PWG5 (Heavy Flavour) status

Alexander Zinchenko

Outline

1. Inner Tracking System (ITS) performance evaluation
2. “Vector Finder” approach to track reconstruction in ITS
3. Leptonic decays: energy loss simulation in TPC
4. Charmonia and exotics

MPD Inner Tracking System based on MAPS

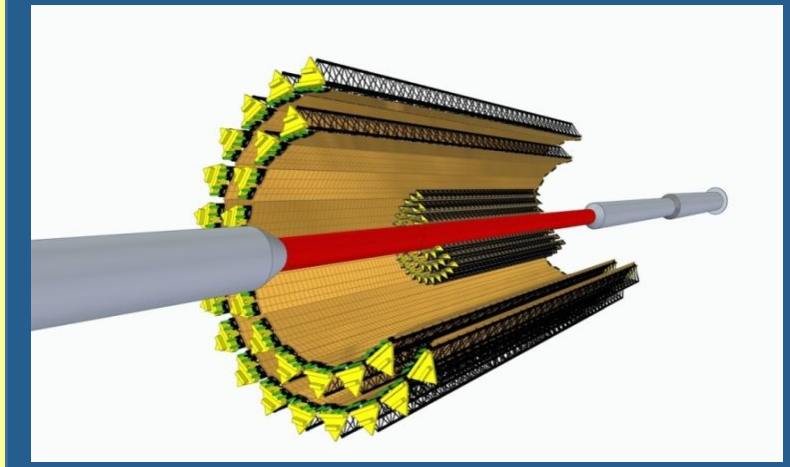
MPD ITS project:

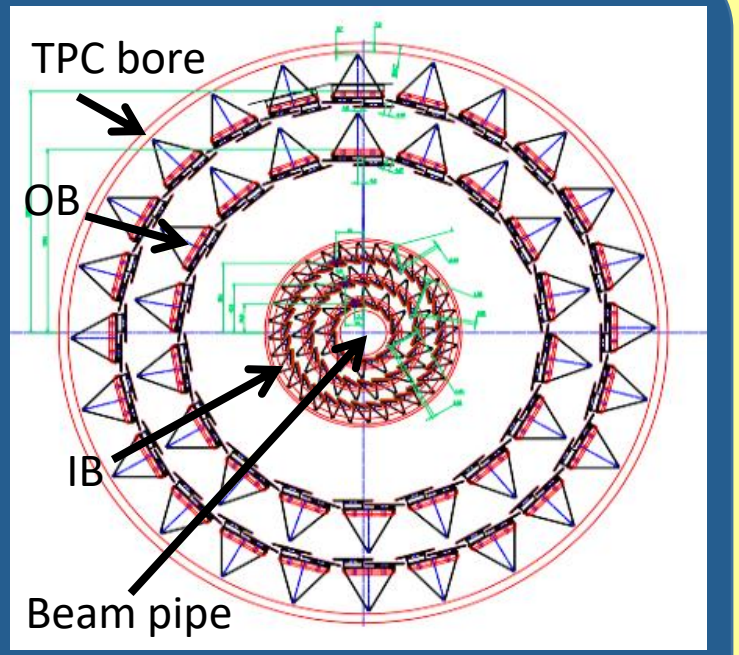
- The two stages construction scenario – C.Ceballos (MPD ITS TDR Coordinator):

Stage 1: The outer barrel (by 2022/2023)

Stage 2: The inner barrel (by 2025/2026)

- Work by LHEP STS Dept. (Yu.Murin), 3 China Univ., SPbSU, MSU + experts L.Musa (CERN), P.Senger (GSI), N.Xu (CCNU)
- ITS TDR – 50% ready, expected by next Collaboration Meeting
- Detector performance results: tracker design by Sergey Igolkin; simulation, reconstruction and analysis by Valery Kondratev





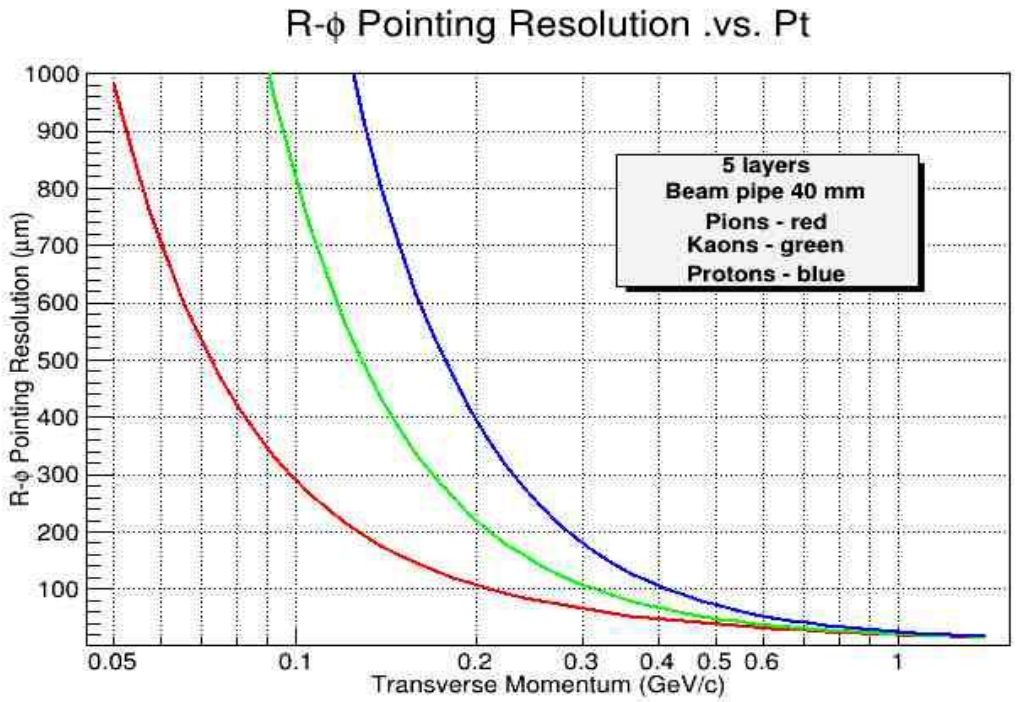
Layer	Number of ladders	Number of MAPS	R_{min}, mm	Ladder length, mm	Effective thickness, μm
1	12	288	22.4	750	50
2	22	528	40.7	750	50
3	32	768	59.8	750	50
4	36	3528	144.5	1526	700
5	48	4704	194.4	1526	700

IT pointing resolution for π, K and p

V. Kondratev

The spatial resolution of the IT5-40 model was evaluated in the framework of the simplified code developed by ALICE collaboration, which performs tracking of charged particles through cylindrical silicon layers with a given radiation thickness.

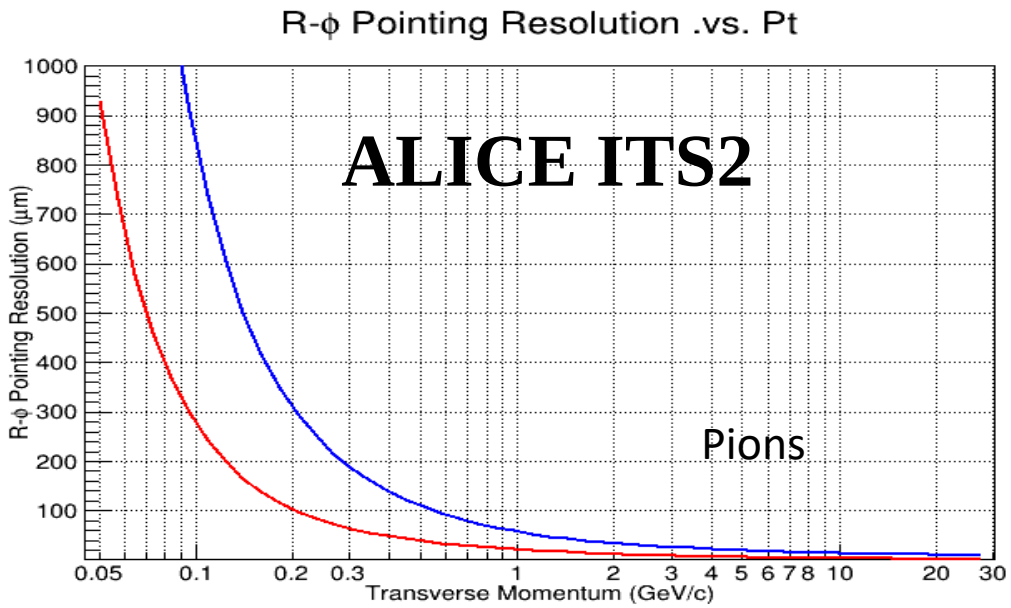
Layer	Mean r, мм	σ(ρφ), um	X/X_0, %
Beam pipe	20.0	-	0.22
1	24.6	4.0	0.30
2	43.3	4.0	0.30
3	62.5	4.0	0.30
4	146.2	4.0	0.30
5	196.0	4.0	0.30

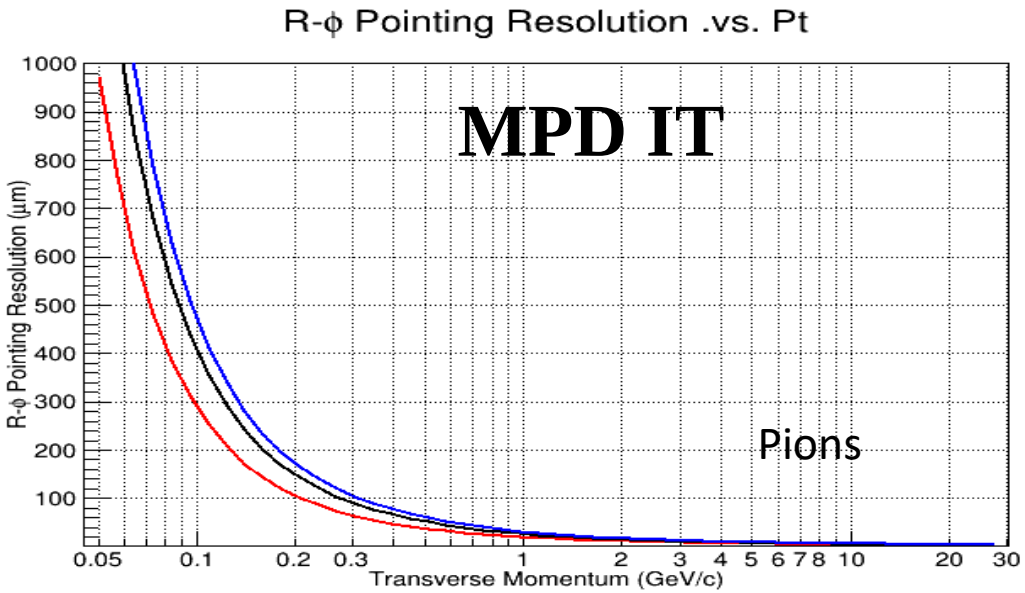


Evaluated resolution of IT5-40 provides, for example, the possibility of D^0 decay vertex reconstruction in the channel
$D^0 \rightarrow K^- + \pi^+$ (λ = 123 μm) with small p_T up to 300 MeV/c.

MPD IT pointing resolution compared to ALICE ITS

V. Kondratev





New ITS2

Old ITS1

Beam pipe Ø = 40 mm

Beam pipe Ø = 50 mm

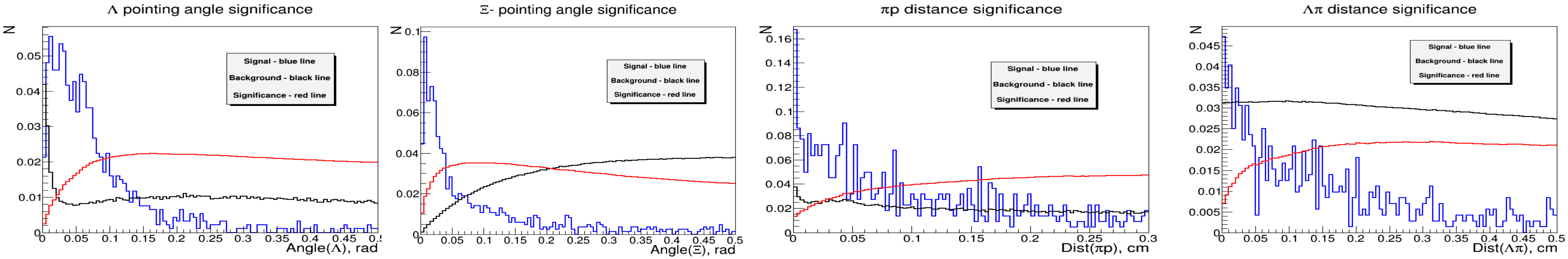
Beam pipe Ø = 60 mm

MPD IT pointing resolution with a beam pipe Ø = 40 mm is comparable with ALICE ITS2.

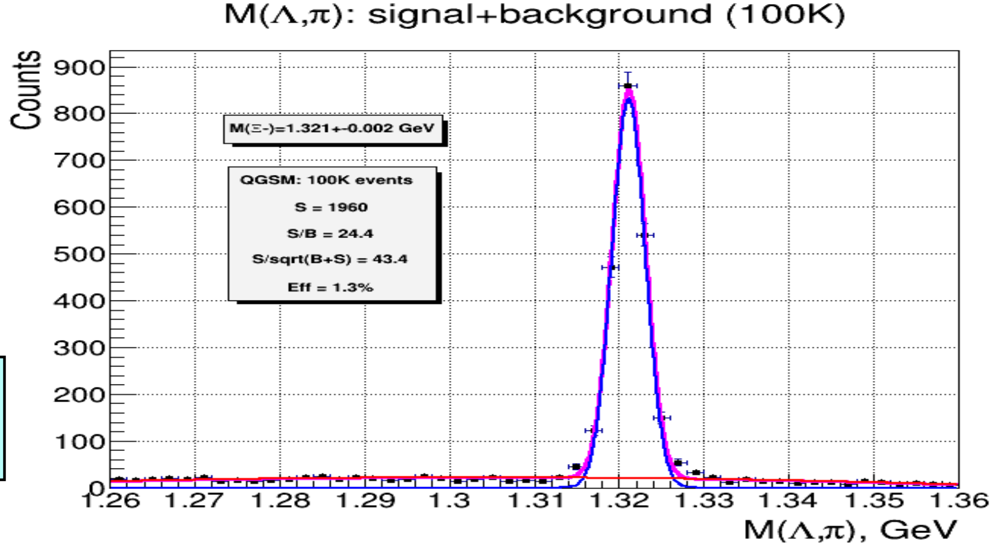
Ξ^- reconstruction (10^5 events):

V. Kondratev

$\Xi^- \rightarrow \Lambda + \pi^-$
$\quad \llcorner\!\rightarrow p + \pi^-$



dca(p)>0.3 cm & dca(π)>0.3 cm & dca(Λ)>0.1 cm & dist(πp)<0.05cm & dist(Λπ)<0.2 cm & θ(Λ)>0.02 rad & θ(Ξ)<0.05 rad

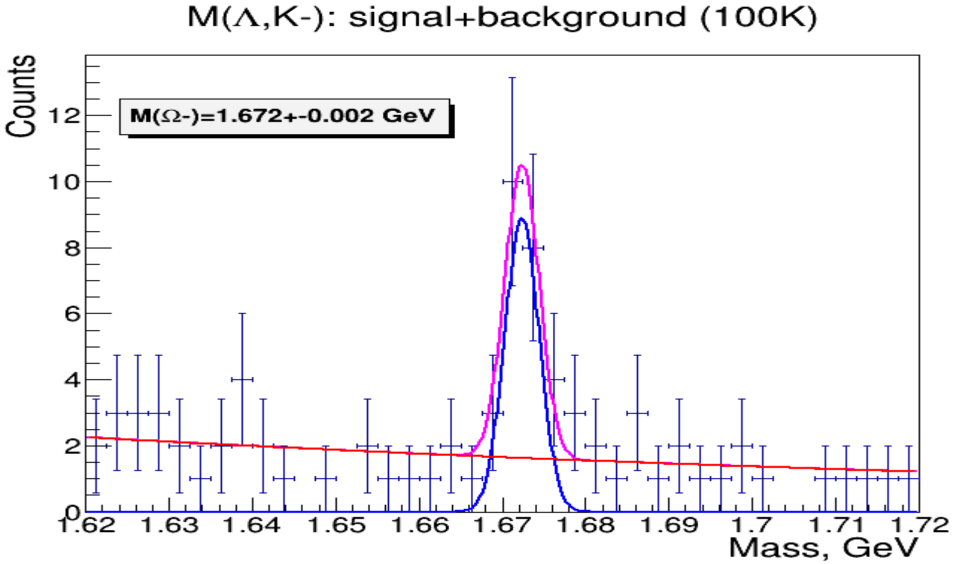


The use of optimized selection criteria allows to reconstruct Ξ^- with an efficiency of 1.3% at sufficiently high level of significance of 43.4

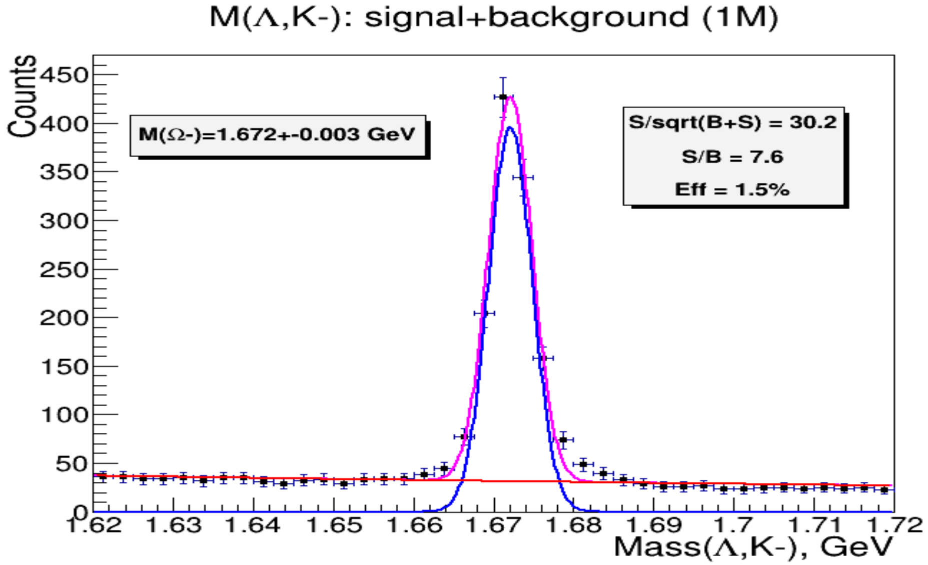
Ω^- reconstruction (10^6 events): V. Kondratev

$\Omega^- \rightarrow \Lambda + K^-$
$\quad \llcorner\!\rightarrow p + \pi^-$

dca(π)>0.05 cm & dca(p)>0.05 cm & dca(K)>0.1 cm & dca(Λ) >0.1 cm & dist(πp)<0.3 cm & dist(ΛK)<0.1 cm & θ(Λ)>0.01 rad & θ(Ω)<0.015 rad & λ(Λ)>5 cm & λ(Ω)<8 cm



Signal – QGSM generator
Background – QGSM generator



Signal – thermal generator
Background – QGSM generator

Increasing the statistics to 1M events allows to reconstruct Ω^- with an efficiency of 1.5% at a significance level of 30.2

Charmed particle reconstruction in central Au+Au collisions at $\sqrt{S_{NN}}$ = 9 GeV

Particle	Mass [MeV/c^2]	Mean path $c\tau$ [mm]	Decay channel	BR
D^+	1869.62±0.20	0.312	$\pi^+ + \pi^+ + K^-$	9.13%
D^0	1864.84±0.17	0.123	$\pi^+ + K^-$	3.89%

Background simulation - using QGSM generator (100K events)
Signal simulation – using thermal generator (1M events)

Two methods are used for signal selection:
1) Method of topological cuts (TC)
2) Method of multivariate data analysis (MVA)

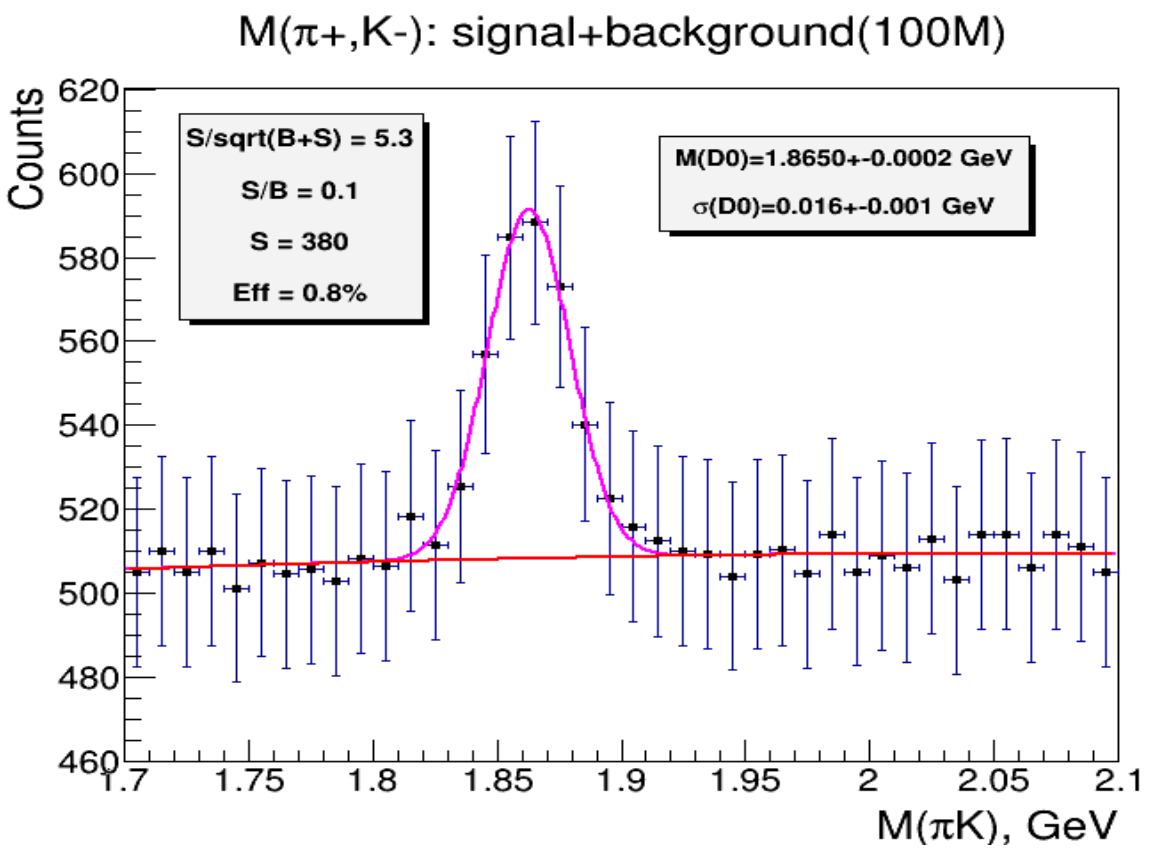
V. Kondratev

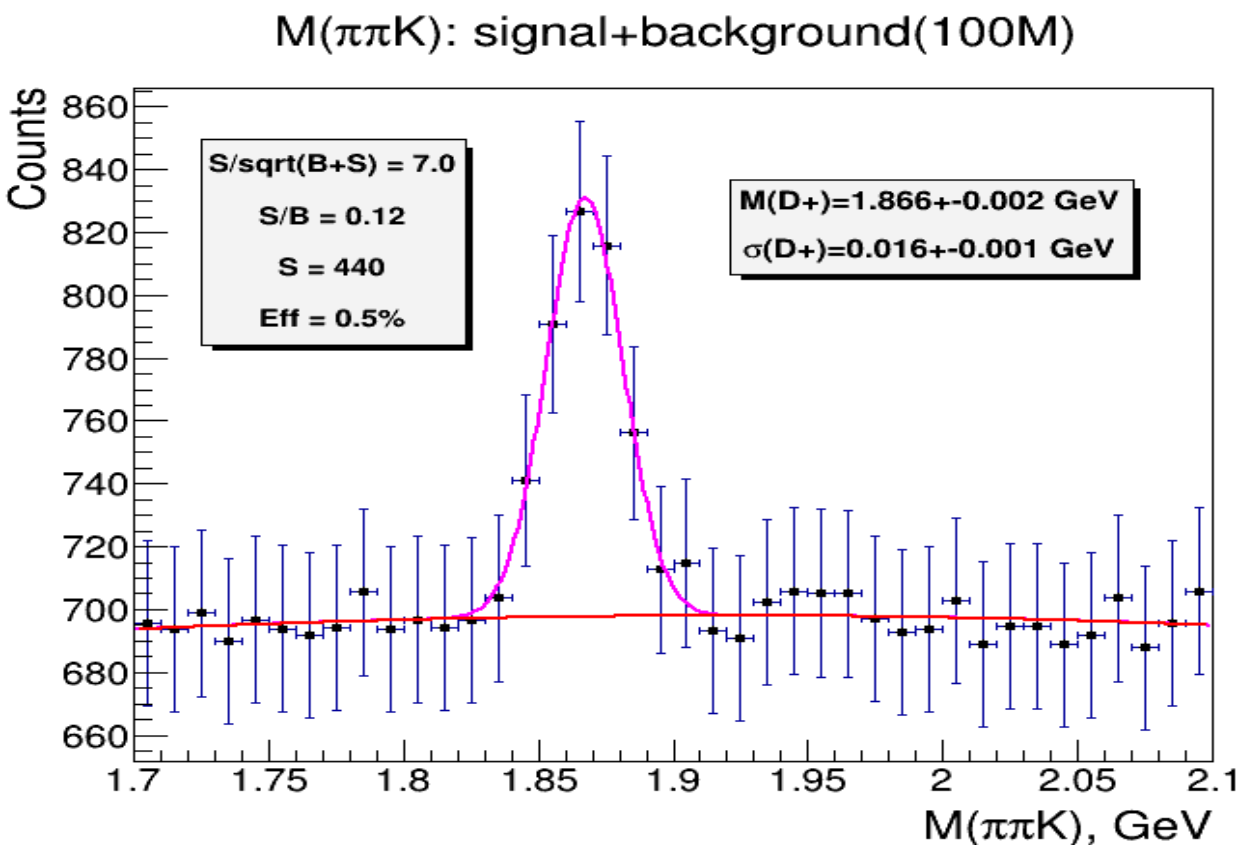
D mesons reconstruction by TC method: invariant mass spectra

V. Kondratev

$D^0 \rightarrow K^- + \pi^+$

$D^+ \rightarrow K^- + \pi^+ + \pi^+$





Using the method of topological cuts allows to reconstruct D^0 and D^+ with an efficiency of 0.8% and 0.5% respectively.

Toolkit for MultiVariate Analysis

V. Kondratev

TMVA is a ROOT package for training, testing and performances evaluation of multivariate classification techniques.

Analysis is generally organized in 2 steps :

- **Training phase**

  At this stage the variables from the signal and background samples are trained according the classifier chosen by the user. The results of the classification is written into weight files, traducing the initial **N** input variables **V** to one dimensional variable **R** (response) :

  $$V^N \rightarrow R$$

- **Application phase**

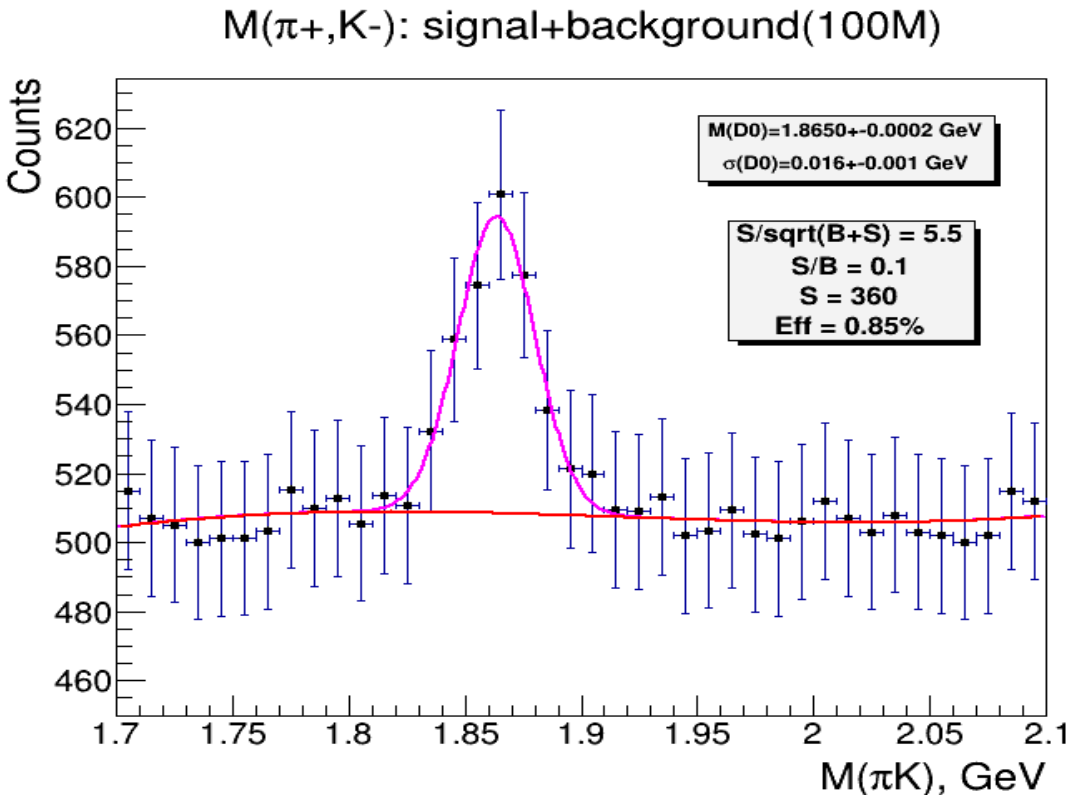
  At this stage the data classification, reading from the weight files, is applied to the data to be analyzed.

The classifier BDT (Boosted Decision Trees) has been chosen for the analysis phase when reconstructing D mesons

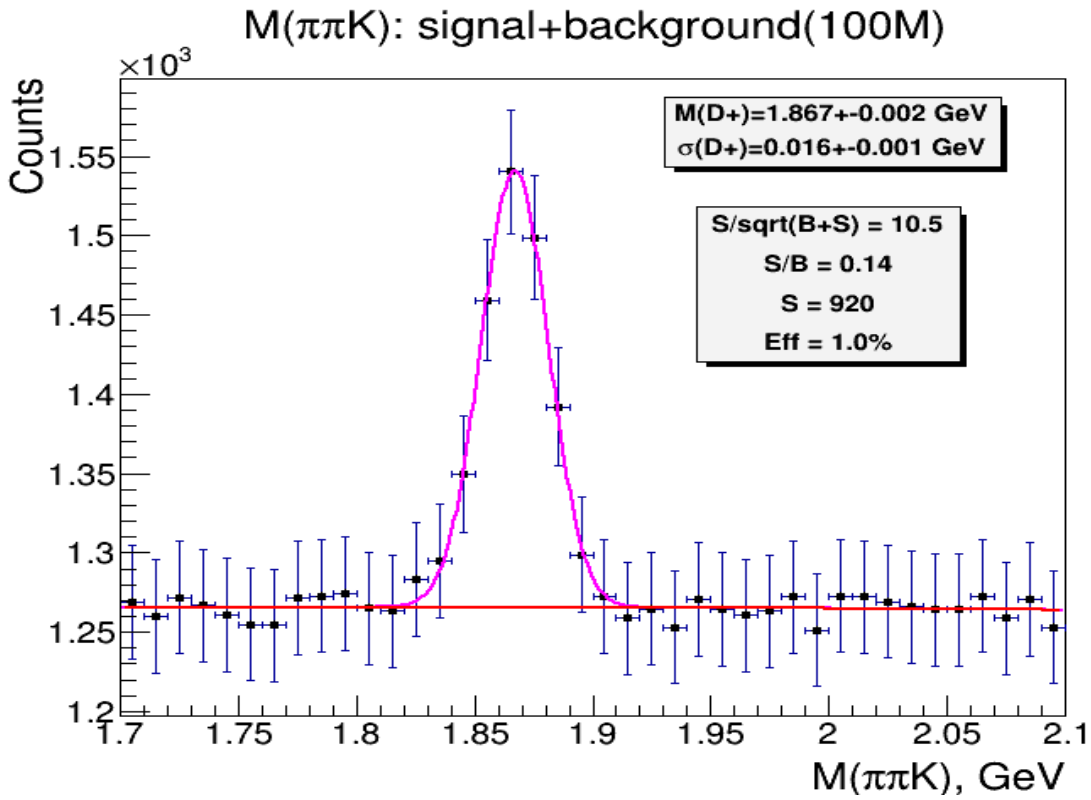
D mesons reconstruction by MVA method: invariant mass spectra

V. Kondratev

$D^0 \rightarrow K^- + \pi^+$



$D^+ \rightarrow K^- + \pi^+ + \pi^+$



Using the optimal BDT cut allows to reconstruct D^0 and D^+ with an efficiency of 0.85% and 1.0% respectively.

V. Kondratev

Reconstruction parameters of strange and charmed particles in central Au+Au collisions at $\sqrt{s_{NN}} = 9$ ГэВ

Particle	Λ	Ξ^-	Ω^-	D^0		D^+	
Method	TC	TC	TC	TC	MVA	TC	MVA
Multiplicity	20	1.2	10^{-1}	10^{-2}	10^{-2}	10^{-2}	10^{-2}
Number of events	$5 \cdot 10^3$	10^5	10^6	10^8	10^8	10^8	10^8
Efficiency, %	8.0	1.3	1.5	0.80	0.85	0.50	1.0
Significance $S/\sqrt{S+B}$	112.6	43.4	30.2	5.3	5.5	7.0	10.5
S/B(2σ) ratio	11.3	24.4	7.6	0.10	0.10	0.12	0.14
Yield per month	$2 \cdot 10^9$	$3 \cdot 10^7$	$2 \cdot 10^6$	$6 \cdot 10^3$	$7 \cdot 10^3$	$1 \cdot 10^4$	$2 \cdot 10^4$

If D^0 reconstruction efficiencies by MVA and TC are similar, then the use of MVA in the case of D^+ allows doubling the efficiency with a higher level of significance.

ITS Project activity – status and future steps

Reports / publications:

- Yu.A. Murin, A.D. Sheremetev, A.I. Zinchenko (JINR, Dubna, Russia), S.N. Igolkin, V. P. Kondratev (SPbSU, St.Petersburg), Yaping Wang (CCNU, Wuhan, China), A MAPS-based Inner Tracking System for the Multi-Purpose Detector at the NICA collider, Poster at QM 2019, Wuhan
- V. Kondratiev, C. Ceballos, S. Igolkin, A. Kolozhvari, Y. Murin, A. Sheremetiev, DETECTION OF D + MESON DECAYS IN THE TRACKING SYSTEM OF NICA-MPD, NICA days 2019-IV MPD Collaboration Meeting
- А.И. Зинченко, С.Н. Иголкин, В.П. Кондратьев, Ю.А. Мурин, Идентификационная способность вершинного трекового детектора установки NICA-MPD при реконструкции распадов странных и очарованных частиц. (Identification capability of the NICA-MPD vertex detector during reconstruction of strange and charmed particles). To appear in PEPAN Letters 2020.

Future: cooperation intensification with ALICE ITS3 physics group

Supported by the RFBR Grant 18-02-40119

Vector Finder in ITS

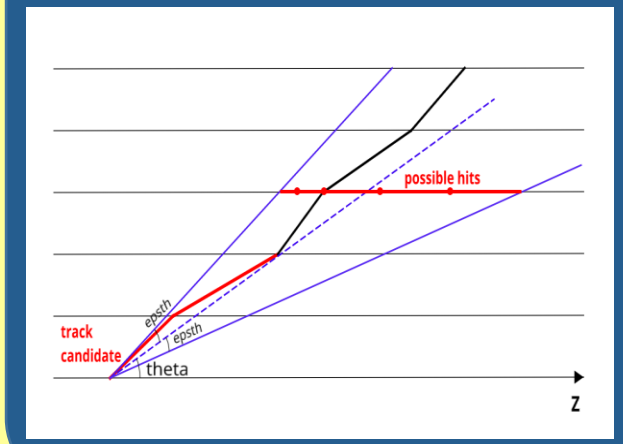
Method:

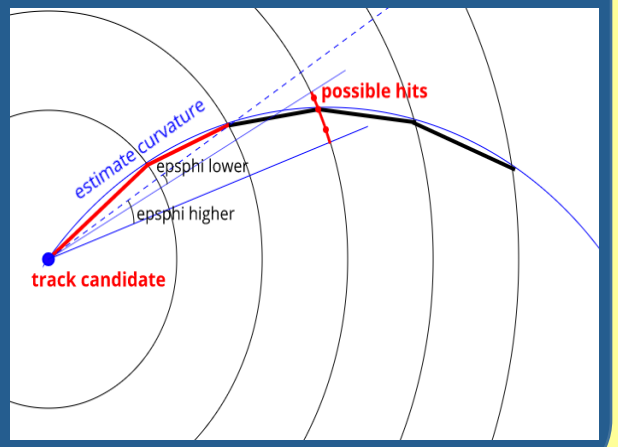
- Track finding is based on combinatorial search with prior constraints – constraints on angular positions in two projections (epsth in longitudinal, epsphi – in transverse projection)

D. Zinchenko, A. Zinchenko – LHEP JINR

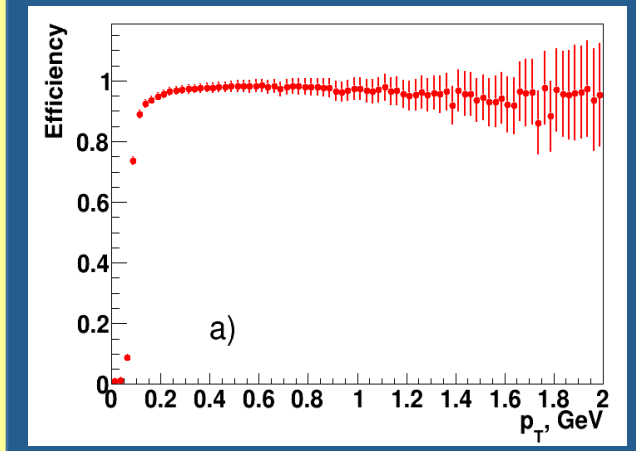
E. Nikonov – LIT JINR

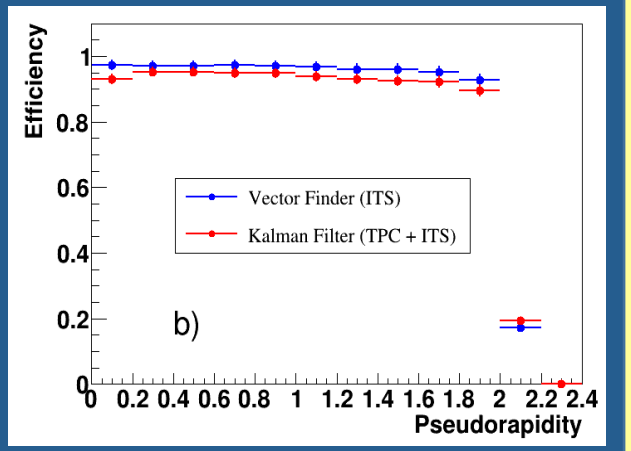
Track finding scheme in two projections



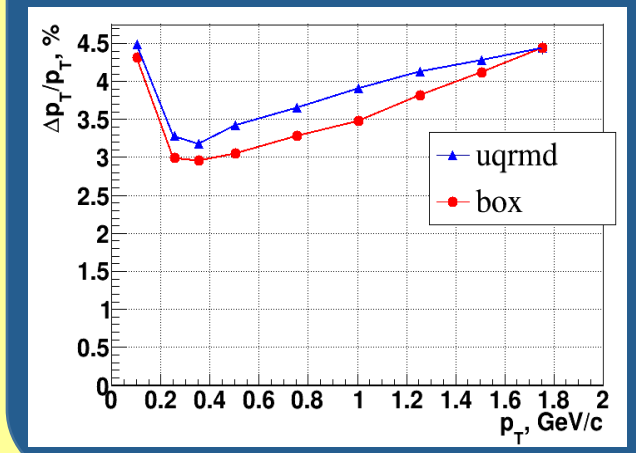


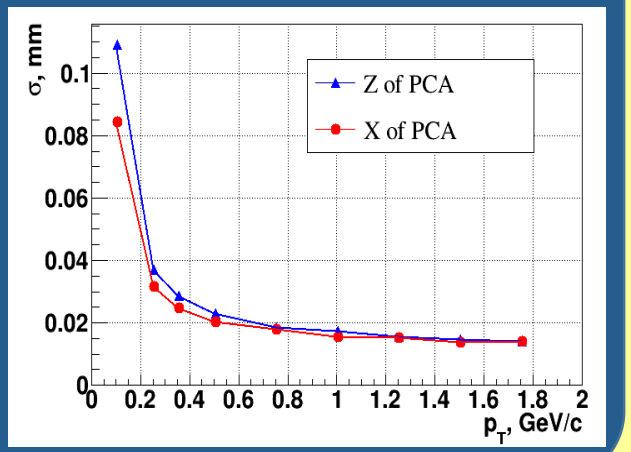
Track reconstruction efficiency



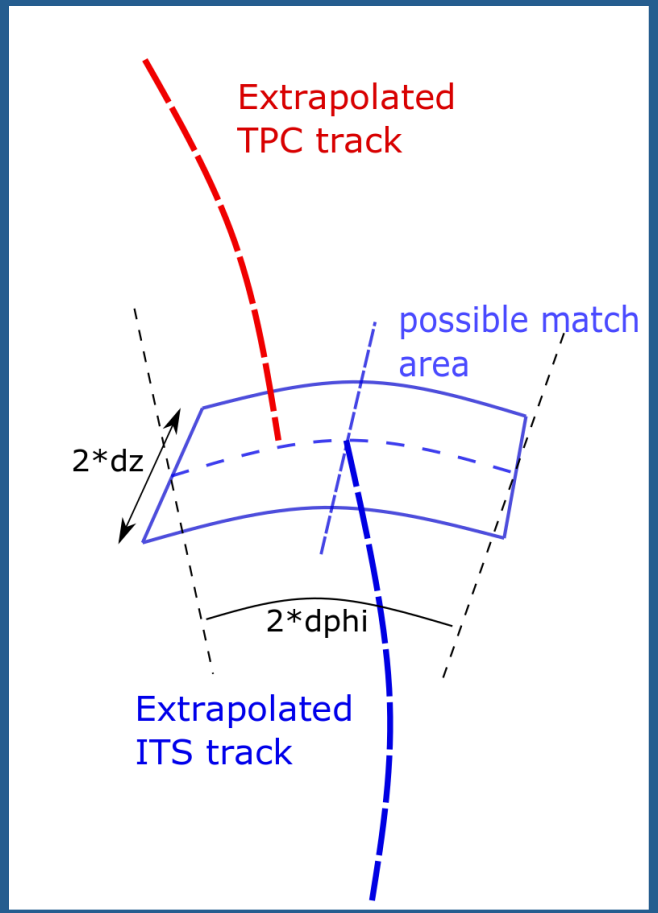


Reconstruction accuracy

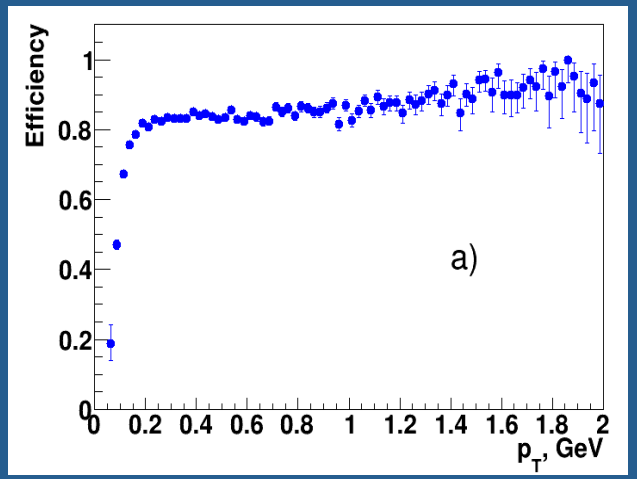


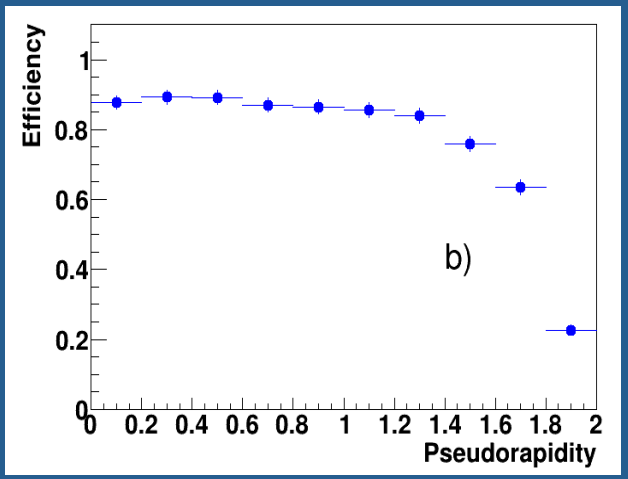


ITS-to-TPC track matching



Track matching efficiency





Vector Finder activity – status and future steps

Reports / publications:

- D. Zinchenko, A. Zinchenko, E. Nikonov, A ``vector finder'' approach to track reconstruction in the inner tracking system of MPD/NICA, 23rd International Scientific Conference of Young Scientists and Specialists (AYSS-2019), AIP Conf. Proc., v.2163, 2019, p.060006
- D. Zinchenko, A. Zinchenko, E. Nikonov, Development of algorithms for track reconstruction and matching in the ITS and TPC detectors at MPD/NICA, NICA days 2019 – IV MPD Collaboration Meeting

Future: method tuning for secondary tracks; possible extension to TPC tracking (kink finding)

Supported by the RFBR Grant 18-02-40060

Leptonic decays – energy loss simulation in TPC

History:

GEANT3/4 did not properly described energy losses in TPC gas

Method:

Implement energy loss simulation in TPC based on parameterization of results obtained from the microsimulation package GARFIELD++ - now simulation agrees with measurements in STAR and ALICE TPC

I. Rufanov - LHEP JINR

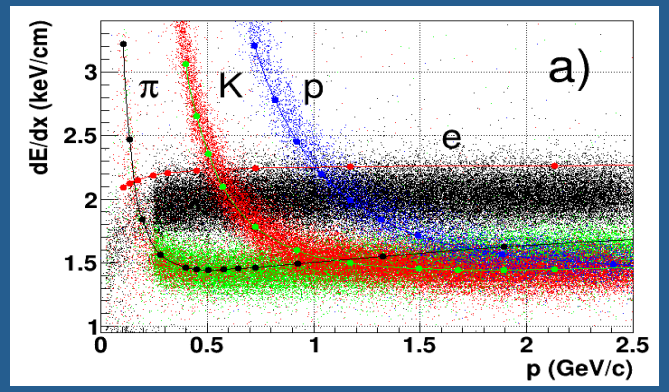
Work ongoing:

Tuning of dE/dx reconstruction procedure – tune particle identification

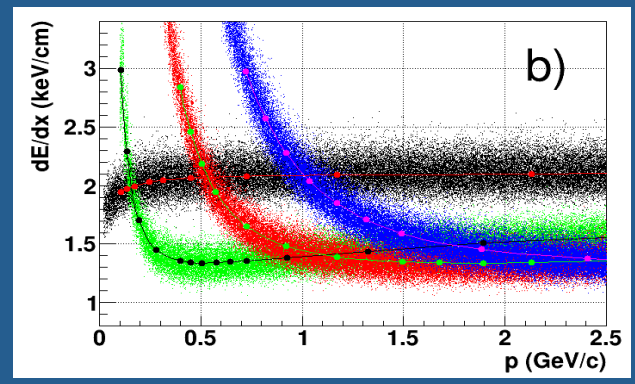
Supported by the RFBR Grant 18-02-40060

dE/dx in TPC

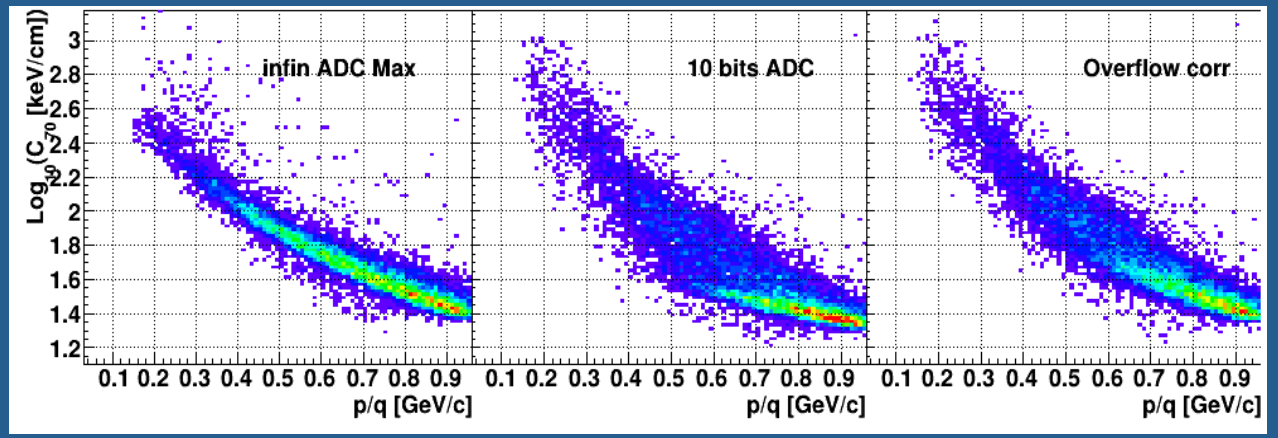
GEANT



GARFIELD++



Reconstructed *dE/dx* for He^4



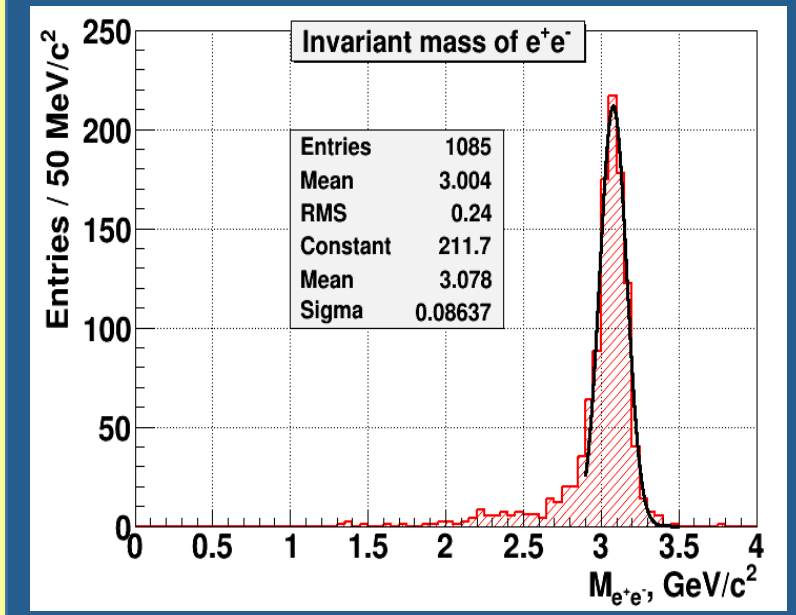
Charmonia and exotics

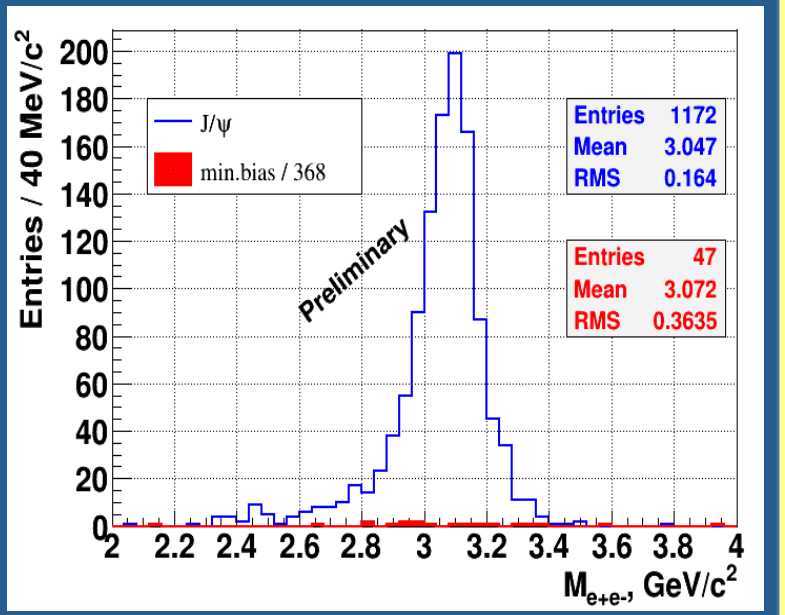
J/ψ + states:

- Some work has been done to evaluate MPD performance for charmonia / exotics decays to e^+e^- in pp at $\sqrt{s}$ = 25 GeV using Pythia generator. Ideal particle identification.

This topic is being looked after by M. Barabanov (LHEP).

$J/\psi \rightarrow e^+e^-$





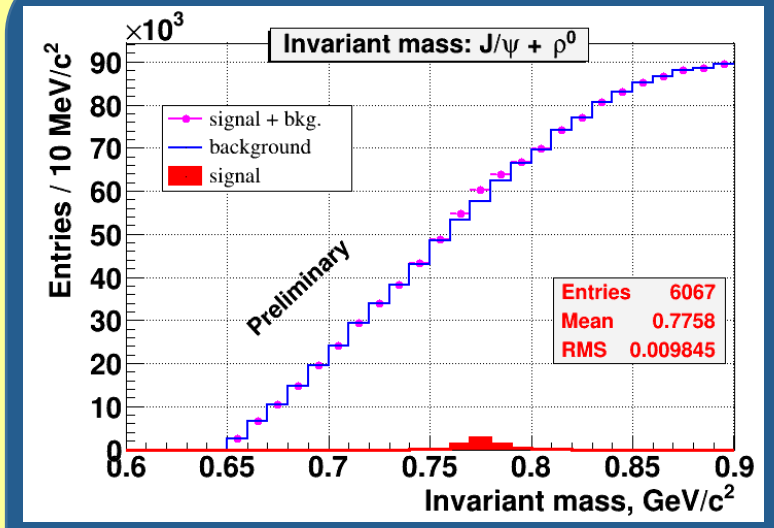
Charmonia and exotics

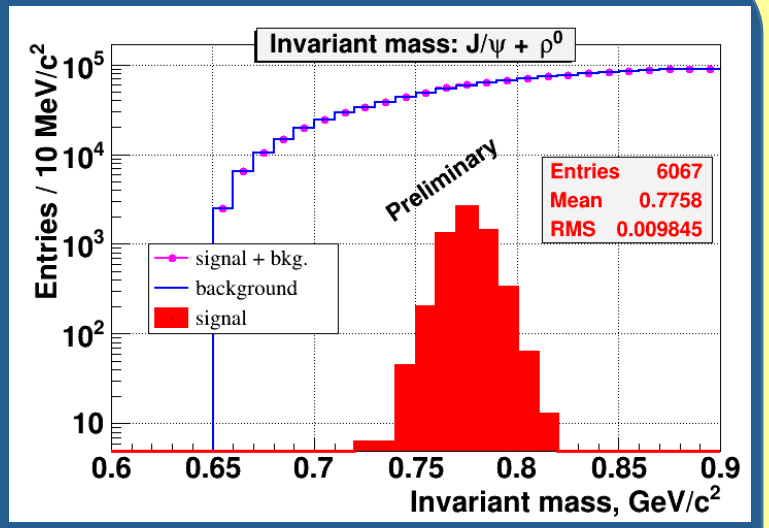
$$X(3872) \rightarrow J/\psi + \rho^0 \rightarrow e^+e^-\pi^+\pi^-$$

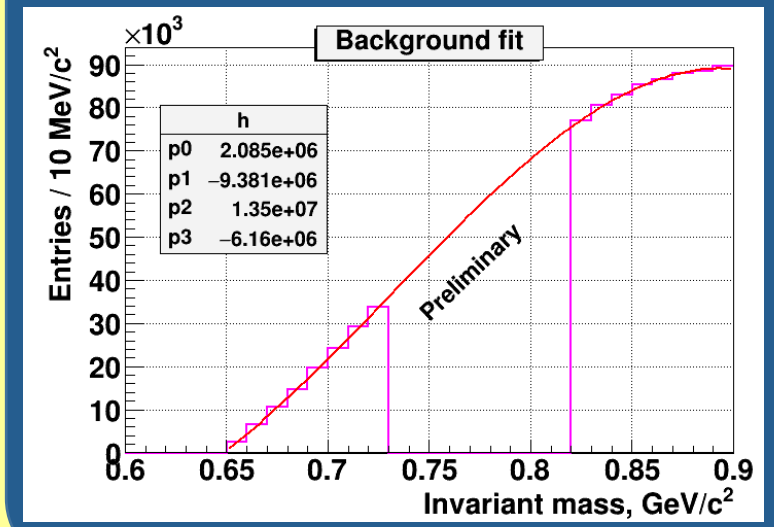
- Muon identification with EMC and MCORD - ??? This work can be synergetic with efforts on MCORD software preparation for commissioning run.

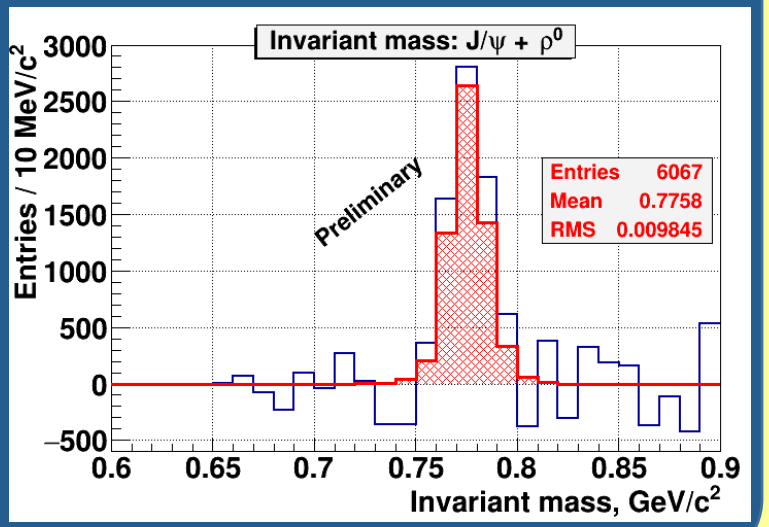
M.Yu. Barabanov, A.S. Vodopyanov, A.I. Zinchenko, Probing of XYZ exotics with hadron and heavy ion collisions, Nuovo Cimento , V. 42, N. 2-3, 110-113 (2019)

Exotic spectroscopy -
next talk by Elena Santopinto









Summary

- MPD ITS project is moving forward in different aspects: physics justification, technical and construction issues, event reconstruction methods and software;
- Leptonic decay mode feasibility evaluation is addressed, but not sufficiently yet;
- Charmonia and exotics studies need better justification in terms of their feasibility;
- People with good ideas and/or interest in their realization are welcome to join PWG5.