Energy spoiler design for CLIC

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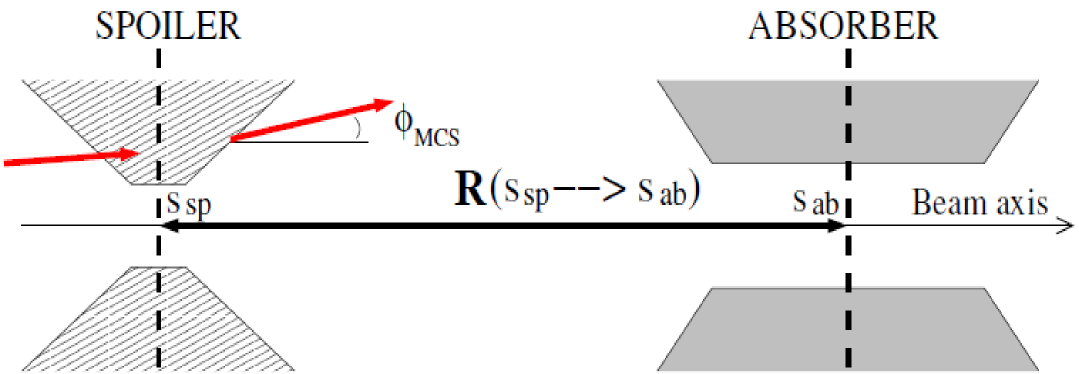
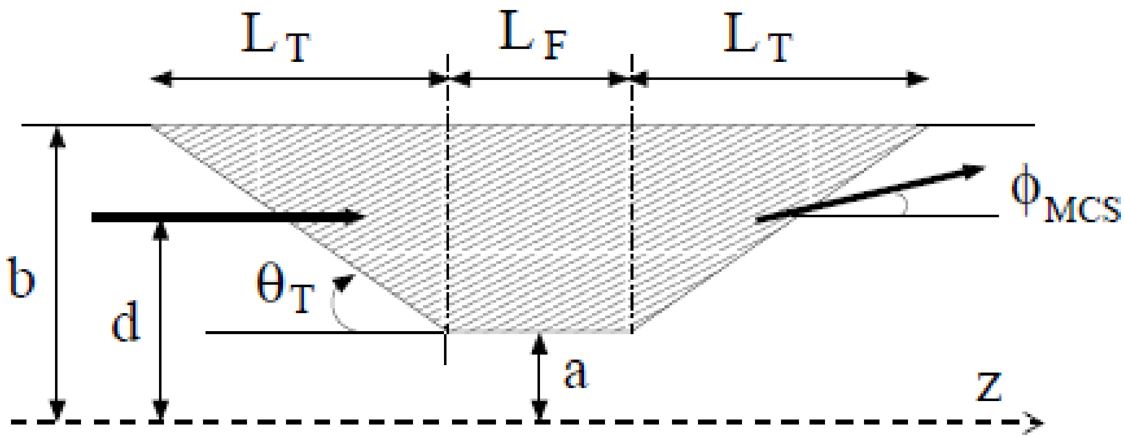
The collimator mission is to clean the beam halo from e- or e+ off orbit which could damage the equipment and mainly to stop the photons generated during the bending of the beam towards the Interaction Point. These photons, if not removed, would generate a noise background that would not allow the detectors to work properly.

The spoiler serves as protection for the main collimator body as it will disperse the beam, reducing the beam energy density by multiple Coulomb scattering, in case of a direct bunch hit avoiding severe radiation damage.

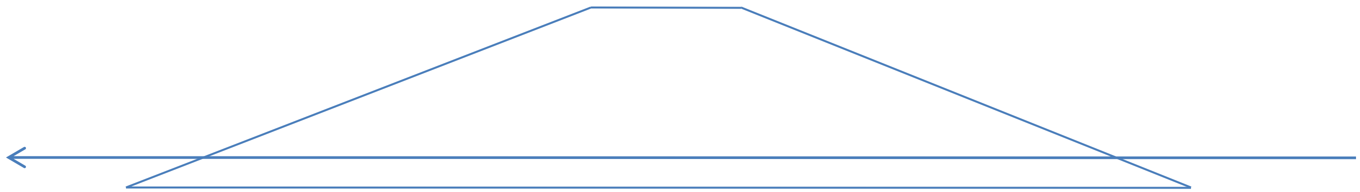
	Energy spoilers
Energy	1500 GeV
Bunches it has to resist	312
Particles per bunch	3.72E9
σ_x in the spoiler position	779.6 μm
σ_y in the spoiler position	21.9 μm
Material length needed to spoil beam	0.05 Xo



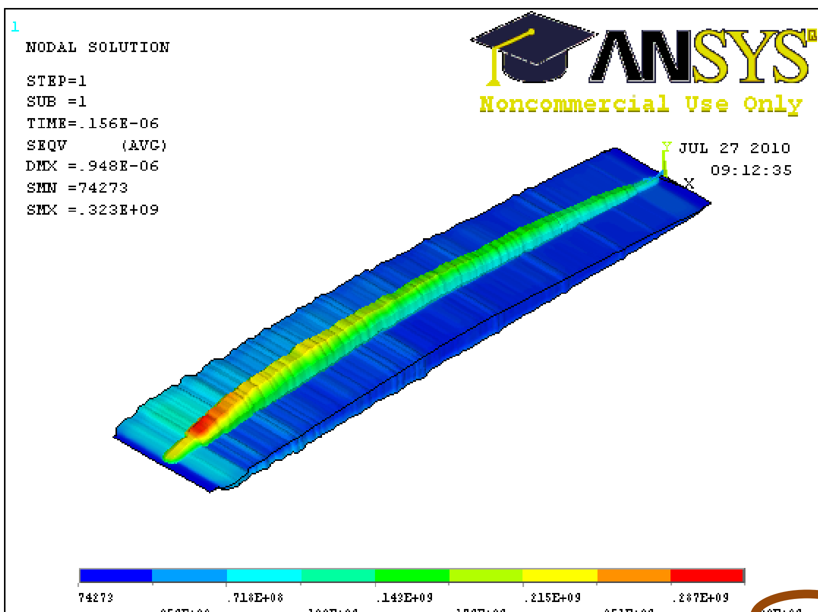


Parameter	ENGYSP (spoiler)	ENGYAB (absorber)
Geometry	Rectangular	Rectangular
Hor. half-gap a_x [mm]	3.51	5.41
Vert. half-gap a_y [mm]	8.0	8.0
Tapered part radius b [mm]	8.0	8.0
Tapered part length L_T [mm]	90.0	27.0
Taper angle θ_T [mrad]	50.0	100.0
Flat part length L_F [radiation length]	0.05	18.0
Material	Be	Ti alloy–Cu coating

At IPAC 2010 I showed the resulting stress (using FLUKA and ANSYS) right after a CLIC bunch train has hit the spoiler at 0.2 mm from its bottom (or 4.29 mm from its top). Being the normal orbit of the beam at 8 mm from the bottom of the spoiler (3.51 from the top) that represents a deviation from normal orbit of **$10\sigma_x$**.

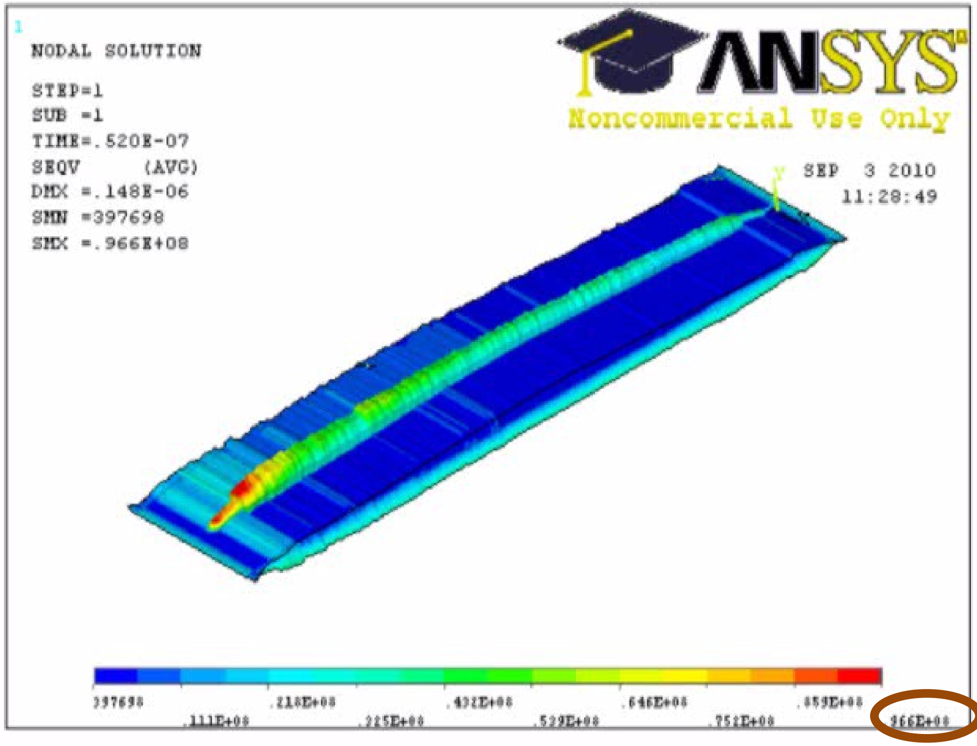


The results right after the time the bunch train has hit the spoiler, 156 ns, showed that there would be permanent deformation but not fracture.



~325MPa compressive stress

T_{melt} [K]	1560
Y [10^5 MPa]	2.87
α_T [10^{-6} K^{-1}]	11.3
σ_{UTS} [MPa]	370
ΔT_{fr} [K]	228
Yield Tensile Strength [MPa]	240
Yield Compressive Strength [MPa]	270
Specific Heat Capacity [J/g°C]	1.925
Density [g/cm^3]	1.844



I added then that I needed to let the ANSYS calculation go on, after the beam has hit the spoiler, to see if there would be any stress build up that could reach fracture levels. And…

…it kind of does.

950MPa, and tensile, which is way above tensile strength limit.

$$\sigma_{eq} = \frac{1}{\sqrt{2}}\sqrt{(\sigma_1-\sigma_2)^2+(\sigma_2-\sigma_3)^2+(\sigma_3-\sigma_1)^2}$$

T_{melt} [K]	1560
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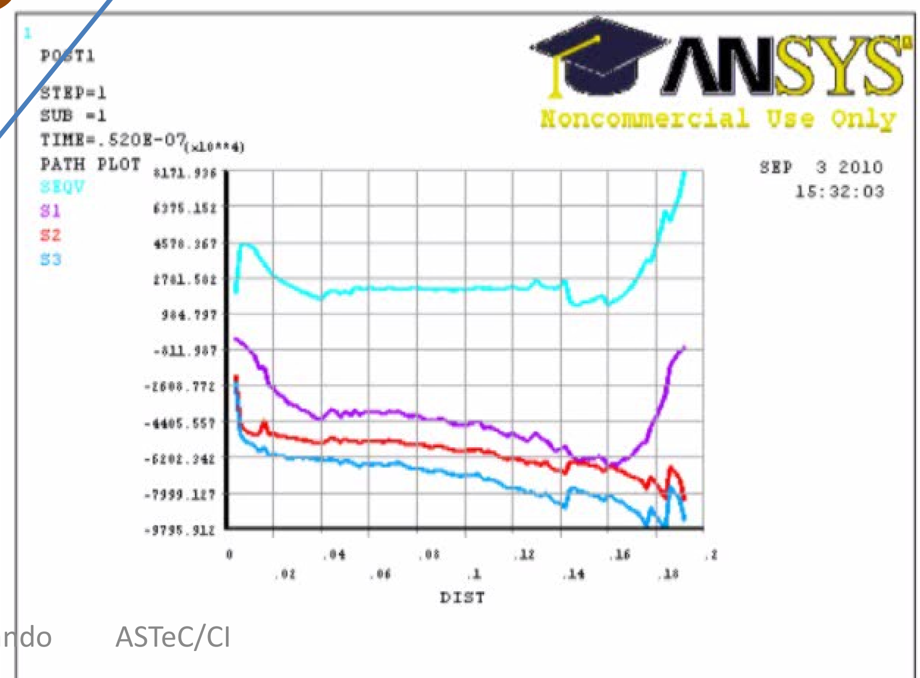
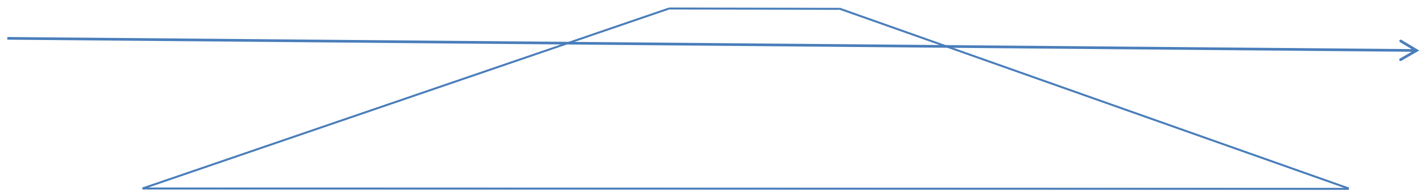
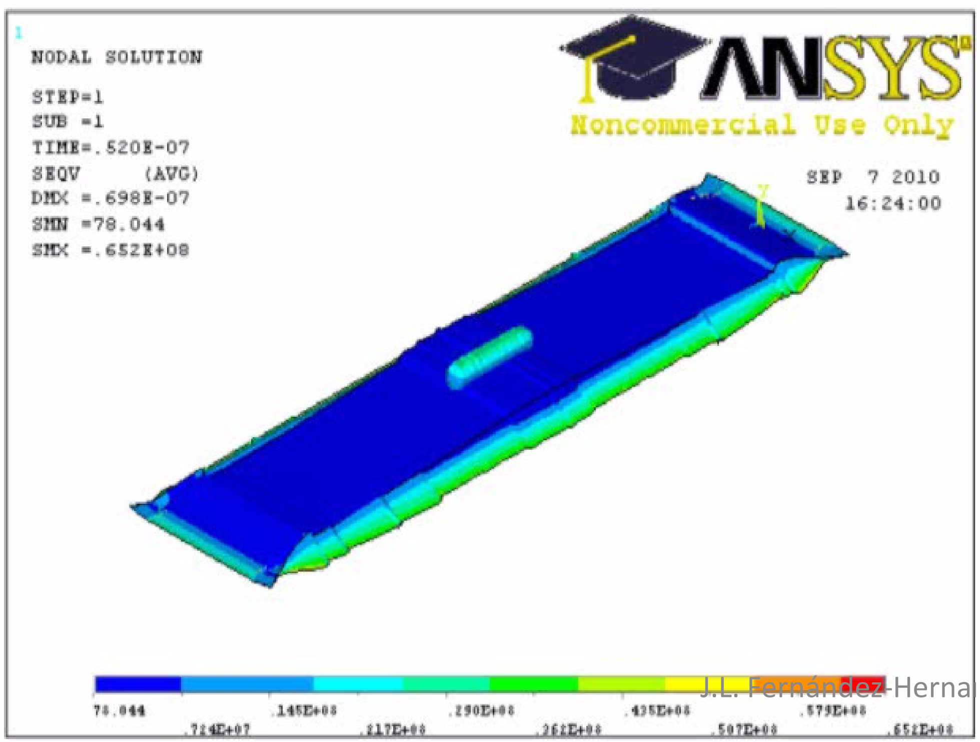


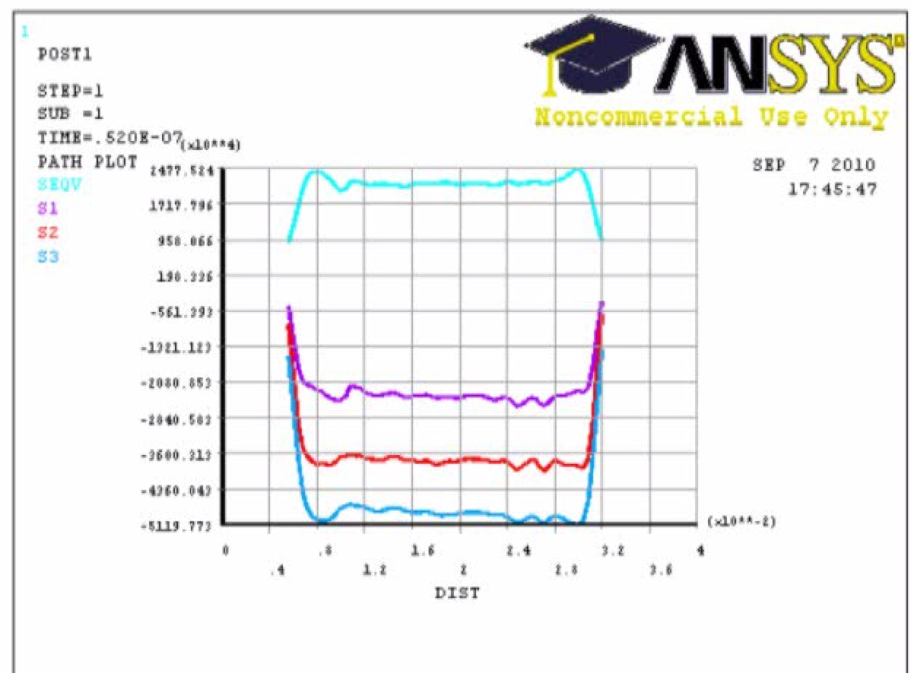
But… is a deviation of 10 sigmas even possible?

I have also calculated the stresses when the bunch train hits 0.2mm from the top instead of 4.29 mm (or 4.29 mm from the bottom instead of 0.2). Which means a deviation of “just” **4.75σ_x**.

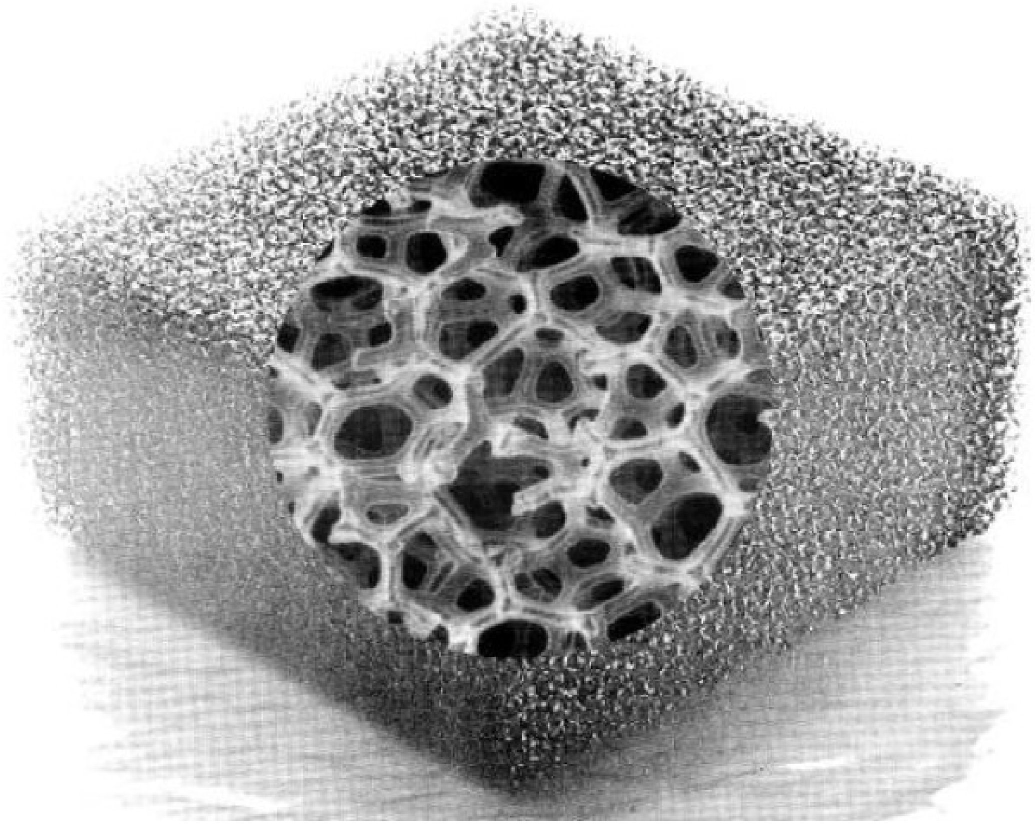


The top value of stress is ~340MPa and compressive. Meaning that **there will not be fracture** but **there will be a permanent deformation**, and in this case it is a vertical deformation of 5 μm, which represents **a 0.1% of the half gap**. Can we live with that?





Silicon carbide (SiC) foam



SiC is a material with good thermomechanical properties. Used for LHC collimation phase 2, in F1 brakes, and aerospace applications.

It can be used as core material for CLIC spoilers, coated with metal (Be, Cu...)

Material	Radiation length Xo [cm]
Copper	1.44
Ti alloy	3.56
Beryllium	35.3
SiC (solid)	8.1
SiC (foam 8%)	337

Very long radiation length of the foam at 8% of nominal density allows for low energy deposition of the particle beam.

Pros and cons for using SiC foam as core material in CLIC energy spoilers covered by 0.05Xo (in the z direction) of beryllium:

Pros:

- It will not matter the depth the beam hits as it will always see 0.05Xo of beryllium (the contribution of the SiC foam can be negligible).

- Save some beryllium.

Cons:

- The junction of two different materials is a complicate thing, mechanically speaking. The different thermal properties can lead to dislocation or fracture of the junction when the bunch train hits. A single material spoiler is more “whole” in that aspect.

Conclusions:

It would be very important to identify the failure modes and accident scenarios to know by how much the bunch train can be deviated from orbit as the energy spoiler design could perfectly withstand the worse case scenario… or not.

Studies on how to attach the spoiler to its mount are required to avoid concentration of tensions in the attached points.

Studies of using a SiC foam core would give us the maximum stress in the material junction and therefore tell us if it would survive a bunch train hit at any depth position.

If studies of accident scenarios reveal that the beam orbit cannot be deviated by more than ~170 σ's (could be more) then the full beryllium body would survive the impact of a bunch train.

Outlook:

Apart from the already mentioned: mechanical support, cooling and activation studies.