L. Keller
3/18/02

Beam-Gas-Bremsstrahlung and Coulomb Scattering in the NLC Beam Delivery System

Conditions for Calculation:

1. Program is DECAY TURTLE modified for BGB and Coulomb scattering. Used at PEP-I, SLC, PEP-II, and PEP-N. Now called Lost Particle TURTLE (LPTURTLE).

2. BDS model is P. Raimondi, BDS112, with E_{beam} = 500 GeV.

3 Residual gas is 62% H_2, 22% CO, 16% CO_2 by pressure (L. Eriksson). This gives a radiation length of 771 m at 1 atm.

4. Start with P = 50 nTorr ==> Lrad = 1.17×10^{13} m, $N_{e-} = 1.4 \times 10^{12}$ / pulse train

5. LPTURTLE forces BGB and coulomb scattering uniformly along the 1433 m beam line.

6. Output histograms in PAW (T. Fieguth format, modified for NLC BDS). Make separate histograms for BGB electrons, BGB photons, and coulomb scattered electrons. All histograms are arbitrary units. Tables 1 and 2 are actual rates.

7. Apertures (radius):

Octupoles	0.8 cm, 1.0 cm	3 absorbers in FF	0.3-0.9 cm
Sextupoles	1.0 cm	Vertex detector	1.2 cm
Quadrupoles	1.0 cm, 2.0 cm	Energy slit	0.34 cm (1.7%)
Dipoles	5.0 cm	New coll. at Z=55m,	0.5 cm

Conditions for calculation (cont.):

8. Octupoles off, apertures in place.

9. “Final doublet” includes two quadrupoles, two sextupoles, one octupole. All final doublet apertures and 1st quadrupole in dump line are 1.0 cm radius.

Rough Estimate of Rates

BGB

N_{BGB}/pulse train = $t \ln(E_2/E_1) N_{e-}$,

where,

E_2 = maximum photon energy = E_{beam}

E_1 = minimum photon energy = 0.01 E_{beam}

t = # of radiation lengths in 1500 m beam line at 50 nTorr = $(1500/1.17 \times 10^{13}) = 1.28 \times 10^{-10}$ rl

$N_{e-} = 1.4 \times 10^{12}$ / pulse train

N_{BGB} = 825 electrons and photons/pulse train in the BDS

Coulomb Scattering

$$N_{coul} = 4.52 \times 10^{-11} P(\mathrm{Torr})\, N_{e-} (1/E_{beam})^2 (L_{beam})(1/\theta_{min}^2 - 1/\theta_{max}^2)$$

where,

$\Theta_{min} = 10^{-5}$ rad,

$\Theta_{max} = 2 \times 10^{-3}$ rad

E_{beam} = 500 GeV

L_{beam} = 1500 m

N_{coul} = 190 electrons/pulse train in the BDS, @ 500 GeV/electron

Rate Estimates for Other Processes
(ZDR and P. Tennenbaum, LCC Note 0051)

Inverse Compton Scattering from Thermal Photons

$N_{thermal}$/pulse train = $\sigma_T n_\gamma N_{e-} L_{beam}$,

where,

σ_T ($\Delta E > 0.01 E_{beam}$) $\approx$ 1.2 barns @ E_{beam} = 500 GeV

$n_\gamma \approx 20T^3$ γ/cm^3 = 5 x 10^8 γ/cm^3 , T = 300 K

N_{e-} = 1.4 x 10^{12} / pulse train

L_{beam} = 1500 m

$\langle E_\gamma \rangle$ = 0.07 ev @ T = 300 K

$N_{thermal}$ = 126 electrons/pulse train

Moller Scattering

N_{Moller} = 6.4 x 10^{-12} P(Torr) N_{e-} $(1/E_{beam})^2 (L_{beam})(1/\theta_{min}^2)$

(for small Θ_{min} and "NLC" gas)

where,

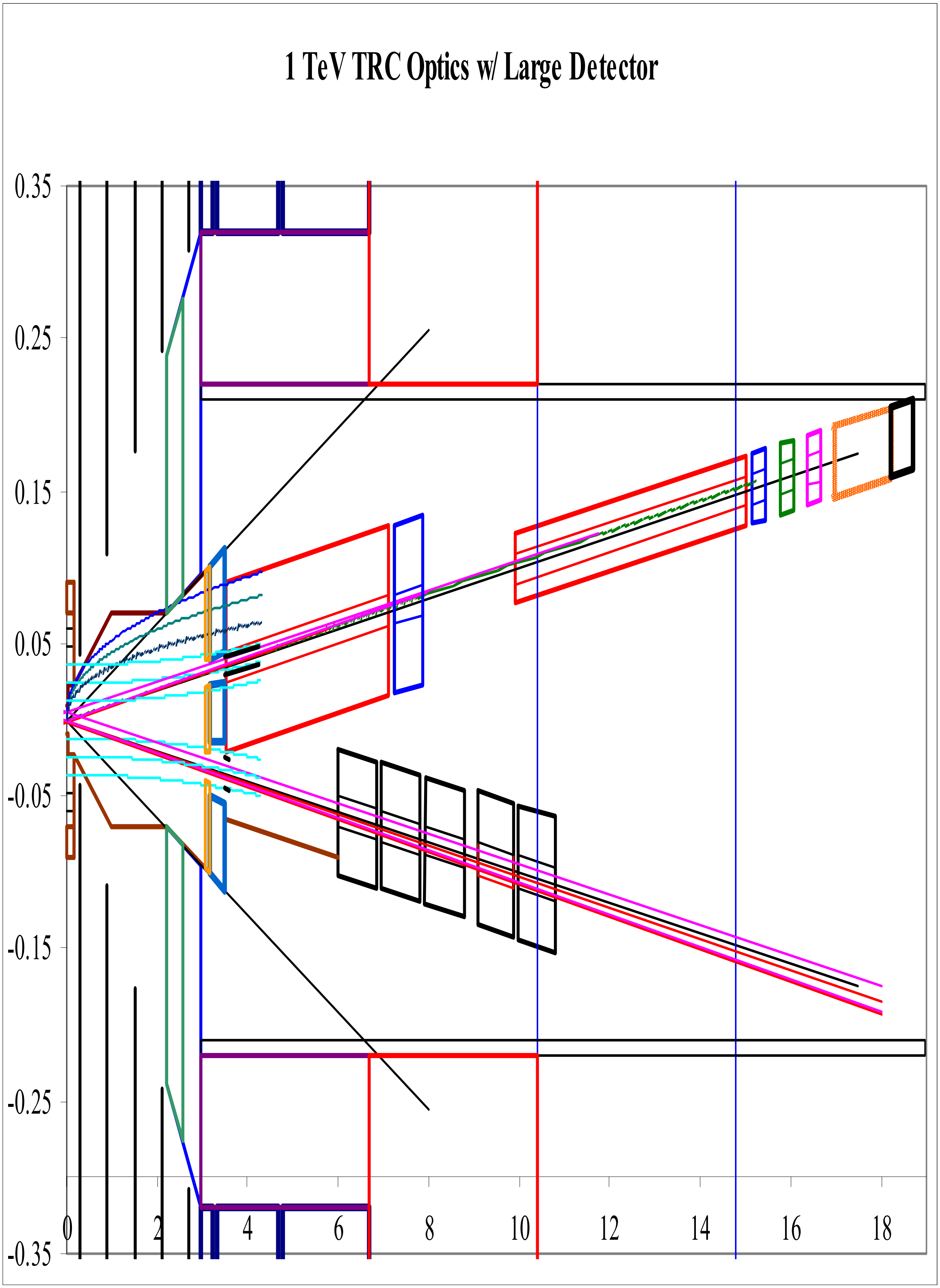
Θ_{min} = 10^{-5} rad,

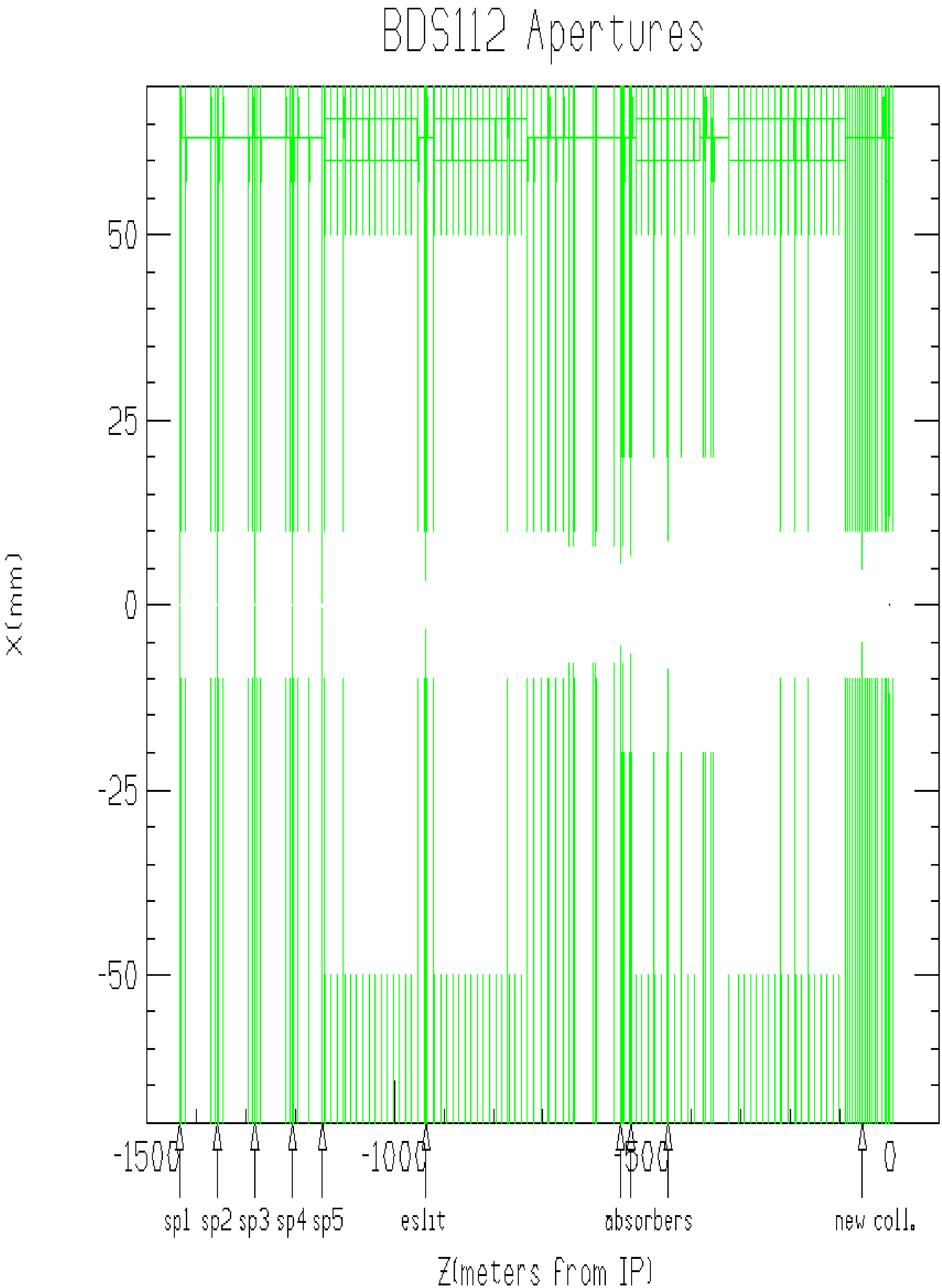
E_{beam} = 500 GeV

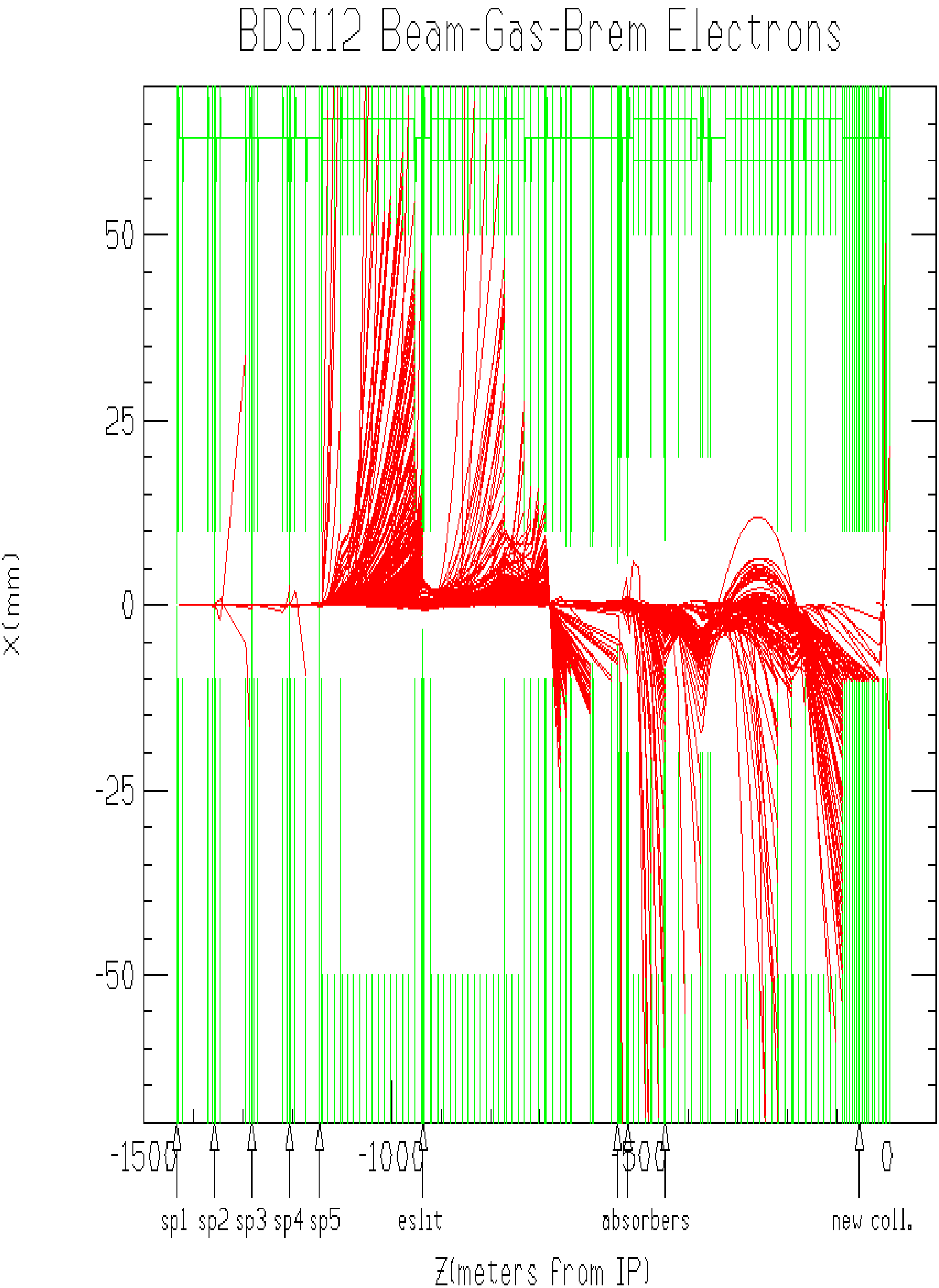
L_{beam} = 1500 m

N_{Moller} = 26 electrons/pulse train @ $\approx$500 GeV/electron

1-TeV Final Doublet with New Masks

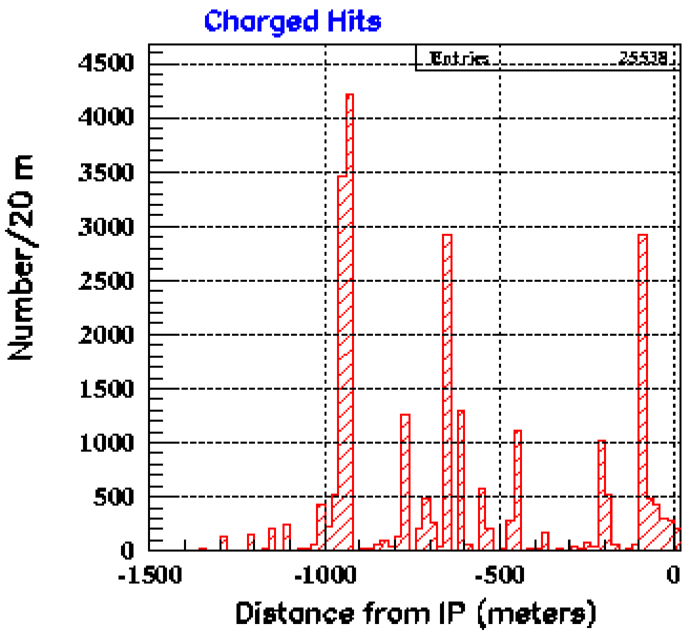


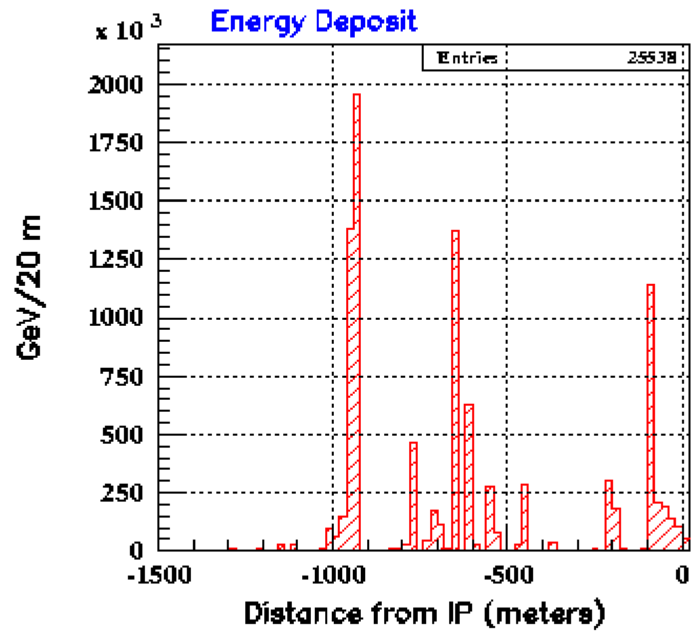

BDS112 Apertures
X(mm)
50
25
0
-25
-50
-1500
-1000
-500
0
sp1
sp2
sp3
sp4
sp5
eslit
absorbers
new coll.
Z(meters from IP)

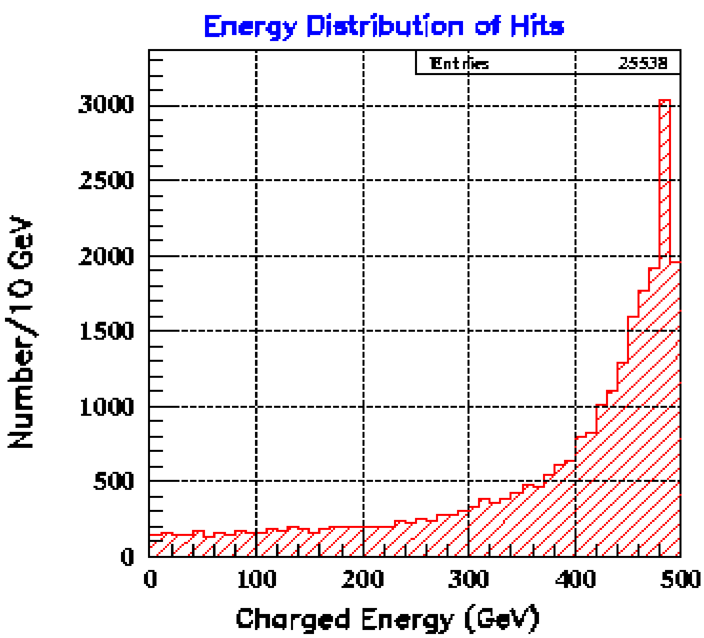


BDS112 Beam-Gas-Brem Electrons
X(mm)
50
25
0
-25
-50
-1500
-1000
-500
0
sp1
sp2
sp3
sp4
sp5
eslit
absorbers
new coll.
Z(meters from IP)

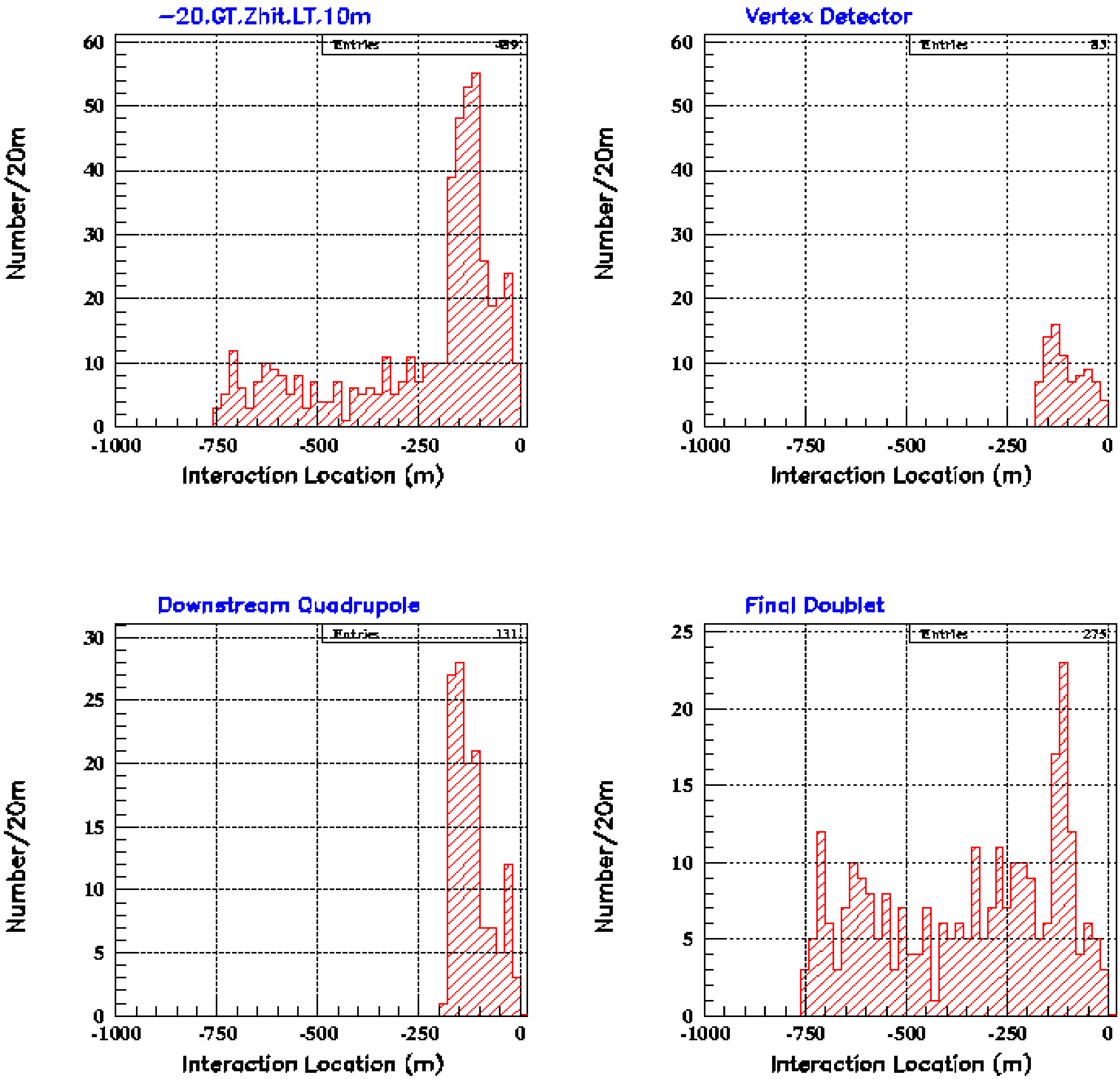
1 NLC BGB Charged Hits and Energy Deposited vs Z, BDS112



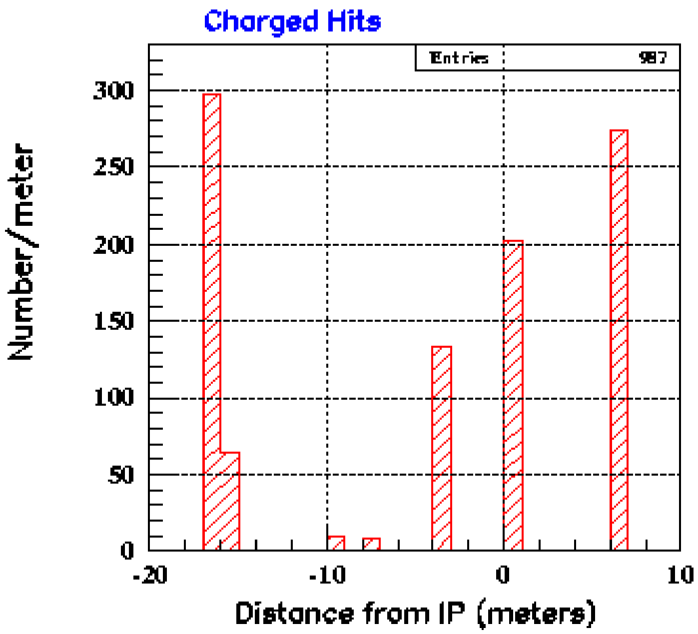


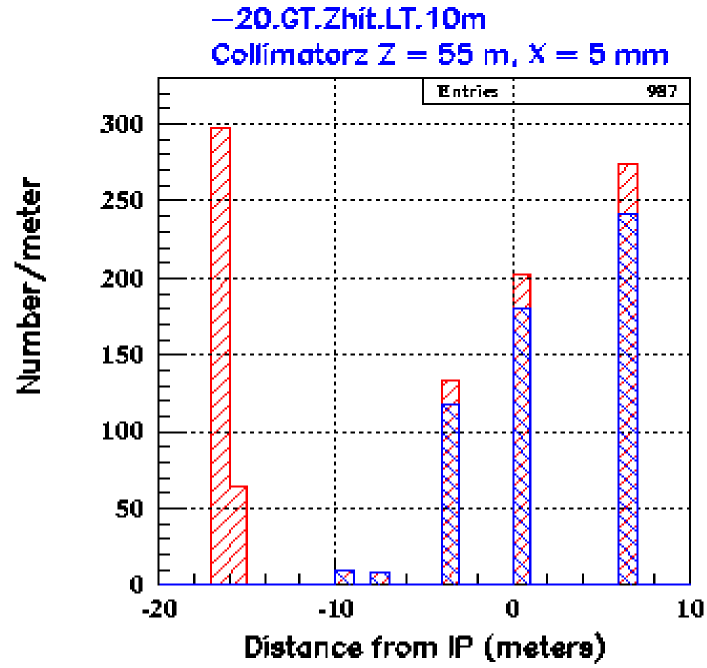


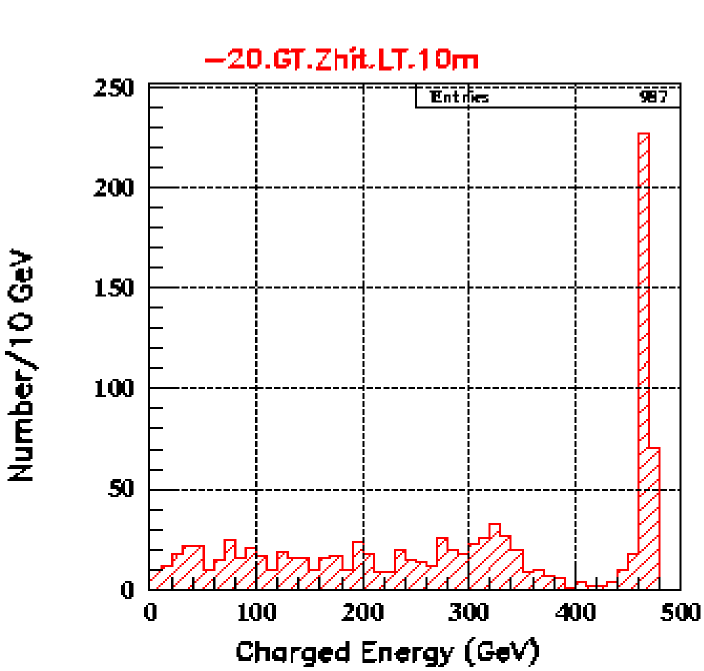
2 NLC BGB Interaction Locations for Hits Near IP, BDS112

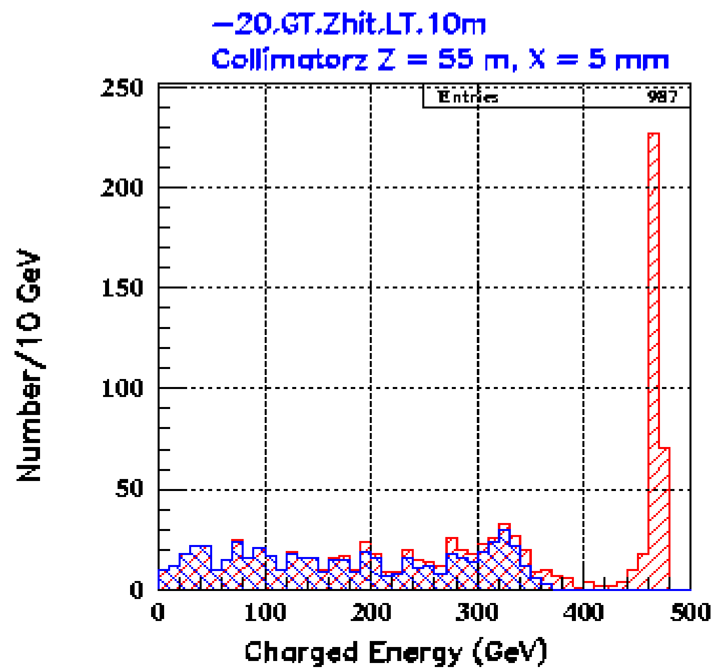


4 NLC BGB Charged Hits and Energy Distribution Near IP, BDS112

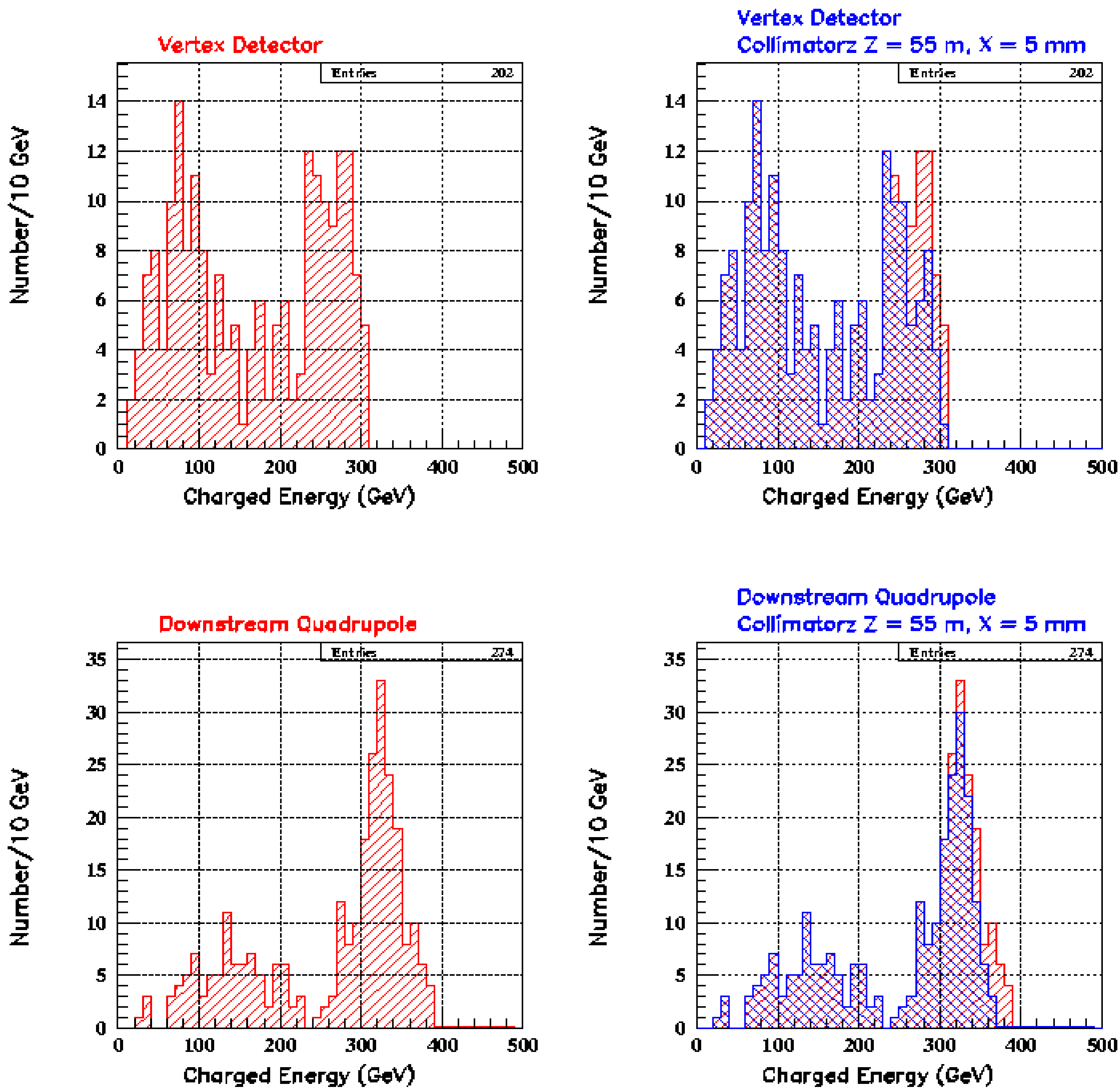




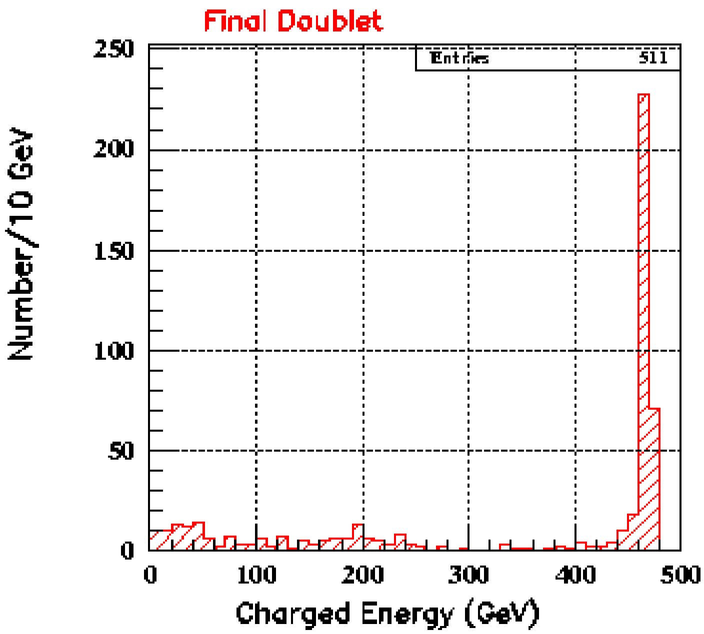


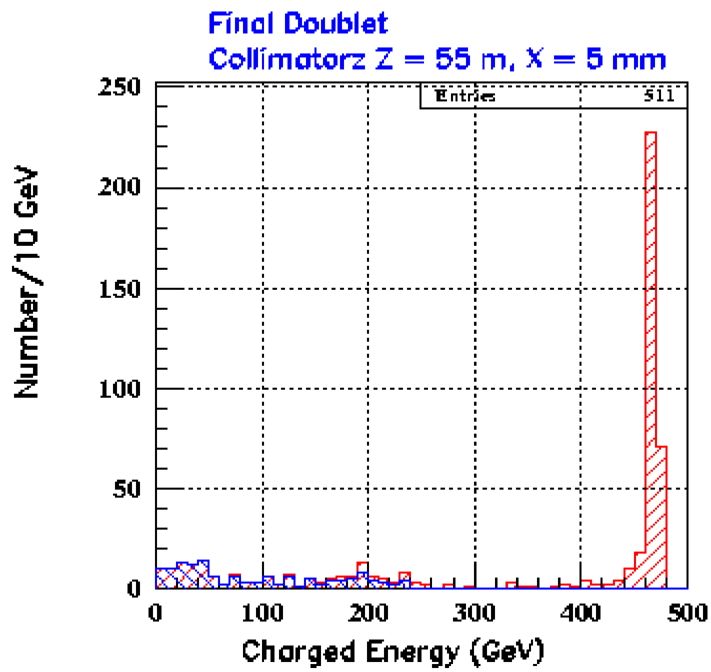


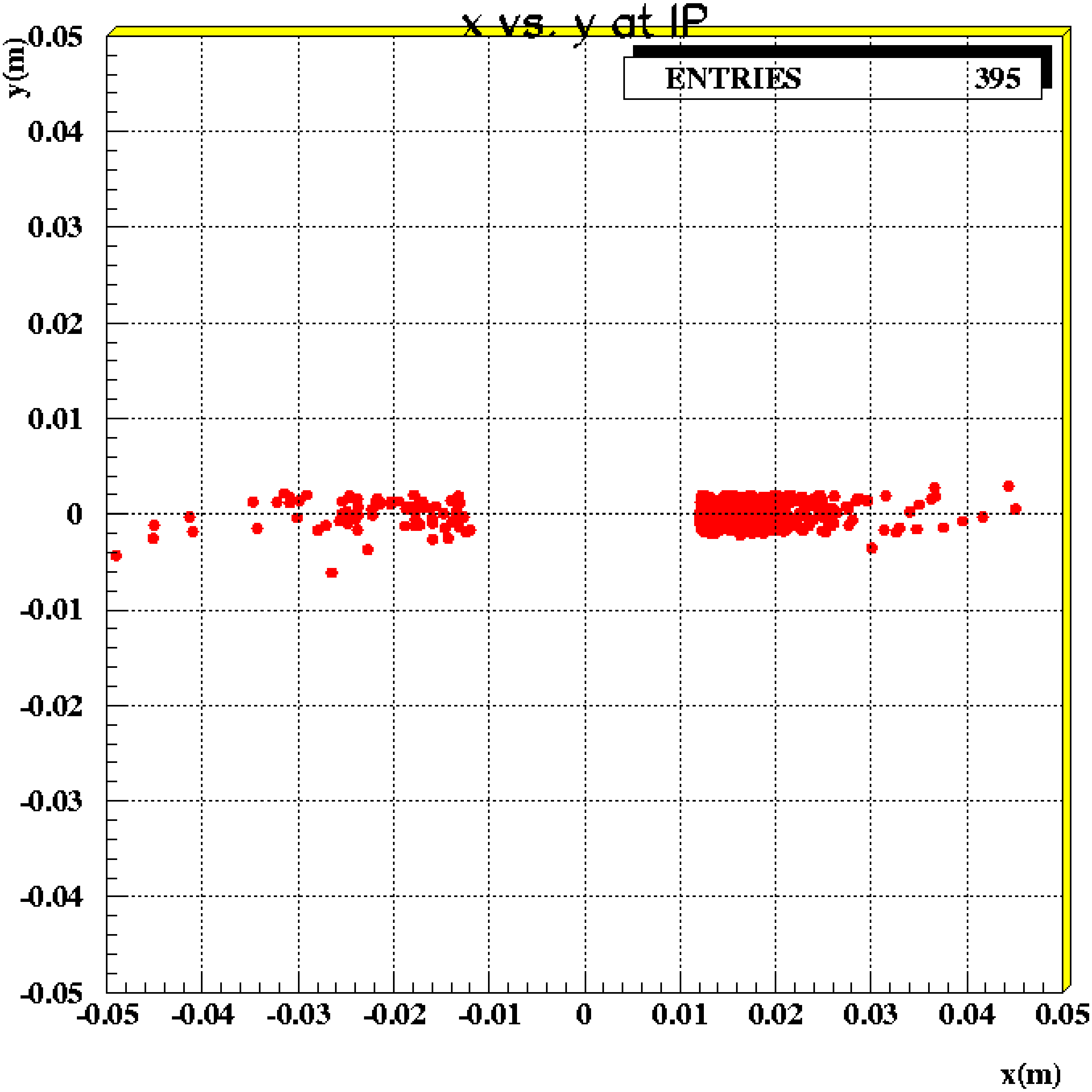
5 NLC BGB Energy Distribution Near IP, BDS112

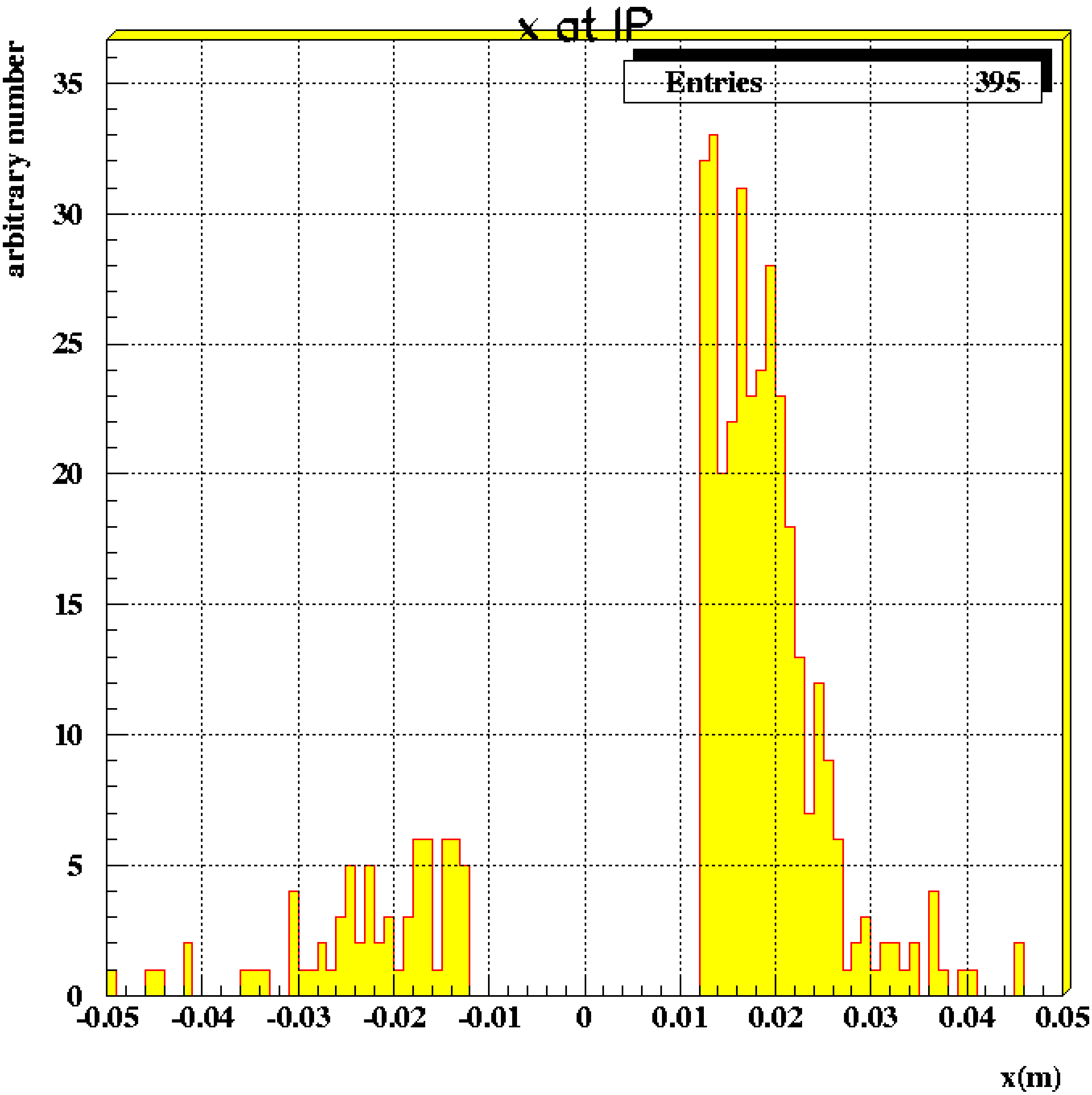


6 NLC BGB Energy Distribution Near IP, BDS112

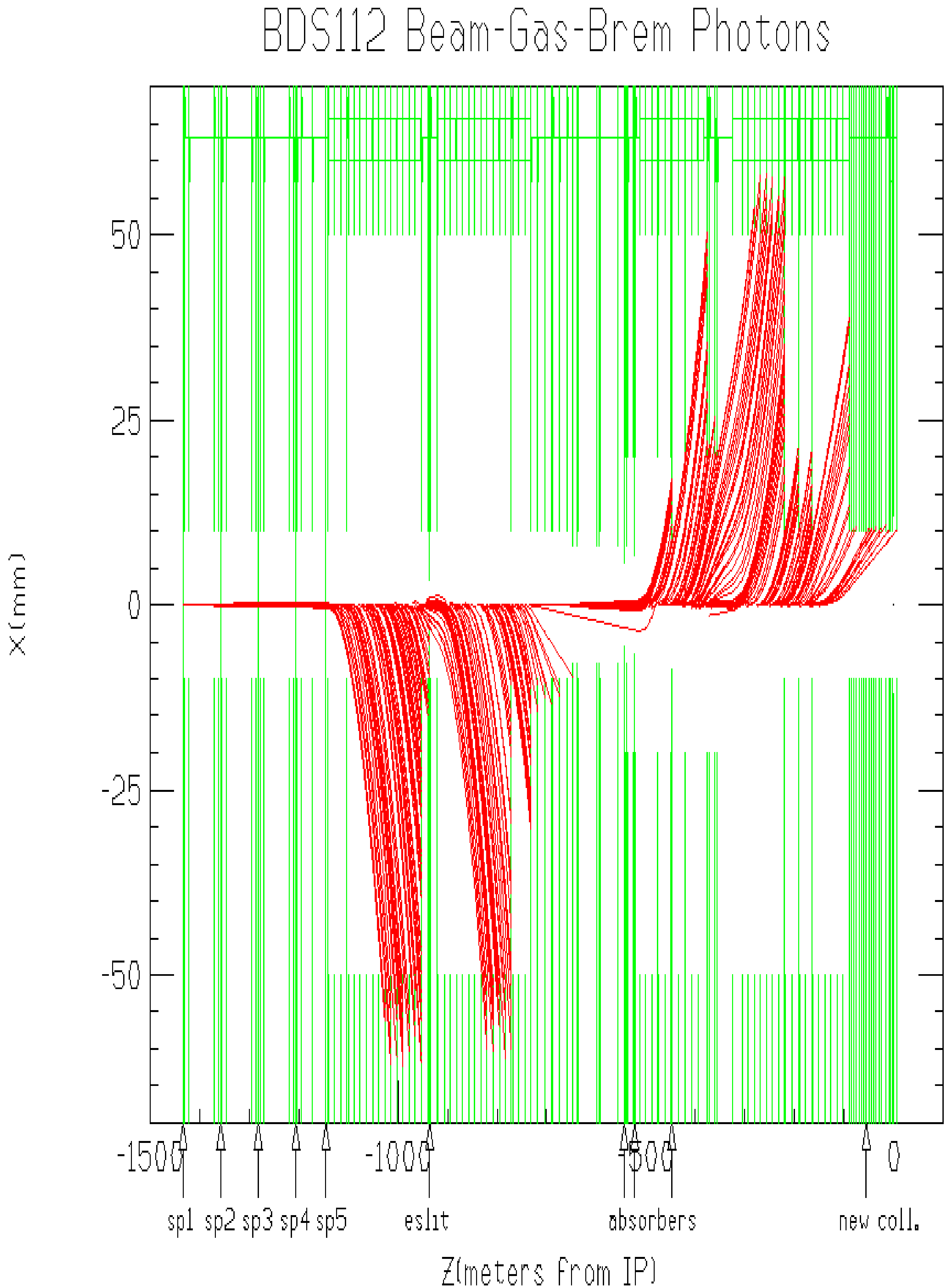




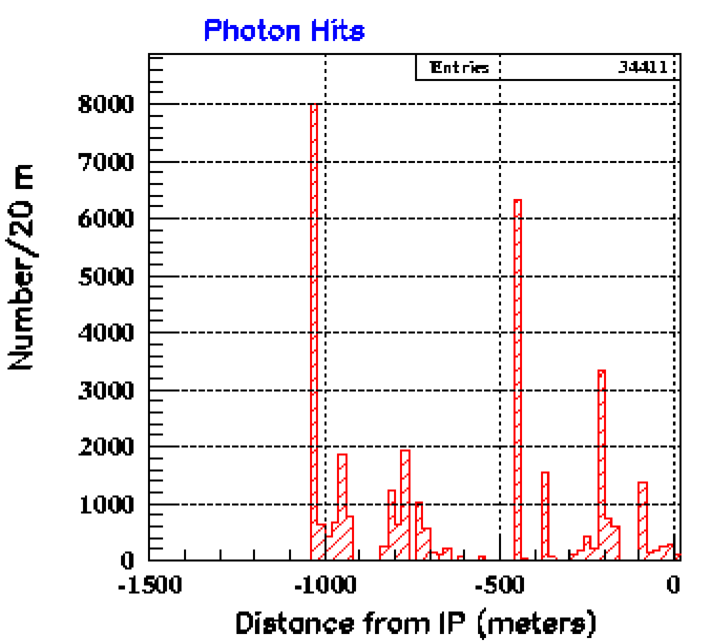

x vs. y at IP
ENTRIES 395
y(m)
0.05
0.04
0.03
0.02
0.01
0
-0.01
-0.02
-0.03
-0.04
-0.05
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05
x(m)

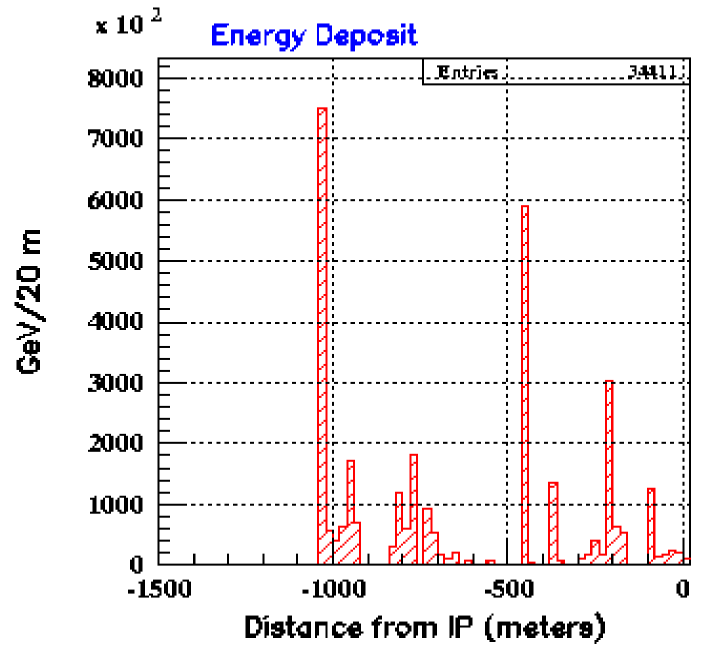


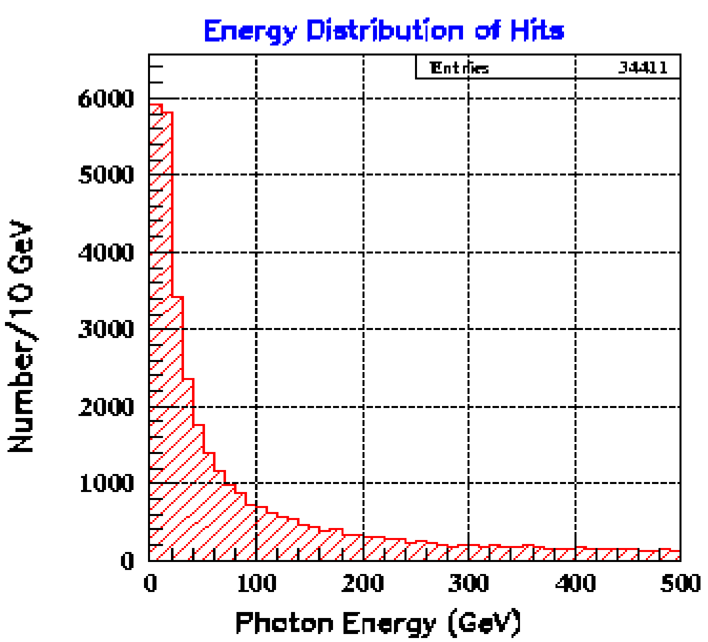
x at IP
Entries 395
arbitrary number
x(m)
0
5
10
15
20
25
30
35
-0.05
-0.04
-0.03
-0.02
-0.01
0
0.01
0.02
0.03
0.04
0.05


BDS112 Beam-Gas-Brem Photons
X(mm)
50
25
0
-25
-50
-1500
-1000
-500
0
sp1 sp2 sp3 sp4 sp5
eslit
absorbers
new coll.
Z(meters from IP)

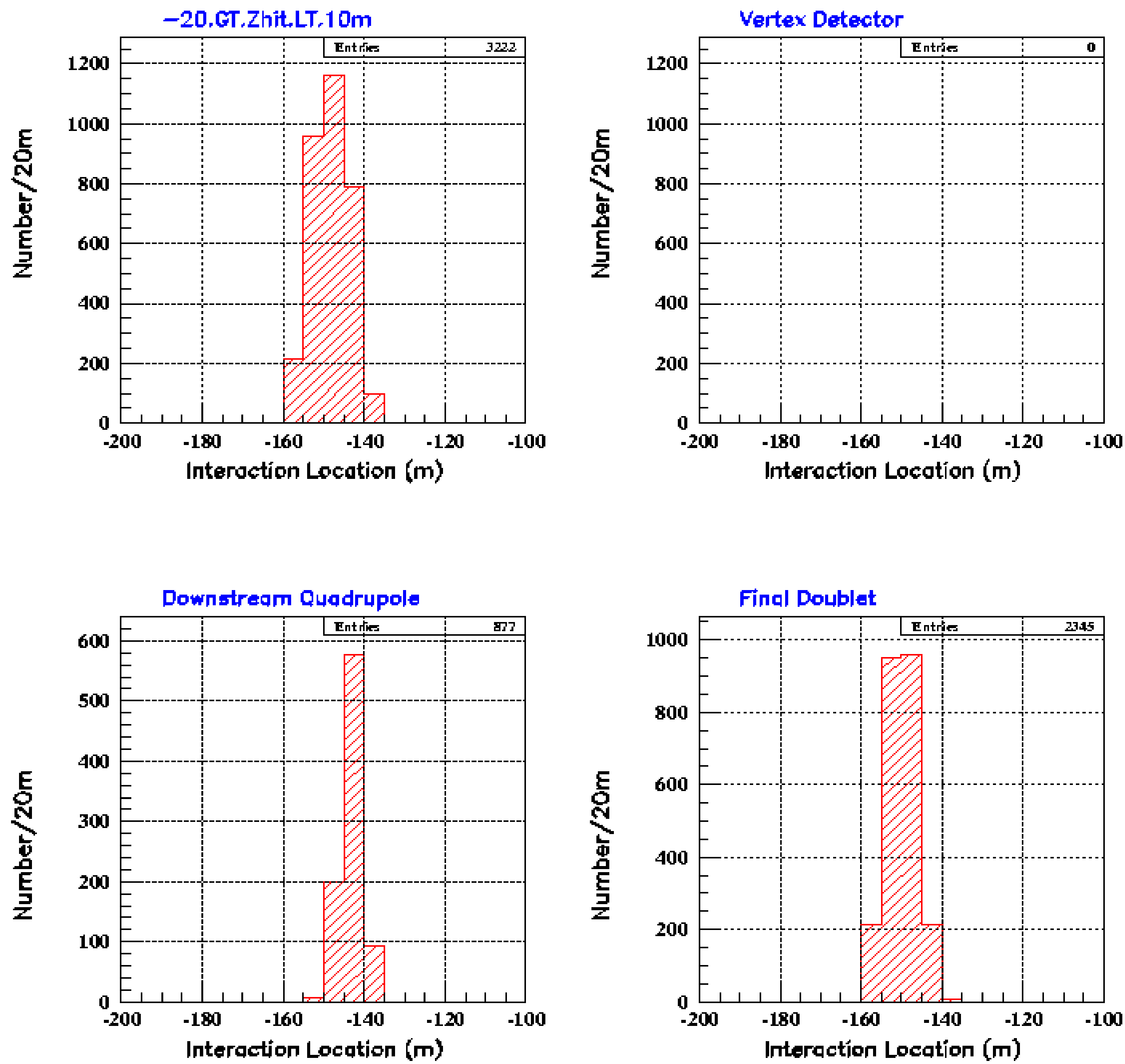
1 NLC BGB Photon Hits and Energy Deposited vs Z, BDS112



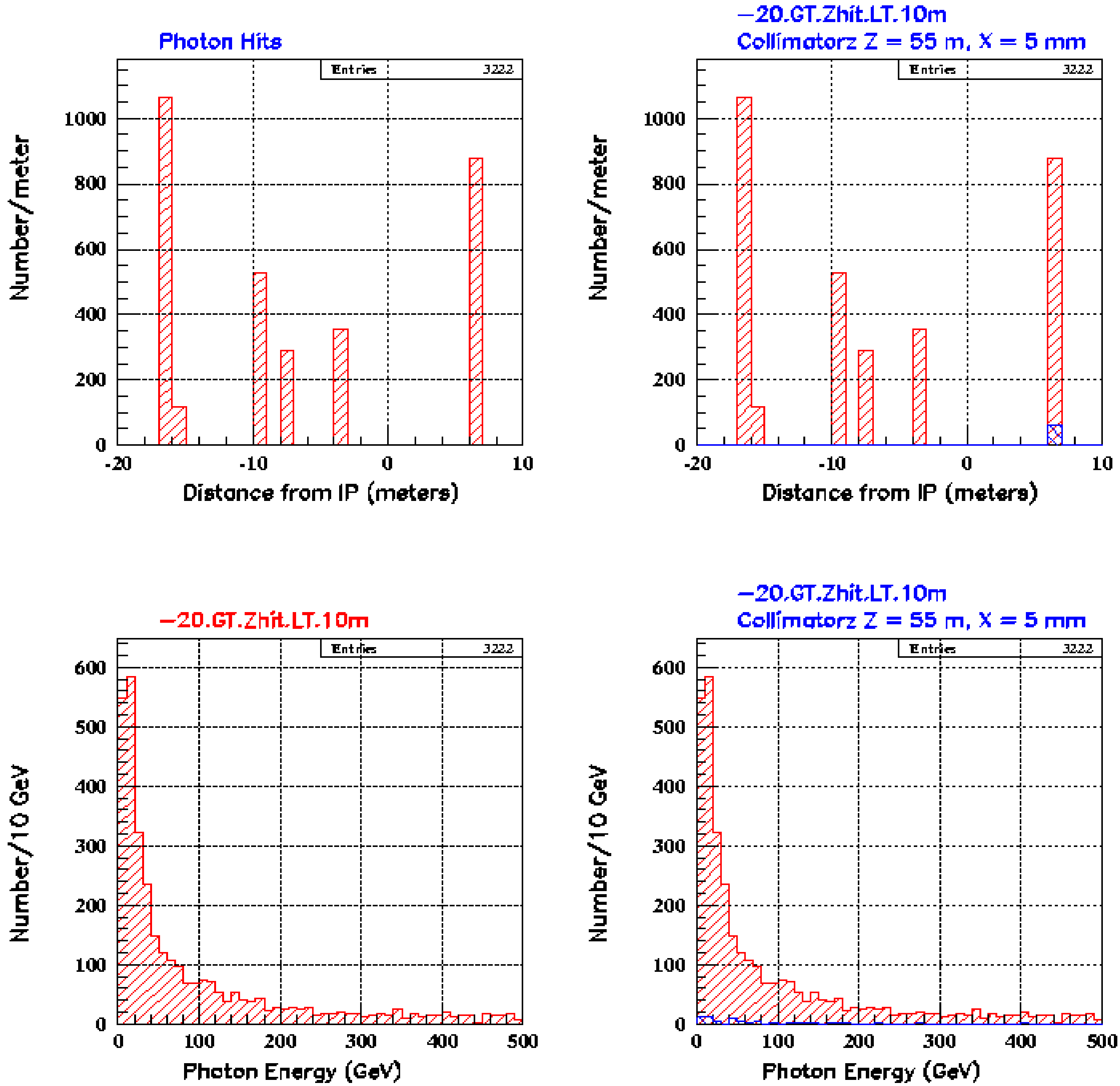


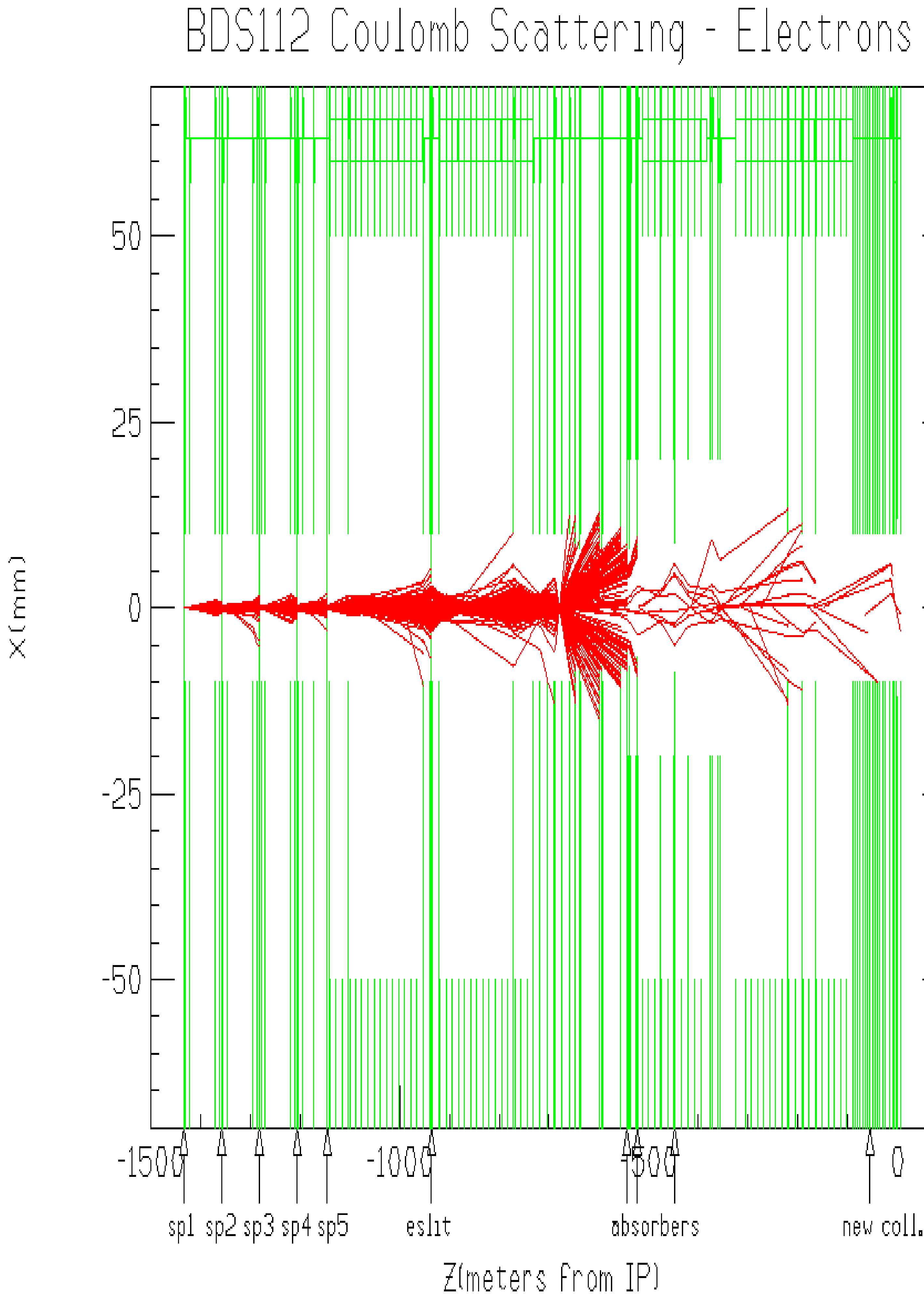


2 NLC BGB Interaction Locations for Photon Hits Near IP, BDS112



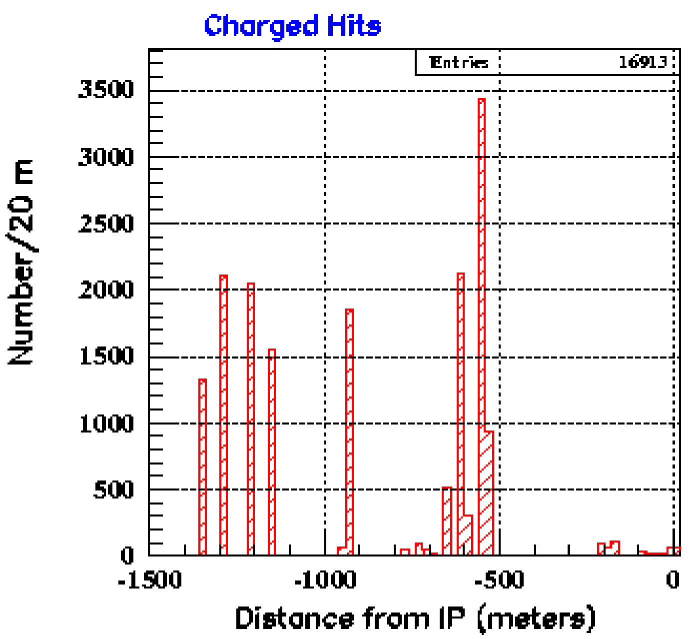
4 NLC Photon Hits and Energy Distribution Near IP, BDS112

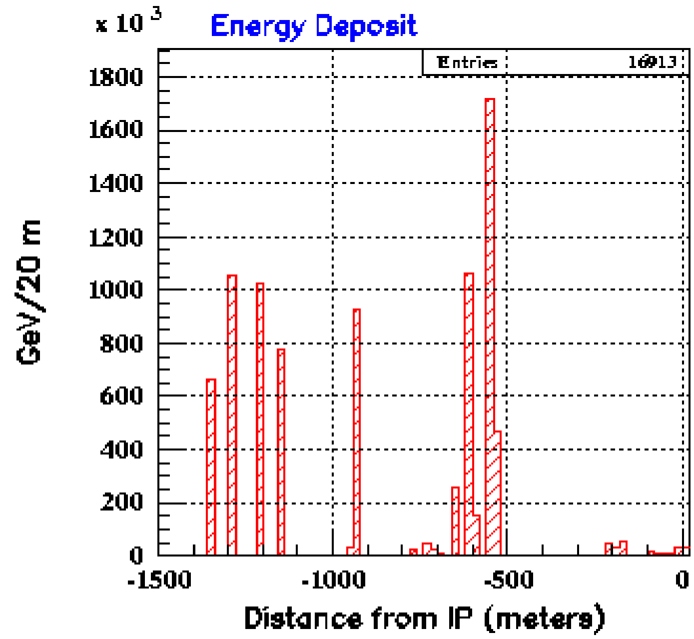


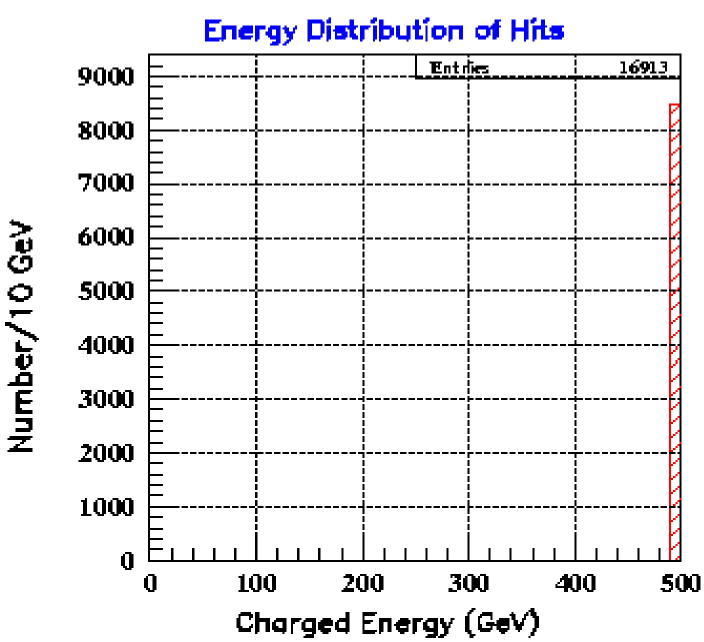


BDS112 Coulomb Scattering - Electrons
X (mm)
50
25
0
-25
-50
-1500
-1000
-500
0
sp1 sp2 sp3 sp4 sp5
eslit
absorbers
new coll.
Z(meters from IP)

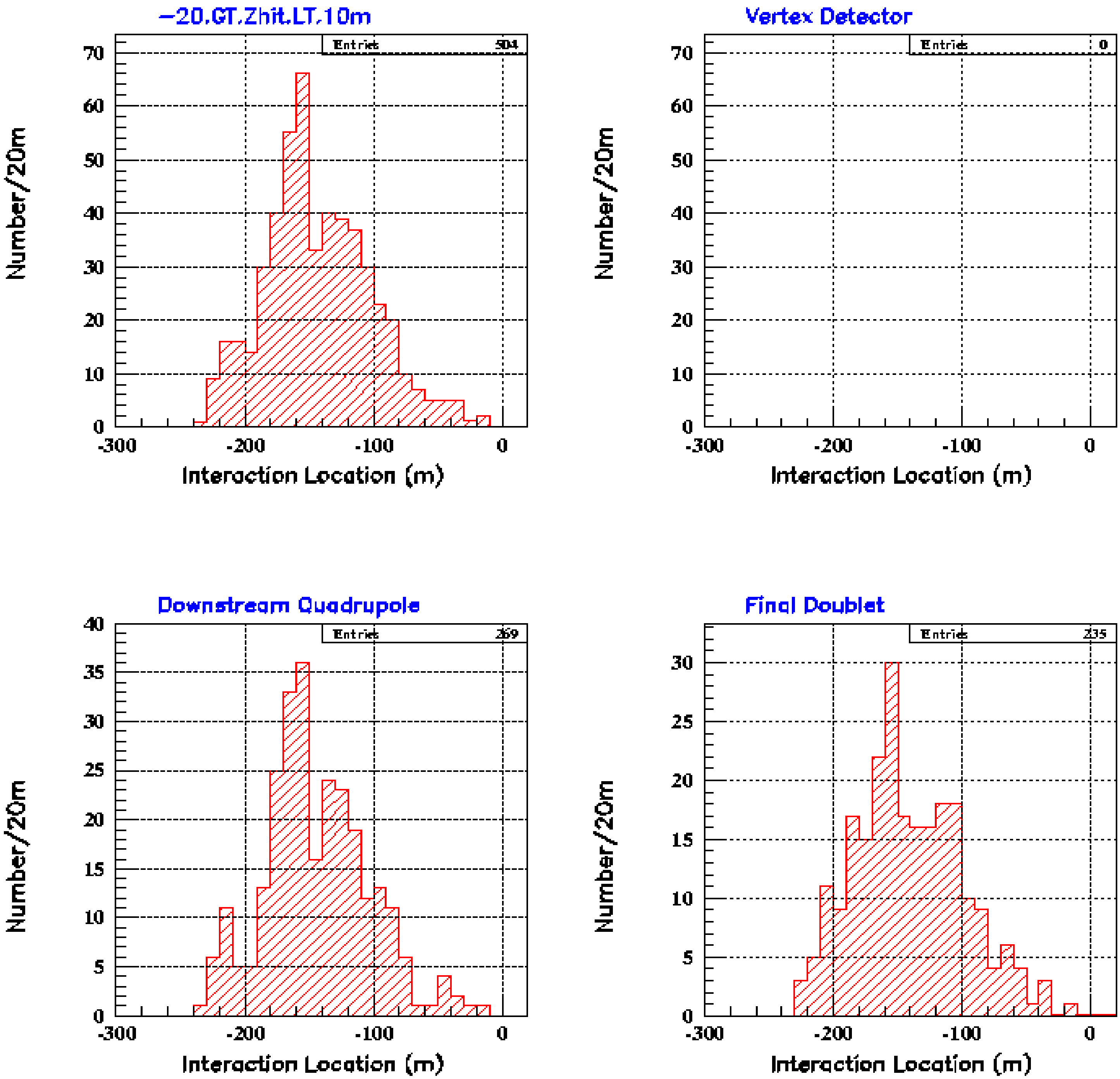
1 NLC Coulomb Hits and Energy Deposited vs Z, BDS112



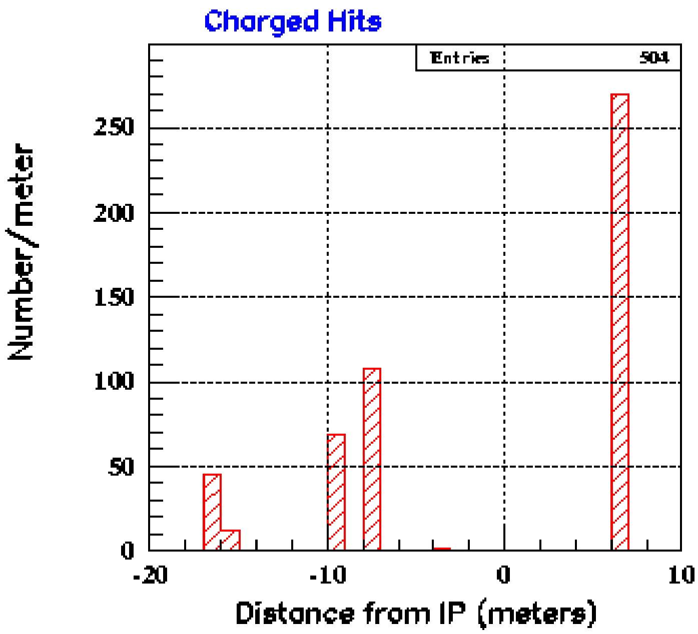




2 NLC Coulomb Interaction Locations for Hits Near IP, BDS112



4 NLC Coulomb Hits Near IP, BDS112



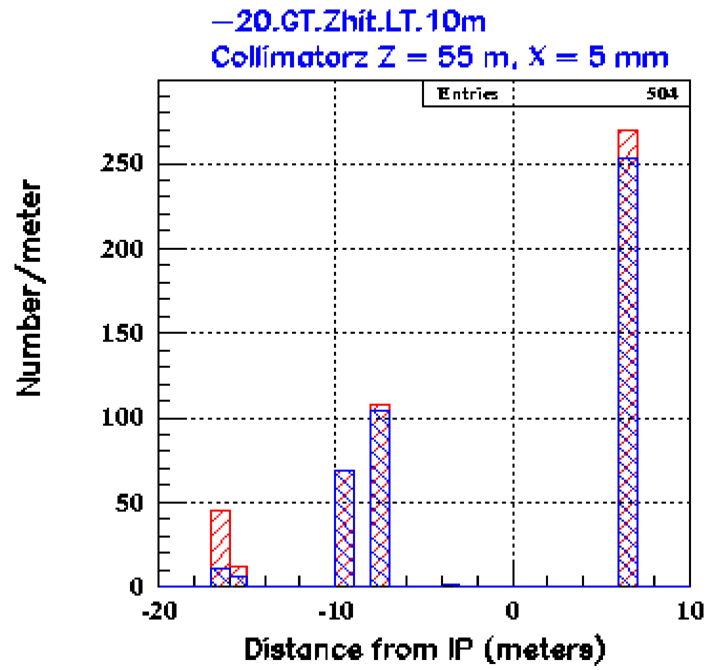


Table 1. Hits and Energy Deposited Near IP (per pulse train)

No new collimator for BGB
P = 50 nTorr

Hit Location	BGB charged		BGB photons		Coulomb Scattering		All lost particles	
	N	E_{dep} (GeV)	N	E_{dep} (GeV)	N	E_{dep} (GeV)	N	E_{dep} (GeV)
Downstream Quad	3.8	1000	2.3	206	0.31	50	6.4	1356
Vertex Detector 1.2 cm	2.8	470	0	0	0	0	2.8	470
QD0	1.8	210	0.9	77	0.01	~0	2.71	287
SD0	0.1	~0	0.7	69	0.12	60	0.92	129
QF1	0.2	~0	1.3	121	0.10	50	1.6	171
SF1	0.5	225	0.3	36	0.01	~0	0.81	261
Octupole (Z=16m)	4.3	2050	2.7	244	0.06	30	7.0	2324
							22.3	4998

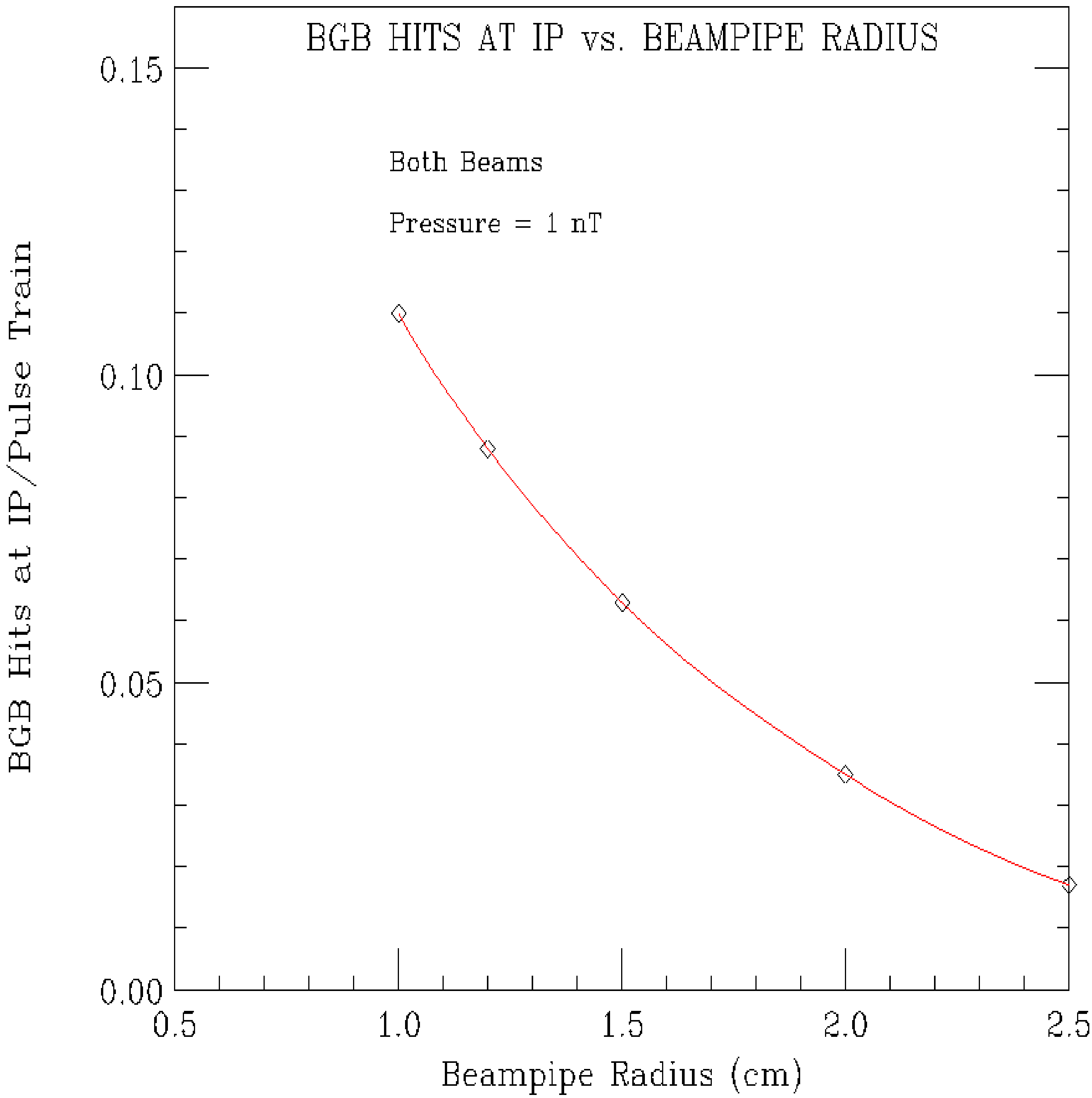
Table 2. Hits and Energy Deposited Near IP (per pulse train)

New horizontal collimator at 55m from IP, half-aperture = 0.5 cm
P = 50 nTorr

Hit Location	BGB charged N	BGB charged E_{dep} (GeV)	BGB photons N	BGB photons E_{dep} (GeV)	Coulomb Scattering N	Coulomb Scattering E_{dep} (GeV)	All lost particles N	All lost particles E_{dep} (GeV)
Downstream Quad	3.3	834	0.13	13	0.3	150	3.73	997
Vertex Detector 1.2 cm	2.5	360	0	0	0	~0	2.50	360
QD0	1.7	165	0	0	0.01	~0	1.71	165
SD0	0.1	~0	0	0	0.11	55	0.21	55
QF1	0.2	~0	0	0	0.10	50	0.30	50
SF1	0	0	0	0	0.01	~0	0.01	~0
Octupole (Z=16m)	0	0	0	0	0.01	~0	0.01	~0
							8.5	1627

Table 3. Compare Beam-Gas and e^+/e^- Pair Backgrounds

	NLC Beam-Gas-Brem, 1 nT			NLC e^+/e^- pairs			BaBar Beam-Gas-Brem, 1 nT
Hit Location	N #/PT	E_{ave} GeV/hit	E_{tot} Gev/PT	N #/PT	E_{ave} GeV/hit	E_{tot} Gev/PT	E_{tot} Gev/usec
Vertex Detector	0.10	150	15 ($1.8x10^3$ GeV/sec)	$2.9x10^4$	0.02	580 ($7x10^4$ GeV/sec)	10 ($1x10^7$ GeV/sec)
Lum. Monitor	0.15	270	40 ($4.8x10^3$ GeV/sec)	$1.3x10^7$	1.0	$1.3x10^7$ ($1.6x10^9$ GeV/sec)	


BGB HITS AT IP vs. BEAMPIPE RADIUS
Both Beams
Pressure = 1 nT
BGB Hits at IP/Pulse Train
0.15
0.10
0.05
0.00
0.5
1.0
1.5
2.0
2.5
Beampipe Radius (cm)

Compare NLC with TESLA TDR

TESLA TDR, p. IV-138:

$P = 5 \times 10^{-9}$ mbar (of CO) = 5×10^{-12} atm = 3.8 nTorr of CO

1 R.L. of CO = 304 m @ 1 atm,   (NLC used R.L. = 771 m @ 1 atm (different gas))

TESLA Result: "3×10^{-3} electrons/bunch crossing leave the beam pipe near the IP"
(no information about aperture and beam pipe sizes).

For a TPC with 55 μsec sensitive time (163 bunch crossings) this is
$(3 \times 10^{-3})163 = 0.5$/TPC sensitive time

Scale NLC Results to TESLA:

NLC = (8.5/pulse train) (3.8 nT/50 nT)(771/304)($2 \times 10^{10}/1.4 \times 10^{12}$)

= 23×10^{-3}/pulse train (NLC)   vs. 3×10^{-3}/bunch crossing (TESLA)

Why a factor of ≈ 8 different? Need to understand the TESLA result in detail to make sure we are comparing the same conditions. (If only NLC vertex detector hits are counted, the NLC/TESLA difference is only a factor of two.)

Summary and Conclusions

1. For a residual gas pressure of 50 nT get 8.5 hits/pulse train (1627 GeV) on apertures within ±15 m of the IP, and 2.5 hits/pulse train (360 GeV) on a 1.2 cm radius vertex detector. Rates are for each beam.

2. If the residual gas pressure was reduced to 1 nT in the last 250 m of the BDS, the above rates would be 0.2 and 0.05 hits/pulse train/beam respectively.

3. Adding a new collimator 55 m from the IP intercepts nearly all of the BGB photons and those BGB electrons which would otherwise have hit the outboard end of the final doublet

4. BGB hits in the vertex detector region are concentrated in the horizontal plane on on side of the IP beampipe. Increasing the beampipe radius from 1.0 to 2.0 cm eliminates about 2/3 of the hits in that region.

5. The energy/pulse train from BGB hits in the vertex detector region is about a factor of 40 less than the energy from e+/e- pairs for a 1 cm radius beampipe. However, the average energy/hit is 150 GeV for BGB and only 20 MeV/hit for e+/e- pairs.

6. There are not enough beam-gas-bremsstrahlung and coulomb scatters to cause a muon problem, even at 50 nT.

Future Work

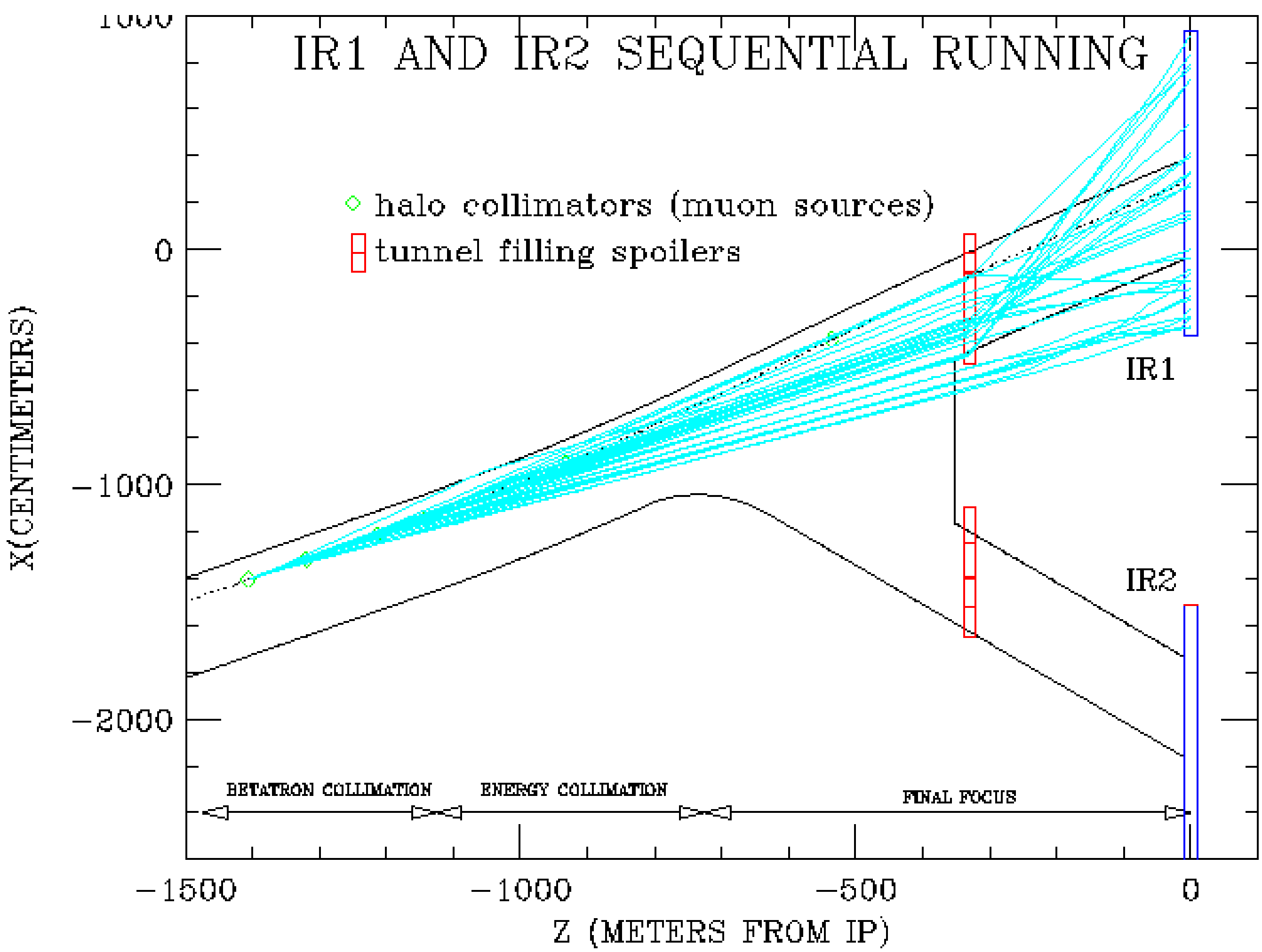
1. Use GEANT for a BGB calculation. Need to make the radiation length of the residual gas large enough to force a statistically significant number of interactions, but small enough to make secondary interactions negligible, probably about 1% r.l.

2. Find out the details of the TESLA BGB calculation and understand the difference between the NLC and TESLA results.

3. For input to the detector GEANT simulation, use LPTURTLE to write out ntuples for particles that hit the vertex detector and other objects near the IP.

4. Put beam-gas-bremsstrahlung, coulomb scattering, inverse Compton scattering, and Moller scattering in the new Woodley/Raimondi version of TURTLE.

5. Check trigger rate from electroproduction of hadrons off gas molecules near the IP.



IR1 AND IR2 SEQUENTIAL RUNNING
halo collimators (muon sources)
tunnel filling spoilers
IR1
IR2
BETATRON COLLIMATION
ENERGY COLLIMATION
FINAL FOCUS
X(CENTIMETERS)
Z (METERS FROM IP)
1000
0
−1000
−2000
−1500
−1000
−500
0