Accelerator Physics Overview

J. Galambos

Accelerator Advisory Committee, May 7-9, 2013

Outline

- 2012-2013 Progress
  - Selected accelerator physics activities
  - Community involvement
- RFQ detuning incident

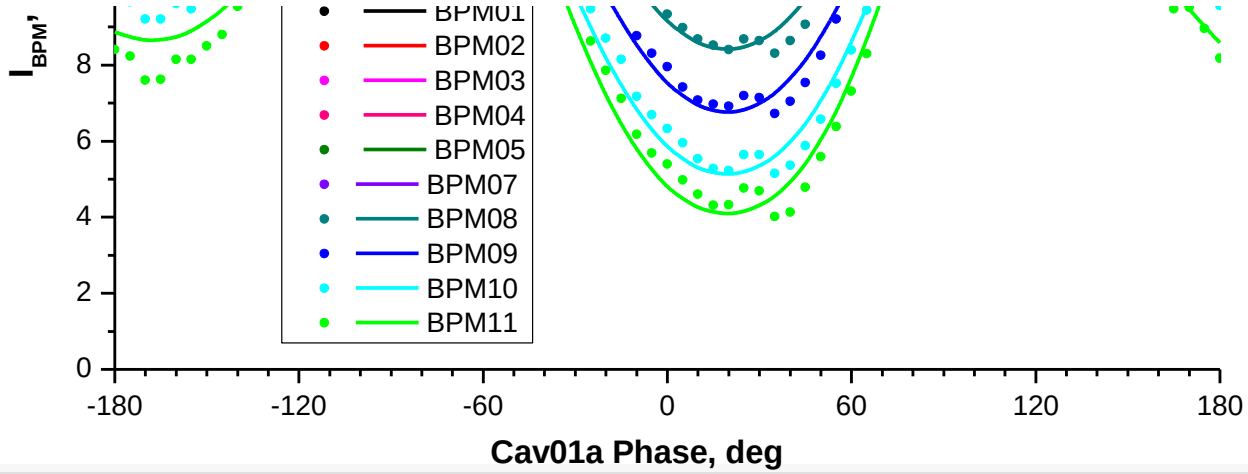
Longitudinal Twiss Measurement in the Linac (*Shishlo*)

- **Use BPM amplitude signal as a measure of bunch length (strength of induced signal ~ bunch length)**

Measured SCL input Twiss below, seems to work!

XAL Units	Alpha	Beta	Emittance
Design	**0.21**	**6.07**	**$0.30*10^{-6}$**
Measured	**0.25+- 0.03**	**10.1 (+4.1,-1.8)**	**$(0.97+- 0.21)*10^{-6}$**

Submitted to PRST-AB

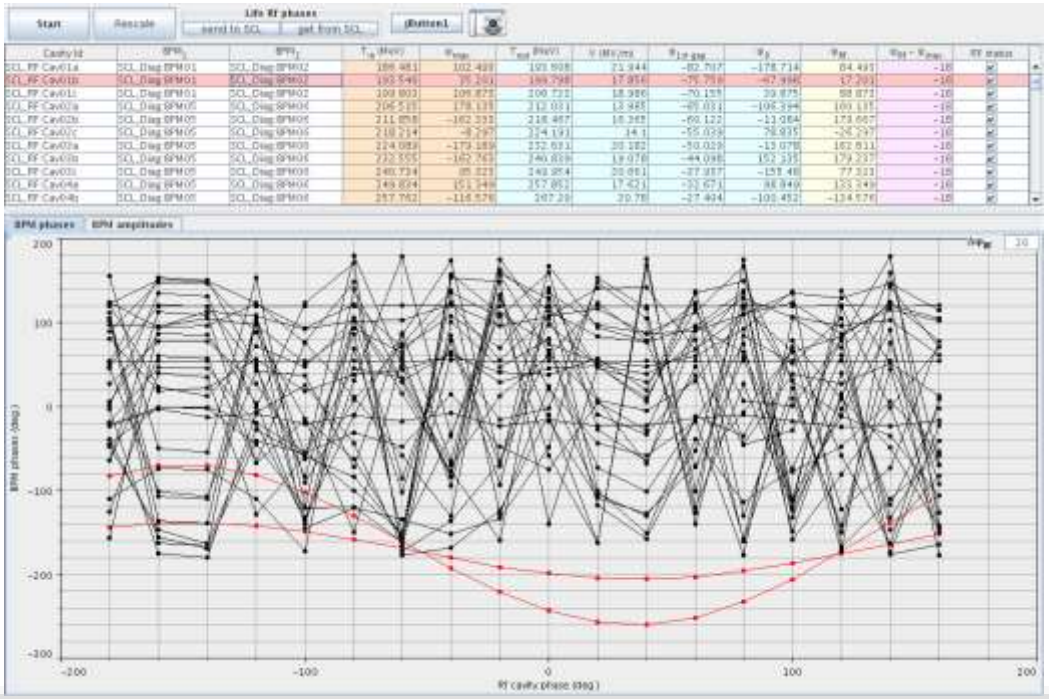


SCL RF Setup – Automated!

T. Gorlov

- **Process of setting each klystron (1-per-cavity) phase is beam based process – involving scan**
  - **Original setup took a few days**
  - **Last 1-2 years reduced to fraction of 1 day**
  - **Now ~ 30 minutes**

Also get more information now during the scans – e.g. used in new Twiss measurement method



Open XAL – Collaboration

T. Pelaia, C. Allen

Primary development at SNS

Target Date	Task	Progress (as of Apr 25, 2013)
May 3, 2010	Workshop at SNS	
Oct 31, 2010	Project Creation and Architecture	100%
Dec 31, 2010	Website Development	100%
Feb 15, 2011	Application Framework Migration	100%
Apr 30, 2011	New Online Model Implementation	100%
Sep 30, 2011	Fix All Compiler Warnings with Strictest Settings	100%
Feb 28, 2012	JSON Framework Implementation	100%
Feb 28, 2012	Common Package Migration	100%
Oct 31, 2012	New Service Implementation	100%
Dec 13, 2012	Workshop at FRIB	
Dec 31, 2012	Common Services Migration	100%
Jun 30, 2013	Milestone 1 Tickets	67%
Dec 31, 2013	Milestone 2 Tickets	5%

Python-ORBIT Development and Support

A. Shishlo, J. Holmes, S. Cousineau

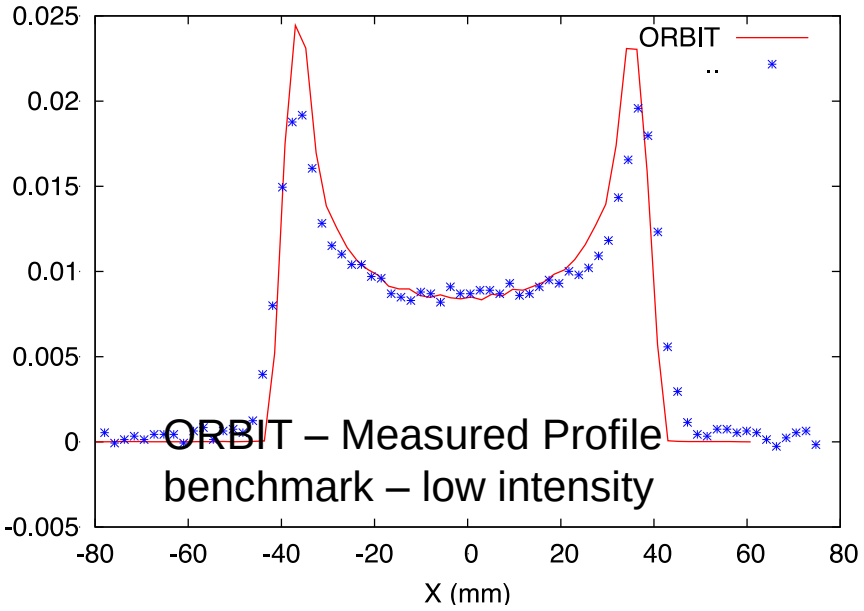
- **ORBIT is a high intensity beam simulation code developed at SNS, used around the world (FNAL, CERN, ISIS, J-PARC, GSI, LANL, CSNS, …)**
  - **Supported by SNS physics group**
  - **Being ported to a more modern, more easily maintainable structure (python script interface)**
  - **Background activity for 3-4 years, past year concerted effort, nearing completion**
  - **Linac simulation supported !**

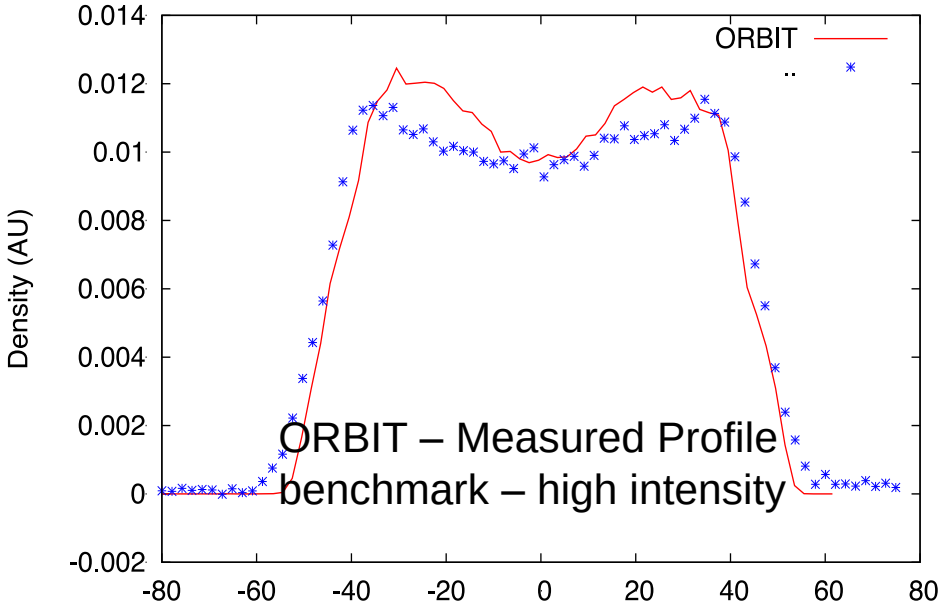
"Joe Physicist" Assessment

Level	Comparison with old ORBIT
User only	Easier, more flexible, more powerful
Python level developer	Same difficulty, more flexible, more powerful
Core C++ developer	More difficult (more levels of structure)

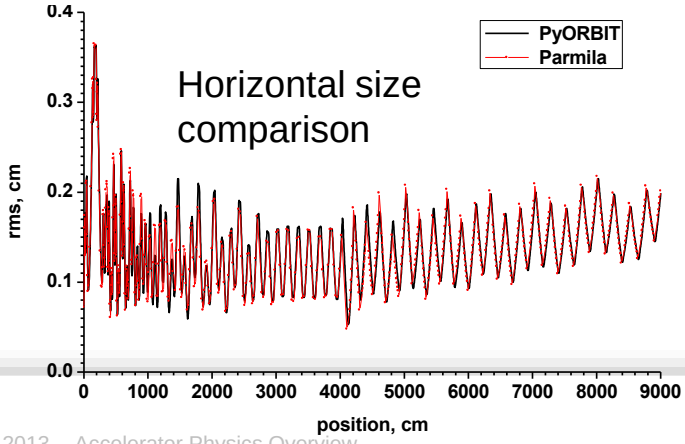
Emphasize Benchmarks Measured Data

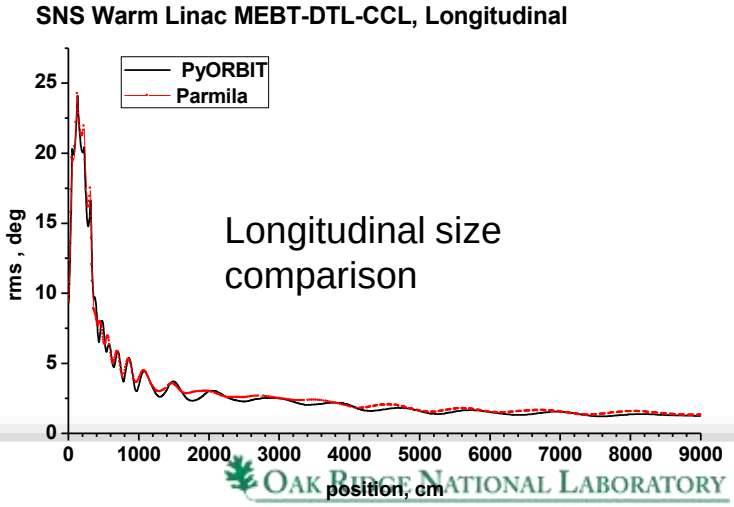
Ring Simulations - Collective Effects:





Linac simulations - starting

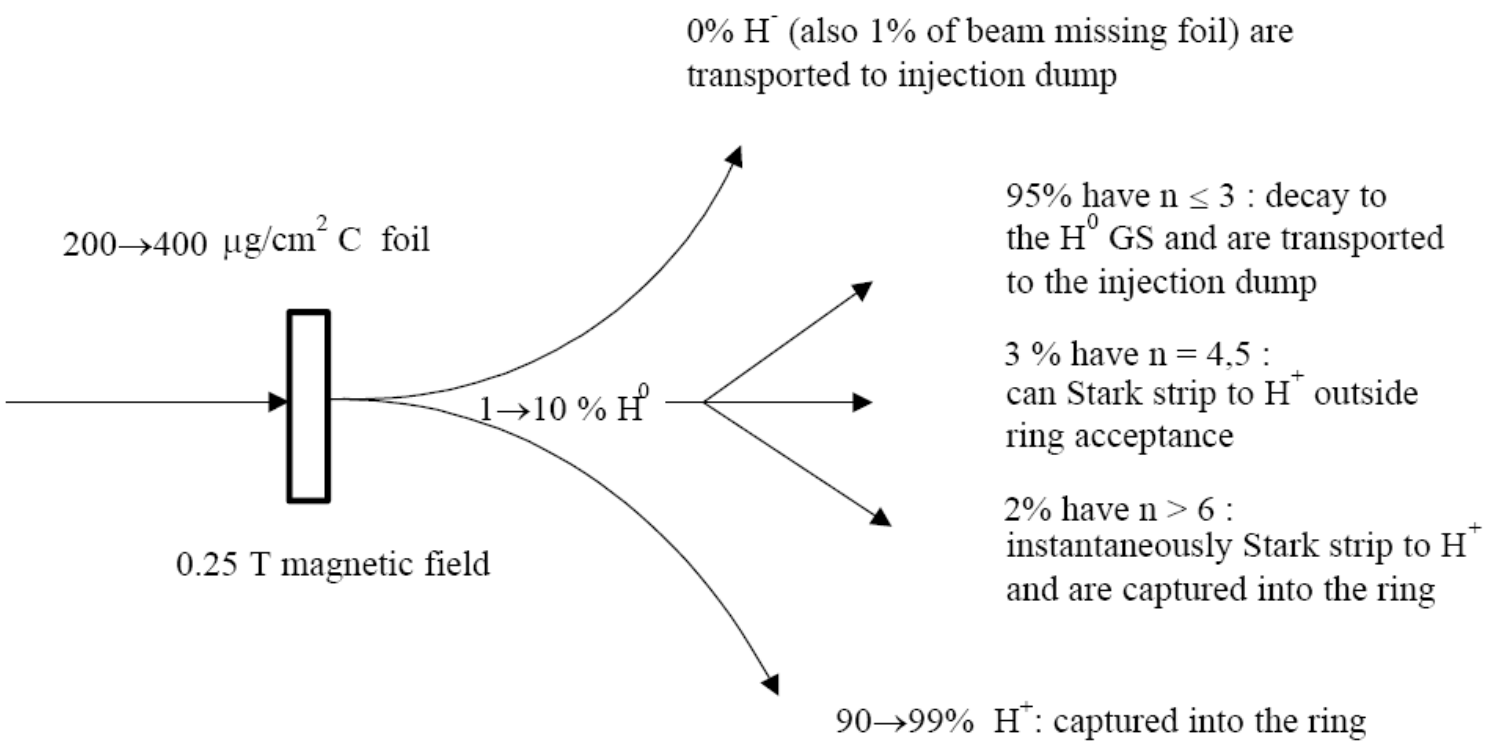




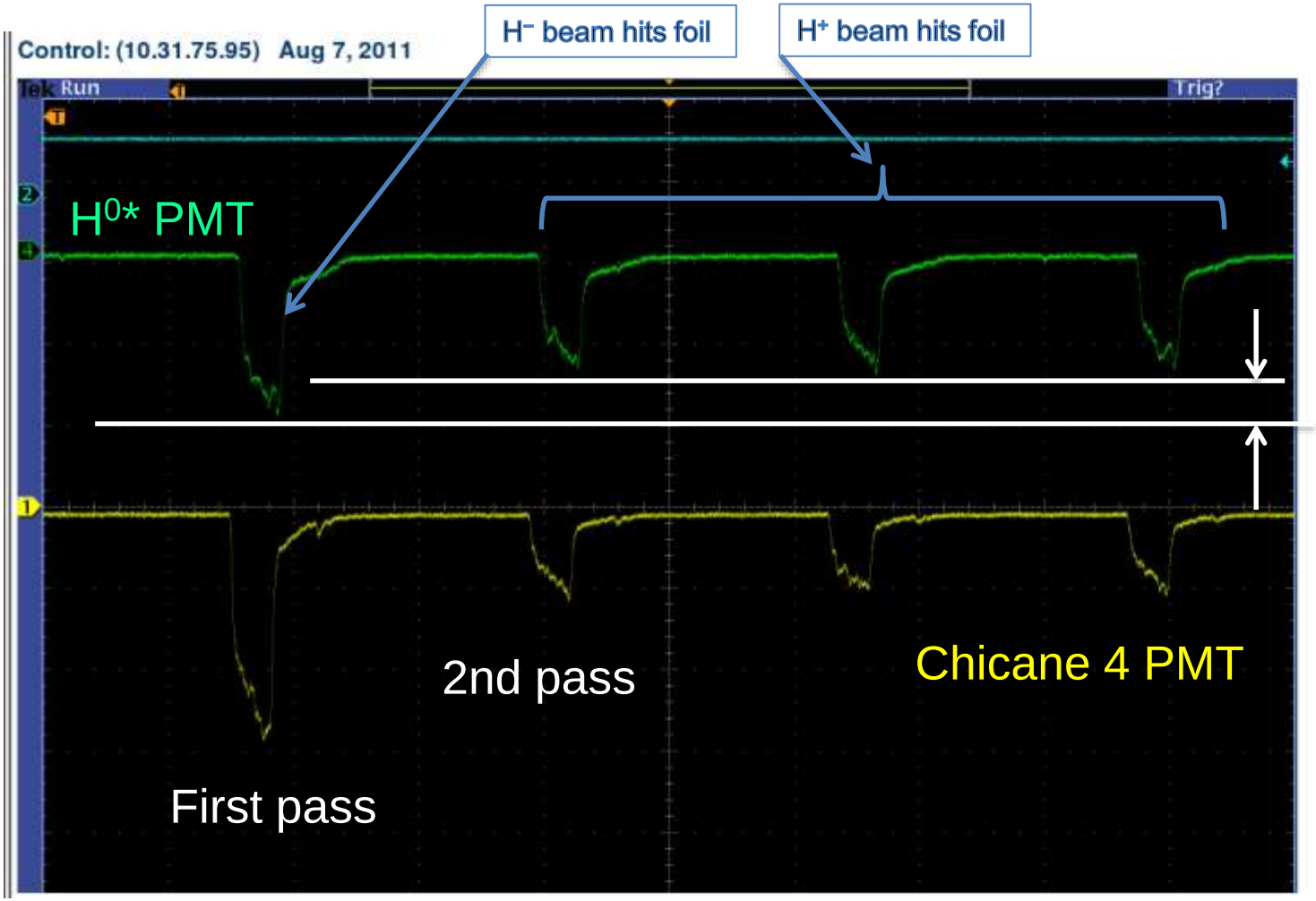
Ring Injection Stripping: Excited state H^0

M. Plum

- **SNS injection design minimizes impact of excited state losses**
  - **Large impact on upgrade design**
  - **But how important is it really – need to measure!**



H0* Loss Measurements:

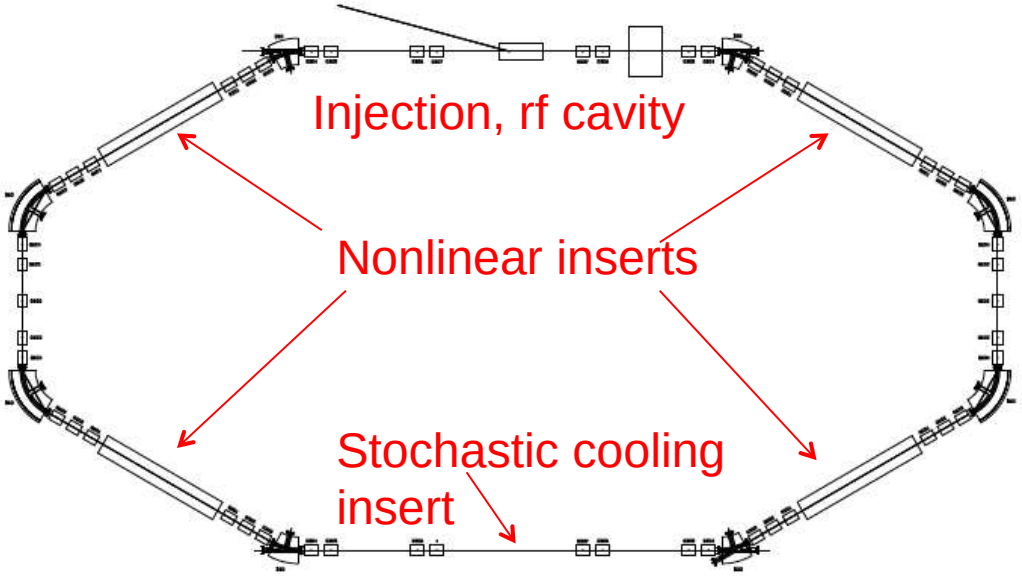


- Difference between 1st foil pass and subsequent passes = excited state loss
- Measured loss not severe for baseline, or purposefully high H^{O*} loss setups

Nonlinear lattices / Integrable Optics, Gaining Community Attention

V. Danilov, S. Nagaitsev, *PRSTAB* 2010, Selected as one of best papers of 2010

- **Avoid resonances – allow large tune spread**
- **In general these are non-trivial solutions, identified a practical implementation**
- **Proposed electron beam experiment at FNAL: IOTA**

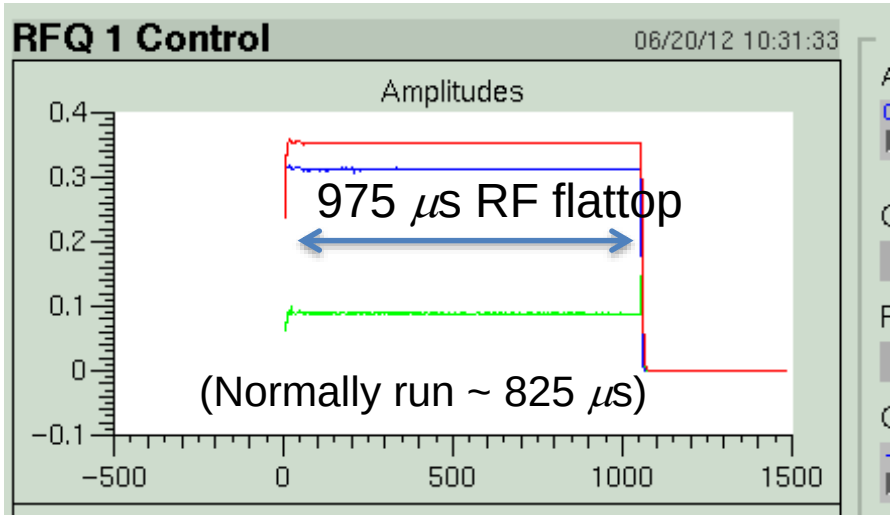


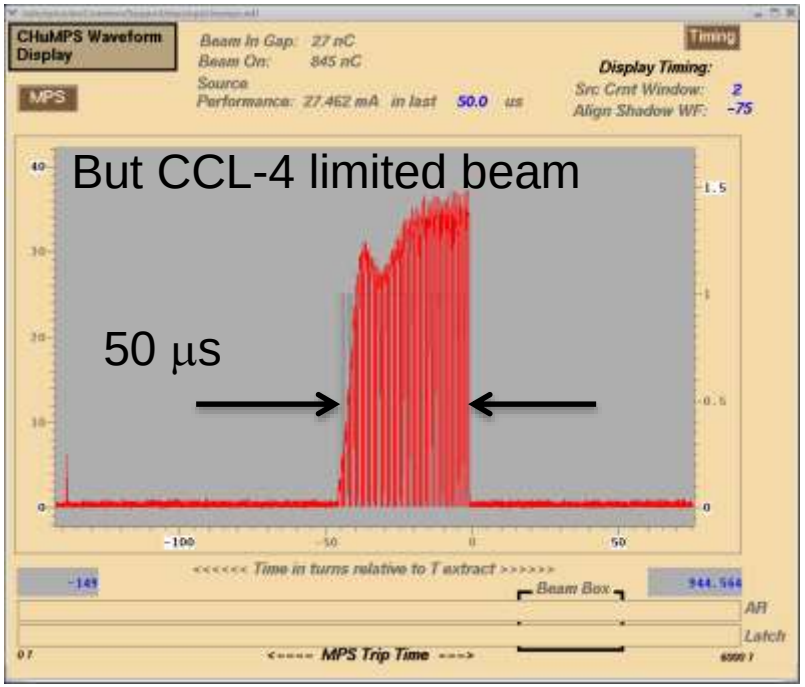
pc = 150 MeV
36 m circimference

High Power "Look-Aheads" Ongoing

AAC 2012: Resume high power beam studies in the ring

June 2012 – RF supported full pulse



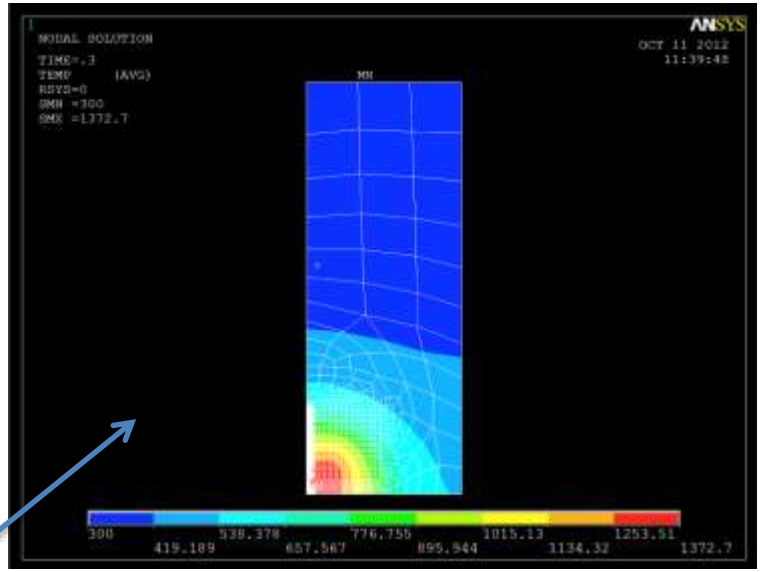


- **Setup the RF to support the full pulse length**
- **Plan to try again May 30-31, aim for 1.1 – 1.2 MW for ~ 1 day**

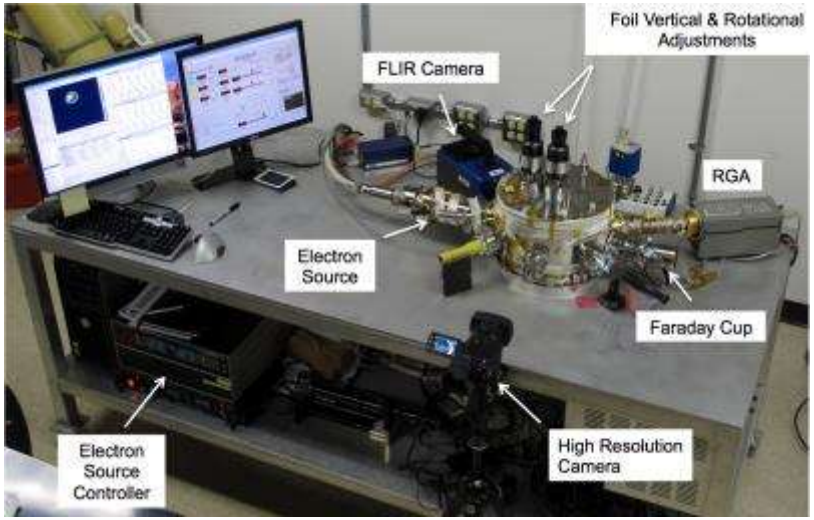
Stripper foil development program

M. Plum, et al.

- Foils are fabricated at ORNL using CVD
  - Testing new lithography patterns to reduce foil shaking and curling
  - Testing boron doping to improve foil conductivity
  - New foils in machine used with about 1 month period
- Simulating with beam the 1.4 MW heat load
  - Modeling (Y. Takeda from KEK)
  - E-beam lab setup
- Concerns
  - Foil lifetime – increasing powers
  - Shaking and curling / wrinkling



Detailed finite-element foil temperature simulation



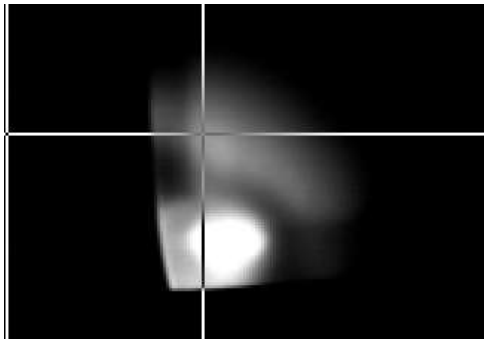
Electron-beam foil test stand

Simulated Full Power Foil Heating

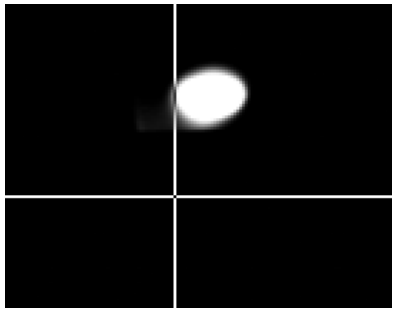
M. Plum

- **By using "sub-optimal" injection painting we increased the foil traversals to simulate increased foil heating expected at 1.4 MW – for 8 hours**

Foil image during test
Beam power is ~850 kW,
equivalent heat load for 1.4 MW



Foil image at 850 kW with nominal painting



Laser Stripping Re-Started
(M. Plum's talk)

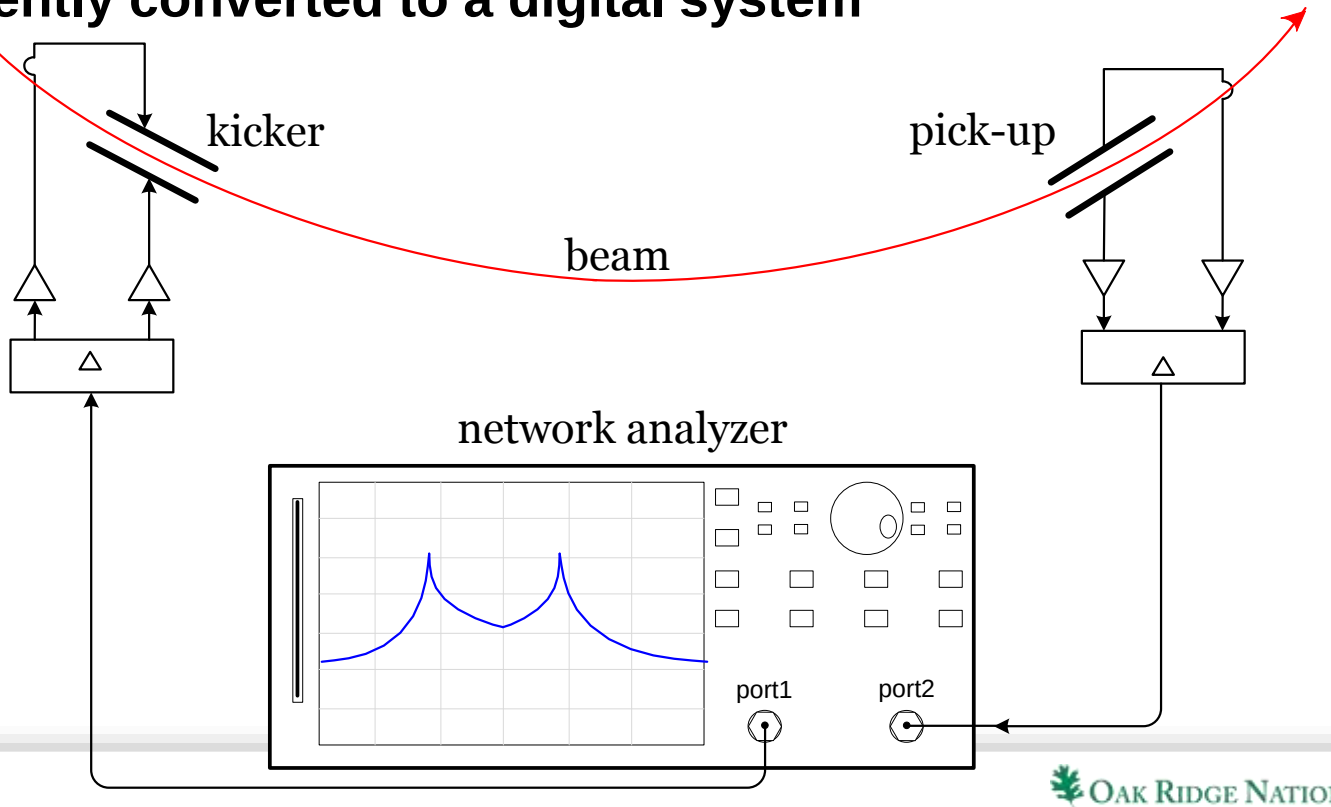
AAC 2012: Explore ways of bringing more accelerator science and technology graduate students and post-docs to the SNS.

- **Successful HEP accelerator R&D grant through the University of Tennessee**
  - **S. Cousineau is the PI**
  - **3 year, $825 k**
  - **Post Doc + grad student support**
- **Demonstrated a 10 ns laser stripping in 2005**
- **Planning an intermediate 10 μs demonstration**
  - **Lattice insert for experiment**
  - **Beam Studies to produce correct optics needed**
  - **Laser development efforts (e.g. Fabry-Perot light recycling)**

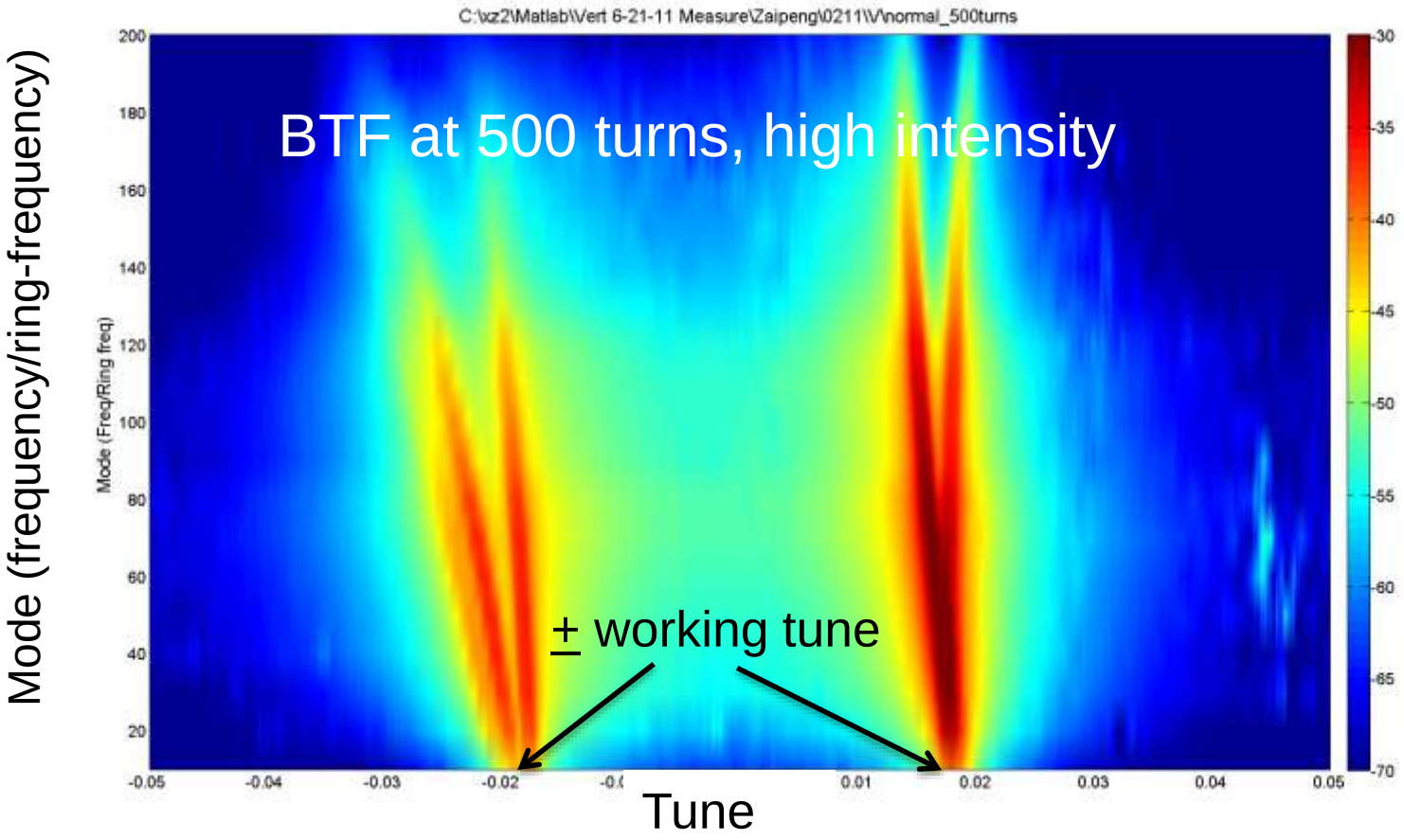
Beam Damper System Studies

Z. Xie, C. Deibele

- **Damper system may be needed for high intensity applications**
- **Beam Transfer Function (BTF) measurement**
  - **Characterize beam response to kick**
  - **Recently converted to a digital system**



Measured BTF Mystery



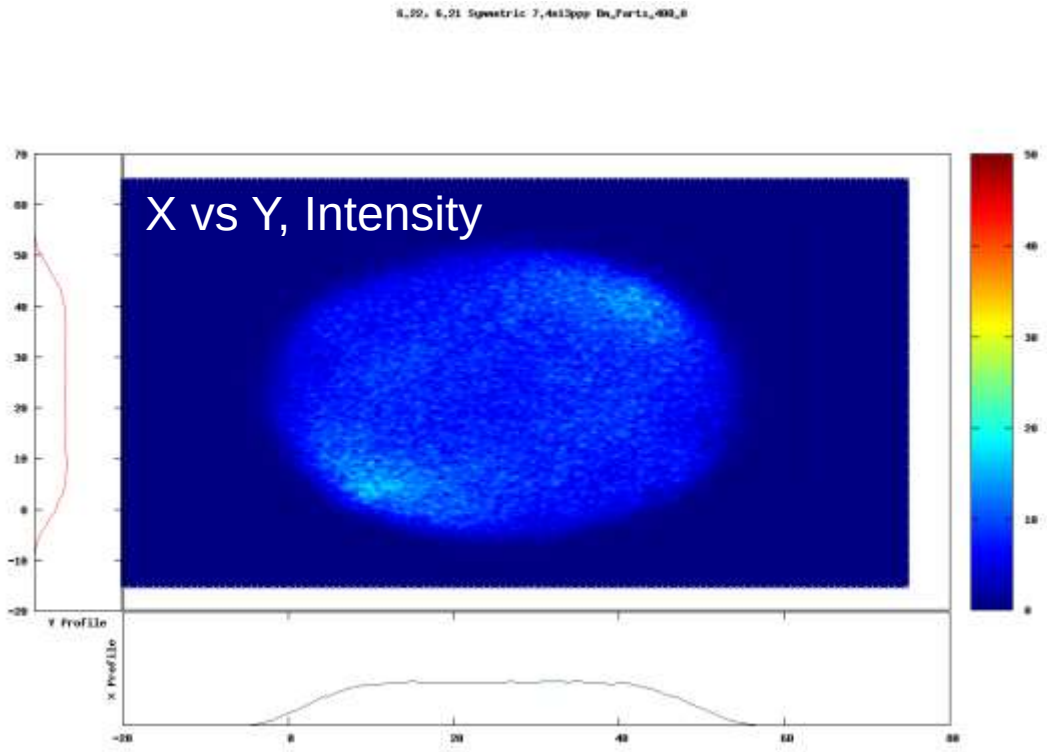
- Transfer function bifurcation occurs at high intensity
- Not understood

High Intensity Beam Simulations

(R. Potts, S. Cousineau) PhD dissertation project

Performing systematic study of beam evolution versus*:

- **Intensity**
- **Transverse betatron tune**
- **Initial emittance aspect ratio**



ORBIT simulation connection with experiment challenging because:

- Measurable profiles don't contain distribution details.
- Evolution sensitive to precise parameter knowledge.
- No analytic theory governing distribution evolution.

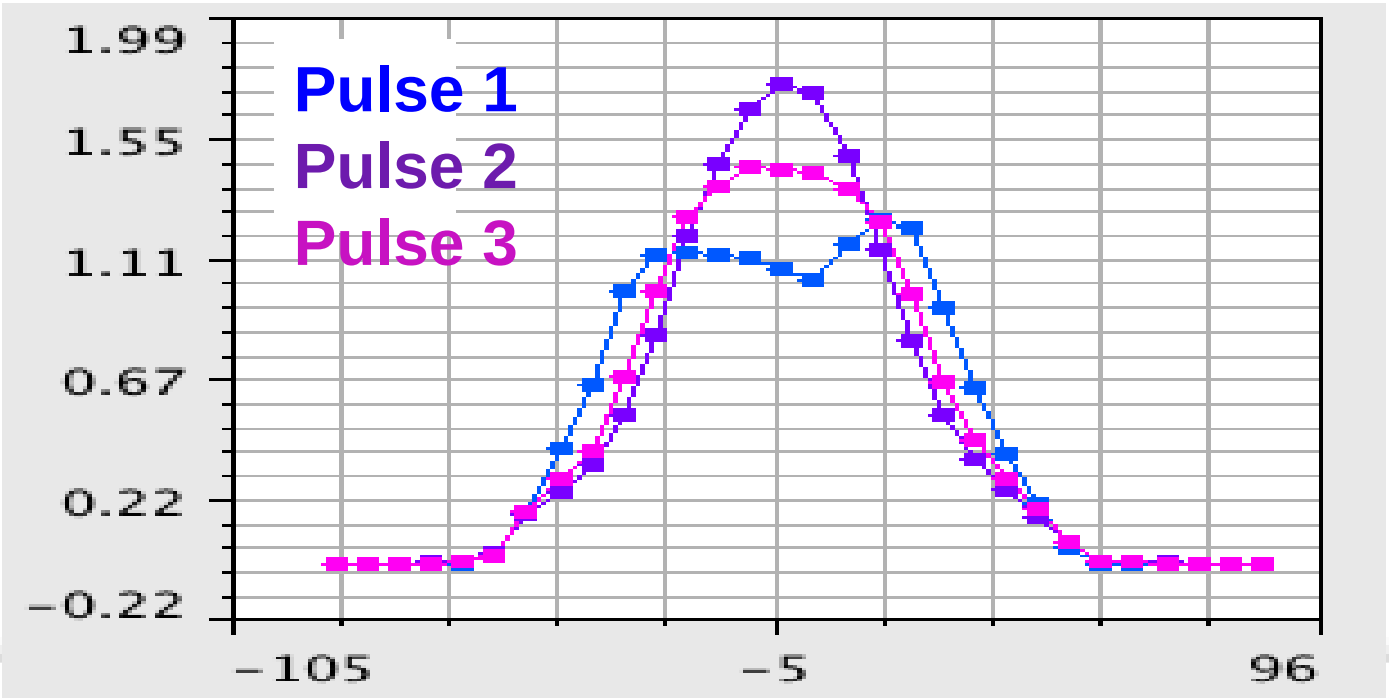
Ring High Intensity Effects
R. Potts PhD Topic

Interesting space charge phenomena observed at intensities > 1x10^{13} ppp.

- **Shot to shot variation of transverse profiles (see below).**
- **Coupling between planes.**
- **Dynamics sensitive to initial conditions.**

Harp shot-to-shot vertical profiles for identical beam configuration

(Space charge studies, March 2013. ~1.3e13 ppp)



Accelerator Community Involvement (2012-2013) Physics, Instrumentation, Ion Source

- Workshop / Conference Organization
  - Stockli - Symposium on Negative Ions Beams and Sources 2012, Workshop on Performance Variations of H- Sources
  - Pelaia: Open XAL workshop
  - Galambos: 2013 Accelerator Applications (session organizer), 2012 LINAC SPC, Convener HEP Snowmass 2013 working group on proton machine capabilities, SPC Tech. and components of ADS
  - Cousineau: ICAP IOC, NAPAC SPC,
  - Plum – ICFA HB2012 convener
  - Holmes – USPAS organizing committee, ICFA HB2012 convener, IOC CERN Space Charge 2013.
- Beam Measurements
  - Gas luminescence detector development for ESS
  - ITER radiation detector
- Hosted visitors
  - FNAL (LEBT), FNAL (profiles / emittance), J-PARC (foils), ESS (Instrumentation + physics), U- Md (high intensity modeling), CERN (H- injection)

Accelerator Community Involvement (2012-2013) Physics, Instrumentation, Ion Source

- Reviews
  - Aleksandrov: PAC'13 Scientific Program Committee, IFMIF Beam Diagnostics Design Review, FRIB Beam Diagnostics Design Review, FRIB Independent Readiness Review
  - Galambos: ESS TAC5,6 and 7, CSNS TAC, C-ADS TAC, MYRHHA International Design Review, ESS diagnostic review, ESS Accelerator Physics Review, FNAL PXIE review Project-X MAC, HEP General Accelerator R&D review
  - Plum: J-PARC ATAC, ORNL enriched stage isotope production facility
- Taught courses
  - Stockli: CERN school, Ion Sources
- Committee Membership
  - Cousineau: APS DPB Executive Committee Member at Large, (2010 – 2013), PRST-AB editorial board member (2013 - 2016)
  - Galambos: ANS AAD Executive Committee Member (2013 - 2016)
  - C. Deibele: Editorial board IEEE Microwave Theory & Techniques, IEEE board for PE exams
- Student Mentoring
  - 1 PhD graduated, 3 PhD students ongoing
  - 1 Post-doc
  - 5 Undergrad and high school interns

AP Summary

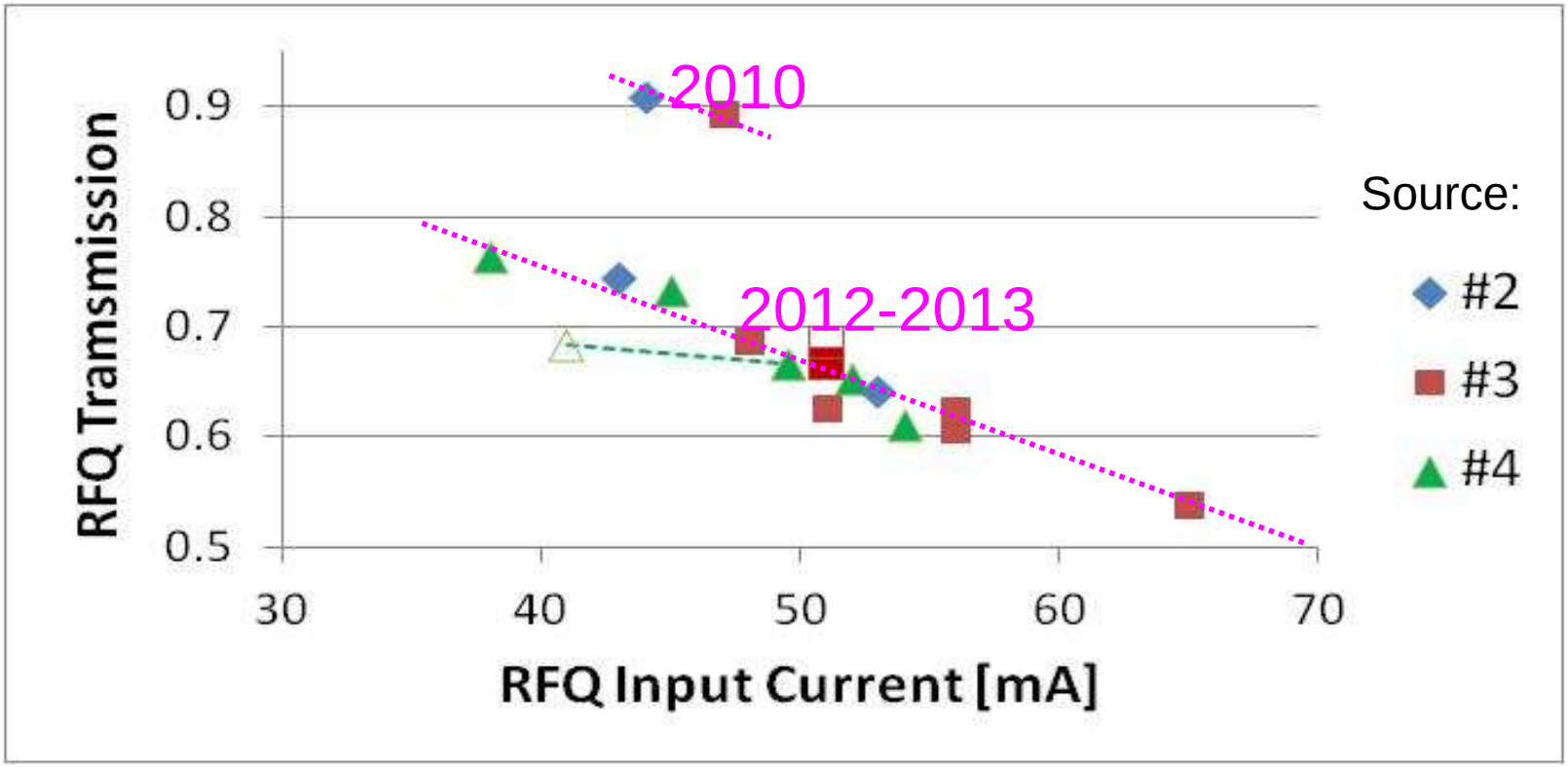
- Accelerator physics activity still moving forward, even though power ramp-up has stalled
- Important to keep physics staff engaged to enable reaching the short-term 1.4 MW level and longer term 3 MW operation

RFQ Detuning - reprise

- We had 2 earlier RFQ detuning incidents
  - 2003 (cooling) and 2009 (maintenance)
  - Required retuning the RFQ to return to resonance
  - Initiated spare procurement
- There appears to have been another occurrence
  - Systematic reduction of RFQ exit current observed, beginning about 1.5 years ago
  - Comparison of beam current transmission from historical levels showed reduction
  - RFQ Field profile measurements indicate another anomaly
  - Transmission vs. RFQ power also changed from historical measurements
  - But, this time the structure can operate at correct frequency

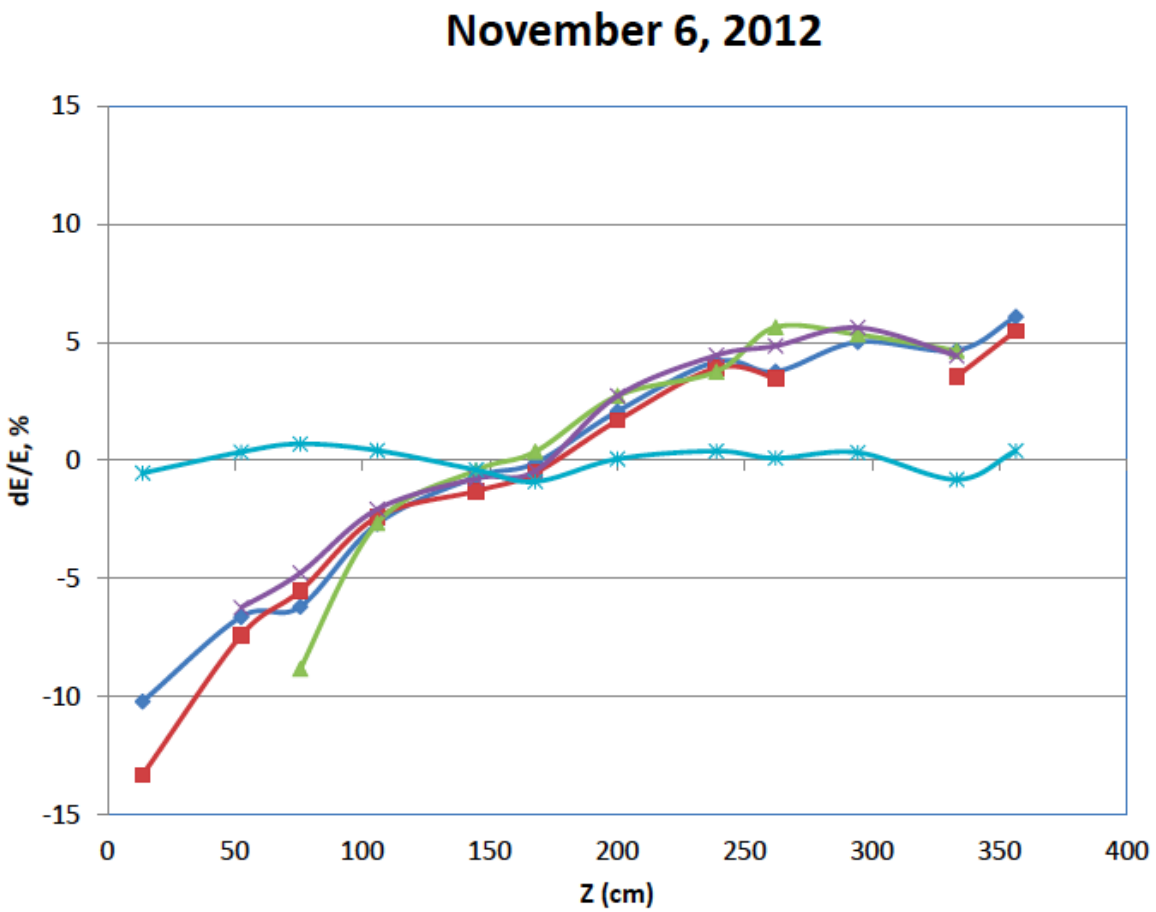
RFQ Beam Transmission Indicates a Problem

M. Stockli



- **Input current measured by collected charge of fully chopped beam at LEBT exit, exit current measured by current monitor**
  - **Same technique used in 2010**
- **Systematic reduction in transmission**

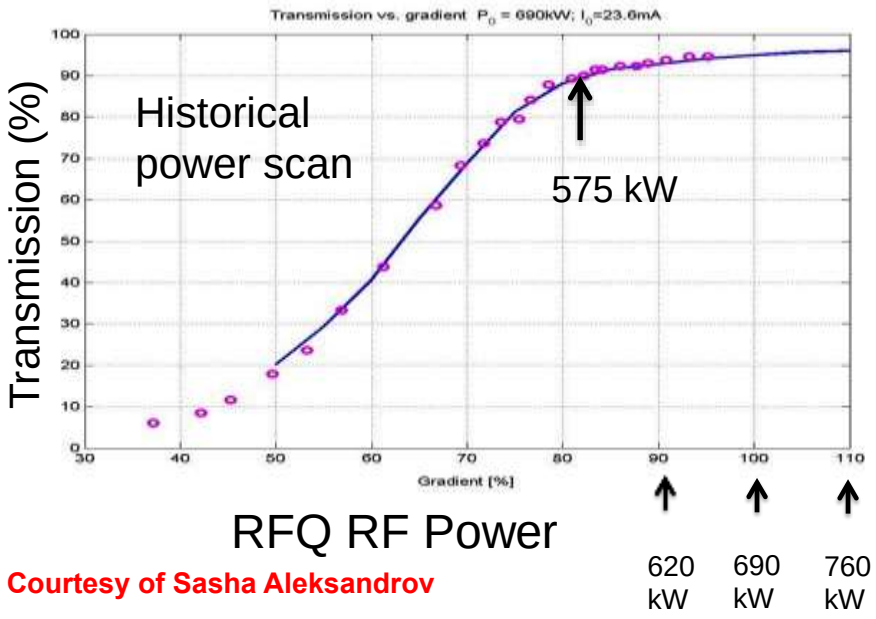
RFQ Field Measurement Indicates a Problem



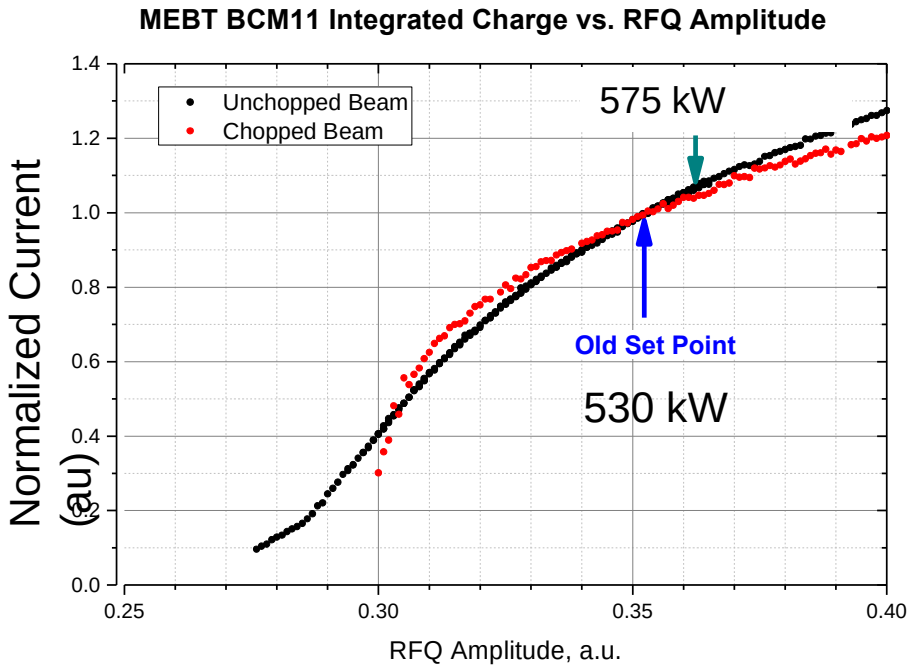
A,B,C,D = different quadrants
2009 = expected field profile

- **Clear indication of field tilt from expectation**
- **At low energy end some non-quadrupole mode?**

RFQ Power Scans Indicate a Problem



Courtesy of Sasha Aleksandrov



- **We are operating significantly below "transmission saturation" RF power level**
  - **Resonance control (cooling) cannot support too large an input power**
  - **Nervousness about too large an increase in power before retune and spare RFQ procurement**

RFQ Detuning Summary

- It happened again – we are quite concerned
  - RFQ power archive records indicate that it happened during the 2011 summer outage
- We plan to retune the RFQ this summer
- This incident puts more importance on the spare RFQ (see Y. Kang's talk)
- Spare RFQ test plans
  - RF test: this summer-fall, see Y. Kang's talk
  - Beam tests: late 2013, 2014, see S. Aleksandrov's talk on test stand plans