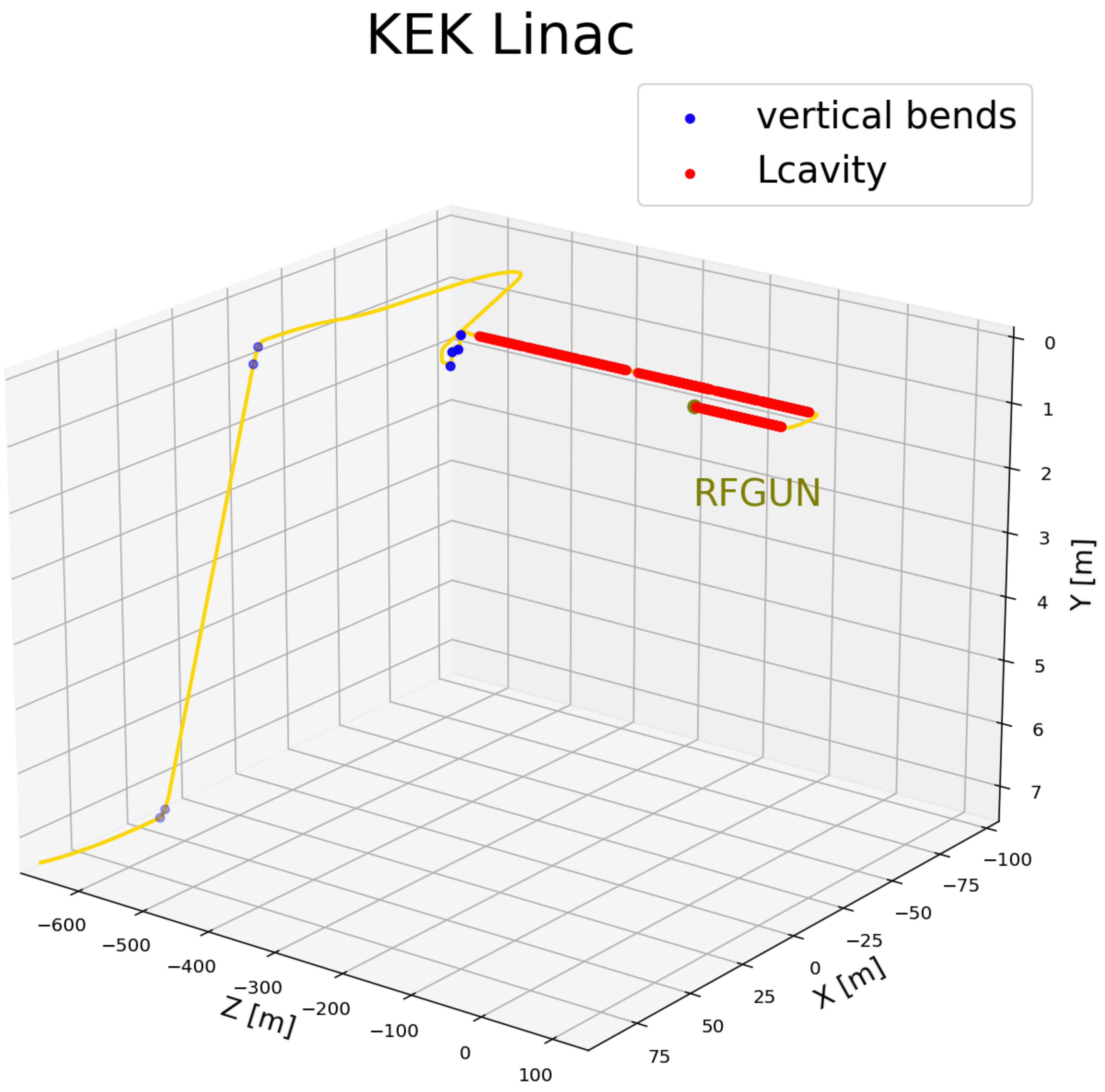
Linac Polarization



Yuhao Peng

2022.06.06

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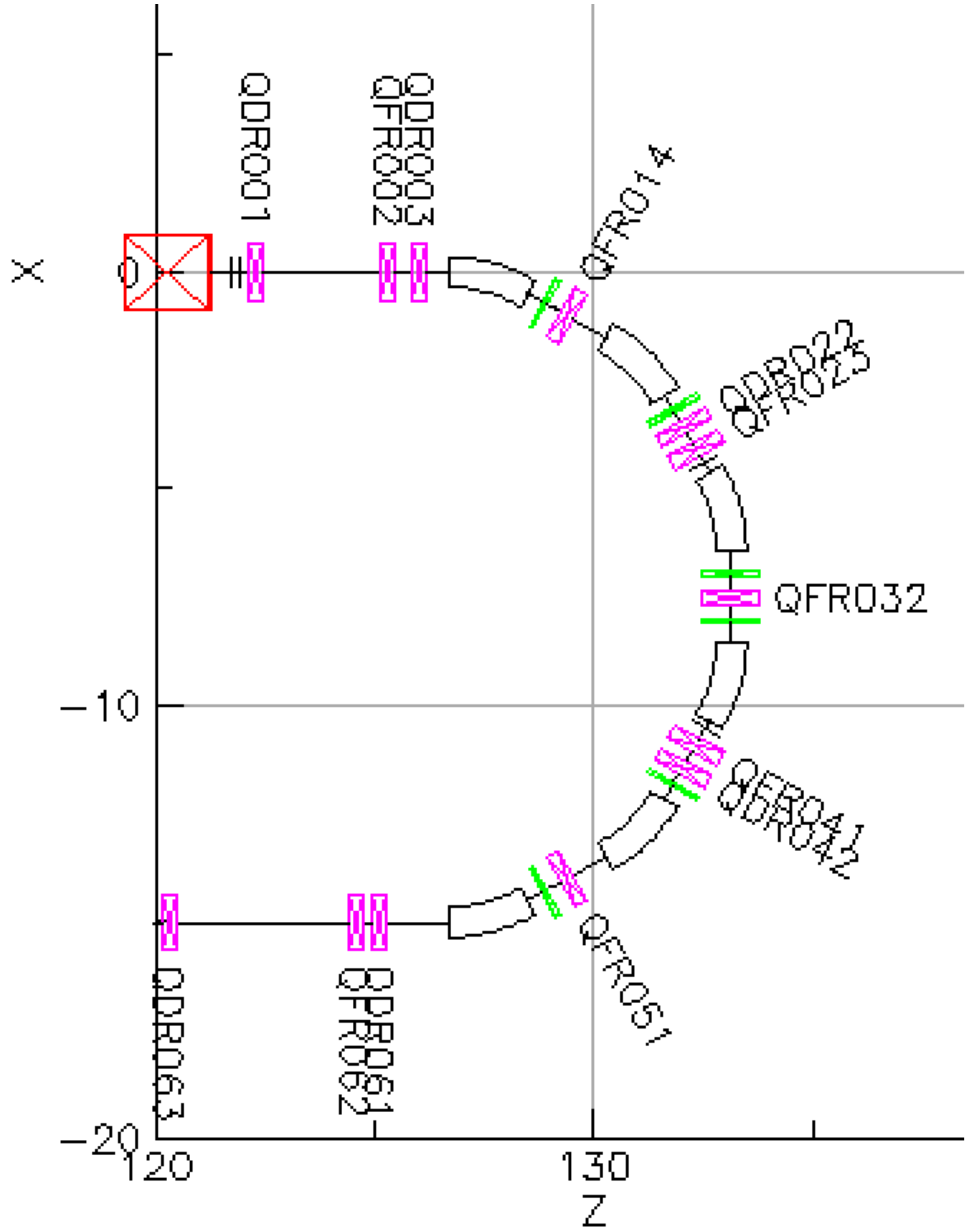

Beam needs to be vertically polarized before it reaches the J-arc section to avoid the depolarization due to the bend, a spin rotator needs to be installed after the beam is generated

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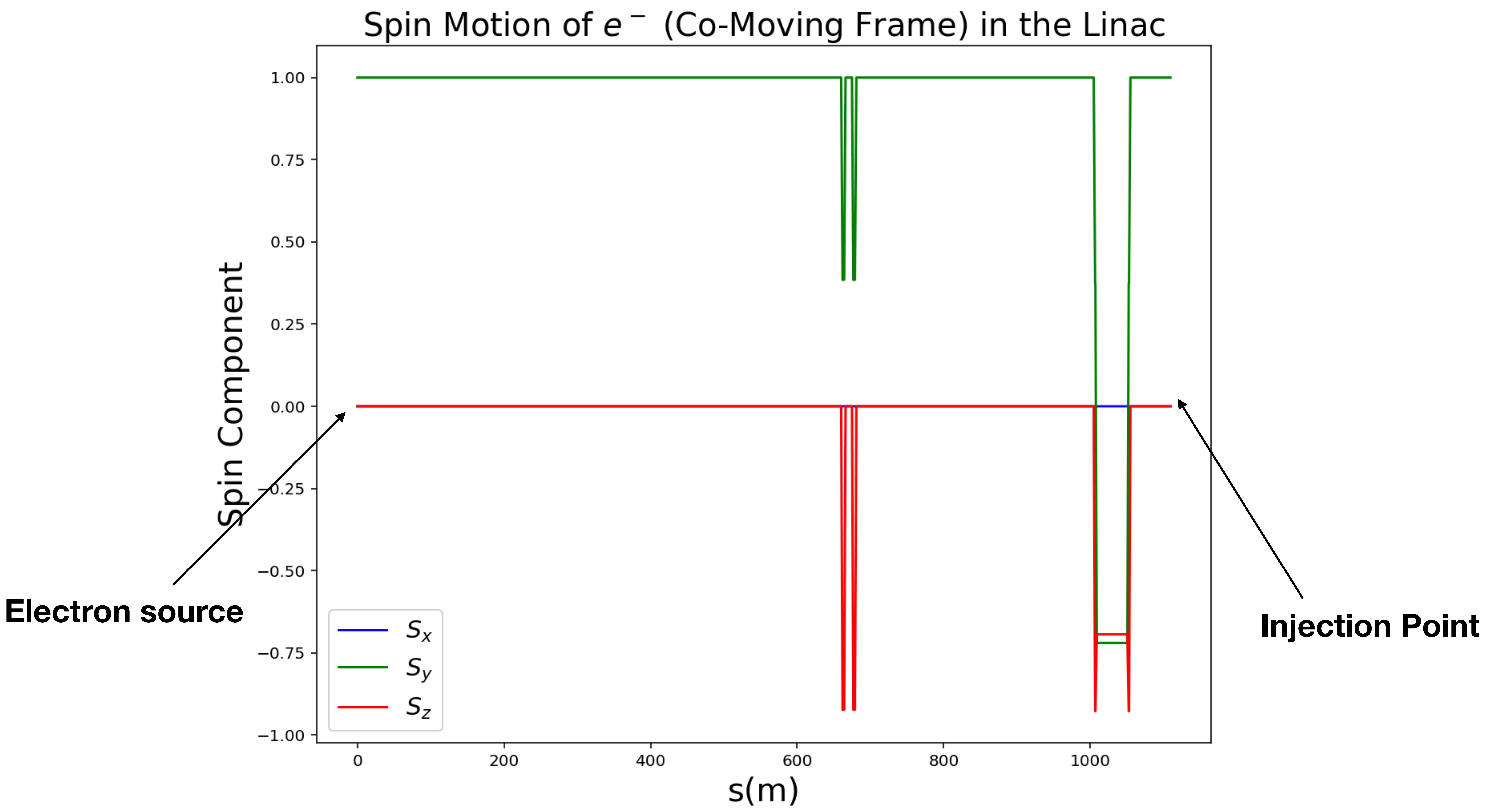

If the beam is vertically polarized at the source, the polarization is maintained at the injection point

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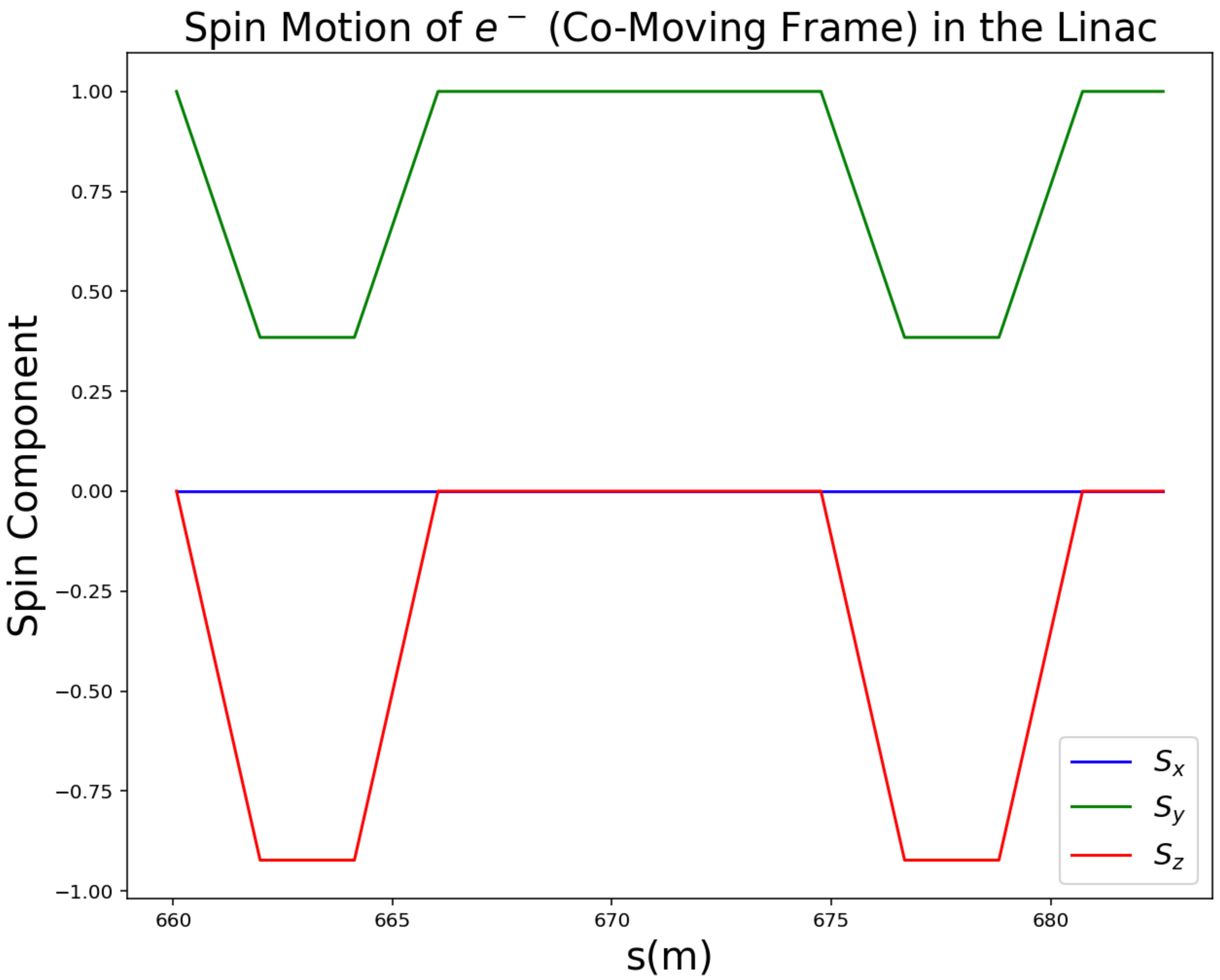
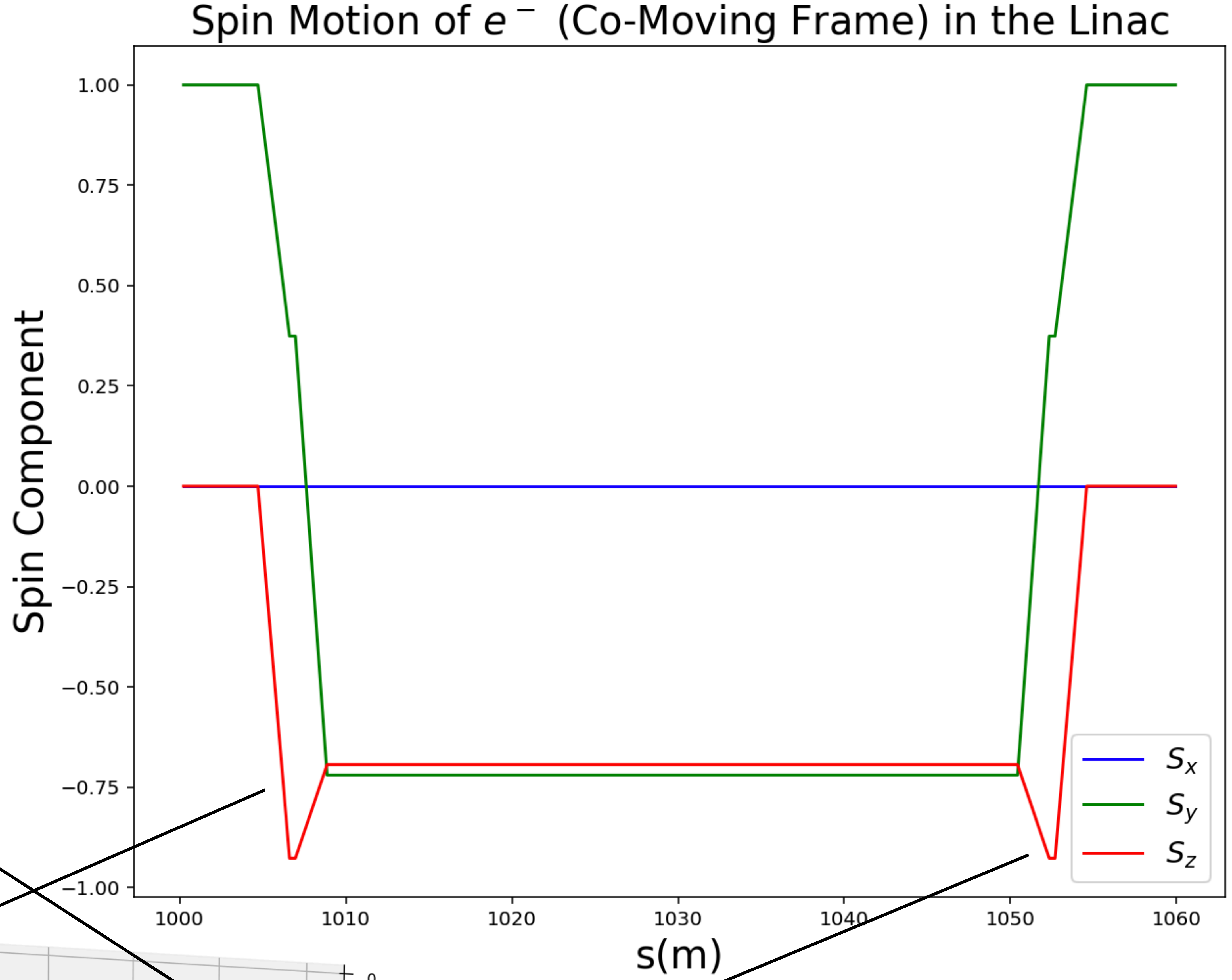
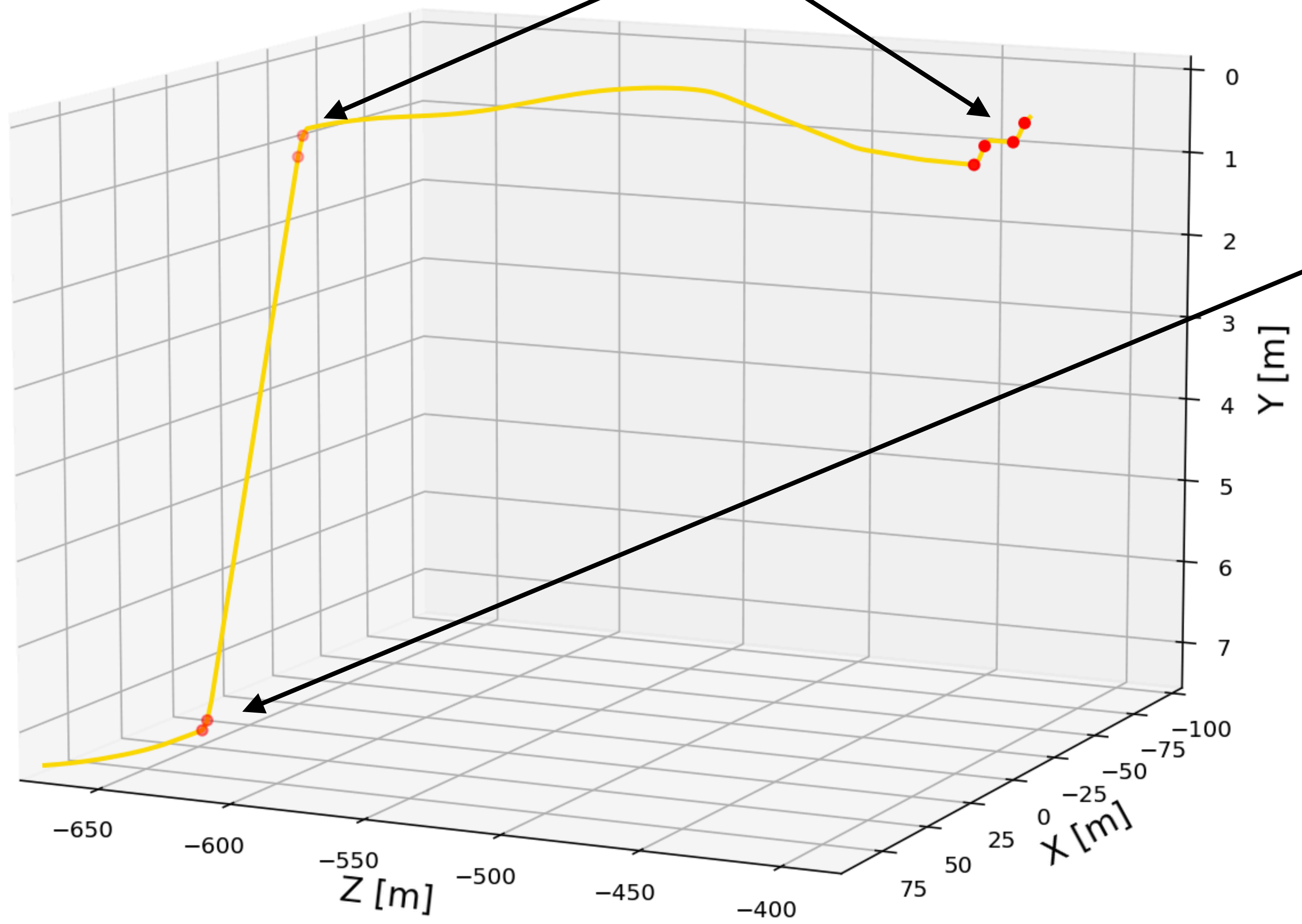

Spin Motion of e^- (Co-Moving Frame) in the Linac
Spin Component
s(m)
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
660
665
670
675
680
S_x
S_y
S_z


Spin Motion of e^- (Co-Moving Frame) in the Linac
Spin Component
s(m)
1.00
0.75
0.50
0.25
0.00
−0.25
−0.50
−0.75
−1.00
1000
1010
1020
1030
1040
1050
1060
S_x
S_y
S_z


Z [m]
X [m]
Y [m]
−650
−600
−550
−500
−450
−400
−100
−75
−50
−25
0
25
50
75
0
1
2
3
4
5
6
7

	Index	name	key	s(m)	l(m)	REF_TILT_TOT	B_field	floor.y	spin.x	spin.y	spin.z
0	3499	BV1UE	Sbend	661.981	1.906	-1.5708	-0.90687	0.070517	-5.656700e-16	0.38464	-9.230700e-01
1	3505	BV1DE	Sbend	666.036	1.906	1.5708	-0.90687	0.300000	-4.302700e-16	1.00000	7.612600e-16
2	3538	BV1UE	Sbend	676.670	1.906	-1.5708	-0.90687	0.370520	1.266100e-15	0.38464	-9.230700e-01
3	3544	BV1DE	Sbend	680.726	1.906	1.5708	-0.90687	0.600010	1.398400e-15	1.00000	-1.354100e-17
4	4134	BV2UE	Sbend	1006.619	1.906	-1.5708	-0.91564	0.671210	2.237800e-15	0.37411	-9.273800e-01
5	4139	BV2UE	Sbend	1008.875	1.906	-1.5708	-0.91564	0.910540	2.627600e-15	-0.72008	-6.938900e-01
6	4219	BV2DE	Sbend	1052.333	1.906	1.5708	-0.91564	7.312200	2.435100e-15	0.37411	-9.273800e-01
7	4224	BV2DE	Sbend	1054.589	1.906	1.5708	-0.91564	7.409500	2.182700e-15	1.00000	-4.510300e-16

The anti-symmetric vertical B field can recover the vertical polarization

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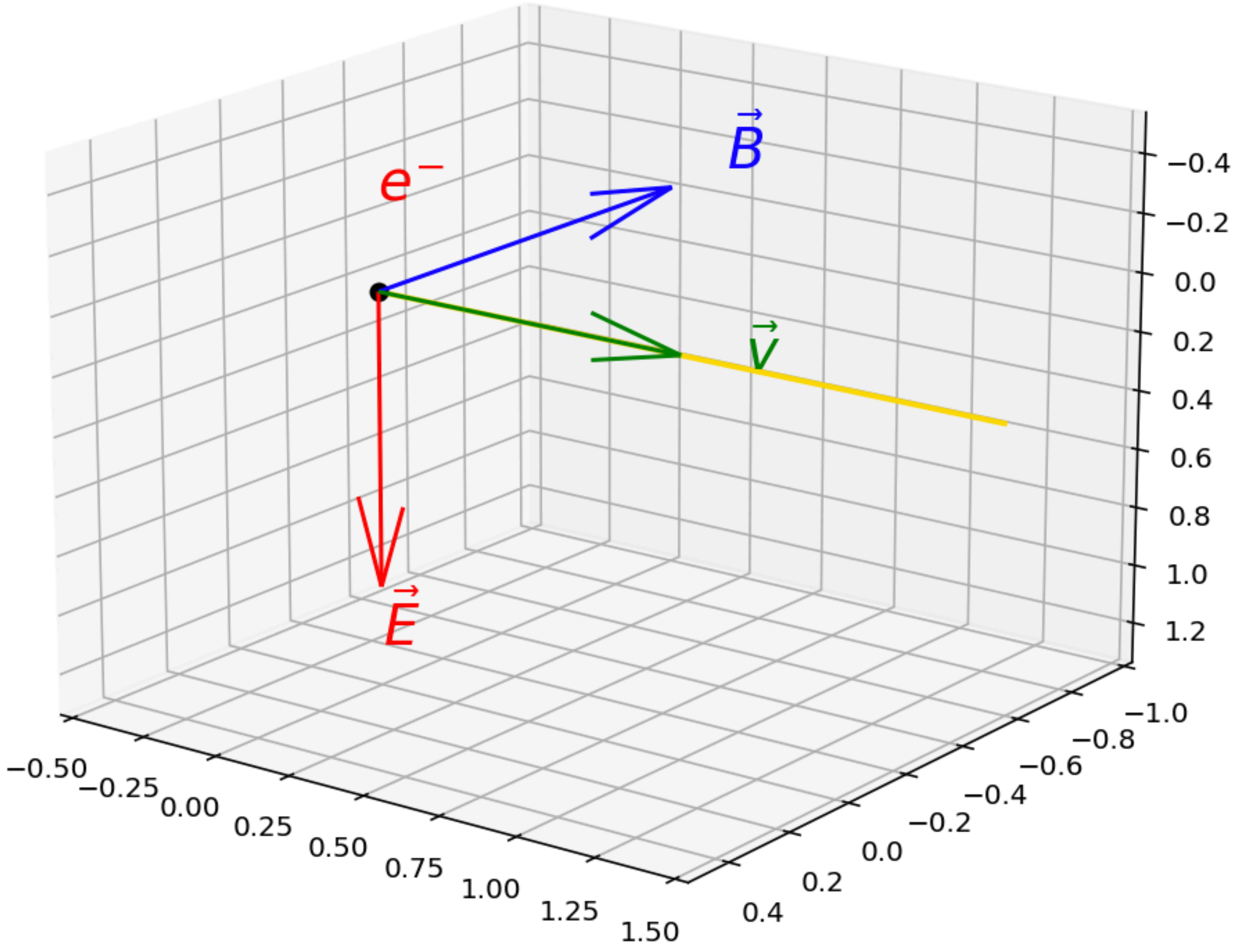
Wien Filter

If we consider using the Wien filter to vertically polarize the electron beam at the source and keep the beam following the straight trajectory

The Wien Filter is a combination of B and E field, using E field to cancel out the Lorentz force experienced by the electron



Spin Motion

The equation of spin motion in the Wien Filter is given by:

$$\frac{d\vec{S}}{ds} = \frac{q}{p}\vec{S} \times \vec{\Omega}$$

Where $\vec{\Omega} = (1 + G\gamma)\vec{B}_{\perp} + (G + \frac{1}{\gamma + 1})\gamma\frac{\vec{E} \times \vec{\beta}}{c}$, q = -e for the electron

The additional constraint on the E field to cancel out the Lorentz force

$$q\vec{E} + q\vec{v} \times \vec{B} = 0$$

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Spin Rotation

The angular speed is given by:

$$\Omega = (1 + G\gamma)B_{\perp} - (G + \frac{1}{\gamma + 1})\gamma \frac{\mathrm{vE}}{c^2}$$

With $\mathrm{E} = \mathrm{v}\mathrm{B}_{\perp}$, it reduces to:

$$\Omega = \frac{1 + G}{\gamma} \frac{B_{\perp}}{B\rho}$$

The desired rotation is $\frac{\pi}{2}$ (from longitudinal to vertical), then

$$B_{\perp} = \frac{\pi}{2} \frac{\gamma B\rho}{(1 + G)\mathrm{L}}$$

Where L is the length of the Wien Filter

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Example of the Wien Filter

For the EIC, the electron energy is 350 keV requiring a 1.5 m long Wien Filter with a B_field of 0.00407 T and a E_field of 0.98294 MV/m to achieve the 90 degrees spin rotation

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Concerns

The electron energy is too high when it leaves the RFgun, pc = 8.5 MeV, which requires the large E field when using Wien Filter

Need to investigate how to implement the Wien Filter before the 8.5 MeV acceleration stage

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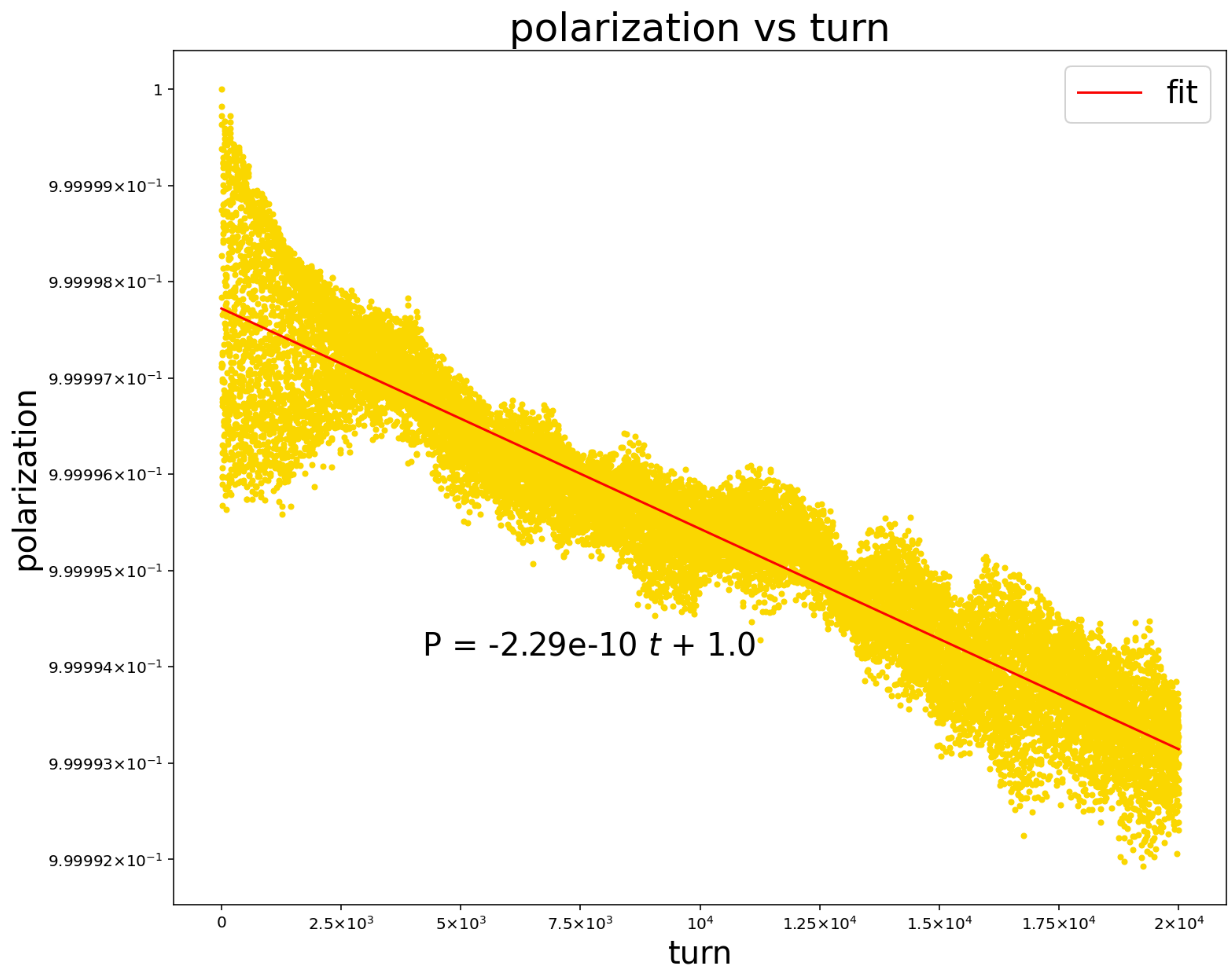
Vertical Polarization at the IP vs Turn



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