PWG5 (Heavy Flavour) status

Alexander Zinchenko

Outline

1. Scope of activities
2. Inner Tracking System (ITS) performance evaluation
3. “Vector Finder” approach to track reconstruction in ITS
4. Semi-leptonic decays and charmonia: energy loss simulation and reconstruction in TPC (*dE/dx* PID)

Scope of activities

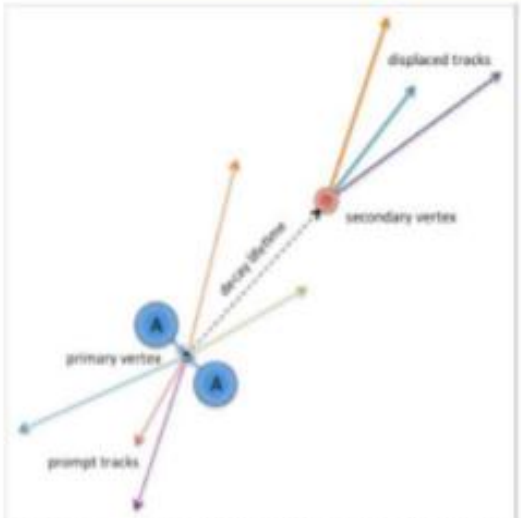
1. Open charm studies: exclusive decays -> Inner Tracking System (ITS) performance evaluation (synergy with ITS project) -> dedicated track reconstruction methods (“Vector Finder”)
2. Semi-leptonic decays and charmonia -> lepton (electron) tagging (synergy with dilepton studies) -> energy loss simulation and reconstruction in TPC for *dE/dx* PID

MPD Inner Tracking System based on MAPS

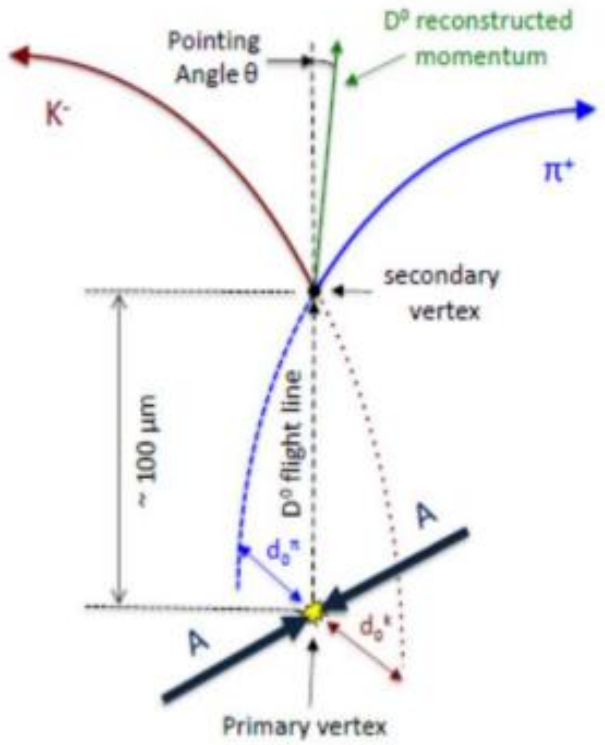
Secondary Vertex Determination

Open charm

Particle	Decay Channel	cτ (μm)
D^0	$K^-\pi^+$ (3.8%)	123
D^+	$K^-\pi^+\pi^+$ (9.5%)	312
D_s^+	$K^+K^-\pi^+$ (5.2%)	150
Λ_c^+	$pK^-\pi^+$ (5.0%)	60

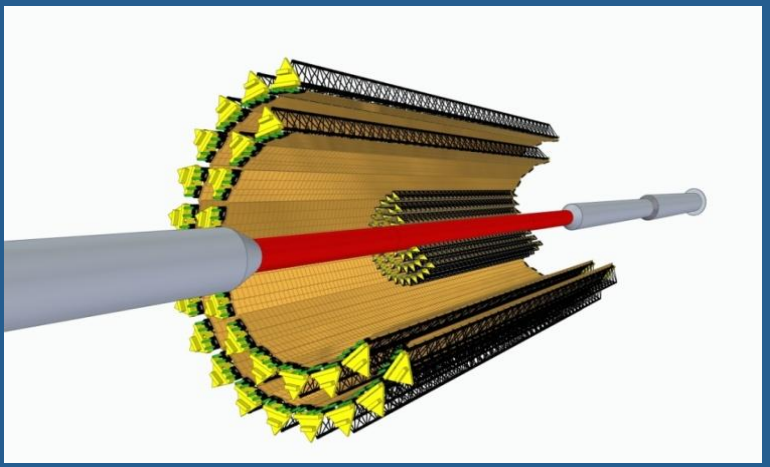


Example: D^0 meson



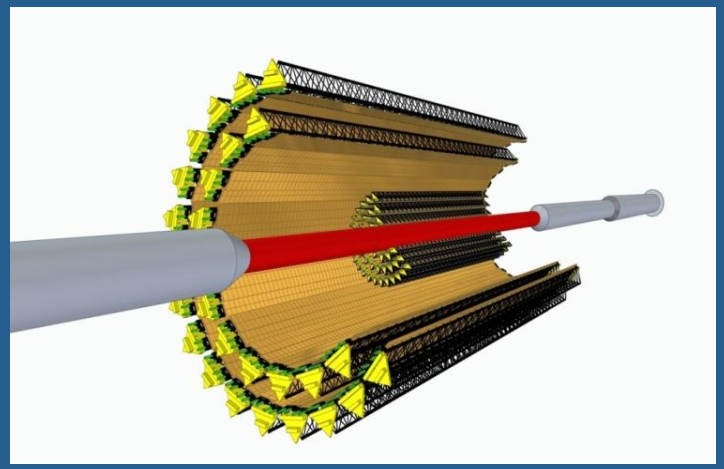
Analysis based on invariant mass, PID and decay topology

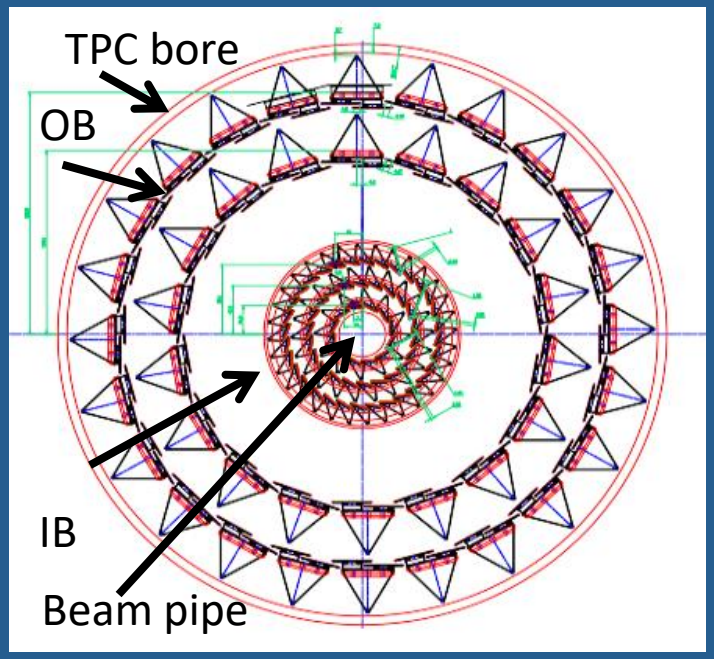
L. Musa (CERN) – International Winter Meeting on Nuclear Physics, Bormio, 8-11 Jan 2019



Yu. Murin

MPD Inner Tracking System based on MAPS

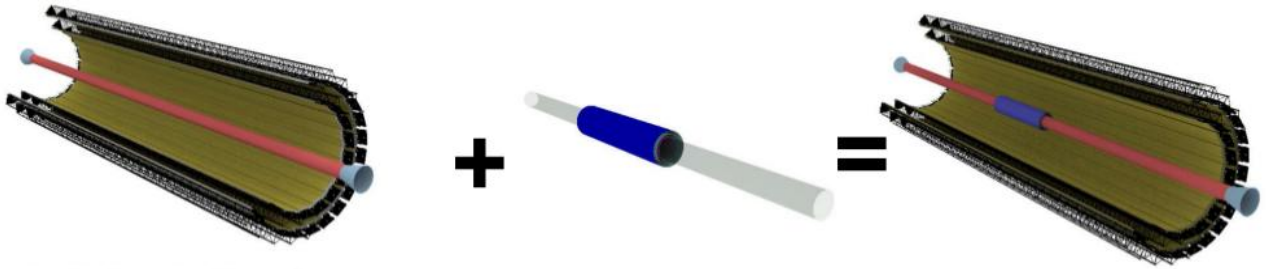




Yu. Murin

The two-stages of the MPD-ITS production

2020-2023 **2020-2024** **2025**



Participants Russia:
JINR (Dubna), SPbSU(St.Petersburg), SINP MSU(Moscow)
Participants China:
CCNU(Wuhan), IMP CAS(Lanzhou), USTC(Hefei), HZU(Huzhou)

Potential participants:
GSI(Darmstadt), WUT(Warsaw)

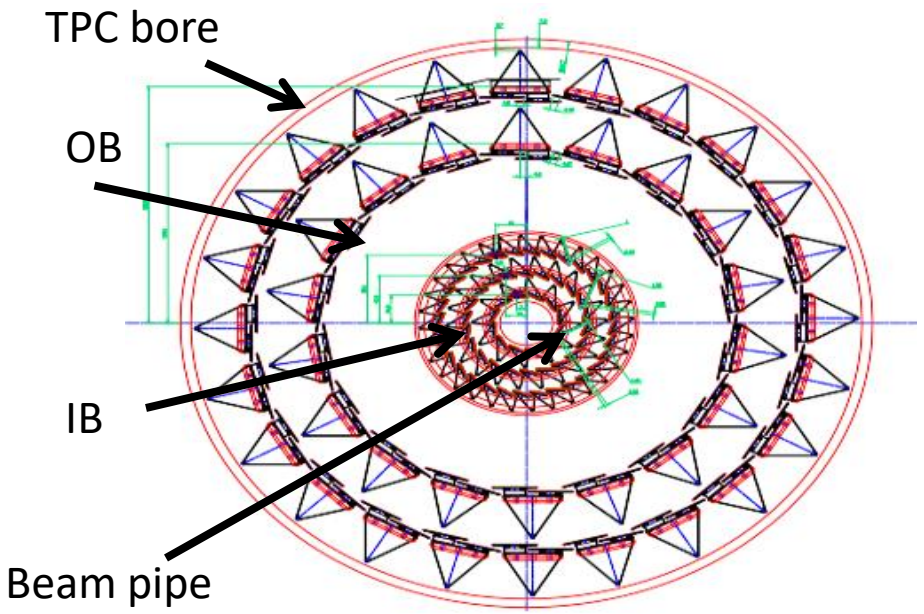
NICA

RFBR grants for NICA, 20-23.10.2020

JINR

IT geometric model used for simulation

V. Kondratev



Model IT5-40 (basic configuration):
5-layer IT for a beam pipe with the smallest possible diameter of 40 mm with a staggered arrangement of ladders in Outer Barrel (OB) and a fan-like arrangement of ladders in Inner Barrel (IB)

OB: ladders with MAPS similar to ALICE ITS2
IB: ladders with MAPS similar to ALICE ITS3

Layer	Number of ladders	Number of MAPS	R_{min}, mm	R_{max}, mm	Ladder length, mm	Effective thickness, μm
1	12	288	22.4	26.7	750	50
2	22	528	40.7	45.9	750	50
3	32	768	59.8	65.1	750	50
4	36	3528	144.5	147.9	1526	700
5	48	4704	194.4	197.6	1526	700

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)

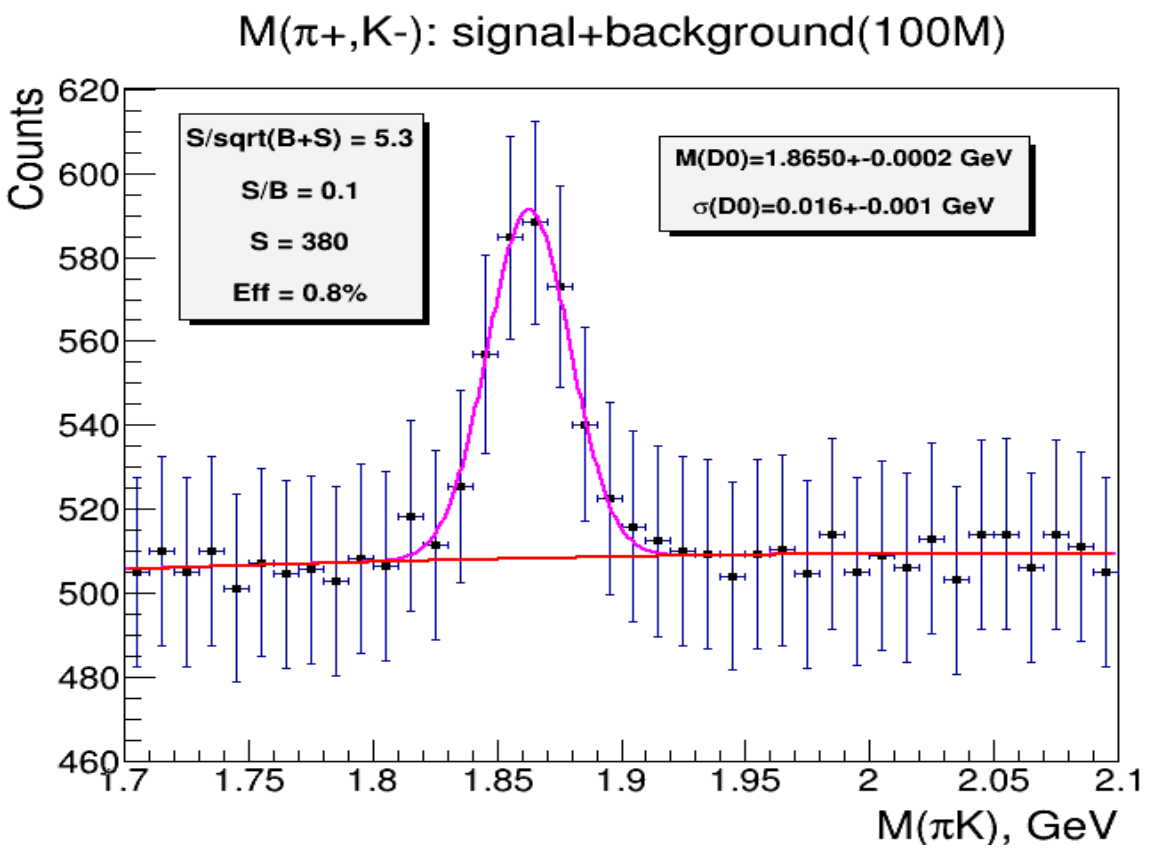
V. Kondratev

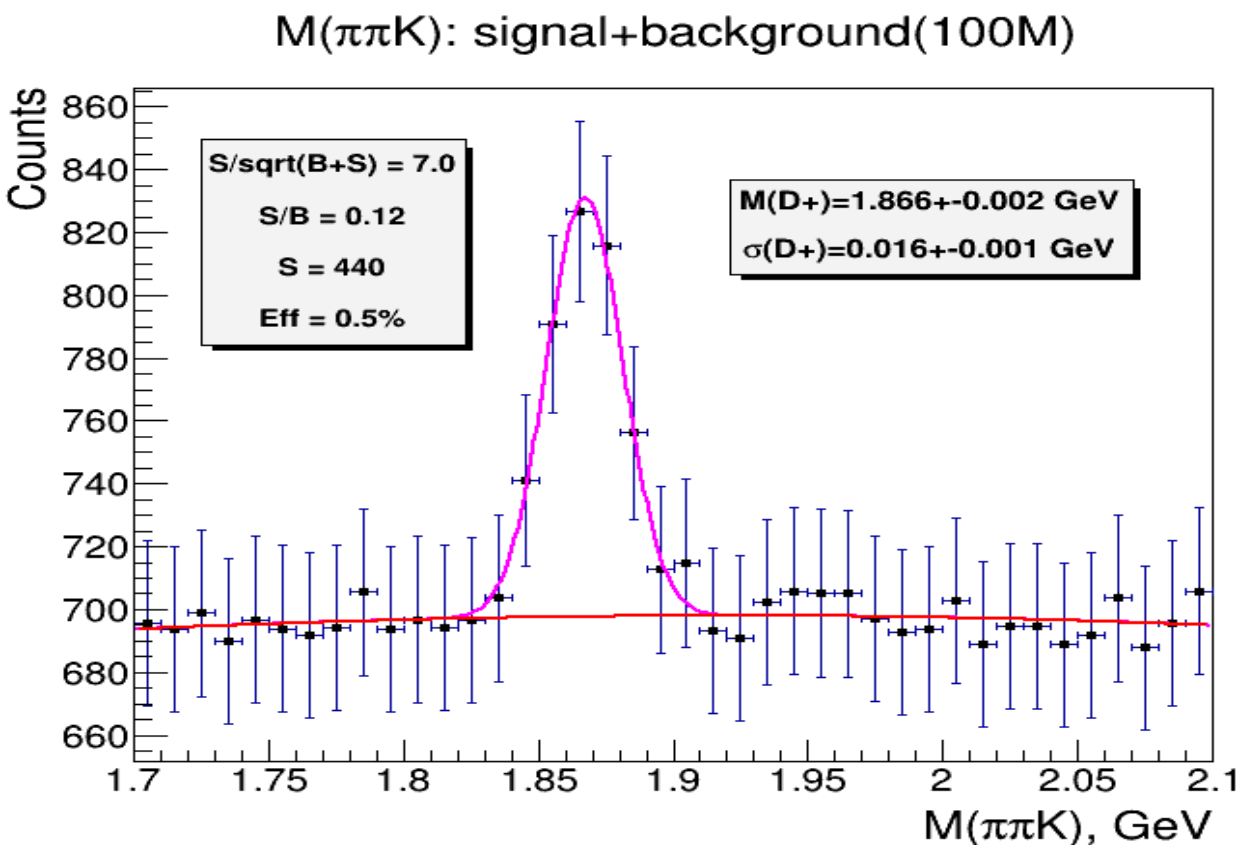
D mesons reconstruction by TC method: invariant mass spectra

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**

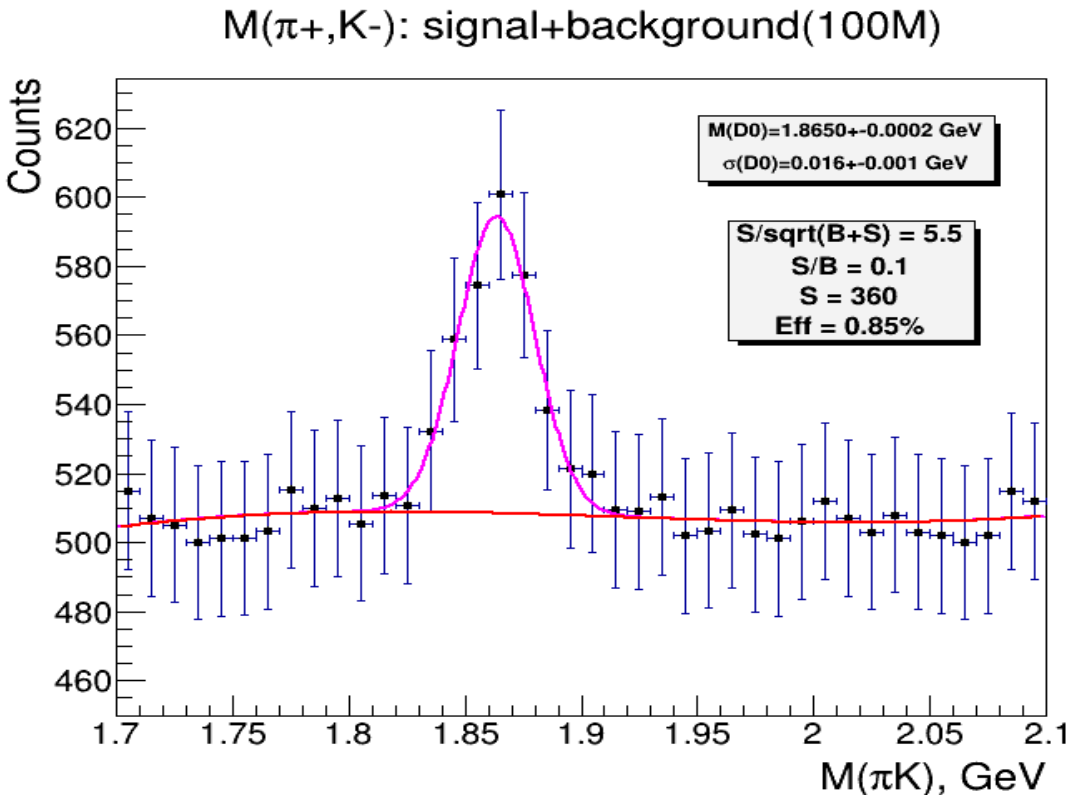
  At this stage the data classification, reading from the weight files, is applied to the data to be analyzed.

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

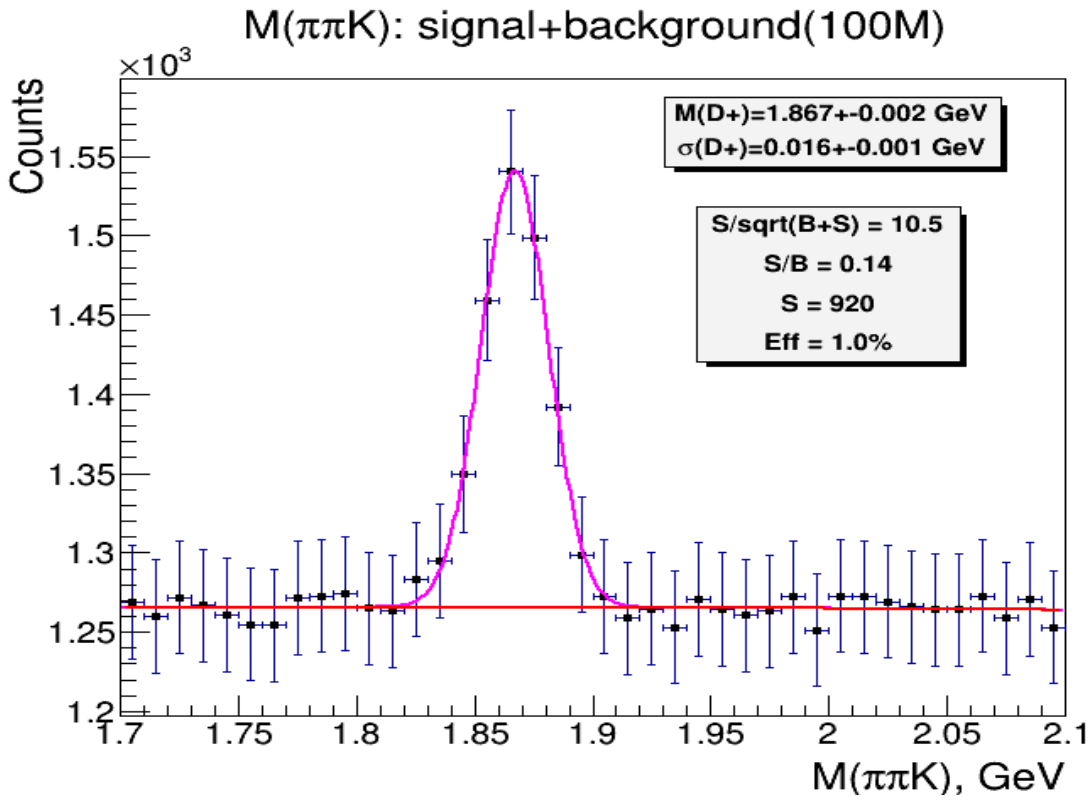
D mesons reconstruction by MVA method: invariant mass spectra

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 D mesons in central Au+Au collisions at $\sqrt{s_{NN}}$ 9 ГэВ with IT5-40

Particle	D^0		D^+	
Method	TC	MVA	TC	MVA
Multiplicity	10^{-2}	10^{-2}	10^{-2}	10^{-2}
Number of events	10^8	10^8	10^8	10^8
Efficiency, %	0.80	0.85	0.50	1.0
Significance $S/\sqrt{S+B}$	5.3	5.5	7.0	10.5
S/B(2σ) ratio	0.10	0.10	0.12	0.14
Yield per month	$6 \cdot 10^3$	$7 \cdot 10^3$	$1 \cdot 10^4$	$2 \cdot 10^4$

D^0 reconstruction efficiencies by both MVA and TC are similar. Using the MVA in the case of D^+ allows to double the efficiency with a higher level of significance.

ITS Project activity

Reports / publications:

- V. Kondratev, N. Maltsev, Yu. Murin, The quality assessment of the MPD tracking system for the detection of charmed particles in Au-Au collisions at the NICA collider, Conf. NUCLEUS 2020
- V. Kondratiev, N. Maltsev, Yu. Murin, MPD ITS physical simulation with focus on charmed mesons, Conf. RFBR Grants for NICA, 2020

Supported by the RFBR Grant 18-02-40119

Vector Finder in ITS

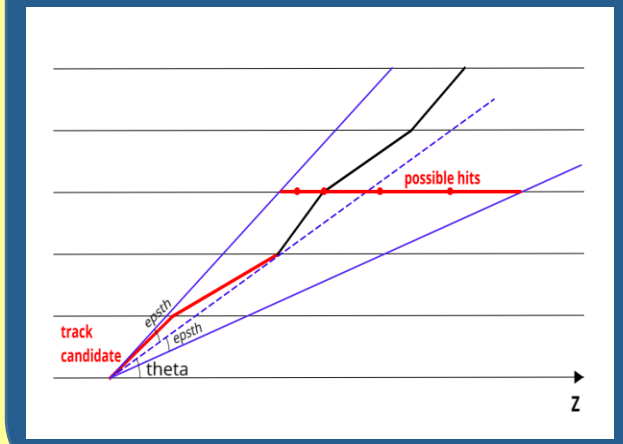
Method:

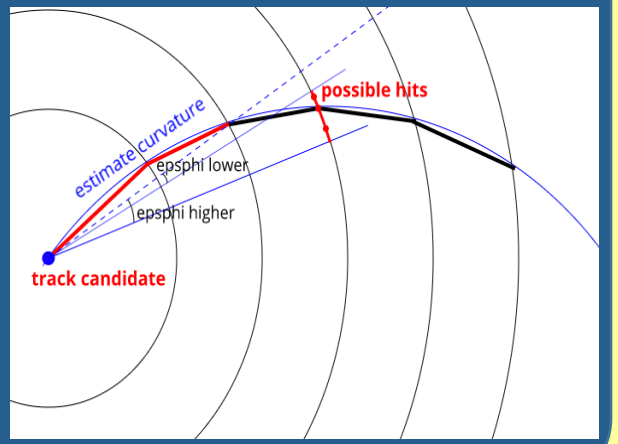
- Track finding is based on combinatorial search with prior constraints – constraints on angular positions in two projections (epsth in longitudinal, epsphi – in transverse projection)

D. Zinchenko, A. Zinchenko – LHEP JINR

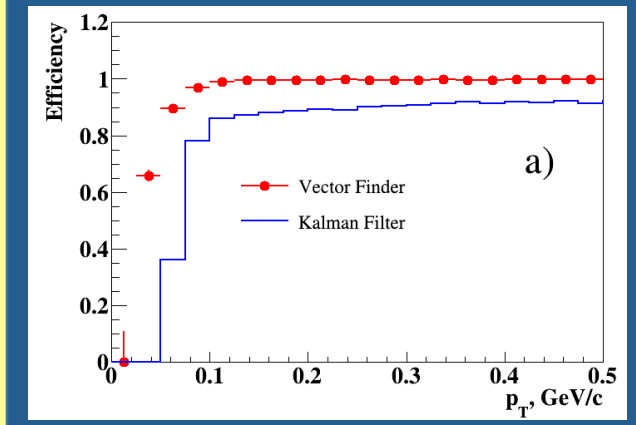
E. Nikonov – LIT JINR

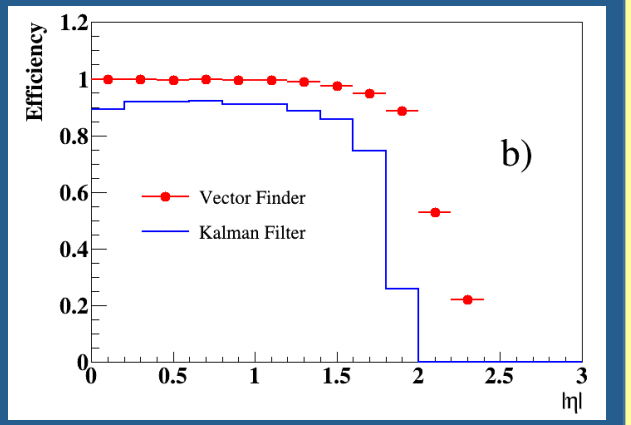
Track finding scheme in two projections



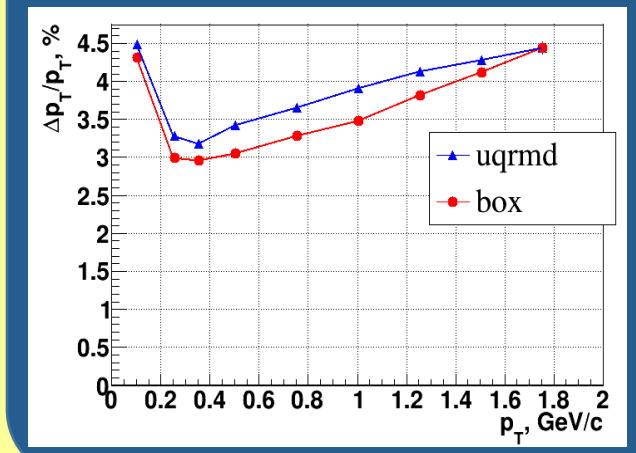


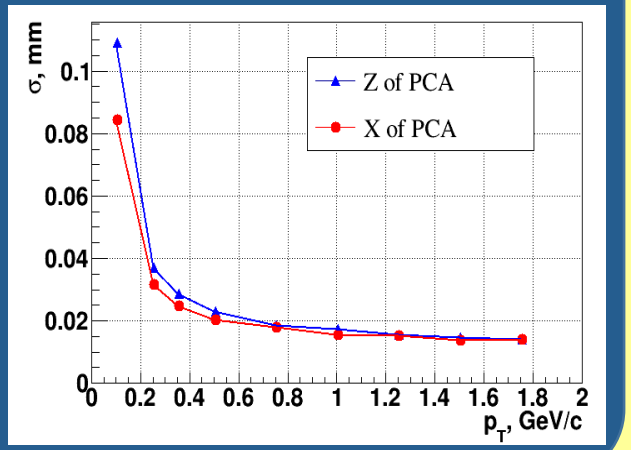
Track reconstruction efficiency



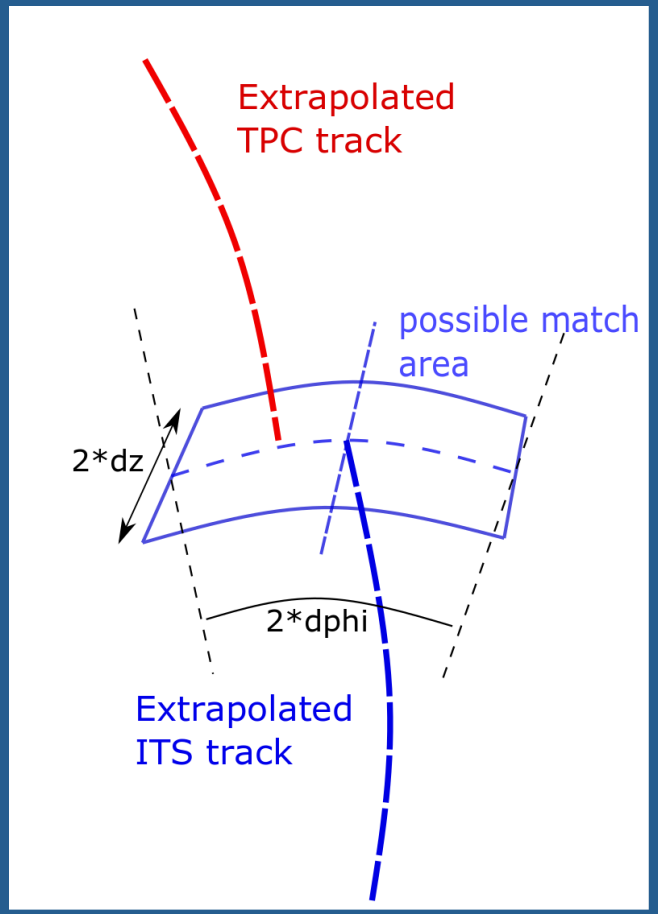


Reconstruction accuracy

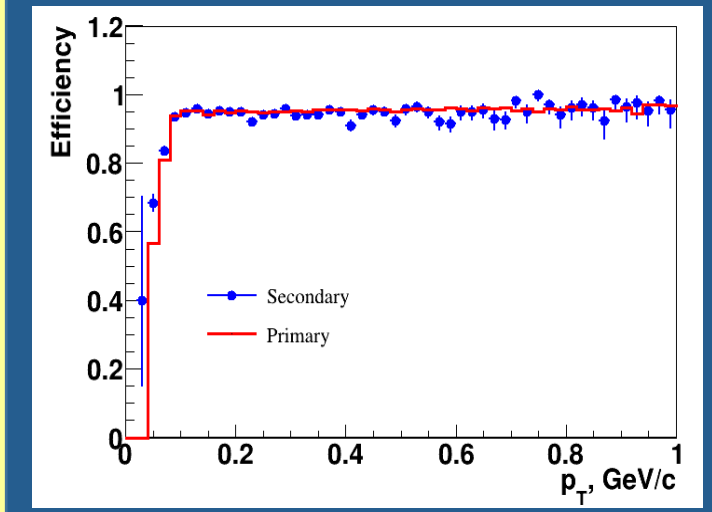


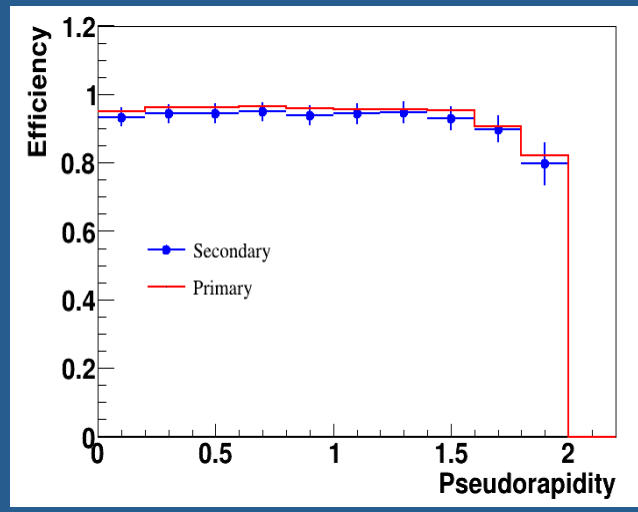


ITS-to-TPC track matching

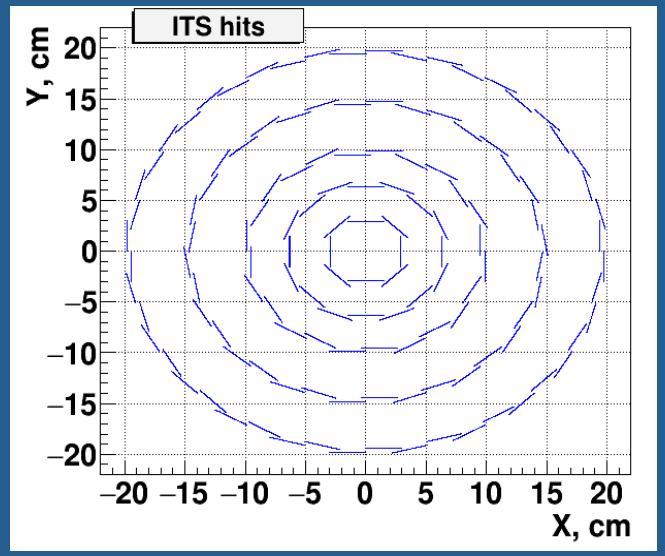


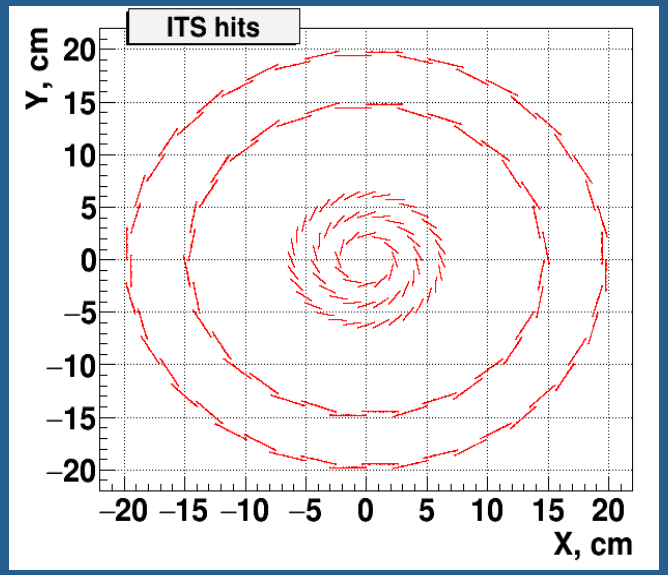
Track matching efficiency



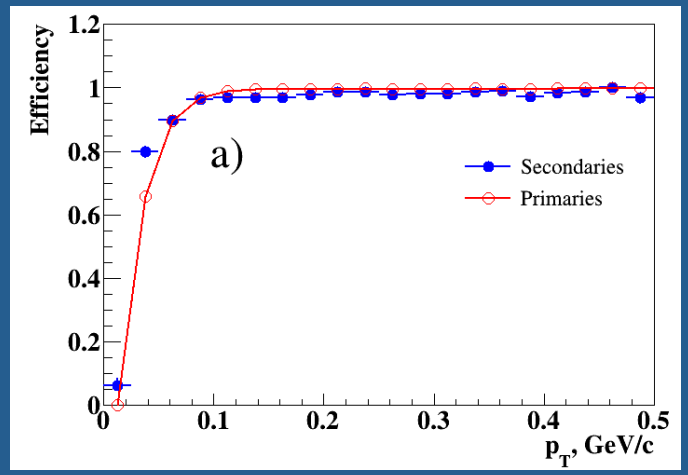


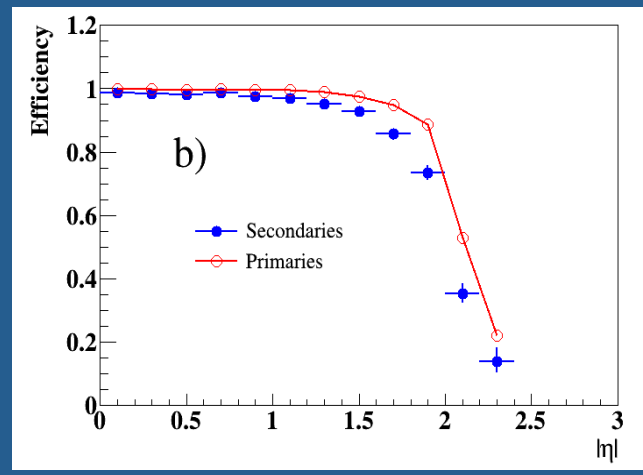
ITS geometry

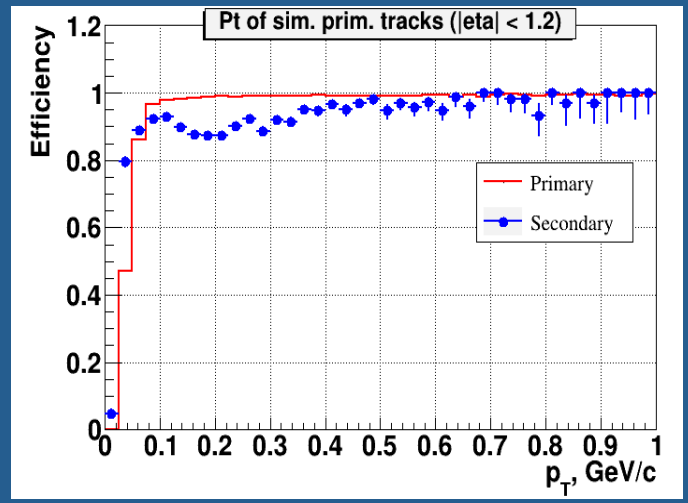


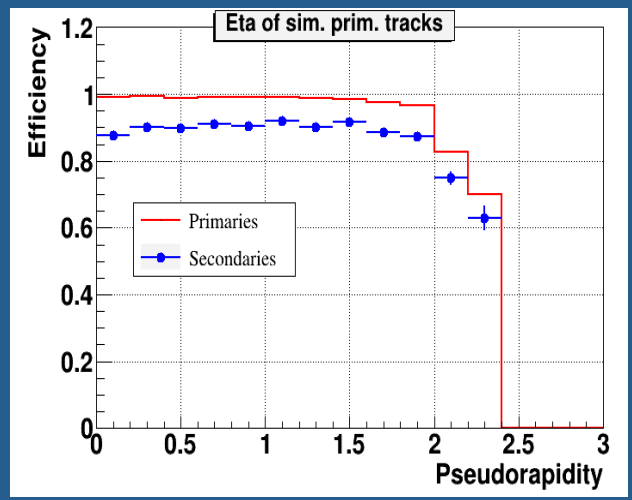


Tracking efficiency









Vector Finder activity – status and future steps

Reports / publications:

- D. Zinchenko, A. Zinchenko, E. Nikonov, Vector Finder – a toolkit for track finding in the MPD experiment, to appear in Phys. Part. Nucl. Lett. 18, no. 1, 2021
- D. Zinchenko, A. Zinchenko, E. Nikonov, Track reconstruction in the upgraded tracking system of MPD/NICA, Conf. NUCLEUS 2020
- D. Zinchenko, A. Zinchenko, E. Nikonov, Development of the Vector Finder Toolkit for track reconstruction in MPD ITS, Conf. RFBR Grants for NICA, 2020

Future: application of the method for ITS geometry optimization and physics performance evaluation; 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 does not properly describe 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

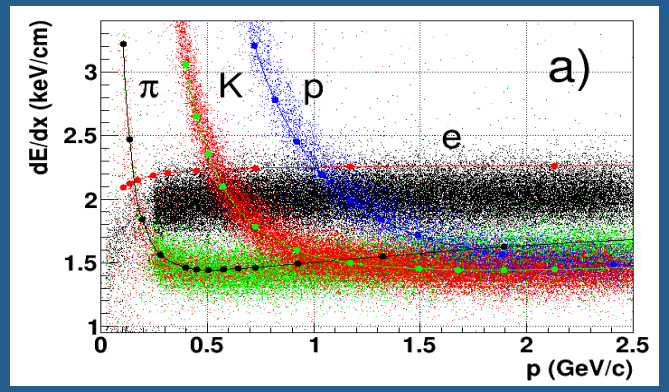
Work ongoing:

Tuning of dE/dx reconstruction procedure – tune particle identification

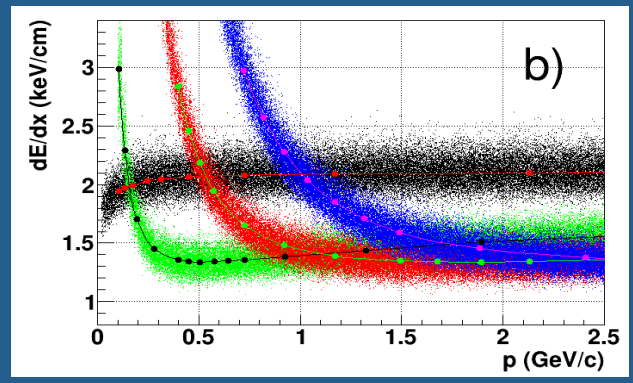
Supported by the RFBR Grant 18-02-40060

dE/dx in TPC

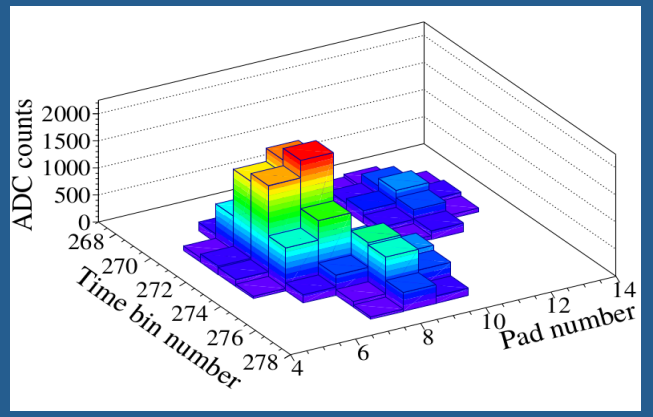
GEANT

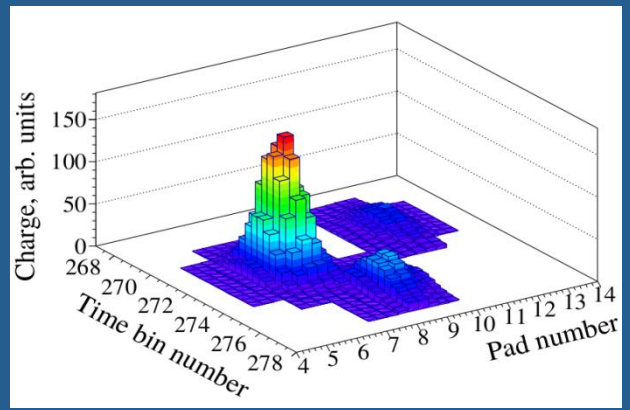


GARFIELD++



Bayesian unfolding





Leptonic decays – energy loss simulation in TPC

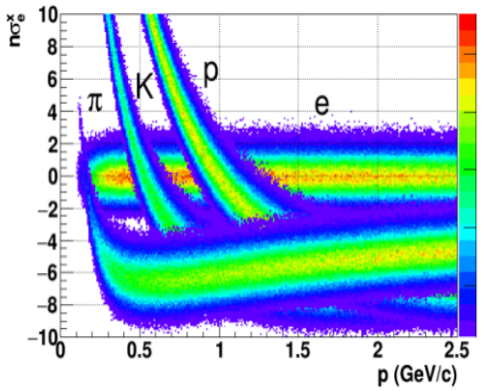
Resolution and $n\sigma$

dE/dx resolution ($|\eta|<1.0$, $N_{hits}>44$, $\chi^2/N<2.5$)

	p (GeV/c)	dE/dx (keV/cm)	σ (%)
π	0.5	1.211	8.12 (MIP)
π	2.0	1.355	7.38±0.04
π	4.0	1.479	6.86
π	10.	1.638	6.44
e	0.5	1.910	6.89
p	0.8	2.449	7.30*
p	0.6	3.605	7.21*

* - including momentum resolution

$n\sigma$ for electron



Mean of 6.8 at p=0.5 GeV/c for π

NIM A 614 (2010) 28-33
STAR for 76 cm track at p_T ~4 GeV/c σ= **7.31%**
- is consistent with the MPDROOT at p>2 GeV/c

I. Rufanov RFBR grants for NICA 22 October 2020 17

Work ongoing:

Tuning of dE/dx reconstruction procedure – tune particle identification: commited to a Git branch, Monte Carlo test production done

Report:

I. Rufanov, A. Zinchenko, Electron identification from dE/dx measurements in the MPD TPC, Conf. RFBR Grants for NICA, 2020

Supported by the RFBR Grant 18-02-40060

Related activity: A.Maevskiy, Fast simulation of TPC response at MPD using Generative Adversarial Networks – integration into MpdRoot requires some code reshuffling (TPC virtual geometry, TPC digitizer)

Organizational issues

Participation in the talk rehearsal / approval procedure for recent conferences

Summary

- MPD ITS – related activity: dedicated track reconstruction package achieved a level allowing people to use it for detector optimization studies;

- Leptonic decays – related activity: energy loss simulation / reconstruction modified / tuned, but requires some more work on the software;

- Charmonia and exotics studies: "Measurement of charmonium and exotic states is promising and important research. Great efforts are required to involve well-known scientists to this activity, and it represents a great challenge to obtain a tight collaboration between different international groups on this topic" (*Mikhail Barabanov, VBLHEP JINR*).