H.Burkhardt CERN-SL

Background from Beam Gas and Thermal Photon scattering

- Off momentum Background, Principle, Spectra
    - Beam Gas
    - Thermal Photon
    - rough estimate for TESLA
- Tracking Tools, Dimad
- Status

see also my contribution to Sitges, CERN-SL-99-057-AP
http://preprints.cern.ch/cgi-bin/setlink?base=preprint&categ=cern&id=sl-99-057
and G.von Holtey, A.H.Ball et al., NIM A 403 (1998) 205-246

Beam Gas scattering

energy spectrum

$$\frac{d\sigma}{dk} = \frac{A}{N_A X_0} \frac{1}{k} \left(\frac{4}{3} \quad \frac{4}{3} k + k^2 \right)$$

$k = E_\gamma / E_b$

k_{min}	$\int_{k_{min}}^{1} \frac{1}{k} \left(\frac{4}{3} \quad \frac{4}{3} k + k^2 \right) dk$
1 %	5.3
2 %	4.4
3%	3.9
10 %	2.3

rad. length $X_0 \sim A / Z (Z+1)$, $\sigma \sim Z (Z+1)$ or roughly $\sigma \sim Z^2$

$CO \approx N_2 \approx 50 \bullet H_2$

for N_2 ($\approx CO$) : $\frac{A}{N_A X_0} = 1.224$ barn

$\sigma = 6.5$ barn for 1% loss

(4.7 barn for 3%, 2.9 barn for 10 %)

Gas Pressure and Density:

$T = 23\ ^oC = 296.15$ K, $P_{gas} = 1n$ Torr $= 1.33\ 10^{-7}$ Pa

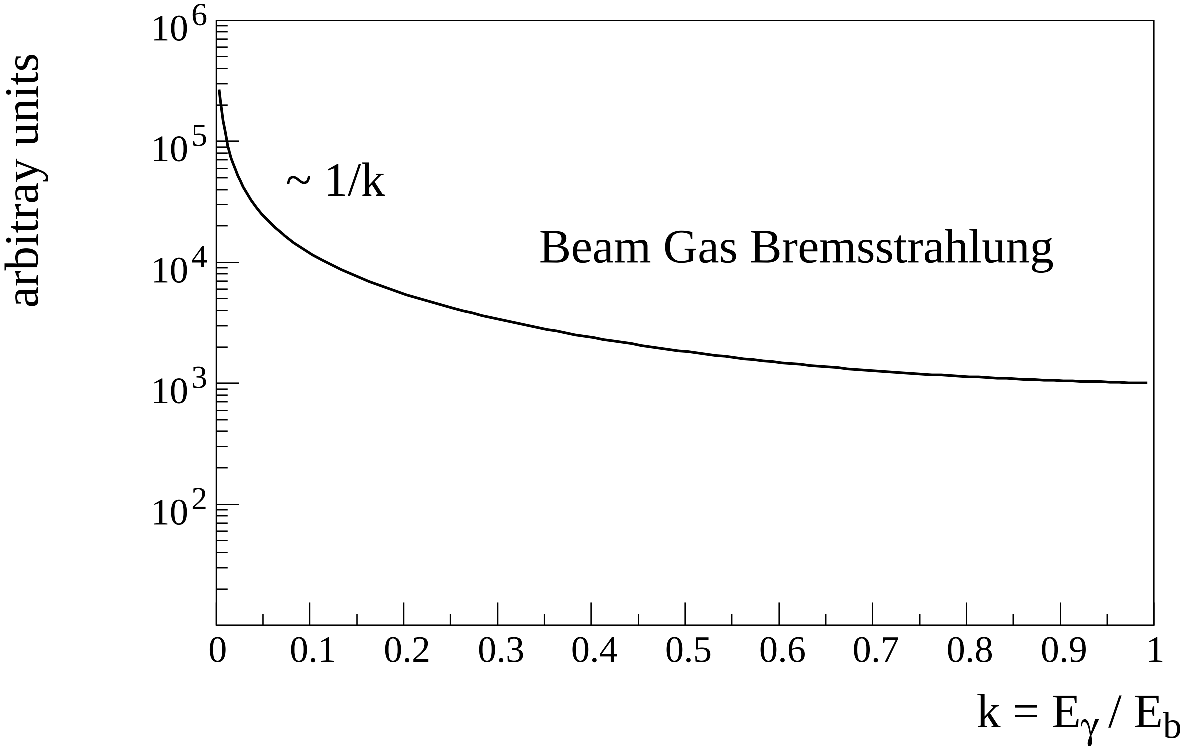
$\rho = P_{gas} / kT = 3.26\ 10^{13}$ molecules / m^3

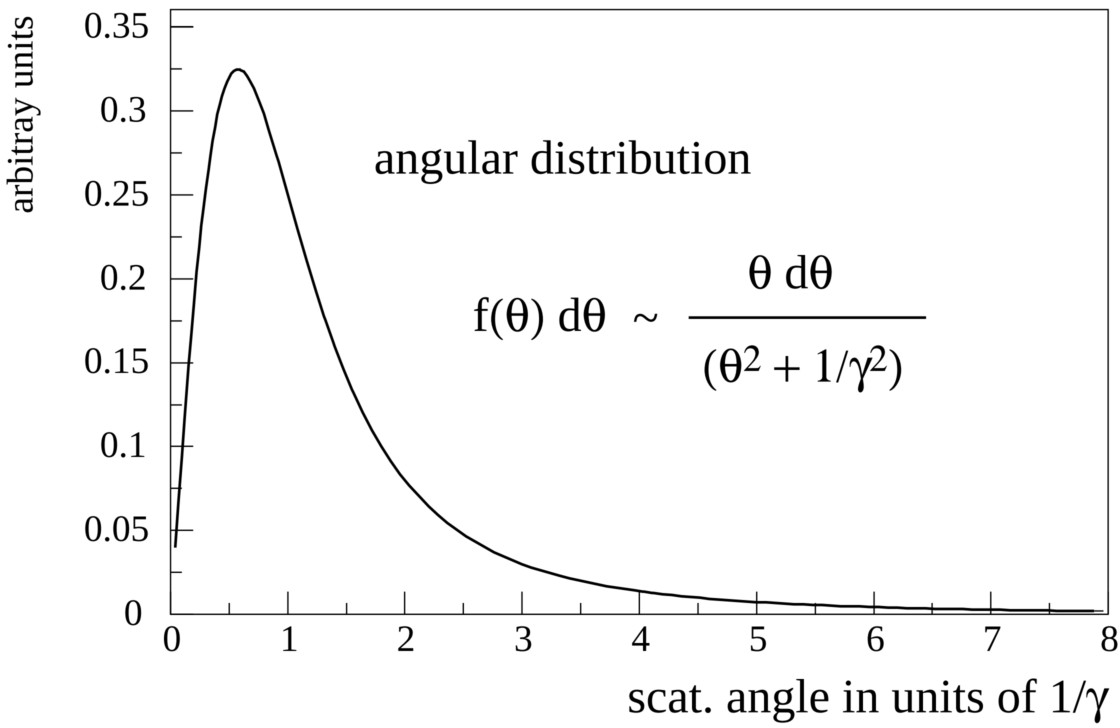
scattering probability with over 1 % eloss = $\rho \bullet \sigma = 2.1 \bullet 10^{-14}$ / m

TESLA 500 GeV, 1000 m length (~ dist Coll. section to IP)

$2 \bullet 10^{10}$ particles : 0.42 off. mom. electrons/bunch with > 1 % loss

0.18 with > 10 % loss

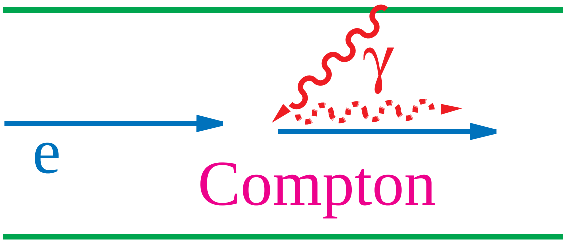




peaked at $1/\gamma$ or 2 μrad at 250 GeV, ~ negligible

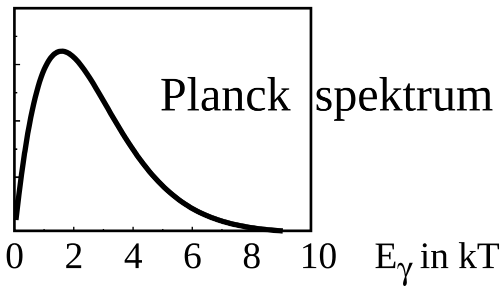
Compton Scattering on Thermal Photons

24^{o}C beam Pipe black body radiator



$\gamma_{LEP2} \approx 2 \cdot 10^5$

$\gamma_{250\ GeV} \approx 5 \cdot 10^5$ for Tesla



mean energies:

initial : $E_\gamma^i = \ 2.7\ kT = 0.07$ eV

e-rest: $E_\gamma = \gamma E_\gamma^i = 6.2$ keV $<< m_e$ — Compton

$\cong E'^{*}_{\gamma\, scat.}$ ~ elastic, Thomson, .67 barn

Lab: $E'_\gamma = \gamma E_\gamma^{*} \cong \gamma^2 E_\gamma^i$

~ 2.4 % E_b 100 GeV (LEP2)

~ 5.3 % E_b 250 GeV (Tesla)

effect in LEP:
particles with more than ~ 1.2% Δp/p get lost (Rf-bucket)
up to 3% Δp/p travelling through arcs, halo / tails
major Background source at low angles
(~ $3 \cdot 10^4$ el./ sec hitting LEP-lumi calorimeters)

detailed Monte Carlo Simulation, event-
generator Planck+Compton (H.B. SL/Note 93-73)
+ tracking through LEP lattice, tail simulation (PAC 1997, CERN SL-99-068 OP)

see my homepage http://home.cern.ch/hbu/ and http://home.cern.ch/hbu/lifetime/lifetime.html

tesla/Padova/thermal.eps

Compton Scattering on Black Body Radiation

LEP:
Observed single beam lifetime (40-70 h) dominated by Compton scattering off thermal photons

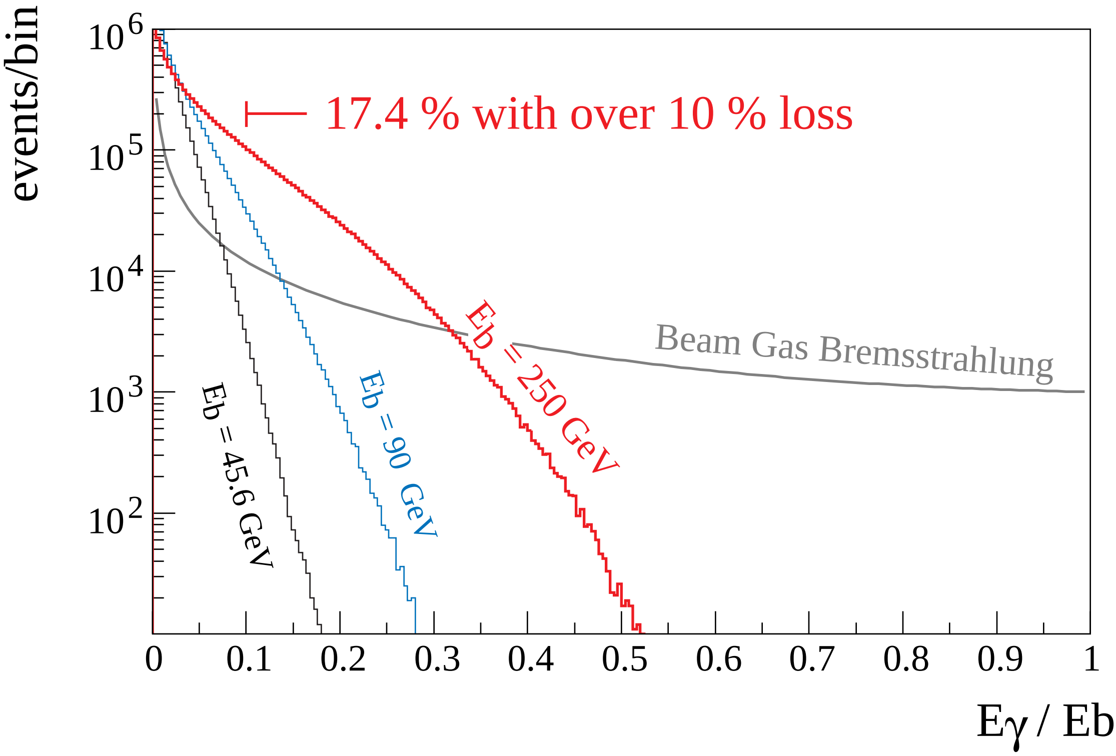
Beam pipe at room temperature ~ 24°C
Photon density from Planck black body radiation:

$$\rho_\gamma = 8\pi \left(\frac{kT}{hc}\right)^3 \cdot \underbrace{\int_0^\infty \frac{x^2}{e^x - 1} dx}_{2\,\xi(3) \approx 2.404} = 5.3 \cdot 10^{14} \ / \mathrm{m}^3$$

V.I. Telnov, NIM A260 (1987) 304-308
idea inspired by γγ-collider, known prev. in astrophysics
Compton Scattering on light from Stars, Feenberg, Primakoff Phys.Rev. 73 (1948) 449
3 K radiation, J.Felten, Phys.Rev. Lett. 15 (1965) 1003

First direct observation of thermal-photon scattered electrons and measurement of energy spectrum in LEP: A.C.Melissinos:
Dehning et al. Phys.Rev.Lett. B 249 (1990) 145.

Spectra and Normalization



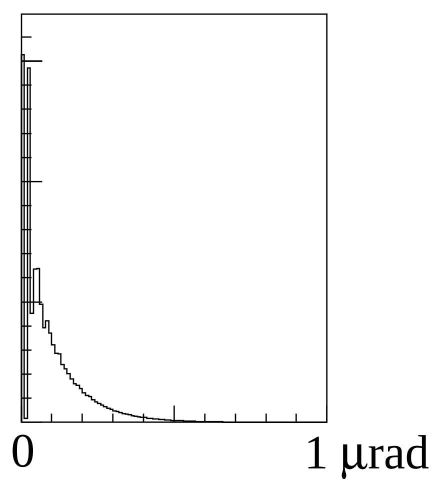
beam lifetime if all scattered particles were lost

$$\tau_{min} = \frac{1}{\rho_\gamma \; c \; \sigma_T} = 26.17 \text{ hours}$$

LEP2, Δp/p accept (RF-bucket) ~1.2 %,
about half of scatt. particles lost -> τ = 55 hour

electron scattering angle
in Lab:

~negligible (~independent of E_b)



tesla/Padova/thermal3.eps

Bkg from thermal photons

cross section:

$\sigma_T = 8\pi/3\ r_e^2 = 0.6652$ barn

at 250 GeV $\sigma = 0.89 \cdot \sigma_T = 0.59$ barn

Photon density at room temperature (24^{o}C) $\rho\gamma = 5.32 \cdot 10^{14}$ /m^3

scat. prob = $3.14 \cdot 10^{-14}$ / m

for bunch of $2 \cdot 10^{10}$ over 1000m : 0.63 Compt. scatt. / bunch

Δp/p	fraction	
0 - 1 %	26 %	(or 74.3 % > 1 %) loss
1 - 2 %	14 %	tail particles
2 - 5 %	24 %	
5 - 10 %	19 %	more locally lost
> 10 %	17 %	

such that for a bunch of $2 \cdot 10^{10}$ particles/bunch, over 1000 m
number of Compt scatt. per bunch:

0.46 with $\Delta p/p >$ 1 %

0.32 with $\Delta p/p >$ 3 %

0.11 with $\Delta p/p >$ 10 %

similar to Bremsstrahlung on 1 nTorr

tesla/Padova/ThermEstim.eps

Rough estimate Beam-Gas + Thermal

wanted (number of off. particle hits / bunch), not much more than

O(1%) in detector (> 20 mrad, to allow veto for searches and good lumi meas.)

and not much more hitting within ~100 m around IP (γ's from shower)

expectations for a bunch of
$2 \cdot 10^{10}$ particles and production over 1000 m:

Beam Gas Bremsstr.:
1 nTorr CO : 0.42 / bunch with >1% loss (.2 for >10%)

of which roughly

~ 1/5 hitting last 200 m 0.08/ bunch
~ 1/10 hitting detector 0.01 / bunch

+ about the same from Compton scattering on thermal Photons
or together about 0.02 / bunch

aim for vacuum of 1 nTorr CO or N_2 (or $.5 \cdot 10^{-7}$ H_2)

Tracking Tools, DIMAD

The properties of off-momentum particles can be quite accurately predicted by using tracking programs like
DIMAD

DIMAD: (my) Beam Gas and Thermal Photon codes have been implemented.
Gave good results in LEP (both for experimental backgrounds and non-Gaussian tails)

Some prelim. results obtained for TESLA BDS version 6 and some tests done for version 8

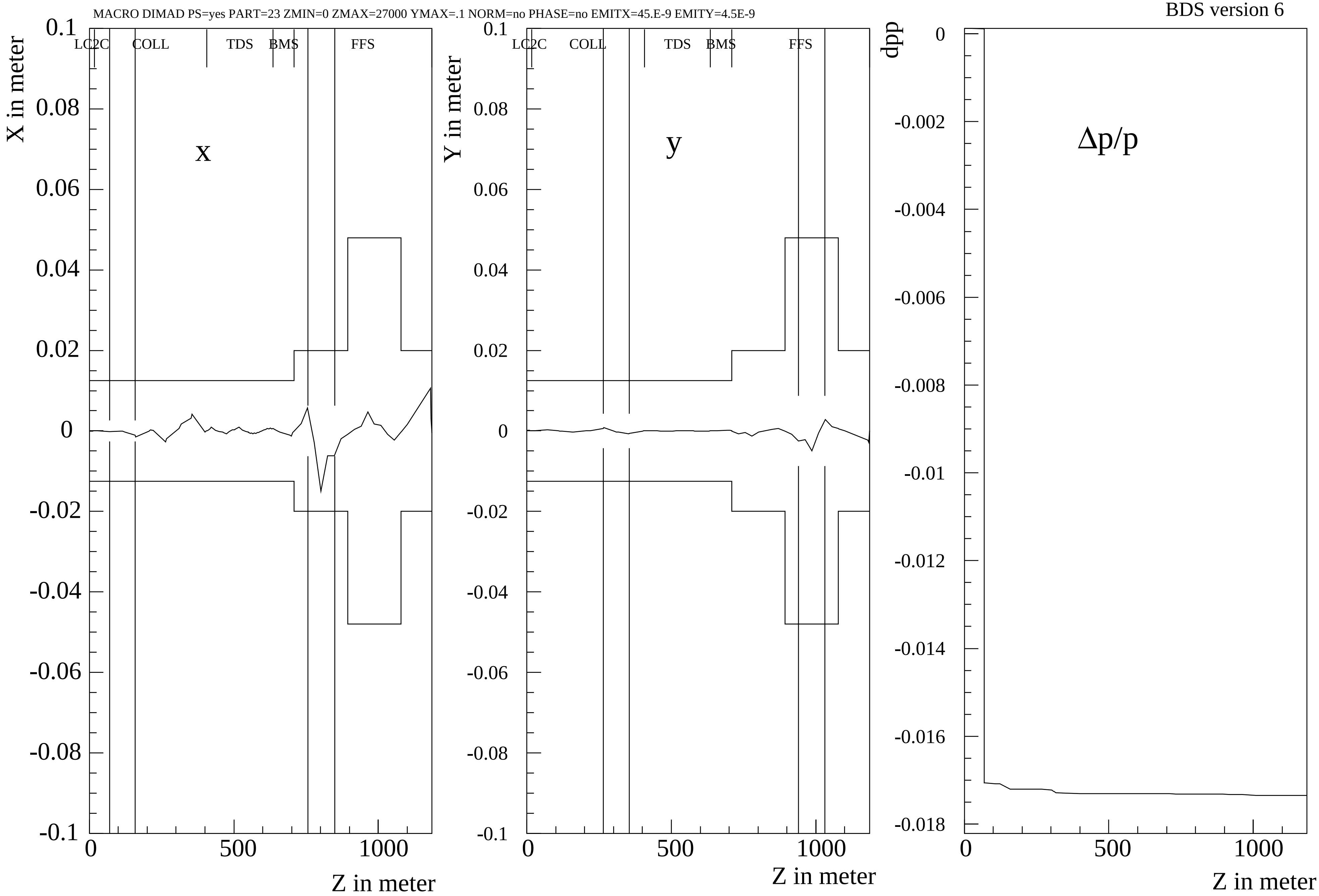
Support rough estimates

More solid quantitative estimates would need some more work

- check/ cross check CERN,SLAC DIMAD/MAD (crash on Linux)
- implement and check apertures
- what about errors, residual dispersion
- interface with detector Monte Carlo ?

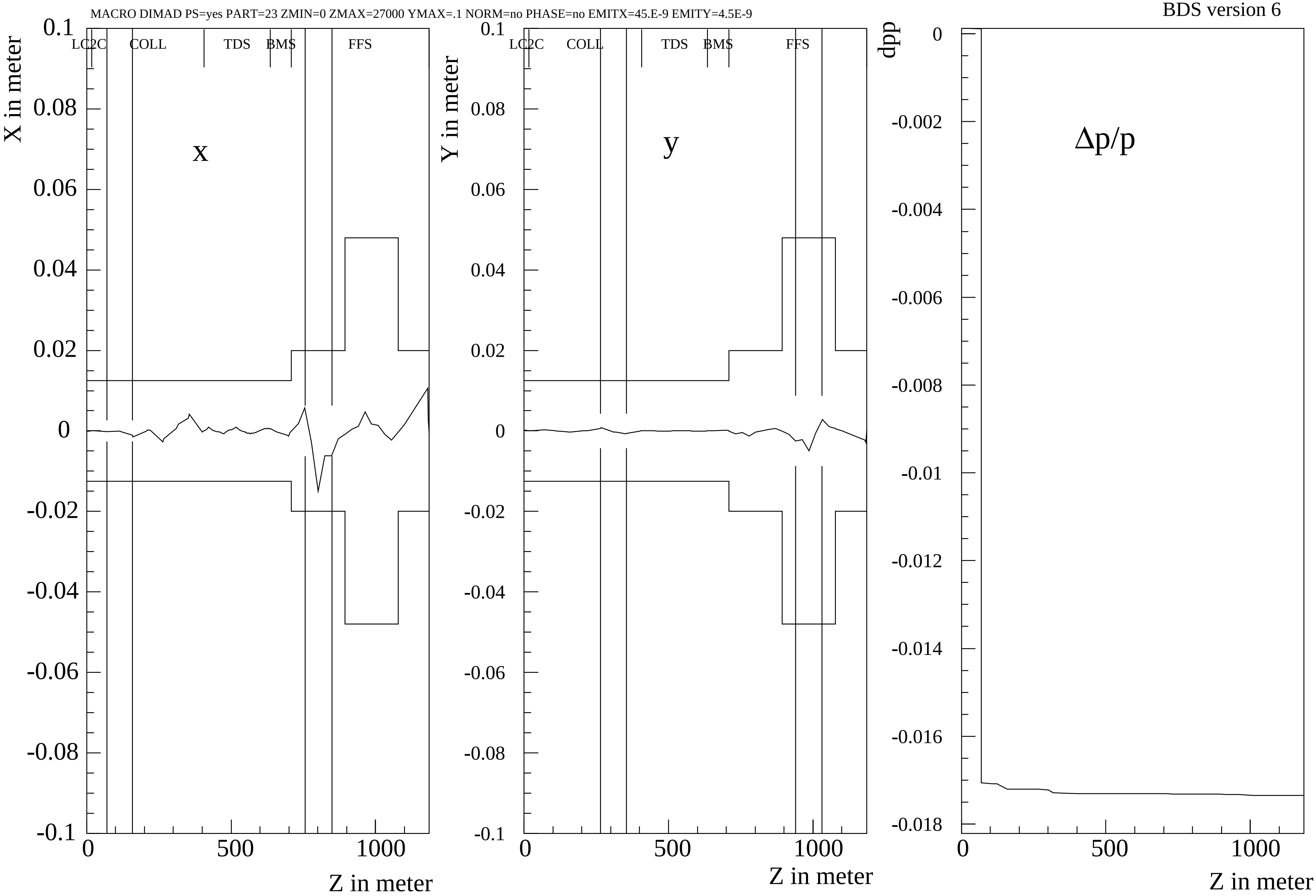
Is this wanted/needed ? (already done for Beam Gas ?)

Example: Tracking through BDS. Particle loosing 1.7 % of Eb at z=69m (1116m from IP) , Dx ≈ 4 cm



tesla/Padova/dimad023.eps

Example: Tracking through BDS. Particle loosing 1.7 % of Eb at z=69m (1116m from IP) , Dx ≈ 4 cm



tesla/Padova/dimad023.eps

Summary

Off (close to) - momentum e+, e- from Beam-Gas and black body Compton are hard to collimate and distinguish from e+, e- particles from collisions
To allow vetoing of background for searches (and good luminosity measurements), the probability of off-momentum BKG particles hitting the detector should be $<< 1$ per bunch crossing.

To achieve this one should aim for good vaccuum conditions in the BDS like 10^{-9} Torr CO (.5e-7 H_2)
The beam gas background is then similar to the off-momentym background from thermal photon - Compton scattering
(assuming there are no hot surfaces)

The amount and properties of off-momentum particles can be predicted in detail by tracking programs like Dimad