Ring Beam Dynamics Progress Report

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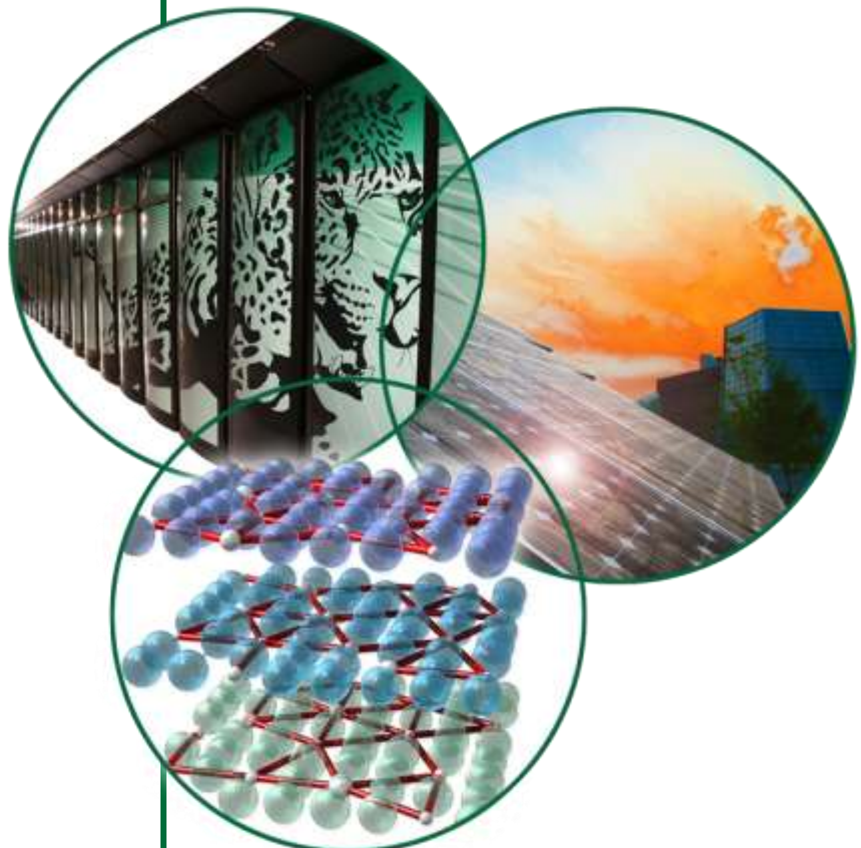

U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
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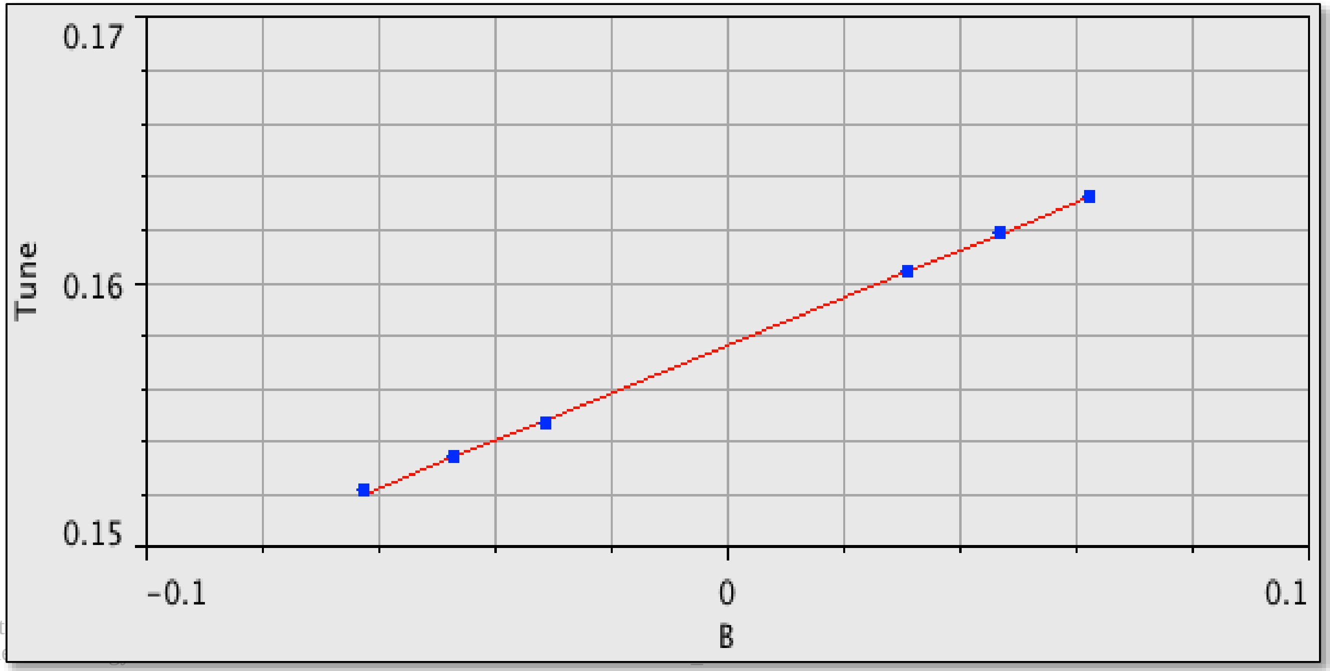
Outline

1. Lattice and optics
   – Twiss beta measurement
   – Chromaticity measurement
2. High Intensity Effects
   – Space charge
     • dilution, broadening
     • intensity dependent transverse coupling
   – e-p instabilities
     • threshold studies
     • longitudinal shape studies
     • production beam observations

Beta Function Measurement

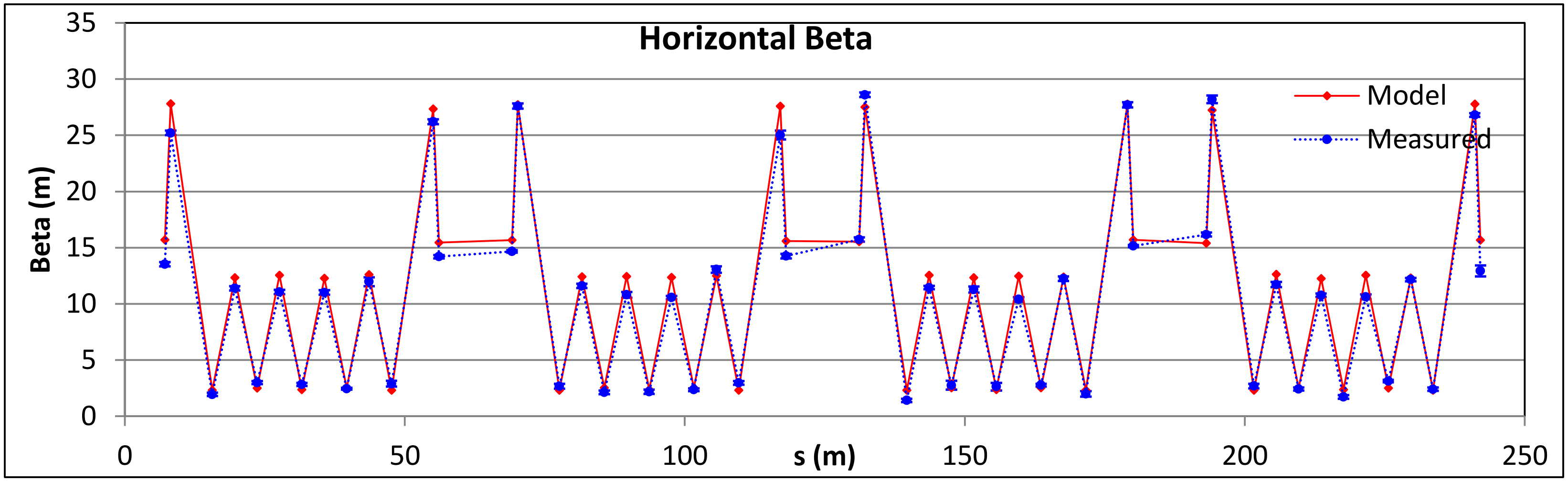
- **Previous MIA based approach showed significant beta beating and large difference from design in certain regions.**
- **Used trim quads to do an independent measurement of beta.**

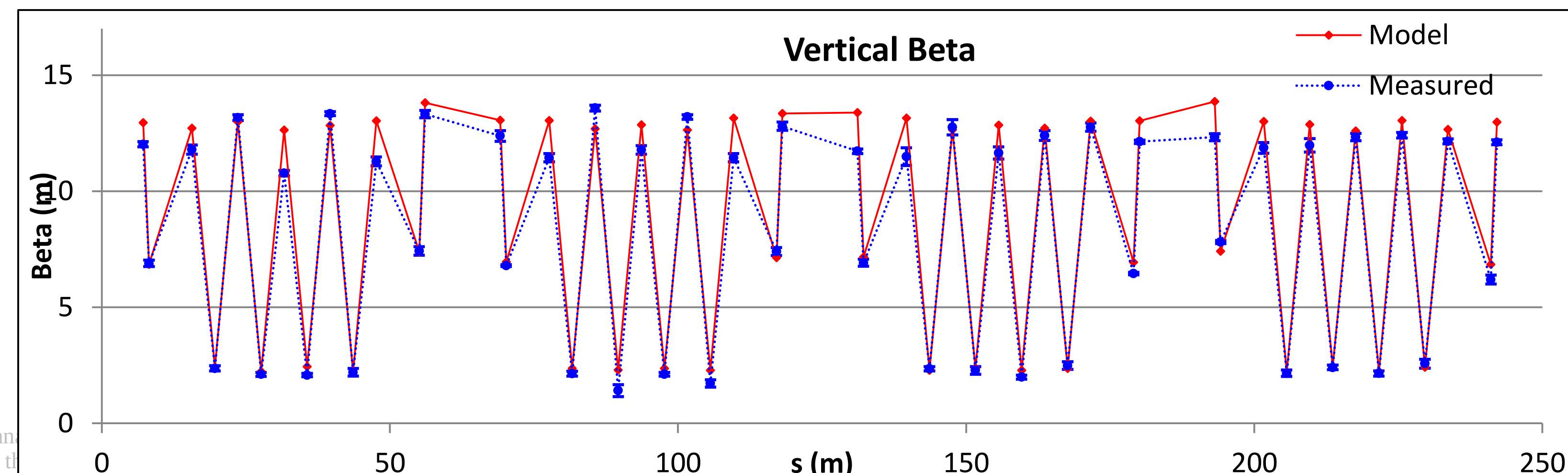
$$\beta = \pm 4\pi \frac{\Delta Q}{\Delta kl}$$



Measurement of Ring Beta Function

- **Deviation from design <= 15%.**
- **There is a discrepancy with MIA based measurement.**





Chromaticity

- **Chromaticity was measured in the range of natural to zero.**
- **From coasting beam theory:**

$$\frac{\partial f^-}{f_0} = \frac{\partial p}{p_0}\left|\eta\left(m - Q_f + \frac{\xi}{\eta}\right)\right|$$

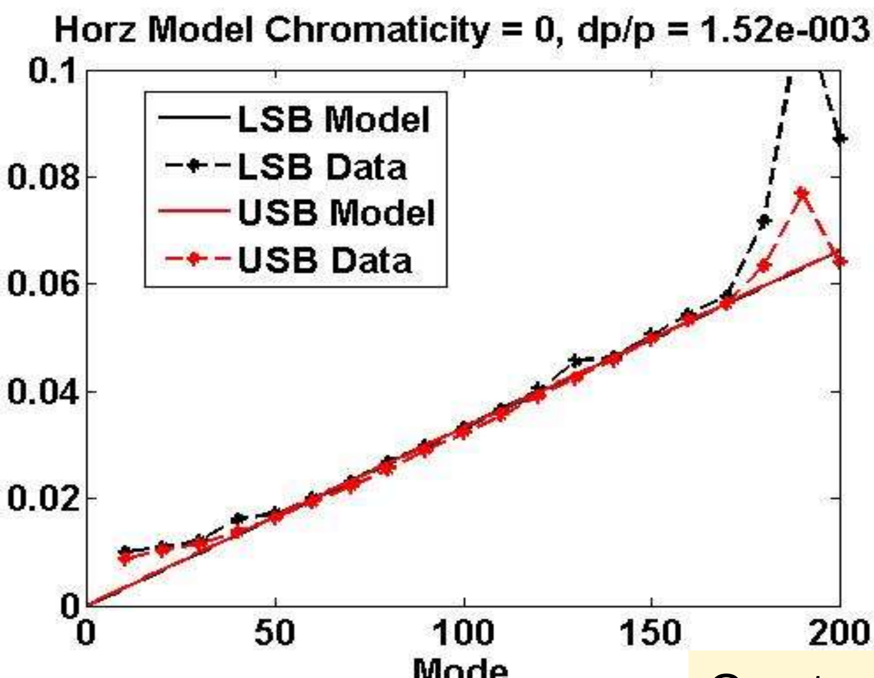
$$\frac{\partial f^+}{f_0} = \frac{\partial p}{p_0}\left|\eta\left(m + Q_f - \frac{\xi}{\eta}\right)\right|$$

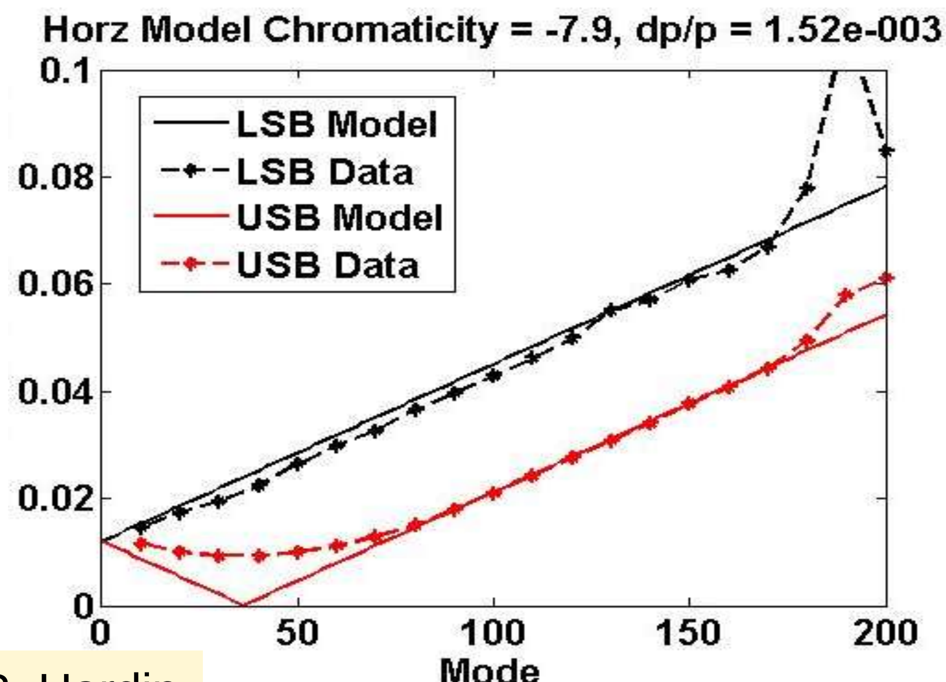
Measured via BTF → $\partial f^{\pm}/f_0$

Measure independently: $\partial p/p_0$, Q_f

m = Mode

η = Slip Factor (-0.2173)

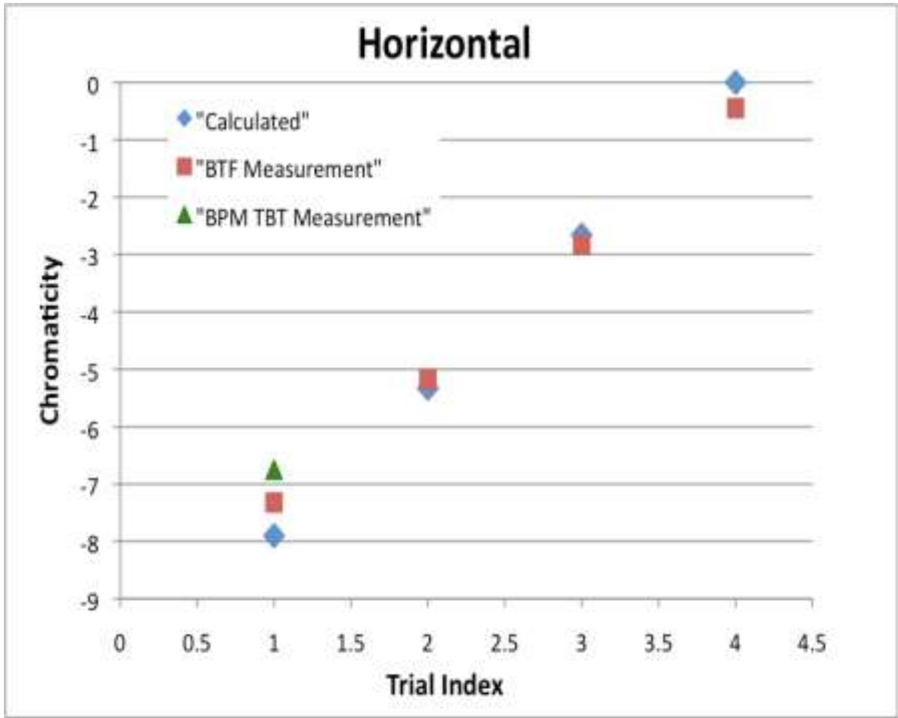


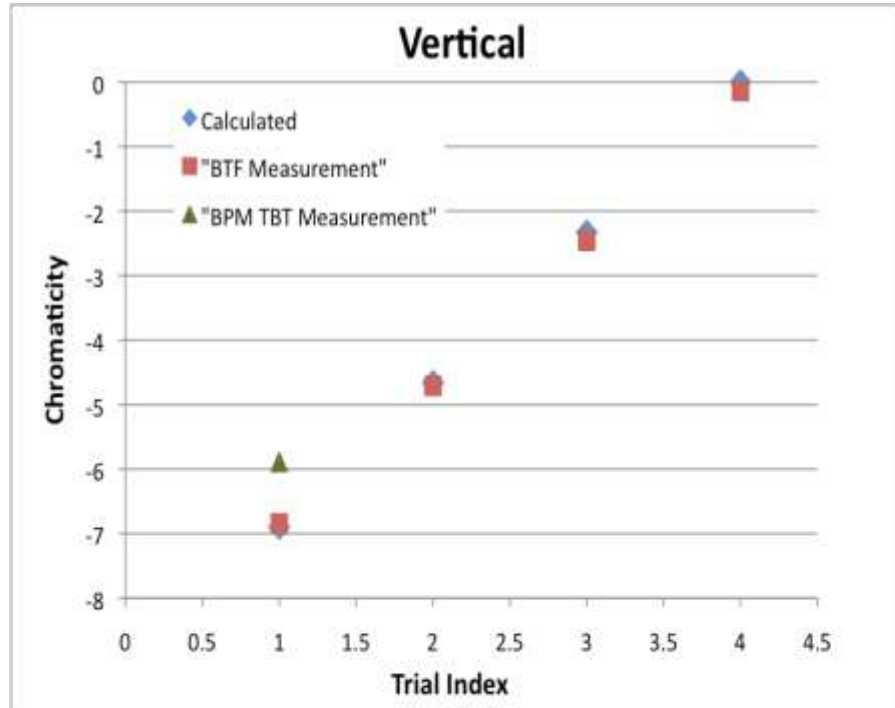


Courtesy R. Hardin

Chromaticity Measurement

- **Measurements agree well with MAD predictions.**

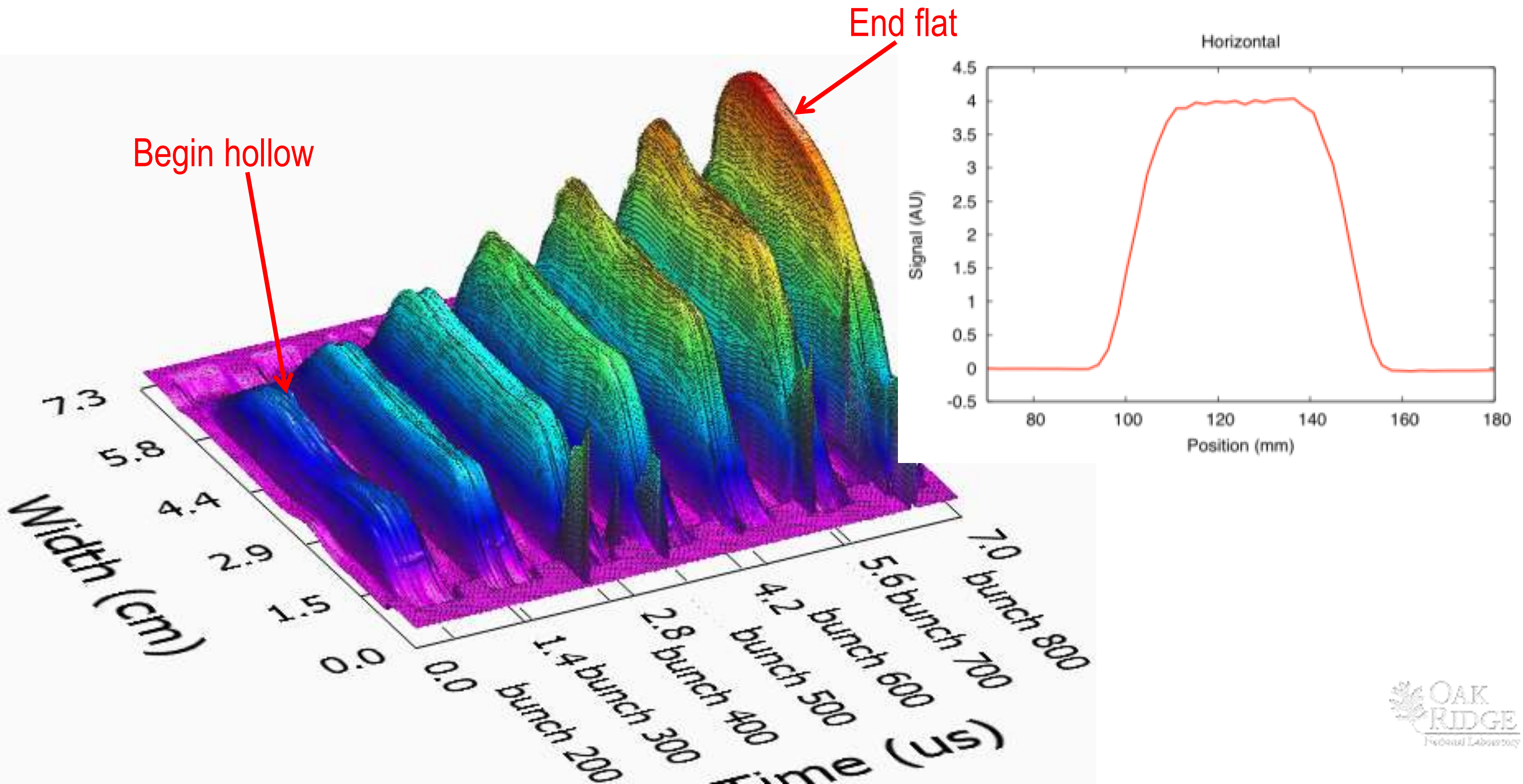




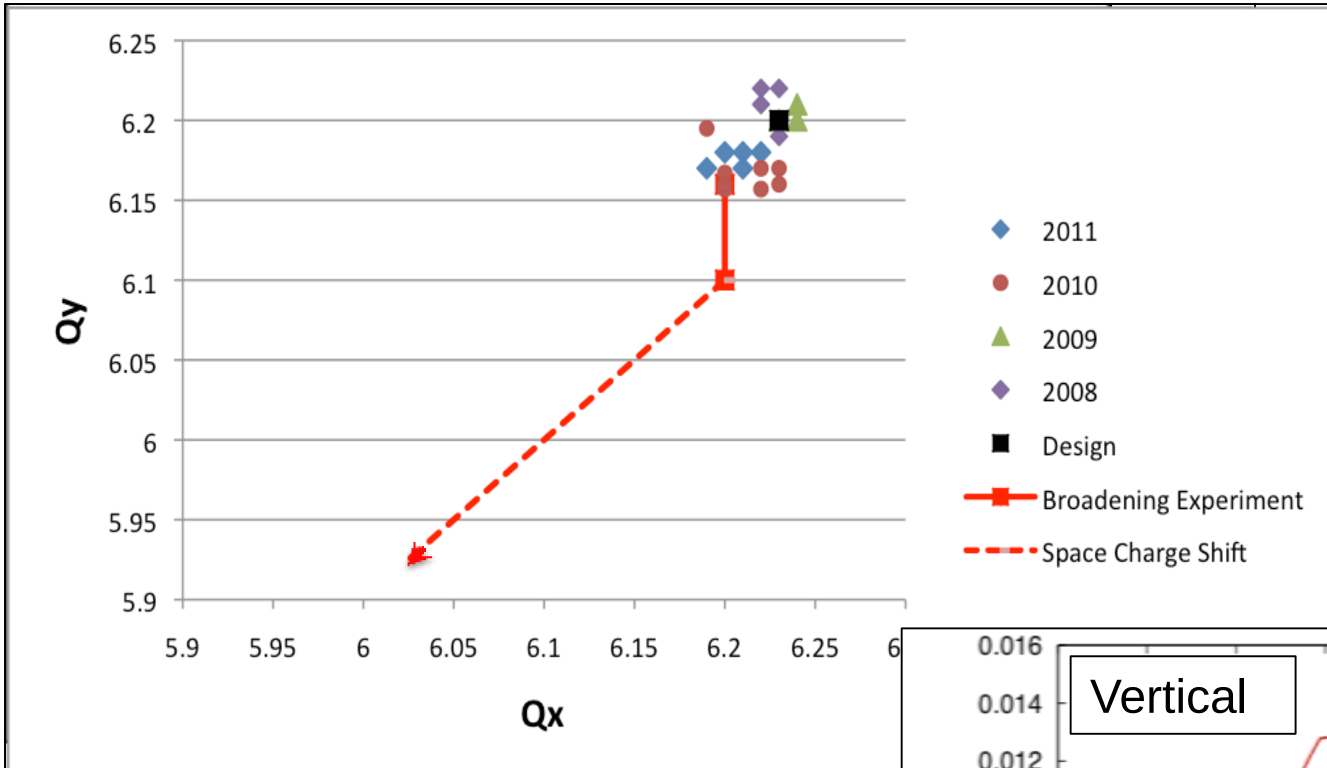
Courtesy R. Hardin, T. Pelaia

Part II: Collective Effects

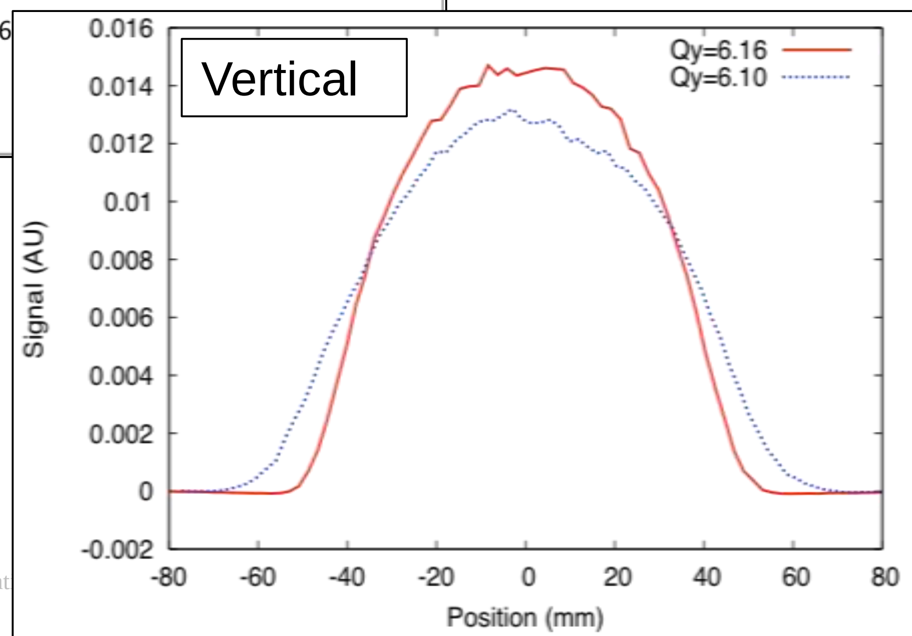
- Presently the ring intensity is not limited by collective effects. However, collective effects strongly influence the final particle distribution.



Working Tune Range



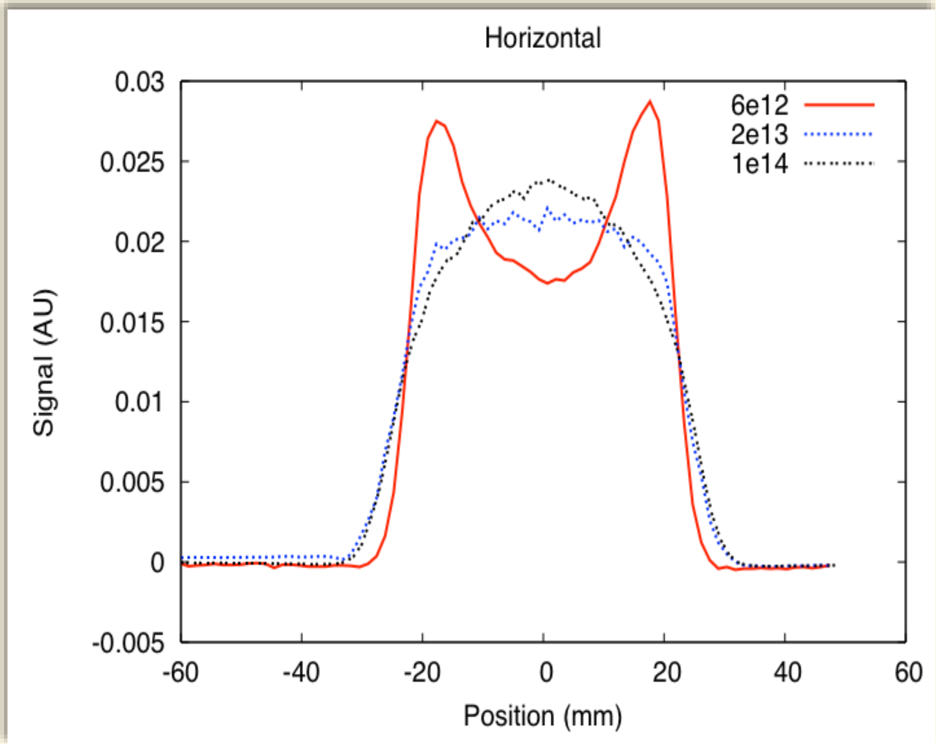
Design tune is (Qx=6.23, Qy=6.20).

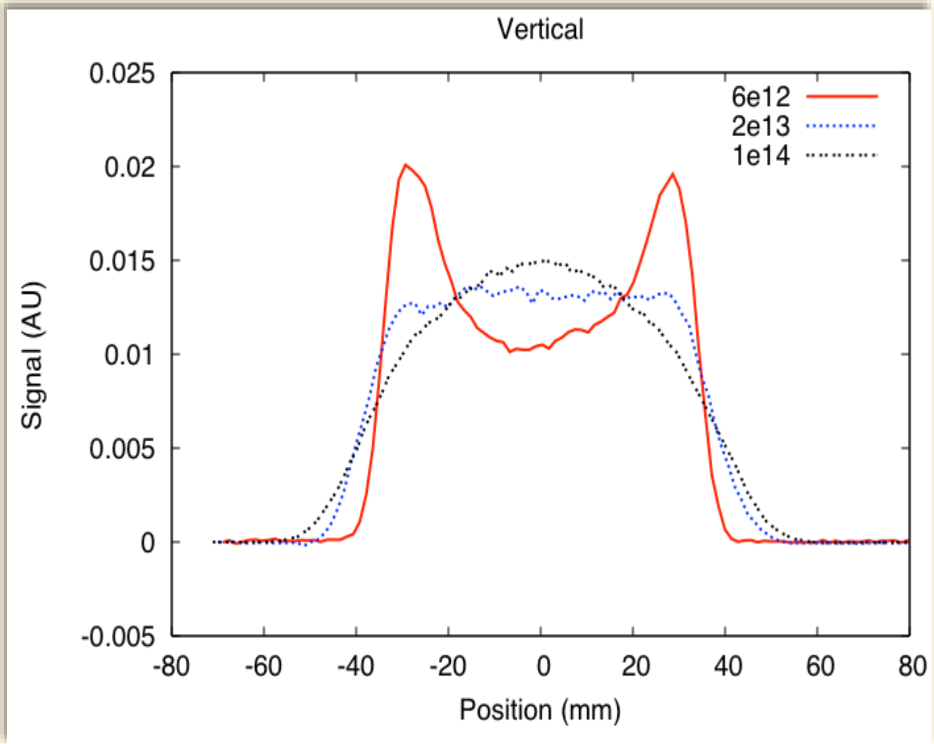


- Working point has varied within 0.05 range on lower side of design.
- Incoherent tune shift down to integer for working tunes.
- Broadening seen as we drive bare tune to 6.1

High Intensity Profile Dilution

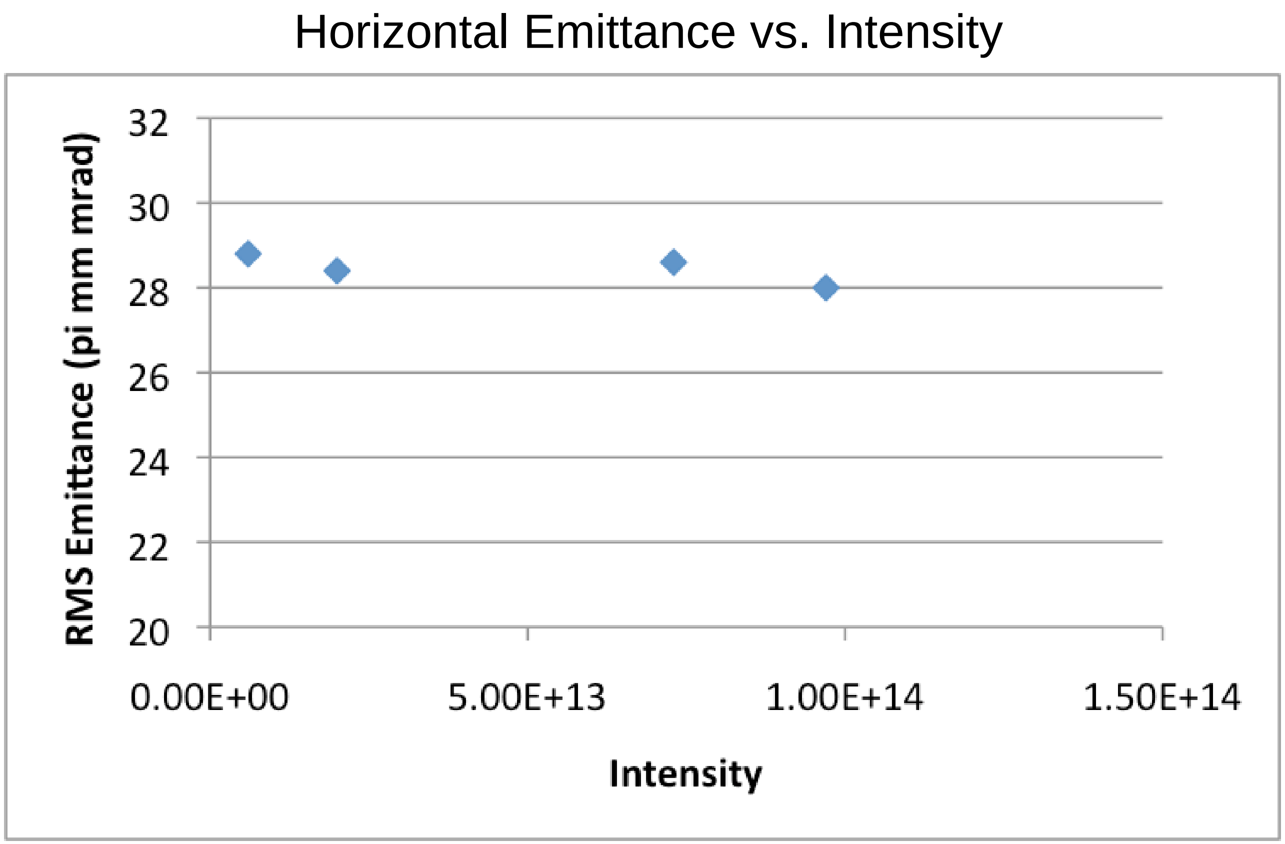
Measured Profiles (March 2011, WS20)





- **Significant profile dilution by 1e13 ppp.**
- **Diluted profile is more ideal for target, e.g. painting scheme is appropriate.**
- **No discernable tails.**

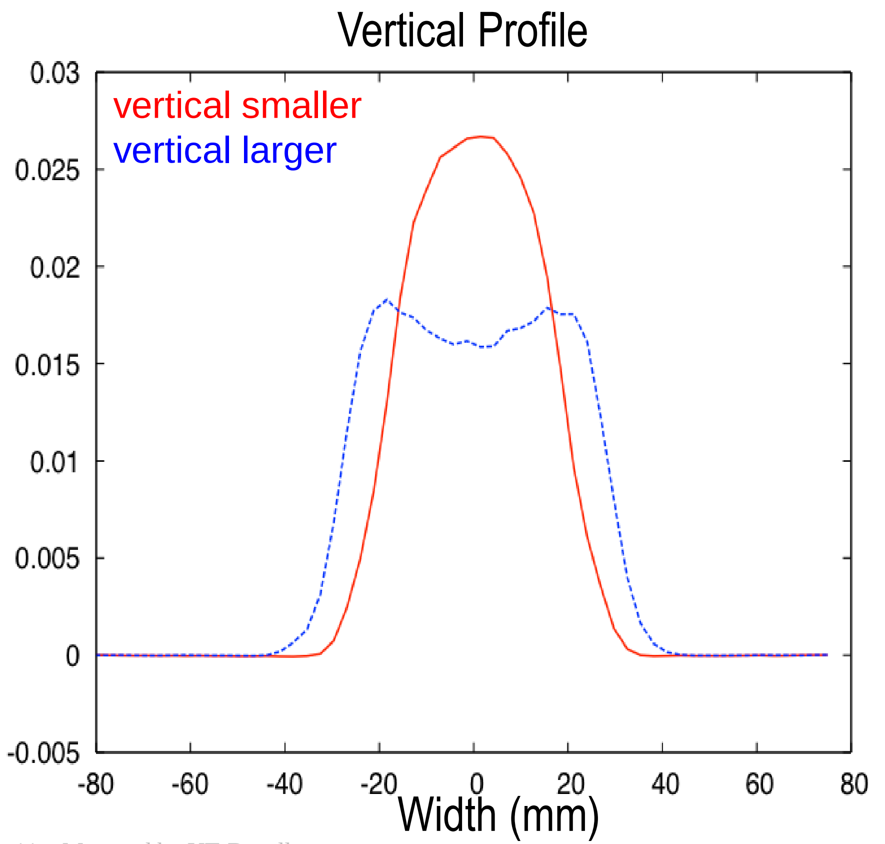
Emittance vs. Intensity

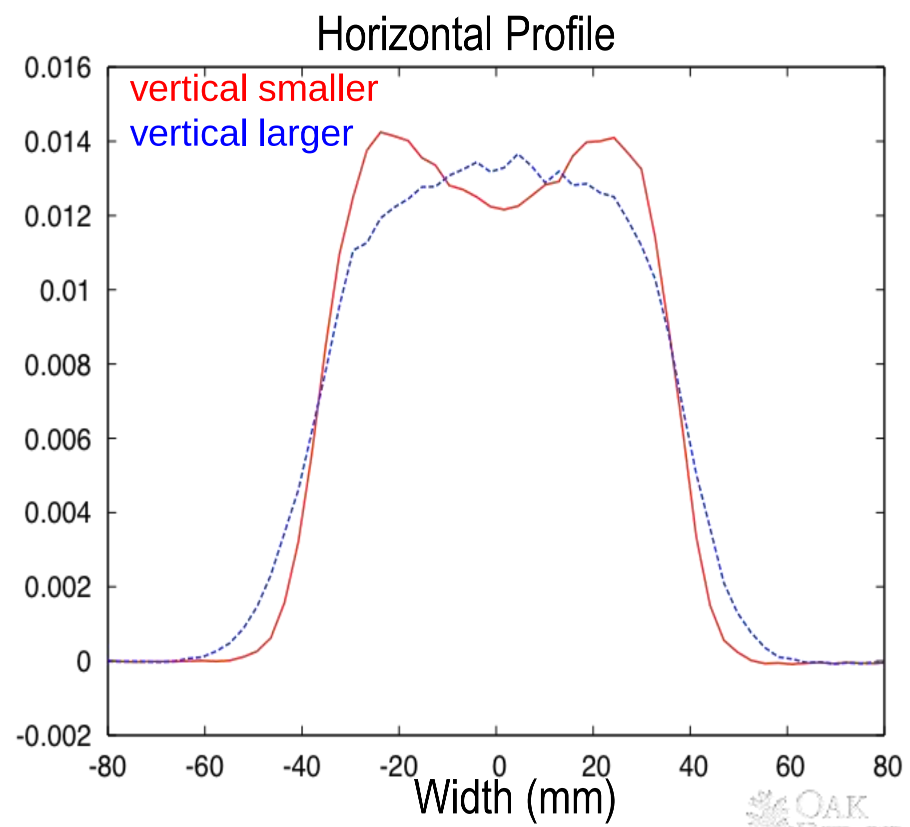


- **rms emittance is not well correlated with profile dilution.**

Intensity Dependent Transverse Coupling

- We observe an intensity dependent transverse coupling that effects profile shapes.
- It compromises our ability to control beam shape on target.

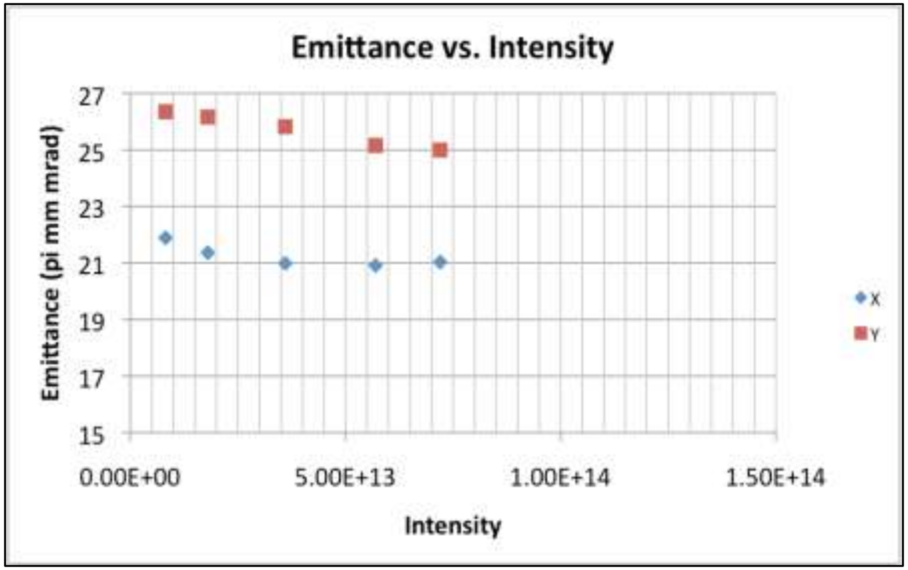




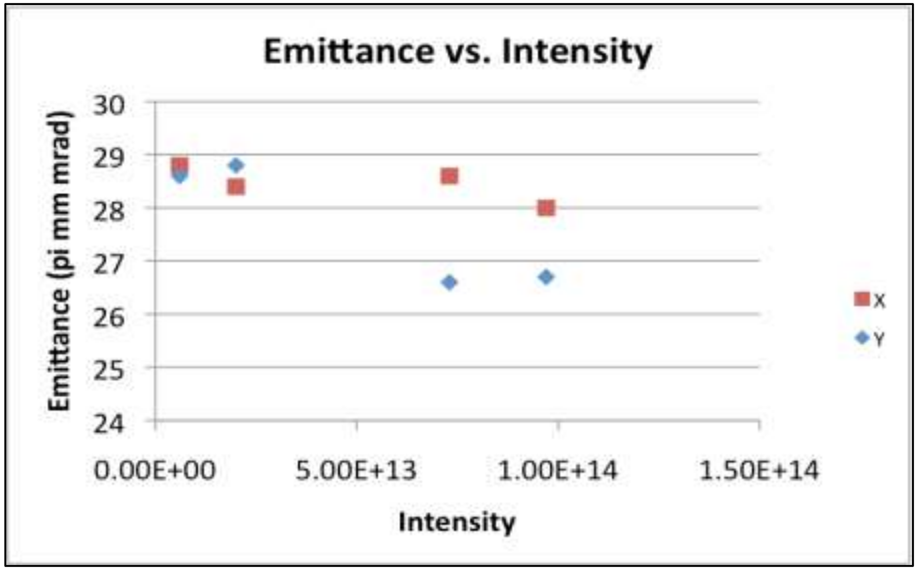
R. Potts, graduate student

Transverse Coupling and Emittance

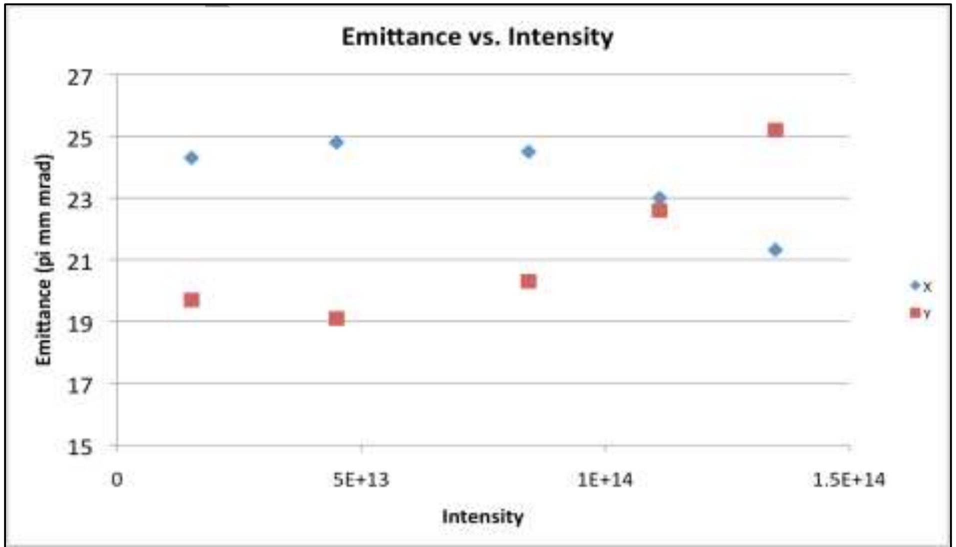
April 2009 Production Beam



March 2011 Production Beam



July 2009 High Intensity

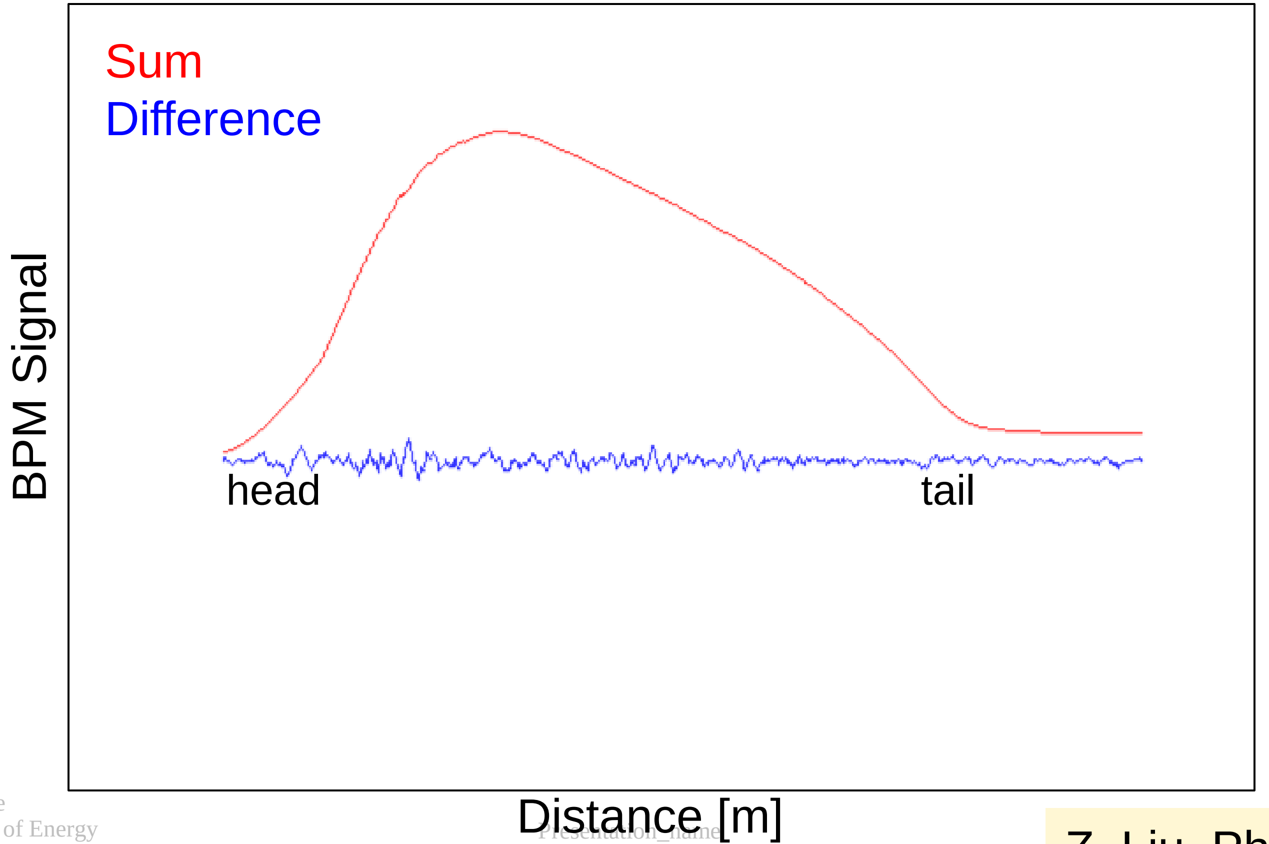


Recent Work on Instabilities

- Instabilities observed in the SNS ring:1) Extraction kicker transverse instability, 2) e-p, and 3) resistive wall.
- Recent instability work has focused on e-p. At SNS it does not have a clear-cut parameter dependence. Case by case variation seen for:
  - Intensity threshold
  - Dependence on 1st and 2nd harmonic RF
  - Leading plane (horizontal or vertical)
  - Trailing or leading edge instability.

Leading versus Trailing Edge e-P

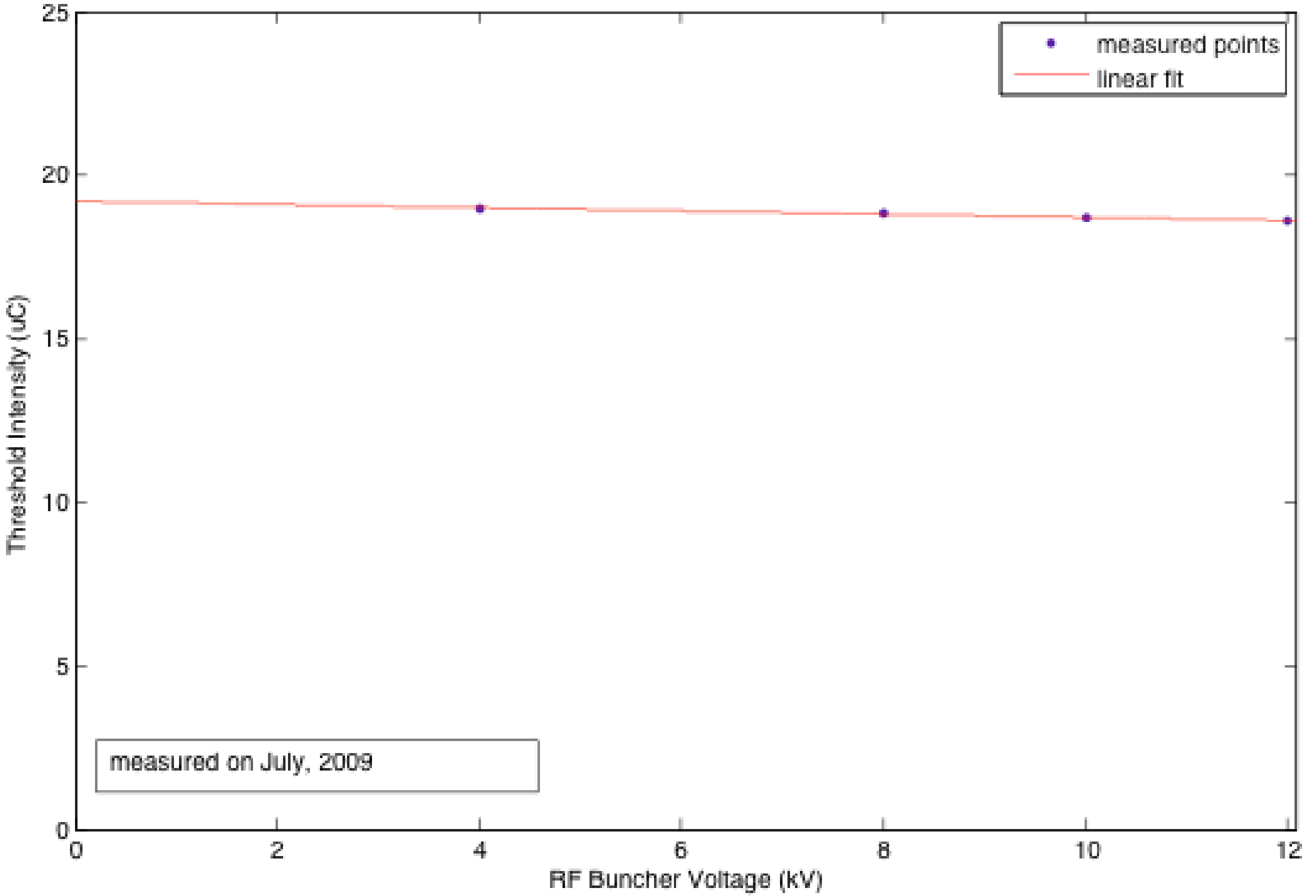
- e-P is sometimes observed on the leading edge of beam, and sometimes on the trailing edge. Sometimes both.



Z. Liu, PhD thesis

e-P vs. 1st Harmonic RF

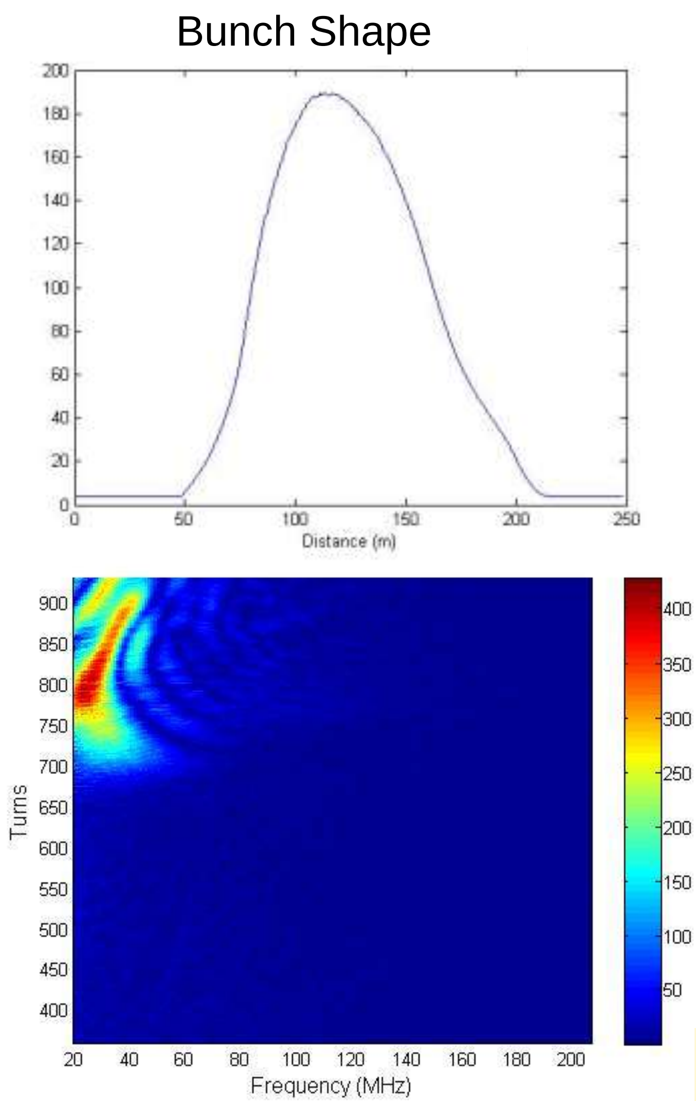
- **The instability is not consistent with Landau damping laws.**



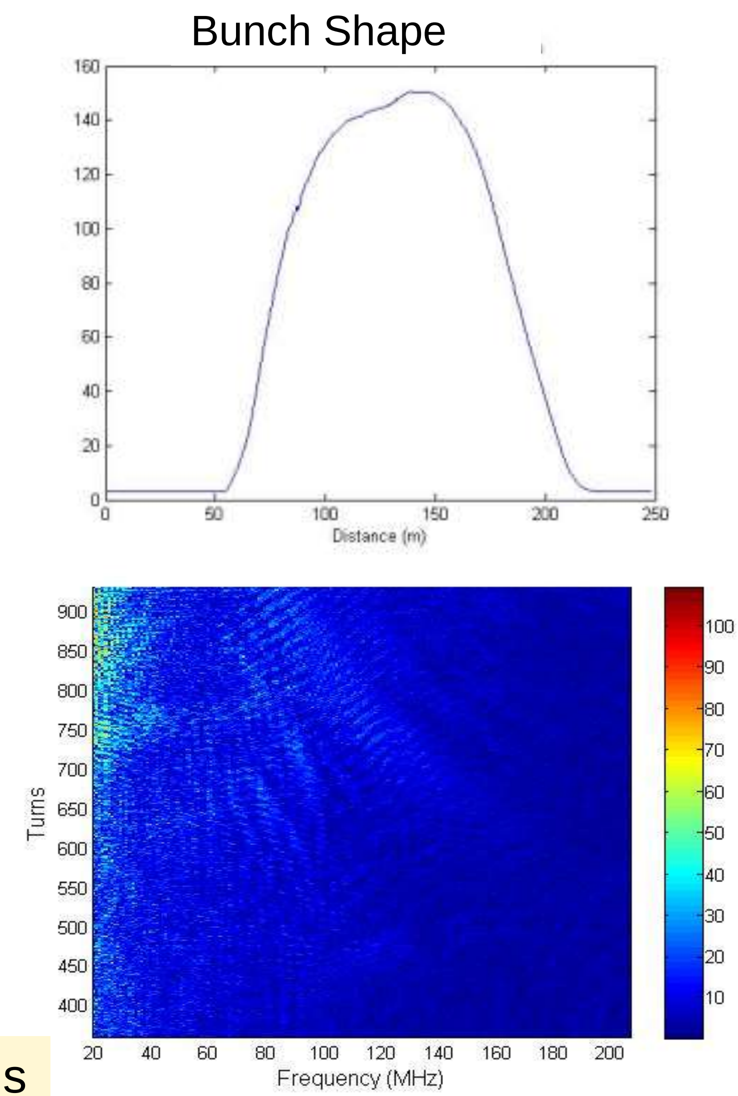
Z. Liu, PhD thesis

Effect of Bunch Shape on Instability

- **The instability can be suppressed by creating a flatter profile.**



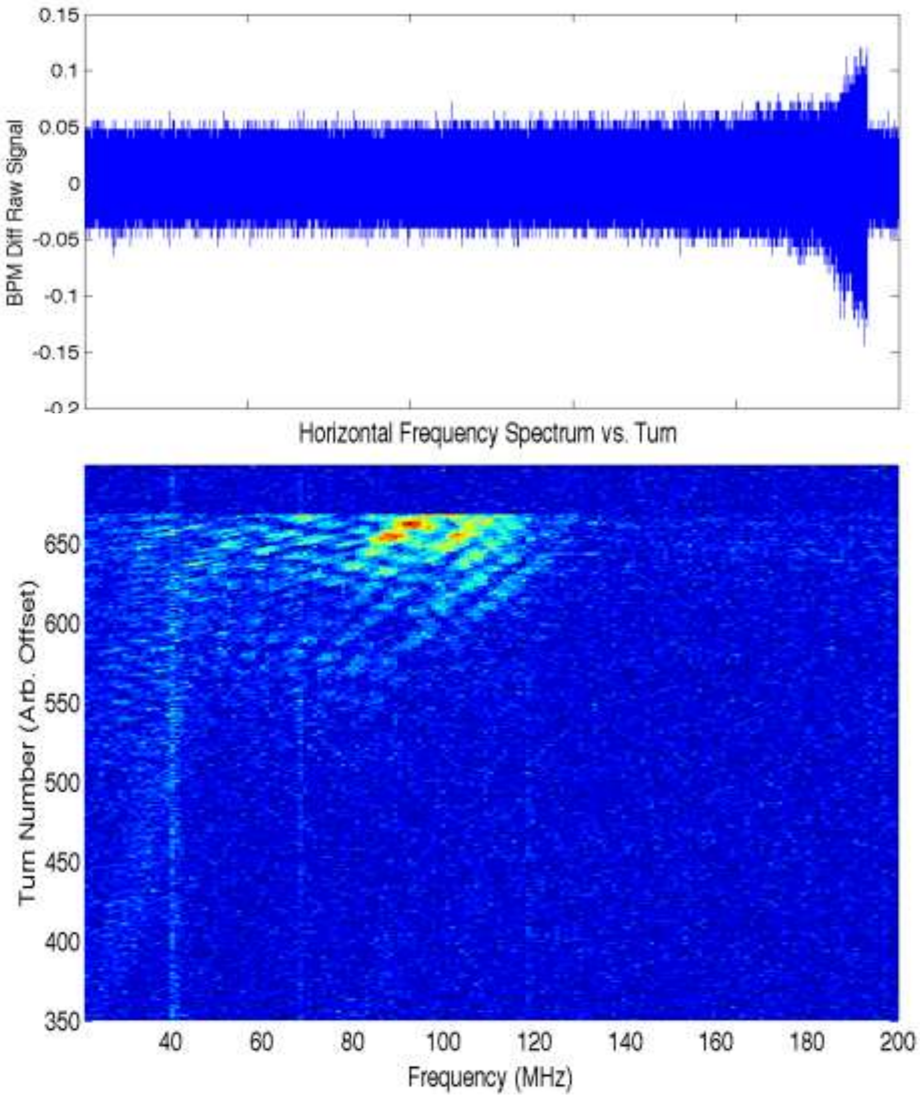
Lower 1st harmonic buncher by 4 kV

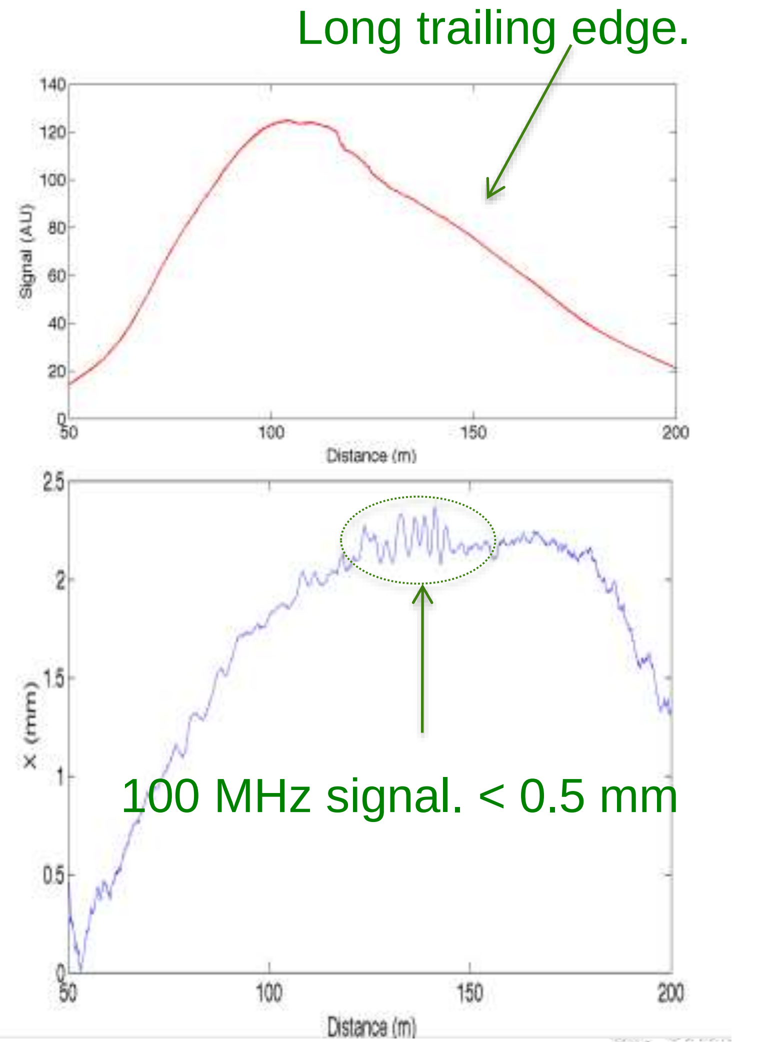


Z. Liu, PhD thesis

e-p Activity During Production

- **Trace e-p activity sometimes observed during operation.**





880 kW production beam on 03/17/2011

Summary of Collective Effects

Phenomenon Observed	During Production?	Impact on Production
Space charge profile broadening	Yes	Makes a flatter beam on target.
Transverse coupling	Sometimes	Loss of independent control of planes.
Broadening due to resonance	No	----
e-p Instability	Yes (trace)	No impact.
Extraction kicker transverse instability	No	----
Resistive wall instability	No	----

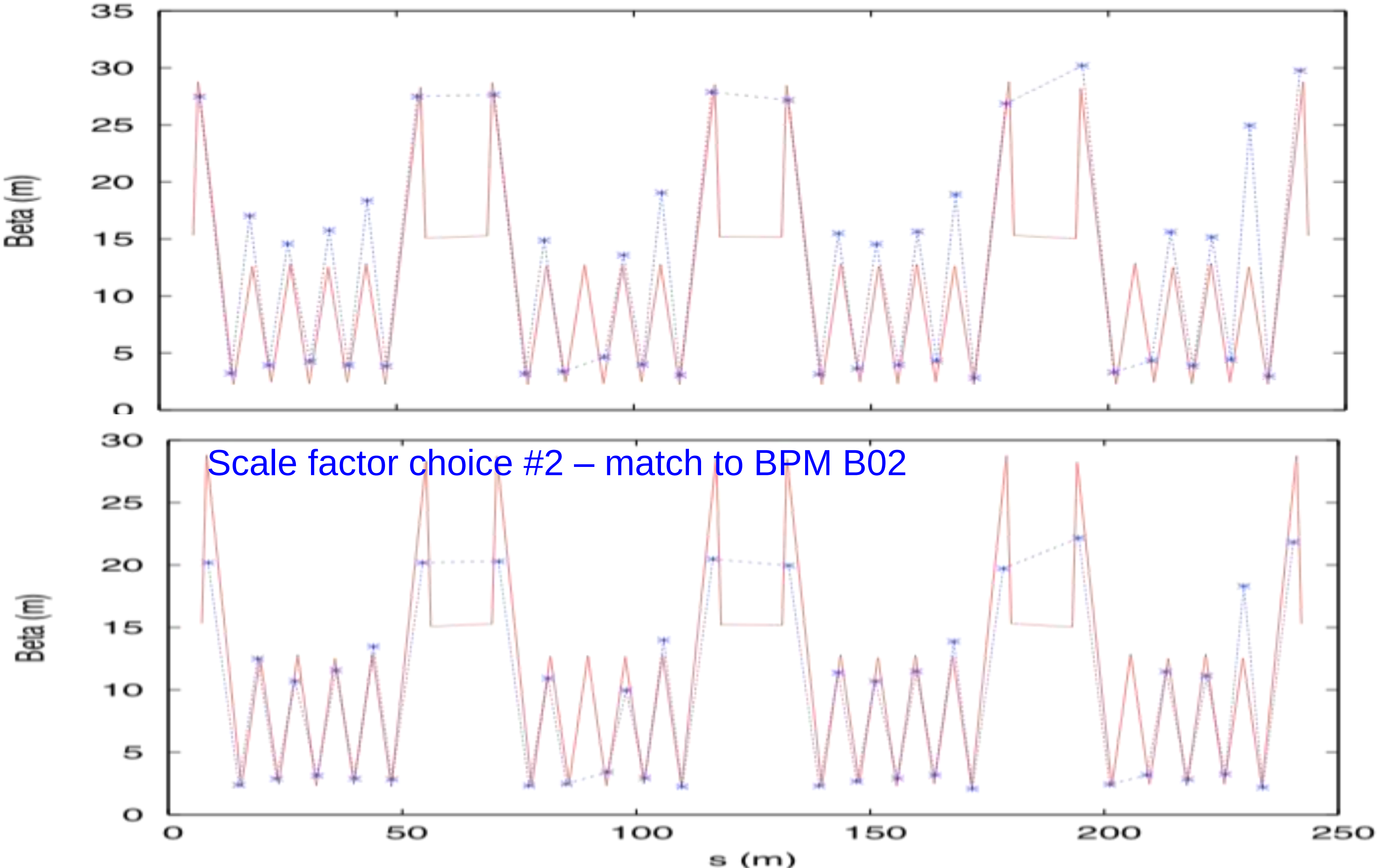
Looking Forward

1. Work to resolve Twiss beta measurement method discrepancy. Data taken on 12-20-2011.
2. Initiate in depth study on intensity dependent transverse beam coupling. Graduate student project (R. Potts).
3. Continue to understand e-P parameter dependence.
4. Understand additional observations not included in this presentation: tune splitting in BTF measurements, benchmark discrepancies, disappearance of tune split dependence in transverse coupling…

Auxiliary Slides

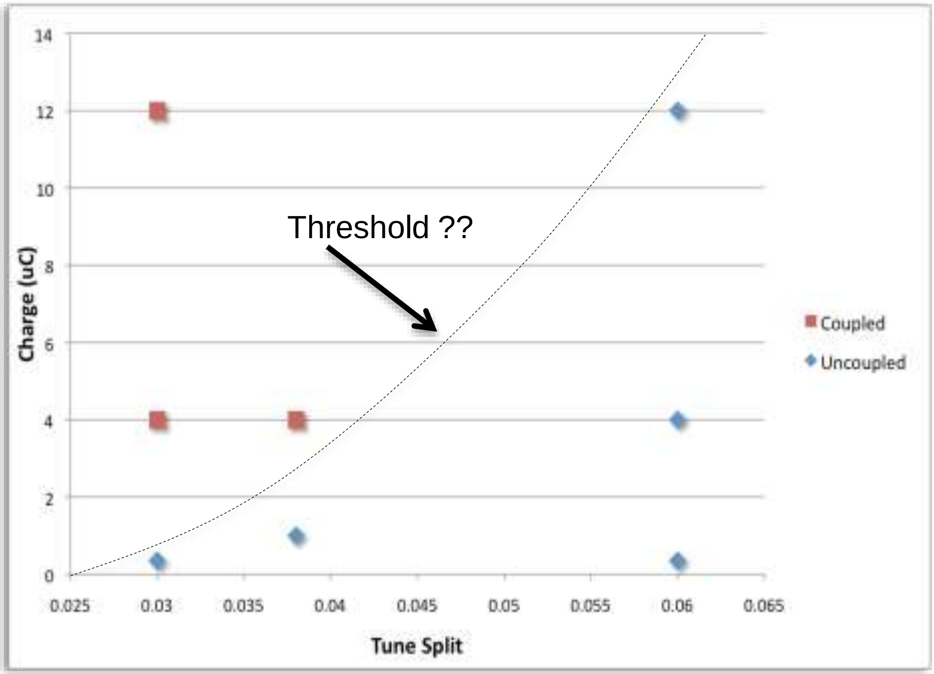
Beta Functions: MIA vs Quad Tune Method

1. Observe a high degree of non-symmetric beta beat, large deviation from model. Level depends on scale factor choice.
2. Ratio between straight section beta and arc beta is too low, seems unphysical.

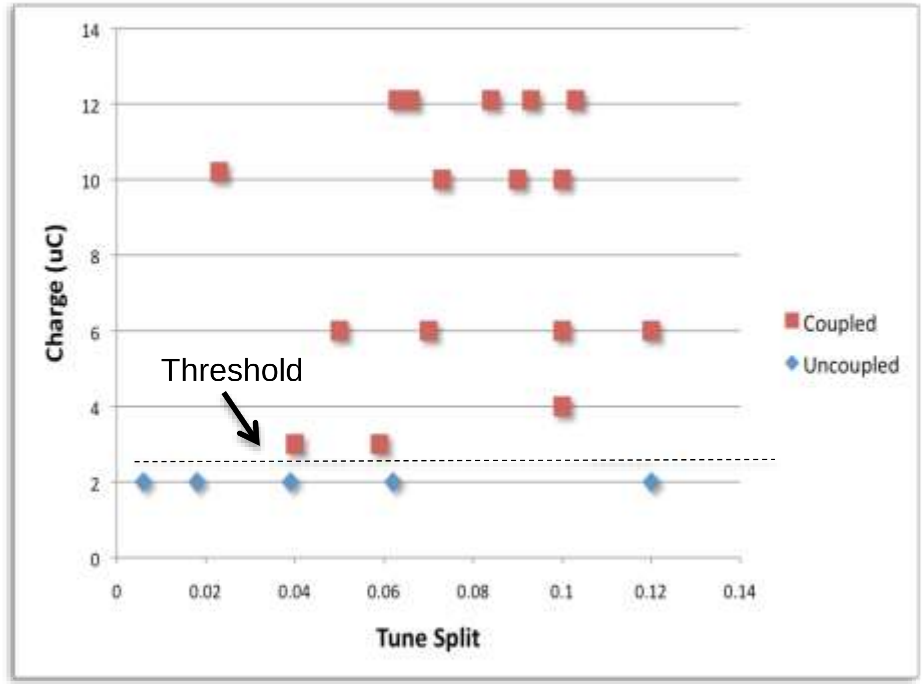


More on Coupling

Case 1: May 2010



Case 2: March 2011



- For some cases the presence of coupling depends only on intensity, and for others it depends on intensity and tune split.
- The two cases above have different machine configurations, specifically the closed orbit in the injection region.