

The United States Defense Laboratories: Lawrence Livermore National Laboratory (LLNL), Los Alamos National Laboratory (LANL), and Sandia National Laboratory (SNL), in conjunction with the Nevada National Security Site (NNSS) is building a 1.7MeV multi-pulse linear induction electron beam accelerator, Scorpius, for use in subcritical experiments that occur at the NNSS facility called U1A.

Diagnostic Design

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$$\text{Emittance Reconstruction: } \tilde{\epsilon} = \sqrt{x^2 x'^2 - x x'^2},$$

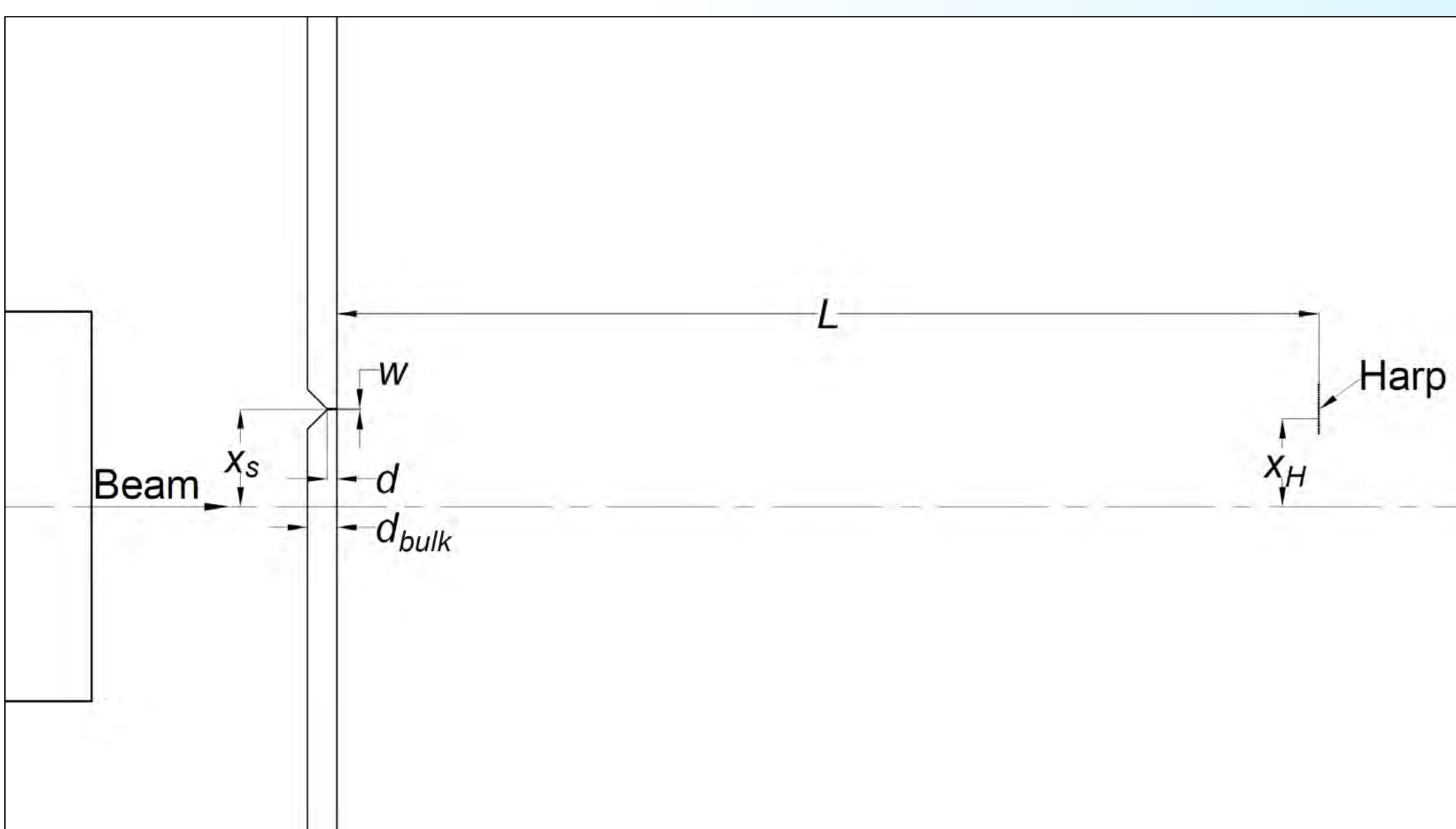
COMSOL Multiphysics Modeling

LLNL Scorpius Beam Tune

- 25000 macroparticles input beam “source” (injector)
- $1.7\text{MeV} \leq E \leq 2.0\text{MeV}$

Create Source-Slit-Harp Geometry

- Source-Slit Distance: S
- Slit-Harp Distance: L
- Slit Aperture Width: w
- Slit Collimator Depth: d
- Slit Center Offset: x_s

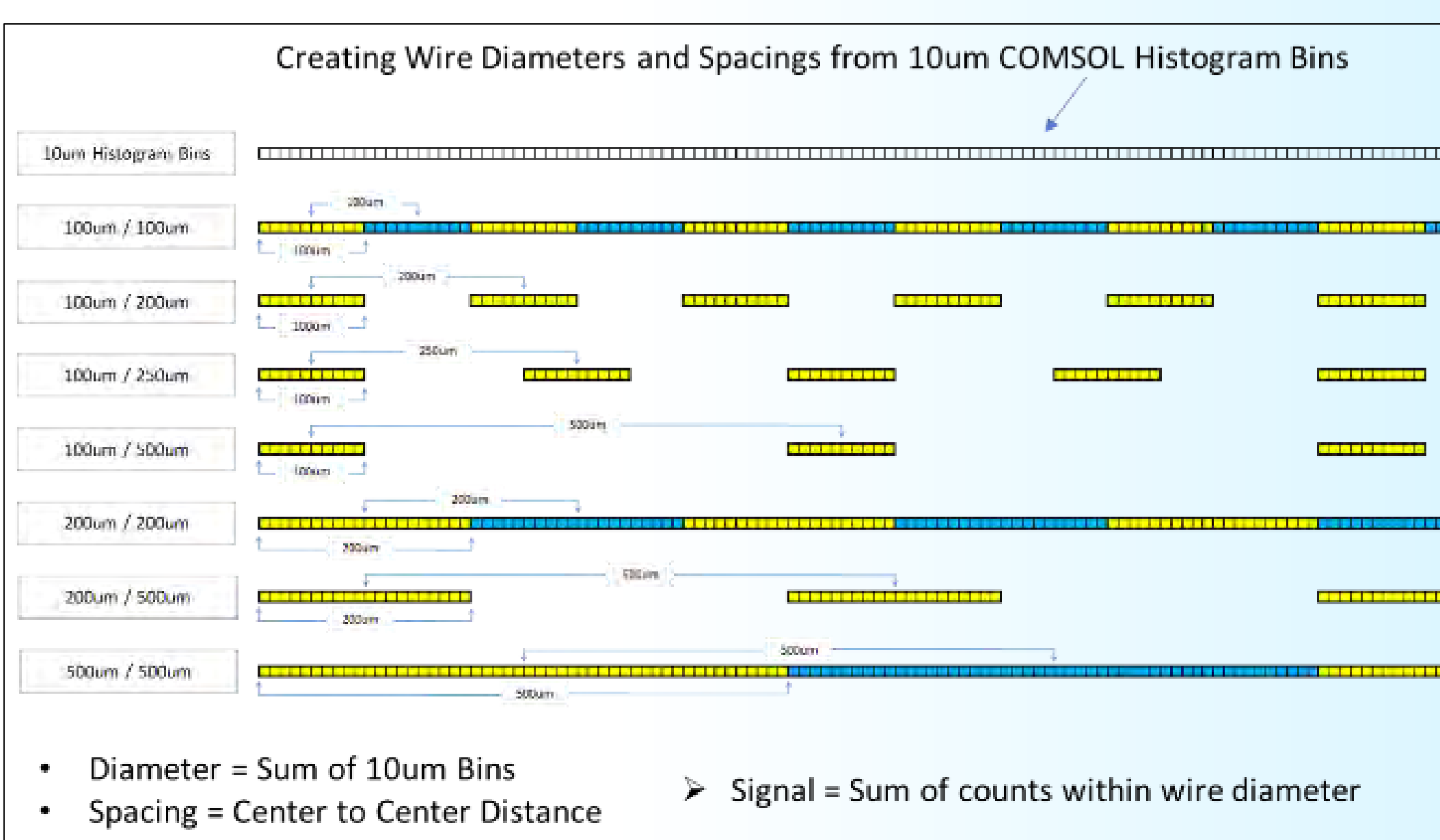


Each COMSOL Simulation:

- Time ($0 \leq t \leq t_{\text{max}}$), steps: 10^{-11}s
- Offset ($-44\text{mm} \leq x_s \leq +44\text{mm}$)

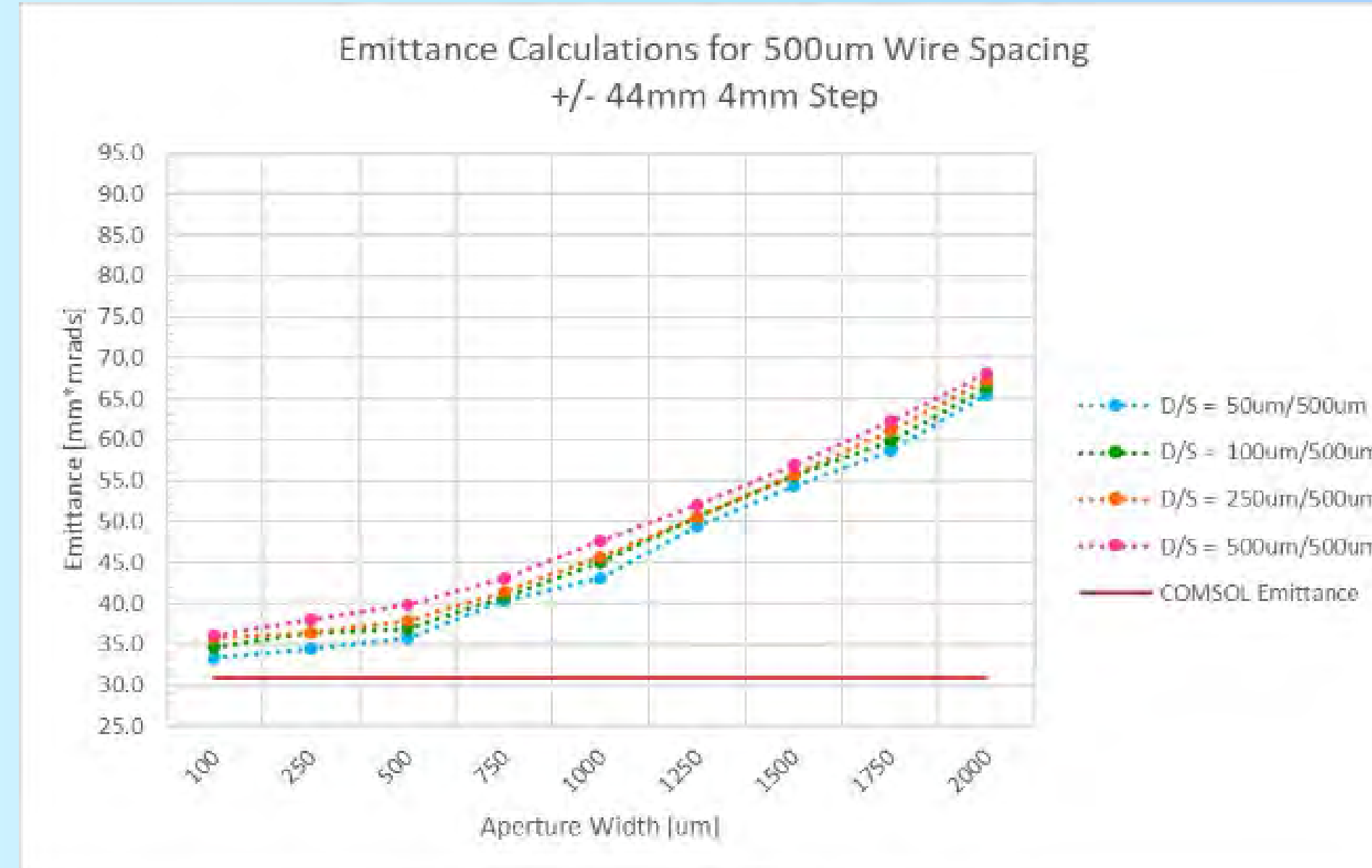
Slit Parameter Variation:

- $100\mu\text{m} \leq w \leq 4000\mu\text{m}$
- $1\text{mm} \leq d \leq 2\text{mm}$

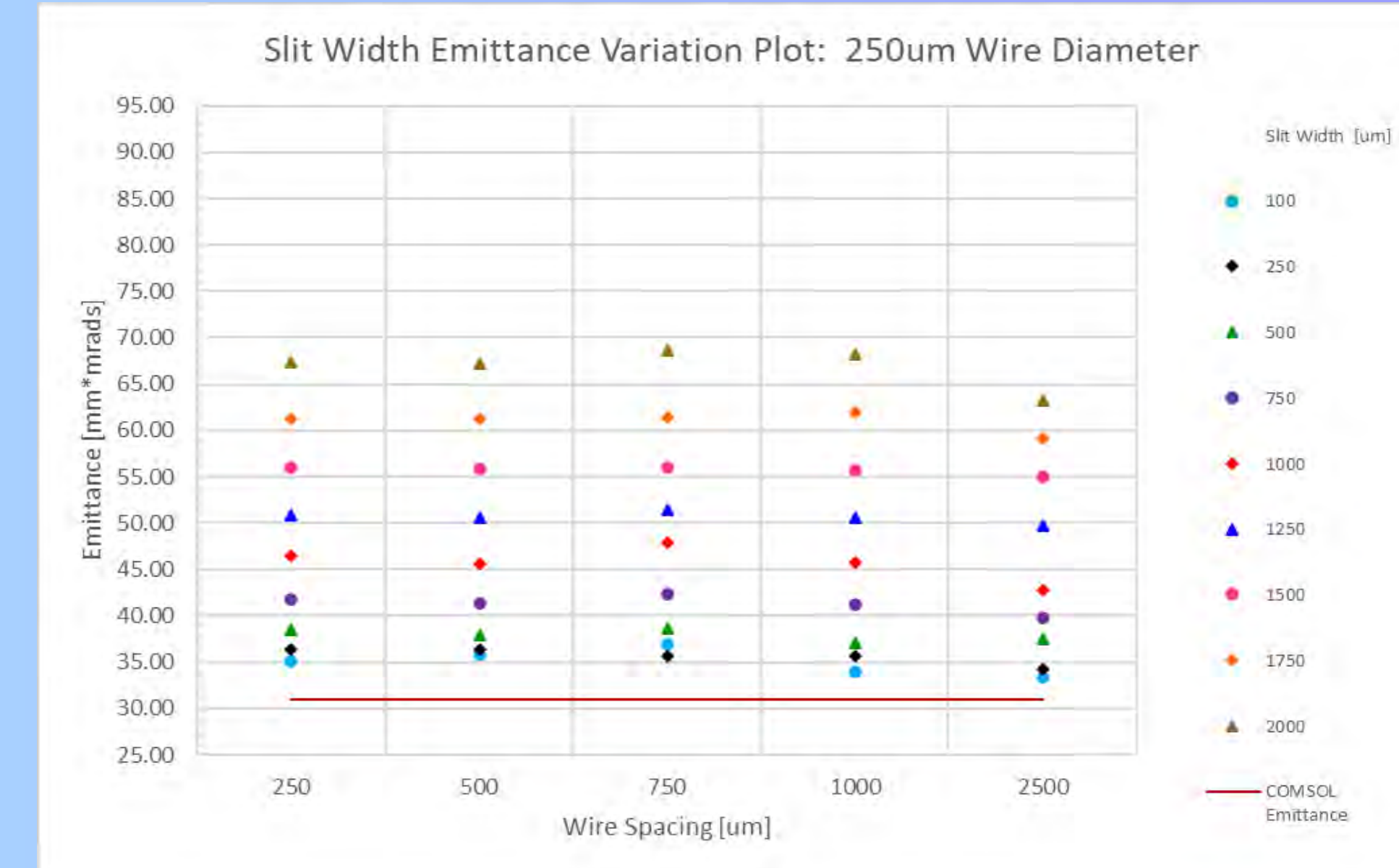


Harp Wire Variation

- $50\mu\text{m} \leq \text{Diameter} \leq 2500\mu\text{m}$
- $50\mu\text{m} \leq \text{Separation} \leq 2500\mu\text{m}$



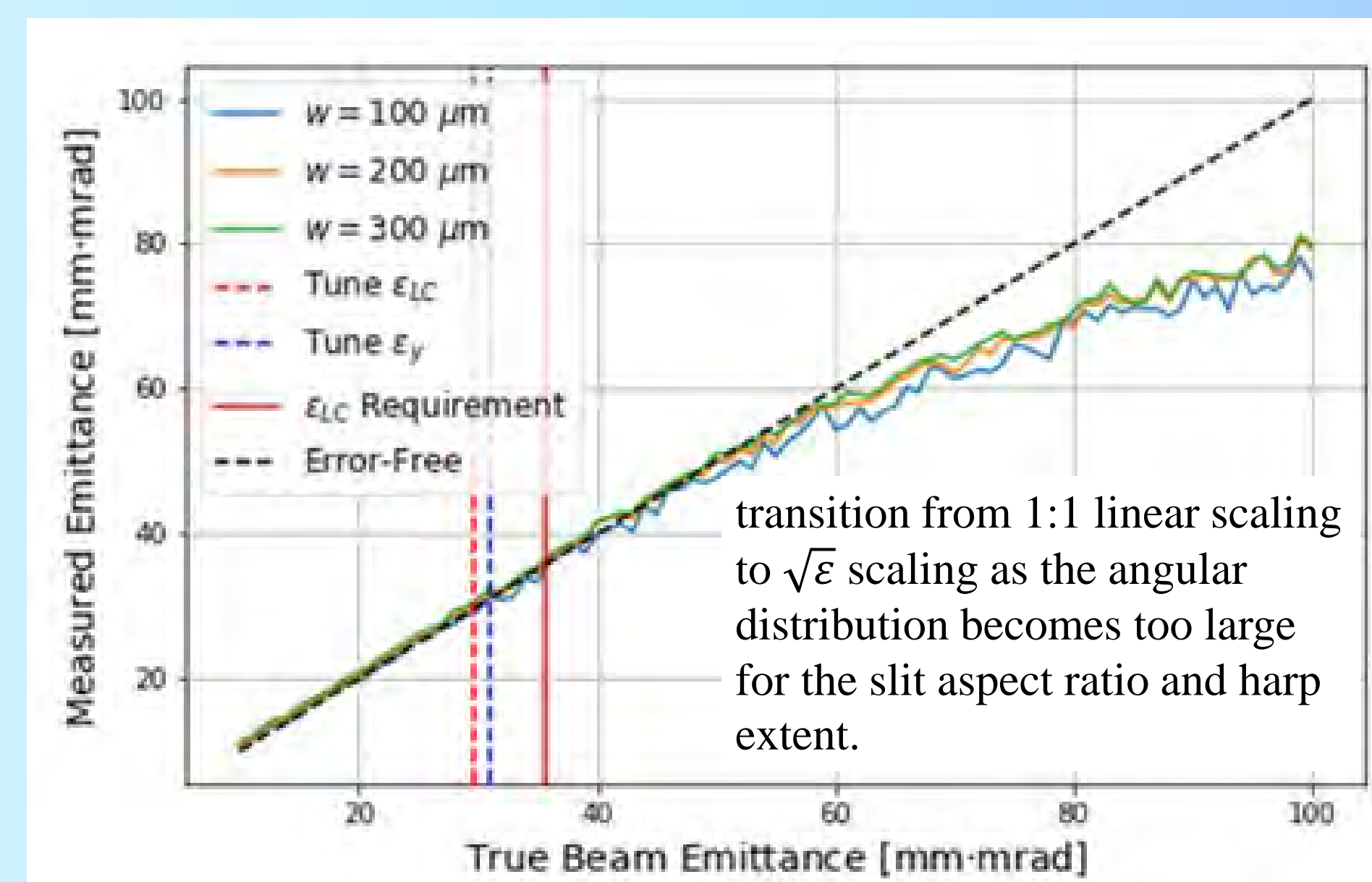
Reconstructed RMS emittance for 500 μm harp wire spacing for different wire diameters and aperture widths.



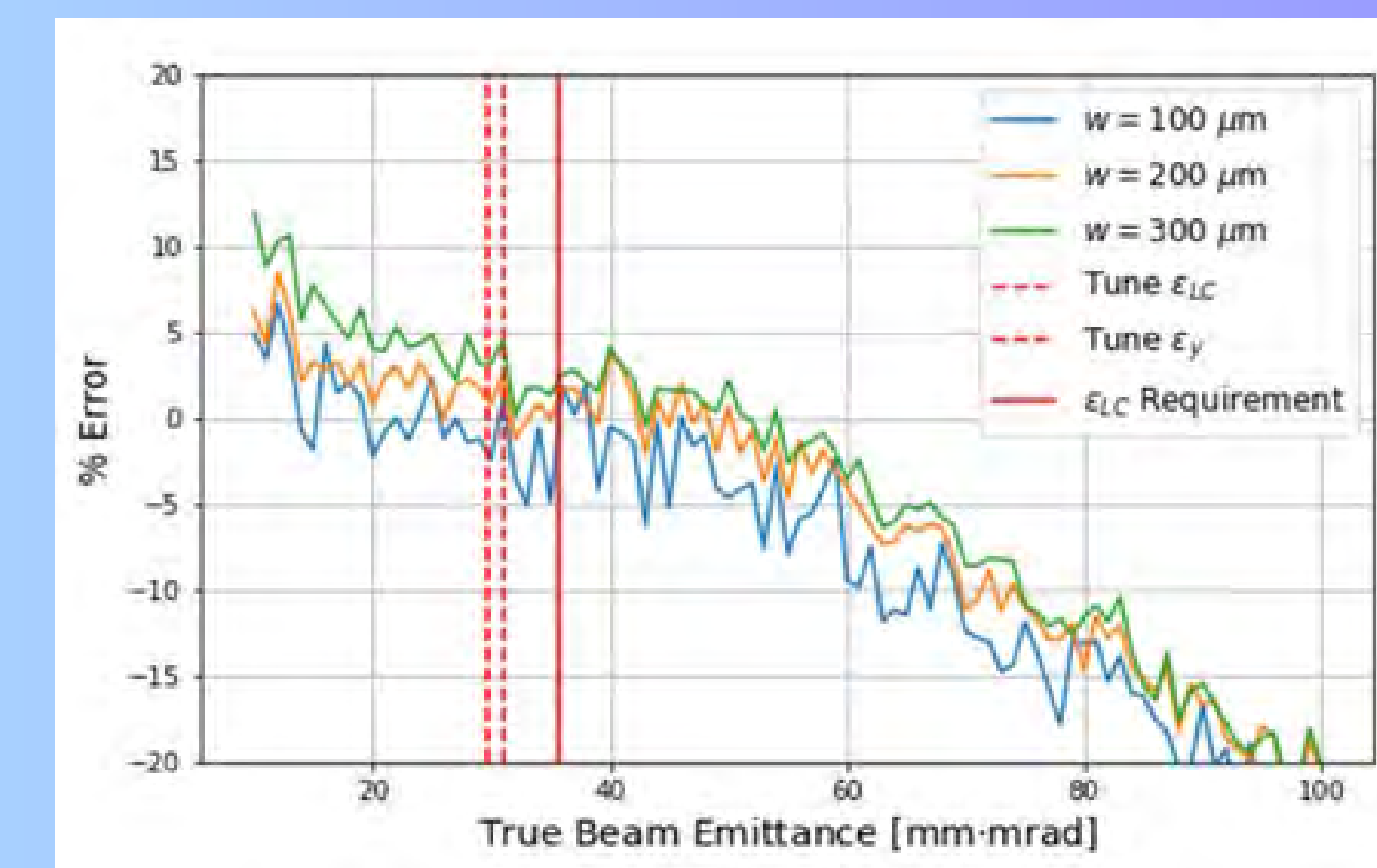
Reconstructed RMS emittance for 250 μm diameter harp wire for different wire spacings and aperture widths.

Errors: Estimation & Mitigation

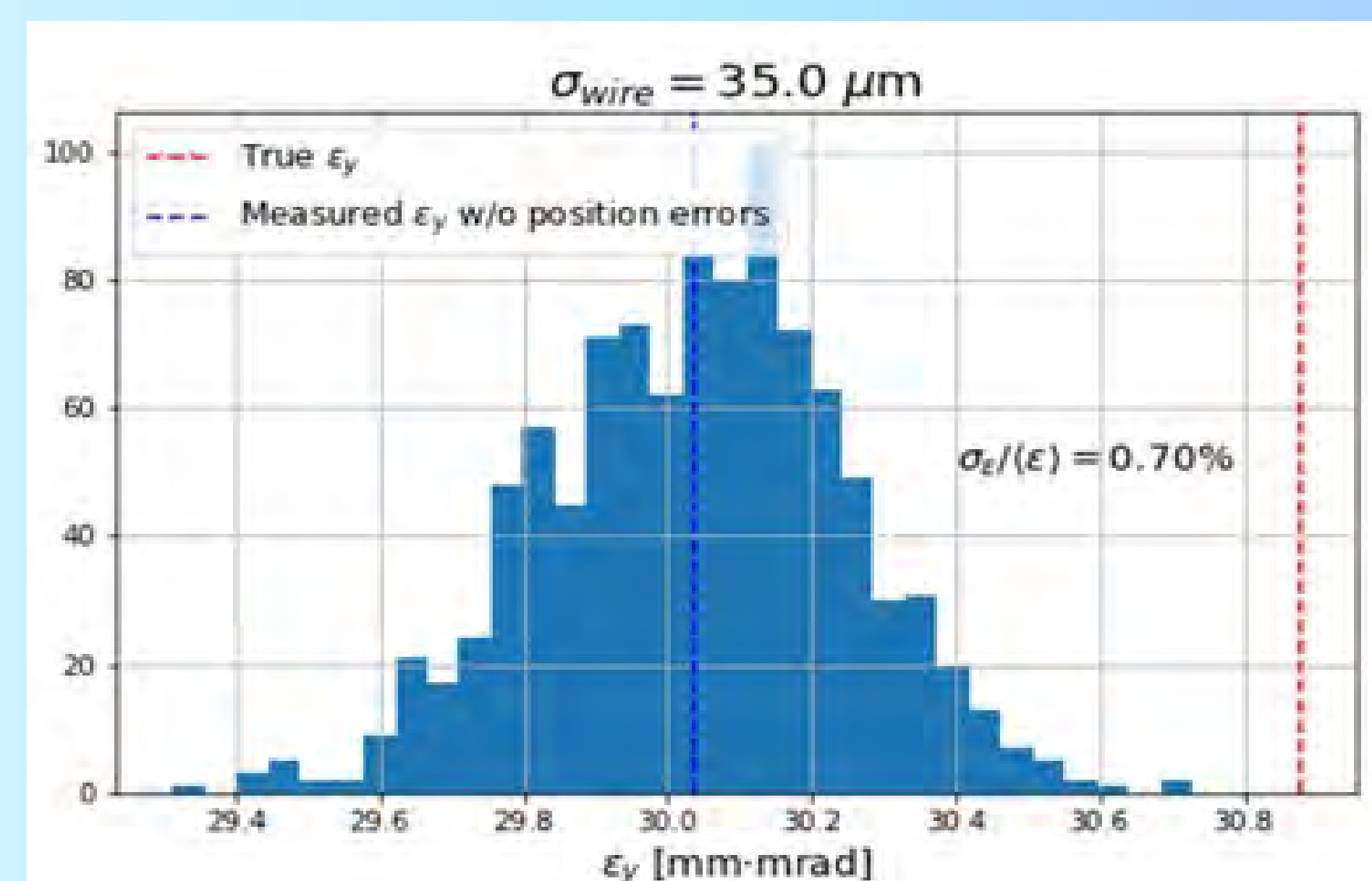
Errors Contribution % ~ 3.4%



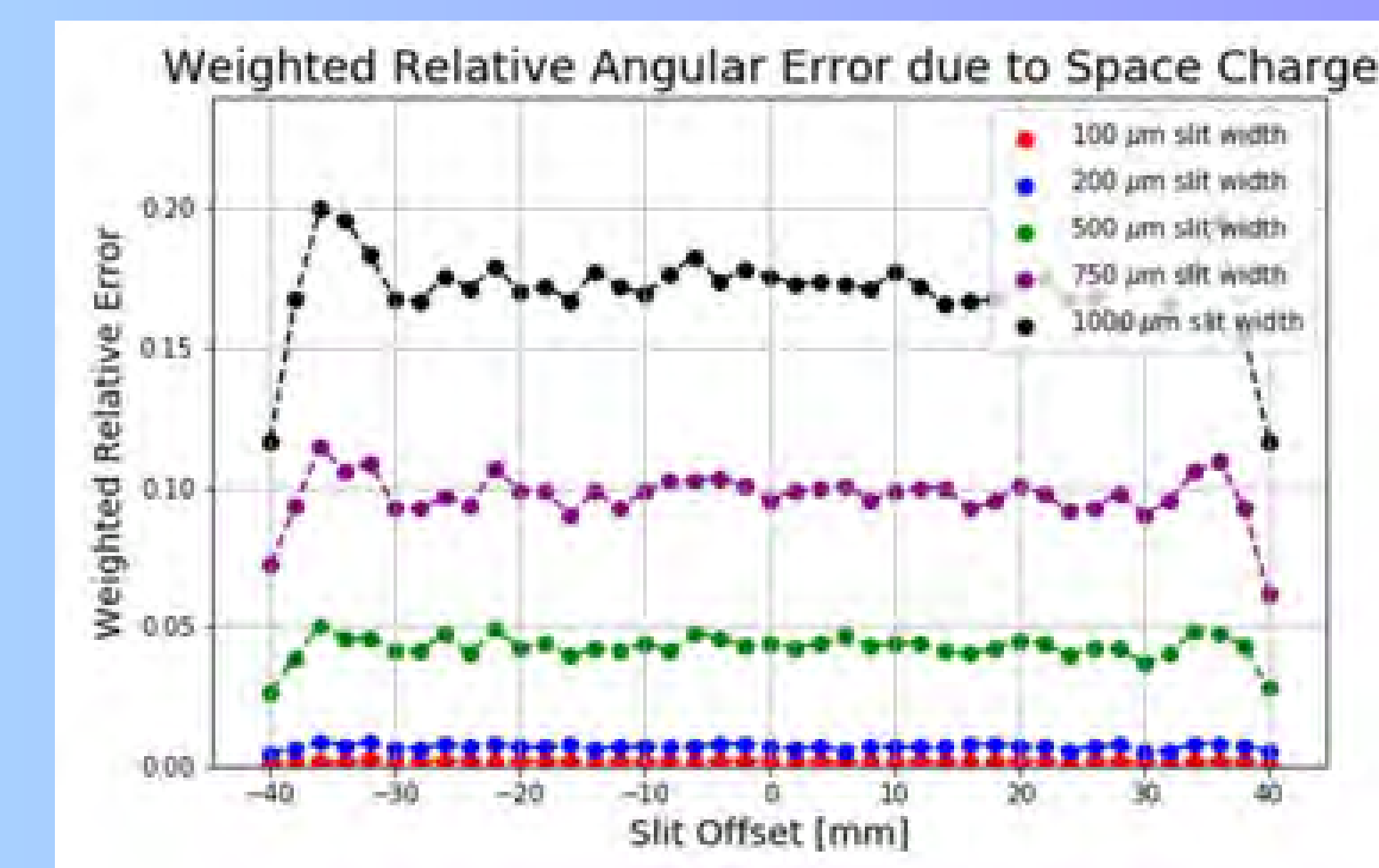
Reconstructed RMS emittance: sampling / binning errors study (measured vs true)



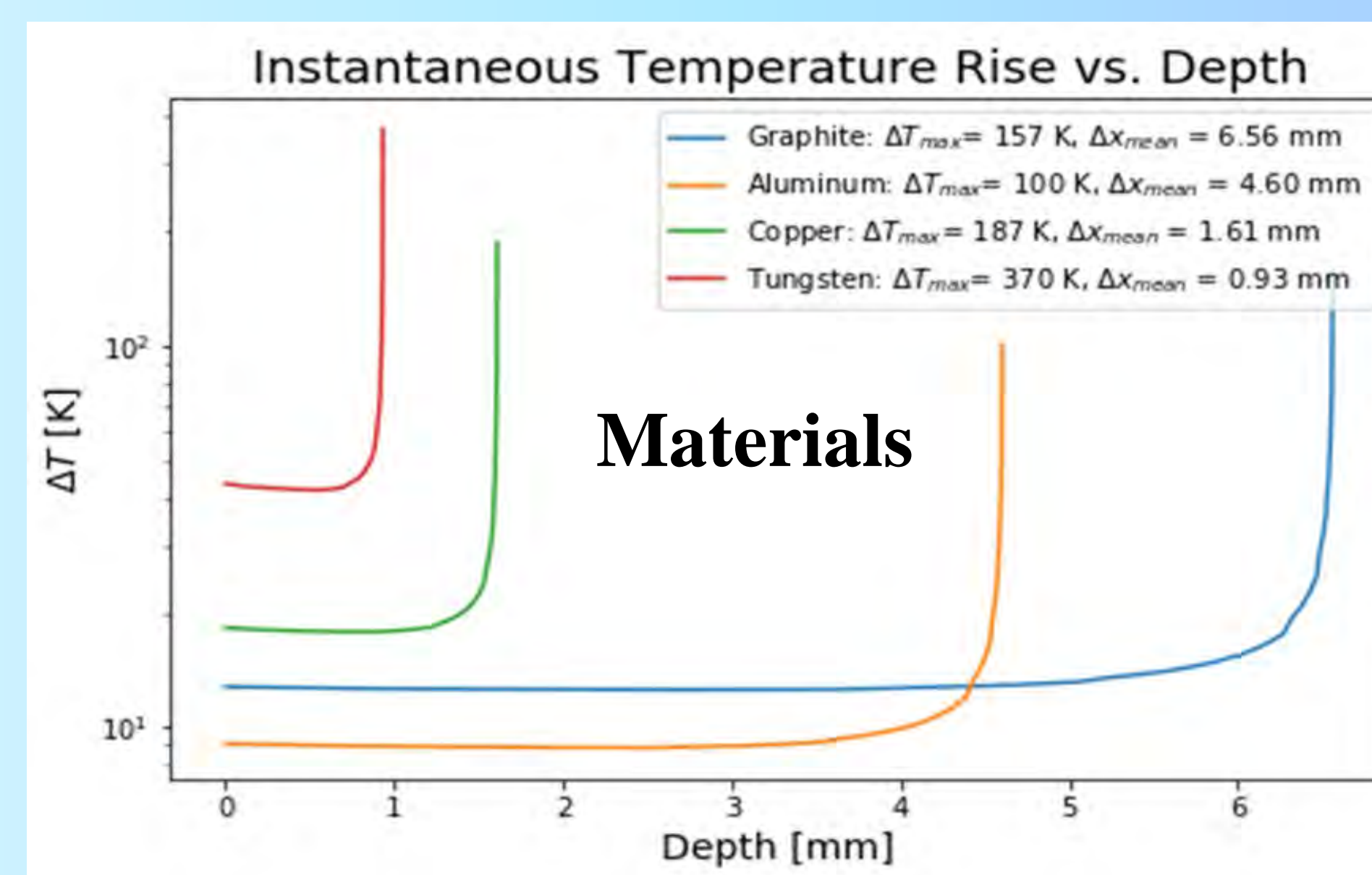
Reconstructed RMS emittance sampling / binning errors study (% error vs true)



Reconstructed RMS emittance: manufacture tolerance study. Wire displacement from nominal positional produced by a normal distribution of $\sigma_x = 35.0\mu\text{m}$



Weighted Relative Error: Plots showing the relative angular error due to space charge weighted by the # of e^- 's in the beam at that radius.



National Institute of Standards and Technology ESTAR was used to estimate the deposited energy density distribution.

Conclusions

In conclusion, the proposed slit-harp emittance diagnostic design should be able to measure the electron beam emittance at the NNSS Scorpius linear induction accelerator to within several percent of its true value. The design of record is a slit having a width w ($100\mu\text{m} \leq w \leq 200\mu\text{m}$), collimation depths $d = 2\text{mm}$, and tunes of energy 1.7MeV ($1.7\text{MeV} \leq E \leq 2.0\text{MeV}$).