B2GM Spin Rotator Update

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University
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Sokolov-Ternov Effect

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- Ohnishi-san's calculation with SAD shows that the Sokolov-Ternov Time for the HER would be ~531 minutes.
- Sokolov-Ternov is not yet implemented in Bmad, but with that lifetime it would be a negligible effect.

Beam-Beam Studies

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- We have begun studying the effect of an opposing beam at the IP on the overall stability of the lattice
- Bmad uses a virtual **beambeam** element to simulate a strong opposing beam
- This beambeam element is sliced and can be prepared with the optical parameters of the LER

The strong beam is divided up into `n_slice` equal charge (not equal thickness) slices. Propagation through the strong beam involves a kick at the charge center of each slice with drifts in between the kicks. The kicks are calculated using the standard Bassetti–Erskine complex error function formula[Talman87].

Even though the strong beam can have a finite `sig_z`, the length of the element is always considered to be zero. This is achieved by adding drifts at either end of any tracking so that the longitudinal starting point and ending point are identical. The longitudinal s–position of the `BeamBeam` element is at the center of the strong bunch. For example, with `n_slice` $= 2$ and with a solenoid field, the calculation would proceed as follows:

1. Start with the particle longitudinally at the **beambeam** element (which is considered to have zero longitudinal length) in laboratory coordinates (§15).
2. Propagate backwards through the solenoid field so that the particle is in the plane of the first beambeam slice. The fact that the plane of the slice may be, due to finite `x_pitch` or `y_pitch` values, canted with respect to the laboratory x-y plane is taken into account.
3. Transform the particle coordinates to the **beambeam** element body coordinates (§15.3).
4. Apply the beam–beam kick due to the first slice including a spin rotation.
5. Transform back to laboratory coordinates.
6. Propagate forwards so that the particle is in the plane of the second slice.
7. Transform the particle coordinates to the **beambeam** element body coordinates.
8. Apply the beam–beam kick due to the second slice.
9. Transform back to laboratory coordinates.
10. Propagate backwards through the solenoid field to end up with the particle longitudinally at the **beambeam** element.

Bmad Manual

https://www.classe.cornell.edu/bmad/manual.html

Beam-Beam Studies

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HER

```
                     A-Mode           |            B-Mode
                 Model       Design   |        Model       Design
         Q    45.531001    45.531001       43.580716    43.580716  ! Tune
     Chrom     1.591891     1.591891        1.621569     1.621569  ! dQ/(dE/E)
    J_damp     0.999102     0.999102        0.999771     0.999771  ! Damping Partition #
 Emittance  4.43303E-09  4.43303E-09     5.34956E-13  5.34956E-13  ! Unnormalized
Emit (photon vert opening angle ignored)   0.00000E+00  0.00000E+00
  Alpha_damp  1.78470E-04  1.78470E-04   1.78590E-04  1.78590E-04  ! Damping per turn
Damping_time  5.63754E-02  5.63754E-02   5.63377E-02  5.63377E-02  ! Sec

                 Model       Design
     Z_tune:  2.73892E-02  2.73892E-02
    Sig_E/E:  6.42272E-04  6.42272E-04
      Sig_z:  5.14535E-03  5.14535E-03   ! Only calculated when RF is on
Emittance_z:  3.30419E-06  3.30419E-06   ! Only calculated when RF is on
Energy Loss:  2.50344E+06  2.50344E+06   ! Energy_Loss (eV / Turn)
     J_damp:  1.99931E+00  1.99931E+00   ! Longitudinal Damping Partition #
 Alpha_damp:  3.57138E-04  3.57138E-04   ! Longitudinal Damping per turn
  damp_time:  2.81721E-02  2.81721E-02   ! Longitudinal Damping time (sec)
    Alpha_p:  4.53858E-04  4.53858E-04   ! Momentum Compaction
      Eta_p:  4.53853E-04  4.53853E-04   ! Slip factor
gamma_trans:  4.69396E+01  4.69396E+01   ! Gamma at transition
  Spin Tune:  9.76895E-02  9.76895E-02   ! Spin Tune on Closed Orbit (Units of 2pi)
       <pz>:  4.73833E-06  4.73833E-06   ! Average closed orbit pz (momentum deviation)
```

HER + BB

```
                     A-Mode           |            B-Mode
                 Model       Design   |        Model       Design
         Q    45.587894    45.587894       43.357465    43.357465  ! Tune
     Chrom     1.204034     1.204034        0.153774     0.153774  ! dQ/(dE/E)
    J_damp     1.031258     1.031258        0.999773     0.999773  ! Damping Partition #
 Emittance  0.00000E+00  0.00000E+00     3.55095E-13  3.55095E-13  ! Unnormalized
Emit (photon vert opening angle ignored)   0.00000E+00  0.00000E+00
  Alpha_damp  1.84217E-04  1.84217E-04   1.78592E-04  1.78592E-04  ! Damping per turn
Damping_time  5.46169E-02  5.46169E-02   5.63369E-02  5.63369E-02  ! Sec

                 Model       Design
     Z_tune:  2.73891E-02  2.73891E-02
    Sig_E/E:  6.42284E-04  6.42284E-04
      Sig_z:  5.14549E-03  5.14549E-03   ! Only calculated when RF is on
Emittance_z:  3.30434E-06  3.30434E-06   ! Only calculated when RF is on
Energy Loss:  2.50347E+06  2.50347E+06   ! Energy_Loss (eV / Turn)
     J_damp:  1.99921E+00  1.99921E+00   ! Longitudinal Damping Partition #
 Alpha_damp:  3.57126E-04  3.57126E-04   ! Longitudinal Damping per turn
  damp_time:  2.81731E-02  2.81731E-02   ! Longitudinal Damping time (sec)
    Alpha_p:  4.53855E-04  4.53855E-04   ! Momentum Compaction
      Eta_p:  4.53850E-04  4.53850E-04   ! Slip factor
gamma_trans:  4.69398E+01  4.69398E+01   ! Gamma at transition
  Spin Tune:  9.76897E-02  9.76897E-02   ! Spin Tune on Closed Orbit (Units of 2pi)
       <pz>:  4.73834E-06  4.73834E-06   ! Average closed orbit pz (momentum deviation)
```

Beam-Beam Studies

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```
!--------- beam-beam element -------------------
bbi: beambeam, e_tot_strong = 4E9,  sig_x = 10.1E-6, sig_y = 48E-9, sig_z = 6.0E-3,  n_slice = 6,
                n_particle = 9E10/6, x_pitch = 0.00415, alpha_a_strong = 0.01648305, alpha_b_strong = -0.00219240,
                beta_a_strong = 0.07952183, beta_b_strong = 0.00099473, bs_field = -1.453446511511663

! e_tot_strong = ! Beam (LER) energy)
! n_particle = 9E10 ! Particles in a bunch
! Bmad by default uses positive charge particles for simulation, so the LER beam would be negatively charged
! bs_field = <Real> ! Solenoid field strength.
! x_pitch = <rad> ! Half crossing angle
! bbi constant automatically calculated by Bmad (dependant)
! z_crossing = 0
! repetition_frequency !bunch rate (must be high precision - use Bmad and not documented rounded numbers)
!---------- rotator magnets --------------------
```

- We now have the crab-waist details, so we are conducting studies using them.
- Preliminary tracking studies ongoing with the HER lattice.

Polarization and Spin Tune

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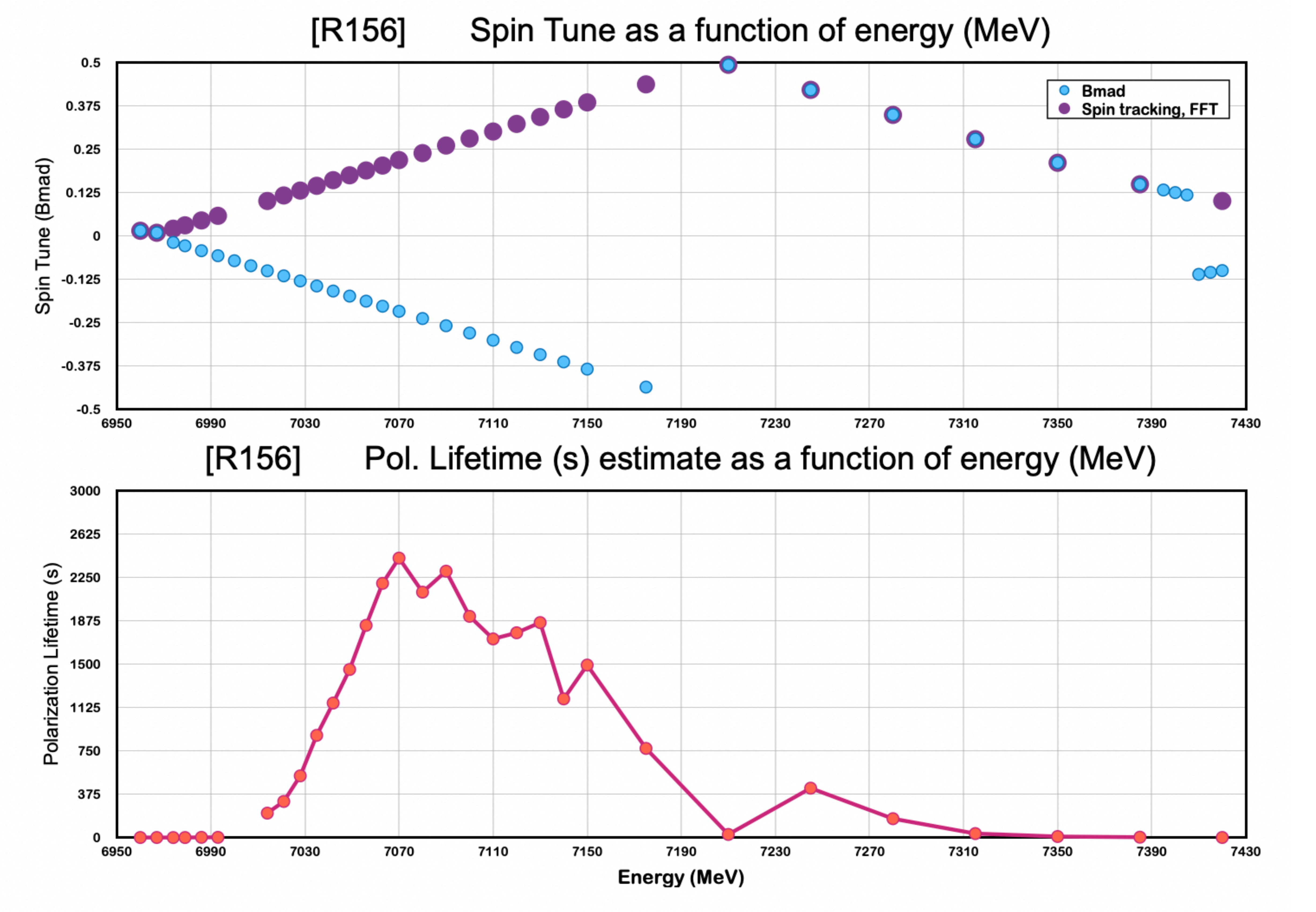
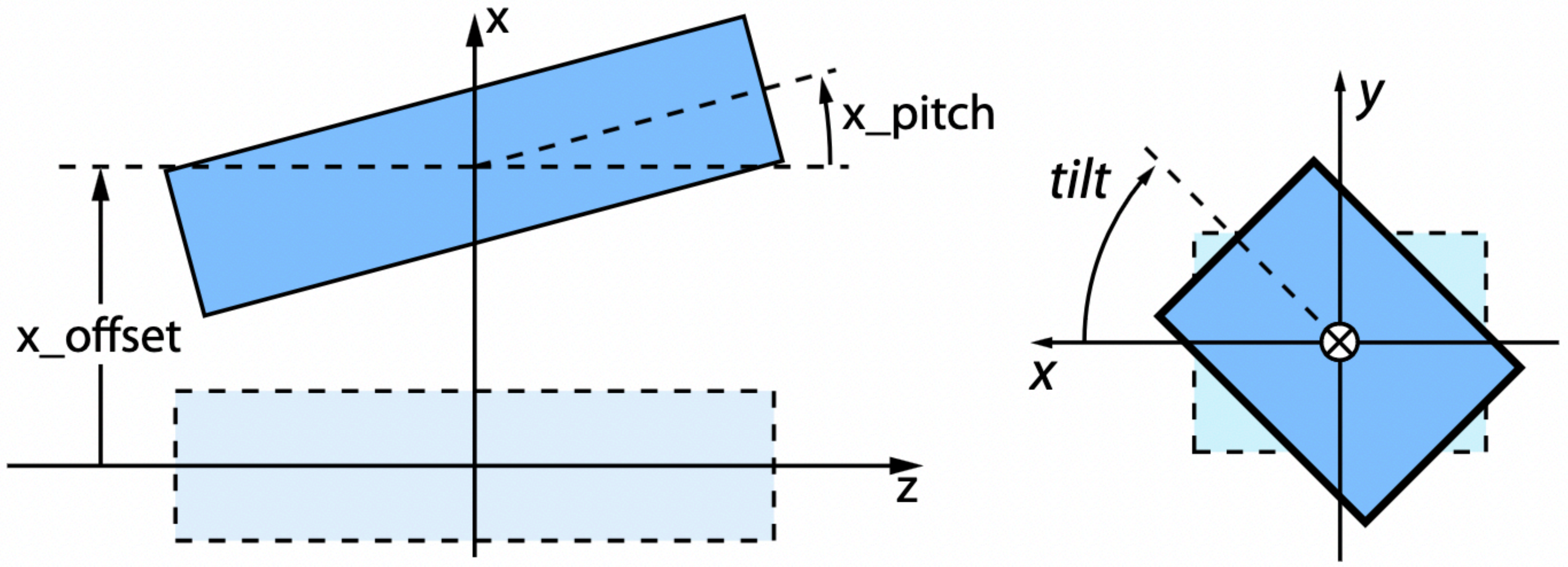
- Over the course of the semester, we have been conducting long term tracking studies to gauge polarization stability for HER+ROT lattices at various energies.
- Long term tracking (LTT) was ran over the course of 20,000 turns using 100 particles, and polarization lifetime was extrapolated through a linear regression fit of the decay on a log plot.
- Currently investigating some post-processing coding errors.



Magnet Misalignments

- We are implementing magnet misalignments within our long-term tracking studies
- Ohnishi-san suggested magnet offset tolerances no greater than 50-100 microns
- Except at a special section near the IP where the error is <10 microns
- Currently, code is being written to generate random errors of <100 microns based on these estimates to propagate offsets to our lattice files



(a) Effect of x_offset and x_pitch on a straight line element

(b) Effect of a tilt on a straight line element.

Figure 19

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Magnet Misalignments

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- In addition, we have been provided rotational measurements for various bending elements of the HER from Ohnishi-san
- Our current task is to cross-check our working HER and spin-rotator lattices with the roll data provided
- Following the above, we plan to implement random roll errors based on this data.

Using the average V

Date	Reference NO	Mag_ID	Type	調整後			Average (mrad)
				Up	Middle	Down	
				RX	RX	RX	RX
9/10/2015	TL114	BLA2LE	HER-B	0.21	0.11	0.19	0.17
	TL139	BLA4LE.1	HER-B	-0.32	-0.73	1.24	0.06
	TL147	BLA4LE.2	HER-B	-0.82	0.00	0.64	-0.06
	TL171	B2E.4	HER-B	0.02	0.08	0.07	0.06
	TL189	B2E.5	HER-B	0.02	-0.06	0.24	0.07
	TL214	B2E.6	HER-B	0.20	0.10	0.05	0.12
	TL222	B2E.7	HER-B	0.18	0.15	-0.04	0.10
	TL247	B2E.8	HER-B	0.24	0.13	0.17	0.18
	TL264	B2E.9	HER-B	0.17	0.07	0.15	0.13
	TL289	B2E.10	HER-B	0.11	0.03	0.17	0.10
	TL298	B2E.11	HER-B	0.08	0.00	0.25	0.11
	TL322	B2E.12	HER-B	0.17	0.04	0.14	0.12
	TL340	B2E.13	HER-B	0.22	0.15	0.06	0.14
	TL364	B2E.14	HER-B	0.10	0.00	-0.10	0.00
	NR364	B2E.15	HER-B	-0.04	0.03	-0.02	-0.01
	…	…	…	…	…	…	…

HER B* rotation data

Provided by Ohnishi-san