Halo und tail generation for low energy electron accelerators

Karlsruhe Institute of Technology

ANKA THZ GROUP

CLIC

CERN

Forschungszentrum Karlsruhe
in der Helmholtz-Gemeinschaft

Universität Karlsruhe (TH)
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Outline

- Halo and tail generation:
  - Motivation
  - Sources of halo and tail generation
- CLIC
  - CLIC two beam acceleration technique
  - Challenges of the CLIC drive beam halo and tail simulation
  - Analytical estimates and Tracking results
- Summary
- Outlook

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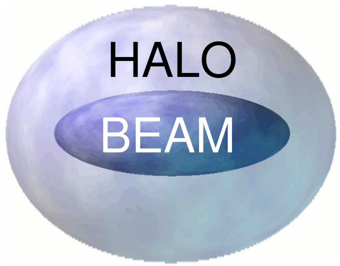
Motivation

Motivation

What is the halo?



What is the motivation behind halo studies?

- Halo particles can be a major source of background and radiation
- Even if most of the Halo particles are stopped by collimators, the secondary muon background can still be significant
- Halo and tail generation can lead to significant beam losses in all parts of an accelerator

➔ Halo and tail generation studies are needed for design studies to estimate and minimise any potential performance limitations from this source

➔ Halo and tail simulation with PLACET-HTGEN:

HTGEN
Generation of Halo Particles

→

PLACET
Beam and Halo tracking

Sources of halo and tail Generation

Particle processes:

- Beam gas scattering (Mott scattering and Bremsstrahlung) and multiple scattering
- Compton scattering
- Touschek effect and intrabeam scattering
- Electron and ion cloud effects
- Space charge effects
- Synchrotron radiation

Optics related effects:

- Mismatch
- Coupling
- Dispersion
- Nonlinearities

Various:

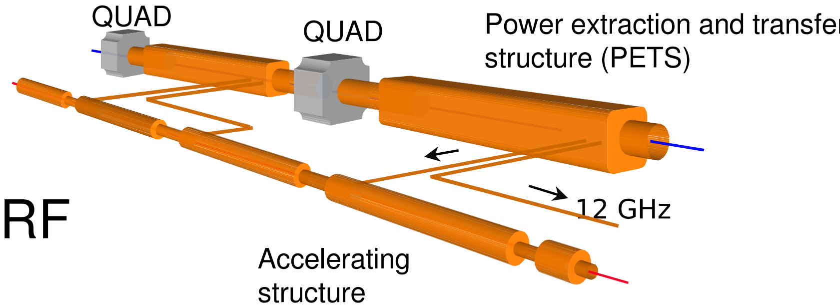
- Noise and vibrations
- Dark currents
- Wakefields
- Spoiler scattering

■ currently included in PLACET-HTGEN

CLIC

CLIC – RF power production

- To reach the design energy of 3 TeV the accelerating gradient has to be very high (100 MV/m)
- Superconducting technology is limited to lower gradients
- Room temperature travelling wave structures at high frequency (12 GHz) are likely to achieve this gradient, but do not provide sufficient RF power for this high gradient



➔ **Two-beam-acceleration technique:**

Long RF pulses with low frequency → **Power stored in** → High current electron beam (long trains+bunches)

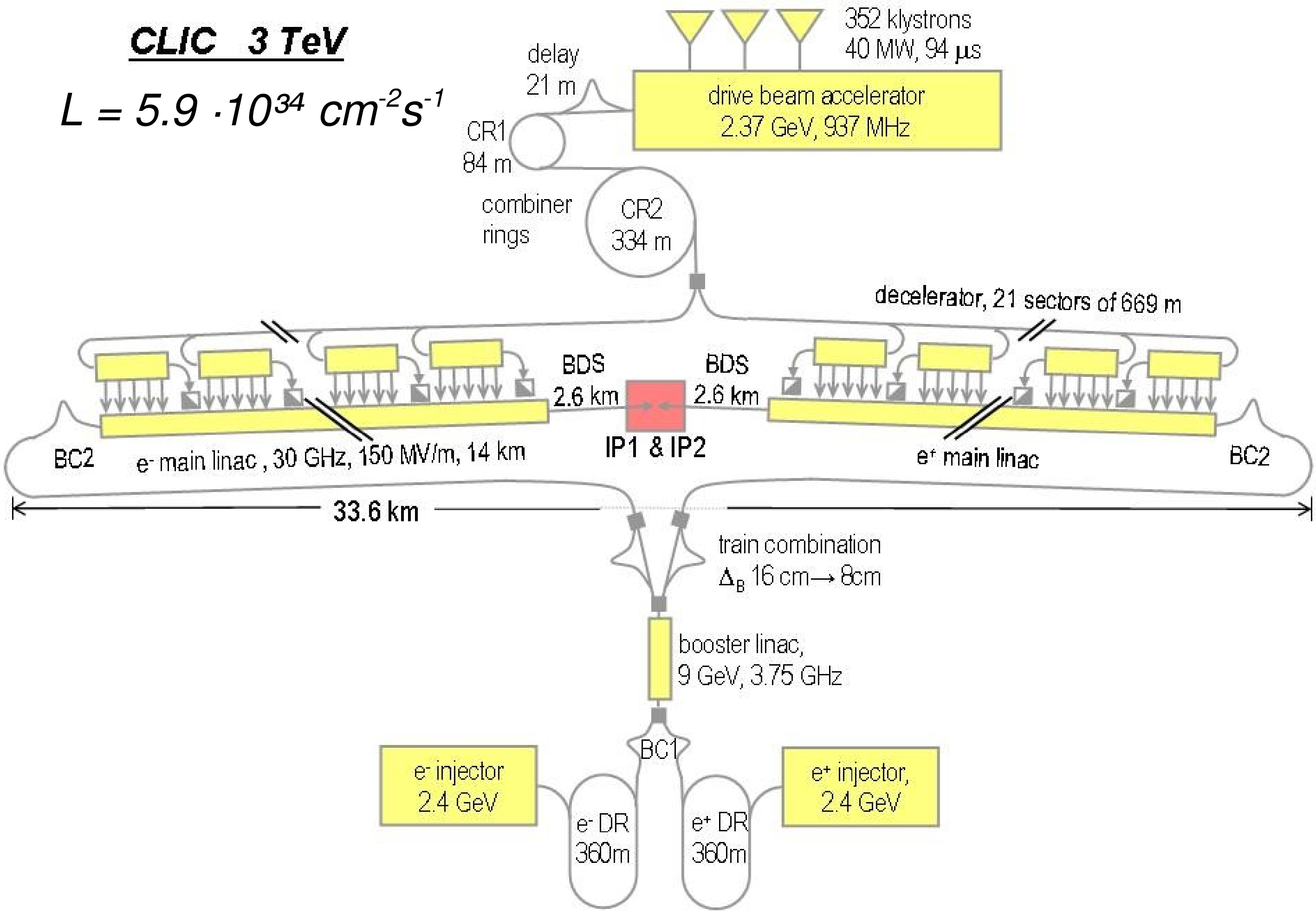
↓ **Electron beam manipulation**

High current electron beam (short trains+bunches) → **Power extracted in resonant structures** → Short RF pulses with high frequency and gradient

CLIC – Compact LInear Collider

CLIC 3 TeV

$L = 5.9 \cdot 10^{34}\ cm^{-2}s^{-1}$



Challenges of the CLIC drive beam halo and tail generation

CLIC drive beam parameters

Parameter	Unit	Value
Drive beam sector length	m	1053
mean initial beam energy	GeV	2.40
mean final beam energy	GeV	0.40
numb. of part. per bunch	10^9	52.5
$\epsilon_{N,y,initial}$	μm	150
$\epsilon_{N,y,final}$	μm	334

Drive beam is a low energy and high intensity beam

HTGEN was written for high beam energies

- Low energy validation of PLACET-HTGEN ✓

Collective effects like wakefields become important

- Implementation of the effect of transverse wakefields of the beam on the halo is needed for a realistic halo tracking ✓

Halo and Tail Generation for the CLIC decelerator

Sources of halo and tail Generation

Particle processes:

- Beam gas scattering (Mott scattering and Bremsstrahlung) and multiple scattering
- Compton scattering
- Touschek effect and intrabeam scattering
- Electron and ion cloud effects
- Space charge effects
- Synchrotron radiation

Optics related effects:

- Mismatch
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Various:

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■ included in decelerator simulation with PLACET-HTGEN

Beam gas and Compton scattering

residual gas constitution: 40% H_2O, 40% H_2, 20 % (CO_2, CO and N_2)

Parameter	Unit	Value
temperature	K	300.0
pressure	nTorr	10.0
k_{min} (Brem.)		0.01
θ_{min} (Mott)	murad	96.9

$\Rightarrow$

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

scattering probability $P = n \cdot \sigma$

density

Mott Scattering is the dominant process

energy spread caused by Compton scattering: $\Delta E/E \leq 0.25\%$

energy spread negligible compared to the energy spread caused by the deceleration of the beam

taking Mott scattering and Bremsstrahlung into account, the total scattering probability integrated over the whole decelerator is:

$P_{tot} = 7.69 \times 10^{-9}$ #halo particles per bunch = 2.67×10^{3}

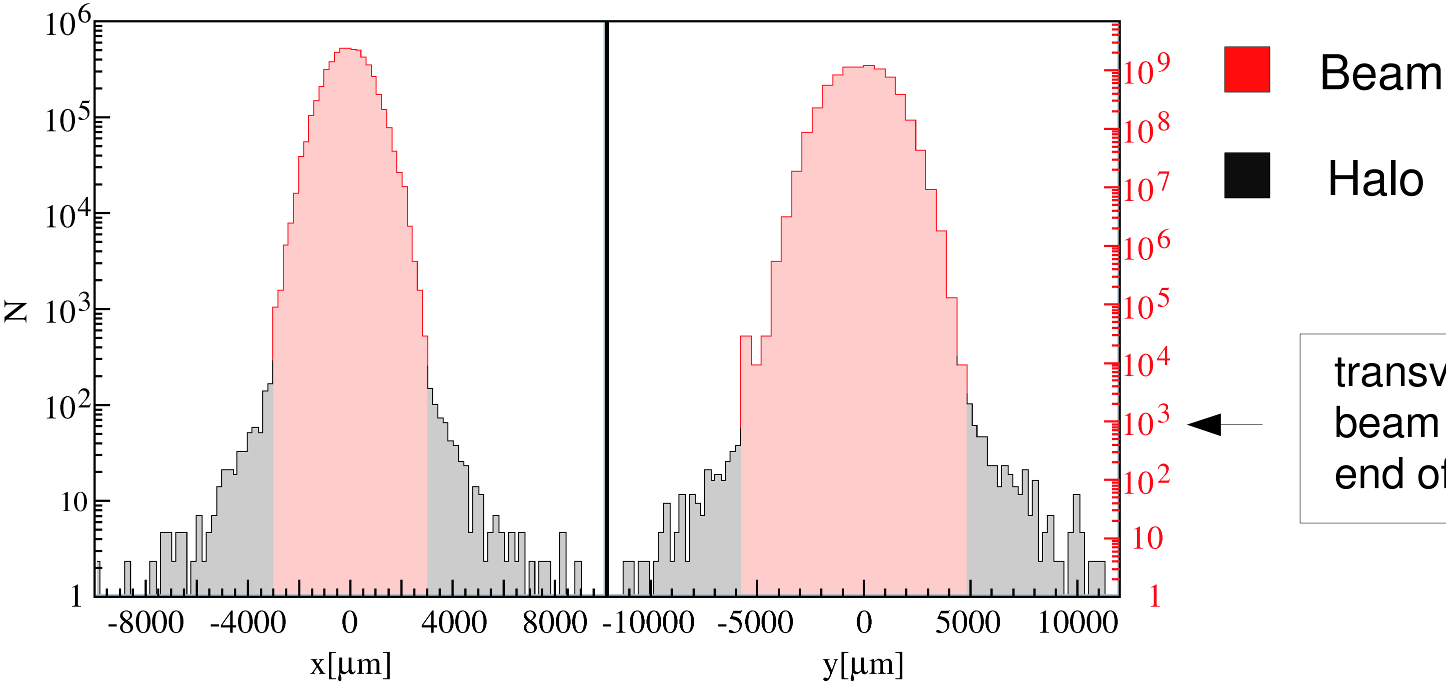
very small halo generation

Tracking results

Model:

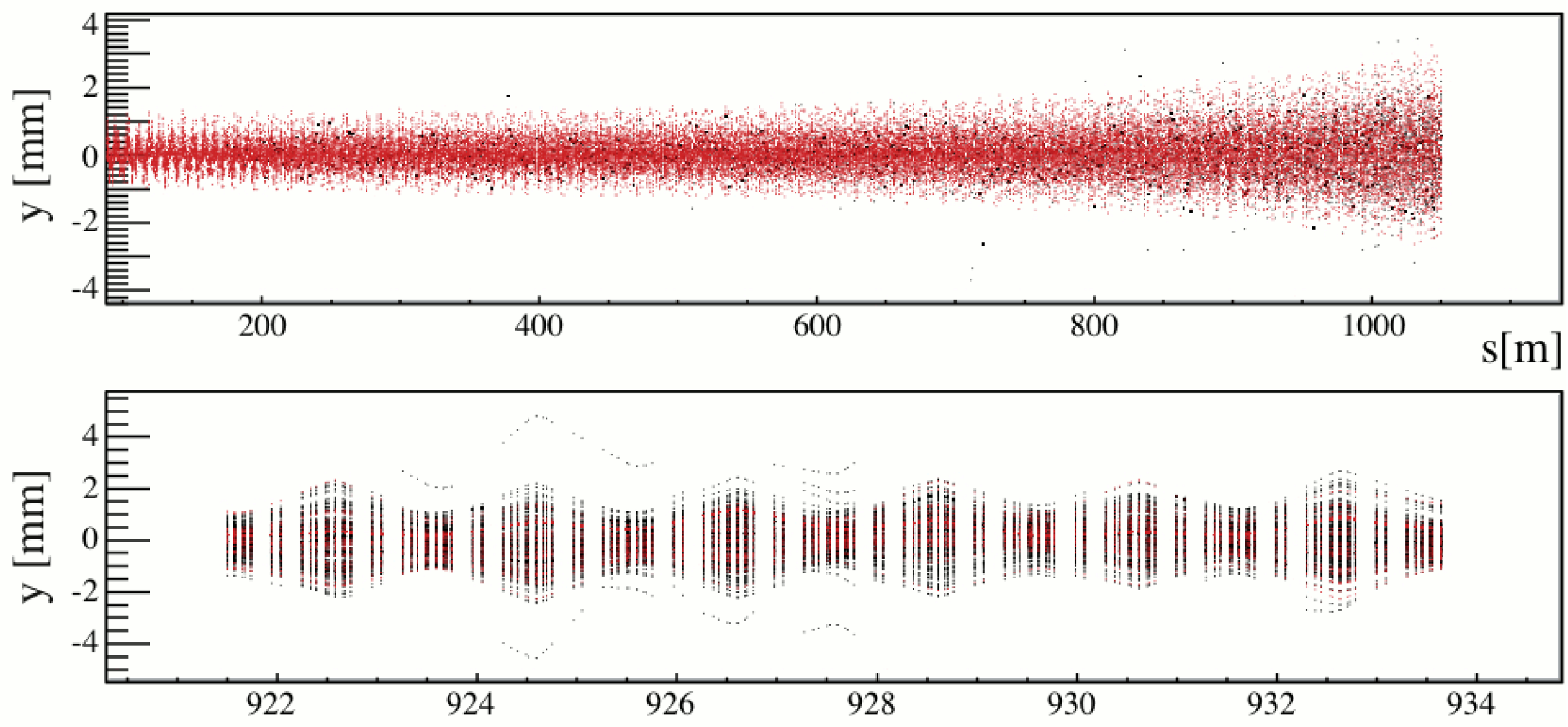
Strongest halo generation is expected for the longest decelerator (1053 m)
for simplicity gas equivalent of N_2

Beam: sliced beam model with a reduced number of bunches (200)
Halo: particle beam model
In tracking included: offset of the beam, misalignment of PETS and quadrupoles, wakefield effects



transverse halo and beam distribution at the end of the decelerator

Tracking results



Beam and halo along the decelerator and an extract of the decelerator

- very small fraction of particles of 10^{-7} is lost (only halo losses)
- most of the lost particles are low energy particles with large scattering angles

Summary and Outlook

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Summary ...

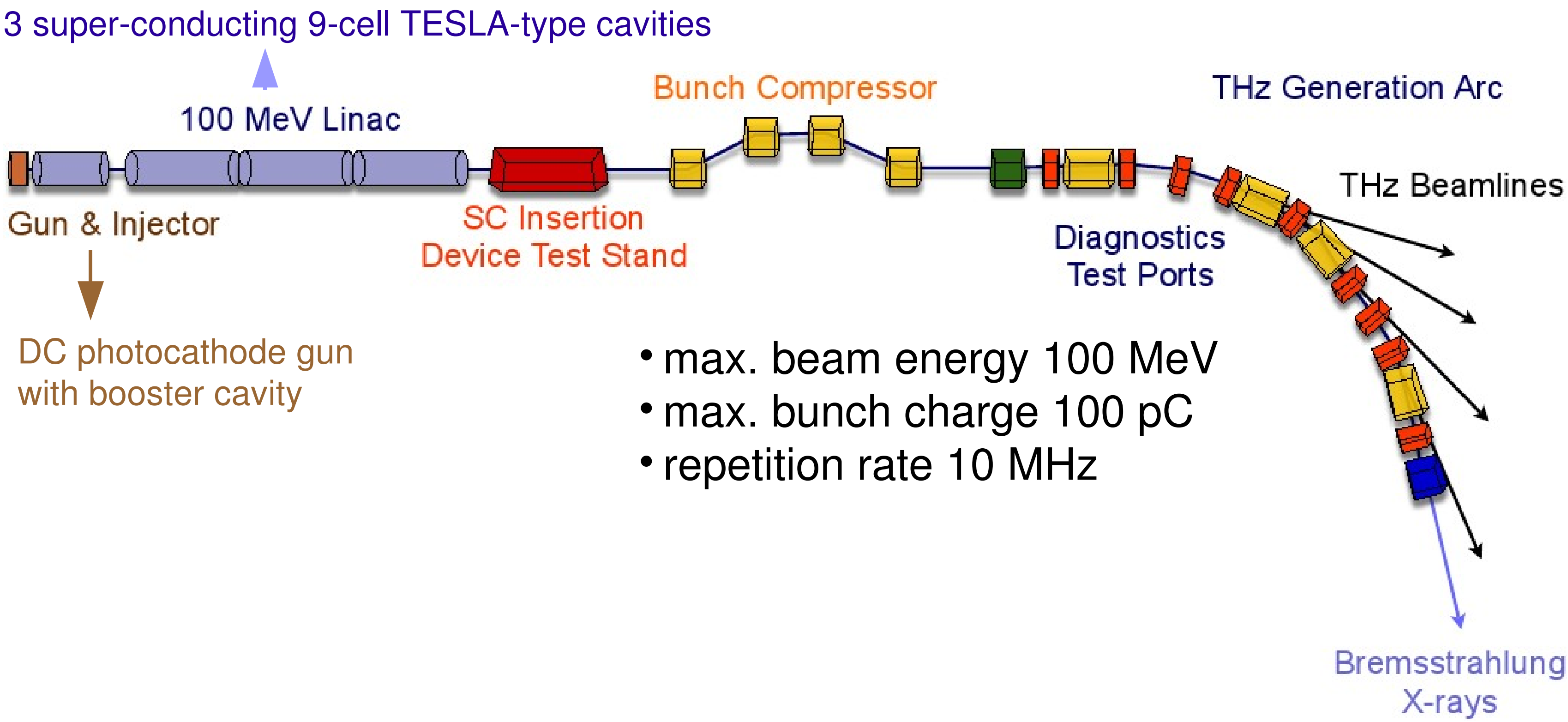
- Extension of PLACET-HTGEN to lower beam energies
- Implementation of halo tracking in the PETS including transverse wakefield effects
- Halo studies for the CLIC drive beam:
  - Analytical estimates indicate very small halo generation
  - Simulations predict very few losses

... and Outlook

- Implementation of halo tracking including wakefield effects in RF cavities is completed (Barbara Dalena)

➡ **Halo tracking now implemented for all present elements of CLIC**

- **Halo and tail generation simulations for TBONE:**



- max. beam energy 100 MeV
- max. bunch charge 100 pC
- repetition rate 10 MHz

Thanks!