

Overview of Theory Presentations

Emanuele Poli

Max-Planck-Institut für Plasmaphysik, D-85748 Garching, EURATOM Association



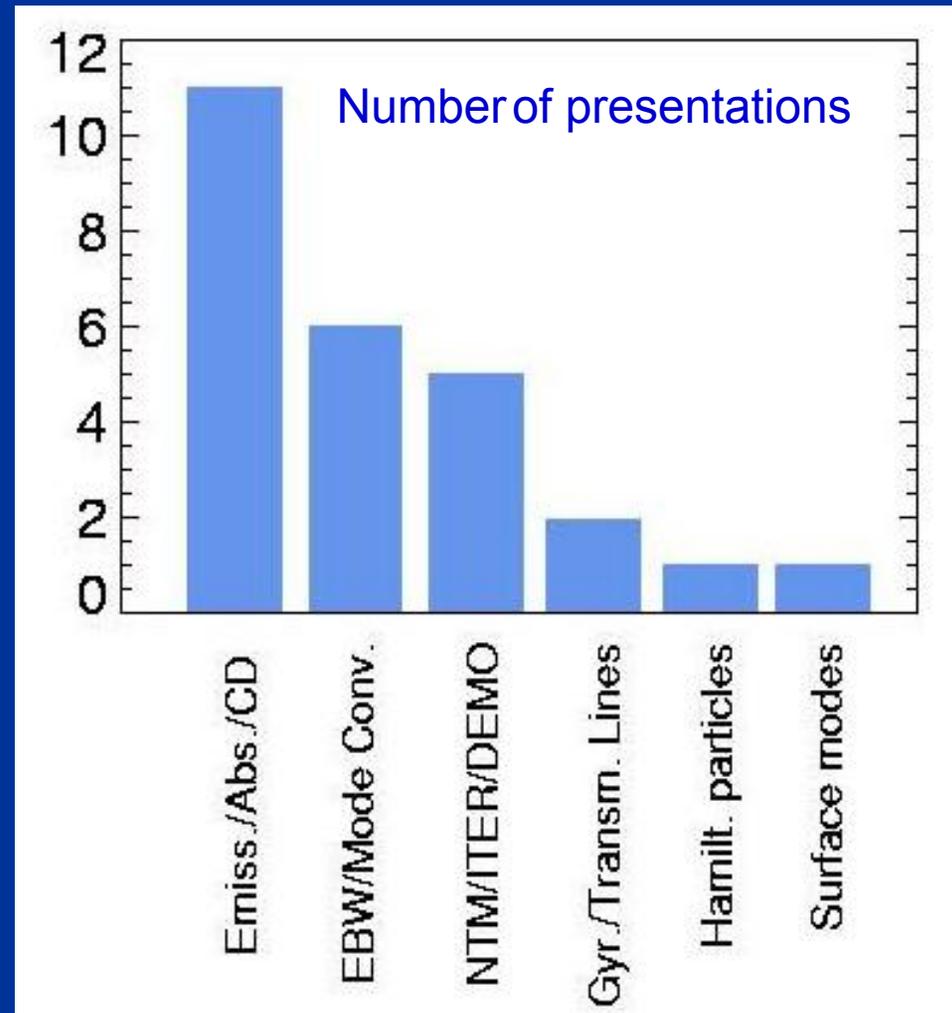
Theory Contributions

26 Theory Papers

- 3 Invited Talks
- 7 Oral Presentations
- 16 Posters

Topics

- Modelling of Emission, Absorption and Current Drive
- Electron Bernstein Waves and Mode Conversion
- NTM/ITER/DEMO Modelling
- Theory of Gyrotrons and Transmission Lines
- Hamiltonian description of Beam-Particle interaction
- Surface modes

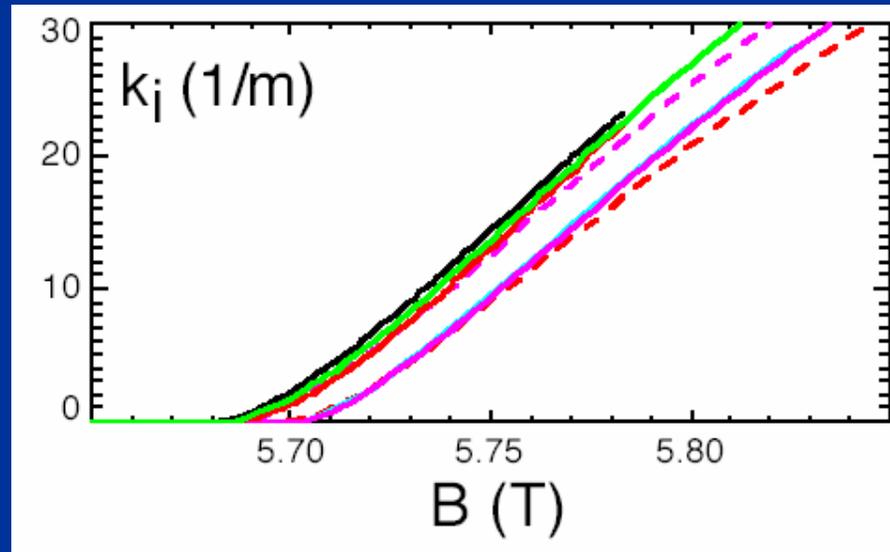


12 Countries, 19 Institutions represented

Modelling of Emission, Absorption and CD

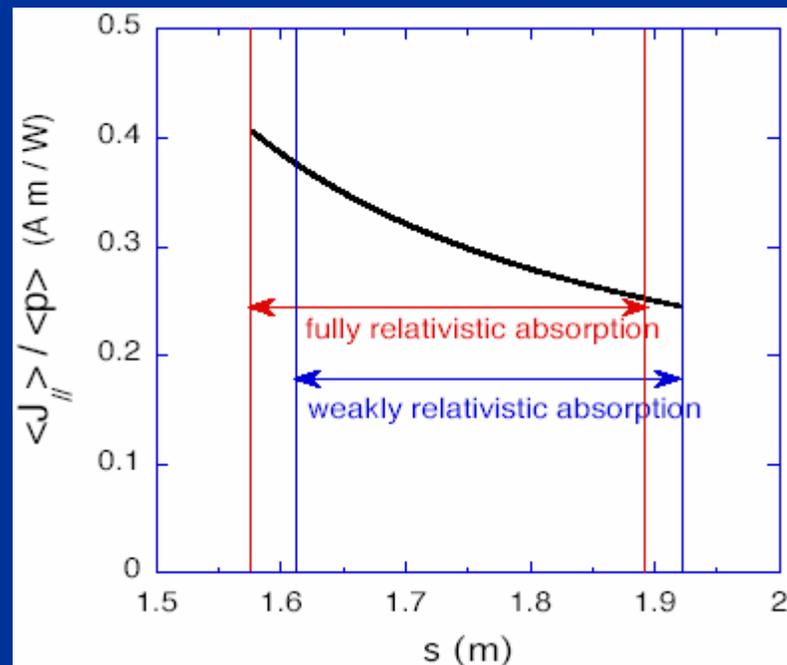
Benchmarking of EC Codes for ITER (R. Prater)

- High agreement (also: linear vs. QL)
- Fully vs. weakly relativistic absorption at slightly different locations
- **Need for further refinement?**



GRAY: quasi optical beam tracing (D. Farina)

- Based on Mazzucato's equations for diffraction effects
- Fully relativistic absorption
- Full polarisation retained in CD routine



Modelling of Emission, Absorption and CD

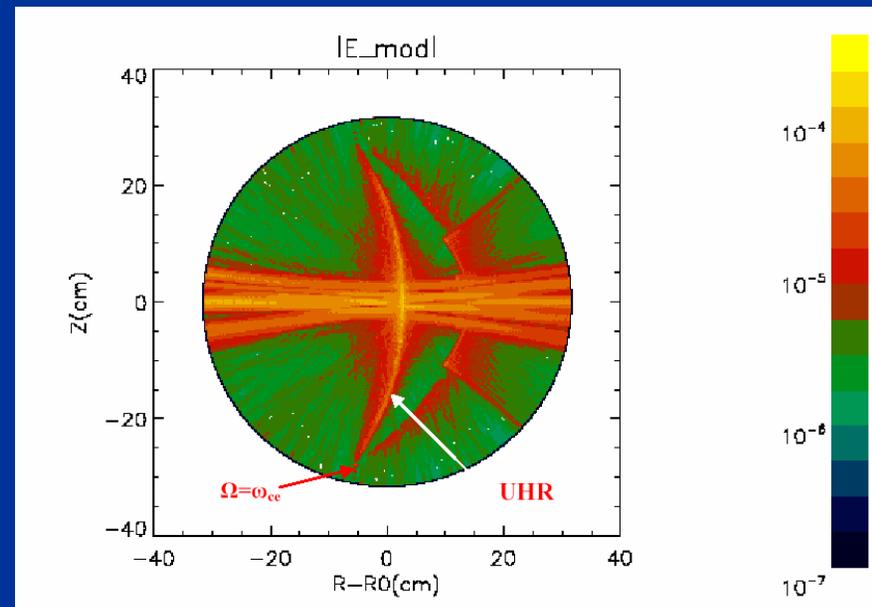
Improved linear ECCD efficiency (Y. R. Lin-Liu)

- Based on the adjoint method
- Full polarisation retained
- Implemented in TORAY-GA
- Other chances for improvement? Collision operator?

Modelling of Emission, Absorption and CD

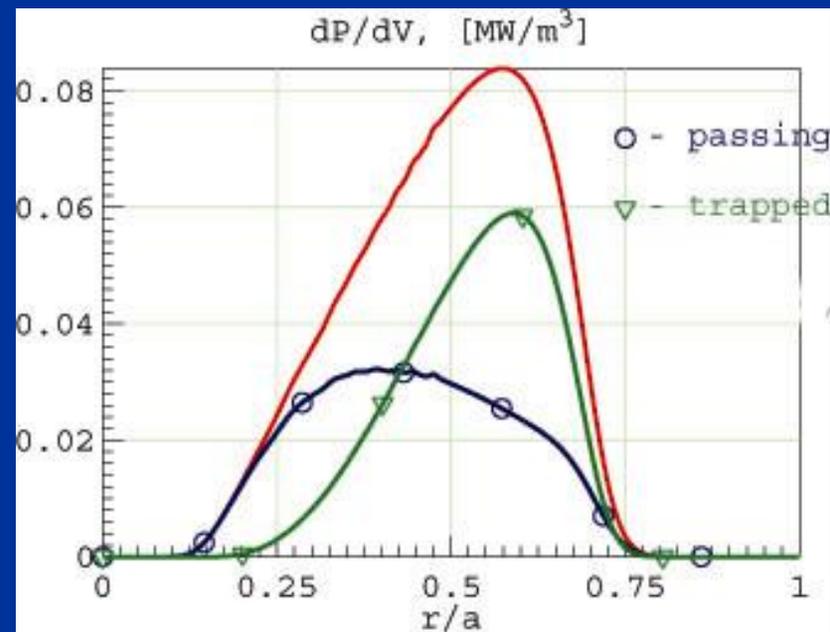
3D Full-Wave Code STELEC (V. L. Vdovin)

- Stellarator_ECH, tokamak as particular case
- Massive computer resources needed
- Effects of the upper hybrid resonance and anomalous mode conversion



3D Ray/Beam Tracing and ECE calculations (N. B. Marushchenko)

- Absorption and emissivity calculated separately for passing and trapped electrons
- Significant power in ripple-trapped electrons predicted for W7-X
- Estimate of localisation and spatial resolution of emission



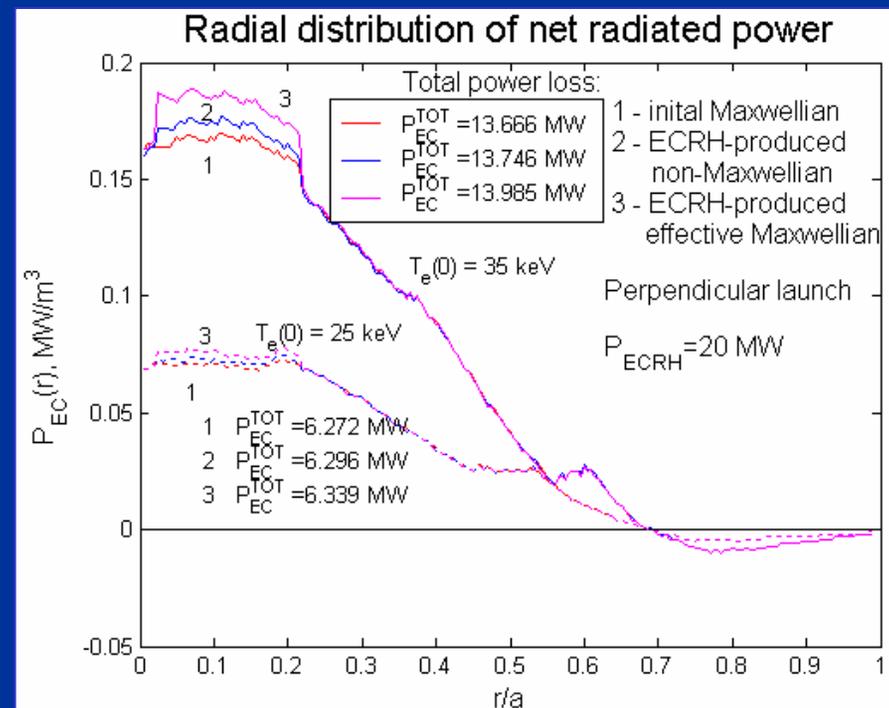
Modelling of Emission, Absorption and CD

ECE in GENRAY (A. P. Smirnov)

- Emission calculated from analytically parametrised distribution functions or from CQL3D (FP)
- Emission from Electron Bernstein Waves (and BXO mode conversion)
- Application to a large number of machines

Generation of suprathermal electrons and effects on ECE (L. K. Kuznetsova)

- ITER parameters considered
- ECRH => Thermal part affected, small effects on the radiated-power profile
- ECCD => bigger fraction of suprathermal, radiation profile up to 20% larger in the core



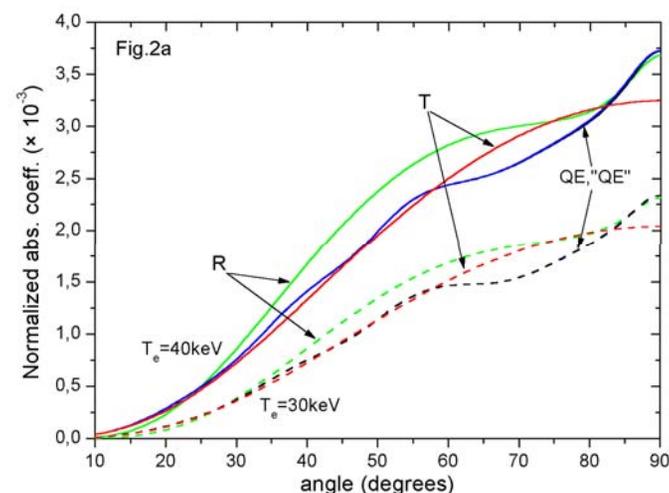
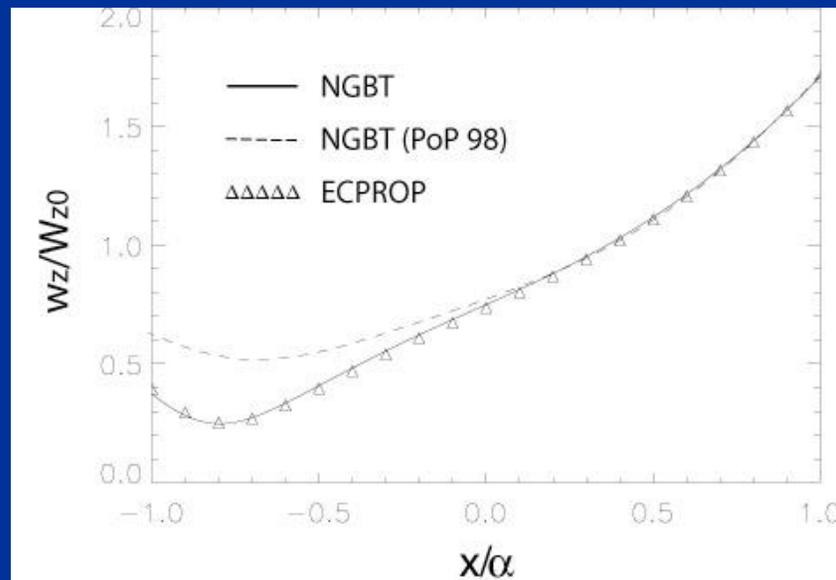
Modelling of Emission, Absorption and CD

Non-Gaussian Beam Tracing (C. Tsironis)

- Extension of Beam Tracing to nongaussian beams within the paraxial WKB method
- Benchmarking successful, ready for implementation
- Fundamental and higher-order modes absorbed at nearly the same rate

Absorption coefficient in High-temperature plasmas (N. Bertelli)

- “Quasi-exact” analytic calculation of the absorption coefficient
- Bateman’s expansion for the product of two Bessel functions
- Benchmark for approximate solutions



Electron Bernstein Waves and Mode Conversion

Relativistic effects and EBW Current Drive (A. K. Ram, J. Decker)

- Access to overdense plasmas (no cutoff) like ST and stellarators
- Wide N_{par} spectrum, energy deposited in energetic electrons
- Current drive through Fisch-Boozer or Ohkawa mechanism
- Shift of the absorption location due to relativistic effects

Relativistic effects on EBW in TJ-II (F. Castejón)

- Relativistic effects important for both ray trajectory and absorption
- Weakly relativistic description sufficient up to 5 keV

Weakly relativistic dielectric tensor for arbitrary wavenumbers (F. Volpe)

- Taylor-expansion of the Lorentz factor in Trubnikov's fully relativistic tensor
- No assumption on parallel and perpendicular wavenumbers
- Suited for EBW

- FX-B mode conversion feasible? (if evanescent layer thin enough...)
- Flexibility (density constraints, fixed N_{par} in OXB schemes)
- Relevance for tokamaks
- Computational costs of relativistic effects, weakly vs. fully relativistic

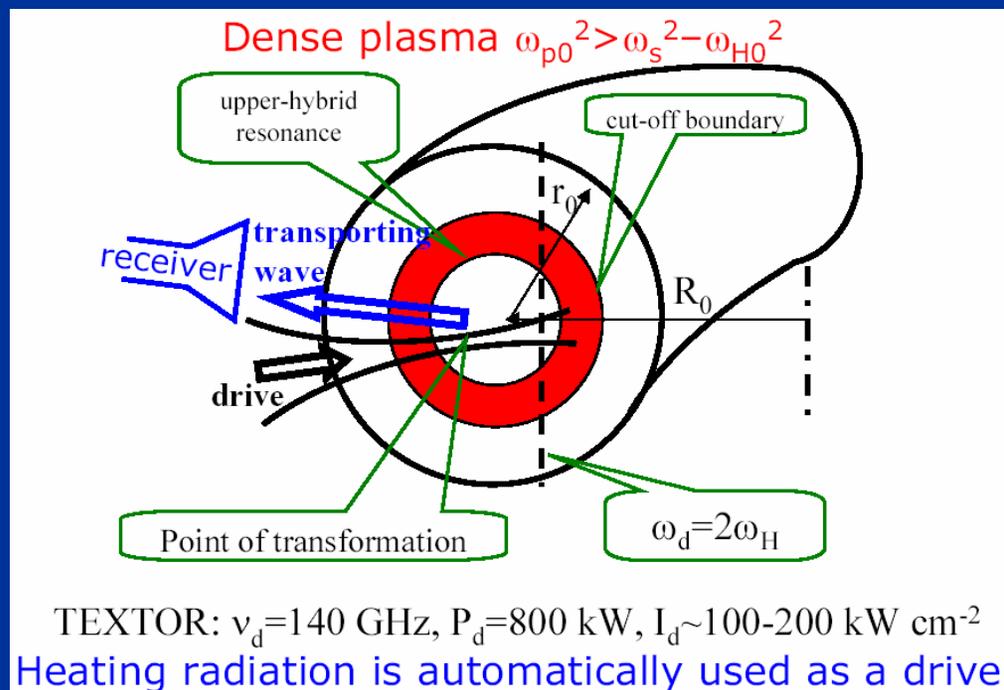
Electron Bernstein Waves and Mode Conversion

O-X transformation in 2D plasmas (E. V. Suvorov)

- Wave equations at the O-mode cutoff accounting for magnetic-field/density inhomogeneity (in different directions)
- Analytic solutions possible (short wavelength approximation)
- “Best incidence” conditions formulated for **finite beam width**

Parametrically induced transparency to detect EBW (A. Yu. Kryachko)

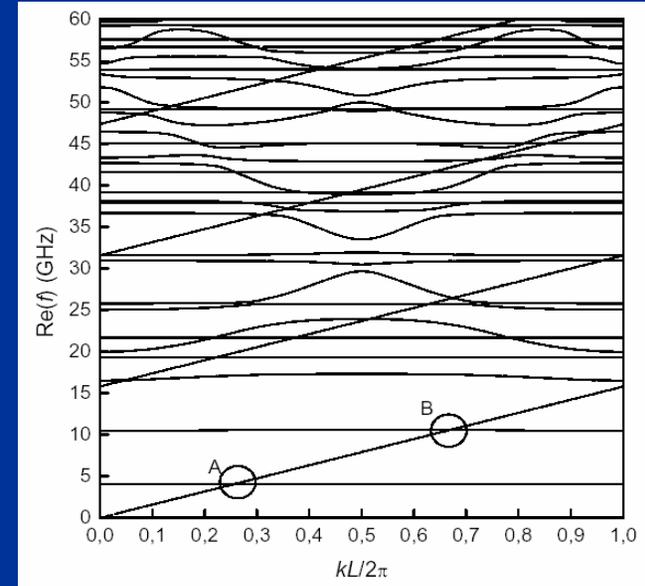
- Nonlinear change of the dielectric properties of the medium induced by an external drive (three-waves coupling)
- Gyrotrons considered as possible source
- Received emission detuned from 1st and 2nd EC harmonics
=> low noise
- Alternative to BXO detection



Theory of gyrotrons and transmission lines

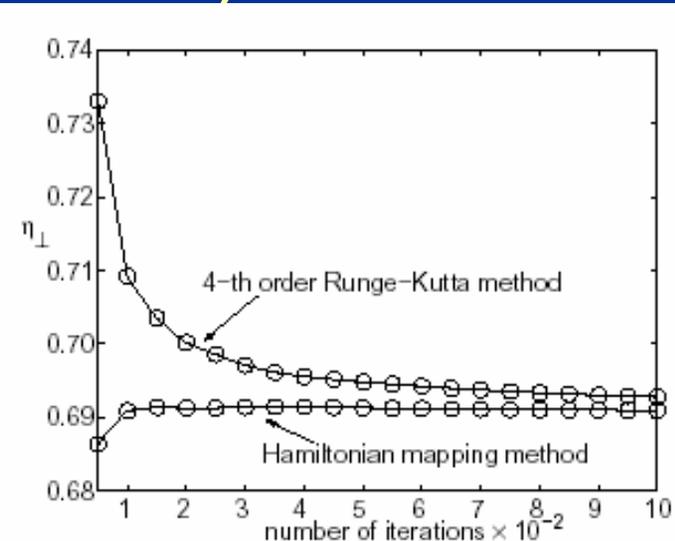
Dispersion properties of beam-loaded corrugated waveguides (G. P. Latsas)

- Field distribution in the (aperiodic) in a beam-loaded waveguide
- Fast solution of the dispersion relation
- Energy transfer between the beam and the modes included
- Importance of varying cross-section?



Electron dynamics in gyrotron resonators (Y. Kominis)

- Dynamics of electrons and RF fields described by Canonical Perturbation Method
- Hamiltonian Map more efficient than Runge-Kutta and preserves invariants
- Good qualitative understanding reached, more quantitative analysis needed?



Interaction of particle with pulses / Surface modes

Transient dynamics of charged particles interacting with localised waves of continuous spectra (Y. Kominis)

- Canonical Perturbation Method extended to RF pulses (“aperiodic“ perturbation)
- Approximate invariants of the motion for the nonintegrable system obtained
- Invariants used to find an approximate solution to the Vlasov equation for the particle distribution

Electron heating due to absorption of Surface Flute Modes (V. O. Girka)

- Poloidal modes propagating along the surface of the plasma column with a frequency in the EC frequency range
- Absorption of the modes in a toroidal-ripple induced resonance possible
=> Edge heating possible
- Stronger absorption for smaller gradients

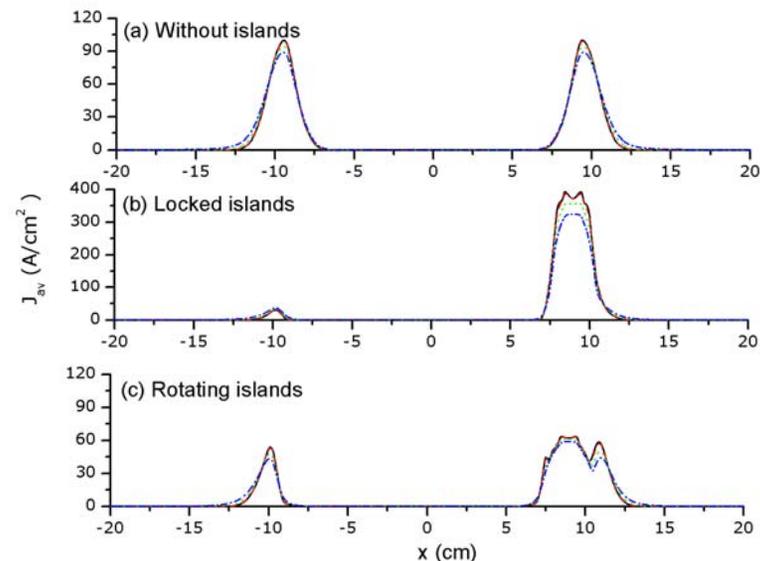
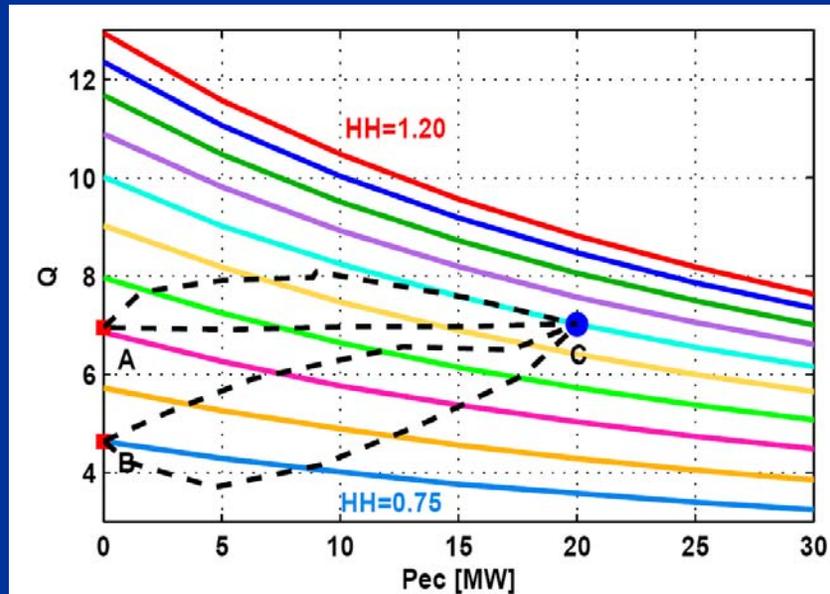
NTM / ITER / DEMO Modelling

Physics of NTM stabilisation by ECCD for ITER (H. Zohm)

- Criterion for stabilisation $j_{\text{ECCD}}/j_{\text{BS}} > 1.2$
- Partial stabilisation preferable if NTMs always present
- Modulation needed for $W_{\text{CD}} > W_{\text{isl}}$
- Heating vs. CD (transport inside the island?)
- ECRH/ECCD in actual island geometry

ECCD in the presence of a magnetic island (P. R. Rosa)

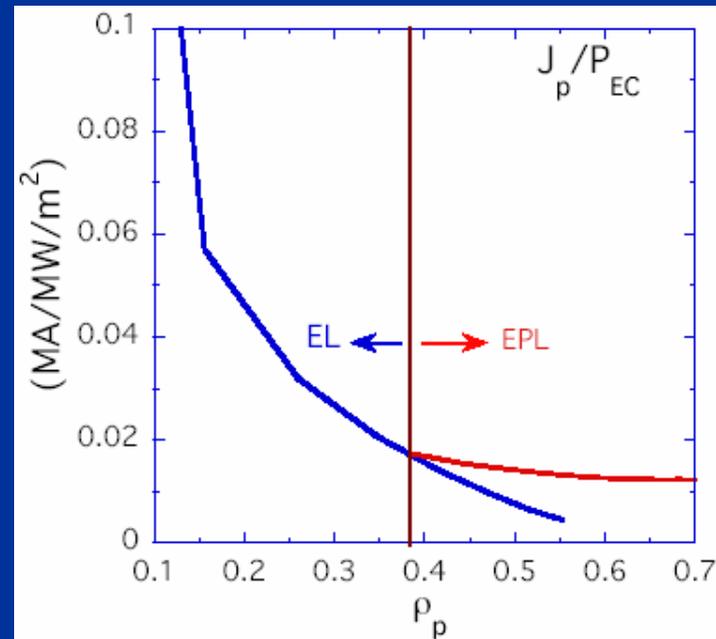
- Numerical solution of the FP equation in slab geometry
- Current density increase inside the island because of the smaller volume
- QL effects negligible



NTM / ITER / DEMO Modelling

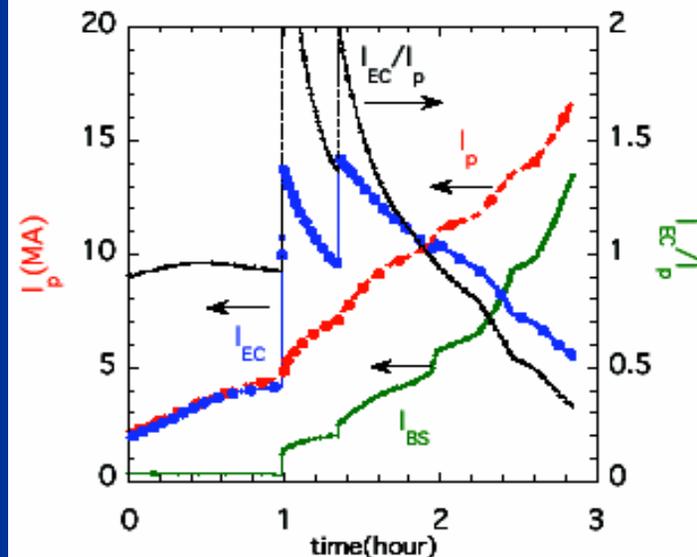
Extended-physics applications of the ITER upper launcher (G. Ramponi)

- Extended steering range, inner surfaces reachable ($\rho_p > 0.4$) with well-localised current profiles
- Current density per injected power higher than for the equatorial launcher ($0.4 < \rho_p < 0.55$)
- Optimisation with respect to multi-beam effects (E. Poli) and beam astigmatism



EC-assisted current ramp-up at DEMO / JAEA design (M. Sato)

- Ray tracing + FP + self-consistent equilibrium
- $P_{fus} = 3$ GW starting ECCD @ $I_p = 2$ MA possible
- Required maximum power $P_{EC} = 170$ MW



How much time is left for discussion?



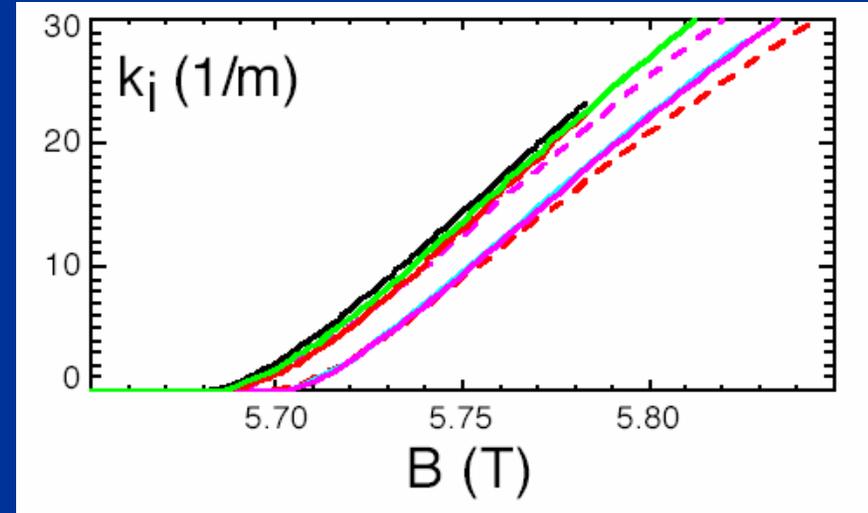
How much time is left for discussion?

- Code benchmarking: further refinement?
- Improvement of linear ECCD efficiency
- Effects of UHR and anomalous mode conversion in full-wave calculations
- Electron Bernstein Waves
 - FX-B?
 - Flexibility
 - Relevance for tokamaks
 - Relativistic effects
 - Finite beam width
- Beam-loaded waveguide description: importance of varying cross-section?
- Hamiltonian equations for gyrotrons: more quantitative analysis needed?
- NTMs
 - Heating vs. CD (transport in the island)
 - ECRH/ECCD in actual island geometry

Modelling of Emission, Absorption and CD

Benchmarking of EC Codes for ITER (R. Prater)

- High agreement (also: linear vs. QL)
- Fully vs. weakly relativistic absorption at slightly different locations
- **Need for further refinement?**



Improved linear ECCD efficiency (Y. R. Lin-Liu)

- Adjoint method, relativistic, full polarisation retained
- Implemented in TORAY-GA

GRAY: quasi optical beam tracing (D. Farina)

- Mazzucato's eqs. for diffraction effects
- Fully relativistic absorption
- Full polarisation in CD routine