Project NA61/SHINE

2018-2020

(JINR participation)

Theme 02-1-1087-2009/17

V.A. Kireyeu

47th meeting of the PAC for Particle Physics

26.06.2017

Project NA61-SHINE

Study of Hadron Production in Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS (SHINE – SPS Heavy Ion and Neutrino Experiment)
(JINR participation)

PROJECT LEADER	A.I. MALAKHOV
DEPUTY PROJECT LEADER	G.L. MELKUMOV

DATE OF THE PHYSICAL SUBSTANTIATION PRESENTATION
AT THE LABORATORY SEMINAR 10.03.2017

JOINT INSTITUTE FOR NUCLEAR RESEARCH

SEVEN-YEAR PLAN

FOR THE DEVELOPMENT OF JINR

2017–2023

(Approved by the Committee of Plenipotentiaries of the Governments of the JINR Member States at its session held on 21–22 November 2016)

Dubna 2016

Стр.17-18 **Expected results:**

1. The start-up of the BM@N first configuration for high-intensity light-ion beams extracted from the Nuclotron. Obtaining first results in the research programme of the BM@N experiment: study of yields of hadrons, hyperons, and light nuclei — 2017–2019.

2. Obtaining results at BM@N using high-intensity heavy-ion beams, including ions of gold. Study of elliptic and directed flows, production of hyperons with S=2 and hypernuclei — 2019–2023.

3. The start-up of the MPD Stage I, obtaining first results in the research programme to study the properties of hot and dense baryonic matter in the central rapidity range, to search for phase transitions (observables – particle yields and spectra) including partial restoration of chiral symmetry (observables – yields of di-leptons), and to search for the critical end-point (observables – event-by-event fluctuations, particle correlations) — 2020–2023.

4. Commissioning of the MPD Stage II. Beginning of the research programme with the MPD detector in the available phase space region — 2023.

5. Obtaining new results in the energy scan programme in the experiments NA61 (SPS) and STAR (RHIC) — 2017–2023.

6. Obtaining new results in the femtoscopy programme in the ALICE experiment (LHC), participation in ALICE upgrade — 2017–2023.

7. Settlement of commitment in the development and commissioning of the CBM set-up under JINR's obligations in accordance with the NICA–FAIR joint research programme — 2017–2023.

Participants from JINR:

V.A. Matveev (*JINR management*);

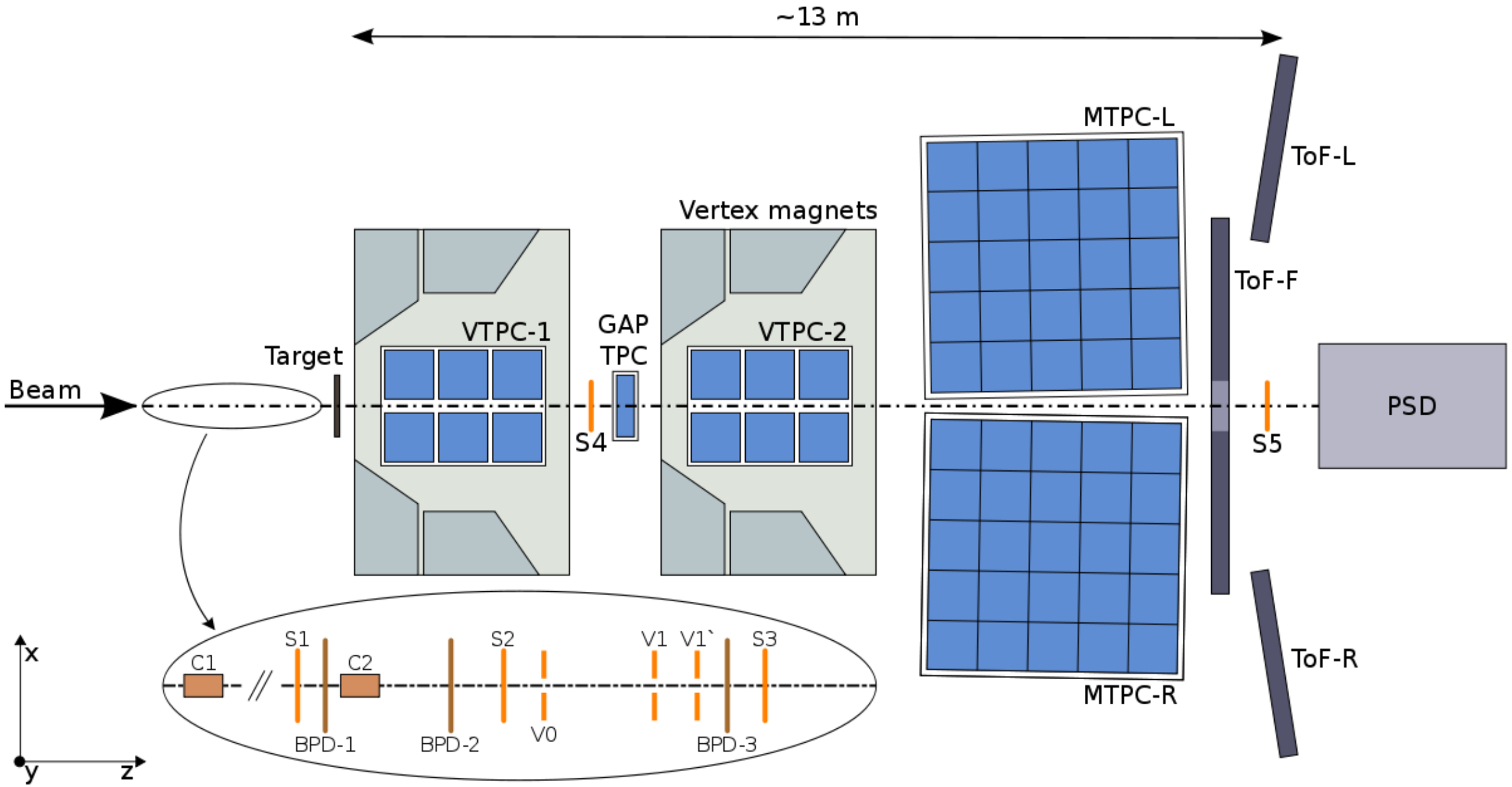
D.A. Artemenkov, V.A. Babkin, M.G. Buryakov,
V.M. Golovatyuk, D.K. Dryablov, V.A. Kireyeu, V.I. Kolesnikov,
A.I. Malakhov, G.L. Melkumov, M.M. Rumyantsev, R. Tsenov
(*Veksler and Baldin Laboratory of High Energy Physics, JINR*);

S.A. Bunyatov, A.V. Krasnoperov, G.I. Lykasov, V.V. Lyubushkin, B.A. Popov, V.V. Tereshchenko (*Dzelepov Laboratory of Nuclear Problems, JINR*);

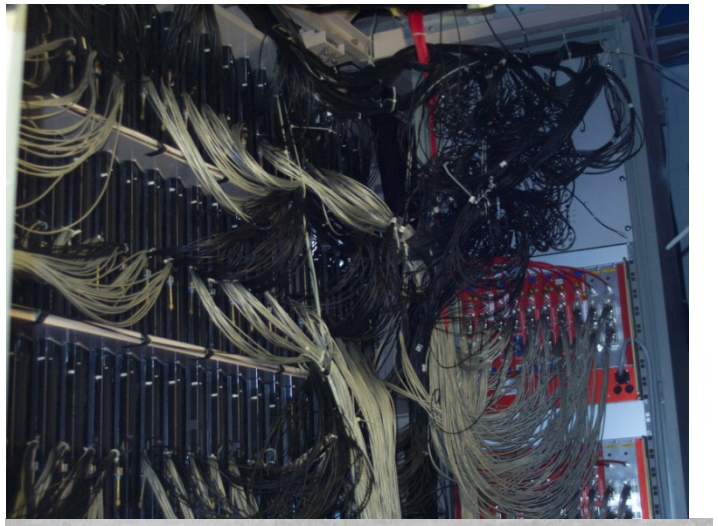
B. Baatar (*Institute physics and Technology of Mongolian Academy of Science, Ulaanbaatar, Mongolia*);

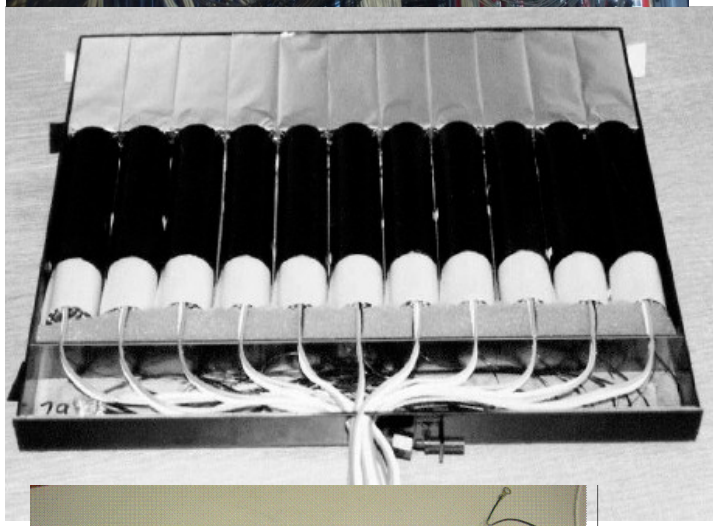
D. Kolev, M. Bogomilov (*Sofia University "St. Kliment Ohridski", Bulgaria*)

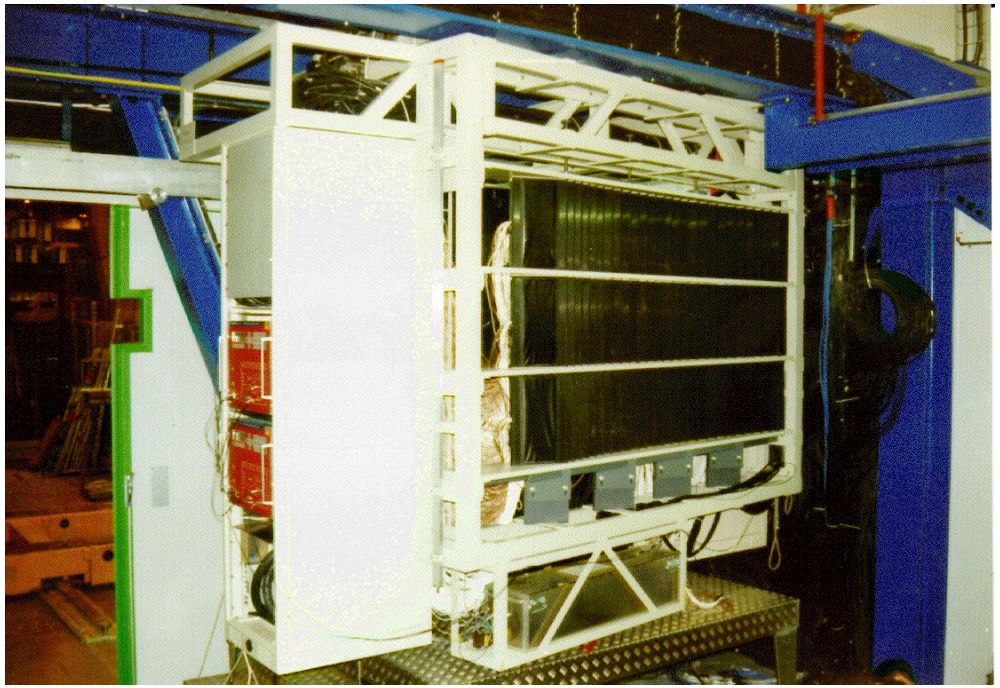
NA61/SHINE general view



NA61 TOF-L/R detector







NA61 TOF-L/R detector:

- 2 x 891 scintillator counters
- TOF-L (**JINR contribution**) put into operation in 1995-96
- Time resolution: 60-70 ps

NA61/SHINE physics program

Hadron production in p+p, p+A, h+A, A+A at various energies

Search for the critical point of strongly interacting matter

Study of the properties of the onset of deconfinemen

Study of hadron fluctuations and single particle spectra

Study high pT particles (energy dependence of nuclear modification factor)

Motivation: suppression of high p_T particles at RHIC and LHC energies (manifestation of parton energy loss in a dense medium)

Hypothesis: for lower energy collisions, where deconfined matter is *not* formed, such suppression should disappear

Precision measurements of hadron spectra in hadron+nucleus interactions

reference measurements of p+C interactions **for the T2K experiment** for computing initial neutrino fluxes at J-PARC

reference measurements of p+C, p+p, p+p, and π+C interactions **for cosmic-ray physics** (Pierre-Auger and KASCADE experiments) for improving air shower simulations

Considered extensions beyond the approved program

measurements of **Pb+Pb** collisions for the ion program

(+ open charm and multi-strange particles, high p_T spectra)

measurements for the **Fermilab neutrino program**

measurements for the **CERN (LBNO) neutrino program**

Recent physics results of NA61

N. Abgrall et al., “Measurements of $\pi^{+/-}$, $K^{+/-}$, K^0_S , Λ and proton production in proton–carbon interactions at 31 GeV/c with the NA61/SHINE spectrometer at the CERN SPS” Eur. Phys. J. C 76 no. 2, (2016) 84.

A. Aduszkiewicz et al., “Production of Λ-hyperons in inelastic p+p interactions at 158 GeV/c”, Eur. Phys. J. C 76 no. 4, (2016) 198.

N. Abgrall et al., “Measurements of π+/- differential yields from the surface of the T2K replica target for incoming 31 GeV/c protons with the NA61/SHINE spectrometer at the CERN SPS”, Eur. Phys. J C 76, 617 (2016).

A. Aduszkiewicz et al., “Multiplicity and transverse momentum fluctuations in inelastic proton–proton interactions at the CERN Super Proton Synchrotron”, Eur. Phys. J. C76, 635 (2016).

T. Anticic et al., "Production of deuterium, tritium, and ^{3}He in central Pb+Pb collisions at 20A, 30A, 40A, 80A, and 158A GeV at the CERN SPS" Phys. Rev. C 94, 044906 (2016).

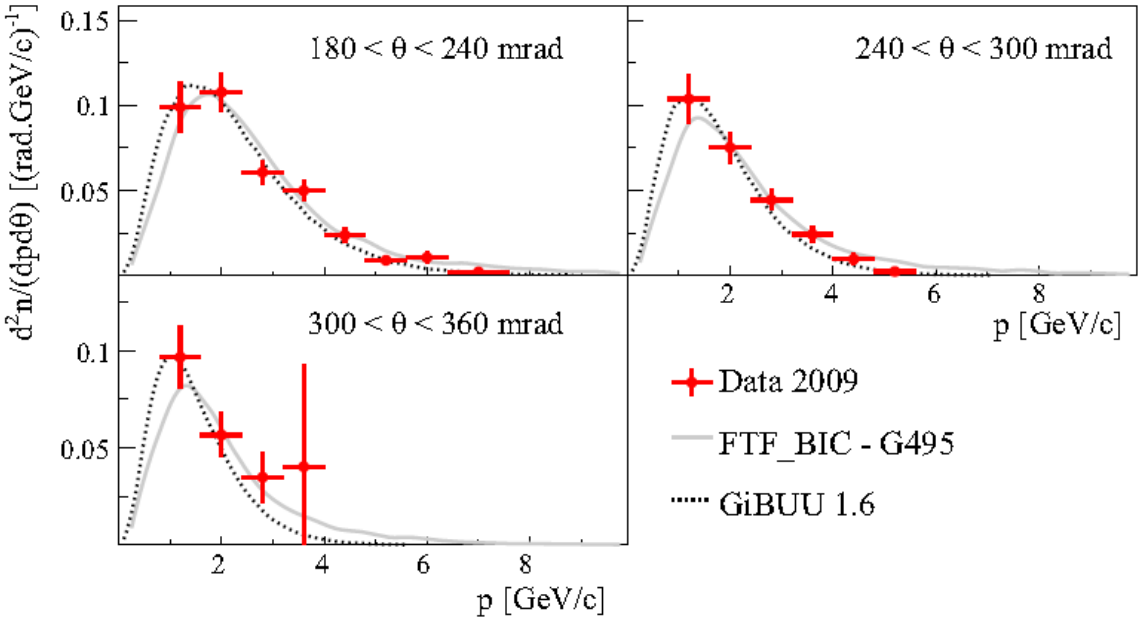
A. Aduszkiewicz et al., “Two-particle correlations in azimuthal angle and pseudorapidity in inelastic p + p interactions at the CERN Super Proton Synchrotron”, Eur. Phys. J. C 77, 59 (2017).

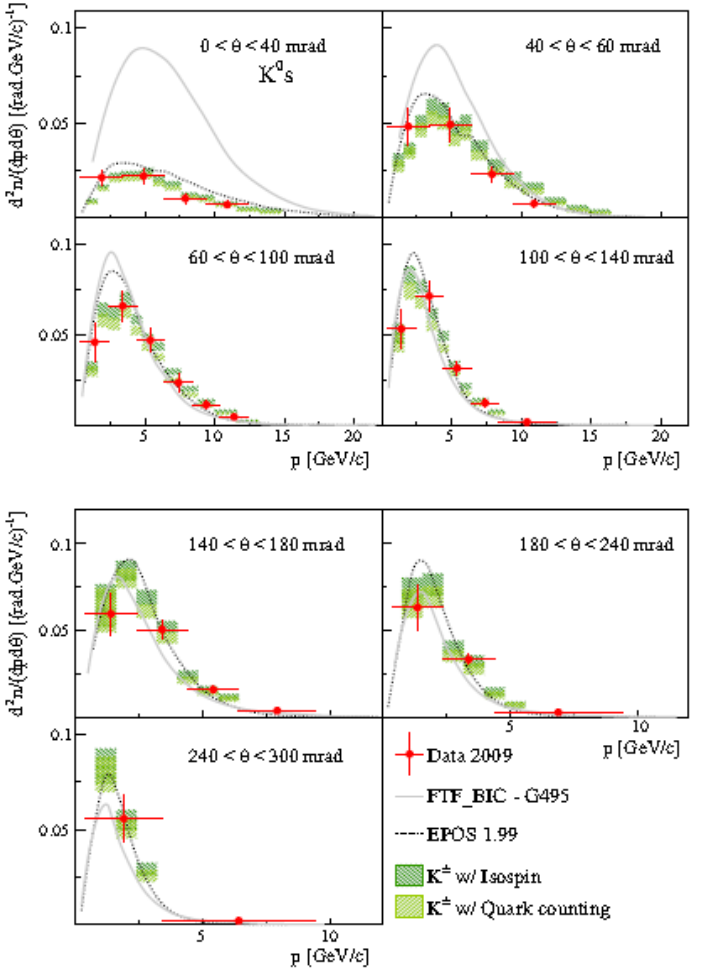
JINR contribution and responsibilities

- **Data taking**
- **R&D for the future TOF upgrade (MRPC-based)**
- **TOF-L/R response simulation within the SHINE framework**
- **Development and maintenance of the software library (legacy chain)**
- **Raw data reconstruction and DST production**
- **Data analysis**

JINR contribution in the data analysis

"Measurements of $p^{+/-}$, $K^{+/-}$, K^0_S , Λ and proton production in proton–carbon interactions at 31 GeV/c with the NA61/SHINE spectrometer at the CERN SPS", Eur. Phys. J. C (2016) 76:8.



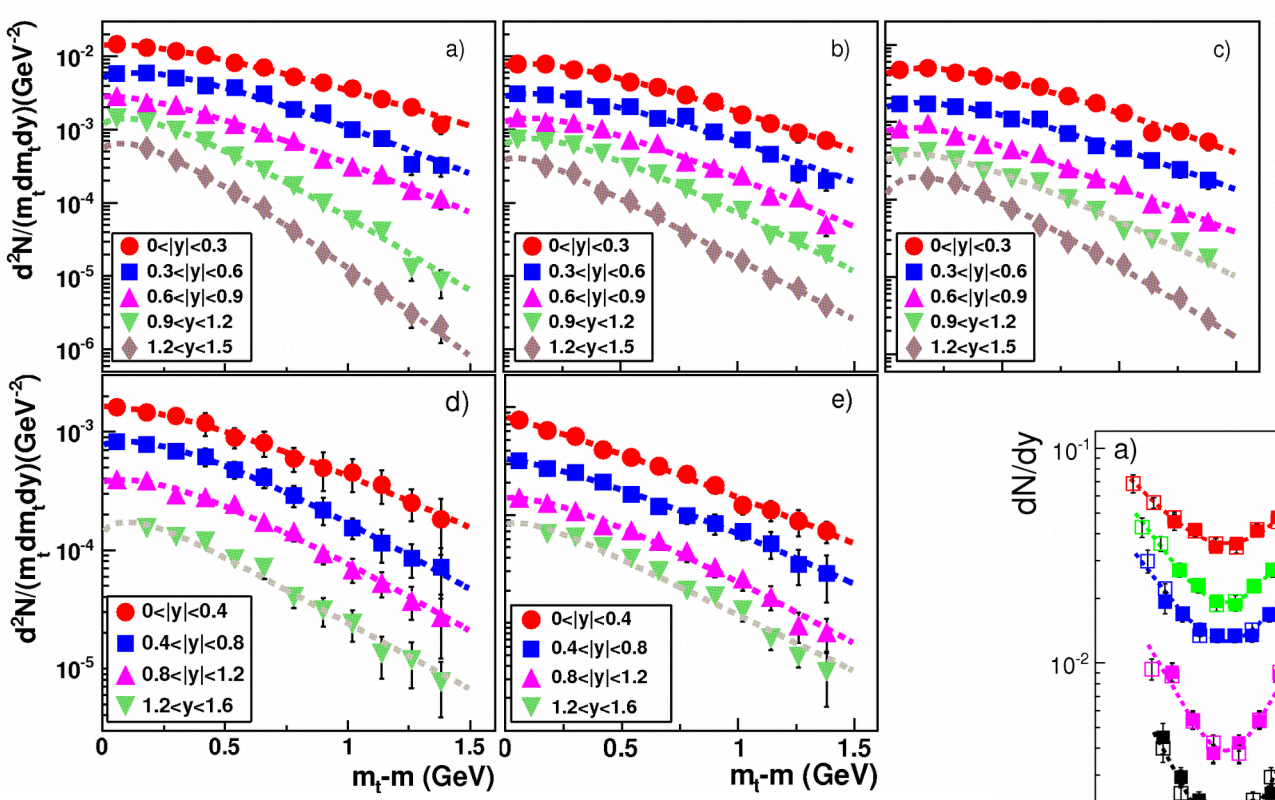


Laboratory momentum distributions of K+ and K^0_S mesons produced in p+C interactions at 31 GeV/c in different polar angle intervals.

- Inelastic and production cross sections as well as spectra of π, K, p, K^0_S and Λ have been measured
- Essential for improved calculations of the initial neutrino fluxes in long-baseline neutrino oscillation experiments

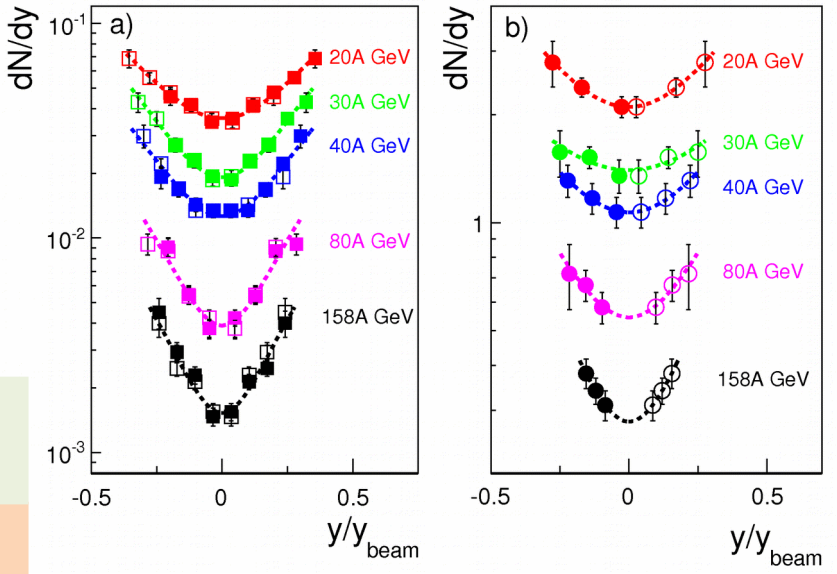
JINR contribution in the data analysis

"Production of deuterium, tritium, and ^{3}He in central Pb+Pb collisions at 20A, 30A, 40A, 80A, and 158A GeV at the CERN SPS", Phys. Rev. C 94 044906 (2016)



Invariant m_t-spectra of ^{3}He at 20A (a), 30A (b), 40A (c), 80A (d), and 158A GeV (e)

(Data from NA49, predecessor of NA61)



- Longitudinal and transverse spectra
- Total yields, ratios
- Energy and mass dependence of yields
- Model comparison

Plans for 2018-2020

Hardware & data taking

- Data taking and shifts
- R&D for the NA61 TOF upgrade (MRPC)

Software development & reconstruction

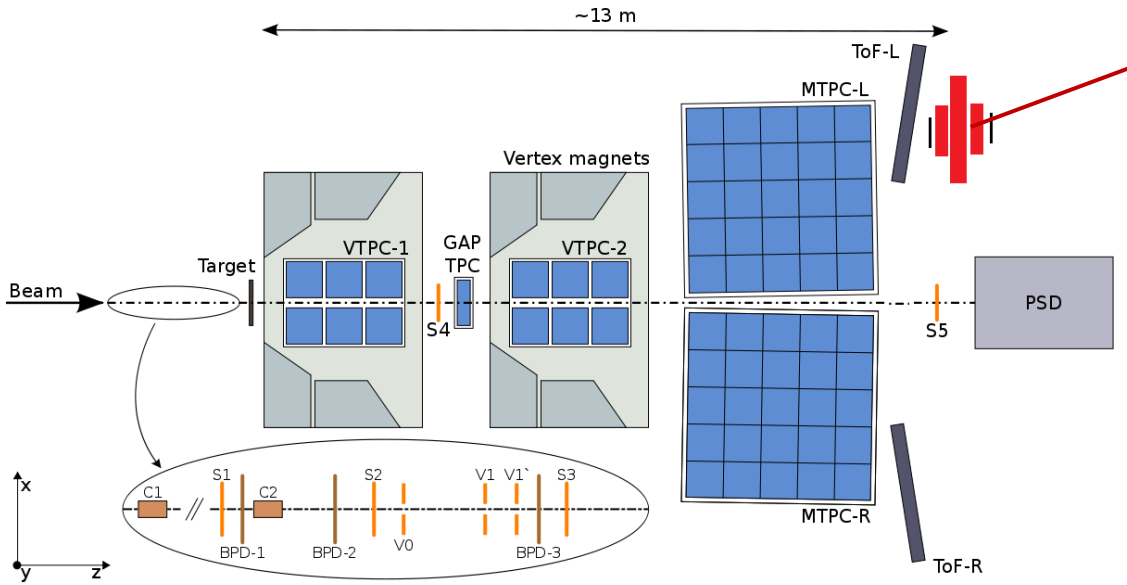
- TOF simulation within the SHINE framework
- DST production

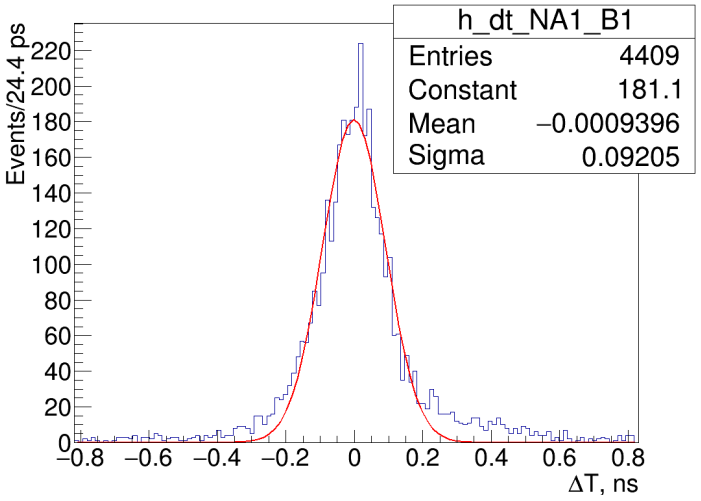
Data analysis

- Study of the system size dependence of (anti)nuclei production (Ar+Sc, Be+Be and Xe+La) – VBLHEP group
- Hadro-production for the Fermilab neutrino program (LNP group)

R&D for the new NA61-TOF

MRPC detectors for NICA
(V. Golovatyuk, V. Babkin)





Test run in November 2016

$$\sigma_{p1} = 66.7\,ps \;-\; Pad\ 1$$
$$\sigma_{p2} = 79.1\,ps \;-\; Pad\ 2$$
$$\sigma_{s} = 63.6\,ps \;-\; Strip$$

R&D for TOF MRPC upgrade:

- Readout electronics integration
- Synchronization between T0 and TOF
- Matching of TPC tracks to MRPC hits
- Hadrons separation
- Developing of new types of readout electronics

Estimate of the JINR budget expenses for the NA61 project (JINR participation)

№	Expenditure	Full cost (k$)	2018	2019	2020
	The direct costs of the project:				
1.	Nuclotron	-	-	-	-
3.	Computer communication	10	4	3	3
4.	Design Department	-	-	-	-
5.	LHEP workshops	-	-	-	-
6.	Materials	35	14	14	7
7.	Equipment	20	8	8	4
9.	Manpower at CERN	210	75	60	75
10	Collaboration common fund	36	12	12	12
	Total:	311	113	97	101

Summary

Continuation of collaboration with NA61 will provide a deeper understanding of the nuclear matter properties at relativistic energies. It is complementary to the studies being carries out at the NICA, and it will be very useful for training young scientists at JINR for the future.

NA61 project was approved with the first priority at the Laboratory STC on April 11.

We ask you to recommend an approval of JINR participation in the NA61 project within the theme 02-1-1087-2009/2020 for a period of 3 years.

Thank you!

BACKUP

Scientific Council
121st meeting,
23-24 February 2017

Results of implementation of the Seven-year plan for the development of JINR for 2010-2017 and plans for 2017-2023

Particle physics and high-energy heavy-ion physics, Information technology

Richard Lednicky

JINR, Dubna

At JINR

Study of the hot & dense baryonic matter at extreme conditions in 2017-2023

The study of heavy-ion collisions in the energy range up to $\sqrt{s_{NN}}$ = 11 GeV will be fulfilled using **BM@N** setup at the extracted Nuclotron beams and in the collider mode using the **MPD** setup.

The main goals of the LHEP in the 7-year plan are:

*To put in operation the **NICA** complex with both **MPD** and **SPD** setups, their final adjustment to the designed objectives and obtaining of new results.*

External experiments:

*Participation in the research programs at the **STAR** (RHIC, BNL). **NA61** (SPS, CERN), **ALICE** (LHC, CERN), and **CBM/HADES** (FAIR, GSI).*

The scale of participation in external projects will be determined by:
- *the consolidation work at the JINR accelerator complex;*
- *the progress in the NICA project realization.*

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Suggested time-table and wherewithal for realization of NA61 project (JINR participation)

Name of components and systems at plants, resources, funding sources			**Cost of components (k$) of plant. Resources requirements**	**Proposals of Laboratory on financing and resources**		
				2018	2019	**2020**
The main units and equipment	Equipment, components		10	4	3	**3**
	Detector maintenance		5	2	2	**1**
	RPC Time of Flight system (R@D)		50	20	20	**10**
Required resources		JINR workshops	-	-	-	**-**
		Design Department	-	-	-	**-**
		LHEP workshops	-	-	-	**-**
		Nuclotron	-	-	-	**-**
Manpower at CERN			210	75	60	**75**
Collaboration common fund			36	12	12	**12**
Sources of financing	**Budget**		**311**	**113**	**97**	**101**

Preliminary cost estimation of MRPC TOF system for NA61

Name of components	Price/ch, €	Price/1 m^2 (576 ch), €
FEE (NINO base)	12	**6.9**
TDC (HPTDC base)	32	**18.4**
Detectors (48 strips, 96 ch)	15	**8.6**
Crates, signal cables	52	**30.0**
LV, YV, cabling	16	**9.2**
Space frame, mechanical construction, gas box	7	**4.0**
Total	**134 €/channel**	**77.1 k€/1 m^2**

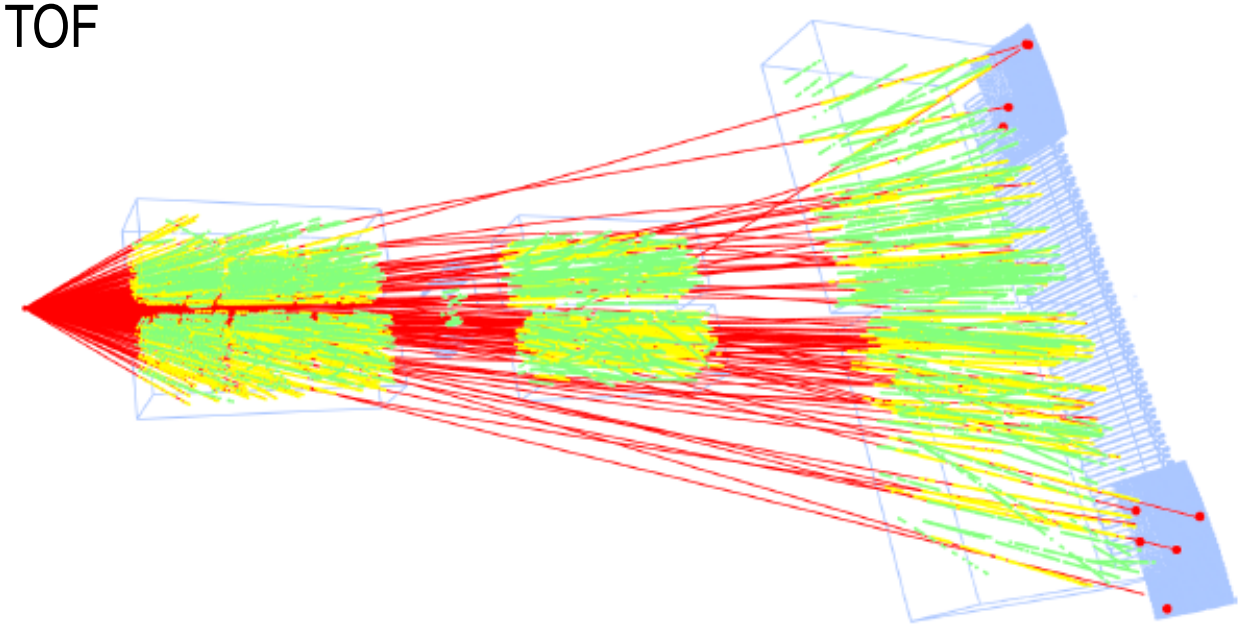
The cost of the gas system for the MRPC TOF is about 100 k€.

Preparation for the "*NA61 beyond 2020*" period

NA61 Physics after 2020: high statistics beam momentum scan with Pb+Pb
for precise measurements of open charm and multistrange hyperon production

Detector upgrades:

- 1 kHz readout
- Large Acceptance Vertex Detector
- New TOF



(Central Pb+Pb collision at 13A GeV/c measured in NA61/SHINE in 2016)