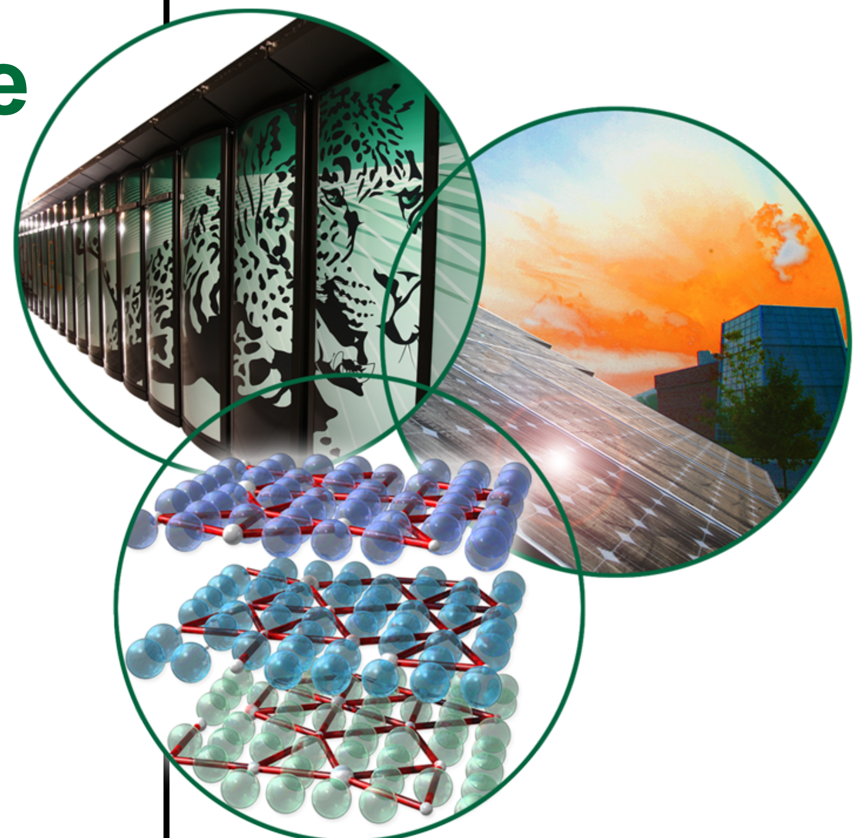
Status of High Intensity Effects in the Spallation Neutron Source Ring



S. Cousineau,
on behalf of the SNS Project
PAC11, New York City

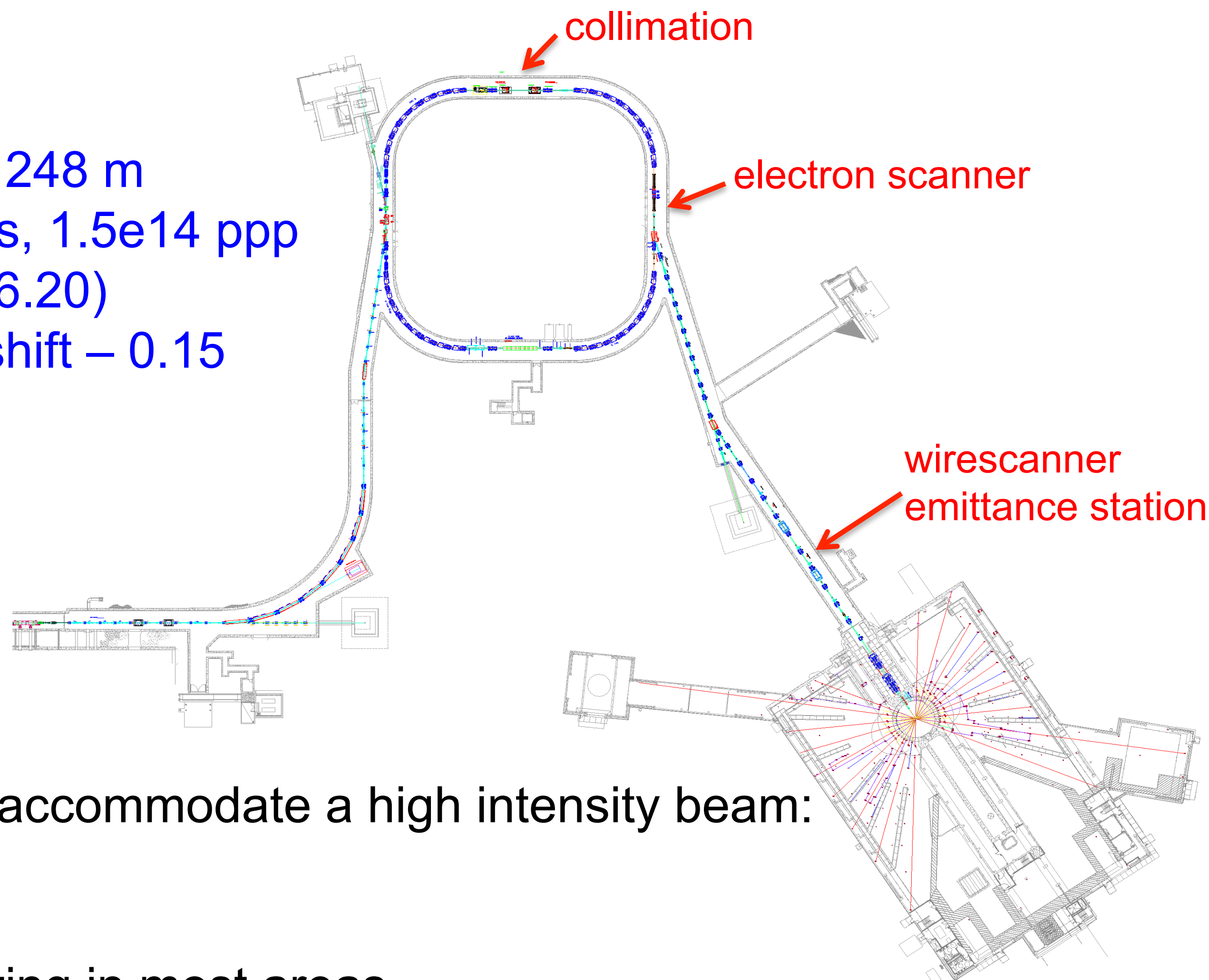
U.S. DEPARTMENT OF ENERGY

OAK RIDGE NATIONAL LABORATORY
MANAGED BY UT-BATTELLE FOR THE DEPARTMENT OF ENERGY

Parameters

Design ring parameters:

- Ring circumference: 248 m
- Beam: 1 GeV, 695 ns, 1.5e14 ppp
- Working point (6.23,6.20)
- Space charge tune shift – 0.15



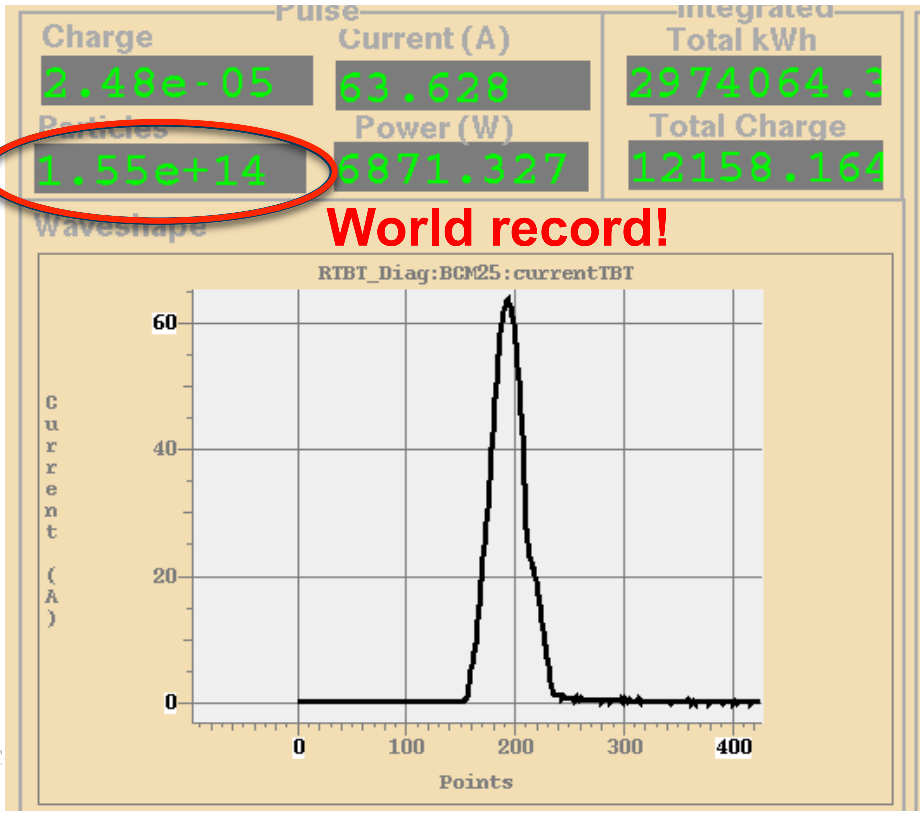
Ring was designed to accommodate a high intensity beam:

✓ Injection painting
✓ Collimation
✓ Titanium nitride coating in most areas
✓ Solenoidal windings in portion of collimation region.

Current Operational Status

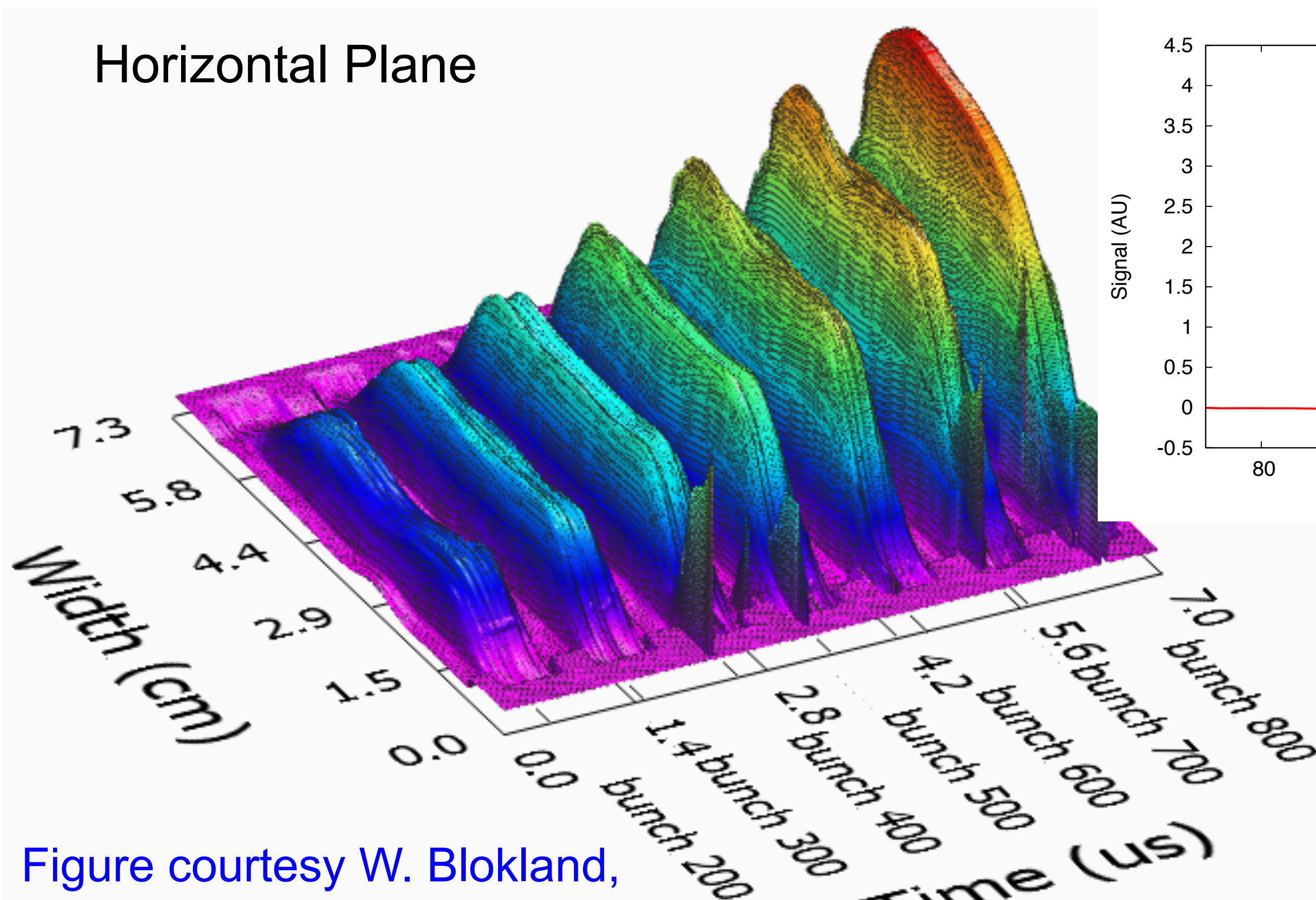
- Ran 1.08 MW (> 1e14 ppp) in previous run cycle. Power lowered in 2011 to save $$$.
- Up to 1.55e14 ppp accumulated in high intensity studies.
- Focus for first few years on ramping beam power, troubleshooting equipment issues. Now we begin to look at collective effects. Much of the data analyzed was taken for another purpose.
- Many interesting high intensity effects observed, both in production beam and in dedicated experiments.

Presently the beam intensity is NOT limited by collective effects.



Profile Evolution of Production Beam

Electron scanner profile measurement shows beam evolution during accumulation of a ~1.1 MW (1.2e14 ppp) production beam.



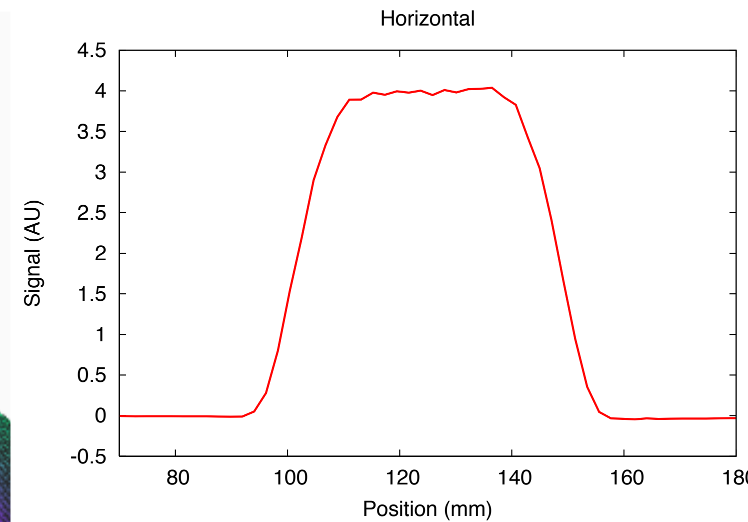
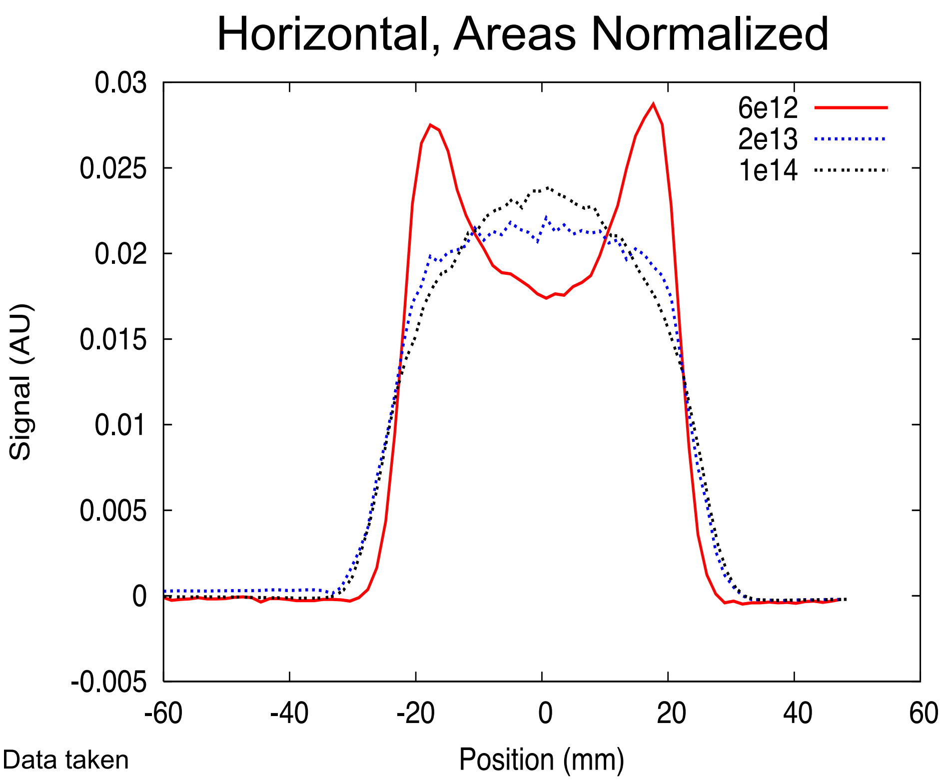
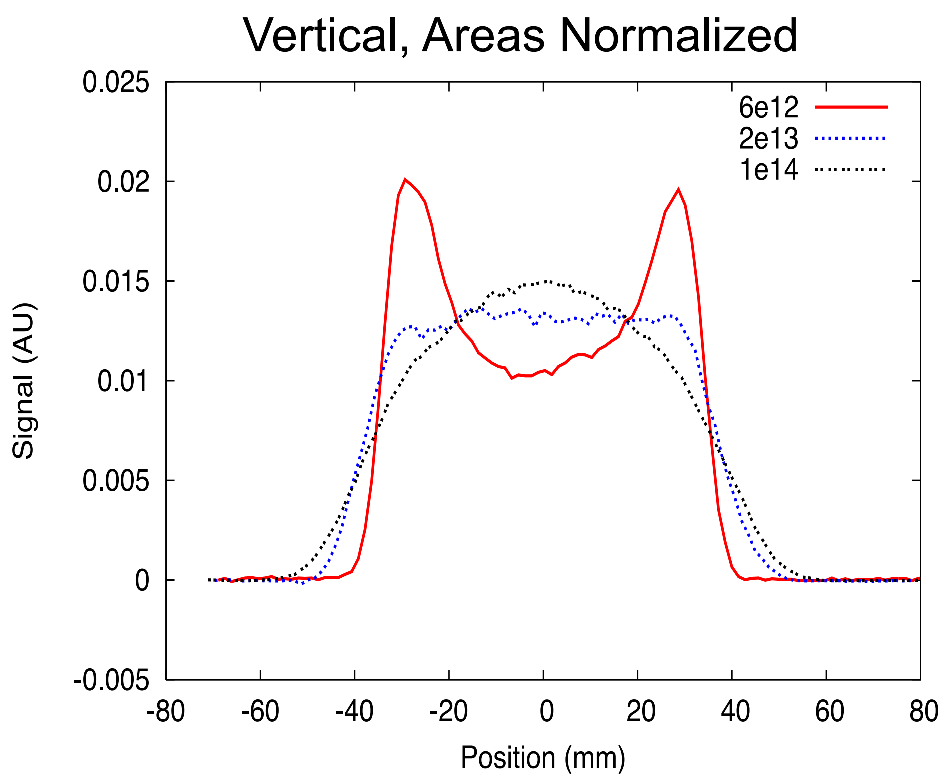


Figure courtesy W. Blokland, PAC11 WEOCN2

Space Charge Profile Dilution Measurements

Fix the painting scheme and vary the intensity via beam decimation.



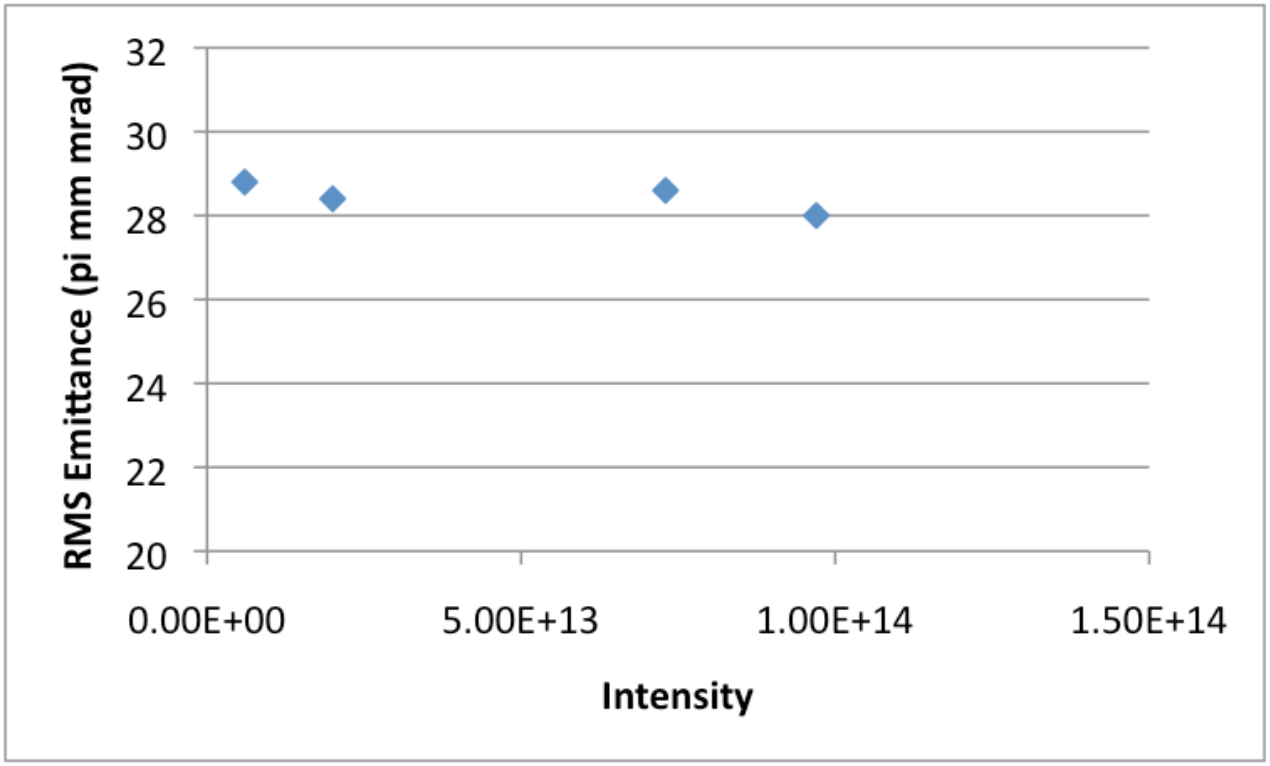


Data taken
March 22, 2011

- Space charge dilutes the beam.
- Significant dilution occurs by ~1e13 ppp.
- Creates a beam shape more ideally suited for the target.
- No significantly extended tails discernable.

Impact on Emittance

RMS emittance measurement for profiles shown on previous slide.

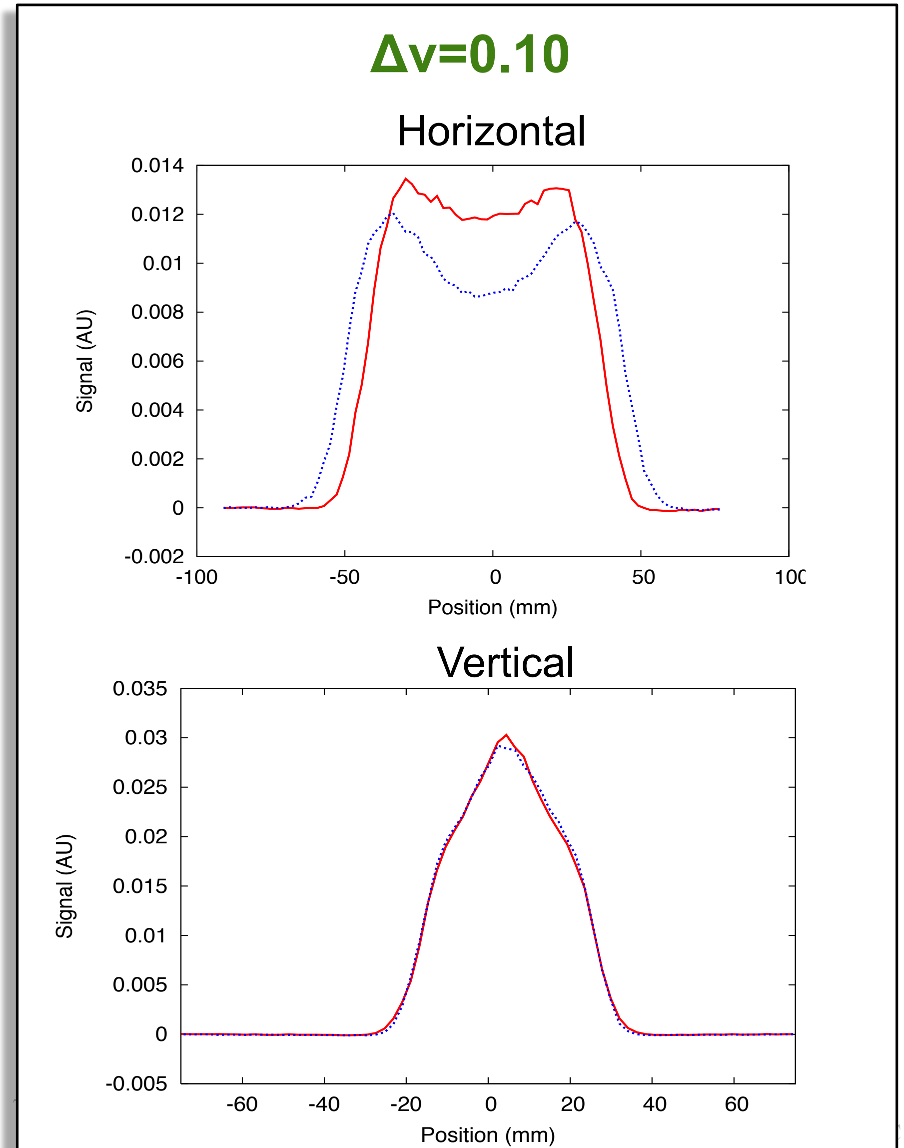


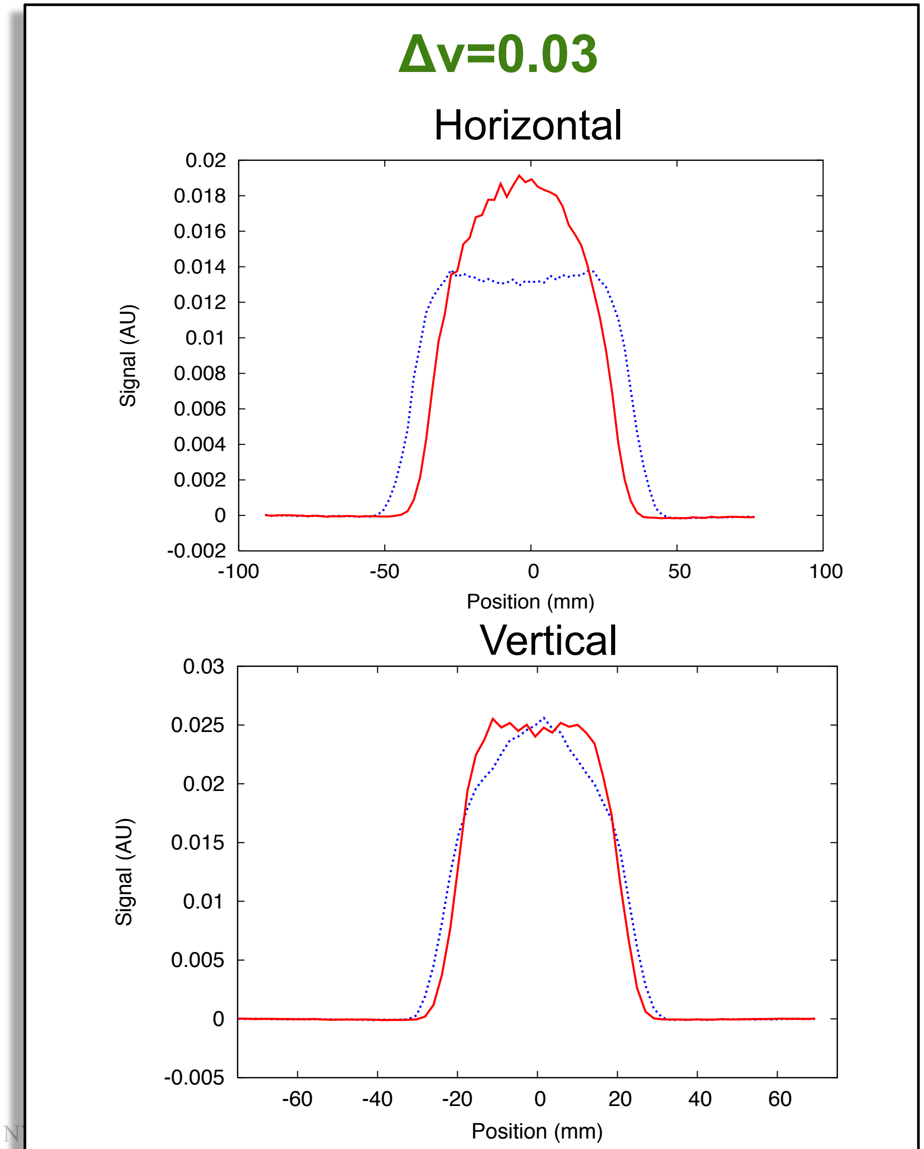
Though profile shape changes with intensity, rms emittance remains fairly constant.

Transverse Coupling: Profiles

Transverse coupling is observed for certain intensities and tune splits.

Example: Horizontal beam size varied using horizontal injection kickers.



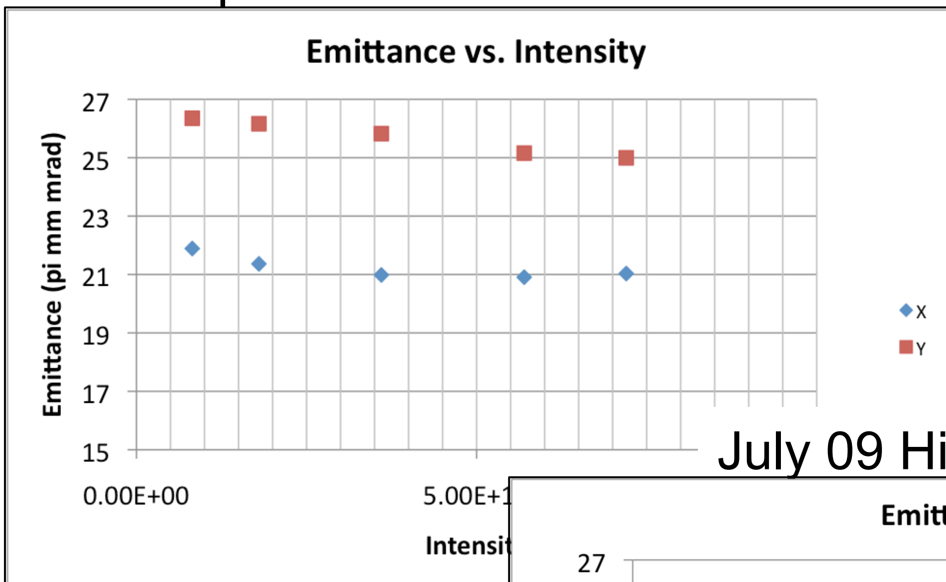


(data Dec 22, 2009. 5e13 ppp)

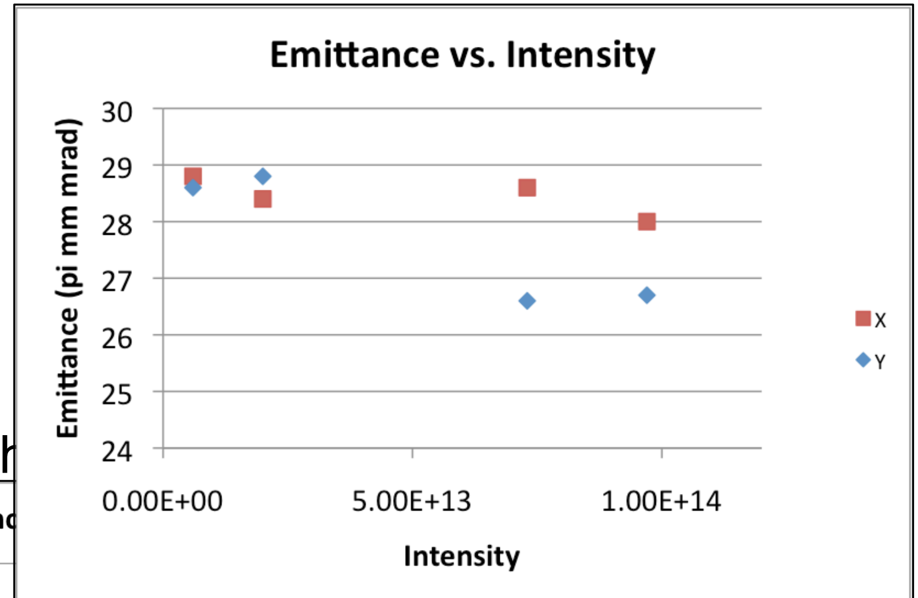
Transverse Coupling: Emittance

Coupling observed in emittance measurements.

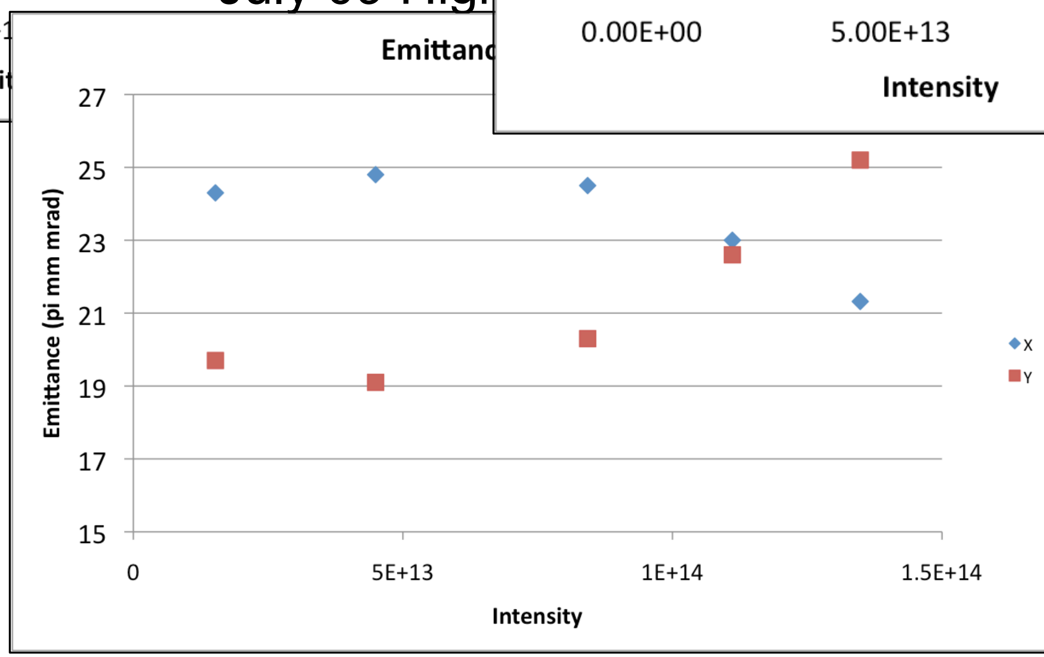
April 09 Production Beam



March 11 Production Beam

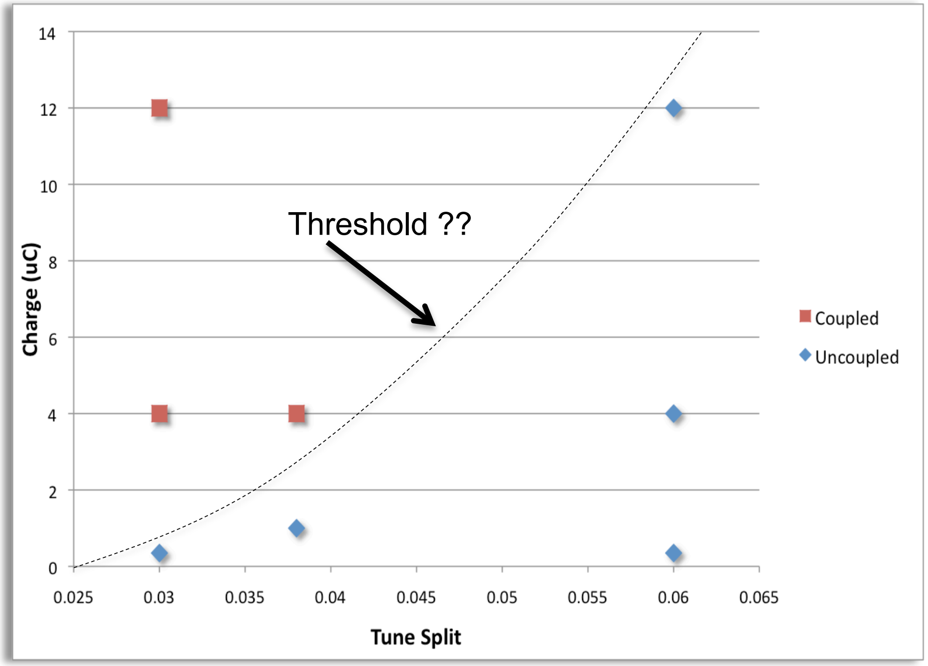


July 09 High

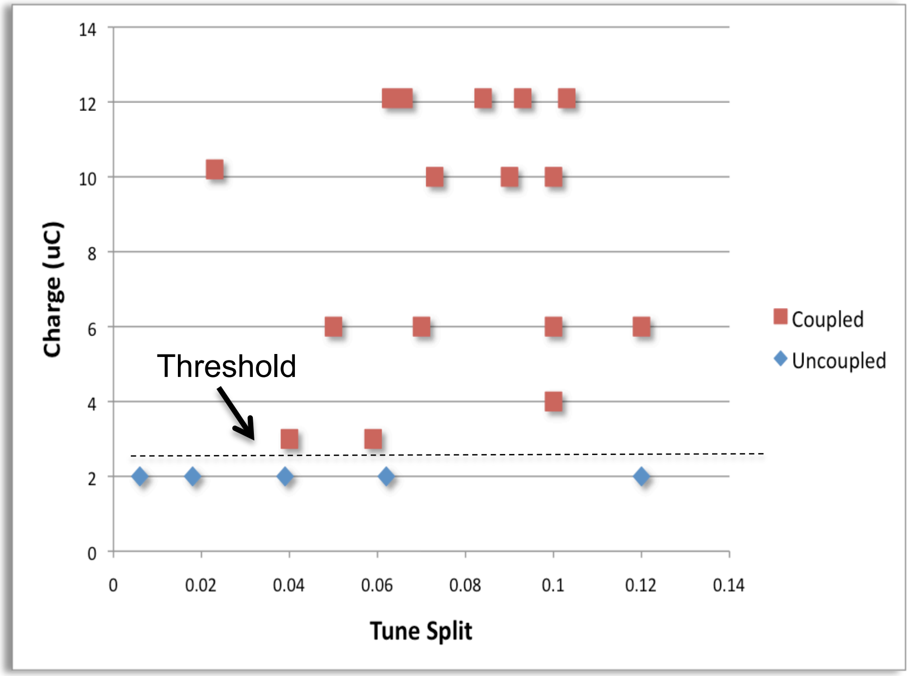


Intensity Dependence Transverse Coupling

Case 1: May 2010



Case 2: March 2011



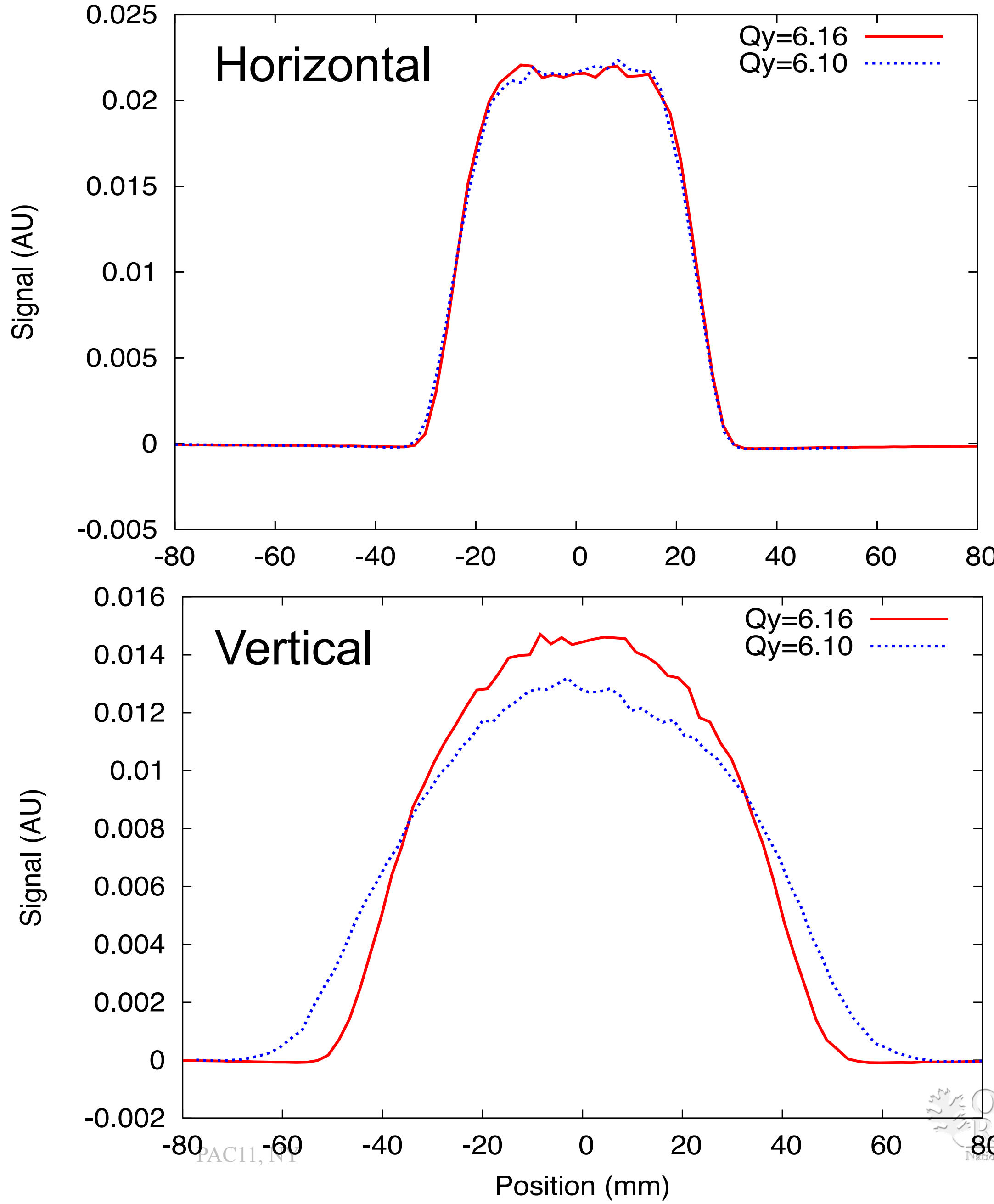
- For some cases the presence of coupling depends only on intensity, and for others it depends on intensity and tune split.
- The two cases above have different machine configurations, specifically the closed orbit in the injection region.
- We have operated production beam in coupled state with no issues. Would be more ideal to restore independent control of transverse planes.

Profile Broadening due to Half-Integer Resonance

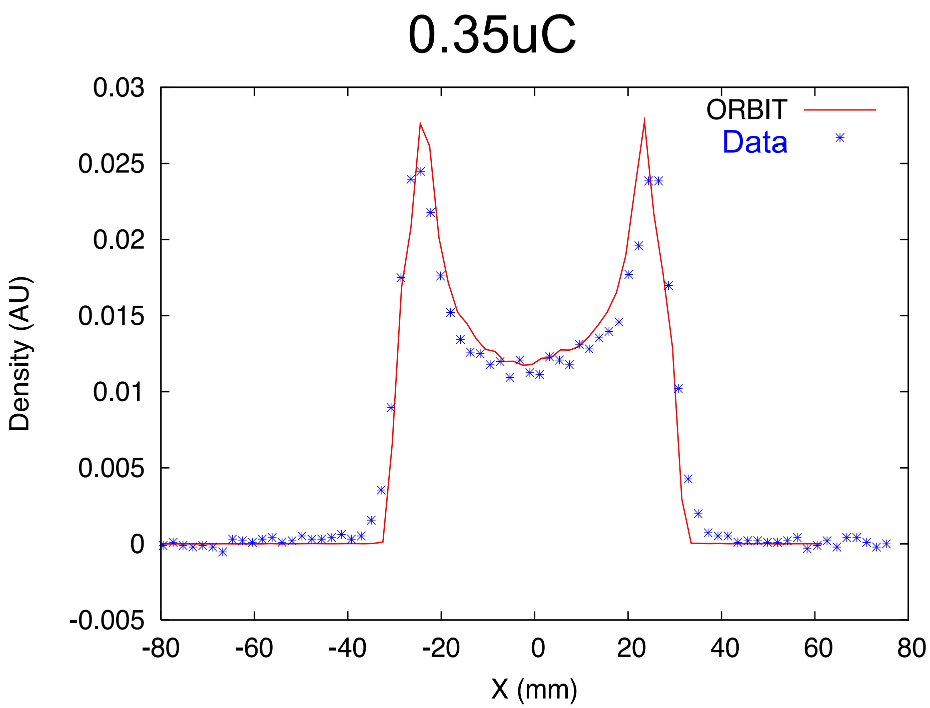
- Intensity 1.2e14 ppp.
(Data taken Dec 14, 2010)

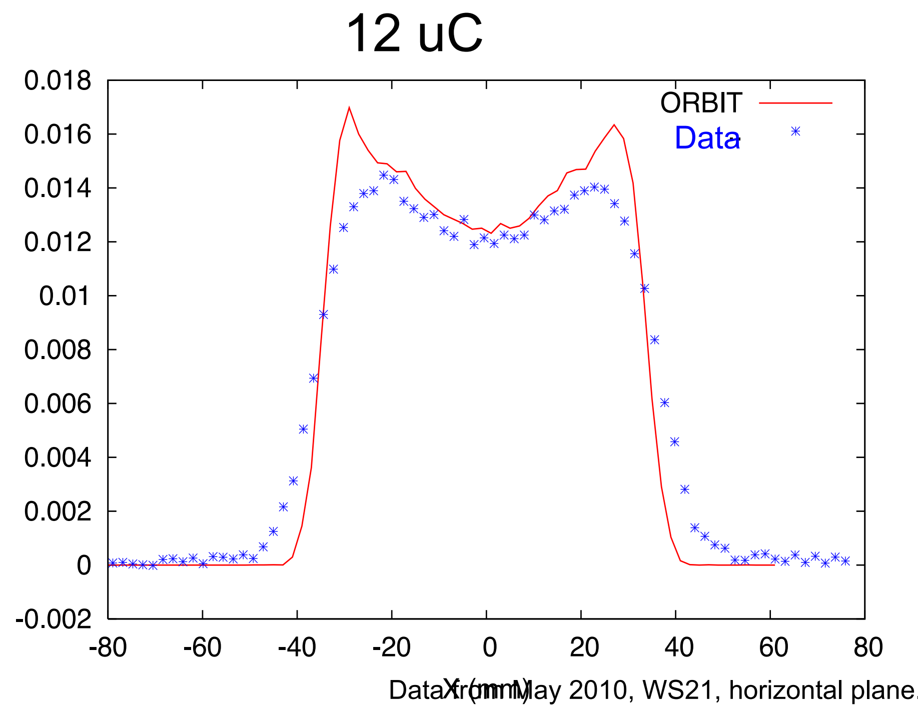
- Lowering vertical tune induces broadening in the vertical plane.

- No effect observed in the horizontal plane.



Comparison with ORBIT Simulations





- ORBIT simulations have reasonable success reproducing measured profiles at both low and high intensity.

- The code slightly underestimates the amount of profile dilution.

- Simulations have not yet been used extensively to understand space charge effects in the ring.

Review of Instabilities Observed at SNS

The following instabilities have been observed during dedicated high intensity studies:

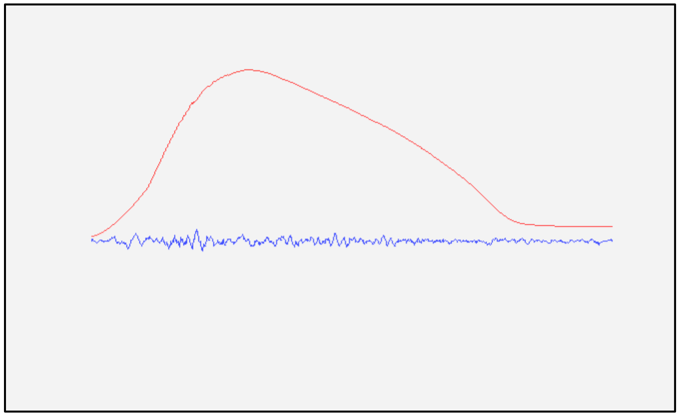
1. Extraction kicker transverse instability, ~6 MHz.
2. Resistive wall instability, ~ 200 kHz
3. e-p instability, 20 – 100 MHz

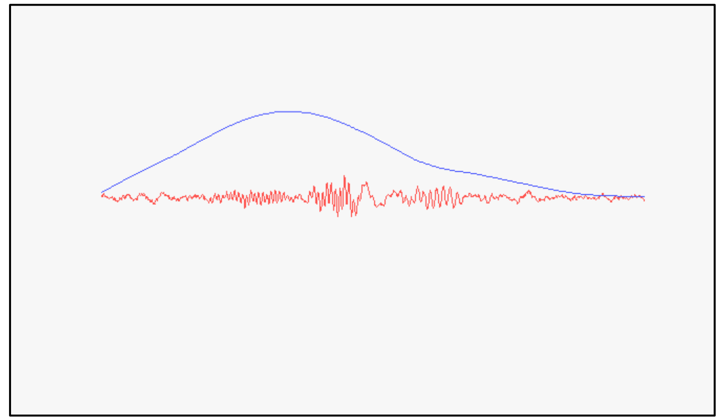
Recent work has focused on the e-p instability. At SNS it does not have a clear-cut parameter dependence. Case by case variation is seen for:

- Intensity threshold for instability
- Dependence on 1^{st} and 2^{nd} harmonic RF
- Leading plane of instability (horizontal or vertical)
- Trailing or leading edge instability

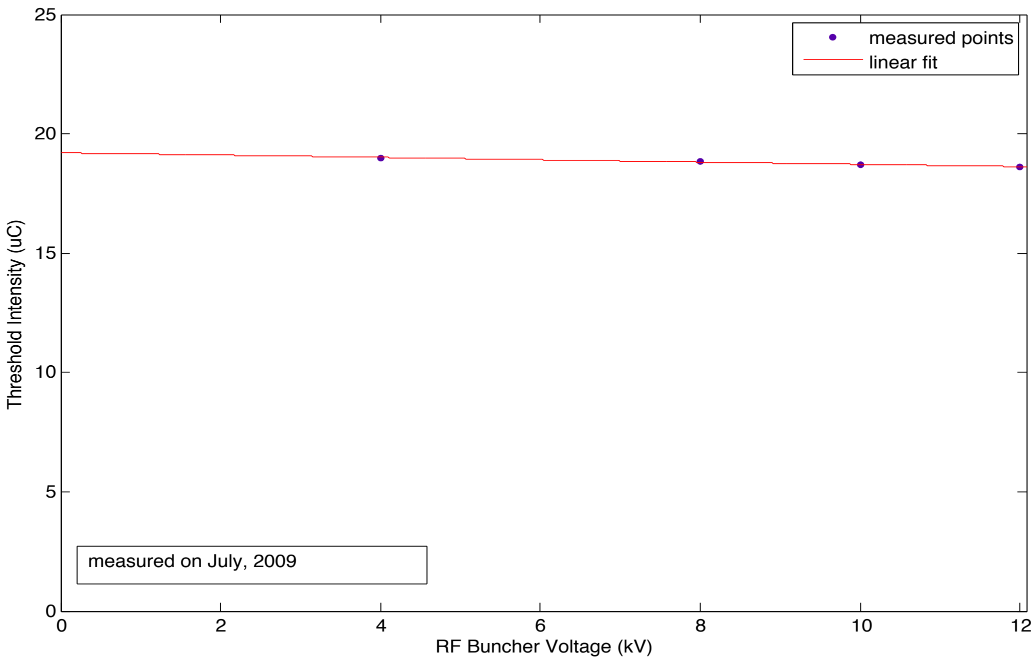
Characteristics of e-p at SNS

- We sometimes observe e-p on the leading edge of the beam, and other times the trailing edge or a combination of both.





- Additionally, the instability not consistent with Landau damping laws.

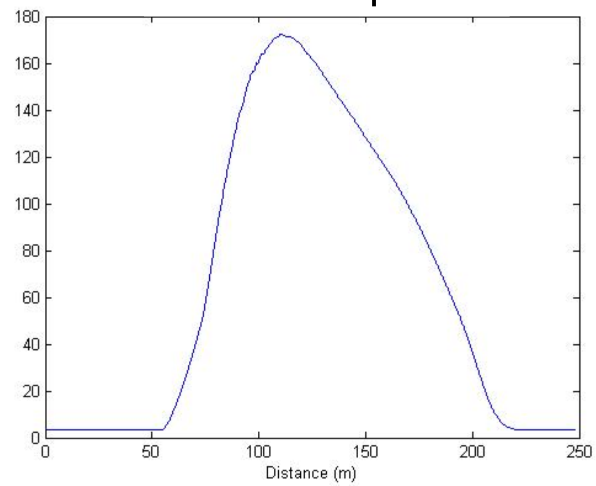


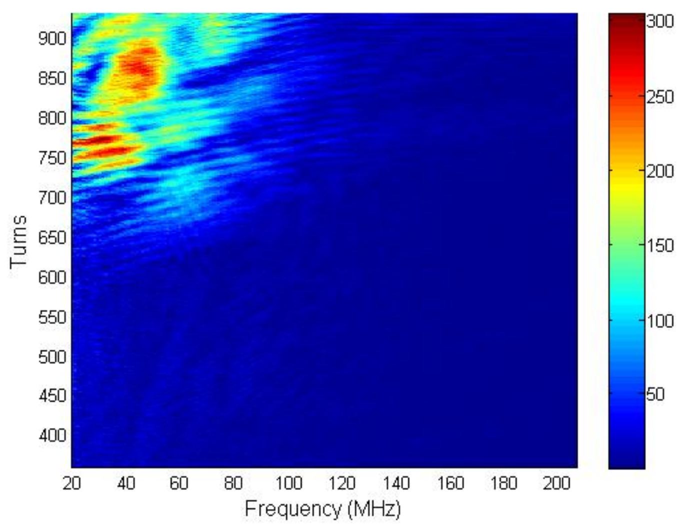
Courtesy Z. Liu, PhD thesis

Effect of Bunch Shape On e-p

The instability can be suppressed by creating a flatter profile using 1st or 2nd harmonic RF.

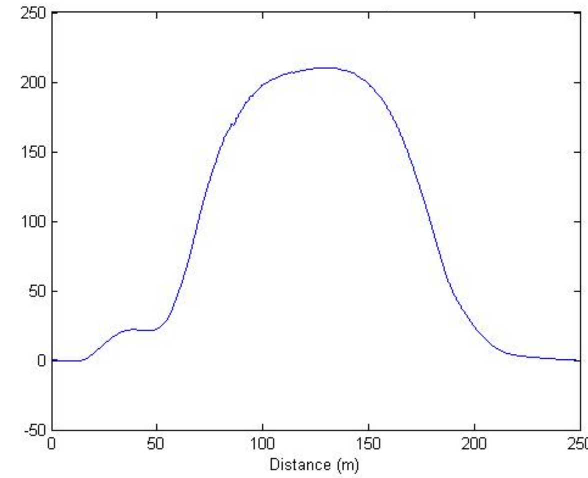
Bunch Shape

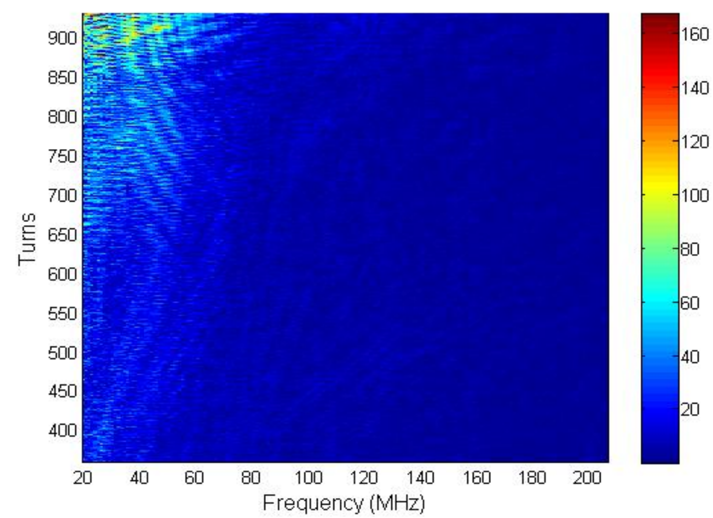




Change phase of 2nd harmonic

Bunch Shape

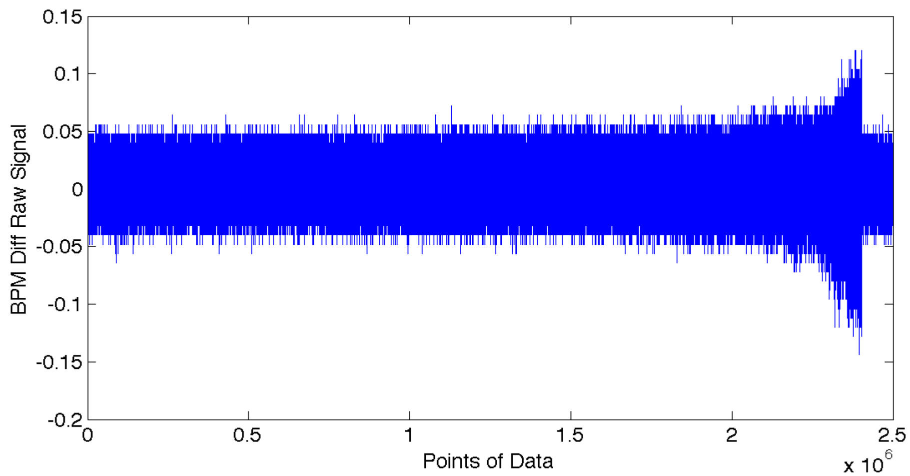


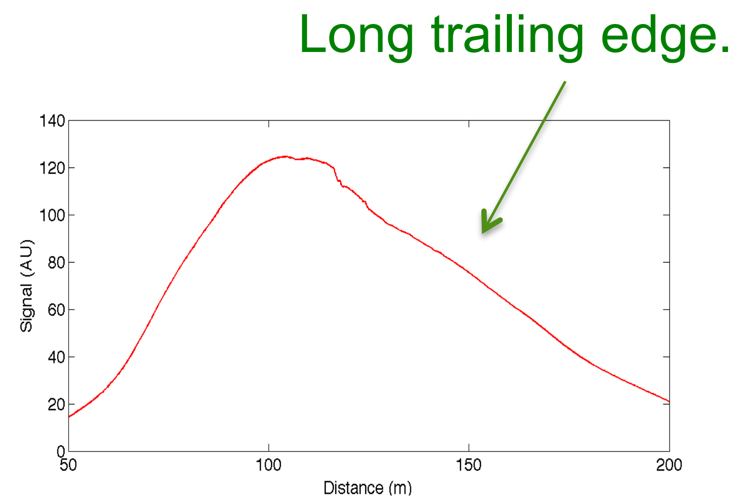


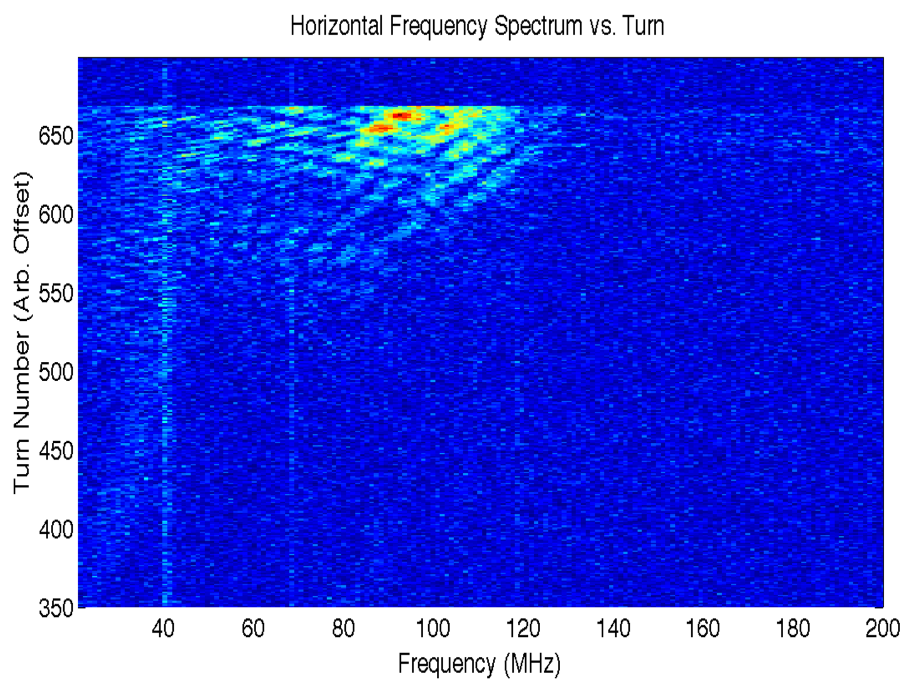
Courtesy Z. Liu, PhD thesis

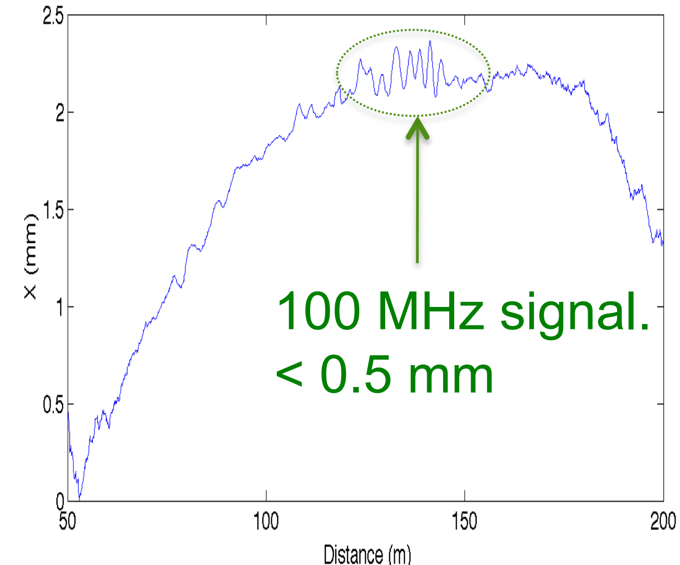
e-p Signatures During Production

- Trace levels of e-p sometimes observed during production.
- Data shown here if from an 880 kW production beam on 03/17/2011.



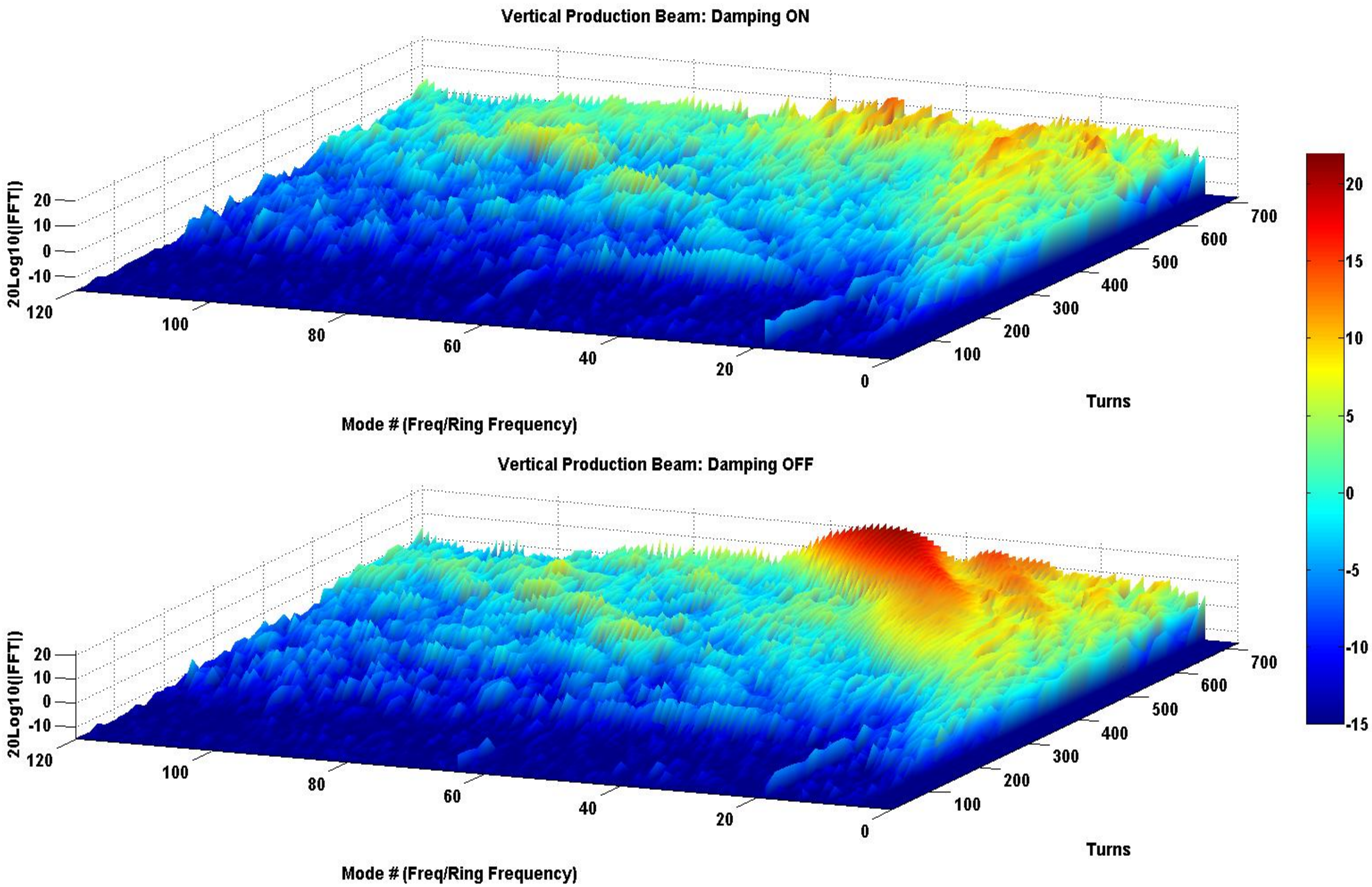






e-p Feedback System

- New e-p feedback system can extinguish low level e-p during production.
- Studies not yet done to evaluate effectiveness for higher levels of e-p activity.

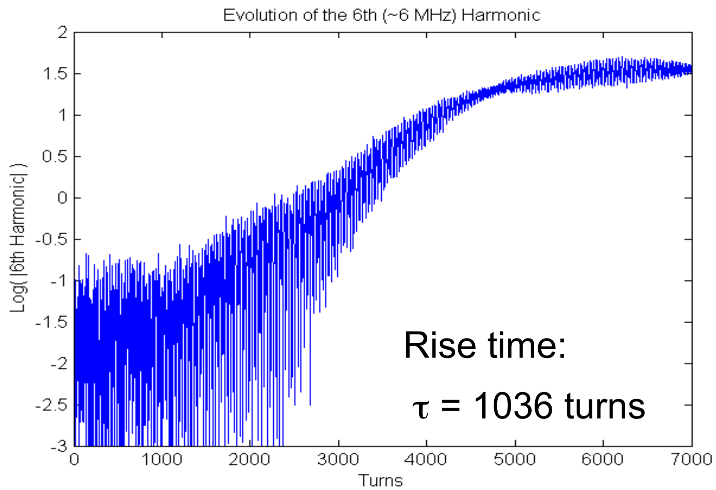


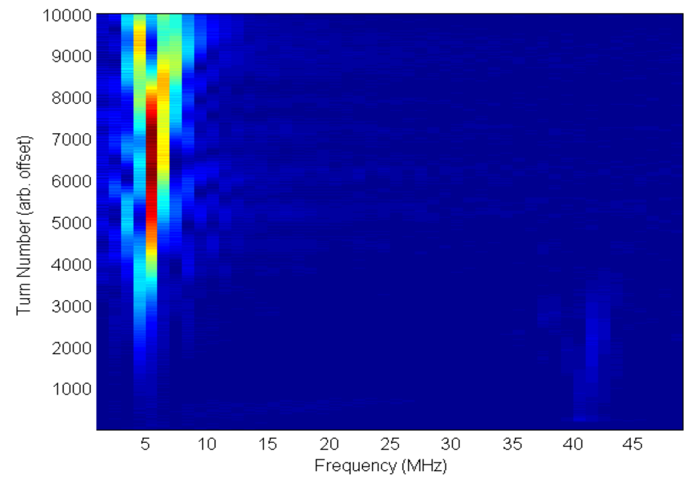
Courtesy R. Hardin, C. Deibele

Extraction Kicker Instability Benchmark

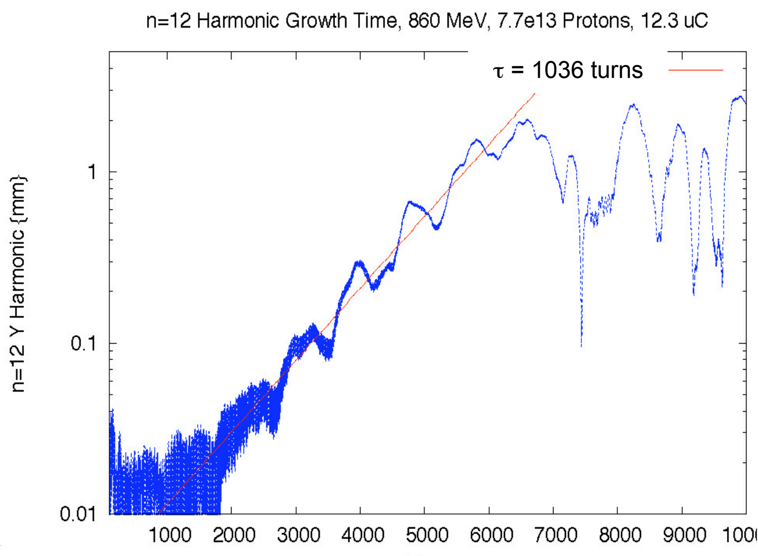
ORBIT's transverse impedance model was successfully used to model the extraction kicker instability.

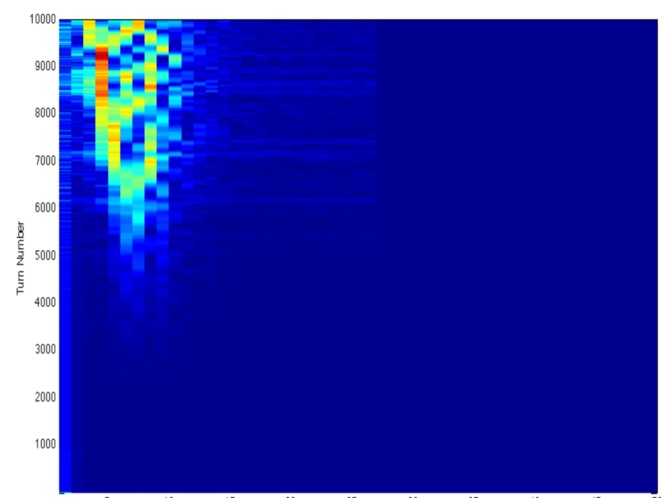
Measured





Simulated





Courtesy J. Holmes

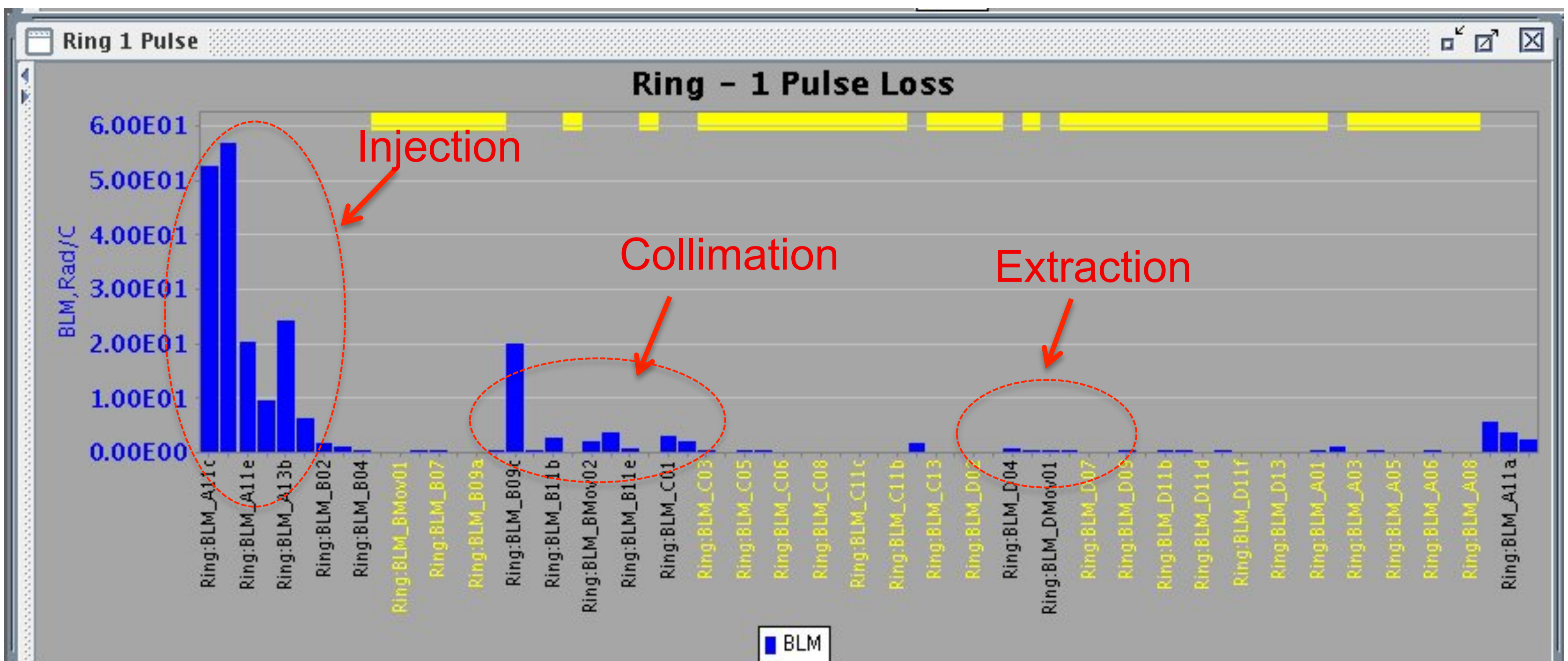
Summary of Collective Effects

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. No impact yet.
Broadening due to resonance	No	----
e-p Instability	Yes (very low level)	No impact.
Extraction kicker transverse instability	No	----
Resistive wall instability	No	----

Ring Loss Pattern for 1 MW Operations

• SNS ring losses are dominated by injection.
• Losses due to high intensity effects show up in the collimation region, along with RF and extraction based losses.
• Beam power is not limited by ring losses. Presently power is limited by SNS mission to provide high reliability for users.

Ring loss snapshot for 1 MW operation.



Nov 26, 2010. 1 MW

Conclusions

The SNS ring is an ideal environment for studying high intensity effects.

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