High efficiency klystrons development. Brief review.

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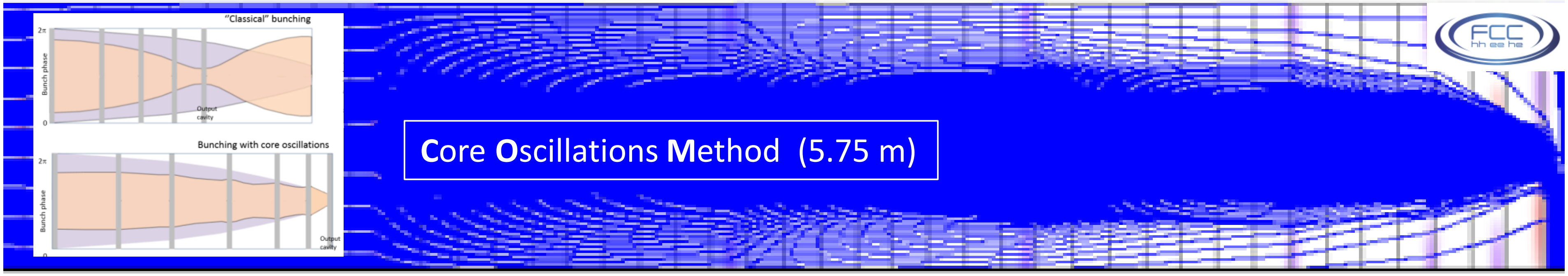
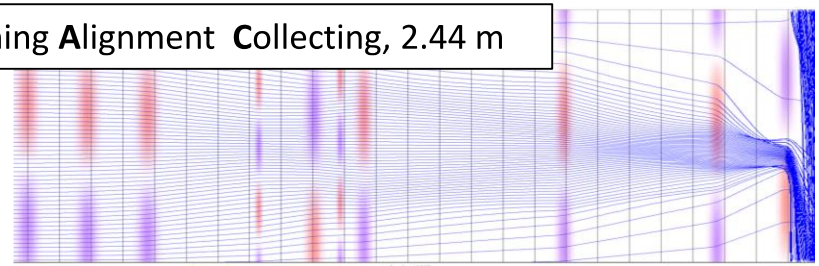
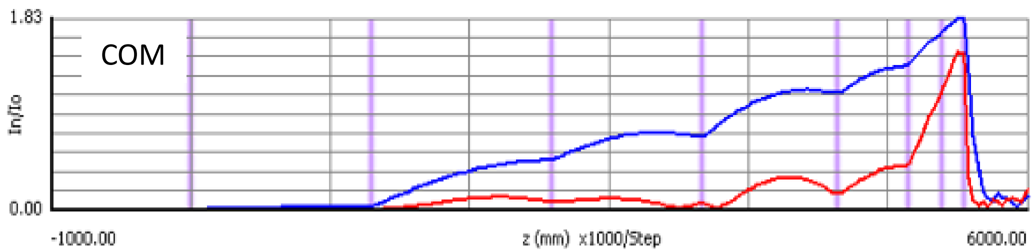
High efficiency klystrons.
New bunching technologies on one slide.

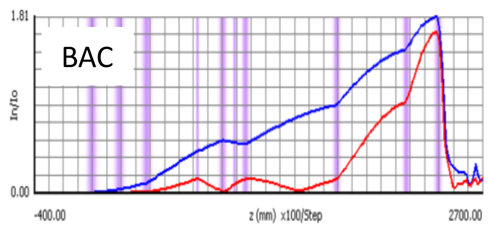


Bunching Alignment Collecting, 2.44 m



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





High Efficiency International klystron Activity

HEIKA

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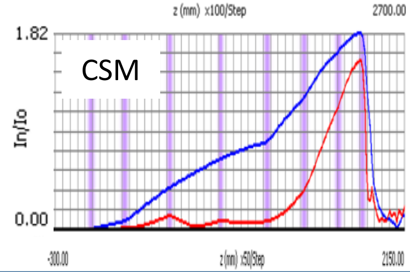
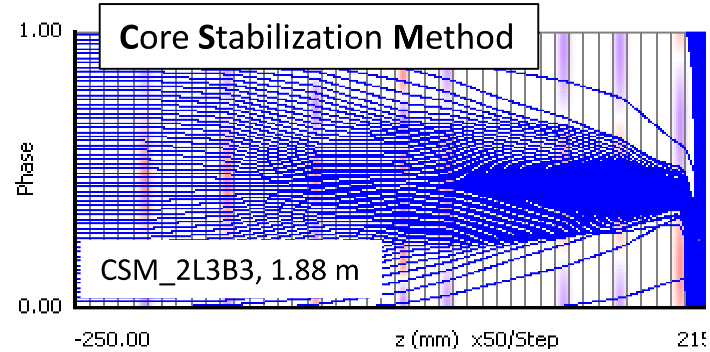
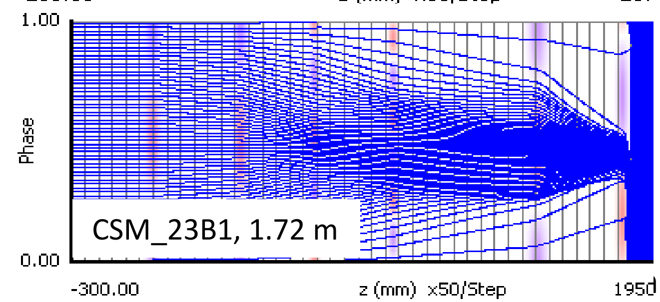
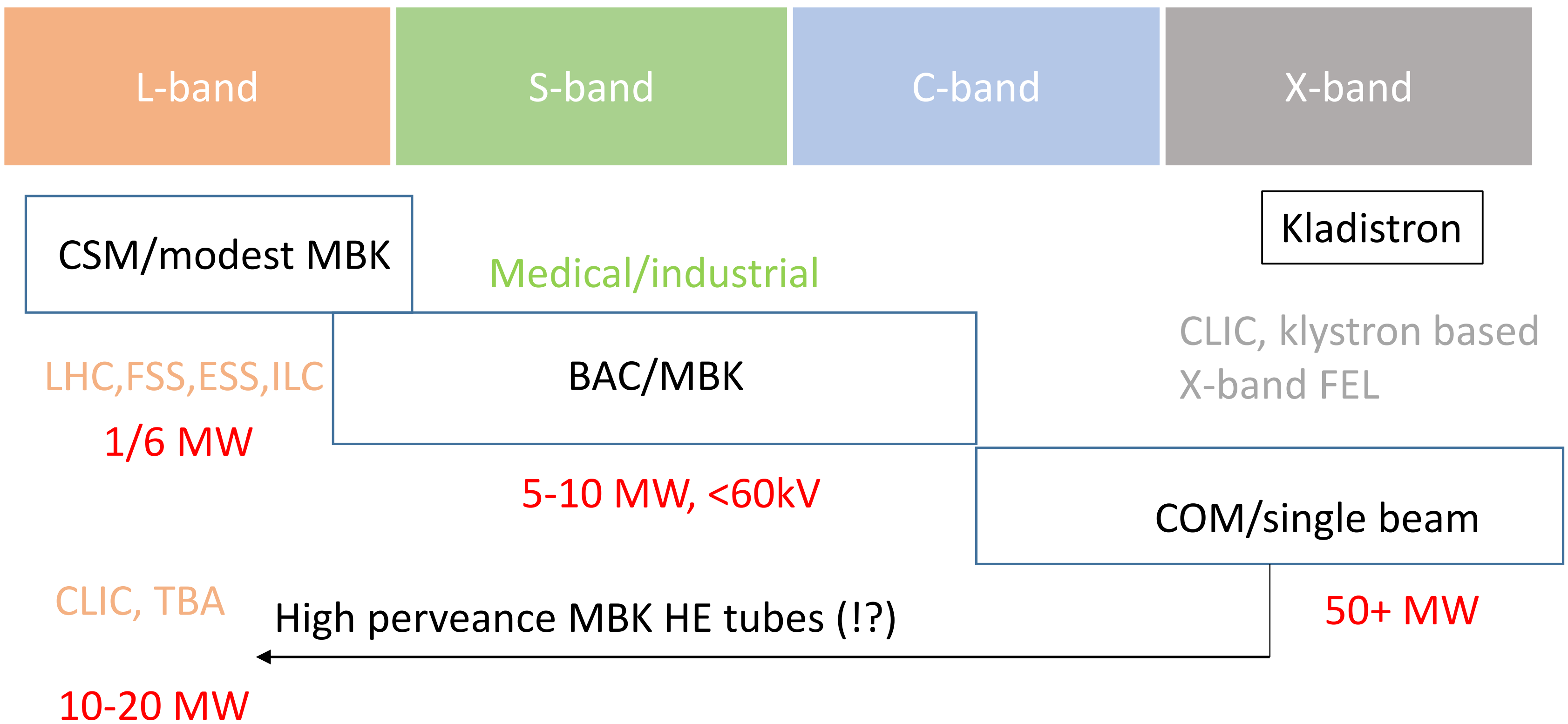






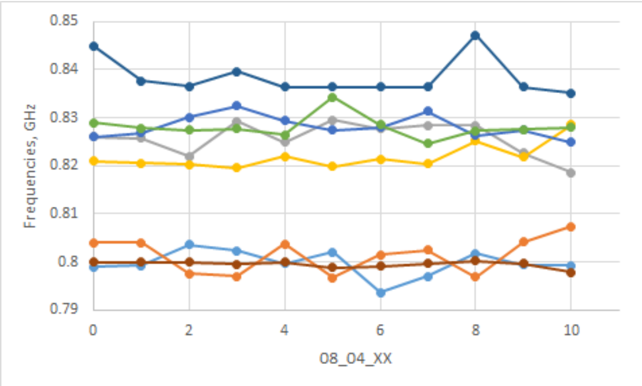
CLIC WS, CERN, March 2016.

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

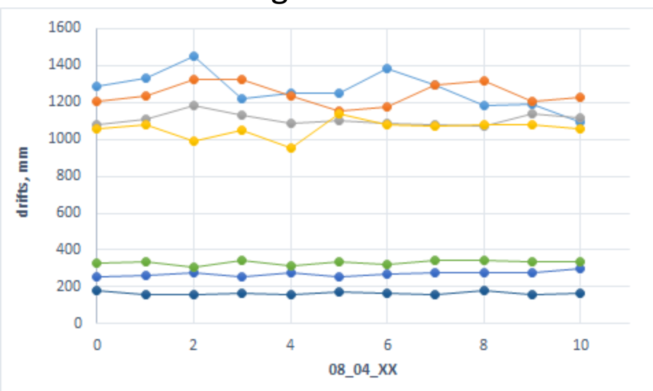


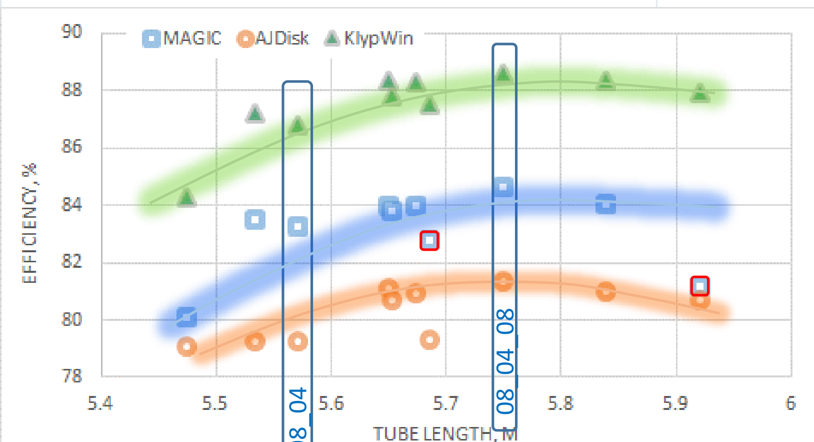
COM. 8_04_XX series of 10 optimised tubes.

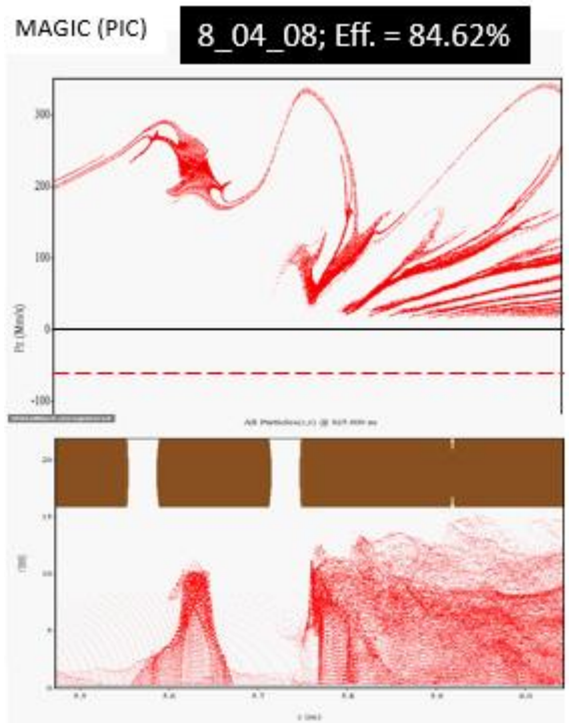
Frequencies scattering



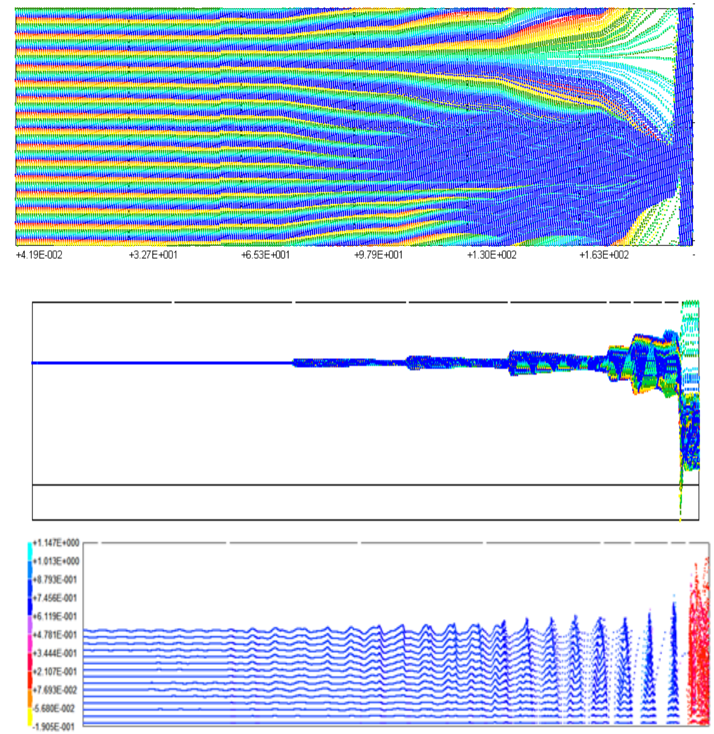
Drifts scattering

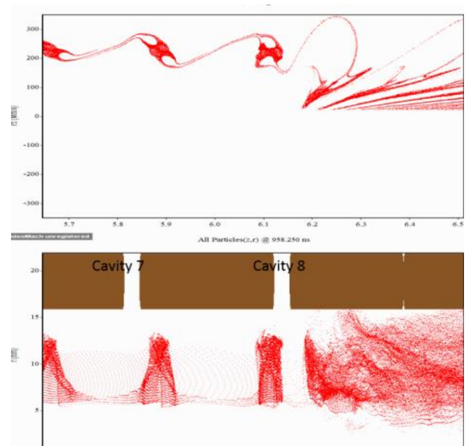






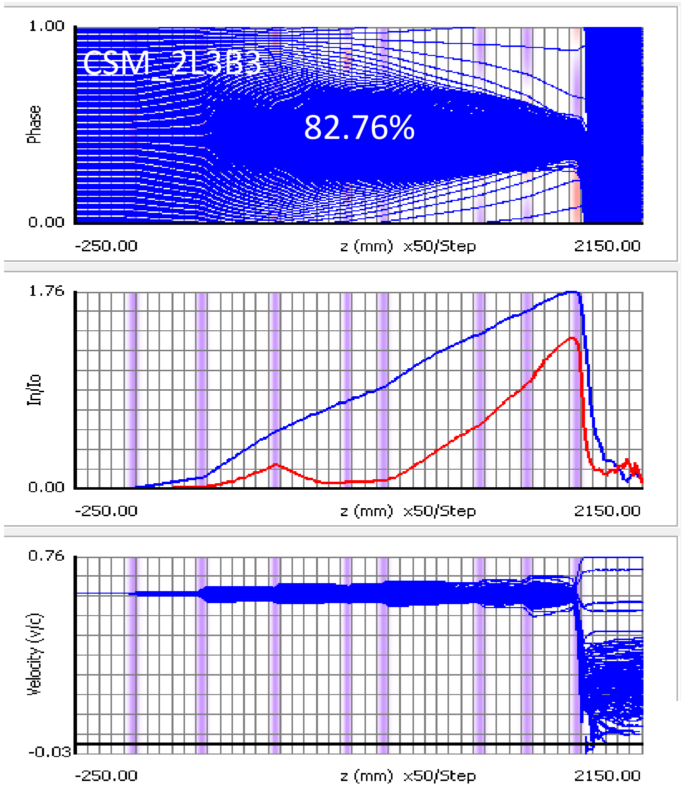
Klys2D (Thales), 81.6%

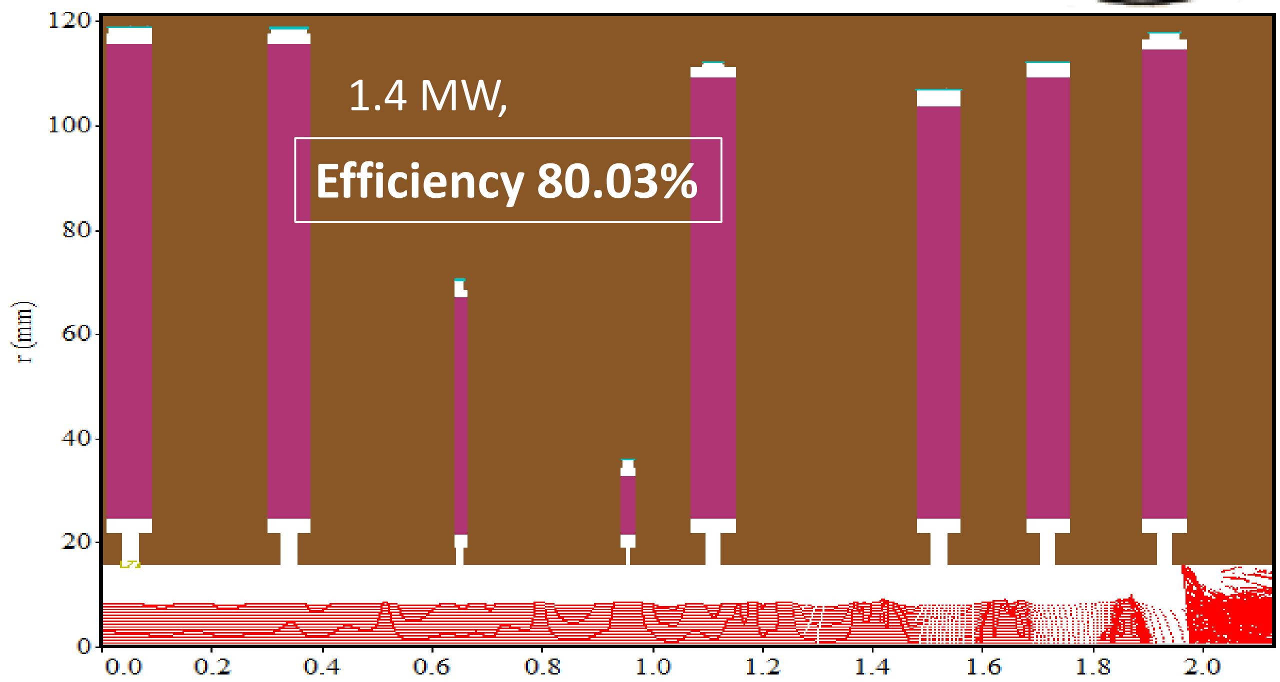




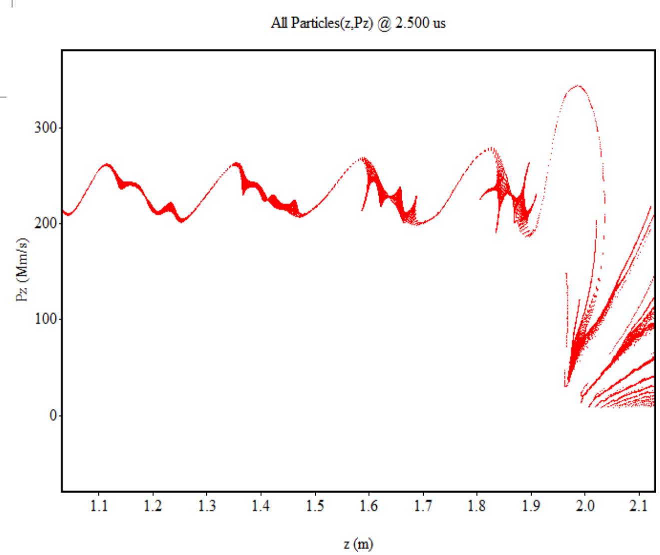
Replacing cylindrical beam by hollow beam efficiency is further increased up to 86%

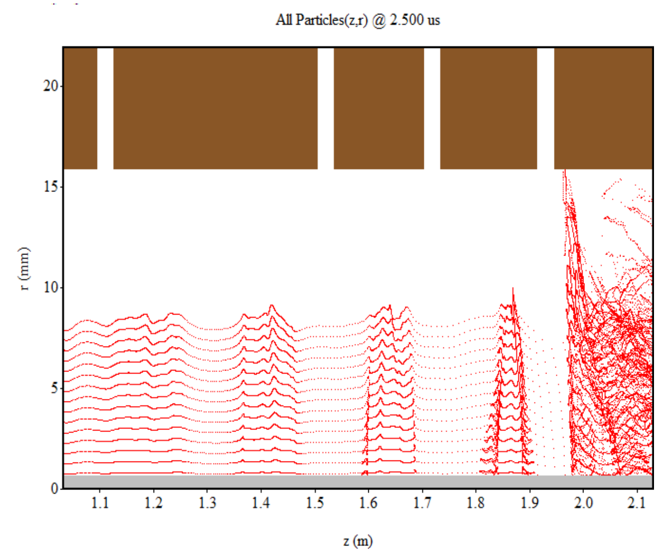
CSM family. Harmonic cavities are used to organize very fast bunch saturation.



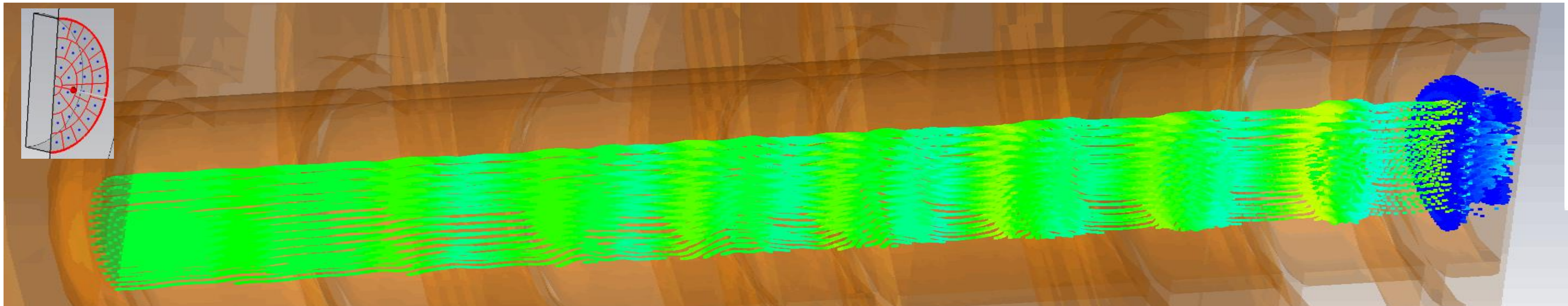


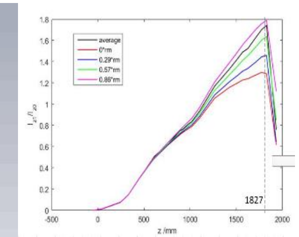
Beam Voltage (kV)	133.850
Beam Current (A)	12.551
Frequency (MHz)	800.000

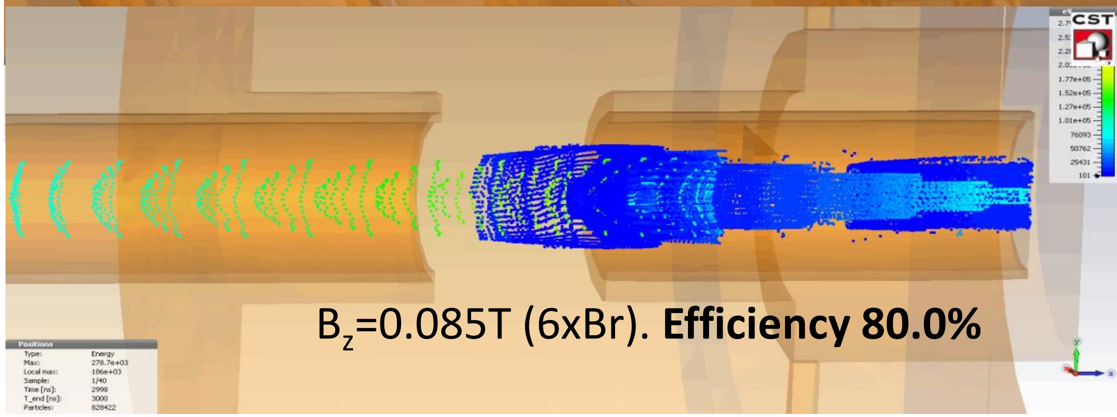


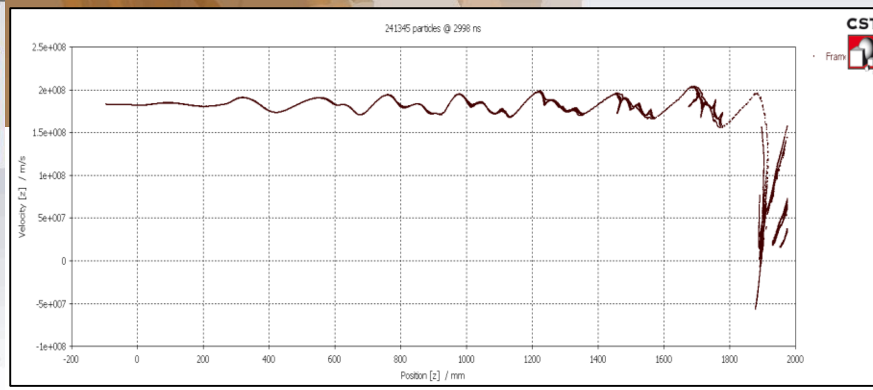


CSM_2L3B3. Full 3D simulations with Microwave Studio.

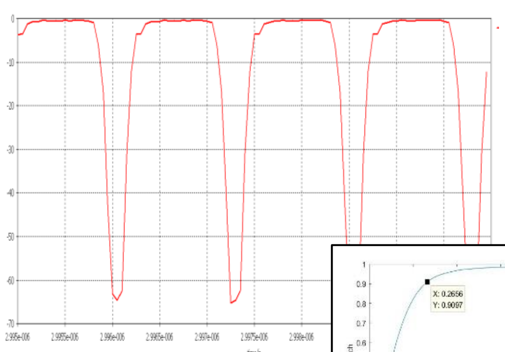


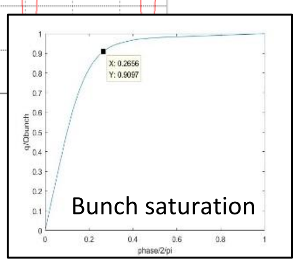




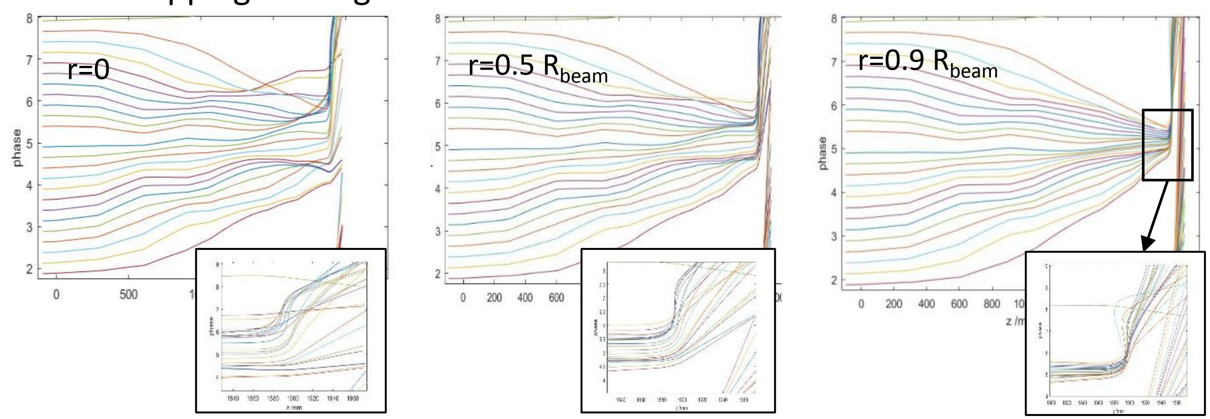


Beam intensity modulation:

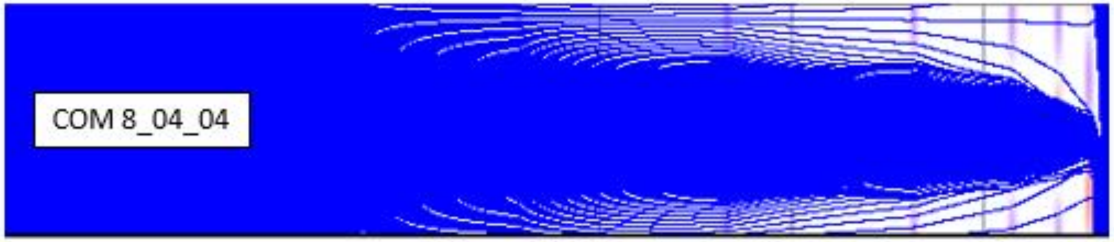




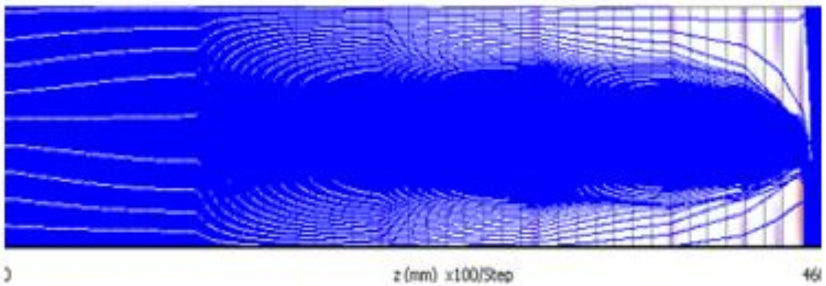
Applegate diagrams for the electrons emitted at different radius:



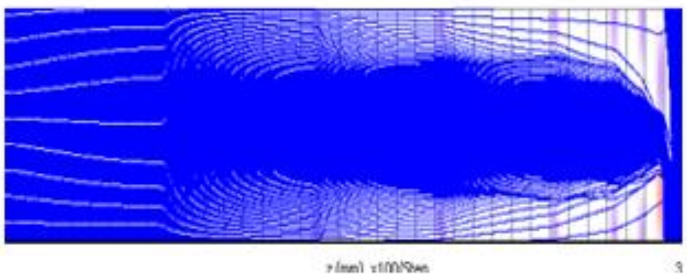
We have developed special procedure (GSP/PSP) which allows to scale the frequency, power, perveance, voltage, number of beams etc., and to preserve the bunching quality of the original tube:



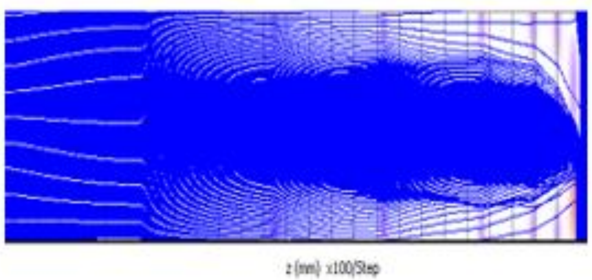
133.85 kV
12.55 A
µK=0.256
5.55 m



115 kV
14.6 A
µK=0.375
4.29 m

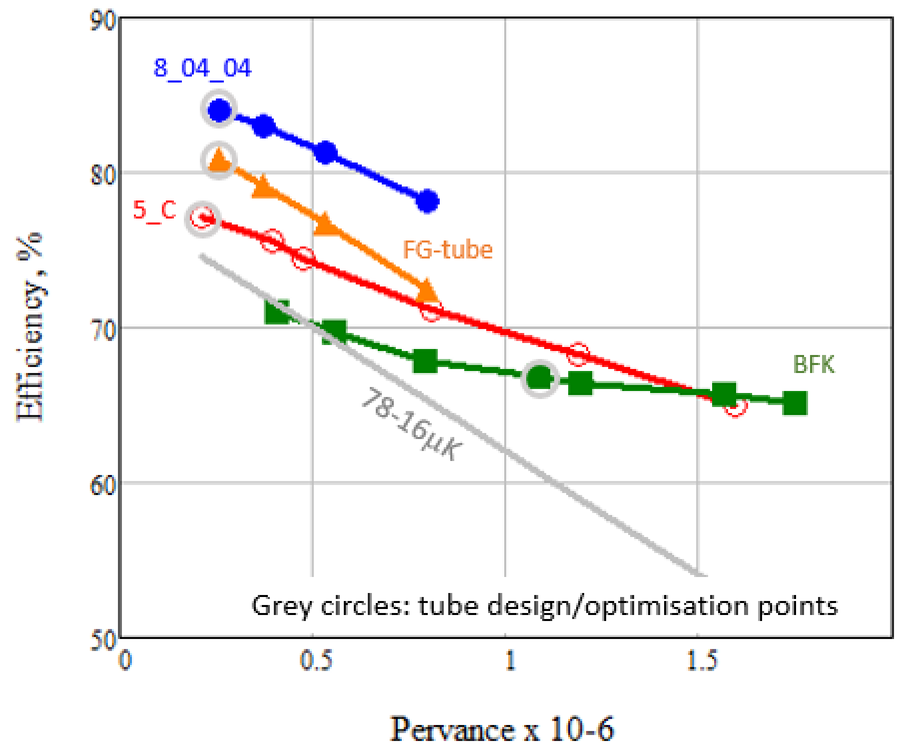


100 kV
16.8 A
µK=0.53
3.38 m

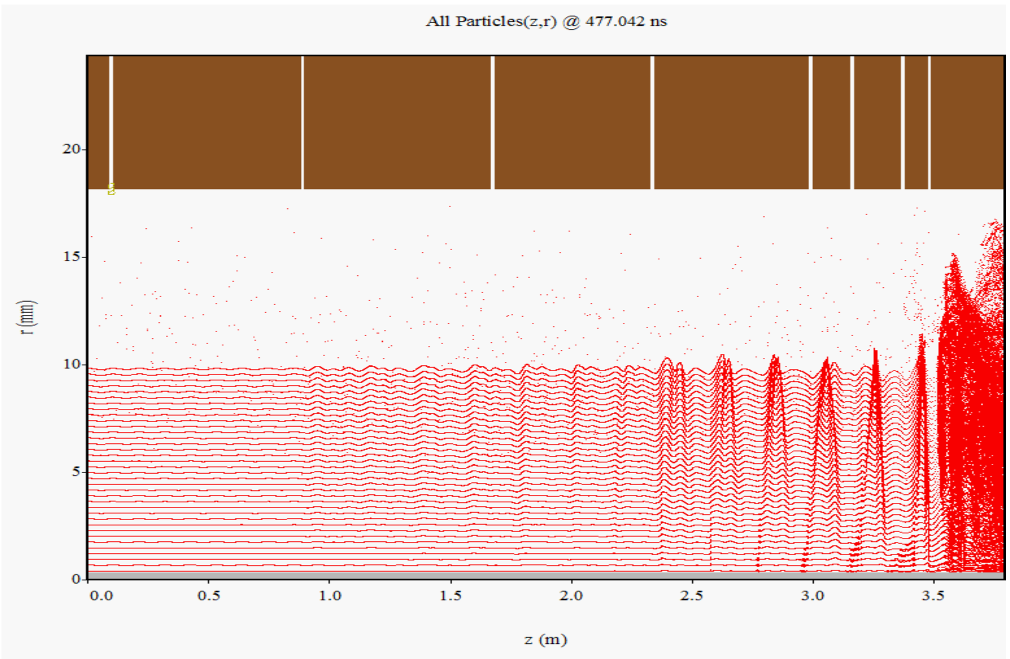


85 kV
19.76 A
µK=0.8
2.56 m

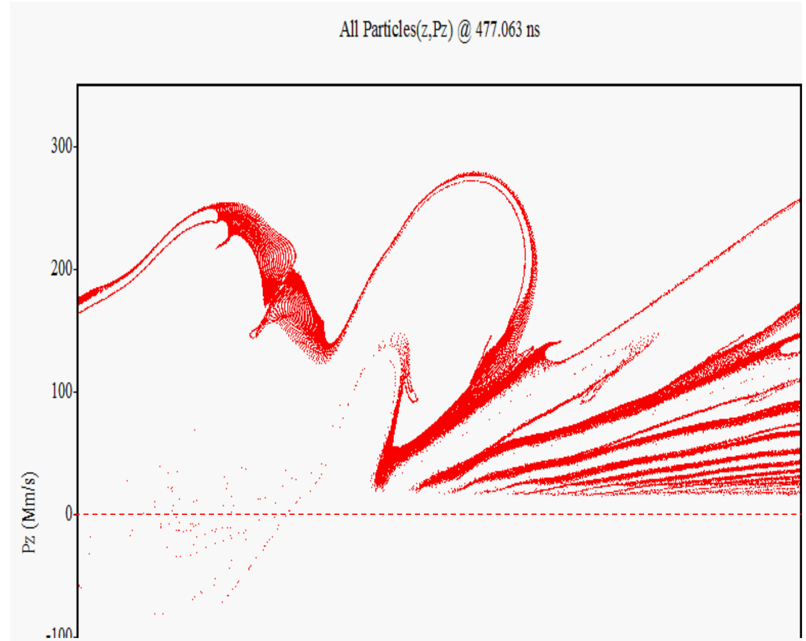
Summary plot

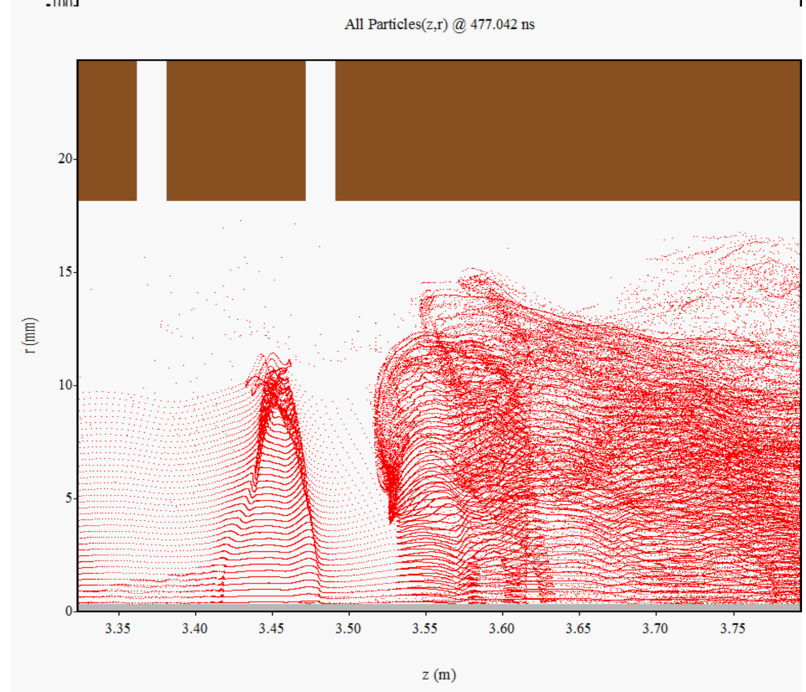


First MAGIC (PIC 2D) results of PSP 08_04_08 tube directly scaled from 133 kV down to 100 V:
Perveance: 0.26uK -> 0.53uK
Tube length: 5.75 m -> 3.37 m
Efficiency: 84.62 -> 80.78



1.4 MW, Efficiency 80.78% (yet reflected electrons)

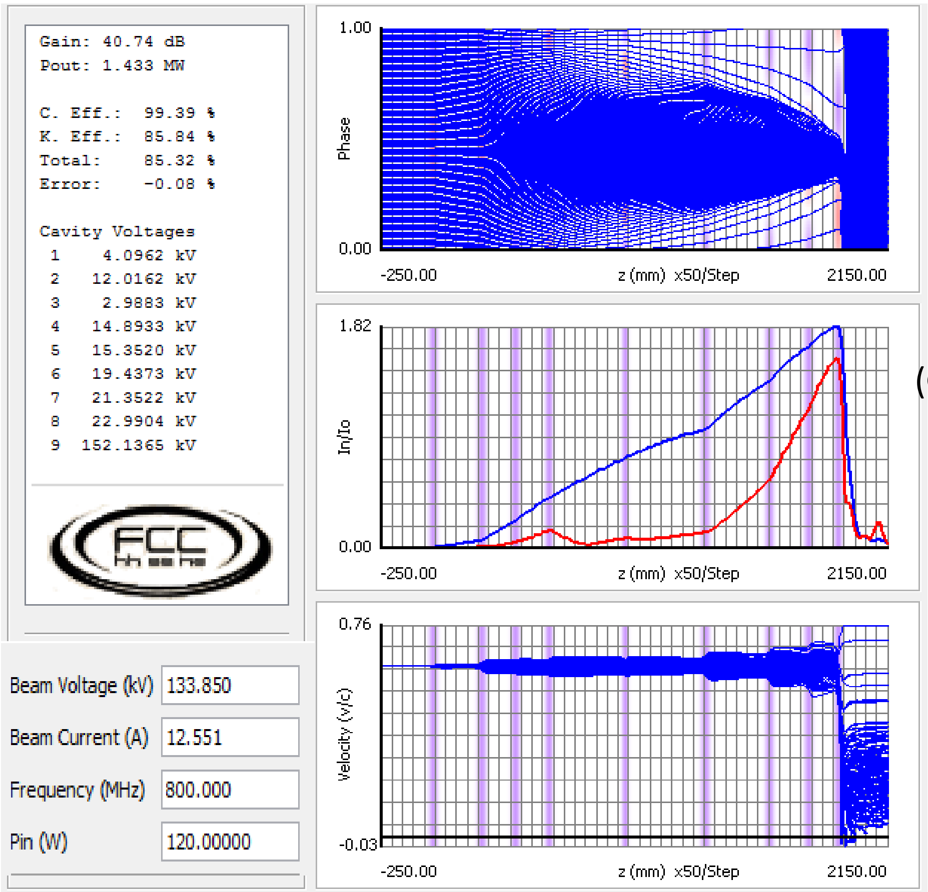




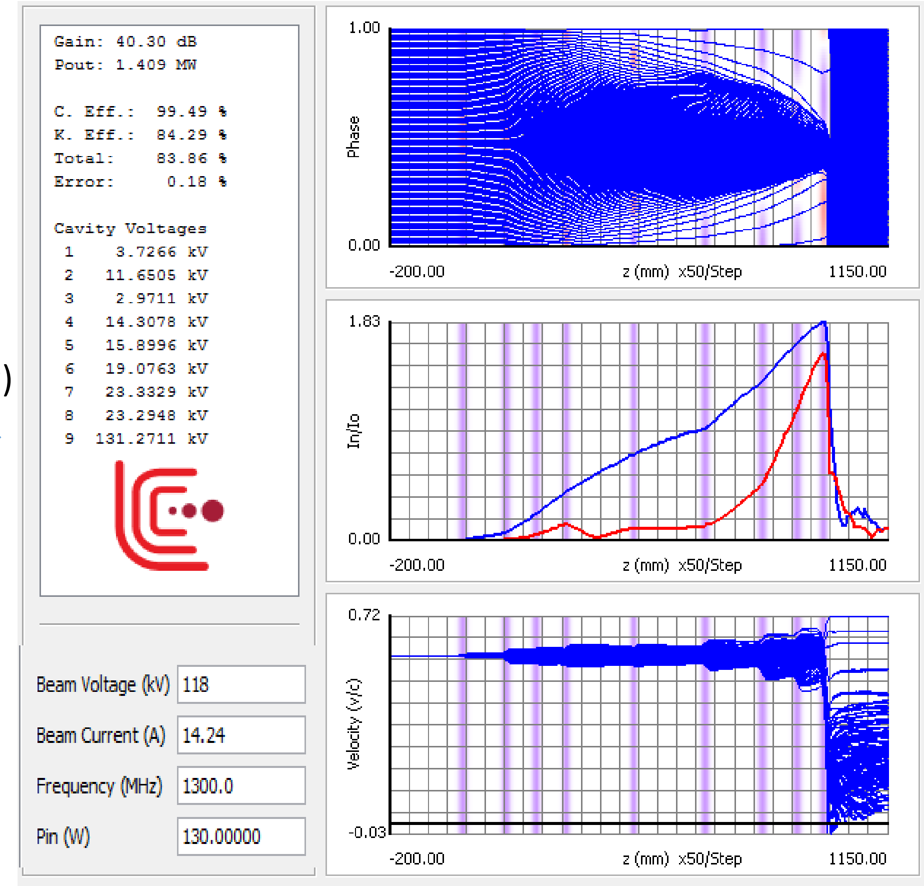
Example of scaled ILC HE klystron.

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

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



(GSP/PSP)

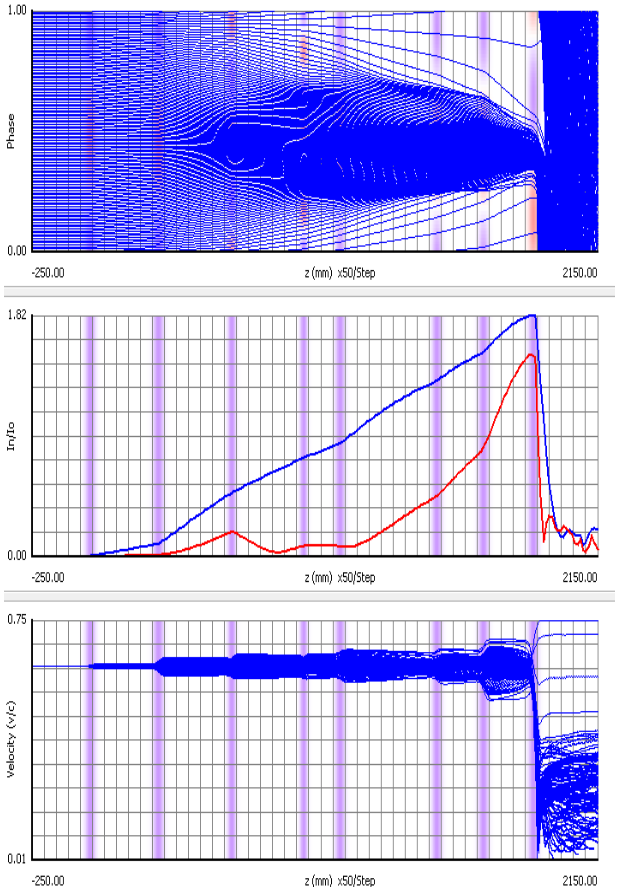


8 beams MBK klystron scaled from 1.3 GHz CSM_123_s is a compact (<1m), 11.4 MW tube with efficiency >80%.

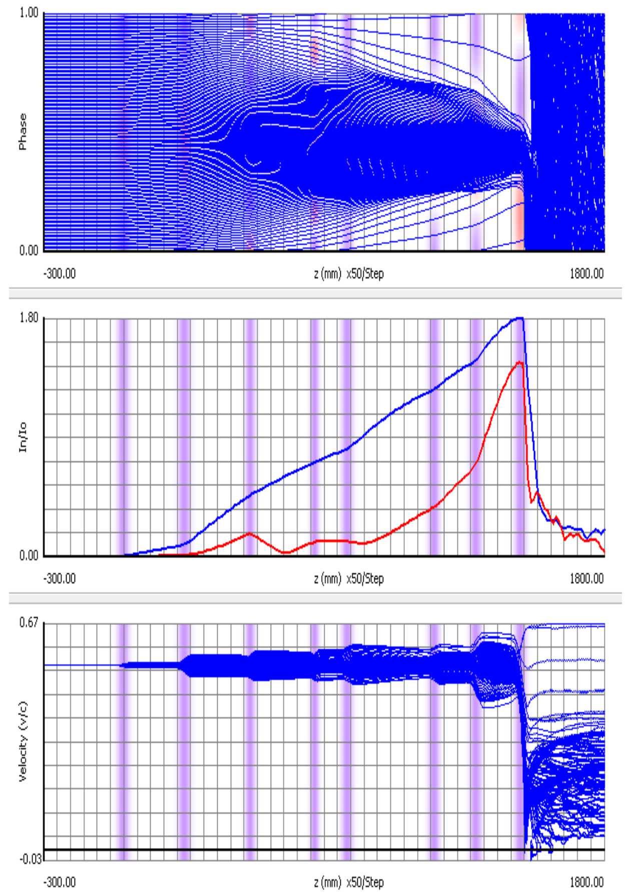
I. Syratchev

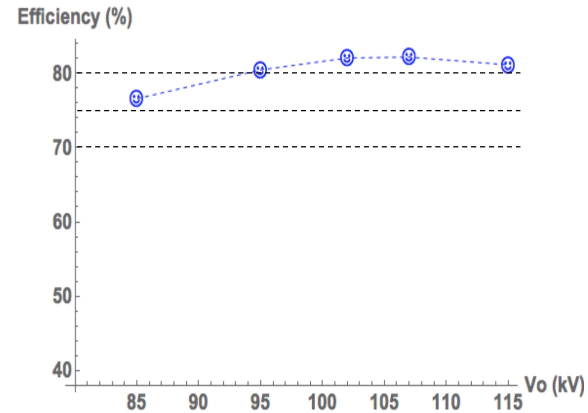
Example of scaled ESS HE klystron.

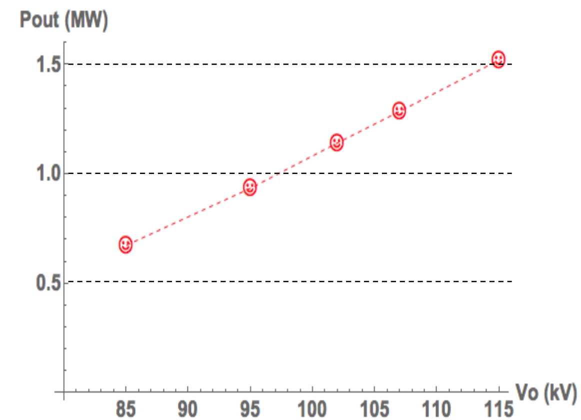
CSM_2L3B3 tube (84.4%), single beam:
0.8 GHz, 1.4 MW, **134 kV, 12.55 A**, L=**1.88m**



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





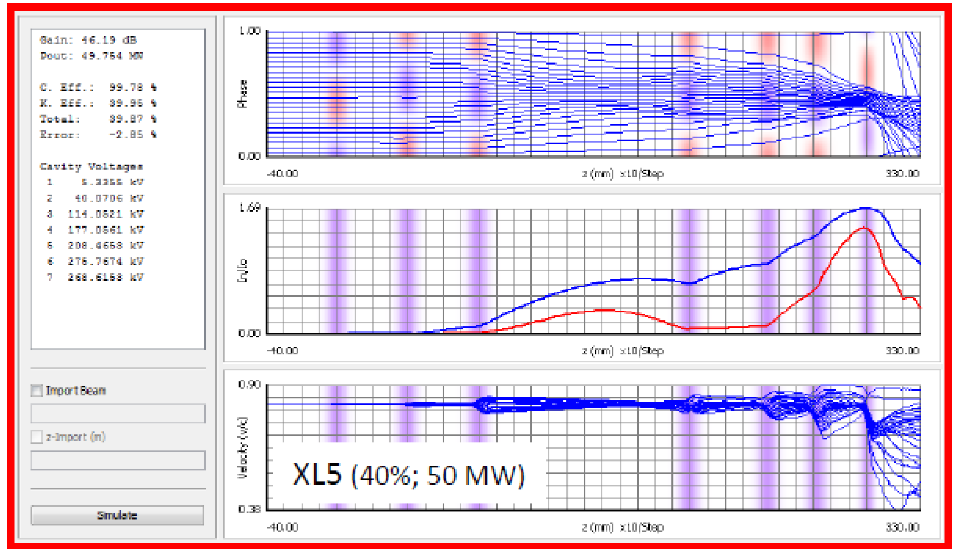


(GSP/PSP)

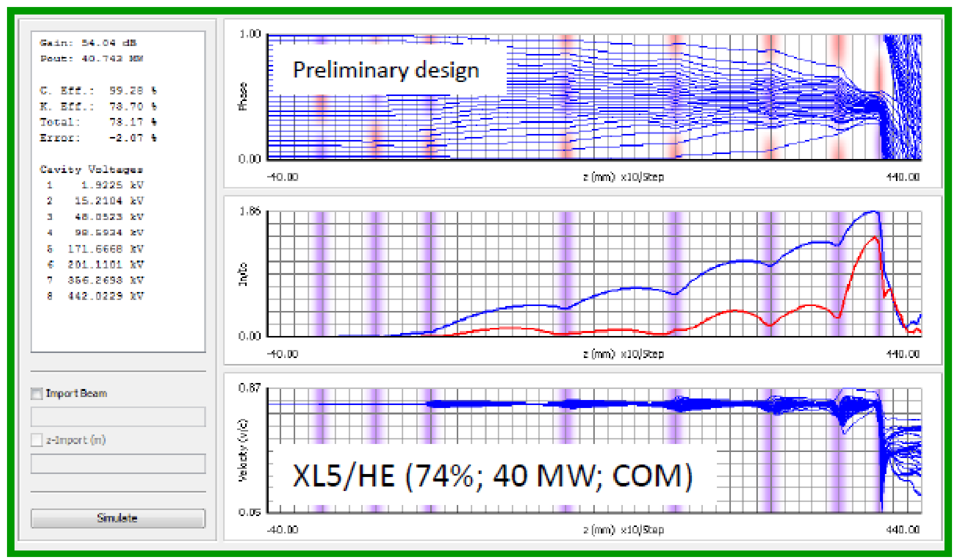
EUROPEAN SPALLATION SOURCE

CERN/SLAC initiative towards high efficiency X-band klystron development

	XL5	XL5/HE
Voltage (kV)	400	290
Current (A)	312	186
Power (MW)	50	40
Efficiency (%)	40	73(*80*)
Last gap voltage (kV)	*270*	*440*



It appeared, that HE klystron (for the fixed perveance) requires higher integrated voltage in the output cavity. Thus the new design will be needed. It also can limit the high RF peak power performance.



CERN/SLAC agreement has being signed.
The detailed results of the tube full optimisation (paper study) will be ready in 6(+?) months.