Feasibility Study of a Low Angle Cerenkov Detector for the NLC

Rory C. Kelly and Christopher S. Takeuchi

November 25, 1999

NLC, the Next Linear Collider

- Advanced linear e^+e^- collider

- Nominal cms beam energy of 1 TeV, with luminosity of $1.1 \times 10^{34} s^{-1} cm^{-2}$

- Intended to explore Physics in the TeV regime, including:

    - Higgs physics

    - Precision tests of QCD

    - Top quark physics

    - Supersymmetry

    - and much more...

The Standard Model and Supersymmetry:

SM particle		Super-partner
$e^\pm$		$\tilde{e}^\pm_L,\ \tilde{e}^\pm_R$
$\mu^\pm$		$\tilde{\mu}^\pm_L,\ \tilde{\mu}^\pm_R$
$\tau^\pm$		$\tilde{\tau}^\pm_L,\ \tilde{\tau}^\pm_R$
$\nu_{e,\mu,\tau}$	$\Longleftrightarrow$	$\tilde{\nu}_{e,\mu,\tau}$
q		$\tilde{q}$
$W^\pm,\ H^\pm$		$\tilde{\chi}^\pm_1,\ \tilde{\chi}^\pm_2$
$\gamma,\ Z^0,\ h^0,\ H^0$		$\tilde{\chi}^0_1,\ \tilde{\chi}^0_2,\ \tilde{\chi}^0_3,\ \tilde{\chi}^0_4$

A Word About R-parity

• In the supersymmetry models that we study, R-parity is a conserved quantity

• R-parity is defined by the equation:

$$R = (-1)^{3B+L+2S}$$

• R-parity conservation implies that supersymmetric particles must always decay into an odd number of SuSy particles plus any number of standard model particles.

• This means that the lightest SuSy particle (LSP) must be stable. At the points we study the LSP is the $\tilde{\chi}_1^0$.

How We Expect to See Supersymmetry

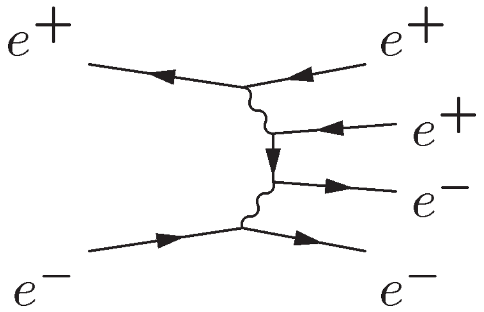
• The LSP is the $\tilde{\chi}_1^0$, and every SuSy event will eventually decay into standard model particles and an even number of $\tilde{\chi}_1^0$s.

• Because the $\tilde{\chi}_1^0$ is massive ($\sim$ tens of GeV) and only interacts weakly, it will exit the detector unseen, carrying off lots of energy.

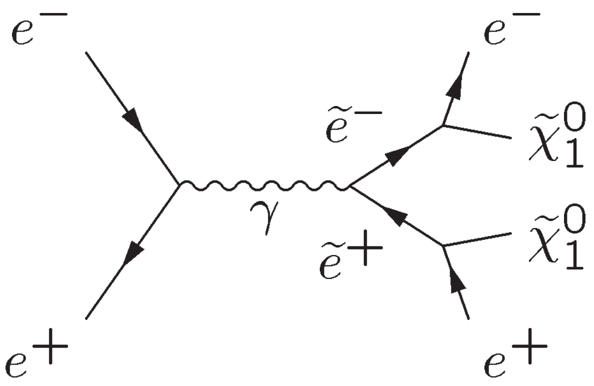
• This gives R-parity conserving supersymmetric events the classic "missing" energy signal.

The Problem Is...

• Many "two photon" events look exactly like SuSy events.

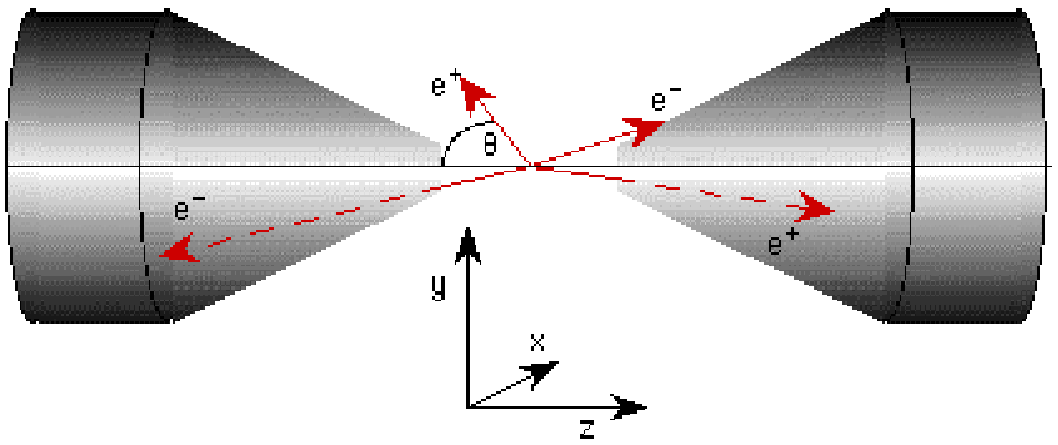


• Two photon events can mimic many supersymmetric signals like a selectron decay.



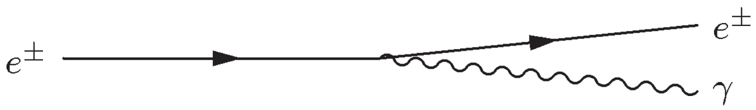
• To detect this background we need a detector at low angles *inside* the beampipe.

A Typical Two Photon Event



The (Beam/Brems)strahlung Background.

• Two photon events are not the only source of low angle electrons. When primary beam particles emit (beam/brems)strahlung photons, two of these photons can annihilate and produce low angle electrons and positrons.



• Fortunately there is a large energy difference between the electrons from these different processes. The electrons from two photon events are ~230 GeV, those from bremsstrahlung and beamstrahlung are ~5 GeV.

Simulation Summary:

- Simulated two-photon events and background from beamstrahlung and bremsstrahlung processes passing through a low angle Cerenkov detector.

- Simulation included the correct magnetic field.

- Simulation included the 10 mrad offset angle of the beams from the z axis.

Detector Properties:

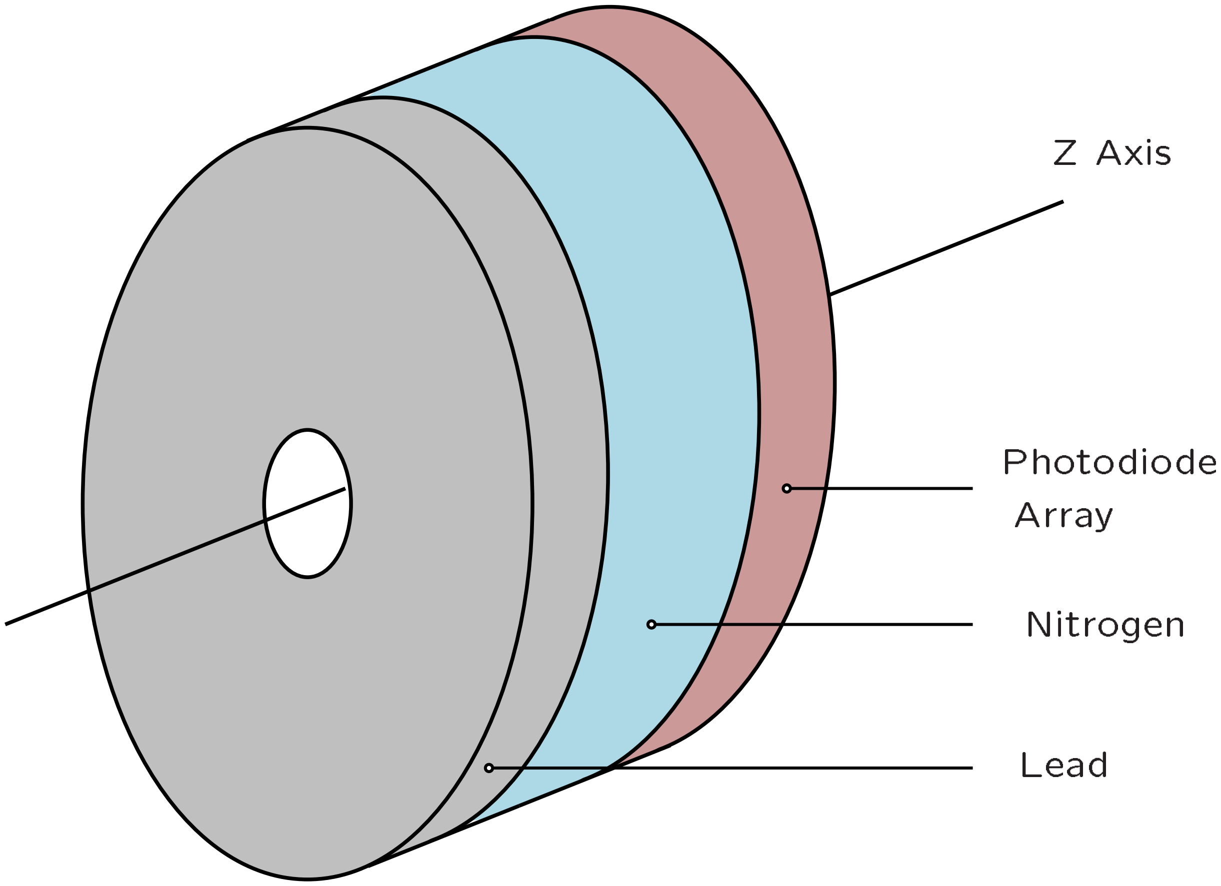
- The detector consists of a cylinder of lead varying in thickness from 1 to 9 radiation lengths, a cylinder of nitrogen gas 30 cm thick, and an array of photodiodes.

- The nitrogen gas is at .1 atm pressure so that only particles with energies above 66 MeV will emit Cerenkov light.

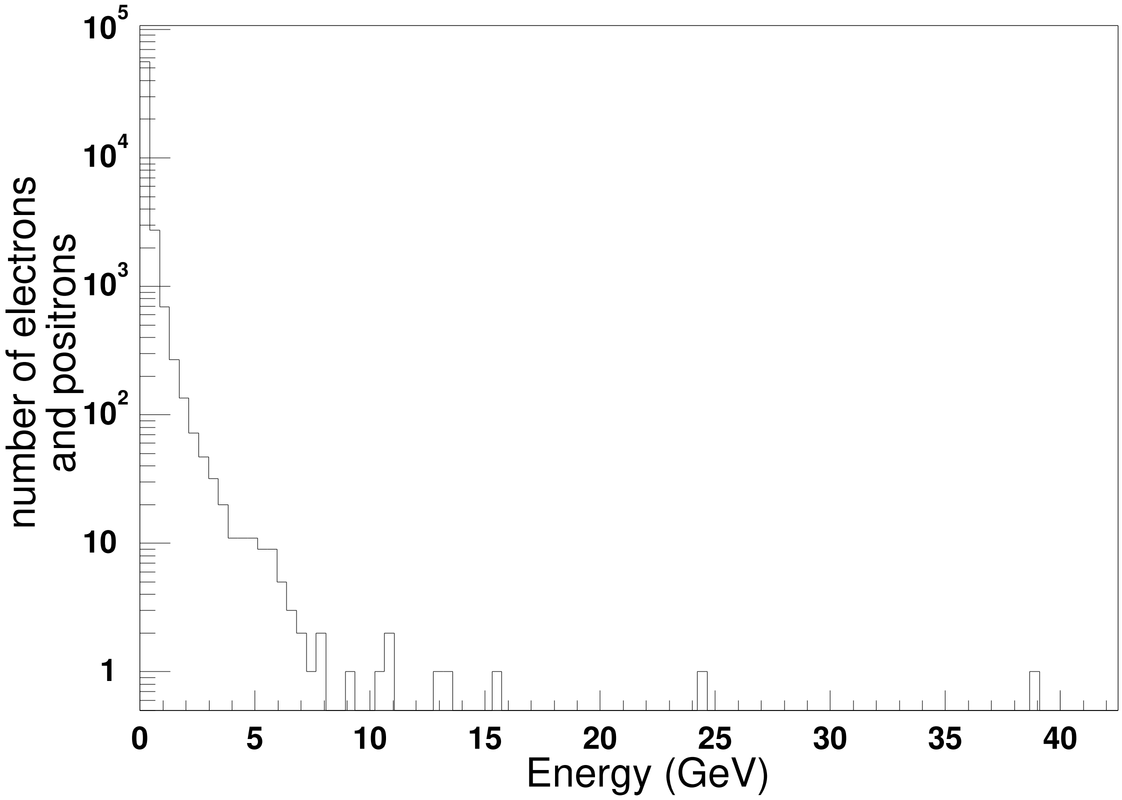
- The radius of the detector is 5 cm.

- The detector sits 150 cm from the interaction point along the z axis.

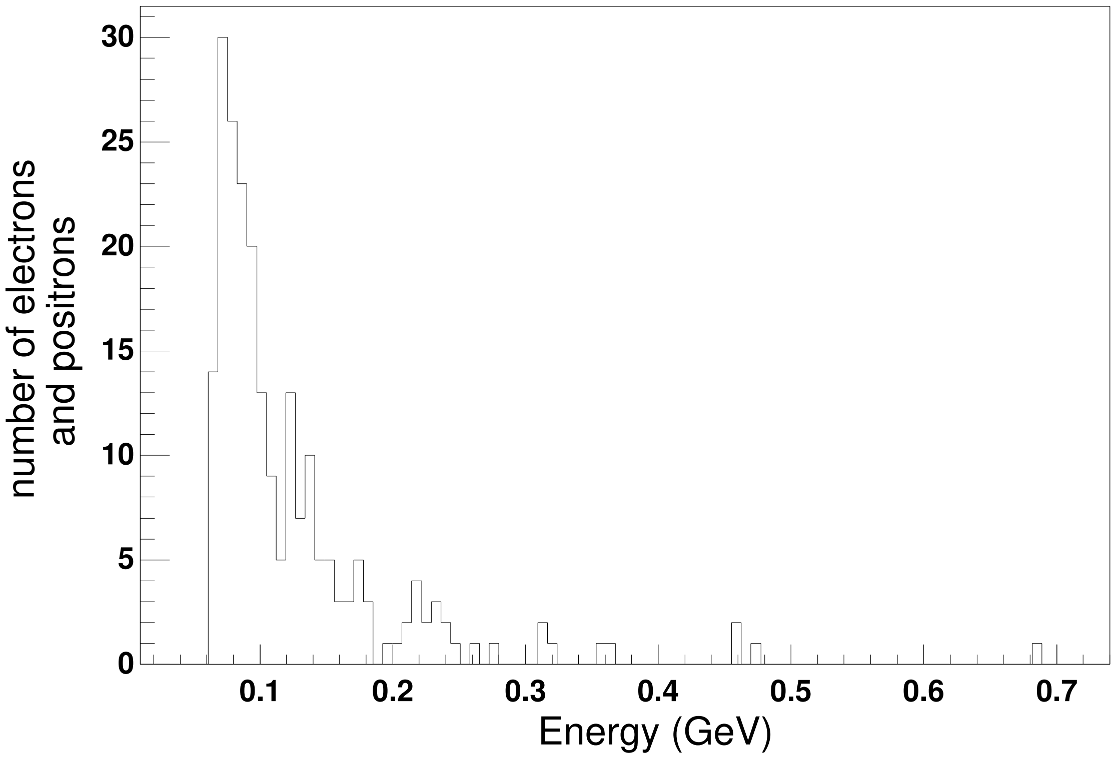
The Detector, A Simple Schematic



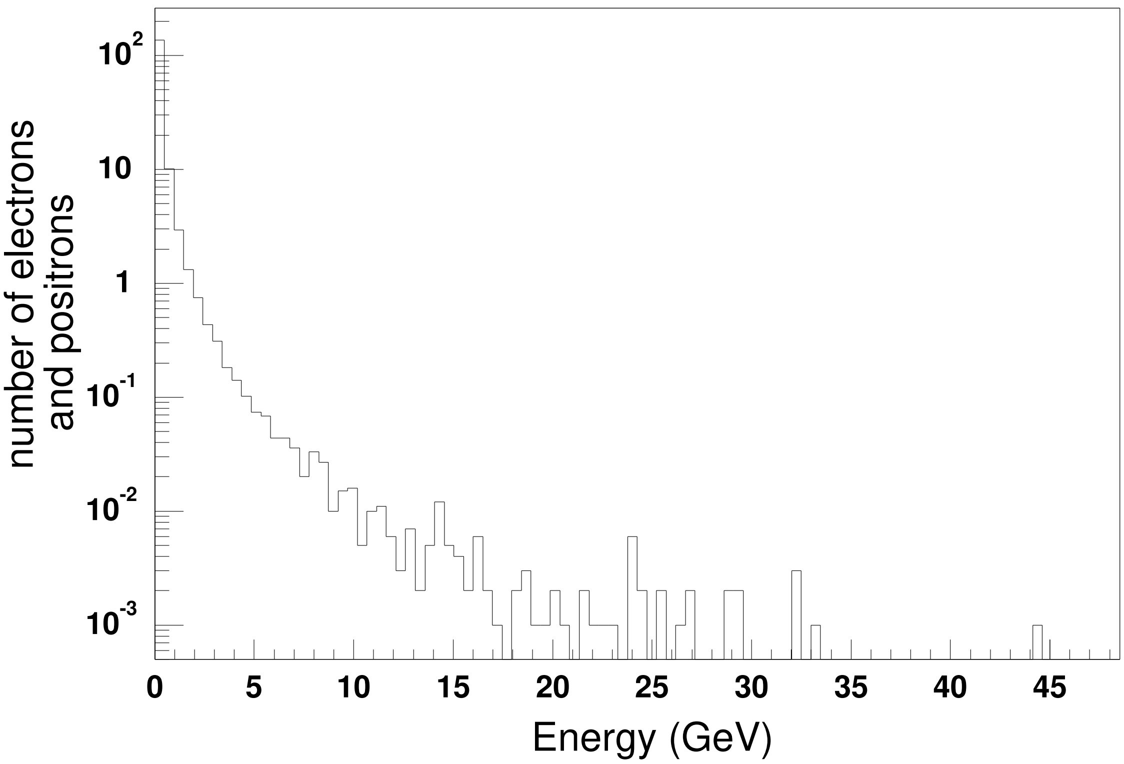
Energy distribution of $e^{\pm}$ remaining after one bunch worth (10^{10} e^- on 10^{10} e^+ collision, with NLC beam dimensions) of bremsstrahlung and beamstrahlung background showers in 8 radiation lengths of lead.



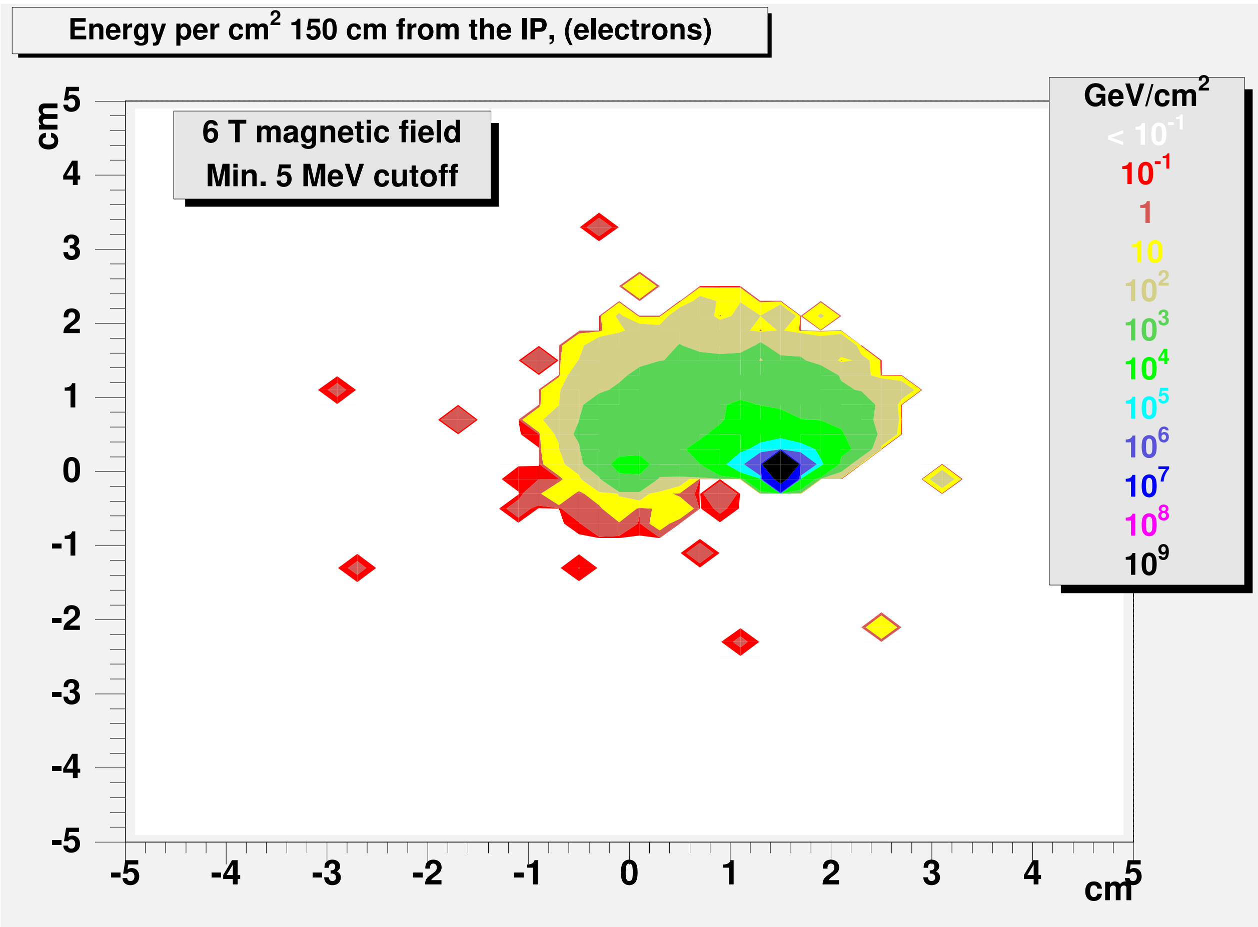
Energy distribution of $e^{\pm}$ remaining after one bunch worth of bremsstrahlung and beamstrahlung background showers in 8 radiation lengths of lead. Only particles with energy $>$ 66 MeV and at $\sqrt{x^2+y^2} > 3$ cm are shown.



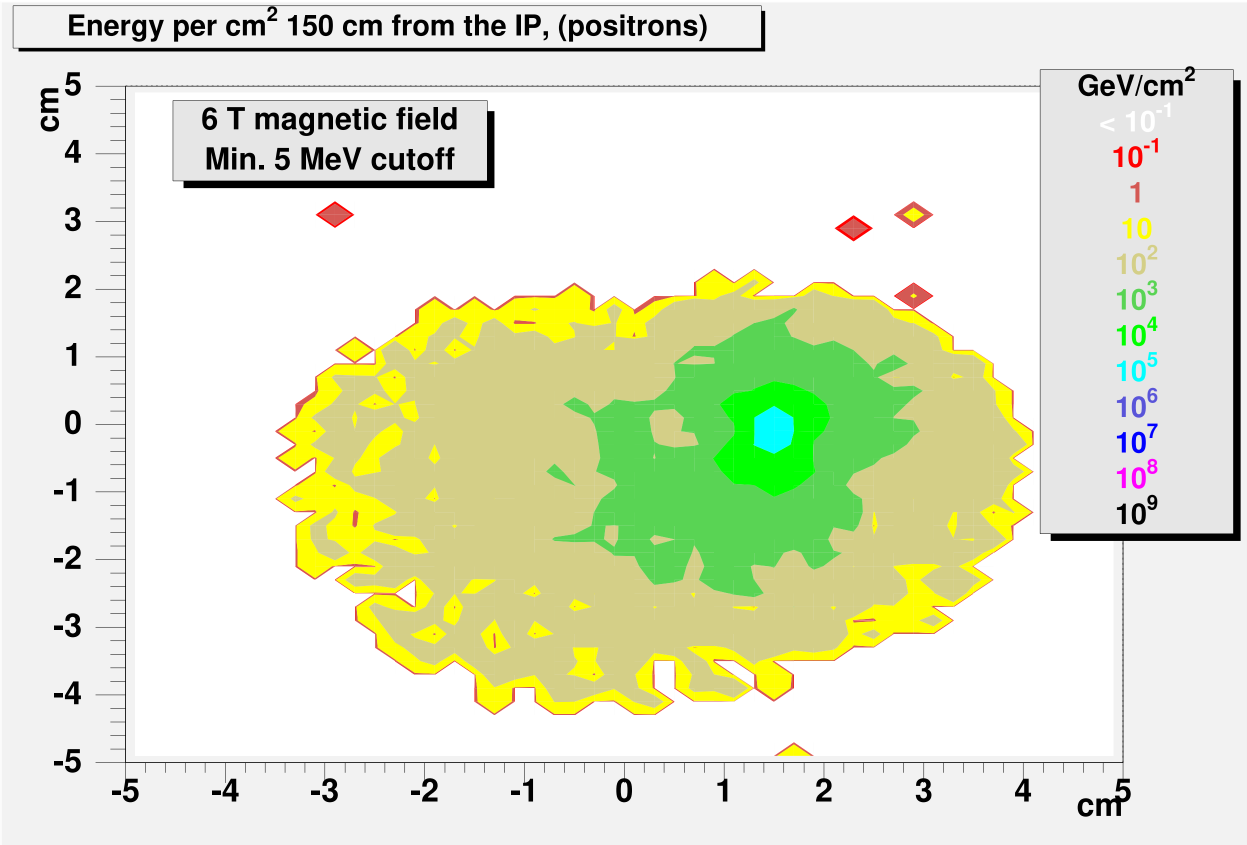
Energy distribution of $e^{\pm}$ remaining after a typical two photon event showers in 8 radiation lengths of lead.



Energy deposition by electrons from bremsstrahlung and beamstrahlung background incident on the detector.



Energy deposition by positrons from bremsstrahlung and beamstrahlung background incident on the detector.



Number of secondary $e^{\pm}$ above the Cerenkov threshold (66 MeV) remaining after the $e^{\pm}$ pairs from a bunch worth of bremsstrahlung and beamstrahlung background shower in 5 radiation lengths of lead. Normalized to number of particles per cm^2.

radius in cm / angle in rad.	0 ↓ .5	.5 ↓ 1	1 ↓ 1.5	1.5 ↓ 2	2 ↓ 2.5	2.5 ↓ 3	3 ↓ 3.5	3.5 ↓ 4	4 ↓ 4.5	4.5 ↓ 5
$-\pi \to \frac{-3\pi}{4}$	9	9	9	15	28	9	9	4	0	0
$\frac{-3\pi}{4} \to \frac{-\pi}{2}$	6	34	52	55	38	38	23	14	0	0
$\frac{-\pi}{2} \to \frac{-\pi}{4}$	13	61	254	280	149	125	55	15	1	0
$\frac{-\pi}{4} \to 0$	10	102	4027	8338	419	100	48	18	2	0
$0 \to \frac{\pi}{4}$	38	474	9700	15504	865	152	31	3	0	0
$\frac{\pi}{4} \to \frac{\pi}{2}$	33	101	241	106	18	4	0	0	0	0
$\frac{\pi}{2} \to \frac{3\pi}{4}$	27	48	20	5	2	0	0	0	0	0
$\frac{3\pi}{4} \to \pi$	21	19	10	8	4	2	0	0	0	0

Number of secondary $e^{\pm}$ above the Cerenkov threshold (66 MeV) remaining after the $e^{\pm}$ pairs from a bunch worth of bremsstrahlung and beamstrahlung background shower in 6 radiation lengths of lead. Normalized to number of particles per cm^2.

radius in cm / angle in rad.	0 → .5	.5 → 1	1 → 1.5	1.5 → 2	2 → 2.5	2.5 → 3	3 → 3.5	3.5 → 4	4 → 4.5	4.5 → 5
$-\pi \to \frac{-3\pi}{4}$	5	4	8	17	17	15	6	6	0	0
$\frac{-3\pi}{4} \to \frac{-\pi}{2}$	5	16	31	32	22	19	17	4	1	0
$\frac{-\pi}{2} \to \frac{-\pi}{4}$	6	53	170	180	127	69	39	13	1	0
$\frac{-\pi}{4} \to 0$	6	108	3434	7568	357	82	29	13	3	0
$0 \to \frac{\pi}{4}$	23	362	8125	13744	695	82	25	3	0	0
$\frac{\pi}{4} \to \frac{\pi}{2}$	23	66	155	79	24	2	0	0	0	0
$\frac{\pi}{2} \to \frac{3\pi}{4}$	10	30	5	5	0	0	0	0	0	0
$\frac{3\pi}{4} \to \pi$	9	5	3	7	4	2	0	0	0	0

Number of secondary $e^{\pm}$ above the Cerenkov threshold (66 MeV) remaining after the $e^{\pm}$ pairs from a bunch worth of bremsstrahlung and beamstrahlung background shower in 7 radiation lengths of lead. Normalized to number of particles per cm^2.

radius in cm / angle in rad.	0 ↓ .5	.5 ↓ 1	1 ↓ 1.5	1.5 ↓ 2	2 ↓ 2.5	2.5 ↓ 3	3 ↓ 3.5	3.5 ↓ 4	4 ↓ 4.5	4.5 ↓ 5
$-\pi \to \frac{-3\pi}{4}$	2	3	4	8	11	6	7	1	0	0
$\frac{-3\pi}{4} \to \frac{-\pi}{2}$	5	14	21	16	20	9	12	4	0	0
$\frac{-\pi}{2} \to \frac{-\pi}{4}$	3	29	113	125	71	42	21	13	1	0
$\frac{-\pi}{4} \to 0$	4	65	2806	6464	249	67	14	7	2	0
$0 \to \frac{\pi}{4}$	21	230	6123	11516	523	66	12	12	0	0
$\frac{\pi}{4} \to \frac{\pi}{2}$	14	41	104	59	21	3	0	0	0	0
$\frac{\pi}{2} \to \frac{3\pi}{4}$	8	22	11	3	0	0	0	0	0	0
$\frac{3\pi}{4} \to \pi$	7	6	1	2	0	2	0	0	0	0

Number of secondary $e^{\pm}$ above the Cerenkov threshold (66 MeV) remaining after the $e^{\pm}$ pairs from a bunch worth of bremsstrahlung and beamstrahlung background shower in 8 radiation lengths of lead. Normalized to number of particles per cm^2.

radius in cm / angle in rad.	0 ↓ .5	.5 ↓ 1	1 ↓ 1.5	1.5 ↓ 2	2 ↓ 2.5	2.5 ↓ 3	3 ↓ 3.5	3.5 ↓ 4	4 ↓ 4.5	4.5 ↓ 5
$-\pi \to \frac{-3\pi}{4}$	0	2	1	3	5	1	2	2	0	0
$\frac{-3\pi}{4} \to \frac{-\pi}{2}$	1	3	7	10	10	9	5	0	1	0
$\frac{-\pi}{2} \to \frac{-\pi}{4}$	0	31	85	86	44	40	18	5	0	0
$\frac{-\pi}{4} \to 0$	1	32	2085	5163	183	59	11	4	0	0
$0 \to \frac{\pi}{4}$	8	182	4449	8639	374	41	14	0	1	0
$\frac{\pi}{4} \to \frac{\pi}{2}$	4	25	46	34	6	3	0	0	0	0
$\frac{\pi}{2} \to \frac{3\pi}{4}$	0	6	6	1	2	0	0	0	0	0
$\frac{3\pi}{4} \to \pi$	4	2	0	2	2	0	0	0	0	0

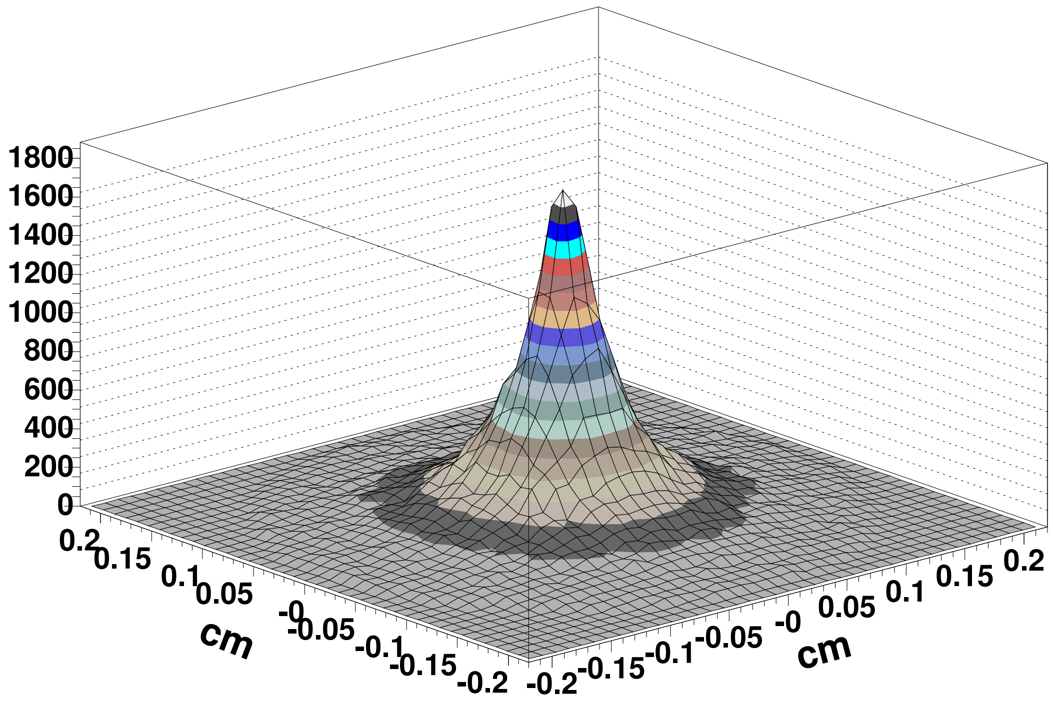
Number of secondary $e^{\pm}$ above the Cerenkov threshold (66 MeV) remaining after the $e^{\pm}$ pairs from a bunch worth of bremsstrahlung and beamstrahlung background shower in 9 radiation lengths of lead. Normalized to number of particles per cm^2.

radius in cm / angle in rad.	0 ↓ .5	.5 ↓ 1	1 ↓ 1.5	1.5 ↓ 2	2 ↓ 2.5	2.5 ↓ 3	3 ↓ 3.5	3.5 ↓ 4	4 ↓ 4.5	4.5 ↓ 5
$-\pi \to \frac{-3\pi}{4}$	1	1	3	1	1	1	1	1	0	0
$\frac{-3\pi}{4} \to \frac{-\pi}{2}$	2	3	7	3	7	2	4	4	1	0
$\frac{-\pi}{2} \to \frac{-\pi}{4}$	0	17	67	84	32	23	12	4	0	0
$\frac{-\pi}{4} \to 0$	0	29	1452	3958	129	21	8	2	3	0
$0 \to \frac{\pi}{4}$	1	139	3002	6561	273	18	6	1	0	0
$\frac{\pi}{4} \to \frac{\pi}{2}$	2	9	30	21	1	0	0	0	0	0
$\frac{\pi}{2} \to \frac{3\pi}{4}$	3	6	6	1	0	0	0	0	0	0
$\frac{3\pi}{4} \to \pi$	1	0	0	0	1	0	0	0	0	0

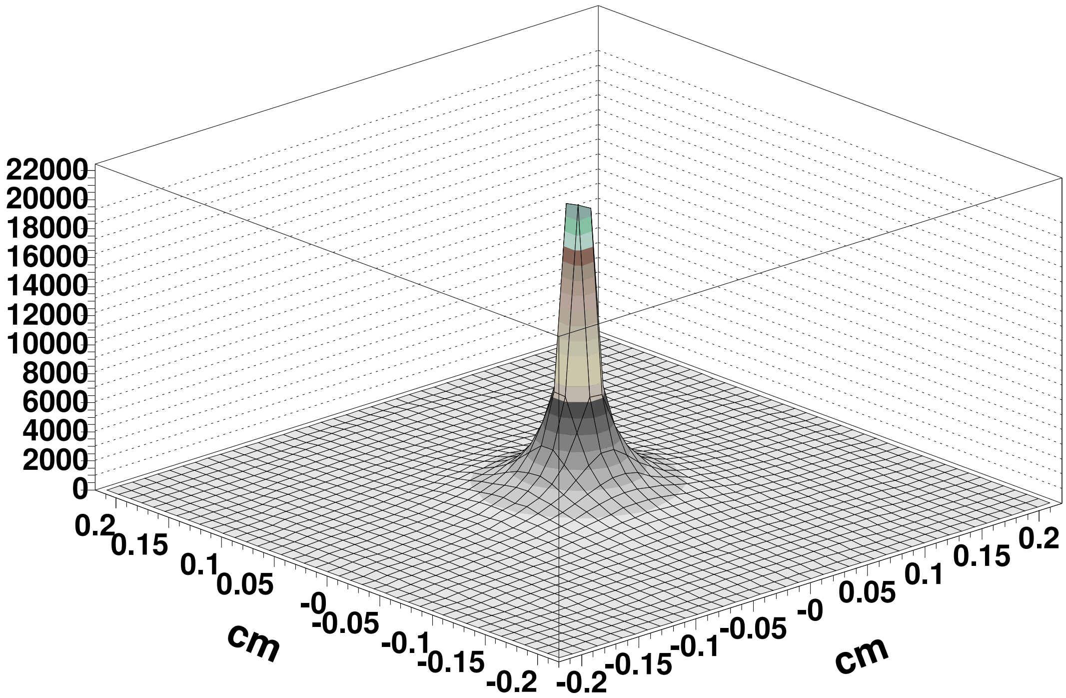
Number of $e^{\pm}$ remaining after a single two-photon event of various initial energies showers in various thicknesses of lead.

Width of Pb (radiation lengths)	Energy of Incident $e^{\pm}$ (GeV)	Number of Outgoing $e^{\pm}$ above 66 MeV
5	200 220 240	132 143 152
6	200 220 240	151 171 177
7	200 220 240	150 166 181
8	200 220 240	140 154 171
9	200 220 240	120 133 148
10	200 220 240	99 109 123

Spatial spread of the shower created by a single electron from a bremsstrahlung background process (E $\sim$ 5 GeV). Note that the plot is unnormalized.



Spatial spread of the shower created by an electron from a two photon event (E $\sim$ 220 GeV). Note that the plot is unnormalized.



Number of Cerenkov photons detected per one $e^{\pm}$ for various energies while traveling through the 30 cm, .1 atm nitrogen Cerenkov counter. This demonstrates that a typical two-photon event, showering in 8 radiation lengths of lead, will produce $\sim$ 80 photons. Here we have assumed a conservative photodiode detection efficiency of .5 for wavelengths between 3000 and 5000 angstroms.