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Recent Progress on ATF

by

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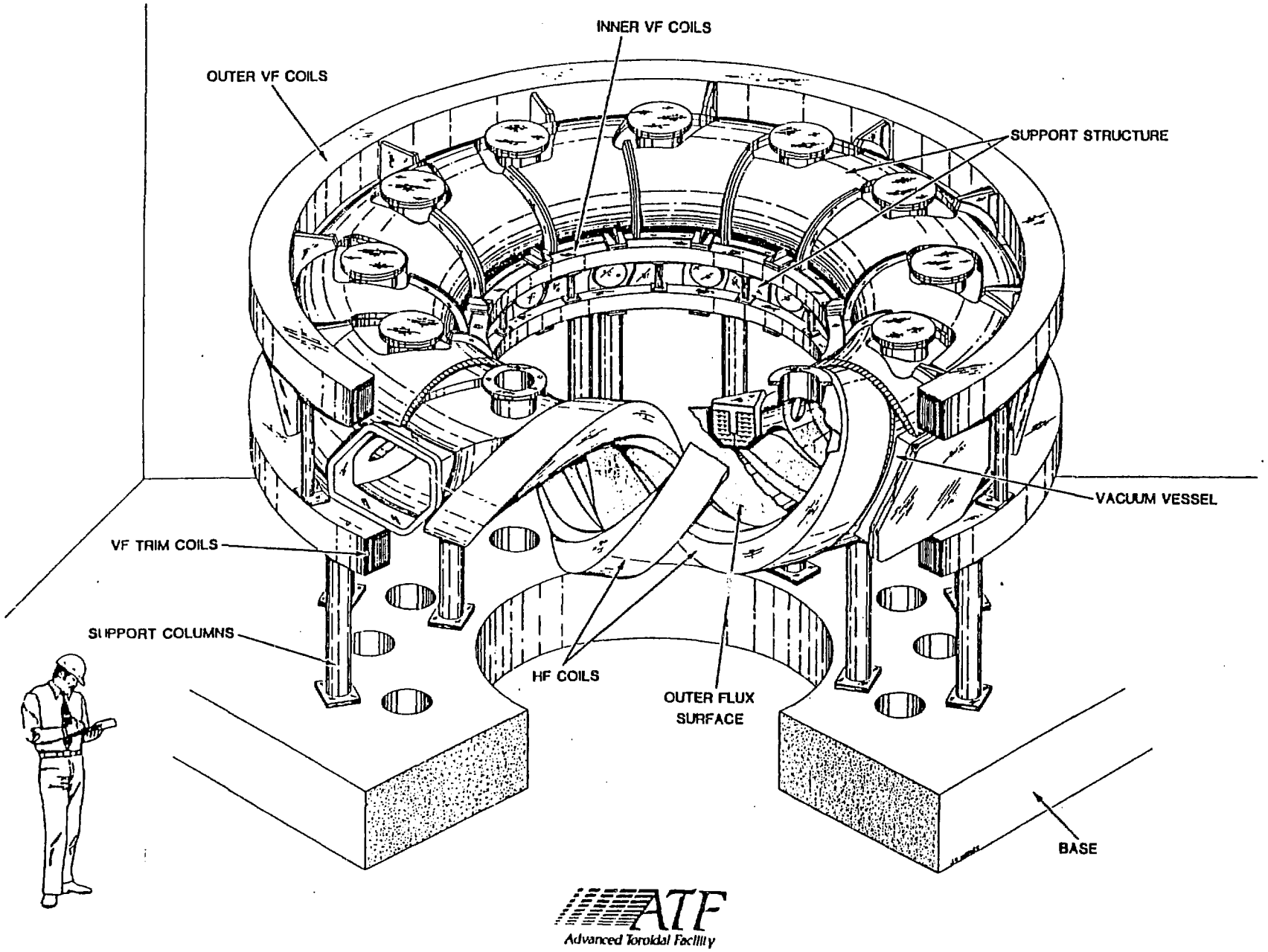
THE ATF EXPERIMENT WILL TEST IMPROVEMENTS TO HIGH-BETA, STEADY-STATE TOROIDAL CONFINEMENT USING EXTERNAL HELICAL FIELDS. THE DEVICE DESIGN HAS BEEN OPTIMIZED TO

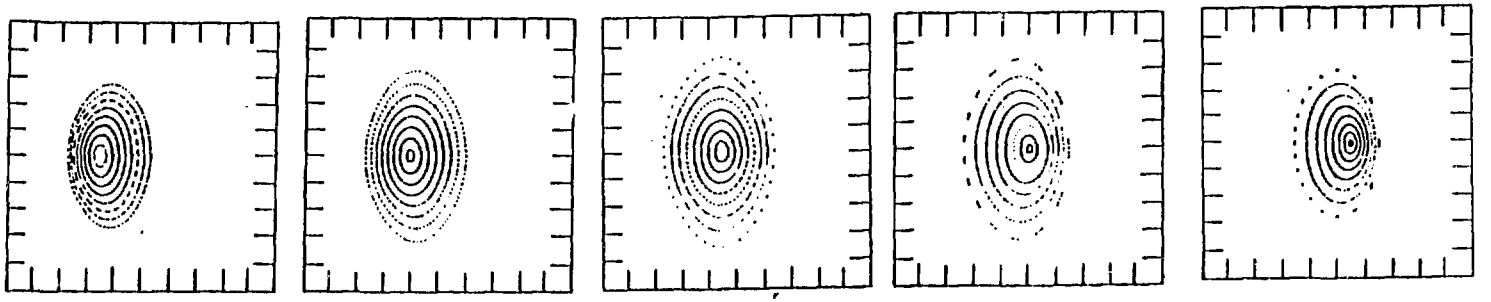
- PROVIDE DIRECT ACCESS TO THE HIGH-BETA SECOND-STABILITY REGIME
- HAVE SUFFICIENT FLEXIBILITY TO STUDY A LARGE RANGE OF TOROIDAL CONFIGURATIONS BOTH WITH AND WITHOUT PLASMA CURRENT
- TEST THE REDUCTION OF LOW-COLLISIONALITY TRANSPORT BY EXB DRIFTS INDUCED BY THE SELF-CONSISTENT RADIAL ELECTRIC FIELD
- PERMIT STEADY-STATE, HIGH-BETA OPERATION WITHOUT DISRUPTIONS

CONTINUED PHYSICS STUDIES AT ORNL AND RECENT RESULTS FROM FOREIGN STELLARATOR EXPERIMENTS HAVE INCREASED CONFIDENCE IN ATF PERFORMANCE.

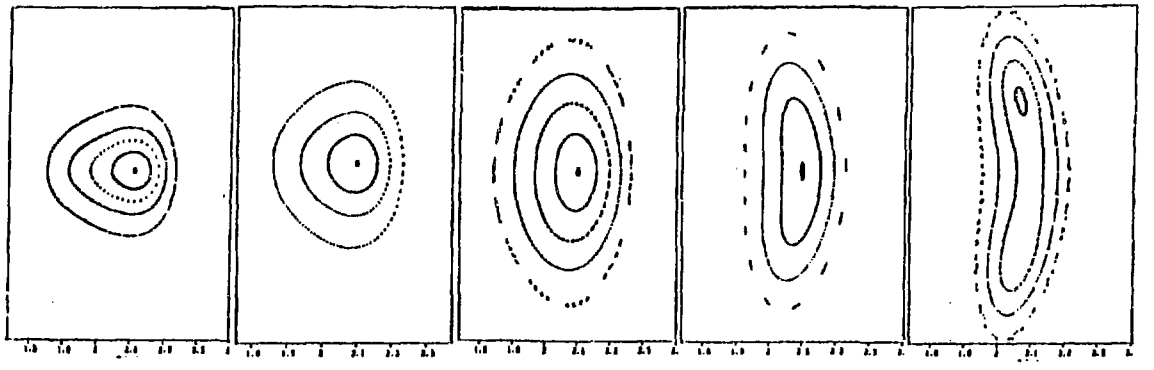

INNER VF COILS
OUTER VF COILS
SUPPORT STRUCTURE
VACUUM VESSEL
VF TRIM COILS
SUPPORT COLUMNS
HF COILS
OUTER FLUX SURFACE
BASE
ATF
Advanced Toroidal Facility

THE ATF VERTICAL FIELD COILS ALLOW TO EXPLORE A WIDE RANGE OF CONFIGURATIONS

Shifting the magnetic axis

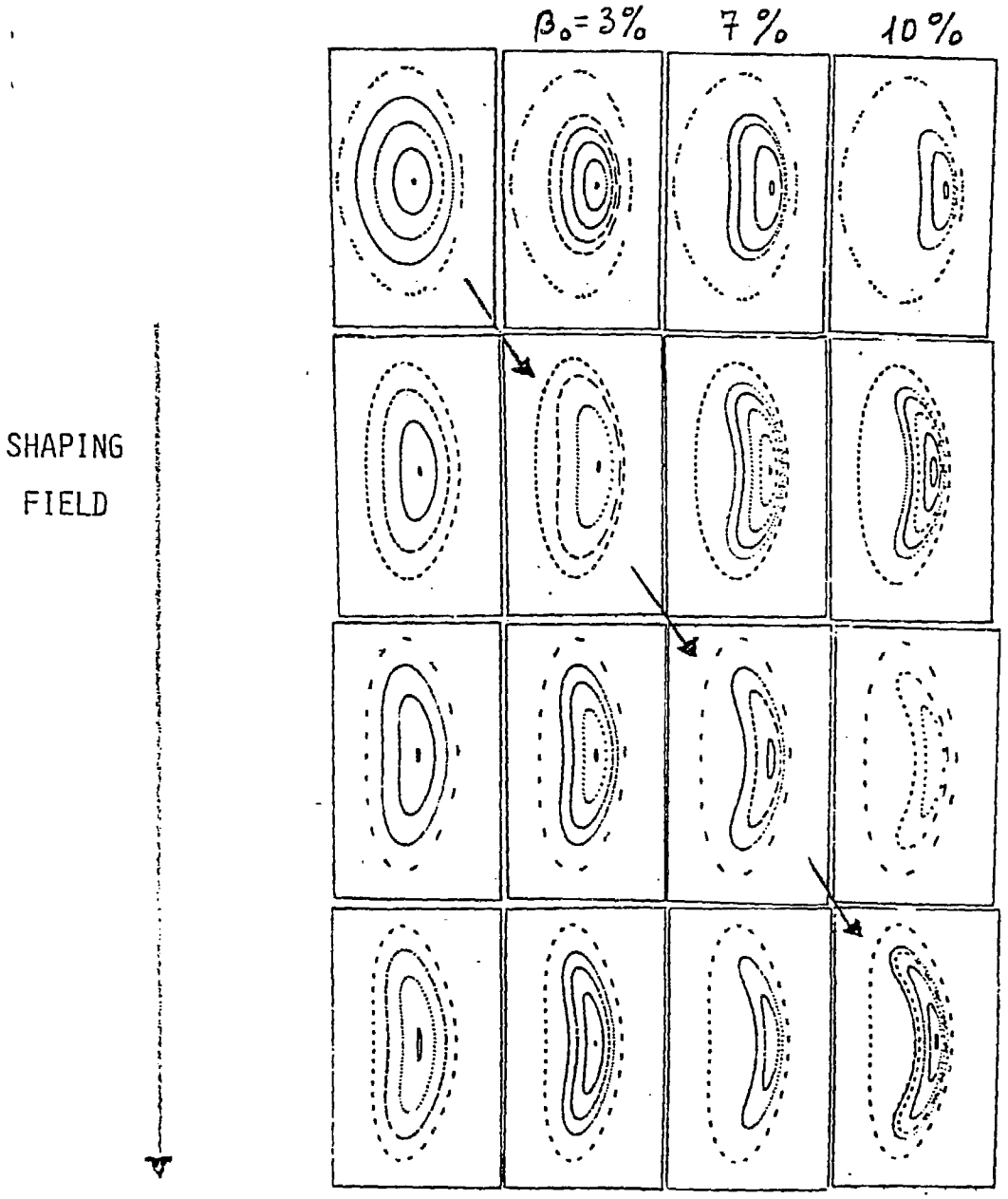


Changing the shape of the poloidal field



POLOIDAL FIELD SHAPING → VARIETY OF HIGH-BETA CONFIGURATIONS

- DIFFERENT PATHS TO HIGH-BETA POSSIBLE WITH PROGRAMMING OF SHAPING FIELD
- VARYING DEGREES OF BEAN-SHAPE AT HIGH-BETA
- DIAGONAL PATH (SHOWN) HAS MINIMUM CHANGE TO ROTATIONAL TRANSFORM PROFILE



TRANSPORT STUDIES FOR ATF EXTEND STUDIES OF ELECTRIC FIELD EFFECTS IN NONAXISYMMETRIC TOROIDAL CONFIGURATIONS

- MODEST RADIAL ELECTRIC FIELDS OF EITHER SIGN GREATLY REDUCE RADIAL LOSSES AT LOW-COLLISIONALITY VIA INCREASED POLOIDAL ROTATION VELOCITIES

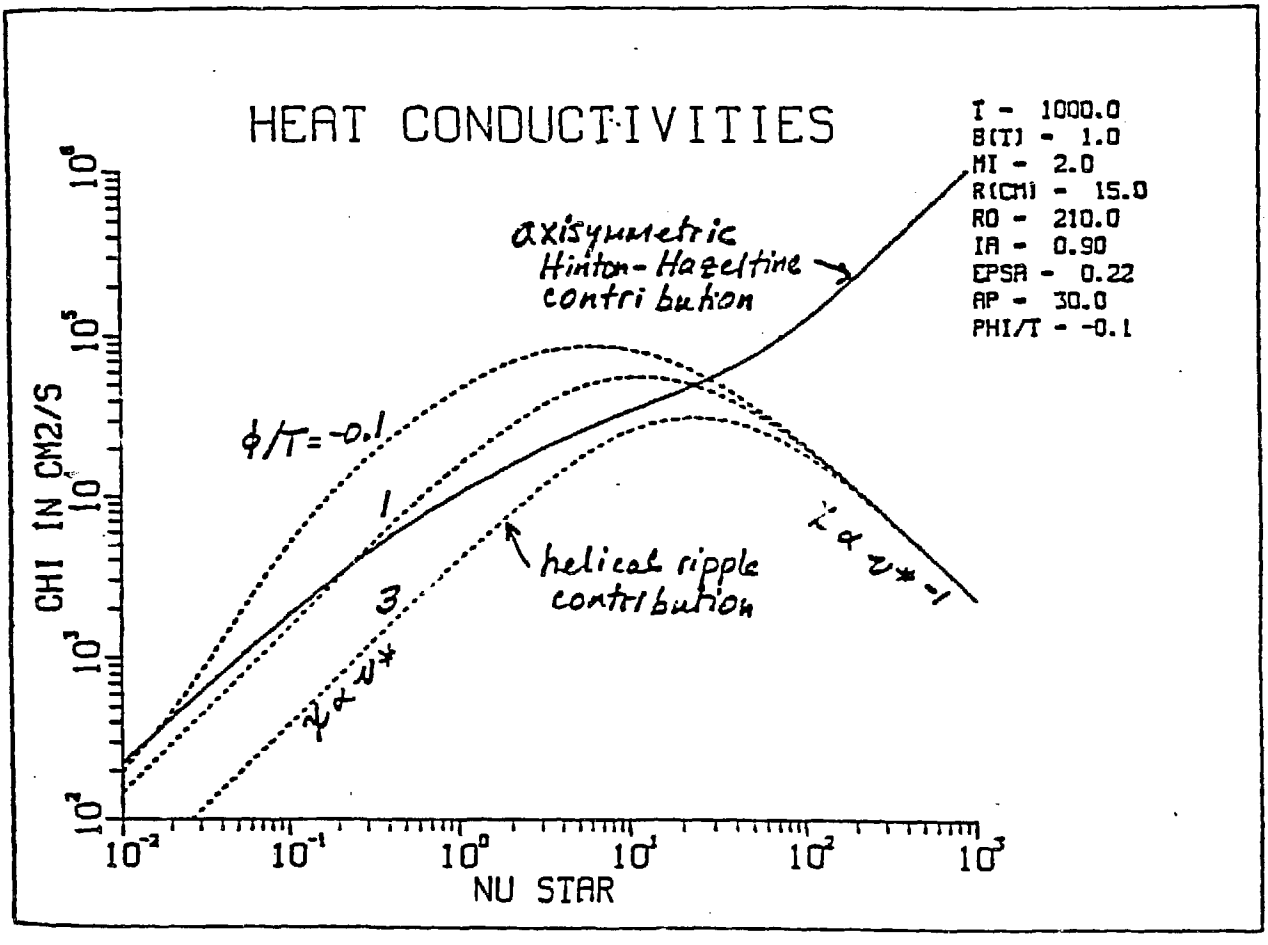
- SIMILAR EFFECTS MAY ALSO BE IMPORTANT IN TOKAMAKS (LARGE Φ IN ISX-B)

- MULTIPLE VALUES FOR THE AMBIPOLAR ELECTRIC FIELD CAN OCCUR FOR CERTAIN PLASMA PARAMETER RANGES

- DETERMINATION OF SELF-CONSISTENT ELECTRIC FIELD AND COMPARISONS BETWEEN ANALYTIC THEORY, MONTE-CARLO CALCULATIONS AND EXPERIMENT ARE UNDER STUDY

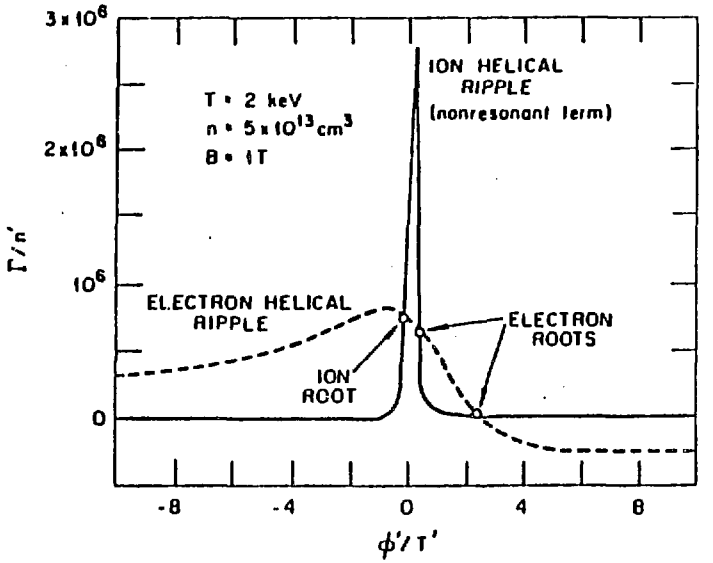
CONFINEMENT IMPROVEMENT WITH ELECTRIC FIELD

- MODERATE ELECTRIC FIELD MOVES TRANSITION TO FAVORABLE SCALING ($\chi \sim \nu^*$ INSTEAD OF $\chi \sim \nu^{*-1}$) TO HIGHER COLLISIONALITY



SELF-CONSISTENT ELECTRIC FIELD

- ATF EXAMPLE SHOWING THREE ROOTS FOR THE RADIAL ELECTRIC FIELD WHICH LEAD TO AMBIPOLAR FLUXES. THE ROOT WITH THE LARGEST RADIAL ELECTRIC FIELD LEADS TO MUCH REDUCED LOSSES.

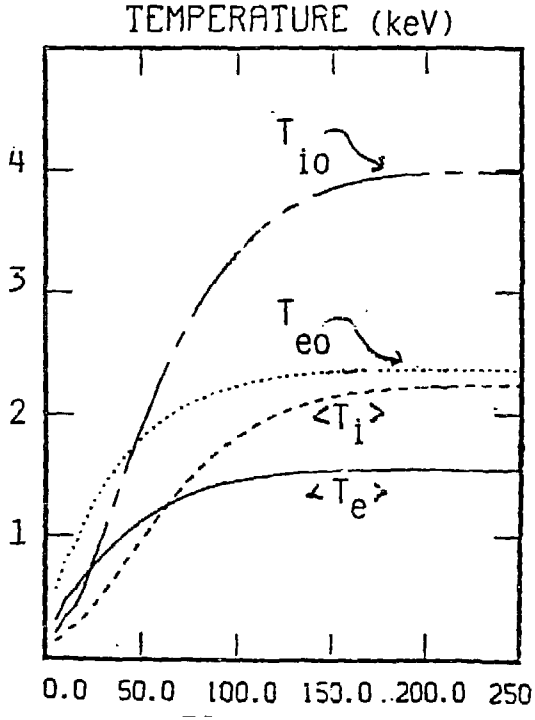


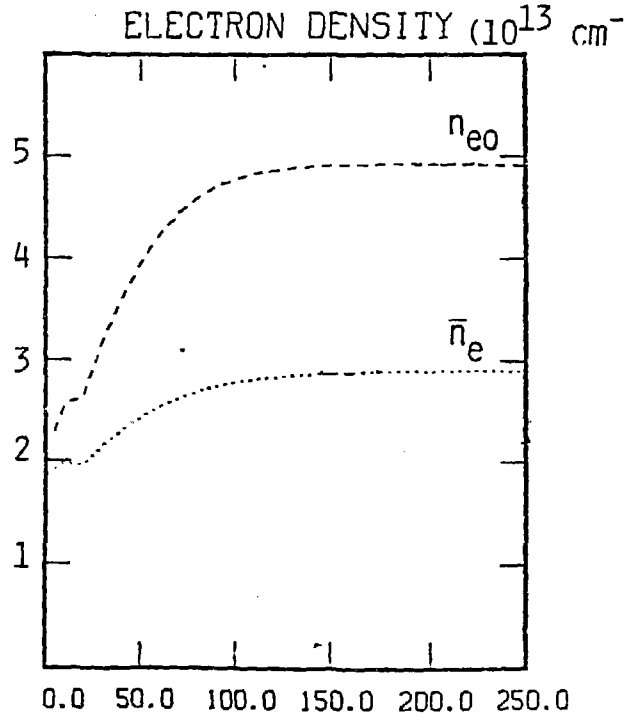
$$\Gamma = -\epsilon_t^2 \epsilon_h^{1/2} \nu_D^2 n \int_0^\infty \frac{dx\, x^{5/2} e^{-x} \frac{\nu(x)}{\epsilon_h}\left[\frac{n'}{n} + \frac{e\phi'}{T} + \left(x - \frac{3}{2}\right)\frac{T'}{T}\right]}{\frac{\epsilon_t}{\epsilon_h} 1.67 (\omega_E + \omega_{\nabla B})^2 + \left(\frac{\epsilon_t}{\epsilon_h}\right)^{3/2}\left[\frac{\omega_{\nabla B}^2}{4} + 0.6\,|\omega_{\nabla B}|\,\frac{\nu(x)}{\epsilon_h}\left(\frac{\epsilon_t}{\epsilon_h}\right)^{-3/2}\right] + 3\left(\frac{\nu(x)}{\epsilon_h}\right)^2}$$

NON-RESONANT ($\sim\nu$) | SUPER-BANANA PLATEAU | RESONANT TRANSPORT ($\sim 1/\nu$)

WHIST TRANSPORT CODE CALCULATION FOR ATF

- MODEL: 2 x AXISYMMETRIC NEOCLASSICAL
  + HELICAL RIPPLE TRANSPORT (SHAING-HOULBERG)
  + EMPIRICAL ANOMALOUS TRANSPORT
- INCLUDES TIME-EVOLUTION OF SELF-CONSISTENT RADIAL ELECTRIC FIELD
- COMPARES WELL WITH HELIOTRON-E DATA
- RESULTS FOR B = 1 T, P_b = 3 MW, $H^0 \rightarrow D^+$ PLASMA
  - LOW INITIAL DENSITY (ECH TARGET PLASMA)
    → RAPID TRANSITION TO $E_r > 0$
  - DENSITIES RISE DUE TO FUELING FROM BEAMS AND RECYCLE
  - $\langle \beta \rangle \approx 5.5\%$





PLASMA EDGE STUDIES - PARTICLE AND IMPURITY CONTROL

- IMPURITY AND PARTICLE ACCUMULATION A POTENTIAL CONCERN IN ATF BECAUSE OF LONG PARTICLE CONFINEMENT TIMES IN STELLARATORS

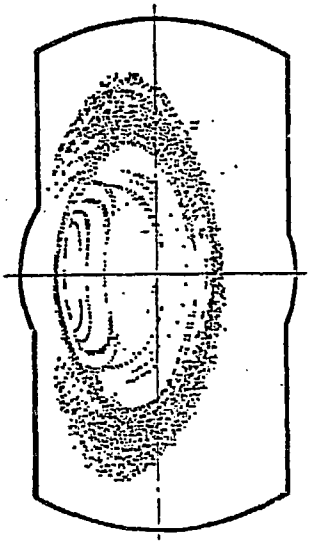
- MAGNETIC LIMITER/DIVERTOR AND PUMP LIMITER OR LOCALIZED LIMITER WILL BE STUDIED IN ATF.

- CALCULATIONS OF FIELD LINES AND ORBITS IN ATF SHOW:

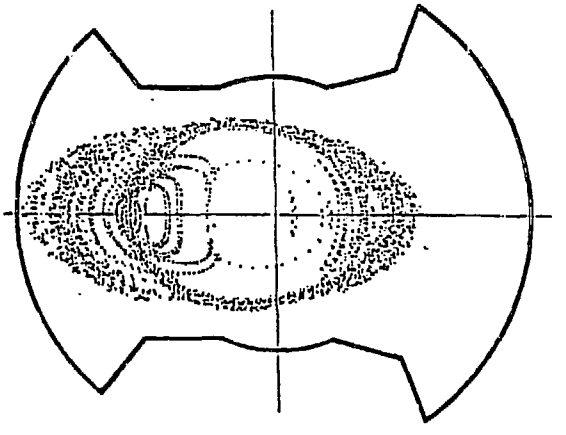
  - MAGNETIC FIELD STRUCTURE IS ERGODIC OUTSIDE LAST CLOSED FLUX SURFACE BUT PARTICLES ARE CONTAINED IN THAT REGION IN A DIVERTOR-LIKE PATTERN

ATF VACUUM VESSEL WALL DESIGNED SO THAT

- TRAPPED PARTICLE ORBITS DO NOT HIT THE WALL (NO COLLISIONLESS LOSS CONE)
- CLOSEST APPROACH TO WALL IS IN A HELICAL STRIP BETWEEN HELICAL COILS ON SMALL MAJOR RADIUS SIDE WHERE PORTS ARE LOCATED
- DISTANCE FROM PLASMA EDGE (LAST CLOSED FLUX SURFACE) IS 6-20 cm



SECTION THROUGH VACUUM VESSEL Ø:0°



SECTION THROUGH VACUUM VESSEL Ø:15°

ATF PROJECT STATUS

- SCHEDULED COMPLETION DATE: SEPTEMBER 1986
- PROTOTYPE HELICAL COIL SEGMENT BEING FABRICATED
- COIL JOINT DESIGNS WHICH MEET ELECTRICAL AND THERMAL REQUIREMENTS HAVE BEEN DEVELOPED AND TESTED
- CONTRACT WITH PPPL TO CONSTRUCT VF COILS