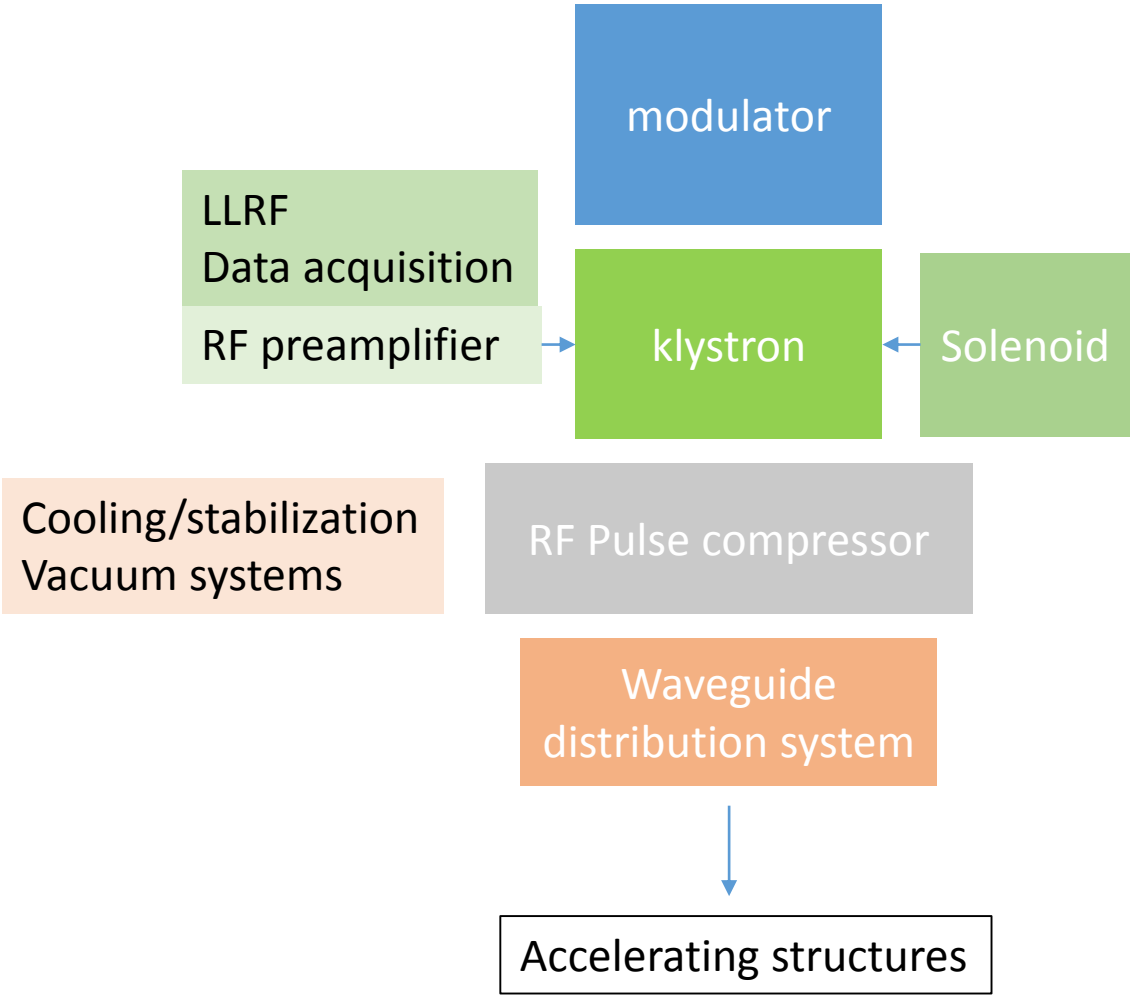
CLIC Klystron based. Updates 2017.

I. Syratchev

Intro. RF power station building blocks:



XBOX#2 example. Industrial components.

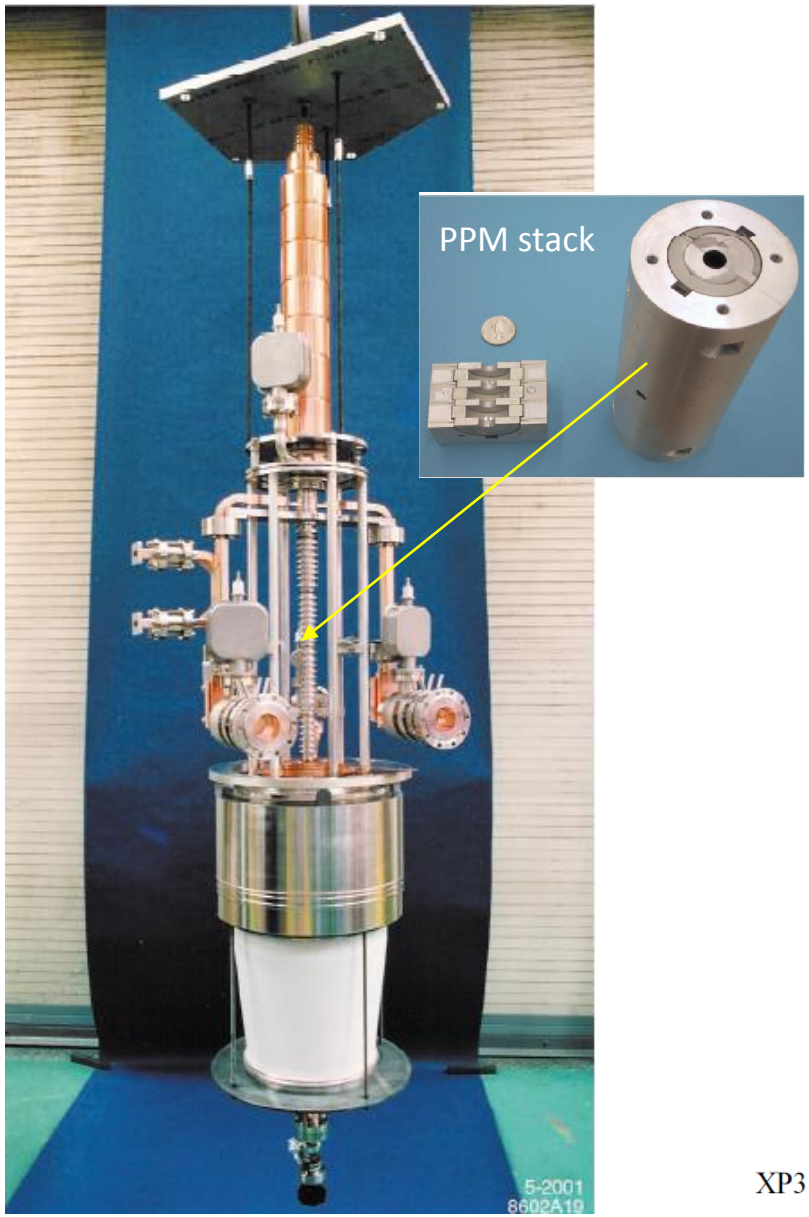
Efficiency:

Modulator:	0.7
Klystron:	0.4
Pulse compressor:	0.6
WG system:	0.95
TOTAL:	0.16

Average power for 250 ns x 50 MW x 50 Hz (0.625 kW) needed is 4 KW.

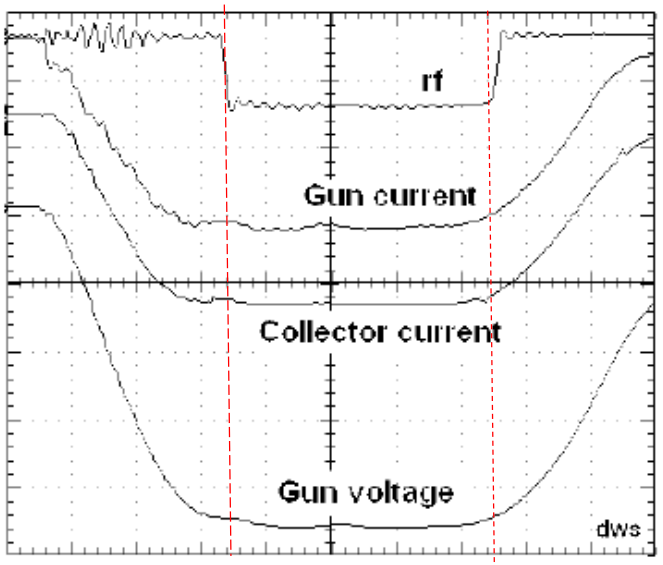
CPI tube convectional solenoid power consumption is ~20 kW. With this our total RF production efficiency today is only **2.5%**.

Prototype of the 75 MW X-band klystron with PPM focusing. SLAC 1996-2002.



Parameter	Value
Frequency	11.424 GHz
Beam voltage	490 kV
Beam Current	257 A
RF Power at loads	75 MW
Pulse length	1.6 to 3.2 μs
PRF	120 Hz
Average Power	14 to 29 kW
Gain	~55 dB
Efficiency	~55 %
Bandwidth	120 MHz

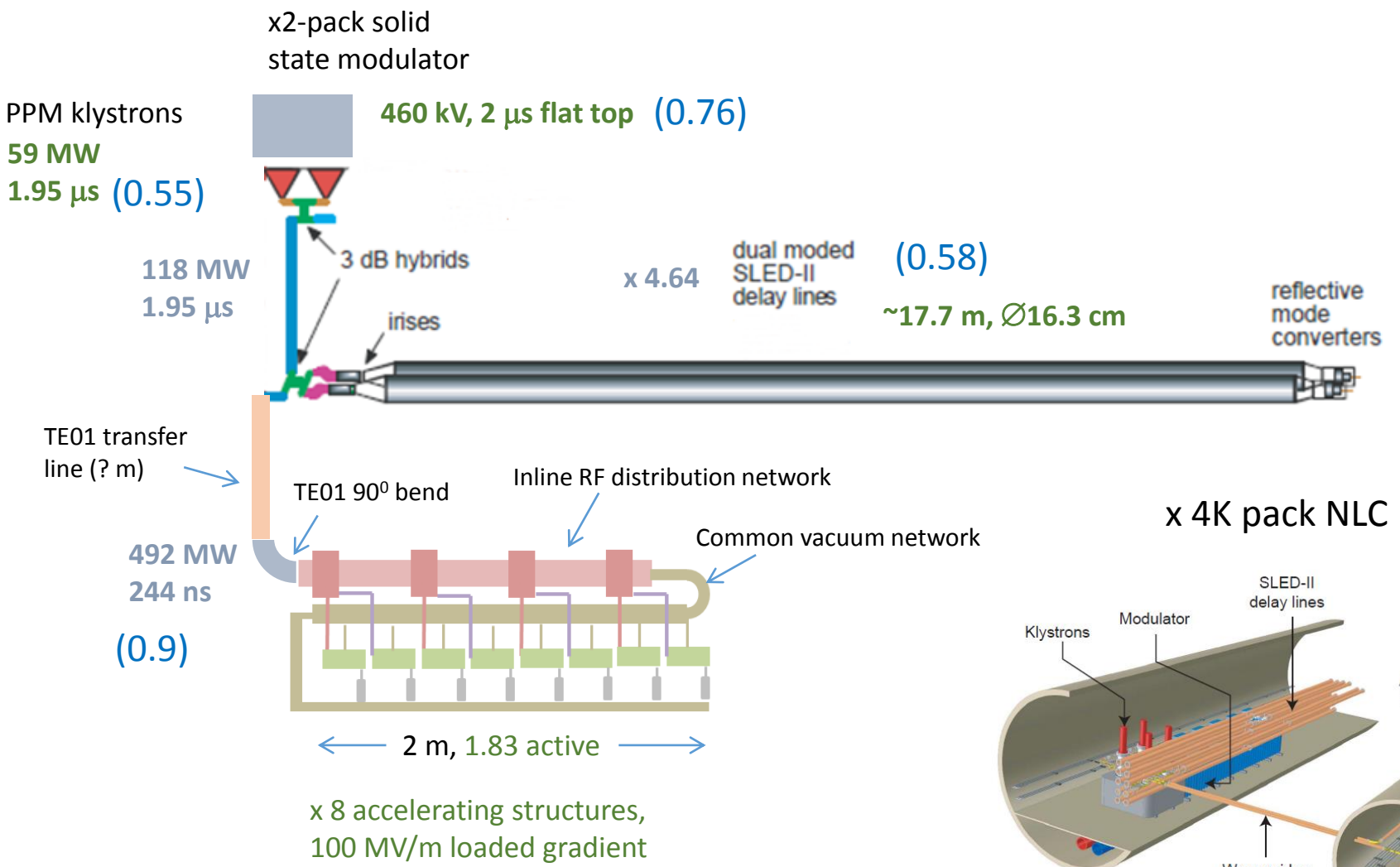
Tests results. XP3-4



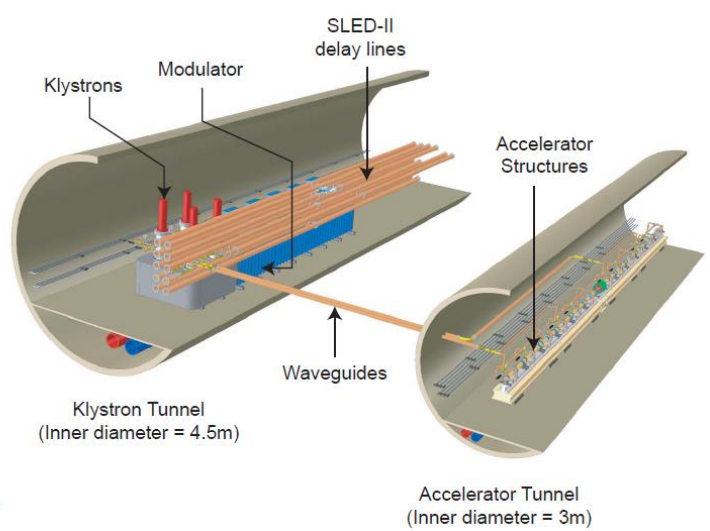
XP3-4 operation at 75 MW, 506 kV, 120 Hz and 1.62 μs with ~60 dB of gain and ~50 %

Beam integrated losses ~1.3%

NLC based CLIC'k linac unit layout. 2012 version.



x 4K pack NLC layout:



Total RF production efficiency: 21.8%.

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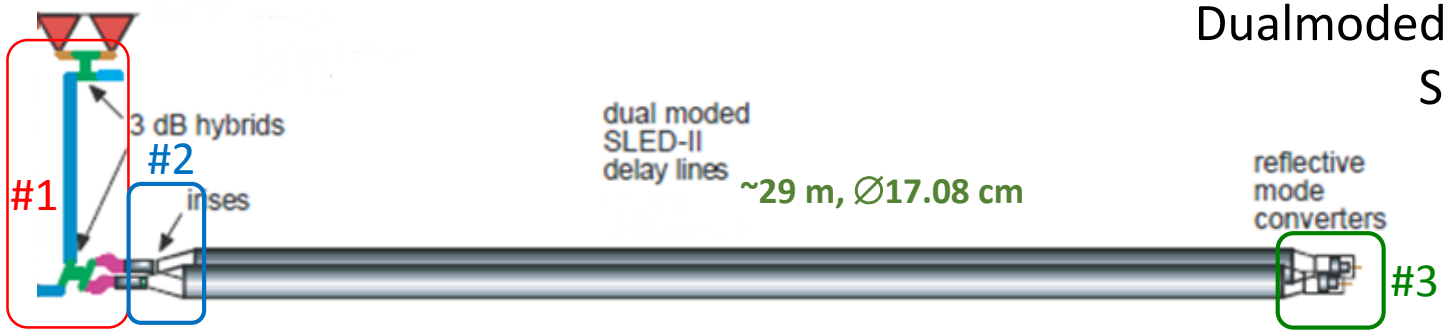
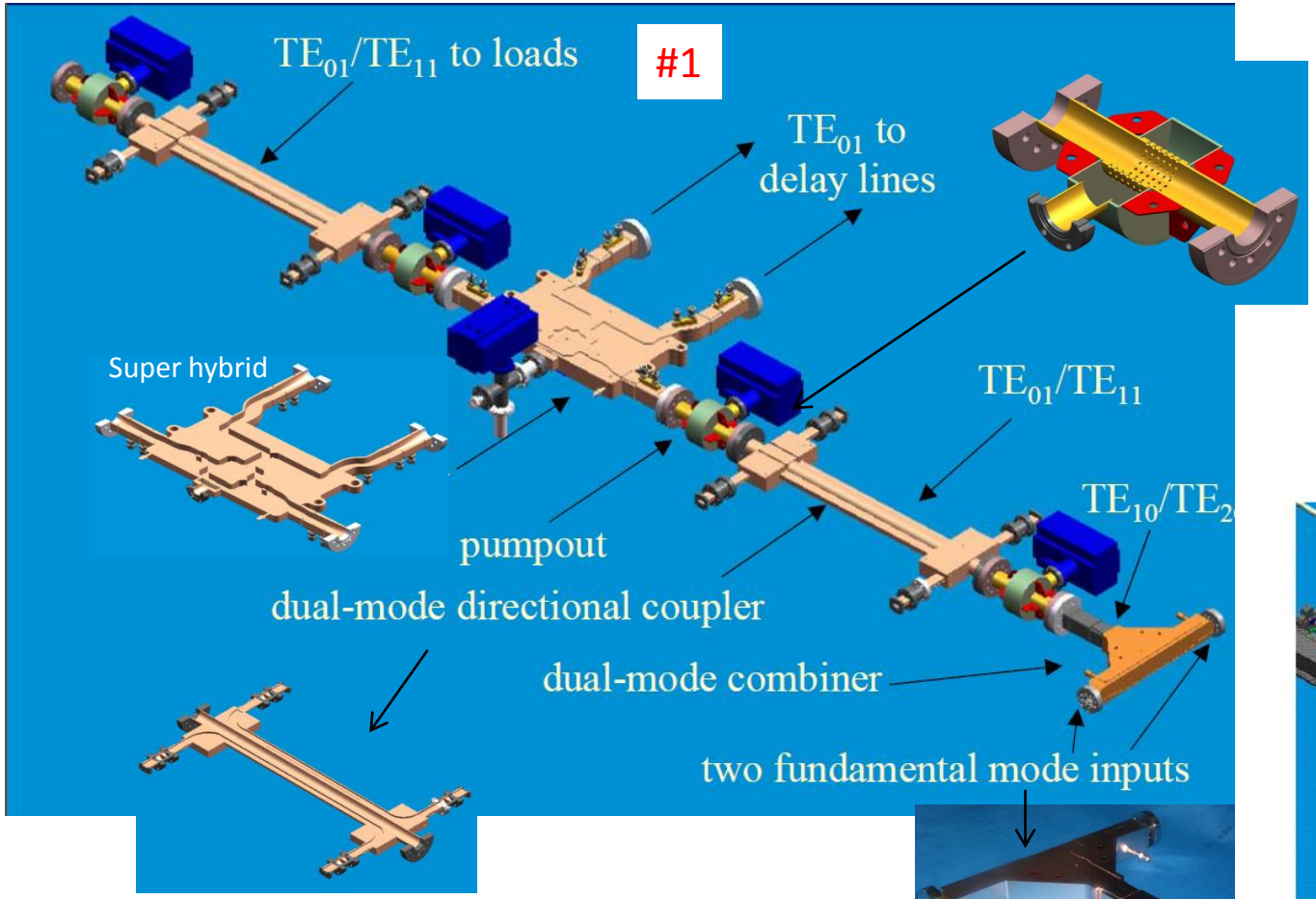
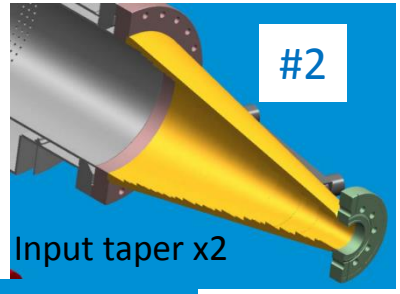
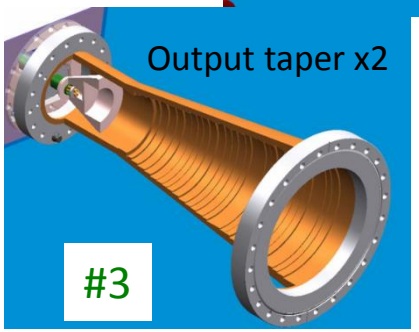
Dualmoded SLED II details

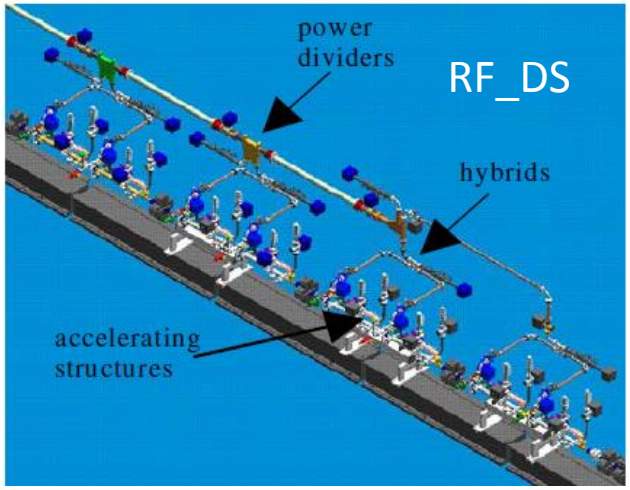
S. Tantawi et. al.



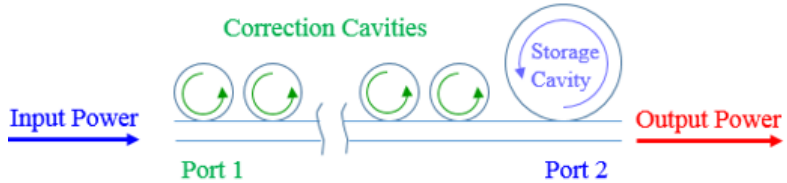




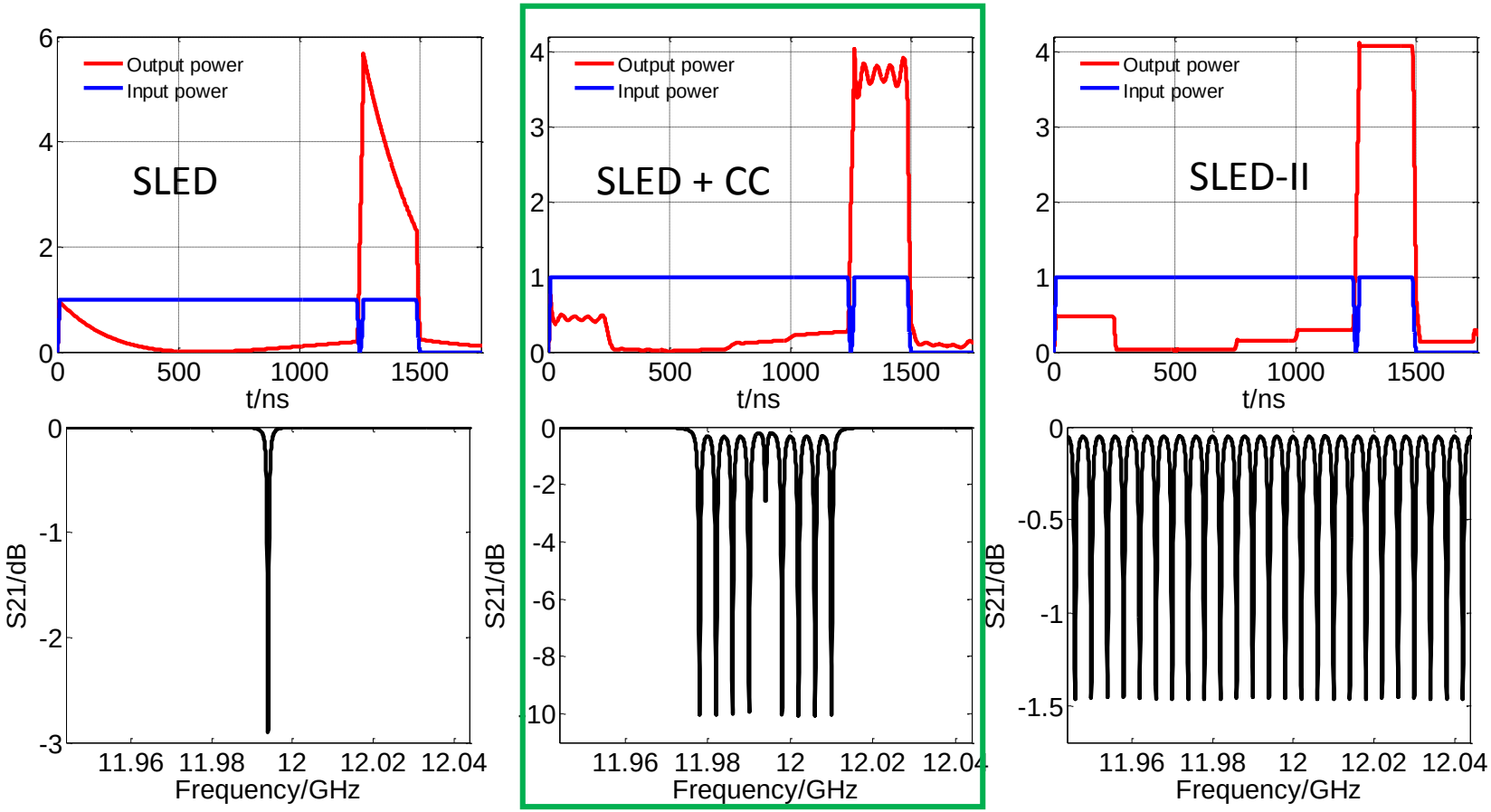




New Pulse compressor with CC (Correction Cavity) chain



- Flat pulse (compared with SLED)
- Very compact (compared with SLED-II)



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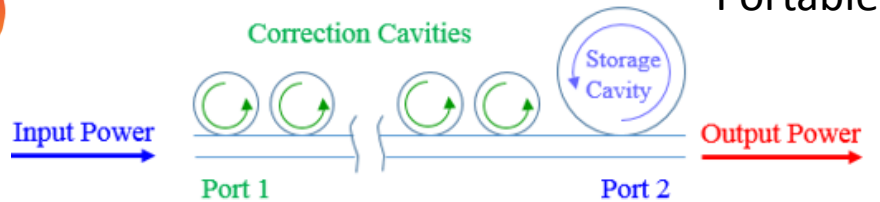
Portable PC with correction cavities. Syratchev & Wang.

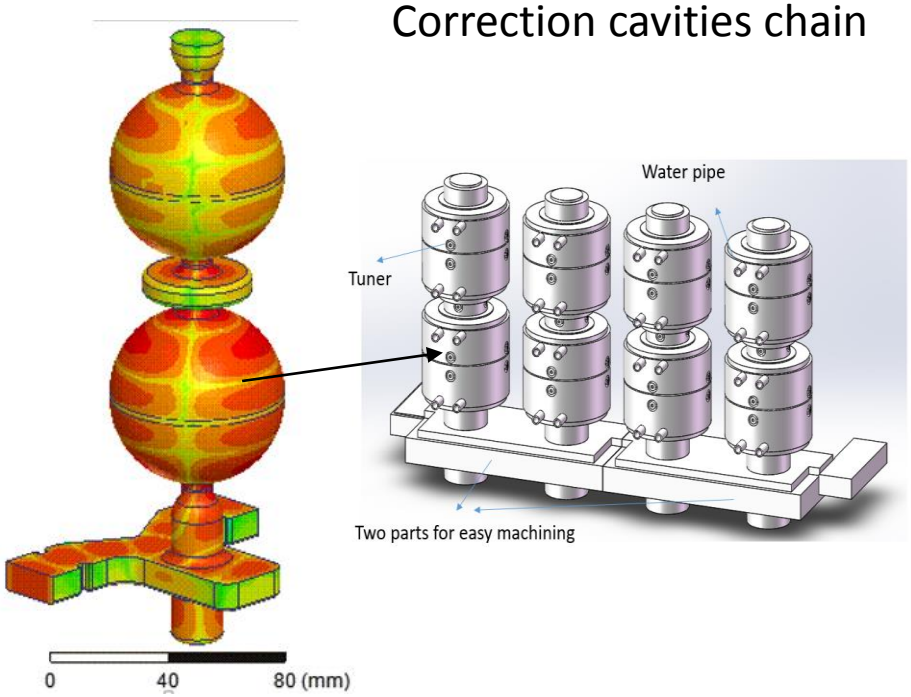


Storage cavity options:

X-band SLED (Xboxes)

X-band BOC (1994)

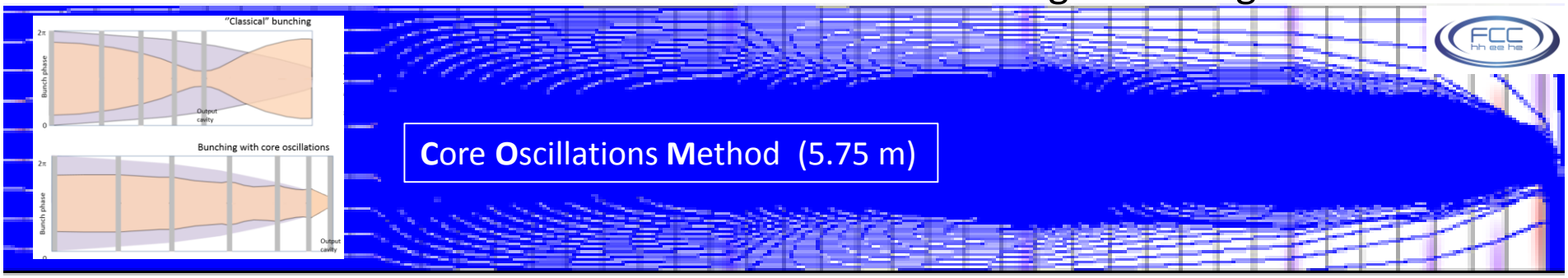
Correction cavities chain



The first set of CC chain for XBOX-2 PC now is in fabrication in Tsinghua U (China), will be shipped to CERN and tested by the end of 2017.

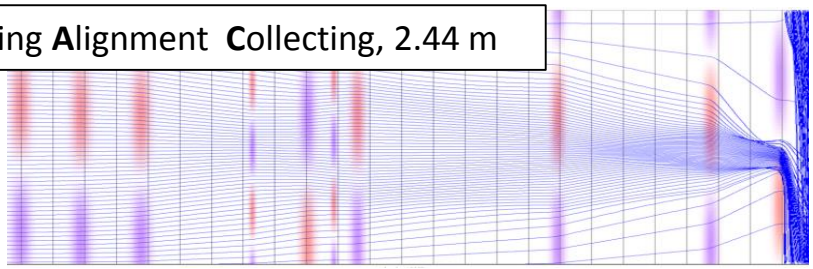
High efficiency klystrons.

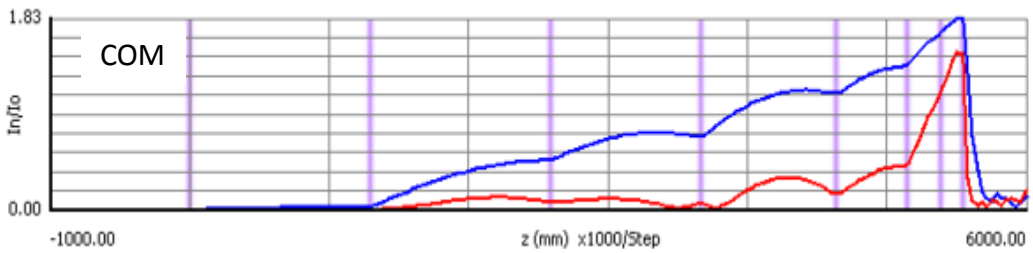
New bunching technologies on one slide.

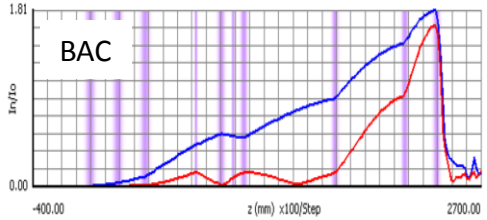


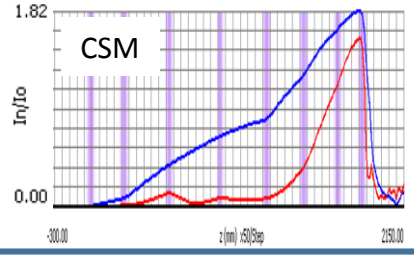
133.8 kV, 12.55 A, 1.4 MW at 0.8 GHz, 80(+)%

Bunching Alignment Collecting, 2.44 m



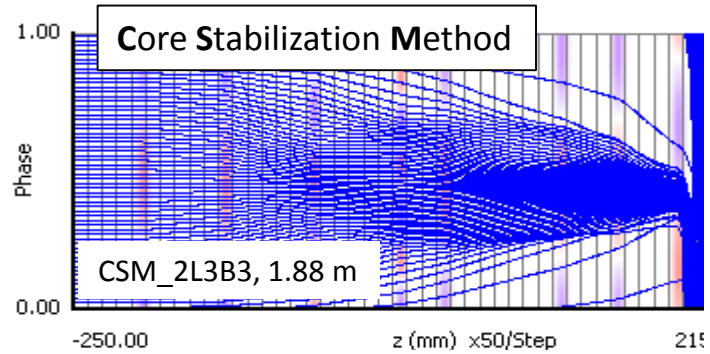


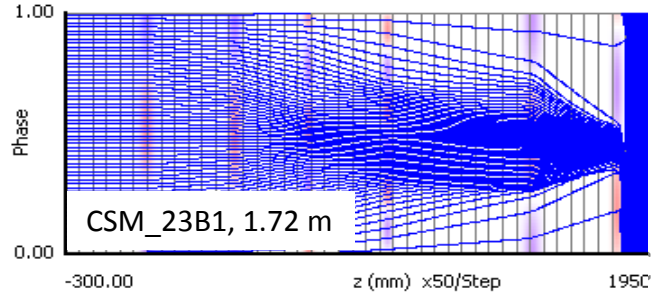




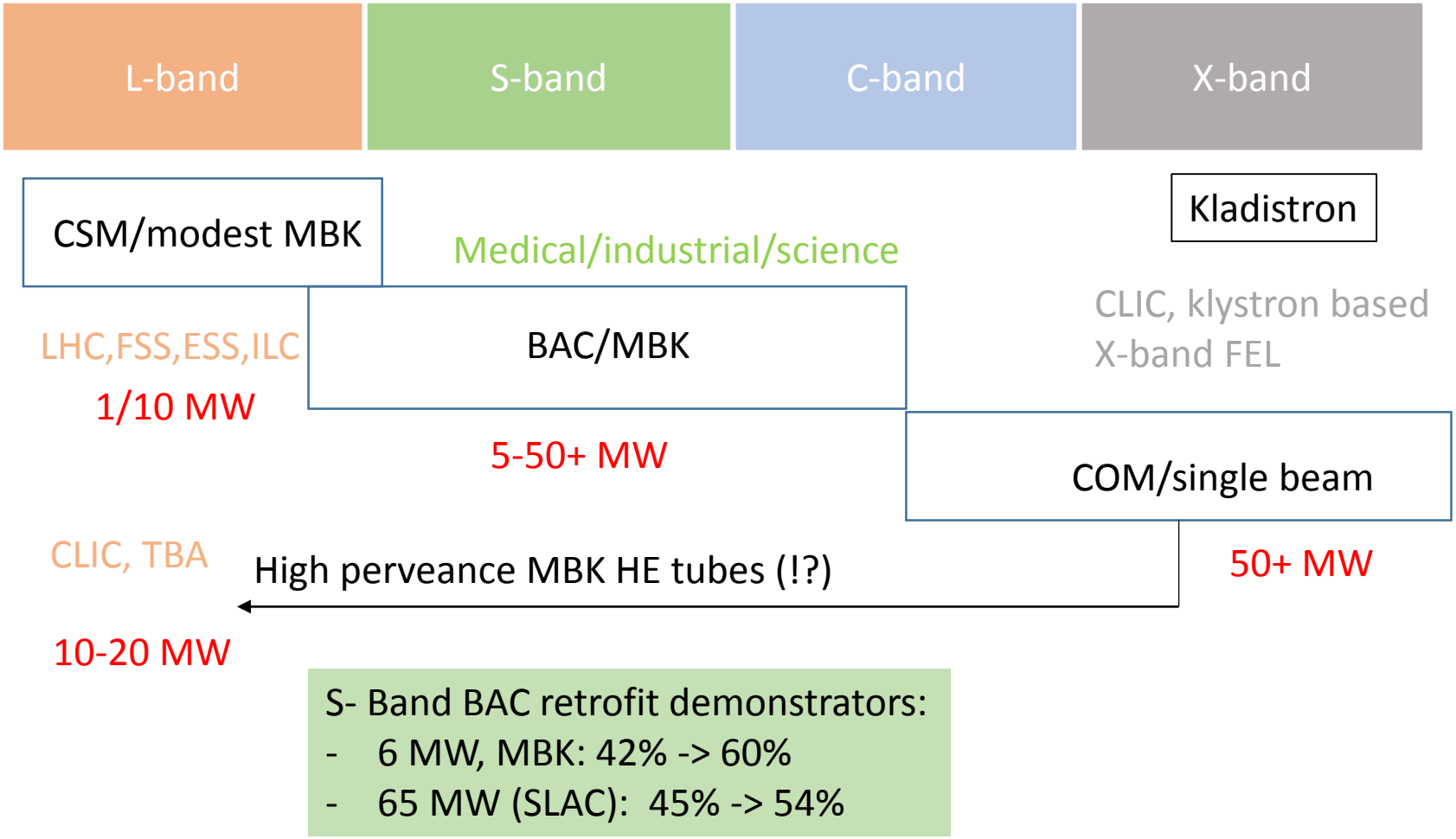
High Efficiency International klystron Activity

HEIKA



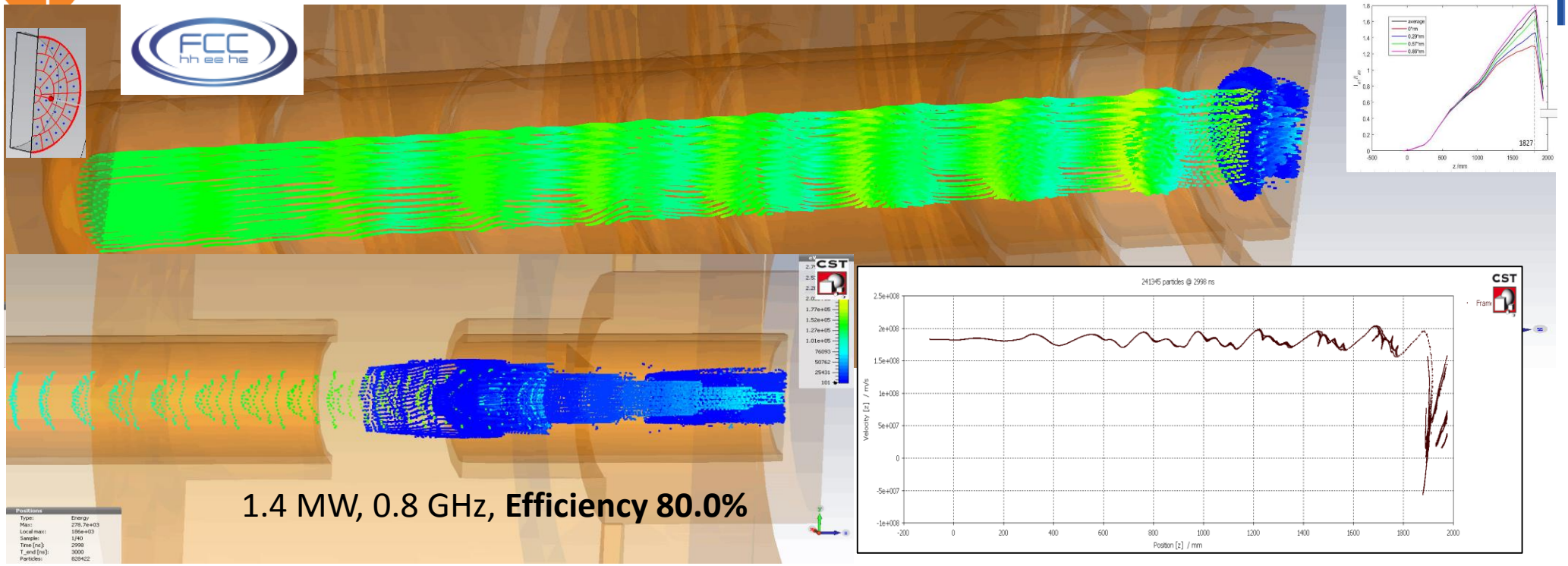


The choice of bunching technology may drive the applicable frequency range and multi-beam options (cost/performance):

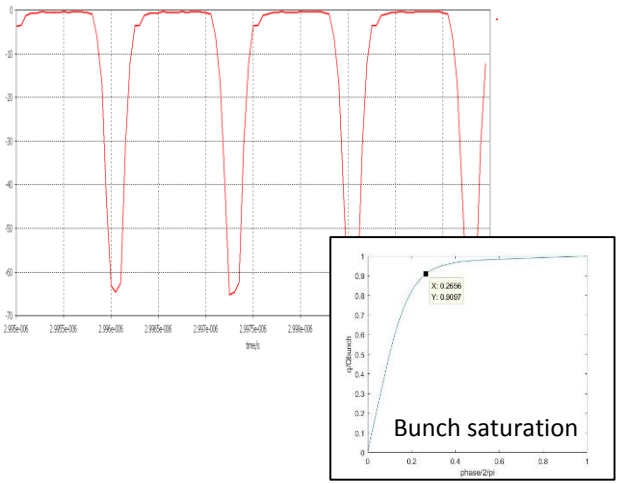


S- Band BAC retrofit demonstrators:
- 6 MW, MBK: 42% -> 60%
- 65 MW (SLAC): 45% -> 54%

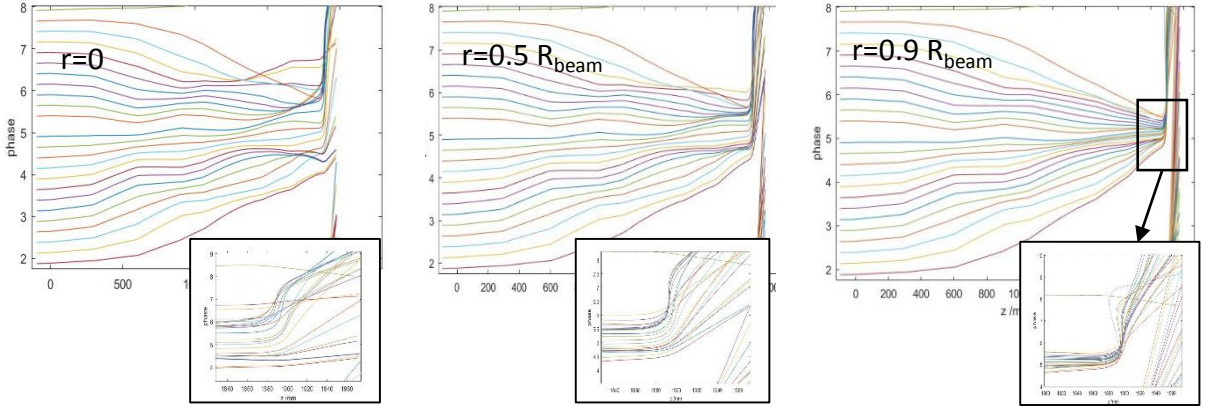
CSM_2L3B3. Full 3D simulations with Microwave Studio.



Beam intensity modulation:

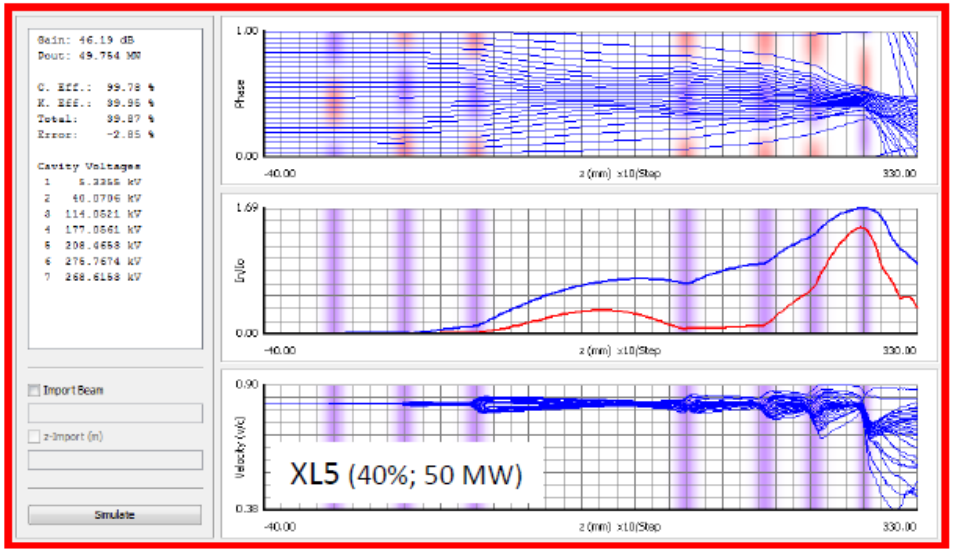


Applegate diagrams for the electrons emitted at different radius:

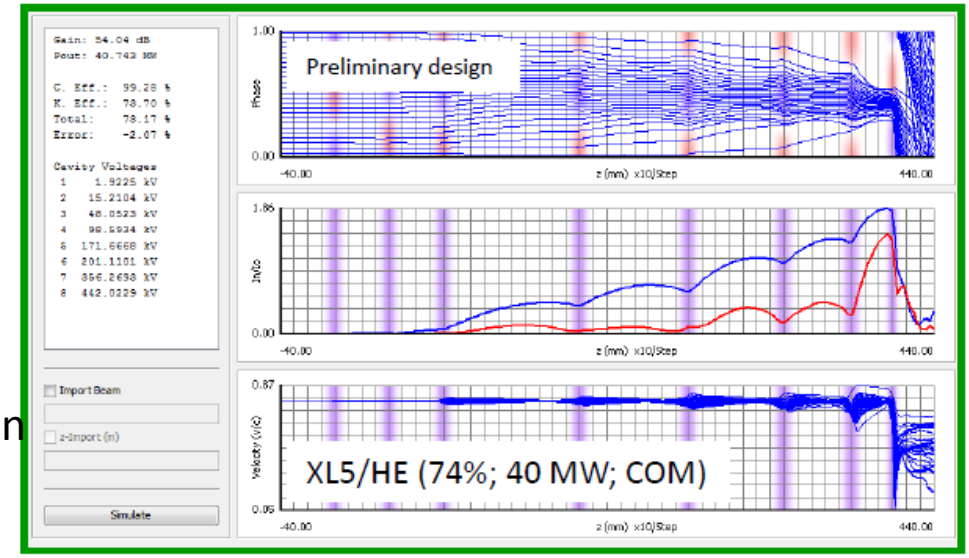


CERN/SLAC initiative towards high efficiency X-band klystron development

	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*



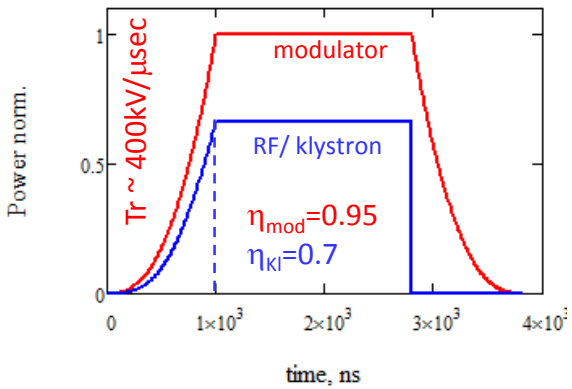
It appeared, that HE klystron (for the fixed perveance) requires higher integrated voltage in the output cavity. Thus the new design will be needed. It also can limit the high RF peak power performance.

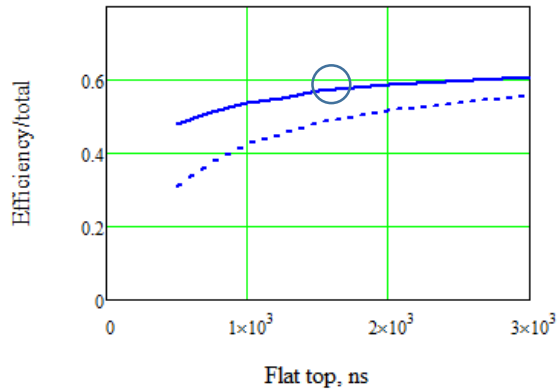


CERN/SLAC agreement has being signed.
The detailed results of the tube full optimisation (paper study) will be ready in 6(+?) months.

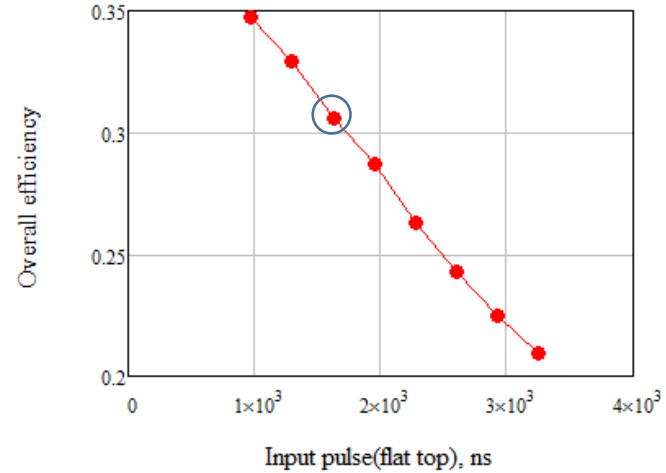
CLIC klystron based. Updates.

1. The klystron efficiency can be increased from 50% to **70(+)%**.
2. Using SLED-type pulse compressor, the useful RF power production period can include the modulator rise time:

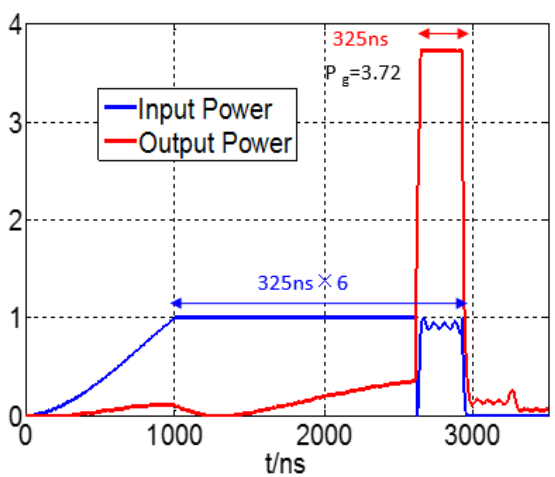


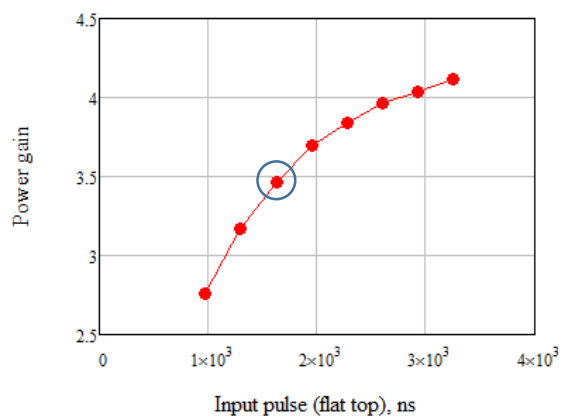


Overall (from plug to AS) RF power production and RF transfer (η_{tr}=0.9) efficiency.

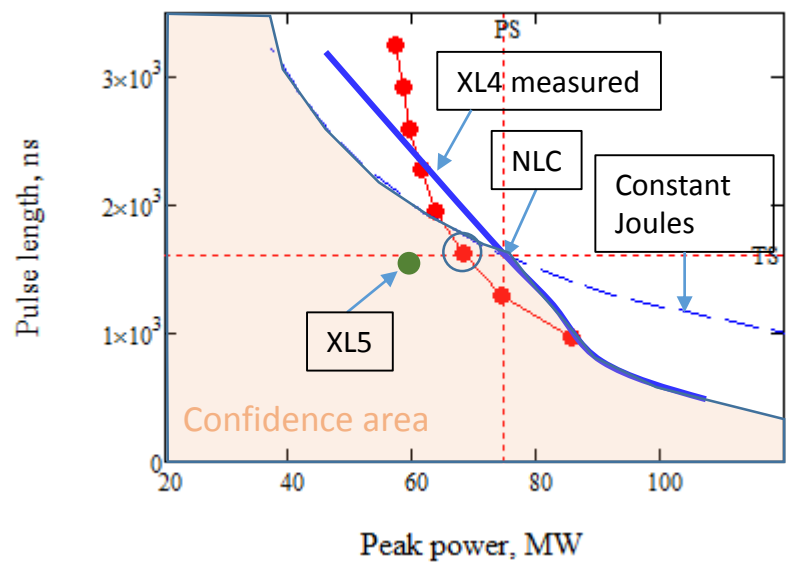


3. Compact SLED/CC pulse compressor:





Example of **10 x CLIC_AS x 42.5 MW x 325 ns**



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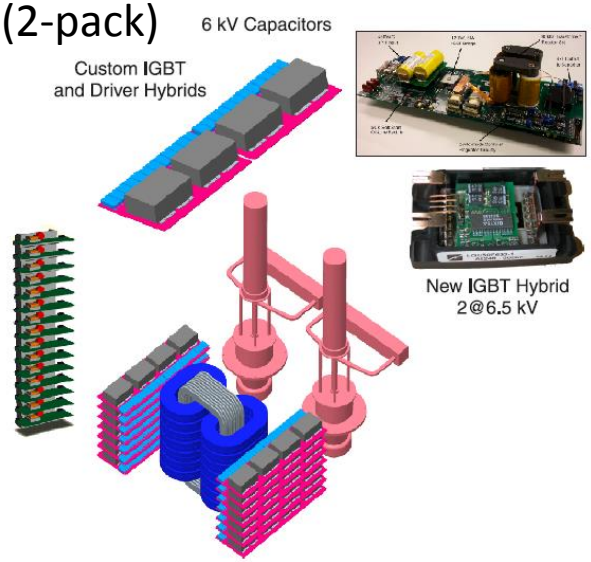
NLC HYBRID SOLID STATE INDUCTION MODULATOR*

R.L. Cassel, J.E. deLamare, M.N. Nguyen, G.C. Pappas @SLAC,
E. Cook, J. Sullivan @ LLNL, C. Brooksby @ Bechtell Nevada

IGBT MODOLATOR FOR X-BAND KLYSTRONS

V. Vogel, Y.H. Chin, M. Akemoto, S. Matsumoto, S. Tokumoto, High Energy Accelerator Researcher Organization (KEK), 1-1 Oho, Tsukuba, Ibaraki, 305-0801, Japan

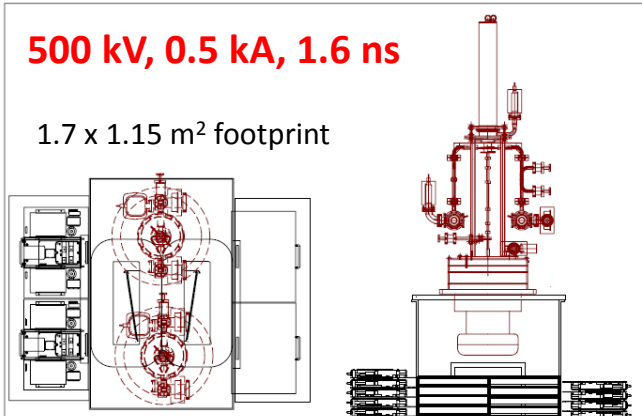
SLAC (2-pack)



2004: Integrated 2-Pack 1:10 Turn Design
Industrialized Custom 2-chip IGBTs
and Modular Power Supply System

500 kV, 0.5 kA, 1.6 ns

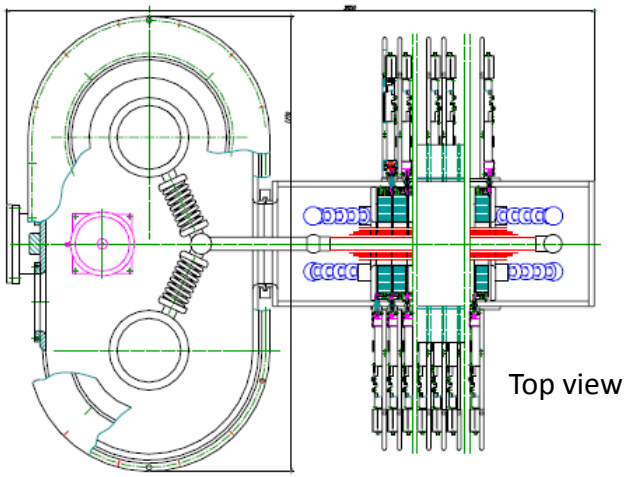
1.7 x 1.15 m^2 footprint



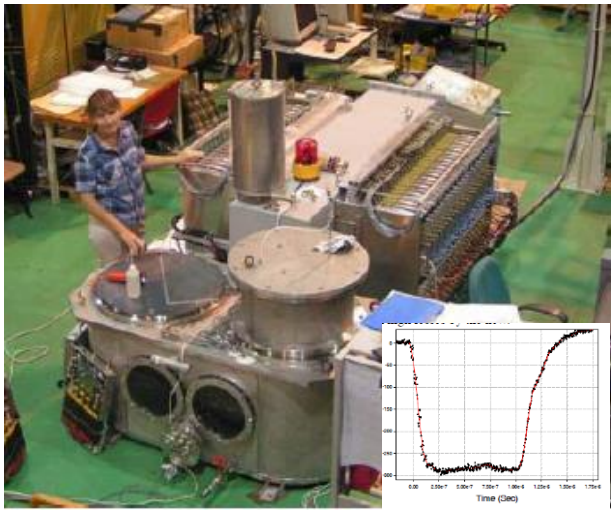
DFM2, concept

KEK(2-pack)

1.8 x 2.9 m^2 footprint.



Top view



These 'compact' modulators were developed back in 2004, but never have been build or tested to the full specs.

CLIC'k Klystron:
68 MW
$\mu K=1.2\ I/V^{3/2}$
1.63 μsec flat top

CLIC'k Modulator:
2-pack
366 KV
0.530 kA
1.65 μsec flat top

New CLIC'k RF unit layout

In a given (not yet fully optimised) example, the resent developments allow for substantial increase of RF power production efficiency (from 21.8% to 30.5%) and significant reduction of the complexity and cost (factor 4?) of the RF distribution system together with improved reliability.