



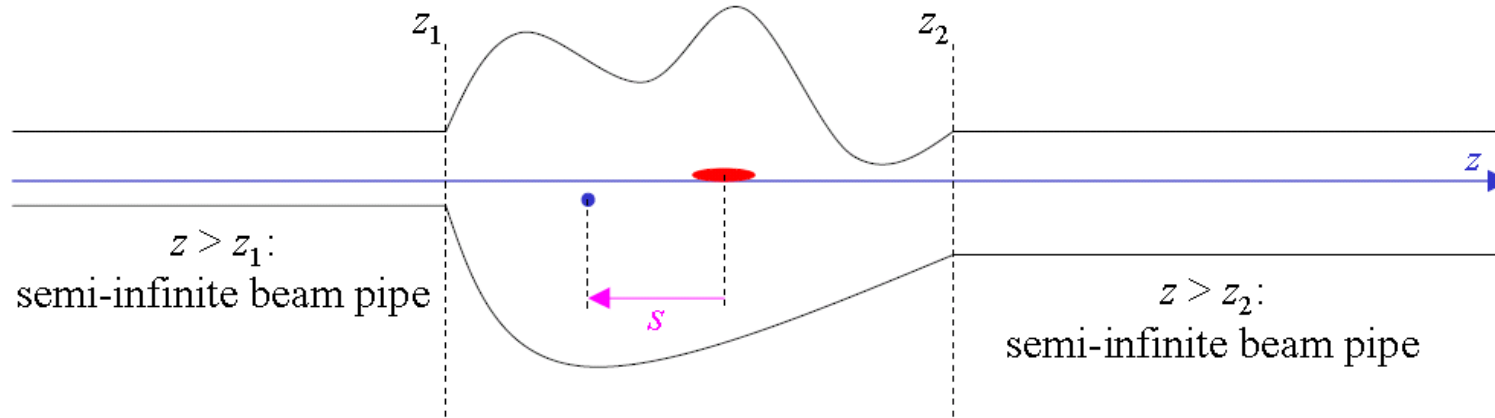
Impedance Budget Database

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3.11.08

BD meeting, DESY

wake potential



source particle \rightarrow source distribution

$$W_{\parallel}(s) = - \int_{-\infty}^s w_{\parallel}(s - s') \lambda(s') ds'$$

wake (Green) function

Wake function model

$$w(s) = \underbrace{w^{(0)}(s) + \frac{1}{C}}_{\text{regular part}} + \underbrace{Rc\delta(s) - c \frac{\partial}{\partial s} [Lc\delta(s) + w^{(-1)}(s)]}_{\text{singular part (cannot be tabulated directly)}}$$

$$Z(\omega) = Z^{(0)}(\omega) - \frac{1}{i\omega C} + R + i\omega [L + Z^{(-1)}(\omega)]$$

capacitive
resistive
inductive

$W \sim \int \lambda(s) ds$
 $W \sim \lambda(s)$
 $W \sim \lambda'(s)$

$$\frac{\partial}{\partial s} w^{(-1)}(s) = o(s^{-1}), \quad s \rightarrow 0. \quad \text{it describes singularities } s^{-\alpha}, \alpha < 1$$

Wake potential for arbitrary bunch shape

$$W(s) = - \int_{-\infty}^s w^{(0)}(s-s') \lambda(s') ds' - \frac{1}{C} \int_{-\infty}^s \lambda(s') ds' - Rc \lambda(s) -$$
$$-c^2 L \lambda'(s) - c \int_{-\infty}^s w^{(-1)}(s-s') \lambda'(s) ds'$$

derivative of the bunch shape

We have N normalized charge distributions λ_i :

$$\int \lambda_i(s) ds = 1, i = 1, \dots, N$$

We can calculate the first two moments of the distributions:

$$\mu_i = \int s \lambda_i(s) ds, \quad \sigma_i = \sqrt{\int (s - \mu_i)^2 \lambda_i(s) ds}$$

The wake potential of the distribution λ_i can be written in the normalized coordinate p as:

$$\widehat{W}(p) = W_i(p\sigma_i + \mu_i).$$

The total wake potential and the averaged bunch shape can be defined as:

$$\widehat{W}(p) = \sum_{i=1}^N \widehat{W}_i(p) = \sum_{i=1}^N W_i(p\sigma_i + \mu_i). \quad \widehat{\lambda}(p) = \frac{1}{N} \sum_{i=1}^N \sigma_i \lambda_i(p\sigma_i + \mu_i).$$

Then the loss factor and energy spread can be defined as:

$$Loss = \int \widehat{W}(p) \widehat{\lambda}(p) dp$$

$$Spread = \sqrt{(\widehat{W}(p) - Loss)^2 \widehat{\lambda}(p) dp}.$$

The main form of data base application contains a list of element types, parameters R, L, C and links to tables w0 and w_1.

Wake Field Calculations for the XFEL Project

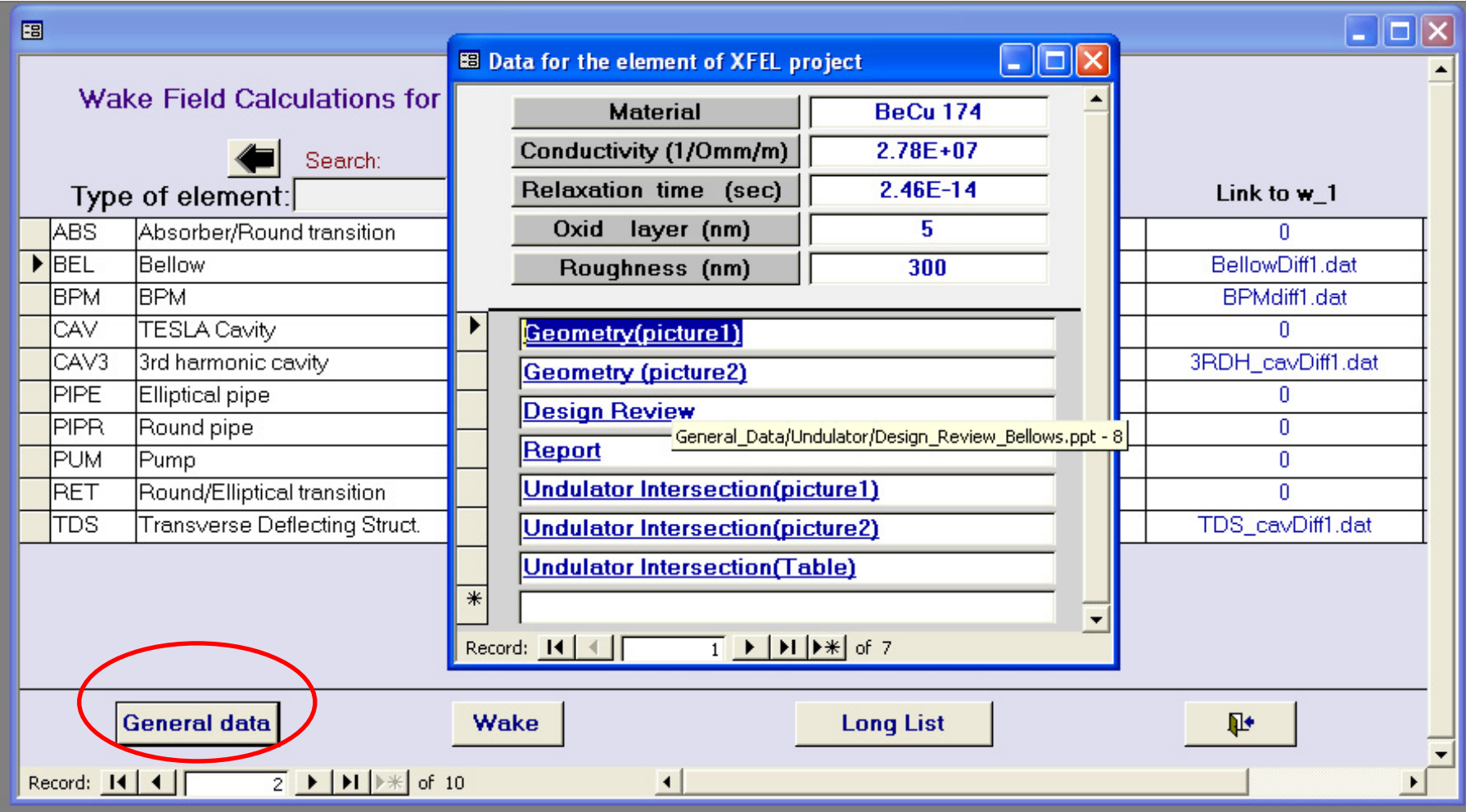
Search:

Type of element:

	Type of element:	R (Omm):	L (H):	C_inv (1/F) :	Link to w0	Link to w_1
▶	ABS Absorber/Round transition	2.04E+01	0.00E+00	0.00E+00	AbsRes22mm.dat	0
	BEL Bellow	7.60E-01	0.00E+00	0.00E+00	BellowRes30mm.dat	BellowDiff1.dat
	BPM BPM	0.00E+00	0.00E+00	0.00E+00	BPMRes100mm.dat	BPMdiff1.dat
	CAV TESLA Cavity	0.00E+00	0.00E+00	0.00E+00	TESLA_Cavity.dat	0
	CAV3 3rd harmonic cavity	0.00E+00	0.00E+00	0.00E+00	3RDH_cav.dat	3RDH_cavDiff1.dat
	PIPE Elliptical pipe	0.00E+00	0.00E+00	0.00E+00	EIPipe5161mm.dat	0
	PIPR Round pipe	0.00E+00	0.00E+00	0.00E+00	RoundPipe652mm.dat	0
	PUM Pump	1.13E+00	1.66E-13	0.00E+00	PumpRes105mm.dat	0
	RET Round/Elliptical transition	1.06E+01	0.00E+00	0.00E+00	0	0
	TDS Transverse Deflecting Struct.	0.00E+00	0.00E+00	0.00E+00	TDS_cav.dat	TDS_cavDiff1.dat

Record: of 10

The click on button „General data” opens a description of the current element. This table can contain a reference to additional material: geometry description, input files for wake field calculations, reports.



The same element types can appear several times along the beam line. Hence, we need to have all combinations of this element with different bunches.

The click on button „Wake” opens a form to assign a bunch to the current element and to calculate the wake potential for all possible combinations

Calculating of the wake potential and Loss parameters

TESLA Cavity

Bunch form	Loss (V/pC)	Spread (V/pC)	Peak (V/pC)	Wake
Gauss2400mkm	7.66E+00	3.40E+00	1.14E+01	TESLA_Cavity_w2.dat Wake
Gauss120mkm	1.67E+01	9.01E+00	2.94E+01	TESLA_Cavity_w3.dat Wake
Gauss25mkm	1.91E+01	1.07E+01	3.57E+01	TESLA_Cavity_w4.dat Wake

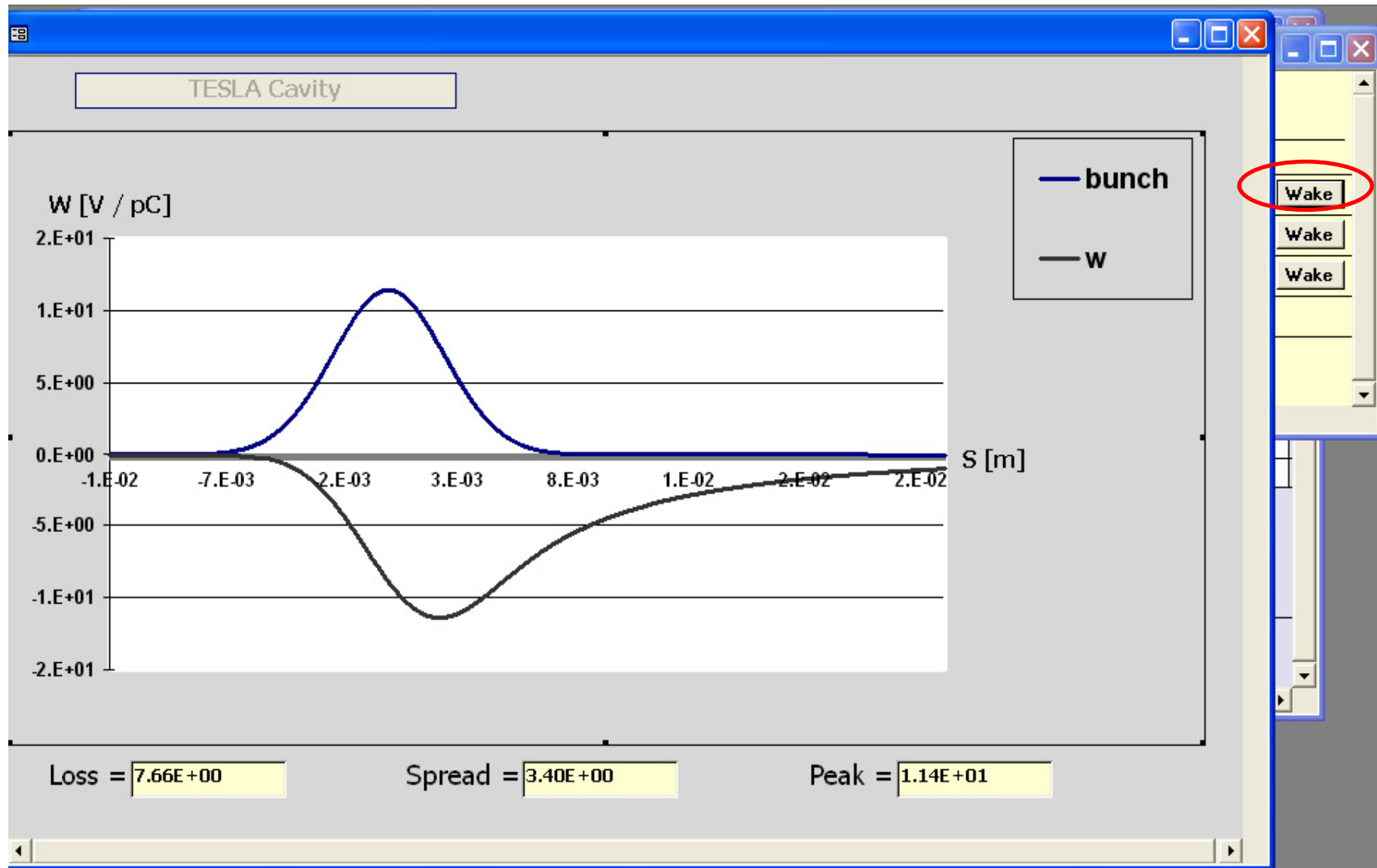
Record: 1 of 3

Buttons: New Wake Potential, Delete record

Main interface buttons: General data, **Wake**, Long List

Record: 4 of 10

Plot with wake potential of the current element with selected bunch shape can be seen.



The next table shows a long list of unique elements and integrated wake field parameters for each of them.

W All elements Number of selected elements in this list: 14

Type of element	Section	Number	Name of element	from (m)	to (m)	Loss (V/pC)	Spread (V/pC/m)	Peak (V/pC/m)	<input checked="" type="checkbox"/>
ABS	I1	8	CAV.32.I1	32.7597	33.7974	7.662E+00	3.402E+00	1.140E+01	<input checked="" type="checkbox"/>
BEL	L1	32	CAV.95.L1	95.2904	96.3281	7.662E+00	3.402E+00	1.140E+01	<input checked="" type="checkbox"/>
BPM	L1	48	CAV3.142.L1	142.8149	143.1608	9.777E+00	4.027E+00	1.403E+01	<input checked="" type="checkbox"/>
BPM	L2	96	CAV.230.L2	230.4536	231.4913	1.673E+01	9.009E+00	2.943E+01	<input checked="" type="checkbox"/>
CAV	L3	800	CAV.464.L3	464.564	465.6017	1.915E+01	1.070E+01	3.565E+01	<input checked="" type="checkbox"/>
CAV	SA1	33	PIPE.2173.SA1	2173.8911	2179.0521	2.387E+02	2.734E+02	5.261E+02	<input checked="" type="checkbox"/>
COL	SA1	32	PUM.2179.SA1	2179.0521	2179.1571	8.662E+00	9.649E+00	1.937E+01	<input checked="" type="checkbox"/>
FLAN	SA1	32	ABS.2179.SA1	2179.1571	2179.1791	6.974E+01	2.773E+01	9.908E+01	<input checked="" type="checkbox"/>
KICK	SA1	32	PIPR.2179.SA1	2179.1791	2179.8311	2.165E+01	3.227E+01	5.865E+01	<input checked="" type="checkbox"/>
PIP2	SA1	32	BPM.2179.SA1	2179.2641	2179.3641	7.119E+01	2.963E+01	1.030E+02	<input checked="" type="checkbox"/>
PIPE	SA1	64	BEL.2179A.SA1	2179.4041	2179.4341	2.518E+01	8.699E+00	3.358E+01	<input checked="" type="checkbox"/>
PIPR	SA1	32	RET.2179.SA1	2179.9911	2179.9911	3.586E+01	1.410E+01	5.071E+01	<input checked="" type="checkbox"/>
PUM	SA2	42	PIPE.2173.SA2	2173.7969	2178.9579	2.387E+02	2.734E+02	5.261E+02	<input type="checkbox"/>
PUM	SA2	41	PUM.2178.SA2	2178.9579	2179.0629	8.662E+00	9.649E+00	1.937E+01	<input type="checkbox"/>
RET	SA2	41	ABS.2179.SA2	2179.0629	2179.0849	6.974E+01	2.773E+01	9.908E+01	<input type="checkbox"/>
TDS	SA2	41	PIPR.2179.SA2	2179.0849	2179.7369	2.165E+01	3.227E+01	5.865E+01	<input type="checkbox"/>

Record: 1 of 34

Record: 1 of 16

Form View

The click on button „Impedance Budget” opens a report with total impedance budget of the selected elements. This table presents the summary results for different sections and bunch shapes.

The screenshot shows a software window titled "Loss, spread, peak parameters" containing a table with the following data:

Section	Name of bunch	Loss (V/pC)	%	Spread (V/pC/m)	%	Peak (V/pC/m)	%	Link to the wake	
L1	Gauss2400mkm	7.145E+02	2	3.009E+02	3	1.035E+03	2	wake_L1	Wake
I1	Gauss2400mkm	6.129E+01	0	2.722E+01	0	9.123E+01	0	wake_I1	Wake
All	Gauss2400mkm	7.758E+02	2	3.279E+02	3	1.126E+03	2	wake_Gauss2400mkm	Wake
L2	Gauss120mkm	1.606E+03	5	8.649E+02	7	2.826E+03	6	wake_L2	Wake
B1	Gauss120mkm	2.524E+02	1	1.178E+02	1	3.952E+02	1	wake_B1	Wake
All	Gauss120mkm	1.859E+03	5	9.820E+02	8	3.221E+03	7	wake_Gauss120mkm	Wake
SA1	Gauss25mkm	1.612E+04	46	1.171E+04	101	2.881E+04	60	wake_SA1	Wake
L3	Gauss25mkm	1.532E+04	43	8.561E+03	74	2.852E+04	60	wake_L3	Wake
B2	Gauss25mkm	1.325E+03	4	5.595E+02	5	1.910E+03	4	wake_B2	Wake
All	Gauss25mkm	3.276E+04	93	1.099E+04	95	4.474E+04	94	wake_Gauss25mkm	Wake
All	bunch_total	3.539E+04	100	1.162E+04	100	4.774E+04	100	wake_total	Wake

Below the table, there is a status bar with the following information: CAV, L1, 32, CAV.95.L1, 95.2904, 96.3281, 7.662E+00, 3.402E+00, 1.140E+01, and a checked checkbox. At the bottom, there are several buttons: "Wake plot", "Impedance budget (bunch types and sections)" (circled in red), "Impedance budget (element types and sections)", and "Select wake". A record indicator at the bottom left shows "Record: 2 of 34".

Print version of the summary results.

Budget

Impedance Budget of XFEL Project

<u>Section</u>	<u>BunchShape</u>	<u>Loss (V/Pc)</u>	<u>%</u>	<u>Spread (V/Pc)</u>	<u>%</u>	<u>Peak (V/Pc)</u>	<u>%</u>
L1	Gauss2400mkm	7.145E+02	2	3.009E+02	3	1.035E+03	2
I1	Gauss2400mkm	6.129E+01	0	2.722E+01	0	9.123E+01	0
AI	Gauss2400mkm	7.758E+02	2	3.279E+02	3	1.126E+03	2
L2	Gauss120mkm	1.606E+03	5	8.649E+02	7	2.826E+03	6
B1	Gauss120mkm	2.524E+02	1	1.178E+02	1	3.952E+02	1
AI	Gauss120mkm	1.859E+03	5	9.820E+02	8	3.221E+03	7
SA1	Gauss25mkm	1.612E+04	46	1.171E+04	101	2.881E+04	60
L3	Gauss25mkm	1.532E+04	43	8.561E+03	74	2.852E+04	60
B2	Gauss25mkm	1.325E+03	4	5.595E+02	5	1.910E+03	4
AI	Gauss25mkm	3.276E+04	93	1.099E+04	95	4.474E+04	94
AI	Total bunch	3.539E+04	100	1.162E+04	100	4.774E+04	100

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This table presents the summary results for different sections and types of elements.

Loss, spread, peak parameters

Section	Type of element	Number of elements	Loss (V/pC)	%	Spread (V/pC/m)	%	Peak (V/pC/m)	%
SA1	ABS	32	2.232E+03	6	8.874E+02	8	3.171E+03	7
SA1	BEL	64	1.611E+03	5	5.567E+02	5	2.149E+03	5
SA1	BPM	32	2.278E+03	6	9.481E+02	8	3.297E+03	7
SA1	PIPE	33	7.876E+03	22	9.023E+03	78	1.736E+04	36
SA1	PIPR	32	6.929E+02	2	1.033E+03	9	1.877E+03	4
SA1	PUM	32	2.772E+02	1	3.088E+02	3	6.199E+02	1
SA1	RET	32	1.147E+03	3	4.513E+02	4	1.623E+03	3
SA1			1.612E+04	46	1.171E+04	101	2.881E+04	60
L3	CAV	800	1.532E+04	43	8.561E+03	74	2.852E+04	60
L3			1.532E+04	43	8.561E+03	74	2.852E+04	60
L2	CAV	96	1.606E+03	5	8.649E+02	7	2.826E+03	6
L2			1.606E+03	5	8.649E+02	7	2.826E+03	6
L1	CAV	32	2.452E+02	1	1.089E+02	1	3.649E+02	1
L1	CAV3	48	4.693E+02	1	1.933E+02	2	6.732E+02	1
L1			7.145E+02	2	3.009E+02	3	1.035E+03	2
I1	CAV	8	6.129E+01	0	2.722E+01	0	9.123E+01	0
I1			6.129E+01	0	2.722E+01	0	9.123E+01	0
B2	TDS	6	1.325E+03	4	5.595E+02	5	1.910E+03	4
B2			1.325E+03	4	5.595E+02	5	1.910E+03	4
B1	TDS	2	2.524E+02	1	1.178E+02	1	3.952E+02	1
B1			2.524E+02	1	1.178E+02	1	3.952E+02	1
All			3.539E+04	100	1.162E+04	100	4.774E+04	100

Number of selected elements in this list: **14**

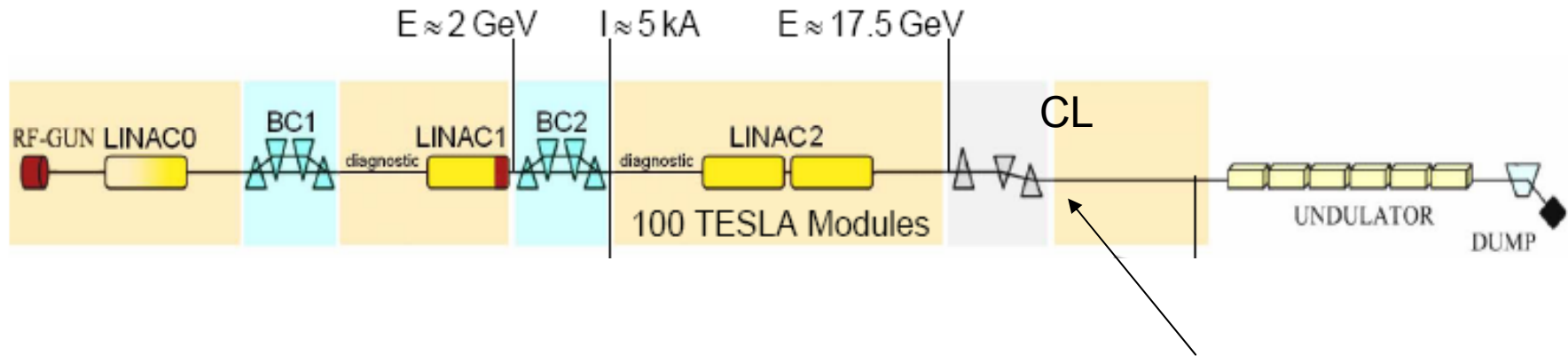
	Spread (V/pC/m)	Peak (V/pC/m)	
E+02	5.890E+01	1.976E+02	<input checked="" type="checkbox"/>
E+02	9.325E+01	3.184E+02	<input checked="" type="checkbox"/>
E+06	1.802E+06	4.217E+06	<input type="checkbox"/>
E+03	4.483E+03	1.474E+04	<input type="checkbox"/>
E+03	5.303E+02	1.737E+03	<input type="checkbox"/>
E+02	2.474E+02	8.975E+02	<input type="checkbox"/>
E+08	3.434E+08	1.199E+09	<input type="checkbox"/>
E+09	9.272E+08	3.239E+09	<input type="checkbox"/>
E+00	3.402E+00	1.140E+01	<input checked="" type="checkbox"/>
E+00	3.402E+00	1.140E+01	<input checked="" type="checkbox"/>
E+00	4.027E+00	1.403E+01	<input checked="" type="checkbox"/>
E+01	9.009E+00	2.943E+01	<input checked="" type="checkbox"/>
E+01	1.070E+01	3.565E+01	<input checked="" type="checkbox"/>
E+02	2.734E+02	5.261E+02	<input checked="" type="checkbox"/>
E+00	9.649E+00	1.937E+01	<input checked="" type="checkbox"/>
E+01	2.773E+01	9.985E+01	<input checked="" type="checkbox"/>

Impedance budget
(element types and sections)

Wake

Record: 1 of 22

European XFEL:



12 cavity BPMs
with step from $R=20.25 \text{ mm}$
to $R=5 \text{ mm}$

Impedance budget

Section	El. type	Num.	Loss (V/pC)	%	Spread(V/Pc)	%	Peak(V/Pc)	%
L3								
	CAV	800	1.53E+04	34	8.56E+03	50	2.85E+04	46
			1.53E+04	34	8.56E+03	50	2.85E+04	46
L2								
	CAV	96	1.61E+03	4	8.65E+02	5	2.83E+03	5
			1.61E+03	4	8.65E+02	5	2.83E+03	5
L1								
	CAV	32	2.45E+02	1	1.09E+02	1	3.65E+02	1

Impedance budget without undulator sections

CL								
	BPMCL	12	7.66E+03	17	2.97E+03	17	1.08E+04	17
			6.13E+01	0	2.72E+01	0	9.12E+01	0
CL								
	BPMCL	12	7.66E+03	17	2.97E+03	17	1.08E+04	17
	COLL	4	5.72E+03	13	2.77E+03	16	8.59E+03	14
	FLANG	500	1.42E+03	3	5.73E+02	3	2.00E+03	3
	KICK	4	4.94E+03	11	2.09E+03	12	7.15E+03	11
	PIP20	1	5.40E+03	12	3.95E+03	23	9.25E+03	15
	PUMCL	78	5.96E+02	1	2.41E+02	1	8.43E+02	1
			2.57E+04	57	1.17E+04	69	3.79E+04	61
B2								
	TDS	6	1.33E+03	3	5.60E+02	3	1.91E+03	3
			1.33E+03	3	5.60E+02	3	1.91E+03	3
B1								
	TDS	2	2.52E+02	1	1.18E+02	1	3.95E+02	1
			2.52E+02	1	1.18E+02	1	3.95E+02	1
All								
			4.50E+04	100	1.70E+04	100	6.25E+04	100

12 cavity BPMs with step from R=20.25 mm to R=5mm produce 17 % of the energy spread in impedance budget from injector to undulator

Impedance budget

Section	El. type	Num.	Loss (V/pC)	%	Spread(V/Pc)	%	Peak(V/Pc)	%
SA2								
	ABS	41	2.86E+03	4	1.14E+03	5	4.06E+03	4
	BEL	82	2.06E+03	3	7.13E+02	3	2.75E+03	3
	BPM	41	2.92E+03	4	1.21E+03	5	4.22E+03	5
	PIPE	42	1.00E+04	15	1.15E+04	46	2.21E+04	24
	PIPR	41	8.88E+02	1	1.32E+03	5	2.40E+03	3
	PUM	41	3.55E+02	1	3.96E+02	2	7.94E+02	1
	RET	41	1.47E+03	2	5.78E+02	2	2.08E+03	2
			2.06E+04	31	1.49E+04	59	3.68E+04	40
L3								
	CAV	800	1.53E+04	23	8.56E+03	34	2.85E+04	31
			1.53E+04	23	8.56E+03	34	2.85E+04	31
L2								
	CAV	96	1.61E+03	2	8.65E+02	3	2.83E+03	3
			1.61E+03	2	8.65E+02	3	2.83E+03	3
L1								
	CAV	32	2.45E+03	1	1.05E+03	1	1.05E+03	1
	CAV3	48	4.69E+03	1	3.01E+02	1	1.05E+03	1
			7.14E+02	1	3.01E+02	1	1.05E+03	1
II								
	CAV	8	6.13E+01	0	2.72E+01	0	9.12E+01	0
			6.13E+01	0	2.72E+01	0	9.12E+01	0
CL								
	BPMCL	12	7.66E+03	12	2.97E+03	12	1.08E+04	12
	COLL	4	5.72E+03	9	2.77E+03	11	8.59E+03	9
	FLANG	500	1.42E+03	2	5.73E+02	2	2.00E+03	2
	KICK	4	4.94E+03	8	2.09E+03	8	7.15E+03	8
	PIP20	1	5.40E+03	8	3.95E+03	16	9.25E+03	10
	PUMCL	78	5.96E+02	1	2.41E+02	1	8.43E+02	1
			2.57E+04	39	1.17E+04	47	3.79E+04	41
B2								
	TDS	6	1.33E+03	2	5.60E+02	2	1.91E+03	2
			1.33E+03	2	5.60E+02	2	1.91E+03	2
B1								
	TDS	2	2.52E+02	0	1.18E+02	0	3.95E+02	0
			2.52E+02	0	1.18E+02	0	3.95E+02	0
All								
			6.56E+04	100	2.51E+04	100	9.28E+04	100

Impedance budget with SASE 2 included

CL

BPMCL

12

7.66E+03

12

2.97E+03

12

1.08E+04

12

12 cavity BPMs with step from R=20.25 mm to R=5mm produce 12 % of the energy spread in impedance budget from injector to undulator