ISOLDE Workshop and Users Meeting 2011

HIE-ISOLDE Beam Characteristics and HEBT Layout

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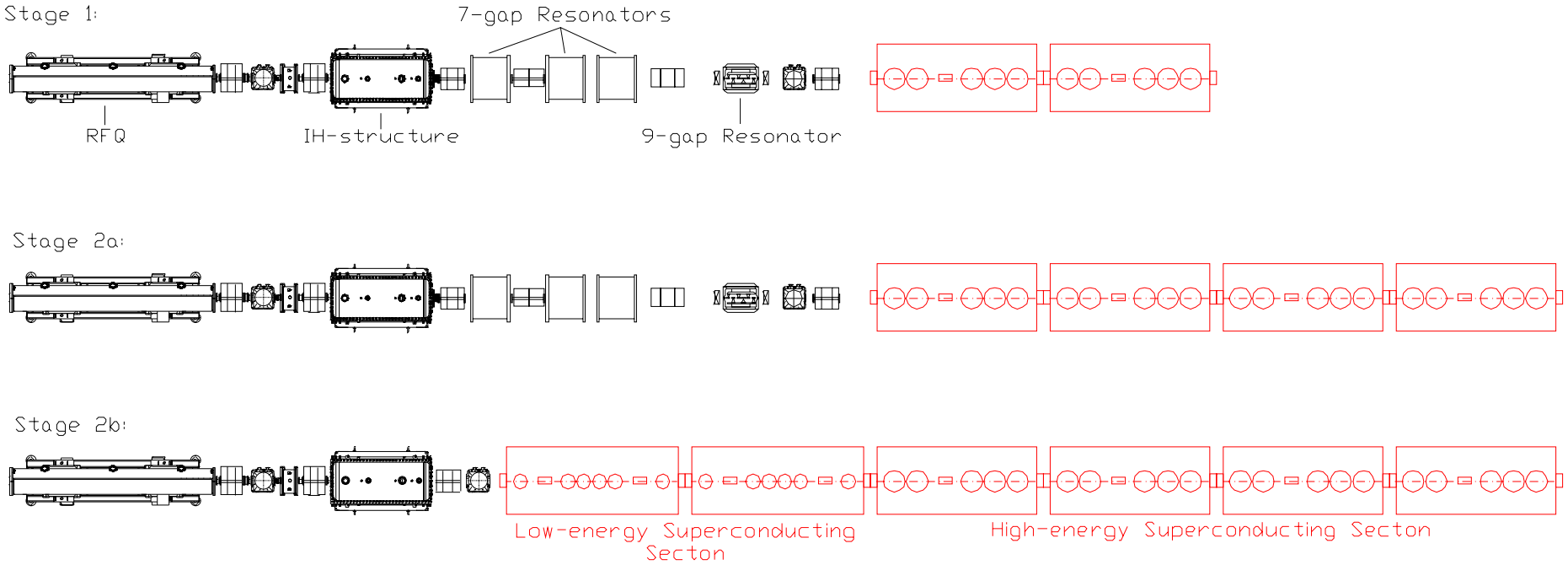
- Work this year…
  - REX simulations
  - Longitudinal emittance measurements
  - Deceleration
  - Summary of beam parameters
- HEBT
- Points for discussion
- Future

INTRODUCTION

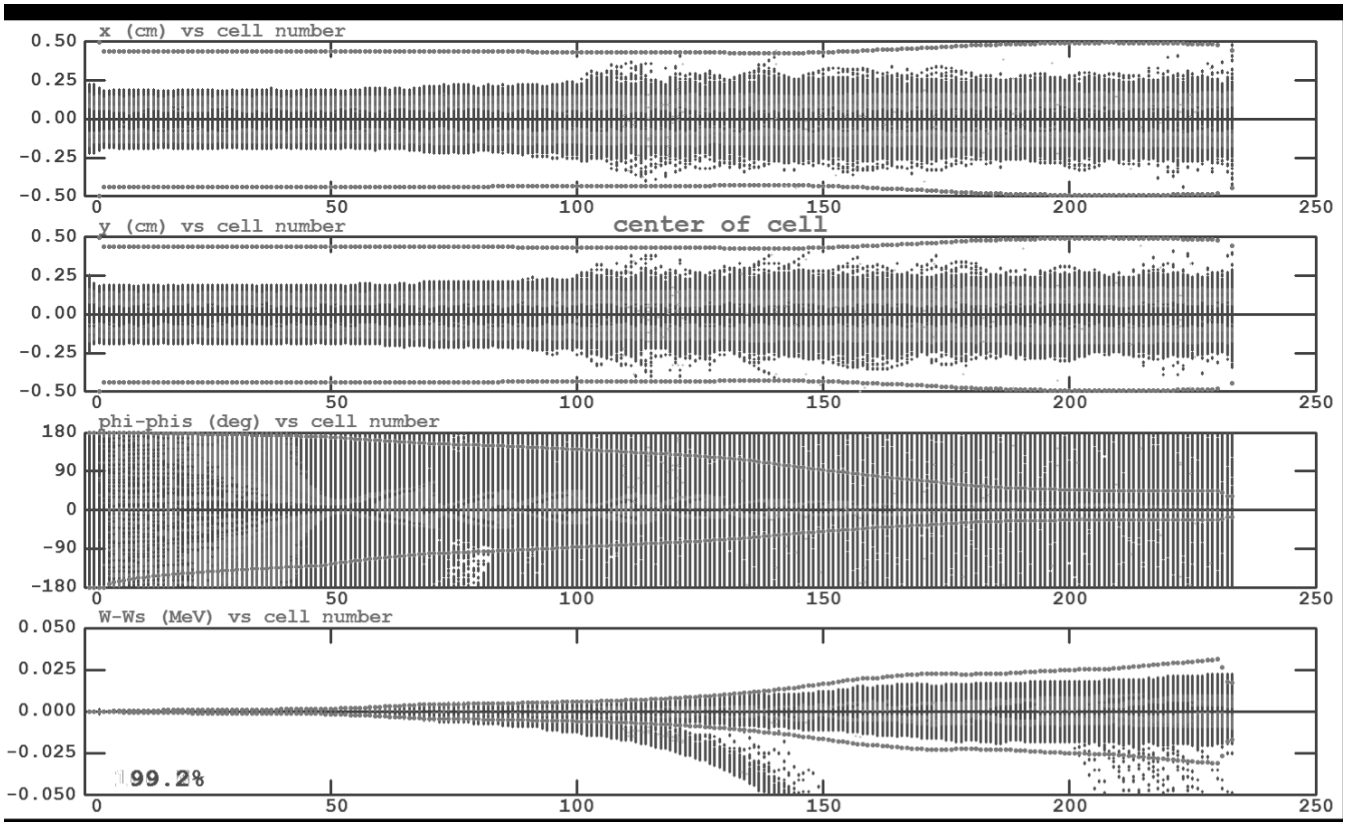
- The staged upgrade of some 40 MV of superconducting linac.
- Work focused on the beam dynamics design of the upgrade itself and REX to understand the input parameters and matching.

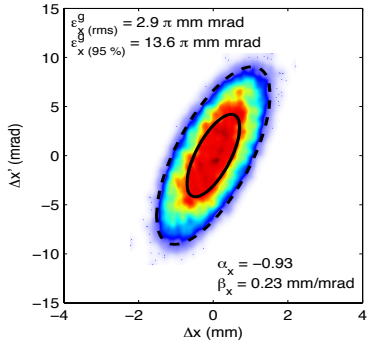


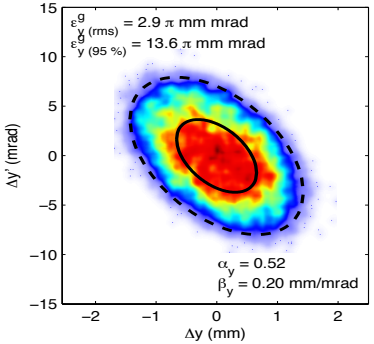
- HIE-ISOLDE beam dynamics design complete, see e.g. M.A. Fraser et al, Phys. Rev ST Accel. Beams, 14 2 020102 (2011)

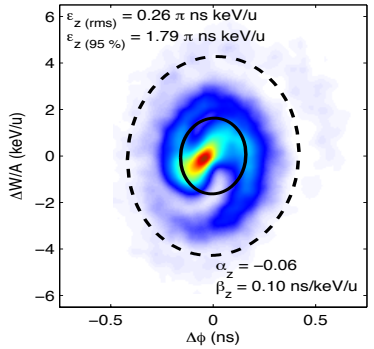
REX SIMULATIONS

- In collaboration with BE/ABP (Piero Posocco et al.) completed an RFQ beam dynamics study.
- To be published internally at CERN.





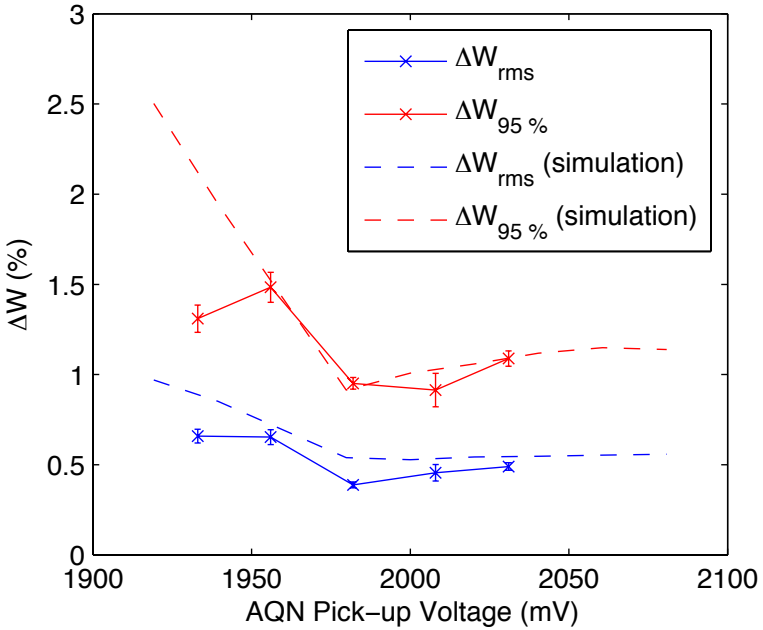




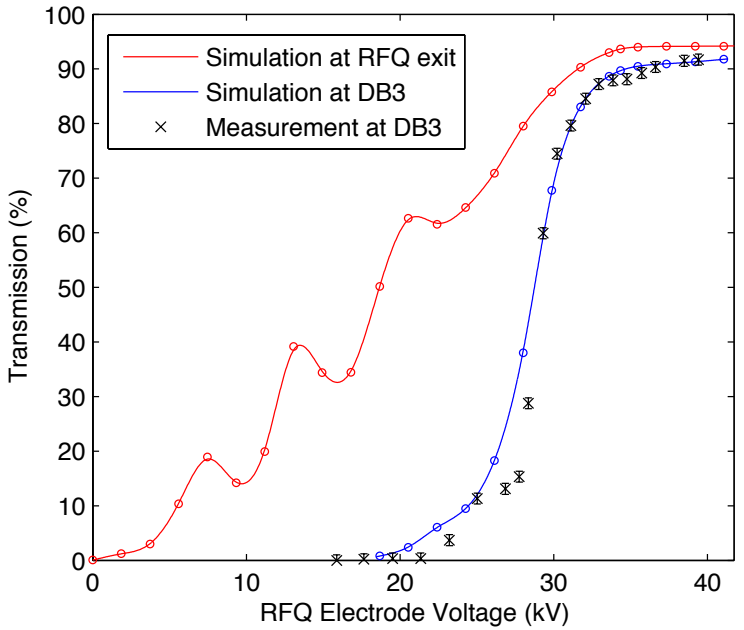
REX SIMULATIONS

- RFQ simulations were benchmarked with beam measurements.

Energy spread with voltage:



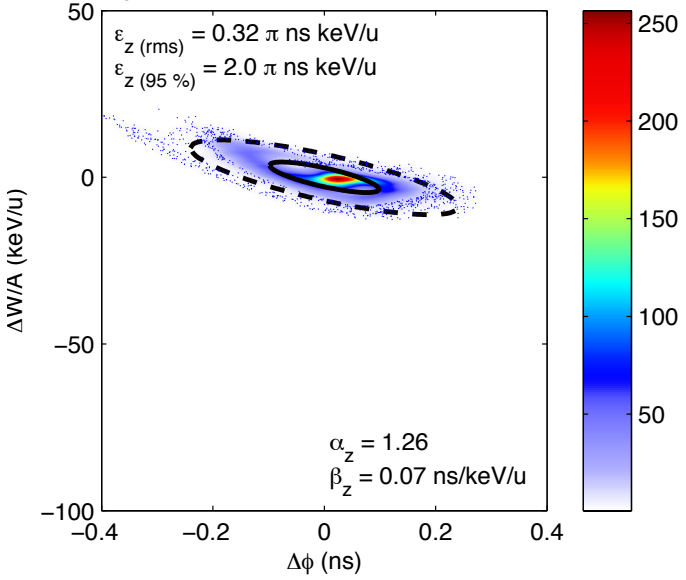
Transmission with voltage:



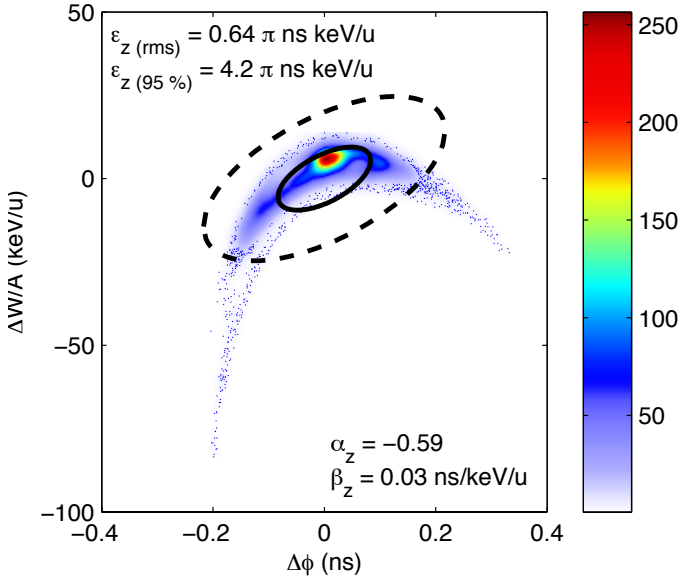
REX SIMULATIONS

- IH structure bead-pull measurements made and used in beam simulations to understand its working point (presented last year).
- 9-gap structure simulations completed, which indicate it will degrade the longitudinal beam properties of the upgrade in the first stages:

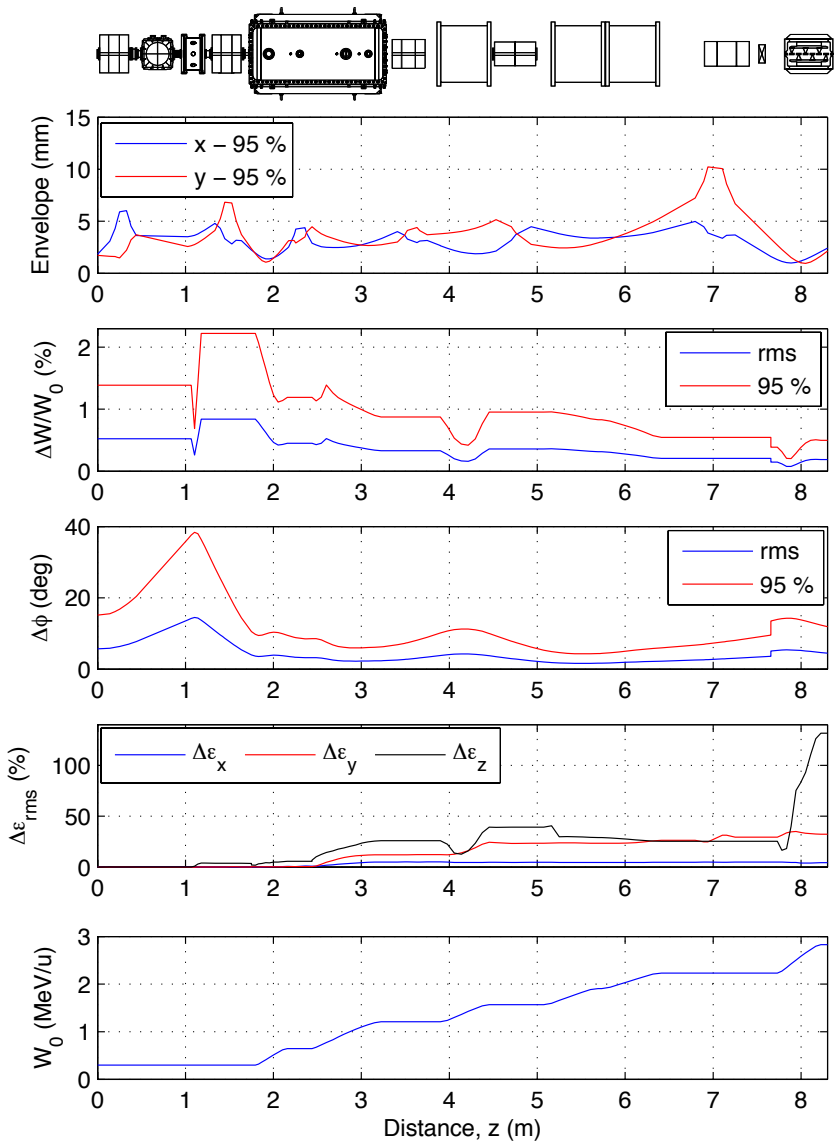
Longitudinal phase-space on entry to 9GP:



Longitudinal phase-space on exit to 9GP:



REX SIMULATIONS



LANA end-to-end simulations.

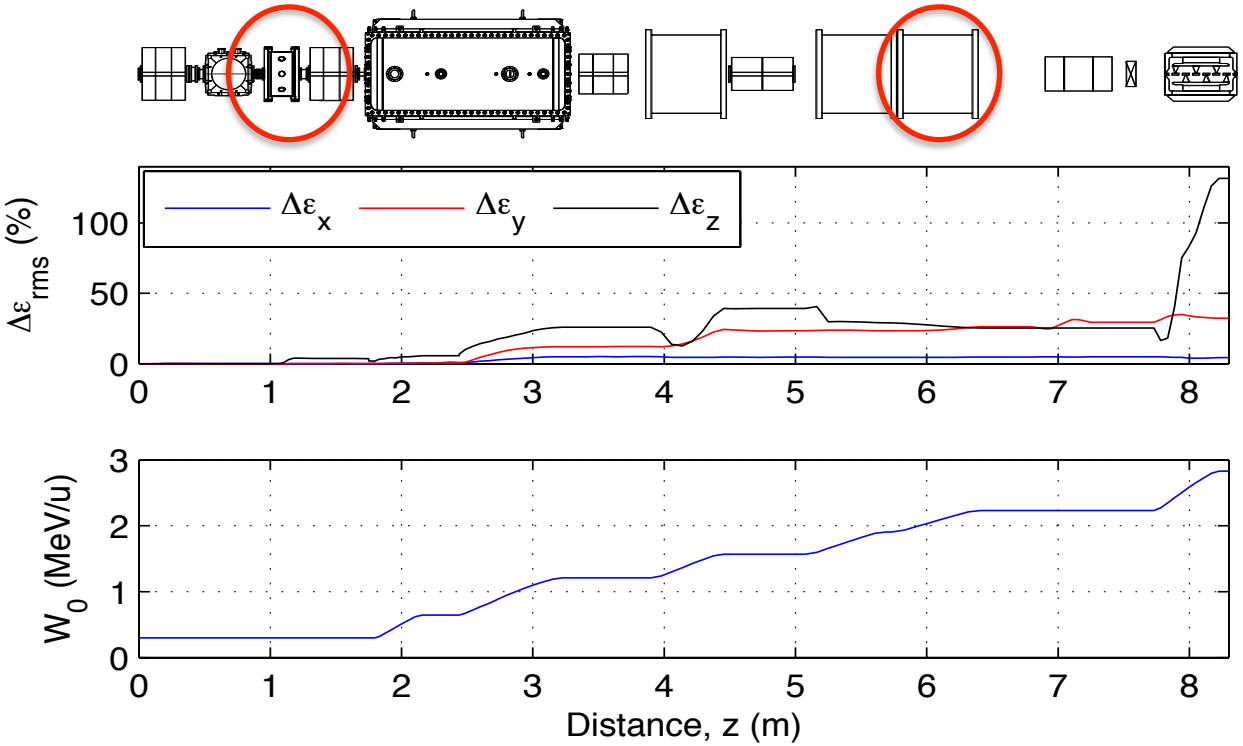
Longitudinal emittance doubles in the 9GP from 2 to 4 π ns keV/u: simulations benchmarked with LORASR.

Longitudinal Emittance Measurements

- Campaign of longitudinal emittance measurements completed, see M.A. Fraser et al, Nucl. Instrum. Methods A663 p.1-9 (2012).

Rebuncher: $\varepsilon_{86\%} = 1.48 \pm 0.2$ π ns keV/u

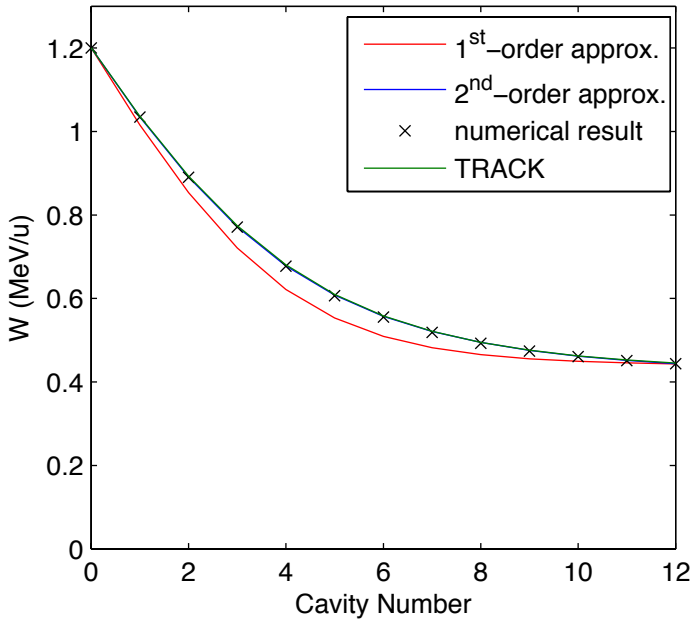
7-gap 3: $\varepsilon_{86\%} = 1.55 \pm 0.12$ π ns keV/u



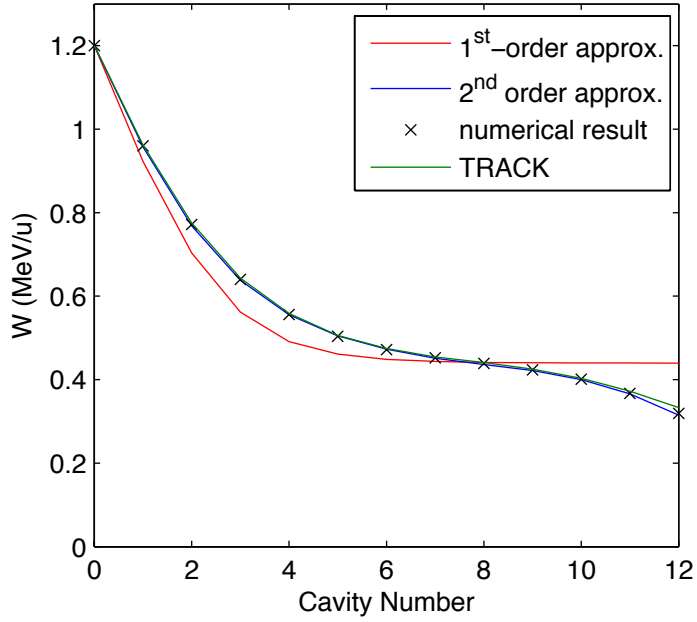
DECELERATION

- In theory, one can decelerate light beams from 1.2 MeV/u to RFQ energy (0.3 MeV/u).
- In practice, due to degradation of the beam quality at low velocity in the cavities we are limited to 0.45 MeV/u.

A/q = 4.5:

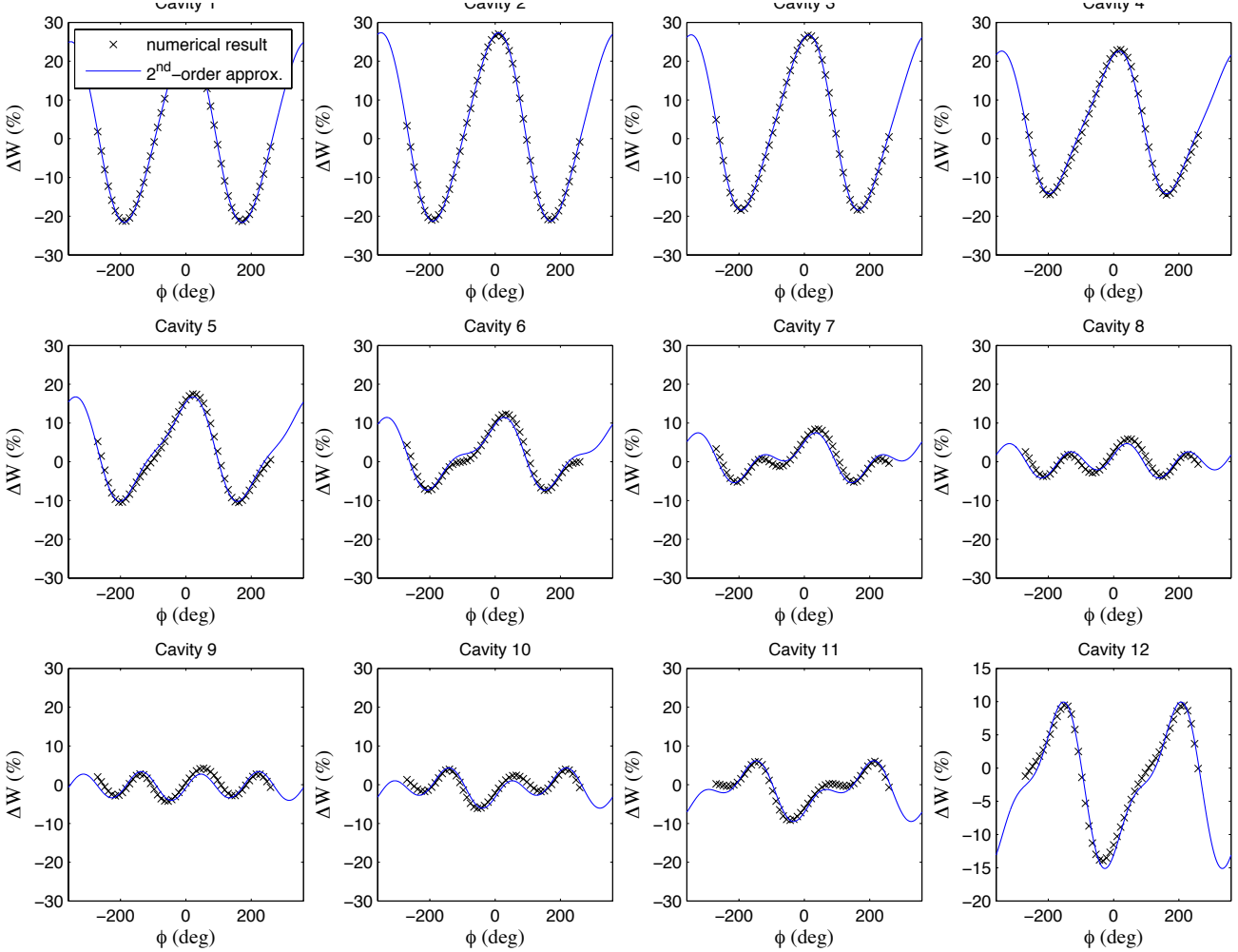


A/q = 3:



DECELERATION

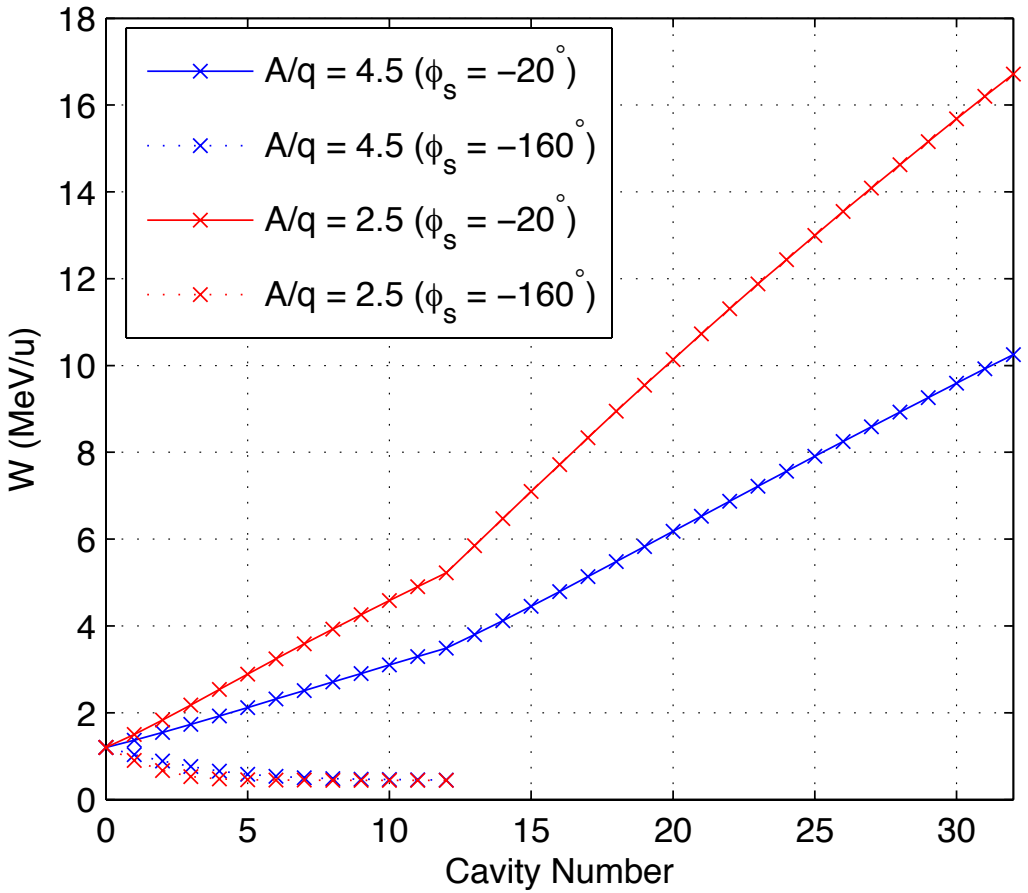
$$\Delta W = q\Delta V_0 \hat{T}(\beta)\cos\phi + \frac{(q\Delta V_0)^2}{W}(\hat{T}^{(2)}(\beta) + \hat{T}_s^{(2)}(\beta)\sin 2\phi)$$



BEAM PARAMETERS

- Beam parameters for 5.5 MeV/u, 10 MeV/u and 0.45 MeV/u are appended, the emittances are summarised next.
- Design of HEBT is based on these numbers.
- Input taken from emittance measurements and limited by the REX front-end, namely:
  - Longitudinal: $\varepsilon_{95\%} = 2\ \pi$ ns keV/u (M.A. Fraser et al.)
  - Transverse : $\varepsilon_{90\%} = 0.3\ \pi$ mm mrad (D. Voulot et al.)
- Comments:
  - SC linac will not significantly degrade existing beam emittance.
  - Adiabatic damping of transverse geometric emittance with velocity: $\sigma \propto 1/\sqrt{\beta}$
  - $\Delta W > \pm 0.1$ %, therefore depending on A/q, either a lower energy is used and cavities in the main linac used to de/re-bunch or a dedicated de/re-buncher is needed in the HEBT. Emittance is compatible with specification!
  - Low energy beams (<2.4 MeV/u) debunched at 101.28 MHz.

ENERGY RANGE



BEAM PARAMETERS

- Emittance given at linac exit and at maximum energy for A/q = 4.5.

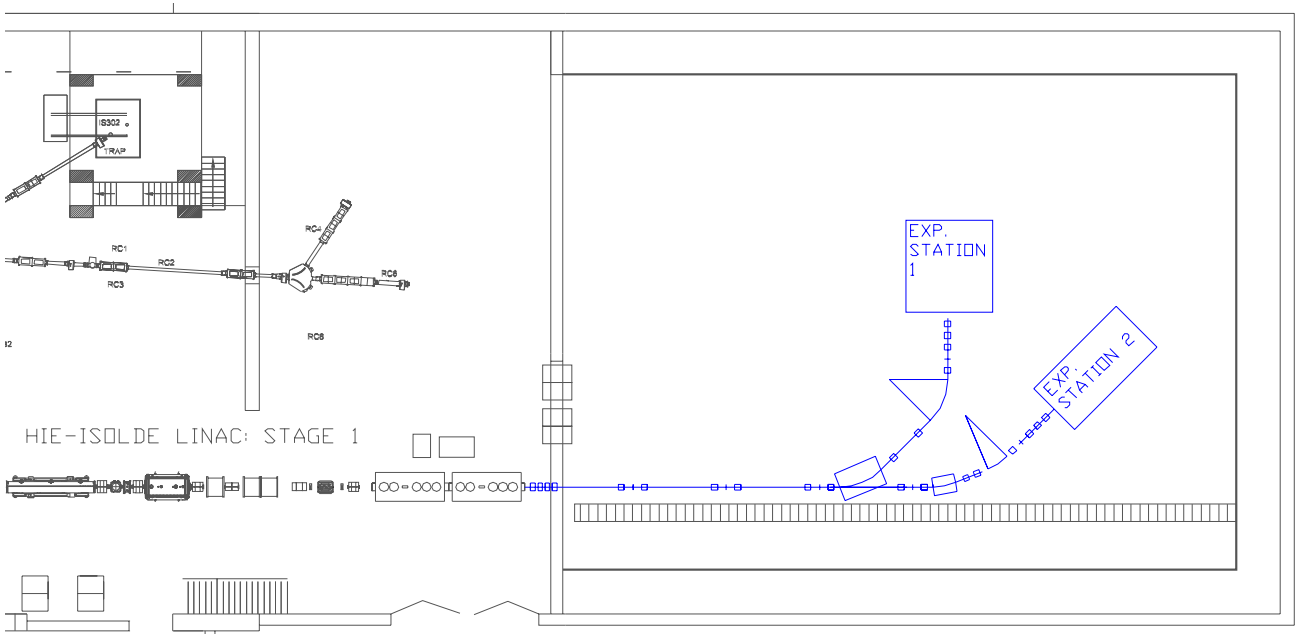
Stage and Energy	95% $\varepsilon_{transverse}$ (π mm mrad) (geometric)	95% $\varepsilon_{longitudinal}$ (π ns keV/u)
Stage 1 at 5.5 MeV/u	≈4	≈4
Stage 2b at 10 MeV/u	≈3	≈2
Stage 2b at 0.45 MeV/u	≈20	≈2.6 (but debunched at 101.28 MHz)

- 95 % of a Gaussian beam equates to the 6-rms emittance, with corresponding projections e.g.: $\Delta W = \sqrt{6}\sigma_{rms}$
- Assuming the focus can be made with the appropriate optical elements, use e.g.:

$$\Delta x \approx \varepsilon / \Delta x'$$

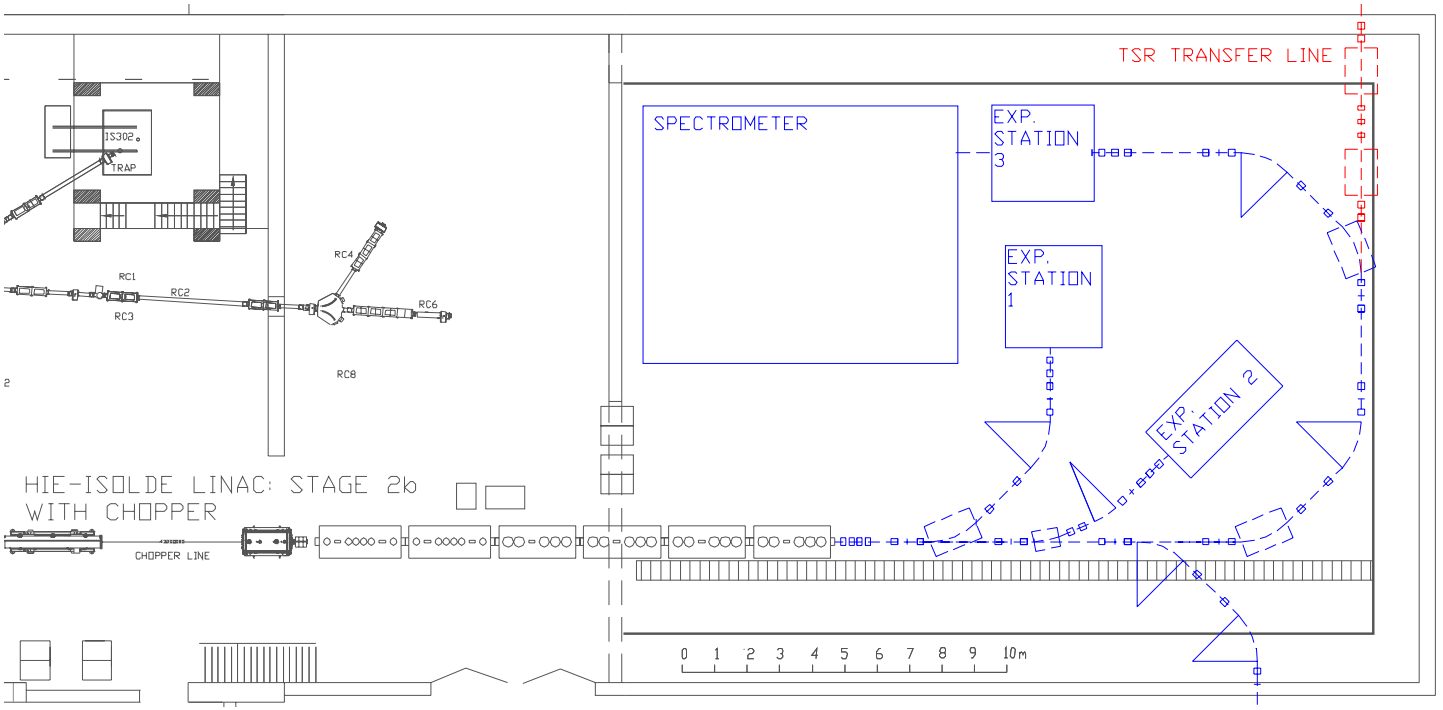
HEBT

- First iteration of the design, which is currently being taken on by TE/ABT/BTP (Brennan Goddard) and has been allocated a Fellow.
- Without a rebuncher at 5.5 MeV/u: $\Delta W = \pm 0.6$ % ($=\pm\sqrt{6}\sigma$) and $\Delta t < \pm 1.6$ ns ($=\pm\sqrt{6}\sigma$)
- A rebuncher will reduce the above parameters by a factor of 3.



HEBT

- With chopper line, difficult to fit rebuncher for Exp Station 1.
- Without a rebuncher at 10 MeV/u (A/q = 4.5): $\Delta W = \pm 0.3$ % ($=\pm\sqrt{6}\sigma$) and $\Delta t < \pm 0.6$ ns ($=\pm\sqrt{6}\sigma$) at Exp Stations 1 and 2.
- With rebuncher at 10 MeV/u (A/q = 4.5): $\Delta W = \pm 0.1$ % ($=\pm\sqrt{6}\sigma$) and $\Delta t < \pm 0.25$ ns ($=\pm\sqrt{6}\sigma$) at Exp Station 2.

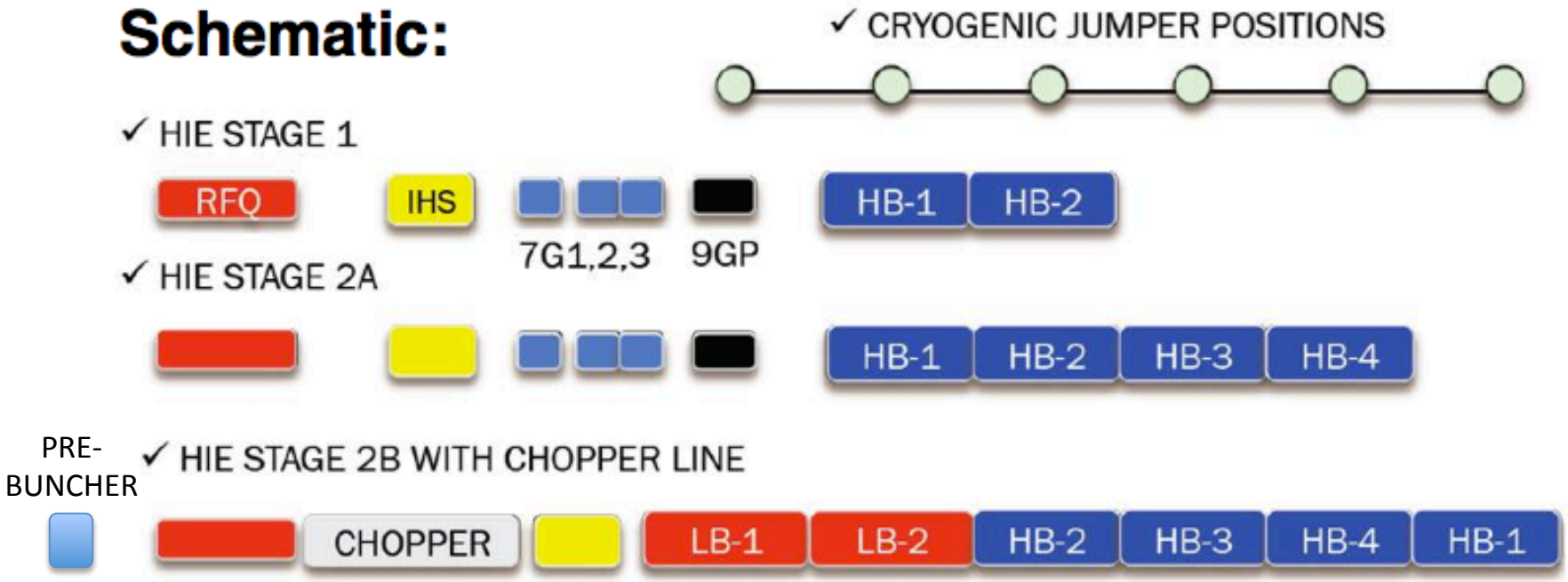


POINTS FOR DISCUSSION

- Requirement of a rebuncher in the HEBT?
  - beams below ≈ 2.4 MeV/u will need rebunching after main linac
  - high energy beams could be bunched in main linac if energy is sacrificed.
  - require upwards of 1 MV at high energy (superconducting QWR).
- Further information/iteration on the footprints of the experiments?
  - in particular for Experimental Station 2.
- Some transverse beam parameters are challenging:
  - spectrometer
  - MINIBALL when beam is decelerated (large geometric emittance)
- Full or half-day meeting will be scheduled for late February to ensure design constraints requirements are understood for HEBT. Brennan Goddard to make the appropriate arrangements.
- A contact person (nuclear physicist) in regular HEBT meetings.

NEXT YEAR...

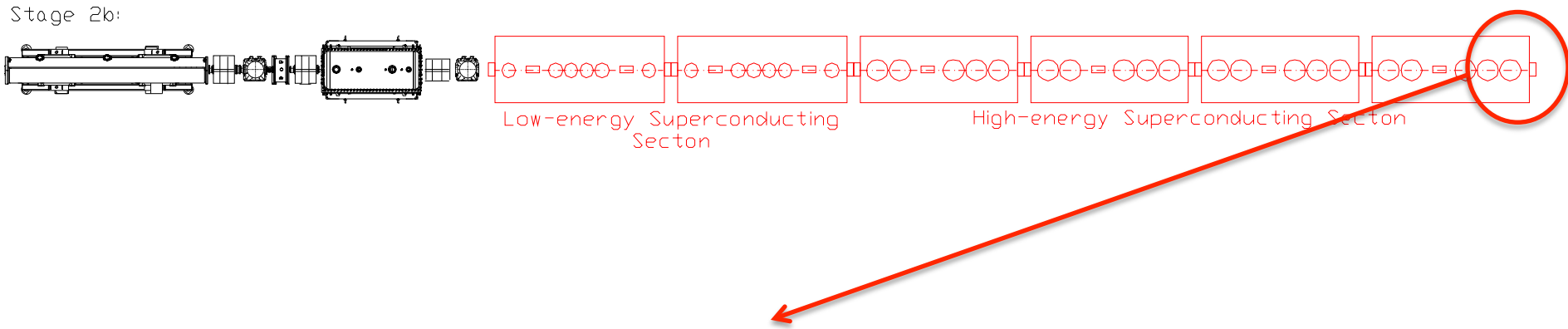
- Finalisation of HEBT design early next year.
- 100 ns bunch spacing:
  - Beam dynamics simulations of RFQ with multi-harmonic pre-buncher
  - Development of the pre-buncher.
  - Development of the chopper line and its associated rf structures.

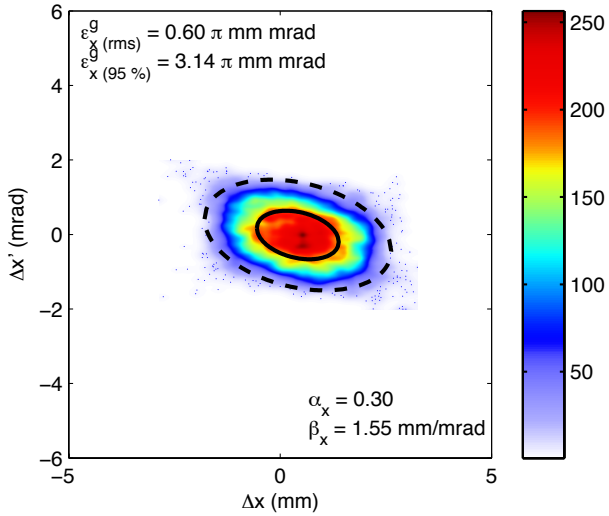


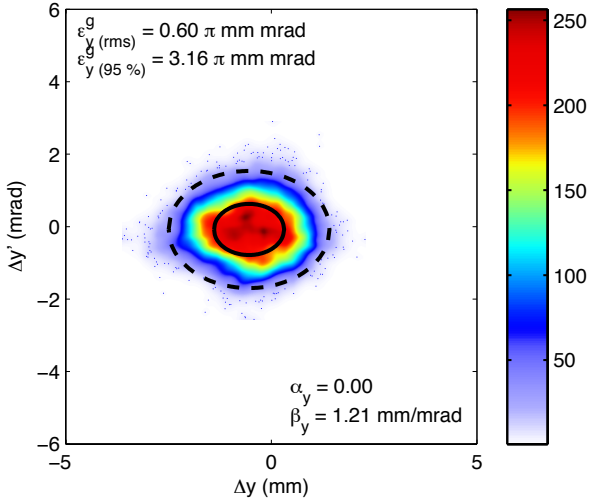
APPENDED BEAM PARAMETERS

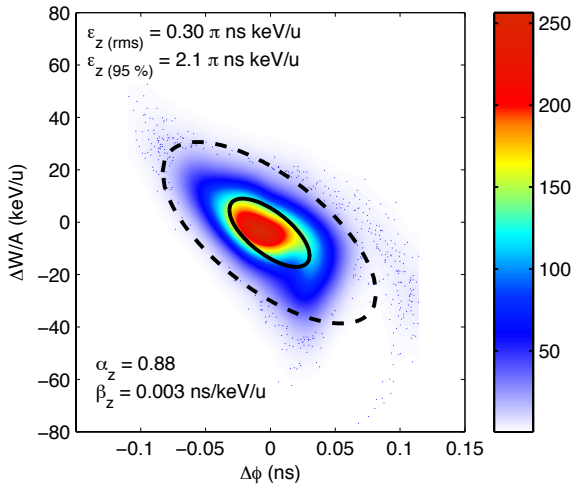
STAGE 2B: 10 MEV/U

- At exit to the HIE-LINAC in Stage 2b:



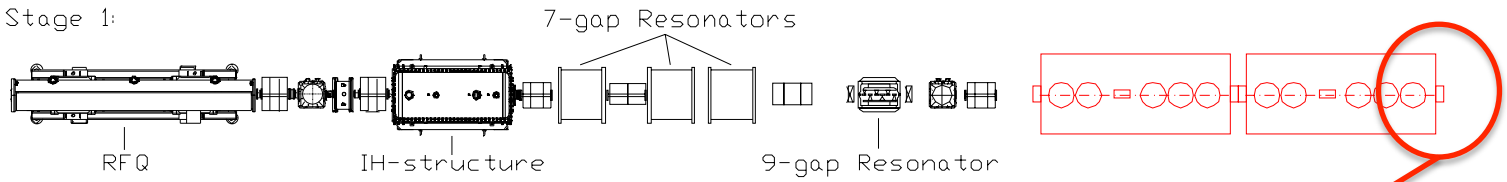


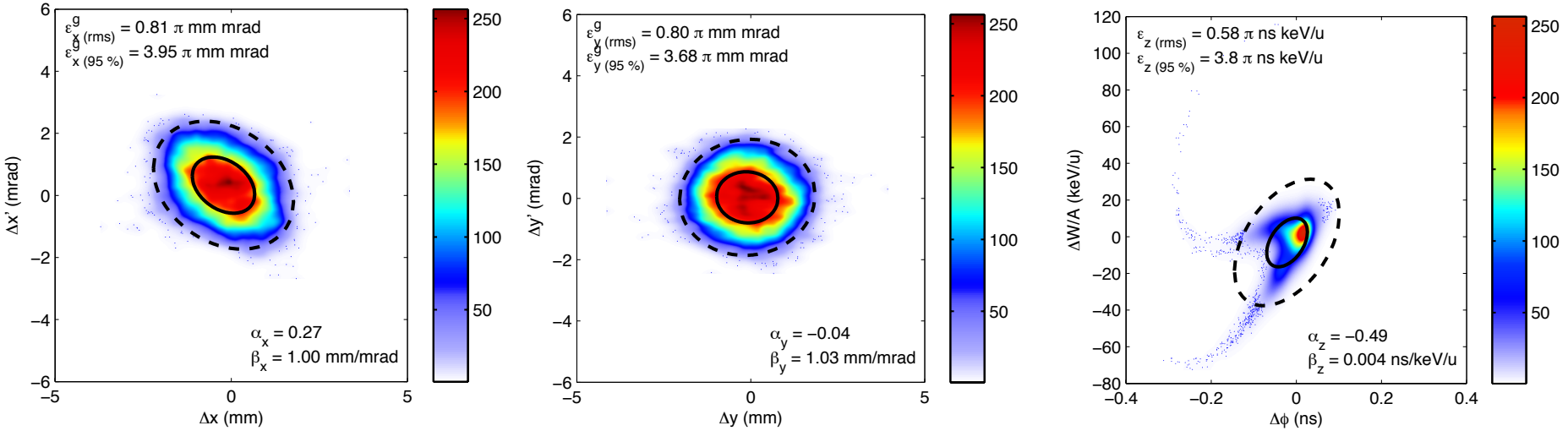




STAGE 1: 5.5 MEV/U

- At exit to the HIE-LINAC in Stage 1:





STAGE 2B: 0.45 MEV/U

- At exit to the HIE-LINAC in Stage 2: