Studies at SLAC's ESA of the transverse kicks due to collimator wakefields

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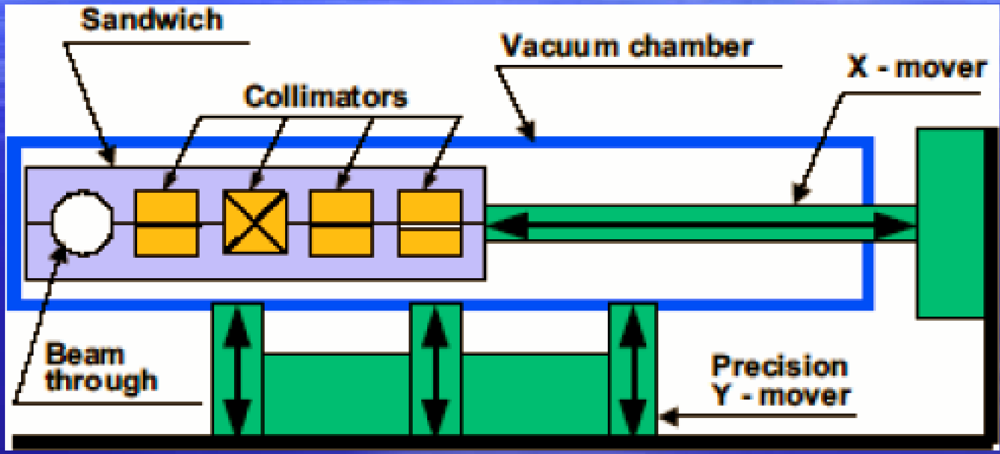
IRENG07, SLAC, 18th Sept, 2007

Motivation for Measurement

- Collimators near ILC IR will cause wakefields
  - Amplify incoming jitter.
  - Dilute emittance.
  - Reduce luminosity.
- Previous studies have shown the complexity of analytical calculations, even in simple cases.
- Goal is to measure the transverse kick for a range of collimator specs, and compare with simulations.
  - Try to improve agreement to ~10%.

Experimental Setup

Beam Energy	28.5 GeV
Charge	~1.5e10
Bunch Length	0.3 – 1 mm
x Size	~1 mm
y Size	~100 um



- Collimators placed in wakefield 'sandwich'.
  - Five slots, allowing four collimators plus extra slot for uninterrupted beam operation.
- Collimator to be tested inserted using X-mover.
- FFTB magnet controllers allow control in y, z, and dy/dz.
  - Readbacks give micron-level position information.

Experimental Setup

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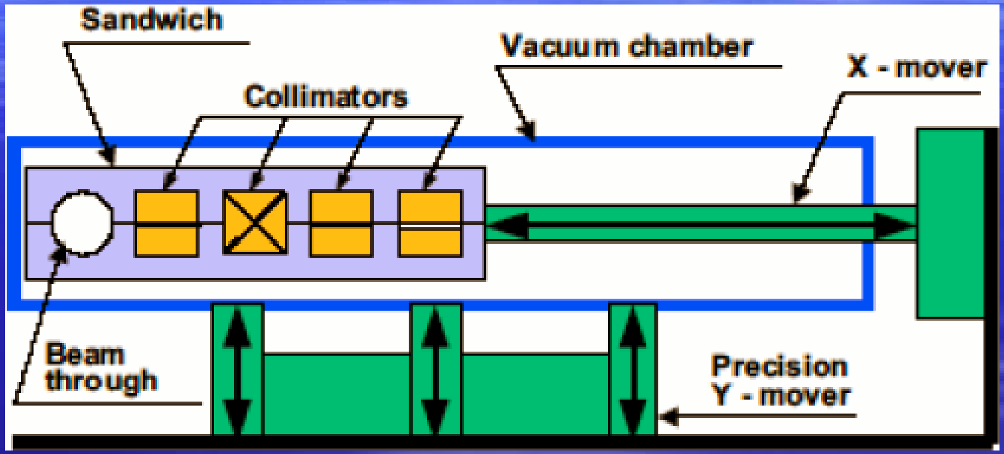
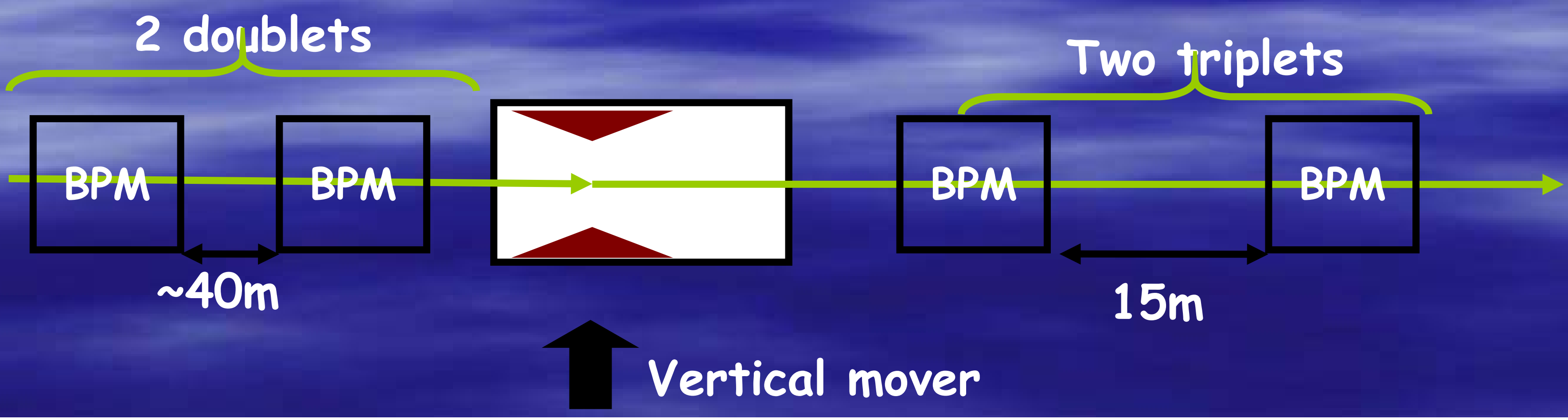
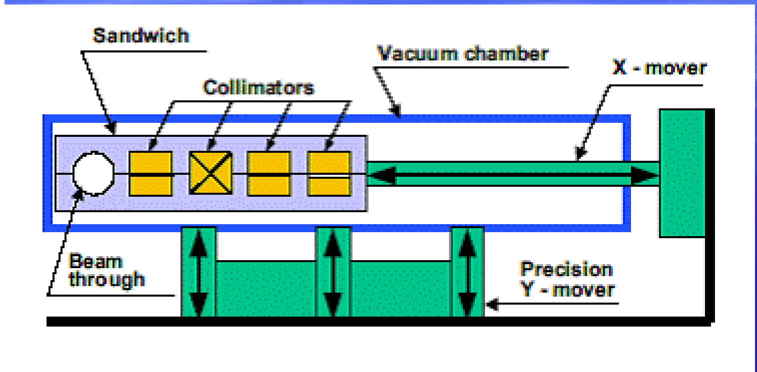
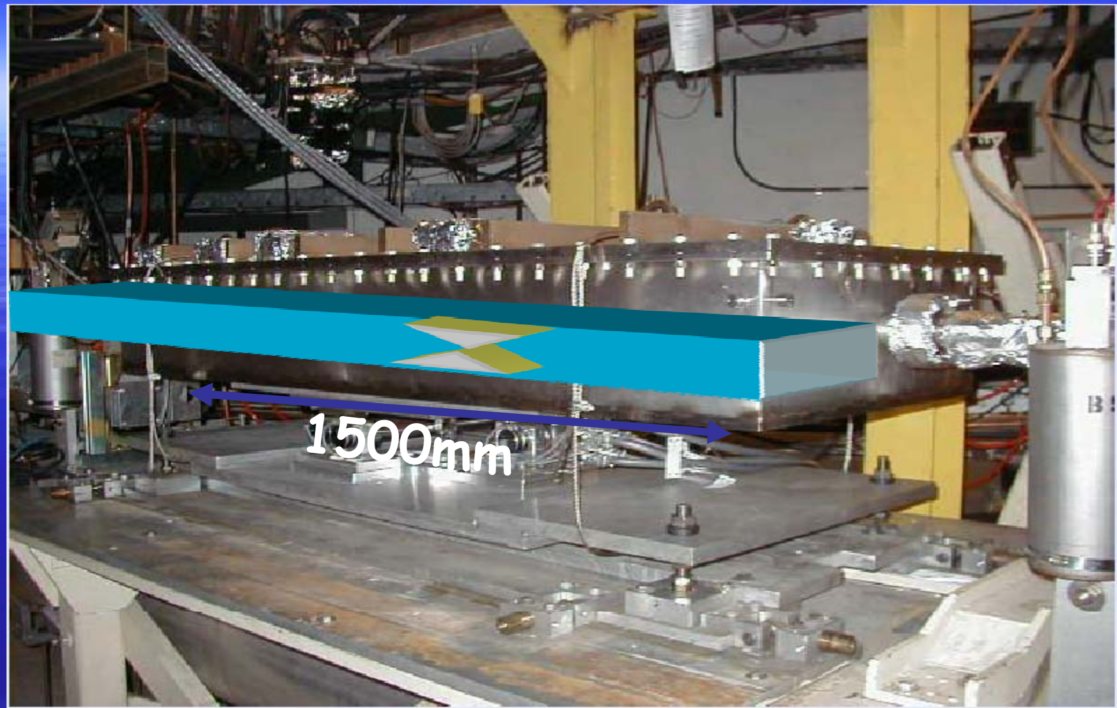


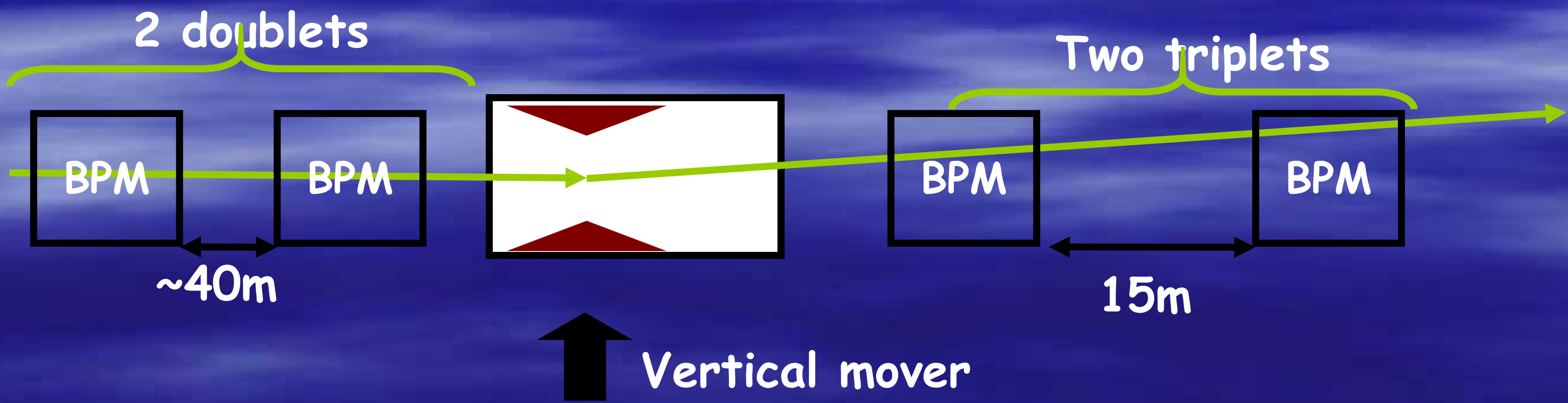
Concept of Experiment



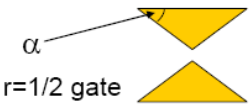
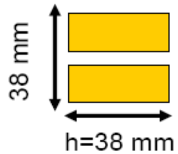
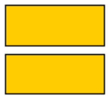
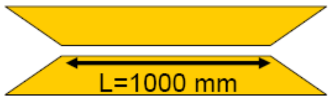
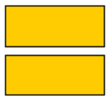
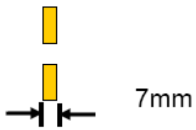
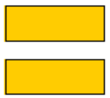


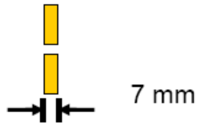
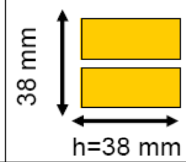
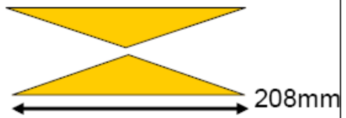
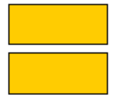
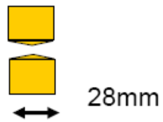
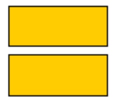
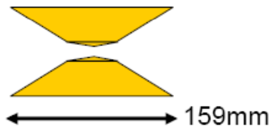
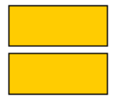


Concept of Experiment



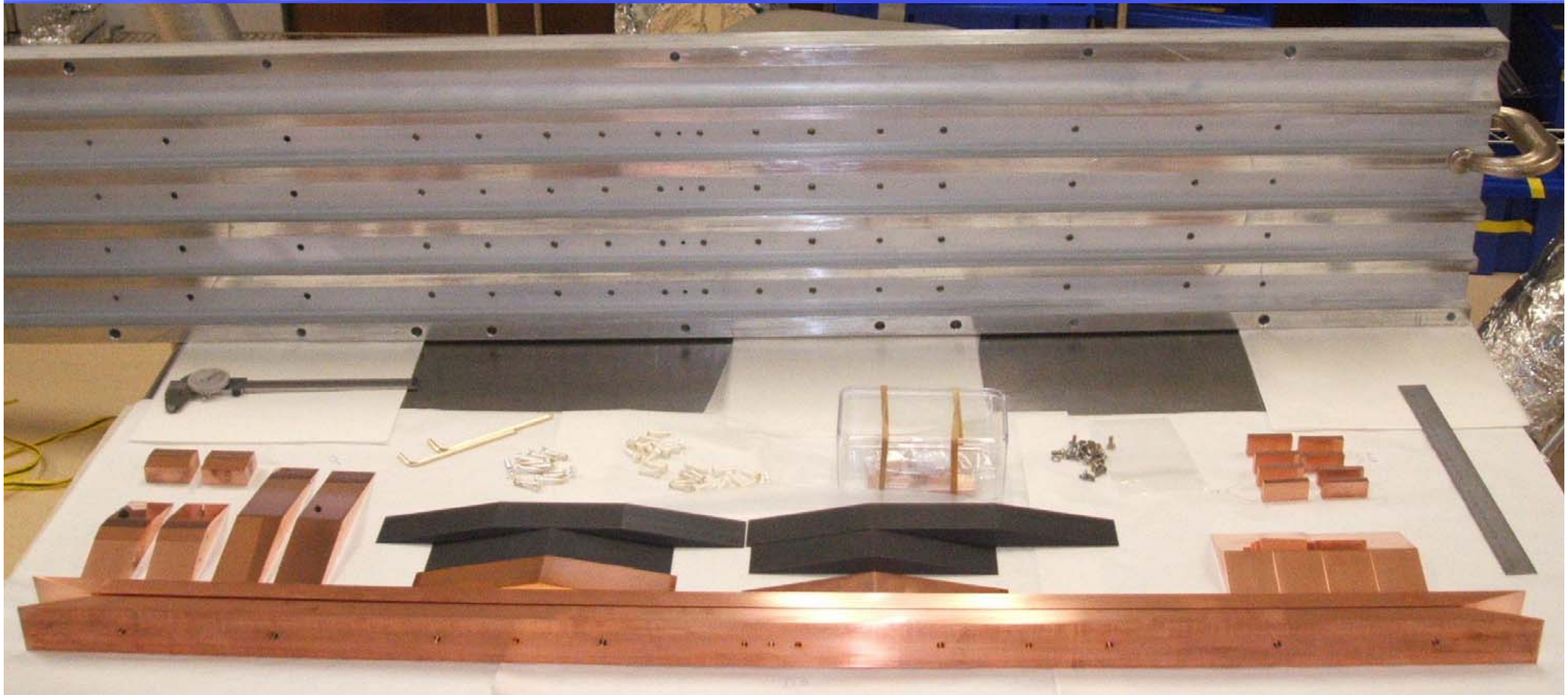
Collimators (Run 1)

Slot	Side view	Beam view	
1			α=335mrad r=1.9mm
2			α=335mrad r=1.4mm
3			α=335mrad r=1.4mm
4			α=π/2rad r=3.8mm

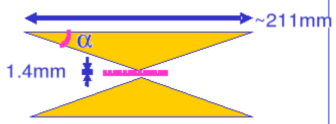
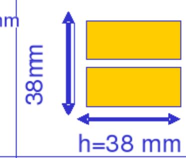
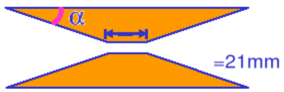
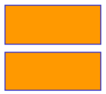
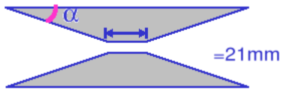
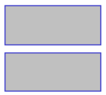
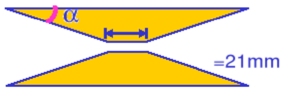
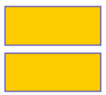
Slot	Side view	Beam view	
5			α=π/2rad r=1.4mm
6			α=168mrad r=1.4mm
7			α_1=π/2 rad α_2=168mrad r_1=3.8mm r_2=1.4mm
8			α_1=298mrad α_2=168mrad r_1 =3.8mm r_2 =1.4mm

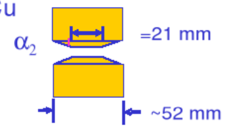
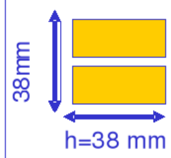
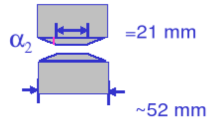
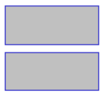
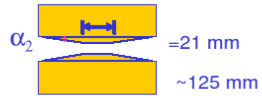
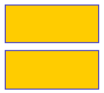
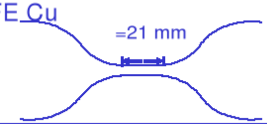
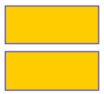
- Collimator #1 is identical to one from a previous test.
- Analytical prediction for #7 and #8 is identical, but 3D simulation hints at differences.
- #3 will have a much larger resistive component than the others.
- This set explores a wide range of taper angles.

Collimators (Run 1)



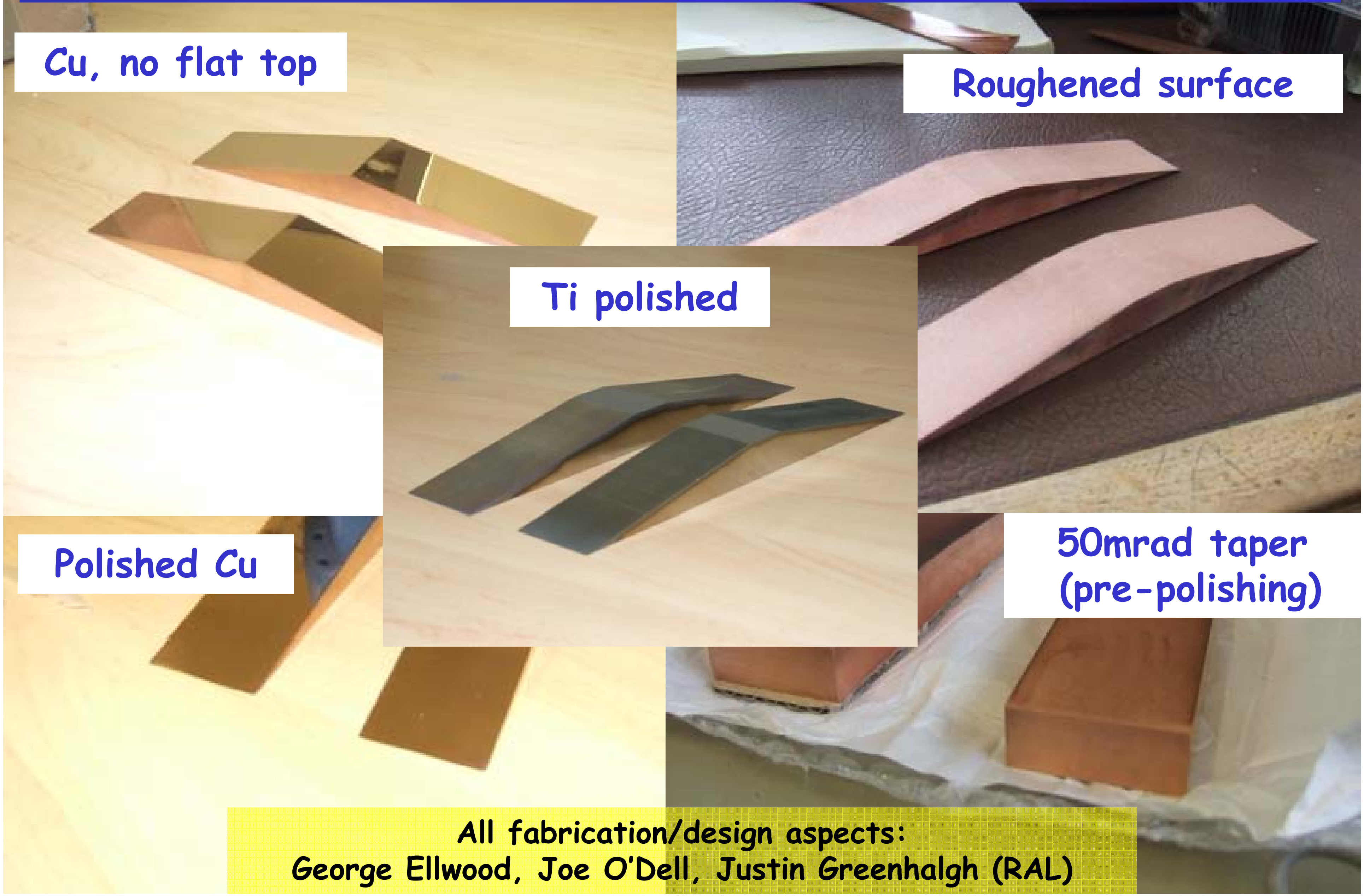
Collimators (Run 2)

Collim.#	Side view	Beam view	Revised 27-Nov-2006
6	 ~211mm α 1.4mm	 38mm h=38 mm	α=166mrad r=1.4mm (1/2 gap)
10	 α =21mm		α=166mrad r =1.4mm
11	 α =21mm		α=166mrad r =1.4mm
12	 α =21mm		α=166mrad r=1.4mm

Collim.#	Side view	Beam view	Revised 27-Nov-2006
13	OFE Cu  α_2 =21 mm ~52 mm	 38mm h=38 mm	$\alpha_1=\pi/2$ rad α_2=166mrad r_1=4.0mm r_2=1.4mm
14	Ti6Al4V  α_2 =21 mm ~52 mm		$\alpha_1=\pi/2$ rad α_2=166mrad r_1=4.0mm r_2=1.4mm
15	 α_2 =21 mm ~125 mm		$\alpha_1=\pi/2$ rad α_2=50mrad r_1=4.0mm r_2=1.4mm
16	OFE Cu  =21 mm		non-linear taper r=1.4mm

- Collimator #6 identical to #6 from Run 1.
- This set investigates the effect of material and surface finish on the kick.
- #16 tested a smooth impedance change.

Collimators (Run 2)



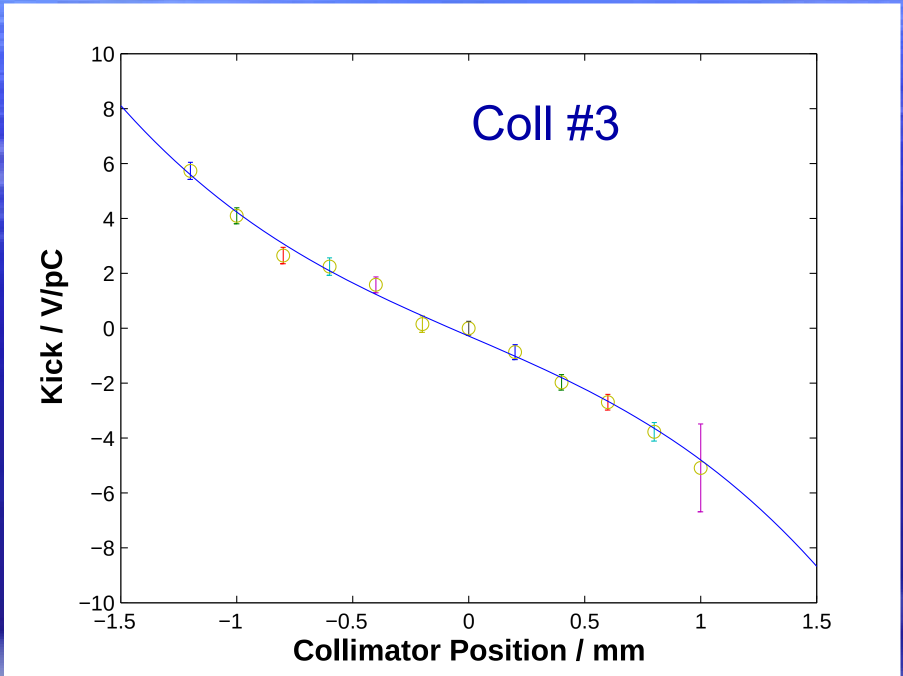
All fabrication/design aspects:
George Ellwood, Joe O'Dell, Justin Greenhalgh (RAL)

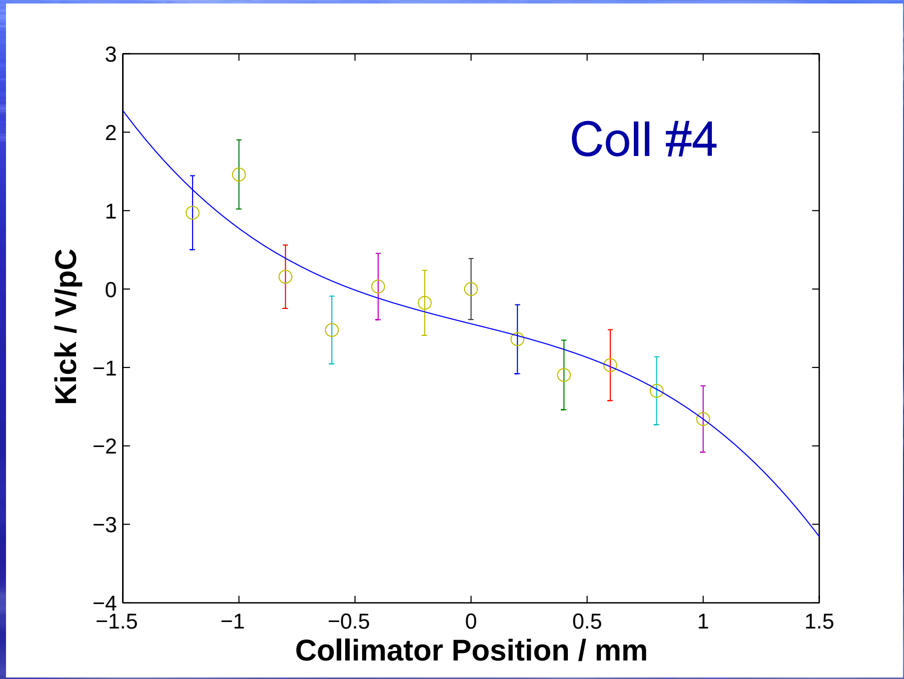
Collimators (Run 2)

Collimator 16

Nigel Watson / Birmingham

Data Analysis





- Kick should be odd function.
- Fit data to 3rd-order polynomial, with quadratic term set to zero.
- Kick factor is the linear term.

Analytical Prediction

Geometric wake

$$\alpha = \theta_T b_1 / \sigma_Z$$

For tapered collimators, the prediction depends on the “regime”.
- α << 1 – *inductive regime*
- α >> 1 – *diffractive regime*

Typical values in our experiment

$$\theta_T = 324, 289, 166, 50\,\mathrm{mrad}$$

$$b_1 = 4.0, 1.4\,\mathrm{mm}$$

$$\sigma_Z = 1.0 - 0.3\,\mathrm{mm}$$

α = 1 – 30 – Collimators are in the intermediate or diffractive regimes.

$$\kappa = \frac{1}{4\pi\varepsilon_0 b_1^2}$$

$$\kappa = 1.35 \frac{1}{4\pi\varepsilon_0} \frac{\sqrt{\alpha}}{b_1^2}$$

Resistive wake

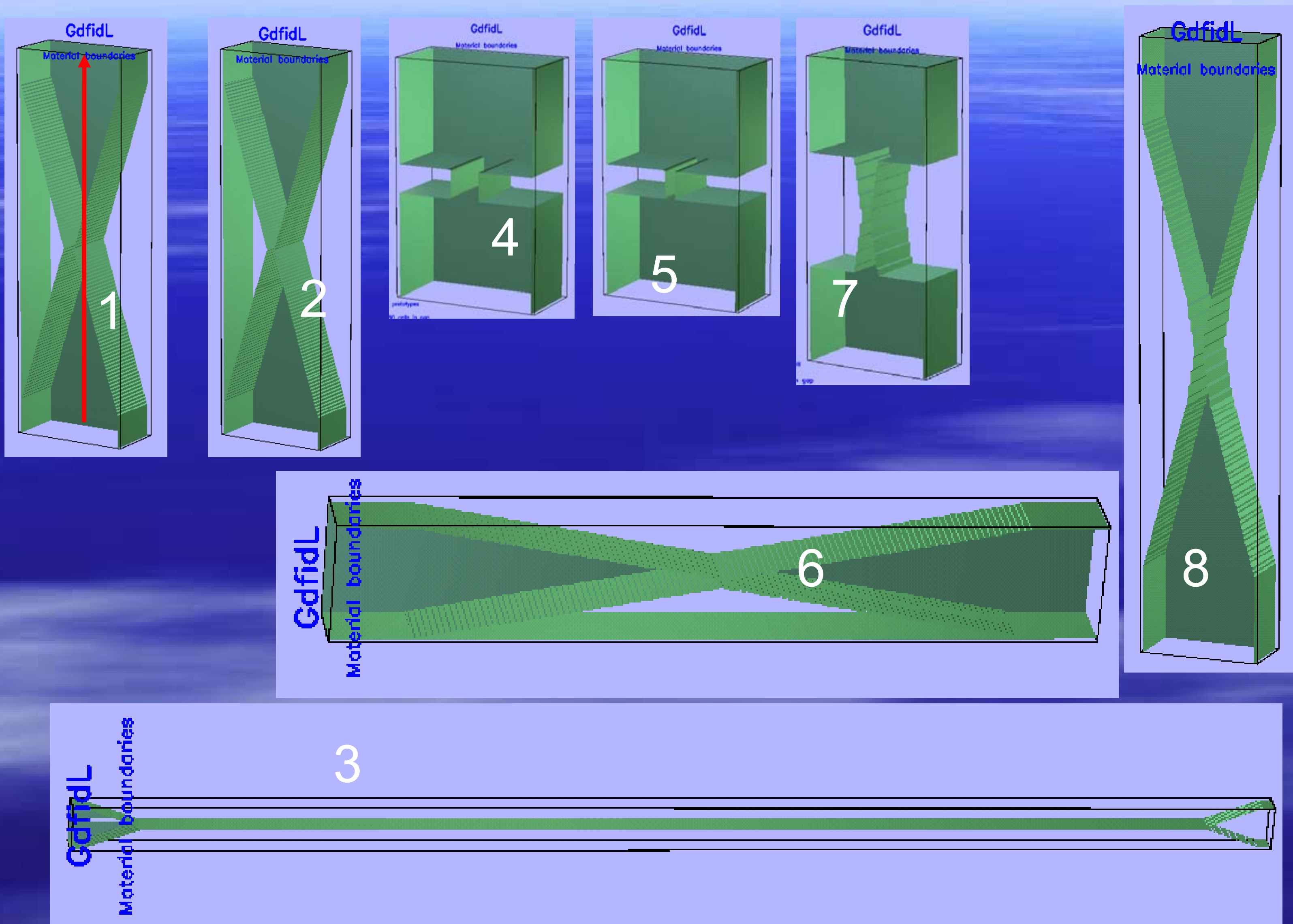
Flat collimator

$$\kappa = F_G \frac{\sqrt{2}}{\pi} \frac{r_e m_e c^2}{e^2} \frac{L}{r^3} \sqrt{\frac{1}{Z_0 \sigma \sigma_z}},$$

Tapered collimator

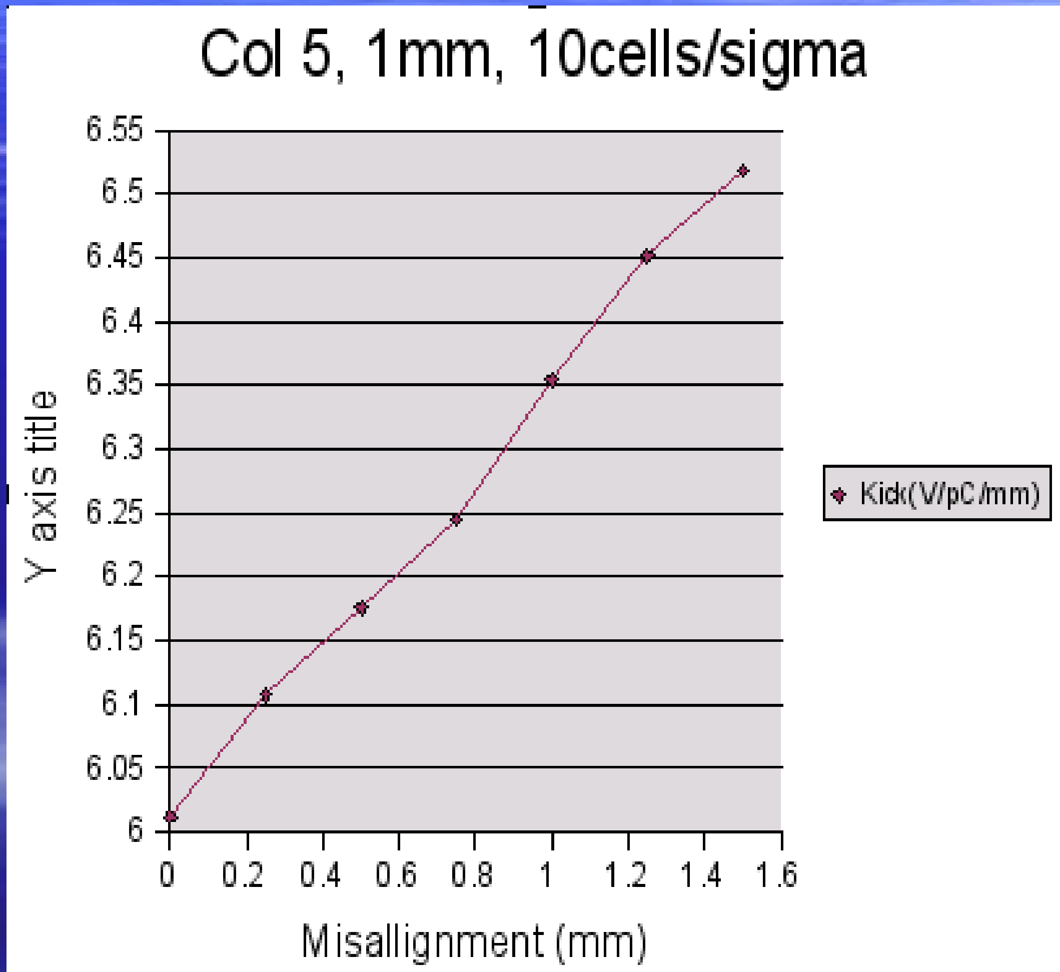
$$\kappa = F_G \frac{\sqrt{2}}{\pi} \frac{r_e m_e c^2}{e^2} \frac{1}{r_1^2 \tan\alpha} \sqrt{\frac{1}{Z_0 \sigma \sigma_z}}$$

EM Simulations with GdfidL

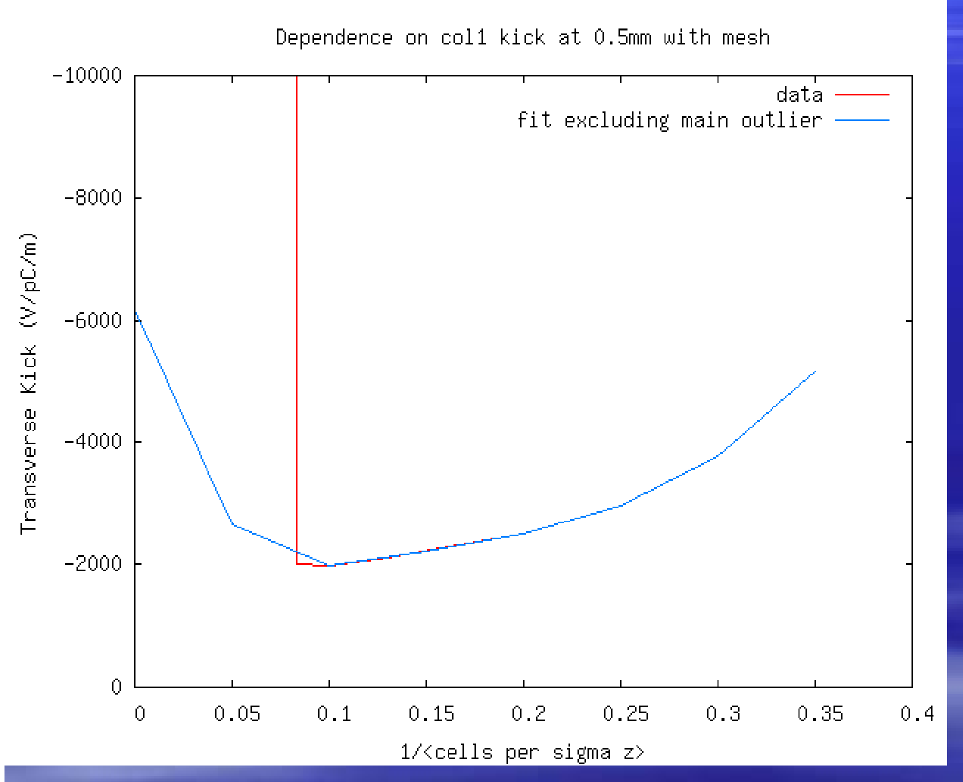


Jonathan Smith, Lancaster

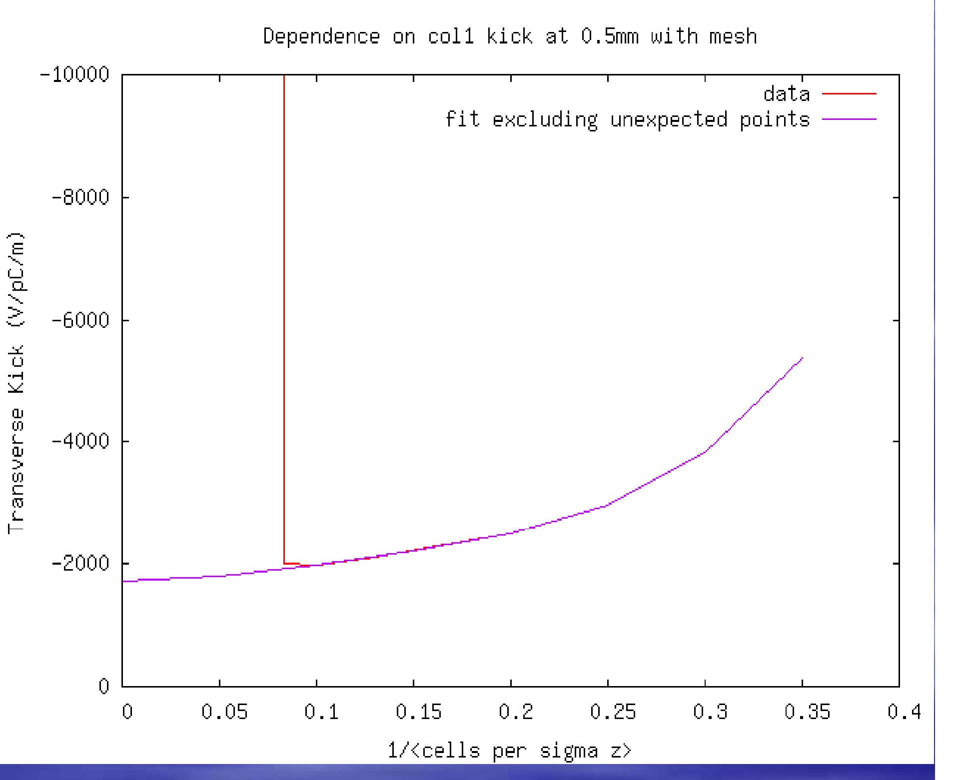
Misalignment of spoiler jaws



Problem…



Dependence on col1 kick at 0.5mm with mesh
-10000
-8000
-6000
-4000
-2000
0
Transverse Kick (V/pC/m)
data
fit excluding main outlier
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
1/<cells per sigma z>



Dependence on col1 kick at 0.5mm with mesh
-10000
-8000
-6000
-4000
-2000
0
Transverse Kick (V/pC/m)
data
fit excluding unexpected points
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
1/<cells per sigma z>

Results

Predictions made for 0.5 mm bunch length.

3D modelling does **not** include resistive effects.

Coll.	Measured Kick Factor / V/pC/mm (Linear Fit)	Measured Kick Factor / V/pC/mm (Linear & Cubic Fit)	Analytic Prediction Kick Factor V/pC/mm	3-D Modeling Prediction Kick Factor V/pC/mm
1	1.4 ± 0.1 (1.0)	1.2 ± 0.3 (1.0)	2.27	1.63 ± 0.37
2	1.4 ± 0.1 (1.3)	1.2 ± 0.3 (1.4)	4.63	2.88 ± 0.84
3	4.4 ± 0.1 (1.5)	3.7 ± 0.3 (0.8)	5.25	5.81 ± 0.94
4	0.9 ± 0.2 (0.8)	0.5 ± 0.4 (0.8)	0.56	0.8
5	3.7 ± 0.1 (7.9)	4.9 ± 0.2 (2.6)	4.59	6.8
6	0.9 ± 0.1 (0.9)	0.9 ± 0.3 (1.0)	4.65	2.12 ± 1.14
7	1.7 ± 0.1 (0.7)	2.2 ± 0.3 (0.5)	4.59	2.87 ± 0.53
8	1.7 ± 0.3 (2.0)	1.7 ± 0.3 (2.2)	4.59	2.39 ± 0.89
13		4.1 ± 0.4 (0.8)		3.57 ± 0.98
14		2.6 ± 0.4 (1.0)		3.57 ± 0.98
15		2.0 ± 0.3 (1.8)		2.51 ± 1.16
16		1.3 ± 0.3 (1.0)		2.35 ± 1.50

- Good agreement with PT's previous measurement of #1.
- Analysis not yet complete on all collimators.
- Some anomalies,
  - Why do #1 and #2 have the same measured kick factor?
  - Why is the measurement for #14 lower than #13?

Further Work

- Determine maximum kick allowable in the different ILC parameter sets.
  - Include collimator wake kicks in BDS tracking studies.
  - Enhance analytical prediction to allow fast turnaround between new collimator suggestion and tracking studies.
- Determine reasons for disagreement between experiment and simulation.
  - Necessary to add resistive wake to simulations?