Design study of PRISM-FFAG magnet

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Contents

- Requirement and Lattice parameters
- Magnet form
- Field distribution
- Particle tracking
- Construction schedule
- Summary
Requirement for PRISM-FFAG

- Scaling FFAG:
  \[ B(r) = B_0 \left( \frac{r}{r_0} \right)^k \]

- Large momentum & space acceptance
  - Large aperture: 100 cm x 30 cm

- Tunable magnetic field
  - Trim coils: k value +- 0.5, F/D ratio +- 2

- Extraction toward injection from ring outside
  - Yoke type: C type
Lattice parameters

- Radial sector DFD Triplet
- Central momentum : 68 MeV/c
- Equilibrium radius : 6.5 m
- Number of cell : 10
- F/D ratio : 6
- Field index (k value) : 4.6
Magnet form

- C type
- Aperture
  - 100 cm (horizontal)
  - 30 cm (vertical)
- Slant pole produce field gradient
- Trim coils are installed to correct magnetic field

Cross section of F magnet
3D calculation

3D calculation code “TOSCA”
Magnetic field distribution

Center of F magnet

Center of D magnet

$k+1=5.62$

$F/D=6.02$
Clamp

PROBLEM DATA

TOSCA Magnetostatic
Non-linear materials
Simulation No 1 of 1
453992 elements
473659 nodes
26 conductors
Nodal interpolates fields

Local Coordinates
Origin: 0, 0, 0, 0, 0
Local XYZ = Global XYZ

UNIT
Length: cm
Magnetic Flux Density: gauss
Magnetic Field: oersted
Magnetic Scalar Pot: oersted-cm
Magnetic Vector Pot: gauss-cm
Electrical Flux Density: C/m²
Electric Field: V/cm
Conductivity: S/m
Current Density: A/cm²
Power: W
Force: N
Energy: J

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k value changed by trim coils

Current distribution

F trim coils

D trim coils

k+1 value distribution

by S. Nakaoka
F/D ratio changed by main coils and trim coils

Current distribution

F/D ratio distribution

by S. Nakaoka
Change of tunes

- Horizontal tune change from 2.55 to 2.95 by changing k value
- Vertical tune change from 1.2 to 2.2 by changing F/D ratio

by S. Nakaoka
Phase space acceptance

\[ P = 68 \text{ MeV}/c \quad \text{Gap height} = \pm 15 \text{ cm} \]

Horizontal phase space (@center of straight section)

Vertical phase space (@center of straight section)

Horizontal acceptance : 35,000 \( \pi \) mm mrad
Vertical acceptance : 5,000 \( \pi \) mm mrad
Zero-chromaticity

**Tune**

- horizontal tune
- vertical tune

**4D Acceptance**

- Gap height = ± 15 cm

- Tune: $\cdot 0.8 \cdot 1 \cdot 1.2$
- 4D-Acceptance (Rel.): $\cdot 0 \cdot 0.2 \cdot 0.4 \cdot 0.6 \cdot 0.8 \cdot 1$

- momentum (MeV/c): $\cdot 50 \cdot 60 \cdot 70 \cdot 80 \cdot 90$
- $P_\mu$ (MeV/c): $\cdot 30 \cdot 40 \cdot 50 \cdot 60 \cdot 70 \cdot 80 \cdot 90 \cdot 100 \cdot 110$

- 68 MeV/c ± 20%
## Magnet parameters

<table>
<thead>
<tr>
<th></th>
<th>F magnet</th>
<th>D magnet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Weight of magnet</td>
<td>17 t / 1 cell</td>
<td></td>
</tr>
<tr>
<td>Current (per 1 coil)</td>
<td>1750 A / 84000 A*T</td>
<td>1034 A / 30000 A*T</td>
</tr>
<tr>
<td>Power</td>
<td>100 kW / 1 cell</td>
<td></td>
</tr>
<tr>
<td>Flow rate of cooling water</td>
<td>61.7 ℓ / min</td>
<td>38.3 ℓ / min</td>
</tr>
<tr>
<td>Pressure drop (per 1 path)</td>
<td>4.8 kg / cm²</td>
<td>1.9 kg / cm²</td>
</tr>
</tbody>
</table>
Construction schedule

- **JFY 2004:**
  - Production of 40 set of D coils
  - Production of 3 set of F coils
- **JFY 2005:**
  - Production of 17 set of F coils
  - Production of 3 set of magnet body
  - Measurement of magnetic field
- **JFY 2006:**
  - Production of 7 set of magnet body
  - Measurement of magnetic field
  - Construction of PRISM-FFAG ring
Summary

- The design of the magnet have been almost completed, and following performances are confirmed.
  - k value and F/D ratio can be varied.
  - Large phase space acceptance: $35000 \pi \text{ mm}^2 \text{ mrad} \times 5000 \pi \text{ mm}^2 \text{ mrad}$
  - Zero-chromaticity
  - Large momentum acceptance: 68 MeV/c ± 20 %
- Construction of the magnets have been started from JPY 2004 and will be finished in JPY 2006.