The Accelerator Facility of the Facility for Antiproton and Ion Research

P. Spiller on behalf of O. Kester
and FAIR@GSI
IPAC15, 5.5.15
FAIR Construction Side
FAIR Injector Facility
UNILAC, p-Linac and SIS18

UNILAC  world’s highest beam power (MW) and beam currents (7 emA) for heavy-ions
SIS18   world’s highest number of heavy-ions per cycle (> 10^{10})
Heavy Ion Accelerator Chain

SIS18

SIS 100
Heavy Ion Accelerator Chain

SIS18

SIS 100

CBM
Heavy Ion Accelerator Chain

SIS18

Super-FRS

SIS 100

CBM

CBM
Heavy Ion Accelerator Chain

SIS18

Collector Ring

Super-FRS

SIS 100

CBM

CBM
Heavy Ion Accelerator Chain

NuSTAR

Collector Ring

Super-FRS

SIS 100

CBM
Anti Proton Accelerator Chain

p-Linac

SIS18

p-bar target

SIS 100
Anti Proton Accelerator Chain

- p-Linac
- SIS18
- Collector Ring
- p-bar target
- SIS 100
Anti Proton Accelerator Chain

- p-Linac
- SIS18
- Collector Ring
- HESR
- p-bar target
- SIS 100
Anti Proton Accelerator Chain

- p-Linac
- SIS18
- Collector Ring
- HESR
- p-bar target
- SIS 100
- PANDA
Anti Proton Accelerator Chain

- p-Linac
- SIS18
- HESR
- Collector Ring
- APPA
- p-bar target
- SIS 100
- PANDA
## System parameter of the FAIR ring accelerators

<table>
<thead>
<tr>
<th>Parameter</th>
<th>SIS18</th>
<th>SIS100</th>
<th>CR</th>
<th>HESR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Circumference [m]</td>
<td>216</td>
<td>1083</td>
<td>215</td>
<td>575</td>
</tr>
<tr>
<td>Max. beam magnetic rigidity [Tm]</td>
<td>18</td>
<td>100</td>
<td>13</td>
<td>50</td>
</tr>
<tr>
<td>Injection energy of protons or anti protons [GeV]</td>
<td>0.07</td>
<td>4</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>Final energy of protons or antiprotons [GeV]</td>
<td>4</td>
<td>29</td>
<td>3</td>
<td>14</td>
</tr>
<tr>
<td>Injection energy of heavy ions [GeV/u]</td>
<td>0.0114</td>
<td>0.2</td>
<td>0.74</td>
<td>0.74</td>
</tr>
<tr>
<td>Final energy of heavy ions U(28+) [GeV/u]</td>
<td>0.2</td>
<td>2.7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Final energy of heavy ions U(/73+/92+) [GeV/u]</td>
<td>1</td>
<td>11</td>
<td>0.74 (92+)</td>
<td>0.2-4.9 (92+)</td>
</tr>
<tr>
<td>Max. beam intensity for protons or antiprotons /cycle</td>
<td>$5 \times 10^{12}$</td>
<td>$2 \times 10^{13}$</td>
<td>$10^8$</td>
<td>$10^{10}$</td>
</tr>
<tr>
<td>Max. beam intensity of U-ions /cycle</td>
<td>$1.5 \times 10^{11}$</td>
<td>$4.5 \times 10^{11}$</td>
<td>$10^8$</td>
<td>$10^8$</td>
</tr>
<tr>
<td>Required static vacuum pressure [mbar]</td>
<td>$&lt; 10^{-11}$</td>
<td>$&lt;5 \times 10^{-12}$</td>
<td>$&lt;10^{-9}$</td>
<td>$&lt;10^{-9}$</td>
</tr>
</tbody>
</table>
GSI Accelerator Upgrade

**UNILAC upgrade**

High power (high intensity), short pulses, system reliability

- Increase of beam brilliance (Beam current / emittance), EMTEX
- Increase of transported beam currents
- Improvements of high current beam diagnostics / operation
UNILAC upgrade
High power (high intensity), short pulses, system reliability
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SIS18 upgrade
Fast ramping, enhanced intensity per pulse, improved vacuum system
→ Increase of injection acceptance
→ Improvement of static lifetime for low-charged U-ions
→ Suppression of dynamic vacuum and ionization beam loss
GSI Accelerator Upgrade

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**Exchange of the 40 years old Alvarez accelerator with modern Rf- structures**
Higher intensities (medium mass range)

- 28 GHz ECRIS
The UNILAC upgrade

- New source extraction system
- Pulsed high pressure H₂ stripper
- EMTEX: Emittance matching to SIS
- New terminal with compact LEBT under preparation
- RFQ re-design
- New Alvarez DTL

MUCIS, MEVVA
LEBT
HSI (RFQ, IH1, IH2)

HLI (ECR, RFQ, IH)
108 MHz

36 MHz
Gas Stripper 108 MHz
Poststripper (Alvarez, Cav.)

Foil Stripper
TKE

EMTEX: Emittance matching to SIS
The SIS18 upgrade program: Booster operation with low charge state heavy ions

- **Injection system for low charged state heavy ions**
- **Charge separator for higher intensity and high quality beams**
- **Power grid connection**
- **Stabilization of dynamic vacuum and minimization of ionization beam loss**
- **Scrapers and NEG coating for pressure stabilization**
- **h=2 acceleration cavities for faster ramping**
### SIS18 Intensity Requirements for FAIR (SIS100 Booster)

<table>
<thead>
<tr>
<th>FAIR module (green paper)</th>
<th>Today</th>
<th>Module 0+1 (SIS100 + CBM, APPA)</th>
<th>Module 2 (Super-FRS, RIBs for NUSTAR)</th>
<th>Module 3 (pbar, CR, HESR, PANDA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reference ion</td>
<td>$\text{U}^{73+}$</td>
<td>$\text{U}^{73+}$</td>
<td>$\text{U}^{28+}$</td>
<td>$\text{U}^{28+}$</td>
</tr>
<tr>
<td>Maximum energy</td>
<td>1 GeV/u</td>
<td>1 GeV/u</td>
<td>0.2 GeV/u</td>
<td>0.2 GeV/u</td>
</tr>
<tr>
<td>Max. intensity / cycle</td>
<td>$4 \times 10^9$</td>
<td>$2 \times 10^{10}$</td>
<td>$1.25 \times 10^{11}$ (*)</td>
<td>$1.25 \times 10^{11}$</td>
</tr>
<tr>
<td>Repetition rate</td>
<td>0.3 – 1 Hz</td>
<td>1 Hz</td>
<td>1 Hz</td>
<td>2.7 – 4 Hz</td>
</tr>
</tbody>
</table>

(*) leads to $5 \times 10^{11}$ at SIS100 injection
World record intensity per cycle for low charge state heavy ions has been achieved in SIS18.

2001 FAIR conceptual design report (FAIR proposal)
The Proton-LINAC

- **Status:**
  - Ion source and LEBT ready in Summer 2015
  - First prototype cross bar (CH) cavity ready for power tests

- **Critical items:**
  - RFQ Design and procurement
  - CH cavities procurement & production follow-up
  - Design of the 325 MHz Modulators

- **H+: 70 mA at 70 MeV**

- **70 MeV, 35 mA**
Synchrotron SIS100

- **Status:**
  - 50% of the SIS100 budget bound in contracts
  - All major components ordered
  - System engineering of SC-magnets nearly completed
  - Accurate mechanical (µm) and magnetic field measurements done
  - Production of First of Series (FoS) Dipole was not according to the specs
  - New production for the yoke is on the way
  - All major RF-systems are ordered (bunch compressor, ferrite cavities)

- **Critical items:**
  - Quadrupole units for the SIS100 Quadrupole Doublet modules production and testing in Dubna until Q1/2020
  - Integration into modules tendered by GSI
  - Cold test of modules
S.C. Quadrupole Modules

Quadrupole units comprise quadrupoles, sextupoles, steerer and BPMs

Arc modules contain cryo-catcher

Quadrupole units installed on a common girder

Inkind- and R&D contracts signed with JINR
Series Dipole Test Facility at GSI

- Civil construction including media supply is ready
- Cryo components are installed
- STF ready for testing in spring 2015
- SAT ongoing: Cold Box and distribution system cold. LHe buffer is filled.

1.5 kW@4 K cold box

450 kW compressor
SIS100 Quadrupole Testing at JINR

Infrastructure at JINR in preparation

- R&D contract on magnet test facility signed.
- 1600 m² main hall
- 700 m² auxiliary facilities
Central Transfer Building H0705A

- branching and crossing point for 8 beam lines (full version)
- several beam lines inclined
- components of many other beam lines are transported through this building
High Energy Beam Transport - HEBT

- **Status:**
  - Three batches → Batch 1: EFREMOV Institute (magnets) and Budker Institute (vacuum chambers)
  - Batch 1 – production of first pre-series dipole magnet running (coil produced, laminations punched), will be finished in May 2015
  - Batch 2 specifications released, Batch 3 specifications available shortly, contract negotiations
  - First In-kind contract with India (Bose Institute, producer ECIL) for quadrupole power converter (78 pieces) of 18/13 Tm beam lines signed
  - Contract of Slovenian in-kind (HEBT Beam Instrumentation – DAQ, pneumatic drives and controls) signed
  - Provider of 65 diagnostics vacuum chambers is currently selected by Bose Institut (India)

- **Critical items:**
  - Magnet production and vacuum chamber (magnets and diagnostics)
  - QA of production in India
Super-Fragment Separator

Remote Handling

Target

SC Multiplets

Local Cryogenics

SC Dipoles

Radiation Resistant Magnets

Driver Accelerator

IPAC 2015, P. Spiller
Super-Fragment Separator

- **Status:**
  - Multiplets $\rightarrow$ negotiation with companies
    Order in Q1/2015
  - Target chamber & plug inserts
    German in-kind in collab. with KVI-CART
  - Target wheel & plug inserts
    $\rightarrow$ German in-kind in collaboration
    with KVI-CART

- **Critical items:**
  Dipole magnet design and procurement.
  $\rightarrow$ Collaboration agreement with CEA/Saclay
  on detailed design & Technical follow-up

  Tender by FAIR starting Q2/2015
  First of Series ready for testing: Q4/2016
  Series production & testing:
  Q1/2017 – Q4/2019

- **Dimensions:**
  - 25 long multiplets
  - 8 short multiplets

- **CEA revised SC dipole design**
Magnet Testing Super-FRS at CERN

- Layout of planned test facility at CERN (building 180) ready
- Cryogenic-infrastructure with 2 pre-cooler
- CERN Controls and data acquisition
- 3 test benches in Q3/2016
cooling and test time ~45 days/unit
The pbar Target and Separator

- **Status:**
  - Detailed concept for handling of activated components finished. Positive response from authorities.
  - Draft specification for magnetic horn system available. Tendering of detailed system design study.
  - Draft specifications for most magnets available (BINP)

- **Critical items:**
  - Magnetic horn pulser (400 kA), switches (semi-conductors).
  - Magnets, however most magnets are CR-type. The first magnets of the series can be used for pbar.
The FAIR Storage Rings

- **HESR**
  - Circumference: 221 m
  - Magn. rigidity: 13 Tm
  - Acceptance: $\varepsilon_{x,y} = 240$ (200) mm mrad
  - $\Delta p/p = \pm 2.7$ (1.5) %

- **SIS100**
- **CR**
- **BINP**

- **ECOOL**
  - 2 MeV
  - $L_c = 2.7$ m

- **JÜLICH**
  - Forschungszentrum

- **APPA**
  - Stochastic Cooling system
  - 800 MeV/u - 14 GeV/u
  - Internal gas jet target
  - Possible position: $\beta_z = 16$ m, $\beta_y = 9$ m, $Q_z = 0.5$ m

- **PANDA**
Large Aperture Storage Ring CR

- **Status:**
  - Technical supervision of CR → Budker Institute
  - CR-Rf system (debuncher cavities) under construction
  - Pick up tank prototype of stochastic cooling system available

- **Critical items:**
  - Dipole magnets, specs ready, but In-kind contract not yet ready
  - No system design freeze yet
The High Energy Storage Ring HESR

- **Status:**
  - Steel for vacuum chambers ordered. First magnets have been accepted, series production launched.
  - Kickers ordered, tanks under construction
  - Stochastic cooling tank in production, amplifiers in tendering process

- **Critical items:**
  - Momentum spread of beam pulse from CR
  - HESR components will be available for installation in 2017 → storage of components

Length 575 m
Arc 132 m
Straight 155.5 m
Status Cryogenic Supply and Distribution

Status:
- Two industry studies successfully performed by Linde and Air Liquide
  - confirmation on space and budget requirements
  - confirmation on time scheduling
  - no technical risks on the cryo plants observed
- Start configuration for the cryogenic supply for SIS100 and Super-FRS
- Specifications for a 25 kW common plant and a cool down unit are in preparation (to 90% completed)
- Technical study on the distribution system of SIS100 successfully performed
  - reliable statements on prize and delivery time

Critical items:
- Civil construction building milestones (commissioning, warranty)
- Reliability on heat loads
- Requirements and operation are dominated by dynamic load

picture from Linde KT