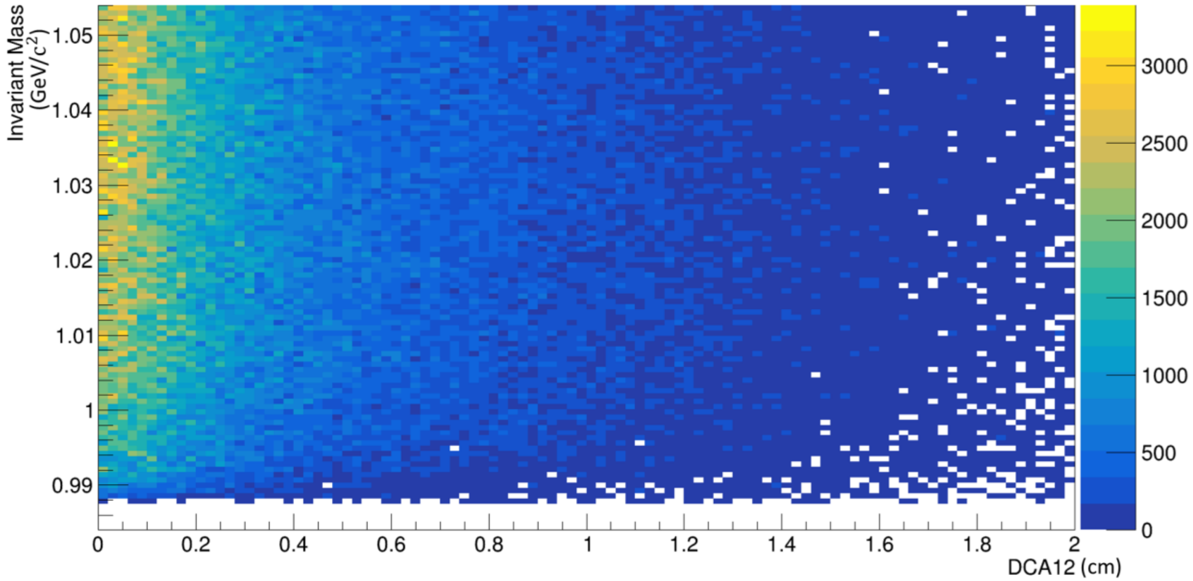


Efficiency = 0.47 %

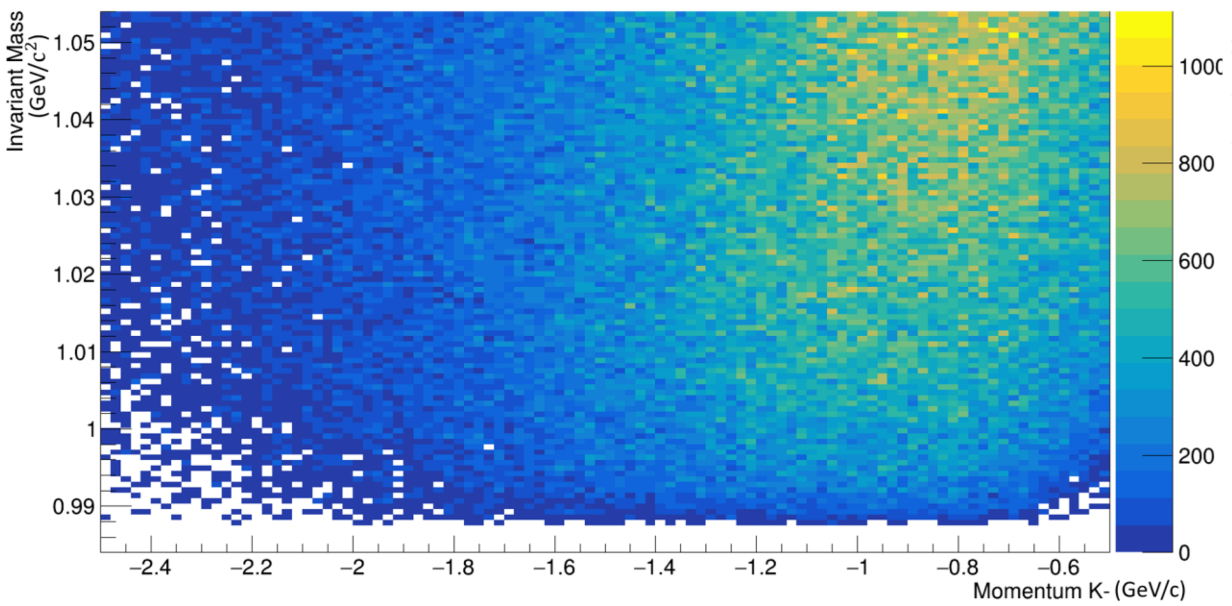
Results


Invariant Mass (GeV/c^2)
1.05
1.04
1.03
1.02
1.01
1
0.99
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
DCA0 (cm)
2000 1800 1600 1400 1200 1000 800 600 400 200 0

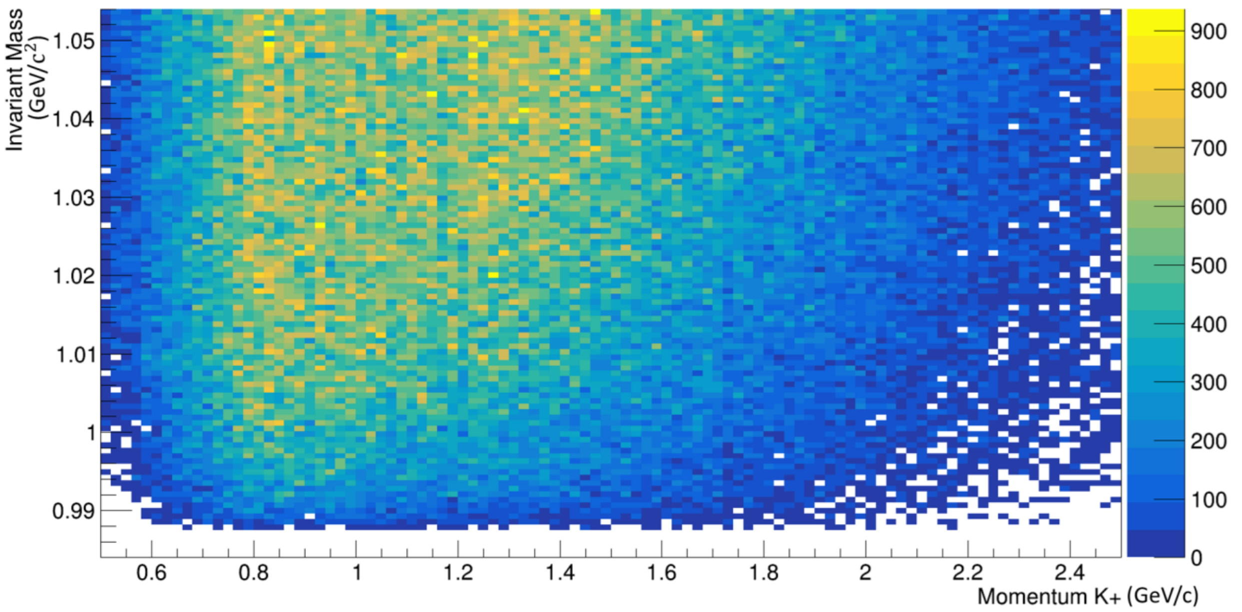

Invariant Mass (GeV/c^2)
1.05
1.04
1.03
1.02
1.01
1
0.99
0 0.5 1 1.5 2 2.5 3 3.5 4 4.5 5
Path (cm)
10000 8000 6000 4000 2000 0


Invariant Mass (GeV/c^2)
1.05
1.04
1.03
1.02
1.01
1
0.99
0 0.2 0.4 0.6 0.8 1 1.2 1.4 1.6 1.8 2
DCA12 (cm)
3000 2500 2000 1500 1000 500 0

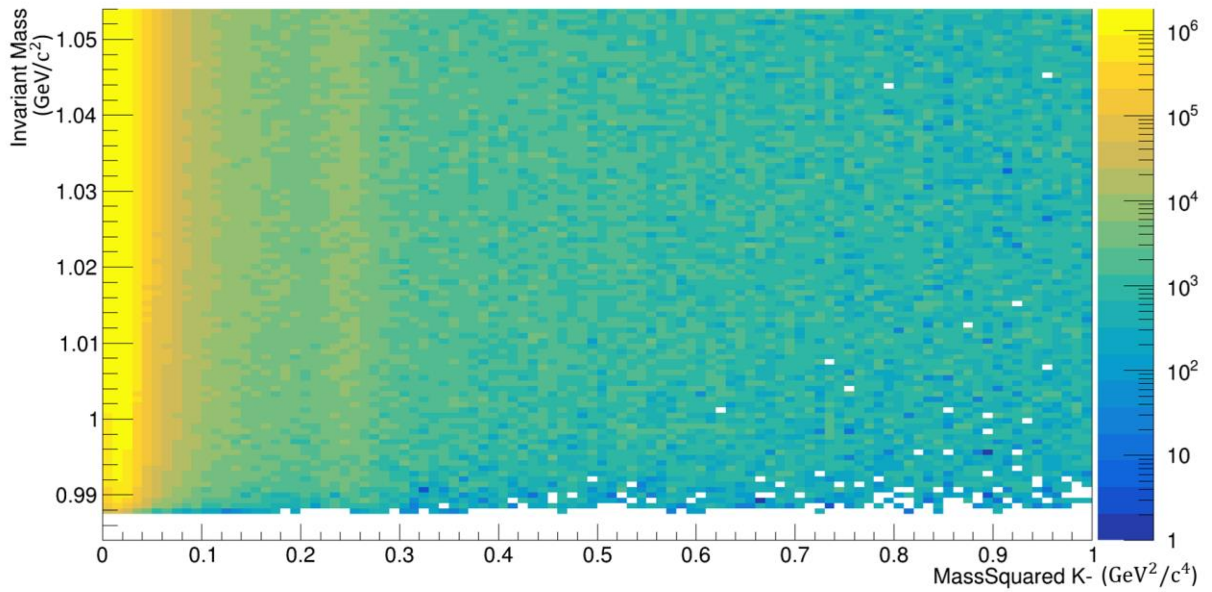
Results



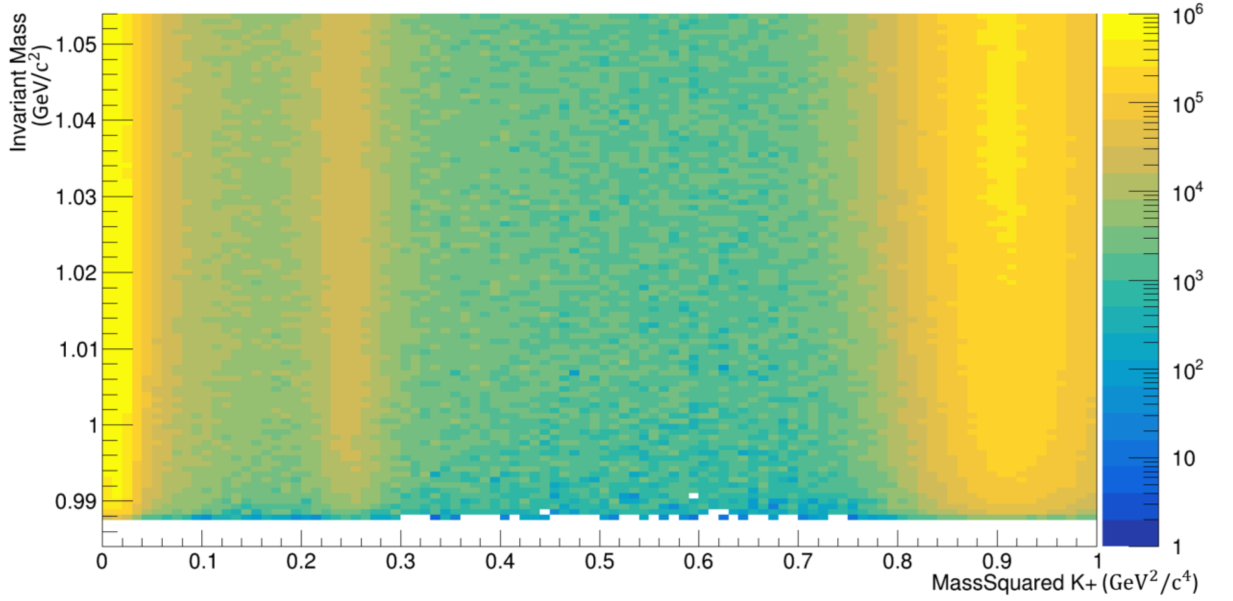
Invariant Mass (GeV/c^2)
1.05
1.04
1.03
1.02
1.01
1
0.99
−2.4 −2.2 −2 −1.8 −1.6 −1.4 −1.2 −1 −0.8 −0.6
Momentum K- (GeV/c)
0 200 400 600 800 1000



Invariant Mass (GeV/c^2)
1.05
1.04
1.03
1.02
1.01
1
0.99
0.6 0.8 1 1.2 1.4 1.6 1.8 2 2.2 2.4
Momentum K+ (GeV/c)
0 100 200 300 400 500 600 700 800 900



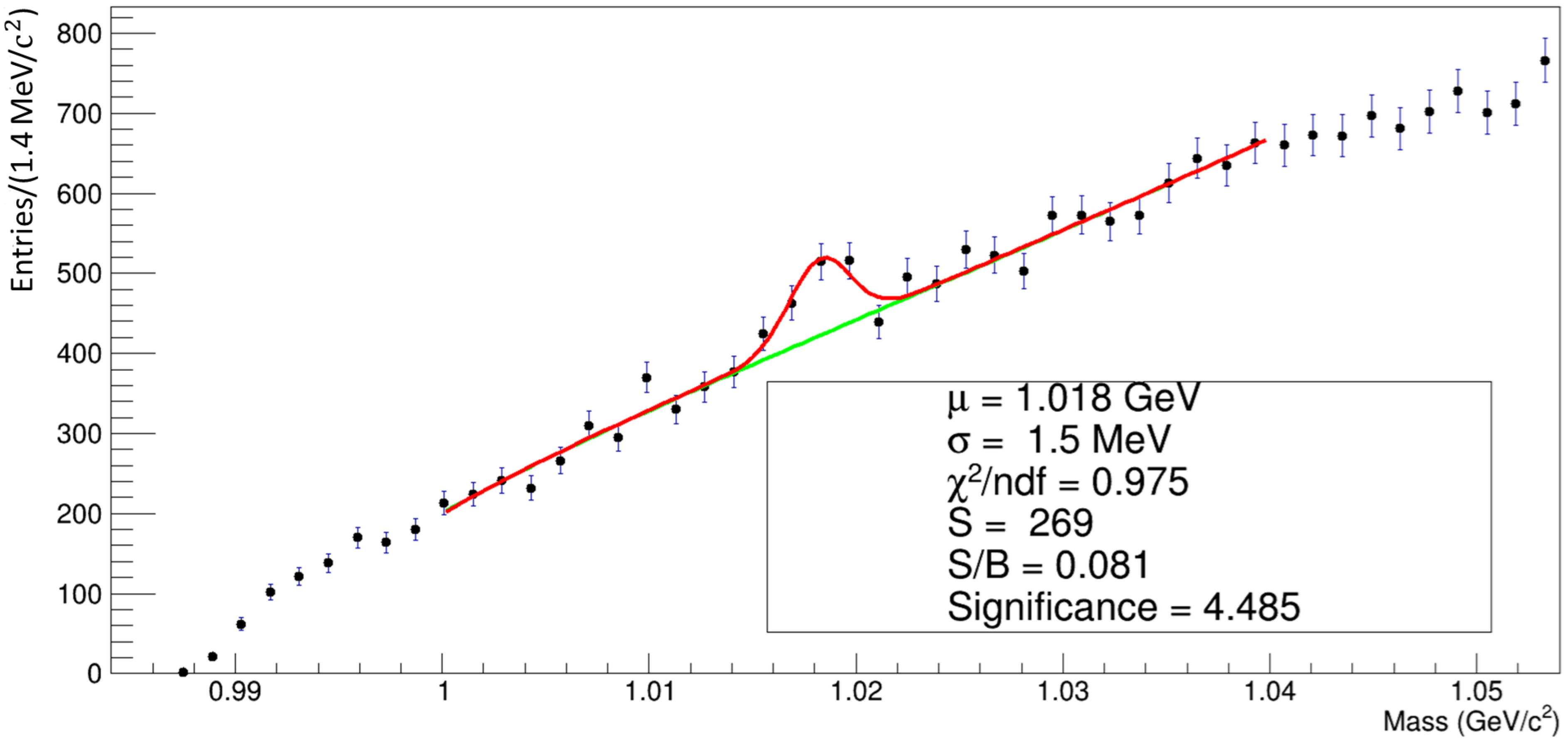
Invariant Mass (GeV/c^2)
1.05
1.04
1.03
1.02
1.01
1
0.99
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
MassSquared K- (GeV^2/c^4)
1 10 10^2 10^3 10^4 10^5 10^6



Invariant Mass (GeV/c^2)
1.05
1.04
1.03
1.02
1.01
1
0.99
0 0.1 0.2 0.3 0.4 0.5 0.6 0.7 0.8 0.9 1
MassSquared K+ (GeV^2/c^4)
1 10 10^2 10^3 10^4 10^5 10^6

Results

EXP



Entries/(1.4 MeV/c²)
800
700
600
500
400
300
200
100
0
0.99
1
1.01
1.02
1.03
1.04
1.05
Mass (GeV/c²)
μ = 1.018 GeV
σ = 1.5 MeV
χ²/ndf = 0.975
S = 269
S/B = 0.081
Significance = 4.485

Conclusion and future work

- φ(1020) signal was observed in both MC and experimental cases.

- Increase the number of analyzed events in order to improve the results regarding experimental data.
- Derive more realistic values for kinematic parameters by means of other MC generators (UrQMD, PYTHIA).
- Compare MC results with experimental ones.
- Perform phase space analysis.

Backup

Cuts

MC:

0.0 cm <= dca12 <= 2.0 cm

0.0 cm <= dca0 <= 1.0 cm

0.15 $\frac{GeV^2}{c^4}$ <= mass_squared_К+<= 0.35 $\frac{GeV^2}{c^4}$

0.7 $\frac{GeV}{c}$ <= momentum_К+<= 2.5 $\frac{GeV}{c}$

-2.5 $\frac{GeV}{c}$ <= momentum_К-<= -0.7 $\frac{GeV}{c}$

EXP:

0.0 cm <= path <= 1.0 cm

0.0 cm <= dca12 <= 1.0 cm

0.0 cm <= dca0 <= 0.05 cm

0.0 $\frac{GeV^2}{c^4}$ <= mass_squared_K+<= 0.75 $\frac{GeV^2}{c^4}$

0.0 $\frac{GeV^2}{c^4}$ <= mass_squared_K-<= 0.75 $\frac{GeV^2}{c^4}$