HTGEN and Muons in the CLIC BDS

HTGEN : generic Halo and Tail generator.

- **Standalone + fully interfaced with PLACET for info, manual, instructions, examples see** **http://hbu.home.cern.ch/hbu/HTGEN.html**

- Recently upgraded by Miriam Fitterer, Erik Adli, Barbara Dalena and myself to also work with sliced beams as required for halo studies of the drive beam.

- Here : returning to the original and probably most important application :

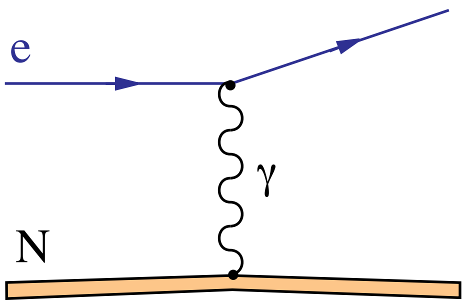
  Halo and collimation in the BDS

  relevant for the design CLIC collimation system, vacuum specification and machine backgrounds to the CLIC Experiment(s). Important to minimize halo production. Halo collimation at high energy results in muon backgrounds (which came as a bad surprise in the SLC)

General recent summary (May 2009) - collimation paper published in PRSTAB 12.081001
Tracking studies of the Compact Linear Collider collimation system,
I. Agapov, H. Burkhardt, and D. Schulte / CERN, A. Latina / FNAL, G. A. Blair, S. Malton, J. Resta-López / John Adams & Royal Holloway University

Among many possible halo source, an important source which is always present and already sufficient to result in a significant muon flux is beam-gas scattering

Elastic scattering Mott (Coulomb)



$$\frac{d\sigma}{d\Omega} = \left[\frac{Zr_e}{2\gamma\beta^2}\right]^2 \frac{1-\beta^2\sin^2\frac{\vartheta}{2}}{\sin^4\frac{\vartheta}{2}} \approx 16/\theta^4$$

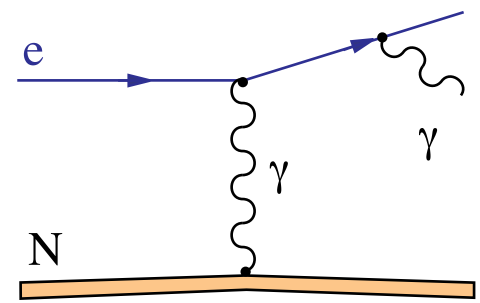
relevant if $\theta >= \theta_{beam} = \sqrt{\varepsilon\, \beta_{x,y}}$

$$\sigma_{el} = \frac{4\pi Z^2 r_e^2 \beta_y}{\epsilon_N \gamma}$$

at const $\varepsilon_N \propto 1/\gamma$

Energy dependent. More halo from low energies. Make sure to have good vacuum at beginning of LINAC or collimation at intermediate energy !

Inelastic scattering Bremsstrahlung



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

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

no E depend., $\int$dk for k > 1%
usually smaller than elastic
Source of off-momentum halo and background

Muon stoppers / tunnel fillers

Conclusion from our 2002 paper.

To clean up :

would require rather massive (magnetized) shielding to be effective

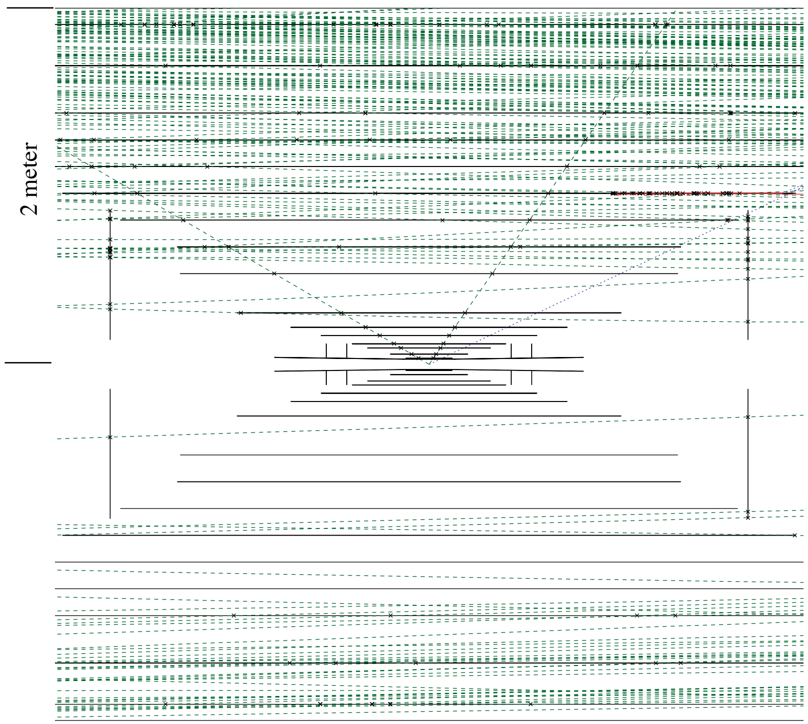
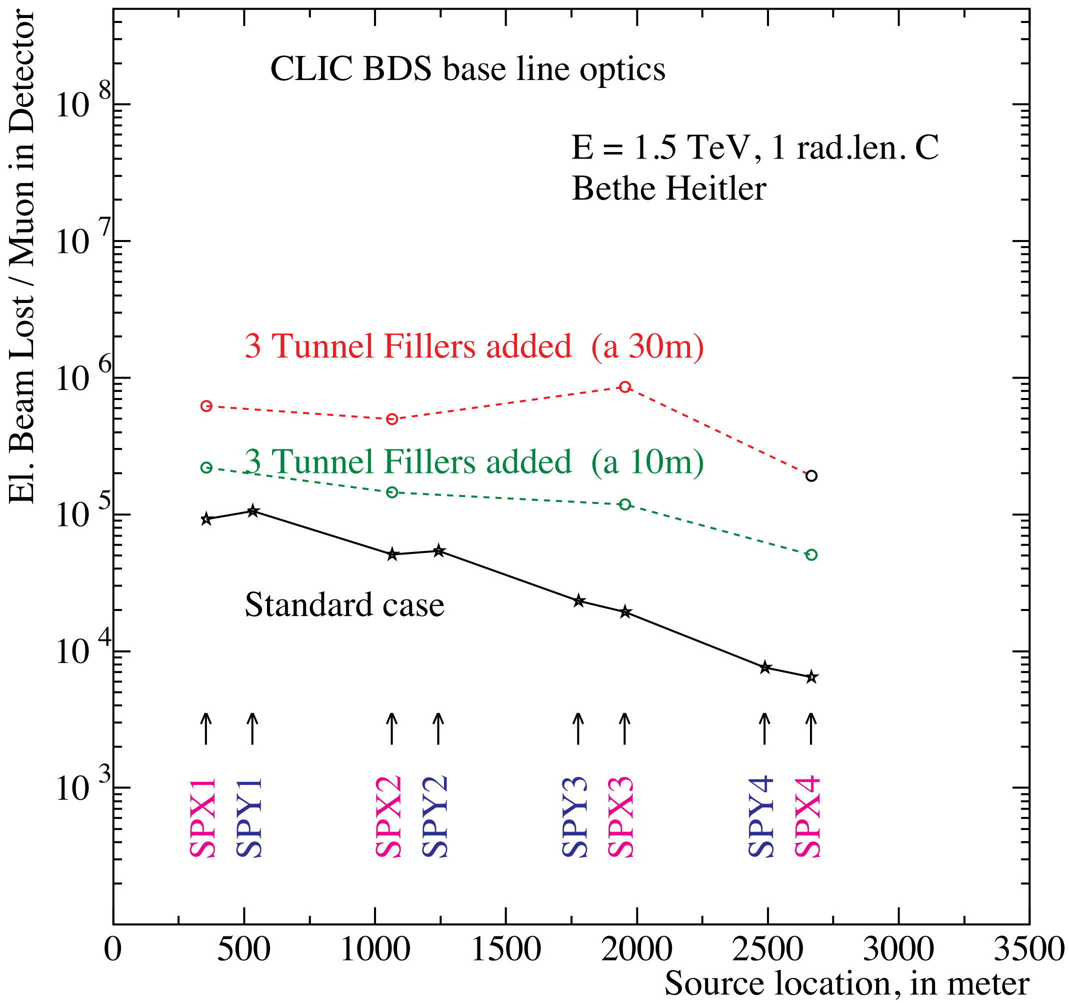
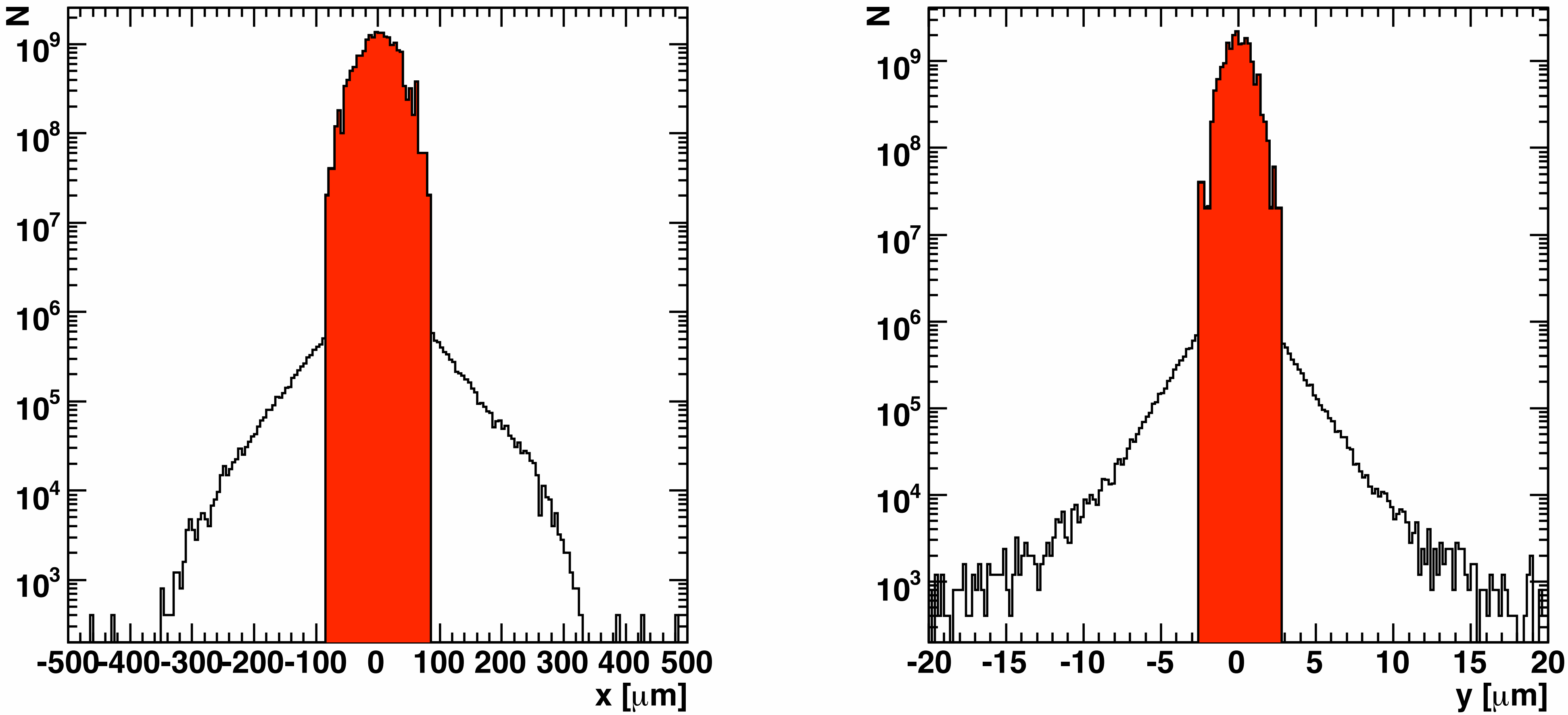


Figure from M.Battaglia



Better invest in keeping halo low in the first place. Include HALO study in design



Transverse beam profiles at from the LINAC at the BDS entrance

PLACET-HTGEN. [**EuroTeV-Report-2008-076**]

HTGEN allows to specify the residual gas individually for each element. For the estimates here, the same values were set to all elements **:**

LINAC section 10 nTorr CO at room temperature (300 K)

BDS section 10 nTorr CO at room temperature (300 K)

CLIC estimate. P = probability / m for scattering > 1 σ divergence

Location	E GeV	Gas	ρ m^{-3}	$\sigma_{\rm el}$ Barn	P m^{-1}
LINAC	9	CO	3.2×10^{14}	2.7×10^{7}	8.9×10^{-7}
BDS	1500	CO	3.2×10^{14}	1.7×10^{5}	1.1×10^{-8}

Elastic : probability 80x higher beginning of LINAC at 9 GeV compared to end at 1.5 TeV and BDS. Integrated over length :

total LINAC Prob. $P = 1.16\times10^{-3}$, BDS $P = 6.0\times10^{-5}$ together 1.2×10^{-3} at 1σ

total LINAC Prob. $P = 1.29\times10^{-6}$, BDS $P = 6.7\times10^{-8}$ together 1.4×10^{-6} at 30 σ (loss)

Inelastic : scattering probability for >1% energy loss : 2.1×10^{-13}/m

summing up over both LINAC and BDS : $P = 5.0\times10^{-9}$/m

Rough analytical particle flux estimate on spoilers and secondary muons

4×10^{9} e/bunch
311 bunches

1.24×10^{12} e/train
2×10^{-4} fraction hitting spoilers, determined with HTGEN tracking
2.4×10^{8} e/train on spoilers
~ 9×10^{-4} fraction resulting in secondary muons (without tunnel fillers)
~ 2×10^{5} muons / train end of BDS
depends critically on vacuum and spoiler layout

A more reliable estimate requires a full simulation with :
Beam + Halo generation (PLACET-HTGEN), full tracking up to spoilers ✓ ☞

Full simulation of the Halo interaction with the spoilers and tracking of the secondary muons. Methods exist : BDSIM - GEANT4
Detailed geometry and acceptance - spoilers to experiments
What is tolerable for the experiment(s) ?

Muon production, Geant4

1. Monte Carlo Generator for Muon Pair Production,
by Burkhardt, Kelner, Kokoulin, CLIC-Note-511, 2002

2. Production of muon pairs in annihilation of high-energy positrons with resting electrons
by Burkhardt, Kelner, Kokoulin, CLIC-Note-554, 2003

Background simulation for the CLIC Beam Delivery System with Geant
by G. Blair, H. Burkhardt, H.J. Schreiber, CLIC-Note-519, 2002

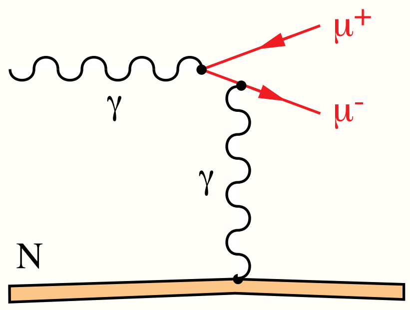
Geant4 Simulation of High Energy Muon Interactions, A. G. Bogdanov, H. Burkhardt, et al.
IEEE-TNS-01462665.pdf, 2004

Geant4 home page and physics reference manual (Vers. 9.2 Dec. 2008) ; Muon production fully implemented

μ from hadronic decay (π, K) and electromagnetic production :

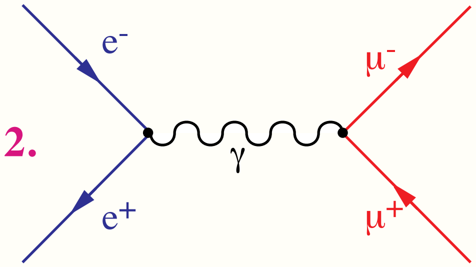
electromagnetic cascade

1.

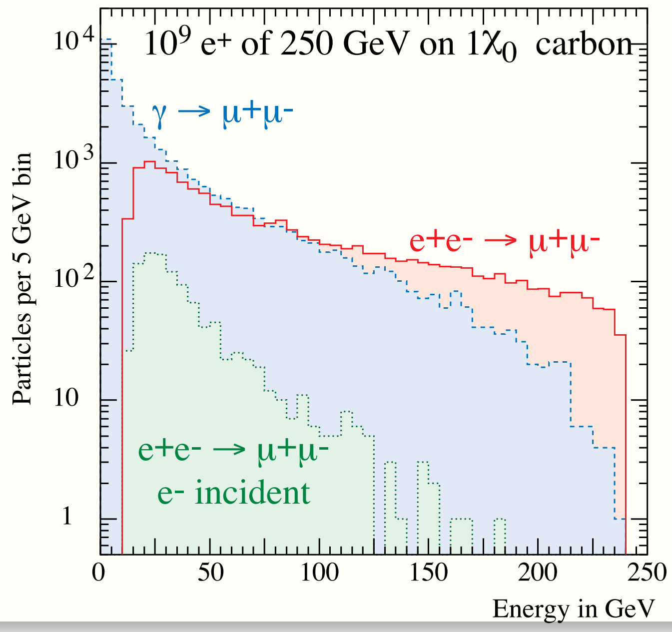


atomic e– at rest

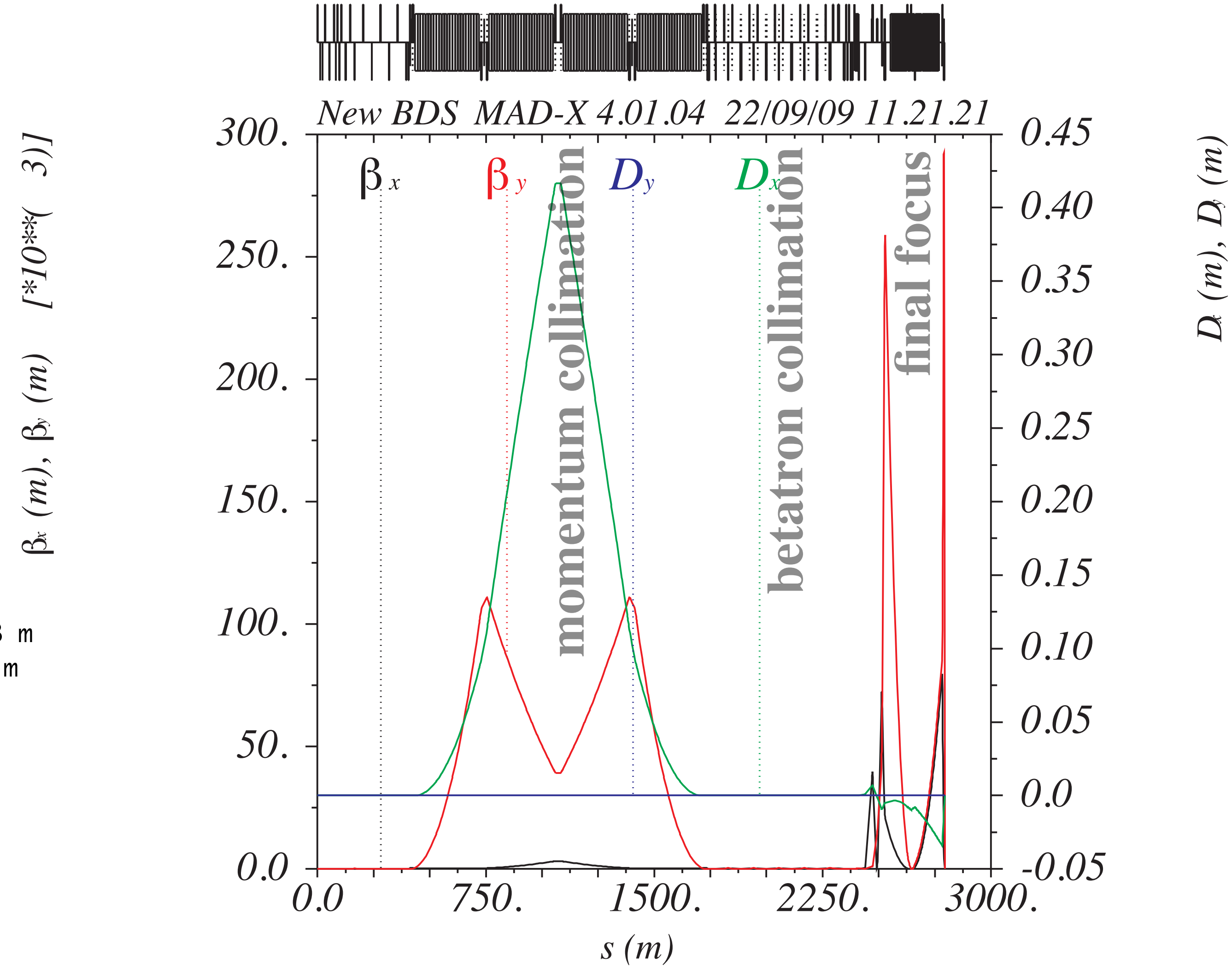
2.



primary or secondary e+



Simulation, CLIC BDS

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        s-position
ENGYSP   907.0980223 m
ENGYAB  1072.098022 m

YSP1 1830.871685 m
XSP1 1846.693635 m

YSP2 1943.714645 m
XSP2 1959.536595 m

YSP3 2056.557605 m
XSP3 2072.379555 m

YSP4 2169.400565 m
XSP4 2185.222515 m

ENG : 0.008 m in both planes
Spoilers  X closed to 0.00012 m  Y closed to 0.0001  m
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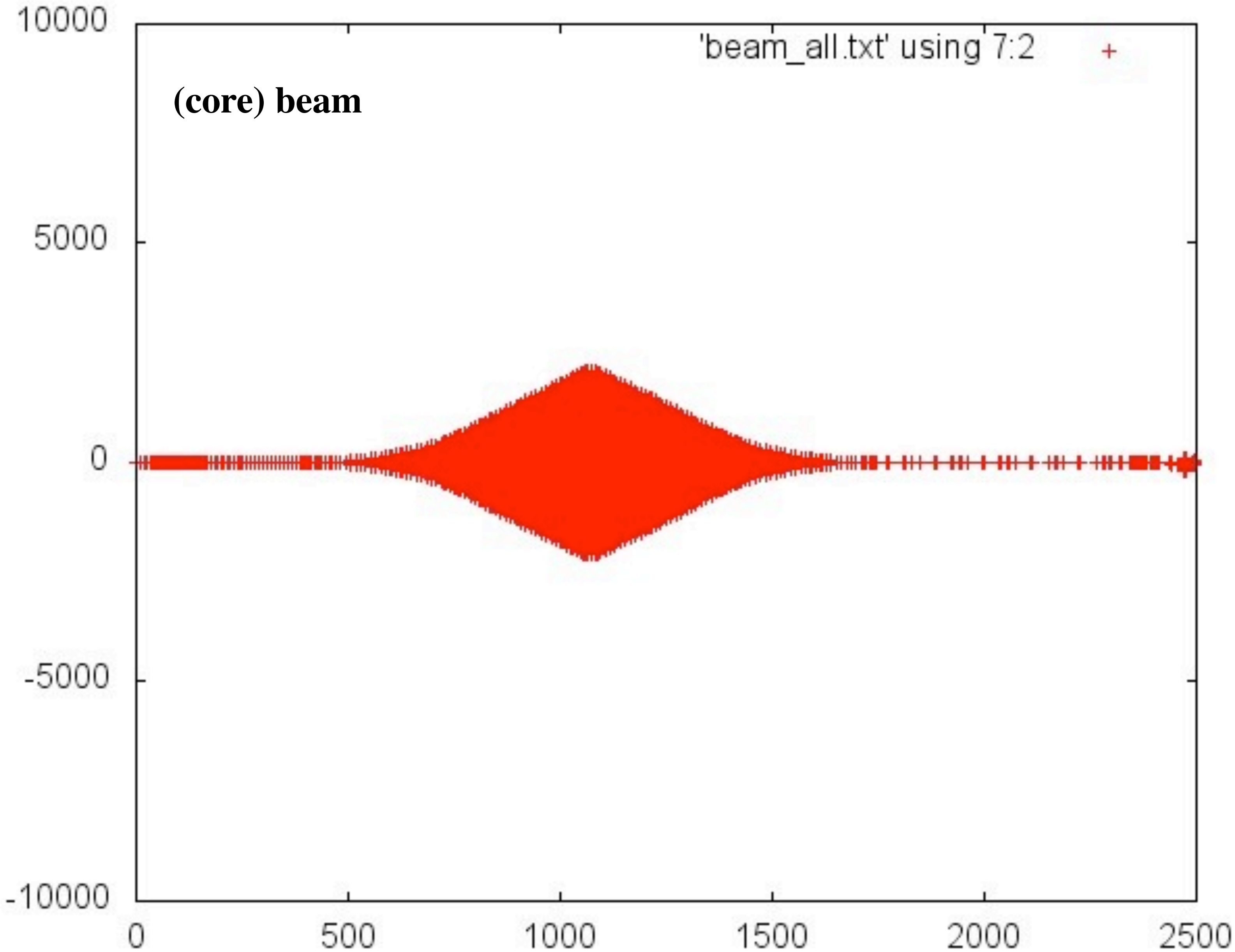
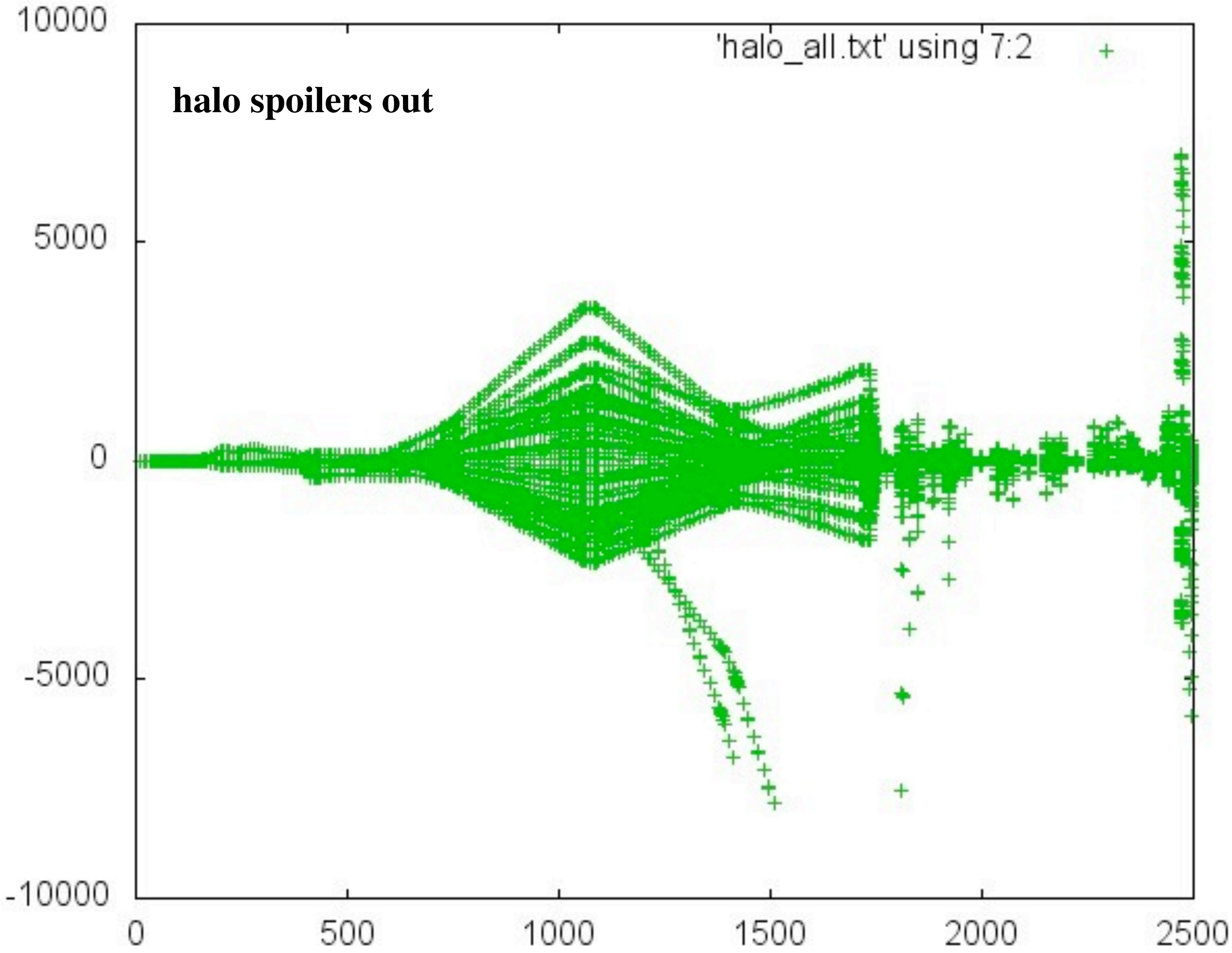
Using the current BDS lattice BDS/v_09_04_01 / job.madx

PLACET-HTGEN tracking

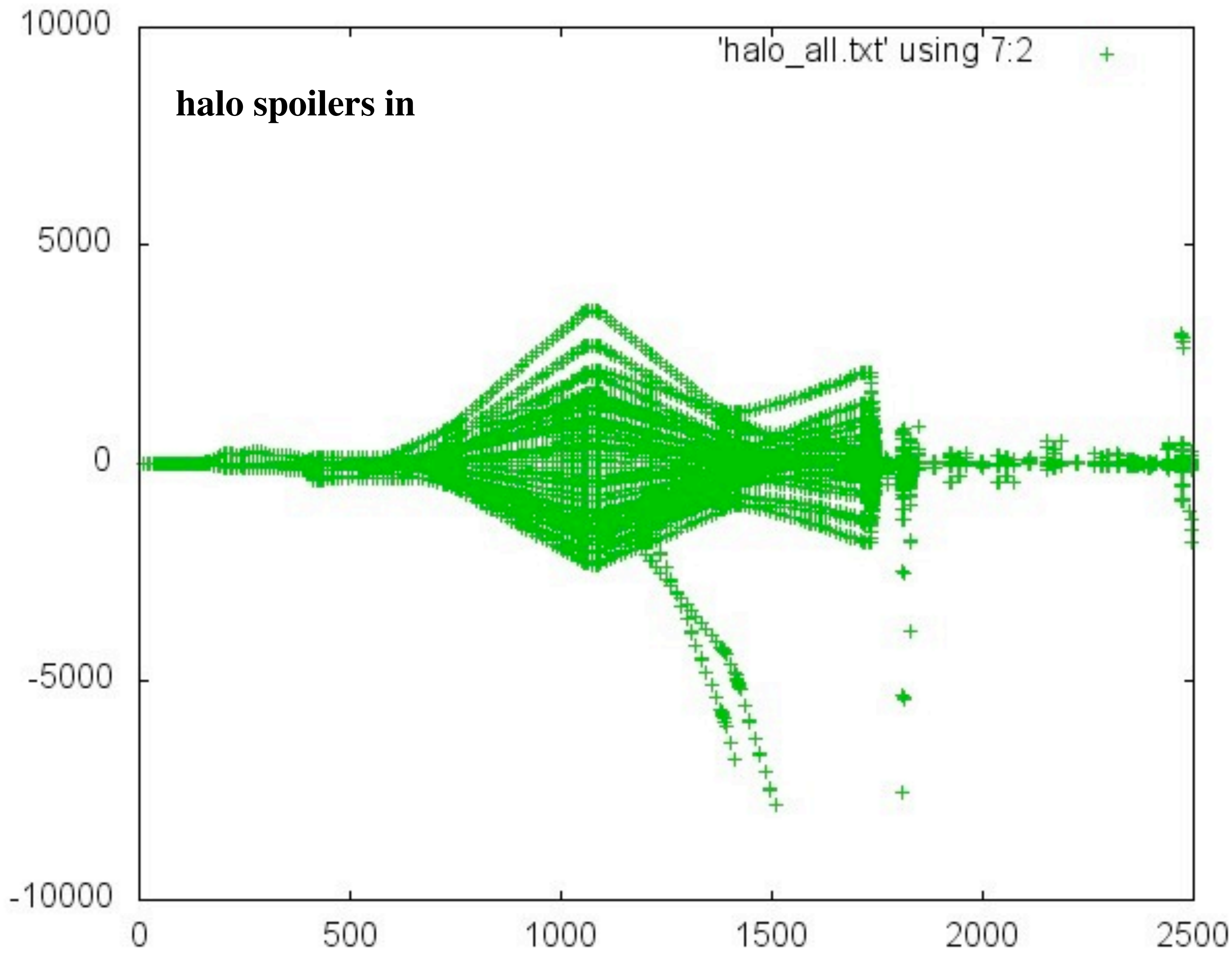


PLACET-HTGEN tracking



v_09_04_01/bds.name.aperture.FixedSR.collaper

PLACET-HTGEN tracking



v_09_04_01/bds.name.aperture.FixedSR.collaper

Collimation and muons

Is our current collimation design ok for muons ?

Feedback from from Lew Keller / SLAC, following the collimation paper, from 1 Sept. 2009 :

... I just saw your nice article on CLIC collimation ...
In ILC we thought it was better to have the energy collimation section after the betatron collimation section so that the energy section could clean up some of the mess from the betatron spoilers, and it was especially useful for dispersing muons.

Do we have to consider the need for muon stoppers / tunnel fillers ?

Time to revisite collimation for muons ?

I could provide the HTGEN support
would require help / resources on the BDSIM / geometry / layout part