Report on progress in reduction of surface current density within nescoil

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Goal of this effort:

Improve nescoil surface current solution, i.e., reduce

- maximum surface current density and complexity of current contours
- without significantly reducing the accuracy of plasma reconstruction

Get "acceptable" accuracy with "better" surface currents

Motivations for using svd within nescoil:

- **Possible to get both higher accuracy and good smoothing**:
  - Increasing the accuracy in NESCOIL requires using more fourier modes
  - But this increases coil complexity
  - Most of the modes are not essential
  - SVD can tell us which combinations of modes are important.

- **Allows exploration of tradeoffs:**
  - between accuracy, complexity, and maximum current density**.**

- **This is a linear problem**: for which svd is generally the better method.

Results found so far:

- **SVD scans** have just been completed for c10 and c82 cases.

  What is an svd scan?

  - Vary nsvd = number of svd weights kept from min to max and calculate

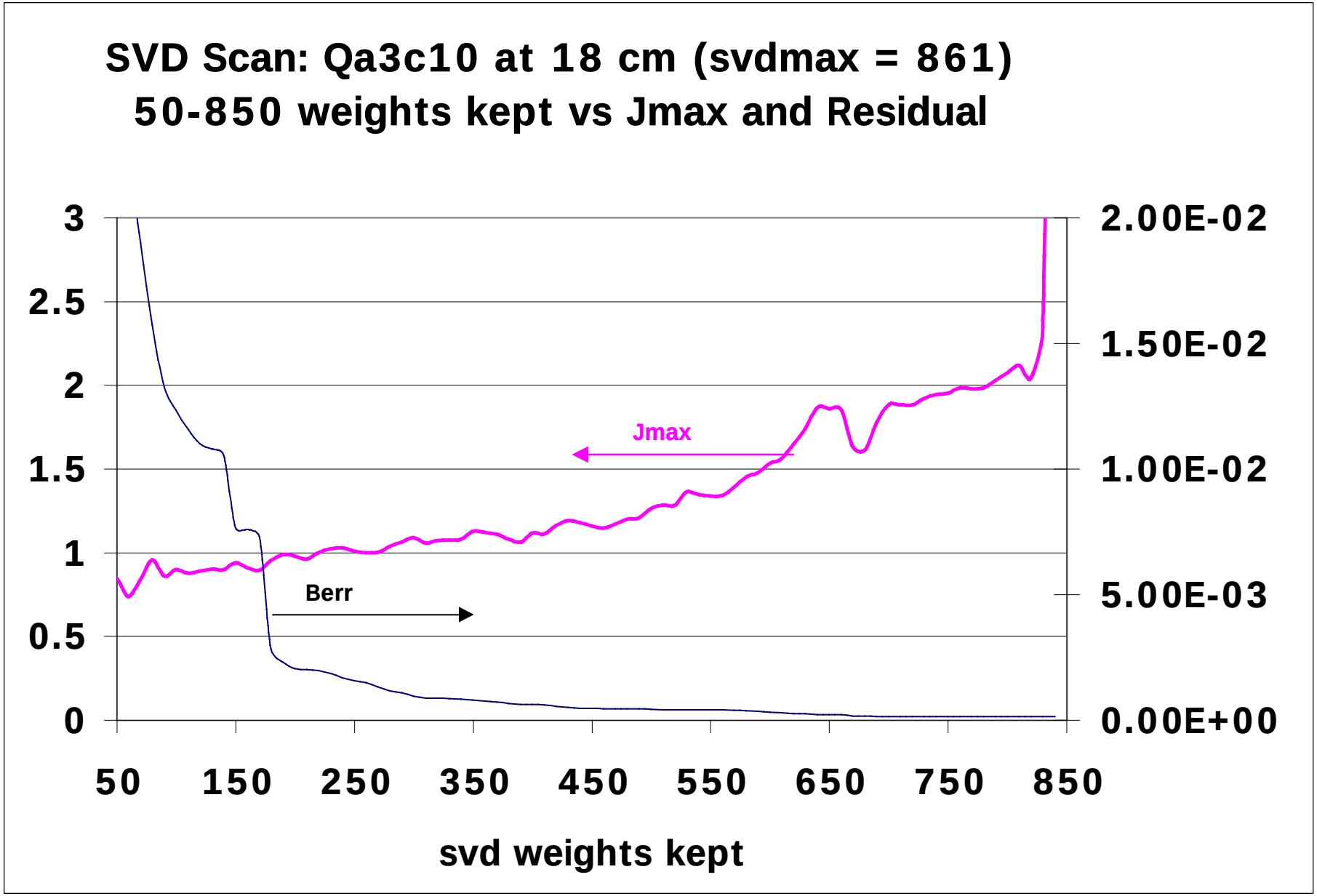
    Berror, **Xerror**, **Jmax**, Max **Curvature** and **Complexity** of solution.

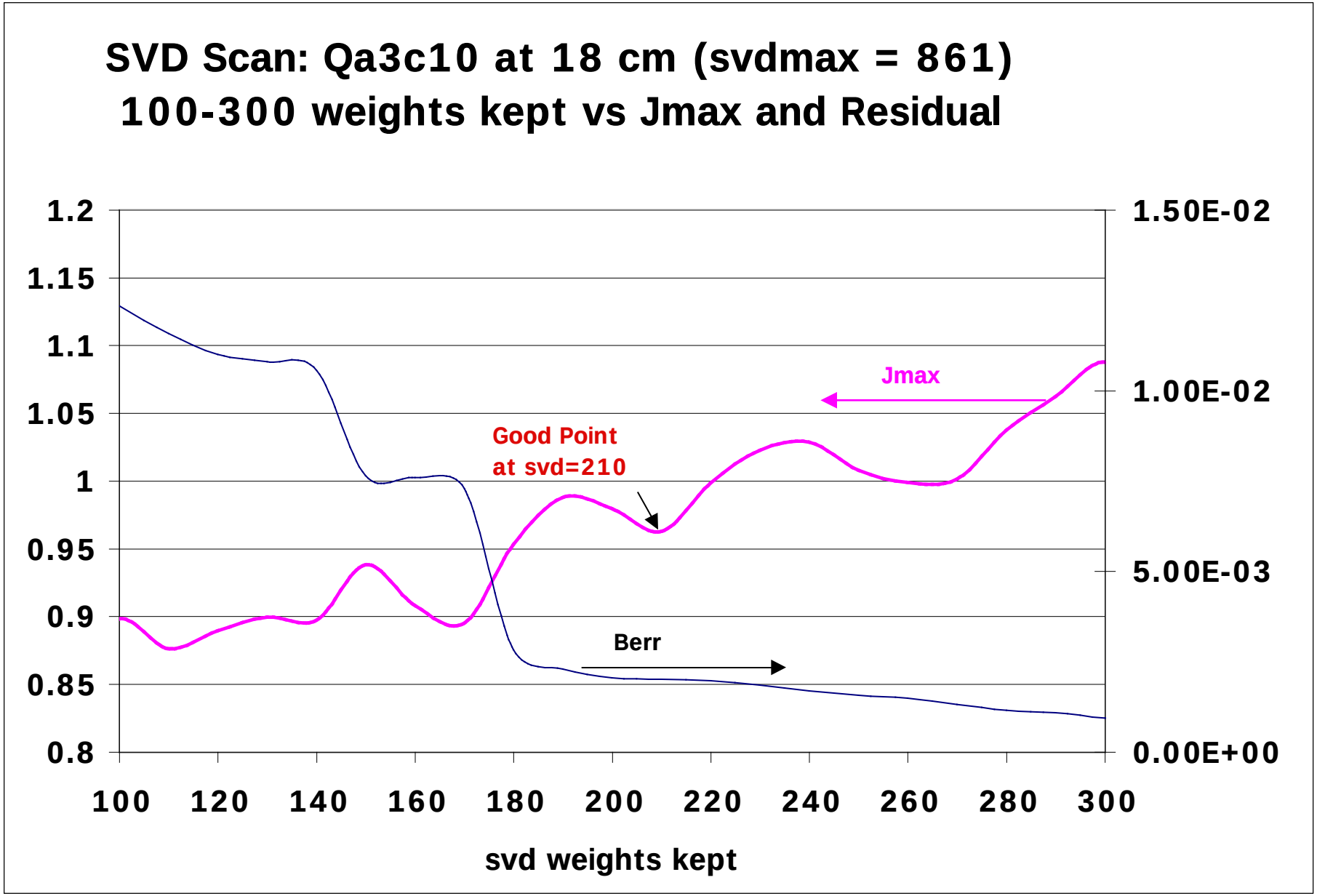
- **Optimum choices** of nsvd have been identified for c10, and c82.

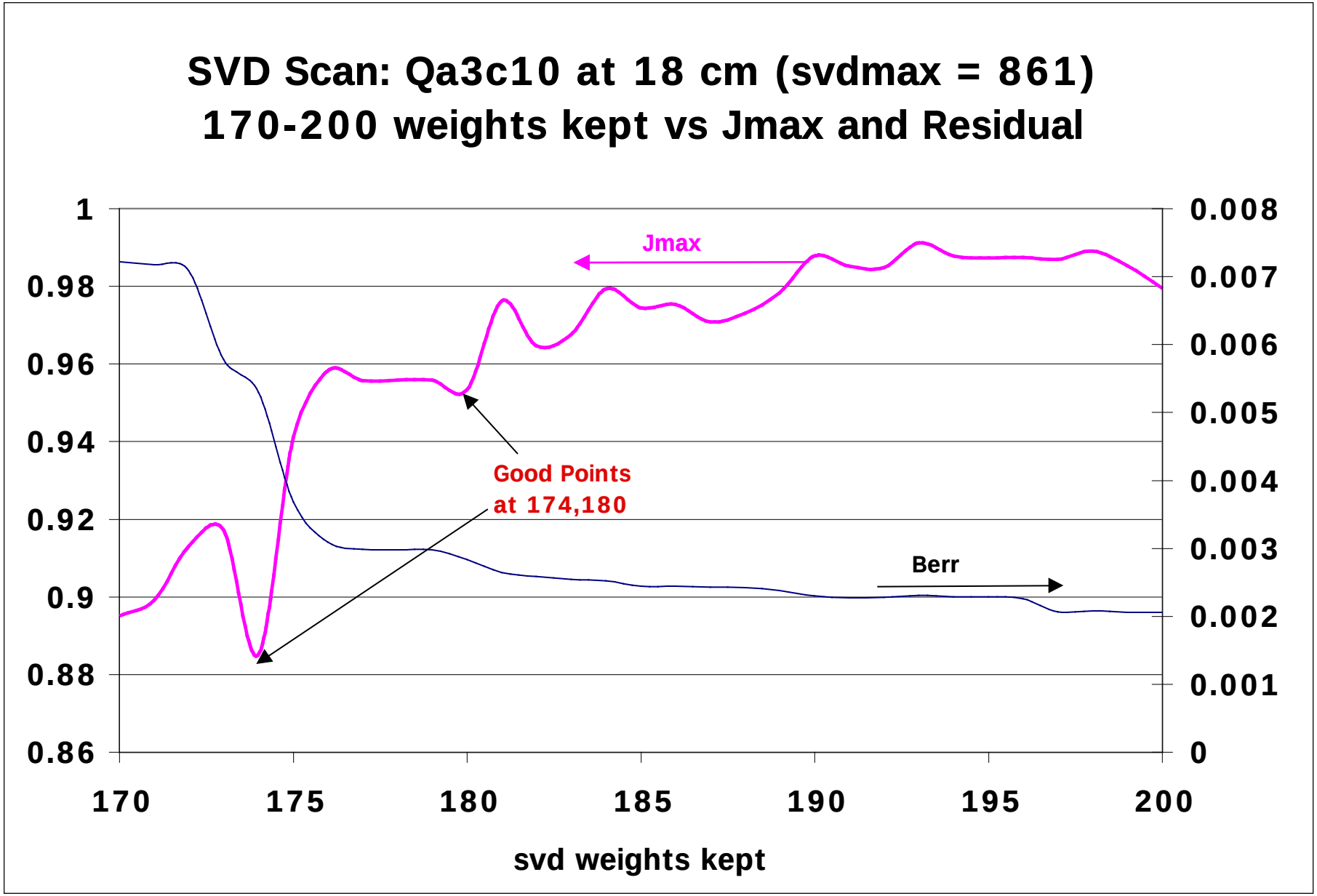
  What is an optimum choice?

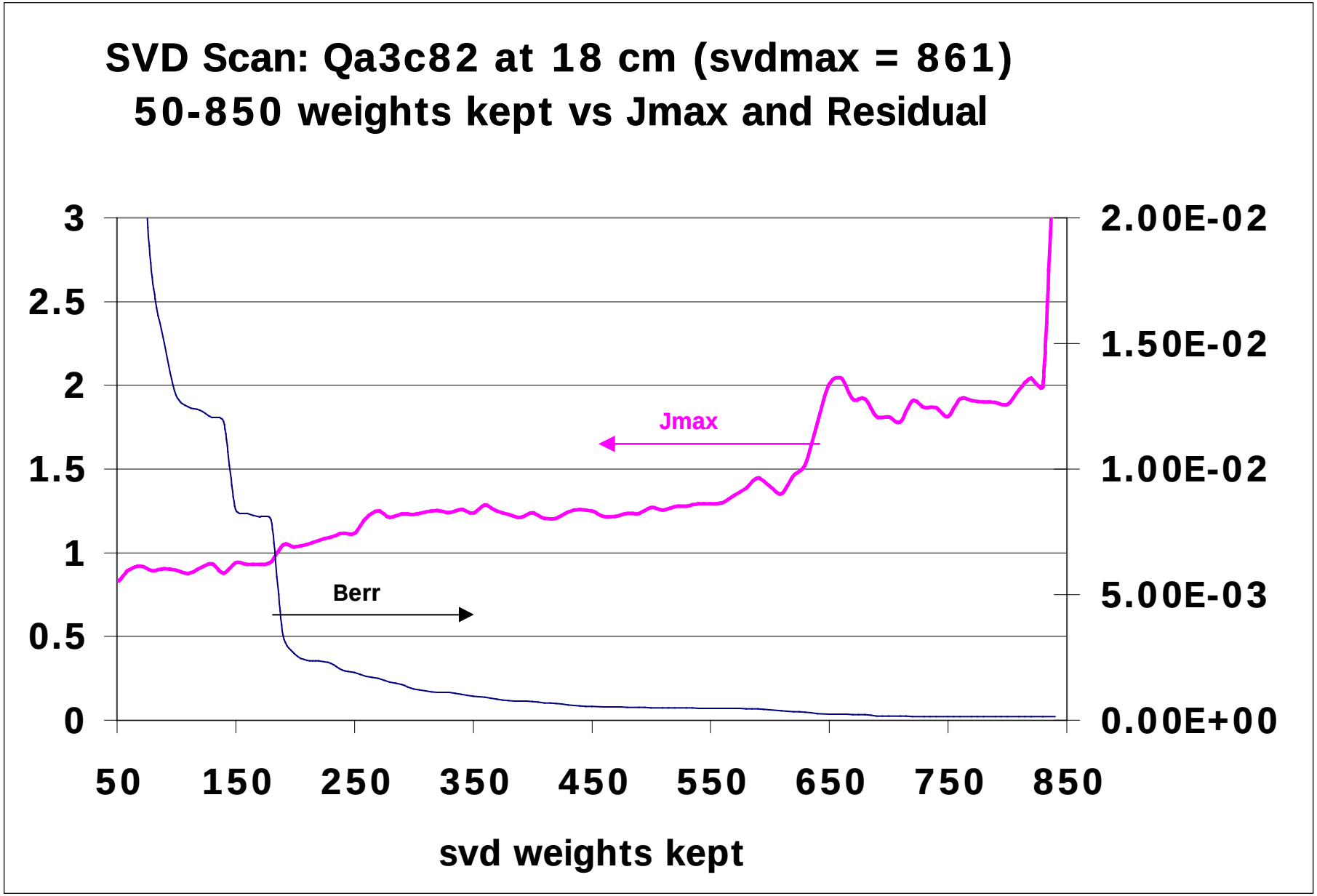
  - The number of svd weights where **Jmax**, **Curvature**, or **Complexity** have

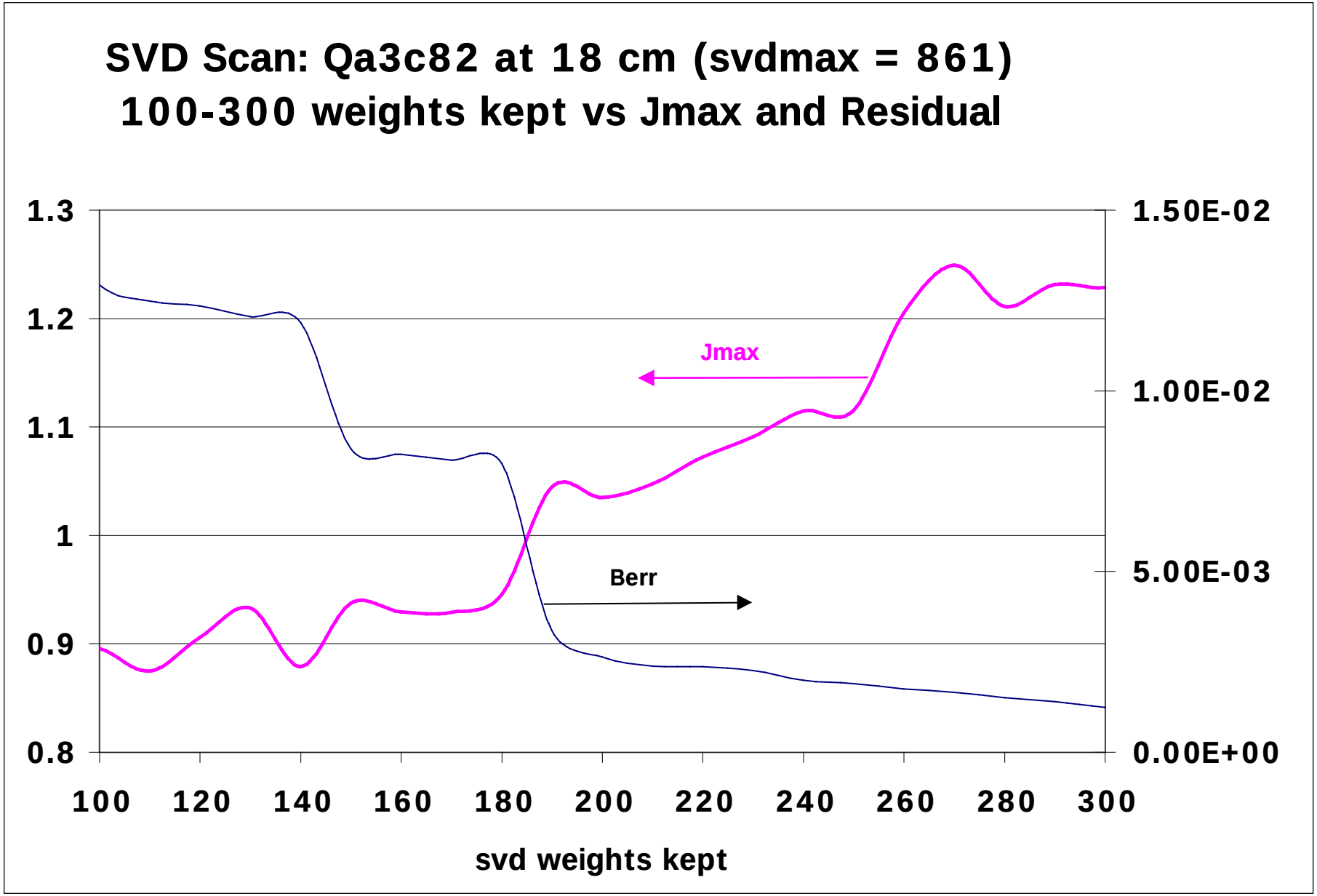
    local minima while Berror stays “acceptably” low.

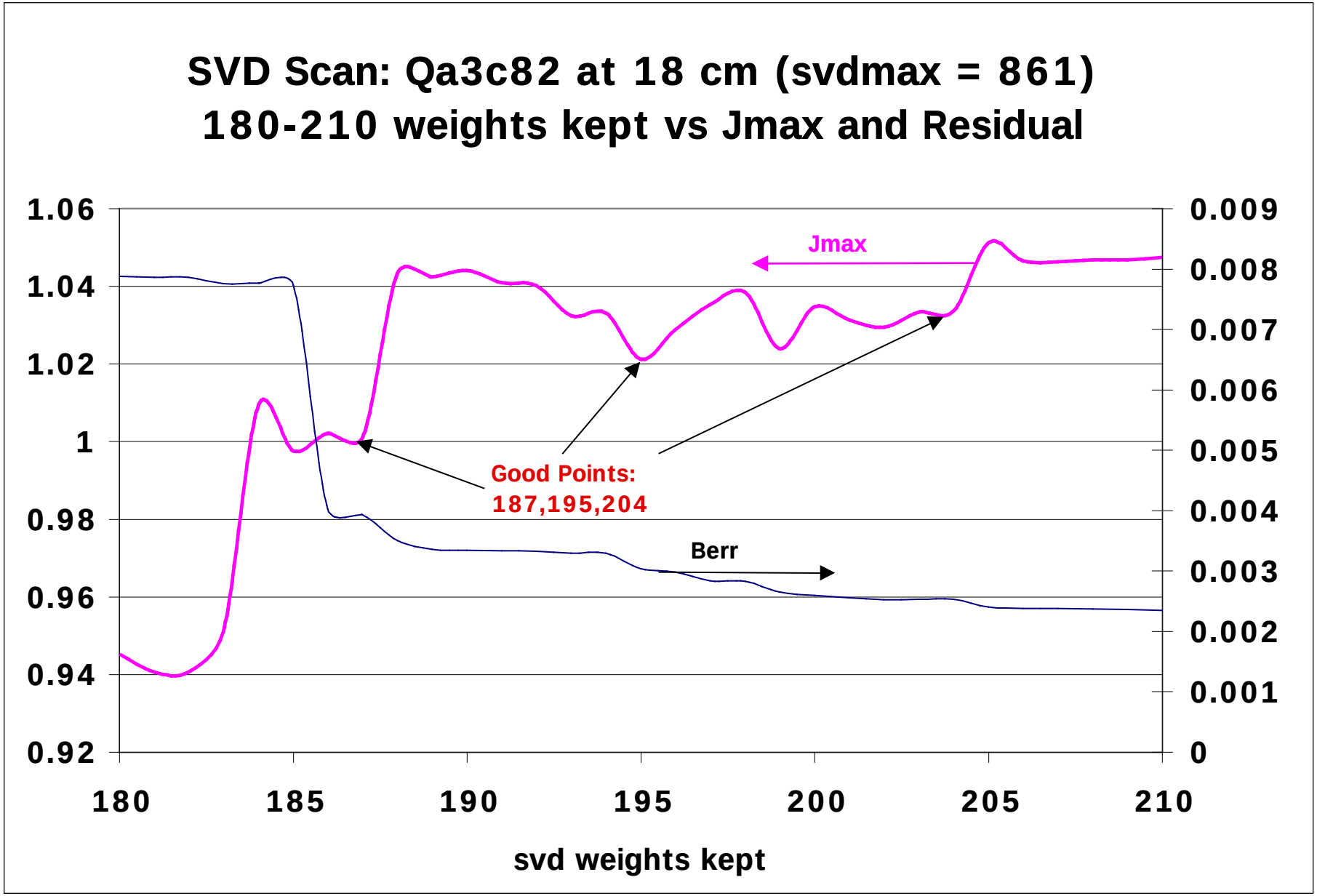

SVD Scan: Qa3c10 at 18 cm (svdmax = 861)
50-850 weights kept vs Jmax and Residual
3
2.5
2
1.5
1
0.5
0
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Jmax
Berr
50
150
250
350
450
550
650
750
850
svd weights kept


SVD Scan: Qa3c10 at 18 cm (svdmax = 861)
100-300 weights kept vs Jmax and Residual
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
0.8
1.50E-02
1.00E-02
5.00E-03
0.00E+00
100
120
140
160
180
200
220
240
260
280
300
svd weights kept
Jmax
Good Point
at svd=210
Berr


SVD Scan: Qa3c10 at 18 cm (svdmax = 861)
170-200 weights kept vs Jmax and Residual
1
0.98
0.96
0.94
0.92
0.9
0.88
0.86
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
170
175
180
185
190
195
200
svd weights kept
Jmax
Berr
Good Points
at 174,180


SVD Scan: Qa3c82 at 18 cm (svdmax = 861)
50-850 weights kept vs Jmax and Residual
3
2.5
2
1.5
1
0.5
0
2.00E-02
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Jmax
Berr
50
150
250
350
450
550
650
750
850
svd weights kept


SVD Scan: Qa3c82 at 18 cm (svdmax = 861)
100-300 weights kept vs Jmax and Residual
1.3
1.2
1.1
1
0.9
0.8
1.50E-02
1.00E-02
5.00E-03
0.00E+00
Jmax
Berr
100
120
140
160
180
200
220
240
260
280
300
svd weights kept


SVD Scan: Qa3c82 at 18 cm (svdmax = 861)
180-210 weights kept vs Jmax and Residual
1.06
1.04
1.02
1
0.98
0.96
0.94
0.92
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
180
185
190
195
200
205
210
svd weights kept
Jmax
Good Points:
187,195,204
Berr

Other scans done so far (but results not examined yet):

- **Scans of number of fourier modes used (mf,nf):**
  - c10, and c82 cases for (mf,nf) going over (5,5), (10,10), (20,20), (30,30)
- **Scans of number of plasma points used (nup, nvp):**
  - c10 and c82 cases for (nup,nvp) going over (32,32), (64,64), (128,128)
  - All with number of coilsurface points (nuc,nvc) > and = number of modes
- **Error post-calculation using finer coil and plasma grid is implemented**
  - More accurate error calculations **between** the (nup,nvp) points where bnorm was minimized by nescoil-svd.

What has been done to get to this point (past 3 weeks):

- **Many necessary additions to nescoil code capabilities were made**:
  - Svd scan capabilities added: allow rapid scan over all svd weights
  - Berr, Xerr, Jmax, Jcurvature, Complexity at each point in svdscan.
  - Ability to target Xerror within nescoil is now extended to svd scan.
  - Xerror can be calculated within nescoil for any minimization target.
  - Weighted optimization to target selected plasma areas for err reduction.
- **All new capabilities had to be validated before using them**:
  - New code has been tested against old cases run by Art and Prashant.
  - Zero error for (m,n) = (nuc,nvc) = (nup,nvp) has been verified.
  - Xerror answers verified by resubstituting in original equation.

Things to do in immediate future:

- **Take a closer look at data from runs made so far to answer following:**
  - At the "optimum" points found so far:
    - Cut coils from these and check reconstructability,
    - Compare c10, c82, and c85.
  - Are the new "optimum" points found much better than what we have?
  - Can we find a better point in the new runs which have larger number of modes (new code lets us use (32,32) modes due to deadwood removal)?

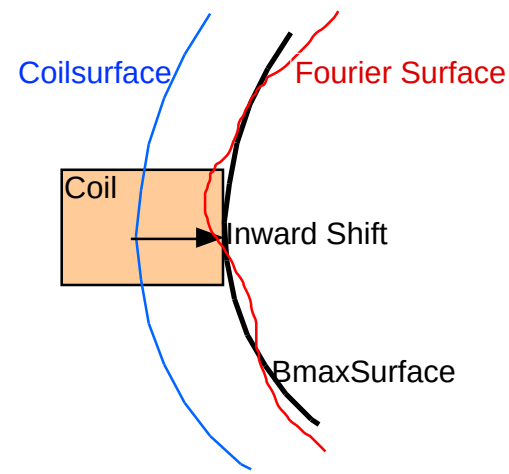
Very important question to answer before more search:

Are the solutions found so far adequate for equilibrium, stability, and transport?

Calculation of B_{max} at coil surface / B_o in plasma using nescoil

P. Valanju, D. Williamson, A. Brooks, W. Reirson, Jim Lyon

- Calculation of $B_{max}/\langle B_o \rangle$ has been implemented within Nescoil using modified nescoil green's function.
- This can now be used within an optimizer.
- B_{max} is calculated on a surface generated from the current-carrying surface at coil center by shifting by 1/2 coil radial depth in the inward normal direction.
- $\langle B_o \rangle$ = flux-surface rms of B_o.
- Benchmarked against solid coil model by Dave Williamson.
- Jim Lyon to provide reactor scenarios (A, Δ, coilbuild, B_o etc) to study.



Summary:

- **Significant progress made in past 4 weeks:**
  - Nescoil capabilities greatly extended and benchmarked:

    to allow rapid scans in nsvd, mf, nf, nu, nv parameters

    to optimize many properties including jmax, complexity, curvature, xerr

    to calculate B_{max}/B_0
  - Preliminary identification of optimum choices made:

    for lowest jmax with acceptable error for c10, and c82
- **Many scans have been made and need to examine output to find:**
  - Better jmax + complexity + current curvature values,
  - Examine effects of xerr on reconstruction and identify bad modes