QUASI-AXISYMMETRIC (QA) COILS FOR QA STELLARATORS

Prashant M. Valanju
Fusion Research Center,
The University of Texas at Austin

We propose to design quasi –axisymmetric (QA) wavy poloidal field (WPF) coils in the background of straight or tilted toroidal field coils for a QA stellarator plasma. These are distorted vertical field coils with a "topology" similar to the mod-B lines in a QA machine. These coils may be important for NCSX-QA, CHS-QA and a QA reactor because they do not exclude a continuous quasi-toroidal divertor. This is in contrast to saddle or modular coils which necessarily interrupt any toroidal or helical divertor. Initial attempts to design such coils for NCSX-QA and CHS-QA plasma at the current sheet level show good results in terms of reduced coil complexity and low maximum current. Attempts are also underway to design planar, torsion-free coils with this topology.

Motivations:

- Since NCSX-QA is supposed to be a slightly distorted tokamak (ARIES-RS), try to design it with slightly distorted tokamak coils.
- Of the 4 coil topologies available, we have explored only one in detail so far:
  - Ipol = 0, Itor = 0 : Saddles (S)
  - Ipol = 0, Itor ≠ 0: Wavy PF (WPF)
  - Ipol ≠ 0, Itor = 0 : Modular (M)
  - Ipol ≠ 0, Itor ≠ 0 : Helical (H)
- "PBX-TF constraint" : only Saddle and WPF
- Saddle coils generally look quite complex.
- WPF coils are "QA" (|B| near them is QA), so may be easier to find than saddles for a QA plasma.
- Initial attempts to design WPF for NCSX-QA and CHS-QA look promising.

Divertor Issues:

- The low-A QA plasma configurations are attractive, but to make a viable QA reactor, one must be able to design a divertor for these plasma configurations.
- Then we must demonstrate coils for QA which are consistent with such a divertor.
- Modular or saddle coils can work but they have to be far enough away from plasma to allow space for a divertor, which has to fit inside these coils or else they intercept it.
- Modular (or saddle) coils get very complex (not realistic) if one takes the coil surface far from the plasma to make room for a divertor.

- QA or helical coils can be relatively near plasma because they do not interrupt the divertor – it can “poke” between two coils – just as it does in LHD.
- This allows one to design simple coils (near plasma) consistent with divertor topology.
- |B| near QA coils also shows QA symmetry – same as |B| on QA plasma surface. This may make it easier to design WPF for QA.
- May find planar distorted VF coils, i.e., with each coil in a Z = constant plane.
- For NCSX, this can be a simpler coil set than saddles. It allows the re-use of PBX TF coils.
- For CHS-QA, this can be a simple and novel coil set with possible reactor extrapolation.

Results so far:

- Only preliminary runs have been done so far because this task was not at high priority.

First run for NCSX-QA C82 Configuration:

Case # svd	err_ave	err_max	Jmax	Cmplx
WPF 127	0.318	4.03	1.53	2.294
Saddle 121	0.600	6.714	0.83	3.119

- Coil complexity, average Bnorm error, and maximum Bnorm error already look better in initial runs with QA coils than with saddle coils (on which we spent months optimizing).
- There are almost no coils in the outer part of torus. This gives excellent diagnostic access.

- These coils can most probably be improved as we try to optimize them further.
- Jmax is large but can be reduced 50% by using the PBX EF coils outside the TF.

Improved Jmax run for NCSX-QA C82 (EF):

Case # svd	err_ave	err_max	Jmax	Cmplx
WPF 133	0.298	4.444	1.08	2.08
WPF 127	0.318	4.03	1.53	2.294
Saddle 121	0.600	6.714	0.83	3.119

Results for CHS-QA-coilsurface distance scan:

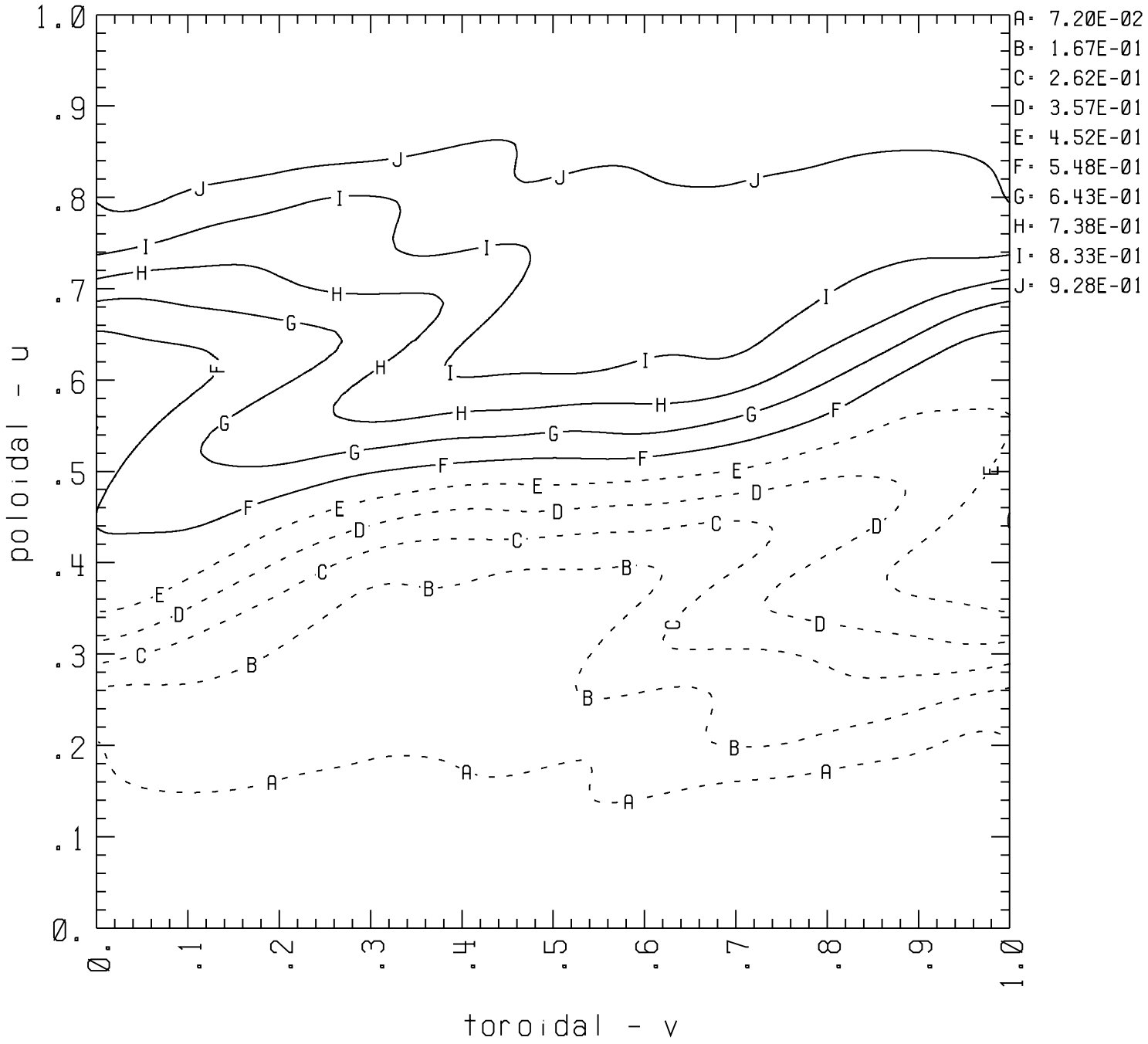
Distance	err_ave	err_max	Jmax	Cmplx
22.5	0.093	0.543	0.82	1.13
26.25	0.118	0.705	0.99	1.20
33.75	0.540	2.162	1.403	1.903

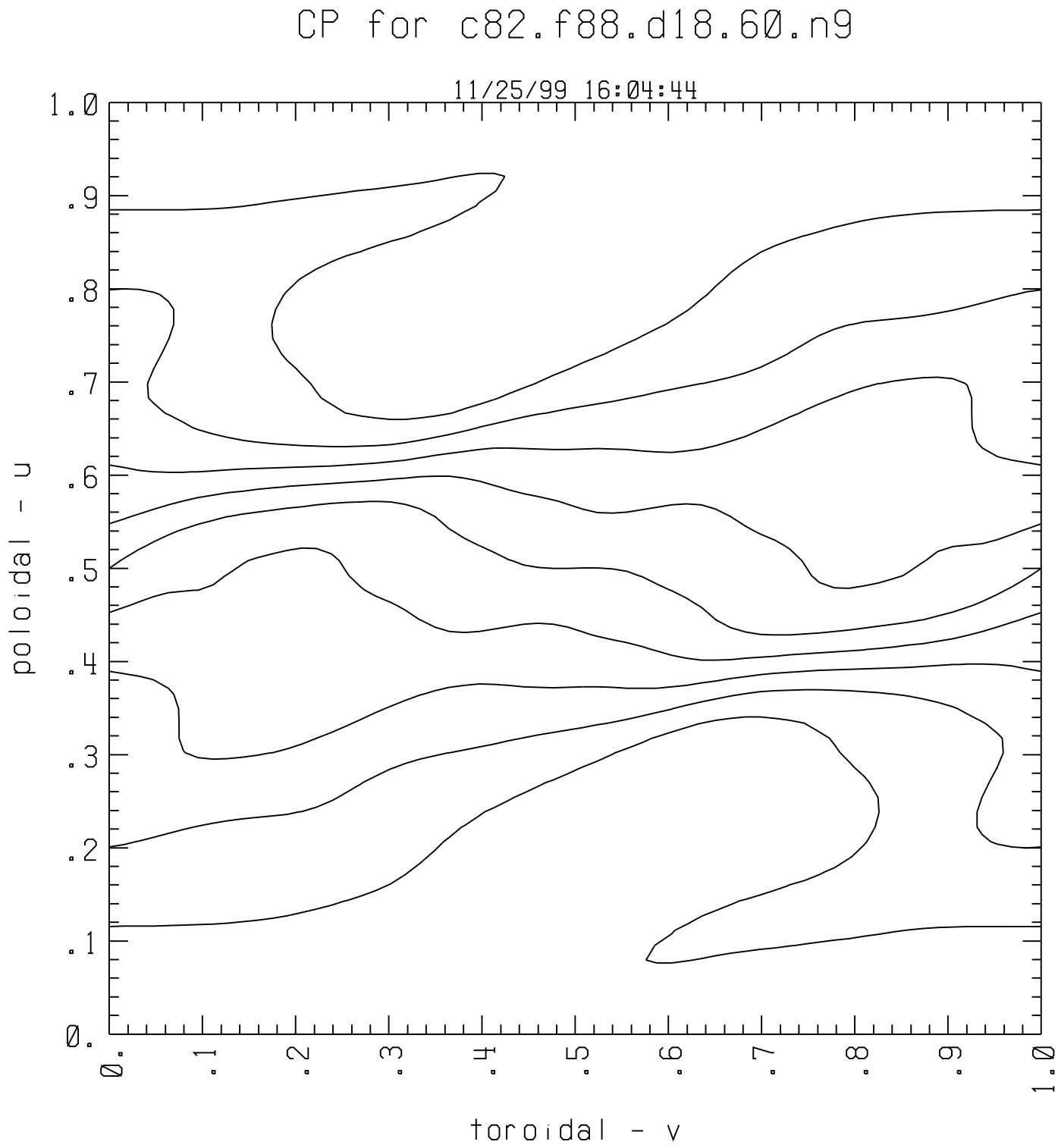
WPF coils may be worth studying further

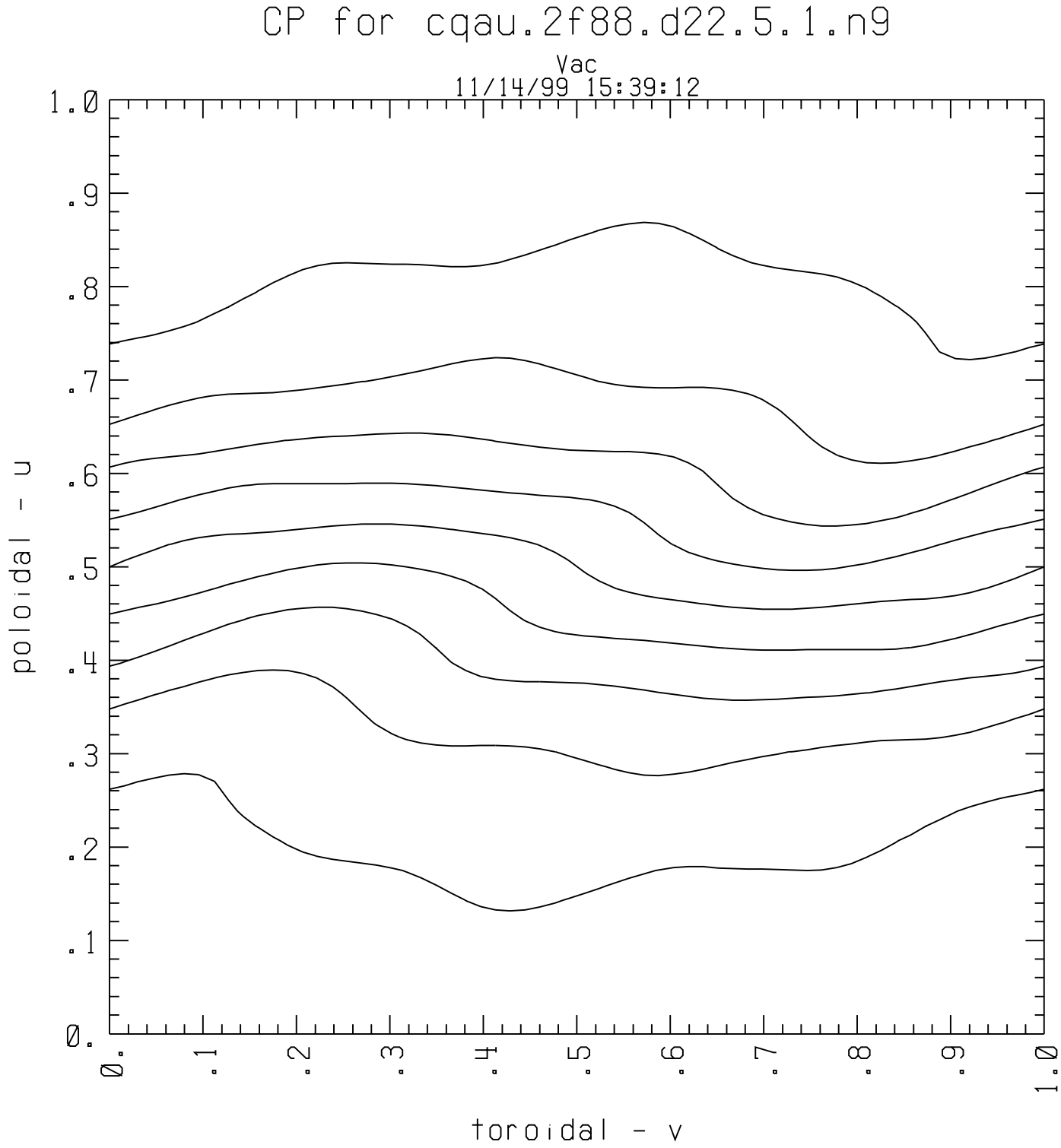
Current Potential c82.f88.d18.48

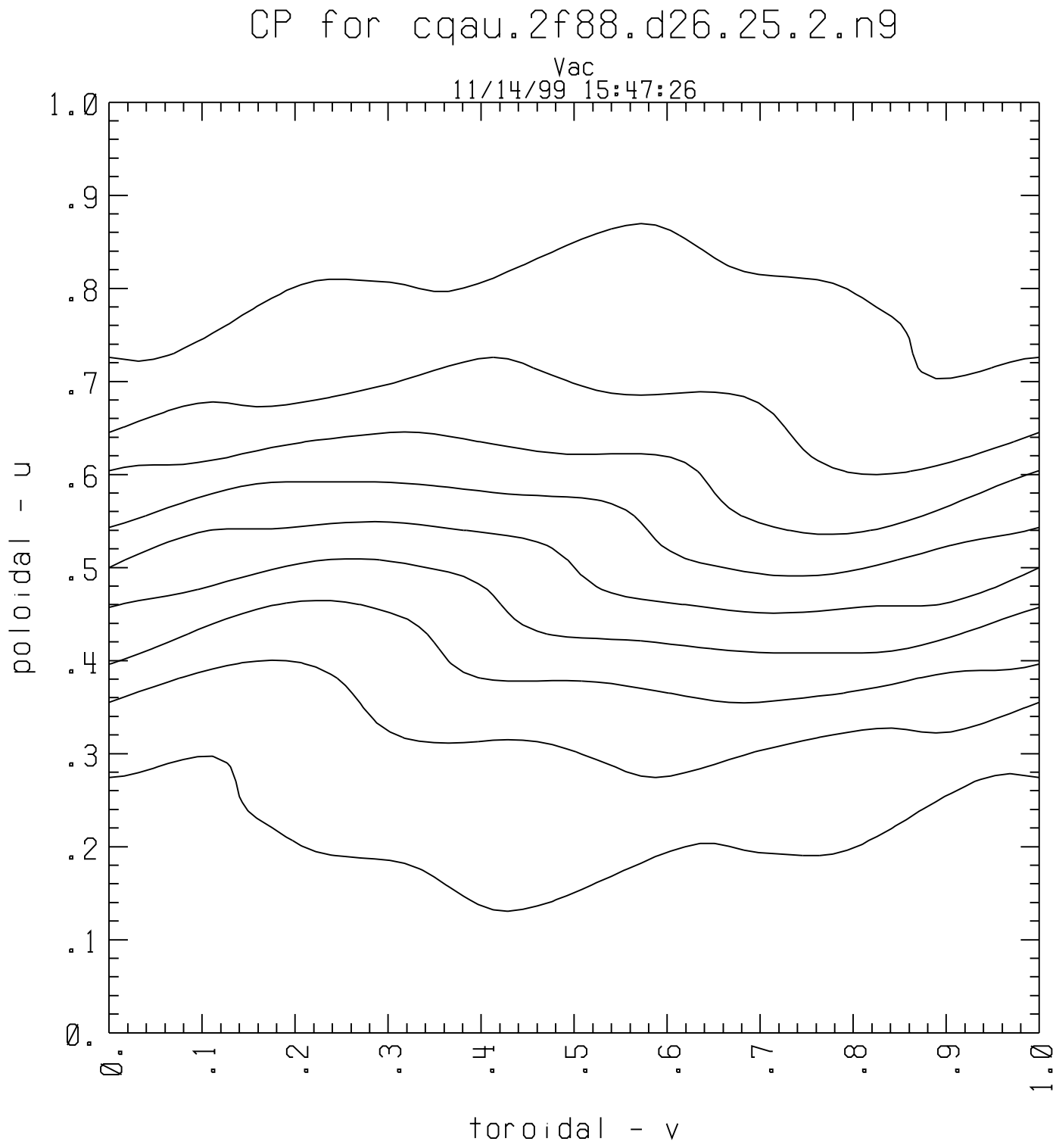
1.0 0.0 ../tfcoils 127 1 .new

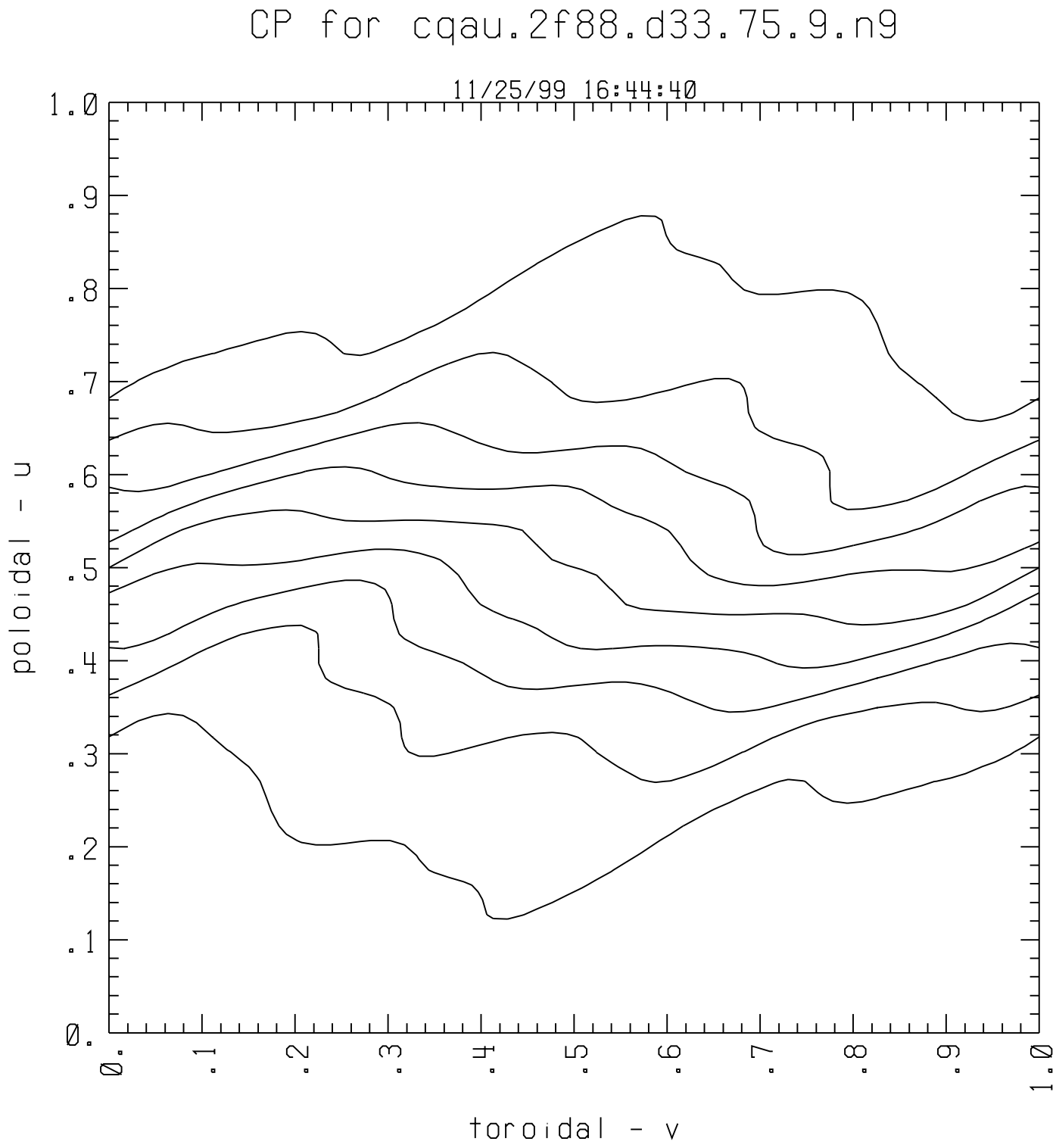
Max Value = 1.02E+00 Min Value = -2.31E-02 Contours = 9.51E-02

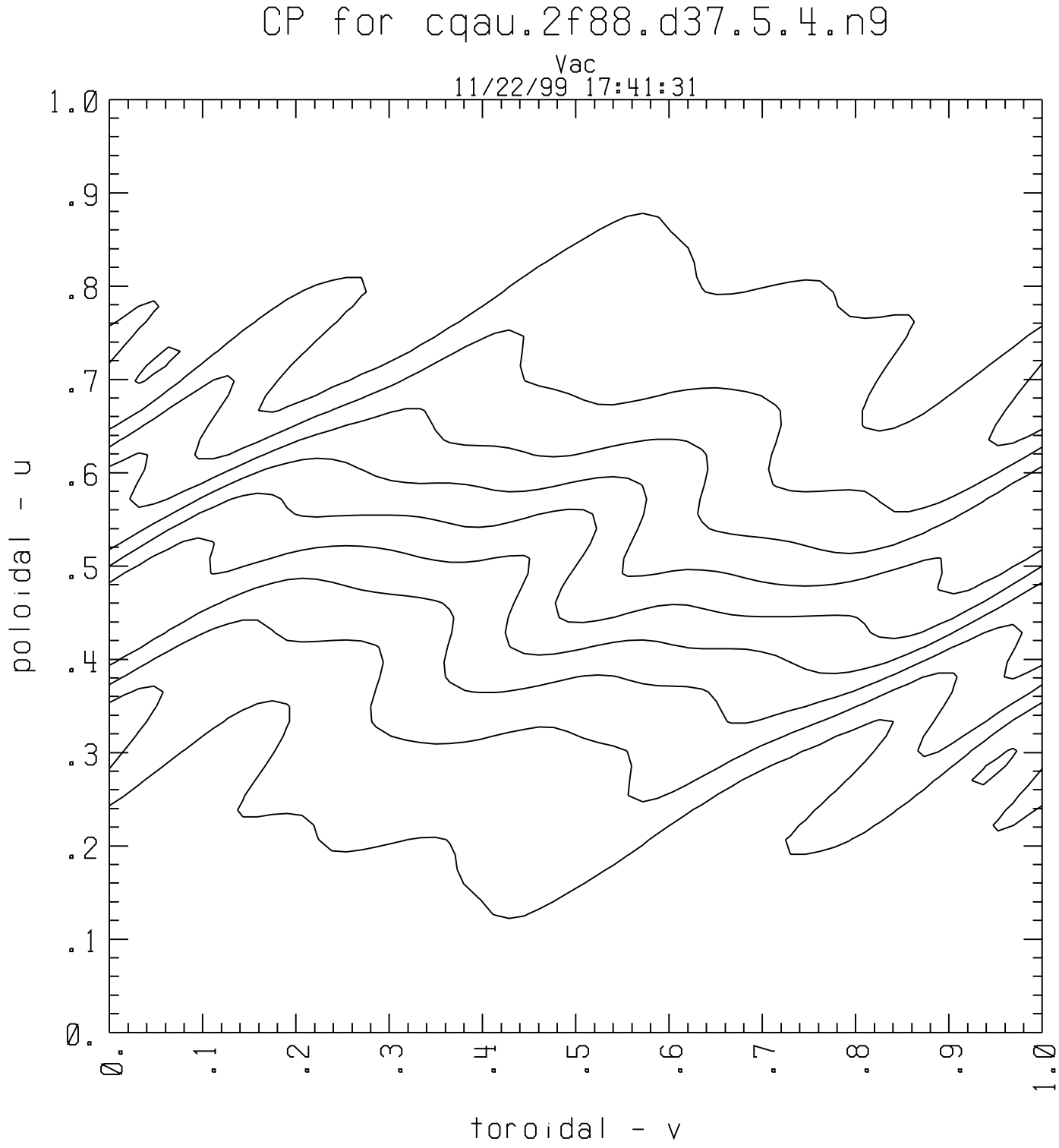



CP for c82.f88.d18.60.n9
11/25/99 16:04:44
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.
poloidal - u
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
toroidal - v


CP for cqau.2f88.d22.5.1.n9
Vac
11/14/99 15:39:12
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.
poloidal - u
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
toroidal - v


CP for cqau.2f88.d26.25.2.n9
Vac
11/14/99 15:47:26
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.
poloidal - u
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
toroidal - v


CP for cqau.2f88.d33.75.9.n9
11/25/99 16:44:40
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.
poloidal - u
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
toroidal - v


CP for cqau.2f88.d37.5.4.n9
Vac
11/22/99 17:41:31
1.0
.9
.8
.7
.6
.5
.4
.3
.2
.1
0.
poloidal - u
0.
.1
.2
.3
.4
.5
.6
.7
.8
.9
1.0
toroidal - v