First analysis of the

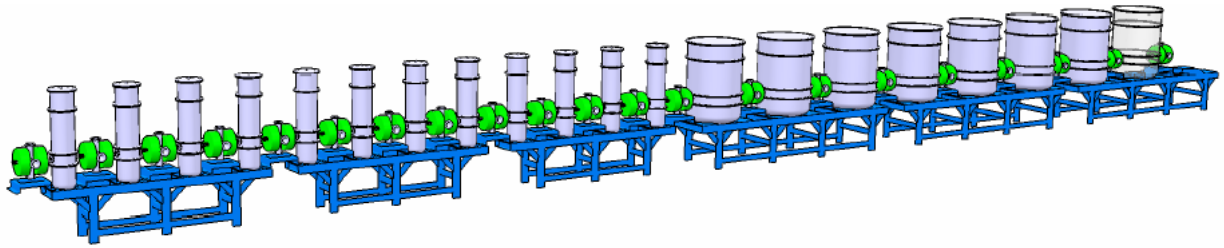
EURISOL Post-Accelerator

SC linac design

Jean-Luc Biarrotte, CNRS / IPN Orsay

SC linac architecture

STARTING POINT = SPIRAL-2 PHILOSOPHY



- Smoothest beam dynamics
  - *Regular FDO lattice*
  - *Nb of matching sections is minimised*
- Modular solution and simplified cryostats (no SC magnets)
- Alignement easier a priori
- Possibility to insert classical diagnostics at each period
- Ease of tuning (regular lattice, round beam at each diagnostic box)

PDS design = RIA / Legnaro philosophy

- SC solenoids in long cryostats
- More compact solution, but many uncertainties (cryostat technology, tuning, alignement)
- Abandonned within the SPIRAL-2 study

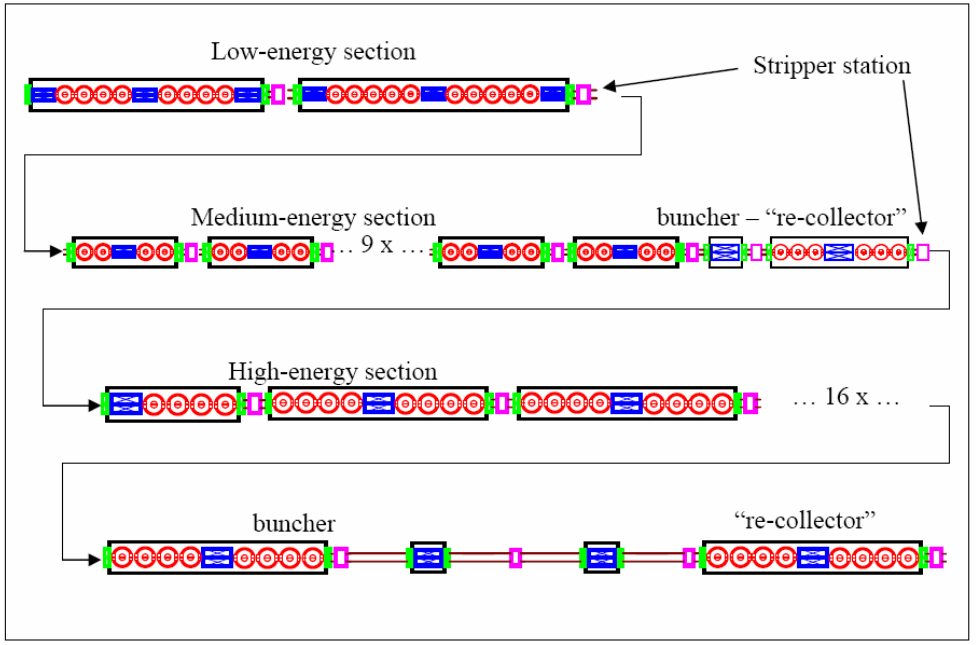
About stripping stations

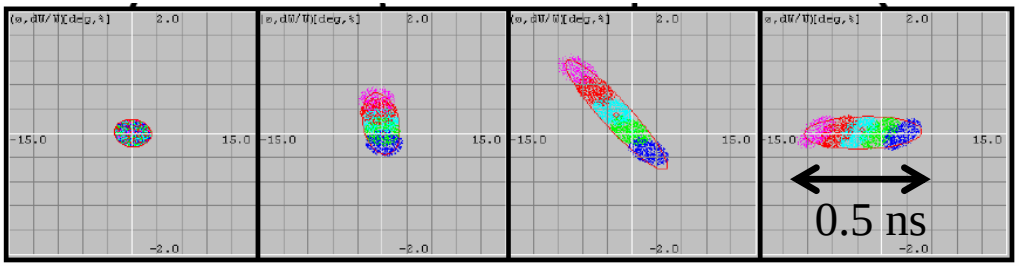
STRIPPING ADVANTAGES

- Decrease the linac length (and cost): *using 2 stripping stations, the linac length decreases from ~160m to ~110m (q/A = 1/5 @ 100MeV/u)*

STRIPPING DRAWBACKS

- Degraded transmission and emittances
  - *74% transmission for $^{132}Sn^{25+}$*
  - *Emittances growth: ×2 (T) and ×3 (L)*
- Implies multi-charge acceleration
  - *Special matching sections*
  - *How do we tune ??*
- High activation (shielding, maintenance)





=> HIGH INCREASE IN COMPLEXITY

=> COST ARGUMENT NOT SO OBVIOUS (TO BE EVALUATED)

Design starting point

MAIN HYPOTHESIS

- Only 2-gap cavities are used for high q/A acceptance *(with $\beta\lambda$ = 40cm max.)*
- Safe max. accelerating fields (Spiral-2 operating point = 6.5 MV/m)
- Distances between elements from the SPIRAL-2 study
- Input beam = RFQ + MEBT exit (we suppose it exists !)
  - *672 keV/u for all ions @ 88.05 MHz*
- Architecture « à la SPIRAL-2 », NO STRIPPING STATIONS

DESIGN OPTIMISATION

- Reference particule = $^{132}Sn^{25+}$
- Optimisation criteria = LINAC LENGTH
- Conservative beam dynamics rules to minimise emittance growth & halo formation:
  - *μ < 90°/lattice to avoid main structure resonances (1/2, 1/3 & ¼)*
  - *Continuity of μ / meter between sections (to minimise sensibility to mismatch)*
  - *Safe synchronous phase law to keep sufficiently large bucket*
  - *+ try to avoid space-charge coupling resonances for the beta-beam tune*

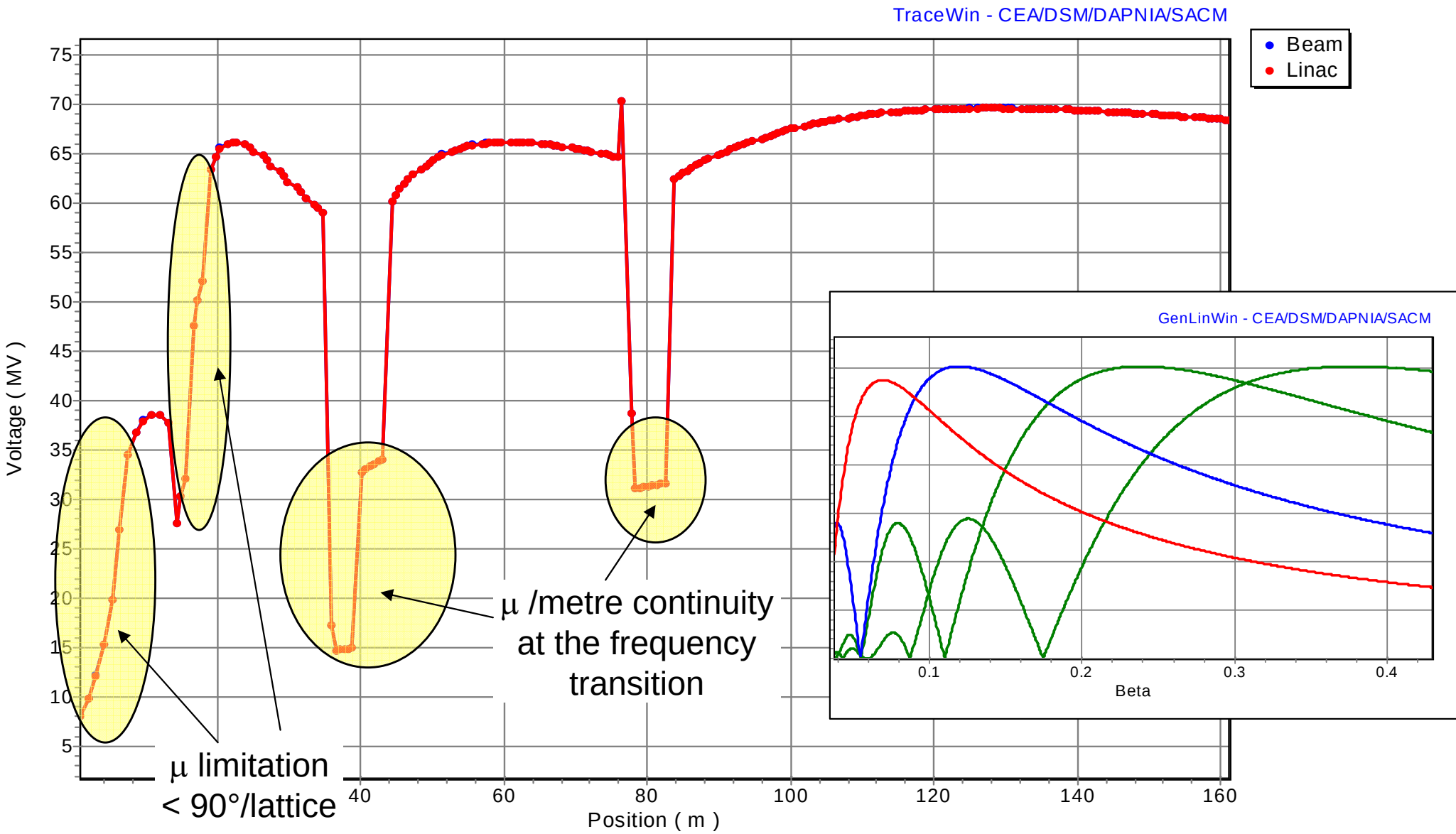
Obtained SC linac design

$^{132}Sn^{25+}$	Section 1	Section 2	Section 3	Section 4	TOTAL
Cavity Freq.	88.05 MHz	88.05 MHz	176.1 MHz	264.15 MHz	-
Cavity β	0.07	0.12	0.24	0.38	-
# cav./ lattice	1	3	6	9	-
# cavities	12 cav	27 cav	60 cav	126 cav	**225 cav**
Length	13.3 m	21.6 m	41.7 m	84.7 m	**161.3 m**
Beam energy	0.67 MeV/u 2.8 MeV/u	2.8 MeV/u 14.3 MeV/u	14.3 MeV/u 39.2 MeV/u	39.2 MeV/u 100.1 MeV/u	**0.67 MeV/u** **100.1 MeV/u**

A FEW COMMENTS

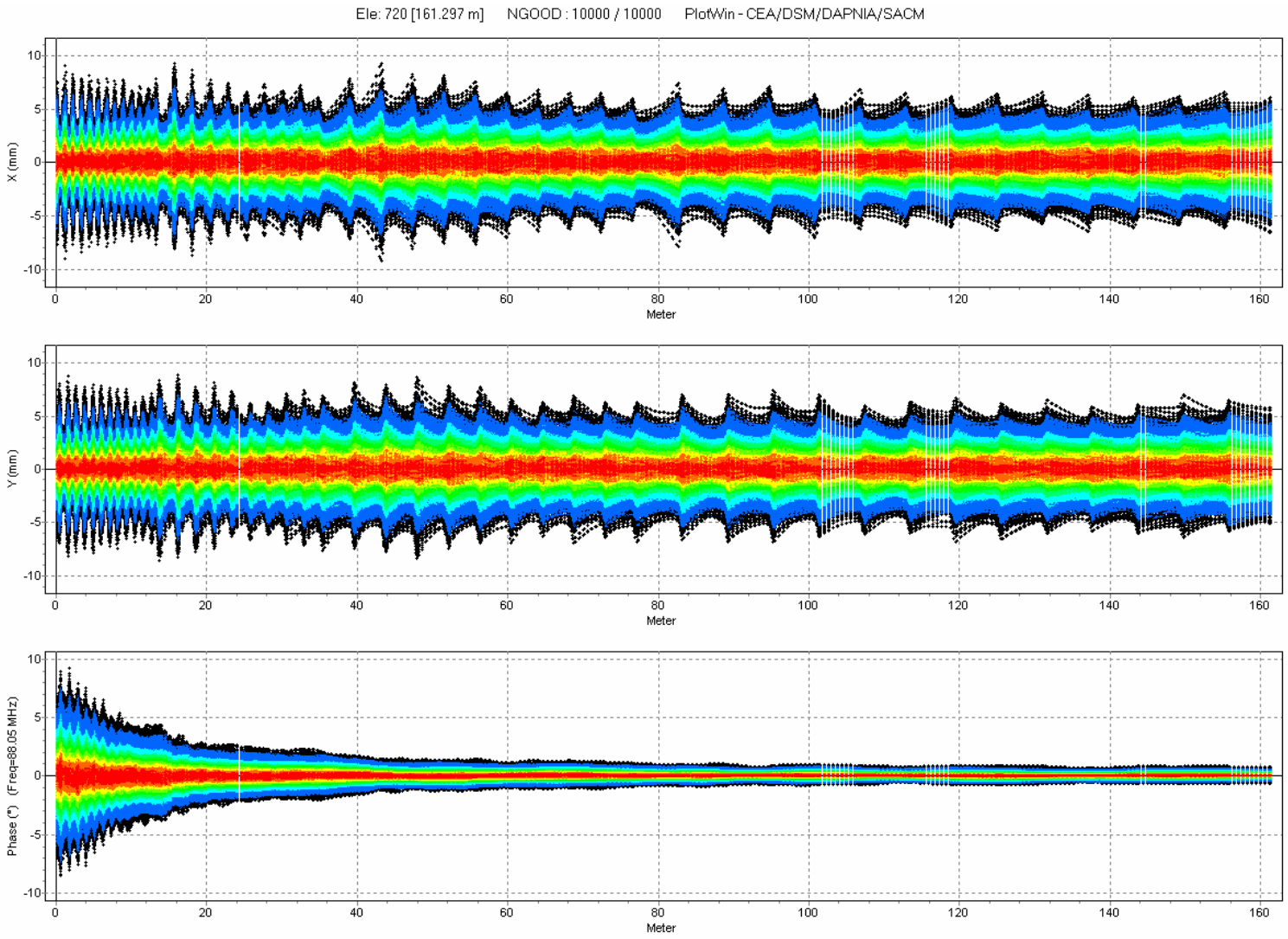
- 2 first sections uses SPIRAL-2 cavities (!!!)
- PDS linac = 114 m, 240 cavities, 60 MeV/ u without strippers
- Our design up to 60 MeV/u = 108 m, 162 cavities

$^{132}Sn^{25+}$ analytical beam dynamics

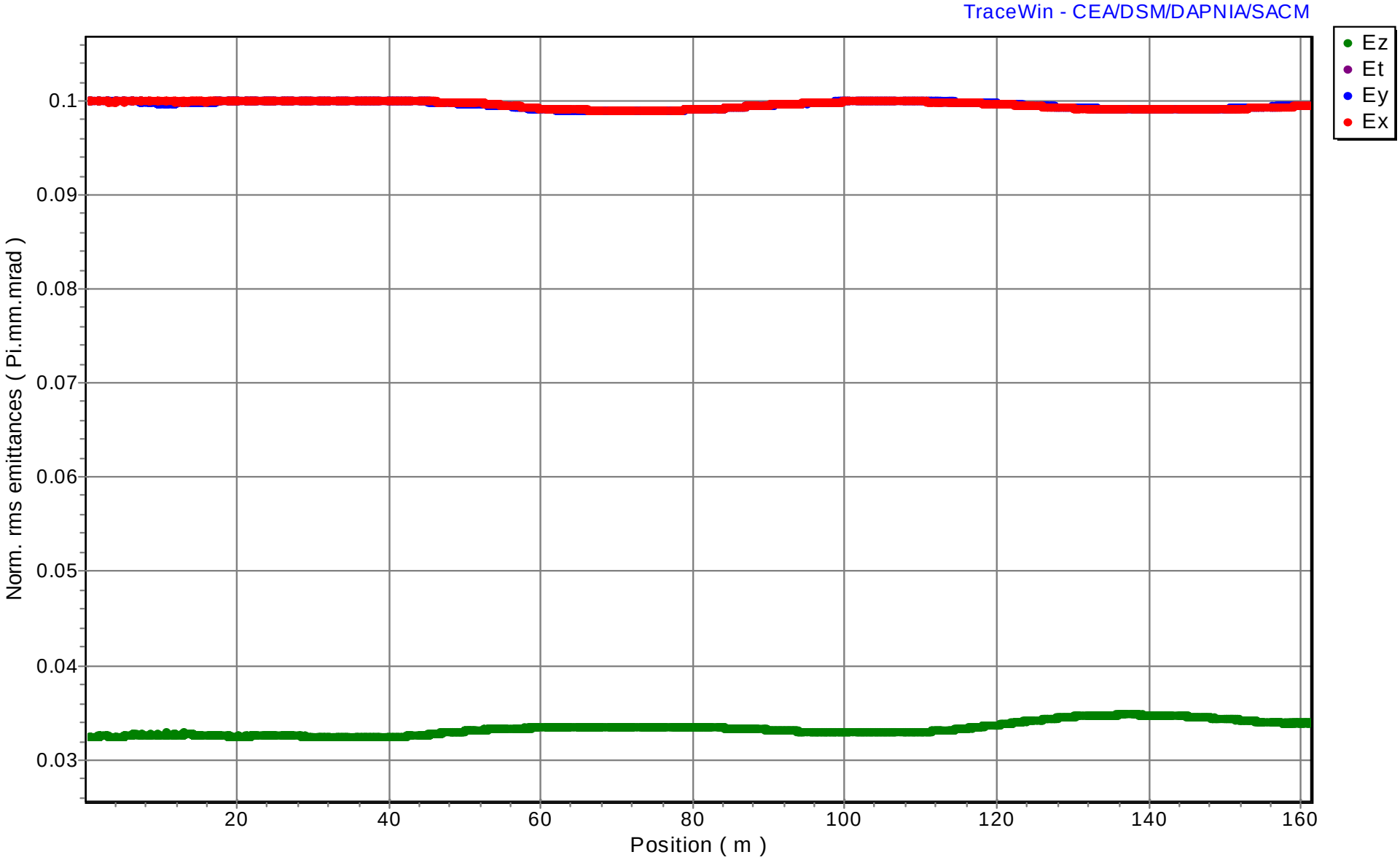


$^{132}Sn^{25+}$ multi-particule beam dynamics

- Input emittances (rms norm.): T = 0.1 pi.mm.mrad, L = 0.42 pi.deg.MeV *(from PDS design)*
- 0 mA, with Gaussian distribution truncated at 4 sigma

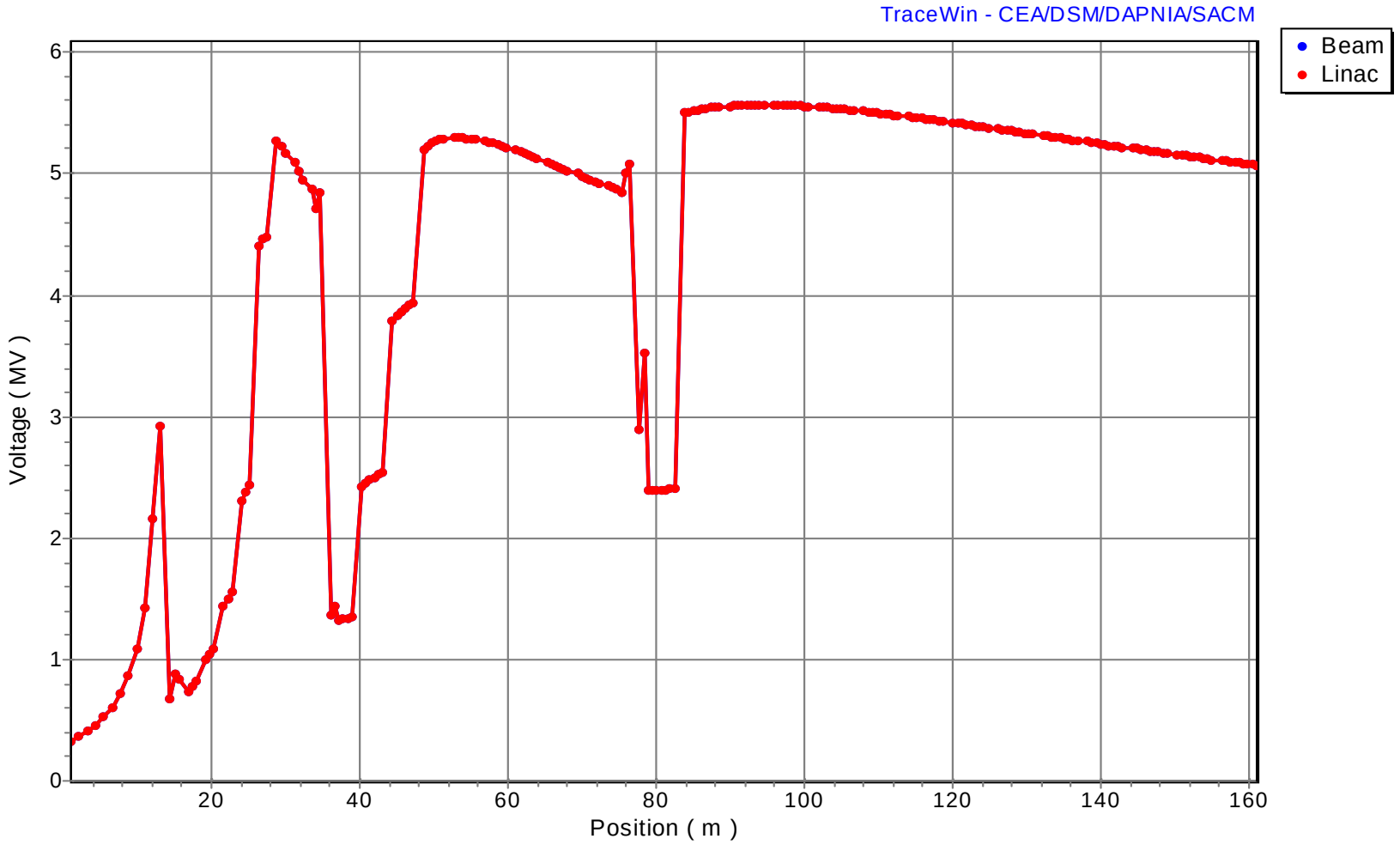


$^{132}Sn^{25+}$ multi-particule beam dynamics



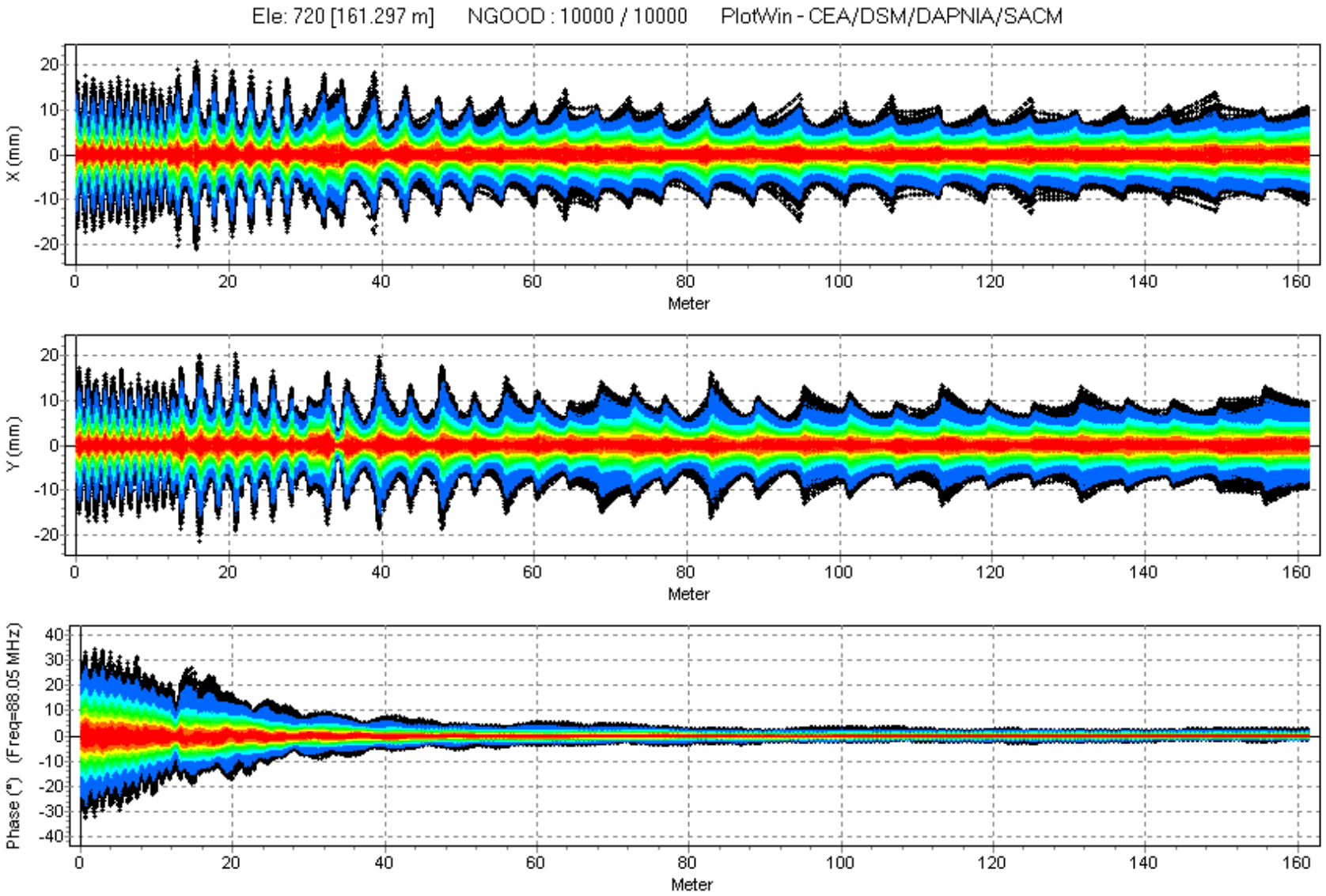
$^{6}He^{2+}$ acceleration

- **Final energy = 161.7 MeV/u**
  - Linac length for 100 MeV/u = 113 m
  - Linac length for 50 MeV/u = 71 m

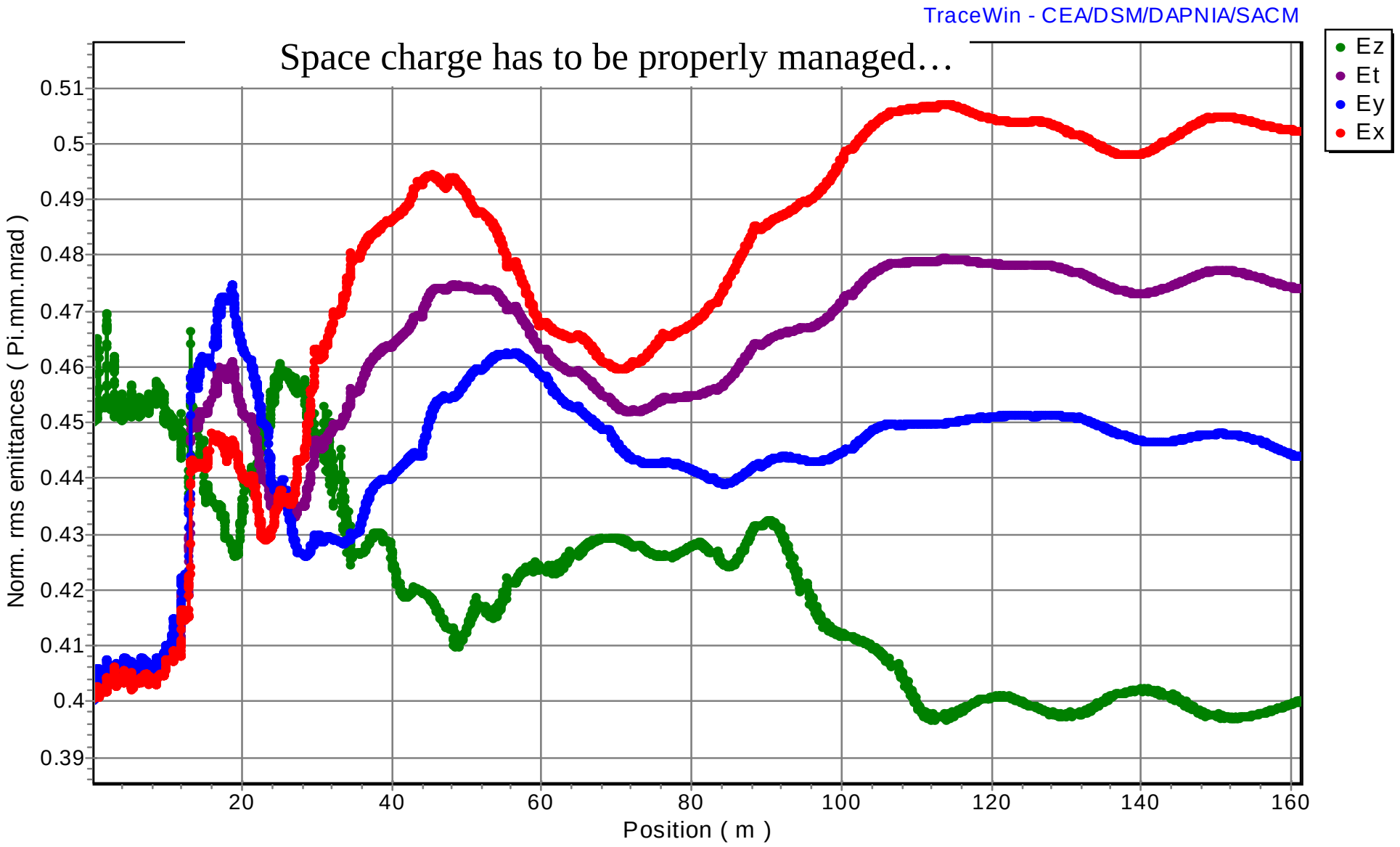


$^{6}He^{2+}$ acceleration at high current

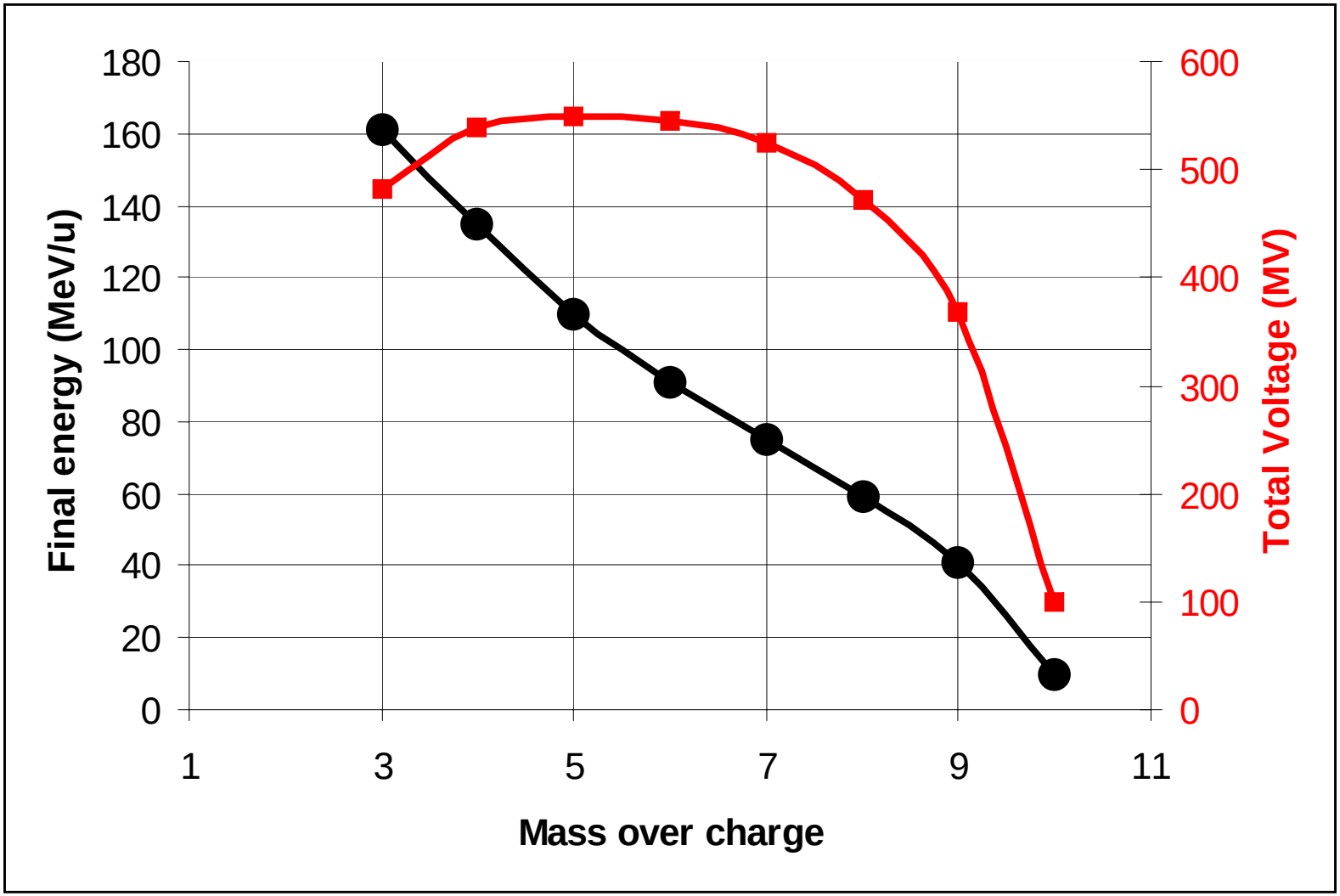
- Input emittances (rms norm.): T = 0.4 pi.mm.mrad, L = 0.27 pi.deg.MeV *(from SPIRAL-2)*
- 7.5 mA, with Gaussian distribution truncated at 4 sigma



$^{6}He^{2+}$ acceleration at high current



Other ions



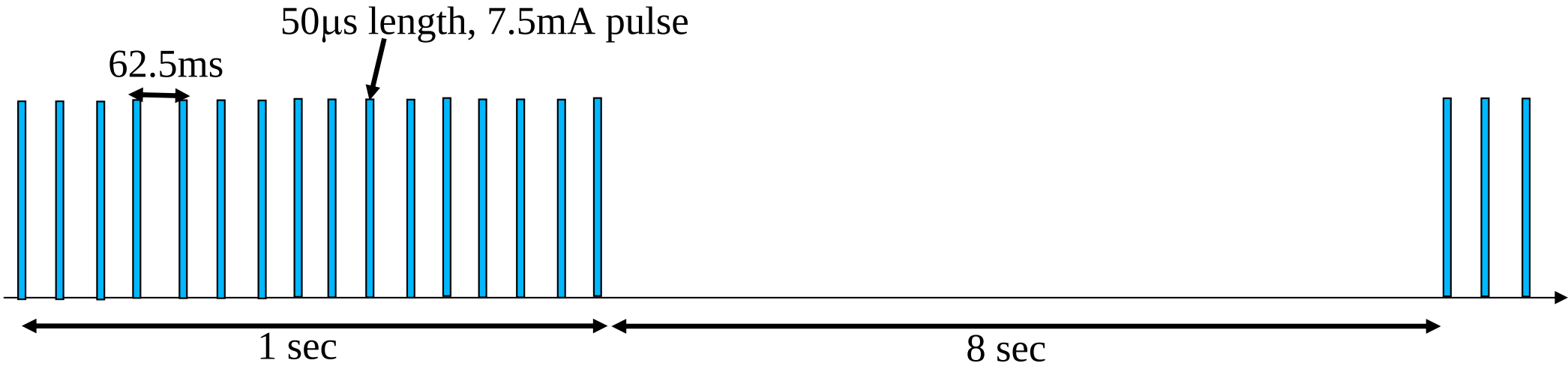
=> IS IT ENOUGH FOR THE EURISOL NEEDS ?? / DO WE REALLY NEED 100 MeV/u FOR ALL IONS ?? DO WE WANT A/Q < 3 ??

=> IF NOT, 2 SOLUTIONS: A LONGER LINAC OR STRIPPING STATIONS

Beta beams requirements

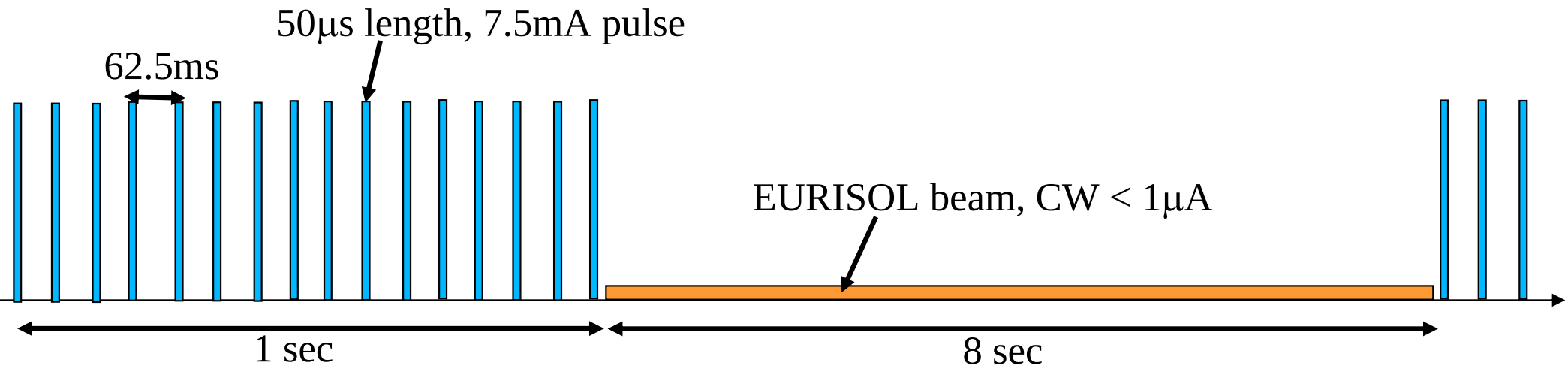
- **Acceleration of $^{6}He^{2+}$ (or $^{18}Ne^{6+}$ = same q/A !!!)**
  - This should be (of course) possible, up to 160 MeV/u
  - Emittance values (and current) to be checked

- **Beam time structure** *(16 Hz pulsing, 50 μs length during 1 sec, no beam during 8 sec)*
  - This is also (of course) possible on the beam dynamics point of view



Compatibility with EURISOL operation

- **Beta-beams = 6 month continuous operation**
  - The EURISOL beam has to fit between the Beta-beam pulses, no choice !!!



- **Switching from the EURISOL beam to the Beta beam**
  - Some adjustement has to be performed on ALL the linac elements (quads, cavities field & phase…) each time we switch (i.e. every 60 ms or more probably every 1 sec)

=> IS IT TECHNICALLY FEASIBLE ???

=> IS IT ACCEPTABLE FOR NUCLEAR PHYSICS ?

Let's suppose it's feasible…

- For EURISOL, we need only a few W per cavity (but 500 W amplifiers are foreseen)
- For Beta-beams, we need typically 20 kW per cavity
  - *High power coupler has to be developped*
  - *Low Qext (high coupling) is needed*
- Can the Qext of the coupler be changed quickly (< 1 sec) ??
  - *If NOT, we will need 5 to 10 kW per cavity, fully reflected, for the EURISOL operation*
- What kind of RF operation can we foresee ?
  - *Pulsed RF for beta-beam may save on operation cost if a fast varying coupler is used, but this may have hard consequences on cavity & RF system design*
  - *In every case, high investment overcost for RF systems (10 to 15 M€, first guess)*

AC power needs *Very rough estimations!!!*	**Fixed coupler**		**Fast movable coupler**	
	CW RF	**Pulsed + CW RF**	**CW RF**	**Pulsed + CW RF**
Beta beam pulse	4.6 MVA	50 kVA	4.6 MVA	50 kVA
EURISOL pulse	1.5 MVA	1.5 MVA	50 kVA	50 kVA
Total	**1.8 MVA**	**1.3 MVA**	**0.5 MVA**	**0.05 MVA**
Electricity cost	600 k€/y	430 k€/y	170 k€/y	20 k€/y

Conclusions

FIRST DESIGN OF A POST-ACCELERATOR FOR EURISOL

- Spiral-2 architecture, No stripping stations, optimised for $^{132}Sn^{25+}$ up to 100 MeV/u
- 161 metres long, 225 cavities *(without injector, which has to be studied)*
- Up to 160 MeV/u for q/A=1/3, but only 10 MeV/u for q/A=1/10 : IS IT ENOUGH ??
- The advantages/drawbacks of using stripping sections should be better analysed
- Input energy from injector(s), emittances values ?

FIRST ANALYSIS OF THE COMPATIBILITY WITH THE BETA BEAM NEEDS

- Hard points are underlined :
  - A fast retuning of all the machine has to performed (at least) every 1 sec
  - Operation overcost around 0.5 M€/year (except if fast movable power couplers are used)
  - Study of a dedicated RF system + overcost is needed (+ SC cavities behaviour under pulsed RF)
- Do we really need $^{18}Ne^{10+}$??? (since $^{18}Ne^{6+}$ & $^{6}Ne^{2+}$ have the same q/A)
  - If YES, a stripping stations is needed anyhow…
- One question to nuclear physicists: do they accept 1 sec beam hole every 8 sec ?
- One question on the EURISOL operation mode: do the targets accept 1s driver beam holes ?