

Проект NA61/SHINE

на 2018-2020 гг.

(Участие ОИЯИ)

Тема 02-1-1087-2009/14

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Заседание Физической секции НТС

Лаборатории физики высоких энергий ОИЯИ

16.03.2017 г.

Проект NA61-SHINE

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

(Участие ОИЯИ)

Тема: Исследования по физике релятивистских тяжелых и легких ионов на ускорительных комплексах НУКЛОТРОН/НИКА ОИЯИ и СПС ЦЕРН.

Шифр темы: 02-1-1087-2009/2020

РУКОВОДИТЕЛЬ ПРОЕКТА

МАЛАХОВ А.И.

ЗАМЕСТИТЕЛЬ РУКОВОДИТЕЛЯ ПРОЕКТА

МЕЛКУМОВ Г.Л.

ДАТА ПРЕДСТАВЛЕНИЯ ФИЗОБОСНОВАНИЯ НА СЕМИНАРЕ
ЛАБОРАТОРИИ 10.03.2017 г.

Содержание

- ❑ NA61/SHINE Эксперимент
 - Состав коллаборации, участники от ОИЯИ
 - Физ. Программа эксперимента
 - Детектор NA61 (вклад ОИЯИ)

- ❑ Основные результаты за период 2015-17 гг.

- ❑ Планы по набору данных на 2018-20 гг.

- ❑ Планы работы группы ОИЯИ на 2018-20 гг.

- ❑ Запрашиваемые ресурсы



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 dileptons), 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.

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



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.*

NA61/SHINE (SPS Heavy Ion and Neutrino Experiment)

<http://na61.web.cern.ch/na61/xc/index.html>

[indico](#) [slides](#) [twiki](#) [elog](#) [edms](#) [cds](#) [svn](#) [inspire](#) [jira](#) [calendar](#)



SHINE

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Home

- Physics goals
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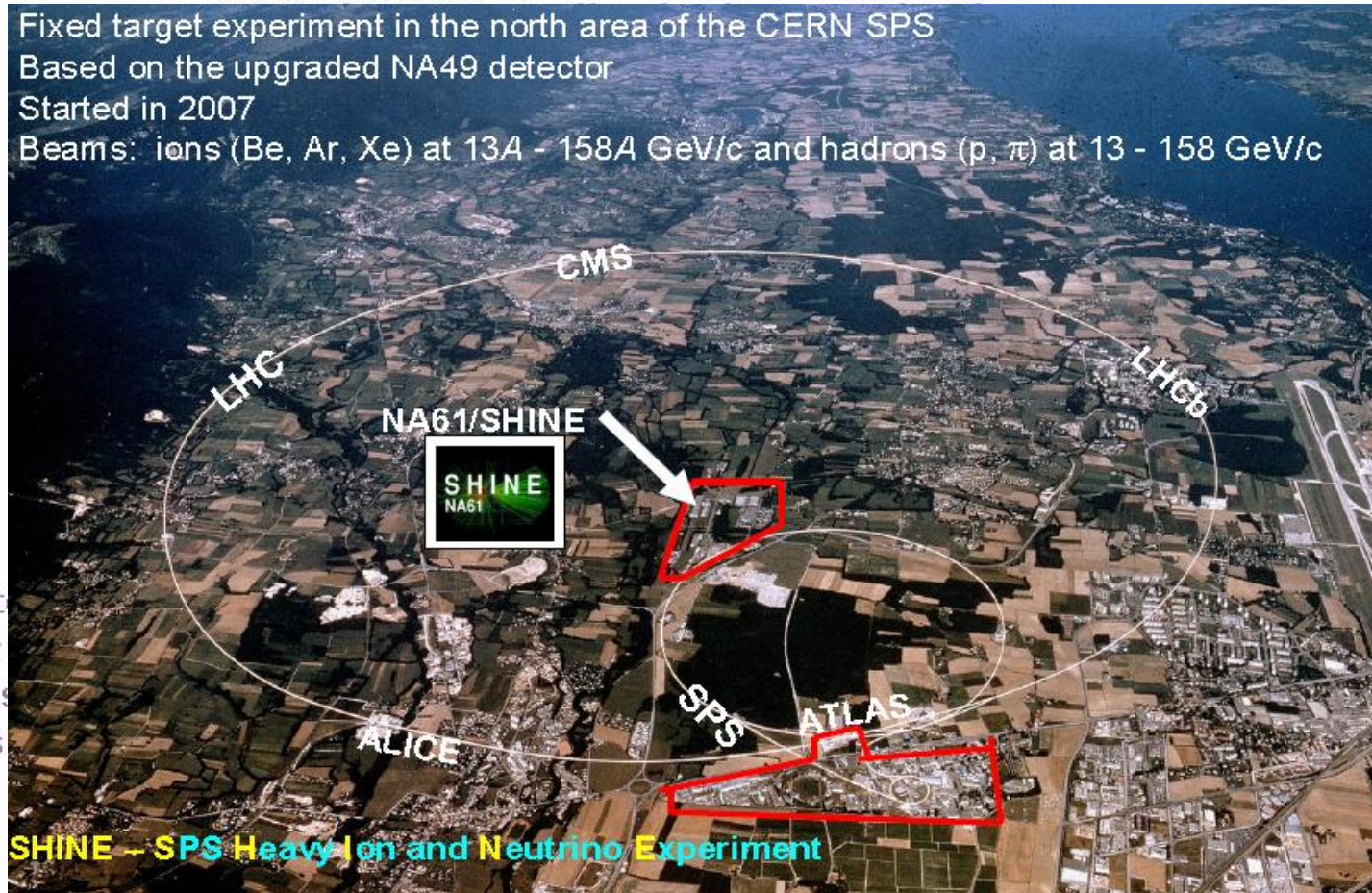
Data taking

- Detector
- Online-QA
- Book-keeping
- DCS java monitor
- Shift scheduler
- Shift crew tasks
- Shift expert ins

Software

- Shine-Offline

Fixed target experiment in the north area of the CERN SPS
Based on the upgraded NA49 detector
Started in 2007
Beams: ions (Be, Ar, Xe) at 13A - 158A GeV/c and hadrons (p, π) at 13 - 158 GeV/c



SHINE -- SPS Heavy Ion and Neutrino Experiment

NA61/SHINE Collaboration



- Azerbaijan
 - ▶ National Nuclear Research Center, Baku
- Bulgaria
 - ▶ University of Sofia, Sofia
- Croatia
 - ▶ IRB, Zagreb
- France
 - ▶ LPNHE, Paris
- Germany
 - ▶ KIT, Karlsruhe
 - ▶ Fachhochschule Frankfurt, Frankfurt
 - ▶ University of Frankfurt, Frankfurt
- Greece
 - ▶ University of Athens, Athens
- Hungary
 - ▶ Wigner RCP, Budapest
- Japan
 - ▶ KEK Tsukuba, Tsukuba
- Norway
 - ▶ University of Bergen, Bergen
- Poland
 - ▶ UJK, Kielce
 - ▶ NCBJ, Warsaw
 - ▶ University of Warsaw, Warsaw
 - ▶ WUT, Warsaw
 - ▶ Jagiellonian University, Kraków
 - ▶ IFJ PAN, Kraków
 - ▶ AGH, Kraków
 - ▶ University of Silesia, Katowice
 - ▶ University of Wrocław, Wrocław
- Russia
 - ▶ INR Moscow, Moscow
 - ▶ JINR Dubna, Dubna
 - ▶ SPBU, St. Petersburg
 - ▶ MEPhI, Moscow
- Serbia
 - ▶ University of Belgrade, Belgrade
- Switzerland
 - ▶ ETH Zürich, Zürich
 - ▶ University of Bern, Bern
 - ▶ University of Geneva, Geneva
- USA
 - ▶ University of Colorado Boulder, Boulder
 - ▶ LANL, Los Alamos
 - ▶ University of Pittsburgh, Pittsburgh
 - ▶ FNAL, Batavia
 - ▶ University of Hawaii, Manoa

~150 physicists from ~30 institutes

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*)



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 deconfinement

Study of hadron fluctuations and single particle spectra

Study high p_T 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)

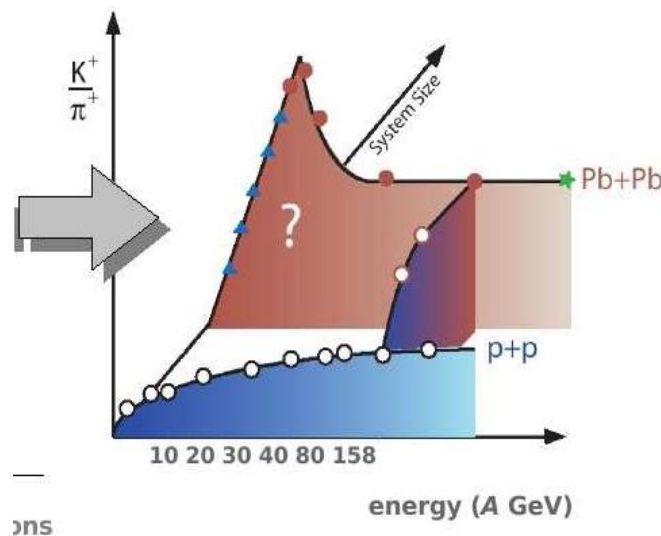
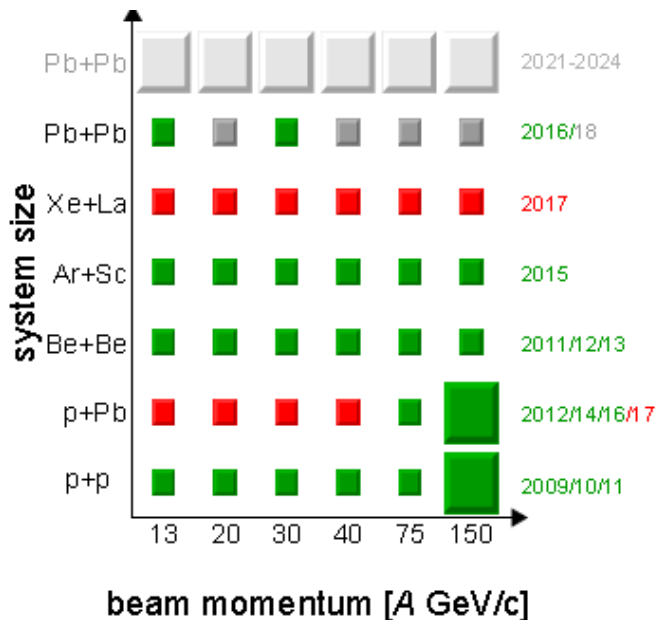
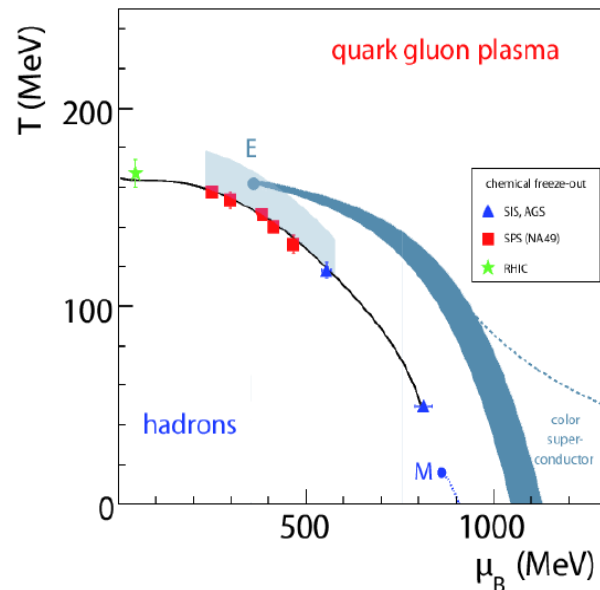
measurements for the **Fermilab neutrino program**

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

NA61 physics. Search for CEP in heavy-ion collisions

Experimental strategy:

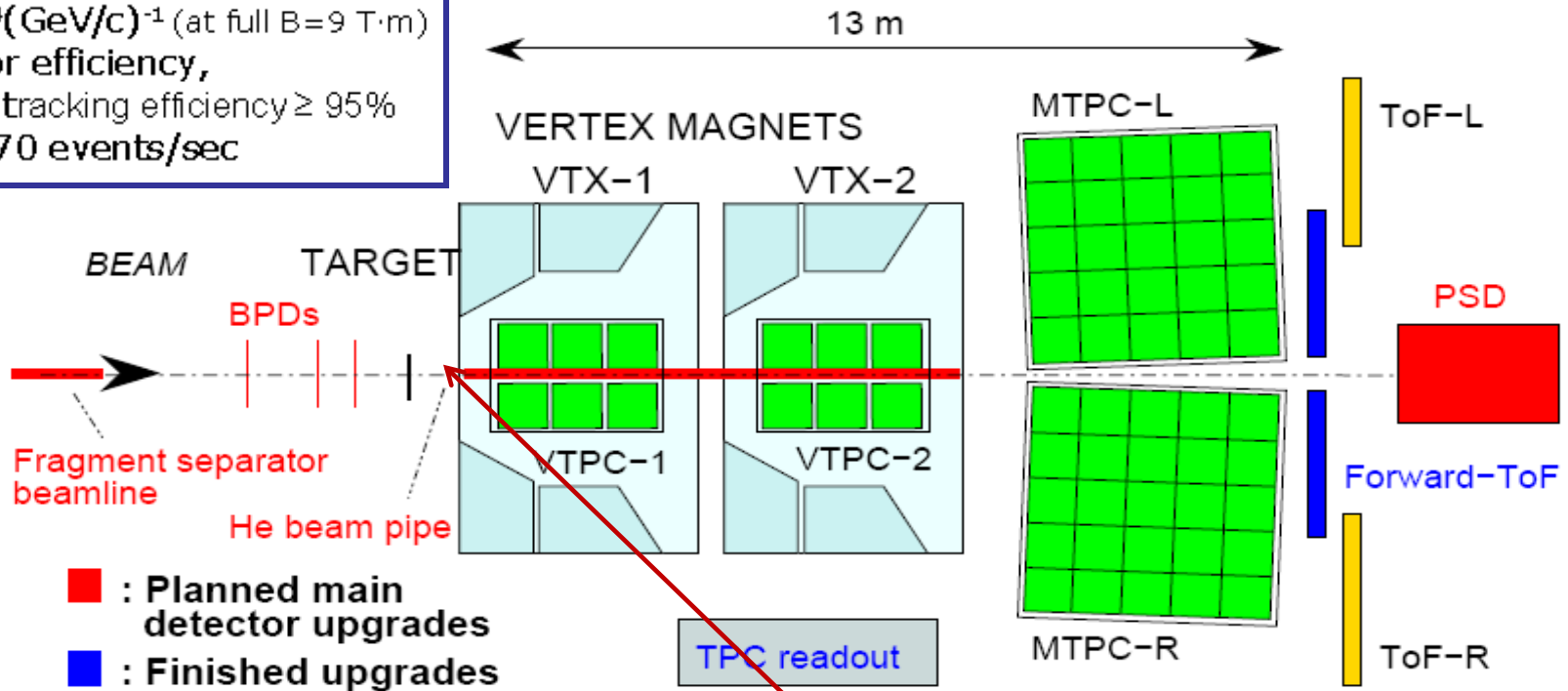
- Perform a 2D (energy-system size) scan with several beam species (p Be, Ar, Xe, Pb) within the energy range from 13 to 158A GeV
- Study as many as possible Event-by-Event fluctuation signals ($\langle pT \rangle$, mult., ratios, etc.)



NA61 strategy: study how the NA49 observables (“Horn”) evolve with system size

NA61/SHINE detector

- Acceptance 50%
- High momentum resolution:
 $\sigma(p)/p^2 \approx 10^{-4} (\text{GeV}/c)^{-1}$ (at full $B=9 \text{ T}\cdot\text{m}$)
- High detector efficiency,
 tracking efficiency $\geq 95\%$
- Event rate: 70 events/sec



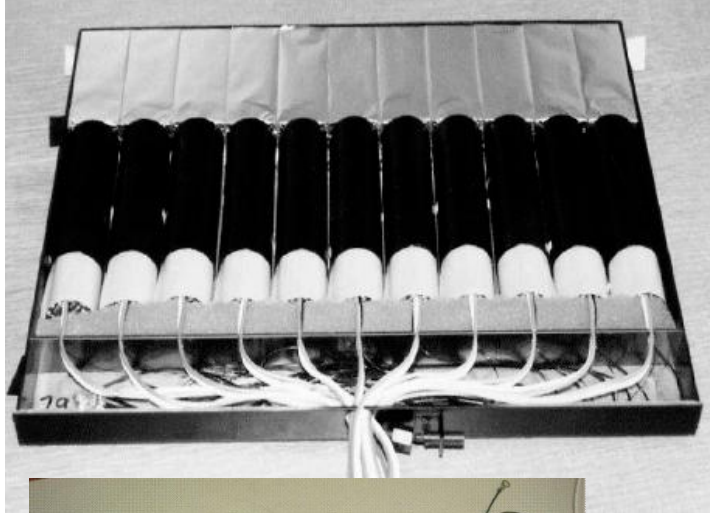
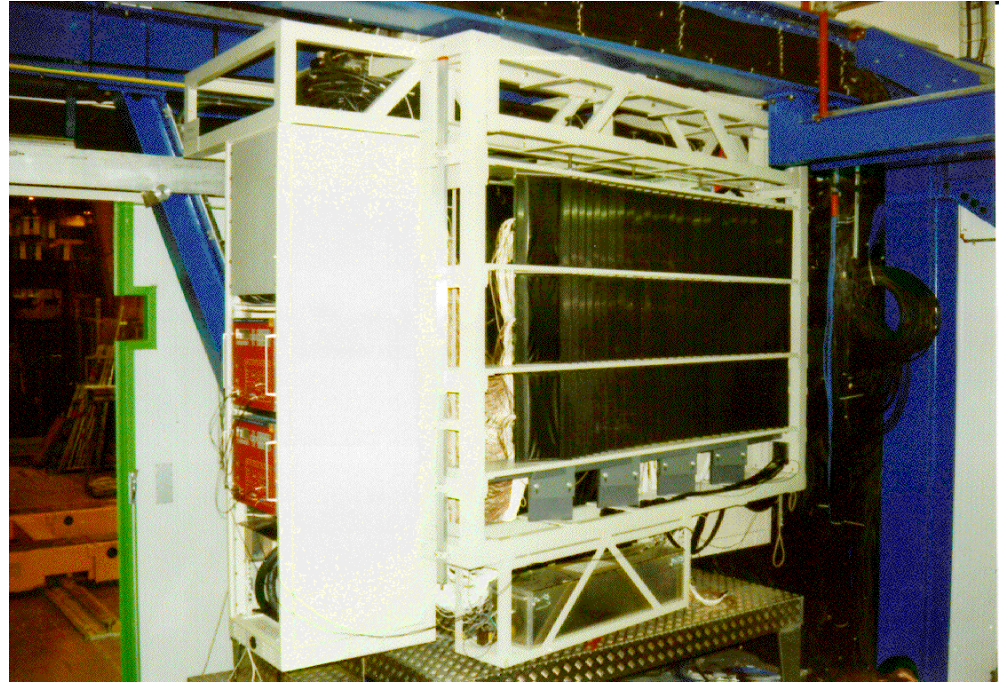
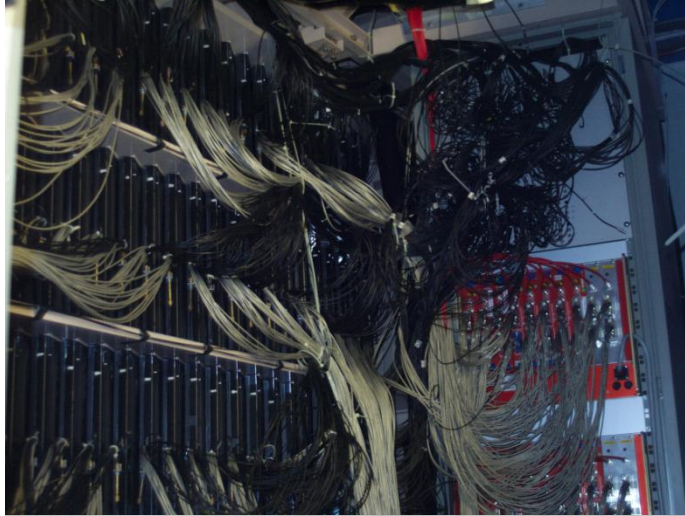
Basic upgrades of the NA61 detector (status):

- TPC read-out to increase event rate (**complete**)
- Forward TOF detector (**complete**)
- He beam pipe and beam line detectors for A+A (**complete**)
- PSD calorimeter (**under completion**)
- TOF-L/R High Voltage (**complete**, read-out (**in progress**))
- Vertex detector (**in progress**)



Small Acceptance Vertex Detector just before installation in 2016

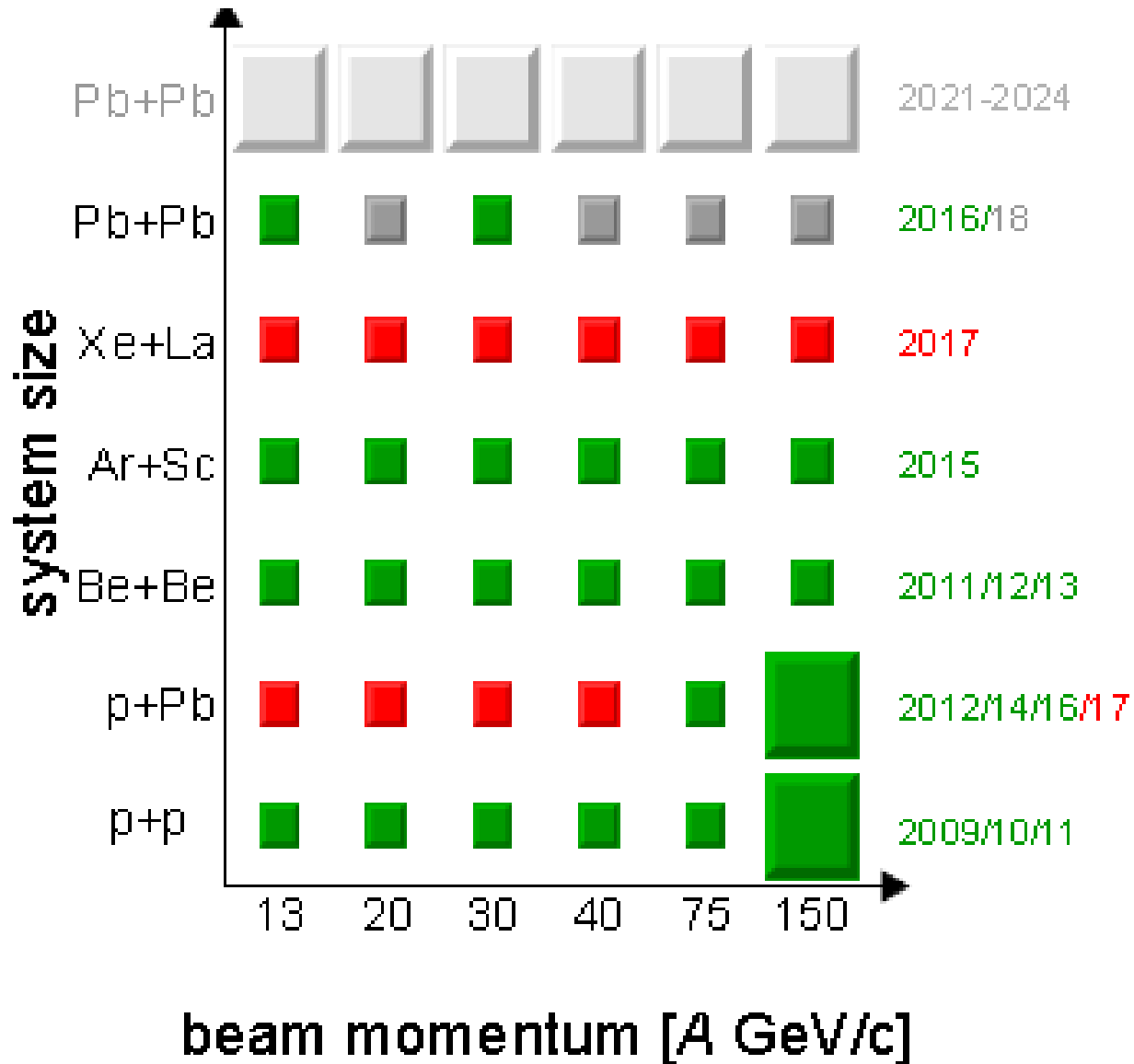
NA61 TOF-L/R detector



- 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

Overall data taking plan

Energy-SystemSize Scan at SPS



The NA61/SHINE data taking plan for 2017-18

SI – measurements for physics of strong interactions,
 ν – measurements for the Fermilab neutrino beams.

- Two-dimensional system size and beam momentum scan will be completed with p+Pb and Xe+La in 2017 and 2018

Beam		Target	Momentum (A GeV/c)	Year	Days	Physics
Primary	Secondary					
P	h ⁺	A	400 40-400	2017	21 days	installation/tests
P	p	Pb	400 30, 40	2017	28 days	SI
P	h ⁺	A	400 30-120	2017	42 days	ν
Xe		La	13, 19, 30, 40, 75, 150	2017	60 days	SI
P	p	Pb	400 13, 20	2018	28 days	SI
P	h ⁺	A	400 30-120	2018	42 days	ν
Pb		Pb	20, 40, 75, 150	2018	60 days	SI

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.

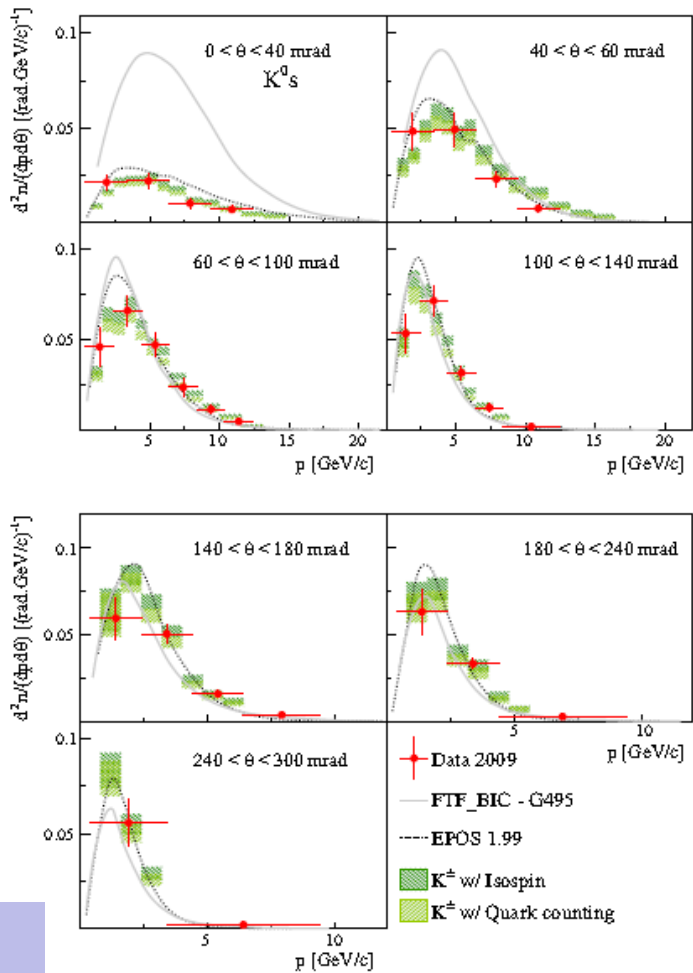
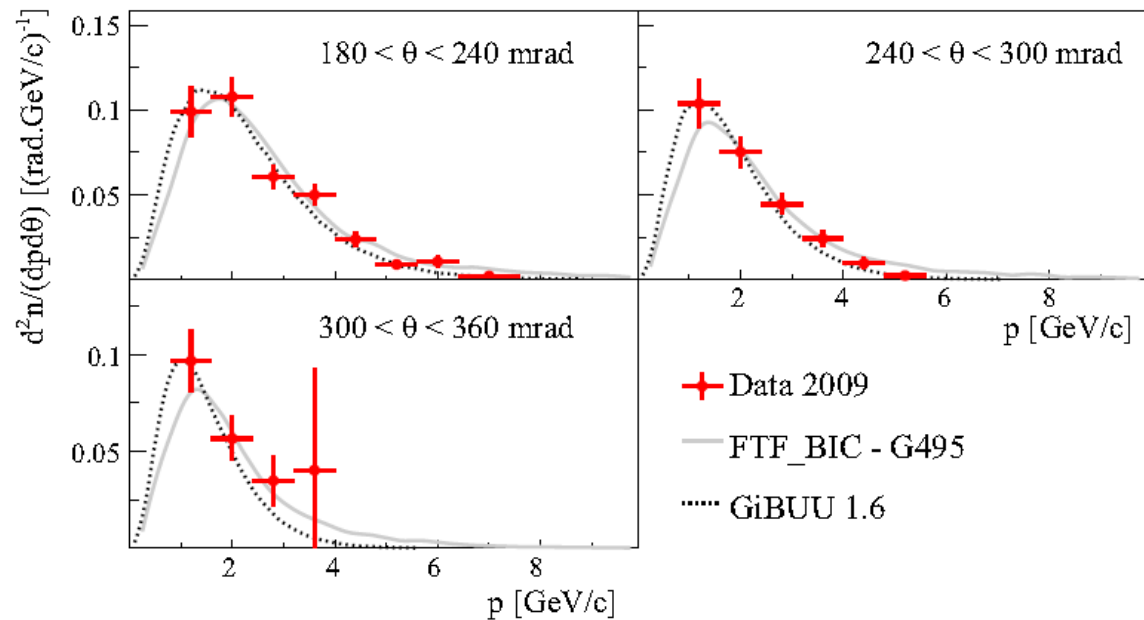
N. Abgrall et al., “Measurements of $\pi^{+/-}$ differential yields from the surface of the T2K replica target for incoming 31 GeV/c protons with the NA61/SHINE spectrometer at the CERN SPS”, Eur. Phys. J C 76, 617 (2016).

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 ^3He 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).

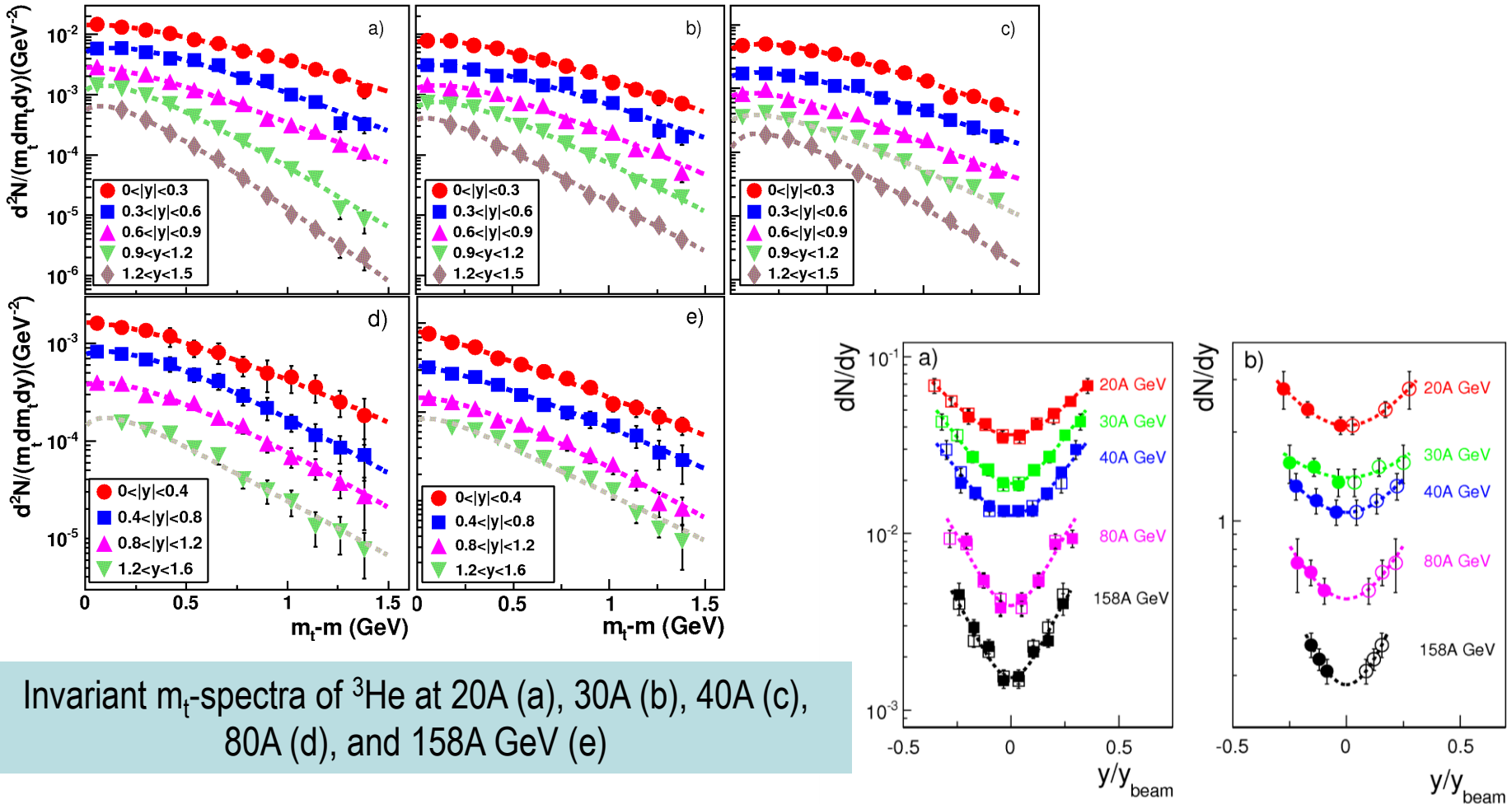
“Measurements of $p^{+/-}$, $K^{+/-}$, K^0_S , Λ and proton production in proton–carbon interactions at 31 GeV/c with the NA61/SHINE spectrometer at the CERN SPS”, Eur. Phys. J. C (2016) 76:8.



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

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



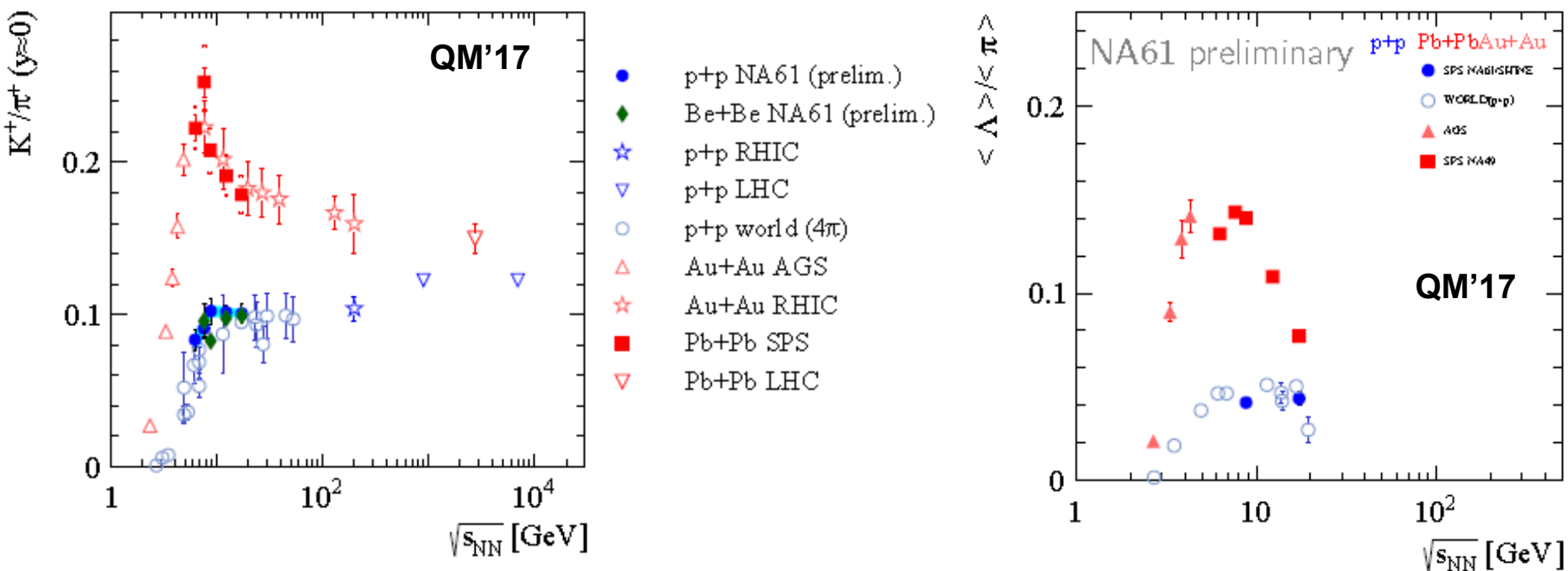
Invariant m_t -spectra of ^3He at 20A (a), 30A (b), 40A (c), 80A (d), and 158A GeV (e)

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

NA61 data. Preliminary results from Energy-SystemSize scan

Study of onset of deconfinement: K^\pm/π^\pm ratio energy dependence

- “Horn” structure in Pb+Pb collisions was predicted (SMES) as a signature of onset of deconfinement



- K^+/π^+ dependence in p+p rapidly reaches a plateau at SPS energies (onset of deconfinement in p+p?)
- Surprisingly the Be+Be points are very close to p+p! (where will be Ar+Sc and Xe+La?)
- $\langle \Lambda \rangle / \langle \pi \rangle$ in p+p reaches a plateau at the SPS energies similarly to $\langle K^+ \rangle / \langle \pi^+ \rangle$

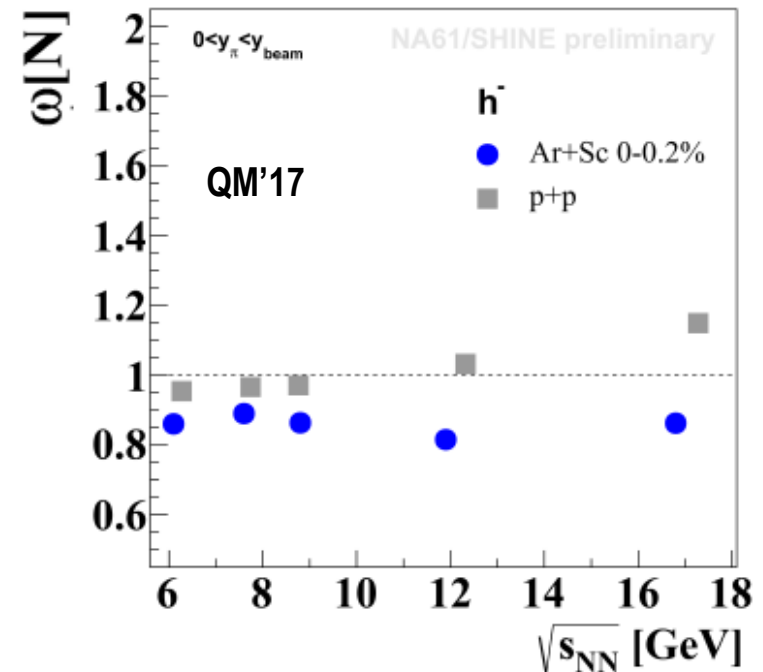
NA61 data. Results on fluctuations

Search for critical point: event-by-event fluctuations

NA61/SHINE searches for the CEP by searching for non-monotonic dependence in fluctuations of hadron production properties

Measure used to quantify fluctuations

▶ Scaled variance $\omega[N] = \text{Var}(N)/\langle N \rangle$



- Selection of 0.2% most central Ar+Sc collisions allows to eliminate volume fluctuations
- $\omega[N]$ decreases with the system size which is not expected in the Wounded Nucleon Model
- No hint of a maximum → no hint for critical point **so far**

JINR contributions/responsibilities

- **Maintenance and operation of TOF-L/R detectors**
- **TOF-L/R data calibration**
- **Software developments and maintenance of software library**
- **Raw data reconstruction and DST production**
- **Data analysis**

Plans for 2018-2020

Hardware & data taking

- TOF-L/R maintenance : Data taking : shifts, TOF on-line monitoring
- R&D for NA61 TOF upgrade

Software development & reconstruction

- TOF simulation tools within the SHINE framework
- DST production

Data analysis

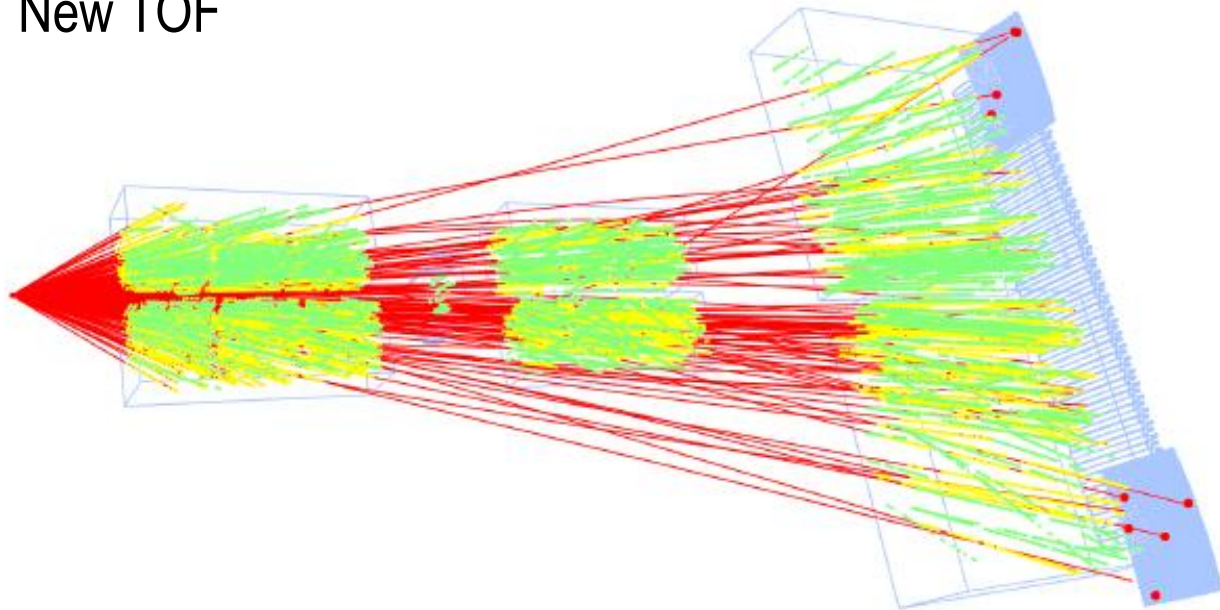
- Production of (anti)nuclei production in Ar+Ca and Xe+La collisions (VBLHEP)
- Hadro-production for the Fermilab neutrino program (LNP)

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:

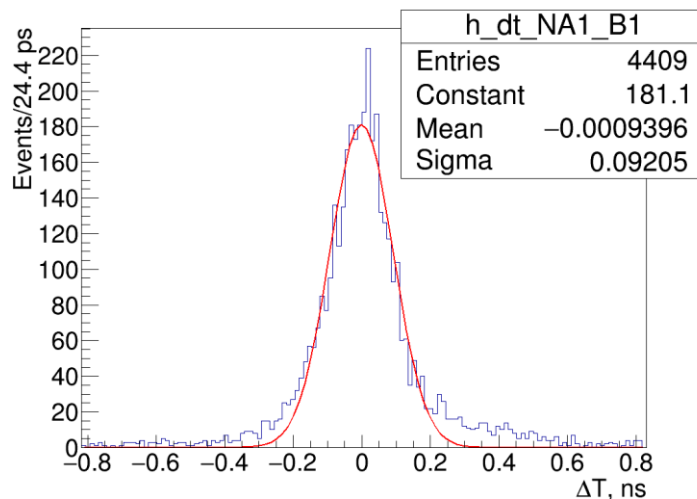
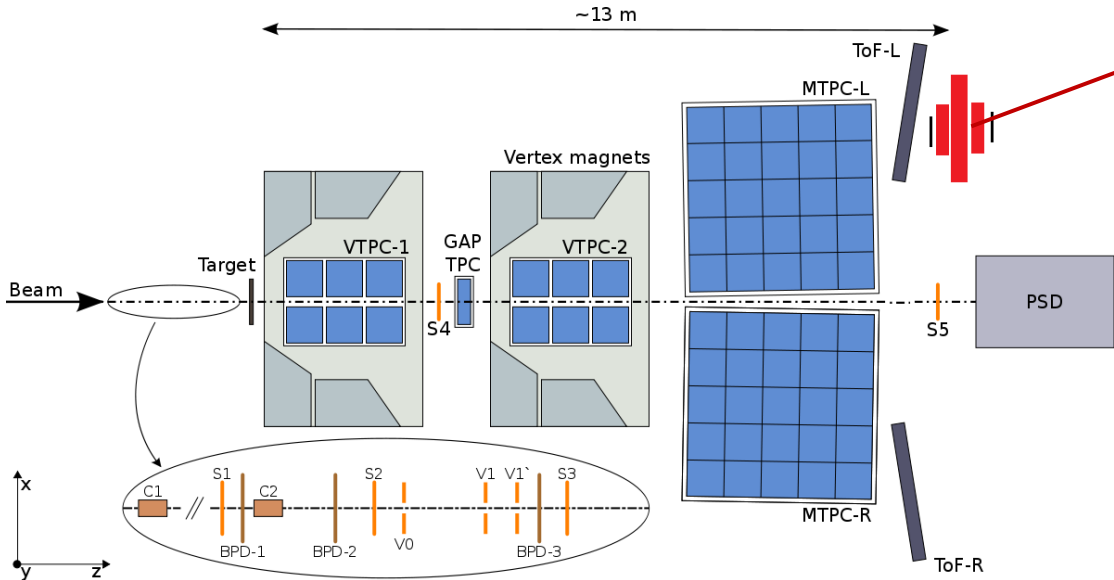
- 1 kHz readout
- Large Acceptance Vertex Detector
- New TOF



(Central Pb+Pb collision at 13.4 GeV/c measured in NA61/SHINE in 2016)

R&D for the new NA61-TOF in 2016

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



$$\sigma_{p1} = 66.7 \text{ ps} - \text{Pad 1}$$

$$\sigma_{p2} = 79.1 \text{ ps} - \text{Pad 2}$$

$$\sigma_s = 63.6 \text{ ps} - \text{Strip}$$

Предлагаемый план-график и необходимые ресурсы для осуществления
проекта NA 61 (участие ОИЯИ)

Наименование узлов и систем установки, ресурсов, источников финансирования		Стоимость узлов (тыс. долл.) установки. Потребности в ресурсах	Предложения лаборатории по распределению финансирования и ресурсов		
			2018 г.	2019 г.	2020 г.
Основные узлы и оборудование	Оборудование, компьютеры	10	4	3	3
	Обслуживание детекторов	5	2	2	1
	Время пролетная система на основе RPC (R@D)	50	20	20	10
Необходимые ресурсы	Нормо- часы	ОП ОИЯИ	-	-	-
		КБ ЛФВЭ	-	-	-
		ЦОЭП ЛФВЭ	-	-	-
		Нуклотрон	-	-	-
МНТС		210	75	60	75
Коллаборационный взнос		36	12	12	12
Источники финансирования	Бюджет	311	113	97	101

Смета затрат по проекту НА61 (участие ОИЯИ)

№ п/п	Наименование статей затрат	Полная стоимость (k\$ США)	2018 г.	2019 г.	2020 г.
	Прямые расходы на проект:				
1.	Ускоритель (Нуклотрон), час.	-	-	-	-
3.	Компьютерная связь	10	4	3	3
4.	КБ ЛФВЭ, час.	-	-	-	-
5.	ООЭП, нормочас.	-	-	-	-
6.	Материалы	35	14	14	7
7.	Оборудование	20	8	8	4
8.	Оплата НИР, выполняемых по договорам	-	-	-	-
9.	Командировочные расходы, в т.ч.	210	75	60	75
	а) в страны нерублевой зоны	174	63	48	63
	б) в городах стран рублевой зоны	-	-	-	-
	в) по протоколам	36	12	12	12
	Итого по прямым расходам:	311	113	97	101

Заключение

- Эксперимент NA61/SHINE успешно реализует намеченную Физ. Программу:
 - данные по $p+p$, $Be+Be$, $Ar+Sc$, $Pb+Pb$ столкновениям анализируются и публикуются
 - Завершен upgrade детектора, подготовка к сеансам с пучками Xe (2017) и Pb (2018) проходит успешно. Начаты R&D для NA61 upgrade for the beyond 2020 program
- Участие ОИЯИ в эксперименте NA61 имеет важное значение с учетом собственной программы Лаборатории по физике А+А столкновений (проект НИКА) – новые данные, новые технологии, опыт работы
- Вклад ОИЯИ и план работы группы на 2018-20 гг. сбалансирован с учетом имеющихся ресурсов
- Просим поддержать наш проект

Спасибо за внимание!

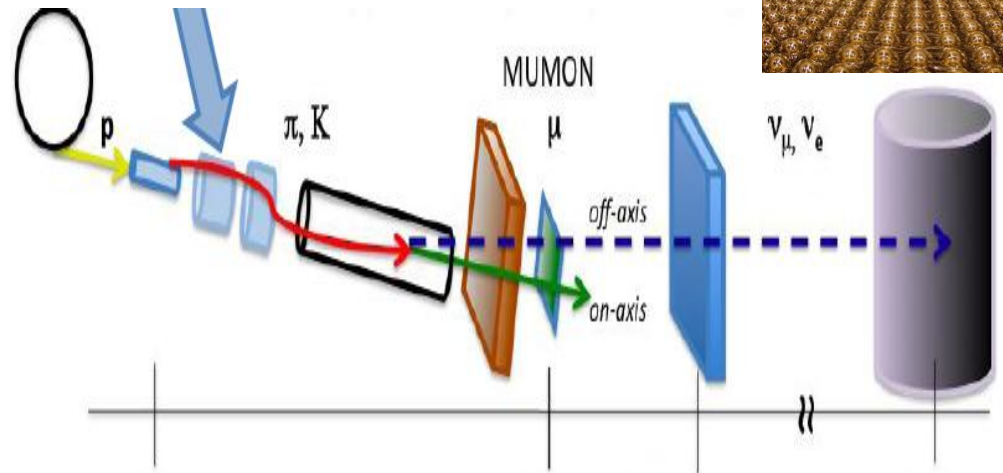
Backup slides

NA61 physics. Data for neutrino and cosmic ray experiments



Precision measurements:

Measure hadron production in the T2K target needed for the T2K (neutrino) physics



Measure hadron production in $\pi+A$ interactions needed for cosmic-ray, Pierre Auger Observatory and KASCADE experiments

