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

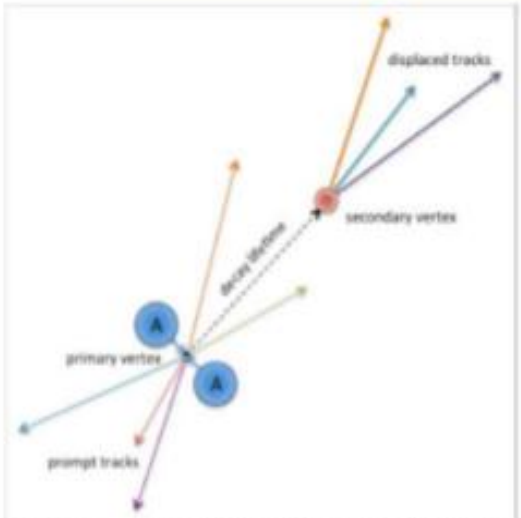
1. Open charm studies: exclusive decays -> Inner Tracking System (ITS) performance evaluation (synergy with ITS project) -> dedicated track reconstruction methods (“Vector Finder”)
2. Semi-leptonic decays and charmonia -> lepton (electron) tagging (synergy with dilepton studies) -> energy loss simulation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

MPD Inner Tracking System based on MAPS

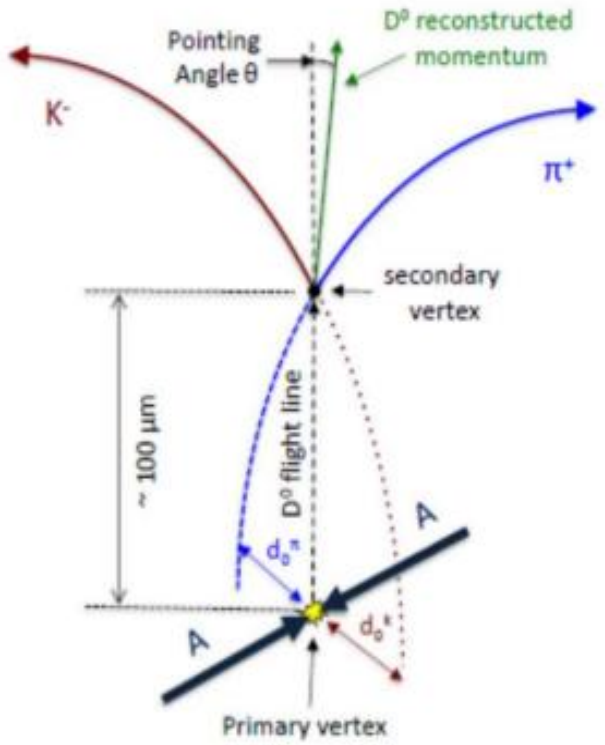
Secondary Vertex Determination

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

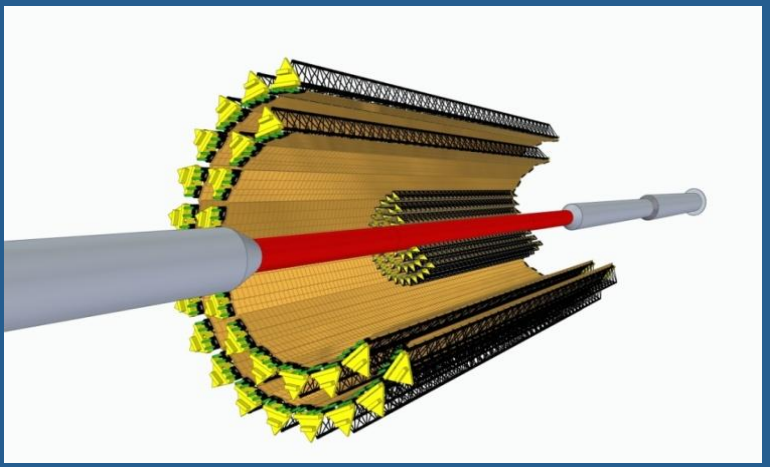


Example: D^0 meson



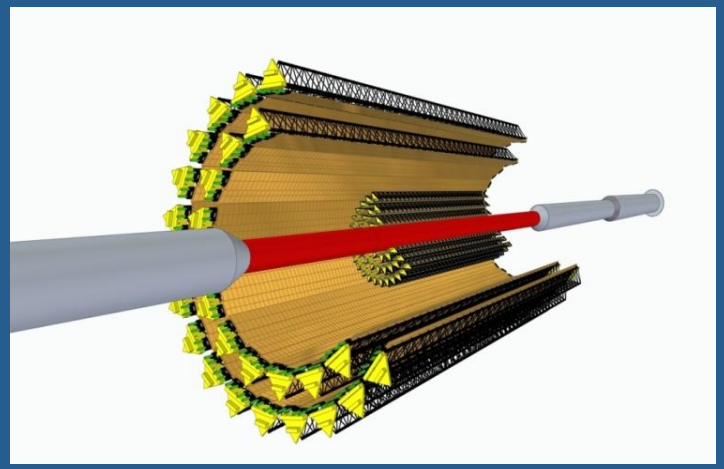
Analysis based on invariant mass, PID and decay topology

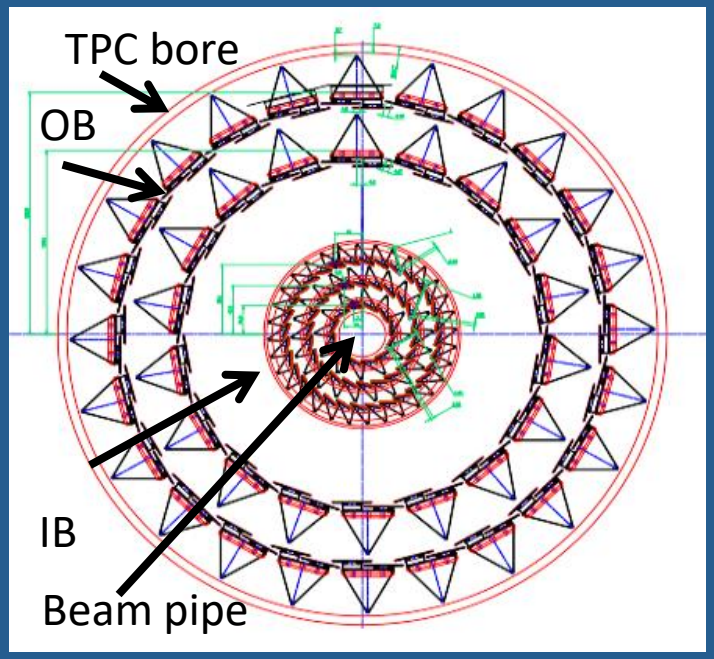
L. Musa (CERN) – International Winter Meeting on Nuclear Physics, Bormio, 8-11 Jan 2019



Yu. Murin

MPD Inner Tracking System based on MAPS

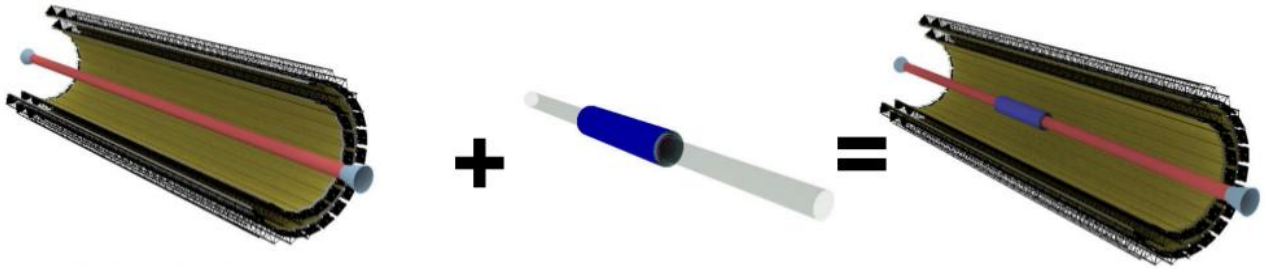




Yu. Murin

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

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

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

Open charm reconstruction and selection in ITS

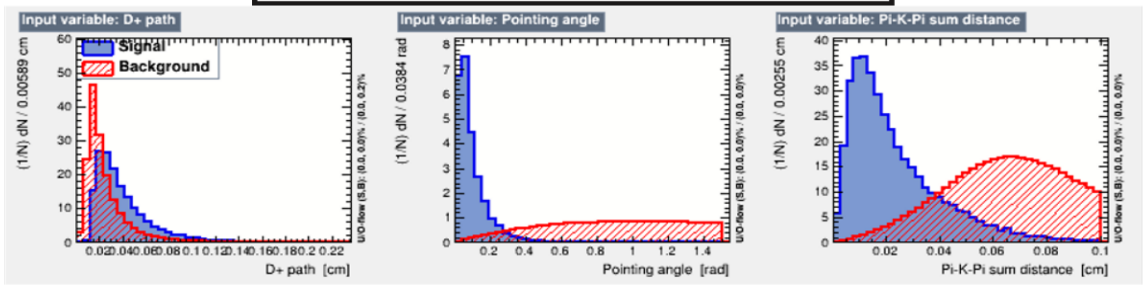
WP1 - Simulations

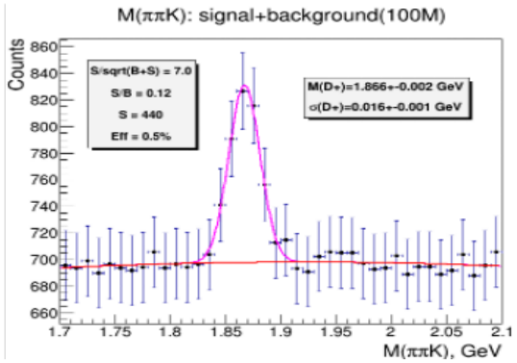
C. Ceballos

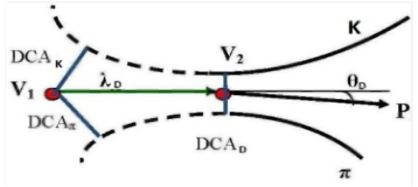
MPD - ITS

D⁺ and D⁰ reconstruction using KF

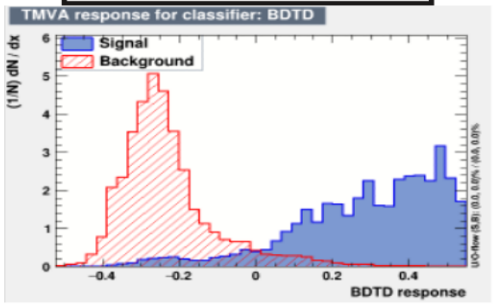
TC: dca[π], dca[K], dca[πK], λ[D], θ[D] cuts

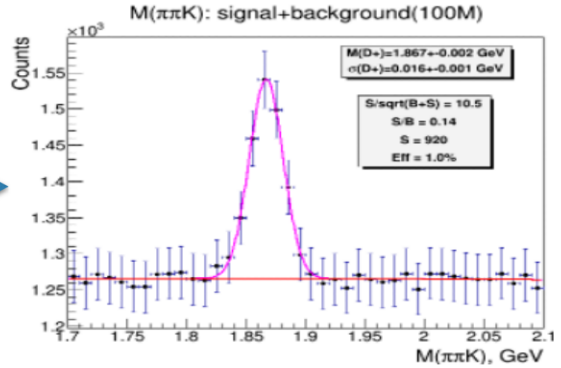






MVA: BDT classifier cuts





Particle	D⁰		D⁺	
Method	TC	MVA	TC	MVA
Efficiency, %	0.80	0.85	0.50	1.0
Significance	5.3	5.5	7.0	10.5
S/B(2σ) ratio	0.10	0.10	0.12	0.14

Using the topological cuts allows to reconstruct D⁰ and D⁺ decays with an efficiency of 0.8% and 0.5% respectively. Using the optimal BDT cut allows to reconstruct D⁰ and D⁺ with an efficiency of 0.85% and 1.0% respectively.

A. I. Zinchenko, S. N. Igolkin, V. P. Kondratiev & Yu. A. Murin" NICA-MPD Vertex Tracking Detector Identification Capability for Reconstructing Strange and Charmed Particle Decays". Physics of Particles and Nuclei Letters , volume 17, pages 856–870 (2020)

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
- A.I.Zinchenko, S.N.Igolkin, V.P.Kondratiev, Yu.A.Murin, NICA-MPD Vertex Tracking Detector Identification Capability for Reconstructing Strange and Charmed Particle Decays, Phys. Part. Nucl. Lett. 17, no.6, 2020, 856.

Vector Finder in ITS

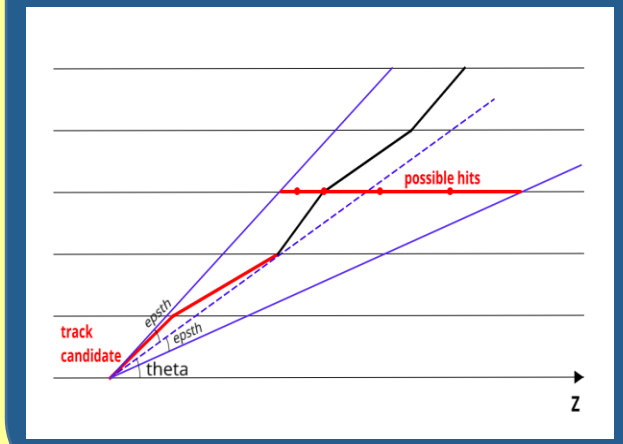
Method:

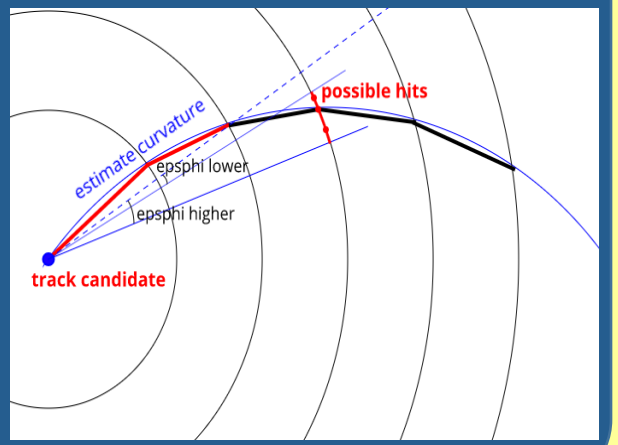
- Track finding is based on combinatorial search with prior constraints – constraints on angular positions in two projections (epsth in longitudinal, epsphi – in transverse projection)

D. Zinchenko, A. Zinchenko – LHEP JINR

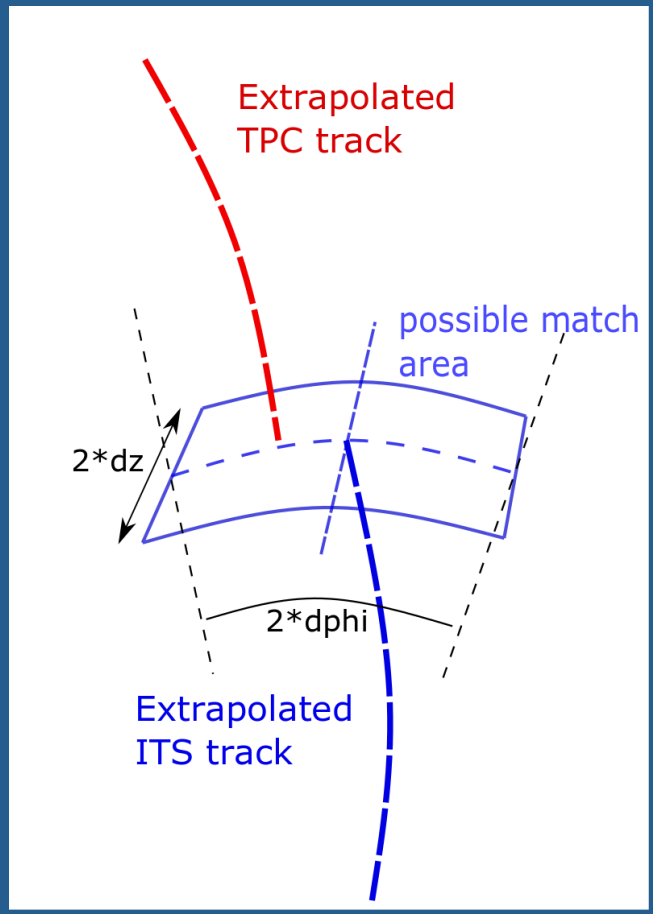
E. Nikonov – LIT JINR

Track finding scheme in two projections

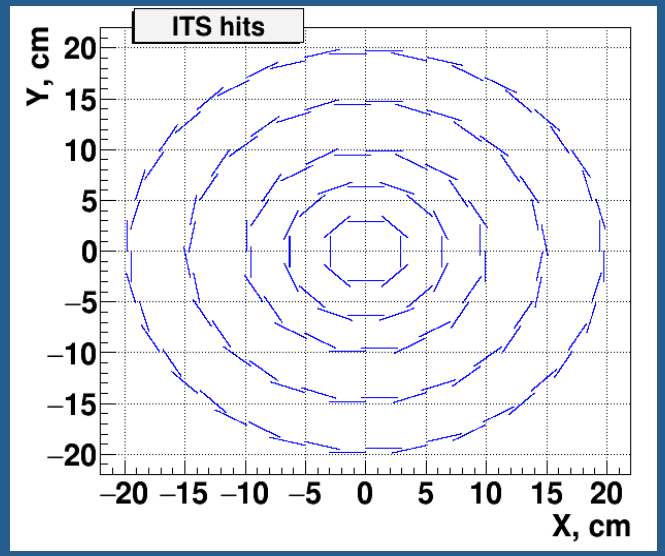


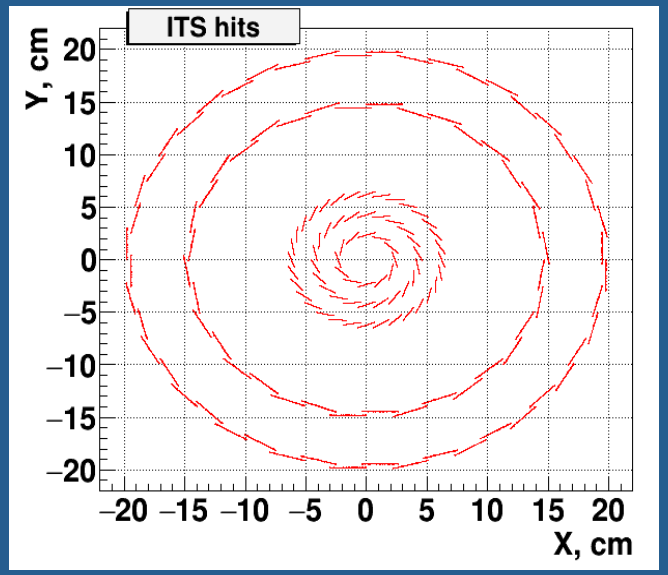


Track matching scheme

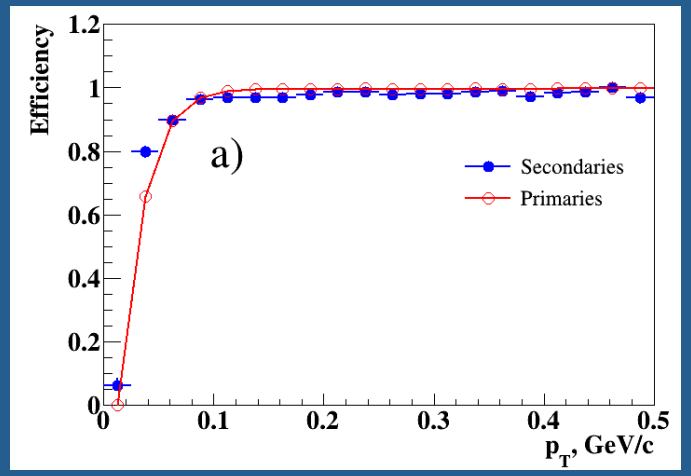


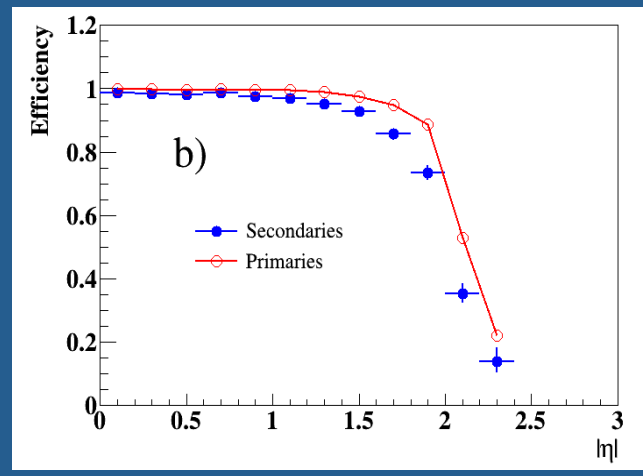
ITS geometry

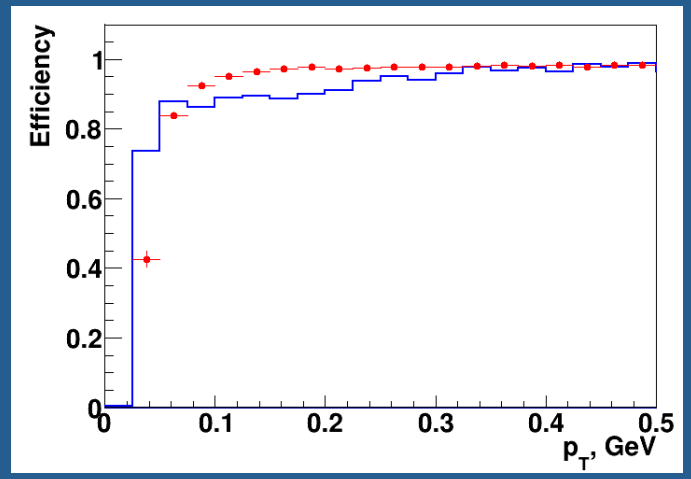


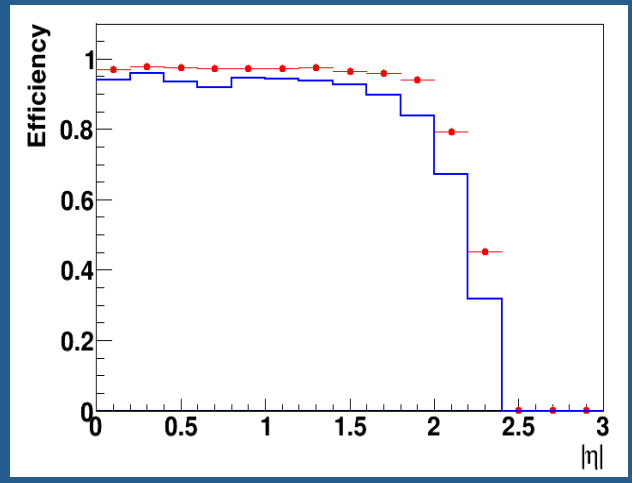


Tracking efficiency



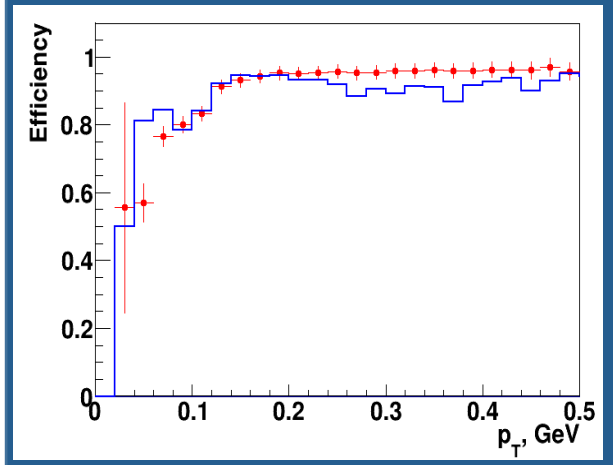


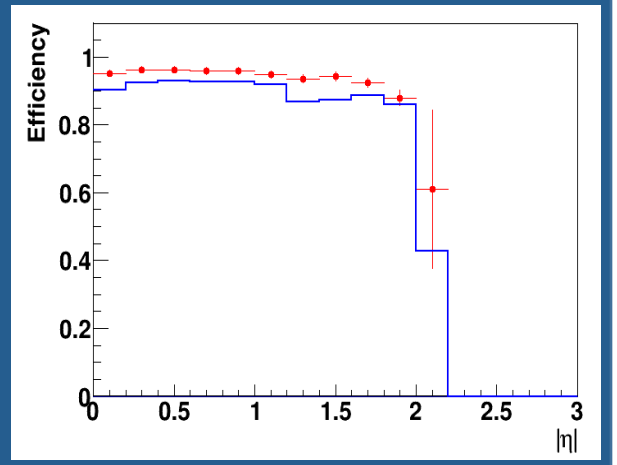




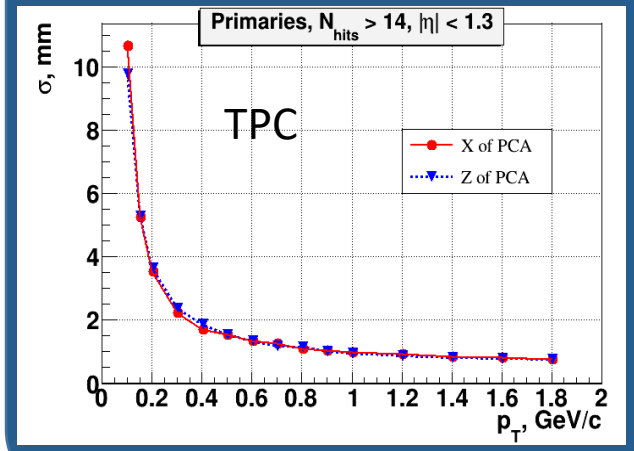
Vector Finder in ITS – performance

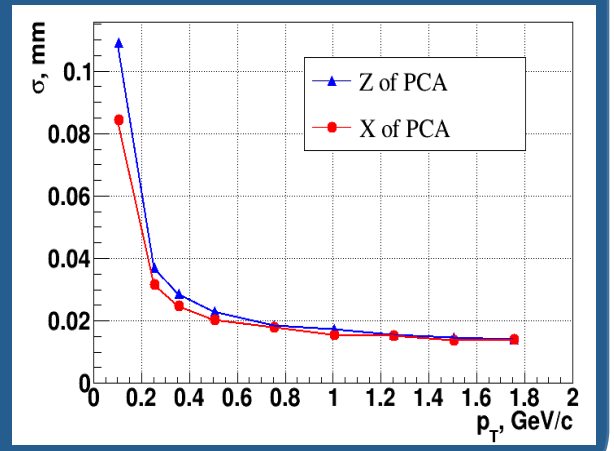
Matching efficiency



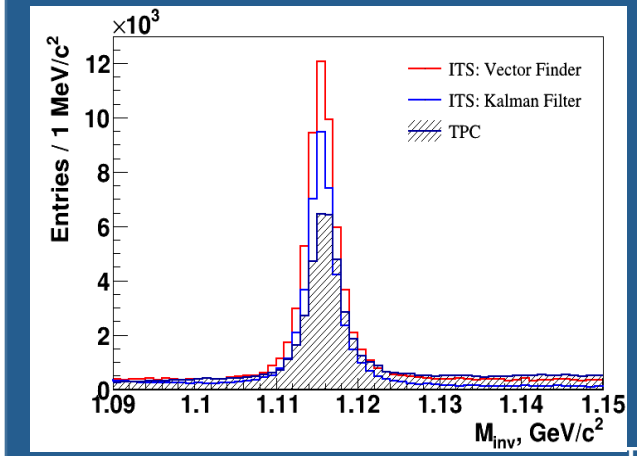


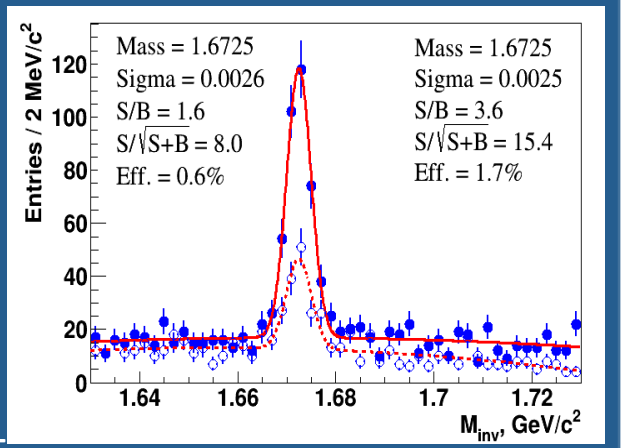
Pointing accuracy





Hyperon reconstruction





Vector Finder in ITS – performance

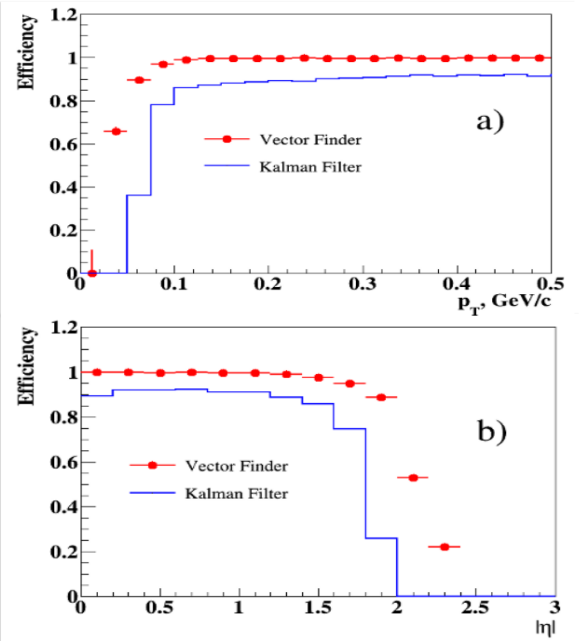
WP1 - Simulations

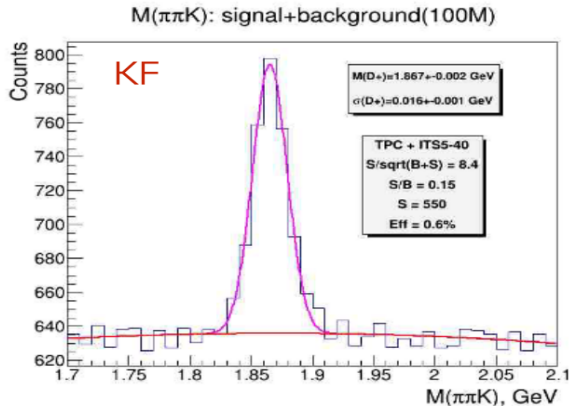
C. Ceballos

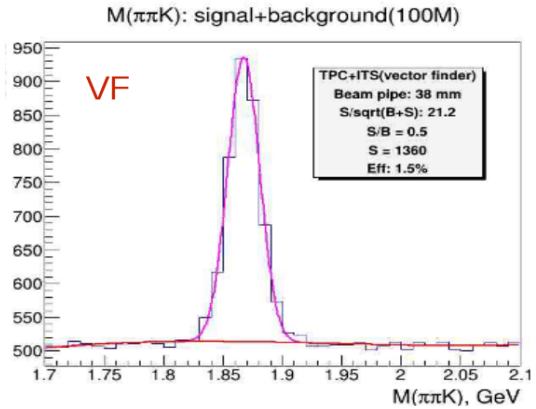
MPD - ITS

D⁺ reconstruction using KF and VF methods: comparison

Vector Finder (VF) vs Kalman Filter (KF) efficiency comparison (by A. Zinchenko)







ITS-5-40	S	S/B	$\frac{S}{\sqrt{S+B}}$	Eff (%)
VF	550	0.15	8.4	0.60
KF	1360	0.50	21.1	1.50

Using VF mechanism allows to reconstruct D+ with an efficiency 2.5 times higher and with higher level of significance compared to KF technique.

Next steps: Studying the reconstruction of D⁰ and D⁺s using VF.

D.A. Zinchenko, A. I. Zinchenko, E. G. Nikonov. «Vector Finder — a toolkit for track finding in the MPD experiment» Письма в ЭЧАЯ. 2021. Т. 18, No 1(233). С. 134

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, Phys. Part. Nucl. Lett. 18, no. 1, 2021, 107
- 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
- D. Zinchenko, E. Nikonov, V.Vasendina, A. Zinchenko, A Vector Finder toolkit for track reconstruction in MPD ITS, Workshop on tracking , reconstruction, and physics performance studies at FAIR and NICA, 8-10 December 2020

Next steps: application of the method for ITS geometry optimization and physics performance evaluation; the approach has been applied for track reconstruction in BM@N – first results are promising

Leptonic decays – energy loss simulation in TPC

History:

GEANT3 does not properly describe energy losses in TPC gas
GEANT4 “has even more problems with this” (statement from some PANDA presentation)

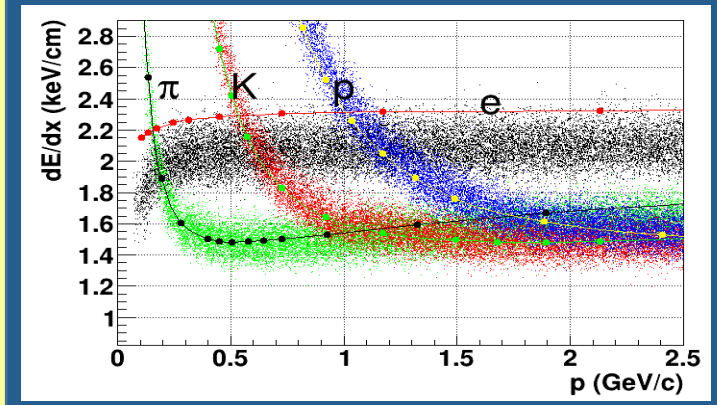
Method:

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

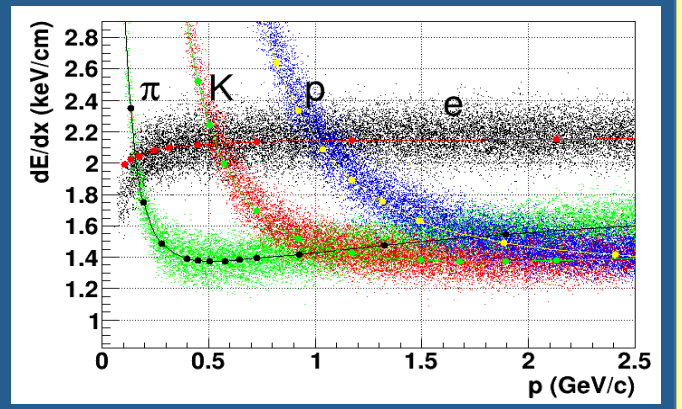
I. Rufanov - LHEP JINR

dE/dx in TPC

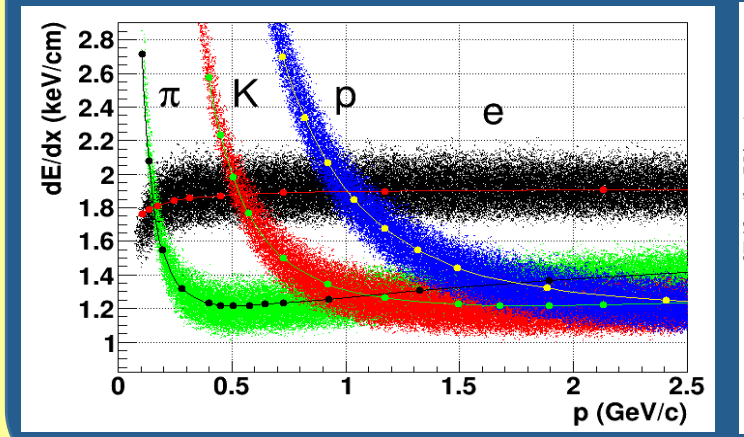
GEANT3



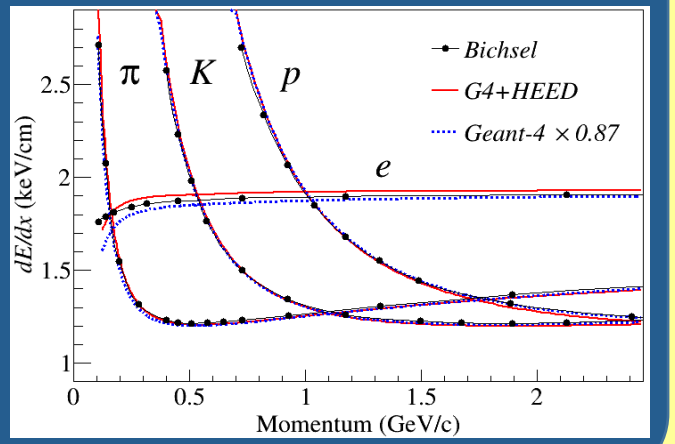
GEANT4



GEANT3(4) + HEED



Hans Bichsel



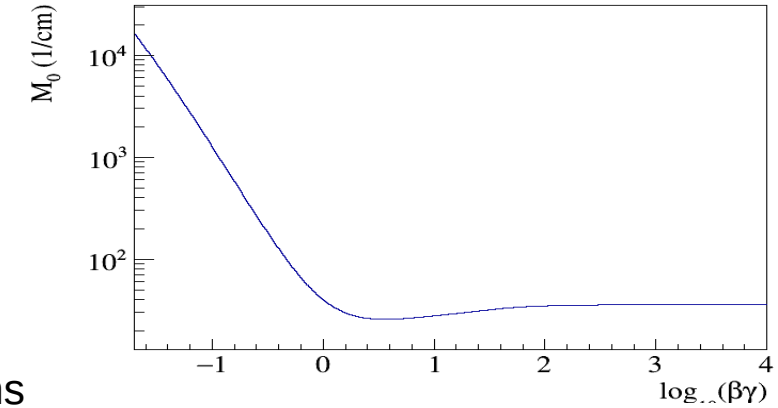
HEED parametrization of TPC *dE/dx*

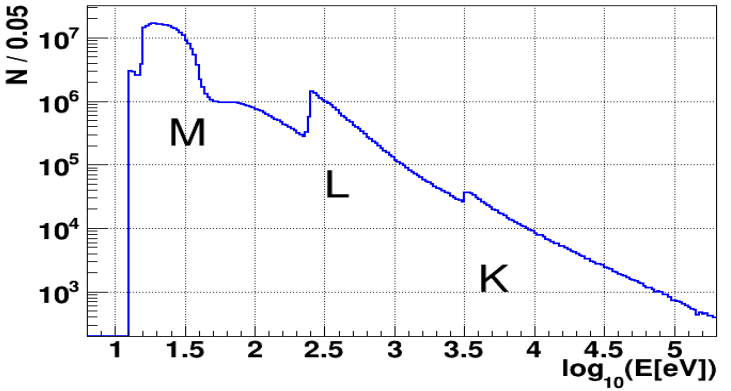
"RFBR Grants for NICA" conf. talk by I.Rufanov

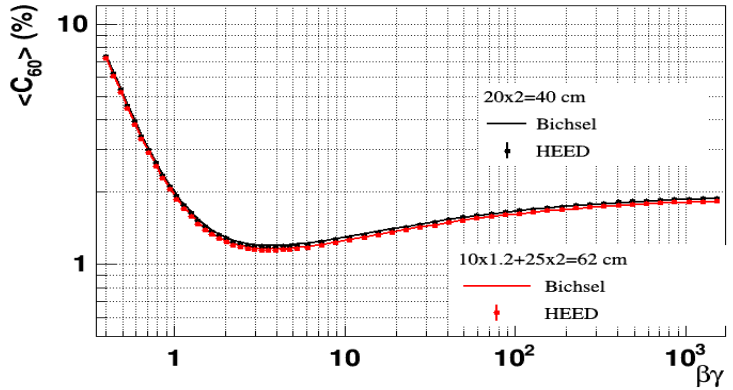
HEED - C++ implemention of PAI model. Integrated in Garfield++ as a model of energy loss.
(*NIM A 554 (2005) 474-493*)
Parametrization of collision density $M_0(Z)$ $Z=\log(\beta\gamma)$ and
energy loss in one collision dN/dE(E,Z) for P10 gas:
dN/dE distributions for 115 equidistant values of Z_i.

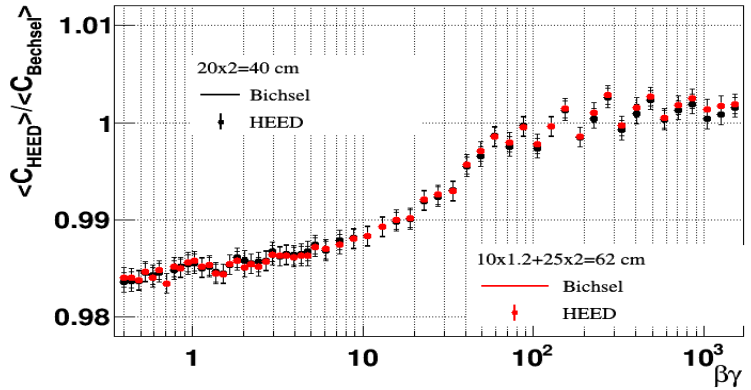
MC track propagation: sum random energy loss from n (Poisson distributed) collisions along the track segment.
The same method is used in ALICE TPC Monte-Carlo.

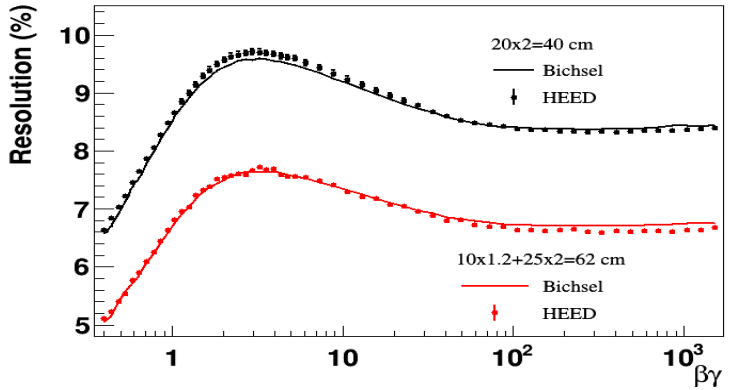
PAI based model was also developed by Hans Bichsel to parametrize $M_0(Z)$ and *dN/dE(E,Z)* for STAR TPC.
(*NIM A 562 (2006) 154-197*)
Comparision with Bichsel's C60 reference functions for 40 and 62 cm tracks shows 1.5% disagreement in both mean and RMS values leading to better e/π separation in HEED.









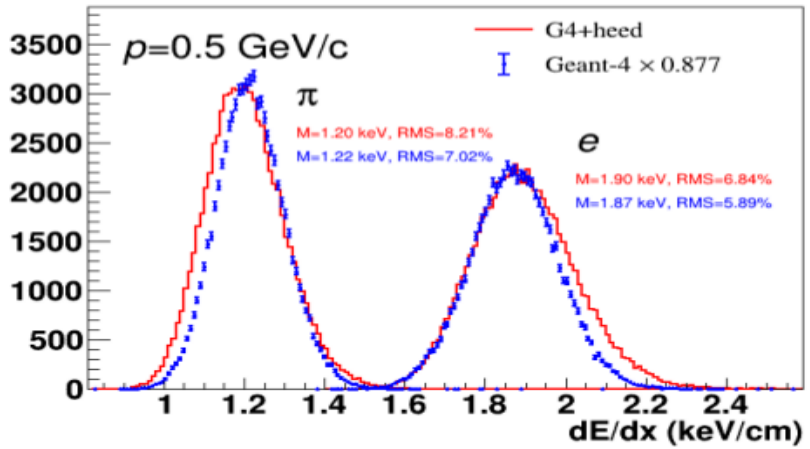


dE/dx resolution

de/dx resolution

Energy resolution RMS/Mean (%). Error for the most of estimates is ±0.05-0.08.					
	e 0.5 GeV/c	π 0.5 GeV/c	π 2 GeV/c	π 4 GeV/c	π 10 GeV/c
Geant-3	6.32	6.13	6.15	6.11	5.99
Geant-4	5.88	6.93	6.48	6.19	5.77
G3+HEED	6.77	8.23	7.44	6.95	6.47
G4+HEED	6.74	8.23	7.42	6.95	6.63

G3+HEED and G4+HEED give the same results
Geant-4 predicts 15% better resolution than G4+HEED
STAR measured σ= **7.31%** for 76 cm pion track at p_T ~4 GeV/*c*



e/π of mean de/dx at p=0.5 GeV/c	
G4+HEED	1.58
Geant-4	1.53
Bichsel's model	1.56

$n\sigma_e^{\pi}$ at p=0.5 GeV/c in log(de/dx) consideration	
G4+HEED	-6.85
Geant-4	-7.41

Leptonic decays – energy loss simulation in TPC

Report:

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

Proposal:

To use GEANT3/4 with HEED (with somewhat worse e/π separation at low momenta than GEANT4)

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, GEANT3/4+HEED will be made a baseline option.