CTF3/CLIC Beam Loss Simulations

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Compact Linear Collider (CLIC)

- Proposed design for e^+/e^- linear collider based at CERN
- 3-5 TeV CM energy
- 10^{34}-10^{35} cm^{-2} s^{-1} max luminosity
- Two beam acceleration scheme
- 150 MV/m acceleration gradient

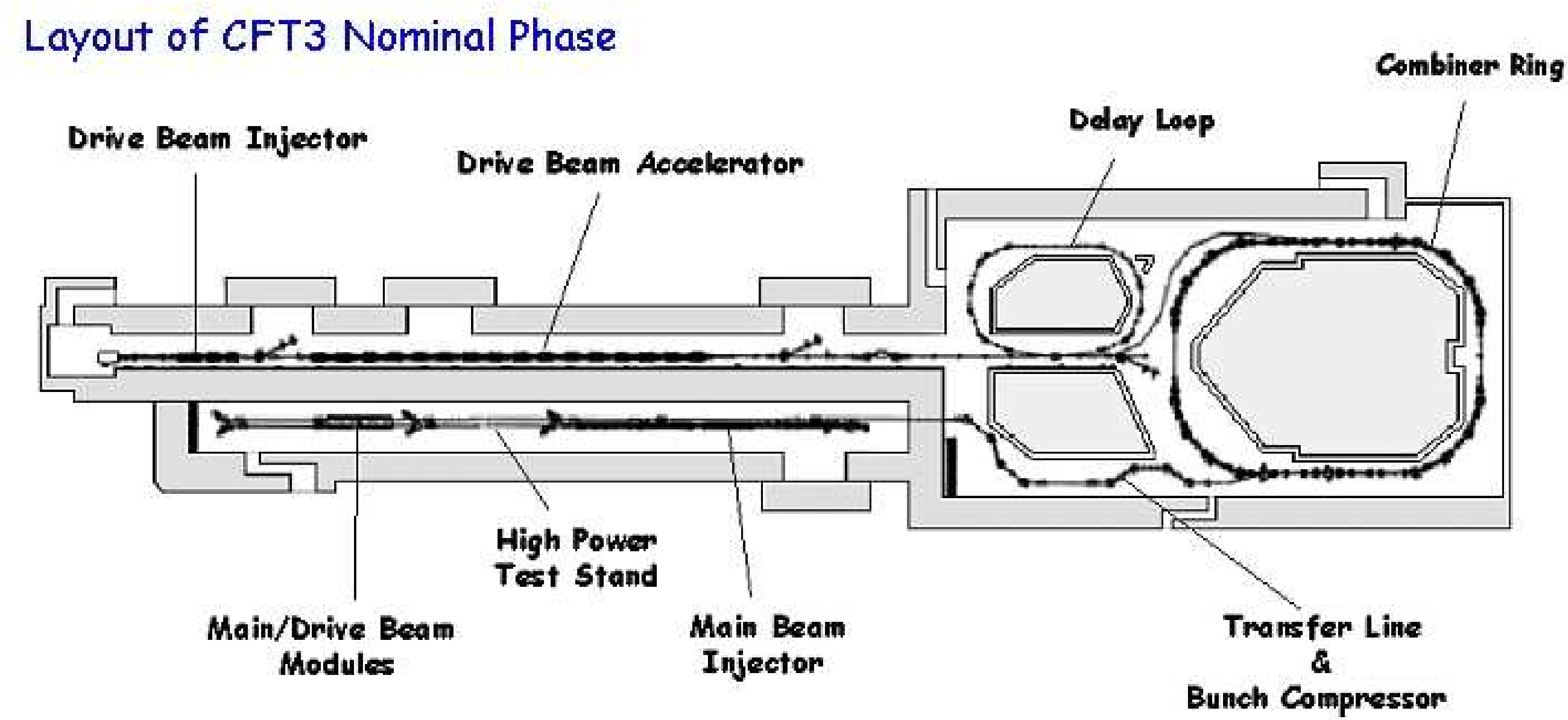
Third CLIC Test Facility (CTF3)

- Prototype facility that will demonstrate the essential technologies of CLIC
- Critical issues for CTF3:
  - Achieving a high current and high frequency drive beam
  - Stability of drive beam decelerator
  - Achieving 150 MV/m acceleration gradient

CTF3/CLIC Beam Loss Simulations

Current Status of CTF3

- Housed in the LEP Pre-injector complex (LPI) at CERN
- Drive Beam Accelerator currently under construction
- Scheduled completion in 2008

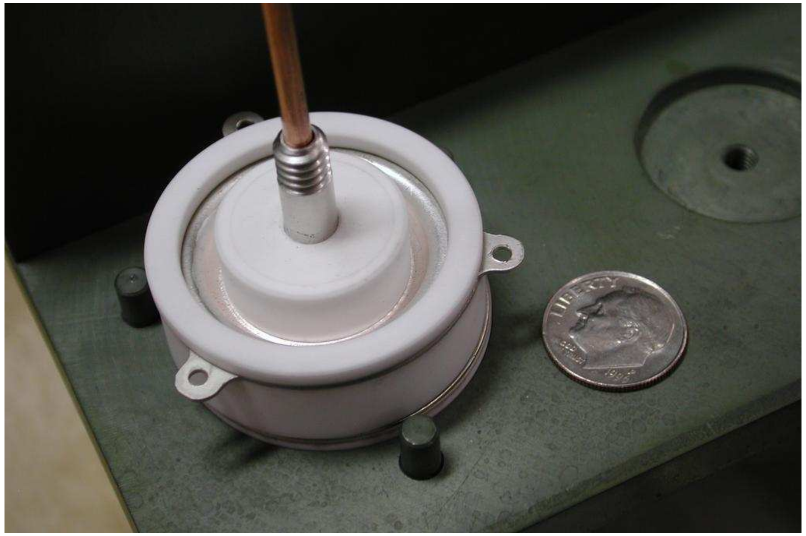


Development of a Beam Loss Detection System at CTF3/CLIC

- Northwestern University will design and build a beam loss detection system for CTF3 based on the detection of secondary particles
- First test in the drive beam accelerator of CTF3 during 2004/2005
- Motivation for Beam Loss Detection System:
  - Machine protection
  - Tuning of machine parameters
  - Detailed studies of beam halo and other beam loss mechanisms
- Beam losses also measured with wall current monitors (sensitive to % level) – sufficient for machine protection at CTF3 but beam loss detectors still useful for machine tuning
- A future CLIC accelerator will have much higher beam current and energy
  - Beam losses will need to be kept at a much lower level than CTF3 ($<$ ‰)
  - CLIC will need to rely more heavily on beam loss detectors for machine protection

Small Ionization Chamber (SIC)

- Detector chosen for the CTF3 beam loss detection system
- Developed at Northwestern University (Mayda Velasco and Anne Dabrowski) in conjunction with Fermilab (Gianni Tassotto) and Richardson Electronics
- SIC characteristics:
  - Radiation Hard
  - Can be operated with gas (ionization) or vacuum (secondary emission)
  - Large Dynamic Range (10^7-10^{13} $cm^{-2}s^{-1}$)
  - Effective detecting surface of 1 cm^2



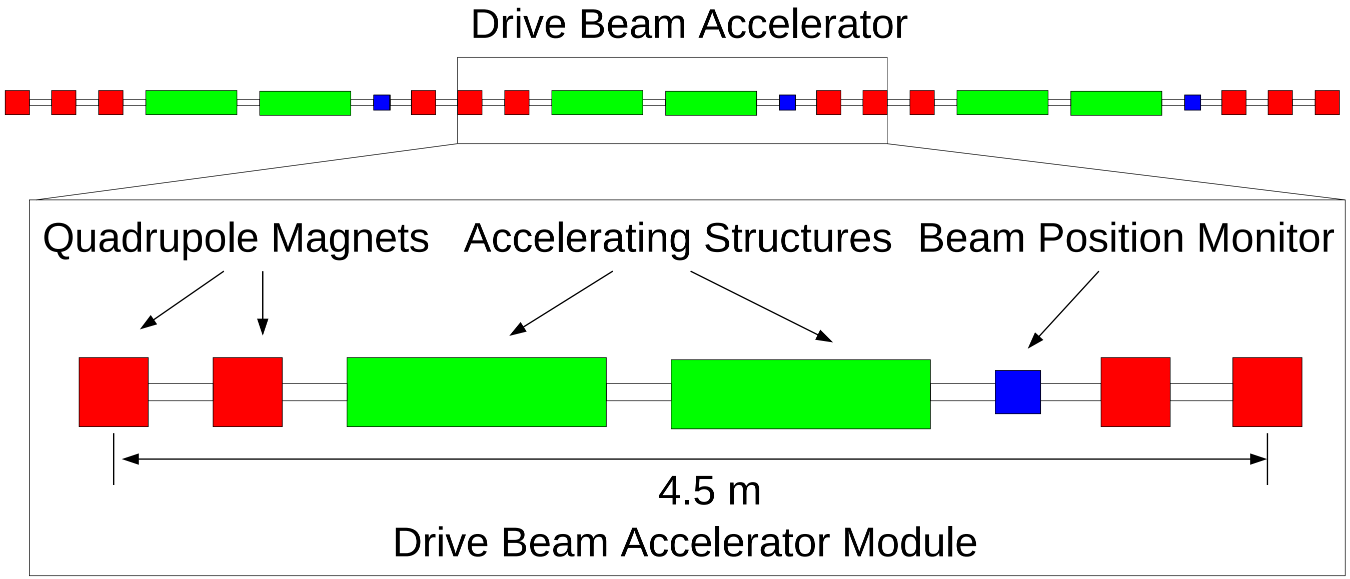
Beam Loss Simulations for CTF3/CLIC

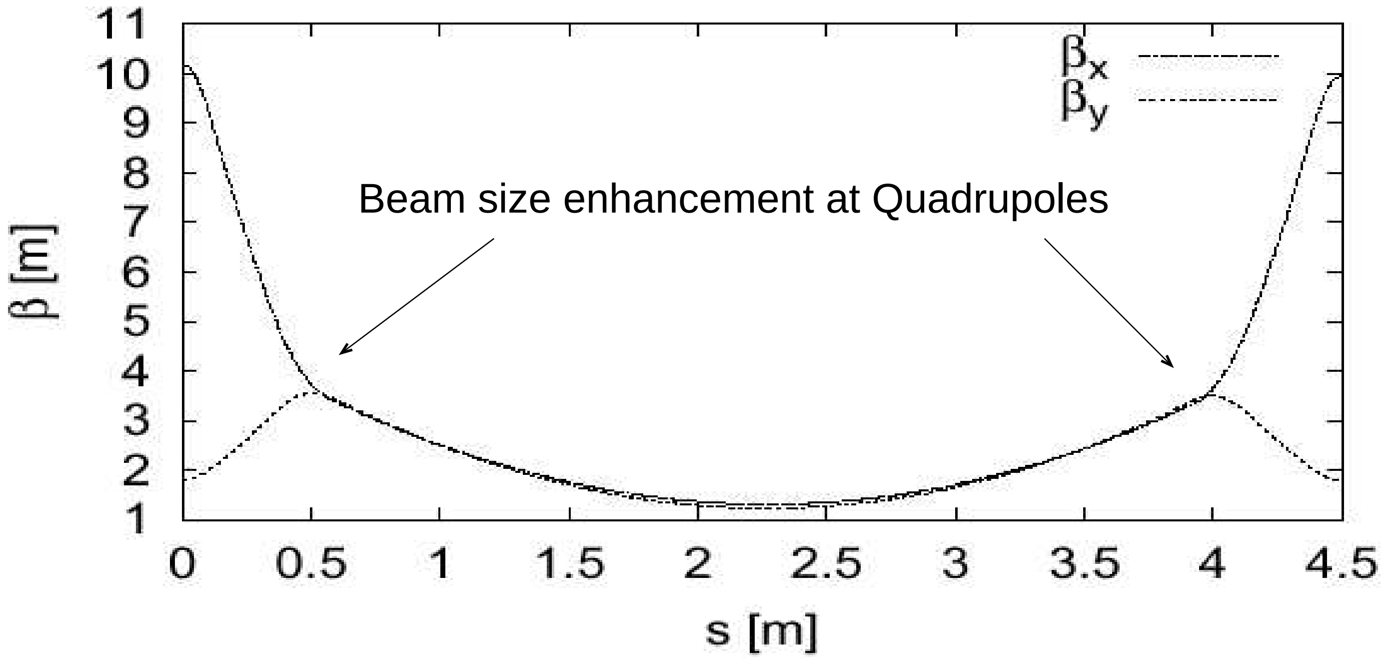
- GEANT 3.21 simulations will be used in the design of the beam loss detection system
- Simplifying Assumptions:
  - Beam loss occurs at a single position in the linac – $\phi = 90^o$ $\theta = 1 - 10$ mrad
  - No divergence in beam energy, angle, or position – should average out in secondary fluxes
  - Minimum energy cut on production of secondary particles – 100 keV
- General Observations:
  - Secondary fluxes fall off as 1/r^2 from the point of beam loss
  - Secondary fluxes scale linearly with beam energy
  - Secondaries are all electrons, positrons, or photons (small hadron component not represented in simulations)
  - Photon fluxes are $\sim$ 10 times greater than electron/positron fluxes
- Secondary fluxes normalized with respect to a beam loss of 1 mA

Drive Beam Accelerator Simulations

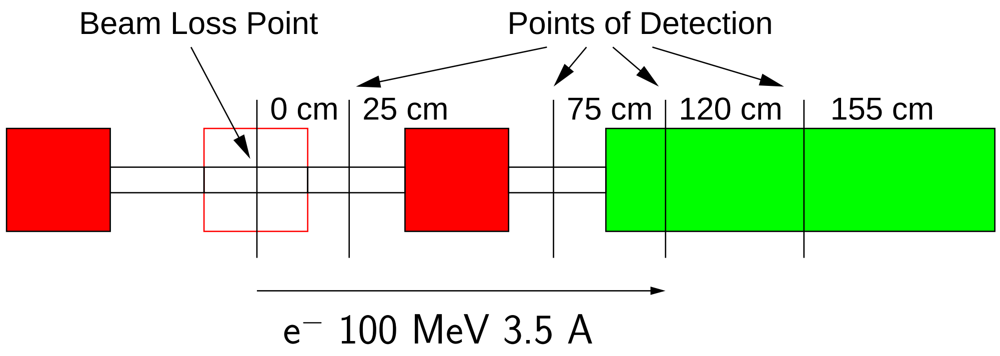
- Initial focus on simulations of the CTF3 Drive Beam Accelerator (DBA) where the beam loss detectors will first be installed
- DBA has a modular organization with each module containing:
  - 2 Accelerating Structures
  - 3 Quadrupole Magnets
  - 1 Beam Position Monitor
  - 1 Dipole Magnet (not represented in simulations)
- Some approximate parameters for the CTF3 Drive Beam Accelerator:
  - Initial Beam Energy: 20 MeV
  - Final Beam Energy: 150 MeV
  - Beam Current: 3.5 A
  - Pulse Length: 300 ns ($\sim$ 1.5 μs nominal)
  - Linac Module Length: 4.5 m

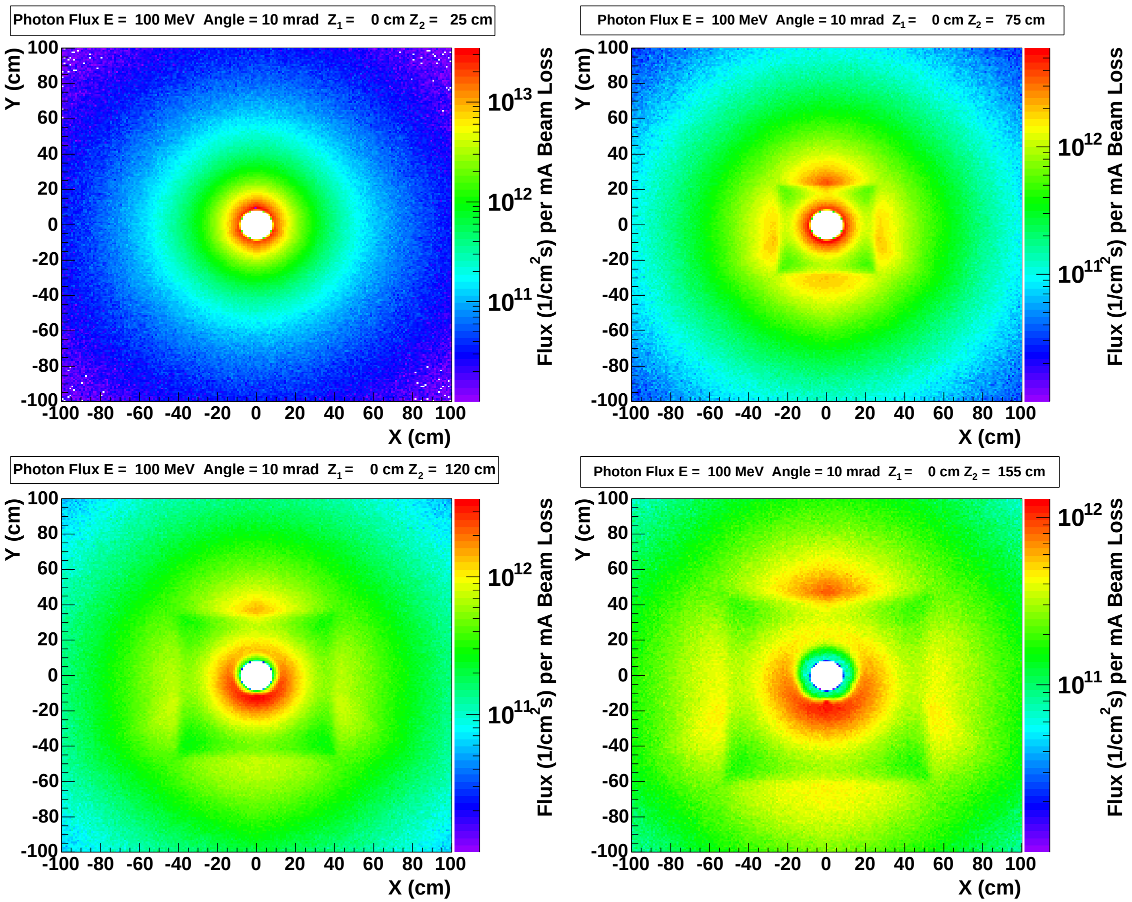
CTF3/CLIC Beam Loss Simulations





CTF3/CLIC Beam Loss Simulations



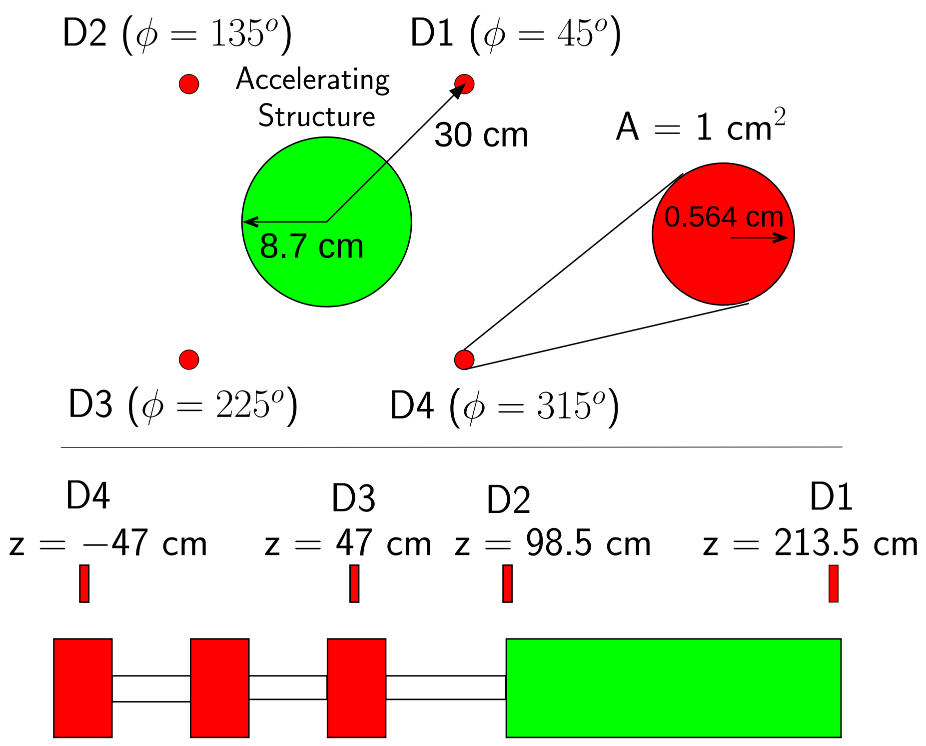


CTF3/CLIC Beam Loss Simulations

Hypothetical System for DBA

- One set of detectors per DBA module
- Detectors are 1 cm^2 (detecting surface of SIC)
- Detect only electrons (SEM-mode) or photons and electrons (ionization-mode)

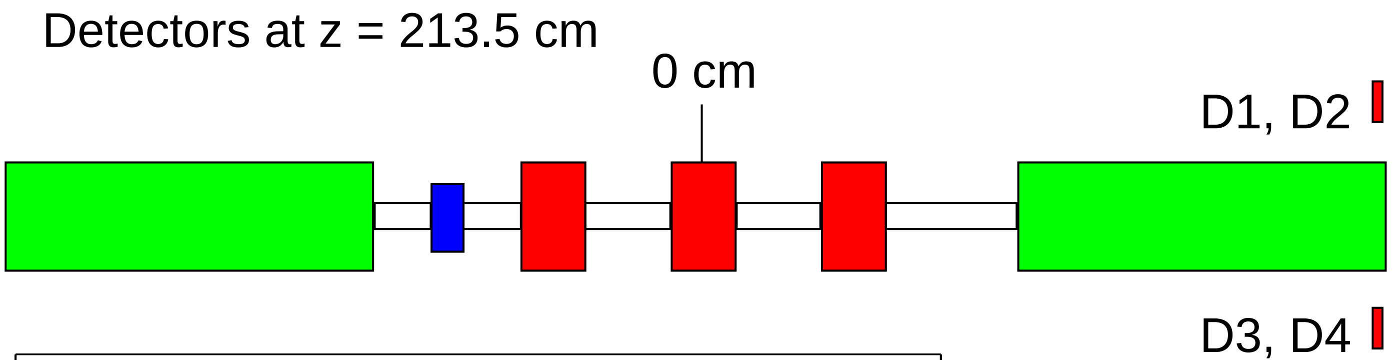
- Place all detectors at a single zed and different ϕ positions
  - Sensitive to ϕ of beam loss
  - Less sensitive to z and intensity of beam loss
- Place detectors at a single ϕ and different zed positions
  - No sensitivity to ϕ of beam loss
  - More sensitive z and intensity of beam loss

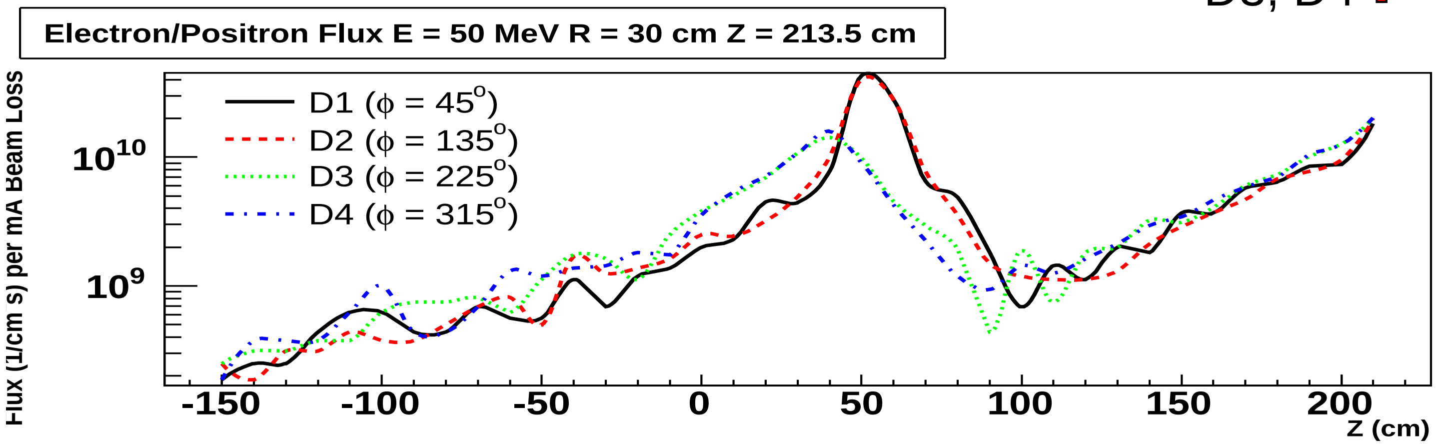


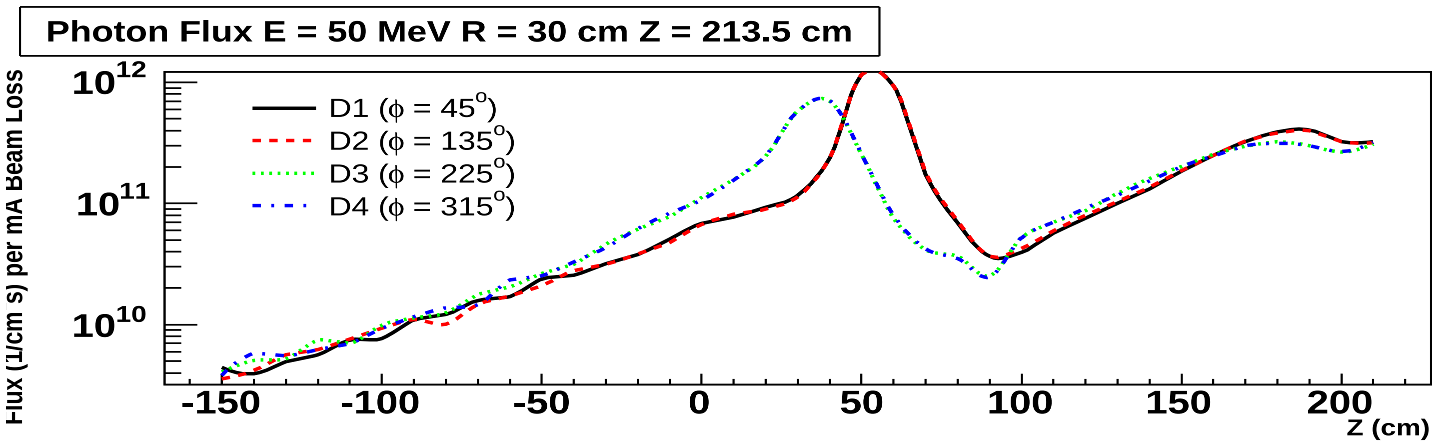
CTF3/CLIC Beam Loss Simulations

- Goals for Beam Loss System
  - Intensity of beam loss
  - Position of beam loss (z, ϕ)
  - Time structure of beam loss $\rightarrow$ not relevant for simulations
- Challenges for Beam Loss System
  - Disentangling intensity from position of beam loss
  - Beam loss at multiple positions
  - Beam loss in accelerating structures (hard to detect)

CTF3/CLIC Beam Loss Simulations

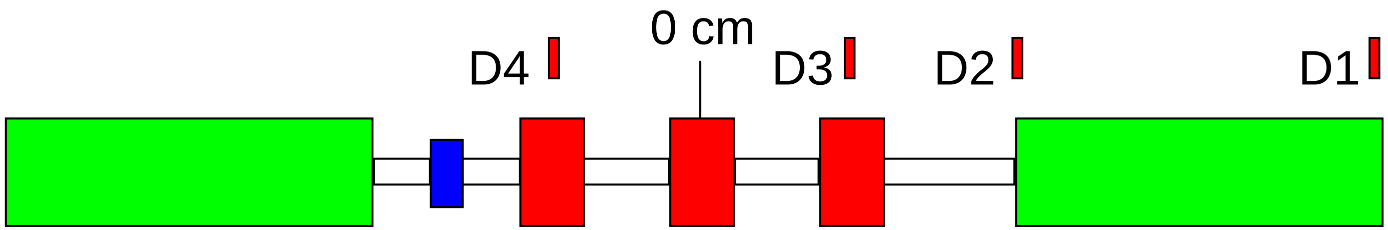


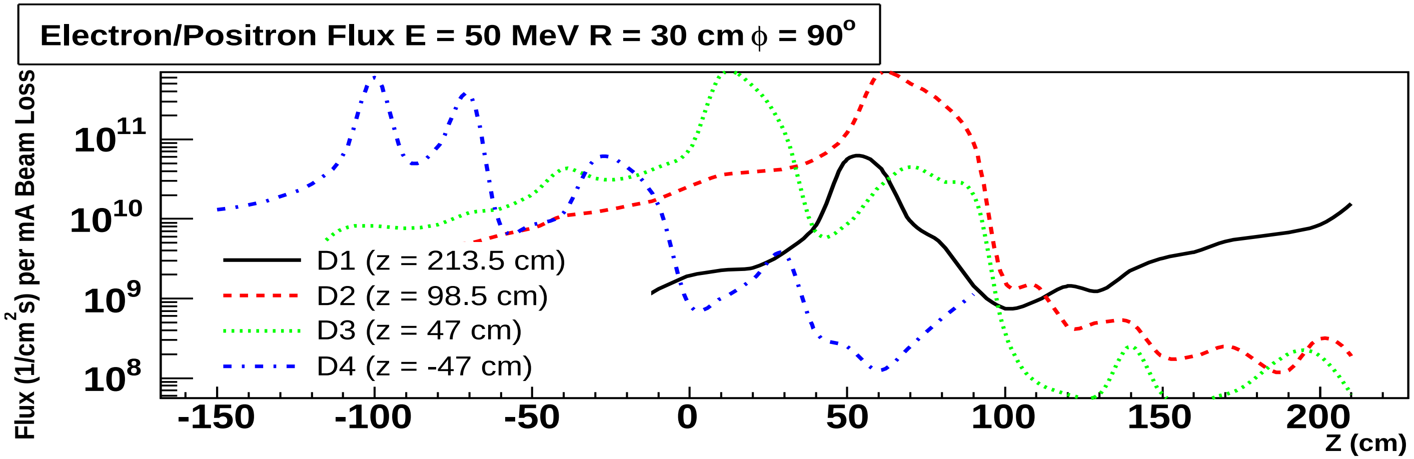


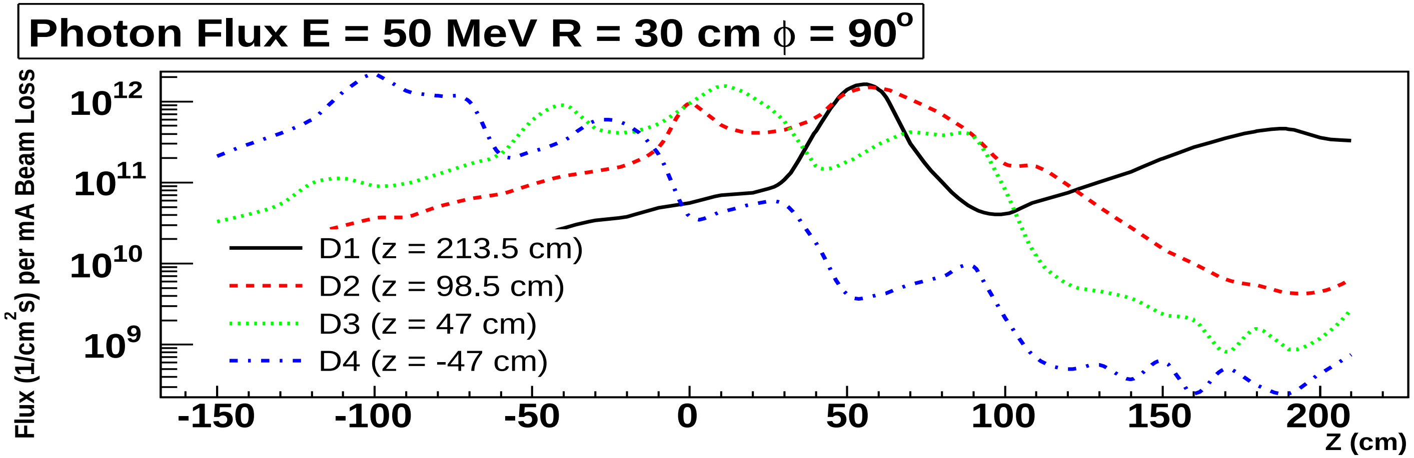


CTF3/CLIC Beam Loss Simulations

Detectors at multiple zed positions $\phi = 90^o$







Method of Analysis

- Zed of the beam loss can be parameterized as a function of the relative signals on the detectors in the module

$$z = \alpha_0 + \sum_i \alpha_i \frac{D_i}{S}, i = 1, ...N \quad (1)$$

  where S is the sum of the detector signals and N is the number of detectors in a module

- Intensity is then calculated directly from simulations knowing the zed position, beam energy, and magnitude of the detector signals
- Free parameters α_i are obtained from a straightforward minimization with GEANT data
- This method can be applied to any arrangement of detectors
- Parameterization could also include other variables such as ϕ, beam energy, and beam angle

Conclusions and Future Plans

- Placing detectors at a single zed position
  - Difficult to distinguish losses in the accelerating structure from those in the quads
  - Determining ϕ of loss is not straightforward – depends on z
  - Difficult to separate effects of z and I $\longrightarrow$ 1 mA loss at x looks like 10 mA loss at y
- Placing detectors at multiple zed positions
  - Can determine z independently of I
  - No information on ϕ but this is ultimately less important for machine protection
- Compare results with another simulation code – GEANT4
- Do more comparisons with data obtained in controlled tests at CTF3
  - Several beam tests with ACEM detectors run in November 2003
  - GEANT simulations and data generally agreed well