Status and plans for RMP modeling with NIMROD

V.A. Izzo, *et. al.*

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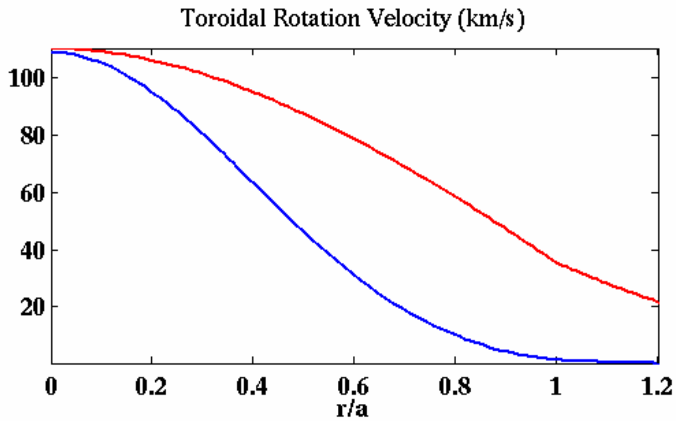
Overview

- Status:
  - Simulations of 113317 with fully penetrated vacuum fields: various rotation profiles, comparison with analytic theory– published in NF
  - Simulations of 119690: Comparison of odd/even I-coils, S Scaling, eventual experimental comparison
- Plans:
  - Ramp up of I-Coil boundary fields in progress

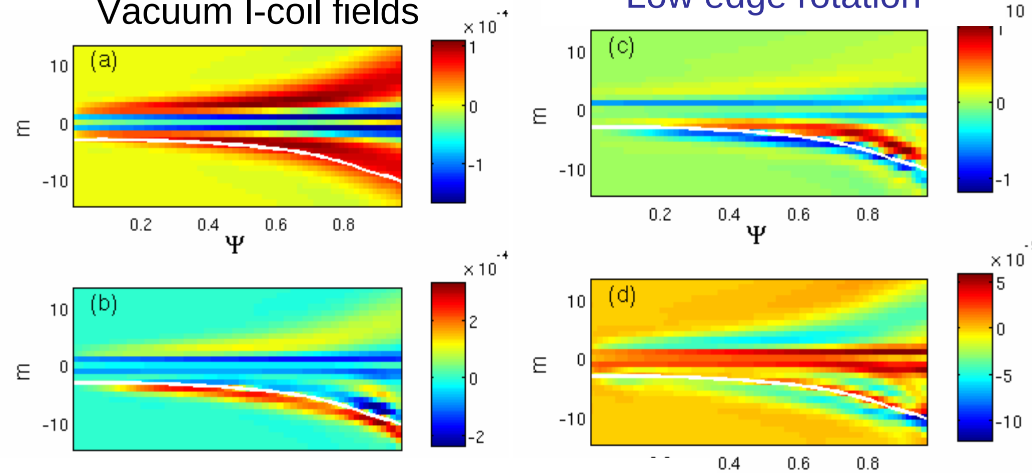
Rotational screening results from DIII-D shot 113317



Normal component of the n=3 B-fields (T)

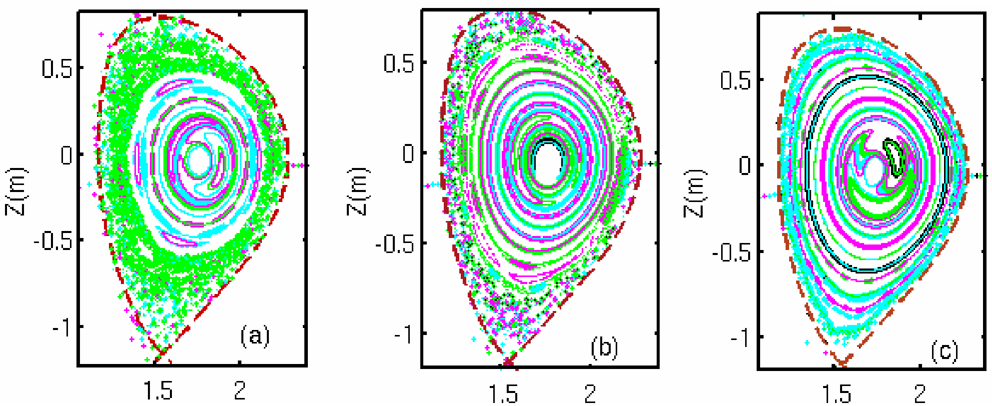
Vacuum I-coil fields

Low edge rotation



Plasma response (no rotation)

High edge rotation

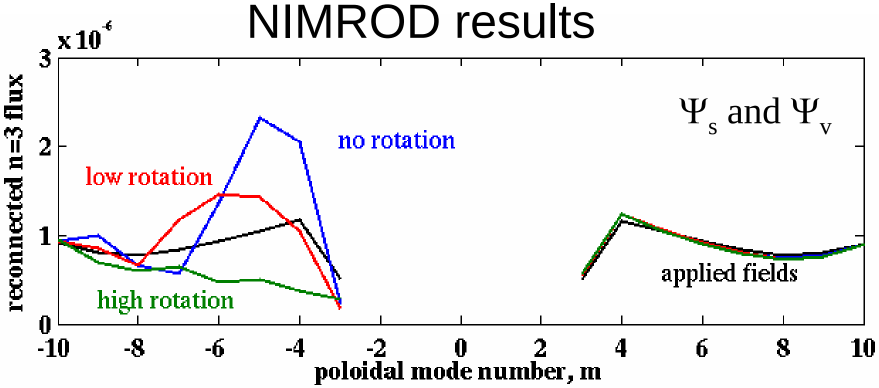


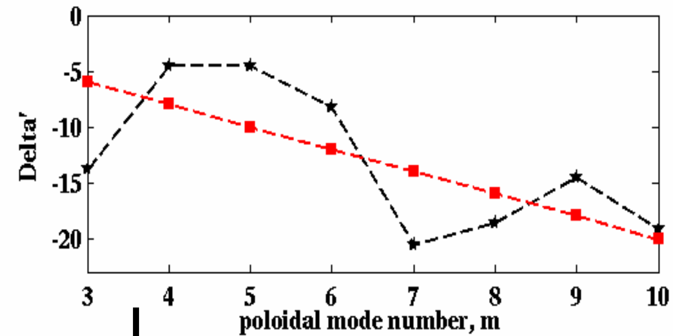
No rotation | Low edge rotation | High edge rotation

- How are the RMP fields modified in the presence of a rotating plasma? Is the DIII-D edge really become stochastic when the RMP coils are turned on?

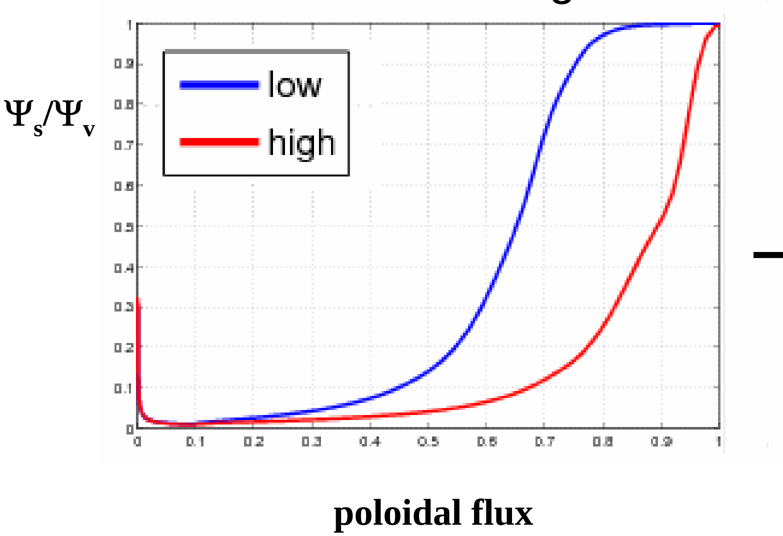
Cylindrical error field theory under-predicts NIMROD mode amplitudes

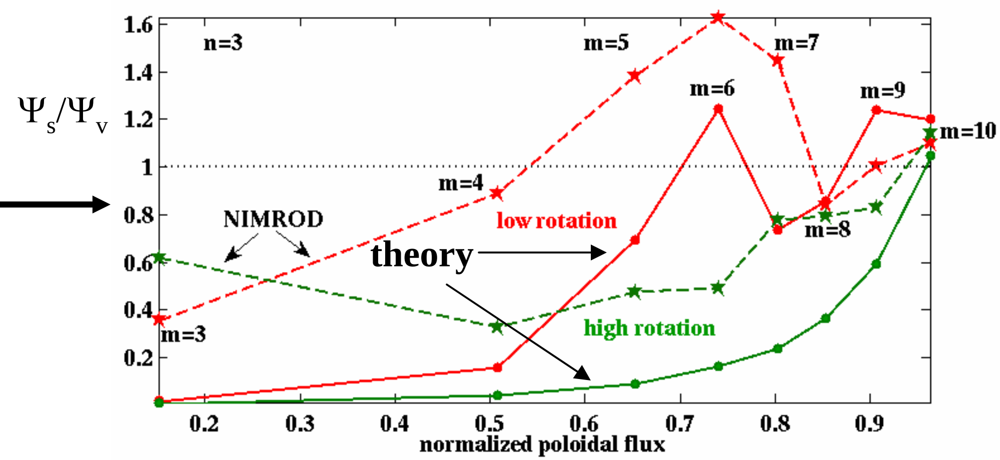
NIMROD results



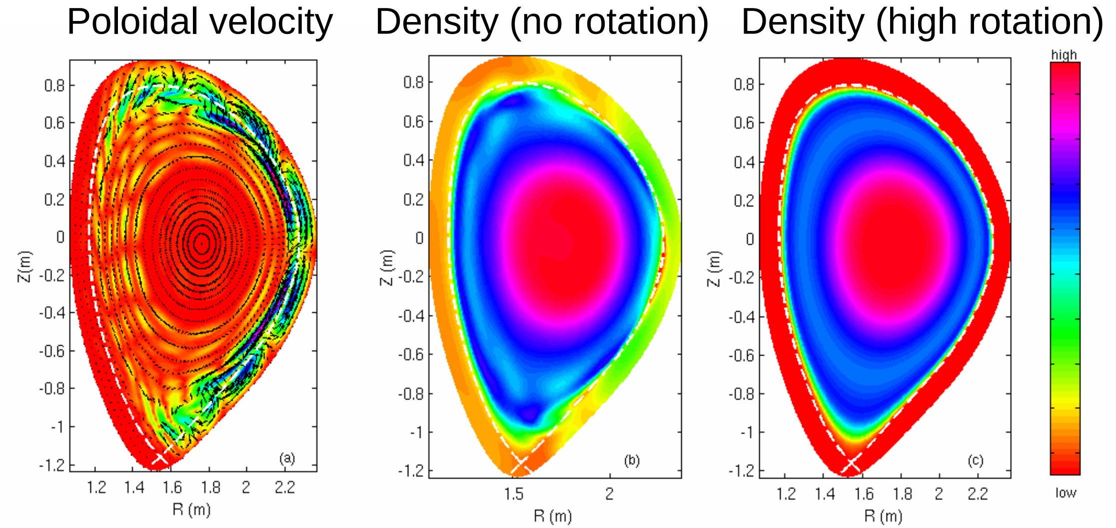


Theoretical screening factors

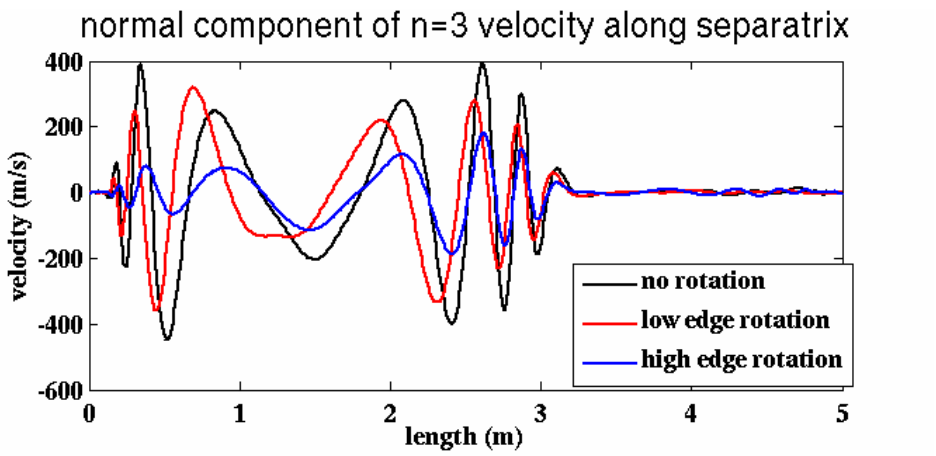


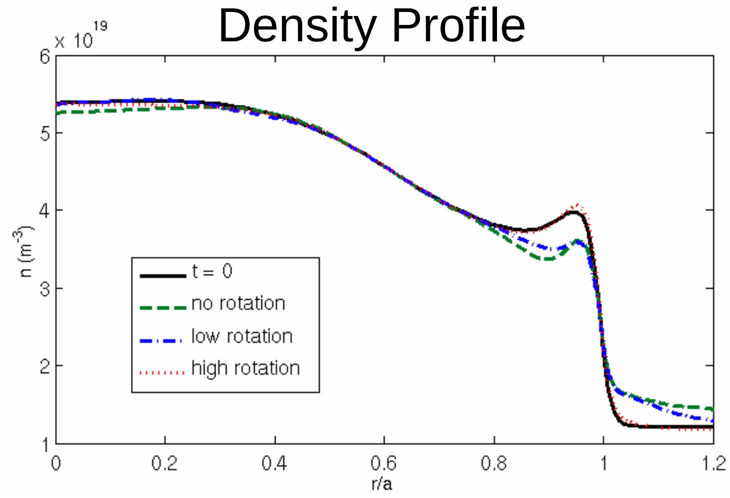


Density pump-out in NIMROD runs due to ExB convection

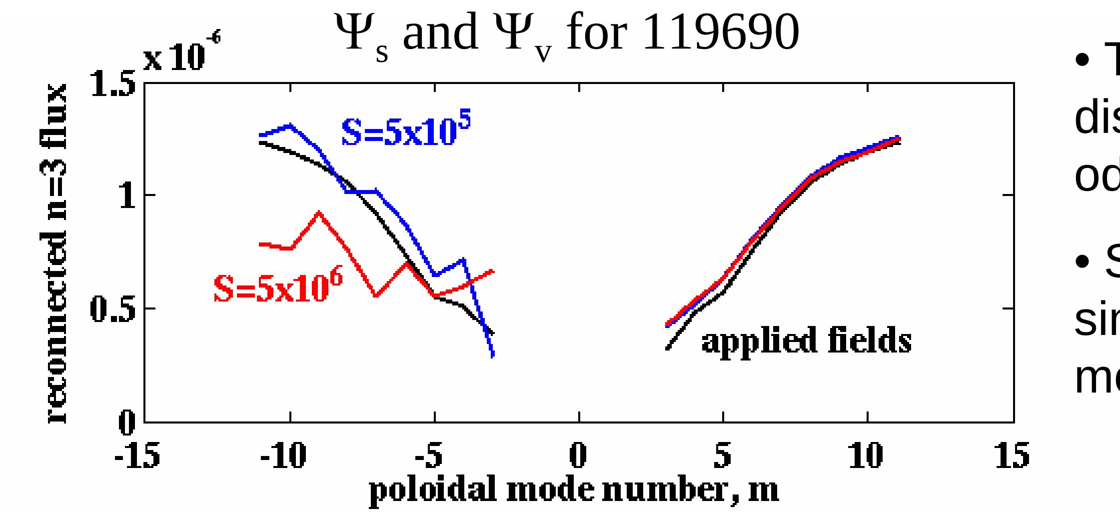


- n=3 ExB convection at the separatrix reduces the pedestal density
- Significant rotation at the edge eliminates this effect

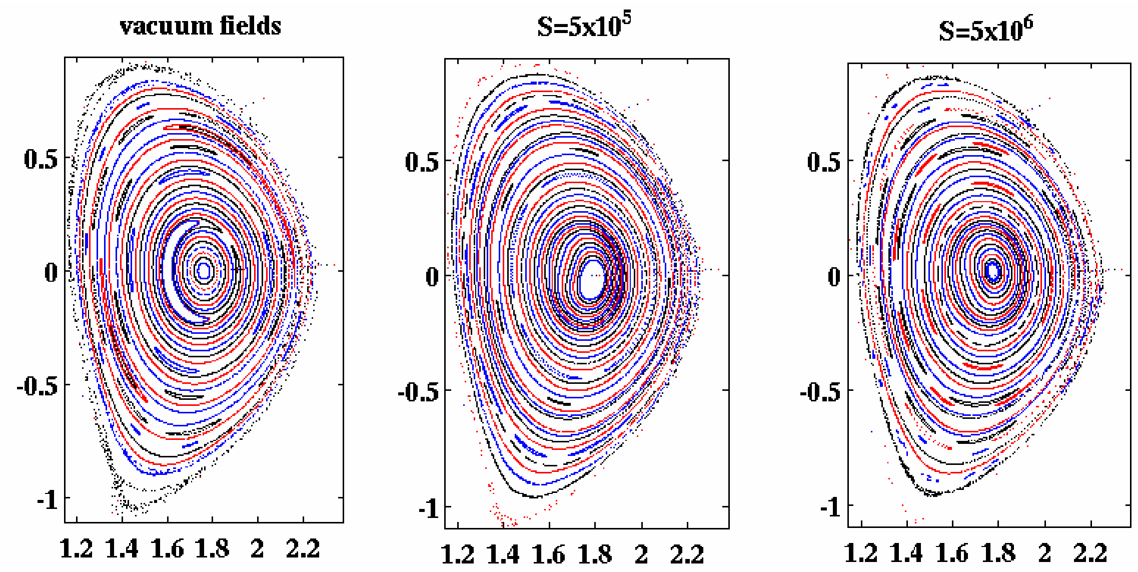




Simulations of 119690 with goal of experimental comparison

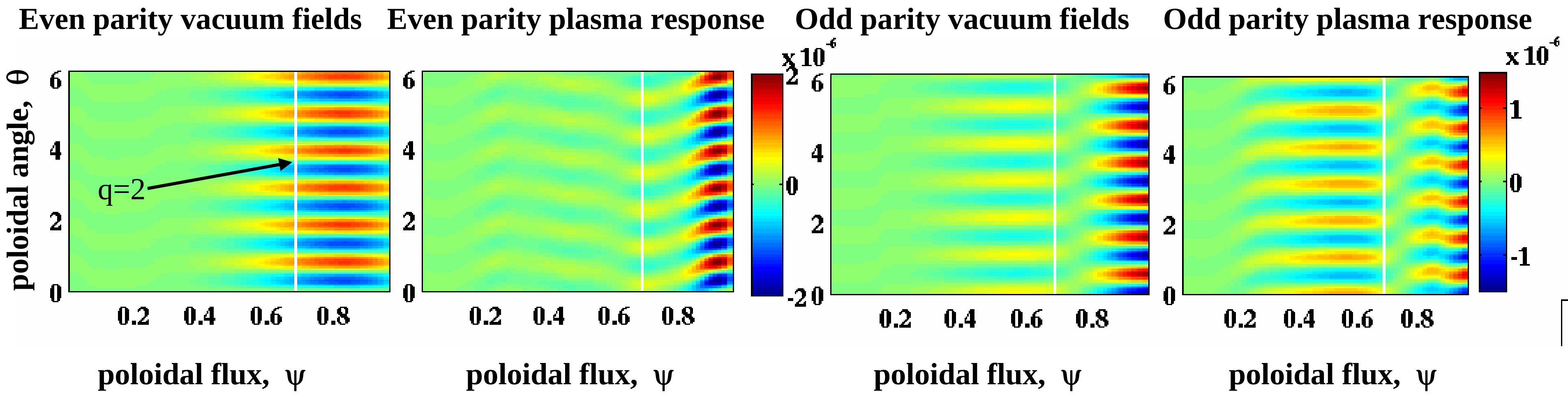


- This was an RMP experimental discharge at high collisionality and odd-parity I-coil fields
- S is increased above previous simulations and reduction in n=3 mode amplitude is seen for most m



Simulations with both I-Coil parities

m=6, n=3 component of B_n in straight field line coordinates



Screening of the odd parity fields is a bit more complicated

Time changing RMP fields in NIMROD is in the works

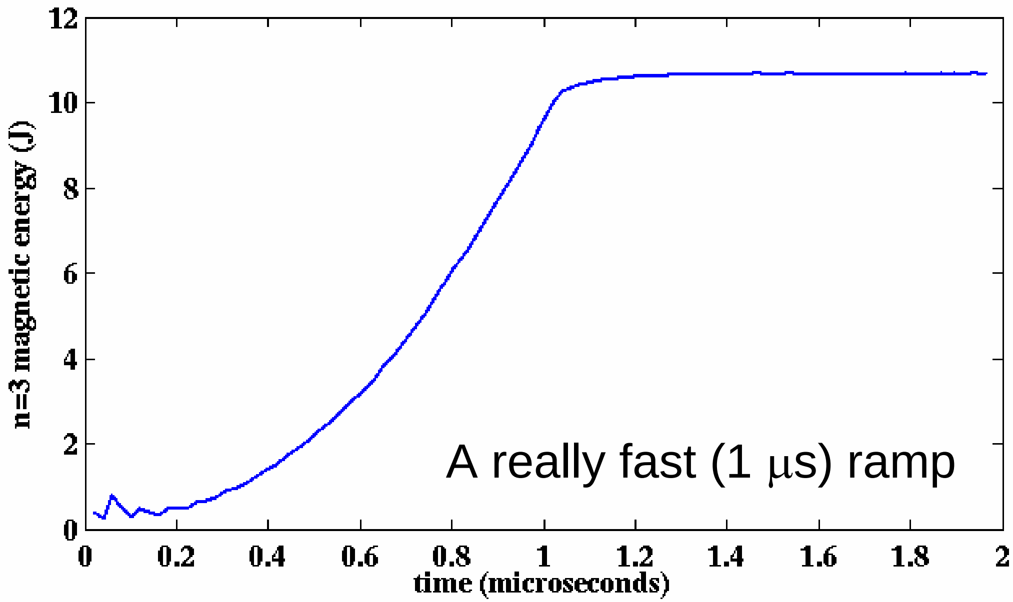
1) Use the existing routines for reading in RMP fields as initial condition, then multiply by a small factor (10^{-4}), so that they are negligible at t=0

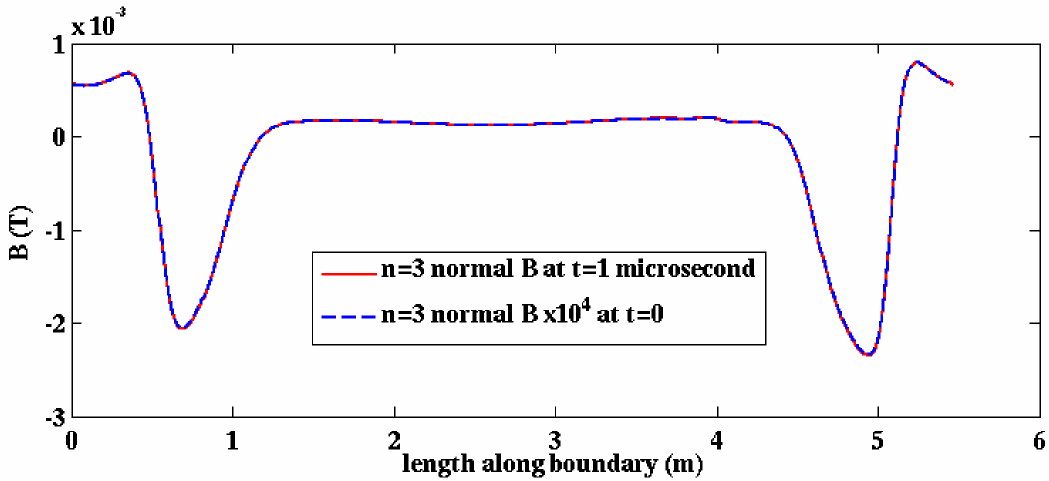
2) This specifies the form of the RMP normal fields at the boundary, which can subsequently be increased self-similarly with time

3) Impose a purely poloidal electric field that satisfies Faraday's Law while requiring only toroidal derivatives (easiest in NIMROD → ik)

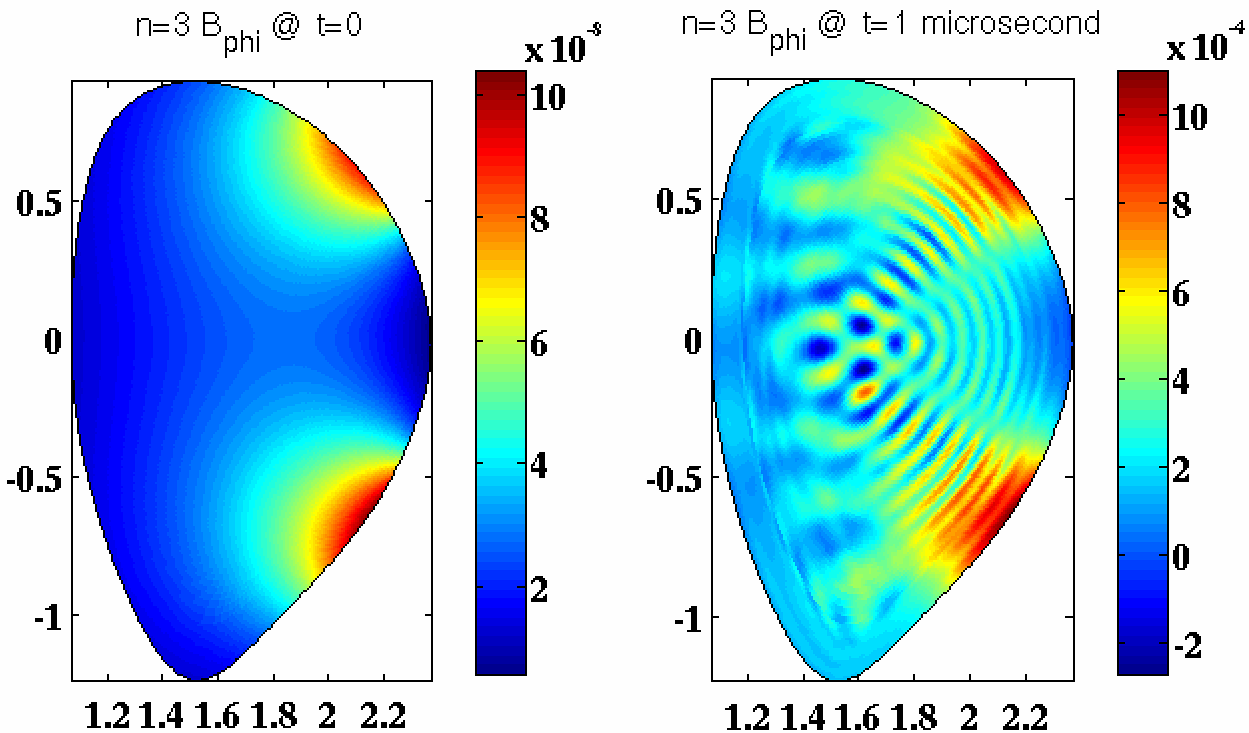
4) The applied poloidal E fields allow toroidal magnetic fields to enter

Initial test of NIMROD modifications





Toroidal fields are growing at the boundary



Summary

- A major goal for NIMROD RMP simulations in the future will be experimental validation– ideally 2-fluid calculations w/ time dependent RMP fields
- Questions: Does the ExB pump-out play any role at DIII-D parameters? Will it play any role in ITER? How are the ELMs stabilized in high-collisionality, Odd parity experiments? Can we say something about how the success of RMP experiments will translate to ITER?

dB/dt coding in NIMROD

```
c-------------------------------------------------------------------
c   IZZO subroutine for ramped RMP boundary conditions
c-------------------------------------------------------------------
      SUBROUTINE RMP_dirichlet_b(rb,seam,b_pass)
 …

…

      mode_loop: DO im=1,nmodes
        IF (keff(im)==0) CYCLE
        vert: DO iv=0,rb%mxe
          ! Vertices
          norm=rb%norm%fs(:,iv);   tang=rb%tang%fs(:,iv)
          btang=SUM(rb%b_edge%fs(1:2,iv,im)*tang)
          bnorm=SUM(rb%b_edge%fs(1:2,iv,im)*norm)

c          IZZO  Set the RMP normal field recursively
          IF (t<t_RMP) THEN
              bnorm=bnorm+1e4_r8*bnorm*dt/(t_RMP+t*1e4_r8)
          ENDIF
          rb%b_edge%fs(1:2,iv,im)=bnorm*norm+btang*tang
```

```
! Interior nodes
          IF(seam%vtype(iv)=='v') THEN
           DO is=1,SIZE(rb%rzedge%fsh,2)
             norm=rb%norm%fsh(:,is,iv); tang=rb%tang%fsh(:,is,iv)
             btang=SUM(rb%b_edge%fsh(1:2,is,iv,im)*tang)
             bnorm=SUM(rb%b_edge%fsh(1:2,is,iv,im)*norm)

c          IZZO  Set the RMP normal field recursively
             IF (t<t_RMP) THEN
                 bnorm=bnorm+1e4_r8*bnorm*dt/(t_RMP+t*1e4_r8
             ENDIF
             rb%b_edge%fsh(1:2,is,iv,im)=bnorm*norm+btang*tang
           ENDDO
          ENDIF

        ENDDO vert
      ENDDO mode_loop

      …
c-------------------------------------------------------------------
c    terminate.
c-------------------------------------------------------------------
      RETURN
      END SUBROUTINE RMP_dirichlet_b
```

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Surface E coding in NIMROD

```
 SUBROUTINE e_tangential_RMP(int,bigr,rb,norm,tb,alpha,ig)

      COMPLEX(r8), DIMENSION(:,:,:,:), INTENT(INOUT) :: int
      TYPE(rblock_type), INTENT(INOUT) :: rb
      TYPE(tblock_type), INTENT(INOUT) :: tb
      INTEGER(i4), INTENT(IN) :: ig
      REAL(r8), DIMENSION(:,:), INTENT(IN) :: norm
      REAL(r8), DIMENSION(:), INTENT(IN) :: alpha, bigr
      INTEGER(i4) :: iv,nv,ncx,nfour,im
      ! Convenience parameters
      ncx=SIZE(int,2)
      nv=SIZE(int,3)
      nfour=SIZE(int,4)
c-----------------------------------------------------------------------
c     Surface integral from -Exn
c     -Exn = -n_Z E_phi e_R
c            +n_R E_phi e_Z
c            -(n_R E_Z - n_Z E_R) e_phi
c-----------------------------------------------------------------------
      int=0

      DO im=1,nfour
      DO iv=1,nv
       int(1,:,iv,im)= 0.0
       int(2,:,iv,im)= 0.0
IF (t<t_RMP .AND. keff(im)/=0) THEN
       int(3,:,iv,im)=-alpha(iv)*dt*(rb%qrzedge%qpf(1,:,ig)/
      $ (keff(im)*(0.0_r8,1.0_r8)))*1e4_r8*
      $ ((rb%qb_edge%qpf(1,:,im,ig)*norm(1,:)+
      $ rb%qb_edge%qpf(2,:,im,ig)*norm(2,:))/(t_RMP+t*1e4_r8))
       ELSE
       int(3,:,iv,im)= 0.0
       ENDIF

       ENDDO
       ENDDO
c-----------------------------------------------------------------------
c      terminate.
c-----------------------------------------------------------------------
       RETURN
       END SUBROUTINE e_tangential_RMP
```