NA61/SHINE Project

Study of Hadron Production in Hadron-Nucleus and Nucleus-Nucleus Collisions at the CERN SPS

Extension for 2022-2024

JINR partisipation (Theme 02-1-1087-2009/23)

Project leader: A. Malakhov
Deputies: A.Dmitriev, A.Zaitsev

JINR Management (1):
V.Matveev

VBLHEP (11):
V.Babkin, M.Buryakov, A.Dmitriev, V.Kireyeu, R.Kolesnikov, V.Kolesnikov, V.Lenivenko, A.Malakhov, G.Melkumov, M.Rumyantsev, A.Zaitsev

DNLP (4):
G.Lykasov, V.Lyubushkin, B.Popov, V.Tereshenko

Institute Physics and Technology of Mongolian Academy of Science, Ulaanbaatar, Mongolia (1):
B.Baatar

Sofia University "St. Kliment Ohridski", Bulgaria (4):
M.Bogomilov, D.Kolev, S.Ileeva, R.Tsenov

NA61/SHINE Collaboration

Azerbaijan:	National Nuclear Research Center, Baku
Bulgaria:	Faculty of Physics, University of Sofia, Sofia
Croatia:	Ruđer Bošković Institute, Zagreb
France:	LPNHE, University of Paris VI and VII, Paris
Germany:	Karlsruhe Institute of Technology, Karlsruhe
	University of Frankfurt, Frankfurt
Hungary:	Wigner Research Centre for Physics of the Hungarian Academy of Sciences, Budapest
Norway:	University of Bergen, Bergen
Poland:	Jan Kochanowski University in Kielce
	Institute of Nuclear Physics, Polish Academy of Sciences, Cracow
	National Centre for Nuclear Research, Warsaw
	Jagiellonian University, Cracow
	AGH – University of Science and Technology, Cracow
	University of Silesia, Katowice
	University of Warsaw, Warsaw
	University of Wrocław, Wrocław
	Warsaw University of Technology, Warsaw
Russia:	Institute for Nuclear Research, Moscow
	Joint Institute for Nuclear Research, Dubna
	National Research Nuclear University (Moscow Engineering Physics Institute), Moscow
	St. Petersburg State University, St. Petersburg
Serbia:	University of Belgrade, Belgrade
Switzerland:	University of Geneva, Geneva
USA:	Fermilab, Batavia
	University of Colorado, Boulder
	University of Pittsburgh, Pittsburgh

About 140 partisipants, 26 institutions, 12 countries

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)

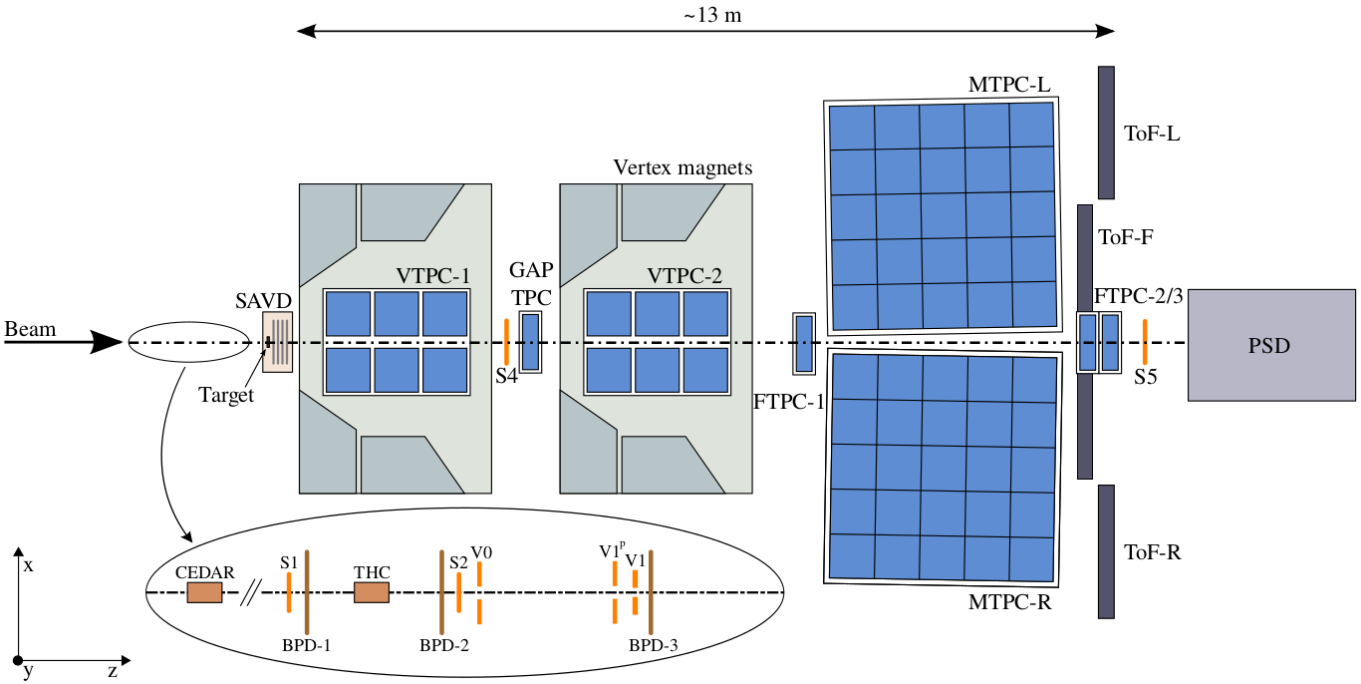
Dubna 2017

p.18-19

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

NA61/SHINE detector

Fixed target experiment located at the H2 beam line of CERN – North Area



Beams:

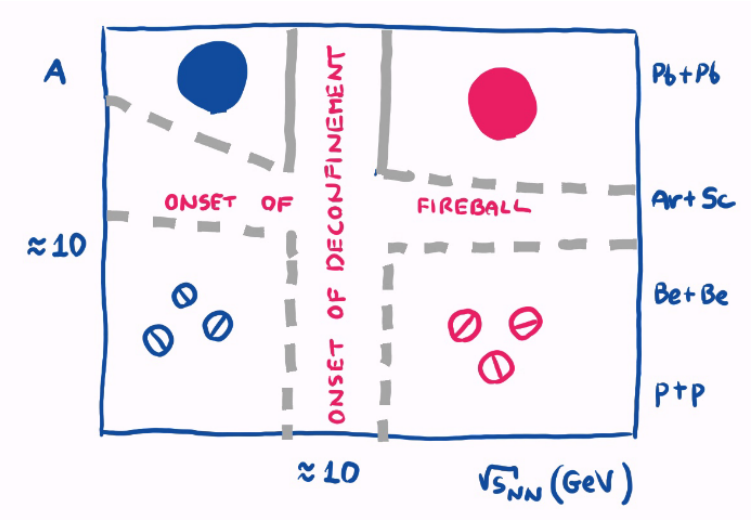
- ions (Be, Ar, Xe, Pb)
  p_{beam}=13A-150A GeV/c
- hadrons (π, K, p)
  p_{beam}=13-400 GeV/c
- $\sqrt{s_{NN}}$=5.1-17.3(27.4) GeV

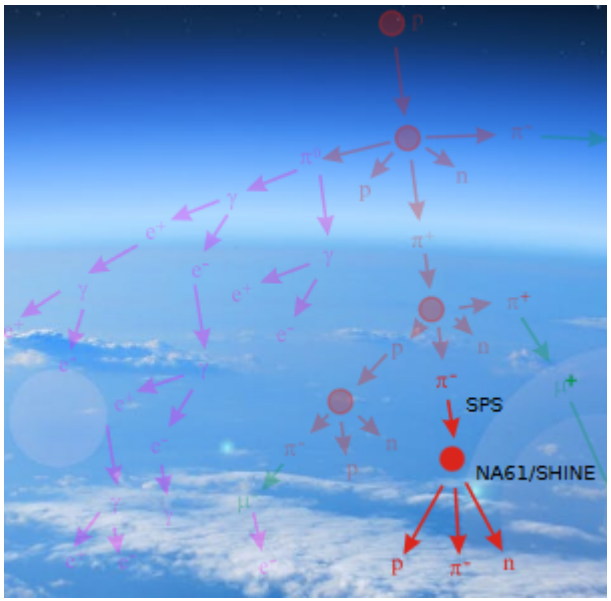
NA61/SHINE physical program

- The study of the QCD phase diagram of strongly interacting matter:

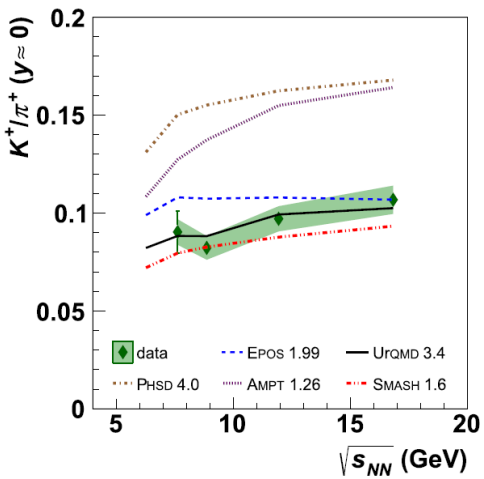
  search for the critical point
  study the properties of the onset of deconfiment
  study the properties of the onset of fireball

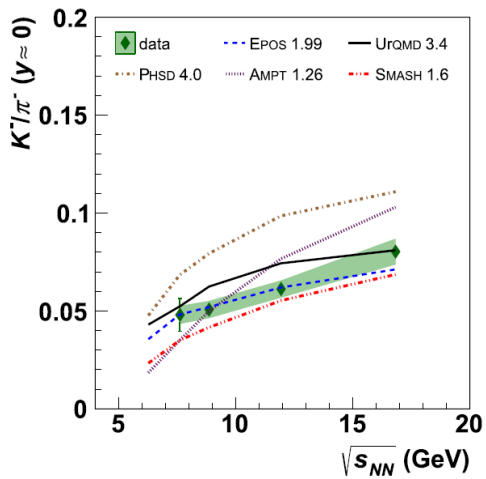
- The study for the measurement of the hadron production in h+A interaction for the neutrino and cosmic ray experiments



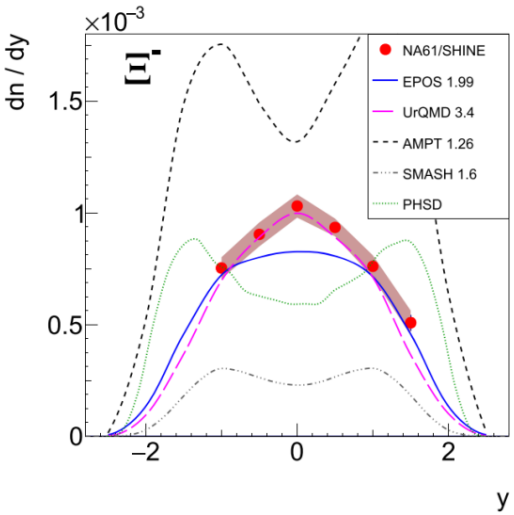


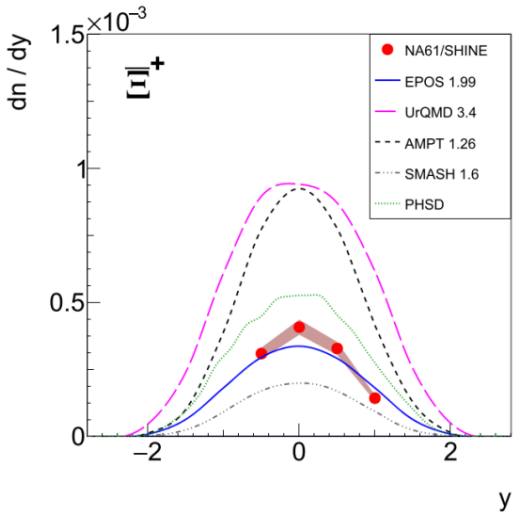
The main activities of the JINR group in the NA61/SHINE experiment in 2019-2021





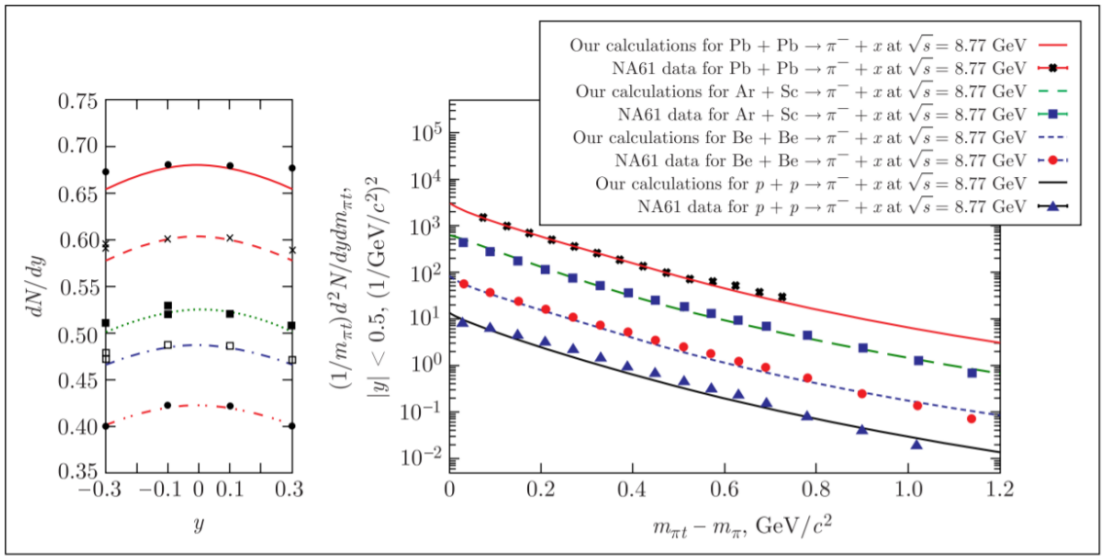
- Measurements of $\pi^{\pm}$, $K^{\pm}$, p and anti-p spectra in $^{7}\mathrm{Be} + {}^{9}\mathrm{Be}$ collisions at beam momenta from 19A to 150A GeV/c with the NA61/SHINE spectrometer at the CERN SPS. *(Eur. Phys. J. C (2021) 81:73)*





- Measurements of Ξ^- and anui-Ξ^+ production in proton–proton interactions at $\sqrt{s_{NN}} = 17.3$ GeV in the NA61/SHINE experiment. *(Eur. Phys. J. C (2020) 80:833)*

The main activities of the JINR group in the NA61/SHINE experiment in 2019-2021

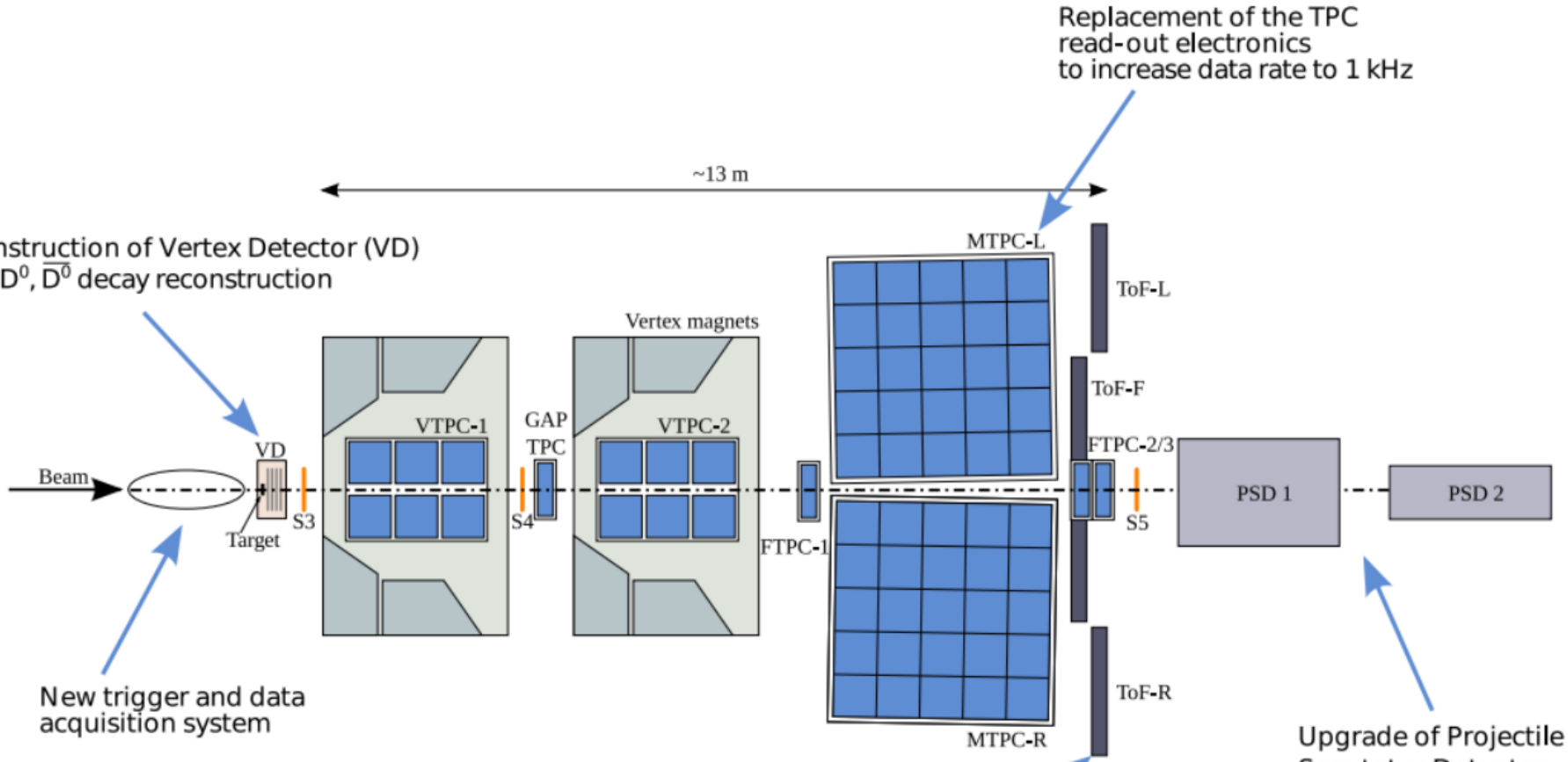


- A.I.Malakhov, G.I.Lykasov. Mid-rapidity dependence of pion production in p-p and A-A collisios. *(Eur. Phys. J. A (2020) 56:114)*

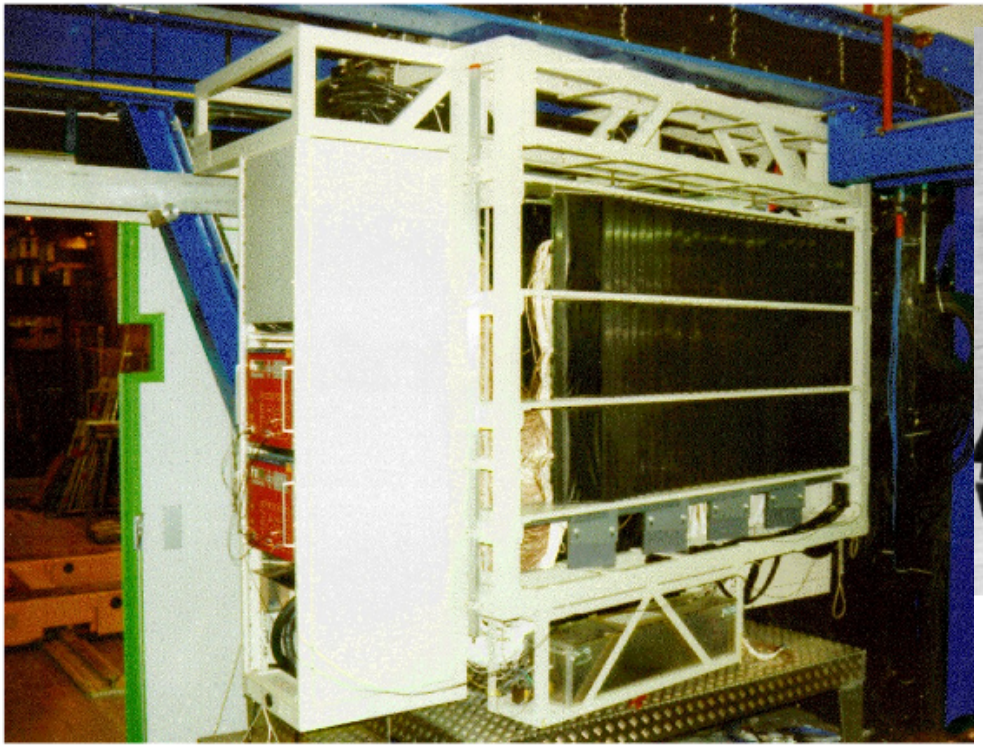
Other activities:

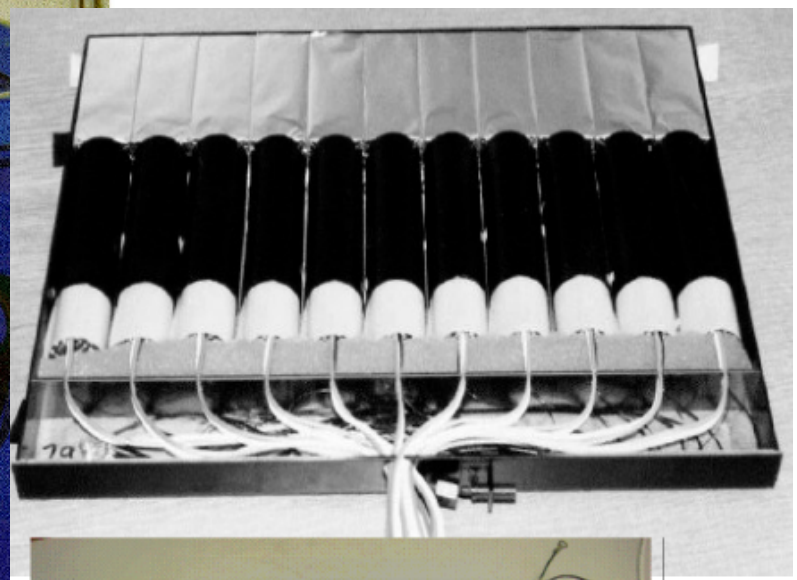
- Neutrino/cosmic ray program **(B.Popov co-convener of WG)**
  Measurements of production cross section of 31 GeV/c protons on carbon via beam attenuation in a 90-cm-long target. Phys. Rev. D 103 (2021)
- Data analysis of anti-matter production in $Ar + Sc$ collisions **(A.Zaitsev)**
- Development of the model independent cluster finding library psMST for better understanding light nuclei data **(Kireyeu.V)**
- Participation in data taking (2021)

Detector upgrade during LS2



Old NA61/SHINE TOF-LR system



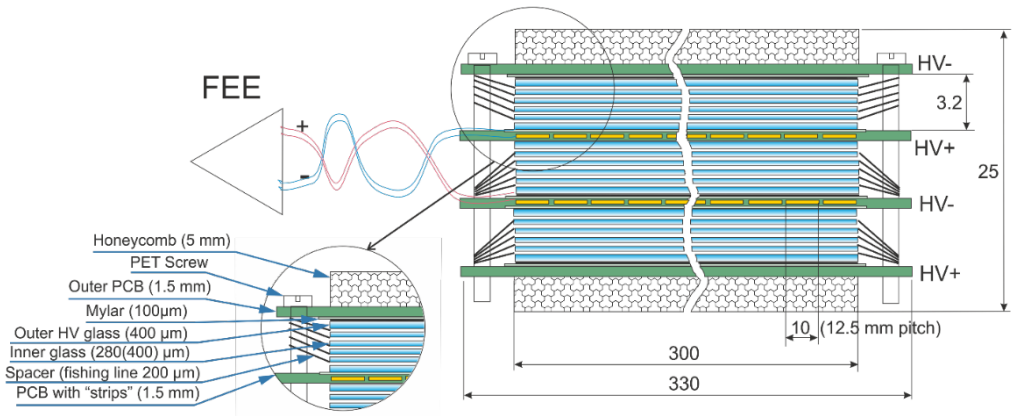


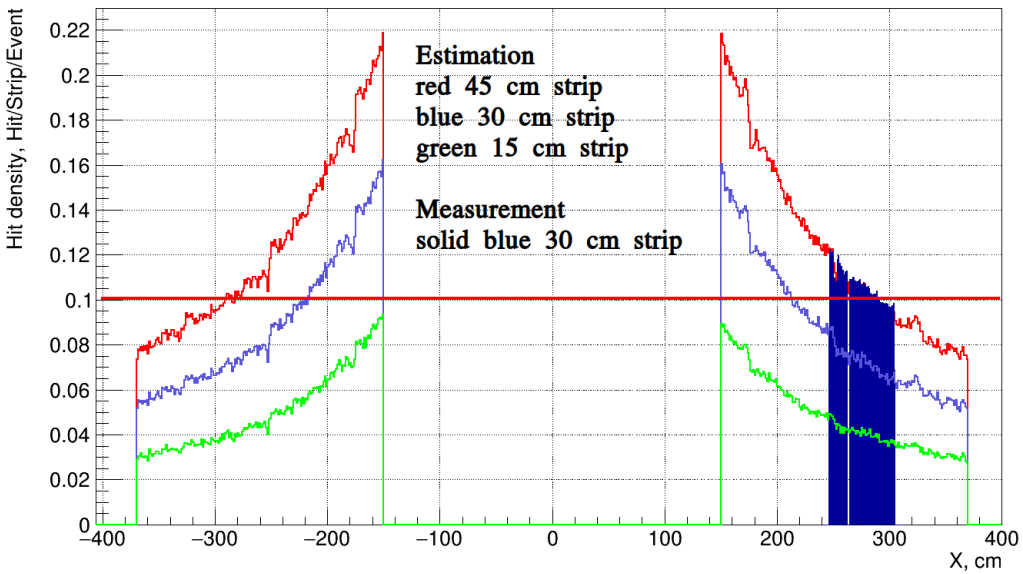
Requirements for the NEW ToF:

- efficiency $> 95\%$;
- time resolution < 75 ps;
- the system occupancy below 10%;
- position resolution < 1 cm;
- low power dissipation in MTPC hut.

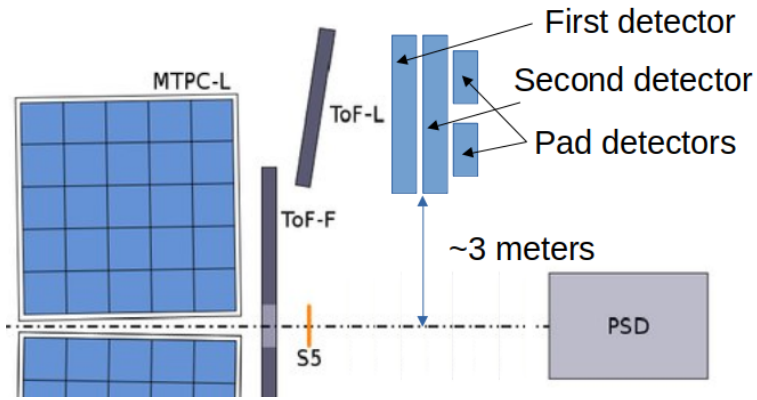
- 2 x 891 scintillator counters
- TOF-L (JINR contribution) put into operation in 1995-96
- declared time resolution: ~ 75 ps

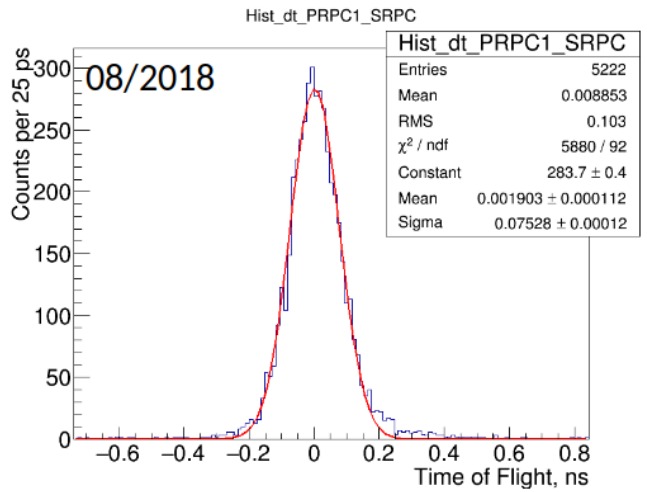
ToF R&D with the NINO+HPTDC readout





Additional material budget (old ToF) affected on measurement





$$\sigma_{mrpc} \approx \sqrt{76^2 - 58^2_{pad}} \approx 50ps$$

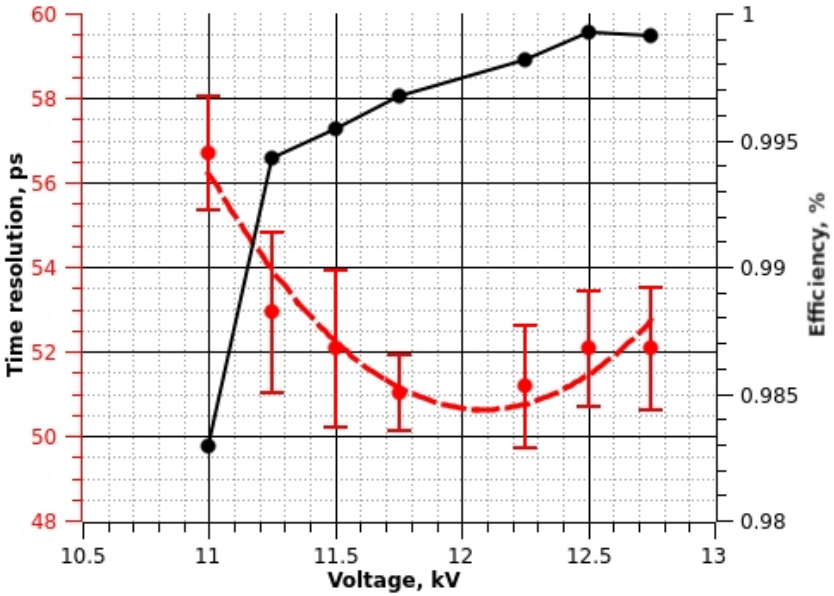
Tracks to hits matching (position resolution)

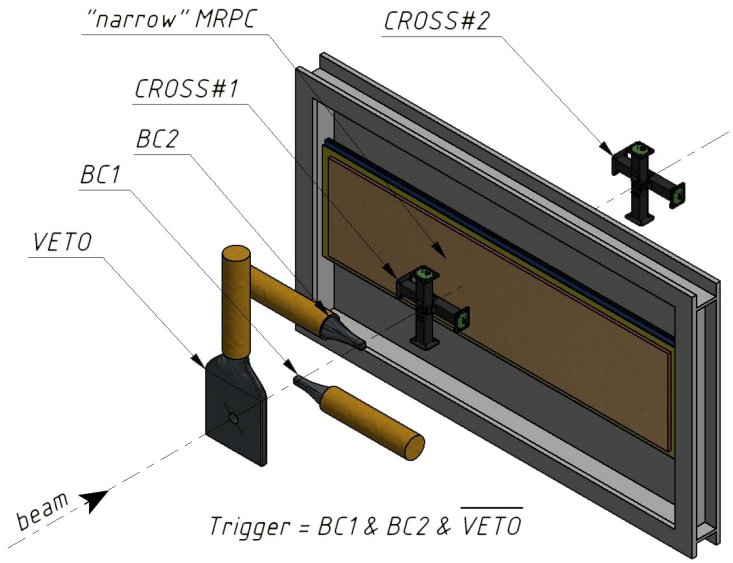
$$\sigma_{ResX} \approx 0.70\ cm$$

$$\sigma_{ResY} \approx 0.65\ cm$$

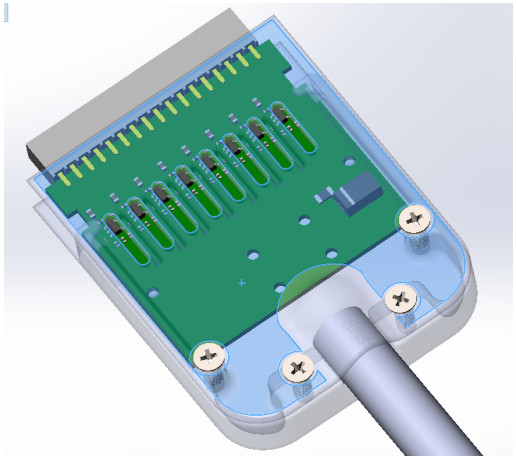
ToF R&D with the analogue readout (AFE+DRS4)

$\sigma_{mrpc} \approx 52ps$

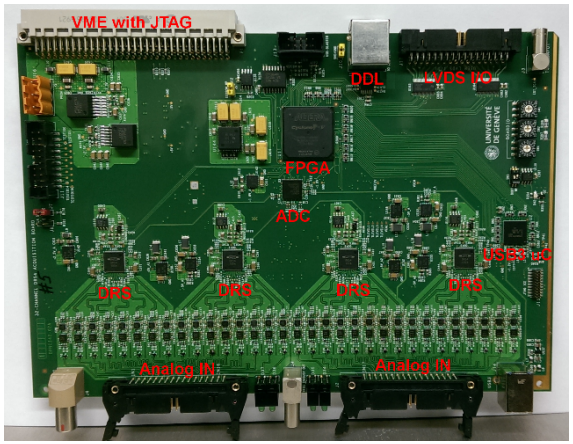




AFE_v5 prototype

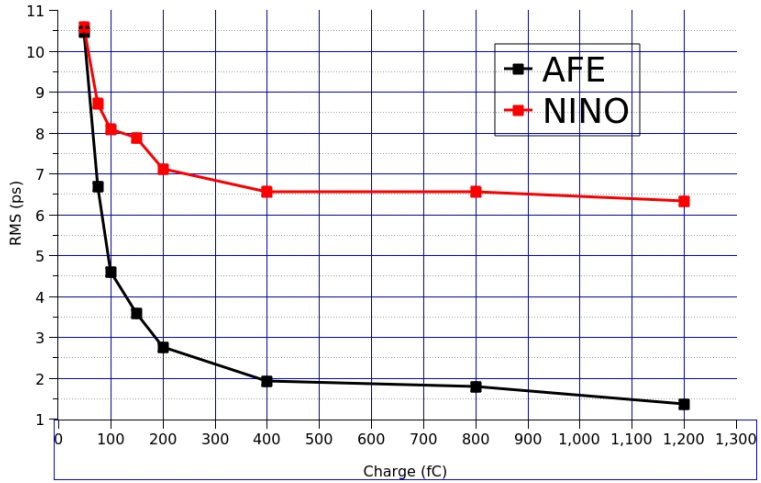


DRS4 board



candidate for ToF MPD EndCaps

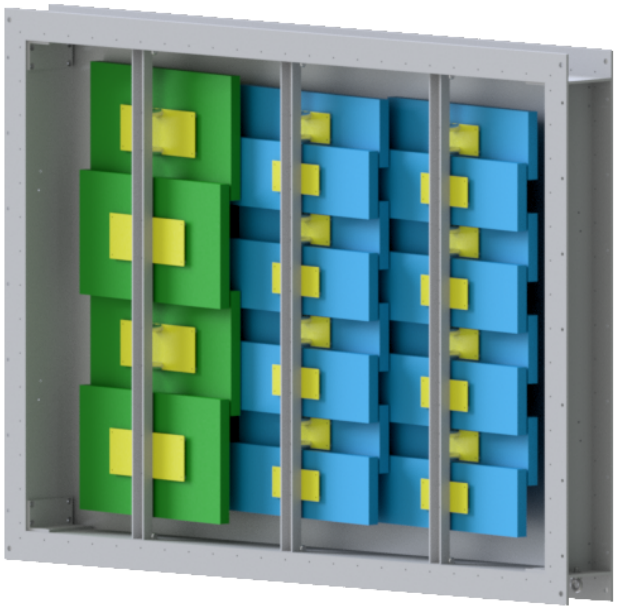
RMS (jitter) vs charge



NINO 7m 30awg cable
AFE 8m 26awg cable

New Time-of-Flight system

ToF-R
(possible commisioning in 2022+)

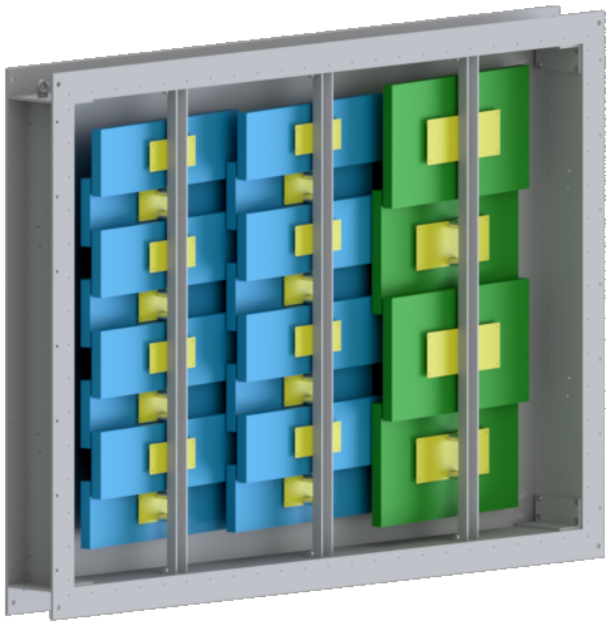


- MRPCs with gas module (16+4)
- modification of HV and gas systems

- LV system
- Front-end electronics (∼2000 ch)
- DRS4 readout
- Cooling system

beam

ToF-L
(commisioning in 2021)



- MRPCs with gas module (16+4)
- Closed-loop gas system for two modules (CERN responsibility)
- HV & LV systems
- Front-end electronics (∼2000 ch)
- DRS4 readout (CERN responsibility)
- Cooling system

Publications in the 2019-2021

1. Measurements of production cross section of 31 GeV/c protons on carbon via beam attenuation in a 90-cm-long target. **Phys. Rev. D 103** (2021) 012006.
2. Measurements of $\pi^{\pm}$, $K^{\pm}$, p and anti-p spectra in $^{7}\mathrm{Be}+^{9}\mathrm{Be}$ collisions at beam momenta from 19A to 150A GeV/c with the NA61/SHINE spectrometer at the CERN SPS. **Eur. Phys. J. C 81** (2021) 73.
3. Two-particle correlations in azimuthal angle and pseudorapidity in central $^{7}\mathrm{Be}+^{9}\mathrm{Be}$ collisions at the CERN Super Proton Synchrotron. **Eur. Phys. J. C 80** (2020) 1151.
4. Measurements of π^{-} production in $^{7}\mathrm{Be}+^{9}\mathrm{Be}$ collisions at beam momenta from 19A to 150AGeV/c in the NA61/SHINE experiment at the CERN SPS. **Eur. Phys. J. C 80** (2020) 961.
5. Measurements of Ξ^{-} and anui-Ξ^{+} production in proton–proton interactions at $\sqrt{s_{NN}} = 17.3$ GeV in the NA61/SHINE experiment. **Eur. Phys. J. C 80** (2020) 833.
6. $K^{*}(892)_{0}$ meson production in inelastic p+p interactions at 158 GeV/c beam momentum measured by NA61/SHINE at the CERN SPS. **Eur. Phys. J. C 80** (2020) 460.
7. Measurement of ϕ meson production in p+p interactions at 40, 80 and 158 GeV/c with the NA61/SHINE spectrometer at the CERN SPS. **Eur. Phys. J. C 80** (2020) 199.
8. A.I.Malakhov, G.I.Lykasov. Mid-rapidity dependence of pion production in p-p and A-A collisios. **Eur. Phys. J. A 56** (2020) 114.
9. A.I.Malakhov, V.A.Matveev. New results and research perspectives of experiment NA61/SHINE on SPS at CERN. **JINR News, No.3,** 2020, pp.12-17.
10. Proton-proton interactions and onset of deconfinement. **Phys. Rev. C 102** (2020) 011901.
11. Search for an exotic $S = -2, Q = -2$ baryon resonance in proton-proton interactions at $\sqrt{s_{NN}} = 17.3$ GeV. **Phys. Rev. D 101** (2020) 051101.
12. Measurements of hadron production in π^{+}+C and π^{+}+Be interactions at 60 GeV/c. **Phys. Rev. D 100** (2019) 112004.
13. Measurements of production and inelastic cross sections for p+C, p+Be, and p+Al at 60 GeV/c and p+C and p+Be at 120 GeV/c. **Phys. Rev. D 100** (2019) 112001.

NA61/SHINE JINR group plans for 2022-2024

Hardware & data taking:

- ToF-L maintanance and data taking
- ToF-R production and commisioning

Software development & reconstruction:

- design of the ToF-L geometry
- implementation of the ToF-L reconstruction chain to the SHINE framework
- DST production

Data analysis:

- the study of the formation of light nuclei (d, t, $^3\mathrm{He}$, ..) in nucleus-nucleus interactions
- the study of hyperon and hypernuclei production in $Be + Be$, $Ar + Sc$, $Xe + La$, $Pb + Pb$ collisions
- analysis of anti-matter production in relativistic interactions
- participation in the study of open charm production in heavy ion collisions
- measurement of hadron production for neutrino and cosmic ray physics
- further development of theory models for better understanding collected data

Manpower and activities

VBLHP manpower

№	Name	Category	FTE
1	Babkin V.	MRPC	0.2
2	Burykov M.	MRPC	0.2
3	Dmitriev A.	MRPC	0.5
4	Kireyeu V.	Theory, Analysis, data taking	0.5
5	Kolesnikov R.	MRPC	0.3
6	Kolesnikov V.	Analysis, data taking	0.1
7	Lenivenko V.	Analysis, data taking	0.1
8	Malakhov A.	Project leader	0.3
9	Melkumov G.	Analysis, data taking	0.8
10	Rumyantsev M.	MRPC	0.2
11	Zaitsev A.	Theory, Analysis, data taking	0.8
		Σ	**4.0**

DLNP manpower

№	Name	Category	FTE
1	Lykasov G.	Theory	0.1
2	Lyubushkin V.	Analysis, data taking	0.2
3	Popov B.	Analysis	1.0
4	Tereshenko V.	MRPC, data taking	0.3
	Σ		**1.6**

The age of young employees

№	Name	Age
1	Babkin V.	38
2	Burykov M.	29
3	Dmitriev A.	27
4	Kireyeu V.	31
5	Kolesnikov R.	35
6	Lenivenko V.	30
7	Rumyantsev M.	32
8	Zaitsev A.	29

Requred resources

	Name of the items cost	full cost(k$)		2022		2023		2024	
		1087	1124	1087	1124	1087	1124	1087	1124
1.	Accelerator (Nuclotron), hour	-	-	-	-	-	-	-	-
2.	Computer communications	3	-	1	-	1	-	1	-
3.	LHEP Design bureau	-	-	-	-	-	-	-	-
4.	LHEP Workshop	-	-	-	-	-	-	-	-
5.	Materials	270	-	140	-	110	-	20	-
6.	Equipment	15	-	5	-	5	-	5	-
7.	Payment research	-	-	-	-	-	-	-	-
8.	Travel allowance includung:	178	24	60	8	60	8	58	8
	(a) to non-rouble zone countries	150	12	50	4	50	4	50	4
	(b) in the rouble zone	4	-	2	-	2	-	-	-
	(c) protocol-based	24	12	8	4	8	4	8	4
Σ		466	24	206	8	176	8	84	8
Total direct expenses:		490		214		184		92	

Thank you!

Backup slides

4. Оценка бюджета проекта (форма №26), расходы на 3 года

Форма №26

Предлагаемый план-график и необходимые ресурсы для обеспечения проекта NA61 (участие ОИЯИ)

Расходы, ресурсы, источники финансирования			Стоимость (k$) Потребности в ресурсах		Предложение Лаборатории в распределении финансов и ресурсов					
					2022		2023		2024	
			Тема 1087	Тема 1124	Тема 1087	Тема 1124	Тема 1087	Тема 1124	Тема 1087	Тема 1124
Расходы	Основные узлы оборудования, работа по его обновлению, настройке и т.д.		15	-	5	-	5	-	5	-
	Строительство / ремонт помещений		-	-	-	-	-	-	-	-
	Материалы		270	-	140	-	110	-	20	-
Требуемые ресурсы	Нормо-час	Конструкторское бюро ЛФВЭ	-	-	-	-	-	-	-	-
		Опытное производство ОИЯИ	-	-	-	-	-	-	-	-
		Опытное производство ЛФВЭ	-	-	-	-	-	-	-	-
		Nuclotron	-	-	-	-	-	-	-	-
Σ			285	-	145	-	115	-	25	-
ИТОГО:			285		145		115		25	
Источник финансирования		Бюджет. Тема 1087	285		145		115		25	

Тема 1087 - ЛФВЭ.
Тема 1124 - ЛЯП

РУКОВОДИТЕЛЬ ПРОЕКТА А.И. Малахов

21

Backup slides

5. Смета затрат по проекту (Форма № 29)

Форма №29

Предполагаемые расходы по проекту: «Исследование рождения адронов в адрон-ядерных и ядро-ядерных взаимодействиях на ускорителе SPS в ЦЕРН (NA61/SHINE - SPS Heavy Ion and Neutrino Experiment)»

№	Наименование статей затрат	Полная стоимость (тыс.долл.)		2022		2023		2024	
		Тема 1087	Тема 1124	Тема 1087	Тема 1124	Тема 1087	Тема 1124	Тема 1087	Тема 1124
1.	Ускоритель (Нуклотрон), час	-	-	-	-	-	-	-	-
2.	Компьютерная связь	3	-	1	-	1	-	1	-
3.	Конструкторское бюро ЛФВЭ	-	-	-	-	-	-	-	-
4.	Опытное производство ЛФВЭ	-	-	-	-	-	-	-	-
5.	Материалы	270	-	140	-	110	-	20	-
6.	Оборудование	15	-	5	-	5	-	5	-
7.	Оплата НИР	-	-	-	-	-	-	-	-
8.	Командировочные расходы, в том числе:	178	24	60	8	60	8	58	8
	(a) в страны нерублевой зоны	150	12	50	4	50	4	50	4
	b) в города стран рублевой зоны	4	-	2	-	2	-	-	-
	c) по протоколам	24	12	8	4	8	4	8	4
Σ		466	24	206	8	176	8	84	8
Итого по прямым расходам:		490		214		184		92	

Тема 1087 – ЛФВЭ
Тема 1124 - ЛЯП

РУКОВОДИТЕЛЬ ПРОЕКТА А.И. Малахов

ДИРЕКТОР ЛФВЭ В.Д. Кекелидзе

ДИРЕКТОР ЛЯП В.А. Бедняков

ВЕДУЩИЙ ИНЖЕНЕР-ЭКОНОМИСТ ЛФВЭ Г.Г.Волкова

ВЕДУЩИЙ ИНЖЕНЕР-ЭКОНОМИСТ ЛЯП

22