Design Studies of a Radiobiology Experimental Beamline and Acceleration Line

Eduardo Martinez-Lopez[a], Nuria Fuster-Martinez[a], Marça Boronat[a], Alexej Grudiev[b], Benito Gimeno[a], Daniel Gonzalez-Iglesias[a], César Blanch[a], Pablo Martín-Luna[a], Abraham Menéndez[a], Juan Carlos Fernandez-Ortega[a], Laura K. Pedraza[a], Daniel Esperante[a]

[a]Instituto de Física Corpuscular (IFIC-University of Valencia, CSIC), Carrer del Catedrátic José Beltrán Martínez 2, Paterna, 46980, Valencia, Spain
[b]European Organization for Nuclear Research (CERN), Esplanade des Particules 1, 1211, Geneva, Switzerland

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The ALMA linear injector

ALMA is a linear injector in which C^{6+} carbon ions, He^{2+} helium ions, and protons will be accelerated for hadron therapy studies.

- As of today, this is the general design of the first phase of the injector, featuring the following characteristics:

E	β	I_p (Source)	F_{rep}	L_{pulse}	F_{RF}	ϕ_{RF}
10.15 MeV/u	0.15	100μA	200 Hz	<10 μs	750 MHz	10 deg

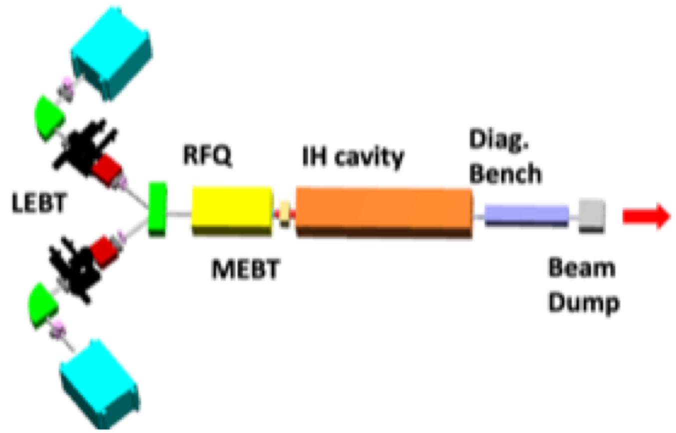
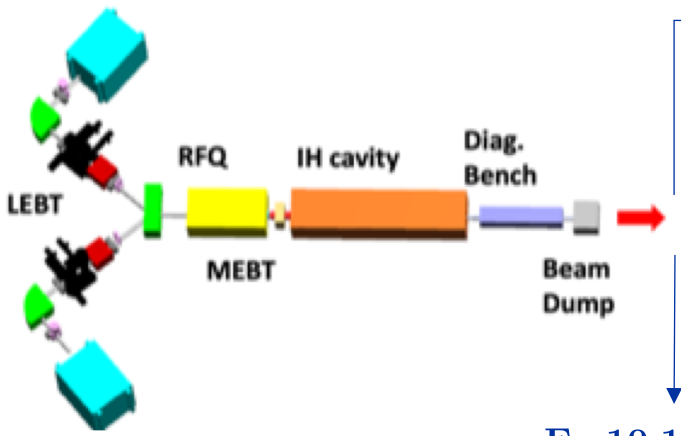


Figure. General layout of the injector.

What comes next?

- We are currently designing an extraction line for radiobiology experiments aimed at delivering highly homogeneous irradiation to cellular monolayer samples. This requires a broad beam with sufficient energy and a uniform transverse spatial distribution.

- In parallel, we are developing 3 GHz SCDTL structures as optimal candidates for extending the acceleration line, with the goal of increasing the beam energy to enable irradiation of deeper volumes.



Ex. line for radiobiology studies

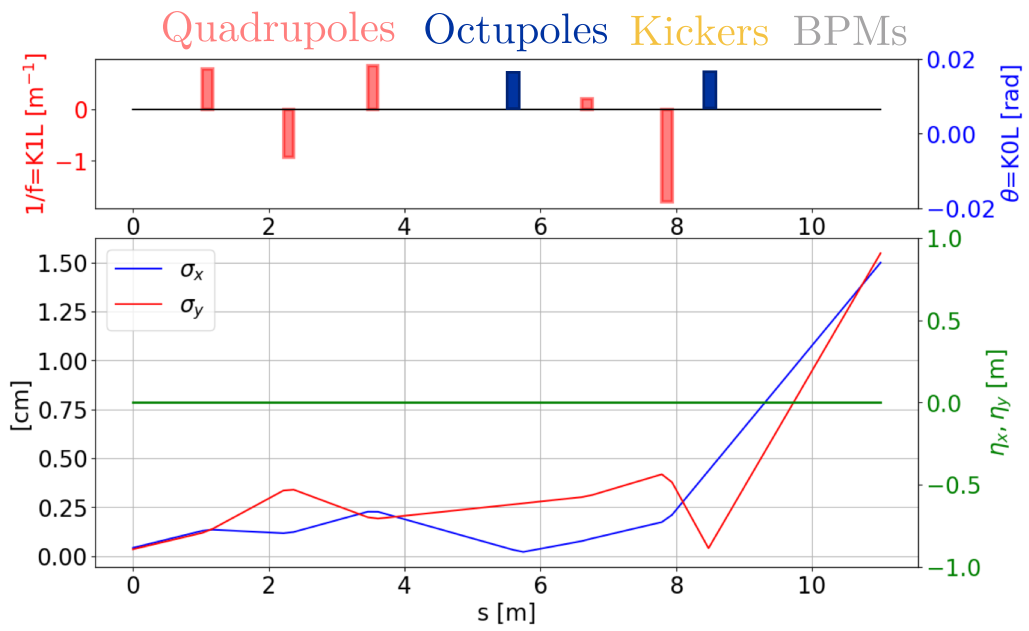
Multi-species 3 GHz SCDTL

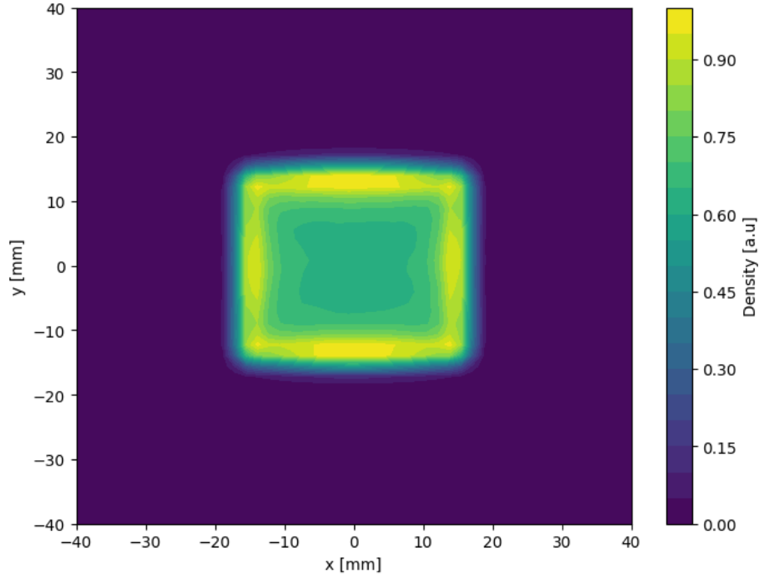
E=10.15 MeV/u

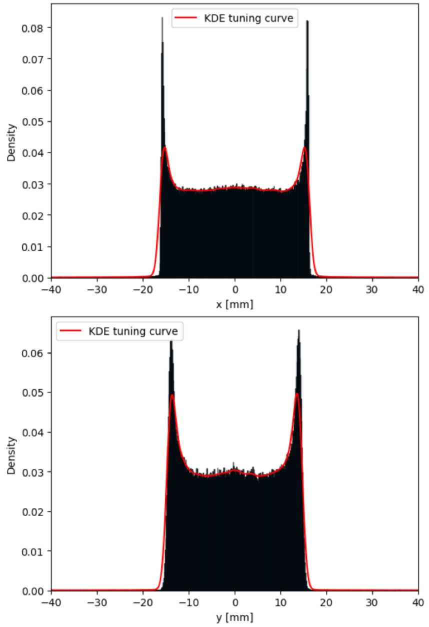
Figure. Current work on the injector.

Extraction line for radiobiology studies

- To achieve these objectives, several beamline, configurations were designed, incorporating scattering foils, quadrupole magnets, and nonlinear magnets either individually or in combination. The optimal solution consists of a combined lattice of quadrupole and nonlinear magnets.



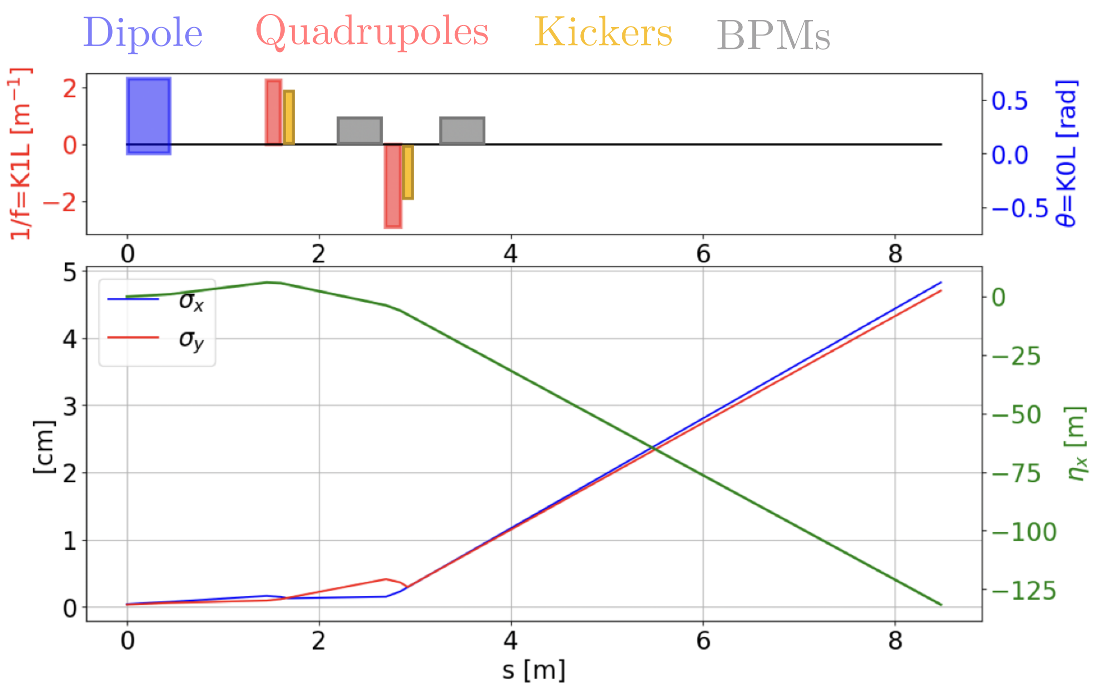


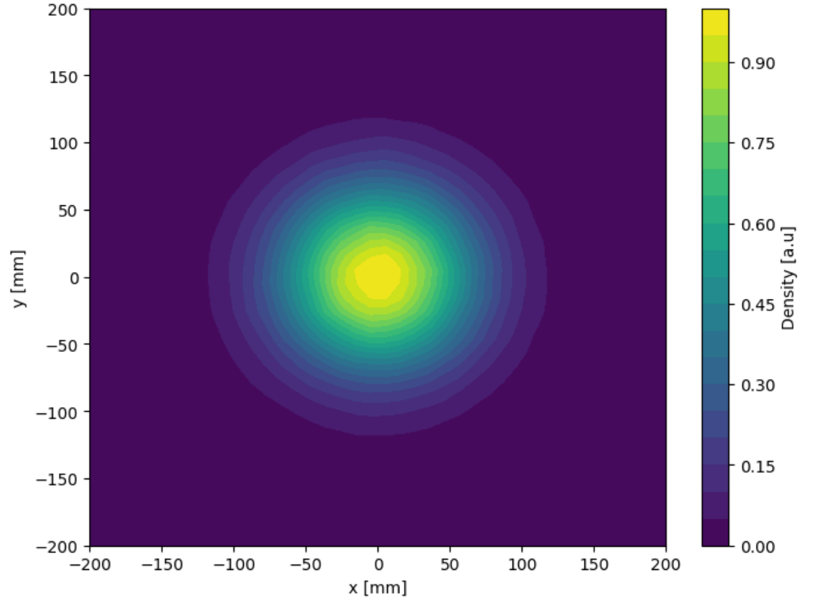


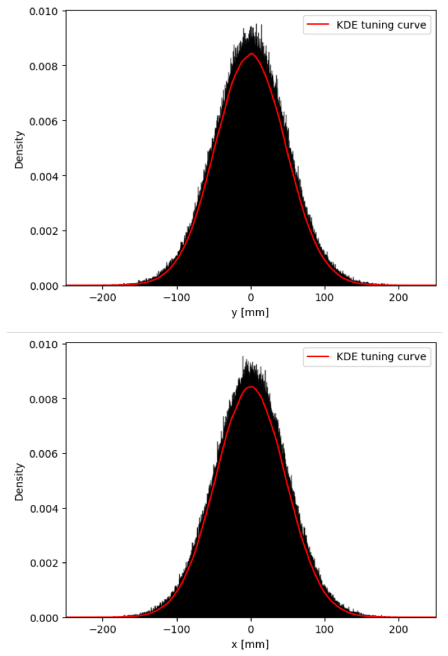
Relative standard deviation of the volumetric dose distribution = 1.8 %

Extraction line for radiobiology studies

- A more affordable approach: we selected a two-quadrupole configuration that produces a broad beam with a Gaussian spatial profile, resulting in a less homogeneous dose deposition.



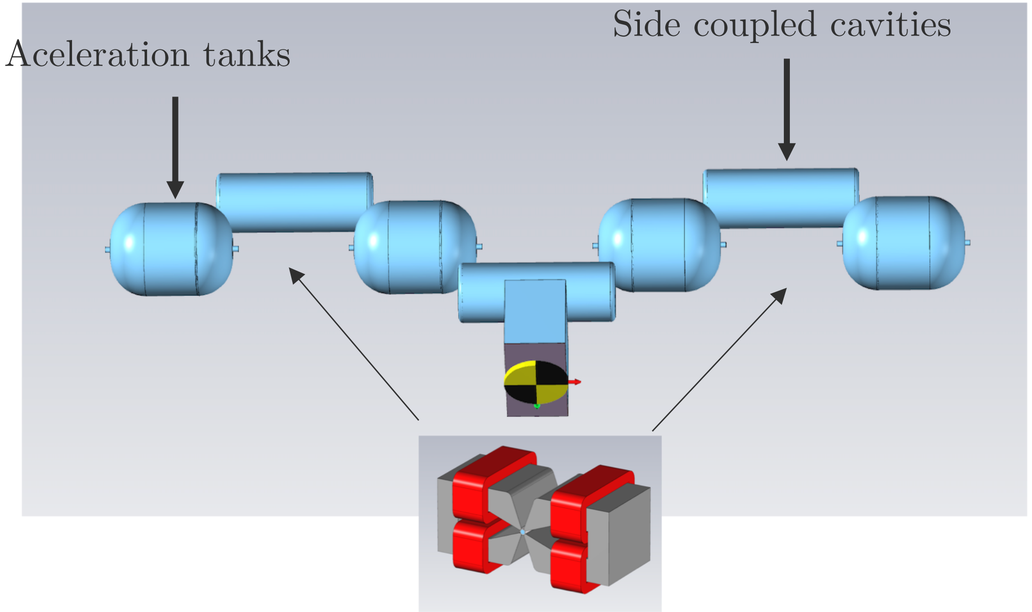




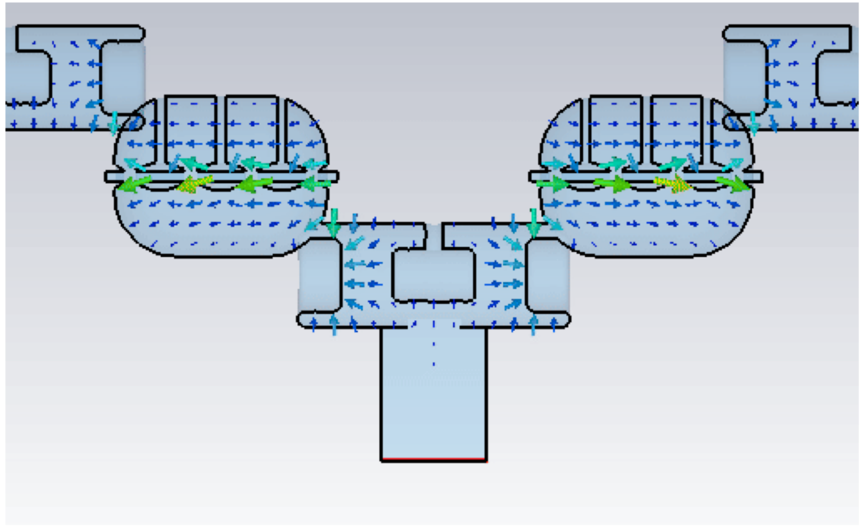
Relative standard deviation of the volumetric dose distribution = 7.3 %

Multi-species 3 GHz SCDTL structures

- To extend the acceleration line, we selected 3 GHz SCDTL structures, consisting of accelerating tanks coupled laterally through coupling cavities. The accelerating tanks are separated by resistive quadrupole magnets.

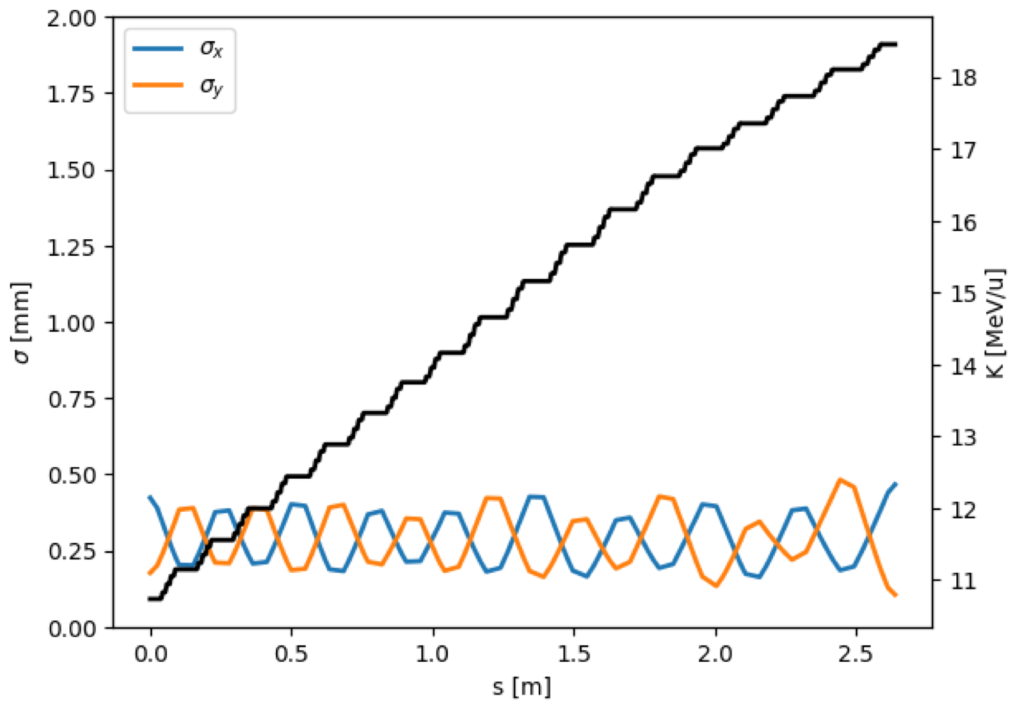


Dedicated quadrupoles


EM field distribution

Multi-species 3 GHz SCDTL structures

Parameter	Value
Frequency	3.00 GHz ($\pi/2$ mode)
Q_0	15000
Q_{Load}	7500
Mean active gradient	16.2 MV/m
Gradient	6.8 MV/m
Beta (Coupling)	1 for conditioning
Beta (velocity)	0.15 – 0.20
Coupling factor, K	3.6%
ZTT	147.2 Mohm/m
Peak power over length	2.5 MW/m



Beam dynamics results for C^{6+} ions in the β range 0.15–0.20

- A prototype of a single cell of the structure will be manufactured in order to experimentally determine the maximum achievable accelerating gradient.