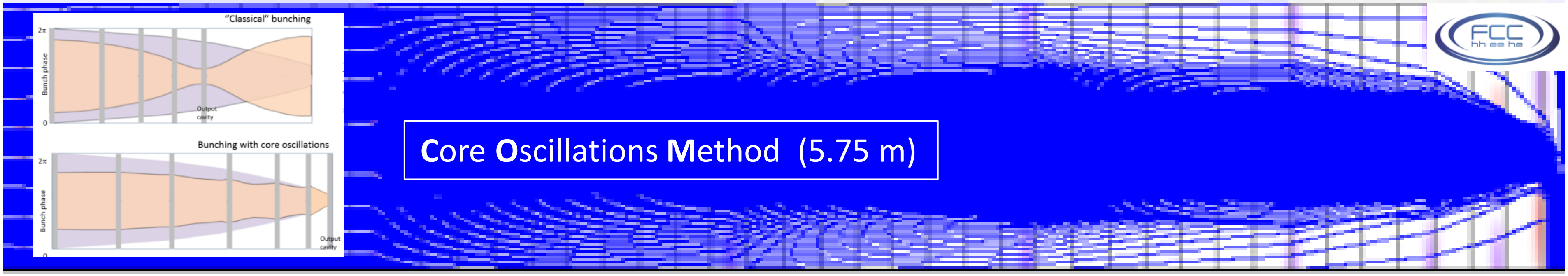
Development, fabrication and testing of the new High Efficiency klystron prototype in collaboration between CERN and Thales.

E. Jensen, I. Syratchev

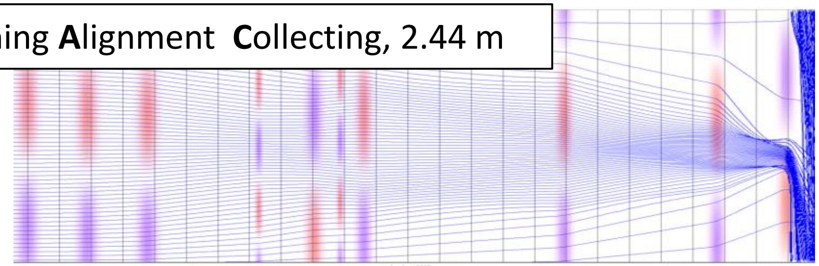
High efficiency klystrons.
New bunching technologies on one slide.

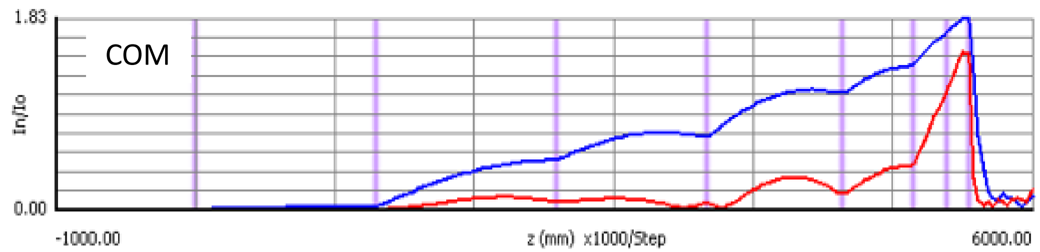


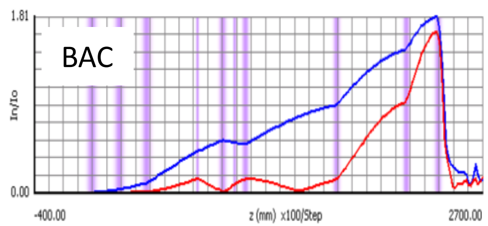
Core Oscillations Method (5.75 m)

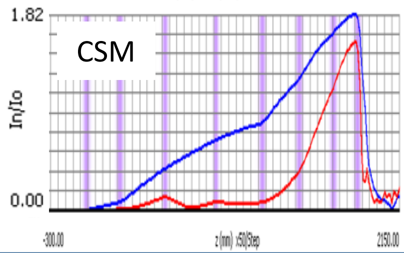
133.8 kV, 12.55 A, 1.4 MW at **0.8 GHz**, **80(+)%**

Bunching Alignment Collecting, 2.44 m







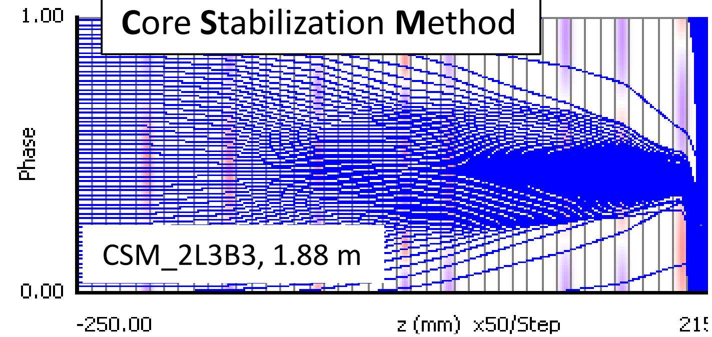


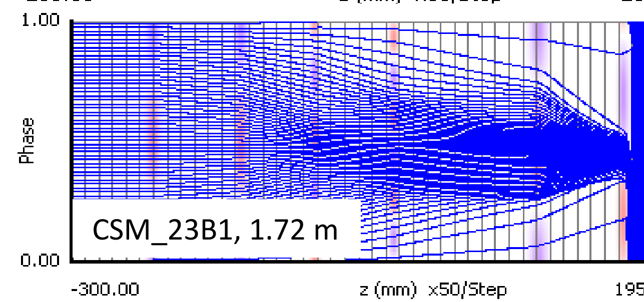
High Efficiency International klystron Activity

HEIKA

igor.syratchev@cern.ch

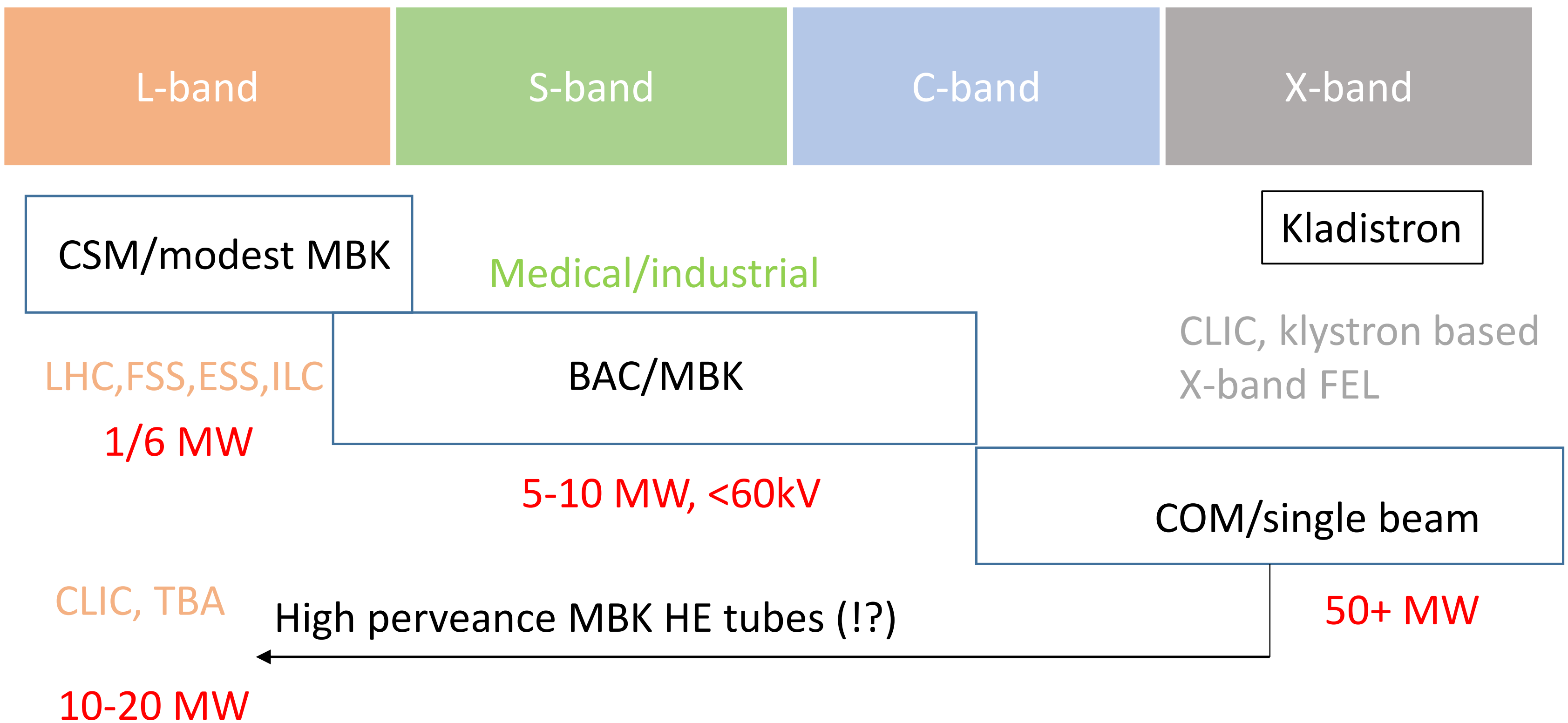
Core Stabilization Method





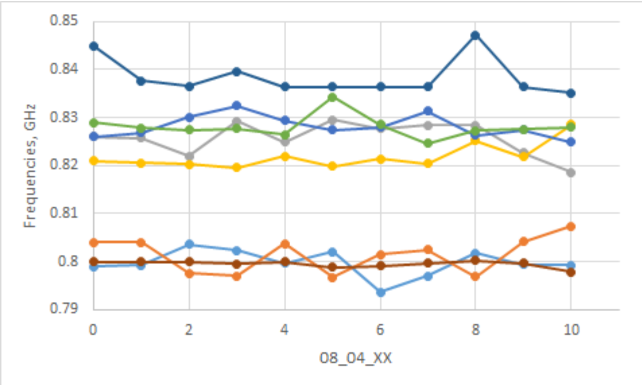
CERN/TED first HE technical meeting. April 2017.

The choice of bunching technology may drive the applicable frequency range and multi-beam options (cost/performance):

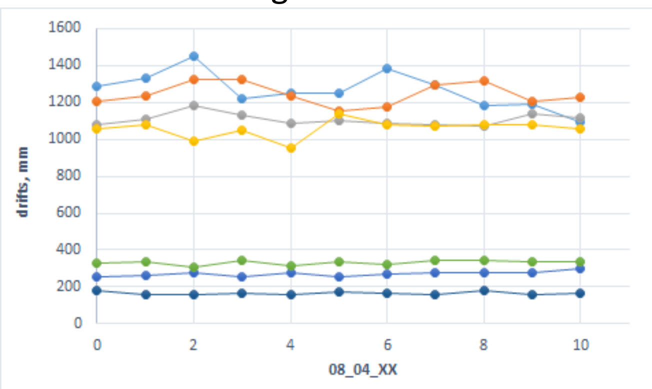


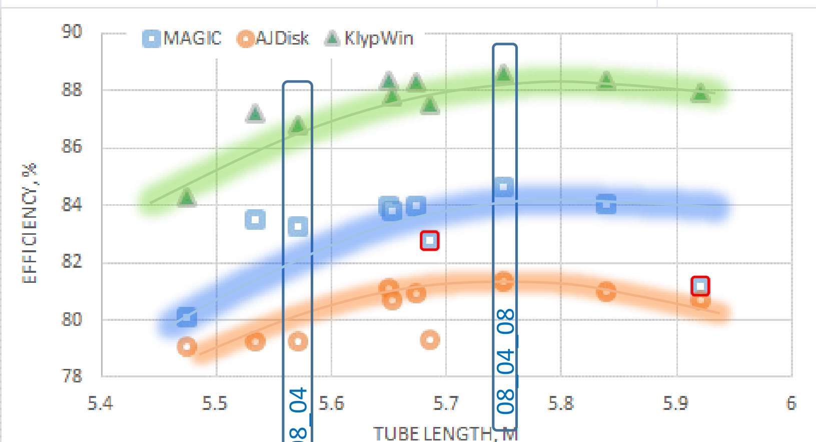
COM. 8_04_XX series of 10 optimised tubes.

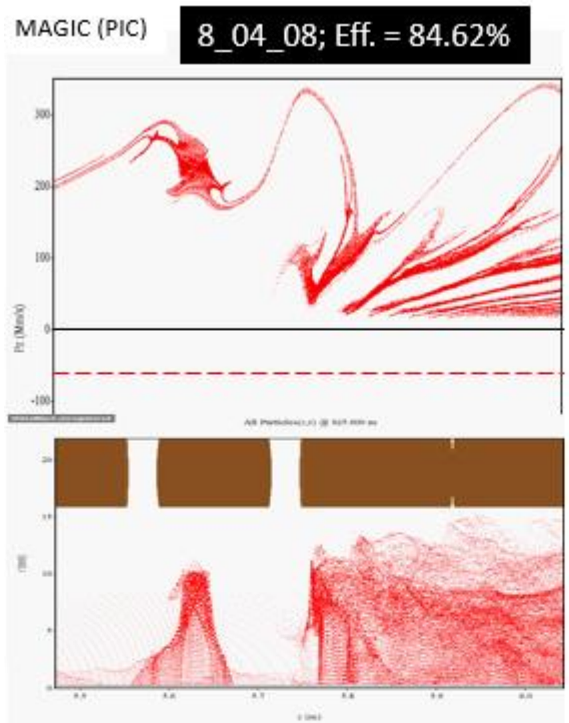
Frequencies scattering



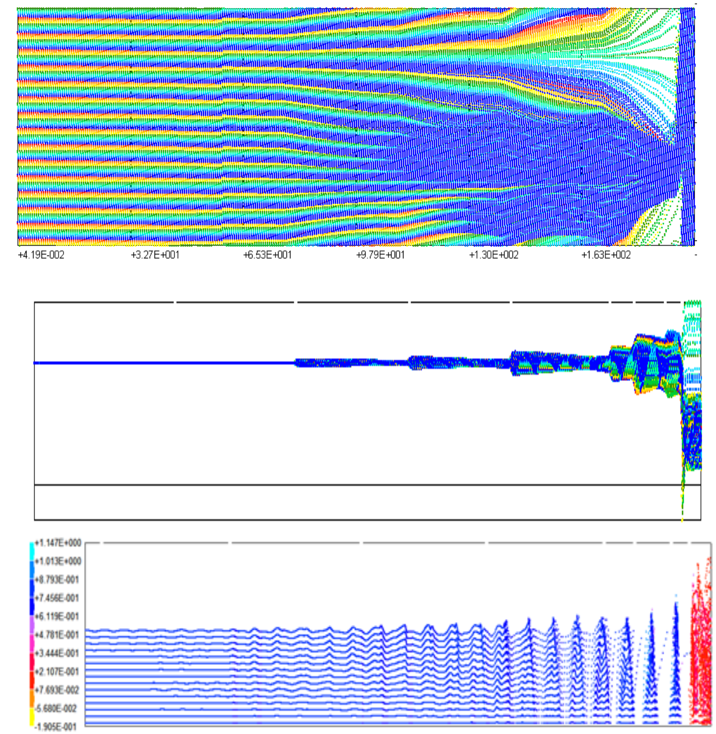
Drifts scattering

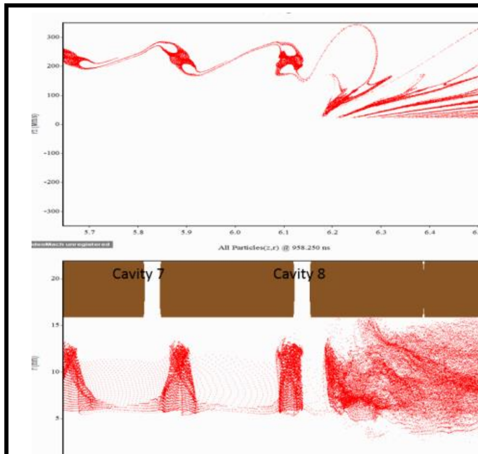






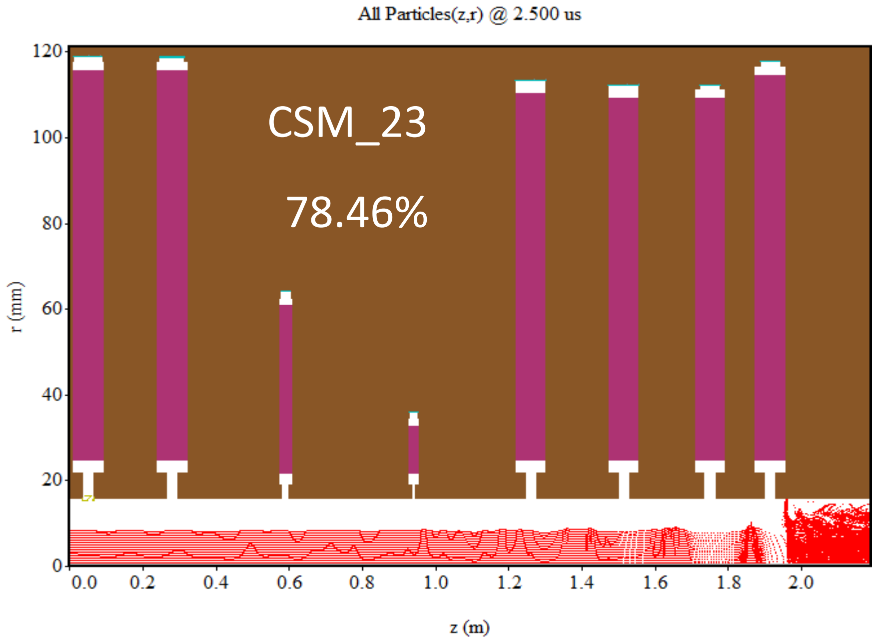
Klys2D (Thales), 81.6%

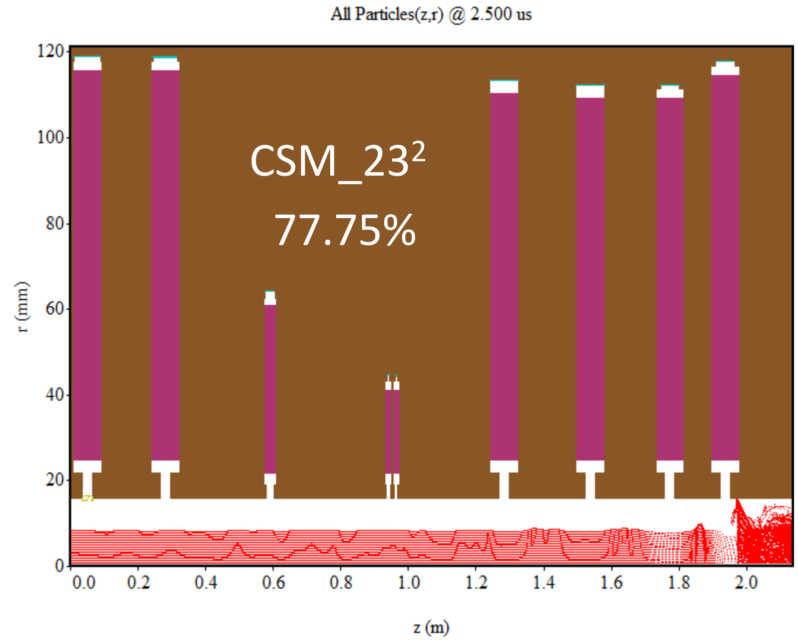


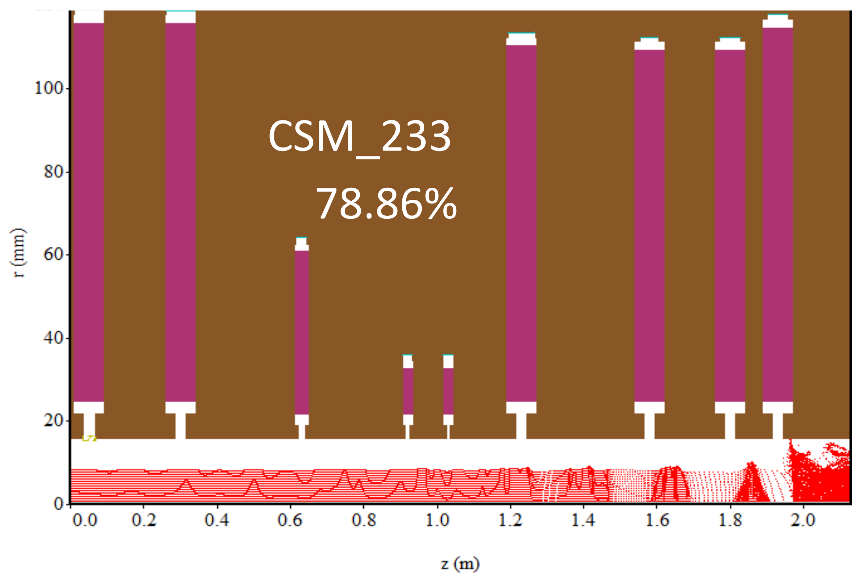


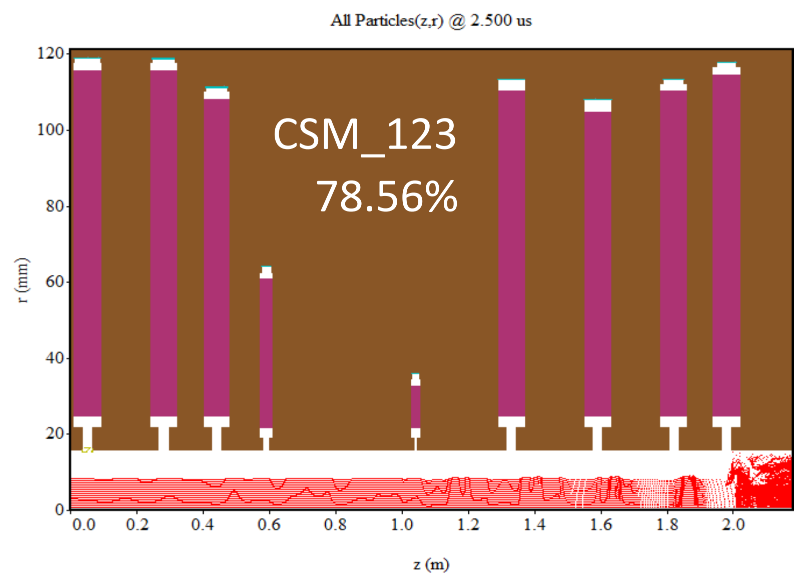
Replacing cylindrical beam by hollow beam efficiency is further increased up to 86%

CSM family. Harmonic cavities are used to organize very fast bunch saturation.

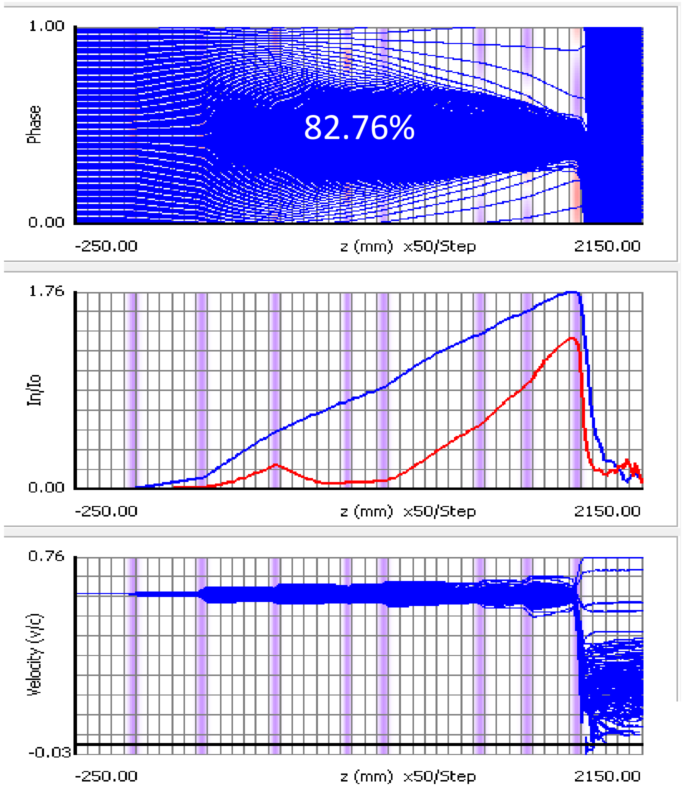




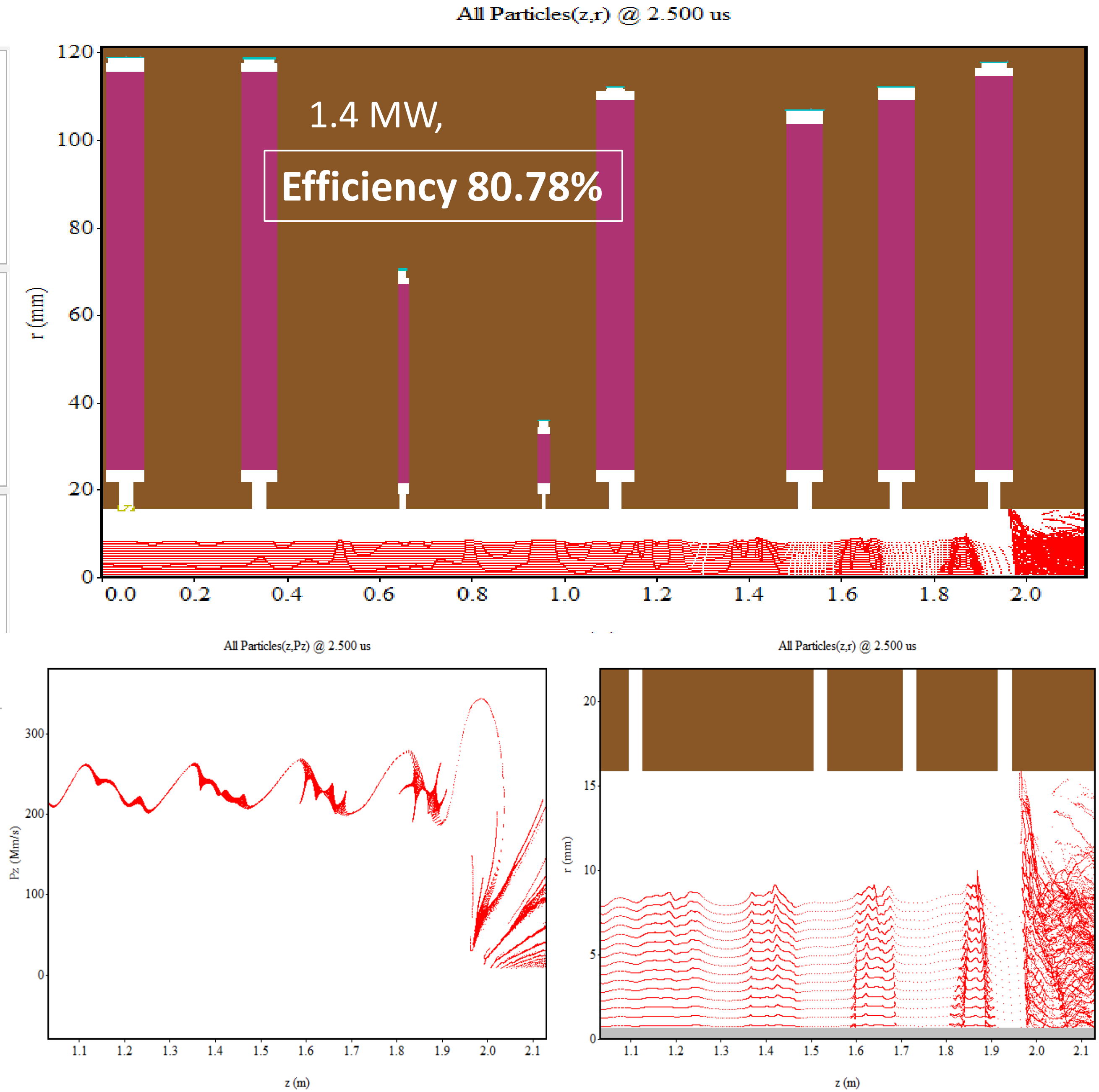




CSM_2L3B3



Beam Voltage (kV)	133.850
Beam Current (A)	12.551
Frequency (MHz)	800.000



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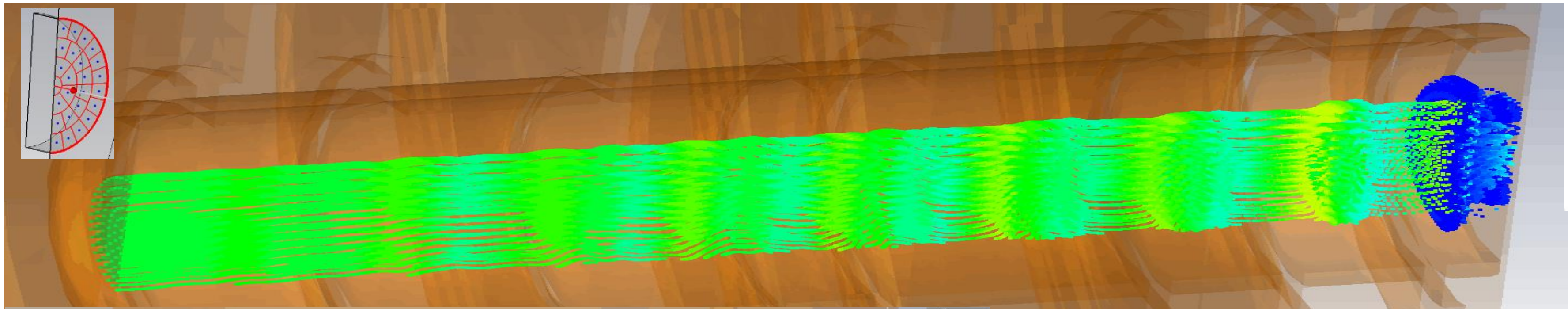
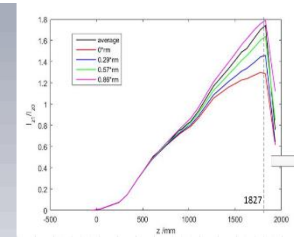
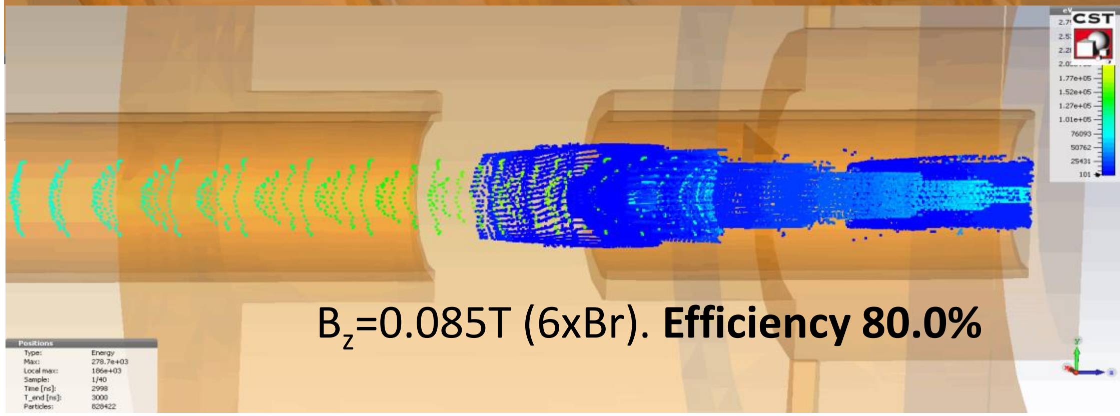
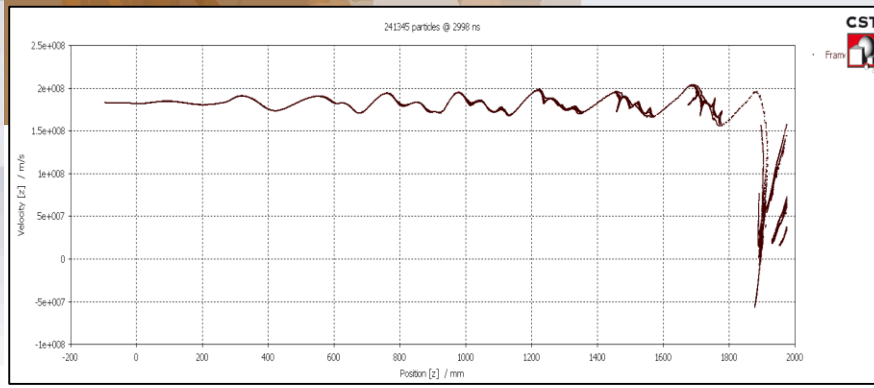
CSM_2L3B3. Full 3D simulations with Microwave Studio.



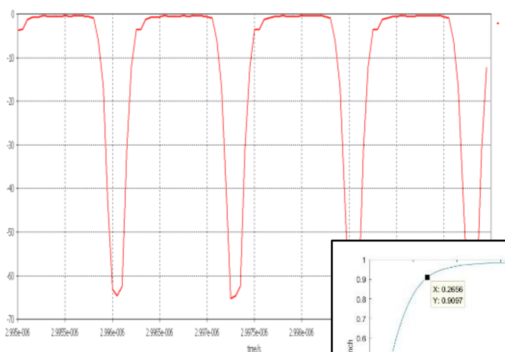


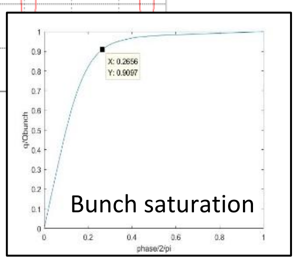


B_z=0.085T (6xBr). **Efficiency 80.0%**

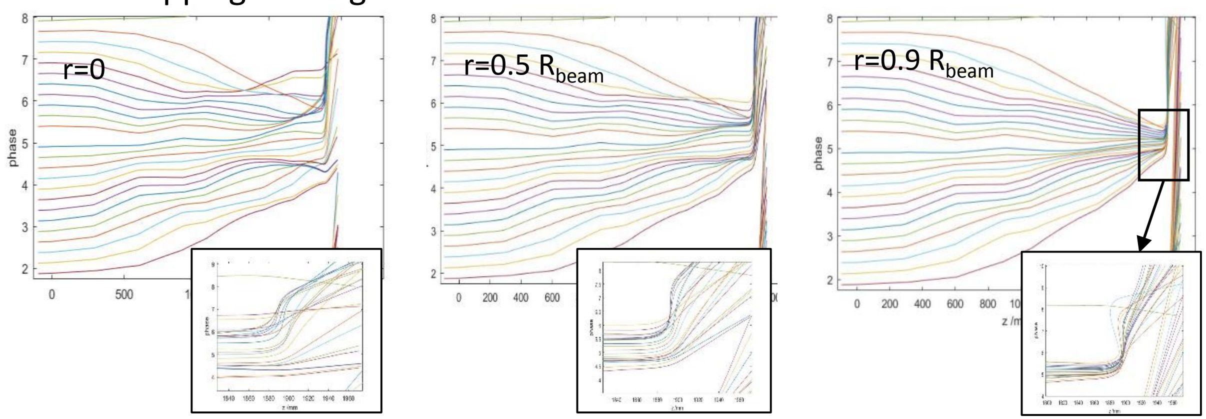


Beam intensity modulation:





Applegate diagrams for the electrons emitted at different radius:



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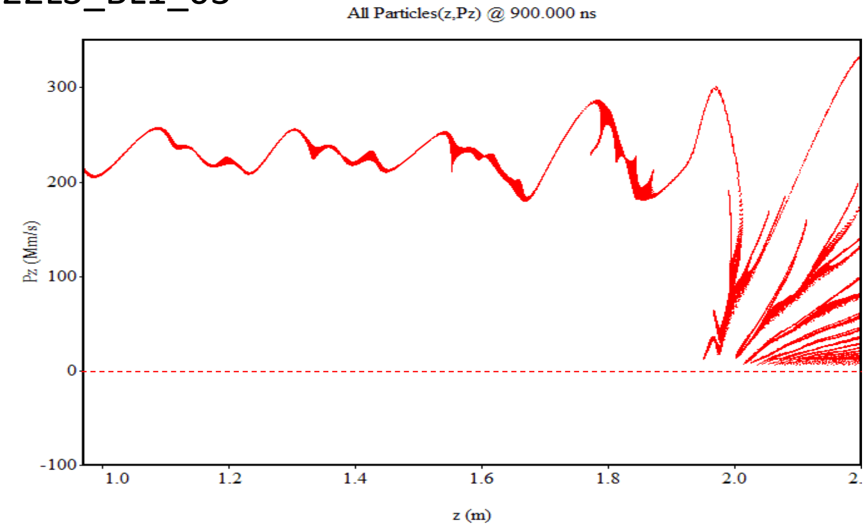
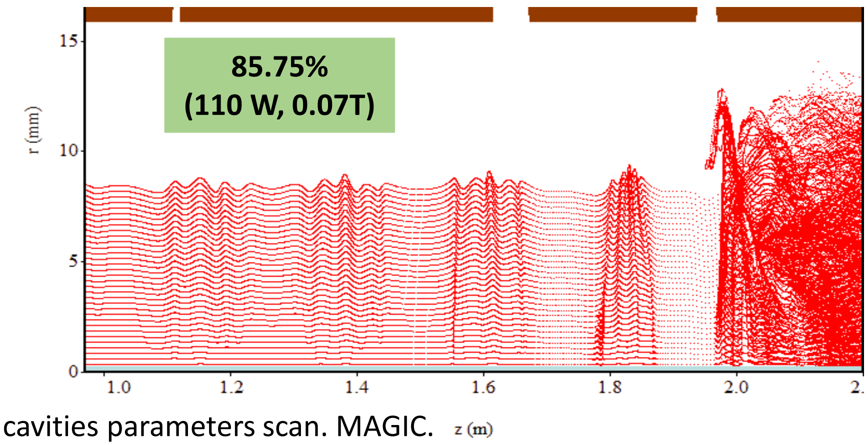
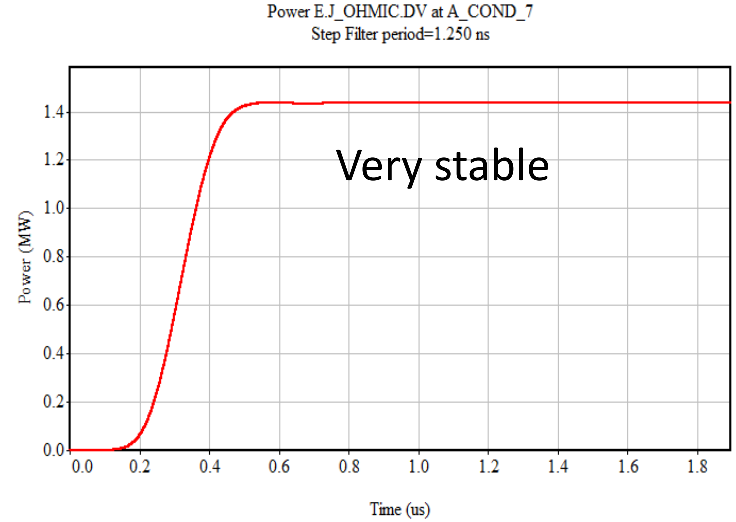
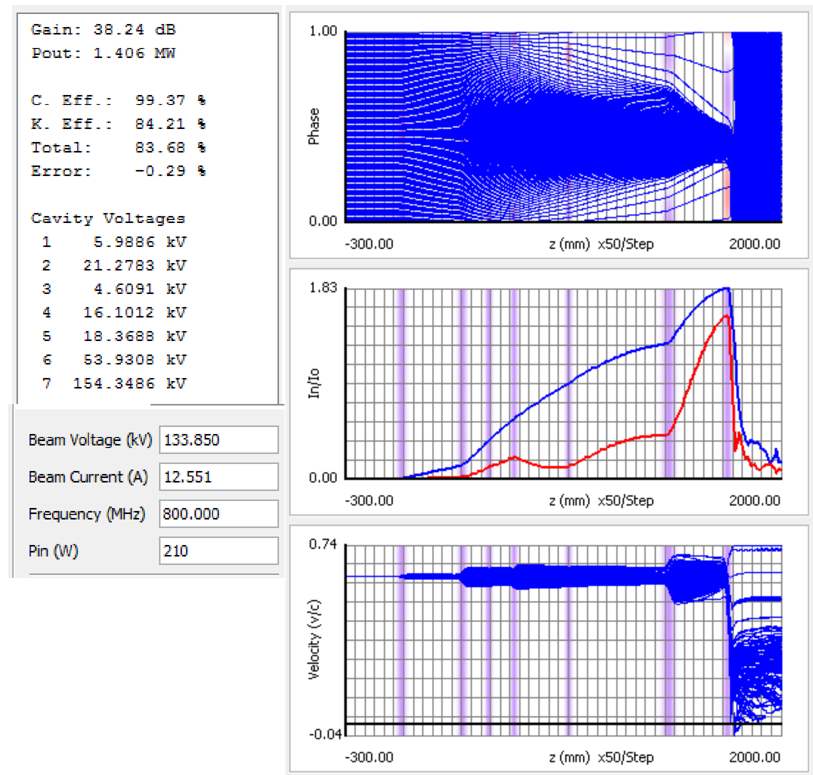
CSM 22L3_BL1_03









#6,#7 cavities parameters scan. MAGIC.

Cavity					
6 / 7	Frequency (MHz) (Gap = 56mm)				
Gap (mm) (Freq = 799.6MHz)	812.45	814.95	815.45	815.95	818.45
28	82.68		84.28		83.4
29.75		85.24			
30	84.52	85.401	85.35	85.288	
30.25		85.53			
30.5		**85.75**			
32		81.5			

	Bz
	0.085T
	0.08T
	0.075T
	0.07T

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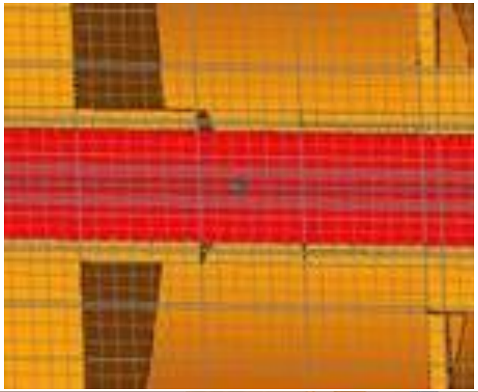
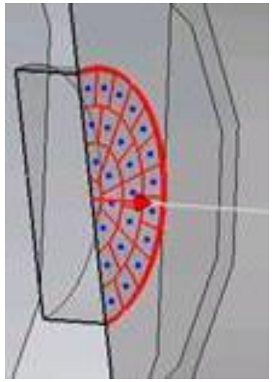
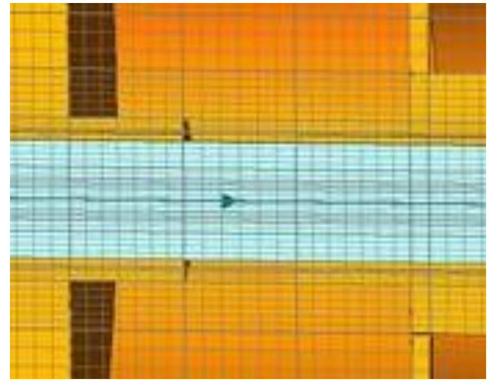
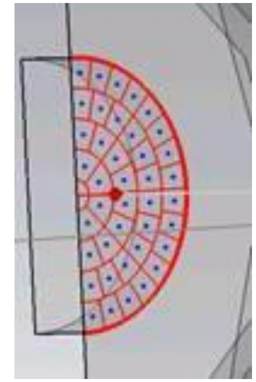
CSM 22L3_B1_03 (85.401% with MAGIC tunings). CST.

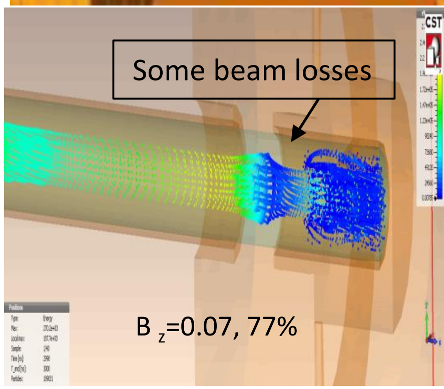
Refined mesh (x2.5 in drift tube) and more emitters (25 -> 40)

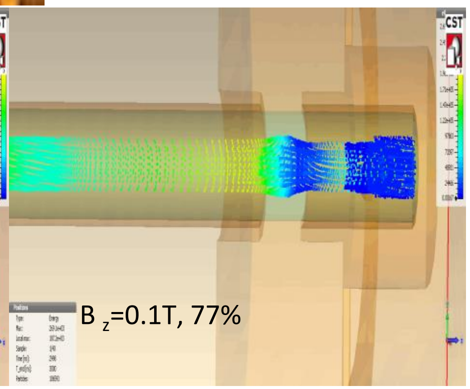


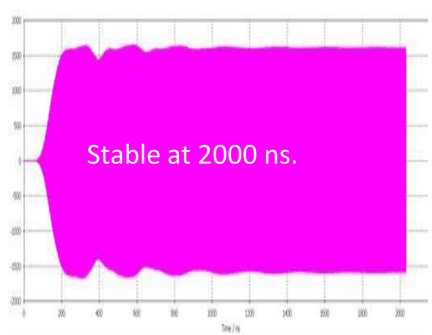


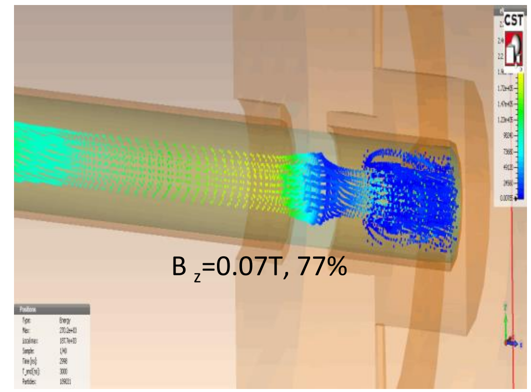


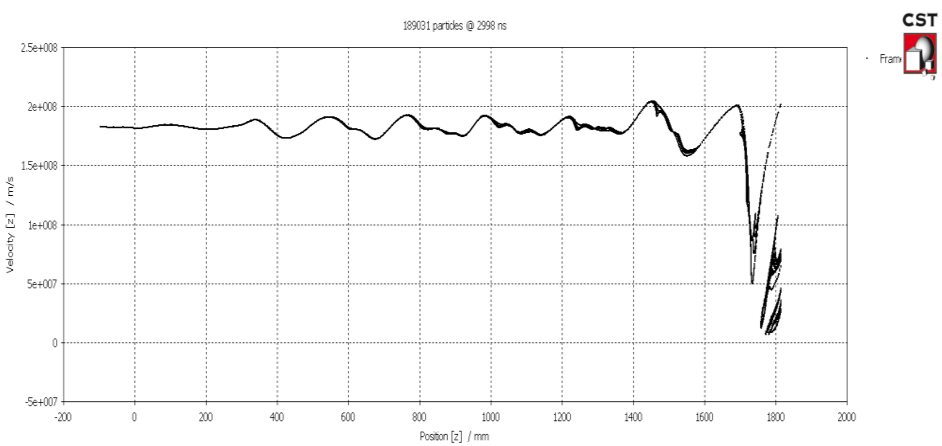


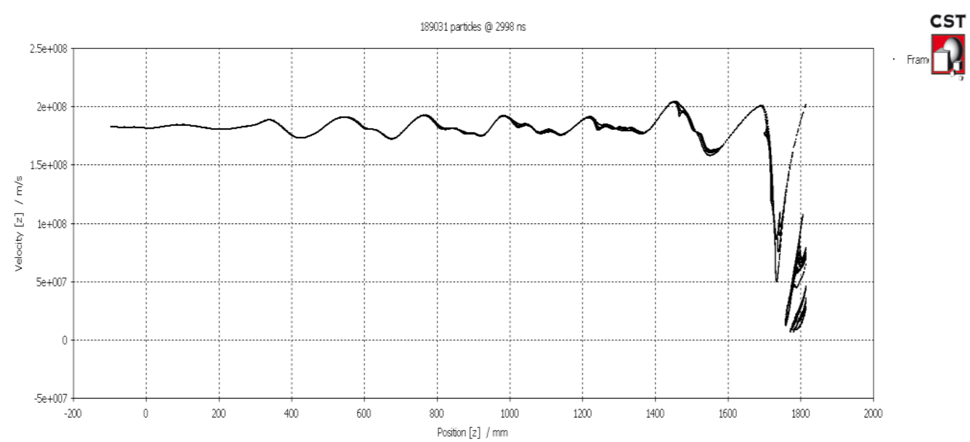












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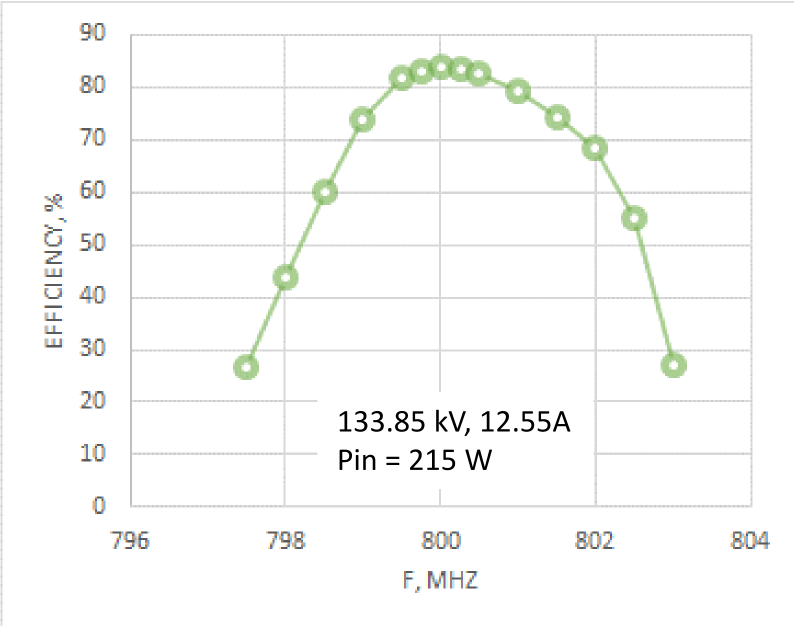
CSM 22L3_B1_03 (85.401% with MAGIC tunings). AJDisk.

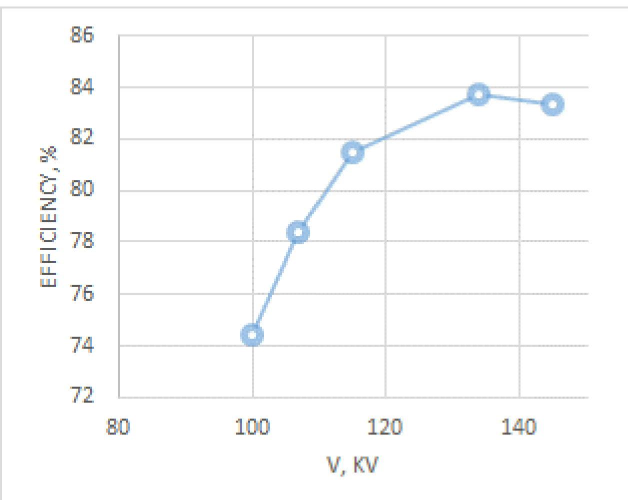
Measured at 0.6x R beam in MAGIC

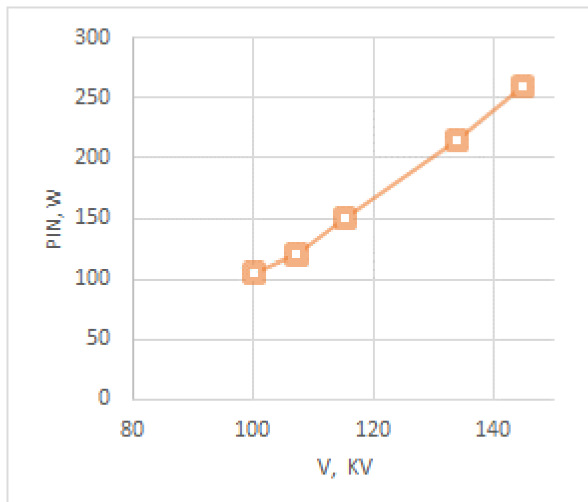


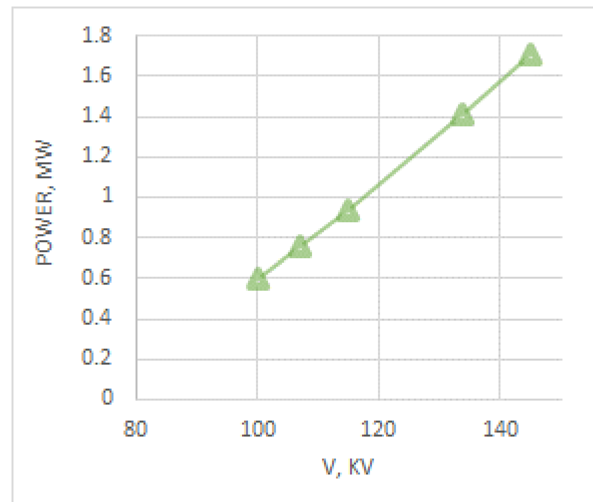
Used for AJDisk input

Qin=205
Q out=60

In saturation



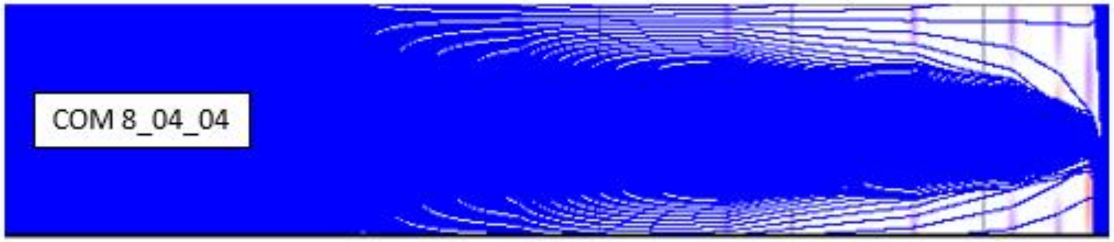




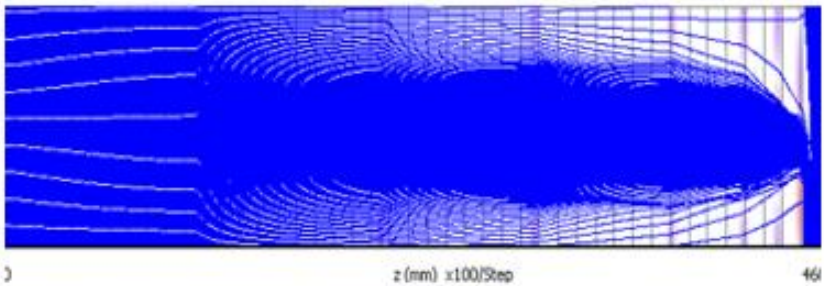
CSM HE tube for FCC. Summary table.

CSM 22L3_BL1	Original	Discussion 13/4
Frequency	800 MHz	704 MHz
Number of beams	One	One
# cavities (harmonics)	7(3)	7(3)
Beam diameter	17.26 mm	21.7 mm
Beam tunnel aperture	31.8 mm	40 mm
Voltage	133.9 kV	115 kV
Current	12.55 A	14.6 A
Micro Perveance	0.256	.375
RF circuited Length	1.72 m	1.6 m
Projected efficiency	>85%	>85%
Peak RF power in saturation	>1.43 MW	>1.43 MW
Power gain	>40 dB	> 40 dB
Solenoidal field	0.07 T	0.04 T ?

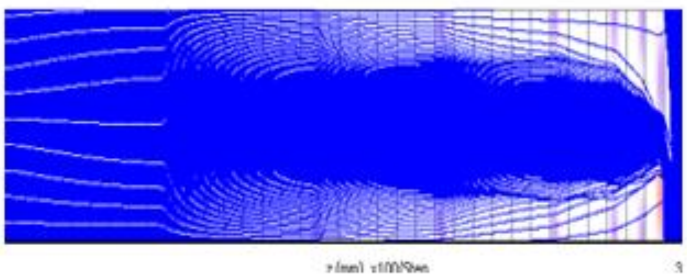
We have developed special procedure (GSP/PSP) which allows to scale the frequency, power, perveance, voltage, number of beams etc., and to preserve the bunching quality of the original tube:



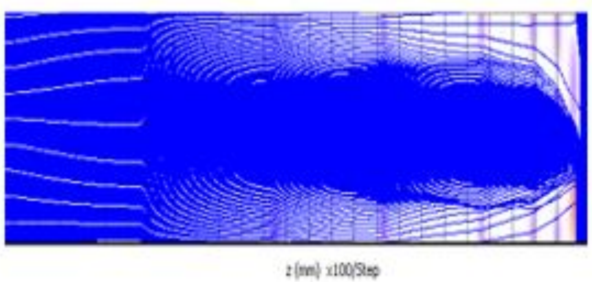
133.85 kV
12.55 A
µK=0.256
5.55 m



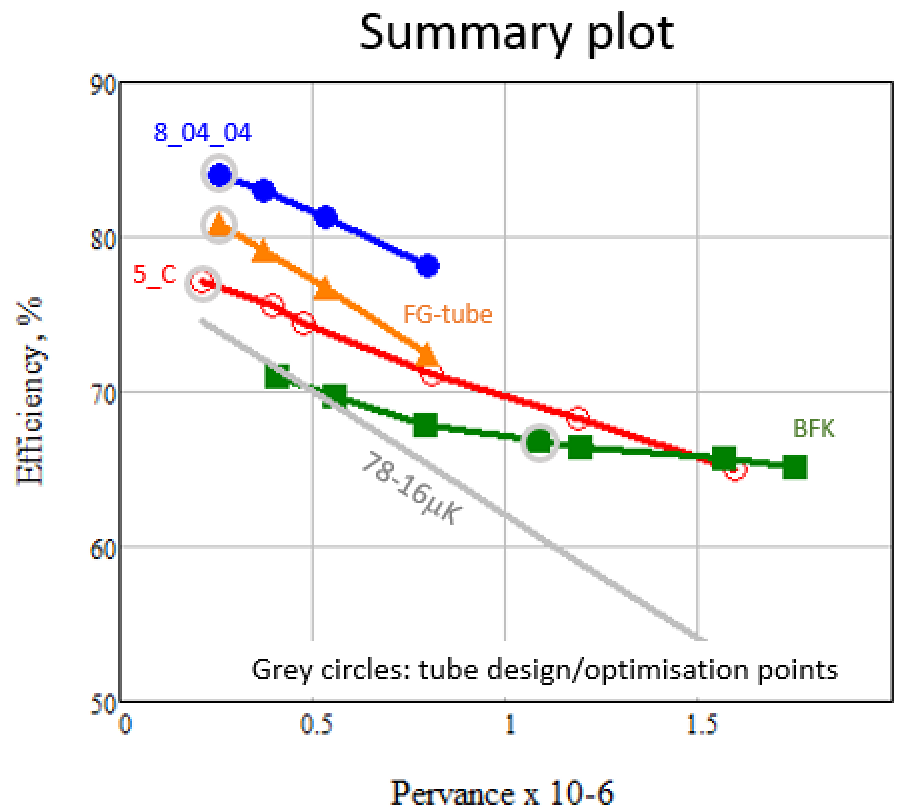
115 kV
14.6 A
µK=0.375
4.29 m



100 kV
16.8 A
µK=0.53
3.38 m



85 kV
19.76 A
µK=0.8
2.56 m



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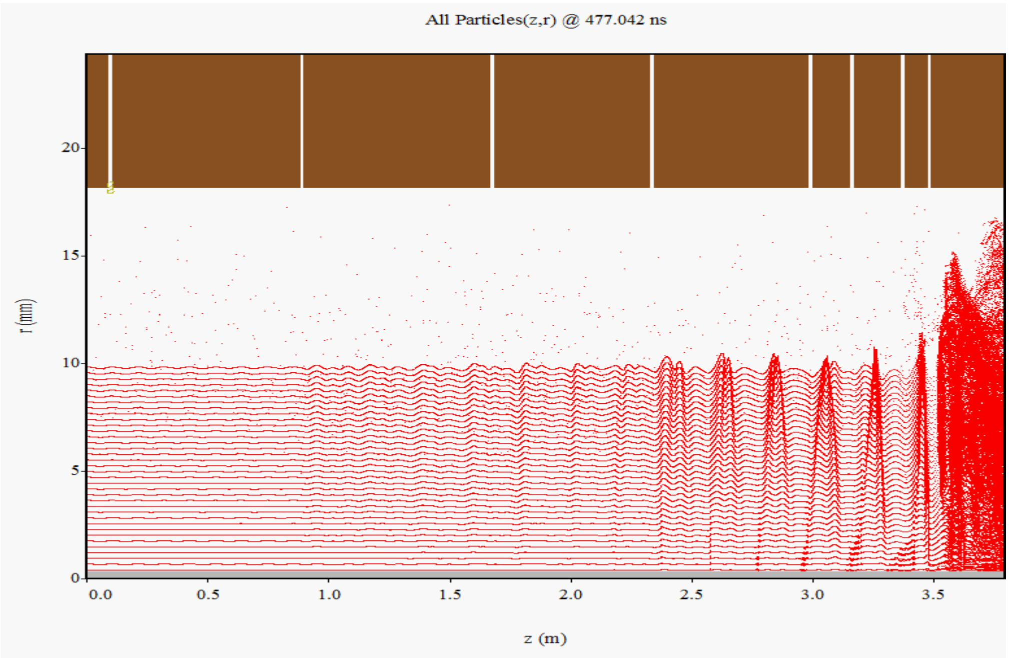
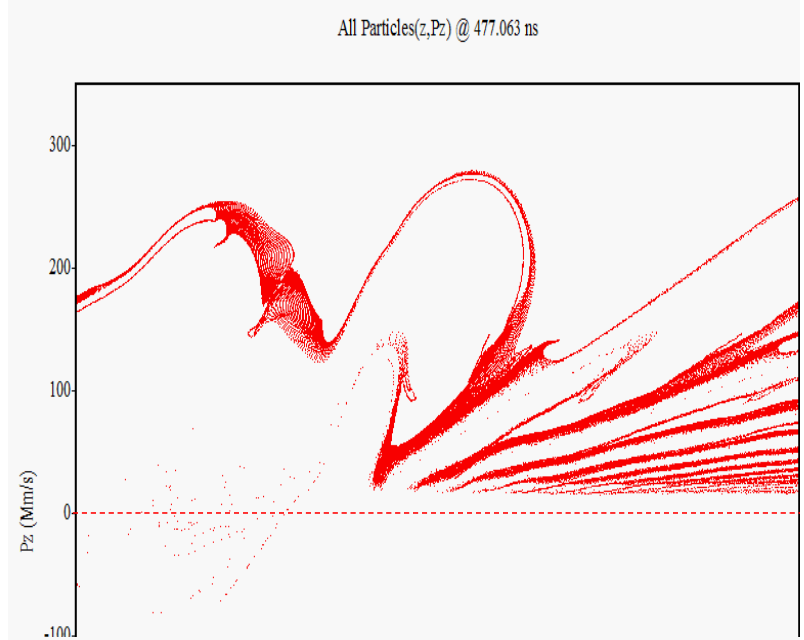
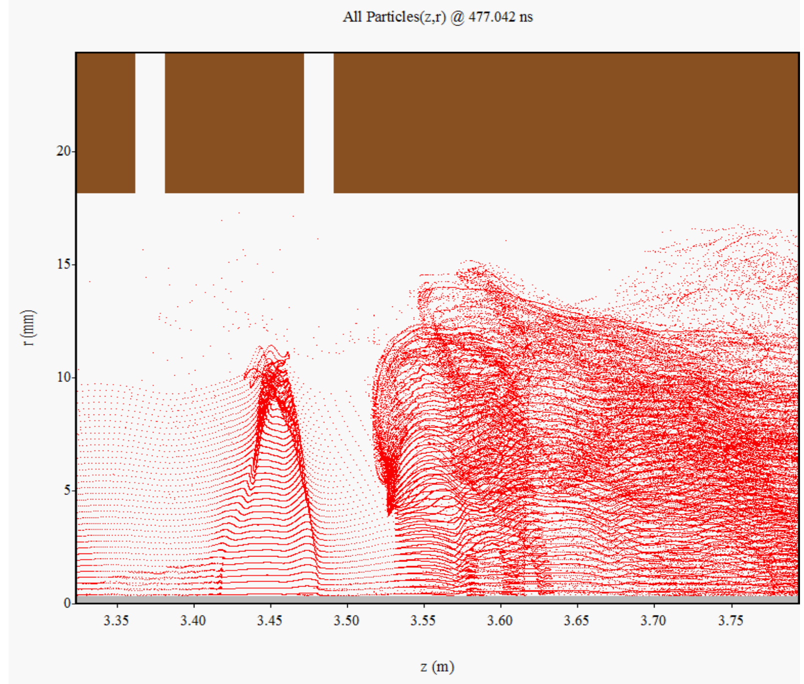
First MAGIC (PIC 2D) results of PSP 08_04_08 tube directly scaled from 133 kV down to 100 V:
Perveance: 0.26uK -> 0.53uK
Tube length: 5.75 m -> 3.37 m
Efficiency: 84.62 -> 80.78







1.4 MW, Efficiency 80.78% (yet reflected electrons)

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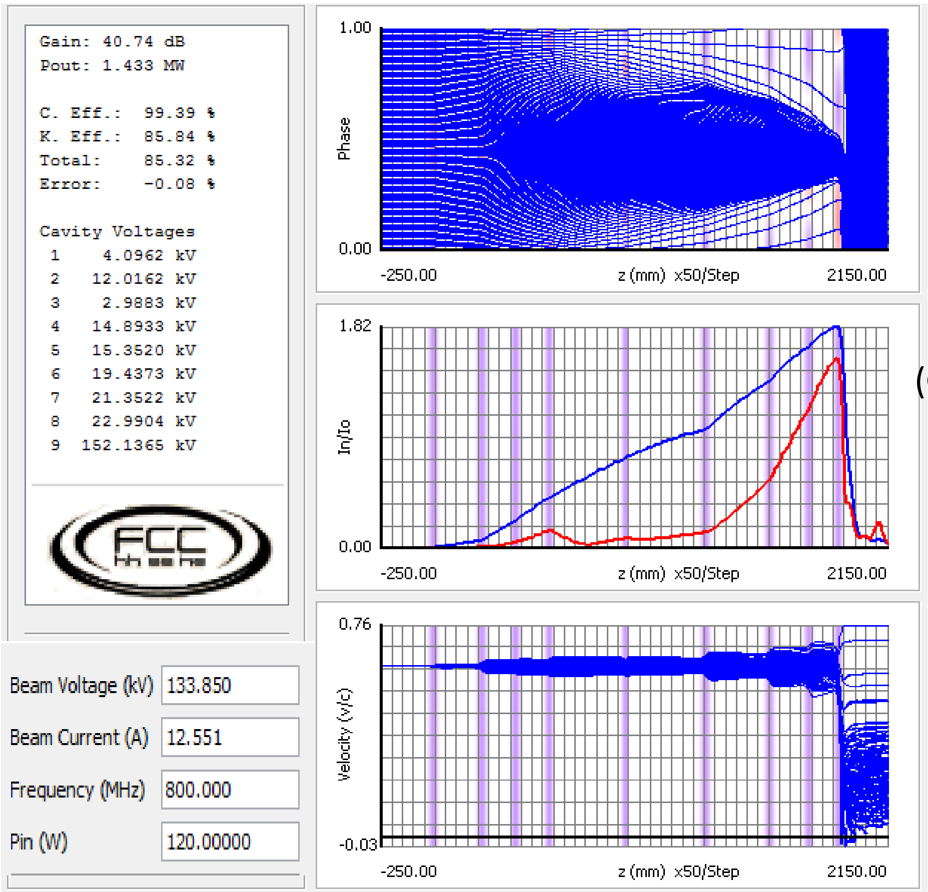
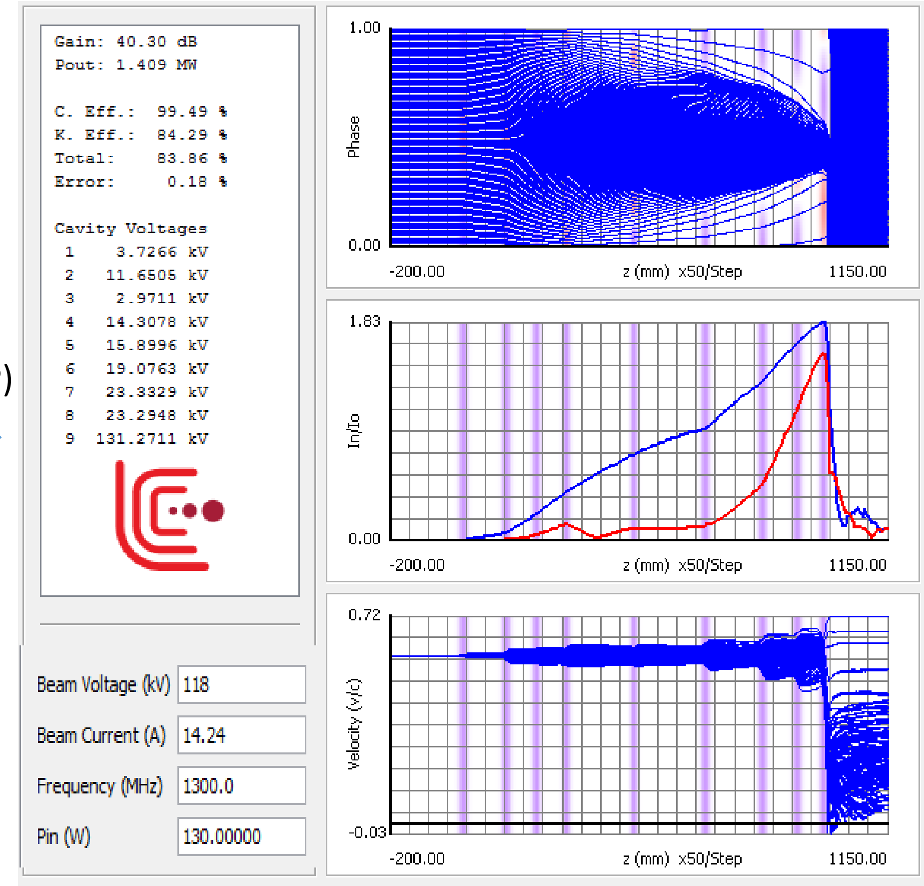
Example of scaled ILC HE klystron.

CSM_123B3 tube (85.3%), single beam:
0.8 GHz, 1.4 MW, **134 kV, 12.55 A**, L=**1.96m**



(GSP/PSP)

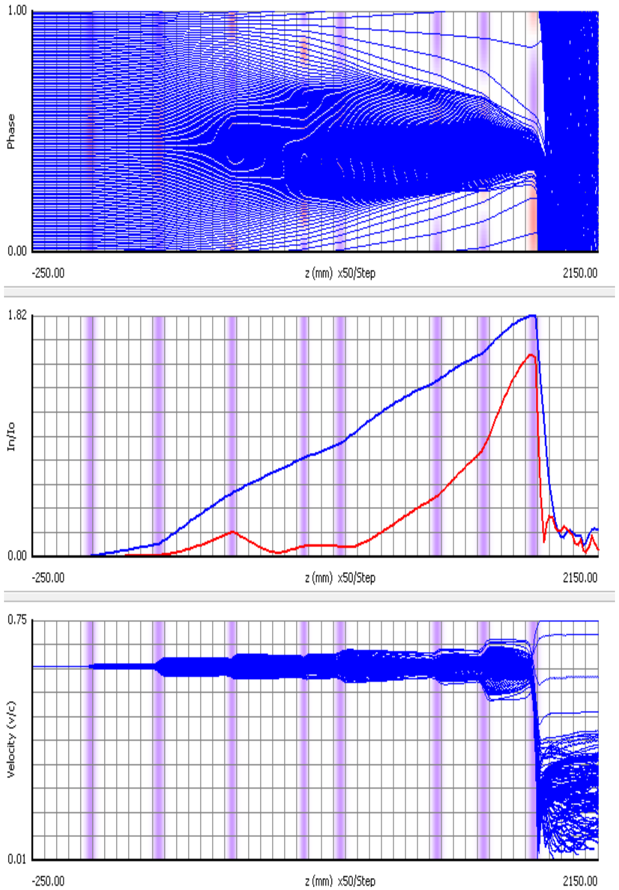
CSM_123B3_s tube (83.9%), single beam:
1.3 GHz, 1.4 MW, **118 kV, 14.24 A**, L=**0.98m**



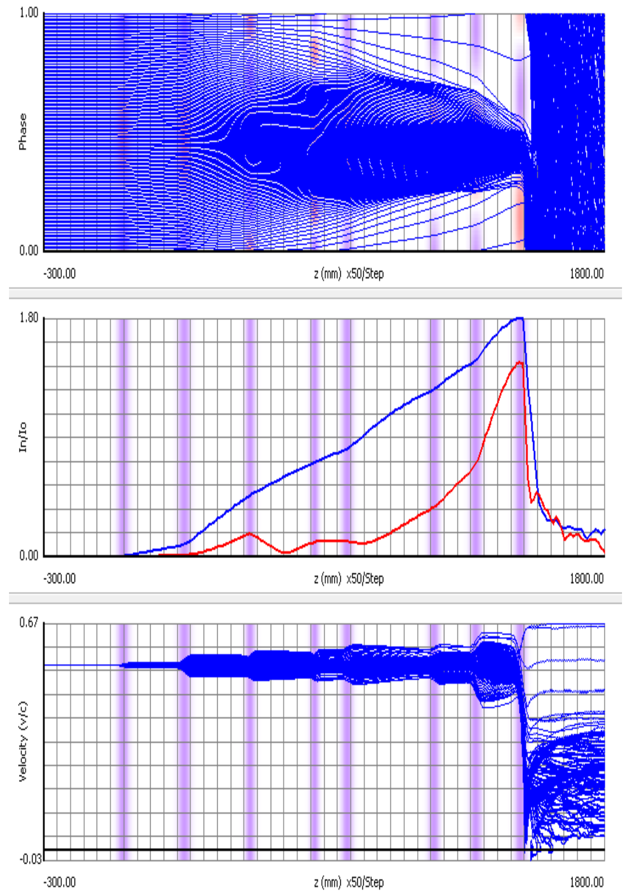
8 beams MBK klystron scaled from 1.3 GHz CSM_123_s is a compact (<1m), 11.4 MW tube with efficiency >80%.

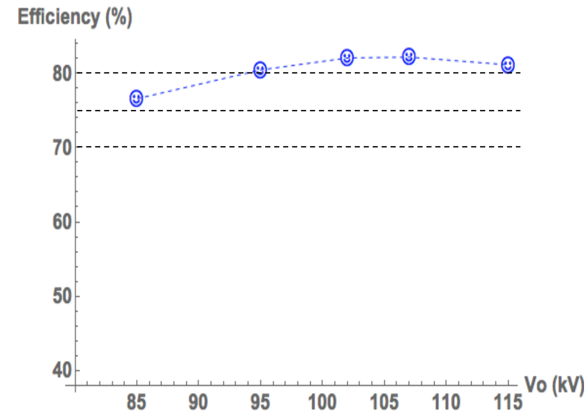
Example of scaled ESS HE klystron.

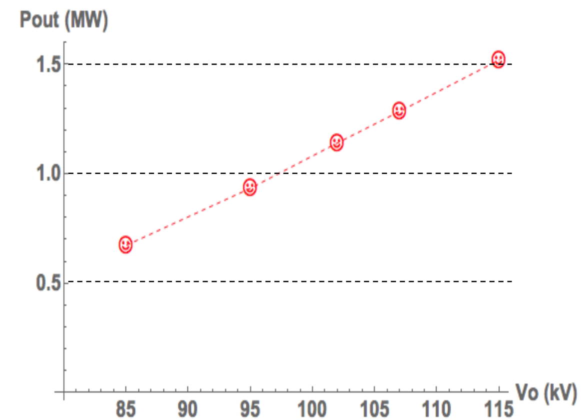
CSM_2L3B3 tube (84.4%), single beam:
0.8 GHz, 1.4 MW, **134 kV, 12.55 A**, L=**1.88m**



CSM_2L3B3_s tube (82.2%), single beam:
0.704 GHz, 1.14 MW, **102 kV, 13.65 A**, L=**1.5m**







(GSP/PSP)

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