HIE-ISOLDE Spectrometer Workshop
HIE-ISOLDE technical aspects

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- IMPACT OF THE CLEAN 100NS BUNCH SPACING
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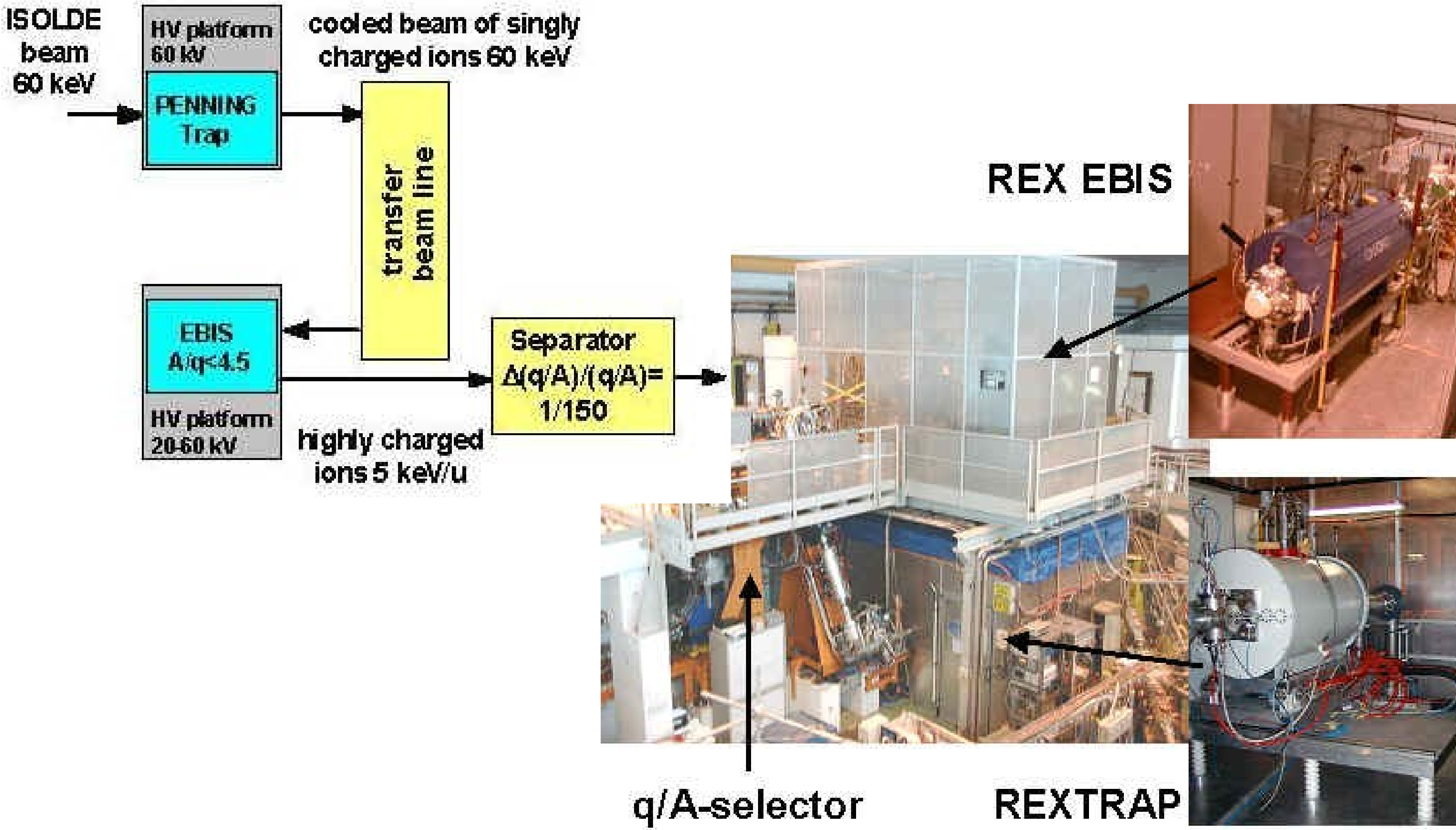
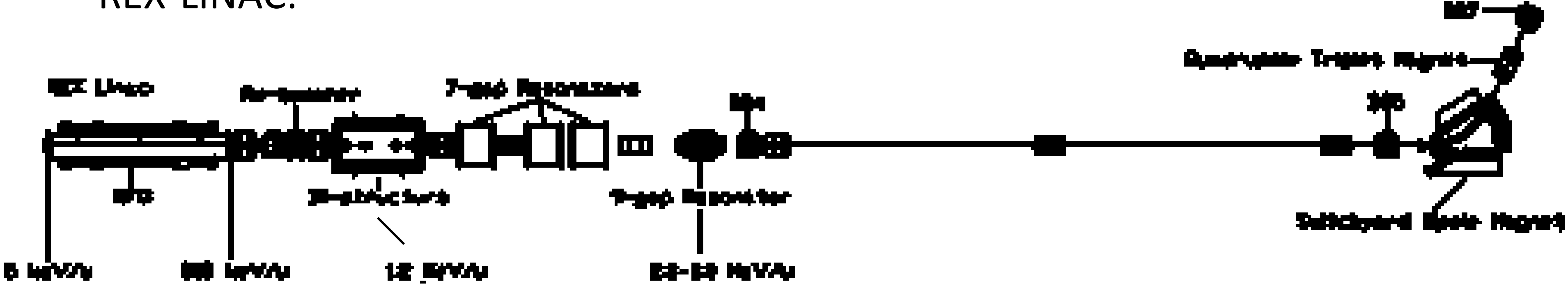
- REX BEAM PARAMETERS
- LONIGTUDINAL DIAGNOSTICS FOR HIE-ISOLDE
- SUMMARY OF BEAM PARAMETERS AT HIE-ISOLDE
  - DECELERATION
- HEBT
  - OPEN QUESTIONS

INJECTION IN THE LINAC

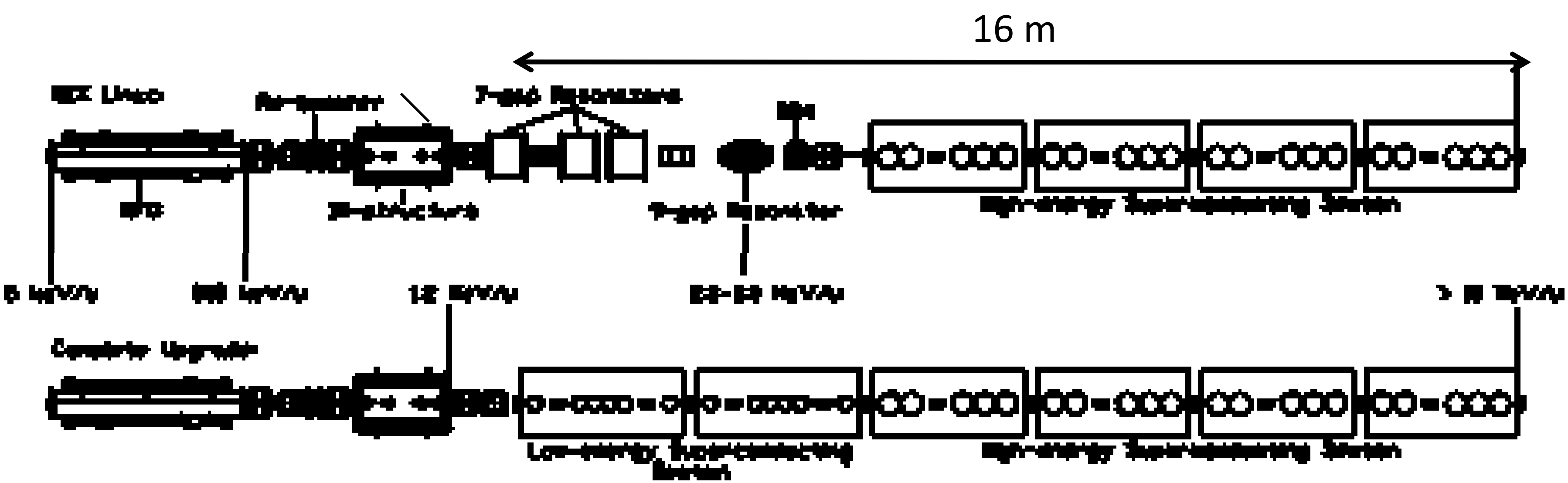


THE HIE-LINAC UPGRADE

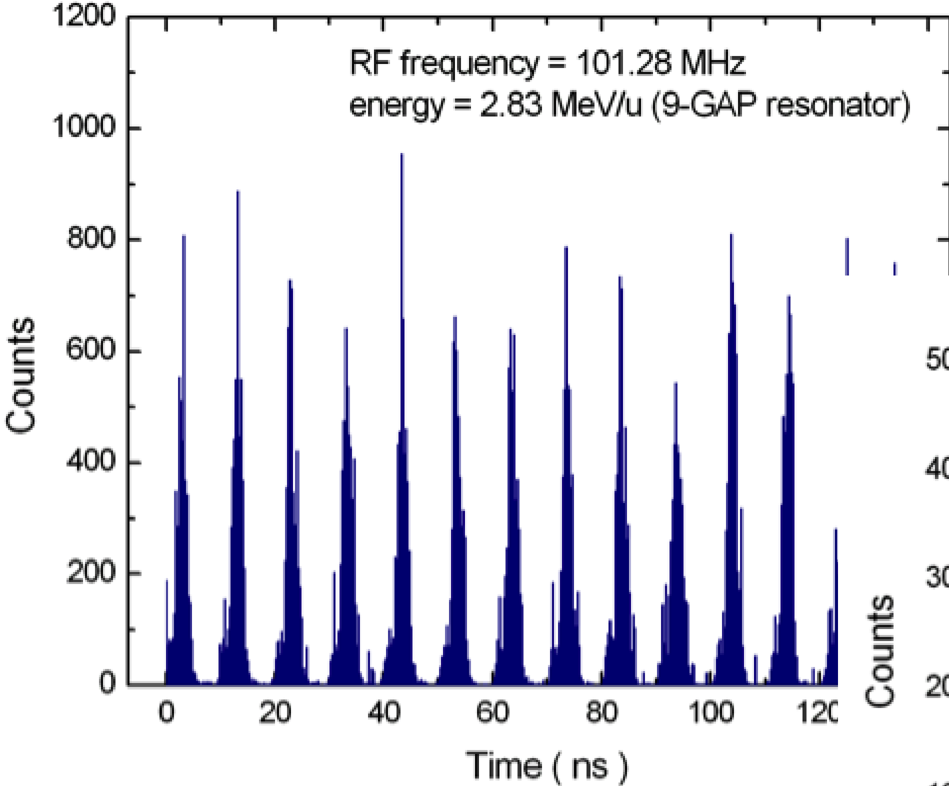
- REX-LINAC:

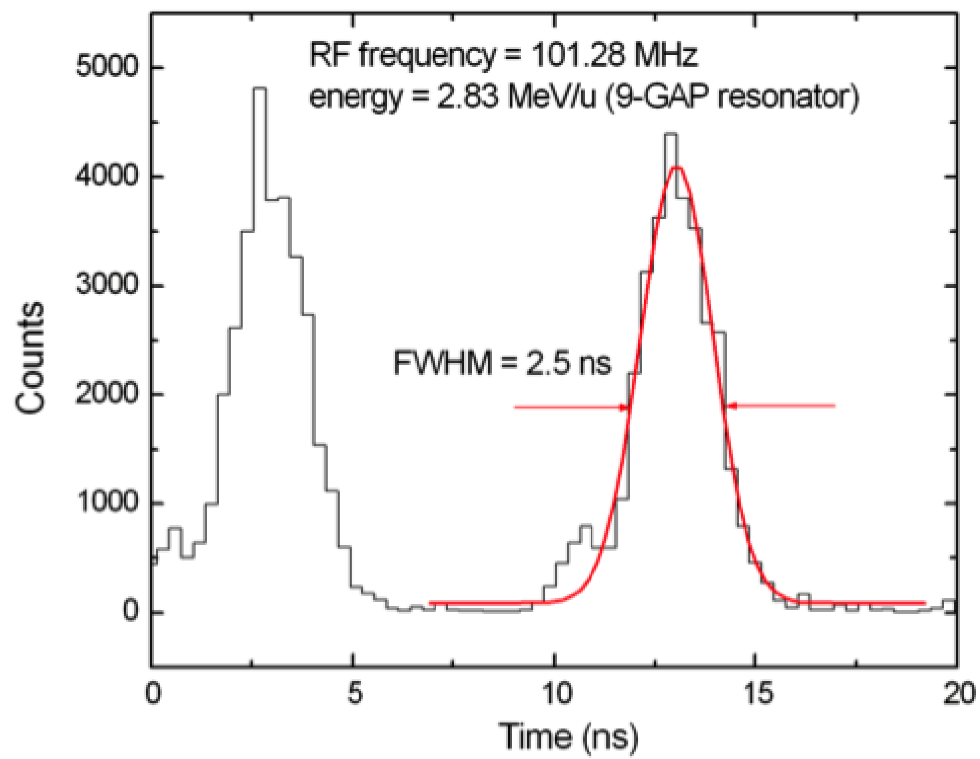


- HIE-LINAC:
  - MODULAR INSTALLATION OF SC CRYOMODULES
  - ACCELERATION TO 10 MeV/u



Micro Bunch in the Linac

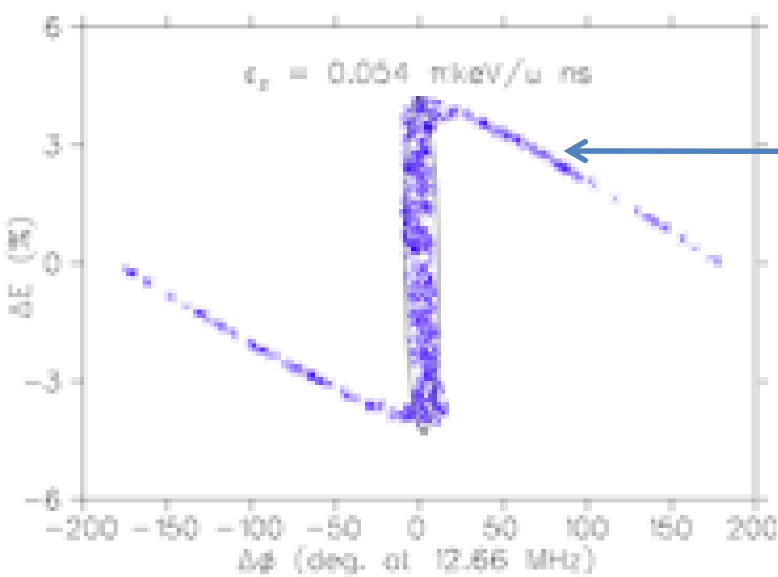




First time of microbunch length measurement at REX-ISOLDE

Towards a 100 ns bunch spacing

- Easy way: to chop the beam at the end of the linac, but that means to lose 90% of the beam
- Difficult way: add a pre-buncher upstream of the RFQ. We can preserve at least 80% of the original intensity



We can minimize the tail down to 10% intensity, can you live with that?

CHOPPER/KICKER

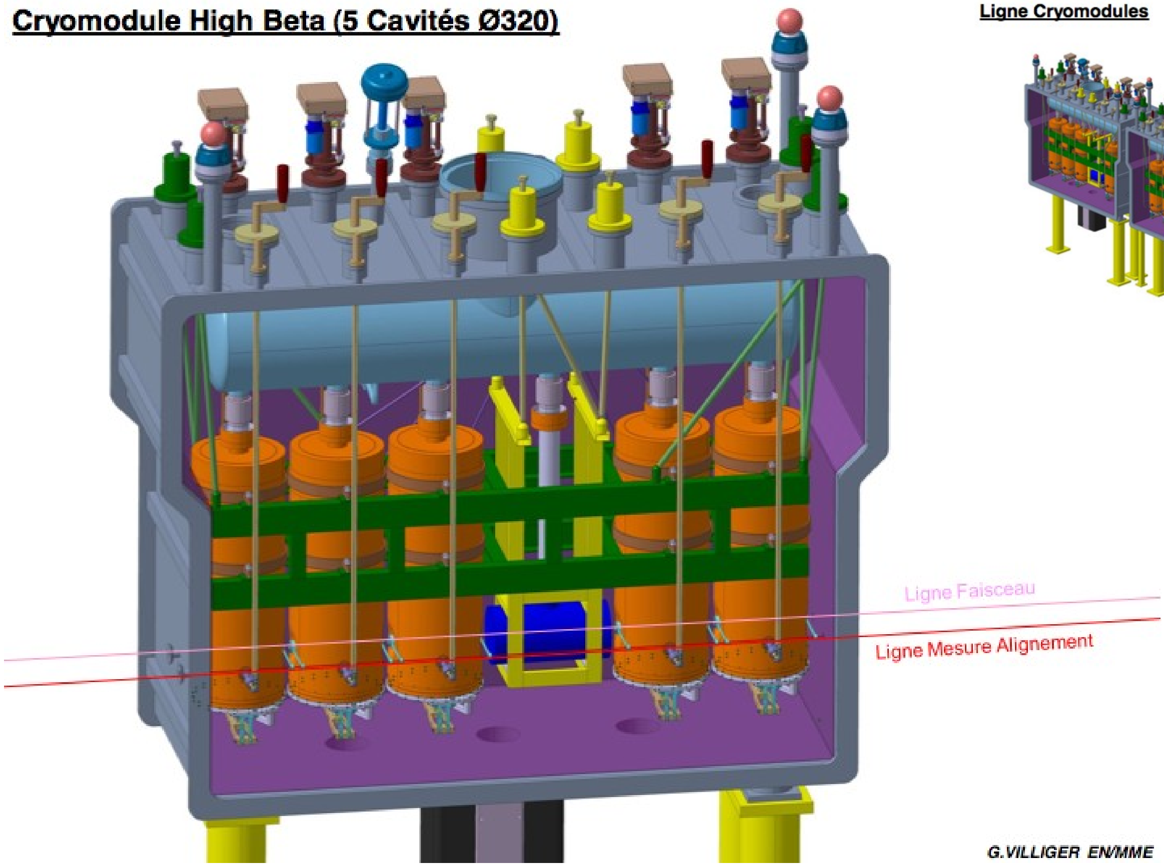
CASE OF CHOPPER AFTER THE SC-LINAC

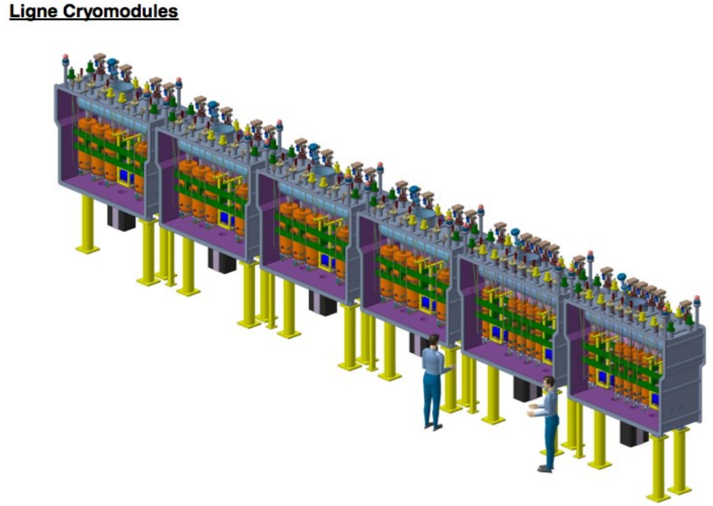
- REQUIRED VOLTAGE IS 45KV FOR A/Q=4.5 AND ENERGY OF 10MEV/U FOR 1MRAD DEFLECTION!

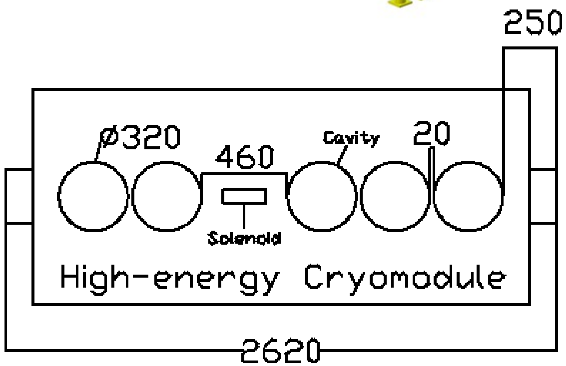
CASE OF CHOPPER AFTER THE IH-STRUCTURE

- NEED ADDITIONAL SPACE BEFORE THE SC LINAC (MAJOR CHANGE IN THE LAYOUT) (AT LEAST AT COUPLE OF METER)
- VOLTAGE REQUIRED IS STILL HIGH: 6KV FOR A/Q=4.5 AND ENERGY OF 1.2MEV/U FOR 1MRAD DEFLECTION

The HIE-LINAC Upgrade



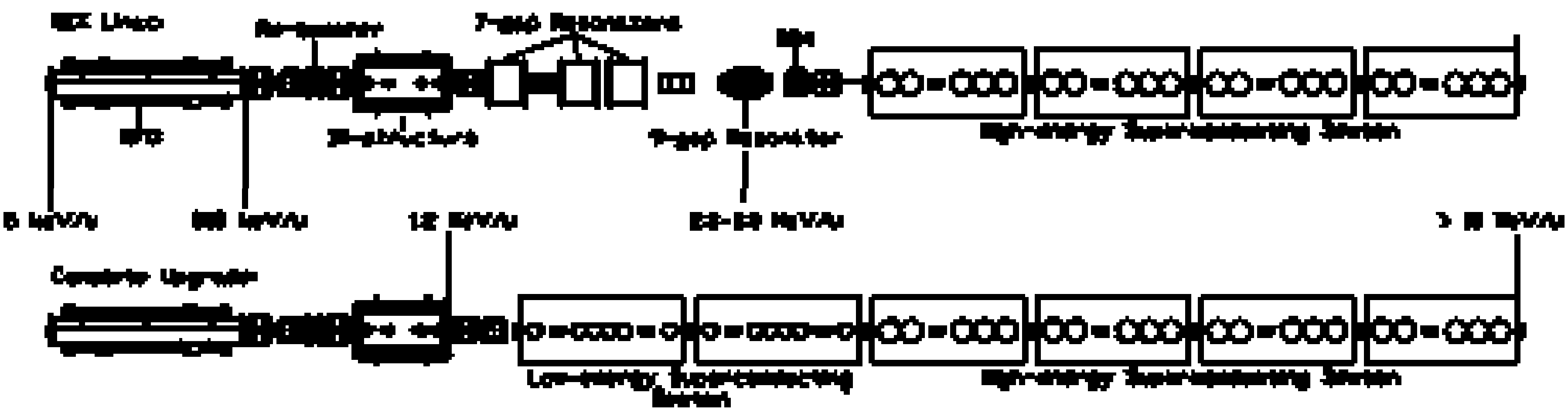




- A Total of 32 SC Cavities and 8 SC Solenoids housed in 6 Cryomodules
  - 12 low-beta (β = 6.3 %) and 20 high-beta (β = 10.3 %) quarter-wave resonators
  - Cavity gradient specified at 6 MV/m
  - Solenoids specified at 16.1 T^2 m

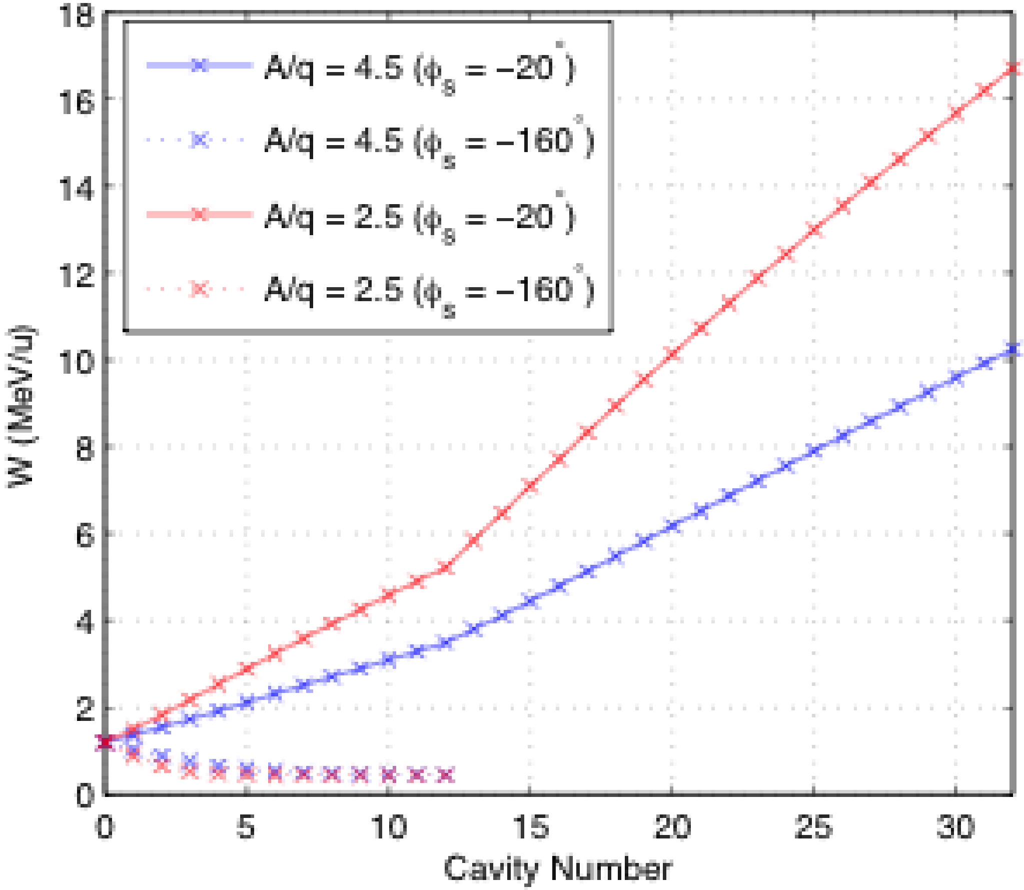
Energy Reach (*A/Q = 4.5)

Installation Phase	Achievable Beam Energies* (MeV/u)	Linac Infrastructure
REX	0.3, 1.2 – 2.8	Existing
Stage 1	0.3, 1.2 – 4.3 0.3, 1.2 – 5.9 0.3, 1.2 – 7.6 0.3, 1.2 – 9.3	REX + 1HB Cryomodule REX + 2HB Cryomodules REX + 3HB Cryomodules REX + 4HB Cryomodules
Stage 2	0.3, 0.5 – 10.0	REX RFQ + IHS + HIE-LINAC

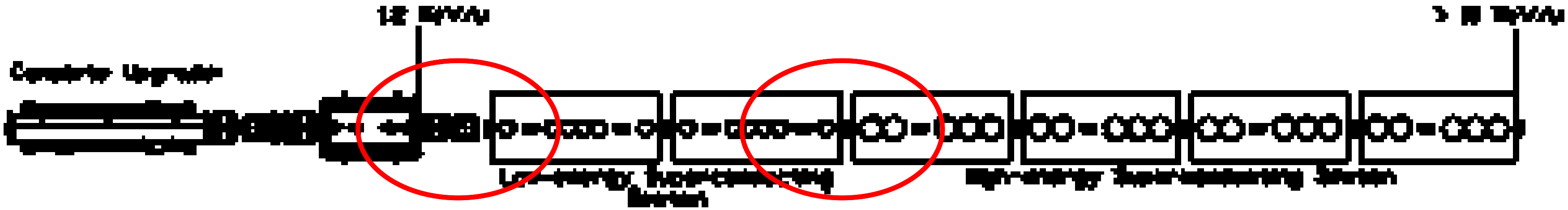


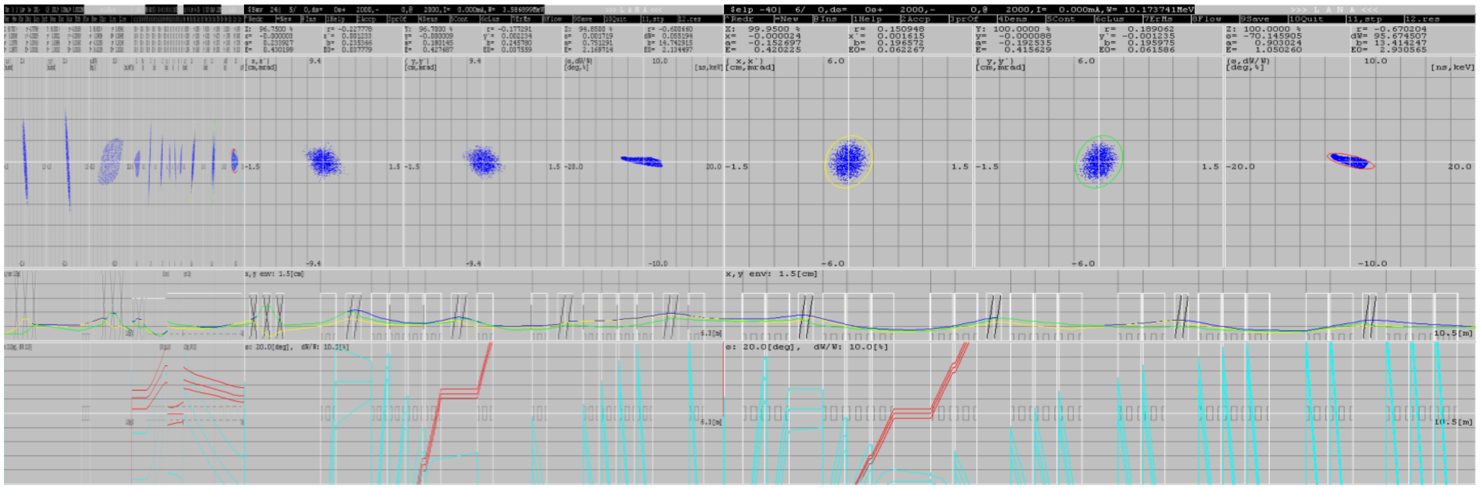
FULL ENERGY FLEXIBILITY

- THE VELOCITY PROFILE IN THE SC LINAC IS FLEXIBLE DUE TO THE SHORT AND INDEPENDENTLY PHASED QWRS
- A/Q ACCEPTANCE OF REX: 2.5 < A/Q < 4.5



Key Points in the Optics Design

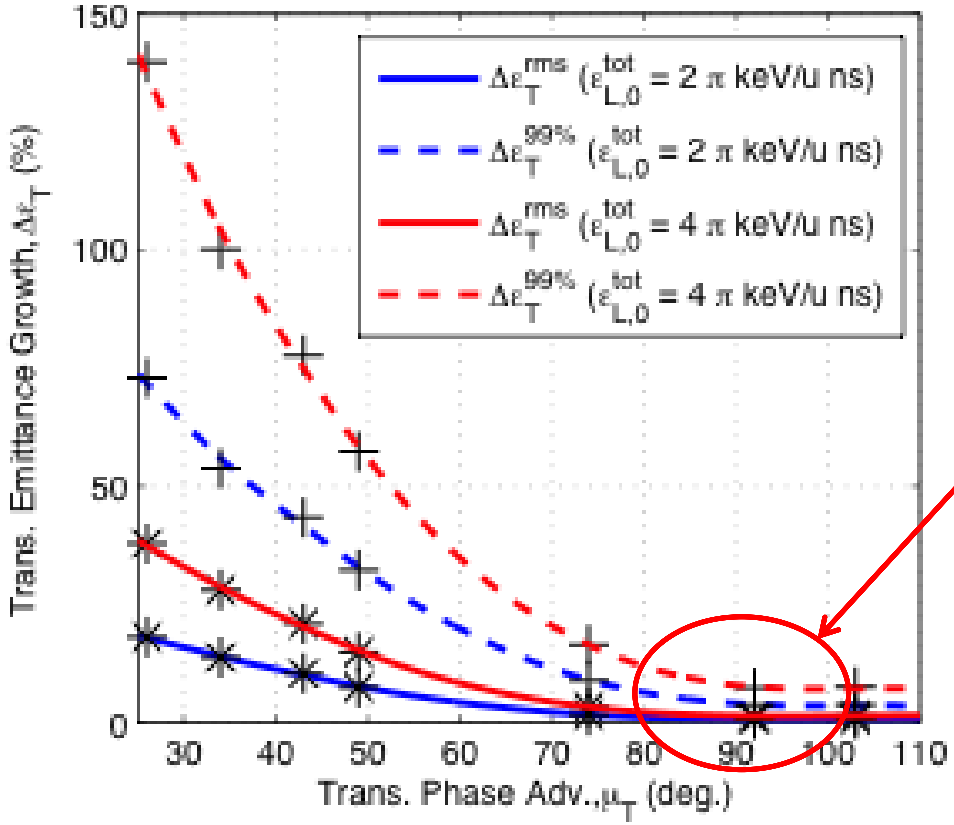




- In-line Longitudinal Matching Section
  - saving valuable space in the ISOLDE hall
  - use the first SC cavity as a buncher with the bunching drift used with a solenoid
- No Dedicated Transverse Matching Section Between Low and High Energy Sections
  - matching can be done in-line
- Asymmetric Lattice in the High Energy Section

BEAM DYNAMICS STUDIES

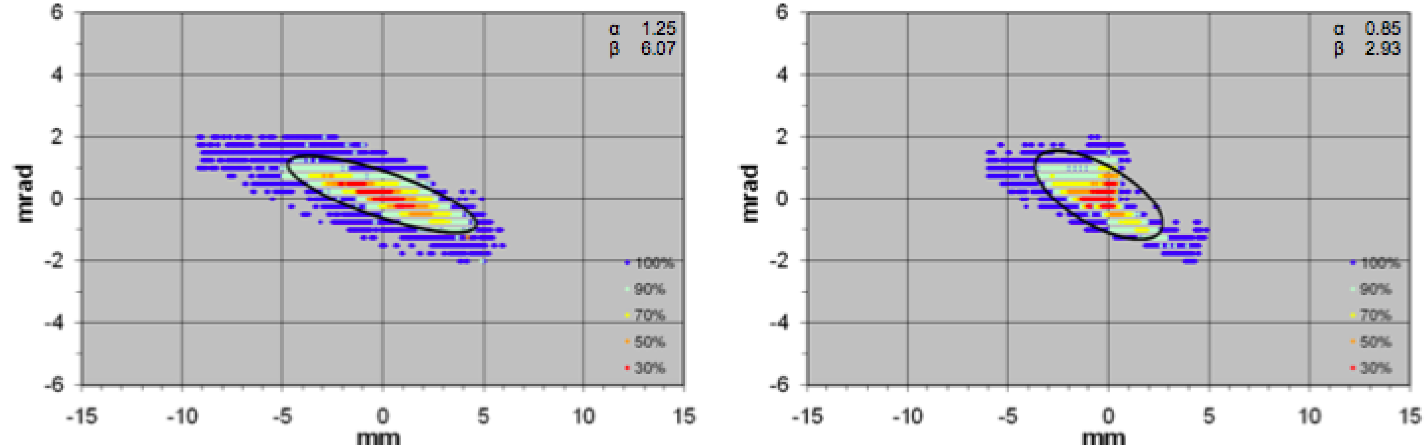
- SPECIFICATION OF THE STRENGTH OF THE SOLENOID FOCUSING CHANNEL
  - CHOSEN AT 90° PHASE ADVANCE PER SOLENOID PERIOD.
  - DECOUPLES THE EFFECT OF THE LONGITUDINAL EMITTANCE ON THE TRANSVERSE DYNAMICS



WORKING POINT:
16.1 T^2 m

REX BEAM PARAMETERS

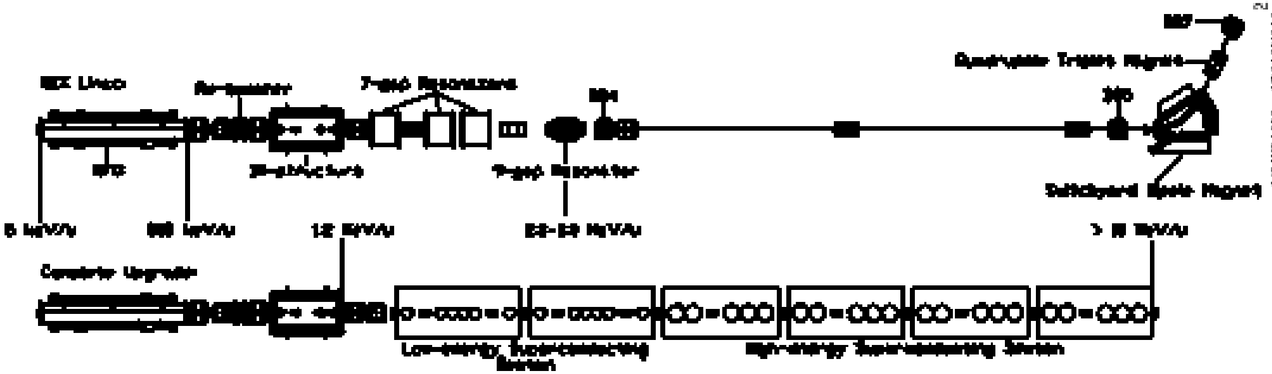
- AS INPUT PARAMETERS FOR THE HIE-LINAC SIMULATIONS
- TRANSVERSE EMITTANCE MEASUREMENTS MADE BY D. VOULOT IN 2006:

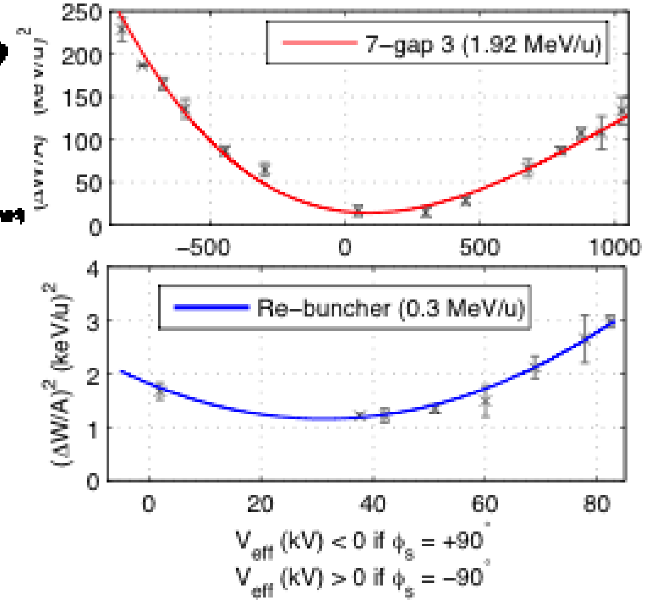


MEASUREMENT	TRANSMISSION (%)	$\varepsilon_{n,rms}$ (π mm mrad)	$\varepsilon_{n,90\%}$ (π mm mrad)
RFQ (0.3 MeV/u)	75	0.03	0.16
9GP (2.85 MeV/u)	90	0.06	0.30
INPUT FOR HIE-LINAC SIMULATIONS (6D WATERBAG DISTRIBUTION)	N/A	0.07	0.30

REX Beam Parameters

- Longitudinal Emittance Measurement Made at RFQ and 7GP3 Energy



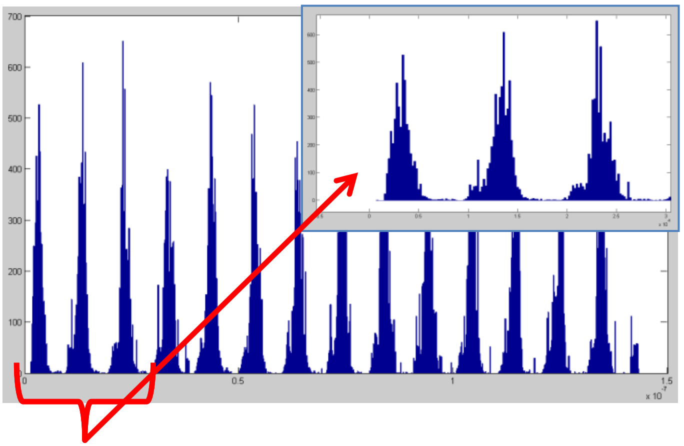


$$\frac{\Delta W_1^2}{A^2} = \epsilon_0 \left[\left(\frac{q}{A}\right)^2 \beta_0 V_{eff}^2 \pm 2 \left(\frac{q}{A}\right) \alpha_0 V_{eff} + \gamma_0 \right]$$

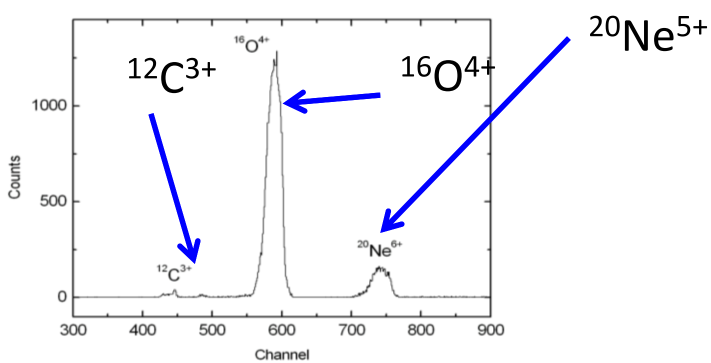
Measurement	Transmission (%)	$\varepsilon_{n,rms}$ (π kev/u ns)	$\varepsilon_{n,tot}$ (π kev/u ns)
RFQ (0.3 MeV/u)	50	0.18 ± 0.02	1.62 ± 0.18
7GP3 (1.96 MeV/u)	80	0.35 ± 0.04	3.15 ± 0.36
Input For HIE-LINAC Simulations (6D Waterbag Distribution)	N/A	0.5	4

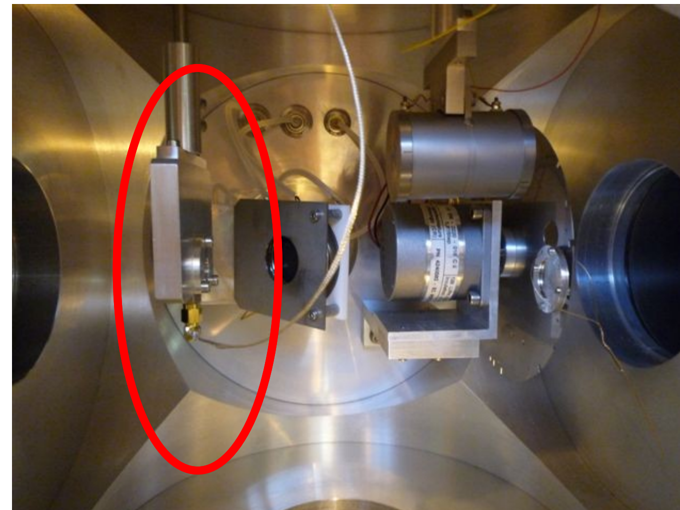
HIE Diagnostics

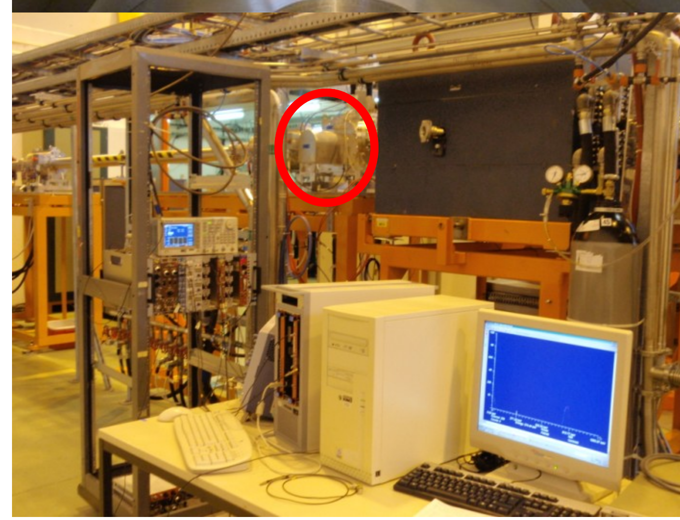
- Francesca Zocca has been Developing a Si Detector Setup for Longitudinal Beam Diagnostics at HIE-ISOLDE
- Time Structure at 2.85 MeV/u after 9GP



- Spectroscopy on an A/Q = 4 Stable Beam

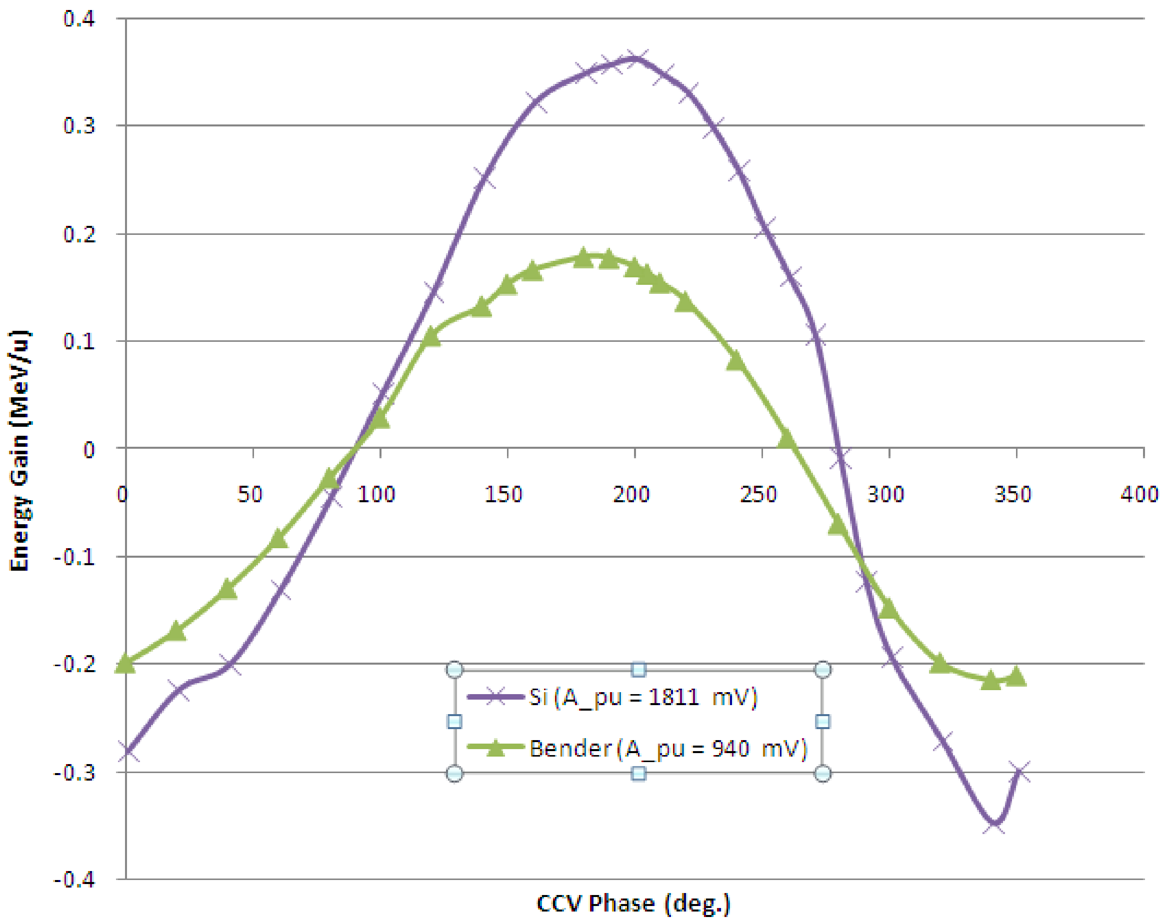






HIE DIAGNOSTICS

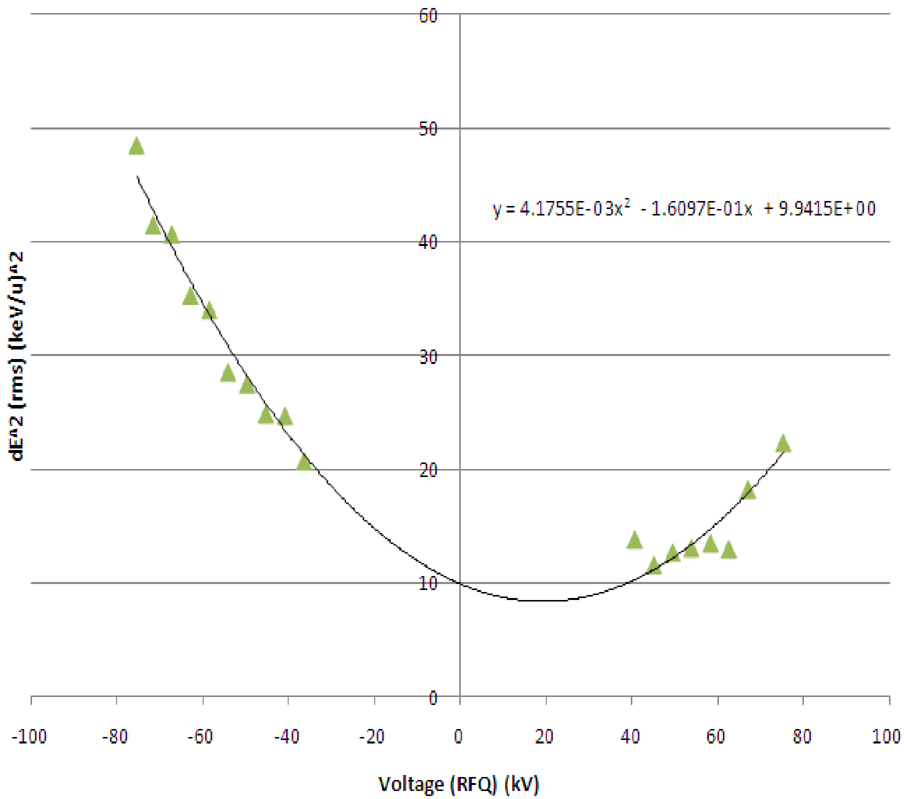
- DEMONSTRATED THE PRINCIPLE OF CAVITY PHASE-UP USING 7GP3

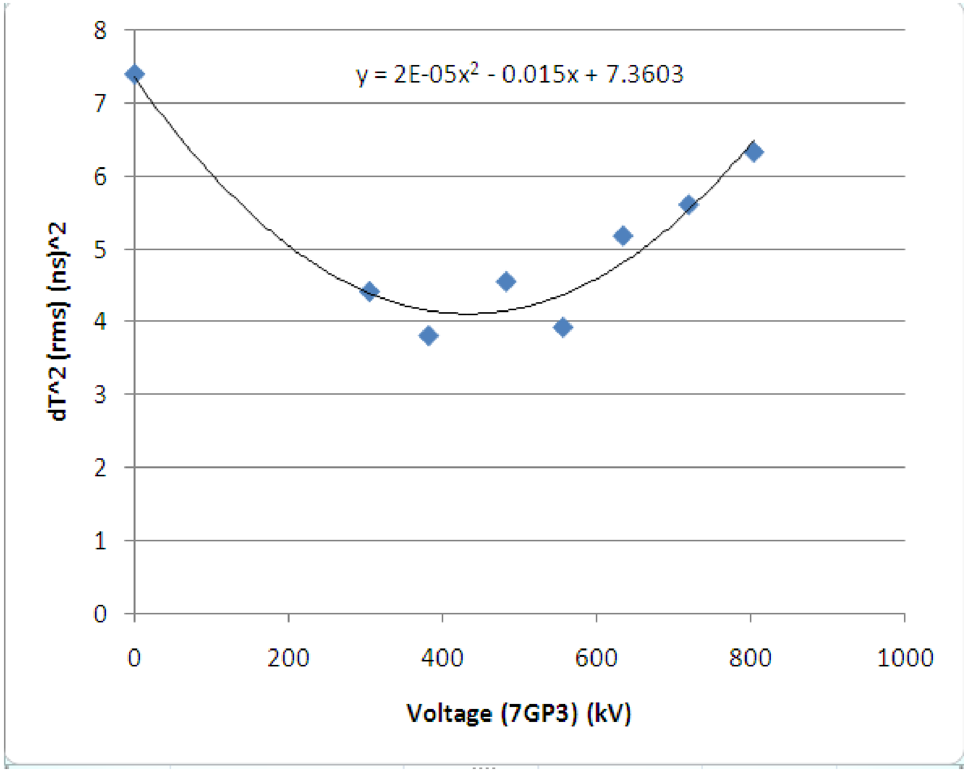


- ALSO USED TOF BUT REQUIRE A CHOPPED BEAM TO PHASE UP A CAVITIY QUICKLY.

HIE DIAGNOSTICS

- LONGITUDINAL EMITTANCE MEASURED USING THE SILICON DETECTOR:
  - IN THE ENERGY DOMAIN WITH THE REBUNCHER
  - IN THE TIME DOMAIN WITH THE 7GP3
  - DATA ANALYSED A NOTE WILL BE PUBLISHED SOON

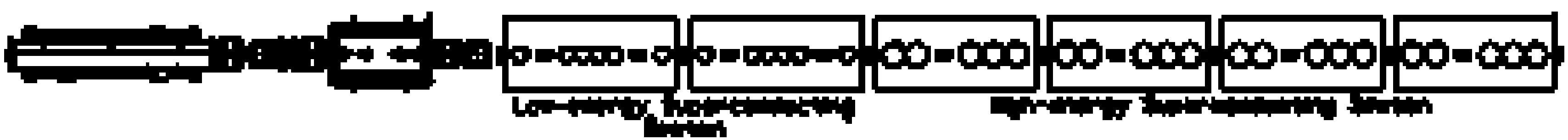




HIE TIME STRUCTURE

- SC Linac CW but Beam Time Structure will be identical to REX

Energy (MeV/u)	Time Structure at HIE-Linac Exit (RF Bunching inside EBIS Pulse)	Linac Section Utilised
0.3	Debunched	RFQ
0.5 – 2.4	Debunched	SC (First Cryomodule of Low Energy)
2.4 – 10.0	Bunched	SC (High Energy)



* A/Q = 4.5

HIE Beam Parameters*

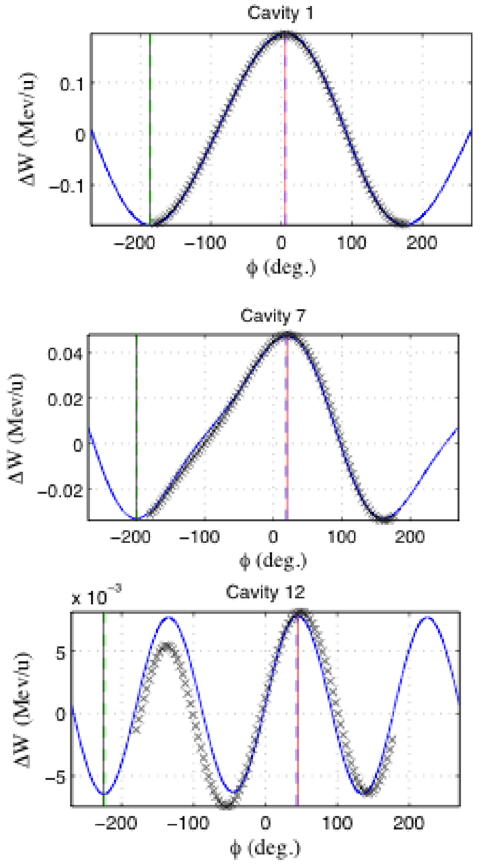
- Realistic Beam Parameters at HIE-LINAC Exit:

Parameter	Value	Units
Energy	0.3, 0.45 – 10	MeV/u
$\varepsilon_{T,norm,rms}$ / $\varepsilon_{T,,norm,tot}$	0.07 / 0.60	π mm mrad
$\Delta\varepsilon_T$	< 5	%
$\varepsilon_{L,norm,rms}$ / $\varepsilon_{L,norm,tot}$	0.52 / 4.2	π keV/u ns
$\Delta\varepsilon_L$	5-10	%
Transmission	>99	%

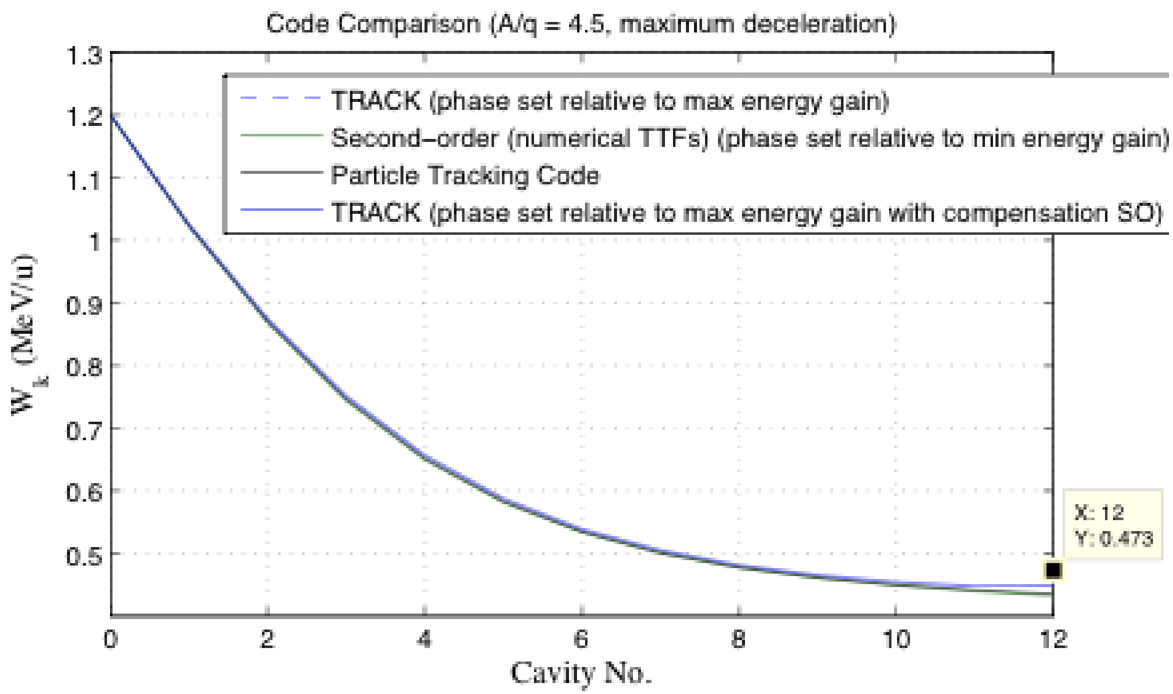
- A/Q = 4.5 @ 10 MeV/u

Deceleration

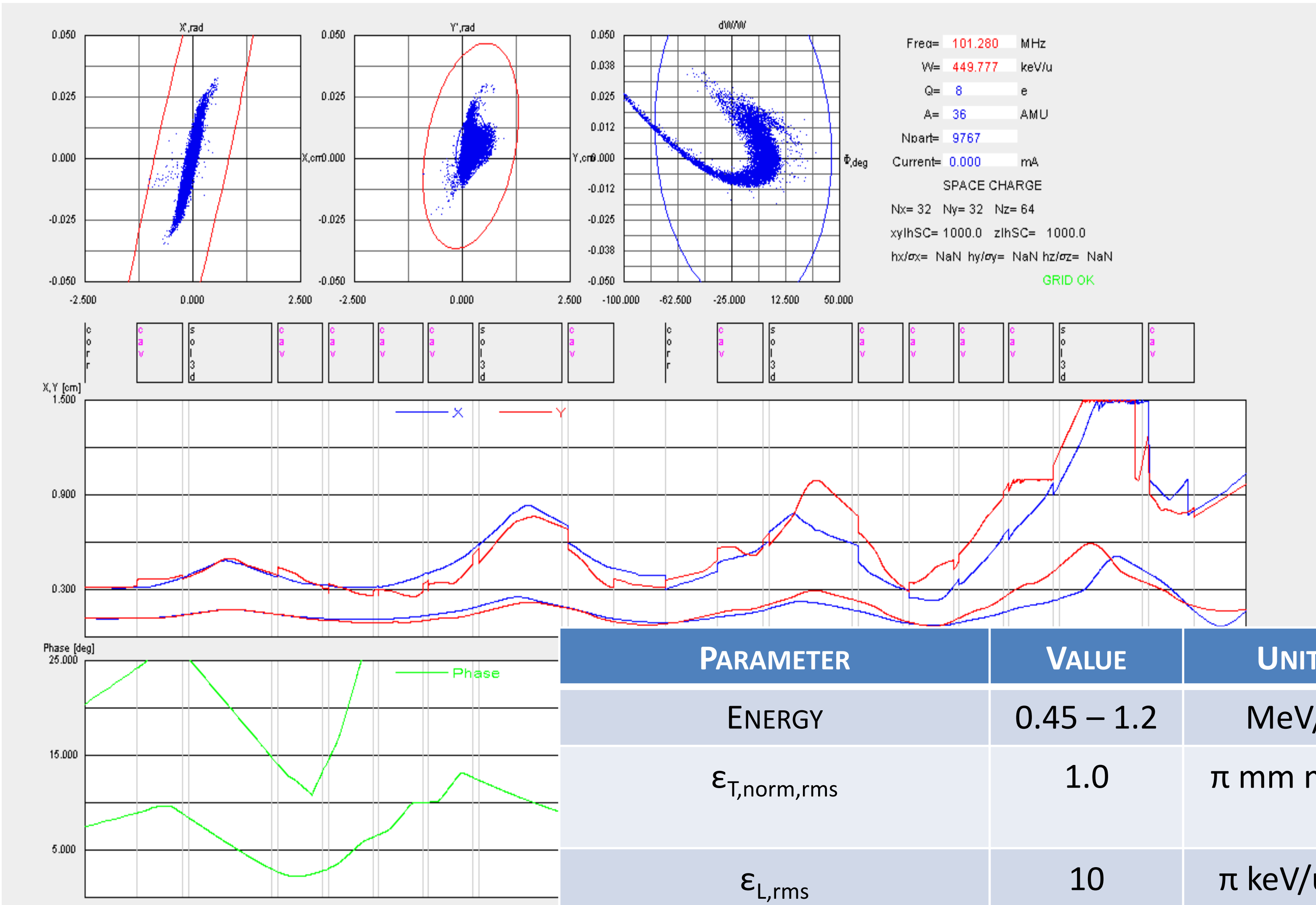
- Require Careful Phasing of The Cavities to Control the Beam Steering at Low Velocity.
- Use Jean Delayen's 2[ND] Order Formalism to Calculate Energy Gain and To Correctly Phase the QWRs.



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



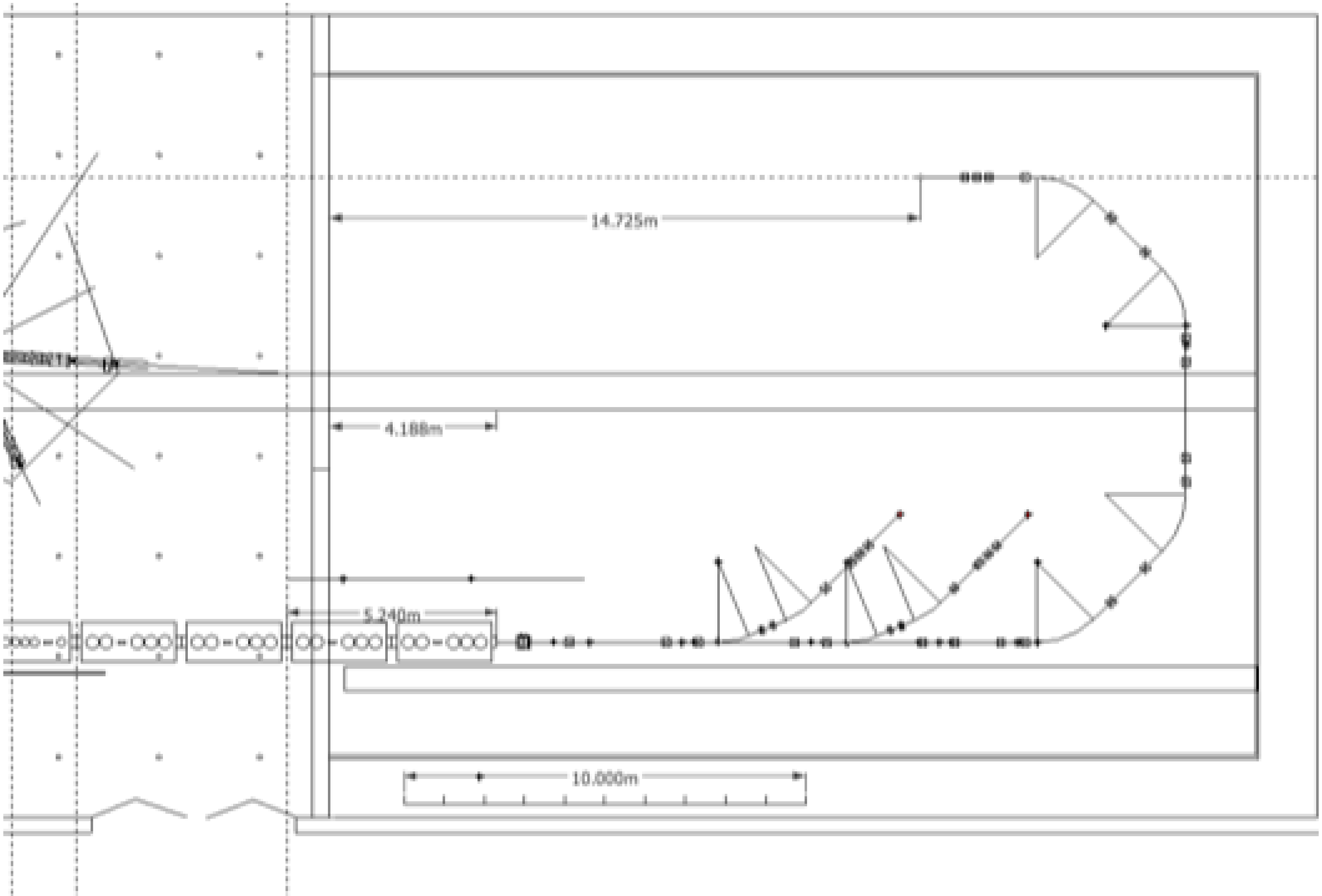
Deceleration*



Parameter	Value	Units
Energy	0.45 – 1.2	MeV/u
$\varepsilon_{T,norm,rms}$	1.0	π mm mrad
$\varepsilon_{L,rms}$	10	π keV/u ns
Transmission	97	%

* A/Q = 4.5 @ 0.45 MeV/u

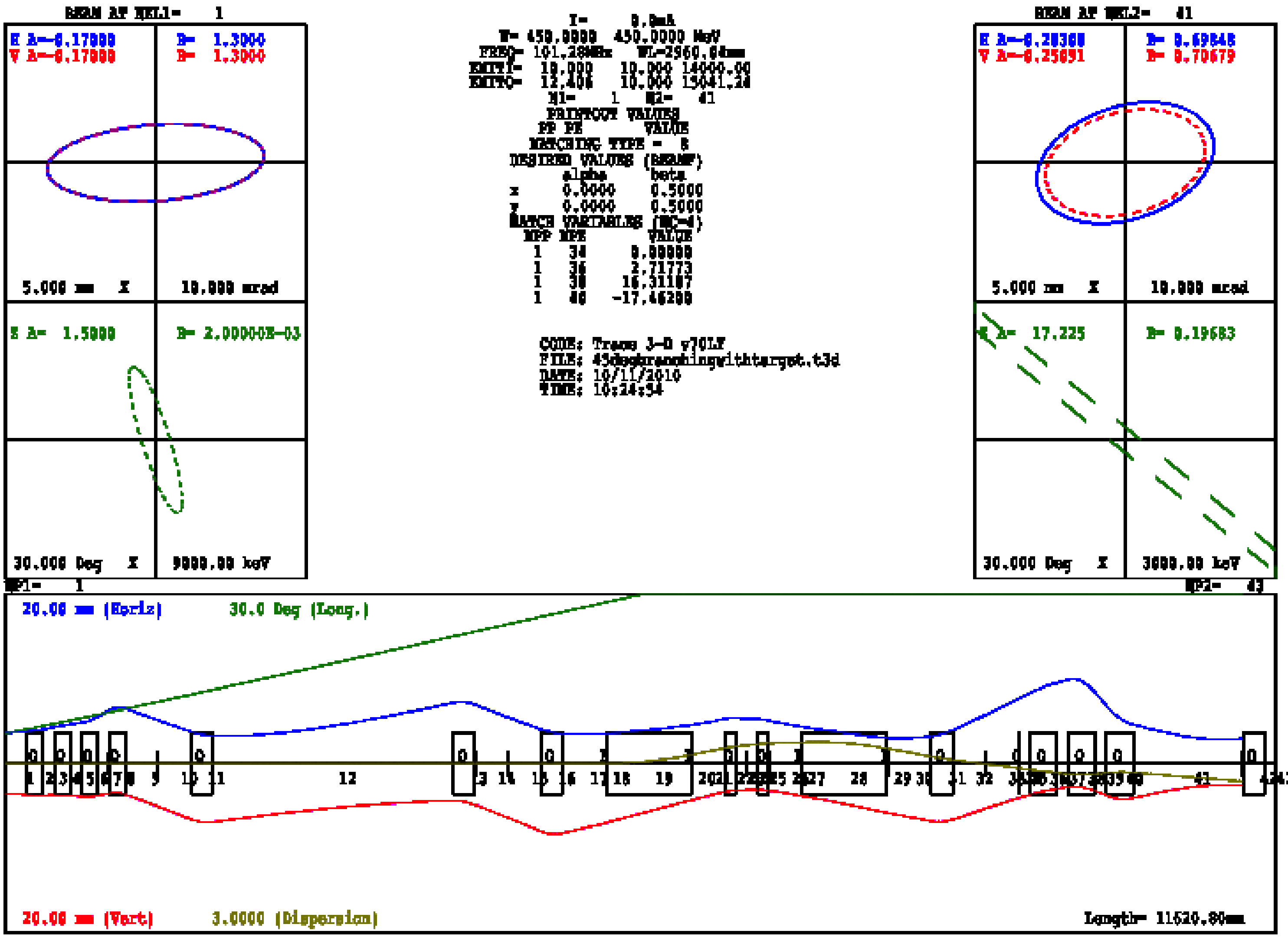
HEBT



- BEAM SPOT SITE AT EXPERIMENT:

$$\sigma_{rms} = \sqrt{\varepsilon_{n,rms}(\beta\gamma)_{rel}\beta_{twiss}}$$

HEBT BEAM DYNAMICS



Open Questions

- Do you need a bunched structure? If so where?
- Do you need a re-buncher only in case of the 100ns bunch spacing?
- Can you accept a dispersion function different from zero in your Spectrometer?
- What is energy spread and Bunch length desired at the target position?
- What kind of energy resolution do you need?

THANK YOU FOR YOUR ATTENTION