Spin Rotator Stability Studies

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What we've been working on:

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- Improvements to the Spin Rotator Design in BMAD
  - Mixed Slice Studies
  - Increased Slice Studies
- Long-Term Tracking (LTT) of the 156 slice spin rotator with radiative dampening (RF on) and quantum fluctuations (LTT takes into account non-linear effects)
  - PMID studies
  - Polarization/Spin Retention Studies
  - Spin Tune Analysis
- Frequency Map Analysis (FMA) of the 156 slice spin rotator

Difficulties with other slice models

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The complete optical rematch is difficult.

- Yuhao believed that beyond 96 slices, it would be very difficult to match. We thought it would be quick, but…
- Optimizers are extremely sensitive, tend to find local minima instead of true minima.
- Many steps that took little time optimizing in the 96 model require alternative approaches to succeed in the 156 model
- Some models early on simply couldn't be optimized or failed (120, 144)

Mixed Slice Studies

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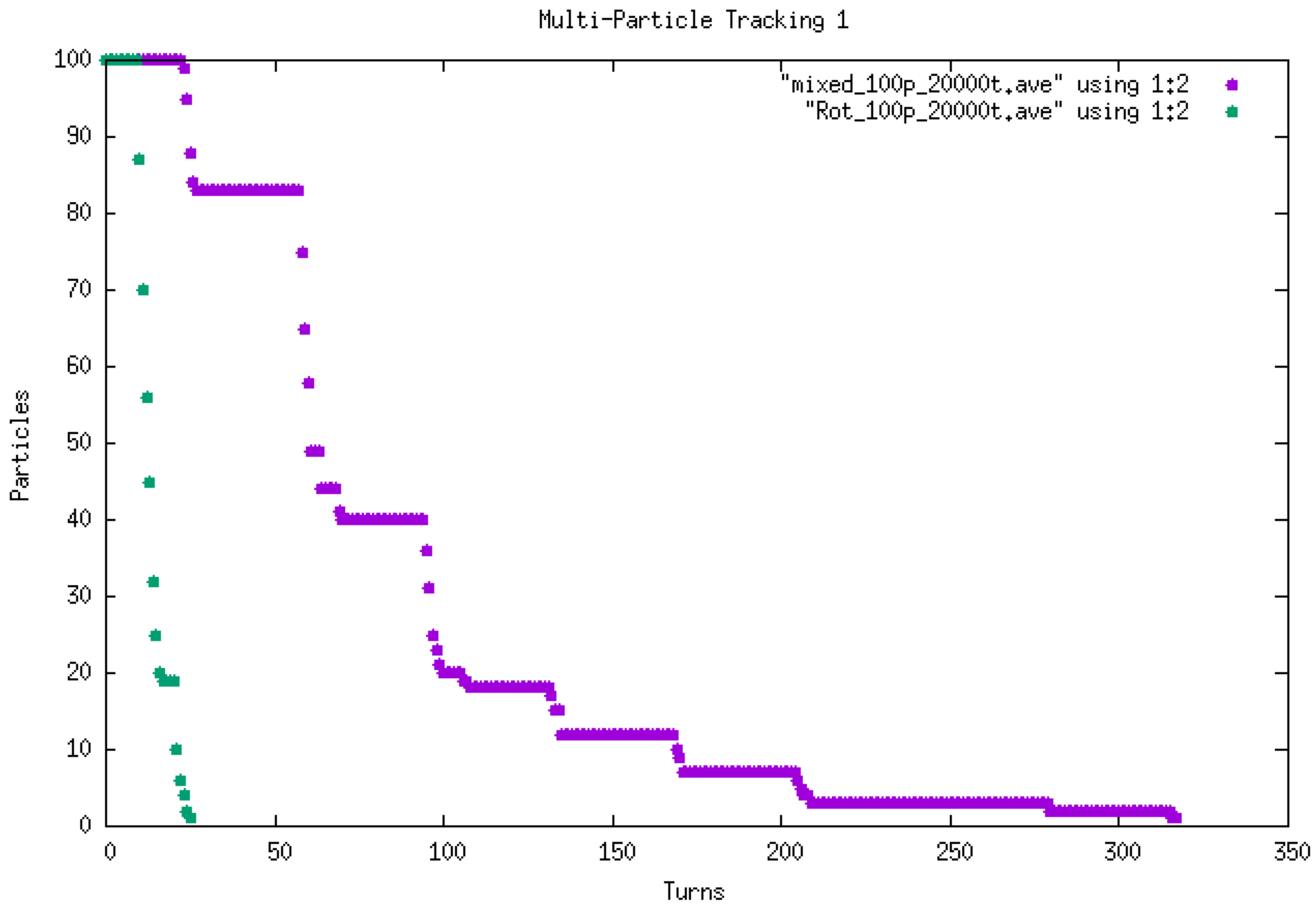
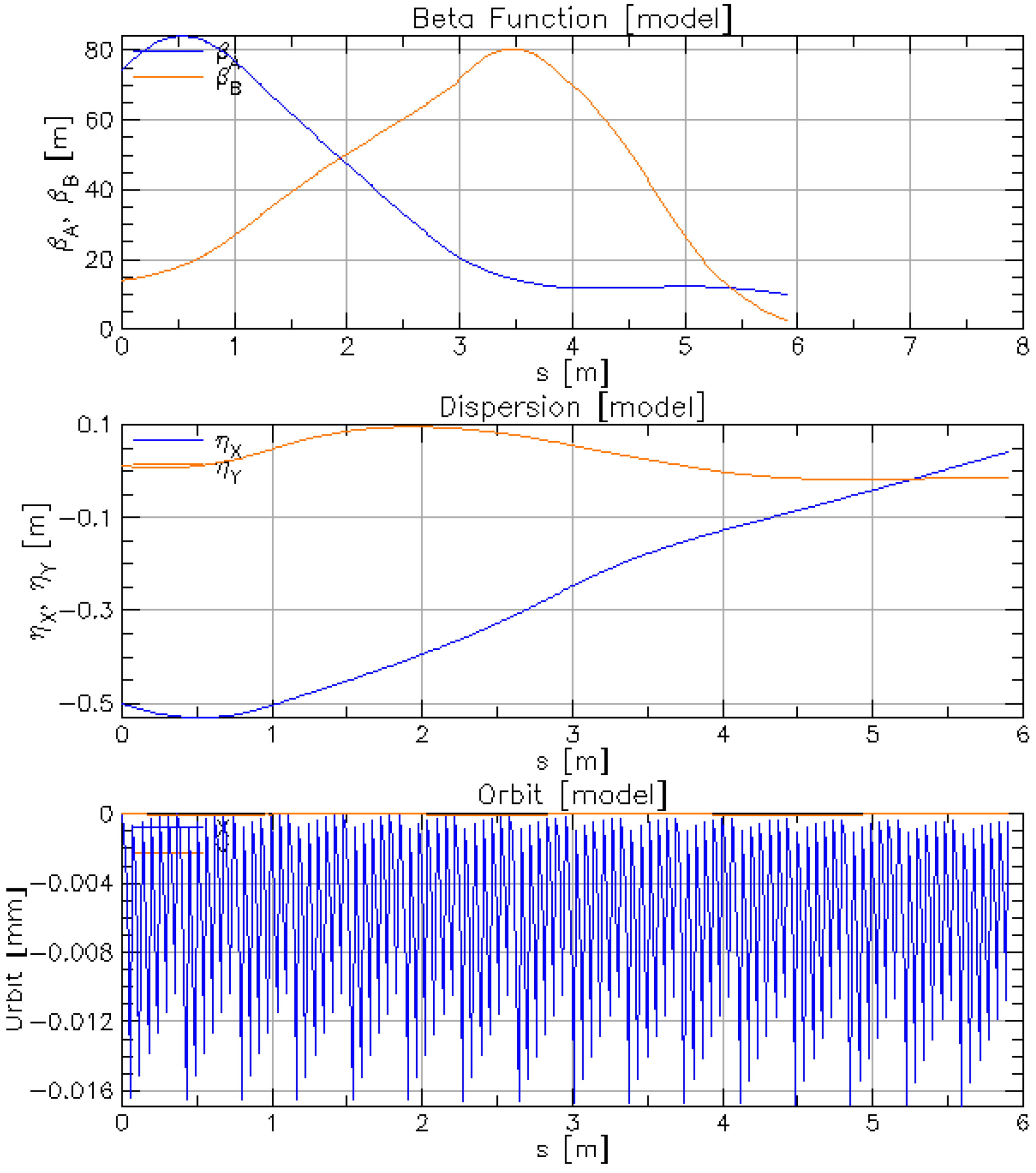
We settled on the 156 slice model since we had success rematching the left rotator (but not the right rotator)

- We decided to use the lrot of the 156 slice rotator alongside the rrot of the 96 slice rotator
- Beta and dispersion functions looked **more HER**-like with increased slicing.
- Performing long term tracking on this mixed rotator showed some initial promising results
- Eventually found a solution and was able to make a complete 156-slice Spin Rotator model

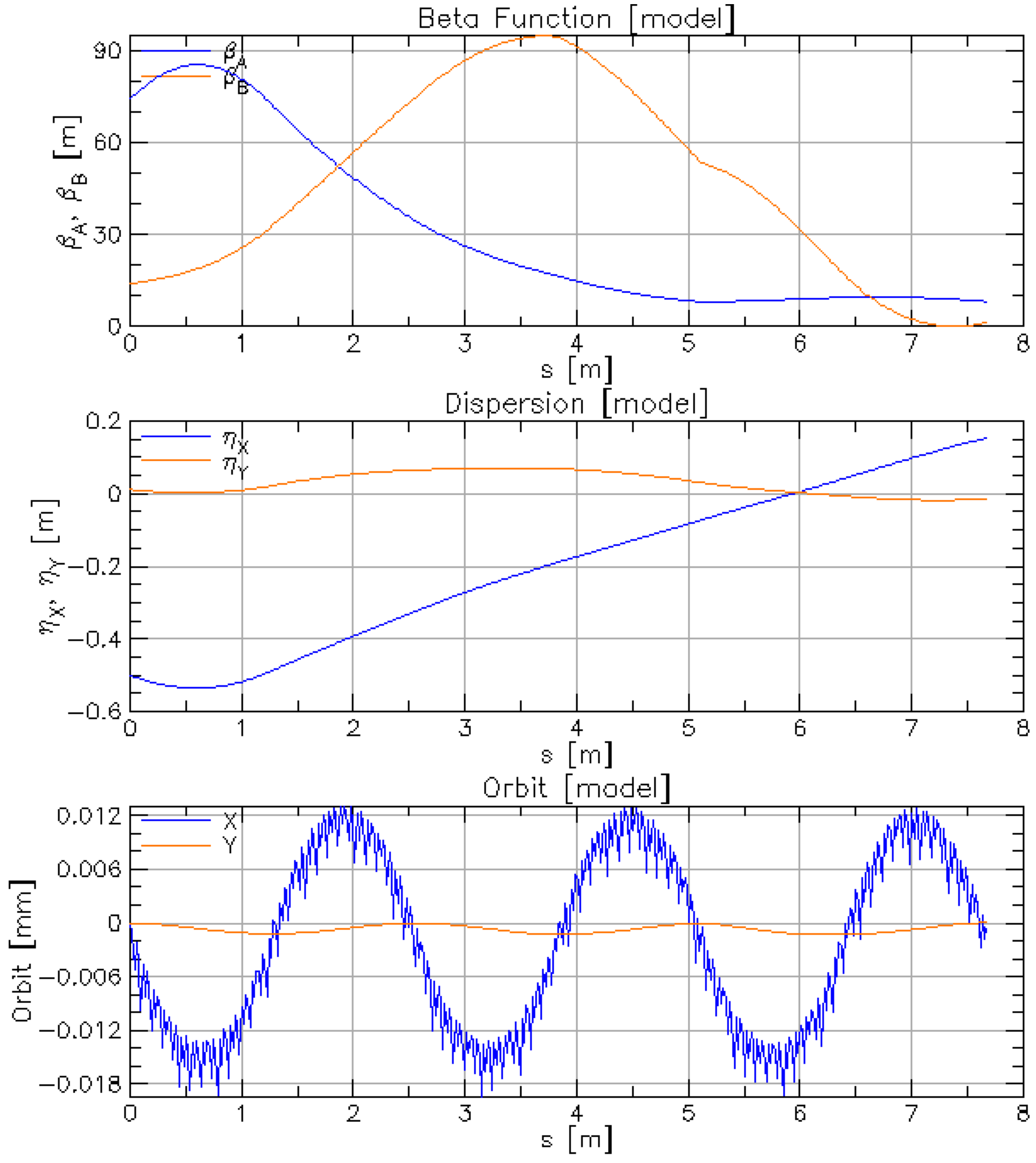


R156 rrot issue discovered

RROT R96 (correct length)



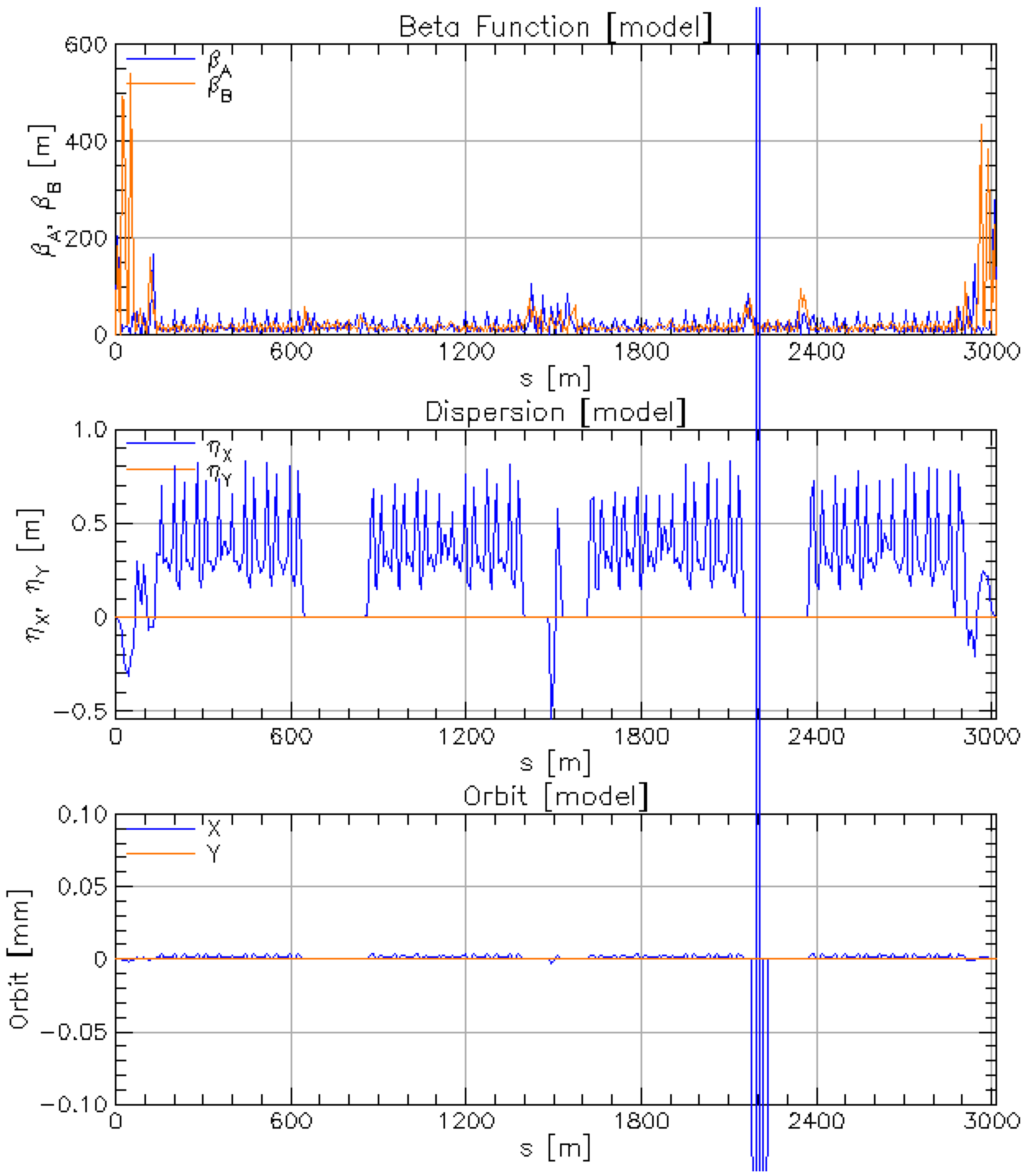
old RROT R156 (incorrect length)



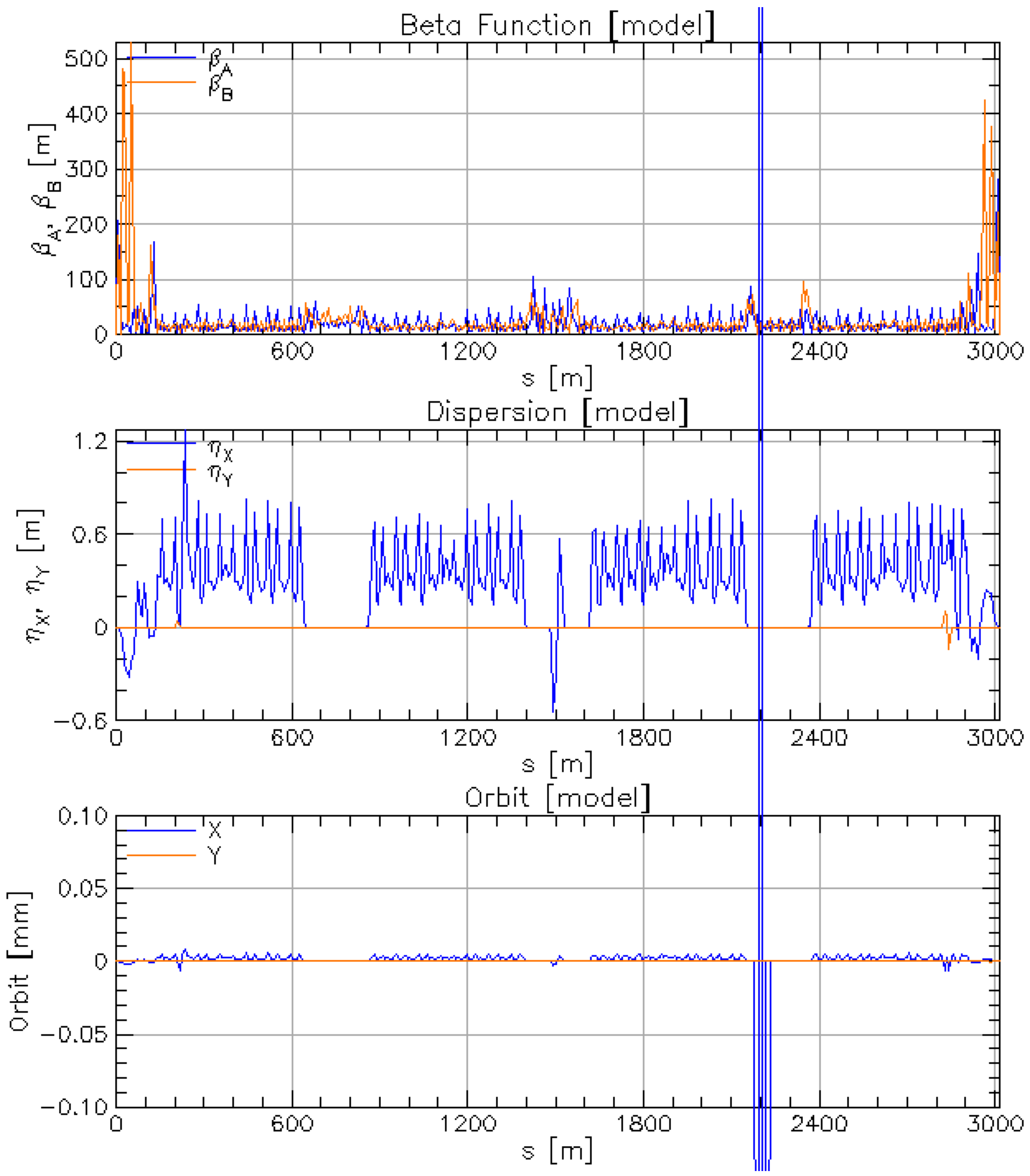
- How I fixed it: went straight to the beginning and found out there was a discrepancy in the length of the right rotator (rrot)
- This + a number of fine adjustments to the fitters over the course of debugging the rrot was enough to completely match

R156 optical rematch results

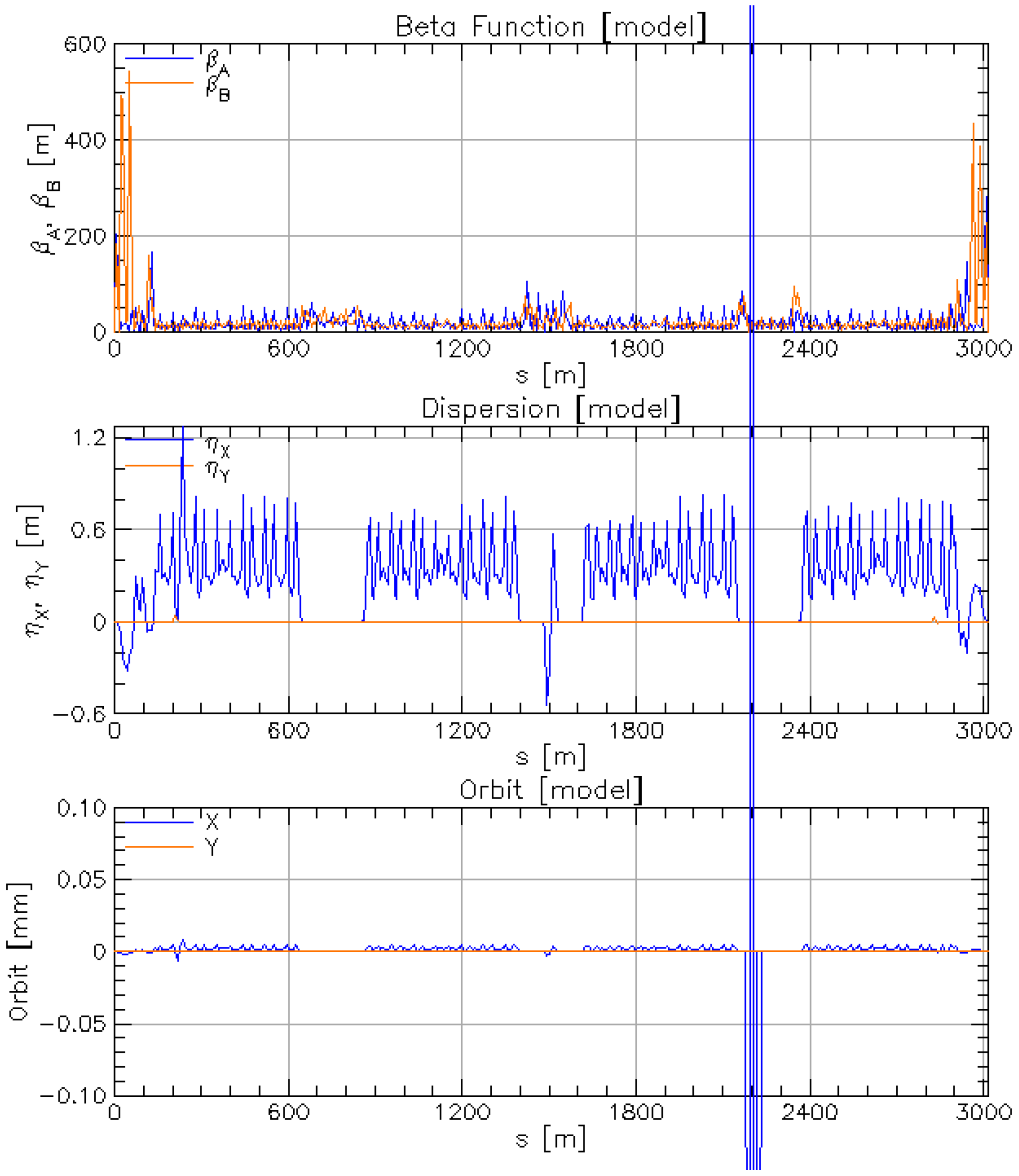
HER only



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>**

R156 spin-retention issues

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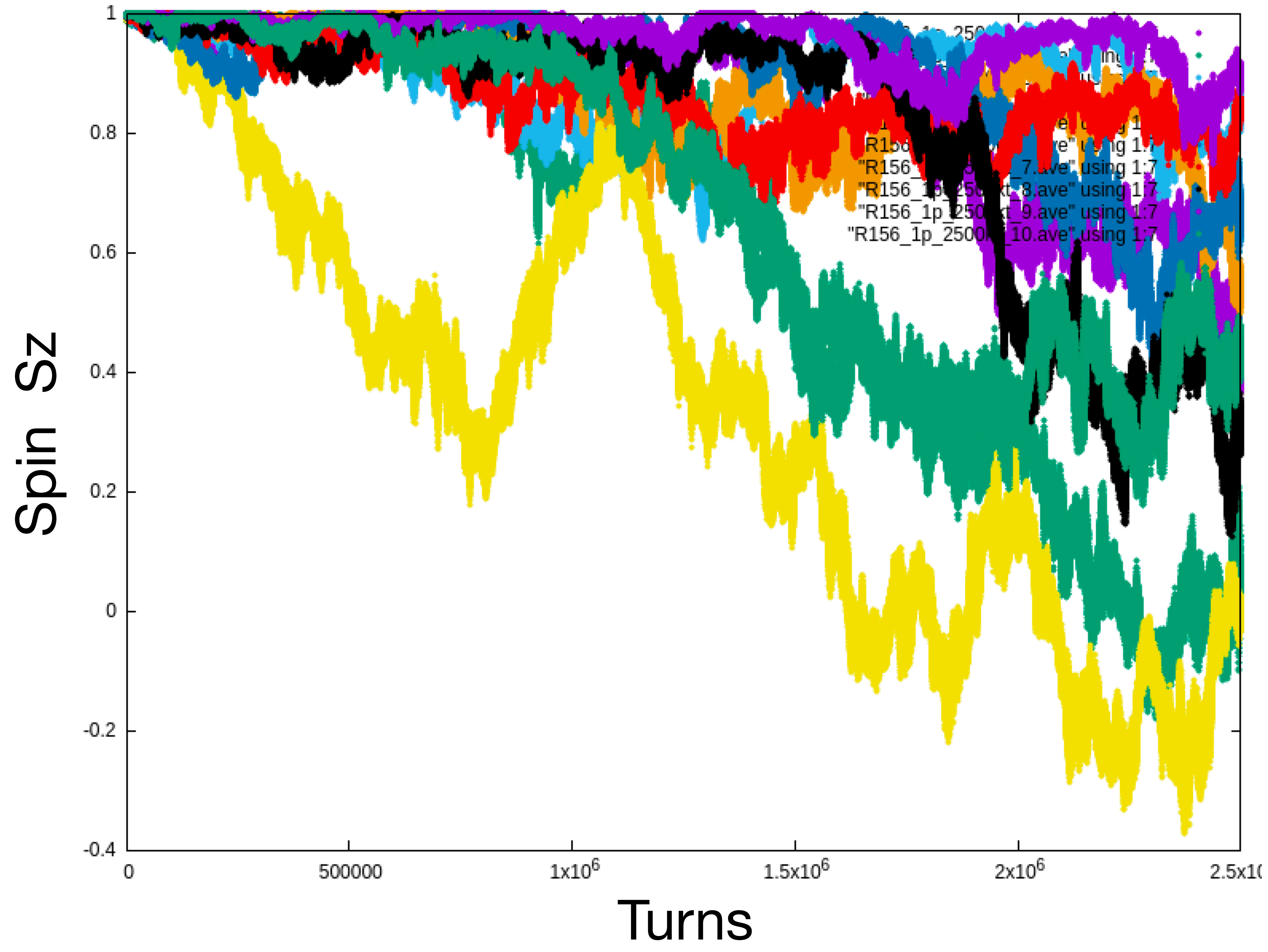
Individual particle spins over 2.5m turns



- However, there is significant loss in spin stability the longer the particle is present in the ring.
- Physics analyses is still possible, though we don't know if this is acceptable.

R156 spin-retention issues

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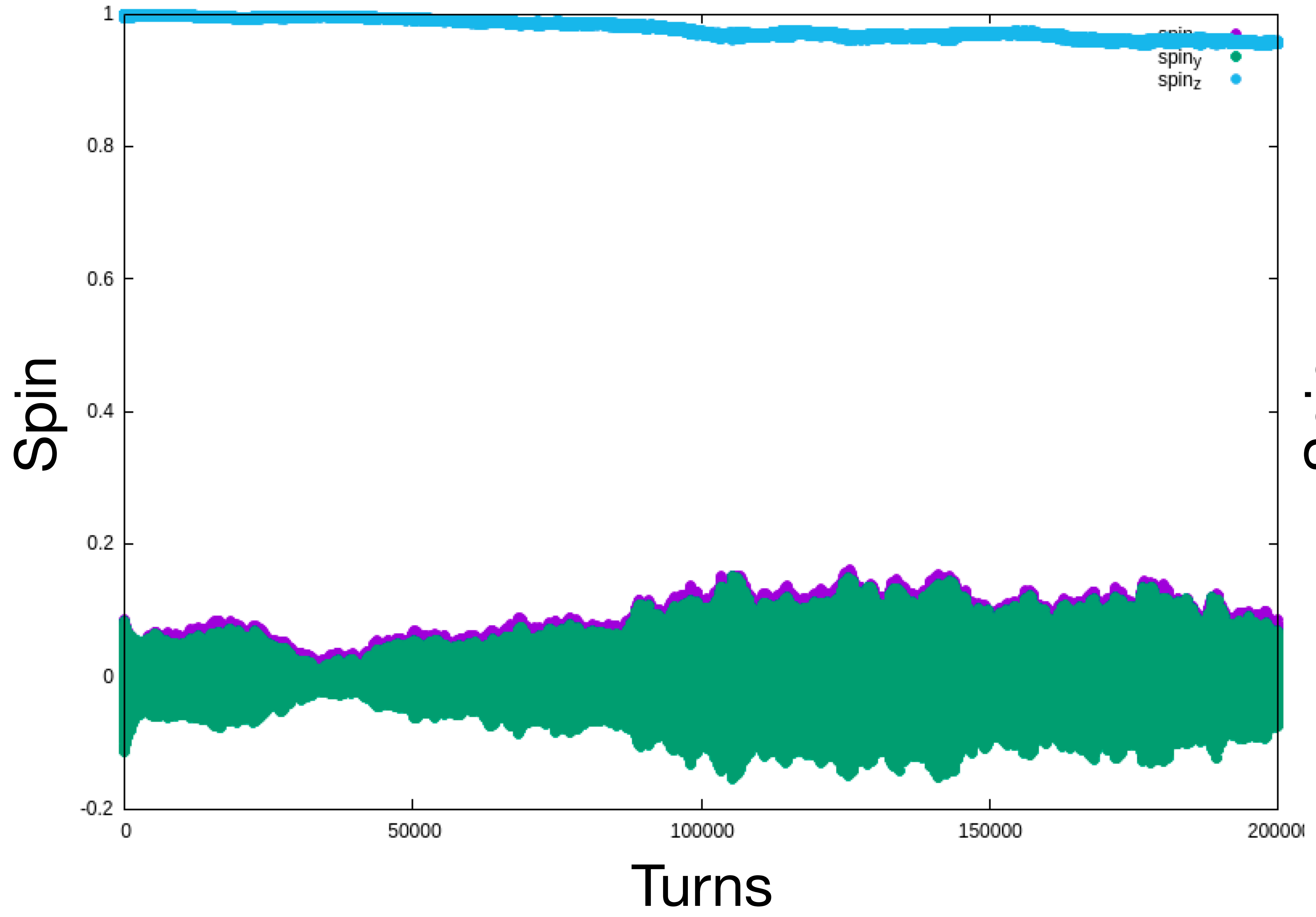
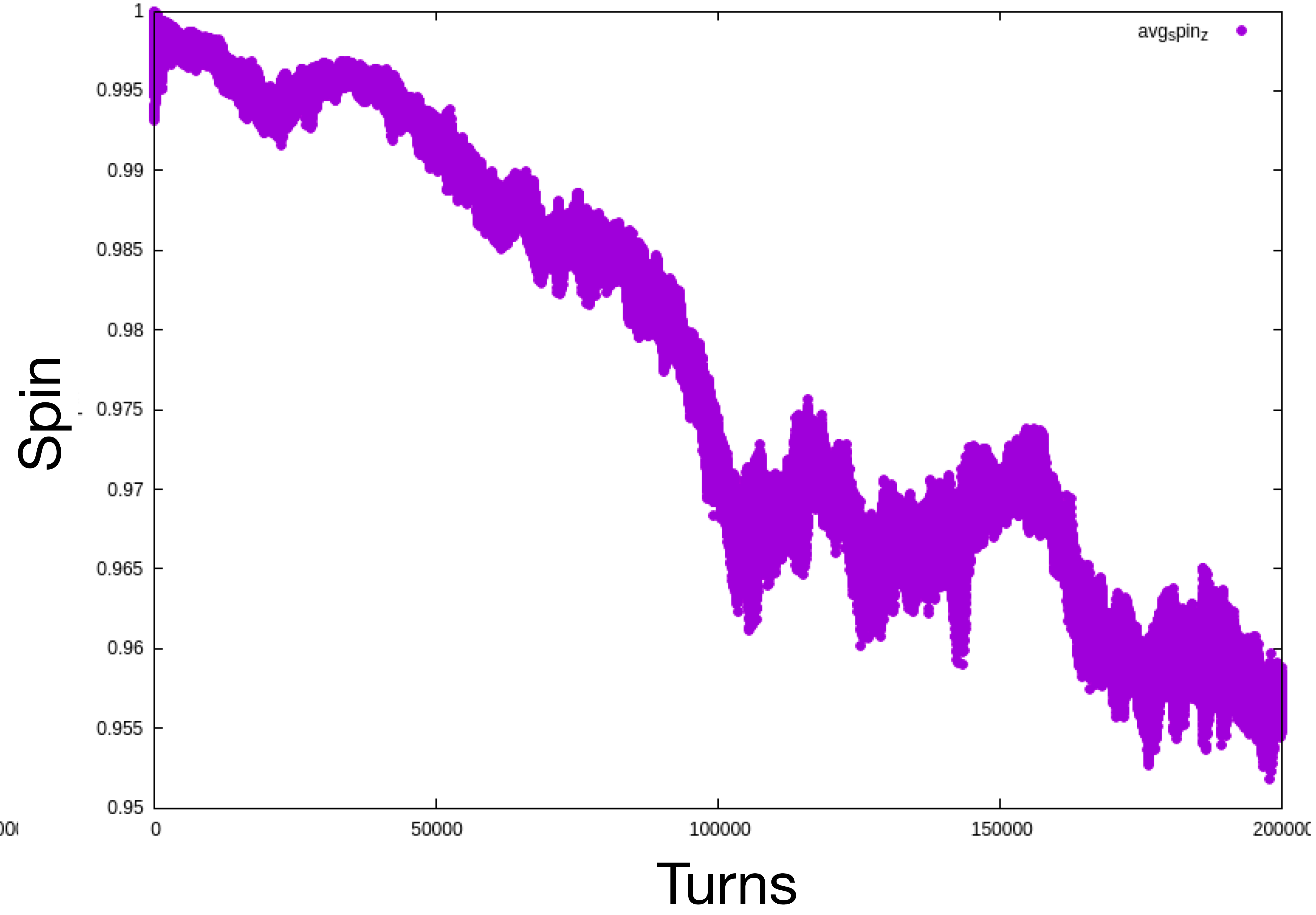
Average spin over 200,000 turns



Average spinz over 200,000 turns



R156 PMID spin-retention issues

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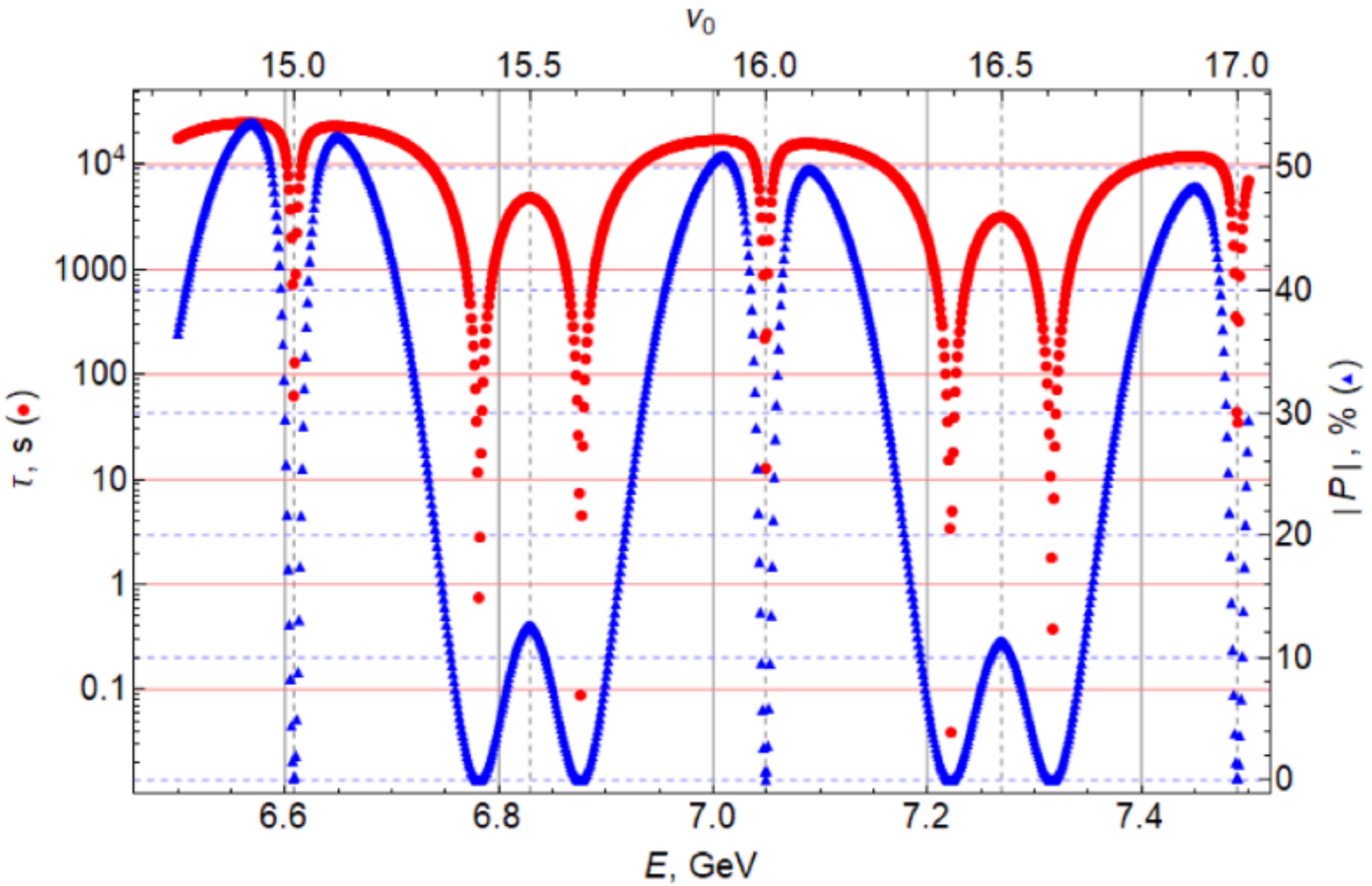
- PMID is located directly opposite of the IP
- For posterity, changed the starting point of long term tracking (as well as the initial spin) to the PMID for 10 particles across 2.5m turns
- Spin degradation is still a problem.

Sx	Sy	Sz
-0.643798056	0.491665199	0.586335566
-0.532653004	0.617455862	-0.578816928
-0.868979448	0.487254551	0.086358101
…	…	…

Final spin values for 3 of the 10 particles

Spin Relaxation

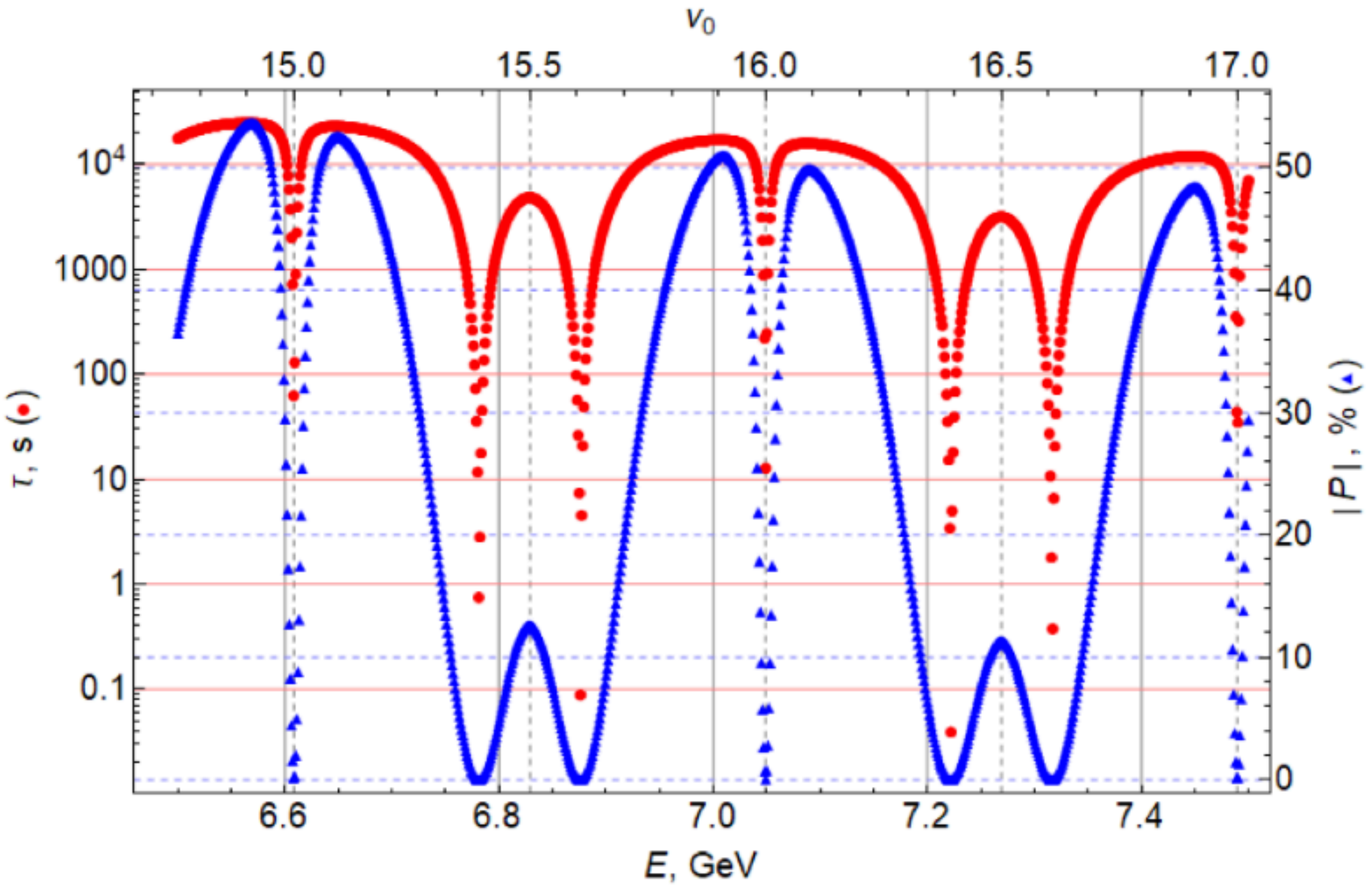
- Overall spin diminishment may be caused by radiative effects.
- The Novosibirsk group conducted a study with their alternative model
- The spin relaxation time plateaus around the working point of the SuperKEKB HER
- We want to probe this region across various energies using LTT.



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

Spin Relaxation

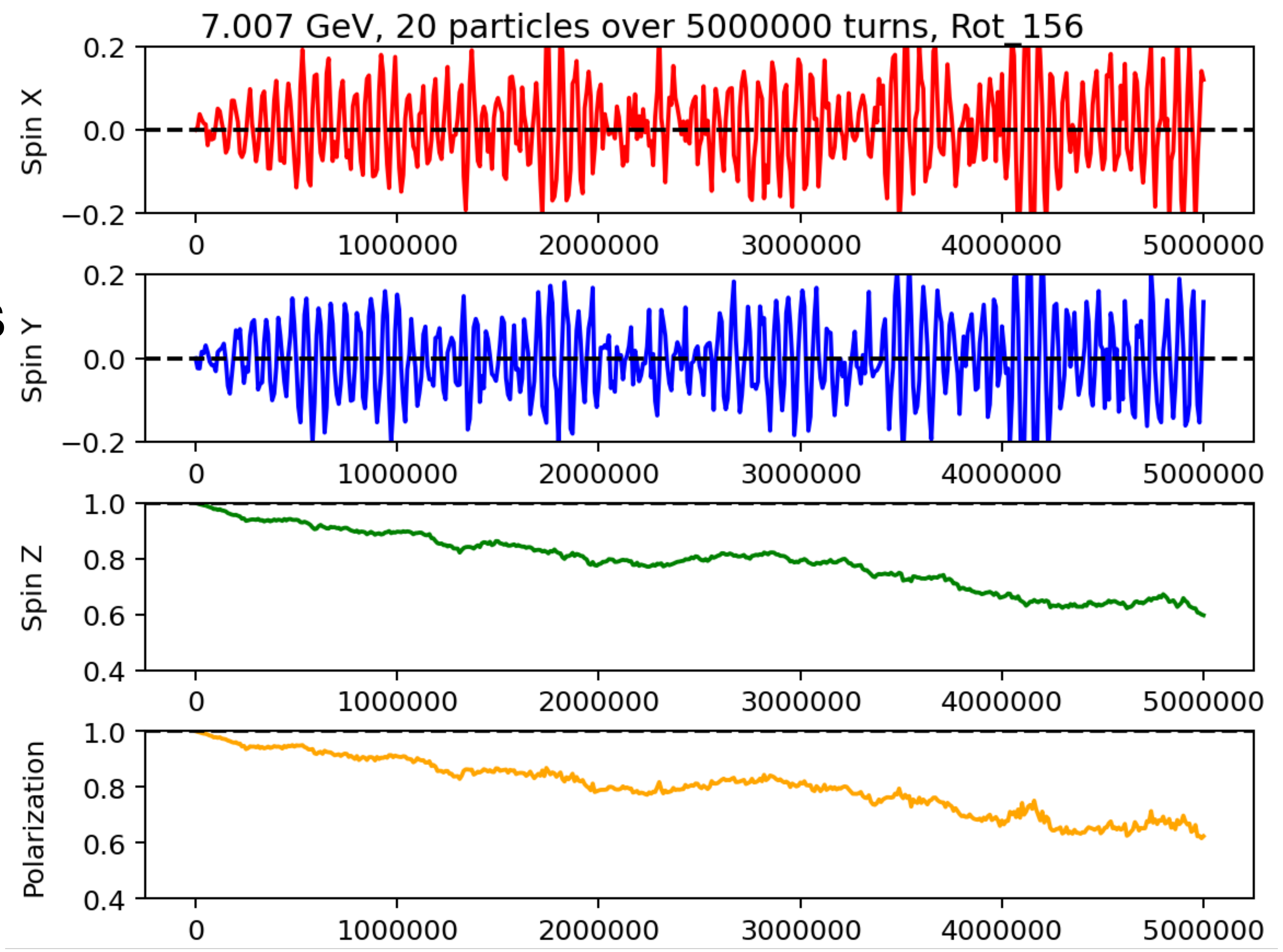
- Need to re-optimize the R156 model several times for alternate energies, since the beam energy effects various optical parameters
- Unfortunately wasn't able to simply optimize the closed lattice. Need to break it down into pieces again
- Currently doing at the open geometry rematch stage for these models



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

Alternative Energies and LTT

- 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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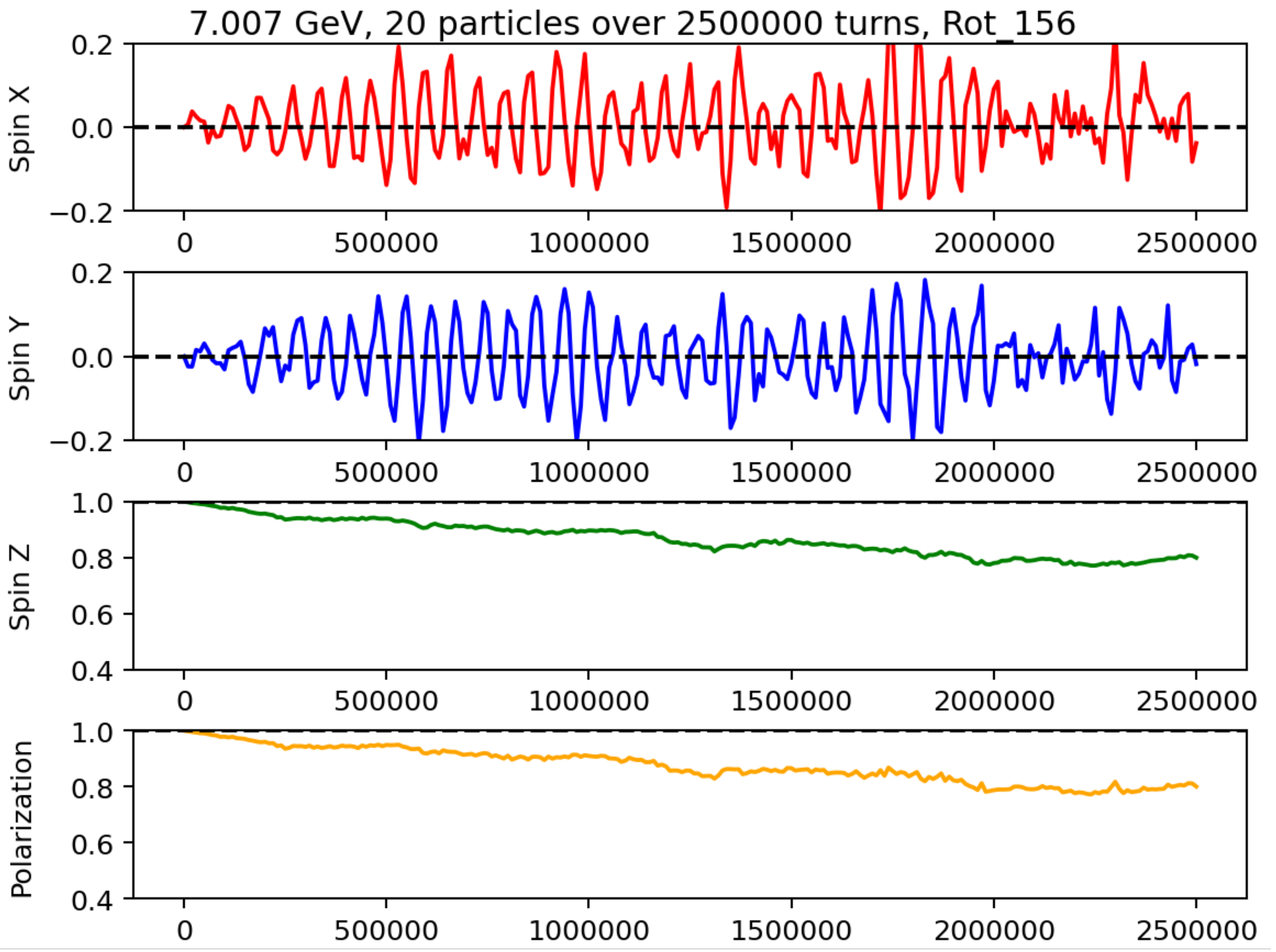
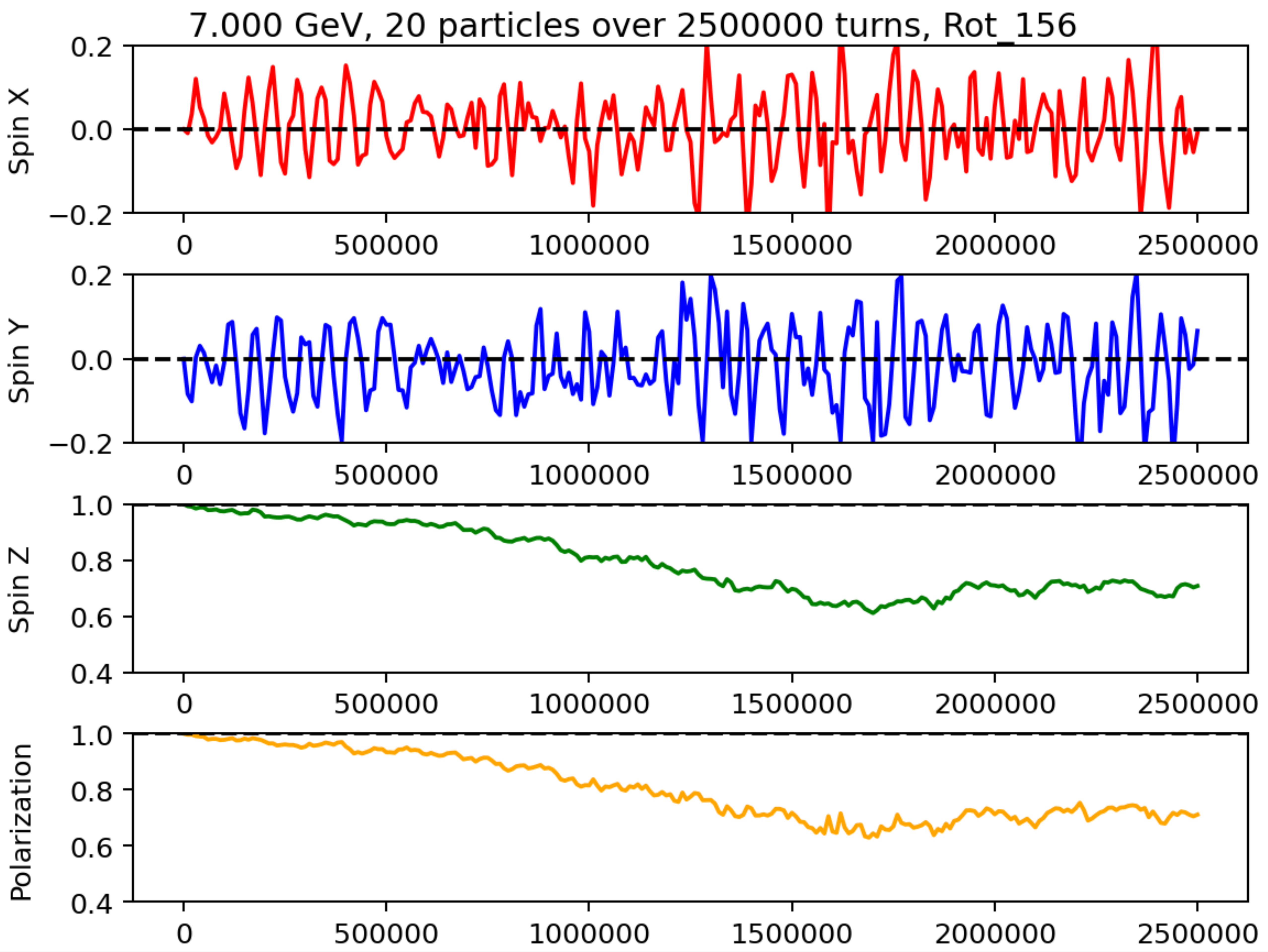


Nominal Energy



Nominal -7 MeV

(Plotted are averages)

Alternative Energies and LTT

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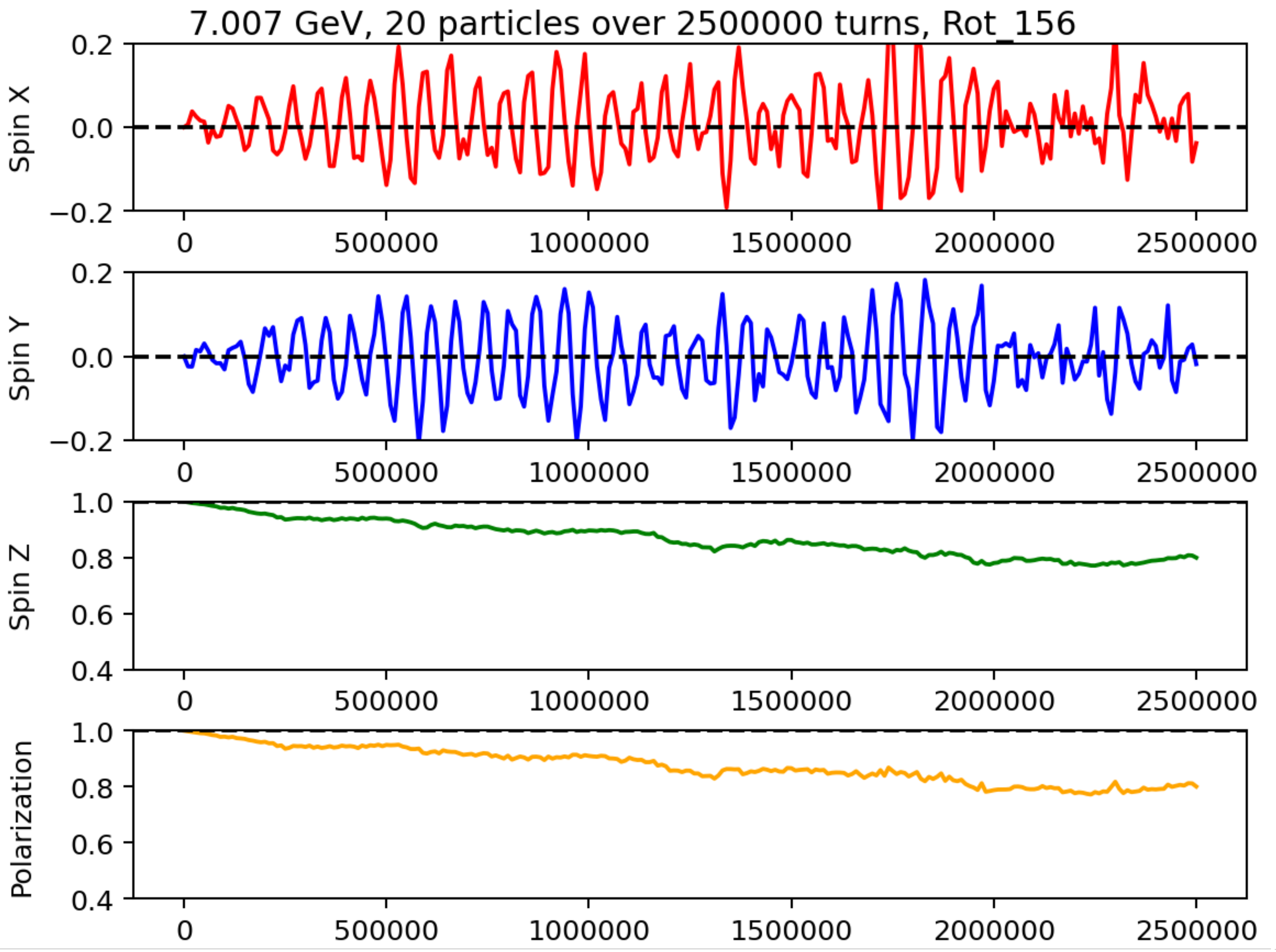
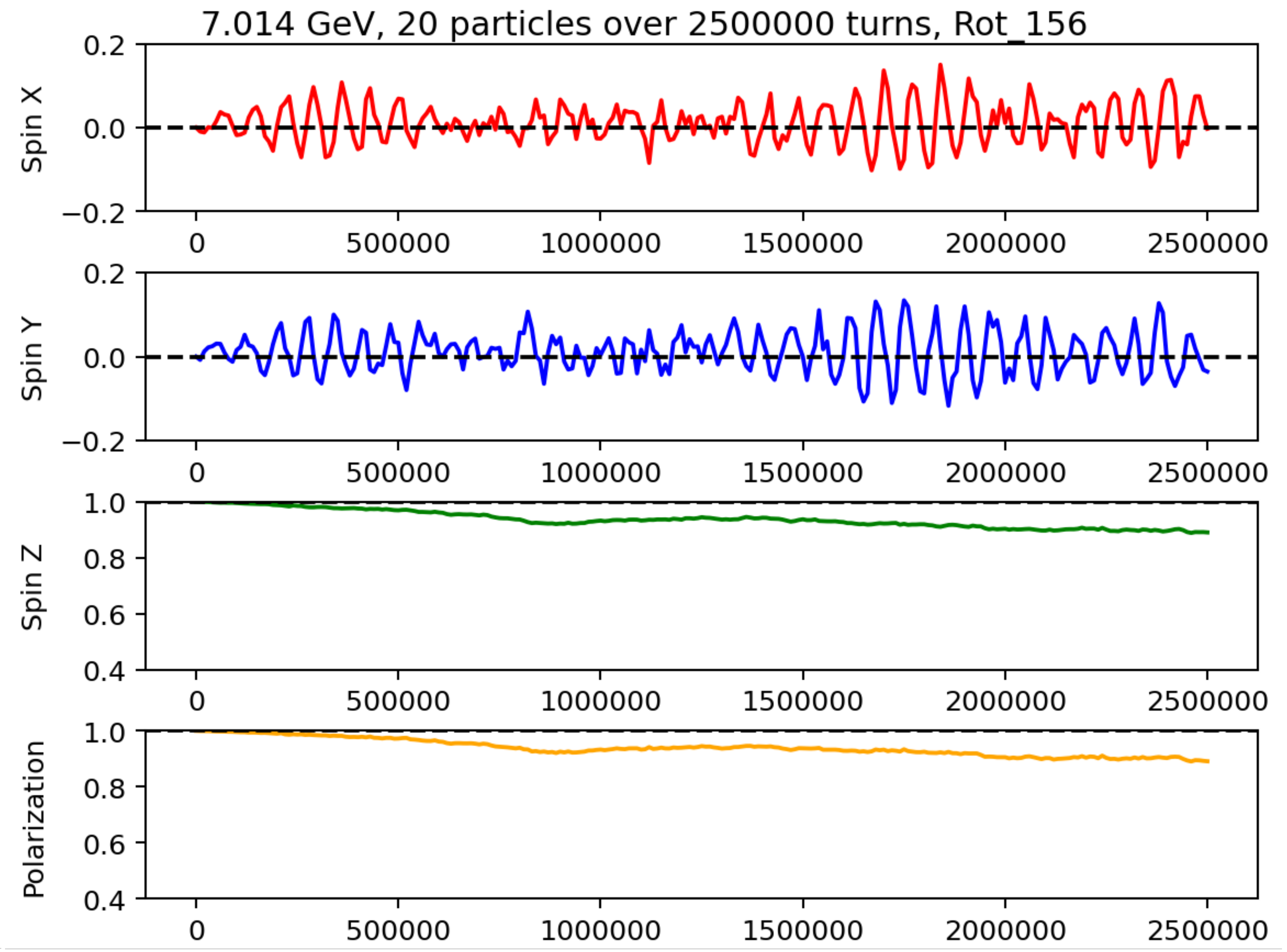


Nominal Energy

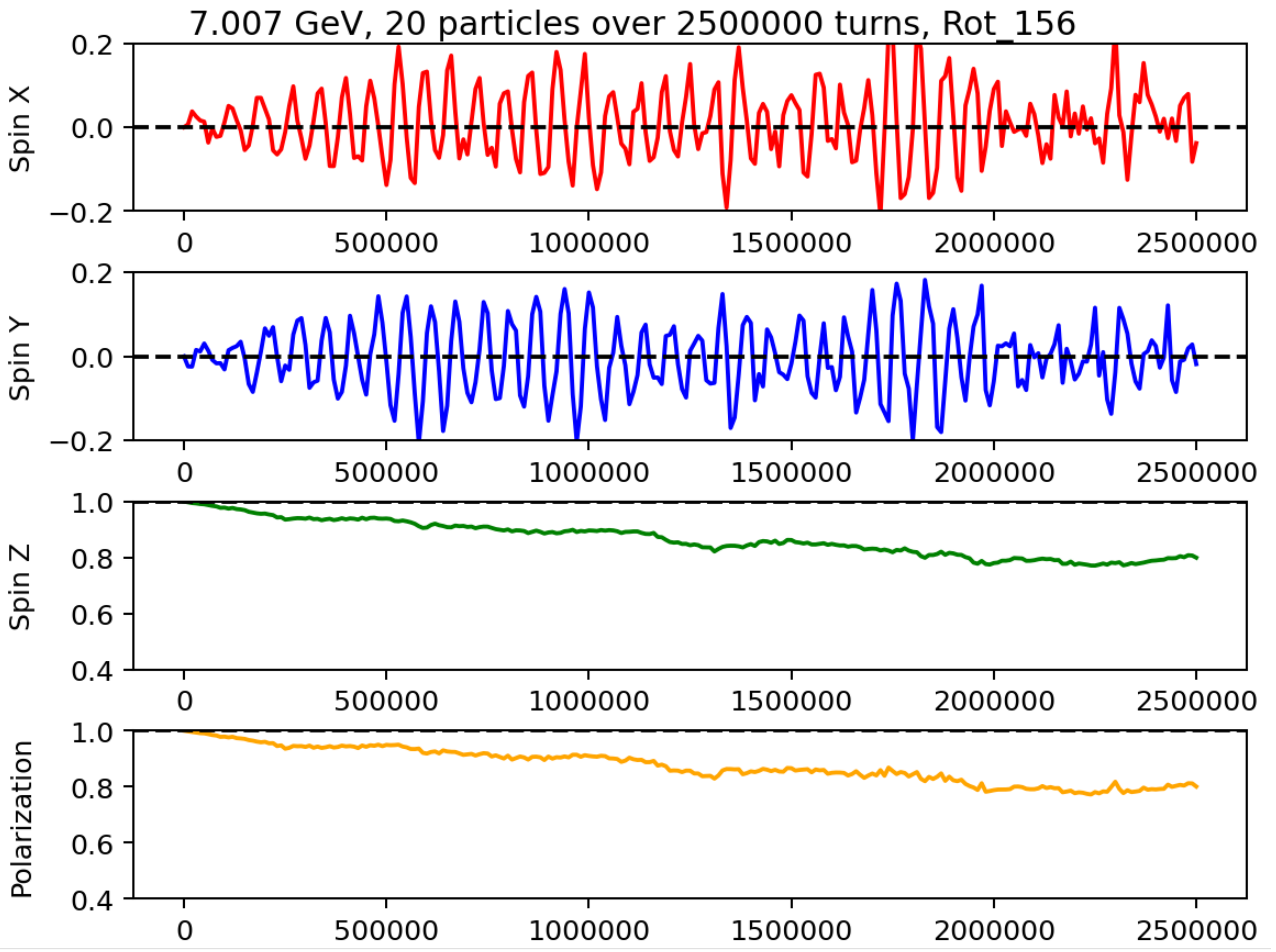


Nominal +7 MeV

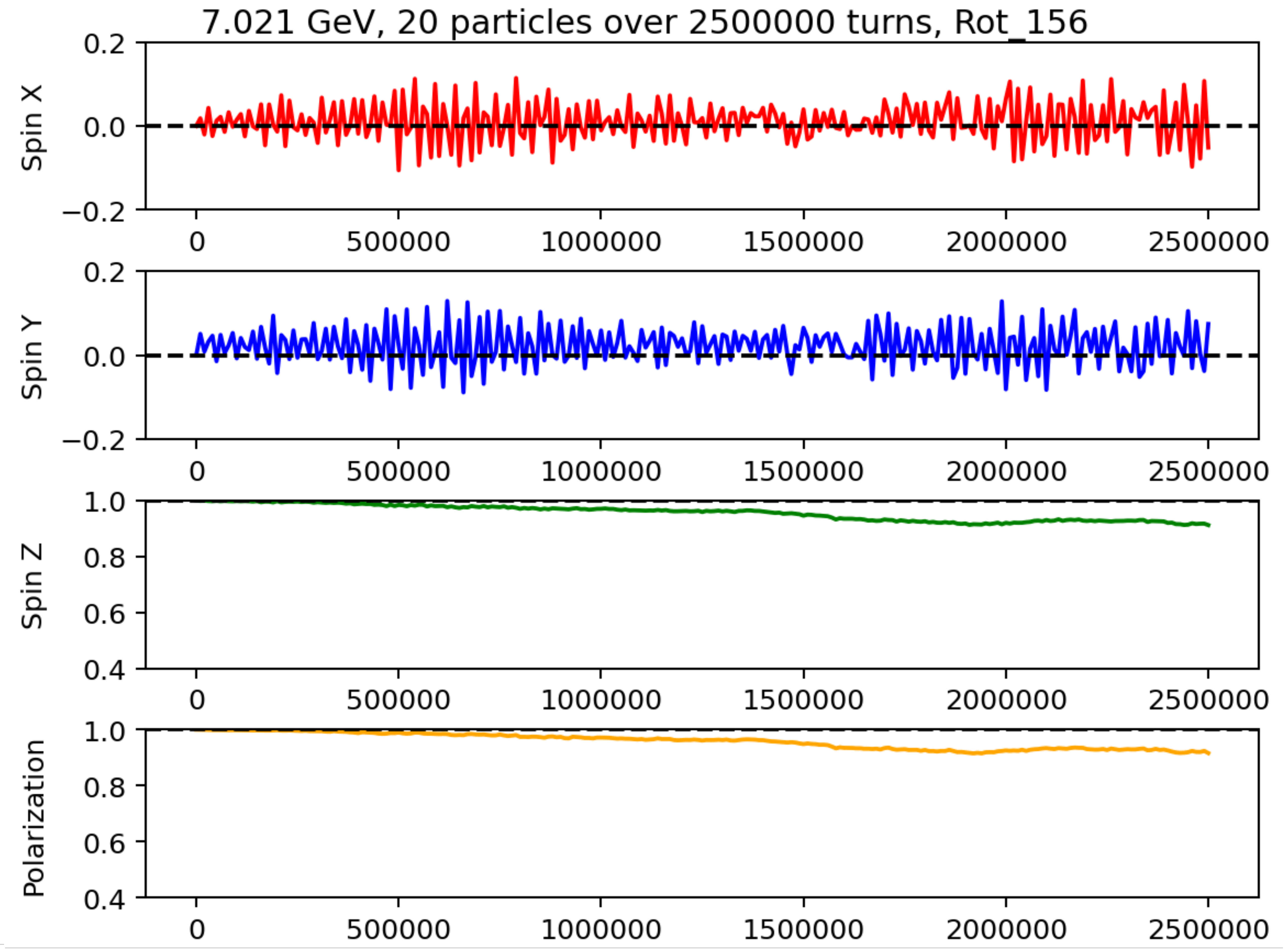
(Plotted are averages)

Alternative Energies and LTT

University of Victoria



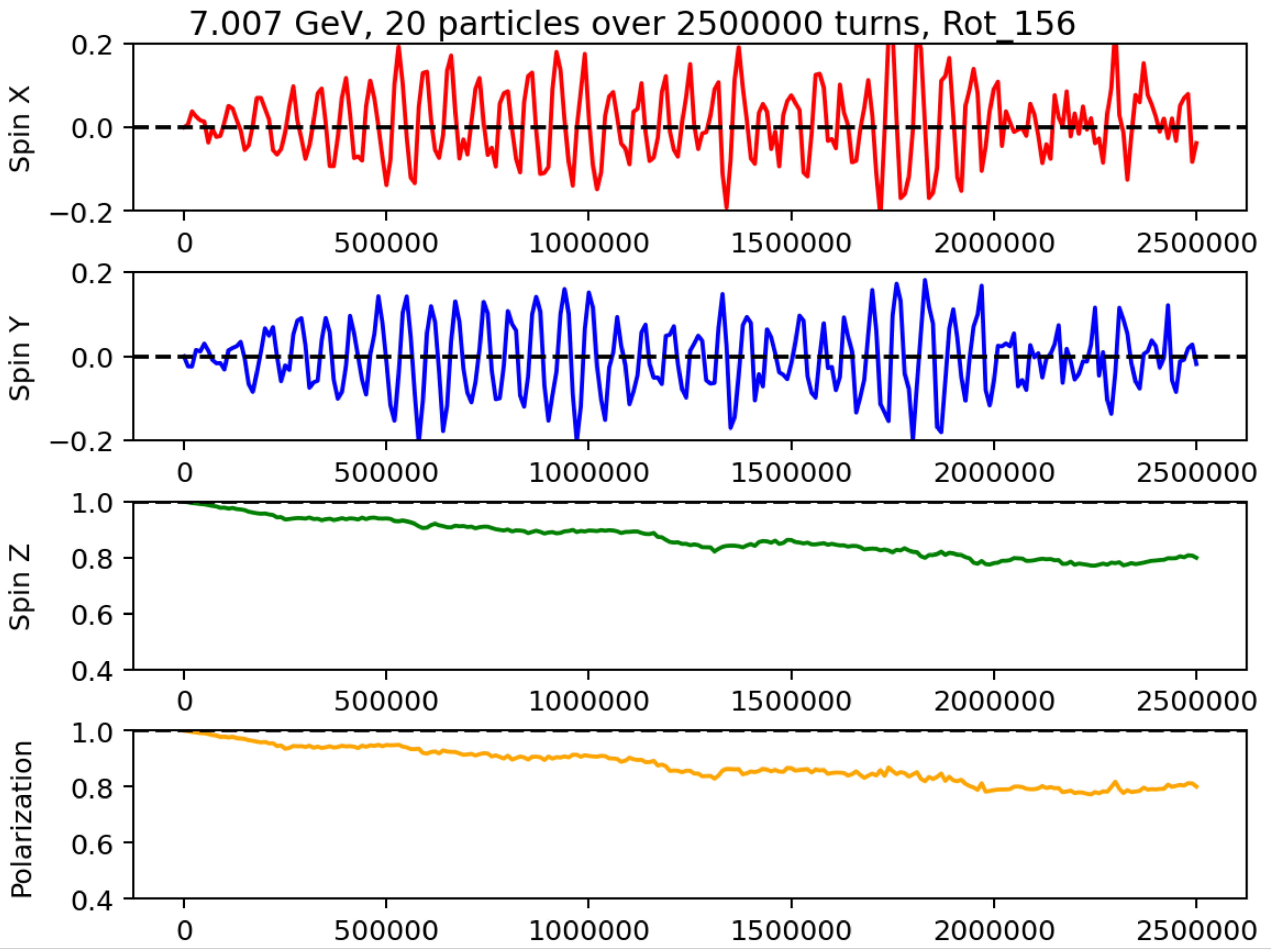
Nominal Energy



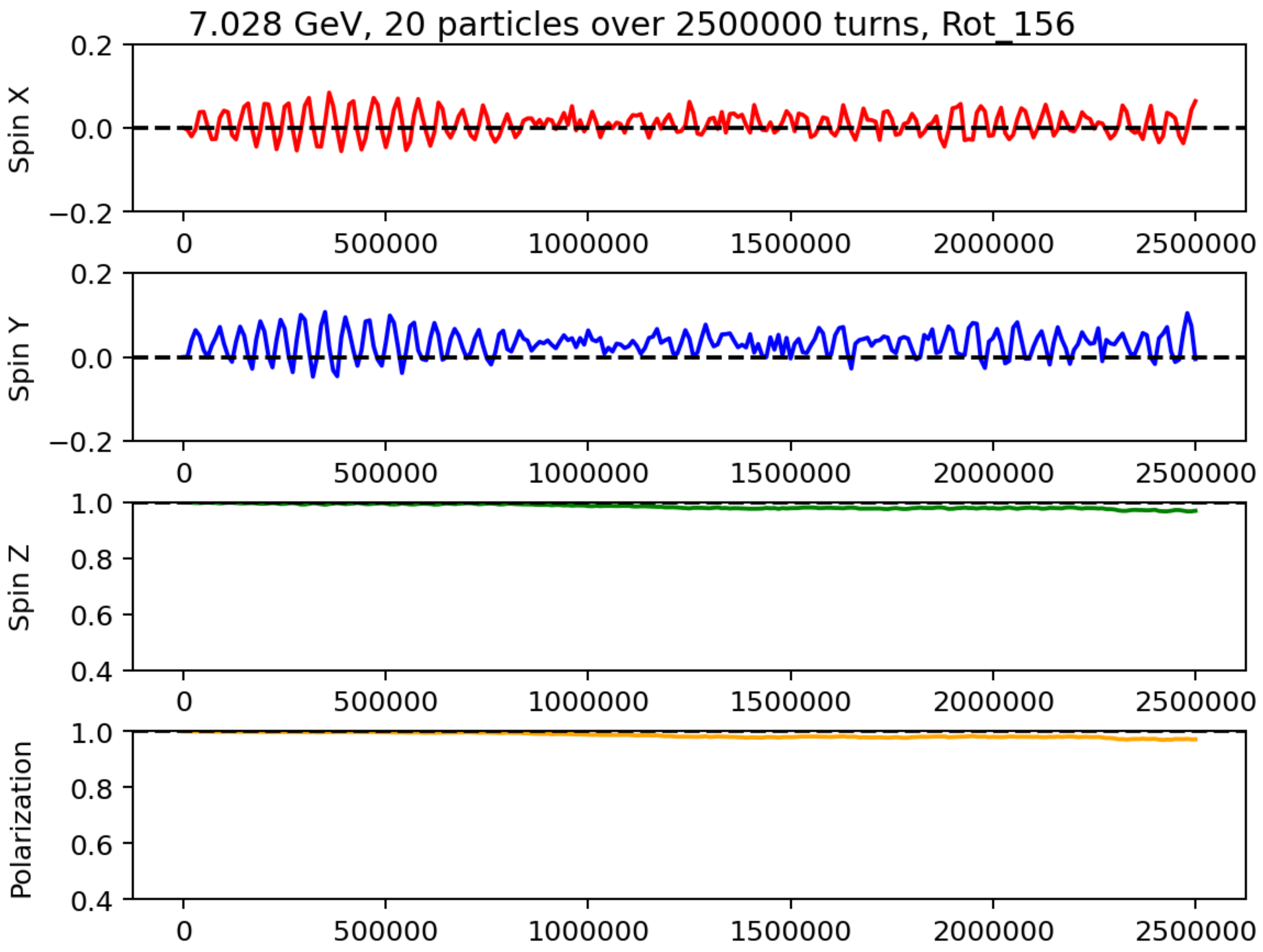
Nominal +14 MeV

(Plotted are averages)

Alternative Energies and LTT



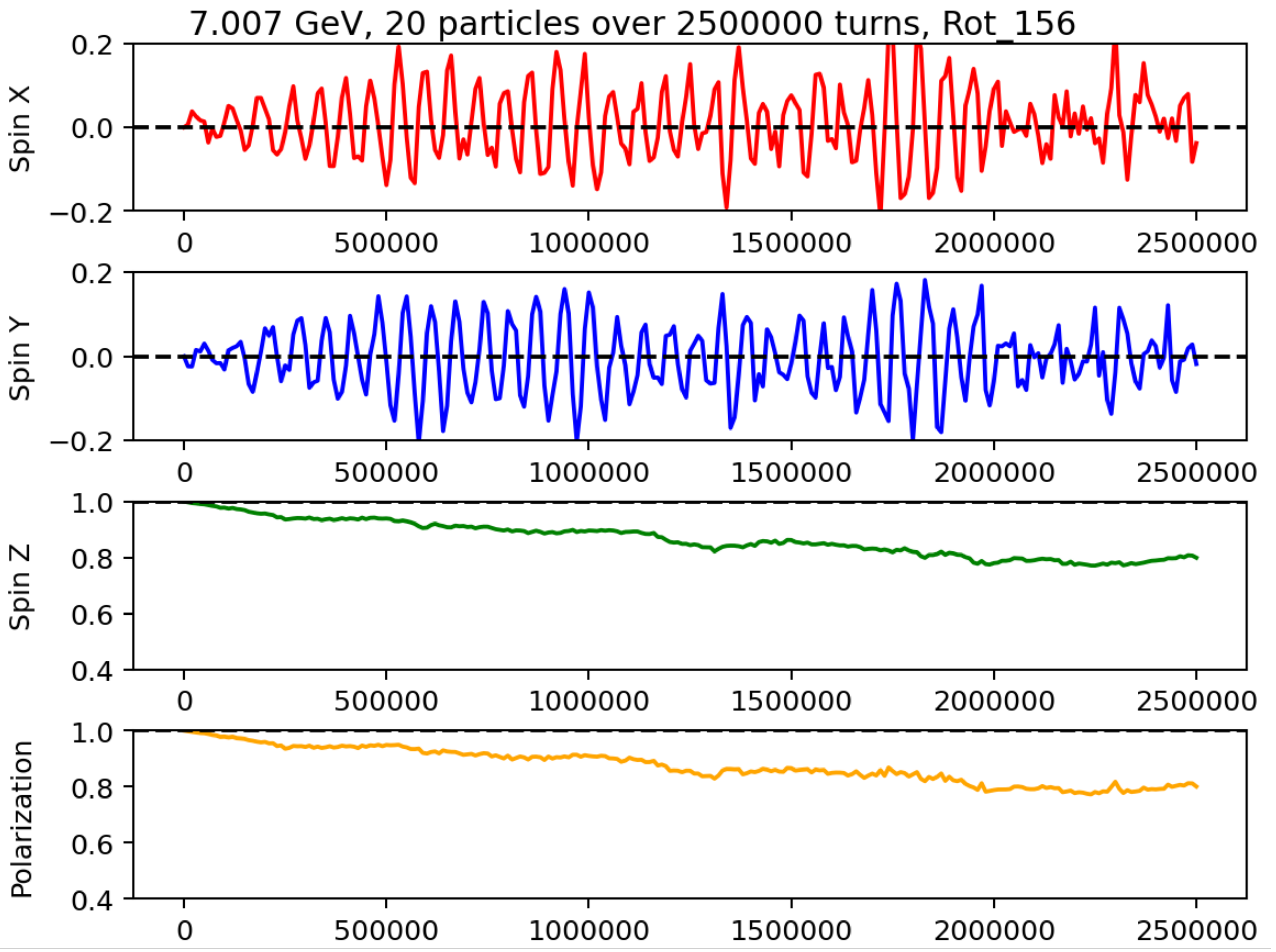
Nominal Energy



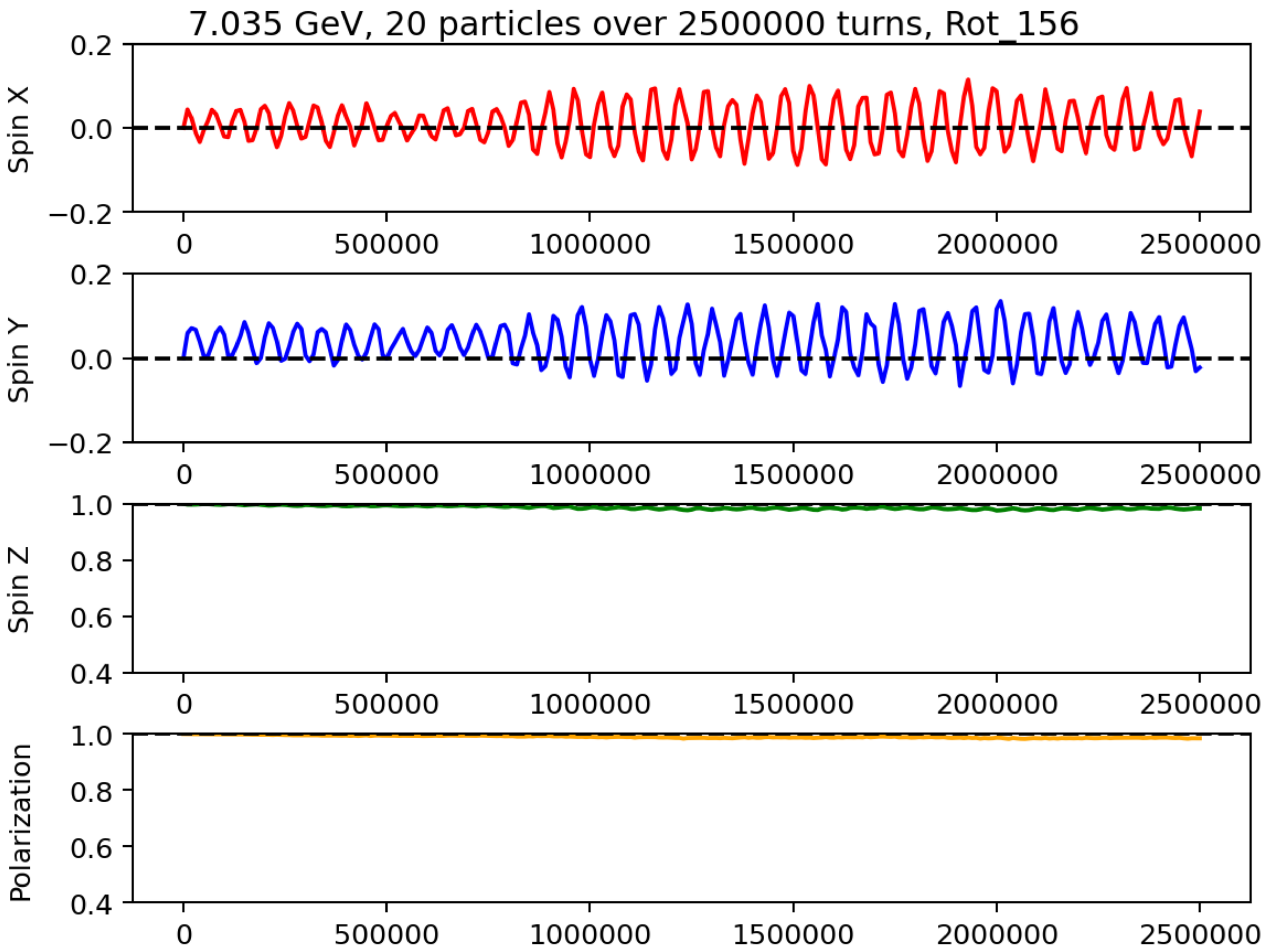
Nominal +21 MeV

(Plotted are averages)

Alternative Energies and LTT



Nominal Energy



Nominal +28 MeV

(Plotted are averages)

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)

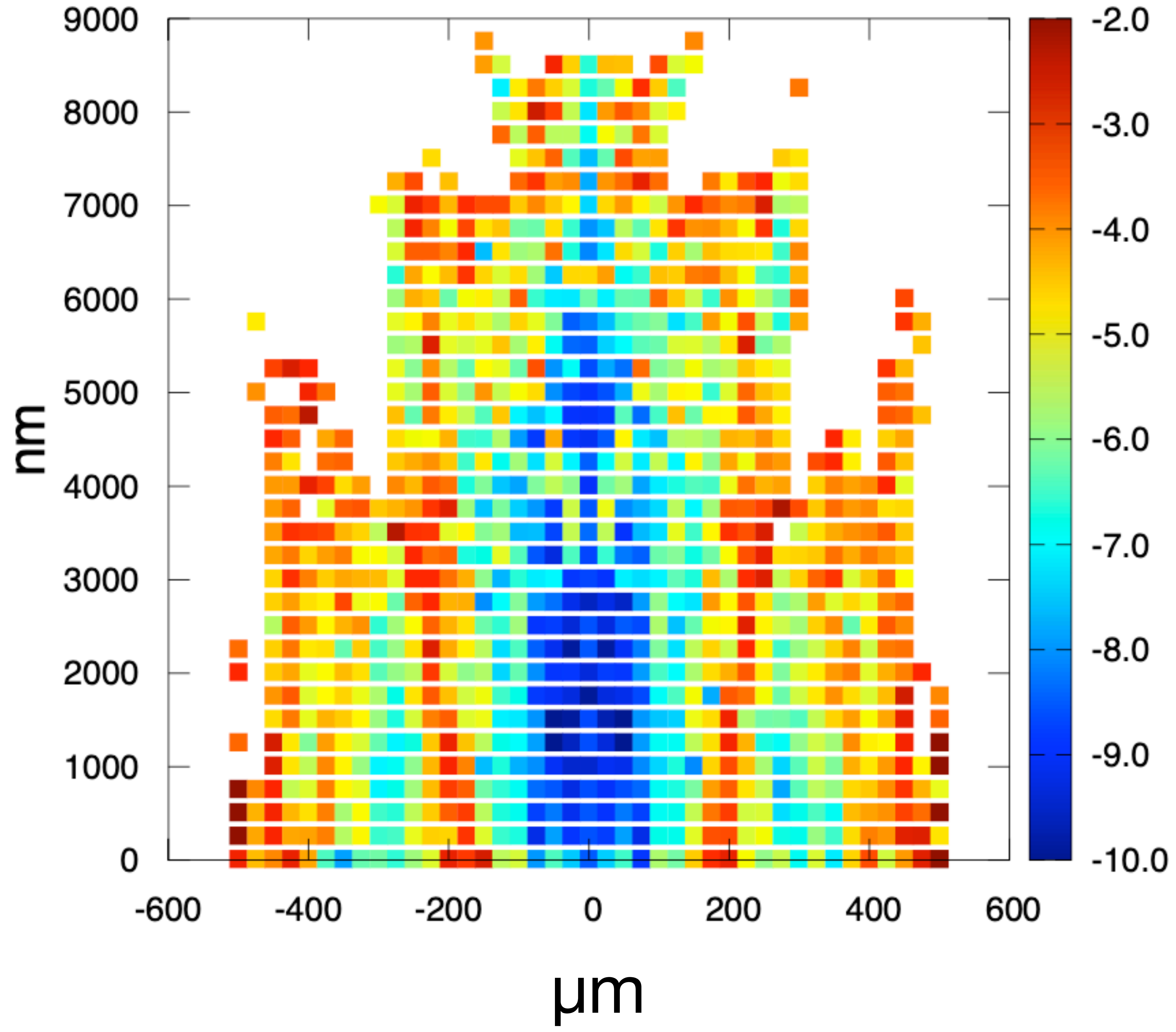
Spin Tune Studies

Peak Frequency: 0.08617

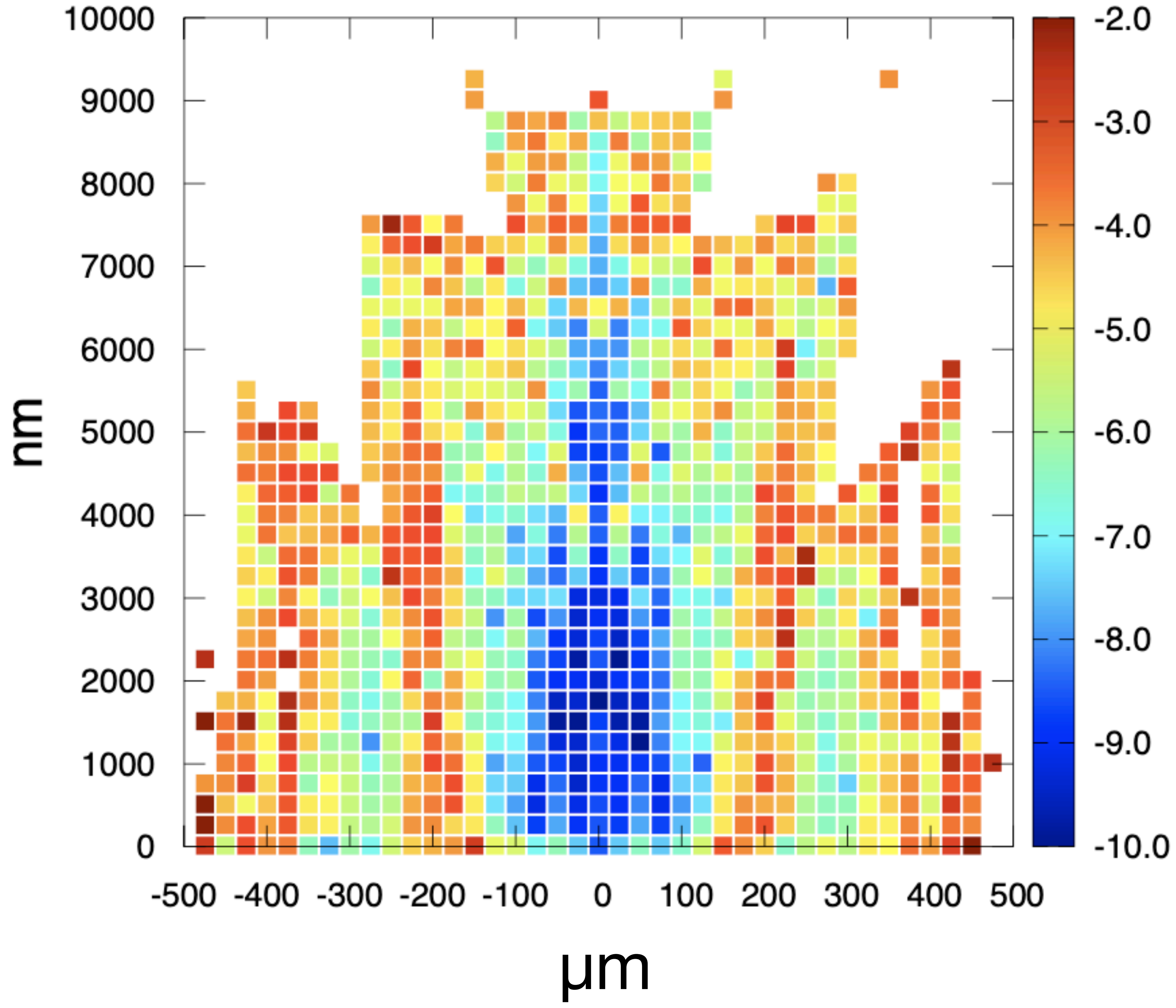
(Scaled)

Preliminary FMA of R156

R156



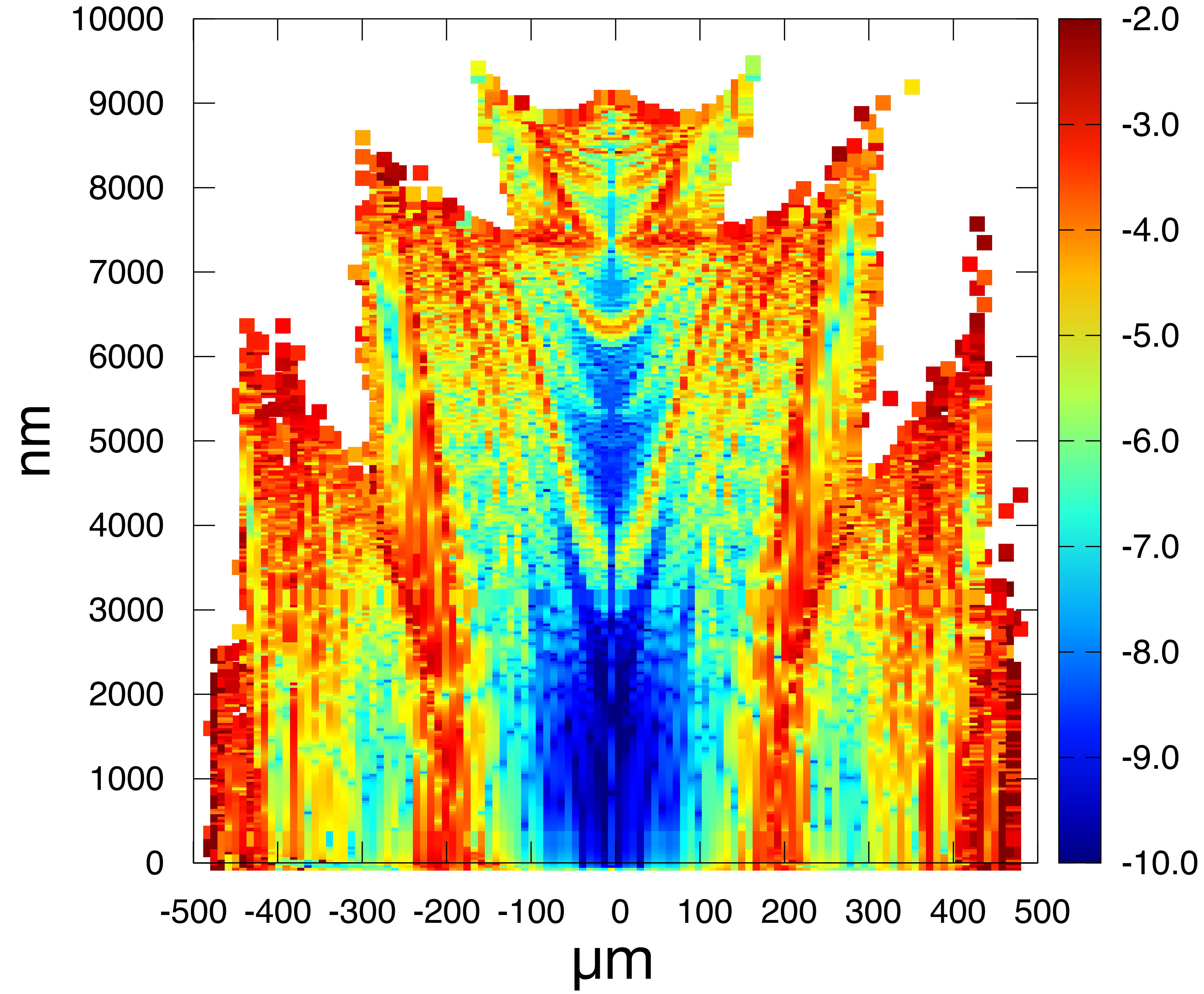
R96 (Yuhao)



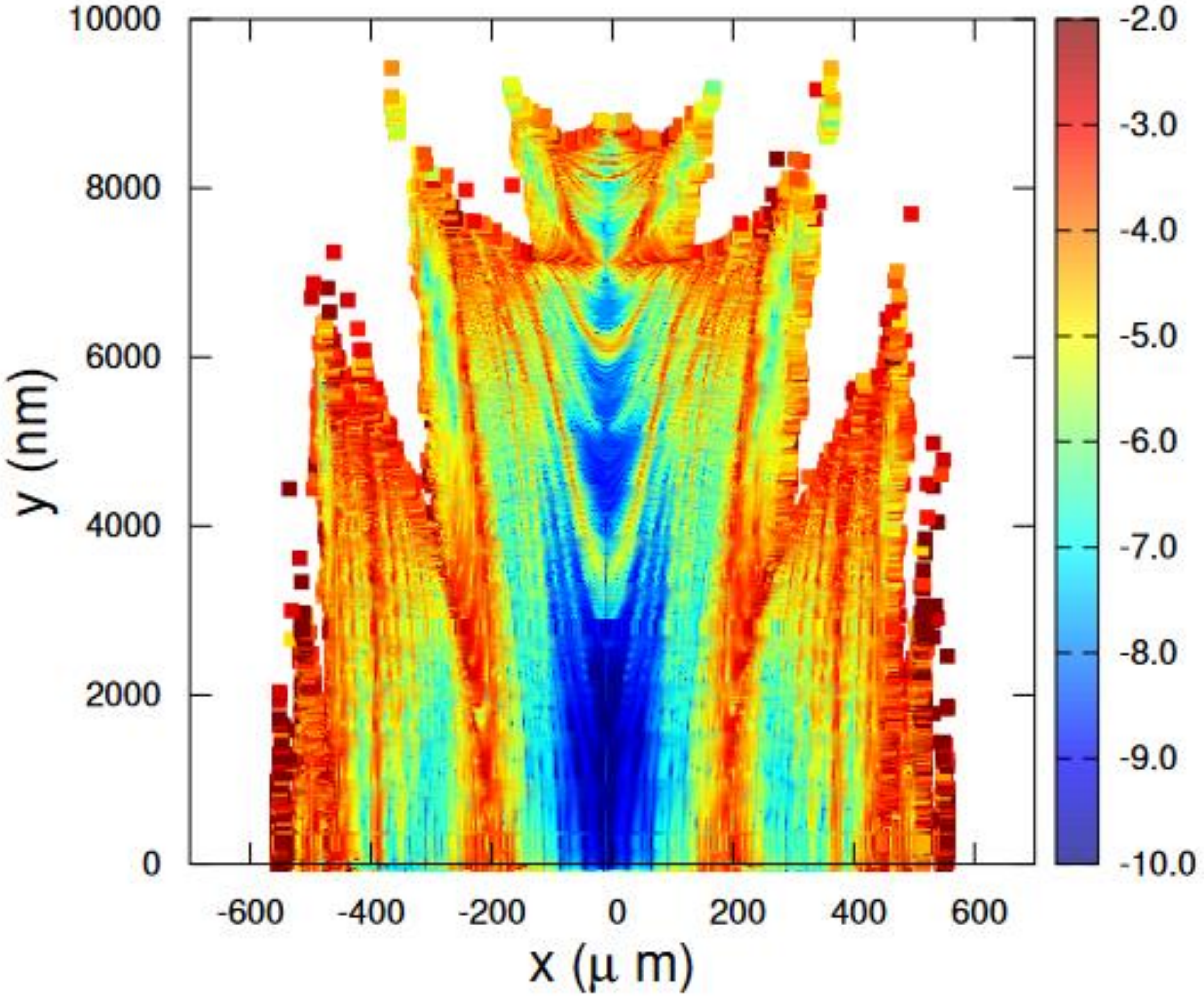
(Still need higher resolution final plots)

Preliminary FMA of R156

R96



HER



(Previous Results from last year)

Preliminary FMA of R156

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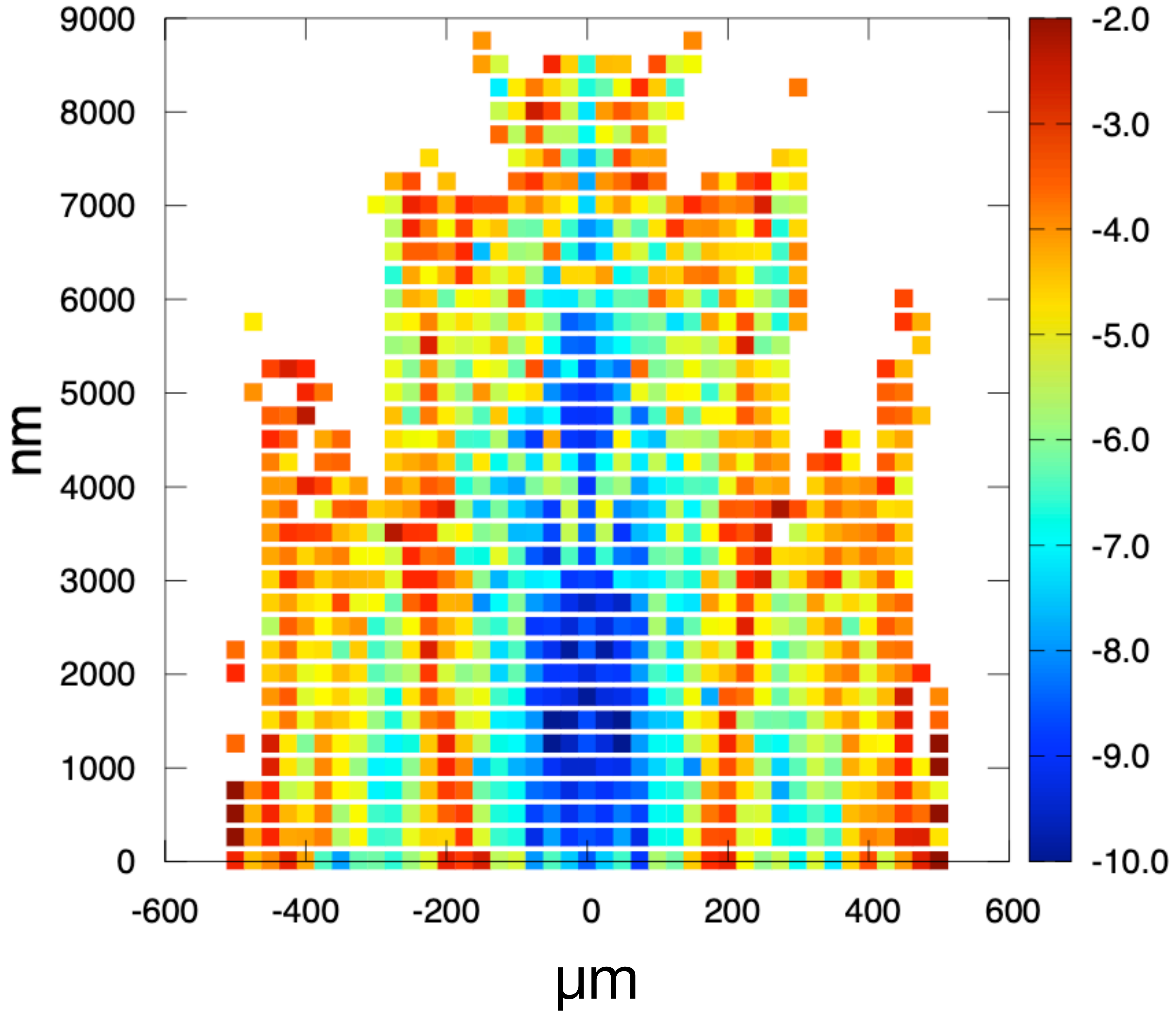
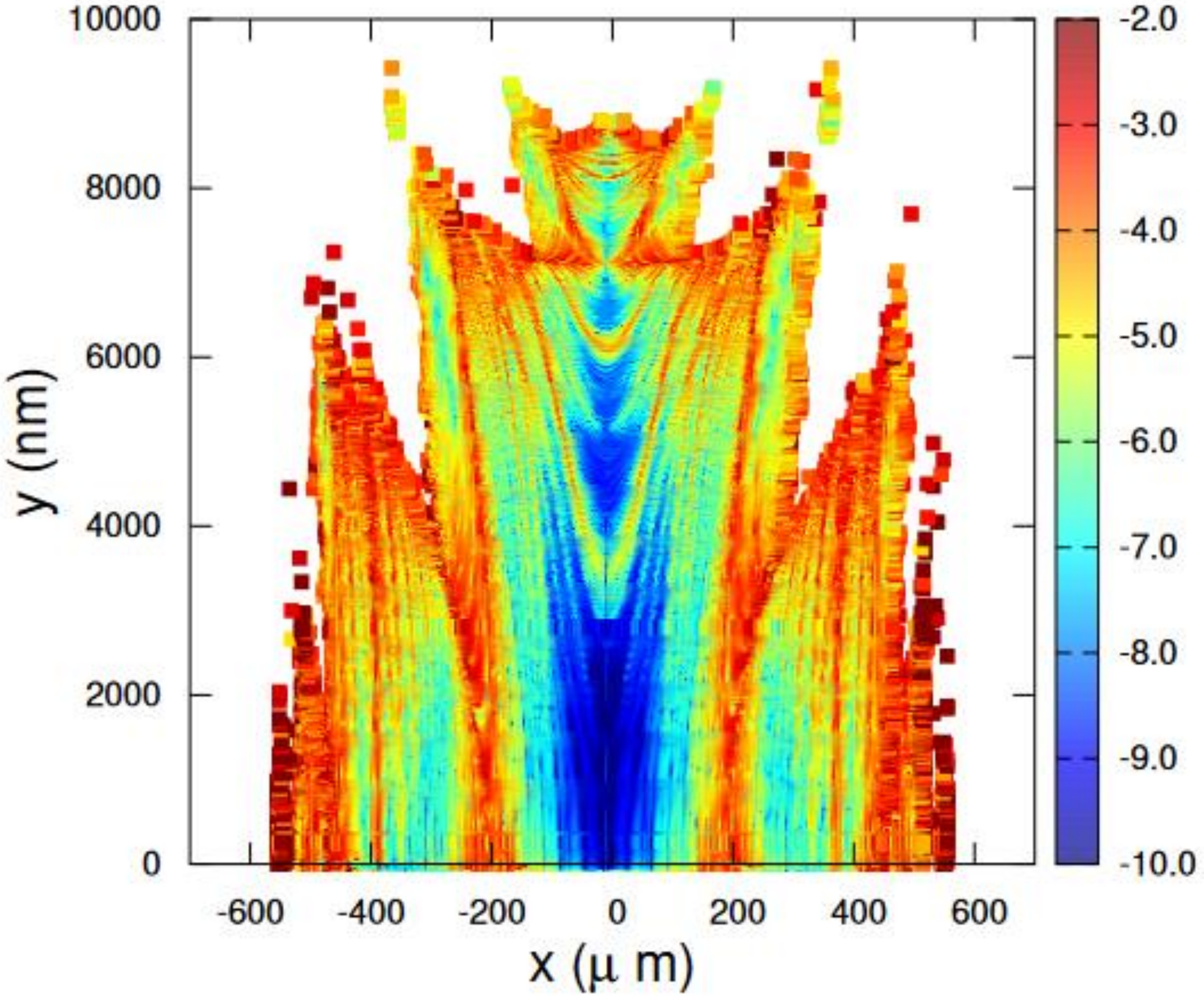
R156



HER



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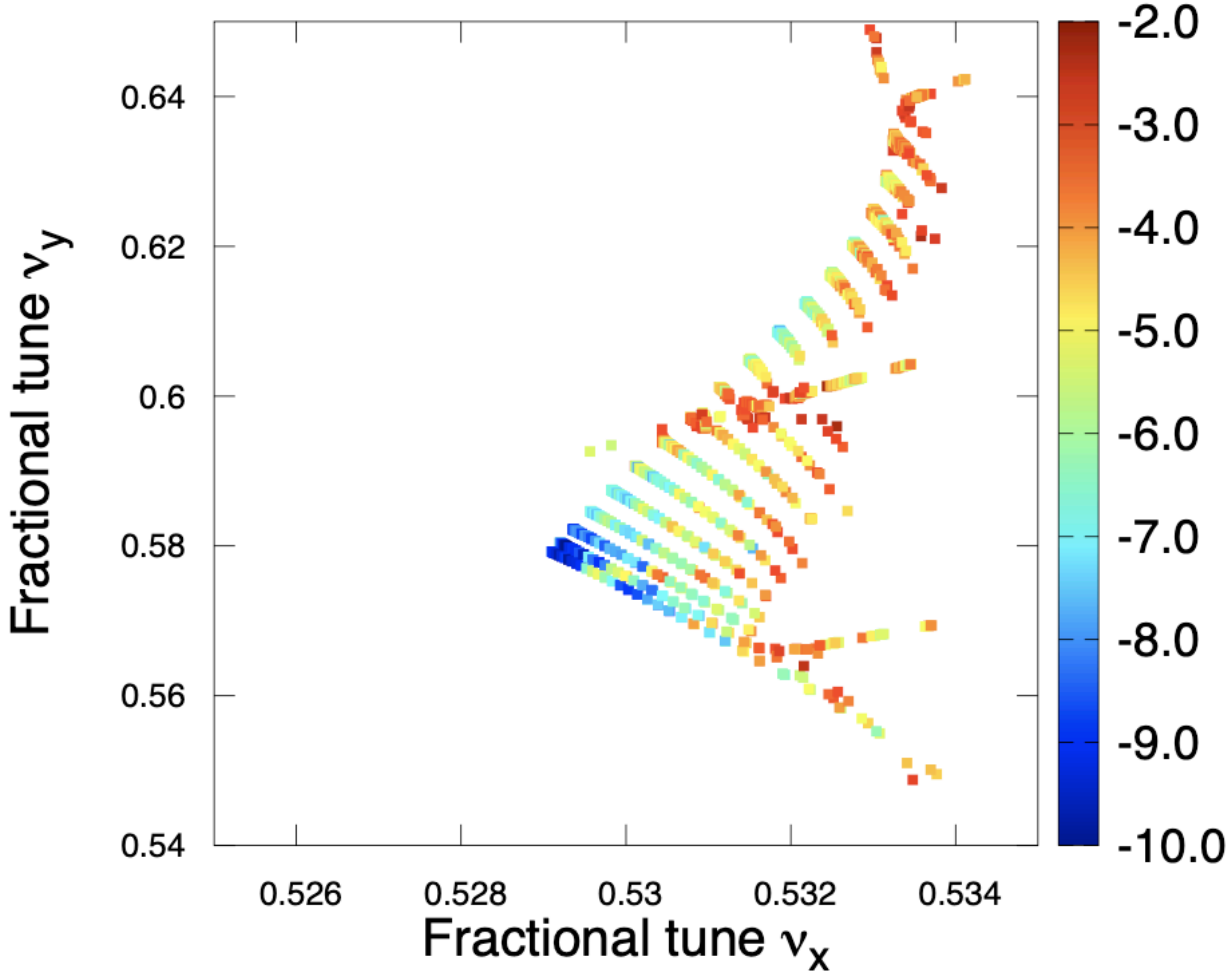

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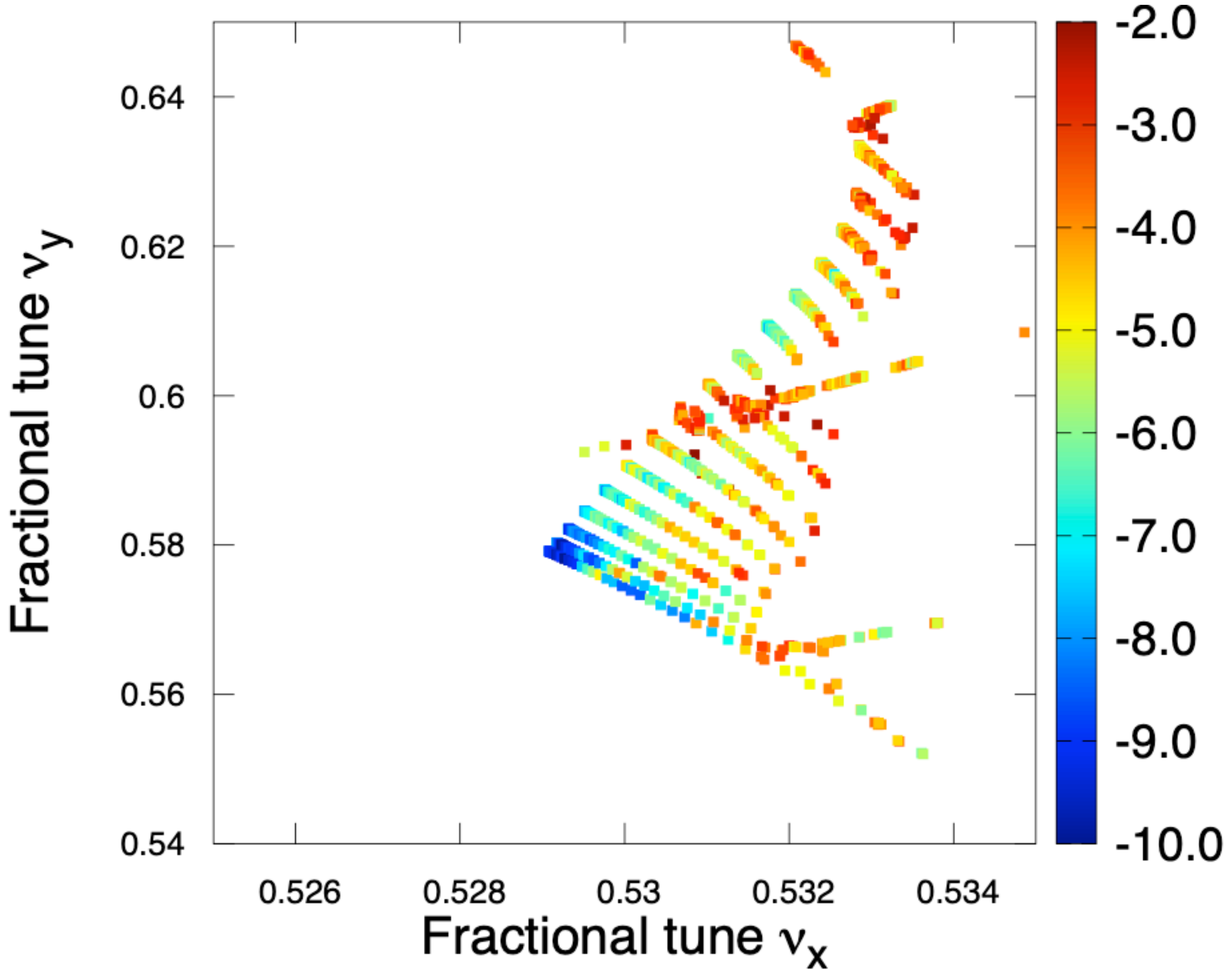

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Preliminary FMA of R156

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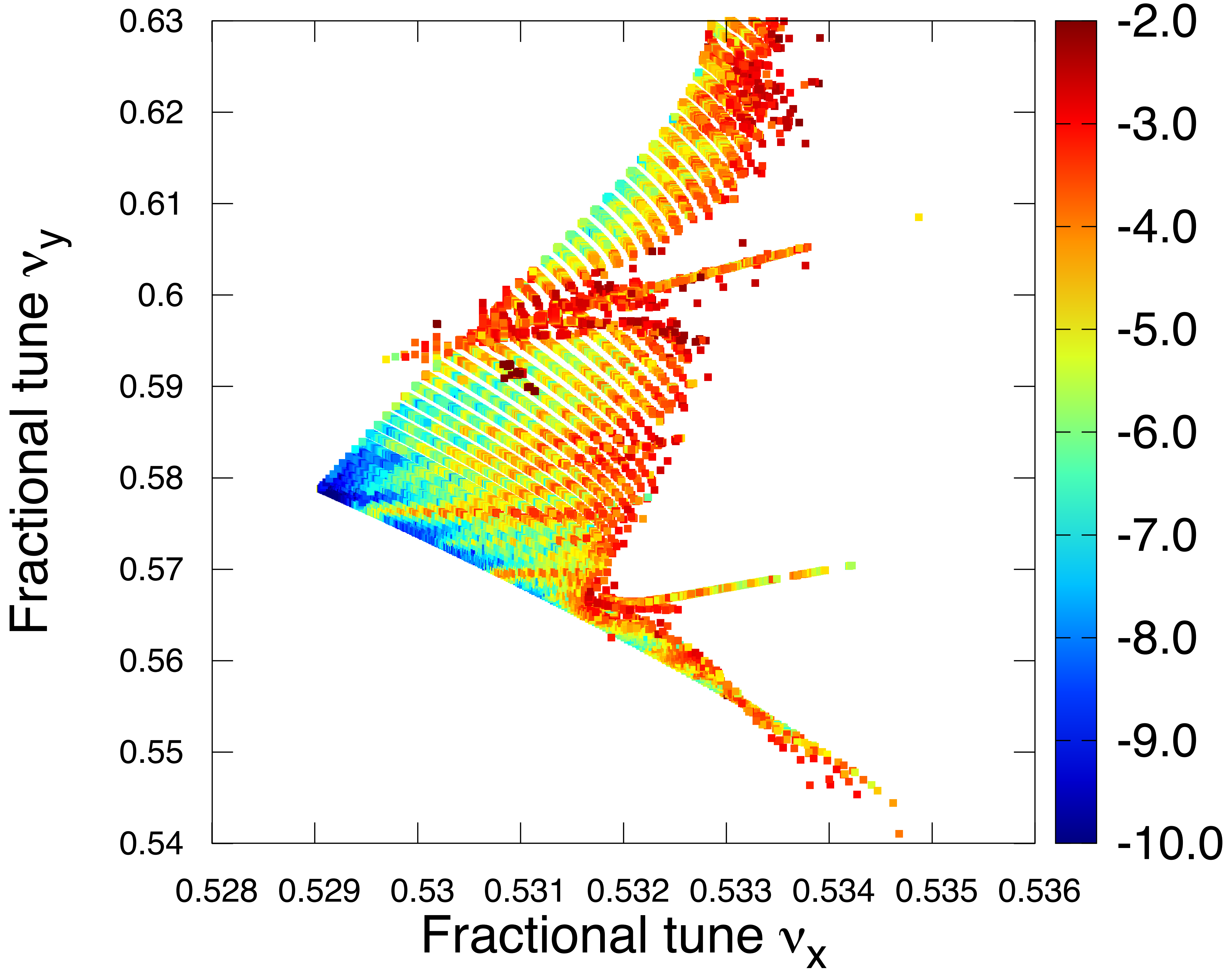
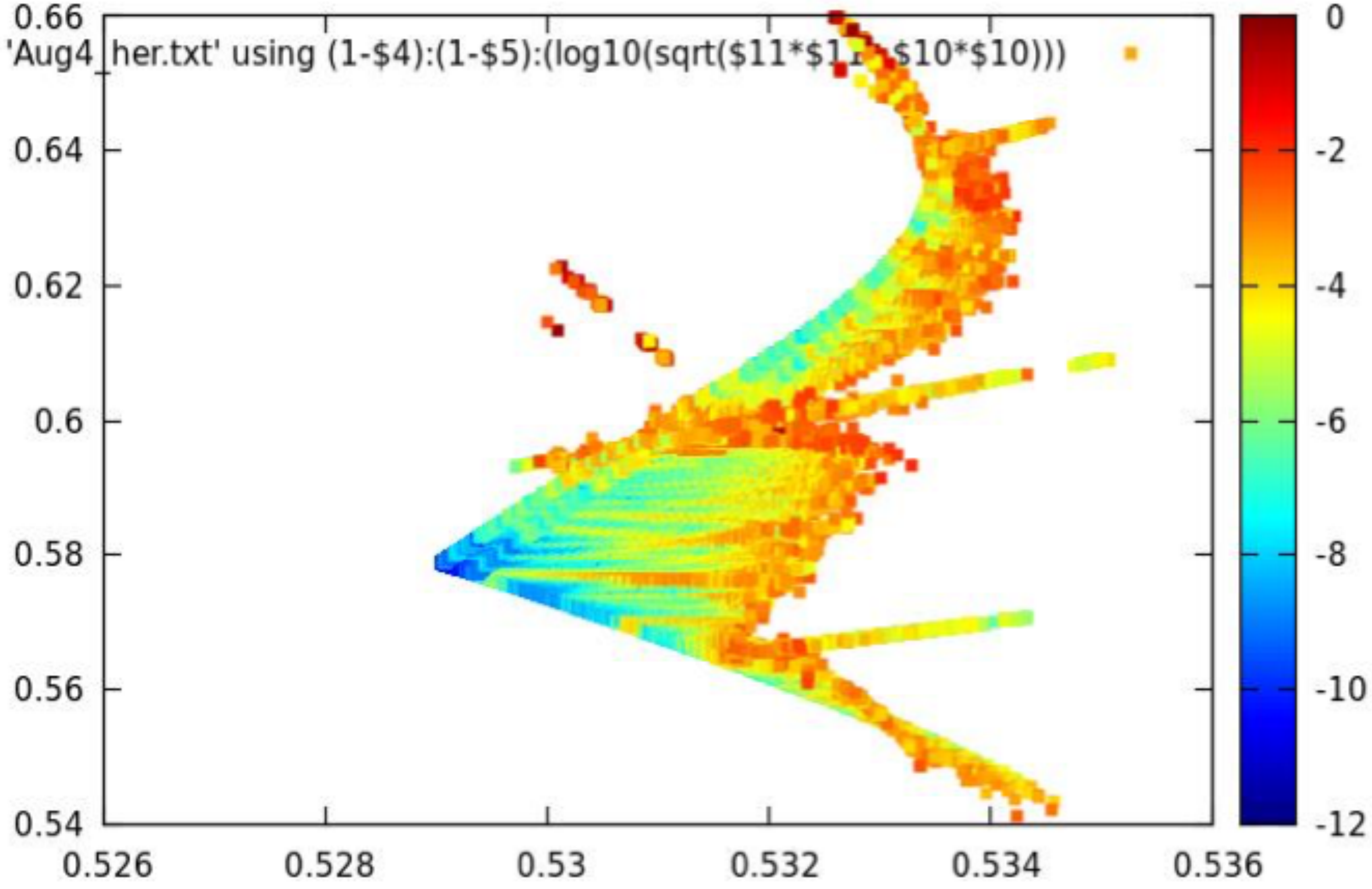
R96



HER (old)



Immediate Plans

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- Complete energy scan to find the optimal energy for the polarization lifetime
- Comprehensive rematch of R156 using optimal energy
- 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

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

Summary

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- Validated with Long Term Tracking to 5M turns, no particle loss in the new Rot_156 model (20 particles)
- Nominal Energy is not optimal for maximizing polarization lifetime.
  - Adjusting by +28MeV increases polarization lifetime (from ~1.7 min to ~20 min)
  - Top up is every 50 seconds for 2500 bunches at 50Hz, so 30 top up times

- **It works**