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MICE Step 4.5 Cooling Performance

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Measuring Cooling Performance

- Basic question: does MICE step 4.5 cool?
  - Currently using old baseline: AFC-CAV-ABS-CAV-AFC
- Start with a distribution, properly matched, with a given emittance
- No cheating: *a priori* select a distribution
- Find transmission and final emittance

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Measuring Cooling Performance

- Phase space density increase

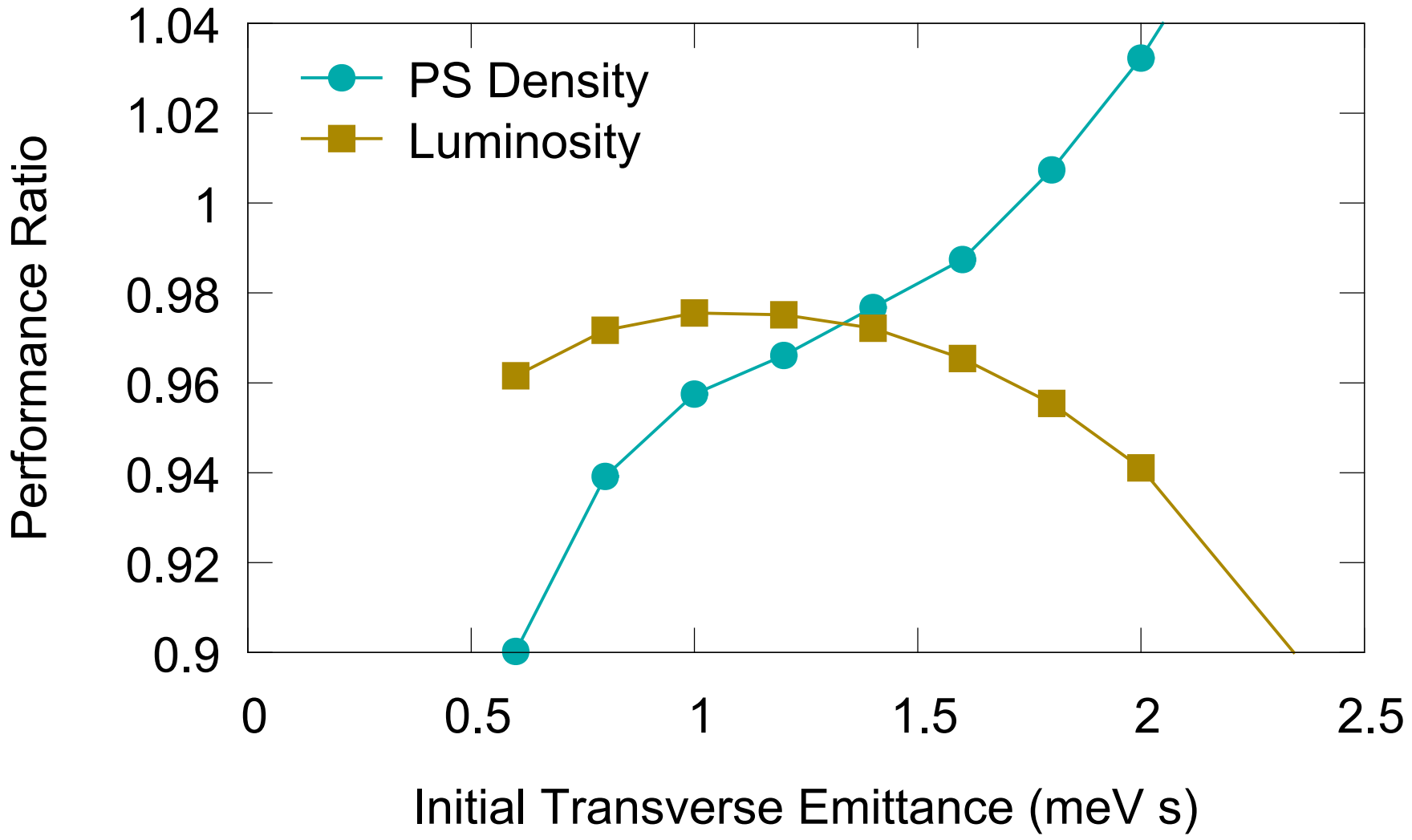
$$\frac{N_f \epsilon_{6i}}{N_i \epsilon_{6f}}$$

- Luminosity increase

$$\frac{N_f^2 \sqrt{\epsilon_{6i}}}{N_i^2 \sqrt{\epsilon_{6f}}}$$

- Plot quantities vs. initial emittance for MICE Step 4.5 baseline
  - Only include transverse for now

Measuring Cooling Performance



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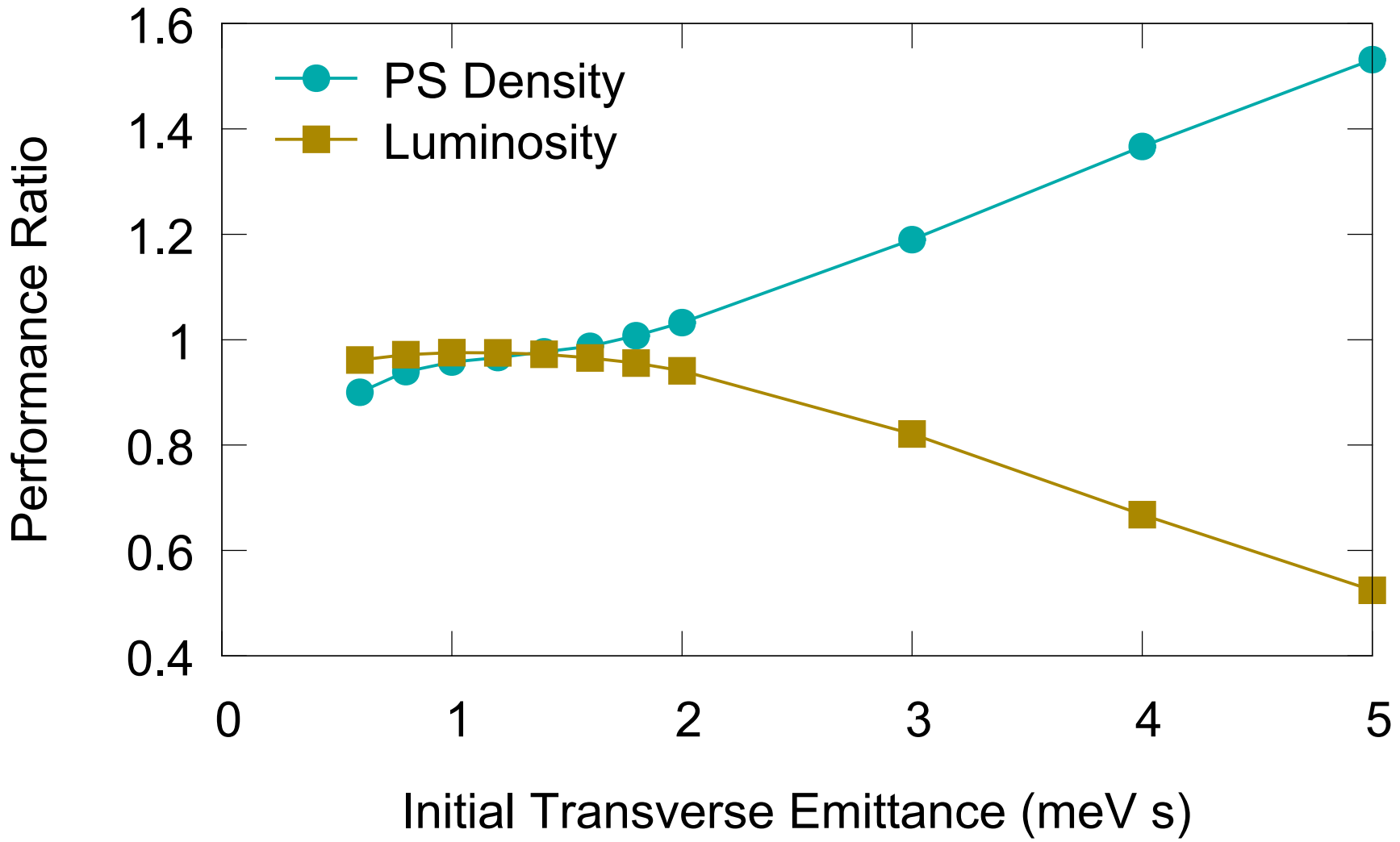
Measuring Cooling Performance



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Measuring Cooling Performance

- No gain in luminosity
- We increase the measure of phase space density
  - But this is clearly bogus: ratio grows to absurd values
  - This is cooling by truncation
- Need a better measure of phase space density increase

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Phase Space Density

- Measure local phase space density
- Launch a distribution, uniform in 4-D (later 5-D) phase space, ellipsoidal
- At exit, histogram into bins with equal 4-D (5-D) phase space volume
  - Assume match based on solenoid field
  - Compute actions, $J = J_x + J_y$, bin number is $\lfloor n_{\mathrm{bin}} J^2 / J^2_{\mathrm{max}} \rfloor$
- Cooling if bin contains more particles than corresponding initial volume would have had

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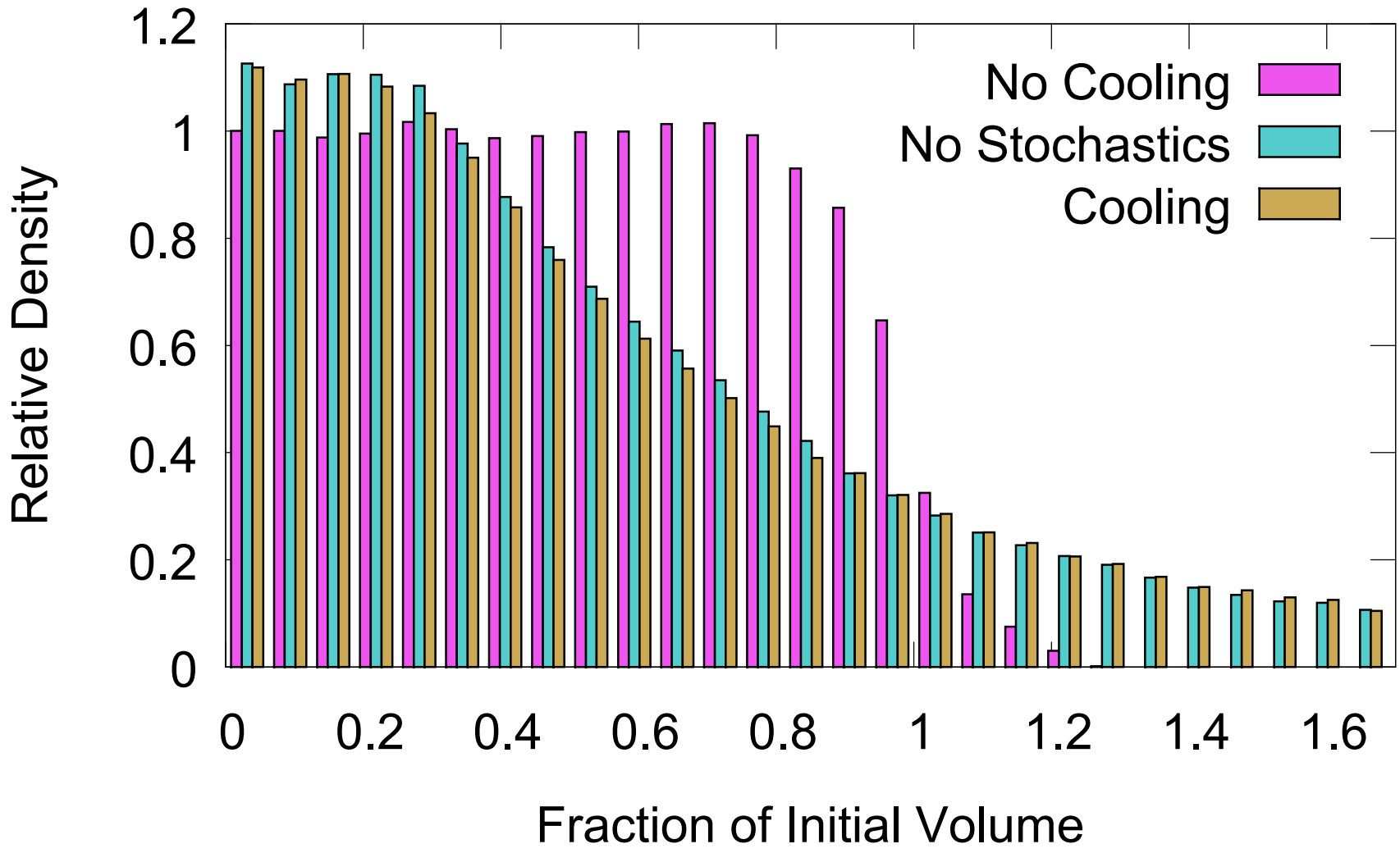
Density Change



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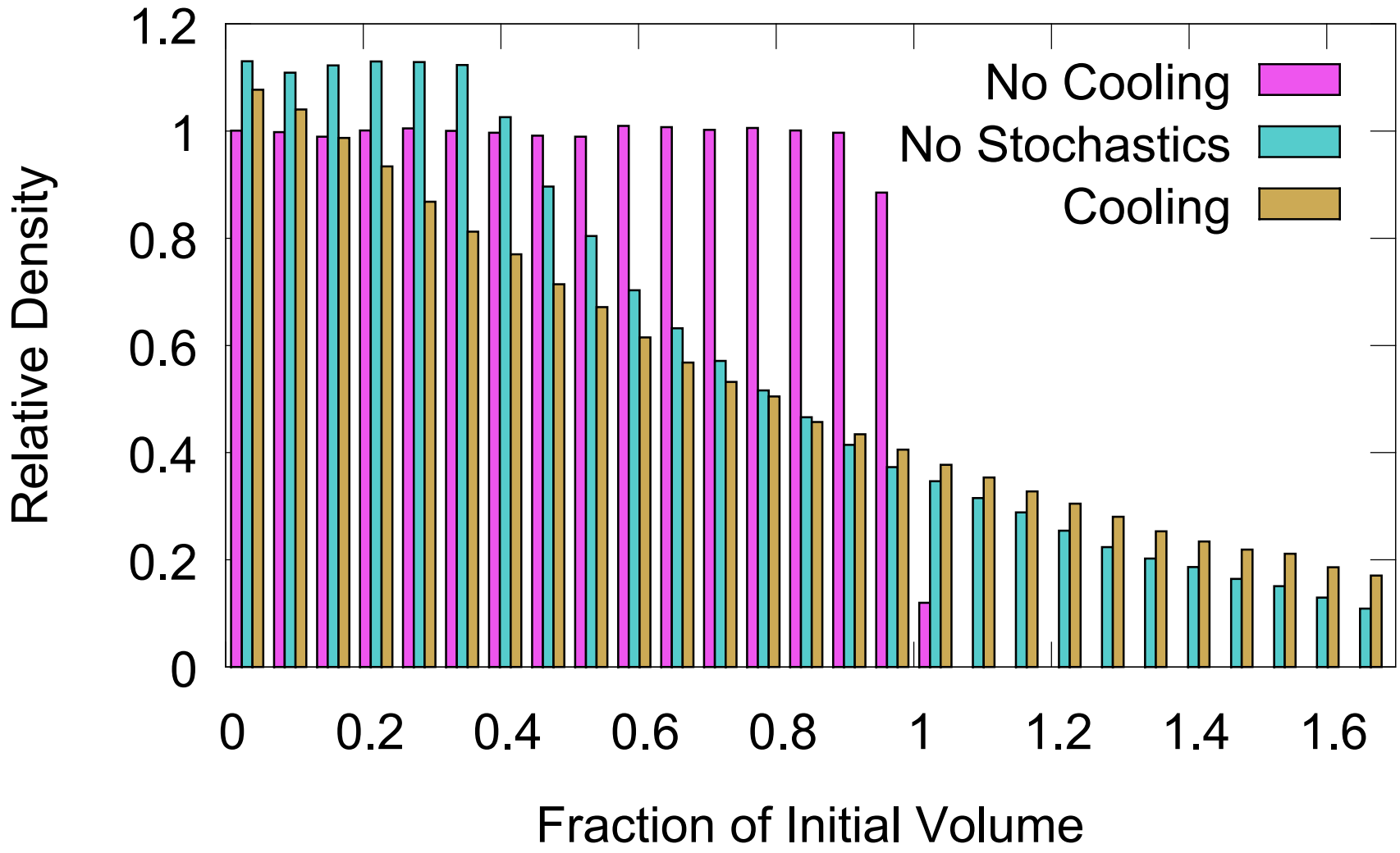
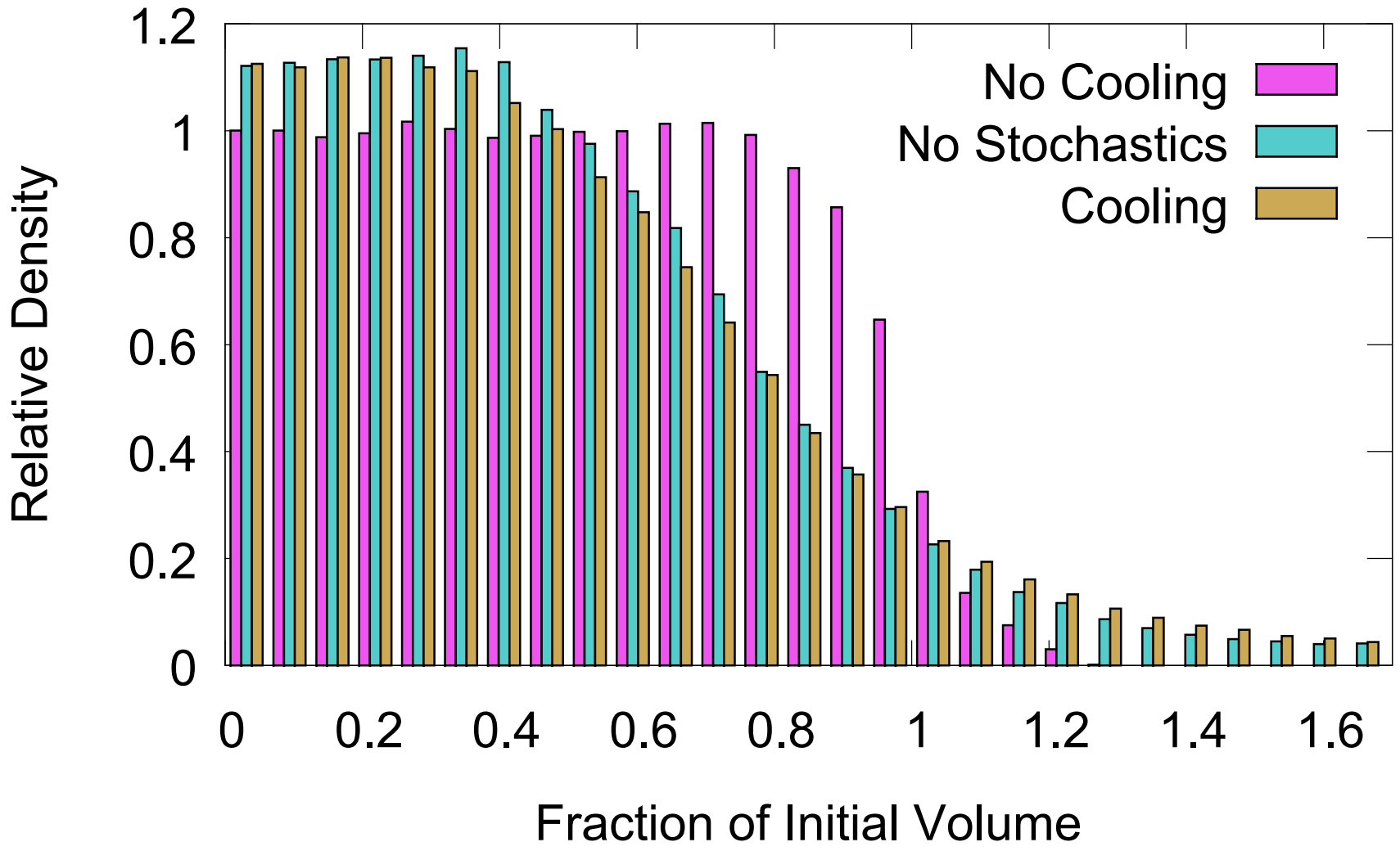
Density Change

- Density increase for low amplitude particles
- No cooling: spreading in high amplitude particles
  - Nonlinear: goes away at low amplitude
- With cooling: even more spreading in high amplitude particles
  - Assumed beam matched to solenoid
  - Occurs without stochastics
  - Does not go away at low amplitude
  - Seems too large for amount of cooling
- Try finding match which maximizes particles with $J < J_{\text{max}}$

Density Change, Low Amplitude



Density Change with Rematch



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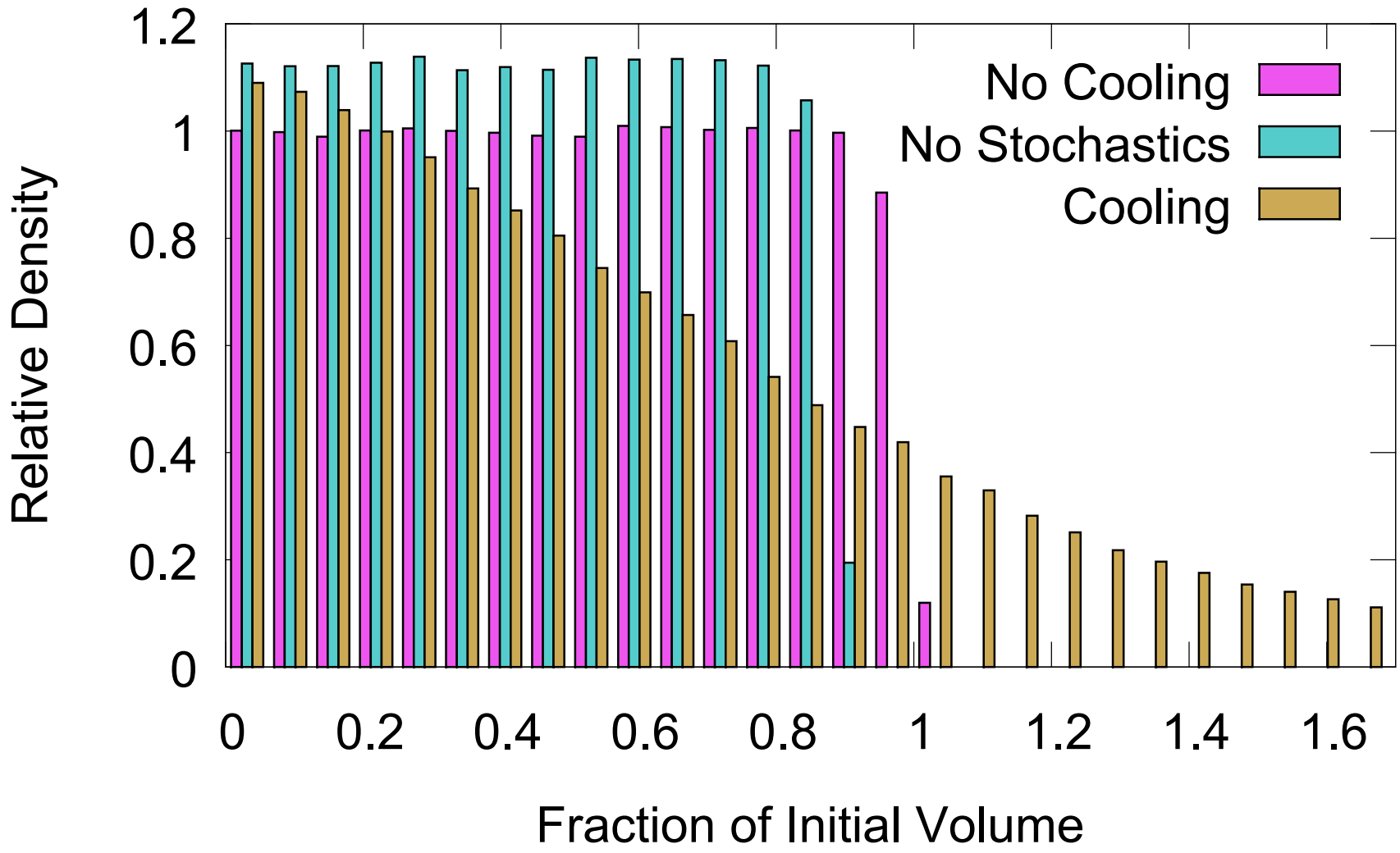
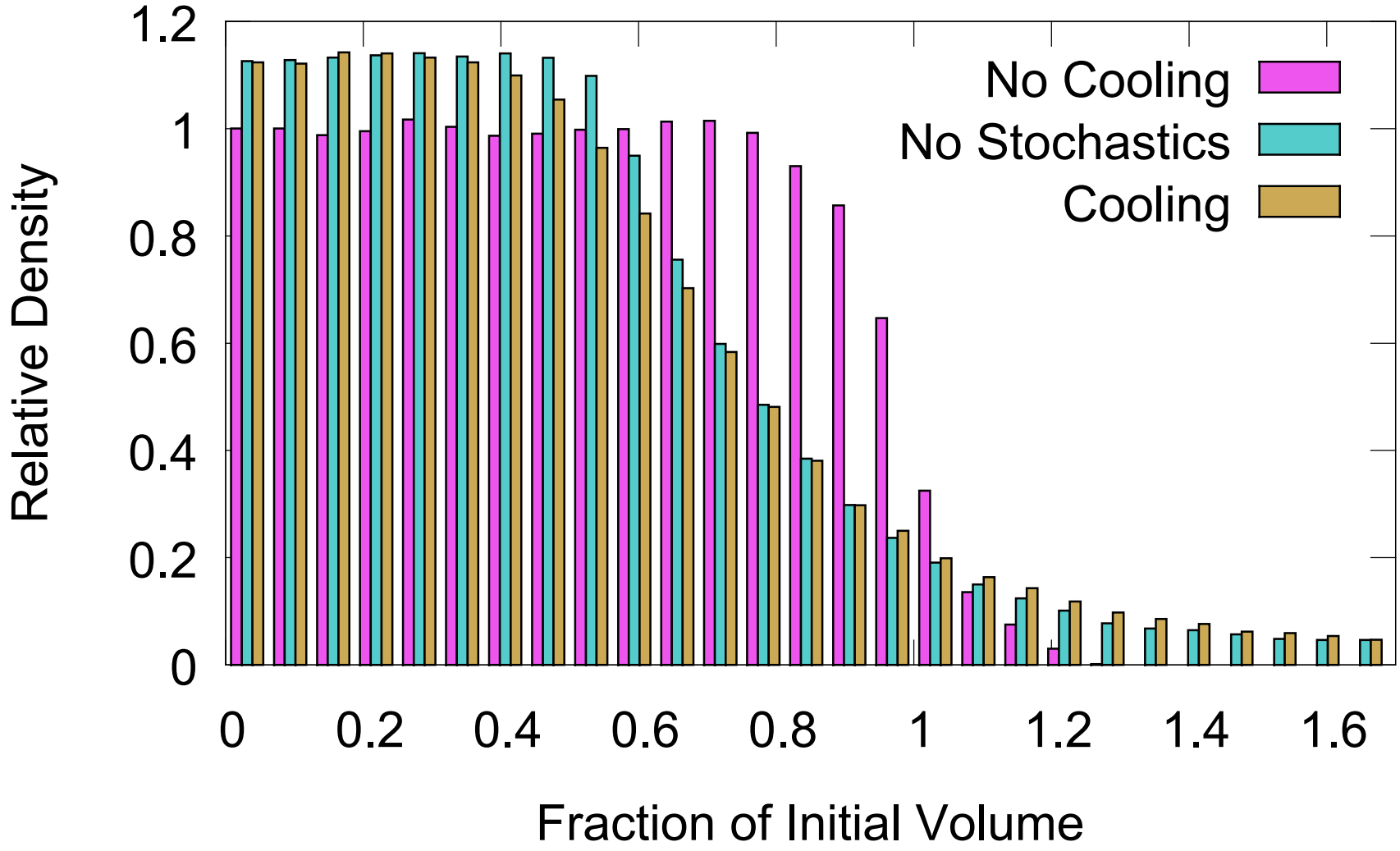
Density Change with Rematch

- Choosing best match increases fraction of the beam showing cooling
- Angular momentum is close, but aspect ratio off by almost 50%
- Still seeing tail at higher amplitudes, even without stochastics
- Effect is nonlinear, without stochastics disappears at low amplitude
- At high amplitude, letting α be free is worse
  - Criterion maximizing particles with $J < J_{\max}$ is probably wrong

Rematch, Low Amplitude



Density Change with Rematch, no α



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Conclusions

- Cooling can be measured by starting with a uniform phase space density and looking for an increase in that density
- MICE Step 4.5, at least the old configuration, cools in 4-D
- There is a significant mismatch at the final spectrometer that arises when the absorber is added
  - The lattice should be re-matched to take this into account
- Unfortunately the lattice does not appear to increase luminosity

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Next Steps

- Switch to current lattice
- Re-tune lattice to be matched with cooling
- Look at 5-D cooling: include energy spread
- Look at 6-D effects: selecting a correlation to keep time spread together