Oak Ridge National Laboratory
SNS Spallation Neutron Source
Oak Ridge Institute for Science and Education

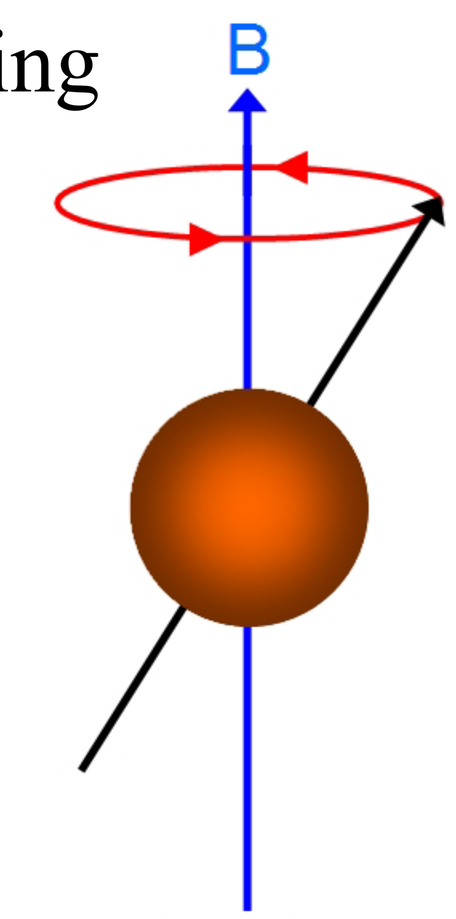
GPU Parallelization of Spin-Tracking Simulations

M. Kline[1,*], L. J. Broussard[2]
[1]Transylvania University, [2]Oak Ridge National Laboratory *mckline22@transy.edu

Transylvania University

Introduction

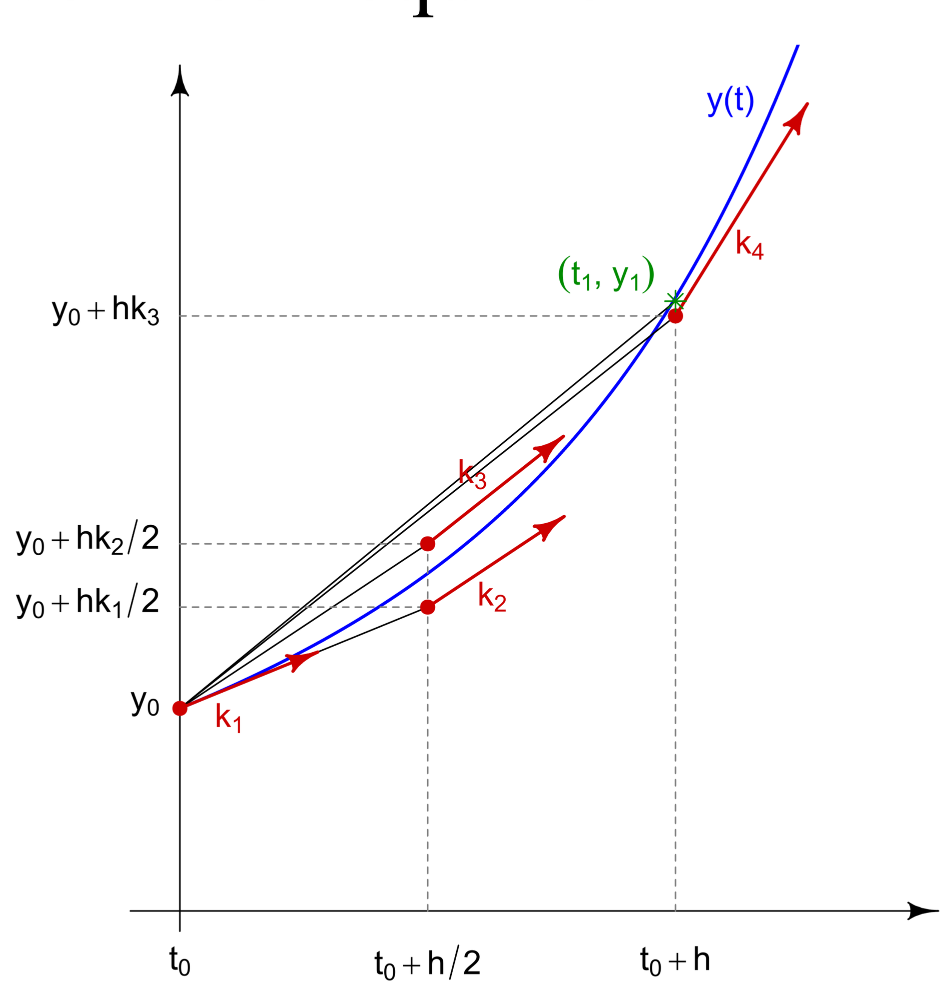
Finding a nonzero neutron electric dipole moment (nEDM) would help to find an explanation for the baryon asymmetry in the universe. The nEDM measurement is dependent on spin precession. Spin-tracking simulations of neutrons in the measurement cell are needed to understand systematic effects, but are slow using only CPUs



$$\dot{\sigma} = \gamma \sigma \times B - \frac{2d_n}{\hbar} \sigma \times E$$

Methods

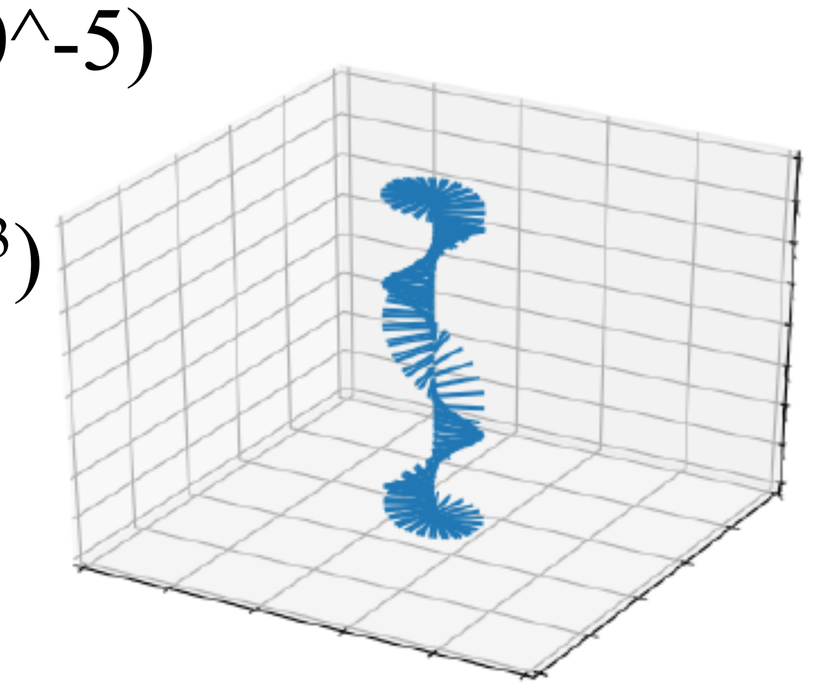
- Julia language
- Parallelization with GPU kernels
  - CUDA.jl package
- 5^{th} order Runge-Kutta method to solve Bloch equation



Runge-Kutta method[2]

Approach

1. Initialize neutrons
   a) Velocity in random direction up to 5m/s
   b) Random position in measurement cell
   c) Same initial spin vector (perpendicular to B_0)
2. **2.** Move (with gravity)
   a) Currently has fixed step size, but can be variable
   b) Periodic boundary conditions for specular reflections
   c) Wall absorption (prob. ~10^-5)
   d) Diffuse reflections (prob. incident angle dependent[3])



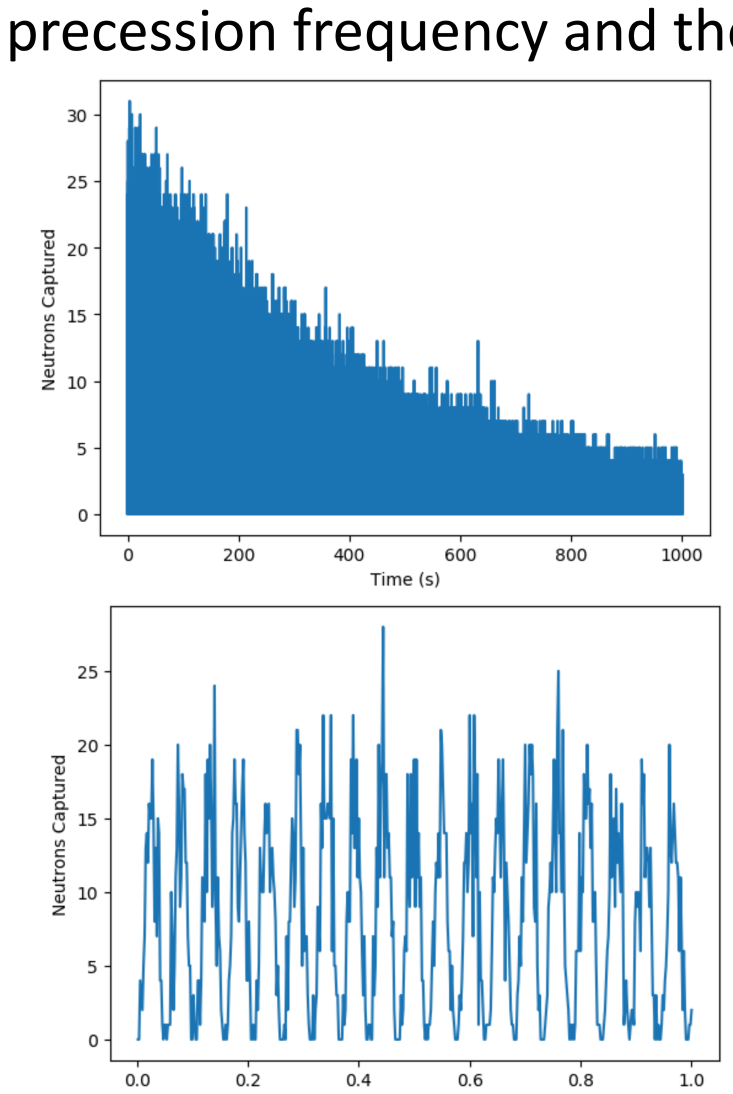
3. Precess
a) Current assumptions are uniform and constant E- and B-fields (which can be relaxed)

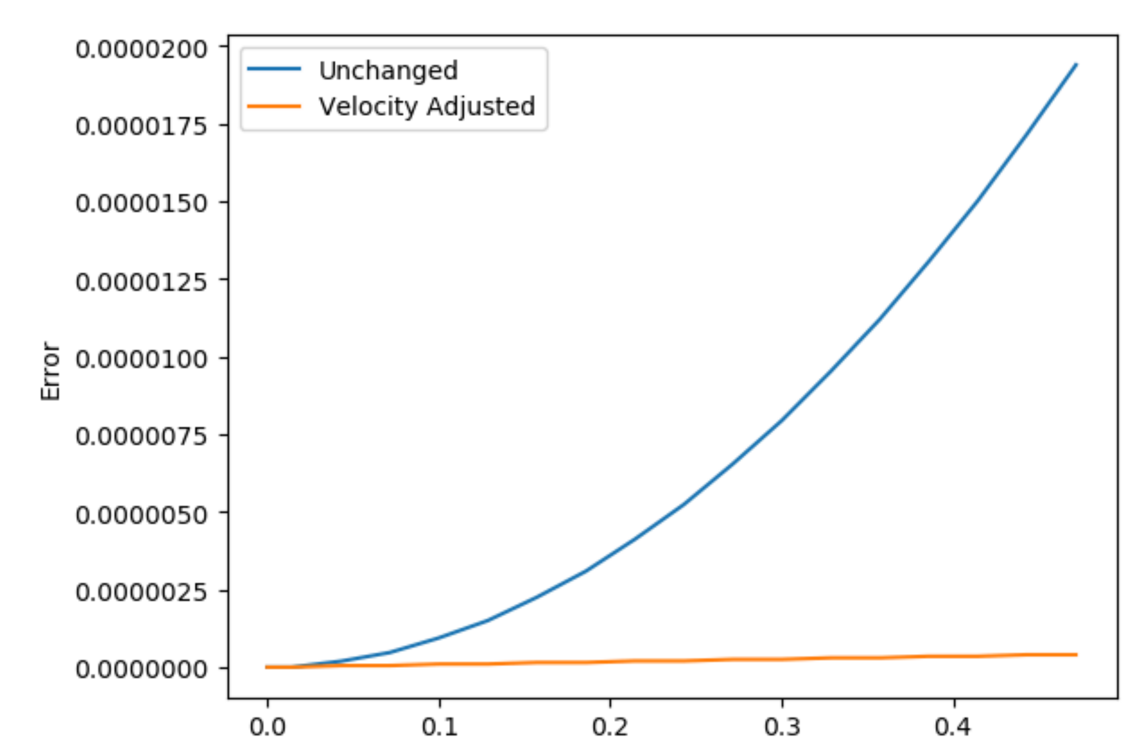
4. n + ^{3}He capture (spin-dependent probability[4])

5. β decay (constant probability/step)

Results

The total rate decays due to the losses on the walls, the ^{3}He captures, and β decay. The sine wave is caused by the precession – we fit that to get the precession frequency and the nEDM

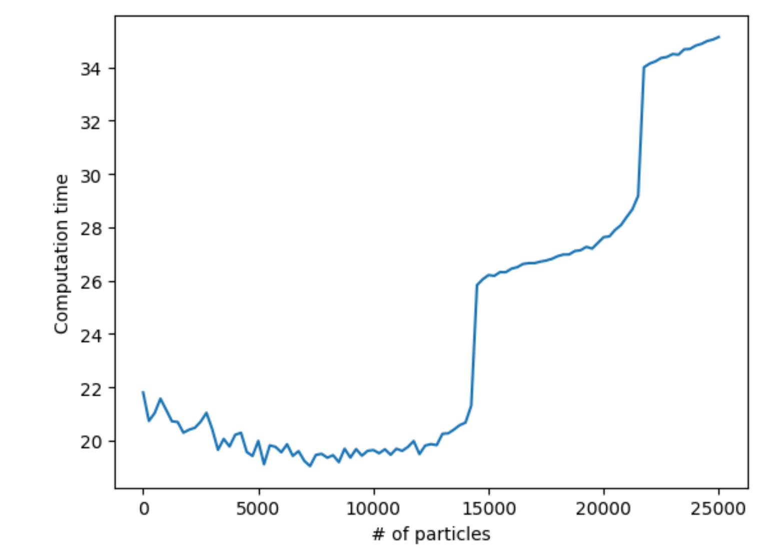




Reflections in the z-direction lead to an exponential accumulation of error, but can be corrected by adjusting the speed

Conclusions

- Efficient GPU parallelization to simulate many particles simultaneously
- GPU-based code may not be optimal for all studies, but could be a powerful tool in conjunction with CPU-based code



Computation time vs number of particles

Future Work

- Adding relevant physics:
  - Realistic B-field maps
  - Time-dependent systematics
  - Tracking ^{3}He
- Use for studies of possible false EDM effects
- Good candidate for Summit

Acknowledgements

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References

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