Spin Rotator Design for the SuperKEKB High Energy Ring in a Proposed Polarization Upgrade

Yuhao Peng
University of Victoria

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SuperKEKB

Location: Japan

Circumference: 3km

Collides 7 GeV electron – 4 GeV positron for precision flavour studies, CP violation, and searches for new physics beyond the Standard Model
Purpose and Physics Motivation

Design a spin rotator for SuperKEKB High Energy Ring (Electron Ring), to polarize the spin of the electron beam in the longitudinal direction at the interaction point (IP)

• Study of asymmetry between the identical processes with different electron beam handedness, which provides high precision electroweak measurements (requires longitudinal polarization at the IP)
Rotator Magnet

Follows Uli Wienands’s idea (at Argonne National Laboratory):

- Replace some existing ring dipoles near the IP with the solenoid-dipole combined function magnets and maintain the original dipole strength

- Install 6 skew-quadrupole on top of each rotator section to compensate for the x-y plane coupling caused by solenoids
*Right rotator* is to rotate the vertical spin to the longitudinal direction.

*Left rotator* is to rotate the longitudinal back to vertical.
Constraints of the Design

- **Transparency**: Need to maintain the original beam dynamics, make the spin rotator transparent to the ring as much as possible.

- **Physical constraints**: All new magnets must be manufacturable and installable.
Simulation Tool

- **Bmad** is an open-source software library created/maintained by David Sagan at Cornell University for simulating charged particles and X-rays, also allows full tracking studies for the lattice.

- Optimization Algorithm: **LMDIF** is to minimize the sum of the squares of nonlinear functions by a modification of the Levenberg-Marquardt algorithm.
Procedure of Design and Maintaining Transparency

• Design:
  • Find the appropriate dipoles to replace
  • Fit the strength of solenoids

• Transparency:
  • Decouple the x-y plane with skew quads
  • Rematch the optics by tuning ring quads near/in the rotator region
  • Tune the chromaticity with ring sextupoles
  • Maintain Tune value Q
Current status

The BMAD simulation shows the rotator is working properly

• The longitudinal spin alignment at the IP is achieved

• Transparency is guaranteed
Lattice Comparison at L-Rot Tuning Region

Outside the red box, dynamics maintained as the original.
Lattice Comparison at R-Rot Tuning Region

Original

R-Rot
Comparison of full-lattice

Original                                 Rotator Installed

Beta Function [model]

Dispersion [model]

Orbit [model]

IP                                      IP

Rotator Installed
Longitudinal spin alignment

- The spin track result shows a longitudinal spin alignment >99.99% with the rotator installed in the High Energy Ring.

<table>
<thead>
<tr>
<th>Spin Component</th>
<th>Spin at the entrance of the Rotator</th>
<th>Spin at the IP</th>
<th>Spin at the exit of the Rotator</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>0.00139185</td>
<td>0.00094458</td>
<td>-0.00284127</td>
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<tr>
<td>Y</td>
<td>0.99999508</td>
<td>-0.00115044</td>
<td>0.99999508</td>
</tr>
<tr>
<td>Z</td>
<td>0.00281270</td>
<td>0.99999889</td>
<td>-0.00133075</td>
</tr>
</tbody>
</table>
Future Steps

• Do the multi-turn beam tracking with BMAD to figure out beam lifetime, and maintain the Tune value Q

• Modify the design if beam lifetime does not meet the expectation