Shared directory : https://cernbox.cern.ch/index.php/s/k3KcXwAV5PU0TwM

(Herman Alexej Giulia Sarvesh JB Ricardo you have it in myshares)

RFQ3 beam dynamics design

Questions

Alessandra Lombardi

6/5/2021

Skip to slide 7 for update 15/7/2021
Skip to slide 13 for update 14/10/2021
Skip to slide 23 for update 4/11/2021
Skip to slide 25 for update 27/01/2022
Skip to slide   32 for update 3/3/2022

Some improvements that will try

- Smoother rms :
  - to ease the matching from the LEBT
  - to aloow for more space between the last solenoid and the rfq

- Output rms :
  - to simmetrise the beam before exiting the RFQ
  - Entails readjustment of the MEBT

Source

- Forget about the 80mA, lets fix 50mA peak current?
- Extraction energy : lower / higher : what is the acceptable range

Transverse acceptance

- Higher acceptance? Is this a good idea? We need to consider the next bottleneck in the linac/PSB transfer
- 95% transmission ?

Maximum electric field on the vanetip

- This is an input to the beam dynamics design currently 33MV/m
- What shall we take?
- Constant along the vanes or concentrated in one point?
- Shall we avoid max efield in loss area? Is there a correlation?

Meeting 1 -6/5/2021

- Summary:
  - Ok for 50 mA as limit
  - No particular feedback on input energy
  - No more than 35MV/m

RFQ3 beam dynamics design

Update and first draft

Alessandra Lombardi

15/7/2021

File in directory D:\352RFQreprise2021\designthecapturefirst

- Fixed parameters :
  - 35MV/m max field on vanetip
  - Current 60mA and emit=0.4 rms norm mm mrad
  - Energy from 35 to 55 kV
  - Rho/ro = 0.75 no room to furthere reduce Emax-what I quote in the next slides is already minimized

- Divide capture and acceleration-design capture choose together and then optimize acceleration that goes with it

- LINAC4 present RFQ:
  - Designed for 80mA , 0.25 mm mrad T=93%
  - Capture 45keV to 400KeV length =118cm + 182 cm acceleration
  - V=78KV, emax 35 MV/m
  - At the time of design we were not considering emittances bigger than 0.25 mm mrad, we had the acceptance =1.5 emittance that is 0.375 mm mrad

Version 1- 35keV

- First design the capture (to about 0.4 MeV) then worry about acceleration to the final energy
- Start at 35keV to 400kV

V kV Emax MV/m	Min a // B	L	T (%) 60mA 0.4mmmrad	T (%) 60 mA 0.3 mm mard	filename	
75	1.9// 6.11	76cm	84%	87%	RFQ1.in	
75 //33MV/m	2.1 // 5.99	80cm	81%	85%	RFQ2.in	Parametric res see losses and phase ramps
70/29MV/m						

Losses correspond to too fast phase ramp - smooth the phase from 30 to 40

Version 2

- Increase the energy
- Start at 58keV
- Bunch and capture to 350keV

Higher long emittance but we have margin in the DTL

V Emax	Min a // B	L	T 60mA 0.4mmmrad	T 60 mA 0.3 mm mard	filename	
70//29 MV/m	2.3//5.7	98cm	93%	96%	RFQ3.in	Higher long emittance but we have margin in the DTL
75					RFQ4.in	

Version 3

This is similar to the existing linac4 RFQ with a tradeoff between transverse acceptance and longitudinal emittance delivered to the DTL and a lower voltage

- Stay at 45 kev
- Bunching to 350 keV

V Emax	Min a // B	L	T 60mA 0.4mmmrad	T 60 mA 0.3 mm mard	filename	
70//29	2.3 //5.7	171 cm	96%	97%	RFQ5.in	
75//29??	// 5.1	120	88%	91.%	RFQ6.in	

Next steps

- Accelerate to 3 MeV (forego exact length of 3 m for the moment)
- Track into and through the DTL
- Emittance measurement at the new source at 35 and 45 keV
- Track particles from measurements
- Check point with this group beginning September 2
- Switch to sinusoidal
- Track with higher than nominal voltage

RFQ3 beam dynamics design

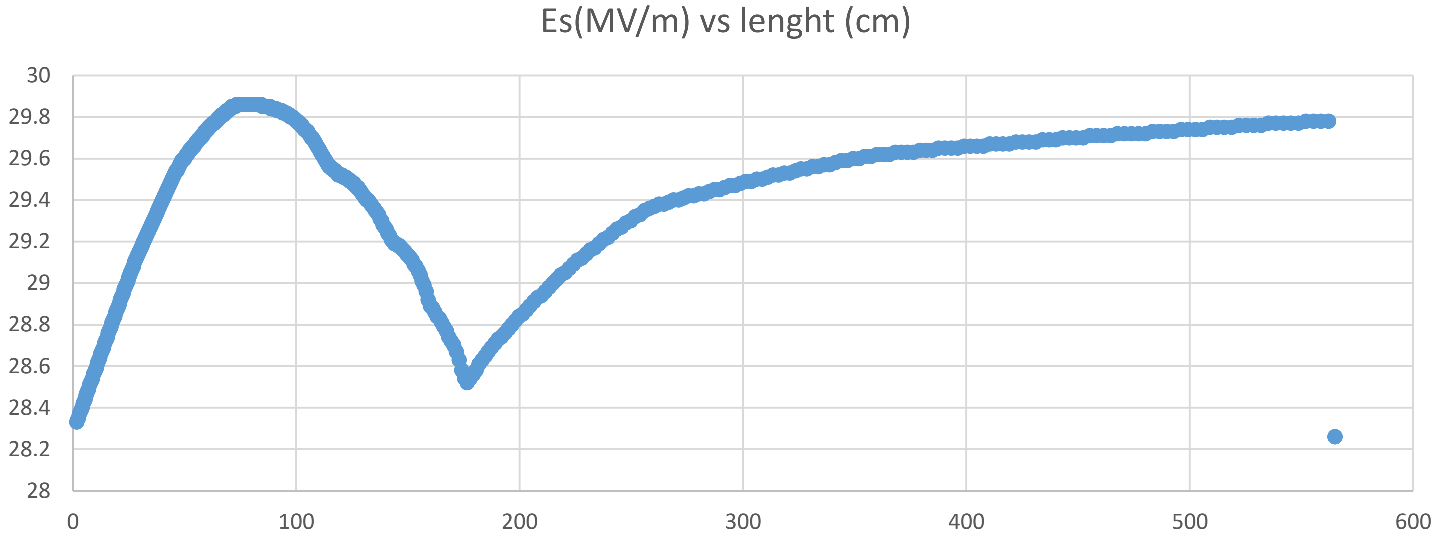
Update

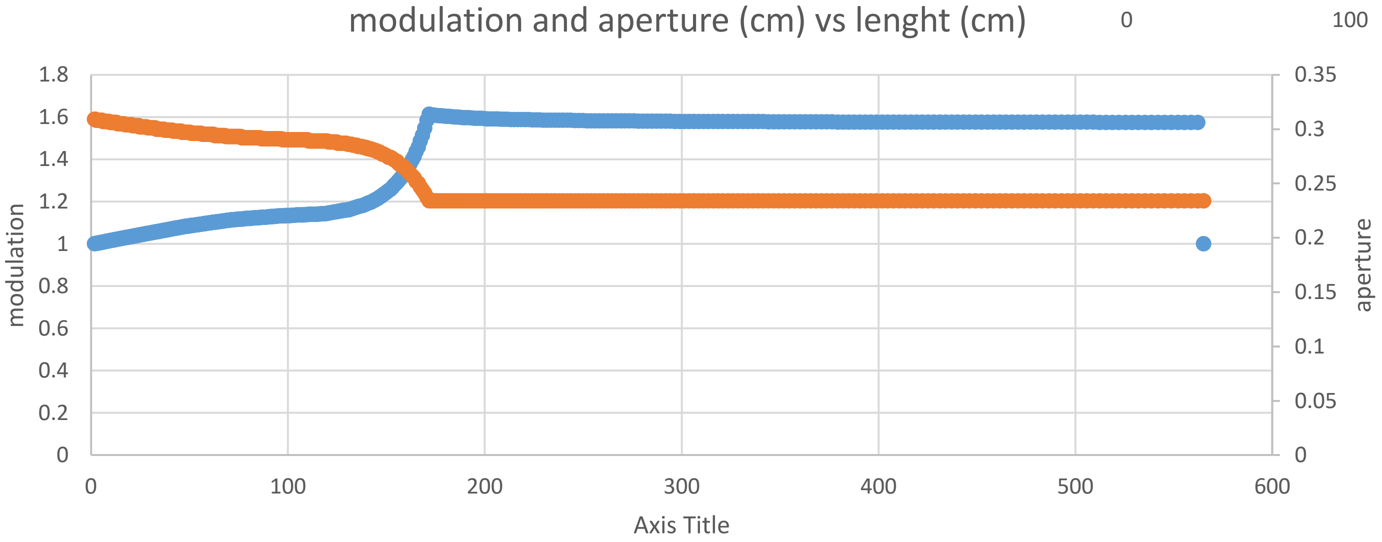
Alessandra Lombardi

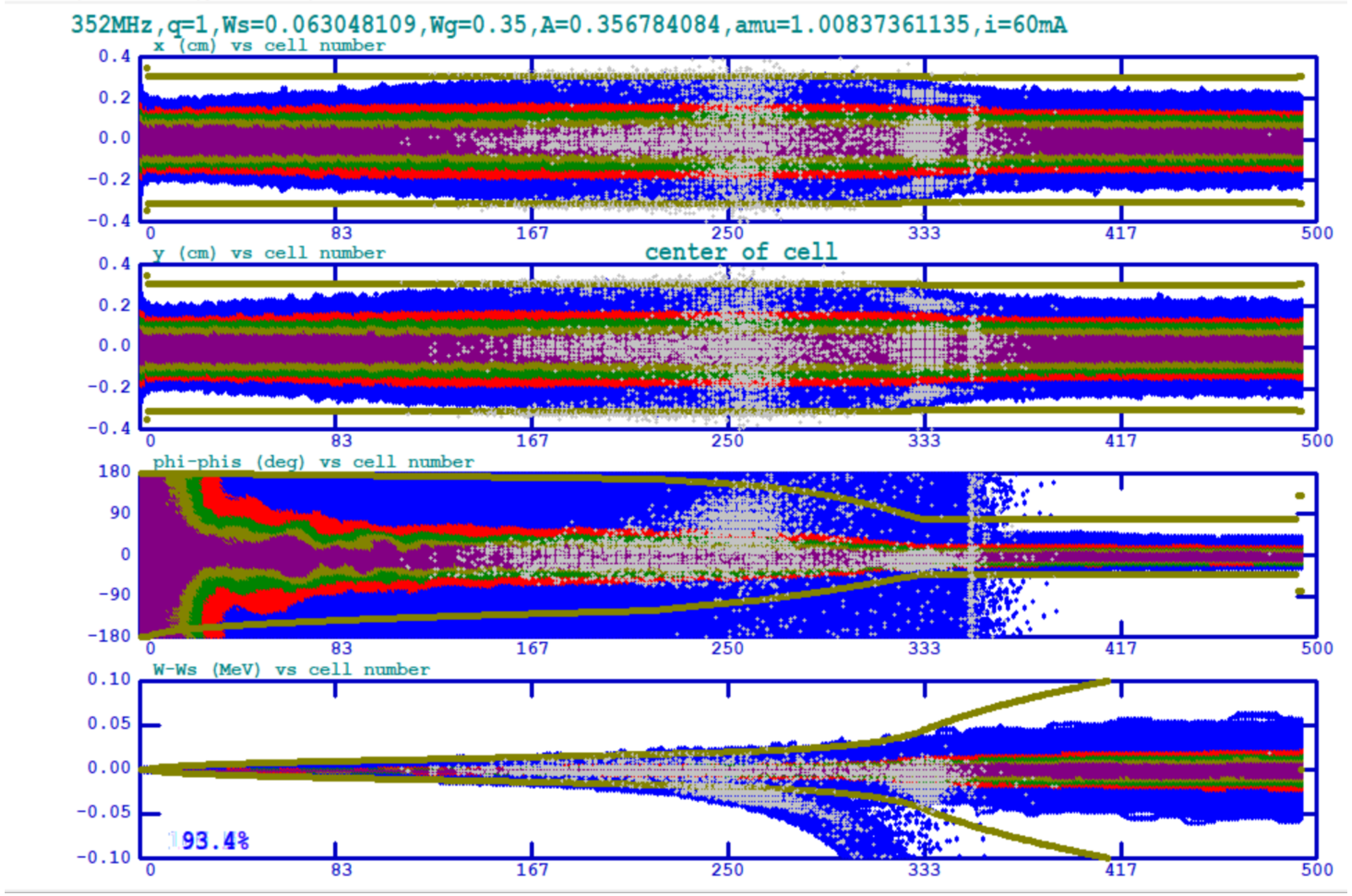
14/10/2021

Bring to the final energy after efficient capture-continue what presented in July

- RFQ7.in







V=70kV

Emax= 29 MV/m

L=5.6 m

I =70mA

Emit=0.4 mm mrad

redo

soft and safe but 5.5 m long (can be optimised but 5 m absolute minimum)

Take another approach

- LINAC4 RFQ
  - 78 kV nominal Voltage / 35MV/m maximum field
  - Bfactor=5.585 , min aperture = 1.77
  - Transmission
    - 93% 70mA emit=0.25 mm mrad
    - 80% 70mA emit=0.5 mm mrad

- Higher voltage : V=85 kV but keep Emax=35MV/m
- Lets aim at increasing min aperture but keep B factor
- Lets design for I=70mA and emit=0.5 pi mm mrad aiming at T>90%

Iteration 1 – keep length and max field

V (kV)	E_max	L cm	B	Min a (mm)	T (70mA , E=0.25)	T (70mA , E=0.5)	Filename
81	34	300		1.85	94%	83%	
85	35	300	5.4	1.92	95%	85%	
85	35	300	5.7	1.94		80%	
85	35	300	5.8	1.89		87%	
85	35	300	5.9	1.87		88.5%	
85	35	300	6.0	1.86	95.4%	89%	RFQ9.IN

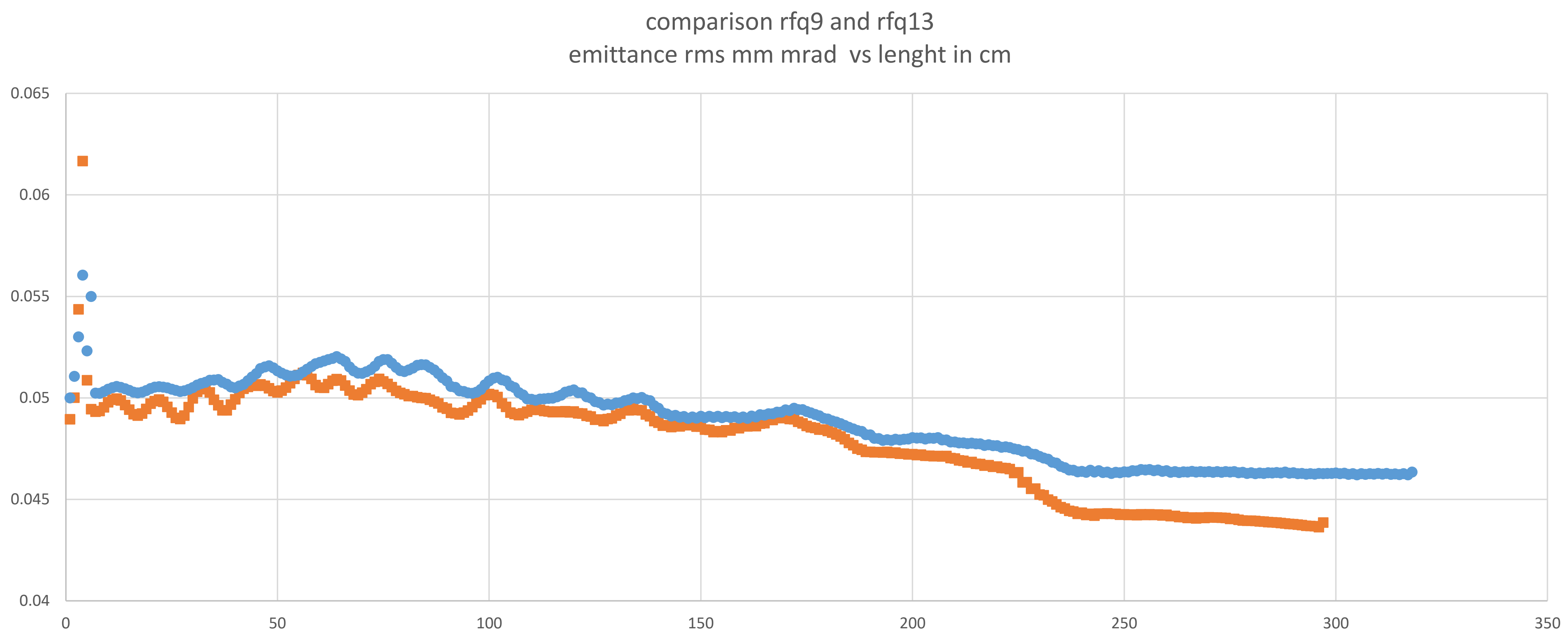
Remnant losses are due to the fact that we keep the length and the modulation in the final part is too high

Iteration 2 – reduce final modulation and allow length above 3 m

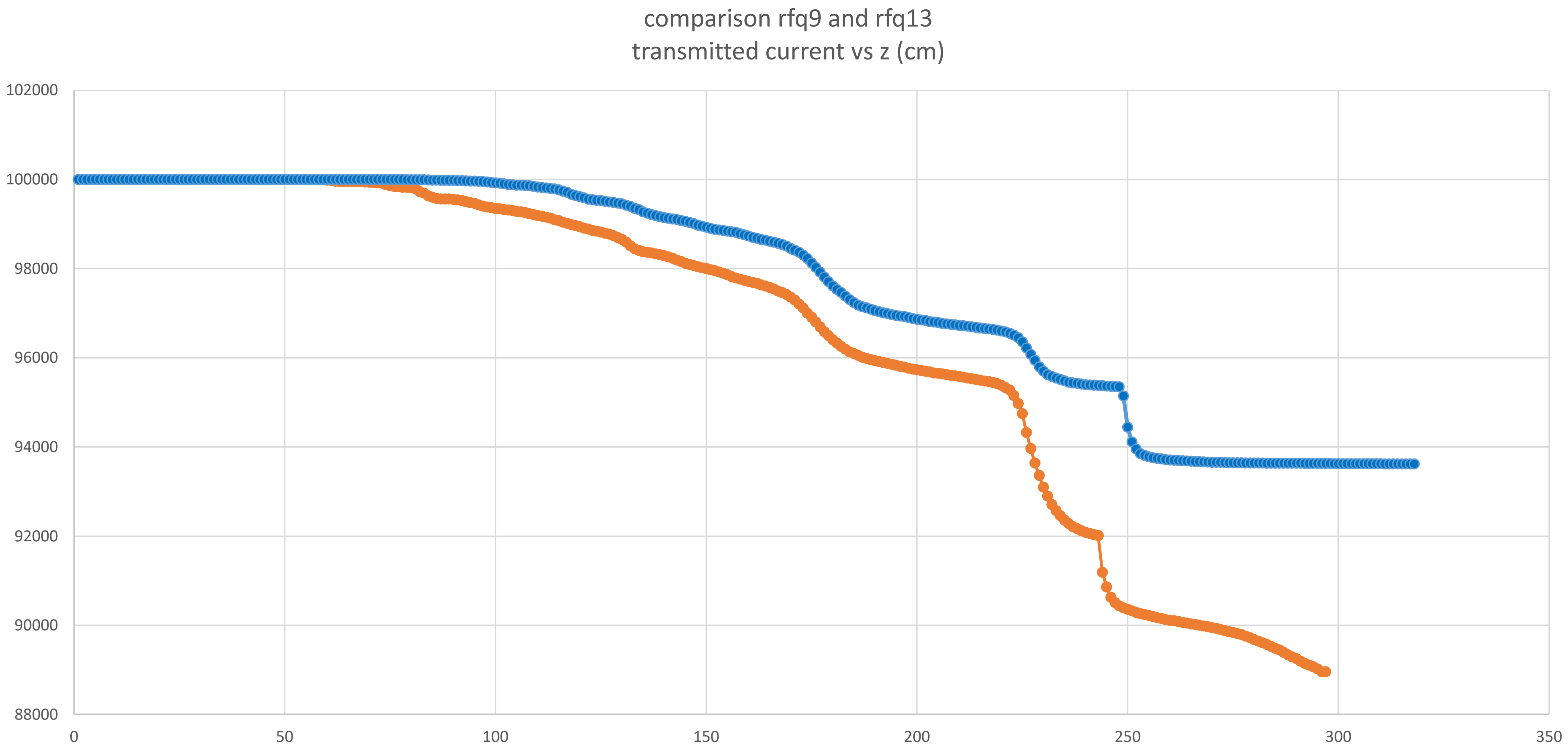
B	Final m	L	T (70mA , E=0.25)	T (70mA , E=0.5)		
6	2.1	301		90%		
6	1.9	310		90.4%		RFQ10.IN
6	1.82	325	96.7%	91.6%		RFQ11.IN
6	1.72	342	96.9%	92.3%		RFQ12.IN
6	1.72	343	96.9	93.6		RFQ13.in matching and longer rms

We are left with 3% longitudinal losses and 3 % transverse losses

Evolution from iteration 1 to iteration 2

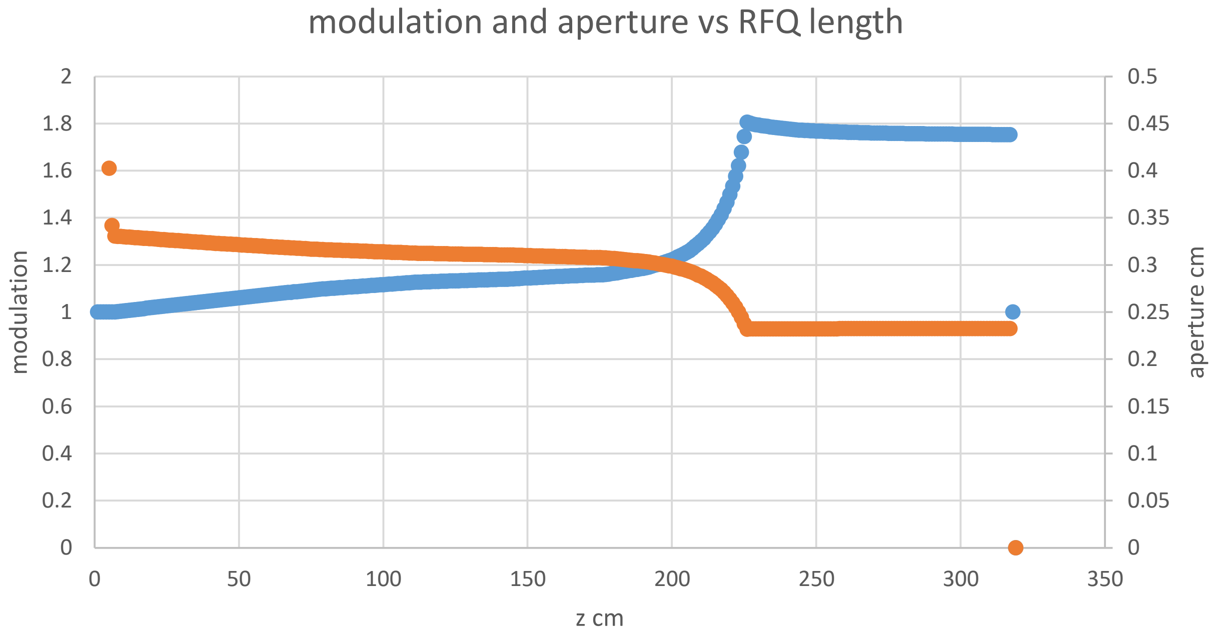


Evolution from iteration 1 to iteration 2



Details of the last iteration

- Ro=0.3306 cm
- For rho/ro=0.75 , rho=0.2479 cm Emax = 34.25 MV/m
- For rho/ro=0.85 , rho=0.2810 cm Emax = 35MV/m



LINAC4 RO=0.3256 ;rho=0.2768 cm

Summary

	V (kV)	L (cm)	Emax (MV/m)	T (70mA, 0.5mm mrad)	Power
LINAC4	78	300	35	80%	
Redesign 1 (conservative field)	70	550	29	94	+34%
Redesign 2	85	343	35	94	+20%

Next steps :

concentrate on redesign 2 for further optimisation (1month)
Start RF design by end of October (fix Ro, rho and length)
try more radical approach (2 RFQs ….)

RFQ3 beam dynamics design

Update

Alessandra Lombardi

4/11/2021

Fix parameters for RF design

R0=0.33 cm

Rho=0.28 cm

L=352 cm

V=85 kV

Sinusoisal modulation profile

Give most critical cell (higher Efield) – max efield along the vanes

Questions :

One or 2 rf tanks?

RFQ3 beam dynamics design

Update

Alessandra Lombardi (soon to be joined by S. Kumar)

27/01/2021

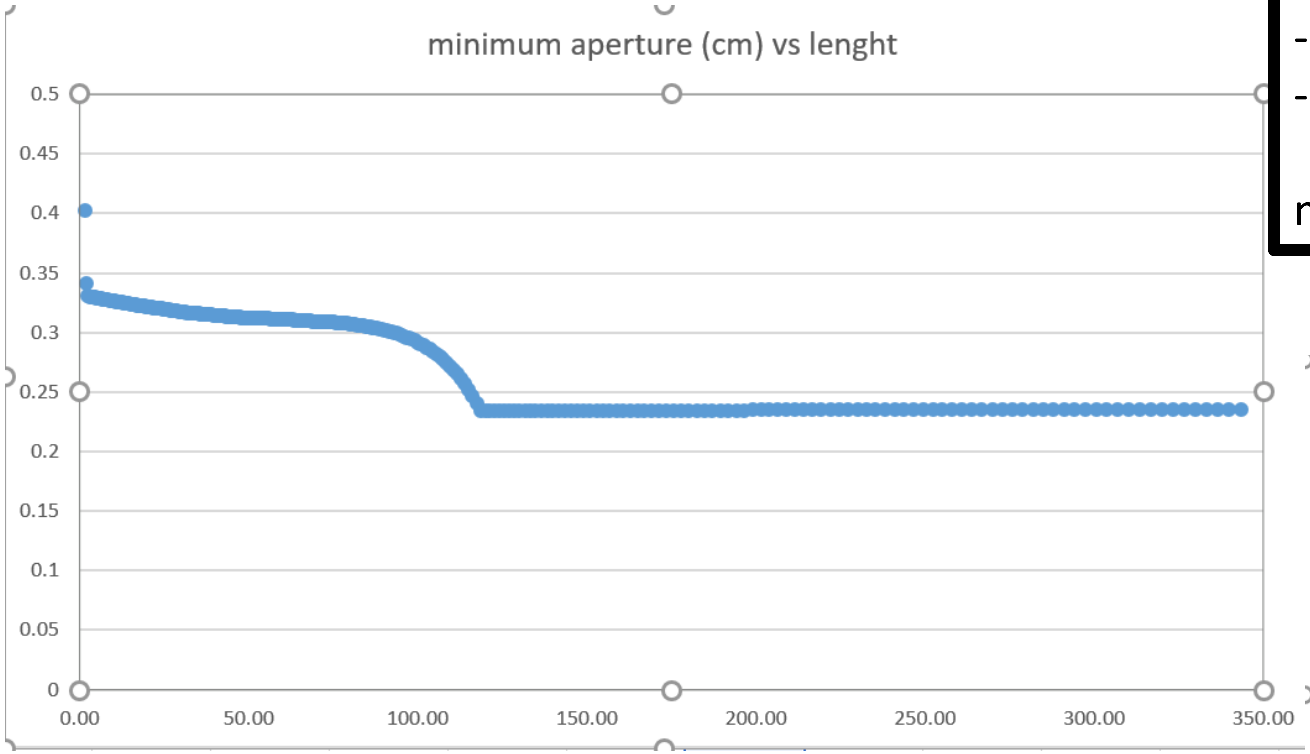
Since the last time we met formally

R0=0.33 cm
Rho=0.28 cm
L=345 cm
V=85 kV

All the above constant

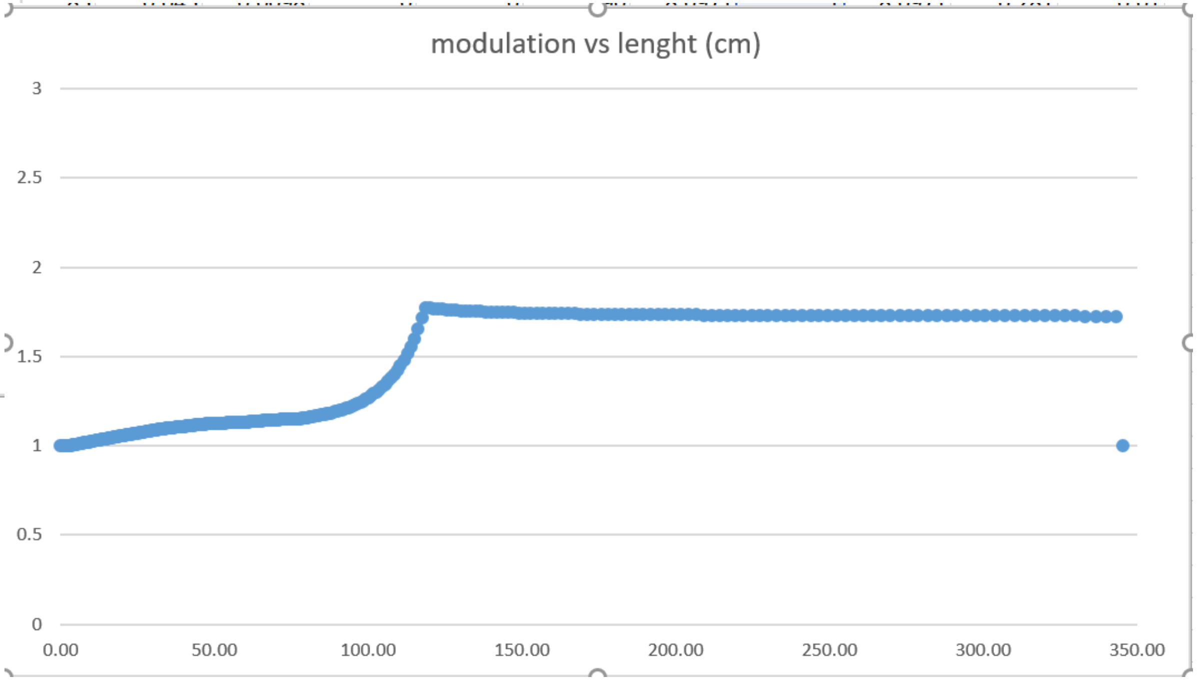
- Just relatively small changes to the geometry
- Few exchanges with Alexej/Hermann on geometry
  - Sinusoidal vs 2TERM potential
  - Ending of the RFQ electrodes and radius of curvature
- Set up a cern box with reference files : https://cernbox.cern.ch/index.php/s/k3KcXwAV5PU0TwM
- Created a 3d field map for accurate tracking including vane profile

Final-draft geometry : minimum aperture and modulation

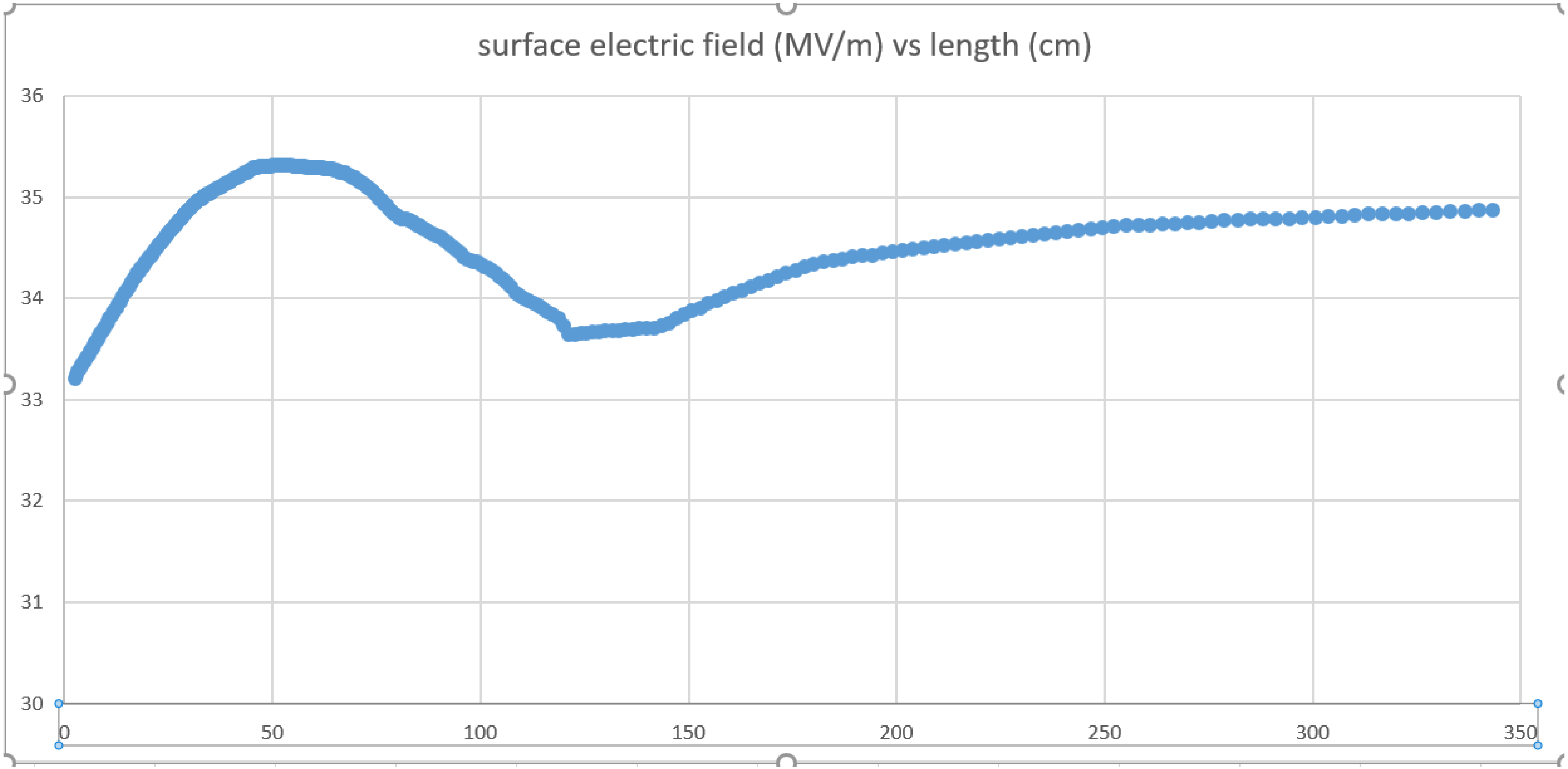


For reference min aperture RFQ1 is 0.18

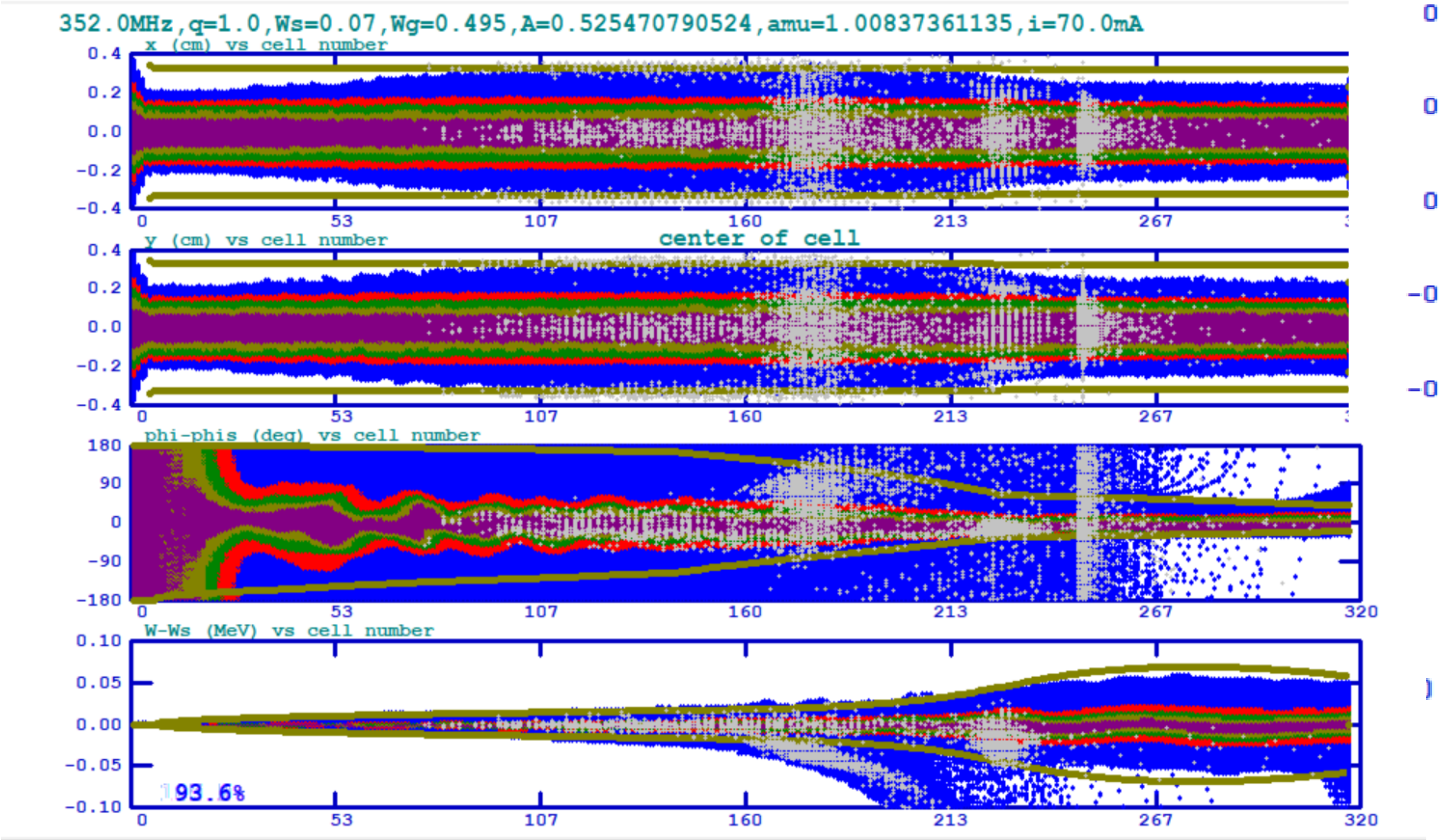
Guideline design principle (wrt RFQ1):
-easy on the modulation and bigger aperture
-higher vane voltage , same surface field, longer RFQ
resulting in
more transverse focusing i.e. higher transverse acceptance



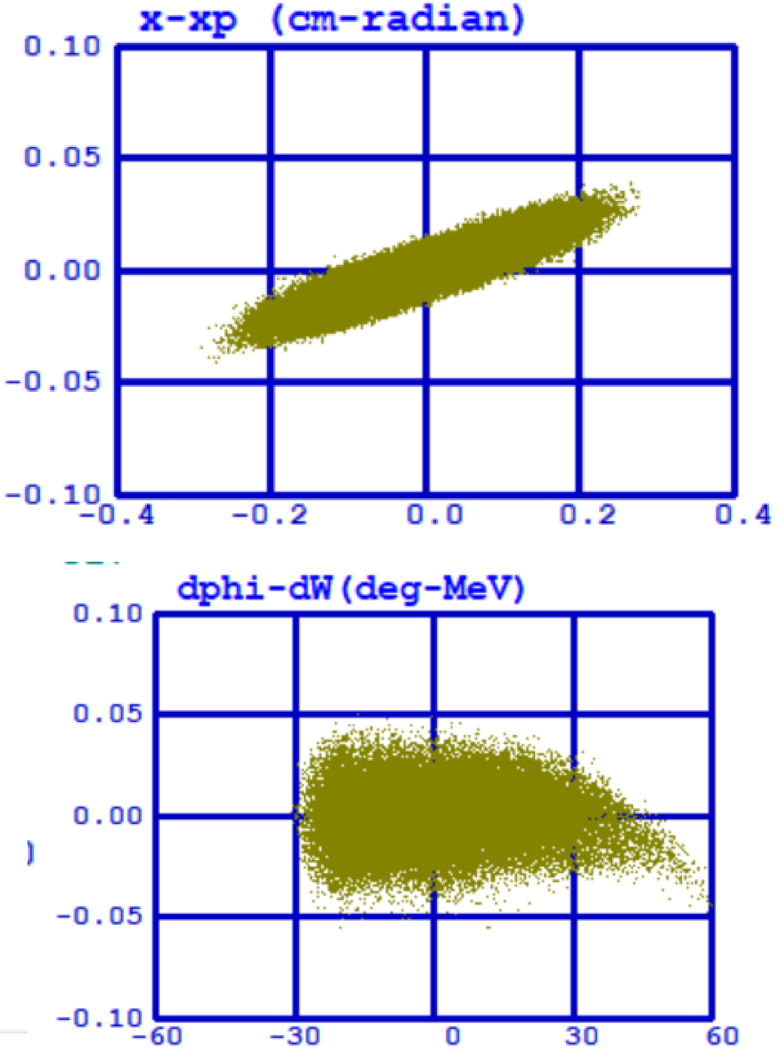
Final-draft geometry : max electric field



Beam dynamics – 70mA emit =0.5mm mrad

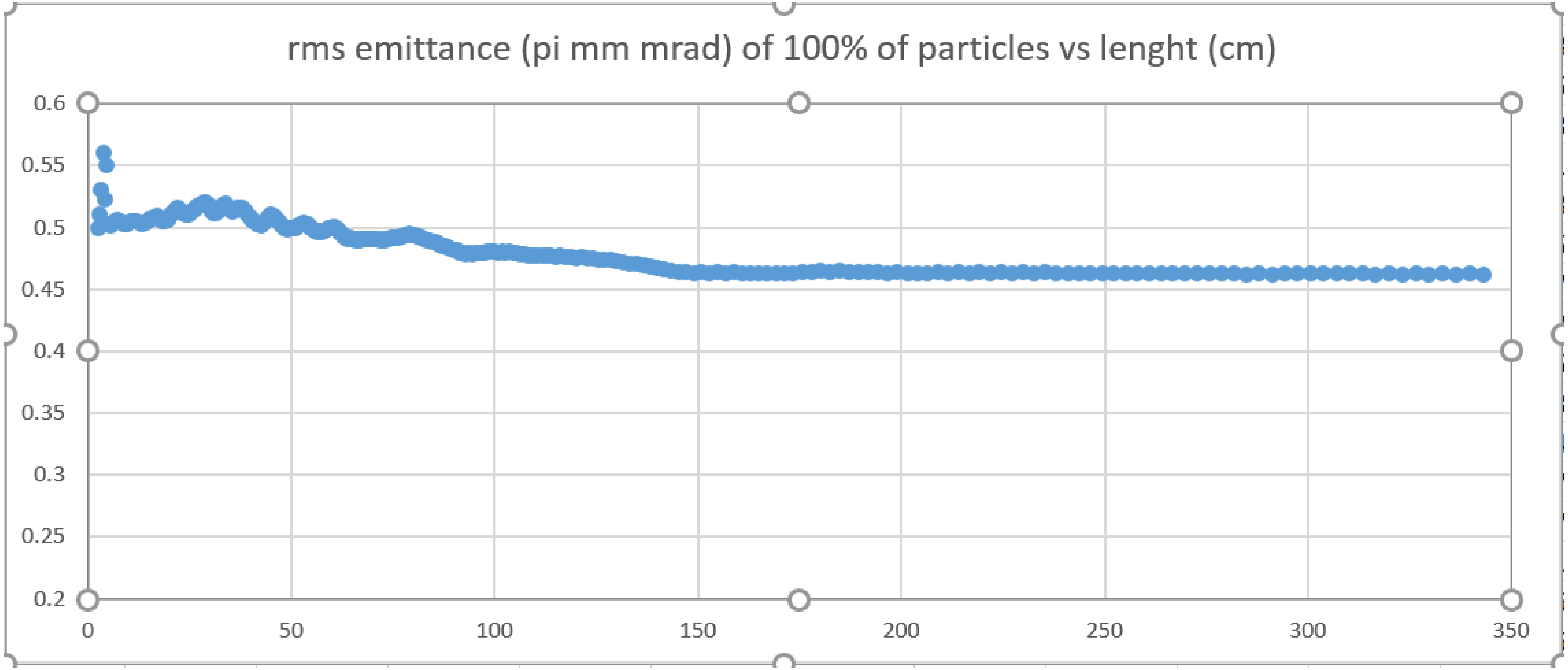


Transverse (x, y top) and longitudinal planes (phase, energy spread) along the RFQ



Beam at the RFQ output plane

Emittance along the RFQ (70mA , 0.5 mm mrad)



Next steps

- Generate field map for the latest version and run with the particle distribution measured at the test stand

- Error studies (I do not expect big difference with RFQ1)
  - field flatness - tuning
  - field jitter – klystron regulation
  - Alignment between sections
  - Machining accuracy needed

RFQ3 beam dynamics design

Update on the 4.5m version

Alessandra Lombardi (and welcome S. Kumar)

03/03/2022

4th feb 2022 AG,GB HP meet and decided to try a 4.5m long alternative . The idea is to avoid dipole rods.

Back to slide 22 we were 14/10

Making the RFQ about 4.5 m

- Reduce synchronous phase in the accelerator

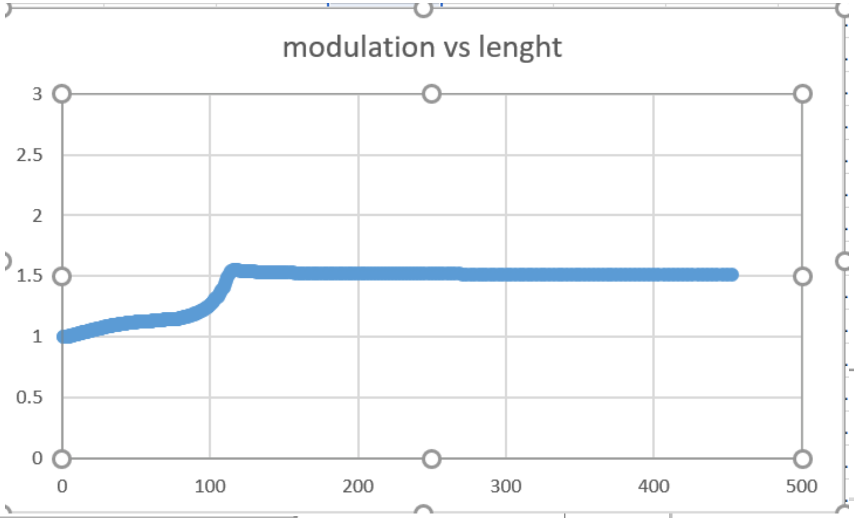
(more longitudinal bucket area-ok but then we have to inject into DTL).

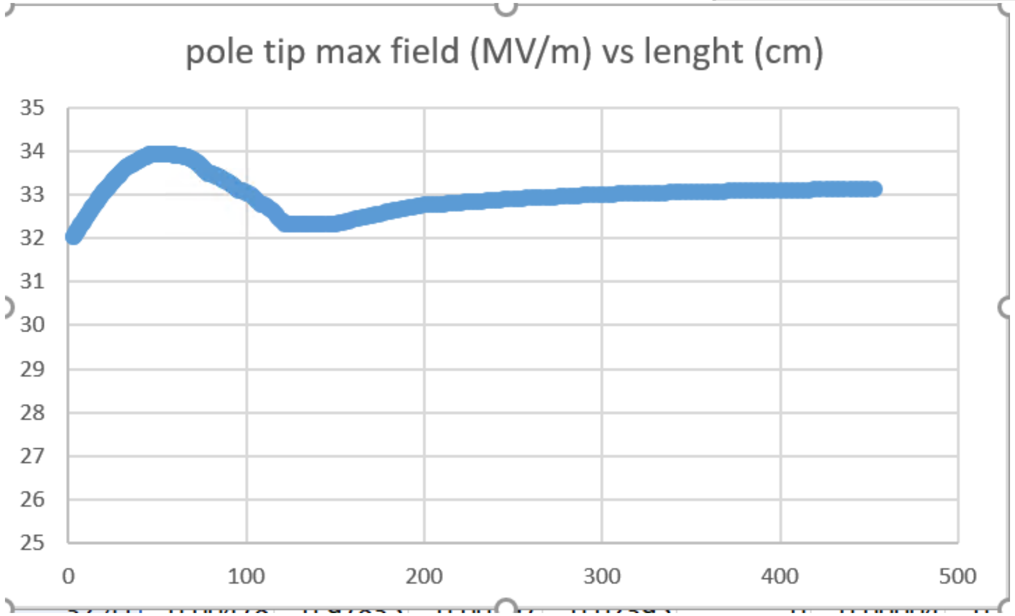
- Reduce modulation (this increases the transverse acceptance)

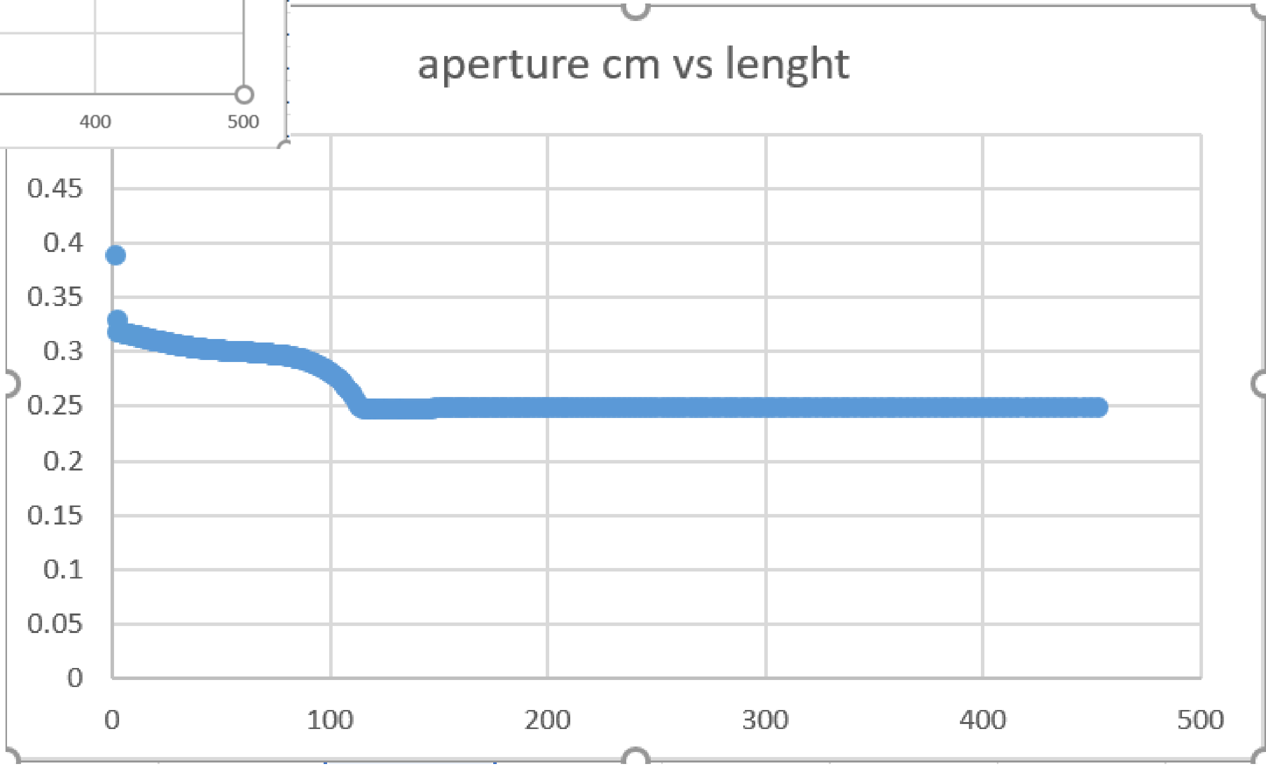
- Reduce the voltage (good for max field on vanetips)

RFQ length 4.53 m , V=79kV, Emax=34MV/m

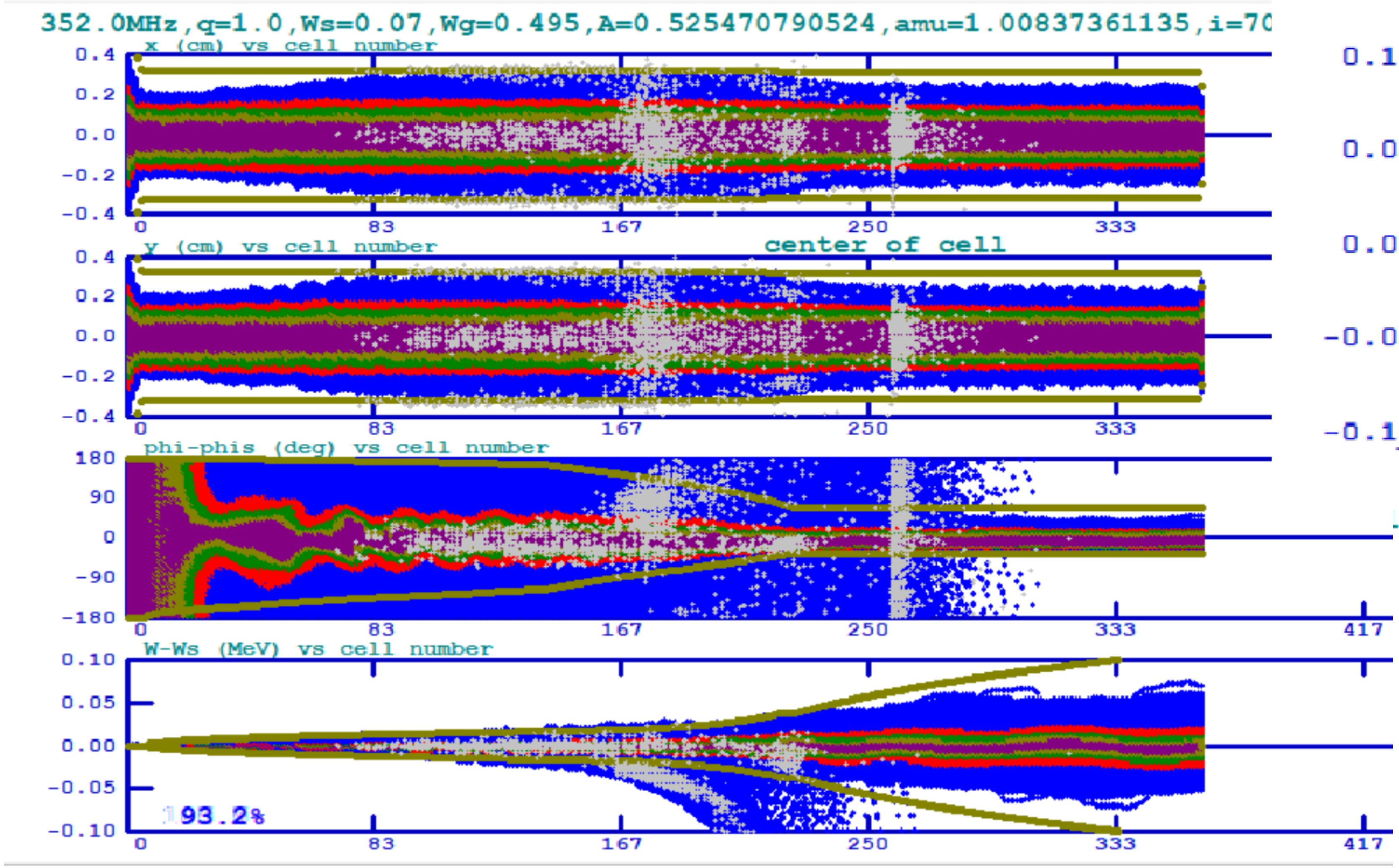
V kV	79
R0 cm	0.3187
Rho cm	0.2709
a_min cm	0.25
modulation max	



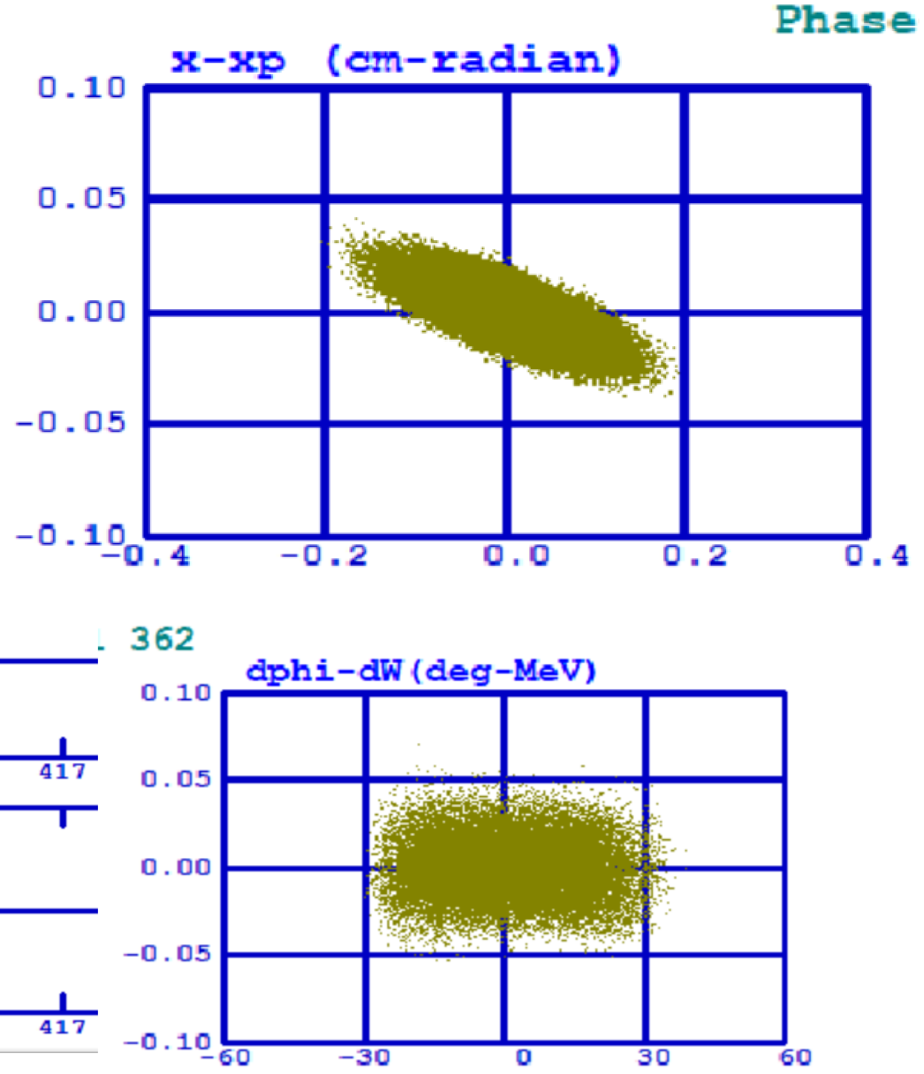




Beam dynamics – 70mA emit =0.5mm mrad



Transverse (x, y top) and longitudinal planes (phase, energy spread) along the RFQ



Beam at the RFQ output plane