MEMO

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Date: July 24, 2001
Subject: CO_2 laser sight lines

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1. Introduction

A short IDL procedure has been written to calculate the magnetic field rotation angle (B_{pol}/B_{tor}) for a selection of ASDEX Upgrade discharge scenarios and a selection of possible sightlines for the CO_2 scattering diagnostic. The procedure calls the kklib routines of Wolfgang Schneider (`kkrzPTFn` for poloidal mapping and `kkrzBrzt` for B field components) with `FPP` flux surface fitting. Three sightlines were identified as possible candidate configurations. The chosen sightlines are not meant to be too literal but they are fairly realistic considering the physical limitations of the AUG port locations. The precise sightline geometry will of course be determined by technical considerations on the placement of mirrors and beam reflectors. However the range of rotation angles is not expected to vary considerably from the examples given below. The sightlines are defined by a start and stop end points (r1,z1) and (r2,z2) for the major radius and z-plane coordinates in metres.

- L1: A diagonal sightline running from the upper outboard plane of a A-port to a reflector positioned below the inner heat shield.
  r1 = 2.24 ; z1 = +0.48 ; r2 = 1.11 ; z2 = -0.59

- L2: A diagonal sightline running from the lower outboard corner of a A-port to a reflector positioned immediately above the inner heat shield.
  r1 = 2.16 ; z1 = -0.51 ; r2 = 1.15 ; z2 = +0.84

- L3: A vertical sightline running through the plasma from a lower E-port to an upper E-port.
  r1 = 1.78 ; z1 = -0.70 ; r2 = 1.78 ; z2 = +0.85

2. Results

For each of the four typical discharge scenarios a series of figures are included showing: (1) the flux surface geometry at an appropriate time in the discharge where scattering measurements are likely to be of most interest. The flux surfaces contours are in units of ρ_{pol} with the green solid line showing the separatrix. Overlaid on the plot are the three lines of sight (LOS). (2) plots for the three lines of sight showing the B field components as a function of distance along the LOS, the corresponding ρ_{pol} coordinate, and the field rotation angle (defined as $-B_z/-B_t$), and finally the rotation angle vs ρ_{pol}.

Case 1: Shot 13553 : An ITB with an L-mode edge (inner limiter). A -2.5T, -1.0MA shot recorded on 02/05/00 at 0.5 seconds (old Mk.IIa divertor) with triangularity of $\delta_{upp} = 0.06$, and $\delta_{low} = 0.11$, elongation $\kappa = 1.4$, $q_{95} \sim 3.2$. Both L1 and L2 give similar ranges of rotation angle from +7^o to -2^o from the low field to the high field side. L1 has a slightly higher angle range, but L2 reaches slightly further in to the core with a minimum $\rho_{pol} < 0.2$. The vertical LOS (L3) has an appalling angle range of only 1^o or so, and only reaches in to $\rho_{pol} \sim 0.4$.

Case 2: Shot 14034 : An ITB configuration with an upper single null X-point. A -2.7T / 0.8MA shot recorded on 29/06/00 at 0.8 seconds with old Mk.IIa divertor. Triangularity is higher at $\delta_{upp} = 0.35$, and $\delta_{low} = 0.13$, elongation $\kappa = 1.81$, and $q_{95} \sim 7.5$. Again Both L1 and L2 give excellent rotation angle ranges from +7.5^o to -3.5^o from lfs to hfs. As before L1 has a slightly higher angle range, but with similar radial coverage as L2 reaching a minimum $\rho_{pol} < 0.1$. L3 has as slightly better angle range and radial coverage than the previous limiter shot, but again this LOS is practically useless.

Case 3: Shot 14483 : An 'Improved H-mode' with a lower single null X-point. A -2.5T / 1.0MA shot recorded on 13/07/01 at 2.0 seconds with the new Mk.IIb divertor (note flux surface plot shows old divertor). Triangularity is moderate at $\delta_{upp} = 0.25$, and $\delta_{low} = 0.44$, elongation $\kappa = 1.73$, and $q_{95} \sim 5.0$. With the new divertor the magnetic axis is substantially lower resulting in an excellent radial range - almost to the core with excellent rotation angle ranges from +9.5^o to -5.0^o from lfs to hfs for L1 LOS. L2 has a slightly lower angle range but this is still an excellent range. L3 improves in radial coverage.

Case 4: Shot 14541 : A high beta normalized discharge with lower single null. A -1.7T / 0.8MA shot recorded on 20/07/01 at 4.0 seconds with new Mk.IIb divertor (again note old divertor shown in flux plot). Triangularity $\delta_{upp} = 0.36$, and $\delta_{low} = 0.50$, elongation $\kappa = 1.71$, and $q_{95} \sim 3.53$. Similar wide angle ranges for both L1 and L2 from +12.5^o to -7.0^o from lfs to hfs. Again L1 has a slightly higher angle range and similar radial coverage as L2 reaching again almost to the core with a minimum $\rho_{pol} < 0.1$.

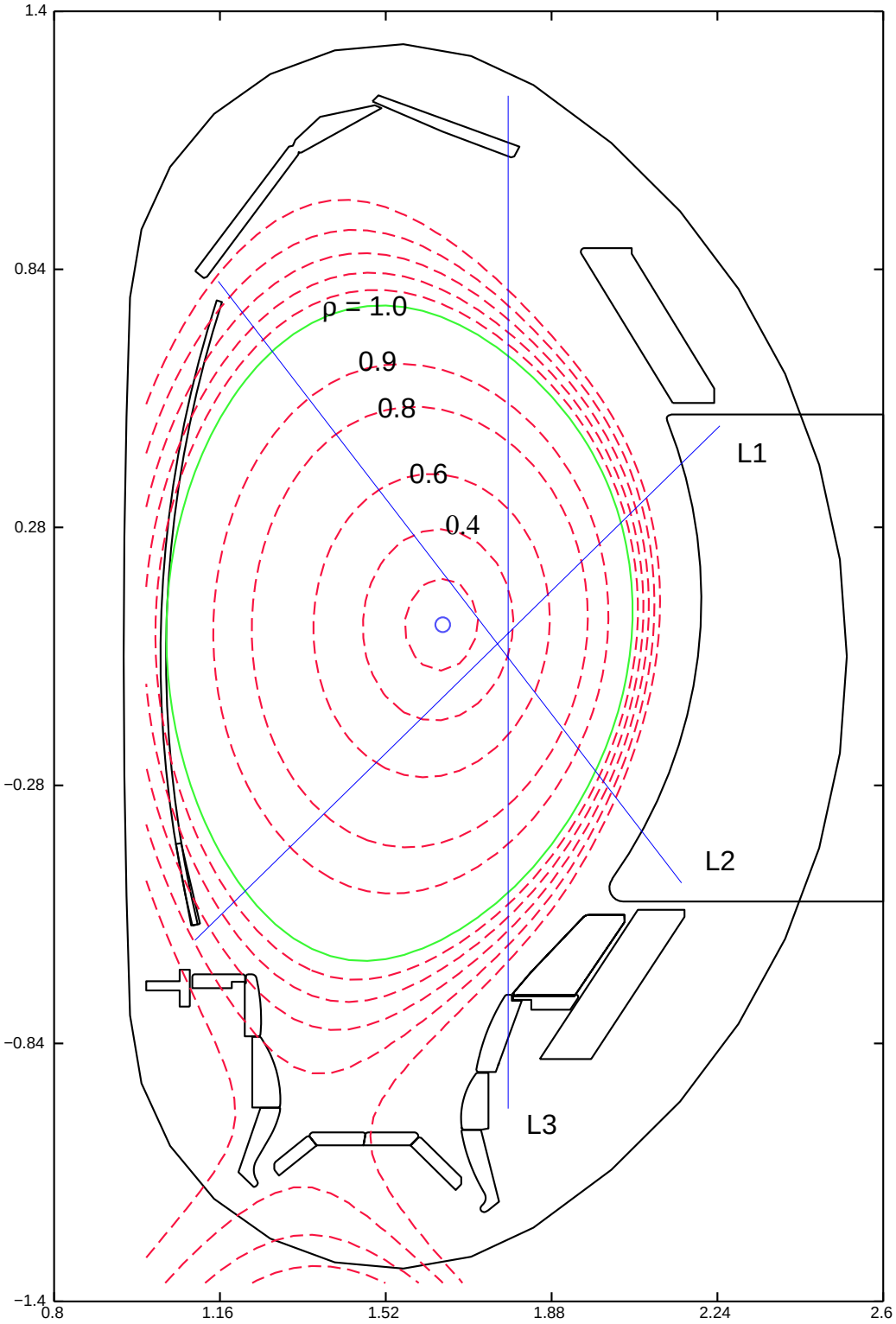
3. Conclusion

3.1 For the four case studies both diagonal sightlines L1 and L2 give more than acceptable ranges in the rotation angles and quite adequate radial coverage. With the new divertor some discharge configurations almost give sightlines passing through the plasma core. The two ITB discharges are unlikely to improve much further with the new divertor since they have no lower X-point, however they may be run with slightly lower magnetic axis which will improve the range extents.

3.2 Although there is little to choose between L1 and L2 in terms of rotation angle range coverage, there are technical considerations which suggest L1 may offer a more robust sightline. With the L1 sightline the beam reflector may be recessed further in to the shadow of the heat shield offering better protection. For the L2 sightline there is less physical space available above the inner heat shield, plus it may be subject to more interference during vertical displacement disruptions.

3.3 The vertical sightline L3 using a single pass through the E-ports suffers several critical disadvantages. Since the LOS only passes through the low field side of the plasma the field rotation angle never crosses zero resulting in an insufficient range to provide any significant localization. Further the radius of the vertical LOS will never pass close to the plasma axis. Finally, on a technical point it is most unlikely that the required minimum 6cm diameter clear beam aperture would be allowed in the divertor plate above the lower E-port

3.4 Of the options studied the diagonal line of sight L1 offers the best prospect and is hence the sightline recommended for technical study.



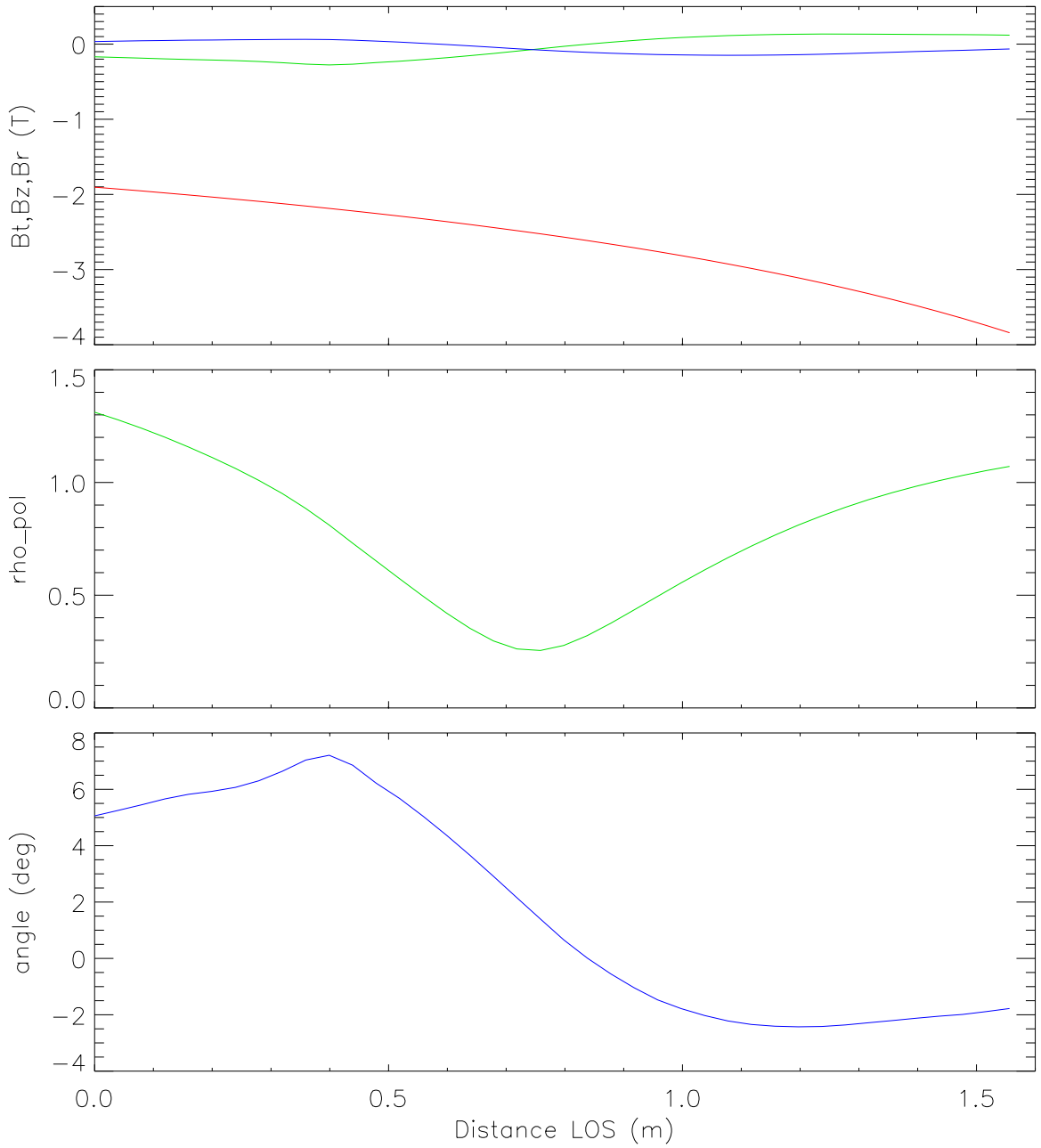
AUG shot 13553
Time: 0.51s

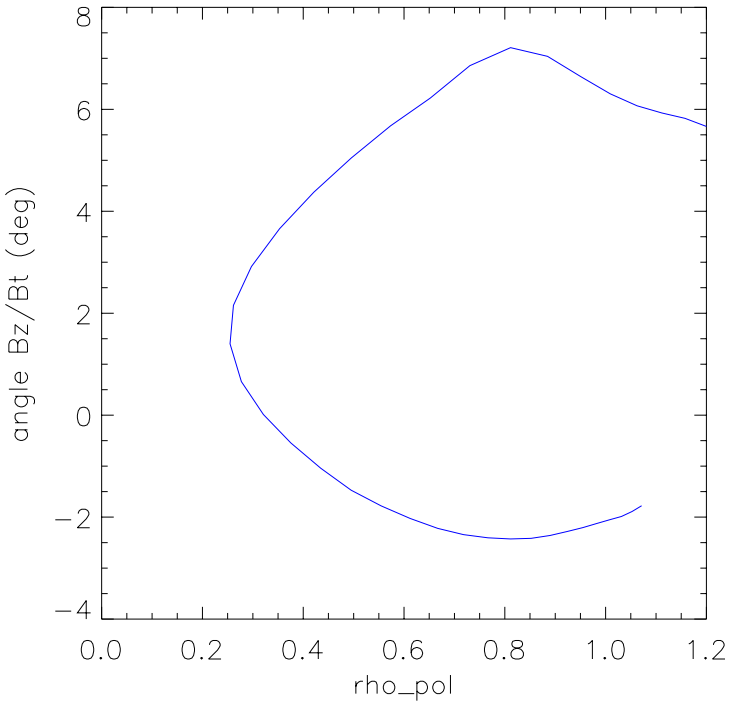
02/05/00

ITB with L-mode edge - inner limiter

-2.6T / -1.0MA
Mk-IIa divertor

δo = 0.06
δu = 0.11
κ = 1.4
q95 = 3.2





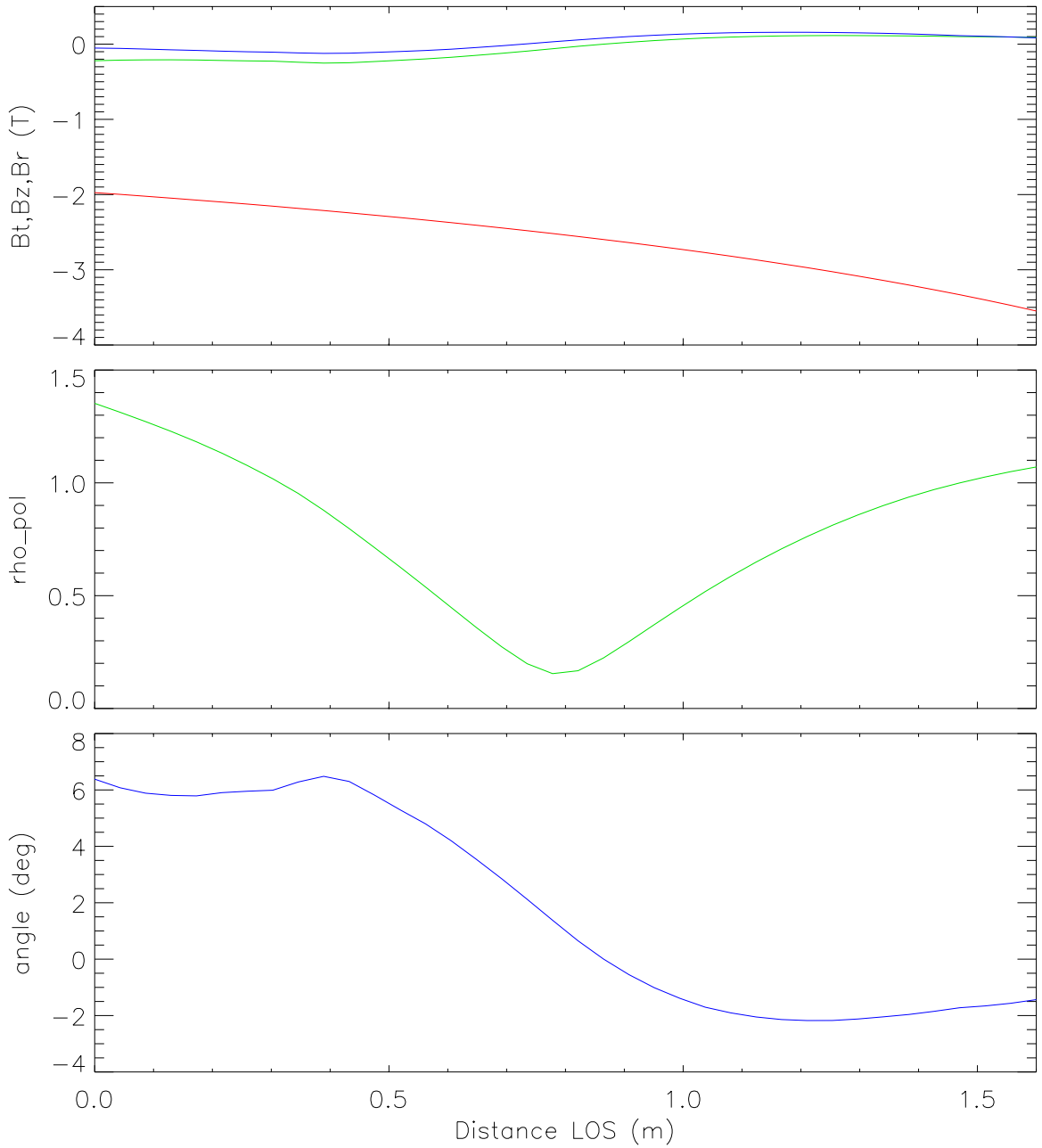
AUG Shot: 13553 @ 0.510 s

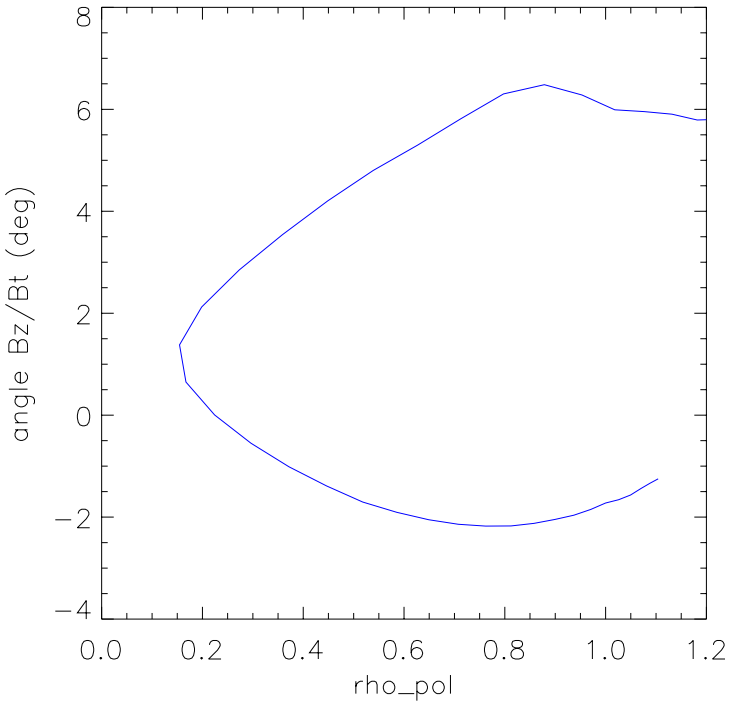
LOS Start R,z (m): 2.24 : 0.480

LOS Stop R,z (m): 1.11 : −0.59

No. of points: 40

Bangl (gdc) v1.05 – User: grc : Tue Jul 24 10:05:11 2001





AUG Shot: 13553 @ 0.510 s

LOS Start R,z (m): 2.16 : −0.51

LOS Stop R,z (m): 1.15 : 0.840

No. of points: 40

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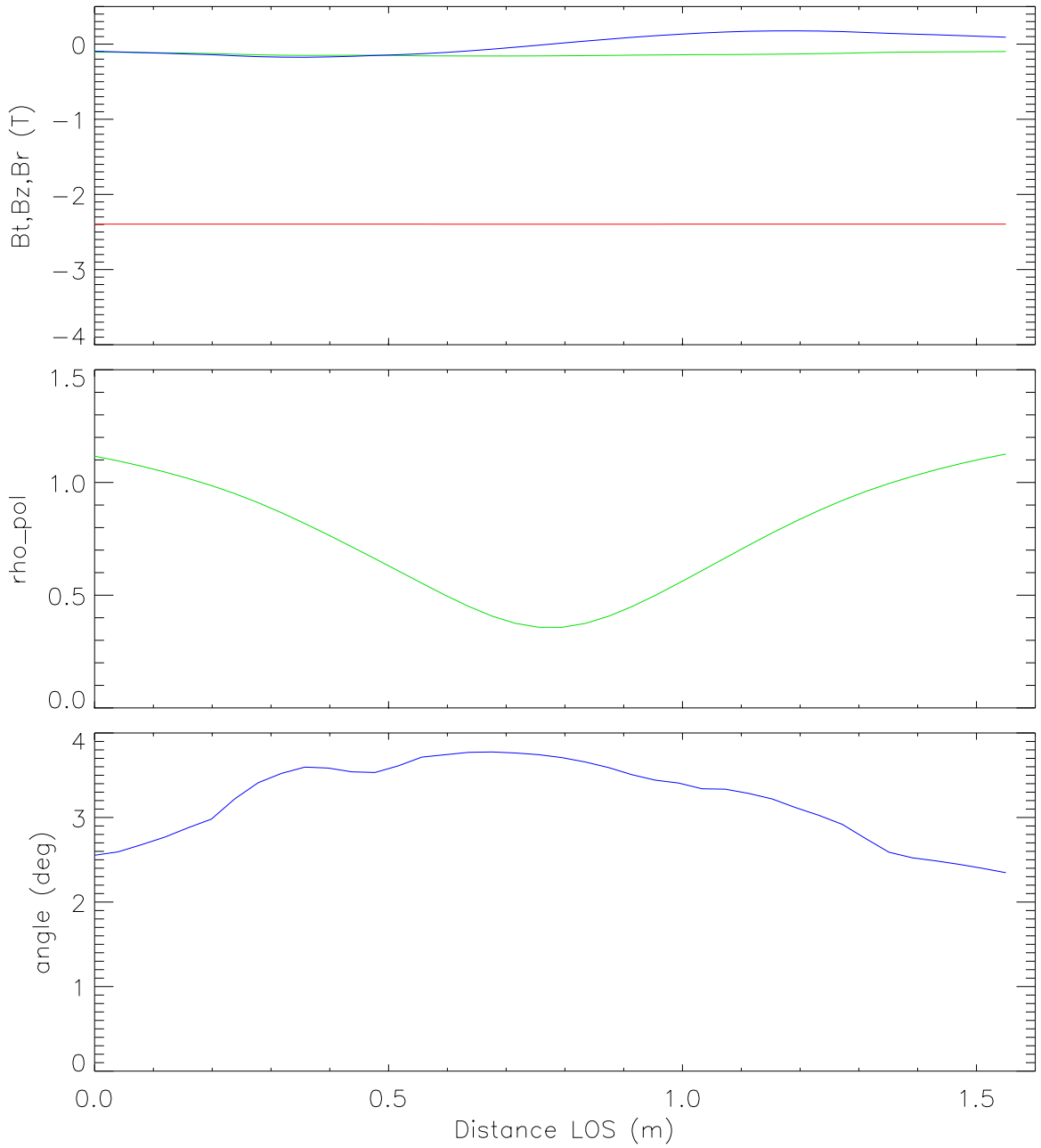

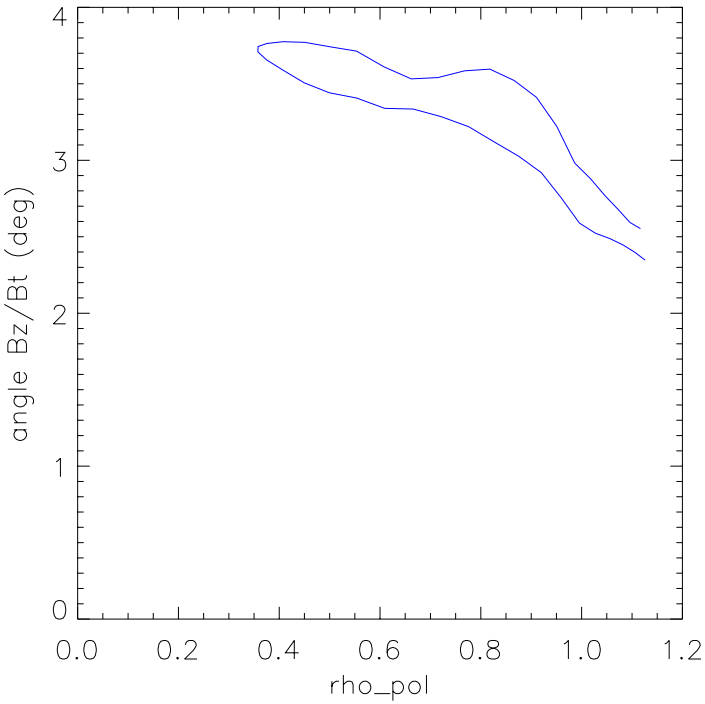

AUG Shot: 13553 @ 0.510 s

LOS Start R,z (m): 1.78 : −0.70

LOS Stop R,z (m): 1.78 : 0.850

No. of points: 40

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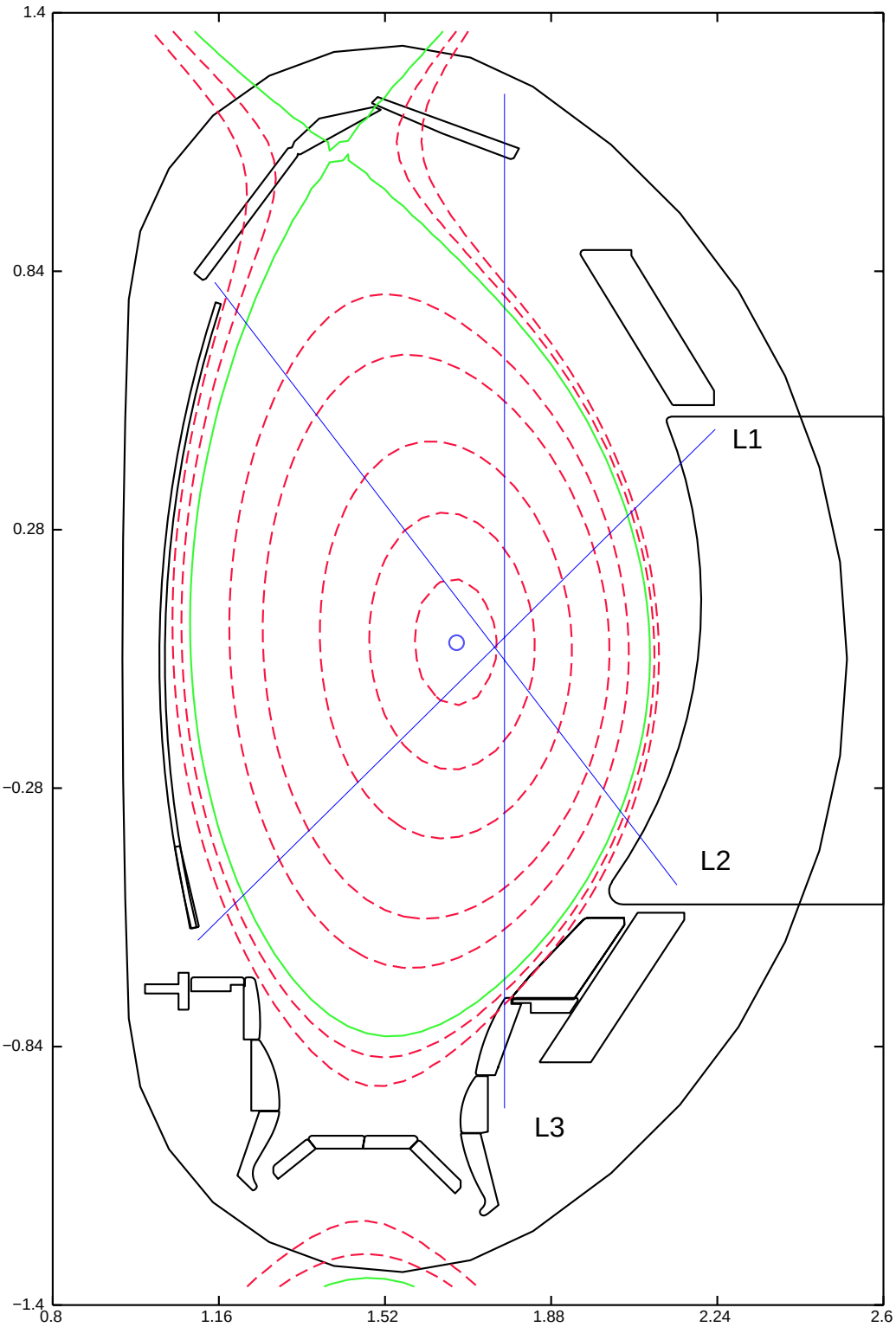


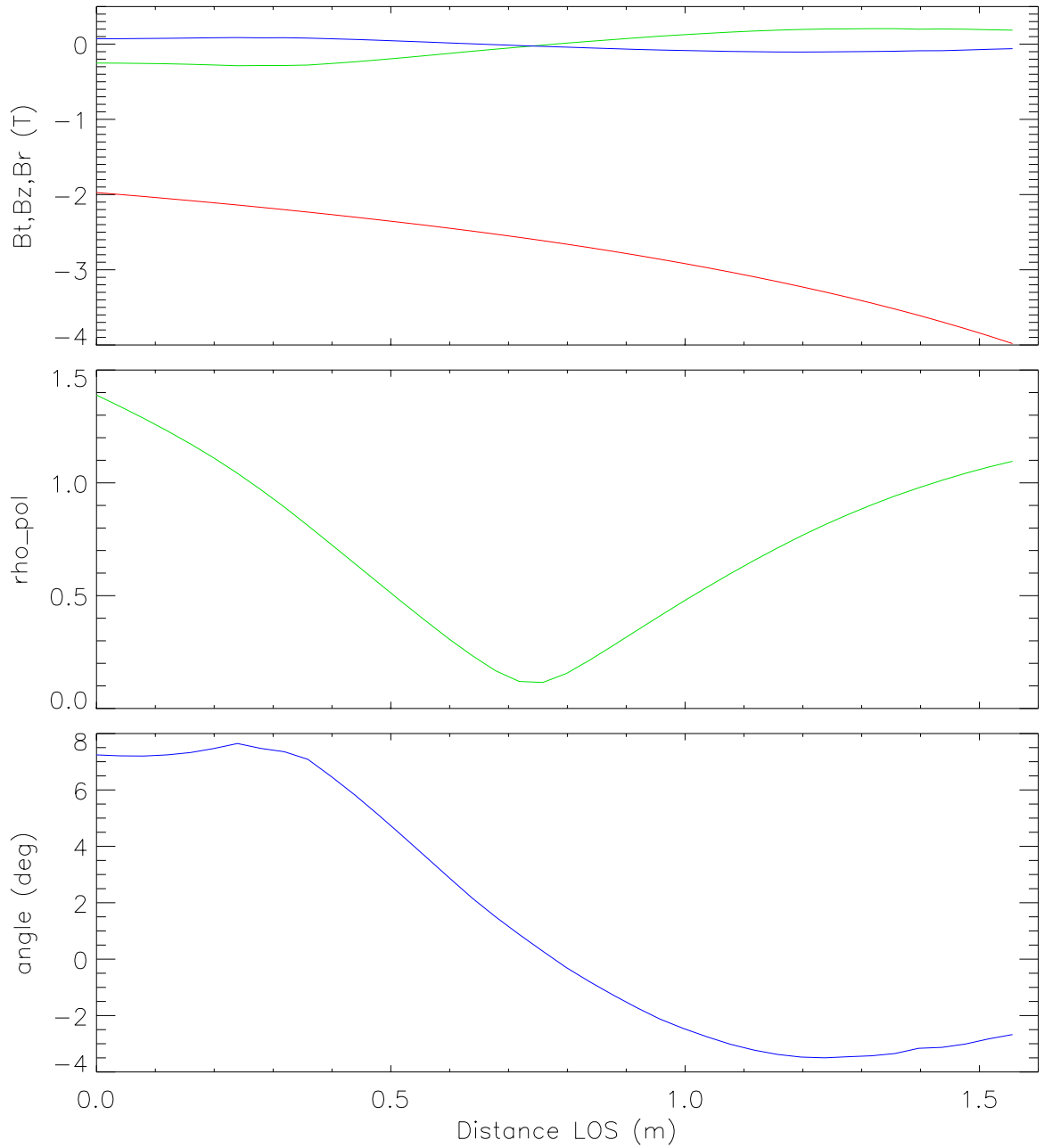
AUG shot: 14034
Time: 0.8s

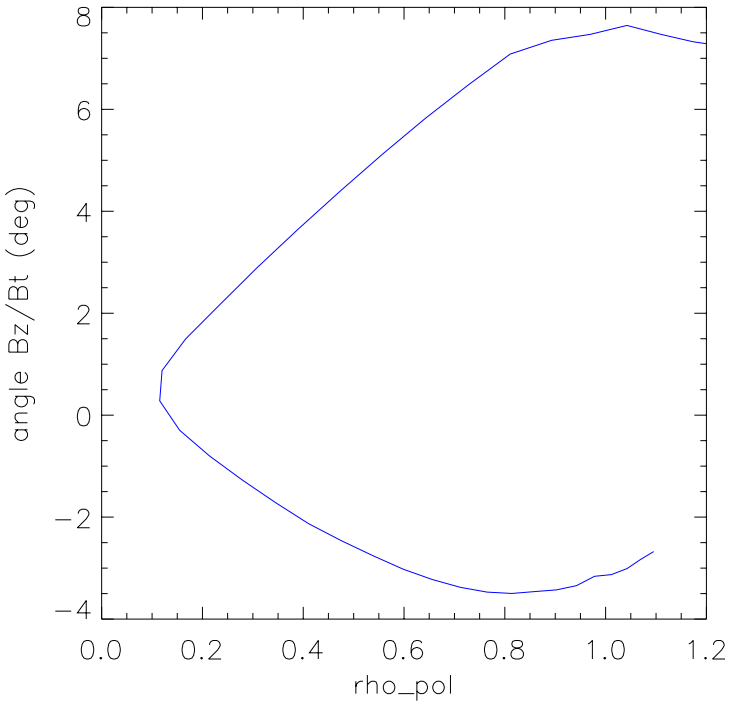
29/06.00

ITB with single upper null configuration

-2.7T / -1.0MA
Mk-IIa divertor

δo = 0.35
δu = 0.13
κ = 1.81
q95 = 7.5





AUG Shot: 14034 @ 0.800 s

LOS Start R,z (m): 2.24 : 0.480

LOS Stop R,z (m): 1.11 : −0.59

No. of points: 40

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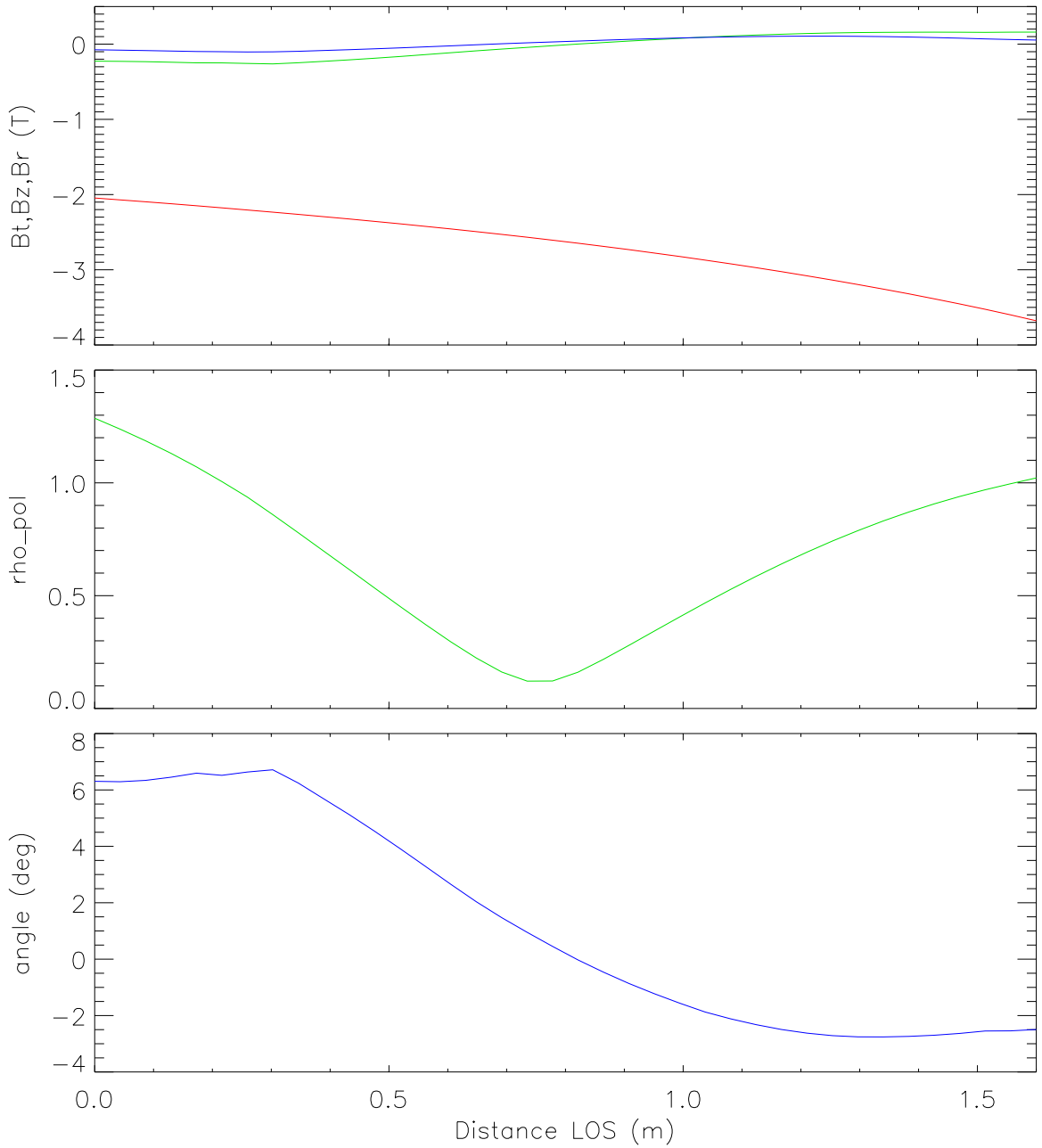

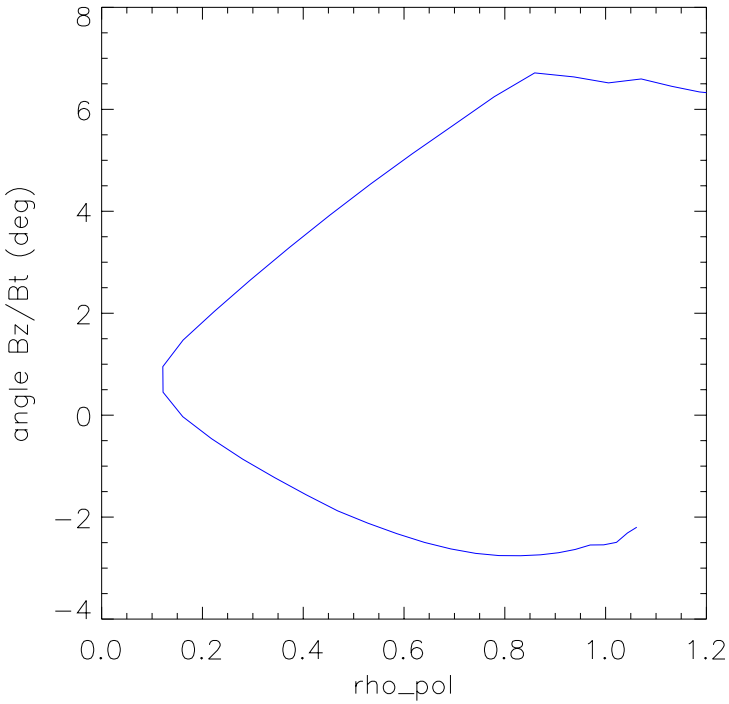

AUG Shot: 14034 @ 0.800 s

LOS Start R,z (m): 2.16 : −0.51

LOS Stop R,z (m): 1.15 : 0.840

No. of points: 40

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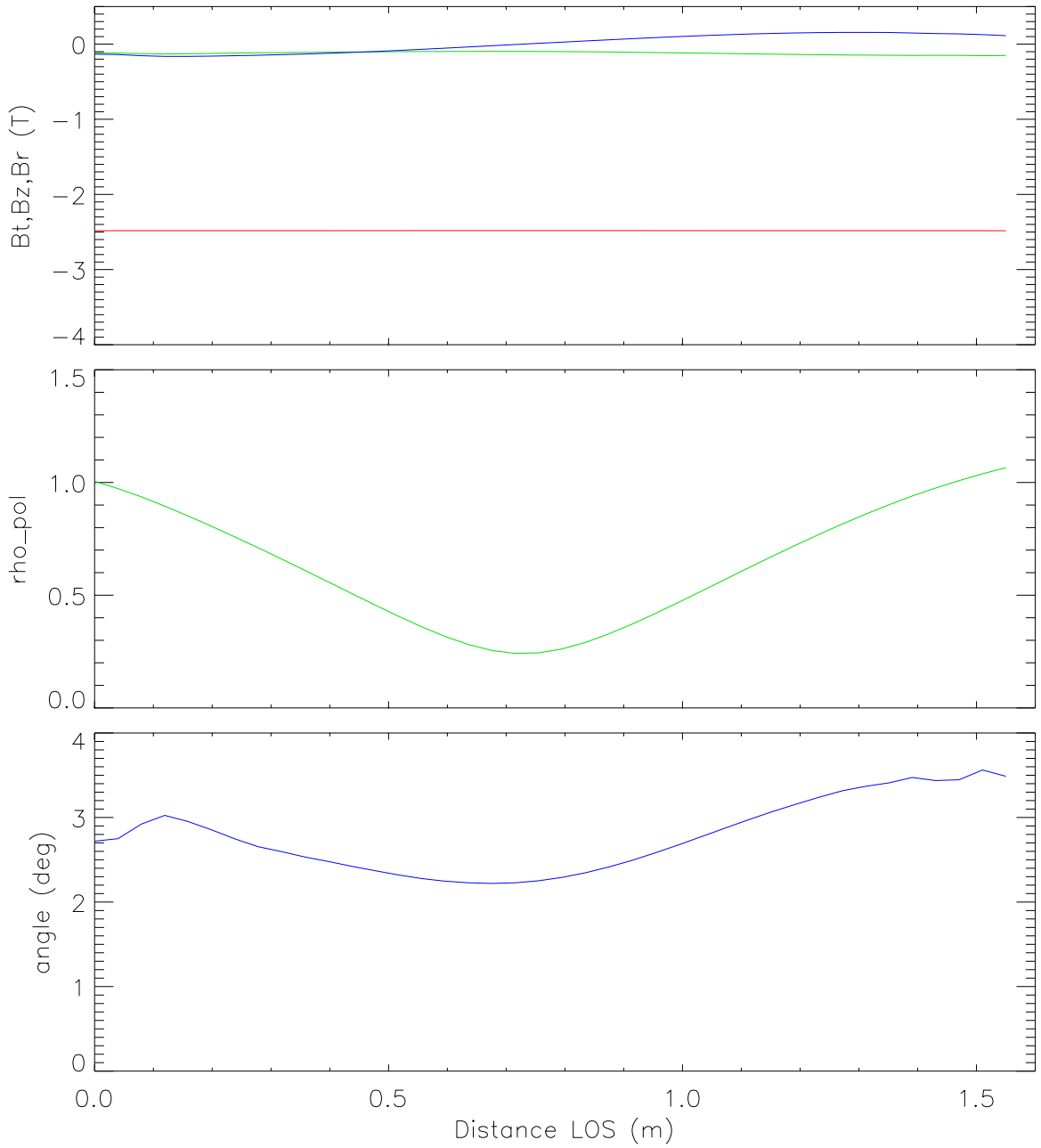
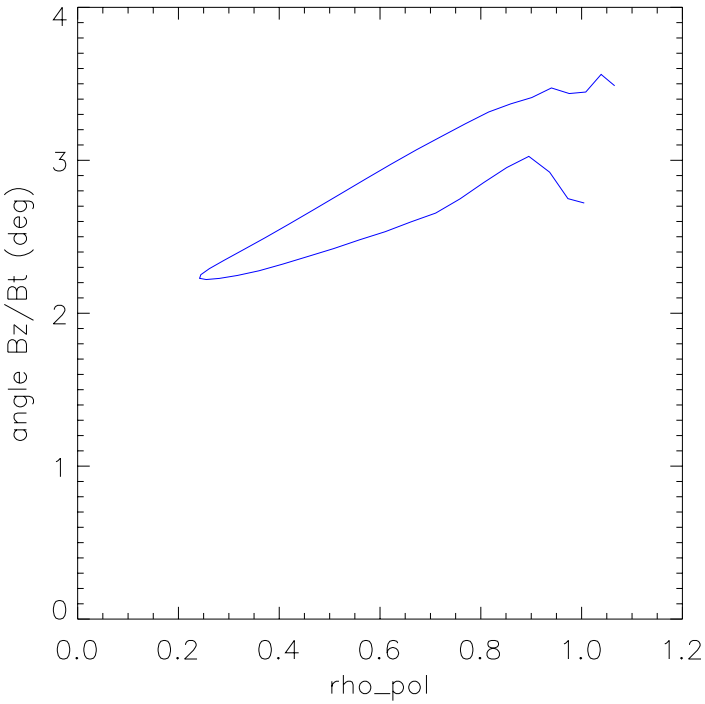




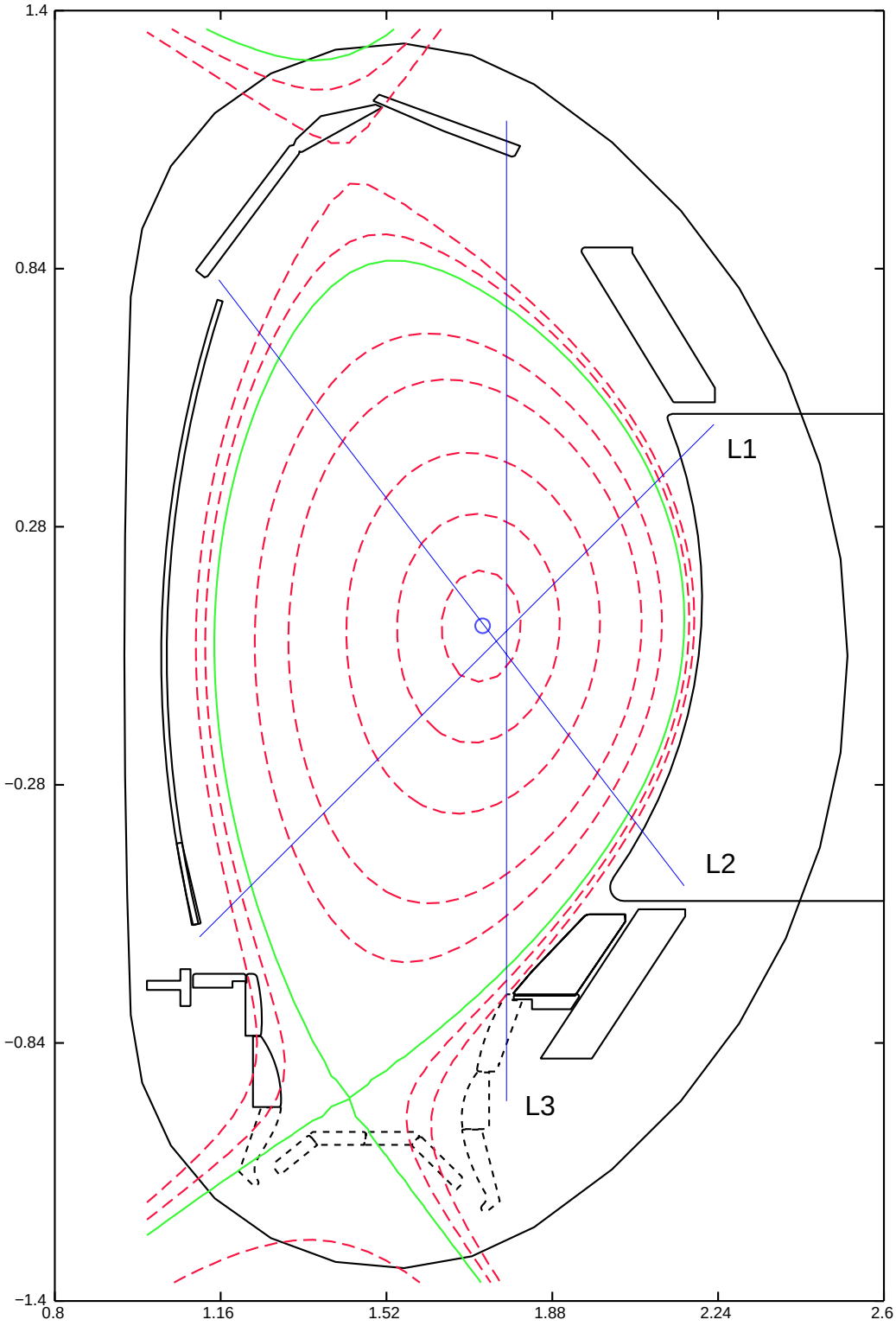
AUG Shot: 14034 @ 0.800 s

LOS Start R,z (m): 1.78 : −0.70

LOS Stop R,z (m): 1.78 : 0.850

No. of points: 40

Bangl (gdc) v1.05 – User: grc : Tue Jul 24 10:16:35 2001



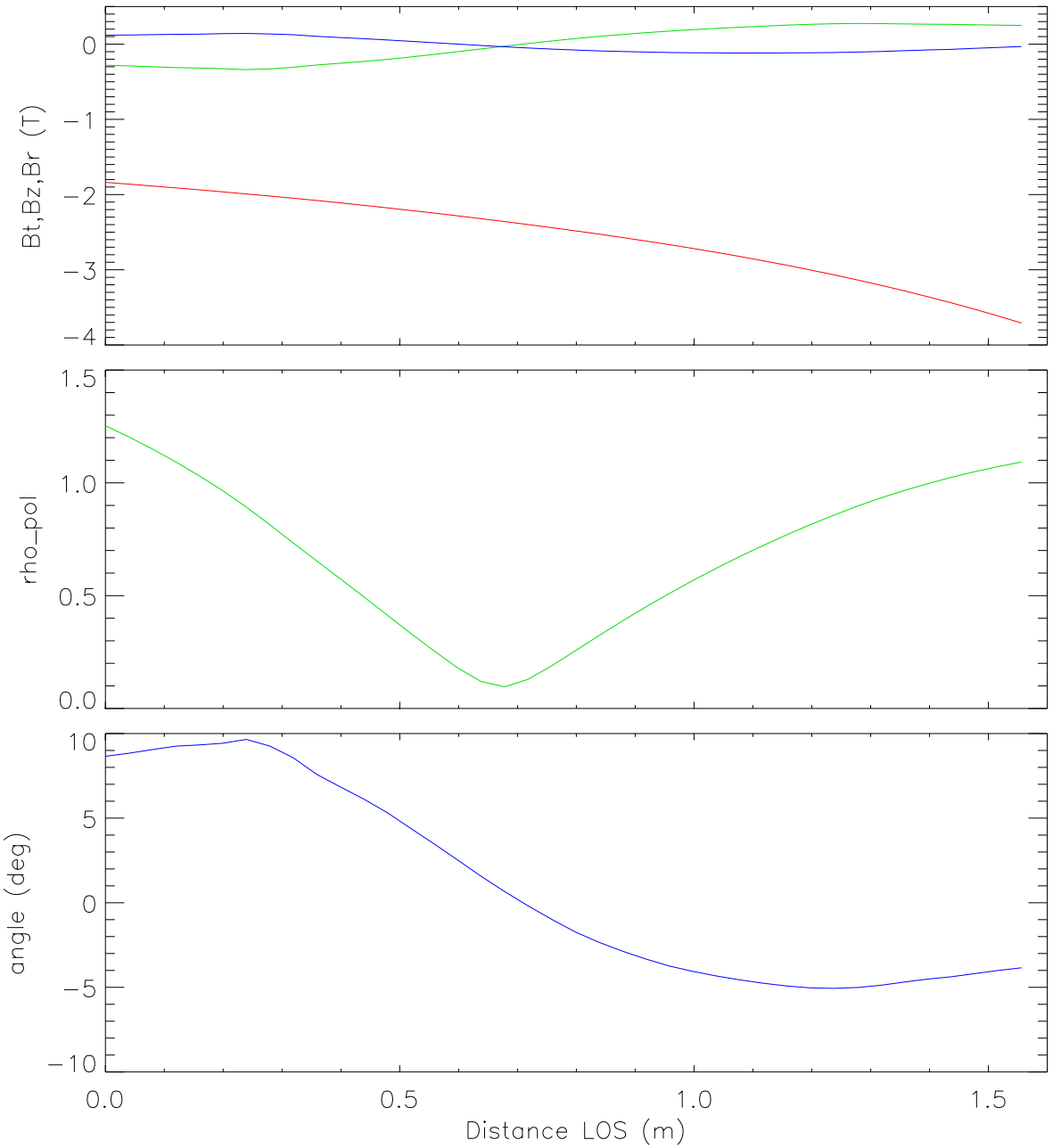
AUG shot: 14483
Time: 2.0s

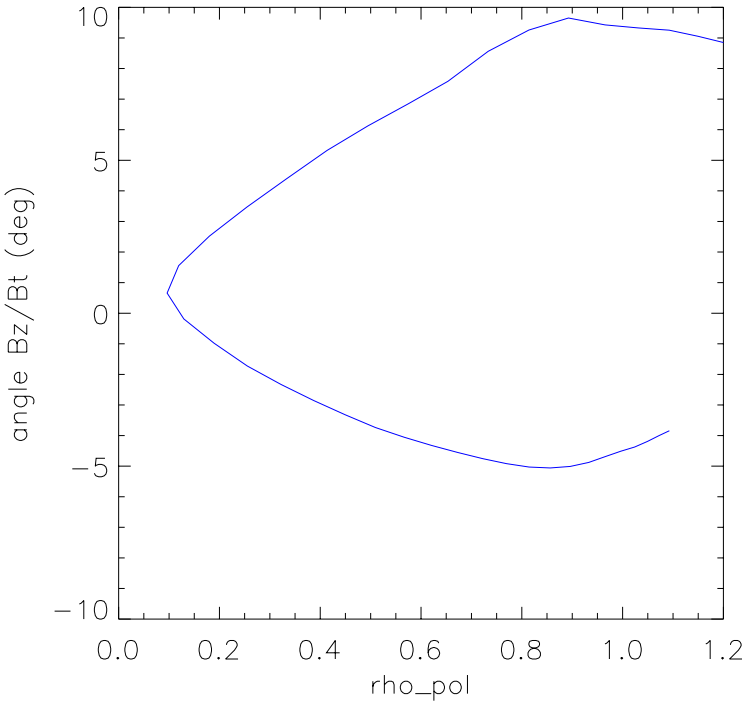
13/07/01

Improved
H-mode

-2.5T / -1.0MA
Mk-IIb divertor

δo = 0.25
δu = 0.44
κ = 1.73
q95 = 5.0





AUG Shot: 14483 @ 2.000 s

LOS Start R,z (m): 2.24 : 0.480

LOS Stop R,z (m): 1.11 : −0.59

No. of points: 40

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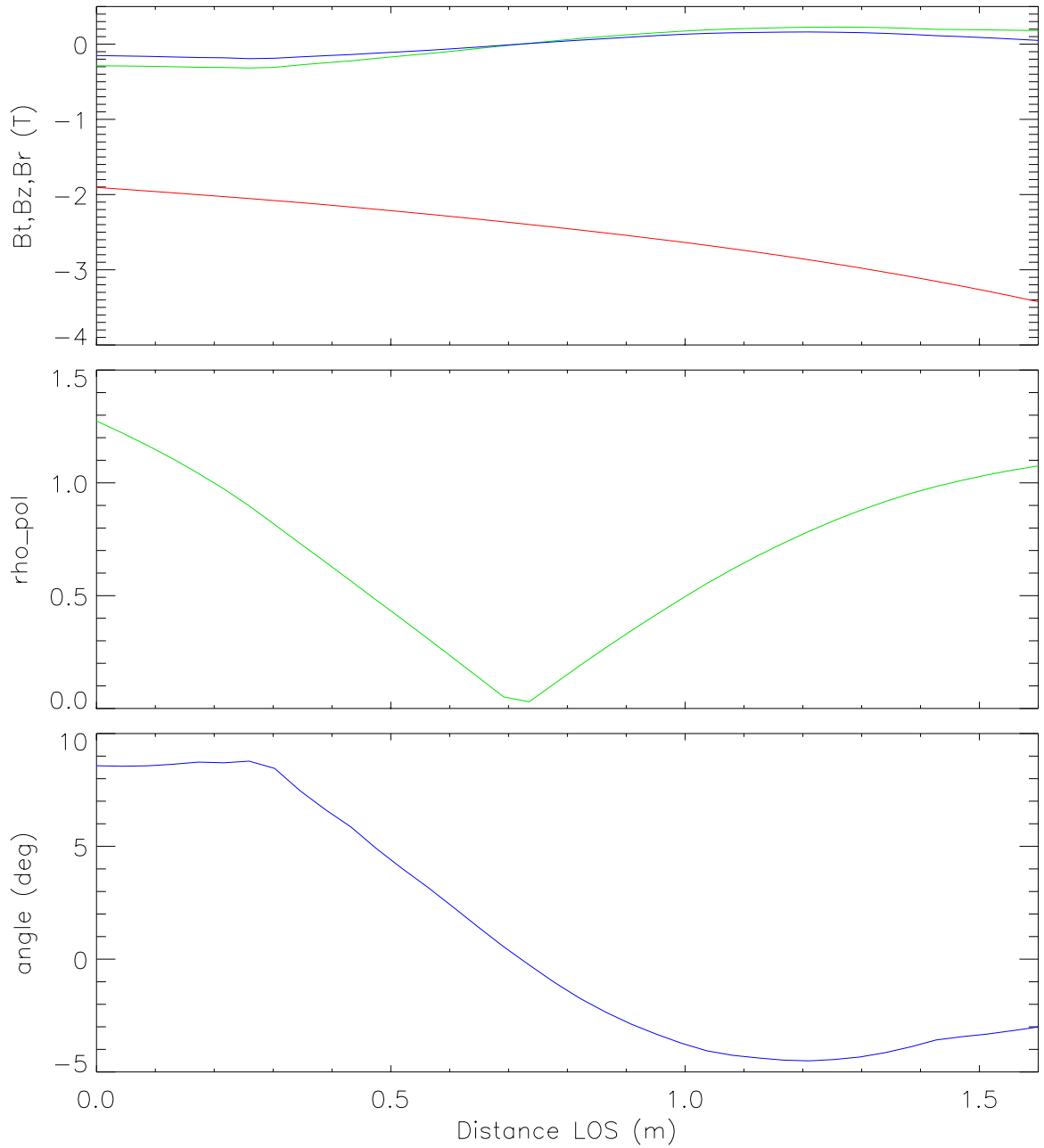
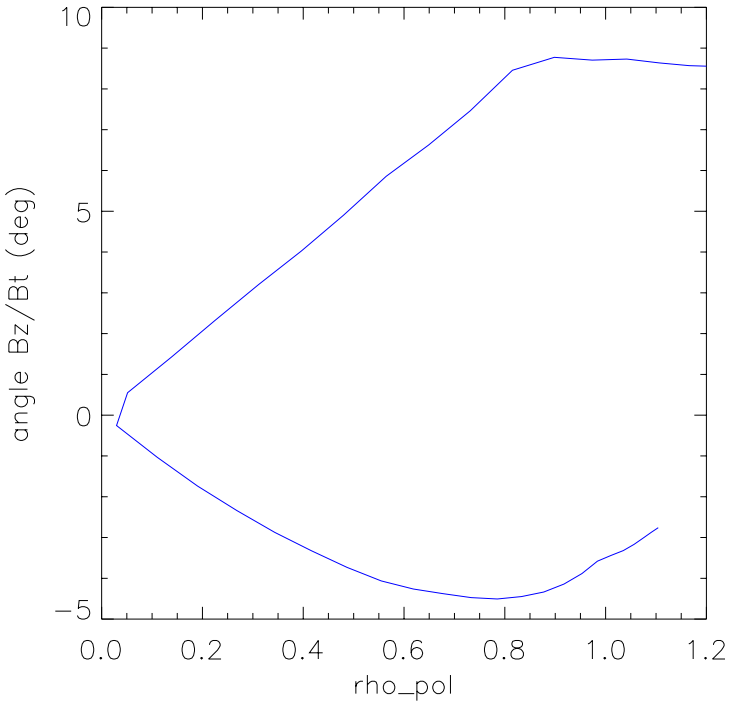




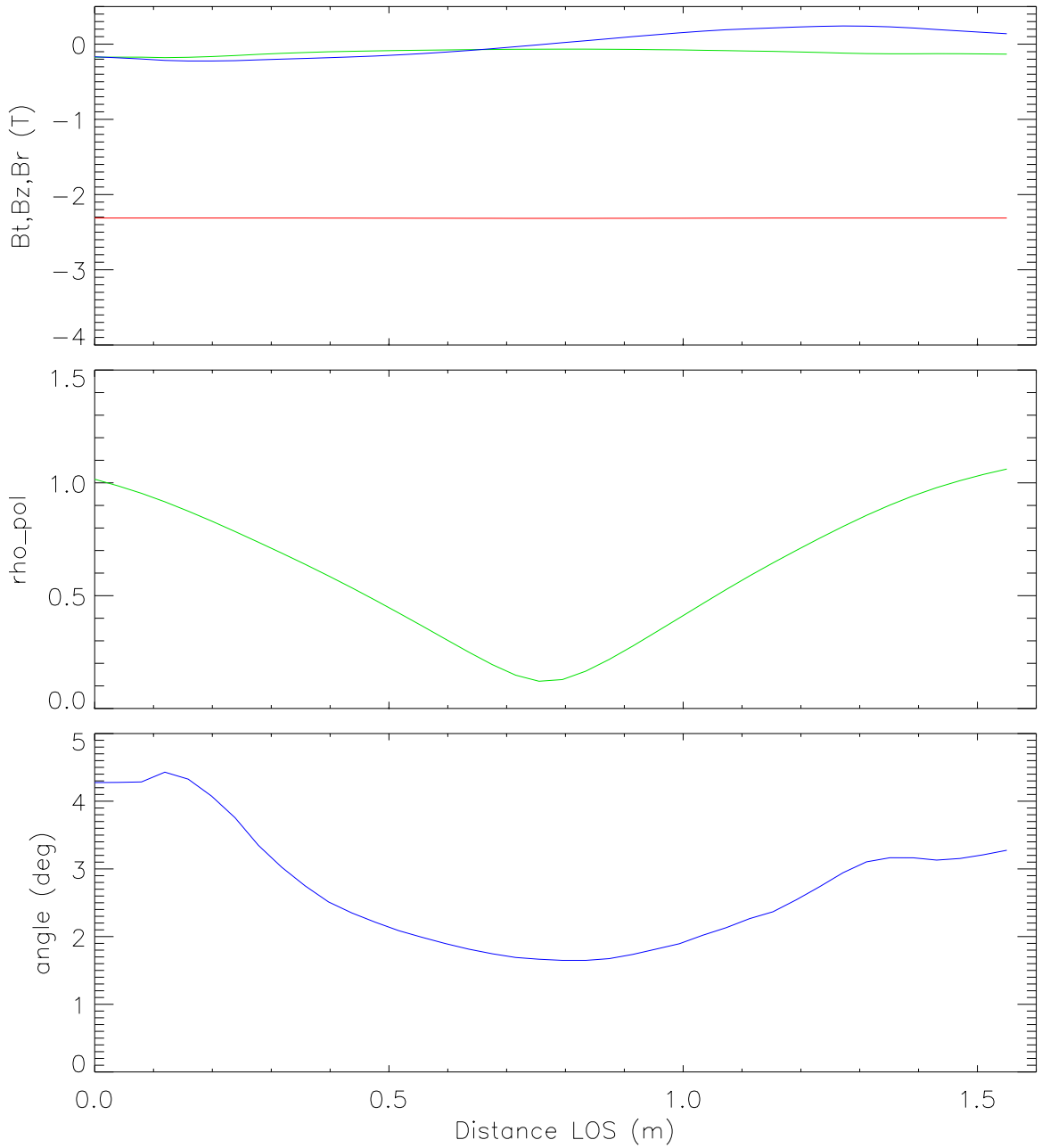
AUG Shot: 14483 @ 2.000 s

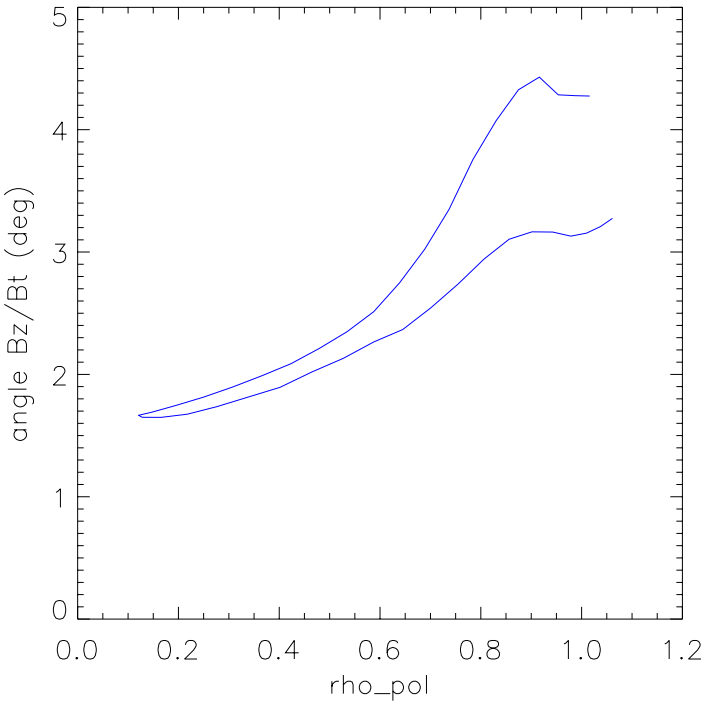
LOS Start R,z (m): 2.16 : −0.51

LOS Stop R,z (m): 1.15 : 0.840

No. of points: 40

Bangl (gdc) v1.05 – User: grc : Tue Jul 24 10:14:25 2001





AUG Shot: 14483 @ 2.000 s

LOS Start R,z (m): 1.78 : −0.70

LOS Stop R,z (m): 1.78 : 0.850

No. of points: 40

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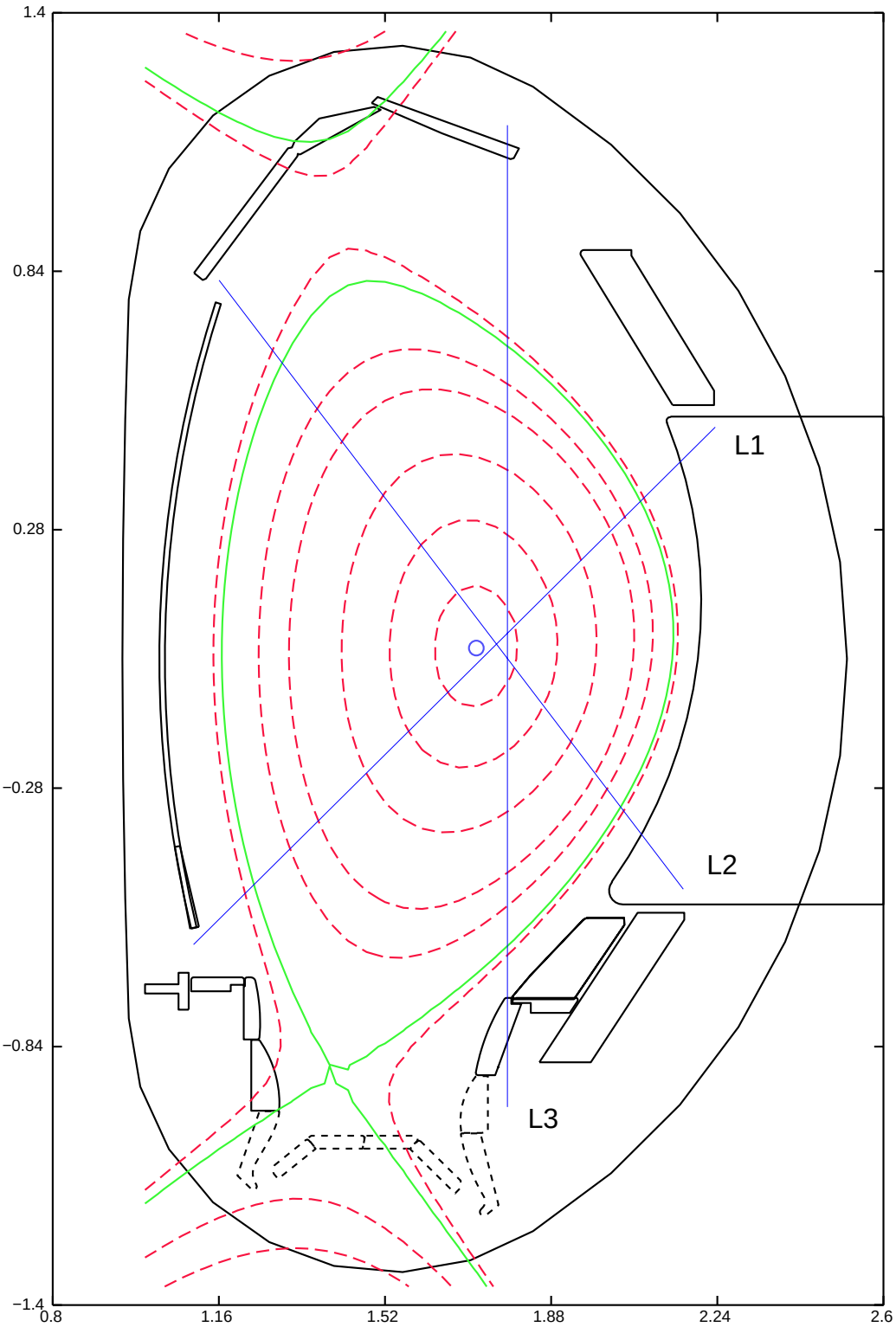


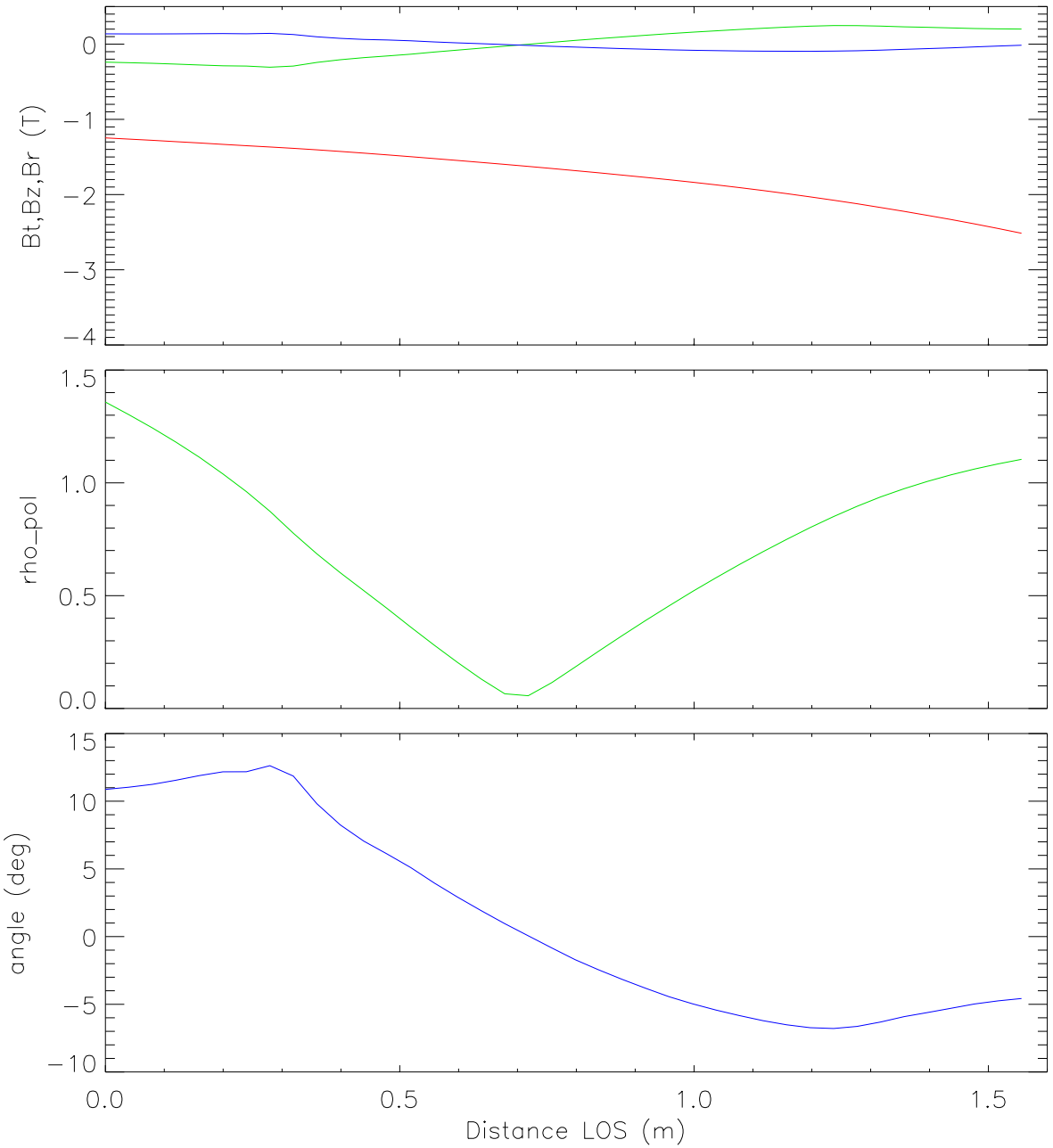
AUG shot: 14541
Time: 4.0s

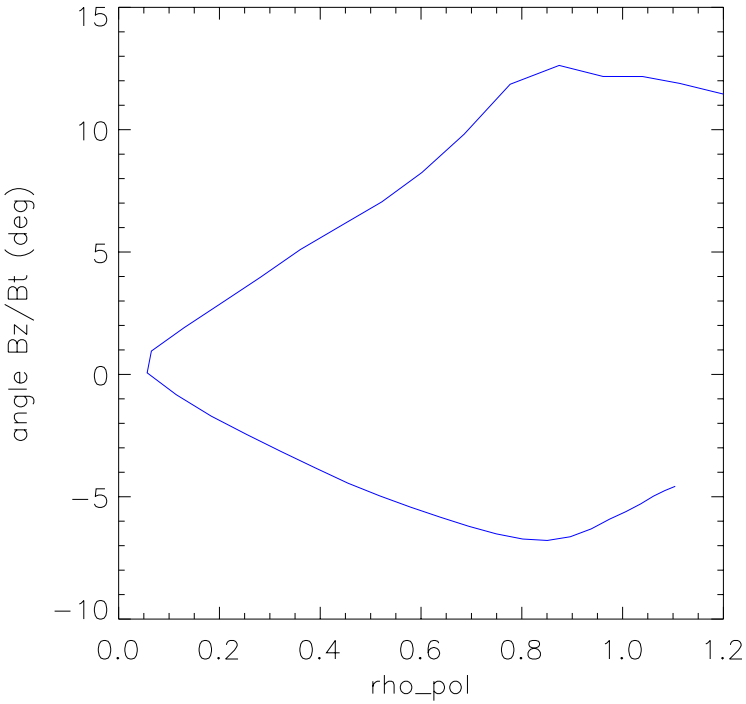
20/07/01

High beta_N

-1.7T / -0.8MA
Mk-IIb divertor

δo = 0.36
δu = 0.50
κ = 1.71
q95 = 3.55





AUG Shot: 14541 @ 4.000 s

LOS Start R,z (m): 2.24 : 0.480

LOS Stop R,z (m): 1.11 : −0.59

No. of points: 40

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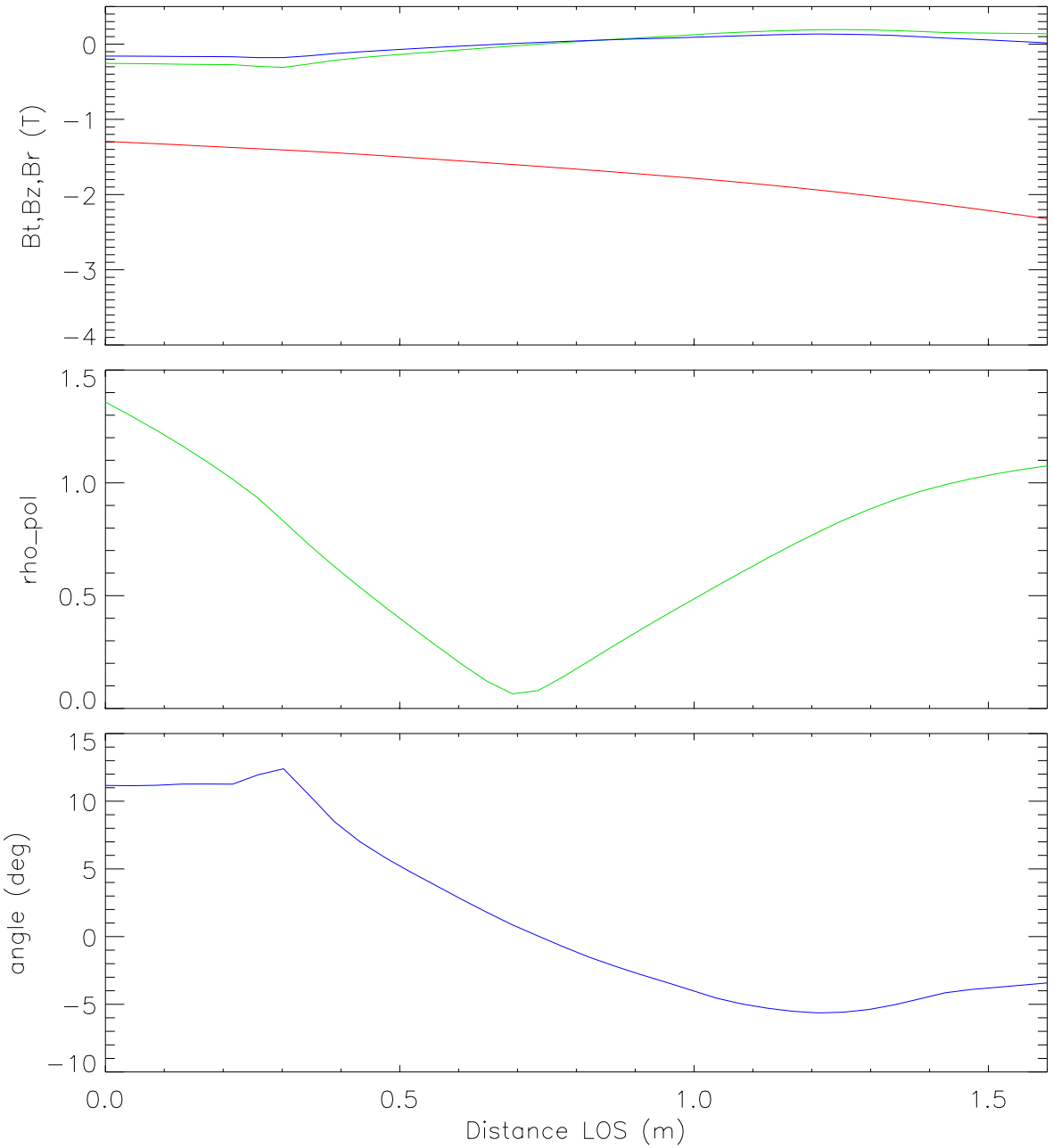

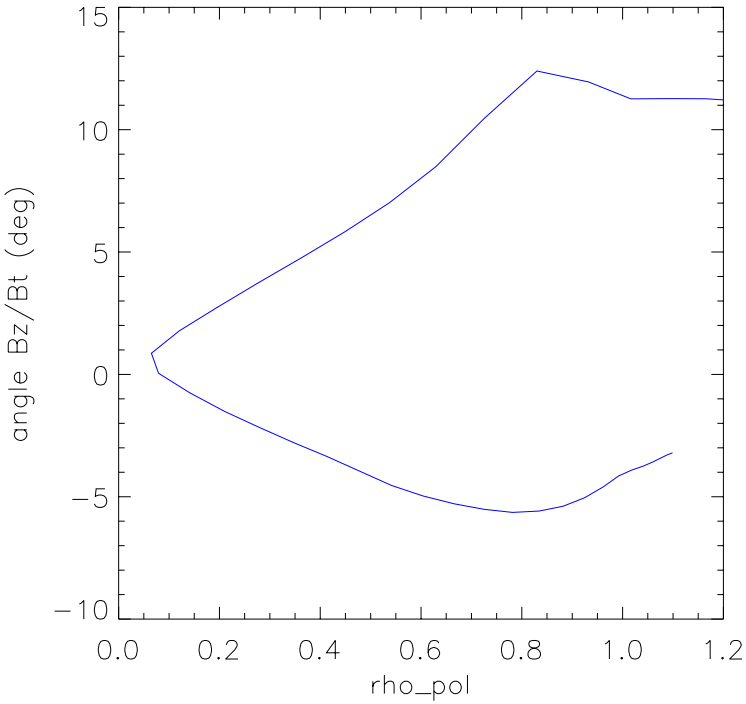

AUG Shot: 14541 @ 4.000 s

LOS Start R,z (m): 2.16 : −0.51

LOS Stop R,z (m): 1.15 : 0.840

No. of points: 40

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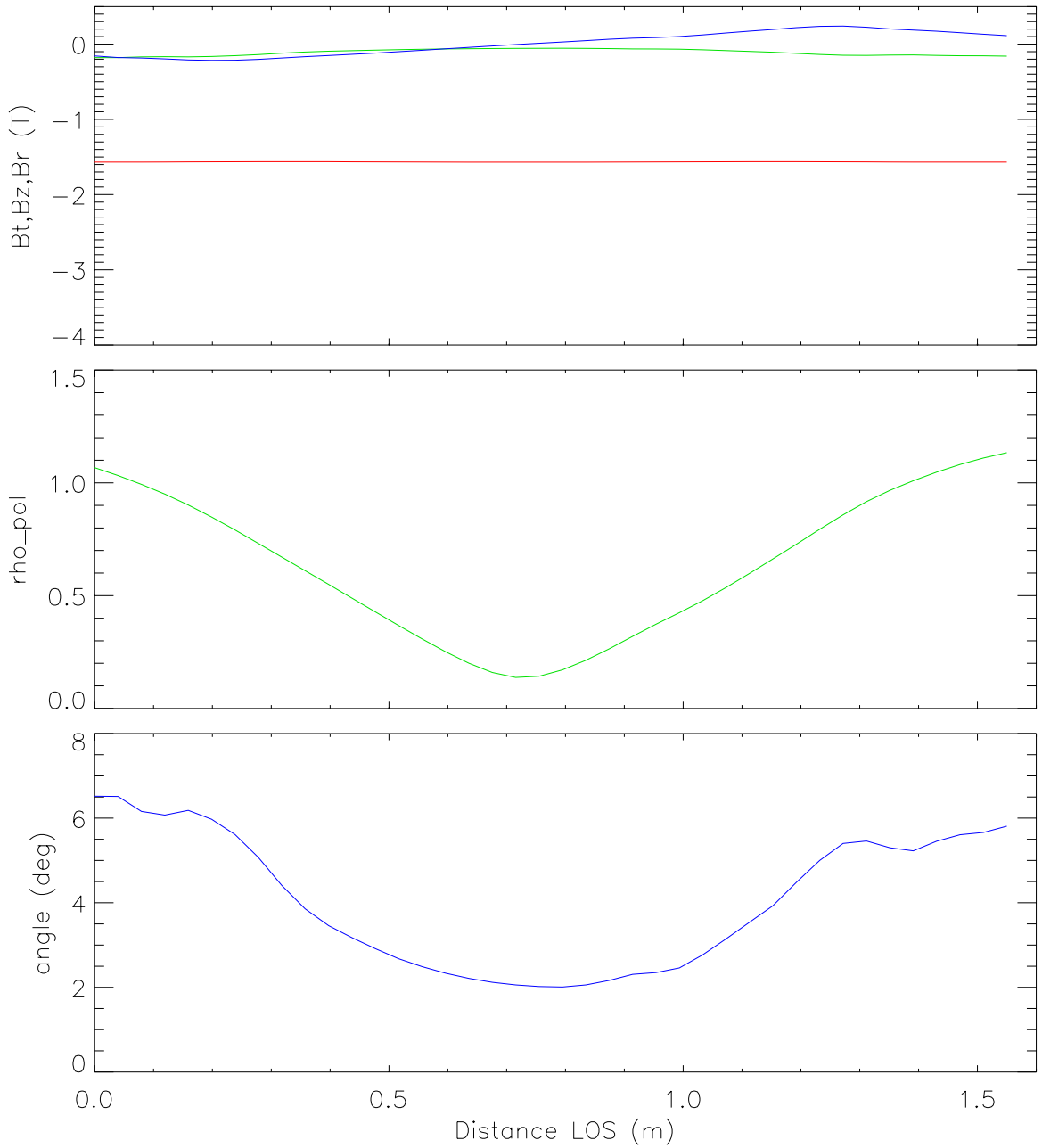

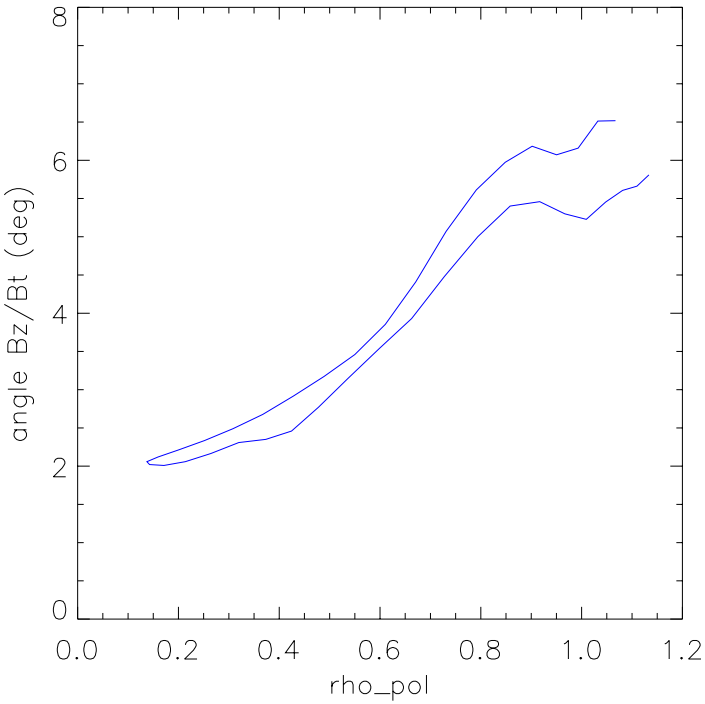

AUG Shot: 14541 @ 4.000 s

LOS Start R,z (m): 1.78 : −0.70

LOS Stop R,z (m): 1.78 : 0.850

No. of points: 40

Bangl (gdc) v1.05 – User: grc : Tue Jul 24 10:07:32 2001