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Connection length calculation for the divertor-relevant vacuum magnetic configurations of W7-X

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Abstract

For the divertor-relevant W7-X configurations (with restriction to vacuum fields), the connection lengths (target to target) were computed for the standard, low ι, high ι and low-shear configurations. In each case, the connection lengths were determined for a variation of the total control currents from -25 kA to 25 kA with 5 kA steps. The calculation of the connection lengths on the poloidal cross-section at φ = 0 also provides the structure and size of the islands.

Introduction

As known from W7-AS island-divertor experiments, the island size and the internal field-line pitch are two important geometrical parameters, which strongly affect the plasma transport in the divertor region [1]. The determination of the island sizes and connection lengths for vacuum magnetic configurations of W7-X will be helpful for both simulation and experiment, as they affect, for example, the plasma transport, the behaviour of neutrals and impurities in the edge region and the design of the island divertor.

The connection lengths and the island sizes for four W7-X vacuum configurations (standard, low ι, high ι and low-shear) and for total control currents from 25 kA to -25 kA (with 5 kA steps) have been computed and documented in this paper. This geometric information is an essential part of a data base for the W7-X divertor. The calculations are restricted to vacuum fields. However, it is planned to extend them to equilibrium configurations.

The radial-poloidal calculation domain is defined on the poloidal plane φ = 0 by a quadrangle bounded by the target plates, a baffle and a cut limiting the extension of the domain to its divertor-relevant size (see Fig. 1.1.1). The field lines started from the mesh points inside this quadrangle are followed in forward and backward directions with the GOURDON code until they hit the divertor structure or a maximum of 15 toroidal turns is reached. Representation of these connection lengths (as colour contours) shows the structure of the island sizes at φ = 0.

The island geometry is shown to be sensitive to the control currents. This has to be taken into account in the optimization of the divertor configurations.

The coil currents, magnetic fields, control currents and the related factors entering the calculations are listed in Table 1 and Table 2. For more information about the vacuum magnetic configurations of W7-X see the IPP-Report III/270 [2].

Table 1: Distribution of the nominal coil currents I_n, the related magnetic field B_0 and the individual coil current factors F_c, with $I_c = I_n * F_c$.

Configuration	I_n	$<B_0>$	F_c						
Standard	1.45	2.5	1.00	1.00	1.00	1.00	1.00	0.00	0.00
Low ι	1.32	2.5	1.00	1.00	1.00	1.00	1.00	0.25	0.25
High ι	1.60	2.5	1.00	1.00	1.00	1.00	1.00	-0.23	-0.23
Low shear	1.47	2.5	1.13	1.12	1.05	0.85	0.84	-0.20	0.20

Table 2: Control currents I_{cc} and the related factors F_{cc}, with $I_{cc} = -1.74E10^6 * F_{cc}$.

$Fcc*10^3$	14.40	11.50	8.60	5.70	2.90	0.00	-2.90	-5.70	-8.60	-1.15	-1.44
Icc	25.00	20.00	15.00	10.00	5.00	0.00	-5.00	-10.00	-15.00	-20.00	-25.00

The connection lengths of the target plate and the island structure on the poloidal plane φ =0 have been computed for each of the four configurations in table1 and for each control current in table 2. The results are shown in Figures 1.1.1 – 4.11.2:

Figures 1.1.1 – 1.11.2: standard configuration;
Figures 2.1.1 – 2.11.2: low ι configuration;
Figures 3.1.1 – 3.11.2: high ι configuration;
Figures 4.1.1 – 4.11.2: low-shear configuration;

A) Poincaré plot and plate positions for φ = 0;
B) colour contours of the island structures at the poloidal plane φ = 0;
C) colour contours of the connection lengths on the target plates;
D) detailed profiles of the connection lengths over R or Z at poloidal planes indicated by a solid line in C).

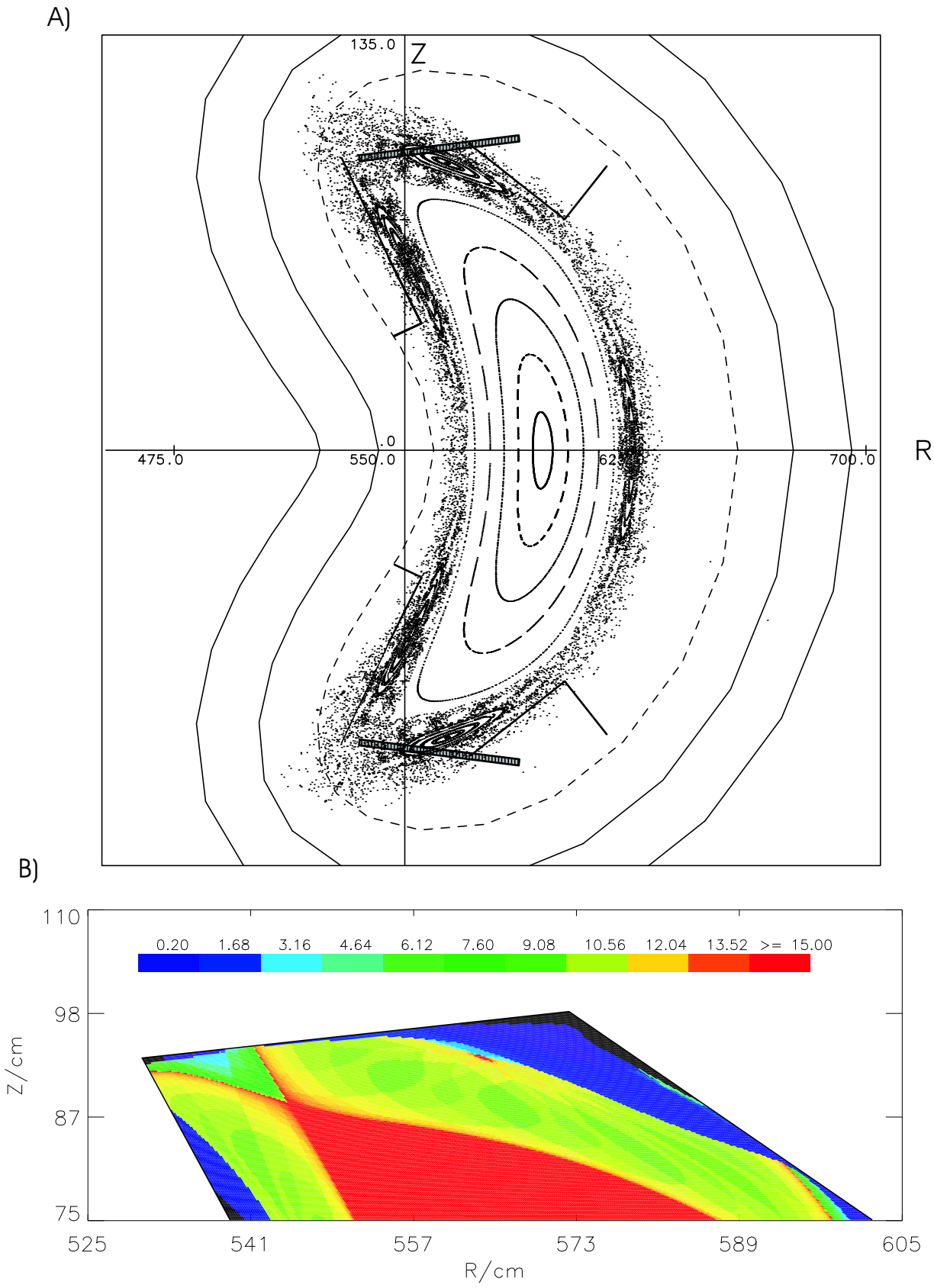

Fig.: 1.1.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = -25 kA.

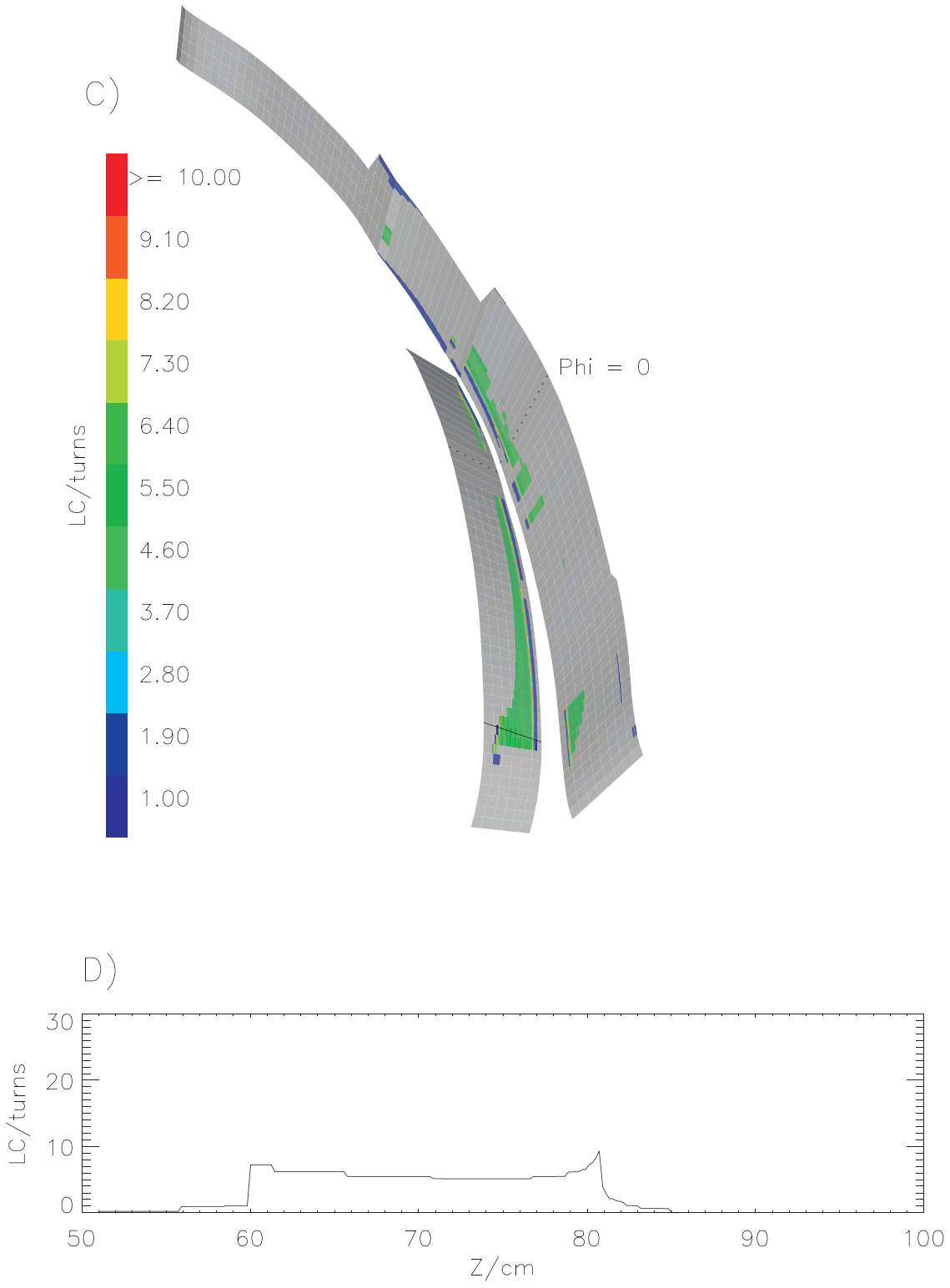

Fig.: 1.1.2
Connection length Lc of the standard configuration.
Control current Icc = -25 kA.

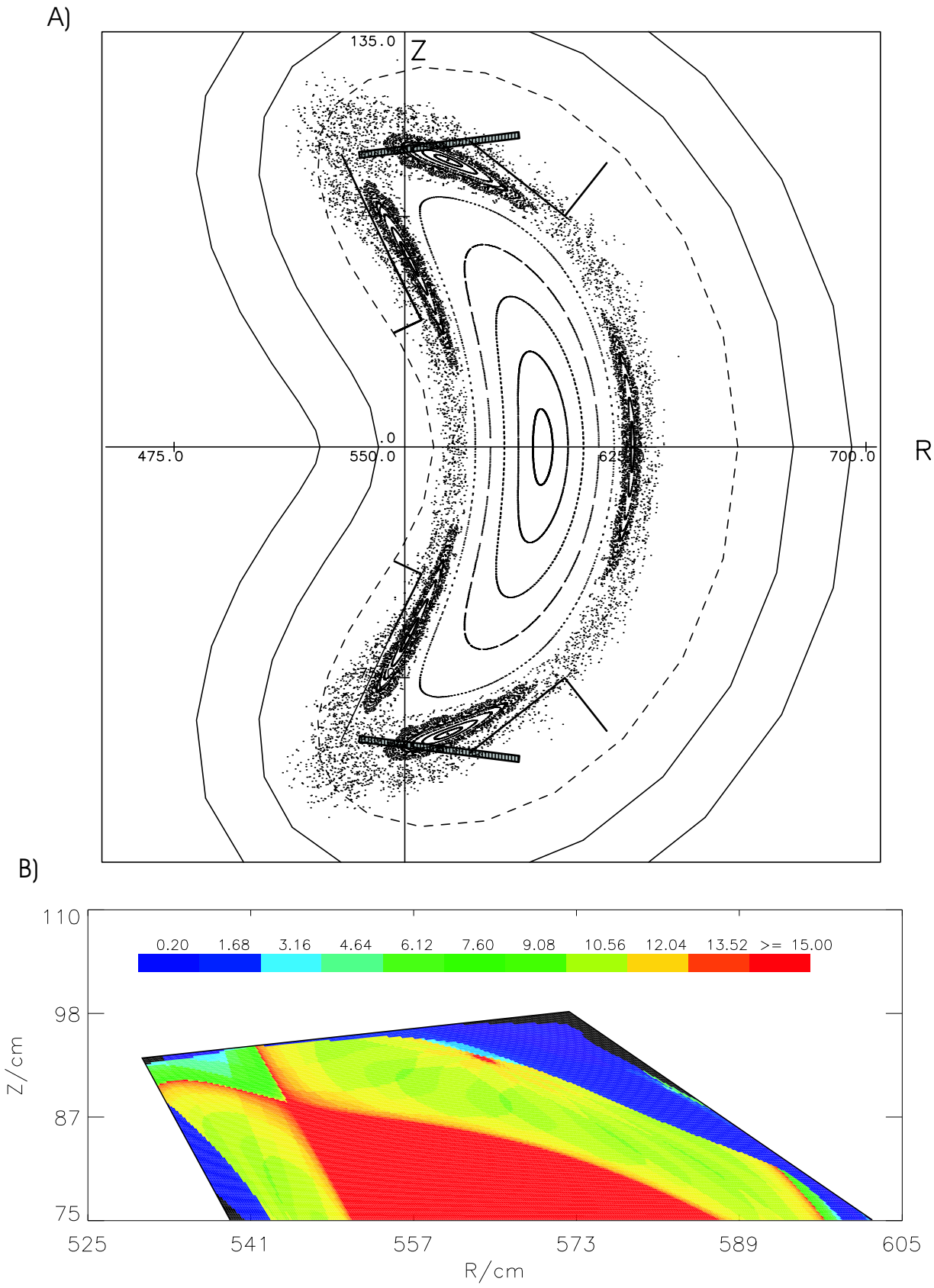

Fig.: 1.2.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = -20 kA.

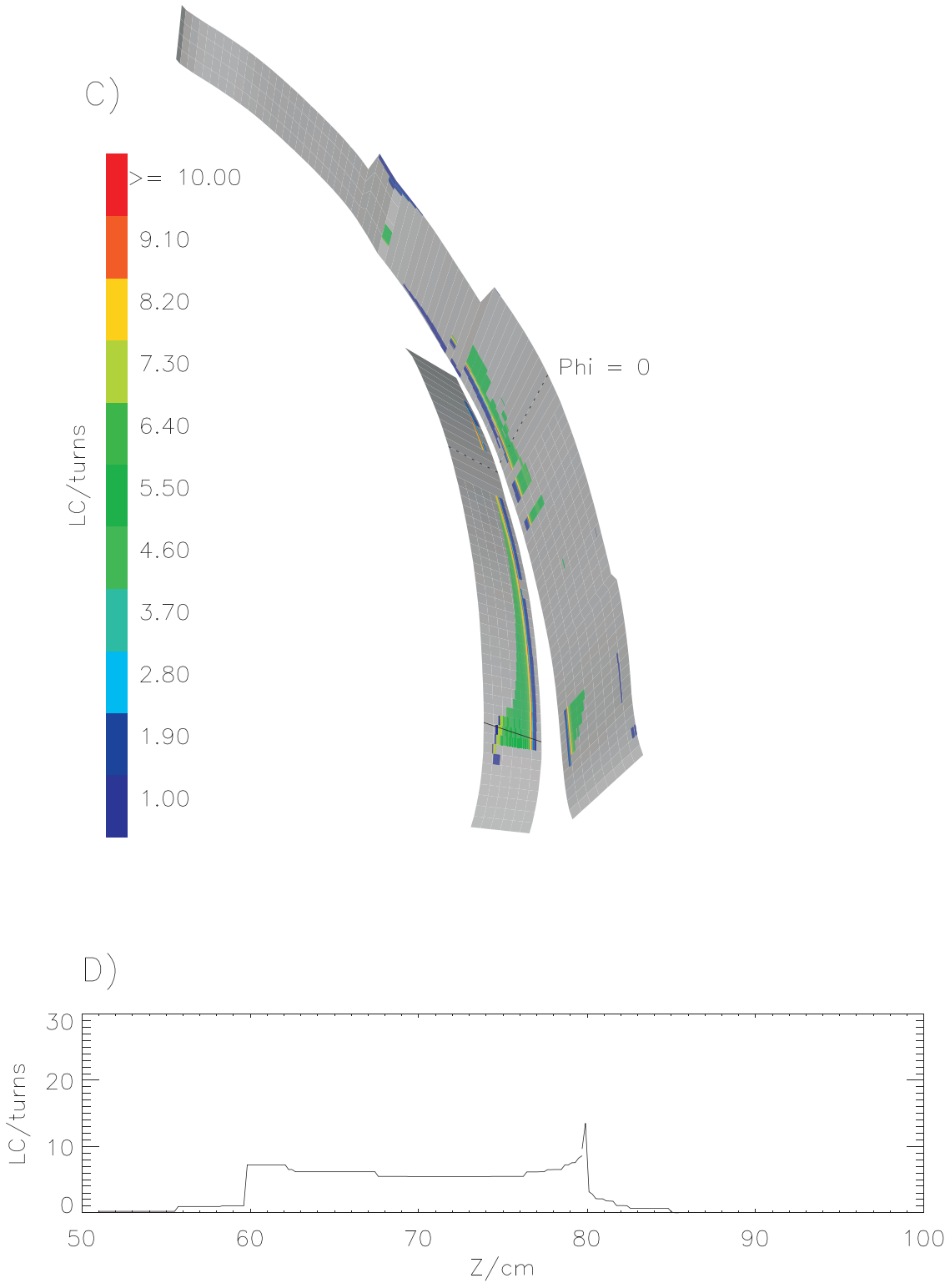

Fig.: 1.2.2
Connection length Lc of the standard configuration.
Control current Icc = -20 kA.

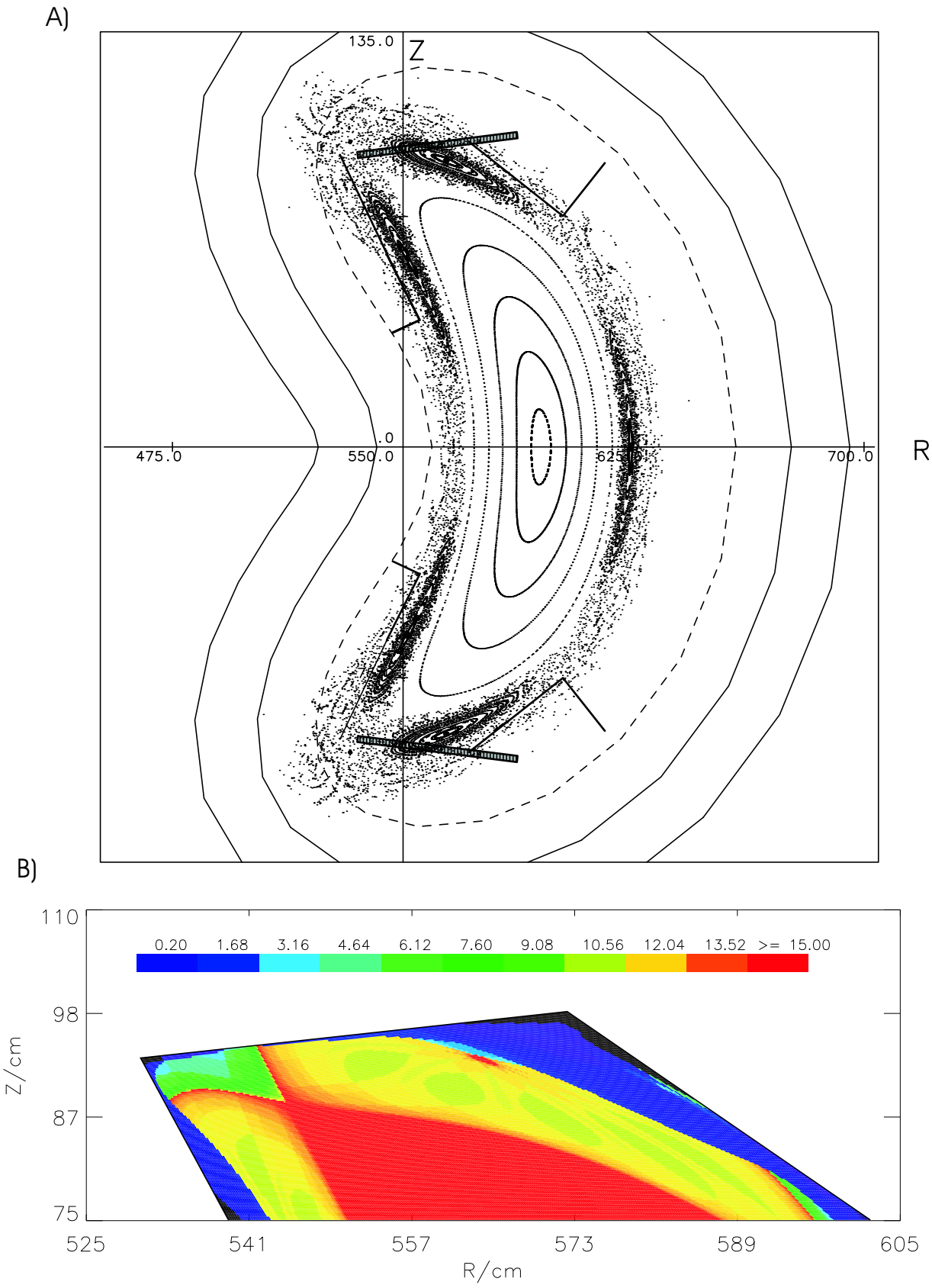

Fig.: 1.3.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = -15 kA.

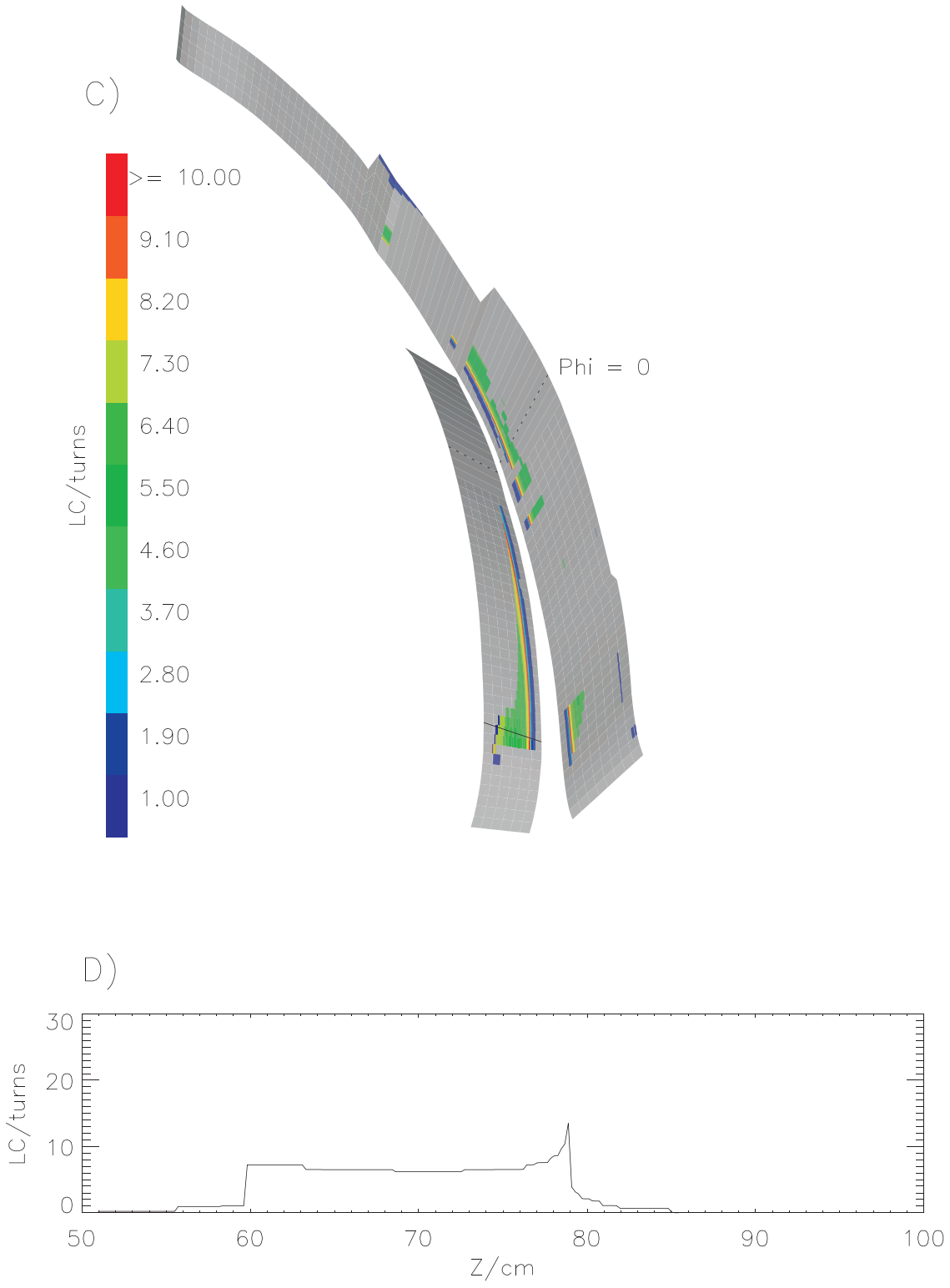

Fig.: 1.3.2
Connection length Lc of the standard configuration.
Control current Icc = -15 kA.

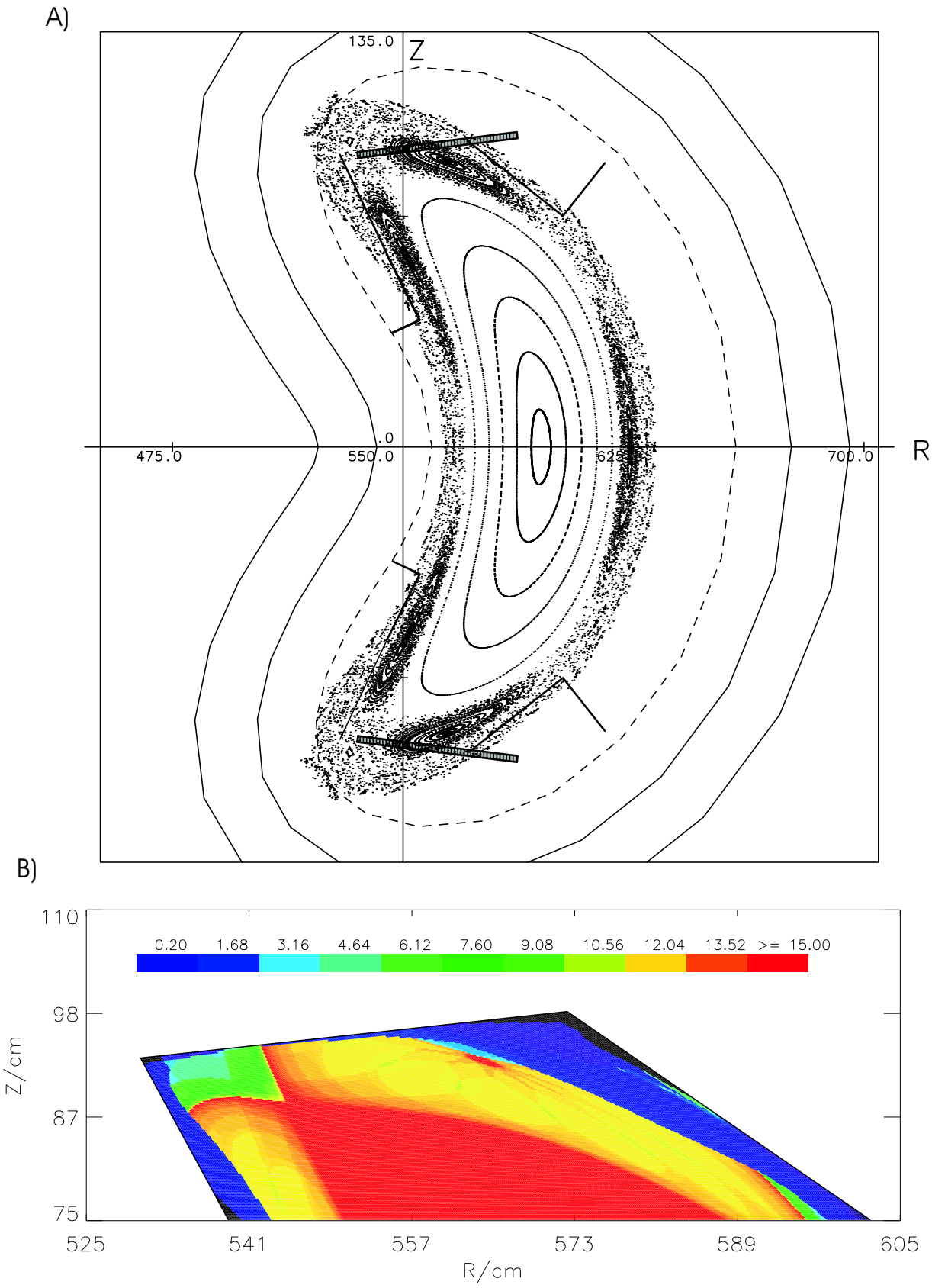

Fig.: 1.4.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = -10 kA.

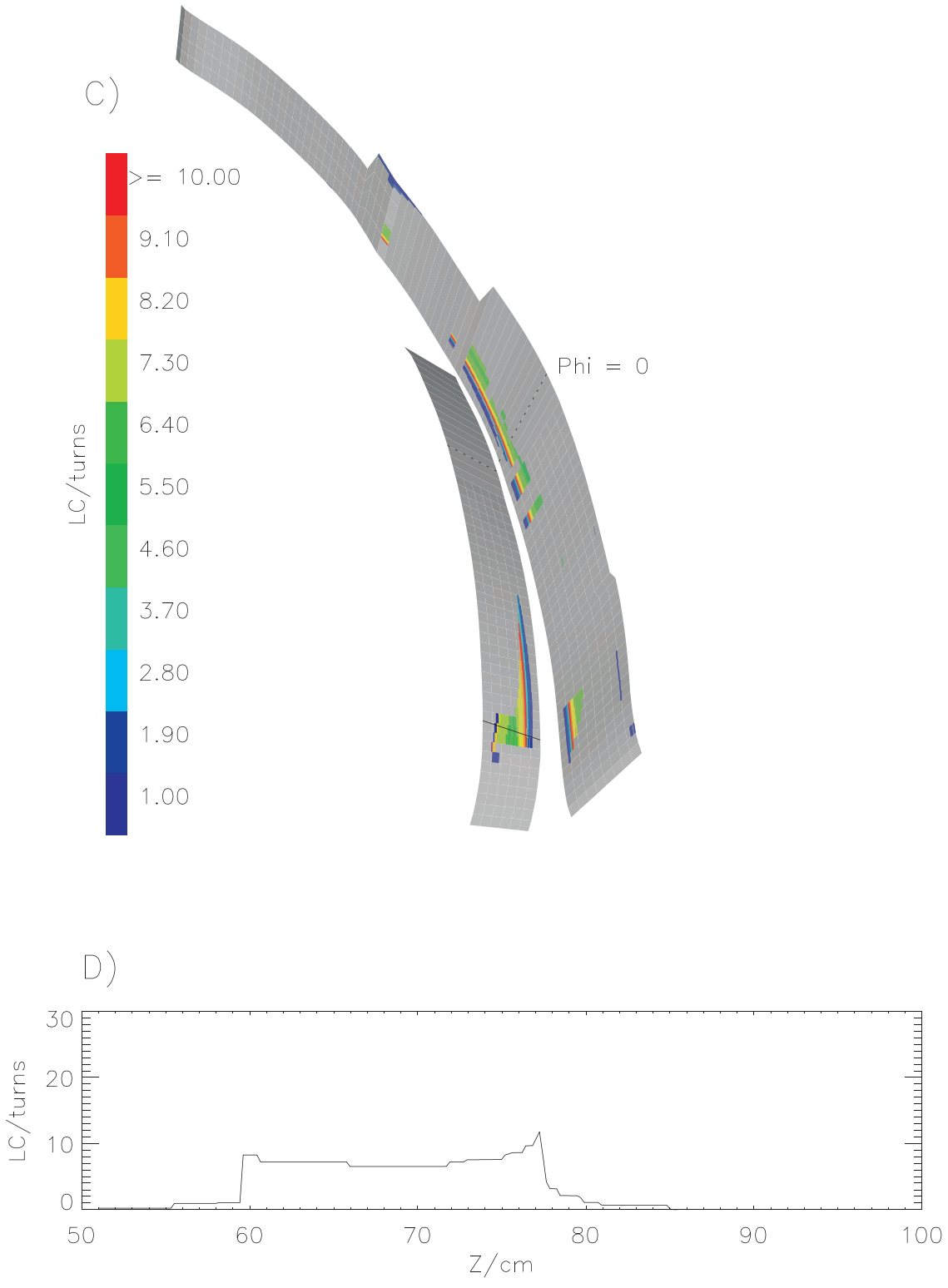

Fig.: 1.4.2
Connection length Lc of the standard configuration.
Control current Icc = -10 kA.

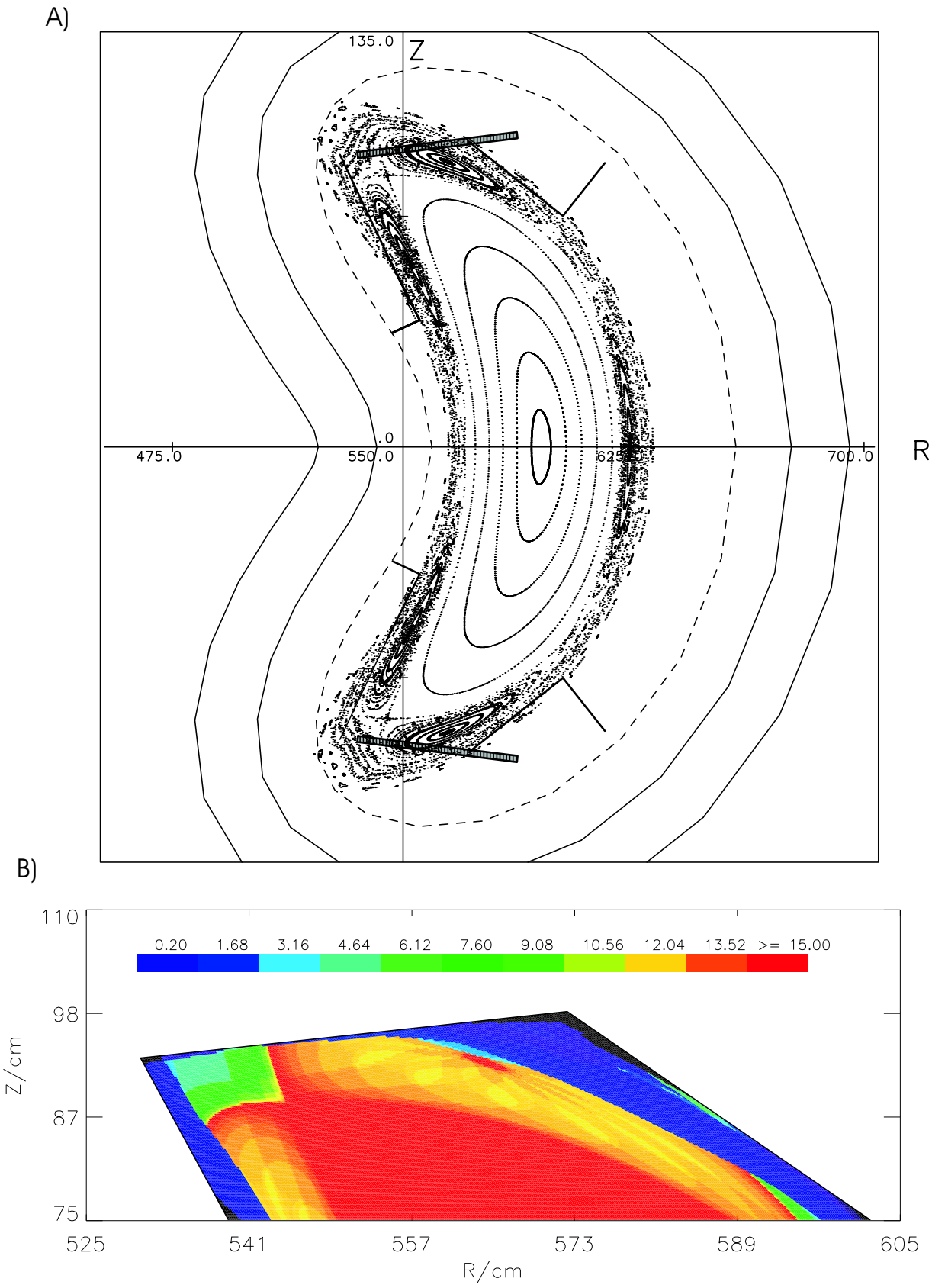

Fig.: 1.5.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = -5 kA.

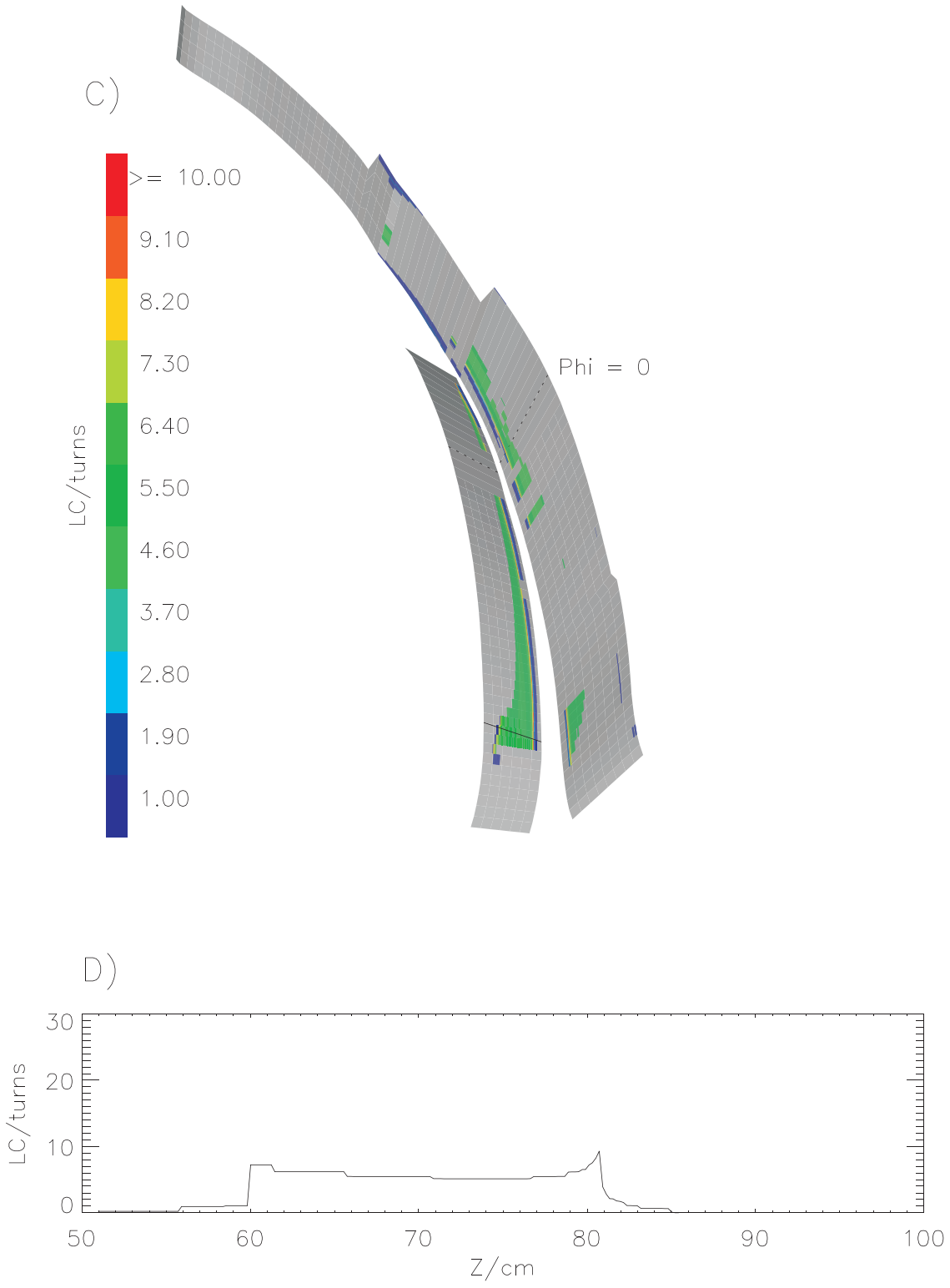

Fig.: 1.5.2
Connection length Lc of the standard configuration.
Control current Icc = -5 kA.

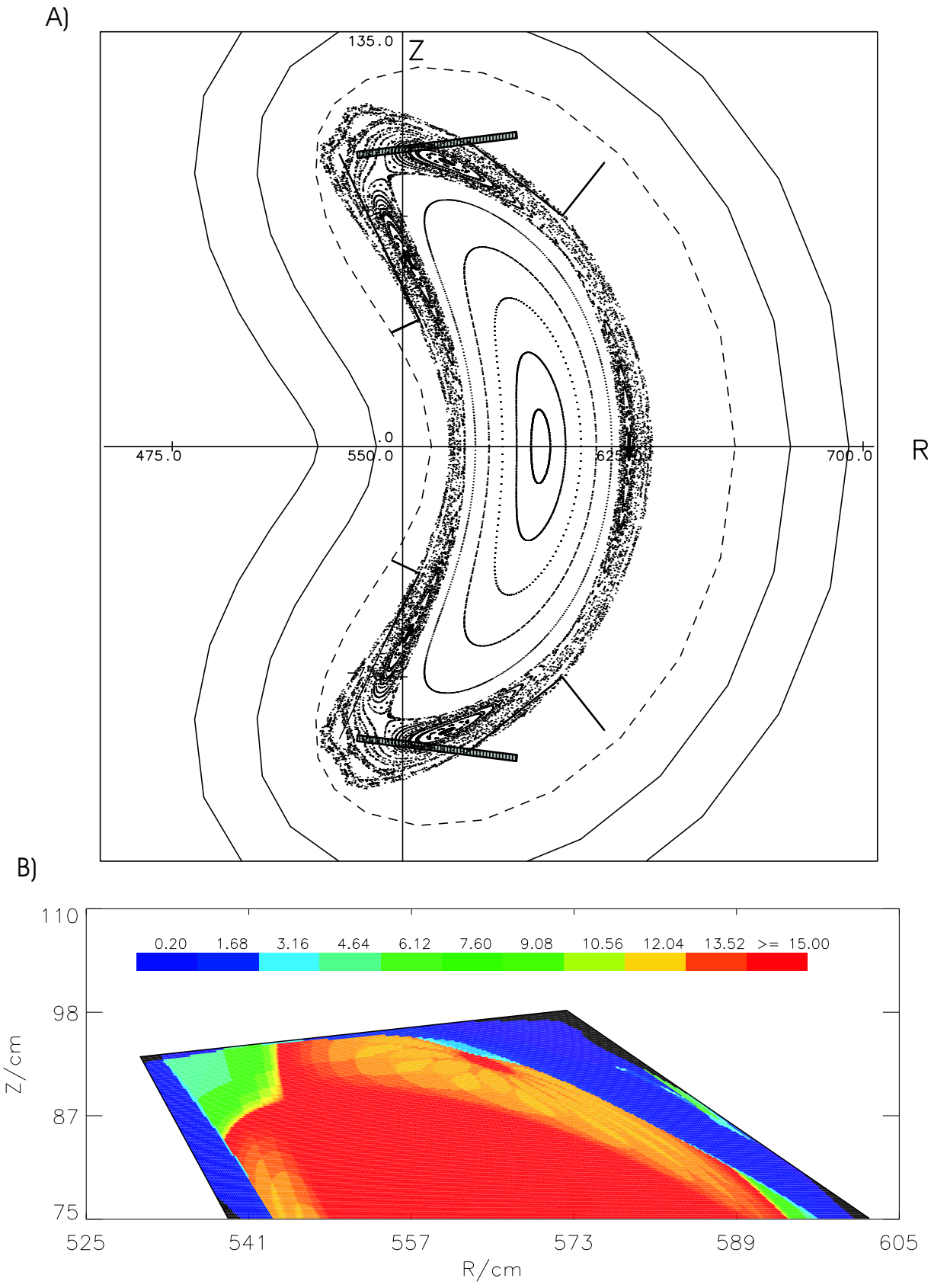

Fig.: 1.6.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = 0 kA.

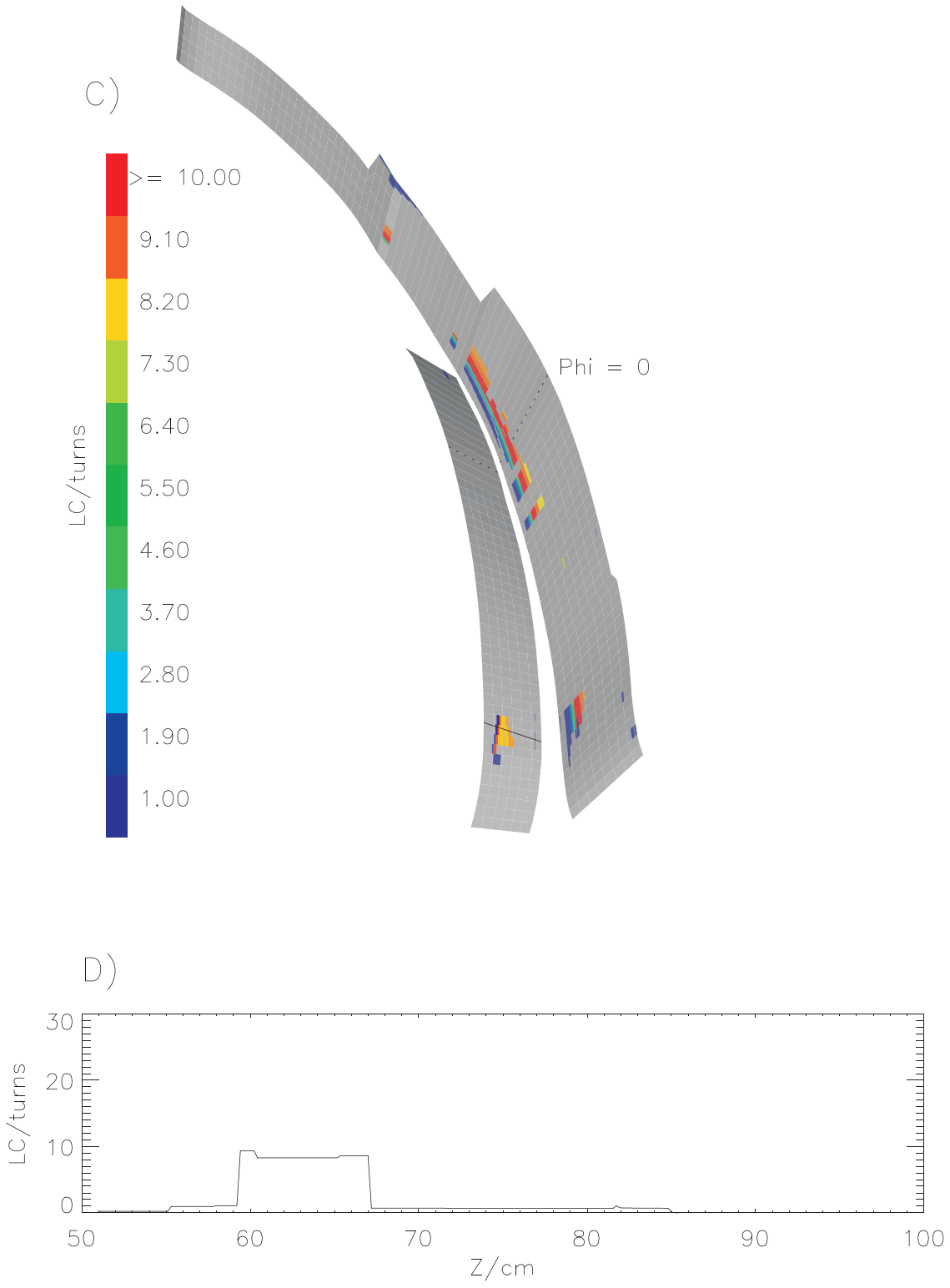

Fig.: 1.6.2
Connection length Lc of the standard configuration.
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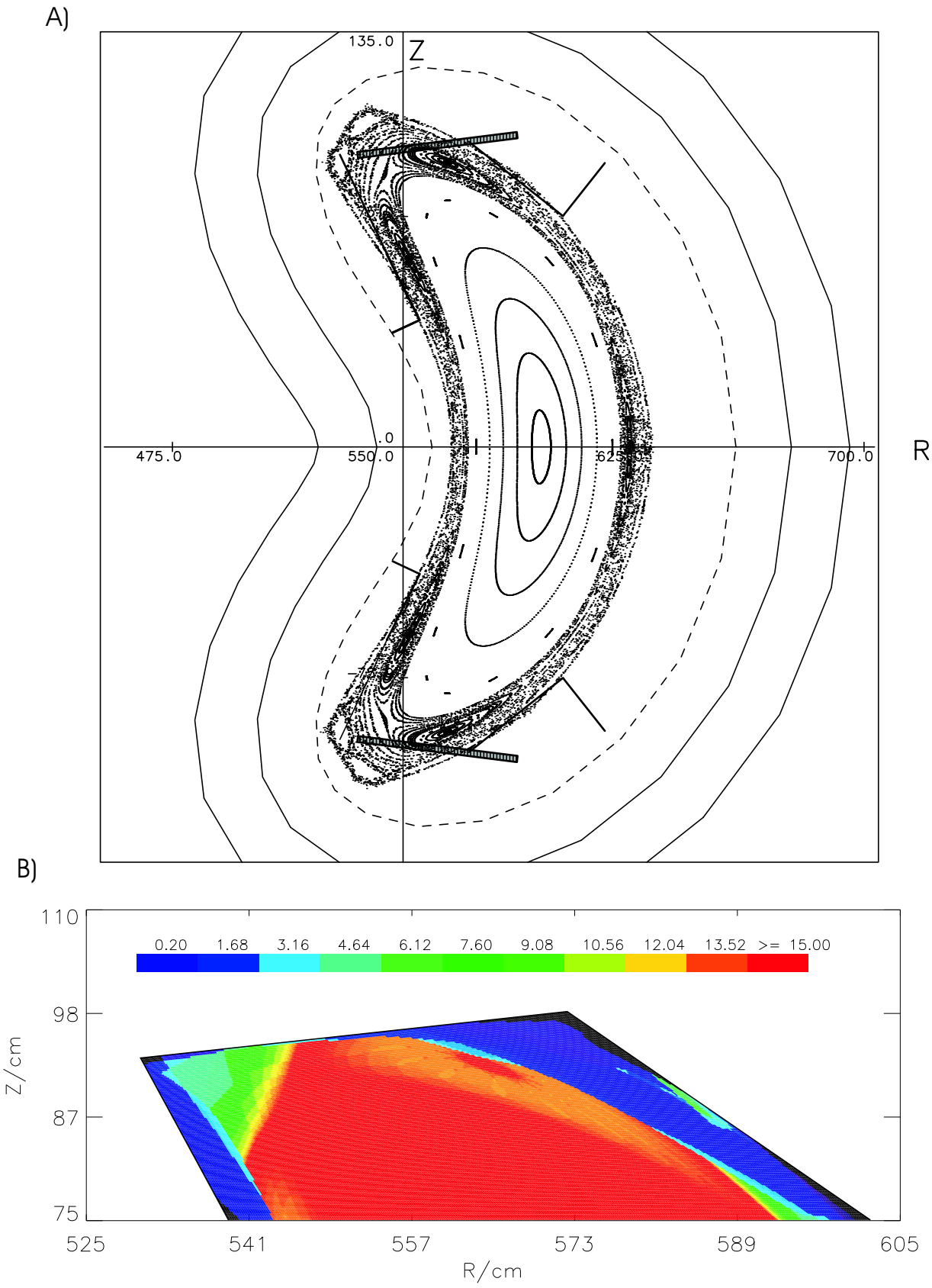

Fig.: 1.7.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = 5 kA.

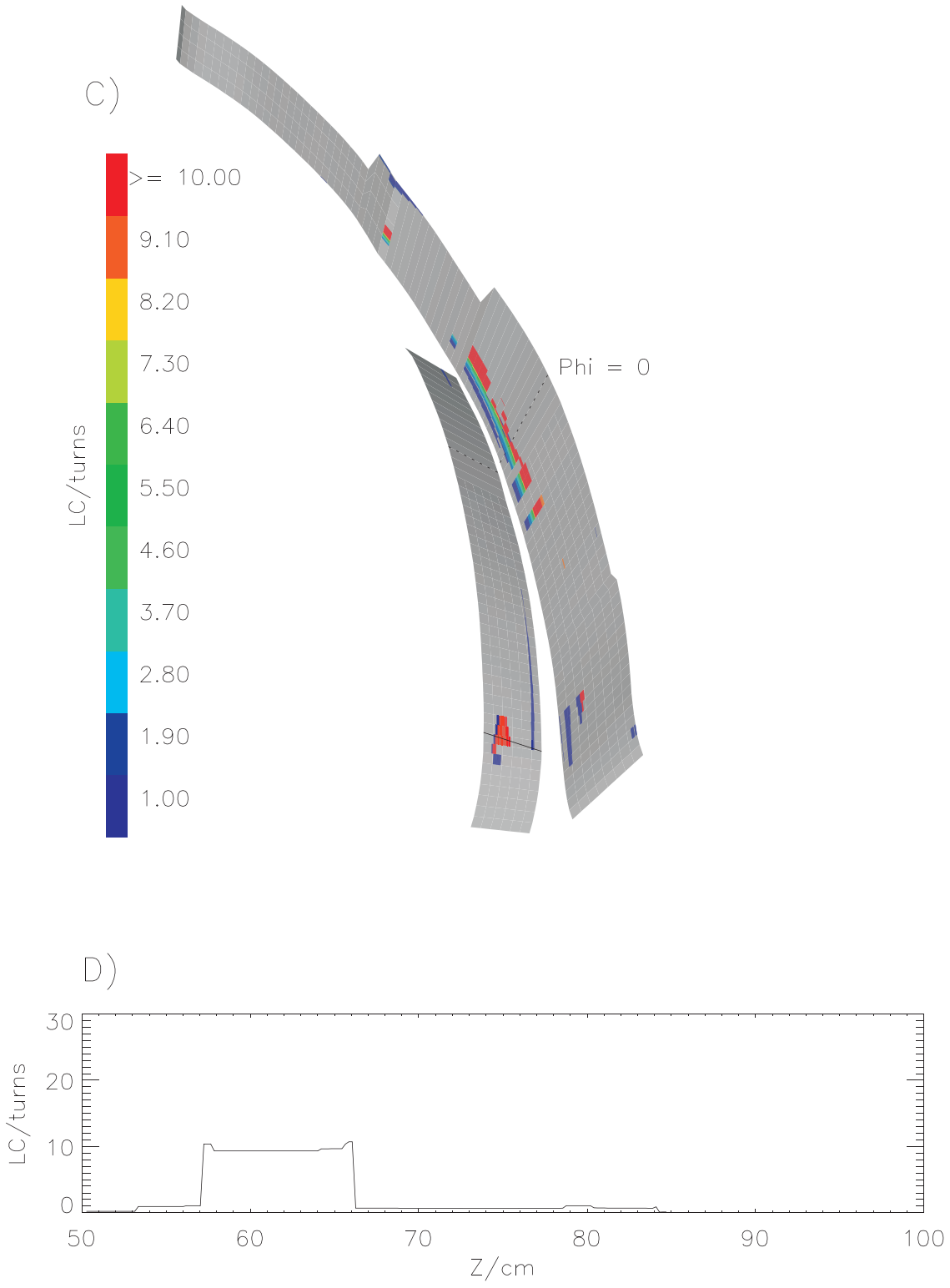

Fig.: 1.7.2
Connection length Lc of the standard configuration.
Control current Icc = 5 kA.

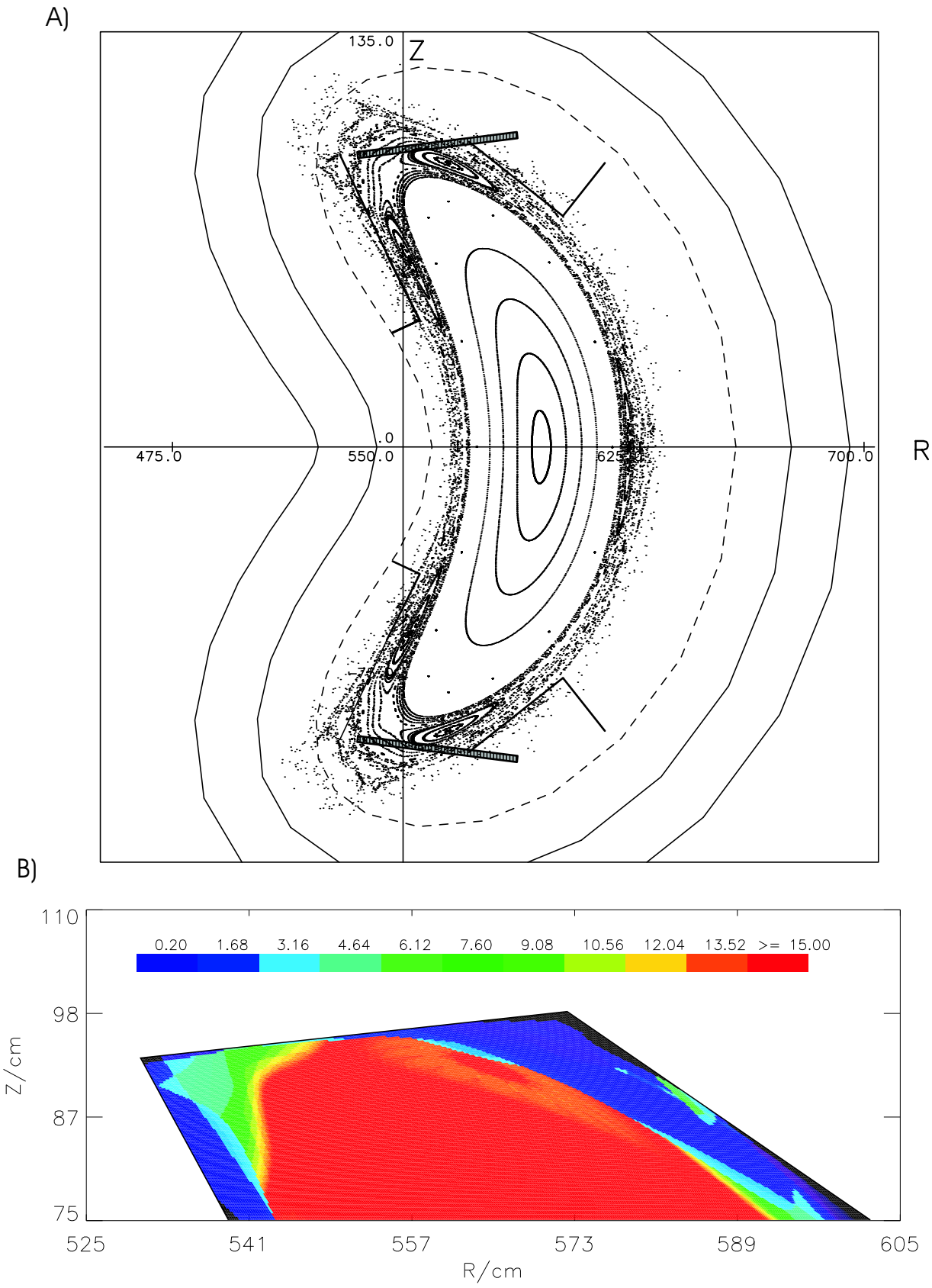

Fig.: 1.8.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = 10 kA.

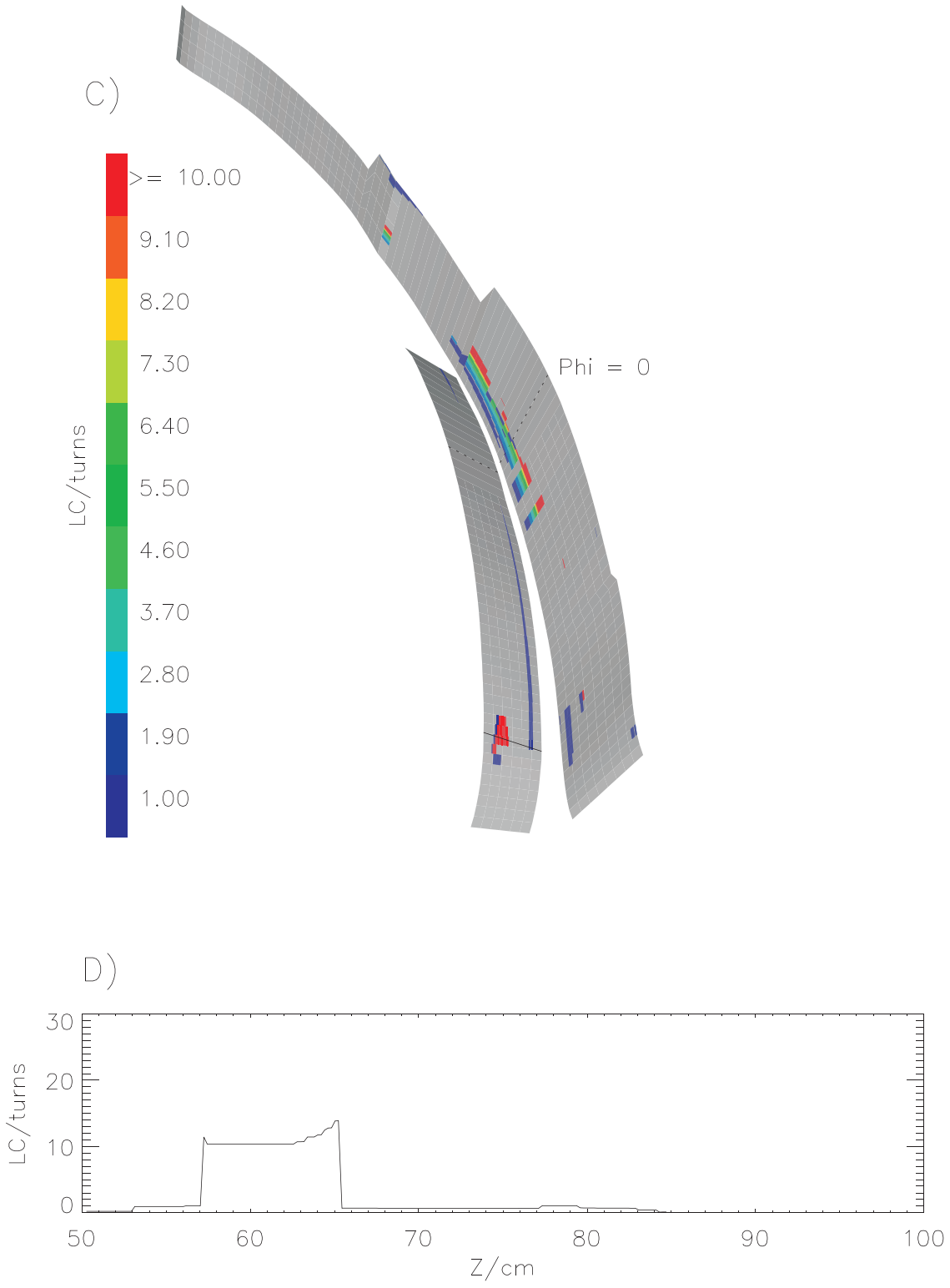

Fig.: 1.8.2
Connection length Lc of the standard configuration.
Control current Icc = 10 kA.

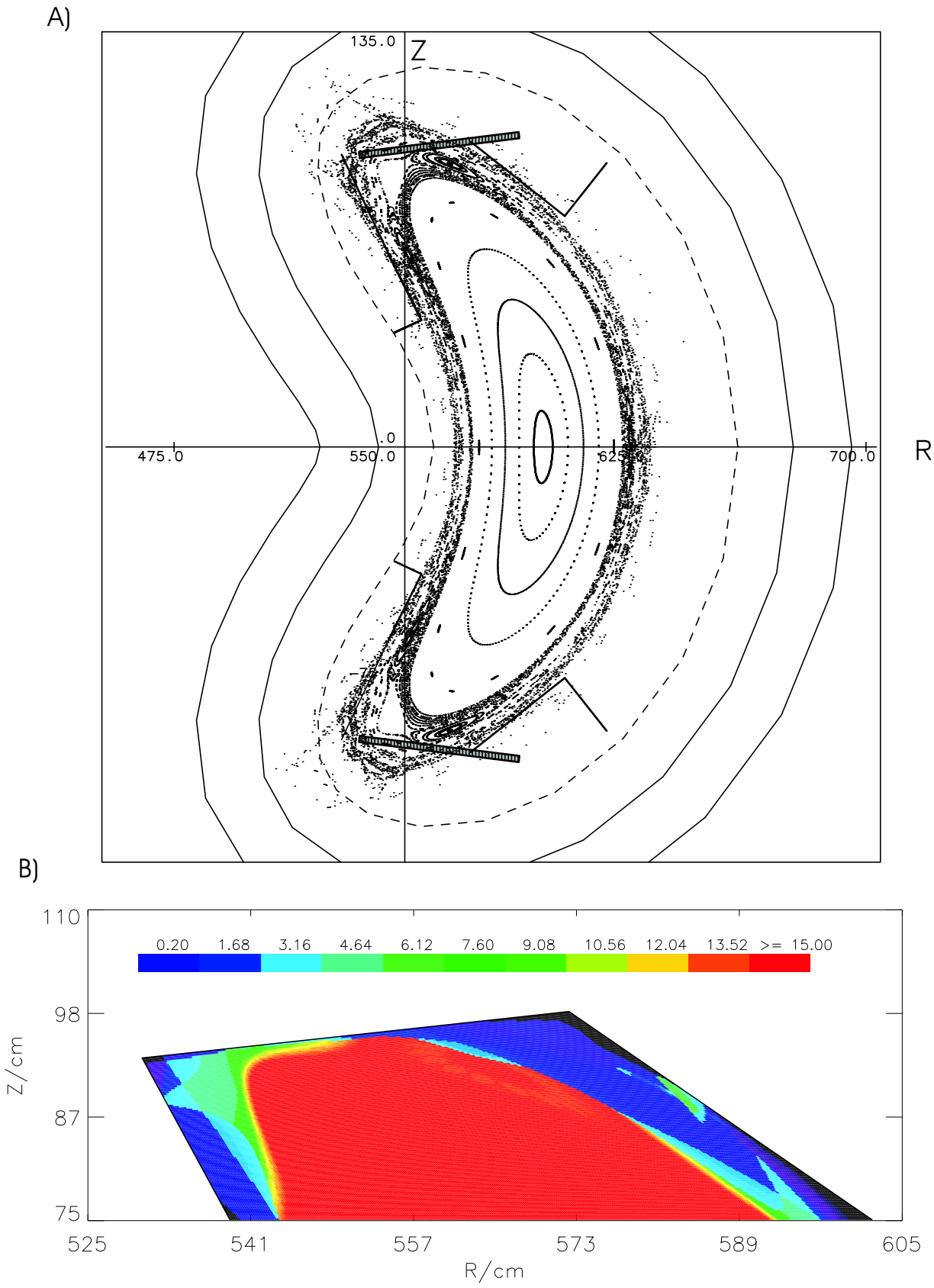

Fig.: 1.9.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = 15 kA.

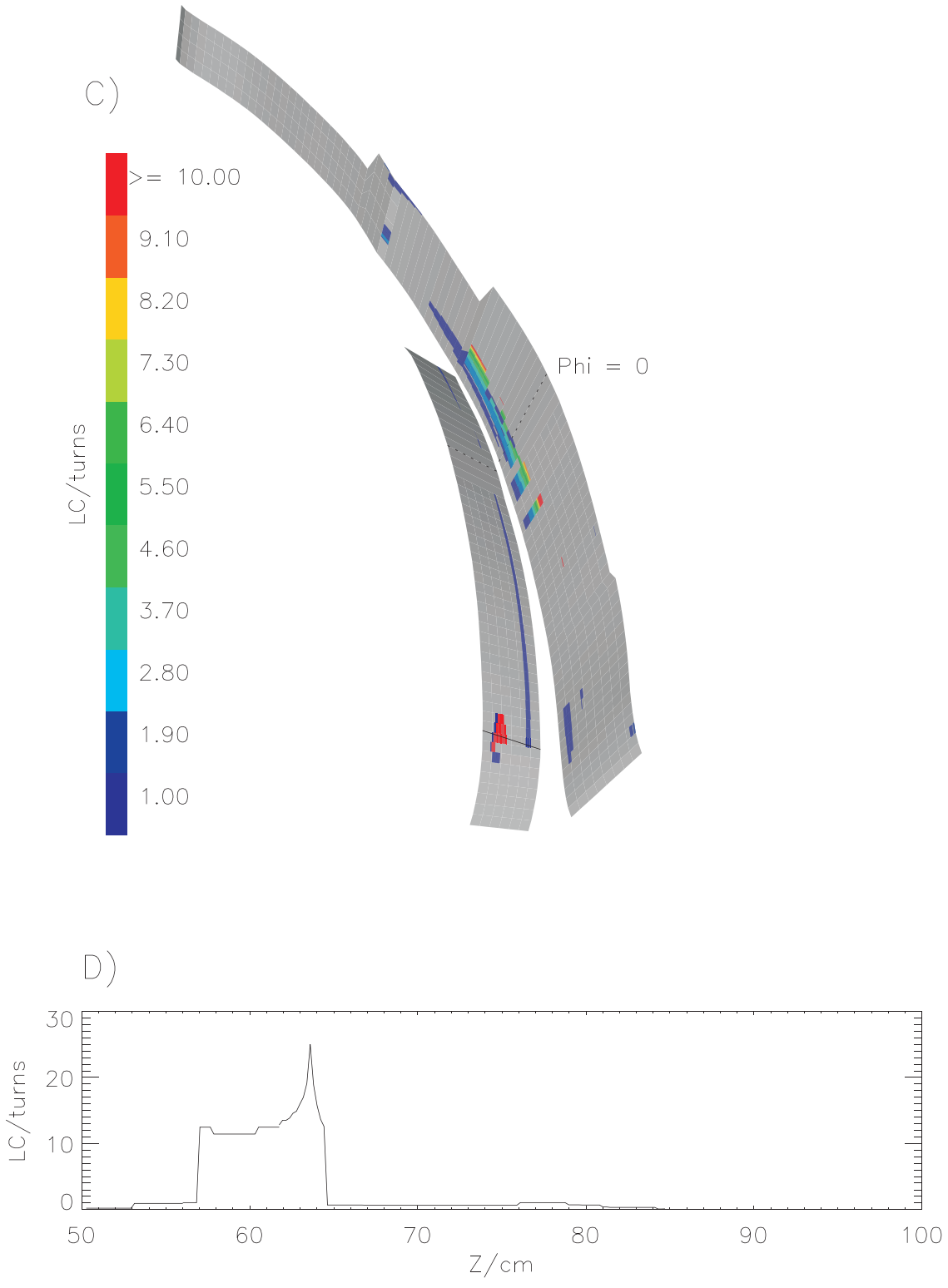

Fig.: 1.9.2
Connection length Lc of the standard configuration.
Control current Icc = 15 kA.

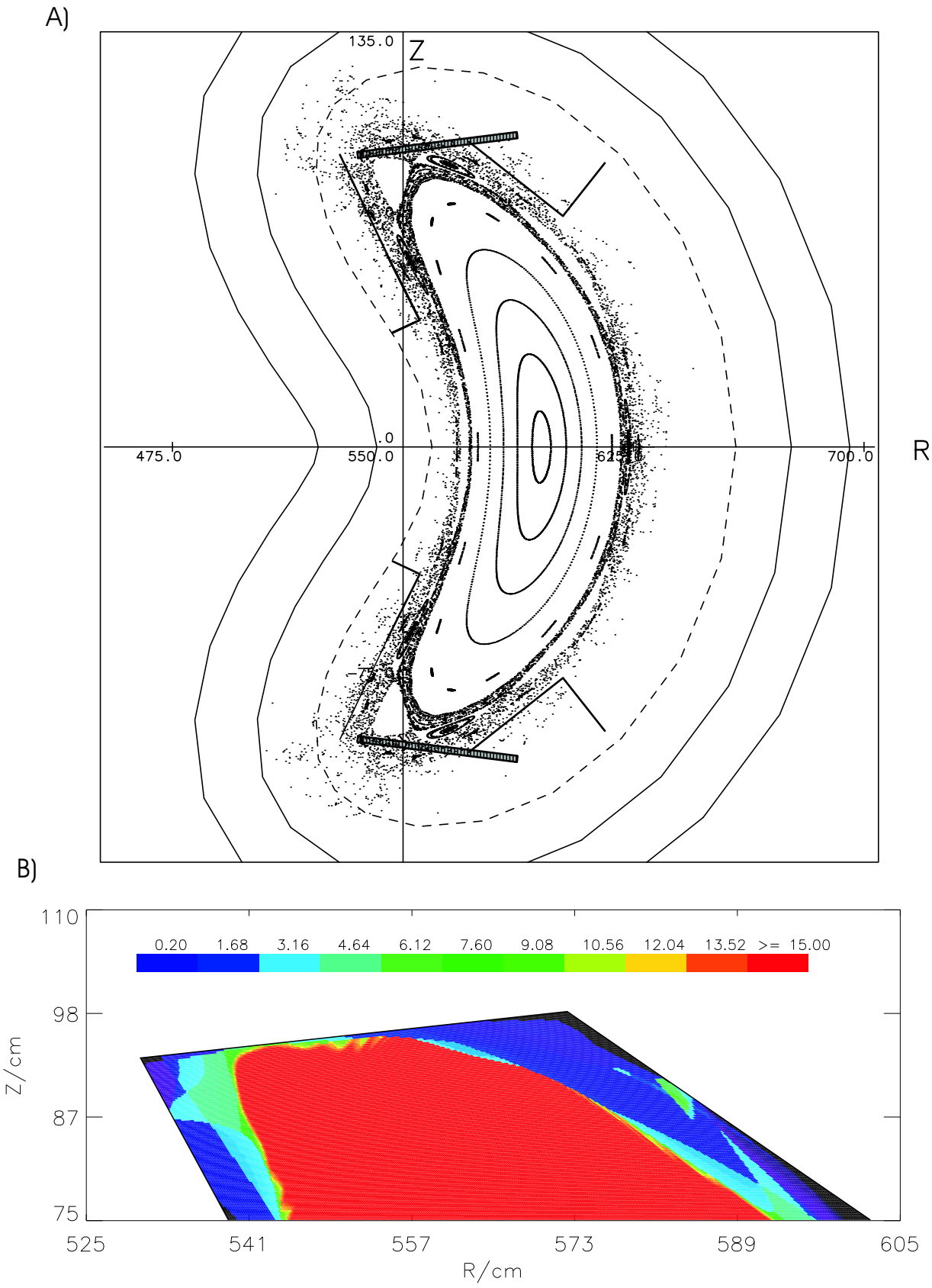

Fig.: 1.10.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = 20 kA.

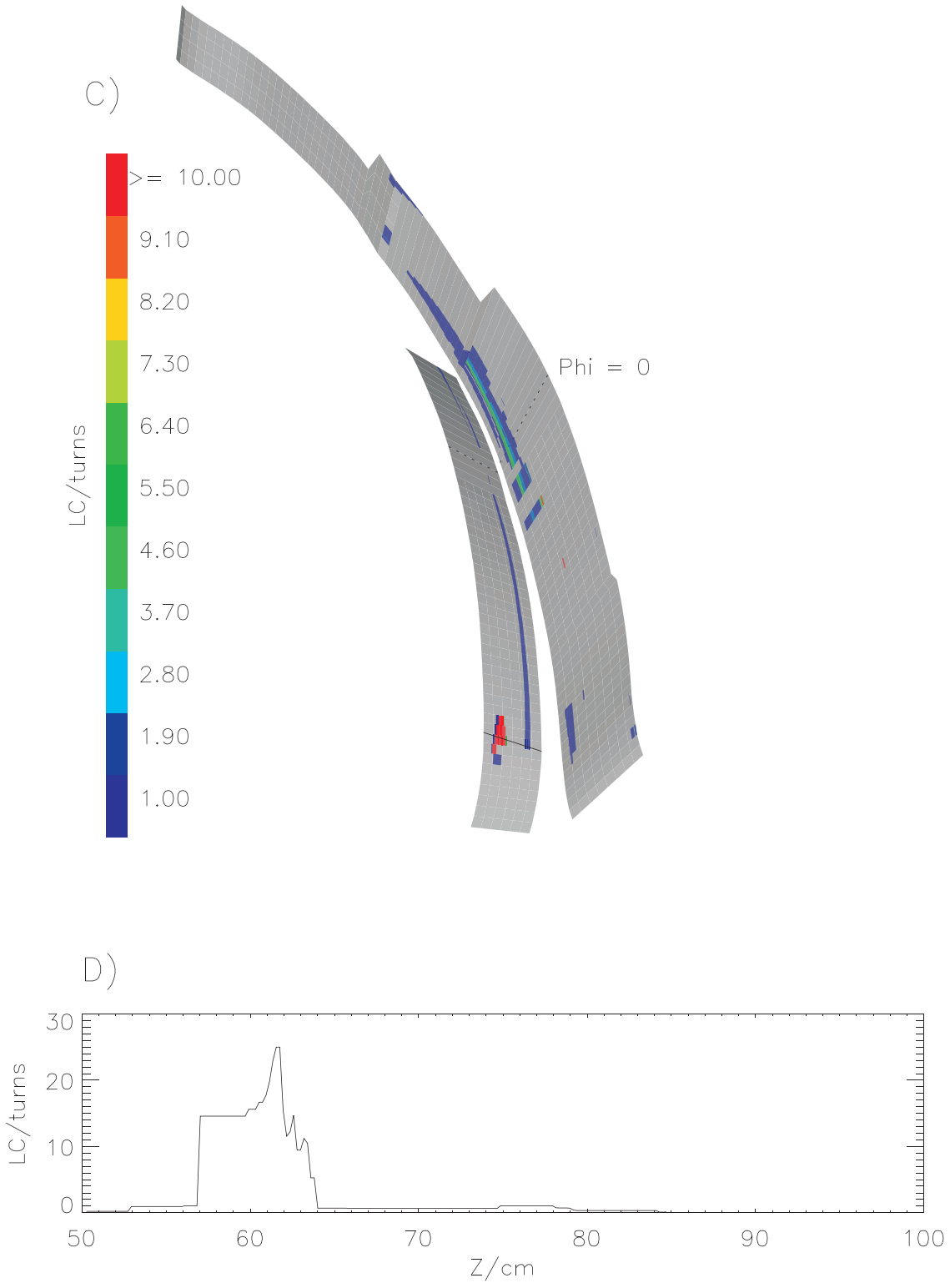

Fig.: 1.10.2
Connection length Lc of the standard configuration.
Control current Icc = 20 kA.

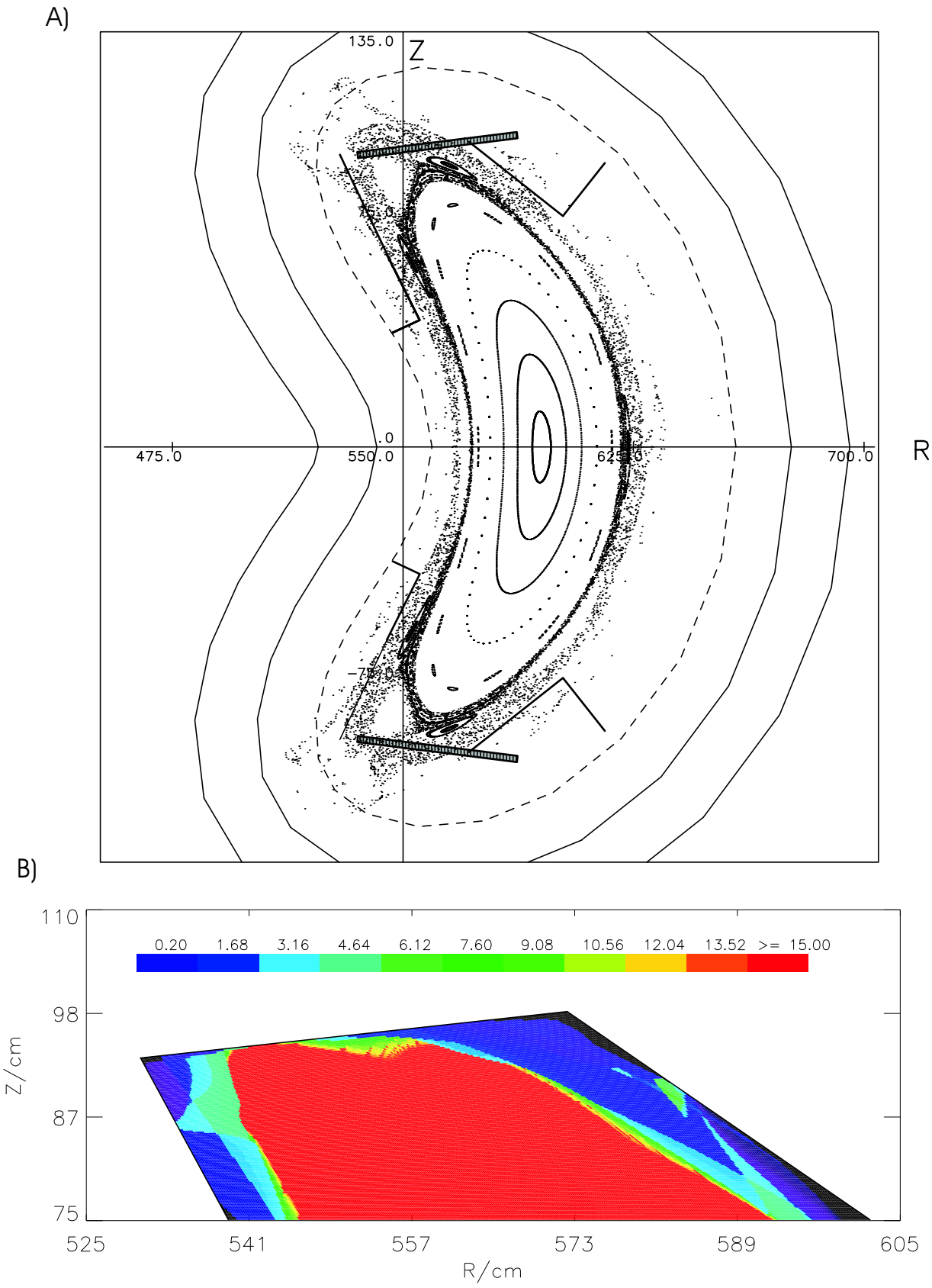

Fig.: 1.11.1

Poincaré plot and colour contour of the standard configuration.

Control current Icc = 25 kA.

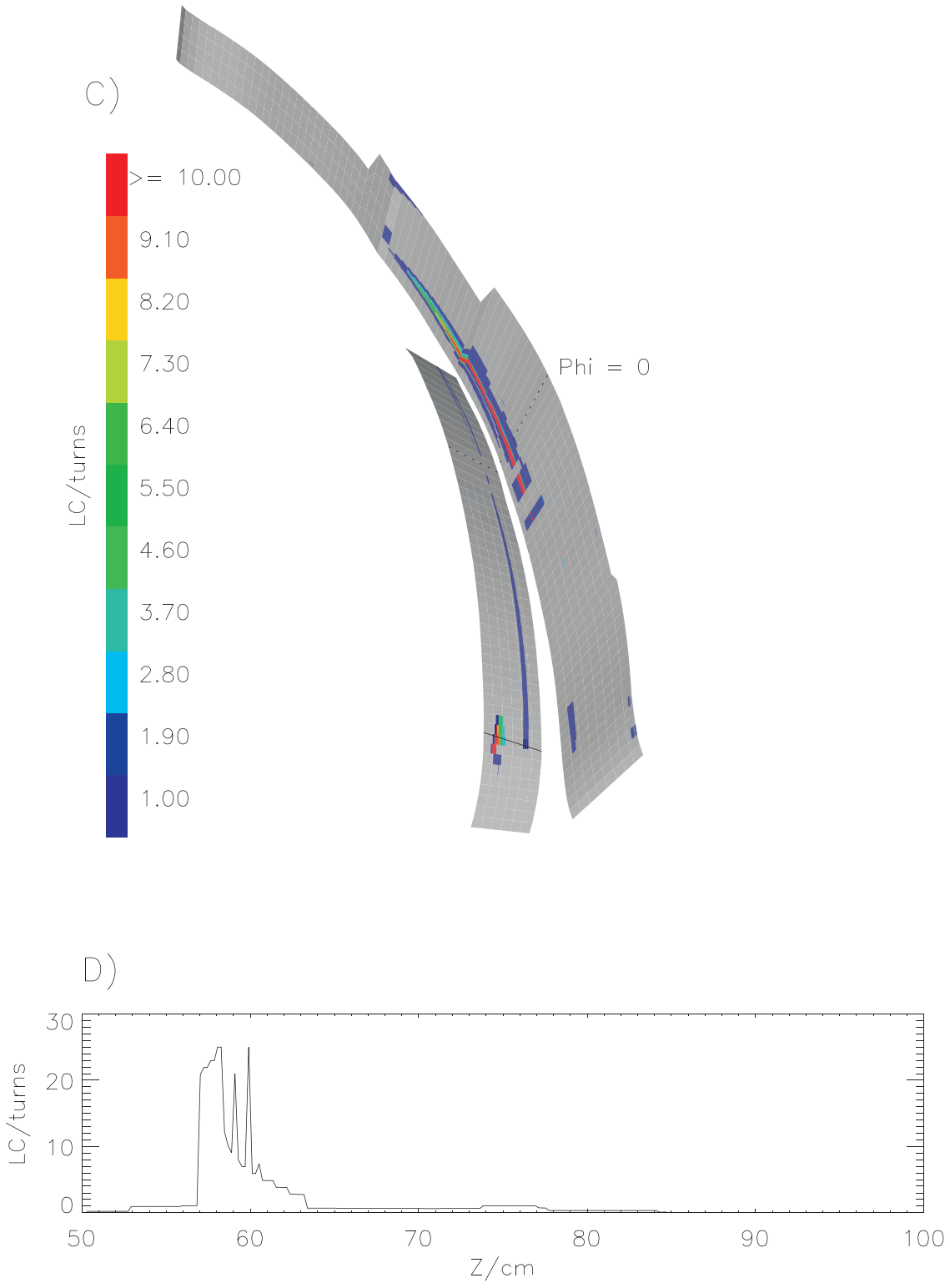

Fig.: 1.11.2
Connection length Lc of the standard configuration.
Control current Icc = 25 kA.

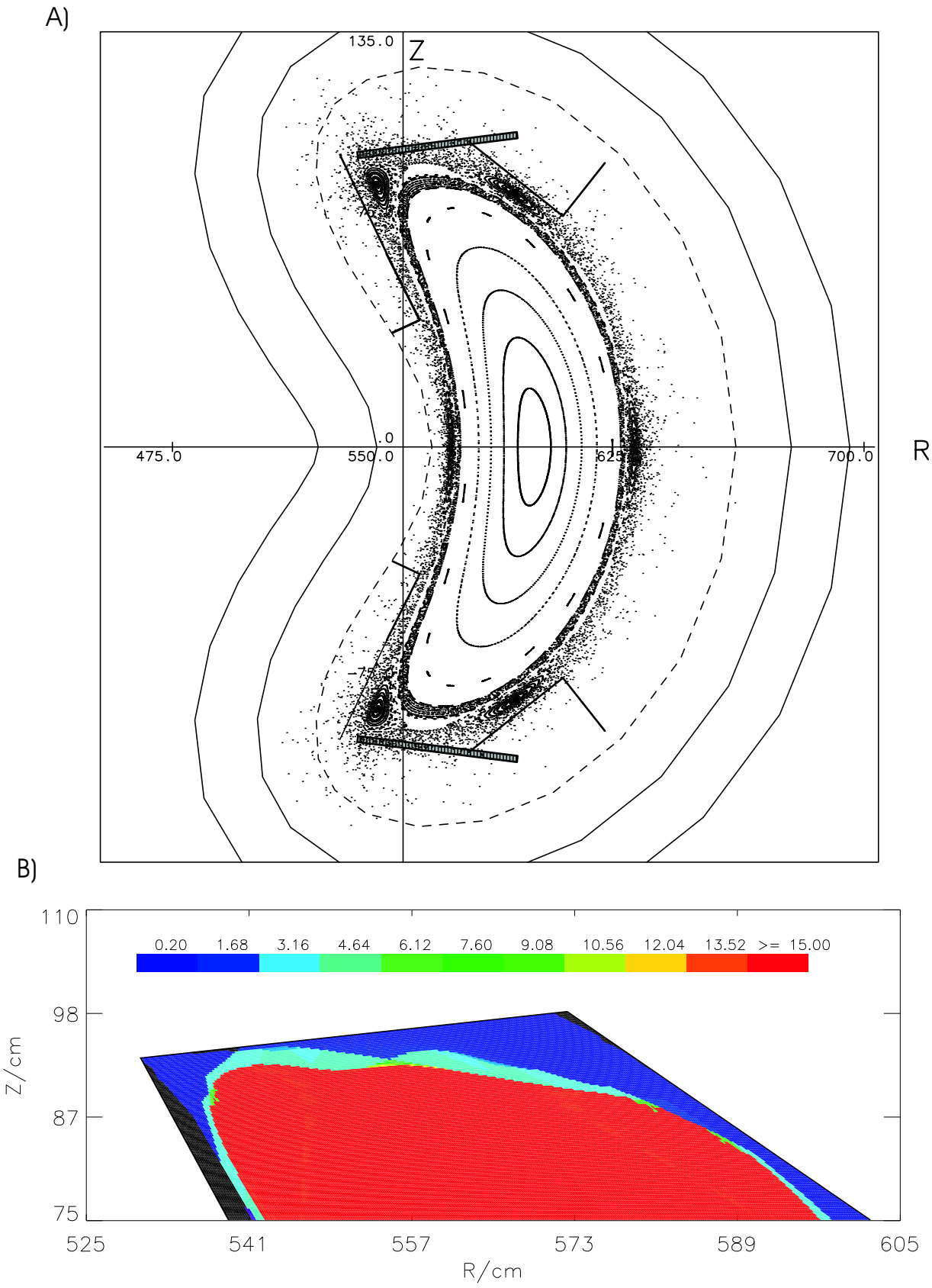

Fig.: 2.1.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = -25 kA.

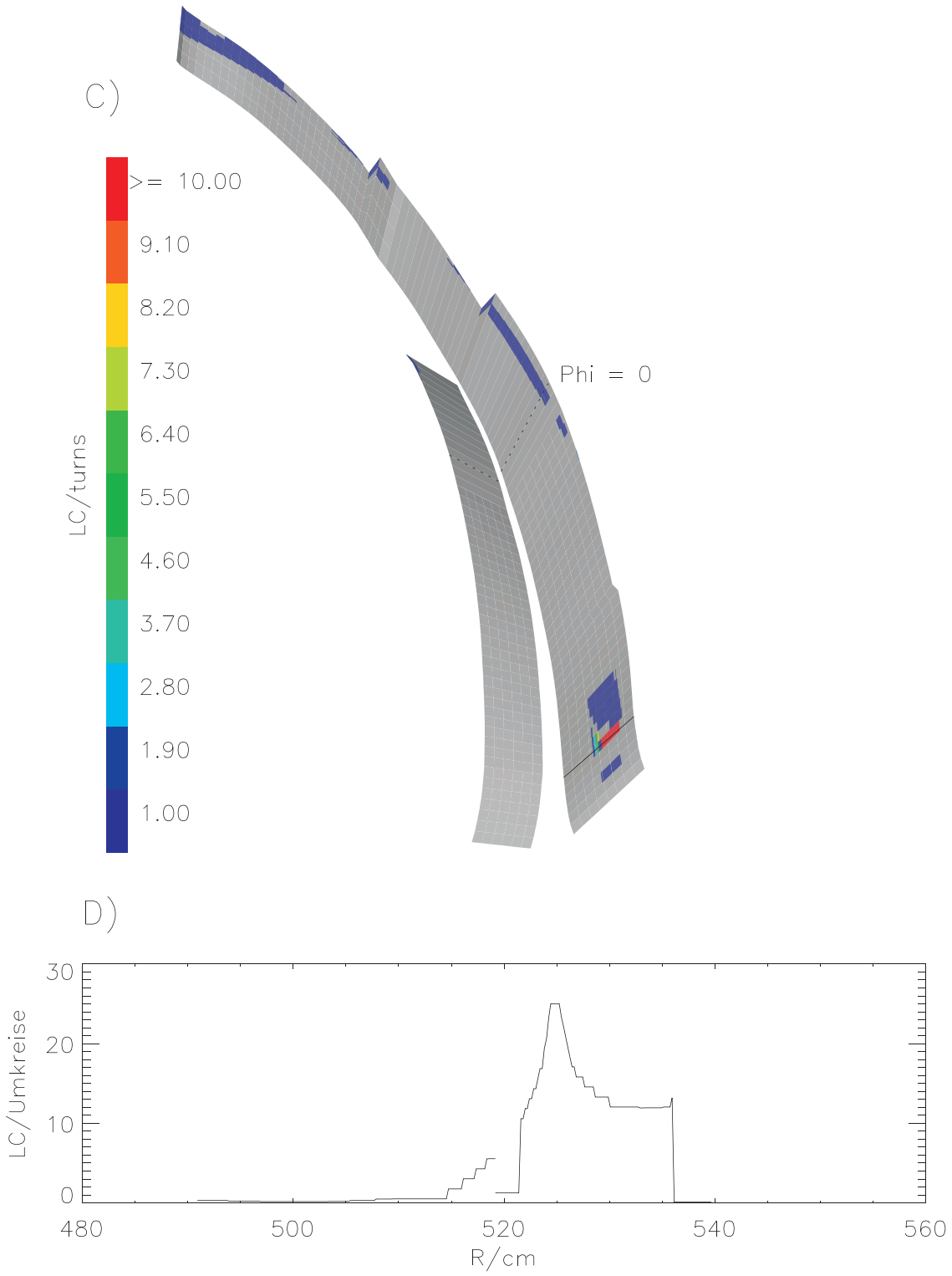

Fig.: 2.1.2
Connection length Lc of the low iota configuration.
Control current Icc = -25 kA.

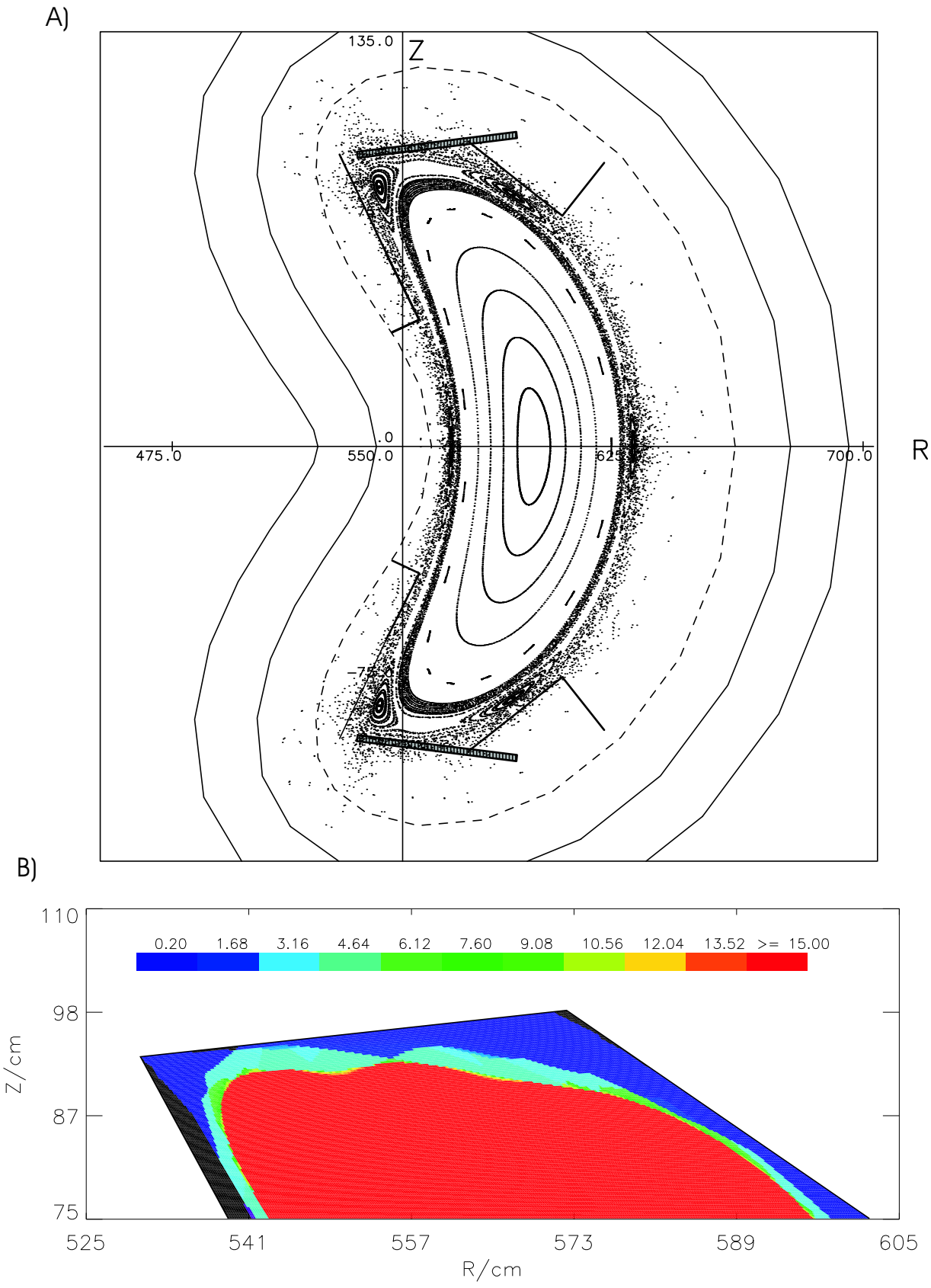

Fig.: 2.2.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = -20 kA.

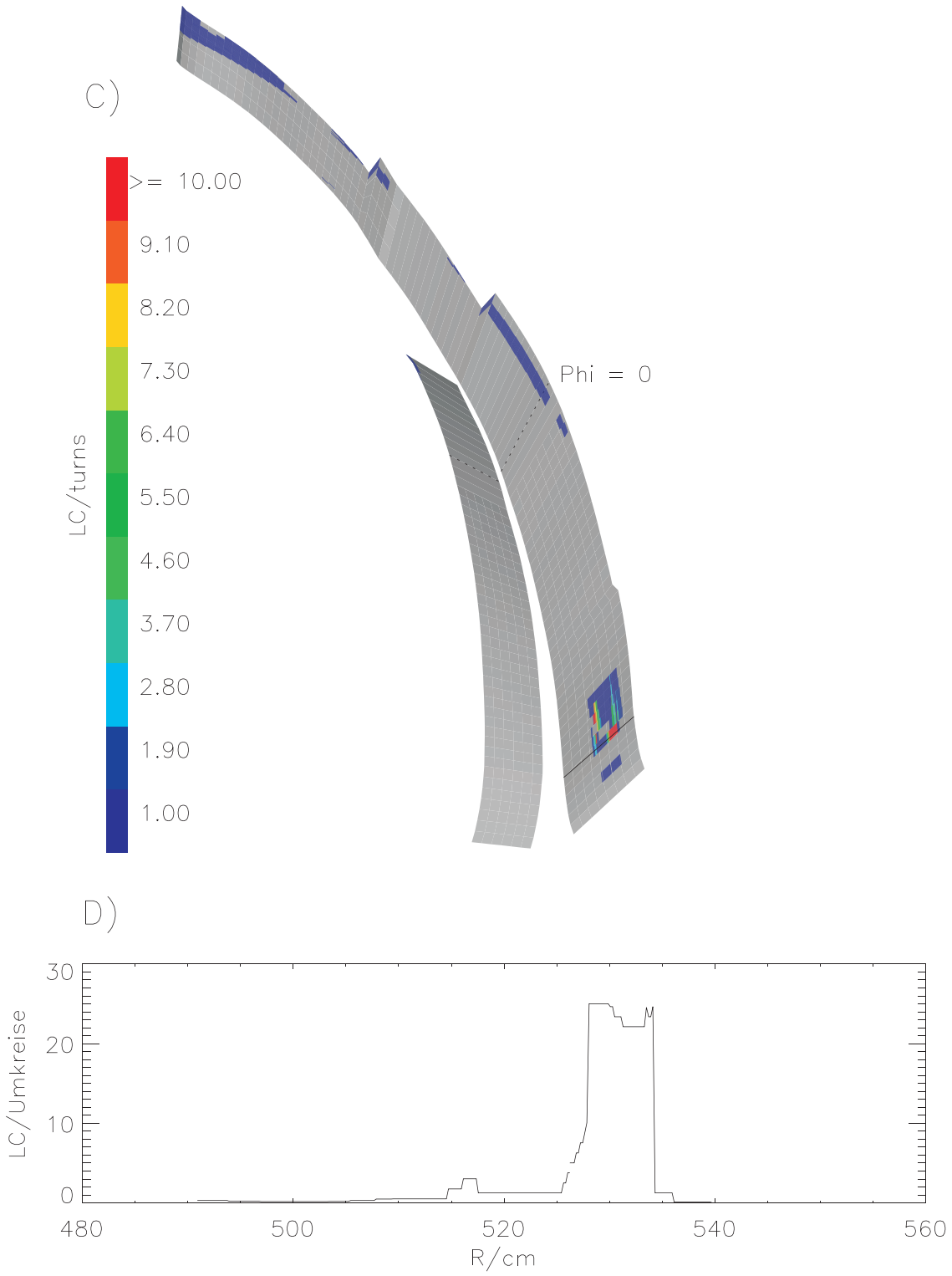

Fig.: 2.2.2
Connection length Lc of the low iota configuration.
Control current Icc = -20 kA.

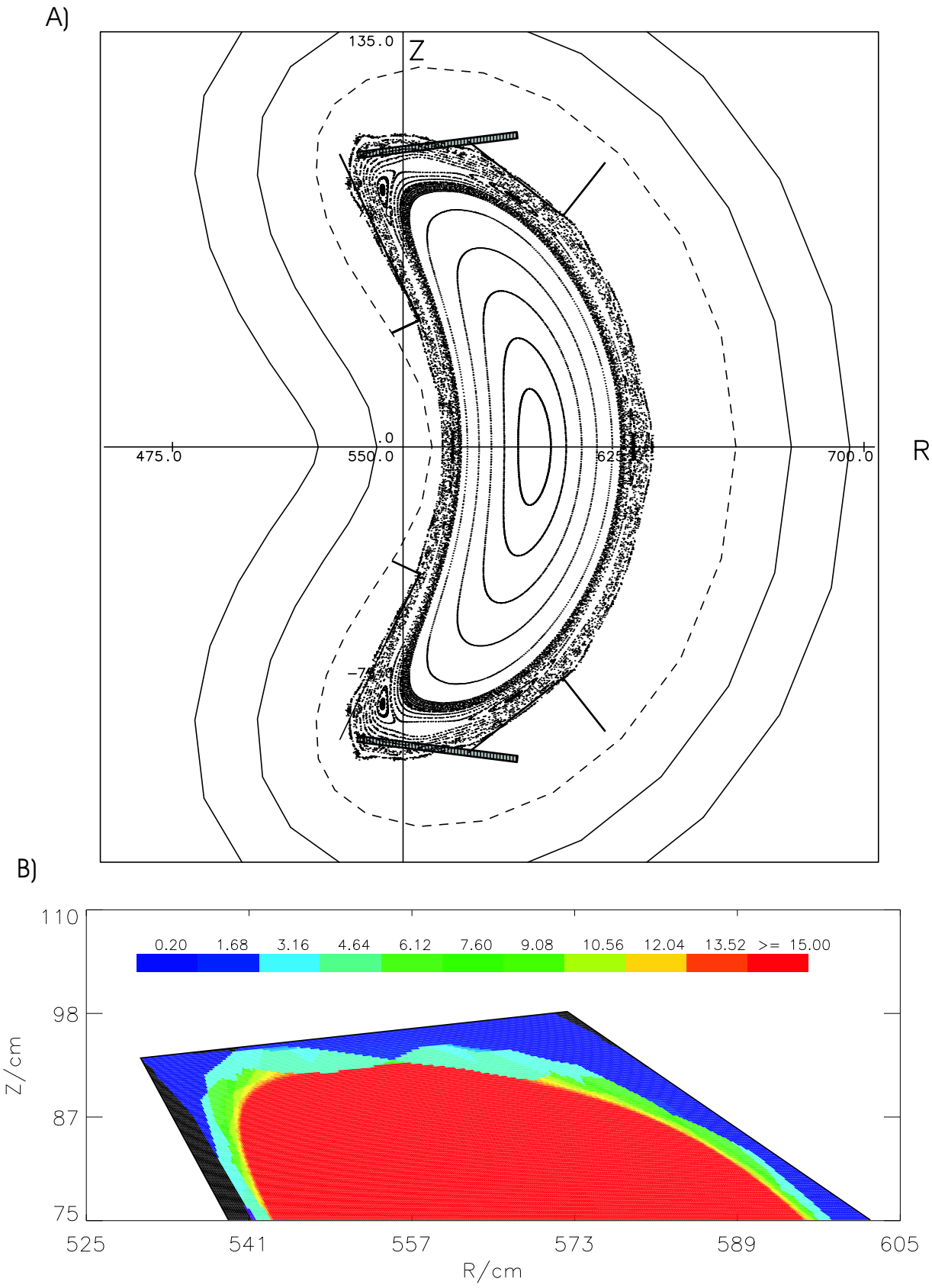

Fig.: 2.3.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = -15 kA.

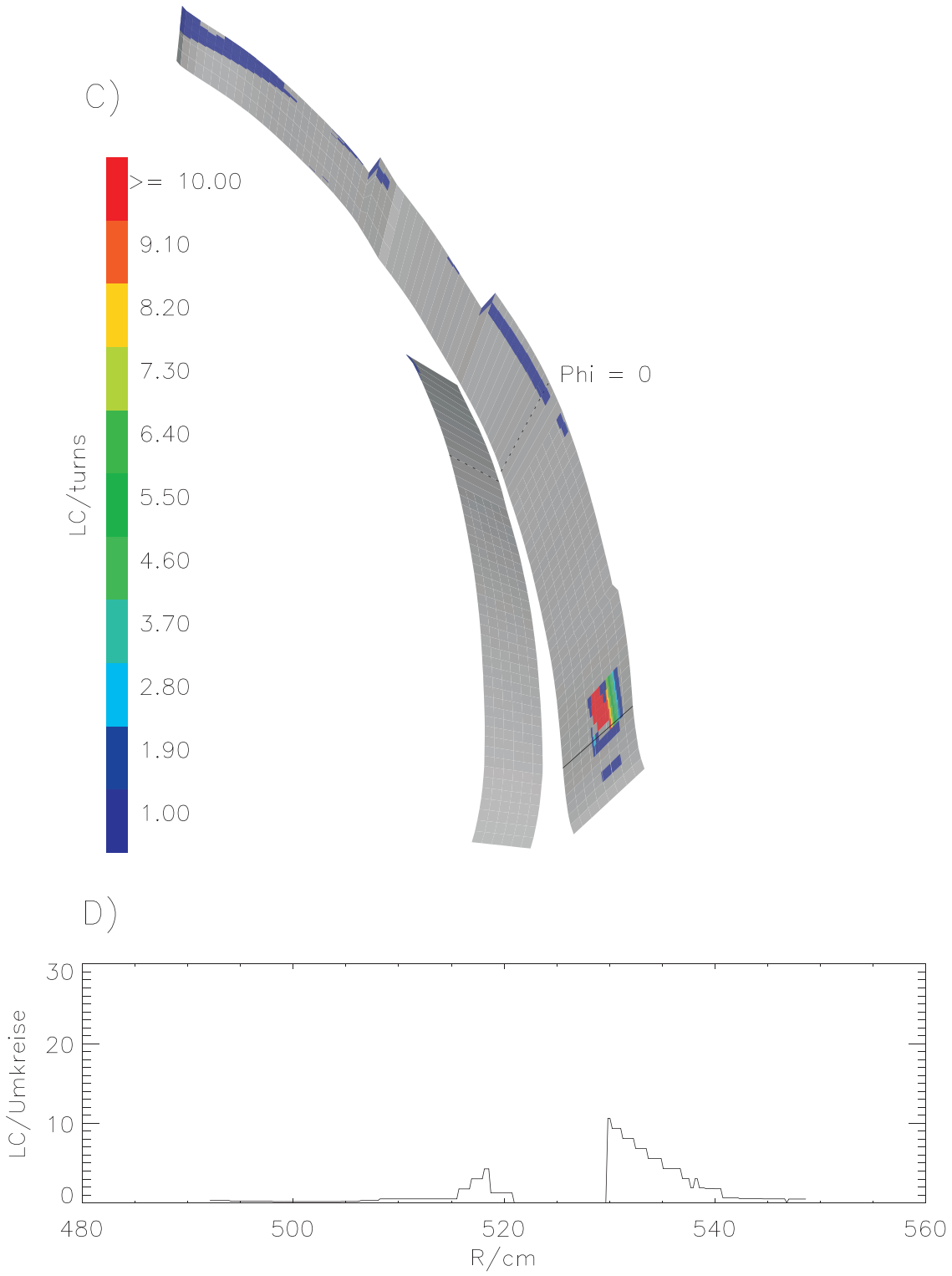

Fig.: 2.3.2
Connection length Lc of the low iota configuration.
Control current Icc = -15 kA.

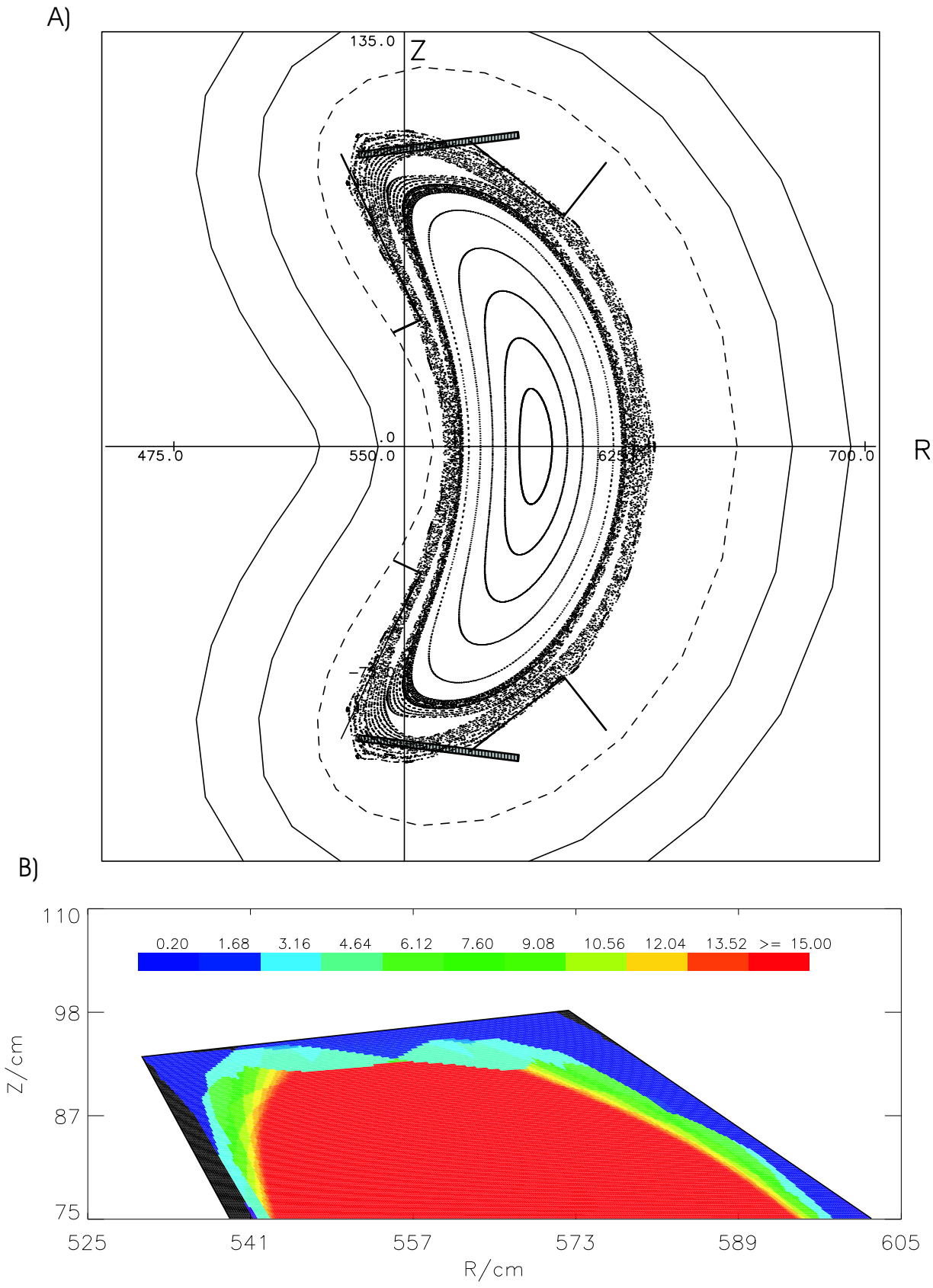

Fig.: 2.4.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = -10 kA.

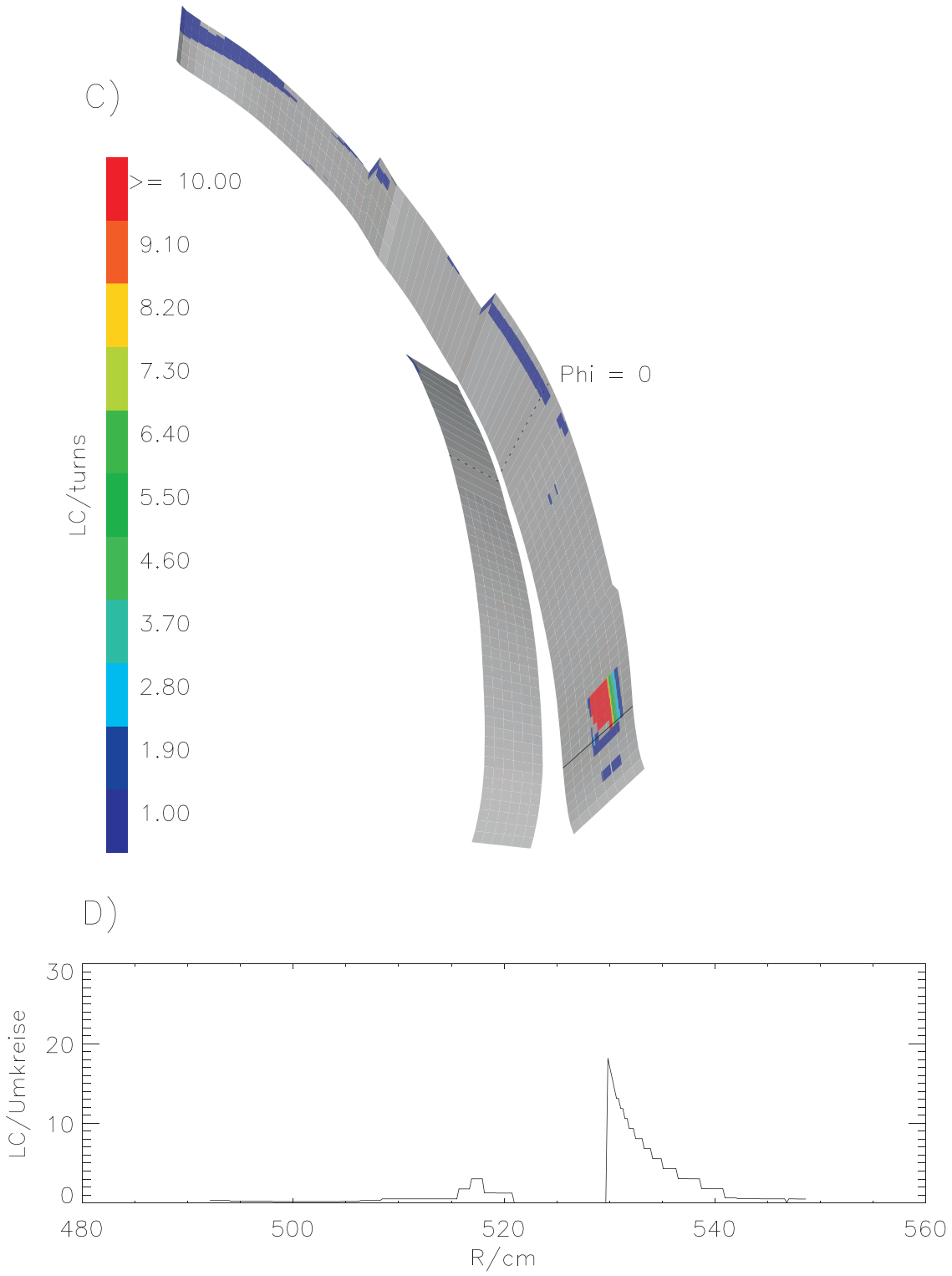

Fig.: 2.4.2
Connection length Lc of the low iota configuration.
Control current Icc = -10 kA.

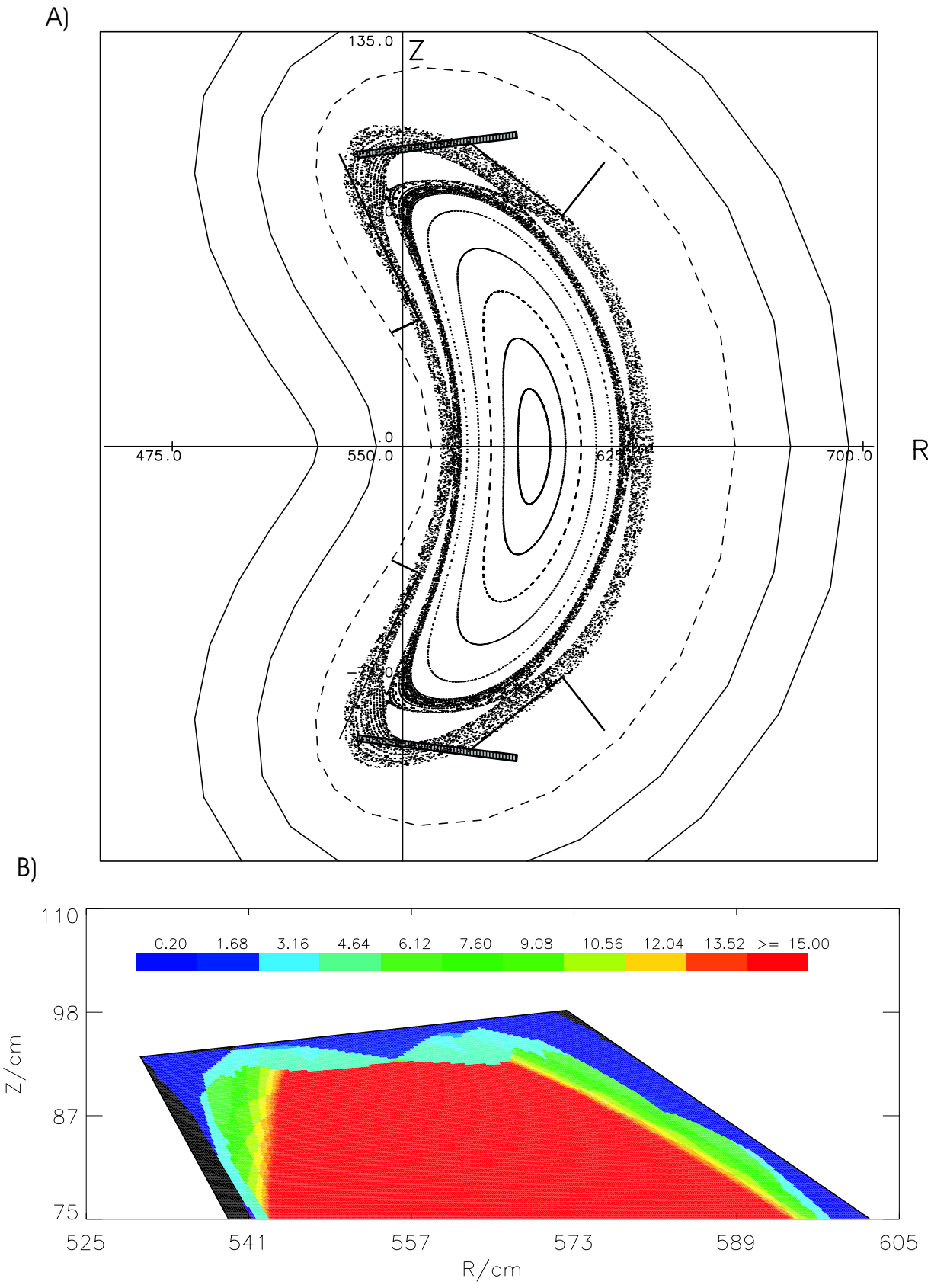

Fig.: 2.5.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = -5 kA.

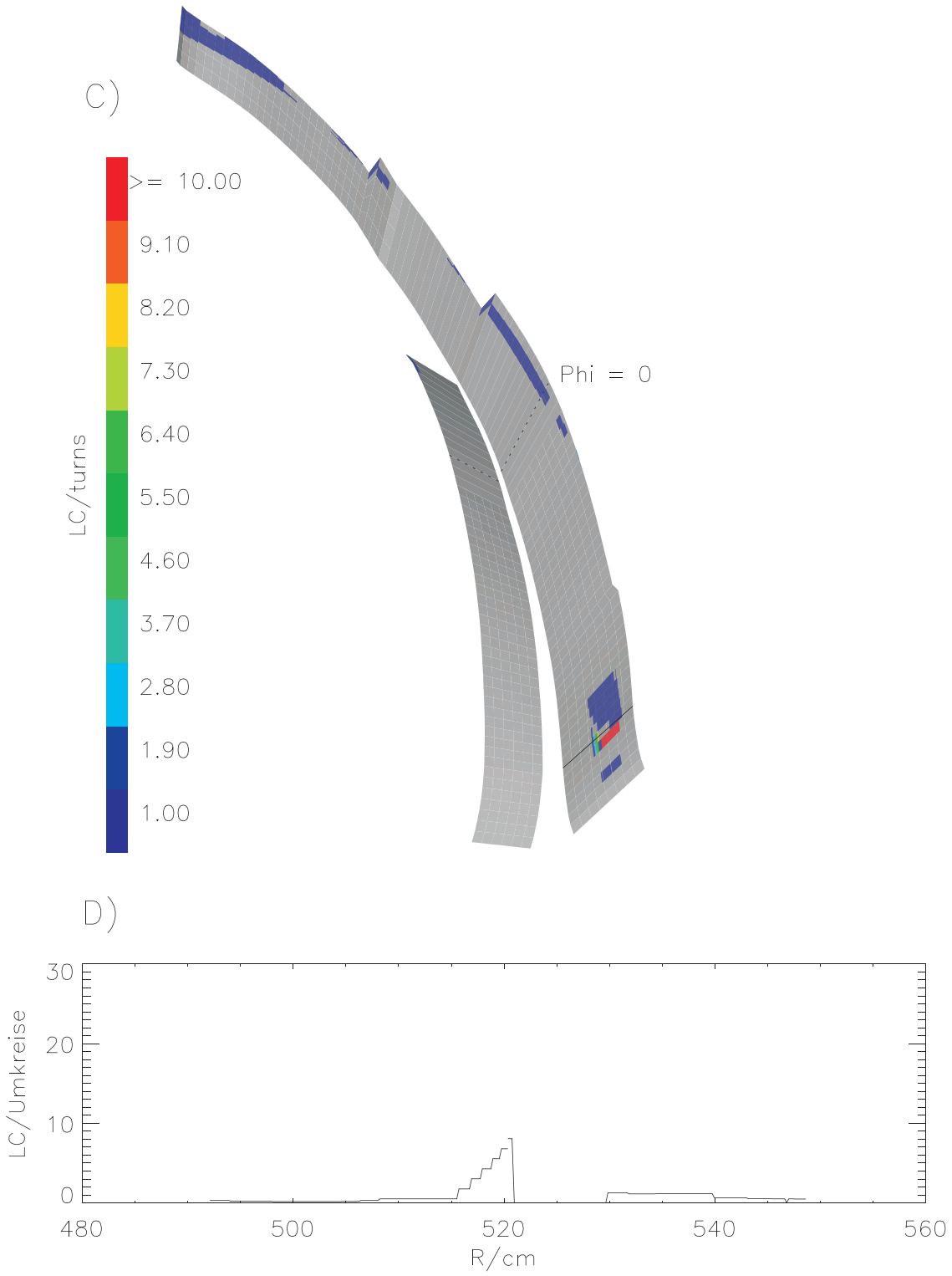

Fig.: 2.5.2
Connection length Lc of the low iota configuration.
Control current Icc = -5 kA.

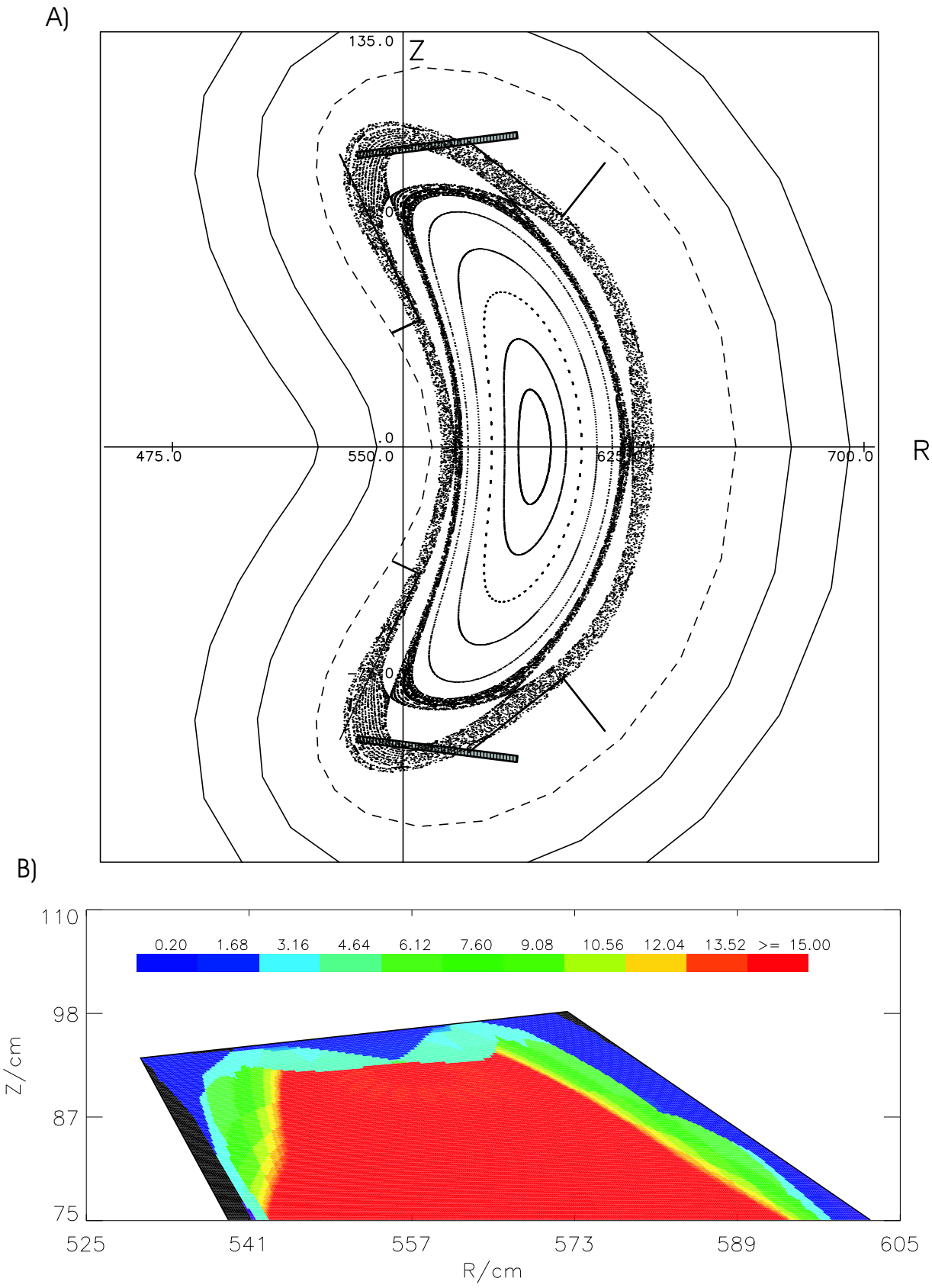

Fig.: 2.6.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = 0 kA.

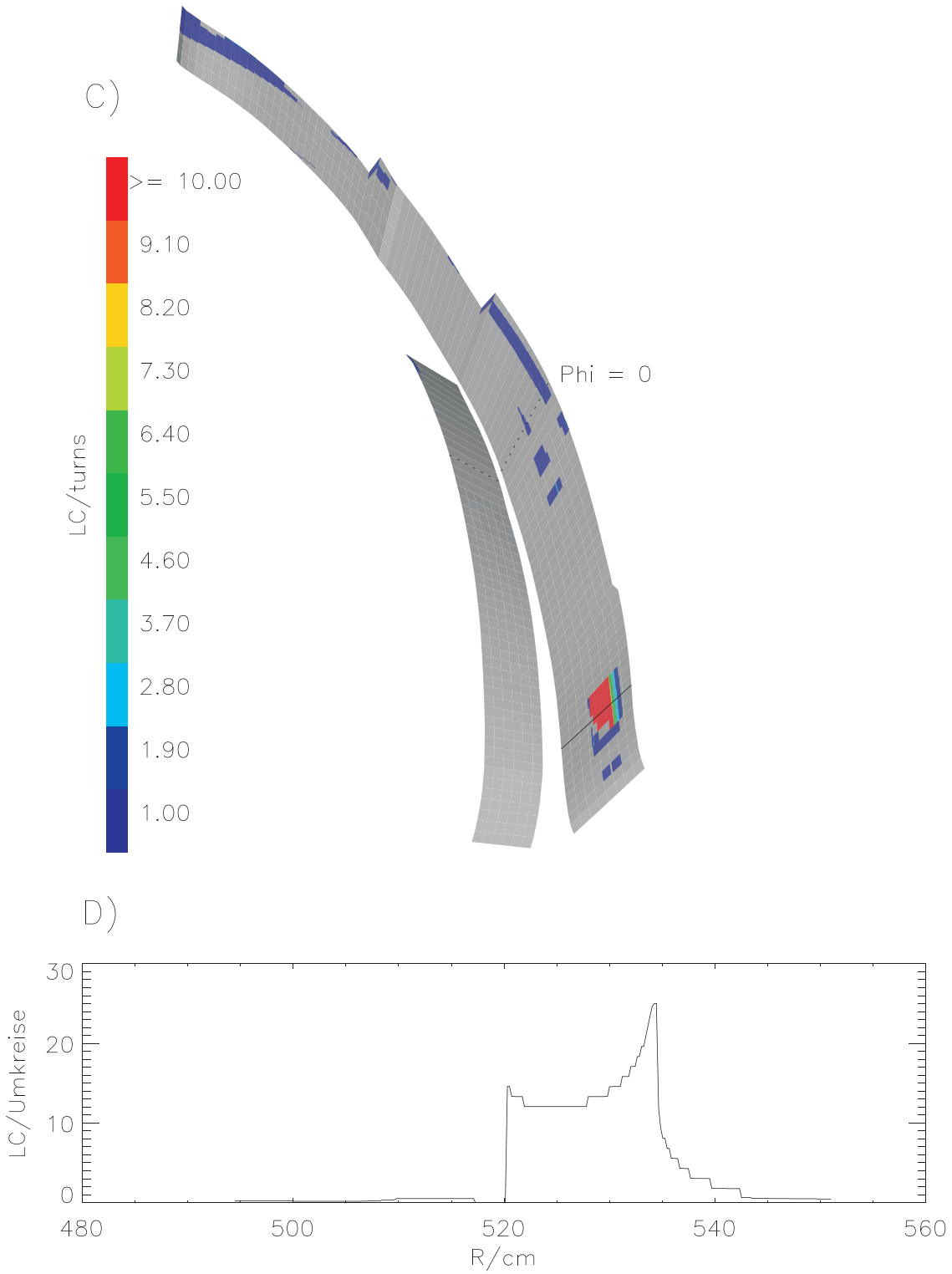

Fig.: 2.6.2
Connection length Lc of the low iota configuration.
Control current Icc = 0 kA.

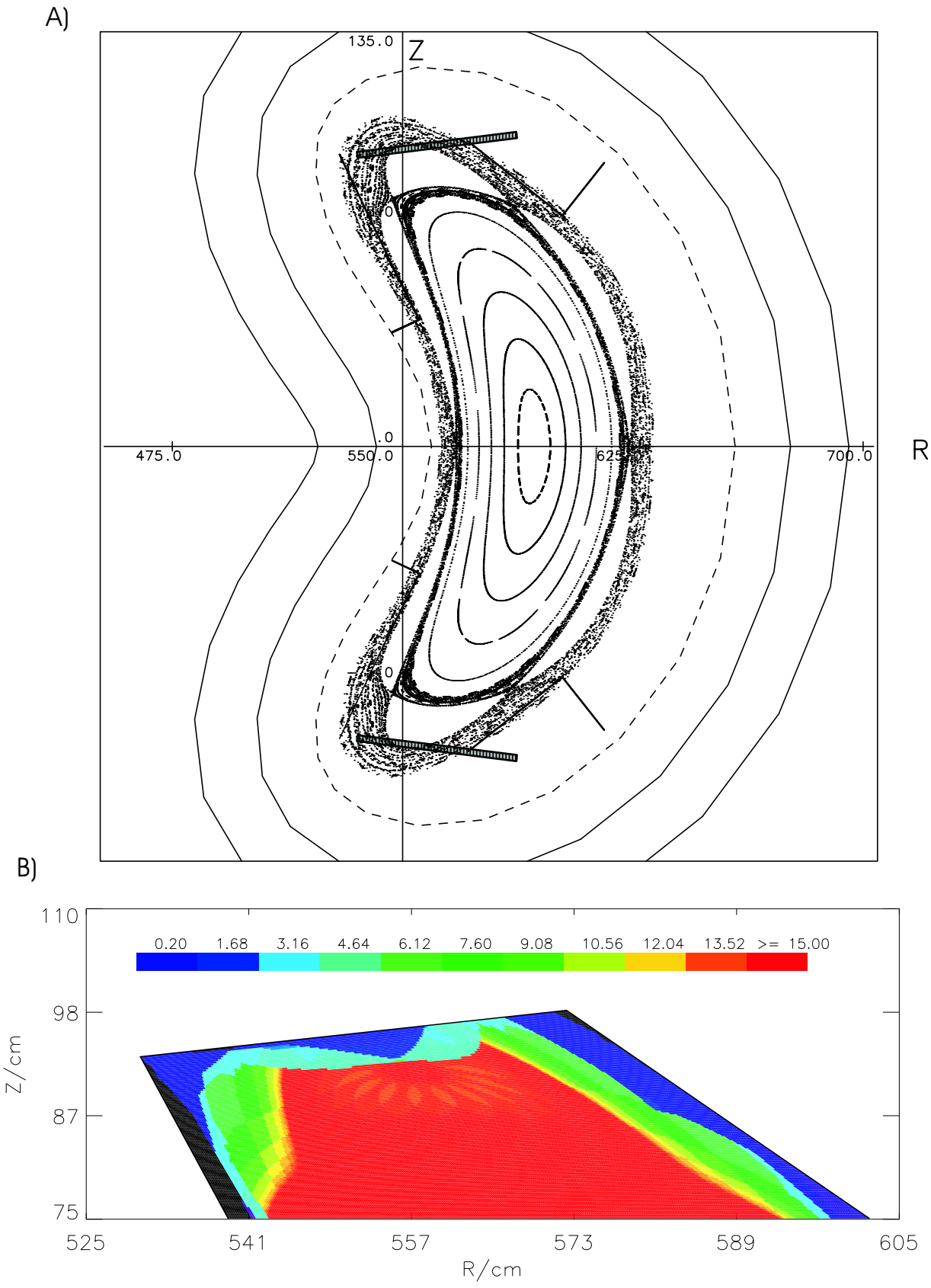

Fig.: 2.7.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = 5 kA.

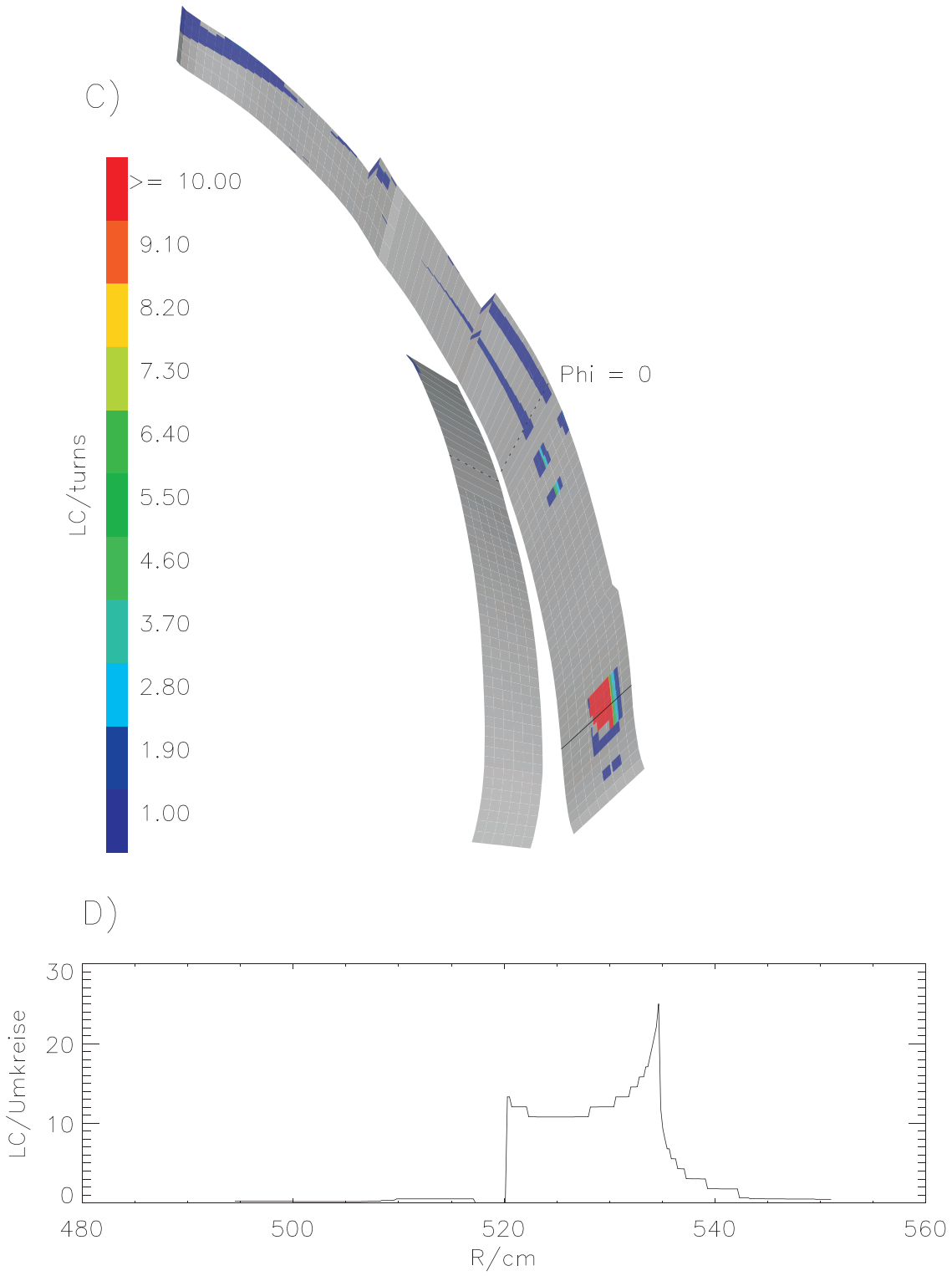

Fig.: 2.7.2
Connection length Lc of the low iota configuration.
Control current Icc = 5 kA.

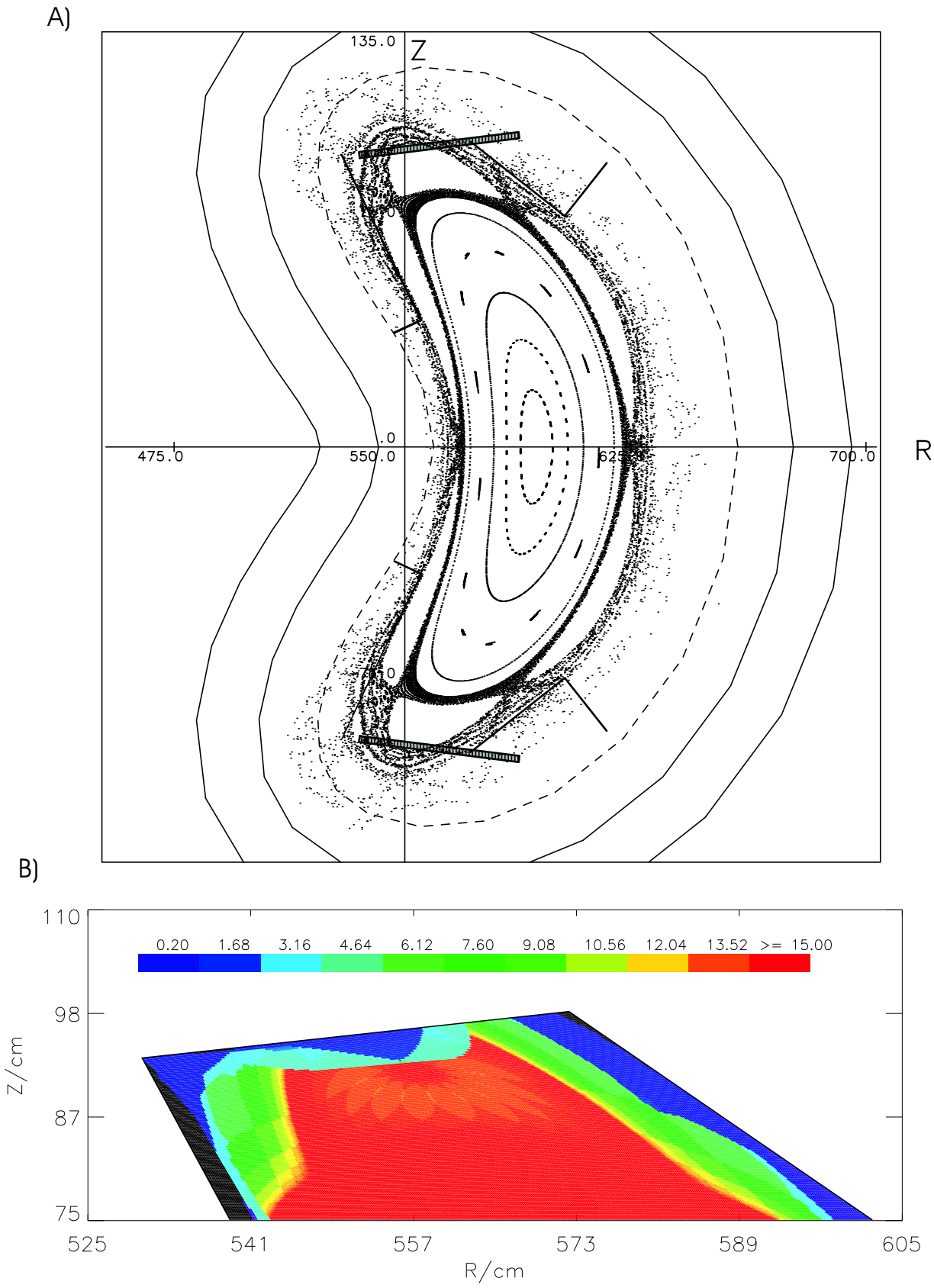

Fig.: 2.8.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = 10 kA.

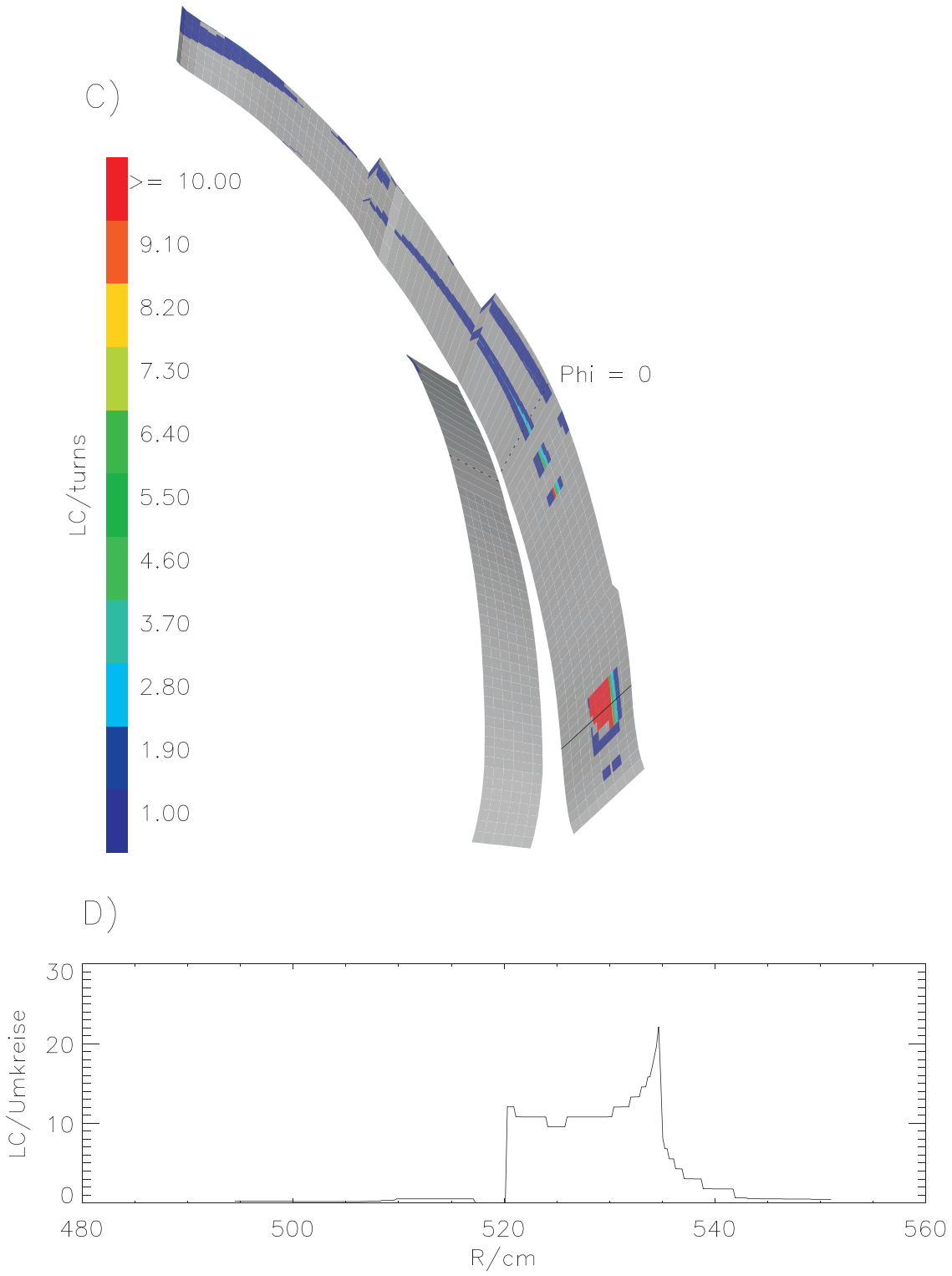

Fig.: 2.8.2
Connection length Lc of the low iota configuration.
Control current Icc = 10 kA.

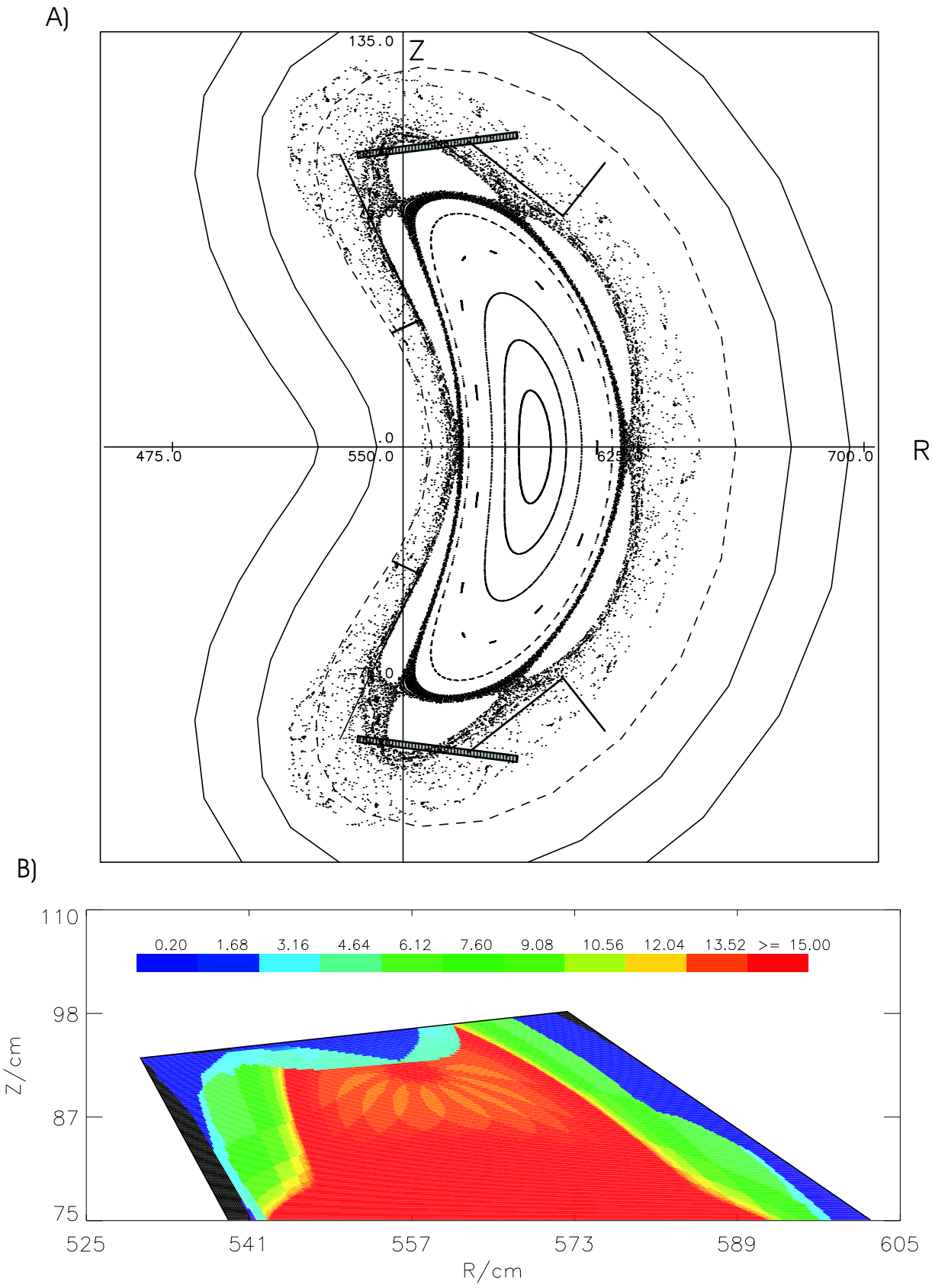

Fig.: 2.9.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = 15 kA.

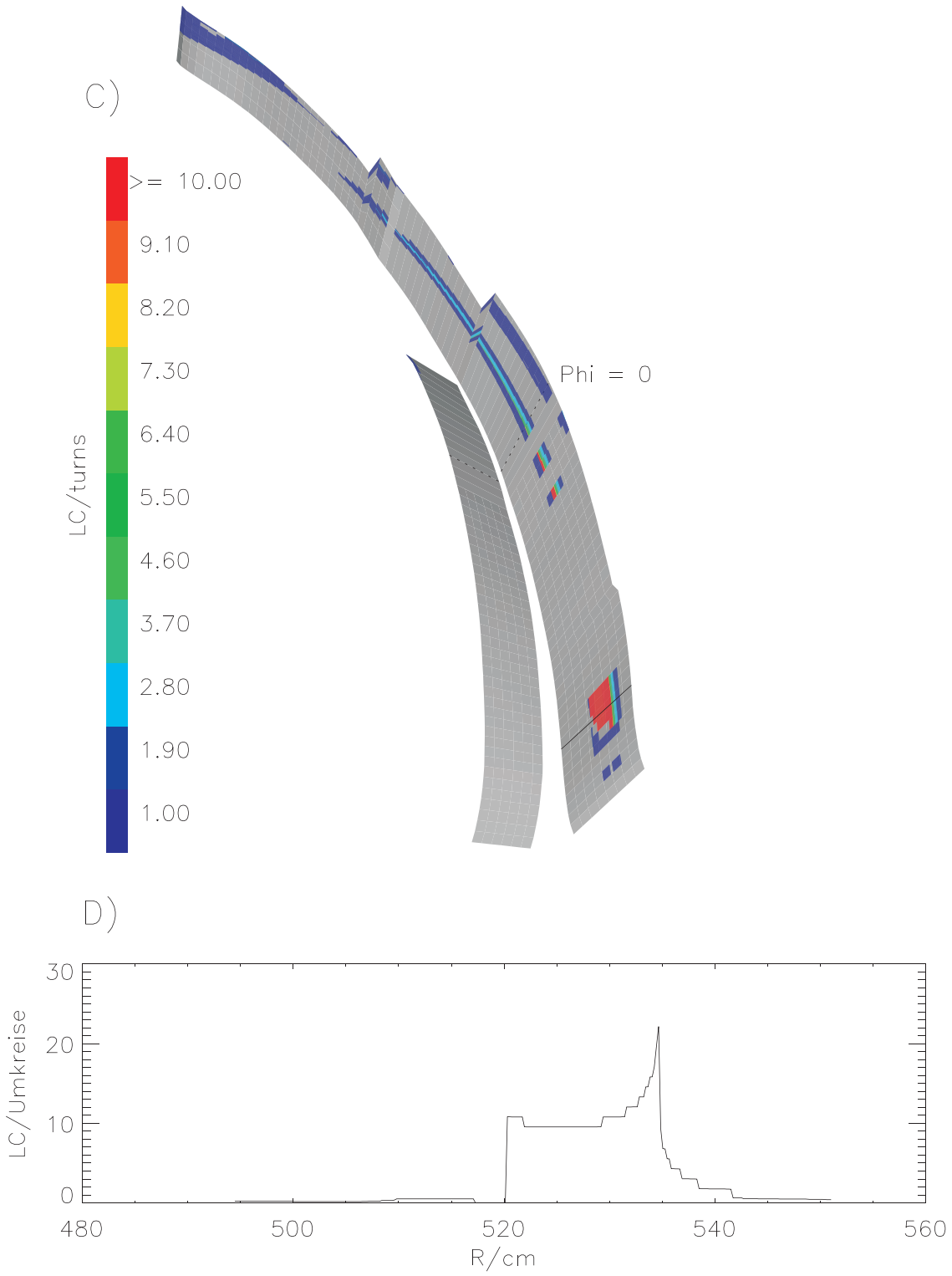

Fig.: 2.9.2
Connection length Lc of the low iota configuration.
Control current Icc = 15 kA.

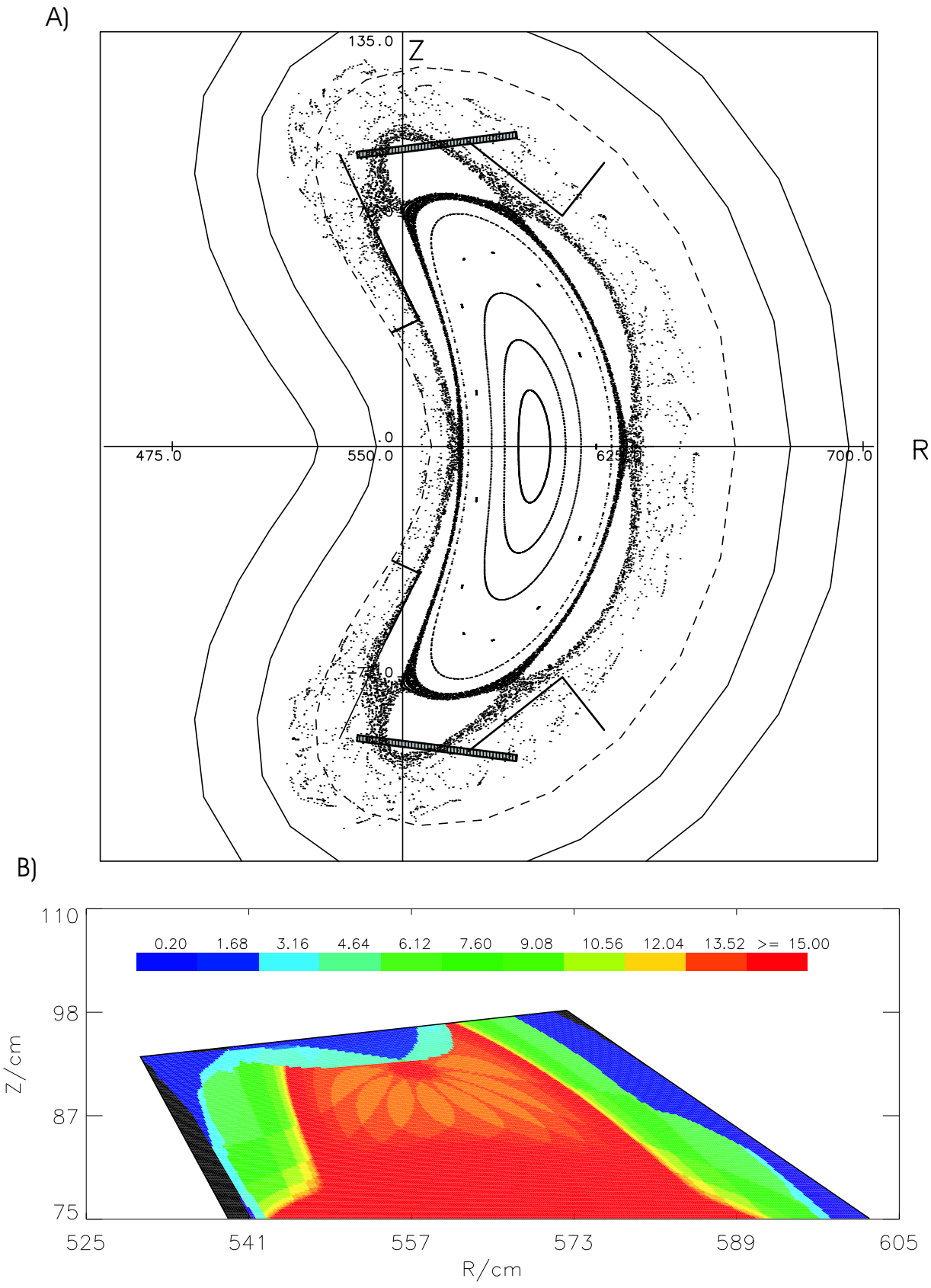

Fig.: 2.10.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = 20 kA.

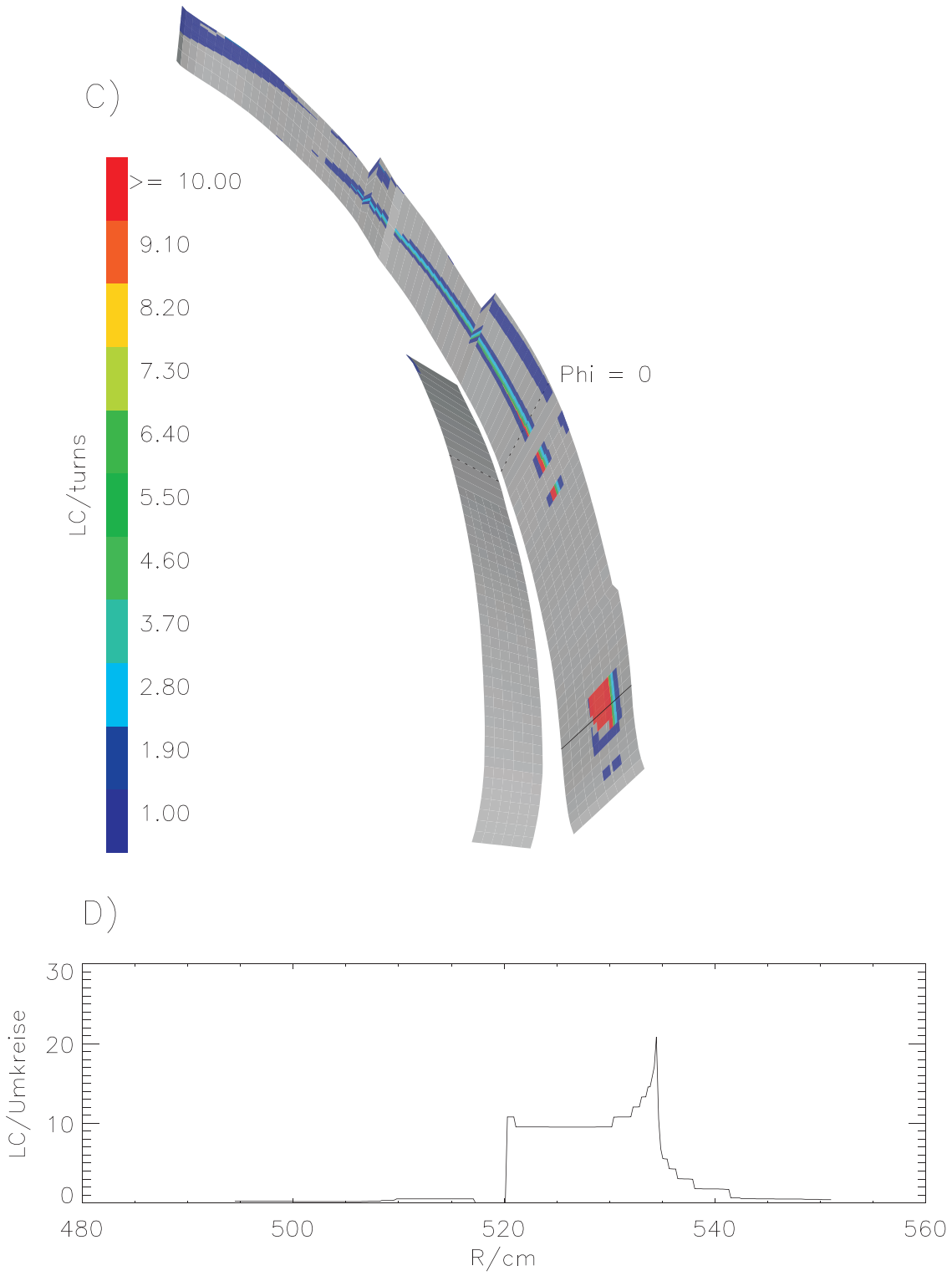

Fig.: 2.10.2
Connection length Lc of the low iota configuration.
Control current Icc = 20 kA.

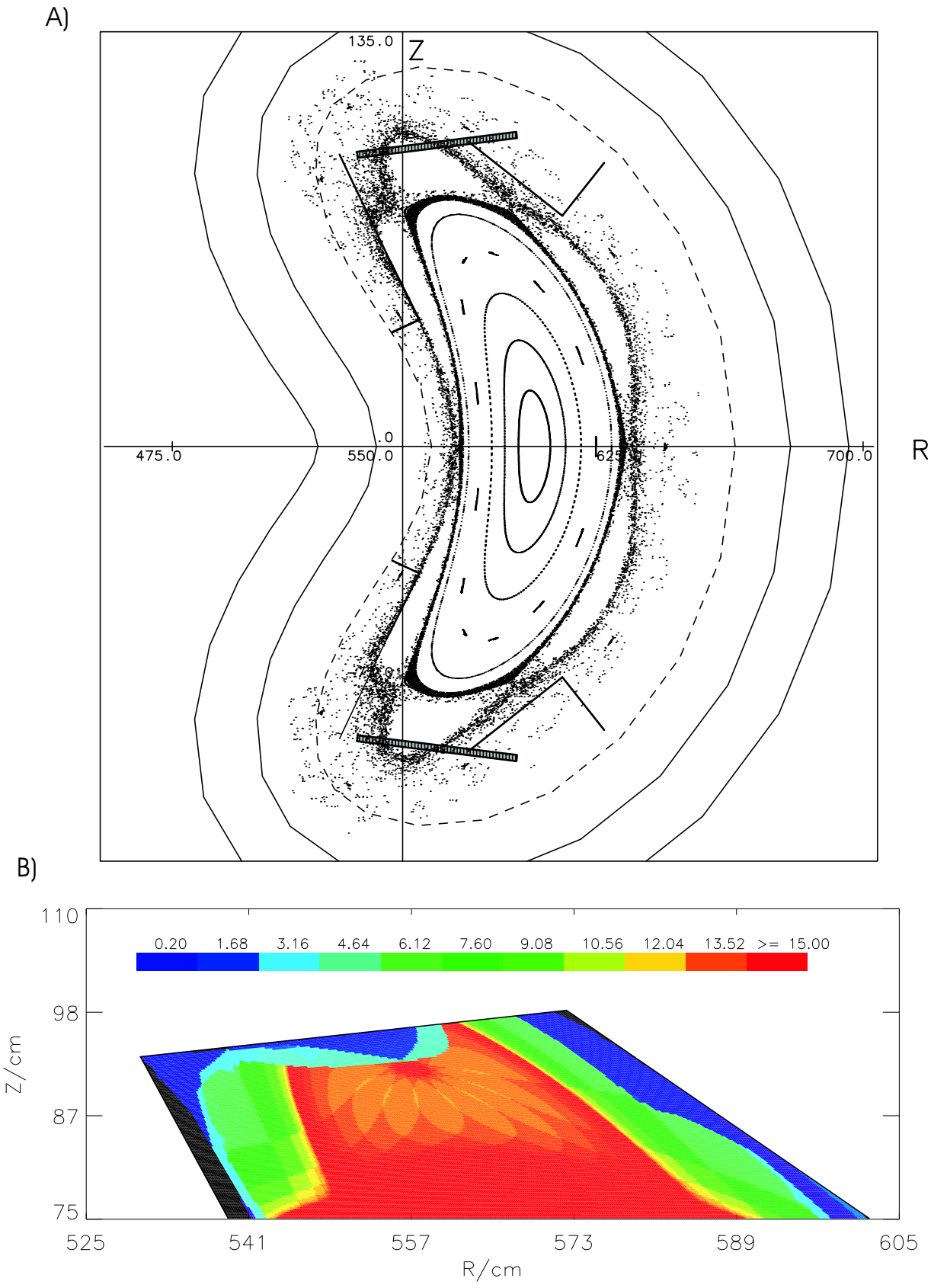

Fig.: 2.11.1

Poincaré plot and colour contour of the low iota configuration.

Control current Icc = 25 kA.

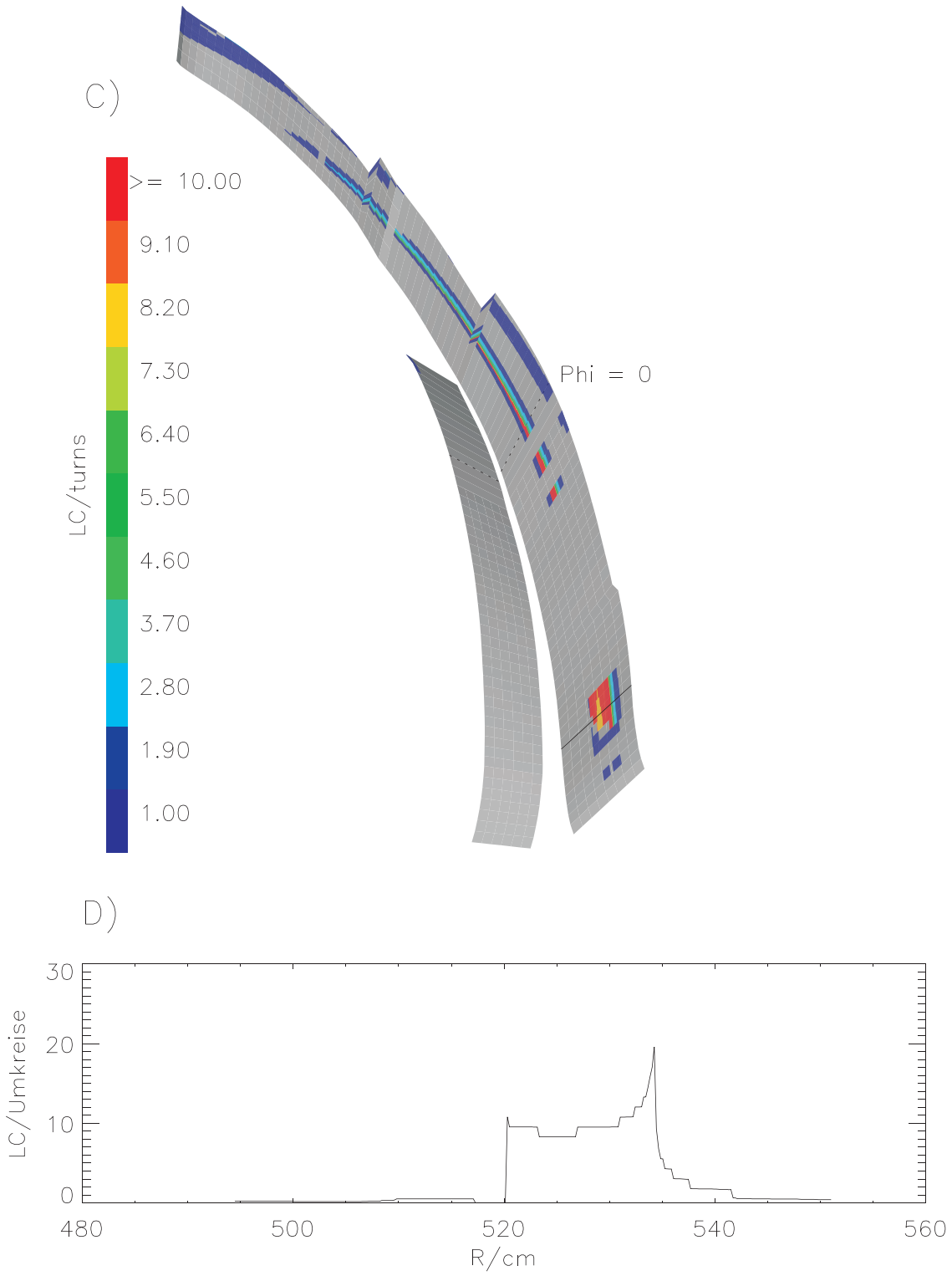

Fig.: 2.11.2
Connection length Lc of the low iota configuration.
Control current Icc = 25 kA.

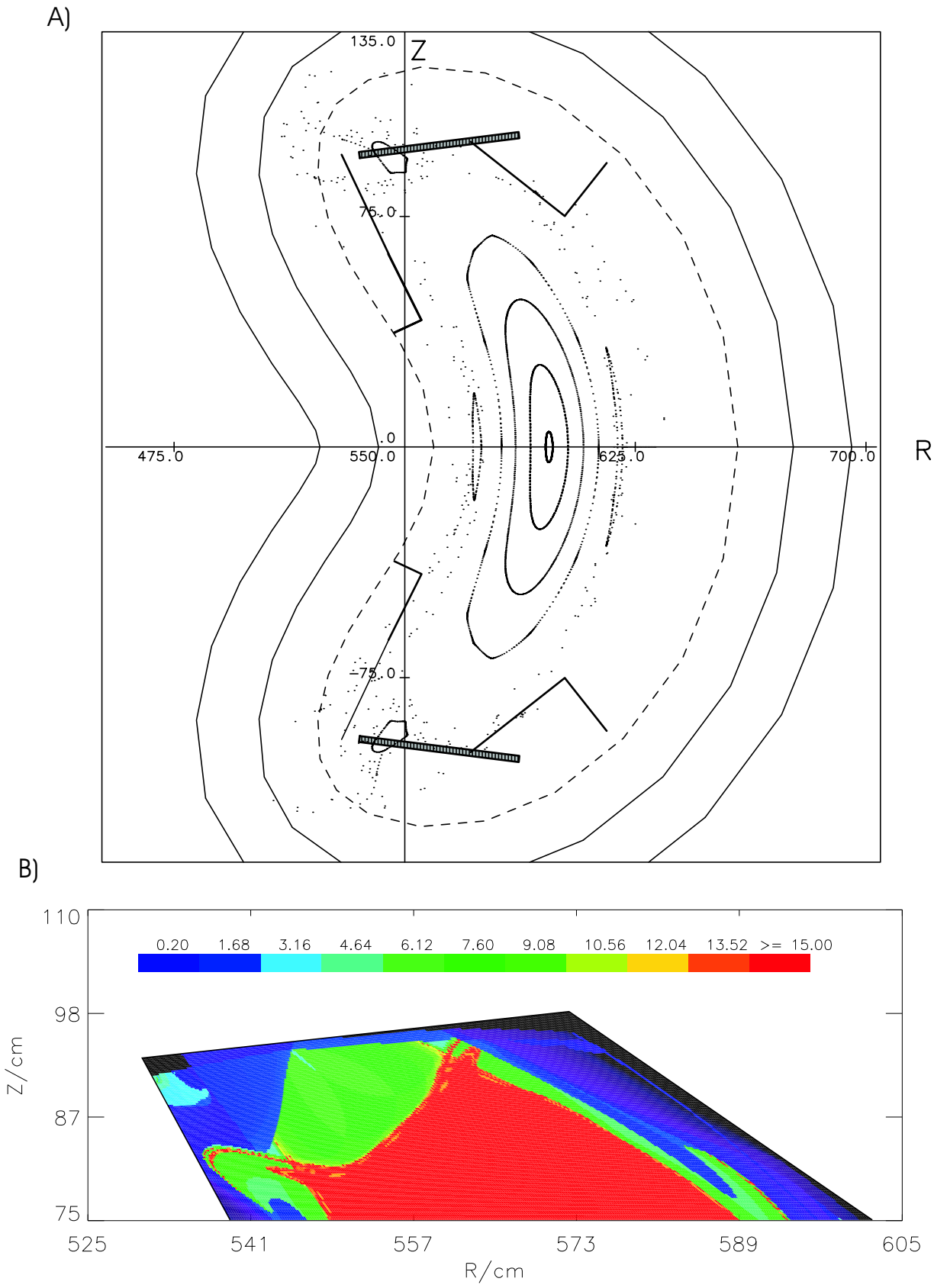

Fig.: 3.1.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = -25 kA.

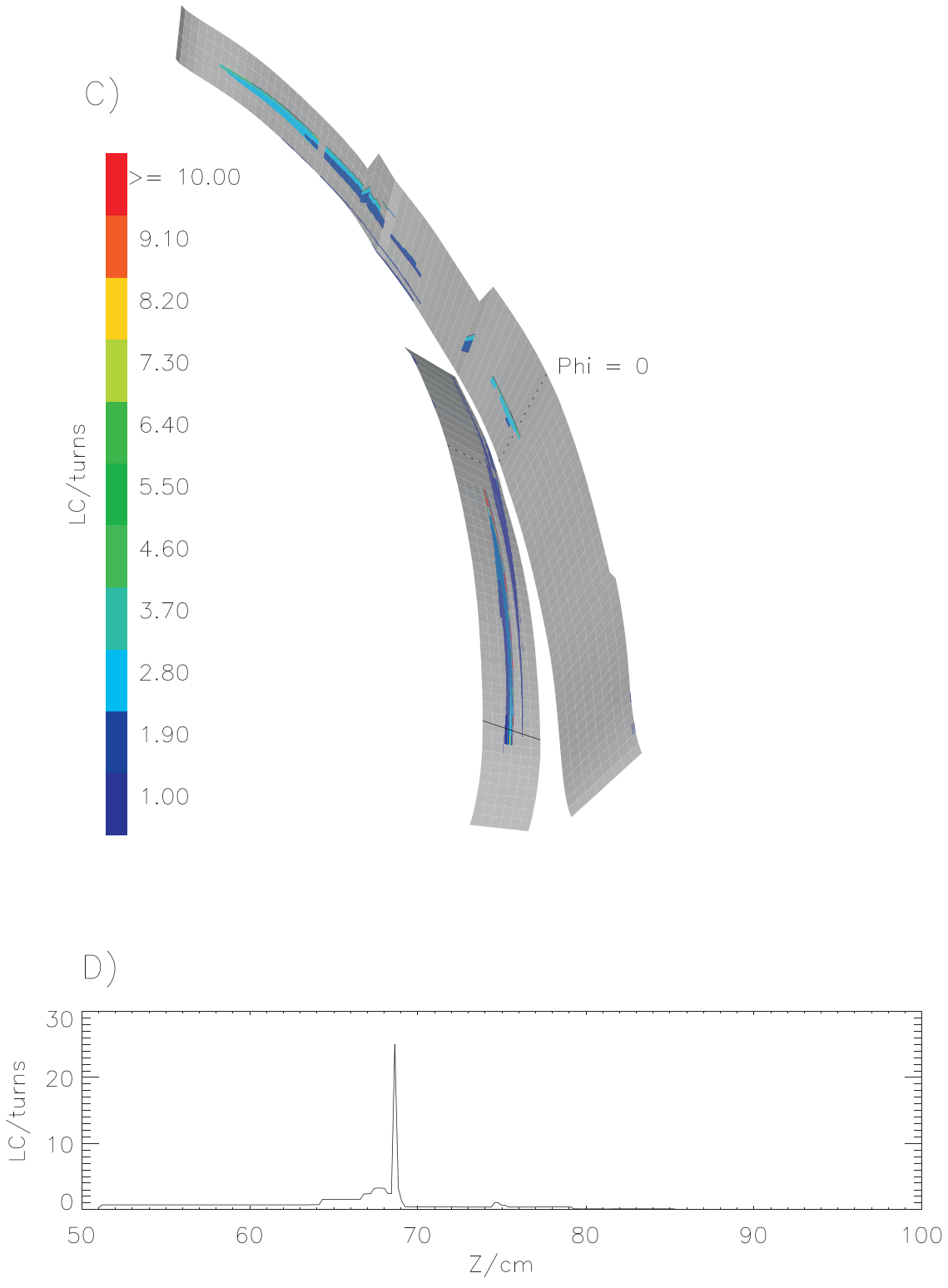

Fig.: 3.1.2
Connection length Lc of the high iota configuration.
Control current Icc = -25 kA.

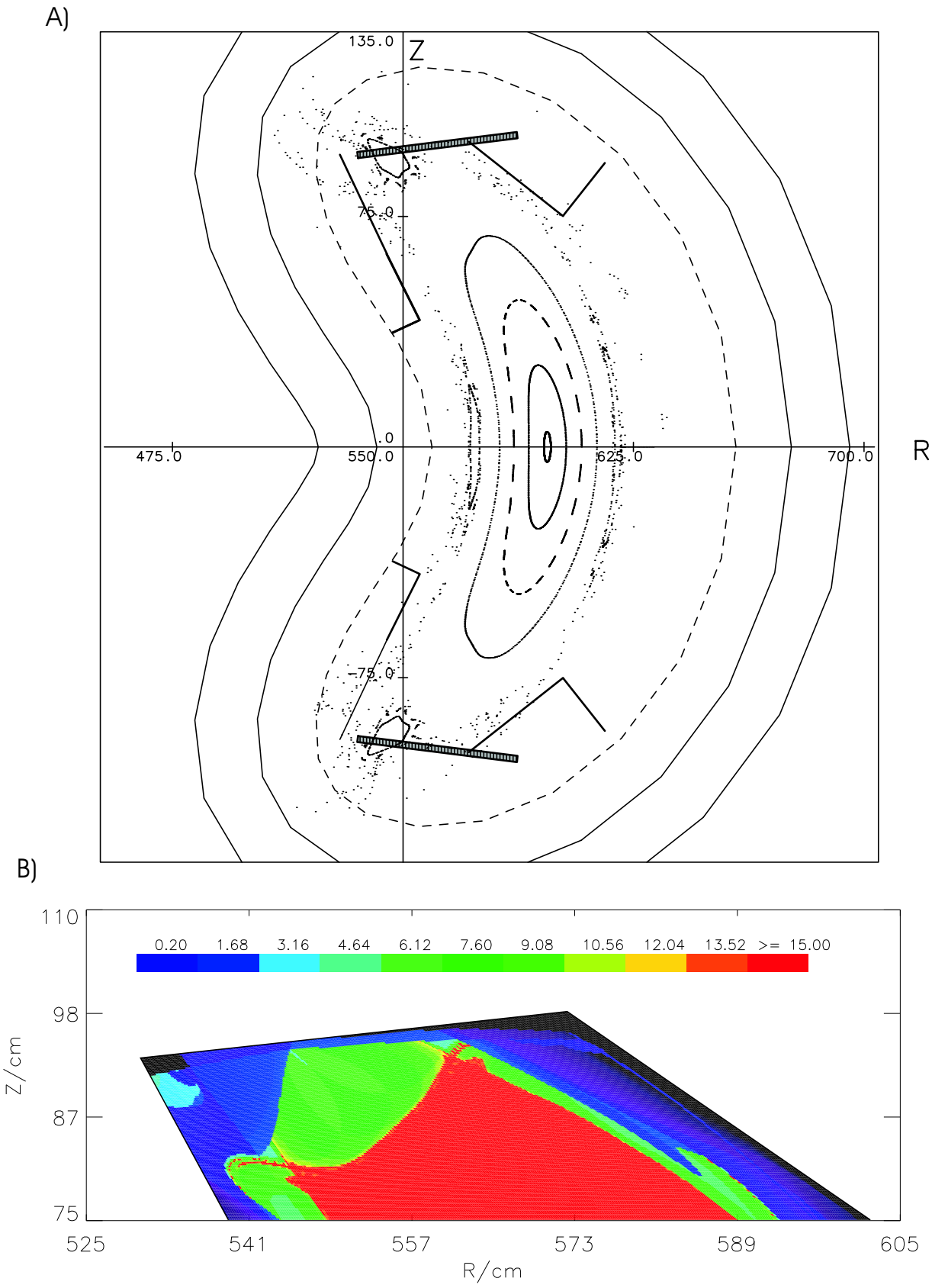

Fig.: 3.2.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = -20 kA.

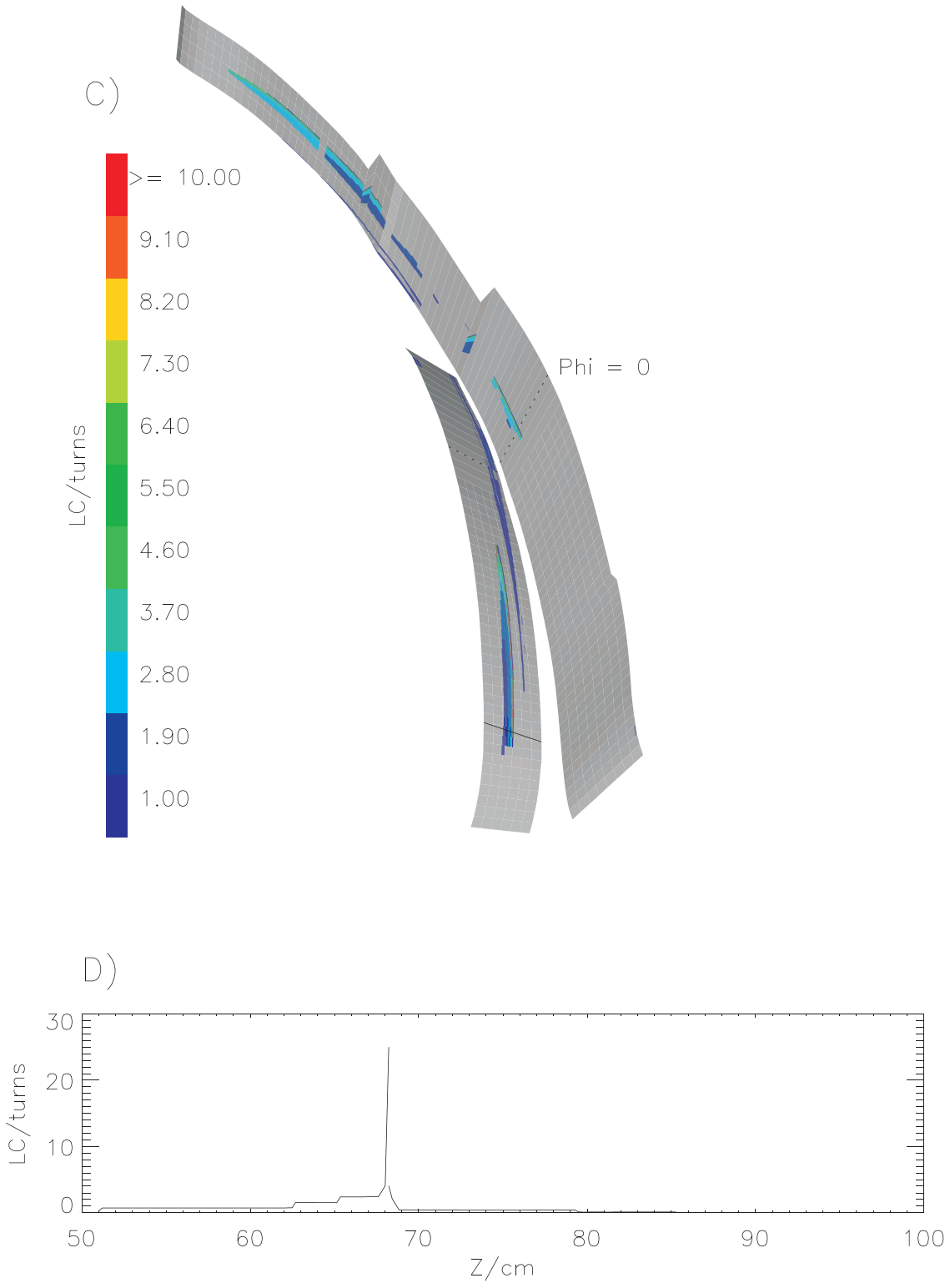

Fig.: 3.2.2
Connection length Lc of the high iota configuration.
Control current Icc = -20 kA.

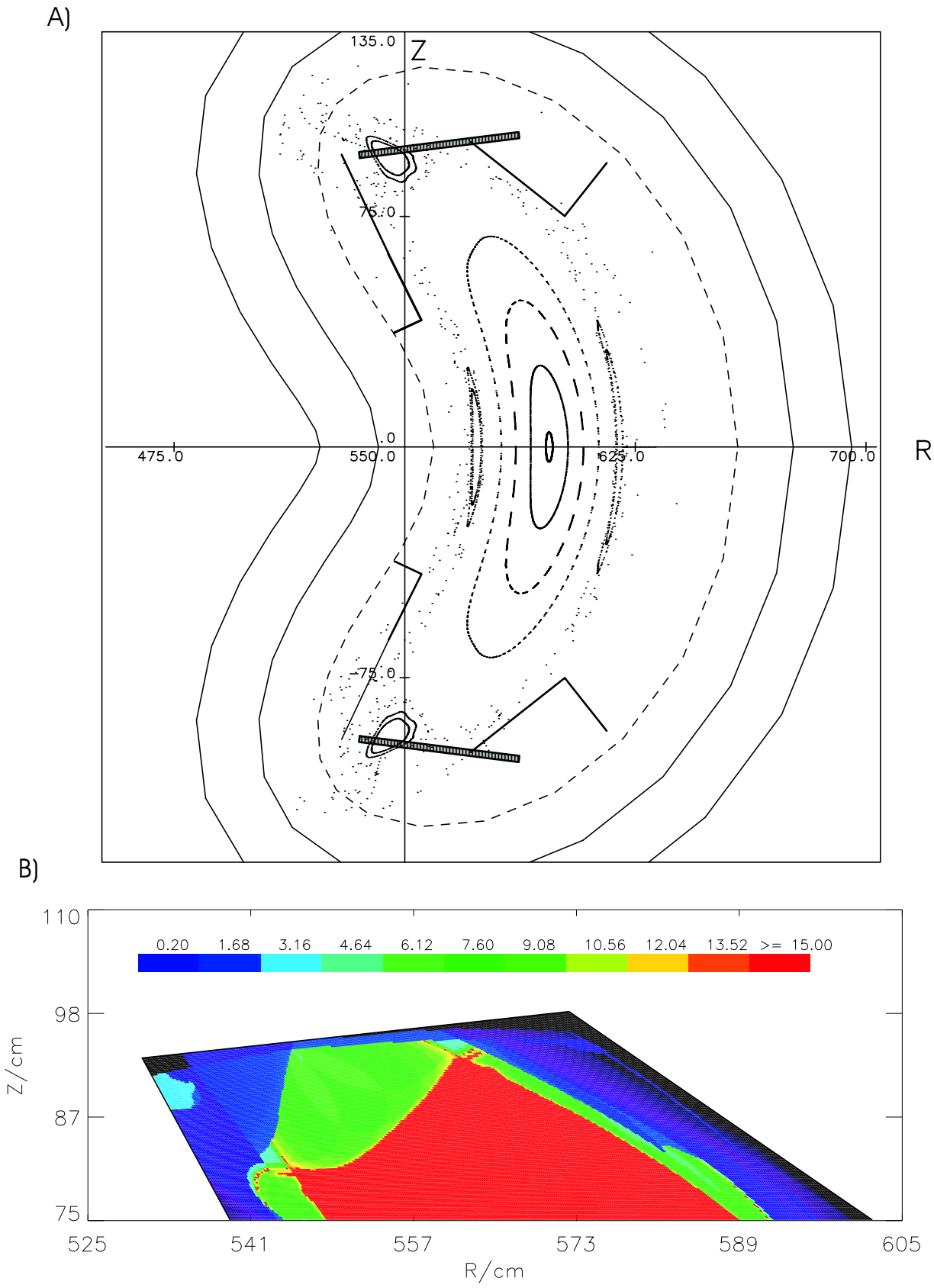

Fig.: 3.3.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = -15 kA.

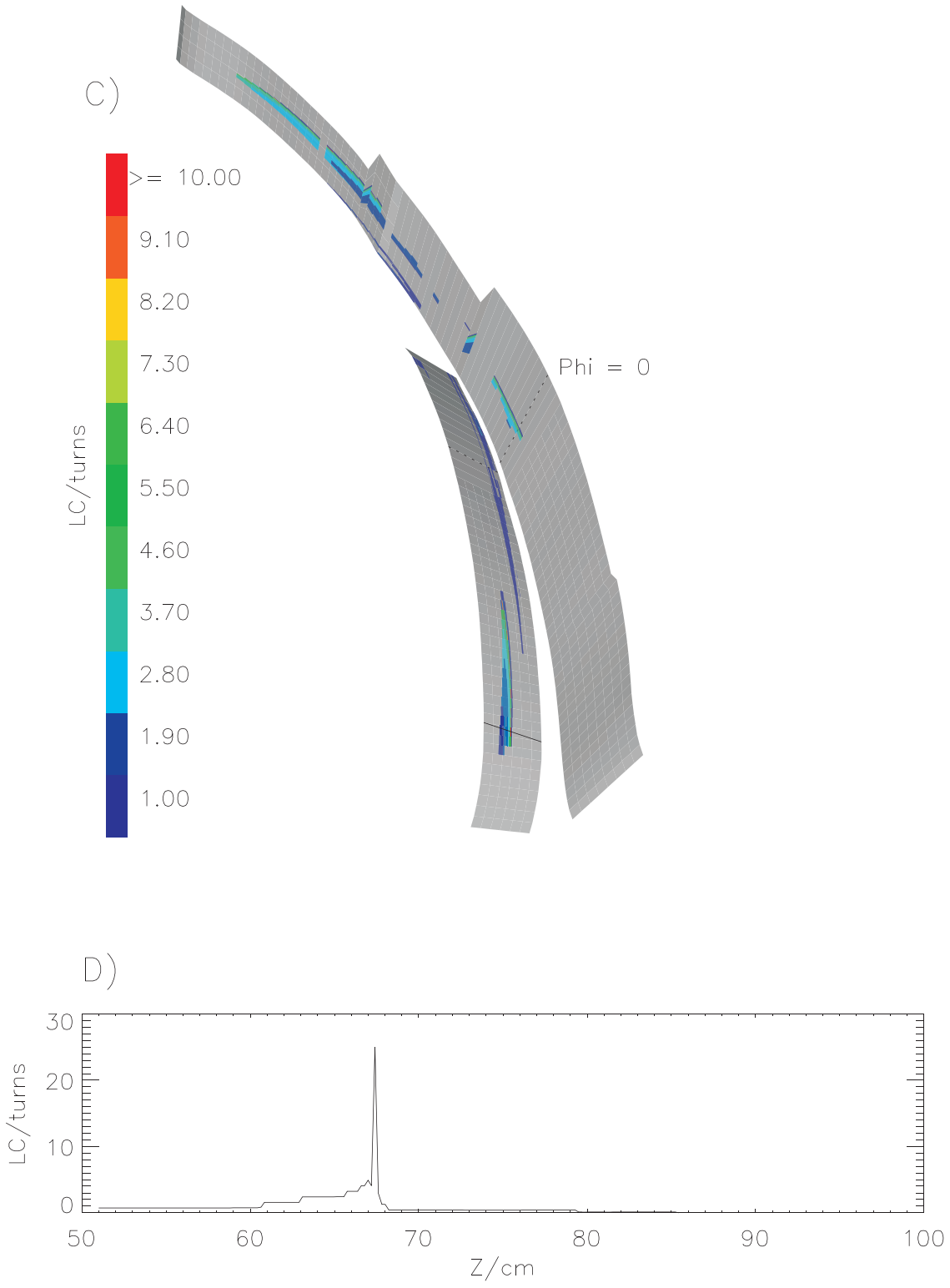

Fig.: 3.3.2
Connection length Lc of the high iota configuration.
Control current Icc = -15 kA.

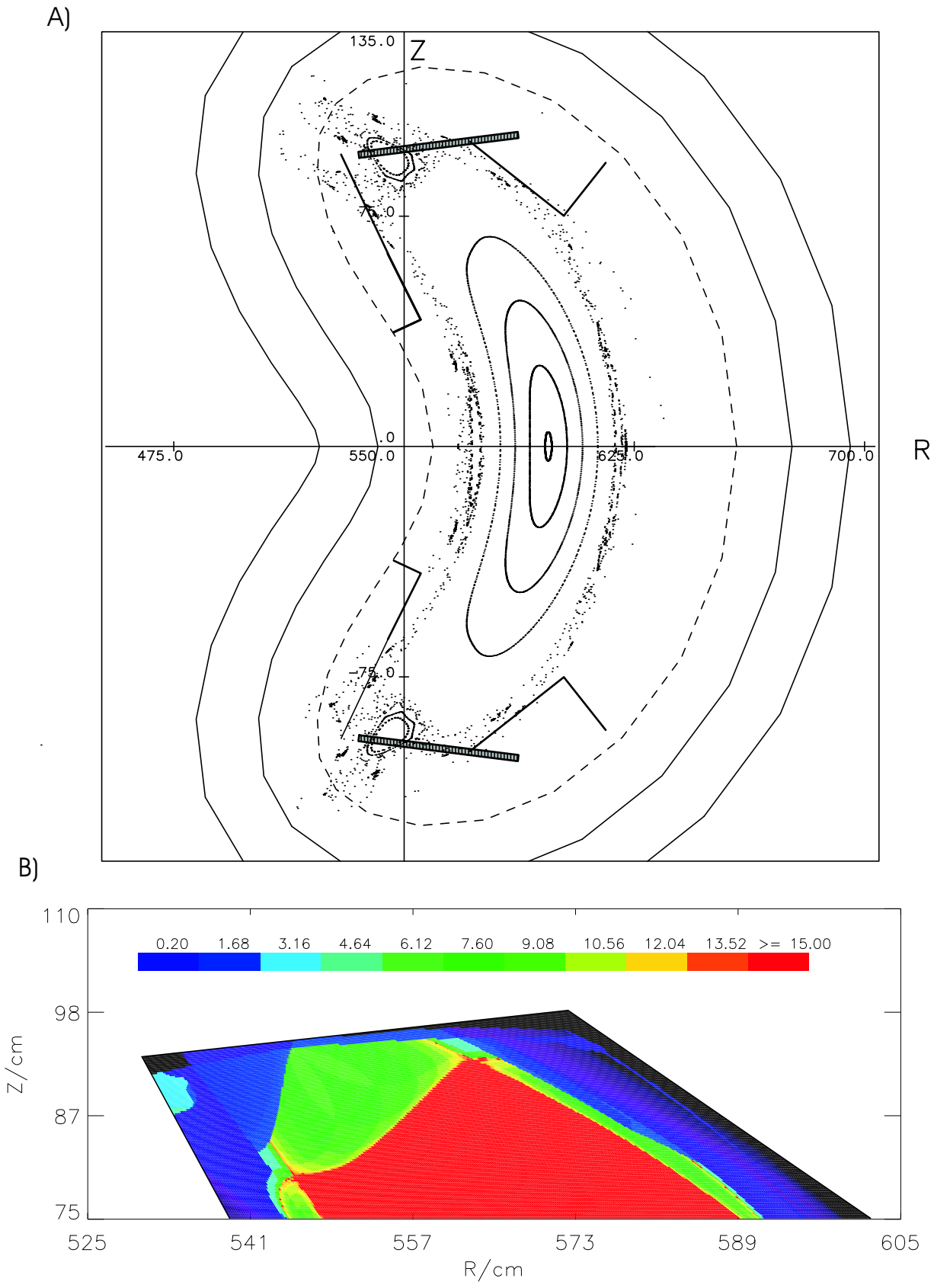

Fig.: 3.4.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = -10 kA.

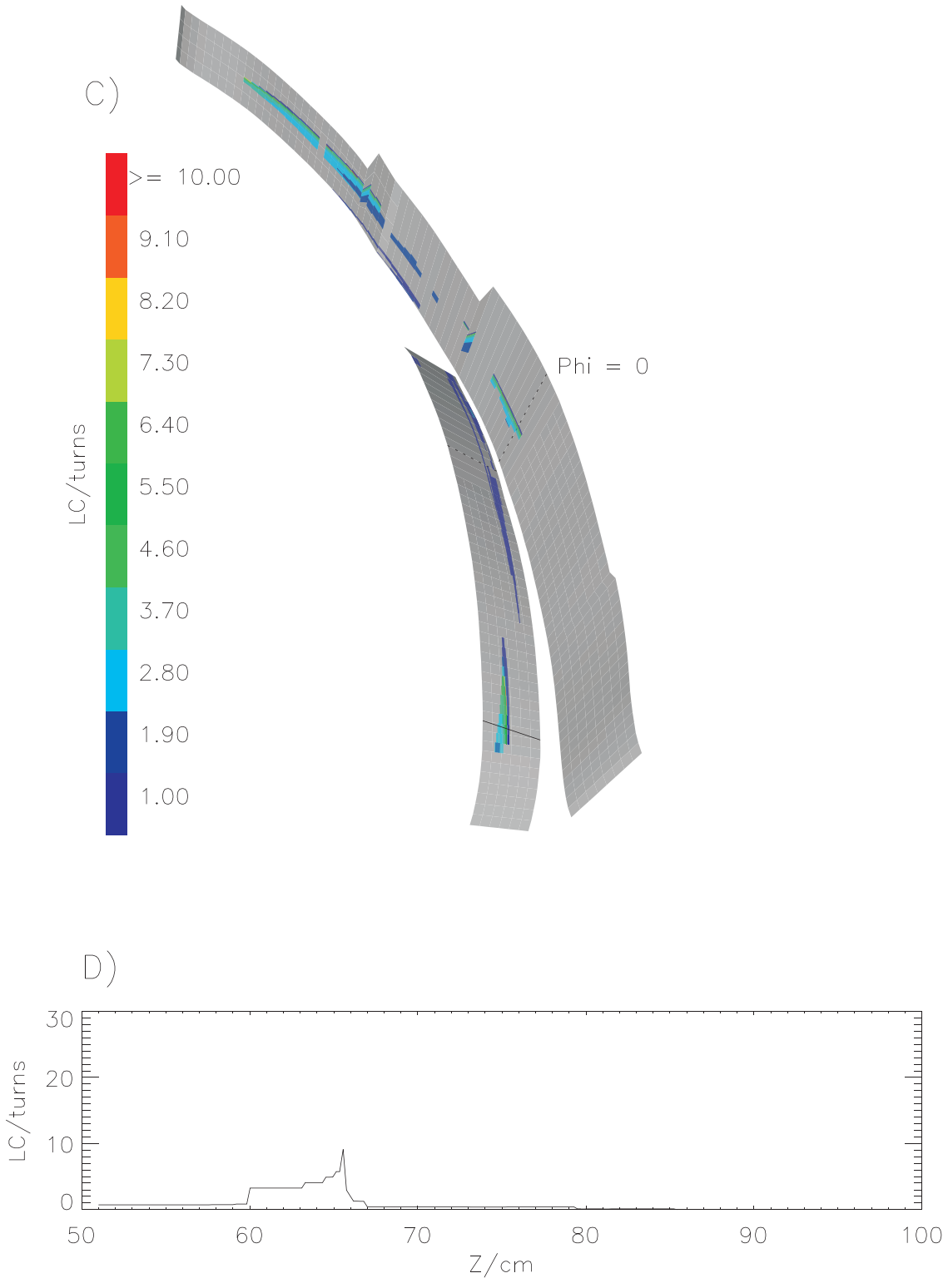

Fig.: 3.4.2
Connection length Lc of the high iota configuration.
Control current Icc = -10 kA.

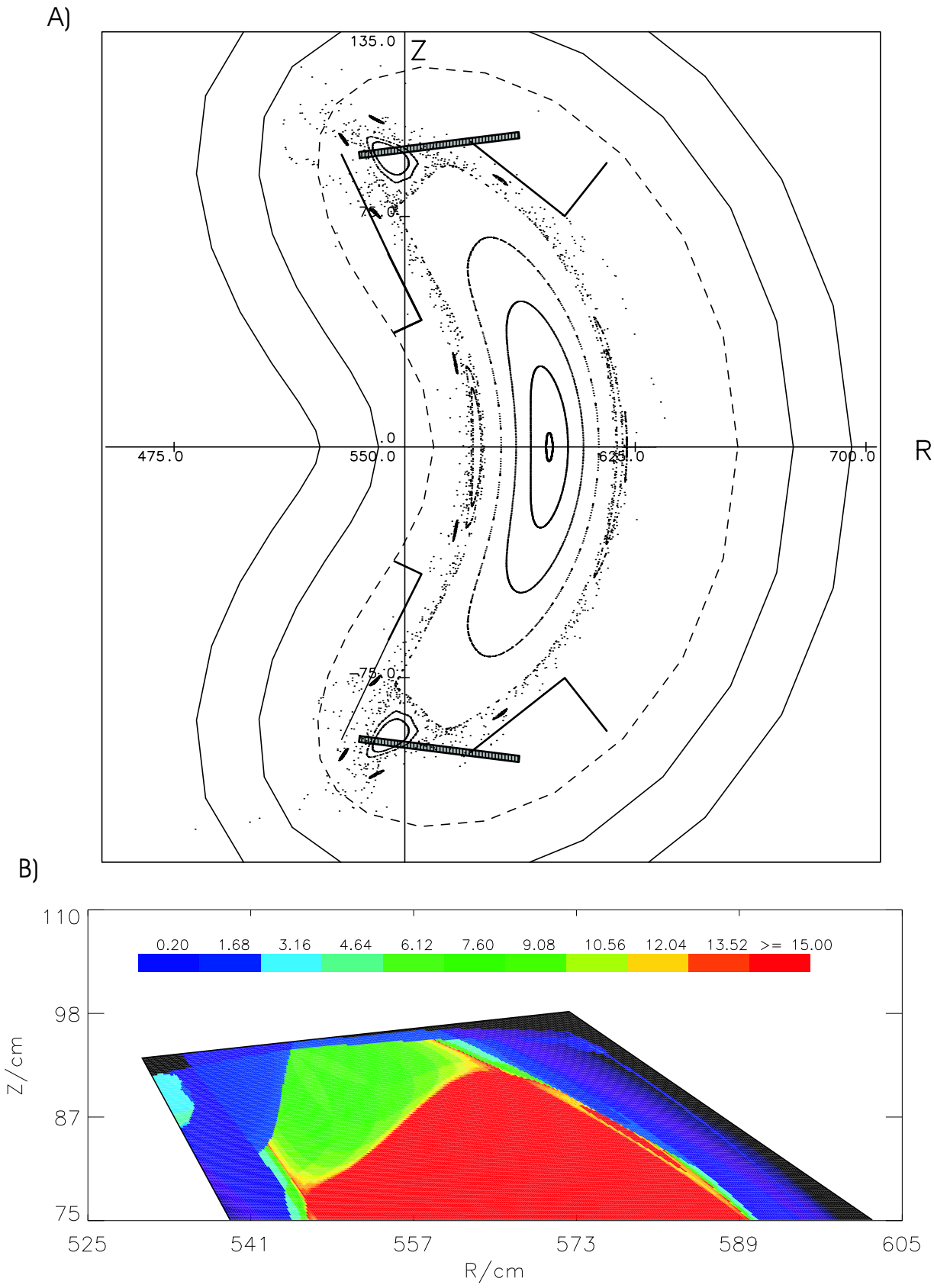

Fig.: 3.5.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = -5 kA.

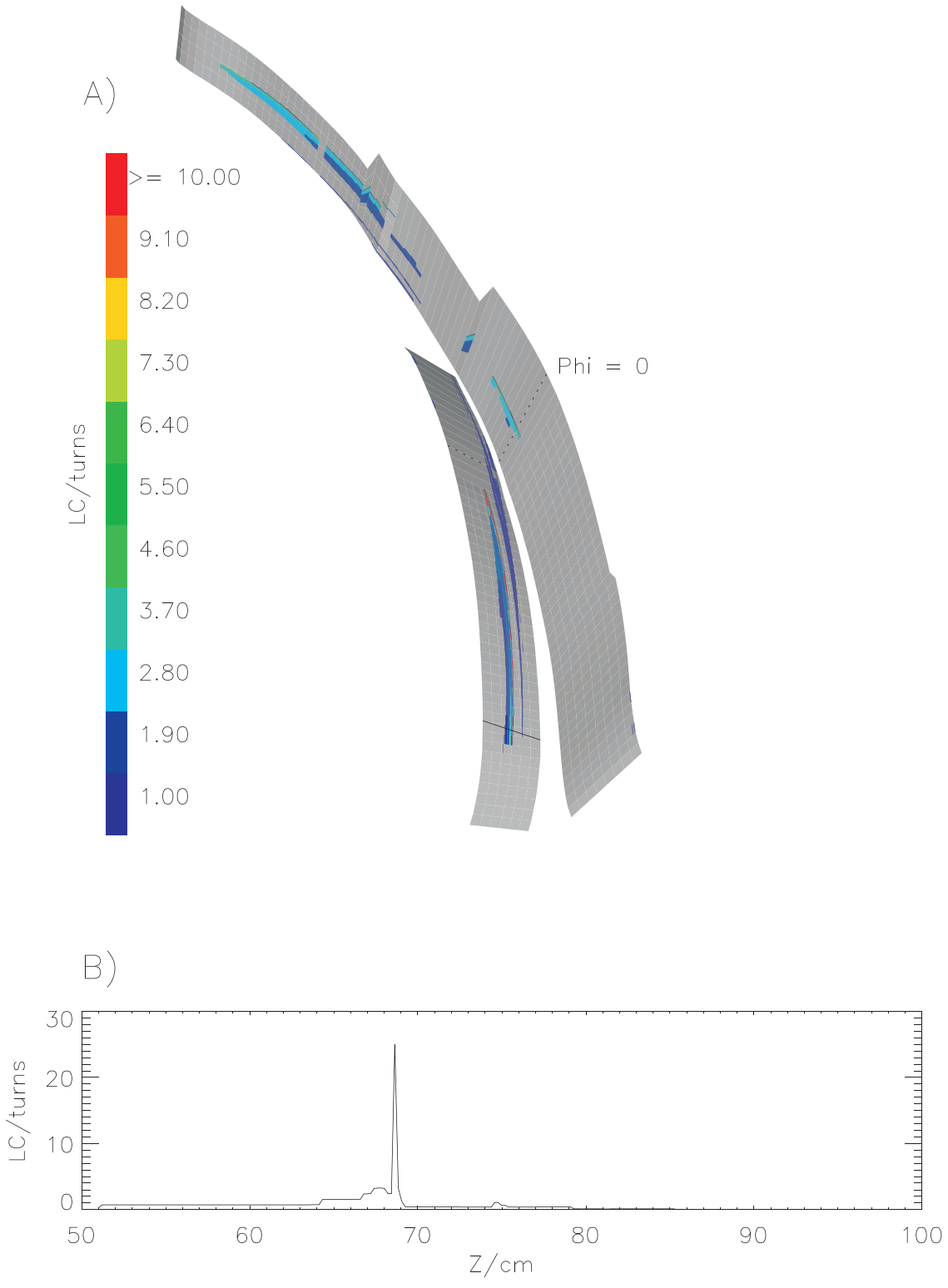

Fig.: 3.5.2
Connection length Lc of the high iota configuration.
Control current Icc = -5 kA.

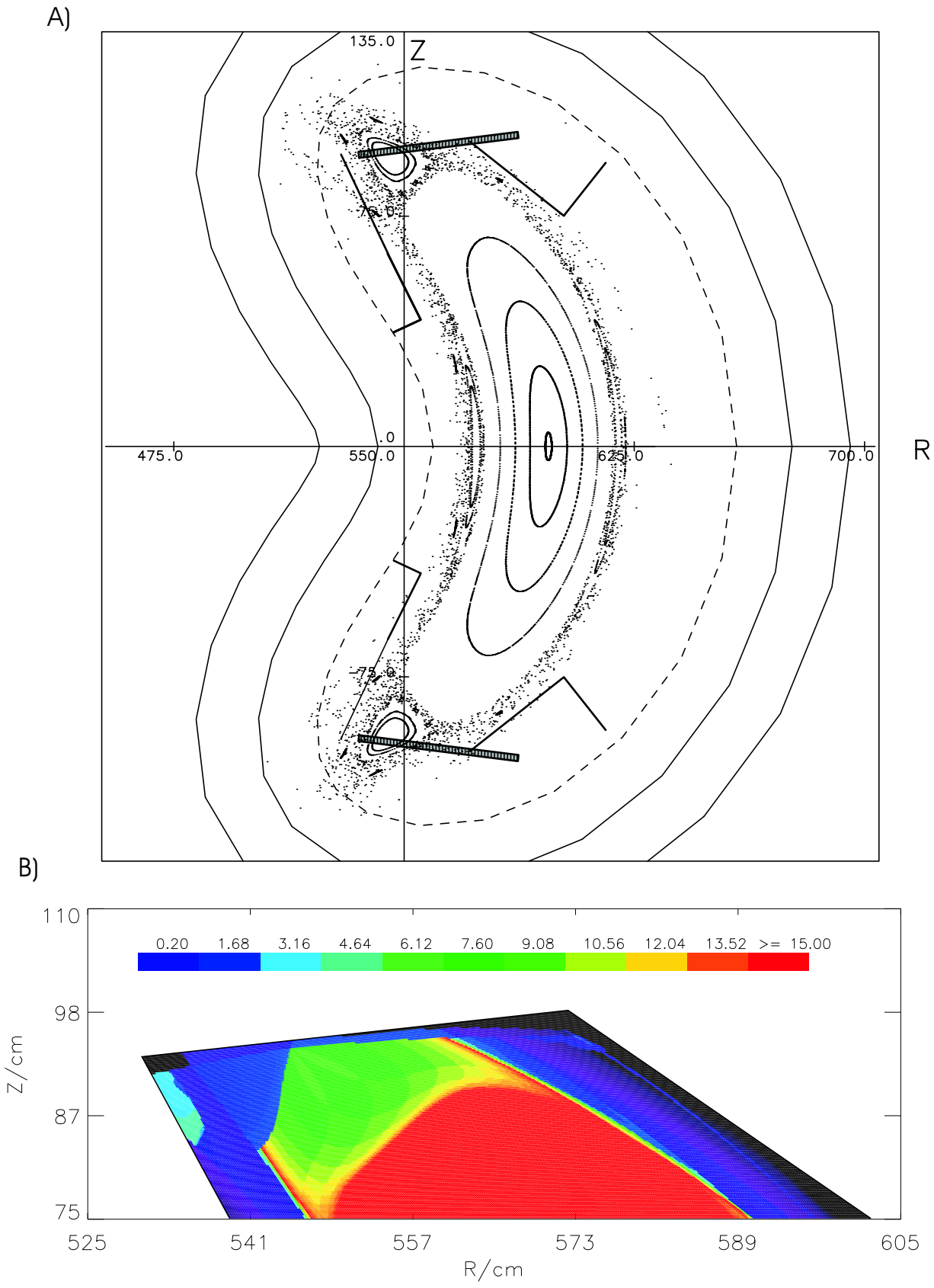

Fig.: 3.6.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = 0 kA.

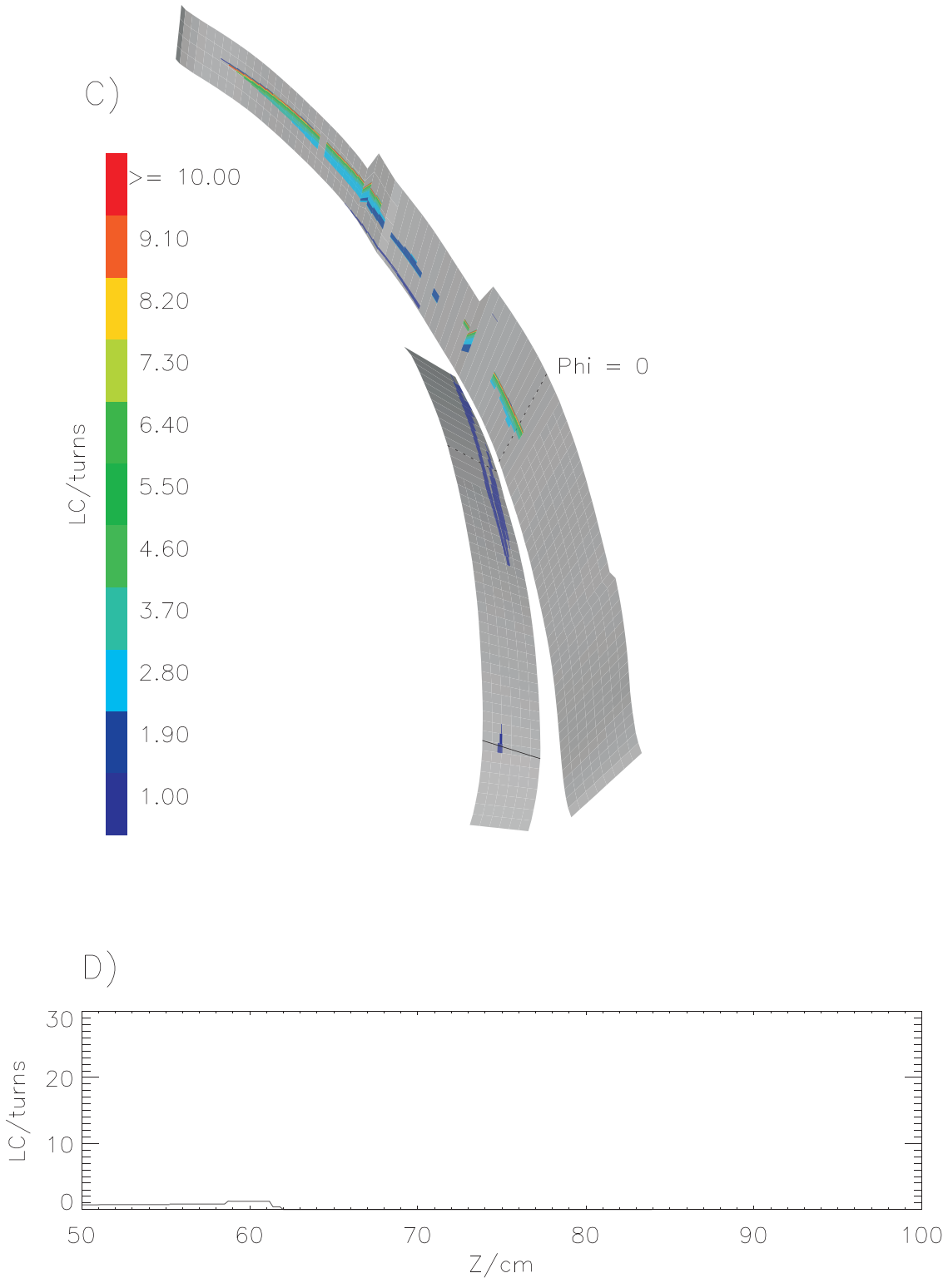

Fig.: 3.6.2
Connection length Lc of the high iota configuration.
Control current Icc = 0 kA.

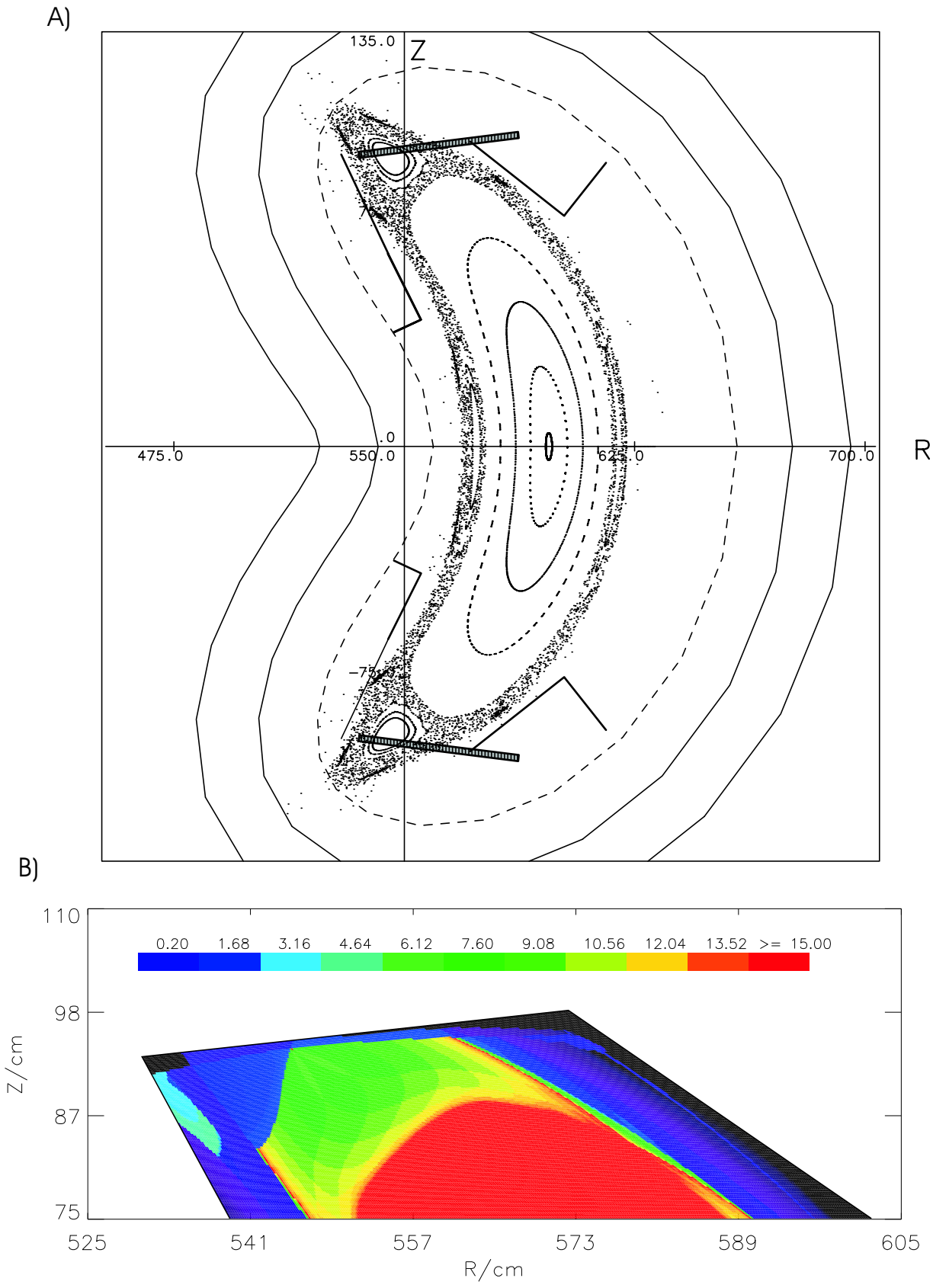

Fig.: 3.7.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = 5 kA.

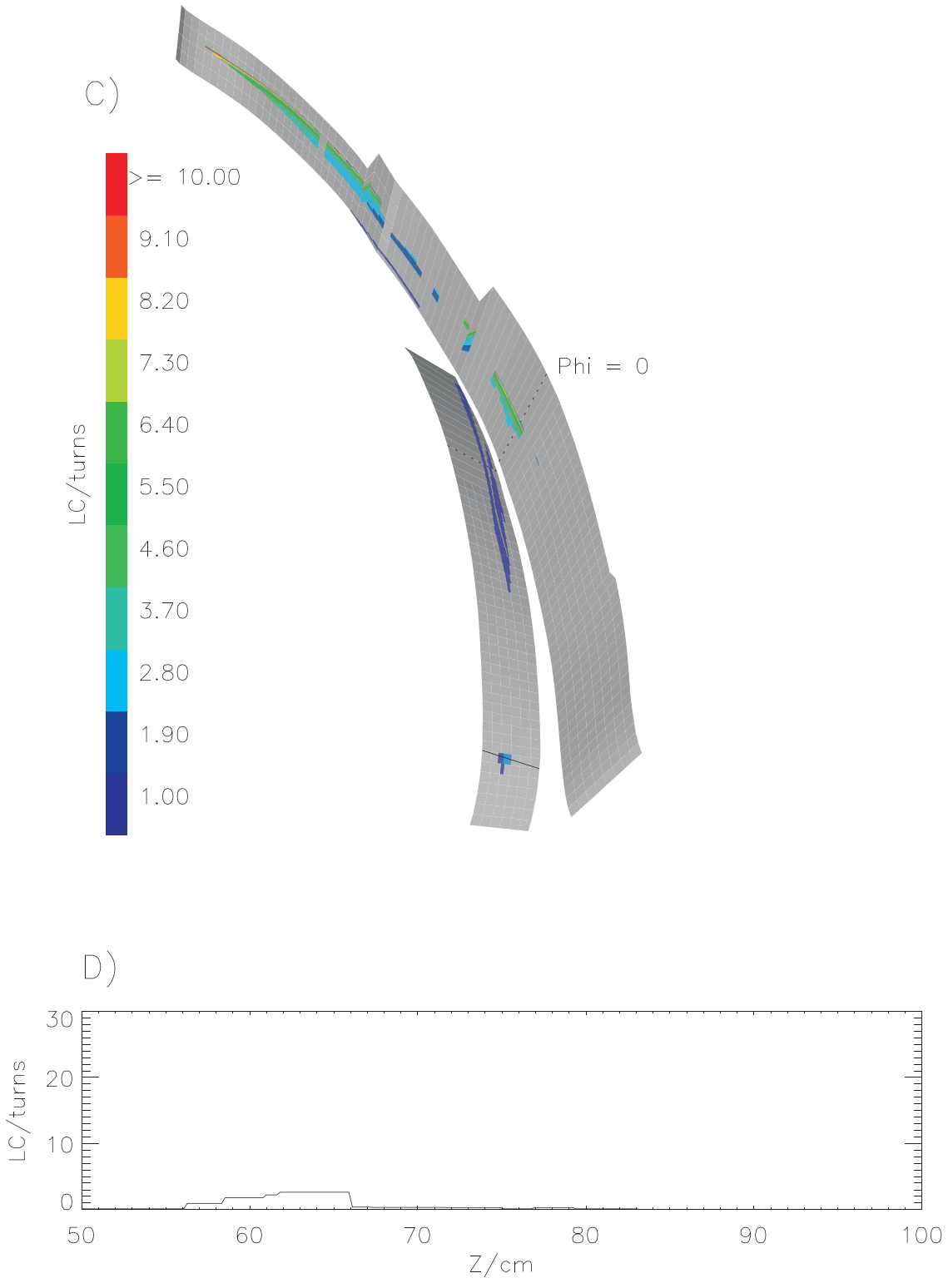

Fig.: 3.7.2
Connection length Lc of the high iota configuration.
Control current Icc = 5 kA.

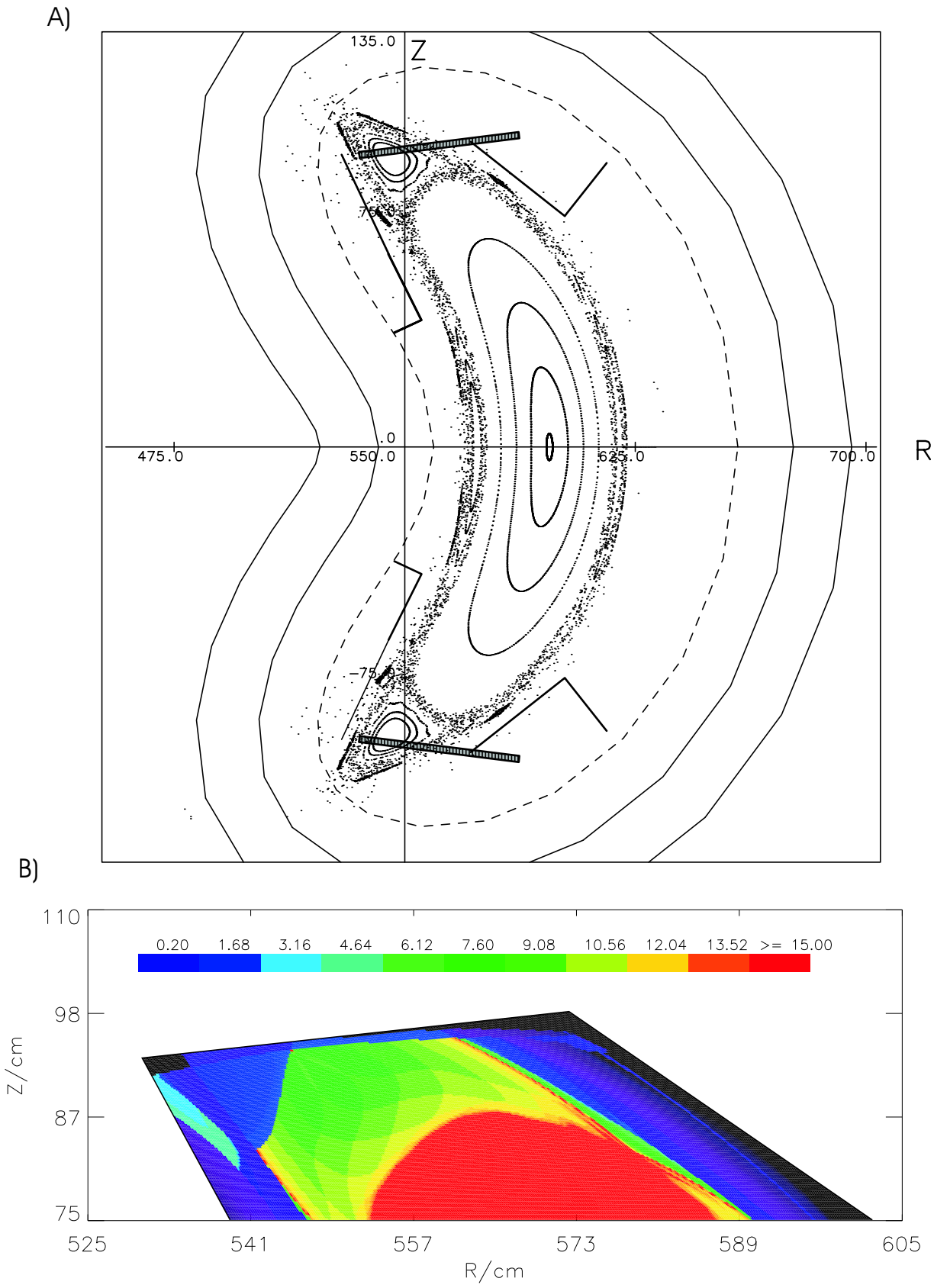

Fig.: 3.8.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = 10 kA.

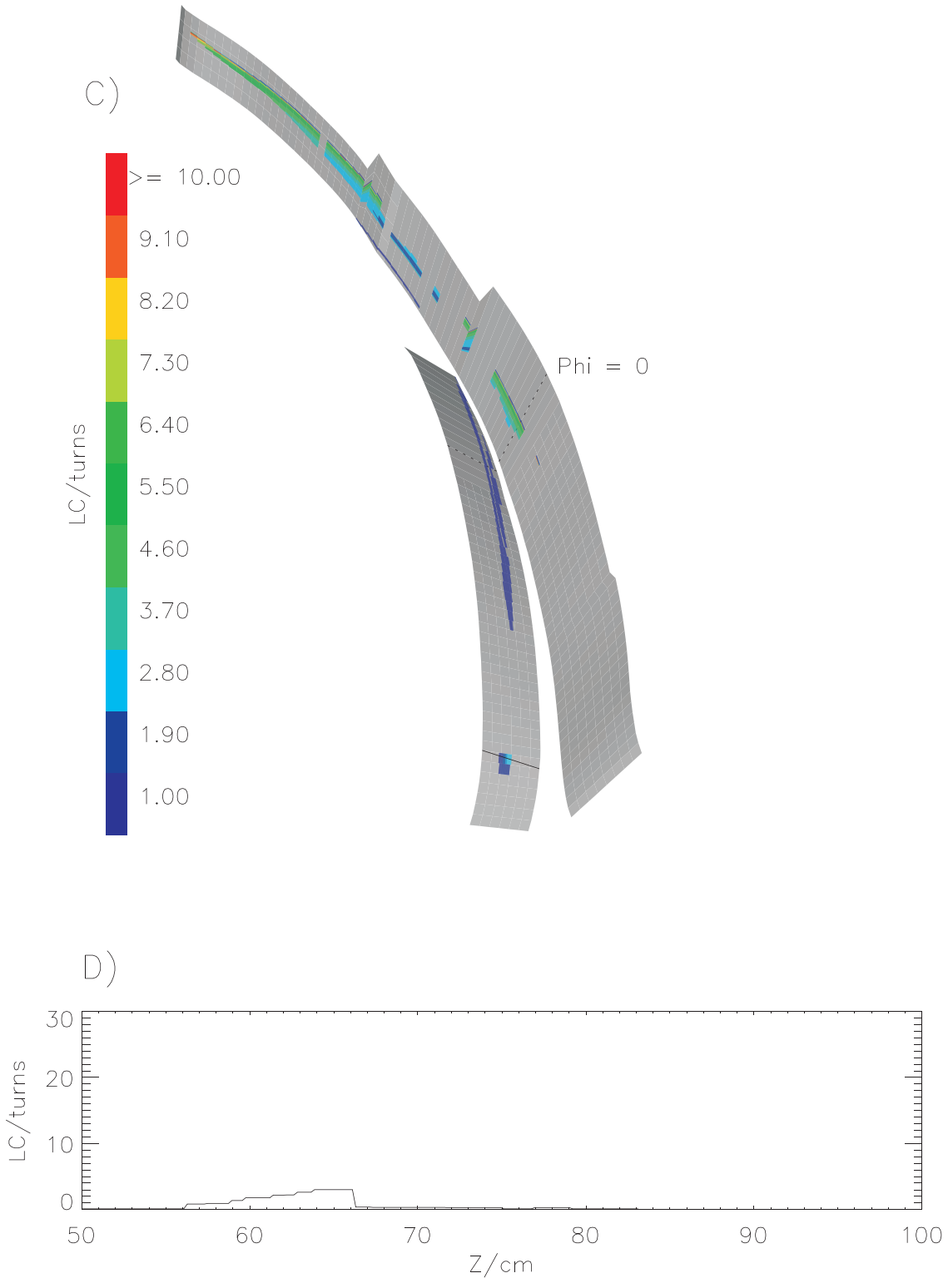

Fig.: 3.8.2
Connection length Lc of the high iota configuration.
Control current Icc = 10 kA.

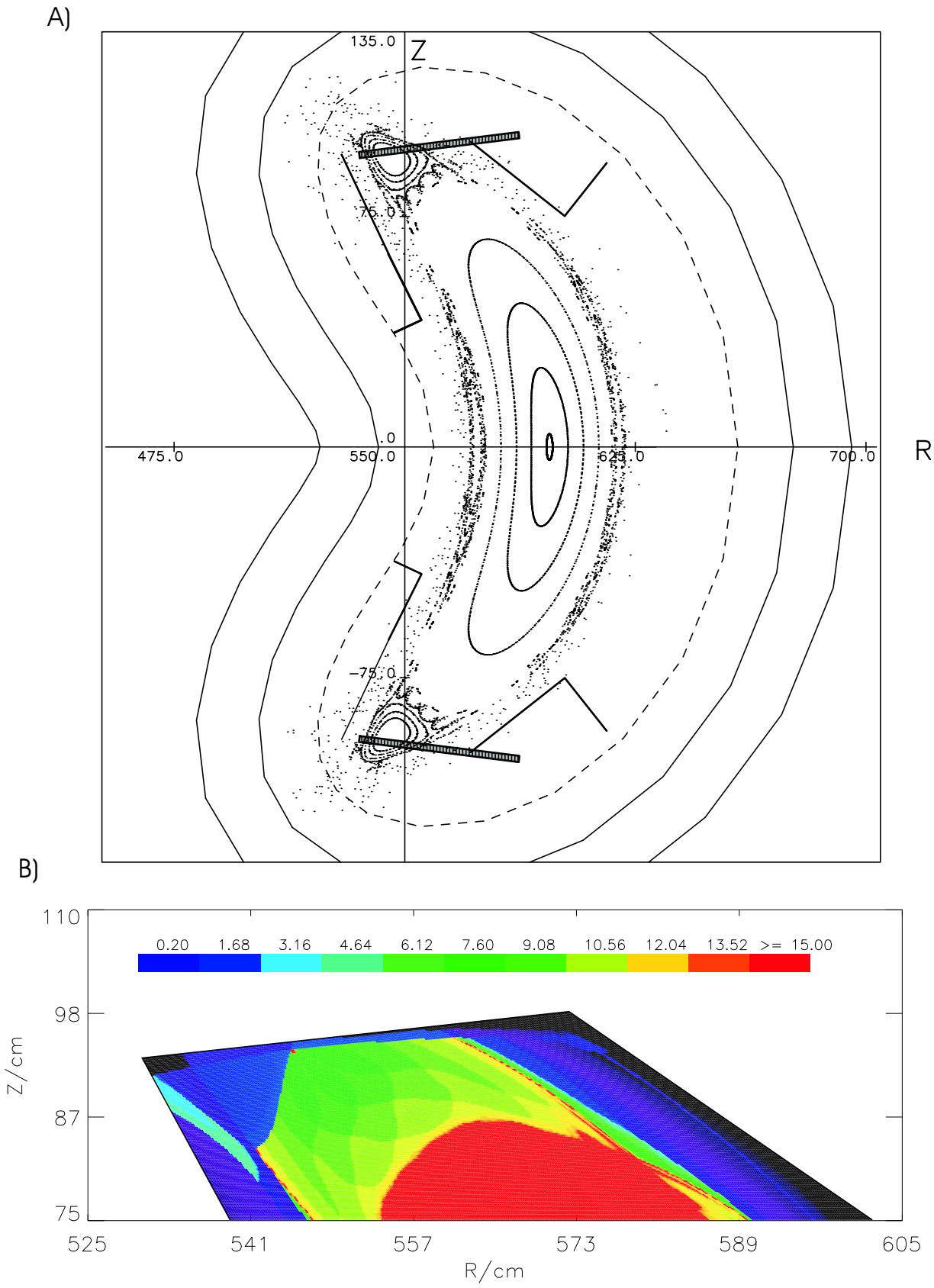

Fig.: 3.9.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = 15 kA.

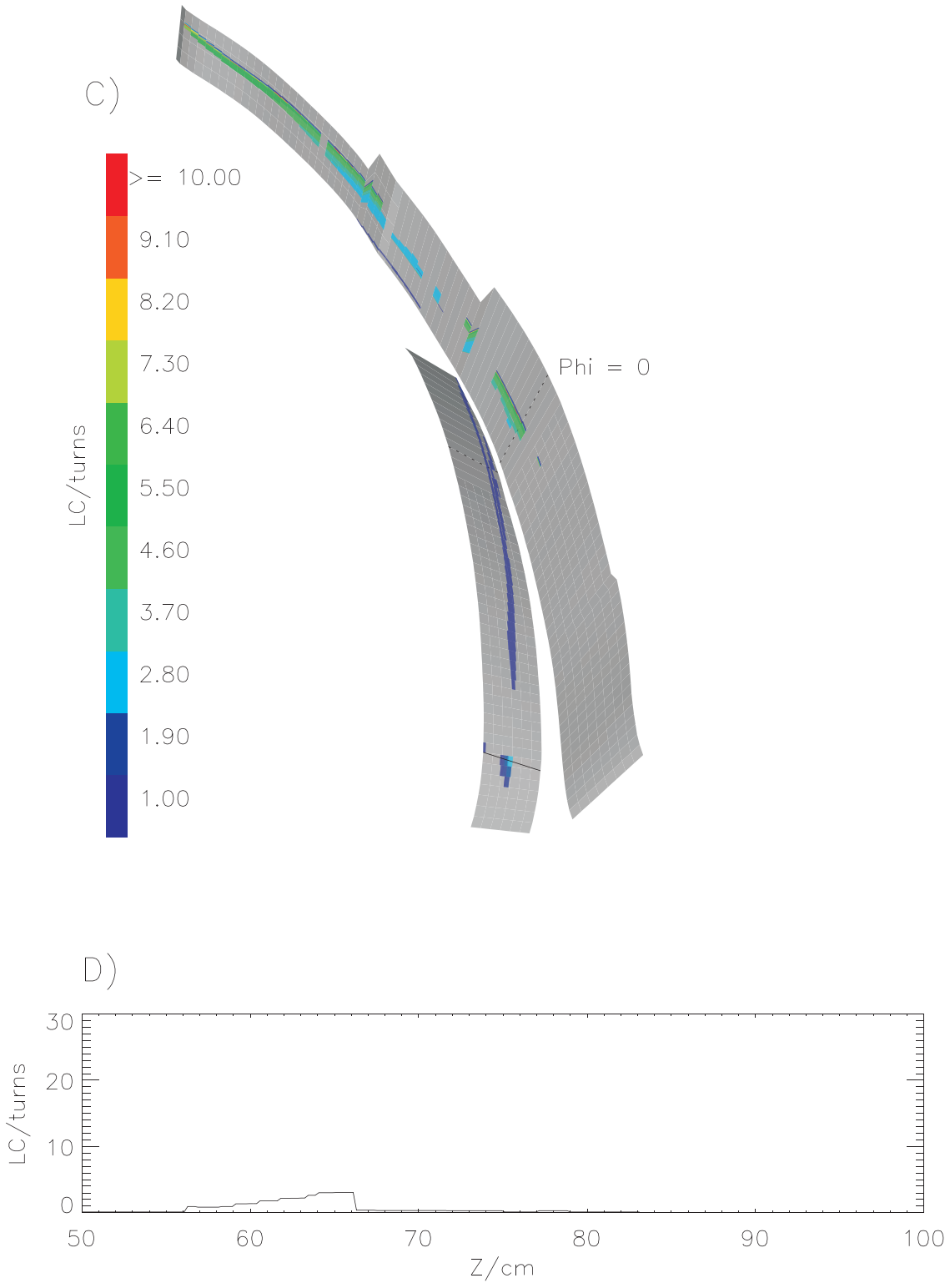

Fig.: 3.9.2
Connection length Lc of the high iota configuration.
Control current Icc = 15 kA.

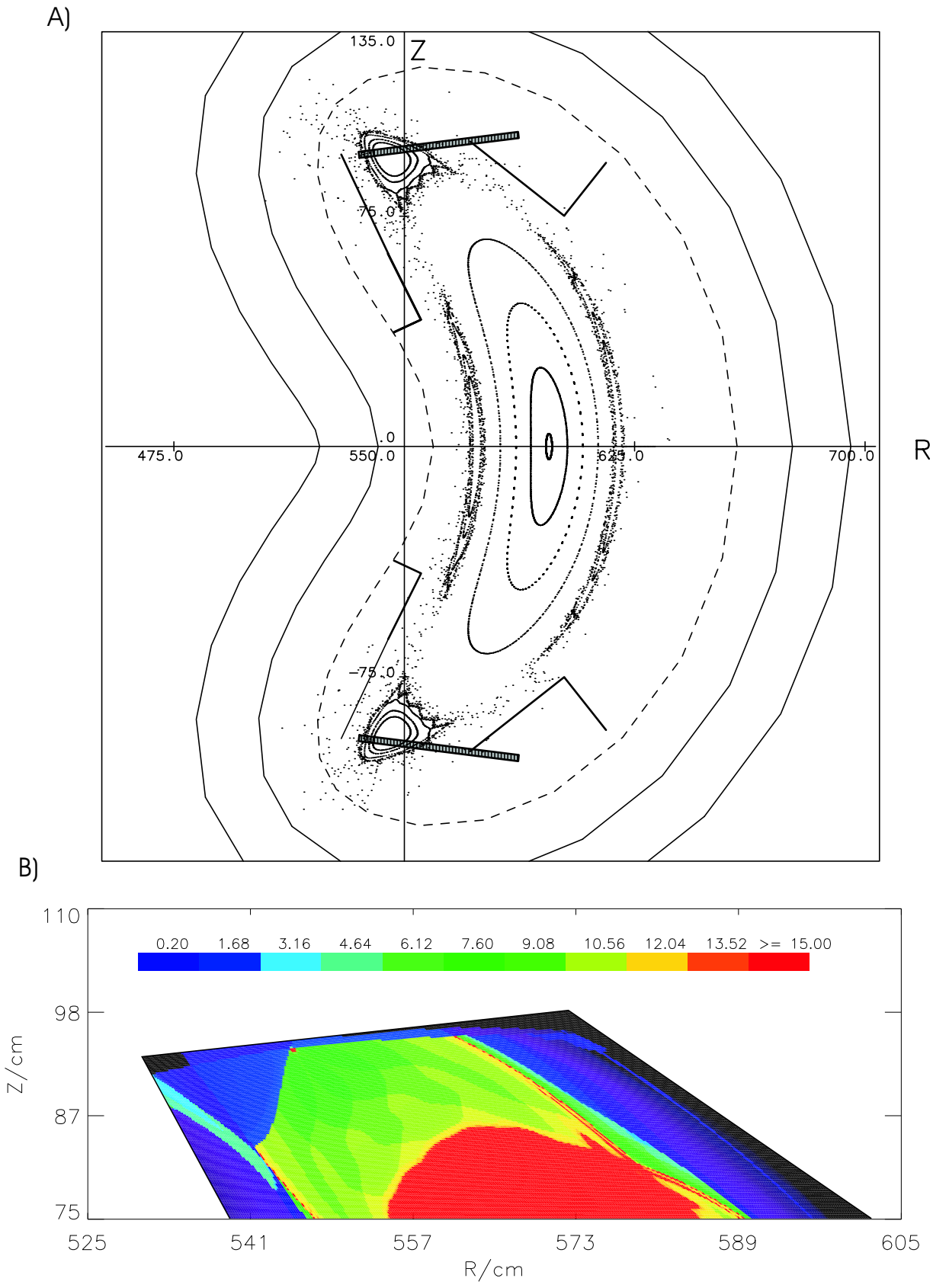

Fig.: 3.10.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = 20 kA.

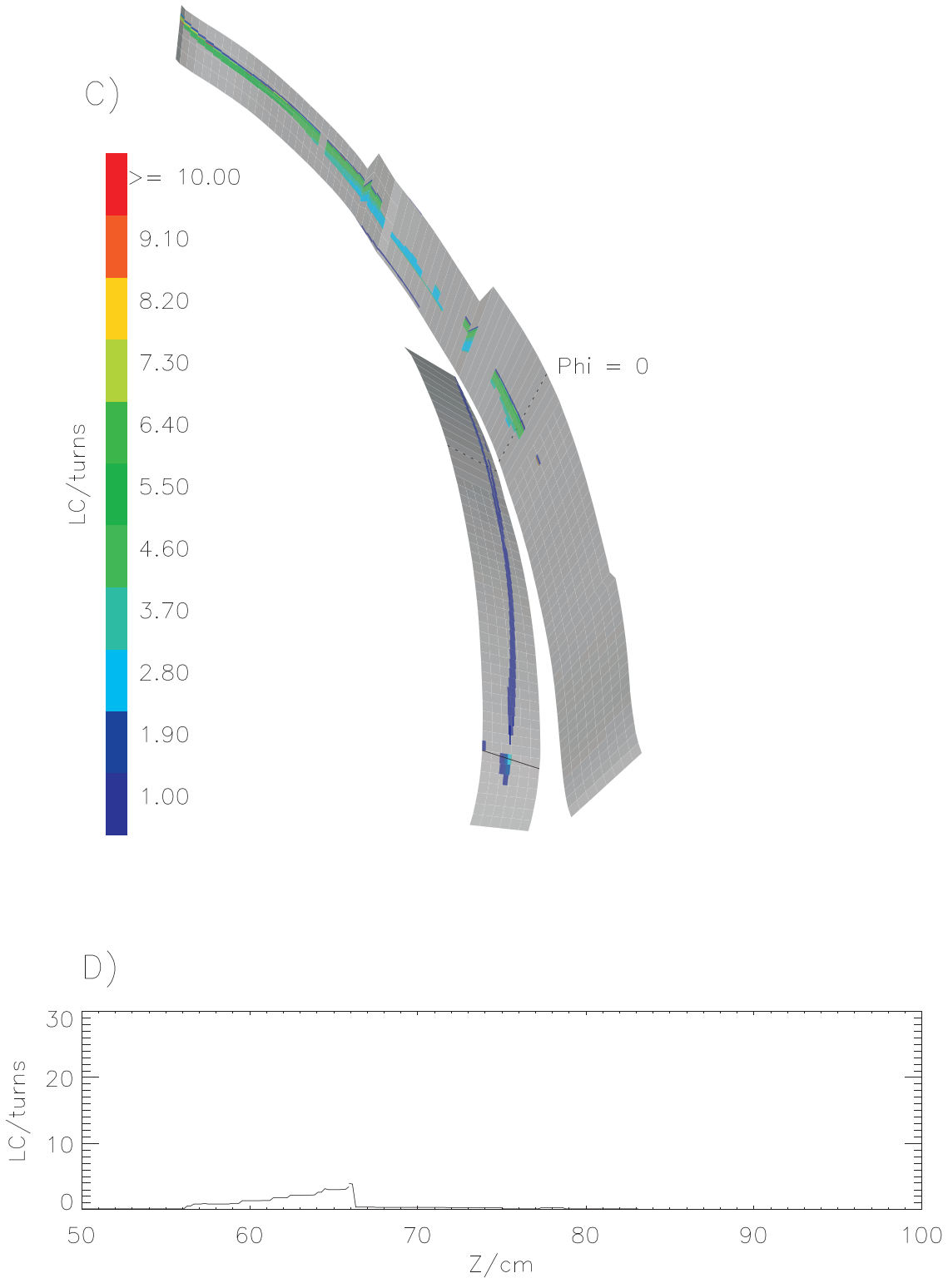

Fig.: 3.10.2
Connection length Lc of the high iota configuration.
Control current Icc = 20 kA.

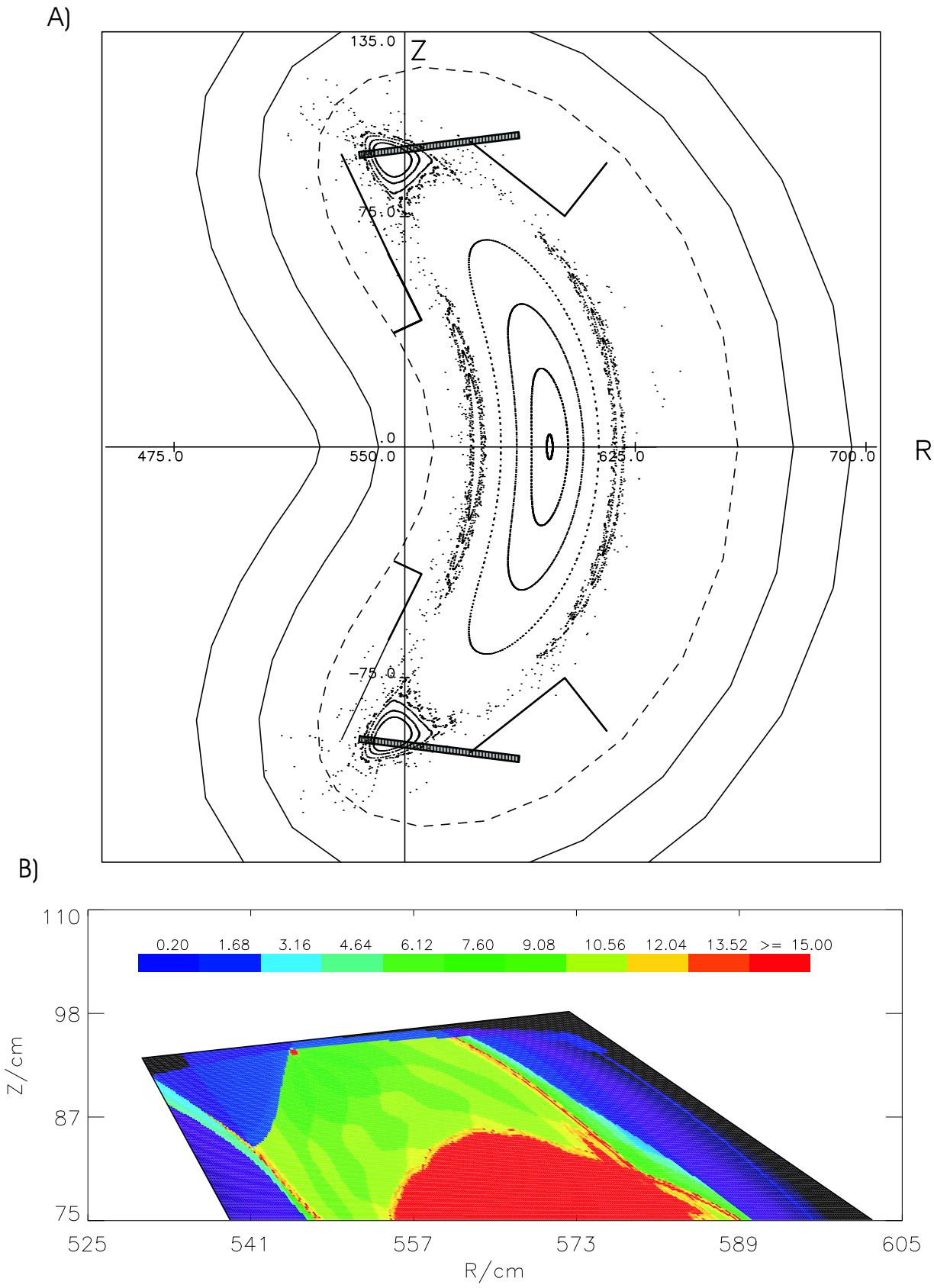

Fig.: 3.11.1

Poincaré plot and colour contour of the high iota configuration.

Control current Icc = 25 kA.

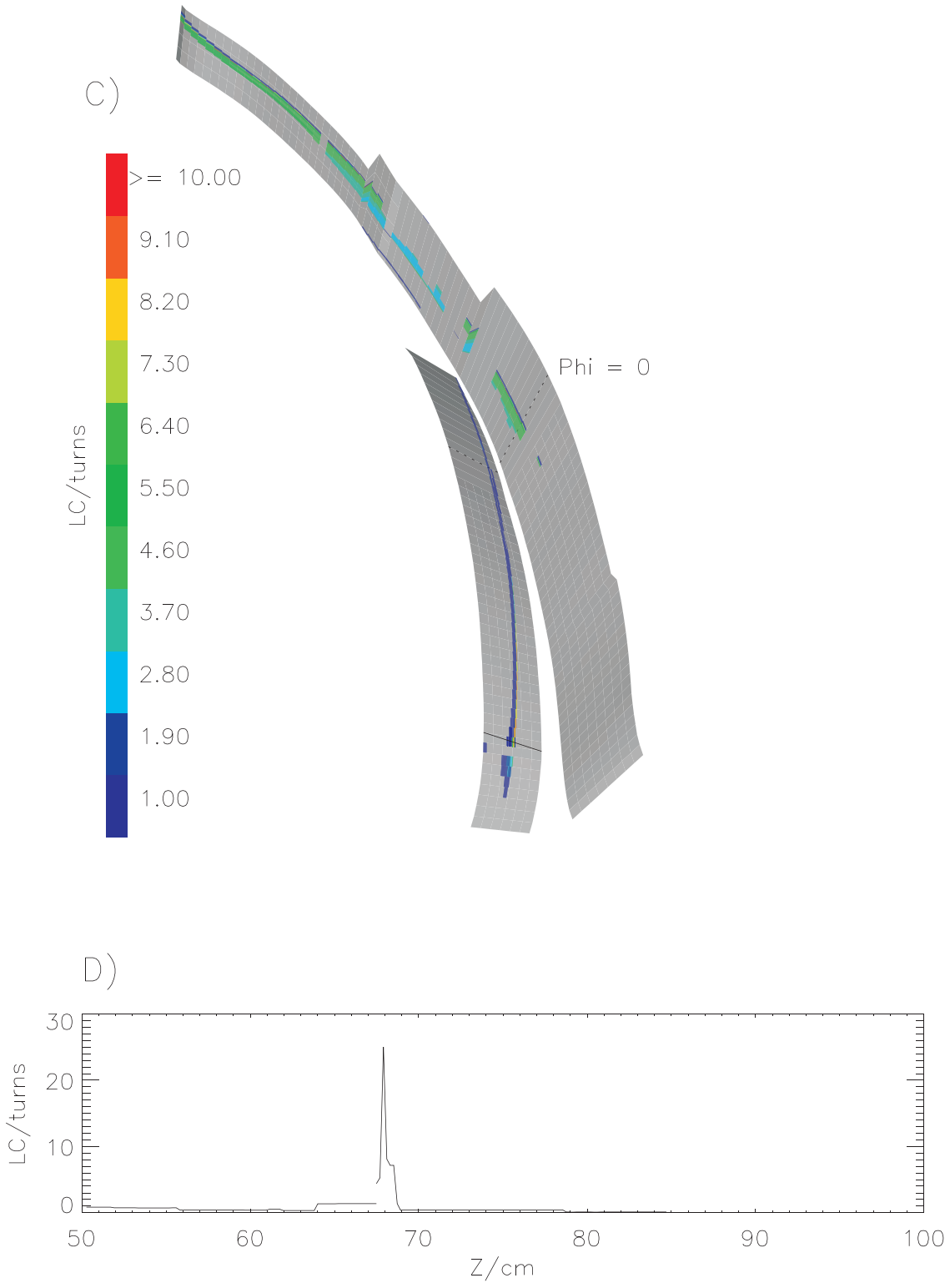

Fig.: 3.11.2
Connection length Lc of the high iota configuration.
Control current Icc = 20 kA.

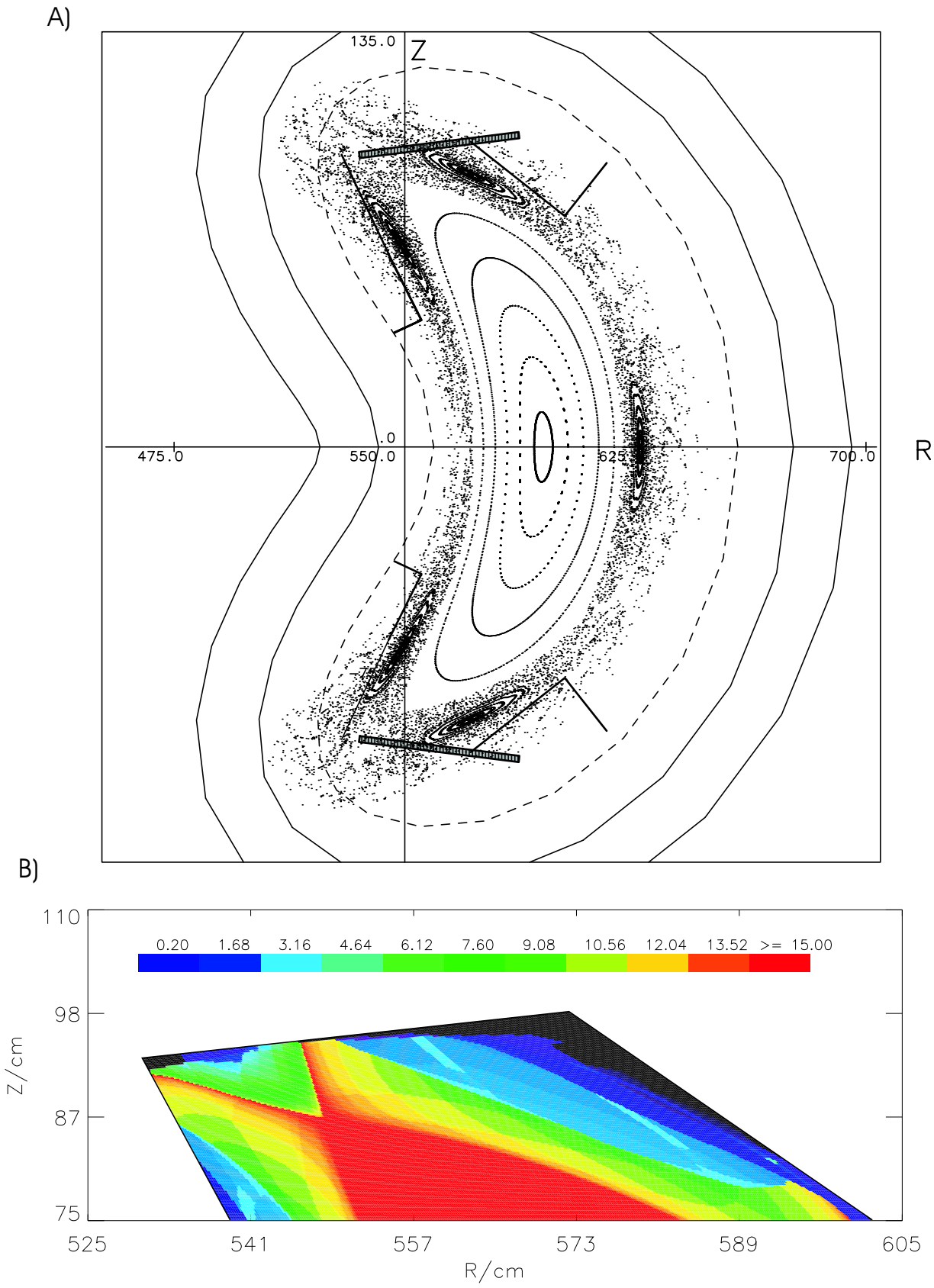

Fig.: 4.1.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = -25 kA.

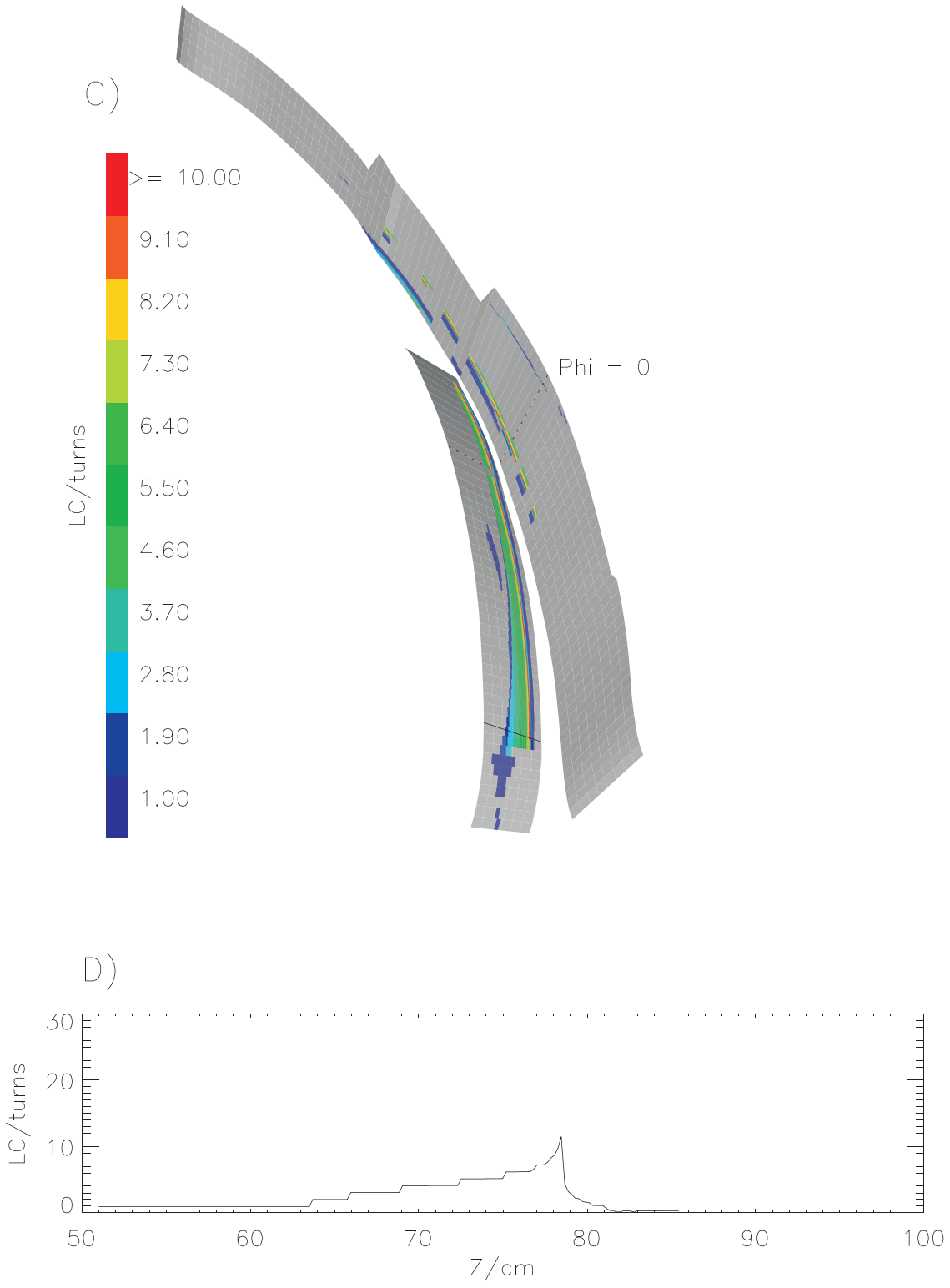

Fig.: 4.1.2
Connection length Lc of the low shear configuration.
Control current Icc = -25 kA.

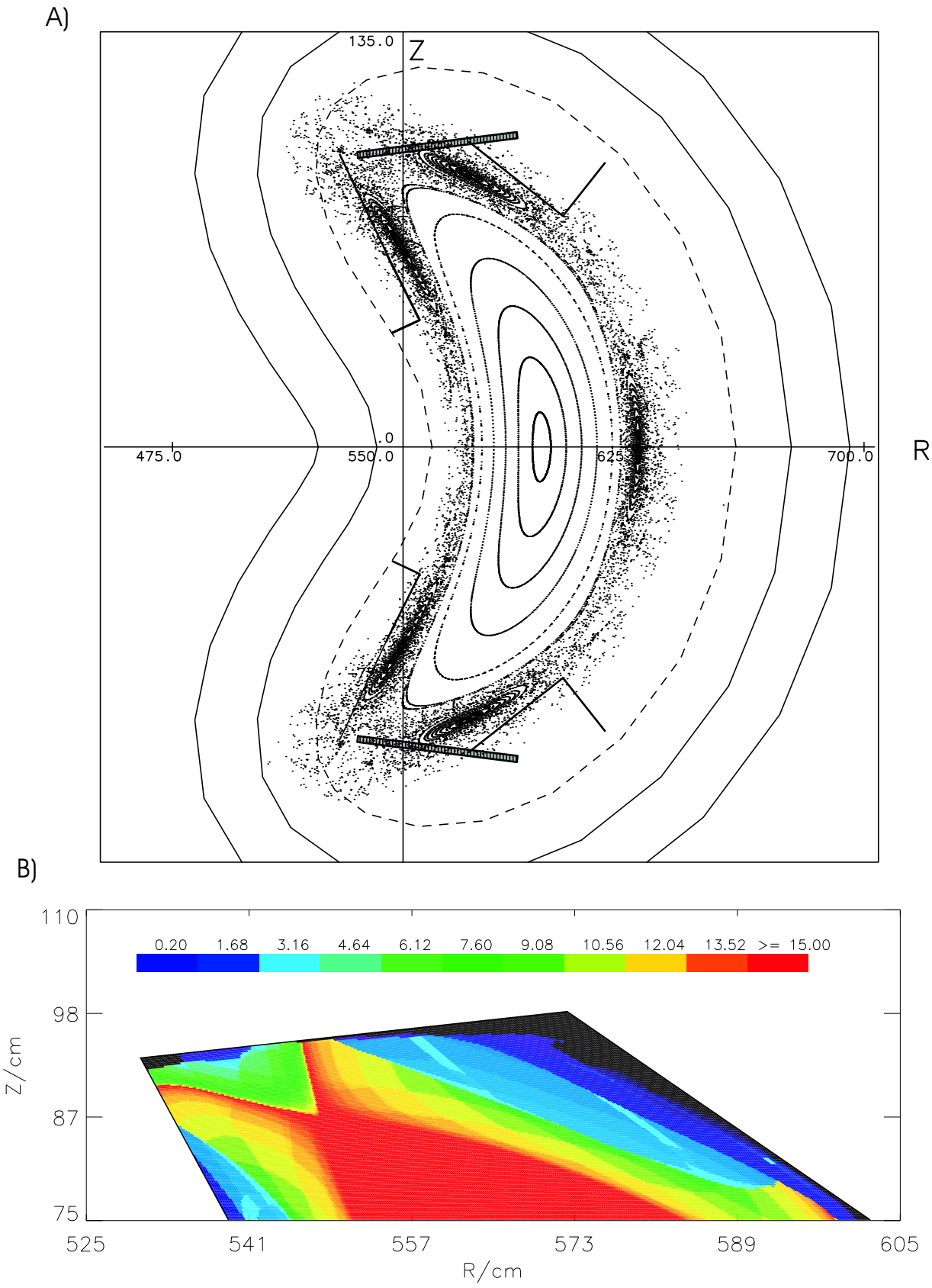

Fig.: 4.2.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = -20 kA.

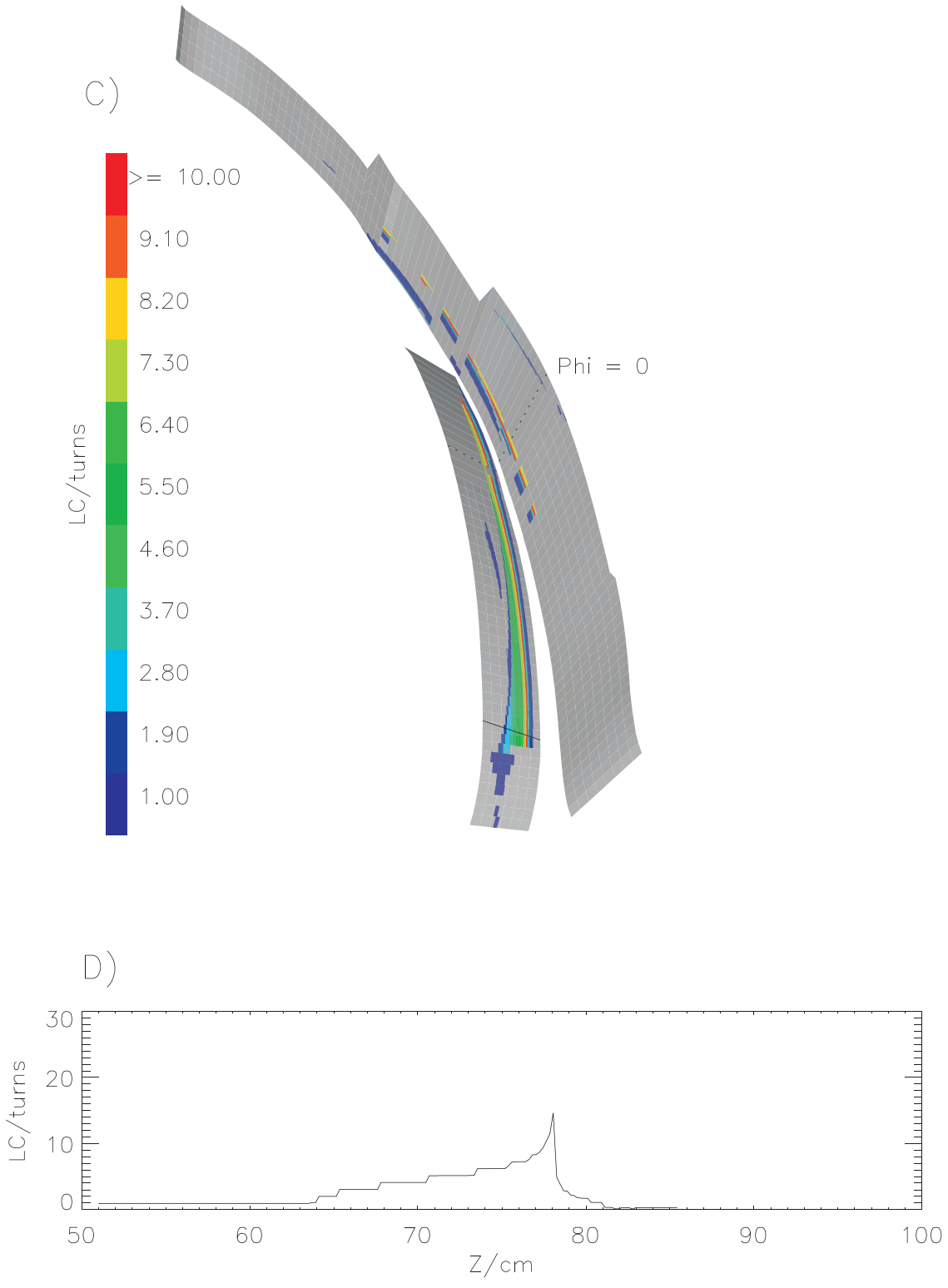

Fig.: 4.2.2
Connection length Lc of the low shear configuration.
Control current Icc = -20 kA.

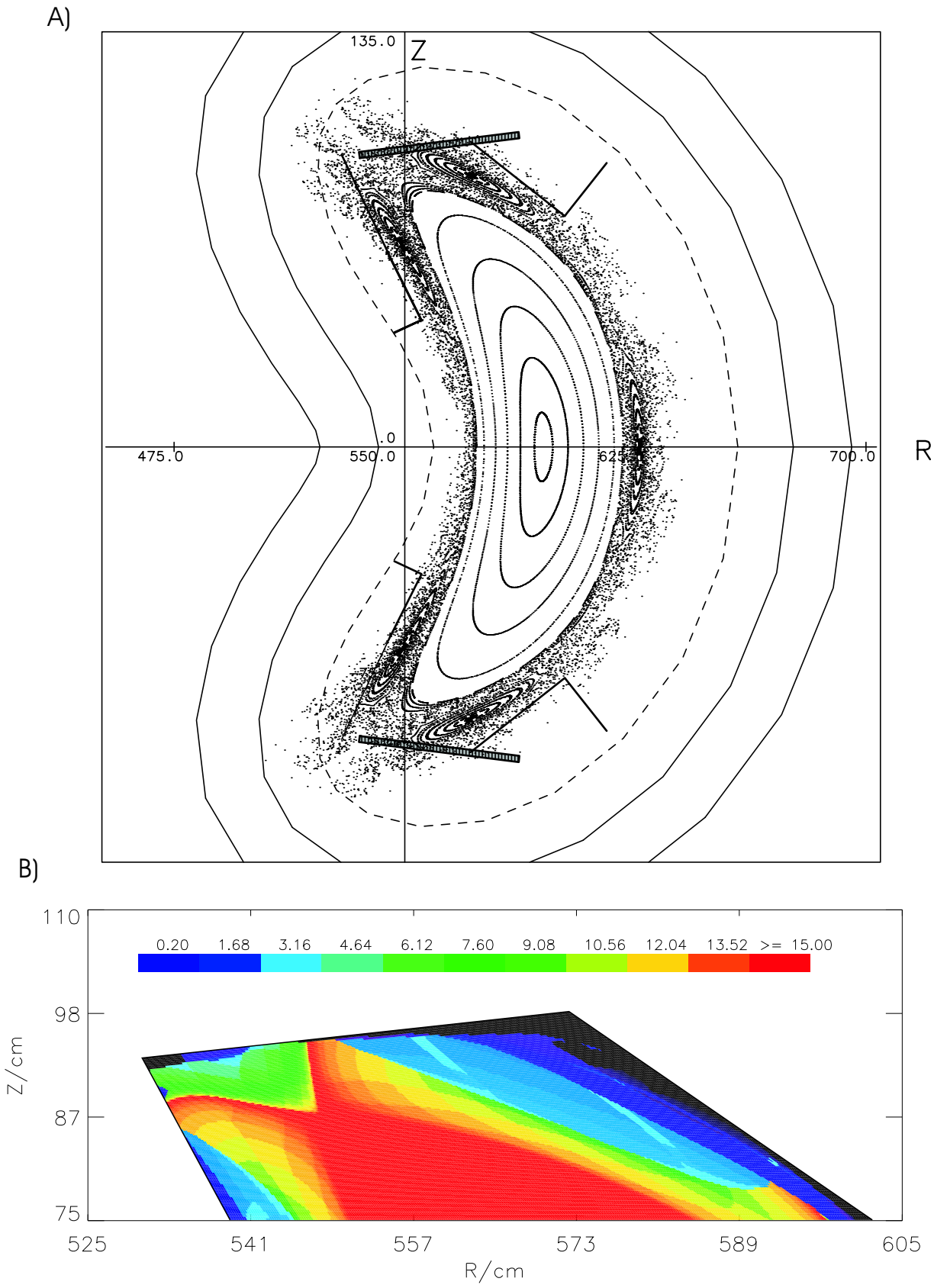

Fig.: 4.3.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = -15 kA.

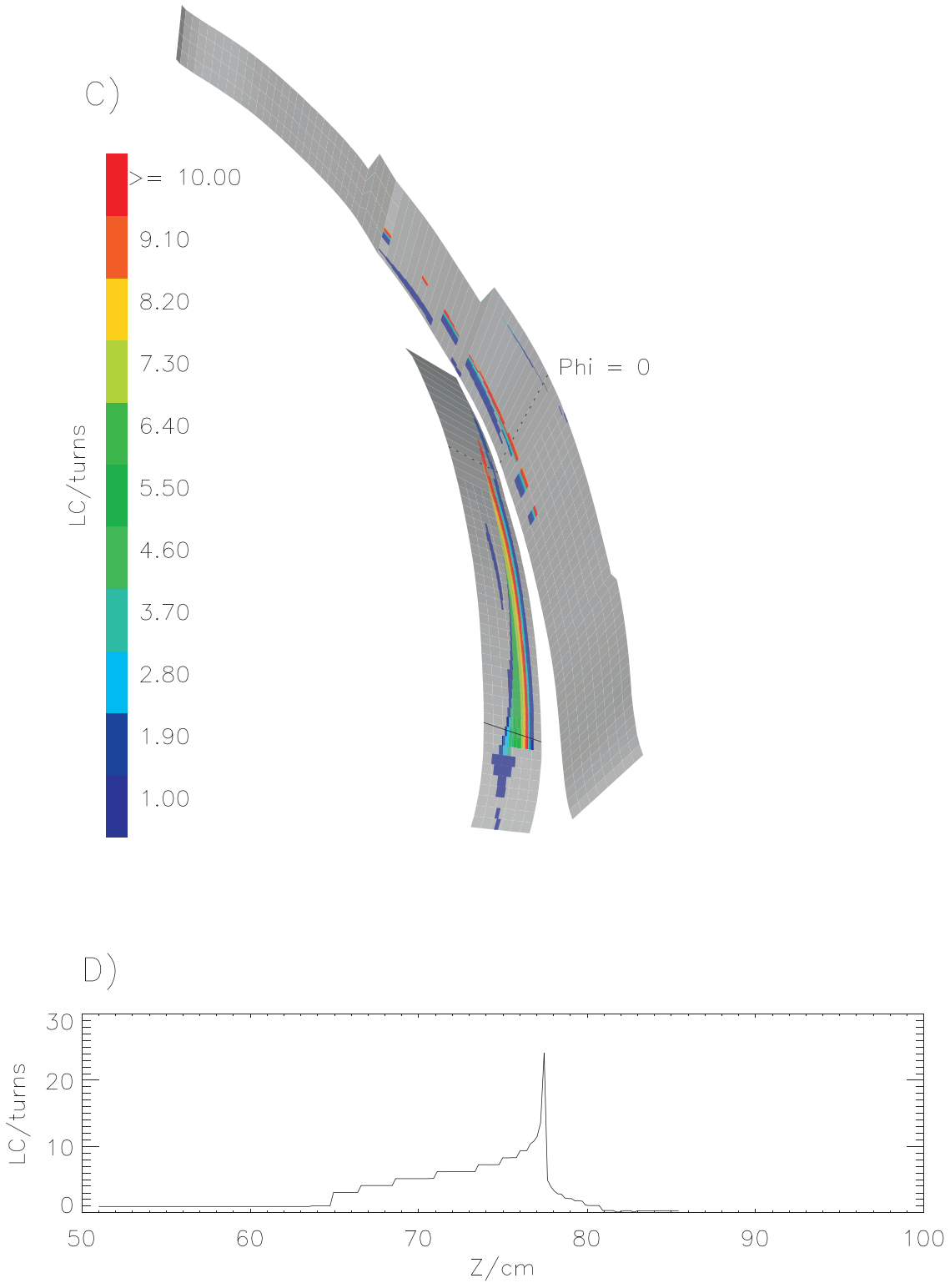

Fig.: 4.3.2
Connection length Lc of the low shear configuration.
Control current Icc = -15 kA.

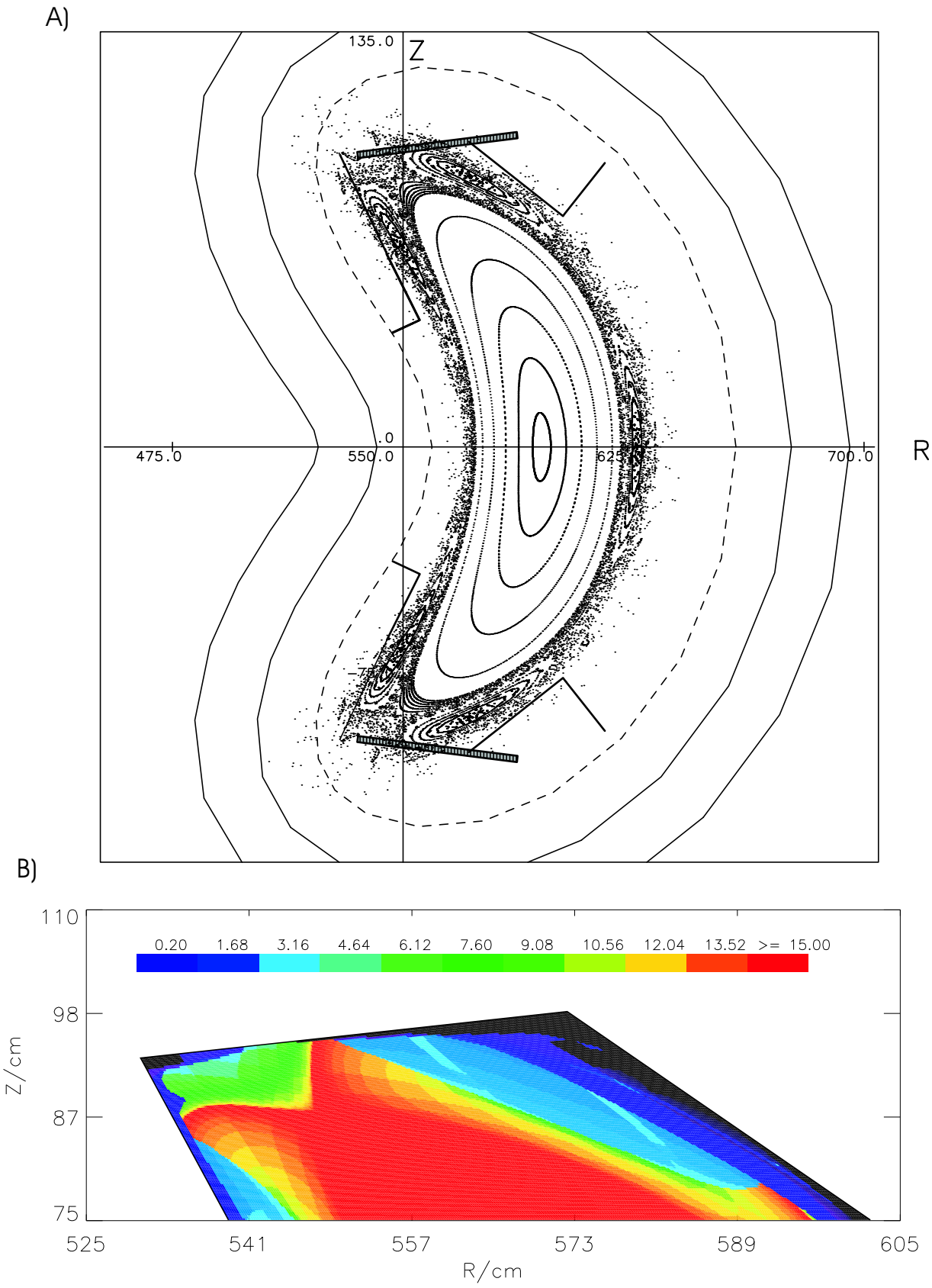

Fig.: 4.4.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = -10 kA.

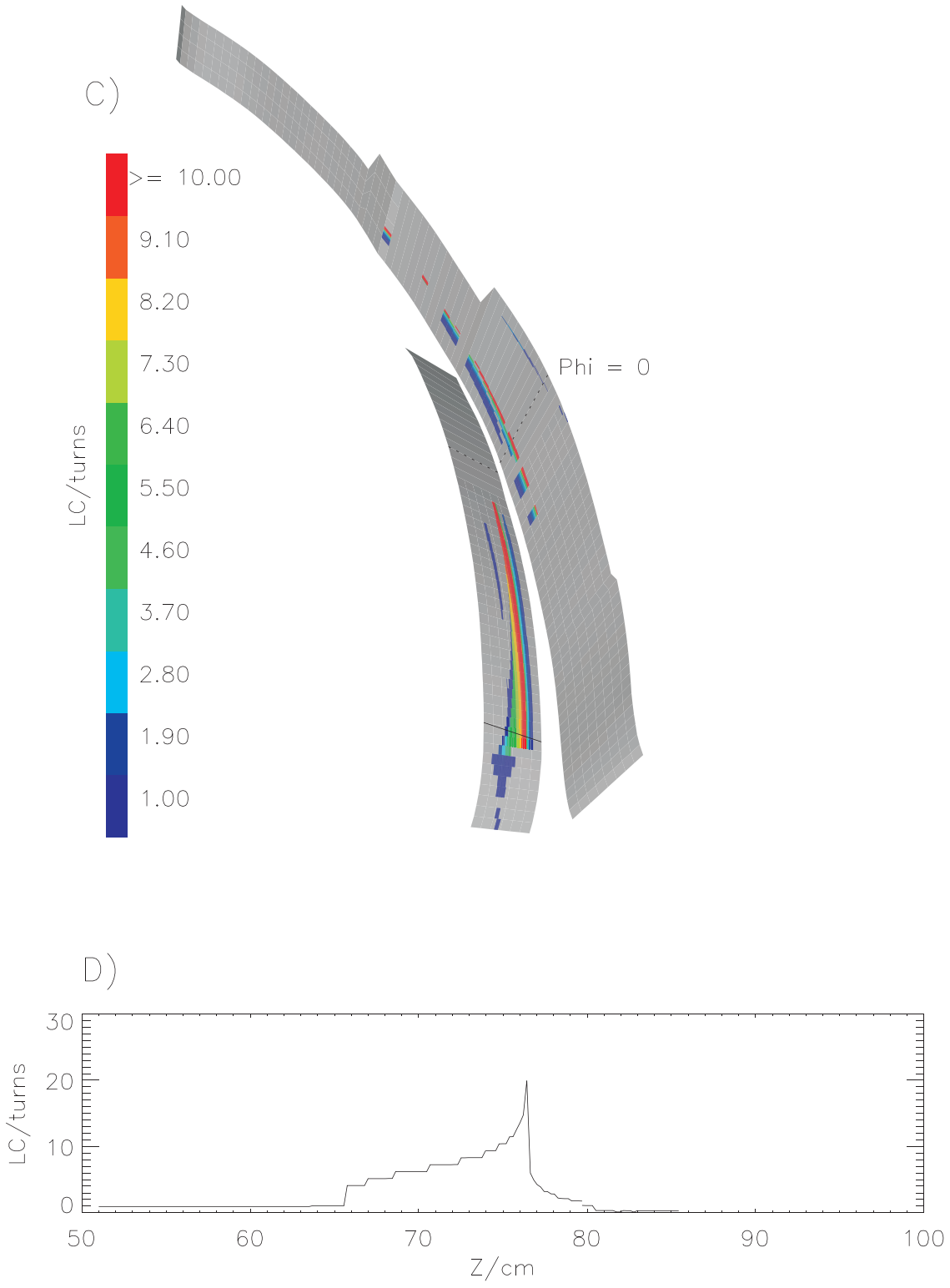

Fig.: 4.4.2
Connection length Lc of the low shear configuration.
Control current Icc = -10 kA.

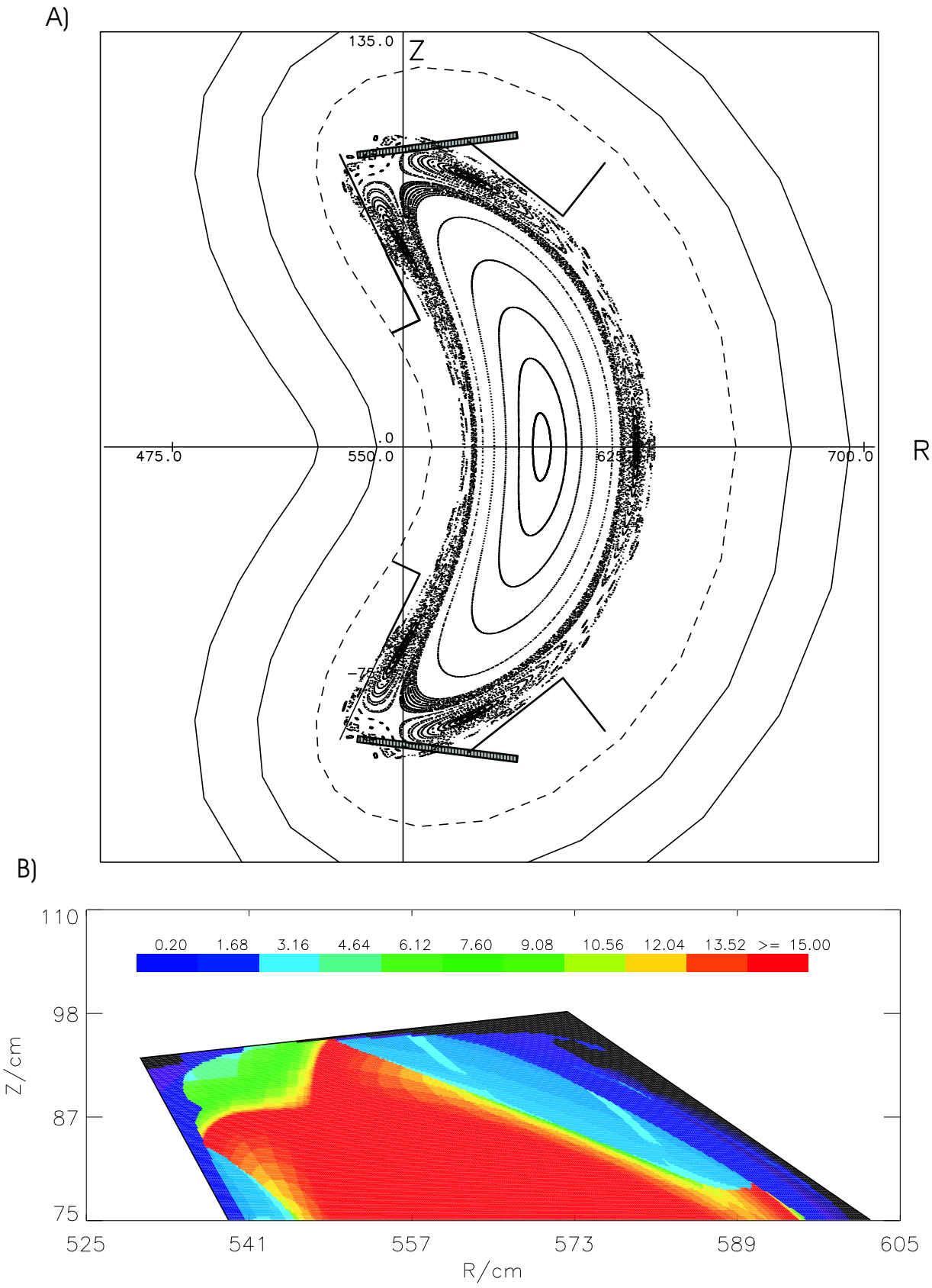

Fig.: 4.5.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = -5 kA.

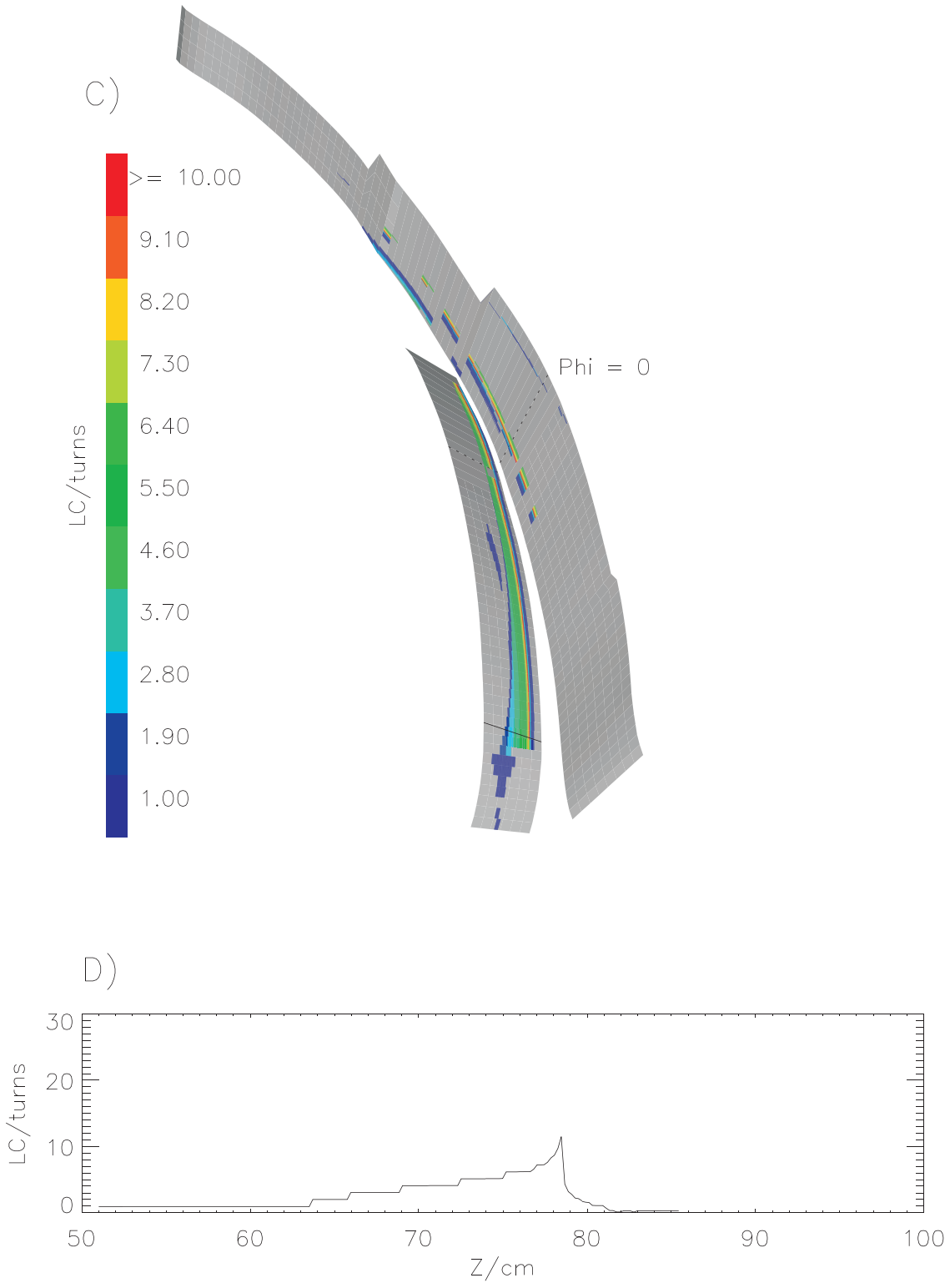

Fig.: 4.5.2
Connection length Lc of the low shear configuration.
Control current Icc = -5 kA.

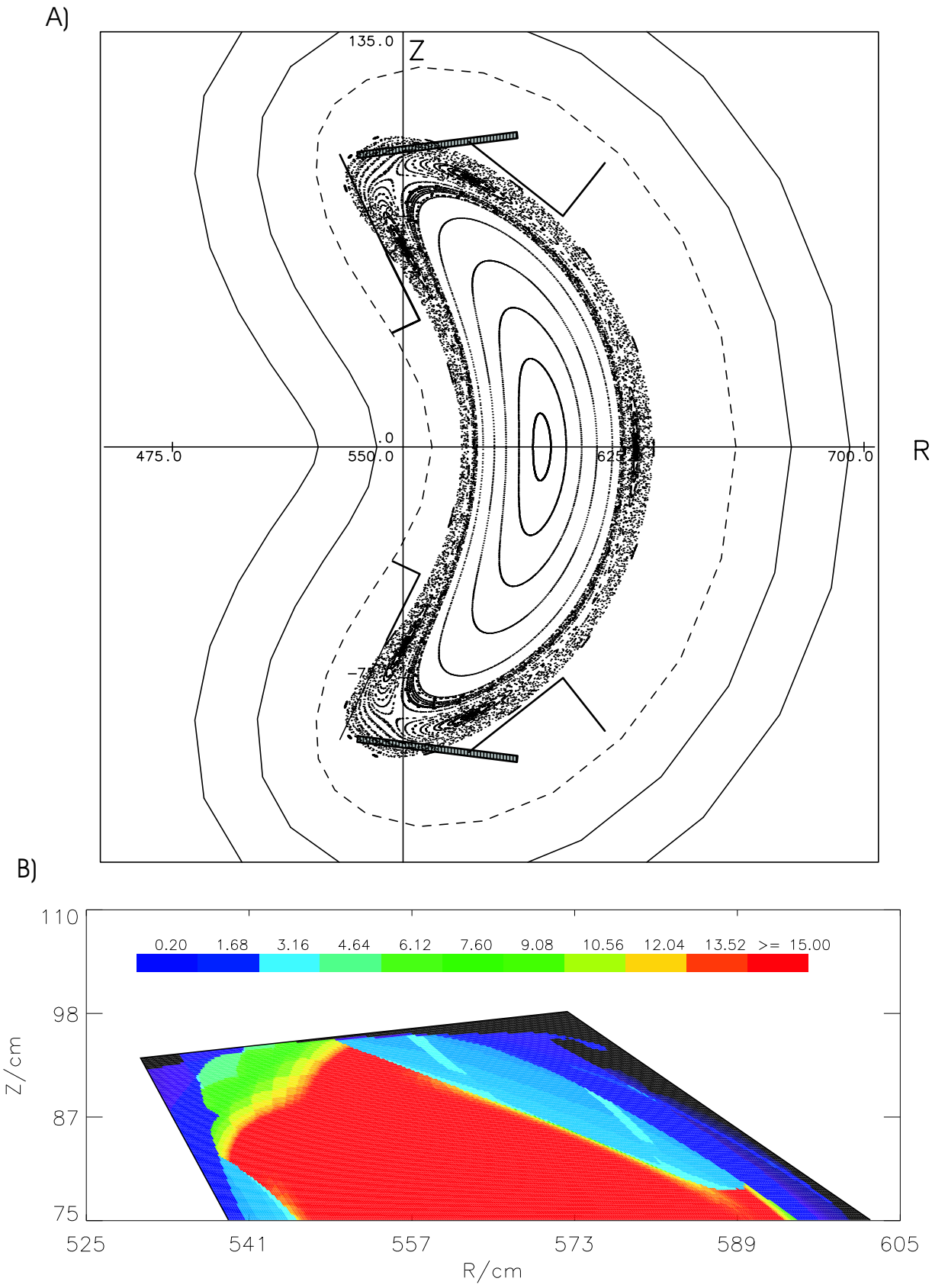

Fig.: 4.6.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = 0 kA.

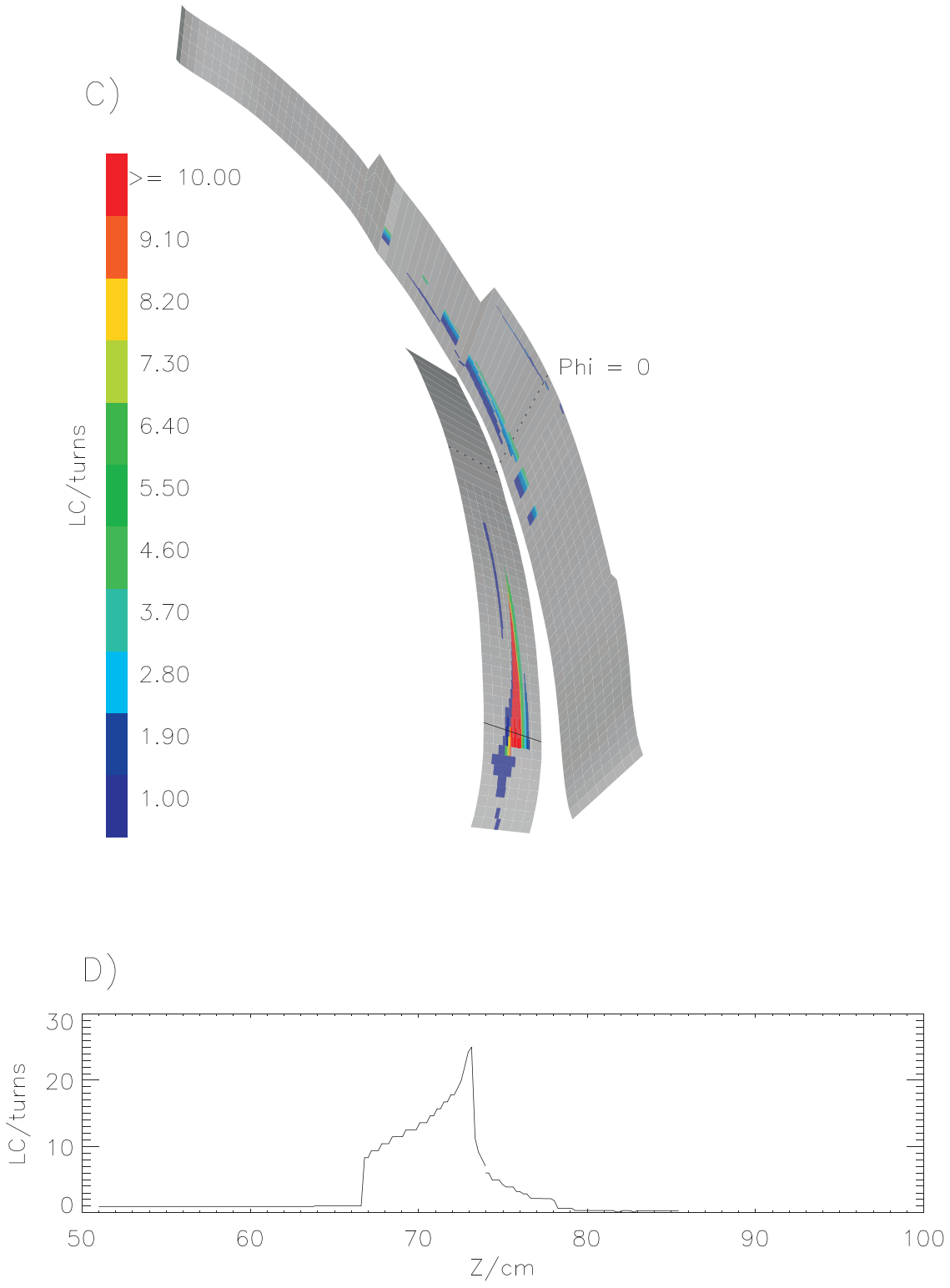

Fig.: 4.6.2
Connection length Lc of the low shear configuration.
Control current Icc = 0 kA.

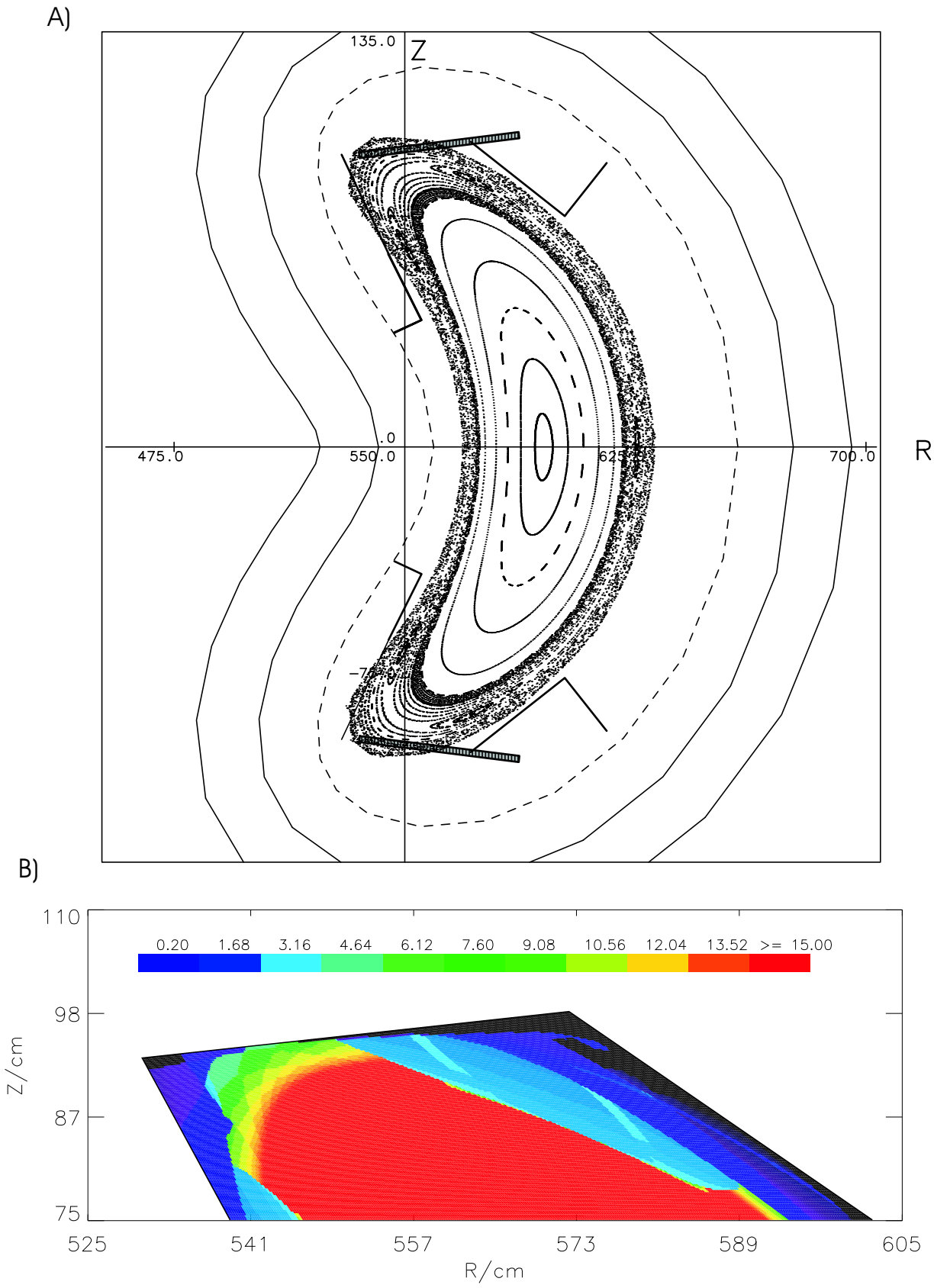

Fig.: 4.7.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = 5 kA.

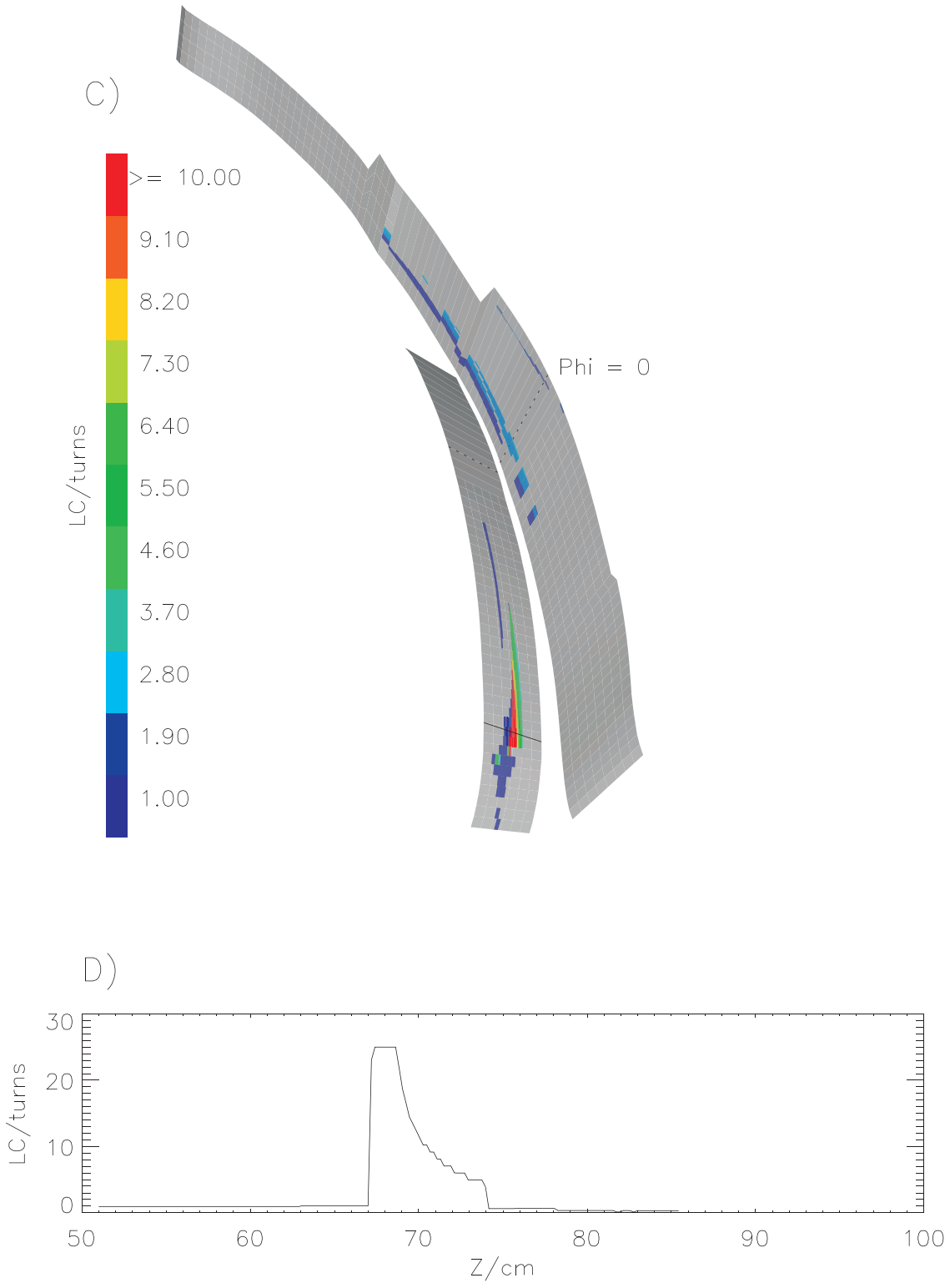

Fig.: 4.7.2
Connection length Lc of the low shear configuration.
Control current Icc = 5 kA.

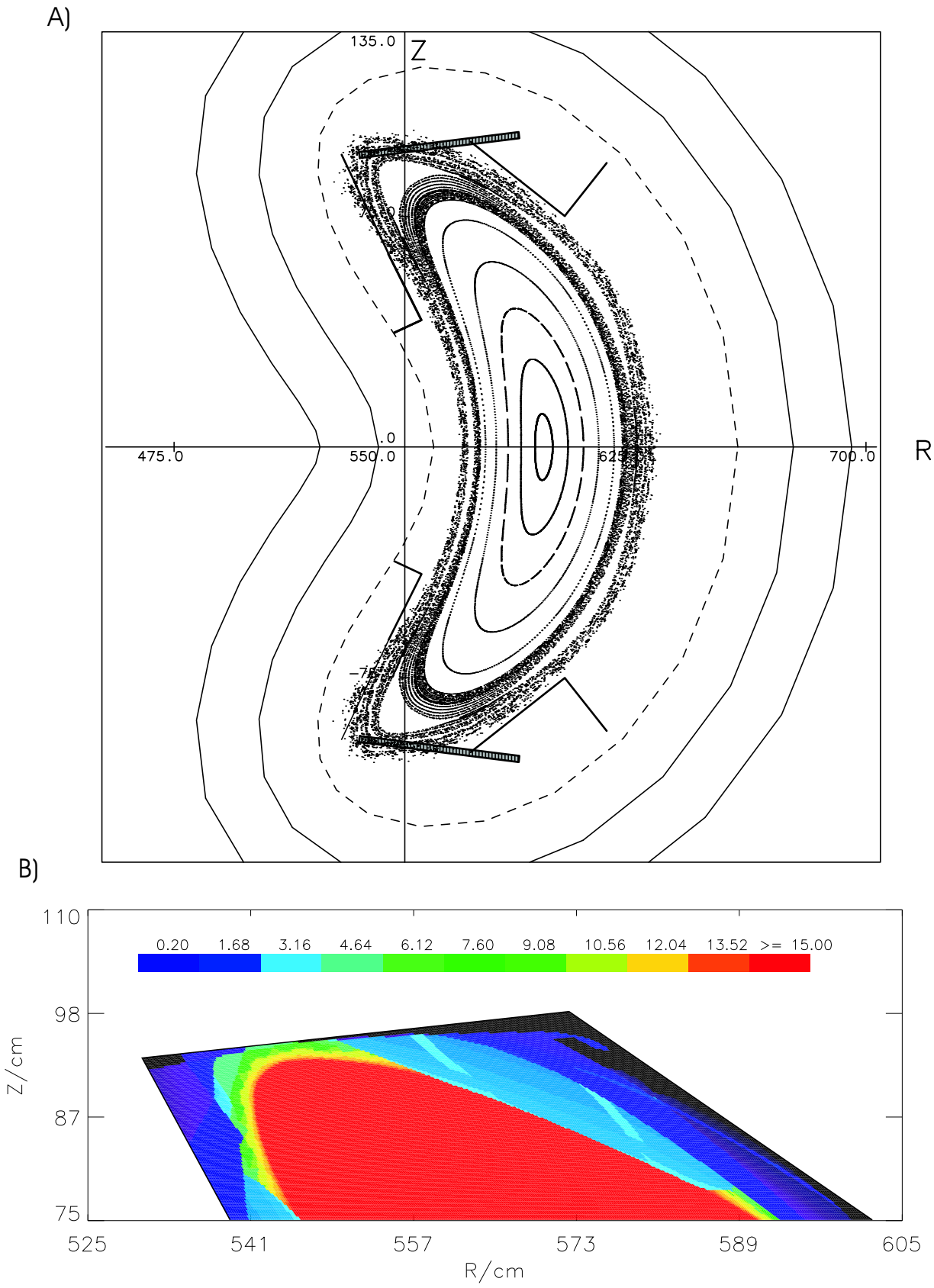

Fig.: 4.8.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = 10 kA.

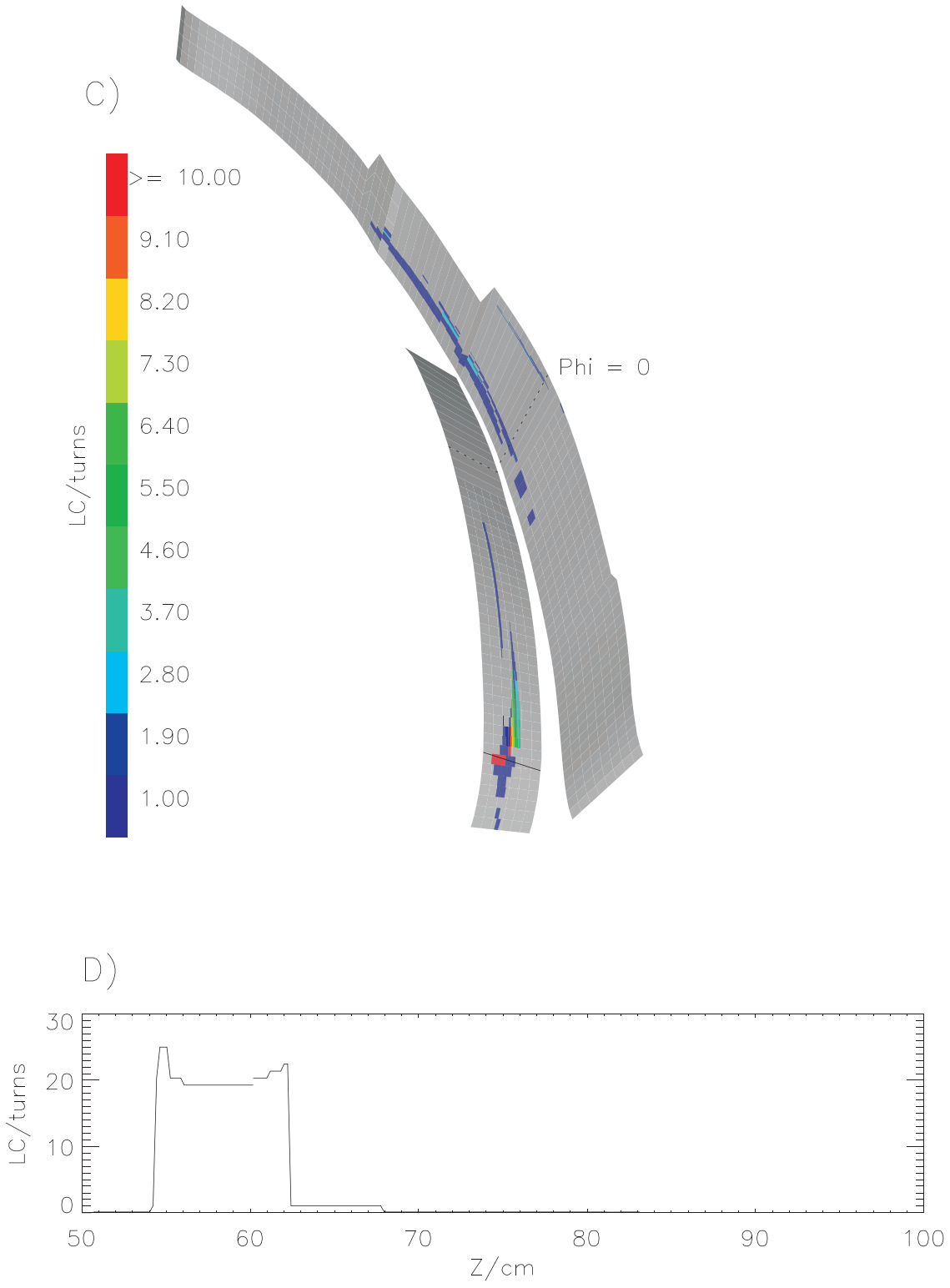

Fig.: 4.8.2
Connection length Lc of the low shear configuration.
Control current Icc = 10 kA.

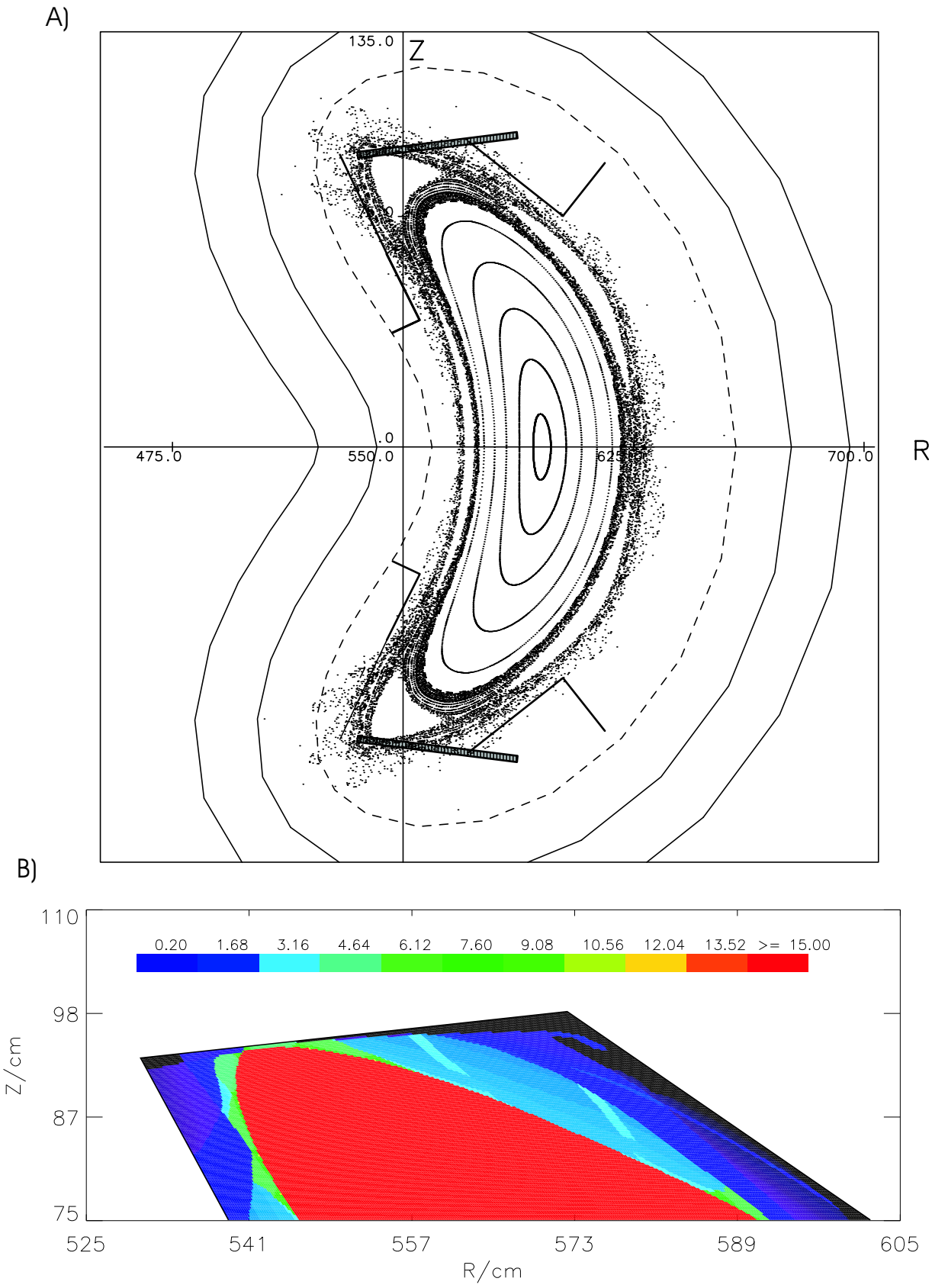

Fig.: 4.9.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = 15 kA.

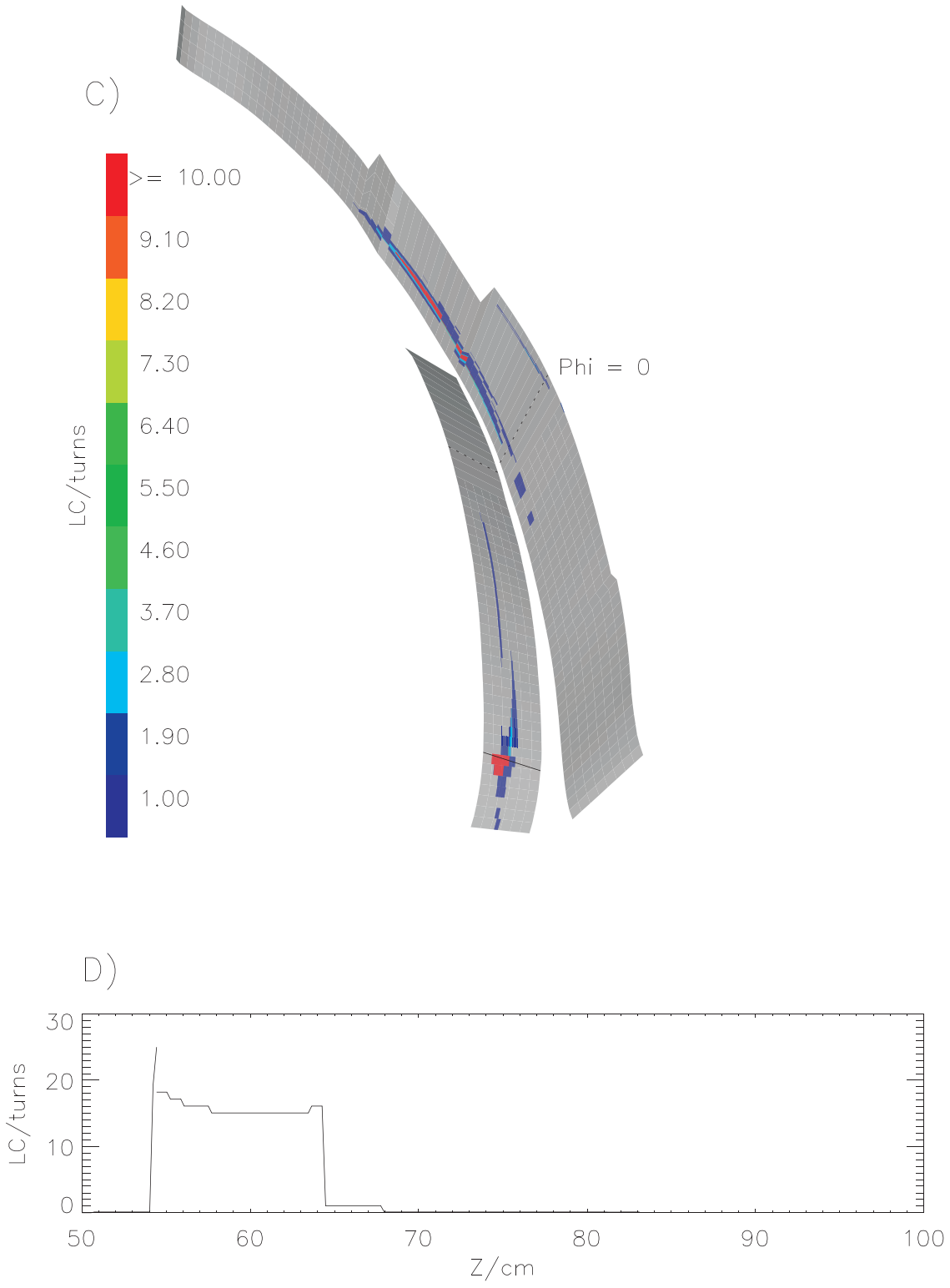

Fig.: 4.9.2
Connection length Lc of the low shear configuration.
Control current Icc = 15 kA.

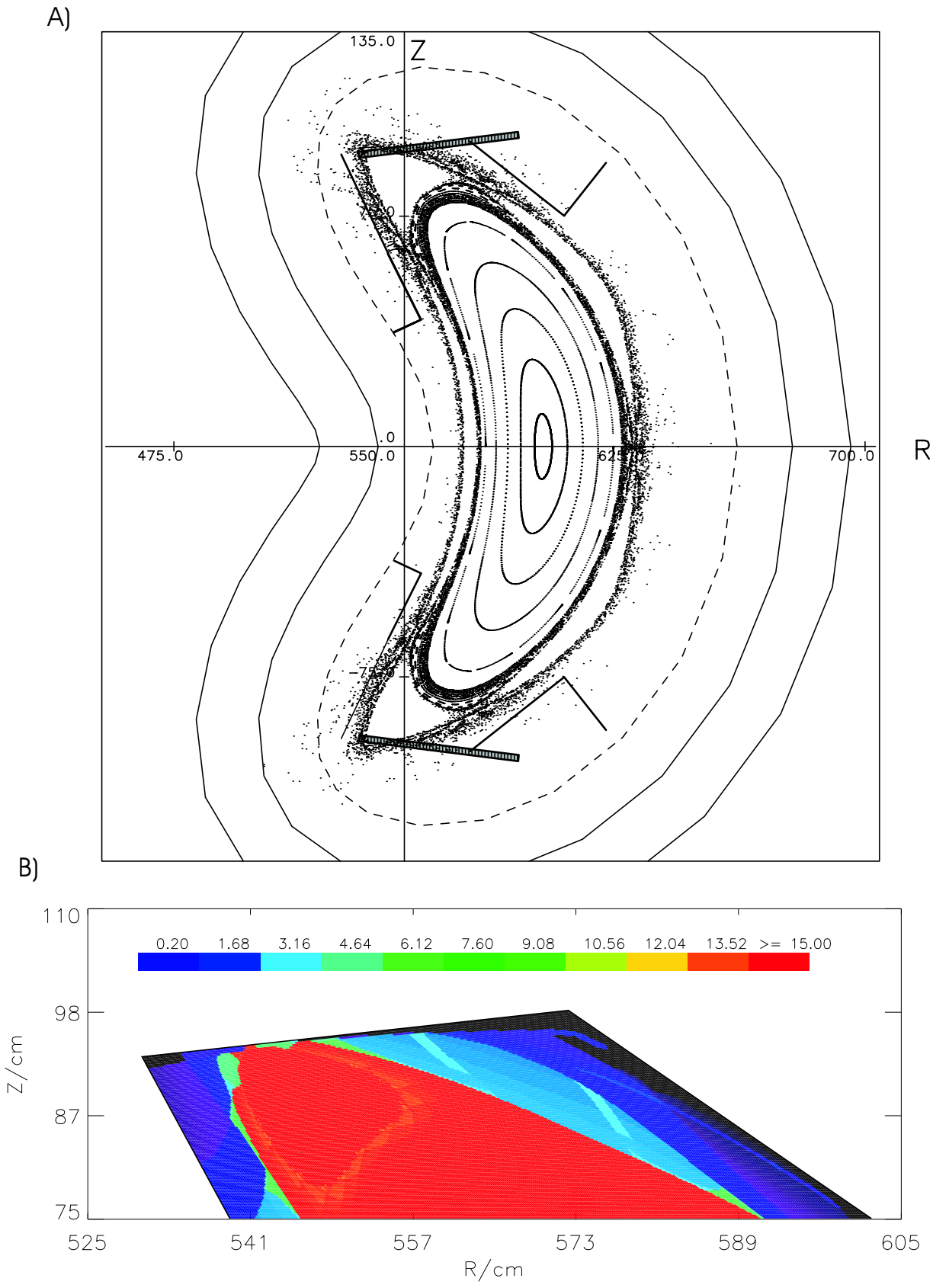

Fig.: 4.10.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = 20 kA.

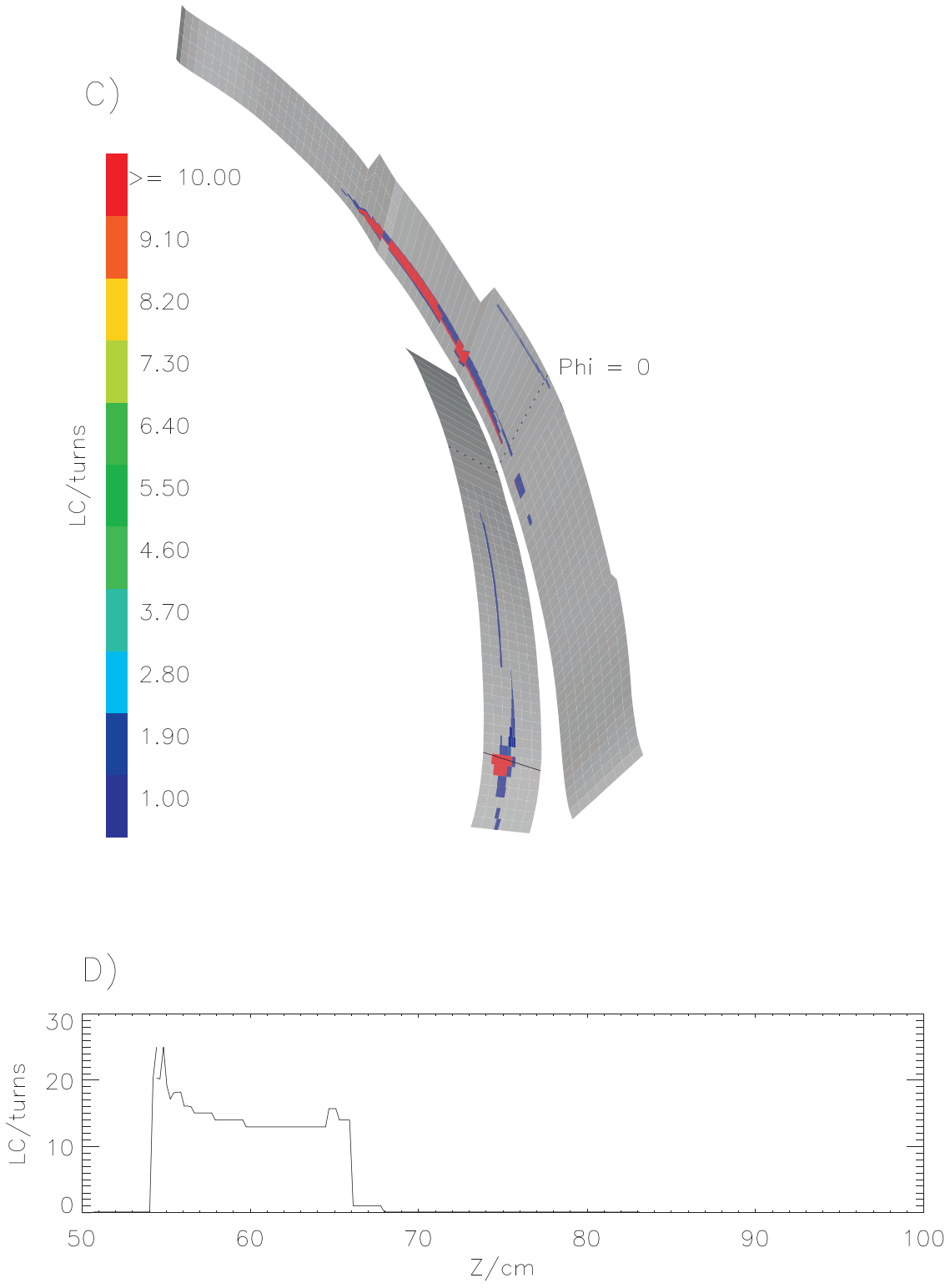

Fig.: 4.10.2
Connection length Lc of the low shear configuration.
Control current Icc = 20 kA.

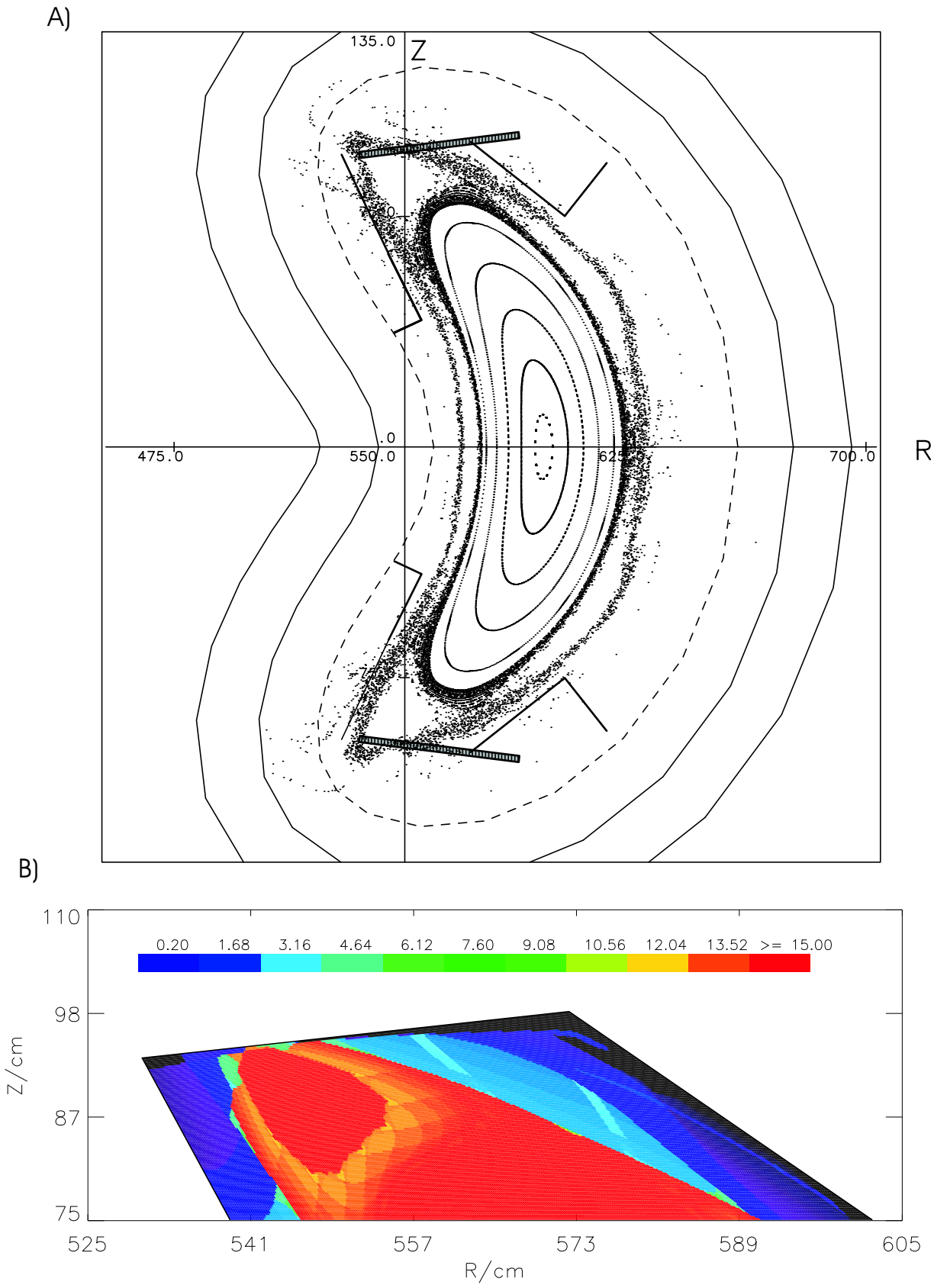

Fig.: 4.11.1

Poincaré plot and colour contour of the low shear configuration.

Control current Icc = 25 kA.

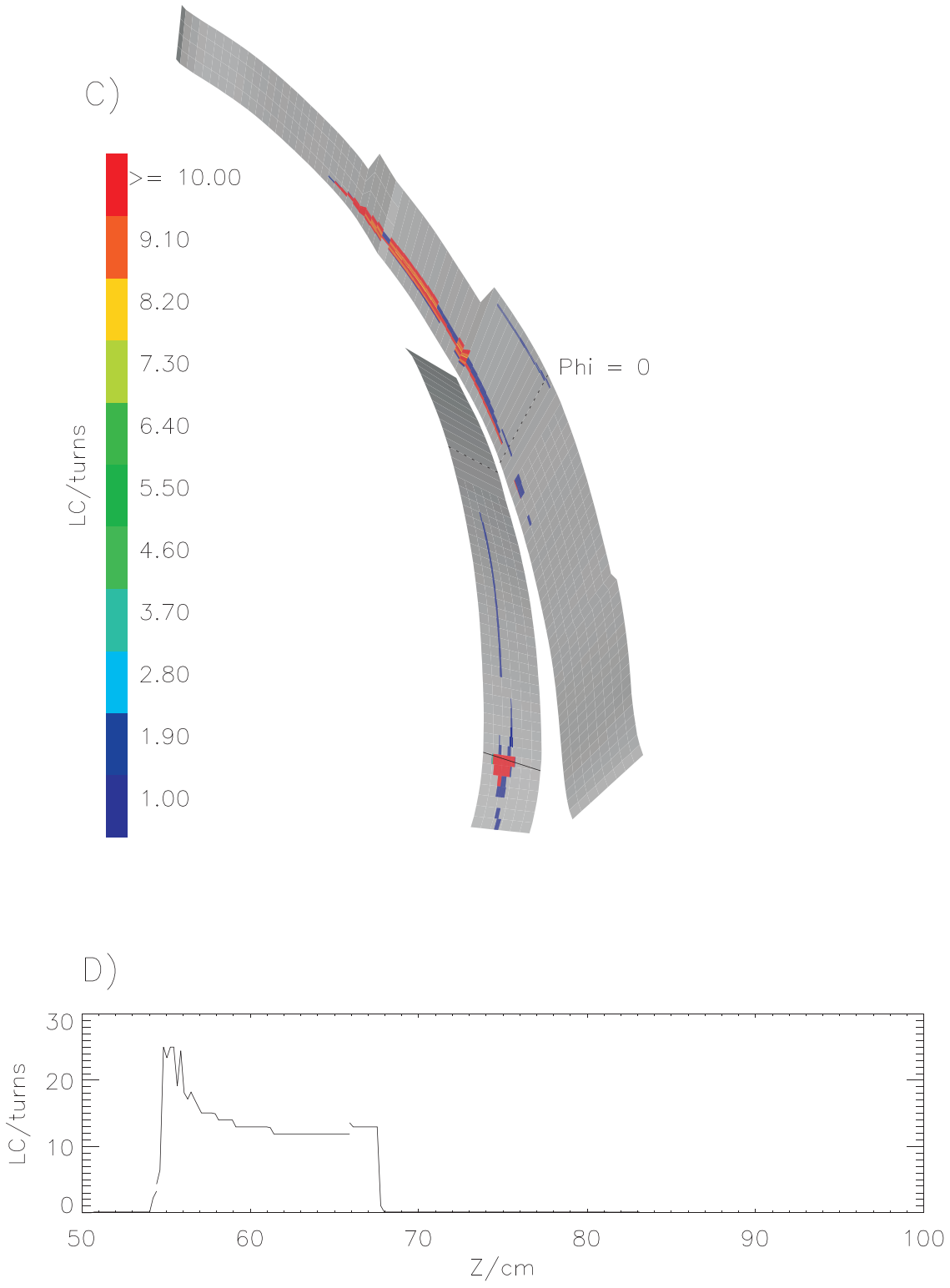

Fig.: 4.11.2
Connection length Lc of the low shear configuration.
Control current Icc = 25 kA.

Reference

[1] P. Grigull et al., 2001 plasma Phys. Contr. Fusion 43 A175.

[2] T. Andereeva, Vacuum Magnetic Configurations of Wendelstein 7-X, IPP III/270 (Mai, 2002).