MultiPurpose Detector – MPD

V.A. Babkin on behalf of the MPD/NICA collaboration
The problem of studying hot and dense baryonic matter

MPD/NICA heavy ion program:

- Main properties, EOS – particle yields & spectra, ratios, femtoscopy, flow
- In-Medium modification of hadron properties – onset of low-mass dilepton enhancement
- Deconfinement (chiral) phase transition at high $\rho_B$ – enhanced strangeness production
- QCD Critical Point – event-by-event fluctuations & correlations
- Exotic (hypernuclei, etc.)

To study properties of phase diagram it is important:

- to have possibilities of fine scan on collision energy;
- to have variety of beam nucleus.
Present and future heavy ion collider and fixed target experiments

The region of maximum baryon density

Collision rate [Hz]

Collision energy $\sqrt{S_{NN}}$ [GeV]
Main properties of the NICA collider:

\[ \sqrt{s_{NN}} = 4 - 11 \text{ GeV}; \text{ion beams p ... Au} \at L \sim 10^{27} \text{ cm}^2 \text{ s}^{-1} (\text{Au}^{79+}), \]
\[ \sqrt{s_{NN}} = 6 - 26 \text{ GeV}; \text{polarized beams p} \uparrow \text{ and } d \uparrow \at L \sim 10^{32} \text{ cm}^2 \text{ s}^{-1} \]
Stages of the MPD commissioning

**First stage (2019-2020):** $|\eta|<1.3$
- Particle yields and spectra ($p,K,p,\text{clusters},L,X,W$)
- Event-by-event fluctuations
- Femtoscopic involving $\pi,K,p,\Lambda$
- Collective flow for identified hadron species
- Electromagnetic probes (electrons, gammas)

**Second stage (2023):** $|\eta|<2 + IT$
- Total particle multiplicities
- Asymmetries study (better reaction plane determination)
- Di-Lepton precise study (ECal expansion)
- Exotics (soft photons, hypernuclei)
1. **Particles identification system:**
   - Time Projection Chamber (TPC) is measure momentum and $dE/dx$ of charged particles;
   - Time of Flight (TOF) system for charged particles identification by time-of-flight;
   - Electromagnetic Calorimeter (ECal) to identify electrons and photons and measure their energy.

2. **Tracking system:**
   - Inner Tracker (IT) system provides precise tracking and vertex determination;
   - Time Projection Chamber (TPC) is the main device for tracking;
   - Endcap Straw Tracker (ECT) is provide tracking for particles travelling in forward direction;
   - TOF & ECal can used for additional tracking information.

3. **Trigger system used for trigger definition, T0 and centrality determination:**
   - Fast Forward Detectors (FD);
   - Forward Hadron Calorimeter (FHCal).
Superconducting solenoid of the MPD

\[ B_0 = 0.5 \, \text{T}; \text{ weight } \approx 900 \, \text{t}; L = 8970 \, \text{mm}, \varnothing 6625 \, \text{mm} \]

High level magnetic field homogeneity in the TPC region \( \approx 3 \times 10^{-4} \)

**ASG superconductors**
(Genova, Italy):
- *Cold Mass + Cryostat*
- *Vacuum System*
- *Trim Coils*
- *Control System*
- *General responsibility*

**VHM** (Vitkovice, Czech Republic):
- *Yoke production*

**SPETSMASH** (Kazan, Russia):
- *Forging (support rings, poles, plates)*
Superconducting solenoid of the MPD

Forging production

Support ring

Plates
Time Projection Chamber (TPC)

$R = 1400 \text{ mm}, \quad L = 3400 \text{ m}, \quad N_{\text{pads}} = 95232$

$\sigma_x, \sigma_y, \sigma_z \sim 0.6 \text{ mm}, \quad 1 \text{ mm}, \quad 2 \text{ mm}$

$\delta p/p < 2\%, \quad \text{dE/dX} \sim 8\%$

Detailed description of the TPC in the next presentation of S. Vereschagin «Time-projection chamber development...»
Time-of-Flight system (TOF)

\[ D = 3200 \text{ mm}, \quad L = 5900 \text{ mm}, \quad \text{FEE} = 13,440\text{ ch}, \quad \sigma_t < 80 \text{ ps} \]

Combined \(\frac{dE}{dx}\) and TOF particles identification for \(0.5 < p < 1 \text{ GeV/c}\)

Triple-stack multi-gap resistive plate chamber (MRPC)

Time resolution and efficiency of the MRPC
Time-of-Flight system (TOF)

Workshop staff: 3 physicists, 5 technicians, 2 electronics engineers
Productivity: ~1 detectors per day.
Fast Forward Detector (FFD)

Distribution of the FFD modules around the beam line

FFD module size: $64 \times 64$ mm$^2$

FFD array with 20 modules and 80-channel granularity

Time resolution of different FFD modules
Forward Hadron Calorimeter (FHCal)

Structure of module:
- 60 lead/scintillator sandwiches (sampling ratio 4:1)
- 10 longitudinal sections
- 6 WLS-fiber/MAPD per section
- 10 MAPDs/module

15x15x110 cm³

45 modules (~1 m²)

\[ \sqrt{s} = \begin{align*} 
& 11 \text{ AGeV} & 2 \text{ detectors} \\
& 9 \text{ AGeV} & 2 \text{ detectors} \\
& 7 \text{ AGeV} & 2 \text{ detectors} \\
& 5 \text{ AGeV} & 2 \text{ detectors} 
\end{align*} \]
Barrel ECAL ~ 43000 ECAL modules

“Shashlyk” type calorimeter: Pb(0.3 mm)+Scint(1.5 mm) (4x4 cm²)
Readout: WLS fibers + MAPD

Prototype of one module
CERN & JINR have signed MoU for manufacturing the STS carbon fiber space frames for NICA (BM@N & MPD) and FAIR.

Inner Tracker System (IT)

Detailed description of the ITS in the presentation of D. Dementev «Silicon Tracking Systems...»
**Event generators**

- **UrQMD 2.3**
- **LA QGSM**
- **SHIELD**
- **HSD**
- **UrQMD 3.4**
- **3FD + particlization**

- inherits basic properties from FairRoot (developed at GSI), C++ classes;
- extended set of event generators for heavy ion collisions;
- detector composition and geometry; particle propagation by GEANT3/4;
- advanced detector response functions, realistic tracking and PID included.
Physical performance of the MPD

Production of multi-strange hyperons to study the properties of the strongly interacting system and signal for QGP

Momentum anisotropy (elliptic flow) originates from initial spatial anisotropy. $v_2$ depends on matter properties and EOS.

Dileptons - good probes to indicate medium modifications of spectral functions due to chiral symmetry restoration in A+A collisions; effect is proportional to baryon density

Hypernuclei @ MPD

25.06.2017
V.A. Babkin, MultiPurpose Detector - MPD, BNO-50, Nalchik
Conclusions
Conclusions

March 25, 2016. Laying the first symbolic stone in the construction of the accelerator complex NICA.
Conclusions

http://nucloweb.jinr.ru/nucloserv/205corp.htm
Conclusions

http://nucloweb.jinr.ru/nucloserv/205corp.htm
**Conclusions**

- Significant progress achieved in MPD project realization
- MPD TDR preparation is going further
- Successful preparation for mass-production of MPD elements (TPC, TOF, FFD, FHCAL)
- Integration plan for MPD is ongoing, the plan is to be ready for work at 2020
Thank you for the attention!
Extra slides
The problem of studying hot and dense baryonic matter

Asymptotic freedom of quarks. The strength of the coupling $\alpha_s$ decreases with increasing energy.

The transition from a hadron gas to a quark gluon plasma. The arrow indicates growing temperature and/or chemical potential for baryon density.
The problem of studying hot and dense baryonic matter
STAR/PHENIX @ BNL/RHIC
Создан для области высоких энергий ($\sqrt{s_{NN}} = 20-200$ ГэВ), Светимость $L < 10^{26}$ cm$^{-2}$s$^{-1}$ для Au$^{79+}$ при низких $\sqrt{s_{NN}}$

NA61 @ CERN/SPS
Фиксированная мишень, малый акцептанс, Диапазон энергий (10,20,30,40,80,160 AГэВ)

CBM @ FAIR/SIS-100/300
Фиксированная мишень, $\sqrt{s_{NN}} = 2-5(9)$ GeV, большая светимость

MPD @ NICA
Коллайдер: $\sqrt{s_{NN}} = 4-11$ ГэВ (~100 МэВ шаг сканирования), ионы от p до Au. $L \sim 10^{27}$ cm$^{-2}$s$^{-1}$ для Au$^{79+}$
Quantum chromodynamics (QCD) is the basic theory of strong interactions. In particular, the basic properties of QCD, such as confinement and breaking chiral symmetry, which are related to the origin of hadronic masses, can be investigated in heavy-ion collisions. A quantitative understanding of these two phenomena is still lacking, and, consequently, presents a challenge for future research. The experimental approach consists in seeking changes in the properties of hadrons under the conditions of a dense and hot nuclear medium and deconfinement of matter consisted of quarks and gluons. In other words, formation of the so-called "quark-gluon plasma". This is the main problem of studying hot and dense hadronic matter.
The problem of studying hot and dense baryonic matter

Немонотонная энергетическая зависимость отношения $K^+ / \pi^+$ ("Horn") – деконфайнмент?

Плато в средних температурах каонных спектров ("Step") – сигнал смешанной фазы?
Conclusions

International collaboration of the NICA

Armenia
Australia
Azerbaijan
Belarus
Bulgaria
Brazil
CERN
China
Cuba
Czech Rep.
DPRK
France
Georgia
Germany
Greece
India

Italy
Japan
Kazakhstan
Moldova
Mongolia
Poland
Romania
RSA
Russia
Serbia
Slovakia
Ukraine
USA
Uzbekistan
Vietnam