

36GHz HOM MBK design status

2020/06/12

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Outline

- Beam-wave interaction analysis
- Beam optics Design

KlyC simulation results

The screenshot displays the KlyC simulation software interface. The top-left panel contains file management buttons (New, Open, Save, Save as, Simulate) and a 'Power Ramp' control set to 10. The 'Beam Para.' section shows: Beam Voltage (kV) = 60.000, Beam Current (A) = 6.000, Outer Radius (mm) = 0.800, Inner Radius (mm) = 0.000, Tube Radius (mm) = 1.000, Beam Number = 20, and Layer Number = 4. The 'Accuracy Setting' section includes: Space Charge Field Order = 8, Division Number in λ_e = 256, Division Number in RF = 128, Max Iterations = 50, Iteration Residual Limit = 0.001, and Iteration Relaxation = 0.5. The 'Excitation source' section shows: Pin (W) = 180.000, degree = 360.000, and chirp = 0.000. The 'Simulation results summary' section displays: Pout = 2418 kW, Gain = 41.28 dB, Eff.RF = 34.09 %, Eff.BI = 33.58 %, Re.RF = 0.0009066, Re.EI = 0.0003415, IJ1/J0|i = 1.451, IJ1/J0|o = 1.875, ve/c.min = 0.1906, |Gama| = 0.2847, pha.s = -176.7 °, and Tcpu = 8.425 min. A table of results shows |Vg|(kV) and phi(d.)/E kV/m values. The 'Cavity Parameters' table is as follows:

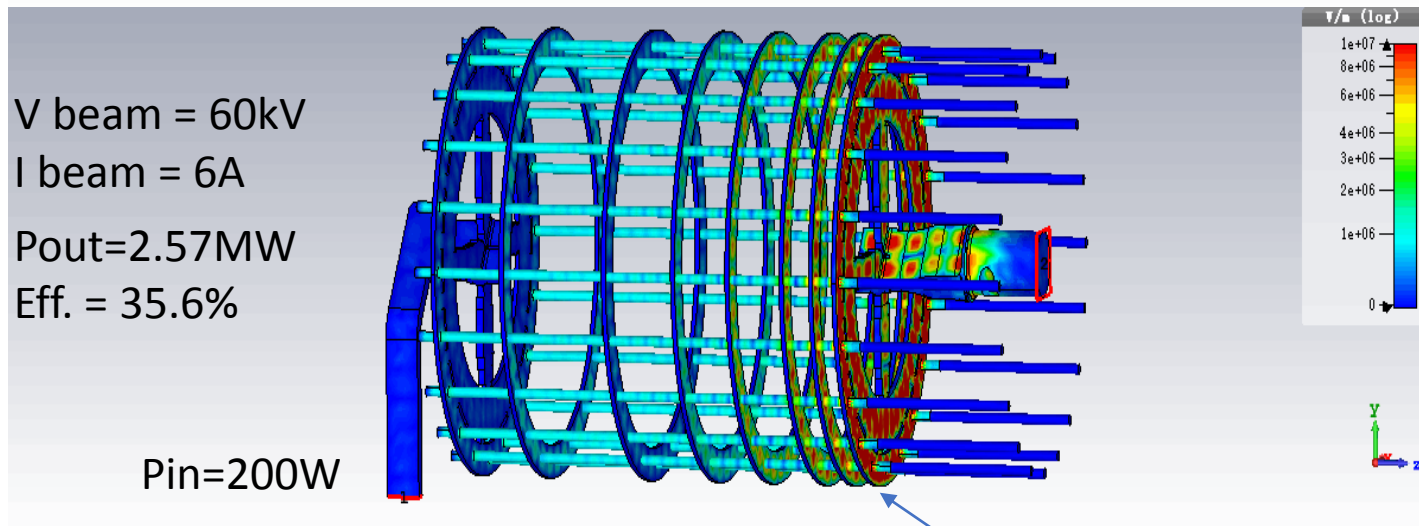
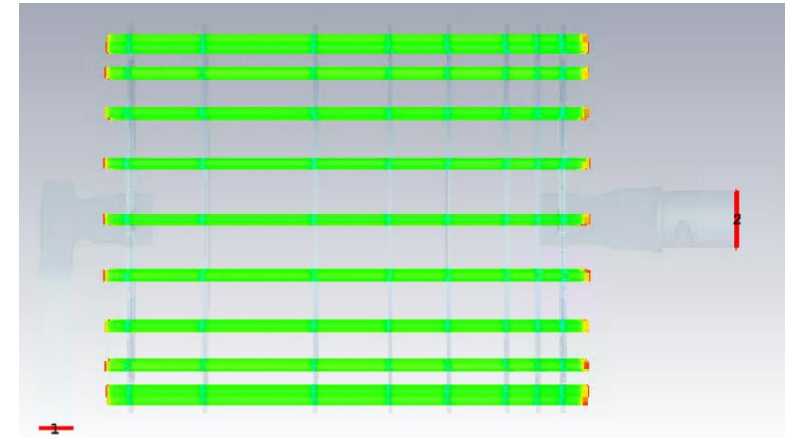
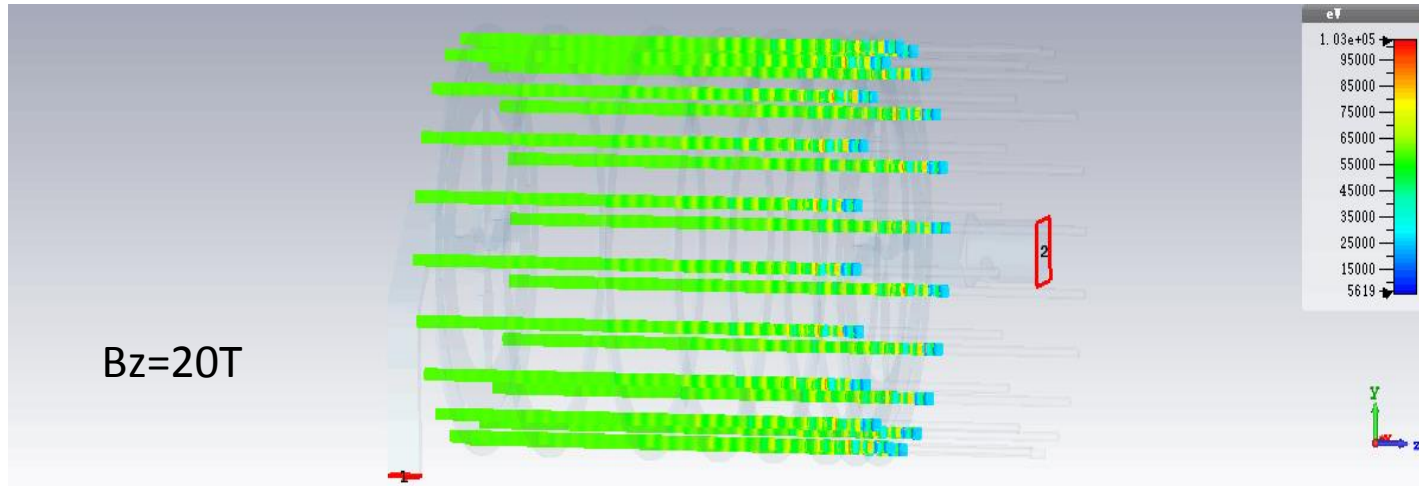
ber	Type	Harm...	f0(MHz)	R/Q (Ω)	M	Qe	Qin	z (mm)
1	0	1	36000	1.0744	0.5680	840	2550	0
2	1	1	36062	1.3452	0.5638	9.7362e+04	2450	16.6000
3	1	1	36067	1.3450	0.5637	9.7361e+04	2450	41.3000
4	1	1	36113	1.3433	0.5630	9.7355e+04	2450	58
5	1	1	36123	1.3429	0.5629	9.7353e+04	2450	71.1000
6	1	1	36134	1.3425	0.5627	9.7352e+04	2450	84.1000
7	1	1	36062	1.3452	0.5638	9.7362e+04	2450	91.1000
8	-1	1	35996	1.0745	0.5681	840	2550	96.7000

The bottom panel shows 'Cavity Number' = 8, 'Add Cavity', 'Behind of No.' = 1, 'Delete Cavity', 'No.' = 2, 'coupling' = zero, 'Update Cavity', 'No.' = 8, 'field map', and 'Edit' buttons. The 'KlyC' logo is visible in the bottom right corner.

- ✓ The saturation output power is 2.4MW
- ✓ The saturated efficiency is 33.6%
- ✓ Gain=41dB
- ✓ Emax=67kV/mm
- ✓ -3dB bandwidth is [-22MHz, +28MHz]

- ✓ Tube is compact as a whole and could be installed quite close to the linearizer as plug-in/ plug out module
- ✓ Frequency tuning for each cavity will be a technical challenging
- ✓ Bandwidth is little bit narrow, which leads to 80% linearizer performance comparing with infinite bandwidth;
- ✓ More results will be available in coming weeks

CST 3D simulations of entire 20 beams 36GHz MBK (KlyC benchmark, $B_z=20T$)



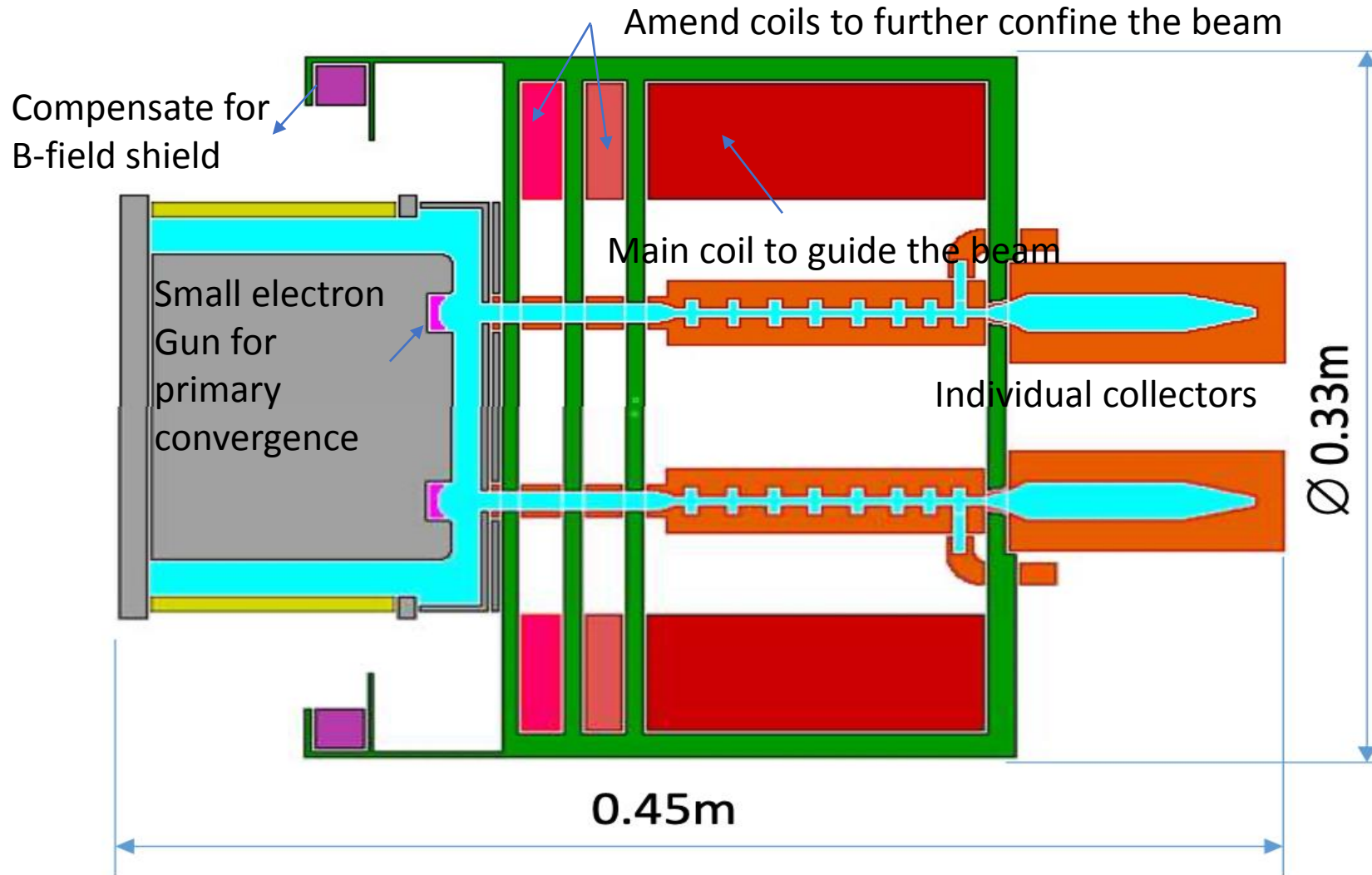
$E_{max} \sim 90kV/mm$

- RF circuit was optimized in KlyC.
- Input (output) coupler combiner topology provides efficient extraction of RF power into H_{01} in the circular waveguide.
- RF circuit length 11cm.

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Basic Topology of the optics



- ✓ $V=60kV$, $I=6A$, $r_m=0.8mm$, $r_c=1mm$
- ✓ 20 beamlets on radial position of 38.4mm
- ✓ The radial margin for each beamlets on the cathode is 6mm;
- ✓ Limited control electrode makes double convergence necessary
- ✓ Individual collectors are used for power dissipation
- ✓ Design could be based on single beamlet if beam-beam interference and transverse magnetic field could be ignored

Simulation Tool

- CGUN (home-made 2D code), benchmarked with CST TRK, DGUN, Michelle...

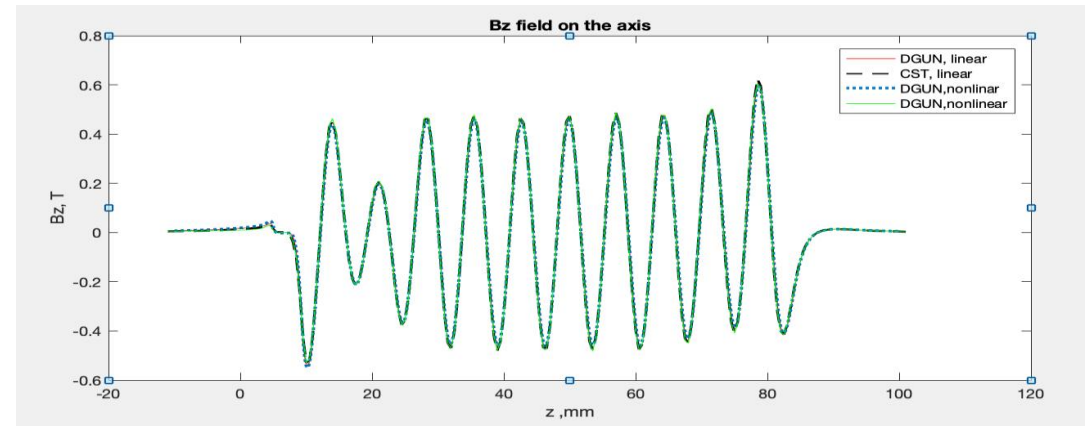
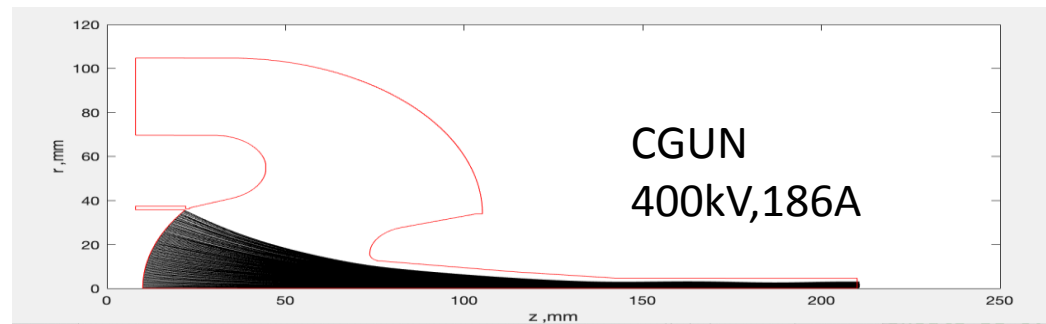
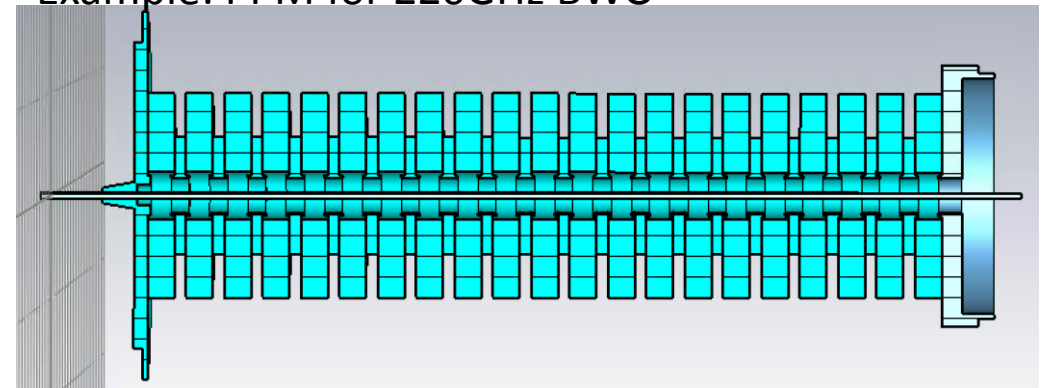
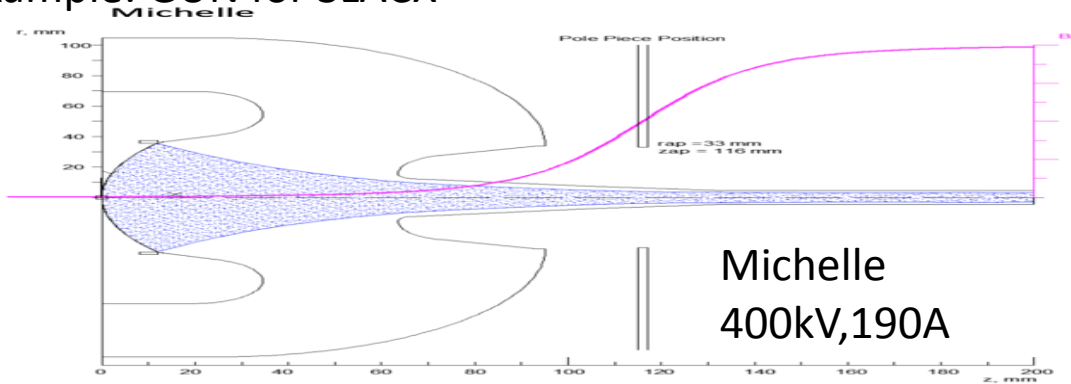
Beam optics module

Some benchmark results for complicated cases

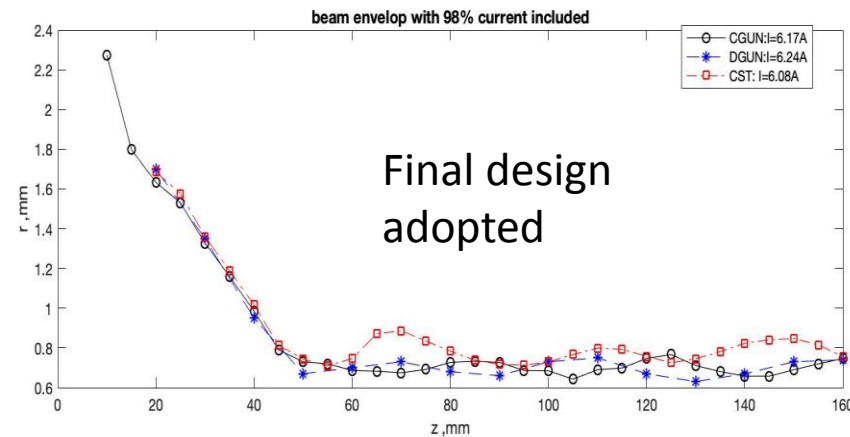
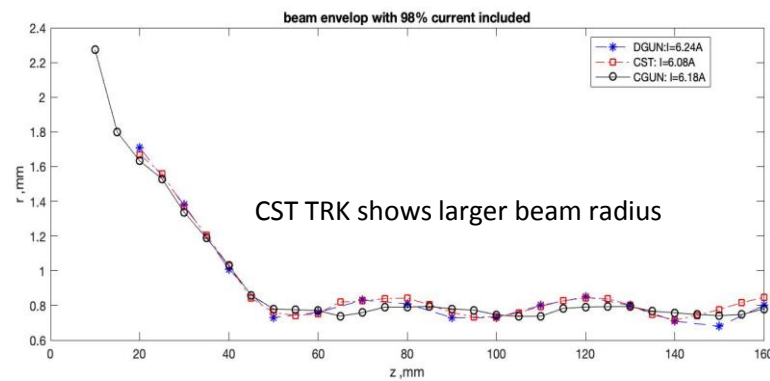
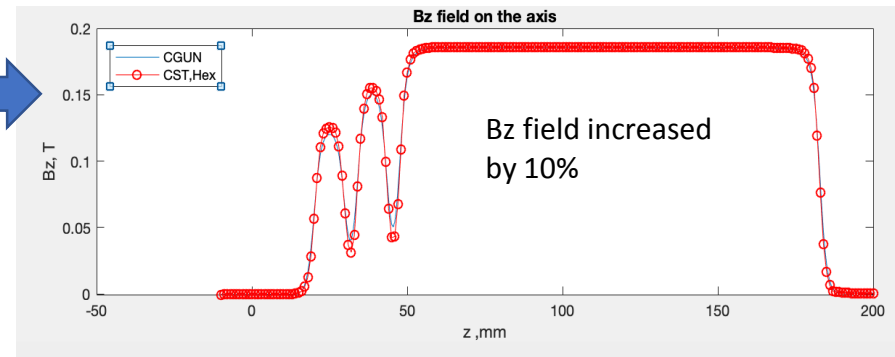
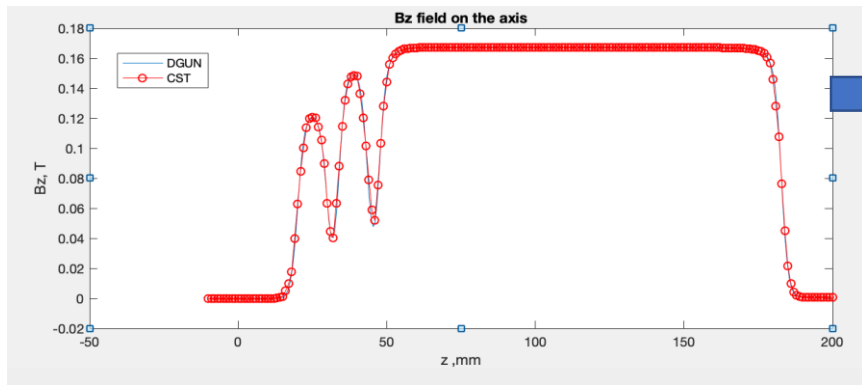
Magnetic module

Example: GUN for SLACX

Example: PPM for 220GHz BWO



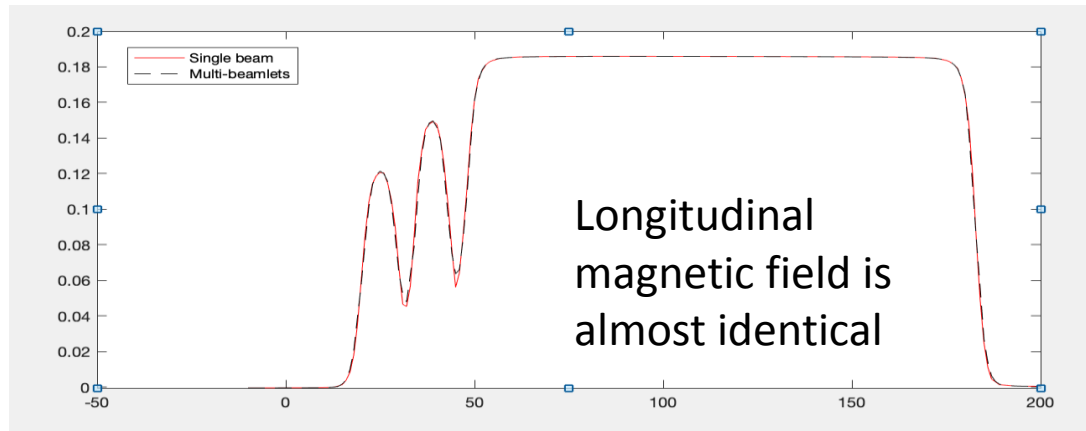
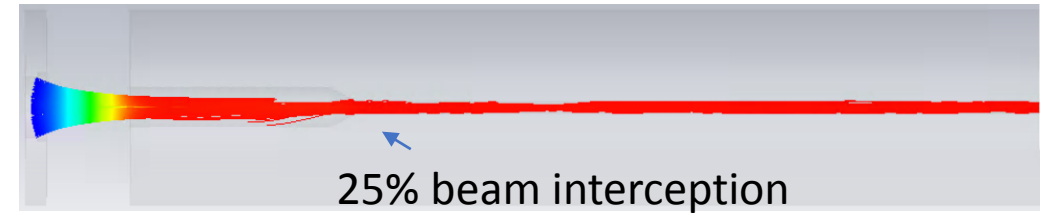
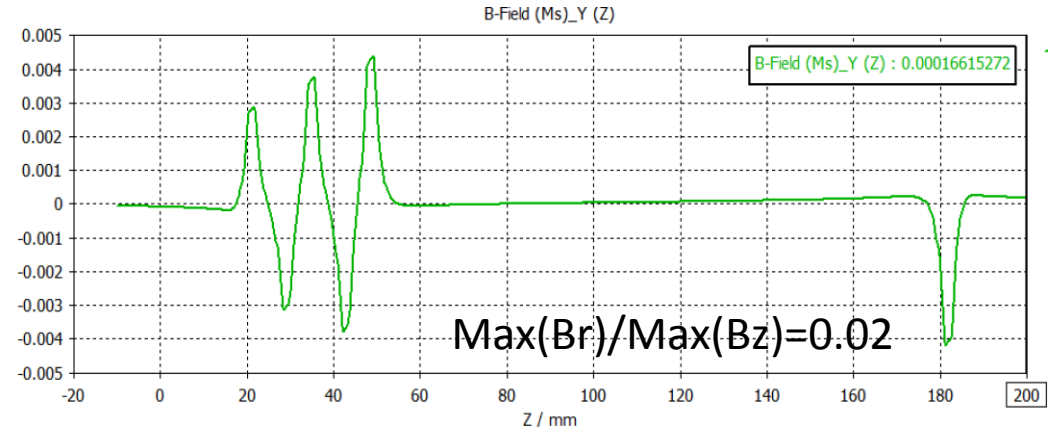
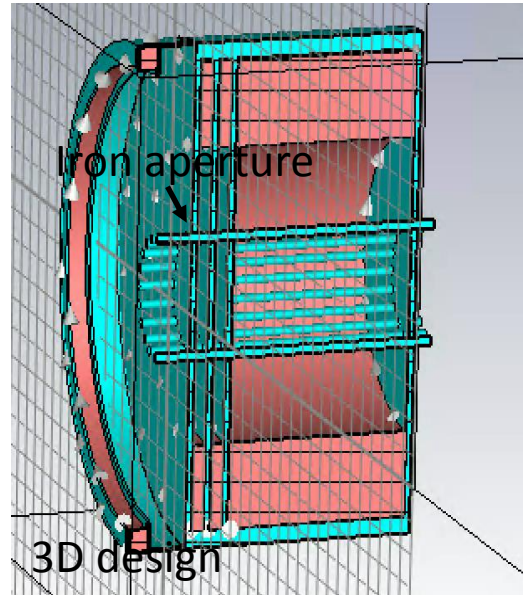
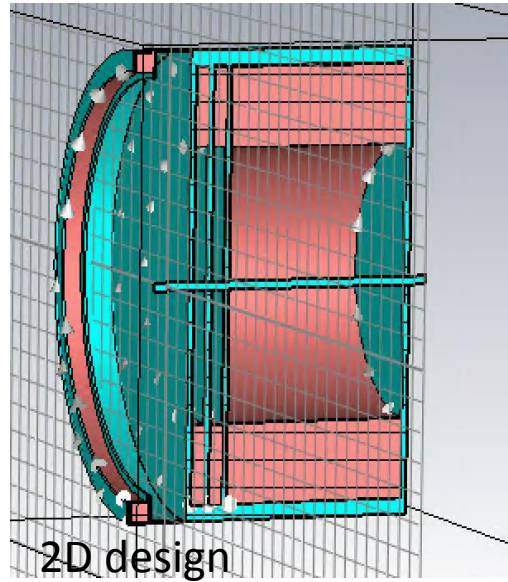
Optimization by CGUN – CERN home made tool (benchmarked with CST)



- CGUN demonstrated very good agreement with other available codes.
- Final optics tuning will be done in CST, that allows to include the MB effects.

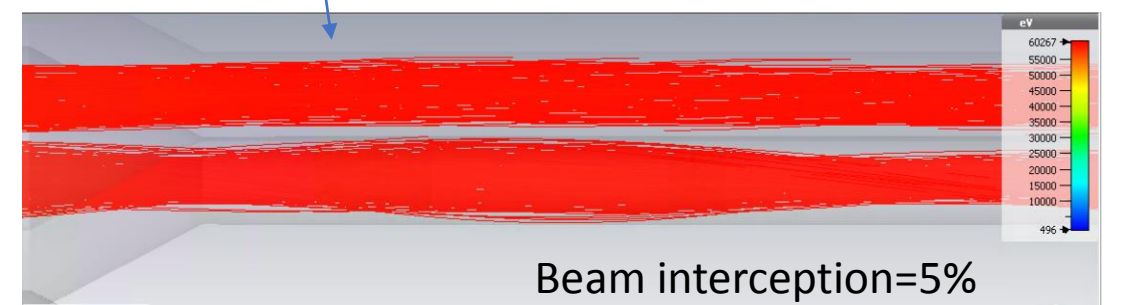
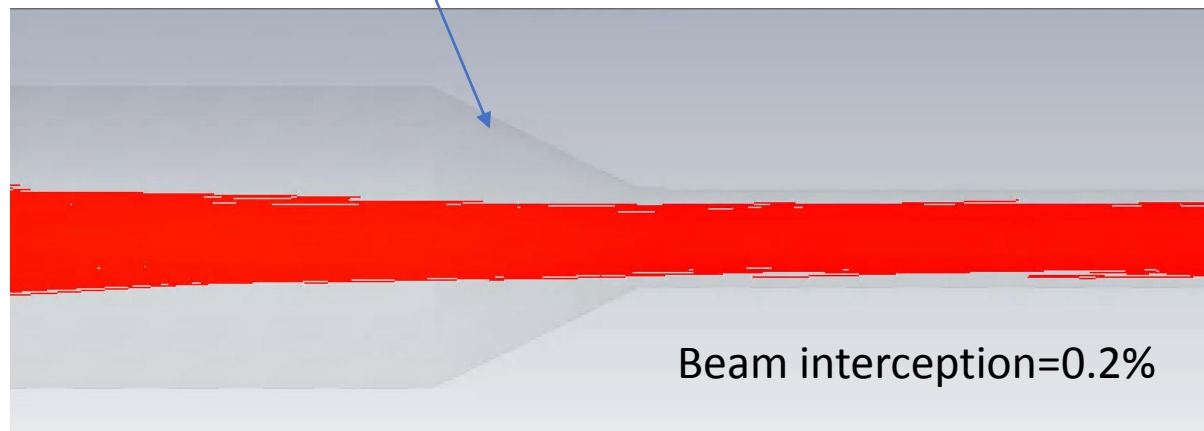
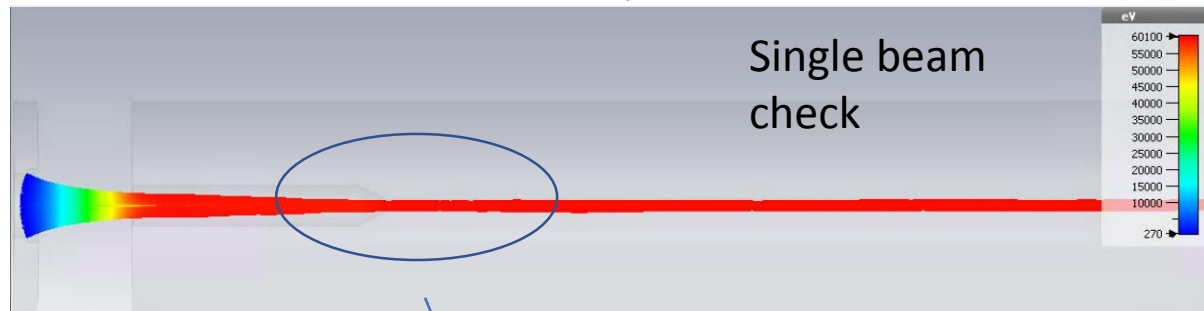
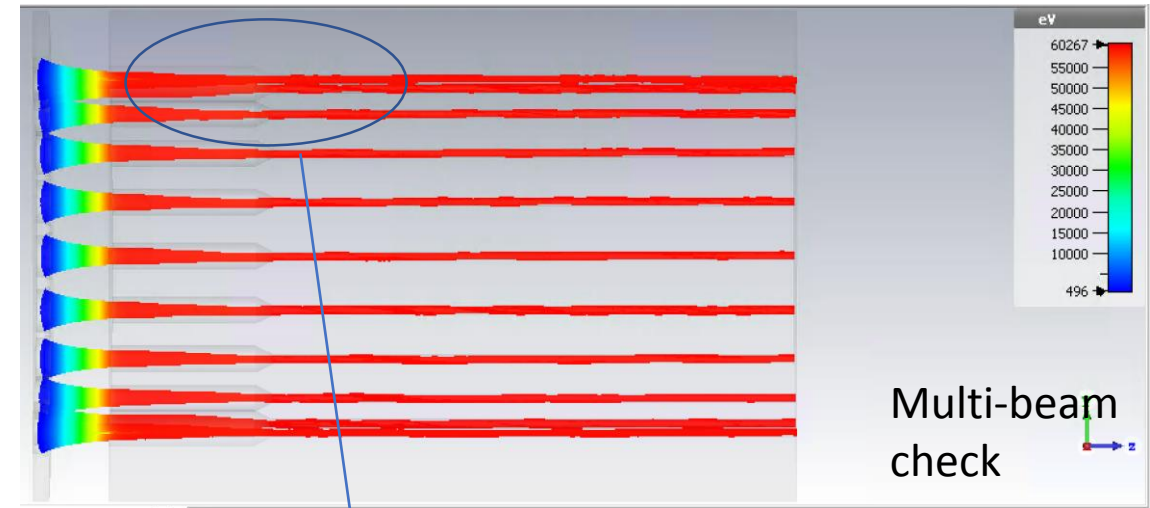
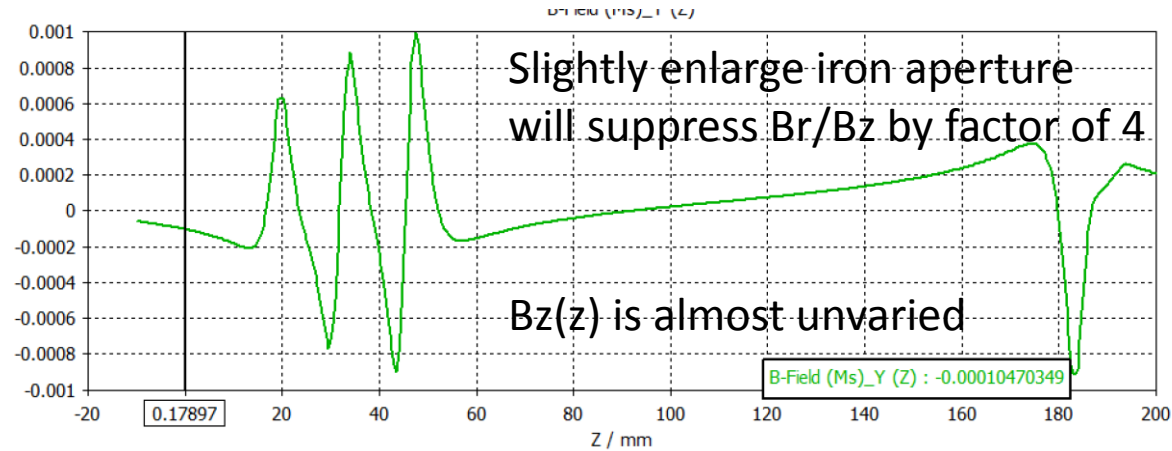


Transverse Magnetic field issues in MBK topology



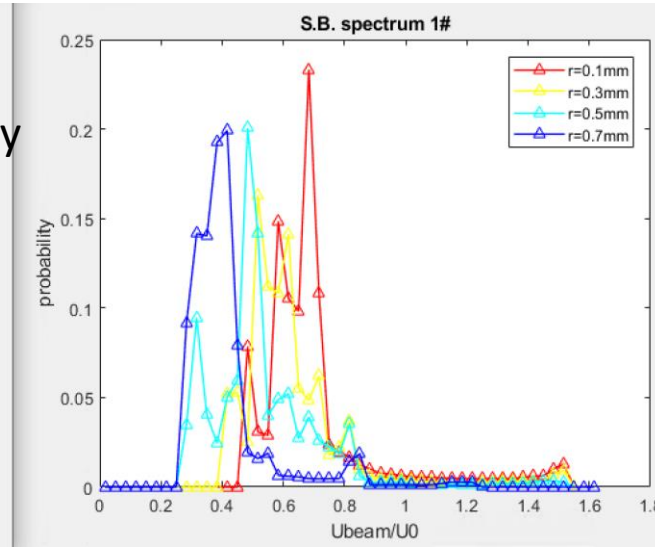
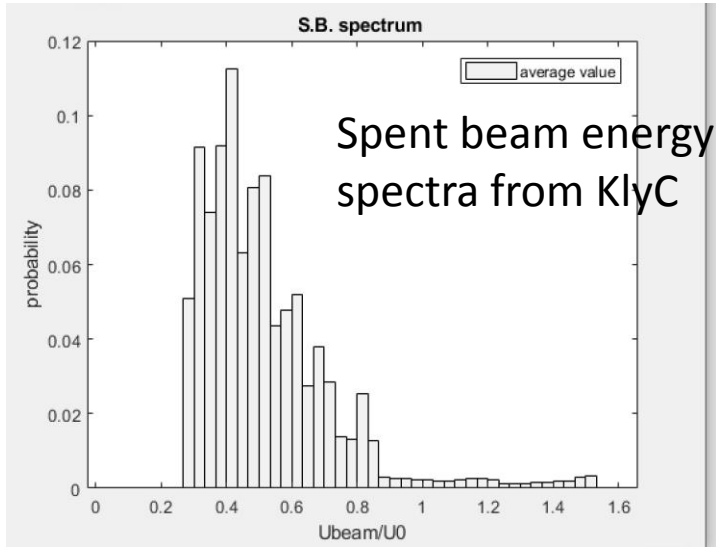
- ✓ 3D magnetic field map used for single beam simulation is done. Beam losses are heavy.
- ✓ To reduce the transverse magnetic field, the inner/outer radii of the magnet, beam apertures in the iron shields have been adjusted.

Efforts to Mitigate the transverse Magnetic field effect

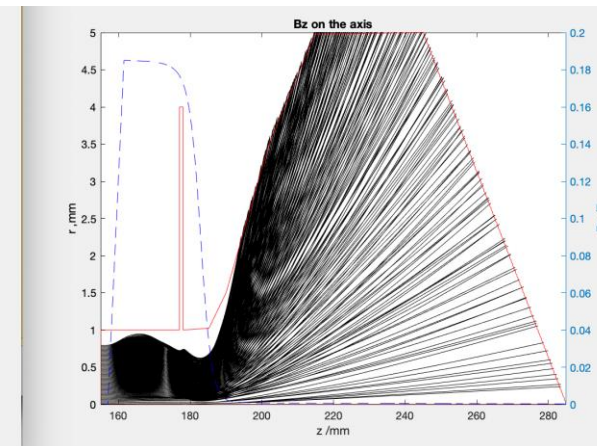
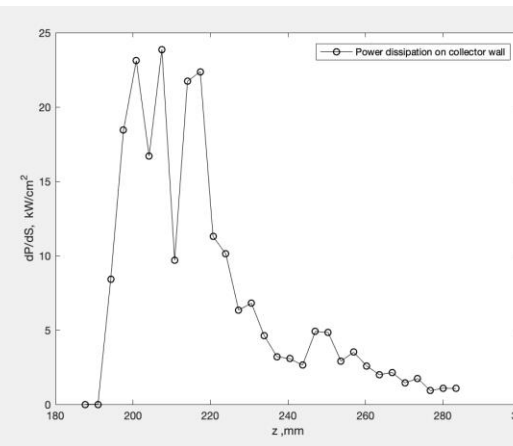
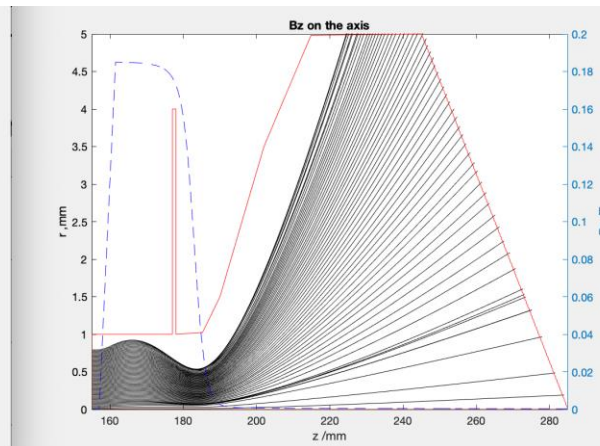
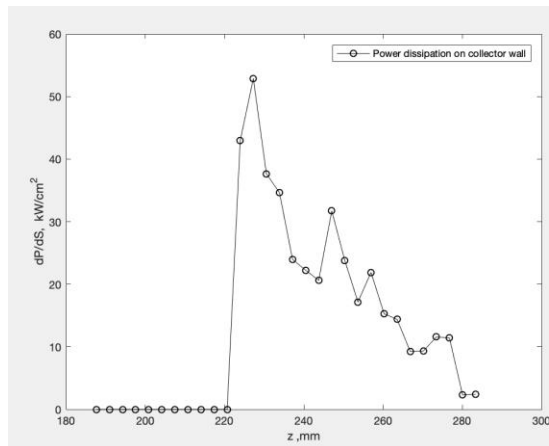


- ✓ Because of beam-beam interference in GUN area, transverse shift of beamlets becomes more pronounced which leads to higher beam interception
- ✓ Next, the radial position of iron apertures will be optimized in attempt to reduce transverse B field further.

Preliminary design of the Individual Collector with KlyC/CGUN



- ✓ For diode mode, $V=60\text{kV}$, $I=6\text{A}$, $r_m=0.8\text{mm}$, $r_c=1.0\text{mm}$;
- ✓ For RF mode, $V=31.2\text{kV}$ corresponding to electron efficiency (KlyC); In preliminary study, Energy spread of $\mp 10\text{kV}$ is used for all the radial layers;
- ✓ Considering the duty circle is 1/1000 (1000ns, 1kHz), the Maximum dP/dS should be below 100kW/cm^2 according to empirical recommendations.



For DC, $V=60\text{kV}$, $I=6\text{A}$, $\max(dP/ds)=55\text{kW/cm}^2$.

For RF, $V=31.2\text{kV} \mp 10\text{kV}$, $I=6\text{A}$, $\max(dP/ds)=25\text{kW/cm}^2$.

36 GHz, 2.5 MW MBK parameters

Voltage: 60 kV (no oil insulation needed)

N beams: 20

Current/beam: 6A

Current/total: 120 A

Power in saturation: 2.57MW

RF efficiency: 37.5%

Power gain: 41dB

Bandwidth -3dB (KlyC): 50MHz

Solenoidal field: ~ 0.2 T

Tube length total: 0.45m

Max. Cathode current density: $9\text{A}/\text{cm}^2$

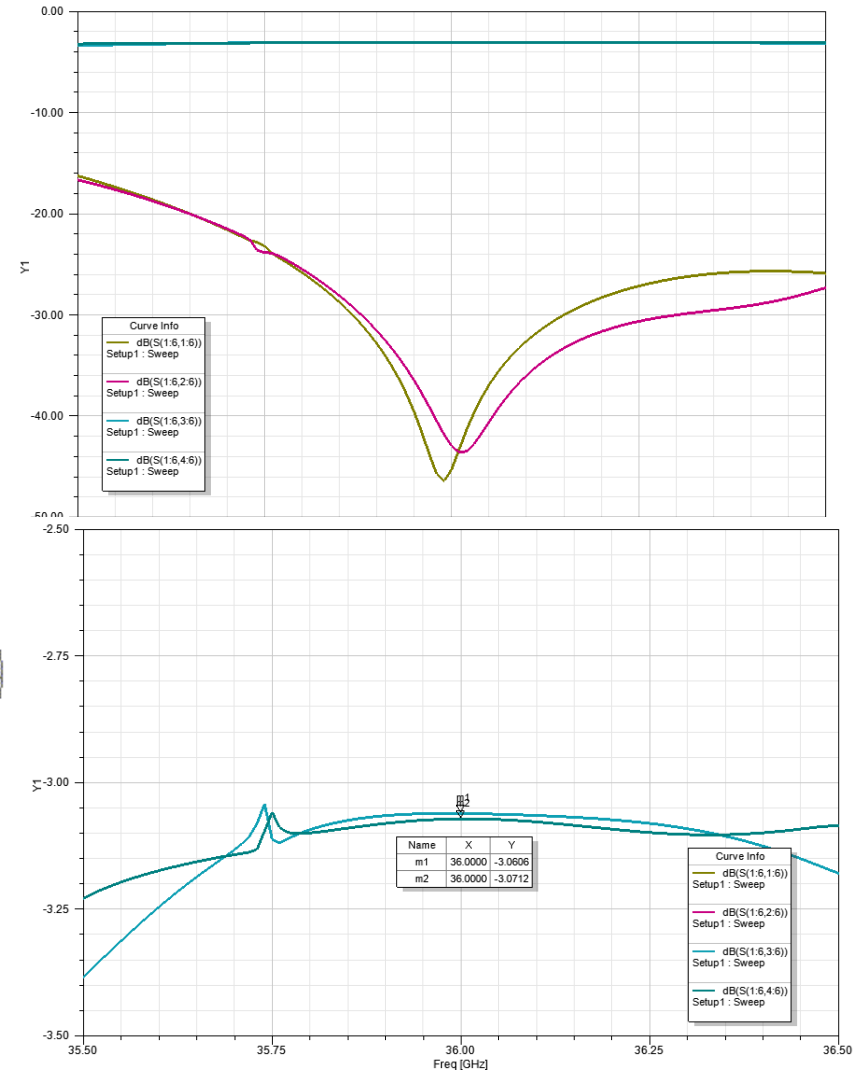
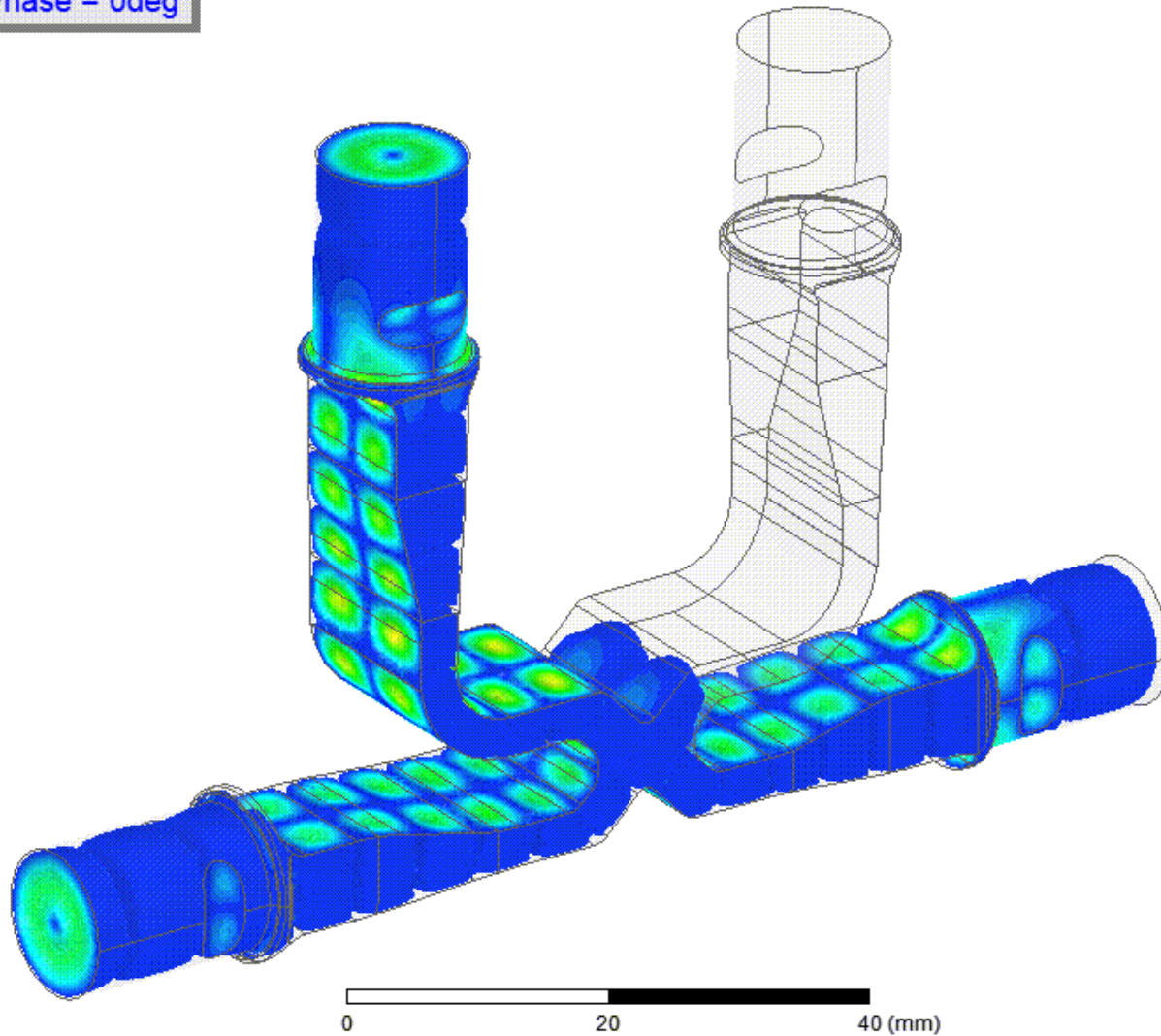
RF pulse length (tentative): 1000 ns

Max repetition rate (diode mode): $< 2\text{kHz}$

Max repetition rate (RF mode): $< 4\text{kHz}$

3dB E01_H20 hybrid. Power head for PC and/or klystrons combiner

Phase = 0deg



Summary and outlook

- CGUN code is self-developed and has been well benchmarked with other codes.
- MBK GUN and Magnetic system design are almost finished. Further optimizations are ongoing to improve the beam transmission.
- Preliminary design for Collector is done, to be checked with full tube simulation in CGUN/KlyC (required modification is almost finished).
- PIC simulation with practical beam optics imported from TRK will be done as a final verification (Cathode-RF circuit-Collector).
- Evaluation of the cooling circuit (feasibility analysis)