Measurements program and user specifications for the movable test bench

G Bellodi-BE/ABP/HSL

Functionality

modular commissioning of RFQ, MEBT and DTL Tank1: see EDMS 1004908

	Commissioning scenario (nominal/probe)	Nominal operation
Pulse length	50-100 μs	400 μs
Rep rate	1Hz	2 Hz
Beam current	5-65mA	65mA
Beam energy	3MeV (RFQ, MEBT), 12 MeV (Tank1)	
Beam emittances at structure output planes (RMS norm)	RFQ - 0.3 mm mrad MEBT - 0.3 mm mrad DTL tank1 - 0.3 mm mrad	

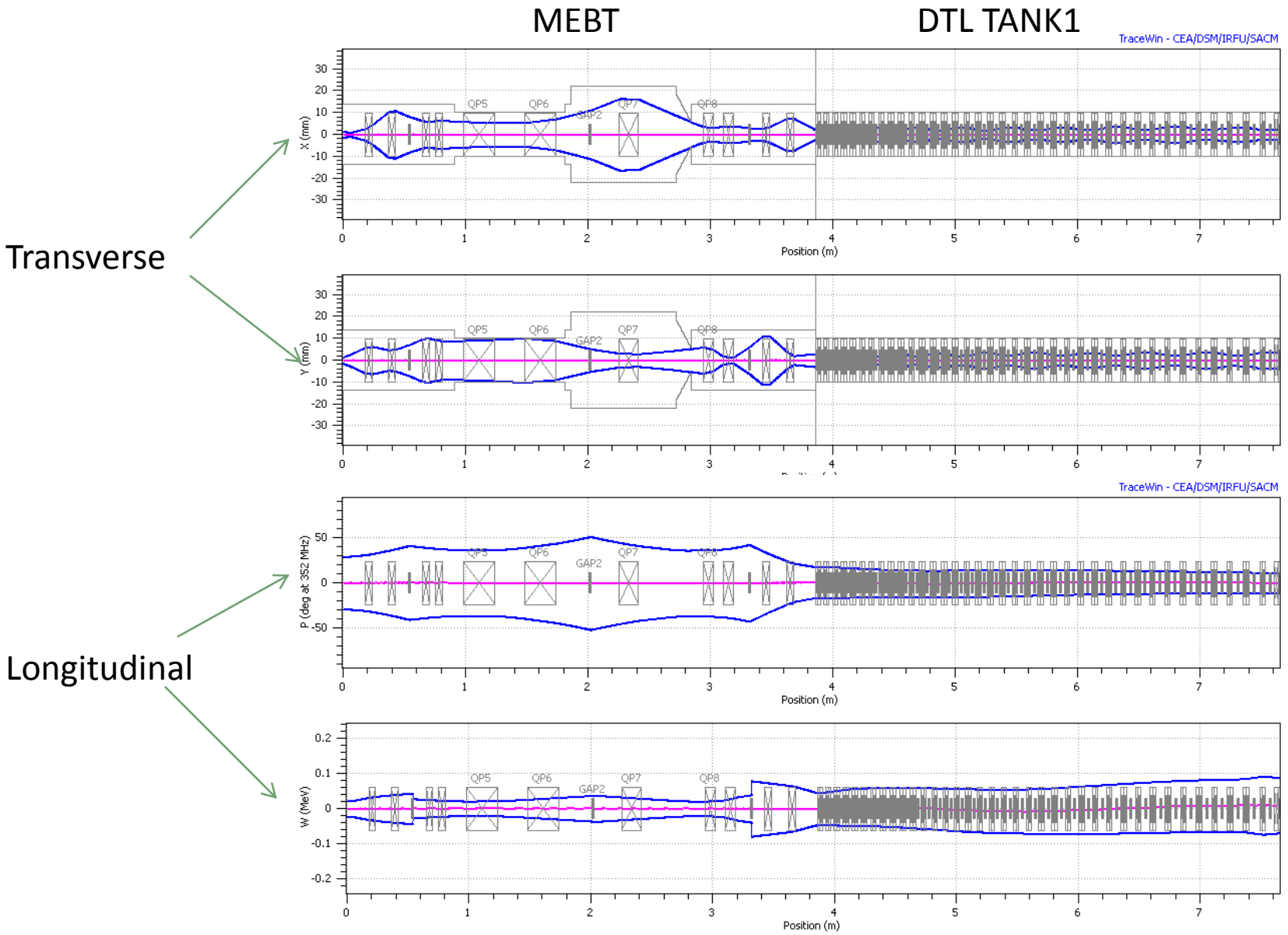
Transverse measurements

- Beam profiles
- Beam emittances
- Transverse halo
- Beam position

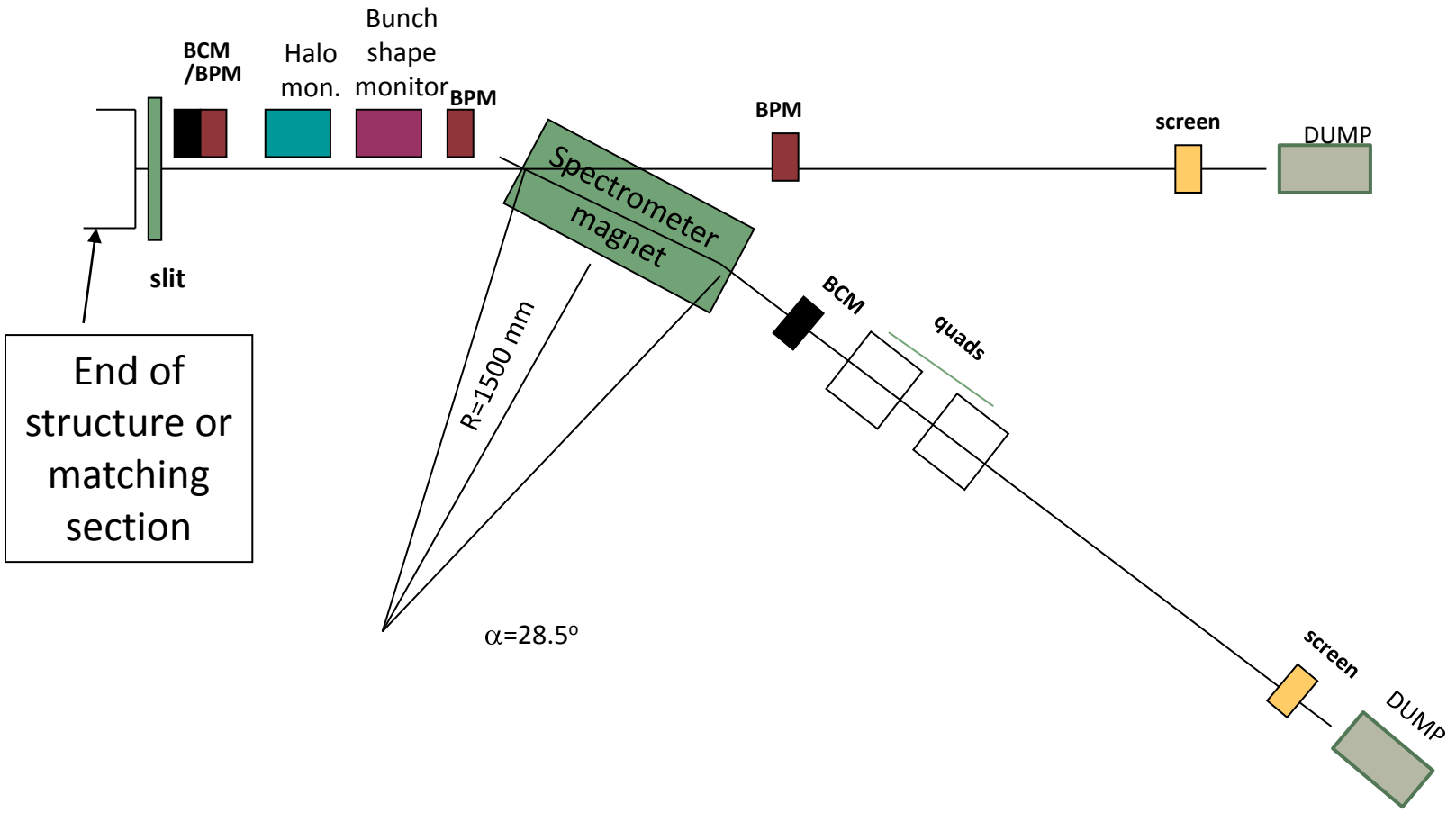
Longitudinal measurements

- Transmission
- Average energy
- Chopping efficiency
- Energy spread
- Bunch shape profile
- Longitudinal emittance?

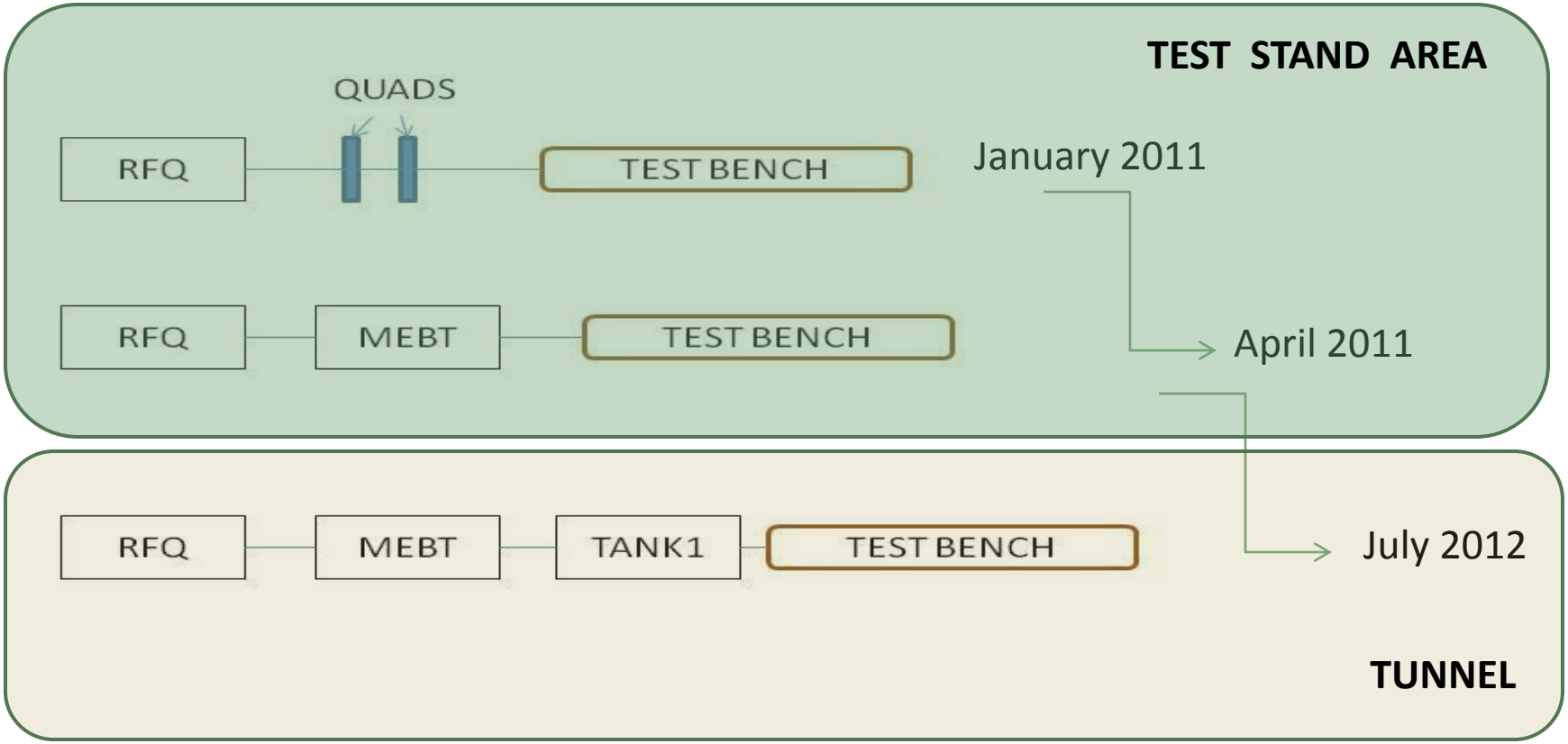
Nominal envelopes



Block layout



What/where/when



Measurements program/specifications

General:

alignment tolerances: <0.5mm with a center positioning accuracy of 0.1mm

time resolution: pulse to pulse (1Hz), with a gating resolution of ~20μs

1) Beam intensity and transmission

Two transformers, one inline and one on spectrometer line downstream of bending magnet

	specs
Min/max current	0-80mA
Resolution	1mA
Max pulse length	500 μsec
Accuracy	1mA
Time resolution	2 μsec

2) Beam position/phase

Measure

- absolute beam position
- relative beam intensity between pick-ups
- absolute beam intensity through calibration with BCM
- absolute beam phase
- average energy (TOF technique)

Resolution

Beam position	0.1 mm
Beam intensity	1% peak current
Beam phase	1 degree
Energy resolution (TOF)	1 per mille

TOF measurements are intended to complement/cross-check average energy measurements with spectrometer line (PUs calibration).

PUs to be installed at locations where beam is not already debunched. Current beam phase widths vary between 20 and 100 deg RMS at proposed locations (define max beam spread for PU reading) .

Minimum intensity threshold should allow operation with pencil beam with reduced current (a few mA) .

TOF measurement

PUs at 582, 1291, 2416 mm (from start of diagnostics test bench)

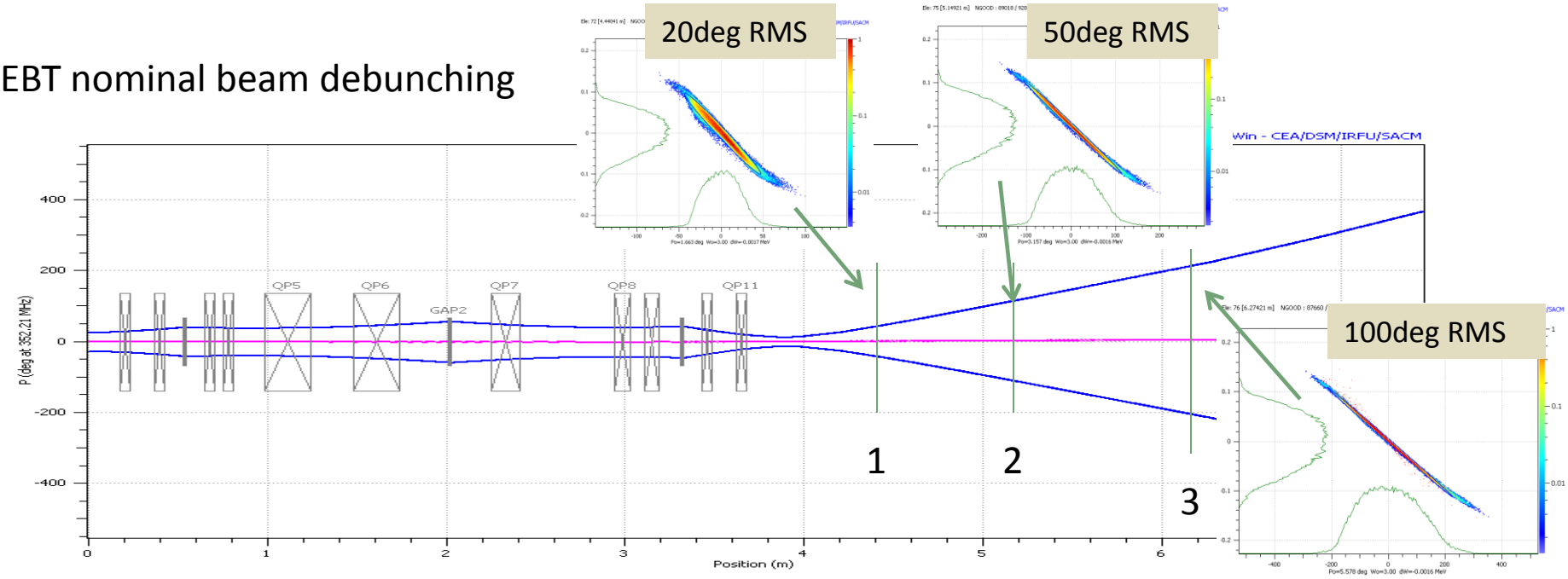
Case1 : dϕ=2deg, dL=0
Case2 : dϕ=1deg dL=0.3mm

Resolution in keV (analytical)

PUs	3 MeV		12 MeV	
	Case1	*Case2*	*Case1*	*Case2*
1-2	4.1	3.01	28.5	16.9
2-3	2.58	1.9	18	10.7
1-3	1.58	1.16	11	6.54

~ok for case2 and 1 per mille sensitivity requirement

MEBT nominal beam debunching



3) Spectrometer line

a) *Average energy measurements and RF cavities set-up*

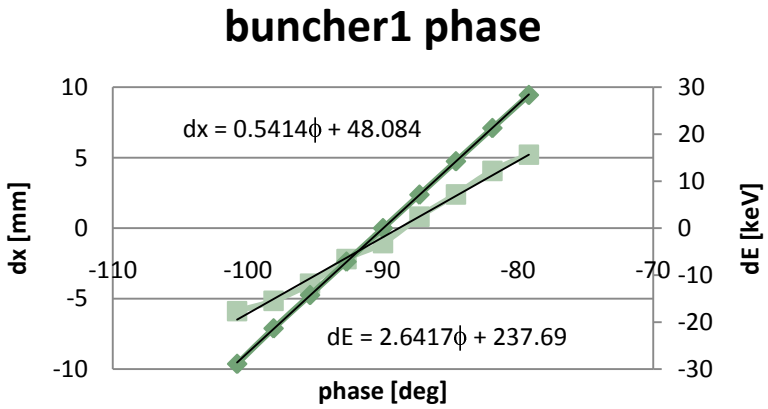
Use pencil beam, slit in retracted position and quadrupoles switched off.

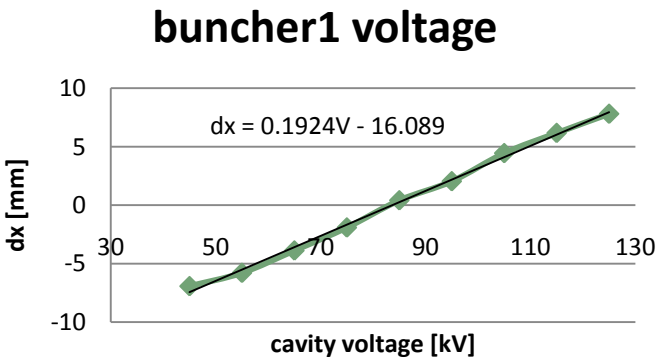
Measure beam centroid displacement on SEM grid when changing RF settings
Beam is swept across entire monitor width : $\Delta p/p=\pm 1\%$ corresponds to a deviation of ±13.5mm

Need *0.5-0.75mm screen* resolution and *20μs gating time* to measure variation of beam energy in time

A magnetic field measurement (NMR probe) is needed to monitor the dipole B field (at ~1 per mille stability level).

Ex: MEBT buncher1 tuning





3) Spectrometer line

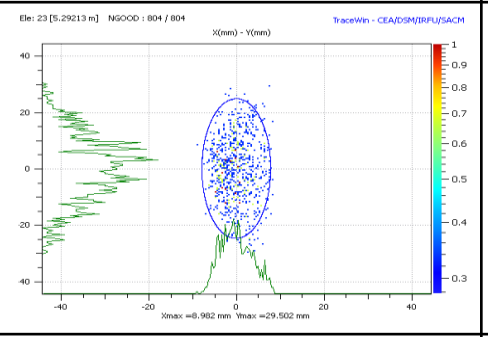
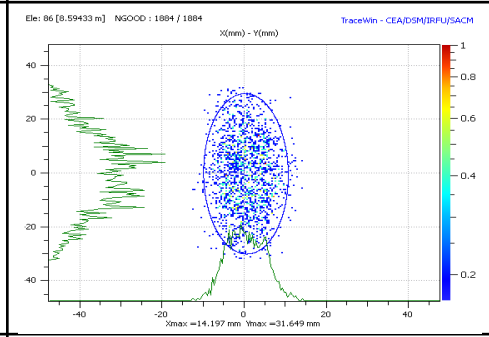
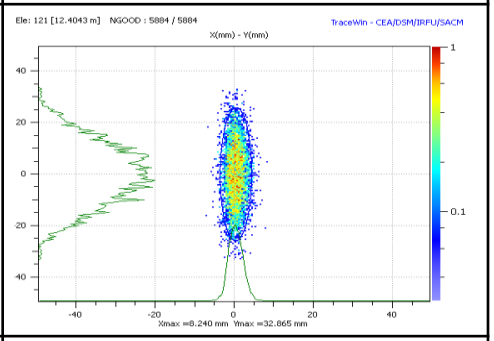
b) *Energy spread measurement*

Beam energy spread is derived from measurements of the beam sizes at the SEM grid by knowledge of the local dispersion function.

Nominal simulation results - slit closed to 0.2mm half aperture, sector bend, downstream quadrupole focusing (-2.8/1.6 T/m at 3 MeV , -5.6/3.2 T/m at 12 MeV)

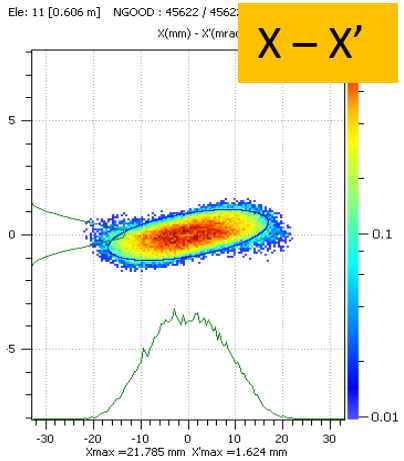
5 rms values	ΔE at exit [keV]	ΔE at slit [keV]	Δx at SEM [mm], ΔE=0	Δx at SEM [mm]	Resolution [keV/mm]
RFQ	±23	±41	±1.6	±7.7	5.3
MEBT		±52	±2.7	±11	4.7
DTL Tank1		±72	±2	±4.5	16

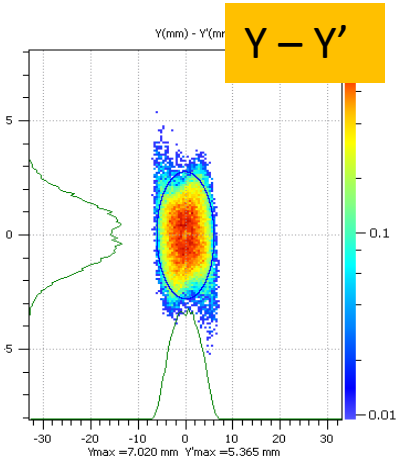
Nominal beams on the SEM grid

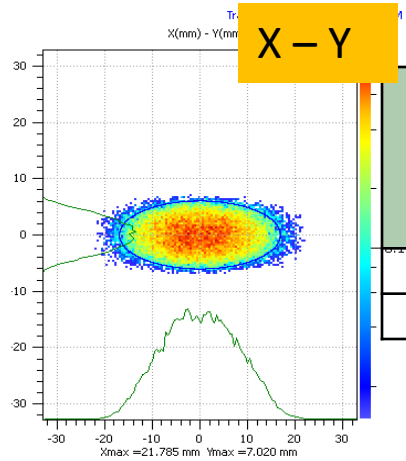
RFQ beam, nominal, 3MeV	MEBT beam, nominal, 3MeV	Tank1 beam, nominal, 12MeV
		
I=1.15mA Δx (5 rms) = ±7.7mm, Δy(5 rms)=±25mm	I=2.7mA Δx (5 rms) = ±11mm, Δy(5 rms)=±29.5mm	I=8.4mA Δx (5 rms) = ±4.5mm, Δy(5 rms)=±26mm
ΔE=0 at slit Δx=±1.6mm Δy=±25mm	ΔE=0 at slit Δx=±2.7mm Δy=±29.5mm	ΔE=0 at slit Δx=±2mm Δy=±26mm

4) Beam profiles/emittances (slit+SEM grid)

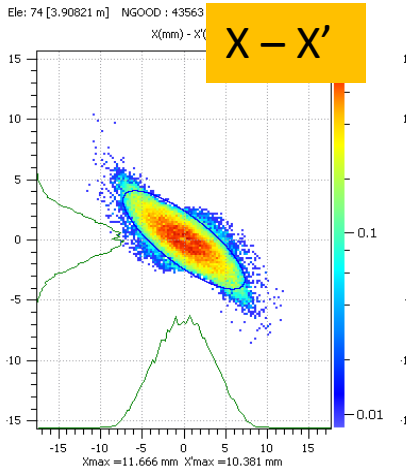
Nominal distributions at the slit

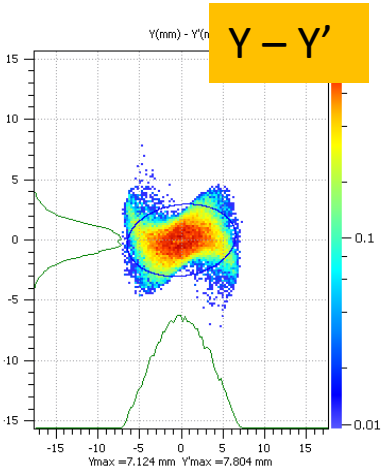


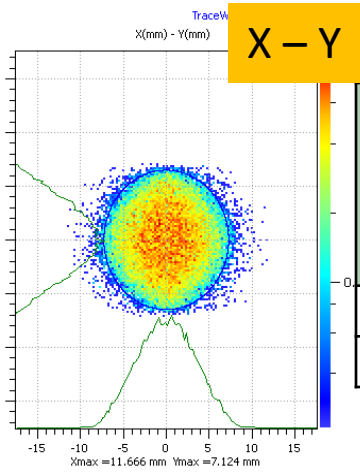




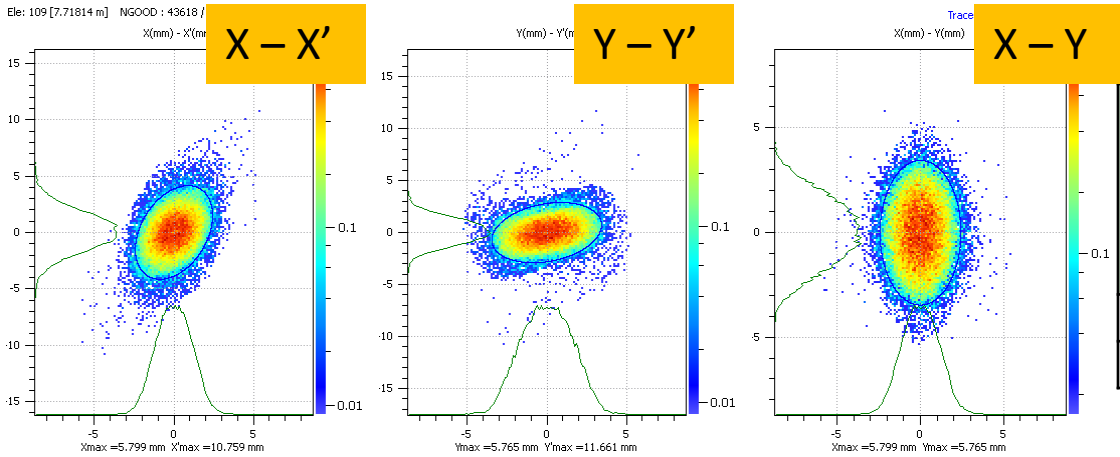
RFQ	Emit RMS norm [mm mrad]	Emit 93% norm [mm mrad]	5 rms Beam width[mm]
x	0.26	1.3	17
y	0.27	1.3	6







MEBT	Emit RMS norm [mm mrad]	Emit 93% norm [mm mrad]	5rms Beam width[mm]
x	0.28	1.41	7.3
y	0.31	1.54	6.5



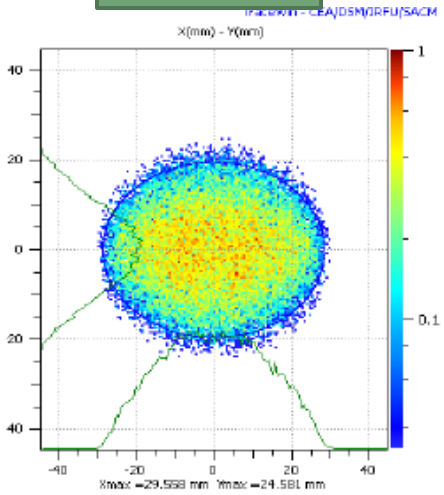
tank1	Emit RMS norm [mm mrad]	Emit 93% norm [mm mrad]	5rms Beam width[mm]
x	0.30	1.52	2.5
y	0.31	1.57	3.5

Simulations assumptions/requirements

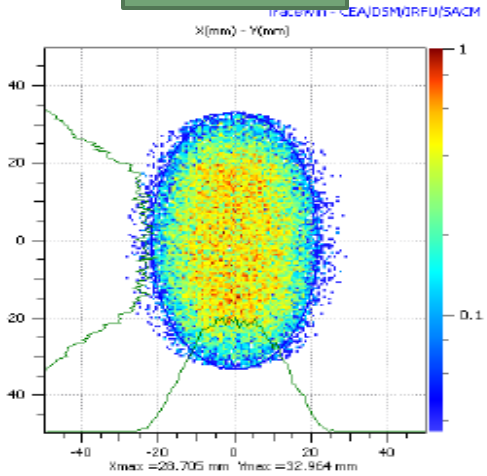
- Slit half aperture=0.2mm, total height=5cm, to be scanned through whole beam width (range of movement ±3cm)
- Motor minimum step ~ 0.2mm (relative positional accuracy 0.05mm)
- SEM wire spacing ≤ 0.75mm
- Measurements should be performed pulse to pulse (or integrated over several pulses if scanning over the beam width), with ~20μs gating resolution to synchronize acquisitions at different points along the beam pulse.

Nominal beams at inline dump

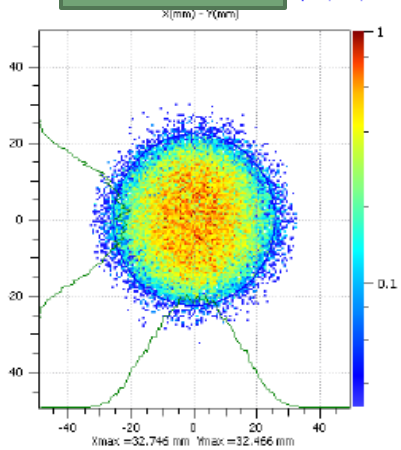
RFQ



MEBT



tank1



X-Y plane slit retracted

	RFQ (3 MeV)			MEBT (3MeV)			DTL Tank1 (12 MeV)		
	Emit RMS norm [mm mrad]	Emit 93% norm [mm mrad]	5 rms Beam width [mm]	Emit RMS norm [mm mrad]	Emit 93% norm [mm mrad]	5rms Beam width [mm]	Emit RMS norm [mm mrad]	Emit 93% norm [mm mrad]	5rms Beam width [mm]
x	0.33	1.63	28.6	0.30	1.48	21.7	0.33	1.66	25.8
y	0.27	1.33	19.5	0.35	1.77	33.1	0.33	1.63	22.5

Inline beam dump specs (3 MeV case)

Similar specs for spectrometer line dump if local interlock in place to prevent quads powering when slit is retracted

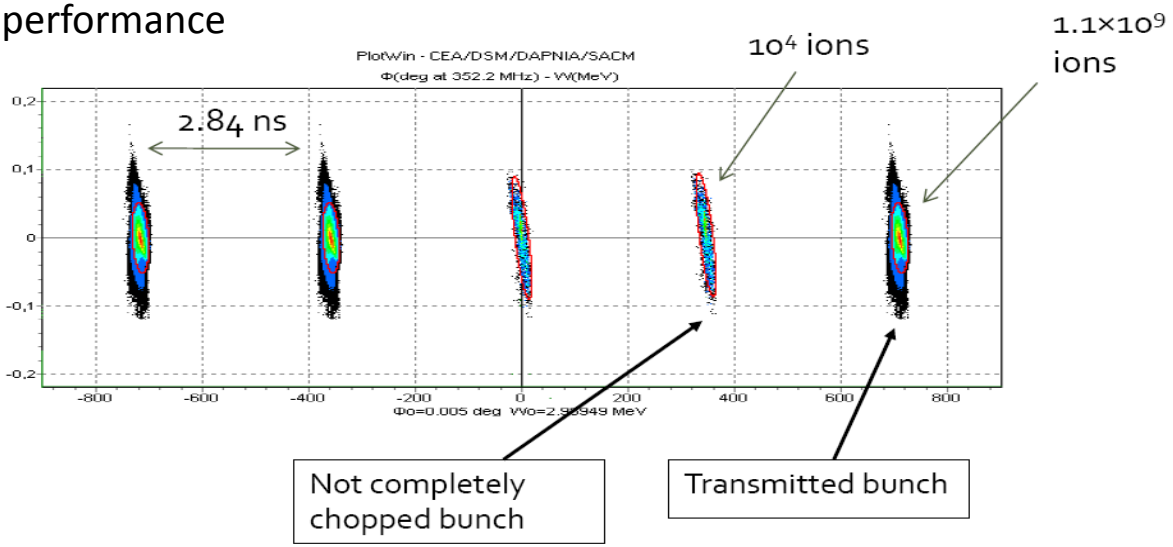
	Beam parameters		Design	Accident
Beam at dump	Particle energy	MeV	3	3
	Avg current at dump	μA	51.2	-
	Particles/s	$10^{14}s^{-1}$	3.2	-
	No of full power pulses	-	∞	4
	Mean power	W	154	-
	Reference bam size at dump	mm x mm	22 x 33	-
	Minimum beam size at dump	mm x mm	-	5 x 5
	Orthogonal power flux	MW/m^2	0.068	-
Macropulse	Avg pulse current	mA	64	64
	Duration	μs	400	400
	Spacing	ms	500	500
	Rep rate	Hz	2	2
	Duty cycle	%	0.08	0.08
	Particles per pulse*	10^{14}	1.6	1.6
micropulse	Avg micropulse current	mA	64	64
	Bunch duration	ns	0.24	0.24
	Bunch spacing	ns	2.84	2.84
	Bunch rep rate	MHz	352.2	352.2
	Bunch duty cycle	%	8.6	8.6
	Part per bunch	10^9	1.14	1.14

* Chopper off

5) Halo measurements (BSHM)

a) *Longitudinal:*

measure residual H- ions in partially chopped buckets for time resolved commissioning of the chopper performance



Require:

sensitivity of 10^3 ions, >10^5 dynamic range, gating rate ~1ns
beam should not be debunched

b) *Transverse*:

to assess general beam quality and matching inter-structures

6) Bunch shape measurements (Feshenko monitor)

• Check longitudinal quality of the beam and matching to the DTL; acquire experience for later use when diagnostics is permanently installed after Linac4

• Possibility of longitudinal emittance measurement (3-points bunch rotation method) after chopper line (to be investigated)

• Possibility of calibration with pencil beam scans of longitudinal acceptance

• Possibility of longitudinal halo studies (if dynamic range of electron multiplier gain allows)

Specs:

pulse-to-pulse acquisitions
1 deg phase resolution
at position where beam is not debunched

7) Software applications wishlist

- Transformers : simple readout
- PUs: trajectories, TOF
- BSHM : stand-alone
- Feschenko: stand-alone
- Emittance scanner:
    - emittance reconstruction
    - select profiles within time window
    - plot beam width and centre as f(t) to study evolution through pulse
    - mountain range plots
- Spectrometer SEM grid application
- General purpose dual parameter scanner
- ….
- …

to be finished …