Collimator Design

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People - SWMD collaboration

Birmingham: N.Watson, M Slater

SFTF: L.Fernandez, G.Ellwood, J.Greenhalgh, B.Fell, S. Appleton

CERN: G.Rumolo, D.Schulte, A.Latina

Lancaster: D.Burton, J.Smith, R.Tucker

Manchester: R.Barlow, A.Bungau, R.Jones

Darmstadt: M.Karkkainen, W.Muller, T.Weiland

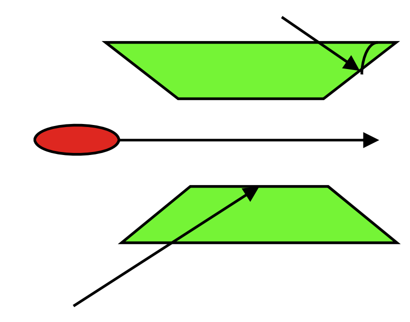
Also: a strong collaboration with **SLAC** (S.Molloy and M.Woods) for wakefield beam tests and **KEK** for collimator damage.

Requirements

Significant problems:

- short-range wakefields ->lead to emittance dilution and beam jitter at the IP

- impact of a no of high density bunches can damage the spoilers



1. Spoiler geometry must reduce the wakefields to an acceptable level

- long, shallow tapers of ~20 mrad,
- short flat upper section of 0.6 r.l.
- high conductivity surface coating

the wakefield aspects of the design are addressed by experimental work centered around T480 project at SLAC-ESA and simulations with Gdfidl, Echo, Merlin, Placet (see Daniel's talk)

2. Spoilers are required to survive 2 bunches at 250 and 1 bunch at 500 GeV

- use bulk material to minimise fractures, stress but optimal for heat flow
- long path length for errant beams striking spoilers (large r.l : graphite, beryllium etc)

the design approach consider simulations with FLUKA, Geant4, EGS4, ANSYS and experimental work at KEK

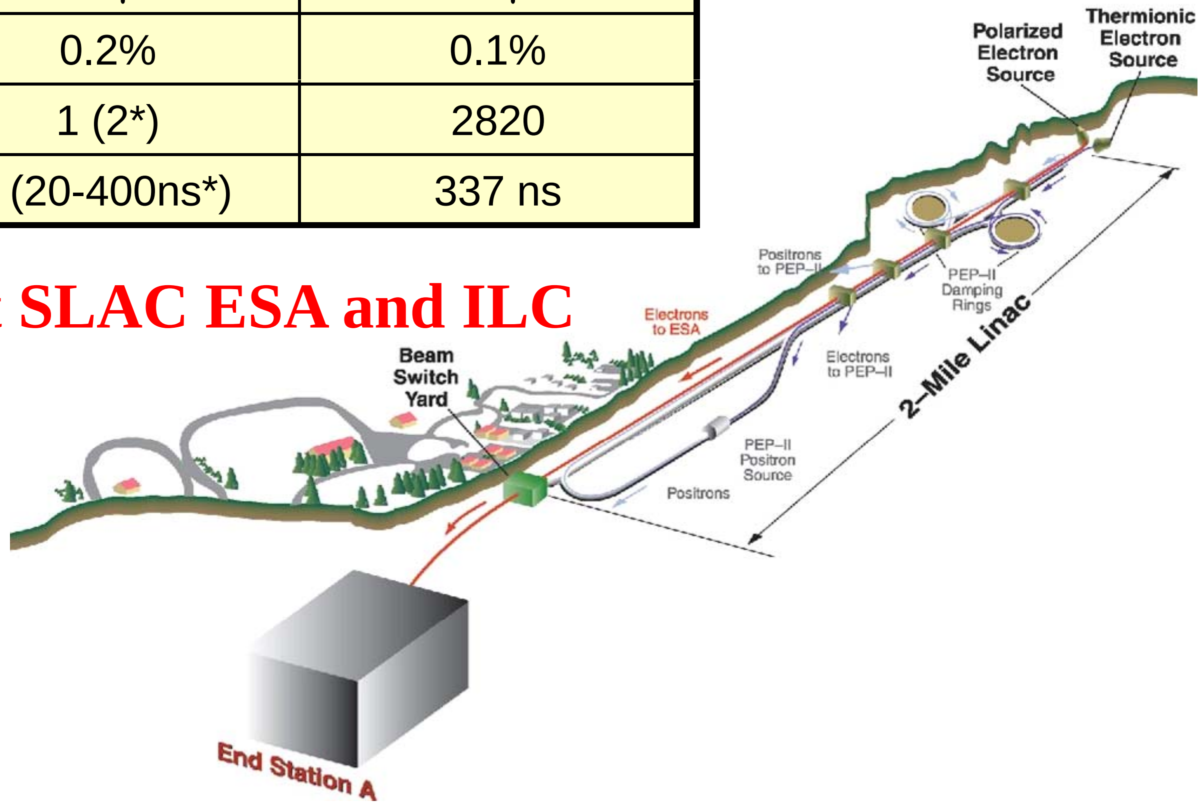
T480 experiment at SLAC-ESA

Wakefield tests at SLAC-ESA

Parameter	SLAC ESA	ILC-500
Repetition Rate	10 Hz	5 Hz
Energy	28.5 GeV	250 GeV
Bunch Charge	2.0×10^{10}	2.0×10^{10}
Bunch Length	300 μm	300 μm
Energy Spread	0.2%	0.1%
Bunches per train	1 (2*)	2820
Microbunch spacing	- (20-400ns*)	337 ns

Aim: measure the beam kick and compare it with theoretical predictions and simulations

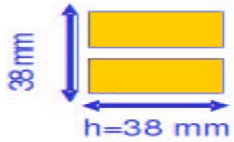
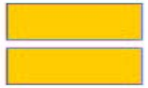
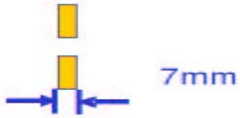
Beam Parameters at SLAC ESA and ILC

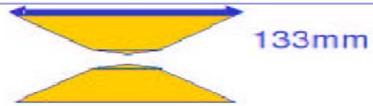
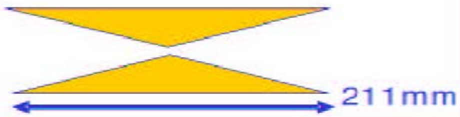
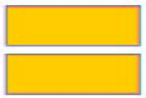
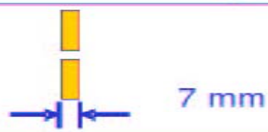
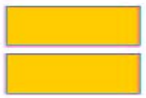


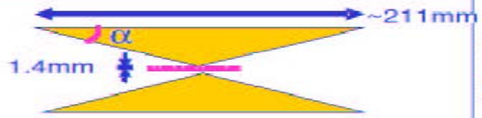
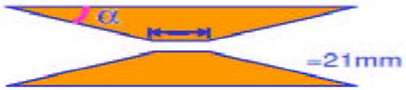
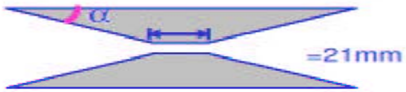
Beam size:

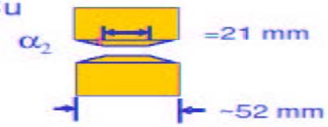
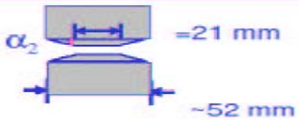
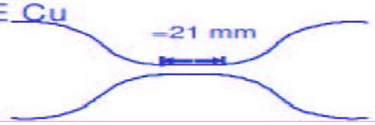
100 um vertically

0.5-1.5 mm longitudinally

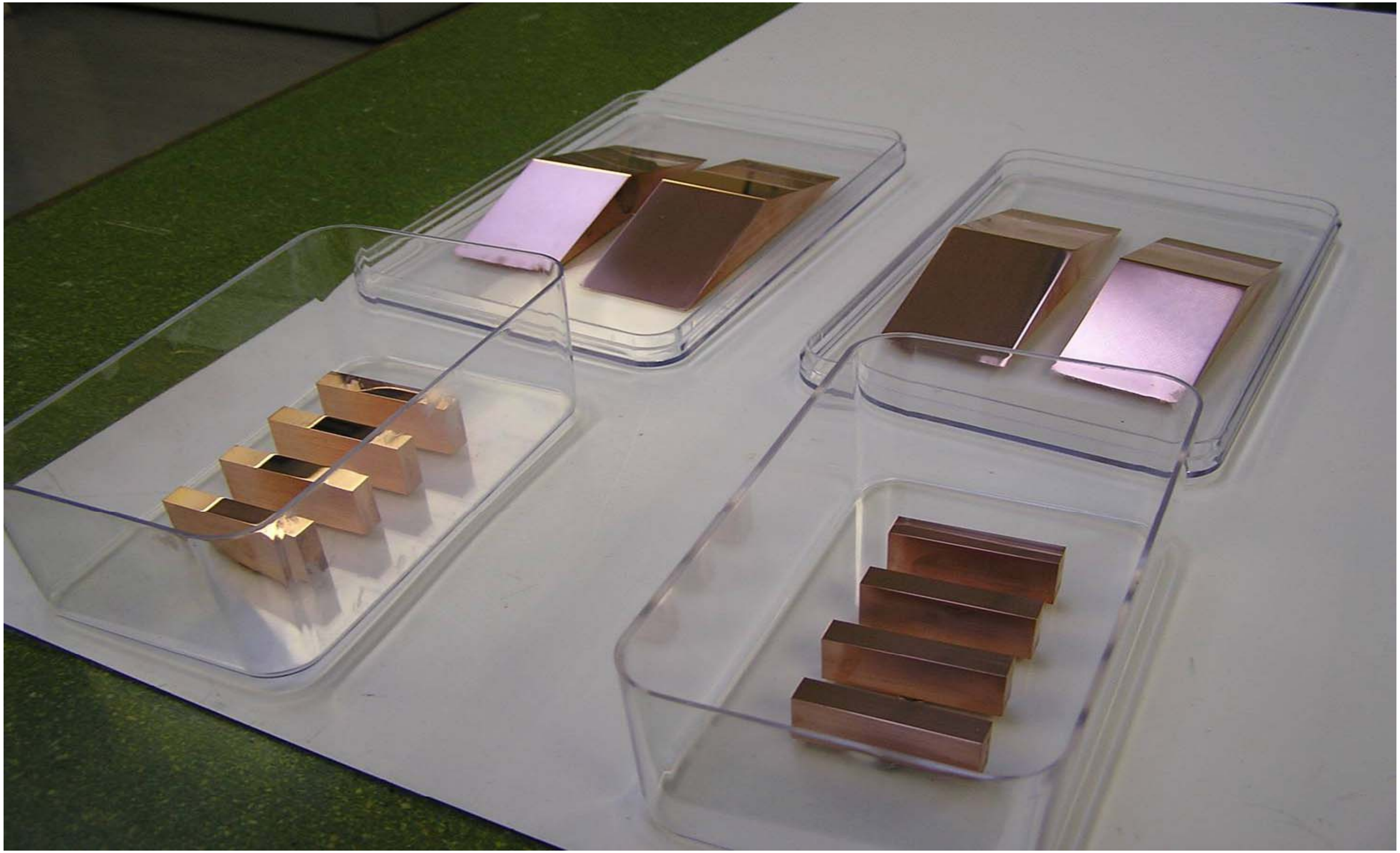
Collim. #	Side view	Beam view	Revised 4-May-2006
1			α=324mrad r=2.0mm
2			α=324mrad r=1.4mm
3			α=324mrad r=1.4mm
4			$\alpha=\pi/2$rad r=4.0mm

Collim.#	Side view	Beam view	Revised 4-May-2006
8			r_1 =4.0mm r_2 =1.4mm α_1=289mrad α_2=166mrad
7			$\alpha_1=\pi/2$ rad α_2=166mrad r_1=4.0mm r_2=1.4mm
6			α=166mrad r=1.4mm
5			$\alpha=\pi/2$rad r=1.4mm

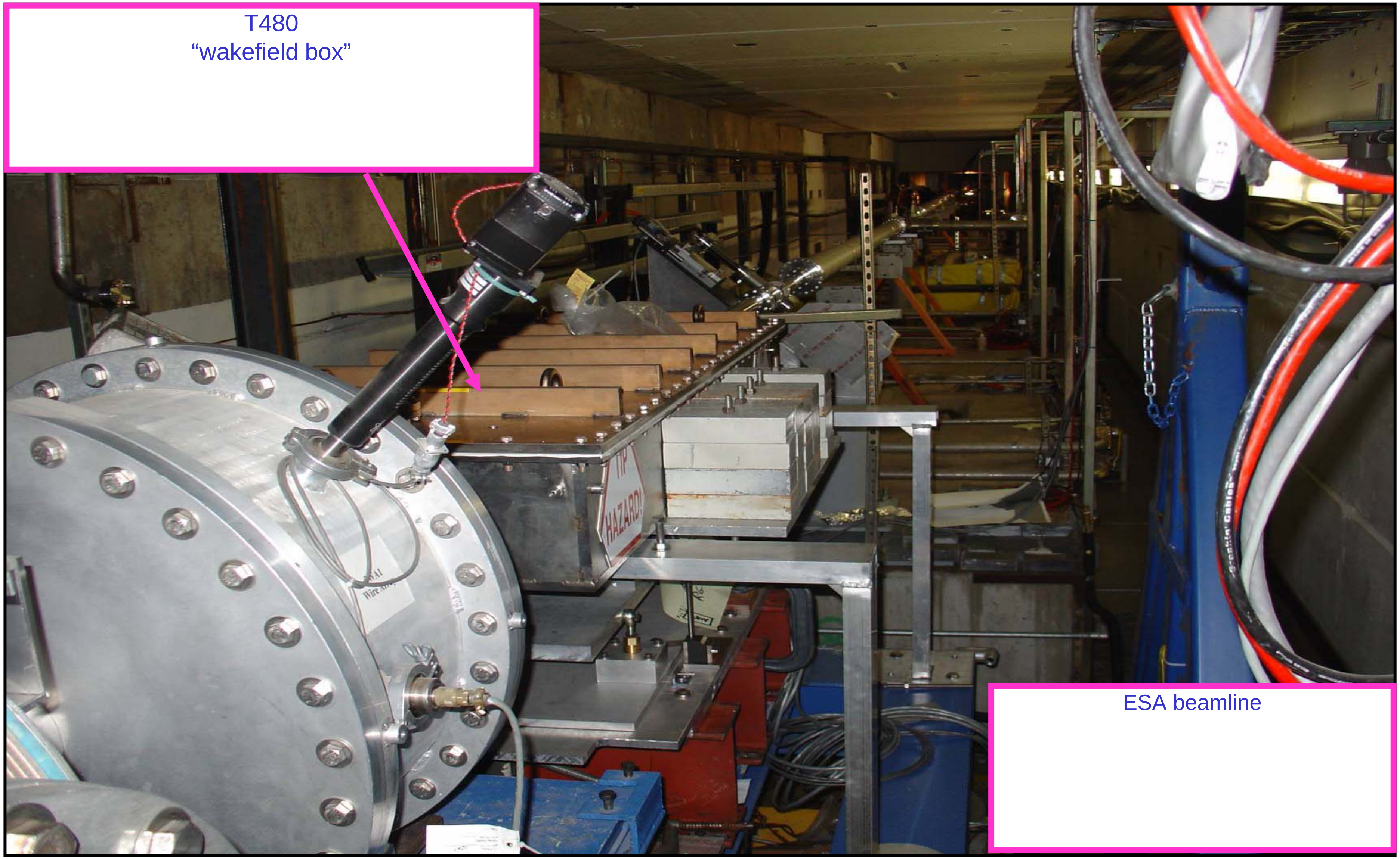
Collim.#	Side view	Beam view	Revised 27-Nov-2006
6			α=166mrad r=1.4mm (1/2 gap)
10			α=166mrad r =1.4mm
11			α=166mrad r =1.4mm
12			α=166mrad r=1.4mm

Collim.#	Side view	Beam view	Revised 27-Nov-2006
13	OFE Cu 		$\alpha_1=\pi/2$ rad α_2=166mrad r_1=4.0mm r_2=1.4mm
14	Ti6Al4V 		$\alpha_1=\pi/2$ rad α_2=166mrad r_1=4.0mm r_2=1.4mm
15			$\alpha_1=\pi/2$ rad α_2=50mrad r_1=4.0mm r_2=1.4mm
16	OFE Cu 		non-linear taper r=1.4mm

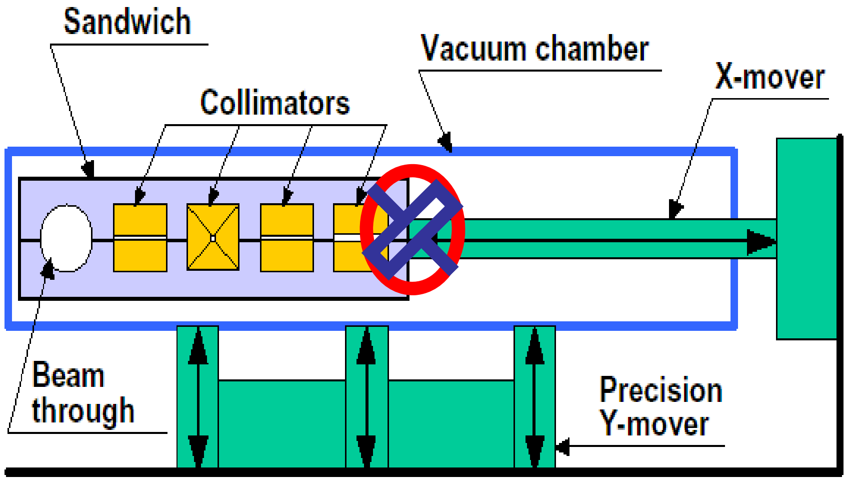
Designed Collimators

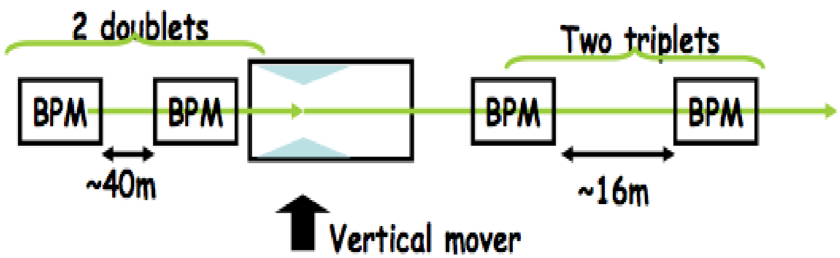


ESA beamline



Wakefield Box



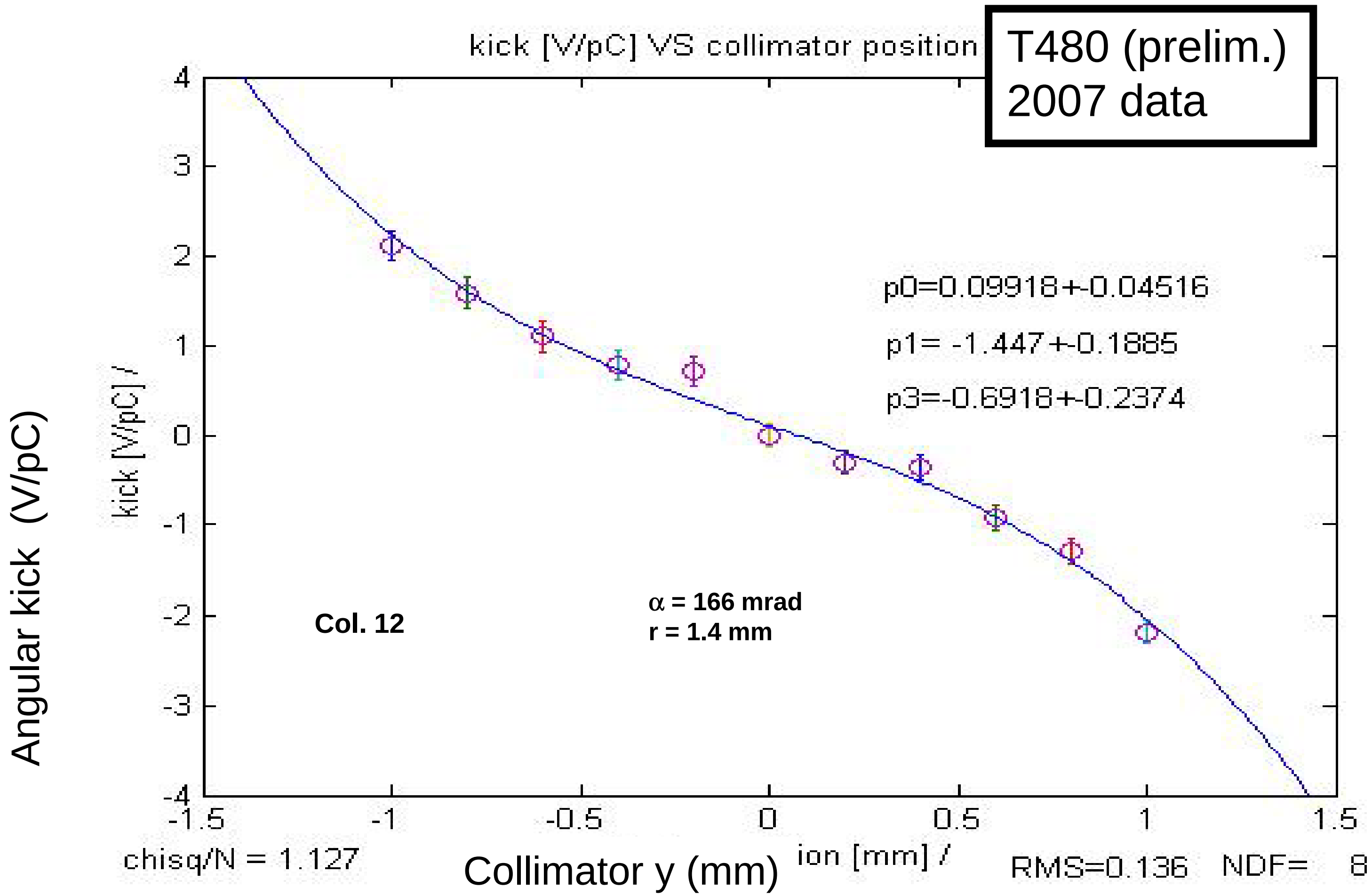


- readings from each BPM were recorded together with the bunch charge and energy

- the kick was determined by performing a straight line fit to the upstream BPM and a separate one to fit the downstream ones

- the kick was calculated as the difference in the slopes of these fits

Data analysis



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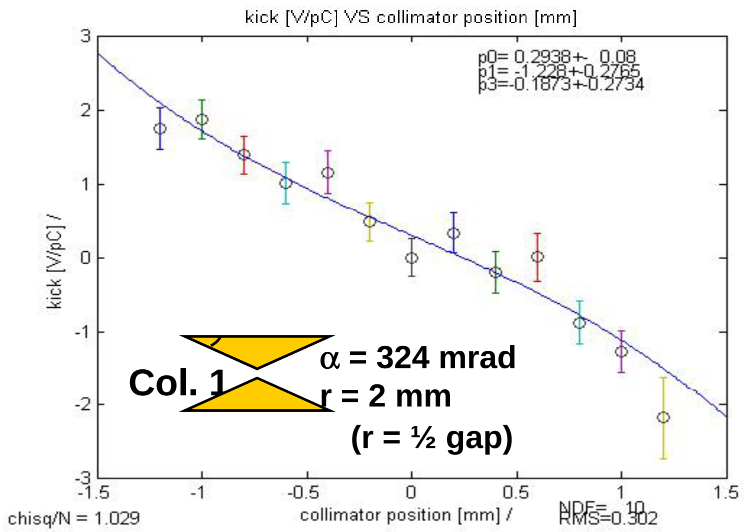

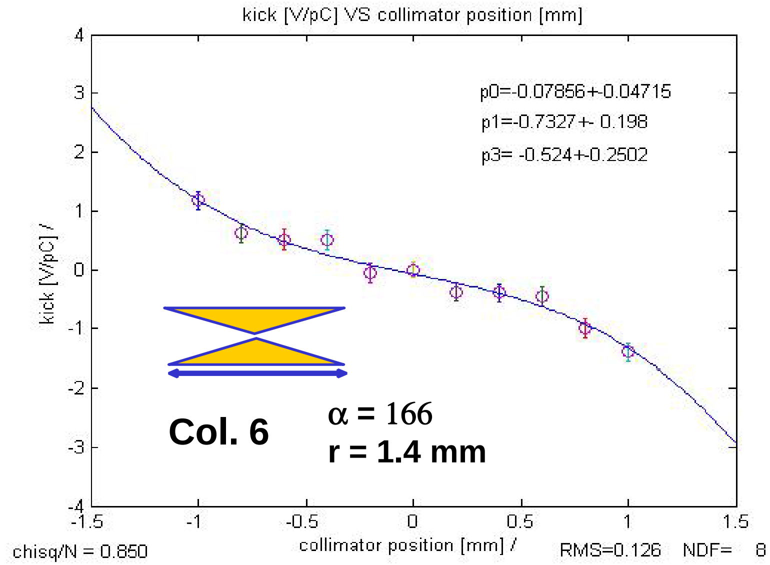

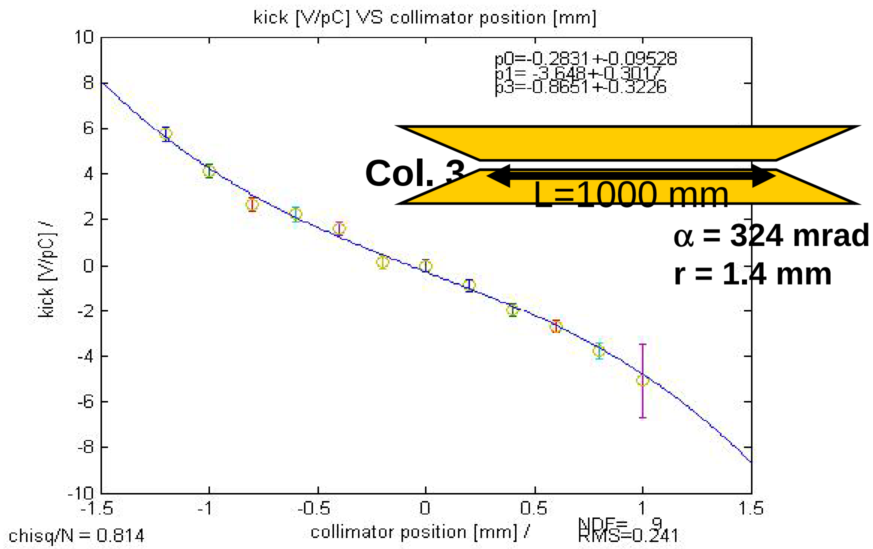

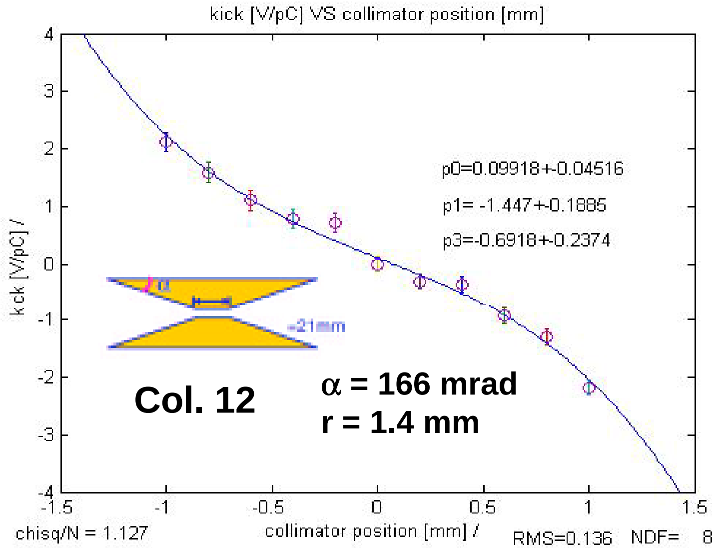

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Measured and calculated kick factor

Collim No	Experimental measurements (V/pC/mm)	Gdfidl calculations (V/pC/mm)	Analytic predictions (V/pC/mm)	3-D Modeling prediction kick (V/pC/mm)
1	1.2 0.3	1.7 0.4	2.27	1.63 0.37
2	1.9 0.2	3.1 0.8	4.63	2.88 0.84
3	4.4 0.3	7.1 0.9	5.25	5.81 0.94
4	0.6 0.4	0.8	0.56	0.8
5	4.9 0.3	6.8	4.59	6.8
6	1.0 0.1	2.4 1.1	4.65	2.12 1.14
7	1.4 0.3	2.7 0.5	4.59	2.87 0.53
8	1.0 0.2	2.4 0.9	4.59	2.39 0.89
10	1.4 0.2			
11	1.7 0.1			
12	1.7 0.1			
13	1.9 0.2	1.2 0.3		3.57 0.98
14	2.6 0.1			3.57 0.98
15	1.6 0.1			2.51 1.16
16	1.6 0.2			2.35 1.50

Note: quoted errors are estimates

Collimator Damage Experiment at ATF

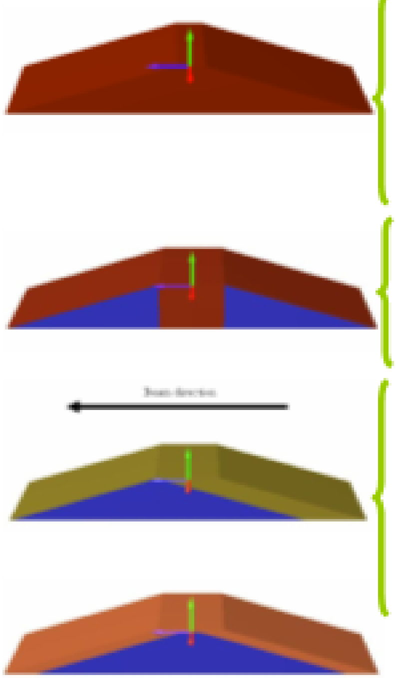
Previous simulations

Aim: the collimators can be damaged by the impact of several bunches

Exceeds fracture temp.

Exceeds melting temp.

Temperature increase from 1 bunch impact



	2mm depth		10mm depth	
	250 GeV e- 111×9 μm²	500 GeV e- 79.5×6.4 μm²	250 GeV e- 111×9 μm²	500 GeV e- 79.5×6.4 μm²
Solid Ti alloy	420 K	870 K	850 K	2000 K
Solid Al	200 K	210 K	265 K	595 K
Solid Cu	1300 K	2700 K	2800 K	7000 K
Graphite+Ti option 1	325 K	640 K	380 K	760 K
Beryllium+Ti ≈ option 1	-	-	-	675 K
Graphite+Ti option 2	290 K	575 K	295 K	580 K
Graphite+Al option 2	170 K	350 K	175 K	370 K
Graphite+Cu option 2	465 K	860 K	440 K	870 K
Graphite+Ti option 3	300 K	580 K	370 K	760 K

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Stress wave

Purpose of the ATF test

First run at ATF

- commisioning of the vacuum vessel, multi-axis mover, beam position and size monitors

- validate the mode of operation required for ATF tests

- measurement of the size of the damage region after individual beam impacts on test target (validation of FLUKA/ANSYS simulations of properties of material)

- ensure that the radiation protection requirements can be satisfied

Next phase at ATF2

- measure the shock waves within the sample (VISAR or LDV) for single bunch and multiple bunches at ~ILC bunch spacing

ATF Schedule

February:

1st week - mover commisioning at RAL

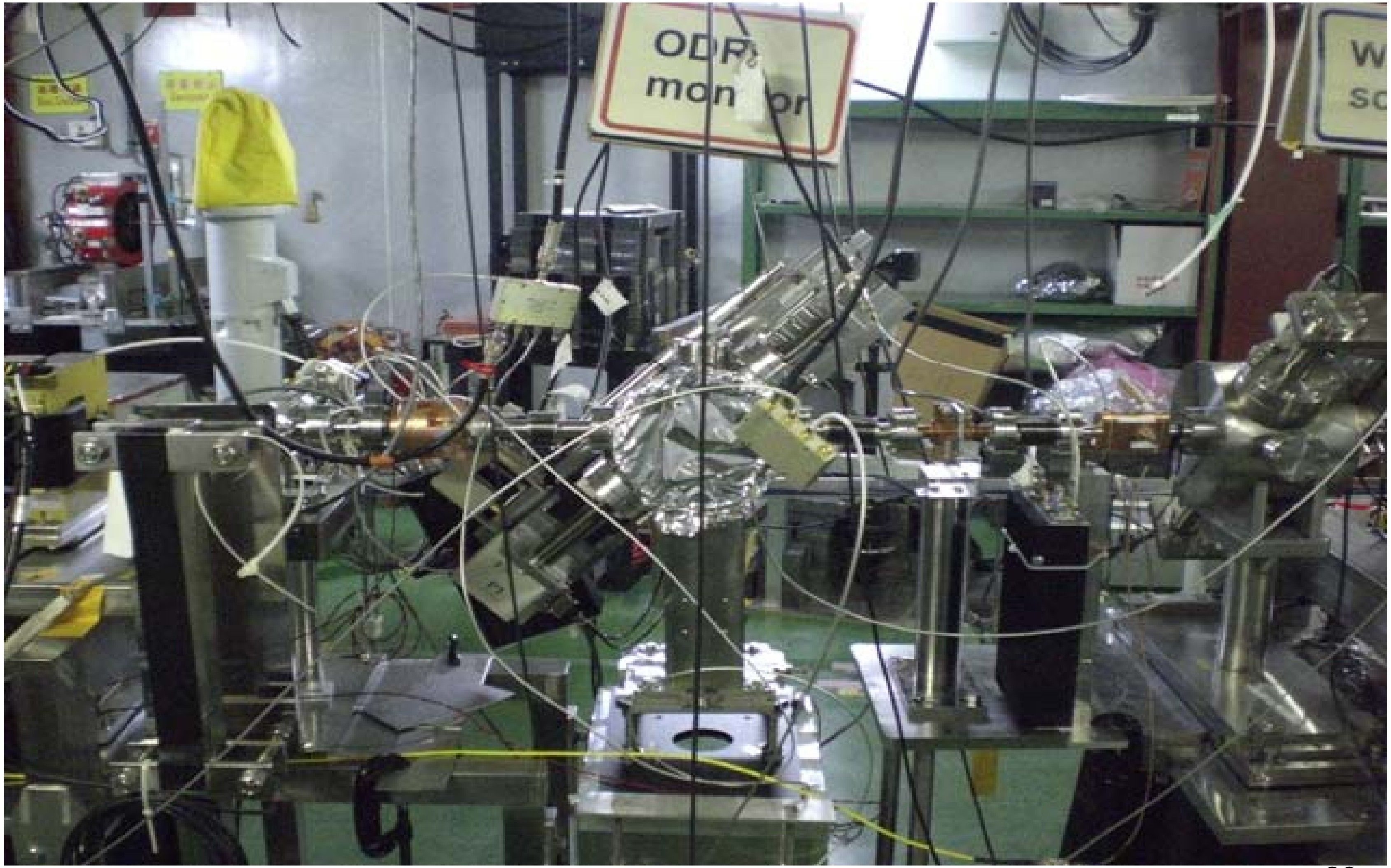
2nd week - installation at KEK

3rd week - testing readout of beamline instrumentation

4th week - measurement of samples

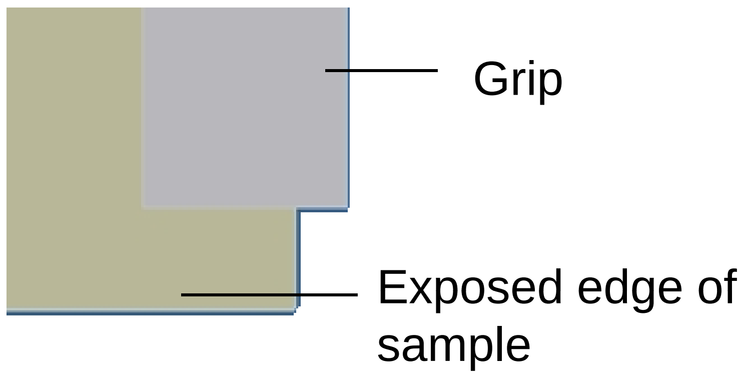
- shock wave measurements are planned at ATF2

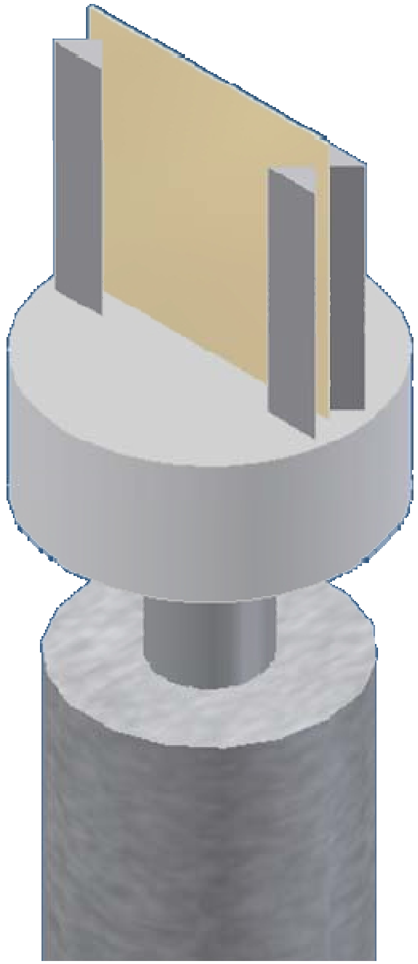
Test location



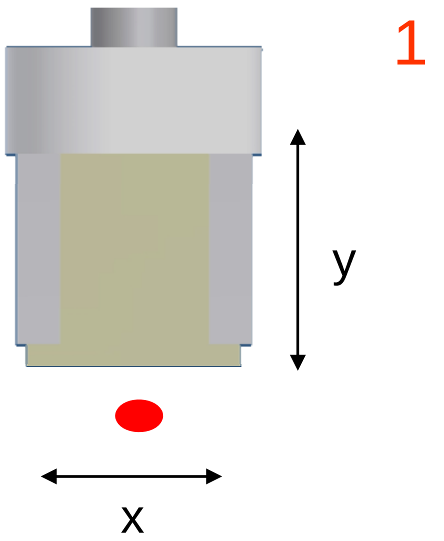
Sample Target

- we would like to use a 100µm thick Ti-6Al-4V sample.
- the sample will probably be held between knife edge grips, similar to those illustrated.
- we could leave the top of the sample free from the grips.



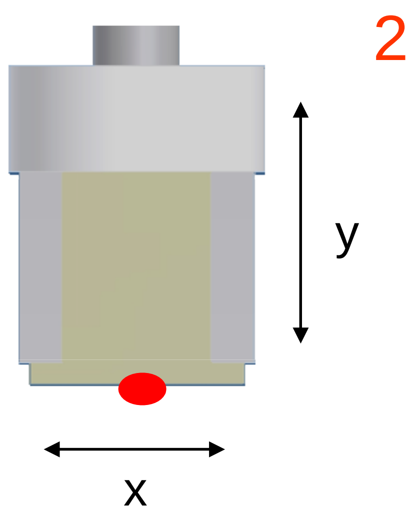


Reference Location



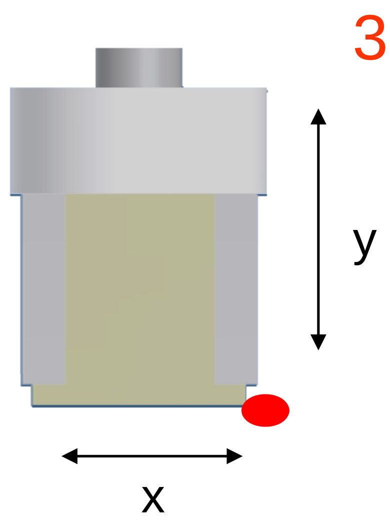
Beam does not touch sample.

No signal from detector



Move sample in Y until beam is in contact.

Signal from detector.



Move sample in X until beam is no longer in contact.

No Signal from detector

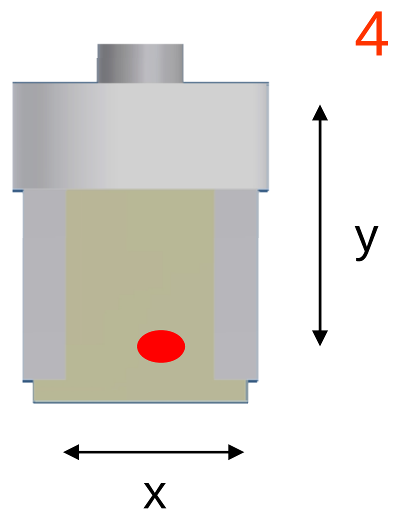
Beam operation

- Once the reference edge has been found we will use the VG manipulator to step the sample a known distance in X and Y.

•We will then increase the charge and try to damage the sample.

•Then we will move the sample to a new location and try to damage with a different charge.

•We will continue to do this until we have performed all the planned tests.



Move sample in X & Y until sample is in required location. Increase charge to damage sample.

Fluka Predictions

- after testing, we intend to measure the are of damage of each impact with a Scanning Electron Microscope

- we will know the location of each damaged region because know the distance from the reference edge.

- this will help validate our predictions on beam damage.

Bunch $\sigma_x \times \sigma_y$ (μm^2), material	**Estimated damage region, x**	**Estimated damage region, y**	**Estimated damage region, z**
1.9×0.5, Ti alloy	11 (14) μm	4 (5.6) μm	5 (8) mm
20×2, Ti alloy	45 (90) μm	5 (9) μm	2 (7) mm

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SWMD Summary

• Wake field simulations and ESA measured kicks agree for some measurements within 10%.
• Possibility of next run at ESA – depends upon funding situation
• Simulations and first beam damage studies will be done in February'08 at ATF.
• First draft mechanical engineering design of the spoilers is made and will be presented at EPAC'08. The details and optimisation of this design will depend upon available engineering resources within STFC.