ILC Test Beam Workshop at Fermilab, Jan. 18, 2007

Collimators R&D

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Outline

- Introduction
- Collimator studies at SLAC End Station A
- Plans for further studies at End Station A
- LHC related studies and longer term plans
- Concluding remarks

Introduction

- Importance of collimator development for accelerator and detector physics (most importantly the vertex detector)
- Precise collimation of the beam halo to prevent beam losses near the Interaction Region that could cause unacceptable backgrounds. Tight apertures of the collimators cause wakefields that can result in beam deflections and increased emittance.
- Minimal beam disturbance and maximal detector protection
- Vertex detector design (e.g. innermost radius, occupancy due to background rate and required radiation tolerance.)
- Particular attention to wakefields induced by the collimators
- Optimization of collimators shape requires simulations and test beam studies.

SLAC 's End Station A Test Facility (ESA)

- **Collimator Wakefield Measurements T-480**
- **Collaborating Institutions:**

  Birmingham University, UK
  CCLRC – ASTeC, UK
  CCLRC – Engineering Department, UK
  CERN
  Manchester University, UK
  Lancaster University, UK
  DESY
  TEMF TU Darmstadt, Germany
  SLAC
- Two sets of collimator wakefield measurements have been performed at the SLAC ESA facility in 2006.

Living the "I" of the ILC — It's Happening Right Here at SLAC

It's a small pre-enactment of things to come when the International Linear Collider (ILC) is built: an international collaboration spending all hours of the day and night in the control room and the experimental hall, working with an high-energy beam with bunches each comprised of 20 billion electrons and of length roughly equal to ten times the diameter of a human hair (namely about 300 microns). Forty physicists from 15 institutions are participating in a two-week run, completing today, for ILC beam tests at the End Station A facility here at SLAC. The physicists are testing prototypes that are needed for the ILC machine to measure and help maintain the high quality of beams of electrons and positrons just before they collide with each other in the interaction region of the ILC. The collaborators come from England, the U.S., Germany and Japan and they are represented just as strongly by university researchers as by laboratory researchers.

To make these tests realistic and useful, the researchers need a beam which has the challenging bunch parameters needed for the ILC. There is only one place in the world where that is possible: here at SLAC. The unique SLAC electron beam is transported faithfully to End Station A, where a mature user facility, ideally suited to efficient and effective testing, exists. Thus in the space of only two weeks, a large variety of experimental tests can be achieved.

One such experiment is testing the effectiveness of collimators. Collimators are metal jaws with a small gap which are placed in the path of the beam to shave off stray electrons that would otherwise cause unacceptable backgrounds in particle detectors. Eight sets of collimators of different shapes and materials are being tested to understand what they do to the core of the electron beam. These devices are critical for acceptable operation at the ILC; however, if improperly designed and implemented, the collimators can have deleterious consequences on the key parameters of the beam, and thereby on the required performance of the ILC.

A second experiment is testing a prototype ILC energy spectrometer. Two such spectrometers are needed to measure the energies separately of the electron and positron beams at the very challenging precision of one part per ten-thousand. The ILC will need such precision energy measurements to determine the exact mass of particles produced at the ILC, such as the long-sought Higgs.

Two other studies are for a) a prototype beam position monitor for the ILC Linac and b) diagnostics for measuring the bunch length. Both these developments also have applicability for LCLS. Instrumentation has also been installed in End Station A to characterize the frequency spectrum of electromagnetic "noise" in an interaction region environment and how it might depend on the key parameters of the bunch. Electromagnetic "noise" is inevitable at accelerators and it will interfere with the operations of electronics needed for the accelerator. By characterizing the noise as is being done in these experiments, one can design the electronics to be immune to the noise.

The ILC test beam program will run at End Station A facility for an additional two weeks this summer, running parasitically with the PEP- II and the BaBar physics program.

SLAC has unique, one-of-a-kind facilities and an enormously talented staff that together provide fertile opportunities for testing advanced accelerator concepts and prototype hardware. We are most pleased to host our national and international colleagues to develop the next generation facilities for discovery and exploration.

—Jonathan Dorfan
SLAC Today, May 8, 2006

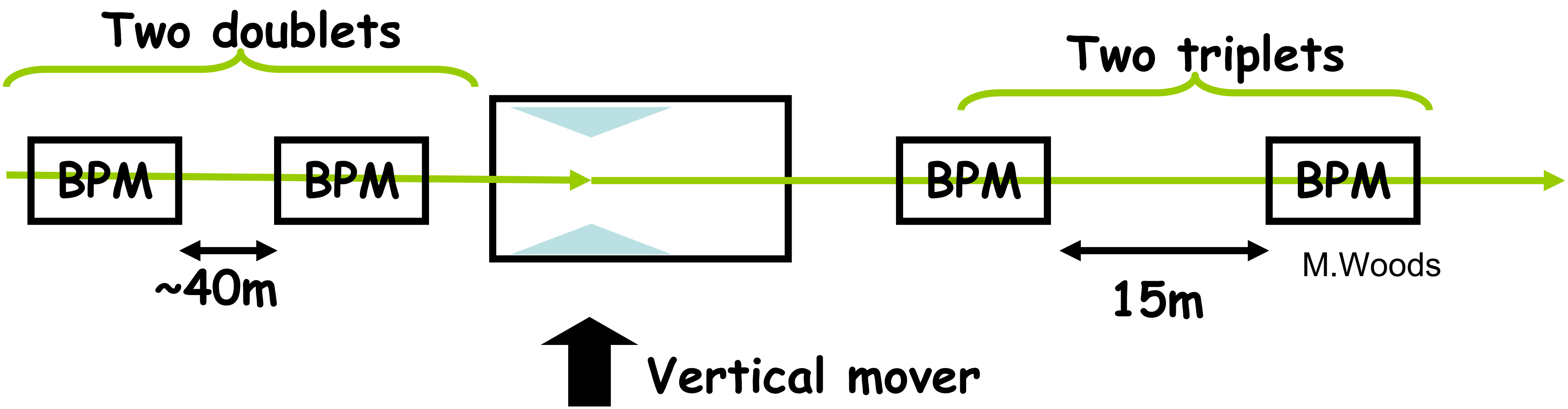
Collimators for Study at ESA in 2006

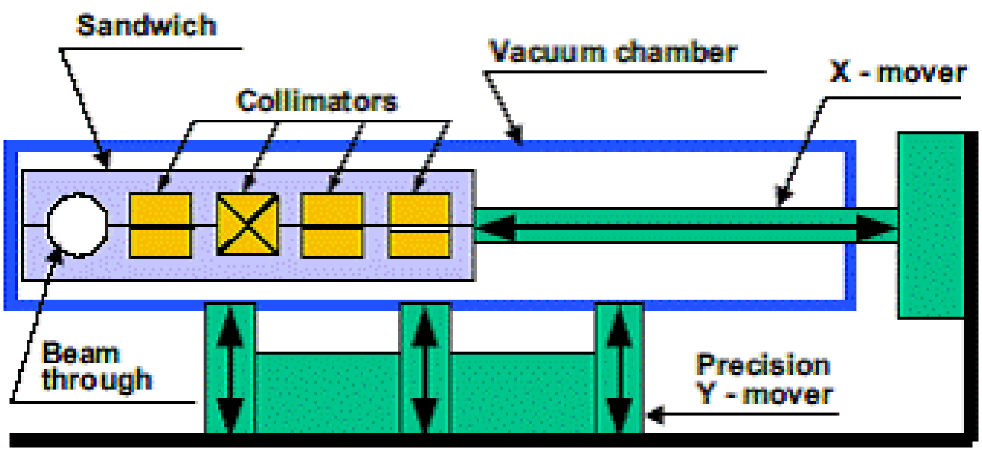
8 collimator shapes produced in UK, shipped to SLAC.

Collim. # (slot #)	Side view ("sandwich 1")	Beam view	
1 (1)	α r = ½ gap 102.1mm	38.10 mm h=38.05 mm	α=324mrad r=2.0mm
2 (2)	e⁻ beam 105.6mm		α=324mrad r=1.4mm
3 (3)	L=1000 mm		α=324mrad r=1.4mm
4 (4)	7mm		α=π/2rad r=4.0mm

Collim. # (slot #)	Side view ("sandwich 2")	Beam view	
8 (1)	α_1 r = ½ gap 132.5mm	38.10 mm h=38.05 mm	r_1 =4.0mm r_2 =1.4mm α_1=289mrad α_2=166mrad
7 (2)	31.3mm		α_1=π/2 rad α_2=166mrad r_1=4.0mm r_2=1.4mm
6 (3)	211.0mm		α=166mrad r=1.4mm
5 (4)	7 mm		α=π/2rad r=1.4mm

Schematic View of Experiment

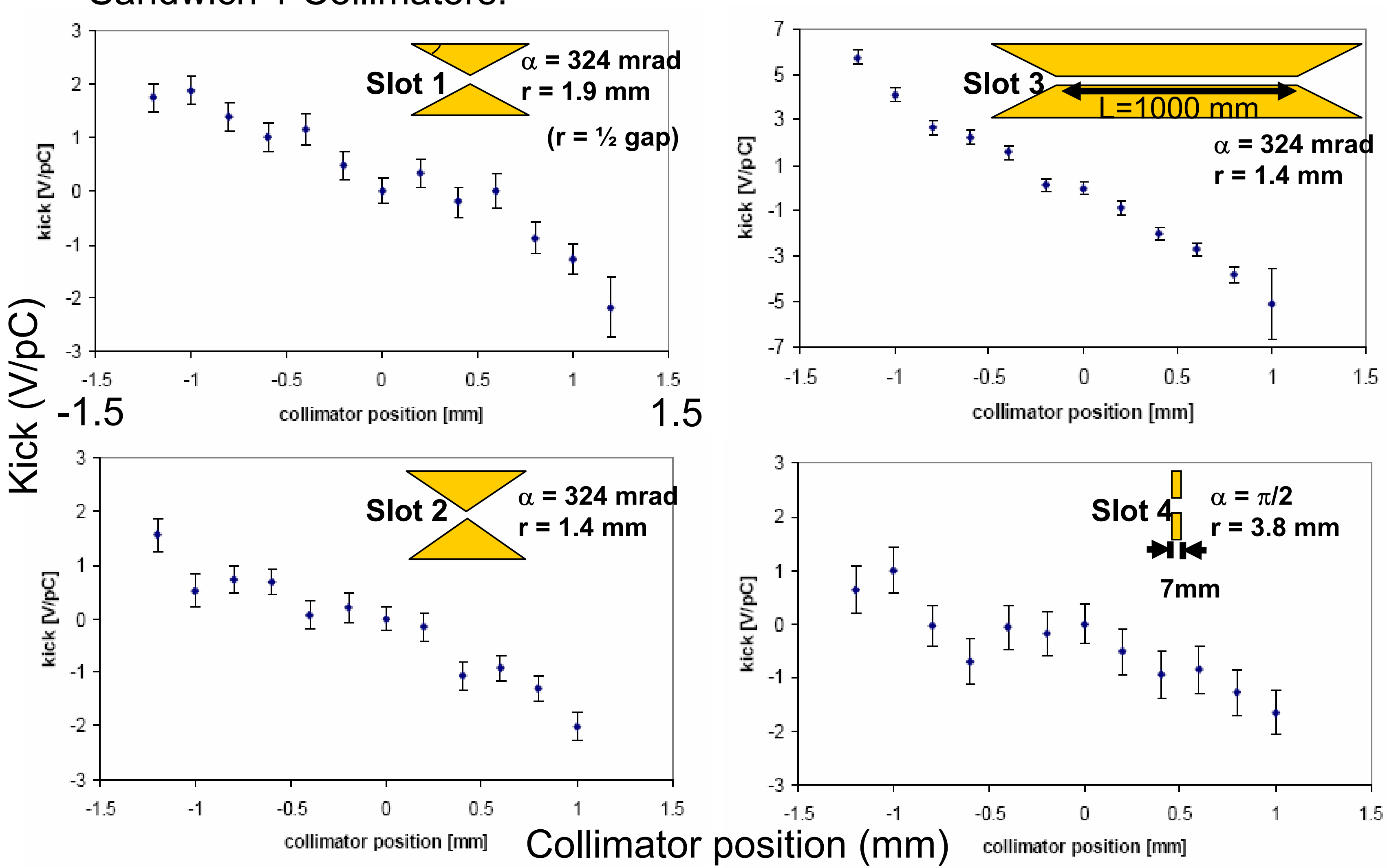




Preliminary Results from ESA'06

M. Woods, SLAC EPAC Meeting, Dec. 2006
Luis Fernando-Hernandes

Sandwich 1 Collimators:



Towards a Comparison of Simulation and Measurements

preliminary:

Collimator	**Measured Kick Factor** V/pc/mm (χ^2/dof) **Linear fit**	**Measured Kick Factor** V/pc/mm (χ^2/dof) **Linear + Cubic Fit**	**Analytic Prediction**[1] **Kick Factor** V/pc/mm	**3-D Modelling Prediction**[1] **Kick Factor** V/pc/mm
1	1.4 ± 0.1 (1.0)	1.2 ± 0.3 (1.0)	1.1	1.7
2	1.4 ± 0.1 (1.3)	1.2 ± 0.3 (1.4)	2.3	3.1
3	4.4 ± 0.1 (1.5)	3.7 ± 0.3 (0.8)	6.6	7.1
4	0.9 ± 0.2 (0.8)	0.5 ± 0.4 (0.8)	0.3	0.8
5	1.7 ± 0.3 (2.0)	1.7 ± 0.3 (2.2)	2.3	6.8
6	1.7 ± 0.1 (0.7)	2.2 ± 0.3 (0.5)	2.4	2.4
7	0.9 ± 0.1 (0.9)	0.9 ± 0.3 (1.0)	2.3	2.7
8	3.7 ± 0.1 (7.9)	4.9 ± 0.2 (2.6)	2.3	2.4

[1]Assumes 500-micron bunch length

Analysis of ESA'06 measurements under way. Goal: determinations of kick factors with less than 10% uncertainty.

Future Measurements at ESA

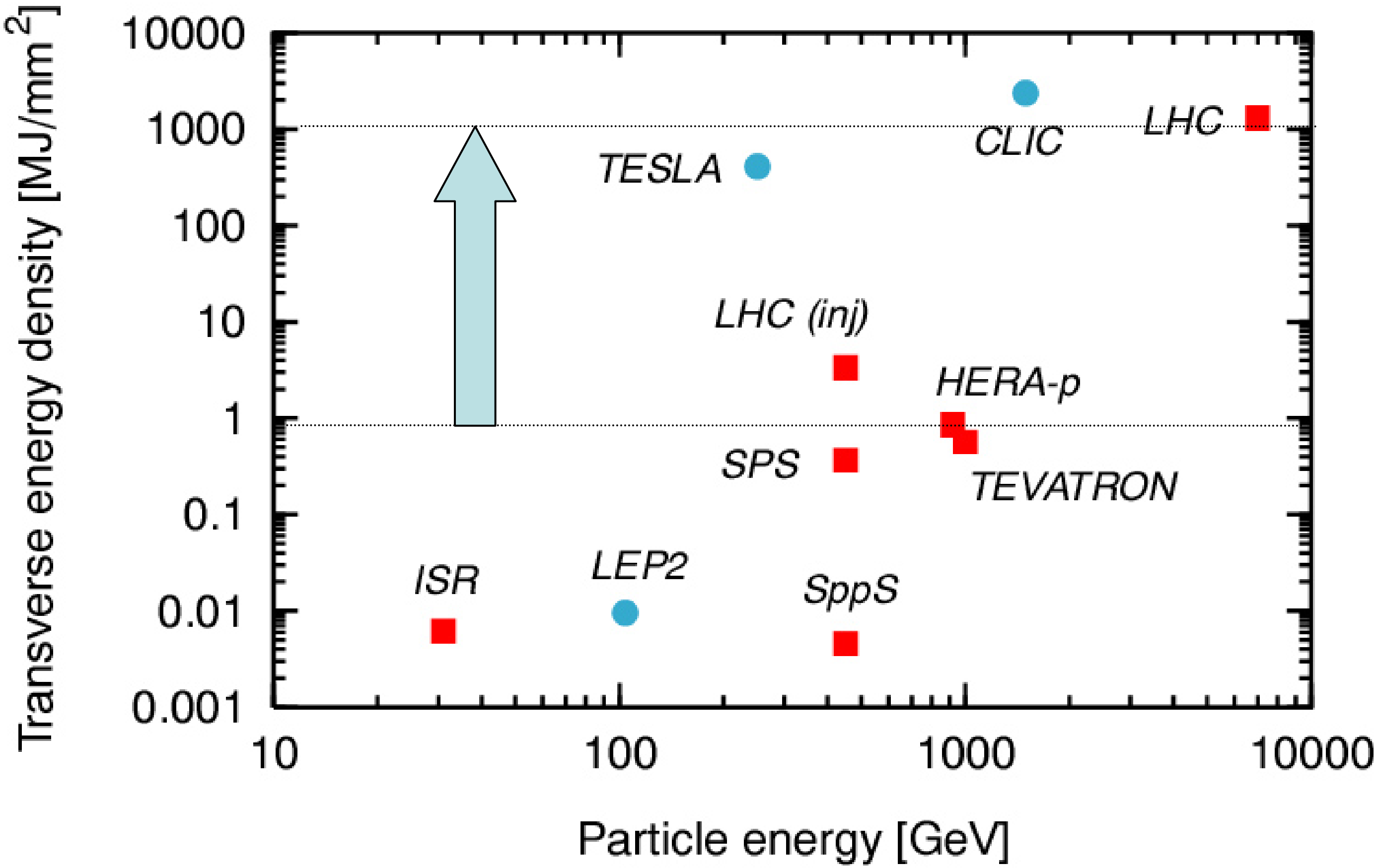
- Based on first results from 2006 ESA measurements a new set of collimators is being produced for 2007 measurements:

1. Shorter collimators
2. Surface roughness
3. Shallow tapers
4. Non-linear tapers (exponential)
5. One collimator identical with 2006 runs

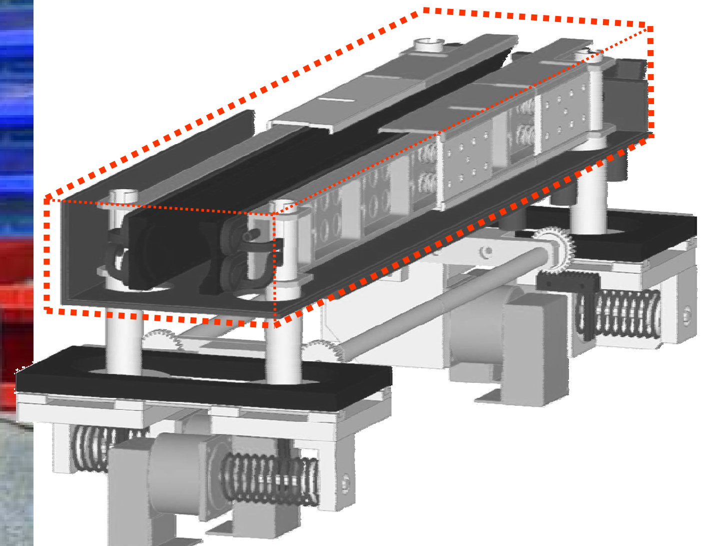
- In 2008 continuation of measurements at ESA expected.

LHC Collimator R&D (R. Assmann et al)

Test beam (2004 and 2006): SPS beam with LHC beam structure (7μs pulse). Energy density 2MJ/mm^2 (≈ 0.5% of LHC beam). Survival of shock impact.



LHC Collimators



➔Up to 500 kW impacting on a jaw (7 kW absorbed in jaw)…

Advanced material: Fiber-reinforced graphite (CFC)

Some Future Collimator Activities

- LHC Phase II collimators. New test stand at CERN possible in 2008. Studies for larger luminosity. Collaboration with SLAC **(US LHC Accelerator Research Program (LARP)**
- EU Framework 7 projects discussions:

1. Phase II collimator development and material damage studies. High density protons. (proposal May 2007).
2. GADGET, **G**eneration **A**nd **D**iagnostics **G**ear for tiny **E**mi**T**tance. Ongoing discussions including ILC collimator wakefield studies. Design aspects: BPM resolution and locations. (proposal March 2008).

Concluding Remarks

- Test Beams are very important for the ILC project. For the collimators the influence on the beam (kick factors for beams off-axis) can be measured and compared to the simulations. Material studies are needed.
- For collimator design studies the numerical calculations are very complex due to the large collimator size compared to the small bunch size. Principle (e.m.) well understood.
- Collimator development is a challenging project which has important implications on the vertex detector design.
- Ongoing machine background studies include the interplay between accelerator and detector physics (beam disturbance and acceptable radiation rate at the vertex detector).
- Test Beams remain an important aspect in the future for the verification and tuning of the required simulations and material studies.