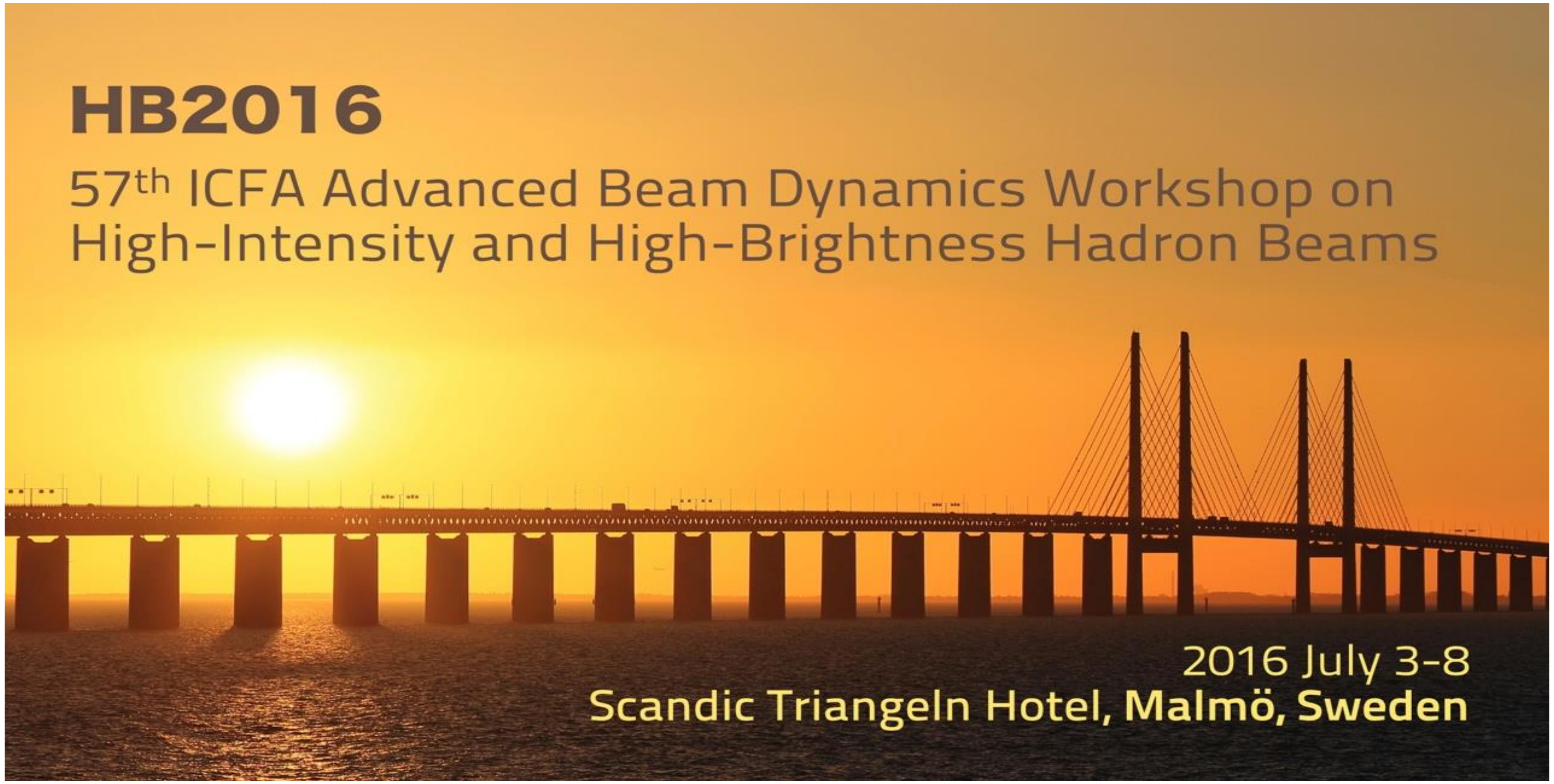


Working Group D: Commissioning and Operations
Summary Talk

Conveners
F.G. Garcia *FNAL*
A. Parfenova *PSI*
H. Hotchi, *JAEA*

WG-D: Commissioning and Operations

- Sharing expertize and experience – invites new conversation
- Interesting to think about:
  - What commissioning lessons can we learn from other labs?
  - What concerned you but did not happen?
  - What you thought was not gonna happen but did happen?

We live in *exciting* times for particle accelerator

- Dramatic success of beam-based basic / material science research for > 50+ years is direct related to research and development in accelerator science and technology
- Facilities capable of operating reliably and safely at multi-MW beam power continue to expand around the world to attend the demand of science
- Opportunities for significant increase in energy and beam currents exist today particularly in SC magnets and RF systems

WG-D: Session 1&2 (Tuesday)	Speaker
Advances in the development of the ESS-Bilbao proton injector	Zunbeltz Izaola
Beam commissioning results for the CSNS MEBT and DTL1	Jun Peng
Operational experience and future plan at ISIS	Dean Adams
IFMIF-EVEDA RFQ, measurement of beam input conditions and preparation to beam commissioning	Michele Comunian
ESS Linac Plans for Commissioning and Initial Operations	Ryoichi Miyamoto
Commissioning of C-ADS Injector I	Jianshe Cao
Commissioning of the SPIRAL2	Jean-Michel Lagniel
Lessons of high-power CW beam commissioning of injector II of Chinese ADS	Huan Jia
Observations of Coupling During Accumulation Using a Non-Destructive Electron Scanner in the Spallation Neutron Source Accumulator Ring	Robert Edward Potts

WG-D: Session 3&4 (Thursday)	Speaker
Reuse Recycler: High Intensity Proton Stacking at Fermilab	Phil Adamson
Operational experience at KOMAC	Yong-Sub Cho
SNS Commissioning and Operations, the first 10 Years. An overview of the components status after high intensity	George Dodson
Investigation to Improve Efficiency and Availability in Control and Operation of Superconducting Cavity at ESS	Rihua Zeng
Lessons from LHC commissioning	Mike Lamont
Path to 1MW -- Beam loss control in J-PARC RCS	Hideaki Hotchi
RHIC Operations and e-lens commissioning	Xiaofeng Gu

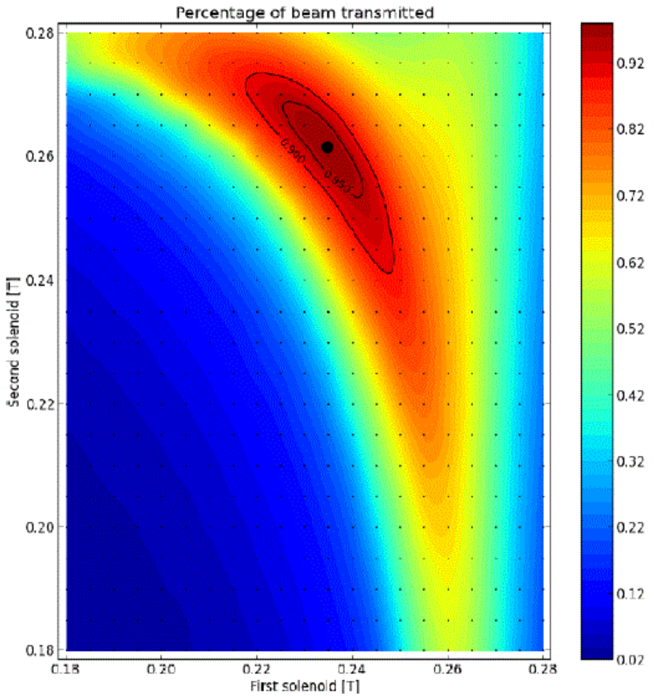
	Location		Type (particle) | Rep. Rate	E_{out} (GeV)	I*E (MW)
ESS	EU	project	Linac (p) | 14 Hz	2	5
C-SNS	Asia	project	H- linac / RCS | 25 Hz	0.23 (H-) / 1.6 (p)	0.1-0.5
IFMIF-EVEDA	Asia	project	D+ linac		2*5
C-ADS	Asia	project	CW	1.5	10
SPIRAL-2	EU	project	CW ion beams (5mA)	0.04	0.165 (p)
SNS	North A.	2006 -	Linac /Ring (p)	0.8 – 1.0	0.85-1.4
ISIS	EU	1984 -	H- linac / RCS | 50 Hz	0.7 (H-) / 0.8 (p)	(0.14 + 0.36)
KOMAC	Asia	2013 -	Linac (p)	0.02 - 0.1	0.16
RHIC	North A.	2000 -	Ring (polarized p / Heavy Ions)	255 / 100	
LHC	EU	2008 -	Ring (p-p)	6,500	
FNAL-MI/Recycler	North A.	1995 -	Ring (p)	120	0.7
J-PARC RCS	Asia	2007 -	Ring (p)	3	1

ESS Linac and Commissioning Overview

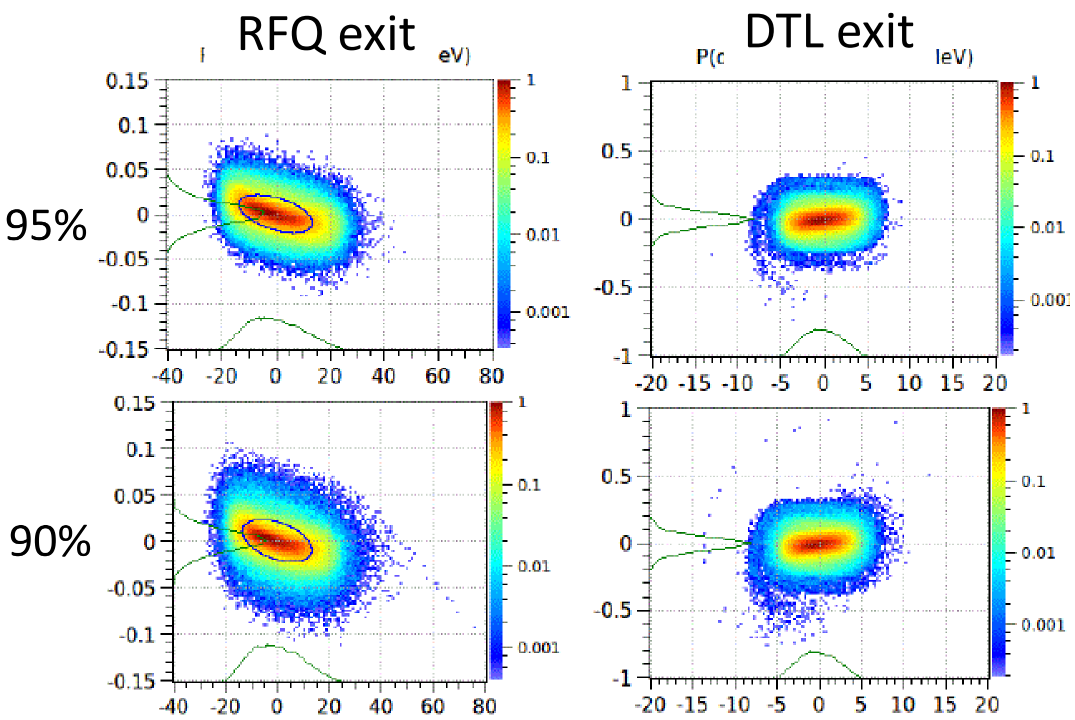
R. Miyamoto

- Phased commissioning is planed and preparations for commissioning are progressing
- Beam physics studies

Solenoid scan and transmission thru RFQ measured



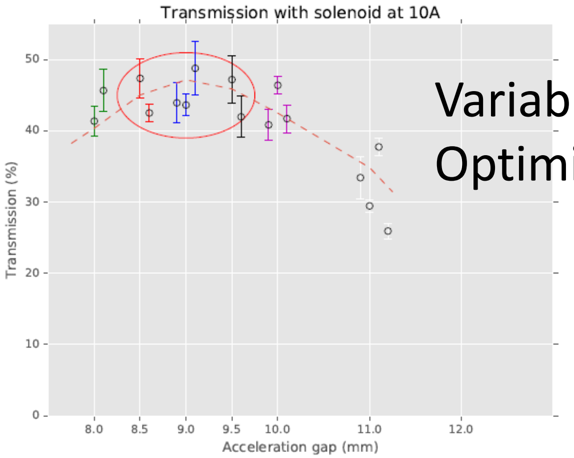
SC compensation anticipated to be 95%



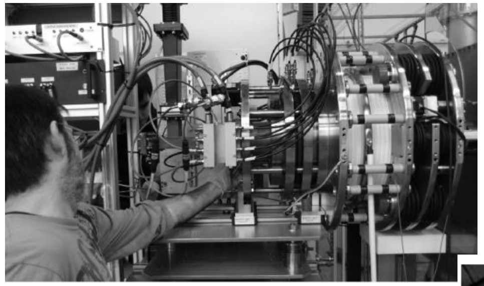
Advances in the development of the ESS-Bilbao proton injector

Z. Izaola

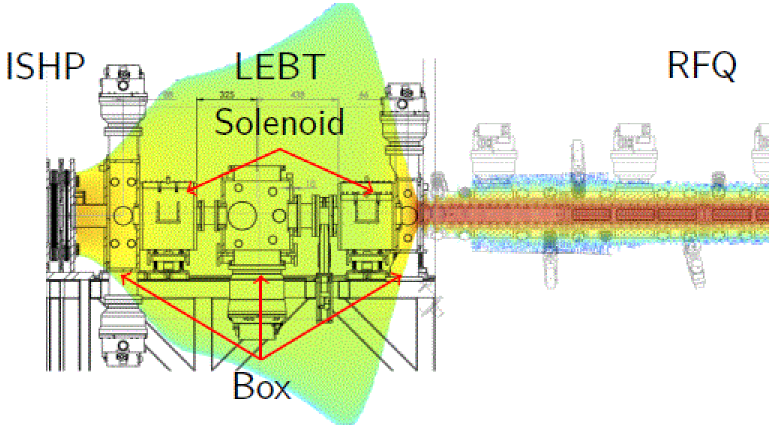
- ESS-Bilbao – in-kind contribution to ESS
  - 4 WPA : MEBT, RF systems, Target & Inst.

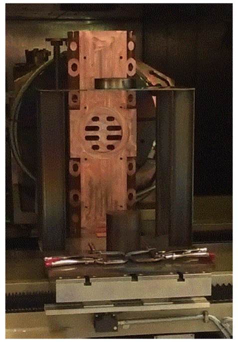


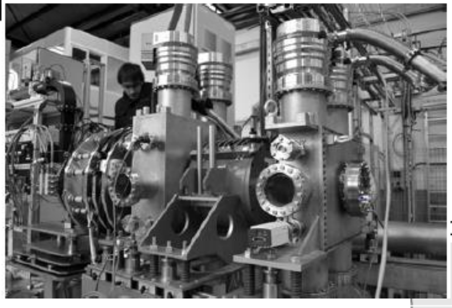
Variable Acc_{Gap}
Optimization 8.5-9 mm



ECR H+ source

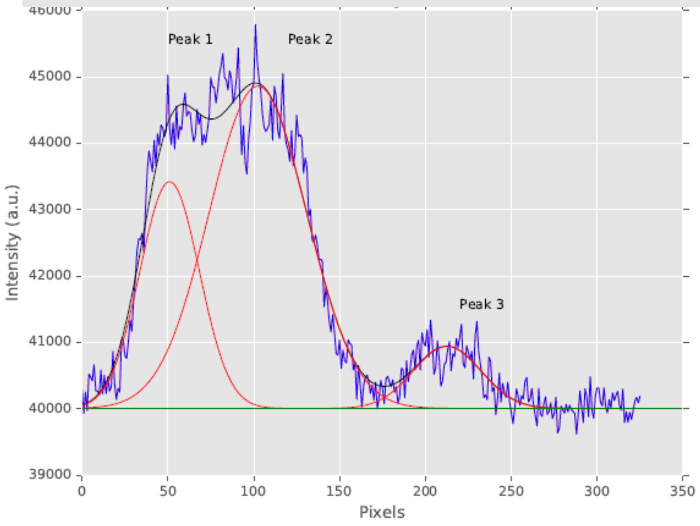


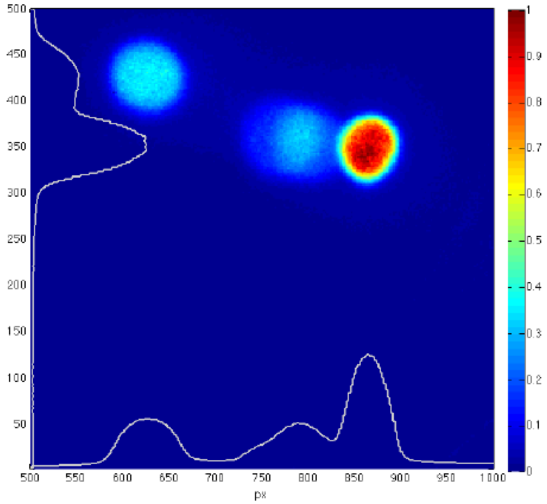




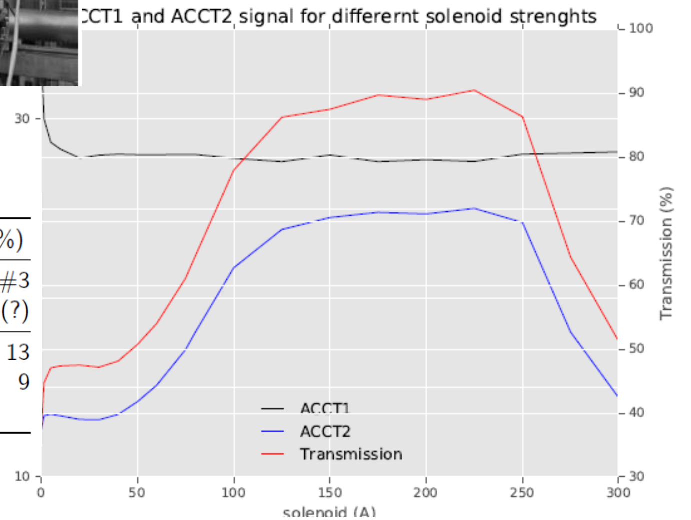
LEBT Solenoid scan
Transmission 85%

Observation of different ions species in the beam





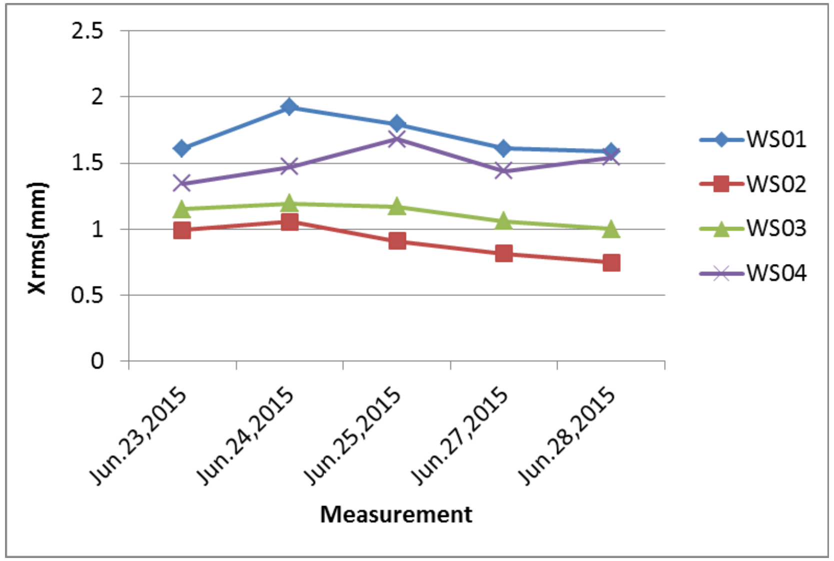
Peak	Position [mm] #1 H^+	#2 H_2^+	#3 $H_3^+(?)$	Composition (%) #1 H^+	#2 H_2^+	#3 $H_3^+(?)$
Family5	30.2	18.1	1.4	64	23	13
Family7	32.1	22.4	1.3	24	67	9
Simulation	30.9	21.4	17.1			

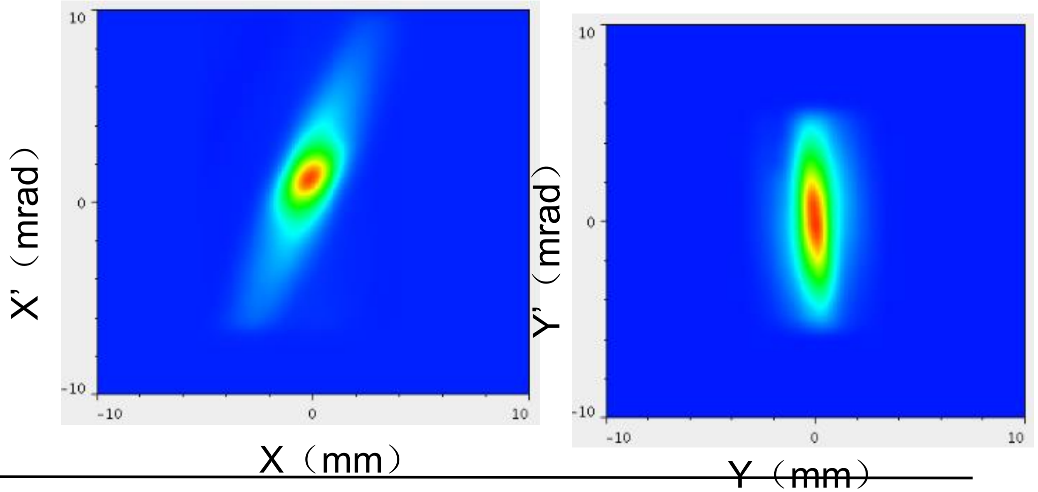


Beam commissioning results for the CSNS MEBT and DTL1

J. Peng

- 80 MeV H- linac, 1.6 GeV RCS p @ 25 Hz,
  P_b 100 kW (phase I) – 500kW (phase II)
  more similar to ISIS facility with Tgt 1: 140 kW (not to SNS)
- MEBT commissioning
  - Transverse emittance measurements – wire scanner
    - Extract twiss parameters
      - poor agreement with simulation
      - experimental errors ~ 20%
      - observation of beam halo formation
  - Energy measurement (TOF): 3.02 +/- 0.15 MeV



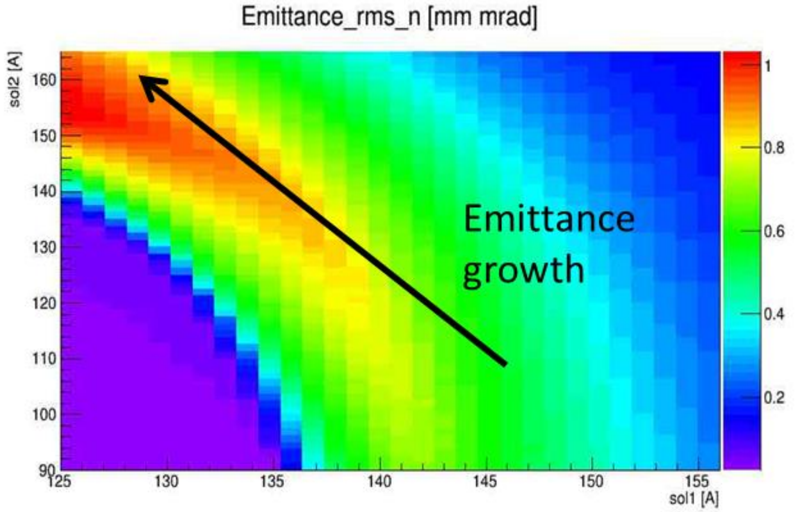


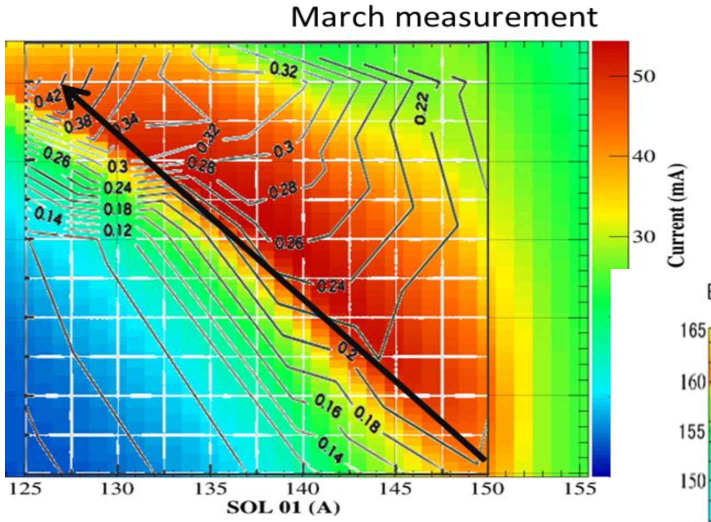
- DTL commissioning
  - RF phase scan at different amplitudes

IFMIF-EVEDA RFQ

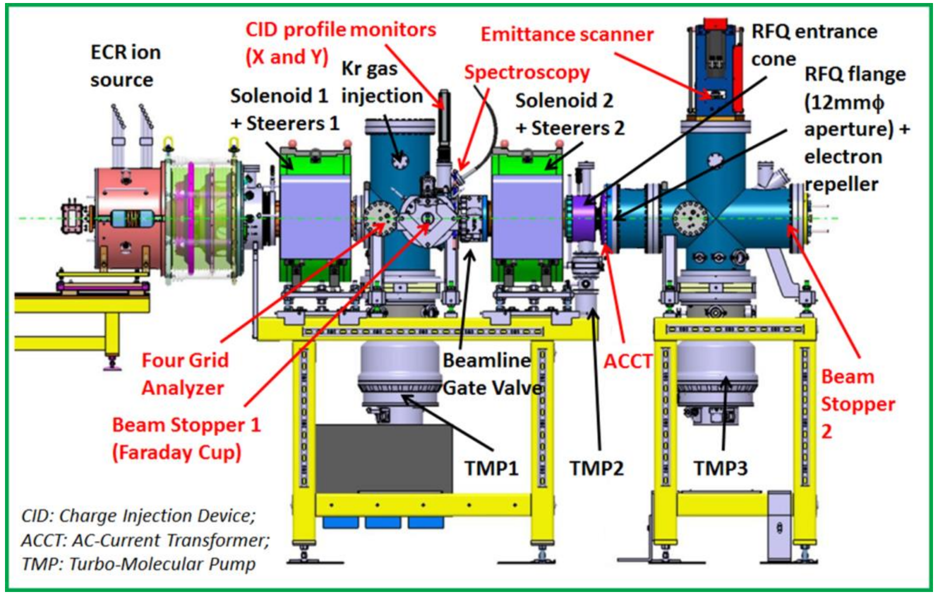
M. Comunian

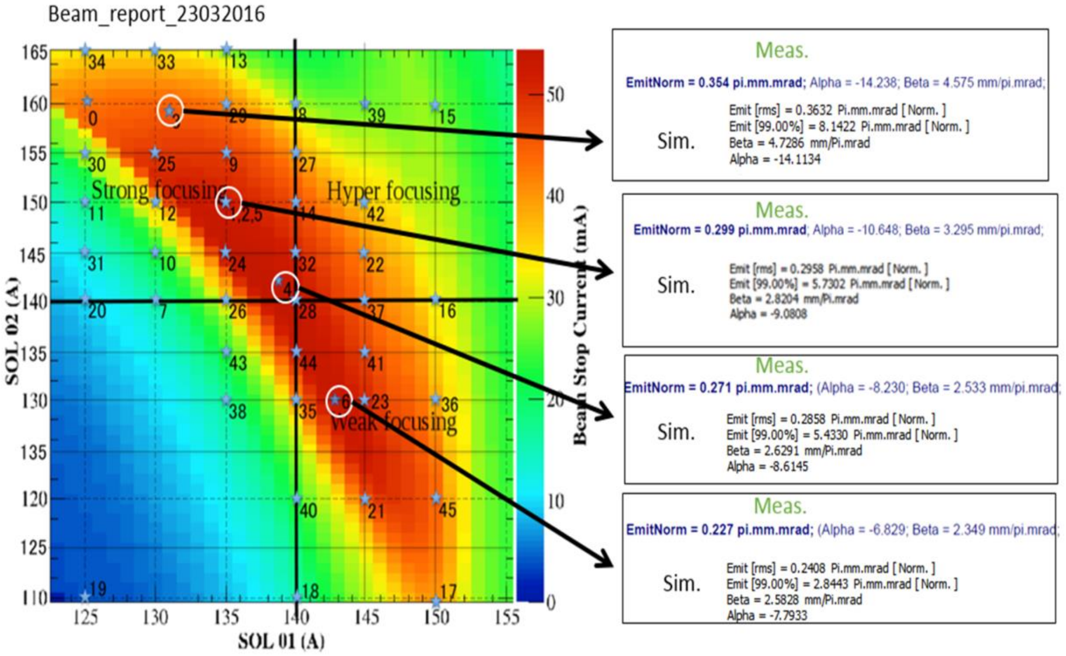
- Ongoing commissioning of the IS-LEBT
- Developed LEBT simulation using TraceWin
  - uniform 4D distribution with energy spread, intermediate I_b





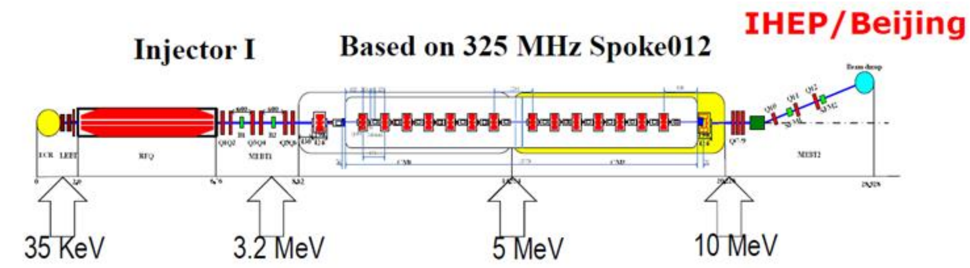
The emittance growth is mainly given by the coupling between the space-charge forces and the first solenoid non-linearity.

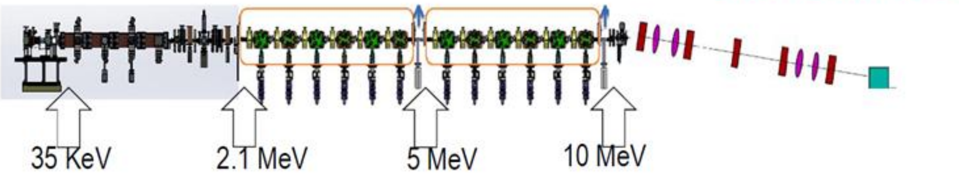




Commissioning of C-ADS Injector I

J. Cao





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
Continuously operating 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

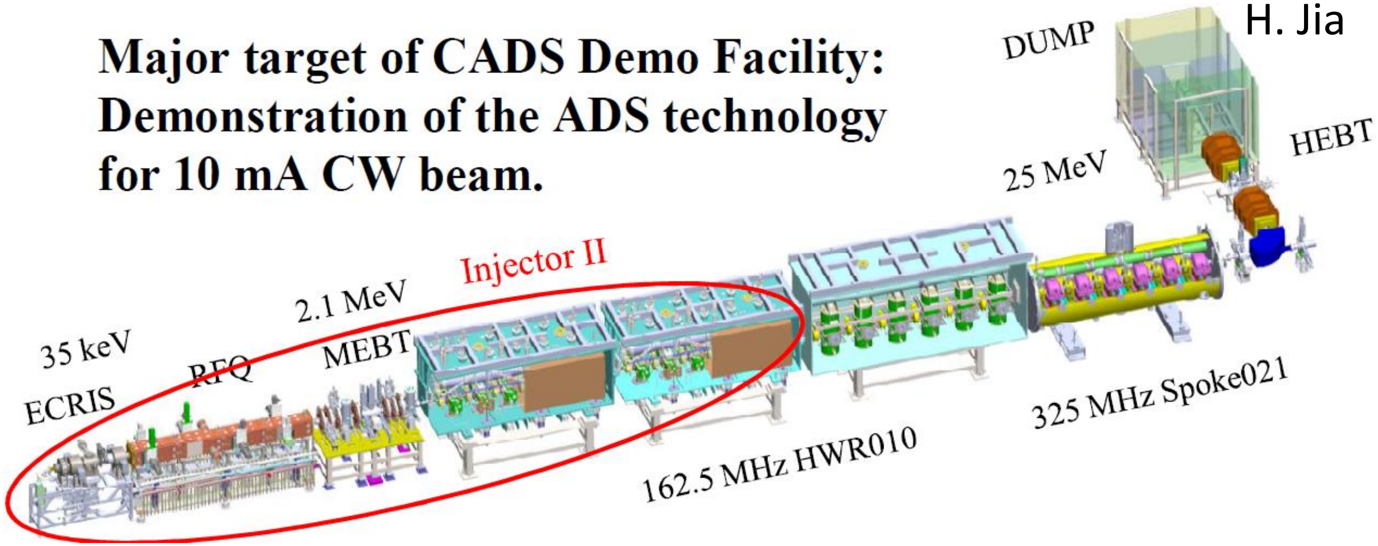
*Interlocked because of the temperature of the beam dump area over 60° .

- C-ADS Strategy (3-phase approach)
  - Parallel development of different schemes/ technology for the injector
    - Injector-I: 3.2 MeV, 325 MHz RFQ and SSR
    - Injector-II: 2,1 MeV, 162.5 MHz RFQ and HWR
- Commissioning Strategy
  - Characterize IS+LEBT with short beam pulse, low intensity and low-duty cycle
  - RFQ RF commissioning at pulse mode
    - issues encountered with CW mode – coupler damage and inexperience

Lessons of high-power CW beam commissioning of injector II of Chinese ADS

H. Jia

Injector II has commissioned CM1 with beam for 400 hours, in which 20 hours are CW beam



- <u>Two incidents</u>

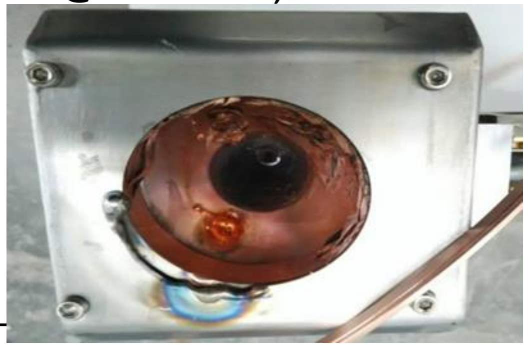
1. BPM signal input to MPS cause false trips to mis-triggered by electronics noise – caused component failure in the MPS system – **chopper** voltage dropped while CW beam was being transmitted

2. Misteering beam punched a hole on the water cooling lines of the FC

4 mA @ 4.6 MeV, CW 1.5 min

Chopper PS was not interlocked to MPS system

Up to 25 MeV, 10 mA, pulse beam commissioning before the end of 2016, collaboration with IHEP



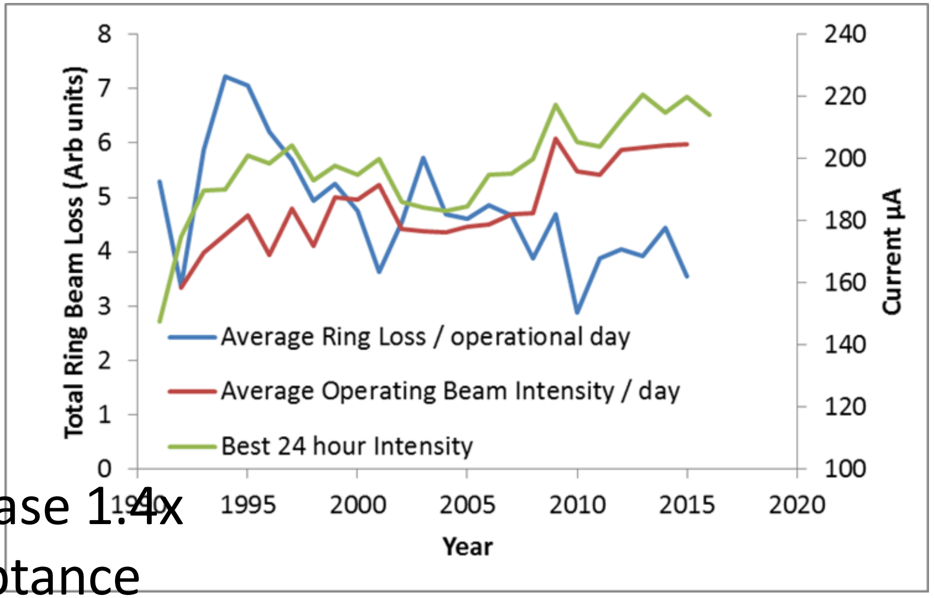
Operational Experience

Operational experience and future plans at ISIS

D. Adams

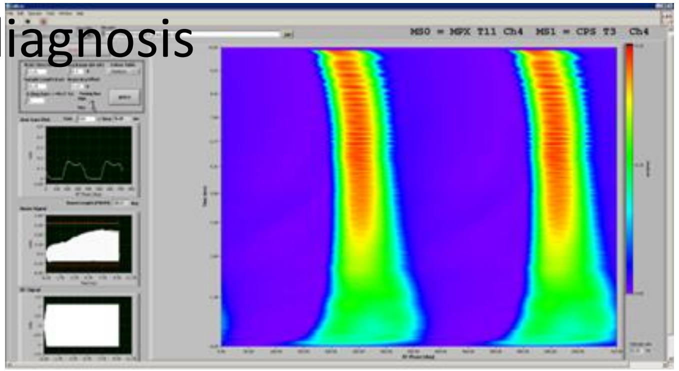
- Neutron and Muon source
- H- ion source (55 mA), 665 keV RFQ (35 (mA)
- 70 MeV linac (26 mA)
- 800 MeV 50 Hz, RCS (2.8×10^{13} ppp)

Tgt 1: 140 kW
Tgt 2: 36 kW



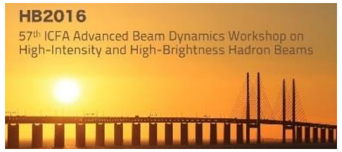
Series of machine upgrades contributed to lower losses

- Injector upgrade (CW 665 keV with RFQ), beam current increase 1.4x
- Added 4 RF cavities h=2, improve BF, improve RF bucket acceptance
- Continue managing beam losses – correct machine optics and envelopes
- Improve instrumentation to aid machine tune – fast measurement as a diagnosis



Future Upgrades

- Improve matching between RFQ and Linac –
- longer MEBT another factor of 1.4x Intensity
- Increase linac energy to 180 MeV or Multi MW Synchrotron or FFAG



Commissioning of the SPIRAL-2

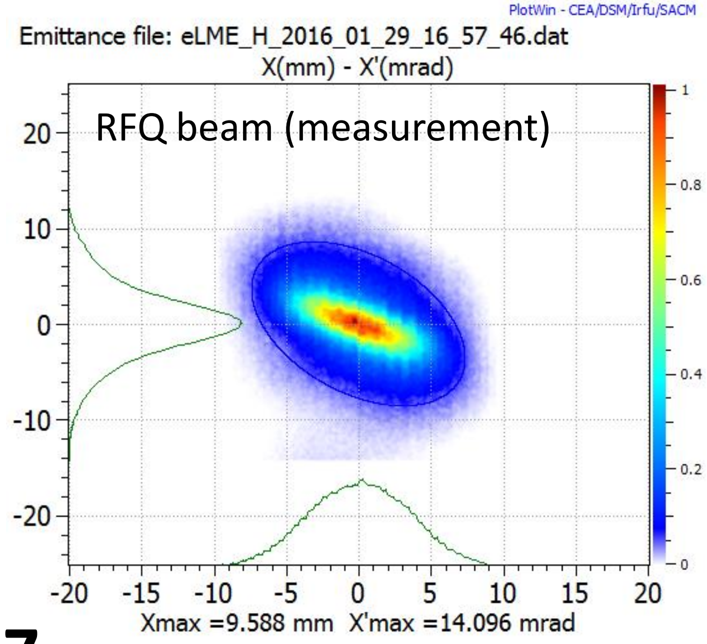
J-M. Lagniel

Good advances of the Spiral 2 project since January 2011

- Both light and heavy ion sources working well
- RFQ working well with protons and A/Q=2 ions (He and O)
  - Dec. 23, 2015 : First 5 mA CW proton beam (~100% transmission)
  - Jun. 04, 2016 : First CW A/Q=2 beam (~1 mA and >99% transmission)
- RFQ conditioned up to 96 kV

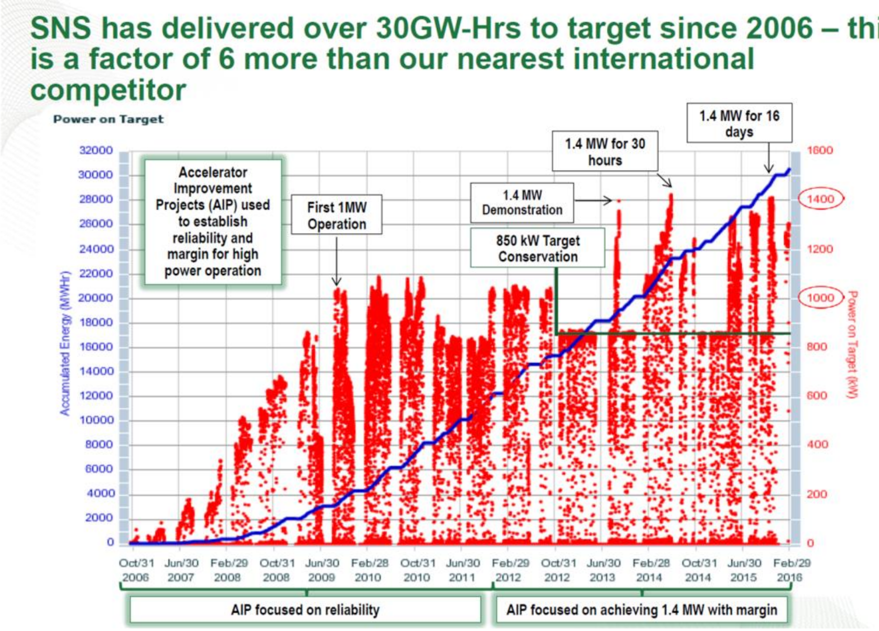
- RFQ improvements
  - RF amplifiers (reliability)
  - LLRF (variable freq. loop)
  - Tuning system (faster and stable)

- Superconducting linac
  - First cooling down this week
  - (cooling down of all the valve-boxes + 2 cryomodules)

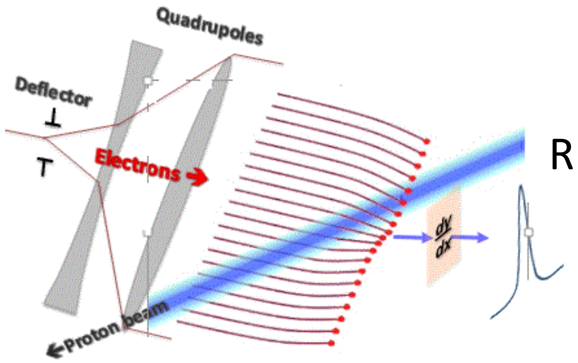


First linac beam beginning 2017

10 years Operation Experience SNS

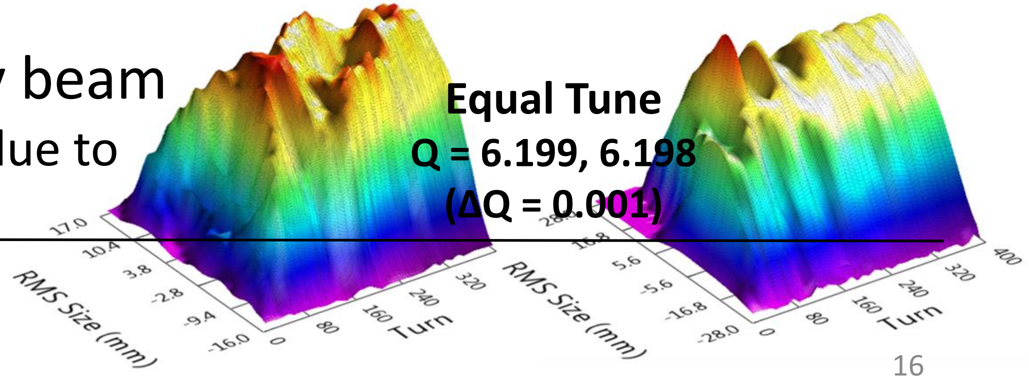


- SNS is an operational MW-class SCL proton accelerator
  - High reliability (90%), well instrumented (long., transv., laser-based), test bed for beam dynamics between H+ vs. H-, interesting beam instabilities at high intensities



R. Potts

- Interesting beam dynamics
  - Observed undesirable coupling between H/V painting planes
  - Only present at small tune split
  - Oscillations damped at high intensity
- ES non-intrusive profile measurement of high intensity beam
  - Look at the deflected projection of a tilted sheet of electrons due to the proton beam charge



Equal Tune
Q = 6.199, 6.198
(ΔQ = 0.001)

Coupled oscillation of beam shape (not just RMS)

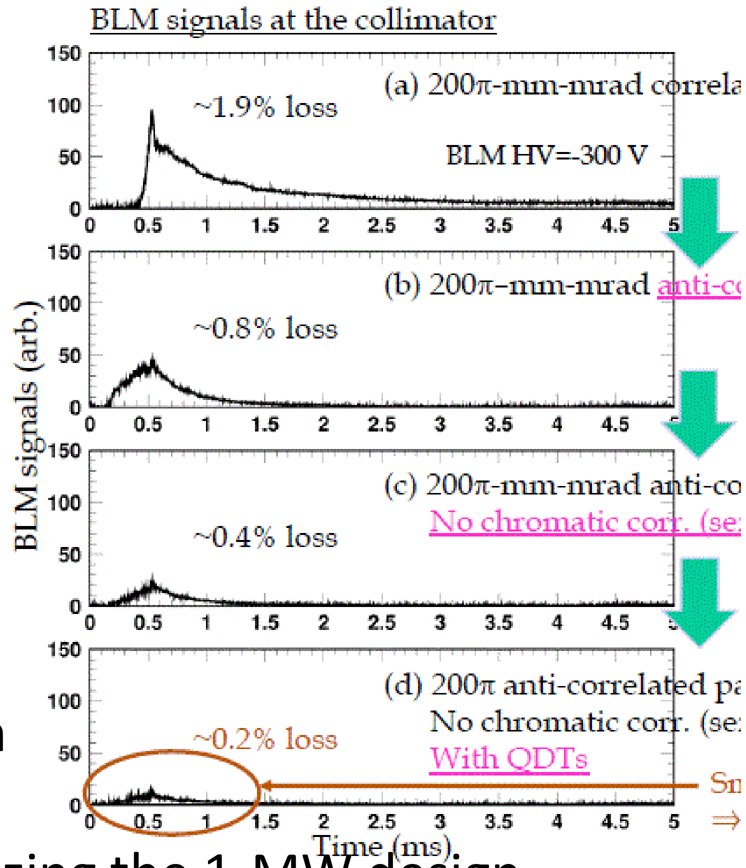
The Path to 1 MW : Beam Loss Control in the J-PARC 3-GeV RCS

H. Hotchi

- The J-PARC 3-GeV RCS successfully achieved a 1-MW beam acceleration in January 2015
- Beam loss control is a key issue for high-power “routine” beam operation

- Major beam losses
  - Space-charge induced beam loss in the low energy region
    - Minimized by transverse and longitudinal injection painting
  - Foil scattering beam loss during charge-exchange injection
    - Reduced by expanding transverse injection painting area via installation of quad. correctors & implementing anti-correlated painting

Transverse painting area was successfully doubly enlarged
foil scattering beam loss was drastically reduced

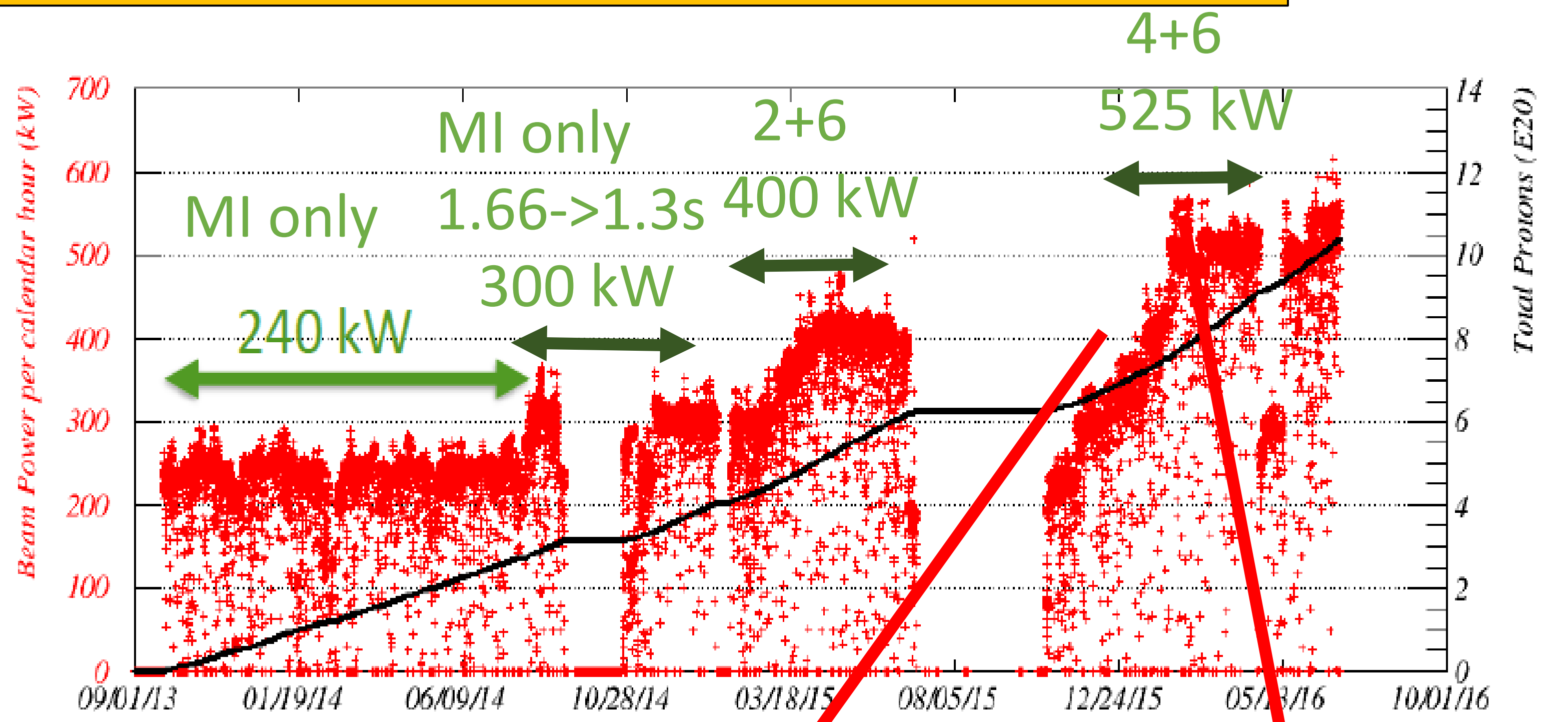


- Beam power temporarily limited to 200 kW => problems with neutron production target
- RCS beam commissioning itself is making steady progress toward realizing the 1-MW design beam operation

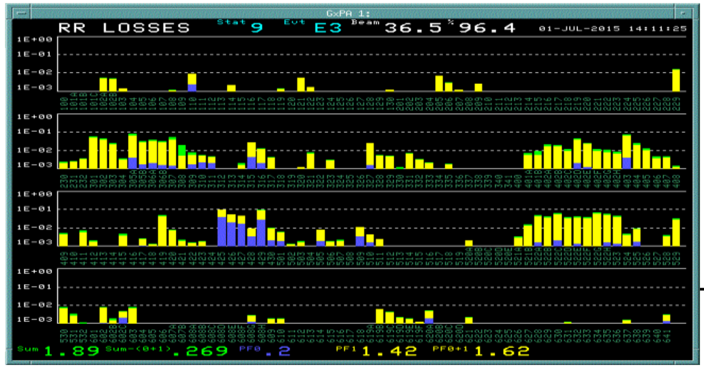
Reuse Recycler : High Power Proton Stacking at Fermilab

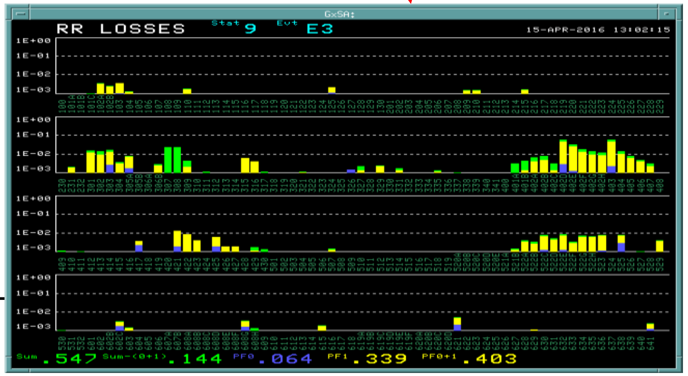
P. Adamson

- Re-purpose Recycler machine as a proton stacker for MI
- 4+6 & 6+6 – refer to number of slip-stacking bunches in Recycler
- Demonstrate 700 kW for 1 min.
  - Need to install collimators before reliably run at this level



Controlling beam losses





Factor of 3.5 reduction in RR losses by improving the apertures

HB2016
57th ICFA Advanced Beam Dynamics Workshop on High-Intensity and High-Brightness Hadron Beams

Operational Experience at KOMAC

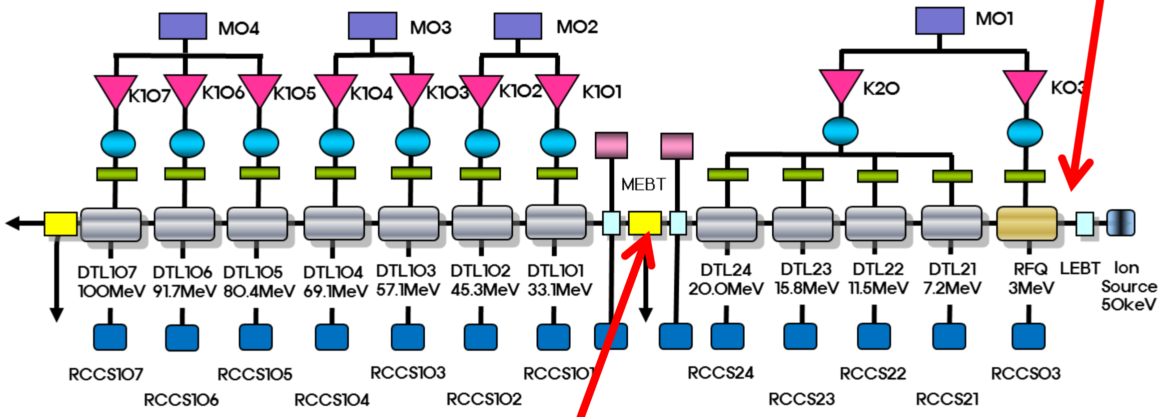
Yong-Sub Cho

- 20/100 MeV , Rep. Rate 120/60 % , up t0 5/1.6 mA

- Linac configuration
- MEBT located @ 20 MeV (not in injector area)
- 4 modulators drive 9 klystrons
- 1 klystron drives 4 cavities up to 20 MeV
  - Feed equal power to each DTL, phase adjusted by separate phase shifter
- 1 klystron / cav to final energy

- Operated weekly-based scheduled through all the year, close to ~90% availability

No MEBT between RFQ and DTL



- **MEBT @ 20 MeV for switch magnet**

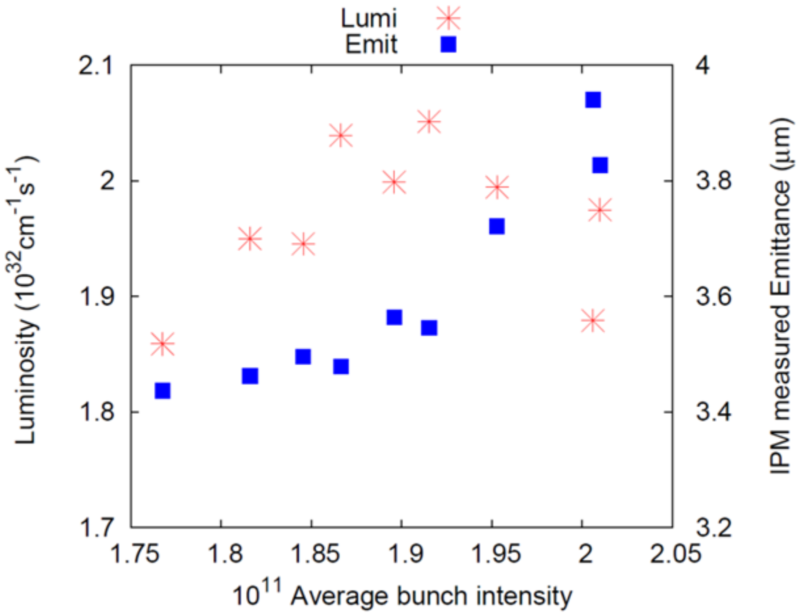
Issues:

CW plasma source coating with BN at high DC – frequent arc between electrode – typically ~ 500 hrs operation

RHIC Operations and E-lens Comm.

Xiaofeng Gu

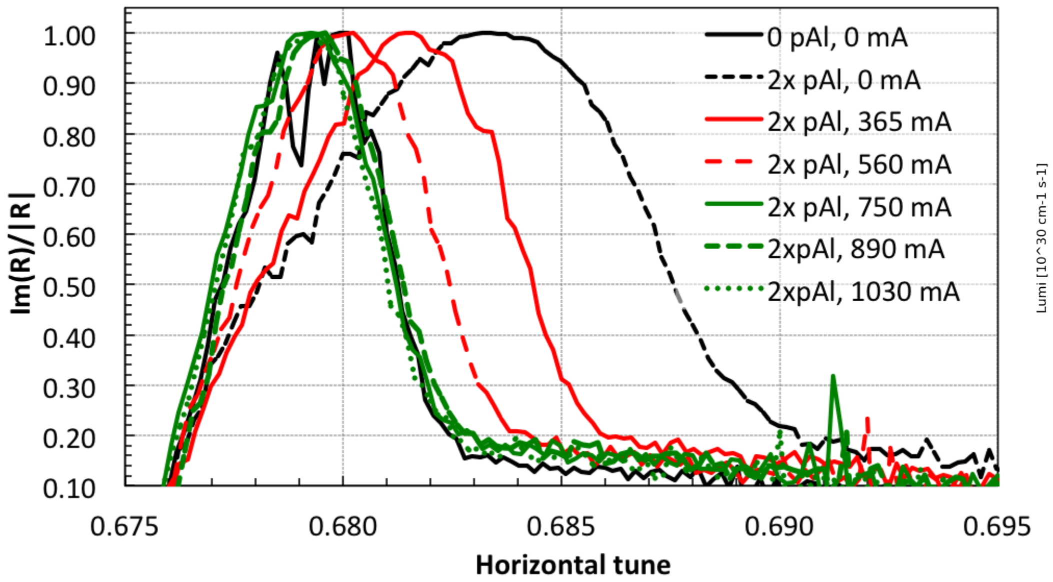
- Intensity limit in RHIC before 2015
- Polarized proton limited by intensity >2E11 emittance blow up
- Beam-beam compensation mechanism implemented using E-lens

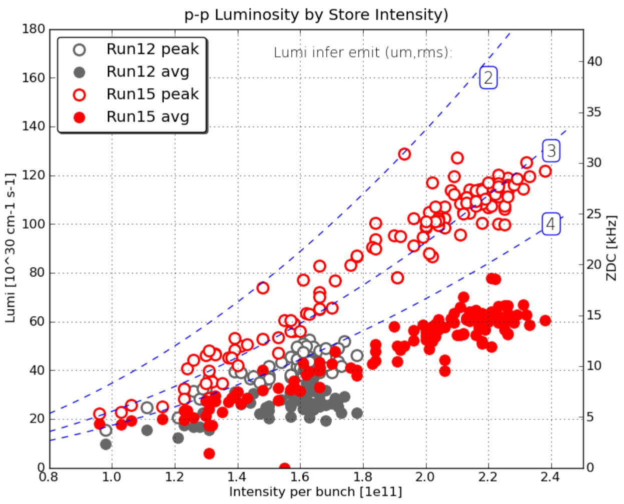


- Demonstration of tune spread compensation

  Tune spread is only compensate

  To the value w/o bb, even at high current





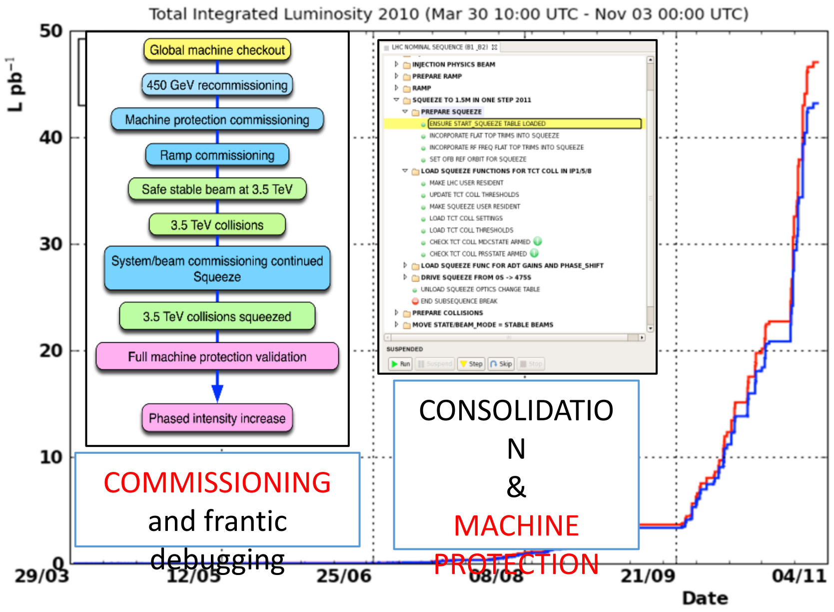
Factor of 1.5x lumi gain with lattice corrections and e-lenses compensation

Lessons from LHC Commissioning

M. Lemont

Nemesis September 19, 2008

- Start up in 2008 followed by a full re-commissioning end of 2009
- Year-long shut down in 2013 to upgrade the LHC up to 6.5 TeV
  - Period of hardware validation -> beam commissioning period
  - *"the ability to tackle problems has proved useful"*



Words of wisdom

- Start early planning – set goals and stick to them
- Pre-beam run is essential to shake out all the hardware systems
  - creates a trustful collaboration with the equipment's and the accelerator physicist's team

Some Takeaways on Commissioning Strategy

- Staged approach of the beam commissioning is crucial
- Schedule enough time in the commissioning phase for hardware checks
  - do not underestimate the time it takes for troubleshooting instrumentation
    - distinguish between instrument artifact and real beam issues
- Characterize the beam during each stage of the machine
  - Perform simulation and beam test comparison
    - facilitate interpretation of the results - **saves time later on…**
  - Initial commissioning at low intensity, low energy and low duty-cycle
  - Set initial set of parameters and measure transverse and longitudinal beam properties
  - Ramp-up current, pulse length and repetition rate
  - Iterative process – beam trajectories, verify transmission and beam losses
  - Long-term stability
- Administrative details
  - shielding assessment, safety approvals
  - accelerator operation readiness reviews

Final Remarks

On behalf of the WG-D conveners I would like to thank

- all the participants for active involvement and useful contributions during this week
- IOC for a successful workshop!