Summary of Linac

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J-PARC (KEK&JAEA)
Japan Atomic Energy Agency

ICFA Mini-Workshop on Beam Commissioning for High Intensity Accelerators

June 8-10, 2015 at CSNS Site
Dongguan, Guangdong, P.R. China

Linac talks and discussion

Monday, June 8, 2015

- Overview linacs by Shinian Fu (IHEP)
- Linac Session Convener: Masanori Ikegami
  - Front end, linac upgrade, and commissioning of J-PARC by Yong Liu (KEK)
  - Front end commissioning of CSNS by Huafu Ouyang (IHEP)
  - Front end commissioning for C-ADS injector-I by Zhijun Wang (IMP)
  - Front end commissioning for C-ADS injector-II by Fang Yan (IHEP)
  - Commissioning experience of SNS linac by Andrei Shishlo (ORNL)
- Discussion on linac commissioning
  - Conveners: Tomofumi Maruta (J-PARC), Andrei Shishlo (ORNL), Yuan He (IMP, CAS), Masanori Ikegami (MSU)
- Operation session (Tuesday, June 9)
  - SNS beam loss and control by Michael Plum (ORNL)

Accelerator Performance: Beam Power

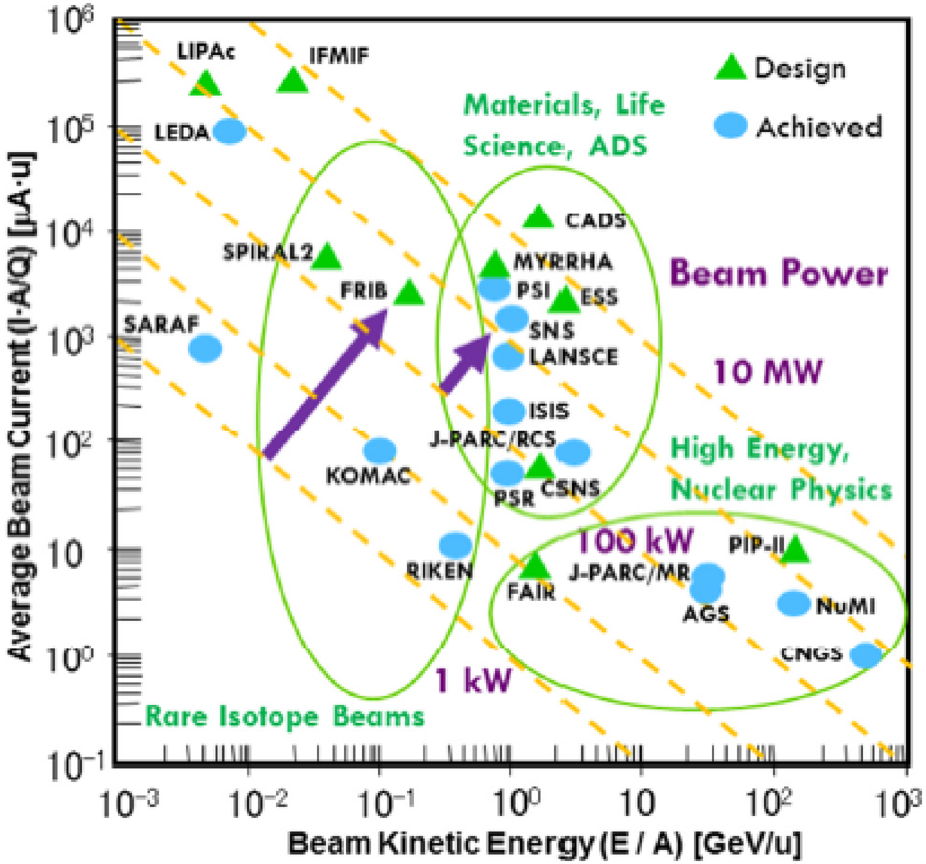


Figure 1: Hadron accelerator power frontier.

J. Wei, IPAC2014

Beam Power (W)
= Beam Energy (V)
X Beam Current (A)

The yield of the secondary particles per second is proportional to the beam power, if the beam energy exceeds the threshold.

On the other hand, the radioactivity is also proportional to the beam loss power. The beam loss rate should be minimized for high power accelerators.

Challenges and Design Principles

- Beam loss control --- <1W/m
- Space-change effect --- Tune depression $\sigma_i/\sigma_0 > 0.5$
- Beam halo formation --- Matched beam

  $\sigma_0 < 90^0$

  K_r , K_l smooth change

  Equipartitionin/Fast cross

  $$\frac{\varepsilon_{nr} z_m}{\varepsilon_{nz} R} = 1$$

- High availability and reliability --- Redundancy, fault compensation

Review of Some High Intensity Linacs

(S. Fu and K. Hasegawa)

	Particle	Energy	PWR@LI (Av.)	Duty	Freq	Note
LANSCE	p,H-	800MeV	800 kW	6%	201/805MHz	LRIP
SNS	H-	1,000	1,100	6	402/805	aim 1.4MW
J-PARC	H-	400	133	1.25	324/972	E/FE upgraded
ISIS	H-	70	18	1	202	85-90% avail.
CSNS	H-	80/250	6/78	1	324	Comm. started
KOMAC	p	24/100	160	24/8	350	82% avail.
Linac4	H-	160	5	0.08	352	Comm.
ESS	p	2,000	5,000	4	352/704	Const.
MYRRHA (ADS)	p	600	1,500/2,400	100	350/700	Higher reliability
C-ADS	p	1,500	15,000	100	162/325/650	Two injectors, higher reliability
HIAF	p to U	70/u(p)		100	81/325	Site selected
FRIB	p to U	200/u	400	100	81/161/322	Const.
RAON	p to U	200/u	400	100	81/162/325	Const.

Accelerator Performance: Reliability

(T. Koseki and S. Cousineau)

Table 1: Summary of Operational Metrics for High Power Proton Facilities

Facility (Operational Beam Power)	**Recent Reliabilty (%)**	**Typical Activation; Peak Activation (rem/h)**	**Measurement Condition (distance, time after shutdown)**
LANSCE (100 kW)	87	Linac: 0.01; 0.05 Ring:	30 cm, 12 hours
SNS (1.3 MW)	86	Linac: 0.03; 0.05 Ring: 0.1; 0.8	30 cm, 12 hours 30 cm, 12 hours
PSI (1.3 MW)	87	Cyclotron: 0.1; 3.0	10 cm, 4-6 hours
J-PARC RCS (400 kW)	90	Synchrotron: 0.002; 0.3	30 cm, 4 hours
ISIS (192 kW)	91	Linac: 0.002; 0.015 Synchrotron: 0.01; 1.2	Contact, 13 hours Contact, 26 days
CERN SPS CNGS (400 kW) CERN SPS LHC (110 kW)	80 90	Synchrotron: 0.1; 1.7 Same as above	100 cm, 30 hours Same as above
Fermilab MI (410 kW)	83	Not available	NA
KOMAC (10 kW)	87	Not available	NA

S. Cousineau, "High Power Proton Facilities: Operational Experience, Challenges, and the Future", Proc. IPAC2015

Reliability: One of the important accelerator performances

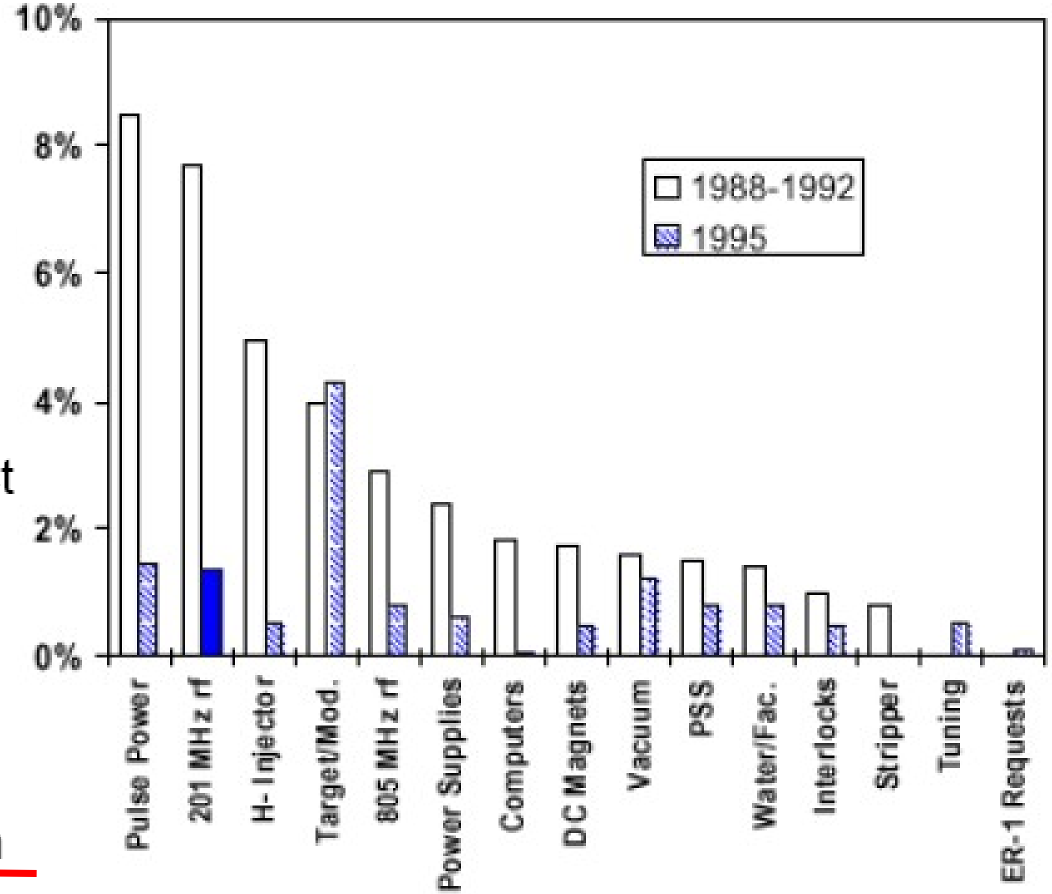
85-90%, Not easy to clear > 90%.

LRIP at LANL

(S. Fu)

Because of the different type of users, with much shorter experiment durations (2-3 days instead of 2-3 months), the impact of availability and down time led to LRIP (LANSCE Reliability Upgrade Project).

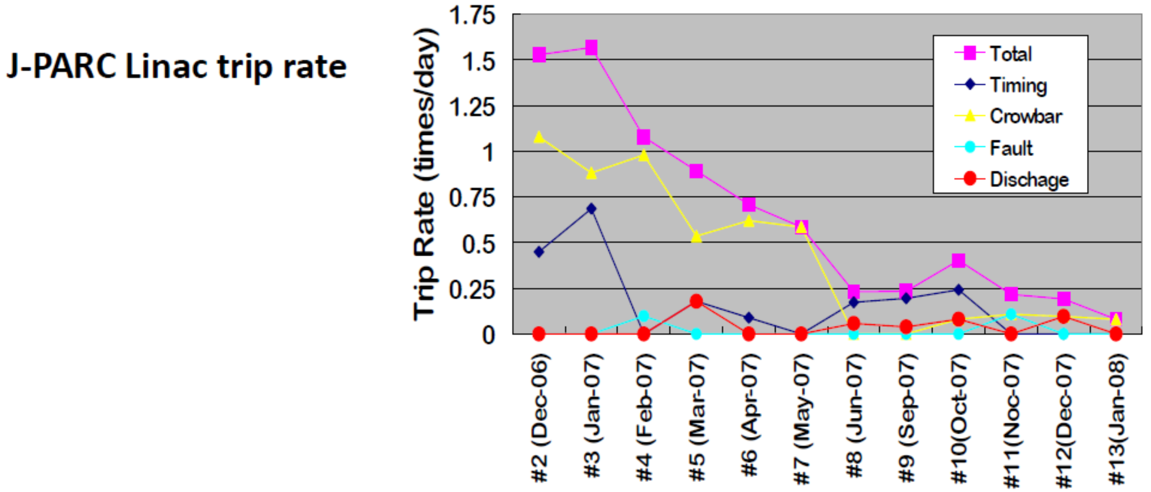
Recent improvements have improved neutron availability from < 75% to >85%.

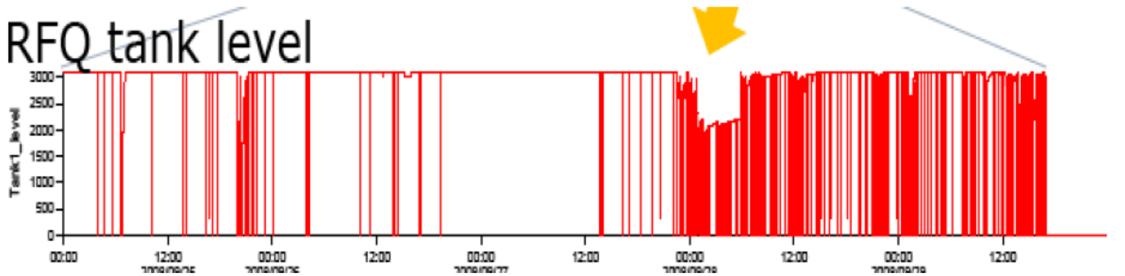


LANSCE-R Project with $200M: Replacing radio-frequency equipment to achieve high reliability and providing adequate spare components; replacing hardware and software in the accelerator controls, data acquisition, and timing systems; refurbishing and replacing vacuum, cooling, and magnet power supplies for the accelerator and beam-transfer lines; and refurbishing and improving the beam-diagnostics systems; replacing some drift tubes.

Trip rate improvement at J-PARC

(S. Fu)





J-PARC RFQ was suffered from discharges in 2008-09, but it was recovered by improving vacuum conditions. Efforts to other components have improved performances.

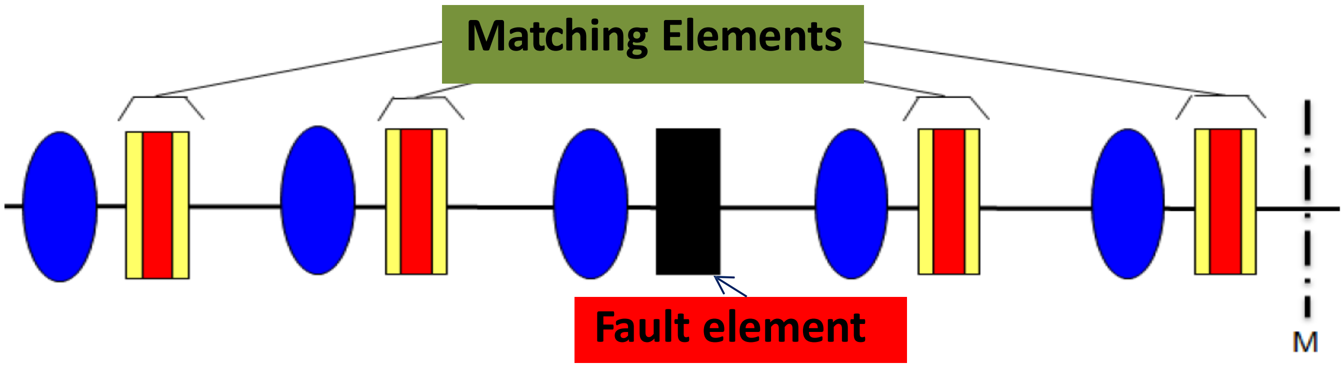
But now, some aged components degrade the availability after about 10 year's operation.

Reliability improvement study at C-ADS Linac

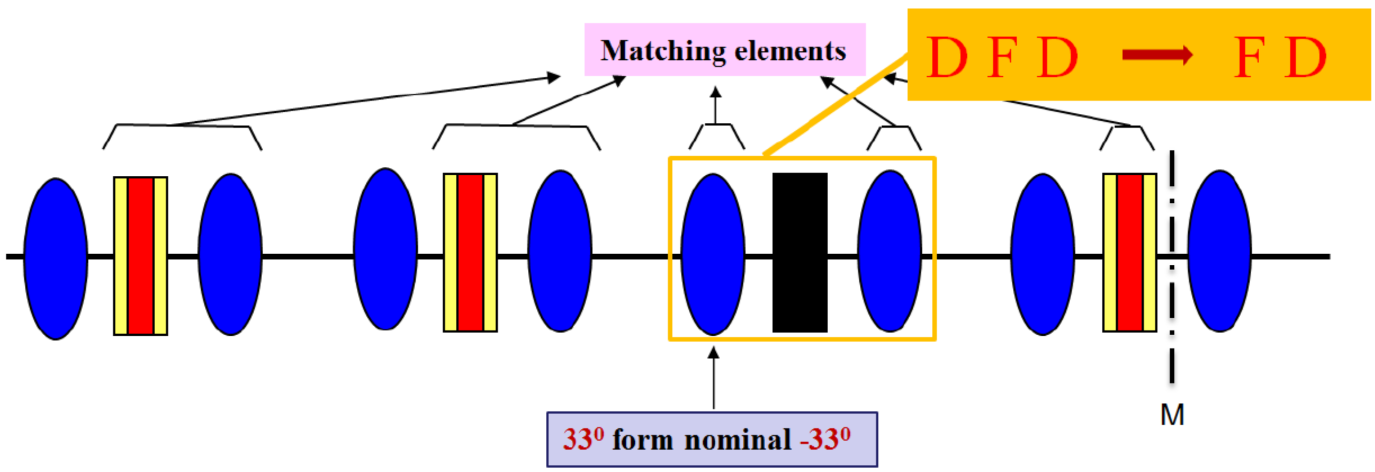
(S. Fu)

- **Local compensation scheme was proposed in design for high reliability in operation.**

For high energy section:



For low energy section:



Front end, linac upgrade, and commissioning of J-PARC (Yong Liu)

- J-PARC Overview
- J-PARC linac upgrade scheme
  181→400MeV, Jan. 2014
  15/25mA → 30/50mA, Oct. 2014
  } → **for RCS output 1MW**
- J-PARC frontend
- Typical Procedures for J-PARC linac commissioning
- J-PARC commissioning for energy upgrade
- J-PARC commissioning for intensity upgrade
- Conclusion and Discussions

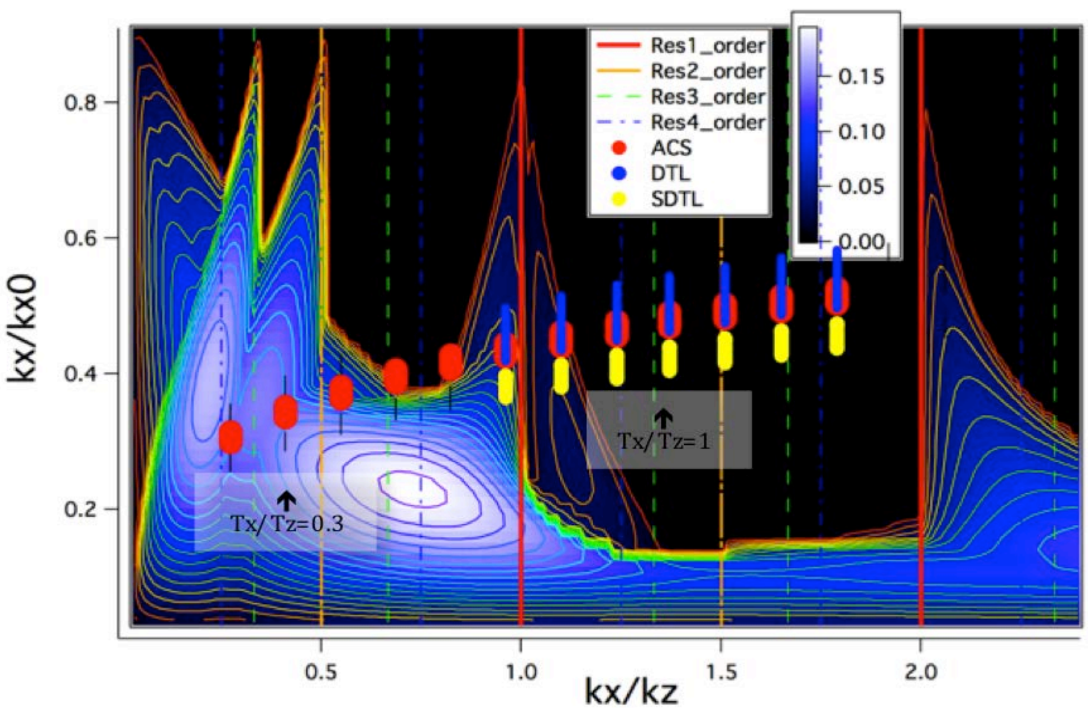
J-PARC linac upgrade
(Y. Liu)

Brief scaling-laws

Linac 15mA→ RCS 0.3MW output
Linac 50mA→ RCS 1MW output

(50mA, 400MeV) same Laslett tune shift at RCS as (15mA, 181MeV)

J-PARC linac apply equi-partitioning (EP) condition for baseline lattice



Typical Procedures for J-PARC linac commissioning

(Y. Liu)

- LEBT tuning

  2d scan for (2) solenoids
  2d scan for steering magnets (h. and v.)
  1d scan for IS HV

  } **maximize RFQ transmission**

- RFQ transmission scan (for verification of tank level)

- MEBT1 tuning

  Bunchers phase scan; based on simulation
  WSM measurement
  Chopper tuning, scraper conditioning
  Orbit correction

  } **trial and error for DTL output $\varepsilon_\perp$**

- Phase scan

  For setting of DTL, SDTL, ACS, bunchers and debunchers amplitude and phase
  Need phase scan data and application, lattice settings and timing for phase scan
  Use low current to avoid wake field of pass-by idle cavities between ToF monitors 5~10mA

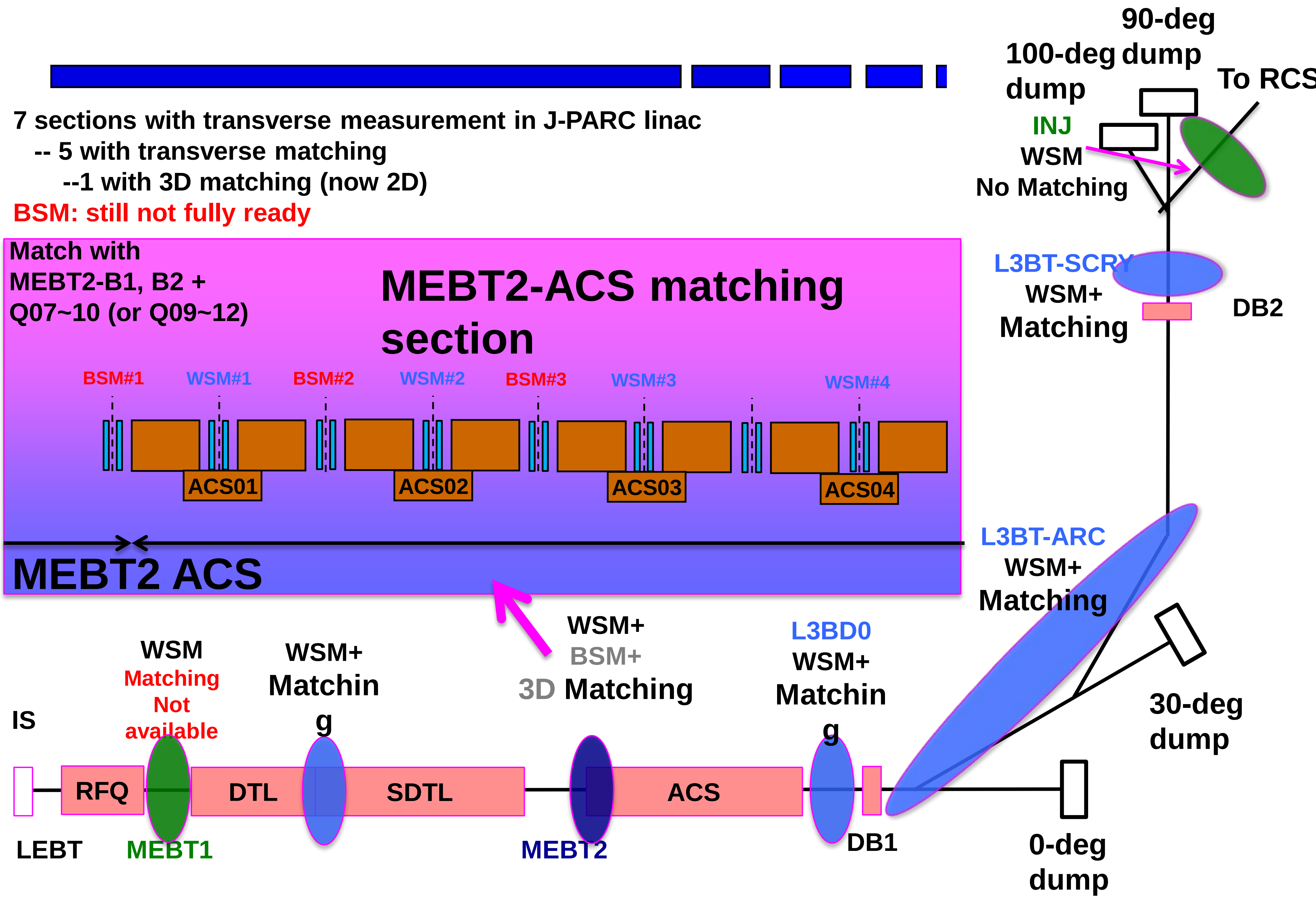
- Transverse matching

- Injection tuning to the RCS

  Inj. orbit, energy, momentum spread, Twiss

J-PARC linac Matching Scheme (Y. Liu)

7 sections with transverse measurement in J-PARC linac
-- 5 with transverse matching
--1 with 3D matching (now 2D)
BSM: still not fully ready



Scheme and main progresses of energy upgrade: Major Tasks/Steps (Y. Liu)

- Establishment of 181MeV

  And monitor check

- Establishment of 400MeV

  Phase scan of SDTL16, ACS accel. cavities, bunchers and debunchers at 5mA

- Fine tunings, matching

  Preparation for user operation at 15mA

  High power study at 25mA

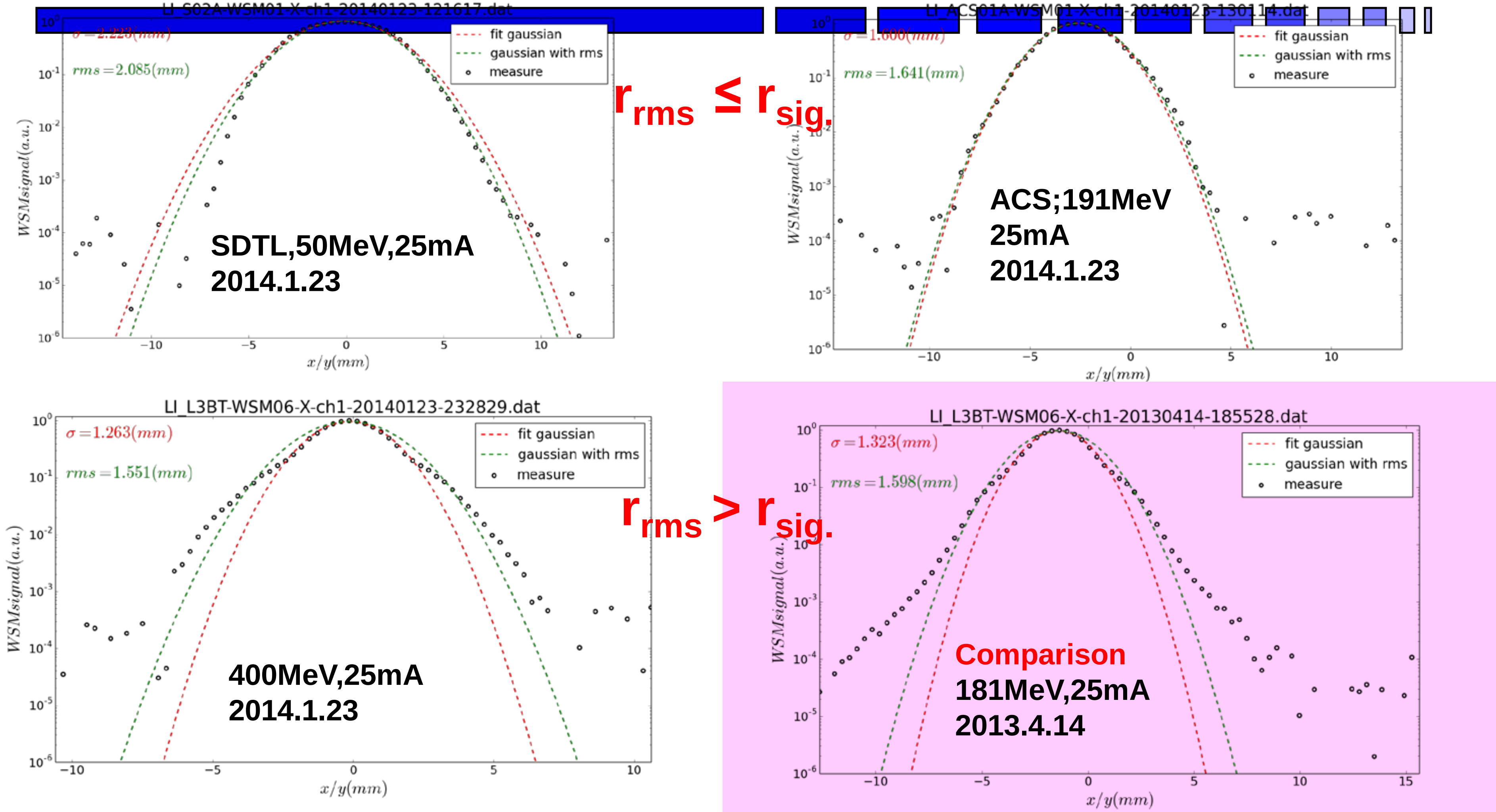
To achieve

Acceptable beam loss along linac and beam line

Acceptable orbit, center energy, energy jitter and emittance for RCS injection

Emittance Growth and Halo Studies:

Halo found at downstream of ACS



Similar phenomena also found in previous high power test at 181MeV, now stronger
Note the changing of correlation of profiles in rms and sigma!
Significant increase of halo after ACS

Emittance Growth and Halo Studies: Lessons Learnt

(Y. Liu)

- Halo found in downstream of ACS

  Imperfect matching at MEBT2-ACS due to absent of BSM, improvement expected after re-installation in coming summer shutdown

  Other reasons? Inconsistencies between modeling and reality,

  No longitudinal measurement in upstream (too)

  Emittance growth at MEBT1

  Longitudinal mismatch in DTL-SDTL

  Imperfect matching at MEBT1

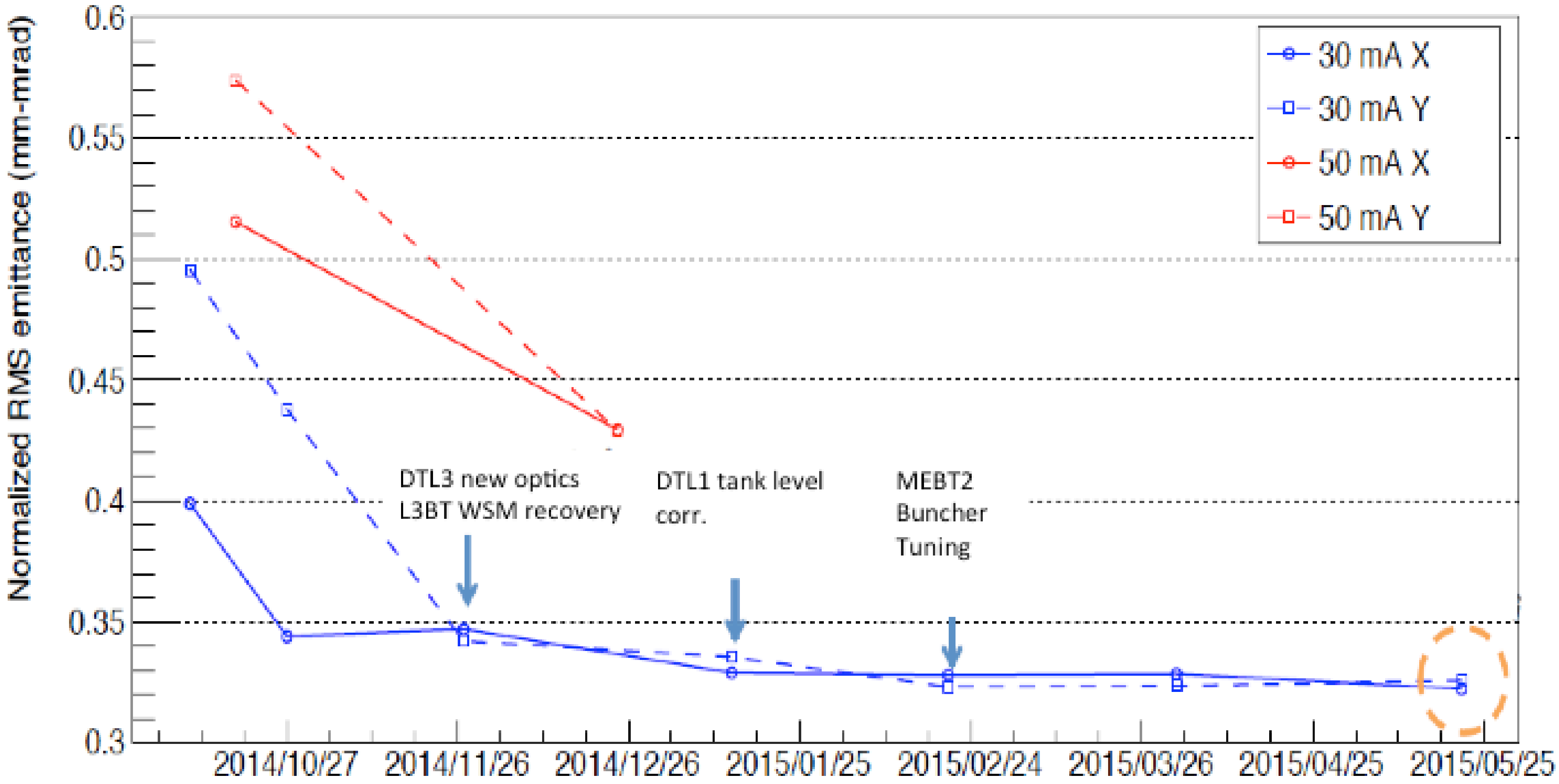
- After the readiness of linac setting for 25mA on Jan.24, an improved second lattice accomplished on Jan. 26, and studied until Jan. 29. The setting is based on applying

  Results from transverse measurement and matching at SDTL

  And with assumption of small longitudinal mismatch between DTL and SDTL

Further improvement requires more efforts for consistency between theoretical model and reality

J-PARC linac output emittance improvements after intensity upgrade (Y.Liu)



Conclusions and Overlook of J-PARC Linac

(Y. Liu)

- Accomplishments of energy and intensity upgrades

  A recent example of commissioning;

  Ready for RCS 1MW output and demonstrated

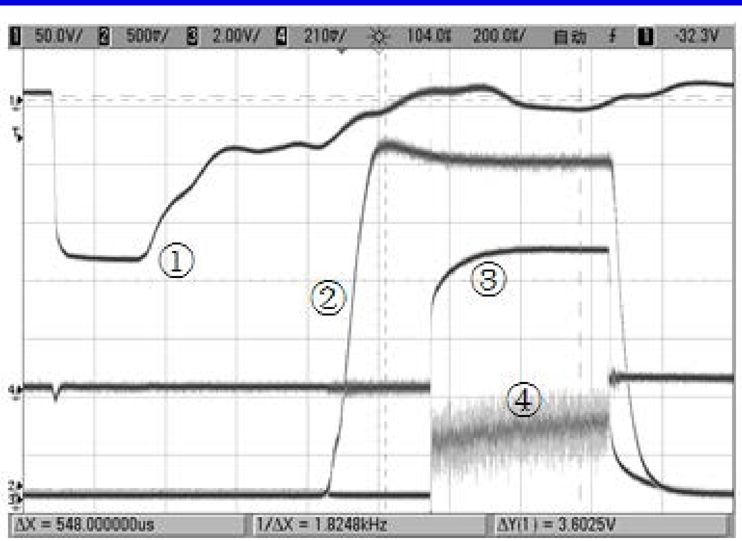
  User operation at 300, 400, 500kW, …, 1MW

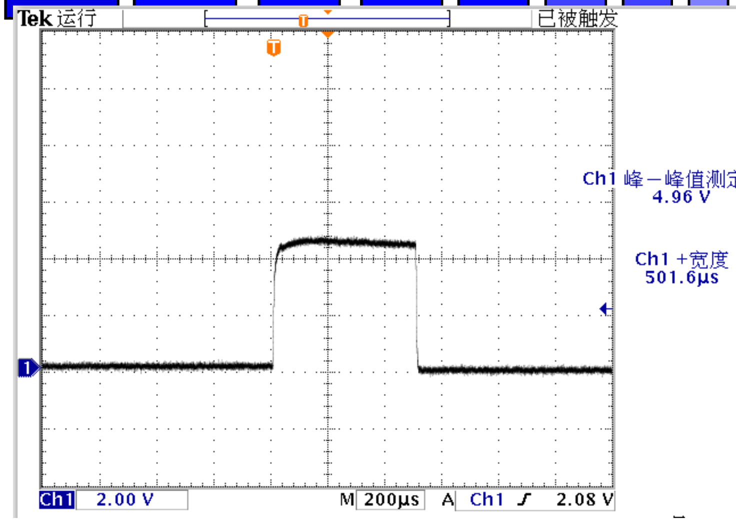
- Encouraging Improvements

  Beam loss mitigation, emittance

Contents

Ion source commissioning
(H. Ouyang)





Typical running parameters:

Output energy	50 keV
Repetition rate	25 Hz
Pulse H$^-$ beam width	500 ms
Pulse H$^-$ beam current	50 mA
Flux of H_2	~10SCCM
Pulse arc width	800 ms

High power RF conditioning of RFQ
(H. Ouyang)

At the Laboratory test:

A duty of 700us and 25Hz

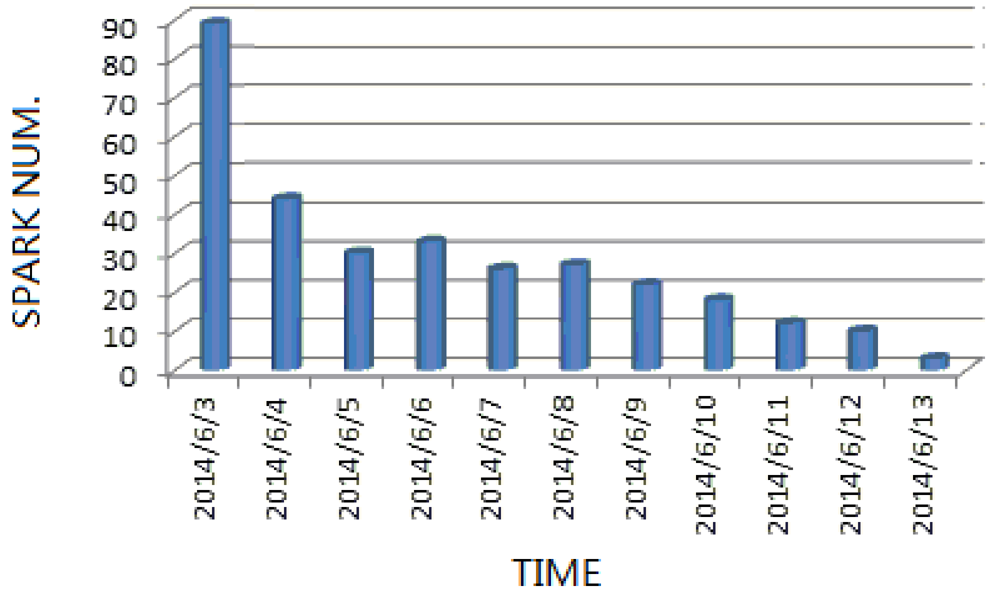
Input power RF power 450kW > 390kW (required)

The reflected RF power is about 60kW

In total , 10days, 24 hours a day

In the tunnel

Input RF power 450-460kW, in total 5days



Spark number of RFQ conditioning in lab.

Beam commissioning of RFQ and MEBT

(H. Ouyang)

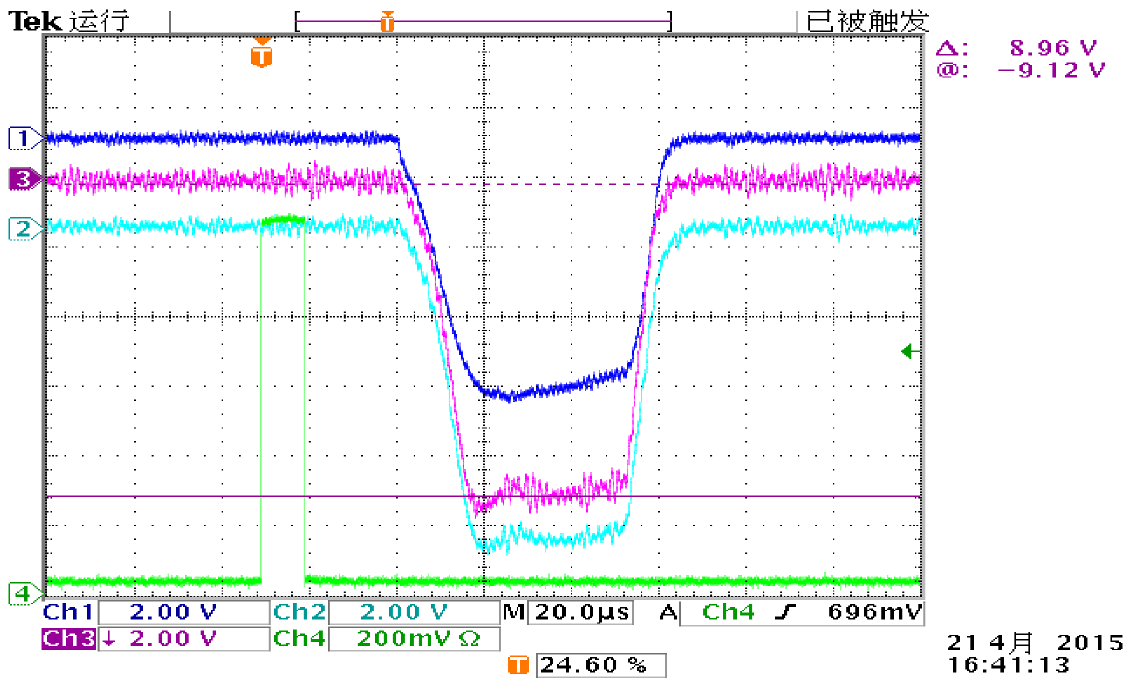
- LEBT parameter set :

	SOL 1	SOL 2	SOL3	DH1	DH2	DV1	DV2
Theo.(A)	96	71	137	0	0	0	0
Exp.(A)	105	49	145	0	0.3	4	-1.6

- MEBT parameters are set to the theo. value.

- No input power for the two bunchers

Beam commissioning results
(H. Ouyang)



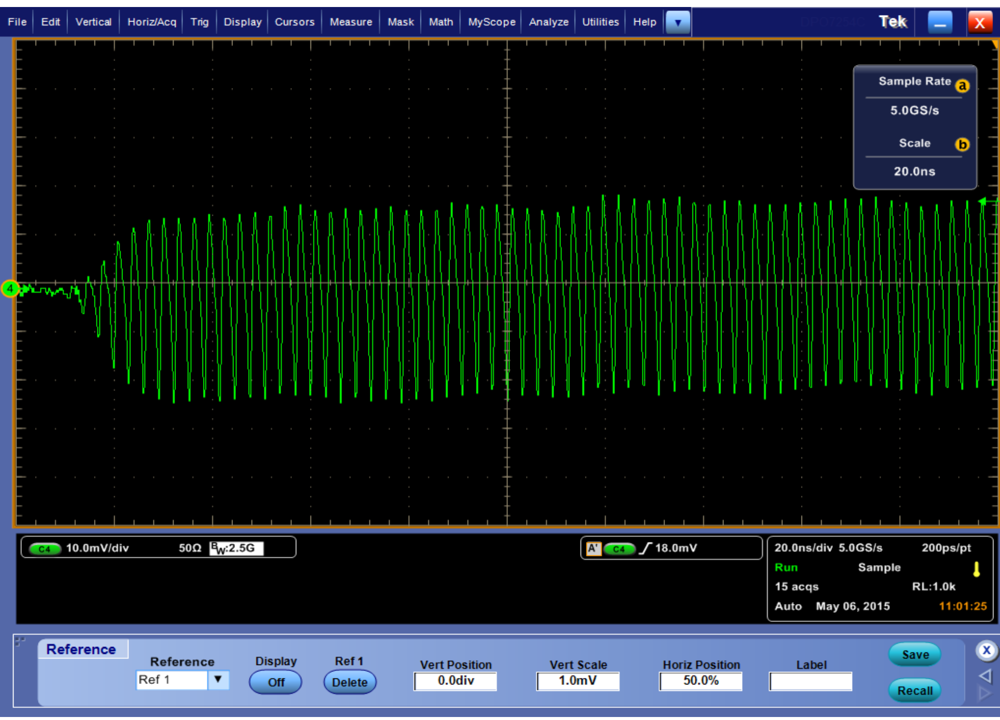
CT signals

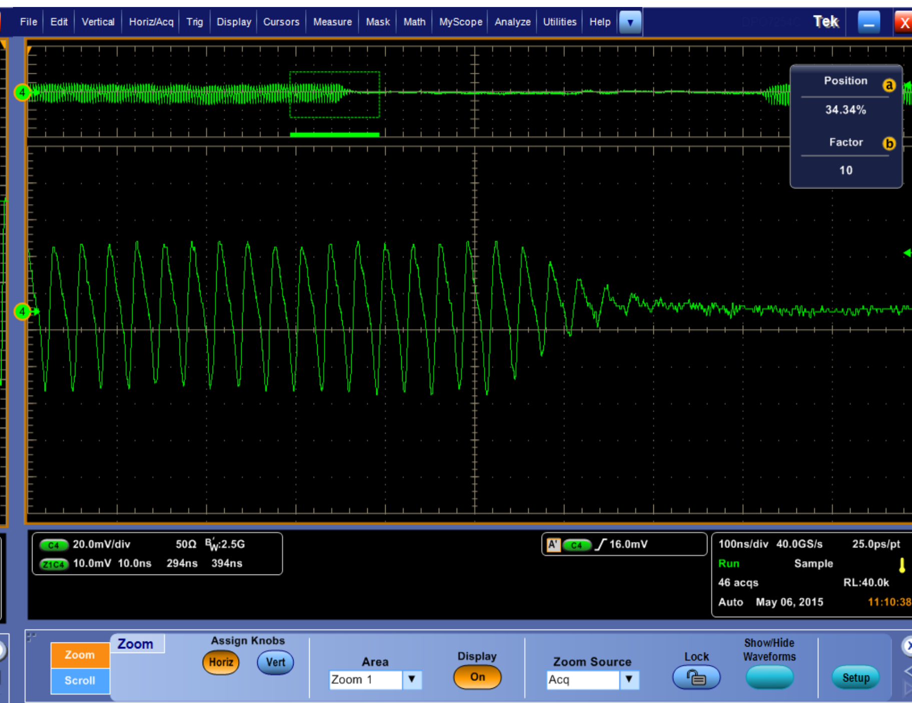
CT1	CT2	CT3	CT4
45mA	37mA	28mA	28mA

LEBT CT value **MEBT**

Chopping Experiments
(H. Ouyang)

Both the rise/fall time for the chopped beam is about 4-5 periods of the working RF (1 period T=3.086ns) . → ~15nsec

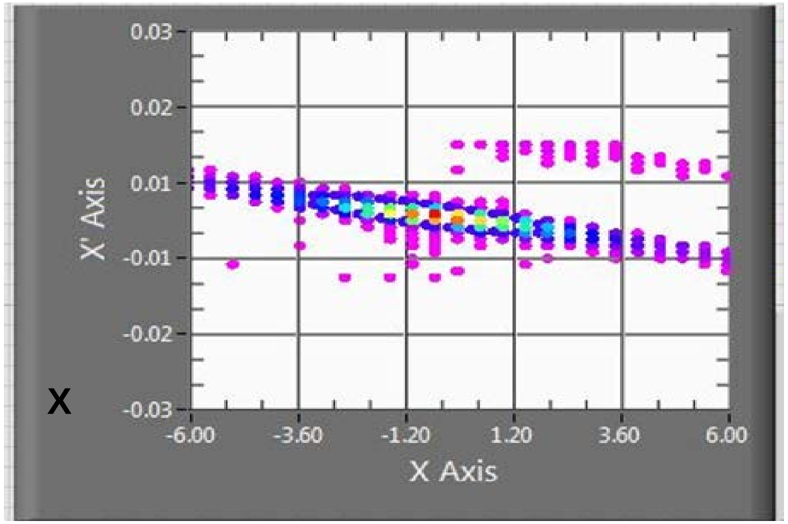


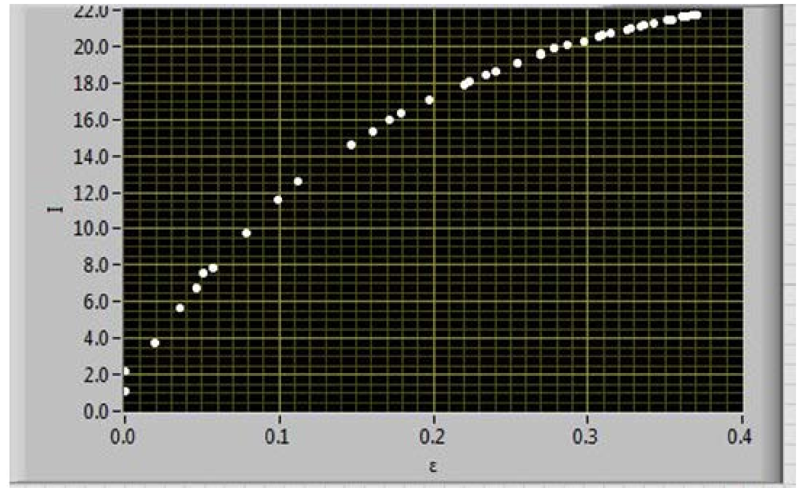


Beam emittance measurements

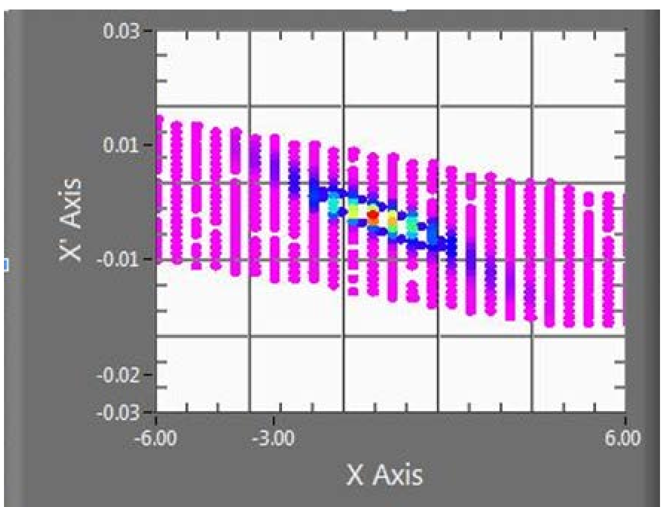
(H. Ouyang)

MEBT emittance measured in

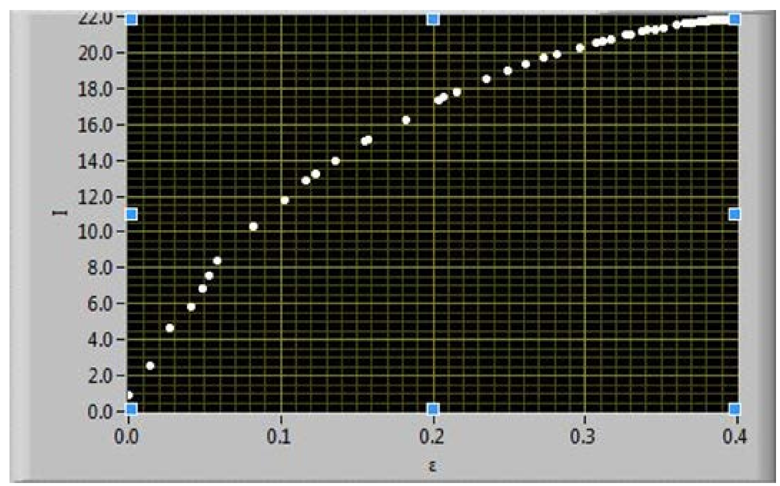




Beam intensity: 22mA, X: 0.2πmm.mrad (norm. rms) with 17mA



Y



Beam intensity: 22mA, Y: 0.2πmm.mrad (norm. rms) with 17.5mA

Front end commissioning for China-ADS Injector-I test facility (Fang Yan)

1 **Introduction**

2 **LEBT commissioning**

3 **RFQ commissioning**

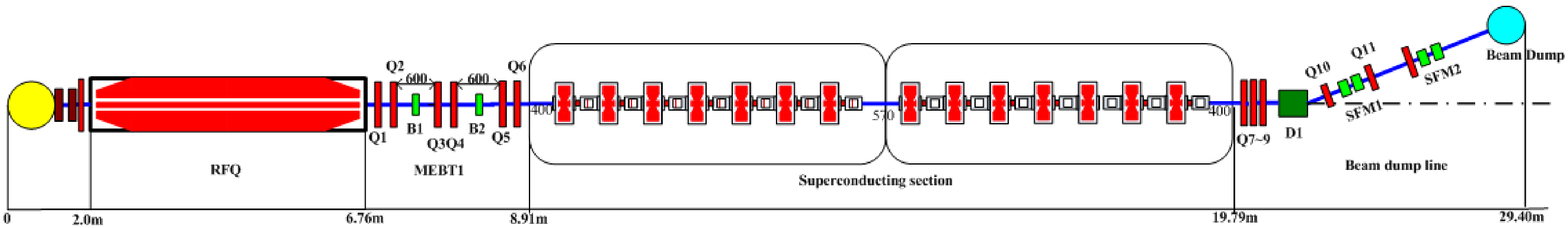
4 **MEBT commissioning**

5 **TCM commissioning**

6 **Summary**

Layout of ADS Injector-I testing facility

(F. Yan)

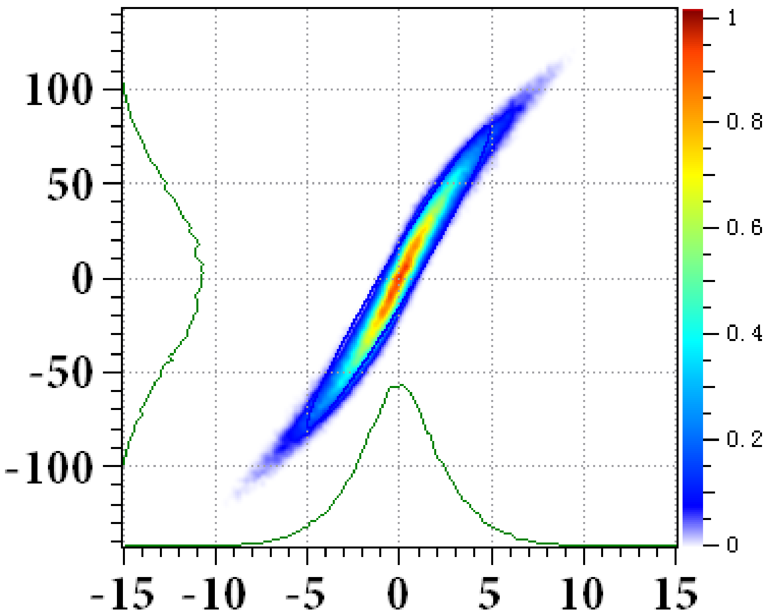


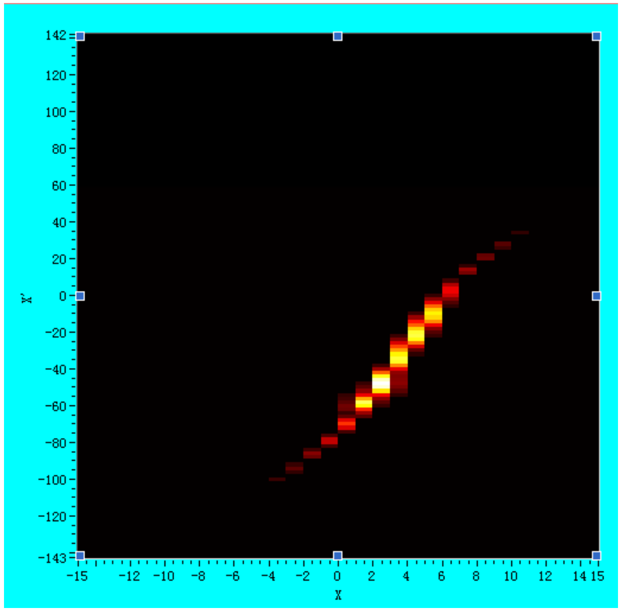
Particle	Proton
Energy (MeV)	10
Current (mA)	10
Beam power (kW)	100
Duty factor (%)	100
RF frequency (MHz)	325

- **Injector I testing facility is being commissioned in stages.**
- **The SOURCE+LEBT+RFQ +TCM have been installed and commissioned.**
- **The TCM with two β=0.12 Spoke cavities are operated stably at 2K.**

2. LEBT commissioning ➡ emittance measurement

- **Beam phase space at the measured location (8.8cm drift downstream the LEBT exit): left for simulation and right for measurement.**





Beam parameters at the LEBT exit and the RFQ entrance

Parameters	I_{beam} (mA)	α	β (mm/mrad)	$E_{n,\,ms}$ (π mm.mrad)
Design goal	10	2.41	0.0771	<0.20
Measurement (backward deduced from the measured location)	11.5	2.18	0.0774	0.14

Alison detector: 5% background assumed

RFQ Commissioning towards CW
(F. Yan)

(Continued from previous history)

- **To Sep 3rd , pulse mode, 19.7 ms/20 ms, RF duty factor 98.5%, 233 kW /CW mode, 152 kW.**
- **On Sep. 4th , RF contact spring discharging were found on #4 coupler.**

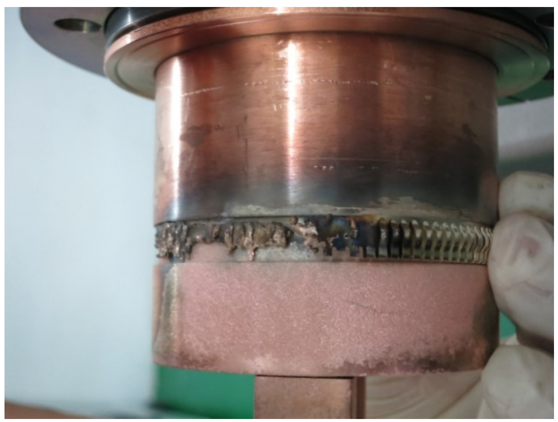
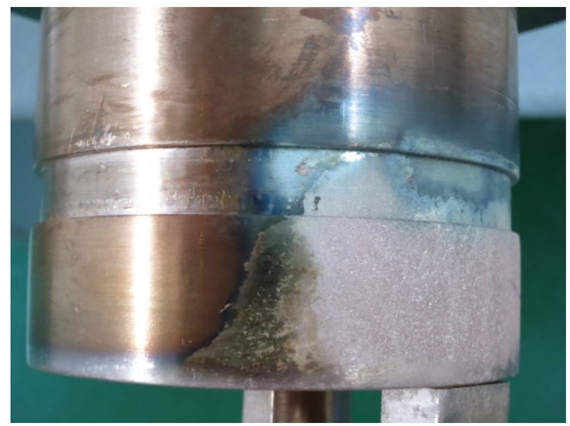



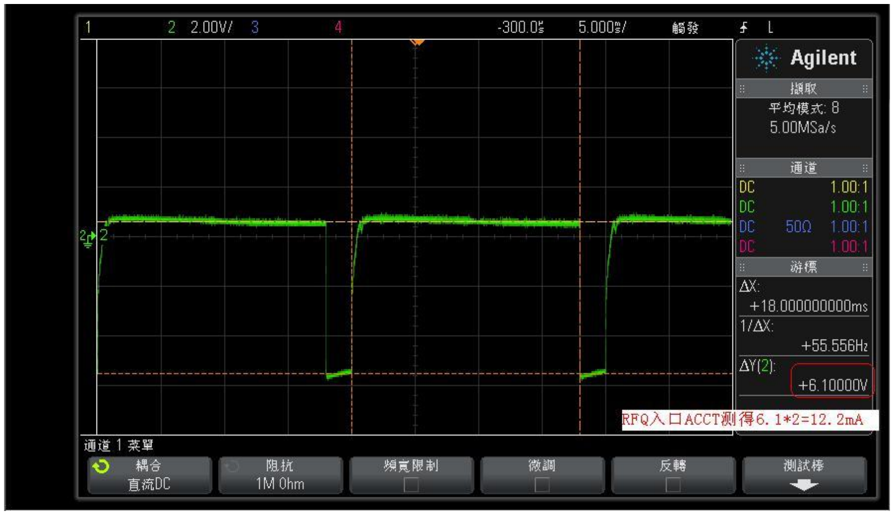
Image courtesy of the internal report "ADS 325MHz RFQ FPC problem review", Huang Tongming

- **On Sep 14th , the 3rd coupler ceramic window cracked due to the inner and outer conductor shorten by the condensate water.**
- **On Sep 19th , the new 3rd coupler installed.**
- **On Sep 26th , 19.8 ms/20 ms, RF duty factor 99%@256 kW**
- **The commissioning was stopped for the scheduled MEBT&TCM installation.**

RFQ commissioning with beam (F. Yan)

Transmission of the beam with duty factor of 90%

Entrance current: 12.2mA (LEBT ACCT)



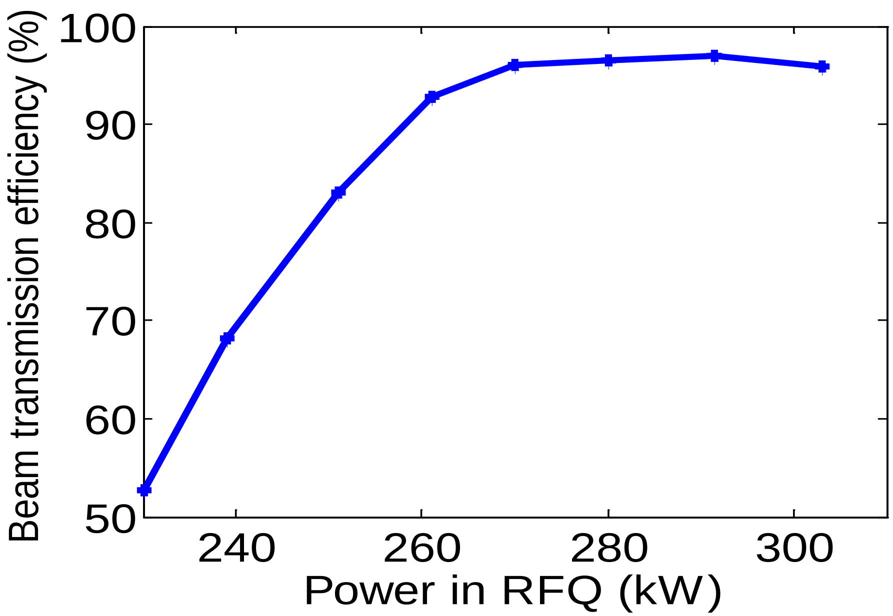
The beam current out of the RFQ: 11mA (DCCT)

Beam Duty factor	50%	60%	65%	70%	90%
Transmission efficiency	95%	95%	95.6%	95%	90%
RFQ output current	11.1mA	10.9mA	10.9mA	10.6mA	11mA
Last time	8.5min	60min	4.3min	5min*	3min
Pulse width/Rep. Freq.	10ms/50Hz	12ms/50Hz	13ms/50Hz	14ms/50Hz	18ms/50Hz
Power in the cavity	289kW	305kW	314kW		298kW
Experiment Date	20140901	20140901	20140901	20140902	20140925

*Interlocked because of the temperature of the beam dump target area over 60° .

RFQ Transmission
(F. Yan)

- **Measurement conditions:**
  300μs/50Hz, beam duty factor: 1.5%
- **Conclusion:**
  Power in RFQ: 270-303 kW, transmission:96%-97%
  Fit well with the Parmteq simulations.



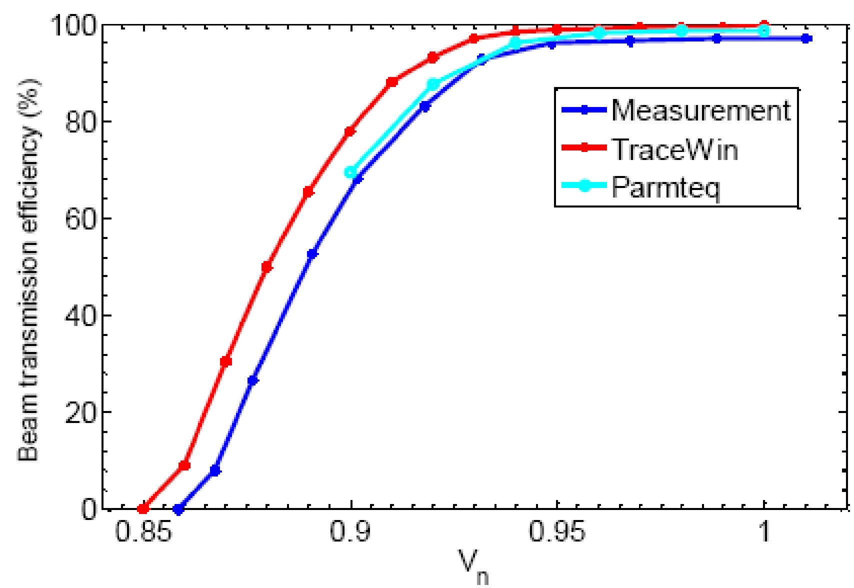


**Image courtesy of the paper, "Beam commissioning of C-ADS injector-I RFQ accelerator",
Cai Meng et al., IPAC2015.**

Summary of C-ADS Injector-I Commissioning
(F. Yan)

- **The source+LEBT+RFQ+MEBT were successfully commissioned with pulsed beam;**
- **The RFQ is still on the way to CW operation;**
- **The maximum RF duty factor achieved during the RFQ commissioning is 99.97% RF duty factor, 12.5 ms/79.975 Hz, 250 kW in cavity;**
- **The highest in cavity power with CW mode is 194kW;**
- **The maximum beam duty factor achieved during the commissioning is 90%, 18ms/50Hz, 298kW in cavity, with beam transmission of 90%;**
- **The TCM commissioning is still on going, the maximum energy achieved is 3.68MeVwith transmission of 93% between the entrance of RFQ and the TCM exit.**

10-mA proton beam commissioning of demo facility of C-ADS Injector II (Zhijun Wang)

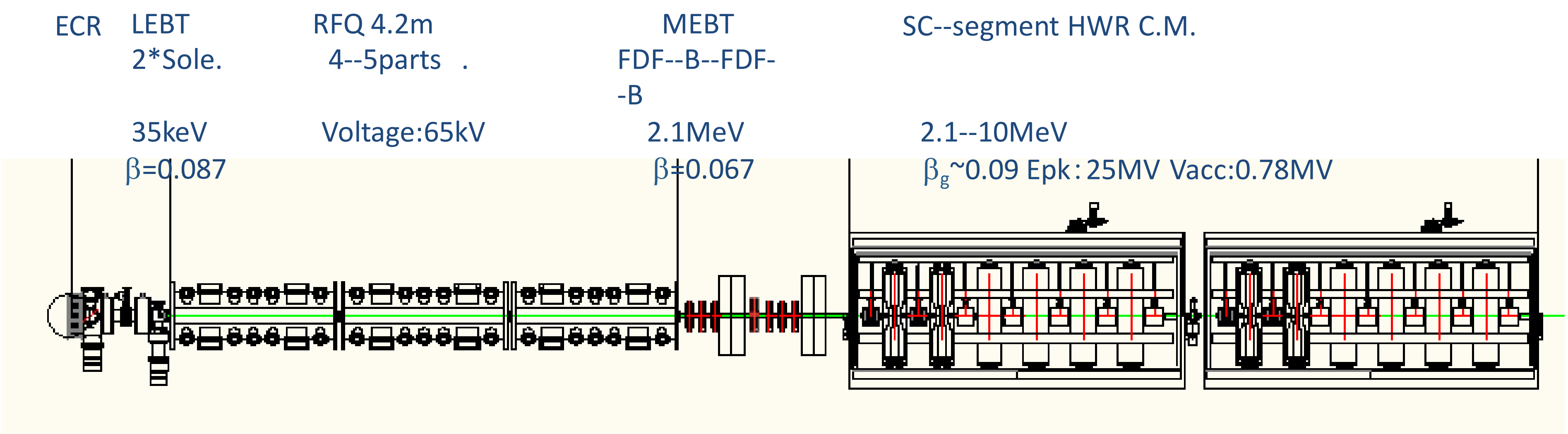
Outline

- **Introduction of C-ADS injector II**
- **The beam commissioning of RFQ**
- **The beam commissioning of MEBT & TCM1**
- **Existing problems and further plans**
- **Acknowledge**

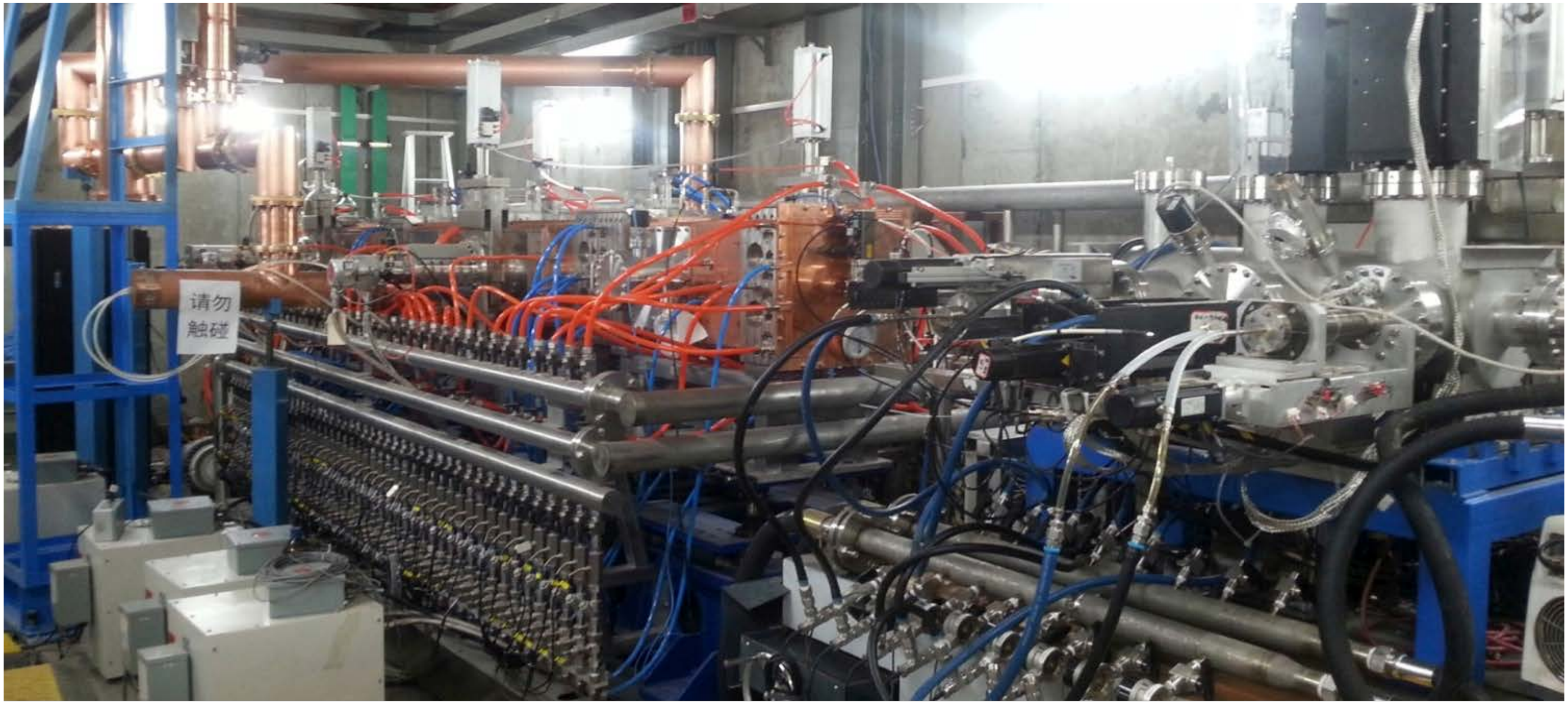
Base line of injector II

(Z. Wang)

- **Basic frequency is 162.5 MHz**
- **Ion source extraction voltage is 35 kV**
- **Extraction energy of RFQ is 2.1 MeV**
- **HWR is the main road to develop**
- **CH cavity will be R&D**



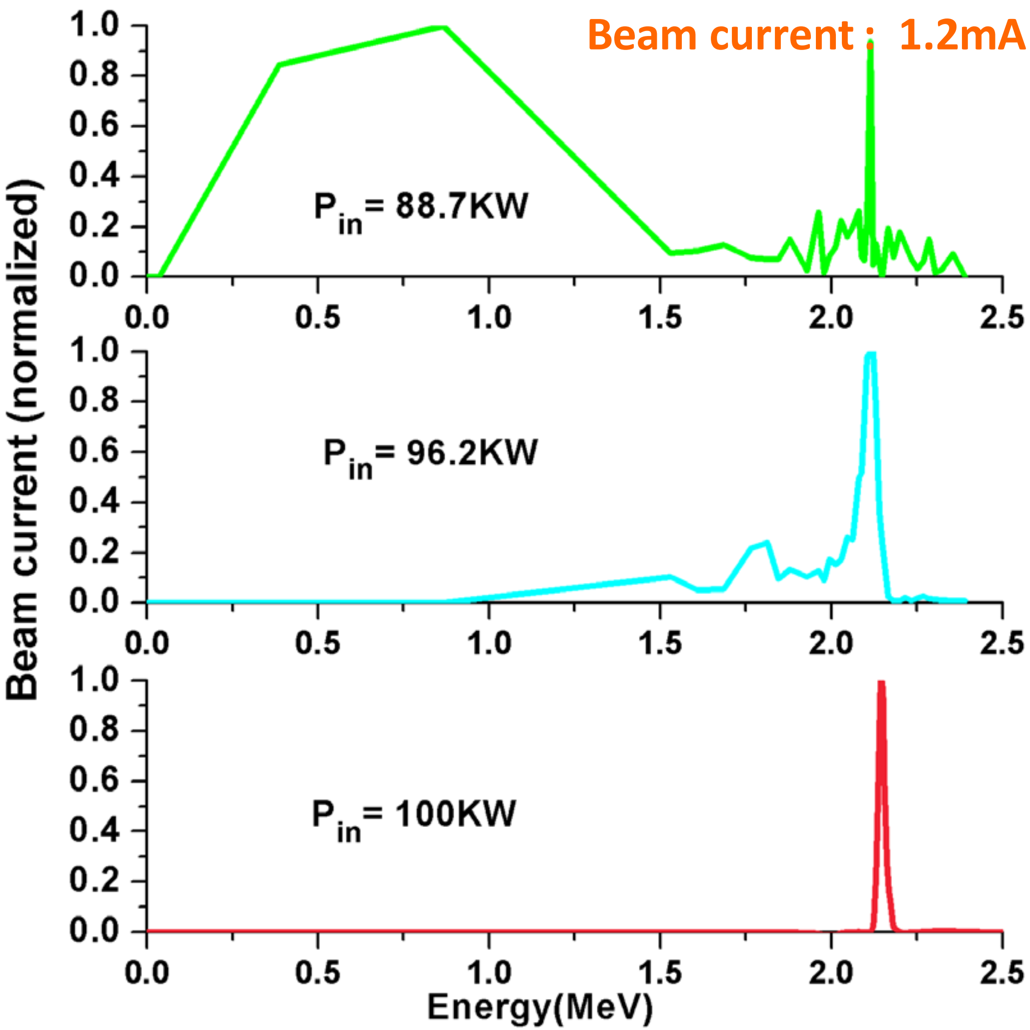
The beam commissioning of RFQ
(Z. Wang)

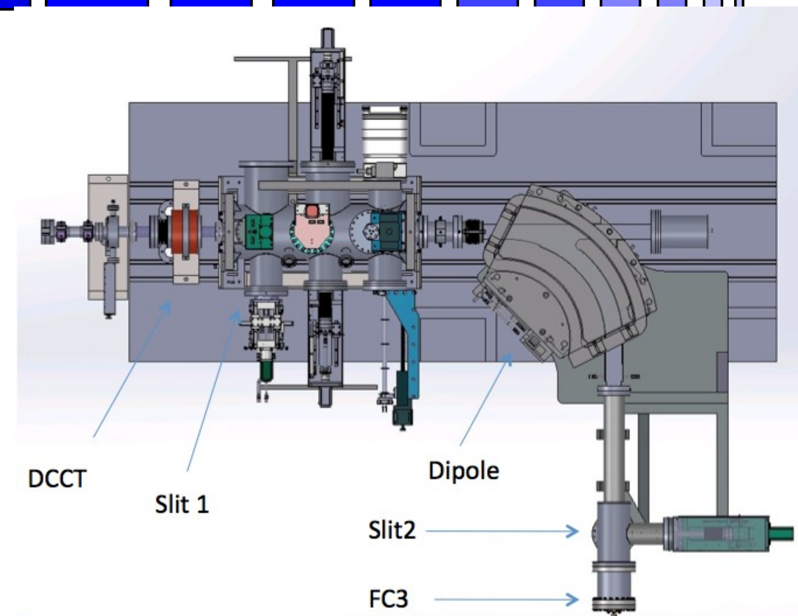


06/06/2014–18/07/2014

- **June 6th, the first beam, energy is 2.15 MeV**
- **June 30th, 10 mA, CW beam, 4.5 hours, beam power 21.6 kW**
- **July 24th, 18 mA, pulse beam, 37.8 kW, transmission 87%**
- **Total operation time is ~850 hours including CW@10mA around 10 hours**
- **Record of no-trip operation is ~220 hours**

Inter-electrode voltage of RFQ
(Z. Wang)



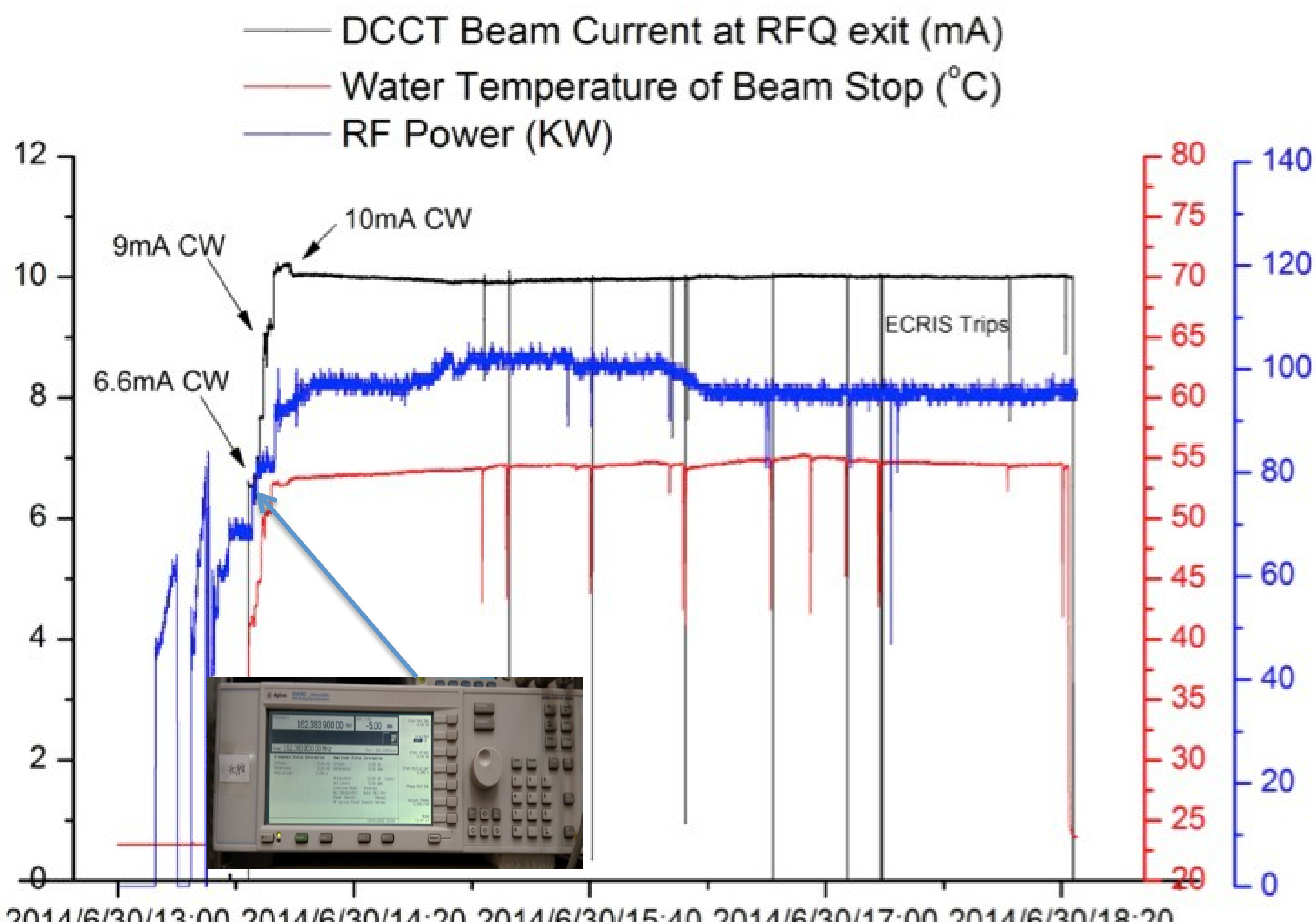


Center energy: 2.145MeV

Energy spread : 0.038MeV(FWHM)

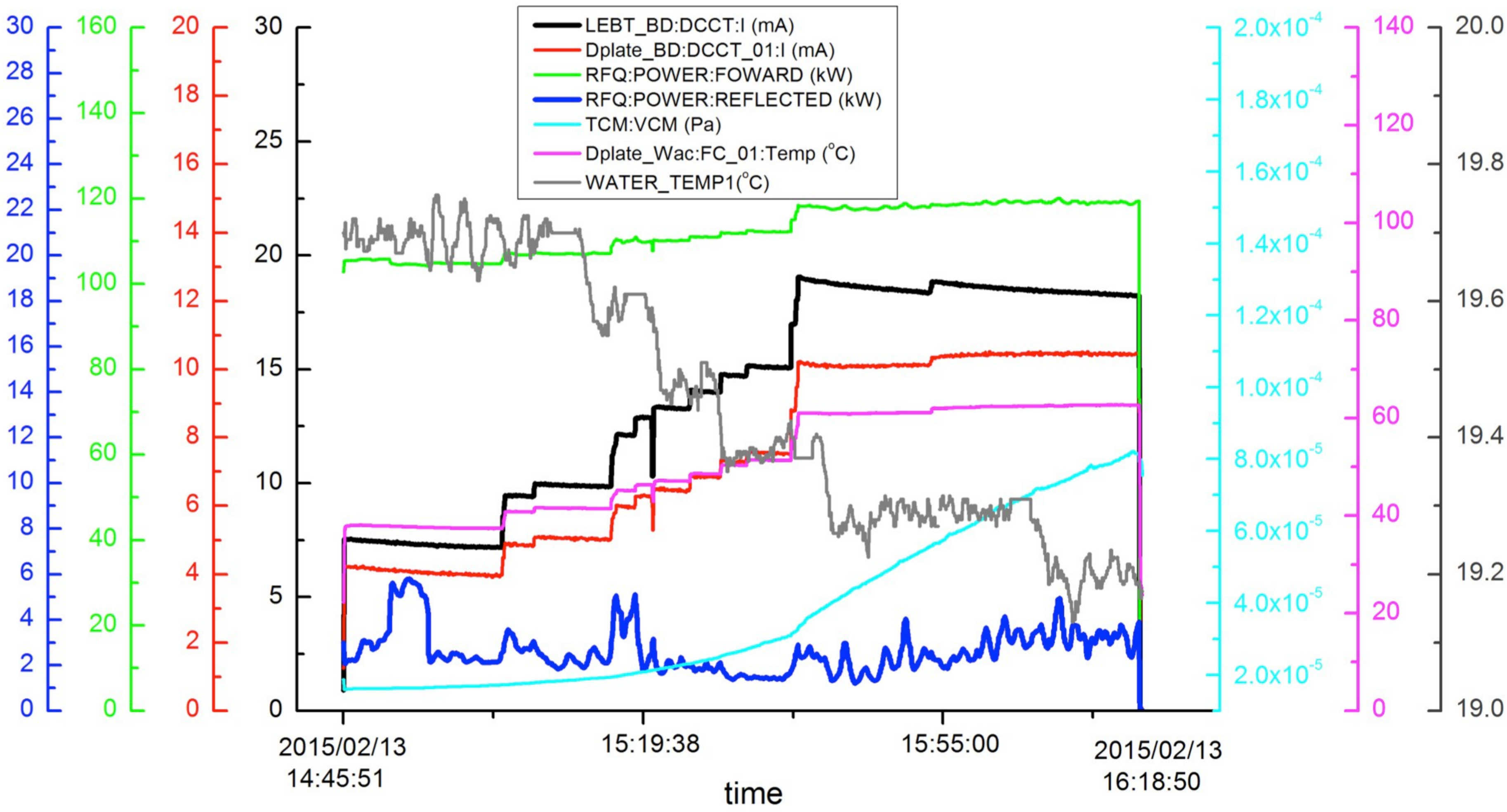
~10 mA CW beam tuning of RFQ

(Z. Wang)



10 mA CW beam tuning of MEBT&TCM

(Z. Wang)



Existing problems and further plans for C-ADS Injector-II (Z. Wang)

- **Beam loss detection for the SC linac**
  1. Temperature sensors
  2. Differential SC BCM
  3. Beam loss monitor, ion chamber, diamond detector
- **MPS for the high beam power machine**
  1. Most important for high power machine
  2. Preliminary MPS was built, more factors need to be considered
- **Beam commissioning software**
  1. OpenXAL was chosen, phase scanning app
  2. Model needed to be modified for Low beta SC linac
- **Calibration of BPM offset for Solenoid**
- ………………

Commissioning Experience of SNS Linac

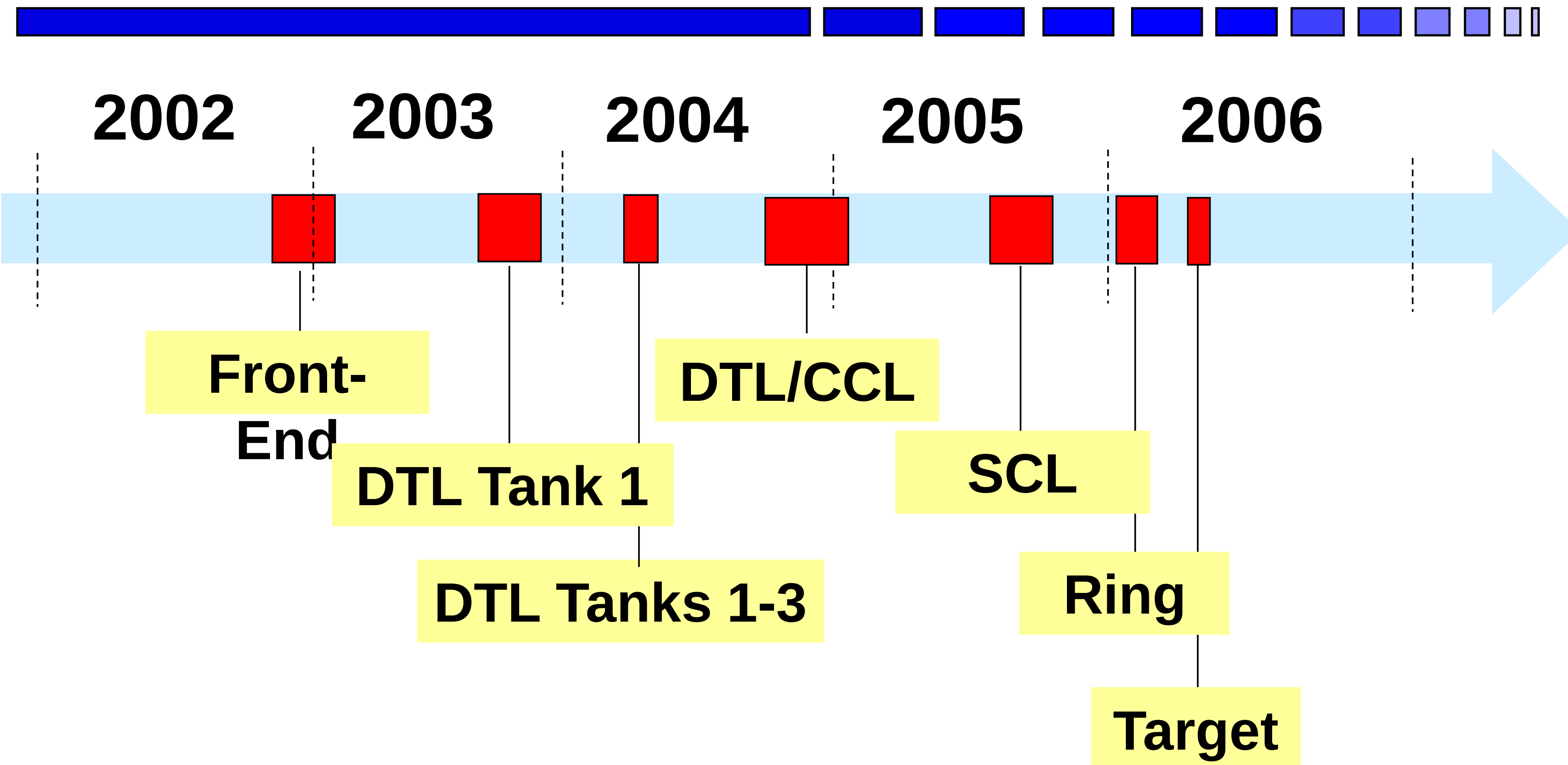
(Andrei Shishlo)

Outline

- Introduction to SNS
- How we commissioned the SNS linac
- What we should have done differently
- What worked well for us
- Lessons learned
- Present day tuning procedures
- Ramp-up Timeline
- Conclusions

Commissioning Timeline

(A. Shishlo)



5 stages of SNS linac commissioning

How long did it take (How much time did we spend)?

(A. Shishlo)

Section commissioned	days actual*
Front end	33
DTL 1	47
DTL 2-3	12
DTL 4-6 and CCL 1-3	135 (incl. ~40 days of planned shutdown)
CCL 4 thru SCL	63 (incl. ~13 days of planned shutdown)

***Some times could have been shorter. For example we spent a large amount of time studying the beam halo, and some of this work never bore fruit. On the other hand, this could be seen as time well spent gaining experience with the machine.**

How we did it
(A. Shishlo)

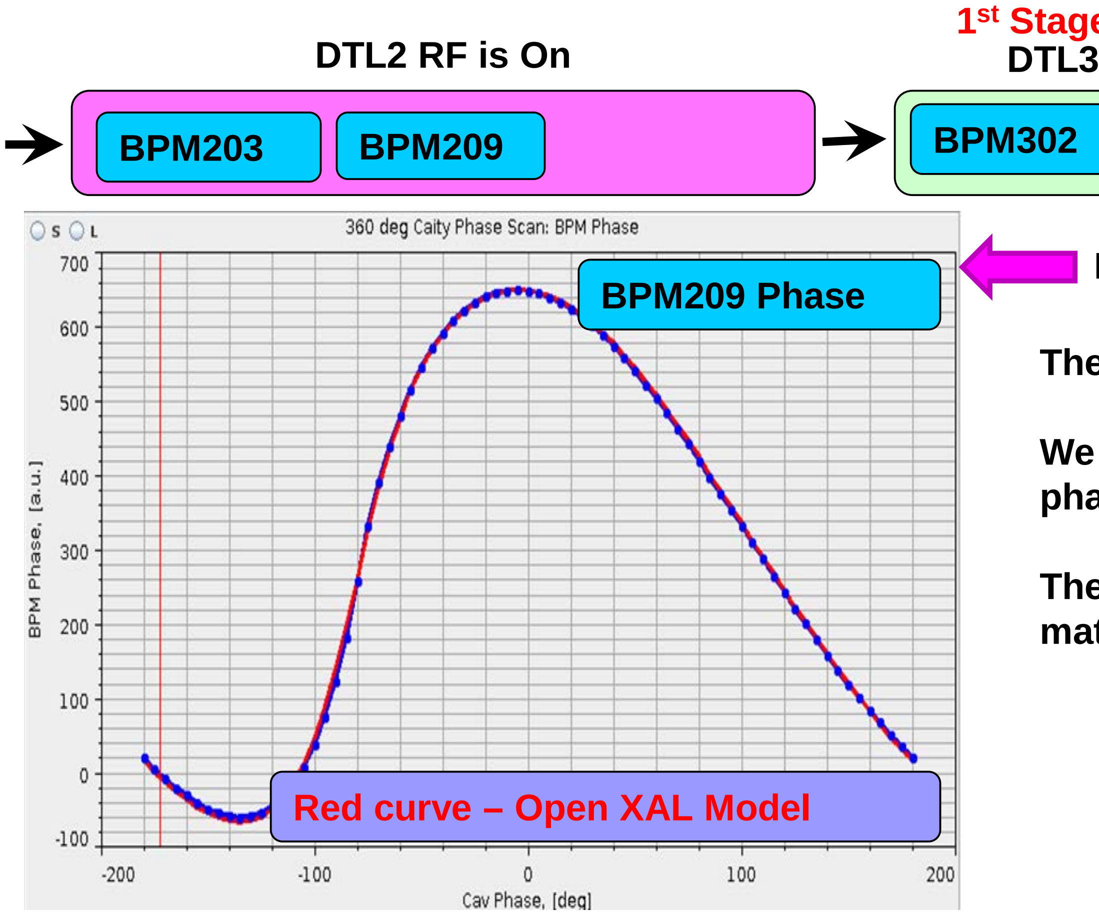
- Staffed 24/7
- Commissioned with beam in 7 stages (5 for linac, 2 for Ring and target) over 3.5 years
- Front End through CCL-3 “control room” was a few computer stations in the Front End building, hard hats and safety shoes were required
- Commissioned DTL-1 (7.5 MeV output energy) with a special diagnostics beam line (D-plate) that had a high-power beam stop. We used it to demonstrate 1.0 MW equivalent power (26 mA pk, 650 us, 60 Hz) in 2003. After that did not return to 1 MW beam parameters until 2009.

How we did it (cont.)
(A. Shishlo)

- Most of used software was developed before particular stage of commissioning
- Today we’re still improving our linac tuning algorithms
  - Utilize beam phase measurements inside the same warm linac cavity whose set points are being determined
  - New algorithms (DeltaT, PASTA, One BPM algorithm)
  - Tuning automation (Warm Linac 6-8 hours -> 50 min , SCL 8 h -> 32 min)

Present Day Warm Linac Tuning
(A. Shishlo)

- Warm Linac Wizard – OpenXAL app for MEBT-DTL-CCL tuning
- It is automated tuning – Operators are just watching the process (< 1h)
- It uses generalized phase signature matching (sometimes even only one BPM is needed) and the BPMs inside the same cavity

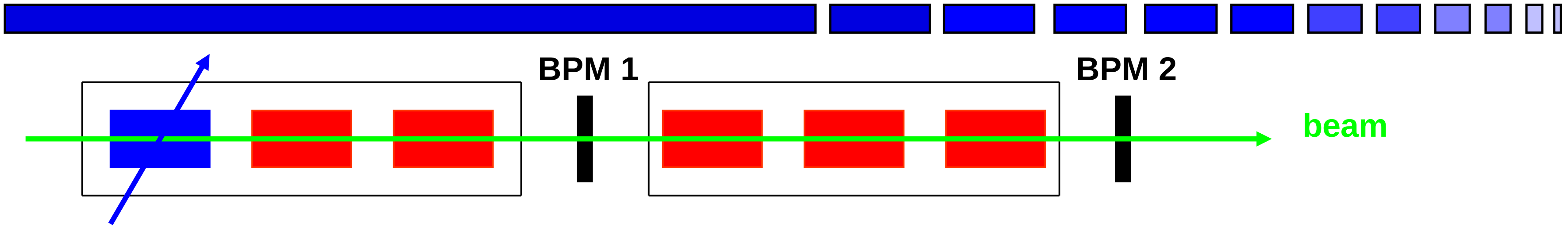


The beam at BPM209 is always present

We can get a good guess of the working phase and amplitude

The 2nd Stage is a nonlinear phase scan matching

Improvements to phase scan method for SCL
(A. Shishlo)



- When we first commissioned the SCL we turned off the RF to the cavities downstream of the cavity whose phase was being scanned. It took about 15 minutes to turn on the next cavity and move on.
- Now we just blank the RF at 1 Hz (59 RF pulses on, 1 pulse off) and that can be turned on or off in about 1 second
- We use low peak currents (~5 mA) and short pulses (~3 us) to minimize the cavity excitations and beam loading
- In the first years of routine operations the SCL phase scans took about 12 hours. Today they are automated and take about 40 minutes.

Some lessons learned
(A. Shishlo)

- Equipment checkout with beam takes a large fraction of the time
  - Beam instrumentation
  - RF & LLRF
  - Control system
  - Machine Protection System
- Initial commissioning at low beam power was easy once the equipment was running properly
- Be careful with modifications to critical systems (e.g. MPS system)
- There could be surprises – SCL beam loss
- Automated applications for long tasks are working better than human
- The high power ramp up was and still is our biggest challenge

Conclusions of SNS Linac Commissioning

(A. Shishlo)

- The commissioning and an initial power ramp-up of SNS was performed according to the planned schedule (even slightly ahead)
- Now our goal is 1.4 MW power at availability more than 90%
- We still improving our knowledge of the machine
- There still have puzzles that we are working on

SNS Beam loss and control (Michael Plum)

H^- vs H^+ beam loss mechanisms

- Residual gas stripping
- Intra-beam stripping
- H^+ capture and acceleration
- Field stripping
- Black body radiation stripping

$\left.\right\}$ **H^- only**

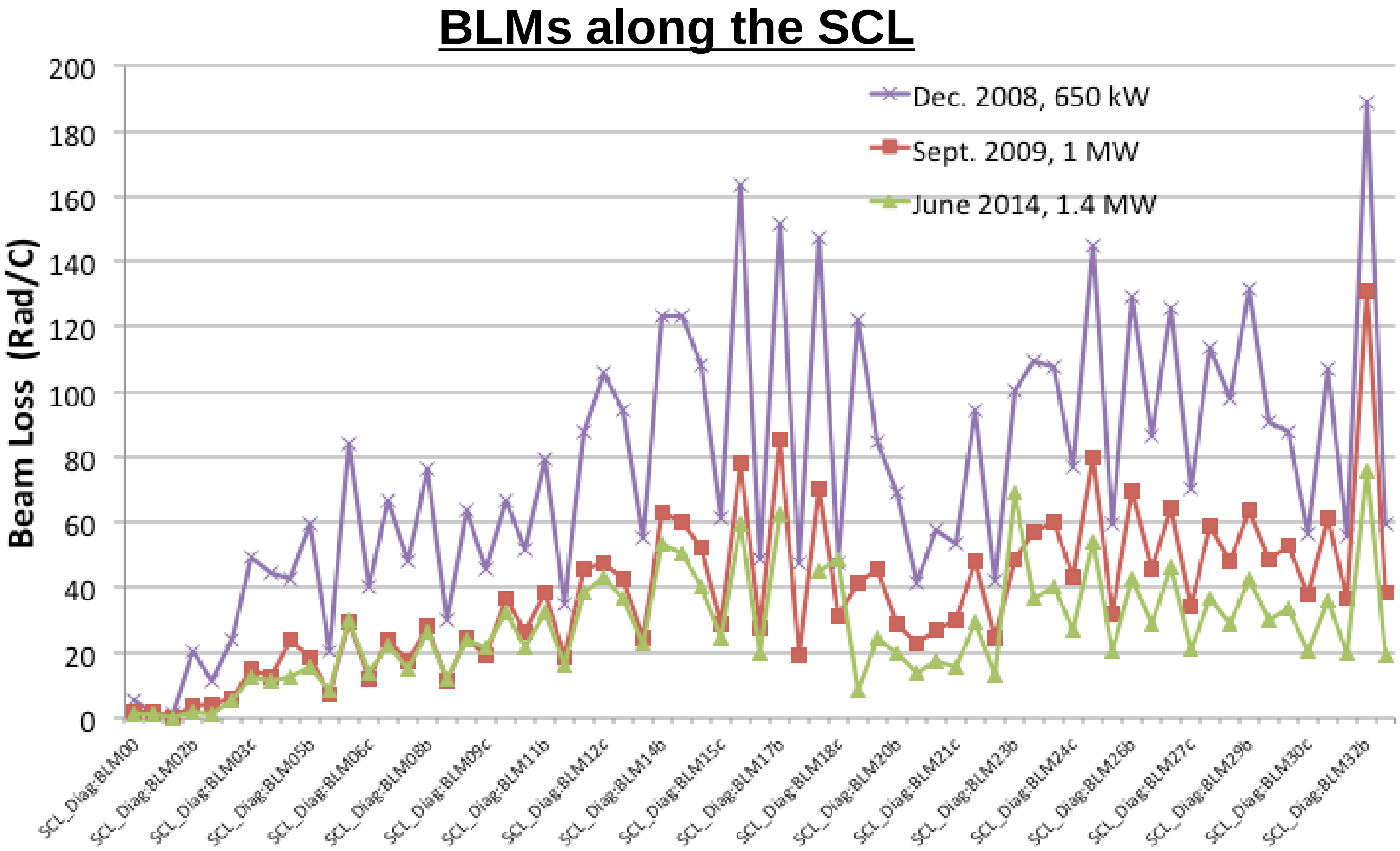
- Beam halo/tails (resonances, collective effects, mismatch, etc.)
- RF and/or ion source turn on/off transients
- Dark current from ion source

Beam loss control and mitigation (M. Plum)

- Scraping – best done at low beam energies
- Increase beam size in superconducting linac, to reduce intrabeam stripping
- Adjust quadrupole magnet and RF phase setpoints to empirically reduce losses

Superconducting Linac beam loss trends

(M. Plum)



- Big drop in losses with focusing strength reduction in early 2009
- Modest benefit since

Summary of SNS beam control (M. Plum)

- During first years of operation beam losses were improved by empirical tuning, adding scrapers, modifications to ring injection / injection dump
- Today losses are stable and reproducible
- SNS beam power is not limited by beam losses
- The ring injection area has the highest levels of activation, due to the stripper foil
- Most beam loss in SCL is caused by intra-beam stripping
  - Linac losses are linear with beam pulse length
  - Linac losses are approx. quadratic with beam current (IBSt)
- The low-loss tune is not the same as the design tune, can only be found by empirical tuning
- Occasional beam loss (errant beams) is mainly due to warm linac RF cavities. We are now working to correct this.
- Unexpected results from commissioning:
  - scraping in MEBT is surprisingly effective
  - beam loss due to intra-beam stripping
  - occasional beam loss (errant beams) degrades SC cavities

Discussion on linac commissioning

Members:

- Masonori Ikegami (MSU),
- Tomofumi Maruta (J-PARC),
- Andrei Shishlo (ORNL), and
- Yuan He (IMP, CAS)

Discussion

- ◆ Issues from learned lessons at J-PARC linac commissioning
  - Matching: core matching and halo matching
  - Beam loss by intra beam scattering
- ◆ Issues of C-ADS CW operation
  - Beam loss monitor at low energy part
  - Online non-intercepting diagnostics
  - Issues of mode (pulse length, beam current) transition

Lessons and further Discussions (for J-PARC Linac)

(Y. Liu)

- Monitors/applications/procedures: basic and optional

  Basic? Transmission measurement, phase scan, (transverse) matching, orbit, …

  Optional? BSM at MEBT1 (RFQ-DTL) could be helpful
- Offline vs. online measurements

  Besides well-planned offline measurements, online systematic measurements might still be needed
- Beam loss esp. for H- linac

  Dark current (RF IS)

  IBSt, intra-beam stripping
- Beam loss localization
- Identification of halo
- Keys for improvements: fight against ambiguities and mistakes

  More beam study time, accumulations of measurements

Lesson learned in J-PARC Linac Commissioning

(T. Maruta)

He introduced 3 kinds of beam loss generated by following issues

1. Intra beam stripping (IBSt) in ACS

Beam losses are measured by changing the focusing condition (Temperature balance T)

Equi-partitioning condition

$$T \equiv \frac{\varepsilon_x k_x}{\varepsilon_z k_z} = 1$$

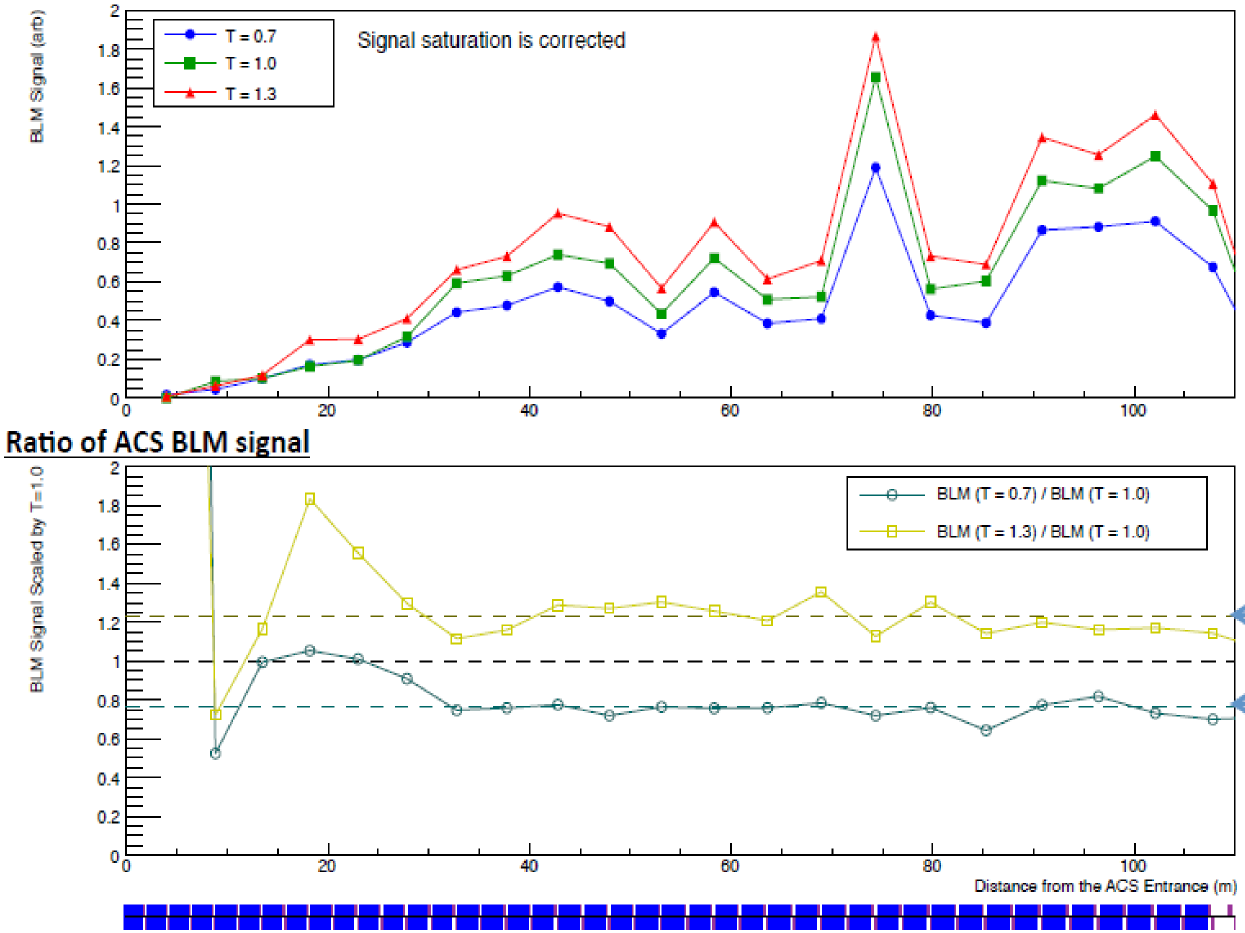
2. Dark current of an ion source
3. Beam accelerated by transient RFQ RF

Solved by modifying the timing and chopping condition

J-PARC ACS BLM Signal Comp. at T = 0.7, 1.0 and 1.3

(T. Maruta)

ACS BLM signal (signal saturation is corrected)



Ratio of ACS BLM signal

Simulation

T = 0.7 : 0.020 W/m

T = 1.0 : 0.026 W/m

T = 1.3 : 0.032 W/m

R (T=1.3/T=1.0) = 1.23

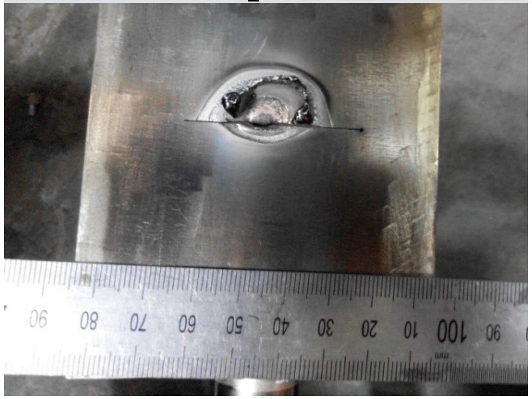
R (T=0.7/T=1.0) = 0.77

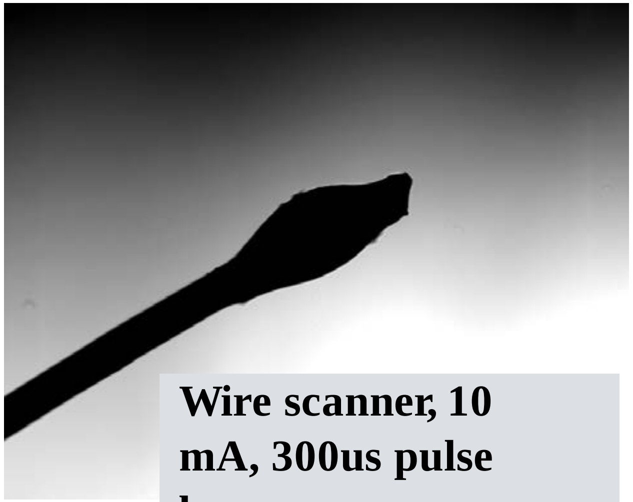
The ratios of BLM signal of each T-ratio is well consistent w/ the simulation after ACS08.

IBSt could be dominant source of the ACS beam loss.

Issues of CW commissioning (Y. He)
Online non-intercepting diagnostics

C-ADS, 2.1MeV, 6 h , 4mA, 1ms, pulsed beam





Wire scanner, 10 mA, 300us pulse beam

Intercepting diagnostics were destroyed by high power beam!
Rapid feedback control base on beam diagnostics required by ADS

- BPM — ***6-D phase space measurement online?***
- RGM/IPM — ***Monitor beam real time?***
- Pillbox…… — ***Rapid recovery and fault compensation base on beam diagnostic?***

Linac Summary of this workshop

- We have discussed on the topics of linac commissioning.
  - Experiences and lessons learned: J-PARC, SNS
    - These experiences are very important.
    - But still unexpected and surprising things happen.
  - Commissioning stage: CSNS, C-ADS Injector-I and –II
    - Not only following the existing machines, but encountered new issues; CW operation, etc.
  - Endless efforts
    - Simulation/benchmark codes improvement.
    - Performance upgrade: beam power, availability.

- Collaboration and information exchange are essential to take advantage of synergy.

Acknowledgement

I appreciate all the presenters, conveners, participants and organizers of this workshop for useful information and discussion.