UT-BATTELLE

Experimental Verification of Halo Formation Mechanism of the SNS Front End

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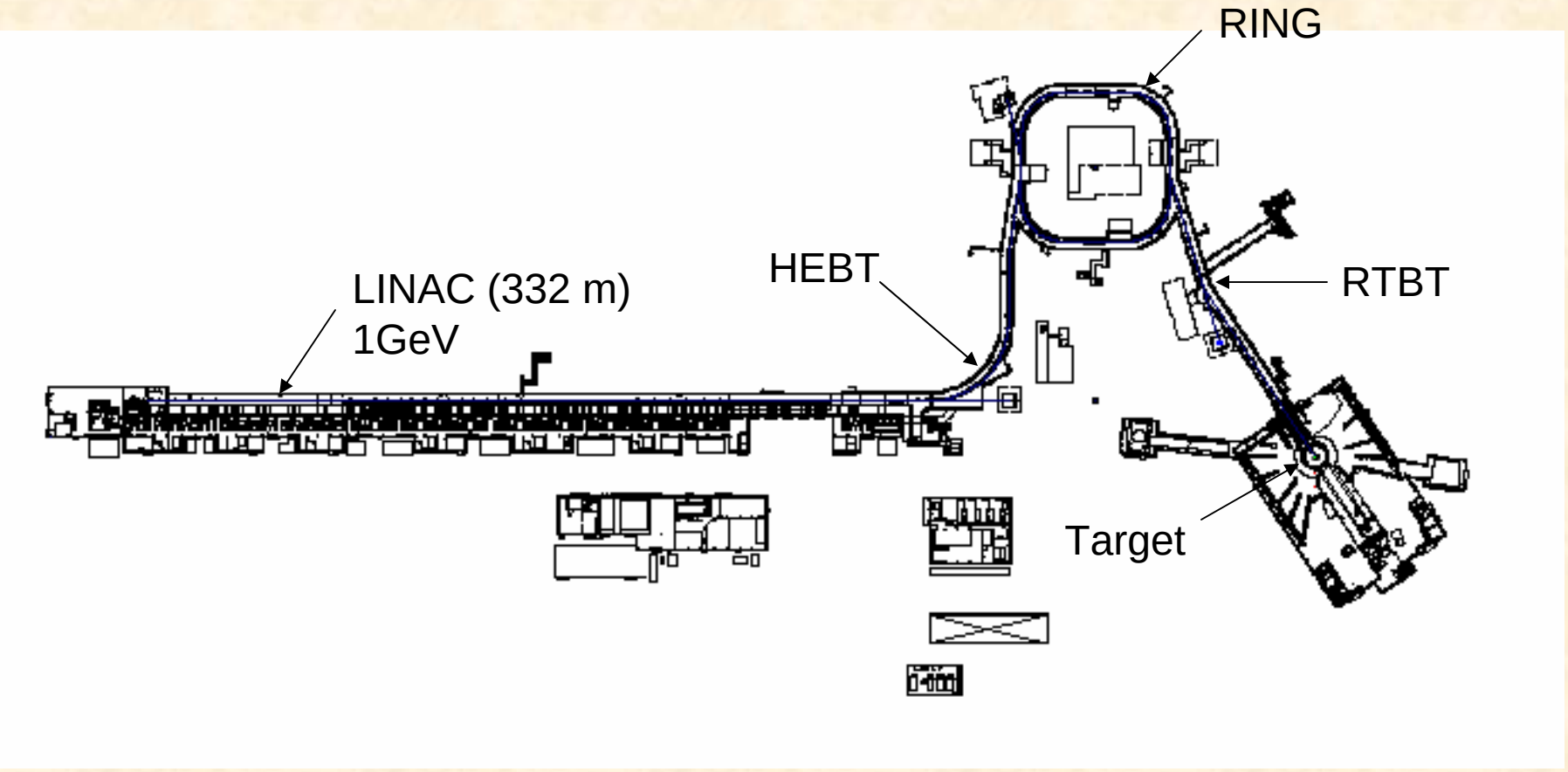
The Spallation Neutron Source

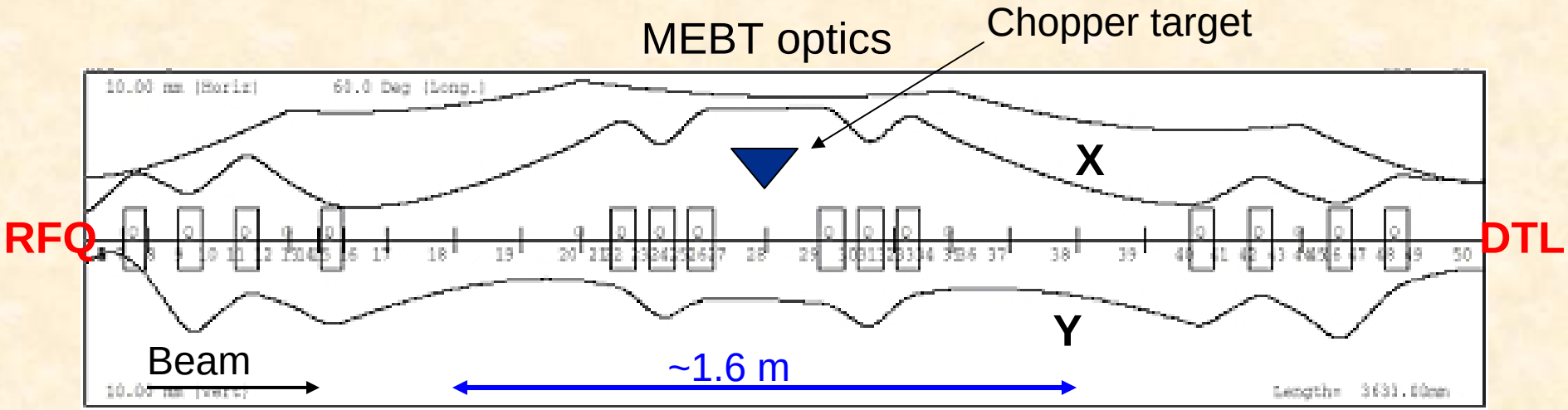
- **The SNS began operation in 2006!**
- **At 1.4 MW it will be the world's leading pulsed spallation source**
- **The peak neutron flux will be ~20–100x ILL**
- **It will be a short drive from HFIR, a reactor source with a flux comparable to the ILL**

Overview of Spallation Neutron Source



Sources of Front End halo generation

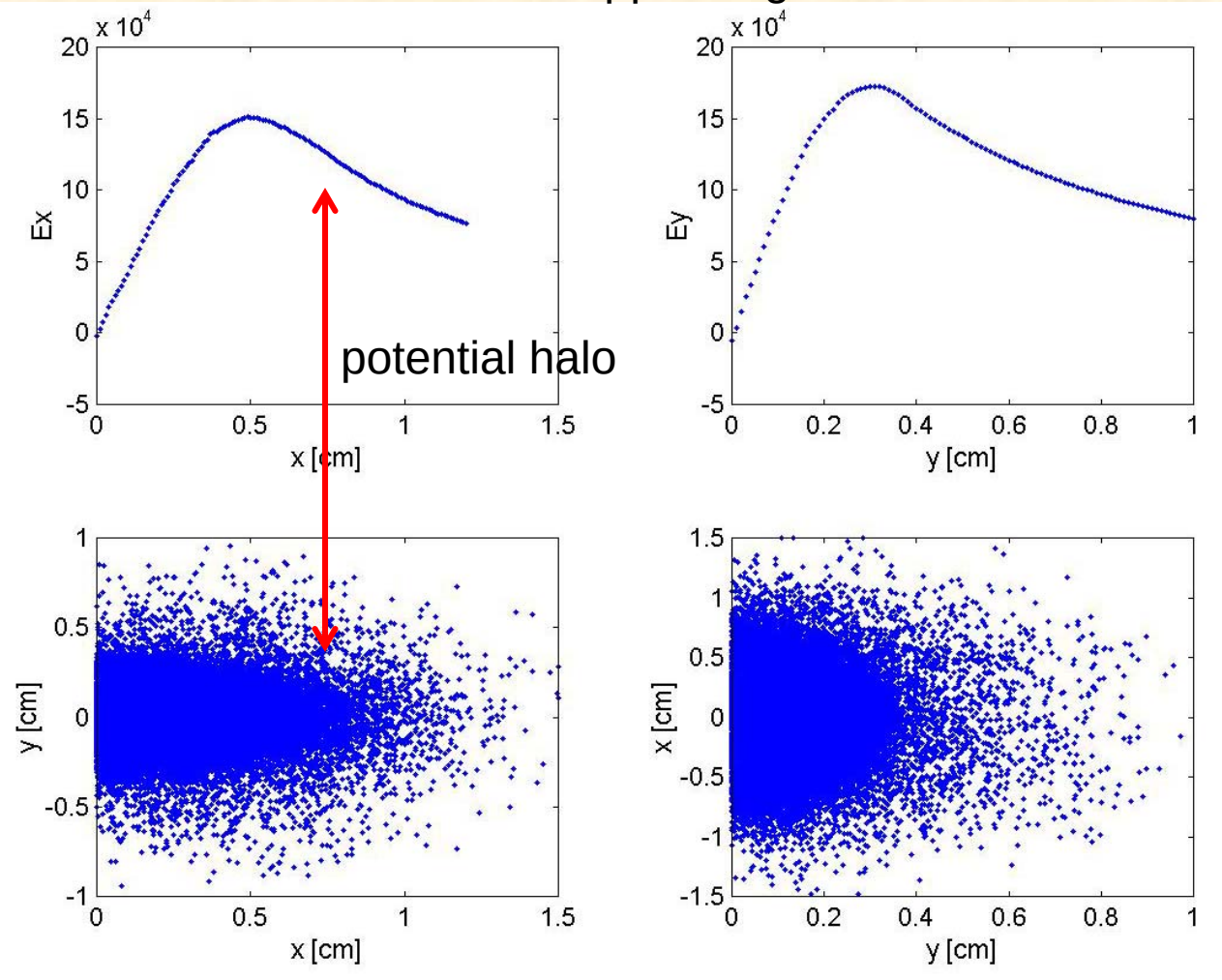
- MEBT is the largest contributor to FE halo generation
- Nonlinear space charge force stemming from a large transverse beam eccentricity generates halo in MEBT
  (D. Jeon *et al*, PRST-AB **5**, 094201 (2002))
- As minor contributors, several FE components and physical effects may contribute to the generation of beam halo



Region with a large transverse beam eccentricity ~2:1

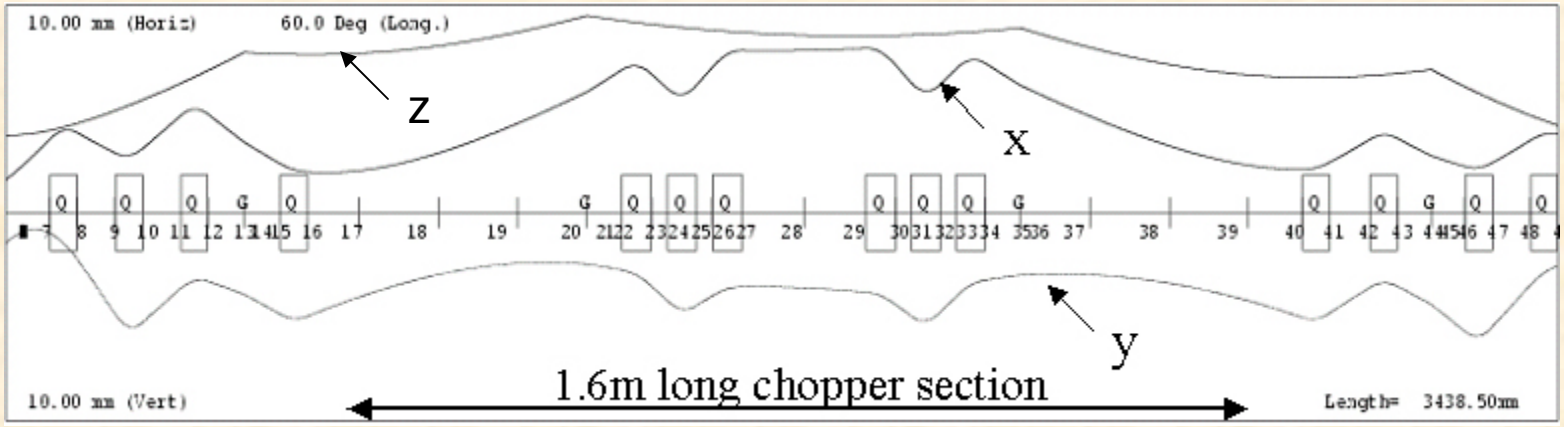
Fraction of core in x plane sees nonlinear space charge force, resulting in halo formation in x plane

Beam at the chopper target

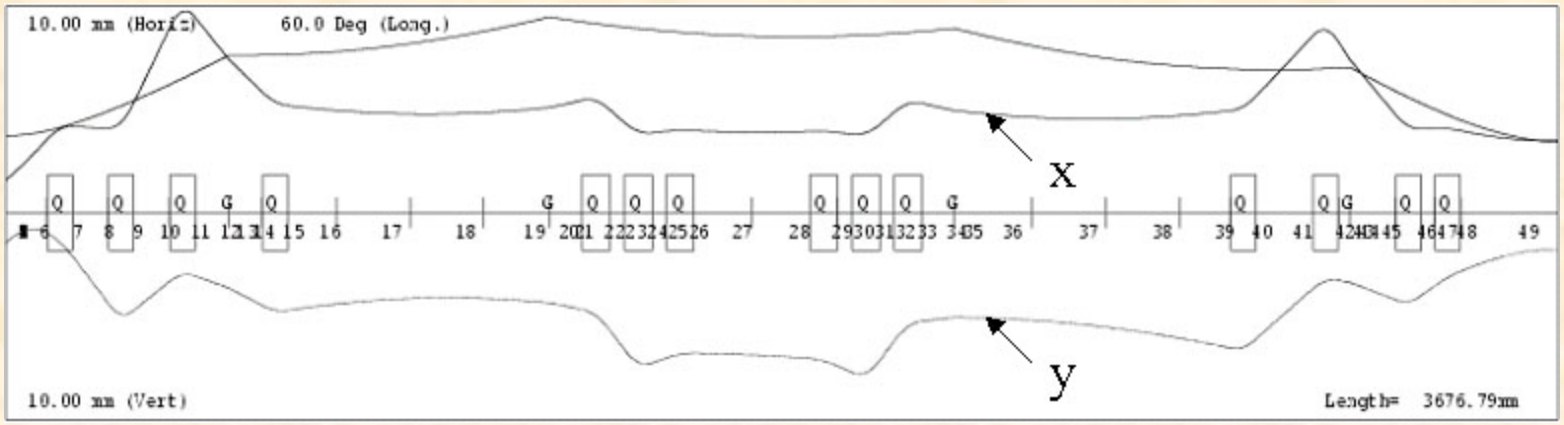


Space charge force and real space distributions

Optics modification improves beam quality

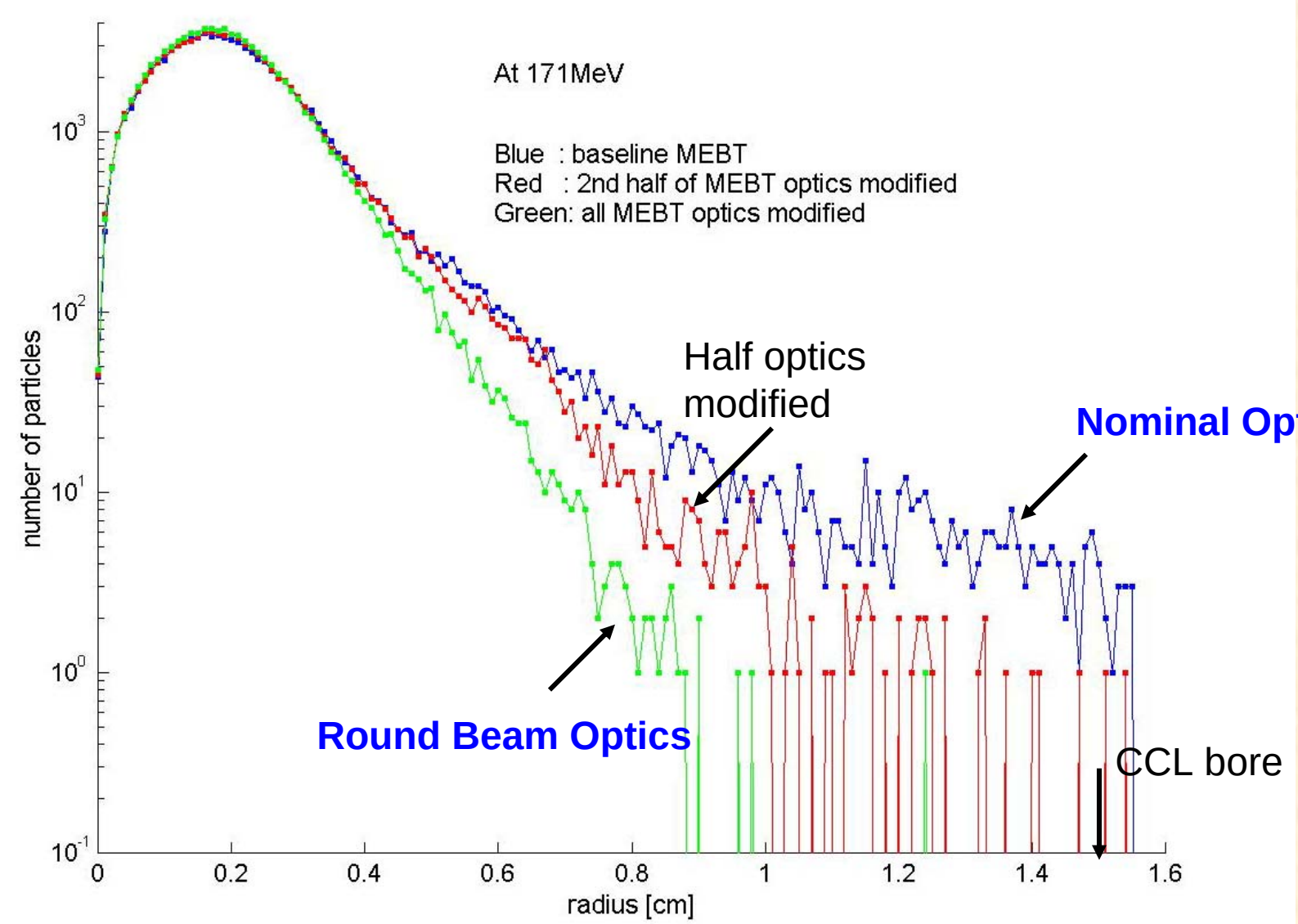


Nominal Optics

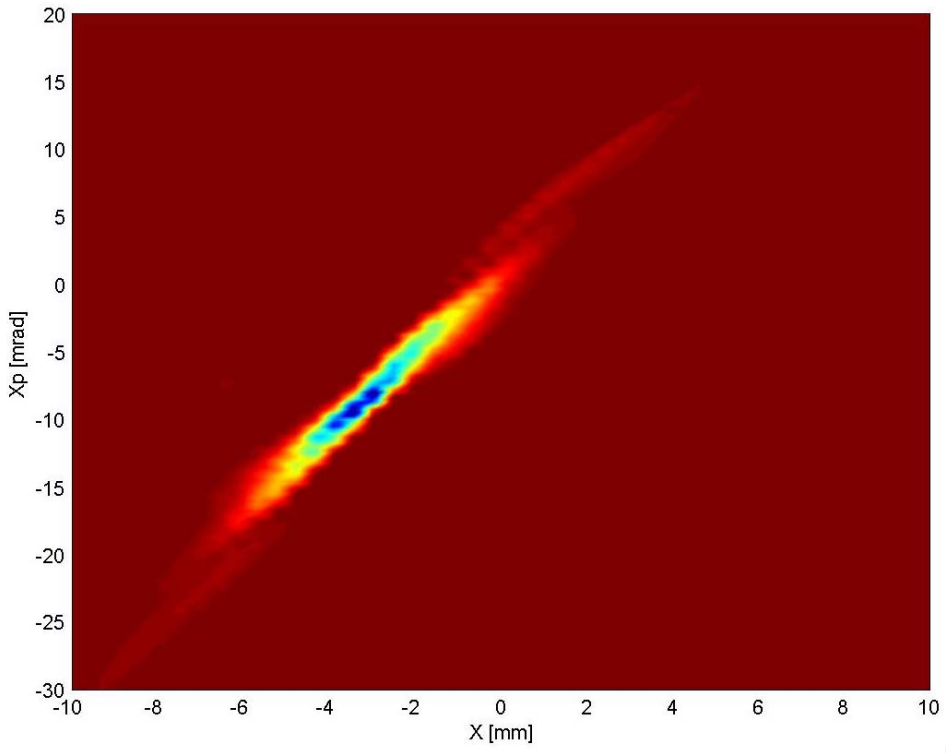


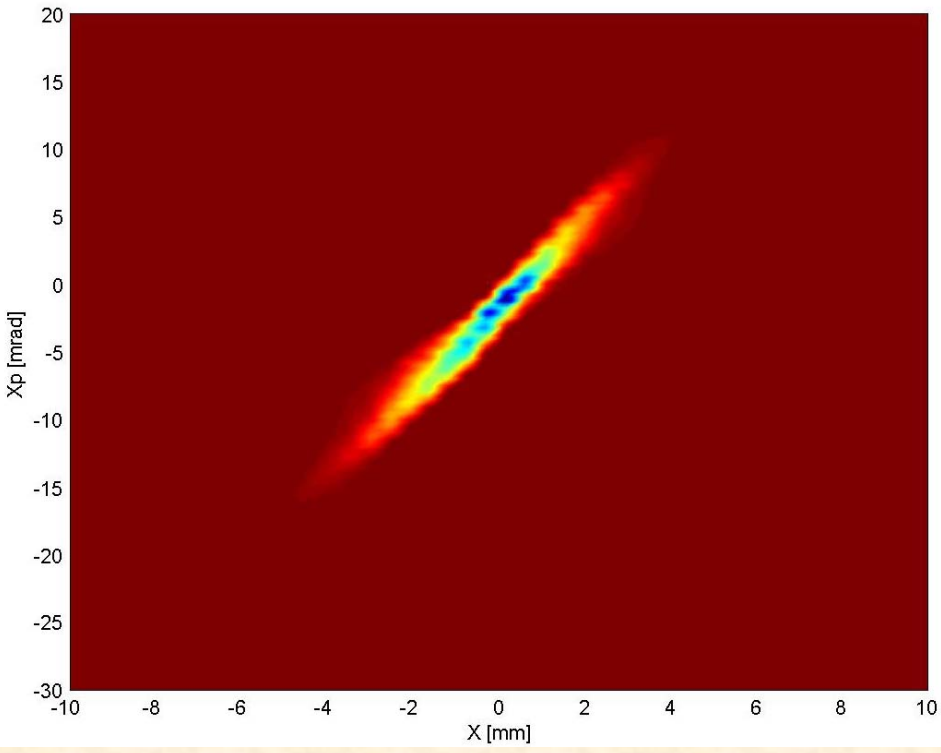
Round Beam Optics

Optics modification alone reduces halo significantly in simulations (Simulation)



Round Beam Optics improves X beam quality (Emittance Measurement)





Nominal Optics

ε_X= 0.349 mm-mrad (1% threshold)

0.454 mm-mrad (0% threshold)

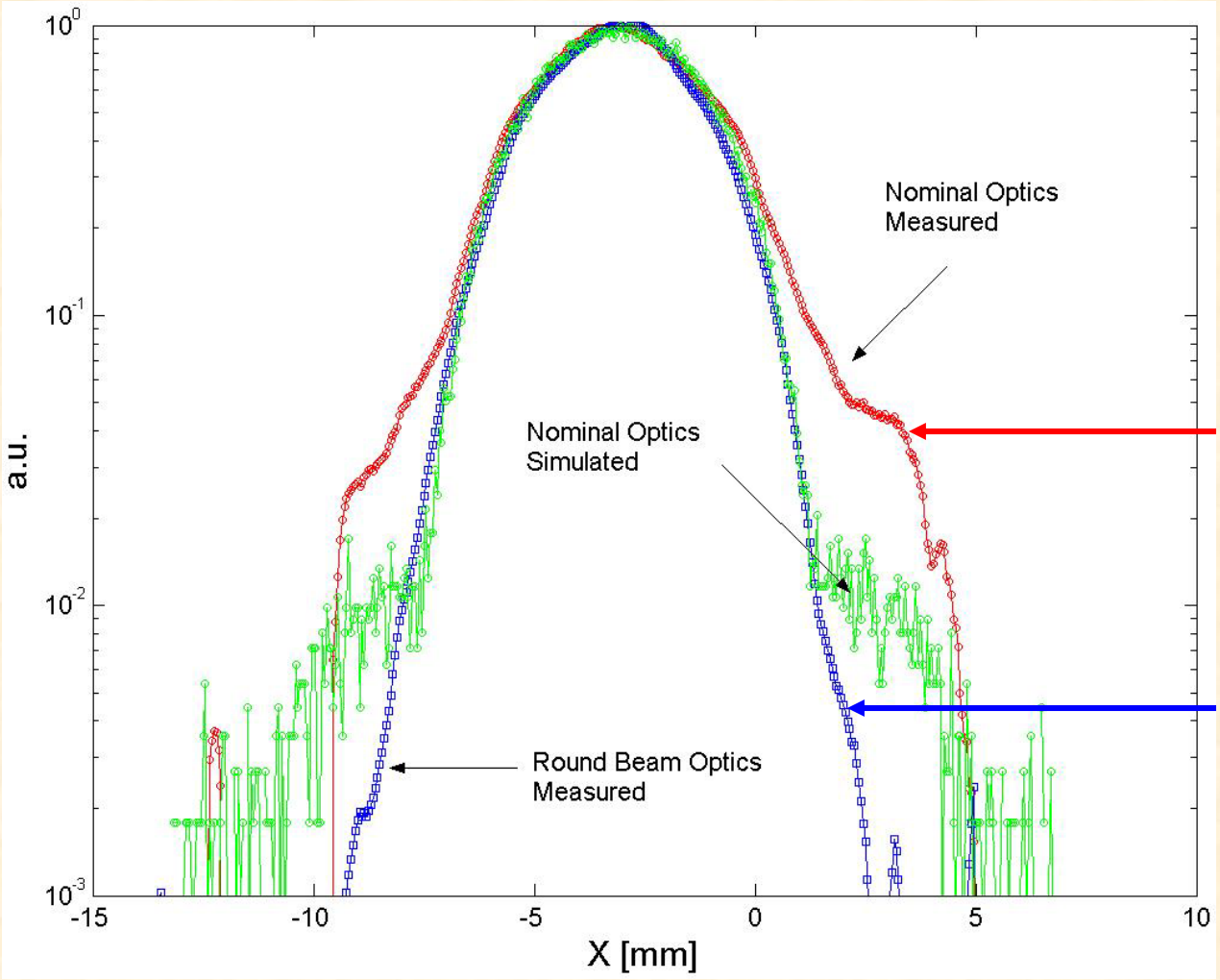
Round Beam Optics

ε_X= 0.231 mm-mrad (1% threshold)

0.289 mm-mrad (0% threshold)

- **Round Beam Optics reduces halo and rms emittance in X significantly**

Tail is significantly reduced for Round Beam Optics



Nominal Optics

Measured

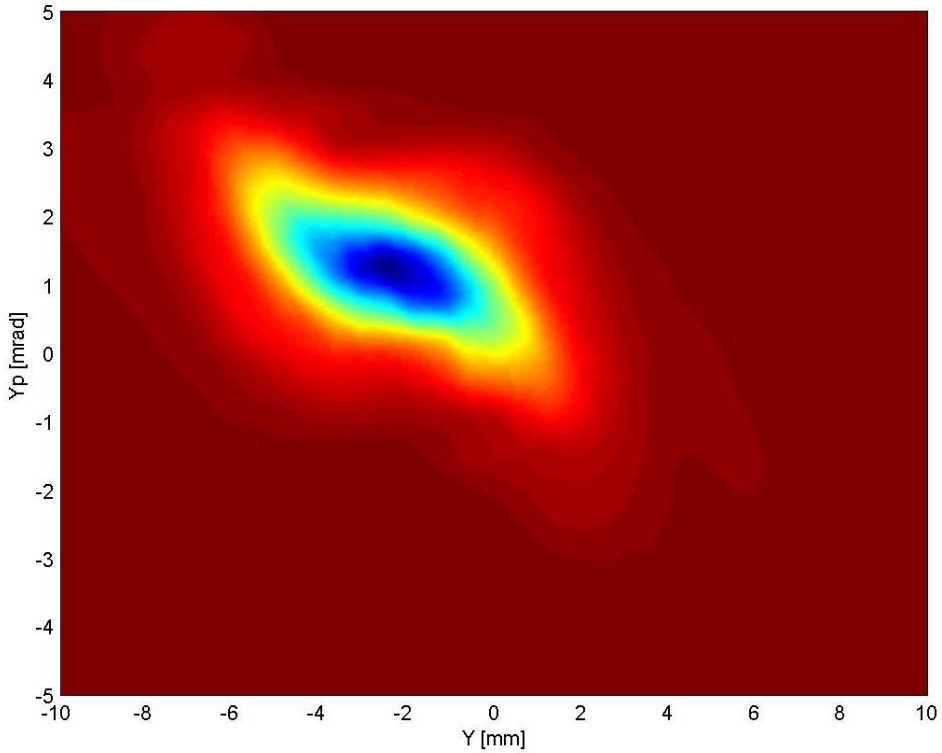
Round Beam Optics

Measured

No Tail!!

- **Round Beam Optics reduces beam tail visibly**
- **This tail is the source of beam loss in downstream linac**

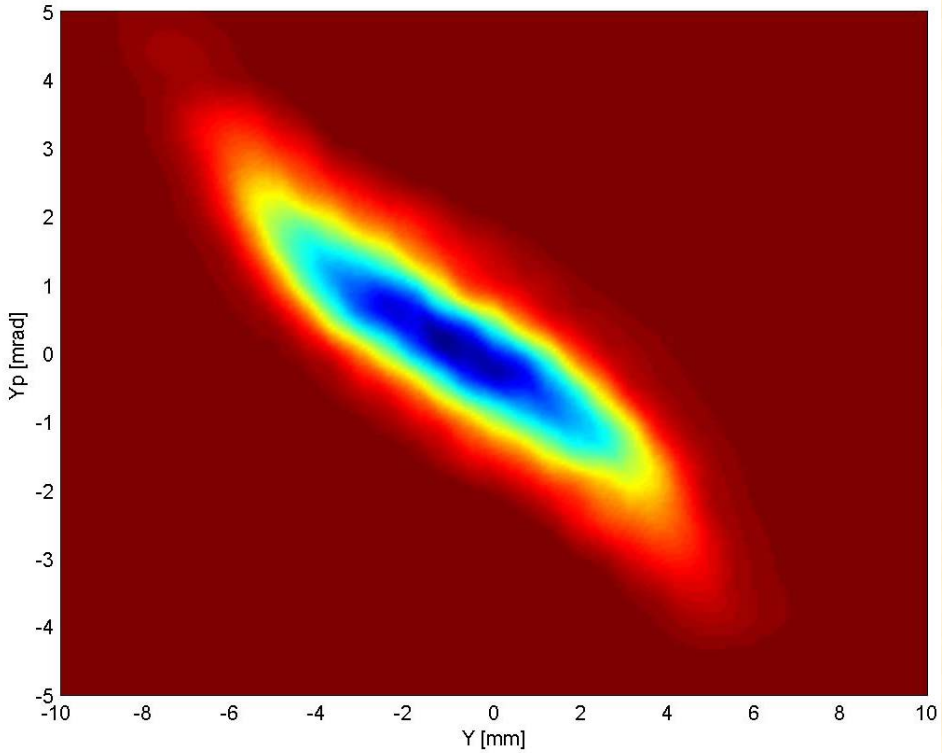
Round Beam Optics improves Y beam quality (Emittance Measurement)



Nominal Optics

ε_Y= 0.353 mm-mrad (1% threshold)

0.472 mm-mrad (0% threshold)



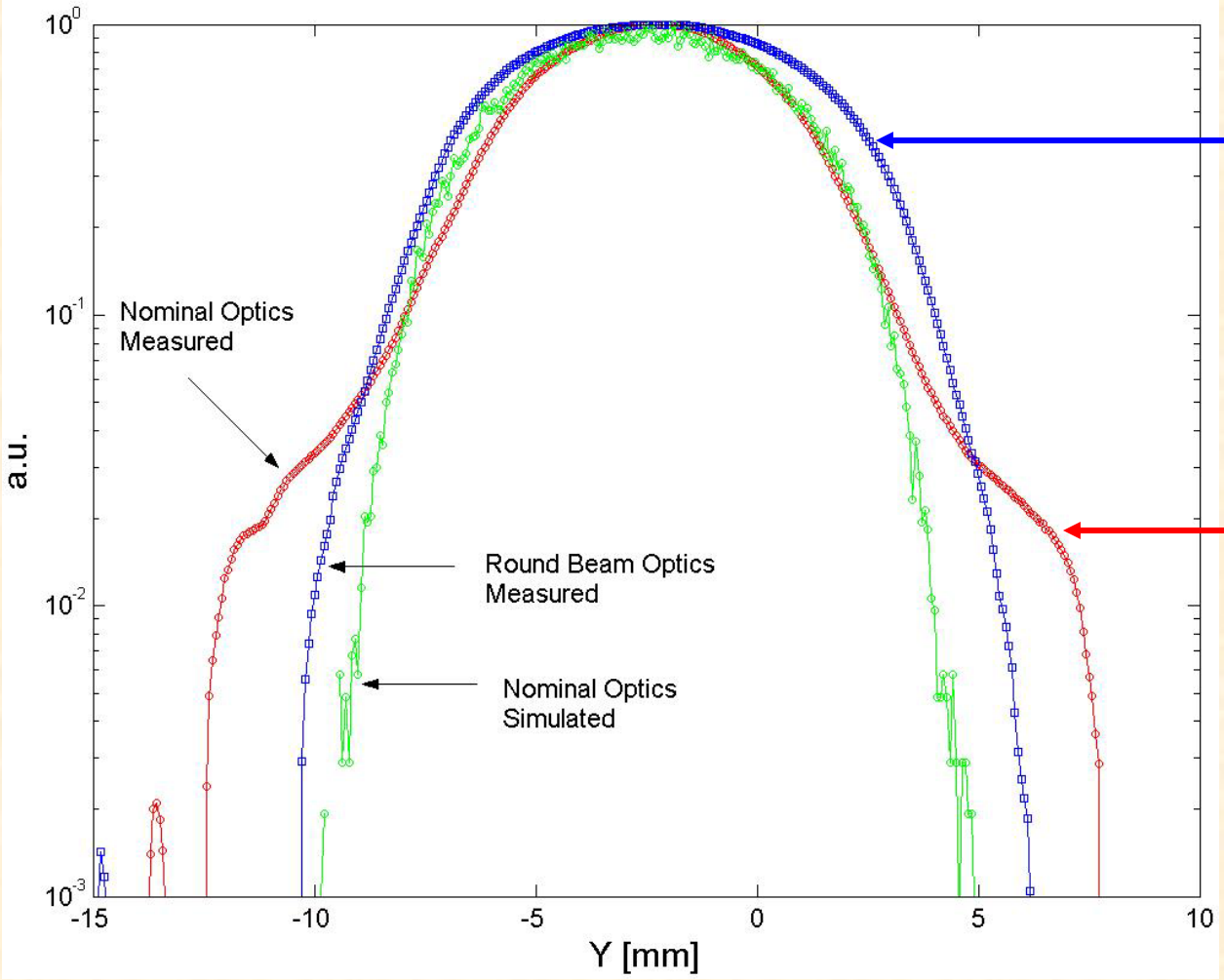
Round Beam Optics

ε_Y= 0.264 mm-mrad (1% threshold)

0.306 mm-mrad (0% threshold)

- **Round Beam Optics reduces halo and rms emittance in Y significantly**

Tail is significantly reduced for Round Beam Optics



Round Beam Optics

Measured

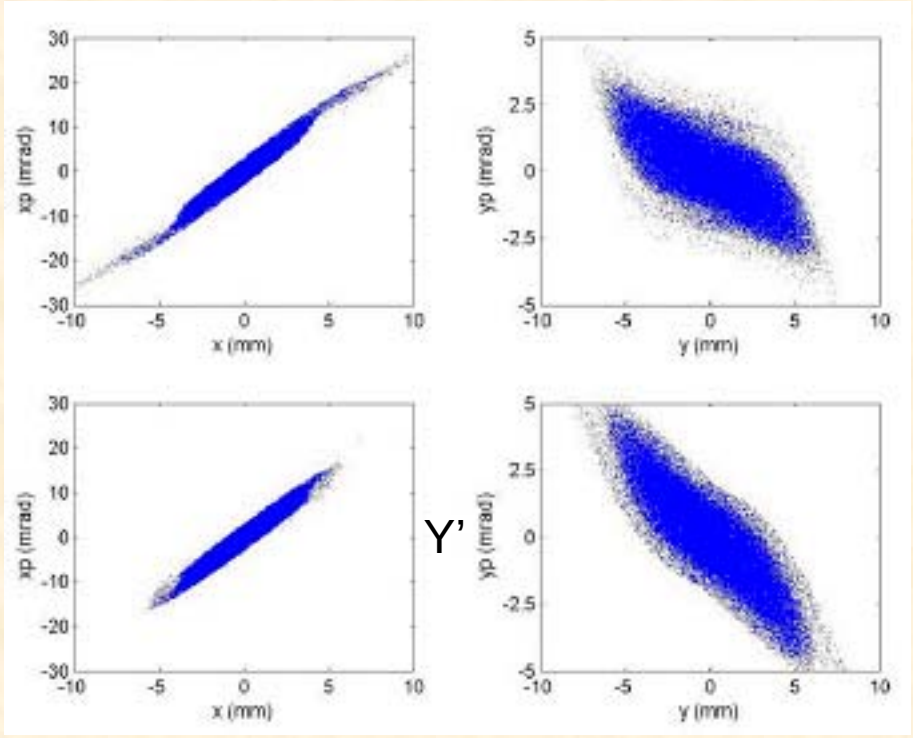
No Tail!!

Nominal Optics

Measured

- **Round Beam Optics reduces beam tail visibly**
- **This tail is the source of beam loss in downstream linac**

Parmila simulation



X' Y'

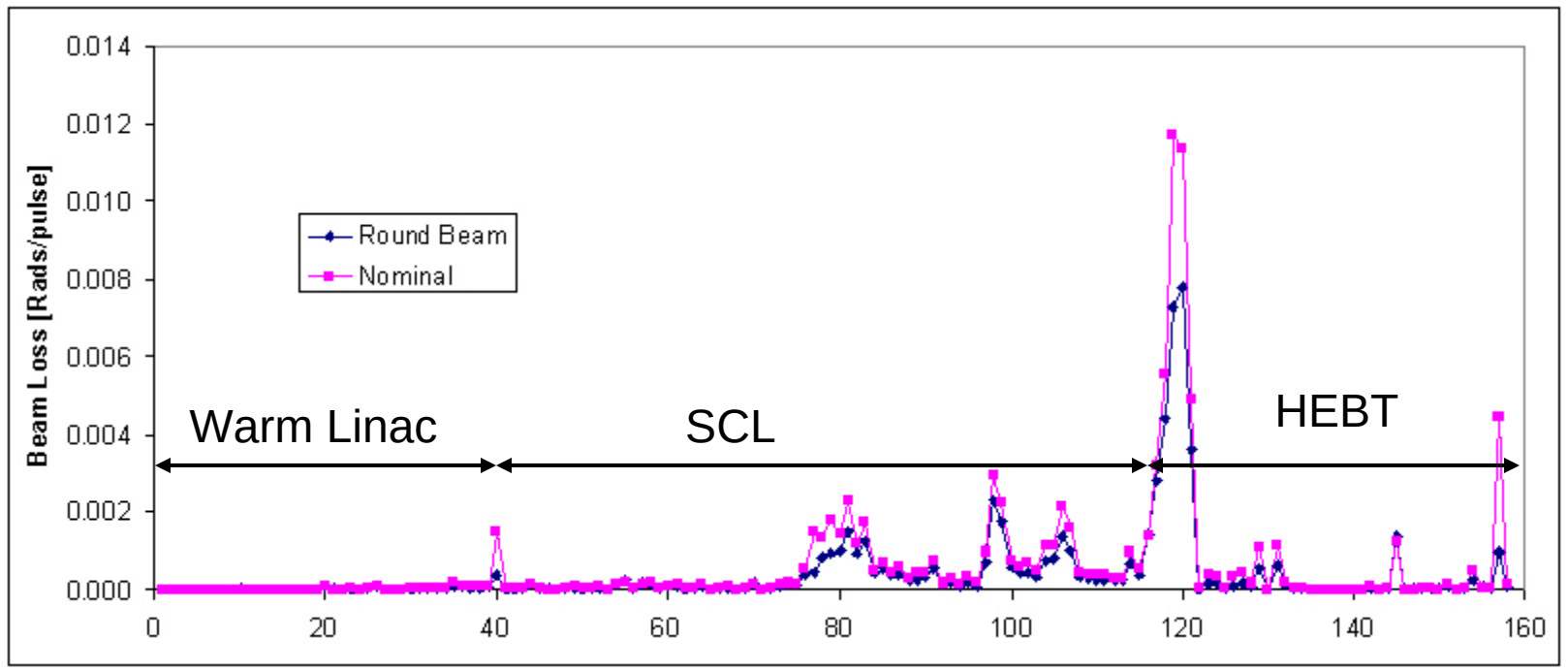
X Y

Nominal MEBT Optics

Round Beam MEBT Optics

- **Consistent with the emittance measurement results**

Round Beam Optics reduces beam loss in the downstream linac



- **Loss in CCL-SCL transition reduced by factor 4**
- **Loss also reduced in the downstream linac**
- **Consistent with the simulation predictions**

Conclusion

- **A new halo mechanism was experimentally verified through emittance measurements!**
- **The proposed “round beam optics” improves beam quality, reducing rms emittance and halo.**
- **The first emittance data showing practically no halo!**
- **Beam loss reduced in the downstream linac.**
- **Valuable benchmarking of space charge codes with measurements.**
- **For mismatched beam, simulations show some limitations.**

Halo formation in Front End and its Mitigation

Beam loss along the linac with Nominal Optics