LEB of Super-FRS

Martin Winkler
HISPEC/DESPEC/PRESPEC Meeting, March 1, 2010, GSI, Germany

- Status Super-FRS
- Status EB Magnet Development (India)
- Status Civil Construction
  (modularized version and consequences)
- Roadmap
Layout and Design parameters for the Super-FRS

Goal: Larger Acceptance

Projectile:
- Elements p - U
- Energy up to 1.5 GeV/u
- Intensity up to $10^{17}$/s (depending on element)
- DC or pulsed operation

Design Parameters:
- $\varepsilon_x = \varepsilon_y = 40 \pi$ mm mrad
- $\Phi_x = \pm 40$ mrad
- $\Phi_y = \pm 20$ mrad
- $\Delta p/p = \pm 2.5\%$

- $B_p = 2 - 20$ Tm
- $R_{mn} = 750 / 1500$
  (first / second stage)
- Spot size on target
  $\sigma_x = 1.0$ mm
  $\sigma_y = 2.0$ mm

Focusing System

Driver Accelerator

Features:
- 2 Separator-stages in achromatic mode
- Separation by $B_p$-$\Delta E$-$B_p$ method (variable degrader)
- Multi-branch system
- Large acceptance utilizing sc magnets
- Handling concept for high-radiation area

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Technical Challenges

Remote Handling

Target & Beam Catcher

Cryogenics

SC Multiplets

Effective length (quads)
0.8 / 1.2 m

Aperture (warm)
± 190 mm

Pole radius
240 mm

Field gradient
1.0 - 10.0 T/m

SC Dipoles

Main-Separator

Beam Dumps

Production Target System

Radiation Resistant Magnets

Degrader 1

Exit Slit Pre-Separator

Degrader 2

Hi

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Layout of the Low-Energy Branch
(Energy Buncher Mode, status TDR)

<table>
<thead>
<tr>
<th>Energy Buncher</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bend</td>
</tr>
<tr>
<td>Max. magnetic rigidity</td>
</tr>
<tr>
<td>Length</td>
</tr>
<tr>
<td>Acceptance</td>
</tr>
<tr>
<td>- horizontal $\Phi_x$</td>
</tr>
<tr>
<td>- vertical $\Phi_y$</td>
</tr>
<tr>
<td>- momentum $\Delta p/p$</td>
</tr>
<tr>
<td>1st order momentum resolution $\left(\epsilon_x = 300 \pi \text{ mm mrad}\right)$</td>
</tr>
</tbody>
</table>
**Quadrupole:**
(separator type)
$L_{\text{eff}} = 0.8/1.2$ m
$R_{\text{Warm}} = 190$ mm
$g_{\text{max}} = 10$ T/m

**Dipole (unit):**
$\rho = 4.35$ m
$\phi = 22.5^\circ$
$B_{\text{max}} = 1.6$ T
$W = \pm 350$ mm
$G = \pm 100$ mm

**Quadrupole:**
$L_{\text{eff}} = 0.8/1.2$ m
$R_{\text{Warm}} = 300$ mm
$g_{\text{max}} = 4.7/5.2$ T/m

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Alternative 2 Layout for the Energy Buncher
(3 x 30° dipole units)

Dipole (unit):
- $\rho = 4.35$ m
- $\phi = 30.0^\circ$
- $B_{\text{max}} = 1.6$ T
- $W = \pm 350$ mm
- $G = \pm 100$ mm

Quadrupole (only 5!):
- $L_{\text{eff}} = \text{only 1.2 m}$
- $R_{\text{Warm}} = 300$ mm
- $g_{\text{max}} = 5.2$ T/m
Status EB Dipole Magnet Design
(Magnetic Design)

File: c:\fair\dipo3d.spw (06-01-10)

FAIR DIPOLE FIELD QUALITY $\Delta B / B$ (3D CALC.)
(Field along the median plane)

- NO PURCELL FILTER
- RECTANGULAR PURCELL FILTER
- CROSS-SHAPED PURCELL FILTER

<table>
<thead>
<tr>
<th>$B / B$</th>
<th>-0.002</th>
<th>0.000</th>
<th>0.002</th>
<th>0.004</th>
<th>0.006</th>
<th>0.008</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ni = 22,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni = 100,000</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Ni = 180,000</td>
<td></td>
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</tbody>
</table>

Horizontal Distance from Centre (cm)
Status Dipole Magnet Design
(Conductor and Coil)

Coil Stress Analysis

- Stress due to magnetic force only
- Thermal analysis is to be performed to include the thermal stress on the coil and its supports

Coice of Conductor

- Superconducting Strands: NbTi
- Filament diameter: (50-105) μm
- No of the filaments: 55
- Diameter of the core wire: 0.63 mm
- Ratio of Cu and no Cu: 14
- Critical current Ic: 813 @ 4.2 K & 1.6 T
- Critical temperature Tcs: 7K
- Operating temperature Top: 4.2 K
- Operating current Iop: 246A
- RRR of Cu in strand: 107 ± 11
- Current density: 109 A/mm2
Status Dipole Magnet Design
(Cryostat Design)

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A. Analysis of Magnetic and Thermal stress on iron
B. Stacking force and tie bolt design
C. End plate chamfer geometry from magnetic field requirement
EB Magnets: Open Questions

• Deflection angle of dipole magnets (4 x 22.5° versus 3 x 30°)
• 5 quads (1 type) versus 6 quads (2 different types); same 'magnetic length'
• Requires 1st dipole magnet better field quality?
• Are higher-order corrections (sextupole magnets) necessary?
• (Later:) India is not equipped to provide cold tests
Super-FRS Buildings
(as presented for ZBau)

- #18 (Target building)
- #103 (Super-FRS tunnel)
- #6a (Service building)
- #6b (Low-Energy cave)
- #6c (High-Energy cave)
- #6 (High-Energy cave)
- #104 (SIS connection)
- Direct beam line to NESR
- CR
- pbar production

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Experimental Area
(as presented for ZBau)

Geb. #6a Service building
- 3 floors (~2000 m²)
- Technique (PS, controls, ...)
- Experiment preparation
- Control room, electronics

#6b Experiment
(LASPEC/MATS)

Geb. #6a
(Cryogenic DB2)

#6b Experiment
(HISPEC/DESPEC Energy Buncher/Spectrometer)

#6 Experiment (R3B)
on top #17.2 Service building
(FAIR technique, PS of GLAD)

CR/NESR
<table>
<thead>
<tr>
<th>Year</th>
<th>Development Stages</th>
</tr>
</thead>
<tbody>
<tr>
<td>2003</td>
<td>Recommendation by WissenschaftsRat – FAIR Realisation in three stages</td>
</tr>
<tr>
<td>2005</td>
<td>Entire Facility Baseline Technical Report</td>
</tr>
<tr>
<td>2007</td>
<td>Phase A</td>
</tr>
<tr>
<td>2009</td>
<td>Modularized Start Version</td>
</tr>
</tbody>
</table>

**2009**

- **Module 0 SIS100**
  - expt areas CBM/HADES and APPA
- **Module 1**
  - Super-FRS fixed target area NuSTAR
- **Module 3**
  - pbar facility, incl. CR for PANDA, options for NuSTAR
- **Module 4**
  - LEB for NuSTAR, NESR for NuSTAR and APPA, FLAIR for APPA
- **Module 5**
  - RESR nominal intensity for PANDA & parallel operation with NuSTAR and APPA
- **Module 6 SIS300**

B. Sharkow, FAIR Monthly, 17.2.2010;
[http://www-win.gsi.de/fjct/monthly/100217/CAEN%20Status%20of%20the%20FAIR%20Project_1.pdf](http://www-win.gsi.de/fjct/monthly/100217/CAEN%20Status%20of%20the%20FAIR%20Project_1.pdf), P5
Accommodate LEB experiments at available Super-FRS branch

- **HISPEC**: In-Flight Spectroscopy
- **DESPEC**: Decay Spectroscopy
- **MATS**: Penning trap system (Masses, Trap Assisted Spectroscopy)
- **LASPEC**: LASER Spectroscopy (Spins, Moments, isotope shifts)

**Primary Beams**
- $10^{12}$/s; 1.5-2 GeV/u; $^{238}$U$^{28+}$
- Factor 100-1000

**Secondary Beams**
- up to factor 10000

**Super-FRS**

- **R$^3$B**: (full capability)
  Reactions with Relativistic Radioactive Beams in complete kinematics

- **ILIMA in CR**:
  Masses and Half-lives for short-lived ions

B. Sharkow, FAIR Monthly, 17.2.2010;
http://www-win.gsi.de/fjct/monthly/100217/CAEN%20Status%20of%20the%20FAIR%20Project_1.pdf, P27
New Experimental Area 2010
(as discussed with DK/FCC Feb. 2010)
New Experimental Area 2010
(how to arrange MATS/LASPEC ?)
New Experimental Area 2010
(how to arrange MATS/LASPEC ?)
Roadmap

- Start of construction activities 2010/11
- Schedule is driven by **civil construction**
- Aim for earliest commissioning of accelerators and respective experiments

<table>
<thead>
<tr>
<th>Module</th>
<th>Construction time (months)</th>
<th>Ready for instalation</th>
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<tbody>
<tr>
<td>0</td>
<td>72</td>
<td>2015 / 16</td>
</tr>
<tr>
<td>1</td>
<td>28</td>
<td>2015 / 16</td>
</tr>
<tr>
<td>2</td>
<td>60</td>
<td>2016</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>2016</td>
</tr>
</tbody>
</table>

B. Sharkow, FAIR Monthly, 17.2.2010;
http://www-win.gsi.de/fjct/monthly/100217/CAEN%20Status%20of%20the%20FAIR%20Project_1.pdf, P39