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Indirect Proton Beam Self - Modulation Instability Measurements.

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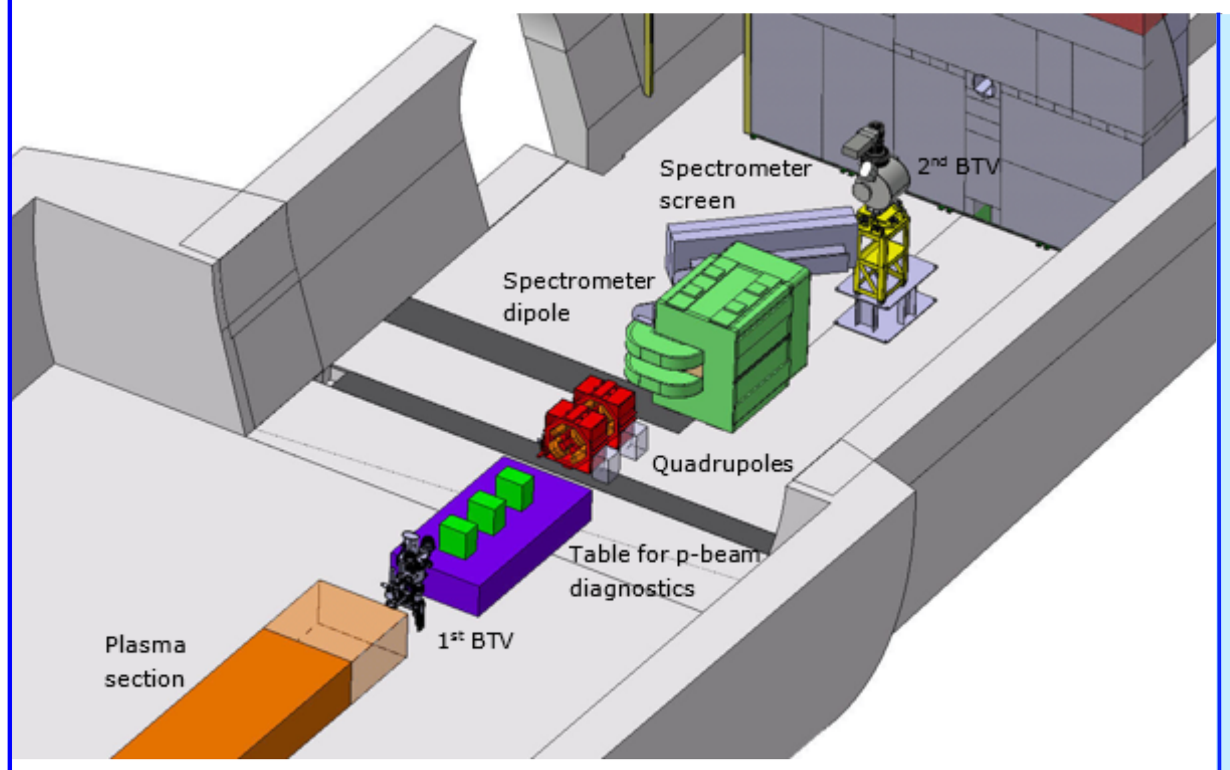

Figure 1: Layout of the Experimental Setup

Abstract

A proton beam going through a plasma cell, with a proton length much longer than the plasma wavelength experiences a Self-Modulation Instability (SMI) producing a train of micro-bunches. Micro bunched protons create plasma waves with strong longitudinal and transverse electric fields useful for particle focusing and acceleration. Studies are performed within the AWAKE experiment. AWAKE is a proof-of-principle R&D experiment on proton driven plasma wakefield acceleration at CERN using a 400 GeV, σ = 12 cm long proton beam (with 3.10^{11} particles per bunch every 30 sec.) from the CERN SPS and a 10 m long plasma section filled with Rubidium vapor with a density of 7.10^{14} atoms/cm³, which corresponds to a plasma wavelength of approx. 0.2 mm. Proton beam defocusing by an angle of around 1 mrad is the clear indication of a fully developed SMI. By using two beam screens (BTV) it is possible to measure both the beam size and its angular divergence.

Proton beam at plasma cell exit

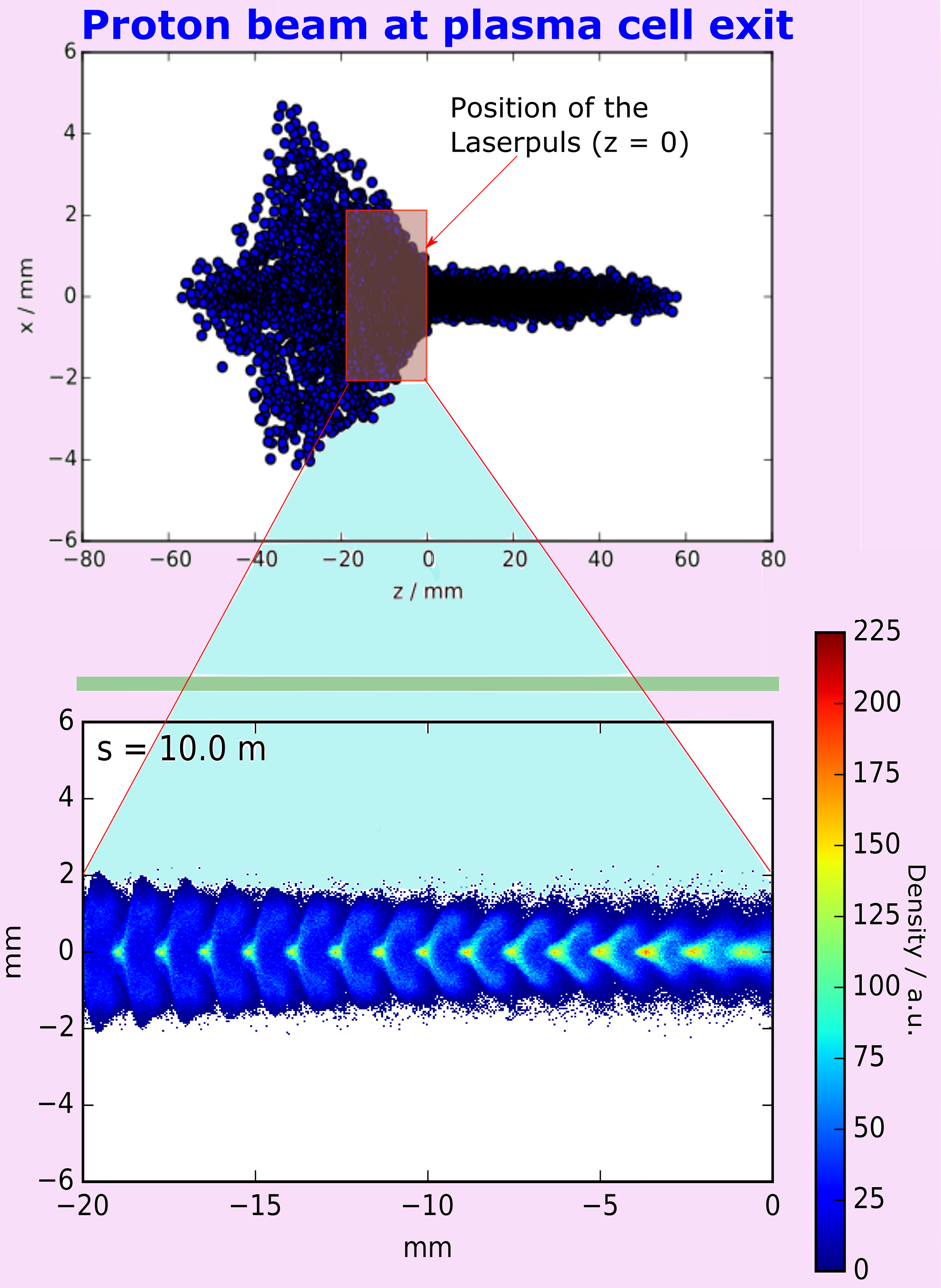

Figure 3: Self-Modulated proton beam at the end of the 10 m plasma cell (simulated with the LCODE program).

Results shown in Figure 4 and 5 were simulated with a Monte Carlo Code (FLUKA) by using as an input a self modulated beam, which is obtained from a LCODE simulation, with AWAKE baseline parameters. The FLUKA simulation comprises the most important elements of the beamline that influence the proton beam (see Figure 1). The design of the BTV stations is made according to those simulations, so that the distinct proton beam edge will be resolvable during the measurements.

Experimental layout

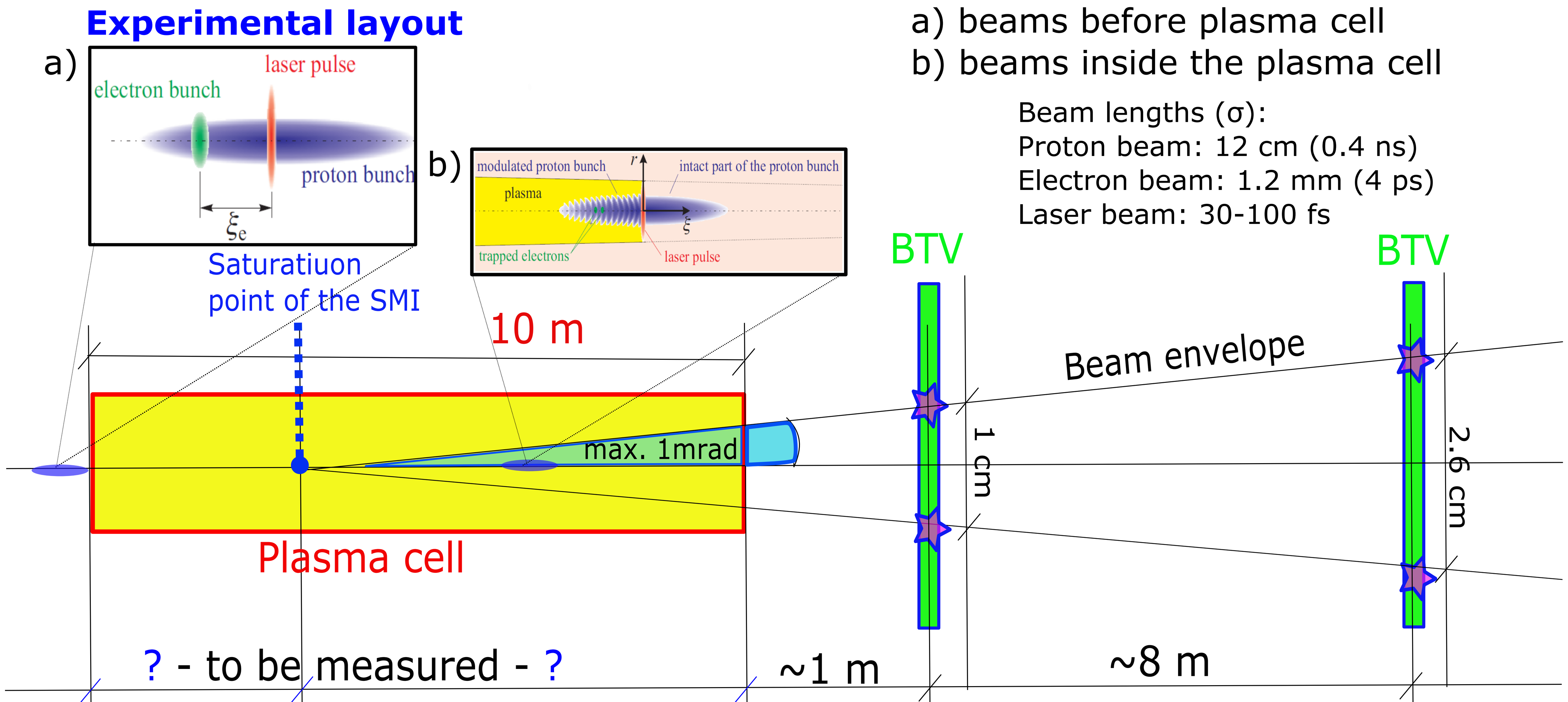

Figure 2: The Saturation point of the SMI can be determined by measuring the defocused beam edge, and tracking back to the origin in the plasma cell. The expected resolution is better than around ± 1 m along the 10 m long plasma cell.

Proton distribution in BTV's

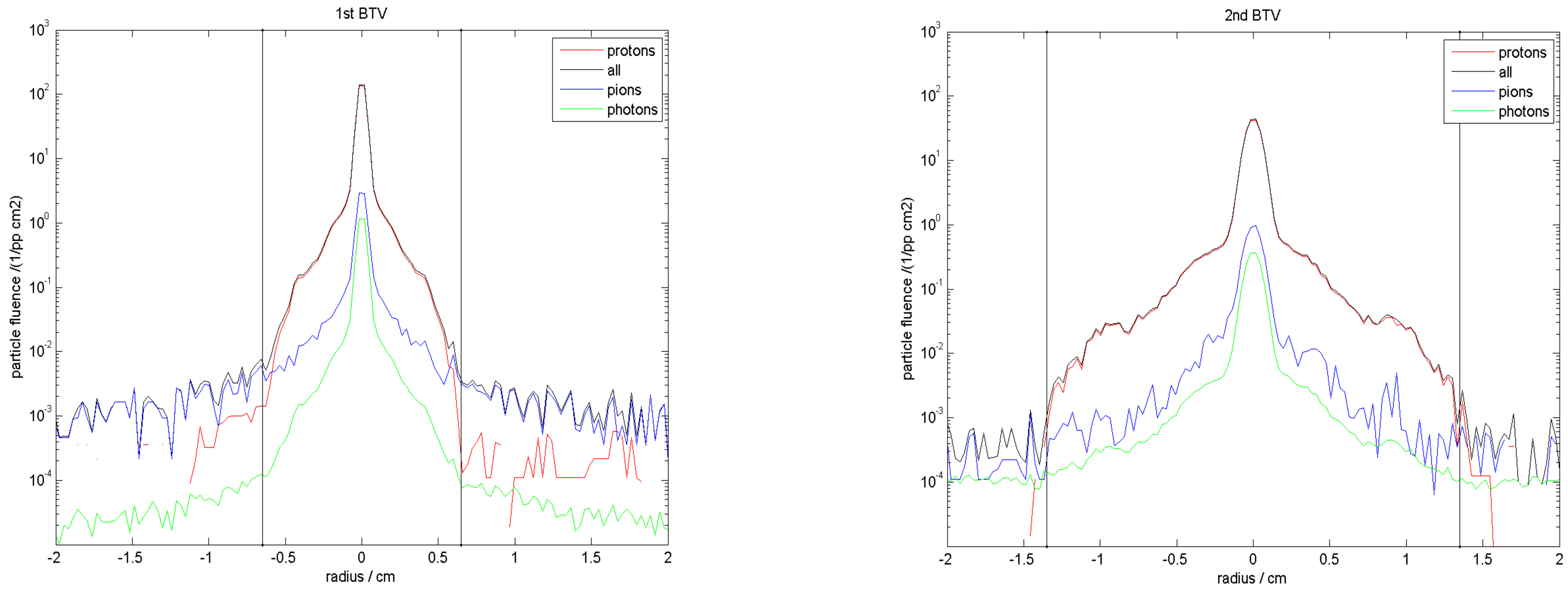

Figure 4: Simulated expected proton distribution and main background contributions, for the two BTV screens. The black vertical lines indicate the sharp edge of the undisturbed, self-modulated proton beam.

Energy distribution in BTV screens

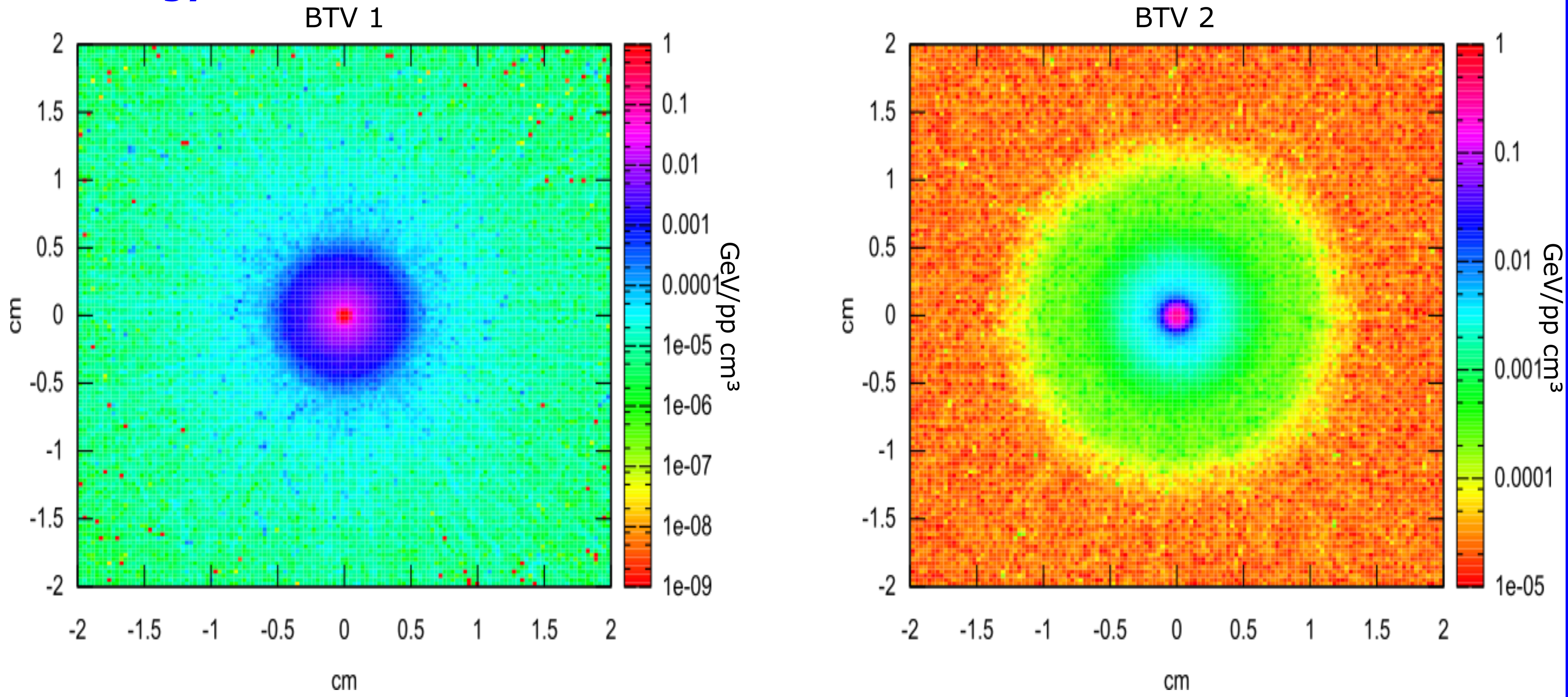

Figure 5: Energy deposit of the self-modulated 400 GeV proton beam in an 1 mm thick Chromox screen obtained from a Fluka simulation using the input beam shown in Figure 3 (left: 1 m, right: 9 m downstream of the plasma cell).

Layout

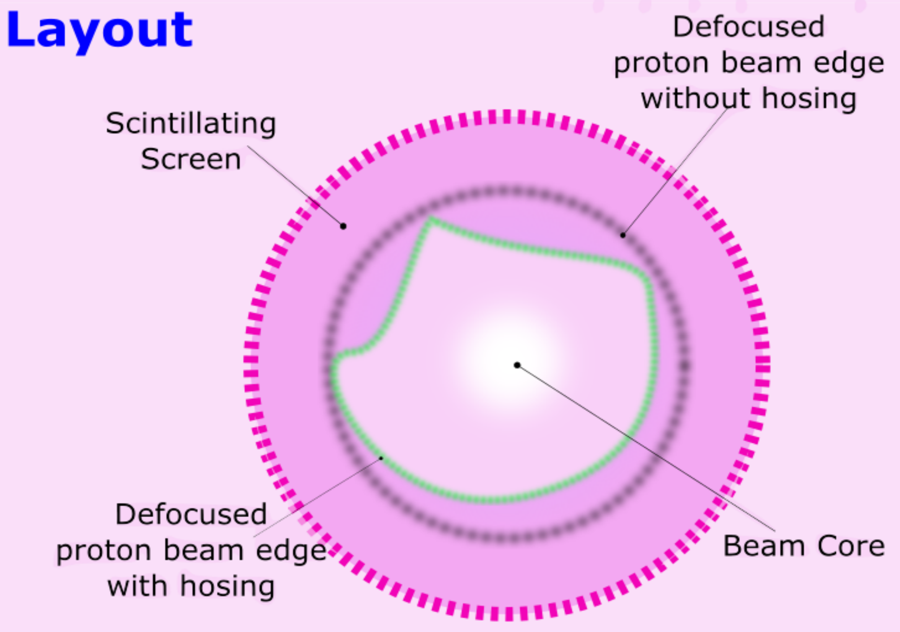

Figure 6: Expected 2D beam edge of the defocused beam (black) compared to a beam shape indicating hosing instability (green) of the proton beam.