Status of the Nuclotron

A.Sidorin
on behalf of Accelerator Division
VBLHEP JINR
LU-20

Internal target

Cryogenic facility

Experimental building #205

BM@N

RuPAC XXV, November 2016
Contents

• Statistics of the operation in 2015 - 2016
• Machine development
• Ion source and new fore-injector
• Nearest plans
• Preparation for Booster assembly and Baryonic Matter at Nuclotron (BM@N) experiment
Statistics of operation

Run #51   26.01-15.03.2015 (1150 h, 70% beam time)

Test of BM@N systems with deuteron and carbon beams

Machine development:

- Development of the beam diagnostics, development of hardware and software for Q-meter
- **Test operation of the system for precise measurements of the power supply currents**
- The works for improvement of the current stability of the transport lines has been started
- **Put into operation new Nuclotron thermometry system**
- Development of the TANGO based control system (each run)
- Methodical experiments for beam bunching and re-bunching, stochastic cooling has been prolonged

Cooling ~ 120 h, preparation of all systems ~ 50 – 100 h
Run #52 “technological” 02.06 - 30.06.2016 (650 h)

RFQ fore-injector commissioning (first stage)

Optimization of SPI regimes

Test of polarimeters:
  after LU-20, at Internal target, at extracted beam

Test of the Booster power supply prototypes at SC load

Test of White Rabbit segment at BM@N

Improvement of beam line current stability

Routine operation with injection at magnetic field plateau
  + adiabatic capture
Run #53  26.10-25.12.2016 (plan duration 1400 h)

SPI optimization, polarimetry

Spin physics experiments

Test of BM@N and MPD elements

Test of the Booster power supply prototypes with beam acceleration

Stochastic cooling
System for precise current measurements

Run #51

Current transformer ITZ Ultrastab. The absolute relative mistake $6.5 \times 10^{-5}$. 
Current at the slow extraction plateau is 3741.8 A,
The ripple amplitude is 0.071 A,
Relative stability 1.9*10^{-5}  !!!
Thermometry

Run #51

10 measurement loops:

8 - octants of the Nuclotron

Measurement period + inflector magnet + electrostatic septum

All insertions + nitrogen shield

Additionally the system registries
input and output pressure in the helium tracts,
hehelium level in liquefiers, nitrogen pressure in the tank

608 thermo-resistors, 28 precise test resistors, 10 64-channel comutators, 10 24-bit USB-2416 (Measurement Computing Corporation)
Thermometry

Run #51

TANGO window
Source of polarized ions (p, d, H)  
JINR+INR RAS

- In August 2012, the ABS was transported from the INR of RAS (Moscow) and assembled at JINR
- All-inclusive SPI-tests are carried out in 2014-2015 at JINR
- ~ 2 mA deuteron beam current was achieved in July 2015
- First operation at injection complex – May 2016
Commissioning of New Light Ion RFQ Linac and First Nuclotron Run with New Injector

A.Sidorin, A. Butenko, next talk
12 of June the deuteron beam was accelerated in the Nuclotron

Run #52 – experiments with polarized deuteron beam

Run #53 – experiments with polarized deuteron beam

Energy 750 MeV/u, intensity $10^9$
# Status of the Nuclotron

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<thead>
<tr>
<th>Parameter</th>
<th>Project</th>
<th>Status (November 2016)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Max. magn. field, T</td>
<td>2</td>
<td>2 (1.8 T routine)</td>
</tr>
<tr>
<td>B-field ramp, T/s</td>
<td>1</td>
<td>0.8 (0.3÷0.6 routine)</td>
</tr>
<tr>
<td>Accelerated particles</td>
<td>p–U, d↑</td>
<td>p–Xe, d↑</td>
</tr>
<tr>
<td>Max. energy, GeV/u</td>
<td>12 (p), 5.8 (d) 4.5( 197Au79+)</td>
<td>5.6 (d, 12C), 1.5 (124Xe42+, 40Ar16+)</td>
</tr>
<tr>
<td>Intensity, ions/cycle</td>
<td>1<em>10^{11}(p,d) 1</em>10^{10} (d↑) 2*10^{9} (A &gt; 100)</td>
<td>d 5<em>10^{10} (2</em>10^{10} routine) d↑ 5<em>10^{8} 124Xe^{24+} 1</em>10^{4} 12C 2<em>10^{9} 40Ar^{18+} 2</em>10^{5} 7Li^{3+} 3*10^{9}</td>
</tr>
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</table>
2017:

Preparation for the Booster construction and BM@N experiment

Test of BM@N detector:

Two Nuclotron runs
-February – March 2017 (laser source d, Li, C)
-November – December 2017 (KRION source, Kr, Ar)

2018:

Booster assembly and commissioning
Preparation for BM@N

Nuclotron to BM@N beam line:

26 elements of magnetic optics:
→ 8 dipole magnets
→ 18 quadruple lenses

~160 m
Improvement of the beam line current stability

Run #52

Prototype of the current control unit

Long-range relative current stability of 50 KB source is better than $10^{-3}$. Ripple at 300 Hz 0.5…1% (depending on output current). (Run #52)
New source at the beam line

Run #53

ИП-600-180 LM Invertor (Moscow)
600 A, 180 V, ripple $10^{-4}$
New source at the beam line

Run #53

22 November

ИП-600-180 LM Invertor (Moscow)
600 A, 180 V, ripple $10^{-4}$
White Rabbit project was started to develop next generation control and timing network for CERN. Later FAIR facility joined the project. Currently, the project is a collaboration of many institutes and companies around the world. The project is both, open hardware and opens software. The project aims at creating an Ethernet-based network with:

- low-latency,
- deterministic data delivery and network-wide,
- transparent,
- high-accuracy timing distribution.

The White Rabbit Network (WRN) is based on existing standards, namely Ethernet, Synchronous Ethernet and PTP.

Sub-nanosecond accuracy
Synchronization: test at BM@N

White Rabbit for BM@N – June 2016

~ 1.5 km

UT24VE — Universal Board with White Rabbit support and Power-over-Ethernet
The Booster power supply

Three companies participate in the tender:

- LM Invertor (Moscow)
- EVPUas (Slovak Republic)
- Frako-Term (Poland)

Prototypes were tested during the Run #52 Operation on SC load for Quadrupole supply
The Booster power supply

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Prototypes are under the test during the Run #52 Operation on SC load for Quadrupoles supply

PS600 (600 A)
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- Frako-term (Poland)

Prototypes are under the test during the Run #52:
Operation on SC load for Quadrupoles supply

This Run:
- Test of dynamic behavior during the beam acceleration
## Development of cryogenic system

### Cryogenic System of Nuclotron

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Consumption of liquid N2, kg/h 850

### Cryogenic System of NICA complex

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Consumption of liquid N2, kg/h 2300
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Consumption of liquid N2, kg/h 2300
HELIUM LIQUIFIER OG1000

The principal scheme of the liquefier OG – 1000:

E50, E51, E52, E53, E54, E61 – heat exchangers;

D71, D72, D60 – turbo expanders;

Th – throttle;

NB – bath of liquid nitrogen.

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<tr>
<td>Operating gas</td>
<td>helium</td>
</tr>
<tr>
<td>Capacity, l/h</td>
<td>1100±100</td>
</tr>
<tr>
<td>Liquid nitrogen consumption, kg/h</td>
<td>≤560</td>
</tr>
<tr>
<td>Energy consumption, kW</td>
<td>1760</td>
</tr>
<tr>
<td>Compressed helium pressure, MPa</td>
<td>2.5</td>
</tr>
<tr>
<td>Compressed helium flow rate, Nm³/h</td>
<td>6600</td>
</tr>
<tr>
<td>Total mass, kg</td>
<td>14000</td>
</tr>
<tr>
<td>External dimensions, m×m×m</td>
<td>5×5×10</td>
</tr>
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Commissioning and successful test of the 1000 l/h helium liquefier

The largest helium liquefier in Russia was installed and successfully launched at JINR in June 2016.
H. Khodzhibagiyan,
The Progress on Manufacturing and Testing of the SC Magnets for the NICA Booster Synchrotron
TANGO: Thermometry at test-bench
Temperature data, collected during the experimental session.
TANGO: Satellite refrigerator control
H. Hoeltermann (BEVATECH, Frankfurt, Germany)
Commissioning of the New Heavy Ion Linac at the NICA Project

this session
TANGO: HILAC beam profiles

HILAC injection beam profiles

Login: operator, password: 123

p1

X0 = 1.287
Y0 = -5.21
WX = 16.626
WY = 14.984
Scale: 5 V

Client

Apache

WebServer

RestDS

DiagnostcsDS

Profiles

JSON

PROXY

DAQmxAI

Hardware

Timestamp: 13:47:24
State: ON
Status: Hilac diagnostics server is ready
Connection: connected!
A. Bubley (BINP),
Commissioning of the 60 keV Electron Cooler for the NICA Booster

Poster presentation

May 2016
Injection from HILac to Nuclotron, Measurement period, Energy evacuation

Satellite refrigerator, Electron cooling

RF

HILac
LU20
A. Tuzikov,
Booster Synchrotron at NICA Accelerator Complex

A. Tuzikov,
Beam Transfer From Heavy-Ion Linear Accelerator HILAC Into Booster of NICA Accelerator Complex

Before coffee-break
Toward Booster and BM@N
Thank you for attention