CLIC Collimation System: Recent Studies and Plans

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CLIC Collaboration meeting
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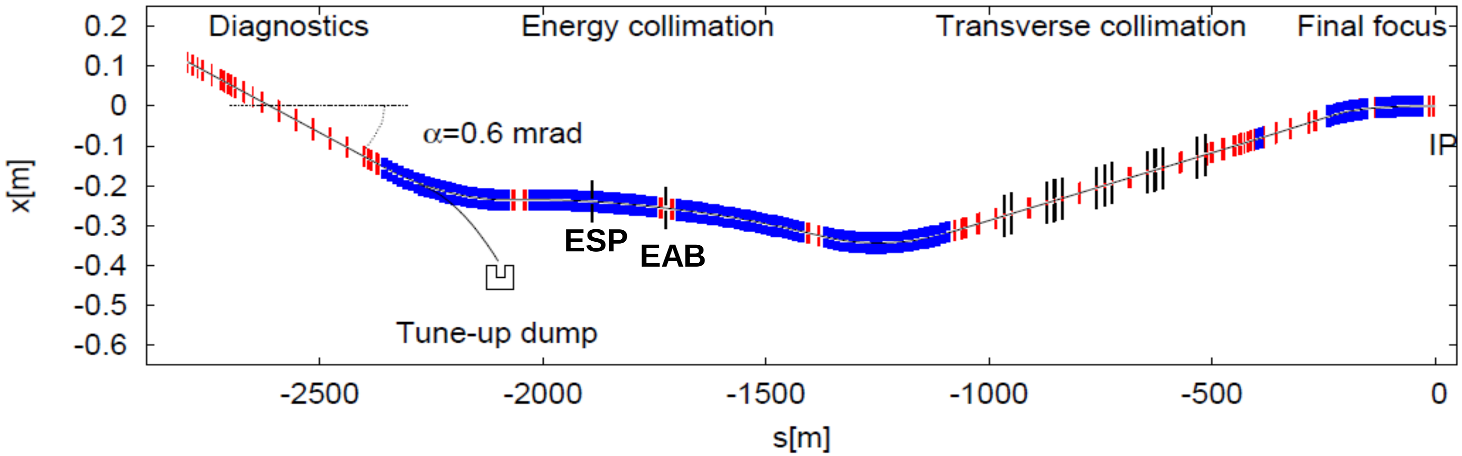
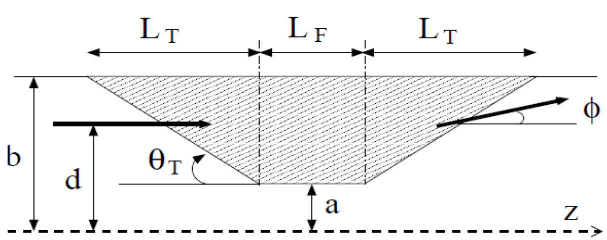
Introduction

- CLIC CDR:

BDS layout



Geometry of spoilers and absorbers



Name	a_x [mm]	a_y [mm]	θ_T [mrad]	L_F [X_0]	L_T [mm]	Mat.
ESP	3.51	8	50	0.05	90	Be
EAB	5.41	8	100	18	27	Ti
the following $\times 4$						
YSP	8	0.1	88	0.2	90	Ti-Cu
XSP	0.12	8	88	0.2	90	Ti-Cu
XAB	1	1	250	18	27	Ti
YAB	1	1	250	18	27	Ti

Studies in progress

- Identify and investigate possible failure mode scenarios in the main linac that could generate significant energy deviation. Important to study the degree of damage to the energy spoiler by beam impact.

- Beam tracking simulations: LINAC + BDS + failure modes

- Thermo-mechanical characterisation of the energy collimators using the output beam distribution from tracking simulations, and the codes FLUKA (energy deposition and temperature rise) and ANSYS (mechanical stress)

- Exploring other collimation alternatives: nonlinear passive protection.

- Alternative collimator design: “hollow” and “semi-hollow” spoilers, other materials (SiC foam).

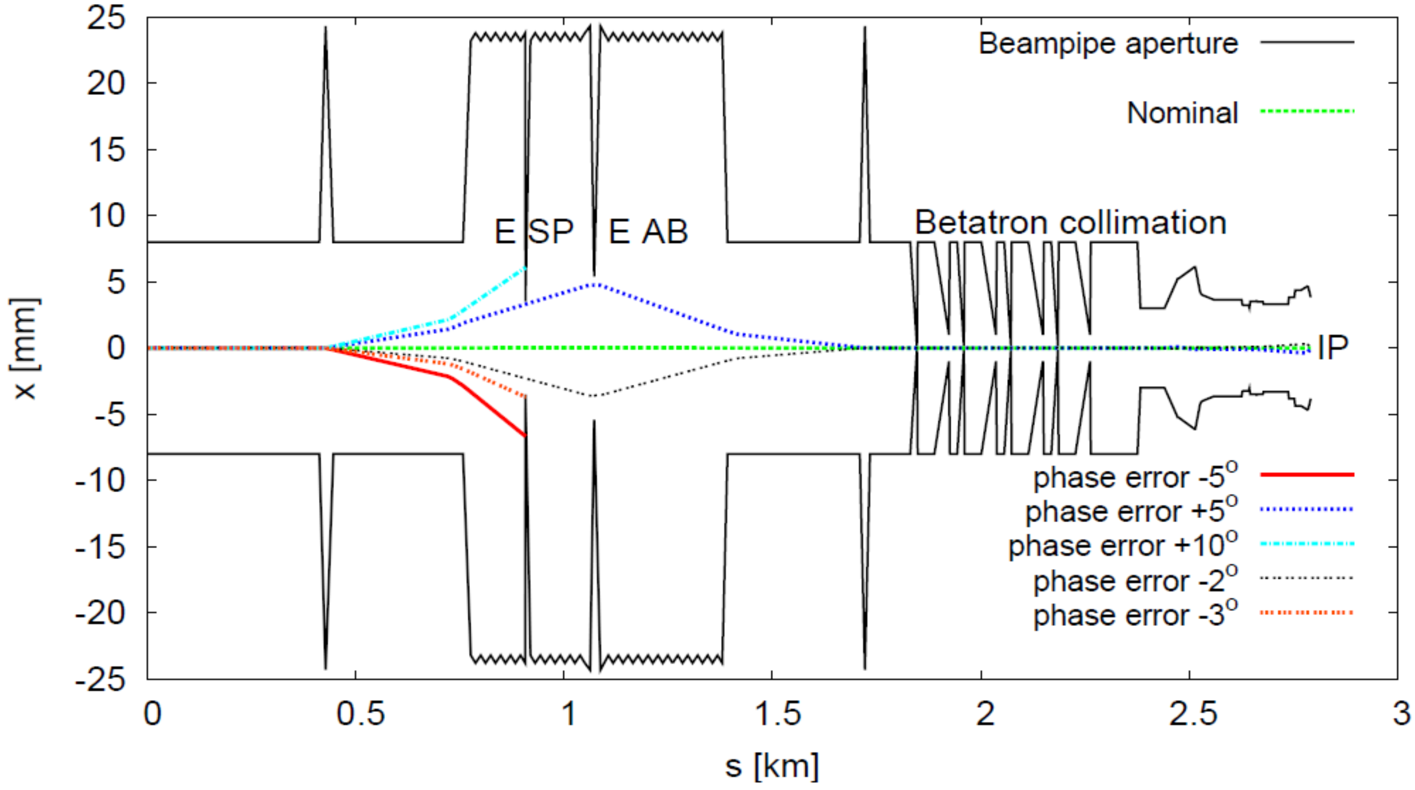
Failure modes

- Review of failure modes in the CLIC main linac which can generate significant energy deviation, in such a way that the beam hits the energy spoiler
- For example: Injection phase error, RF breakdown, missing drive beam, beam charge error
- Tracking simulations LINAC + BDS assuming failures between two pulses. Assuming nominal beam parameters and a perfect linac (no additional lattice imperfections)

Failure modes

- Injection phase error:

Beam centroid trajectory in the BDS for different injection phase errors

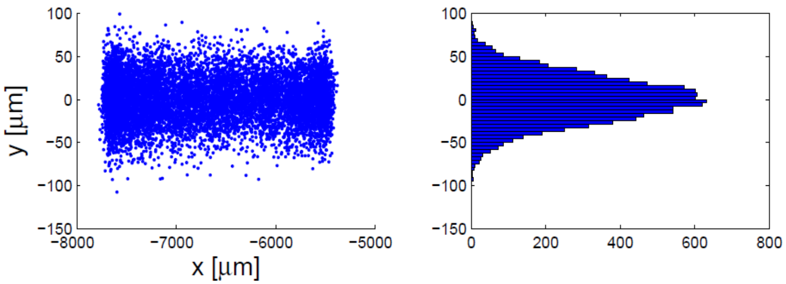


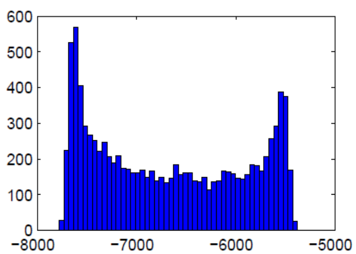
For phase error ~> +5° and <~ -3° the beam hits the energy spoiler (ESP)

Failure modes

- Injection phase error:

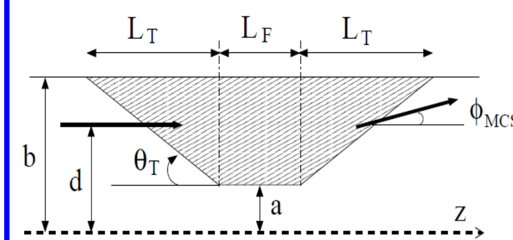
For -5º phase error, transverse beam distribution at ESP





σ_x=757.72 µm
σ_y=26.45 µm
E_{mean}=1463.8 GeV
≈1% full energy spread

Beryllium spoiler



Run
FLUKA and
ANSYS

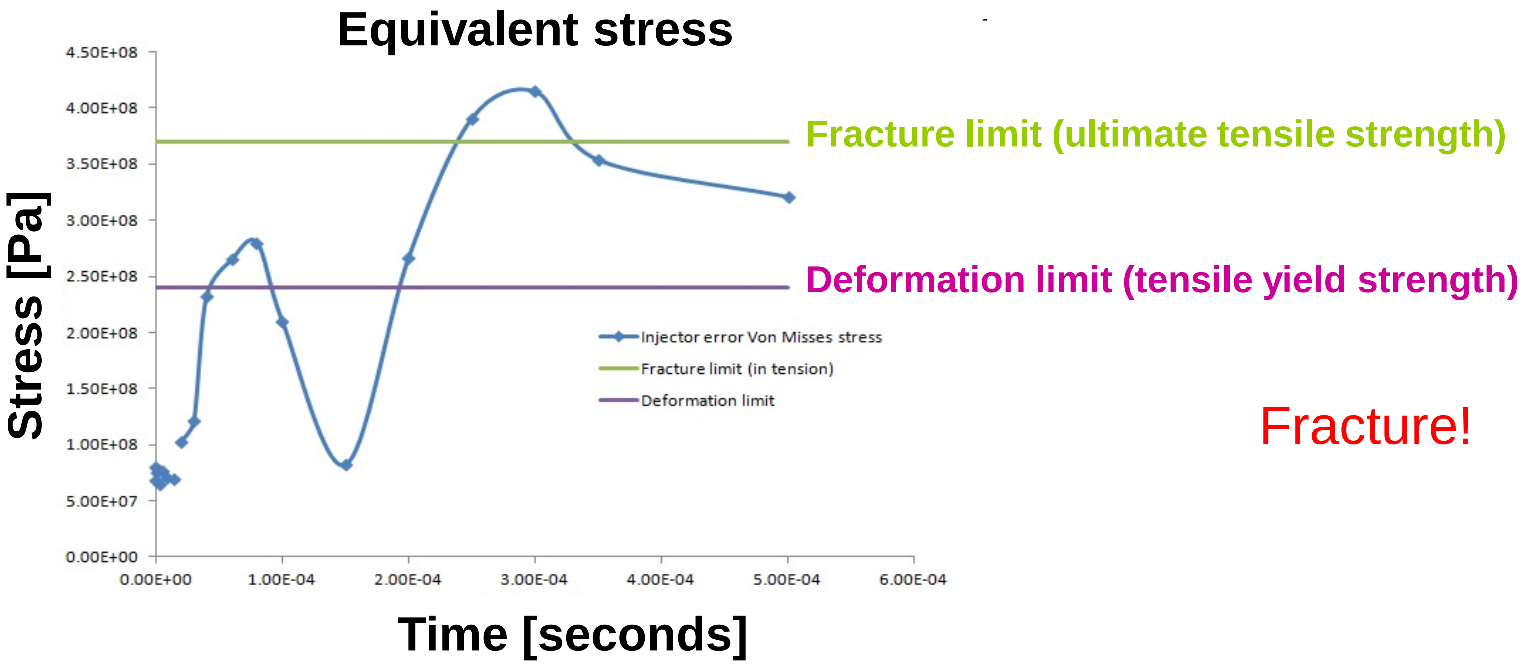
?

Failure modes

- Injection phase error:

For -5^{o} phase error

Result from FLUKA-ANSYS:



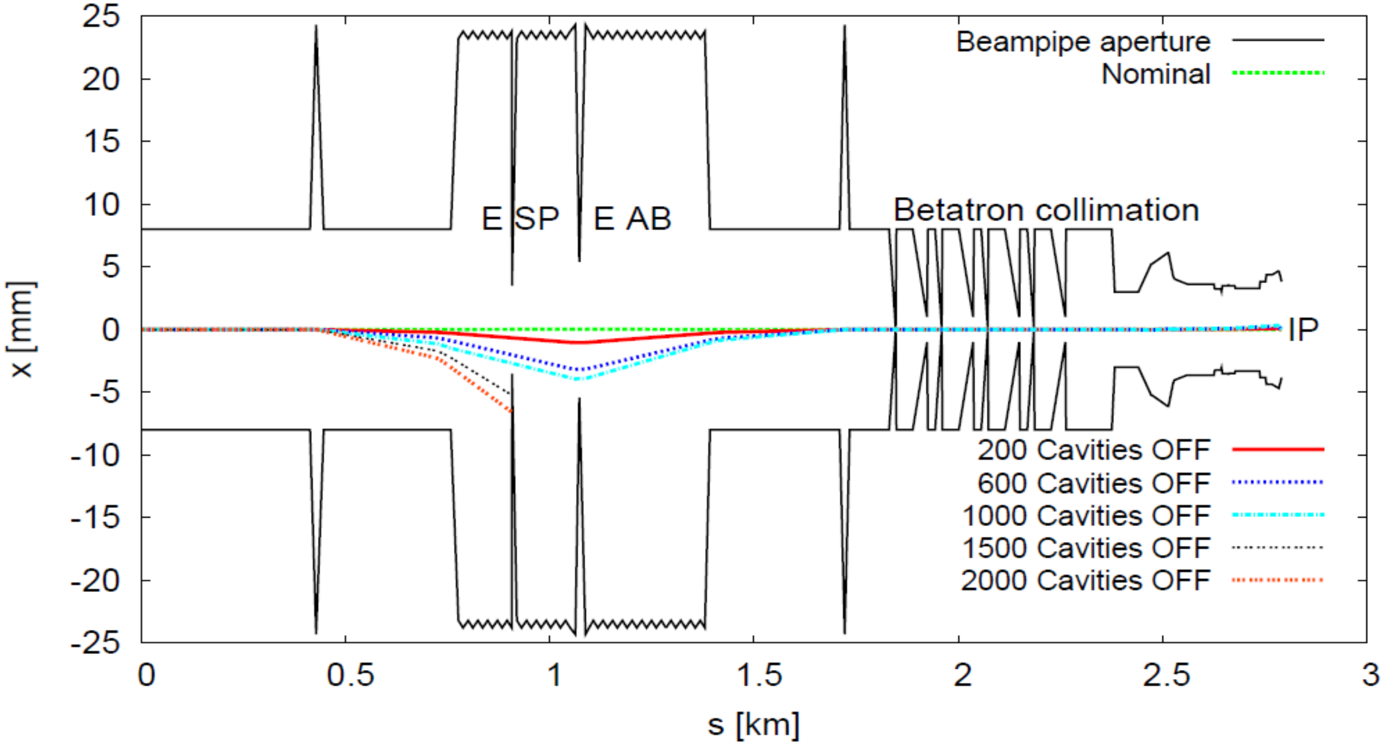
Fracture!

To be presented at IPAC12: J. Resta-Lopez, J. L. Fernandez-Hernando, A. Latina, "THERMO-MECHANICAL ANALYSIS OF THE CLIC POST-LINAC ENERGY COLLIMATORS"

Failure modes

- RF cavity fail:

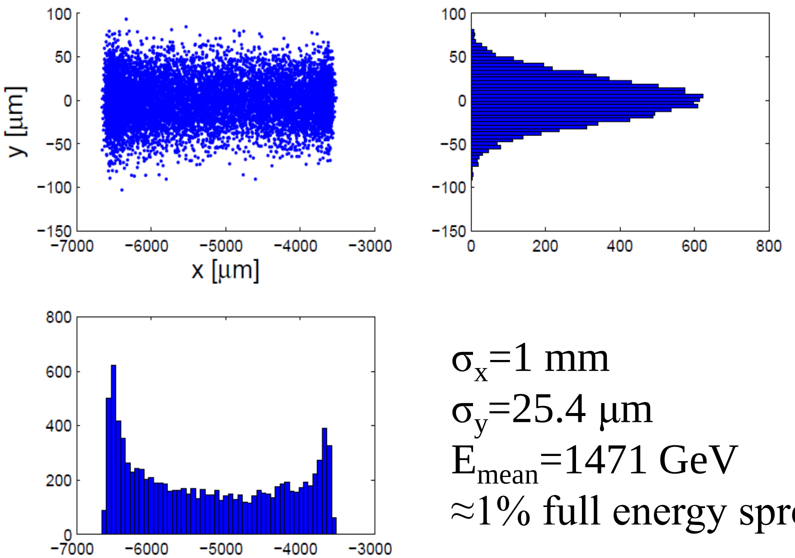
Beam centroid trajectory for different number of RF structures switched off in the last section of the main linac



Failure modes

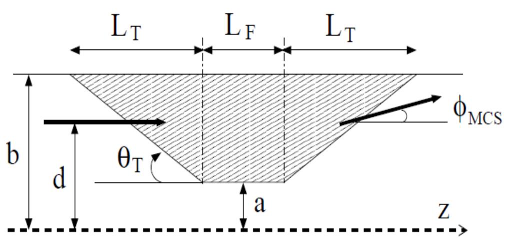
- RF cavity fail:

1500 cavities switched off in the last section of the main linac.
Transverse beam distribution at ESP



σ_x=1 mm
σ_y=25.4 μm
E_{mean}=1471 GeV
≈1% full energy spread

Beryllium spoiler



Run
FLUKA and
ANSYS

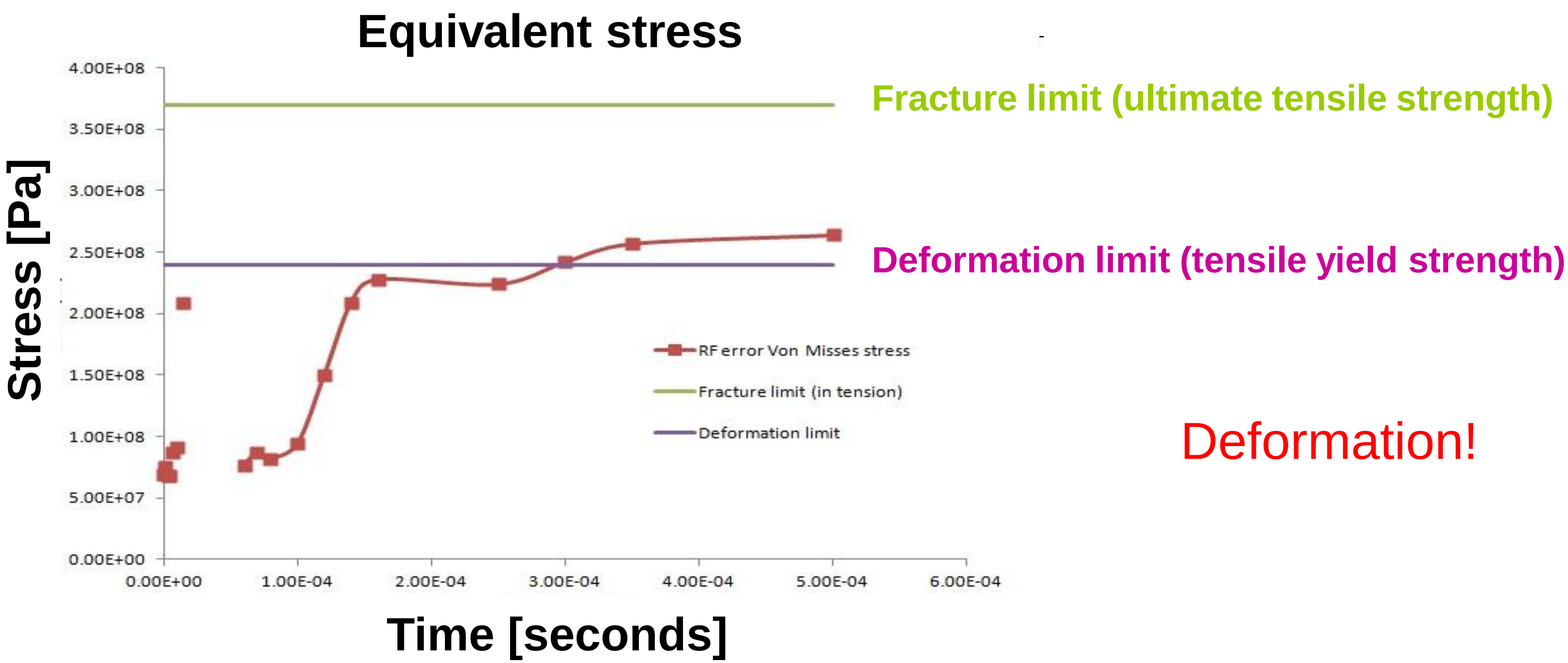
?

Failure modes

- RF cavity fail:

1500 cavities switched off in the last section of the main linac.

Result from FLUKA-ANSYS:



Deformation!

To be presented at IPAC12: J. Resta-Lopez, J. L. Fernandez-Hernando, A. Latina, "THERMO-MECHANICAL ANALYSIS OF THE CLIC POST-LINAC ENERGY COLLIMATORS", TUPPR030.

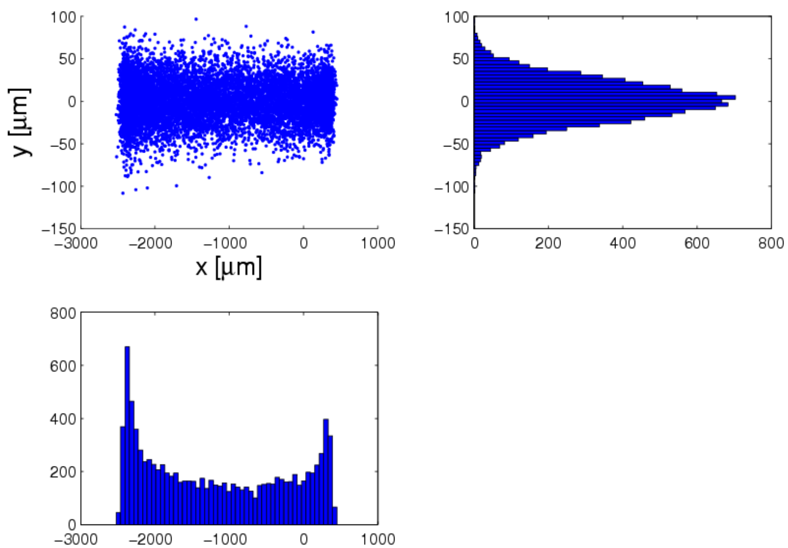
Failure modes

- RF cavity fail:

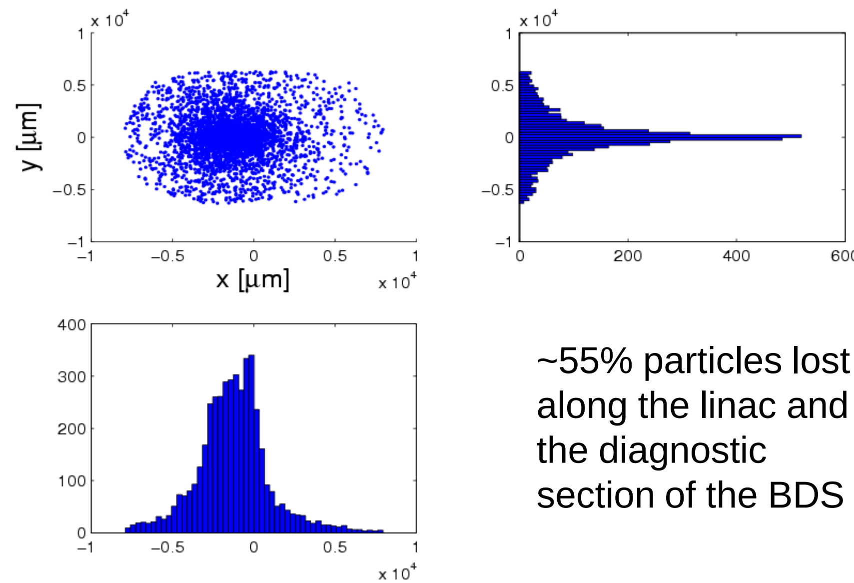
In terms of spoiler damage, the case of the total failure of a series of RF cavities at the start of the linac is less critical, since the energy spread increases and the beam suffers a rapid filamentation

Transverse beam distribution at ESP

300 RF structures OFF



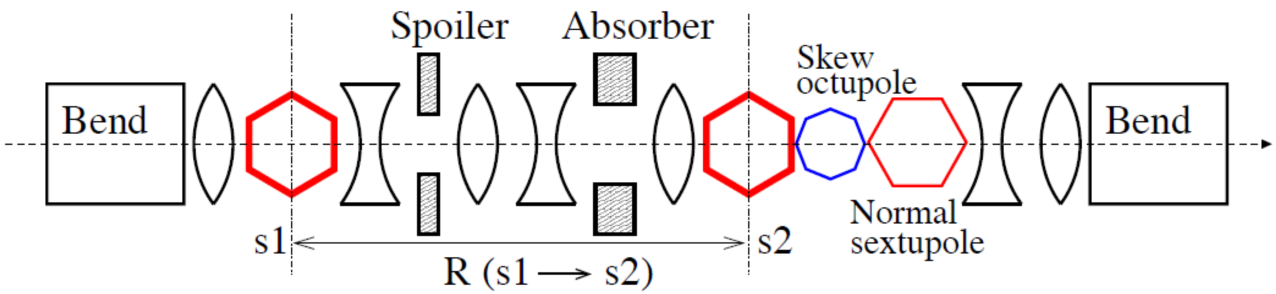
400 RF structures OFF

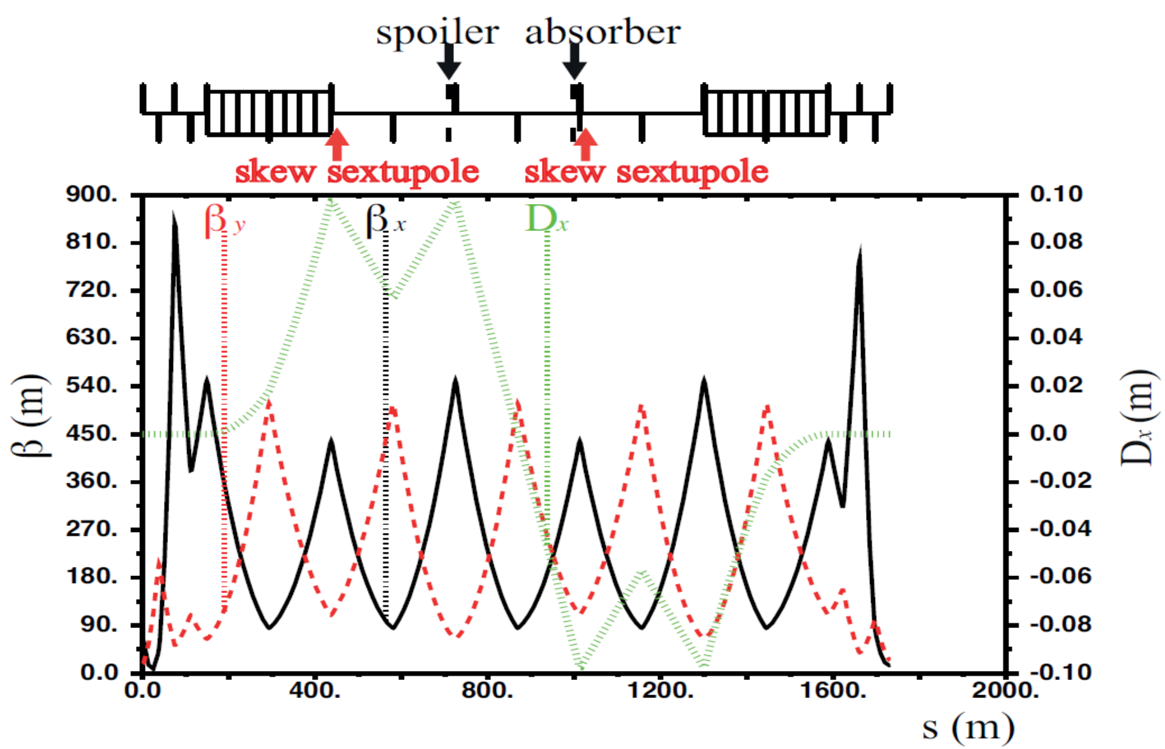


~55% particles lost along the linac and the diagnostic section of the BDS

Alternative collimation

- Nonlinear energy collimation (nonlinear passive protection)

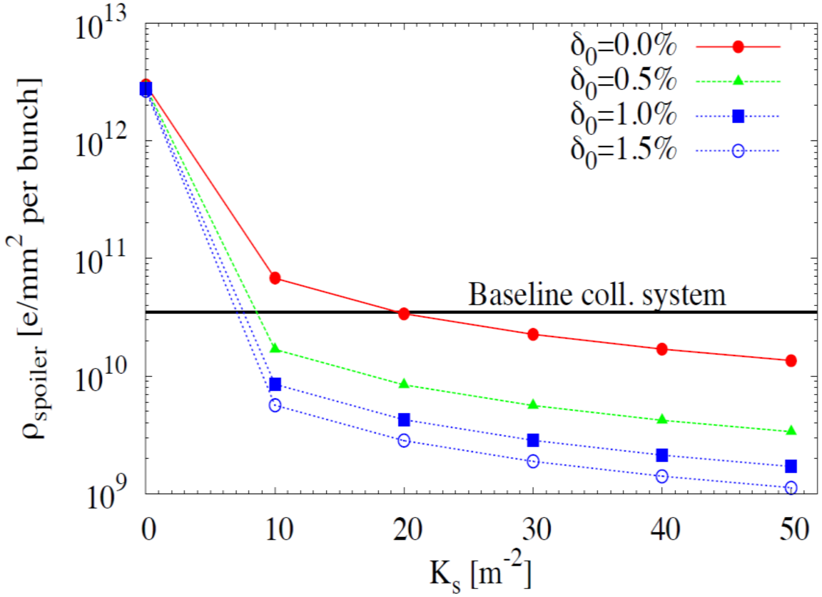




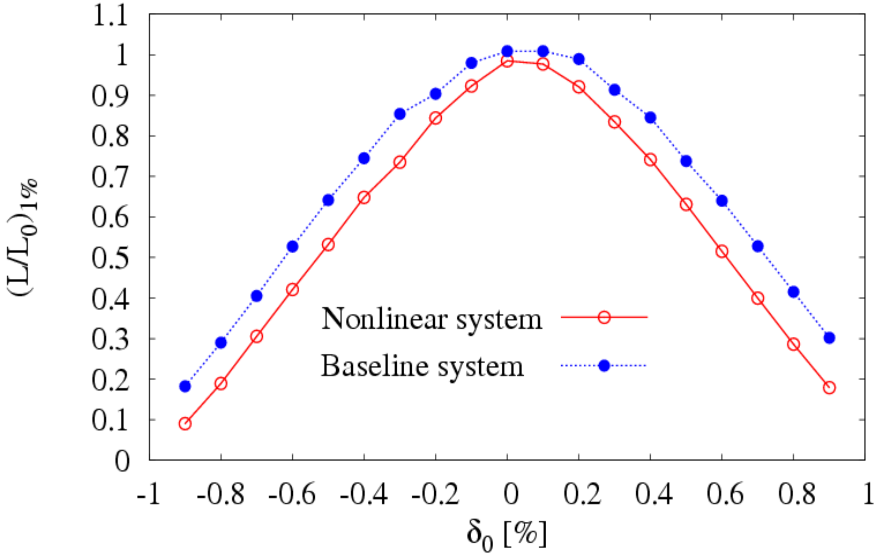
Alternative collimation

- Nonlinear energy collimation
  - Performance

Transverse beam peak density at the spoiler position versus the skew sextupole strength



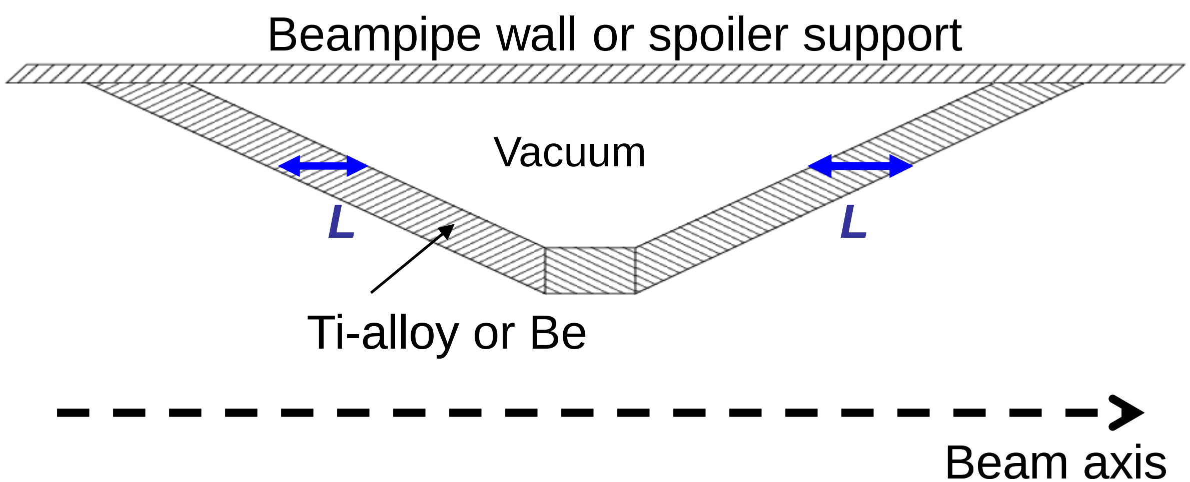
Energy bandwidth comparison (for the case L^*=4.3 m), skew sextupole strength K_s=8 m^{-2}



Results will be presented at IPAC12: J. Resta-Lopez, A. Faus-Golfe, “NONLINEAR ENERGY COLLIMATION FOR THE COMPACT LINEAR COLLIDER”, TUPPR017.

Alternative collimation

- Alternative spoiler design:
  - "Hollow" spoilers

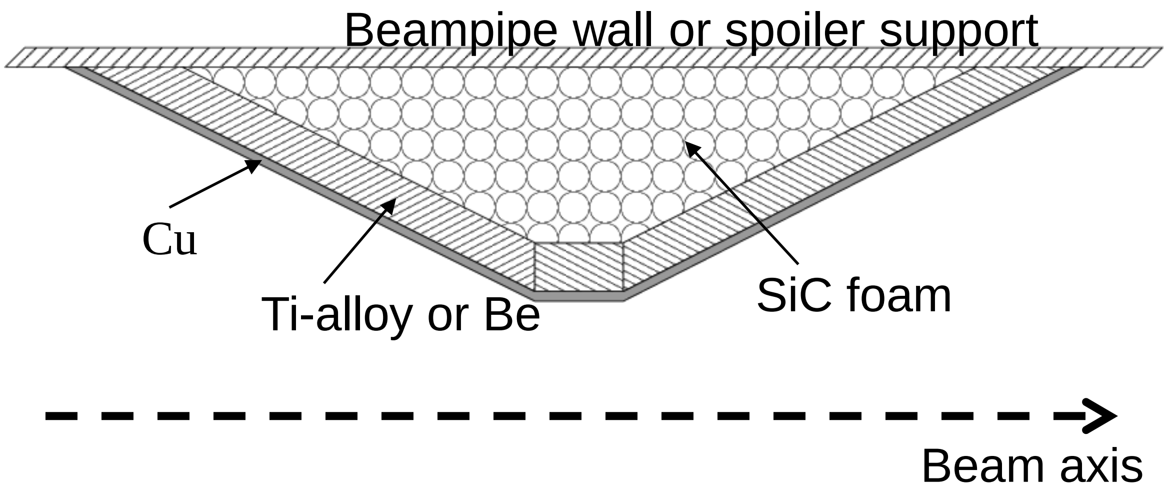


- ***2L*** is the minimum length of material that the beam has to see in order to obtain the necessary angular divergence ***Θ*** by MCS. In this way the beam spot size is increased at the downstream absorber position in order to avoid its damage or fracture.

- The empty inner part of the spoiler could accommodate a water cooling circuit or some other kind of cooling system

Alternative collimation

- Alternative spoiler design:
  - "Semi-hollow" spoilers



We plan to study the thermo-mechanical characteristics of these spoiler designs using the codes FLUKA and ANSYS.

Collimator wakefields

- Collimator wakefields could be an important source of emittance growth and beam jitter amplification in the BDS of future linear colliders (ILC and CLIC)
- New set of measurements would be helpful for a better understanding of the collimator wakefield effects (dependence with bunch length, limit of applicability of analytical estimates in the different regimes, etc.)
- We are working on an experimental proposal at SLAC ESTB, in collaboration with members from SLAC, CERN, Cockroft Institute and JAI (See Mauro Pivi's talk)

Collimator wakefields

- RMS bunch length is a parameter which strongly influences wakefield kick factors
- Accurate bunch length measurement will be essential for a more precise comparison between measured wakefield kick factors, theoretical estimates and simulations
- For the bunch length measurement in ESTB we plan to use a Smith-Purcell Radiation (SPR) monitor [G. Doucas et al., Phys. Rev. ST-AB 12, 032803 (2009)]. Resolution < 50 fs.
- Recently, the IFIC group joined the SPR project collaboration (international collaboration: Oxford, Diamond, SLAC, Orsay, Valencia)
- A PhD student from IFIC-Valencia University will contribute to the SPR monitor development activities

Collimator wakefields

Plans

1) Coll. wakefield measurements with bunch length in the range [100-300] μm

- For a precise benchmarking between experimental results, theory and simulations
- We can use the instruments which are already installed in the ESTB beamline: wakefield box, BPMs
- \+ SPR monitor in ESTB

2) Push to smaller bunch length (< 50 μm)

- Investigate coll. wakefields with CLIC-like bunches

Summary

- Optimisation of the collimation system towards a technical design phase

- Different open fronts:
  - Survivability of the energy spoiler in case of beam impact in accidental cases (machine protection related study)
  - Study and simulation of failure modes in the CLIC main linac
  - Investigate the thermo-mechanical features of the collimators for different failure mode scenarios
  - Alternative optical solutions: nonlinear passive protection
  - Alternative collimator structure design
  - Experimental tests: proposal of collimator wakefield experiment at SLAC ESTB