Halo and Tail Generation Study (HTGEN)

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Outlines

- Introduction
- Sources of halo
- Processes included in HTGEN
- Beam-halo tracking with PLACET
- Halo study in Beam Delivery System
- Analytical estimates (recent development):
  - CTF3 TBL
  - CLIC Drive Beam Beam-halo
- HTGEN: status and plans

Introduction

- Halo particles contribute very little to the luminosity but may instead be a major source of background and radiation.
- Even if most of the halo will be stopped by collimators, the secondary muon background may still be significant.
- Halo and tail considerations are needed for design studies to allow to estimate and minimise any potential performance limitations from this source.

Generic halo & tail generation package HTGEN

Provides analytical estimates + package with code and interface for detailed tracking with samples and application to CLIC (+ ILC within EuroTeV)

CLIC : htgen as standard component of PLACET

Halo and Tail sources

- Particle processes:
  - beam-gas scattering (elastic, inelastic)
  - Synchrotron radiation (coherent/incoherent)
  - Scattering off thermal photons
  - Ion/electron cloud effects
  - Intrabeam scattering
  - Touschek scattering
- Optics related: Halo modeling
- – Mismatch
- – Coupling
- – Dispersion
- – Non-linearities

Various (equipment related, collective)
– Noise and vibration
– Dark currents
– Space charge effects close to source
– Wake fields
– Beam loading
– Spoiler scattering

Mathematical formulas used in HTGEN (Beam-gas scattering)

Multiple scattering cross-section

$$\sigma_{Mott} \approx \frac{2\pi Z^2 r_e^2}{\gamma^2 (1 - \cos\theta_{\min})}, \theta_{\min} > 10^{-6}\, rad$$

$$\sigma_{Mott} \approx \frac{4\pi Z^2 r_e^2}{\gamma^2 \theta^2_{\min}}, \theta_{\min} < 10^{-6}\, rad$$

$$\theta_{\min} = \sqrt{\varepsilon / \beta}$$

Bremsstrahlung cross-section

$$\sigma_{Brem} = \frac{A}{N_A X_0}\left(-\frac{4}{3}\ln k_{\min} - \frac{5}{6} + \frac{4}{3}k_{\min} - \frac{k^2_{\min}}{2}\right)$$

$$where,\ X_0 = \frac{716.4.A}{Z(Z+1)\ln(287\sqrt{Z})}[g/cm^2]$$

Mean free path

$$\lambda_{int} = \frac{1}{n.N_{bunch}.\sigma}$$

Scattering fraction

$$S = P.l$$

Scattering probability

$$P = n.\sigma$$

Residual gas pressure

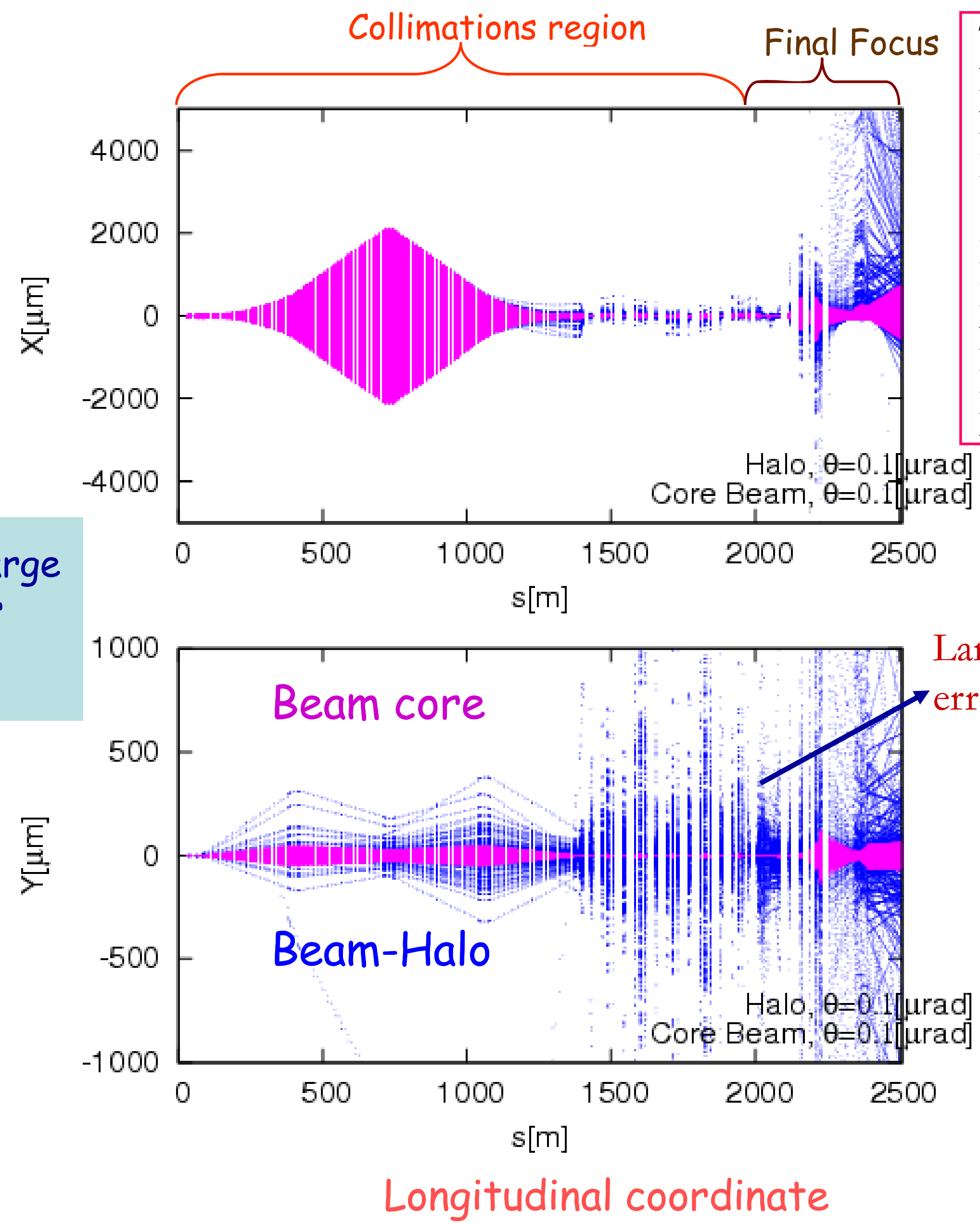
$$p = n.k_B.T$$

Scatter.prob./bunch

$$P_{bunch} = P.N_{bunch}.l$$

collaboration with Forschungszentrum Karlsruhe –student starting 9/2008 using HTGEN (Miriam)

PLACET-HTGEN Tracking (BDS)

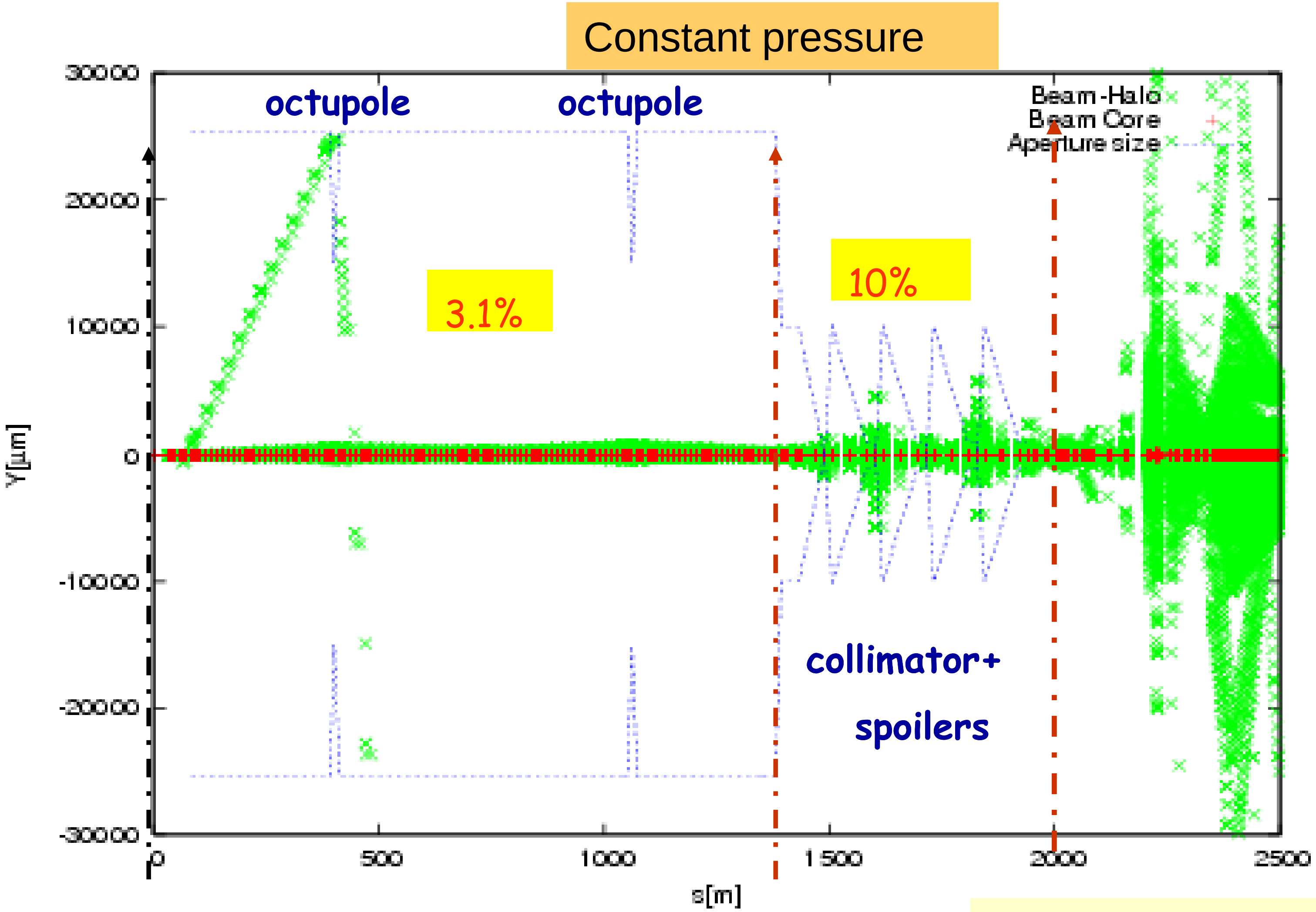


Total no. of elements 637
No. of slices 31
No. of macroparticles 100
Energy 1496 GeV
Charge 4 nC
Emitt. along x-axis 680 nrad
Emitt. Along y-axis 10 nrad
Normal temperature
Resudual gas N_2
Lattice with no collimators

Halo—particles with large betatron mplitudes or with large energy off-sets

Large beta + allignment errors resulting in dispersion

Beam-halo aperture constraints (BDS)



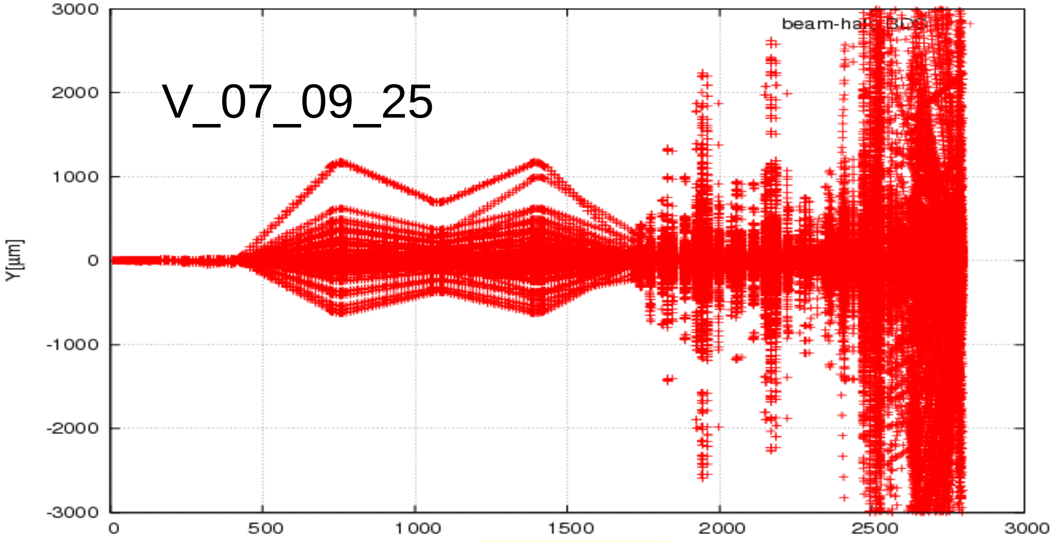
Halo > 102µm = 30%

Halo > 1 mm = ~ 3%

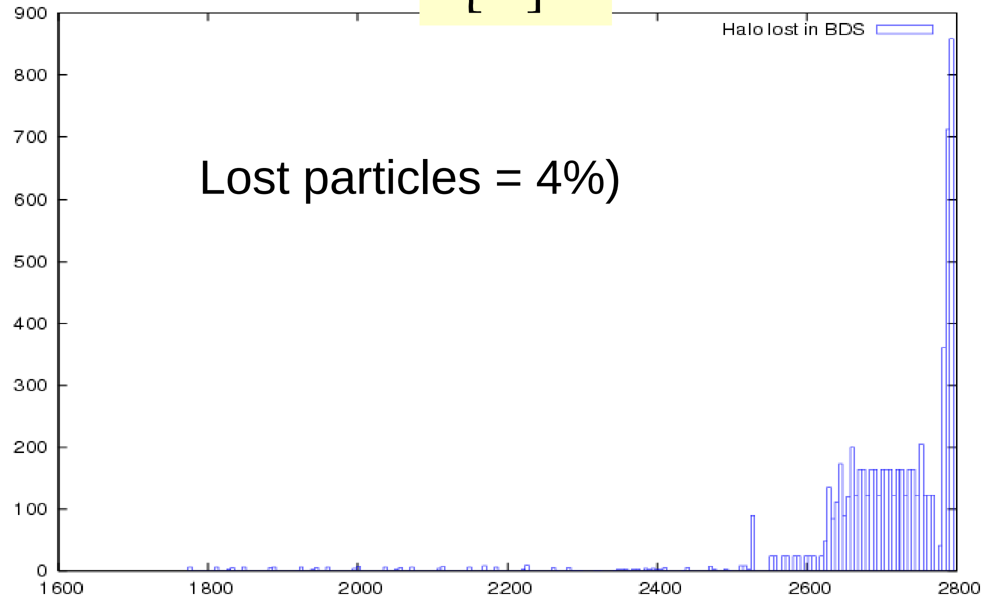
Halo > 10 mm = ~ 0.5%

Thanks to Javier Resta-lopez.

Lattice with low dispersion (BDS)

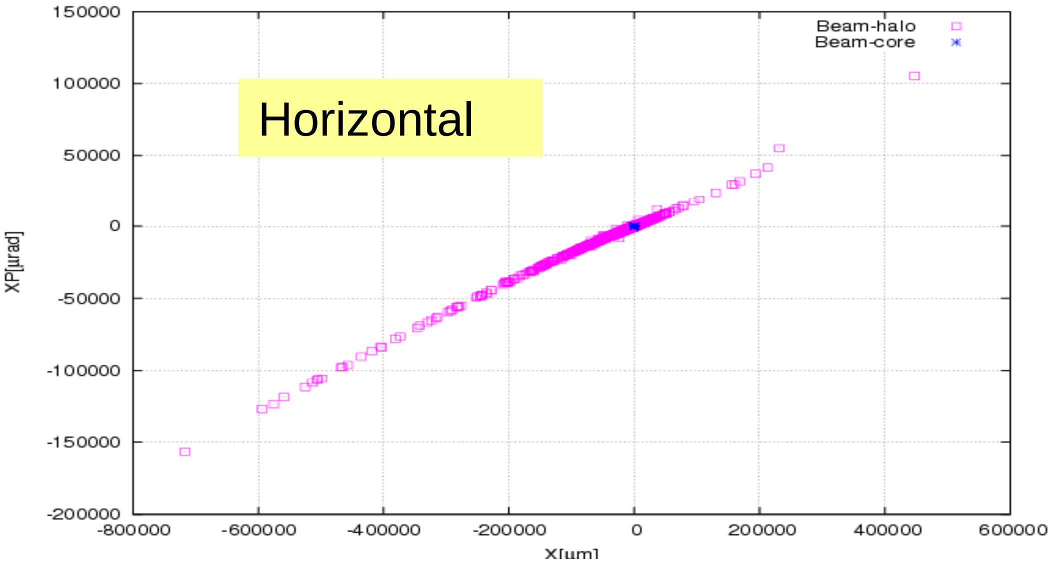


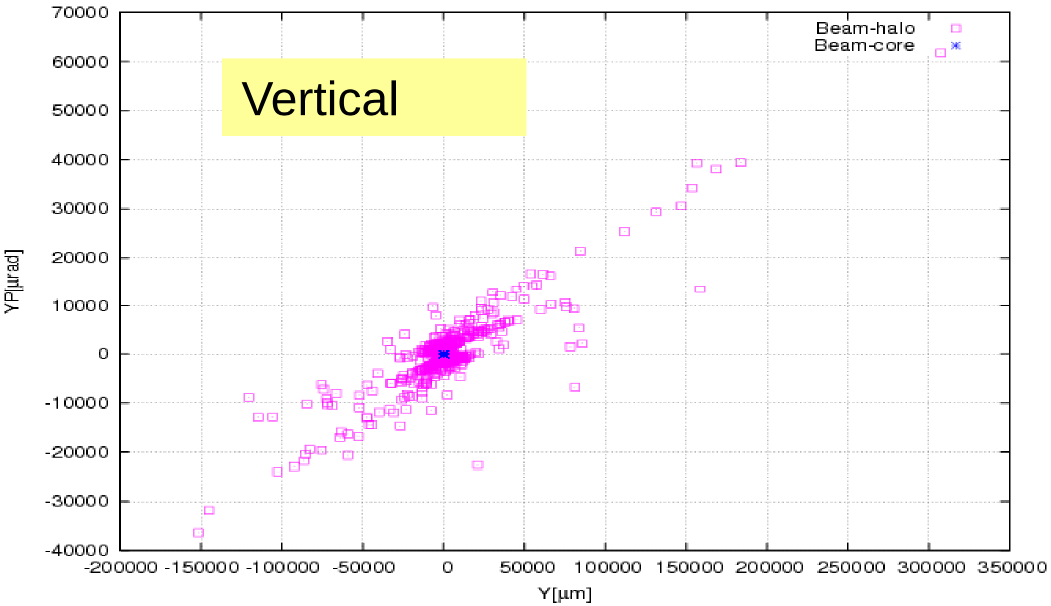
s[m]



s[m]

Transverse phase space of halo at exit of BDS

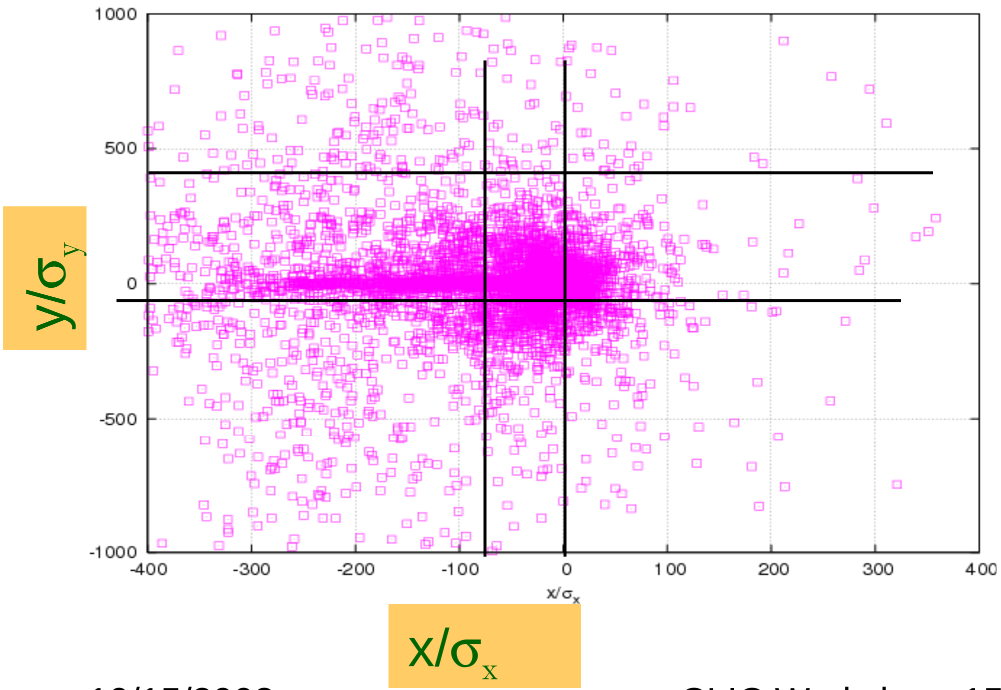


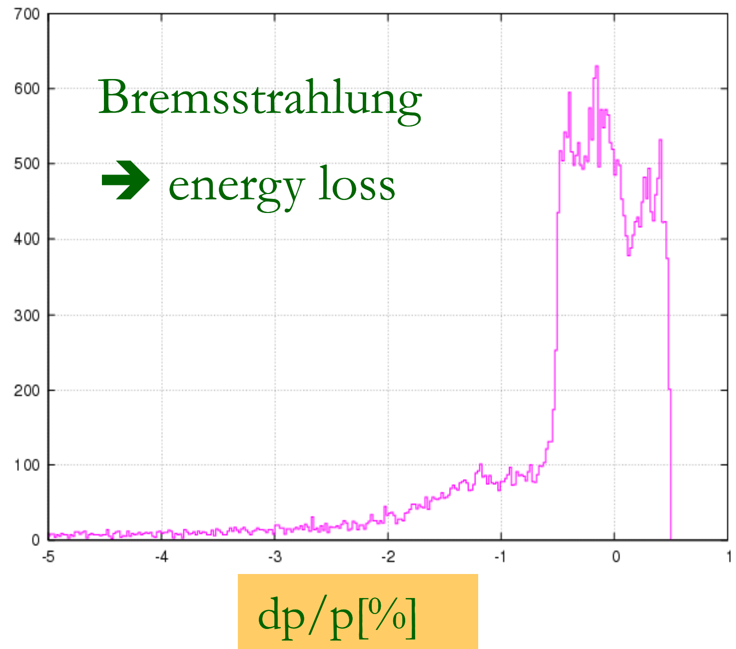


Halo estimation using collimation depth

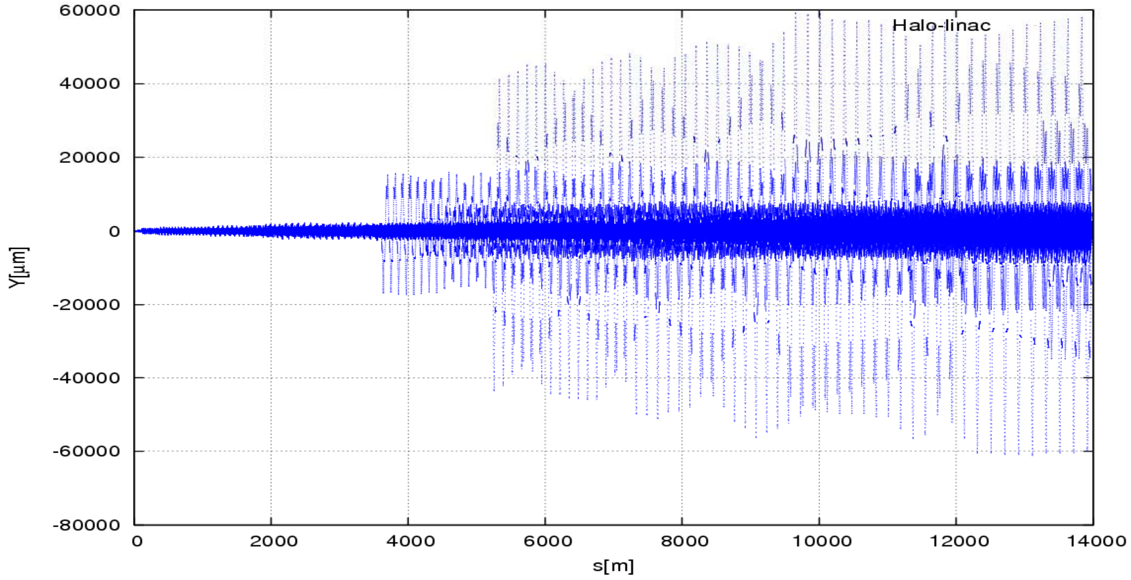
Only 17% of halo particles are outside the window in case of final quad is super conducting final magnet. 25 σ_x and 80 σ_y

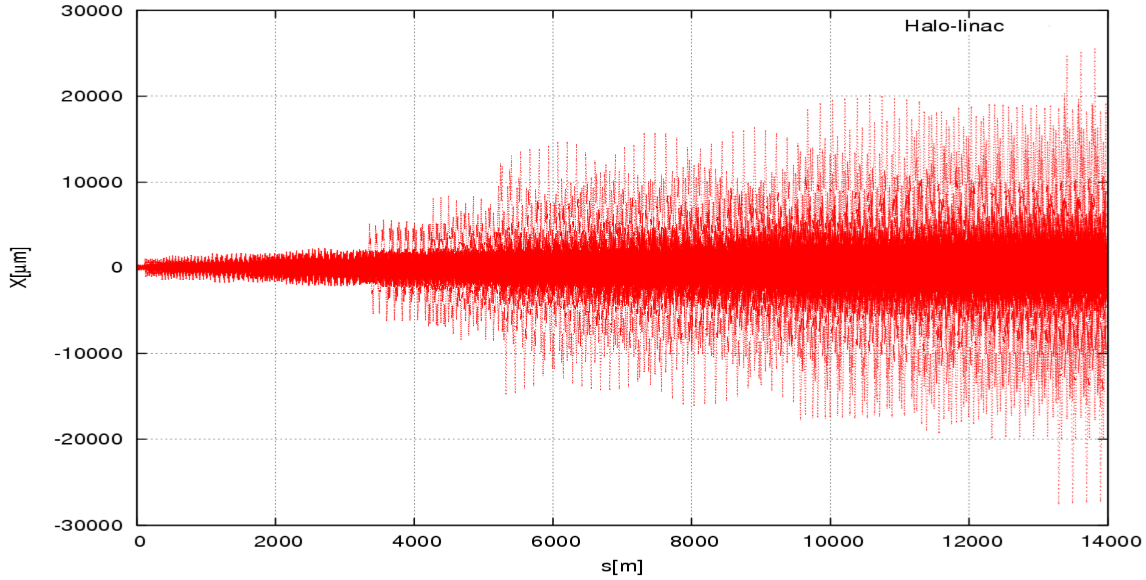
Only 4.5% particles are outside the selected window in case of final quad is permanent magnet. 400 σ_Ξ and 1000 σ_y





Halo tracking (LINAC)





HTGEN- Extended to the Drive Beam

NEW

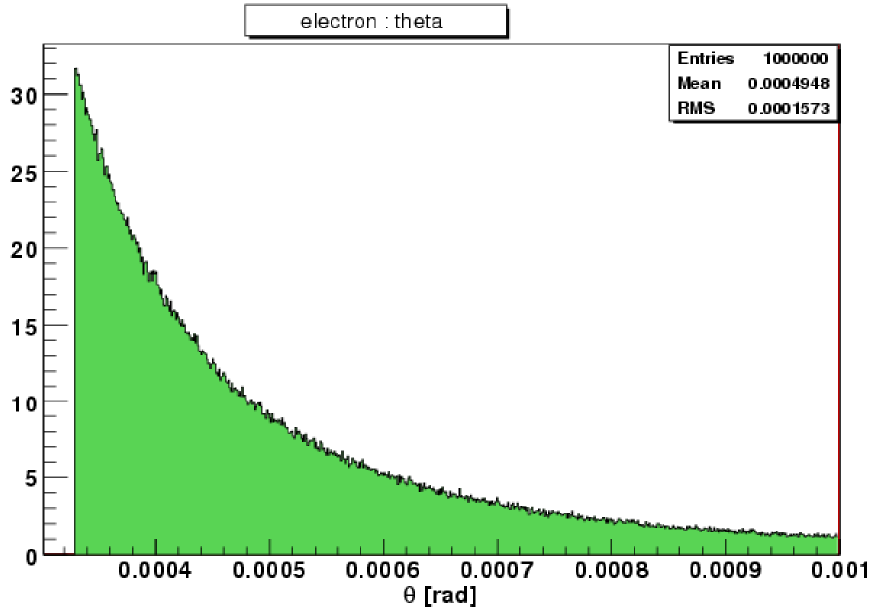
CTF3-TBL LENGTH [m] = 21.99
CLIC Drive Beam Length [m] = 738.349
Z mean (N_2) = 7
PRESSURE [Pa] :1.33322e-06 = 10 nTorr
Temperature [K] = 300
NPart = 4e+09
KMIN = 0.01
Particle density (m^{-3}) = 6.437660e+14 /m3

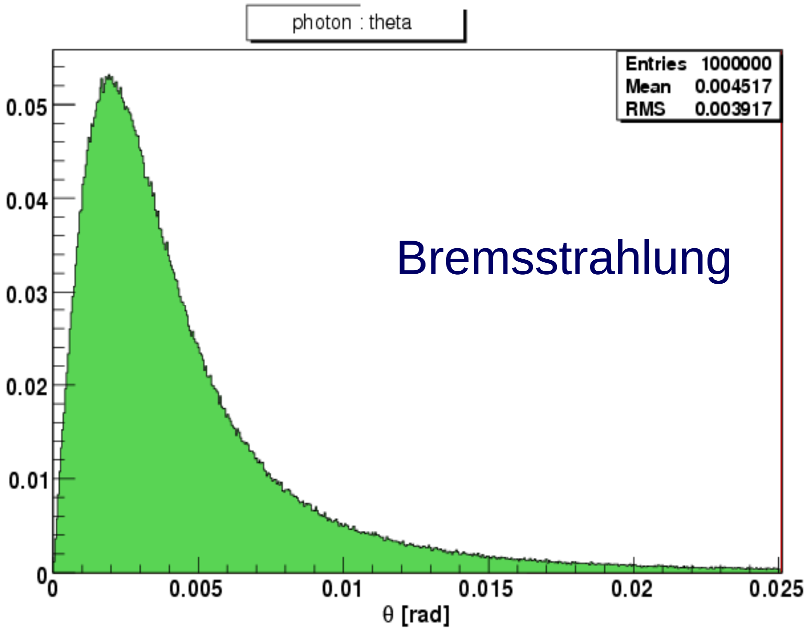
CLIC estimate. P = probability / m for scattering

Location	E (GeV)	Gas	σ_{el} Barn	σ_{in} Barn	P_{el} m^{-1}	P_{in} m^{-1}	Θ_{min} µrad
CTF3-TBL	0.150	N_2	5242	5.5117	3.37e-10	1.77e-13	329
CLIC Drive Beam	2.397	N_2	25146.2	5.5117	1.628e-9	1.77e-13	9.4005

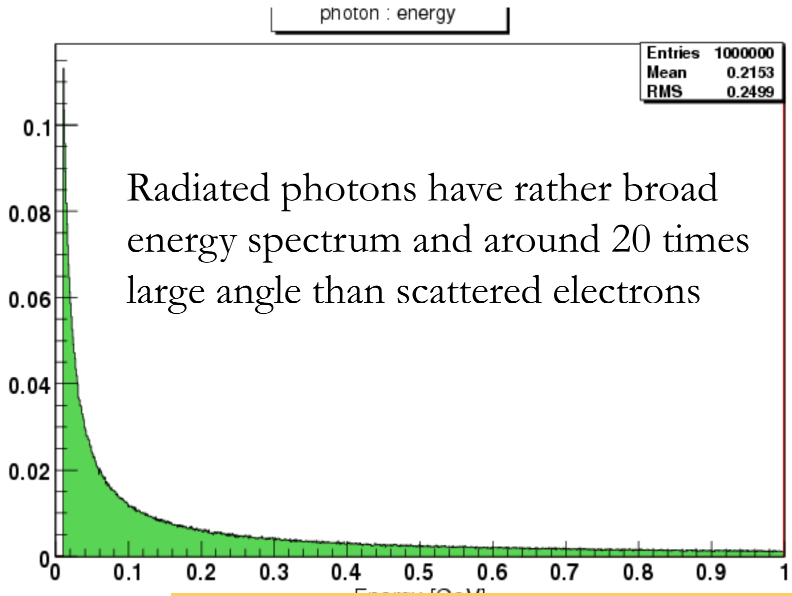
Beam-gas scattering (CTF3-TBL)

Mott scattering





Bremsstrahlung

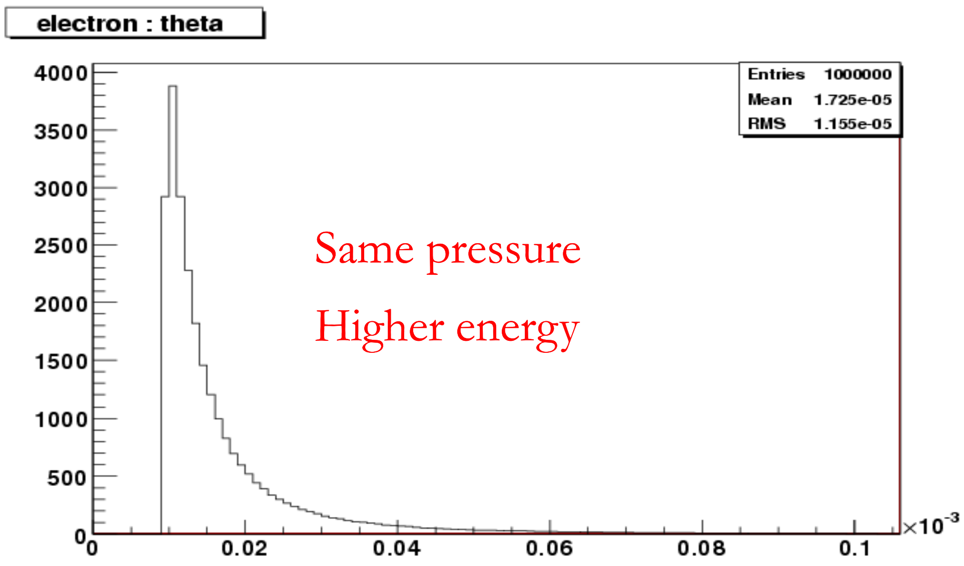


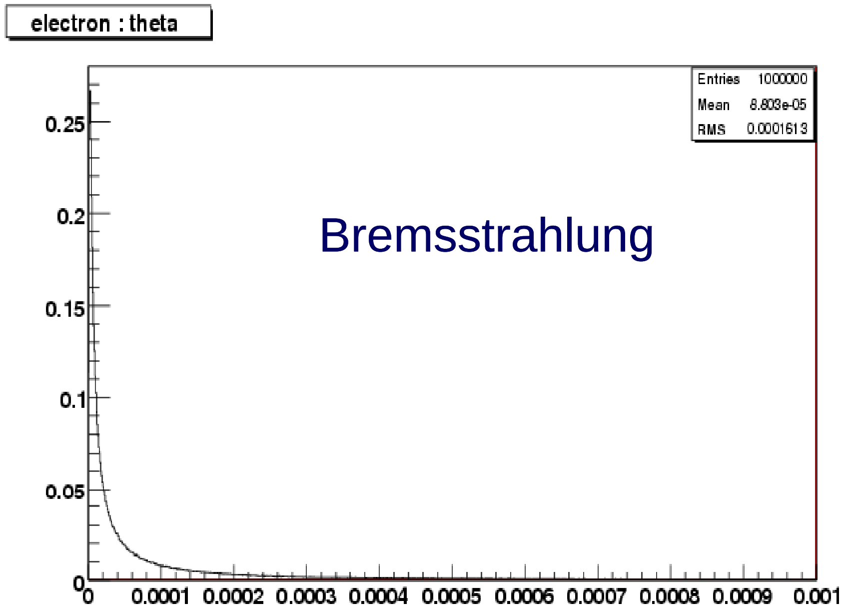
Radiated photons have rather broad energy spectrum and around 20 times large angle than scattered electrons

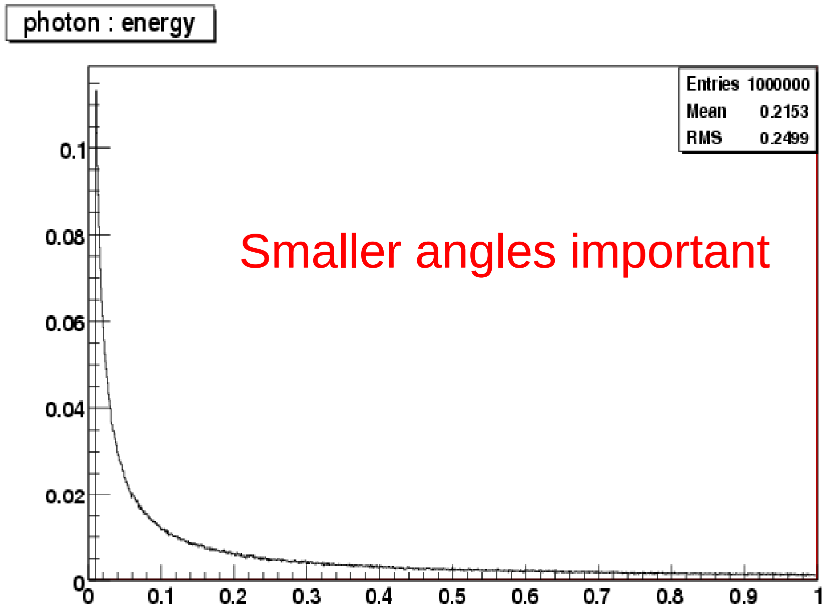
Energy in beam units

Beam-gas scattering (CLIC Drive Beam)

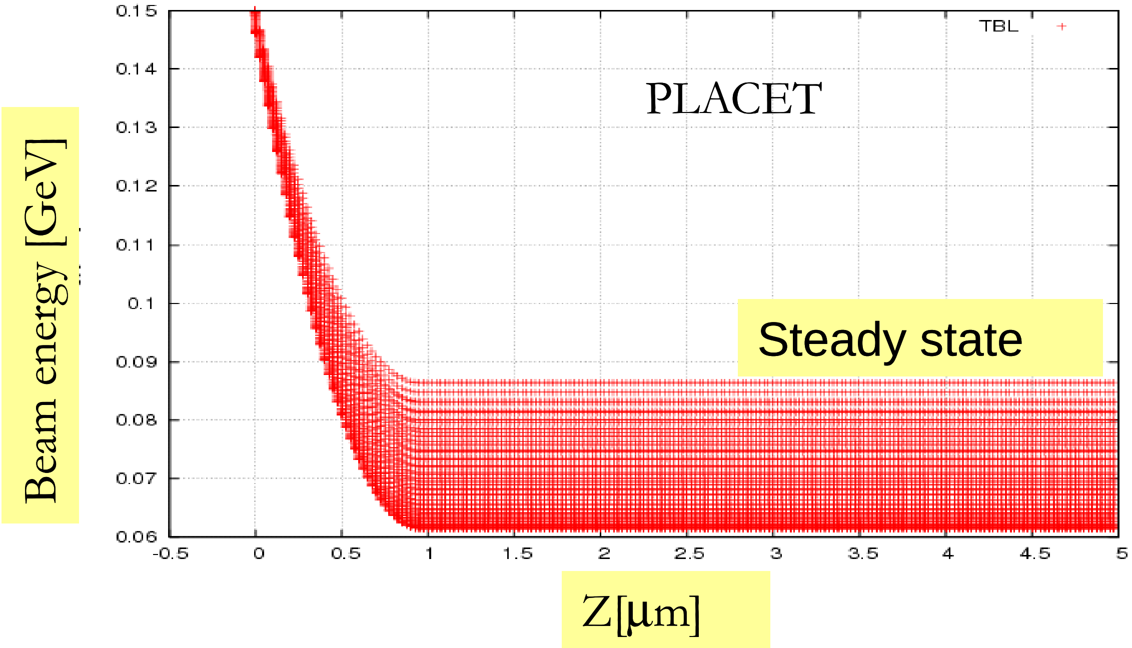
Mott scattering

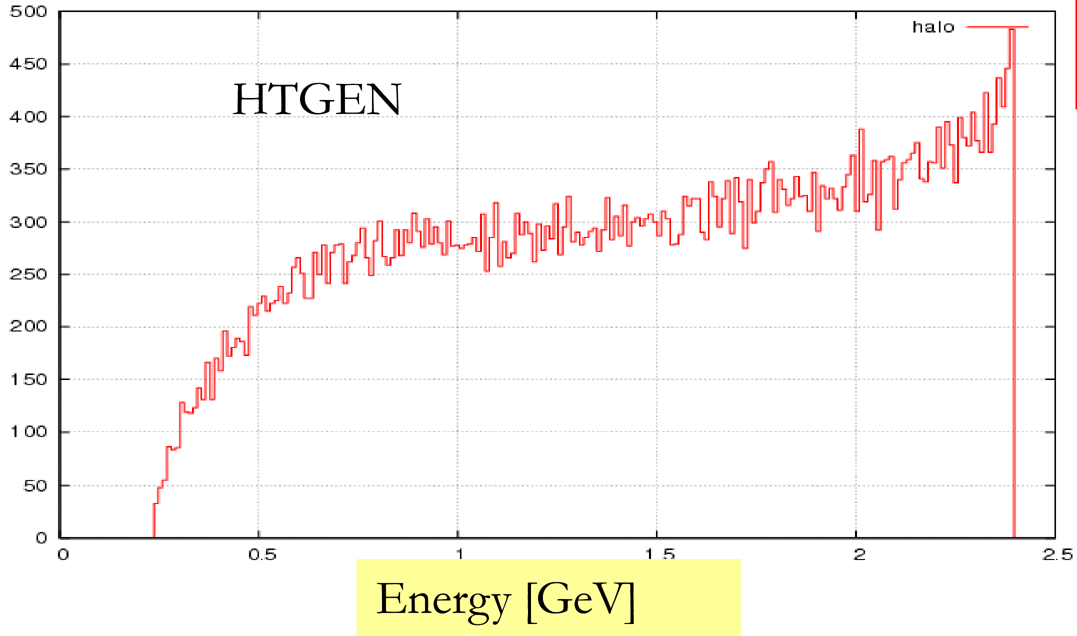






Halo deceleration in PETS (Tracking)





set n_bunches 200
set n_slices 51
set n_macros 1
set d_bunch 0.025
set sigma_bunch 1000
set gauss_cut 3
set charge 1.4575e10
set e0 0.150
set emitt_x 1500.0
set emitt_y 1500.0
Define the longitudinal mode
set beta_l 0.4529
set RQ 2294.7/2
set lambda_l 0.025
beam offset ,
sigmax=134.8,sigmay=329.8

HTGEN+PLACET application to low energy CLIC drive beam, started potential for benchmarking - CTF3

Halo flux estimate (Mott Scattering)

CLIC Drive Beam

e^-/bunch = 5.25×10^{10}
Probability = 1.628×10^{-9}/m
Probability in CLIC Drive beam = 1.202×10^{-6}
Halo/bunch = 6.3×10^{4}

θ_{min}=Divergence

CTF3-TBL

e-/bunch = 1.4575×10^{10}
Probability = 3.37×10^{-10}/m
Probability in CLIC TBL Drive beam = 7.41×10^{-9}
Halo/bunch = 1.08×10^{2}

to be verified by detailed tracking of lattice + collimation (with errors) and combined simulation, HTGEN + PLACET

Reports and Presentations

Reference to all material, software package for download, installation instructions, answers to frequently asked questions:
HTGEN page: http://hbu.home.cern.ch/hbu/HTGEN.html

Reports

Monte Carlo generation of the energy spectrum of synchrotron radiation, by. H. Burkhardt, 8 June 2007, CERN-OPEN-2007-018; CLIC-Note-709; EUROTEV-Report-2007-018

Halo Estimates and Simulations for Linear Colliders, PAC'07 Proc. WEOCC03 ; CLIC-Note-714, CERN-AB-2007-045, EUROTeV-Report-2007-064

Presentations

LC workshop Daresbury : 8-11 Jan 2007, Halo and Tail Generation Studies, by L Neukermans

PAC June 2007 : Halo Estimates and Simulations for Linear Colliders, by H.Burkhardt

CLIC 07 workshop : Halo and Tail Generation, by H.Burkhardt on 17 Oct. 2007

CLIC 07 workshop : Background studies, by I. Ahmed on 17 Oct. 2007

Beam dynamics meetings: http://iahmed.web.cern.ch/iahmed/

Status and plans

Done 2007 :

• HTGEN software package with installation instructions, interfaces to tracking codes and examples made available.

• HTGEN provides simulation and estimates of main halo production.

• Simplify HTGEN commands and provide control and diagnostics output implement further halo production mechanisms processes ; applied to ILC & CLIC provide help and follow up on requests tests and benchmarking : measurements (ATF, CTF3) and with other codes -- Geant4, BDSIM

Done 2008 and ongoing future work :

• Online manual for the htgen software package is available with complete CVS repository structure.

• Improved the HTGEN package with fixing a few bugs.

• Remove dependence on external libs (CLHEP, GS in case of placet)   cleaner interfaces -- less globals and copying of structures

• Update to recent synchrotron radiation code work with HTGEN users.

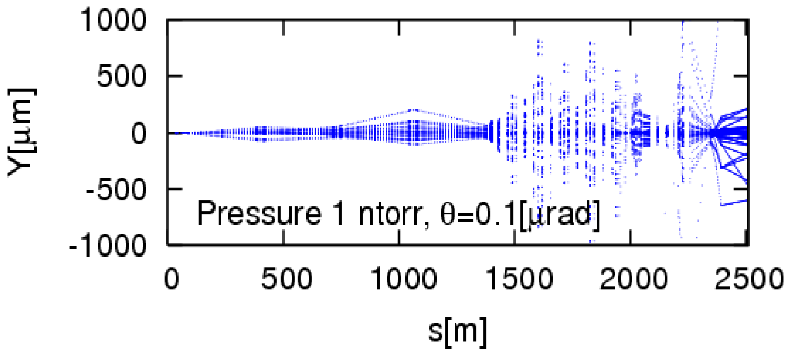
•Extended to the nominal Drive beam.

Summary

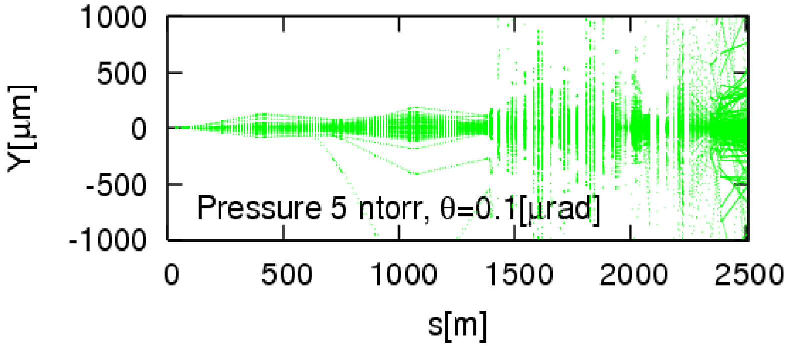
- we provide a generic package HTGEN with interfaces for PLACET and MERLIN, ready to be used
- used as basis for the CLIC vacuum specification (CLIC Technical Committee - Meeting on 17/06/2008)
- the most important particle scattering process in the LINAC+BDS is the elastic beam gas scattering; good vacuum important, particularly at beginning of the LINAC ; from tracking with errors : fraction of about 10^{-4} of beam particles hit spoilers for ILC.
- Drive beam halo generation is currently under study and encouraging results are obtained.
- Package is completely ready to use to CLIC and ILC for BDS and LINAC and soon would be tested for for CLIC drive beam

Backup slides

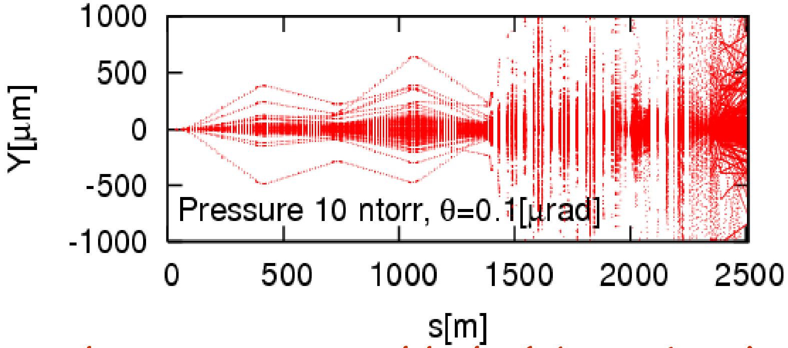
Residual Gas pressure dependence (BDS)



8.4% >1mm
1.7% > 10mm



5.3% >1mm
0.5% > 10mm

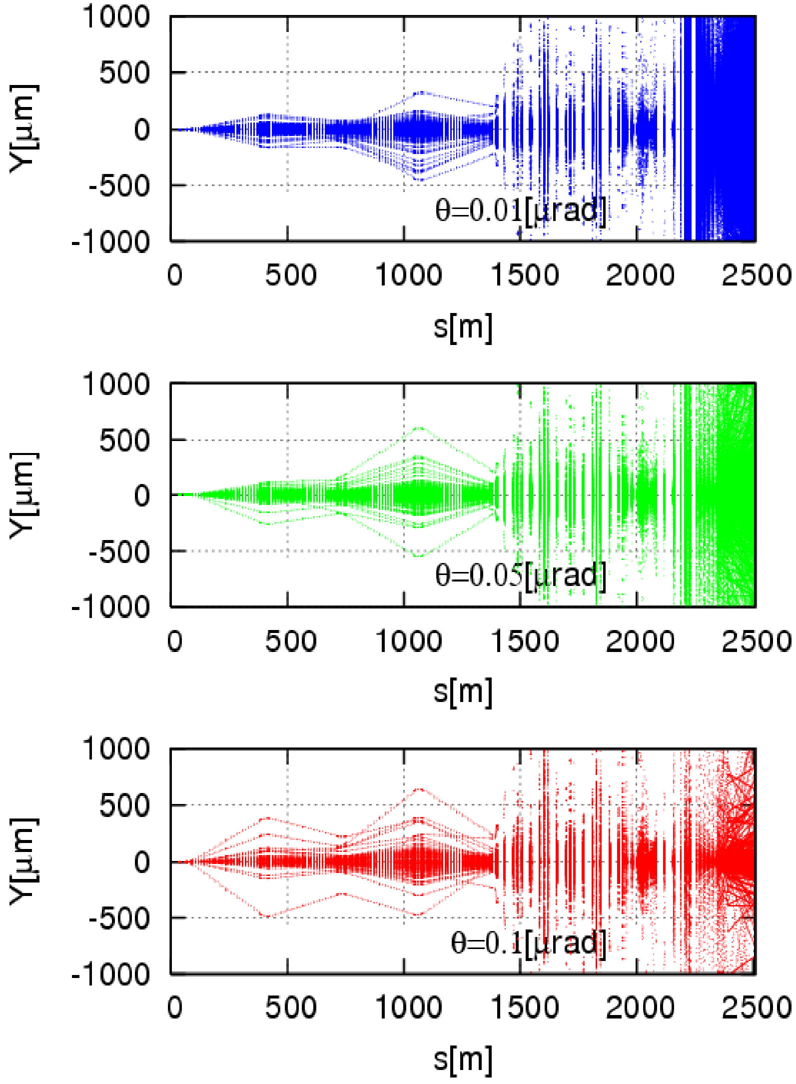


8.2% >1mm
0.4% > 10mm

No significant change in vertical halo (above 1mm) as we go from 1-10 ntorr

Scattering angle dependence (BDS)

Small angle→ less vertical expension



0.3% >1mm)
0.004% >10mm

6.2% >1mm
0.4 > 10mm

8.4% >1mm
1.7 > 10mm