Spin Rotator Polarization Studies

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University of Victoria

Design Goals

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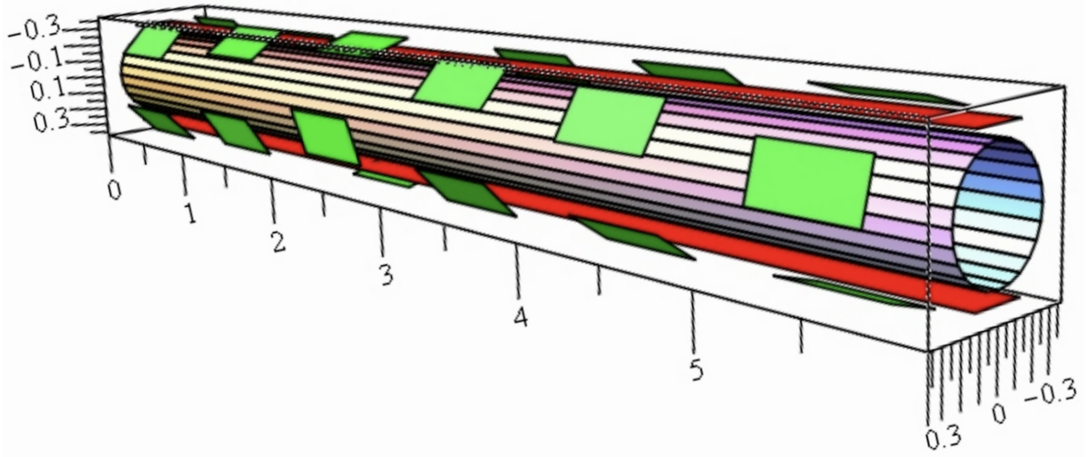
- The design must be “transparent” when not in use (i.e. beam must behave as it always has)
- When in use, the beam must be stable and match as closely as possible to the SuperKEKB parameters
- Must be manufacturable and needs to be able to fit into the existing SuperKEKB HER



Proposed magnet layout of the rotator

Overview of Slice Model:

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- Each half of the Spin Rotator tested in the design contains 6 magnets, which are each subdivided into slices of magnet and patches
    - The slices subdivide the magnet into components of equal length and magnetic field strength
    - The patches correct the horizontal and vertical position of the particle within the overall sliced spin rotator magnet
- Why? SAD/Bmad cannot simulate sol-quads simultaneously with arc dipoles
- The general order:

  SQ(1) + P(1) + SQ(1) + P(1) + … + SQ(2) + P(2) + ….

Preliminary Long Term Tracking

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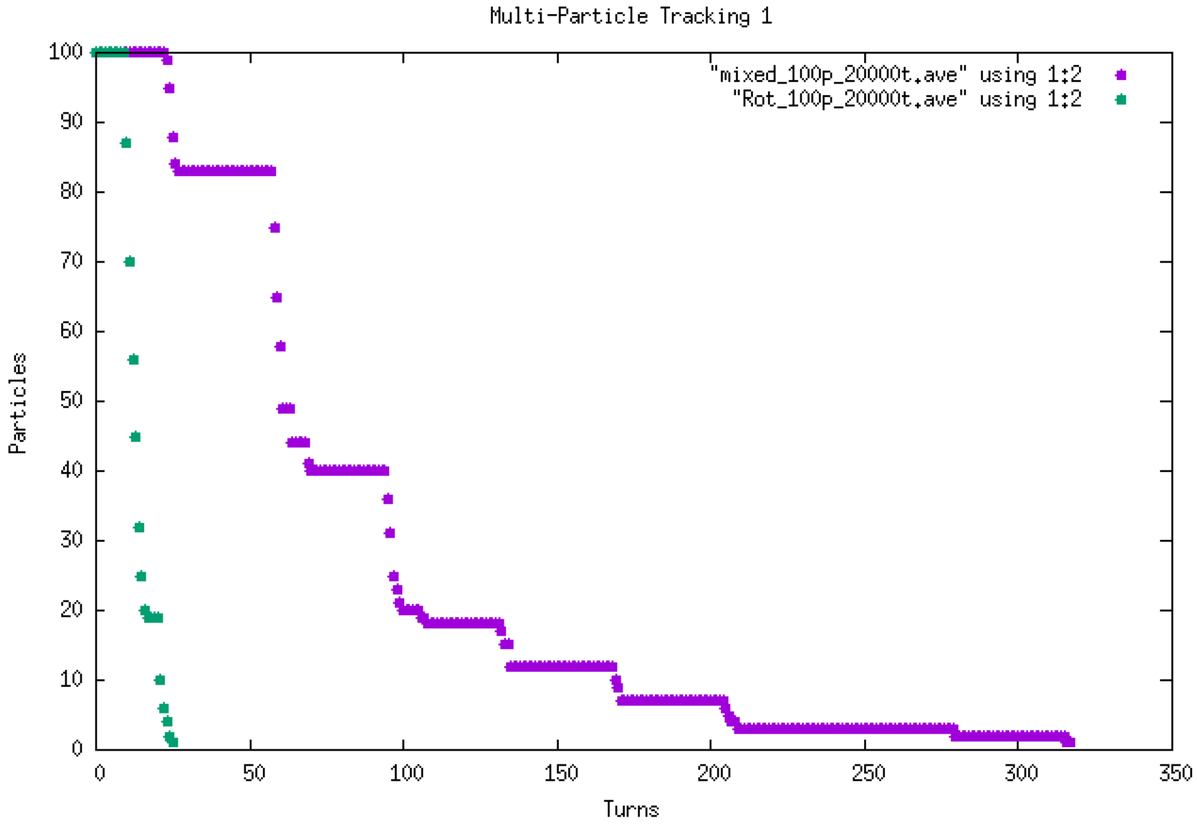
Long Term Tracking (LTT) is a tool used by accelerator physicists to study the non-linear effects of particles in accelerators and storage rings over millions of turns



The 96 slice model, while optically transparent, is unstable.

- This could be caused by the “coarseness” of the slice model - increasing the slices may improve beam stability

Alternative Slice Model Workflow

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Step	Tuning Parameters	Constraints	Progress
OPEN GEOMETRY		Stay within operational limits of magnets	
1. fit for hkicks describing rot region dipoles	hkick value	x-orbit	Lrot and rrot
	patch	floor	72, 96, 120, 144, 156, 192, validation
2. fit for Sol field	Sol field	spin at exit of L-rot region and exit of R-rot reg	Could not optimize 192
with hkicks on & sq quads off	hkick	x-orbit	Lrot and rrot
	vkick	y-orbit	72, 96, 120, 144, 156, validation
3. fit for squew-quad fields and tilt angles	squew quad field (k)	x-y coupling matrix off-diagonal = 0	Could not optimize 192
with hkicks on, Sol field on	tilt angle ('skew angles')	i.e. C matrix = 0	Lrot and rrot
to get rid of x-y coupling	hkick	x-orbit	
	vkick	y-orbit	120, 156, validation
		beta function reasonable when in full lattice	
4. rematch beta,alpha, dispersion, orbit	Local Ring quad strength	beta, alpha, orbit, dispersion same as HER	
at exit of L-rot region and R-rot Region	skew quad strengths in L-rot and R-rot	at exit of L-rot region and R-rot Region	Could not optimize 120, 192
		C=0 at exit	156, validation
CLOSED GEOMETRY			
		Stay within operational limits of magnet	
5. rematch Tunex, Tuney	NICO quads	Tunex and Tuney same as in HER	156, validation
6. rematch Chromaticity	set of ring sextupoles in ARC region	Chromaticity same as in HER	156, validation

More slicing is better

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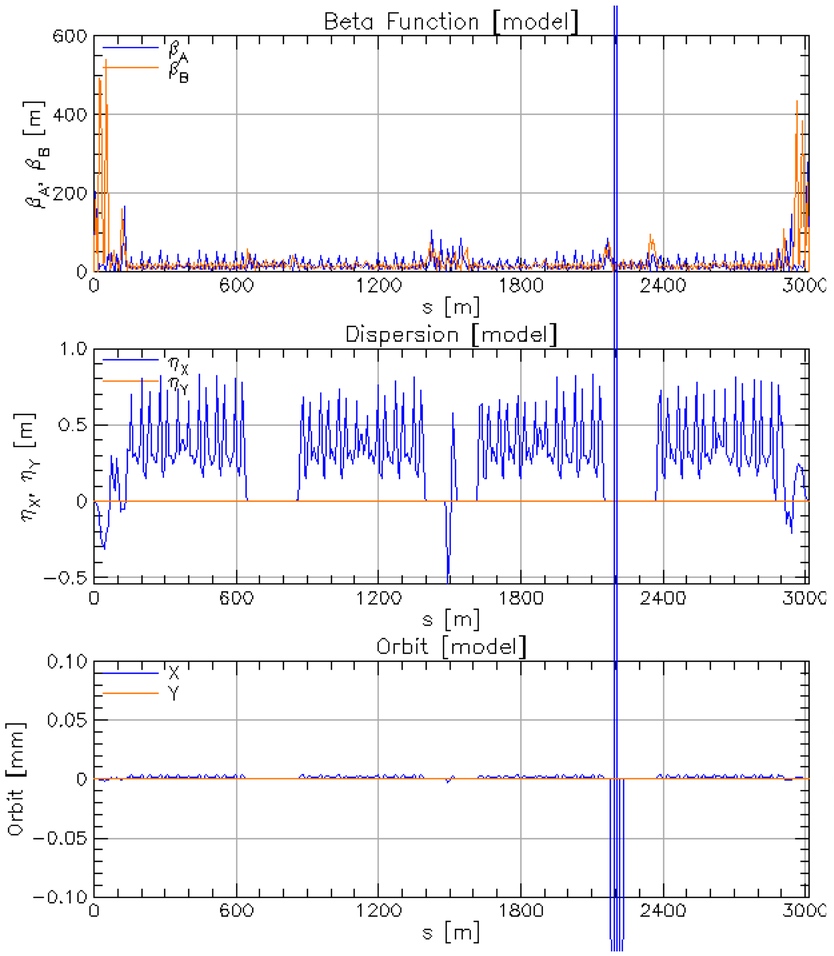
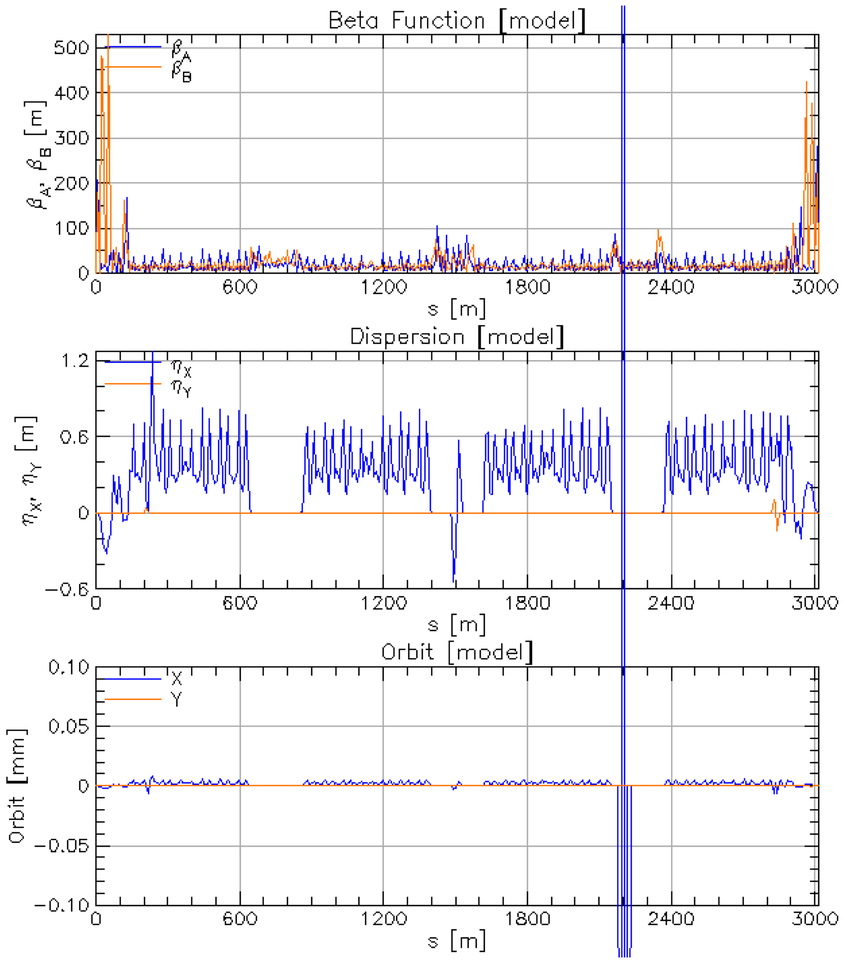
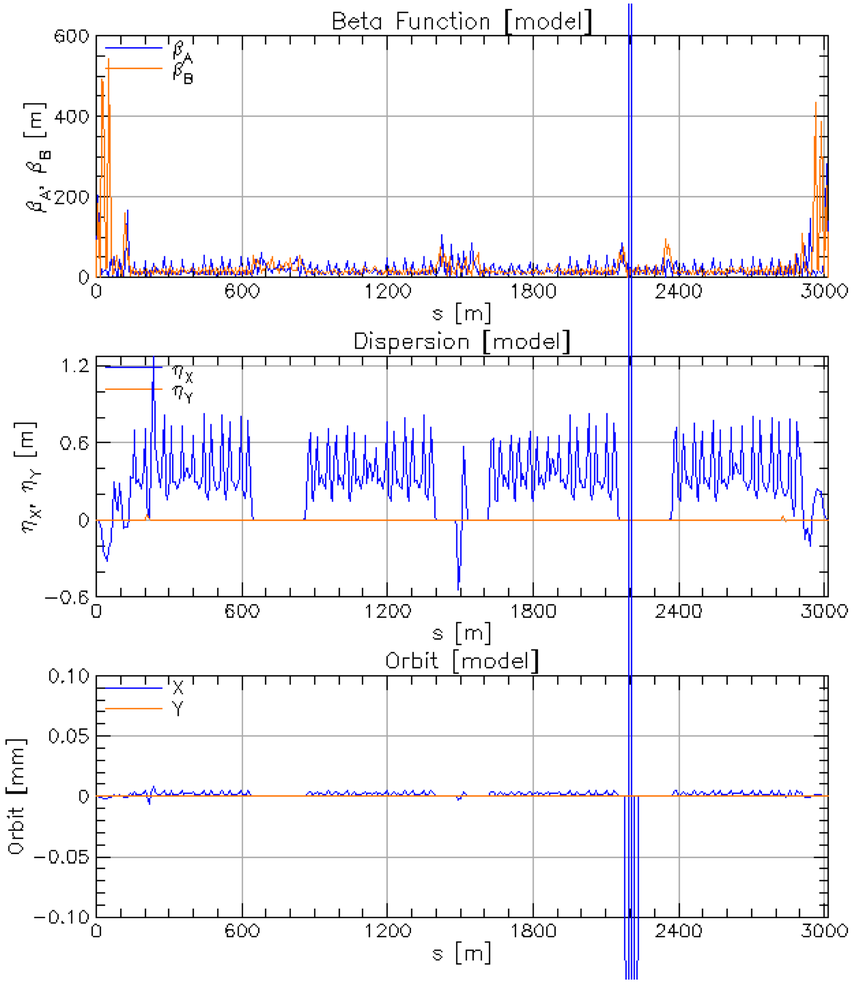
HER only



HER + R96 (Yuhao)



HER + R156



LTT of the R156

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- Good news: The completed R156 spin rotator model looks stable up to 2.5 million turns (the top-up time)
  - 100 particles at 20,000 turns: all survived
  - 20 particles at 200,000 turns: all survived
  - 20 particles at 2,500,000 turns: **all survived!**
  - **20 particles at 5,000,000 turns: <u>all survived!</u>**

Spin Relaxation

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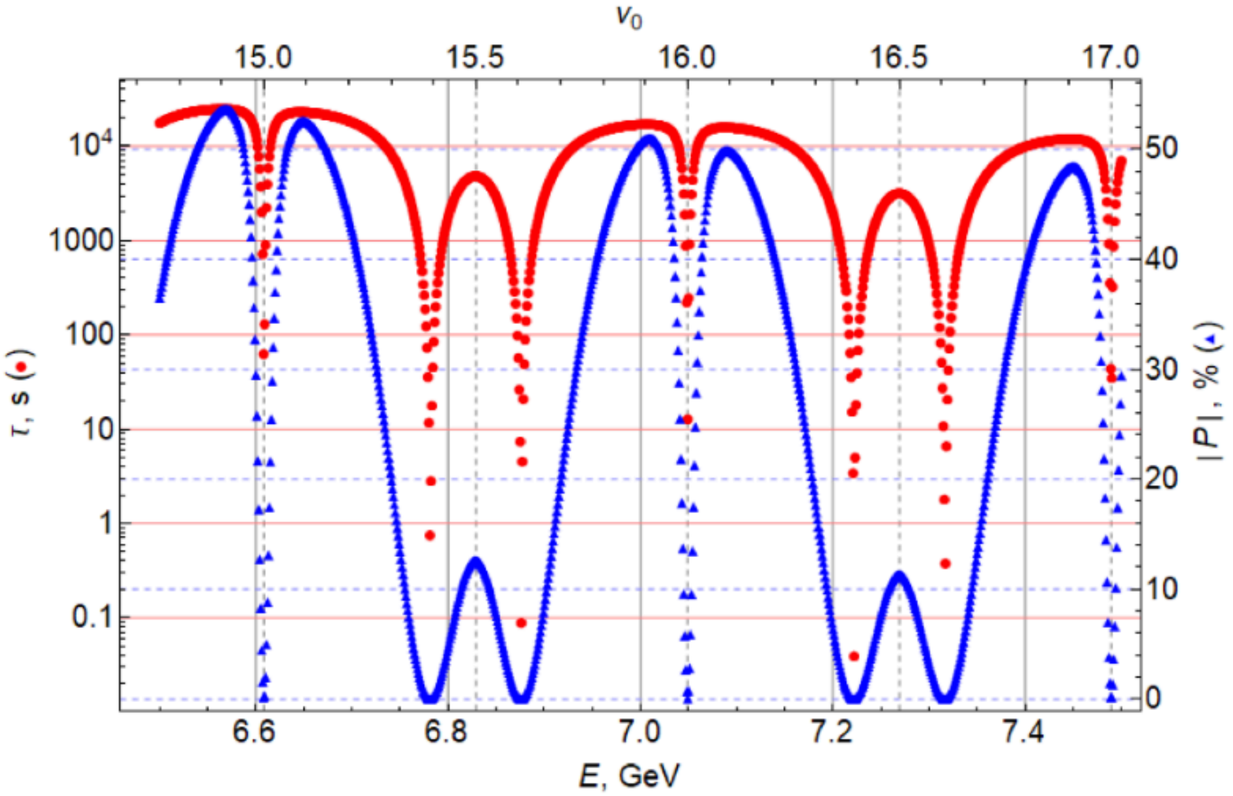
- Overall spin diminishment may be caused by radiative effects.
- The Novosibirsk group conducted a study with their alternative model
- The spin relaxation time plateaus around the working point of the SuperKEKB HER
- We want to probe this region across various energies using LTT.



Radiation spin relaxation time as a function of energy from the Novosibirsk Spin Rotator Group

Alternative Energies and LTT

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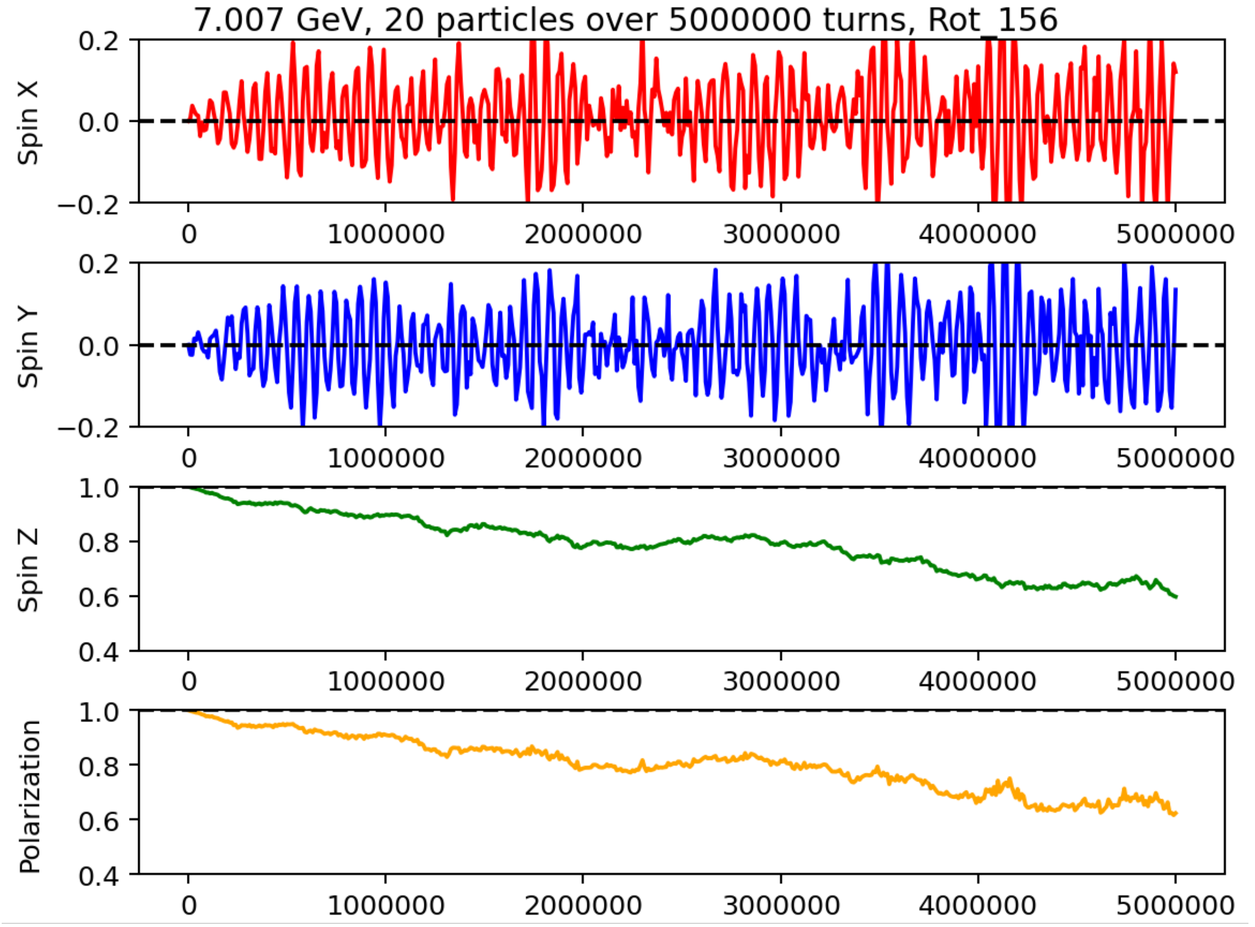
- Uli suggested that small energy changes should be sufficient for the time being to check how polarization is retained (without rematching the Spin Rotator for several energies).
- Changing the energy on order of 1%
  - Original: 7.007GeV
  - Alternatives probed: 7.000, 7.014, 7.021, 7.028, 7.035 GeV



(Plotted are averages)

Alternative Energies and LTT

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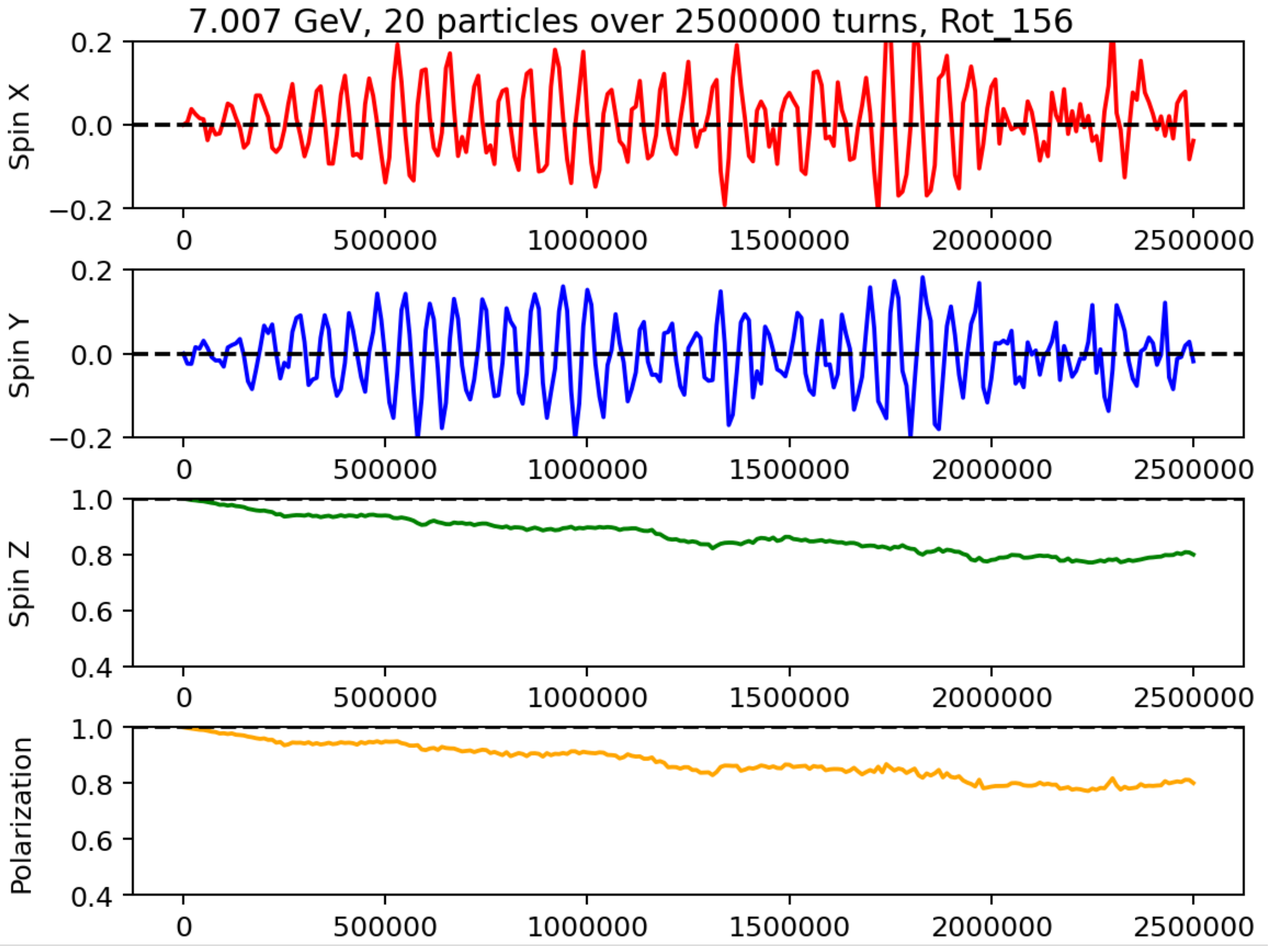
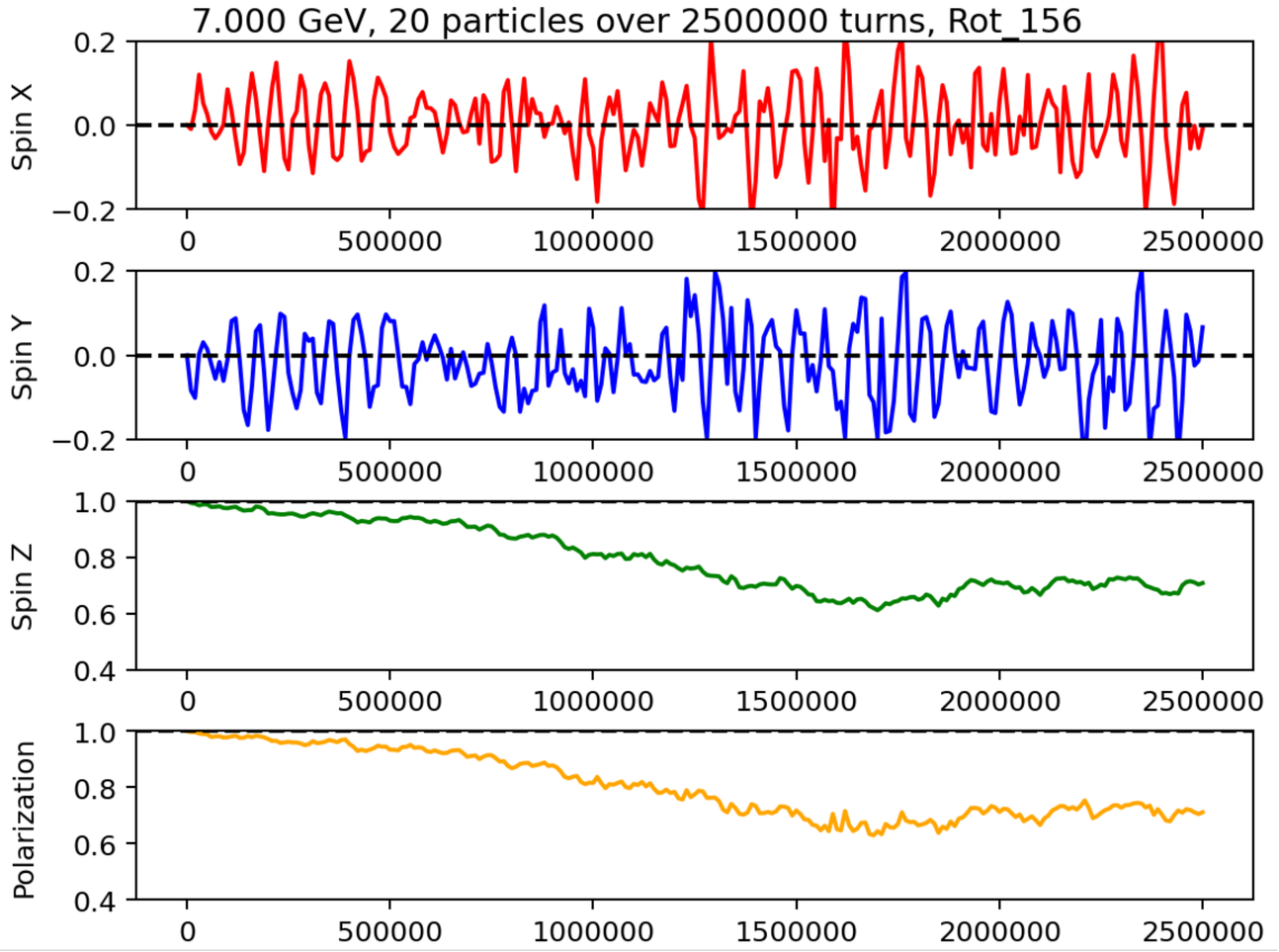


Nominal Energy



Nominal -7 MeV

(Plotted are averages)

Alternative Energies and LTT

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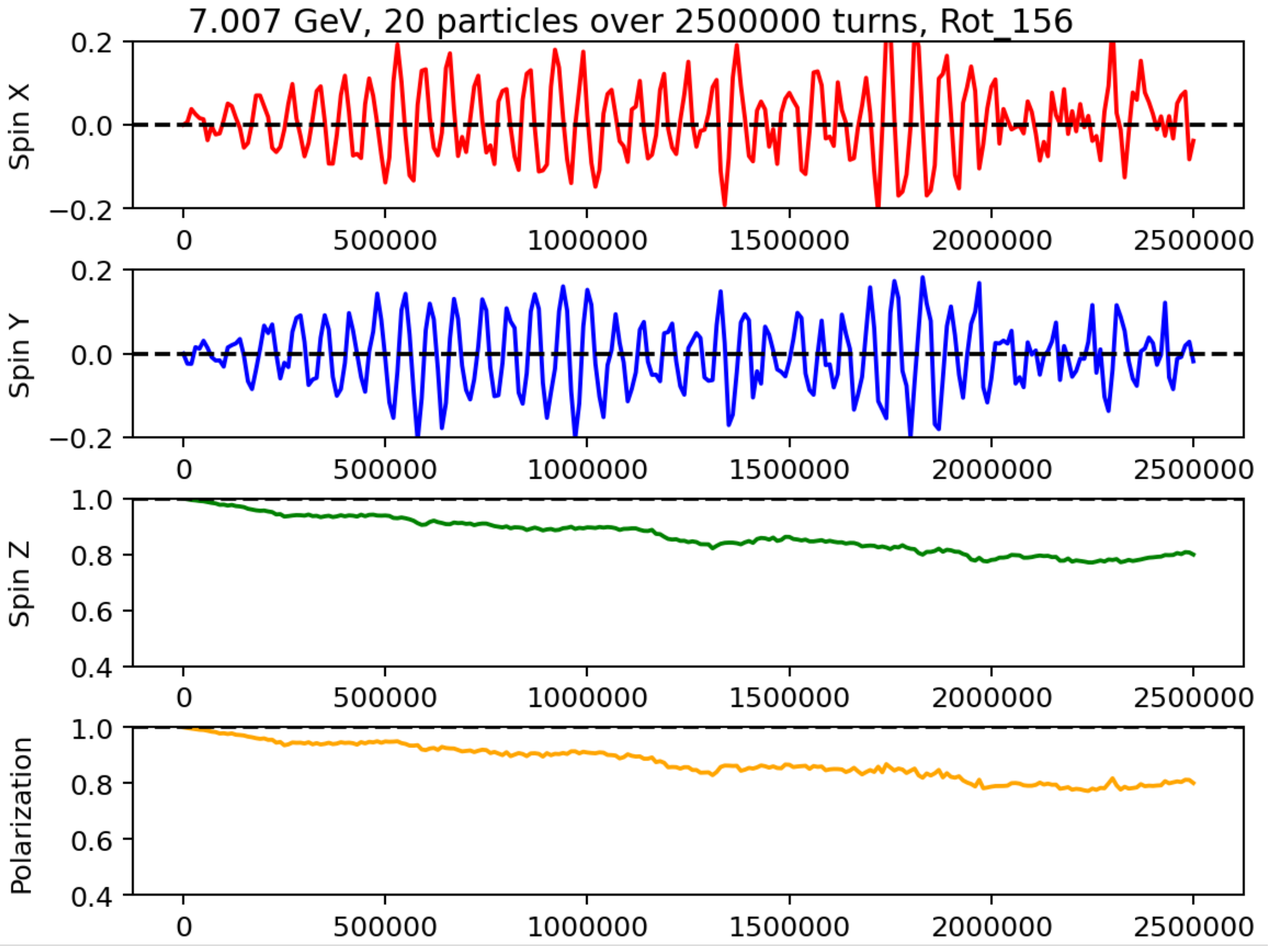
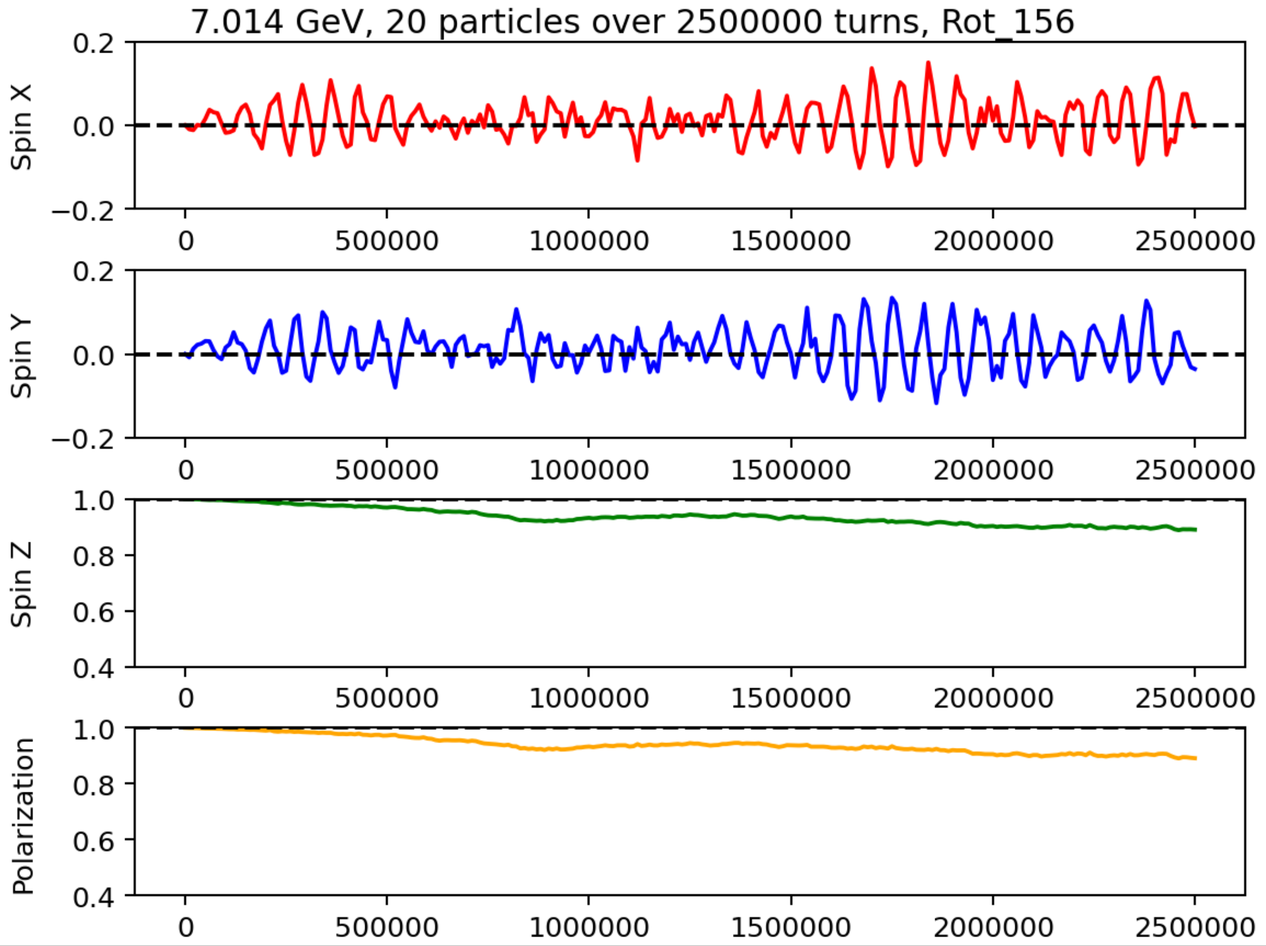


Nominal Energy



Nominal +7 MeV

(Plotted are averages)

Alternative Energies and LTT

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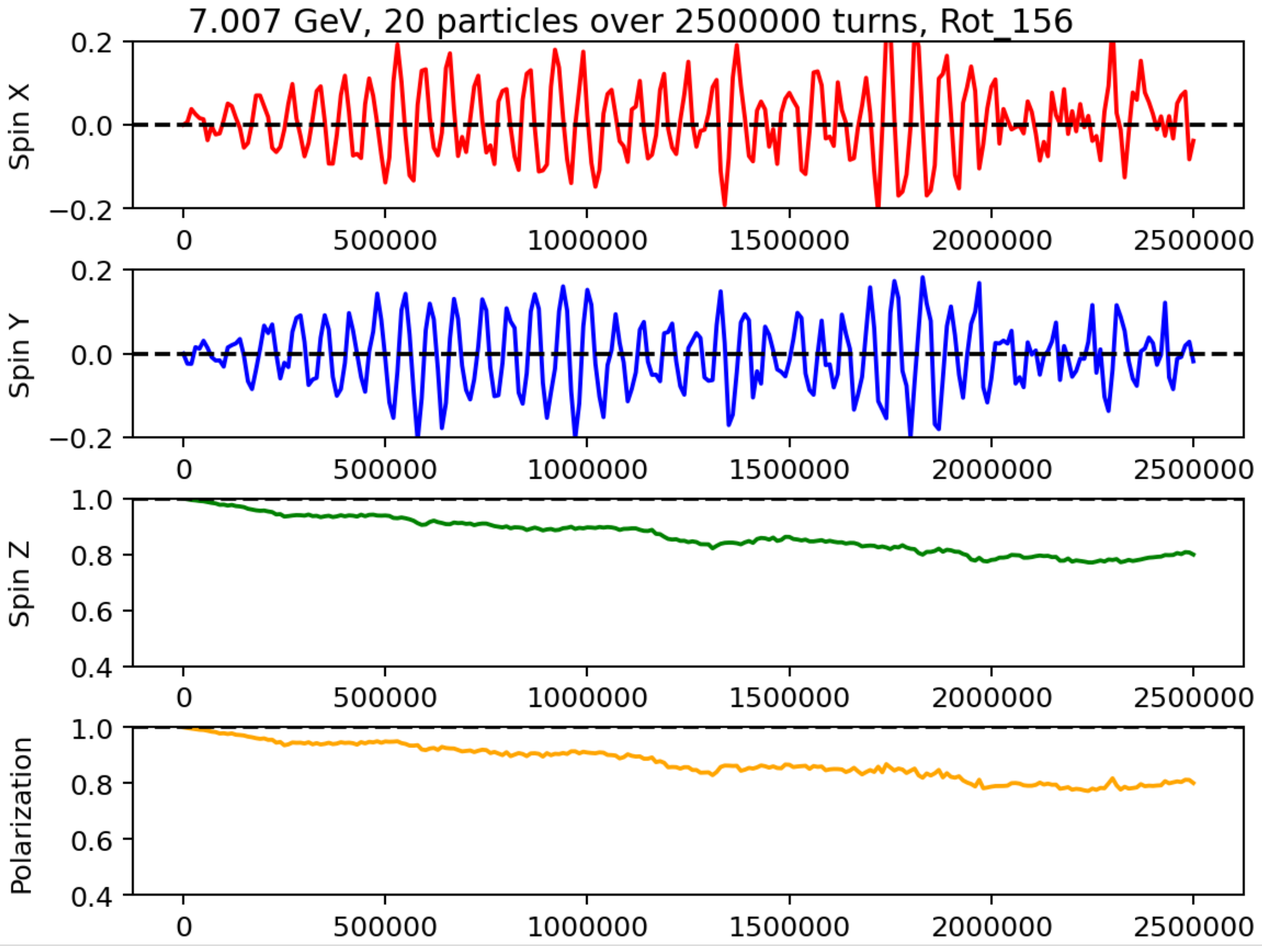
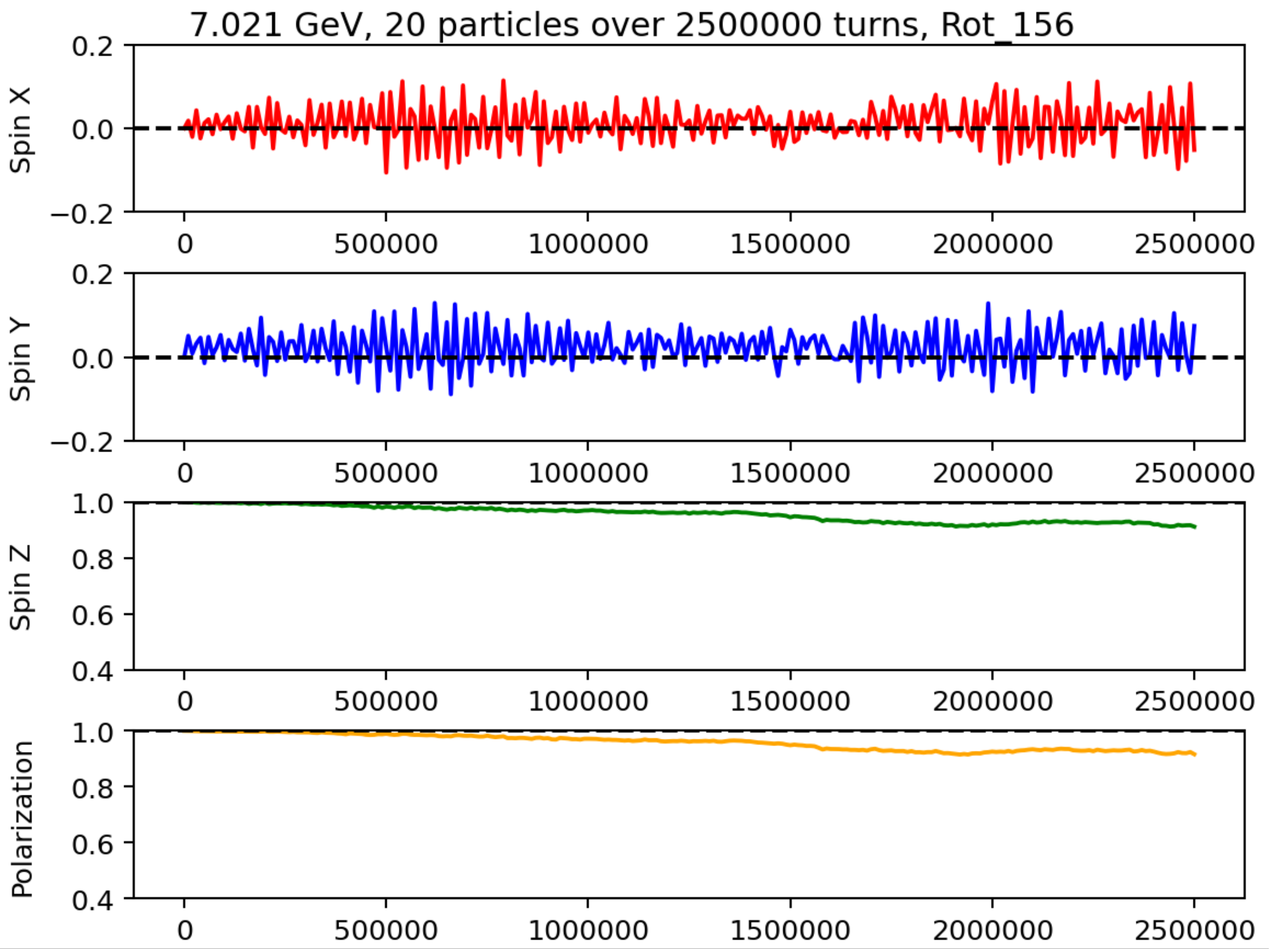


Nominal Energy



Nominal +14 MeV

(Plotted are averages)

Alternative Energies and LTT

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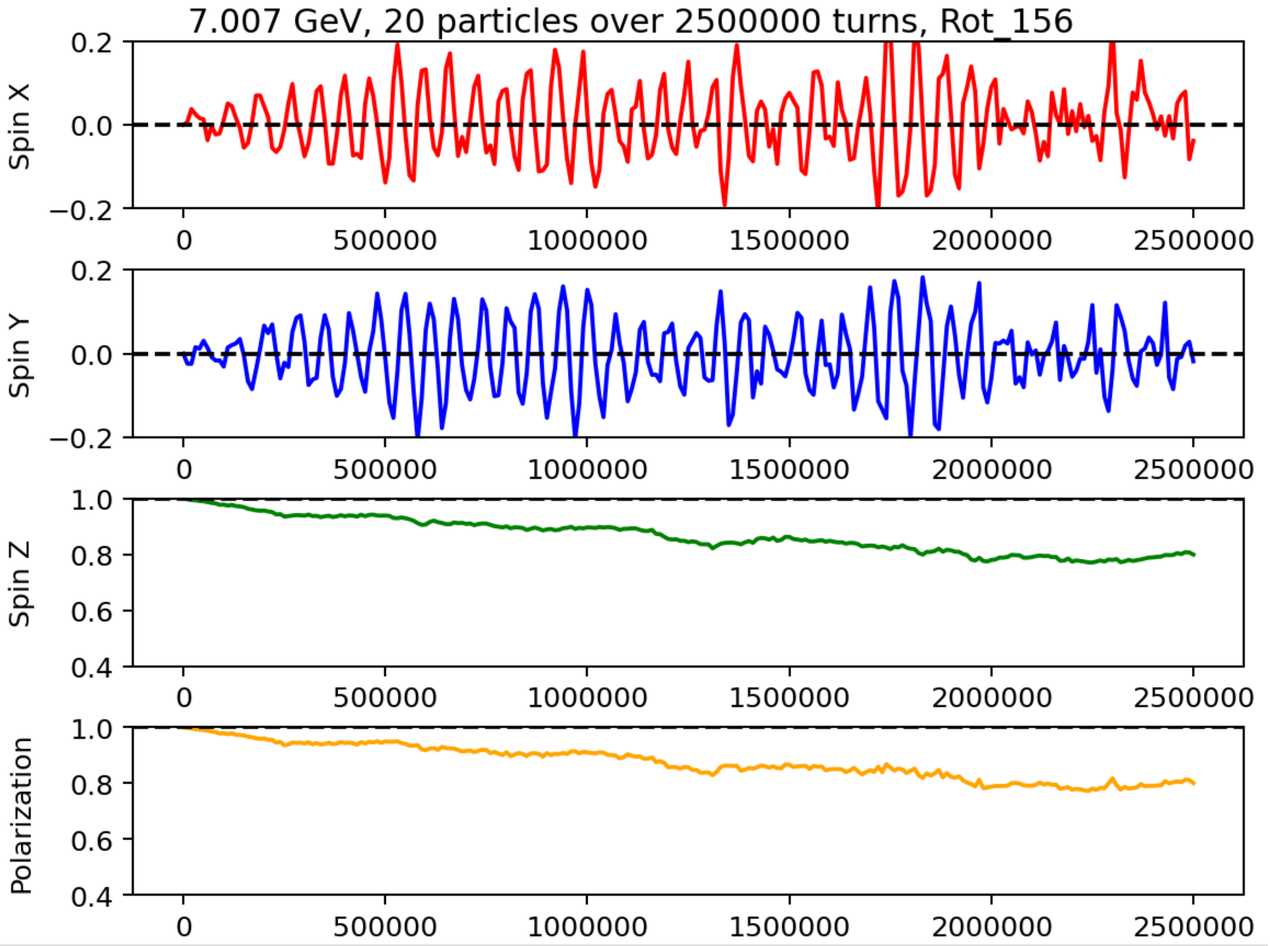
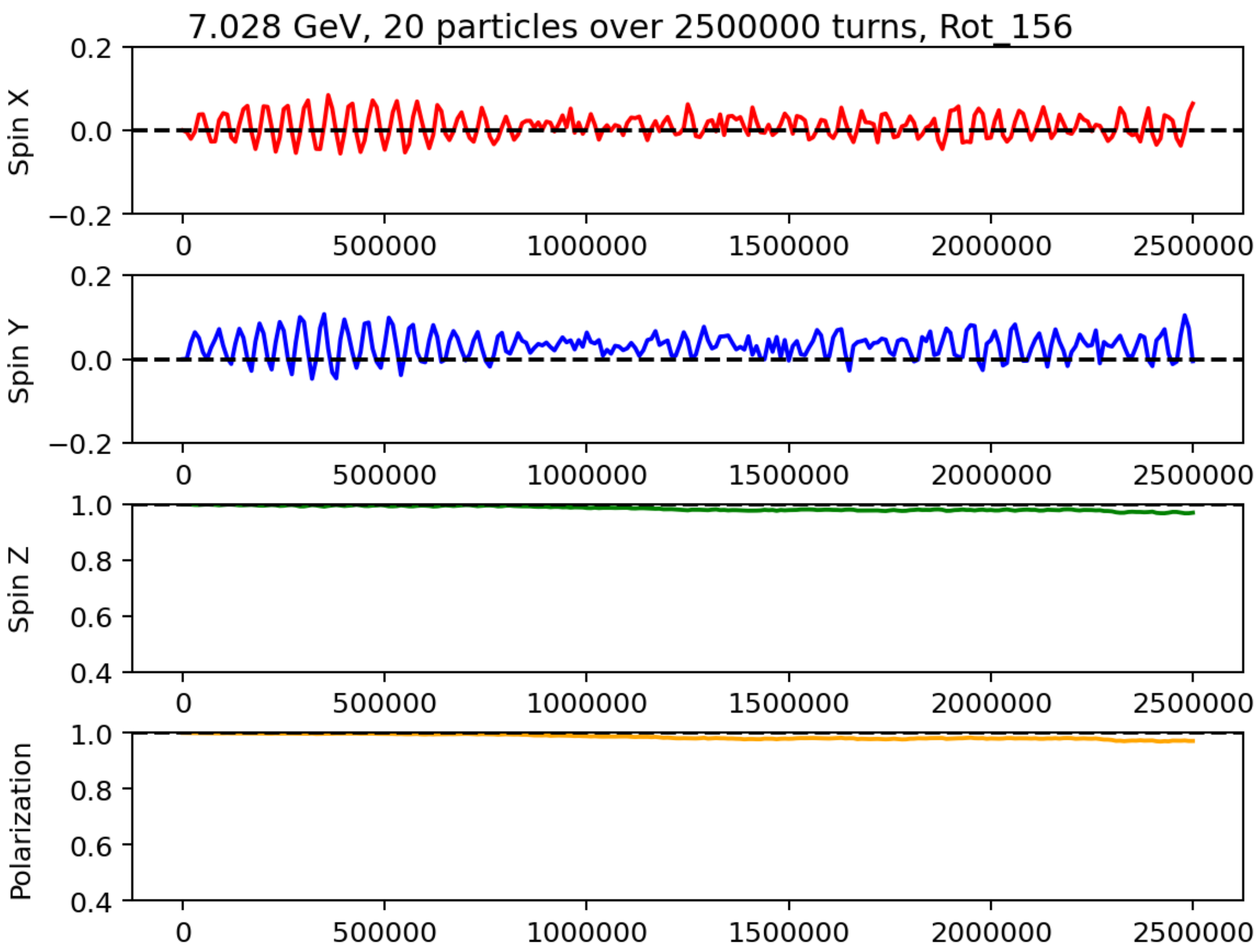


Nominal Energy



Nominal +21 MeV

(Plotted are averages)

Alternative Energies and LTT

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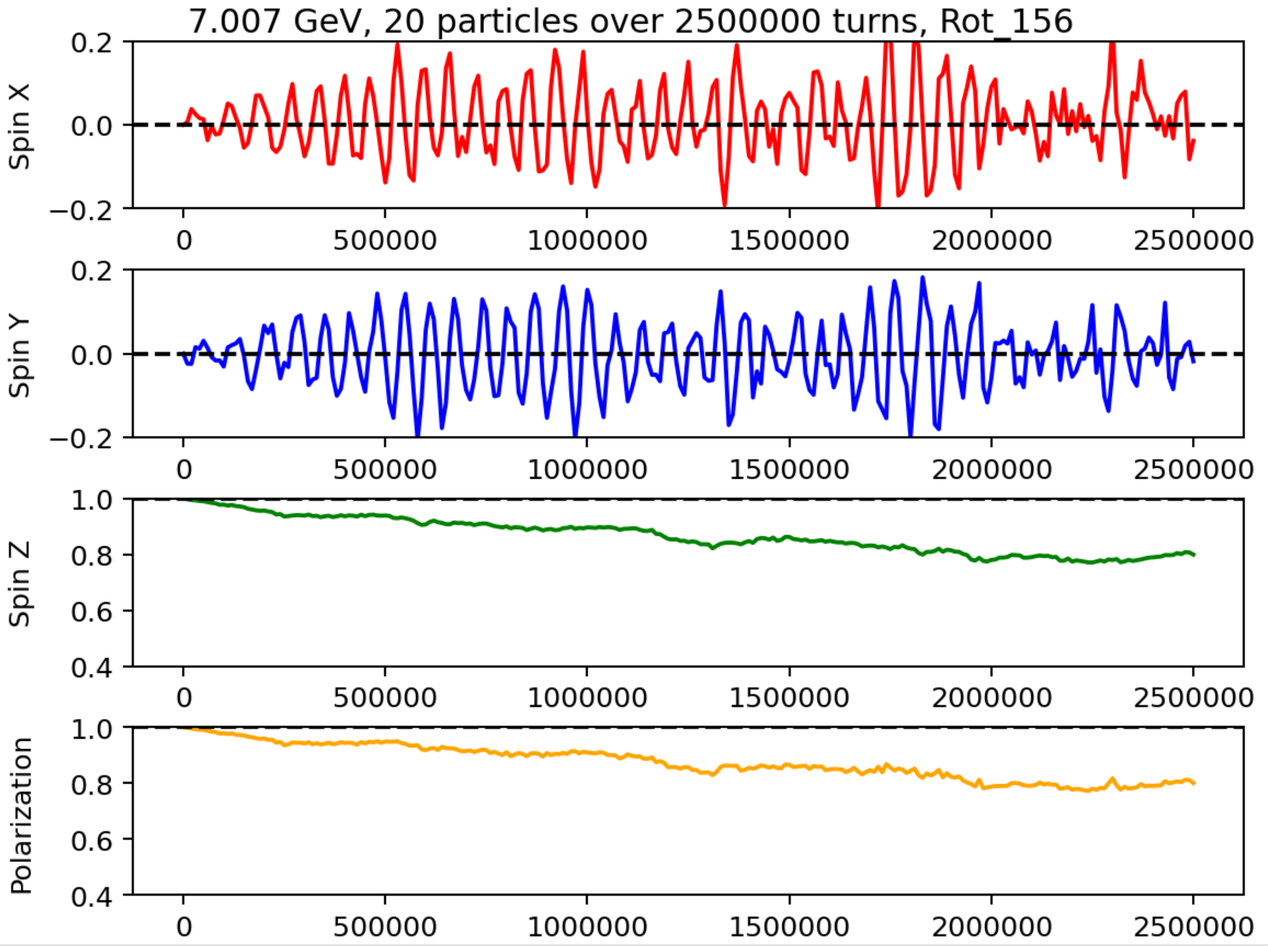
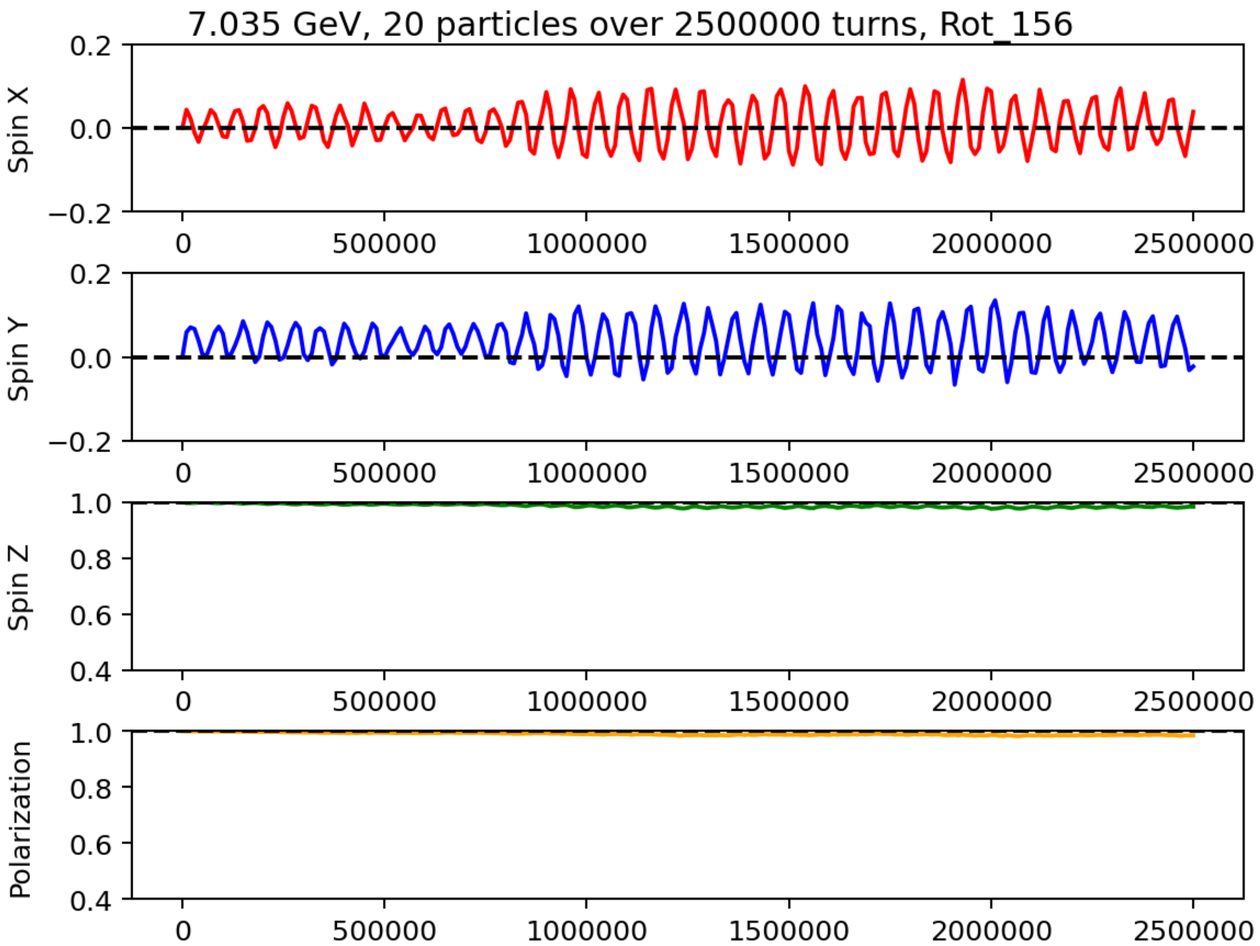


Nominal Energy



Nominal +28 MeV

(Plotted are averages)

Energy Scan Studies

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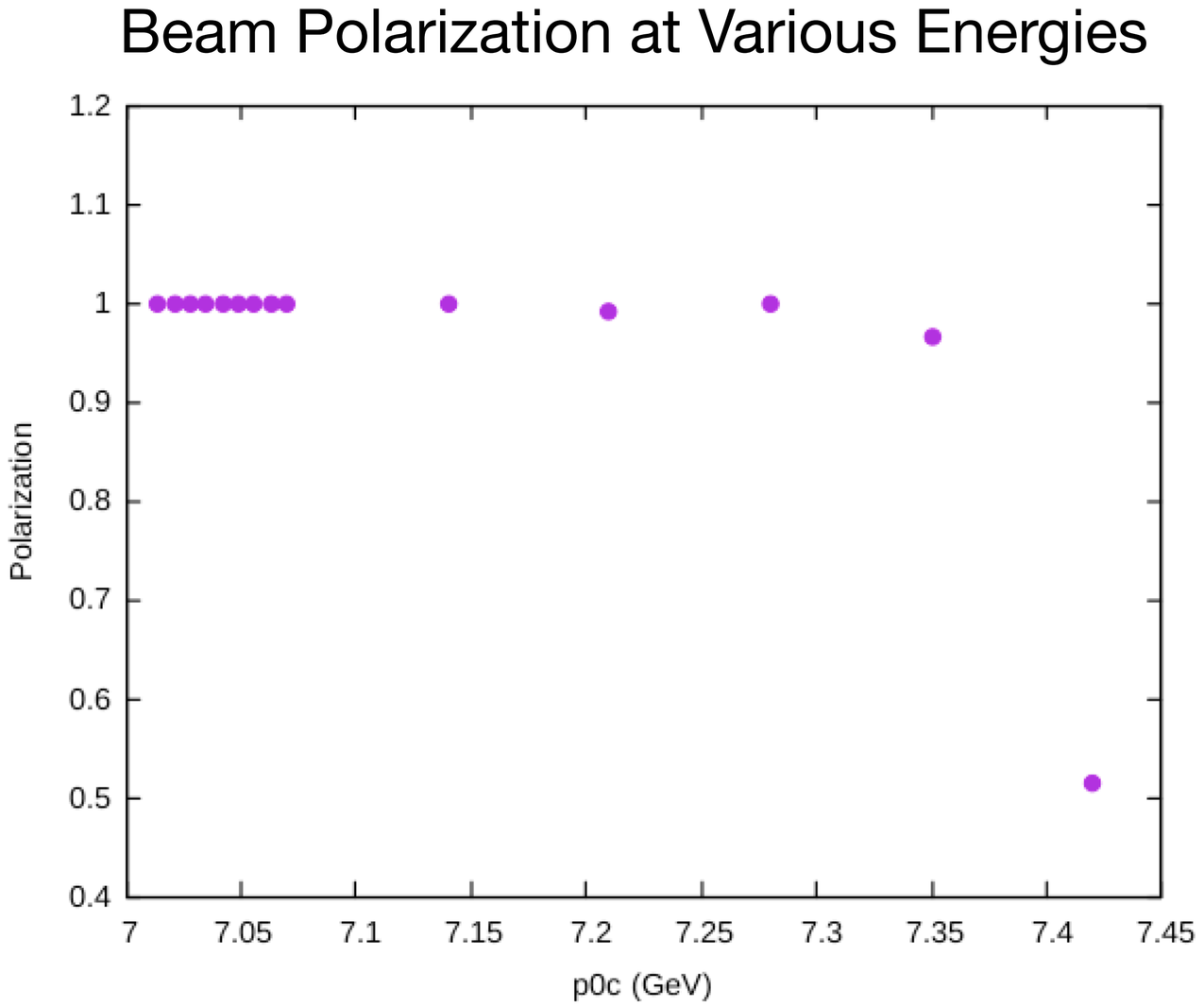
- We are probing the stable R156 spin rotator for various energies up to +5% from the nominal
- 100 particles across 15,000 turns (running currently up to 25,000)
- Ongoing - more tracking studies in the 7.25 to 7.45 GeV region



Polarization Lifetime Studies

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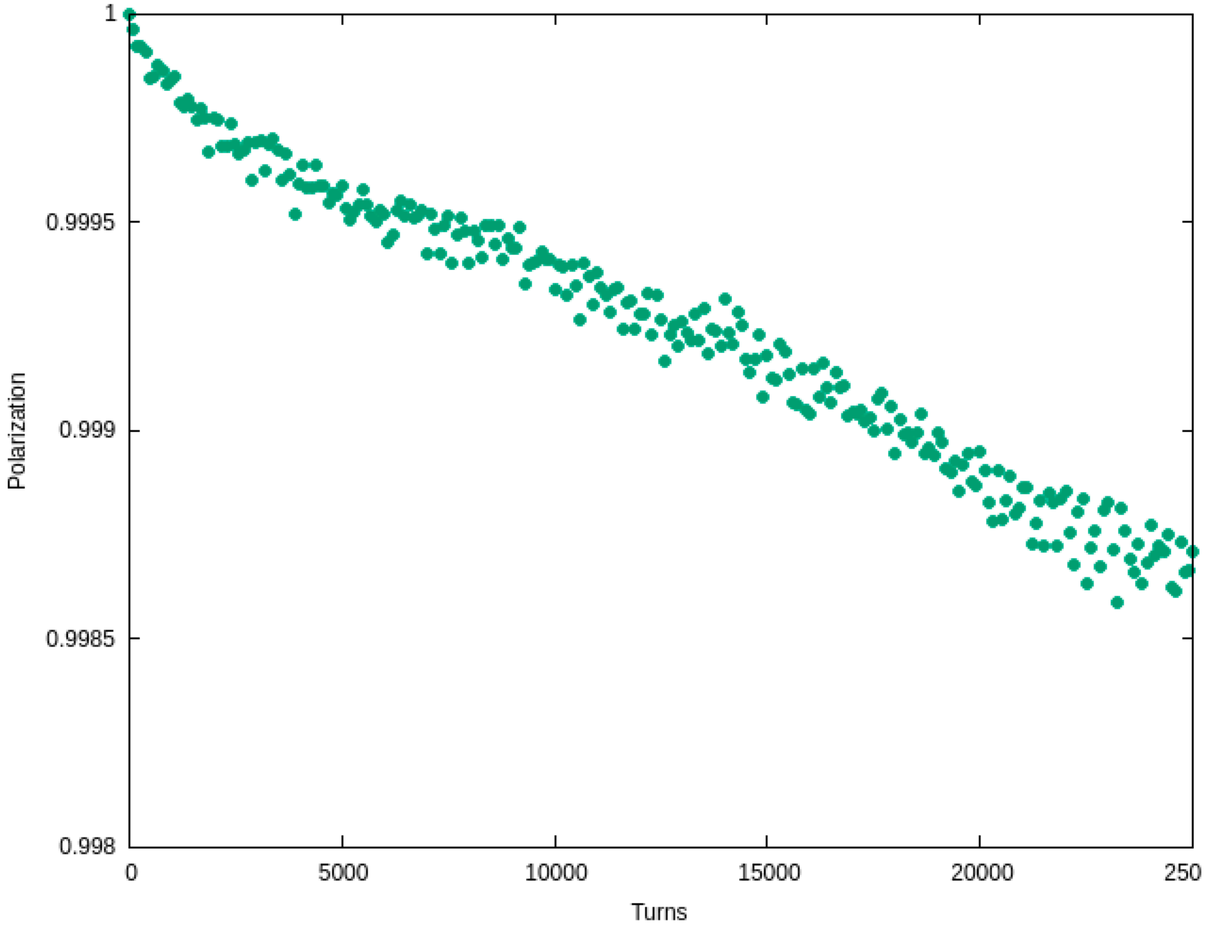
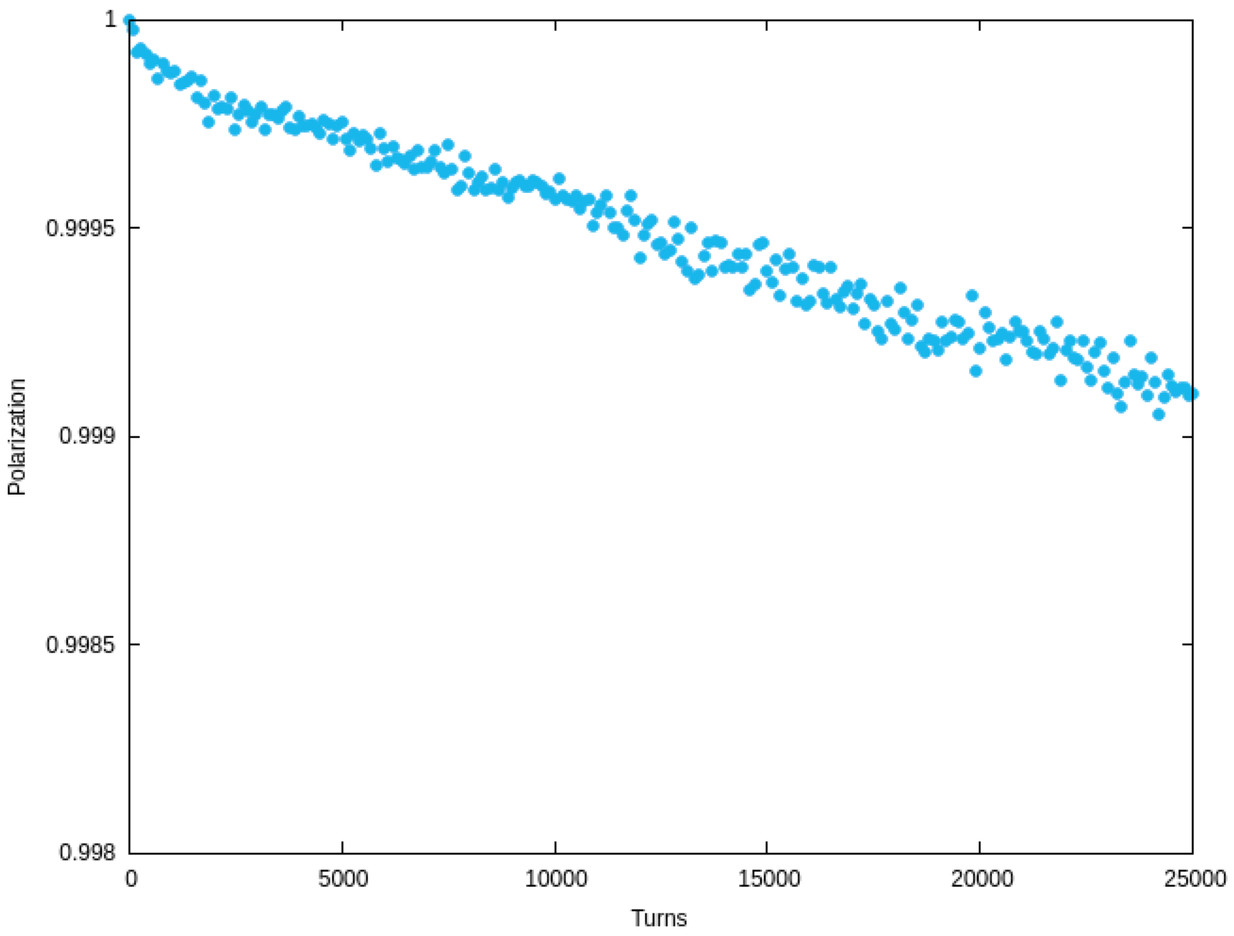
7.014 GeV



τ (1/e) = ~7,670,000 turns (~77 seconds)

7.021 GeV



τ (1/e) = ~17,000,000 turns (~170 seconds)

Polarization Lifetime Studies

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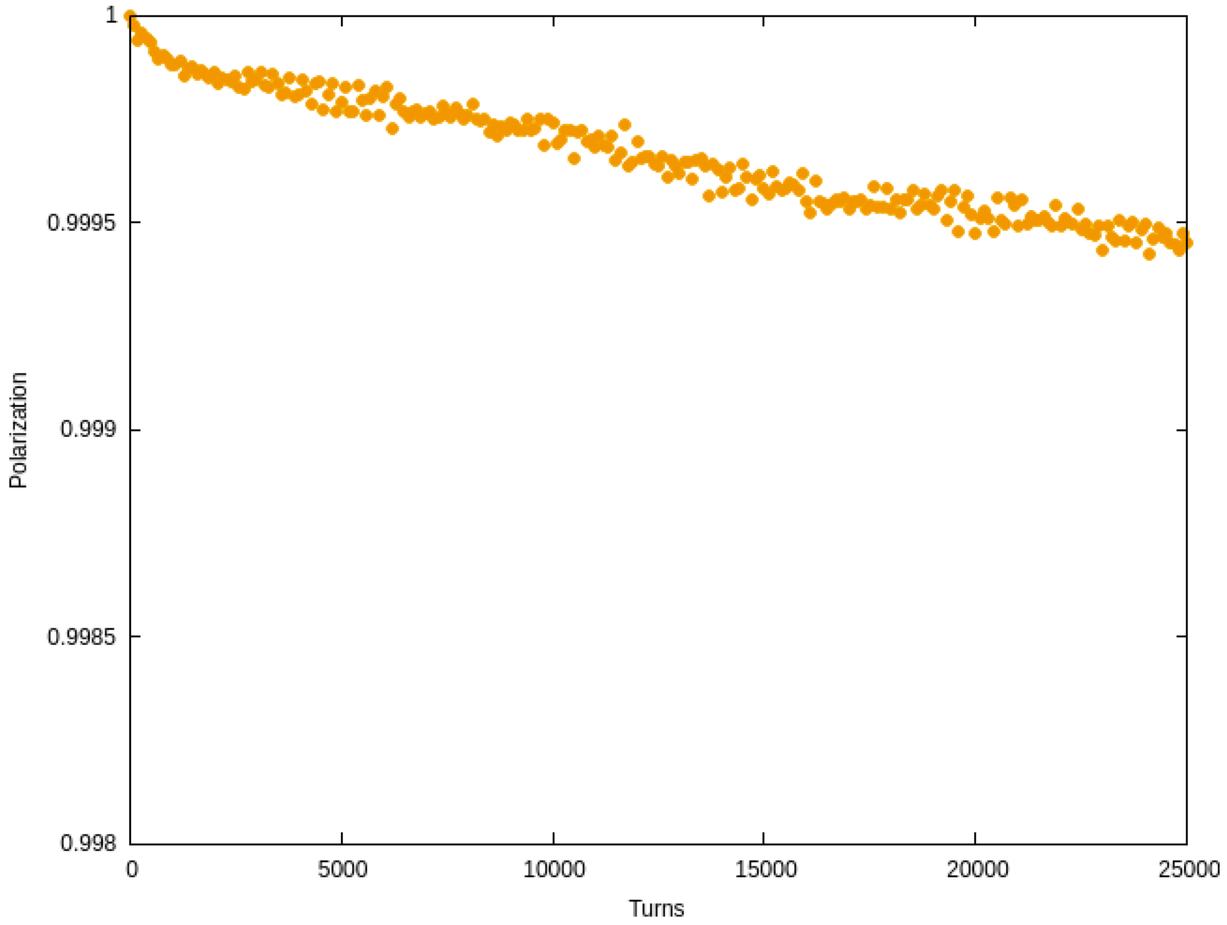
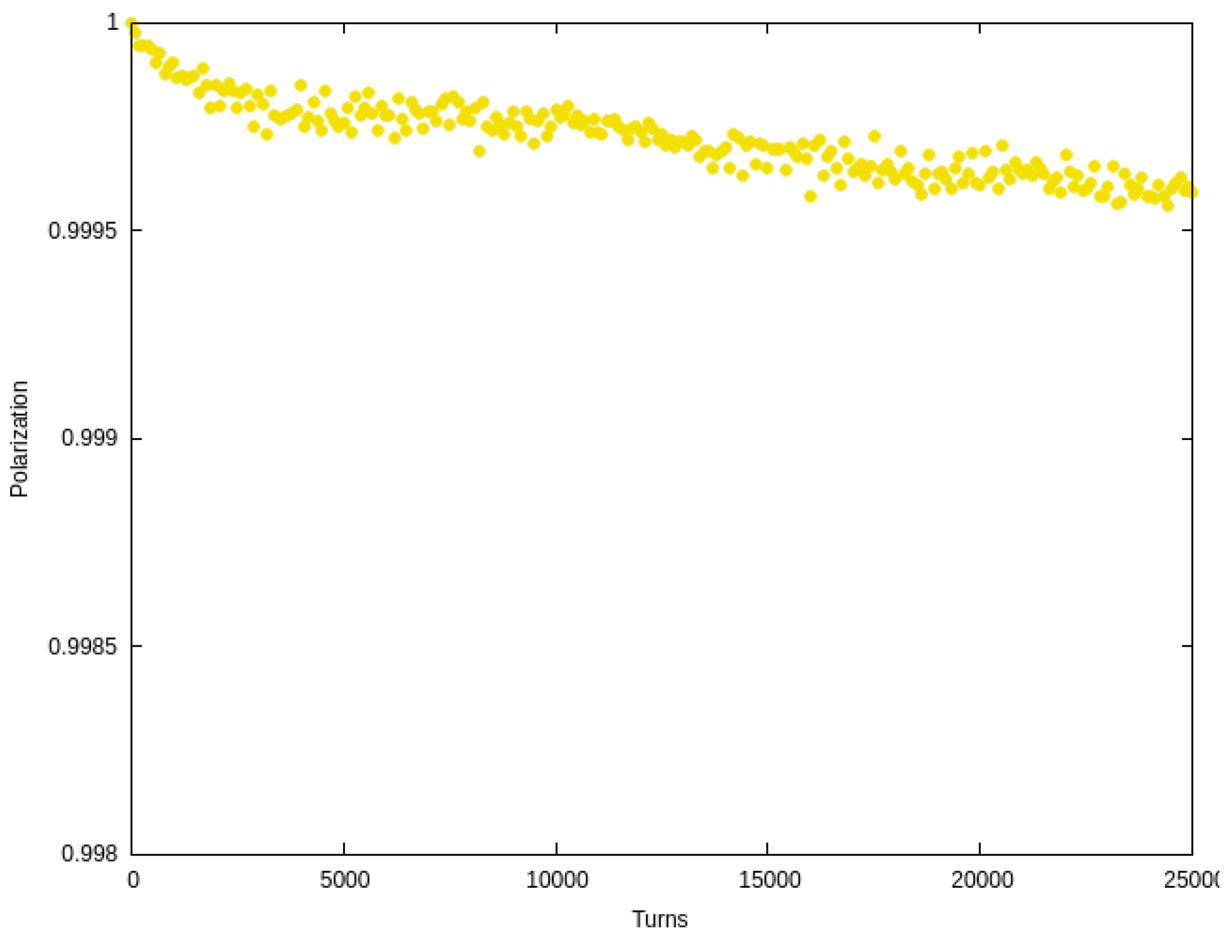
7.028 GeV



τ (1/e) = ~32,400,000 turns (~324 seconds)

7.035 GeV



τ (1/e) = ~43,400,000 turns (~434 seconds)

Polarization Lifetime Studies

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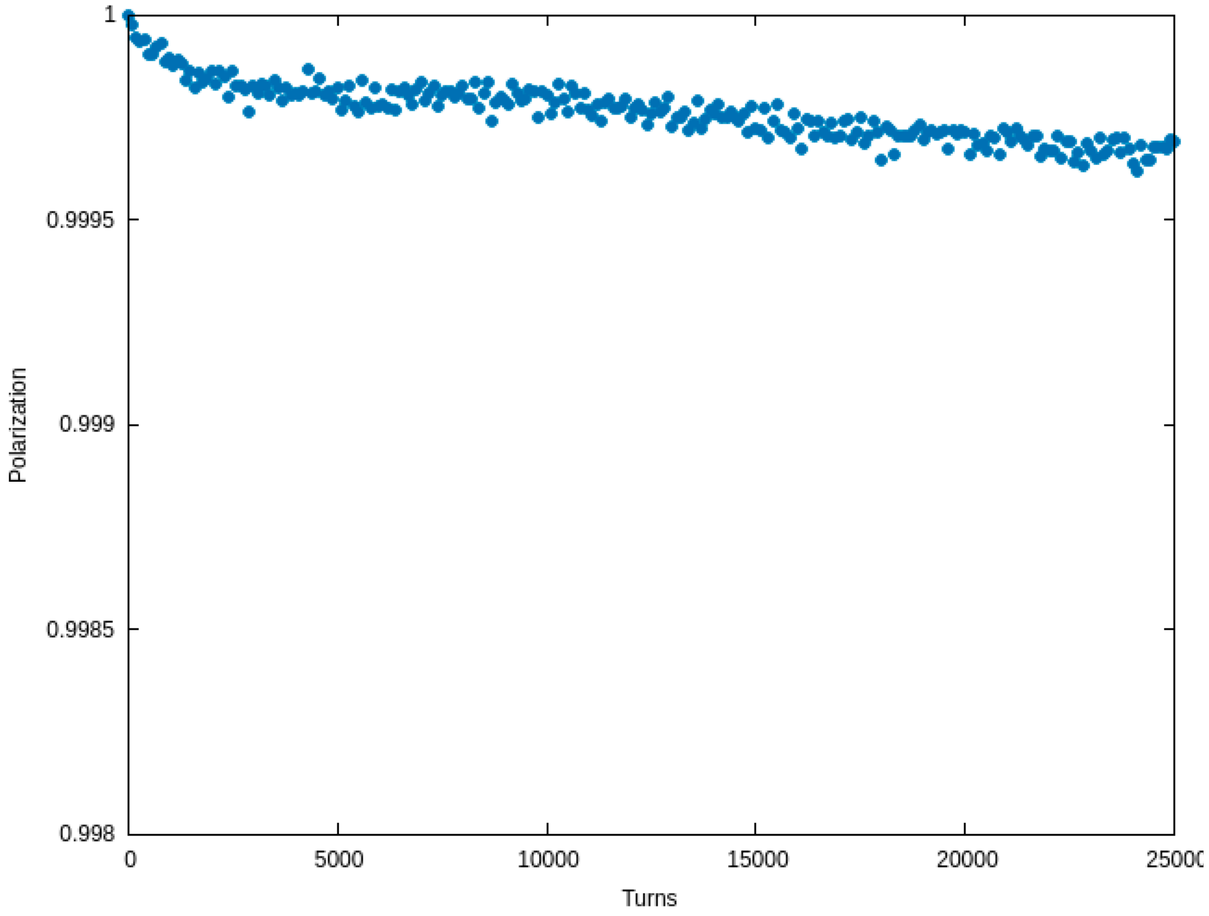
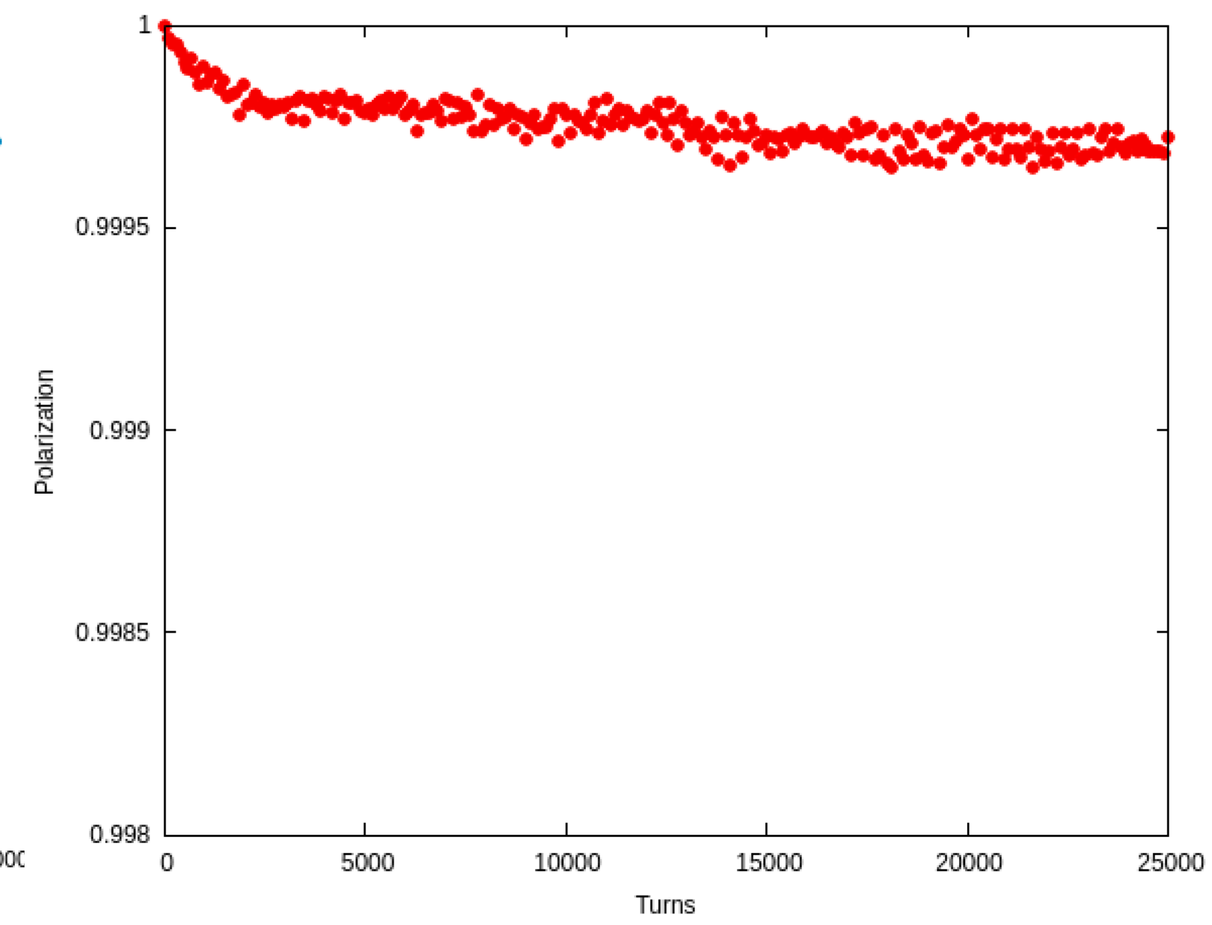
7.042 GeV



7.049 GeV



τ (1/e) = ~70,000,000 turns (~700 seconds)

τ (1/e) = ~83,500,000 turns (~835 seconds)

Preliminary FMA of R156

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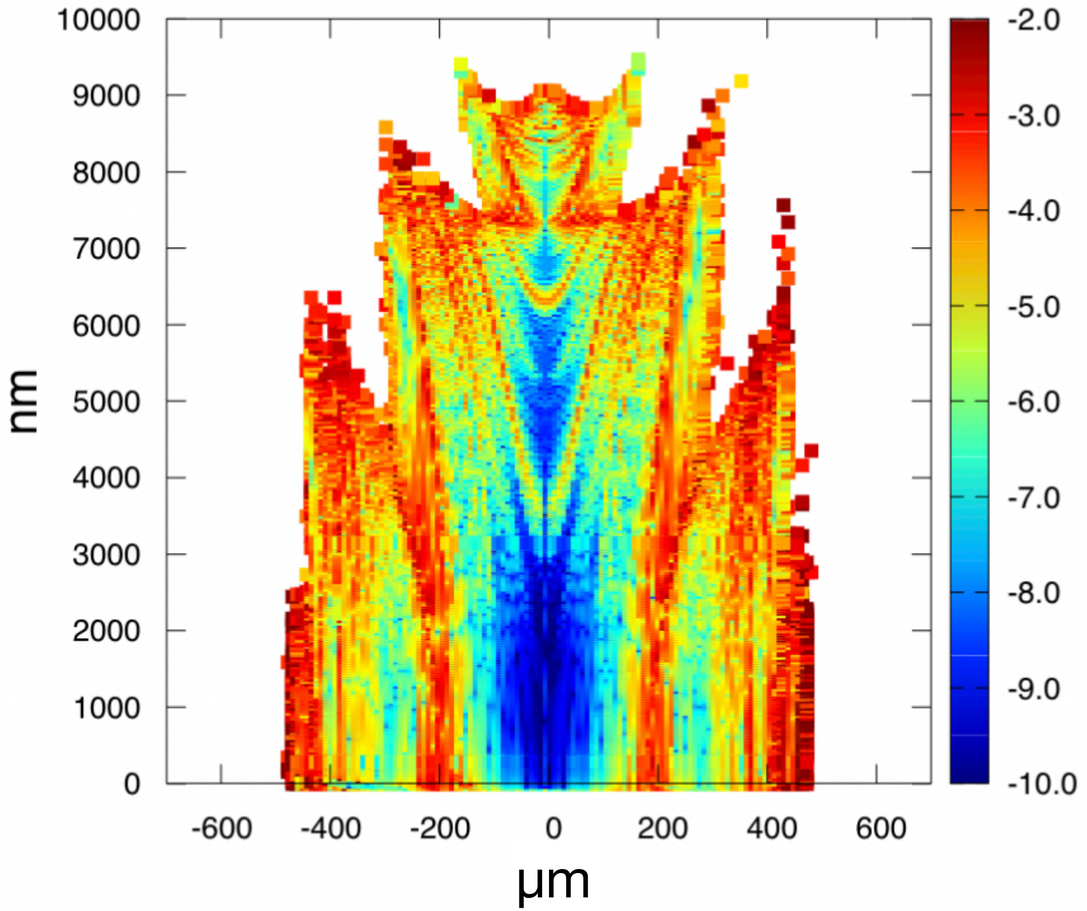
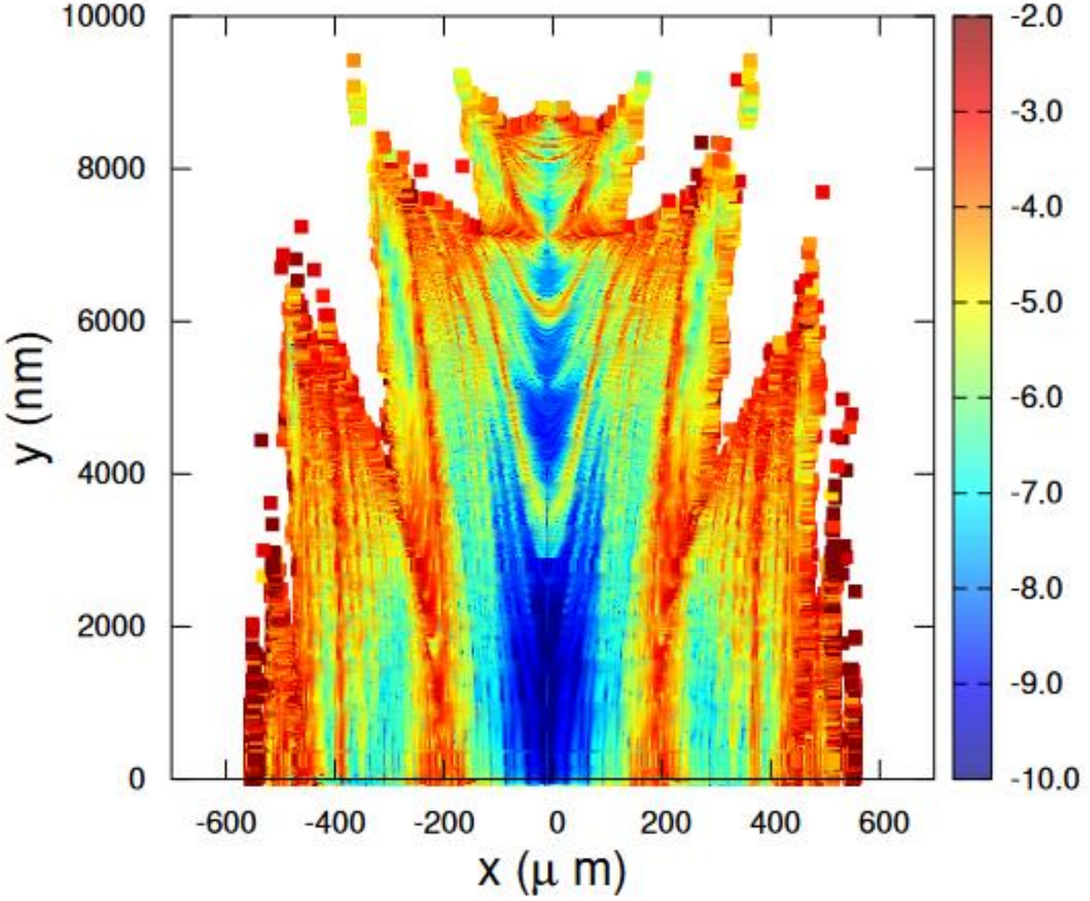
R96



HER



(Previous Results from last year)

Preliminary FMA of R156

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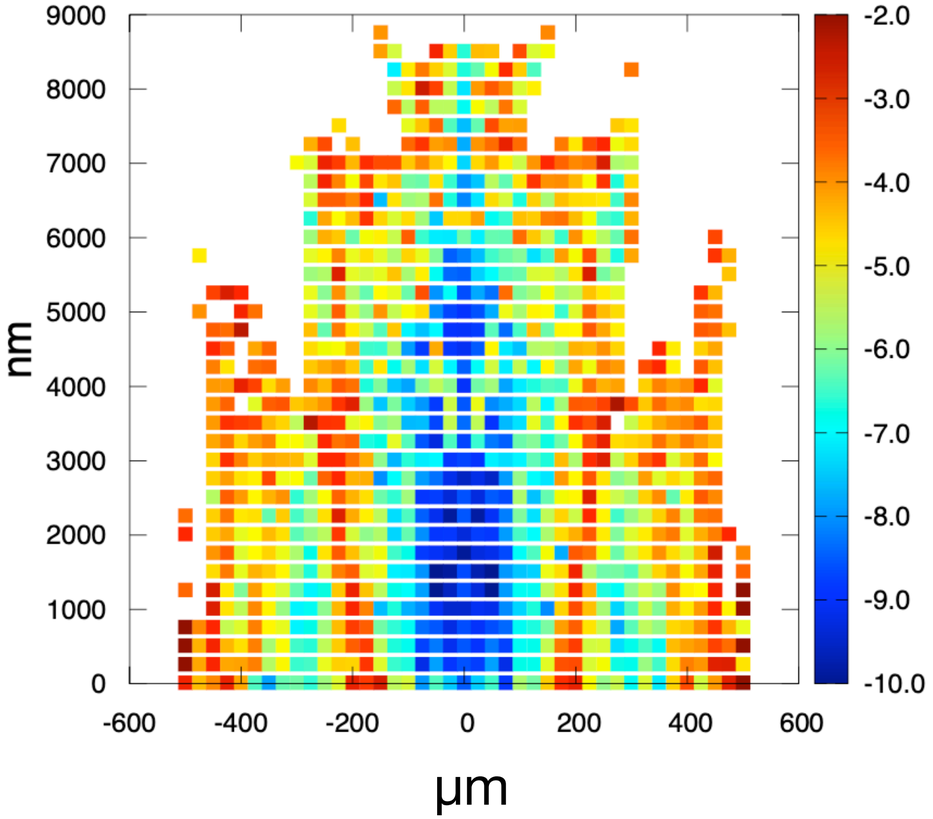
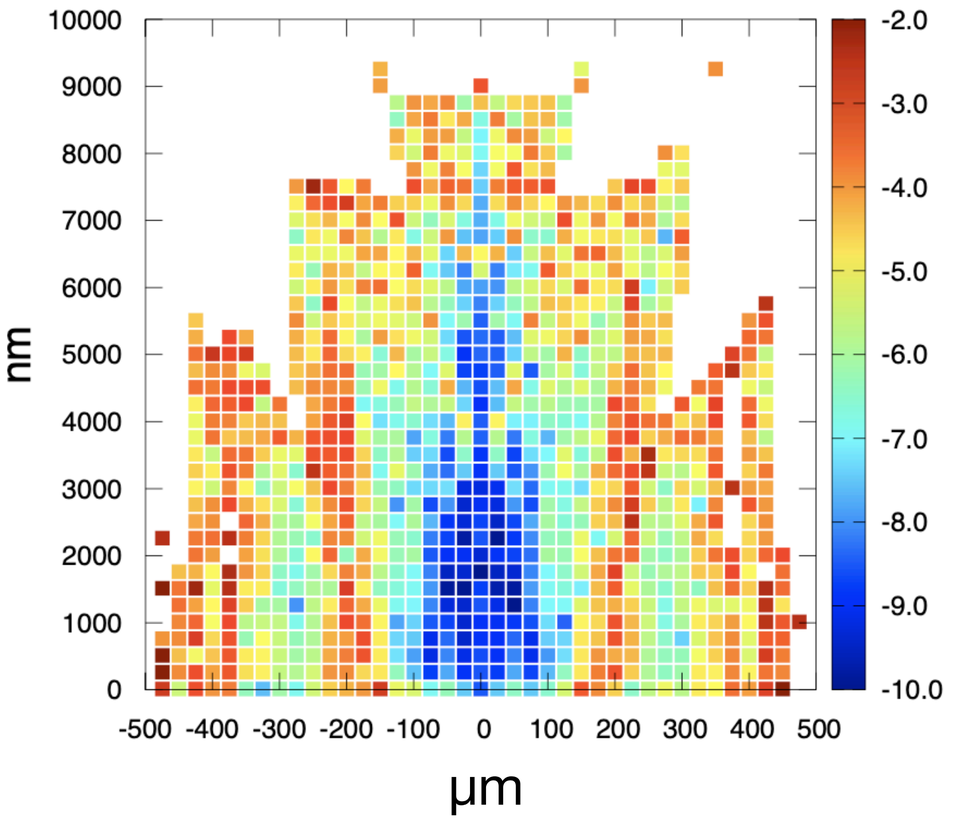
R156



R96 (Yuhao)



(Still need higher resolution final plots)

Preliminary FMA of R156

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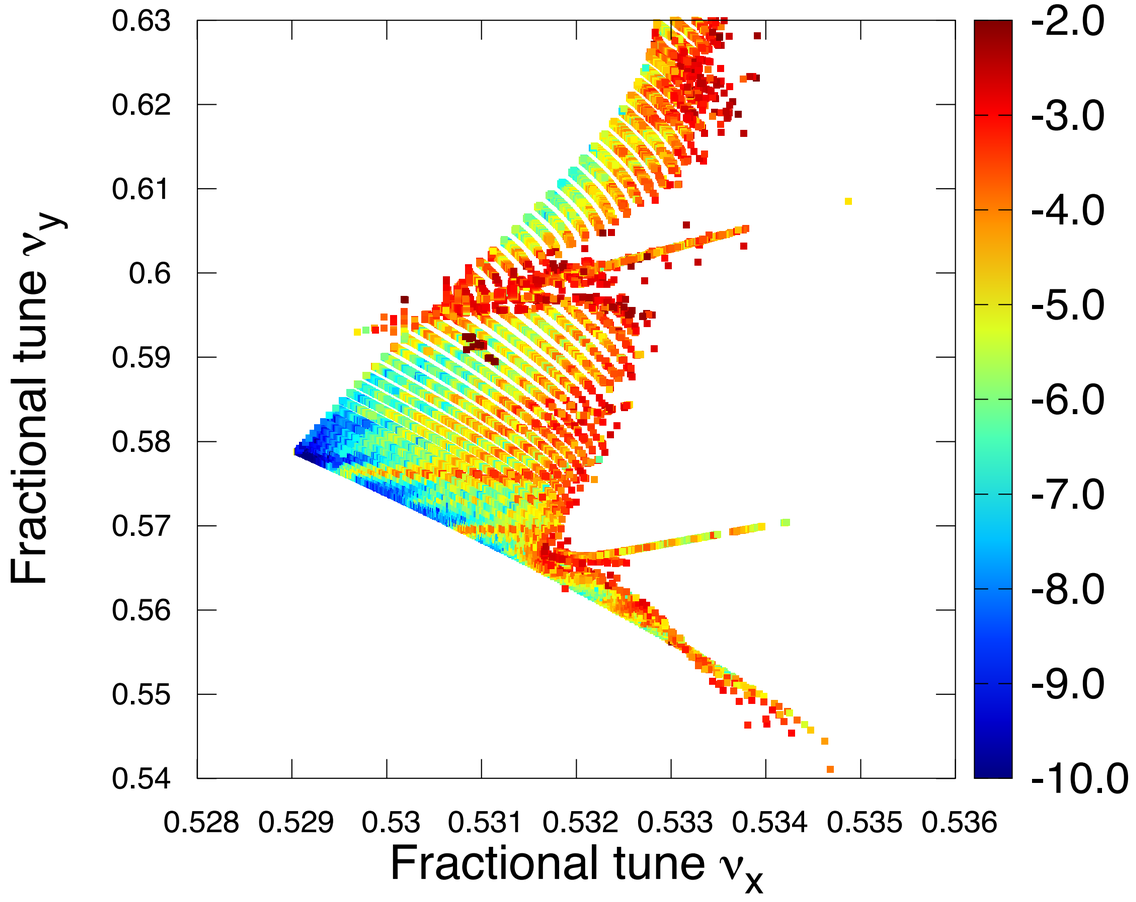
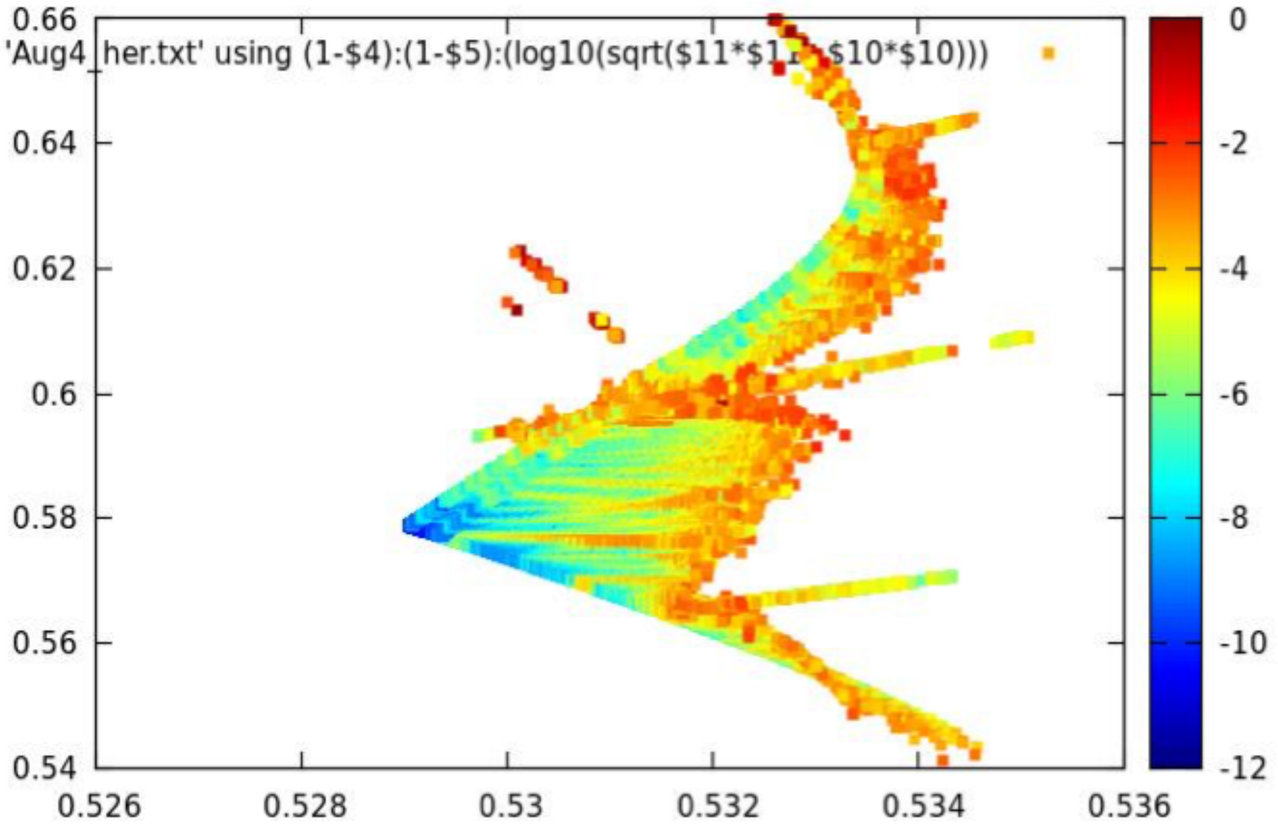
R96



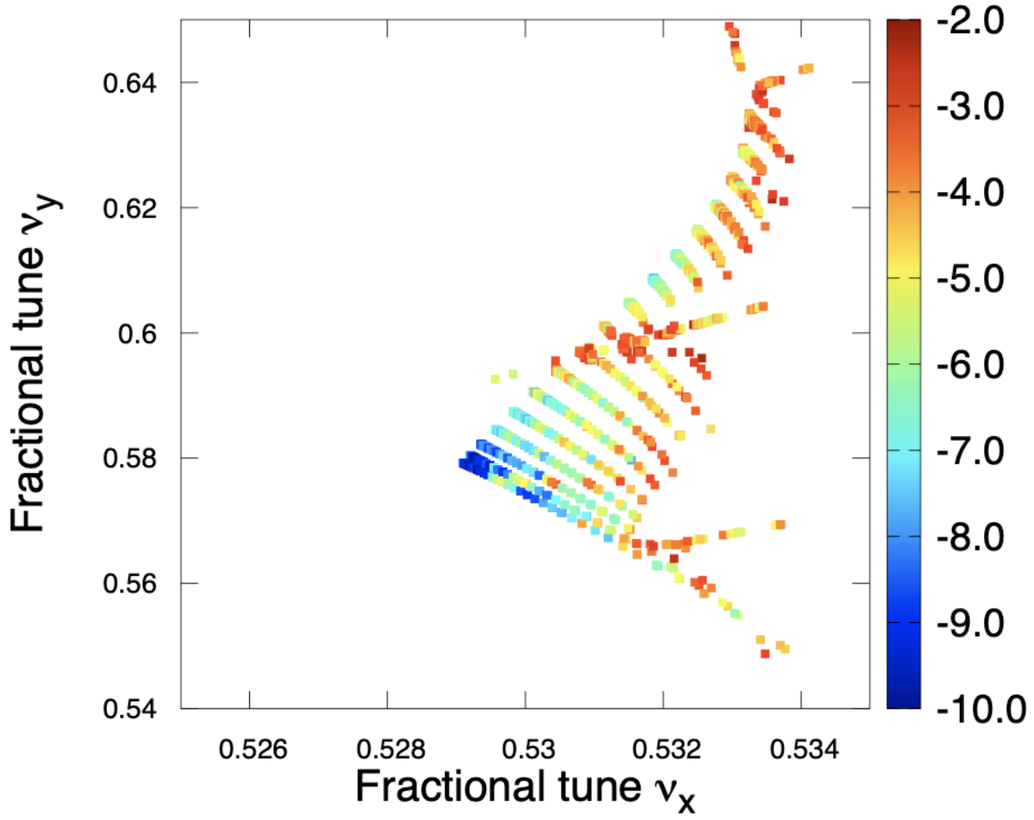
HER (old)



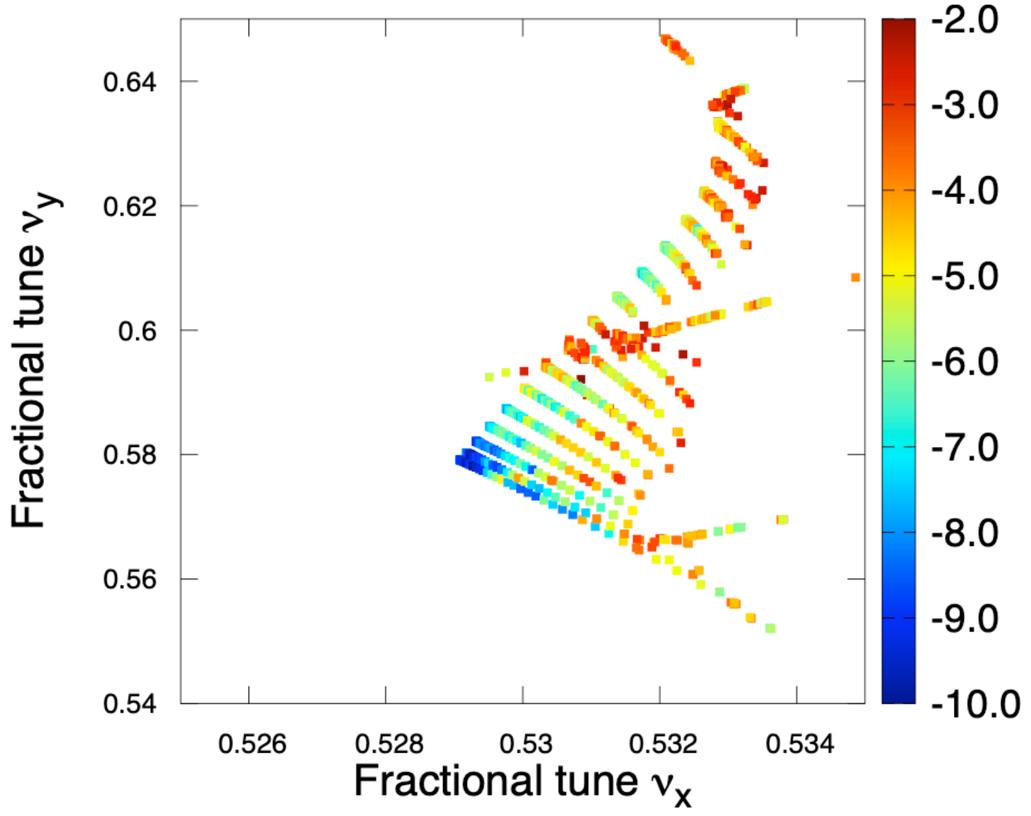
Preliminary FMA of R156

University of Victoria

R156



R96 (Yuhao)



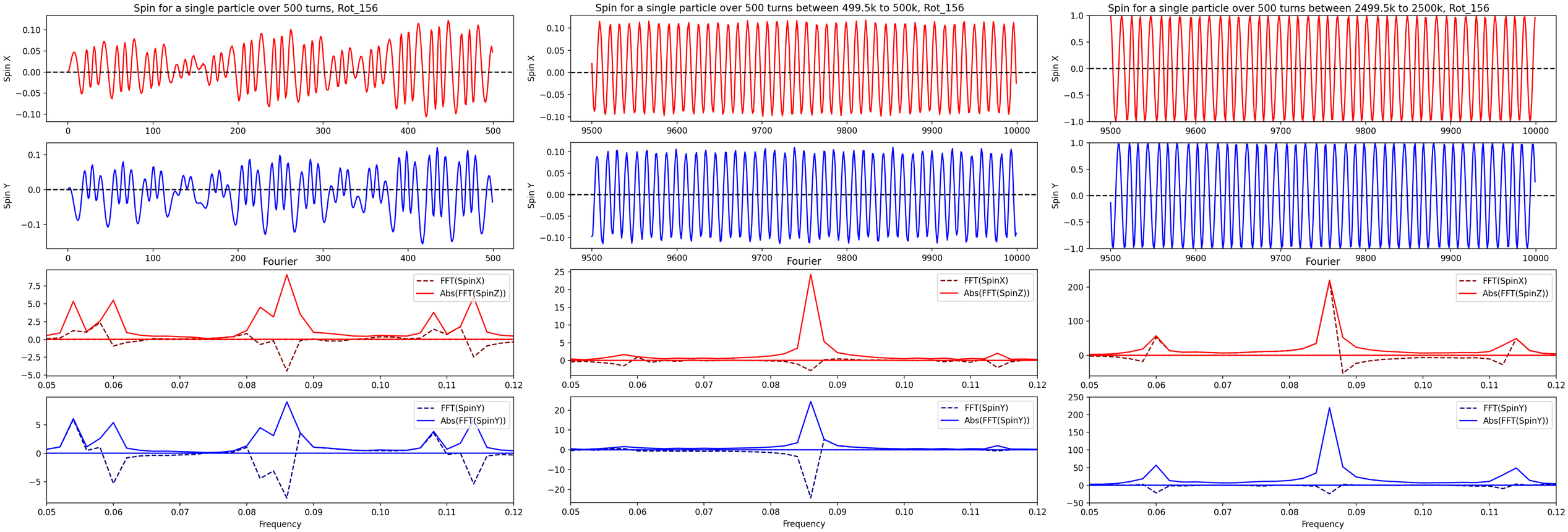
(Still need higher resolution final plots)

Spin Tune Studies

First 500 turns

500 turn window near 500k turns

500 turn window near 2.5M turns



Peak Frequency: 0.08617

(Does not depend on number of turns)

7.007GeV (nominal)

(Unscaled)

Spin Tune Studies

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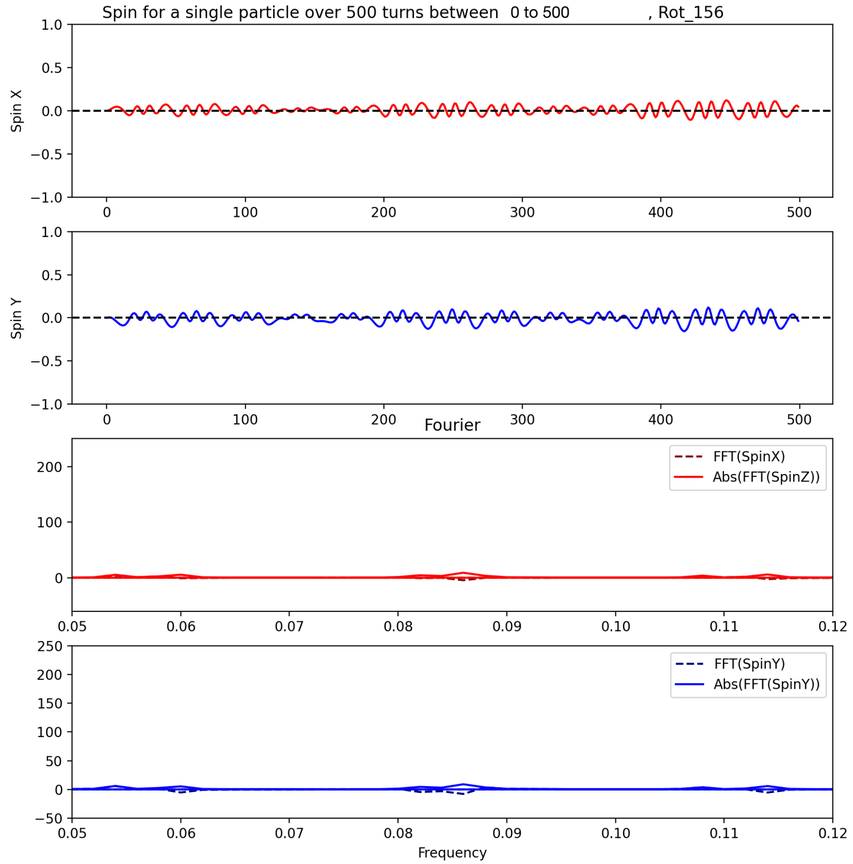

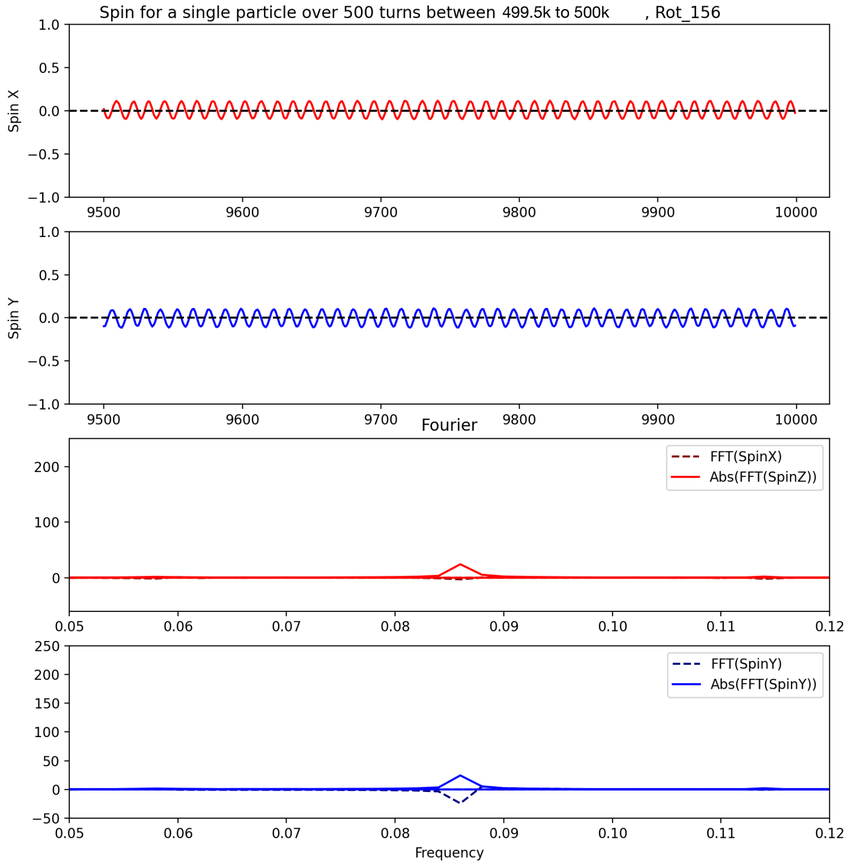

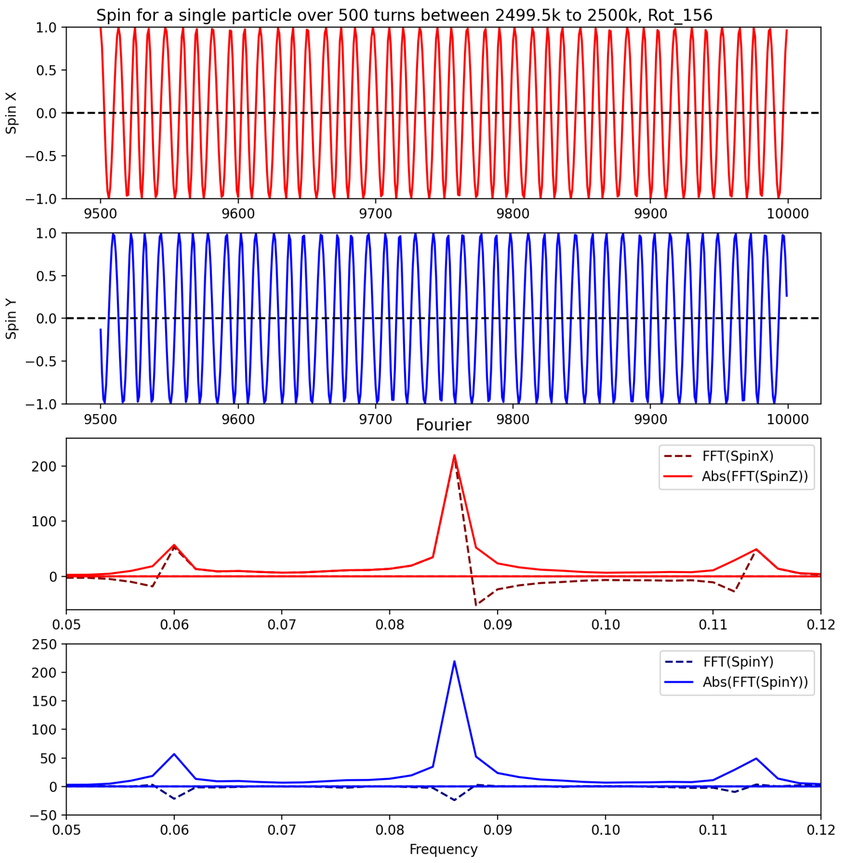

Peak Frequency: 0.08617

(Scaled)

What’s in the works

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- Continue the energy scan/probing
- Comprehensive rematch of R156 using most optimal energy that follows expert guidelines
- Spin Tune analysis at the optimal energy
- Higher resolution FMA studies at optimal energy
- Increased turns and particles for LTT at optimal energy

Future Plans

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- Study the effect of placement tolerances for machine elements
- Translate Rot_156 from BMAD to SAD and repeat studies
- Touschek Scattering
- Beam-Beam effects
- And more…?