

A possible linearizer at 35.982 GHz

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on behalf of the SPARC - LAB collaboration

Summary

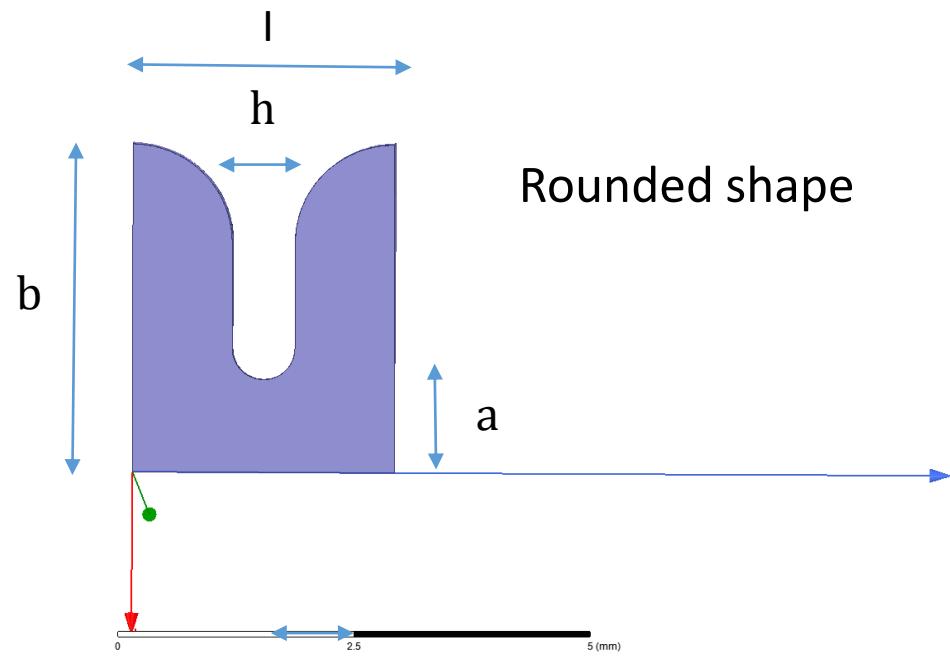
Rounded cavity design (hard shape cavity already discussed in Trieste)

Accelerating electric field estimations

Thermal stress studies

Longitudinal and transverse loss parameters estimations

TW cavity shape for the $2\pi/3$ mode



$l = \text{cell lenght } \lambda/3$

$b = \text{cavity radius}$

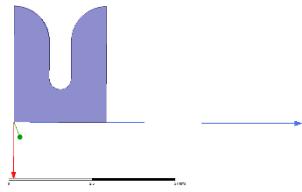
$a = \text{iris radius}$

$h = \text{iris thickness}$

$$\frac{v_{gr}}{c} = \frac{1}{c} \frac{d\omega}{d\Phi}$$

$\Phi = \text{phase advance}$

Shunt impedance and quality factor Q estimations of the rounded cavity as function of the iris radius at F = 35.982 GHz



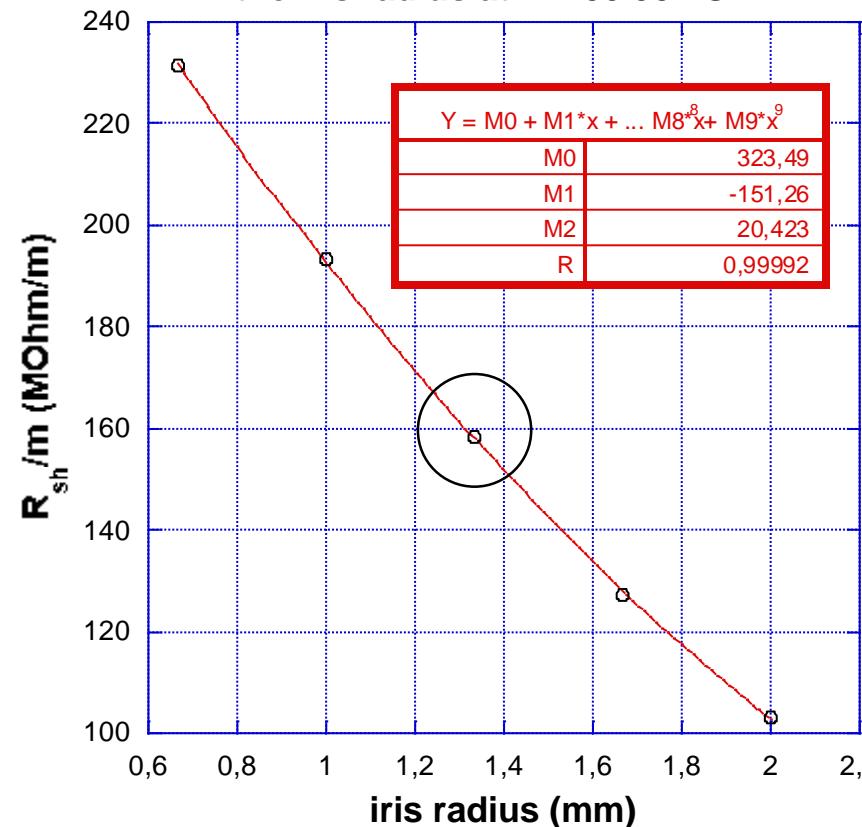
iris radius $a = 1.333 \text{ mm}$

$b = 3.657 \text{ mm}$

thickness iris $h = 0.667 \text{ mm}$

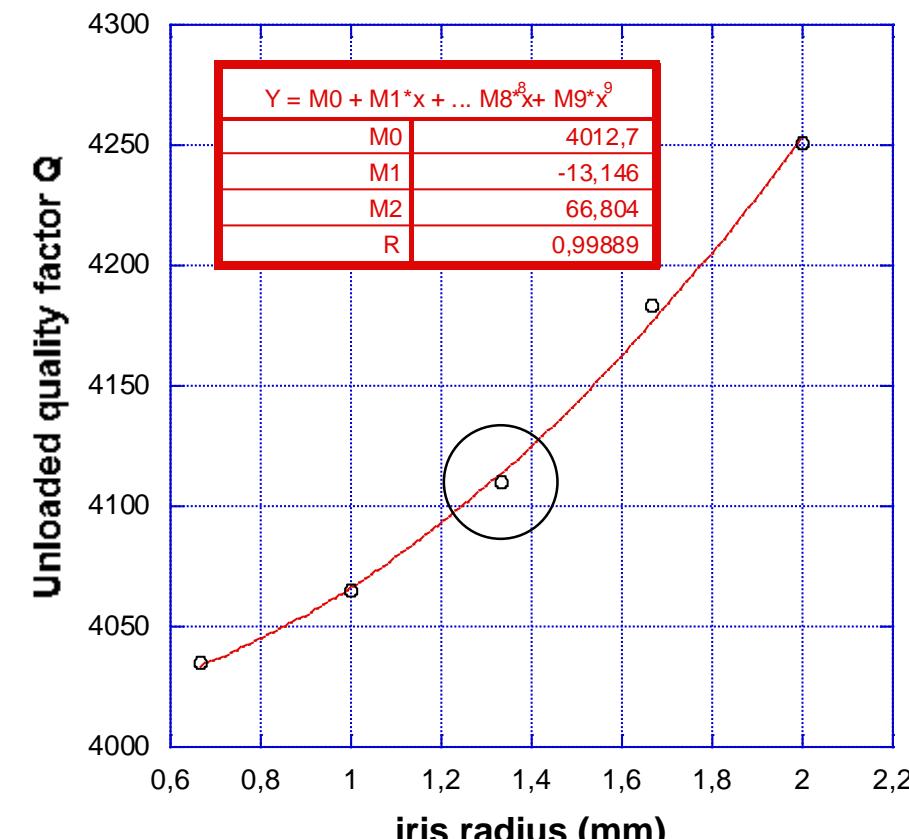
$F = 35.982 \text{ GHz}$

Shunt impedance as function of the iris radius at $F = 35.982 \text{ GHz}$



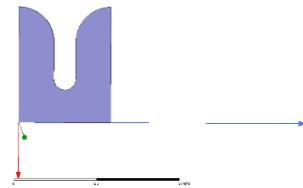
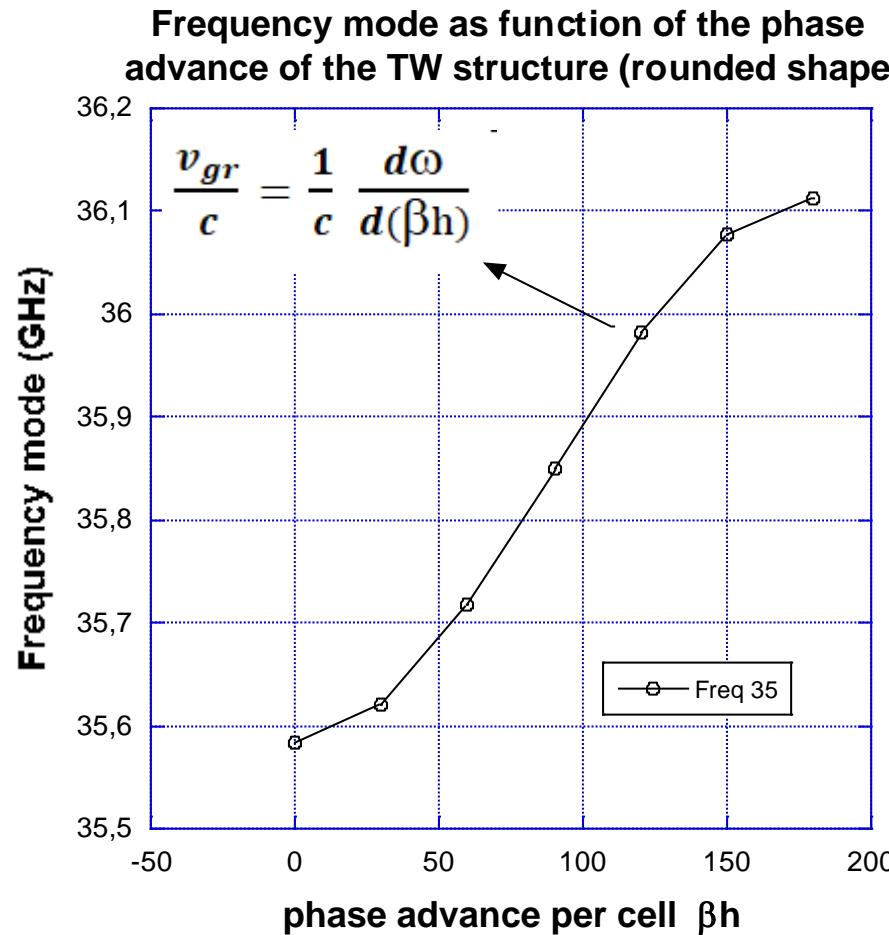
$$R_{sh} / m = 158 \text{ M}\Omega / \text{m} \text{ (144 hard edge)}$$

Unloaded quality factor Q as function of the iris radius at $F = 35.982 \text{ GHz}$



$$Q = 4110 \text{ (} Q = 3718 \text{ hard edge)}$$

Dispersion relation of the rounded shape of the TW structure



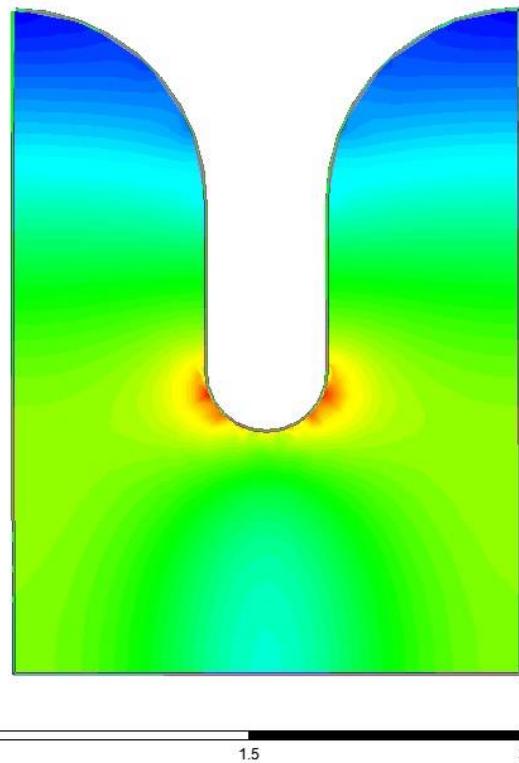
$a = 1.333 \text{ mm}$, $h = 0.667 \text{ mm}$, $b = 3.657 \text{ mm}$

$F = 35.982 \text{ GHz}$ ($2\pi/3$ mode)

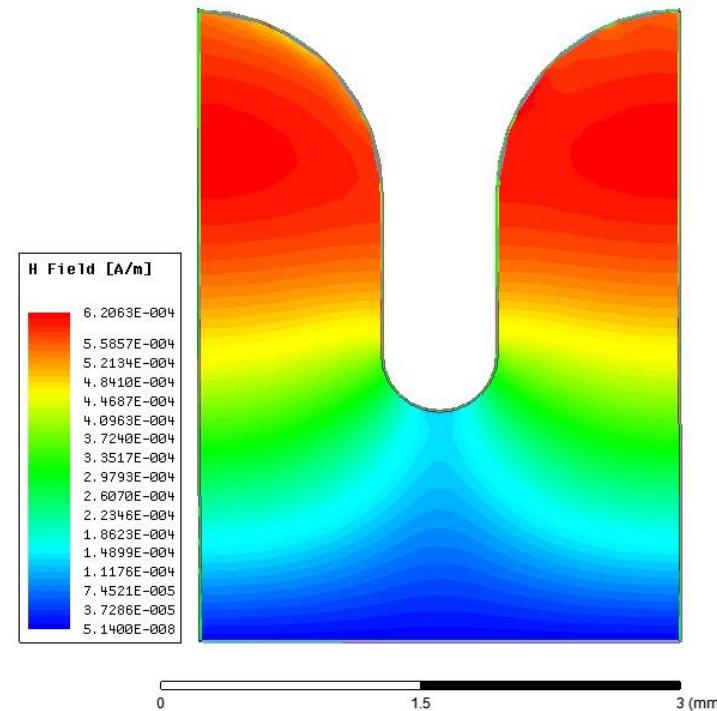
$v_{gr}/c = 0.04$

$K = 1.5 \%$

'Rounded' TW cavity fields estimations for the $2\pi/3$ mode at $F = 35.983$ GHz



Electric field distribution of the TM_{010} mode



Magnetic field distribution of the TM_{010} mode

$$a/\lambda = 0.16$$

$$a = 1.333 \text{ mm (iris radius)}$$

$$b = 3.657 \text{ mm (cavity radius)}$$

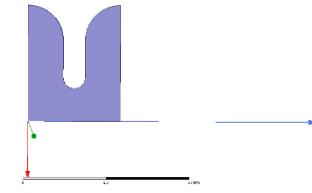
$$h = 0.667 \text{ mm (iris thickness)}$$

$$Q = 4110$$

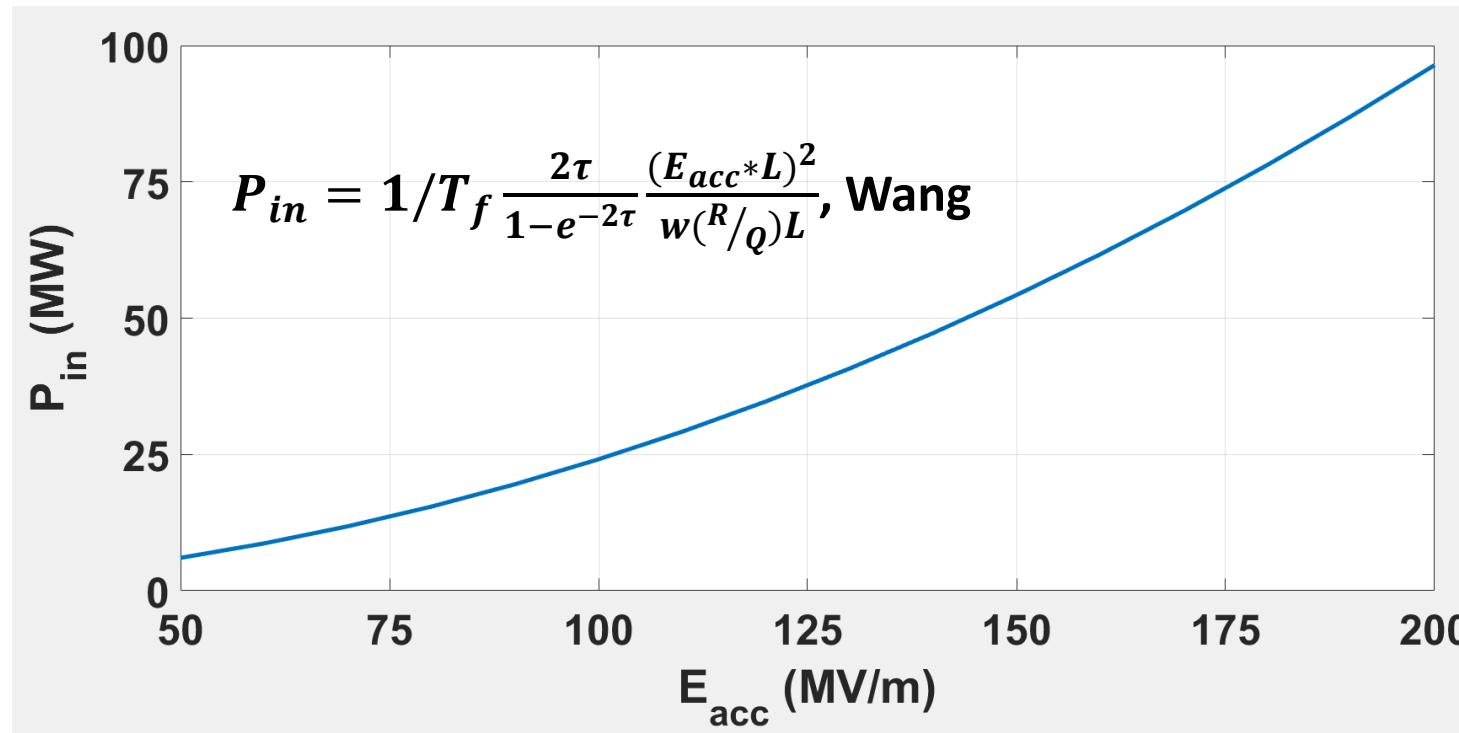
$$R_{sh}/m = 158 \text{ M}\Omega /m$$

$$v_{gr}/c = 0.04$$

Input RF power for different gradients of the rounded shape



Assuming a structure length $L = 25 \text{ cm}$, $T_f = 20 \text{ ns}$ (filling time), $R/Q = 38.4 \text{ k}\Omega/\text{m}$ and $\tau = 0.57$ (attenuation)



Parameter	Value
Filling Time, T _f	20 ns
L, length	25 cm
w, frequency	2pi*35.982 GHz
R/Q	38.4 kΩ/m
τ	0.57

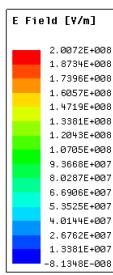
For a CG structure: input group velocity $v_{gr_in}/c = 6.7\%$, output group velocity $v_{gr_out}/c = 2.2\%$,

For a CI structure : $v_{gr} = 0.04 c$

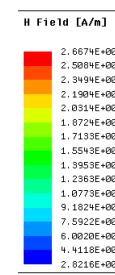
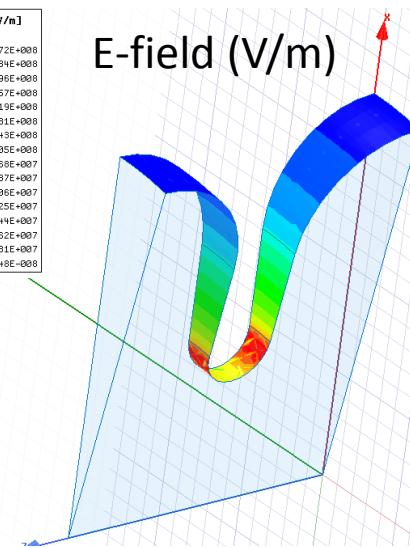
35.982 GHz cavity for the Compact light XLS project at $E_{acc}=100\text{MV/m}$ case

RF Pulsed Heating and Modified Poynting Vector estimations

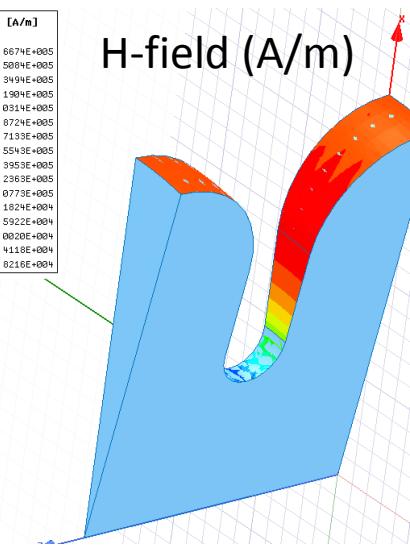
Main RF Parameters	
Frequency	35.982 GHz
Accelerating Gradient	100 MV/m
Shunt Impedance	158 MΩ/m
Quality Factor Q_0	4110



E-field (V/m)



H-field (A/m)



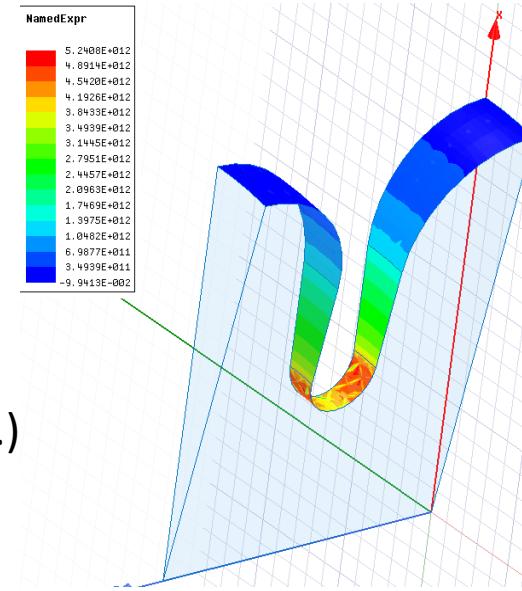
Max $E_{surface} = 200 \text{ MV/m}$
Max $H_{surface} = 0.26 \text{ MA/m}$

$T_{RF} = 50 \text{ ns, flat top}$

RF Pulsed Heating
 $\Delta T = 10.2 \text{ }^{\circ}\text{C}$
(below 50 °C safety threshold)

$Sc \sim 5 \text{ MW/mm}^2$
(below safety threshold)

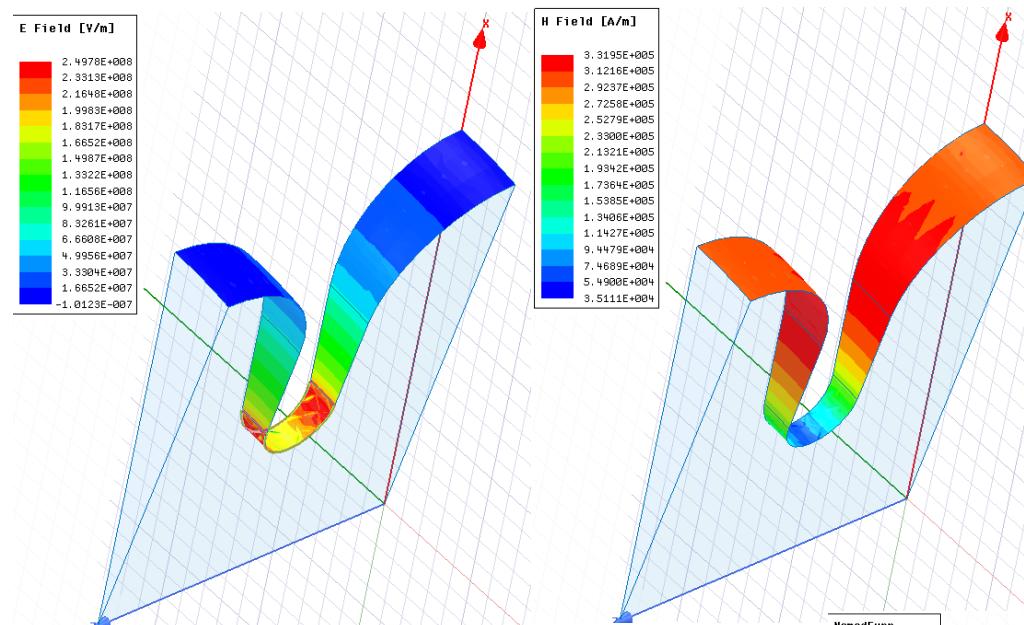
- RF Breakdown rate statistics depends on numerous factors:
RF pulsed heating, peak electric and magnetic field, Poynting vector S (modified)
- Modified Poynting vector $Sc=re(S)+im(S)/6$ (A. Grudiev et. al.)
- Safety threshold $Sc < 6.3 \text{ MW/mm}^2$ @50ns pulse



35.982 GHz cavity for the Compact light XLS project at $E_{acc}=125\text{MV/m}$ case

RF Pulsed Heating and Modified Poynting Vector estimations

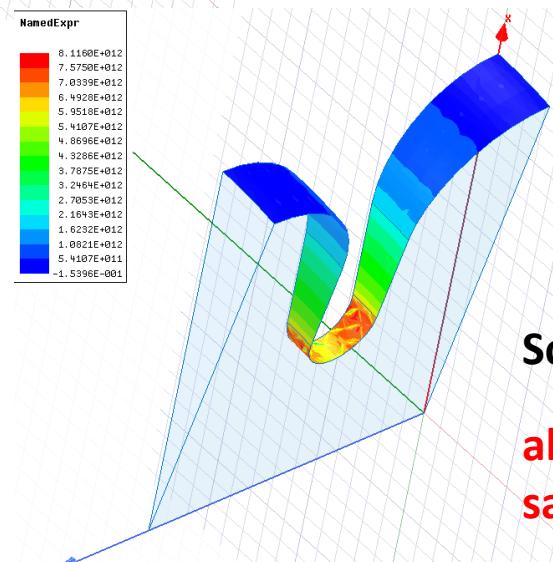
Main RF Parameters	
Frequency	35.982 GHz
Accelerating Gradient	125 MV/m
Shunt Impedance	158 MΩ/m
Quality Factor Q_0	4110



$\text{Max } E_{surface} = 250 \text{ MV/m}$
 $\text{Max } H_{surface} = 0.33 \text{ MA/m}$

$T_{RF} = 50 \text{ ns, flat top}$

RF Pulsed Heating
 $\Delta T = 16.5 \text{ }^{\circ}\text{C}$
(below 50 $^{\circ}\text{C}$ safety threshold)



$S_c \sim 8 \text{ MW/mm}^2$

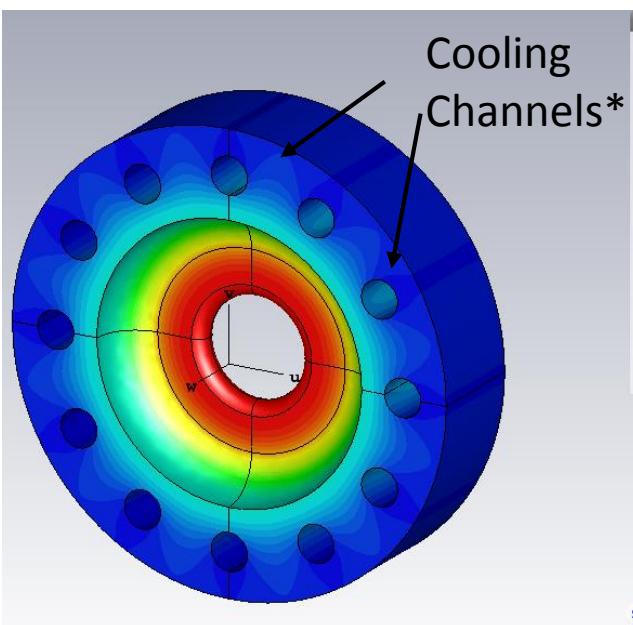
about 30% over safety threshold

- RF Breakdown rate statistics depends on numerous factors:
RF pulsed heating, peak electric and magnetic field, Poynting vector S (modified)
- Modified Poynting vector $S_c = \text{re}(S) + \text{im}(S)/6$
- Safety threshold $S_c < 6.3 \text{ MW/mm}^2$ @50ns pulse

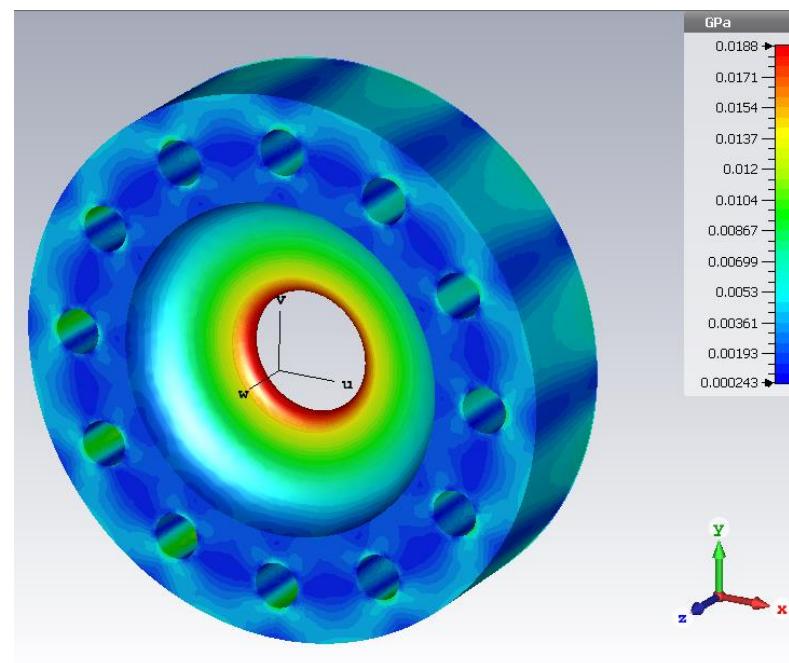
35.982 GHz cavity for the Compact light XLS project

Thermal and Stress Analyses

- Hot spot = 40 °C (standard operation). Possible to vary by adjusting water flux and temperature.
- Stress Analysis shows yield strength (Von Mises) < 20 MPa (below safety threshold for copper ~ 70 MPa)
- Maximum displacement ~ 1 μm (frequency shift negligible)



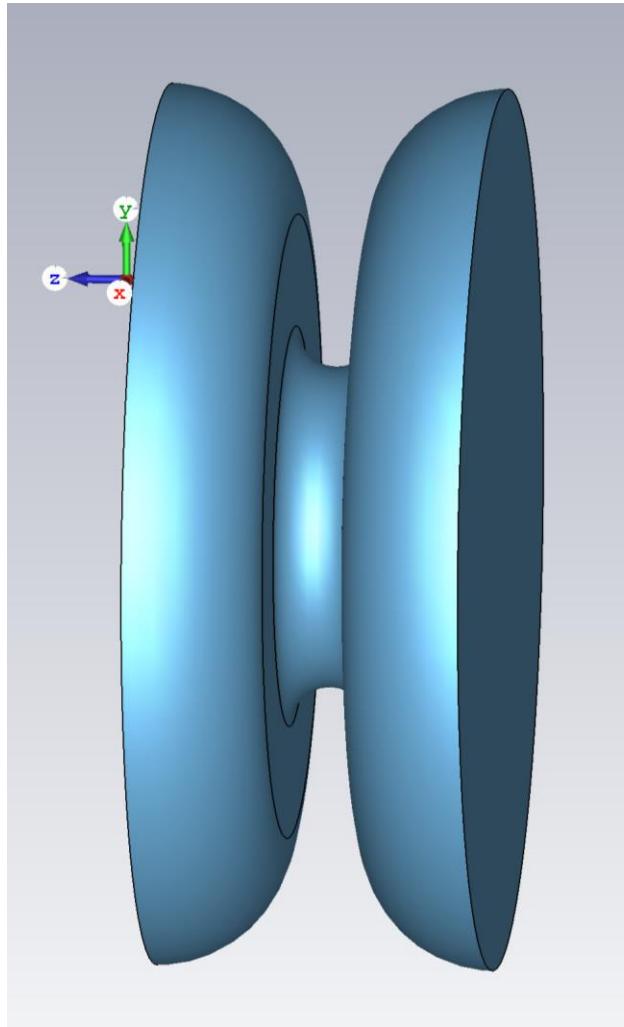
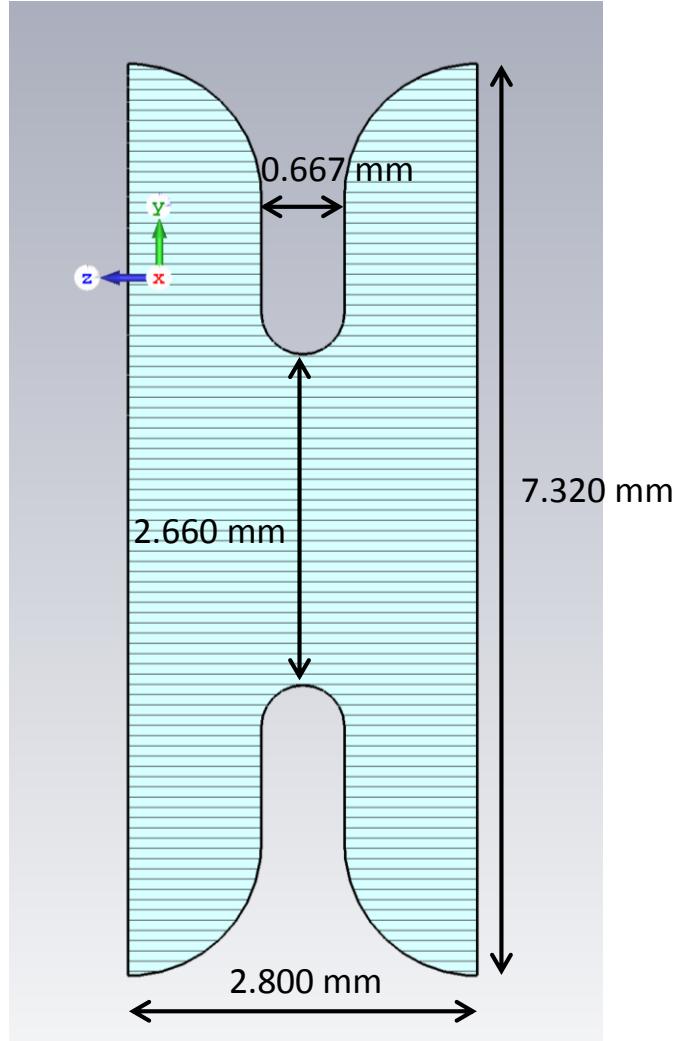
Thermal Simulation, single cell (35.982 GHz)



Stress Analysis (Von Mises), single cell (35.982 GHz)

- Cooling system will be optimized during final engineering (water jacket or brazed channels) in order to avoid water-to-vacuum leaks.

Wake fields studies on the 35.982 GHz structure (CST and ABCI software)



$$a/\lambda = 0.16$$

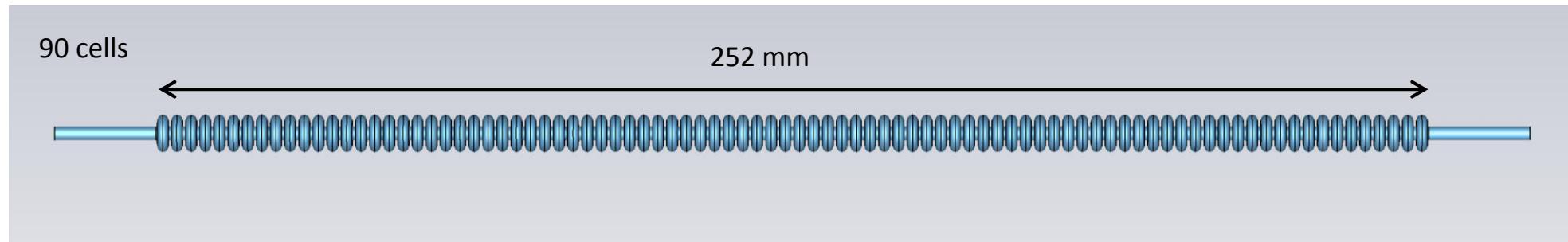
$$R_{sh}/m = 158 \text{ M}\Omega /m$$

$$Q = 4110$$

$$v_{gr}/c = 0.04$$

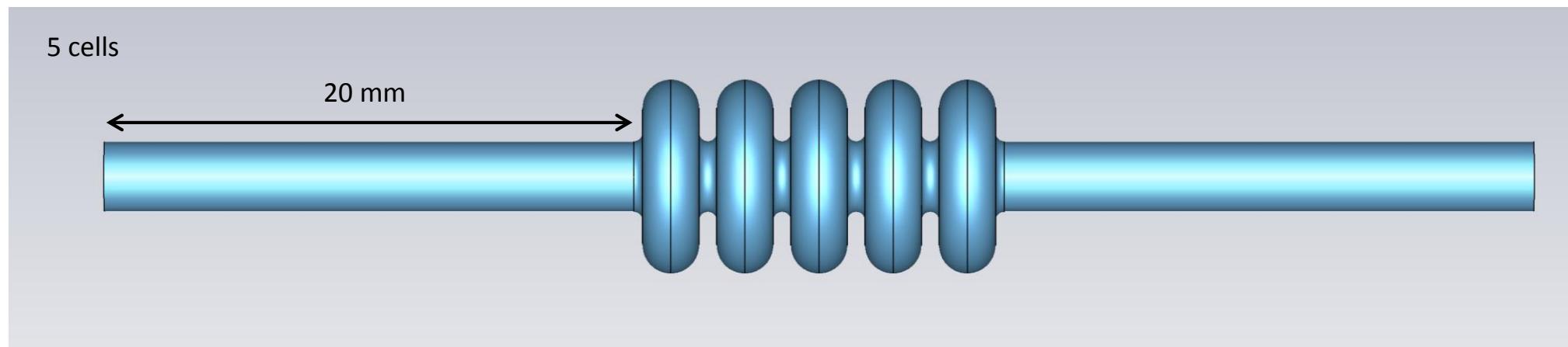
Wake fields studies on the 35.982 GHz structure (CST and ABCI software)

$\sigma = 1 \text{ mm (bunch lenght)}$

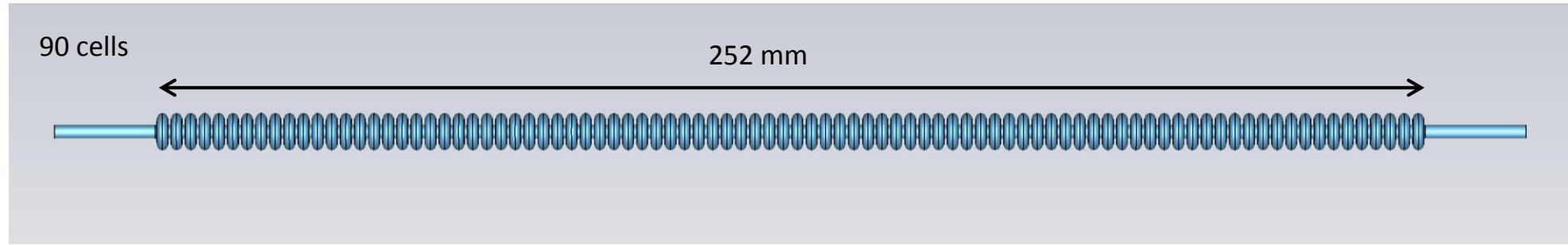


$\sigma = 0.5 \text{ mm (bunch lenght)}$

[in order to confirm the K. Bane's scaling scales for shortest bunches]



Wake fields studies on the 35.982 GHz structure (CST and ABCI software)

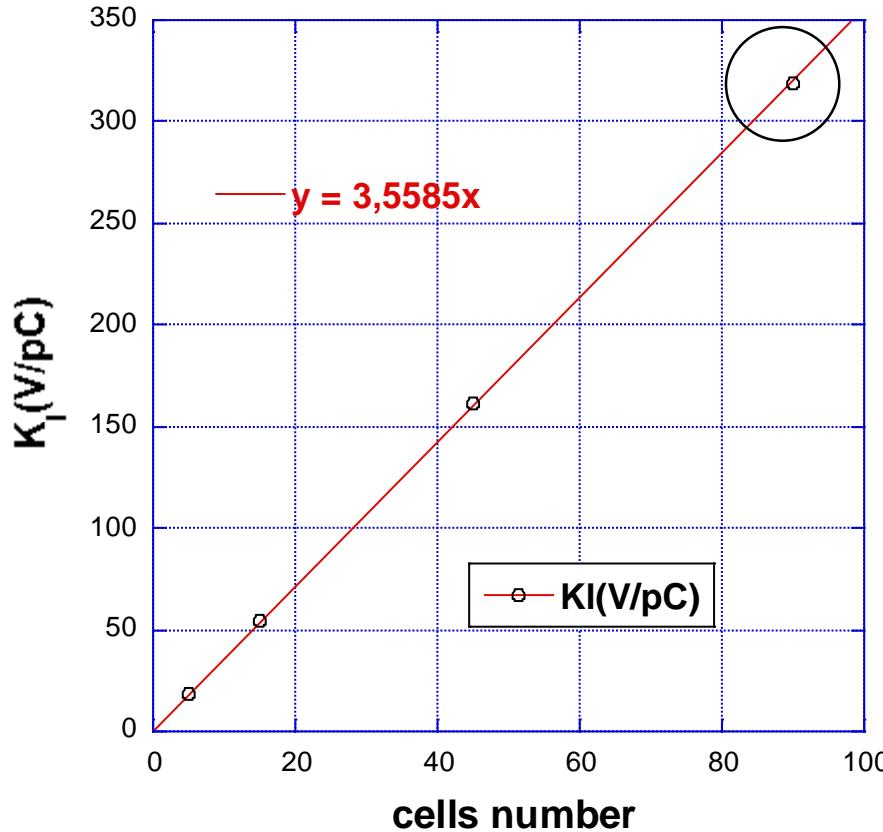


Bunch length (rms) : 1 mm

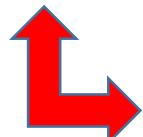
	Longitudinal Loss factor [V/pC]	Transverse loss factor (V/pC/m)
5 cells	18.2	16000
15 cells	54.3	46400
45 cells	161.5	136500
90 cells	319.4	268900

Wake fields studies on the 35.982 GHz structure

Longitudinal loss parameter as function of the cells number of the structure at $F = 35.982$ GHz

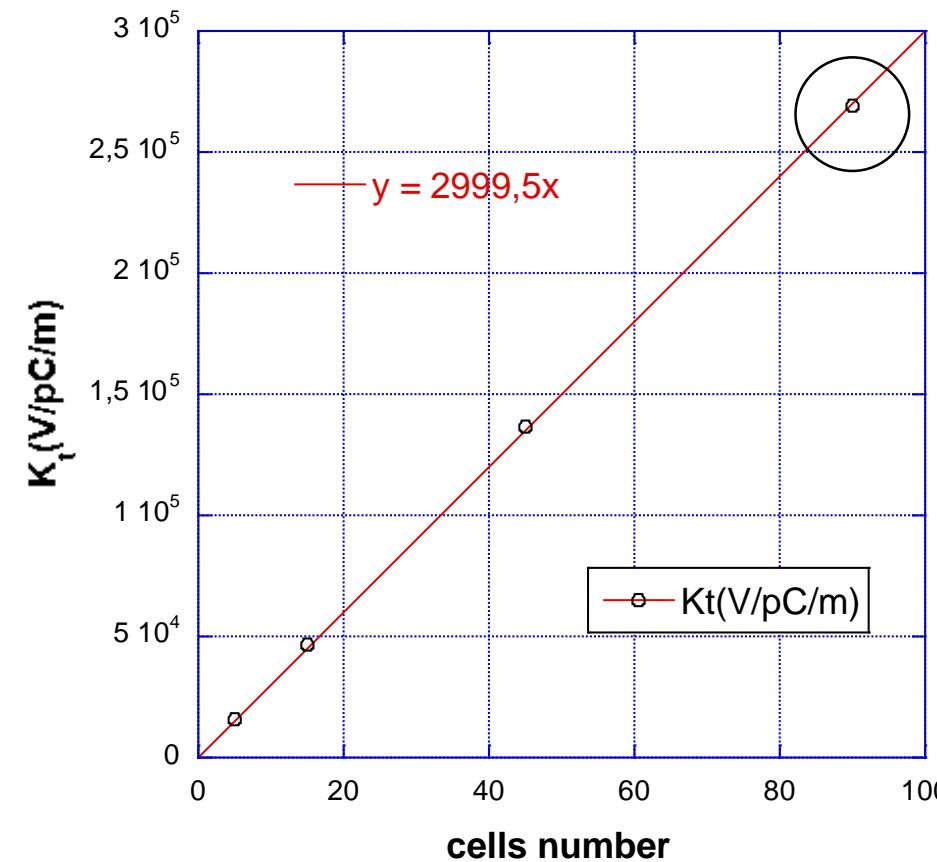


By assuming $N = 90$ cells ($L = 252$ mm),
 $K_l \approx 319.4$ V/pC, $Q = 100$ pC

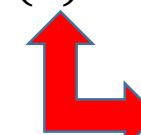


$$E_{\text{losses}} \approx 32 \text{ KeV}$$

Transverse loss parameter as function of the cells number of the structure at $F = 35.982$ GHz

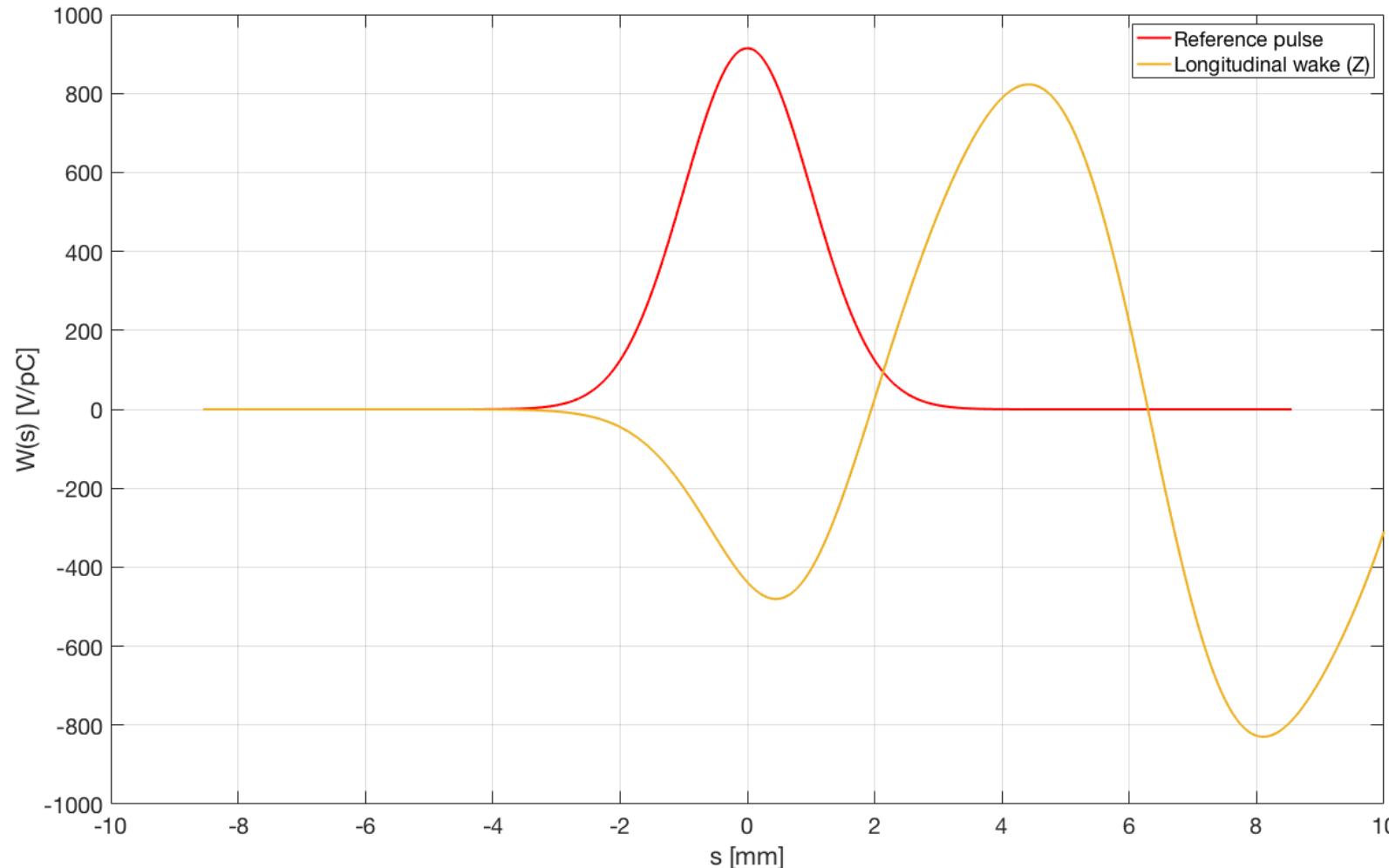


Assuming $N = 90$ cells ($L = 252$ mm), $K_t \approx 2.689 \cdot 10^5$ V/pC/m,
 $y(0) = 10 \cdot 10^{-6}$ m, $Q = 100$ pC ; $E = 20$ MeV



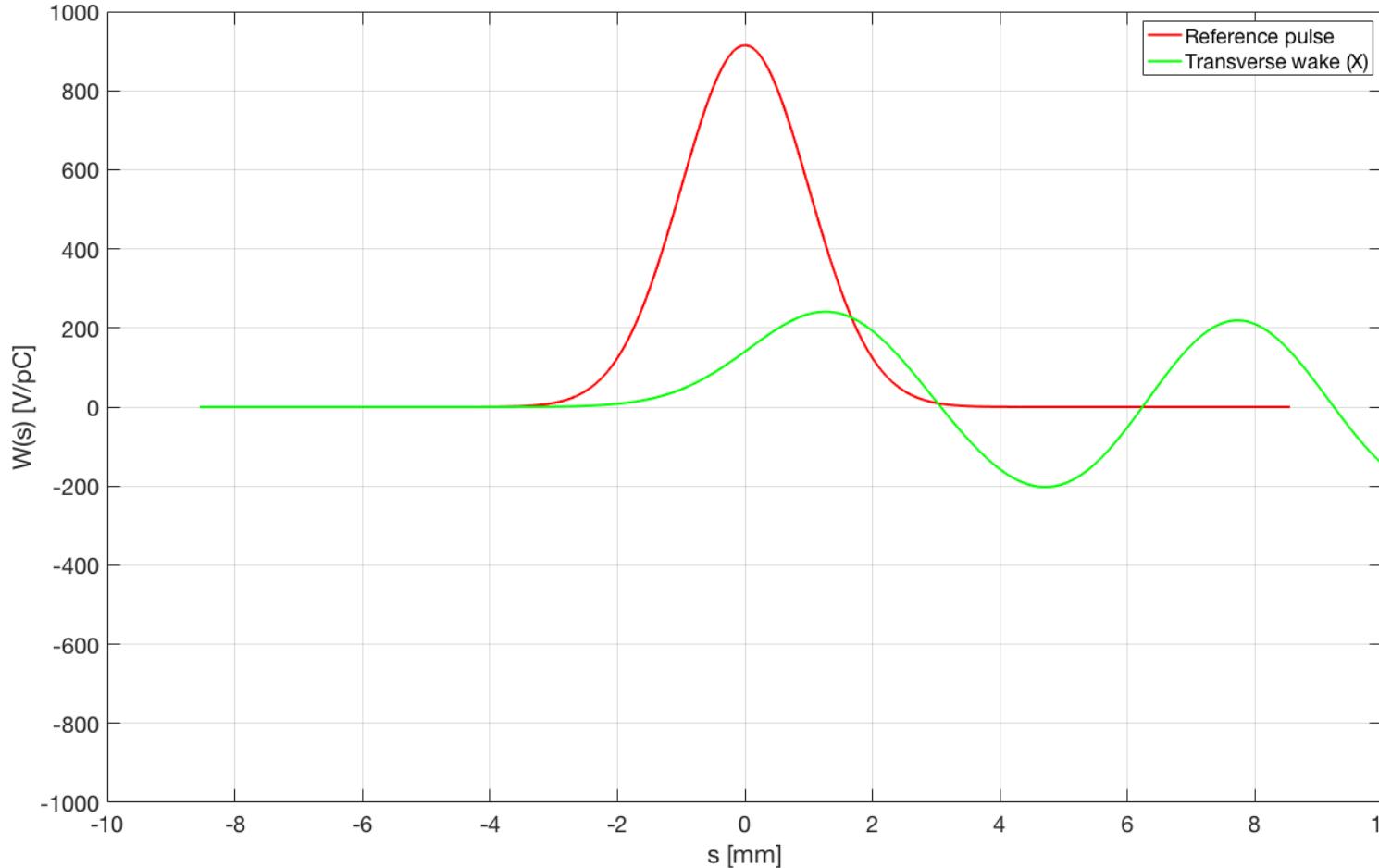
$$\theta = \frac{y(0)}{E/e} Q K_t \approx 13.45 \cdot 10^{-6} \text{ rad}$$

**Longitudinal wakefields as function of the bunch head for a $\sigma = 1$ mm bunch length
with $a = 1.333$ mm, $b = 3.657$ mm, $h = 0.667$ mm (whole structure estimations)**



$$K_L = 319.35 \text{ V/pC}$$

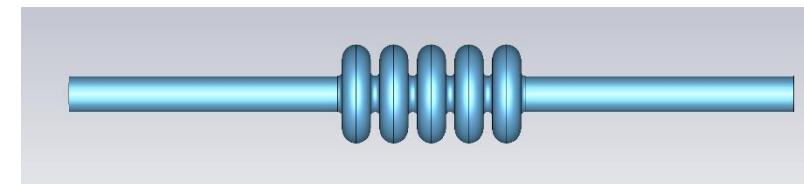
**Transverse wakefields as function of the bunch head for a $\sigma = 1$ mm bunch length
with $a = 1.333$ mm, $b = 3.657$ mm, $h = 0.667$ mm (whole structure estimations)**



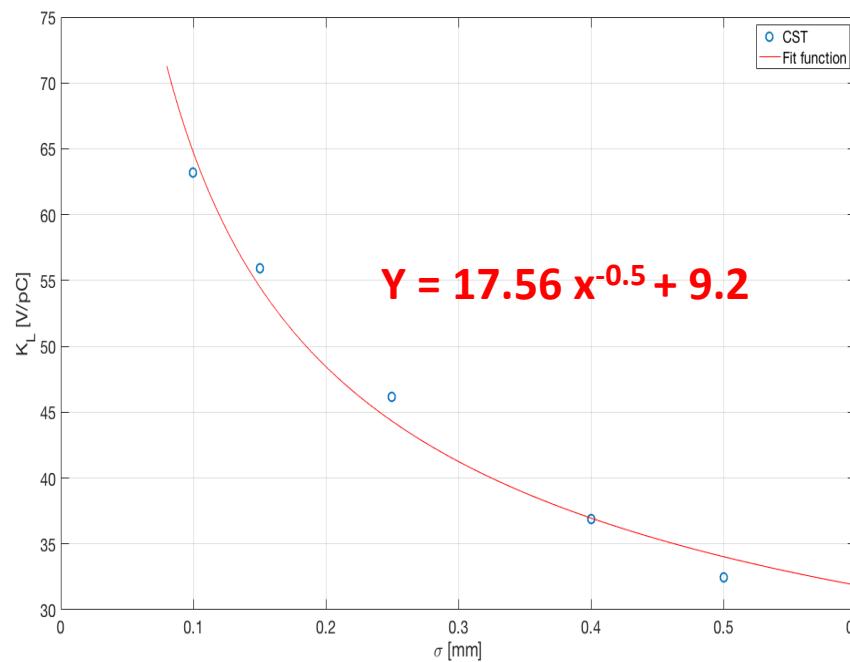
$$K_T = 268900 \text{ V}/\text{pC}/\text{m}$$

Longitudinal and transverse loss parameter as function of the bunch length σ (shorter bunches)

5 cells simulations



Longitudinal

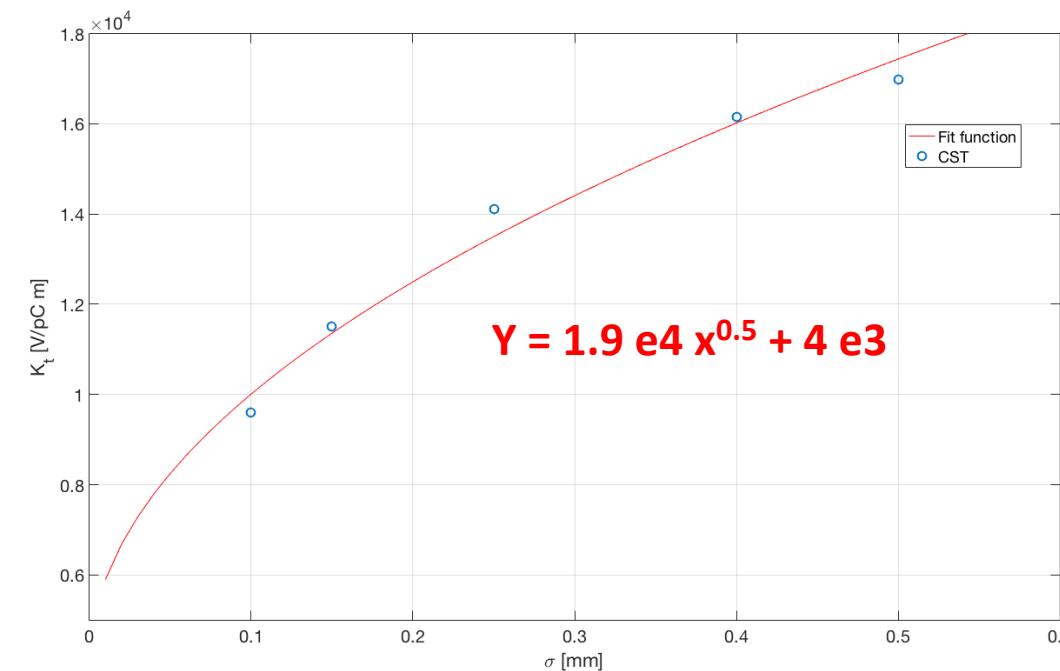


Scaling law

(K. Bane-SLAC)

$$K_l \propto \omega^2 \frac{1}{\sqrt{\sigma}} \frac{1}{a^2}$$

Transverse



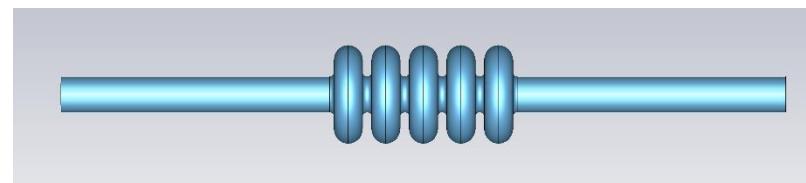
Scaling law

(K. Bane-SLAC)

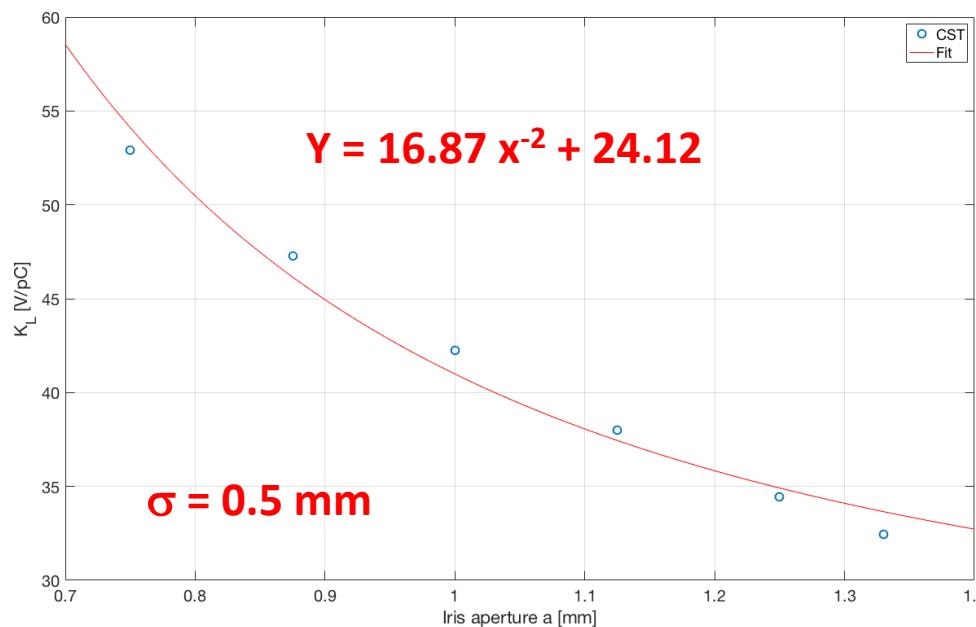
$$K_t \propto \omega^2 \sqrt{\sigma} \frac{1}{a^4}$$

Longitudinal and transverse loss parameter at F = 35.982 GHz as function of the iris aperture a with $\sigma = 0.5$ mm

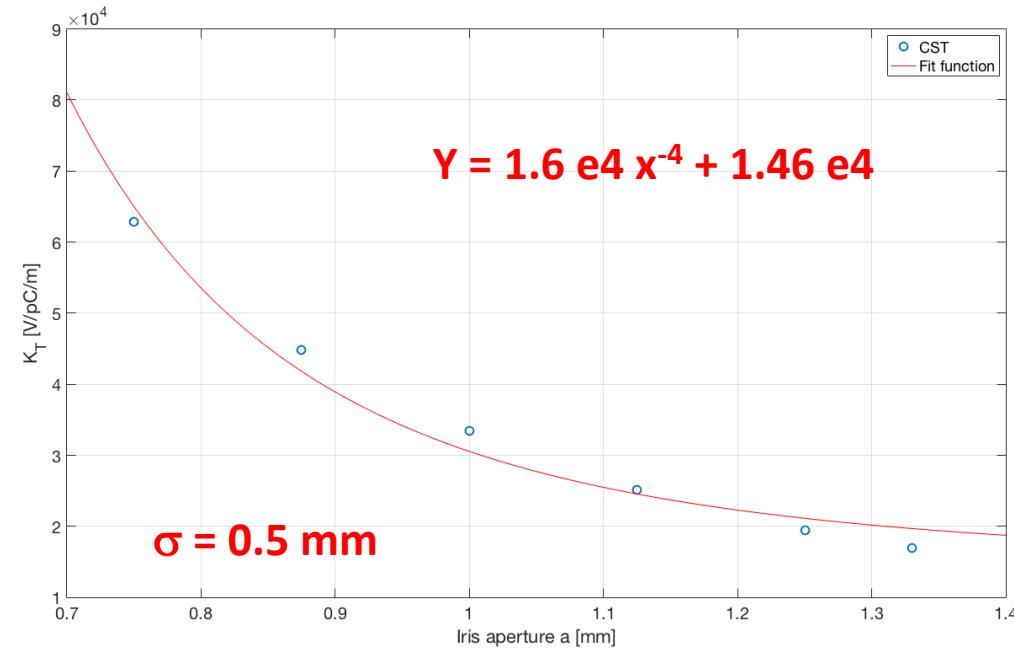
5-cells structure



Longitudinal



Transverse



Scaling law (K. Bane-SLAC)

$$K_l \propto \omega^2 \frac{1}{\sqrt{\sigma}} \frac{1}{a^2}$$

Scaling law (K. Bane-SLAC)

$$K_t \propto \omega^2 \sqrt{\sigma} \frac{1}{a^4}$$

Thank you very much for your attention