Beam Dynamics study in Linear Colliders

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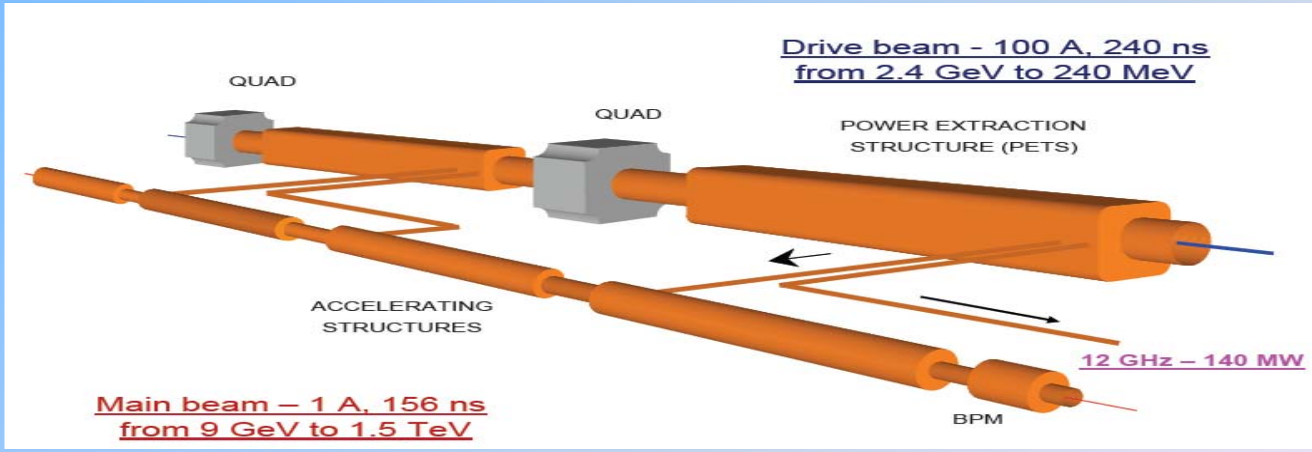


Outlines

- Introduction of CLIC
- Introduction of CLIC Test Facility
- Beam-halo and tail particles generation
  - Beam Delivery System (CLIC,ILC)
  - Linear Accelerator (CLIC,ILC)
  - Drive Beam (CLIC)
  - CTF3 Test Beam Line
- Post Collision Line

World-wide CLIC / CTF3 collaboration

http://clic-meeting.web.cern.ch/clic-meeting/CTF3_Coordination_Mtg/Table_MoU.htm

24 members representing 27 institutes involving 17 funding agencies of 15 countries

Ankara University (Turkey)
BINP (Russia)
CERN
CIEMAT (Spain)
Cockcroft Institute (UK)
Gazi Universities (Turkey)
IRFU/Saclay (France)

Helsinki Institute of Physics (Finland)
IAP (Russia)
IAP NASU (Ukraine)
Instituto de Fisica Corpuscular (Spain)
INFN / LNF (Italy)
J.Adams Institute, (UK)

JINR (Russia)
JLAB (USA)
KEK (Japan)
LAL/Orsay (France)
LAPP/ESIA (France)
NCP (Pakistan)
North-West. Univ. Illinois (USA)

Oslo University (norway)
PSI (Switzerland),
Polytech. University of Catalonia (Spain)
RRCAT-Indore (India)
Royal Holloway, Univ. London, (UK)
SLAC (USA)
Uppsala University (Sweden)

Major Parameters for Linear Collider

Filling factor
Linac length
Gradient

Energy reach

$$E_{cm} = 2 F_{fill} L_{linac} G_{RF}$$

Energy lost by beamstrahlung

Luminosity

$$L = \frac{k_b N_b^2 f_{rep}}{4 \pi \sigma_x^* \sigma_y^*} \quad \alpha \quad \frac{\delta_B^{1/2}}{E_{cm} \varepsilon_{ny}^{1/2}}$$

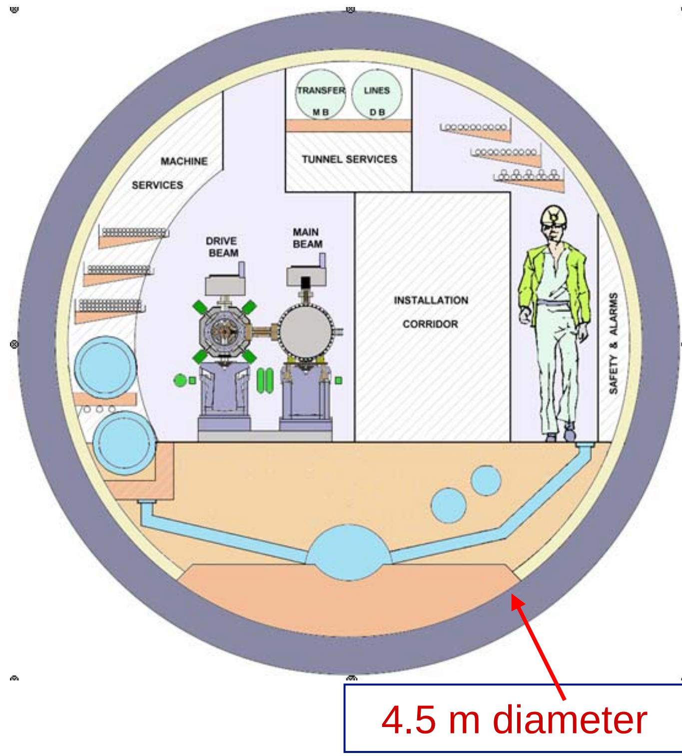
Center-of-mass energy
Vertical emittance

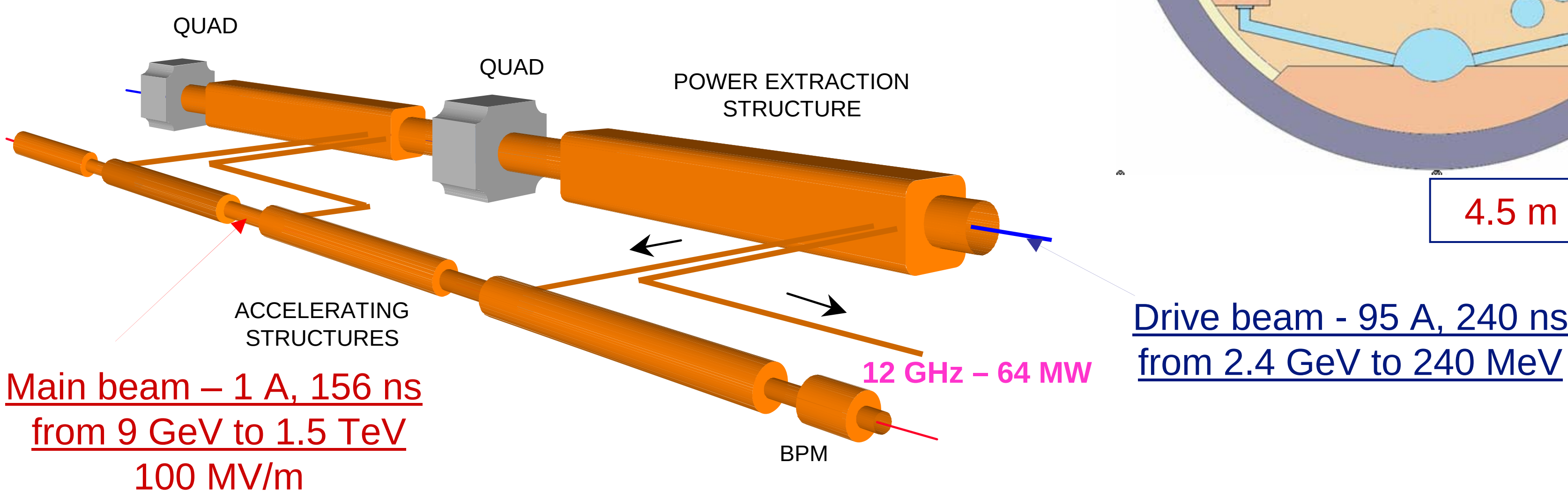
CLIC – Basic Features

- High acceleration gradient: > 100 MV/m

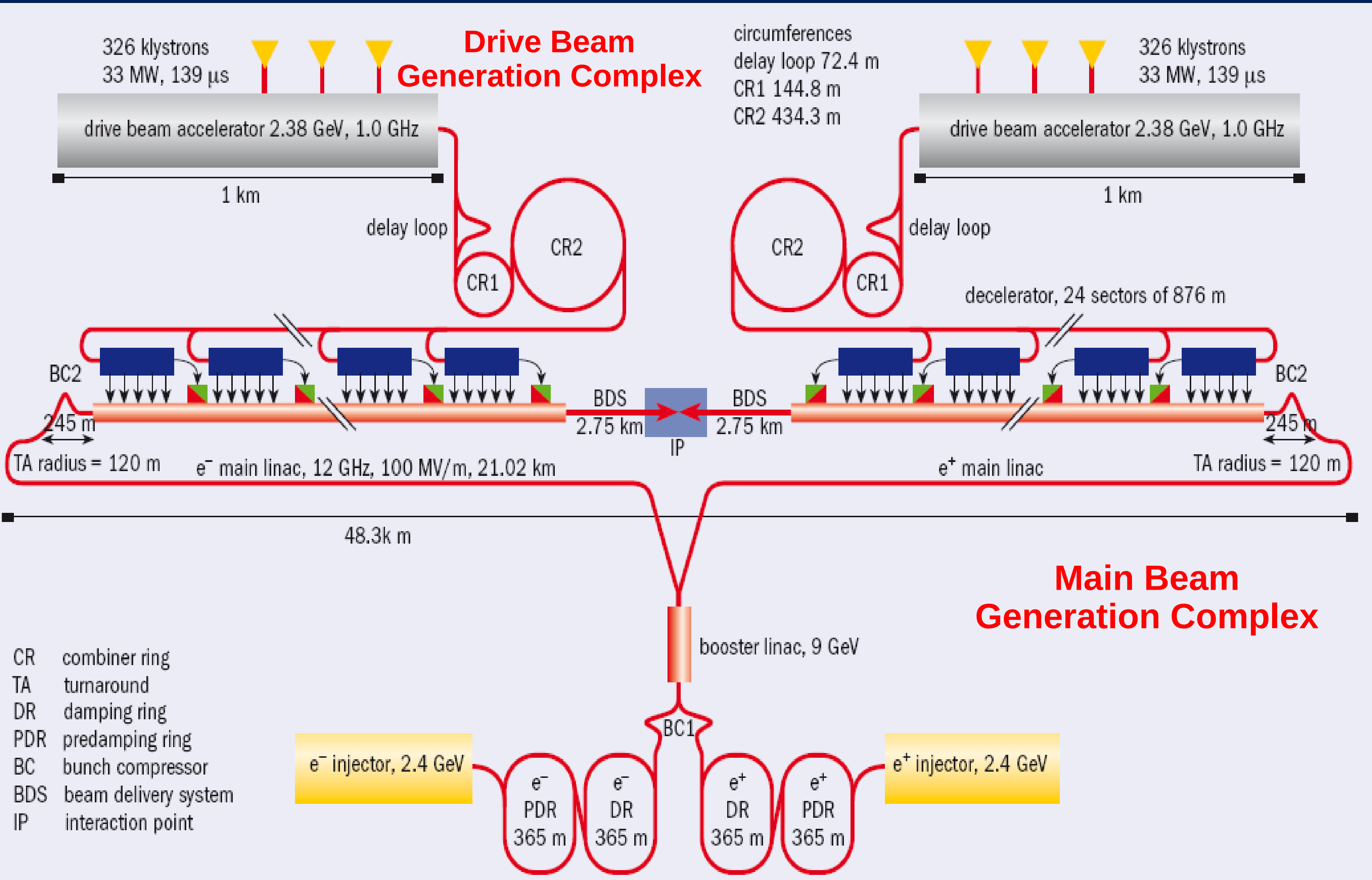
> - “Compact” collider – total length < 50 km at 3 TeV
> - Normal conducting acceleration structures at high frequency
>
> - Novel Two-Beam Acceleration Scheme
>   - Cost effective, reliable, efficient
>   - Simple tunnel, no active elements
>   - Modular, easy energy upgrade in stages

CLIC TUNNEL CROSS-SECTION



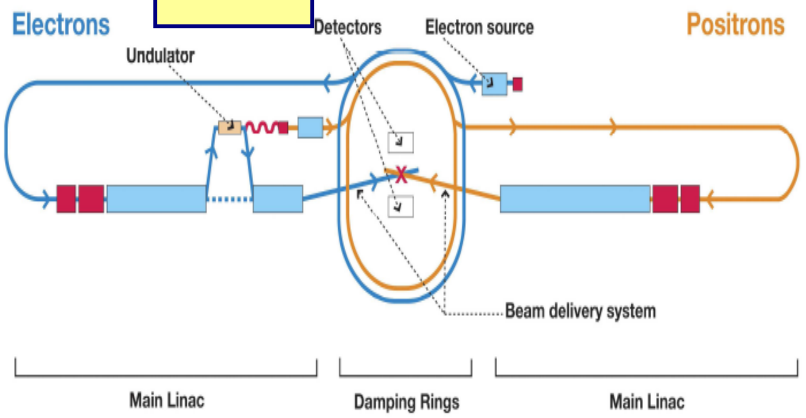


CLIC Schematic

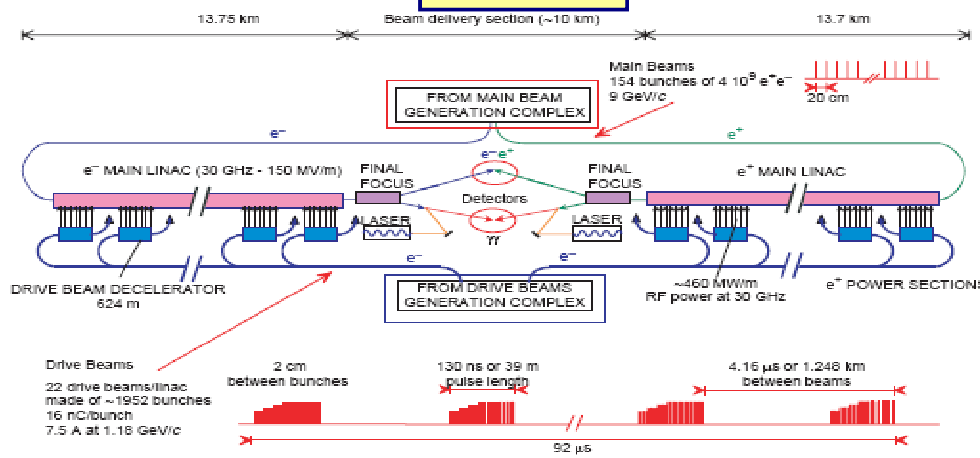


CLIC vs ILC

ILC



CLIC



- Based on superconducting RF cavities
- Gradient 32 MV/m
- **Energy: 500 GeV, upgradeable to 1 TeV**

(possible GigaZ factory at 90 GeV or ZZ factory at ~200 GeV is also considered)

- Detector studies focus mostly on 500 GeV

- Based on 2-beam acceleration scheme (warm cavities)
- Gradient 100 MV/m
- **Energy: 3 TeV**, though will probably start at lower energy (~0.5 TeV)
- Detector study focuses on 3 TeV

Technology available

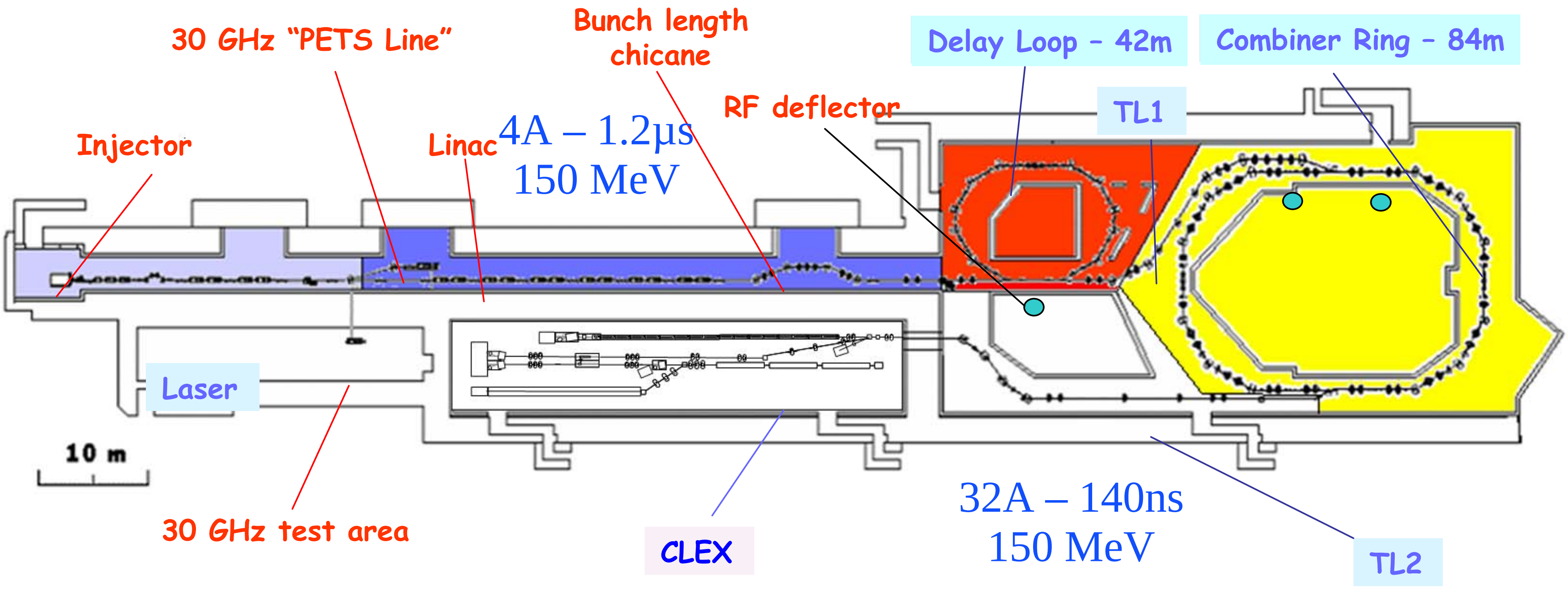
Feasibility demonstrated in 2009

Collider Parameters

Parameter	Symbol	3 TeV	1 TeV	0.5 TeV	ILC	Unit
Center of mass energy	E_{cm}	3000	1000	500	500	GeV
Main Linac RF Frequency	f_{RF}	12	12	12	1.3	GHz
Luminosity	**L**	**7**	**2.25**	**2.24**	**2**	**10^{34} cm^{-2} s^{-1}**
Luminosity (in 1% of energy)	$L_{99\%}$	2	1.08	1.36		10^{34} cm^{-2} s^{-1}
Linac repetition rate	f_{rep}	50	50	100	5	Hz
No. of particles / bunch	N_b	3.72	3.72	3.72	20	10^9
No. of bunches / pulse	k_b	312	312	312	2670	
No. of drive beam sectors / linac	N_{unit}	24	8	4	-	-
Overall two linac length	l_{linac}	41.7	13.9	6.9	22	km
Proposed site length	**l_{tot}**	**47.9**	**20.1**	**13.2**	**31**	**km**
DB Pulse length (total train)	τ_t	139	46	23	-	µs
Beam power / beam	P_b	14	4.6	4.6	10.8	MW
Wall-plug power to beam efficiency	η_{wp-rf}	8.7	6.1	6.1	9.4	%
Total site AC power	**P_{tot}**	**322**	**~150**	**~150**	**230**	**MW**
Transverse horizontal emittance	$\gamma\varepsilon_x$	660	660	660	8000	nm rad
Transverse vertical emittance	$\gamma\varepsilon_y$	20	20	20	40	nm rad
Horizontal IP beam size before pinch	σ^*_x	40		142	640	nm
Vertical IP beam size before pinch	σ^*_y	1		2	5.7	nm
Beamstrahlung energy loss	δ_B	29	11	7	2.4	%

CLIC Test Facility (CTF3)

- Demonstrate remaining CLIC feasibility issues, in particular:
  - Drive Beam generation (fully loaded acceleration, bunch frequency multiplication)
  - CLIC accelerating structures
  - CLIC power production structures (PETS)



Beam-Generated Halo and Tail

- 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.
- 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

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

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

Scattering fraction

$$S = P.l$$

Scattering probability

$$P = n.\sigma$$

Residual gas pressure

$$p = n.k_B.T$$

Scatter.prob./bunch

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

Beam Delivery System (BDS)

Collimation System

- Reduce the background by removing particles at large betatron amplitudes (Halo) or energy Offsets.
- The choice of the collimator apertures should guarantee good cleaning efficiency of Halo.
- To avoid wakefields that might degrade the orbit stability.

Final Focus System

- Need to provide a very strong focusing.
- Reduces the transverse sizes of the beam at the IP sufficiently to provide the required luminosity
- The correction of chromatic and geometric aberrations.

BDS Purpose: Reduce the beam sizes to nanometer sizes to produce the luminosity

Equation of Motion

$$x''(s) - k(s)x(s) = 0$$

Hills equation

$$x(s) = \sqrt{\varepsilon}\sqrt{\beta(s)} \cdot \cos(\psi(s) + \phi)$$

General solution

$$(1) \quad x(s) = \sqrt{\varepsilon} * \sqrt{\beta(s)} * \cos(\psi(s) + \phi)$$

$$(2) \quad x'(s) = -\frac{\sqrt{\varepsilon}}{\sqrt{\beta(s)}} * \{\alpha(s) * \cos(\psi(s) + \phi) + \sin(\psi(s) + \phi)\}$$

$$\varepsilon = \gamma(s) * x^2(s) + 2\alpha(s)x(s)x'(s) + \beta(s)x'(s)^2$$

Twiss Parameters

$$\alpha(s) = \frac{-1}{2}\beta'(s)$$

$$\gamma(s) = \frac{1 + \alpha(s)^2}{\beta(s)}$$

Dispersion Function

$$x'' + x\left(\frac{1}{\rho^2} - k\right) = \frac{\Delta p}{p} \cdot \frac{1}{\rho}$$

general solution:

$$x(s) = x_h(s) + x_i(s)$$

$$D(s) = \frac{x_i(s)}{\Delta p / p}$$

Phase Advance: $\psi(s) = \int_0^s \frac{ds}{\beta(s)}$

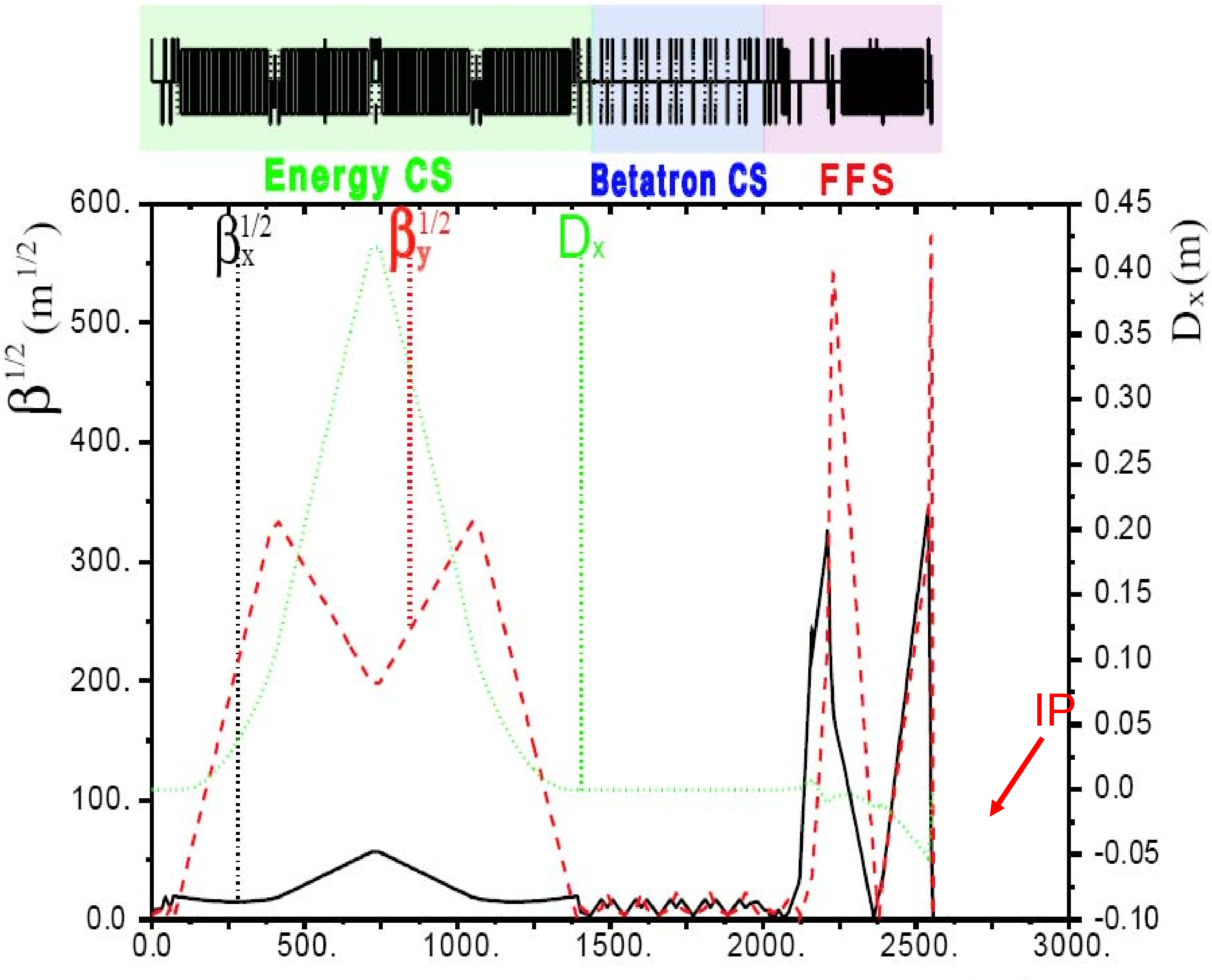
Tune: $Q_y = \frac{1}{2\pi} \cdot \oint \frac{ds}{\beta(s)}$

Chromaticity: $\xi = \frac{-1}{4\pi} * \oint K(s)\beta(s)\, ds$

CLIC BDS Optics

entrance

β_x	64.171 m
α_x	-1.95133
β_y	18.2438 m
α_y	0.605865
β^*_x	7 mm
α^*_x	0.
β^*_y	90 µm
α^*_y	0.
E	1.5 TeV
$\gamma\varepsilon_x$	680 nm
$\gamma\varepsilon_y$	10 nm



βx = 7 mm and βy = 0:09 mm

Simulation : Model of the Beam

If a lattice is linear then particle representation:

$$\sum_i \equiv \begin{bmatrix} \sigma_{x,i}\sigma_{x,i} & \sigma_{x,i}\sigma_{x',i} & \sigma_{x,i}\sigma_{y,i} & \sigma_{x,i}\sigma_{y',i} \\ \sigma_{x',i}\sigma_{x,i} & \sigma_{x',i}\sigma_{x',i} & \sigma_{x',i}\sigma_{y,i} & \sigma_{x',i}\sigma_{y',i} \\ \sigma_{y,i}\sigma_{x,i} & \sigma_{y,i}\sigma_{x',i} & \sigma_{y,i}\sigma_{y,i} & \sigma_{y,i}\sigma_{y',i} \\ \sigma_{y',i}\sigma_{x,i} & \sigma_{y',i}\sigma_{x',i} & \sigma_{y',i}\sigma_{y,i} & \sigma_{y',i}\sigma_{y',i} \end{bmatrix}$$

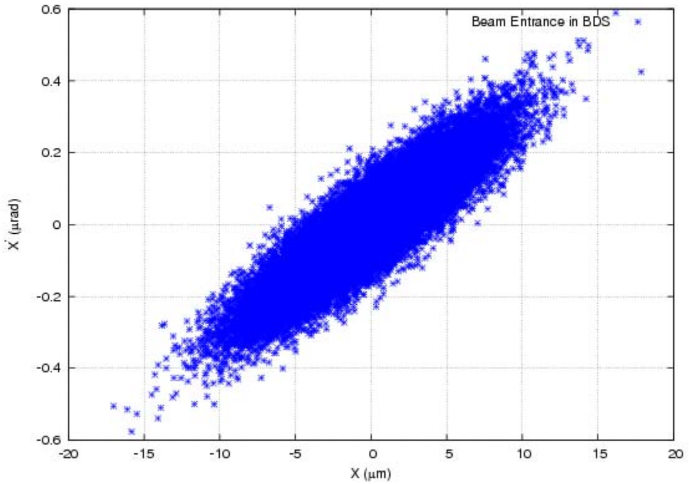
Beam Matrix of pulse representation:

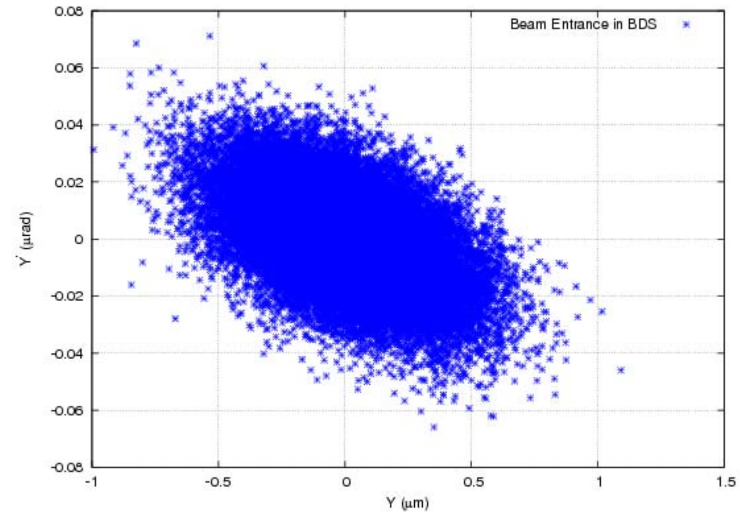
$$\sum \equiv \begin{bmatrix} \sum_{xx} & \sum_{xx'} & \sum_{xy} & \sum_{xy'} \\ \sum_{x'x} & \sum_{x'x'} & \sum_{x'y} & \sum_{x'y'} \\ \sum_{yx} & \sum_{yx'} & \sum_{yy} & \sum_{yy'} \\ \sum_{y'x} & \sum_{y'x'} & \sum_{y'y} & \sum_{y'y'} \end{bmatrix}$$

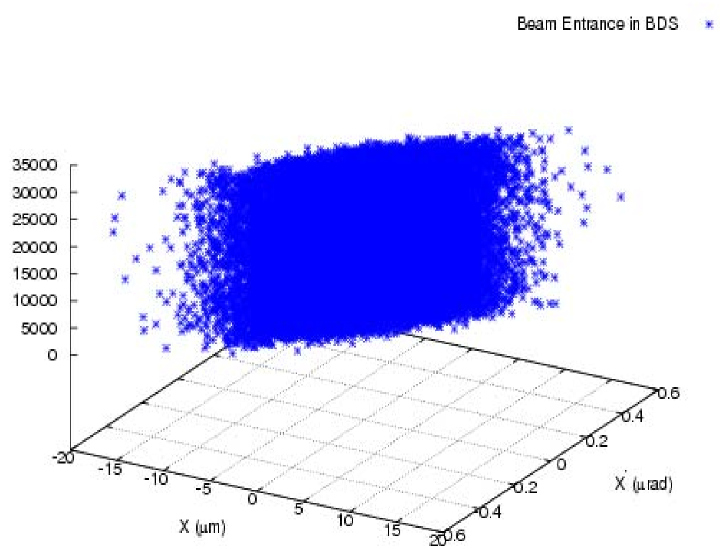
Models of the Elements: Quadrupoles, Drifts, BPMs, Dipoles, RF, Dec. Structures

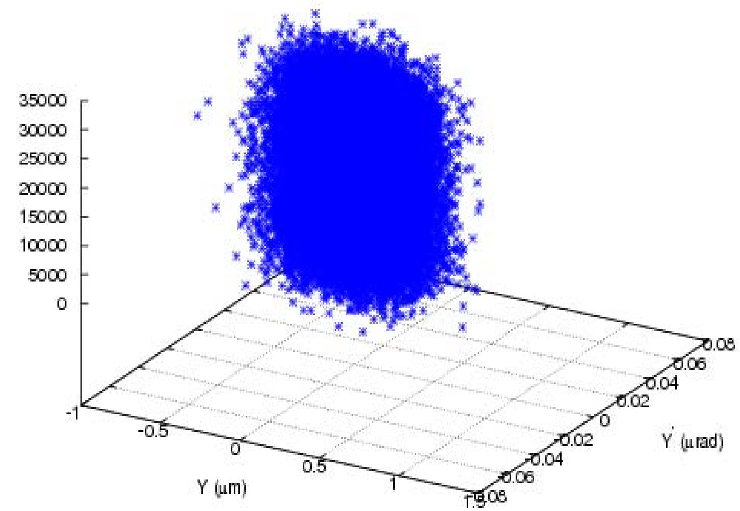
Beam Tracking in BDS (1)

Beam-Entrance Profile in BDS



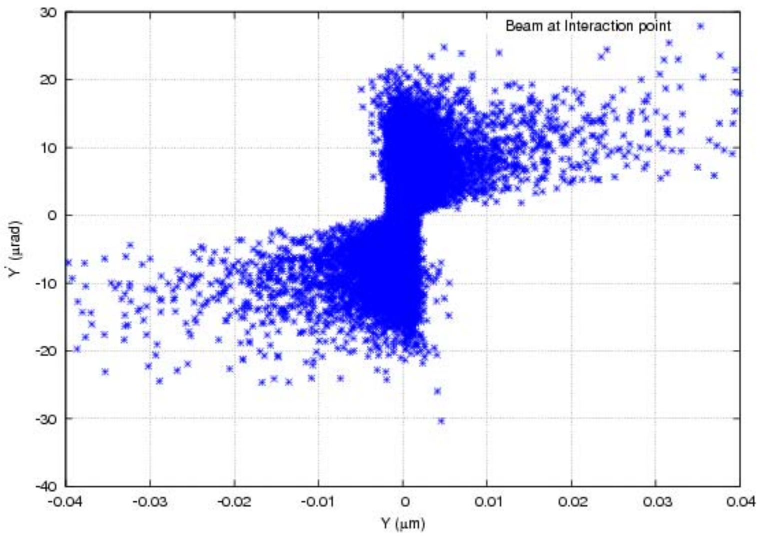


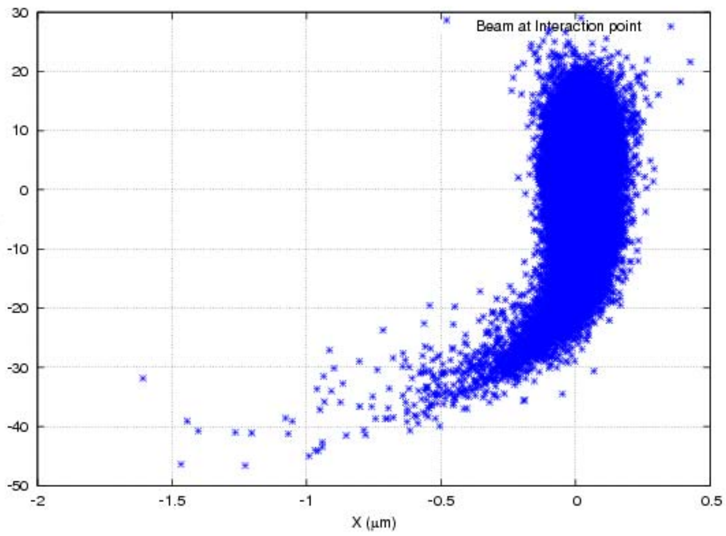


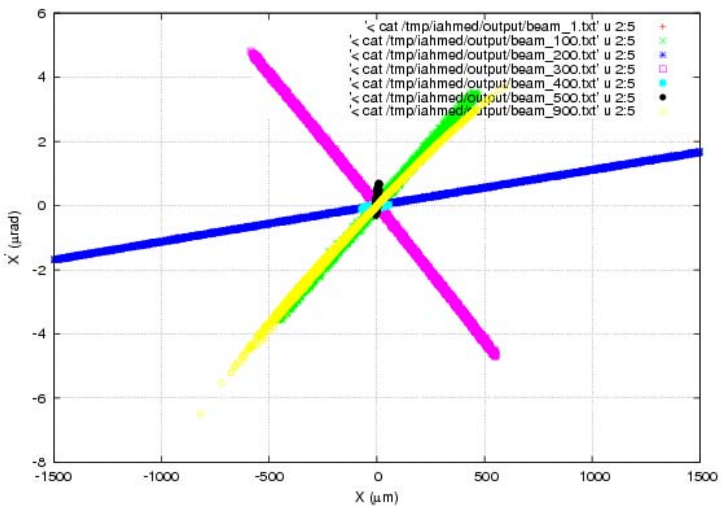


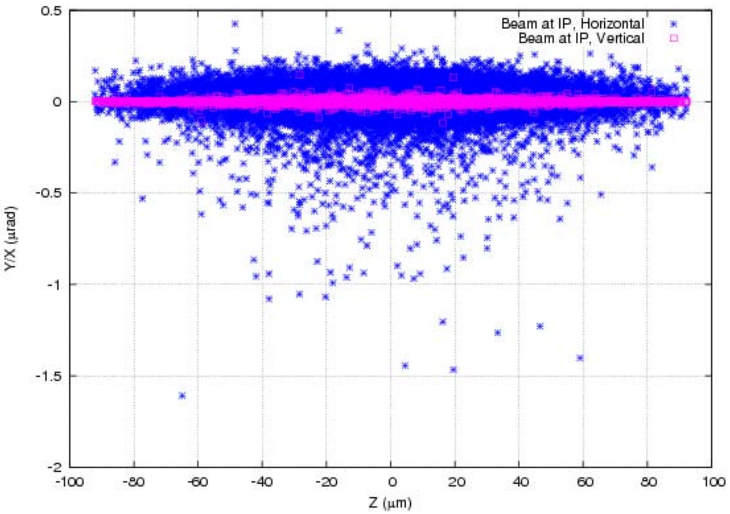
Beam Tracking in BDS (2)

Beam Profile at IP

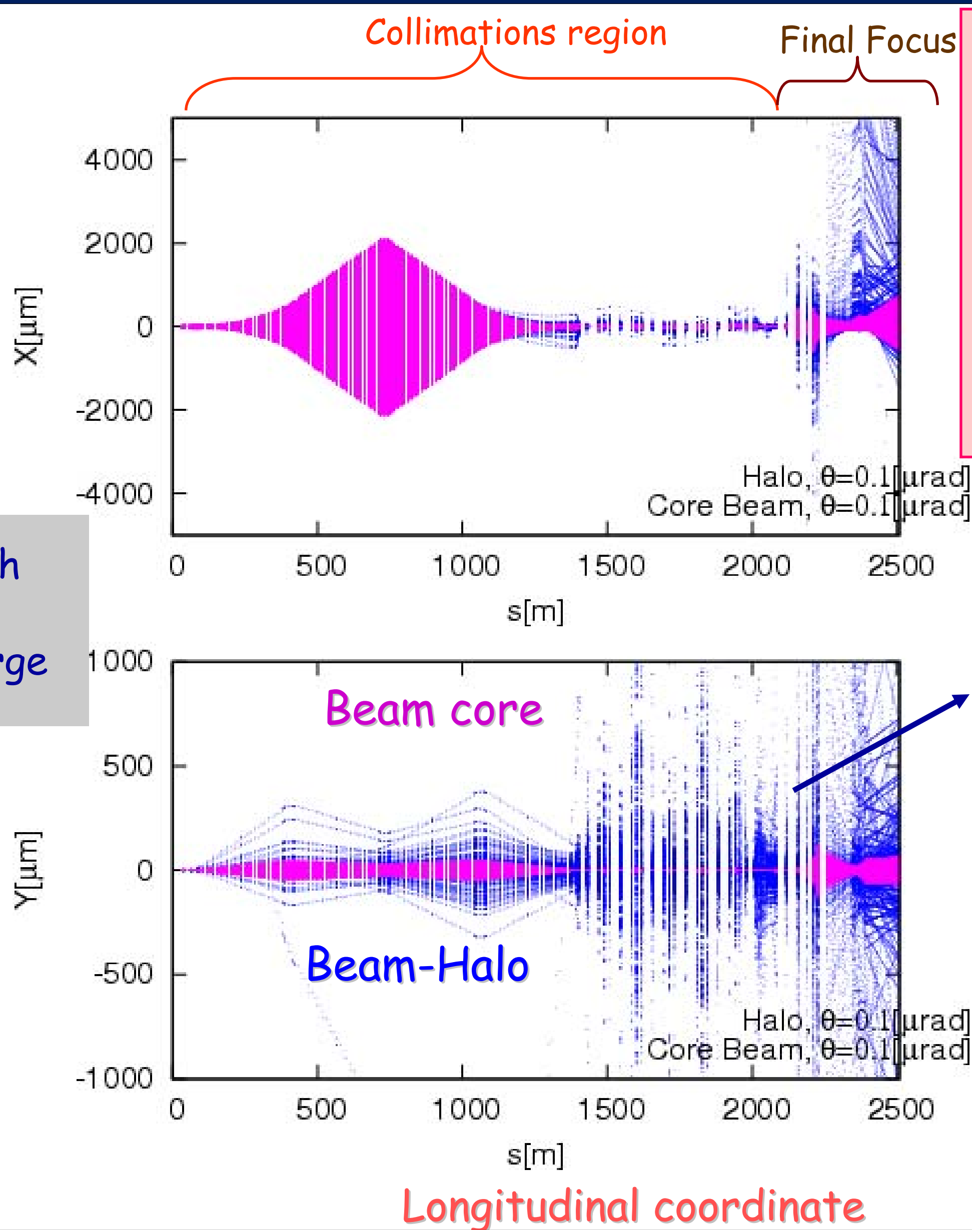








Beam Tracking in BDS (3)

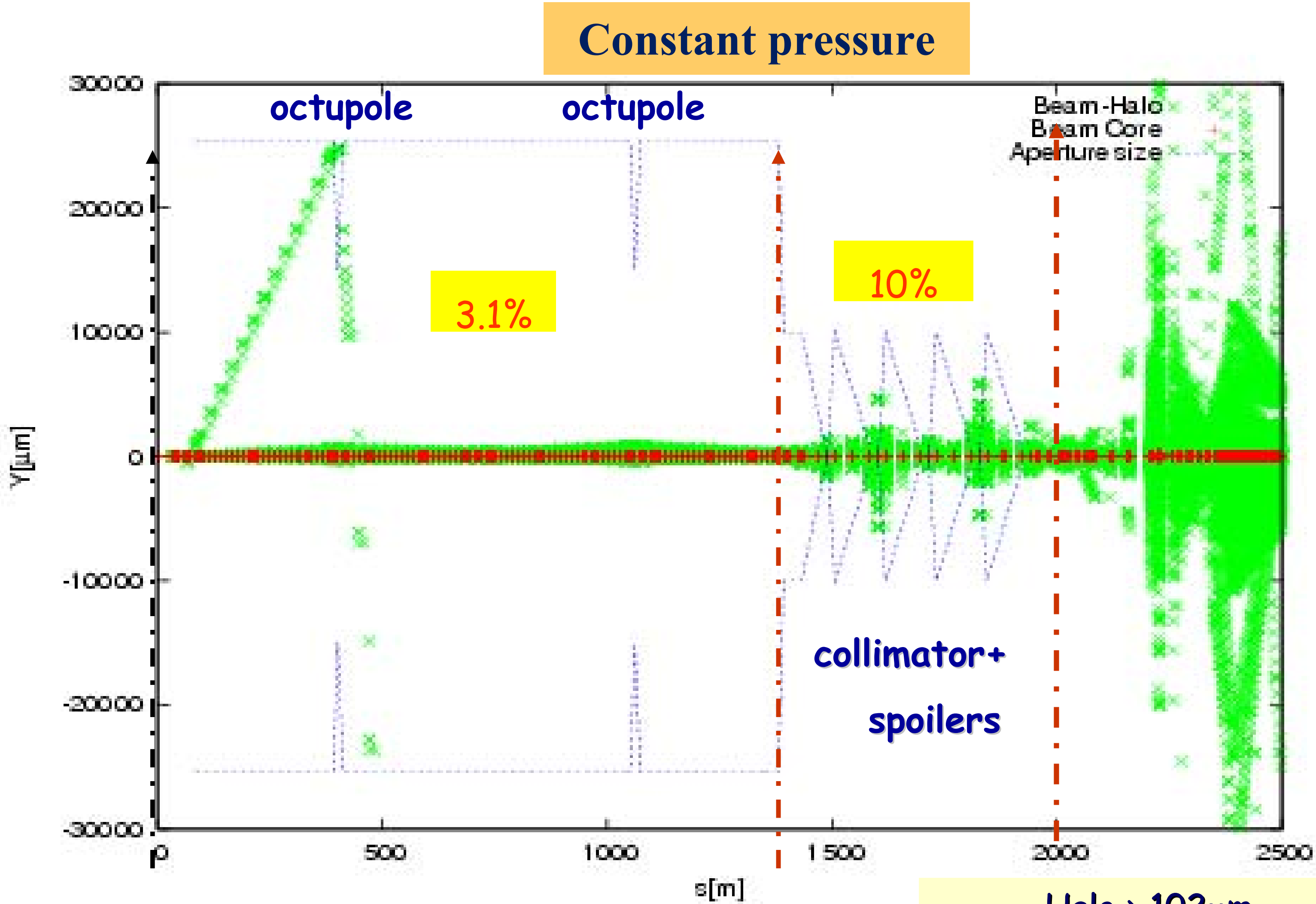


Total no. of elements 637
No. of slices 31
No. of macroparticles 100
Energy 1496 GeV
Charge 4 nC
Emitt. along x-axis 680 μrad
Emitt. Along y-axis 10 μrad
Normal temperature
Resudual gas N_2
Lattice with no collimators

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

Large beta + allignment errors resulting in dispersion

Beam Tracking in BDS (4)



Halo > 102µm = 30%

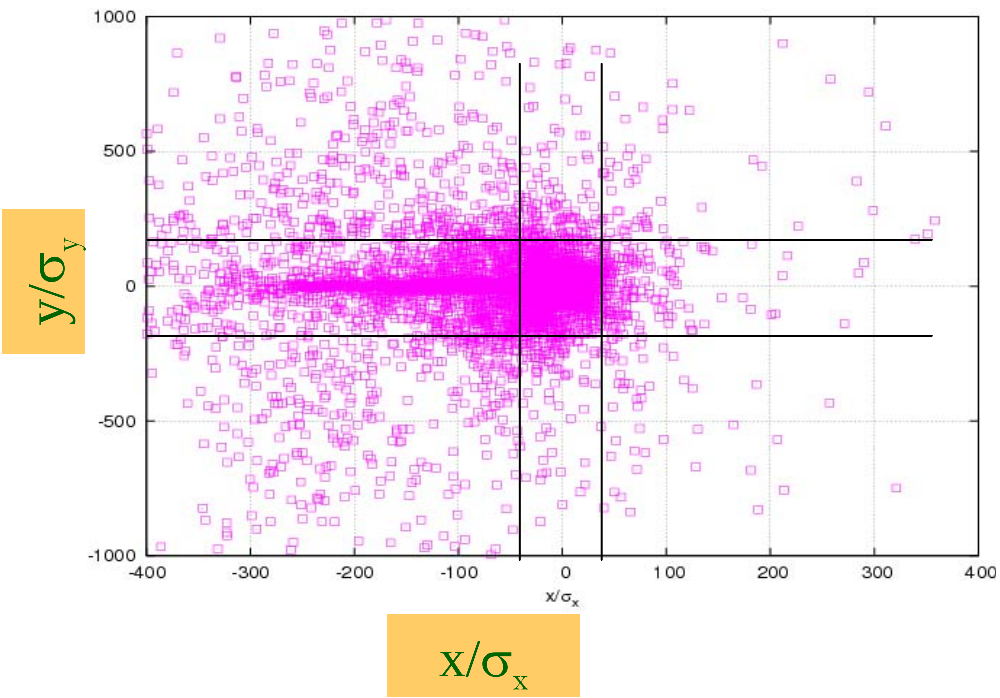
Halo > 1 mm = ~ 3%

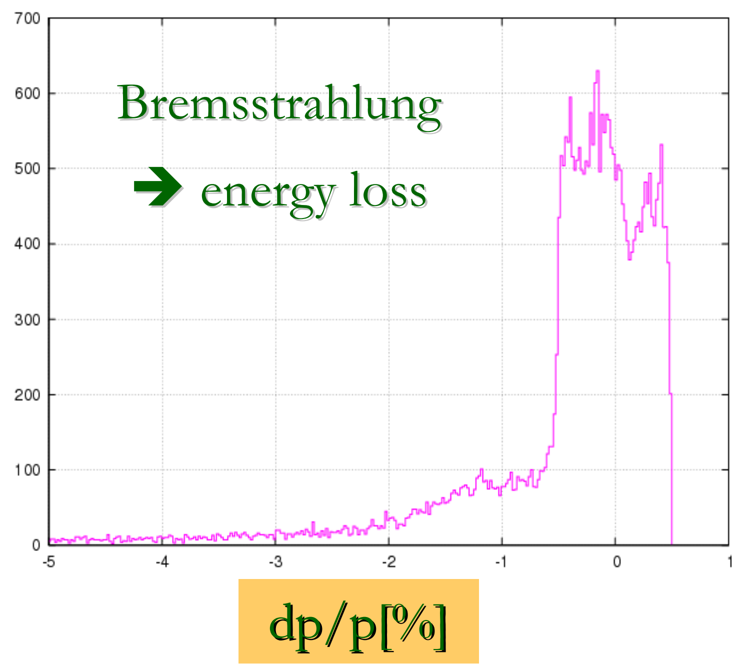
Halo > 10 mm = ~ 0.5%

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





Analytical Estimates and Simulations for CLIC BDS

- Integrated over the Linac, the probability for Mott scattering is then 1.16×10^{-3}
- The total probability for the 2.75 km long BDS is 6.02×10^{-5} .
- For the sum of LINAC and BDS we get a scattering probability of 1.2×10^{-3}.
- The probability for inelastic scattering with a fractional energy loss $K_{min} > 0.01$ is much smaller, about 2.1×10^{-13} m both in the LINAC and BDS.
- Summing up over the full length, we get a probability for inelastic scattering for the combined LINAC and BDS system of 5×10^{-9}.
- A fraction of about 2×10^{-4} of all particles will have large amplitudes and hit the spoilers in the BDS.
- With 1.24×10^{12} particles per train, this would translate into a flux of 2.4×10^{8} particles per train impacting on the spoiler.
- At 1.5 TeV, we expect that a fraction of about 9×10^{-4} of these particles produce secondary muons, resulting in a flux of about 2×10^{-5} muons per train

Parameter	Unit	Value
$e_{N,y,initial}$	nm	5.0
βy	m	100
Residual gas (BDS)		CO
Residual gas (LINAC)		CO
Temperature (BDS)	K	300
Temperature (LINAC)	K	300
Pressure (BDS)	nTorr	10
Pressure (LINAC)	nTorr	10
Length of LINAC Length of BDS	Km Km	15 2.5
Kmin		0.01

Location	E GeV	Gas	ρ m^-3	σ_{el} Barn	P m^-1
LINAC	9	CO	3.2×10^{14}	1.1×10^{8}	3.6×10^{-6}
BDS	1500	CO	3.2×10^{14}	3.6×10^{5}	2.2×10^{-8}

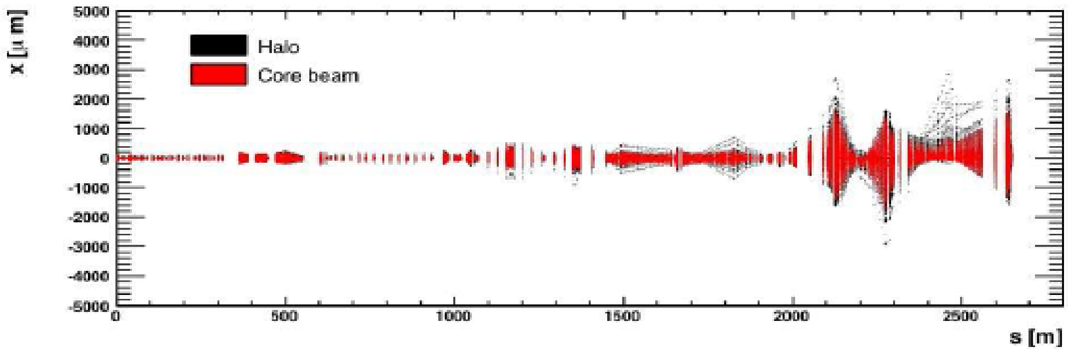
Analytical Estimates and Simulations for ILC BDS

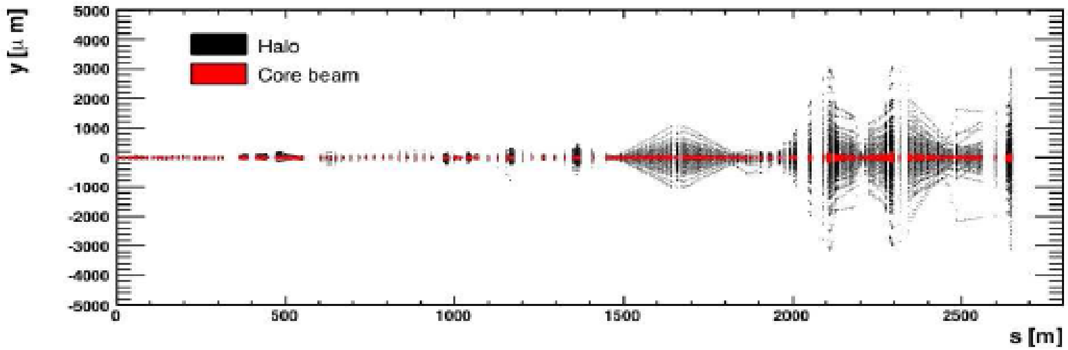
- The probability for elastic scattering at the beginning of the LINAC is about 50 times higher.
- The elastic scattering probability in whole LINAC is 9×10^{-3}.
- Only a fraction of these will hit spoilers or the beam pipe.
- The probability integrated over LINAC with angles exceeding 30 times the beam vertical divergence is 10^{-5}.
- Integrated probability over BDS is 5×10^{-7}.
- The probability for inelastic scattering with a fractional energy loss kmin > 0.01 is small, 1.8×10^{-12}/m in the LINAC and rather similar, 1.0×10^{-12}/m in the BDS.
- Sum of LINAC and BDS inelastic scattering of 2.3×10^{-8}.
- The probability of thermal scattering is still much smaller, about 9×10^{-11} for the BDS and completely negligible for the LINAC.
- The beam-gas scattering from the LINAC and BDS combined results in a fraction of 10^{-4} of the particles impacting on the spoilers.
- For the nominal intensity of 2×10^{10} particles per bunch and 2820 bunches, we expect that 6×10^{9} particles hit the spoilers at each train crossing.

Parameter	Unit	Value
$e_{N,y,initial}$	nm	20.0
βy	m	100
Residual gas (BDS)		N2
Residual gas (LINAC)		He
Temperature (BDS)	K	300
Temperature (LINAC)	K	2
Pressure (BDS)	nTorr	50
Pressure (LINAC)	nTorr	10
Kmin		0.01

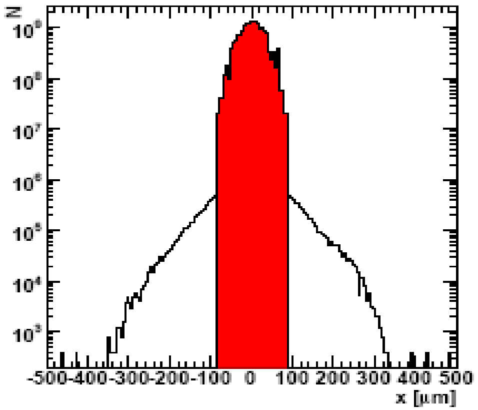
Location	E GeV	Gas	ρ m^-3	σ_{el} Barn	P m^-1
LINAC	5	He	4.8×10^{16}	2.0×10^{6}	9.9×10^{-6}
LINAC	250	He	4.8×10^{16}	3.8×10^{4}	1.8×10^{-7}
BDS	250	N2	1.6×10^{15}	4.6×10^{-5}	1.5×10^{-7}

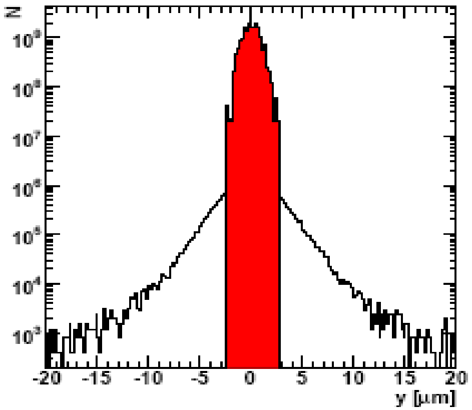
Analytical Estimates and Simulations for ILC BDS





Horizontal (top) and vertical (bottom) beam positions as function of the longitudinal coordinate s in the BDS





Transverse beam profiles at BDS entrance

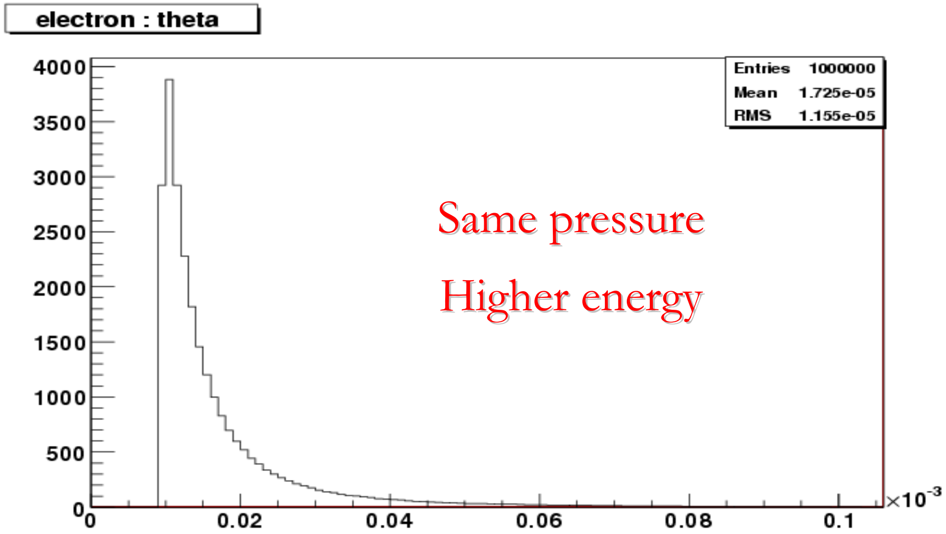
CLIC Drive Beam Tracking (1)

Parameter	Unit	Value
Drive beam sector length	m	1053
numb. of part. per bunch	10^9	52.5
numb. of bunches per train	-	2928
mean initial beam energy	GeV	2.40
mean final beam energy	GeV	0.40
$\varepsilon_{N,y,initial}$	mm	150.0
$\varepsilon_{N,y,final}$	mm	334
Residual gas mixture		40% H2O40%H2, 20% (CO, N2, CO2)
Temperature	K	300
Pressure	nTorr	10
Beam divergence		
K_{min}		0.01

Process	$\rho[m^{-3}]$	$P_{init}[m^{-1}]$	$P_{final}[m^{-1}]$
Mott	$3.22*10^{14}$	$7.96*10^{-12}$	$4.21*10^{-11}$
Brems.	$3.22*10^{14}$	$1.11*10^{-13}$	$1.11*10^{-13}$
Comp.	$5.45*10^{14}$	$3.63*10^{-14}$	$3.63*10^{-14}$

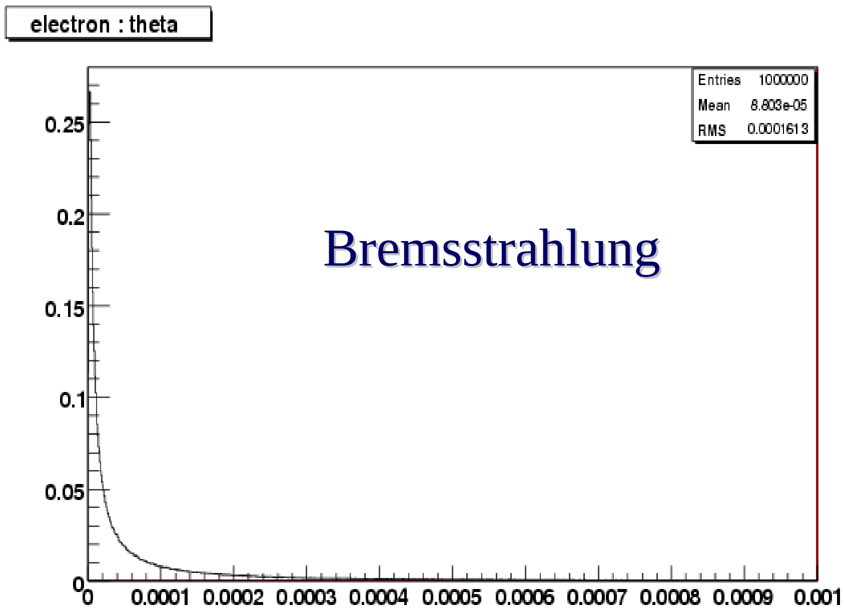
CLIC Drive Beam Tracking (2)

Mott scattering

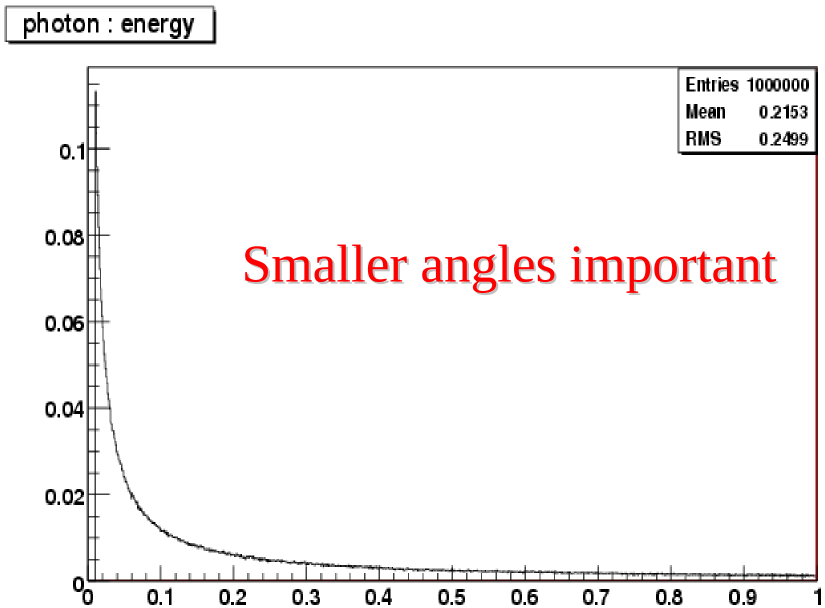


Same pressure

Higher energy



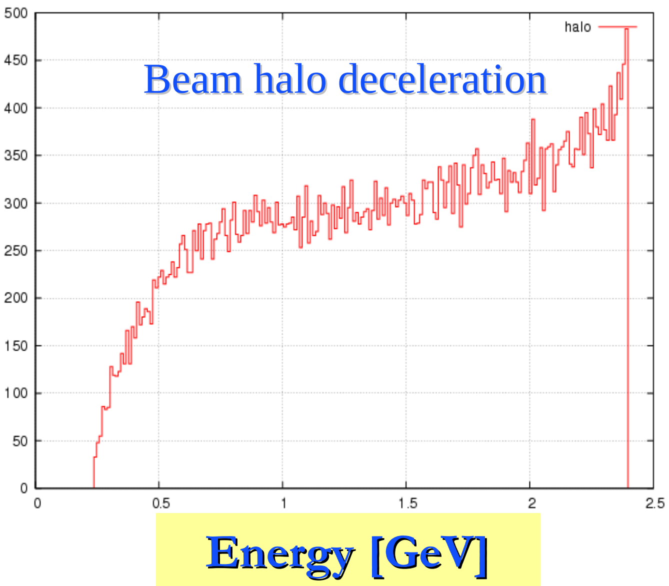
Bremsstrahlung

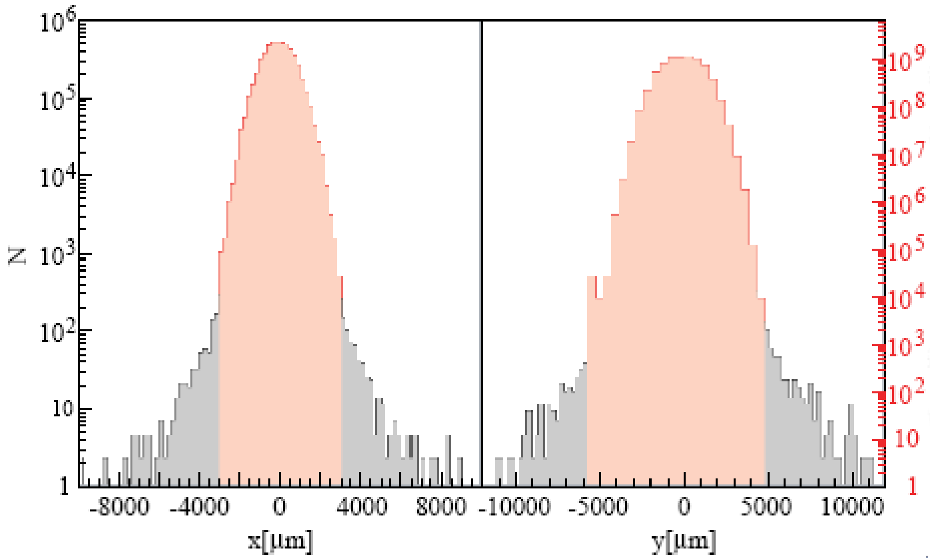


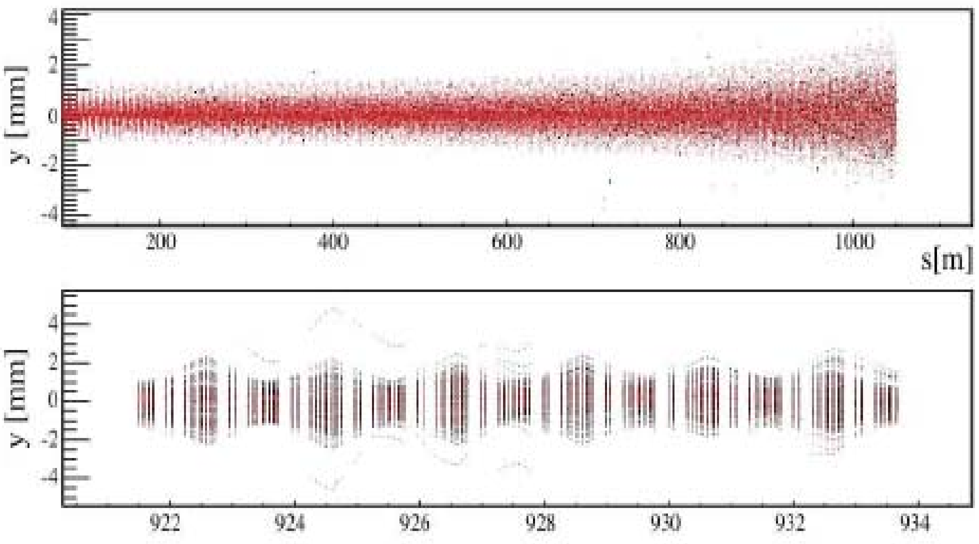
Smaller angles important

CLIC Drive Beam Tracking (3)

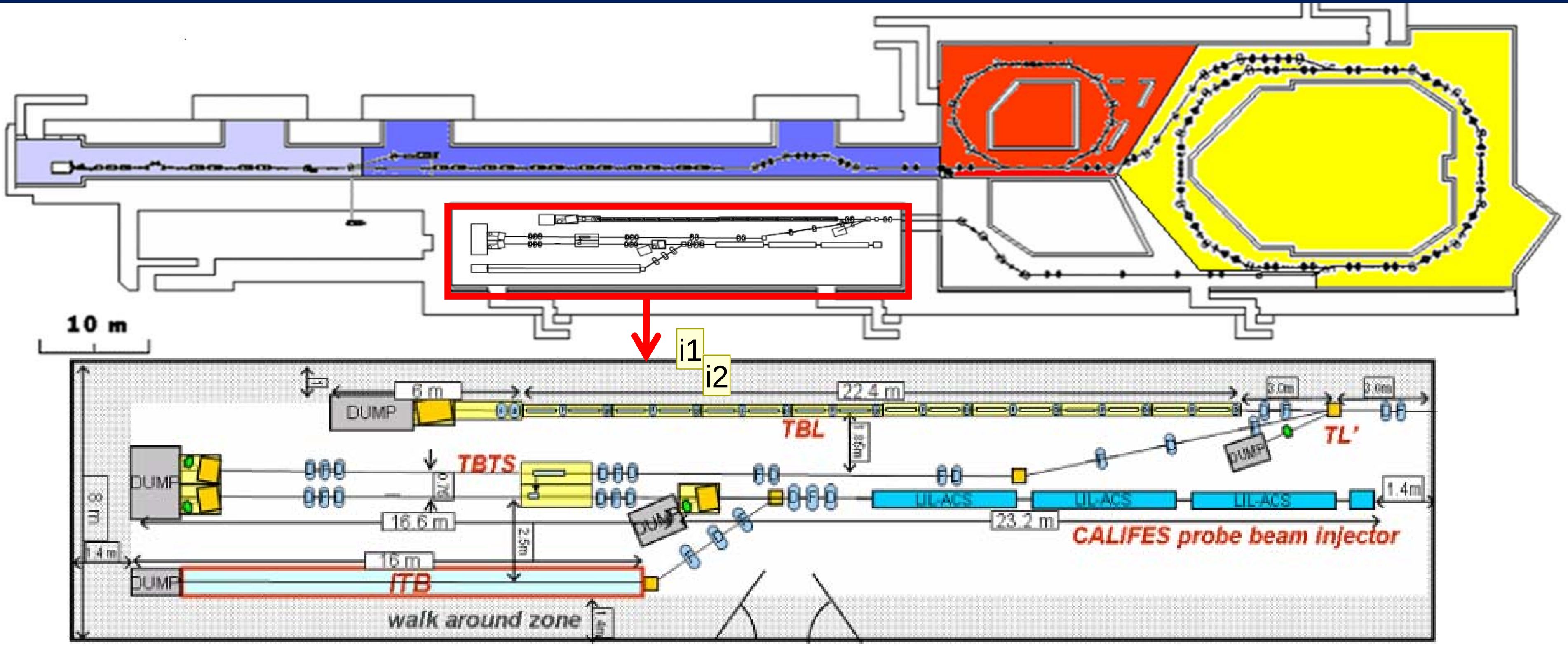
- ❖ Energy spread caused by Compton scattering stays below 0.25%
- ❖ Total scattering probability integrated over the whole decelerator is 7.69 x 10^{-9}
- ❖ Effect of ionization of residual gas shows that the ionization level stays below 3%. So no need of model extension.
- ❖ The total number of intra beam scattering events per unit time scales with 1/β4 and increases with particle density which shows that intra beam as well as Touschek become more relevant with low energy beams and small beam size.
- ❖ Sliced beam -model and particle beam -model
- ❖ Particle is considered to be lost if amplitude exceeds the aperture of element.
- ❖ Small fraction of 10^{-7} particles is lost.

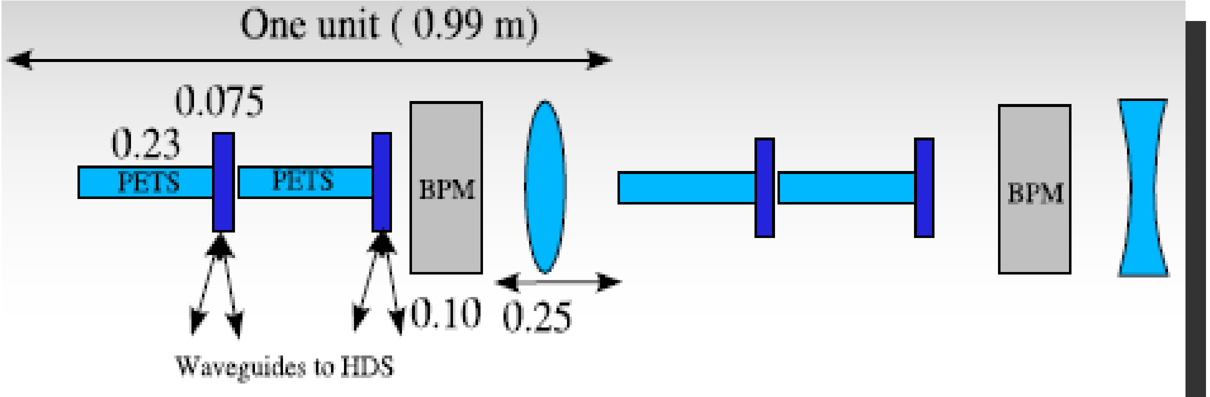






Test Beam Line (CTF3)





Lattice units for Simulation 16 of FODO cells PETS (Coupler as drift) Quadrupole BPM

Slide 28

i1 iahmed, 7/14/2009

i2 iahmed, 7/14/2009

Test Beam Line (CTF3)

```
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
```

Maximum beam energy = 0.150 GeV

Lorentz factor (γ) = 293.543

Velocity (β) = 0.999994

Normalized emittance $\varepsilon_N = \varepsilon_{x,y,N} = 150$ mrad

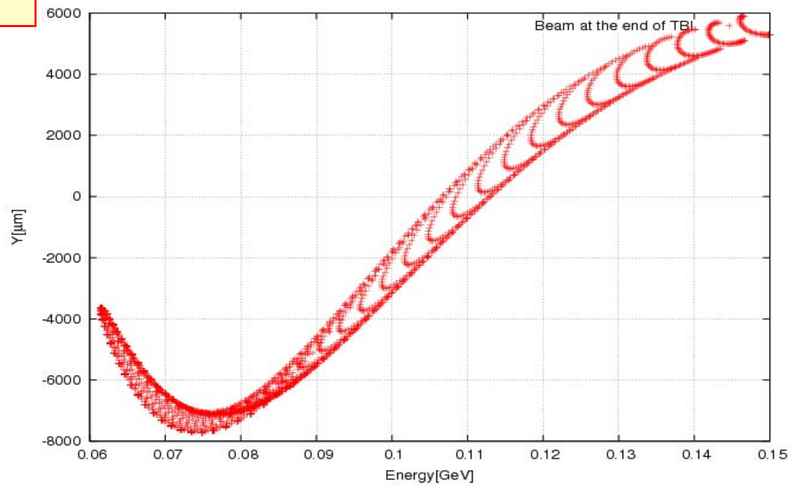
Geometric emittance $\varepsilon = \varepsilon_N/(\beta\gamma) = 0.511001$ mrad

Beta Functions $\beta_x = 0.827$, $\beta_y = 4.72$m

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

$$\theta_x = \sqrt{(\varepsilon_x / \beta_x)} = 0.786 mrad$$

$$\theta_y = \sqrt{(\varepsilon_y / \beta_y)} = 0.329 mrad$$



Drive Beam Halo: CTF3-TBL

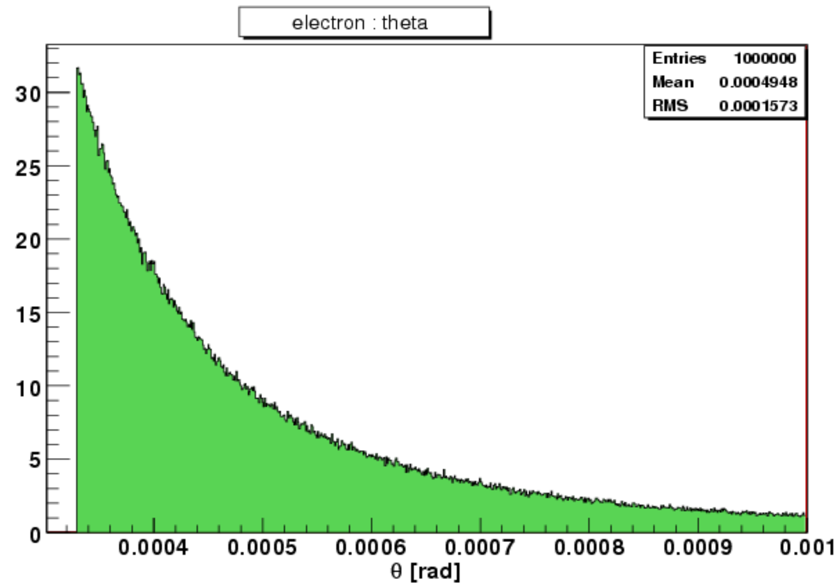
CTF3-TBL LENGTH [m] = 21.99
CLIC Drive Beam Length [m] = 738.349
Z mean (N_2) = 7
PRESSURE [Pa] :1.33322e-06 = 10 nTorr
Temperature [K] = 300
NPart = 4e+09
KMIN = 0.01
Particle density (m^{-3}) = 6.437660e+14 /m3

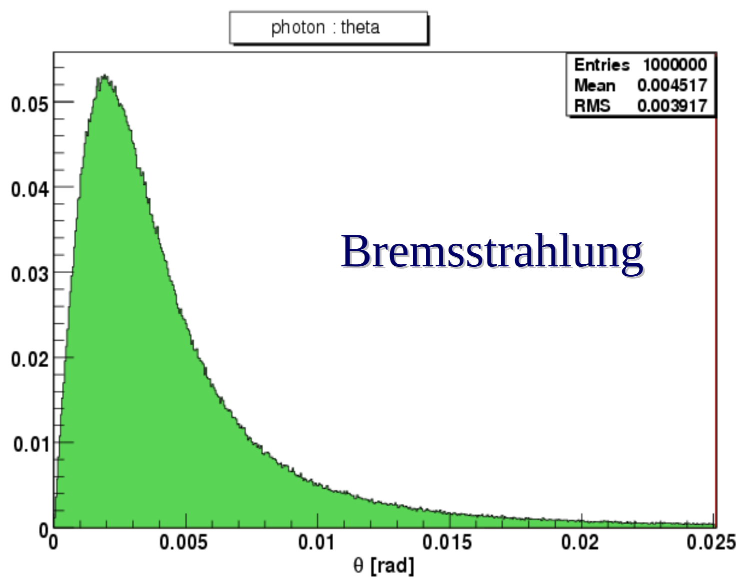
CLIC estimate. P = probability / m for scattering

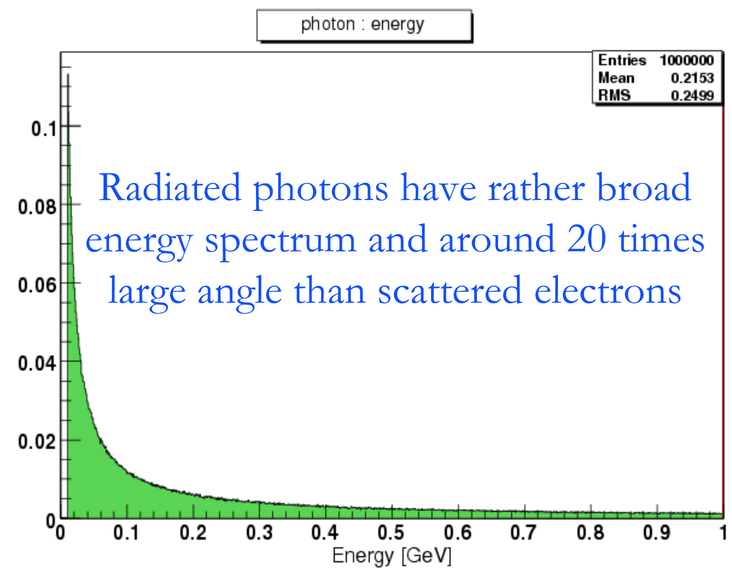
Location	E (GeV)	Gas	σ_{el} Barn	σ_{in} Barn	P_{el} m^{-1}	P_{in} m^{-1}	Θ_{min} mrad
CTF3-TBL	0.150	N_2	5242	5.5117	3.37e-10	1.77e-13	329

Beam-Gas Scattering: CTF3-TBL

Mott scattering

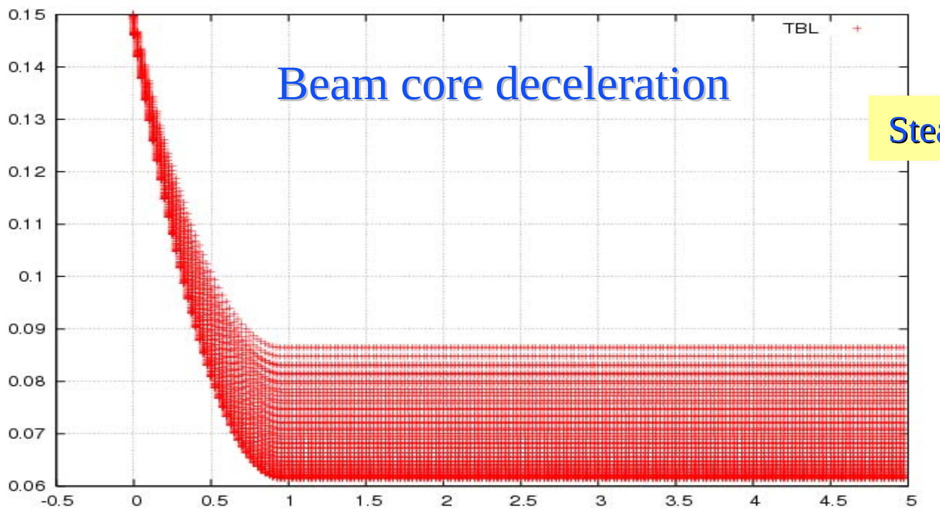






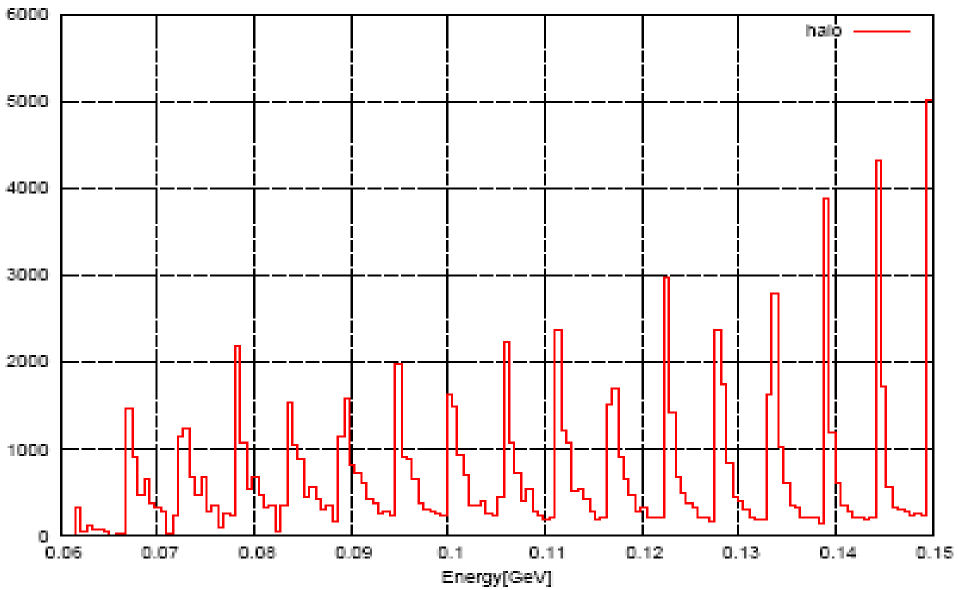
Drive Beam Halo: CTF3-TBL Tracking

Beam energy [GeV]



Z[μm]

Steady State power extraction efficiency = E_{in}/E_{out}



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

Halo Flux Estimate: CTF3-TBL

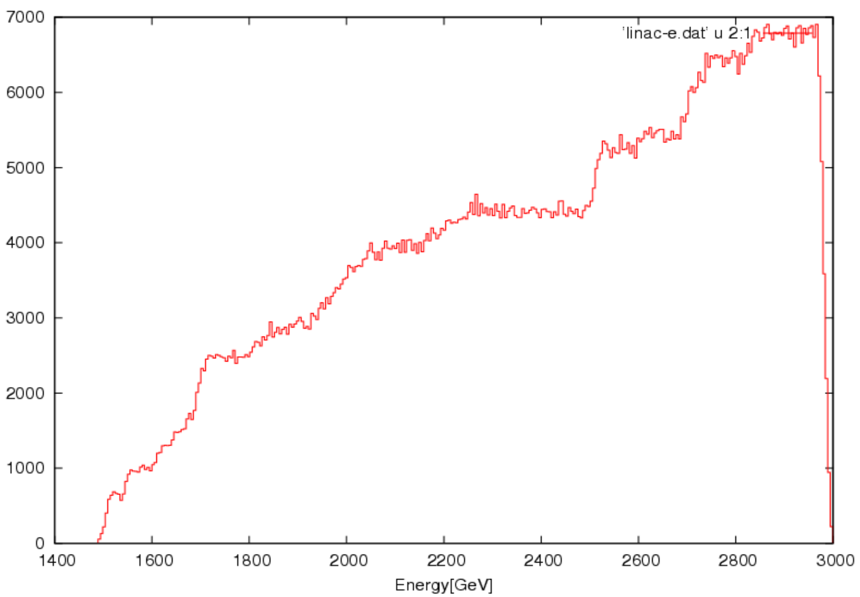
- electrons/bunch = 1.4575×10^{10}
- Probability = 3.37×10^{-10}/m
- Probability in CLIC TBL Drive beam = 7.41×10^{-9}
- Halo/bunch = 1.08×10^{2}

Halo Acceleration in Linac (1)

LINAC Beamline

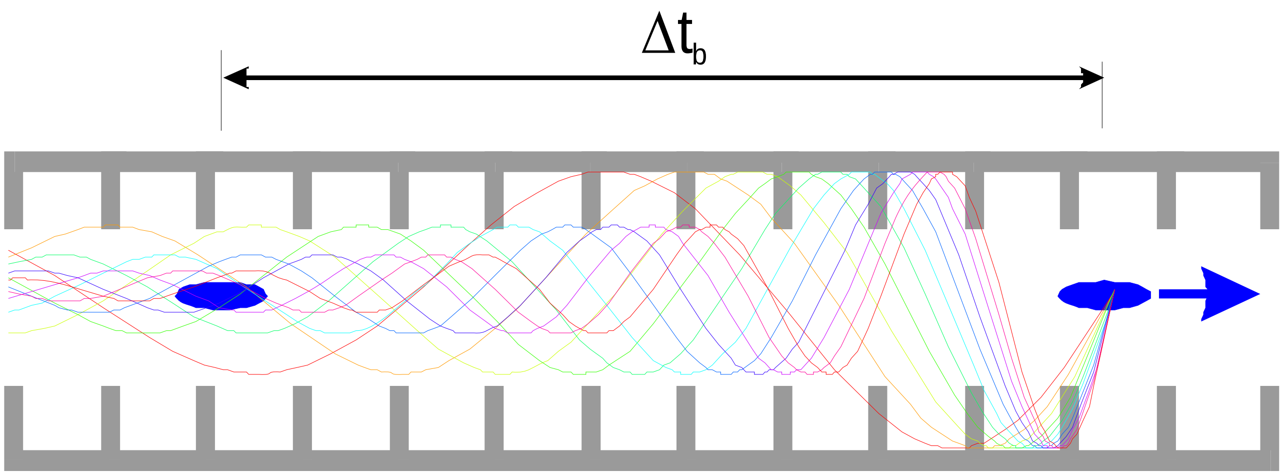
- FullTracking
- Temperature 300 K
- Pressure 10 ntorr
- Scattering angle 10nrad
- Residual Gas

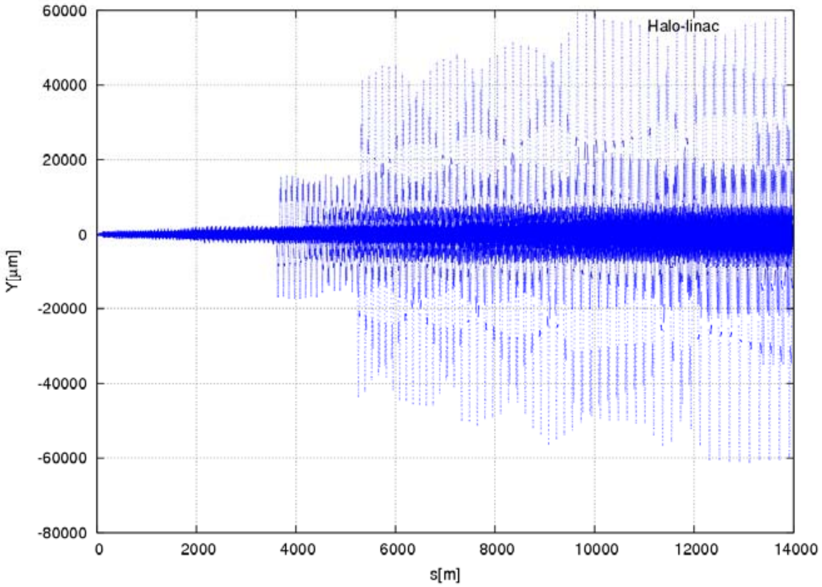
- Standard PLACET lattice
- Total no. of elements 54068
  - No. of Quad. 1324
  - No. of BPMs 1324
- No. of slices 31
- No. of macroparticles 100
- Linac injection energy 9.0 GeV
- Charge 4 nC
- Emitt. along x-axis 680 nrad
- Emitt. Along y-axis 10 nrad

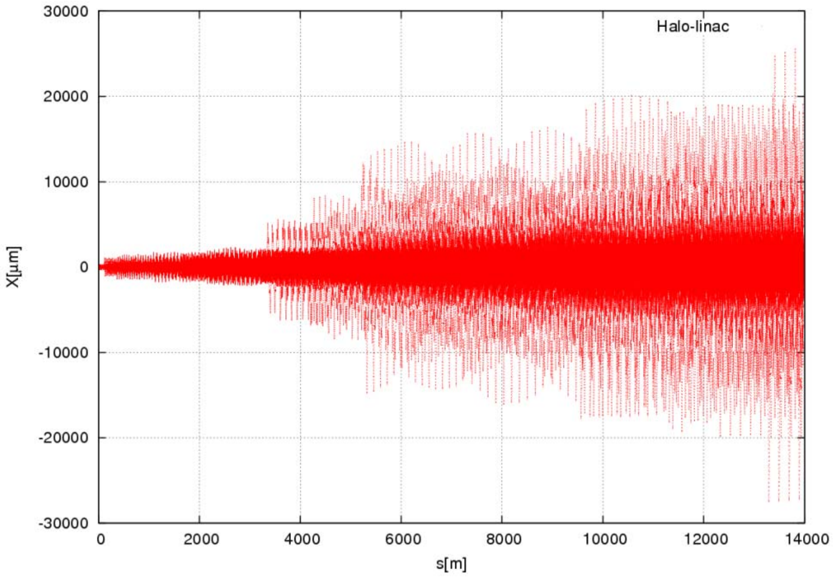


Energy of the halo particles is increasing almost linearly during passing through the accelerating structures of the LINAC

Halo Acceleration in Linac (2)







CLIC Post Collision Line

Benchmarking study between DIMAD and PLACET codes with 20 mrad post collision line

Overview (1)

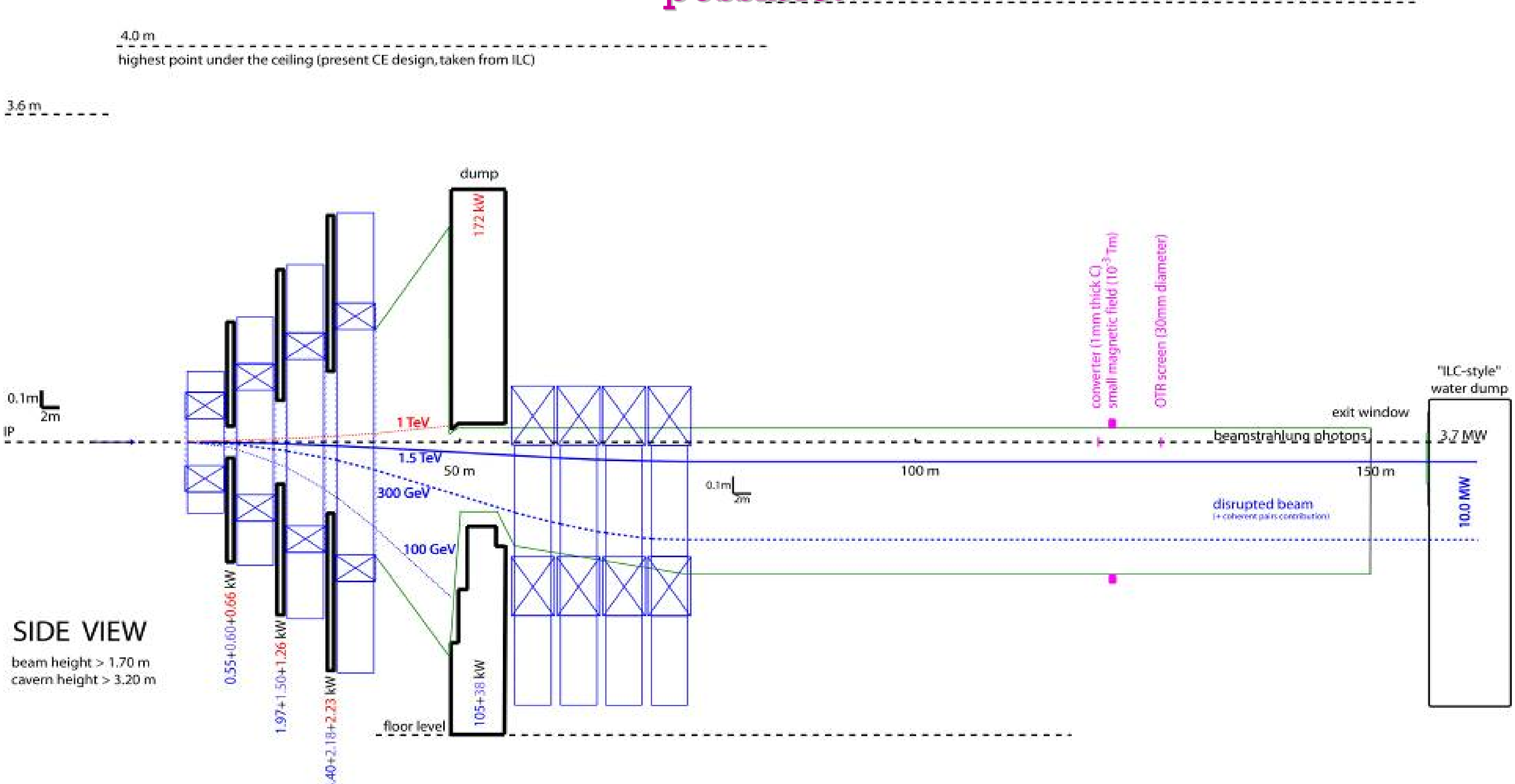
- Comparison between two contemporary codes: DIMAD and PLACET.
- CLIC post collision line for benchmarking purpose.
- We consider current 20mrad extraction line of CLIC
- Tracking performed using
  - 4-particles tracking with different energy deviation.
  - 1K particles
  - Heavily disrupted post collision electrons beam

Overview (2)

- Lattice conversion from DIMAD→MAD-X→PLACET format
- Rotation of beam axes from horizontal to vertical is performed by tilt option inside the sector bend at right angle.
- Few wrong units are corrected:
  - Modification in extraction line lattice
    - Aperture sizes are corrected
    - Removal of aperture constraints from drifts
    - Implementation of aperture constraints on four collimators as well.
- Disrupted beam as DIMAD input
- Tracking performed with PLACET from IP to dump.

Layout of Post Collision Line

Transportation of spent beams and the beamsstrahlung photons from the interaction point to their dumps, with as small losses as possible.



Extraction Line Lattice

Table 1: First set of four magnets, starting 20 m from the interaction point.

	Magnet 1	Magnet 2	Magnet 3	Magnet 4
Length (m)	4.000	4.000	4.000	4.000
Width (m)	0.414	0.682	0.946	1.208
Height (m)	0.833	1.451	2.065	2.677
Gap width (m)	0.167	0.230	0.288	0.344
Gap height (m)	0.260	0.610	0.960	1.310

Table 2: Second set of four magnets, just after the intermediate dump.

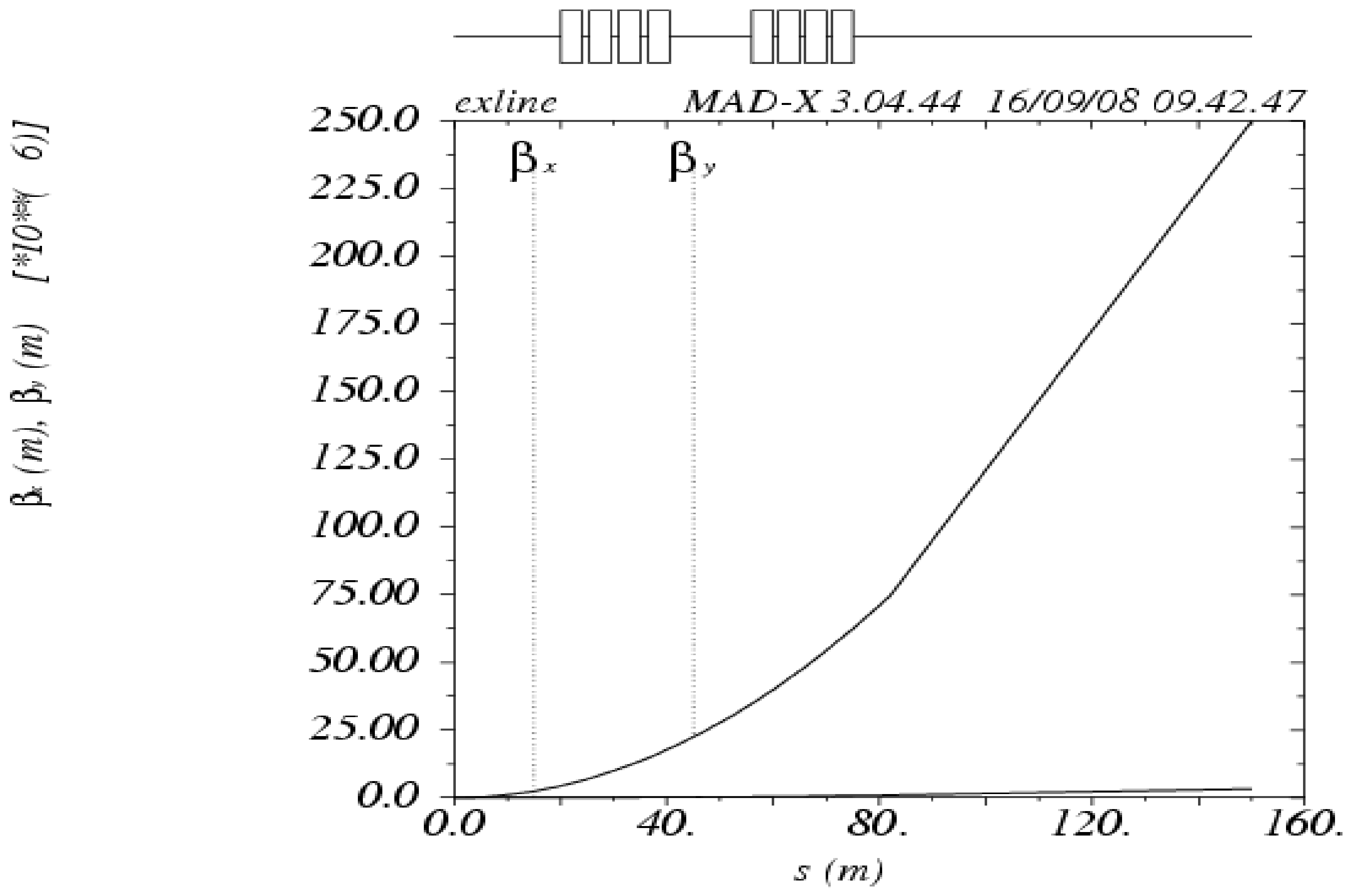
	Magnet 5	Magnet 6	Magnet 7	Magnet 8
Length (m)	4.000	4.000	4.000	4.000
Width (m)	1.870	1.870	1.870	1.870
Height (m)	1.510	1.510	1.510	1.510
Gap width (m)	0.450	0.450	0.450	0.450
Gap height (m)	1.000	1.000	1.000	1.000

- Coll. 1: Y = 0.184 m
- Coll. 2: Y = 0.476 m
- Coll. 3: X = Y = 0.809 m

Optics

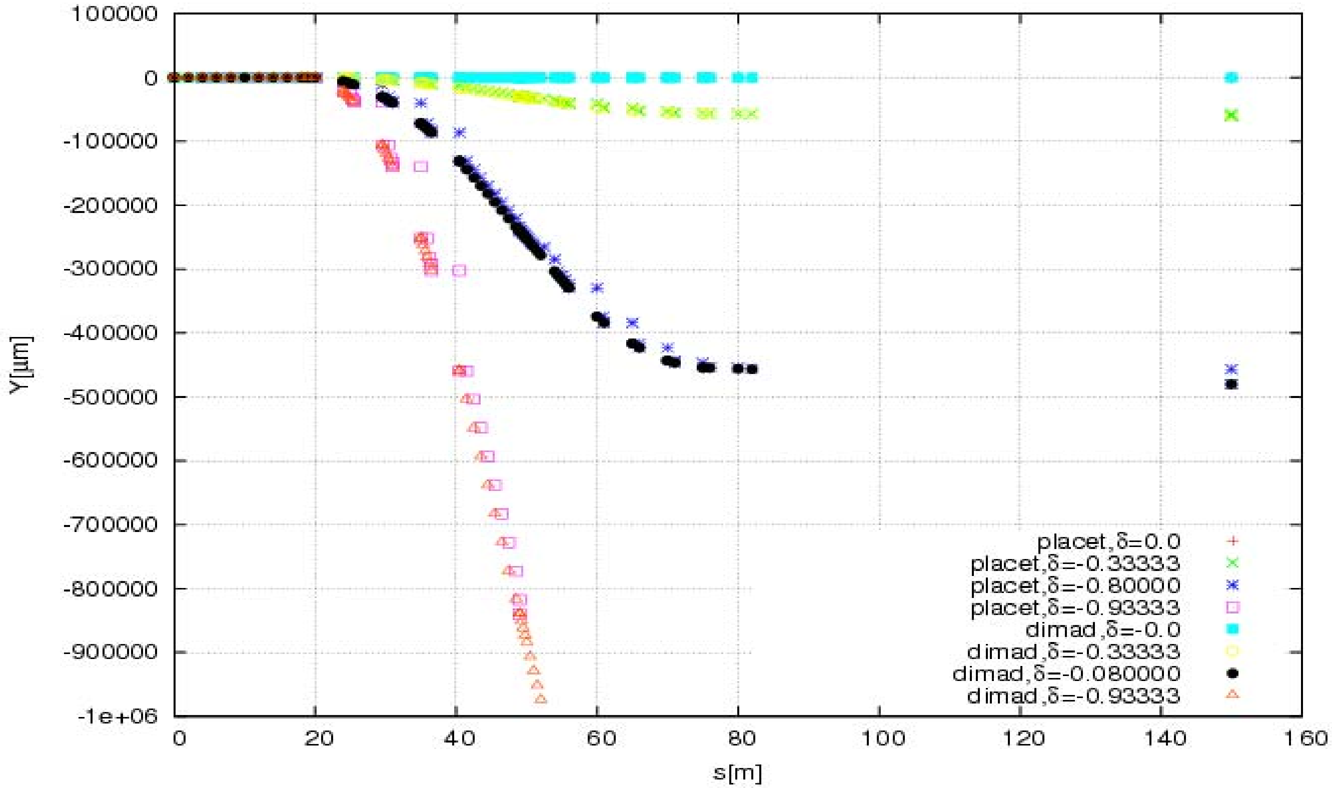
$$\beta(s) = \beta^* + \frac{s^2}{\beta^*}$$

In case when there is no quadrupole, only 2 sets of 4 bending magnets

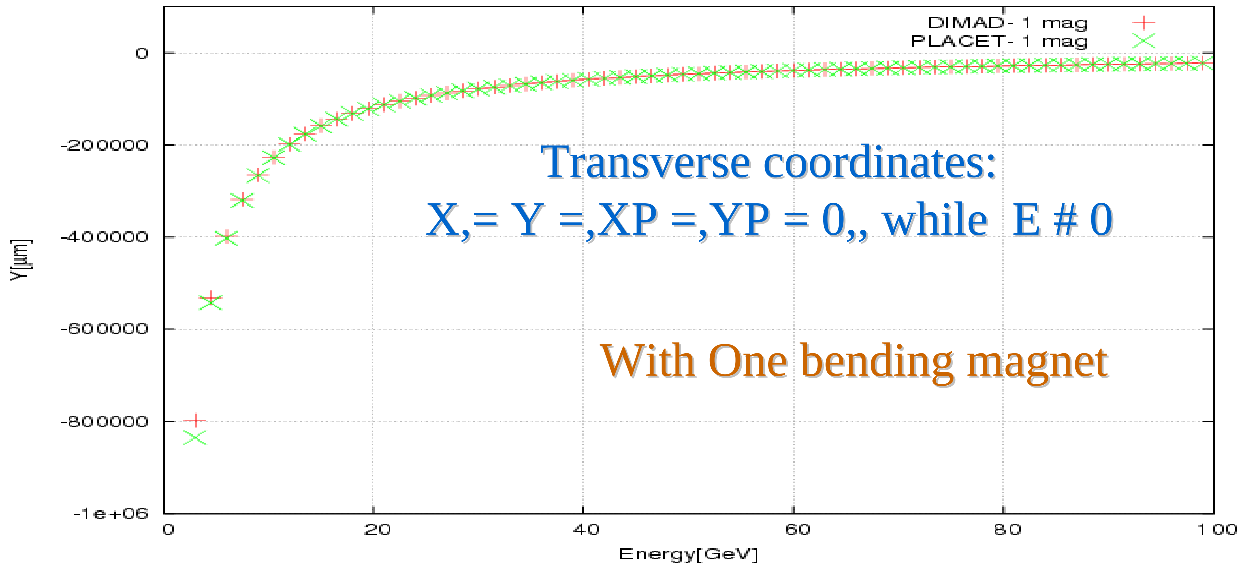


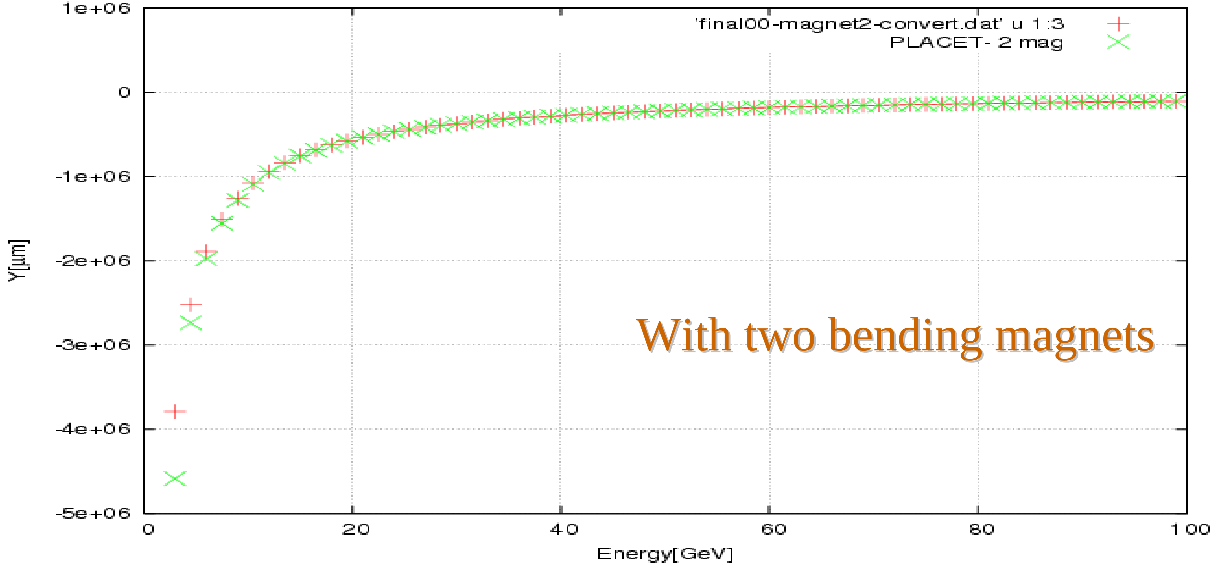
Single Off Momentum Particles Tracking

- Switched off SR
- No need of particle-matter interactions
- Single particle trajectory
- Four particles with transverse components (x = 0, xp = 0, y = 0, yp = 0) at IP
- Energy deviation of each ($\delta = 0$, $\delta = -0.3333$, $\delta = -0.80000$, $\delta = 0.93333$)

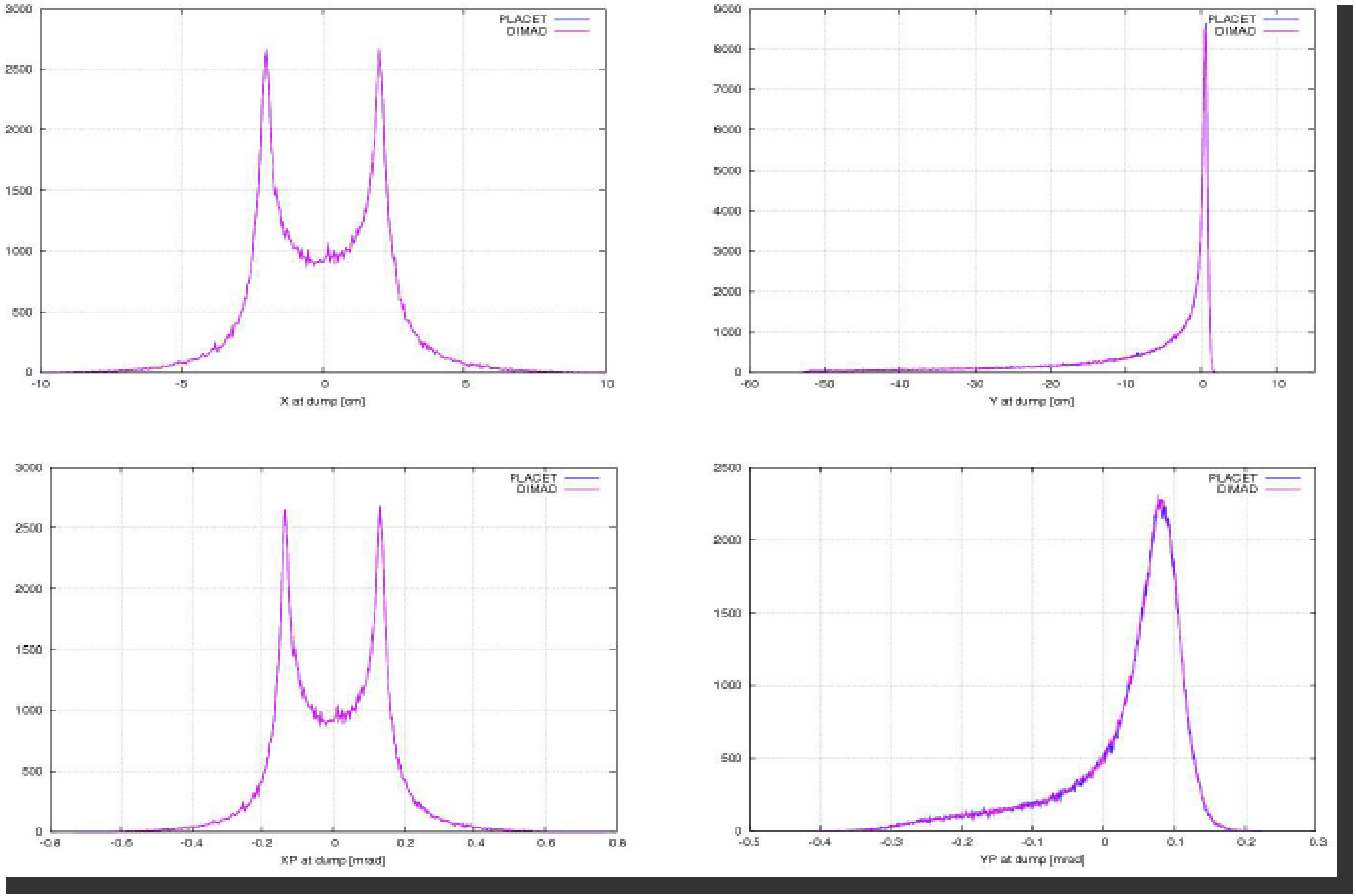


Ideal Beam with Off Momentum Particles

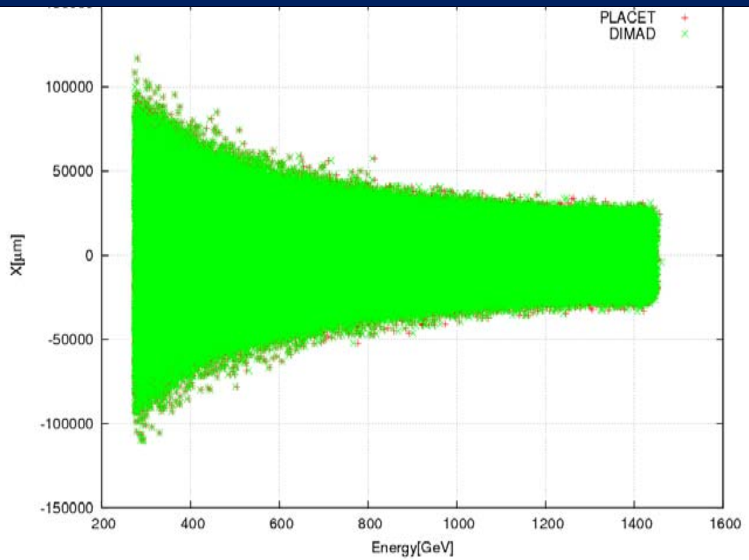


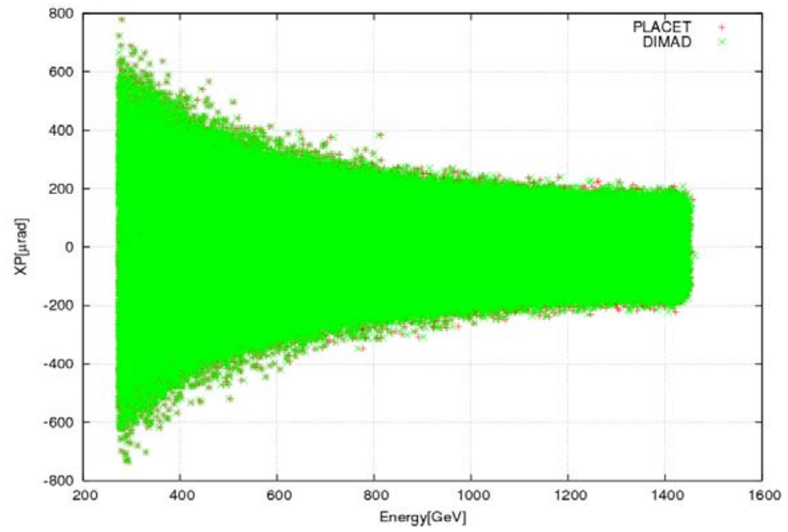


Disrupted Beam: Transverse Distributions

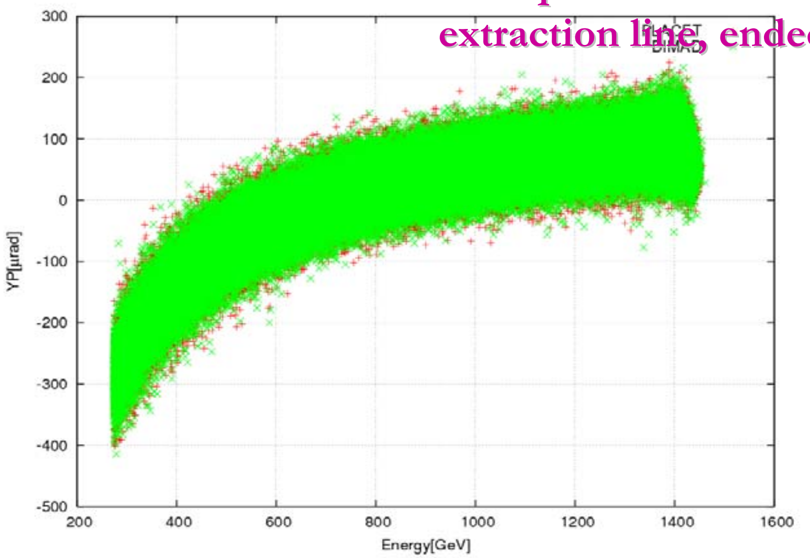


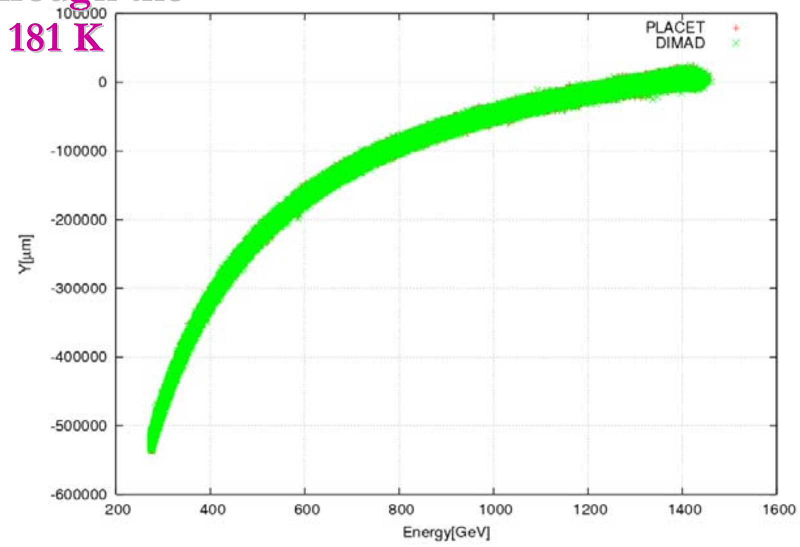
Disrupted Beam: Energy vs Offsets/Angles



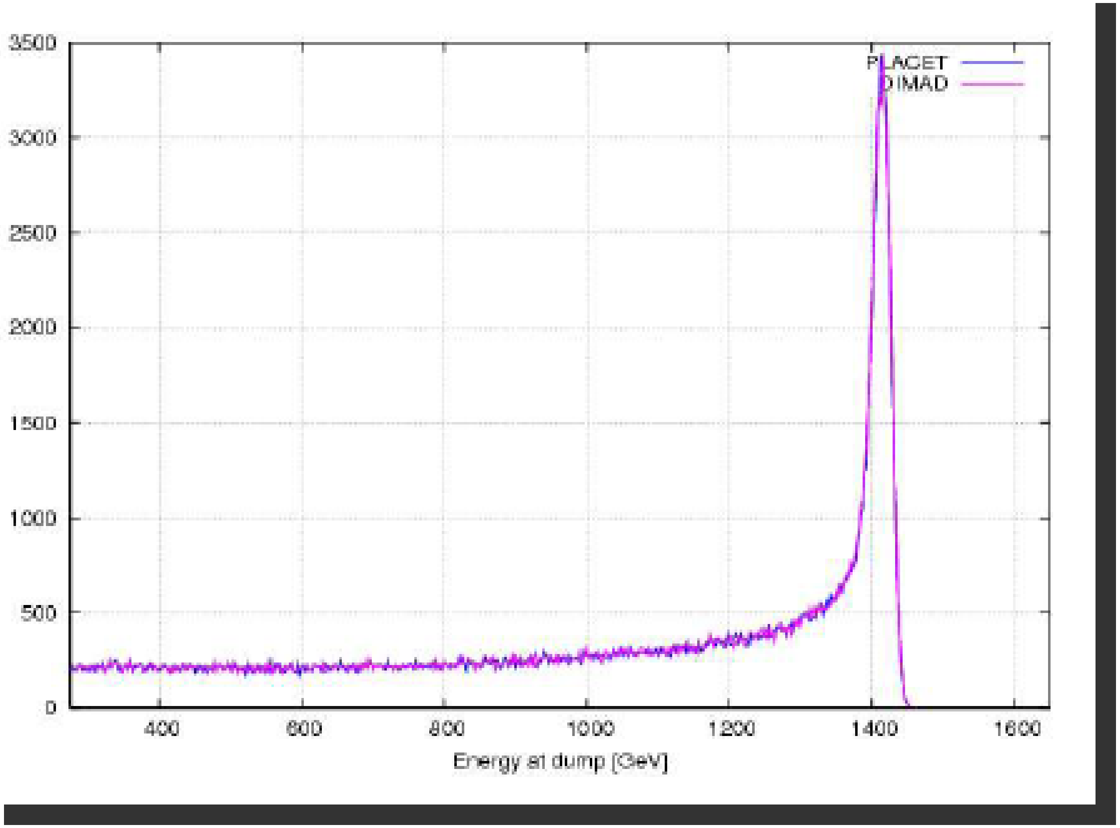


We start tracking the disrupted beam 200K particles and after loss through the extraction line, ended up with 181 K





Disrupted Beam: Energy Histogram



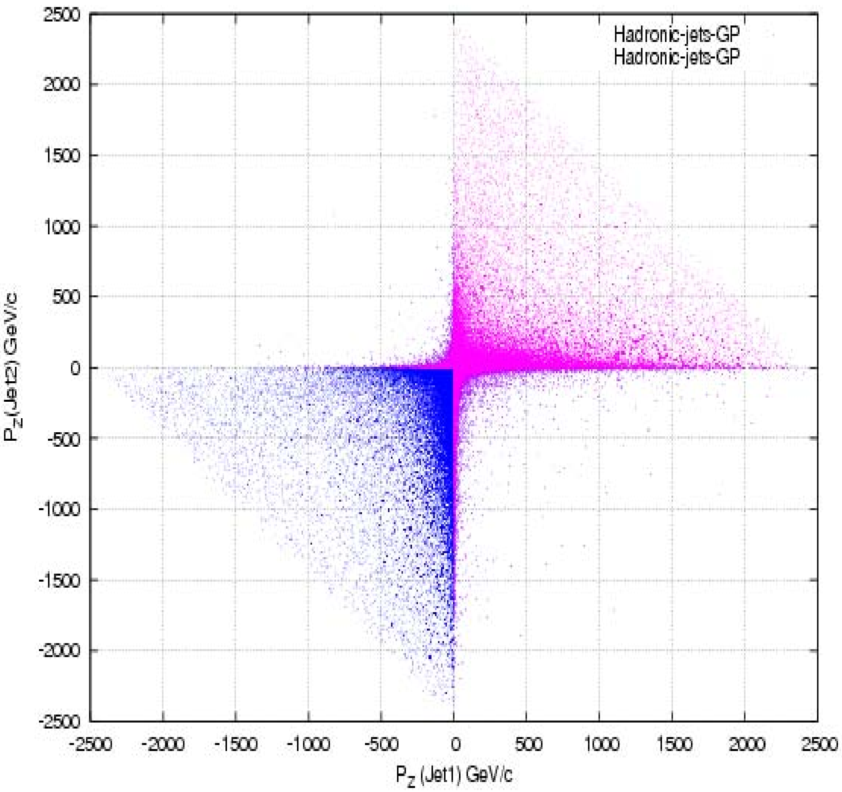
Beam-Beam Interactions: GuineaPig

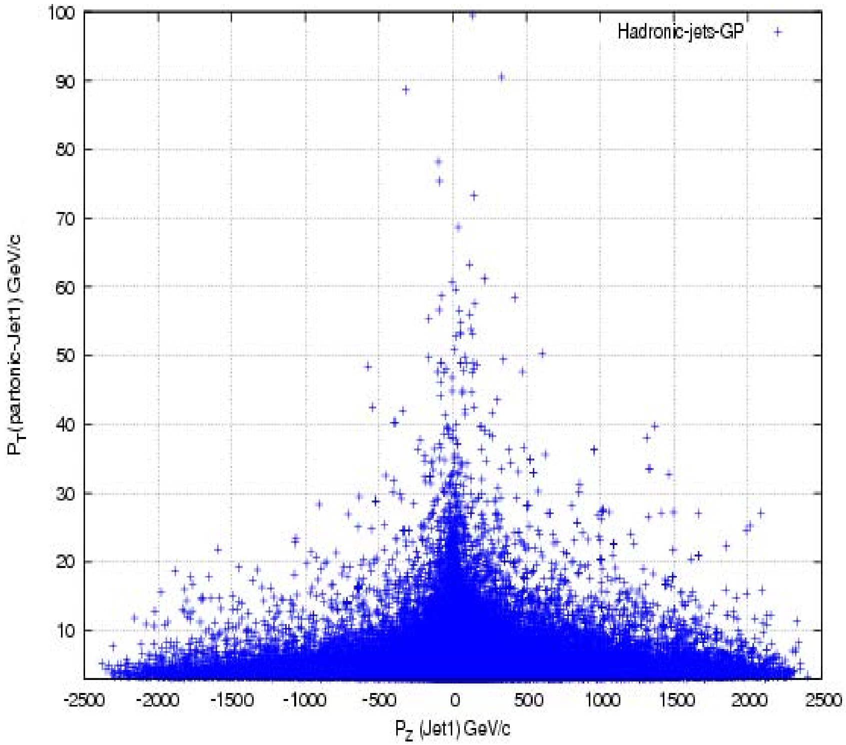
```
ACCELERATOR:: CLIC-2500
{ energy    = 2500.  ;
particles = 0.4 ;
emitt_x  = 0.58 ;
emitt_y  = 0.01 ;
beta_x = 8.0 ;
beta_y = 0.1 ;
sigma_z = 30. ;
dist_z     = 0  ;
espread = 0.0 ;
which_espread = 0;
offset_x  = 0    ;
offset_y  = 0.   ;
waist_x = 0 ;
waist_y = 0 ;
angle_x = 0 ;
angle_y = 0 ;
angle_phi = 0 ;
trav_focus = 0 ;
}
```

```
PARAMETERS::
CLIC_standard_compton
{
n_x=64 ;
n_y=64 ;
n_z=36 ;
n_t=8 ;
cut_x=3.0*sigma_x.1 ;
cut_y=6.0*sigma_y.1 ;
cut_z=3.0*sigma_z.1 ;
n_m=40000 ;
force_symmetric=1;
integration_method=2 ;
do_eloss = 1 ;
do_espread = 1 ;
do_isr = 1;
store_beam=1 ;
electron_ratio=0.1 ;
do_photons=1 ;
photon_ratio=0.1 ;
store_photons=1 ;
do_pairs=0 ;
```

```
track_pairs=1;  grids=7 ;
pair_ratio = 1.0;
pair_ecut = 0.005 ;
beam_size=1;
do_compt = 1;
compt_x_min=0.01;
compt_emax=800;
do_hadrons=1 ;
store_hadrons = 1 ;
hadron_ratio=1000. ;
do_jets=1 ;
store_jets=1 ;
jet_ptmin=3.2 ;
jet_ratio=10000. ;
jet_log=1 ;
do_lumi=1 ;
num_lumi=10000 ;
lumi_p=0.0001 ;
}
```

Jets Production at CLIC



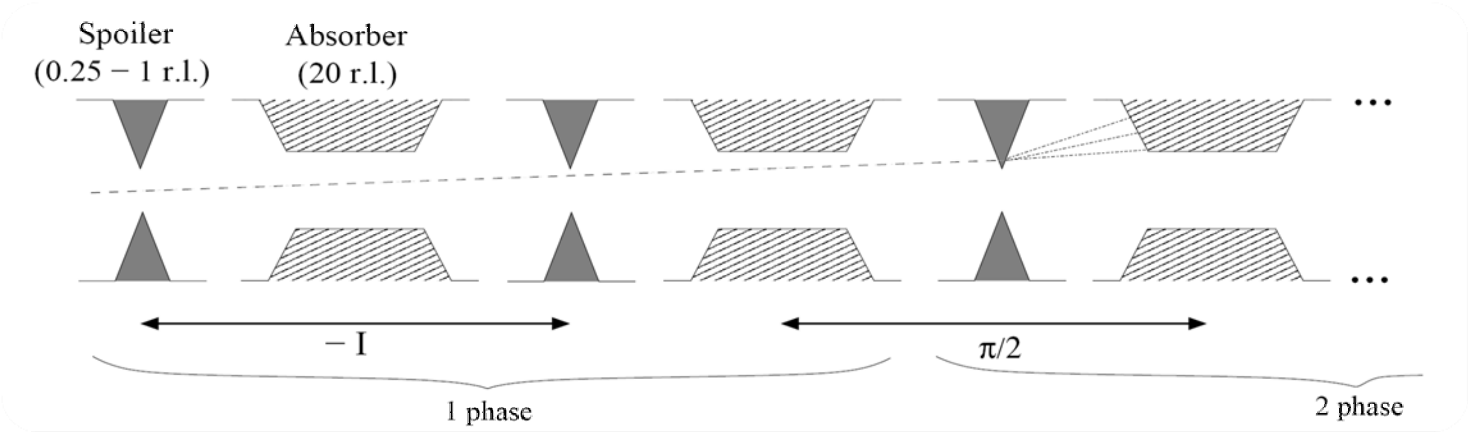


Conclusion

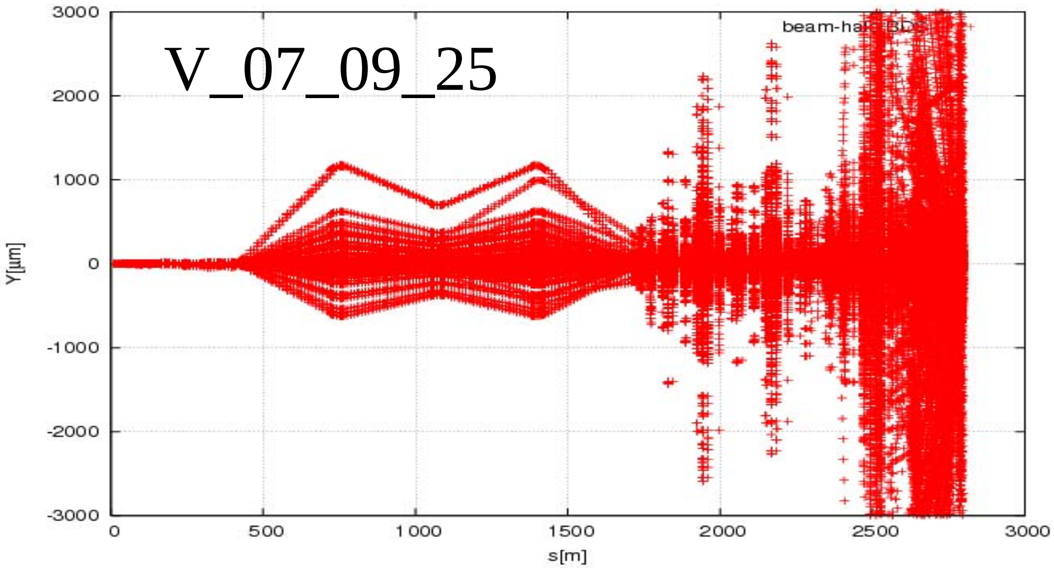
- Analytical estimation of scattering probability of beam-generated halo in:
  - Beam delivery system and LINAC of CLIC
  - Beam delivery system and LINAC of ILC
  - CLIC drive beam
  - CLIC Test Facility 3 drive beam
- Performed a detailed benchmarking study of two particle tracking codes, DIMAD and PLACET using 20mrad post collision line.
- Beam-Beam interaction (study going on……)

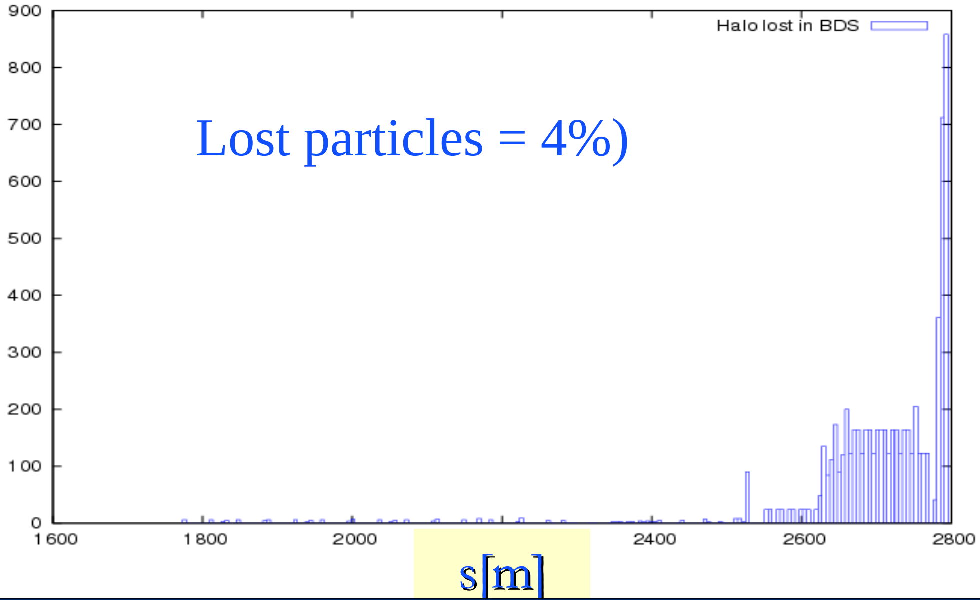
Beam-Halo Collimation

- Beam halo : damping ring, linac, final focus aberrations etc
- The beam halo can result in electromagnetic showers and SR reaching the detector (+ muon background).
- Halo removed by physically intercepting the particles using mechanical spoilers + thick absorbers to remove the debris.
- Thick absorbers then become a source of muons – should be within tolerable levels at the detector.
- IR layout and mainly final doublet dominate.



Lattice with low Dispersion: BDS





Transverse Phase Space: Exit of BDS