TUZGBF5

KLYLAC PROTOTYPING FOR BOREHOLE LOGGING

IPAC2018

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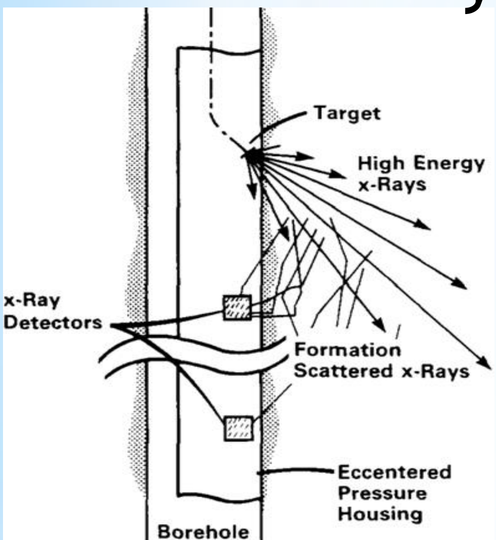
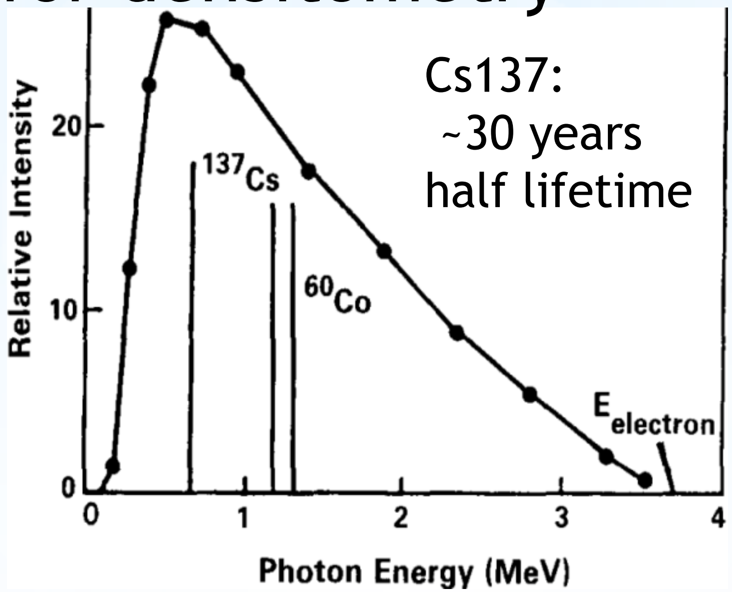
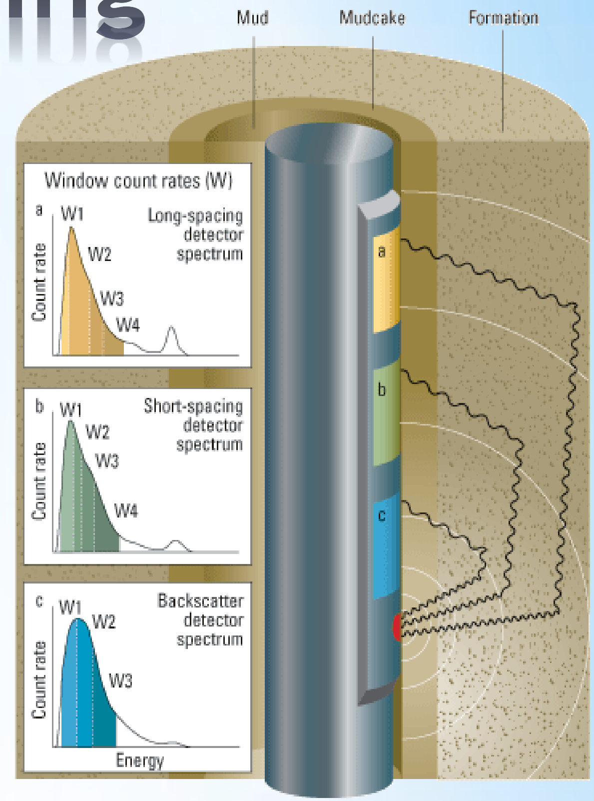
DoE SBIR Phase II 1st year project

X-Ray Well Logging

is employed for ~50 years mostly for densitometry





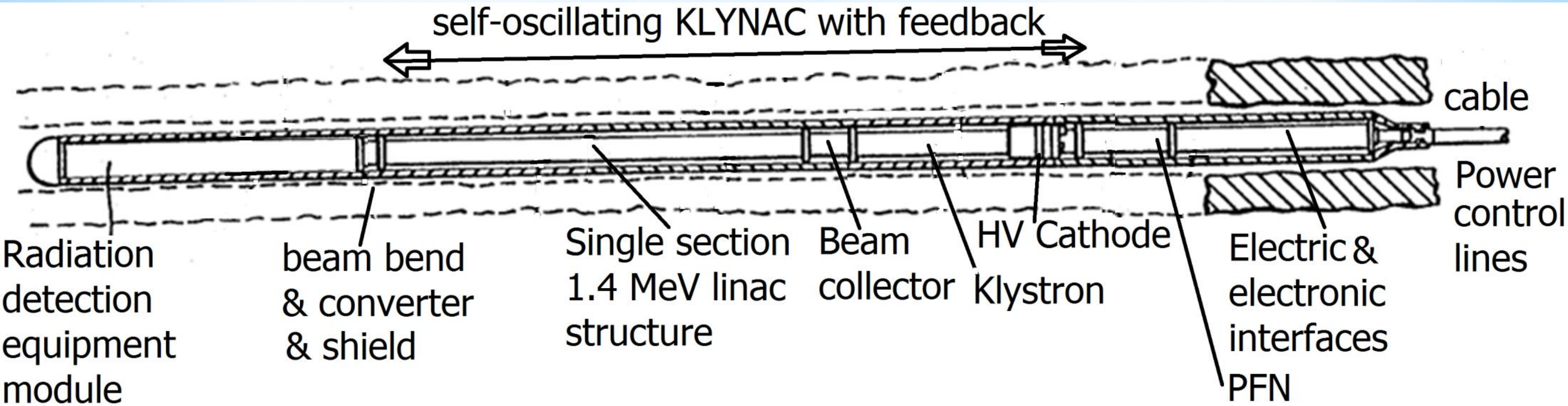


Linac-based source to eliminate proliferation hazard and radiological dispersion ("dirty bomb")

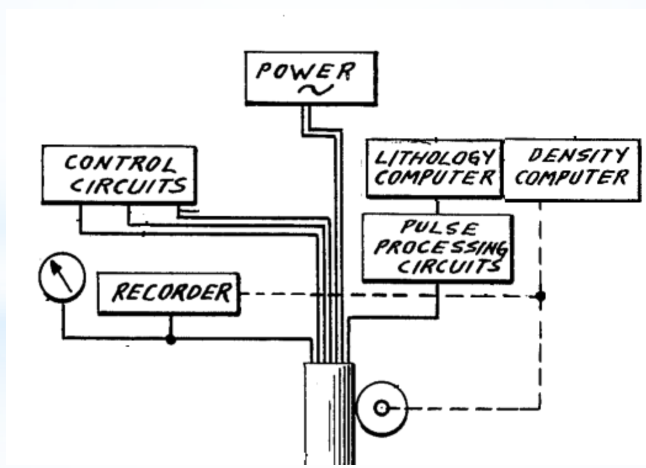
The design should be capable of:

- Scalablity to replace Cs137 source (>~2.5 MeV energy)
- Borehole target: ∅3.5"
- High operating temperature: up to ~140-150°C
- Vibrations: ~(1-2)G
- External magnetic fields (n×100 Gauss)

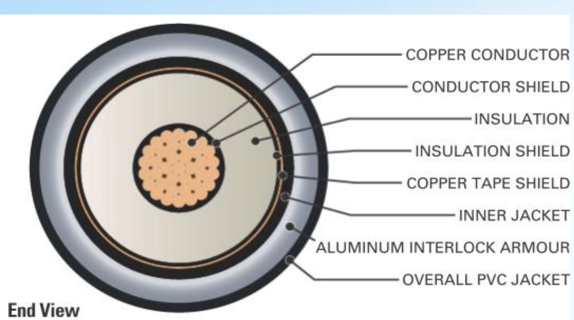
Borehole Tool Schematics



On-ground station



HVTEC CSA C22.2 No. 174
power cable from Southwire



KlyLac concept

C. Nygard, Patent number 2,922,921, 1960

S.O. Schriber, Canadian Patent 1040309, 1978

B.Yu.Bogdanovich PAC’97

KlyNac (LANL)

W.E. Stein, IEEE Trans. NS 30, N2(1983)

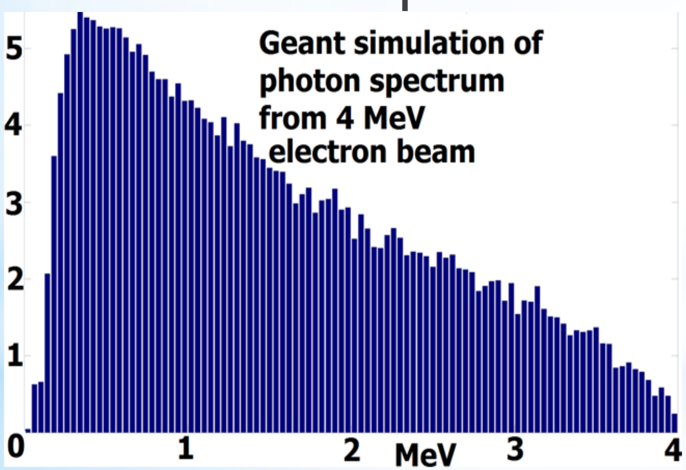
Smirnov

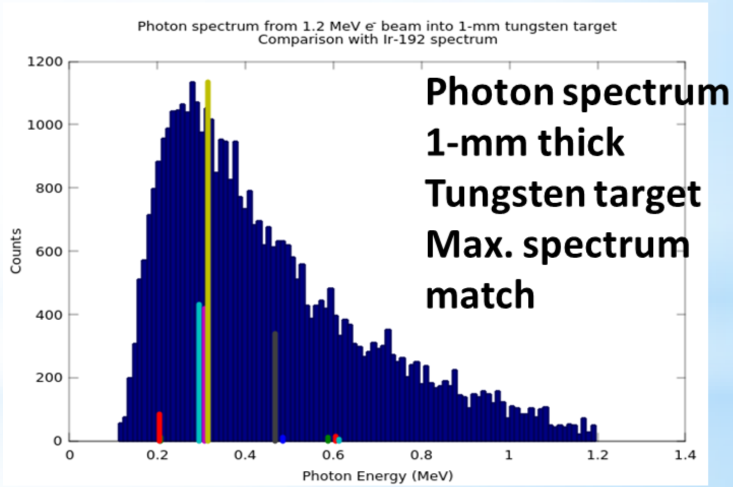
B. Carlsten, K.E. Nichols NIMA877 (2018)

Phase II Technical Goal

The main goal of the Phase II project is to demonstrate operation of a ~1 MeV **KlyLac** prototype capable to produce 5 μA beam current and beam average power >5 W (corresponding to a few Ci activity).

* E-beam energy: ~1 MeV
* Pulse current: >2mA
* Pulse power: >5 kW



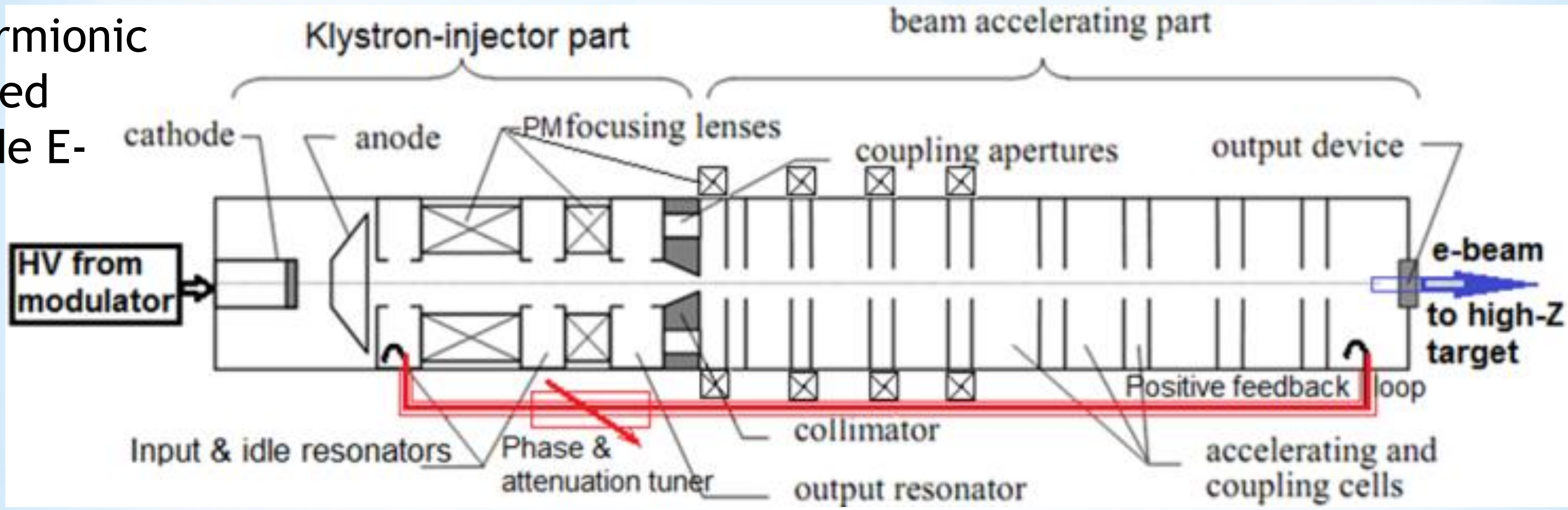


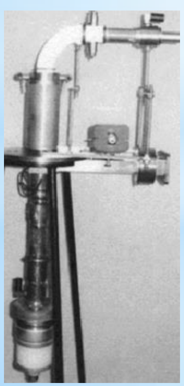
KlyLAC 1 MeV Prototype

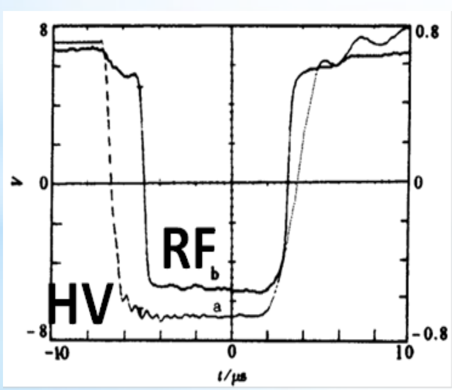
Sheet Beam Klystron (SBK) section

Robust bi-periodic linac structure

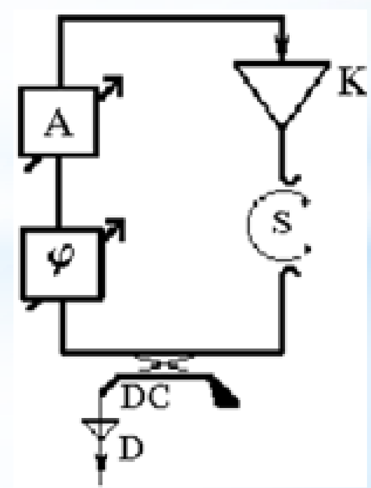
Thermionic Pulsed Diode E-Gun







Positive feedback loop self-oscillating RF system starting from noise.



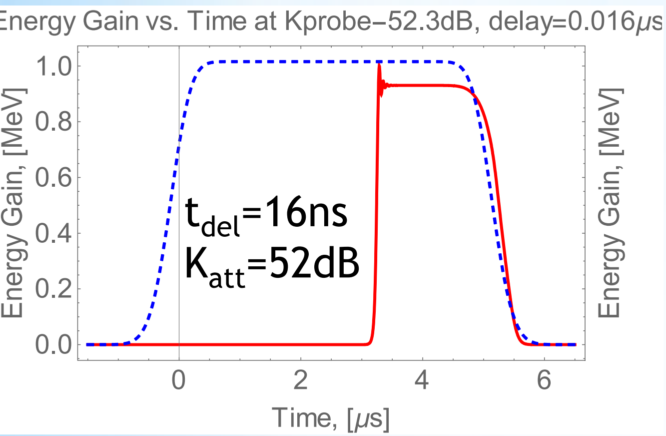
That system enables fast self-adjustment of the frequency provided it is stable

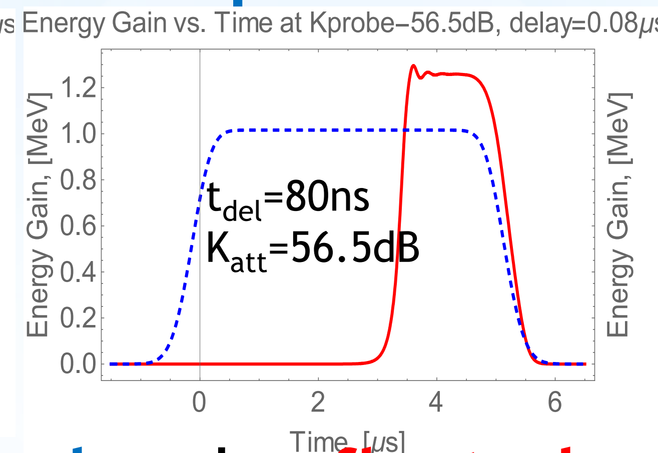
Self-oscillation performance

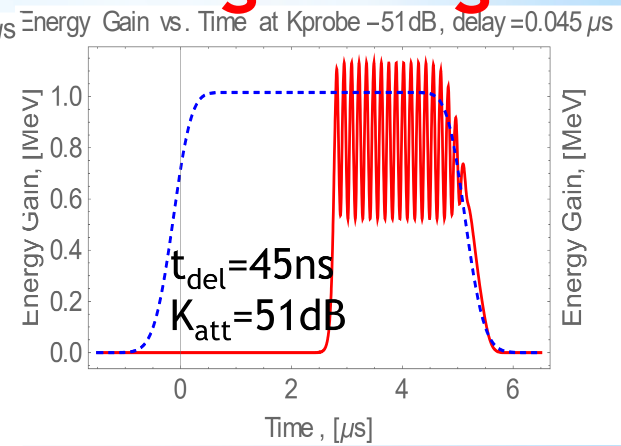
$$\frac{dU}{dt} + (1+\beta_c)\frac{\omega}{2Q_o}\mathrm{U} = \frac{\omega}{Q_o}\sqrt{\beta_c R P_{frwrd}(t,U)}$$

NIMA 868 (2017)

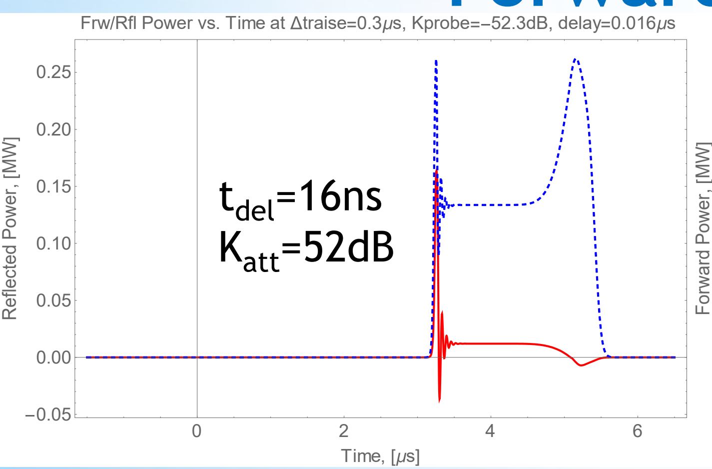
Normalized HV Envelope and accelerating voltage

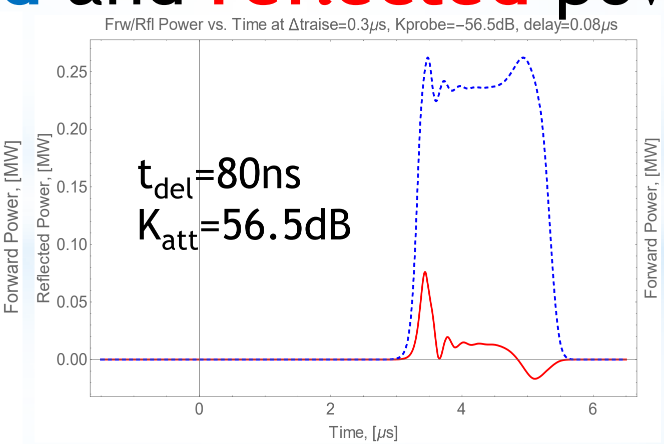


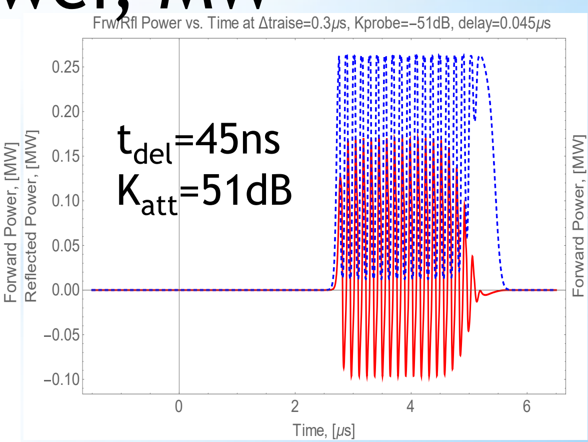




Forward and reflected power, MW



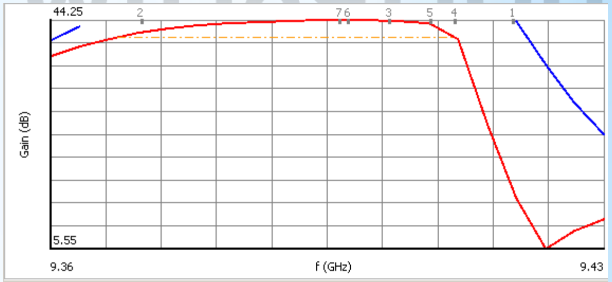


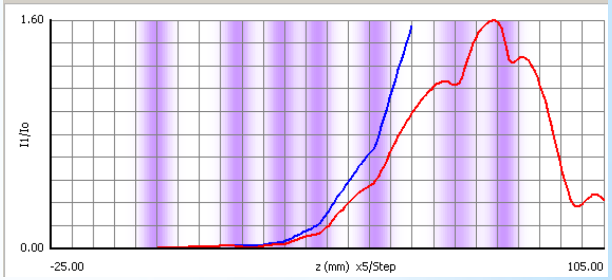


Technical Risk Mitigation

Stabilization of self-oscillation (group delay reduction)

- Flatten the klystron Gain(f) by detuning the cavities;
- Introduce equalizer into the feedback loop (multi-pole filtering).





Other technical solutions for KlyLac Phase II

* Extremely robust linac (high group velocity, Rsh independent on t°).
* Adapt the design to M0.5 ScandiNova modulator 24 kV 23-28 A.
* Increase aspect ratio of the SBK cavities to increase field flatness and coupling coefficient (gain, efficiency).
* 3-section PM “solenoid” for the linac section.

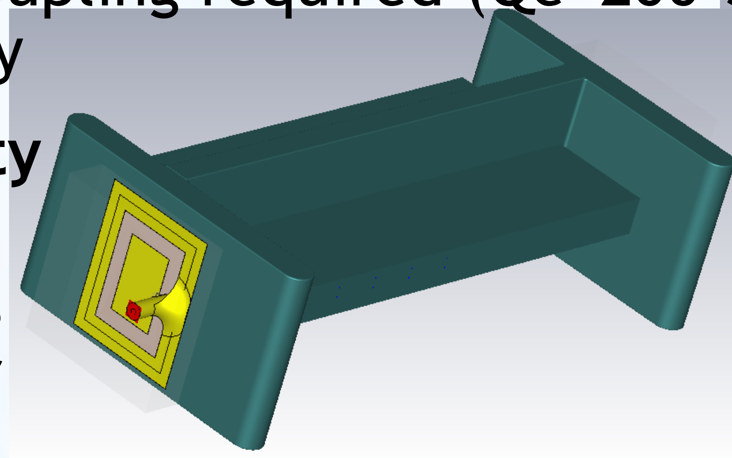
Four Types of SBK Cavities

Challenge: how to provide
1. uniform interaction at
2. right frequency,
3. sufficient beam coupling (M>0.45)
4. i/o RF coupling required (Qe~200-350).
5. Tunability

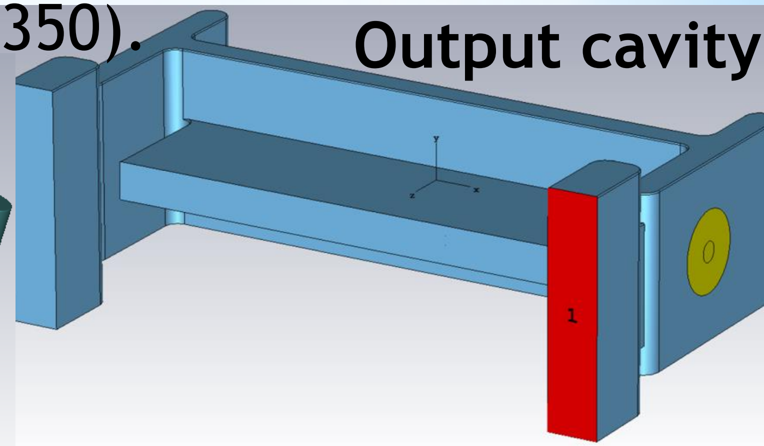
New beam aperture: 3.7 mm × 50 mm (instead of 4.79 mm × 30 mm)

Input cavity

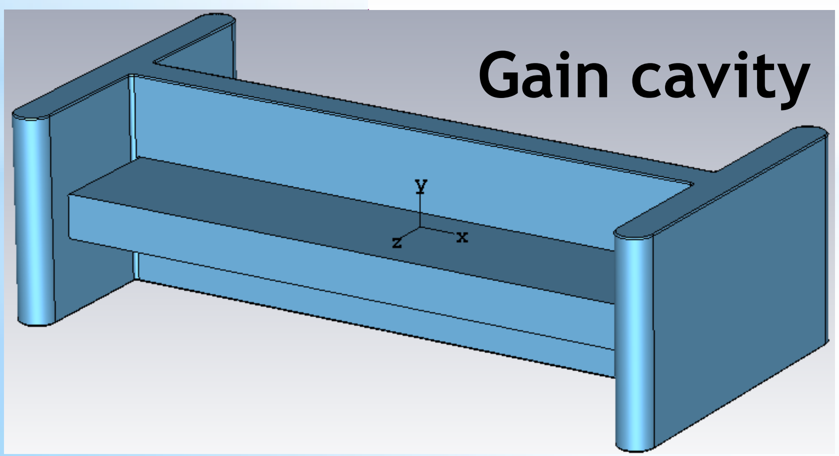
Custom ceramic PCB coupler



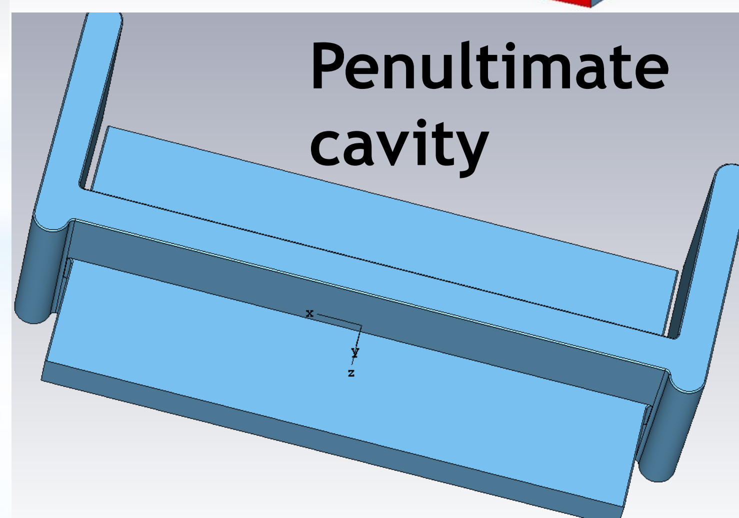
Output cavity



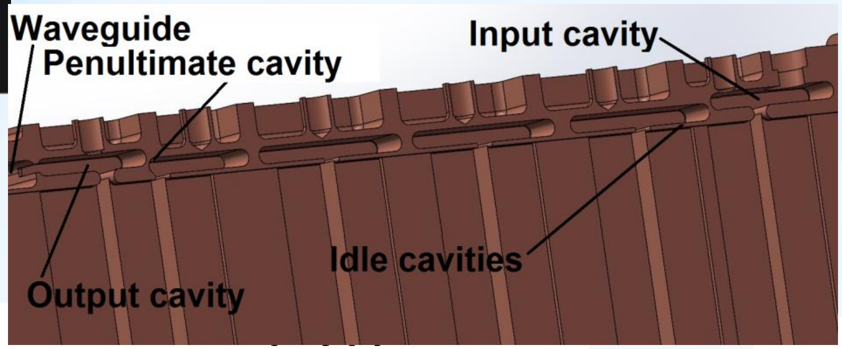
Gain cavity

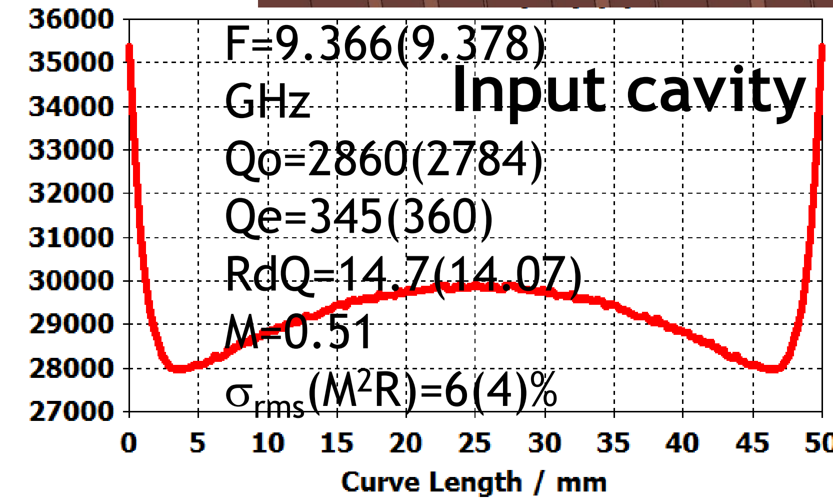


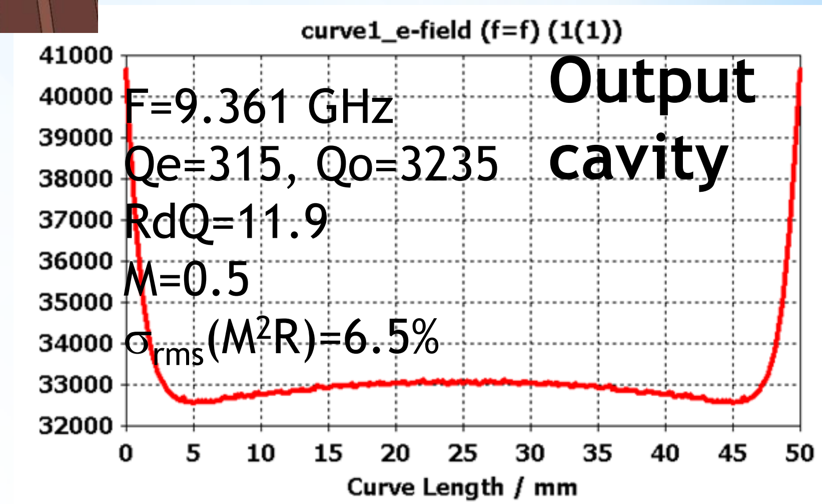
Penultimate cavity

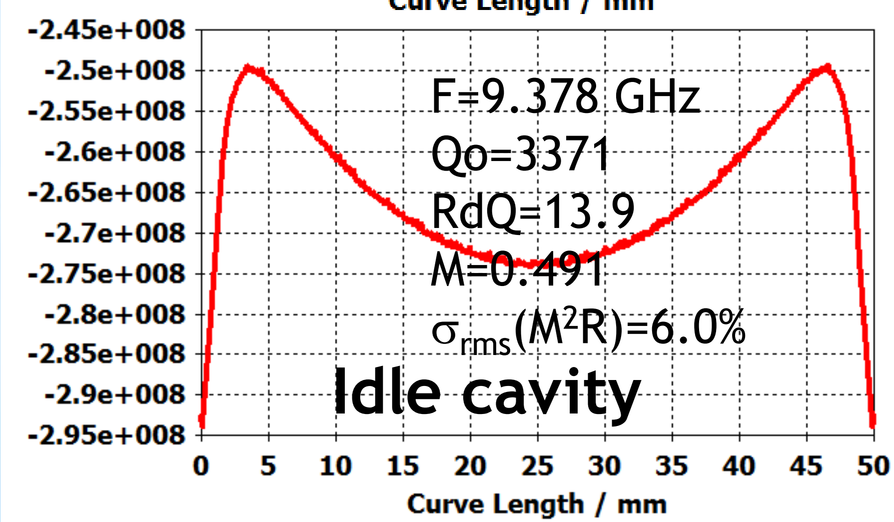


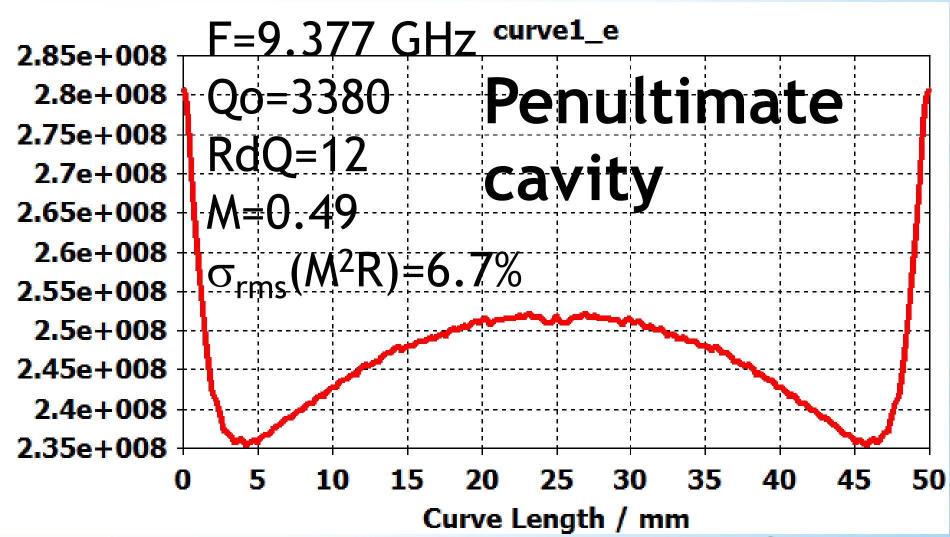
SBK Cavities Performance



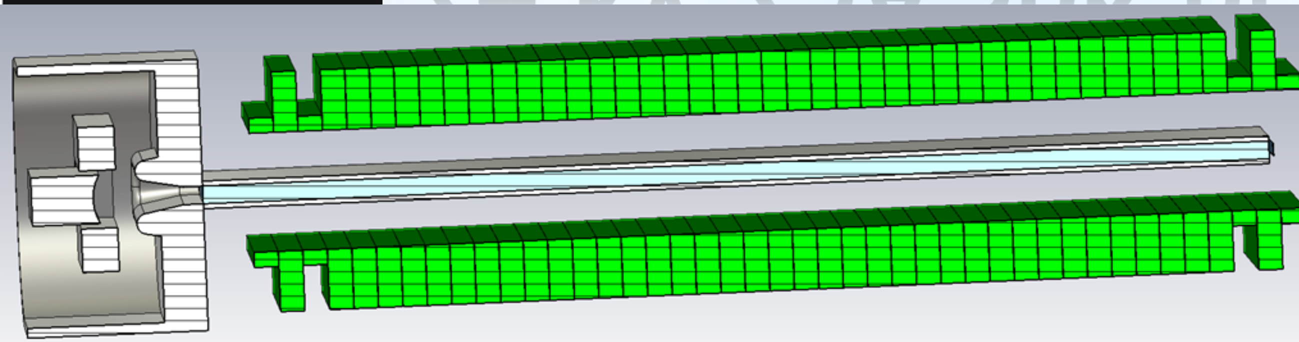


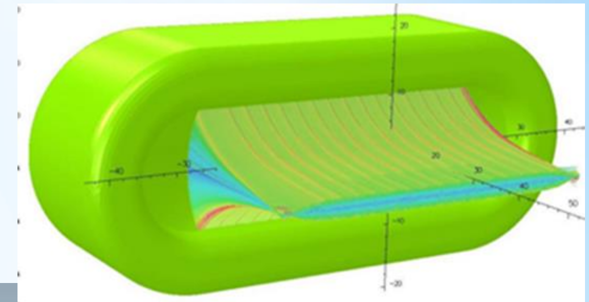


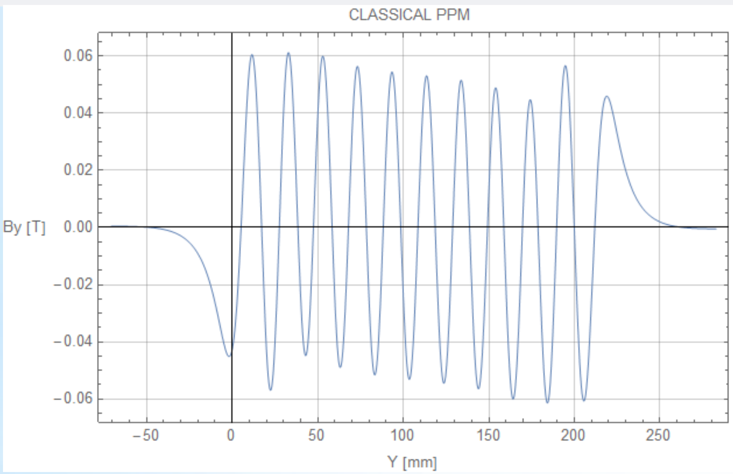


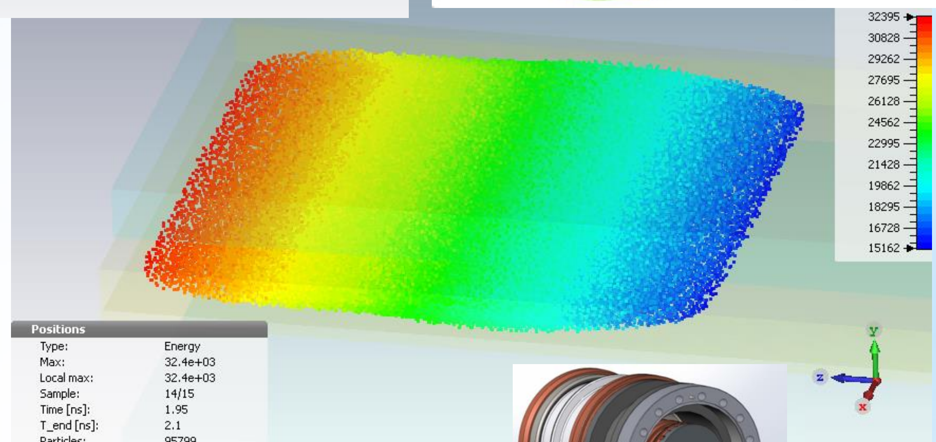


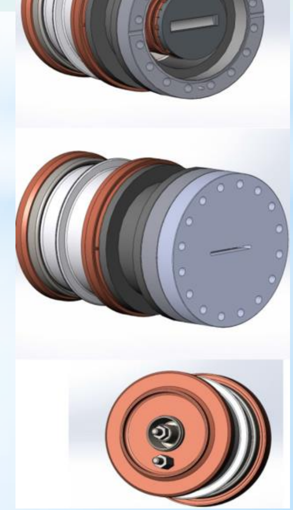
24 kV 23A SBK BEAMSTICK





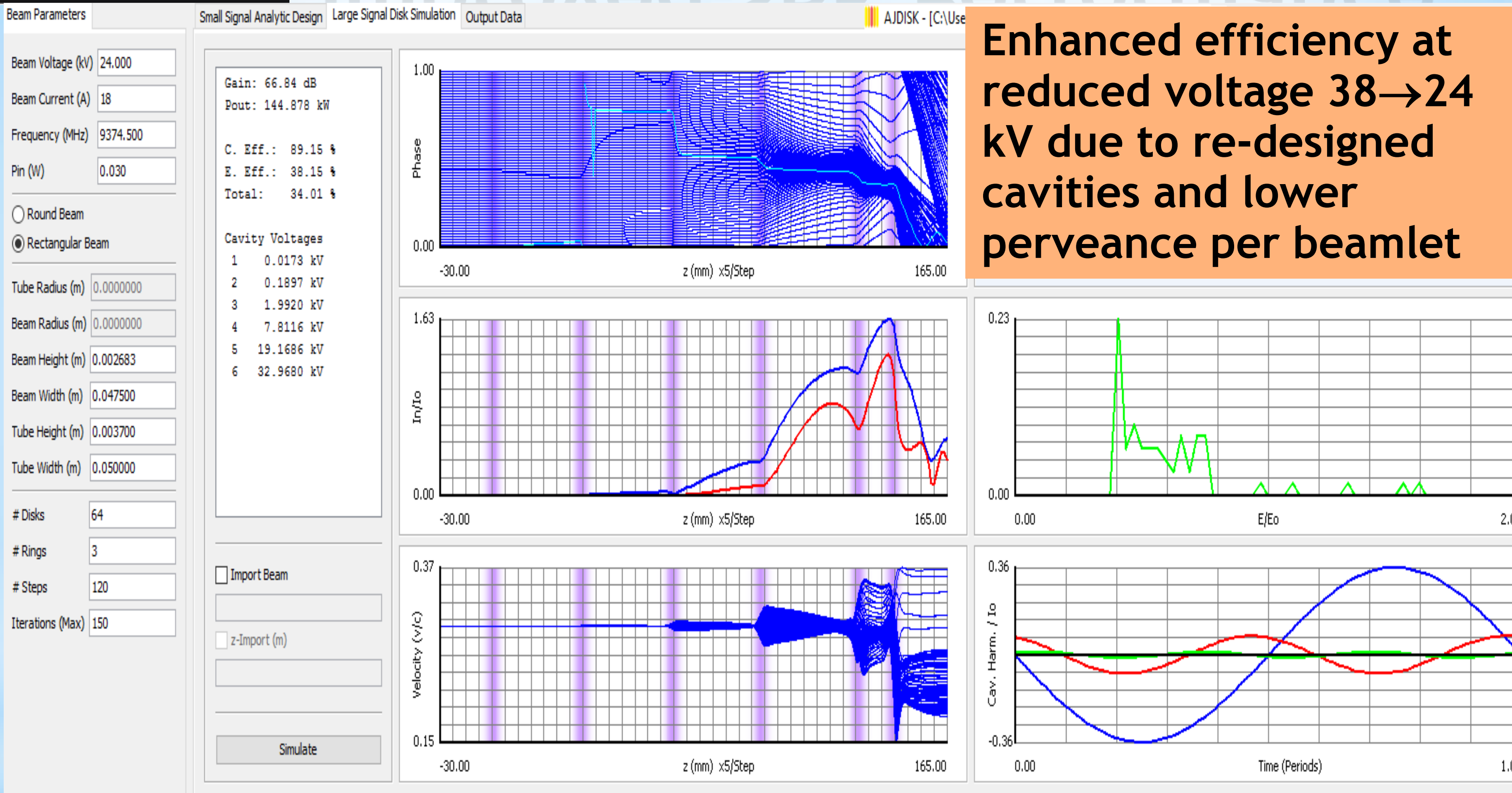






Improved SBK Performance

Enhanced efficiency at reduced voltage 38→24 kV due to re-designed cavities and lower perveance per beamlet

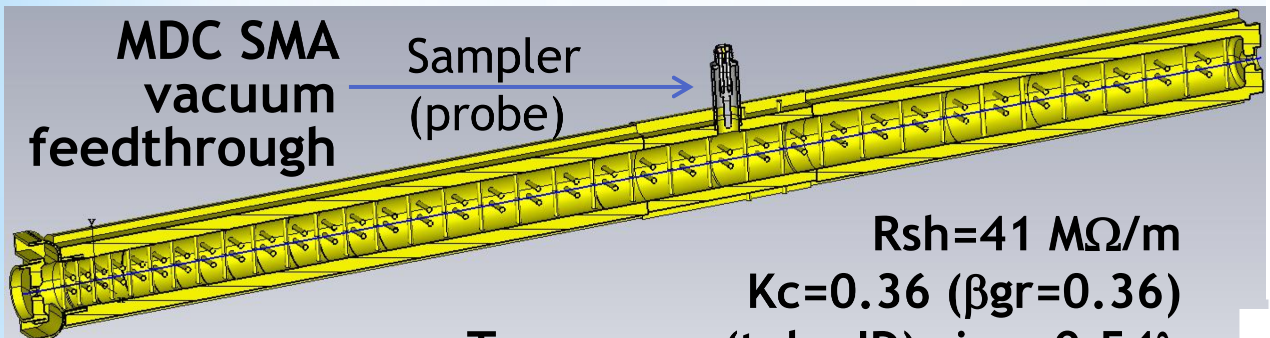


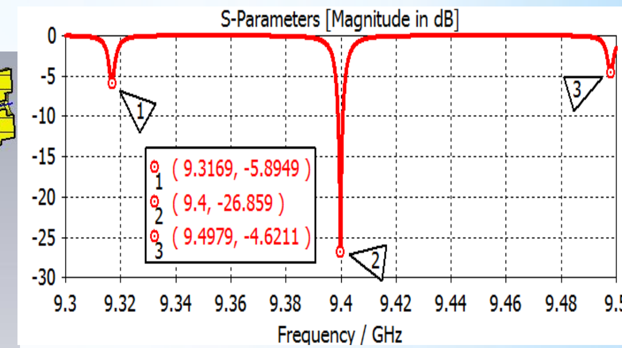
Cavity Parameters

Cavity ID, Unused	R/Q (ohms)	M or SF7 Grid File, z(m)	Qe	Qo	f (MHz)	z (m)	d (m), Unused	Harmonic
1	14.070	0.5100	361.000	2227.000	9359.600	-0.00930	0.0000000	1
2	13.925	0.4914	99000.000	2865.000	9371.000	0.02477	0.0340700	1
3	13.925	0.4914	99000.000	2865.000	9371.000	0.05976	0.0349900	1
4	13.925	0.4914	99000.000	2865.000	9394.000	0.09370	0.0339400	1
5	12.128	0.4920	99000.000	2883.000	9400.900	0.13111	0.0374000	1
6	11.904	0.5000	315.110	2588.000	9360.092	0.14454	0.0134400	1

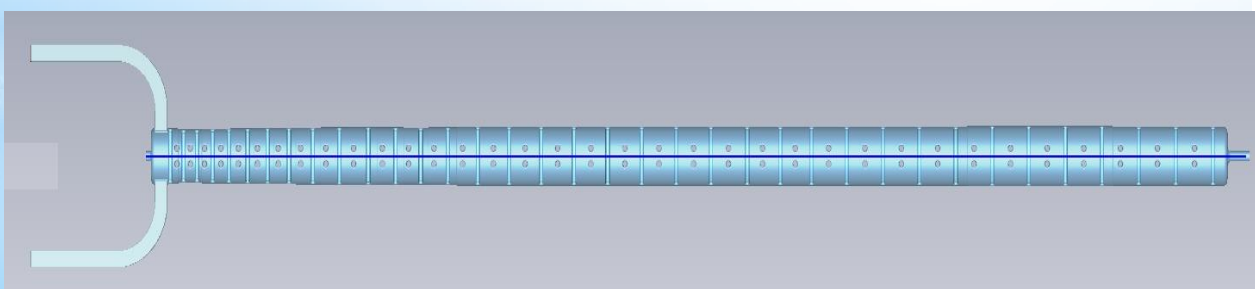
Accelerating section: Design Challenges

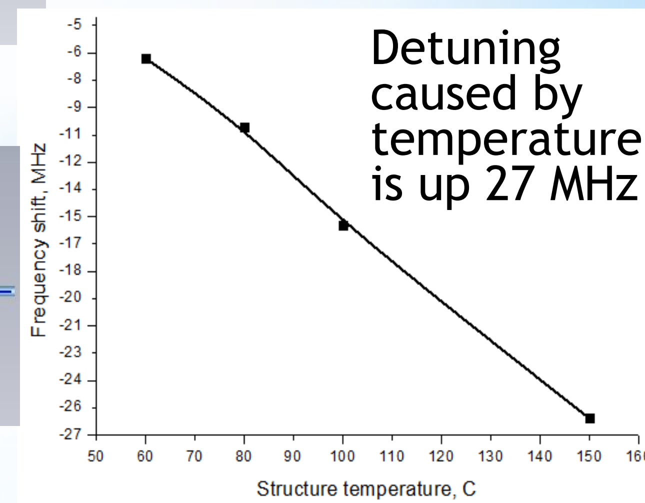
- Extreme robustness:
- No tuners for structure cells
- E(z) and Rsh(z) should not depend on: T°, ∇_zT°, and vibrations
- Minimum possible transverse dimension
- Large frequency separation > thermal detuning



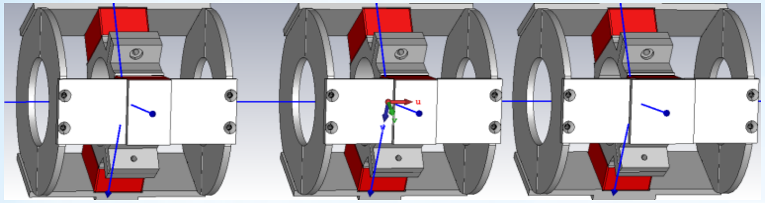


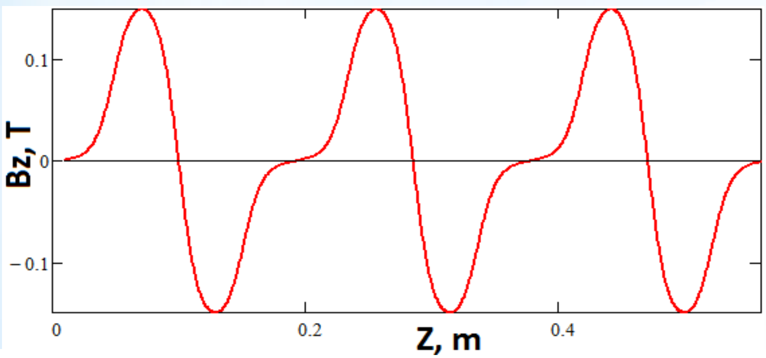
Rsh=41 MΩ/m
Kc=0.36 (βgr=0.36)
Transverse (tube ID) size: 0.54λ
Frequency separation: 80 MHz



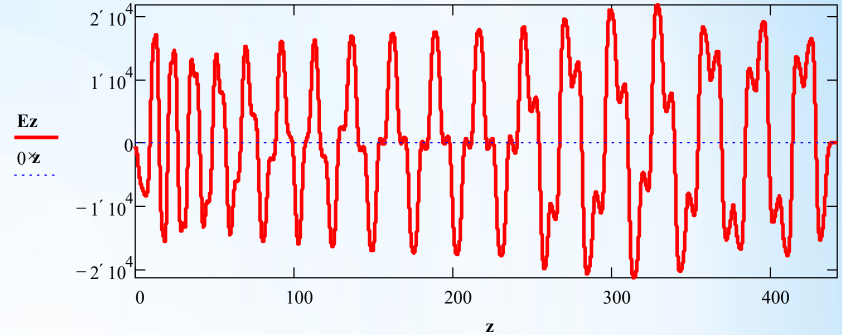


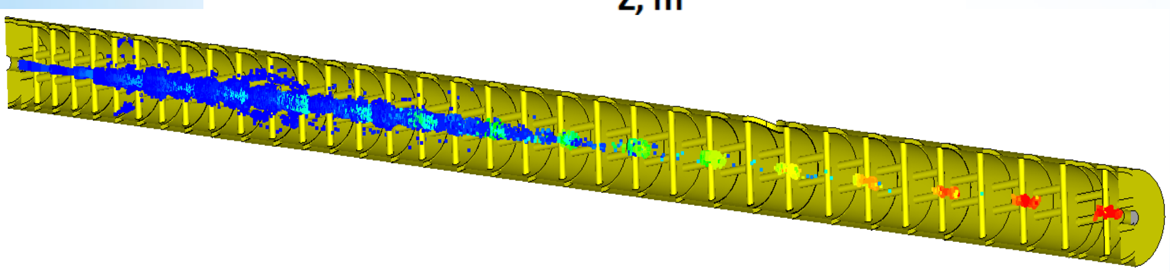
Linac beam dynamics

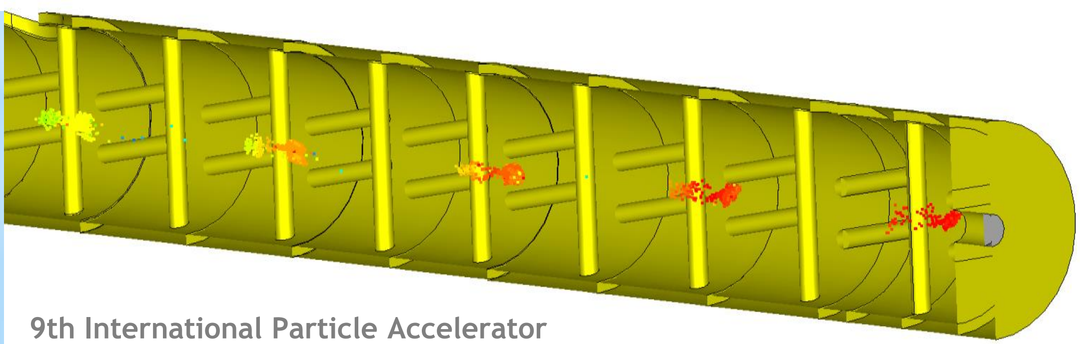




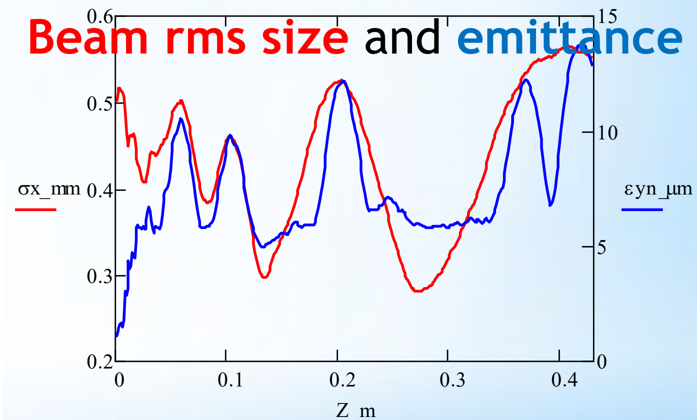
Field profile along the linac

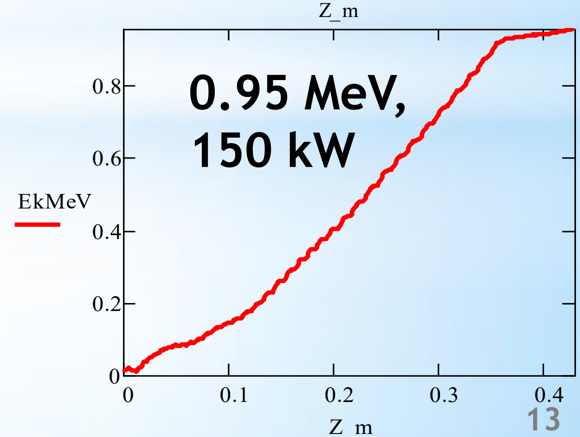






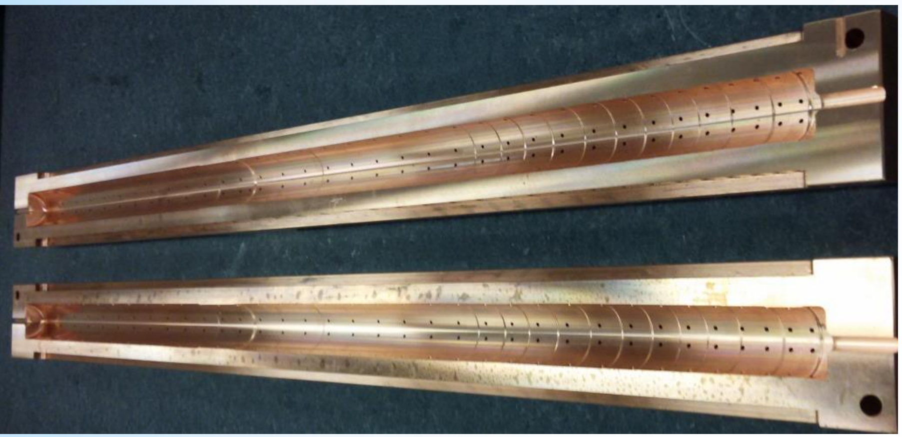
Beam rms size and emittance

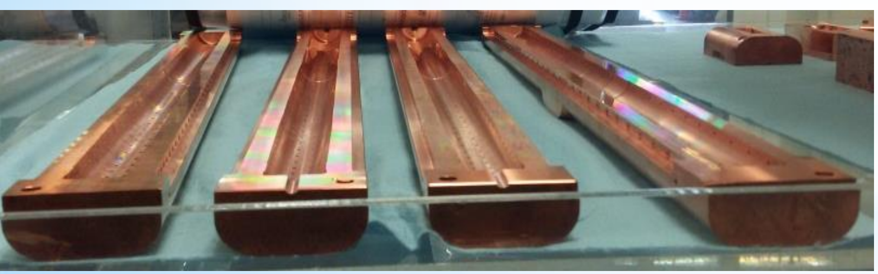




Accelerating section construction & pre-fabrication

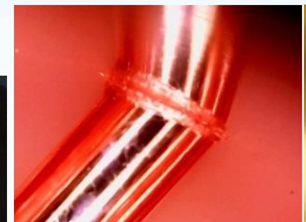
Phase II linac tube with holes EDM-ed for pins

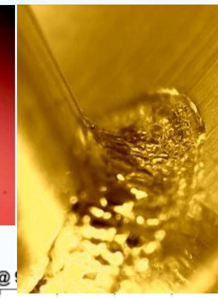


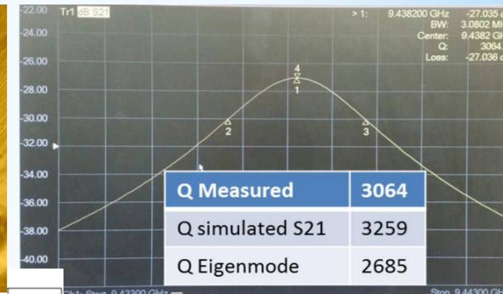


No tuning is required!

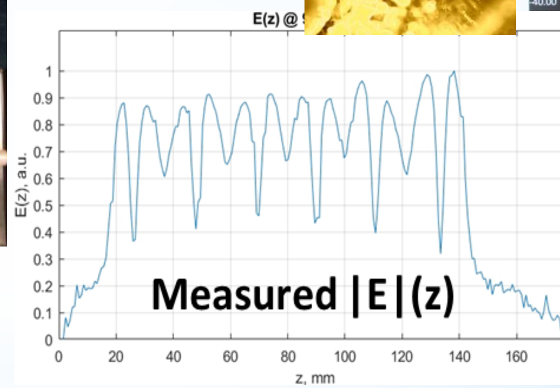
Phase I Cross-pin 6-cell mockup

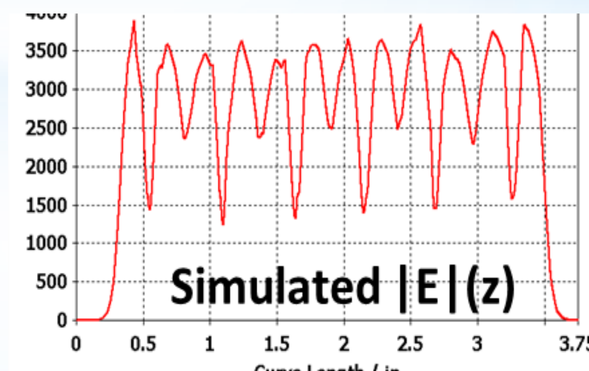


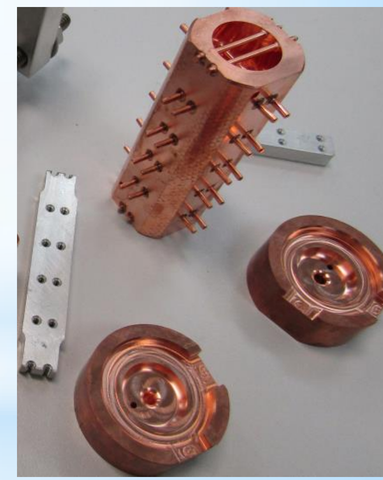




Q Measured	3064
Q simulated S21	3259
Q Eigenmode	2685

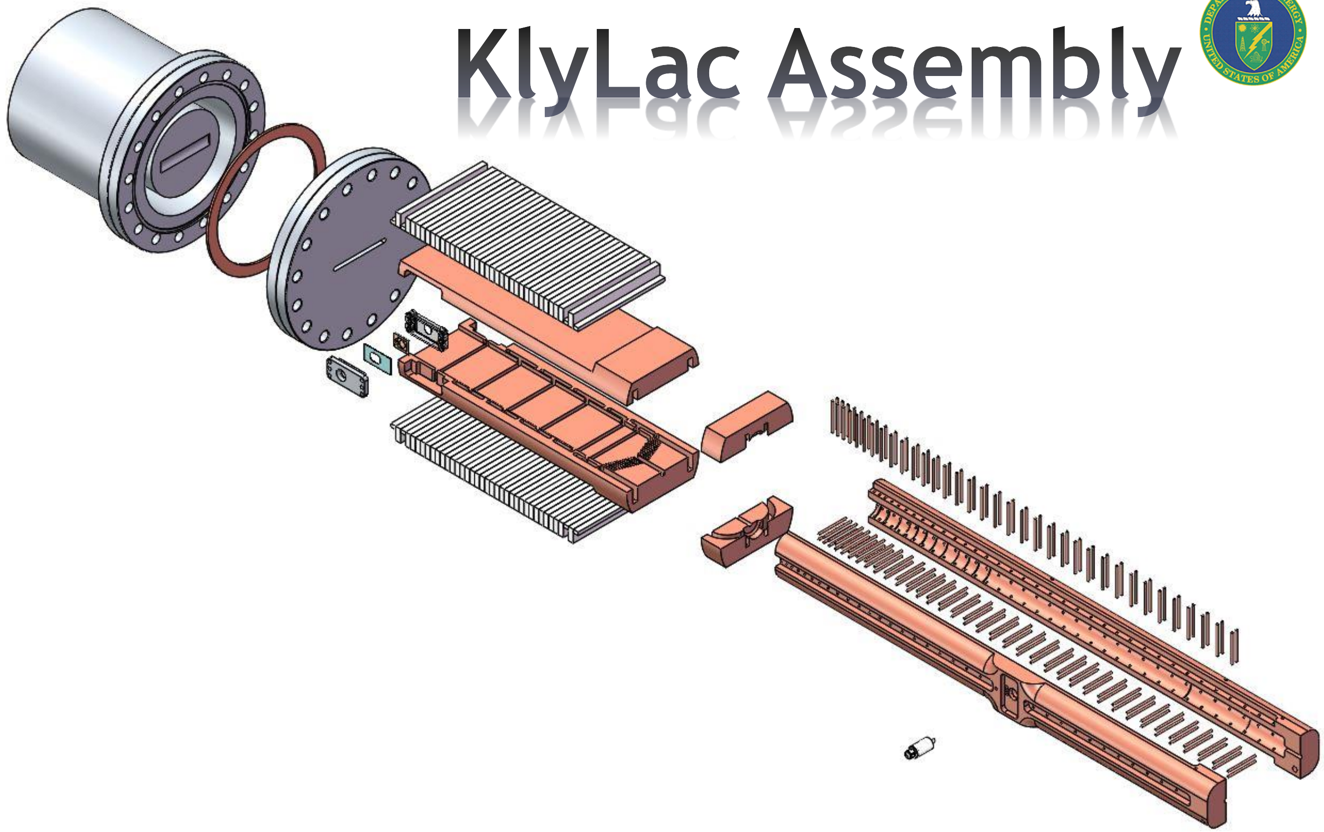


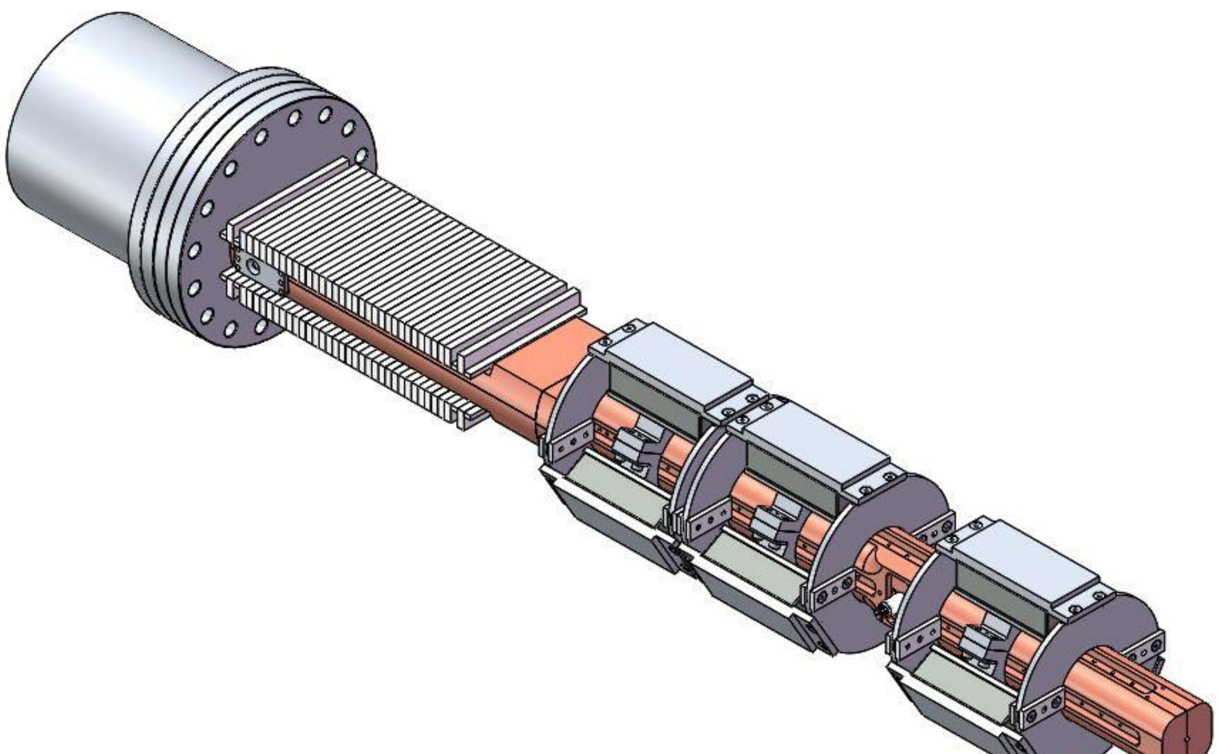




9th International Particle Accelerator Conference, Vancouver, April 29 - May 4, 2018

KlyLac Assembly





9th International Particle Accelerator Conference, Vancouver, April 29 - May 4, 2018

Summary

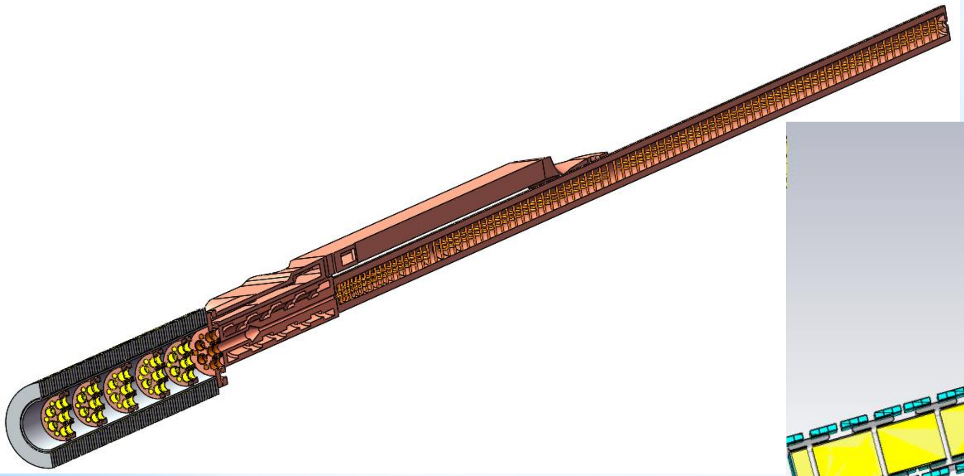
- Stable feedback operation is proved to be feasible
- Low voltage flat beam beamstick is designed
- SBK gun is under fabrication
- PPM SBK is designed
- Extremely robust linac structure is designed, fabrication is in progress.

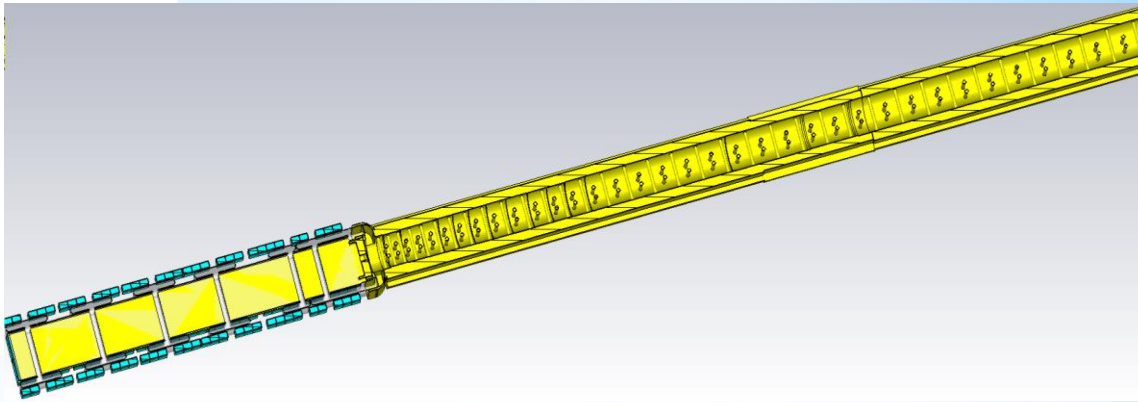
Next steps

* Test the SBK gun under fabrication.
* Assemble beamstick and test it.
* Fabricate SBK structure, assemble and test it.
* Fabricate transition region, attach it to the SBK and the linac.
* Perform KlyLac tests.

Acknowledgements

* Bruce Eric Carlsten, LANL
* Sergey Kurennoy, LANL
* Ahmed Badruzzaman, Pacific Consultants and Engineers
* IPAC2018 Organizing Committee.





THANK YOU!