

Summary WG-B

D. Raparia, P.A.P Nghiem, Z. Li

Summary WG B

Number of Talks 18 + 2 (WG C)

Number poster 16

General beam dynamics 3

Projects design 15

Facility report 2

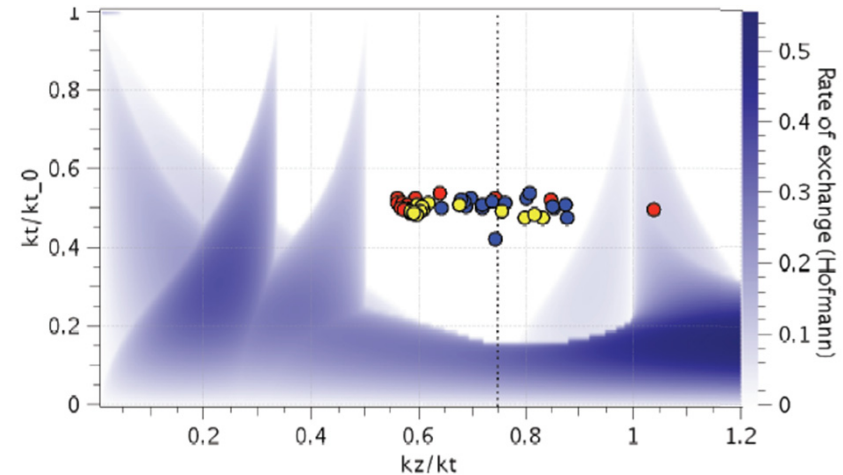
Emittance Coupling in the Intense Beam - I. Hofmann (GSI)

Main observation:

No need for EP from beam physics point of view – large "white areas"!

Questions:

1. Are the colored regions (stop-bands) always of concern?
2. Are the "white" regions (EP or non-EP) safe?
3. Crossing speed of resonances?
4. Is a single chart enough?
5. What is the physics meaning of the EP condition $\epsilon_z k_z : \epsilon_x k_x = 1$
6. ...



Charts indicate (colored) regions, where space charge coupling (by low order space charge modes) may occur

Regime 1: Crossing of main stop-band ($k_{0z}=69^\circ$)

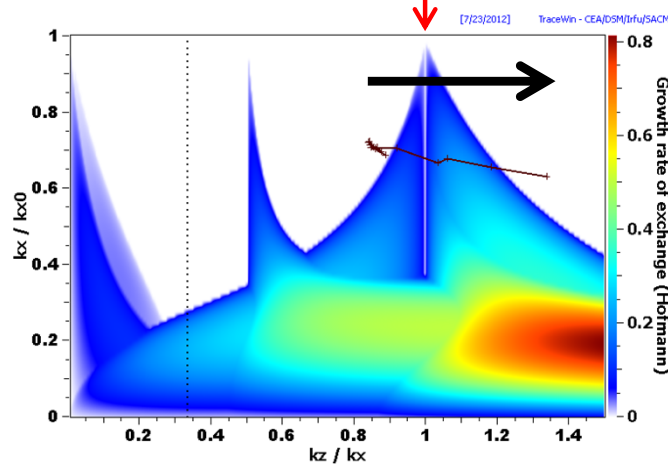
crossing speed dependent

Crossing over 5 FODO cells

$k_{0x}=85^\circ \dots 65^\circ$

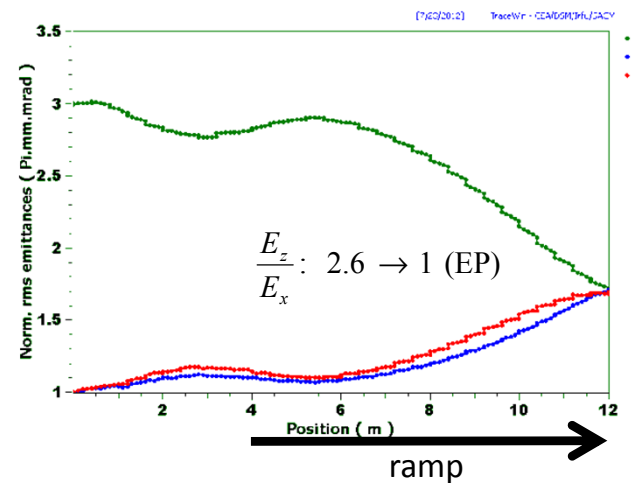
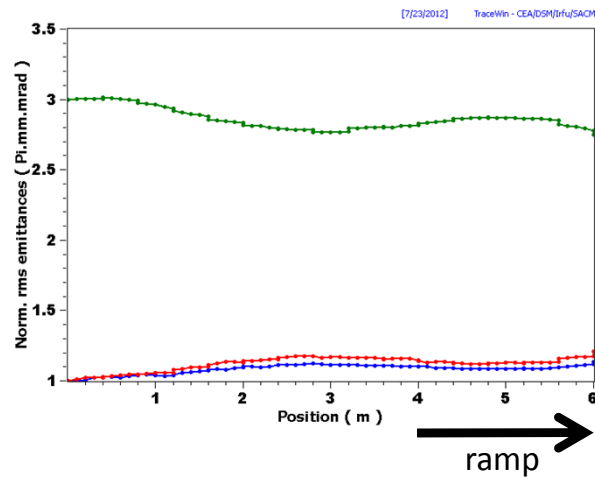
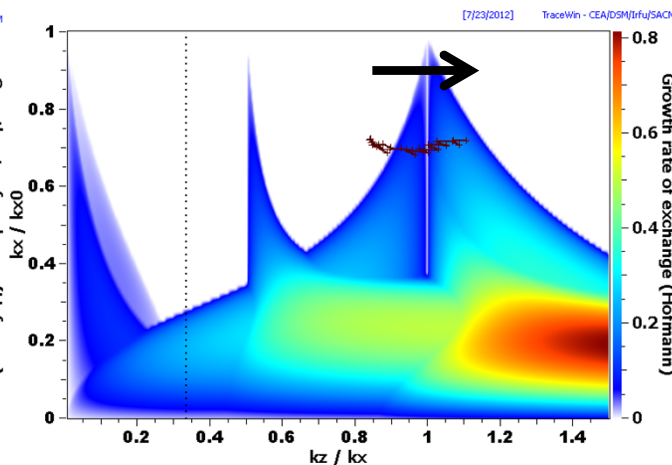
- slight exchange
- too fast!

$$\frac{E_z}{E_x} \equiv \frac{\varepsilon_z k_z}{\varepsilon_x k_x} \approx 3$$



Crossing over 20 FODO cells $k_{0x}=85^\circ \dots 65^\circ$

- leads to $\sim$ EP
- notice about 2x less swing in k_z/k_x



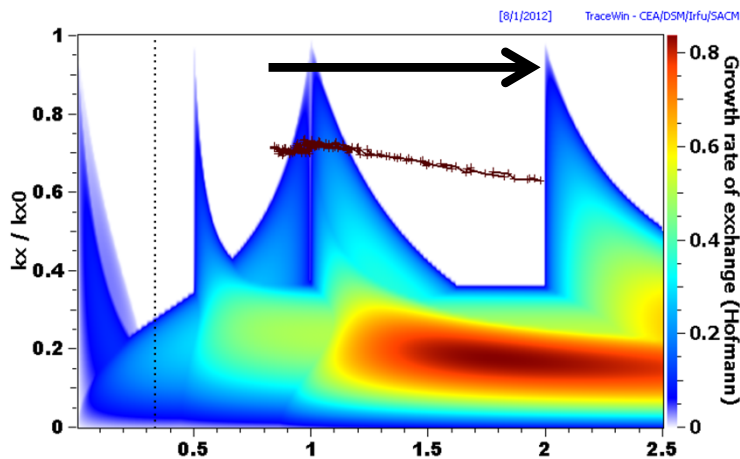
Complex behaviour far beyond ($k_{oz}=69^0$)

splitting of transverse emittances – x-y away from initial EP!

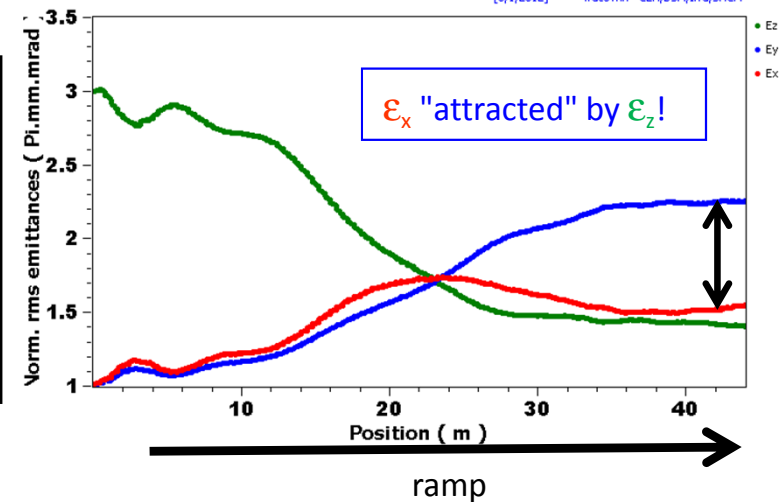
Crossing over 100 FODO cells

$k_{0x}=85^0...45^0$

- full exchange, **splitting of x and y**



$\frac{E_z}{E_x}$	2.6	$\rightarrow$	1	$\rightarrow$	2
$\frac{E_z}{E_y}$	2.6	$\rightarrow$	1	$\rightarrow$	1.2
$\frac{E_x}{E_y}$	1	$\rightarrow$	1	$\rightarrow$	0.6



- Dynamical tune behavior confirms charts - white regions "safe" $\rightarrow$ **EP not necessary!**
- Emittance exchange depends on crossing speed (inversely proportional) of resonance stop-bands
- On resonances emittance evolution "**towards**" EP, but sometimes complex details (splitting of transverse emittances)
- **Additional physics not addressed by stability charts:**
 - Structure resonances or instabilities – how slow tune change?
 - Robustness against mismatch & errors?
 - ...

Equipartition Reality or Swindle

J. M. Gagniel (GNANIL)

- Raises question about validity equipartition
- We had long discussion about it , he summarize as follows
 - 1- The linac beams are out of the EQP theorem validity limit, to apply the “EQP rule” designing a linac is a mistake
 - 2- The application of the “EQP rule” do not prevent emittance exchanges induced by coupling resonances
 - 3- Safe tunes with beam footprints out of the coupling resonances can be found more easily when the “EQP rule” is not respected

Equipartition Reality or Swindle (cont.)

4- The constraint imposed by the “EQP rule” on a linac design can lead to a non optimized beam dynamics and higher construction and operation costs

5- The question of energy exchange / emittance transfer must be analyzed as done in circular machines (tune diagram, evaluation of the excitation strength)

6- The “modern physics” tools developed to characterize the level of disorder (chaos) present in nonlinear Hamiltonian systems could be applied to characterize and optimize our beams

(Service offer !)

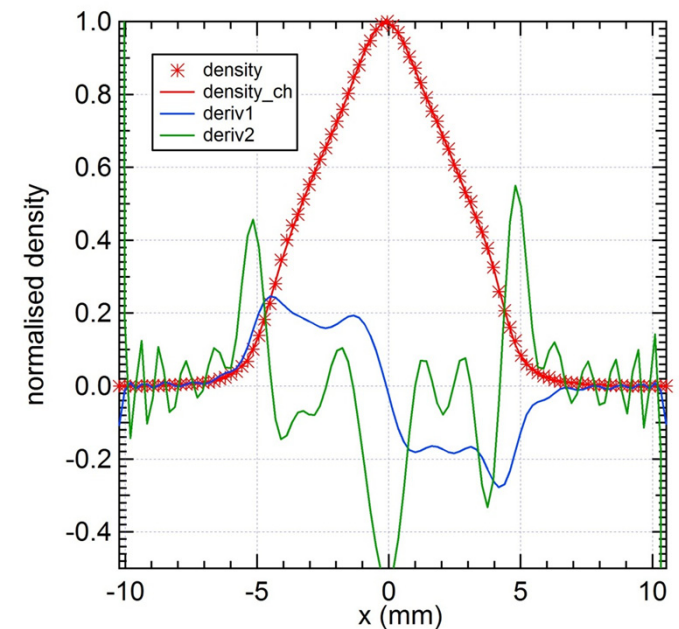
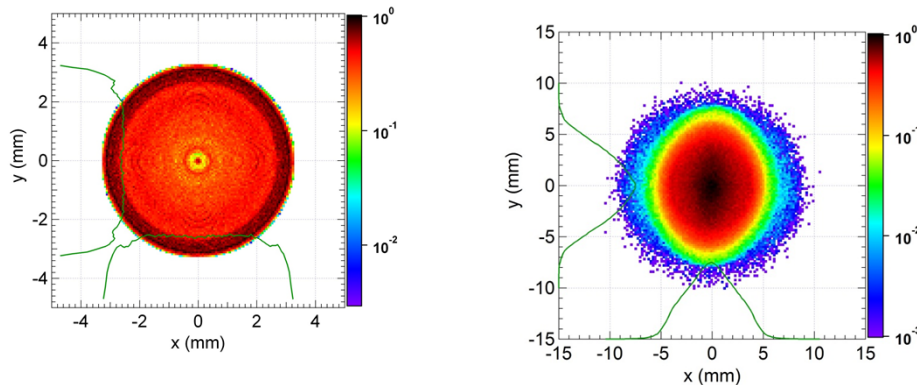
Definition of Halo- P.A.P Nghiem

The diffusion equation

$$dn/dt = D\Delta n$$

states that the diffusion is maximum where the Laplacian of the density is maximum: this is the border between the two parts

1 dimension: max of the second derivative
n dimensions: max of the Laplacian



Once the limit core-halo is defined, the halo can be characterised by

- its size / whole size
- the number of particles within it / whole number of particles

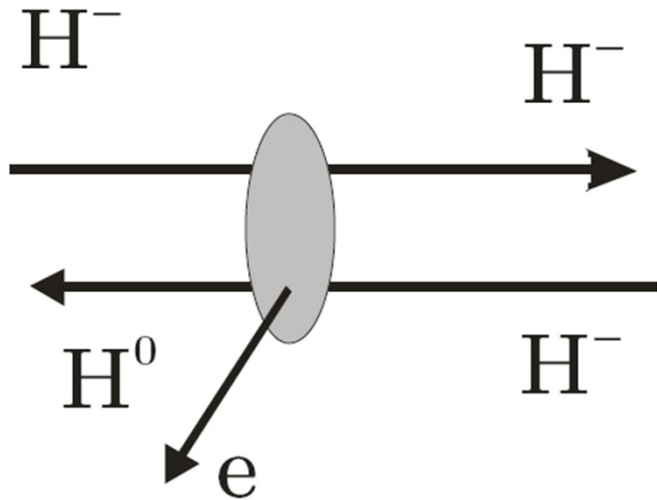
- Halo size (%) or/and NbrPart (%) seem to correspond to Emittance growth
- Even seem to be more detailed beam description, more pertinent than Emittance

Beam Loss Mechanisms in High Intensity Facility- M.A. Plum (ORNL)

- There are many different and interesting beam loss mechanisms in high-intensity H^+ and H^- linacs
 - Intra-beam stripping
 - Residual gas stripping
 - H^+ capture and acceleration
 - Field stripping
 - Black body radiation stripping
 - Dark current from ion source
 - Beam halo/tails (resonances, collective effects, etc.)
 - RF and/or ion source turn on/off transients

Intra Beam Stripping (Valeri Lebedev, FNAL)

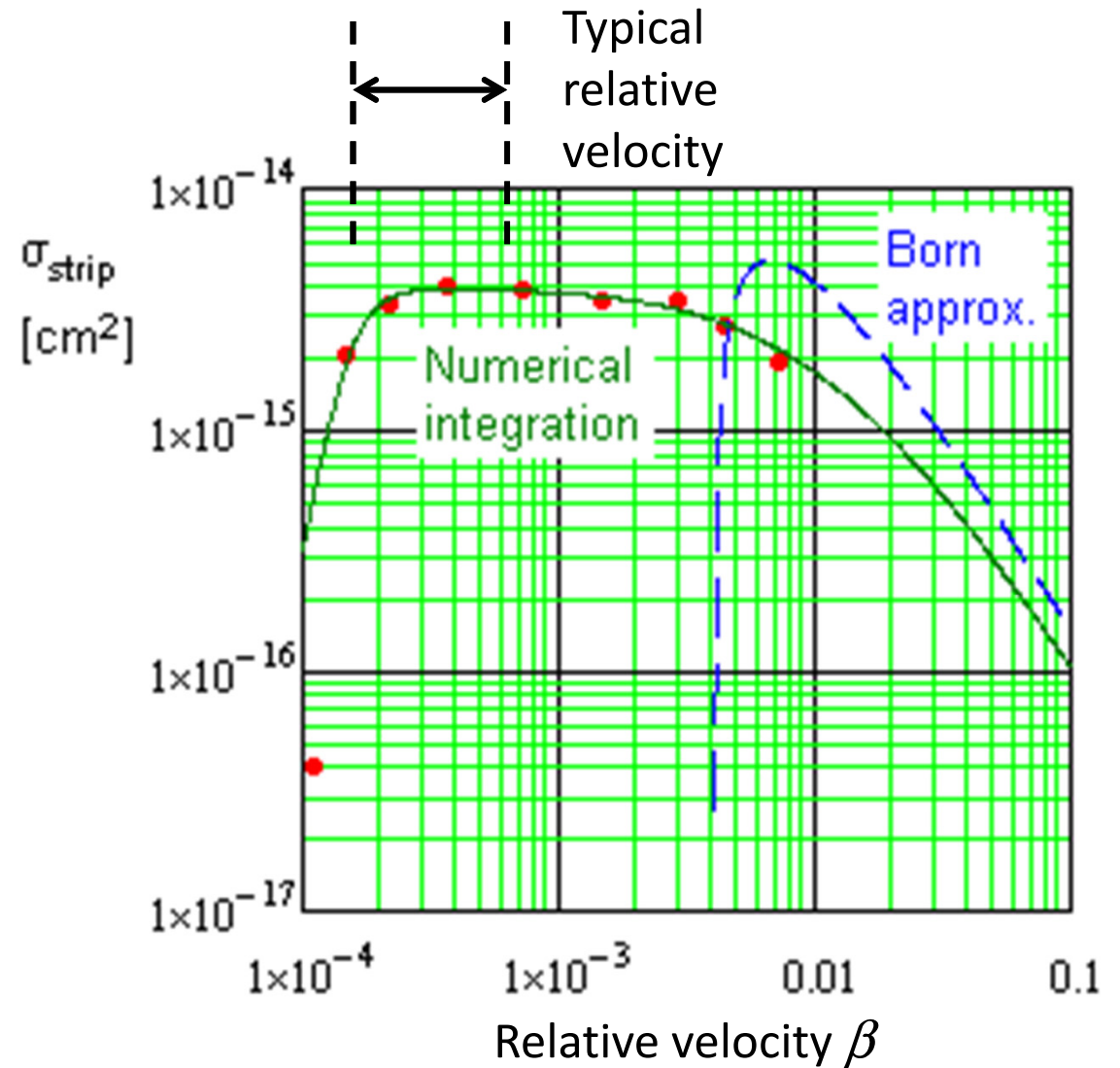
(Talk at SNS, ORNL, October 2010)



Integral SCL losses estimation:
 4×10^{-5} fractional loss

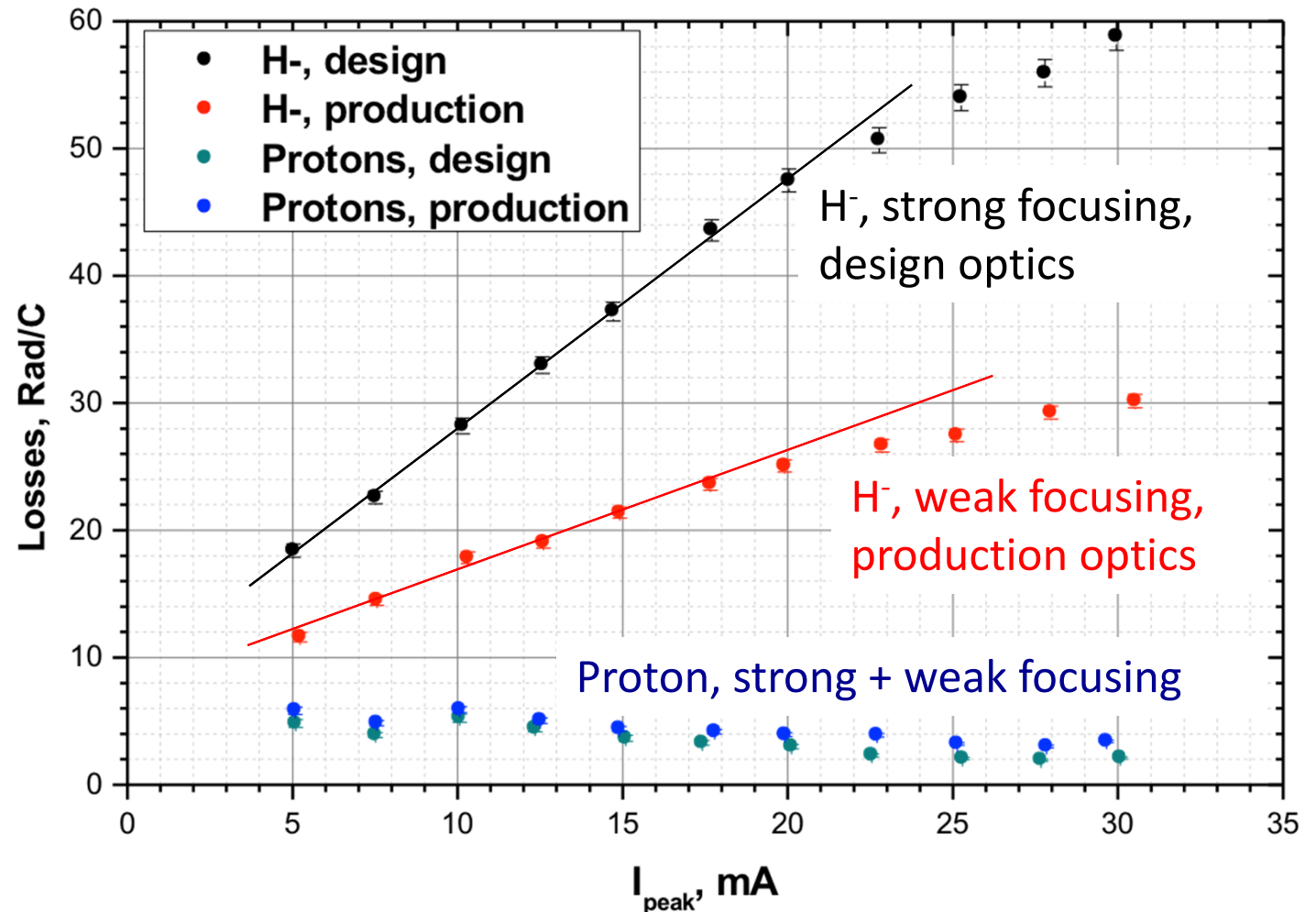
Measured SCL losses
 $(2-7) \times 10^{-5}$ fractional loss

$$dn / dt \propto \sigma \cdot n^2$$



SCL Losses vs. Peak Current

- H^- beam loss is up to 20 times lower than H^+ beam loss
- Normalized H^- beam loss is proportional to ion source current, consistent with IBSt expectations



“First Observation of Intrabeam Stripping of Negative Hydrogen in a Superconducting Linear Accelerator,” A. Shishlo, J. Galambos, A. Aleksandrov, V. Lebedev, and M. Plum, Phys Rev Letters 108, 114801 (2012).

Technical Challenges in Multi MW linacs

V. A. Lebedev (Fermilab)

Spallation Neutron sources

- SNS (Oakridge, USA): 1 MW, 0.9 GeV, 38 mA with 5.1%DF, 0.85 ms@60 Hz
- ESS – (Lund, Sweden): 5 MW, 2.5 GeV, 50 mA, 4% DF, 2.86 ms @ 14 Hz
- CSNS (China): 0.1 MW, 81 MeV H- DTL + 1.6 GeV RCS

ADS – Accelerator driven systems

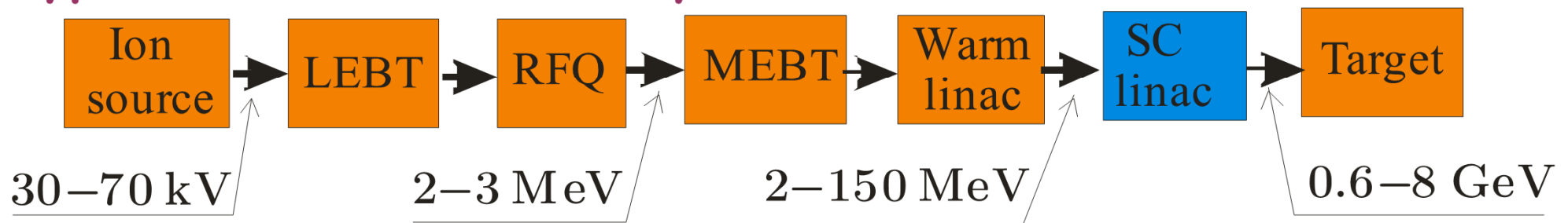
- MYRRRA (Belgium): 2.4 MW, 0.6 GeV, 4 mA, CW
- Indian ADS: 30 MW, 1 GeV, 30 mA, CW
- China ADS: $P \gg 1$ MW, 1.5 GeV SC linac to support operation of 1 GW reactor

Physics intensity frontier

- SPL (CERN): 4 MW, 5 GeV, 40 mA, 0.4 ms with 100%DF, 0.4 ms@50 Hz
- Project X (Fermilab, USA) – 3 MW, 3 GeV, 1 mA*, CW + 8 GeV pulsed linac
 - * Bunch population corresponds to 10 mA @ 325 MHz
- FRIB – 0.4 MW, >0.2 GeV/u, 0.65 mA el. current of multi-charged ions

Introduction (continue)

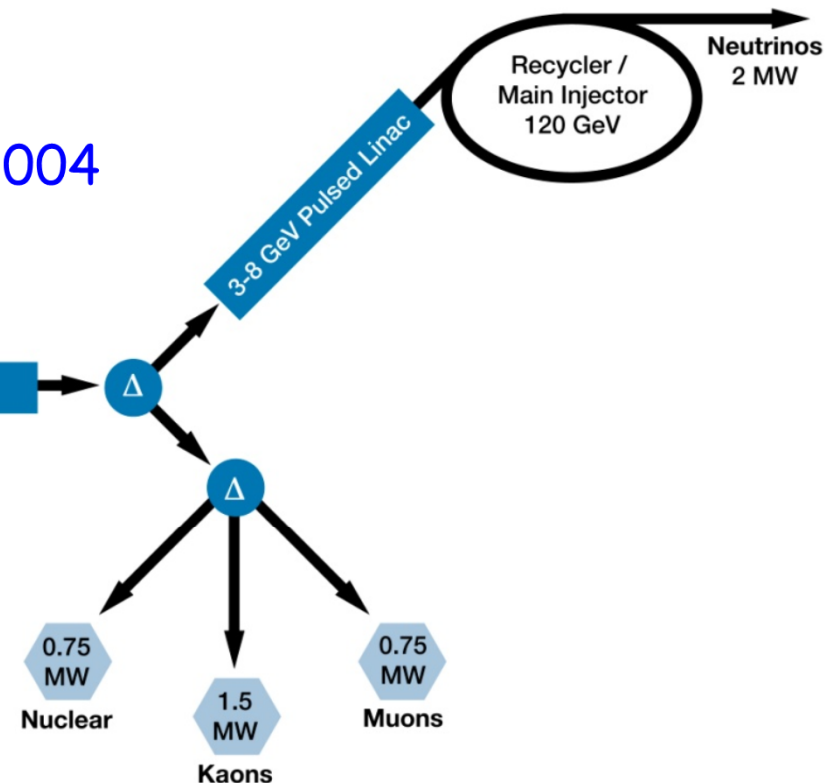
Typical SC Proton Linac Layout



- Length of warm linac is decreasing with development of SC technology

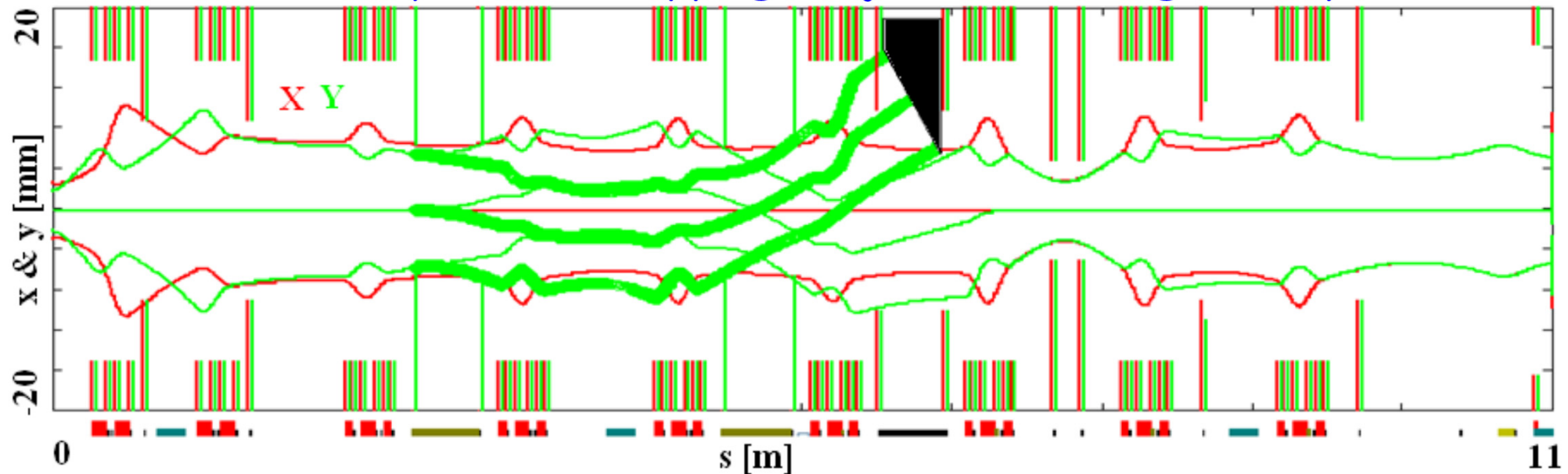
- ◆ SNS: DTL to 87 MeV, CCL to 186 MeV
 - SC part starts with elliptic cavities
 - The only technology “trustable” in ~2004
- ◆ ESS: DTL accelerates to 50 MeV
 - SC part starts with triple spoke
- ◆ Project X linac
 - SC part starts after RFQ

- Project X linac has largest number of different cavity types
 - ◆ Most diverse machine compared to other proposed project



Project X MEBT

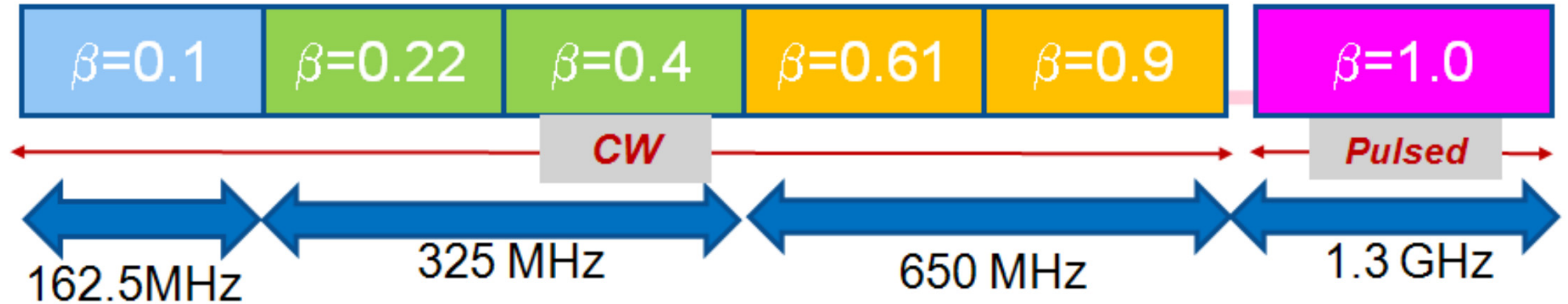
- Due to bunch-by-bunch chopping Project X has long & complex MEBT



- Triplet focusing with ~ 90 deg. phase advance per cell
 - ◆ minimizes beam sizes and creates "smooth" focusing
 - $\Rightarrow$ small emittance growth
- Three RF cavities: 162 MHz, 100 kV (amplitude)
- Two kickers to obtain acceptable voltage (power)
 - ◆ Kickers are separated by 180 deg in betatron phase
- Incoming H^- beam brings large volume of H_2 : $5 \text{ mA} = 4.4 \cdot 10^{-4} \text{ l} \cdot \text{torr/s}$
 - ◆ Differential pumping ($\varnothing 10 \text{ mm}$)
 - to reduce gas flux from absorber to SC cavities

Project X SRF Linac Technology Map

- 5 types of SC cavities are required for Stage I

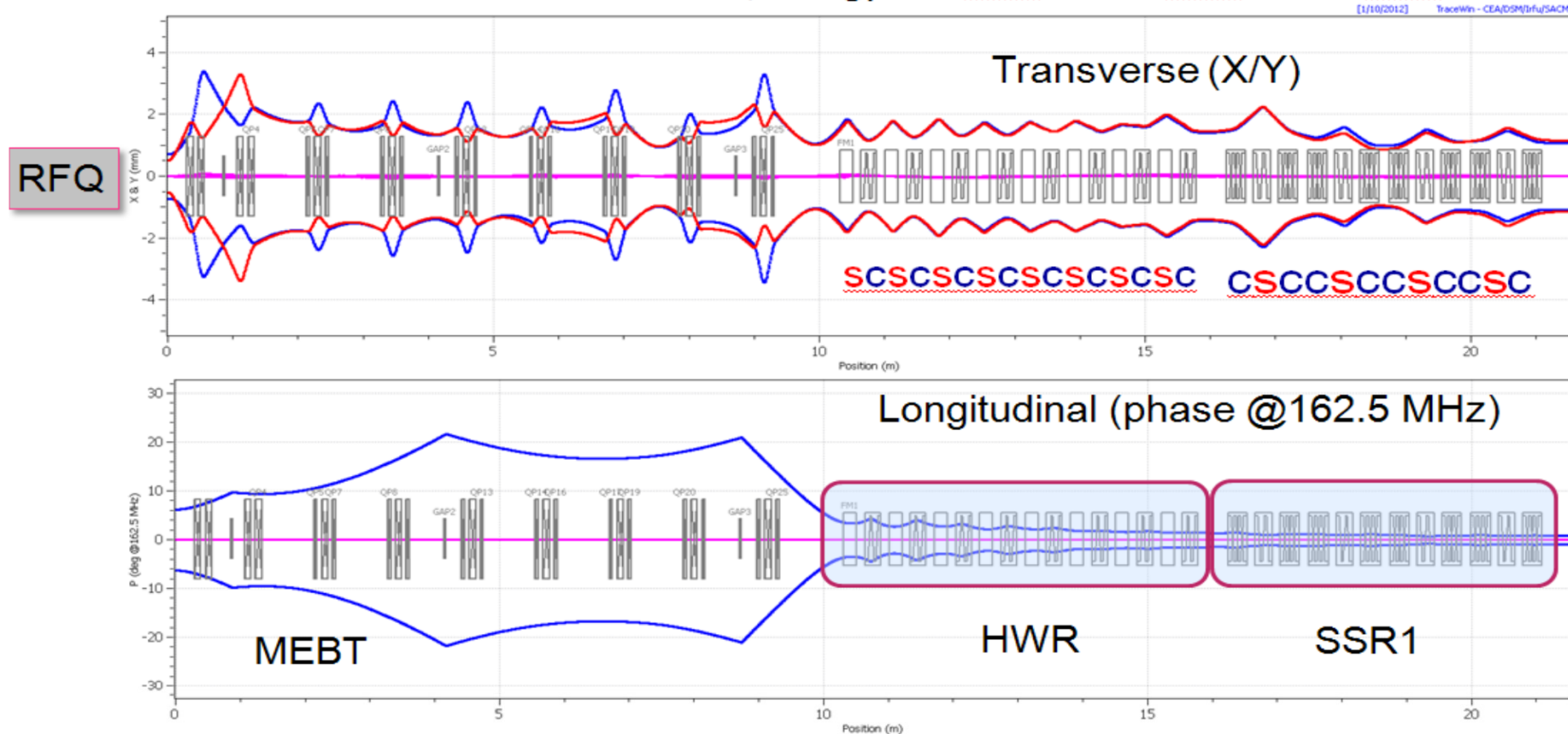


Section	Freq	Energy (MeV)	Cav/mag/CM	Type
HWR ($\beta=0.1$)	162.5	2.1-11	8 /8/1	HWR, solenoid
SSR1 ($\beta=0.22$)	325	11-38	16/8/ 2	SSR, solenoid
SSR2 ($\beta=0.47$)	325	38-177	36/20/4	SSR, solenoid
LB 650($\beta=0.61$)	650	177-467	30 /10/5	5-cell elliptical, doublet
HB 650($\beta=0.9$)	650	467-2000	96/12/12	5-cell elliptical, doublet
ILC-CW($\beta=1.0$)	1300	2000-3000	72/9/9	9-cell elliptical, quad
ILC-pulsed($\beta=1.0$)	1300	3000-8000	224 /28 /28	9-cell elliptical, quad

SC Linac Beam Dynamics

- Strong space charge effects in Project X SC linac
- Bunch population corresponds to 10 mA beam current at 325 MHz
 - ◆ 80% bunches are chopped out & RFQ at half frequency (162.5 MHz)
 - ◆ Nearly the same beam brightness as at the SNS

Current 5 mA@162.5 MHz; Energy: 2.1 MeV – 10.8 MeV – 22.1 MeV



- SC - CS transition between cryomodules
- Moderate emittance growth - 40% - transverse; 60% - longitudinal

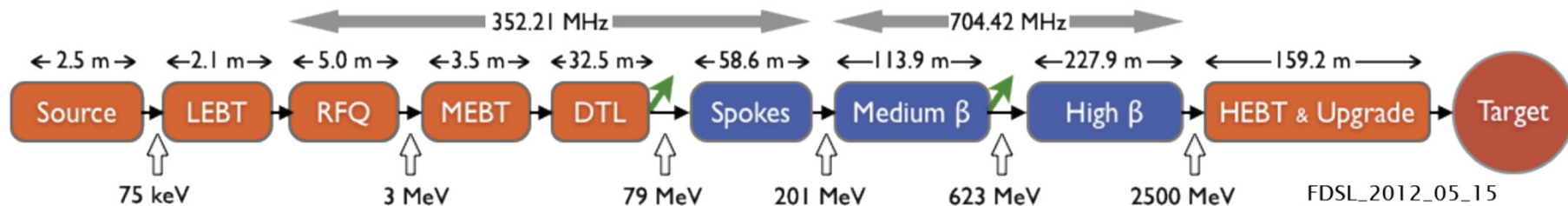
Conclusions

- SC linacs look as a great technology for the multi-MW proton accelerators
- Recent improvements in surface treatment greatly improved Q values for SC cavities and push operating gradient beyond 20 MV/m
 - ◆ At 1.3 GHz the Q-value of 7.5×10^{10} at 2 K and at a 20 MV/m were achieved (A. Romanenko, A. Grassellino, 2012, Fermilab)
- There are no insurmountable physics or engineering problems to be overcome
 - ◆ Making cavities still require extensive R&D
 - ◆ Getting experience in the SRF design and development is irreplaceable for any organization making and/or developing SRF cavities
- These SRF developments will affect many fields
 - ◆ HEP, Nuclear energy, solid state and nuclear physics, chemistry, biology ...

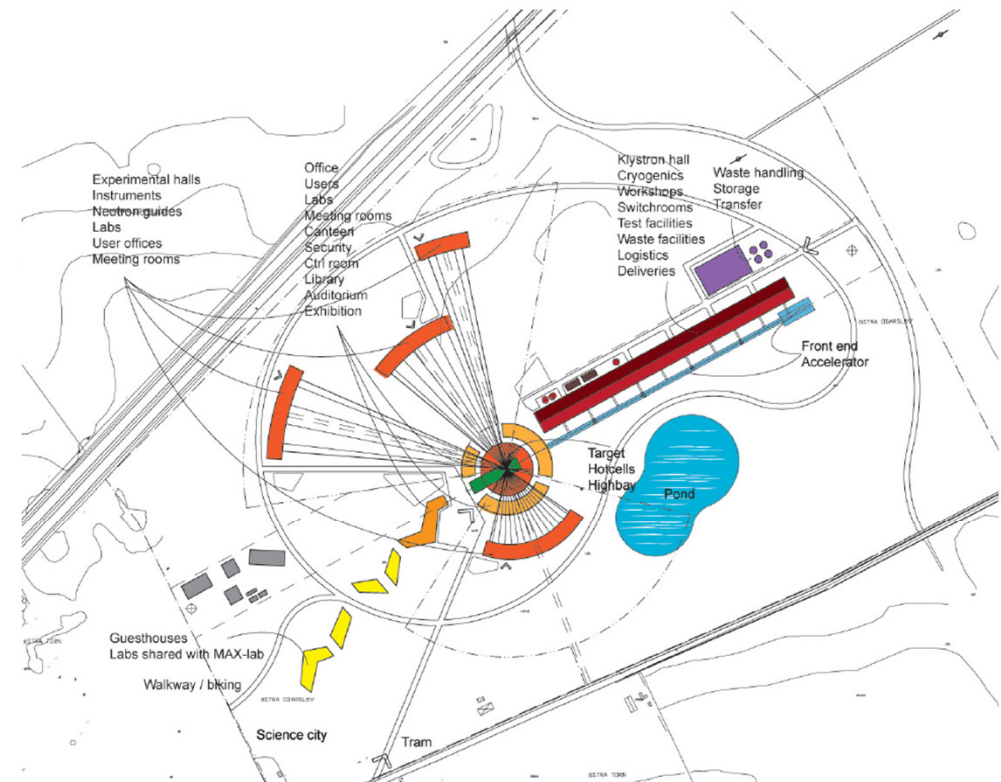
Beam dynamics of ESS

Warm linac: M. Comunian (INFN/LNL)

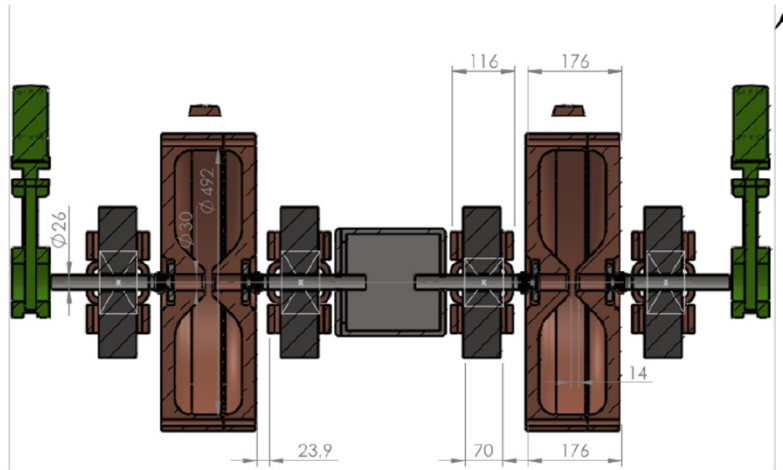
Super conducting linac: M. Eshraqi (ESS)



Particle species	p
Energy	2.5 GeV
Current	50 mA
Average power	5 MW
Peak power	125 MW
Pulse length	2.86 ms
Rep rate	14 Hz
Max cavity surface field	40 MV/m
Operating time	5200 h/year
Reliability (all facility)	95%



From a short to long MEBT

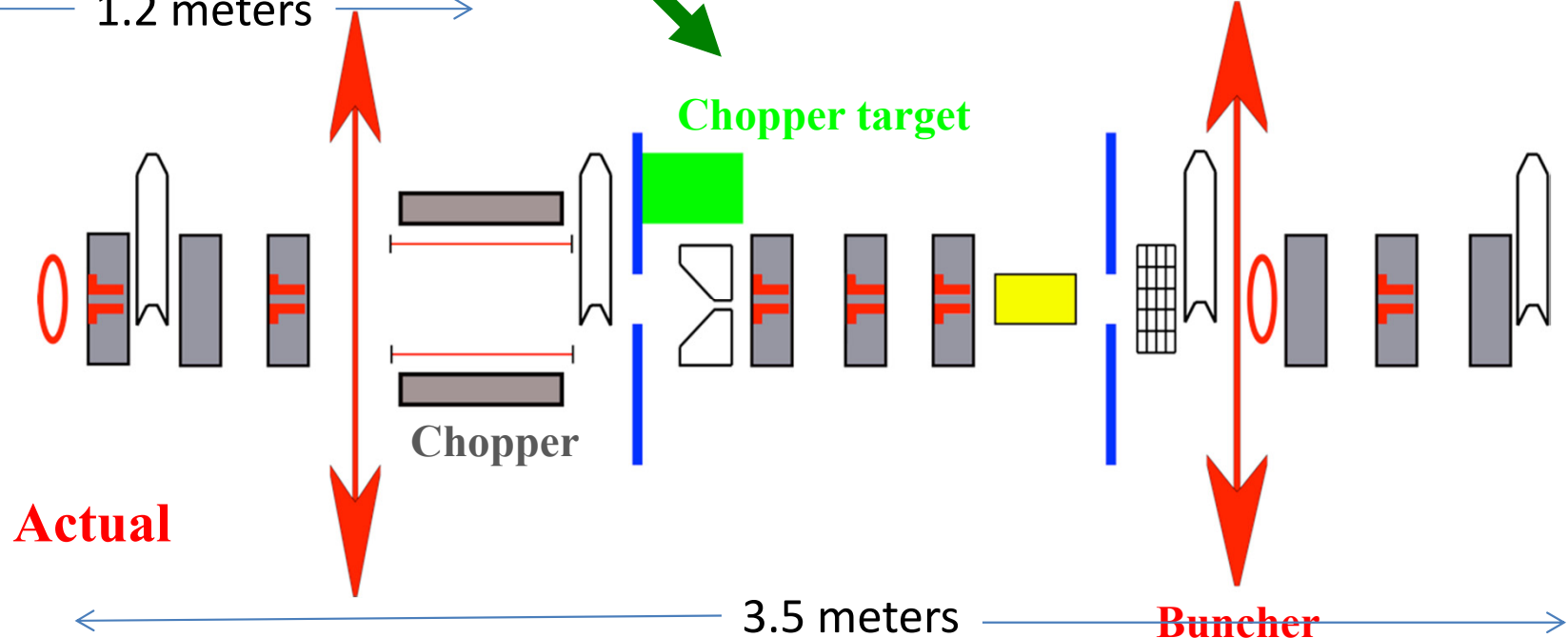


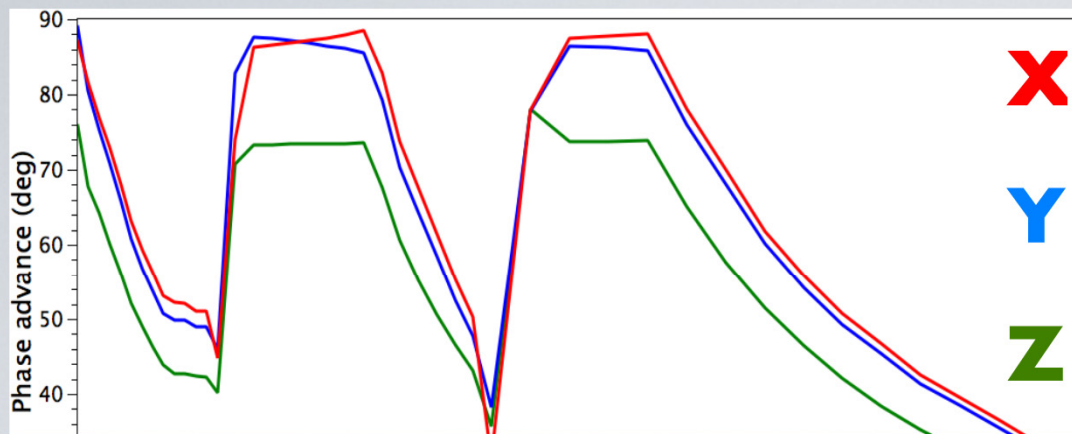
From the May 2012 baseline, the MEBT was extended to include

- Fast chopper
- Beam instrumentation
- Collimation

In CDR

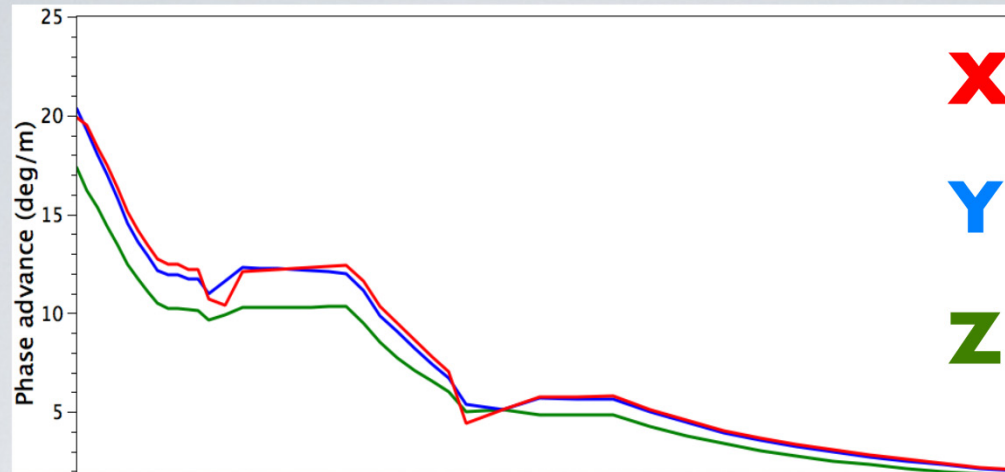
1.2 meters





RULES OF THUMB II

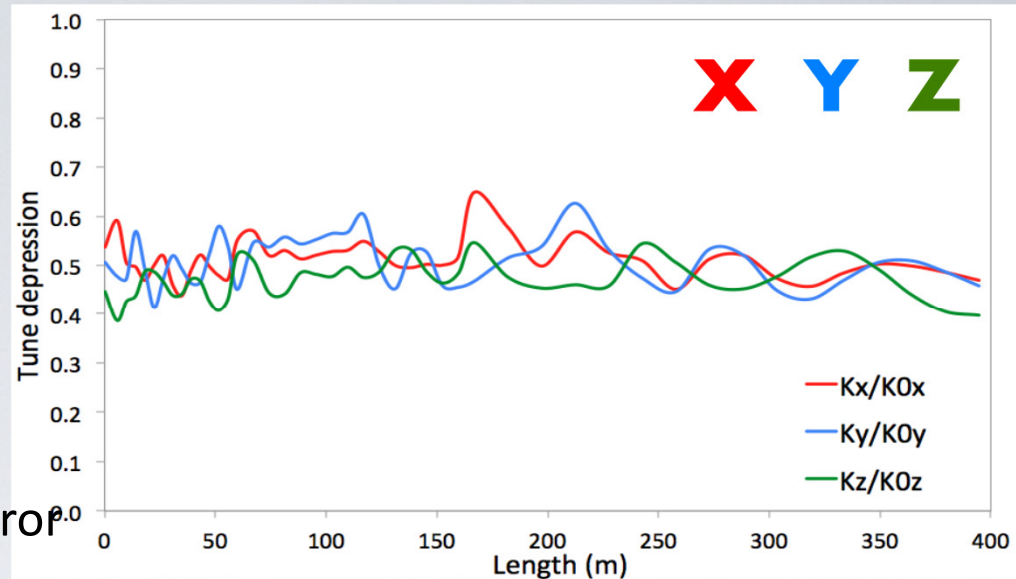
Phase advance per transverse period is limited to 87°



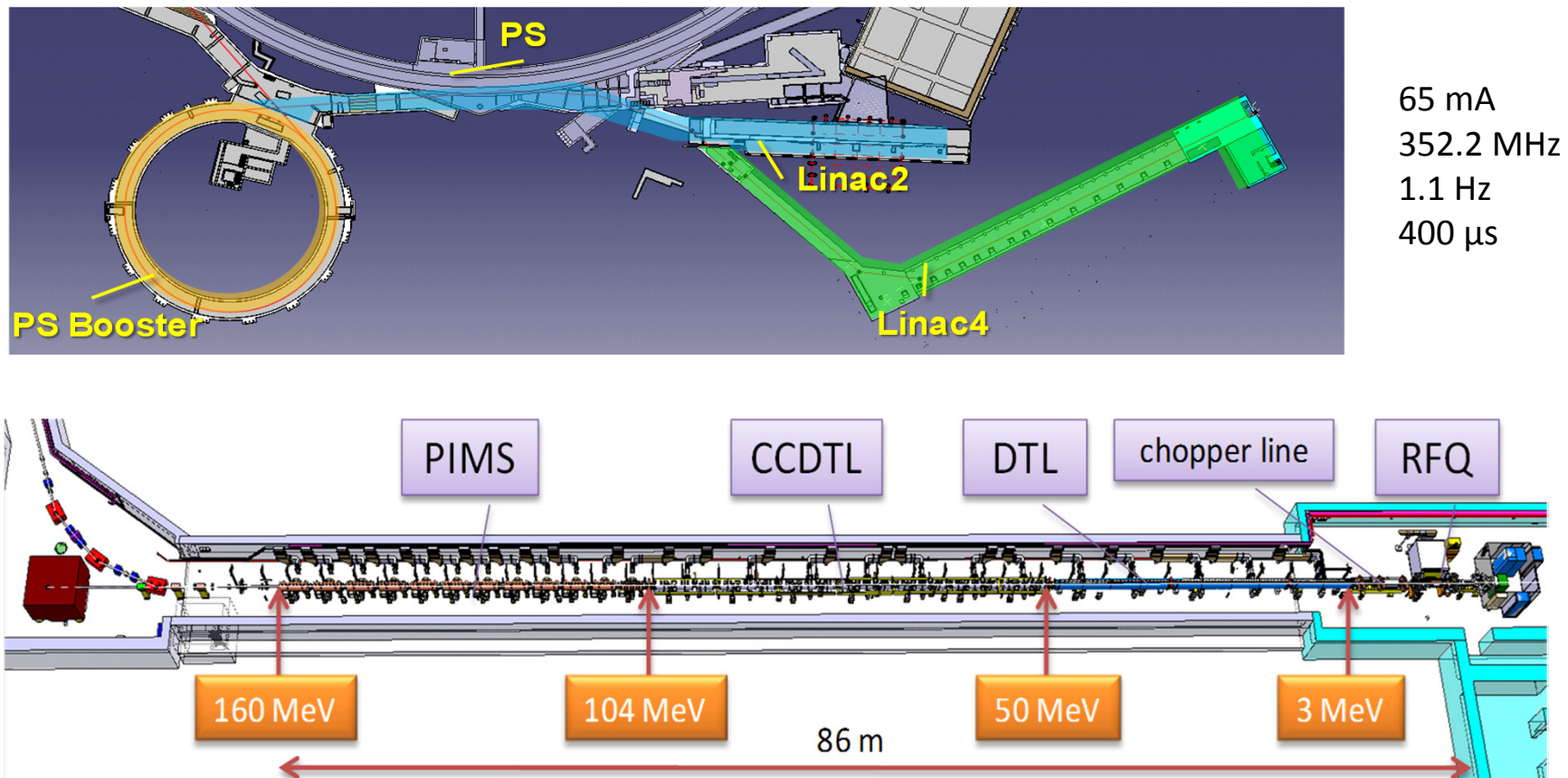
Phase advance per meter is smooth and monotonic

Tune depression stays right above 0.4 along the linac

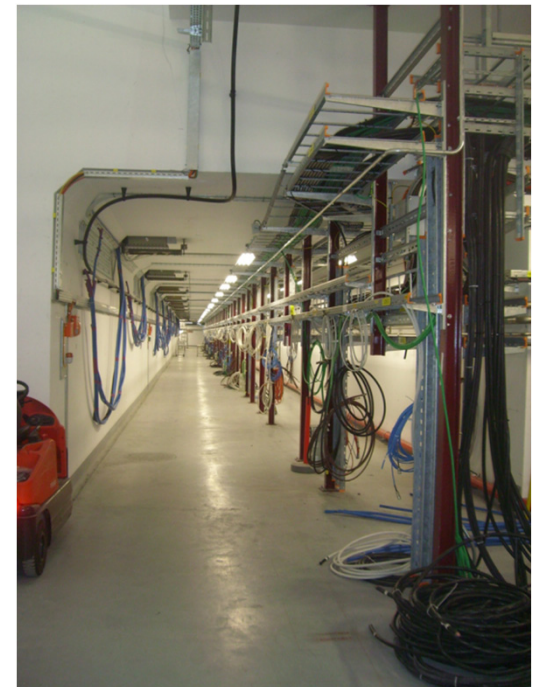
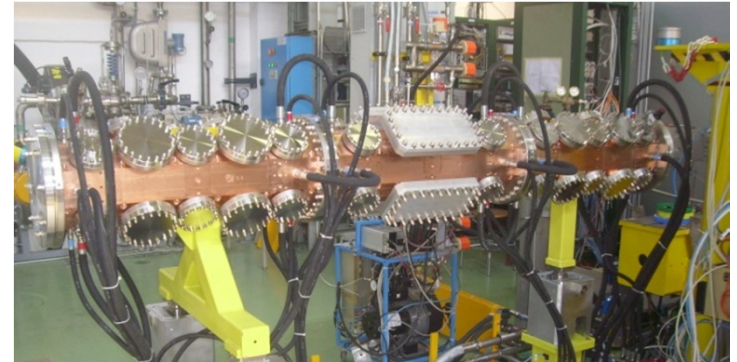
Statistical runs are performed to check the sensitivity of the linac to real life error



- A new 160 MeV H^- ion linac, injector of PS Booster.

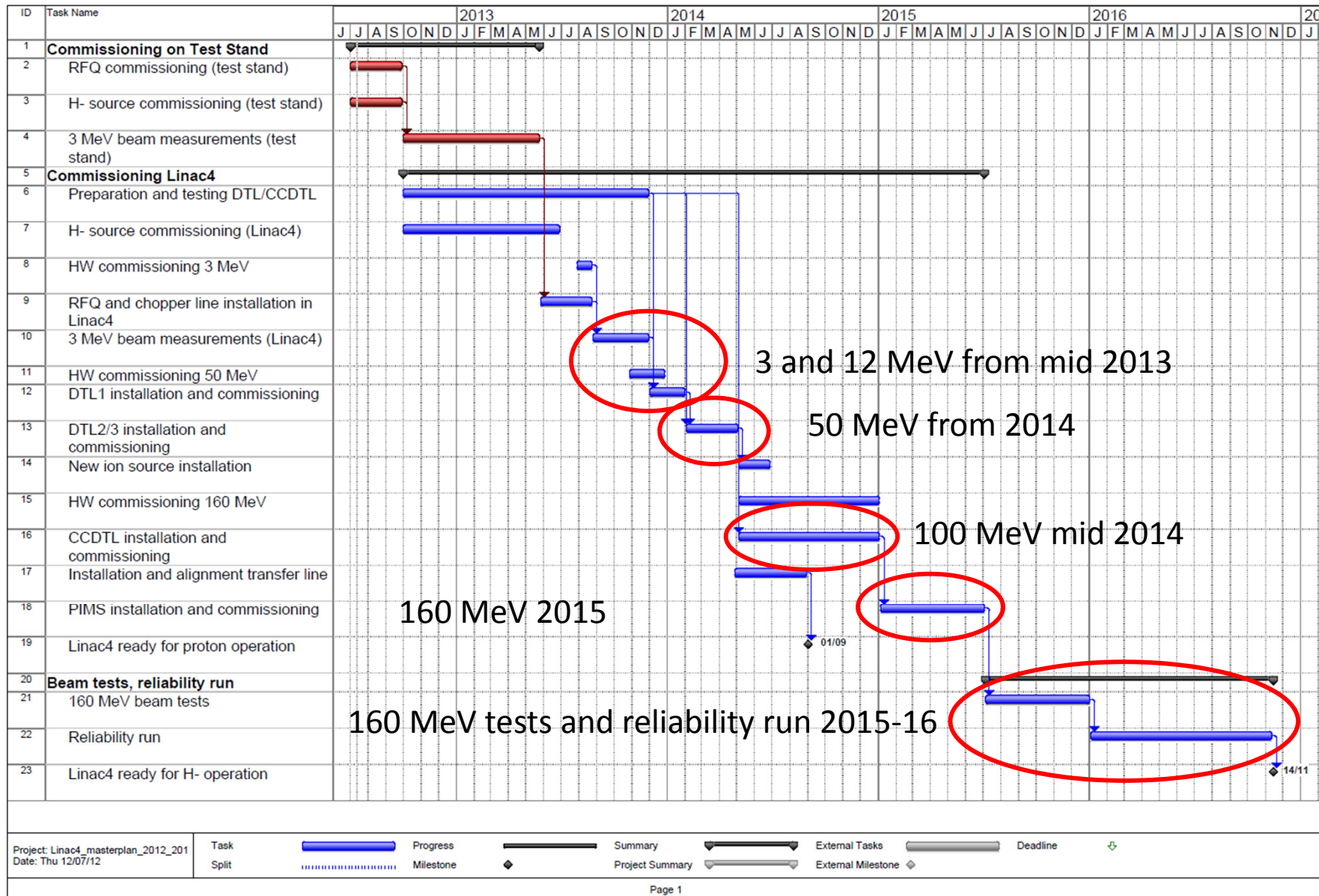


- H- source presently under commissioning.
- RFQ delivered, RF bead-pulls performed.
- DTL, Tank1 assembled.
- First CCDTL modules delivered in October.
- PIMS modules ready from next year.
- Tunnel ready for machine installation.

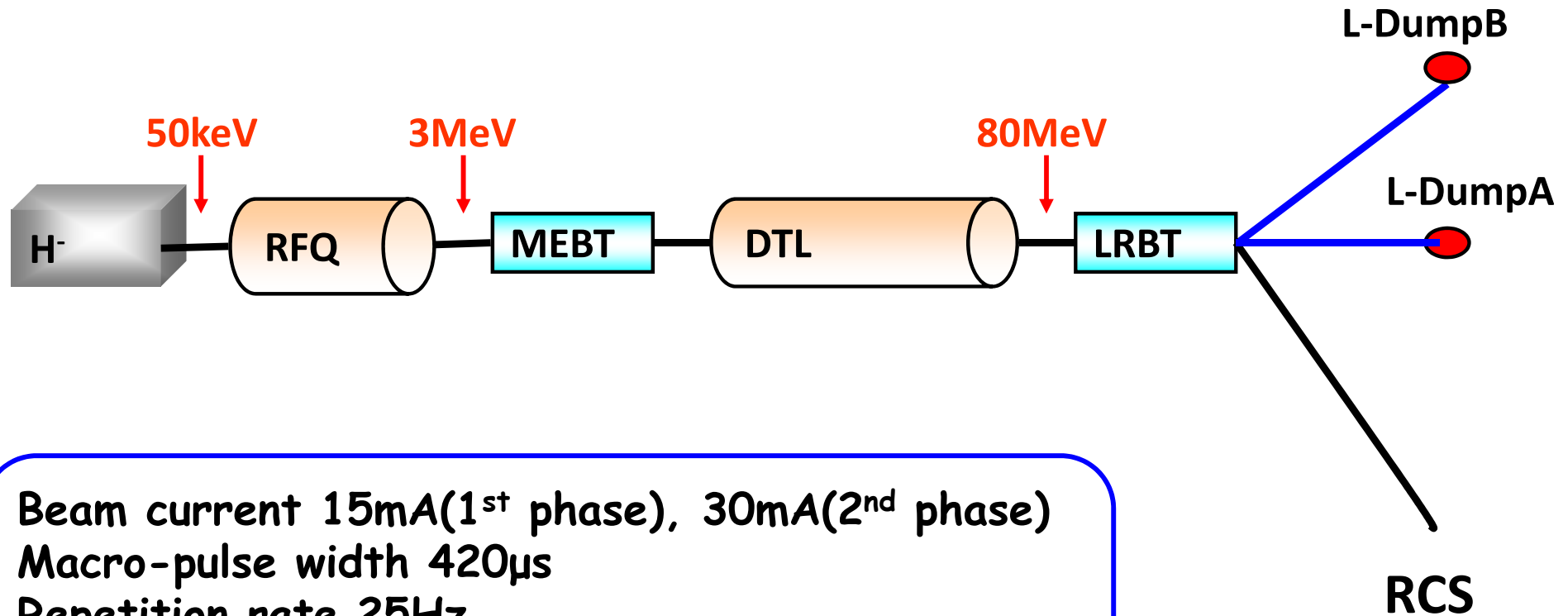




Commissioning Planning



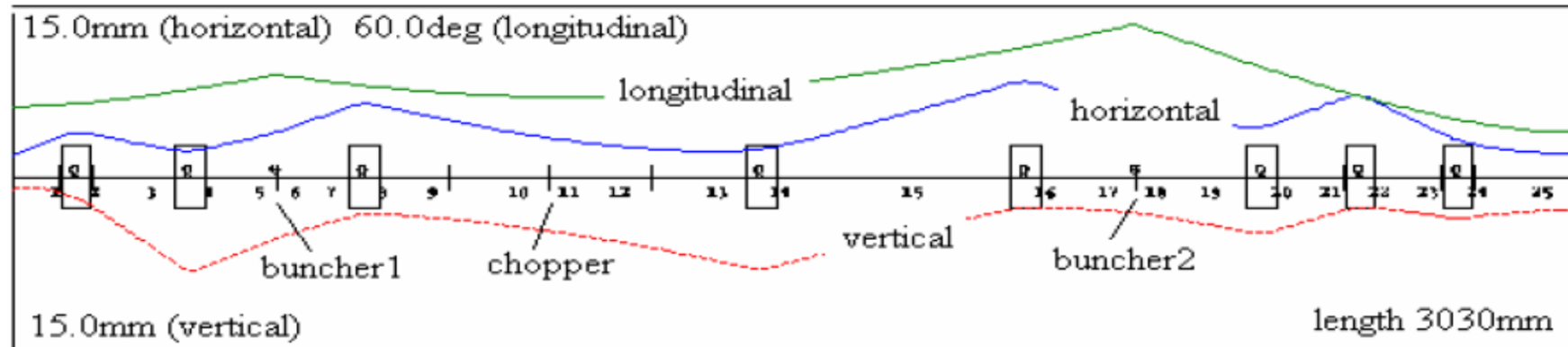
END to end Beam Dynamics design Optimization for CSNS Linac – J. Peng (IHEP)



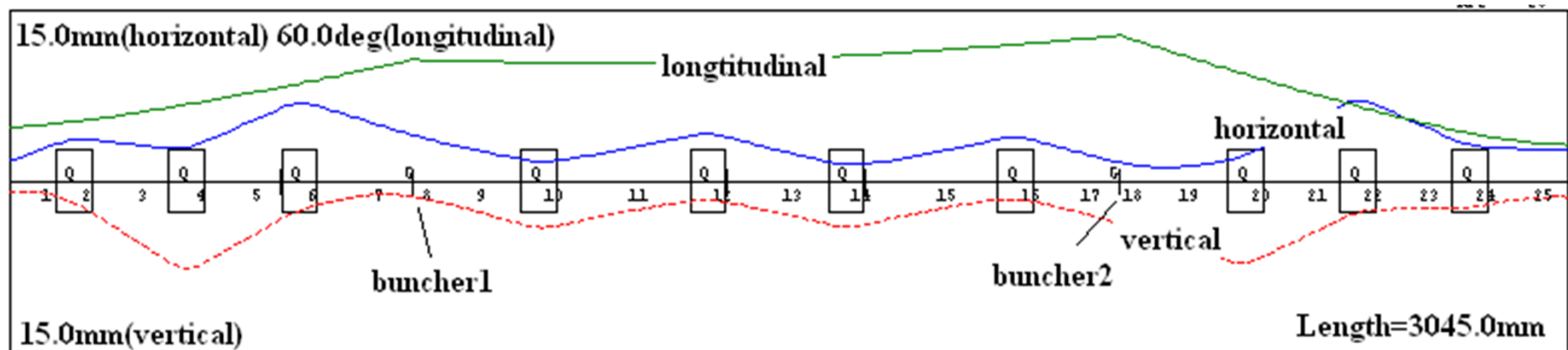
Beam current 15mA(1st phase), 30mA(2nd phase)
Macro-pulse width 420 μ s
Repetition rate 25Hz
Duty factor 1.05%
Chopping rate 50%

Optimization : (1) remove Chopper from MEBT

(2) DTL lattice change FD to FFDD



Old design: the MEBT comprises of a chopper, two 324MHz buncher cavities and eight quadrupole magnets

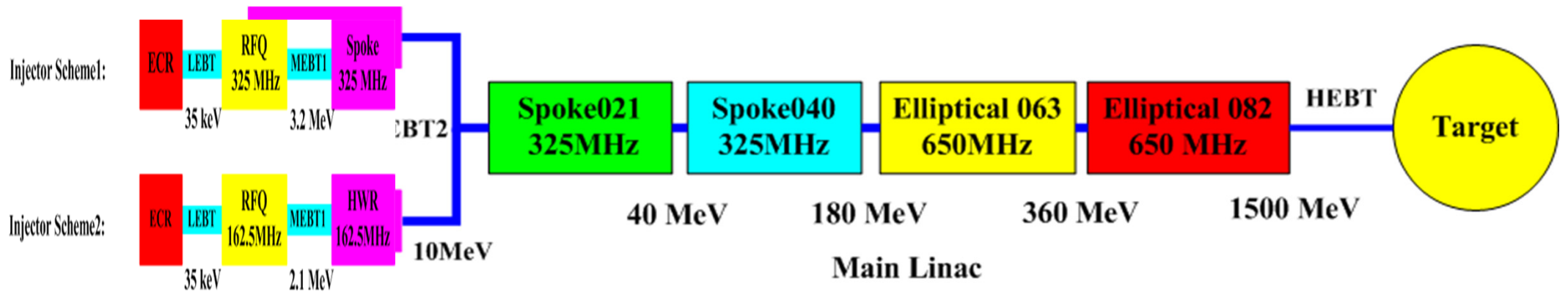


New design: the MEBT comprises of two 324MHz buncher cavities and ten quadrupole magnets

Summary

- ◆ In the old design, the beam loss in the 1st DTL tank was found serious while all errors applied. The reason to this problem was that we don't consider halo formation and emittance growth in the MEBT while optimizing DTL geometric parameters. So end-to-end simulation must be conducted before reaching a final design.
- ◆ Two transverse focusing lattices have been compared, namely FD and FFDD focusing lattice. FFDD lattice was finally chosen for its lower quadrupole gradient and smaller beam loss rate compared with FD one.
- ◆ End to end simulation has shown that the beam loss, emittance growth rate and the ratio of bore radius to rms beam size were acceptable along the linac, and now we reached a final design.

Beam dynamics of China ADS-Z. Li (IHEP)



Particle	Proton	
Energy	1.5	GeV
Current	10	mA
Beam power	15	MW
RF frequency	(162.5)/325/650	MHz
Duty factor	100	%
Beam Loss	<1	W/m
Beam trips/year	<25000 <2500 <25	1s< t <10s 10s< t <5m t >5m

End to End Simulation

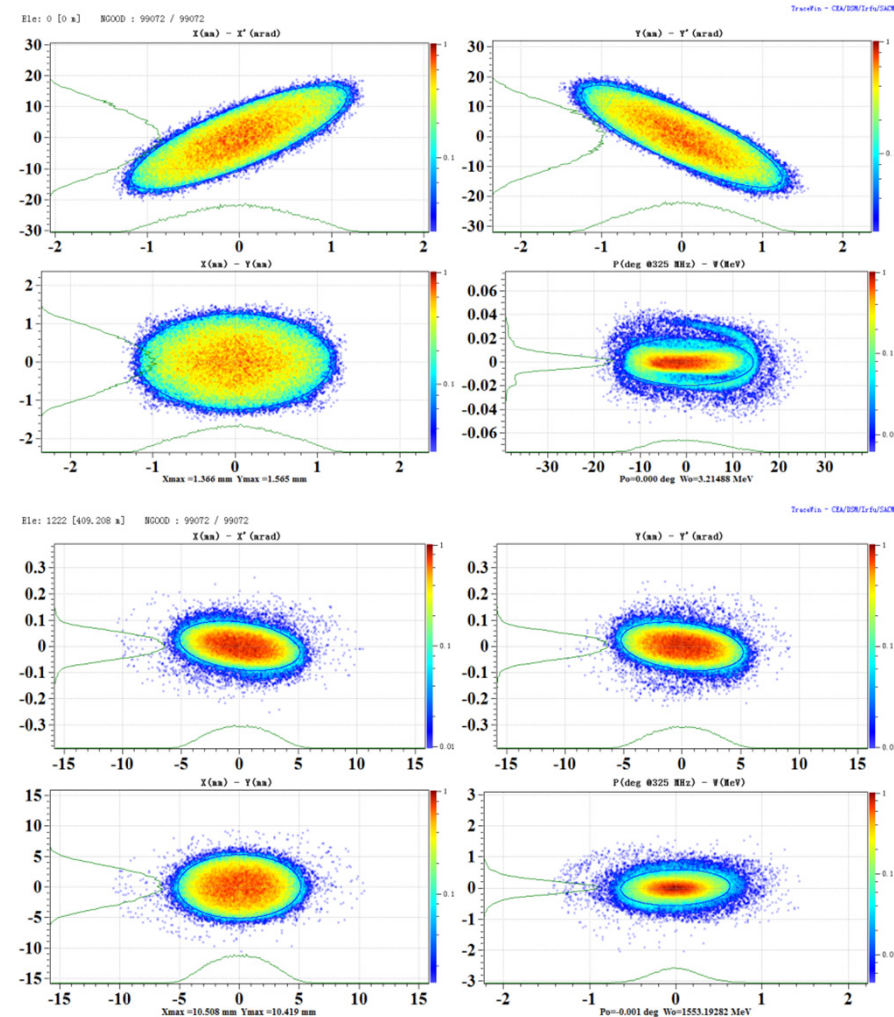
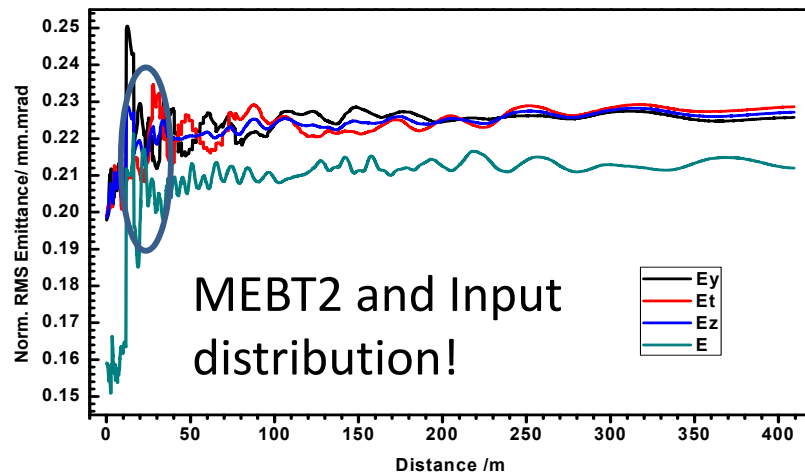
RMS Emittance growth

15% in transverse;

40% in longitudinal ;

Halo particles

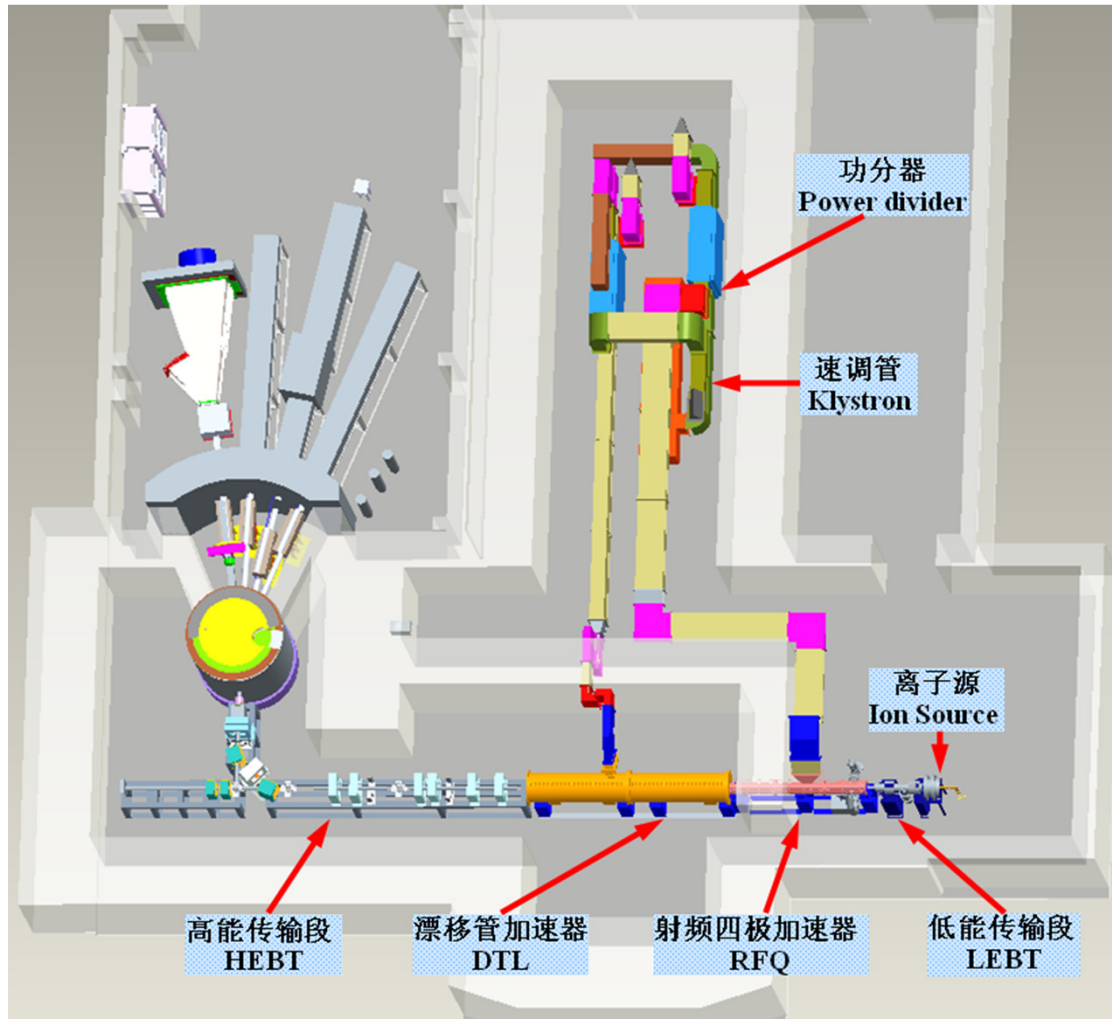
Particle loss with errors;



Beam dynamics of the 13 MeV/50 mA proton linac for the compact pulse hadron source at Tsinghua University- Q. Z. Xing

Xing

Main parameters of the CPHS accelerator system



Ion type	Proton	
Beam power	16	kW
Beam energy	13	MeV
Average current	1.25	mA
Pulse repetition rate	50	Hz
Protons per pulse	1.56×10^{14}	
Charges per pulse	2.5×10^{-5} C	
Pulse energy	0.325	kJ
Pulse length	500	μ s
Peak current	50	mA
Beam duty factor	2.5	%
RF frequency	325	MHz
Output energy of the ion source	50	keV
Output energy of the RFQ	3	MeV
Output energy of the DTL	13	MeV

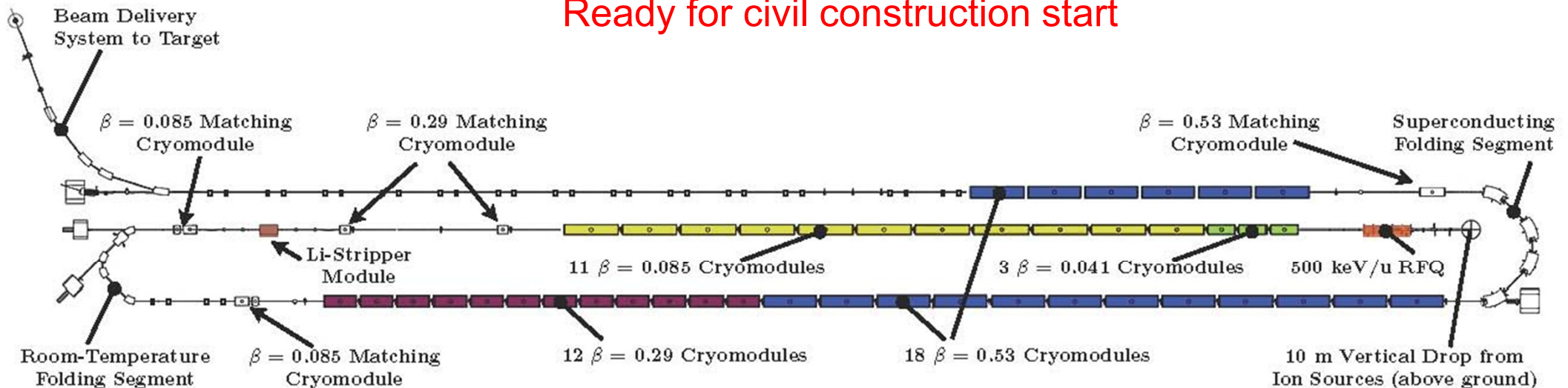
- No MEBT,
- Beam dynamics simulation has been carried out by various codes for the CPHS Linac
- Field aberration of the solenoids is one main reason for the mismatching between the LEBT and RFQ
- With the particle distribution from the LEBT as input, the transmission rate in the RFQ decreases to about 85%
- Transmission in the DTL is almost 100% for the accelerated particles
- Simulation is being cross-checked by TRACK



FRIB Accelerator beam Dynamics Design and Challenges- X. Wu et al (FRIB)

- 400 kW cw machine with uncontrolled beam loss limited to < 1 W/m
- Beam energy on target ≥ 200 MeV/u
- Accelerate all varieties of stable ions $\rightarrow$ uranium is most challenging in design (two and five charge states before and after stripper)
- Minimize project construction costs $\rightarrow$ Compact double-folded layout
- Maintain potential enhancement $\rightarrow$ Energy upgrade, ISOL targets, light ion injector

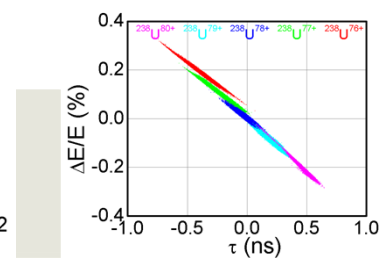
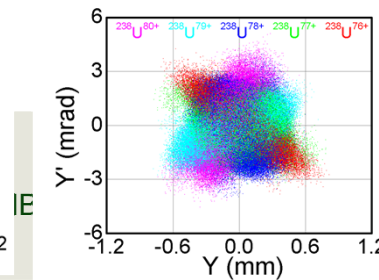
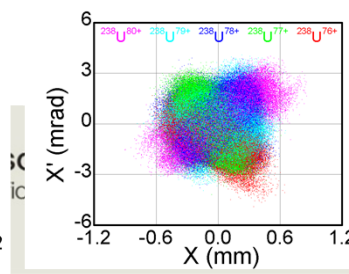
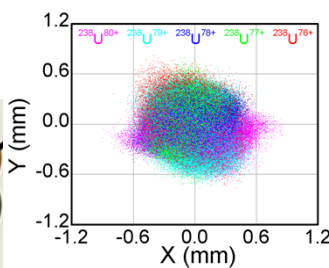
Ready for civil construction start



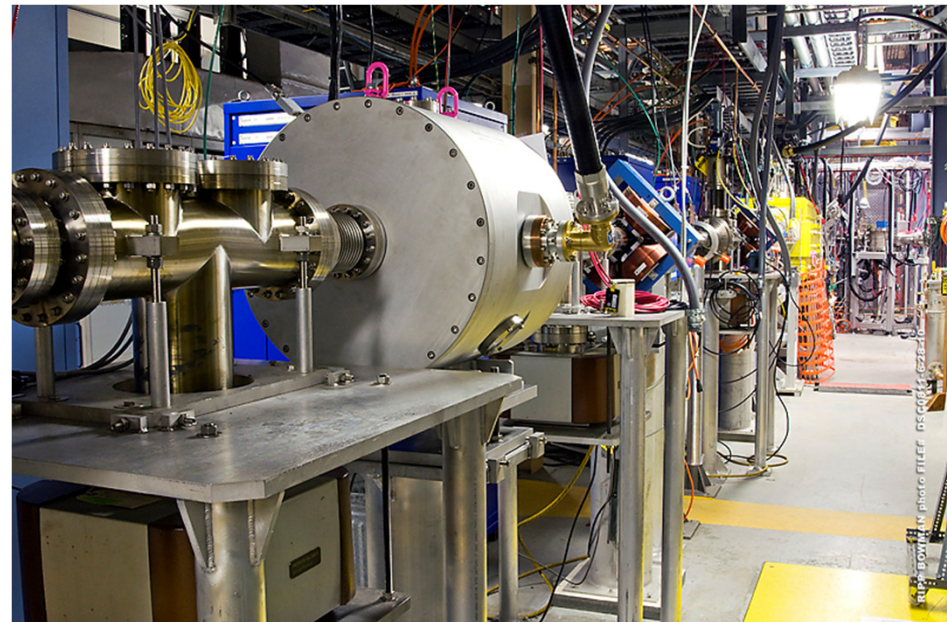
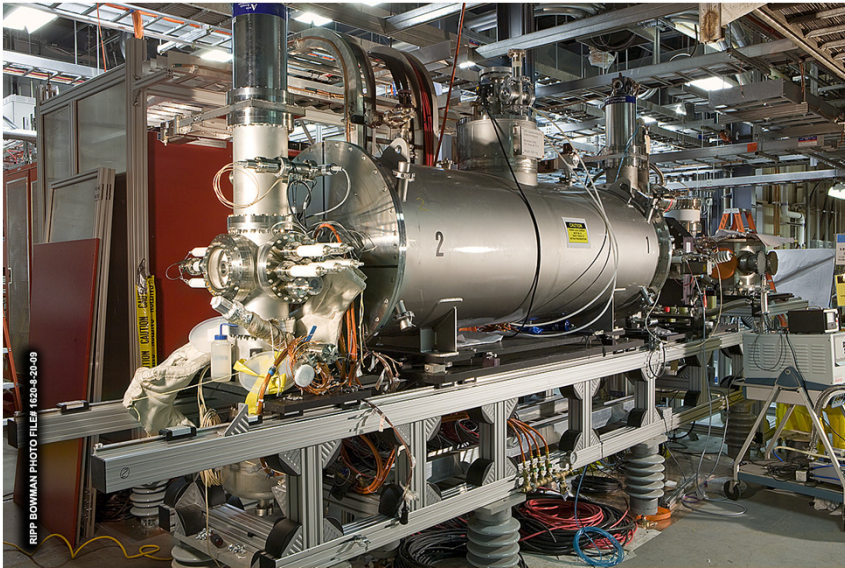
FRIB Accelerator Beam Dynamics Challenges

- Simultaneous acceleration of multi-charge-state beams
 - Velocity equalizer and HV platform at LEBT
 - Variable cavity synchronous phase
 - **Achromatic and isochronous bending optics design**
 - Diagnostics and control capabilities to overlap multi-charge states
- Combined challenges of heavy-ion and high-power accelerator
 - Uncontrolled beam loss at 1 W/m (or 10^{-6}) level
 - ^1H : activation & shielding issues; ^{238}U : material damage & heat load
- Limited aperture of low- β accelerating structures
- Tolerate larger alignment error of “cold” elements in cryomodules
 - SC solenoid to be aligned to < 1 mm under cryogenic condition
- Stringent beam-on-target requirements
 - Requiring corresponding beam diagnostics and control

FRIB



Acceleration and transportation of multi ion species through EBIS Preinjector- D. Raparia (BNL)



Ion Beam Delivered to NSRL and RHIC

IONS	Q/m	delivered to
^3He	0.6667	AGS
$^4\text{He}^{2+}$	0.5000	NSRL
$^{12}\text{C}^6$	0.5000	NSRL
$^{16}\text{O}^8$	0.5000	NSRL
$^4\text{He}^{1+}$	0.2500	NSRL
$^{20}\text{Ne}^{5+}$	0.2500	NSRL
$^{40}\text{Ar}^{10+}$	0.2500	NSRL
$^{63}\text{Cu}^{11+}$	0.1746	RHIC
$^{40}\text{Ar}^{7+}$	0.1750	AGS
$^{48}\text{Ti}^{9+}$	0.1875	NSRL
$^{56}\text{Fe}^{10+}$	0.1786	NSRL
$^{84}\text{Kr}^{20+}$	0.2439	NSRL
$^{131}\text{Xe}^{30+}$	0.2290	NSRL
$^{181}\text{Ta}^{40+}$	0.2210	NSRL
$^{197}\text{Au}^{32+}$	0.1624	RHIC, NSRL
$^{238}\text{U}^{39+}$	0.1638	RHIC

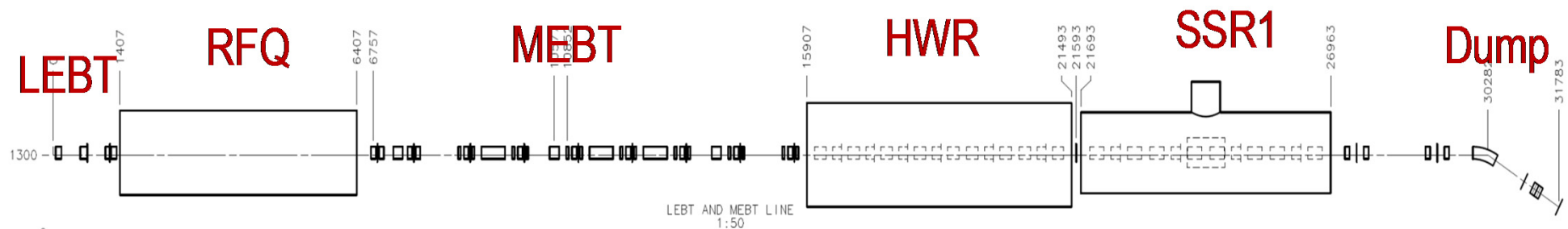
EBIS pre-injector provided Au , U and Cu beam for RHIC Run 12 and tens ions species to NSRL

Acceleration and transport of multi ion species seen in the EBIS pre-injector and Booster

EBIS pre-injector is very stable, reliable and reproducible

PXIE at FNAL- N. Solyak et al (Fermilab)

- PXIE – Front-End of the Project X CW linac
- PXIE should deliver 1 mA CW beam to ~25 MeV energy
 - Arbitrary bunch pattern (5 mA from Ion Source-> 1 mA at the beam dump)
- PXIE includes:
 - *5 mA ion source*
 - *LEBT with pre-chopper*
 - *2.1 MeV 162.5 MHz RFQ*
 - *MEBT with bunch-by-bunch chopper and 11 kW beam dump*
 - *Two SC cryo-modules: HW -162.5 MHz & SSR1 – 325 MHz*
 - *Diagnostics Section and 50 kW beam Dump*



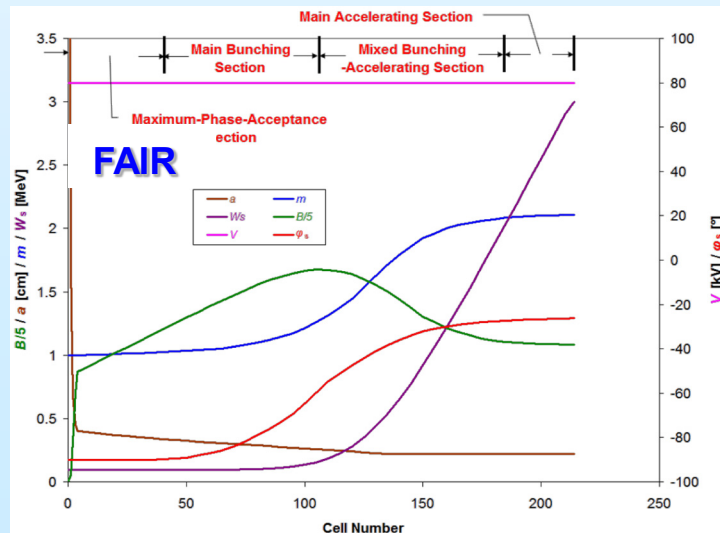
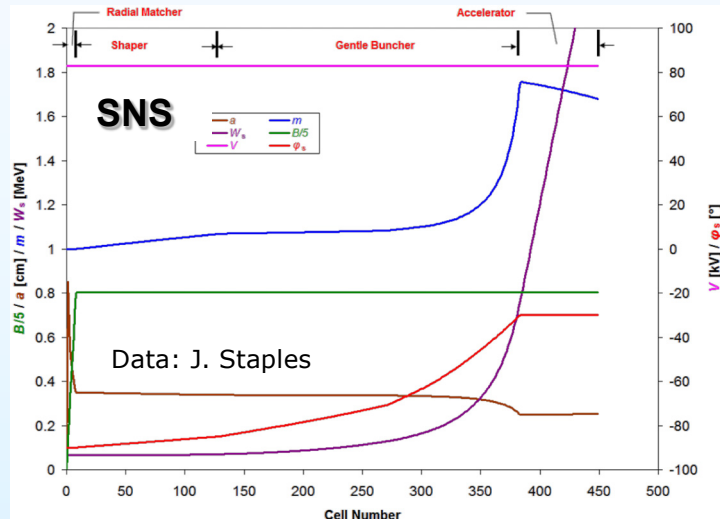
PXIE schematic layout. The total facility length is about 40 m.

Beam Dynamics studies of H- beam chopping in the LEBT for project X-Q. Ji (LBNL)

- PXIE H- ion source has been tested at LBNL. Beam current, emittance, and stability all meet the functional specification requirements.
- A two-solenoid magnetic lens LEBT has been proposed.
- Time-dependent WARP 3D simulations of particle interactions, such as electron detachment, charge exchange, H- ionizations etc. in the LEBT are still ongoing. Preliminary results showed that, from the chopper to the entrance of RFQ, emittance increases $\sim 20\%$.
- Chopper simulation benchmark experiment has been performed at various pulse duty factor and repetition rate. A collection of emittance and twiss parameter data have been taken, which are ready to be used in benchmarking WARP 3D simulations.

RFQ Beam dynamics design for large science facility and accelerator driven systems C. Zhang (IAP)

FAIR Proton RFQ vs. SNS RFQ

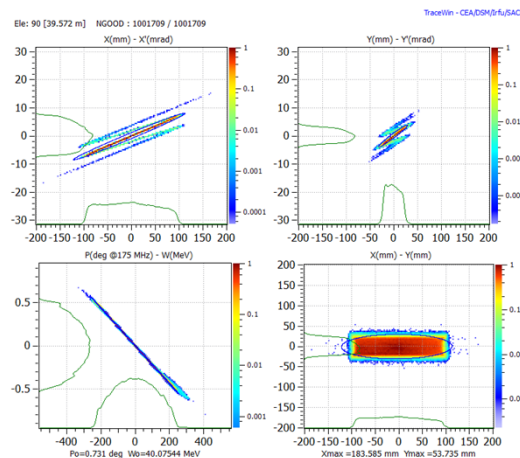
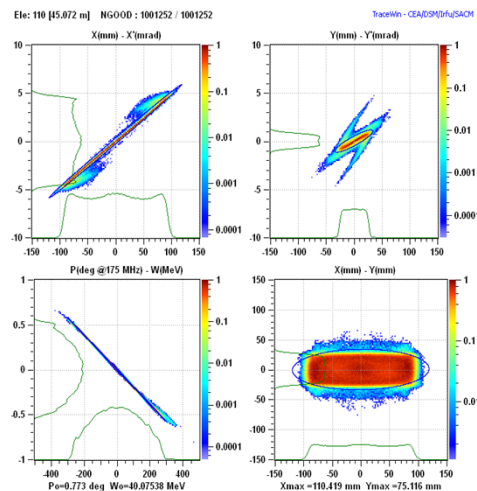
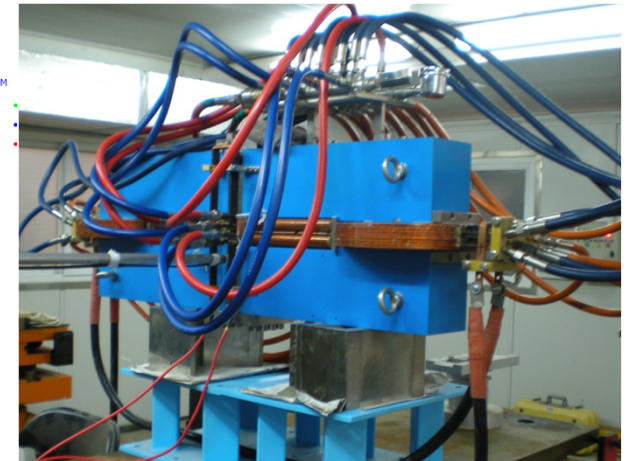
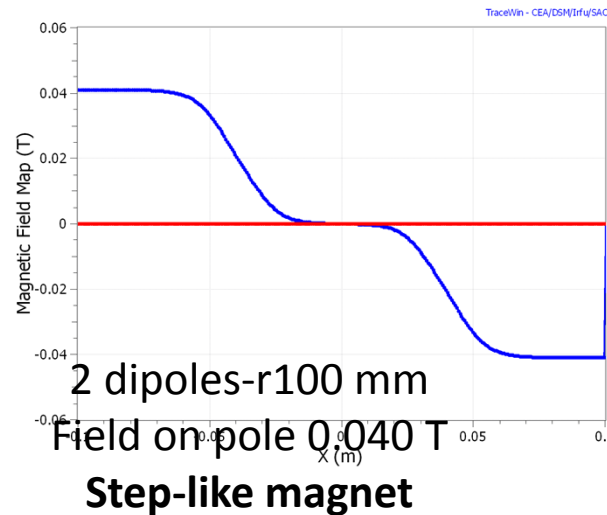
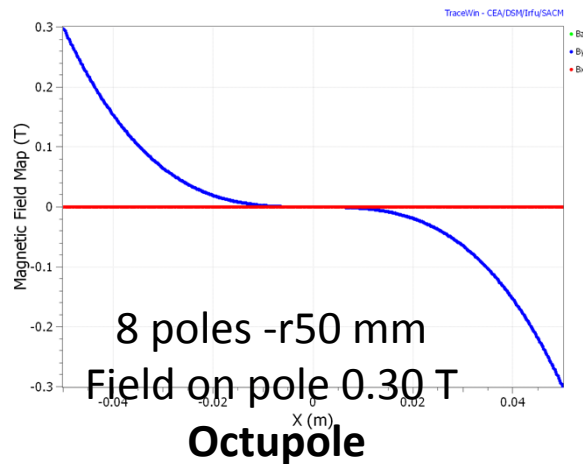


Parameters	SNS	FAIR		
Ion	H ⁻	H ⁺		
Duty cycle [%]	6.2	0.0144		
I_{peak} [mA] ✓	~60 (35)	45	70	100
f [MHz]	402.5	325.44		
W_{in} [MeV] ✓	0.065	0.095		
W_{out} [MeV] ✓	2.5	3		
U [kV]	83	80		
$\epsilon_{\text{in}}^{\text{trans.,norm.,rms}}$ [π mm mrad] ✓	0.2	0.3		
$\epsilon_{\text{out}}^{\text{trans.,norm.,rms}}$ [π mm mrad]	0.21 0.21	0.30 0.30	0.30 0.30	0.31 0.31
$\epsilon_{\text{out}}^{\text{longi.,rms}}$ [π MeV deg]	0.103	0.163	0.153	0.152
L [m] ✓	3.7	3.2		
Transmission [%]	~90	98.7	97.2	95.3

For accelerated particles only

Using Step-like nonlinear magnet for uniformization at IFMIF Target- Z. Yang (IHEP)

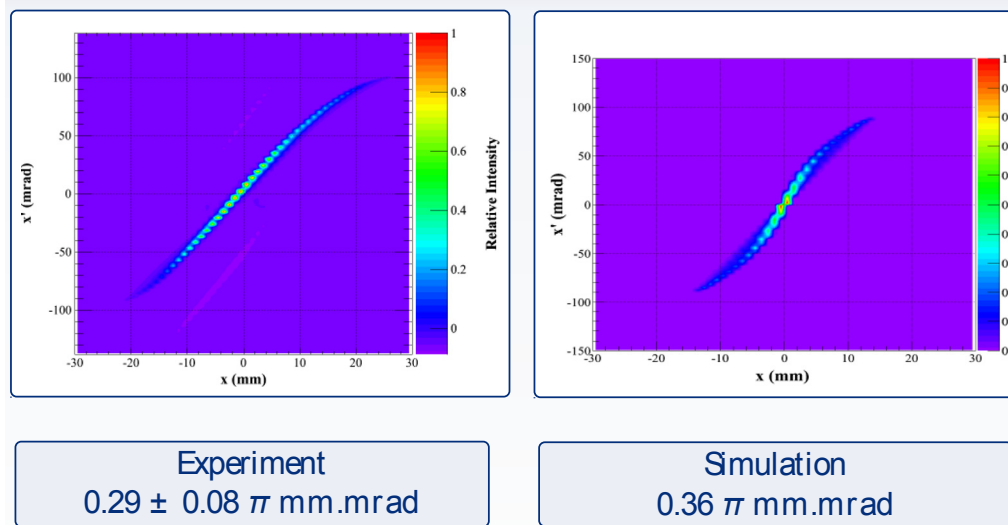
- To create uniform beam on target step like nonlinear magnet is suggested which dose the better job



High intensity aspect of J-park linac, including re-commissioning after earthquake- M. Ikaegami (KEK)

- In the beam commissioning of J-PARC linac after the earthquake, multipactor at an RF cavity forced us to operate with irregular RF settings some of which caused excess beam losses.
- We have performed particle simulation to reproduce the experimentally observed beam loss.
- **Simulation** has not fully reproduced the beam loss behavior, but it **leads us to conclude that the beam loss is caused by satellite (proton?) particles.**
- While it needs further study to confirm it, **the particle simulation provides us with an important insight into the beam loss mechanism** in the J-PARC linac beam commissioning.

Simulations and measurement in the high intensity LEBT with space charge compensation-N. Chauvin (CEA/IRFU)



Conclusions

- A PIC code (with SCC) has been used to design high intensity injectors.
- Simulations are compatibles with preliminary experimental results.
- Emittance at the end of the IFMIF injector are in the specifications.
- Nominal beam current in pulsed mode (20% duty cycle max.).

Intense High charge state heavy ion beam production for the advanced accelerators L. T. Sun (IMP)

- ECRIS-

SPIRAL2 (GANIL), France: ECRIS(1emA Ar¹²⁺)

FAIR (GSI), Germany: ECRIS (1emA U²⁸⁺)

FRIB (MSU), USA: ECRIS (270euA U³³⁺ & U³⁴⁺)

- EBIS

RHIC (BNL), USA: EBIS (1.7emA Au³²⁺/10μs)

- LIS

CERN CO₂ laser, $\lambda=10.6\mu\text{m}$, 100 J, 1 Hz, Laser pulse 15-30 ns, Power density 10^{13} W/cm^2 , Ion pulse 1-10 μs

BNL Nd: YAG Laser, f:100mm, 30cm from target, $\varnothing$:6mm

Posters

Study of HOMs and the associated instability for C-ADS Linac: P. Cheng et al
-HOM couples not need similar result were obtain at SNS linac

Dynamics of particles in a tilted solenoid focusing channel: H.Jiang et al

The study of beam distribution transformation by anti-symmetric multipole magnetic field: M. Jin

Study of Non-equi-partition lattice setting and IBS effects for J-park Linac Upgrade: Y. Liu
Upgrade part 190 MeV to 400 MeV, frequency jump of 3,
if one keep EP lattice the losses will increase due to IBS,
Non EP lattice (bigger beam) increase emittance (50%)

The analysis of stability optimization for superconducting section of C-ADS Injector II

Poster (Cont.)

Beam Dynamics studies for a proposed 800 MeV ISIS Upgrade Linac: D. C. Plostinar

MEBT2 design for the C-ADS : Z. Guo et al

- How to maintain achromaticity with space charge using two bunchers.

Design of C-ADS injector II MEBT I

Error analysis and correction Scheme in C-ADS injector: I C. Meng, et al

Compensation-remach for Major Element failure in rhw C-ADS : B. Sun et al

- possible, further continue, This a one the flexibility provided by SC linac

Physics Design for the C-ADS Main Linac with two different Injector Schemes: F. Yan

- Discuss space charge effected associate with injector I (325 MHz) and Injector II (162.5 MHz)

Beam optics design of 1.5 GeV Transport Line in C-ADS with beam distribution transformation: H. L. Luo

- Compare two methods to create uniform distribution at target : raster system and use nonlinear magnets

Poster (cont.)

Error and Tolerance Studies for injector II doe C-ADS: W. S. Wang

SSC linac end-to end simulations and error analysis based on the Beampath code: X. H. zhang

Medium Energy Beam Transport Design Update for ESS: I. Bustinduy

An Untraditional RFQ Physics design for HIAF: C. Li

Separate out functions of RFQ, i.e bunching and acceleration, Multi-harmonic Buncher
In the LEBT and RFQ with only acceleration section

Code

Development of the Linac design and tracking code PADSC: Y. L. Zhao

Report:

Experimental Results for Beam Halo at IHEP: H. F. Ouyang

Halo measurement in FODO line after RFQ

Discussion Topics

- J-park upgrade: EP vs IBS lattice
- Equipartition: reality or Swindle
- RFQ Beam Dynamics : emphasis of longitudinal beam quality
- Calculated vs empirical lattice

Are operators tuning on halo ?

Transition energy for Super conducting cavities

In case of ESS transition chosen 80 MeV based on emittance growth

- High power vs high intensity

Higher repetition rate, lower peak current, higher energy ,usually fix target losses are concern, challenging engineering rather than beam dynamics

Lower repetition rate, higher peak current, injection, emittance is figure of merit

- H- linac and P linac design issues
- Emittance grow ($\sim 20\%$) vs accelerator length (30m) In ESS Linac