Feasibility Study of $\phi(1020)$ Production at NICA/MPD

Lyubka Yordanova

VBLHEP,JINR,Dubna,Russia

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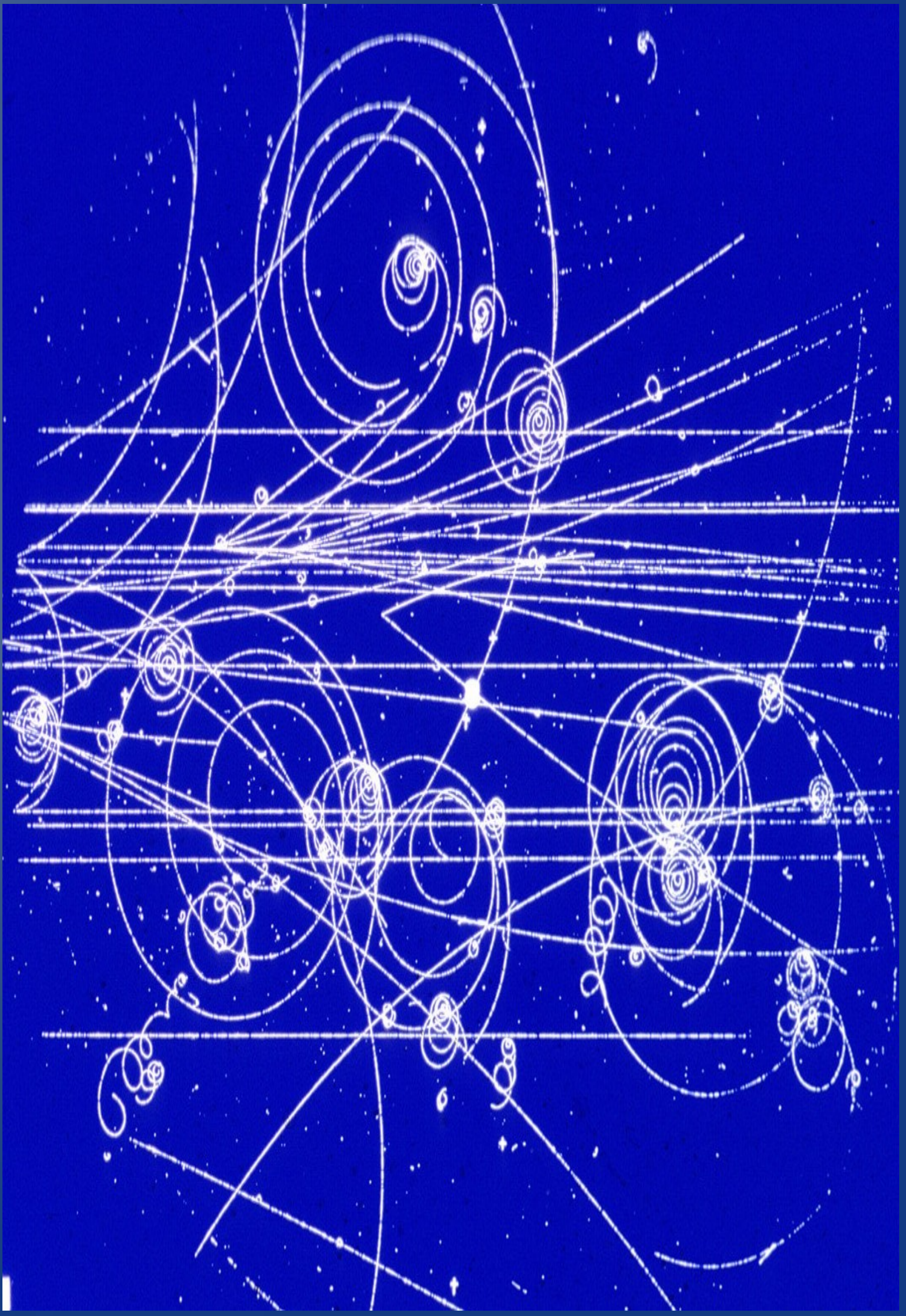
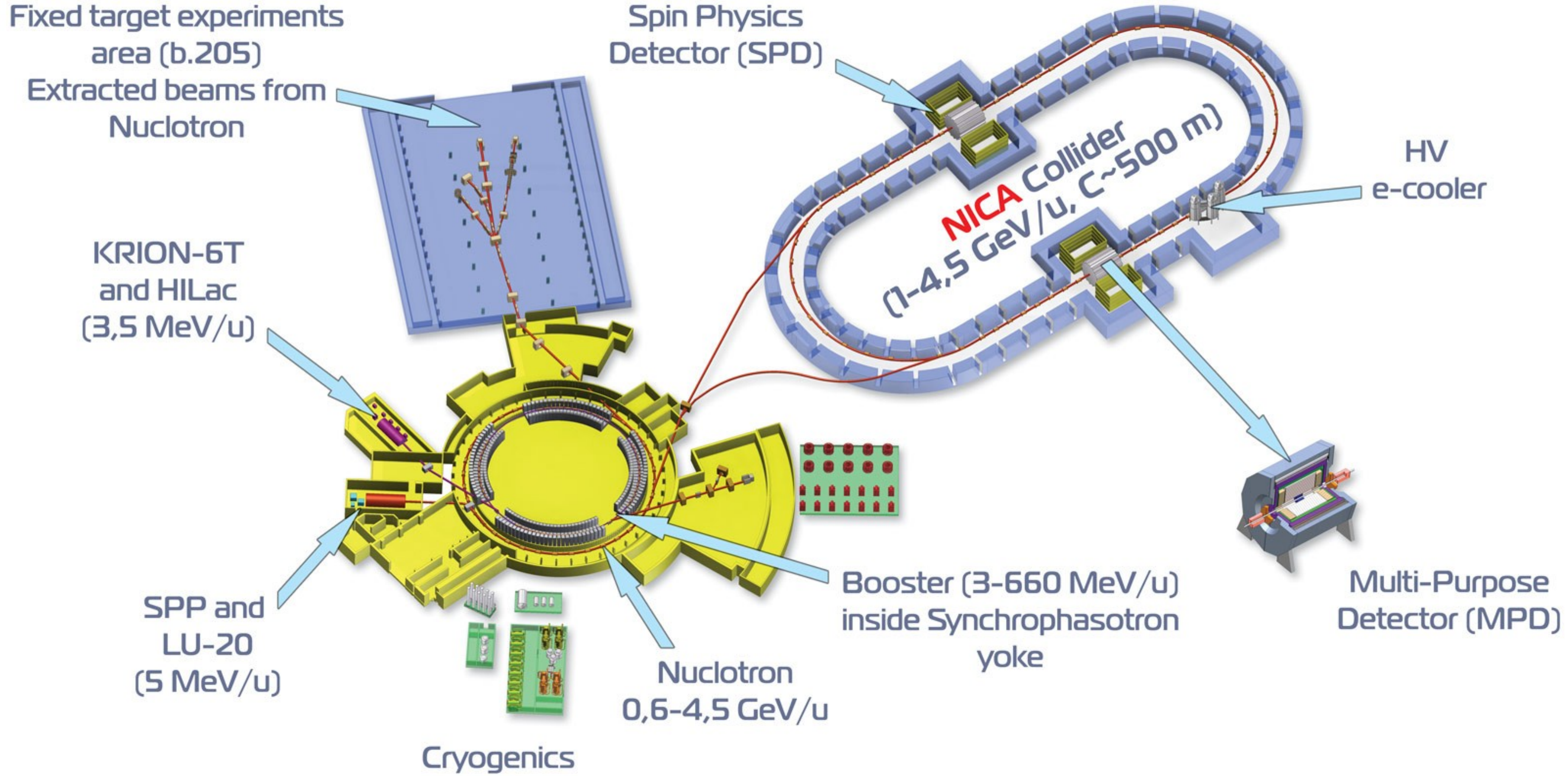


NICA

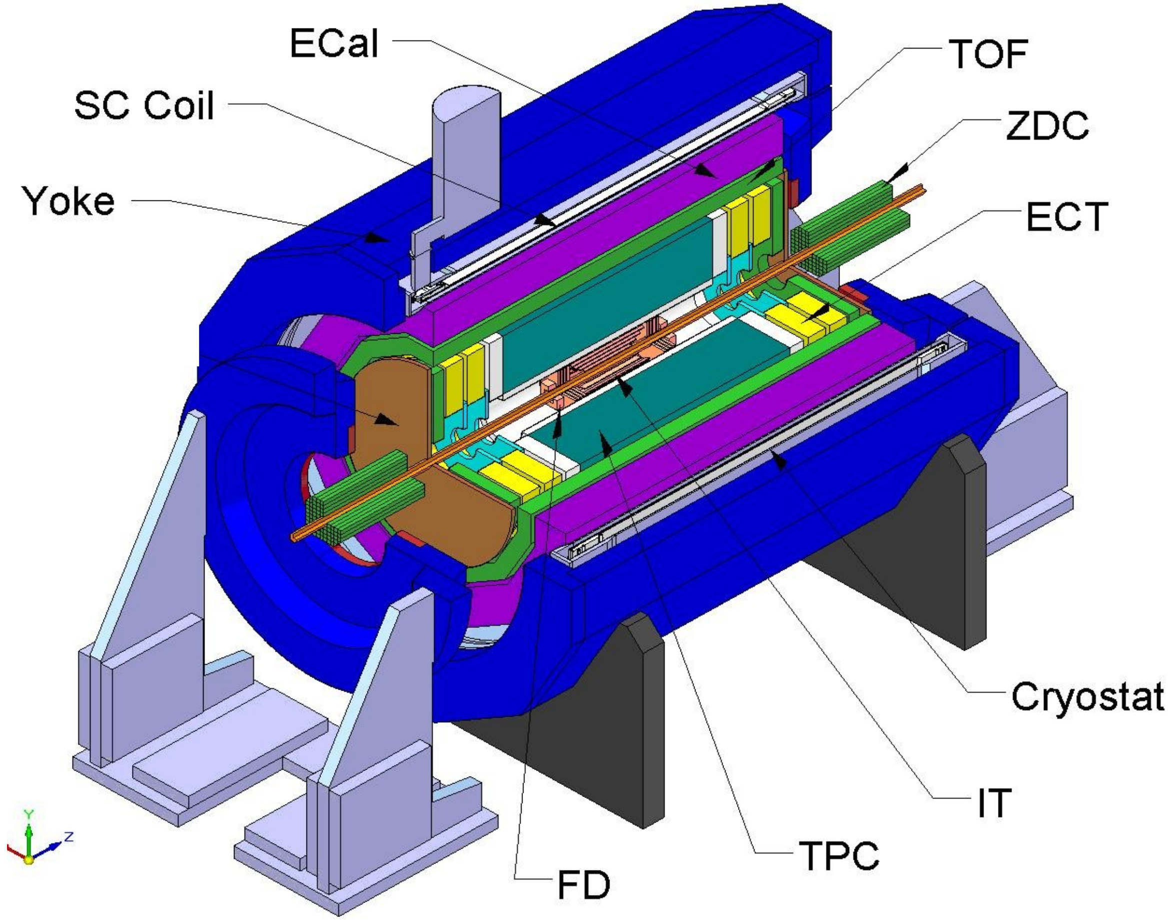
Superconducting accelerator complex NICA
(Nuclotron based Ion Collider fAcility)



NICA parameters

- Energy range: $\sqrt{s_{NN}}$ = 4-11 GeV
- Beams : from p to Au
- Luminosity : L~10^{27} (Au), 10^{32} (p)
- 2 Detectors: MPD (ions), SPD (spin physics)

Multi-Purpose Detector MPD at NICA



Central Detector Volume:
9.0 m (Length)
6.6 m (Diameter)

Magnet :
0.5 T superconductor (1^{st} stage)

Tracking :
TPC (1^{st} stage,|η|<2.0)
ECT, IT (2^{nd} stage,|η<2.5)

Particle ID :
TOF, ECAL, TPC (1^{st} stage, |η|<1.5)

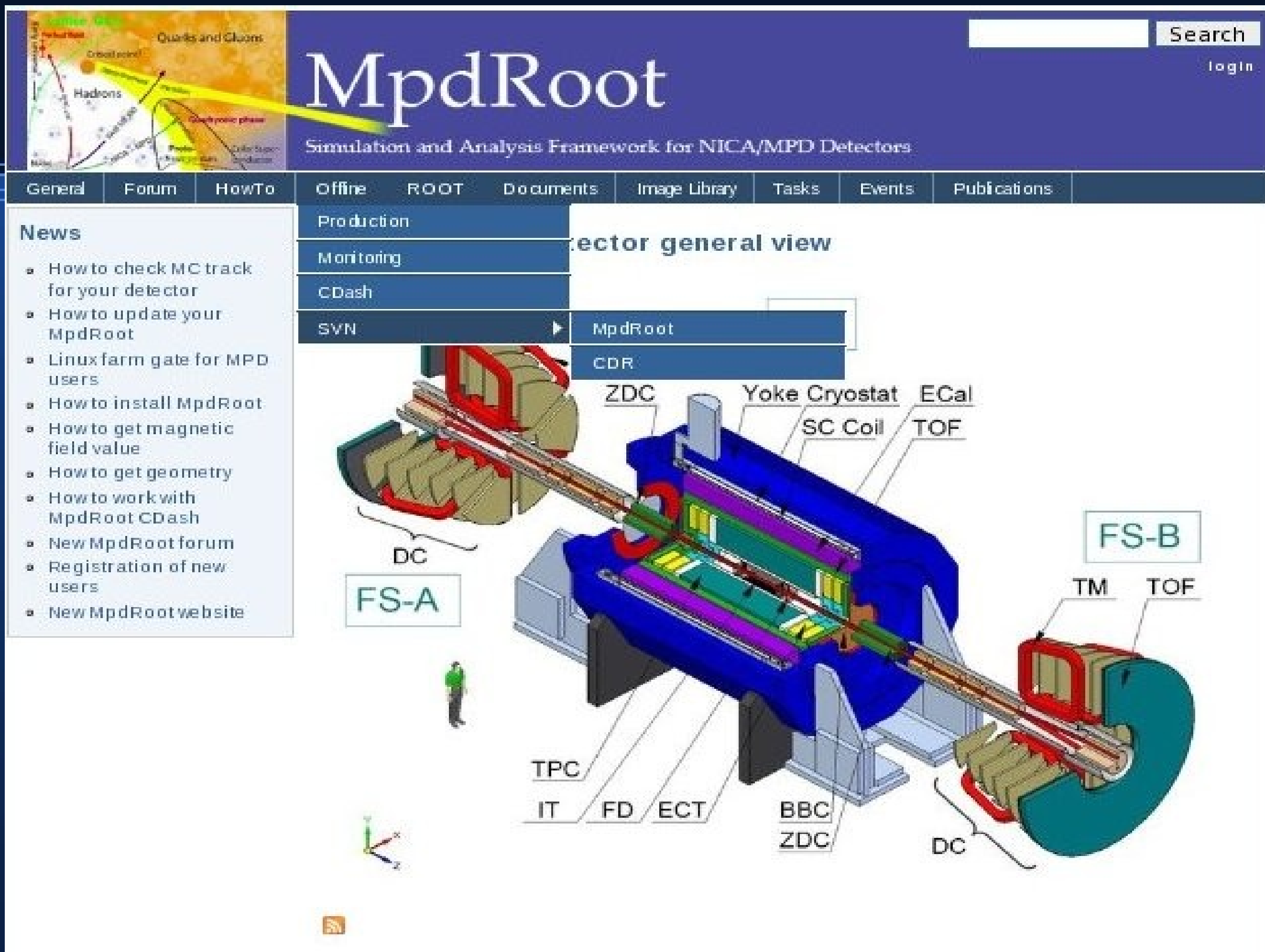
Triggering : FD
(1^{st} stage,2.0<|η|<4.0)

Centrality : ZDC
(1^{st} stage,2.2<|η|<4.8)

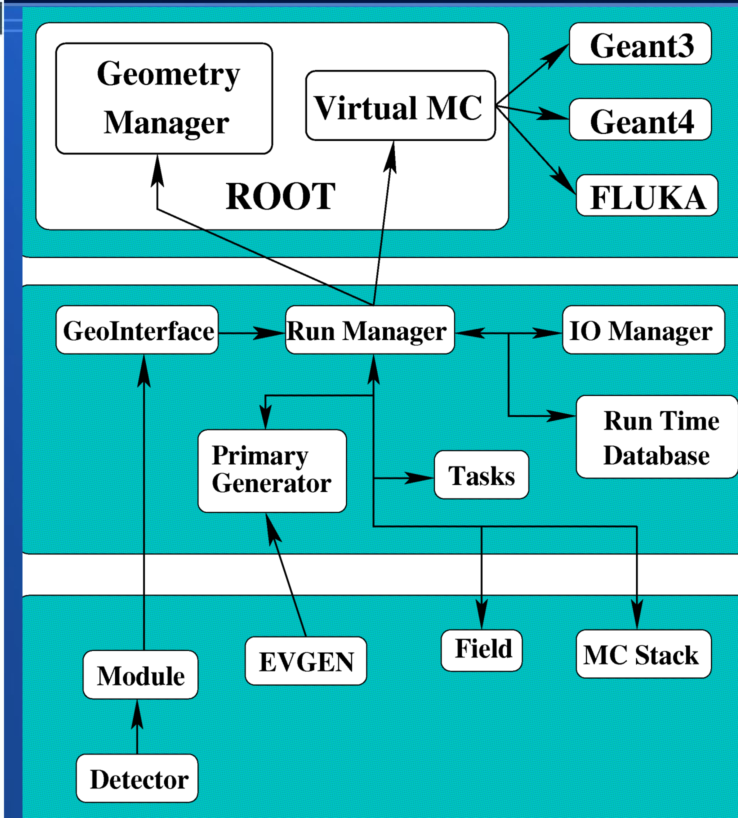
MPD Advantages:

***Hermeticity, homogenous acceptance (2π in azimuth), low material budget**
***Excellent tracking performance and powerful PID**
***High event rate capability and careful event characterization**

Simulation and Analysis Framework for MPD detector



http://mpd.jinr.ru



- MpdRoot inherits basic properties from FairRoot (developed at GSI), C++ classes
- Extended set of event generators for heavy ion collisions (UrQMD, LAQGSM, HSD)
- Detector composition and geometry; particle propagation by GEANT3/4
- Advanced detector response functions, realistic tracking and PID included

Motivation for feasibility study of $\phi(1020)$ production at NICA/MPD

- Strangeness as a probe of deconfinement
- Nuclear dynamics and hadron production under extreme nuclear density
- Low cross-section in nuclear matter, early freeze-out
- Particle properties in dense nuclear matter

Challenge - ***Low yield of*** $\phi(1020)$

Why at NICA/MPD ? - ***High luminosity , high efficiency, detector with precise tracking***

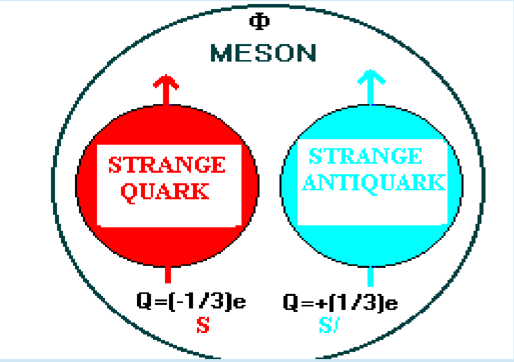
Activities:

1 Generators of HIC at NICA energies (UrQMD), study of model predictions for particle yields and spectra (K, ϕ)

2 Event reconstruction in the MPDRoot framework, study of the MPD particle ID performance for kaons at $\sqrt{s_{NN}}$ = 11 GeV

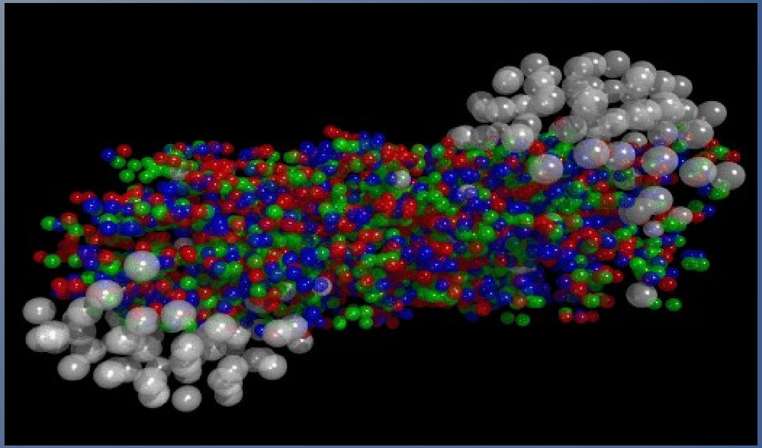
3 Development of algorithms for proper reconstruction of ϕ (1020) and solving problems with statistics

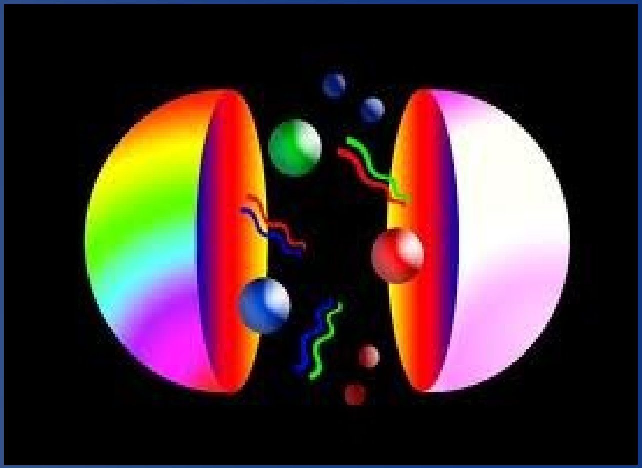
4 Analysis of invariant mass distributions for identified K+K- (ϕ) pairs



The UrQMD model

The Ultrarelativistic Quantum Molecular Dynamics model is a microscopic model used to simulate (ultra)relativistic heavy ion collisions in wide energy range.





Main goals:

* Creation of dense hadronic matter at high temperatures
* Creation of mesonic matter and of anti-matter
* Creation and transport of rare particles in hadronic matter
* Creation, modification and destruction of strangeness in matter
* Emission of electromagnetic probes

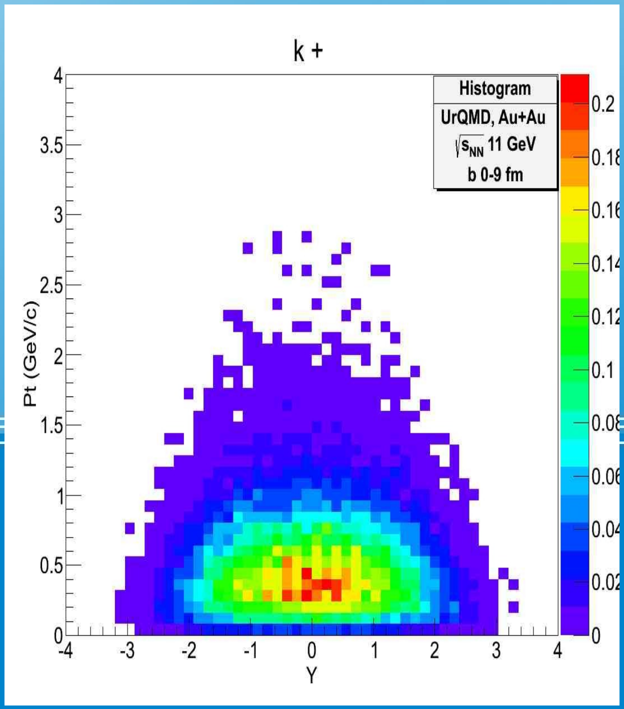
Study of model predictions for particle yields and spectra (K, ϕ)

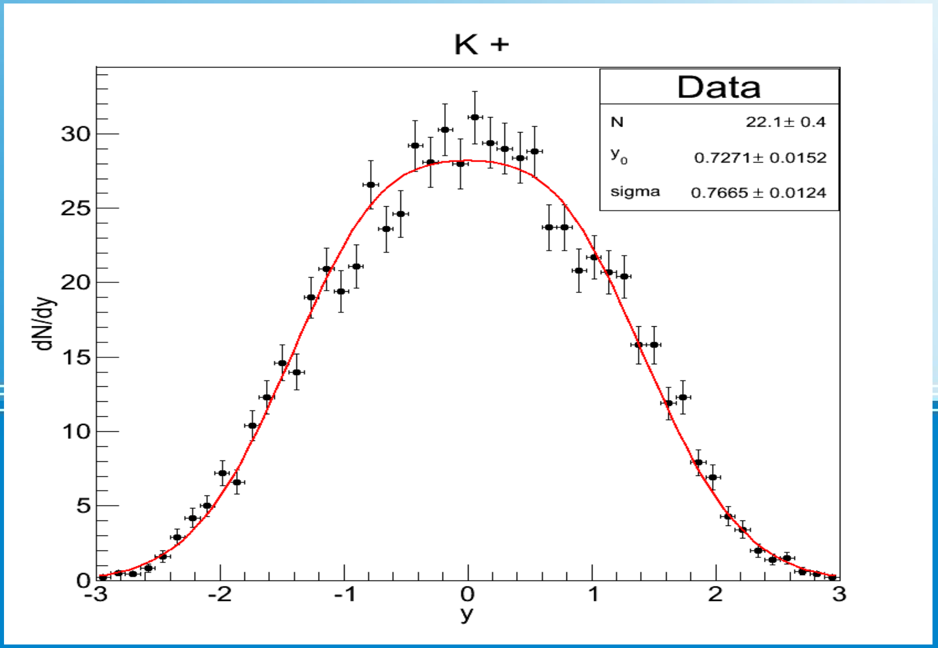
***Phase-space distributions**

***Pt spectra** – Fit function: $\frac{\partial^2 N}{\partial p_T \partial y} \sim p_T.exp(\frac{-\sqrt{p_T^2+m^2}-m}{T})$

***Mt spectra** – Fit function: $F = A.exp(-\frac{m_T}{T})$

***Y spectra** – Fit function: $F = N.(exp(-\frac{(y-y_0)^2}{2\sigma^2}) + exp(-\frac{(y+y_0^2)}{2\sigma^2}))$





Reconstruction of ϕ (1020)

We use the channel decay $\Phi \rightarrow K^{+}K^{-}$ to detect the formation of the φ-meson. This channel is chosen because it has a high branching ratio (49.1%) and kaons are easy to detect.

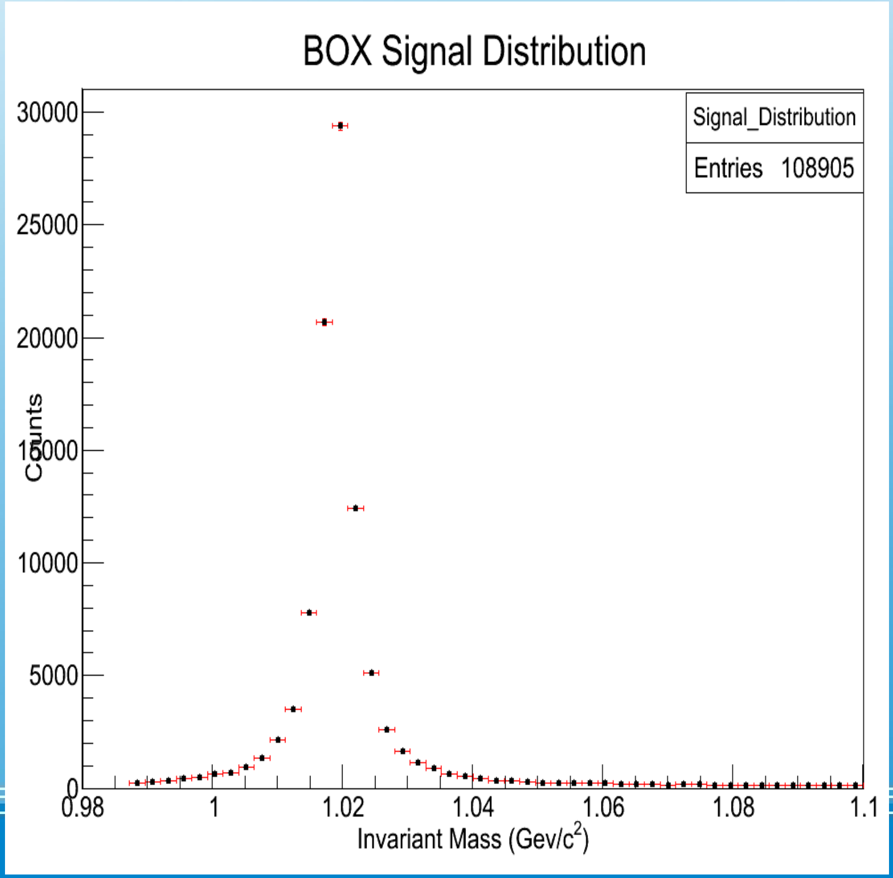
* UrQMD event generator is used
* Energy - $\sqrt{s} = 11$ GeV
*Selection of kaon pairs by track quality cuts and particle identification (PID)

The invariant mass of the kaon pairs is calculated and then the combinatorial background (mixed-event technique) is subtracted. The obtained peak from the invariant mass distribution is then fitted by a Breit-Wigner function and the characteristics of the φ-meson such as its mass and its width are found.

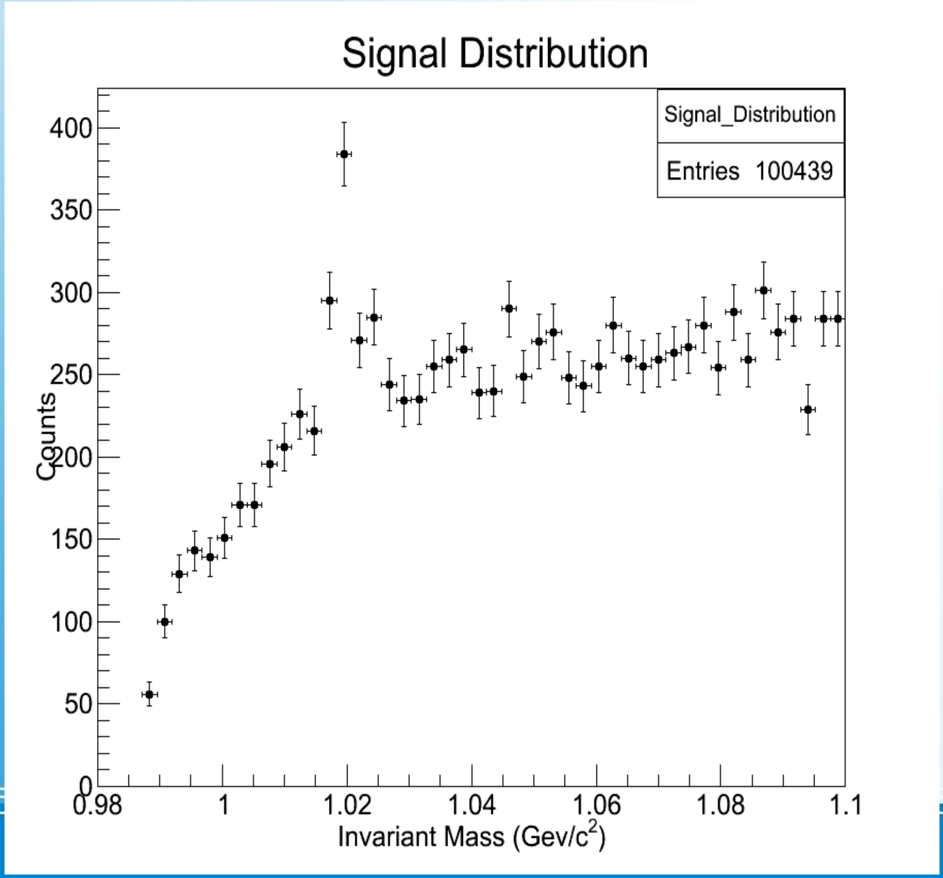
$$M_{inv} = \sqrt{((E_1 + E_2)^2 - (p_{x1} + p_{x2})^2 - (p_{y1} + p_{y2})^2 - (p_{z1} + p_{z2})^2)}$$

Reconstruction of ϕ (1020)
Signal Distributions

Signal distribution – BOX generator

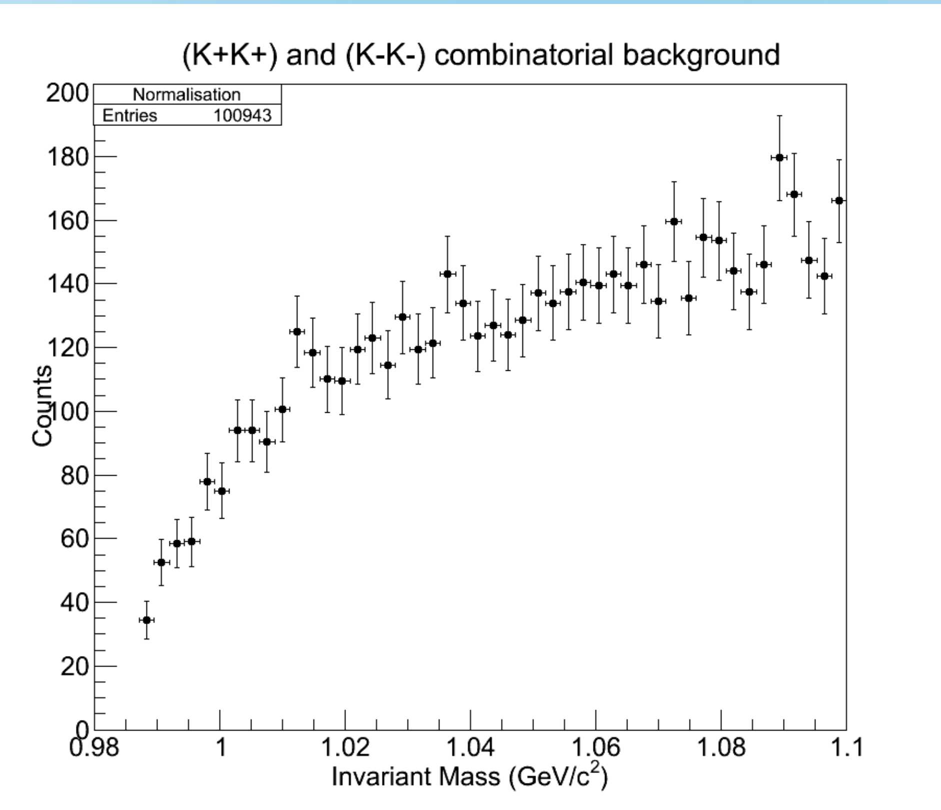


Signal distribution – UrQMD + BOX

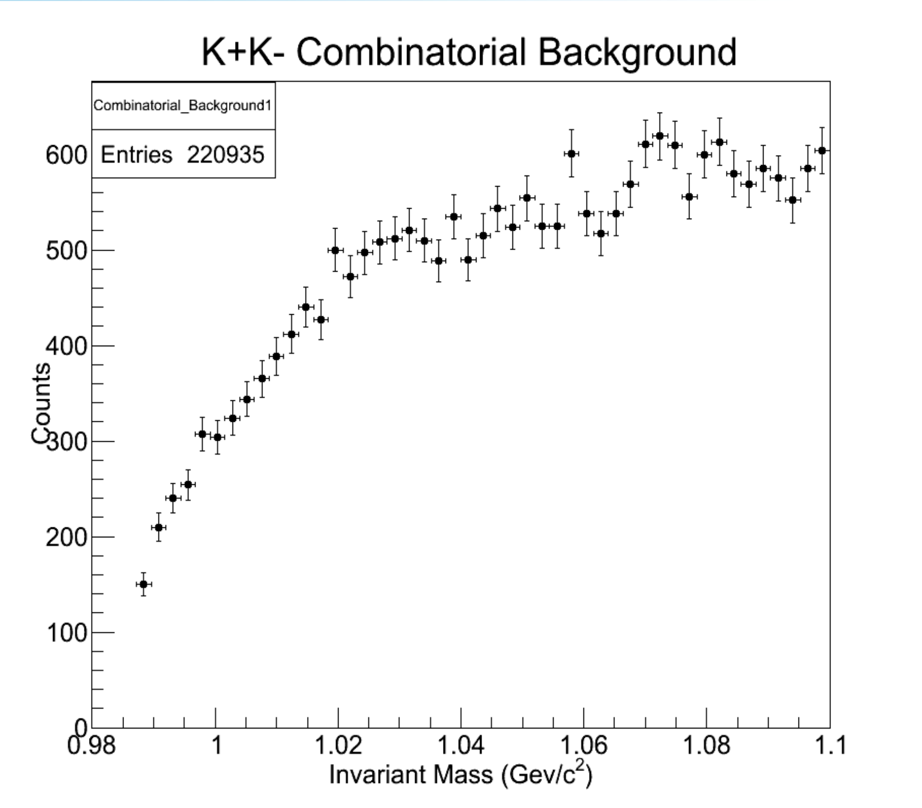


Reconstruction of ϕ (1020) Combinatorial Background

Combinatorial background-same events



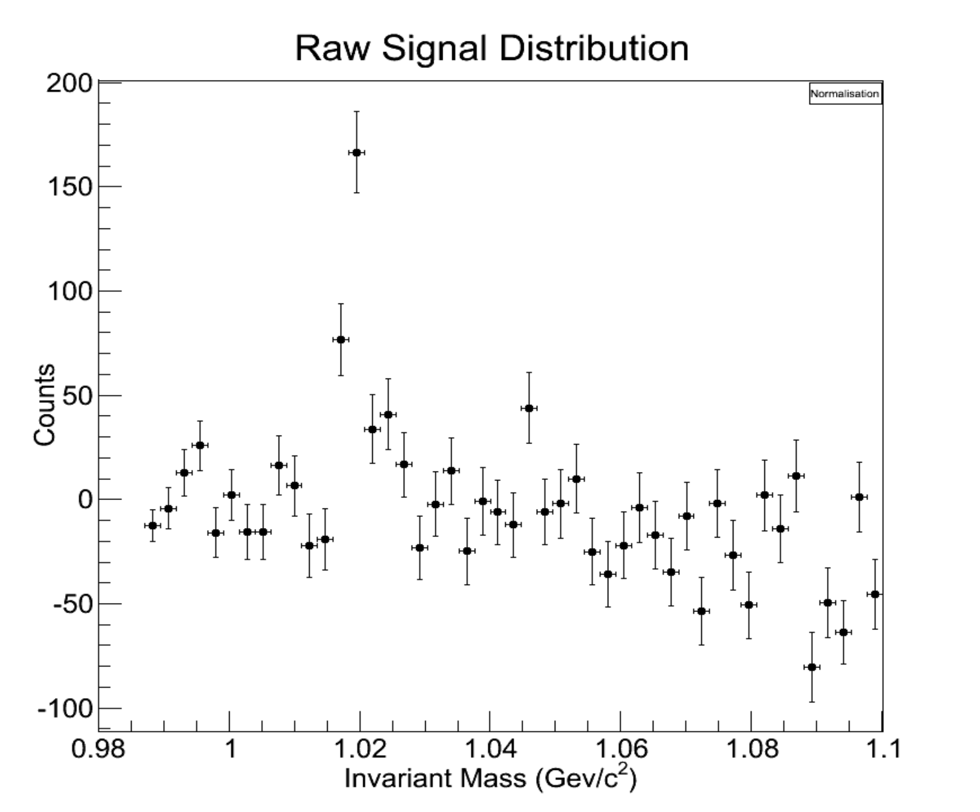
Combinatorial background-different events



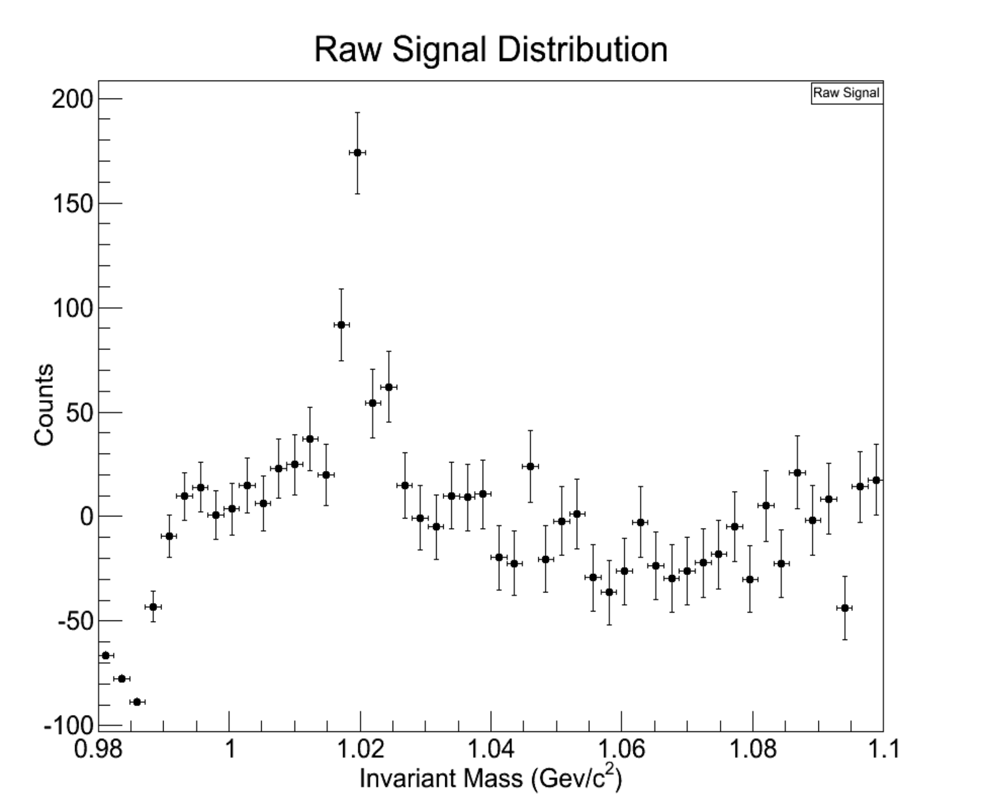
Reconstruction of ϕ (1020)

Signal distribution after subtraction of background

Subtraction of same-event background



Subtraction of mixed-event background



Reconstruction of ϕ (1020) Invariant Mass Distribution Results

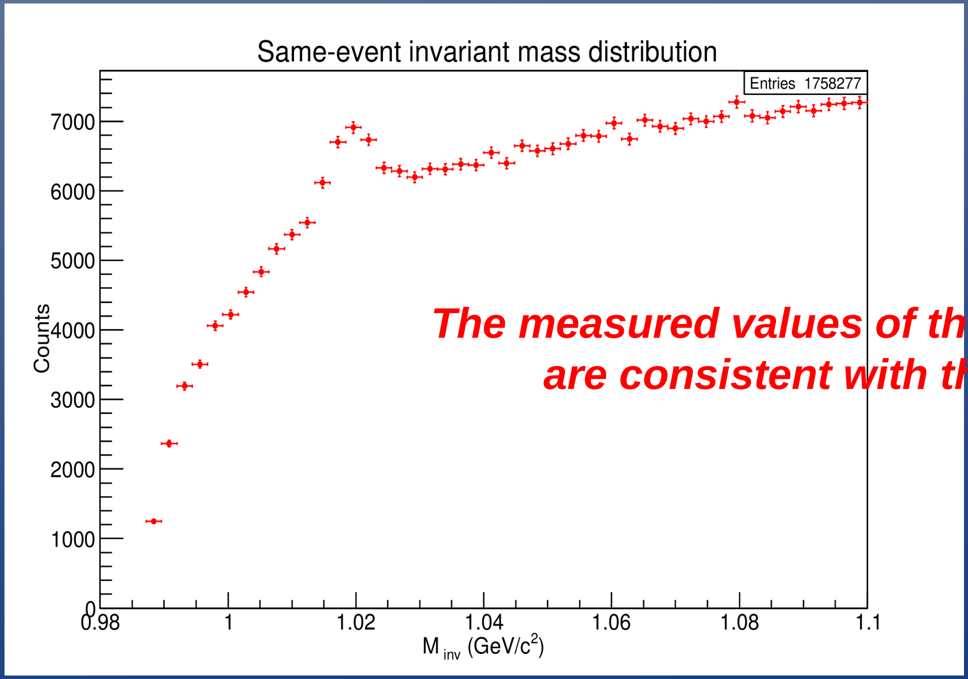
Analysis

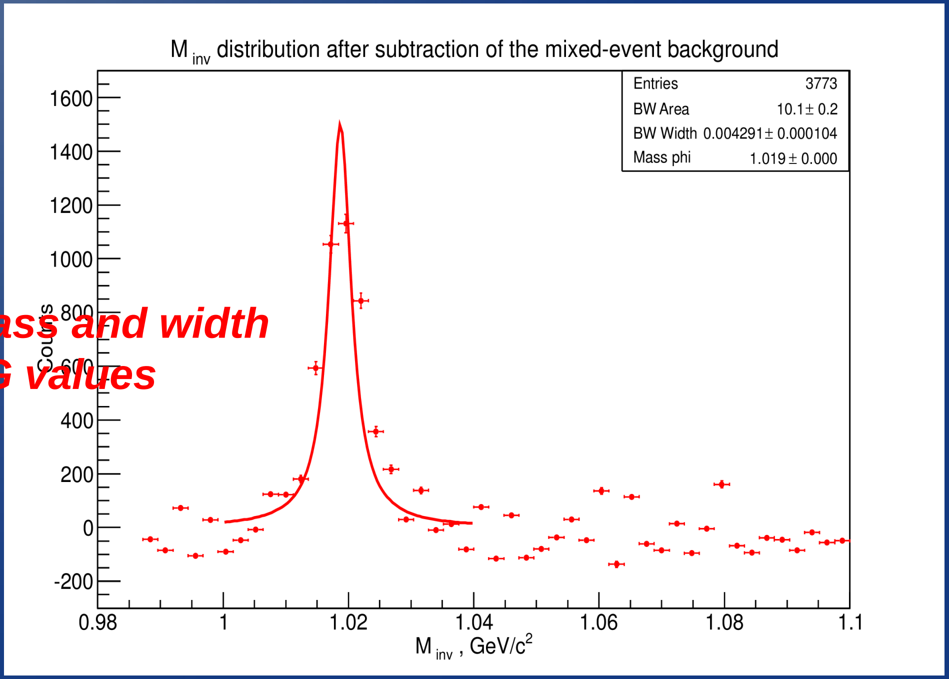
*Channel of decay: $\varphi \longrightarrow K^+K^-$
*Same-event invariant mass distribution
*Usage of mixed-event background
*Breit-Wigner fit function
*Central Au+Au at $\sqrt{s}$ = 11 GeV (UrQMD model)
*PID: TOF, dE/dx
*Selection by track quality cuts and PID

BW Width = 0.004291 ± 0.000104 (GeV/c²)
M_{inv} = 1.019540 ± 0.000012 (GeV/c²)
S/√(S+B) = 18.11

$$M_{inv} = \sqrt{((E_1+E_2)^2 - (p_{x1}+p_{x2})^2 - (p_{y1}+p_{y2})^2 - (p_{z1}+p_{z2})^2)}$$

$$BW(m_{inv}) = \frac{1}{2\pi}\frac{A.W}{(m-m_\phi)^2 + (W/2)^2}$$





The measured values of the φ mass and width are consistent with the PDG values

Conclusion

Measurements of the production of strange particles such as the φ-meson can provide important information on the properties of the medium and particle production mechanisms in ultra-relativistic Au-Au collisions.

Measurements of the φ-meson p_T spectra and their dependence in terms of shape and normalization on centrality may shed light on the constituents of the medium at the time of φ formation as well as the mechanism through which the φ-mesons are formed. Since multistrange hadrons and particles with hidden strangeness are assumed to freeze out early and undergo fewer interactions in the hadronic stage, their v_2 signals should provide a clean signal from the early stage of the system's evolution.

The recent results of the φ-meson study are shown in this presentation. The values of the parameters obtained by the fit are consistent with the values given in literature. This study shows that the measurement of φ-mesons is feasible and we can expect detection of them when NICA/MPD will be put in operation.

Thank you for your attention!