Linac4 DTL Beam Dynamics

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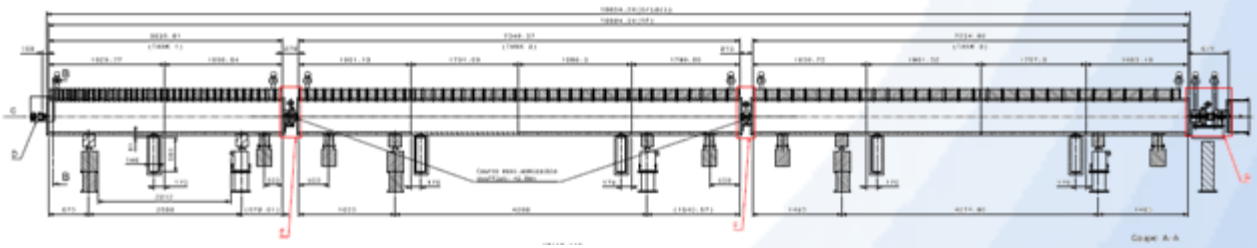
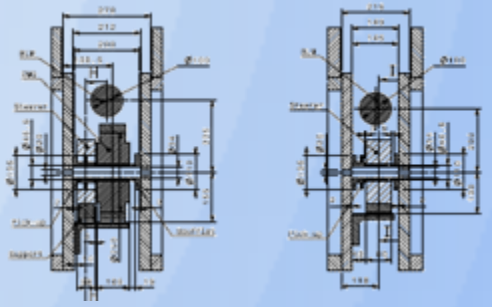
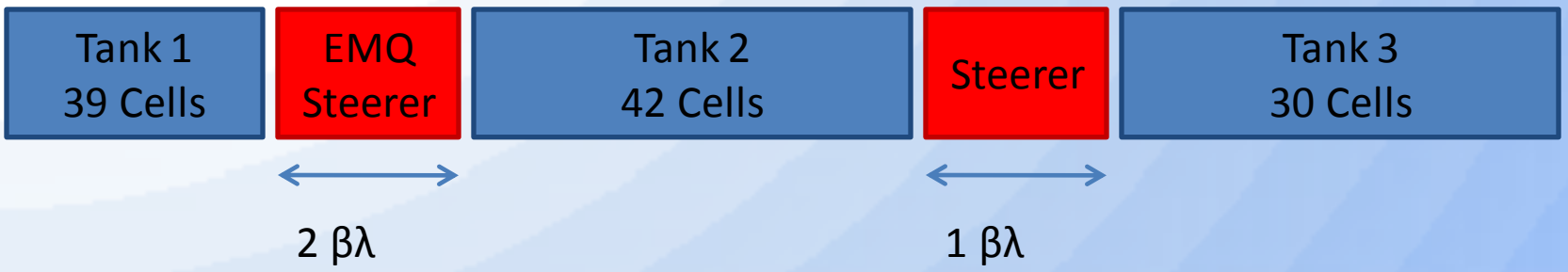
DTL Layout


45 keV
3 MeV
50 MeV
102 MeV
160 MeV
H- source
RFQ
chopper
DTL
CCDTL
PIMS
352.2 MHz

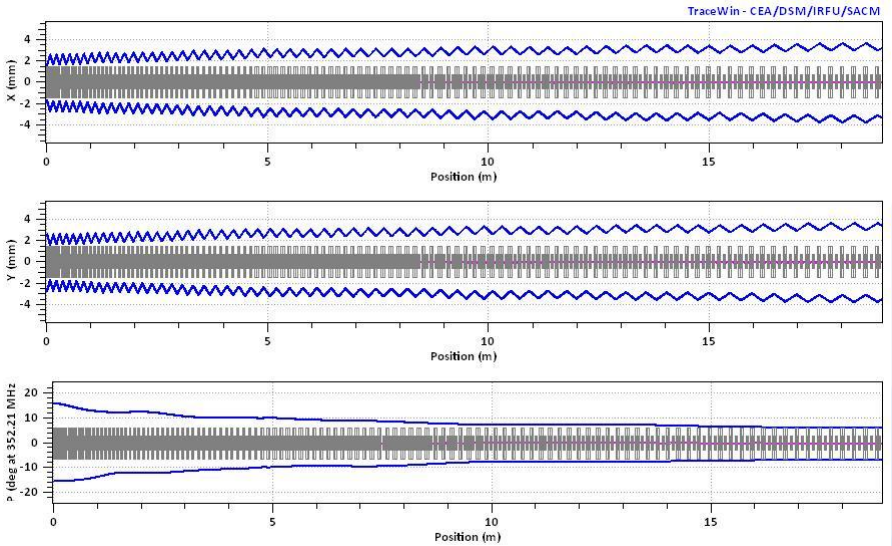




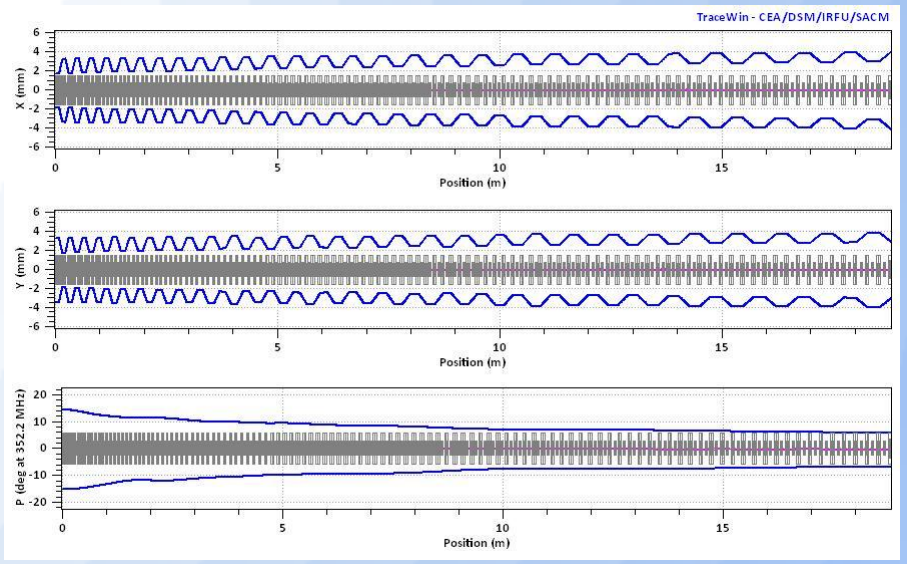

Tank 1
39 Cells
EMQ
Steerer
Tank 2
42 Cells
Steerer
Tank 3
30 Cells
2 βλ
1 βλ

3 possible focusing schemes

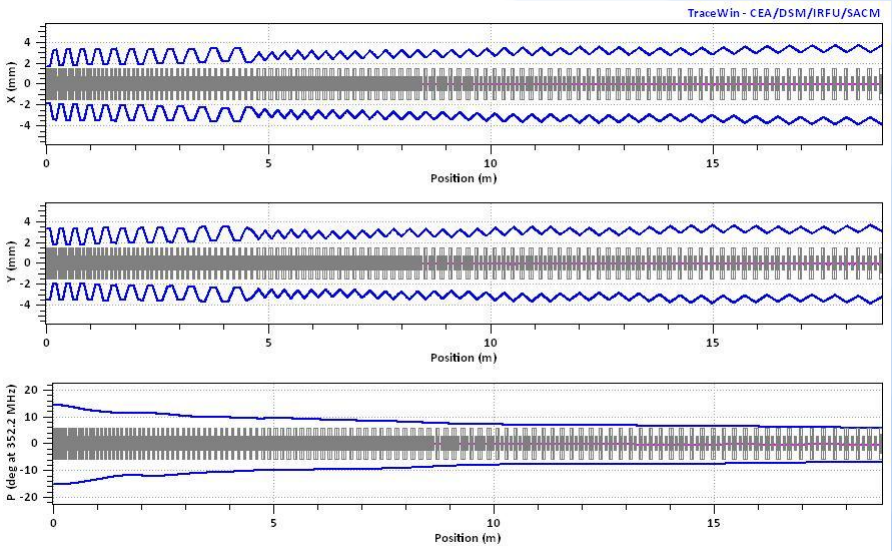
FODO (FD)



FFDD



FFDD and FD



No « exotic » schemes.

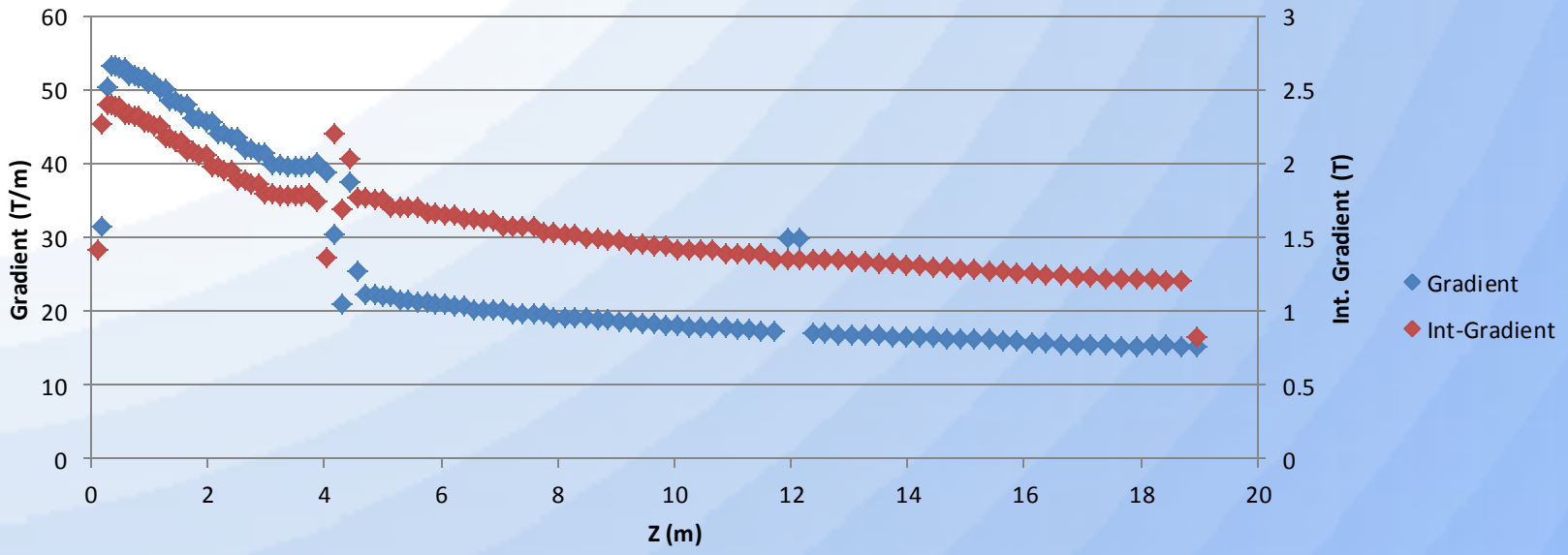
Transverse Focusing Scheme

FFDD	FFDD	FFDD

FFDD !

- FFDD less sensitive to quadrupole gradient and alignement errors.
- FD in tank 1 → 106 T/m for the first quad.

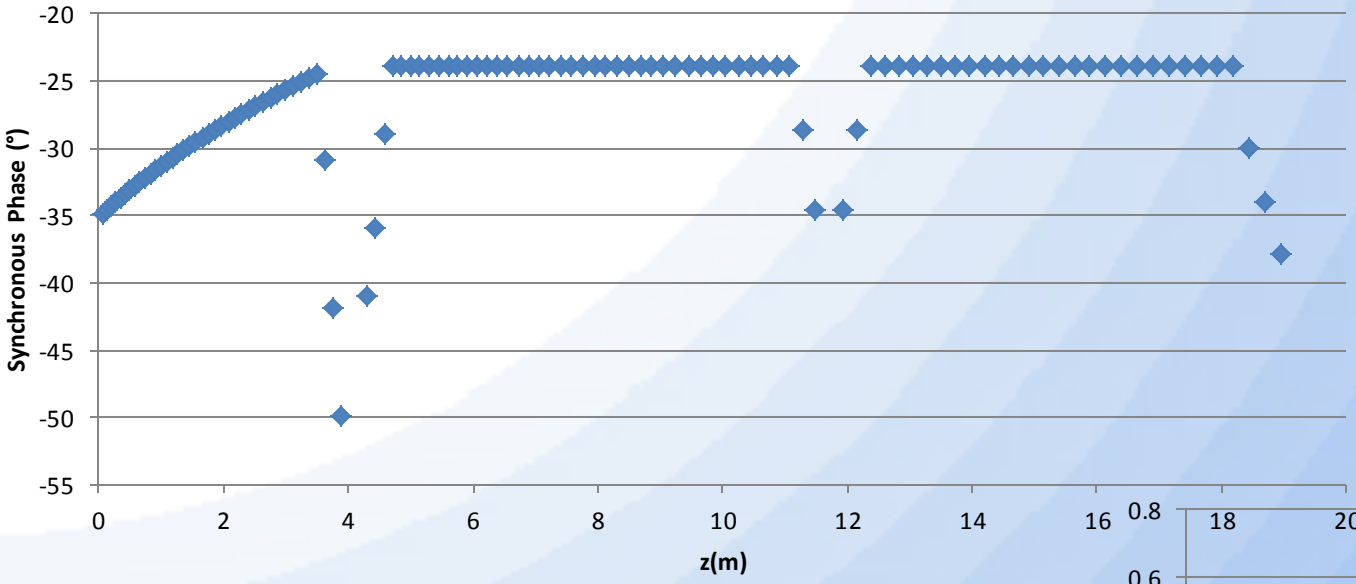
- PMQ focusing 45 mm in tank 1 and in the end-cups.
  80 mm in tank 2&3.
  EMQ 105 mm in intertank 1-2.

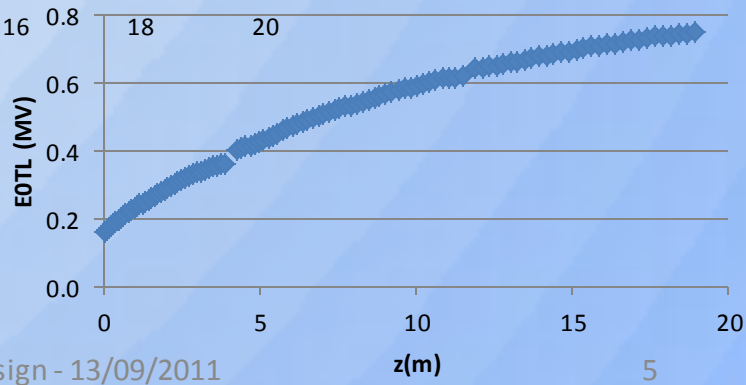


Longitudinal Parameters

3.1 MV/m -35° to -24°	3.3 MV/m -24°	3.3 MV/m -24°

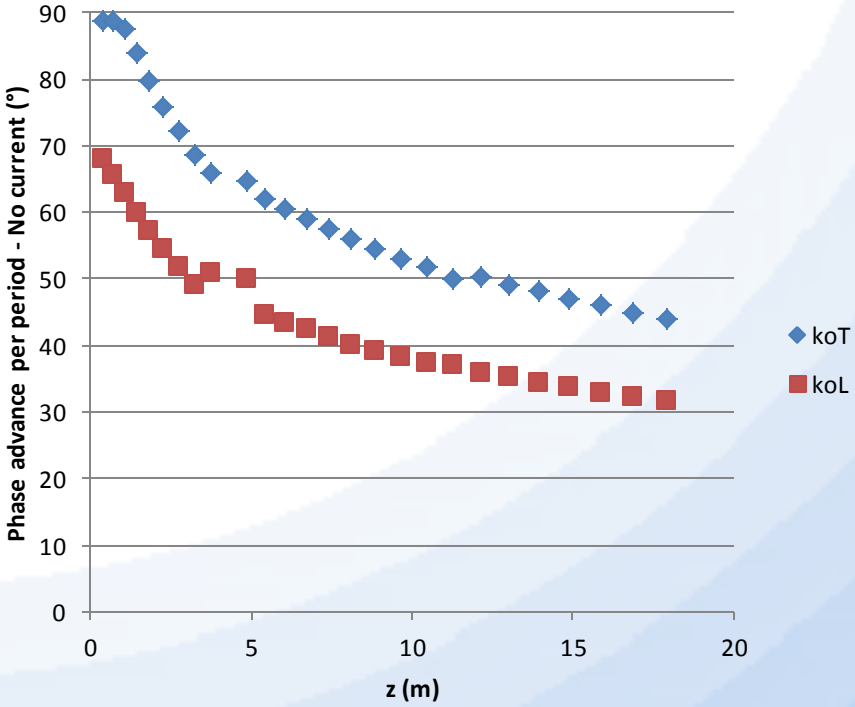
- Phase is adjusted at tank transitions to compensate the missing gap(s).

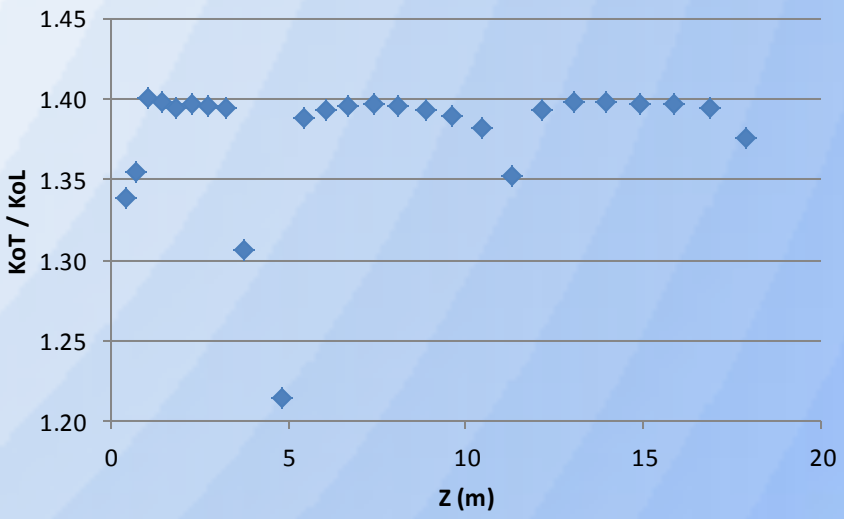




Beam Dynamics “Choices”

- Tranverse phase advance at zero current less than 90°.
- Smooth variation of the phase advance.
- Avoid resonnances.





Hofmann resonance diagram

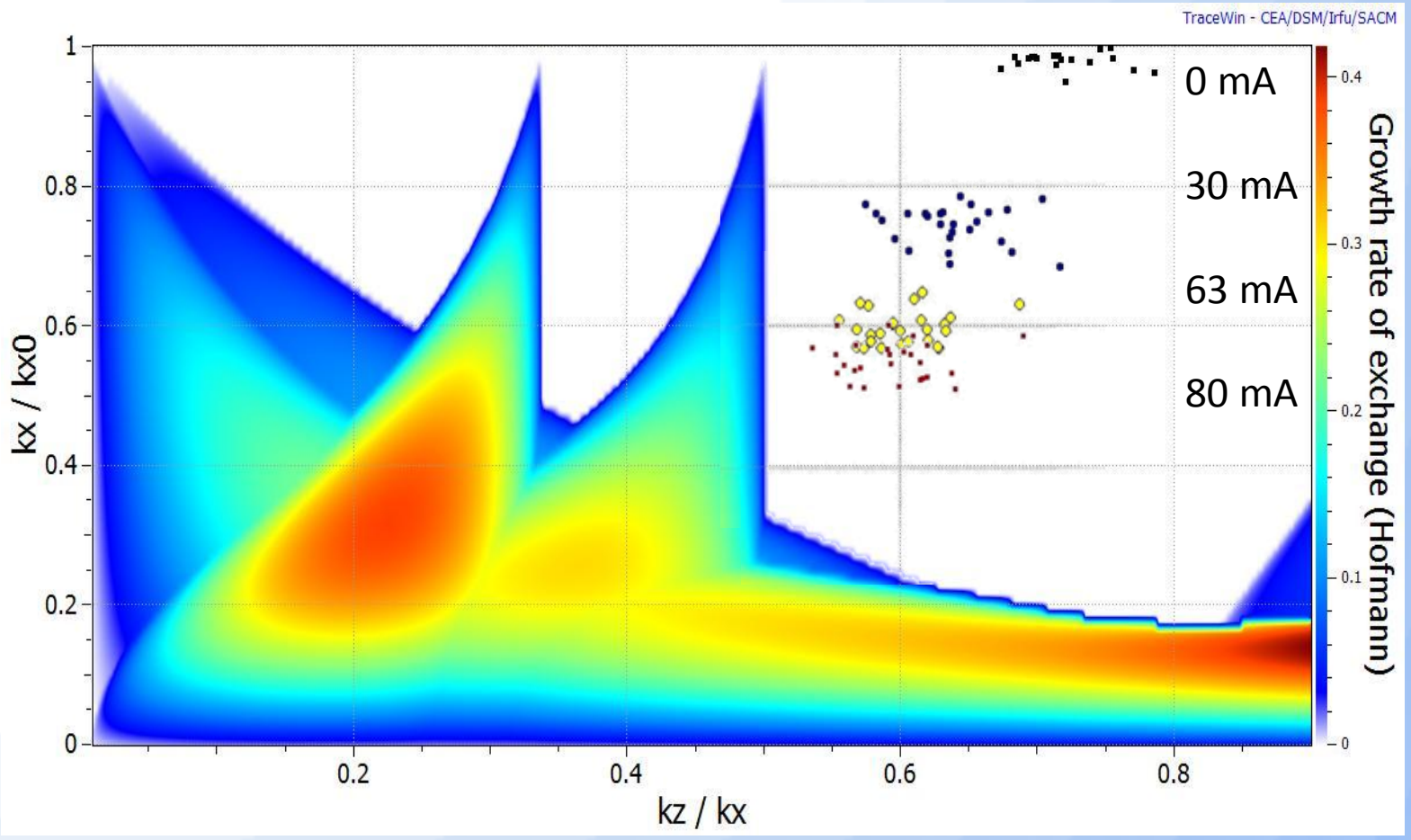
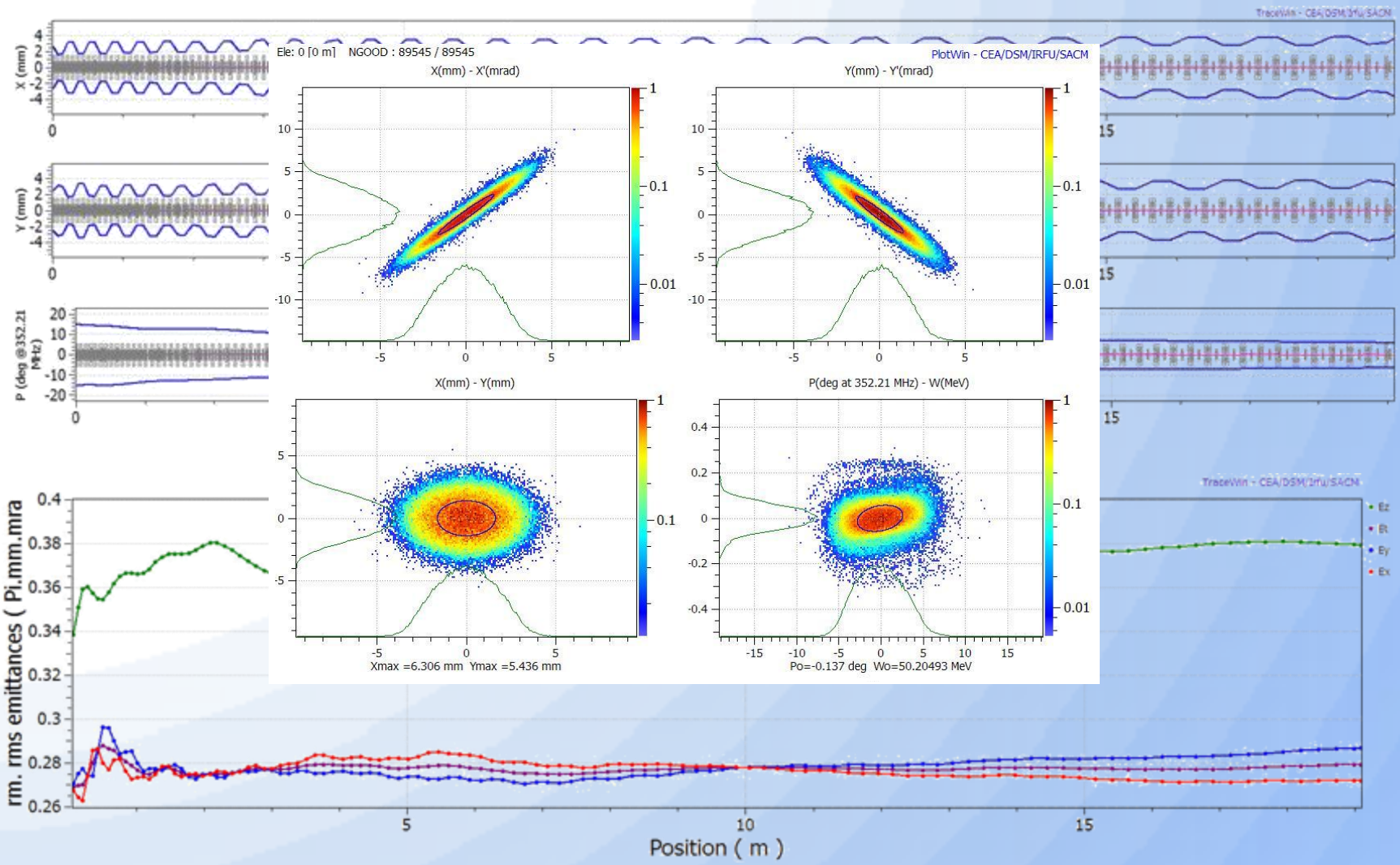


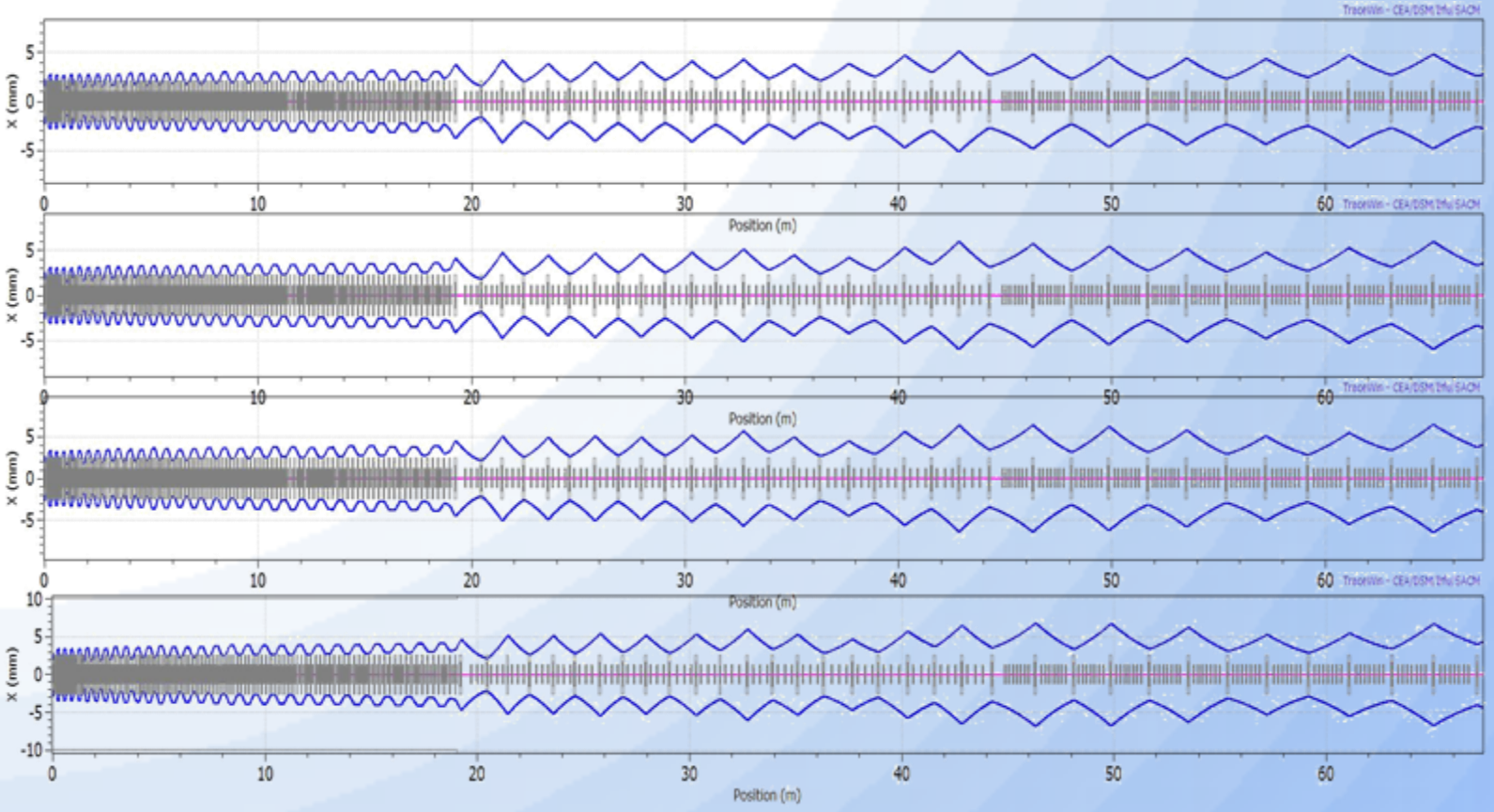
Diagram obtained with “E2E” beam.

DTL Beam Dynamics (1)



DTL Beam Dynamics (2)

- Having PMQ focusing in the DTL does not limit the flexibility of the Linac.
- By adjusting EMQs in the MEBT and at structure transitions, we are able to match the beam for any current from 0 to 80 mA (100…).



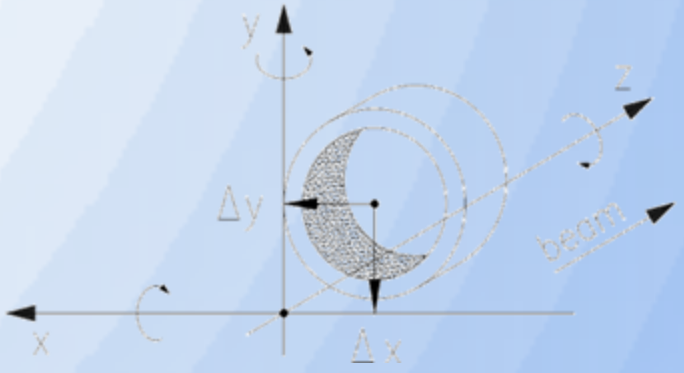
Range of Possible Beam Current in Linac4, Lallement J-B, CERN-BE-Note-2009-017.

Error studies / Definition of tolerances

- Transverse error studies :

  Stay below the limit of 1 W/m at 5% duty cycle!

  - Quadrupole misalignments.
  - Quadrupole gradient errors.
  - Input beam error : 0.3 mm, 0.3 mrad (1 σ cut at 3 σ).



X, Y (1 σ)	Roll (1 σ)	Pitch & Yaw (1 σ)	Gradient
± 0.1 mm	± 1 mrad	± 2 mrad	± 0.5 %

Loss Control and Steering Strategy for the CERN LINAC4, A. Lombardi et al, CERN-AB-Note-2007-033.

Error studies / Definition of tolerances

Remanent beam error : 6 keV

- Longitudinal error studies.
  - Static errors.
    Errors up to 2% can be accepted, provided enough RF power to bring the average field in each tank to nominal value.
  - Dynamic errors.
    Klystron phase and amplitude should be controlled ideally to ± 0.5% ± 0.5°. ± 1% ± 1° is still acceptable.

Table 6 : Effects of tuning errors on the DTL output beam.

	Transmission [%]	**Average Kinetic Energy [MeV]**	**100% Emittance [deg MeV]**	**90% Emittance [deg MeV]**	**RMS Emittance [deg MeV]**	
nominal	99.9977	49.98	10.45	0.734	0.167	
±1%	99.997±0.0009	49.98±0.020	11.82±3.24	0.774±0.010	0.168±0.02	Target value
±2%	99.997±0.0015	49.98±0.038	12.23±4.02	0.776±0.049	0.176±0.011	Acceptable
±5%	99.990±0.03	49.98±0.092	34.26±177.70	0.976±0.307	0.219±0.076	Halo develops
±10%	85	46±13	249±522	4.41±15	1.2±3.5	Affects Trans.

Table 5 : Effects of amplitude and phase jitter on the DTL output beam.

amplitude and phase	Phase jitter [deg] 1 sigma	Energy jitter [keV] 1 sigma	90% Emittance [deg MeV]	RMS Emittance [deg MeV]
nominal			0.734	0.167
±0.5% and ±0.5 deg	0.82	13	0.745±0.014	0.169±0.003
±0.5% and ±1 deg	0.88	18	0.751±0.017	0.171±0.004
±0.5% and ±2 deg	0.92	31	0.774±0.034	0.175±0.009
±1% and ±0.5 deg	1.6	23	0.757±0.024	0.171±0.005
±1% and ±1 deg	1.6	28	0.762±0.027	0.172±0.006
±1% and ±2 deg	1.83	36	0.786±0.047	0.177±0.011

Alignment and Field Error Tolerance in Linac4, A. Lombardi et al, CERN-ATS-Note-2011-021.

Conclusion

- Several years of studies summarized in 10 slides…
- Linac4 DTL beam dynamics design is:

  - Robust:

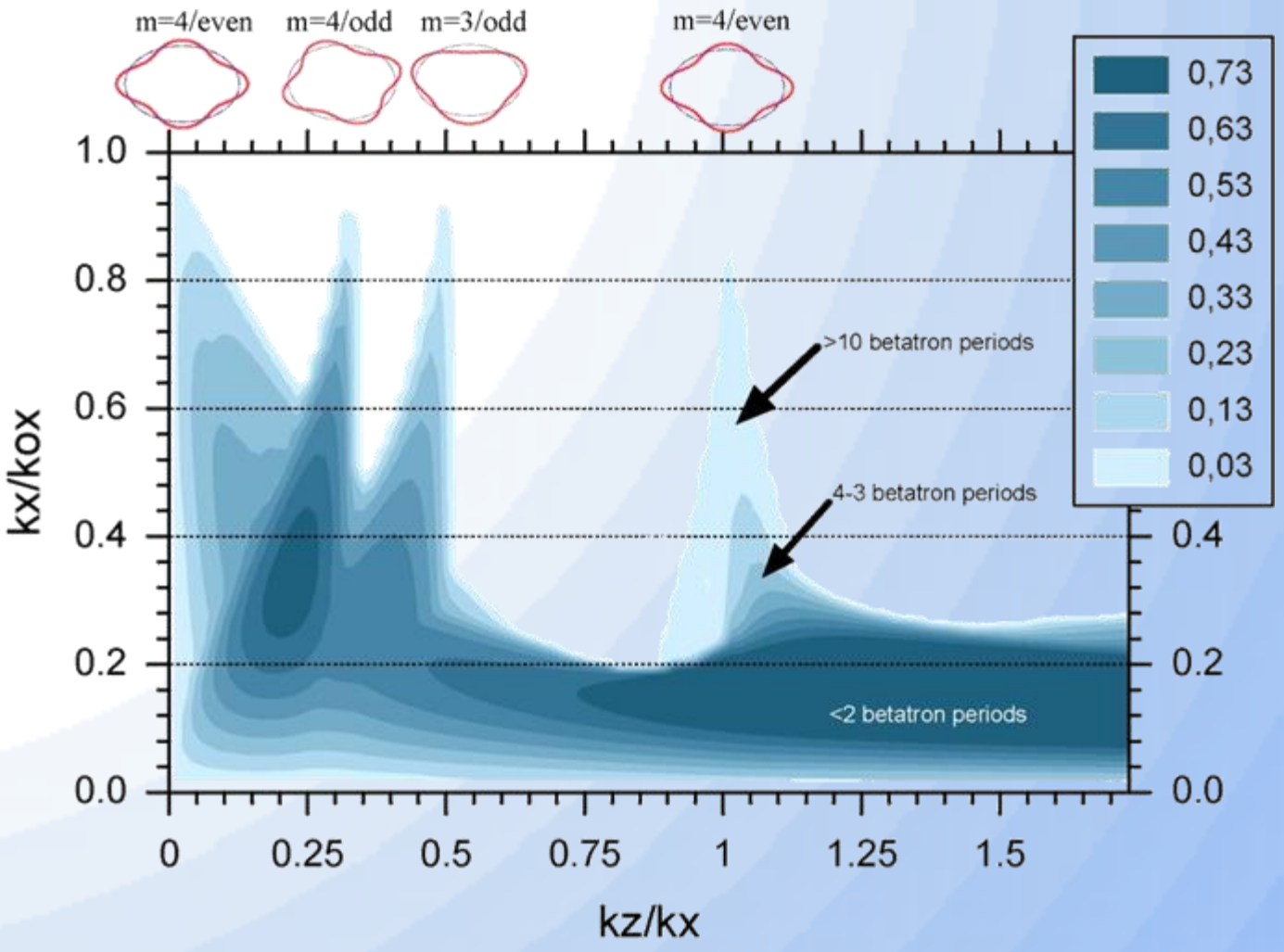
    - Respect of the beam dynamics “laws”.

    - RF and transverse tolerances defined to preserve nominal performances.

  - Flexible: The choice of having PMQ focusing does not limit the flexibility in beam current.

- Hope to measure tomorrow (2013) what we have today on paper…

Thank you for your attention


m=4/even
m=4/odd
m=3/odd
m=4/even
0,73
0,63
0,53
0,43
0,33
0,23
0,13
0,03
>10 betatron periods
4-3 betatron periods
<2 betatron periods
kx/kox
kz/kx
1.0
0.8
0.6
0.4
0.2
0.0
0
0.25
0.5
0.75
1
1.25
1.5

Error Studies – E2E Beam