Front-End and Normal Conducting Linac Overview

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Outline

1. Front-End and NC Linac Performance Overview
2. RFQ Performance
3. MEBT Improvements
4. DTL Issues
5. Beam Dynamics – emittance, losses
6. Summary

Operational vs. design parameters

	Design	Operational
Beam energy	186 MeV	186 MeV
Peak current	38mA	35-38mA
Duty factor	6.6%	5.5 %
Chopper rise time	<10ns	18ns
Chopper on/off ratio	1e-4	<1%(?)
Residual activation	< 100 mRem/h @1ft, 1.4MW	< 100 mRem/h @1ft, 800kW
Transverse RMS emittance	< .4 mm*mrad	< .4 mm*mrad
Longitudinal RMS emittance	< .4 deg*MeV	< .53 deg*MeV

Improvements

- **RFQ**
  - Measures to prevent over-pressurizing/overheating implemented
  - Procuring a spare RFQ
  - Stability improved

- **MEBT**
  - New chopper structure, buncher amplifier, horizontal scrapers
- **DTL**
  - New gate valves
  - DTL6 RF window leak repaired
  - DTL6 Resonance control at high duty factor tested

RFQ Detuning in February 2009

- The reason is believed to be an over-pressurizing/ steep temperature change
- RFQ successfully retuned
- Later studies of a water pressure vs. resonant frequency did not reveal any permanent damage to RFQ

Actions

- High pressure pumps from cooling system were replaced by centrifugal pumps with limited design pressure
- The vane chiller pressure bypass valve is set to a maximum output pressure of 110 psi and administrative control was implemented
- Temperature alarm was added

This will not happen again

Spare RFQ

SNS AAC, February 2009

- It is mandatory to replace the present RFQ by a new one, designed, built and tested with all the care required to guarantee an optimum device, both from the RF and beam dynamics points of view.

SNS Spare RFQ:

- A physical design is basically identical to the existing SNS RFQ
- Will have more strong mechanical structure

Time schedule:

- Received bids from 3 potential vendors after 3 months from bidding notice
- Review and evaluation of the proposals to be completed in February 2010
- About 24 months from manufacturing to delivery after vendor selection

Courtesy Yoon Kang

RFQ Operations at High Duty factor

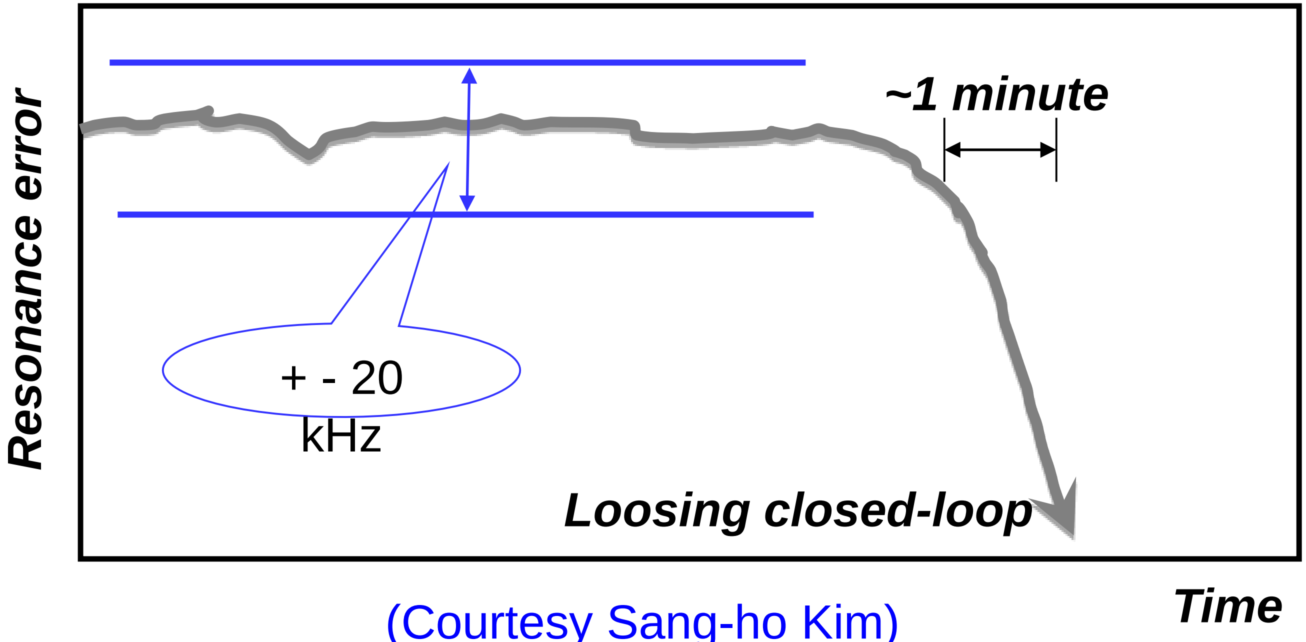
Before it was difficult to get stable operation at 60 Hz, >700us

- **>30 min. down time in a day**

Signature of instability:

- **Resonance error goes down → loosing closed loop → cannot control RFQ**

- **Water cooling system does not drive instability. It is only passively responding.**
- **RF field regulation also does not drive the instability**



(Courtesy Sang-ho Kim)

RFQ Instability; findings (Sang-ho Kim)

- Direct correlation between Net RF power (forward power – reflected power) and res. error
  - Vanes are getting hotter/colder at a constant field, water temperature
  - When Net power > +40 kW → RFQ becomes unstable
- Net power changes are clearly observed when
  - (Source off) vs. (source on/beam off); fast response
  - (Source on/beam off) vs. (source on/beam on); fast response
  - Hydrogen flow rate is changed; slow response
- Theory
  - Vanes absorb hydrogen from ion source
  - Beam (either 65kV beam or beam while acceleration) enhancing hydrogen desorption
  - Local pressure goes up → discharge → Vane temperature → hydrogen desorption → Local pressure goes up
  - Vane temperature changes→ resonance error changes → instability → Loose control

RFQ Status and Improvement in March-July 09

- **Improvement (April, 2009 – August, 2009)**
  - **Lower H2 flow in the Ion Source**
  - **Ion Source alignment**
  - **Run at positive resonance error (around 12 kHz ± 5kHz) (cooler vanes)**
  - **New auto tuning mechanism (LLRF)**
    - **Fine tuning; pulse width adjustment (+/- 30 us)**
    - **Coarse tuning; chiller temperature at 0.1 C step**
    - **Improve algorithm for auto ramp-up**
  - **Different Ion Source gate width for 'No beam condition' (available, but no strong need right now)**
  - **New vane chiller with bigger capacity and better control was installed**
  - **Increase flow rate of coolant for wall side (repiping)**

All improvements had a very positive effect on RFQ stability

- **Stable operation during previous run**
  - **2/3 of time we ran RFQ at ~900 us pulse width, 60 Hz**
  - **No instability driven down time**
- **Further activities under investigation**
  - **Gate valve between LEBT and RFQ**
  - **Smaller aperture at the entrance of RFQ**

Courtesy Sang-ho Kim

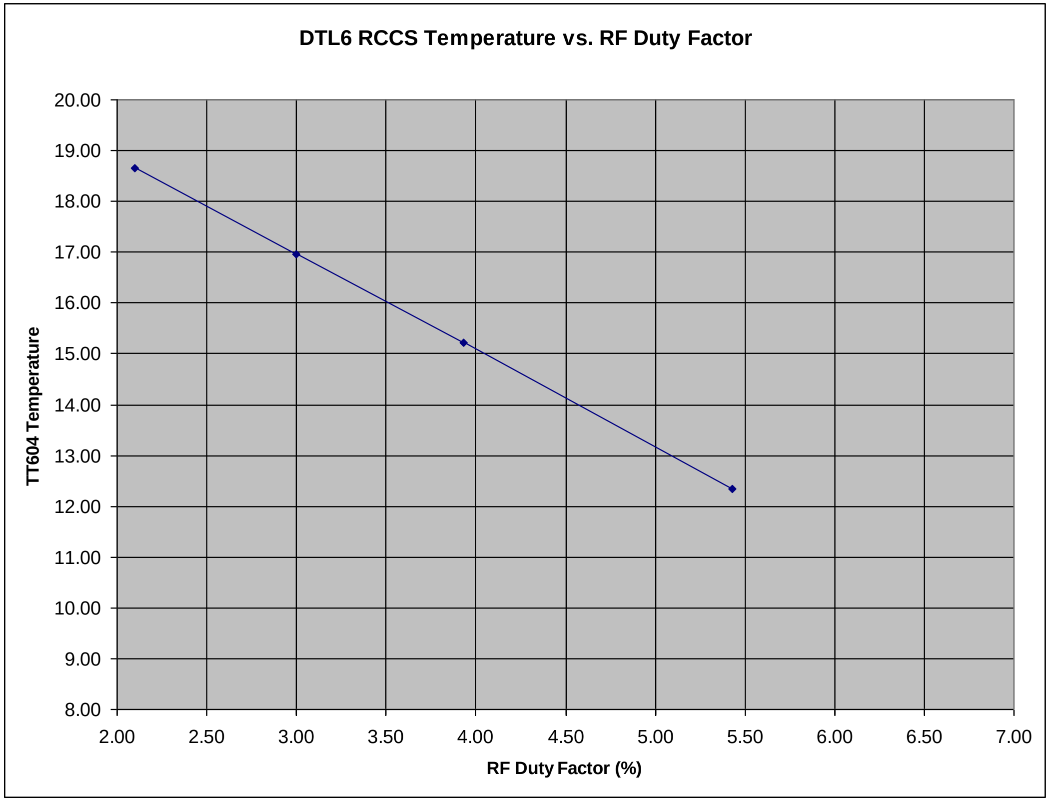
MEBT Improvements

- **A new chopper structure (C. Deibele)**
  - **Solid copper strip line instead of the meander line structure. 16 ns TOF**
  - **Deflection angle was measured. It is about 15% above the design value.**
  - **It reduces extraction losses when they are present**
- **MEBT Horizontal Scrapers (T. Roseberry)**
  - **Usually intercept 3% - 5% beam**
  - **Reduce losses by in CCL and IDmp, sometimes in HEBT**
- **MEBT Rebunchers (T. Hardek)**
  - **Tomco Solid State amplifier was installed for Cavity 4.**
  - **Now we can reach the design amplitude.**
  - **Have remaining Solid State amplifiers on order.**

DTL Improvements

- **DTL and CCL new gate valves**
  - **New valves are hidden from electrons when open due to longer stroke**
  - **RF shield added**
- **DTL6 RF window vacuum leak**
  - **Traced to a braze joint in the vacuum side waveguide section**
  - **May have a similar problem on several windows**
  - **Have 2 spare windows fully RF conditioned and plan to have 3 more**
- **DTL6 resonance control at high duty factor tested**

DTL6 Temperature Control at High Duty (Paul Gibson, Mark Crofford)



- **Historical data**
- **Eventually we need 6.6%**
- **The inlet water temperature should be 10.2^{0} C which could be a problem**

- **The average internal DTL6 temperature is 22.6^{0}C instead of 26^{0}C according to the design**
- **The worst case**

DTL6 Full Power Test of 1/4/2010

- **The cavity was able to operate at 1055 us.**
  - **Still need to go to 1125 us (6 – 7 % more avg.)**
- **Inlet water temperature at resonance 10.26 C**
- **Once stable DTL6 ran until midnight with no interruptions.**
- **Required several flow meter bypasses to keep the system operating.**
- **The water pump was maxed out.**

Courtesy Paul Gibson

We need more head room in the DTL6 resonance control

Possible Actions for DTL6 Resonance Control (P. Gibson, Y. Kang)

Cooling System Modification (preferable)

- more efficient heat exchanger
- more powerful pump

DTL6 Tank Slug Tuners Modification

- Machining DTL6 12 slug tuners with each tuner length increased by 1.2 mm
  - tank temperature increased by 7.65˚C
  - Change in E-field distribution is negligible (flatness error is less than 0.1%)

Beam Dynamics

Accelerator Advisory Committee February 2009

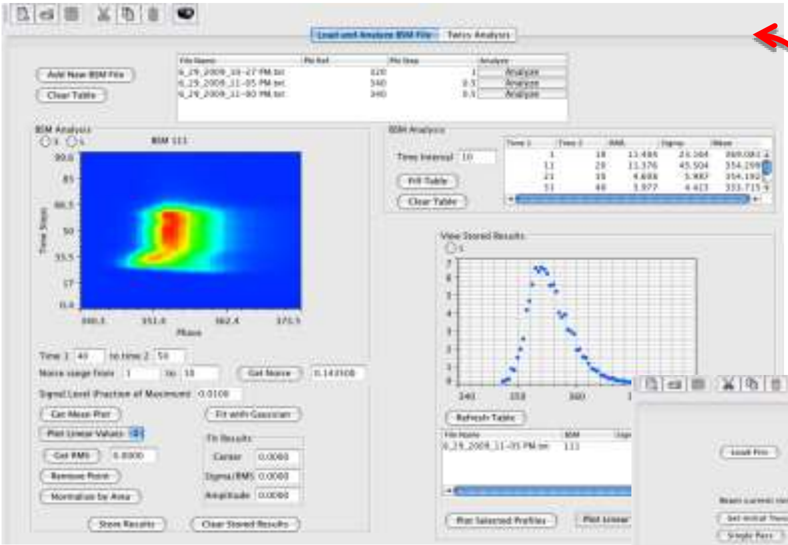
> "The normal-conducting linac has now reached nominal specifications, except for duty factor (4% instead of 6%) and longitudinal emittance. Growth of the longitudinal core emittance to a factor of 1.2 - 2.3 over the design value remains unexplained. This should be addressed even though it does not directly impact on beam loss, because something rather basic may be missed."

Actions (S. Cousineau and A. Aleksandrov)

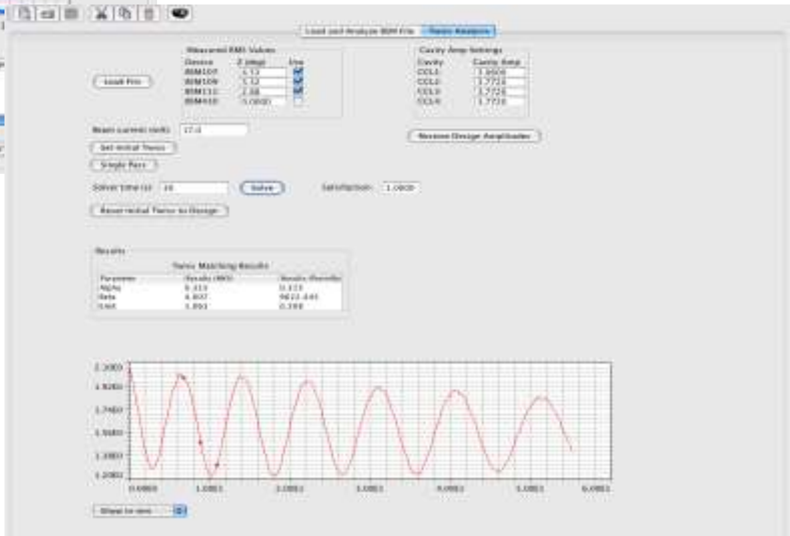
- **Software development**
- **Code benchmarking (XAL online model vs. Parmila)**
- **Systematic BSM measurements vs. key linac parameters**
- **Analysis**

BSM Analysis XAL Application (S. Cousineau)

BSM - Bunch Shape Monitors



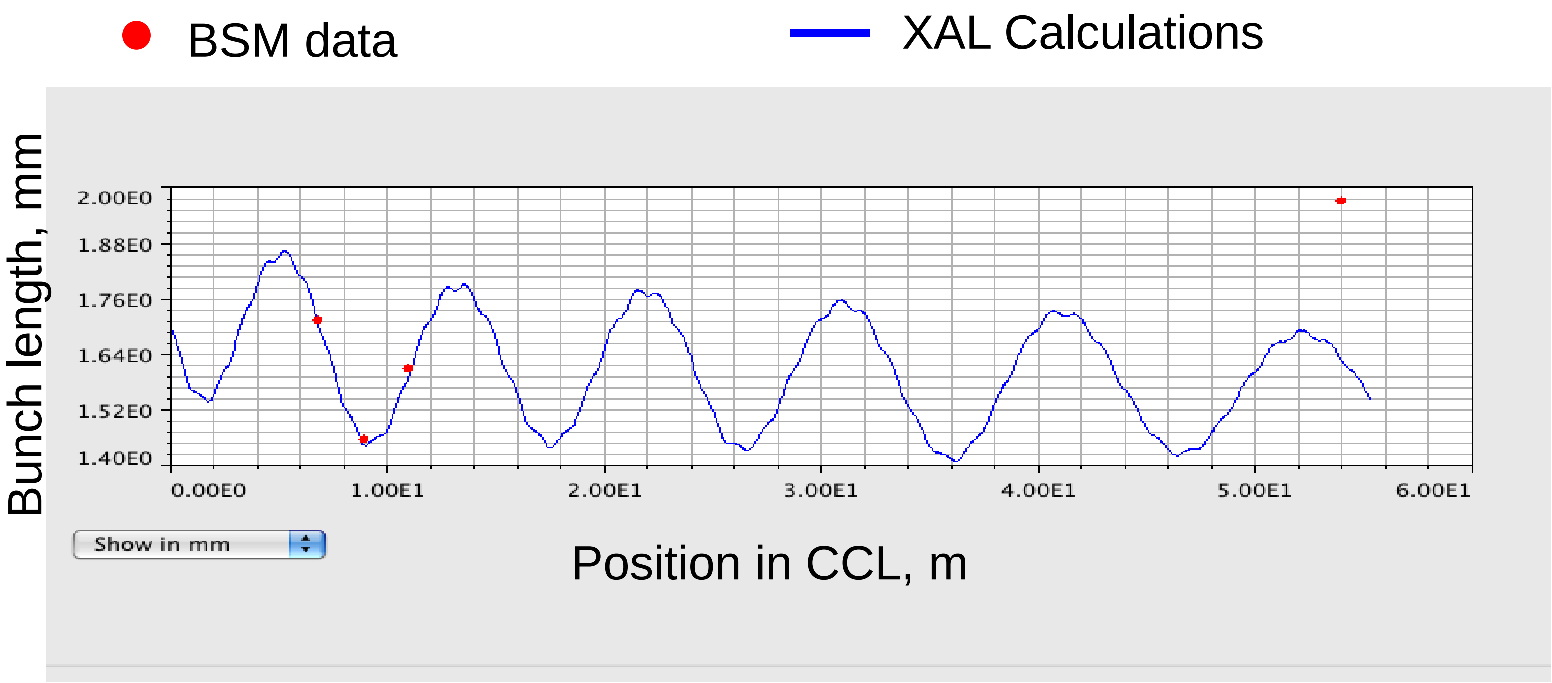
Profile selection and fit.



Twiss solver

A user-friendly interface for BSM data acquisition is under development

Problem with BSM 410

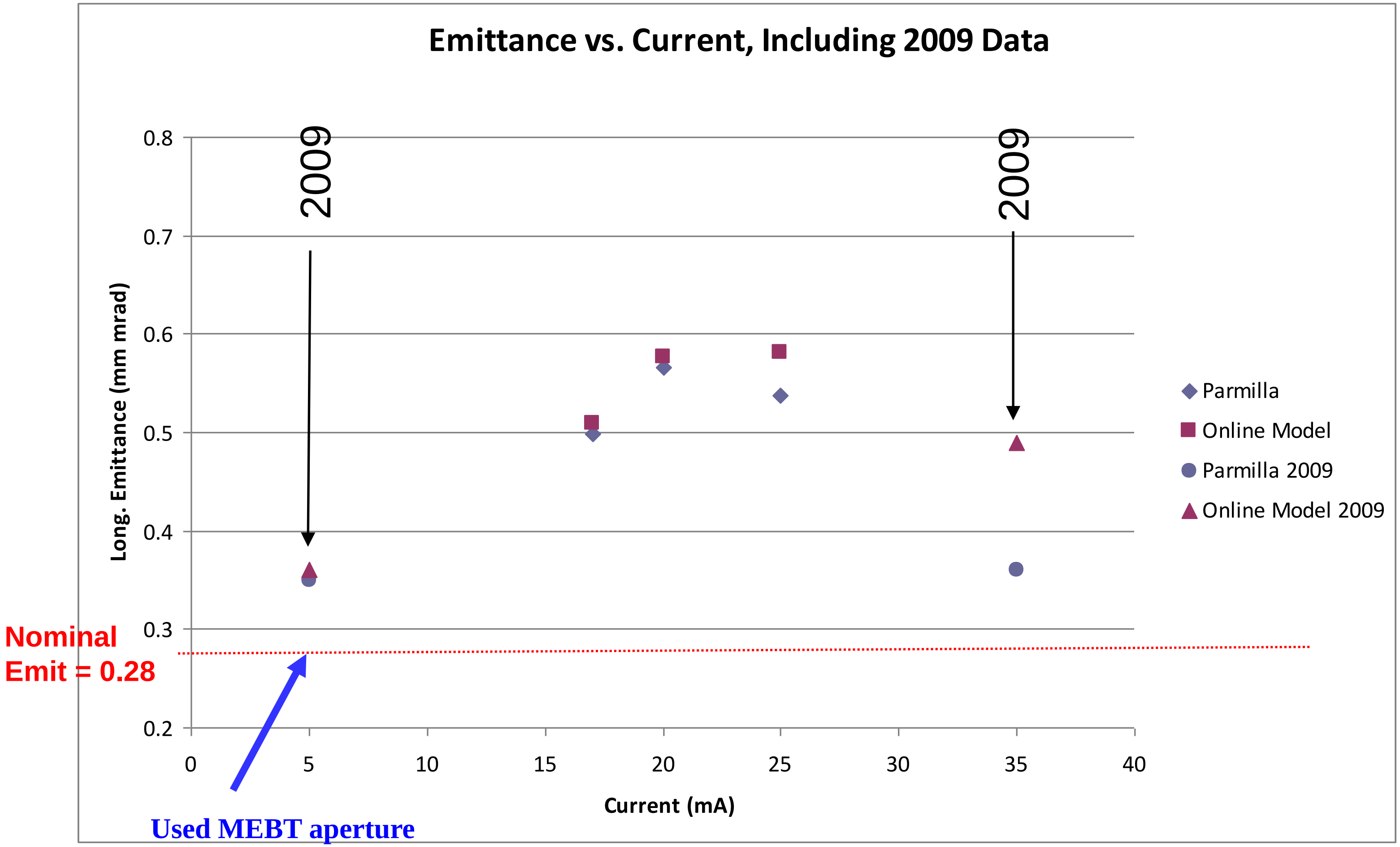


BSM410 values could not be fit with either model. Data looked suspicious. Wire aligned in last outage.

Used only BSM107, 109, and 111 data for the following studies.

Courtesy Sarah Cousineau

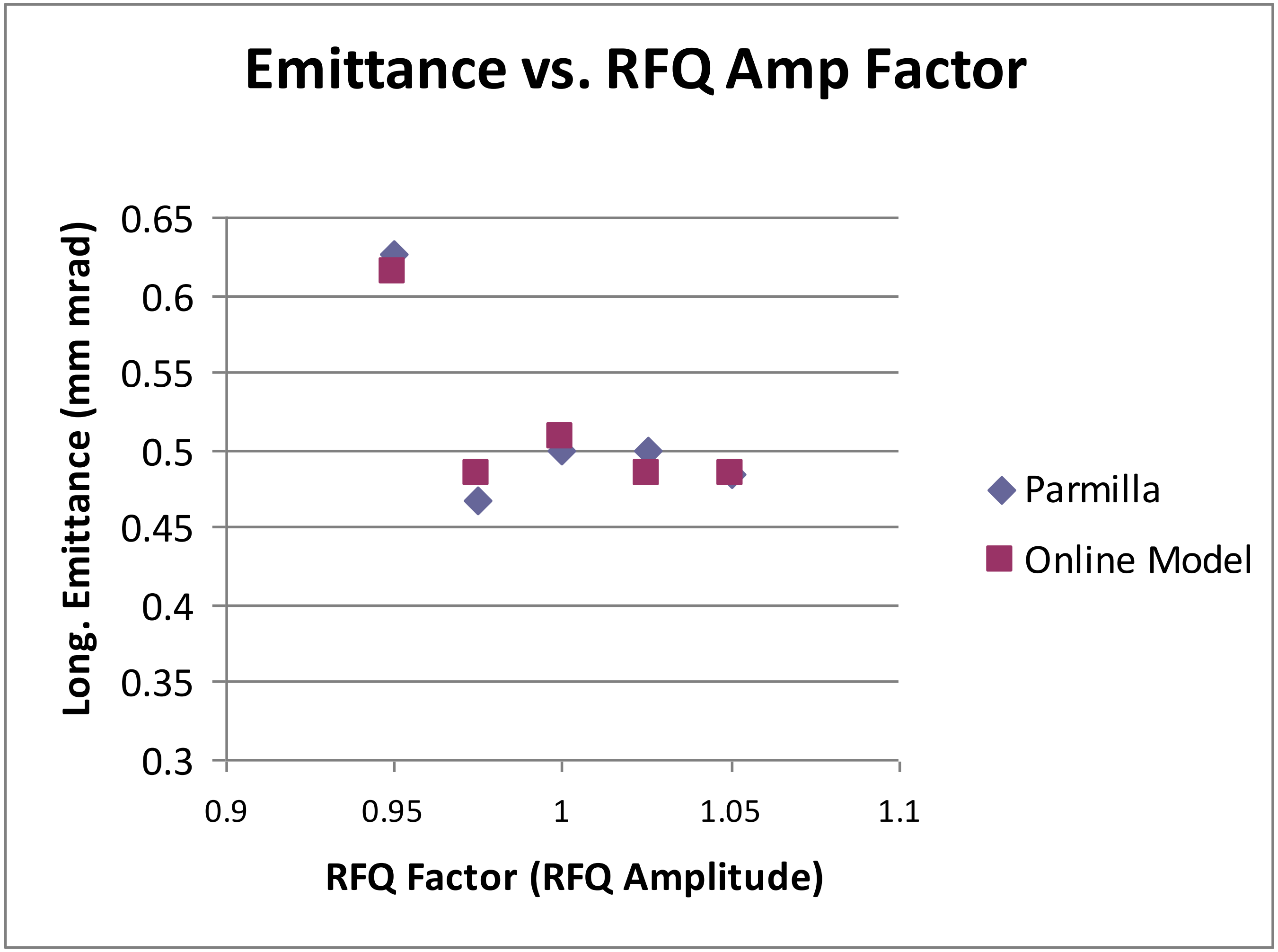
Emittance vs. Intensity



Two 2009 measurements are closer to the design than previous ones

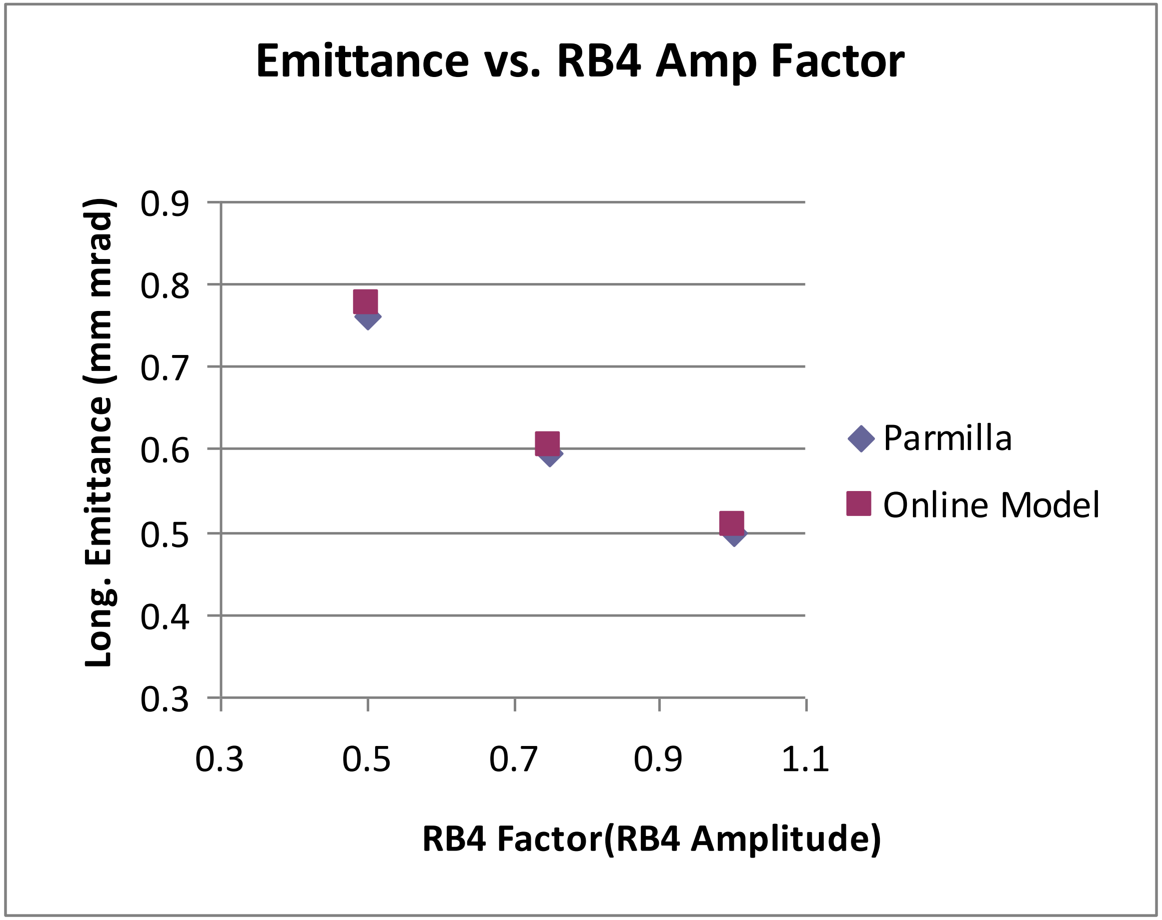
Courtesy Sarah Cousineau

Emittance vs. RFQ Amp (17 mA beam)



Courtesy Sarah Cousineau

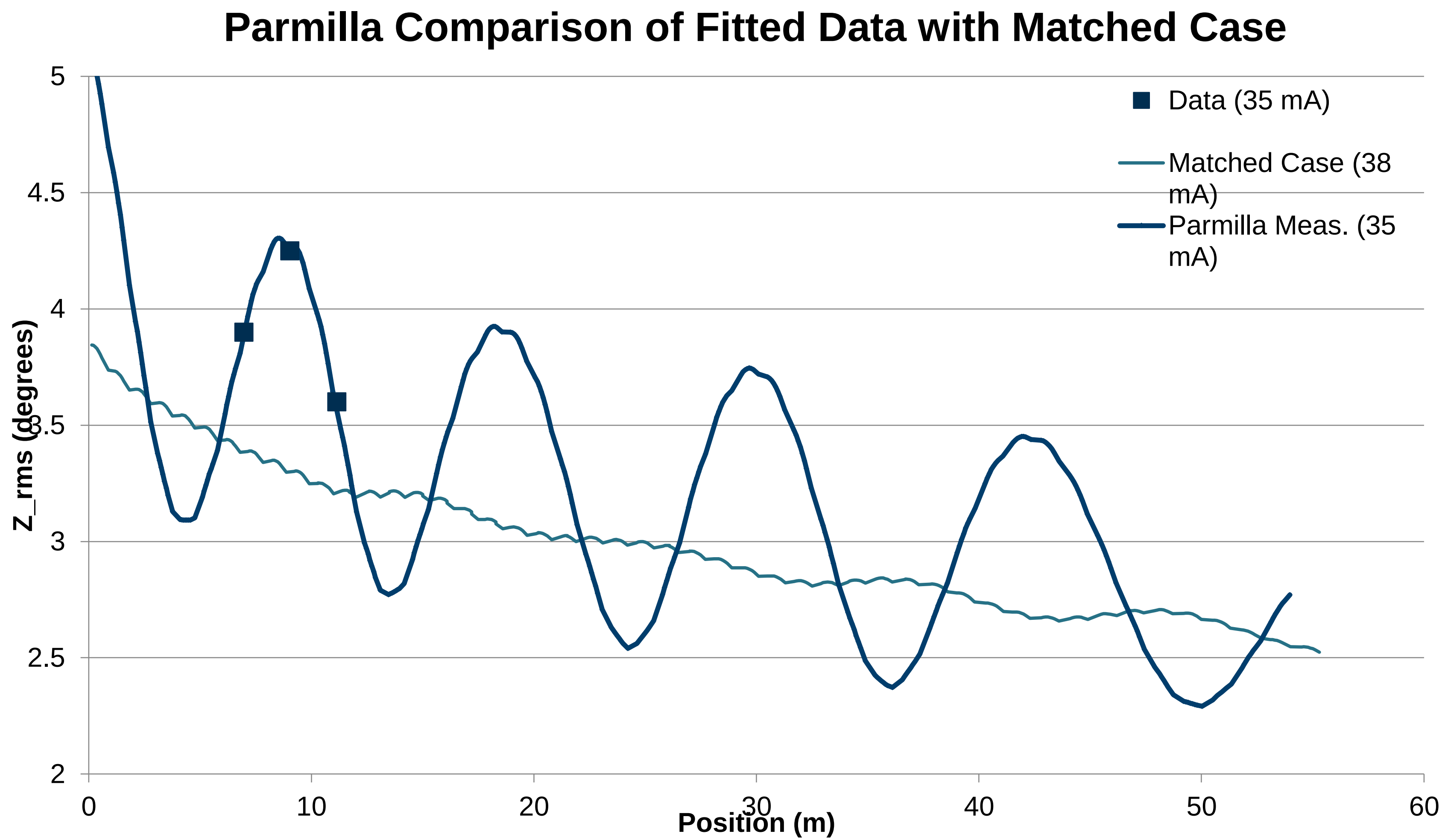
Emittance vs. MEBT RB4 Amplitude (17mA beam)



Design RB4 Amp is 1.2. We operate at 1.0.

Courtesy Sarah Cousineau

Bunch Length: Measurement vs. Design



We are running with a mismatched beam.

Courtesy Sarah Cousineau

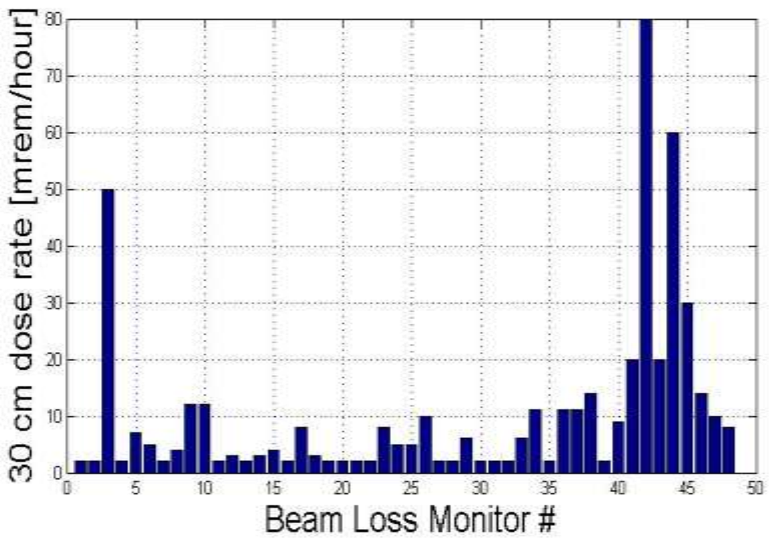
Future Plans for Longitudinal Dynamics Studies

- Fine tuning of all BSMs to confirm larger emittance..
- Continue dependency studies, esp. MEBT 4.
- Continue models benchmarking

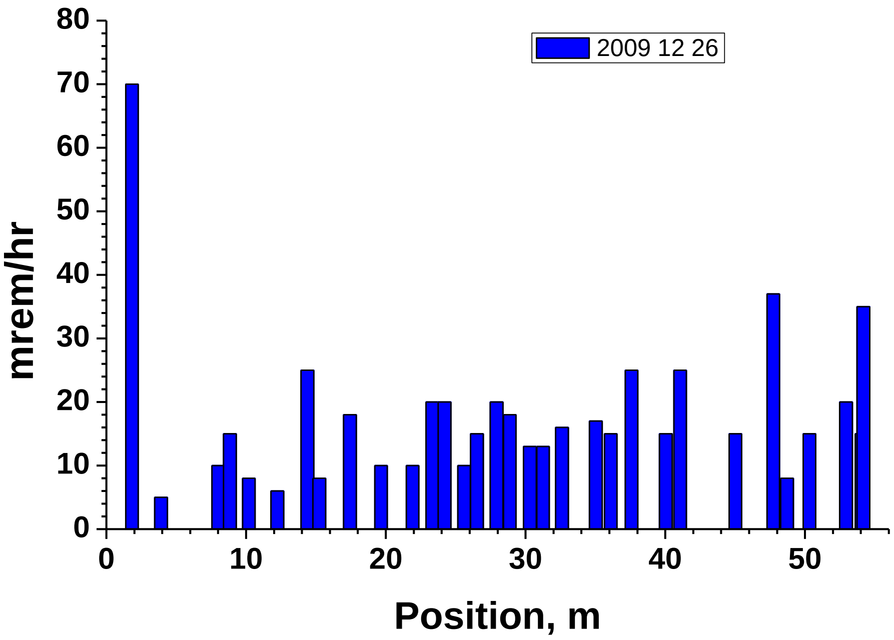
Courtesy Sarah Cousineau

CCL Activation

Beginning of 2009



1 ft, after 48 hrs



1 ft, after 80 hrs

- Longitudinal nature of losses at DTL/CCL transition is a theory
- Additional mitigation measures
  - Stronger longitudinal focusing in MEBT
  - Additional dipole correctors in CCL (AIP project)

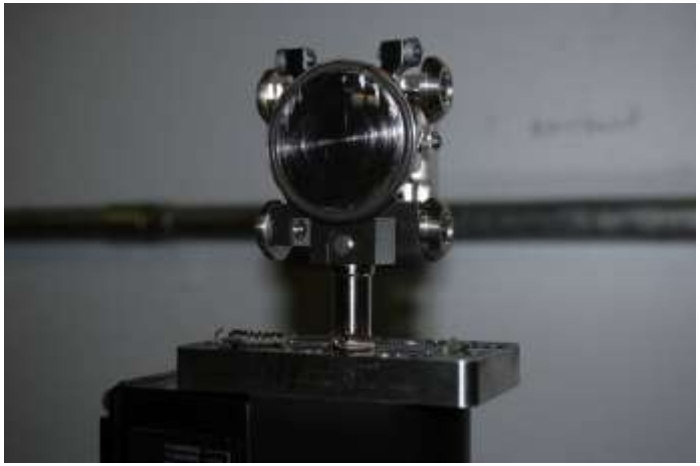
No unexpected changes in activation, < 100 mrem/hr

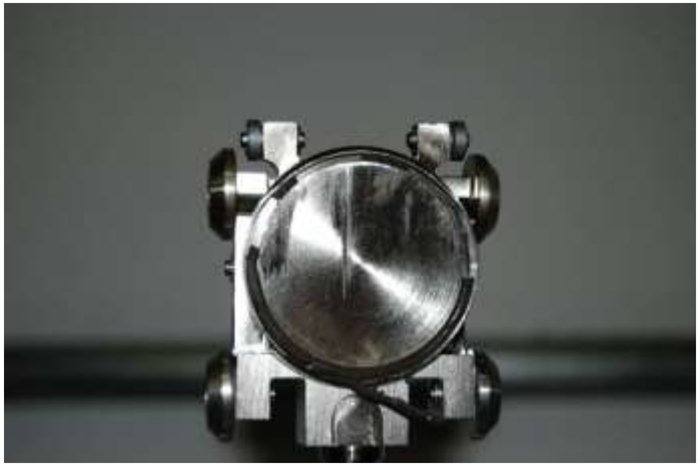
Summary

- **SNS Front-End and Warm Linac have been able to support beam power ramp up plan to date**
- **There are limitations identified and mitigation plans developed**
  - **DTL6 Resonance control**
- **Beam loss and activation in the warm linac is under control**
- **Do not see major problems preventing reaching of the nominal beam power**

Backup Slides

DTL and CCL New Gates Valves (P. Ladd)



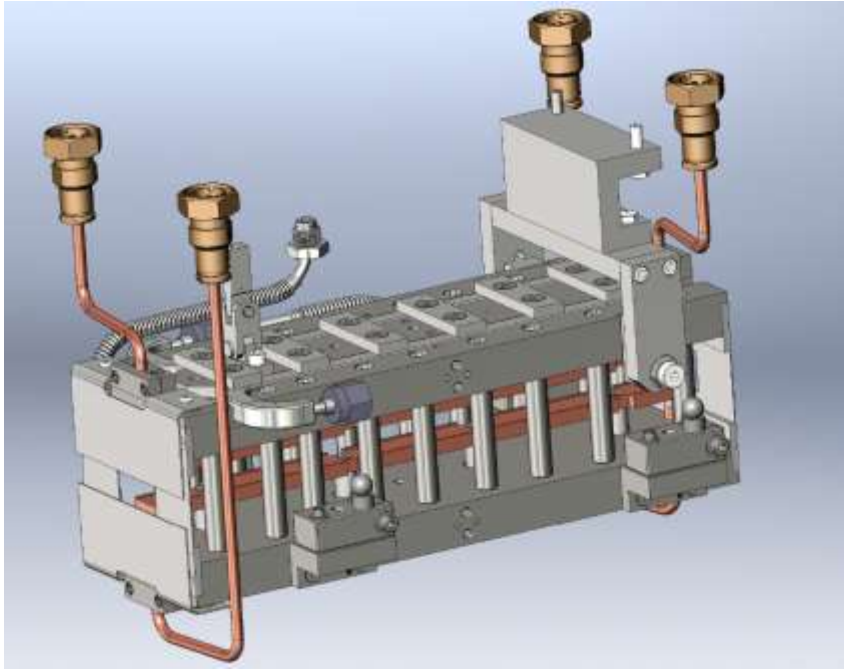


- **New gate valves installed**
  - **New valves are hidden from electrons when open due to longer stroke**
  - **RF shield added**
- **Administrative control**
  - **Do not allow high power RF in DTL or CCL cavity with gate valves closed**

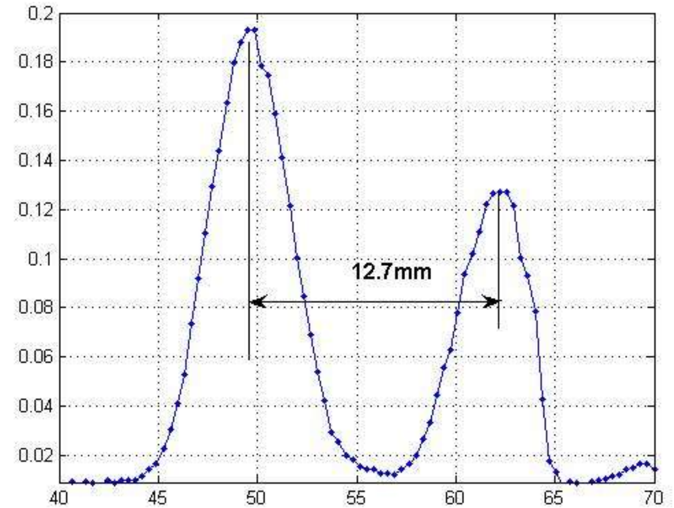
Vacuum Leak on DTL-6 RF window (Tom Hardek)

- Traced to a braze joint in the vacuum side waveguide section
- May have a similar problem on several windows
- Have 2 spare windows fully RF conditioned
- Replaced DTL-6 this maintenance period
- Have 3 spare windows on order. These will have the waveguide joint welded
- Planning to build 3 more spare windows in-house

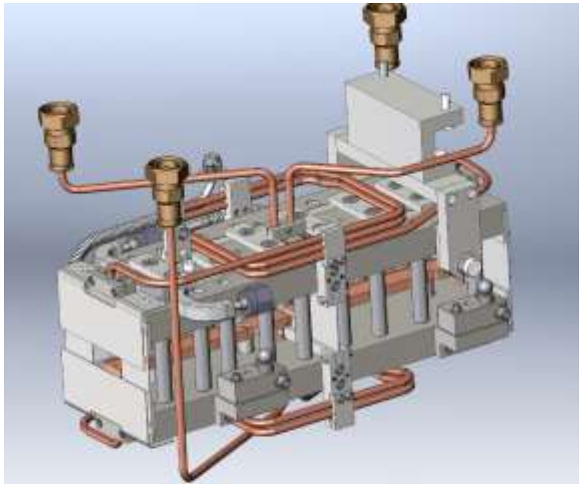
MEBT Chopper (C. Deibele)



Original meander line structure has been replaced by a new structure. It is a simple strip line of solid copper (~16 ns TOF), beam deflection angle is 18% above design (10.7 mm)

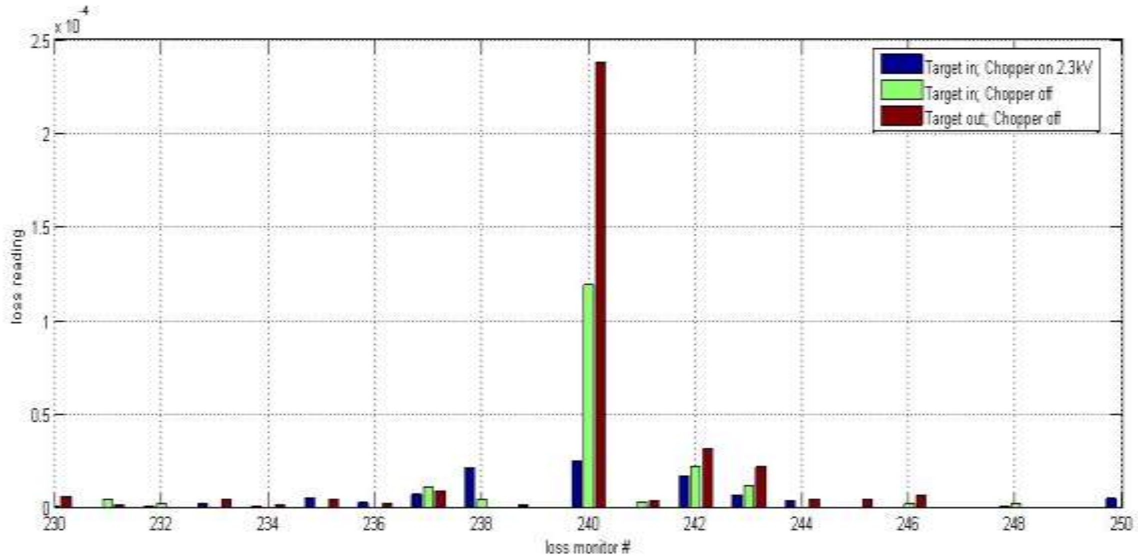


MEBT Wire Scanner



The new design is ready if we need to reduce TOF to 8ns

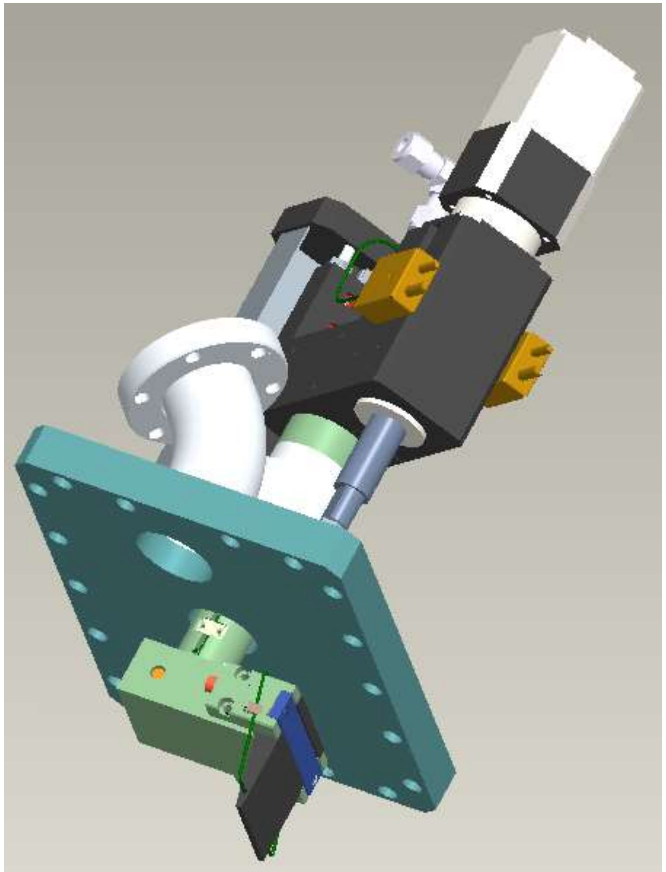
Effect of MEBT chopper on extraction losses



- **MEBT chopper:**
  - **reduces extraction losses when they are present**
  - **does not affect linac or injection losses significantly**
  - **was not critical for 650kW production run because extraction losses were low with LEBT chopper alone**
  - **can become critical at higher power**

Courtesy Sasha Aleksandrov (ACC Talk 2009)

MEBT Horizontal Scrapers (T. Roseberry)



- **New scrapers have been installed**
- **Usually scrapers intercept 3% - 5% beam**
- **Reduce losses by about 10% in CCL and IDmp, some BLMs in HEBT could change by factor 6 sometimes**
- **The MEBT chopper target is used as a vertical scraper**

MEBT Rebunchers (T. Hardek)

- **Tomco Solid State amplifier was installed for Cavity 4**
  - **Has been operational for 6 months**
  - **Operating reliably at the design power of 20 kW**
- **Have remaining Solid State amplifiers on order. Delivery in April**
- **During summer a total of 5 amplifiers will be installed with the 5th amplifier able to be remotely switched to power any cavity**
- **Existing system will remain in place and can be connected if necessary**

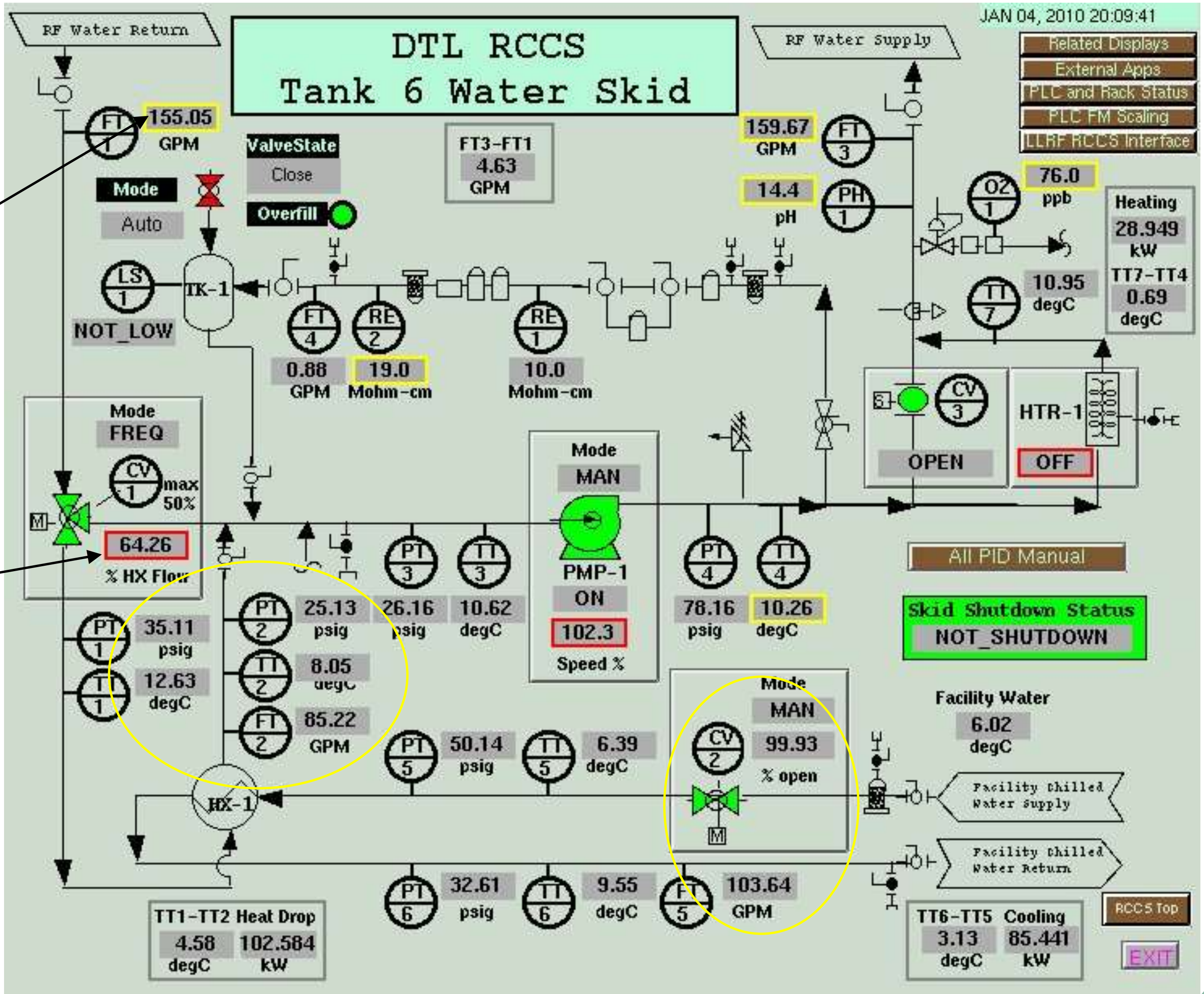
Screen Shot of Pump Skid on 1-4-10

Total flow dropped by 20 gpm vs. lower duty

Control valve open to 65%

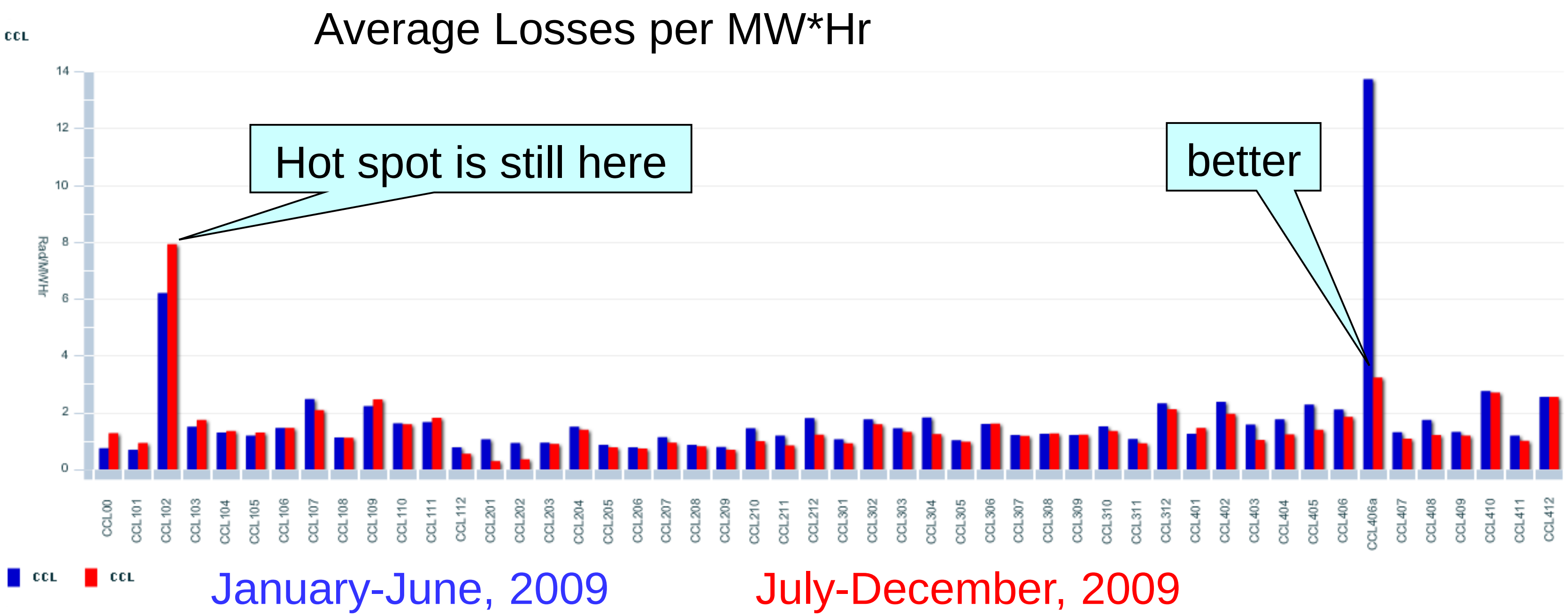
dP in Hx loop ~10 psi

Maximum flow on cold side of Hx



Courtesy Paul Gibson

CCL Losses



(from 2009 talk, A. Aleksandrov)

- Longitudinal nature of losses at DTL/CCL transition is a theory
- Additional mitigation measures
  - Stronger longitudinal focusing in MEBT (will install new RF amplifiers/done)
  - Additional dipole correctors in CCL (under consideration/(AIP project))
  - Modified transverse optics in CCL4 (under study)