LINAC4 beam dynamics

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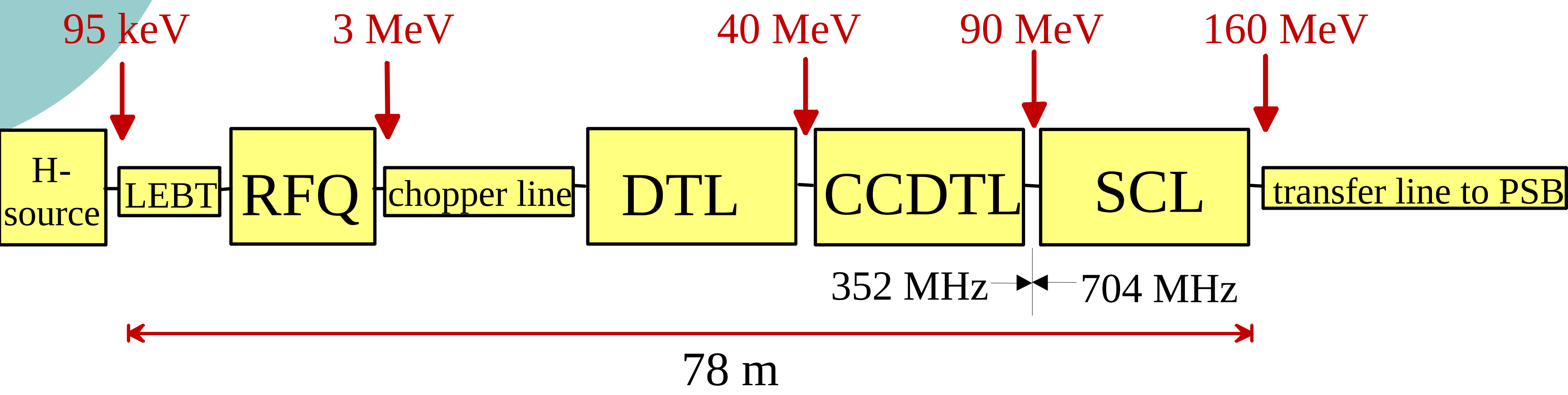
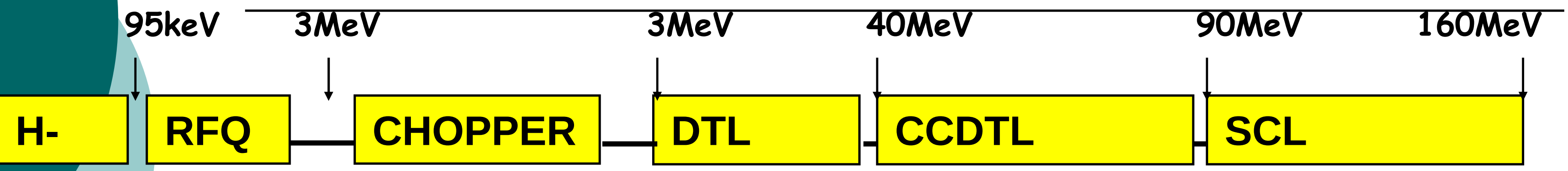


Layout and parameters



H-	RFQ	CHOPPER	DTL	CCDTL	SCL
RF volume source (DESY) 35 kV Extrac. 60kV Postacc.	Radio Frequency Quadrupole (IPHI) 352 MHz 6 m 1 Klystron 1 MW	Chopper 352 MHz 3.6 m 11 EMquad 3 rf cavity	Drift Tube Linac 352 MHz 13.4 m 3 tanks 5 klystrons 4 MW 82 PMQuad	Cell-Coupled Drift Tube Linac 352 MHz 25.3 m 24 tanks 8 klystrons 6.5 MW 24 EMQuads	Side Coupled Linac 704 MHz 28 m 20 tanks 4 klystrons 12 MW 20 EMQuads

Total Linac4:
80 m,
18 klystrons

Duty cycle:
0.1% phase 1 (Linac4)
3-4% phase 2 (SPL)
(design: 15%)

4 different structures,
(RFQ, DTL, CCDTL, SCL)
2 frequencies

current: 40 mA (avg. in pulse), 65 mA (bunch)

Beam dynamics simulations

- Optimisation of each section standalone

  [layout of the accelerator]
- End-to-end simulations with ideal beam and identification of bottlenecks, weak points, acceptance limitations

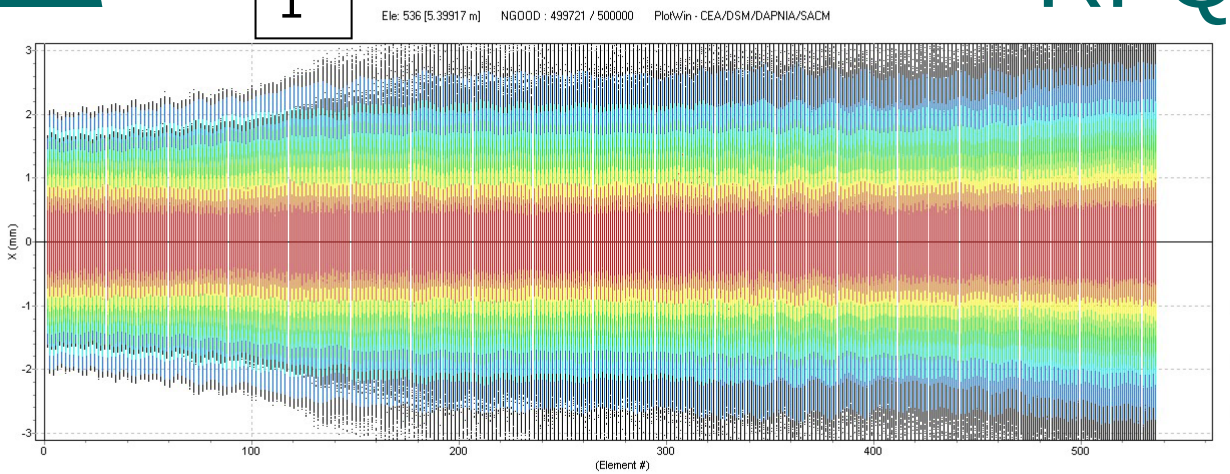
  [fine tuning of layout]
- End-to-end simulation with a “realistic” beam under different working hypothesis

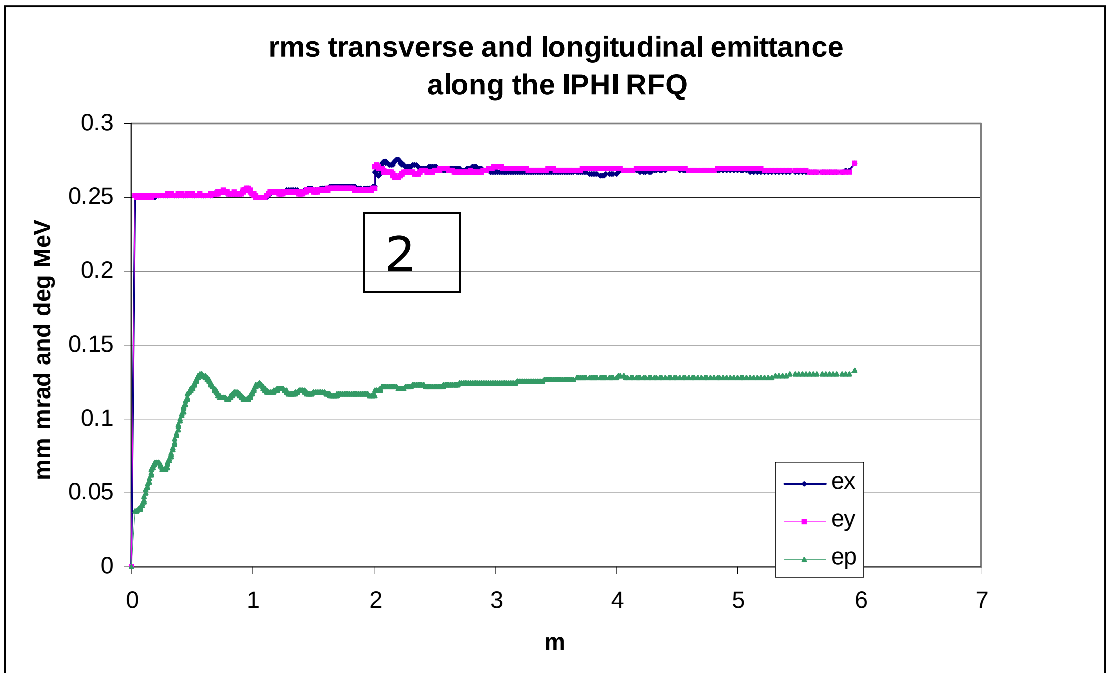
  [solidity of the design against our ignorance]
- Statistical end-to-end simulation with machine tolerances and beam errors

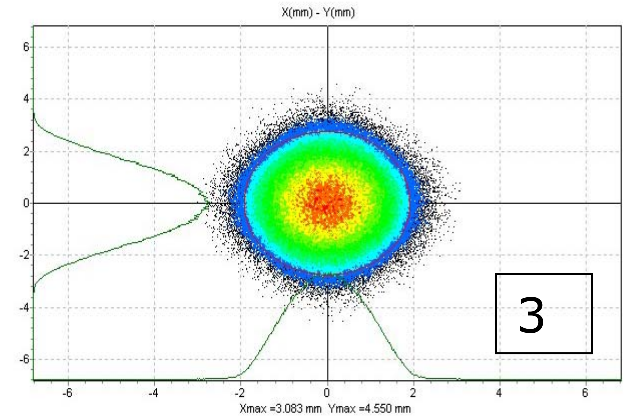
  [solidity of the design against reality]

RFQ (IPHI RFQ)

1





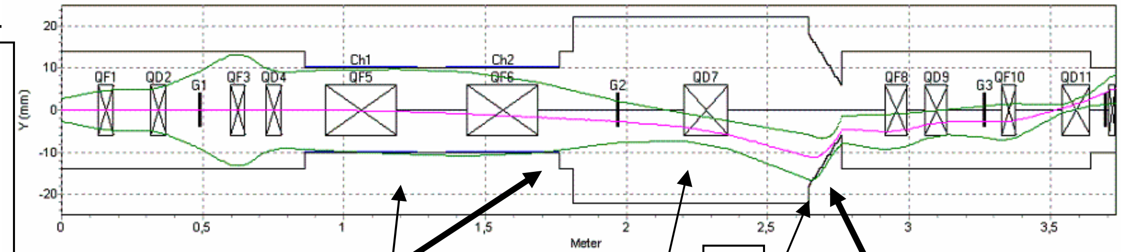


Transverse plane at the RFQ output

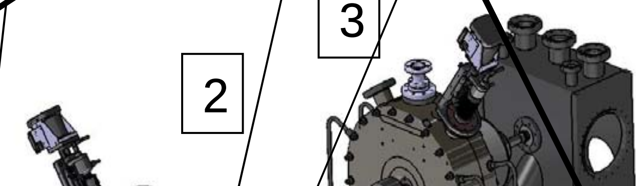
1) Halo formation (10^{-4})
2) Emittance growth in the coupling gap (8%)
3) RFQ doesn't filter halo (also from the source), it is a very good transmission channel and the halo particles must be dealt with in the transfer line at 3 MeV.

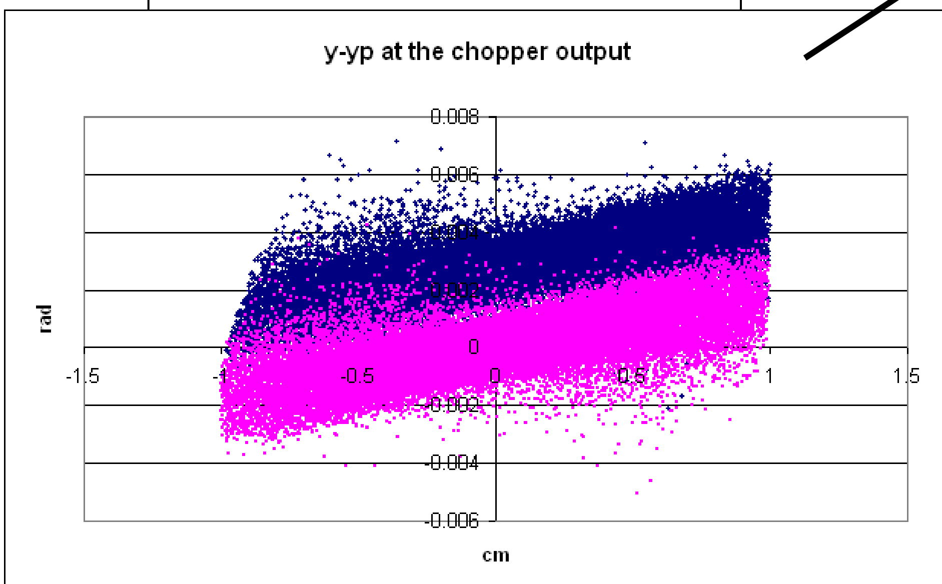
Chopper line

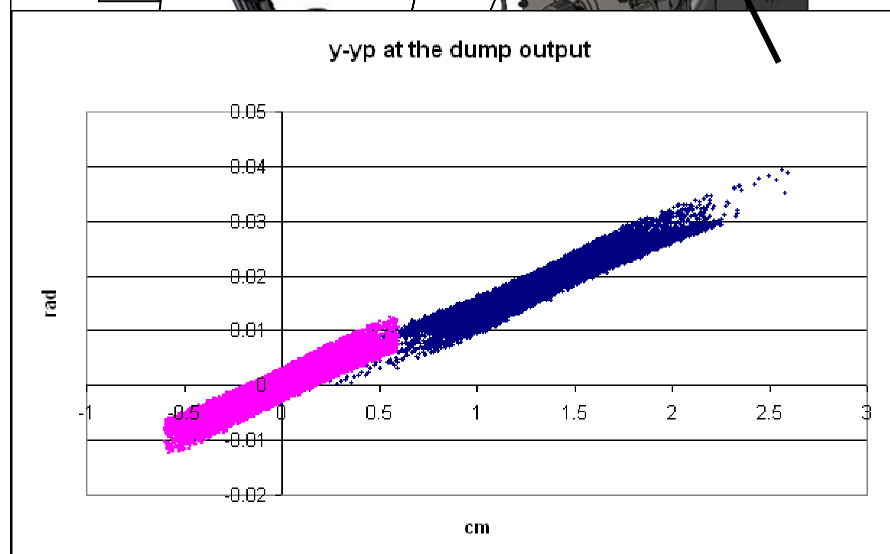
1. House a fast switching electrostatic device able to remove 132/352 microbunches



1
2
3







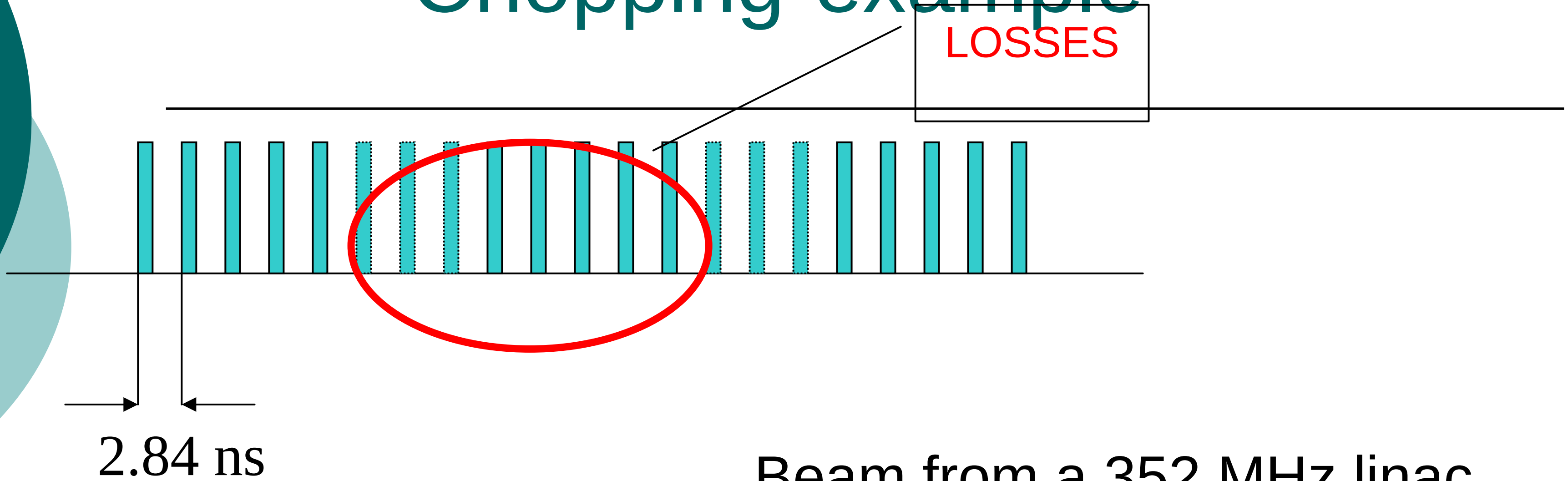
Layout of the chopper line

3) Dump

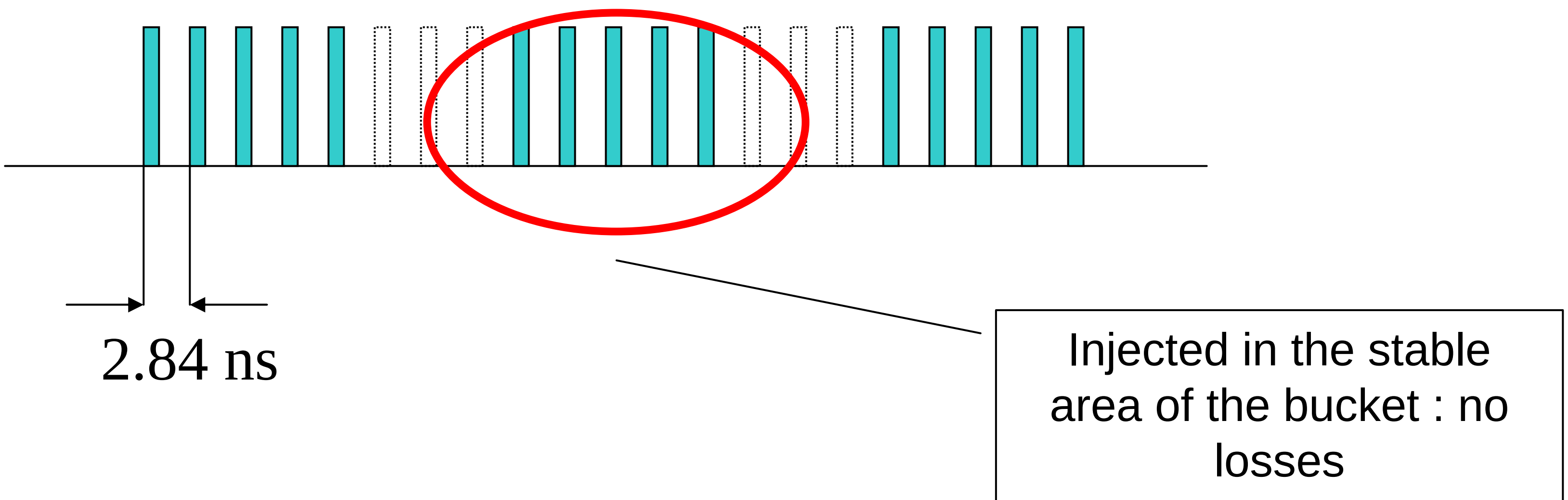
Why chop?

- “longitudinal matching” from a linac to a ring with the purpose of controlling the losses
  - rise time of the injection kickers/length of the machine.
  - Shave the linac beam to match the RF bucket of the ring
- Perform the chopping at low enough energy but when the beam has already imprinted the RF structure, i.e. after the first stage of acceleration.

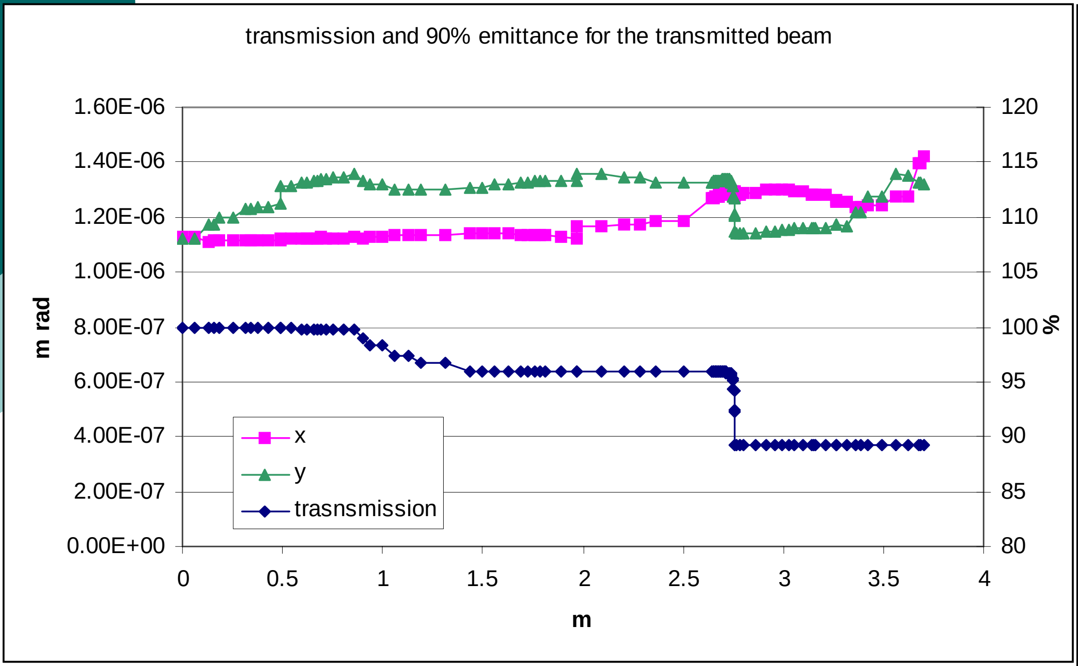
Chopping-example

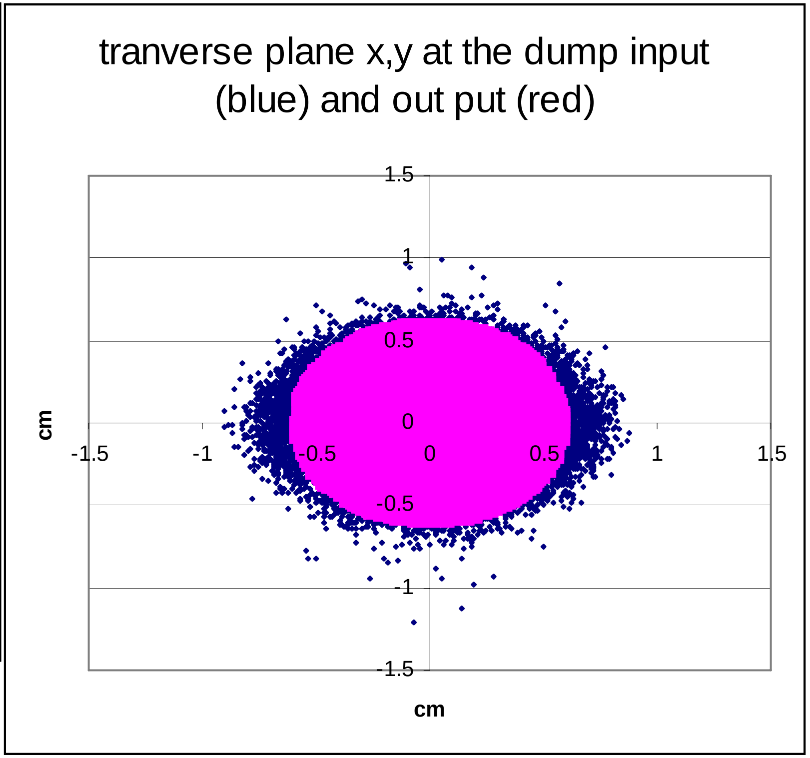


Beam from a 352 MHz linac injected in a 40 MHz ring



Chopper Line : transmitted beam

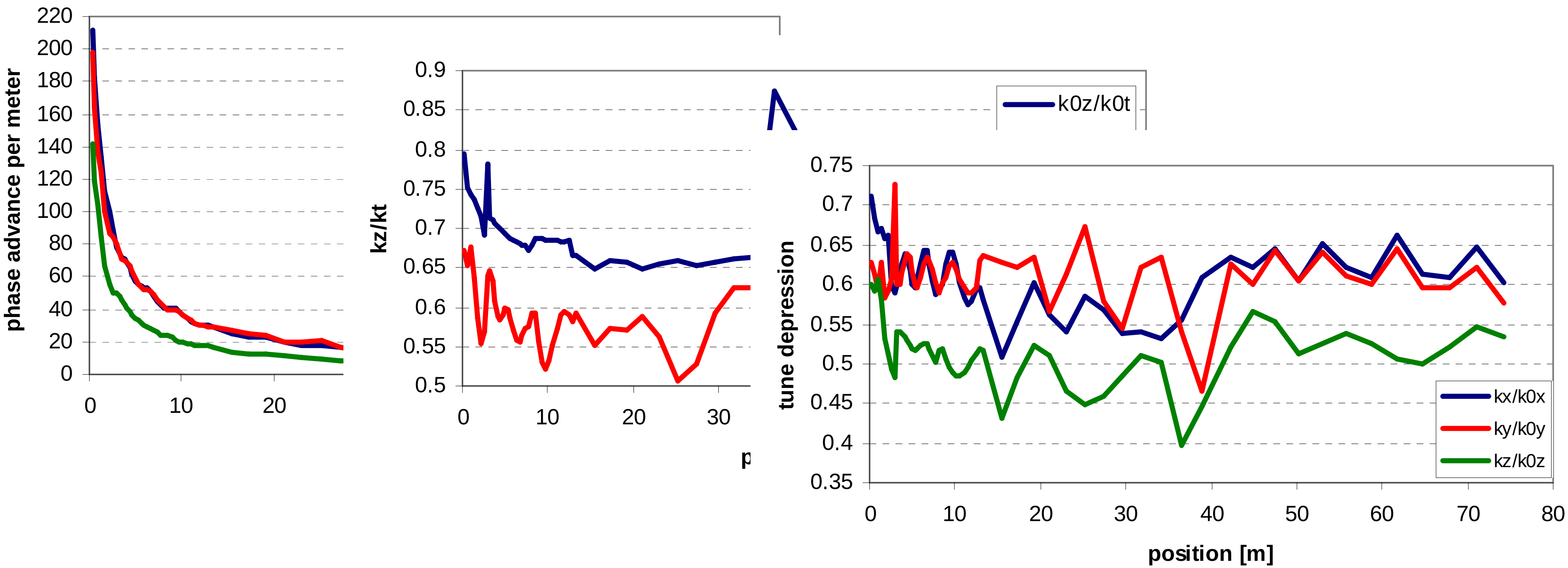




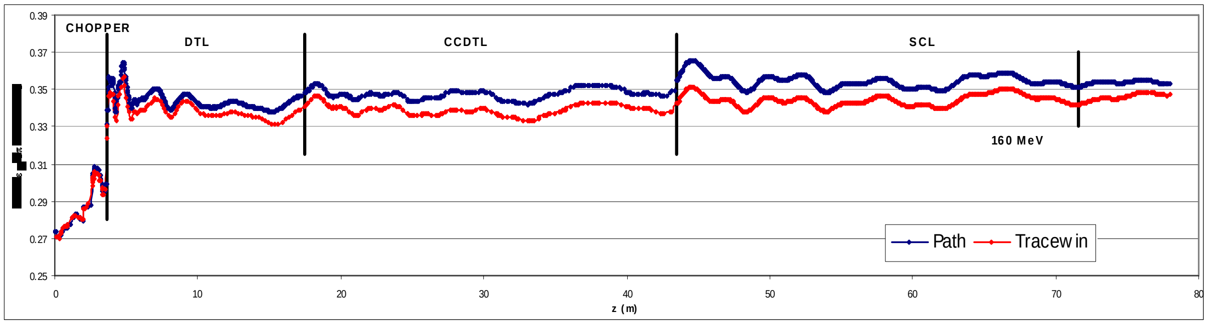
Losses on the chopper plates (4%) and on the dump (8%). Losses on the plates are 1.3 kW at 15% d.c.

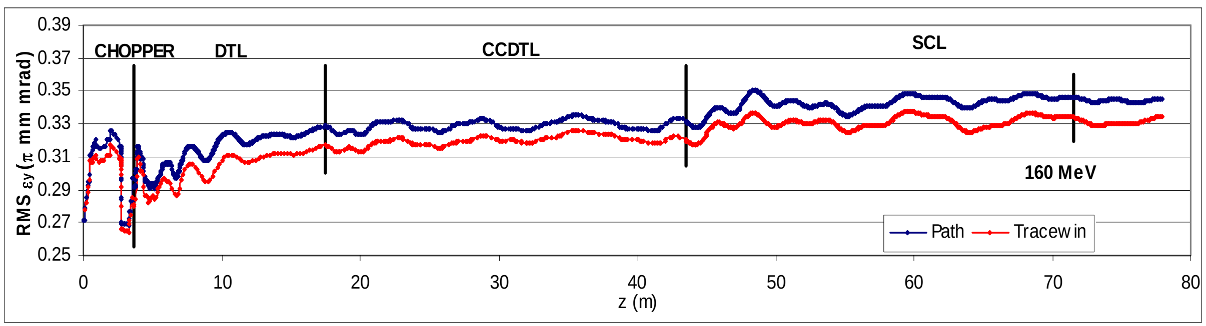
CCDTL and SCL

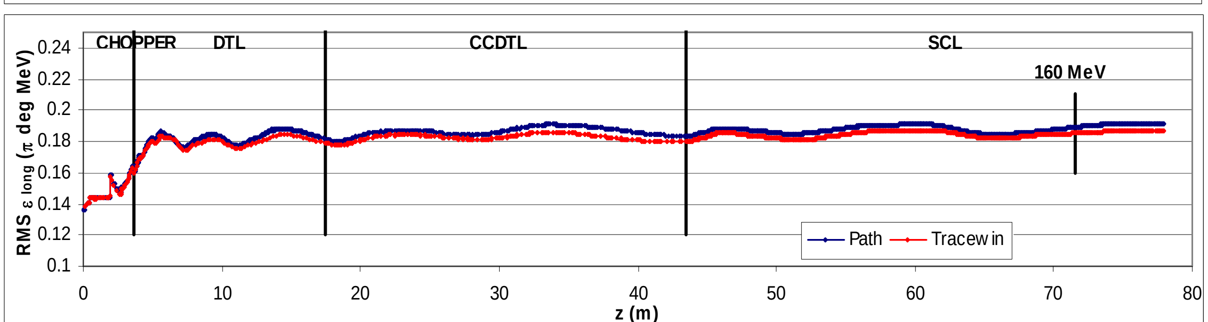
- Transition to a structure which dosen’t follow velocity profile cell by cell (3 cell in CCDTL and 11 in SCL)
- frequency jump
- Costant phase at -20, with matching modules in between the two structures



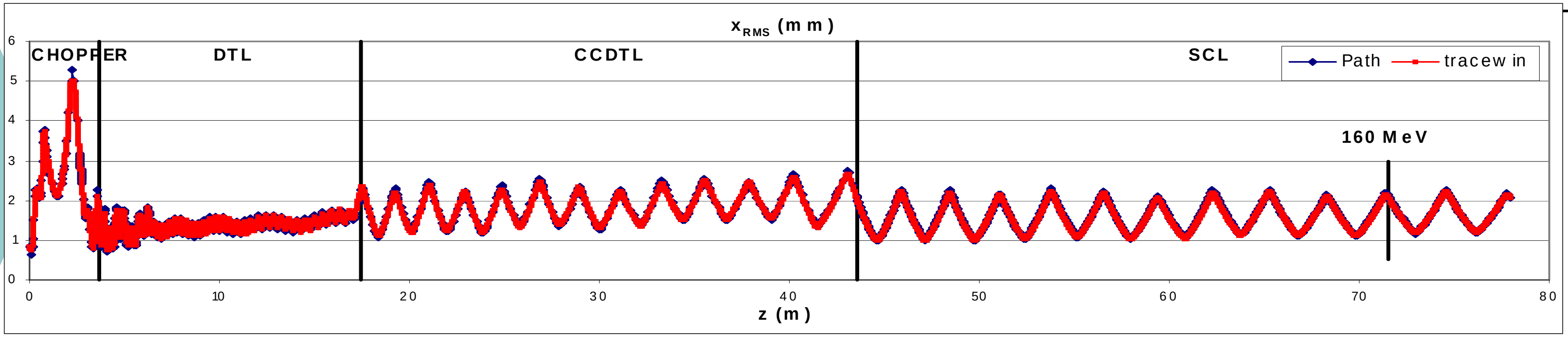
End-to-end : emittances rms

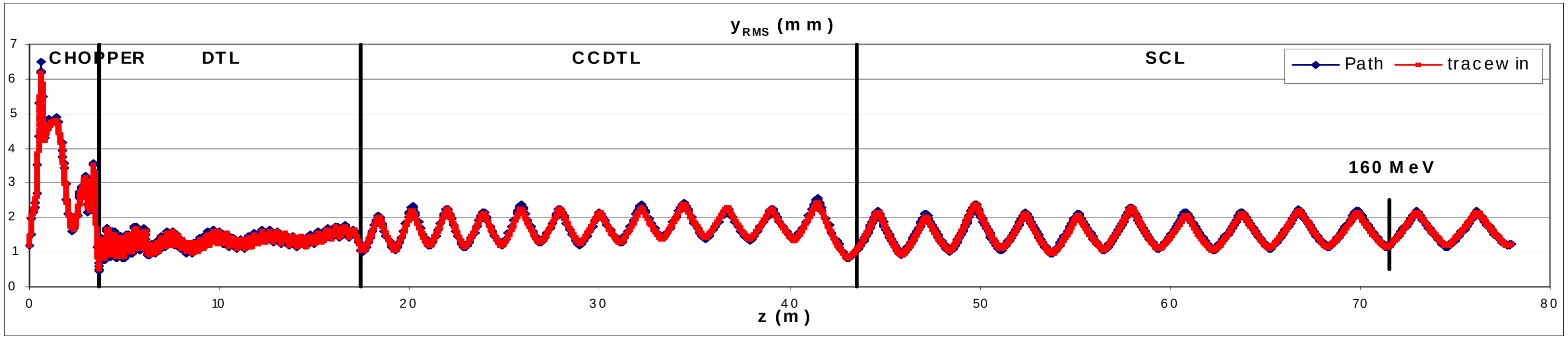


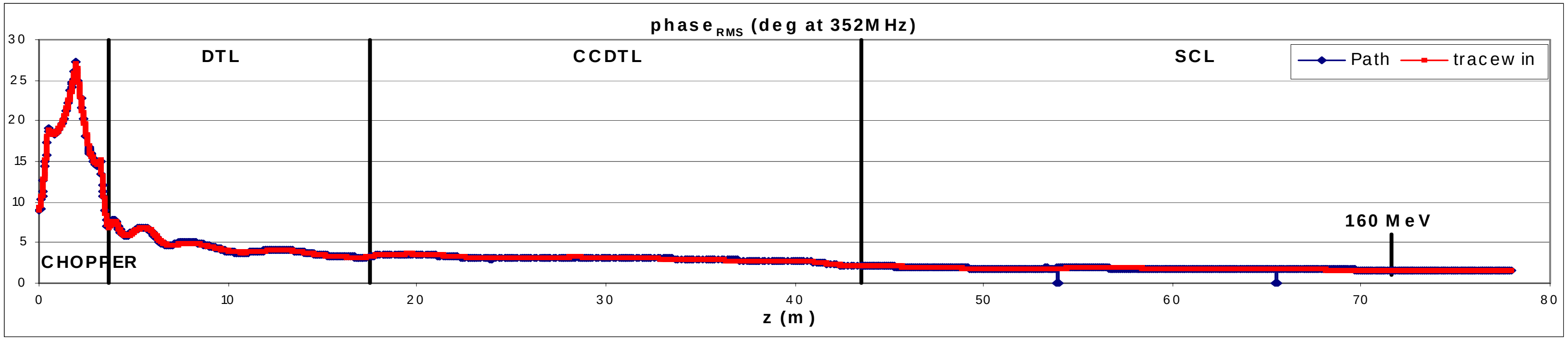




End-to-end : rms x,y,phase

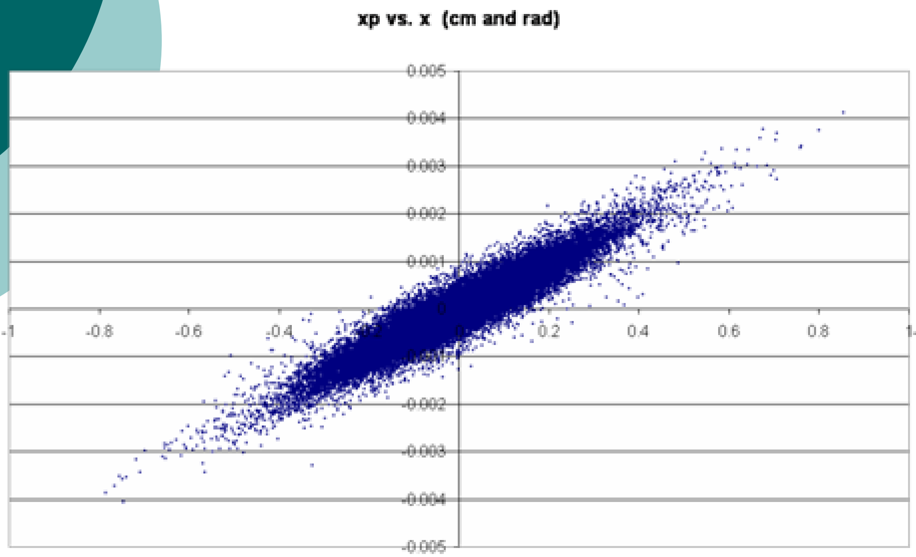


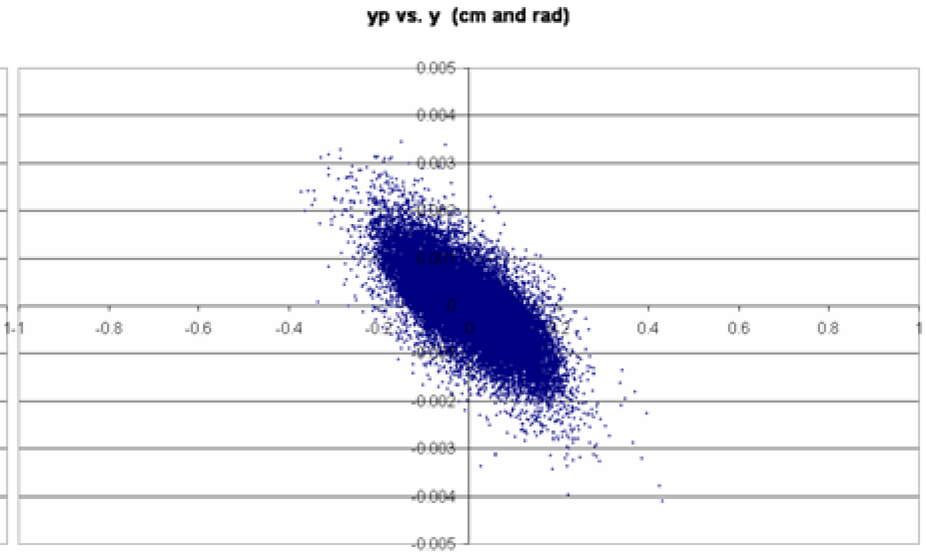




Transverse phase space at the end of the LINAC

Transverse phase space at 160 MeV



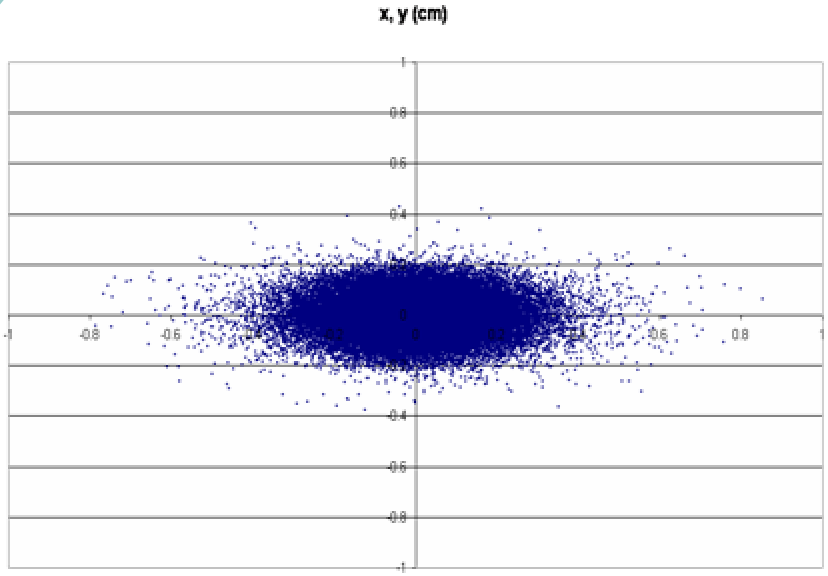


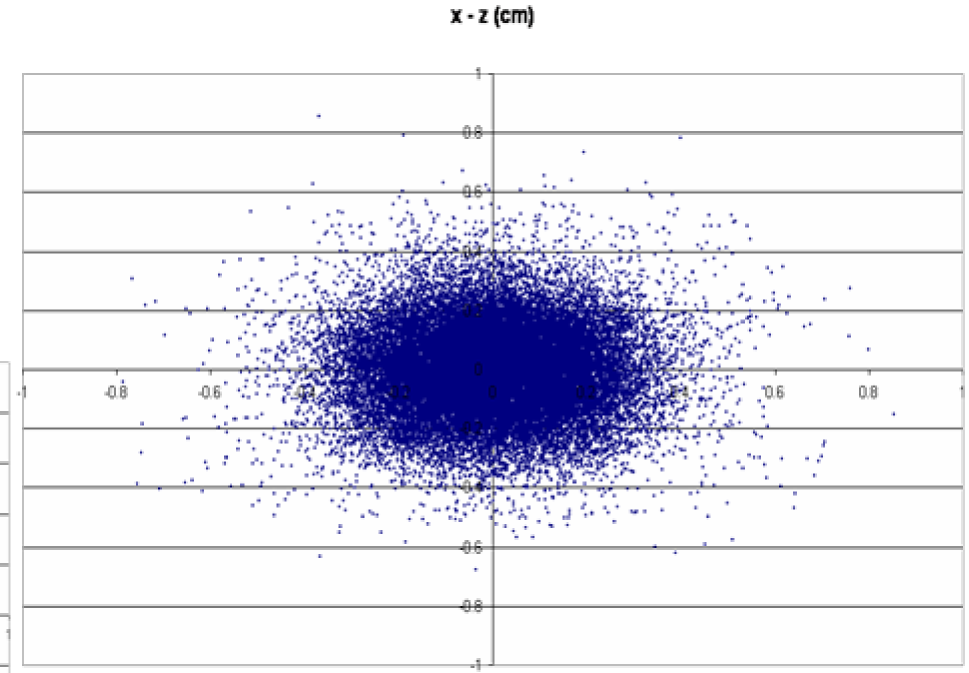
ε_{rms}~0.3 pi mm mrad norm

95% of the beam in xx rms

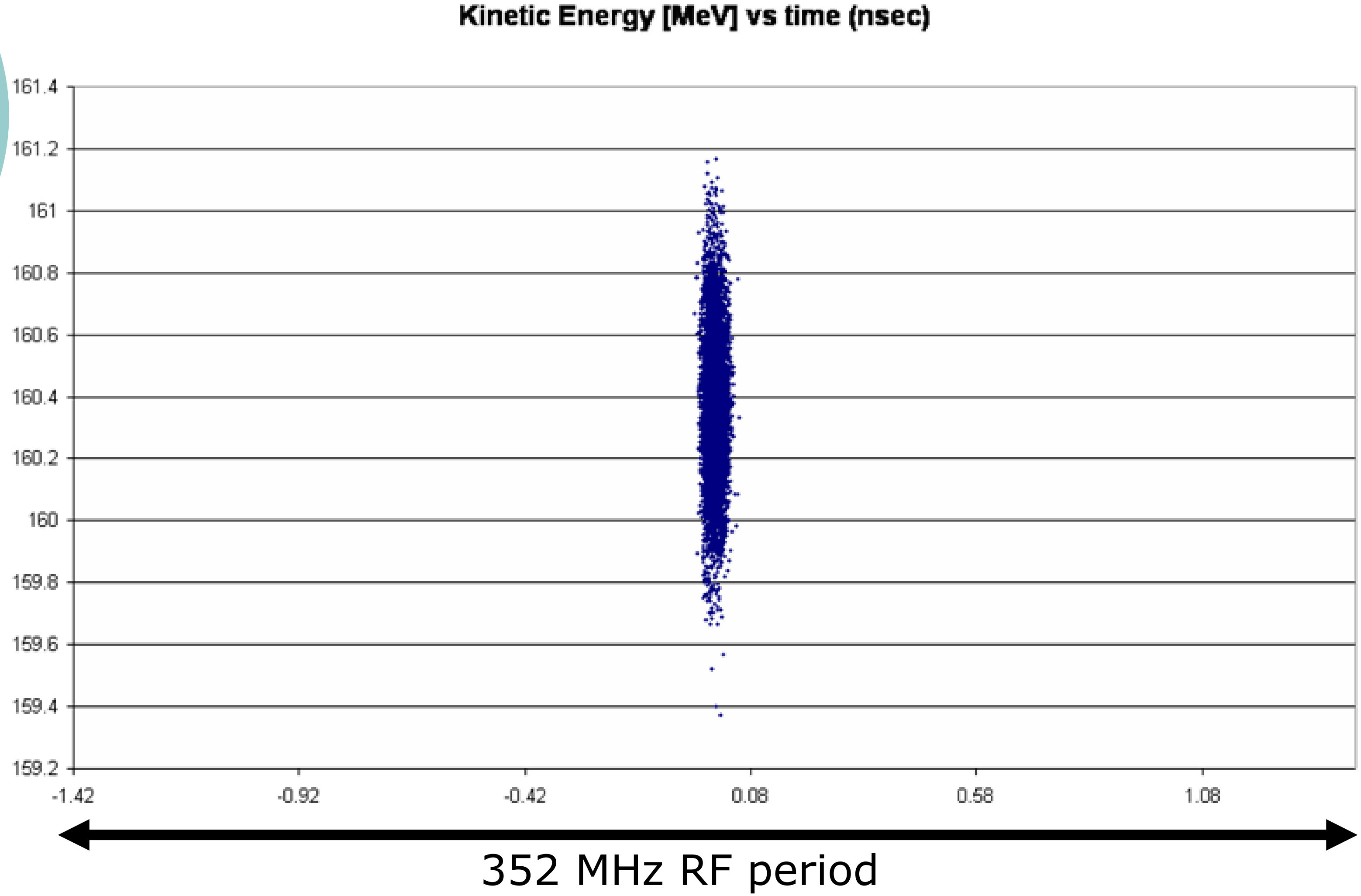
No dispersion

Beam is spherical

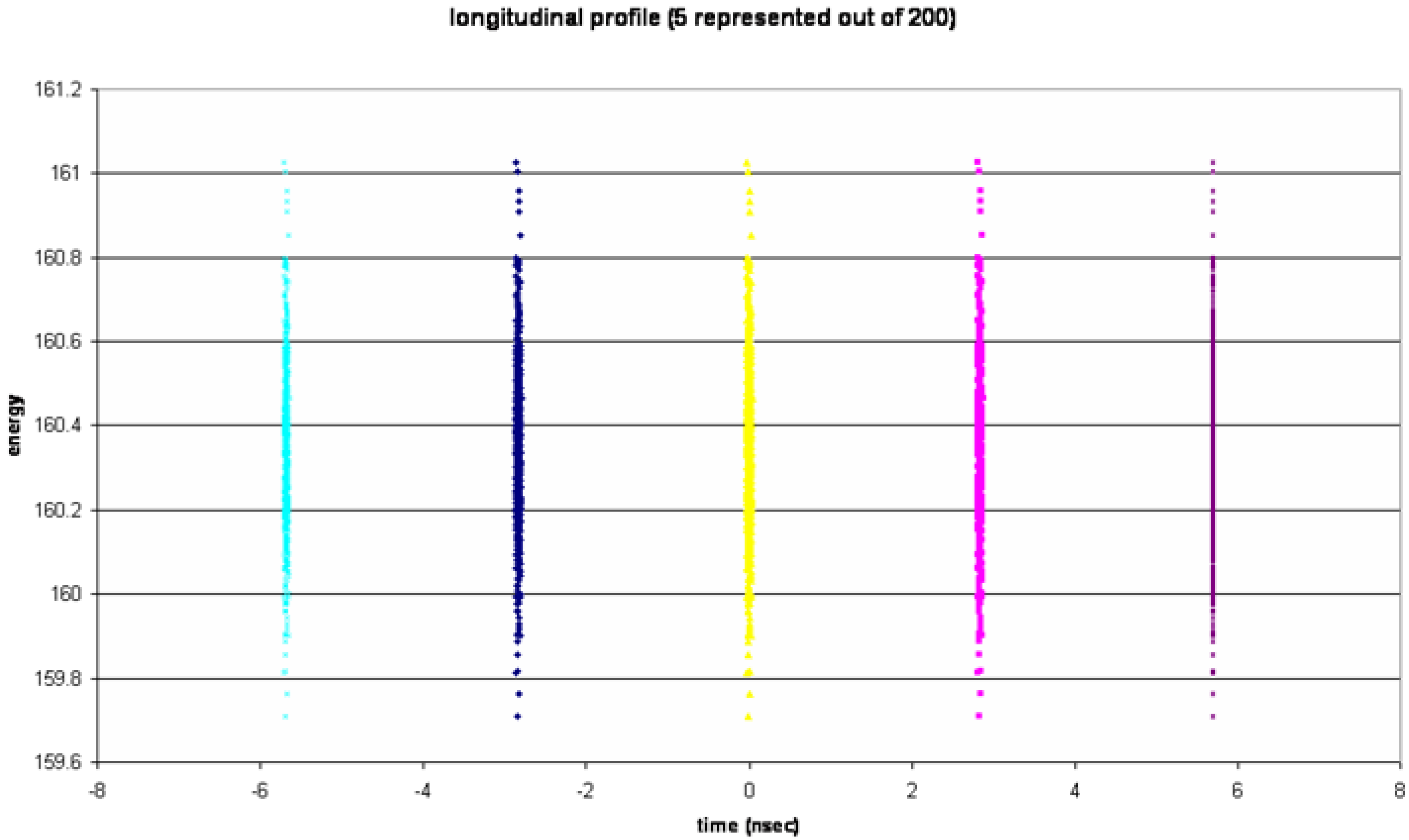




Longitudinal phase space at the end of the LINAC -



Longitudinal phase space at the end of the LINAC – several 352 period



Jitter due LINAC RF errors (klystron + manufacturing tolerances)

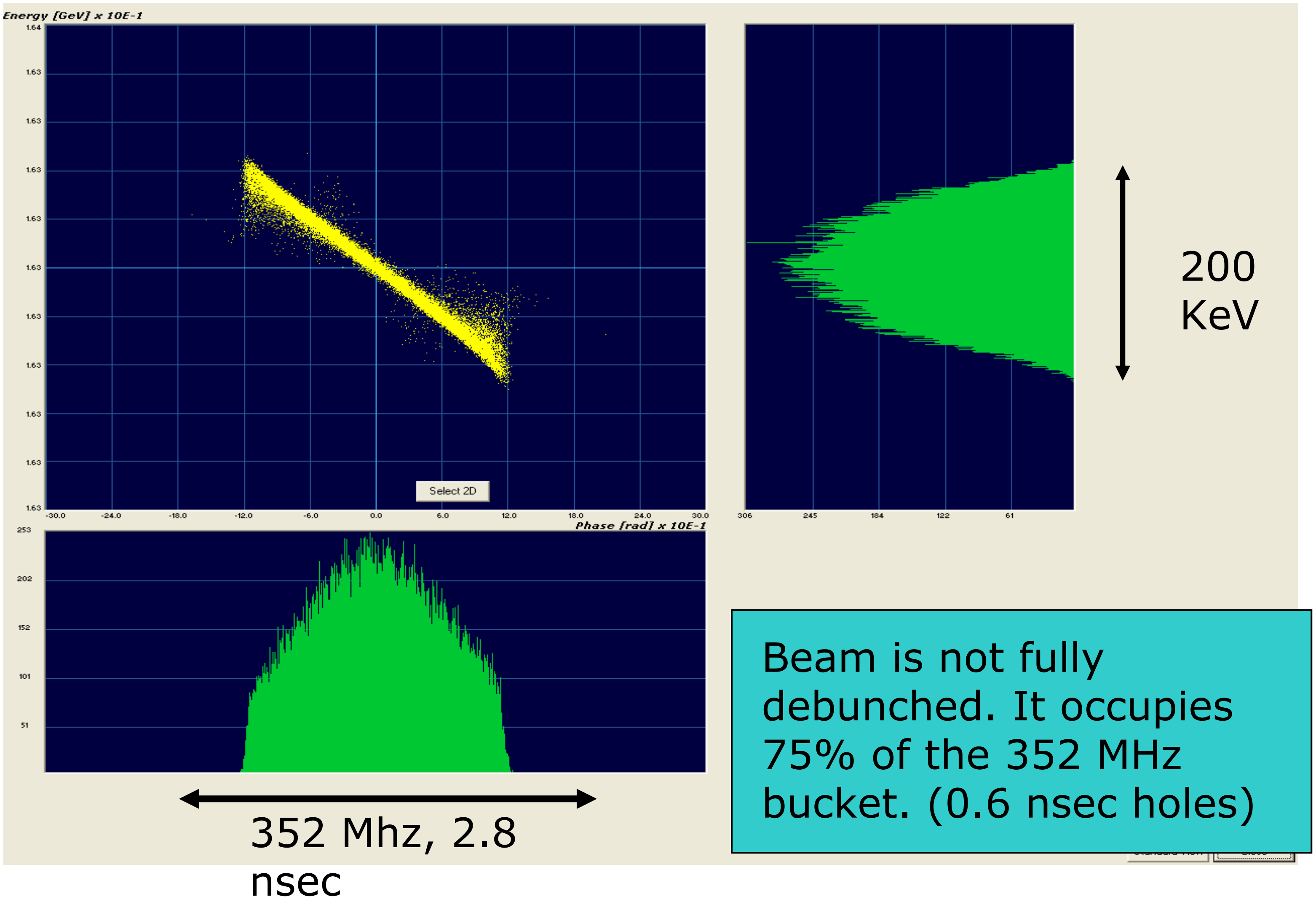
- Average-energy jitter : 270 keV rms
- Average-phase jitter : 1.8 deg at 352MHz i.e. 0.014 nsec

- Random jitter micropulse-to-micropulse (i.e. at 352MHz)

Towards the booster

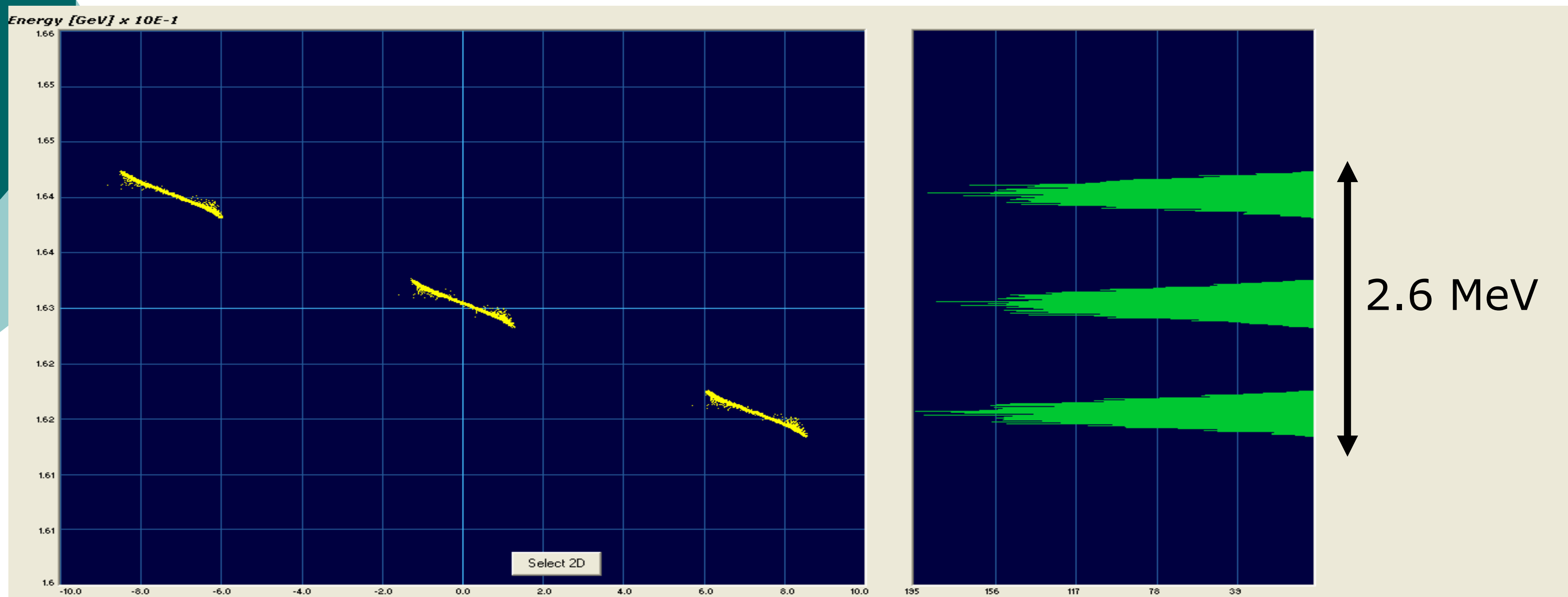
- Transversally : ???
  - Like LINAC2
  - Dispersion less than 1.2 m
- Longitudinally :
  - LINAC2 style : 1 rf cavity
  - LINAC3 style : 2 Rf cavities
  - Nothing at all

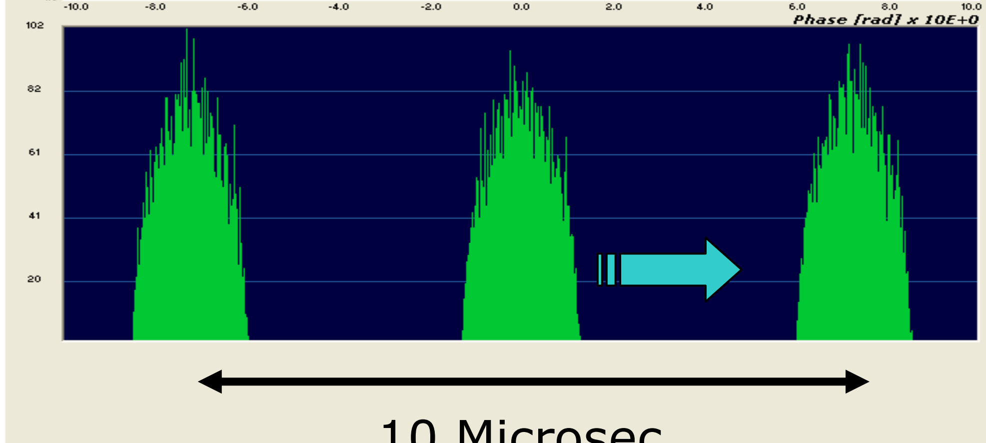
LINAC2 style : control the energy spread, reduce the energy jitter



Beam is not fully debunched. It occupies 75% of the 352 MHz bucket. (0.6 nsec holes)

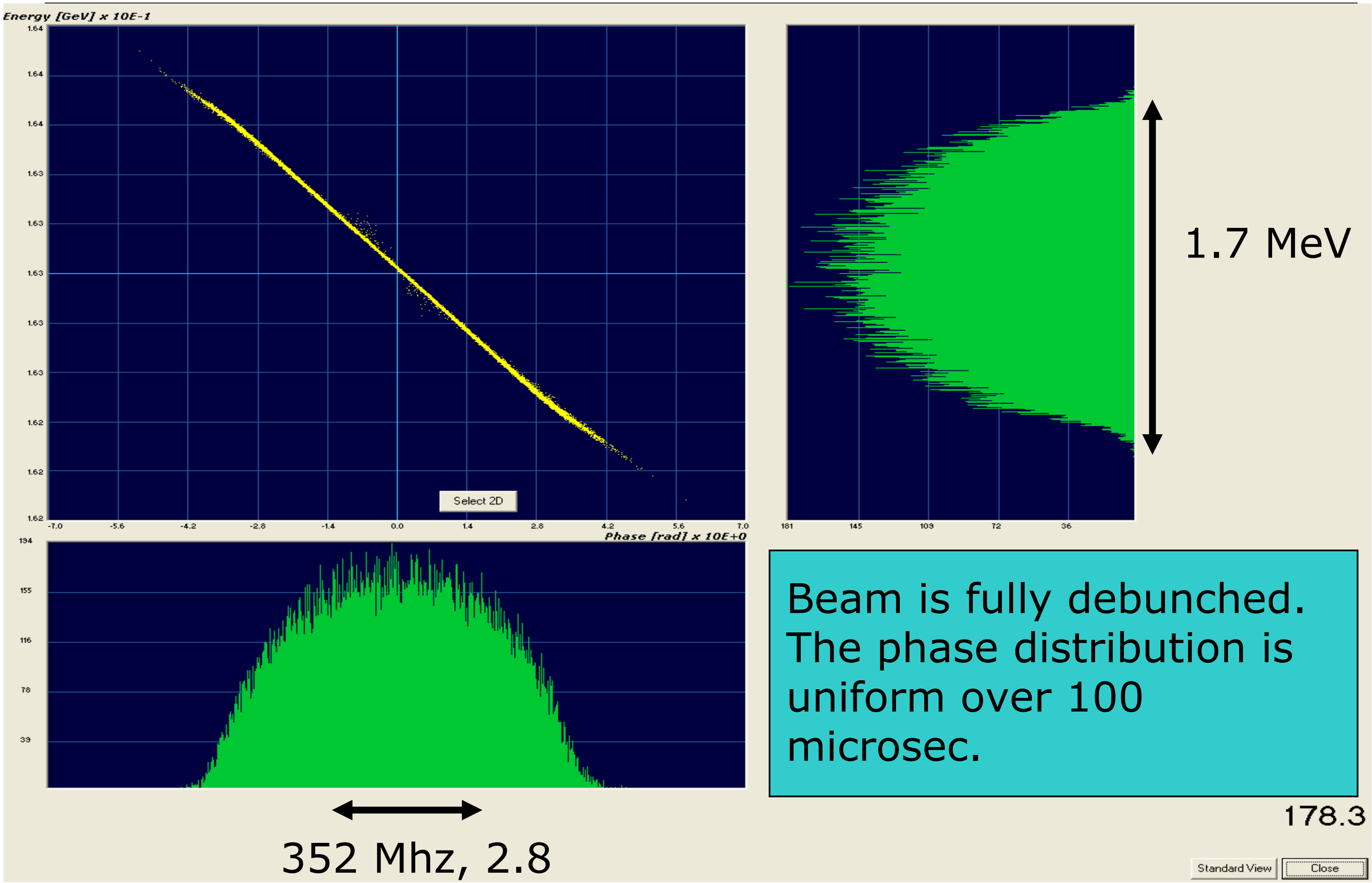
LINAC3 Style : controlled energy ramping and reduction of the micro-pulse energy spread





Full energy ramping on 10microsec (100 kHz), each micro-bunch on a scale of 2.8 nsec (352 MHz). Stretch scale accordingly in your mind

Doing nothing at all.



1.7 MeV

Beam is fully debunched. The phase distribution is uniform over 100 microsec.

352 Mhz, 2.8 nsec

In summary

We have under study 3 possible “longitudinal matching” to the booster.

1 RF	2 RF	No RF
Phase almost uniform. Effective energy spread 400 keV	Phase almost uniform. Effective energy spread 2.6 MeV	Phase uniform. Effective energy spread 1.7 MeV

- The three don’t deliver the same transverse emitt to the booster (path to the booster is “windy”)
- Details on the dynamics/trade off in the transfer line next week by Giulia Bellodi

In summary --continued

LINAC2 (present inj)	50 MeV	protons	160mA	0.01%	$E_{rms,n}$=1.0 mm mrad
LINAC4	160MeV	H-	70mA	0.08%	$E_{rms,n}$=0.4 mm mrad

In order to profit from LINAC4 we need to make sure that we transform the beam from LINAC4 into what is optimized for the booster at 160 MeV and we need your input for the design of the lines.