Simulation of CTF3 Beam Loss Secondaries

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Overview

Goals

- Determine the optimal position, number, and type of detectors for a beam loss detection system in CTF3
- Understand how observed fluxes in such a system can be used to localize the point of beam loss
- Extrapolate results for CTF3 to CLIC

Motivation

- Machine Protection
- Beam Halo Study

Method

- Electrons introduced at a single point along the linac
- Simulation of generated secondaries with GEANT

Representation of Beam Loss

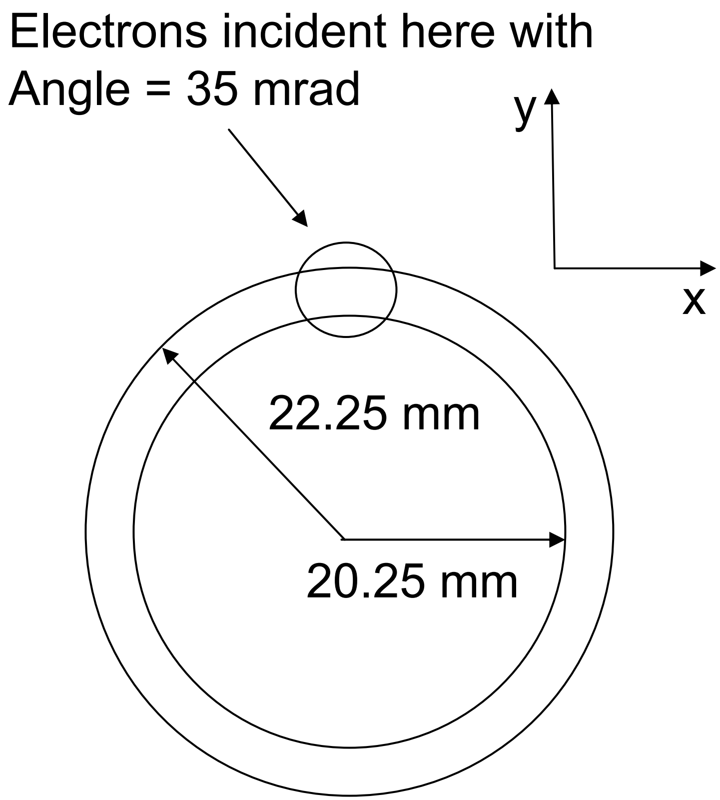
- No realistic representation of halo/tails in simulation
- Beam loss represented by per mil loss of entire beam at a single point on the CTF3 linac

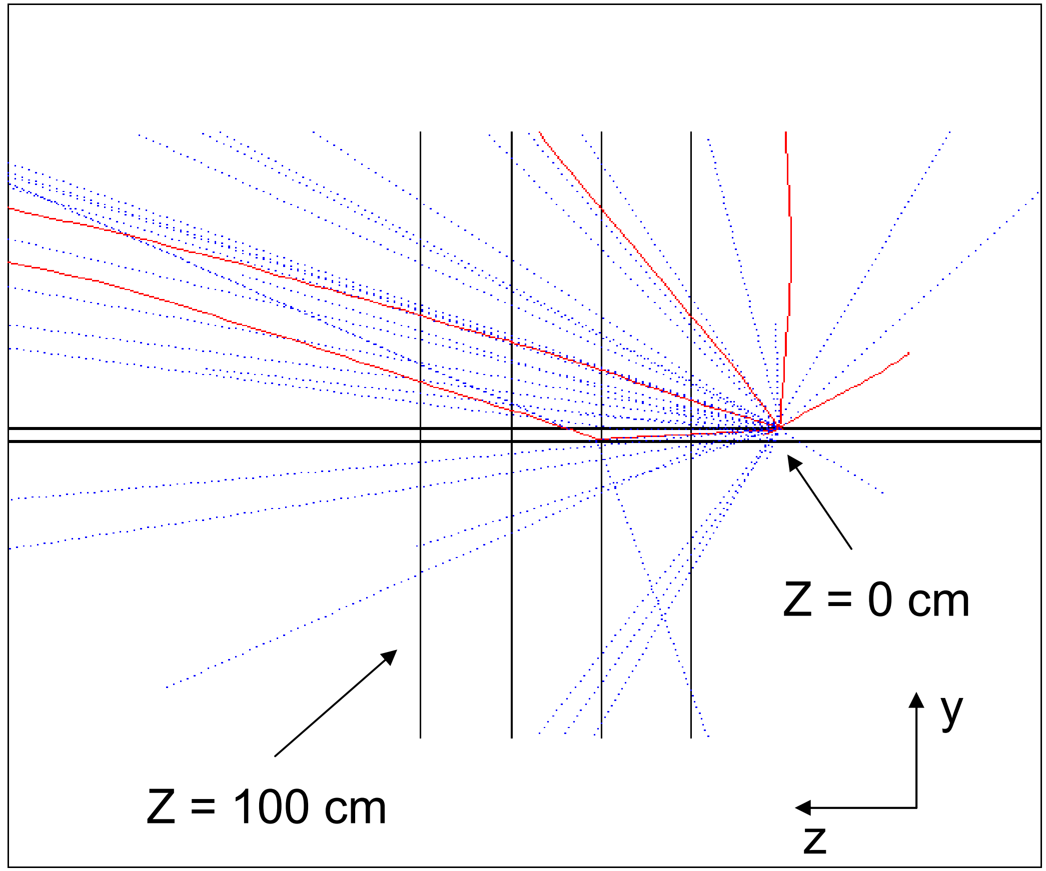
$(3.5\ \text{A})(0.001) = 2.1875 \times 10^{16}$ electrons/s

$= 3.36 \times 10^{10}$ electrons per pulse

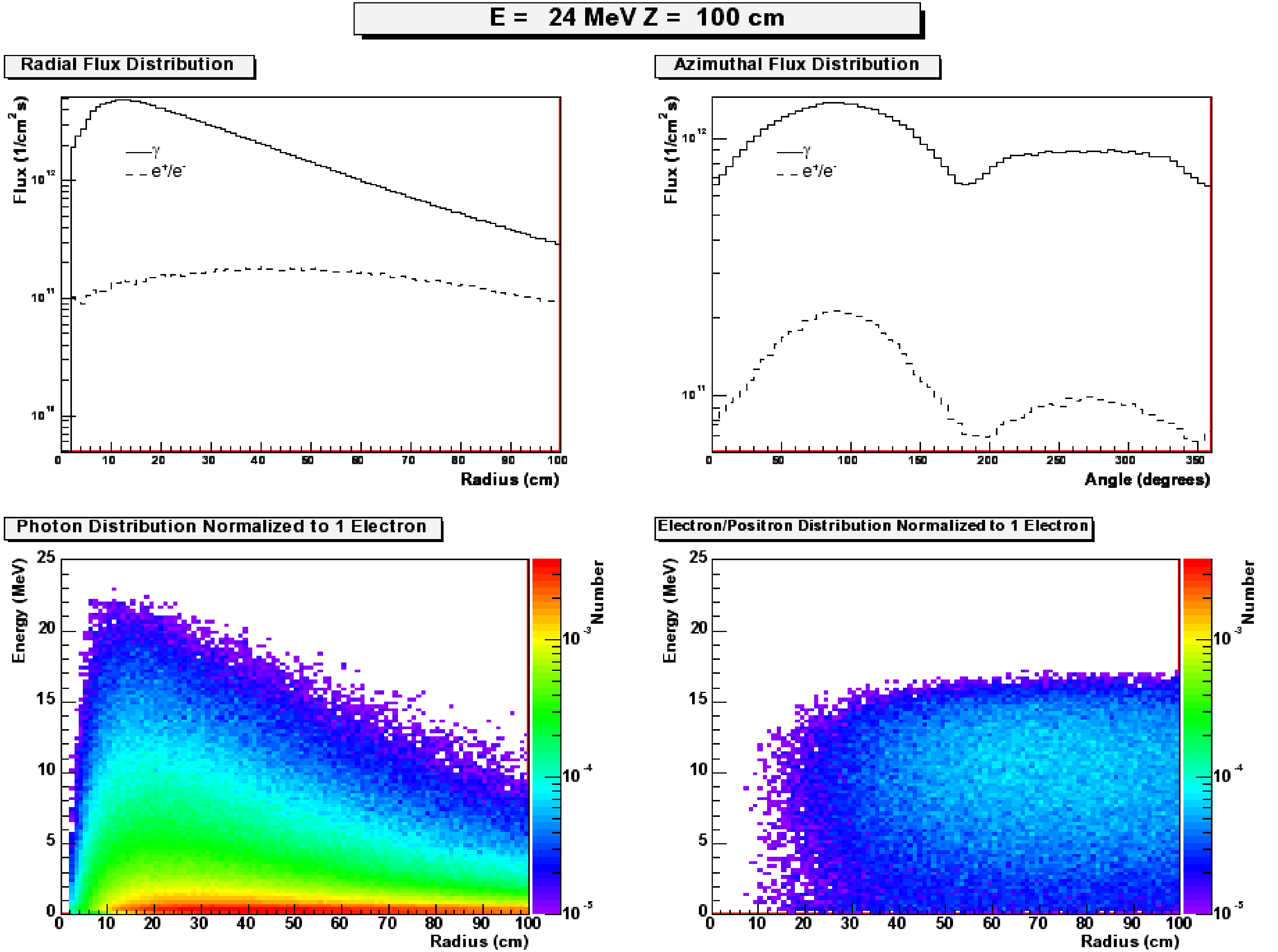
- Electrons assumed to be monoenergetic and monodirectional

Idealized Beam Pipe Simulations

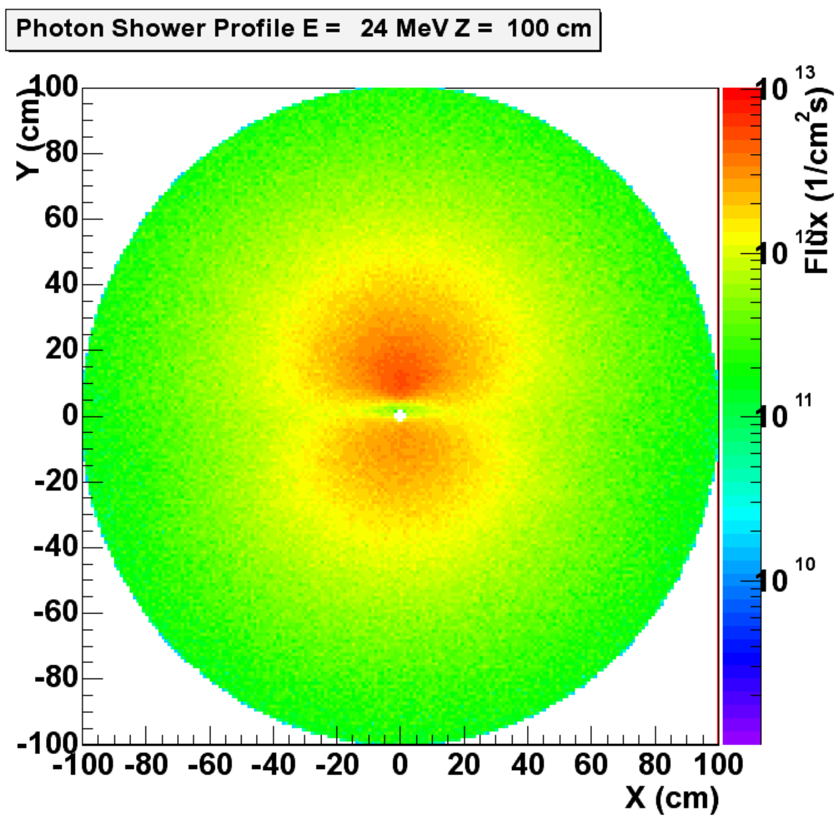


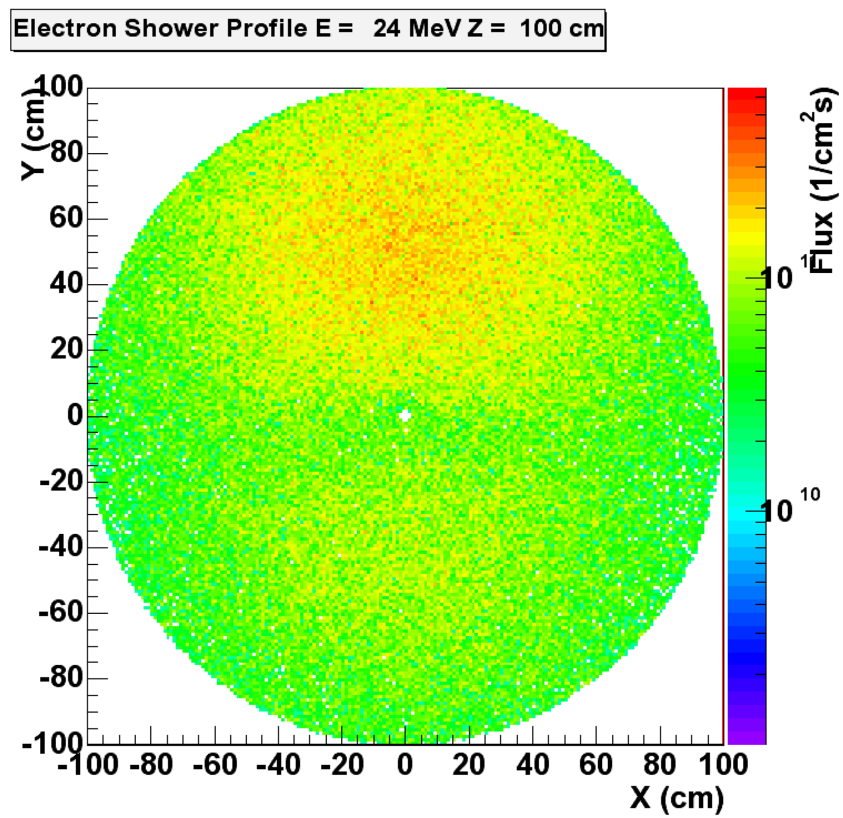


Simulation of Beam Pipe only with no other linac structures
Flux measured with respect to disks along the z-axis

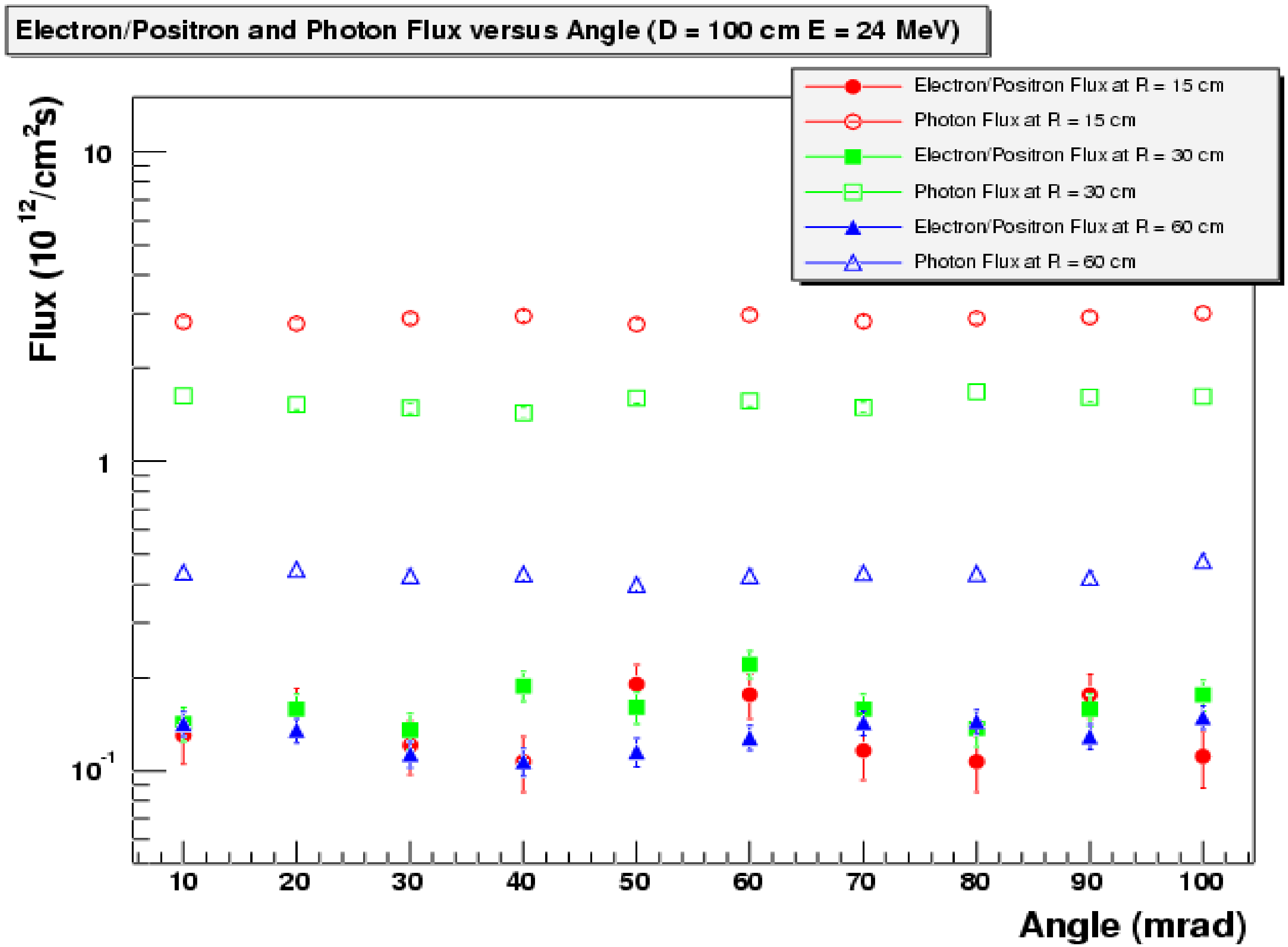

E = 24 MeV Z = 100 cm
Radial Flux Distribution
Flux (1/cm^2 s)
γ
e+/e-
Radius (cm)
Azimuthal Flux Distribution
Flux (1/cm^2 s)
γ
e+/e-
Angle (degrees)
Photon Distribution Normalized to 1 Electron
Energy (MeV)
Number
Radius (cm)
Electron/Positron Distribution Normalized to 1 Electron
Energy (MeV)
Number
Radius (cm)

Photon and Electron/Positron Showers E = 24 MeV Z = 100 cm

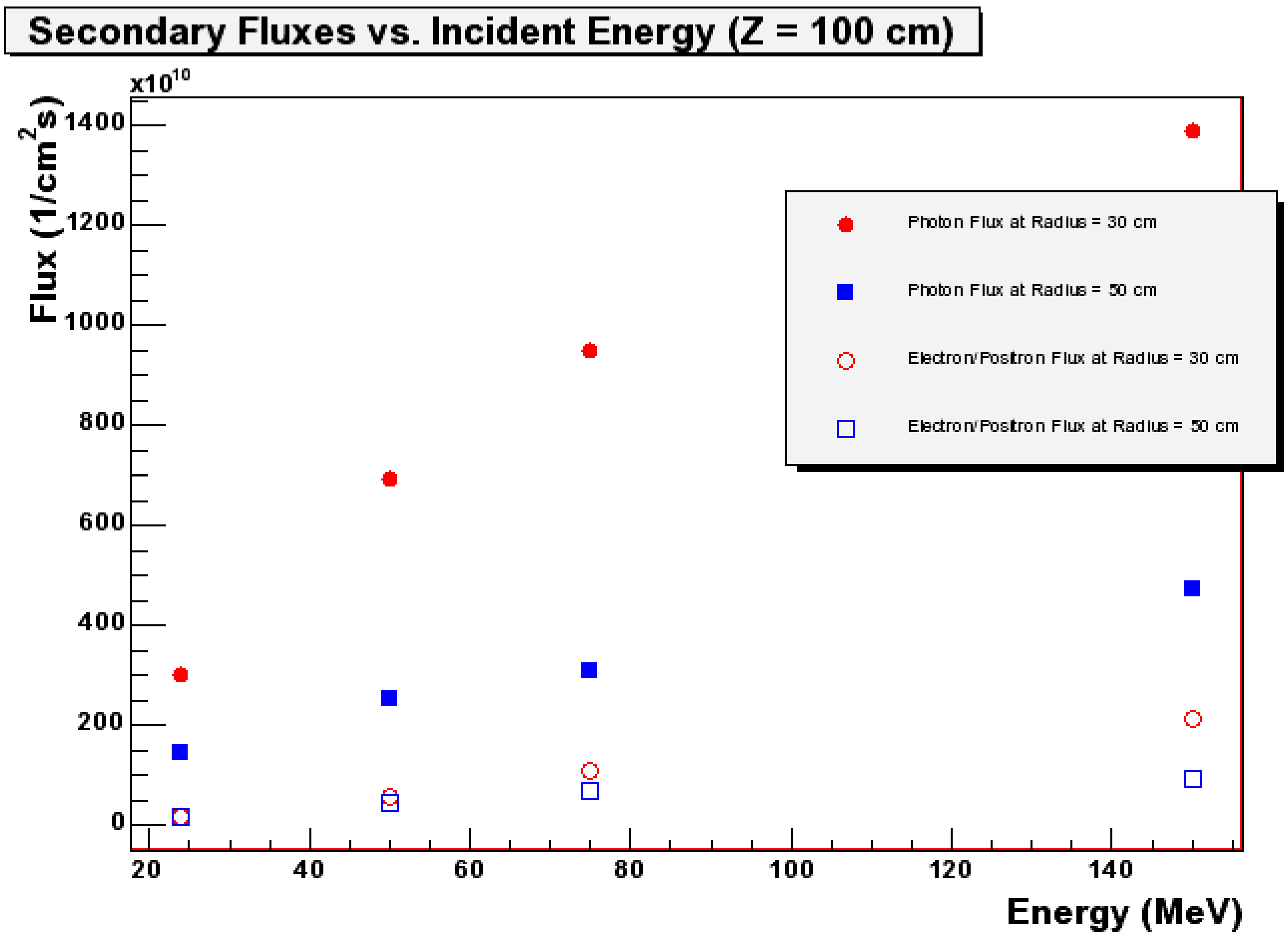




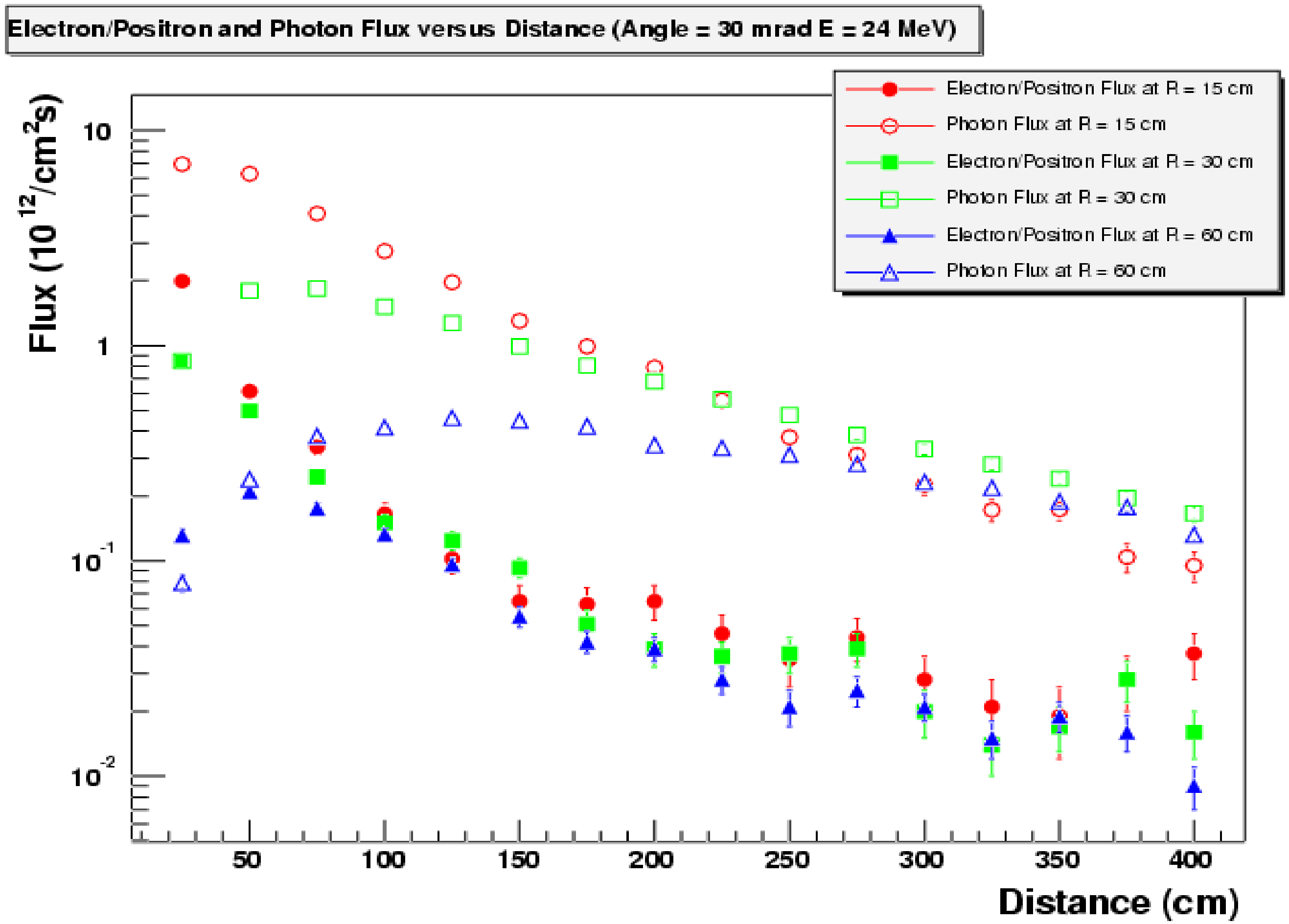
Flux Dependence on Incident Angle



Flux Dependence on Incident Energy



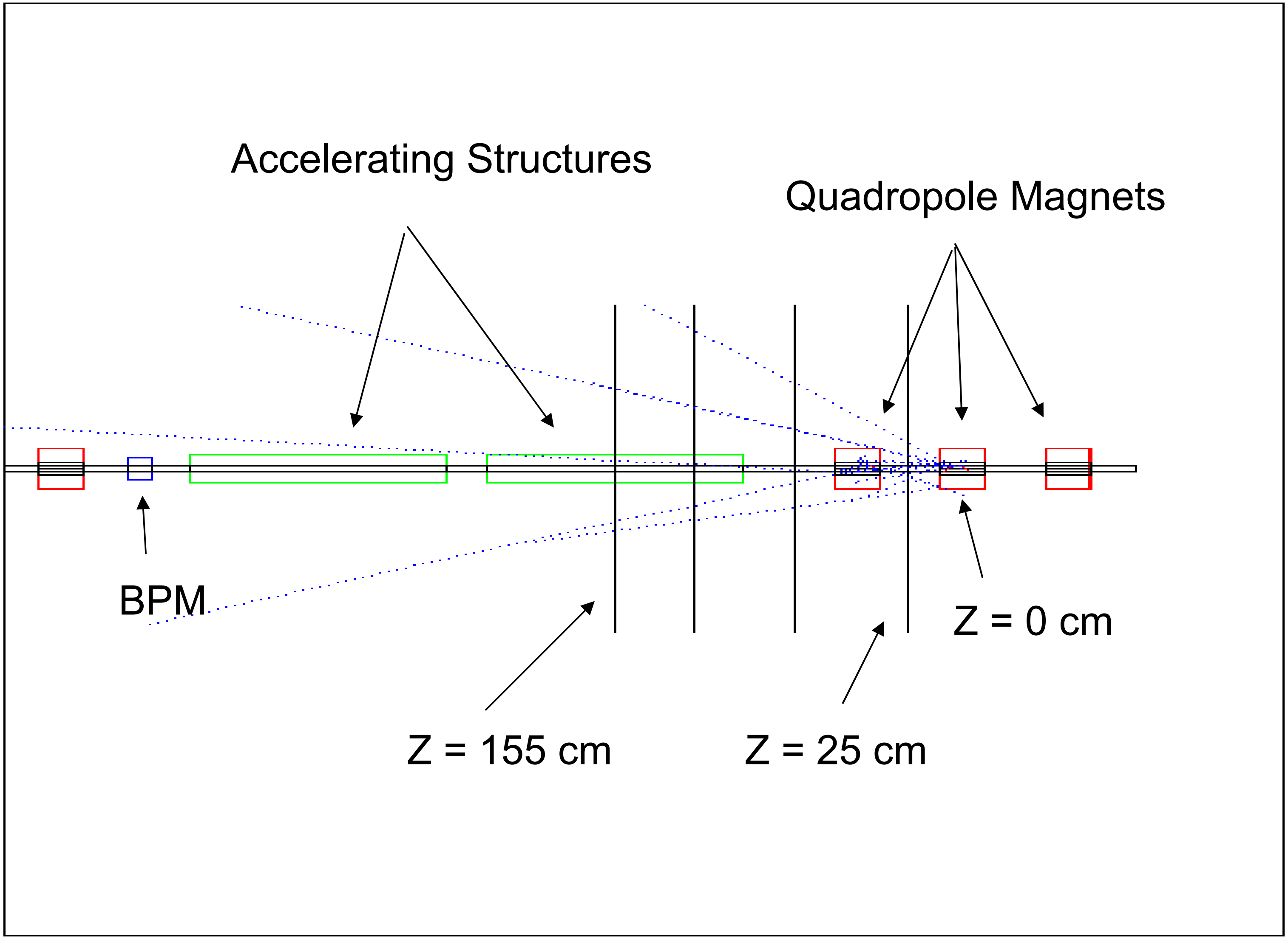
Flux Dependence on Distance



Conclusions from Beam Pipe Simulations

- Incident electrons generate electromagnetic showers (alternately bremsstrahlung and pair-production) – all secondaries are electrons, positrons, and photons
- Observed fluxes are on the order of 10^{12} - 10^{14} $cm^{-2}s^{-1}$ for photons and 10^{11} -10^{13} $cm^{-2}s^{-1}$ for electrons/positrons at a distance of 1 m with beam energies in the range 24-150 MeV
- The flux observed increases roughly linearly with the incident energy and falls exponentially with distance
- Due to multiple scattering at low energies, the generated flux is independent of the incident angle for small angles

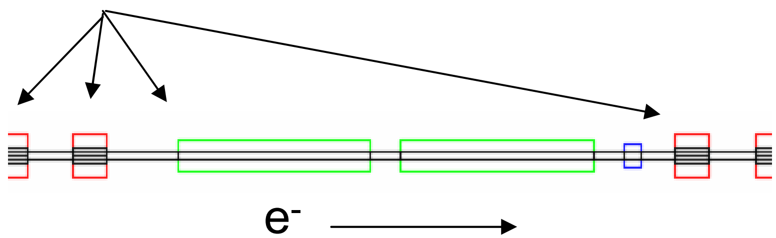
Simulations with ‘Classical’ Geometry

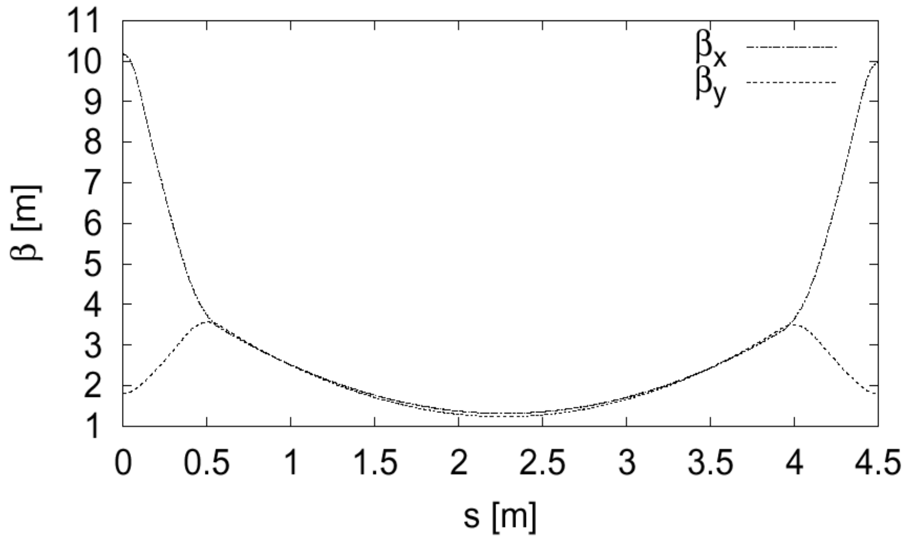


Position of Beam Losses

- Greatest losses will occur at quadropole magnets
- Narrowing of aperture at first accelerating structure may also induce losses

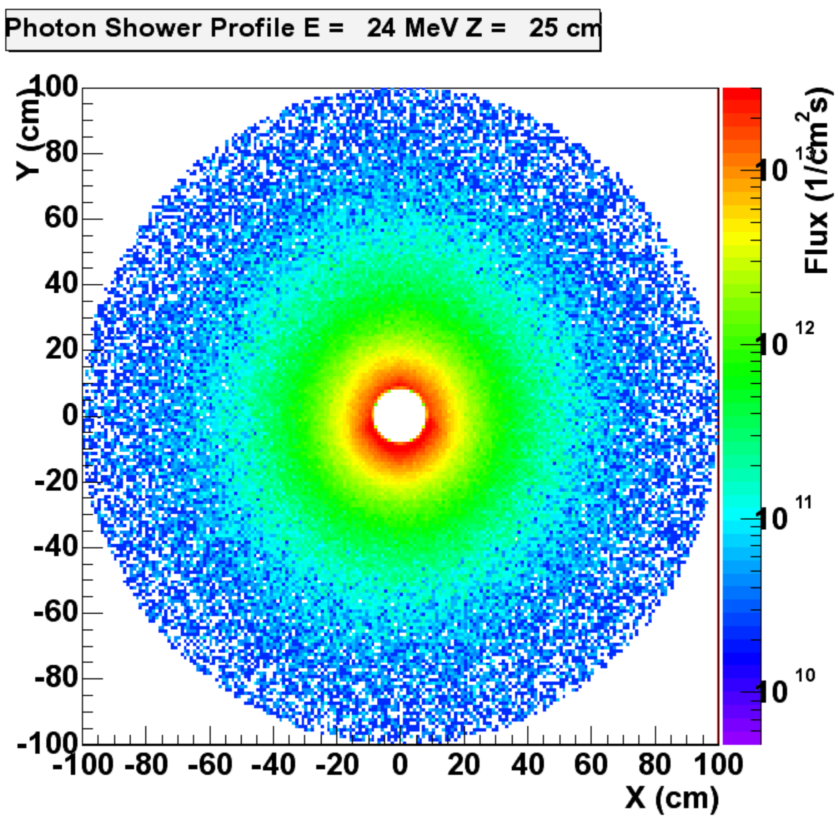
Points where losses will be most likely



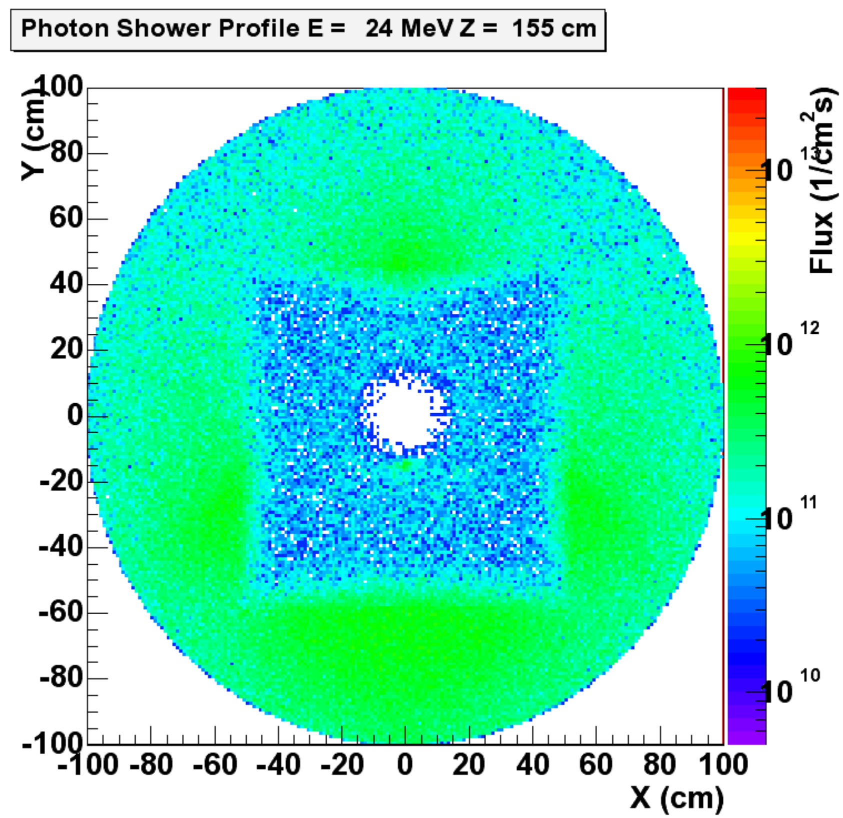


Twiss Parameter versus z along linac

Photon Shower Profile E = 24 MeV with loss at Z = 0 cm (Center Quadropole)

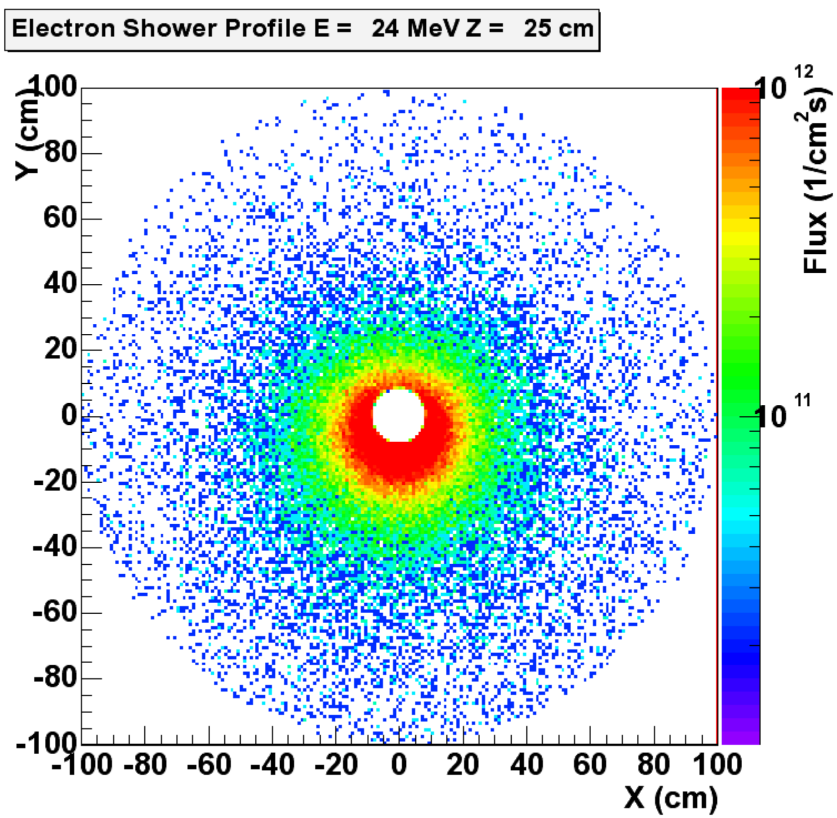


Z = 25 cm

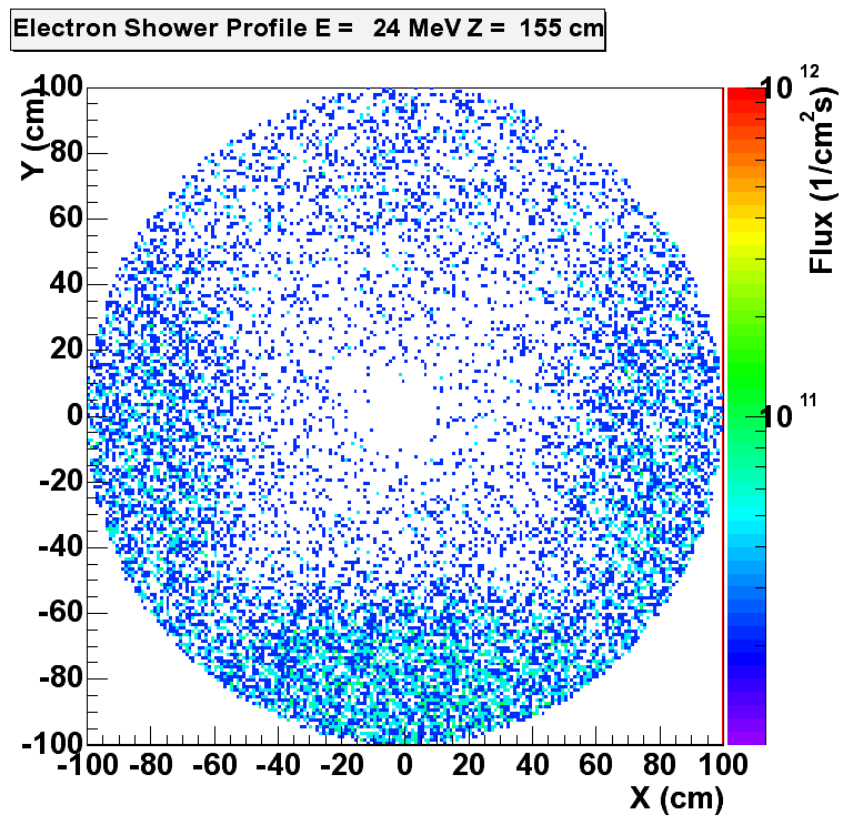


Z = 155 cm

Electron/Positron Shower Profile
E = 24 MeV with loss at Z = 0 cm (Center Quadropole)



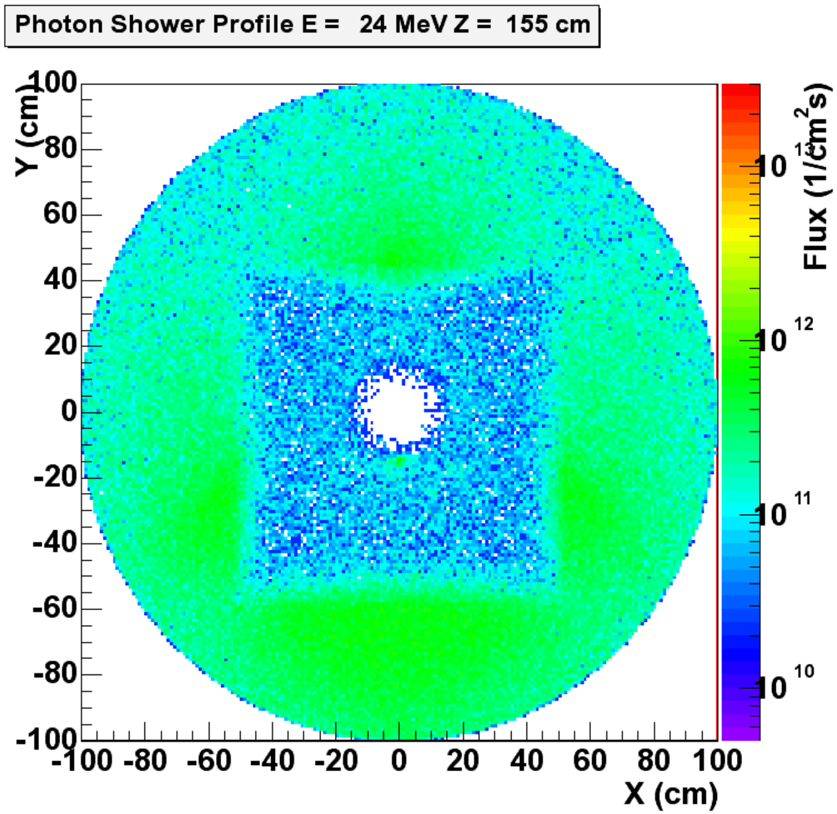
Z = 25 cm



Z = 155 cm

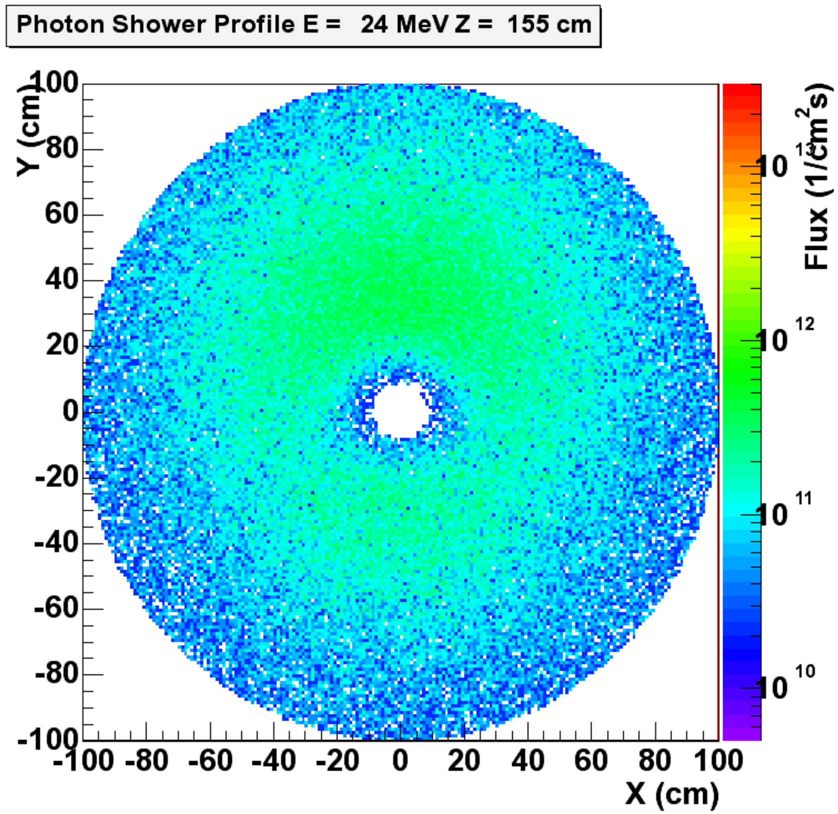
Discriminating Point of Beam Loss

Photons Incident at
Z = 0 cm (Center Quadropole)



Z = 155 cm

Photons Incident at Z = ~ 98 cm
(1st Accelerating Structure)



Z = 155 cm

Conclusions on ‘Classical’ Simulations

- Observed fluxes are diminished by an order of magnitude or more as compared to idealized beam pipe
- Some segmentation in azimuthal angle may be necessary due to asymmetric geometry
- Position of beam loss monitors will depend crucially on their position in both z and phi with respect to the quadropole magnets
- Electrons may be a more sensitive indicator of beam loss position since it will be easier to shield against them

Future Work

- Verify simulations at CTF3 test beam this upcoming week (detectors implemented by Thibaut)
- Analyze effects of parallel drive and probe beams on beam loss detection method
- Look at effects of simultaneous losses at different points on the linac
- Model beam losses more realistically