Sector activity report
and
proposal of the NICA-MPD PWG structure

V. Kolesnikov and O. Teryaev

Part I. Sector 2 activity in the framework of the overall NICA-MPD strategy

Part II. MPD PWG structure

NICA-MPD strategy for the Stage'1 period

..was discussed during the NICA-MPD 1-day workshop on Oct.5 2016 (see Indico page)

NICA parameters at the very beginning (from 2021)

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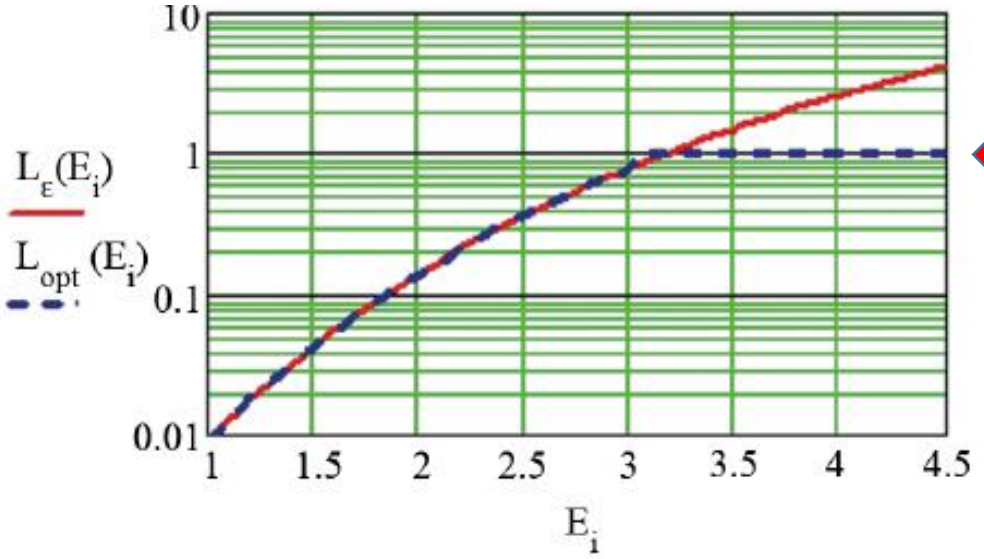
Three stages of the NICA accelerator complex*

V.D. Kekelidze[1], R. Lednicky[1], V.A. Matveev[1,2], I.N. Meshkov[1,3,a], A.S. Sorin[1,2], and G.V. Trubnikov[1,3]



This is the goal for 2023!

Start-up version (2021)

- **Reduced luminosity: $5 \cdot 10^{25}$ at 3-4.5 GeV/A**
- **Increased beam diamond (σ =0.6 m)**

NICA experimental strategy in 2021-2023

Collider: *energy and system size scan from 4 to 11(13,25) GeV in steps of 1-2 GeV GeV*

Beam	CM Energy, AGeV	L 2021-23, $cm^{-2} c^{-1}$	L >2023, $cm^{-2} s^{-1}$
Heavy ions (Au)	11	**$5 \cdot 10^{25}$**	10^{27}
Intermediate (Z/A~0.45)	13	**$3 \cdot 10^{26}$**	10^{29}
p	25	**~10^{29}**	10^{32}

Limitations by the accelerator:

- *lower luminosity (w/o electron cooling for the collider)*
- *extra reduction by 40% because of a larger interaction region (beam diamond)*

Detector constrains:

- ***TPC*** *tracking: $|\eta|<1.8$ (Npoints>10)*
- ***TOF & ECAL*** *coverage: $|\eta|<1.5$*
- ***PID****: combined (dE/dx+TOF+ECAL) $|\eta|<1.5$, $0.1<pT<4$ GeV/c, limited in $1.5 < |\eta| < 1.8$ (only dE/dx)*
- ***FHCAL*** *coverage: $2.2<|\eta|<4.8$*
- ***FD*** *inside the TPC inner pipe*
- ***NO*** *endcaps and vertex detector*

Particle yields in Au+Au collisions @ $\sqrt{s_{NN}}$ = 8 GeV
(*central collisions*)

Stage'1 (2021-23) one week of running at **L = 5 · 10^{25}cm^{-2}s^{-1}** *(duty factor = 0.5)*

Particle	Multiplicity	Decay mode	BR	*Efficiency %	Yield /1 w
π^+	293	----	---	61	$7.7 \cdot 10^8$
K^+	59	---	----	50	$1.5 \cdot 10^8$
p	140	---	----	60	$4.2 \cdot 10^8$
Λ	~35	$p+\pi^-$	64%	10%	$2.5 \cdot 10^7$
Ξ^-	~2	$\Lambda+\pi^-$	~100%	2.5%	$1.5 \cdot 10^5$
ρ	31	e+e-	$4.7 \cdot 10^{-5}$	35	$2.5 \cdot 10^3$
ω	20	e+e-	$7.1 \cdot 10^{-5}$	35	$2.5 \cdot 10^3$
φ	2.6	e+e-	$3 \cdot 10^{-4}$	5	$6.0 \cdot 10^2$
Ω	0.14	Λ+K	0.68	1	$1.0 \cdot 10^4$

*Efficiency includes the MPD acceptance, realistic tracking and particle ID.
Particle Yields from experimental data (NA49), statistical and HSD models.

Particle yields in Au+Au collisions @ $\sqrt{s_{NN}}$ = 8 GeV
(central collisions)

Stage'2 (>2023) Expectations for 10 weeks of NICA running at L = $10^{27}cm^{-2}s^{-1}$ (duty factor = 0.5)

Particle	Multiplicity	Decay mode	BR	*Efficiency %	Yield/10 w
π^+	293	----	---	61	$2.6 \cdot 10^{11}$
K^+	59	---	----	50	$4.3 \cdot 10^{10}$
p	140	---	----	60	$1.2 \cdot 10^{11}$
ρ	31	e+e-	$4.7 \cdot 10^{-5}$	35	$8.0 \cdot 10^{5}$
ω	20	e+e-	$7.1 \cdot 10^{-5}$	35	$8.0 \cdot 10^{5}$
φ	2.6	e+e-	$3 \cdot 10^{-4}$	15	$2.0 \cdot 10^{5}$
Ω	0.14	ΛK	0.68	1	$4.0 \cdot 10^{6}$
D^0	$2 \cdot 10^{-3}$	$K^+\pi^-$	0.038	20	$2.2 \cdot 10^{4}$
J/ψ	$8 \cdot 10^{-5}$	e+e-	0.06	15	10^3

*Efficiency includes the MPD acceptance, realistic tracking and particle ID.
Particle Yields from experimental data (NA49), statistical and HSD models.

SEARCHING for a QCD MIXED PHASE at the NUCLOTRON-BASED ION COLLIDER FACILITY (NICA White Paper)

- NICA is ideally suited for exploring the transition between the hadronic phase and the new plasma phase. This exploration is the top priority of the NICA program
- The first round of NICA experiments should concentrate on a variety of diagnostic observables that have already been employed in experimental programs at RHIC and SPS
- The detector will collect simultaneously centrality-selected high-precision data on double differential spectra of identified hadrons. In consequence, freeze-out conditions will be precisely established for collisions in the transition domain.
- We recommend that the MPD detector at NICA will be optimized for the study of fluctuations and correlations of bulk properties and that a primary goal will be to measure the excitation functions and the dependence of fluctuations&correlations on centrality and system size.
- In the second stage one should consider measurements of open-charm hadrons, di-leptons, and di-photons at NICA.

Strategy of the future activity on MPD feasibility study (proposal) – *a year ago!*

- **Focus on the study of MPD performance for Stage'1 probes**
  - Hadron spectra and yields
  - Flow
  - (multi)Strangeness production (except Ω)
  - Fluctuations and correlations
  - Electromagnetic probes (abundant species only: π^0 and η)

- **MPD performance → towards realistic simulation**
  - Timely upgrades/tuning in TPC tracking (i.e. TPC cluster finder)
  - Realistic TOF reconstruction (detector description, TPC-TOF matching, etc..)
  - ECAL reconstruction

Maximal allowed phase-space even for a limited set of MPD elements!

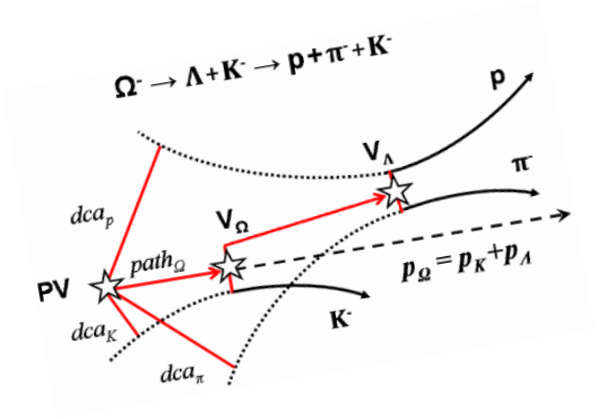
- **Numerous tasks for MPD TDR preparation**

- ***Open questions : simulation of MPD endcaps, IT, GEMs (Stage'2)***

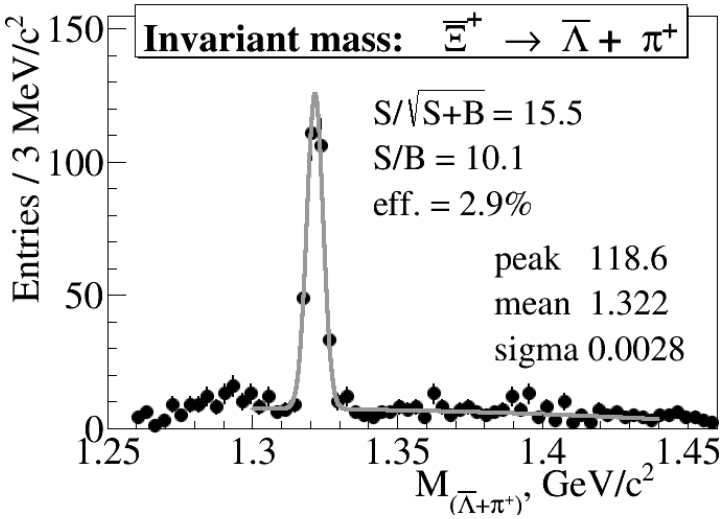
Main problems – time and man power (as usual!)

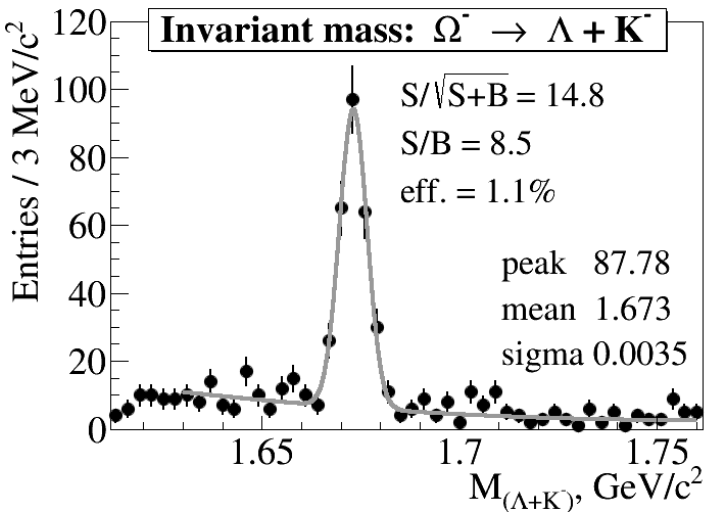
MPD performance: multi-strangeness (Stage'1)

D. Suvarieva, A.Zinchenko, V.Vasendina



- Stage'1 MPD configuration (TPC+TOF)
- Selection criteria dictated by the decay topology



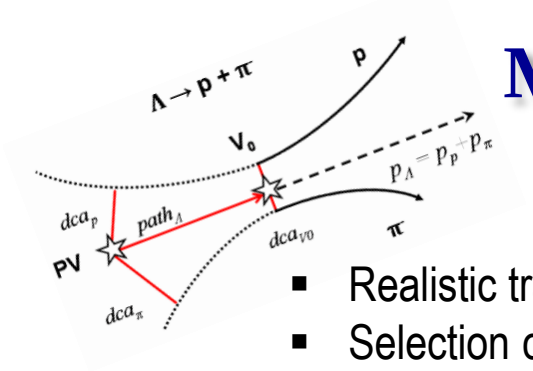


- ~ 5 · 10 [5] central Au+Au at 9 GeV
- Λ- candidates in the invariant mass window ±3σ around the peak combined with kaons
- Topological cuts optimized to maximize significance
- Constrained at low pT (pT>0.2 GeV/c)

Yields for 10 weeks of running (Stage'1)

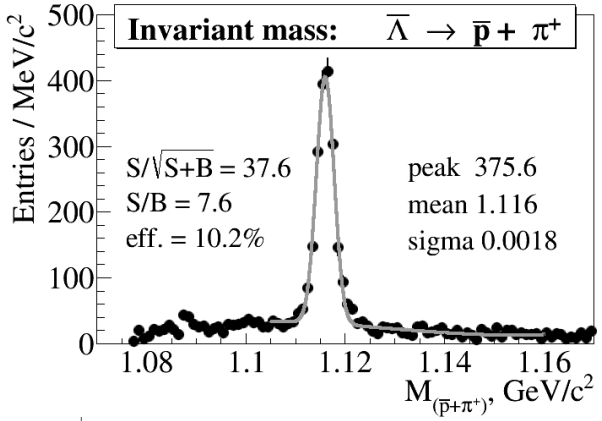
Particle	Λ	anti-Λ	Ξ⁻	anti-Ξ⁺	Ω⁻	anti–Ω⁺
Yield	$3 \cdot 10^8$	$3.5 \cdot 10^6$	$1.5 \cdot 10^6$	$8.0 \cdot 10^4$	$7 \cdot 10^4$	$1.5 \cdot 10^4$

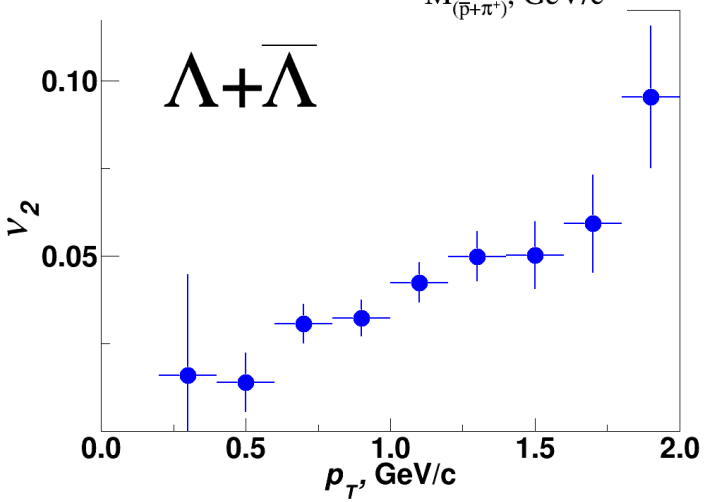
MPD performance: strangeness (Lambda flow)

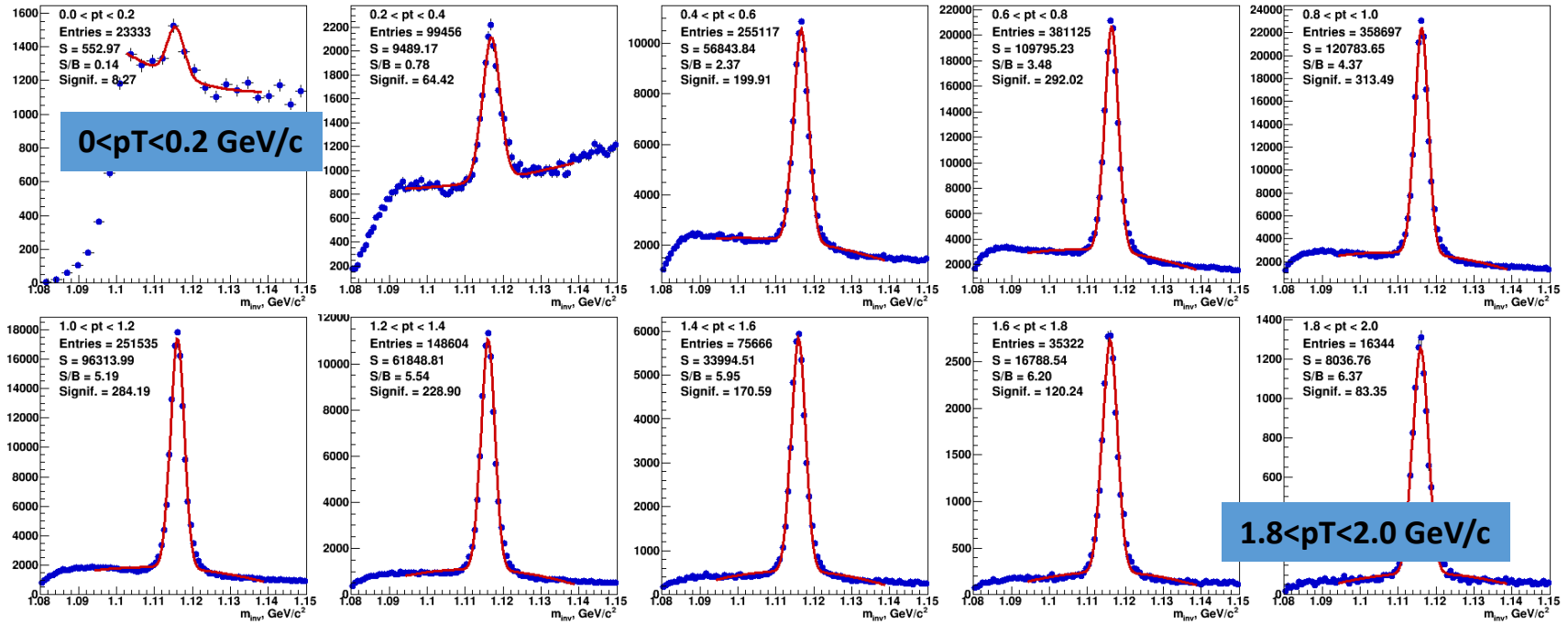


N. Geraksiev

- Realistic tracking and PID
- Selection criteria dictated by the decay topology
- Optimal cut values (i.e. DCA at the primary vertex, two-track separation, etc.) found from multidimentional scan over the set of criteria with a requirement to maximize the significance
- Hyperons studied up to pT=2 GeV/c, low-pT part of the spectra needs further optimization of the selection criteria



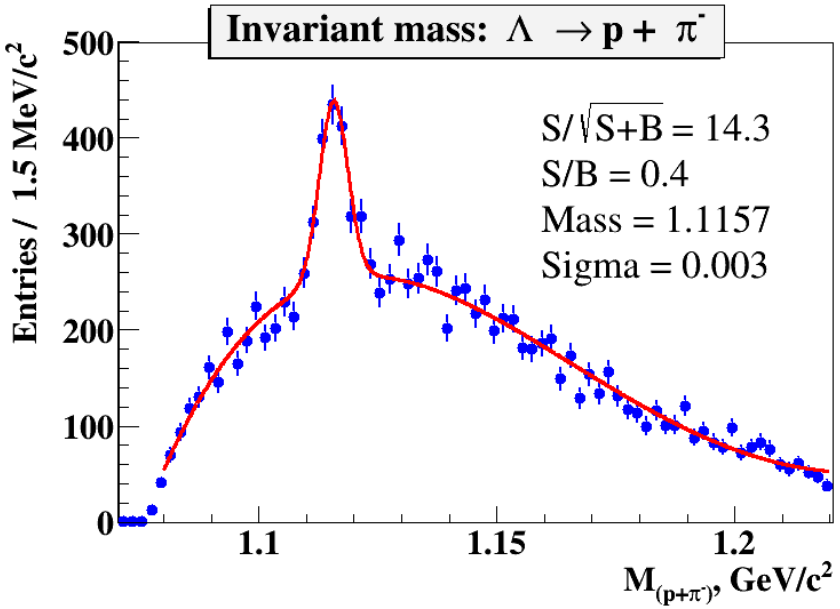


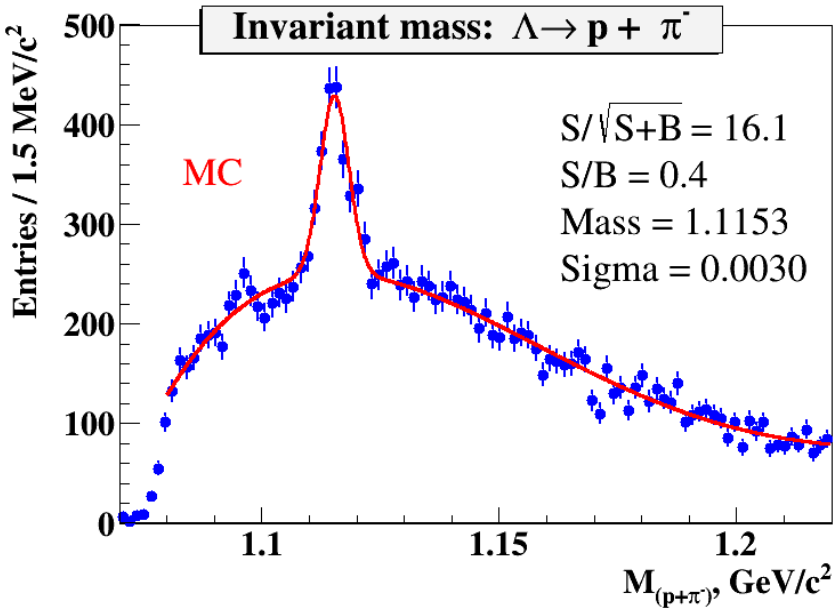


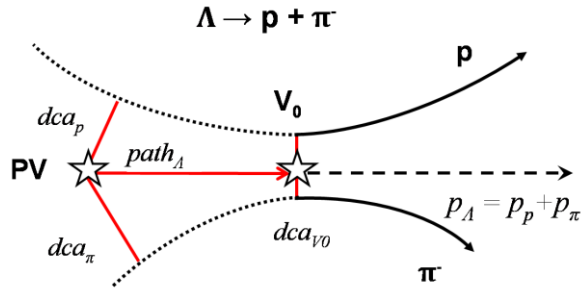
- Min. bias Au+Au @ 11A GeV (UrQMD), TPC+TOF barrel
- Secondary vertex reconstruction
- Event plane from TPC tracks

BM@N: Λ reconstruction (d + Cu, C, CH_2)

A. Zinchenko V. Vasendina







Event topology:

- ✓ PV – primary vertex
- ✓ V_0 – vertex of hyperon decay
- ✓ dca – distance of the closest approach
- ✓ path – decay length

Signal event topology defined selection criteria:

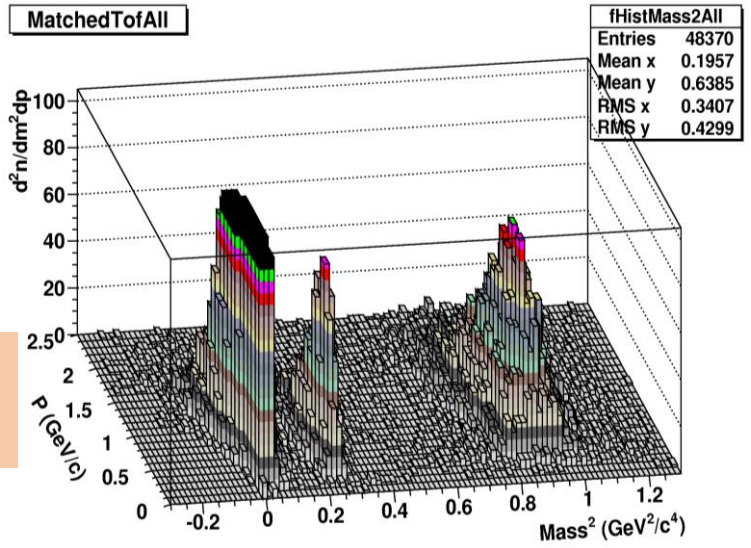
- ✓ relatively large distance of closest approach (DCA) to primary vertex of decay products
- ✓ small track-to-track separation in decay vertex
- ✓ relatively large decay length of mother particle

Λ signal width of 3 MeV and background level is reproduced by MC simulation.

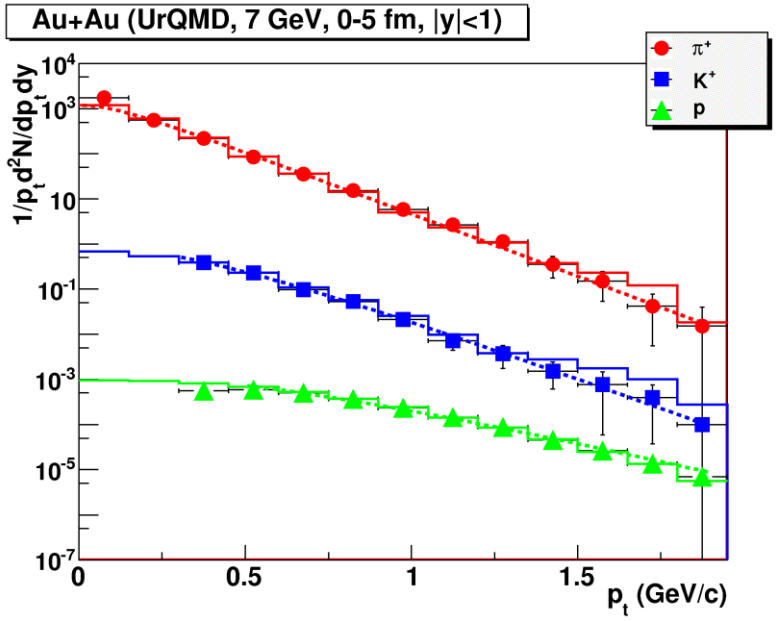
MPD performance study : hadron spectra & yields

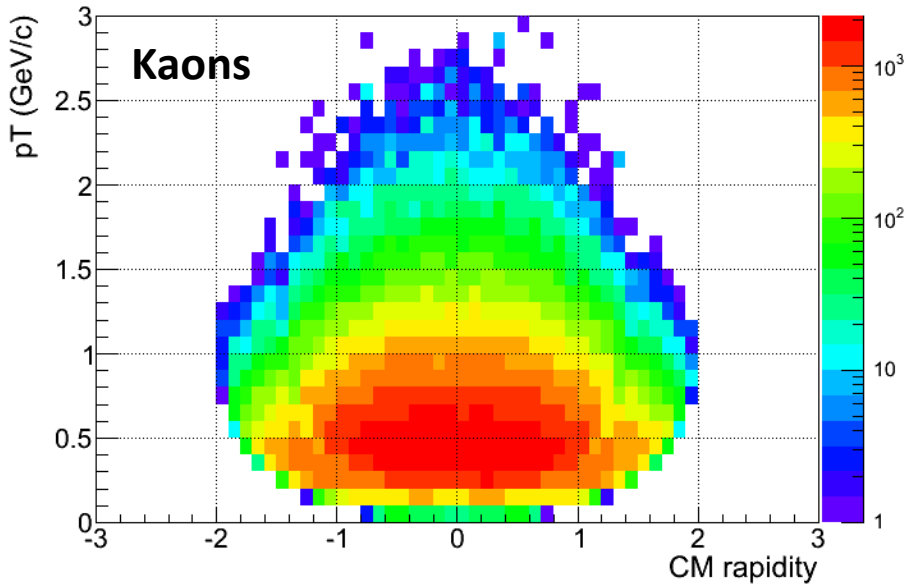
V. Kolesnikov, very old stuff

- **PID: 2σ π/K ~ 1.7 GeV/c, (π,K)/p ~ 3 GeV/c**
- **Full MPD reconstruction chain**
- **Combined TOF + dE/dx identification**
- **Fully corrected pt-spectra of π,K,p**



- *Full reconstruction chain, realistic PID, corrections*
- *Hadron spectra :large rapidity & pT-coverage*



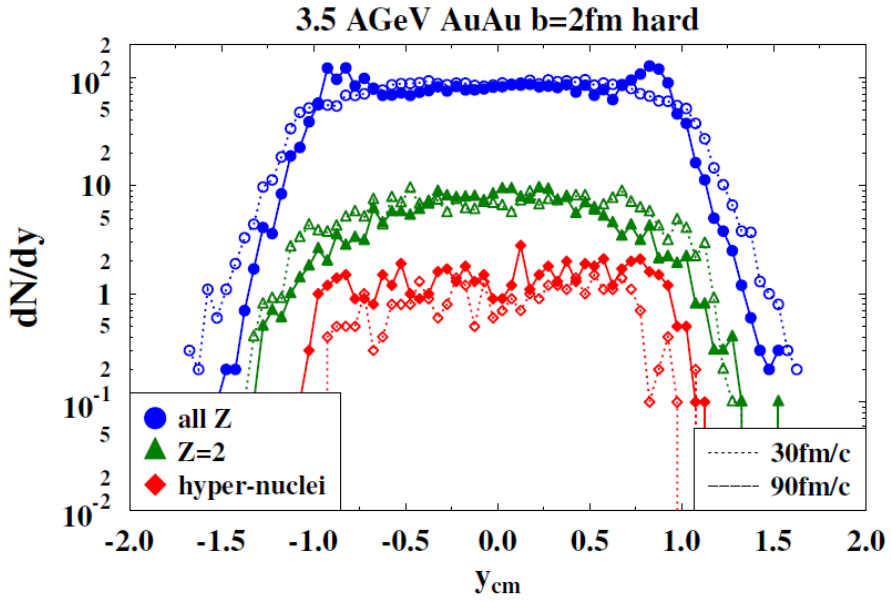


Modeling of fragment and hypernuclei formation

V. Kireev + theory group (Frankfurt, GSI)

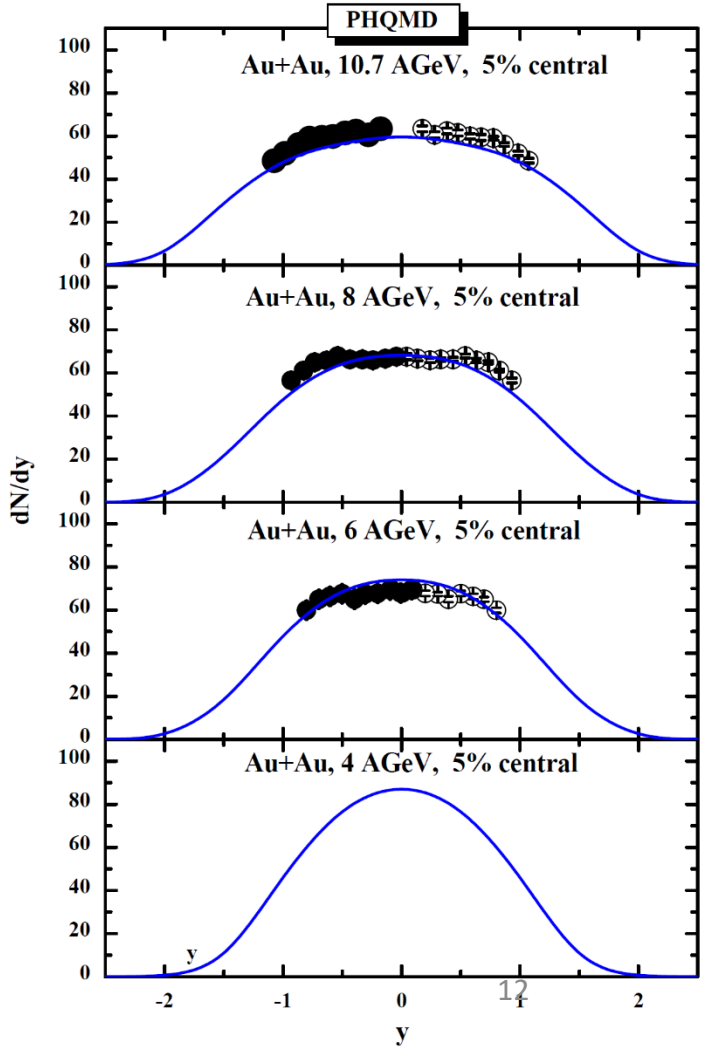
PHQMD – a new model for the NICA/CBM energies which allows - in contrast to all other models - to predict the dynamical formation of fragments:

- allows to understand the proton spectra and the properties of light fragments (dn/dp_t dy, v_1, v_2, fluctuations)
- allows to understand fragment formation in participant and spectator region
- allows to understand the formation of hypernuclei at NICA
- good agreement with the available fragment data from AGS/SPS and single particle spectra



First Results of PHQMD at BMN energy

- fragments are stable from 30 to 90 fm/c
- hyper-nuclei are produced in number
- Protons at midrapidity well described

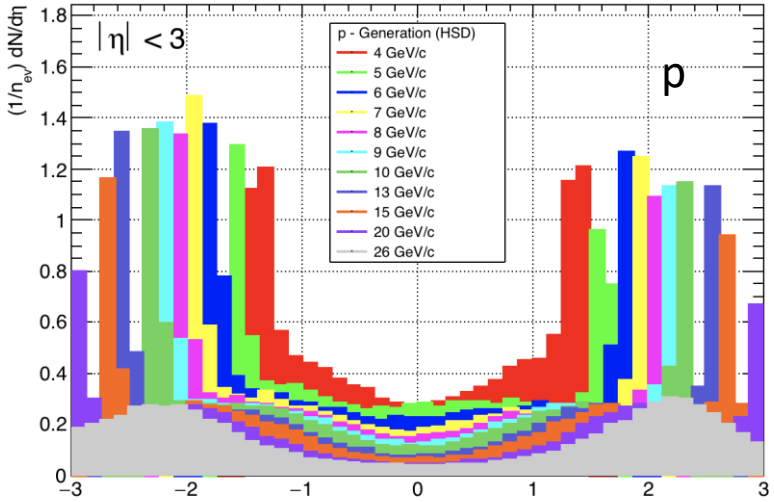


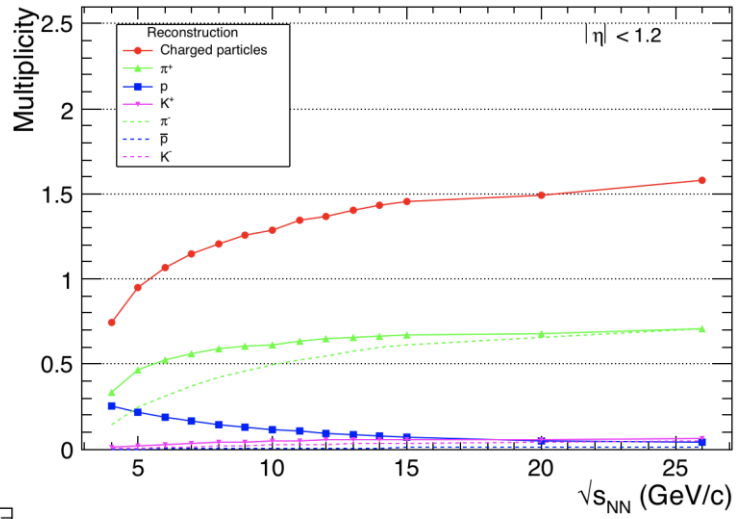
Preliminary simulations of pp collisions for MPD

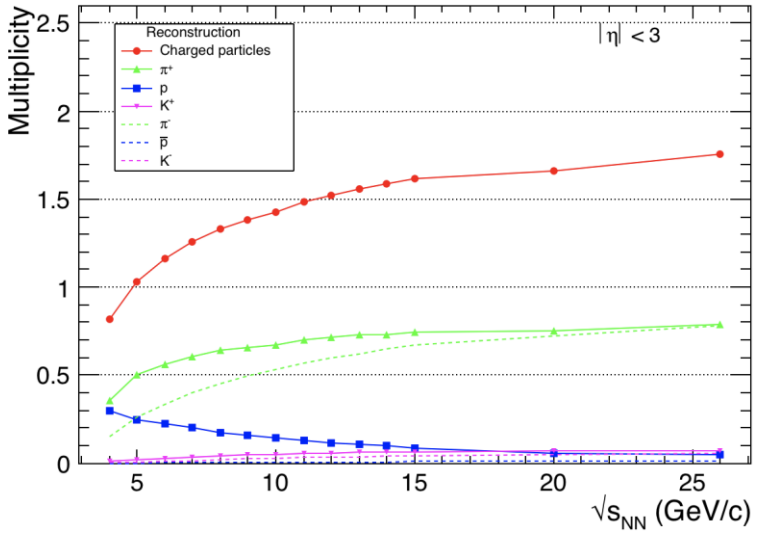
Katherin Shtejer Díaz

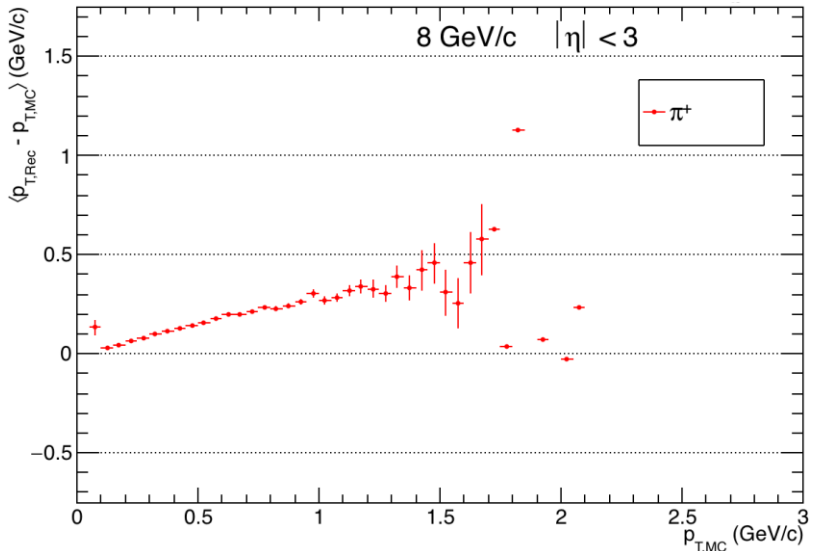
PHSD model (provided by Dr. E. L. Bratovskaya) based on the string formed by quark-quark, quark-diquark and diquark-diquark systems.
High energy inelastic hadron – hadron collision in HSD is described by FRITIOF string model (including PYTHIA)

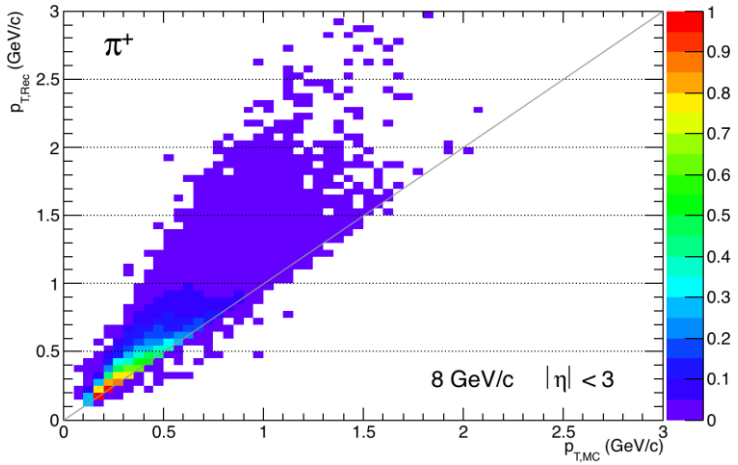
Distributions of charged particles (π^+, π^- , p, $\bar{p}$, K^+, K^-)







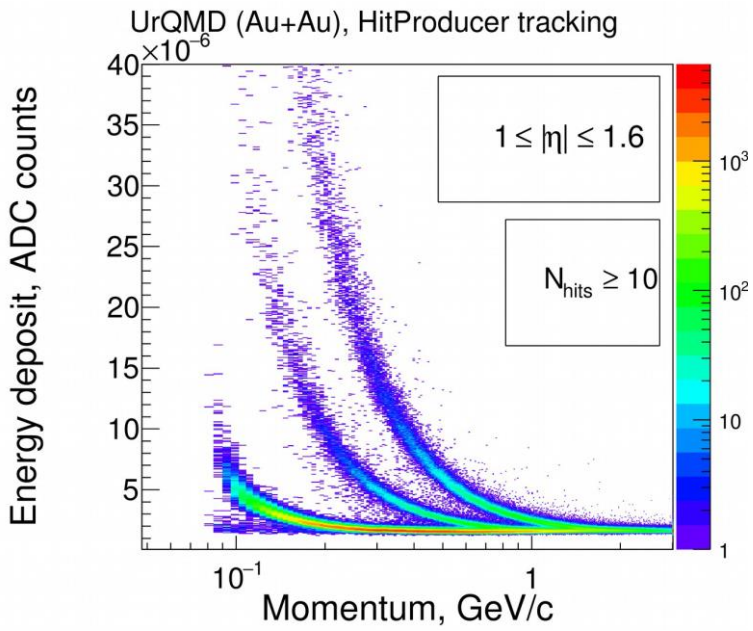


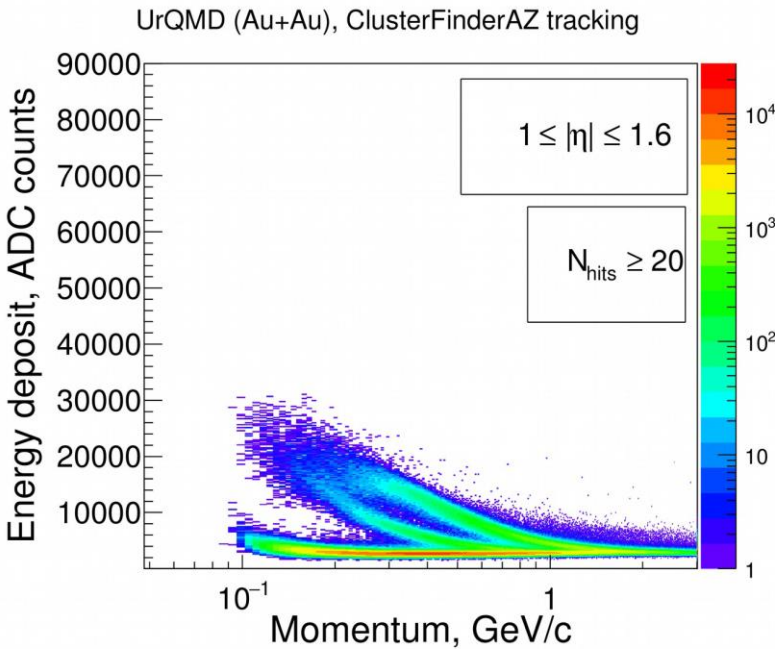


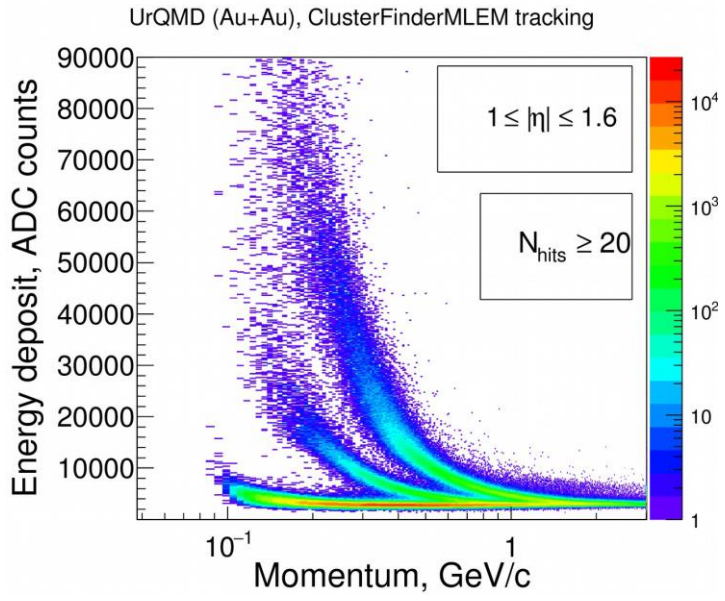
- p+p reactions from 4 to 25 GeV
- Overall MPD efficiency
- QA of the reconstruction chain for low multiplicity events
- Reconstruction is not optimized for p+p! Studies are ongoing

MPD reconstruction QA: PID

A. Mudrokh



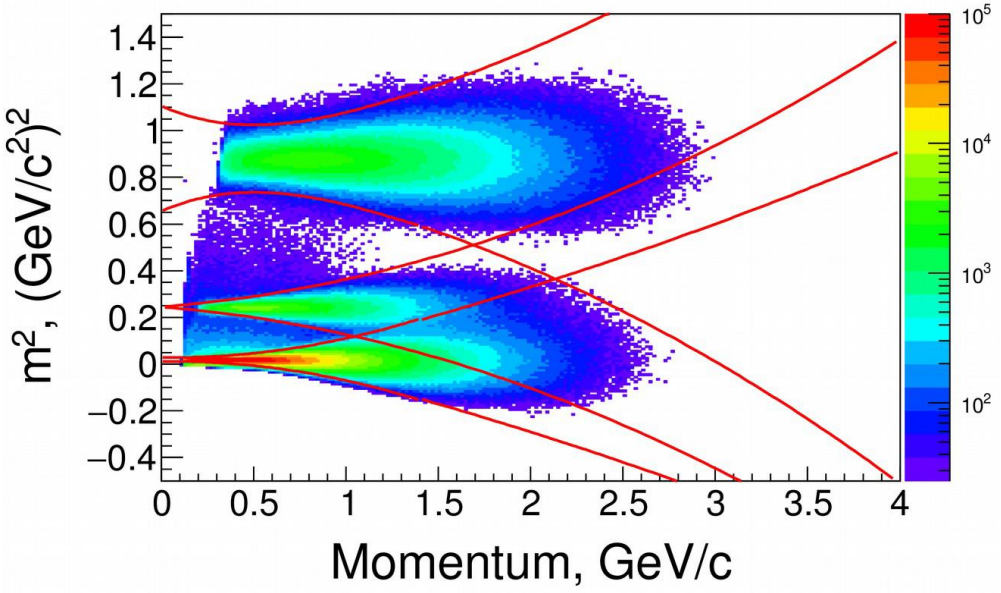


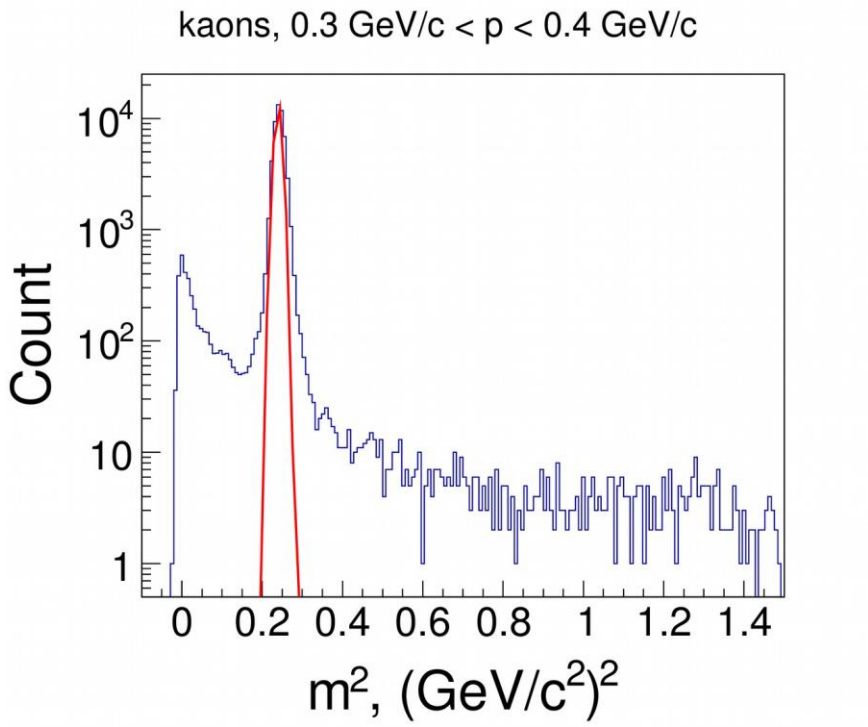


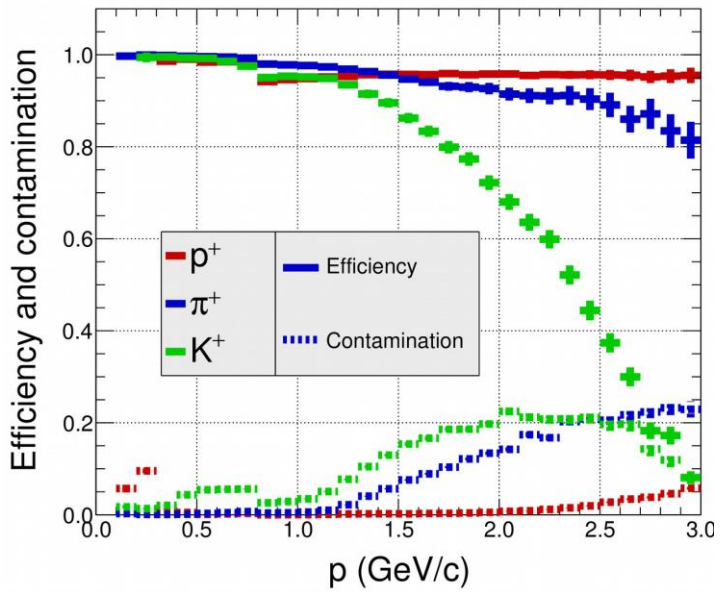
- Phase space is crucial for Ev-by-Ev: how far from |η|>=1 we can go?
- Optimization of clusterfinder/tracking for large eta
- New set of quality selection criteria
- In principle, solved, but took several months

MPD reconstruction QA: PID

A. Mudrokh







- Combined PID efficient up to several GeV/c
- Large tailless at low pT due to TOF mismatches, not solved
- Owing to the large contamination above pT=1.5 GeV/c, a user-defined set of cuts to optimize eff/contam

Summary to Part I

- In principle, most of the signals for the NICA Stage'1 were simulated (hadrochemistry, strangeness, hypernuclei, flow, dileptons, femto).
- There was lack of studies for Ev-by-ev fluctuations – now, hopefully, we'll advance in this direction (Anar + Baku group)
- As it was agreed early – next step should be more realistic tracking + full set of detectors (TPC+TOF+ECAL+FHCAL). **But, slow progress there** (no final ECAL simulation, PID with cluster finder only recently was understood, etc..)
- Optimization of the NICA simulation group structure – why not (see Part II)?

Part II. Structure of the NICA_MPD PWG

Ultimate goal(s)

1) Map the two lists below
2) Fill all the PWG fields (at least, for the NICA Stage'1)

List of Sector

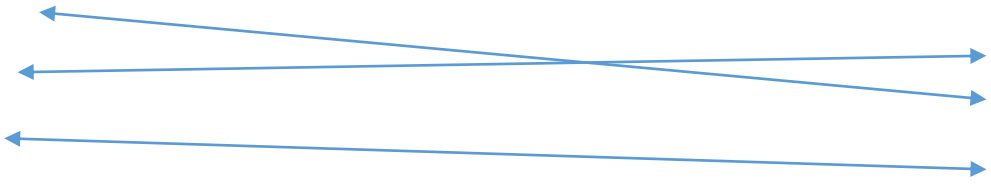
1. Name
2. Name
3. Name
4. ..

….

MPD PWG List

1. PWG1
2. PWG2
3. PWG3
4. ..

….



A proposal for the (optimal) list of the NICA-MPD working groups

O.Teryaev and V.Kolesnikov

meaning of the **"optimal"**:

- there is a group leader (experienced or well-known person)
- more than 3 active persons
- the (proto)group has already some achievements (papers, conferences, etc..)

Femtoscopy (FMT)
Fluctuations (FLC)
Strangeness: hyperons and hypernuclei, phi-mesons (STR)
Flow (FLW)
Electromagnetic probes (ELP)
Polarization (PLR)
Bulk properties: hadron chemistry, spectra, yields, ratios (BLK)
+ ……
Theory: phenomenology and models (THE)
Soft: simul.&analysis framework (SOFT)
Reconstruction: tracking, matching, event characterization, PID, etc. (RECO)

MPD simulation and feasibility study activities (status)

PWG	Members	Activity status
FLW	MEPhI +N.Geraksiev	Very active in FHCAL TDR preparation, no news during recent 6 months
FMT	MSU + P.Batyuk	Quite active, good publicity over last year (papers, conferences)
STR	A.Zinchenko + 4	Little activity after a period of intensive studies with ideal tracking, waiting for realistic simulation, writing thesis
ELP	V.Vasendina +1	No activity after a period of intensive studies with ideal tracking, waiting for the final ECAL simulation, lack of manpower
BLK	V.Kolesnikov + 3	Early preliminary results on hadron spectra, realistic PID is an obstacle for further developments; focus on MPD performance in elementary interactions
RECO	A.Zinchenko+0	Tuning of MPD tracking with cluster finder, PID is still a challenge, no progress in ECAL reconstruction
PLR	~ 3-4 members	Preliminary results were obtained by the theory group and Armen. How well progressing now?
FLC	A.Rustamov + Baku	Very old estimates based on models. Expect more soon …

Sector 2 NEOFSTI, list of activities mapped on the MPD PWG

1) Ilieva M. (**STR**)
2) Kireev V. (**THE + BLK**)
3) Kolesnikov V. (**BLK**)
4) Mudrokh A. (**RECO + BLK**)
5) Geraksiev N. (**STR + FLW**, i.e. hyperon flow)
6) Shtejer K. (p+p reactions in general, **BLK**)
7) Suvarieva D. (**STR + PLR**, *restricted activity*)
8) ***Vasendina V. (**ELP + STR + BM@N**(?!))
9) ***Zinchenko A. (**RECO + STR + ELP +BM@N**(??!!))
10) Yordanova L. (**STR**, phi-mesons, *no activity*)

Remarks:

- (*) Strong overloading, additional manpower is requested
- Optimization of activity sharing for Stage'1 is needed
- 3 out 4 PHD students from Bulgaria (Geraksiev, Suvarieva, Ilieva) have being writing their thesis

THE END