CLIC collimator wakefields and secondary particles

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Introduction

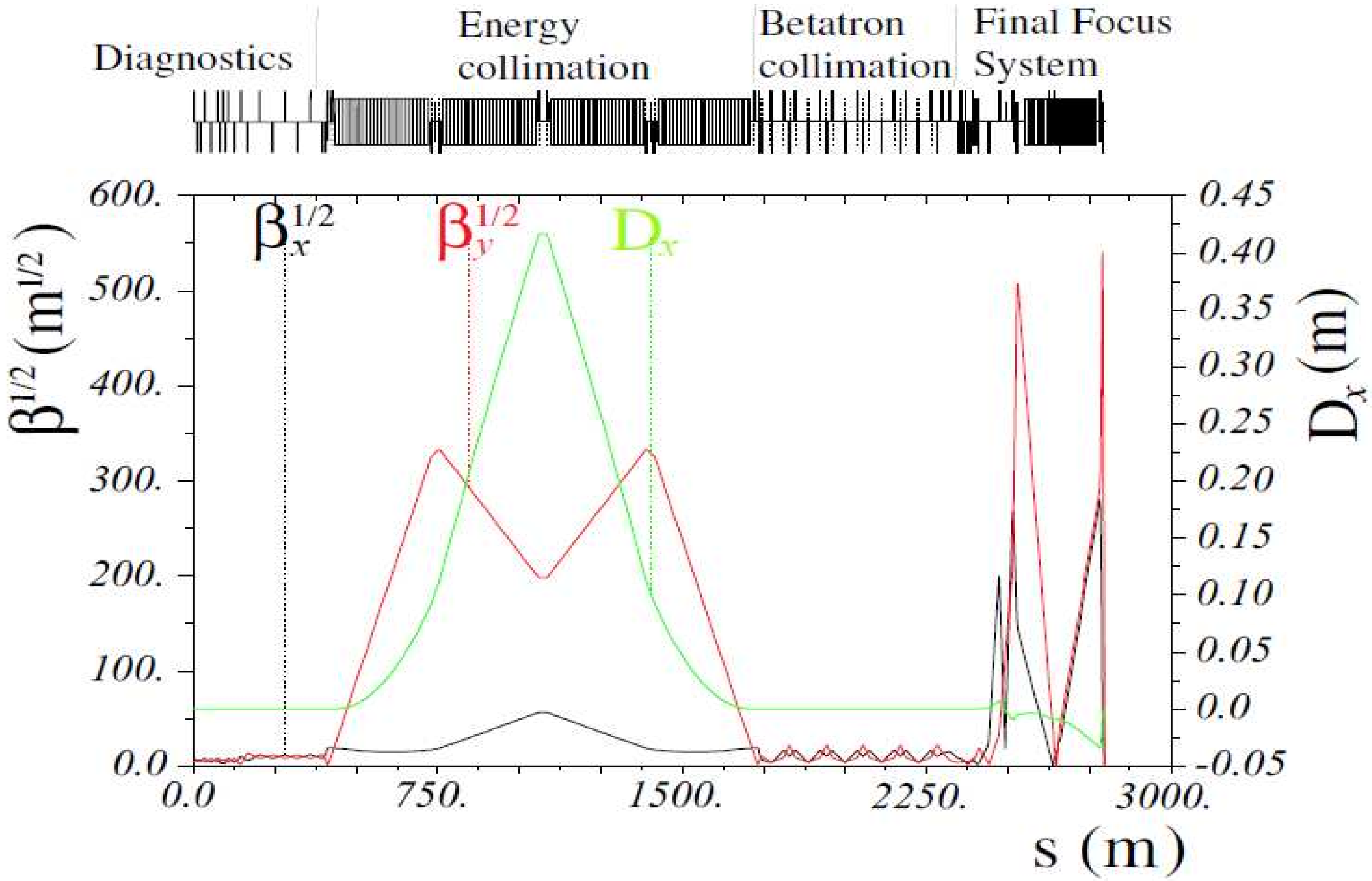
- Since the last CLIC workshop (October 2008) clear progress has been made in the improvement of the CLIC collimation system
  - Study of the collimation efficiency, optimising the collimator apertures
  - Design of spoiler and study of its thermal fracture limit
  - Luminosity loss due to collimator wakefield effects
- Significant progress has also been made in the development of codes for realistic simulations (e.g. BDSIM-PLACET interface), allowing collimation studies simultaneously including wakefield effects and production of secondary particles
- In this presentation we focus on:
  - Update of luminosity performance studies with coll. wakefield effects using the new collimator apertures
  - Discussion of preliminary results from BDSIM-PLACET simulations

Introduction

Collimation wakefields in the BDS, which contribute to luminosity degradation:

- Geometric and resistive wall wakefields of the collimators (spoilers & absorbers)
- Resistive wall wakefields of the beam pipe, e.g. in the regions with high beta-functions such as FD
- Crab-cavity wakefields

CLIC collimation system



Old collimator apertures (version 2008)

Collimator	β_x [m]	β_y [m]	D_x [m]	a_x [mm]	a_y [mm]	Material
E-SP	1406.33	70681.9	0.27	3.51	25.4	Be
E-AB	3213.03	39271.5	0.416	5.41	25.4	Ti/Cu
β_y–SP	114.054	483.253	0.	10.	0.08	Be
β_y–AB	114.054	483.184	0.	1.	1.	Ti/Cu
β_x–SP	270.003	101.347	0.	0.08	10.	Be
β_x–AB	270.102	80.9043	0.	1.	1.	Ti/Cu

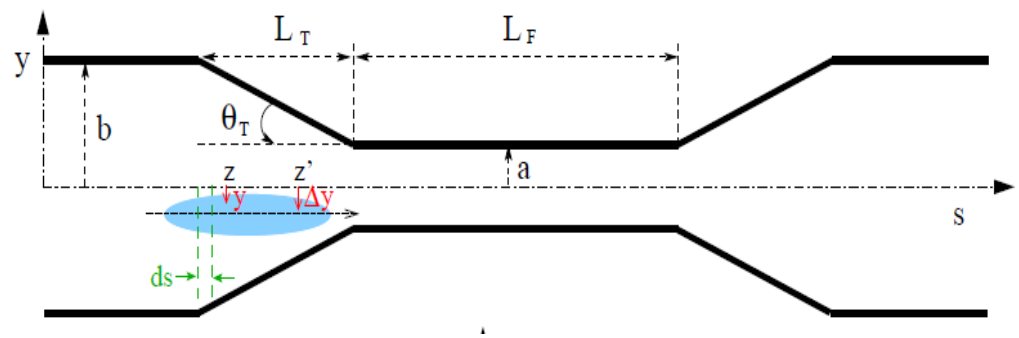
Old collimation depths: 10 σ_x and 44 σ_y

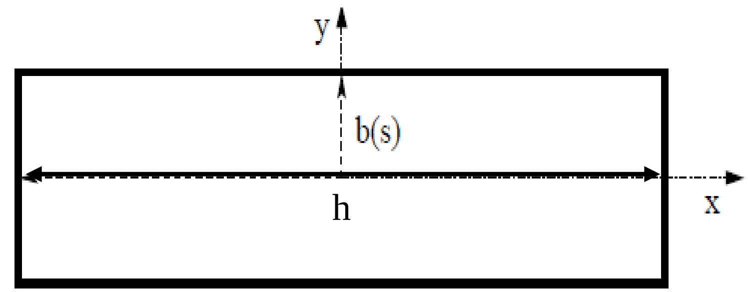
New collimator apertures (version 2009)

Collimator	β_x [m]	β_y [m]	D_x [m]	a_x [mm]	a_y [mm]	Material
E-SP	1406.33	70681.9	0.27	3.51	25.4	Be
E-AB	3213.03	39271.5	0.416	5.41	25.4	Ti/Cu
β_y–SP	114.054	483.253	0.	10.	0.1	Be
β_y–AB	114.054	483.184	0.	1.	1.	Ti/Cu
β_x–SP	270.003	101.347	0.	0.12	10.	Be
β_x–AB	270.102	80.9043	0.	1.	1.	Ti/Cu

New optimisation of betatronic collimation depths from ray-tracing calculations along FD and IR using the code PLACET: 15 σ_x and 55 σ_y (Barbara Dalena)

Spoiler geometric parameters





Parameter	**E-sp**	**β_y-sp**	**β_x-sp**
Vertical half gap a_y [mm]	25.4 (h=2 a_y)	0.1	10.0 (h=2 a_y)
Hor. half gap a_x [mm]	3.51	10.0 (h=2 a_x)	0.12
Tapered part radius b [mm]	6.21	2.8	2.78
Tapered part length L_T [mm]	90.0	90.0	90.0
Taper angle θ_T [rad]	0.03	0.03	0.03
Flat part length L_F [mm]	0.0 (preliminary design)	0.0 (preliminary)	0.0 (preliminary)

Collimator parameters and wakefield regimes

Wakefield regimes for CLIC BDS spoilers:

(From Stupakov's criteria)

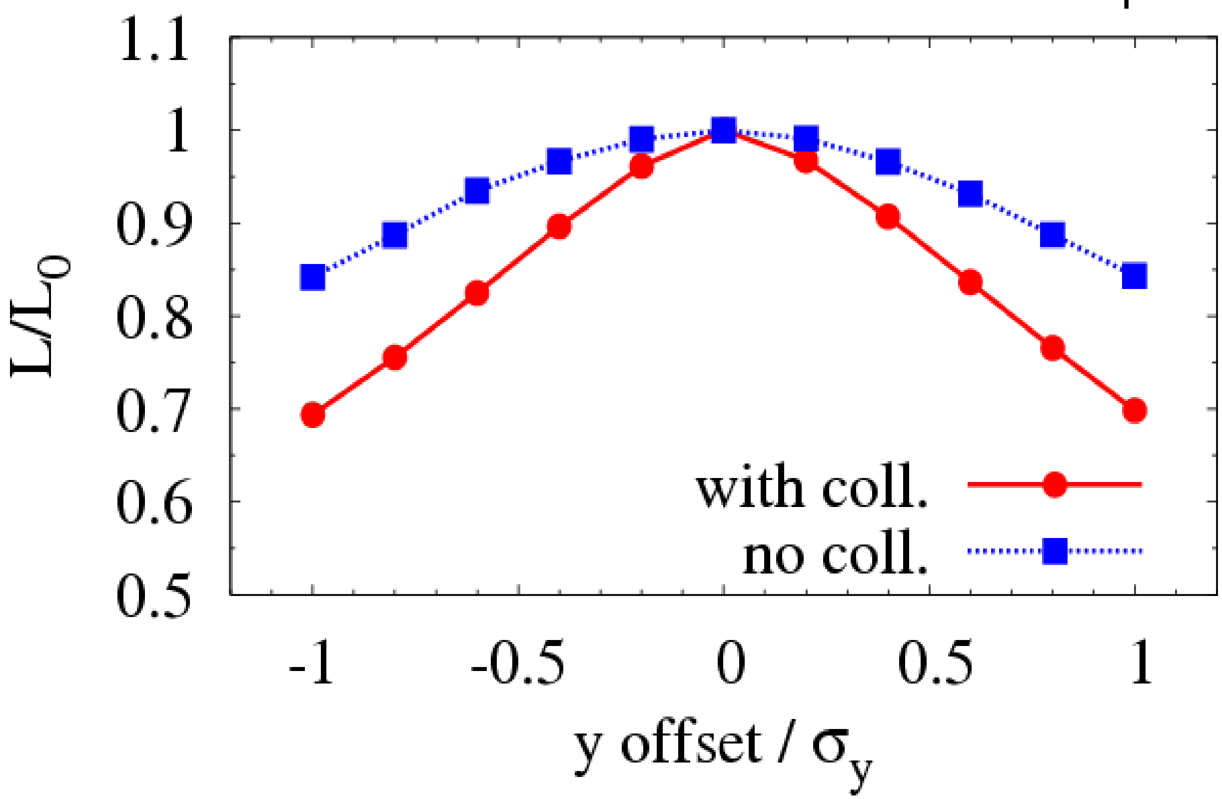
- Geometric wakefields:
  - Energy spoiler (E-sp): σ_z=44 μm; $\sigma_z a/h^2$=5.98e-5; θ_T=0.03 rad → $\theta_T \gg \sigma_z a/h^2$, not smooth transition: diffractive regime
  - Vertical spoiler (β_y-sp): $\sigma_z a/h^2$=1.1e-5; $\theta_T \approx$0.03 rad → $\theta_T \gg \sigma_z a/h^2$, not smooth transition: diffractive regime
  - Horizontal spoiler (β_x-sp): $\sigma_z a/h^2$=1.32e-5; $\theta_T \approx$0.03 rad → $\theta_T \gg \sigma_z a/h^2$, not smooth transition: diffractive regime
- Resistive wakefields for CLIC collimators: intermediate (between short- and long-range regimes)

Luminosity loss

Coll. wakefields + vertical beam position offset

Simulations: macroparticle tracking along the BDS using PLACET + luminosity calculation using GUINEA-PIG

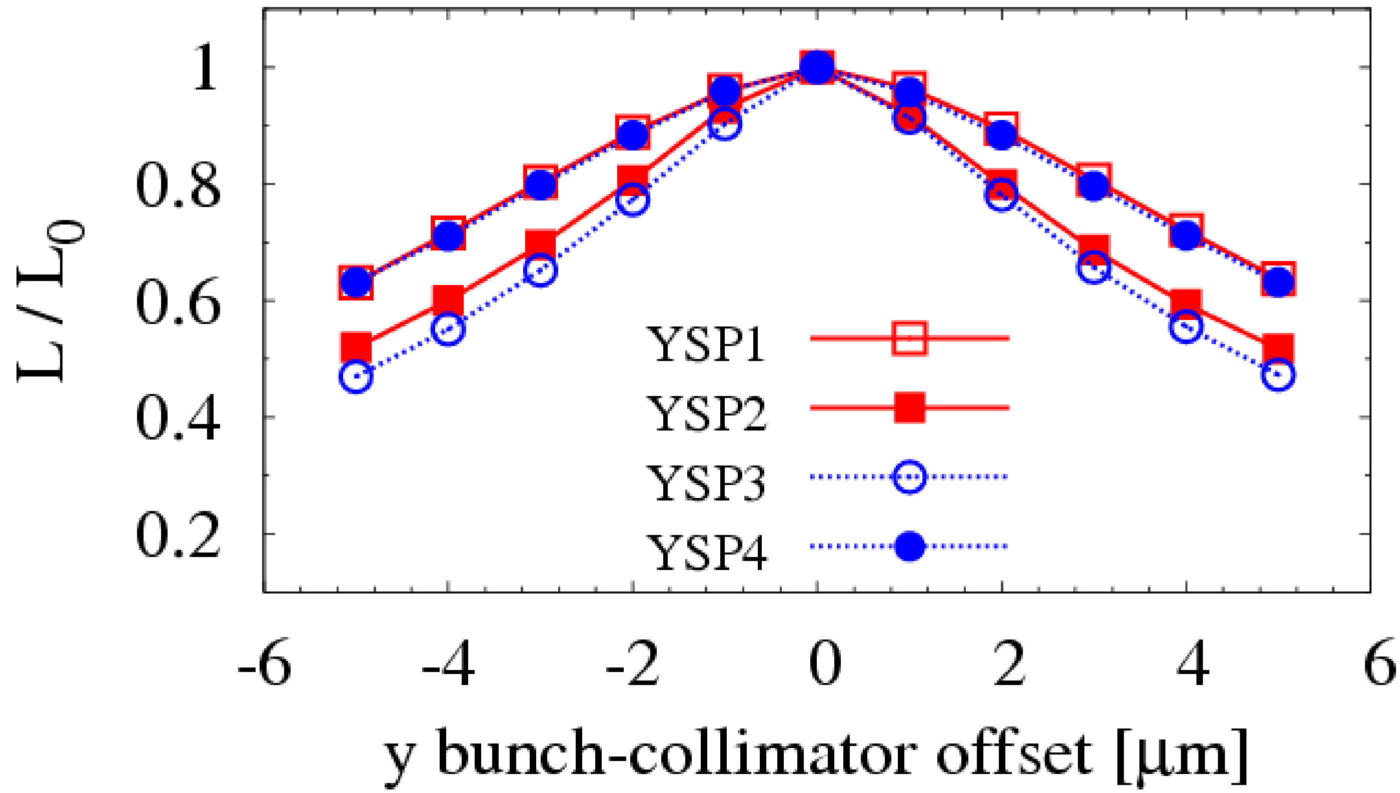
Coll. depths: 15 σ_x ; 55σ_y



Vertical beam offset tolerance <~0.3 σ_y (<~10% luminosity loss)

Luminosity loss

Coll. wakefields + vertical beam position offset

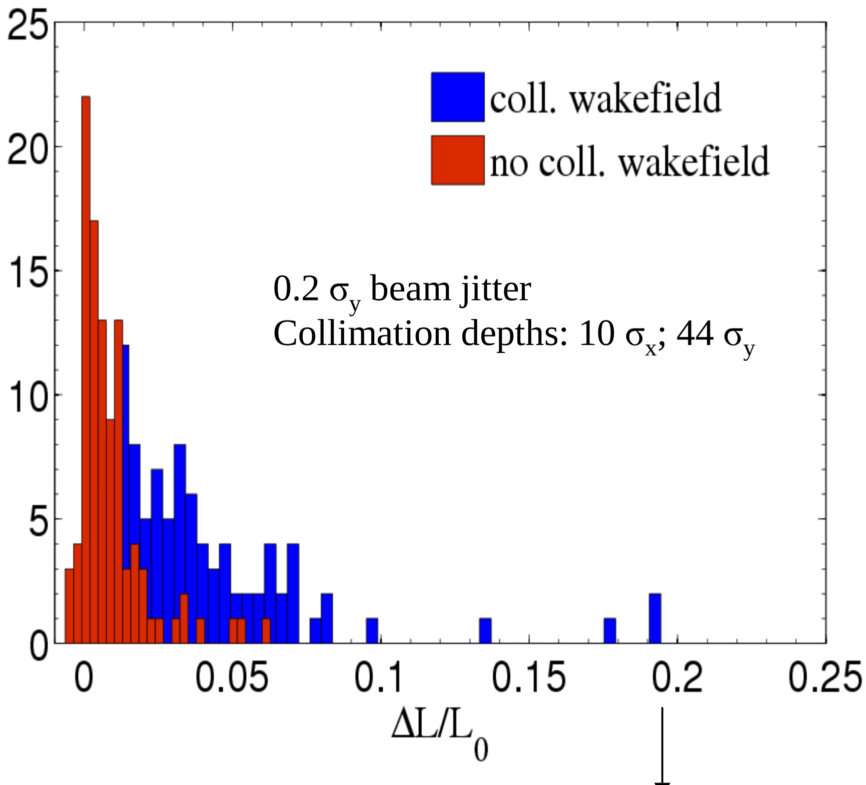


- Dominant contribution from YSP2 & YSP3
- For instance (for YSP2 & YSP3) 5 µm collimator misalignment means about 50% luminosity loss.

Luminosity loss

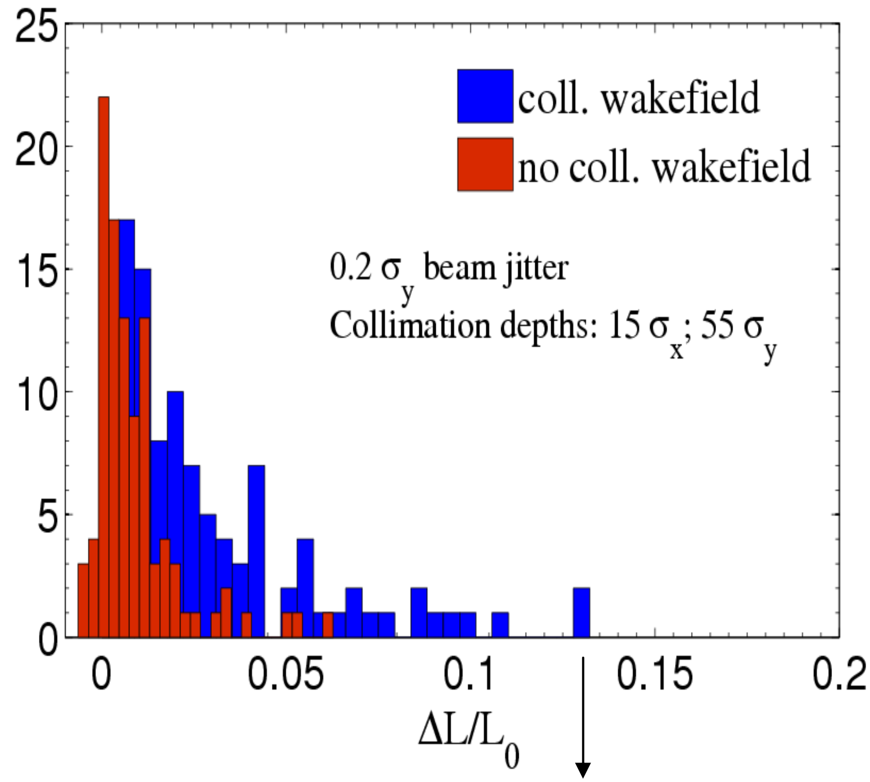
Coll. Wakefields + vertical beam position jitter effect

Old coll. apertures



≈ 19% maximum luminosity loss

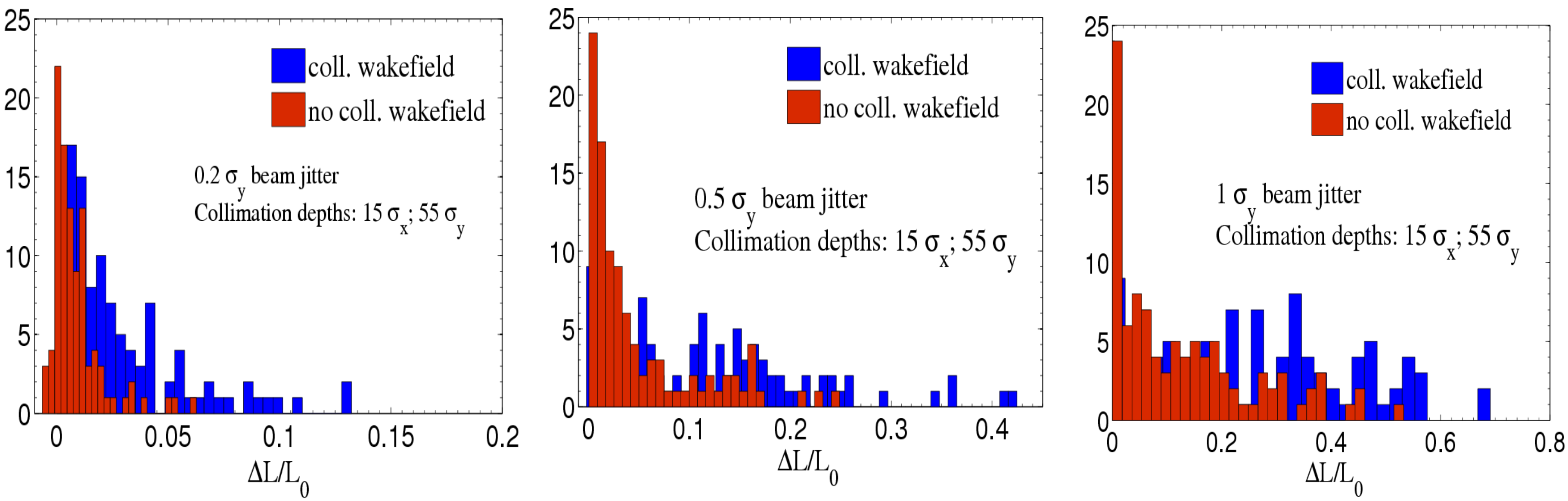
New coll. apertures



≈ 13% maximum luminosity loss

Luminosity loss

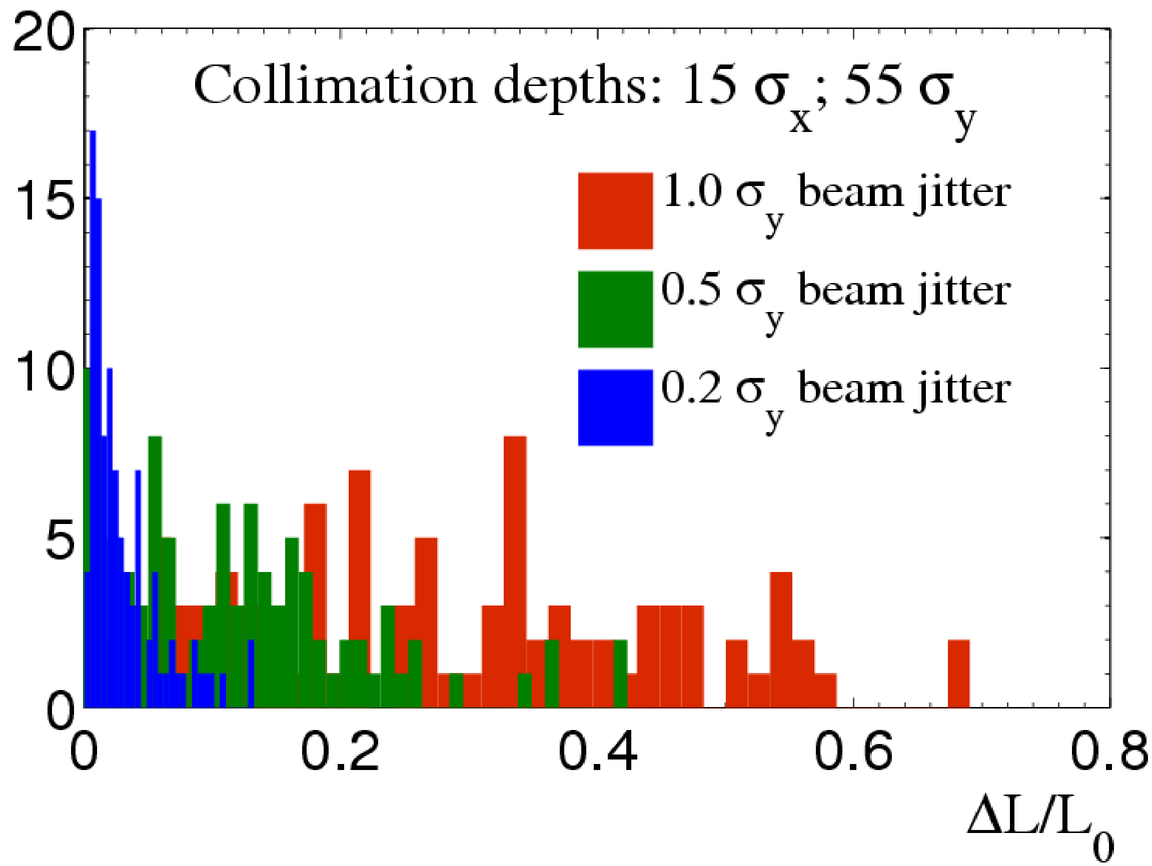
Coll. wakefields + vertical beam position jitter effect



Beam jitter	**rms $\Delta L/L_0$ (no coll. wakefields)**	**rms $\Delta L/L_0$ (with coll. Wakefields)**
0.2 σ_y	1.17%	2.85%
0.5 σ_y	5.72%	9.71%
1.0 σ_y	12.91%	17.58%

Luminosity loss

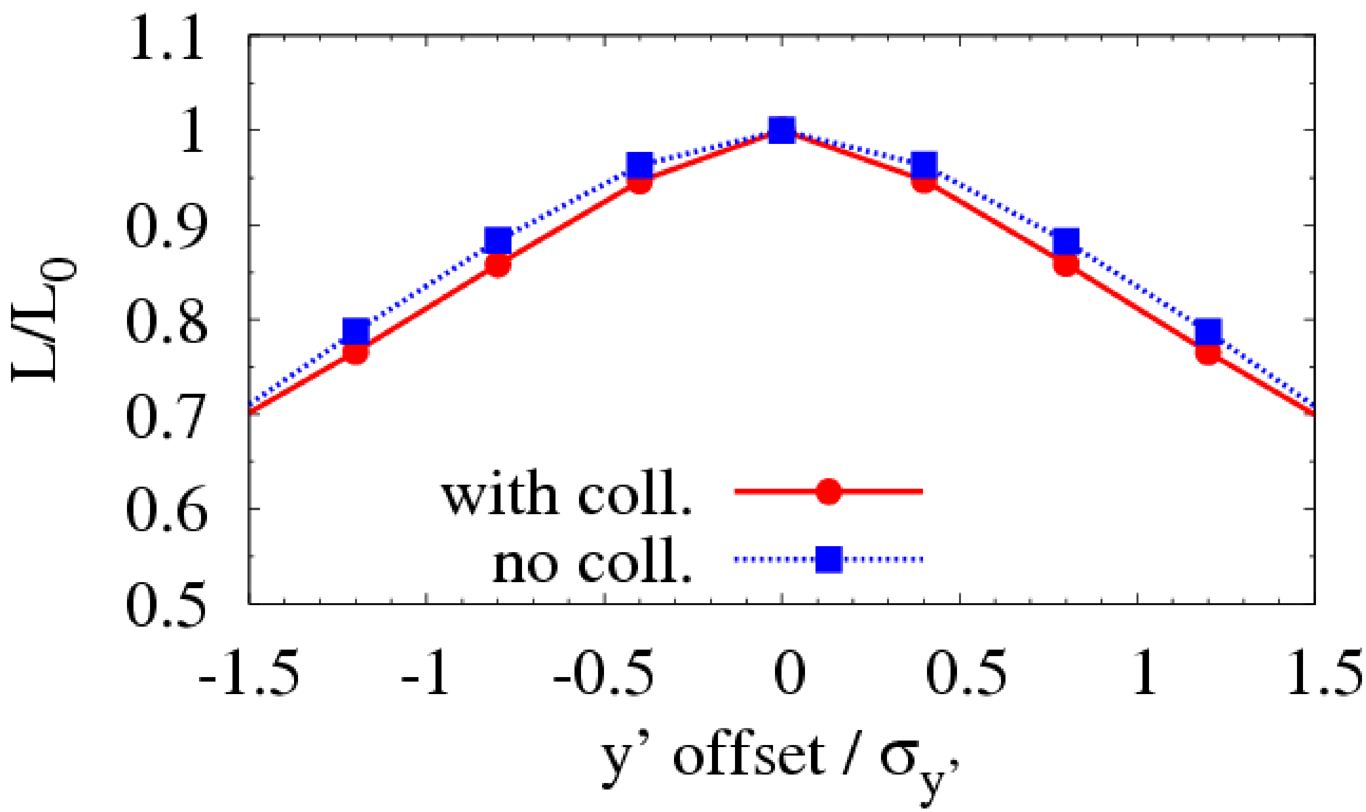
Coll. wakefields + vertical beam position jitter effect



1 σ_y beam jitter could lead to about 70% maximum luminosity loss

Luminosity loss

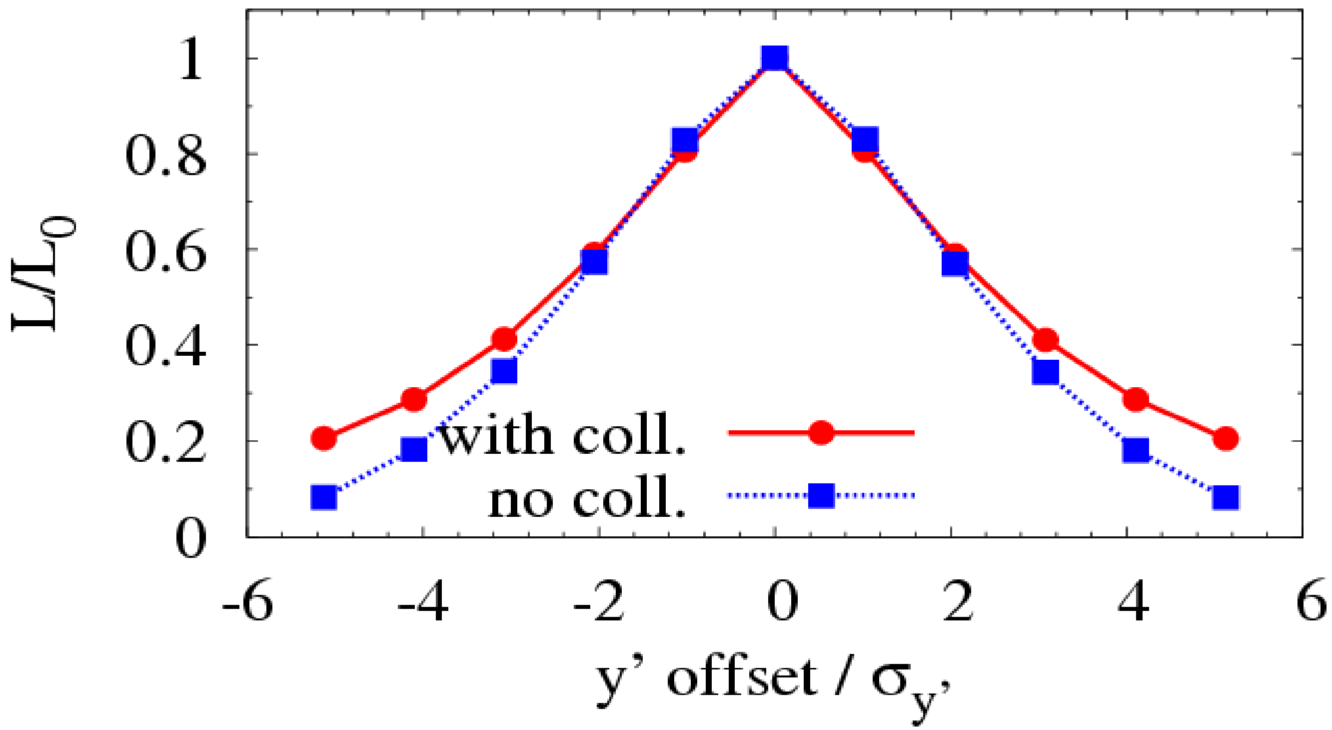
Coll. wakefield + vertical angle jitter effect



For small angle offsets (0 < y' <~ 1.5 $\sigma_{y'}$) luminosity loss increases slightly with wakefields

Luminosity loss

Coll. wakefield + vertical angle jitter effect



For larger y' offsets (y' > ~ 2 $\sigma_{y'}$) the collimator wakefield kick somehow counteracts the angle offset of the incoming beam, helping thus to increase luminosity !

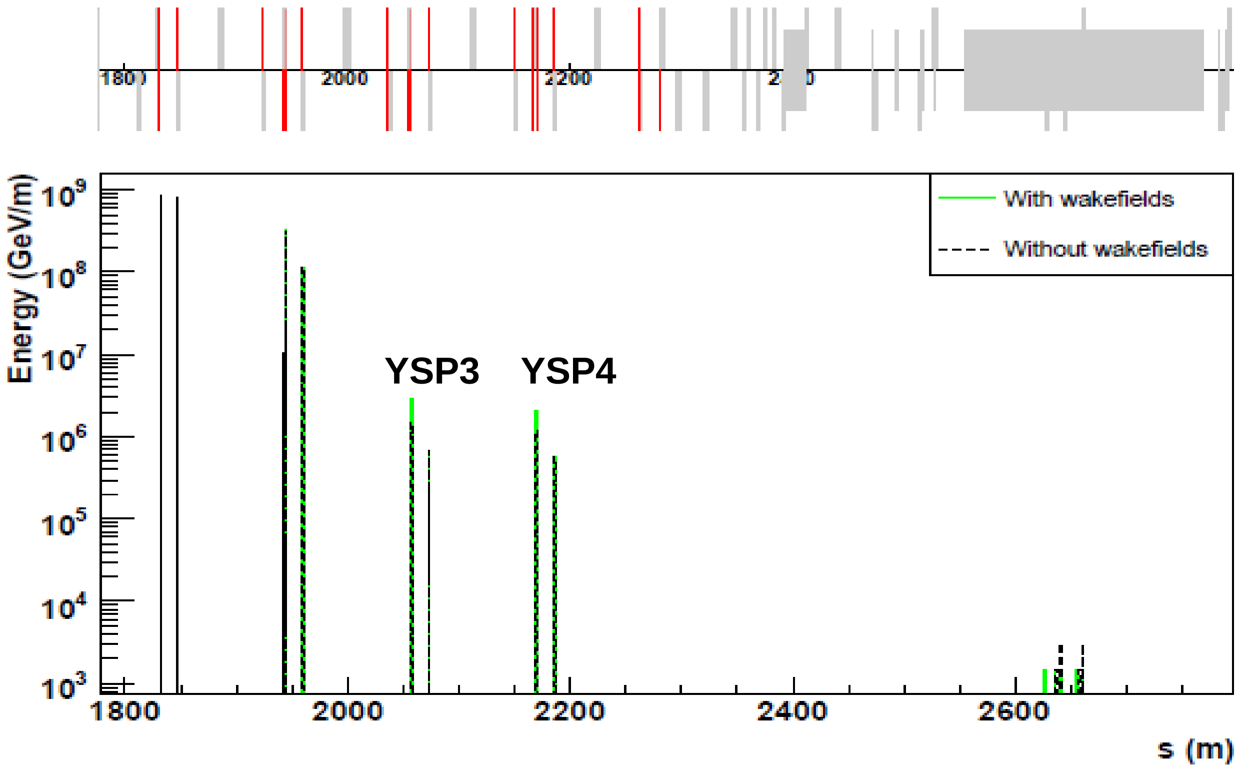
Collimator wakefield + Secondary particles

- "Tracking studies of the CLIC Collimation System", Steve Malton et al., submitted to PRST AB
- PLACET-BDSIM interface: simulations including particle tracking, wakefield effects, energy deposition, multiple Coulomb scattering and secondary particle production
- Detailed loss maps in the BDS
- Initial halo distribution for this study:
  - Concentric ellipses in x-x' and y-y', covering the phase space 0-40 $\sigma_{x,x'}$ and 0-190 $\sigma_{y,y'}$
  - Thickness per ellipse: 5 $\sigma_{x,x'}$ and 10 $\sigma_{y,y'}$ respectively
  - 1/r transverse density profile in each phase-space with 1e4 macroparticles per ellipse; 1.52e6 macroparticles total halo population
  - Flat energy distribution of full width 1% about the mean beam energy of 1496 GeV
  - Gaussian longitudinal profile of width 44 μm

Loss map along the BDS

with collimator wakefield effects (no secondary emission)

Hard-edge collimator assumption, and half-gaps: 10 σ_x and 44 σ_y

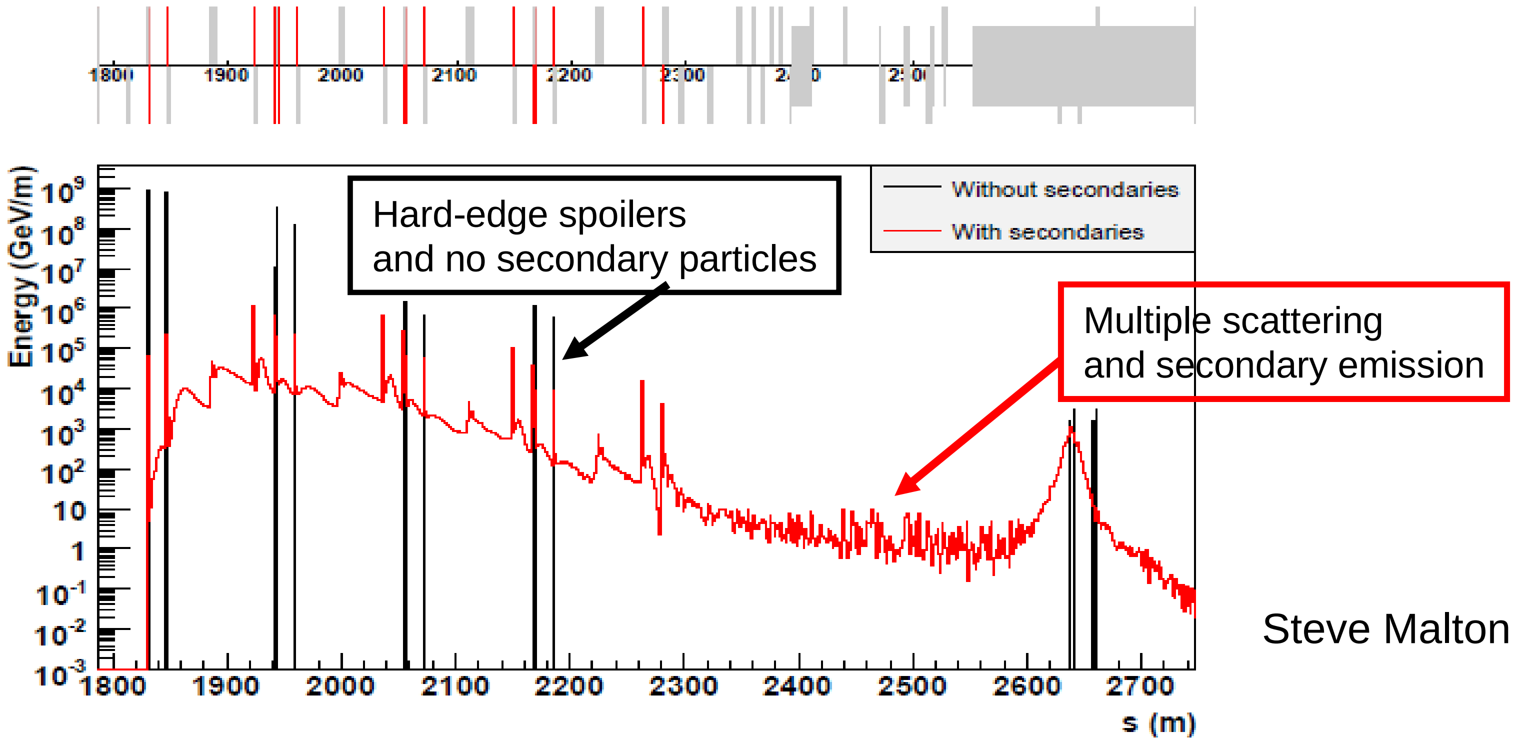


Steve Malton

- Considering that all particles hitting a collimator are absorbed totally at that point, the wakefields lead to approximately double the account of losses on the last two vertical spoilers (YSP3, YSP4)

Loss map along the BDS

with secondary particle production (no wakefields)

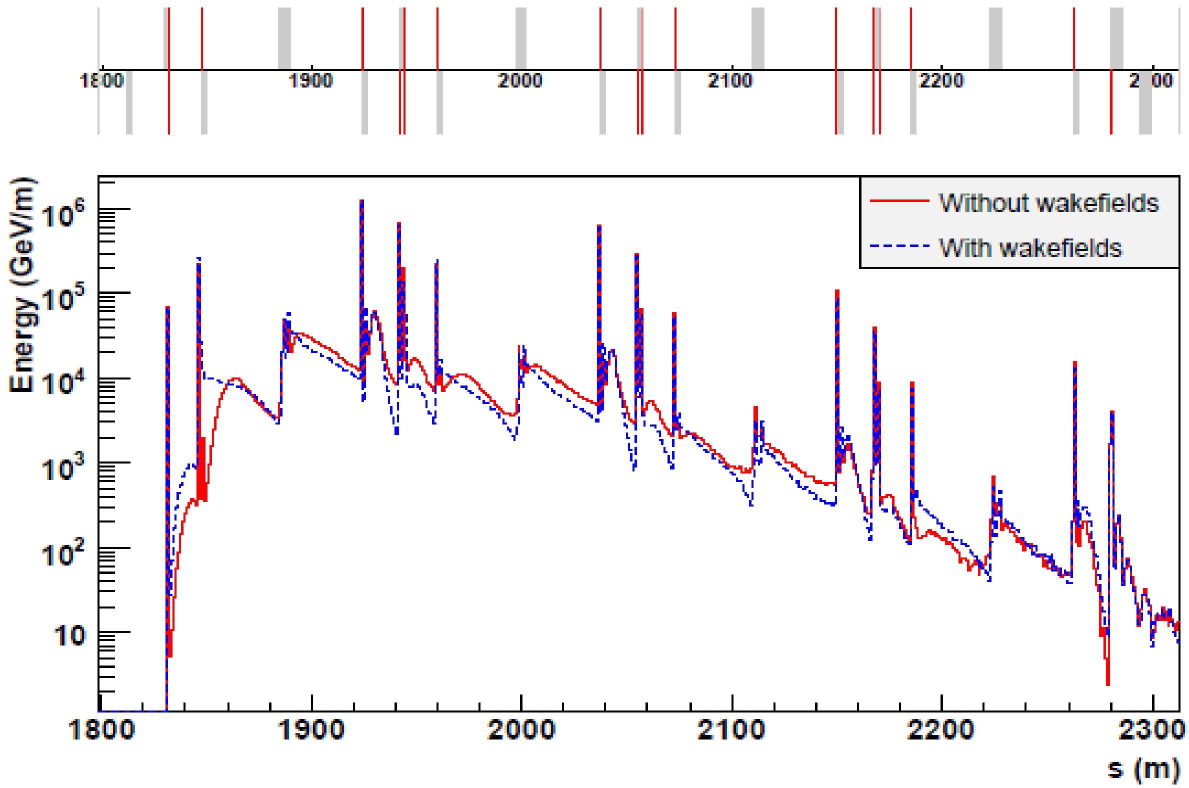


Steve Malton

- Losses occur on the absorbers only when secondary particles are included
- With secondary particle emission the peak of particle loss is reduced approximately by 4 orders of magnitude at the four first spoilers
- There are a number of primary particles lost in the FFS

Loss map along the BDS

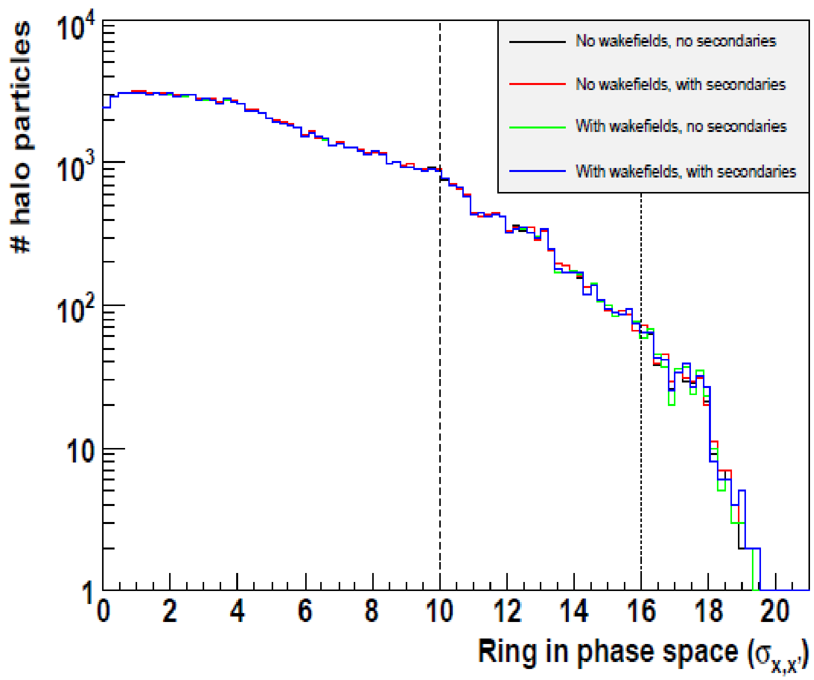
with secondary particle production + wakefields

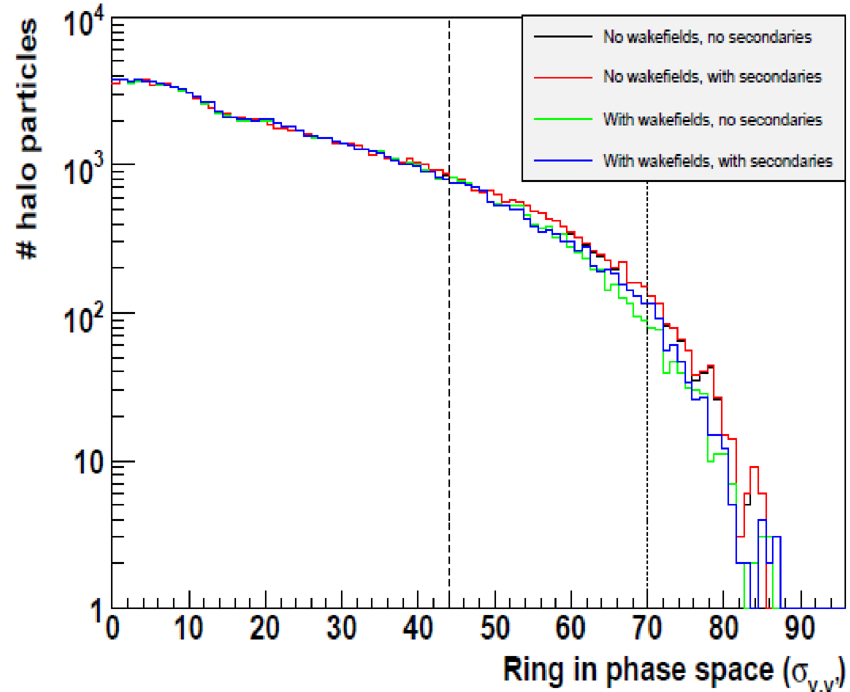


Steve Malton

- Considering secondary particle production, losses on the collimators do not differ significantly between the cases with and without wakefields
- Losses closer to the spoiler when wakefields are included

Halo distribution at QD0





Steve Malton

- The distribution in horizontal phase-space does not vary significantly with either wakefield or secondary particle generation

- Vertical distribution is more sensitive:
  - Wakefields decrease the number of particles above the collimation depth
  - Secondary particles increase this number

Summary and conclusions

- The CLIC collimation system has recently been reviewed
- Looking for a trade-off between high collimation efficiency and low wakefield effects, recently the collimation depths have been optimised
- We have reviewed the collimator wakefield impact on the luminosity with the new collimator apertures:
  - Vertical position jitter tolerance ~ $0.2\sigma_y \rightarrow \mathrm{rms}\ \Delta L/L_0 \approx 3\%$
  - Larger beam angle jitters are somehow counteracted by coll. wakefield kicks
- Remarkable progress in the development of software tools for realistic simulations (e.g. PLACET-BDSIM interface), including wakefield effects, energy deposition and secondary particle generation. ACTION: update collimation efficiency studies (who will make this studies?)
- Fruitful efforts (by international collaboration) towards the consolidation of the CLIC collimation system design (by end of 2009?)