CAS

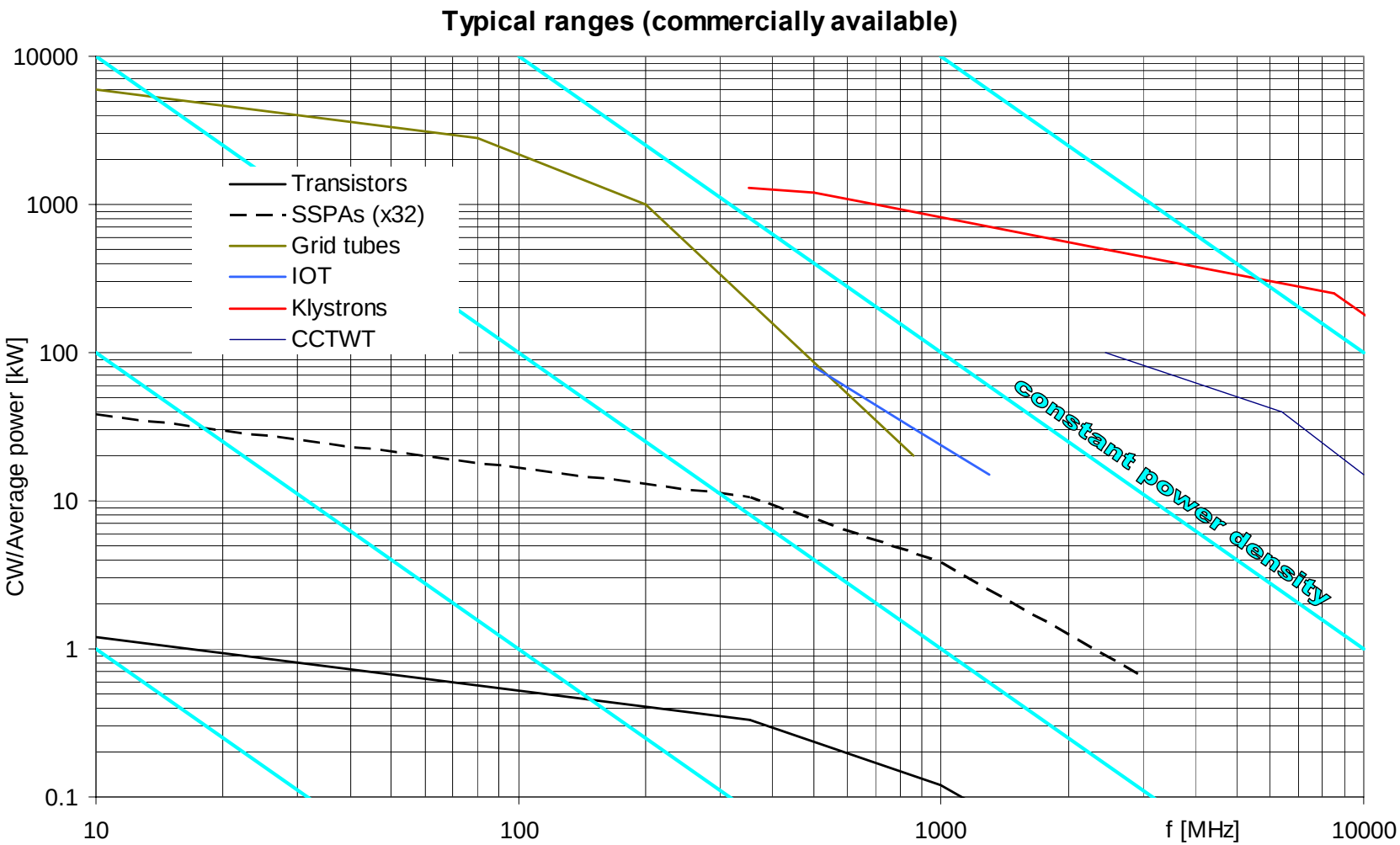
RF for Linacs

Erk Jensen – CERN AB/RF

Outline

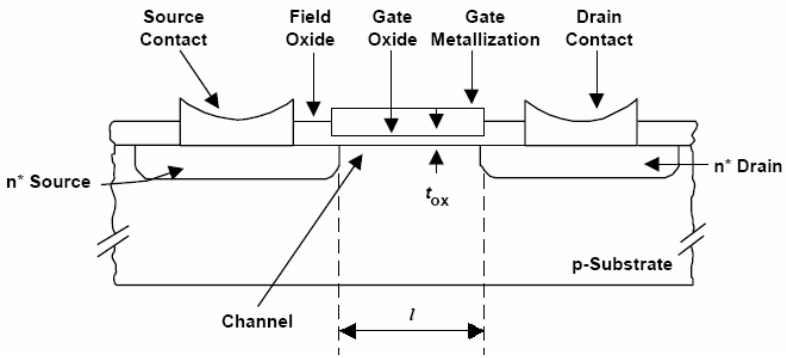
- **RF Power Sources** (solid state, tetrodes, klystrons, ...)
- **RF Pulse Compression** (principle, flat pulses, BOC)
- **Accelerating Structures** (Brillouin diagram, HOMs, beam loading, SC accelerating structures, HDS)

RF Power sources

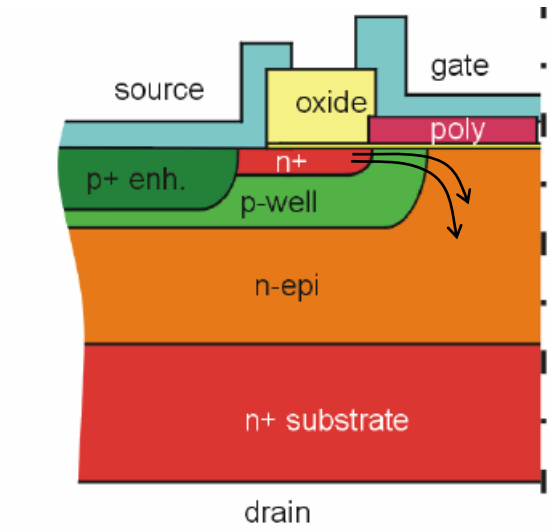


RF power transistors

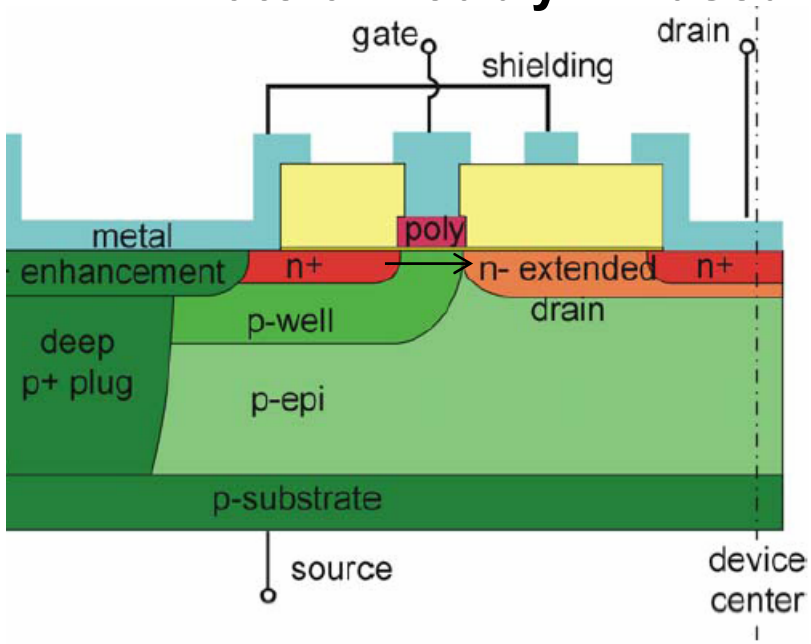
MOSFET



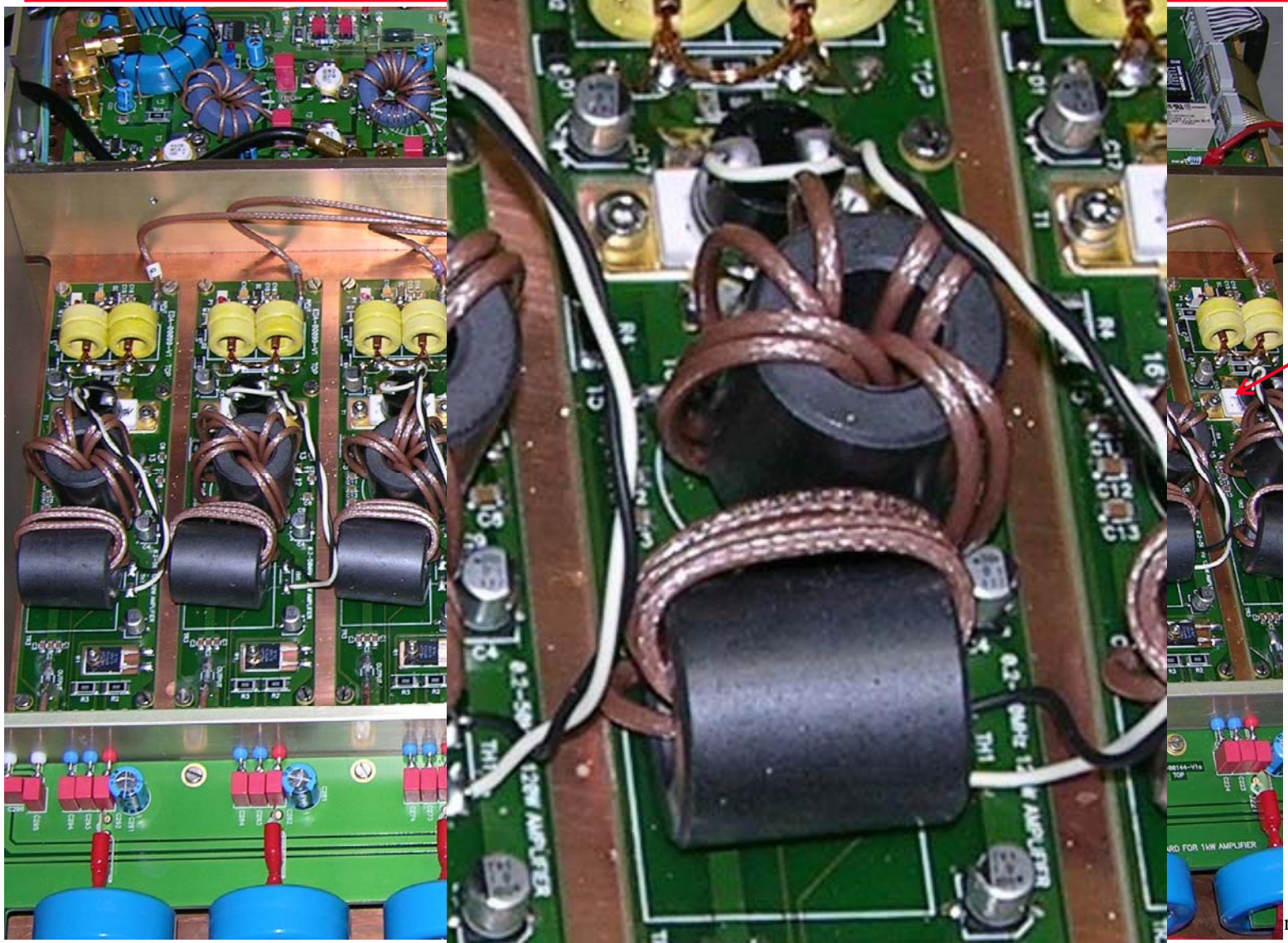
VDMOS
Vertical Doubly Diffused



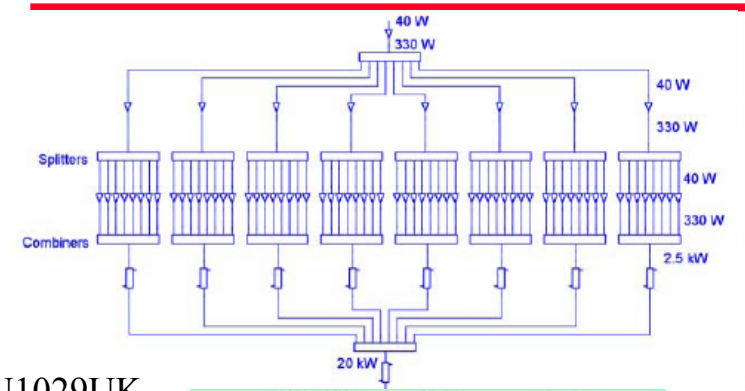
LDMOS
Lateral Doubly Diffused



www.essderc2002.deis.unibo.it/ESSDERC_web/Session_D18/D18_4.pdf

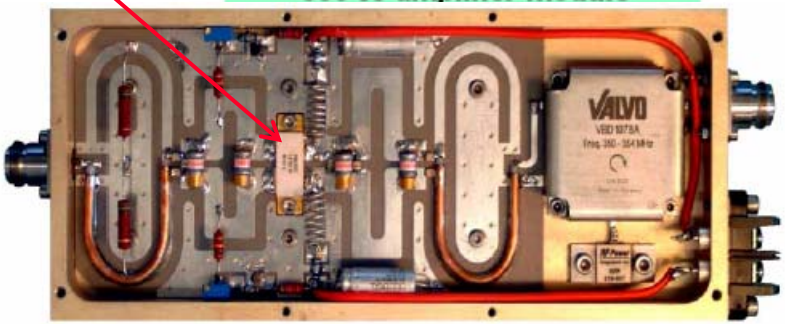

MRF151G

CAS Soleil Booster SSPA, 40 kW, 352 MHz

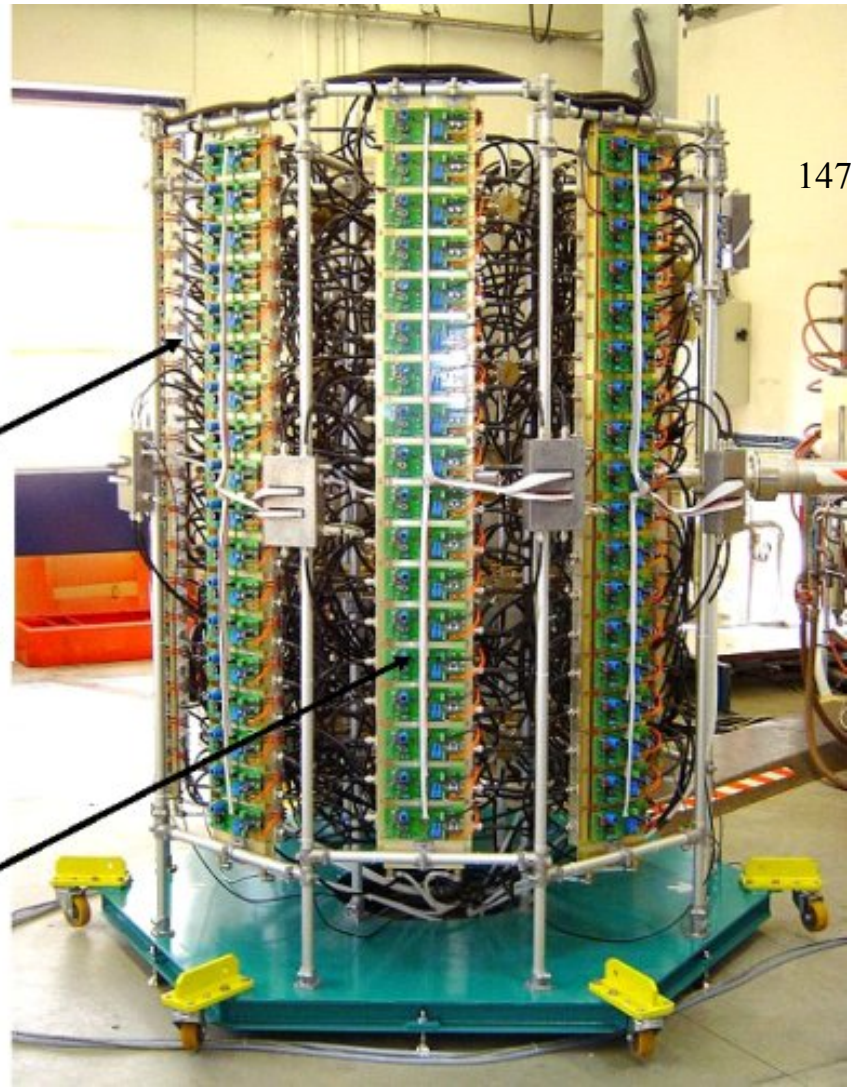


DU1029UK

330 W amplifier module

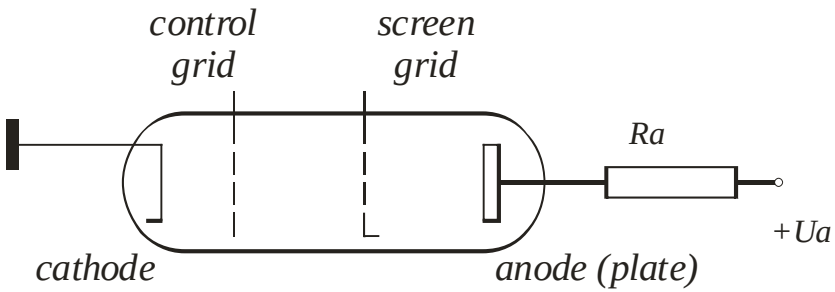


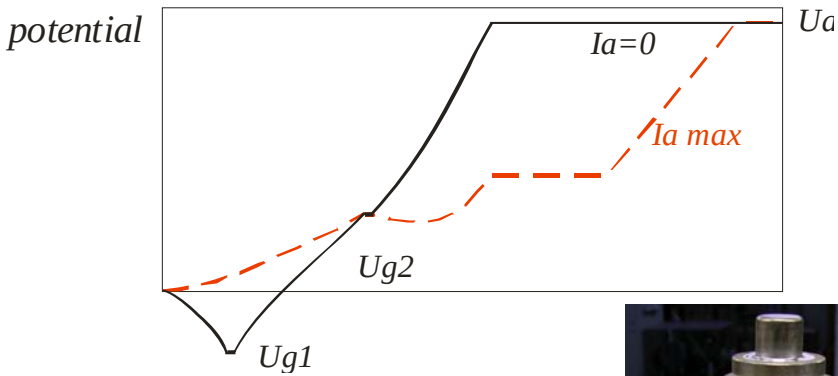
600 W, 300 Vdc / 30 Vdc converter



147 modules

Tetrode



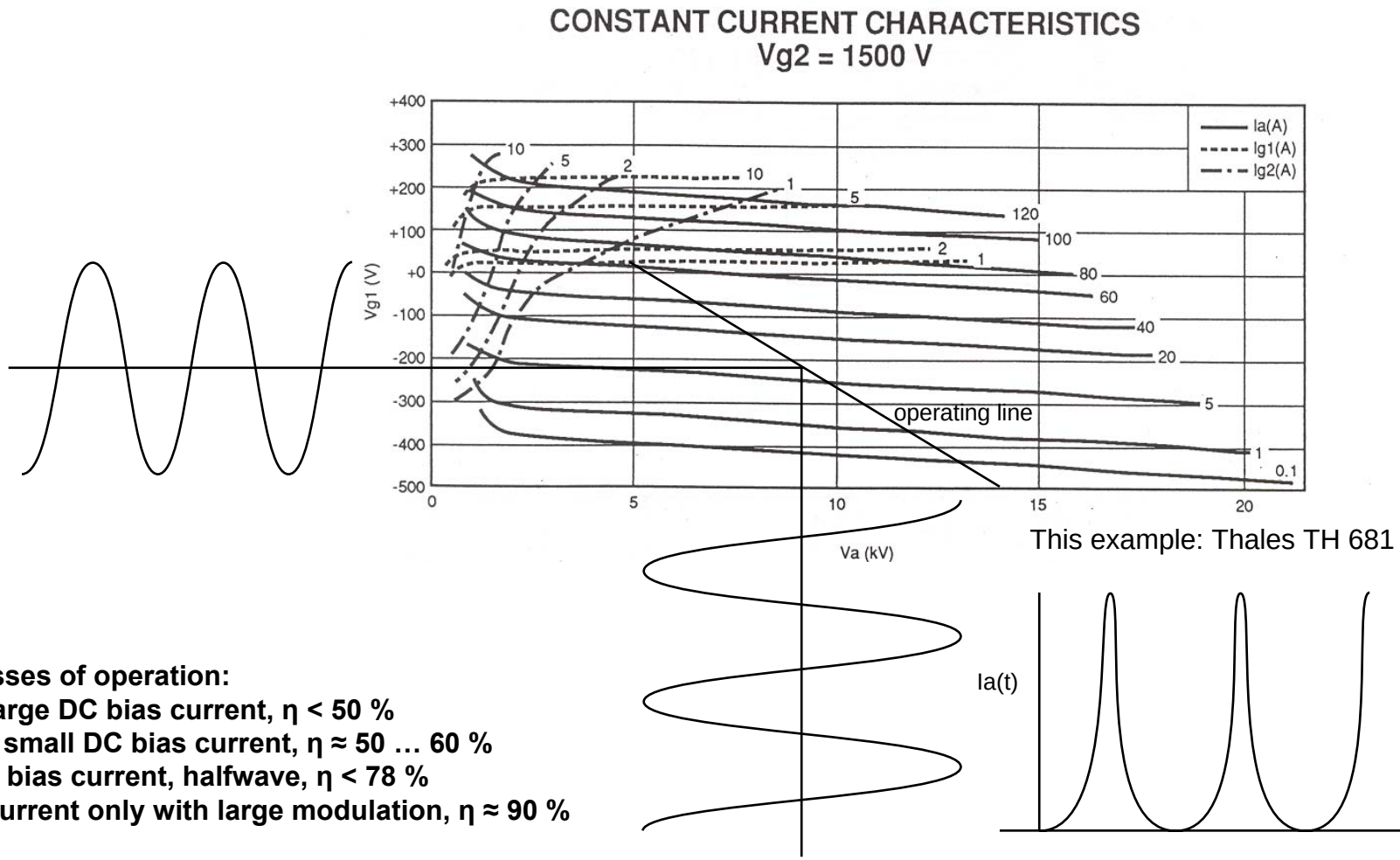


RS 1084 CJ (ex Siemens, now Thales), < 30 MHz, 75 kW

4CX250B (Eimac/CPI), < 500 MHz, 600 W (Anode removed)

YL1520 (ex Philips, now Richardson), < 260 MHz, 25 kW

Tetrode operation (AB1)



This example: Thales TH 681

Classes of operation:
A: large DC bias current, η < 50 %
AB: small DC bias current, η ≈ 50 … 60 %
B: 0 bias current, halfwave, η < 78 %
C: current only with large modulation, η ≈ 90 %

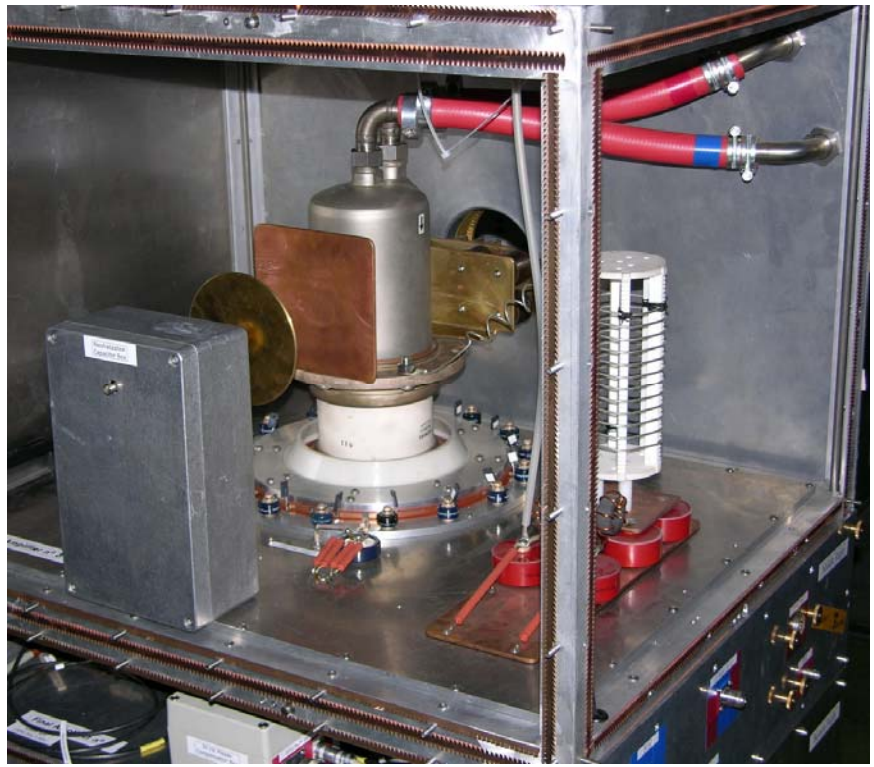
High power tetrode amplifier

CERN Linac3: 100 MHz, 350 kW

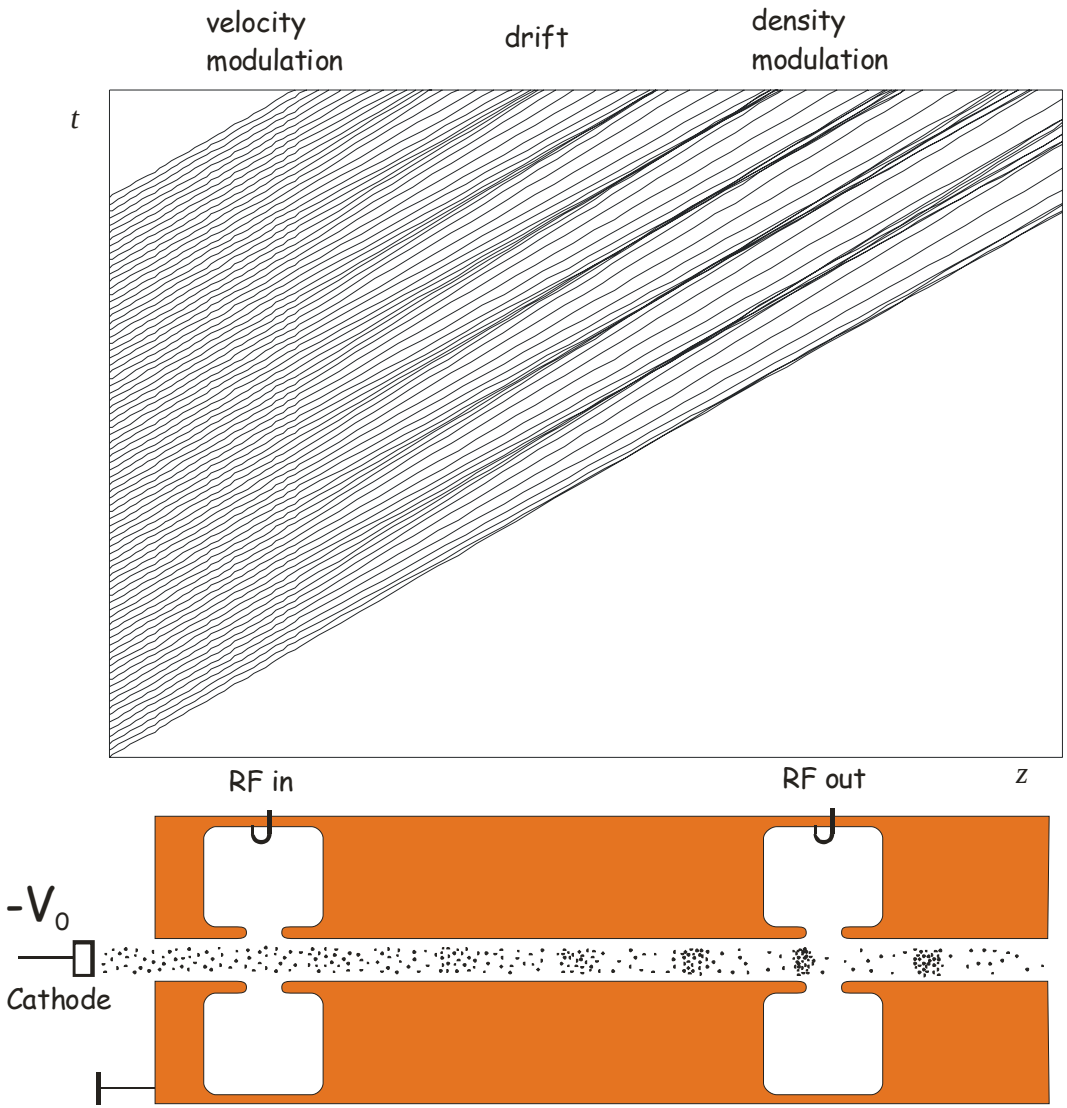
50 kW Driver: TH345, Final: RS 2054 SK

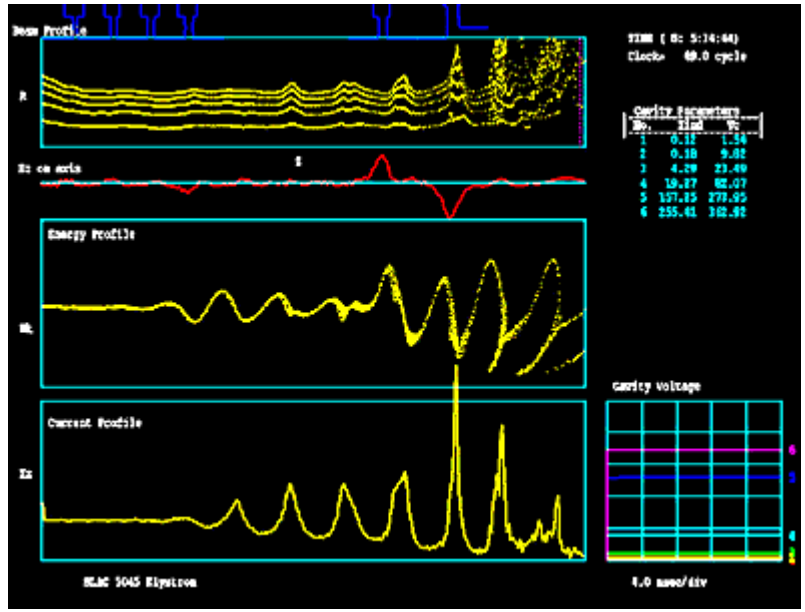
CERN PS: 13-20 MHz, 30 kW

Driver: solid state 400 W, Final: RS 1084 CJSC

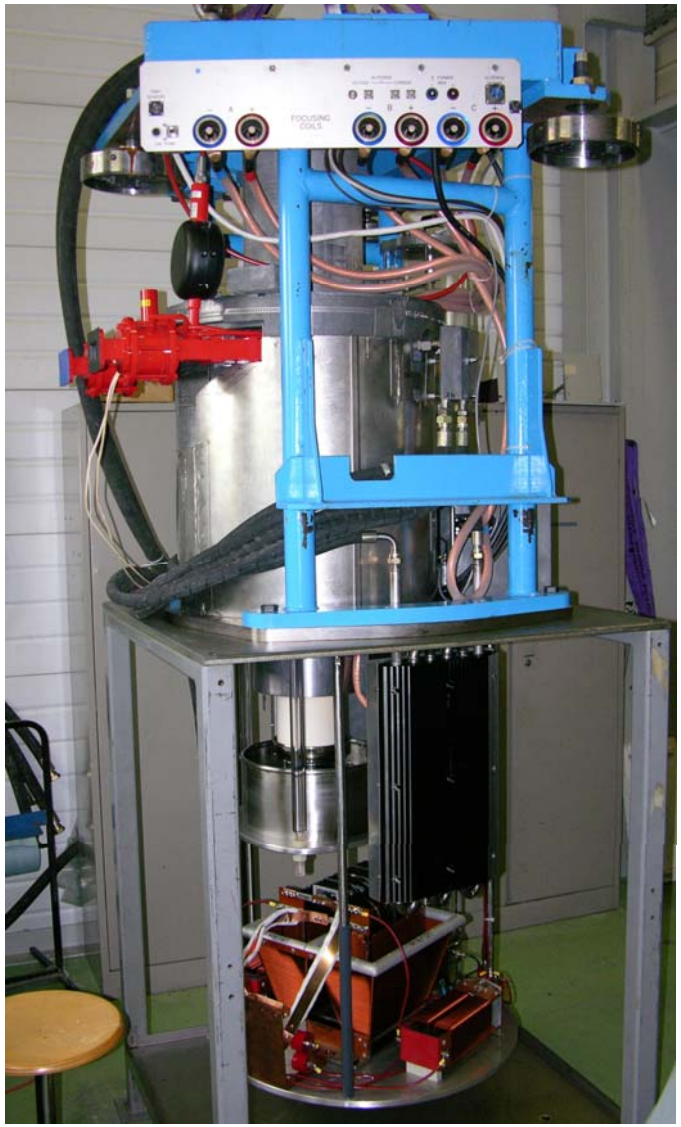


Klystron principle





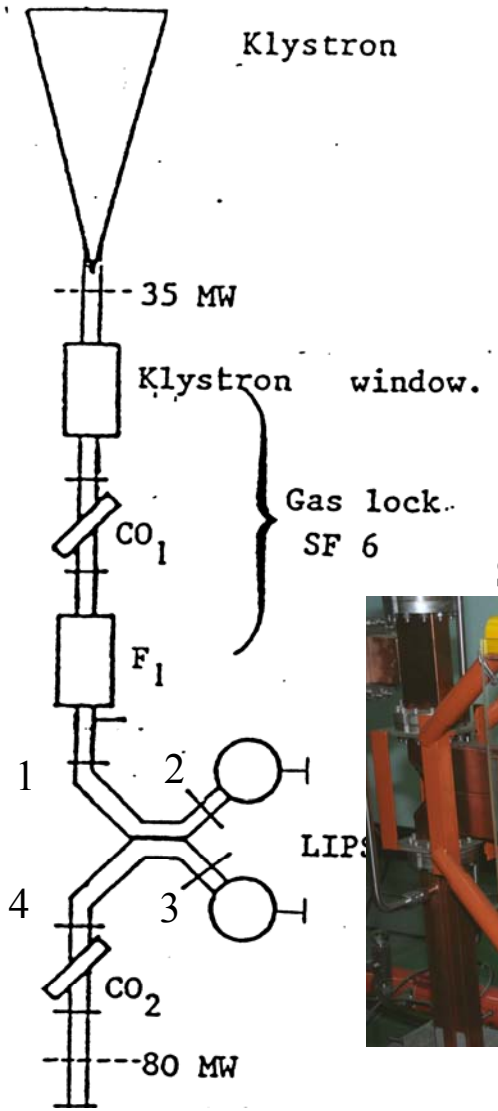
Klystrons



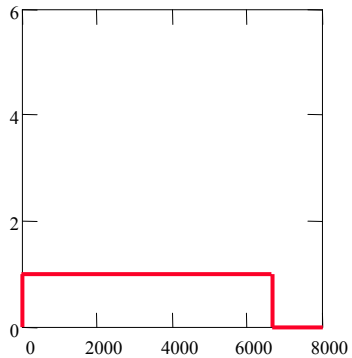
CERN CTF3 (LIL):
3 GHz, 45 MW,
4.5 μs, 50 Hz, η 45 %

CERN LHC:
400 MHz, 300 kW,
CW, η 62 %

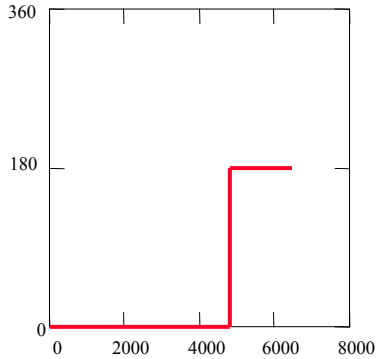
RF Pulse Compression



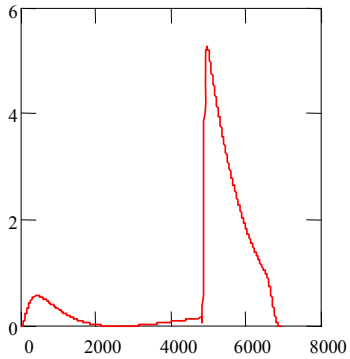
Input pulse



Input phase

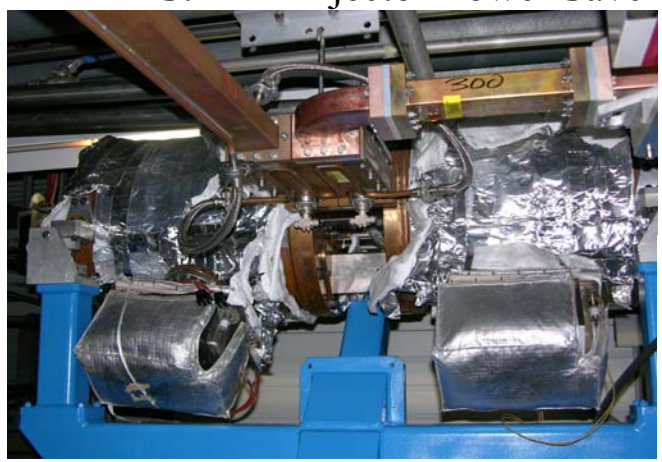


"SLED" output pulse



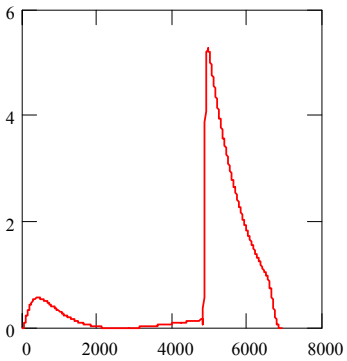
SLED: **SL**AC **E**nergy **D**oubler

LIPS: **L**EP **I**njector **P**ower **S**aver

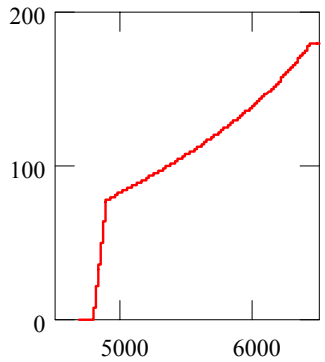


Flat output pulses

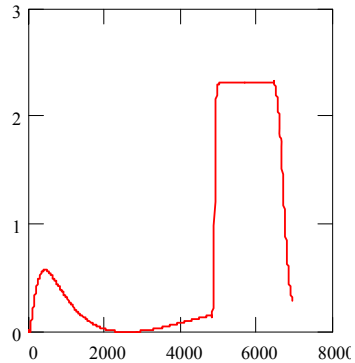
Standard "SLED" Pulse



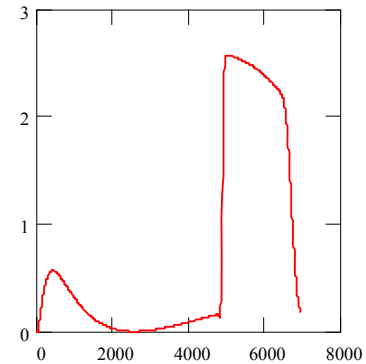
RF phase modulation



Flat pulse

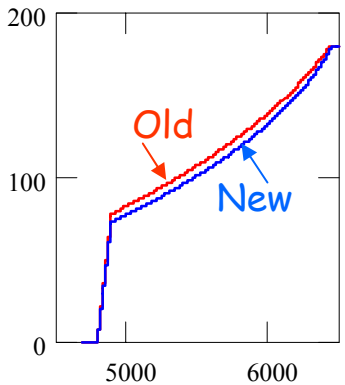


-10 kHz

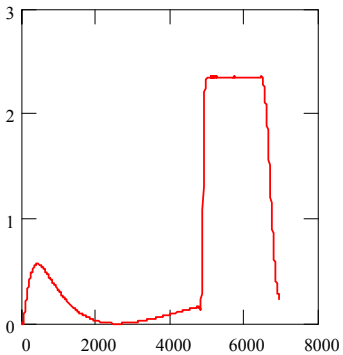


Distorted pulse

RF phase modulation

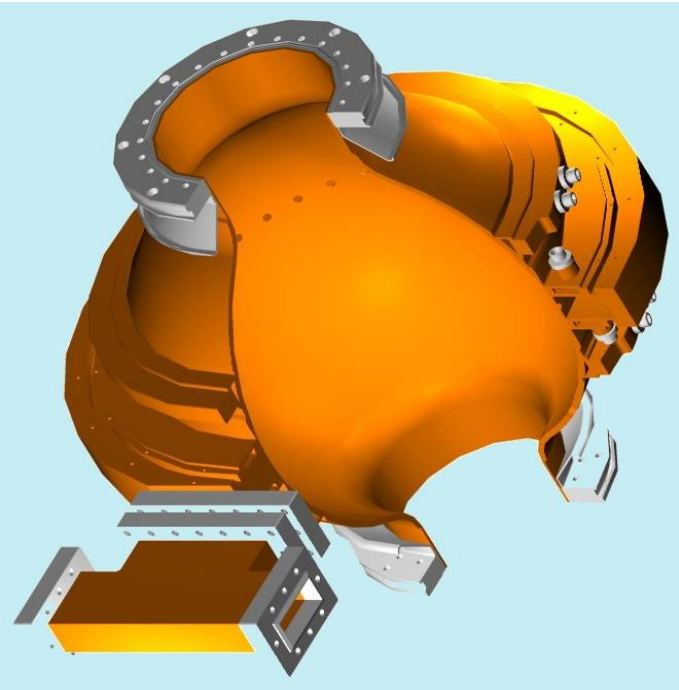


Flat pulse



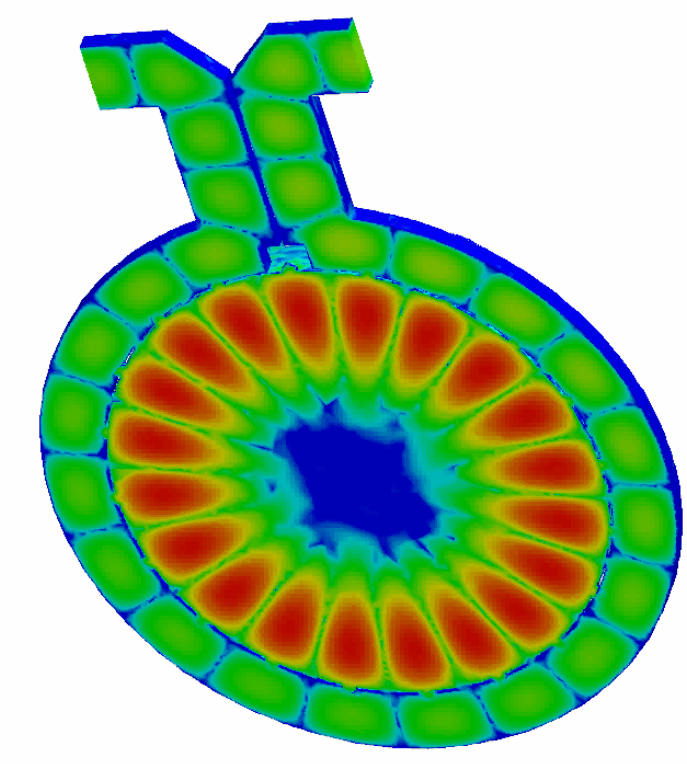
Pulse compressor

BOC „Barrel Open Cavity“

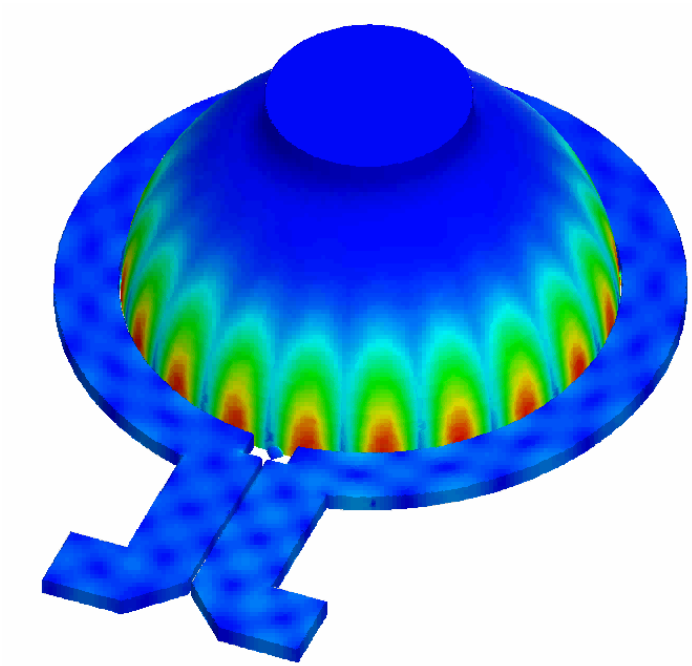


BOC

2.99848 GHz,
S11: -12.9 dB

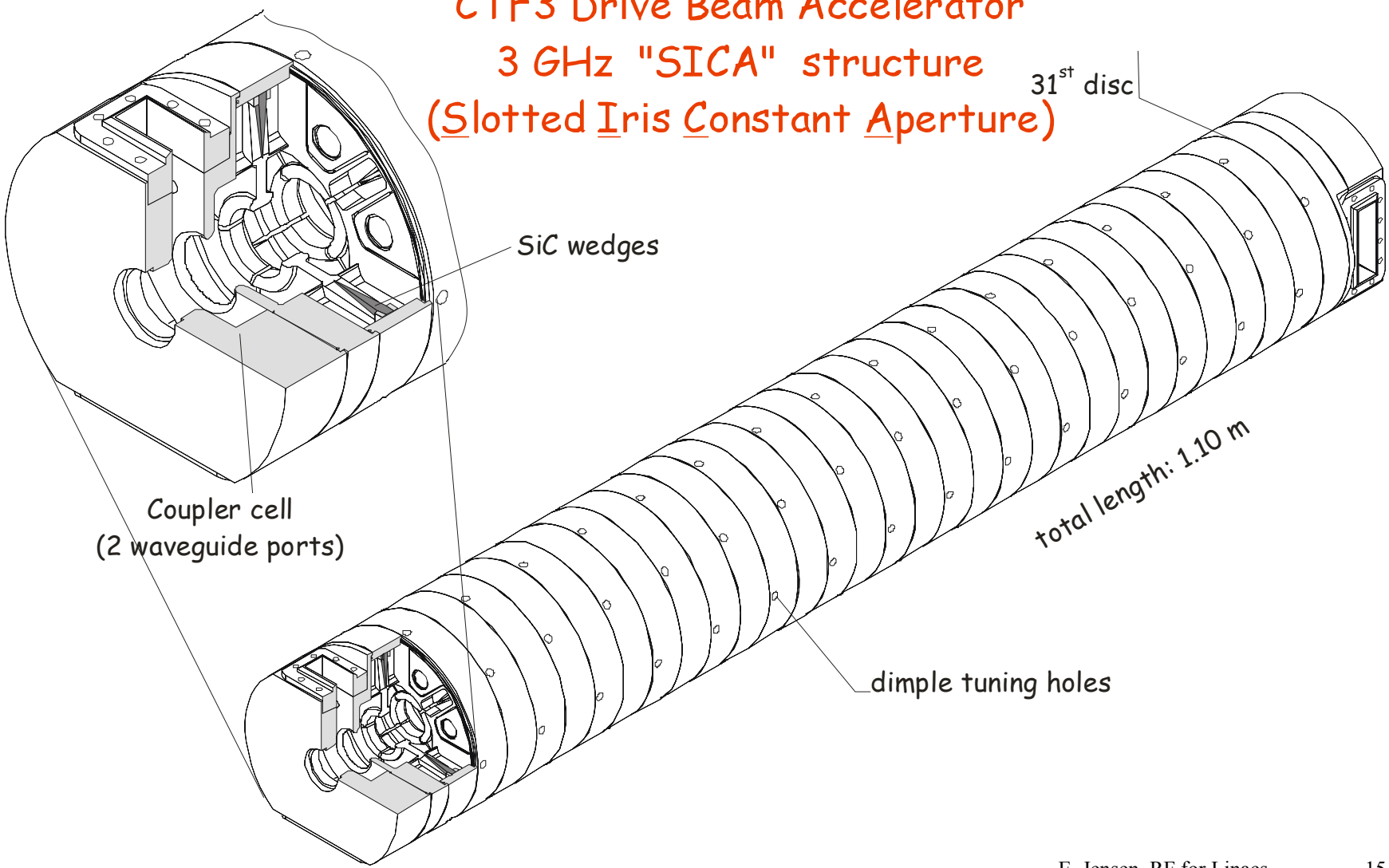


Electric field, logarithmic scale

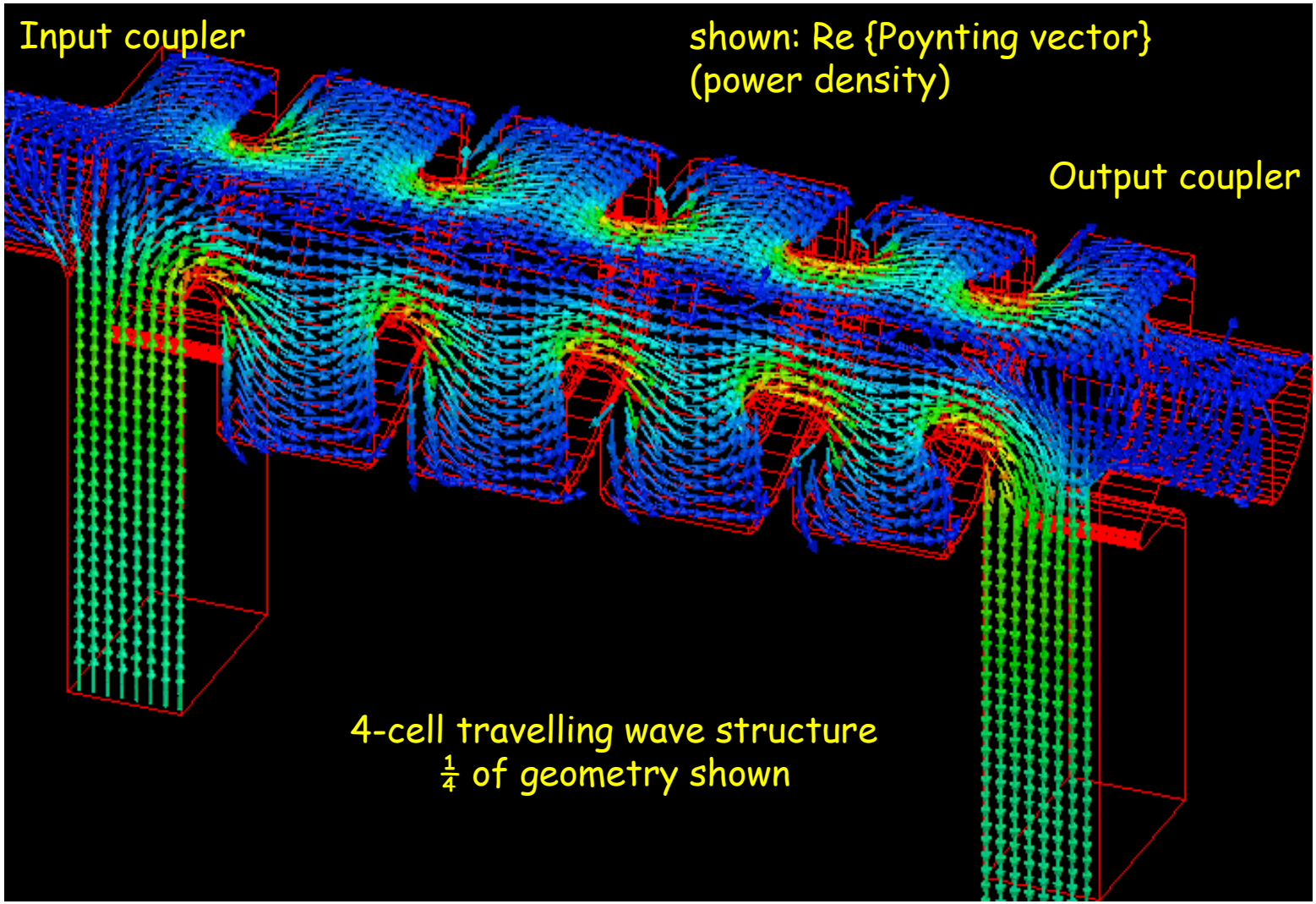


Magnetic field

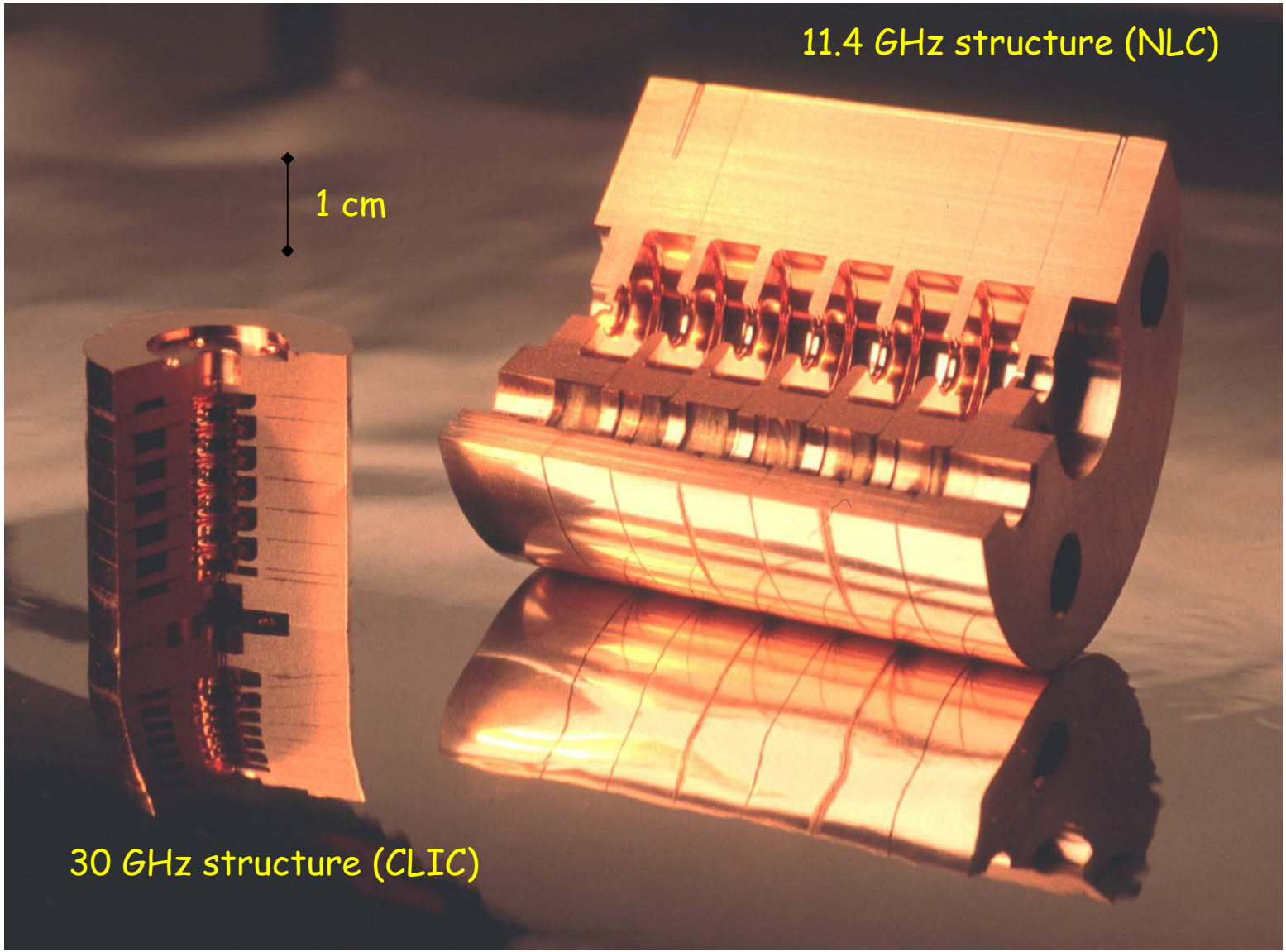
Travelling Wave Structure



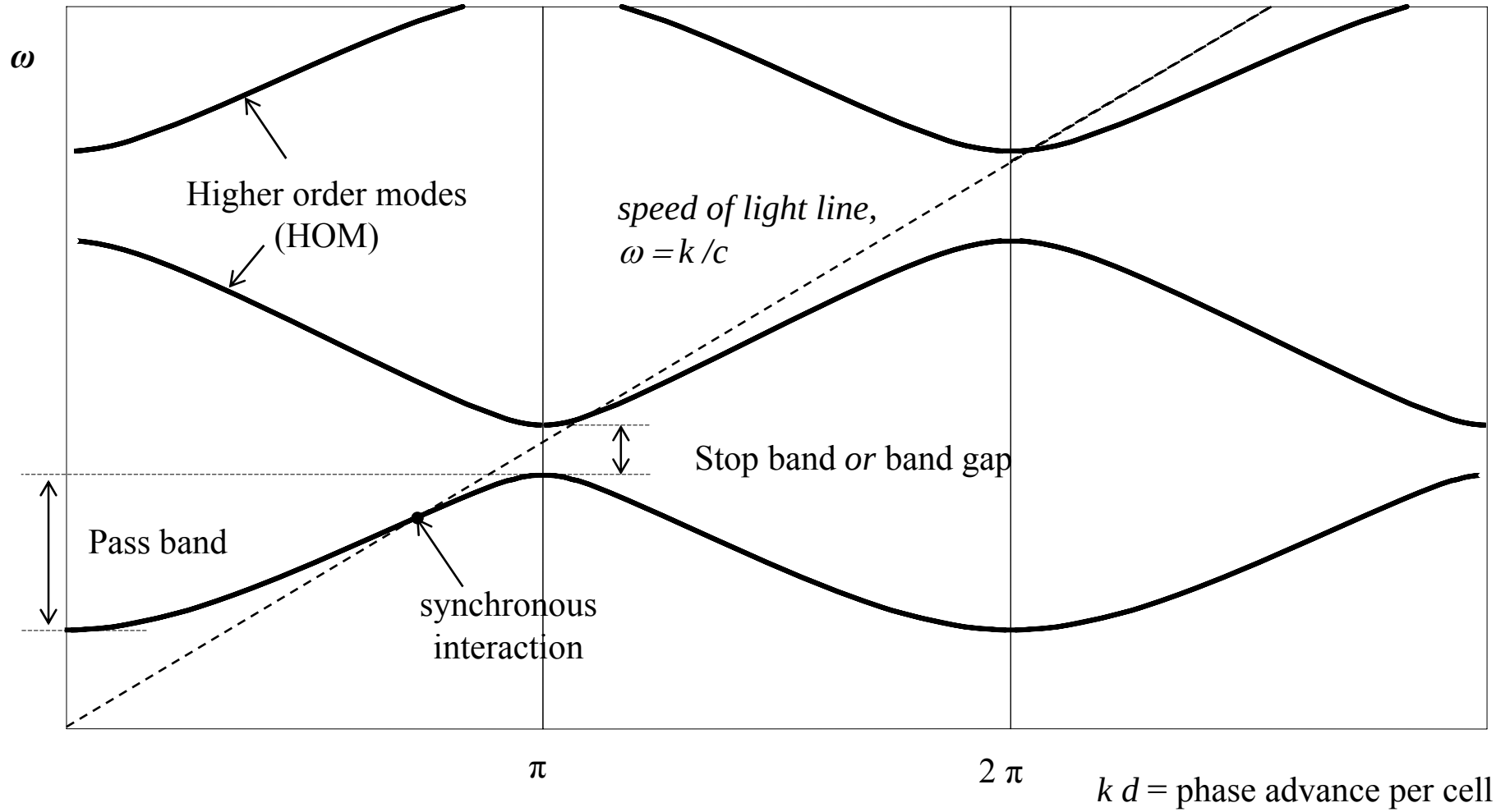
Travelling wave structure



Iris loaded waveguide

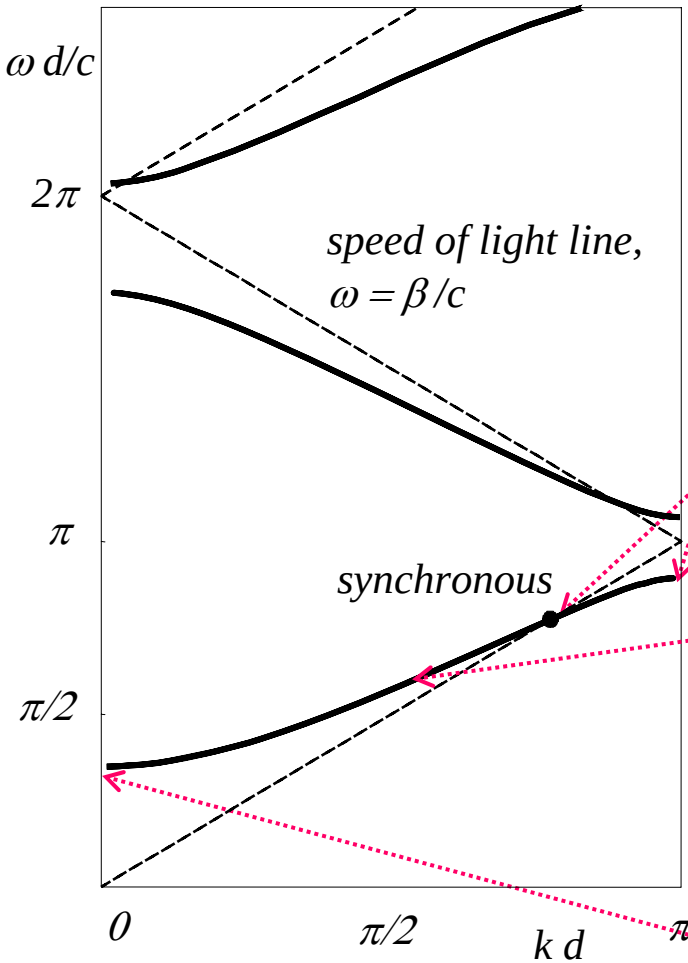


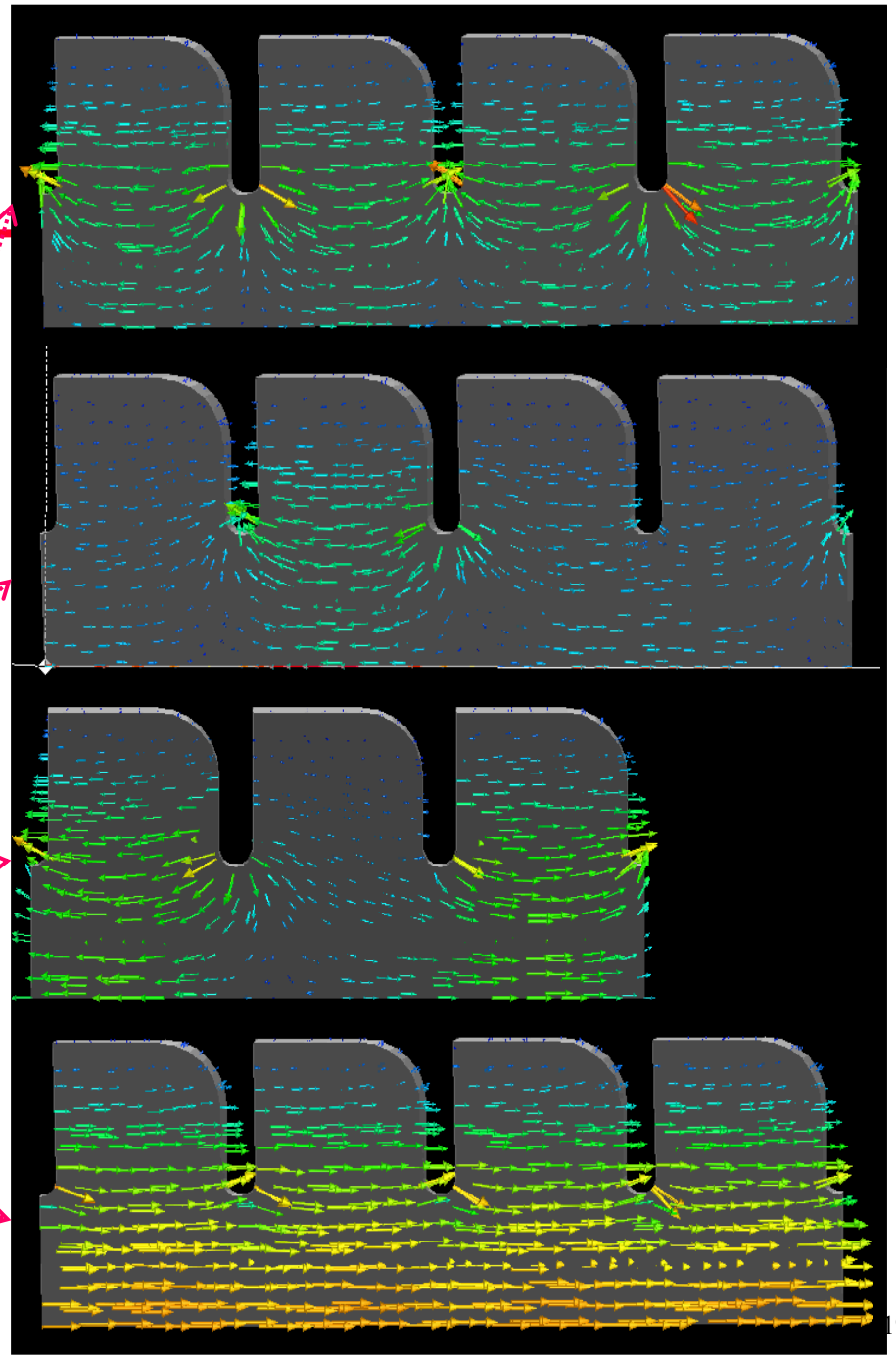
Brillouin diagram



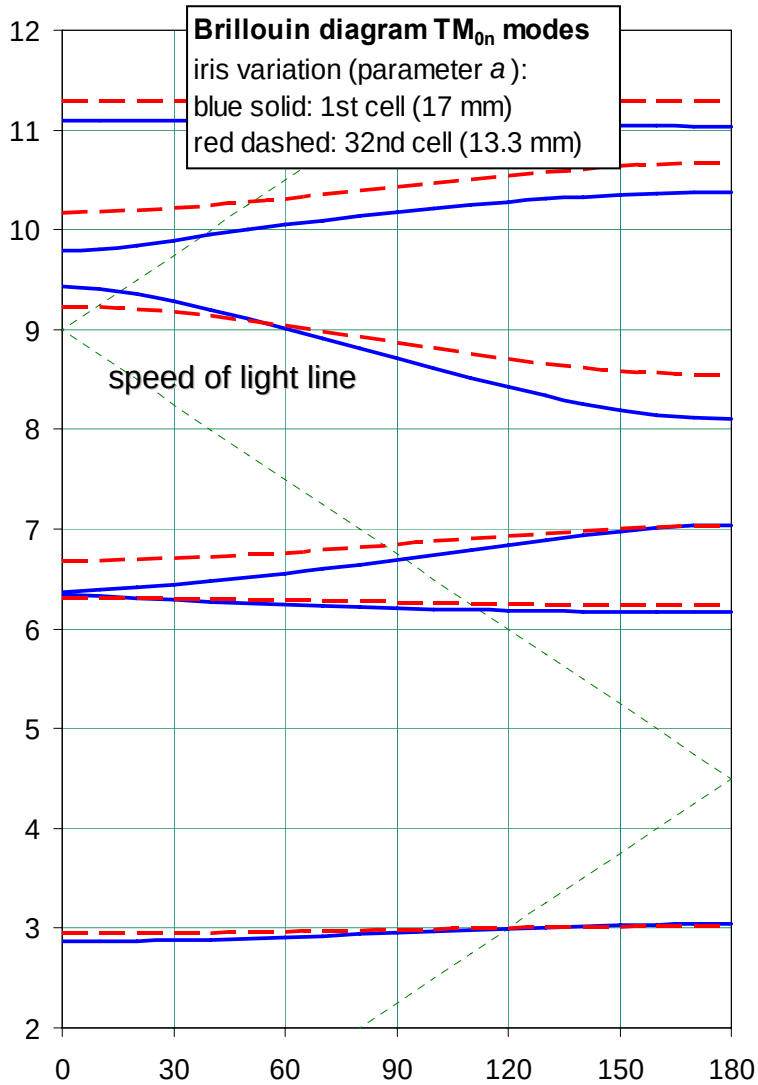
CAS

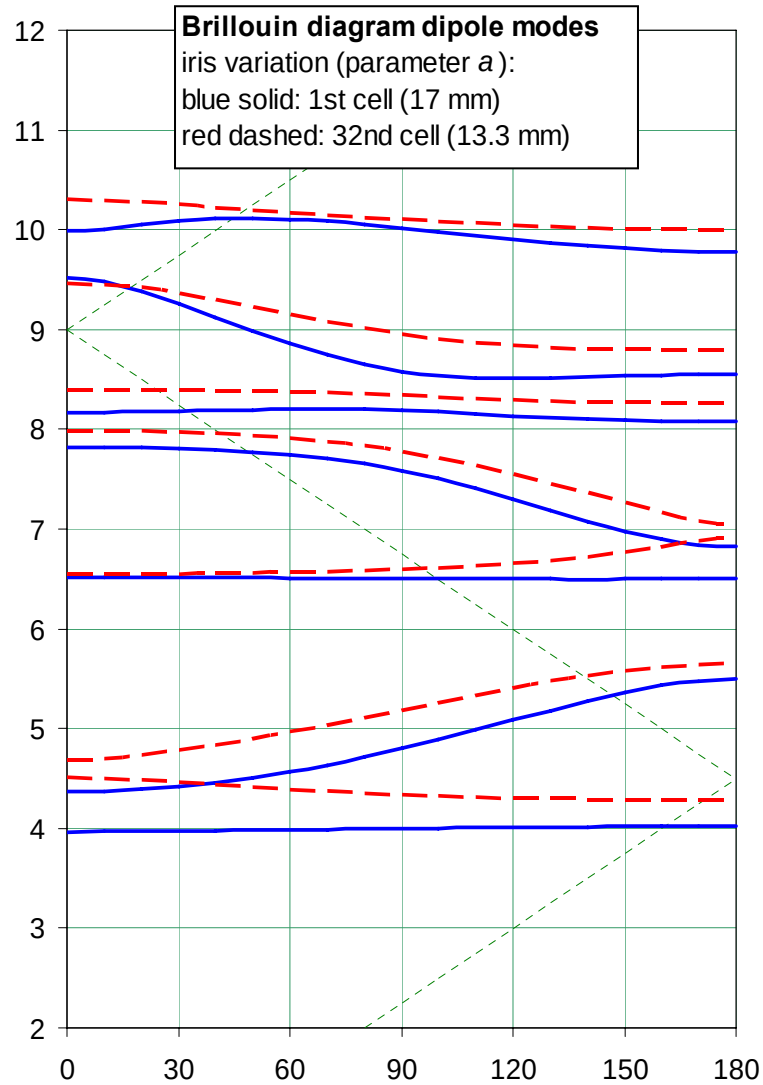
Brillouin Diagram



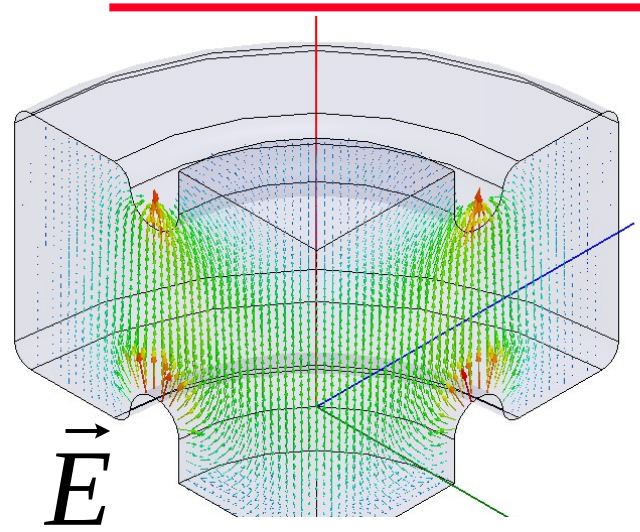


Brillouin diagram



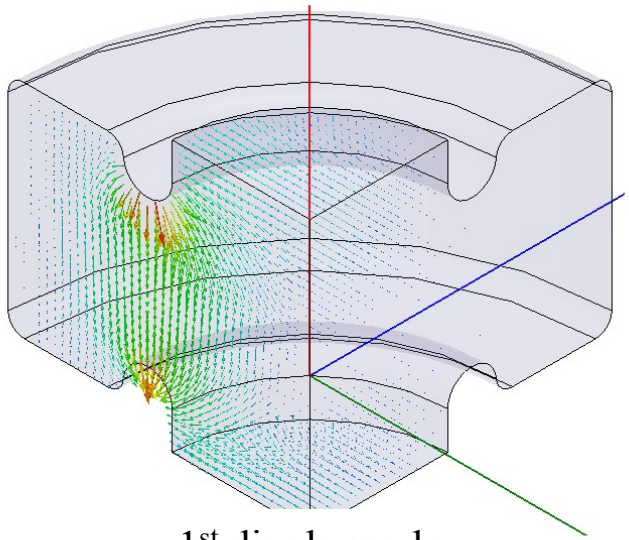


Higher order modes

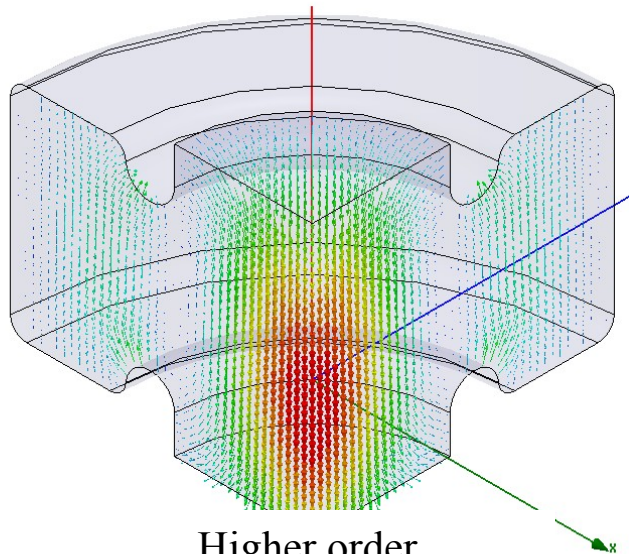


$\vec{E}$

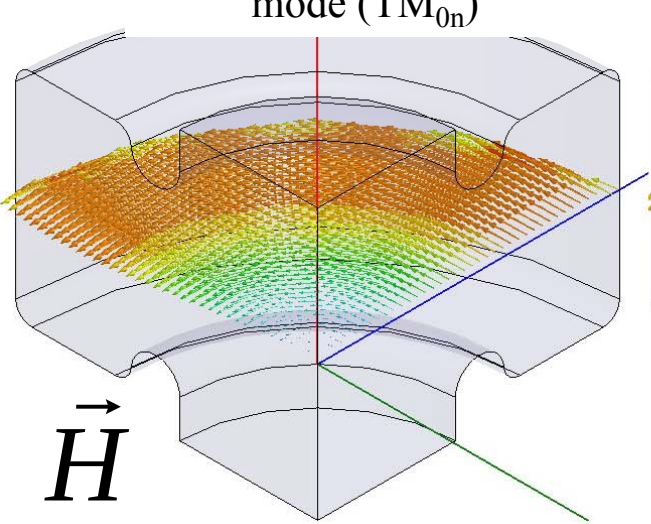
Fundamental accelerating mode (TM_{0n})



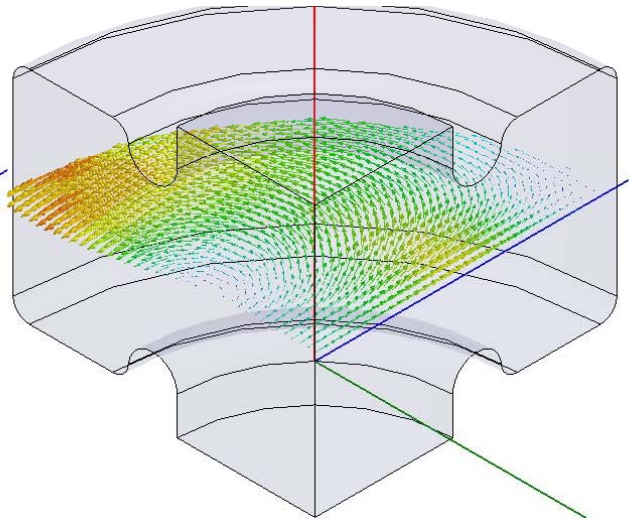
1st dipole mode

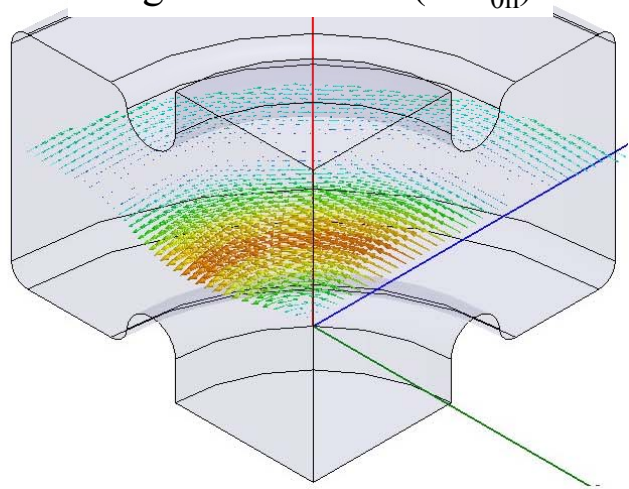


Higher order longitudinal mode (TM_{0n})

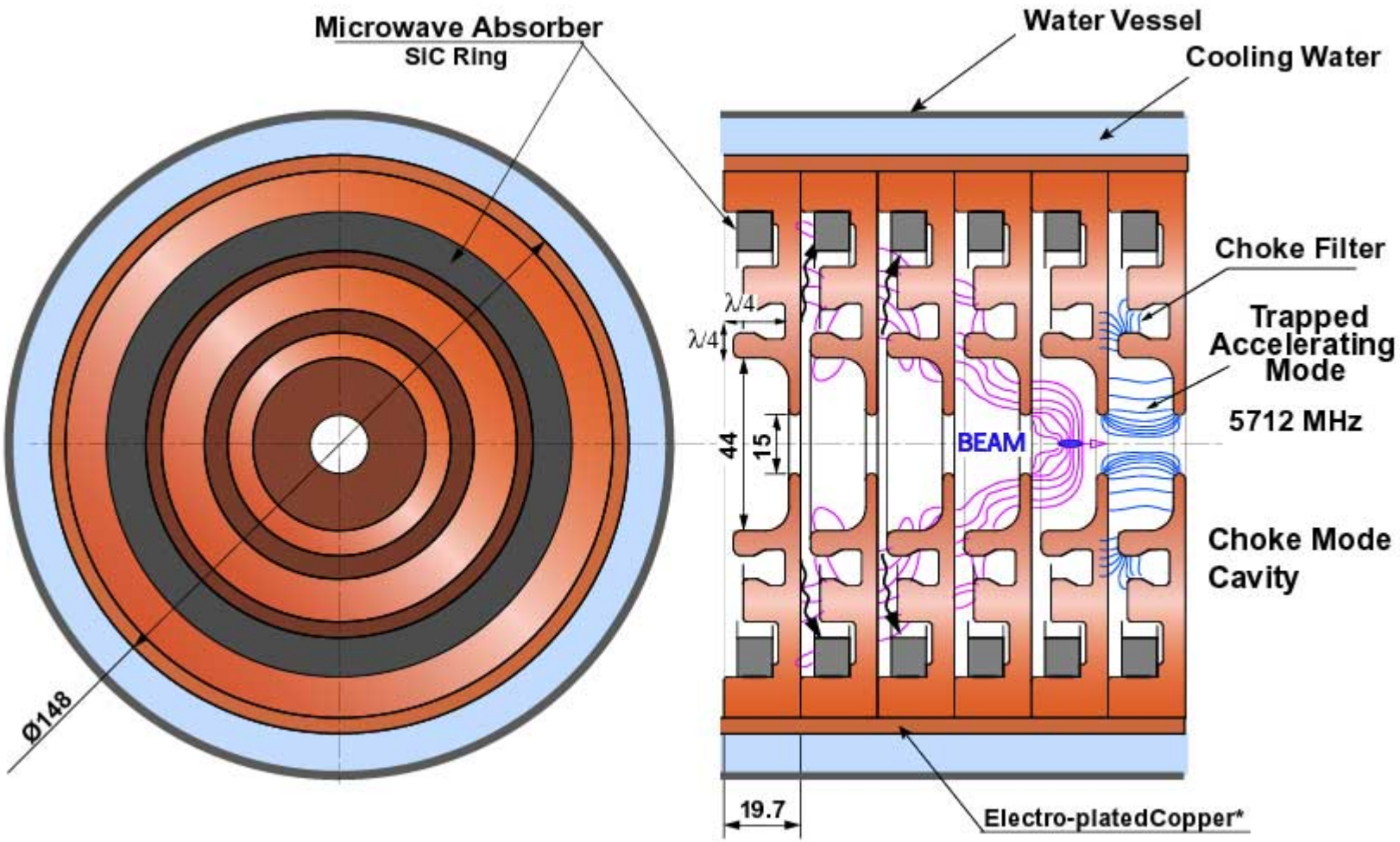


$\vec{H}$

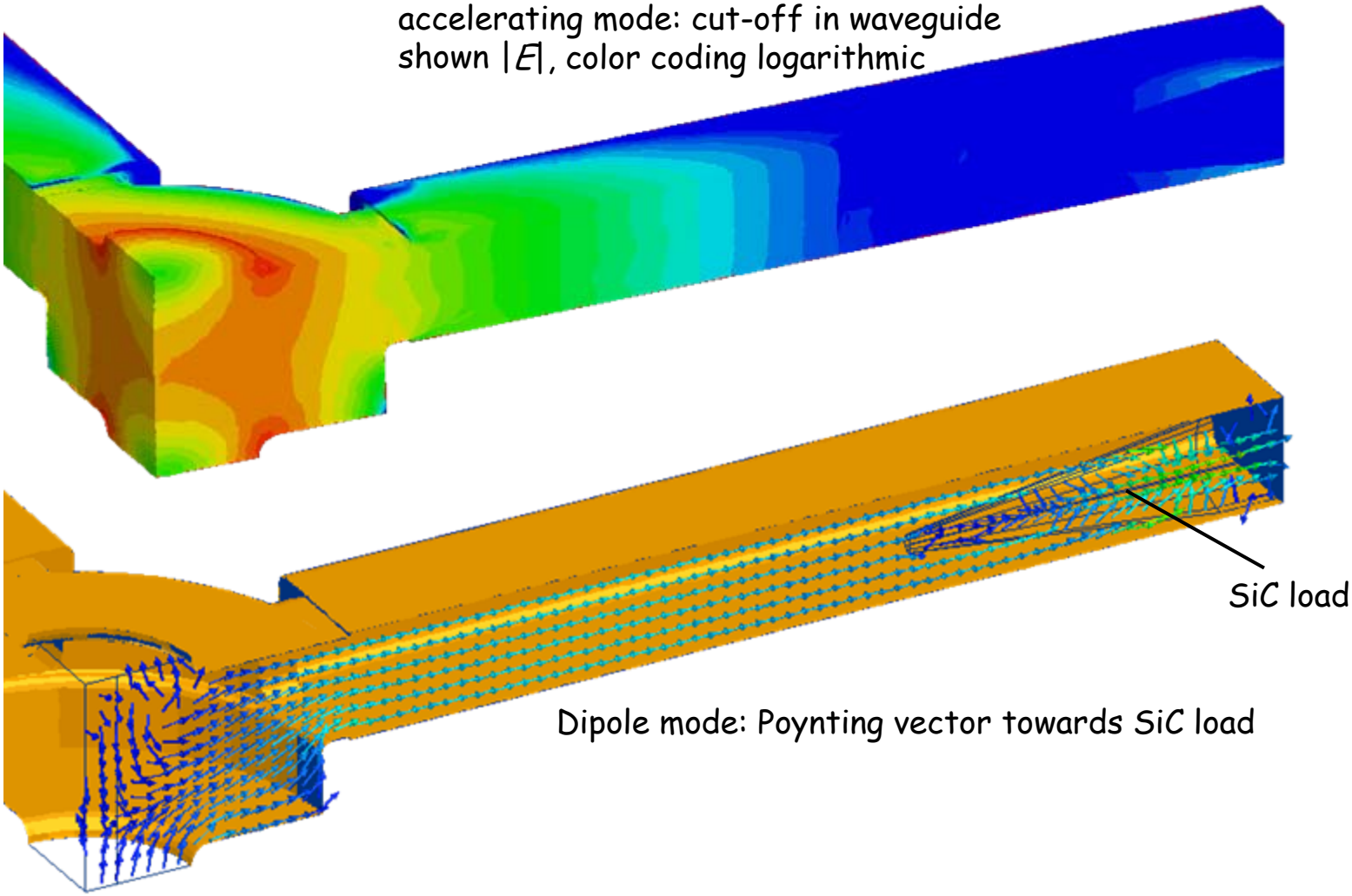




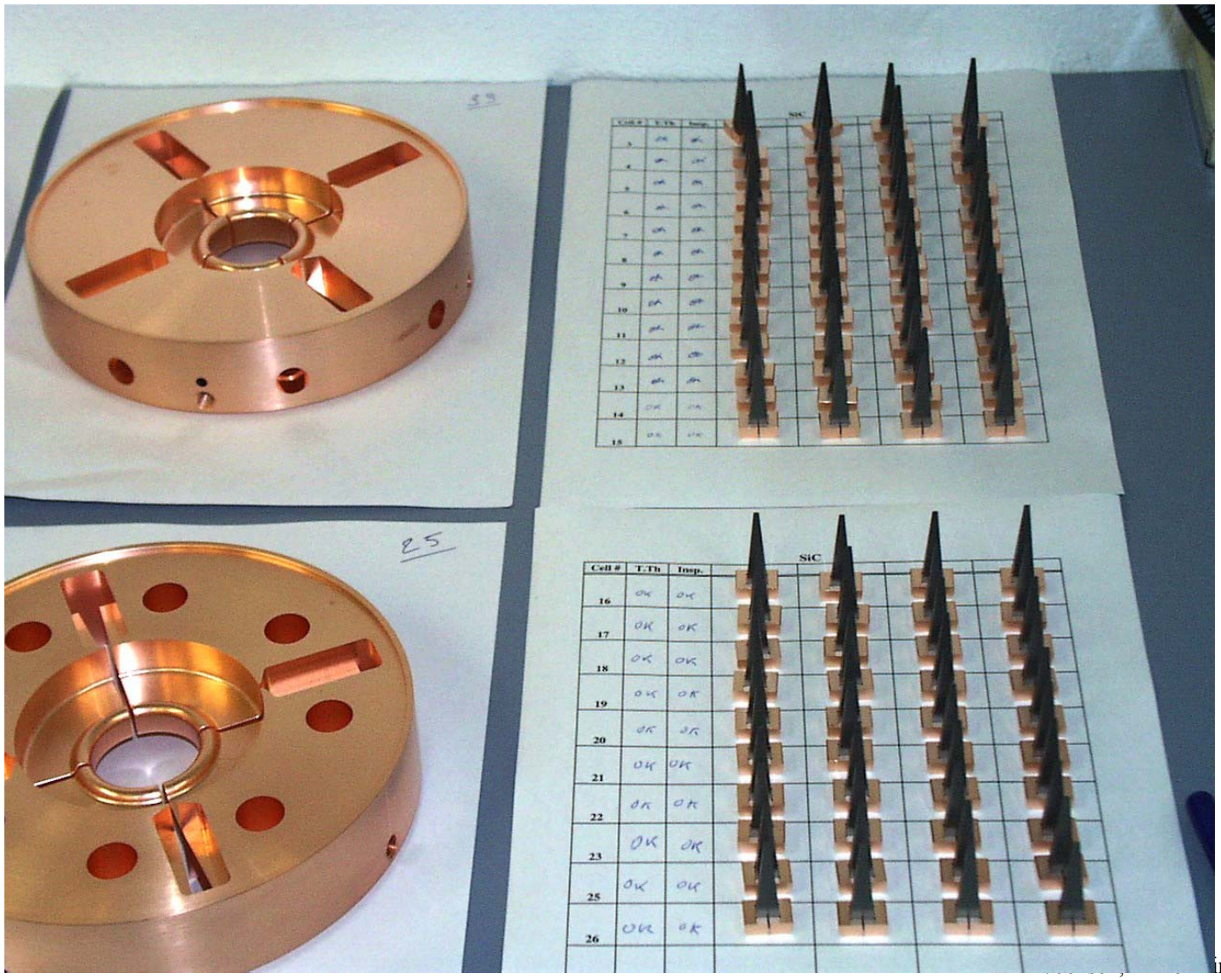
"Choke mode cavity "



TDS: Tapered Damped Structure



Slotted iris structure



HOM damping at work

MAFIA

FRAME: 1 01/06/00 - 17:06:38 VERSION[V4.024] SICA32.DRD

transverse wake for 3 cells.
offset 10 mm, σ 2.5 mm

SI: A+3,10,4, B-5,CELL-6,15
A: 1.700E+01 MM, B: 3.703E+01 MM.
FOR REF., E.J., JUNE 2000

X COMPONENT OF WAKE POTENTIAL IN V [INDIRECT CALC.]

OP-:4024

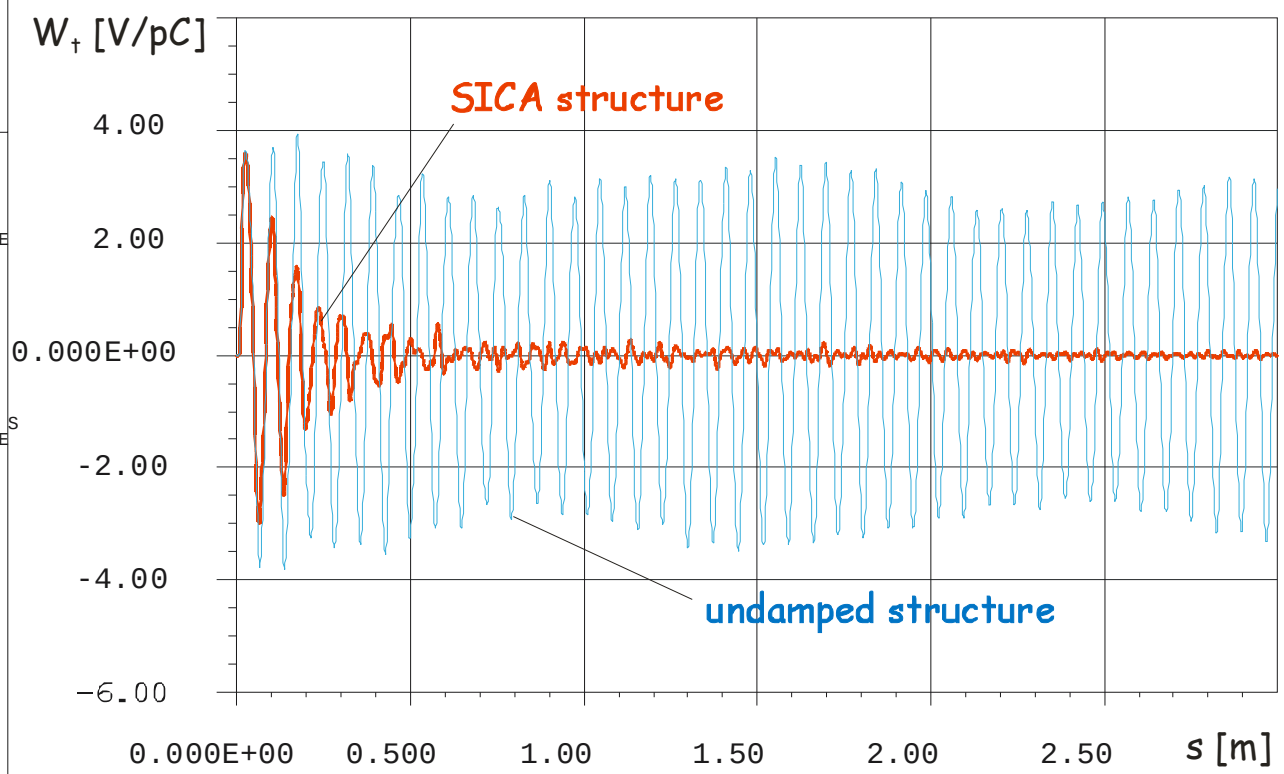
#1DGRAPH

ORDINATE: WAKET
COMPONENT: X

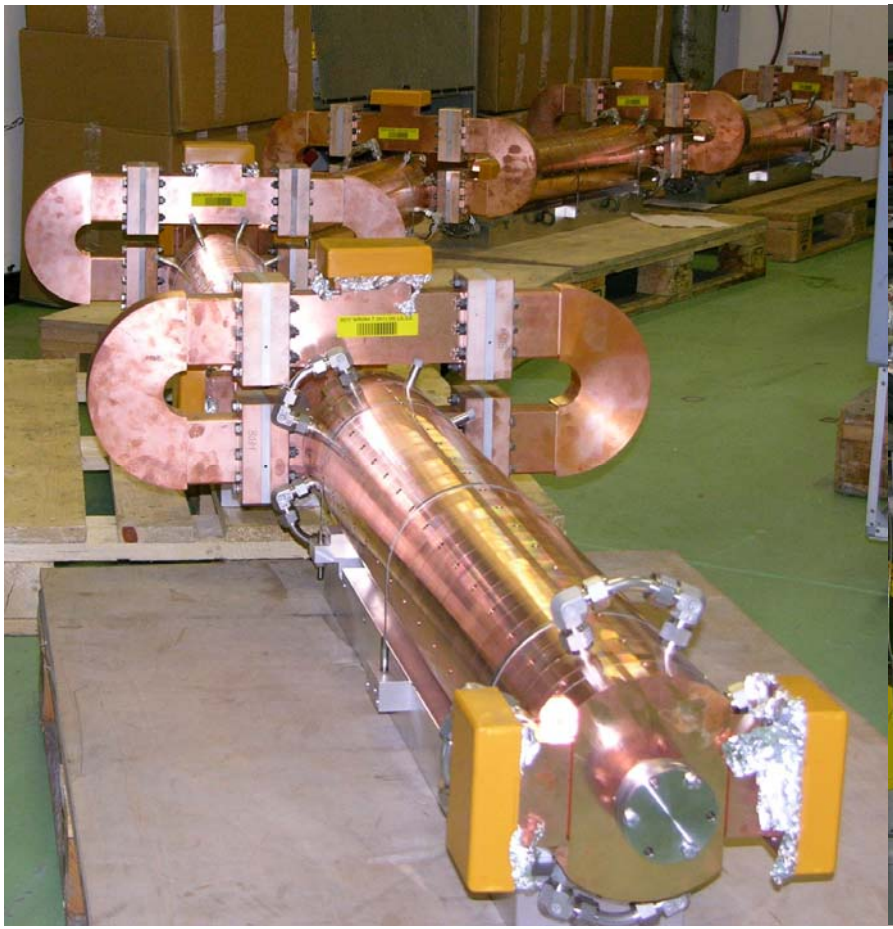
FIXED COORDINATES:
DIM.....MESHLINE
X 11
Y 1

ABSCISSA: GEOMWAKE
[BASE OF WAKET]

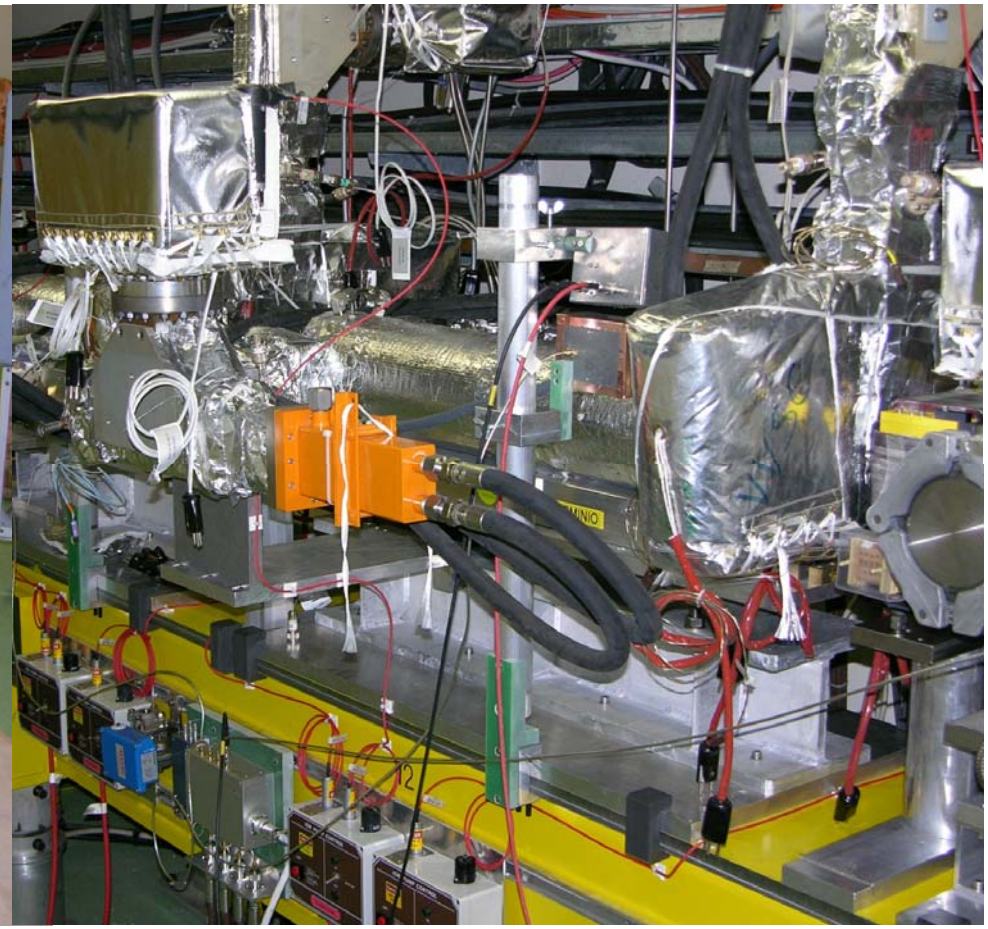
REFERENCE COORDINATE: S
VARY.....MESHLINE
FROM 0
TO 2994



CAS SICA 3 GHz structures



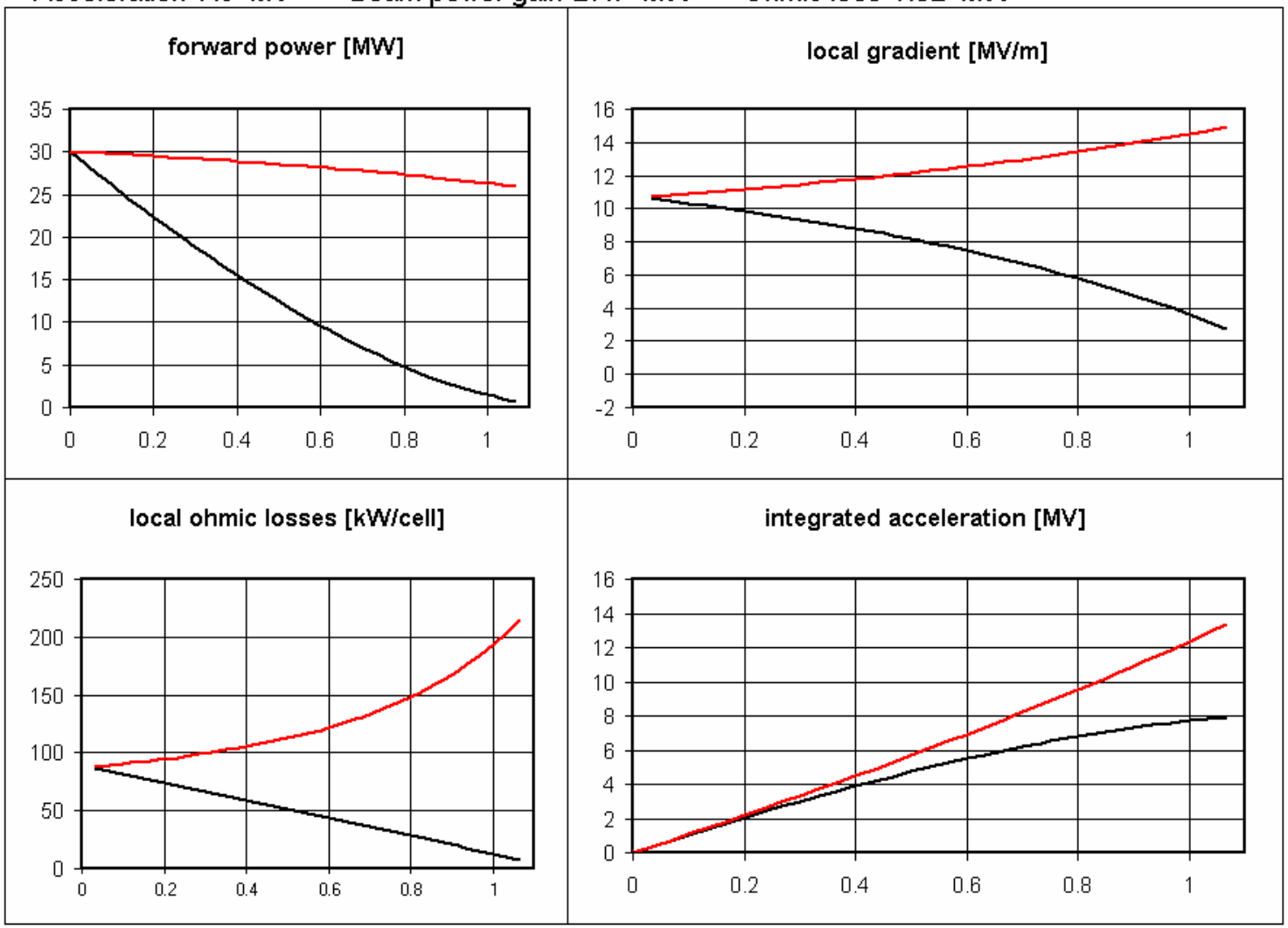
lined up waiting for installation



mounted on the girder in CTF3

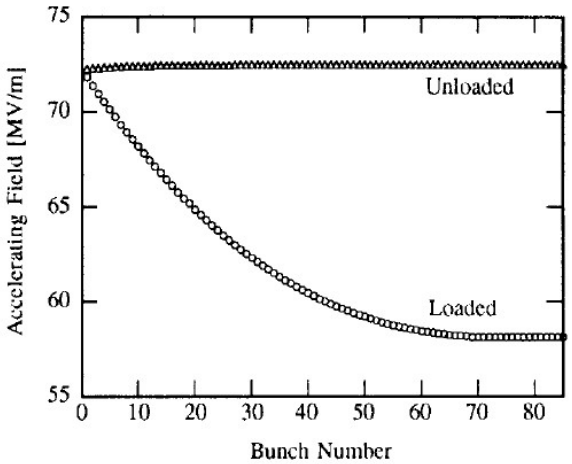
Beam Loading

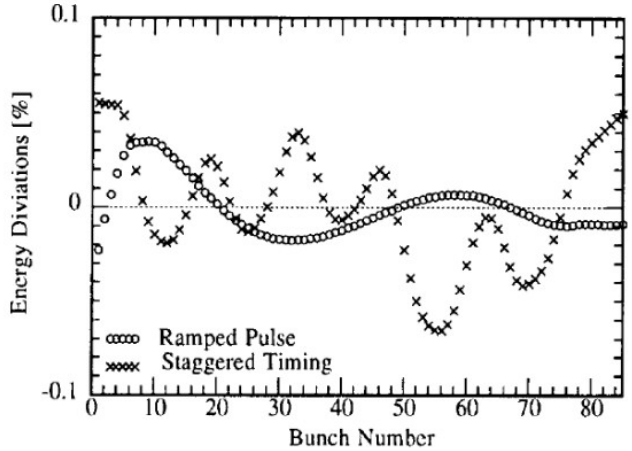
Beam current 3.5 A Input power 30 MW Output power 1 MW η 92.47%
Acceleration 7.9 MV Beam power gain 27.7 MW Ohmic loss 1.52 MW



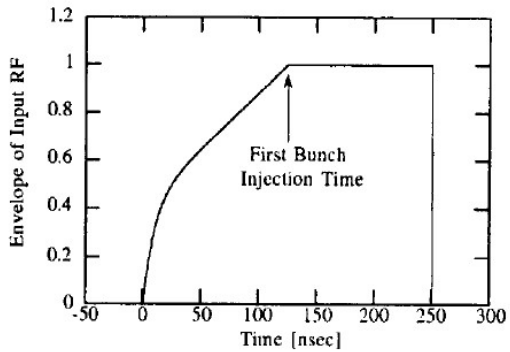
s

Beam loading compensation

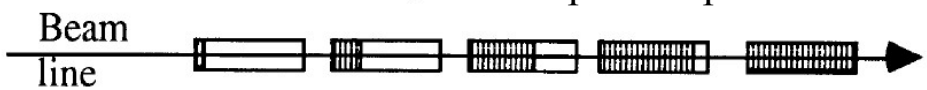




Methods of beam loading compensation:



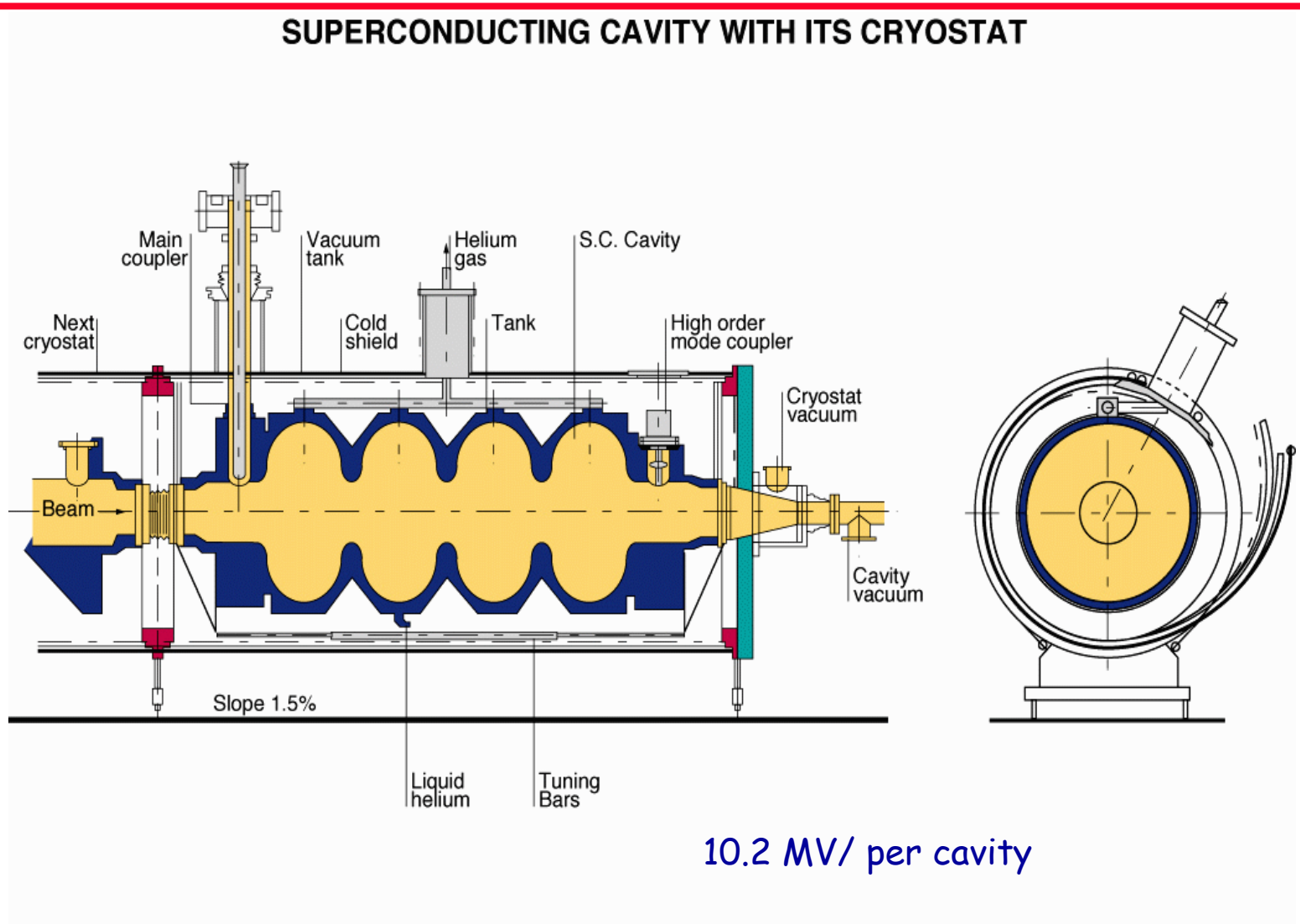
a) Ramped RF pulse



b) Staggered timing

I.V. Syrachev, T.Higo: "Numerical investigation of transient beam loading compensation in JLC X-band main linac", KEK Report 96-8

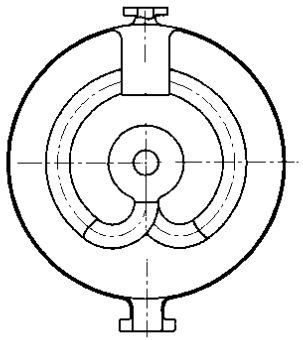
Superconducting RF



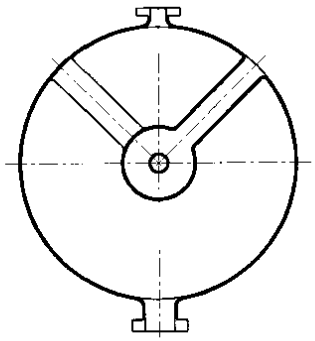
10.2 MV/ per cavity

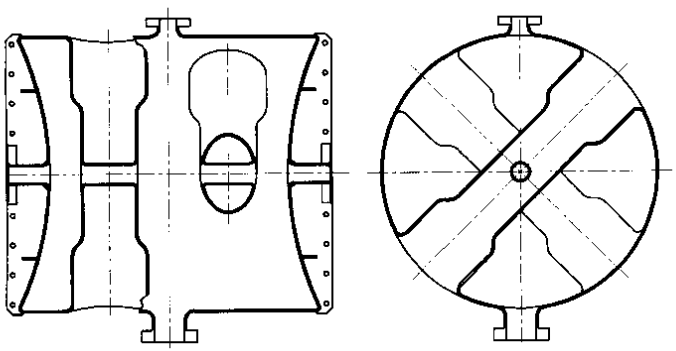
SC cavities for small β

115 MHz split-ring cavity,



172.5 MHz β = 0.19 "lollipop" cavity



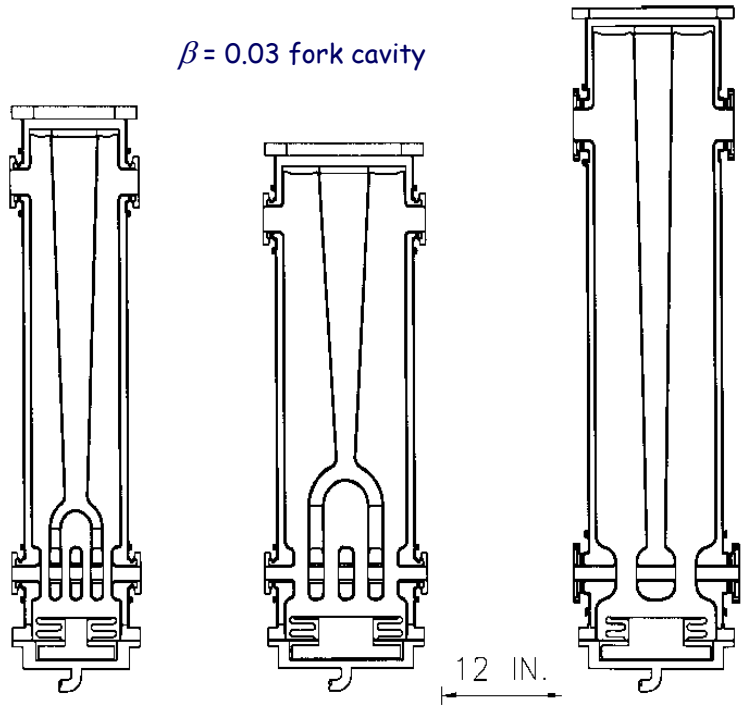


345 MHz β = 0.4 spoke cavity

57.5 MHz cavities:

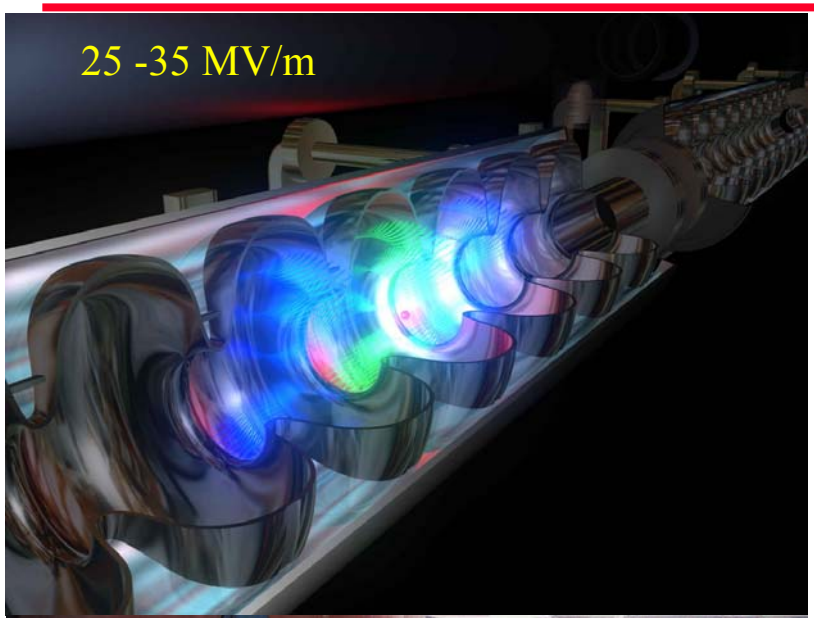
β= 0.06 QWR
(quarter wave resonator)

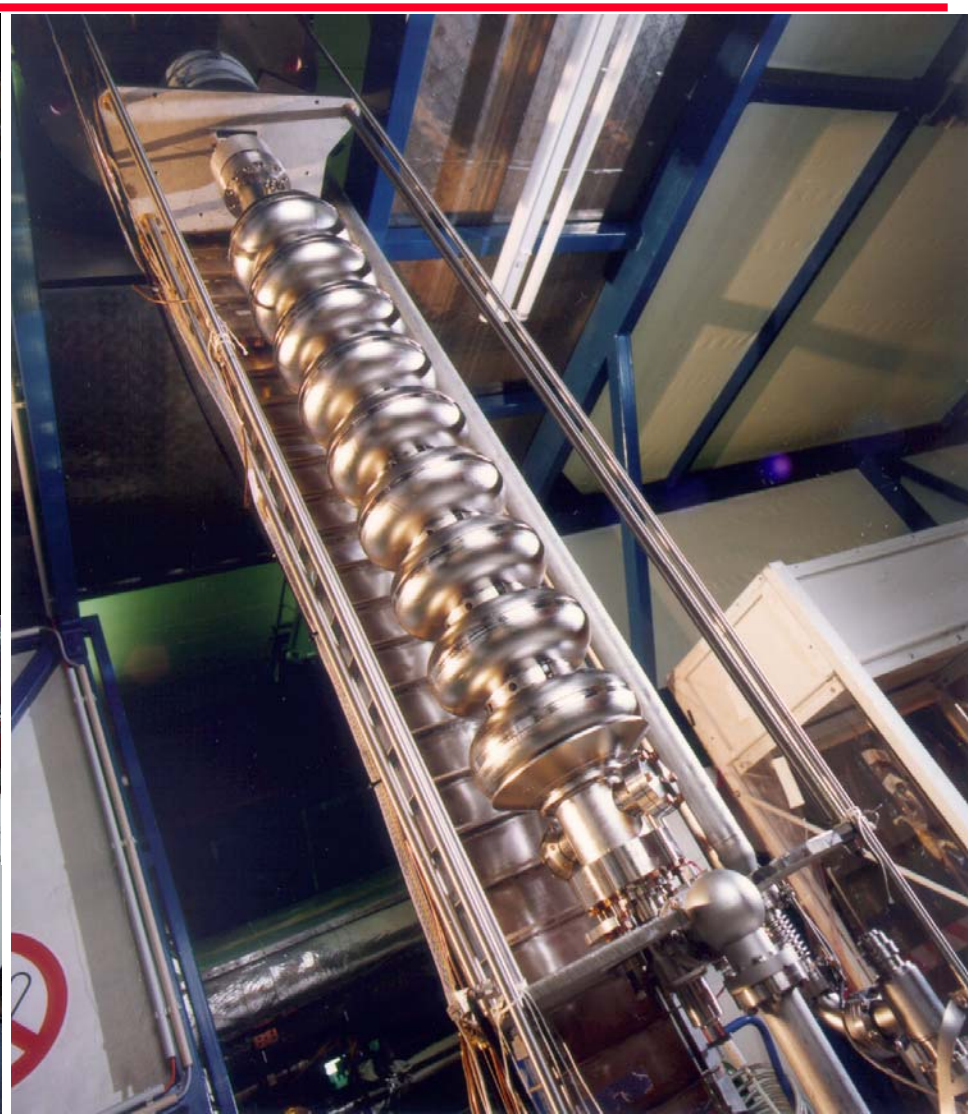
β = 0.03 fork cavity



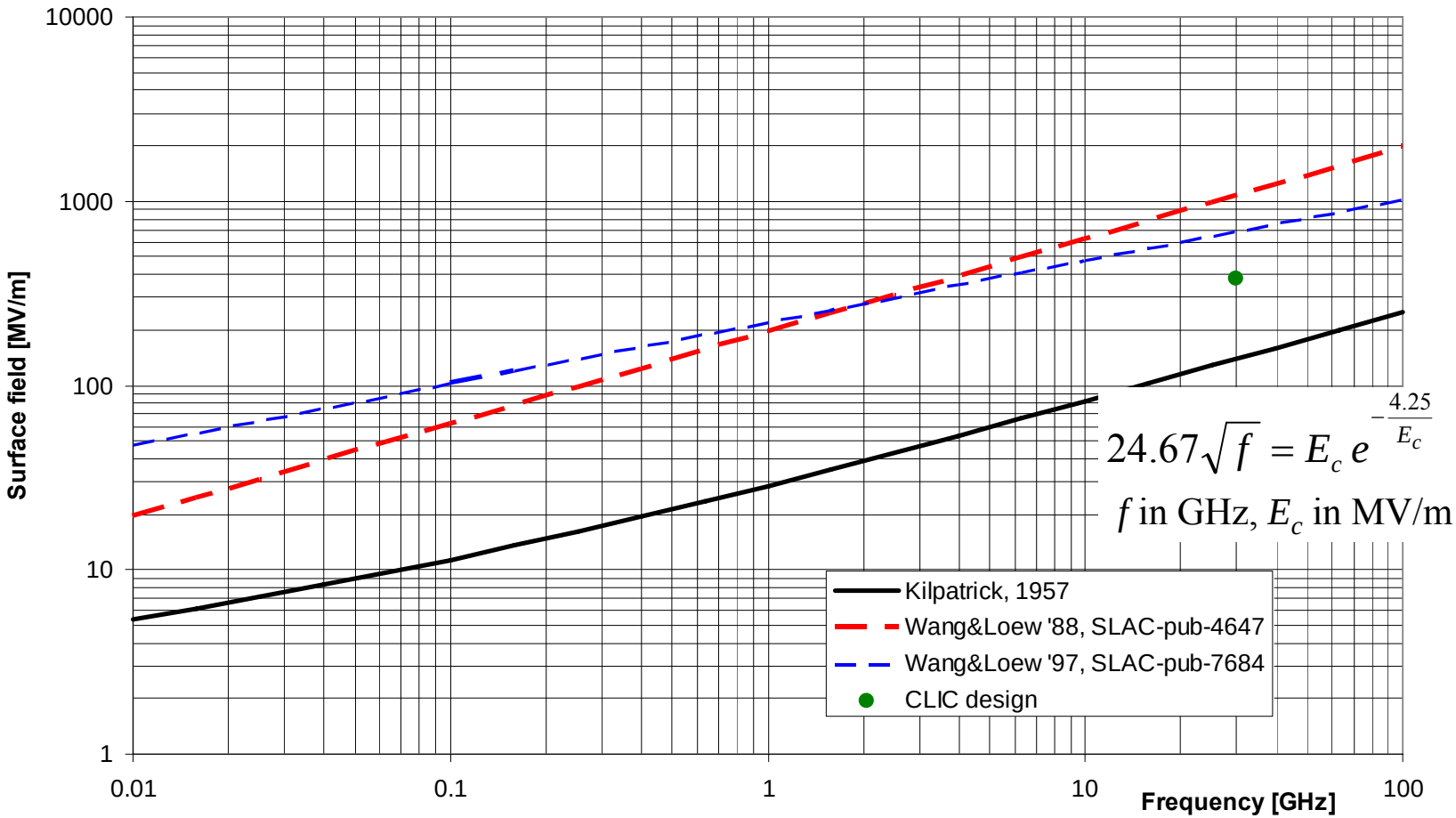
β = 0.021 fork cavity

CAS TESLA/ILC SC cavities



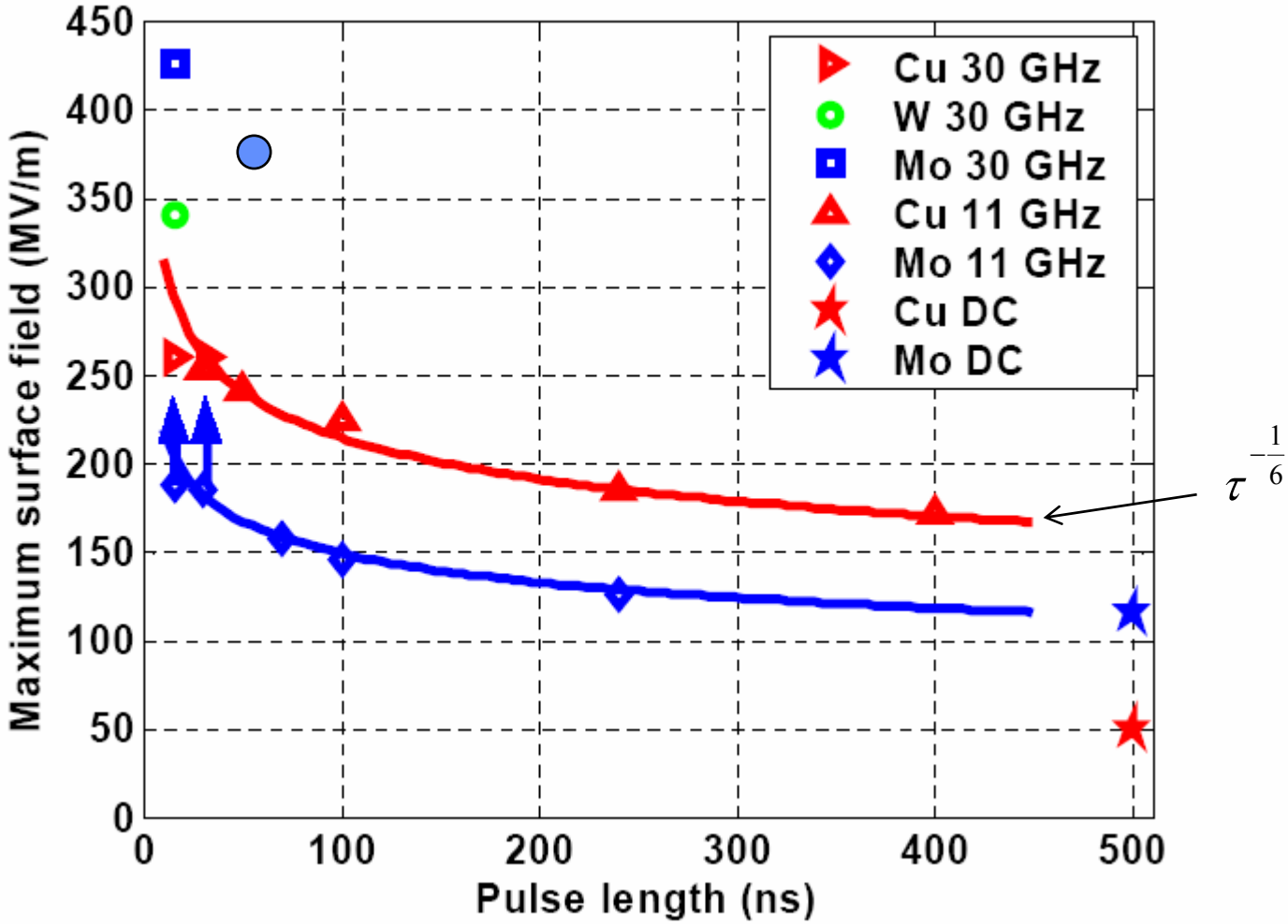


Surface field breakdown limits

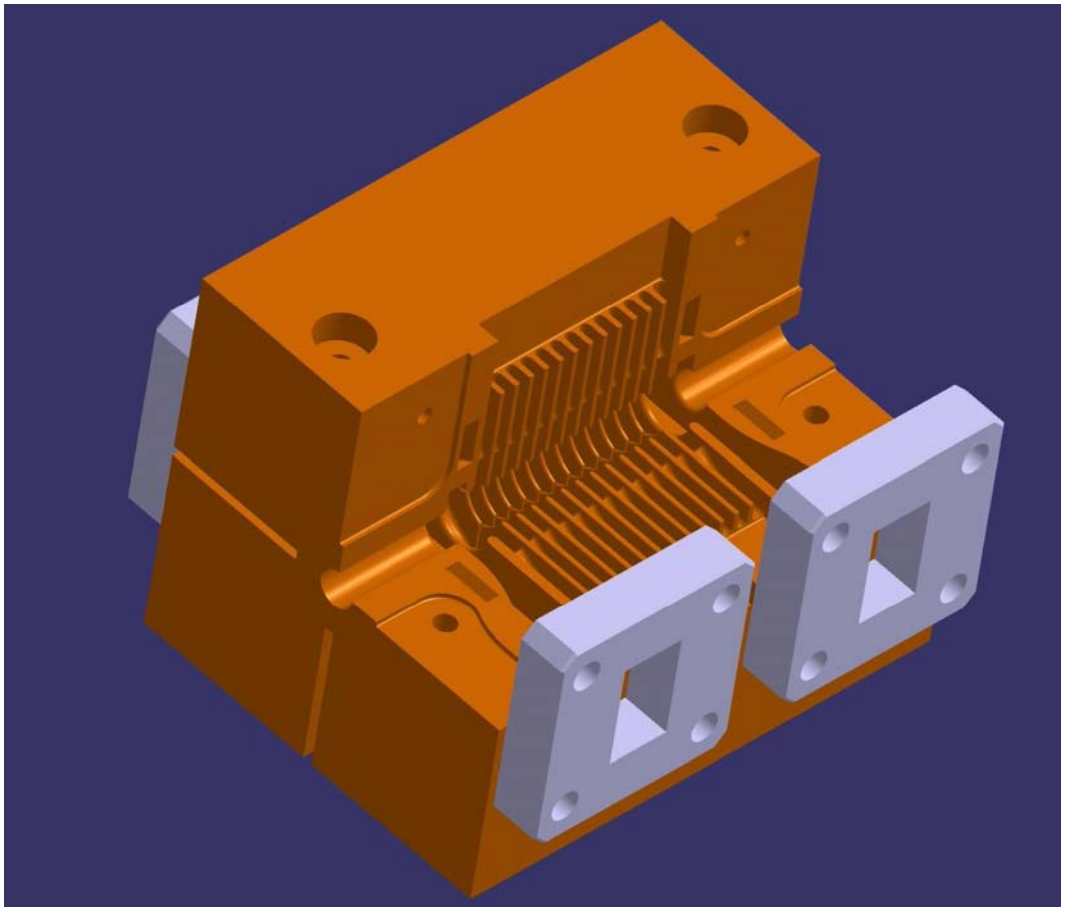


Normal conducting, on Cu

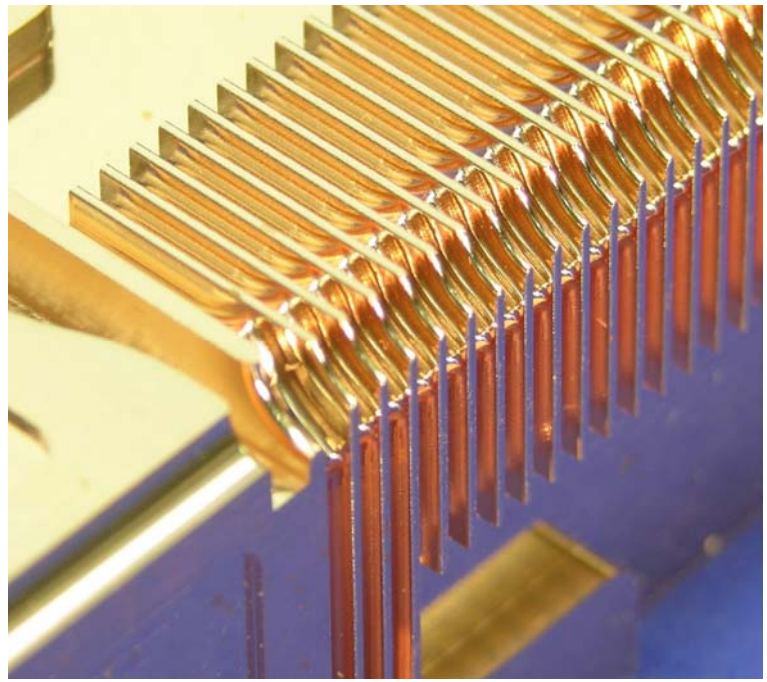
Pulse length dependence



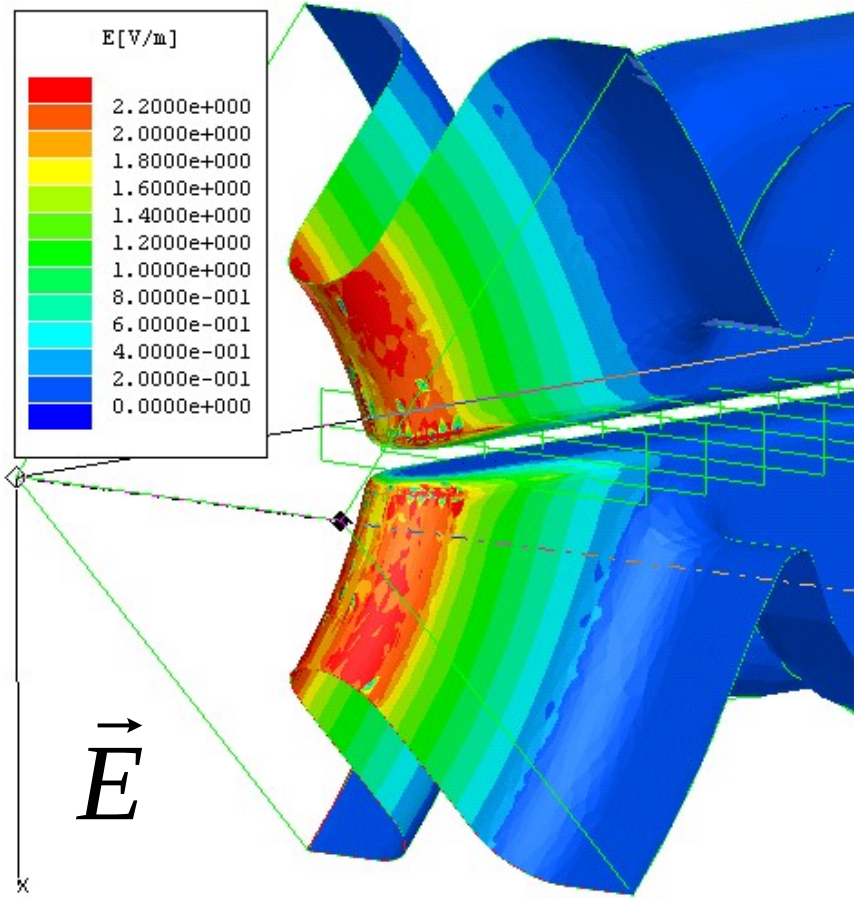
CLIC HDS structure

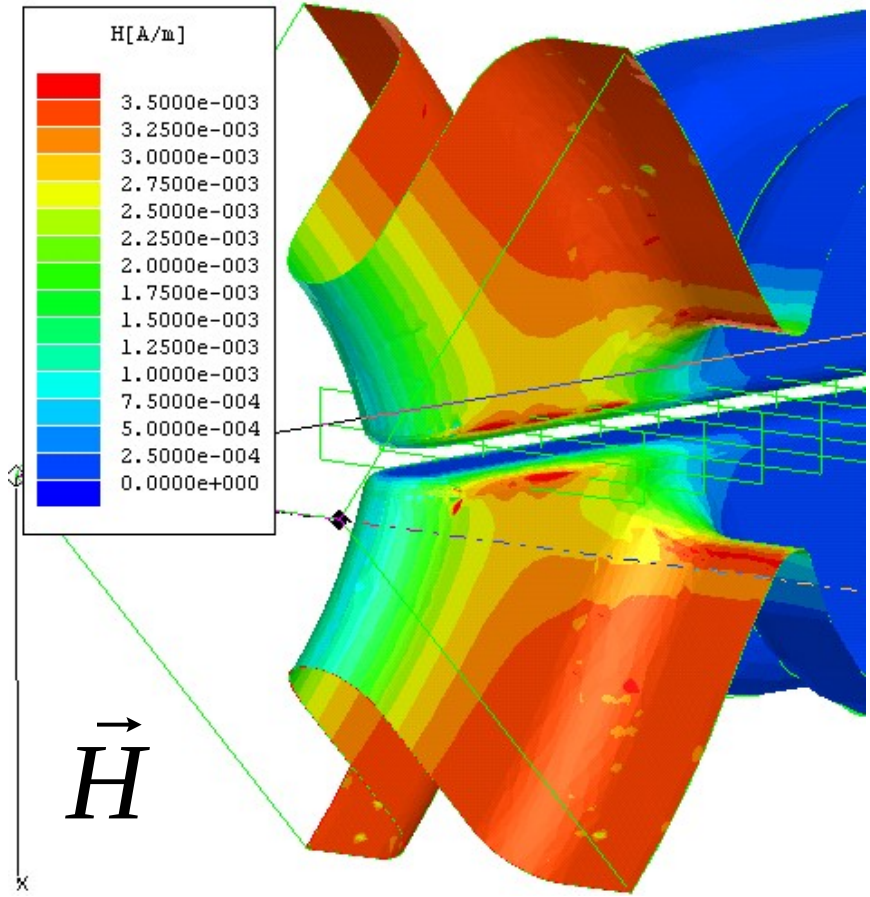


30 GHz, phase advance per cell: 70°,
Cell length: 1.94 mm,
Smallest iris diameter: 3 mm,
accelerating gradient 150 MV/m,
Max surface field 380 MV/m,
max. ΔT 56 K,
Optimized for Mo iris, CuZr cavities



HDS: Optimizing the cavity contour





Field distribution in the optimized HDS cell geometry. The contour optimization is done to prevent hot spots.

HDS: Cu prototype