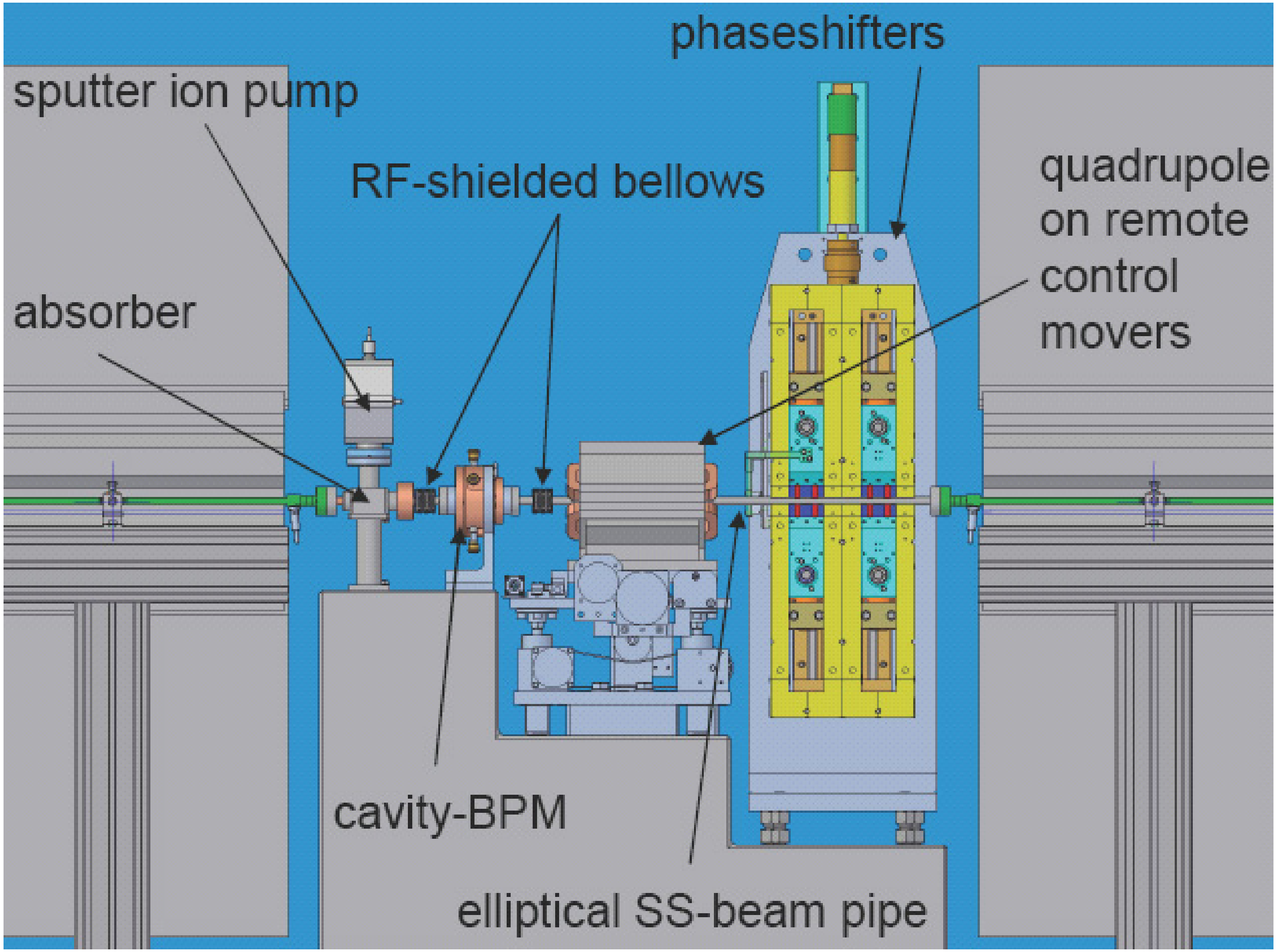
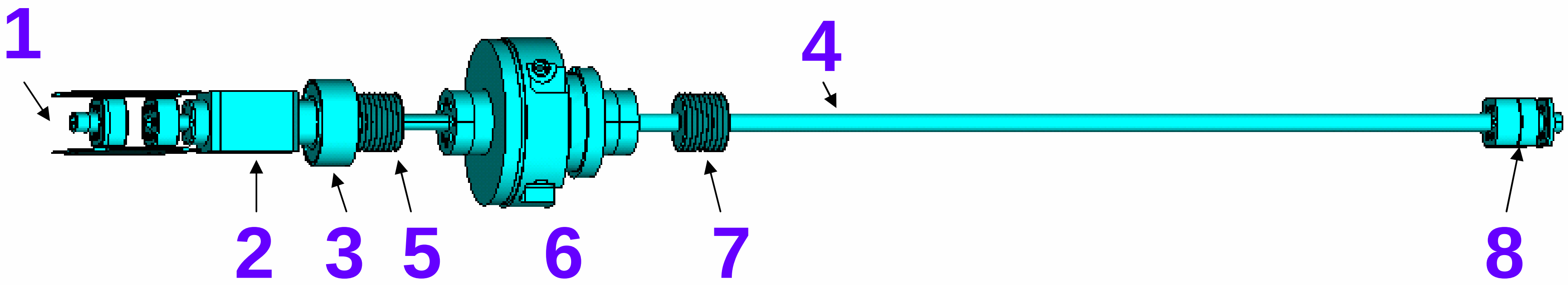
# Longitudinal Impedance Budget in XFEL undulator section

Igor Zagorodnov
Beam Dynamics Group Meeting
19.11.07



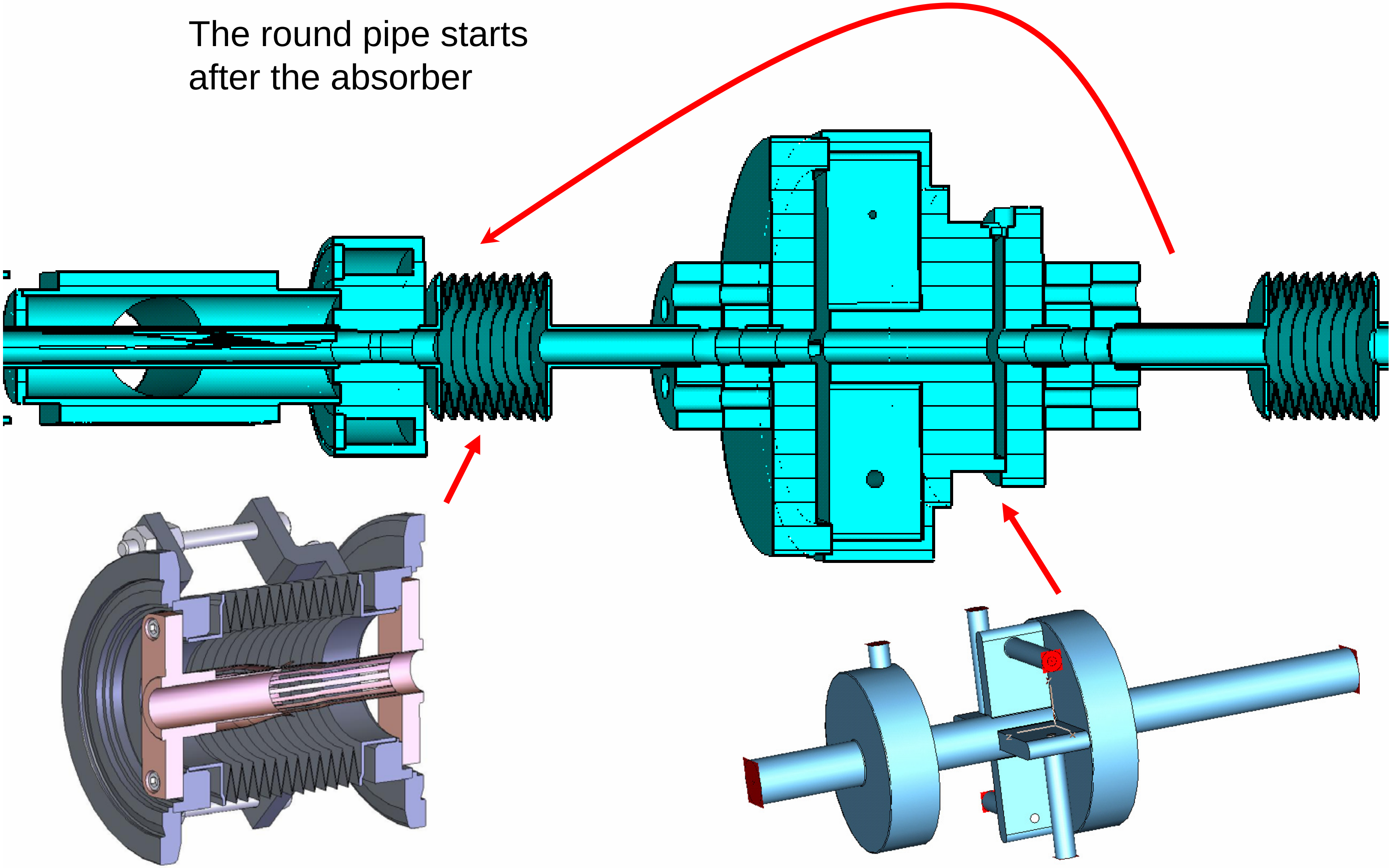
UNDULATOR- CELL(6.1m) = UNDULATOR (5m) + INTERSECTION (1.1m)

| N | Element | from | to | Effective Length | Material | Conduct. | Relax. Time | Oxid layer | Rough ness |
|---|---|---|---|---|---|---|---|---|---|
| | | mm | mm | mm | | 1/Omm/m | sec | nm | nm |
| 1 | Eliptical pipe | 0 | 5288 | 5161 | Aluminium | 3,66E+07 | 7,10E-15 | 5 | 300 |
| 2 | Pump | 5161 | 5266 | 105 | Aluminium | 3,66E+08 | 7,10E-15 | 5 | 300 |
| 3 | Absorber/Round transition | 5266 | 5288 | 22 | Copper | 5,80E+07 | 2,46E-14 | 5 | 300 |
| 4 | Round pipe | 5288 | 6100 | 652 | Copper | 5,80E+07 | 2,46E-14 | 5 | 300 |
| 5 | Below | 5288 | 5318 | 30 | BeCu 174 | 2,78E+07 | 2,46E-14 | 5 | 300 |
| 6 | BPM | 5373 | 5473 | 100 | Stainless Steel 304 | 1,40E+06 | 2,40E-15 | 5 | 300 |
| 7 | Below | 5513 | 5543 | 30 | BeCu 174 | 2,78E+07 | 2,46E-14 | 5 | 300 |
| 8 | Round/Eliptical transition | 6100 | 6100 | 0 | | | | | |
| | | | | 6100 | | | | | |



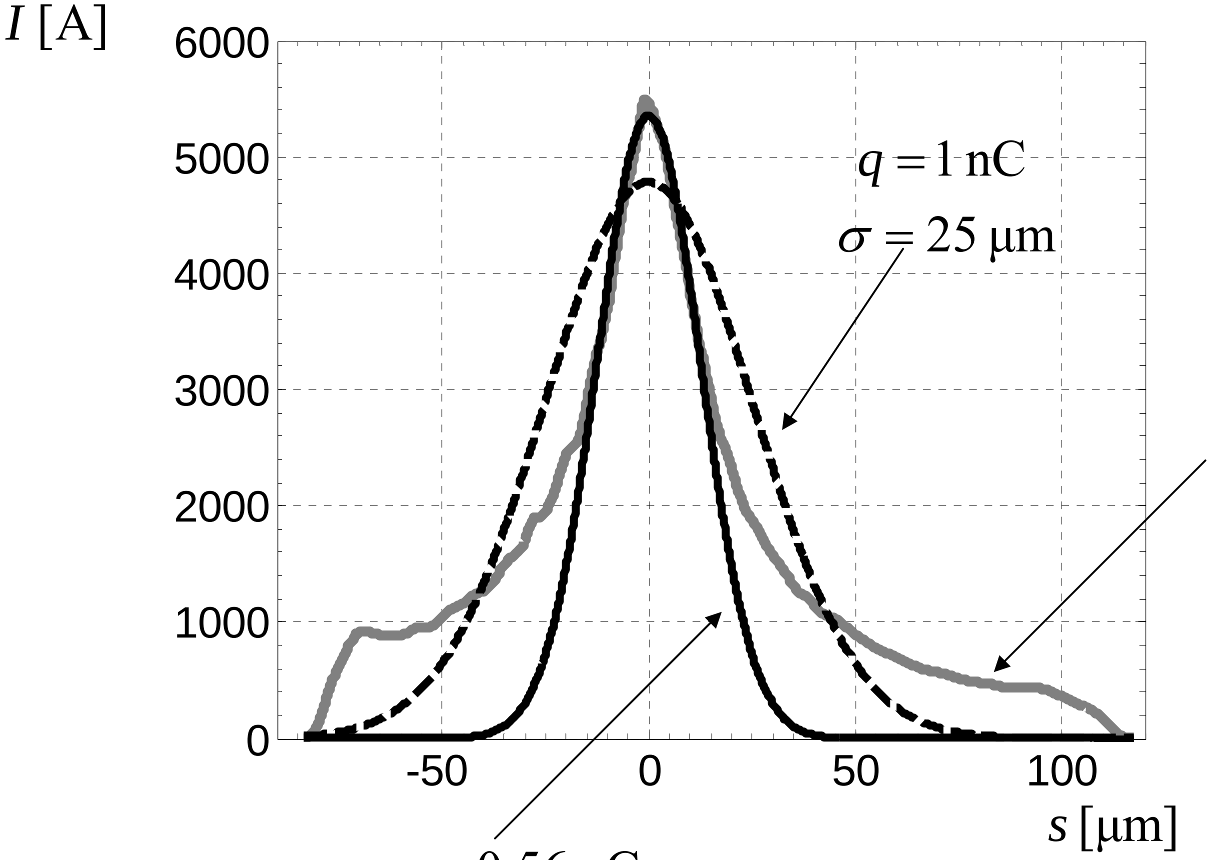
Katrin Schuett, ZM1
Dirk Lipka, MDI

The round pipe starts
after the absorber



SLAC design (Soon-Hong Lee talk)
Torsten Wohlenberg, MVS

Shintake BPM,
Dirk Lipka, MDI



$q = 1$ nC

$\sigma = 25$ μm

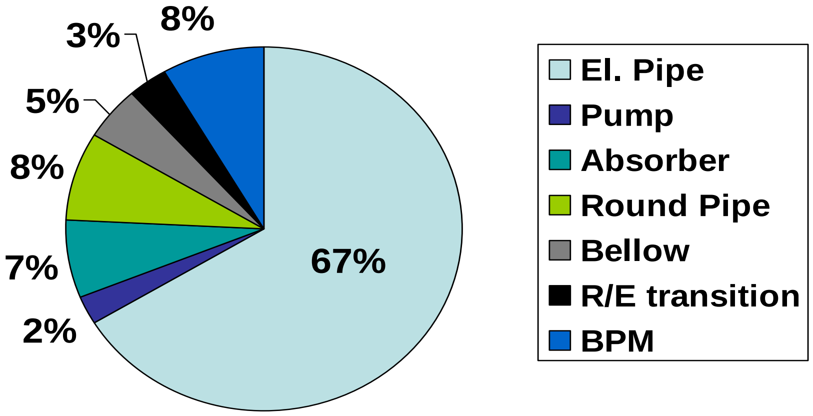
Bunch shape
from S2E simulations
by Martin Dohlus

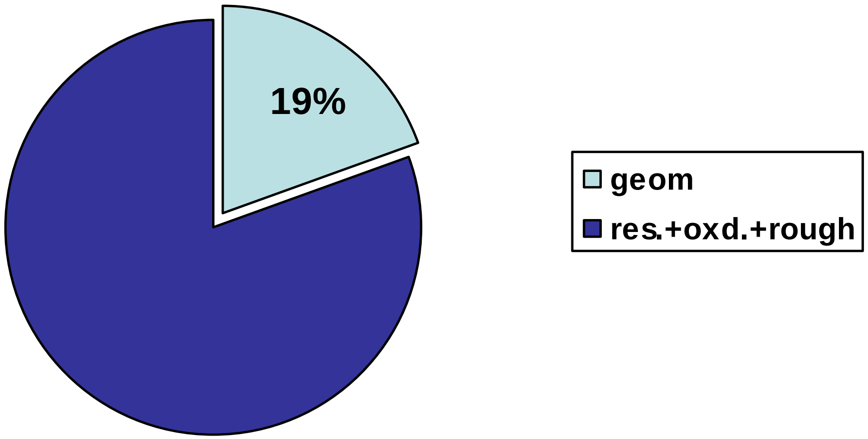
$q = 0.56$ nC

$\sigma = 12.5$ μm

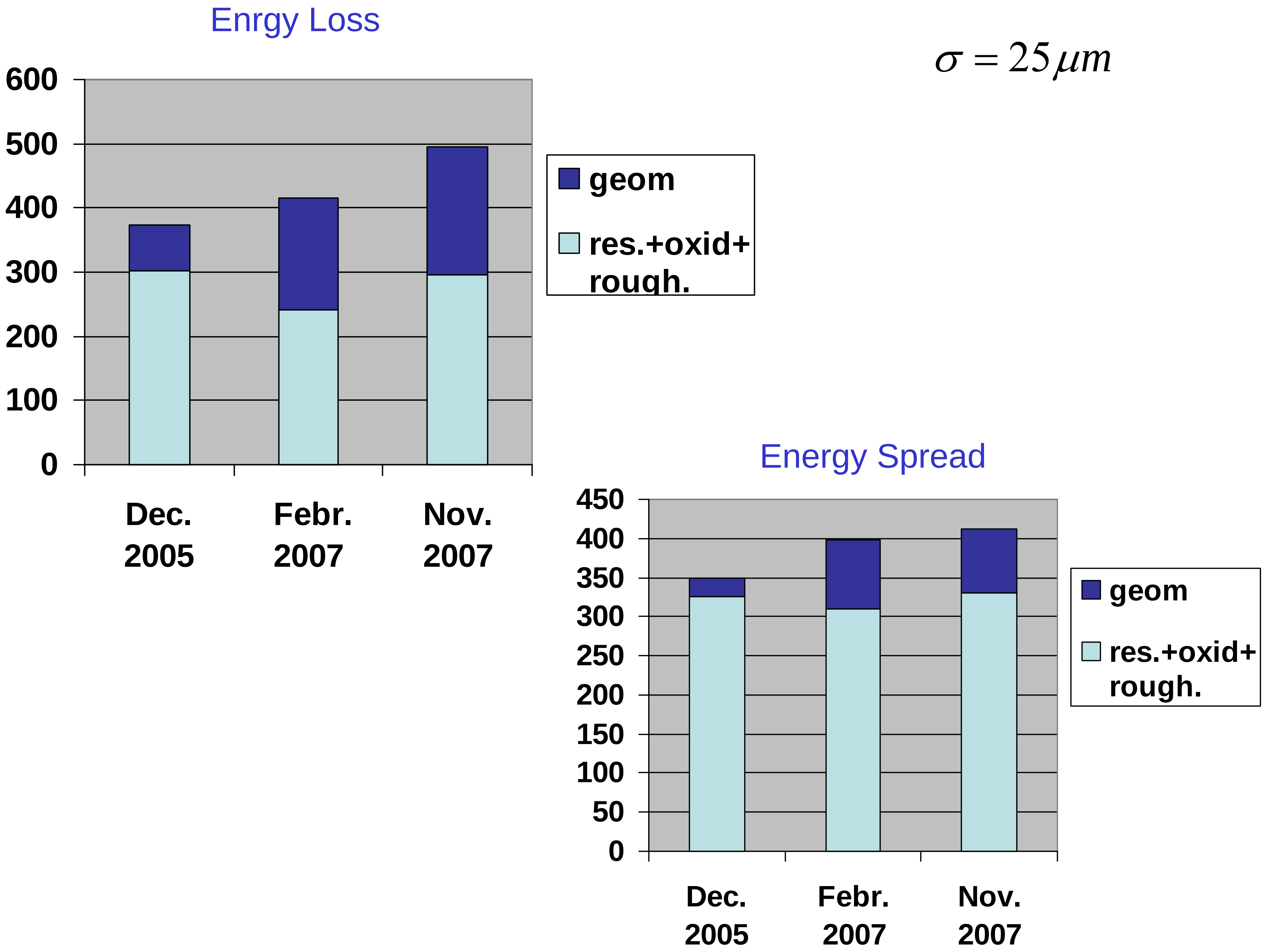
# $\sigma = 25\,\mu\mathrm{m} \quad q = 1\,\mathrm{nC}$

| N | Element | Geom Loss | Geom Spread | Loss | Spread |
|---|---|---|---|---|---|
| | | kV | kV | kV | kV |
| 1 | Eliptical pipe | 0 | 0 | 239 | 274 |
| 2 | Pump | 4,4 | 4,5 | 9 | 10 |
| 3 | Absorber/Round transition | 69 | 27 | 70 | 28 |
| 4 | Round pipe | 0 | 0 | 22 | 32 |
| 5 | Below | 24 | 9 | 25 | 10 |
| 6 | BPM | 42 | 17 | 70 | 34 |
| 7 | Below | 24 | 9 | 25 | 10 |
| 8 | Round/Eliptical transition | 36 | 14 | 36 | 14 |
| | Energy Spread | 199,4 | 80,5 | 496 | 412(365) |





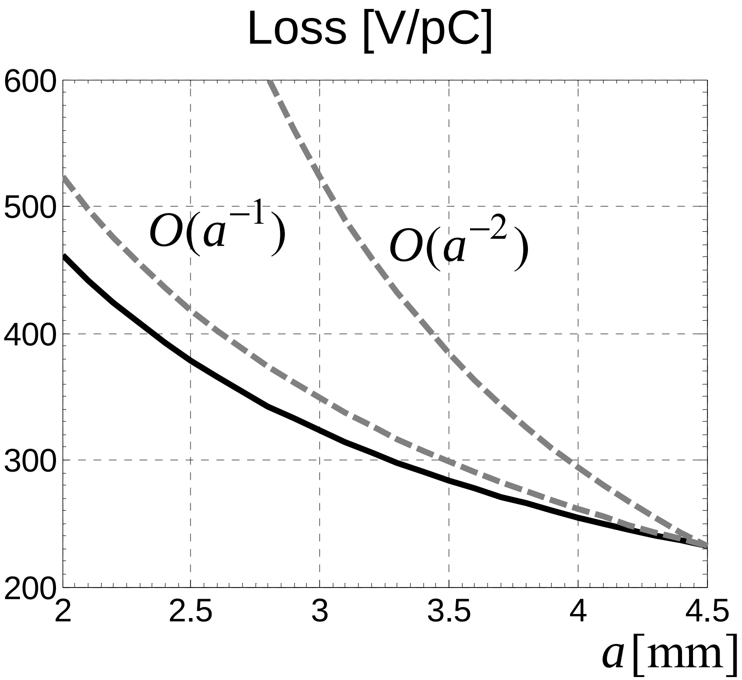
$$\sigma = 25\mu m$$

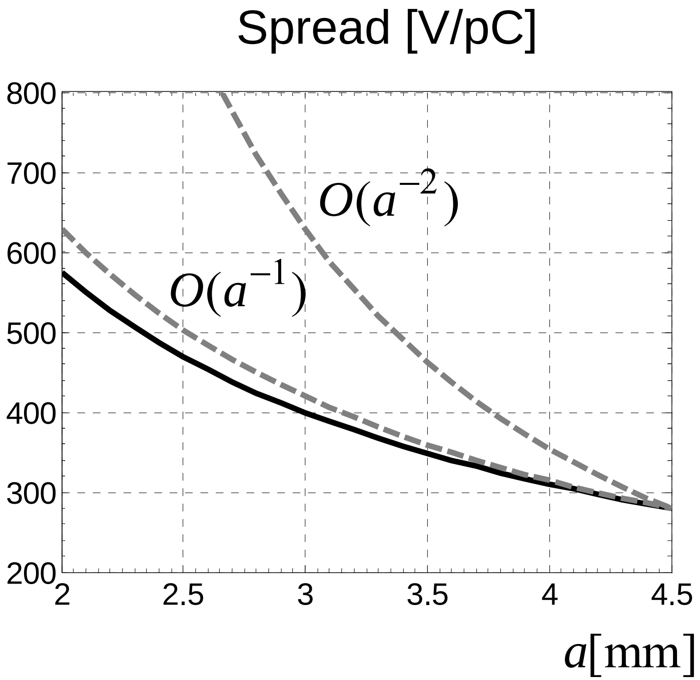

Enrgy Loss
600
500
400
300
200
100
0
Dec. 2005
Febr. 2007
Nov. 2007
geom
res.+oxid+ rough.
Energy Spread
450
400
350
300
250
200
150
100
50
0
Dec. 2005
Febr. 2007
Nov. 2007
geom
res.+oxid+ rough.

# Scaling laws of longitudinal wakes

| | | |
|---|---|---|
| Cavity | $\text{Loss} = \frac{Z_0 c}{4a\pi^{2.5}} \Gamma\left(\frac{1}{4}\right)\sqrt{\frac{g}{\sigma}}$ | O(a$^{-1}$) |
| Periodic structure | | O(a$^{-2}$) |
| Collimator | $\text{Loss} = \frac{Z_0 c}{2\pi^{1.5}\sigma} \ln\left(\frac{b}{a}\right)$ | O(1) |
| Short Range Resistive | | O(a$^{-2}$) |
| Long Range Resistive | $\text{s} >> \text{s}_0 = \left(\frac{2a^2}{k\, Z_0}\right)^{1/3}$ | O(a$^{-1}$) |

$\text{s}_0 = 14\mu m$ for a=4.4 mm and k=3.66e7/Omm/m

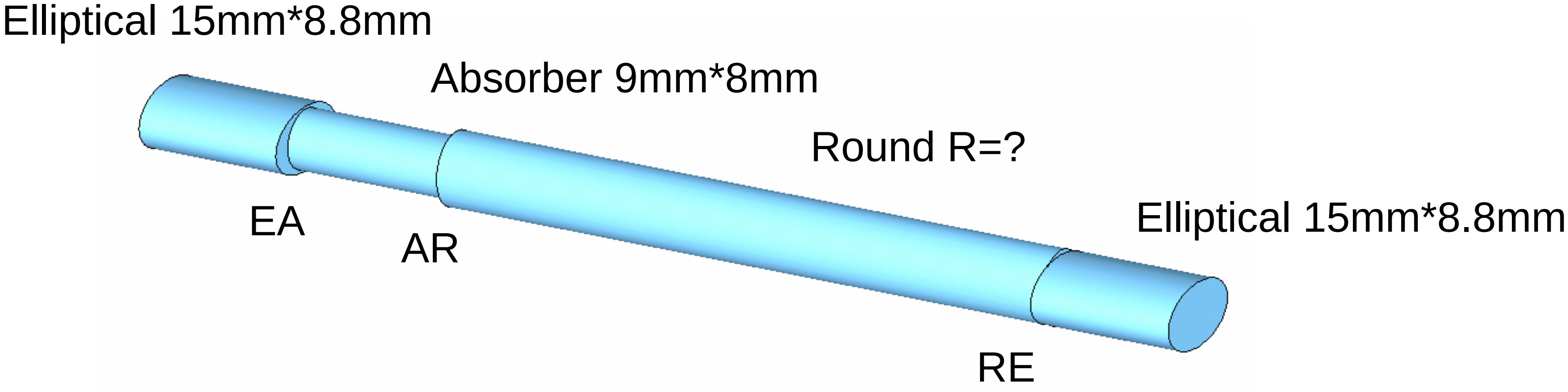

Loss [V/pC]
600
500
400
300
200
2
2.5
3
3.5
4
4.5
$O(a^{-1})$
$O(a^{-2})$
$a$[mm]

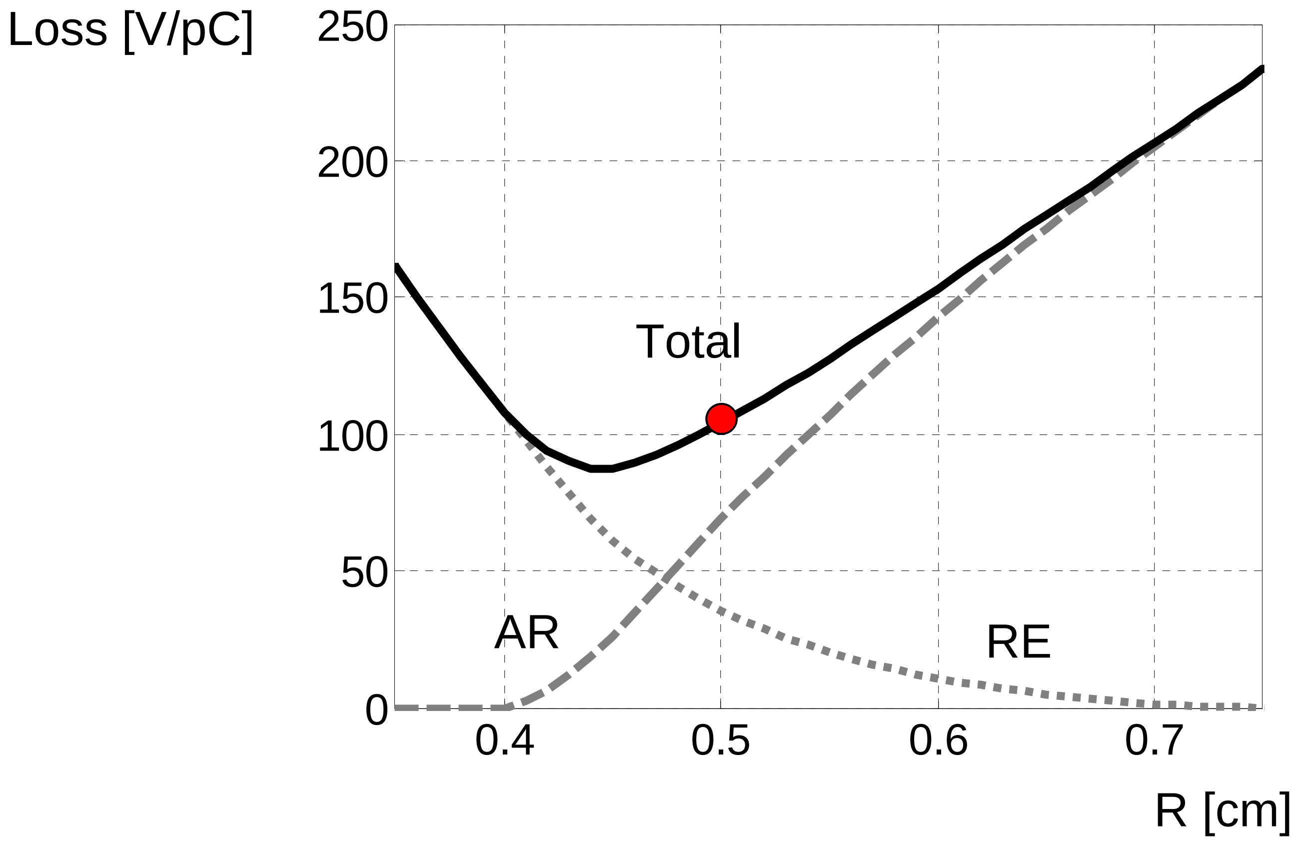

Spread [V/pC]
800
700
600
500
400
300
200
2
2.5
3
3.5
4
4.5
$O(a^{-2})$
$O(a^{-1})$
$a$[mm]

| N | Element | Scaling |
|---|---|---|
| | | |
| 1 | Eliptical pipe | $O(a^{-1})$ |
| 2 | Pump | |
| 3 | Absorber/Round transition | $O(1)$ |
| 4 | Round pipe | $O(a^{-1})$ |
| 5 | Below | |
| 6 | BPM | |
| 7 | Below | |
| 8 | Round/Eliptical transition | $O(1)$ |

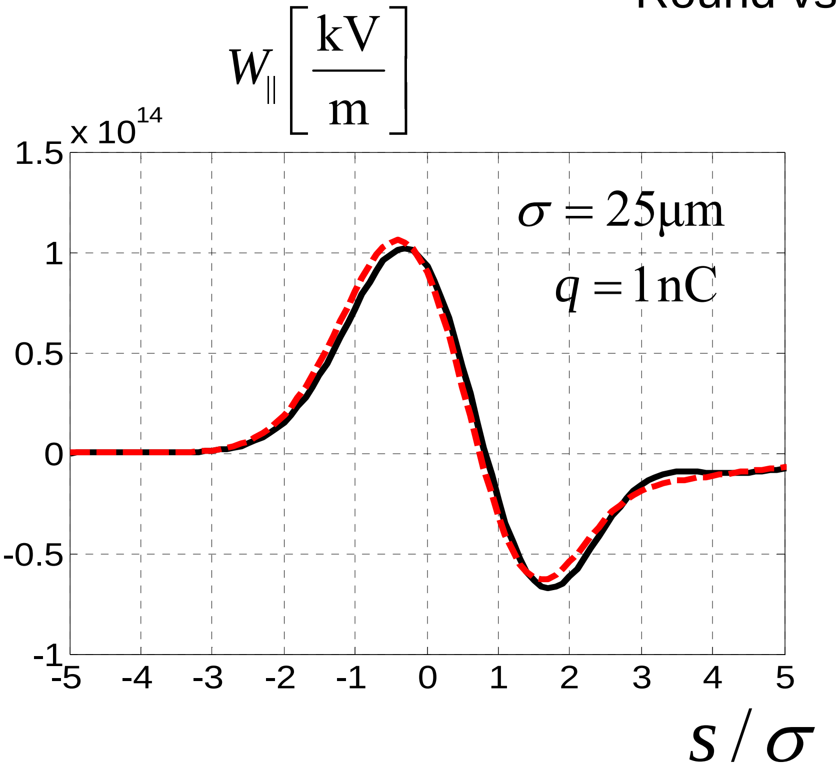
$\sim O(a^{-1})$

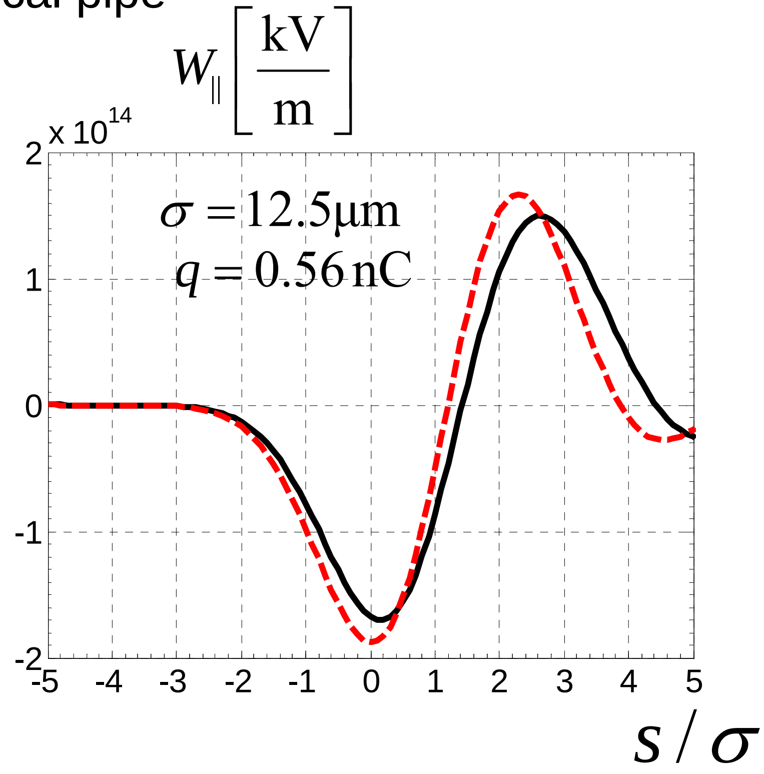
# Absorber+Round Pipe+Elliptical Pipe





# Round vs. Elliptical pipe





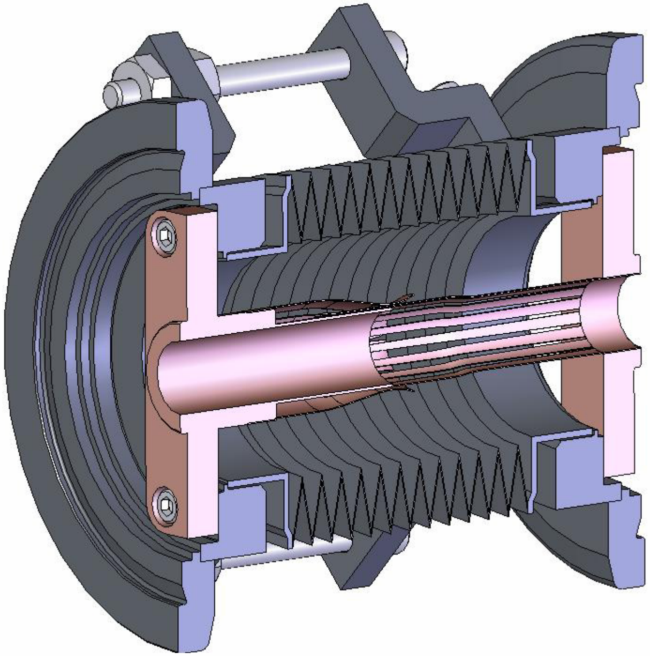
| | Loss, V/pC | Spread, V/pC |
|---|---|---|
| round | 237 | 285 |
| elliptical | 239 | 274 |

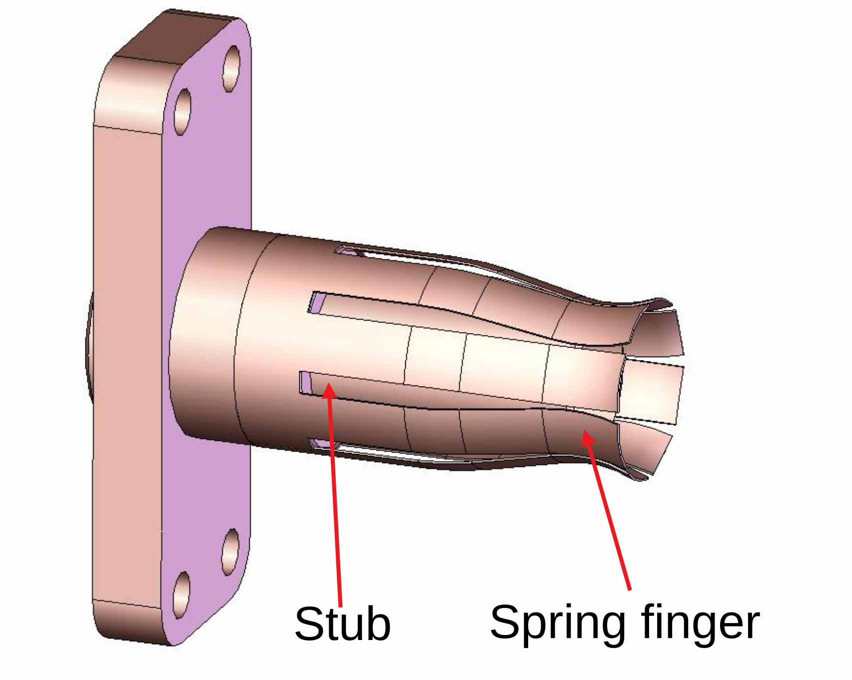
Mathcad script for arbitrary shape (author M. Dohlus)

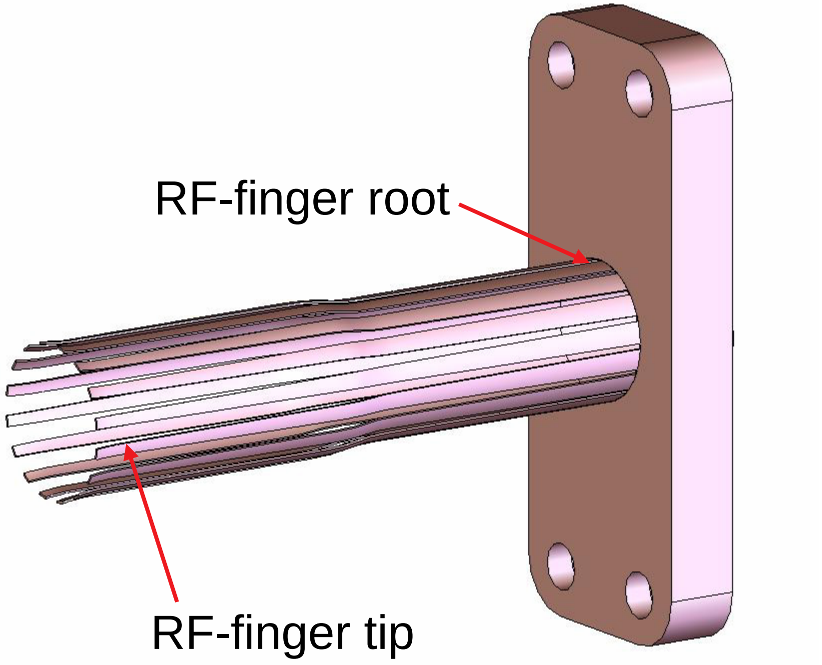
LCLS Undulator Bellows Module

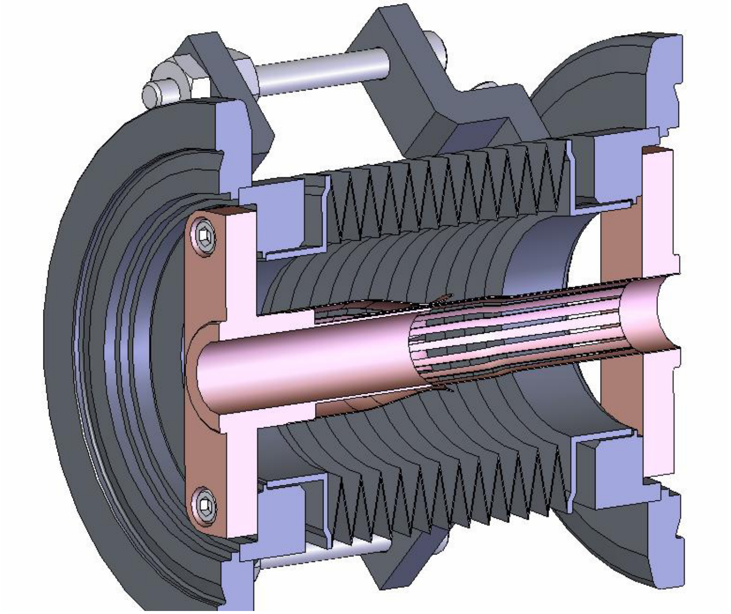
## Internal Design Review

Soon-Hong Lee



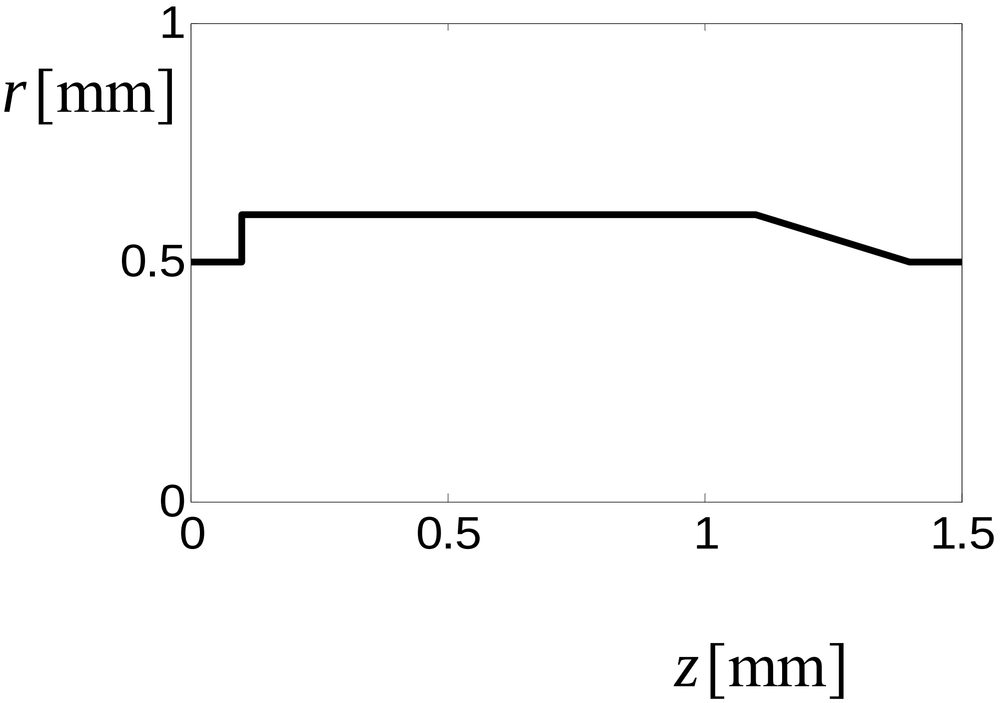






# Shielded bellow

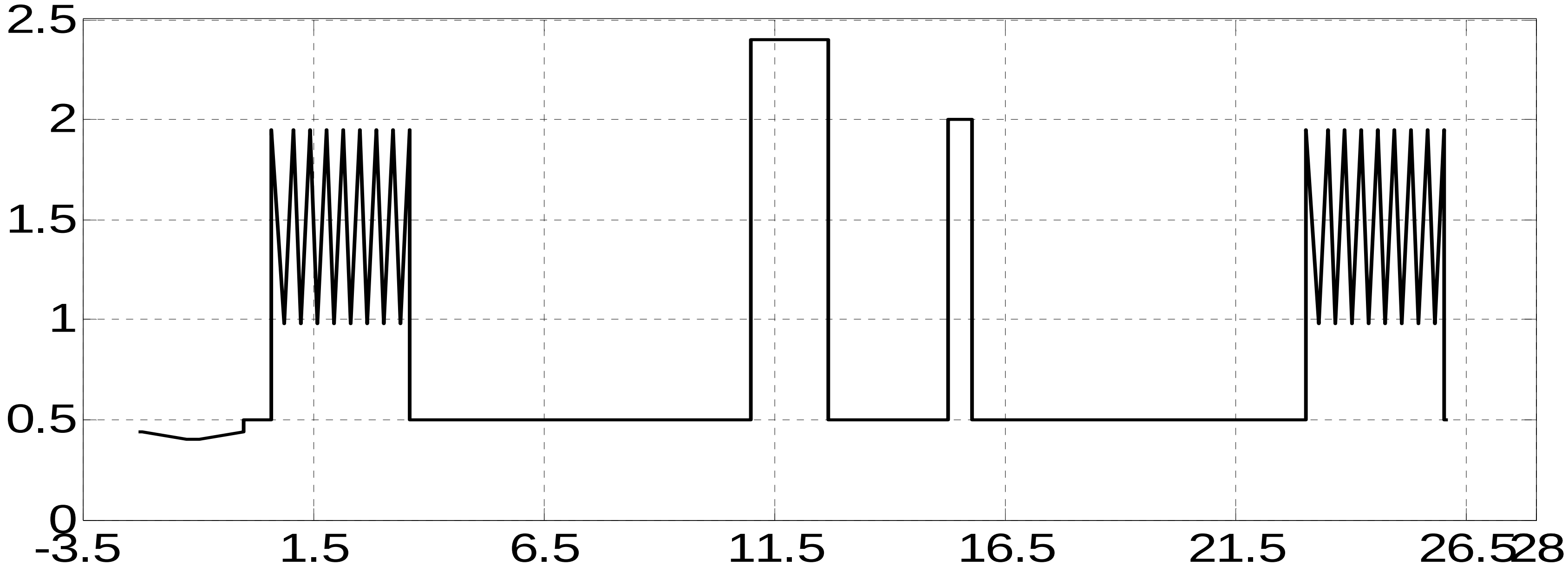
Loss = 23.8 V / Pc
Spread = 9.3 V / Pc



„Now, we extend the vacuum chamber from one side almost all the way through the bellows section leaving a small variable length gap at one end. The maximum length of the variable gap at the end is 7 mm for a fully extended bellows.
… two additional in-line bellows per break section, … each of these bellows can be modeled as three small gaps. (0.77 mm in length).“
Heinz-Dieter Nuhn, SLAC, 13.11.07

# Unshielded bellow

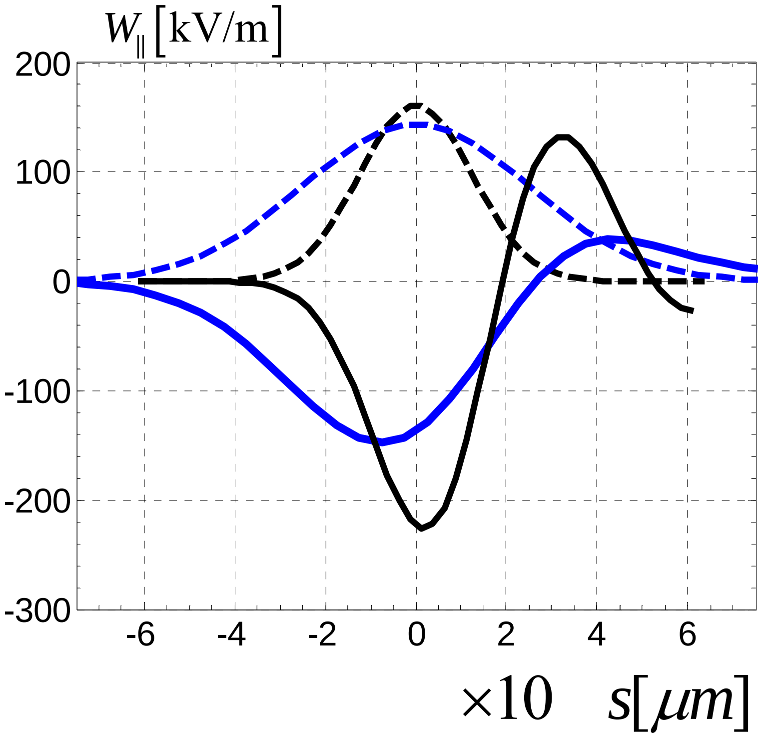
Absorber, bellow, BPM, bellow



| | Loss V/pC | Spread V/pC |
|---|---|---|
| Absorber with step | 57.2 | 25.1 |
| Bellow | 39.1 (24) | 15.8 (9) |
| BPM | 42.2 | 17.0 |
| Absorber, Bellow | 78.6 | 24.9 |
| Absorber, bellow, BPM | 113.0 | 36.9 |
| Absorber, bellow, BPM, bellow | 143.9 | 49.3 |

| | | $\sigma = 12.5\,\mu\text{m}$ $q = 0.56\,\text{nC}$ | | $\sigma = 25\,\mu\text{m}$ $q = 1\,\text{nC}$ | |
|---|---|---|---|---|---|
| N | Element | Loss | Spread | Loss | Spread |
| | | kV | kV | kV | kV |
| 1 | Eliptical pipe | 520 | 363 | 239 | 274 |
| 2 | Pump | 16 | 14 | 9 | 10 |
| 3 | Absorber/Round transition | 79 | 33 | 70 | 28 |
| 4 | Round pipe | 56 | 64 | 22 | 32 |
| 5 | Below | 31 | 14 | 25 | 10 |
| 6 | BPM | 86 | 37 | 70 | 34 |
| 7 | Below | 31 | 14 | 25 | 10 |
| 8 | Round/Eliptical transition | 40 | 17 | 36 | 14 |
| | | 859 | 556(514) | 496 | 412 (365) |

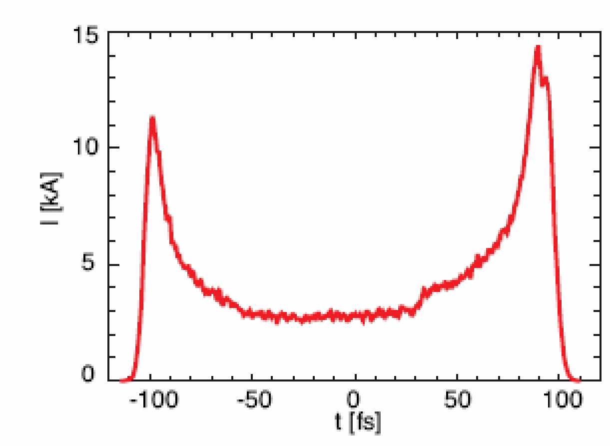
**+40%**

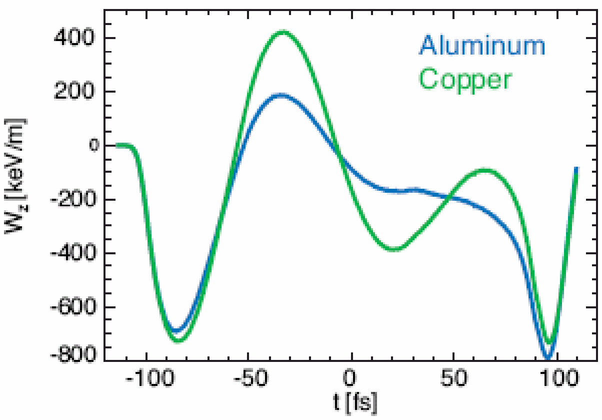


$$\delta_A = \frac{W_A L}{E \rho_1}$$ - fractional energy oscillation amplitude

| | LCLS | XFEL SASE2 (q=1nC, sig=25mkm) | XFEL SASE2 (q=0.56nC, sig=12.5mkm) |
|---|---|---|---|
| $W_A$, kV/m | 200 | 140 | 220 |
| L, m (L_sat) | 100<br>(90) | 200<br>(175) | 200<br>(175) |
| E, GeV | 14 | 17.5 | 17.5 |
| $\rho_1$ | 3.2e-4 | 4e-4 | 4e-4 |
| **$\delta_A$** | **4.5** | **4** | **6.3** |

*K. Bane and G.Stupakov*





# TESLA-FEL Report 2005-10

$\delta_A = 2.4,\ \rho = 7e-4 \qquad \varepsilon = 0.7\,\mathrm{mm*mrad}!$