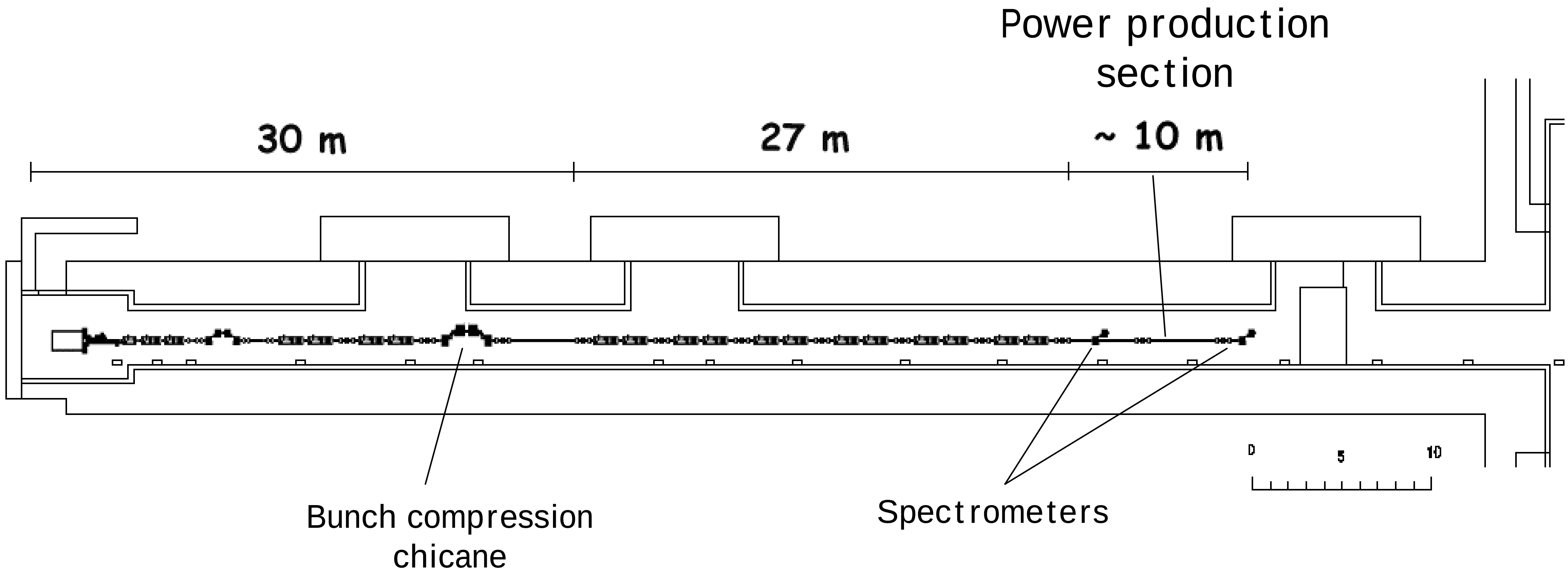
RF Power Production in CTF3 using the DBA

MOTIVATIONS:

- Following recent evidence of high-gradient limitations and damage in 11.4 GHz NLC prototype structures as well as in 30 GHz CLIC prototype structures, the CLIC study group started an intense R&D program, centered on high-power test of components.
- These test are at present carried out in CTF II, which will be shut down at the end of 2002.
- The CLIC study needs a 30 GHz high power source (in the 100 MW range) at an early stage in CTF3 after CTF II shut down and before CTF3 Nominal Phase operations in 2005.

The DBA should be commissioned towards the end of 2003, and be in operation in 2004.
Can the DBA beam be used to produce 30 GHz power with the required characteristics ?

Drive Beam Accelerator Layout



The DBA zone can be separated from the rest of the CTF3 building. High power tests can thus proceed while doing civil engineering and installation work in the rest of the complex.

QUESTIONS:

- What kind of structure is most adapted to such a task ?
- What would be the requirements on the electron beam ?

The basic formula for RF power production in Power Extraction and Transfer Structures (PETS) is (steady-state regime, linac Ω):

Limited by gun & linac performances

Limited by transport and RF losses

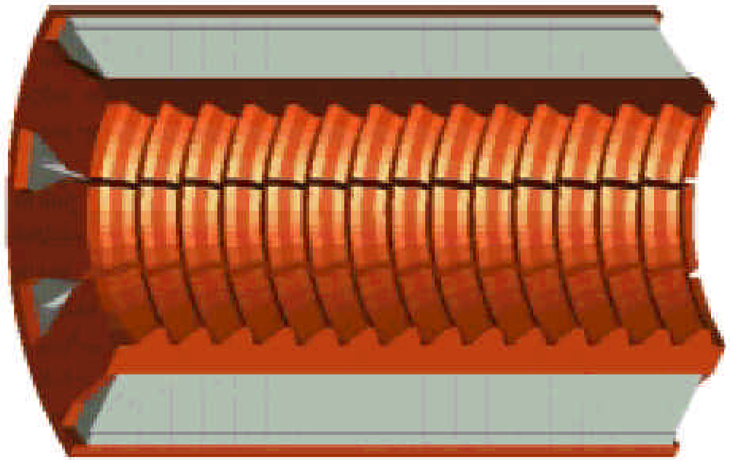
$$P = \frac{w}{4c} I^2 \left(\frac{R'}{Q} \right) \frac{1}{b_g} l_S^2 F^2 \qquad (1)$$

Maximum of about 1 for short bunches, no phase errors

Structure design, linked to aperture and transverse wakes, finally limited by transport

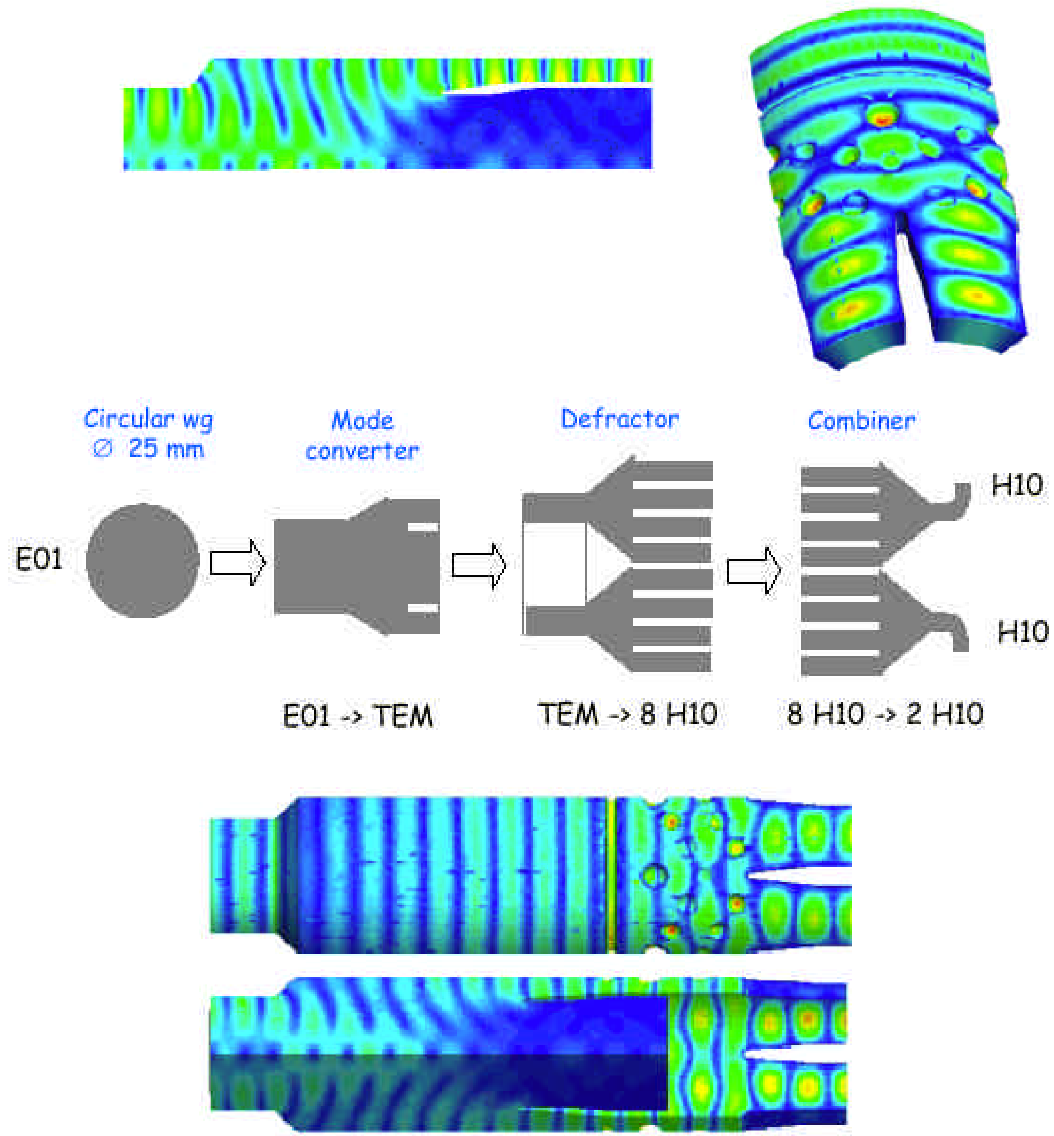
Circularly symmetric PETS

I. Syratchev



Quarter C-PETS geometry
with 12 SiC loads.

Coupler Design for C-PETS



REQUIRED POWER

- At present, about 40 MW, 15 ns pulses used for structure testing in CTF II, limited by breakdowns - such power level in the CTF3 linac would already be an extension of the present tests, since longer pulses (≥ 100 ns) would be possible. The repetition rate is also potentially higher (5 Hz ⇒ 25 Hz).

- A new CLIC accelerating structure is at present under development. 58 MW at the structure input are needed to reach 150 MV/m accelerating field for the new structure design.The surface to accelerating field ratio in this structure is 2.18 - peak surface field » 300 MV/m (I. Syratchev).

- Operational experience with CTF II has shown that in practice, only 2/3 of the theoretical RF power is obtained.

Required power » 100 MW

(including form factor, PETS imperfections, coupler & waveguide losses, but NOT including PETS Q-value, that must be treated in the calculation)

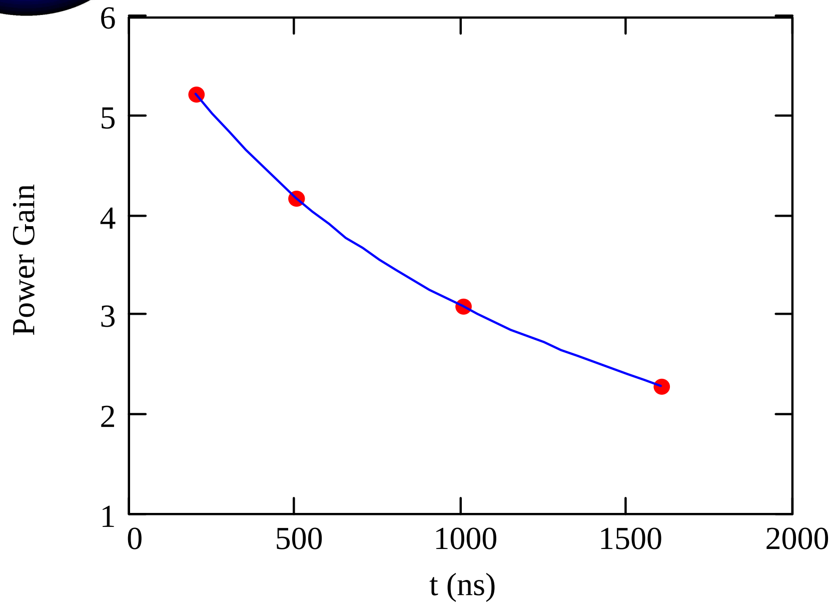
MAXIMUM FIELD IN PETS

Maximum surface field in PETS:

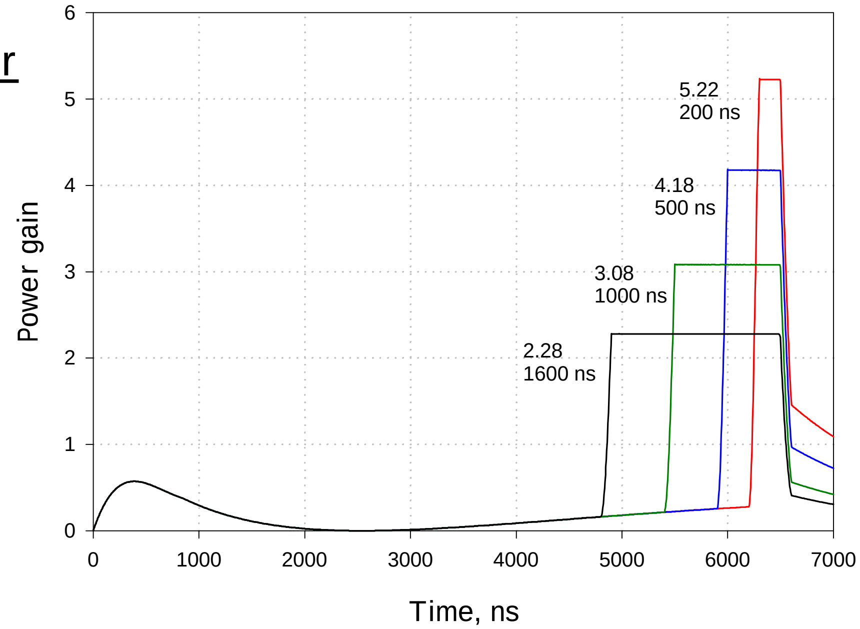
- As mentioned, the max surface field in the accelerating structures to be tested is of the order of 300 MV/m
- It looks reasonable to limit the maximum surface field anywhere in the PETS to a significant lower value (e.g. a factor 2). The PETS themselves should not be part of the breakdown studies !

Required max surface field in PETS £ 150 MV/m

ELECTRON BEAM CURRENT



Data from Igor



- For a reduced electron pulse length (» 200 ns) the current can be increased from 3.5 A to 5 A, for the same beam loading - the beam energy will also increase by the same factor from 150 MeV to 210 MeV

Electron beam current = 5 A

- the power at the DBA structure input would be 60 MW (possible?)
- The RF pulse compression system should manage also twice the nominal power
- the total beam peak power will be 1 GW

Pulse length - Repetition rate

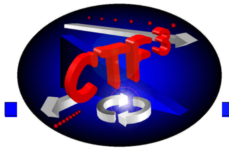
- The filling time of the DBA structure is 100 ns (transient beam loading). The PETS filling time is typically much smaller (< 10 ns ?). For a 200 ns electron pulse length the RF pulse length should be > 100 ns. A longer electron pulse should be possible, with a somewhat reduced current.

- Shorter RF pulses are in principle possible. They will be useful to study the breakdown limit dependence on pulse length, in the region from 15 ns (tested in CTF II) up to the nominal CLIC pulse length.

- A high rep rate would be important to reduce the conditioning time and to perform life-time tests.

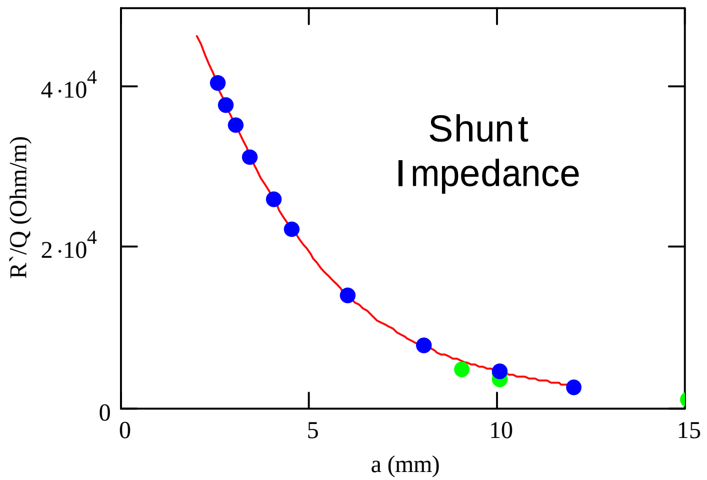
- The average beam power in the DBA for the nominal phase is 4 kW (5 Hz, 3.5 A, 150 MeV, 1.5 μs). The average beam power for DBA RF power production would be 5 kW at 25 Hz. (5 A, 210 MeV, 200 ns).

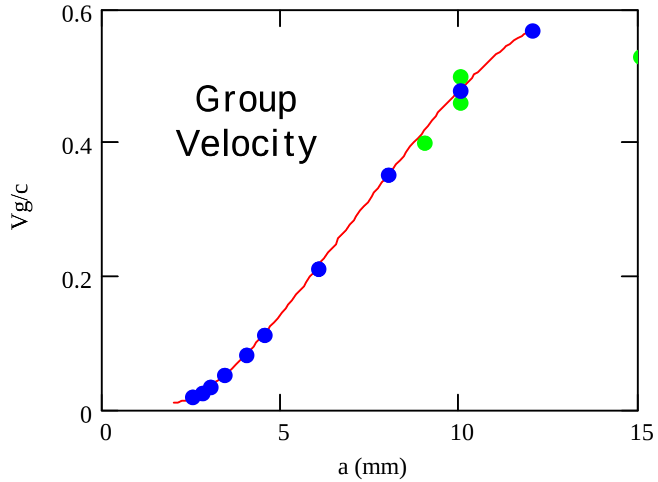
- The CTF3 shielding is designed for an average beam power of 6 kW.



PETS scaling

- Simple PETS design: cylindrically symmetric, iris loaded waveguide $2\pi/3$ phase advance, constant aperture.

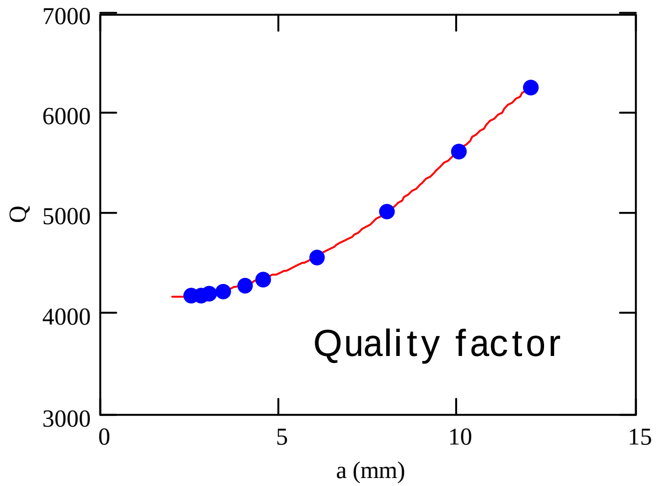




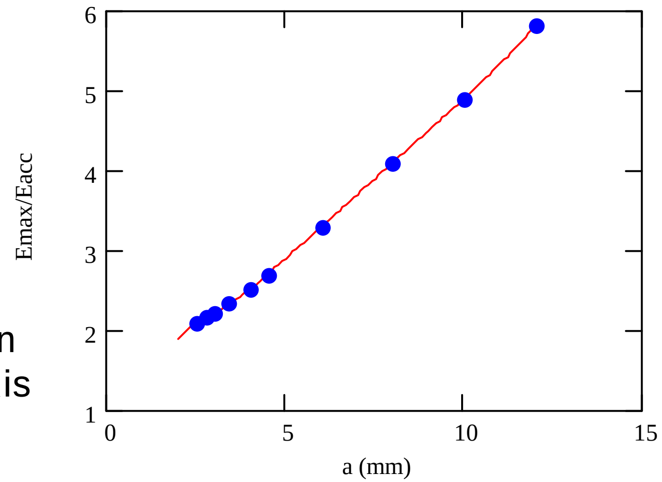
Data from A. Millich (4 wg)

Data from I. Syratchev (iris loaded)

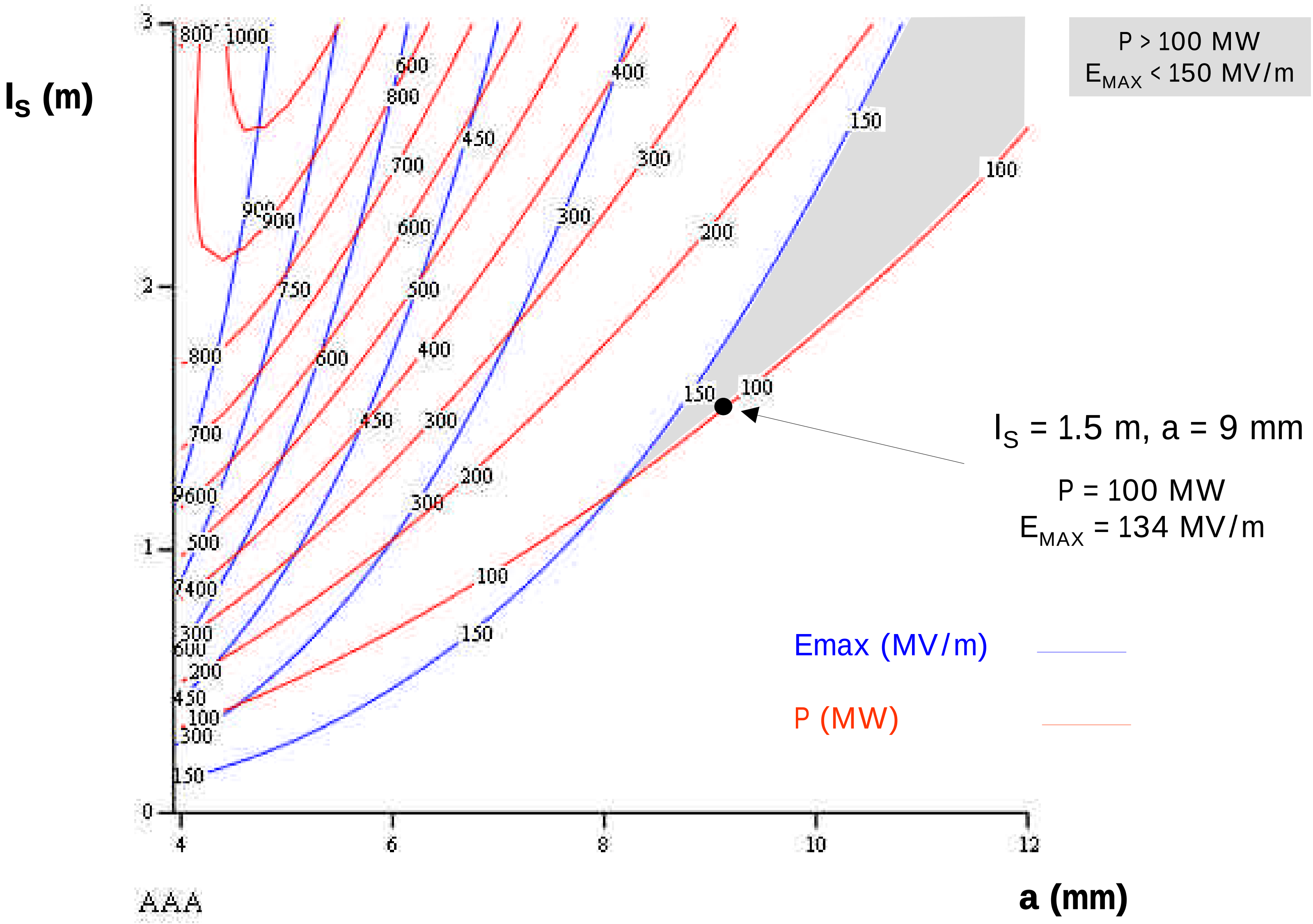
Fit used for power calculation



Ratio between max and on-axis field



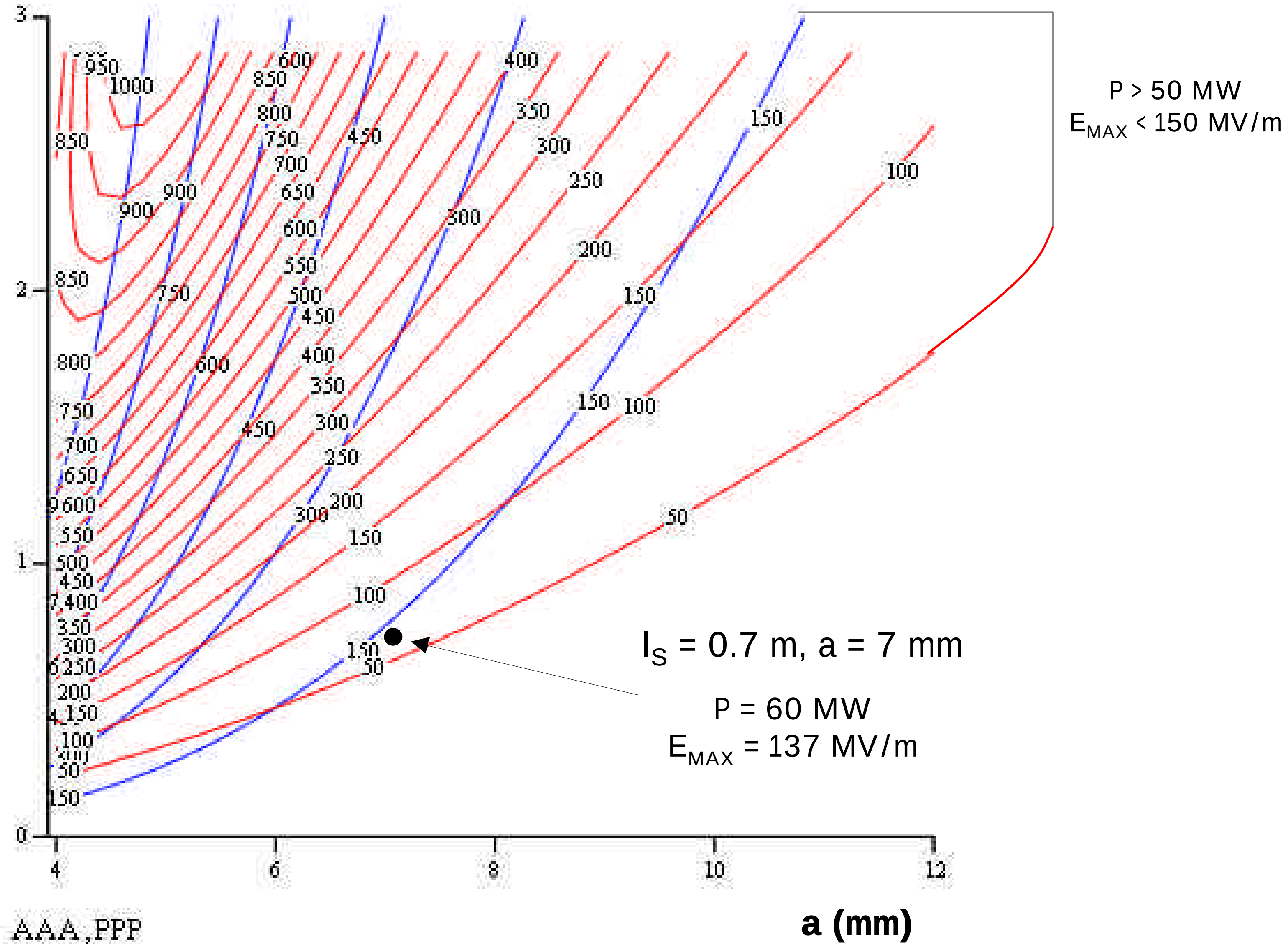
SIMPLE PETS



l_S (m)
P > 100 MW
E_{MAX} < 150 MV/m
l_S = 1.5 m, a = 9 mm
P = 100 MW
E_{MAX} = 134 MV/m
Emax (MV/m)
P (MW)
0
1
2
3
4
6
8
10
12
a (mm)
AAA

TWO "SIMPLE" PETS

l_S (m)



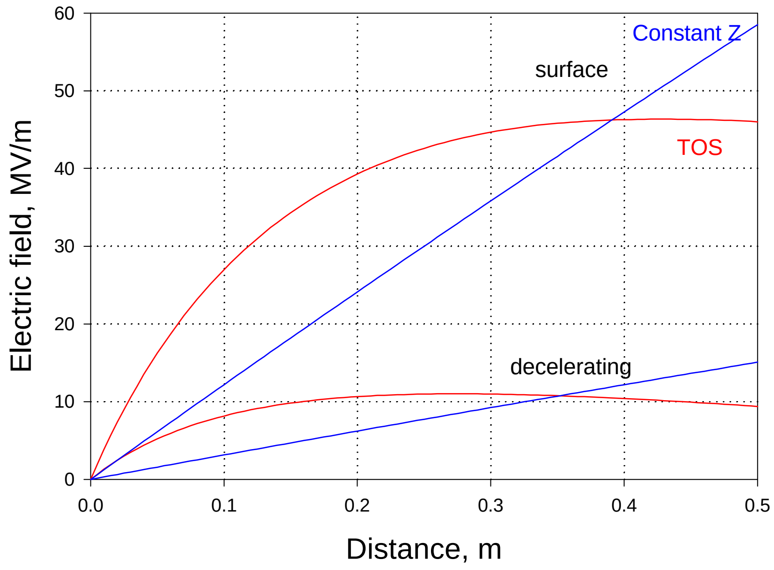
a (mm)

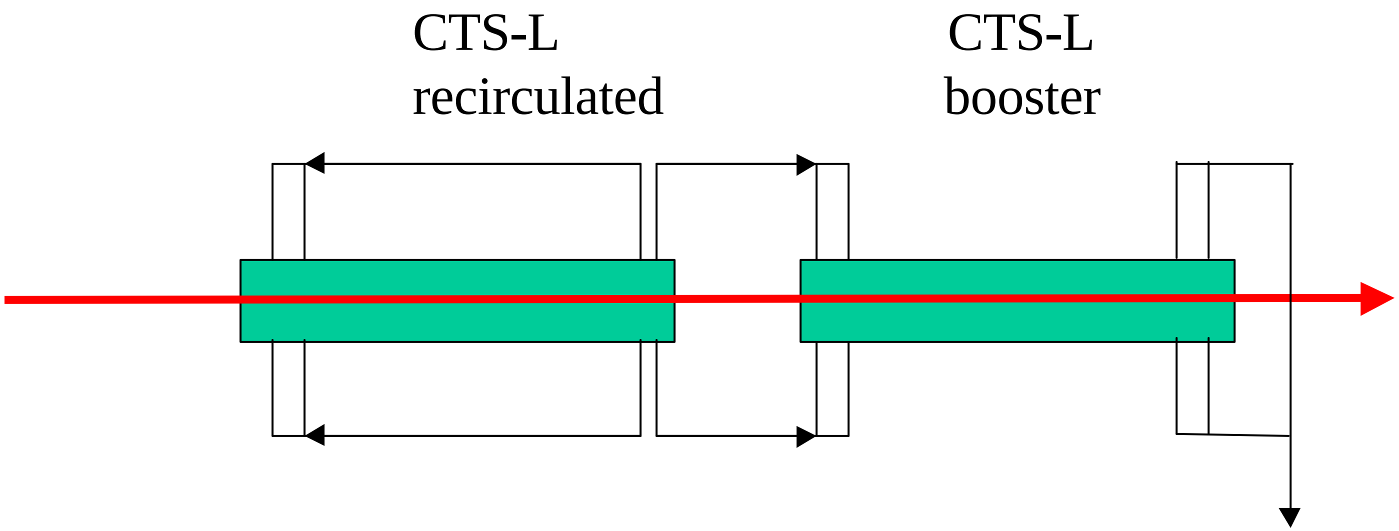
The tapered-out structure.

While the generation of the RF power with the beam, the highest surface field will take place at the end of the structure. The situation can be improved with the tapering the structure starting from the lower group velocity at the beginning towards higher group velocity at the end (Tapered-Out Structure).

Comparison for the 0.5 m structure and 3.5 A current

	Aperture, mm(bg,%)	Max. S. Field, MV/m	Power, MW
Constant z	7.5 (31.5)	58.5	12.54
TOS	5->10 (15-48)	46.0	14.87

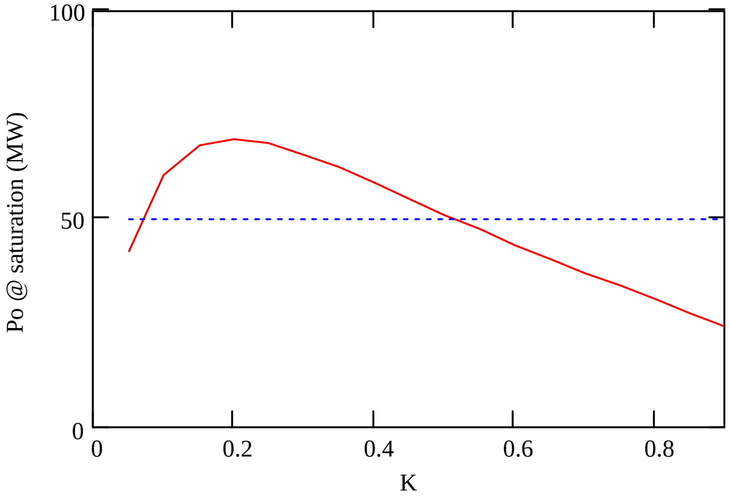


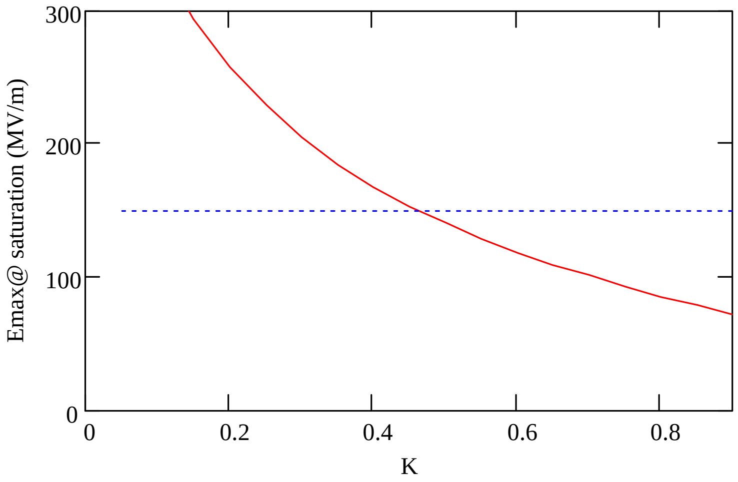


H. Braun

RECIRCULATION

- Not useful for single structure, P > 100 MW , due to limitation in peak surface field
- Can be used for two-structure operation (P> 50 MW), or for "booster" mode
- Example:





l_S = 0.5 m, a = 8.6 mm

P = 51 MW
E_{MAX} = 140 MV/m

Plus second structure in "booster" mode, will give:

P = 120 MW
E_{MAX} = 154 MV/m

SUMMARY - OUTLOOK

- Production of 30 GHz power in the 100 MW range using the DBA looks possible.
- Pulse lengths ranging up to the nominal CLIC value (150 ns) and a repetition rate of 25 Hz should be accessible.
- The optimum PETS design and parameters are still to be identified - some investigation in beam transport & stability must be made to assess that.
- Recirculation + booster operation can possibly be used with some advantage. A proof-of -principle test of recirculation in CTF II would be useful.