Status of the Nuclotron

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Status of the Nuclotron

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   - Development of power supply system
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3. Nuclotron as a basic test facility for NICA
   - Long plateau of the magnetic field
   - Preparation for stochastic cooling
Estimation of the average vacuum in the Nuclotron ring measuring circulating deutron beam lifetime at $E=5 \text{ MeV/u}$ corresponds to the vacuum pressure not worse than $4 \times 10^{-10} \text{Torr}$.
March 2010:

Xe (1 Gev/n) trace on photoemulsion
(experiment “Becquerel”)
Nuclotron-M Results

Field in lenses (2.05 T)
Main Field (2.00 T)
Field in magnets (1.95 T)

December 2010
Nuclotron-M Results

-Full scale modernization of the cryogenic system was carried out.
As result the cooling power at 4.5 K was increased up to 4 kW, the reliable work at maximum magnetic field and at prolonged magnetic cycle duration was provided. The operation term was sufficiently increased; today the new equipment can be used for the NICA/MPD purposes already.

-The vacuum system was modernized.
It permitted to decrease the residual gas pressure in the Nuclotron beam pipe by two orders of magnitude and to provide a possibility of heavy ion acceleration. The obtained result allows solving general task of the Nuclotron as a part of the heavy ion collider injection chain – to provide acceleration of heavy nuclei from 0.6 GeV/u (injection energy from the booster) up to 4.5 GeV/u without losses.
- Modernization of control system, diagnostic and radio frequency accelerating systems was performed. As result new cycle control equipment, digital generator providing relation between accelerating voltage frequency and magnetic field value, new power supply system for corrector magnets, digital orbit measurement system and others were put into exploitation.

- New power supply and quench protection system based on consequent connection of the Nuclotron structural magnets, all supply units and energy evacuation switches was created. Practical realization of this scheme required modernization of existing supply units, development and construction of two new units for current variation in focusing and defocusing lenses, disassembly of old cable lines and assembly of a few kilometers of new ones.

After completion of the Nuclotron upgrade 3 runs (#43 - #45) were performed: Total duration 2900 hours, 1400 hours – experimental program.
Machine development run #43

For the first time at Nuclotron had been performed beam slow extraction

4.5 ÷ 5 \cdot 10^{10} \text{ (d) at } 300 \text{ MeV/u}

3.1 \text{ GeV/u}
Run # 43

Slow extraction at 3.1 GeV/u

Run #44

7.12.2011  $^{+6}$C  3.42 GeV/u,
slow extraction and transport to BM@N area

18.12.2011  d  4 GeV/u (1.47 Тл)

Run #45

Routine operation  d  4 GeV/u (Energy&Transmutation)

At the end of the run – slow extraction  d  4.5 GeV/u
Development of power supply system

Run #44 – passive filter + thyristor rectifier 37TB

Run #45 «fast» disbalance unit:
Development of power supply system

Run 45: SC magnets PS has been optimized to operate at $dB/dt = 0.8 \text{T/s}$ (sufficient for NICA!)
RF system:
- Max phase misalignment decreased up to < 2° (passive devices),
  max phase misalignment < ±10° ;
- New phase detector commissioned ;
- Remote control has been put in operation.

Digital RF control generator:
- tuning/control of the RF on flattop has been commissioned
  (essential for slow extraction and measurement of the dispersion and
  critical energy).

Power supply:
- Stabilization of the working point has been achieved.

The result: no losses during acceleration!
Capture optimization
- Orbit correction at injection,
- Cycle of the correcting magnets,
- Working point optimization,
- Adiabatic RF capture.

Run #45 (Q ≈ 7.2), $x_{pp} \approx z_{pp} \approx 18$mm.
Orbit bump in the slow extraction region in the design working point (Q ≈ 6.8), Run #45
Run #45, Cycle of the correctors ($I = \frac{I_{\text{inj.}}}{B_{\text{inj.}}} \times B$)
Beam dynamics optimization

Working point optimization

- Design Position Q ~ 6.8
- low dispersion.

Q ~ 7.3
Thermometry:
Experimental fragment of new system was tested during runs #44, #45
Diagnostics development

Fast current transformer (BERGOZ FCT)

FEMTO DHPVA-200 Amplifier

Maximum sensitivity
FCT + DHPVA-200 → 5 V/mA

Run #44- 45
Diagnostics development

New quench detectors

A.Sidorin, WEPPD024
Diagnostics development

Ionization profilometer

Control of the horizontal beam position

Beam intensity, 2e10/division

B-field, T

Beam shrinks at acceleration

Beam at slow extraction

Beam position according to profilometer signal
Assembled cryostat and vacuum vessels

E. Donets, oral presentation

New laser source:
Nd-YAG laser
Pulse energy 2.75 kJ,
Pulse duration 10-12 ns

We plan to assemble and TEST SPP at Nuclotron with d in the end of 2012
Fore-injector upgrade

Cascade transformer up to 0.7 MeV

Liu-20

RF amplifiers

Stripper

5 MeV MeV
2.4 - 0.3
2.8 MeV MeV
0.456 MeV MeV
0.024 MeV MeV

laser

p.d.

ESIS

d↑

foreinjector

Rodonit

10 m
- Insulating amplifier for shunt,
- Cycle control system,
- data registration
(on the basis of equipment and software of parametric current transformer BERGOZ).

- shunt up to 6 kA
Run #44
Cycle duration 500 s
8 kG

Run #45
1000 s
1.2 T
d 5 \cdot 10^9
One plans to test consequently for cooling of coasting and bunched beams:

- Longitudinal degree of freedom
  
  Notch filter, Palmer, Time of flight methods.

- Transverse cooling
  
  Bandwidth 2-4 GHz,
  Power up to 60 W,
  Expected cooling time (coasting beam) 10 s
Stochastic cooling test at Nuclotron

Slot-coupler structures, manufactured at IKP FZJ

Vacuum chamber for pick-up

Vacuum chamber for kicker
Thank you for your attention