Magnetic Confinement Theory and Modelling Summary

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Preliminary remarks

- Theory thrives: 147 contributions, 17 oral talks + 2 OV
- A rich variety of subjects
  - Stability (33)
  - Waves and energetic particles (28)
  - Confinement (57)
  - Edge physics (15)
  - Integrated Tokamak Modelling (14)
- Many works presented in the EX sessions (code validation): not covered here

Configuration optimisation, equilibria

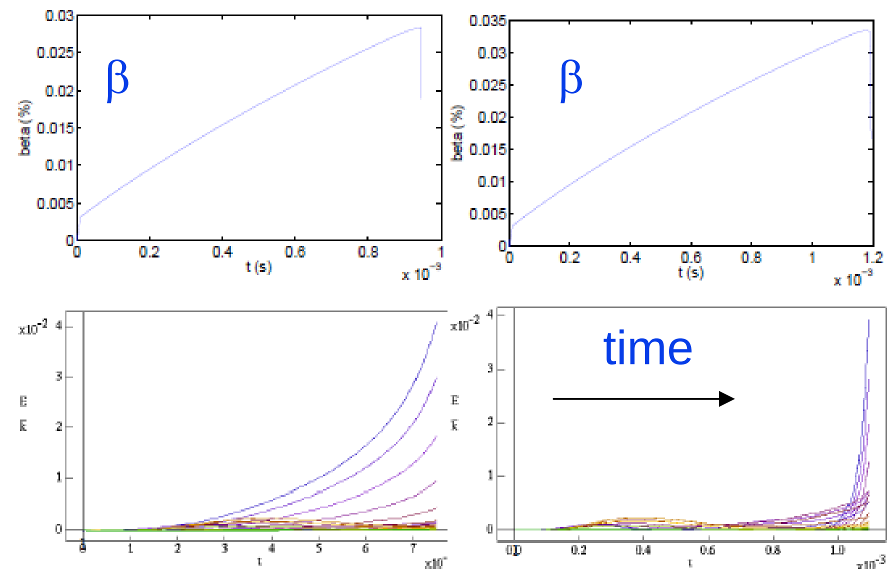
THC/P4-03 Cappello, THC/P5-01 Castejón, THC/P5-03 Ito, THC/P8-01 Gott, THS/P2-02 Ahmad, THS/P5-05 Furukawa, THS/P5-12 Miura, THS/P5-11 Mirnov, THC/P5-04 Reiman, THC/P5-02 Herrera-Velázquez

- RFP: chaos healing at transition to quasi-single helical axis state **Cappello**
- Stellarators:

- optimisation by minimising curvature drift effect **Castejón**
- increased β limit due to pressure local flattening **Ichiguchi**
- 3D configuration can be beneficial to high β **Hegna.**

- Tokamaks equilibrium with stochastic regions **Reiman, Herrera-Velázquez**

Hegna



Symmetric vacuum Instability onset at $\beta \sim 1\%$

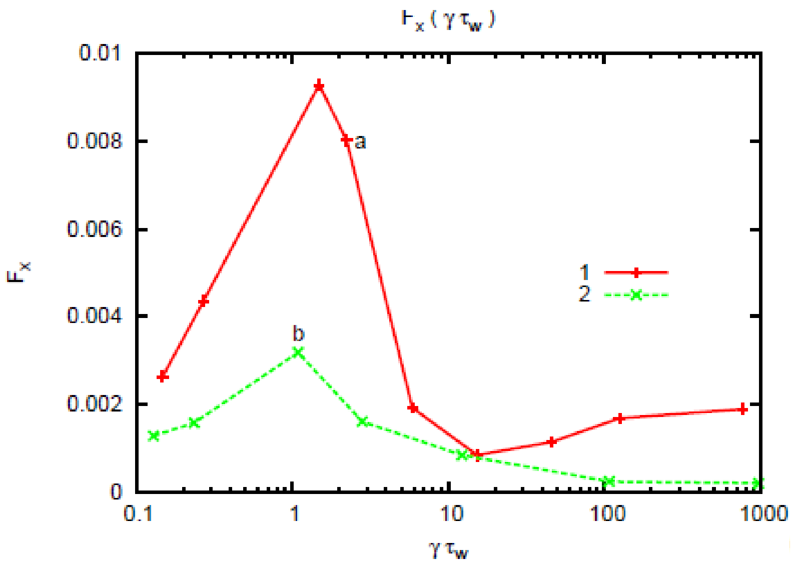
configuration spoiled by small 3-D **B**-fields Instability onset at $\beta \sim 3\%$

Disruptions, β limit

THS/4-1 Hegna, THS/9-2 Izzo, THW/P7-13 Papp, THS/P2-06 Strauss, THS/P5-08 Ichiguchi, THS/P5-14 Shiraishi

- Confinement of runaways scales as R^3 **Izzo** – control with stochastic field lines **Papp**
- Wall force maximum when $\gamma\tau_w \approx 1$ **Strauss**
- Tearing stability in RFPs **Mirnov**
- Stability with flows **Ahmad ,** new matching method for η MHD **Furukawa**, **Shiraishi** LES simulations of Hall MHD **Miura**

Strauss



VDE MHD simulation: sideways force is largest for $\gamma\tau_w \approx 1$.

Edge Localised Modes - Pedestal

THS/1-1 Snyder, THS/7-1 Huysmans, THS/P3-01 Aiba, THS/P3-04 Sugiyama, THS/P3-05 Xu

- Combining peeling/ballooning and KBM stability → height and width of the pedestal **Snyder**
- ELM relaxation:

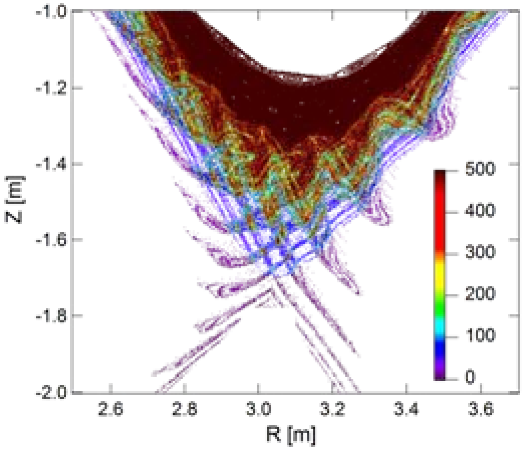
  - ELM destabilised by rotation **Aiba**, pellet **Huysmans**

  - electron viscosity limits radial spreading **Xu .**

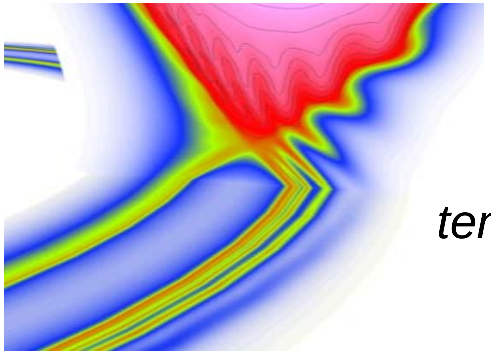
  - scaling of ELM size with ν^* **Huysmans**

  - heat deposition **Sugiyama, Huysmans**

Huysmans



connection length



plasma temperature

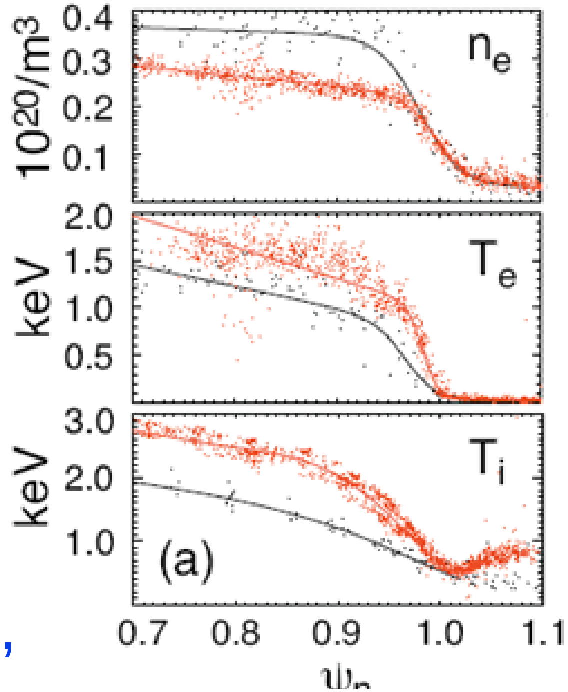
See also Sugiyama

Resonant Magnetic Perturbations

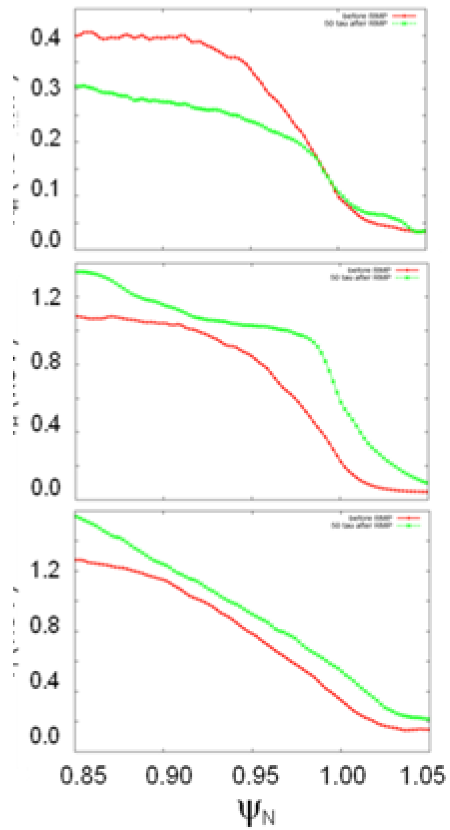
THS/P5-02 Beyer, THS/P5-04 Chu, THS/P2-05 Park, THS/P3-06 Yu, THS/P5-10 Liu, THS/P5-13 Shaing, THD/P3-01 Joseph, THC/P4-04 Chang

- OV by **J. Callen**
- Penetration of RMPs : field is very different from vacuum field. **Chu, Liu**
- Sign of rotation affects density profile **Yu,** particle transport is enhanced by 3D collisional effects. **Chang**
- ELM control with coils **Beyer**, **Park,** currents in the SOL **Joseph**

Chang



Experiment DIII-D #126006.



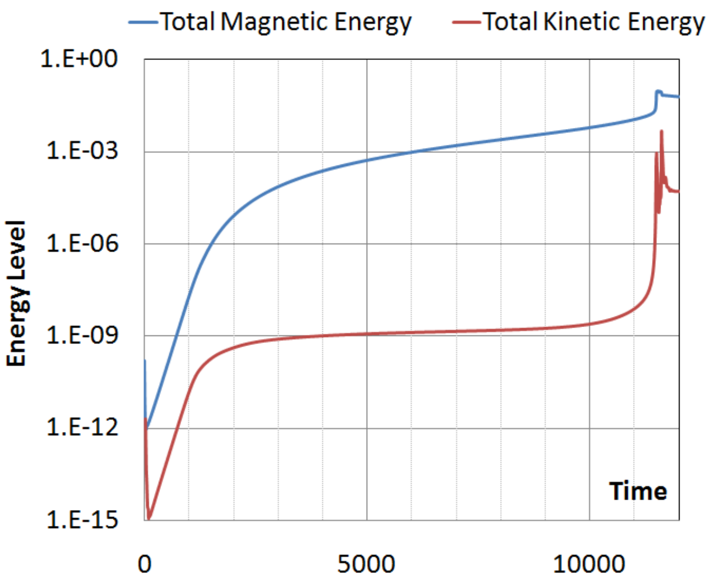
Simulation.

Reconnection , sawteeth, tearing modes

THS/9-1 Graves, THS/P5-06 Halpern, THS/P5-03 Cai THS/P2-03 Breslau, THS/P5-09 Janvier

- Sawteeth control with fast particles produced by ICRF waves **Graves**
- Bi-fluid NL simulations of sawteeth **Halpern**
- Fast reconnection : eMHD **Cai**, Double Tearing: fast reconnection due to secondary instability+zonal magnetic field **Janvier**
- Excitation of a non resonant n=1 mode in NSTX→NTM **Breslau**

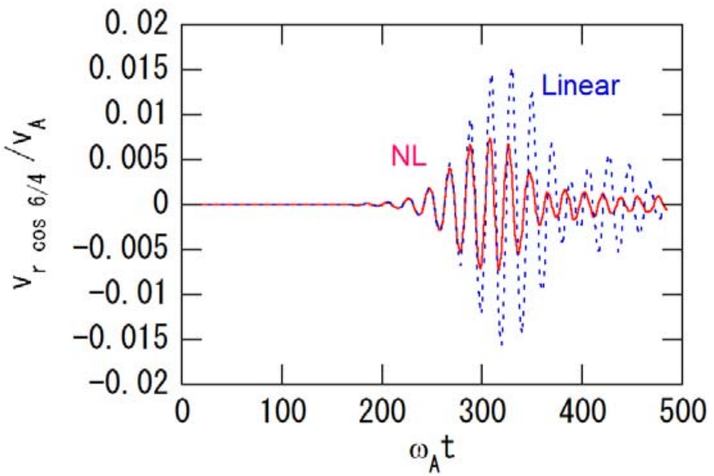
Janvier

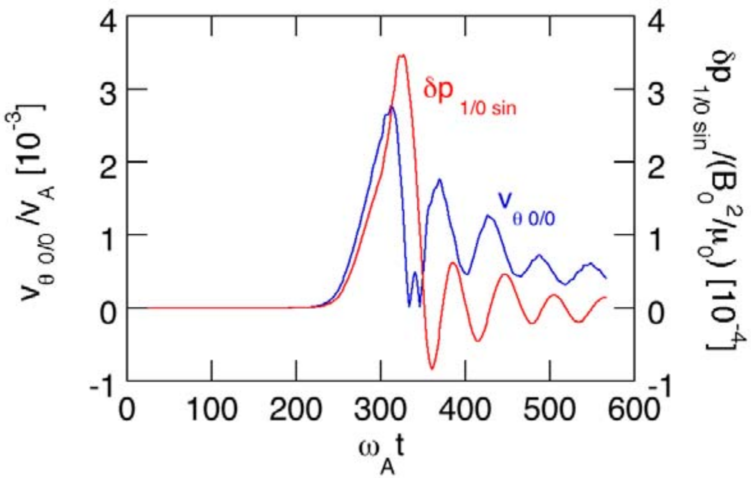


MHD modes driven by energetic particles

THW/2-2Ra Lauber , THW/2-4Ra Wang, THW/2-2Rb Fu, THW/2-3Ra Todo, THS/P7-02 Hirota

Todo





- Beta Alfvén Eigenmodes : kinetic ion effects are important, **Lauber, Wang, Nguyen** cooperate with Toroidal Alfvén Eigenmodes for losses **Lauber**
- TAEs: saturation with collisions, sources and sinks **Fu**
- excitation of poloidal flows: important for non linear saturation **Todo**

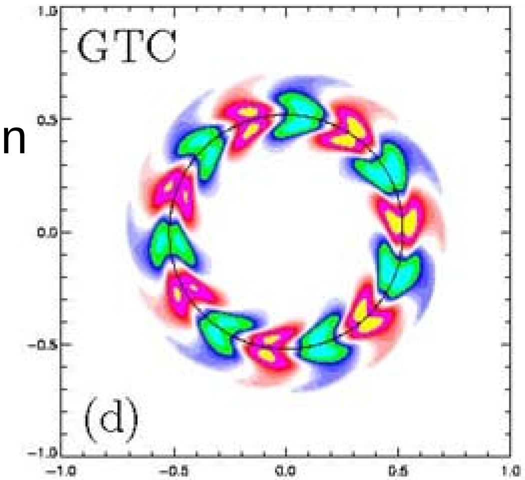
MHD modes driven by energetic particles (cont.)

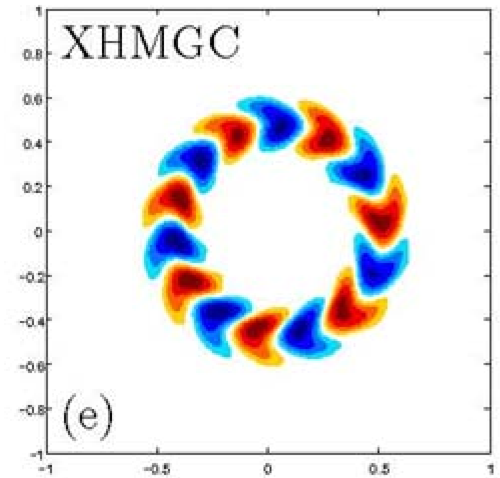
THW/P7-08 Borba, THW/P7-12 Marchenko, THW/P7-02 Breizman, THW/P7-1 Lesur, THW/P7-10 Khorasan, THW/P4-01 Bass, THC/P4-31 Zhang, THW/P7-05 Chen

- NL evolution via wave/particle interaction: collisional drag is important **Breizman,** measurements give access to local drive and damping rate **Lesur**

- Gyrokinetic codes able to reproduce main EP-MHD modes **Bass, Chen** assessment of fast particle transport **Zhang**

L Chen





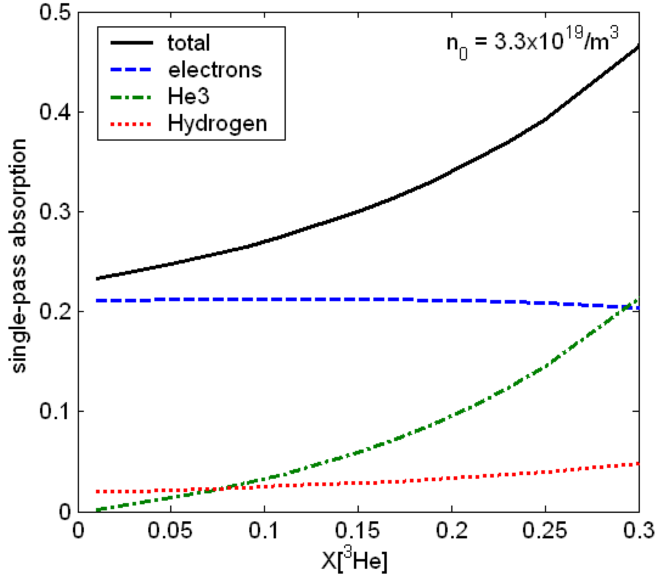
Fast particles and heating

THW/2-1 E.Z. Gusakov, THW/P2-04 Seol, THW/P7-15 Vdovin, THW/P7-16 Velasco, THW/P7-01 Bonoli, THW/P7-06 Choi, THW/P7-09 Harvey, THW/P7-04 Cardinali, THW/P2-03 Lerche, THW/P7-17Yavorskij, THW/P7-03 Bustos, THW/P7-07 Farengo, THW/P7-14 Sorokina, THW/P3-01 Kurki-Suonio

- ECRH: detrimental effect of parametric decay instabilities in presence of a magnetic island **Gusakov**, ITER startup modelling 1st harmonic **Seol, Vdovin**
- ICRF modelling **Bonoli**, **Choi**, **Harvey** scenarios on FAST **Cardinali**
- ITER H plasmas : poor single pass absorption $\rightarrow$ alternative scenarios **Lerche**
- NBI : calculation of losses **Yavorskij, Bustos**
- α particles: bootstrap current **Farengo, Sorokina,** wall load **Kurki-Suonio**

Lerche

μ = (launched – reflected) / launched power



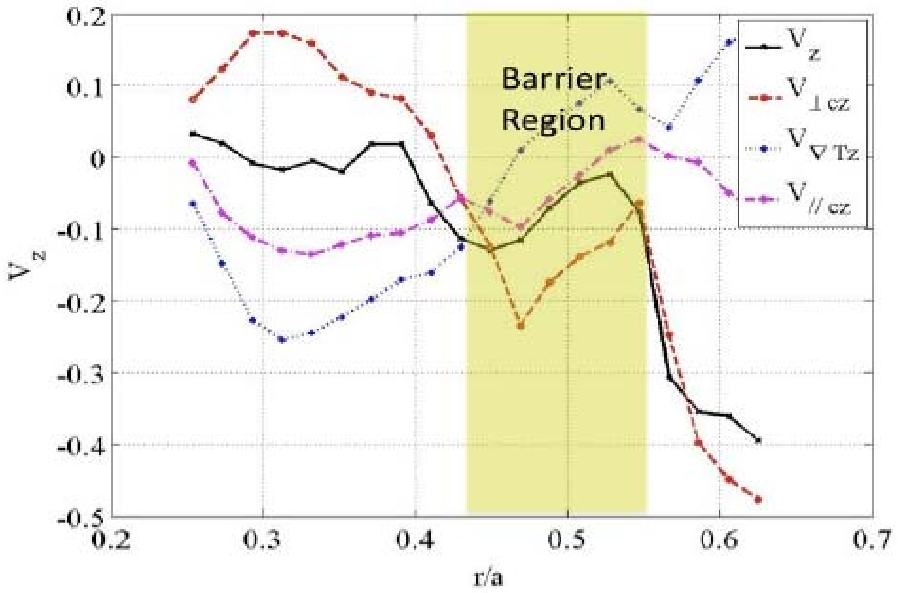
N=2 ^{3}He

Particle transport

THC/P4-09 Fülöp, THC/P4-11 Horton, THS/P4-01 Futatani ,THC/P4-12 Hoshino, THS/P3-03 Shurygin

- Agreement between simulations and QL theory **Fülöp, Horton**
- Reversal of impurity pinch velocity in reversed q profiles **Futatani**
- Effect of E_r on pinch velocity **Hoshino**

Futatani



Toroidal momentum transport

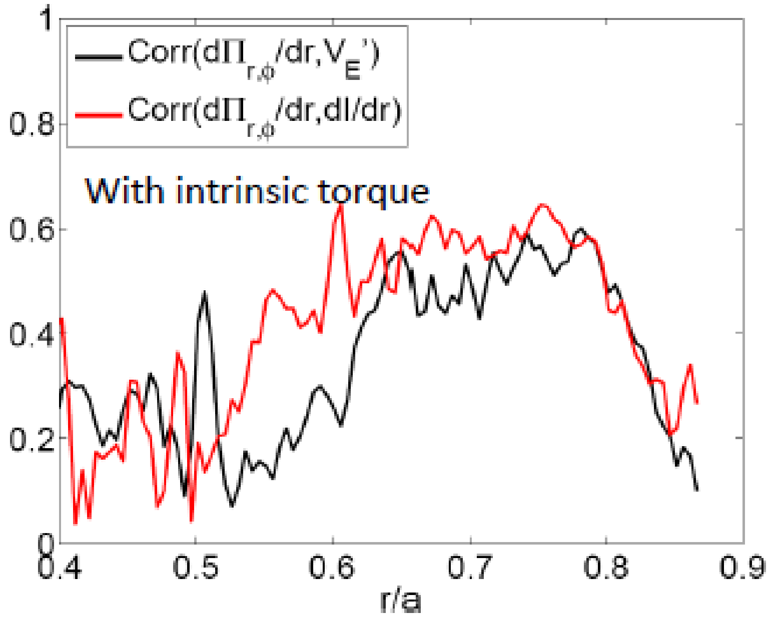
THC/3-4Rb Kwon, **Ku PD-2**, THC/P4-18, Mcdevitt, THC/P4-30 Wang, THS/P4 Pustovitov, THC/P4-07 Dnestrovskij, THD/P4-01 Yarim, THC/P4-25 Singh

- OV by A. Peeters

$$\Pi_{r\varphi} = -\chi_\varphi \frac{\partial \overline{v}_\varphi}{\partial r} + V\overline{v}_\varphi + \Pi_{r\varphi}|_{resid}$$

- Residual stress: mean shear flow and intensity gradient are important **Wang, Kwon, Ku,** polarization stress **McDevitt**
- Curvature (TEP) is dominant in pinch velocity **McDevitt**
- Canonical profiles **Dnestrovskij,** neoclassical flux **Yarim,** Interplay between poloidal and toroidal direction **Singh**

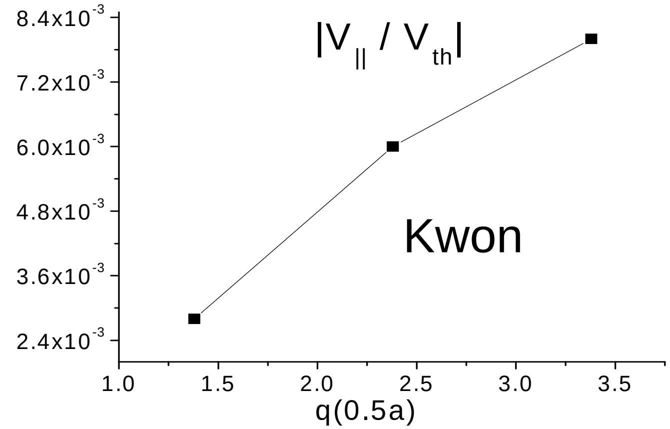
Ku

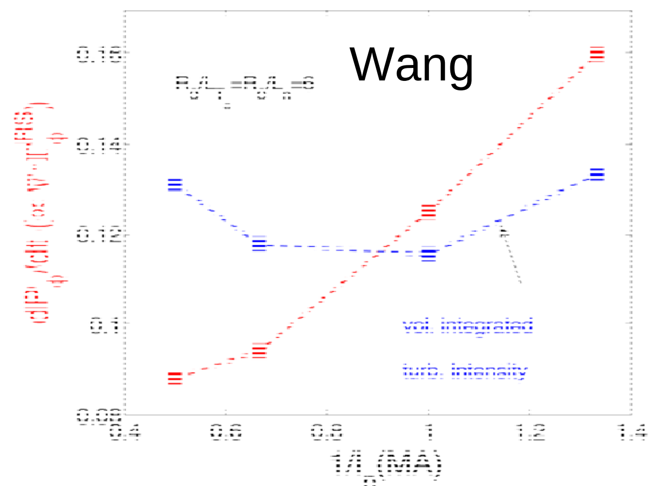


Toroidal momentum transport (cont.)

THC/P4-13 Idomura, THW/P4-02 Gao, THW/P4-03 Murakami, THC/P4-10 Honda, THC/P4-21 Parra

- Turbulent torque increases with temperature gradient. Current scaling recovered **Kwon, Idomura, Wang**
- Requirements for accurate calculation of momentum transport **Parra, Catto, Pustovitov**
- Effect of fast particles, RF waves **Gao**, **Murakami** α losses: little torque **Honda**





Poloidal flows

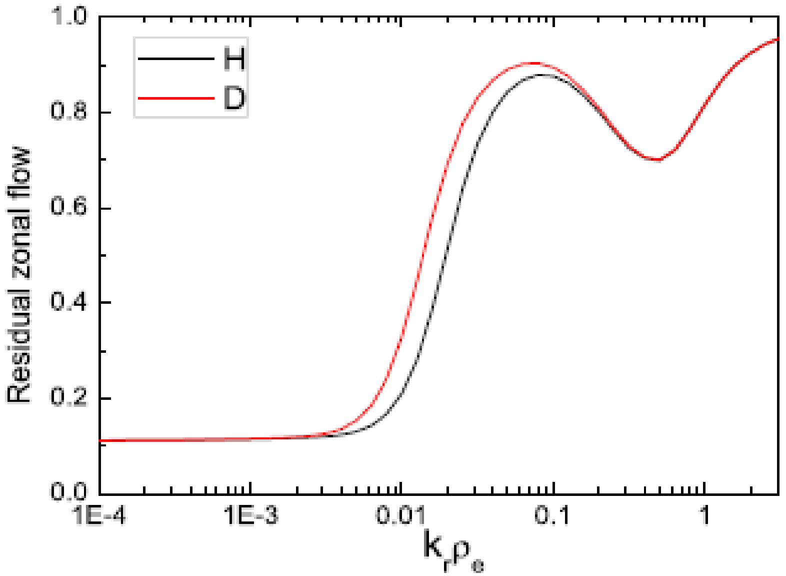
THC/6-1 Watanabe, THC/P8-03 Hahm, THC/P4-20 Nunami ,THC/P4-01 Barnes, THS/P8-03 Mykhaylenko, THW/P8-03 Wang

- NL self-sustainment of a turbulence that is linearly stabilised by ExB mean shear flow **Barnes**
- Residual Rosenbluth-Hinton ZF flow

  - enhanced by mean $E_r \rightarrow$ favourable effect on ZFs level and confinement **Watanabe**

  - mass dependence $\rightarrow$ isotope effect **Watanabe, Hahm**

Hahm

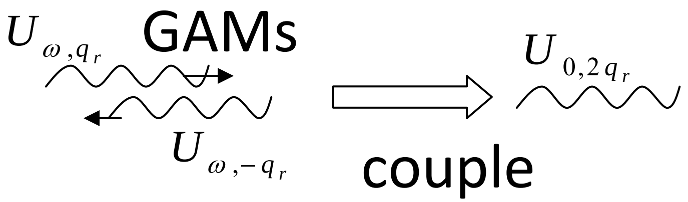


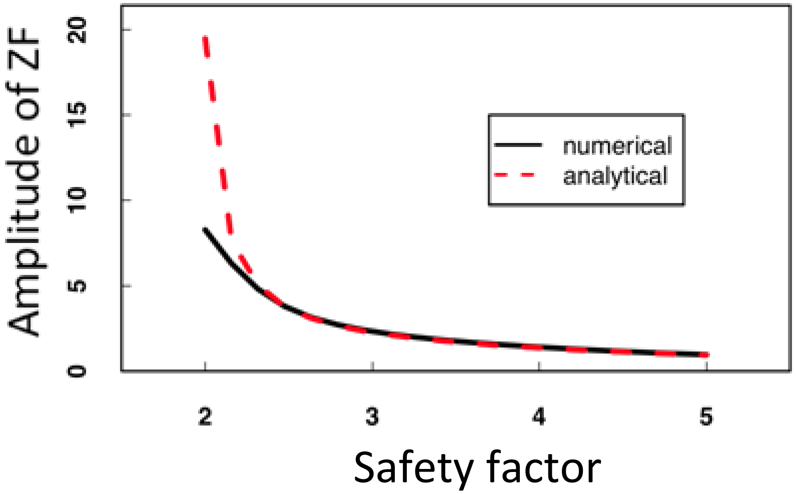
Poloidal flows (cont.)

THC/6-2Rb Sasaki, THW/P8-01 Qiu, THC/P8-04 Hallatschek, THS/P8-01 Ilgisonis, THS/P8-05 Zhang, THS/P8-06 Zhou, THD/P3-08 Umansky, THC/P8-02 Gurcan, THC/P4-27 Terry

- Zonal flows affect wave number spectra **Gürcan** Energy transfer also affected by coupling to damped linear modes **Terry**
- Geodesic Acoustic Modes : radially propagate **Sasaki, Qiu**, **Hallatschek,** coexist with ZFs **Miki** → **EX7-3 Zhao**, affected by mean flow **Zhou**, damped by trapped electrons **Ilgisonis, Zhang**

Sasaki





L-H transition- edge turbulence

THC/3-2 Catto, THC/P3-01 Aydemir, THC/P3-04 Lee, THD/P3-02 Marandet, THD/P3-03 Naulin, THD/P3-07 Sugita, THC/P4-28 Toda, THD/P2-01 Lukash

- Edge turbulence:

- dynamics of blobs **Sugita**

- edge turbulence remains difficult to predict → **EX7-2 Rhodes**

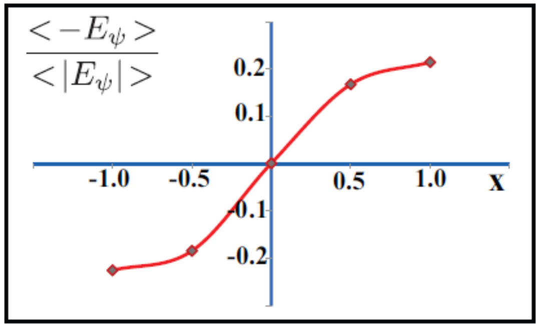
- GAM can quench turbulence

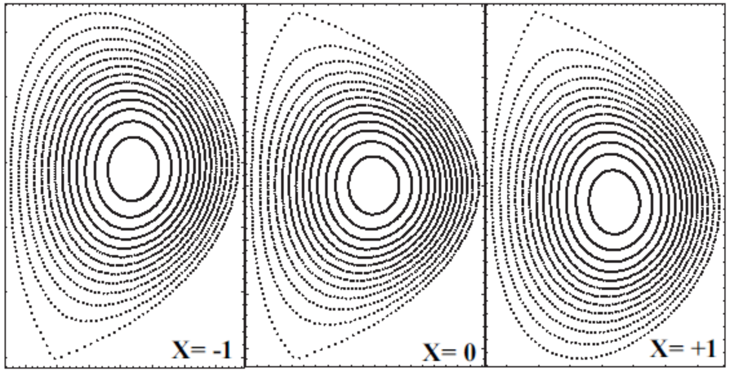
  Hallatschek, Miki → EX7-1 Conway

- Effect of PS flows on radial electric field : favorable ∇B drift for LH transition **Aydemir**

- Impact of strong shear flow on neoclassical transport **Catto**

Aydemir



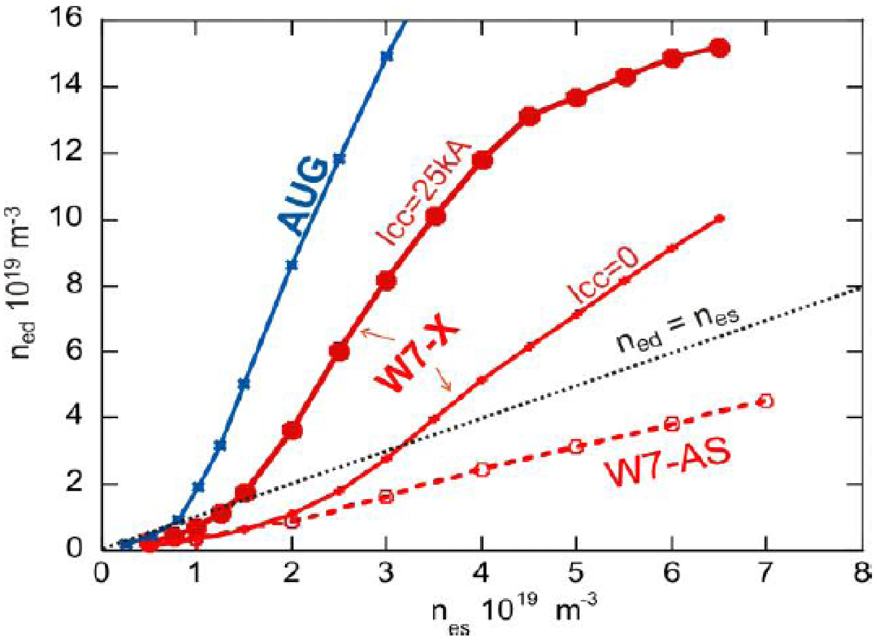


Density limit - divertor physics

THC/8-1 Singh, THD/5-1Rb Feng, THD/5-1Ra Shimizu, THD/P3-05 Rognlien, THD/P3-04 Ohya, THD/P3-06 Rosato, THD/P3-02 Marandet

- Density limit due to zonal flows that become Kelvin-Helmholtz unstable **Singh,** effect of E_r **Toda,** mitigation by Li pellet **Lukash**
- Effect of fluctuations on neutrals: larger penetration **Marandet**
- Optimised stellarator divertor approaches tokamak performances **Feng,** Conditions for detachment in JT-60SA **Shimizu**

Feng

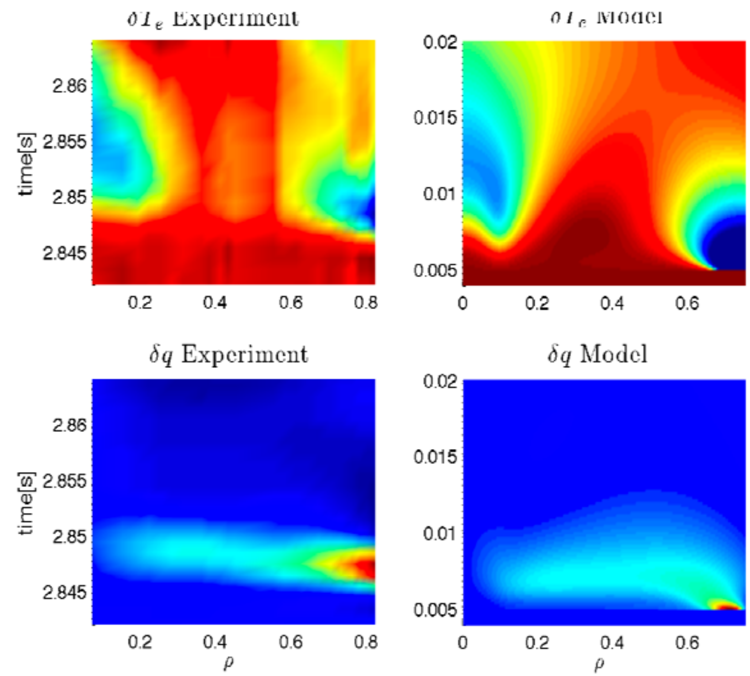


Heat transport : non local effects, avalanches

THC/3-5 Sarazin, THC/P4-06 Dif-Pradalier, THC/P4-14 Jolliet, THC/P4-13 Idomura, THC/P4-05 Del-Castillo-Negrete, THC/P4-22 Pastukhov

- Avalanche dynamics: propagation direction is related to shear rate, limited by ZFs corrugations **Dif-Pradalier, Sarazin, Idomura, Jolliet, Jenko, Ethier** carry momentum **Sarazin,** long range correlation $\rightarrow$ **EX7-4 Inagaki**
- Non local transport: may explain fast pulse propagation **Dif-Pradalier, Del-Castillo-Negrete, Pastukhov**

Del-Castillo-Negrete



Spatio-temporal evolution of temperature and flux perturbations

Heat transport- scaling laws

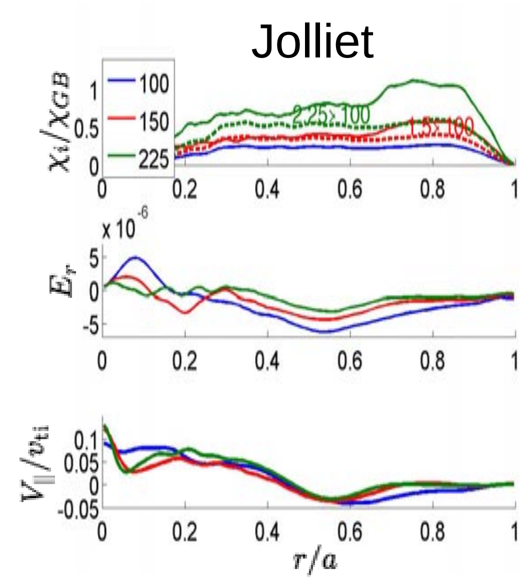
THC/3-1 Jenko, THC/P4-08 Ethier, THC/P4-17 Lin, THC/P4-26 Tangri, THC/P4-03 Cappello

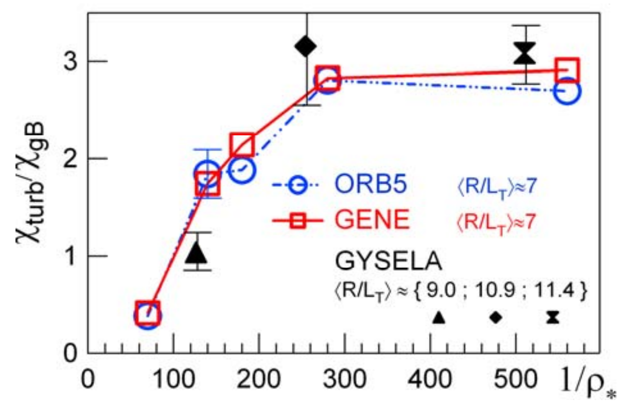
- ETG turbulence explains residual transport in transport barriers **Jenko** also important in low aspect ratio tokamaks **Ethier**
- breaking gyroBohm scaling law at large ρ* and/or close to threshold: quasi-ballistic motion along streamers in CTEM turbulence **Lin** Effect of avalanches in ITG turbulence

  Jenko, Sarazin, Jolliet
- ITG in RFPs : usually stable

  Tangri, Cappello

Jolliet



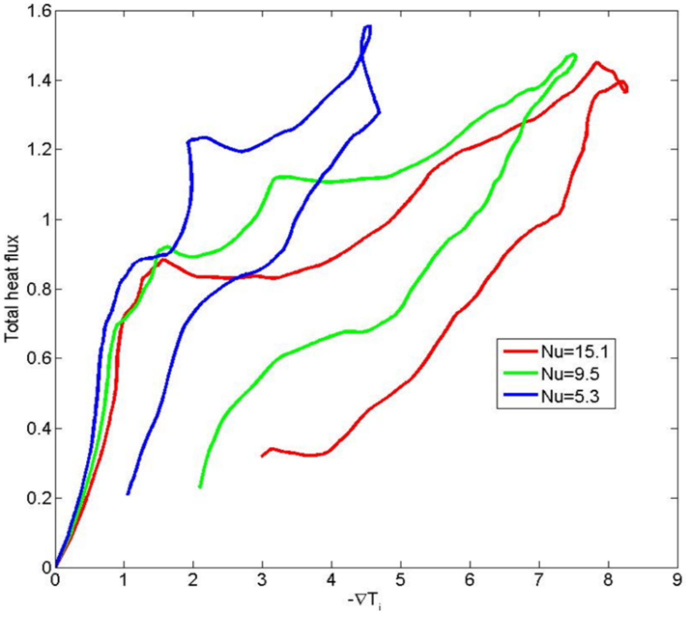


Internal Transport Barriers

THC/3-4Ra Kim, THC/P4-19 Miyato, THS/P8-02 Lakhin, THC/P8-05 Tokunaga, THC/P4-24 Scott

- ITBs: hysteresis due to strong parallel flows **Kim**
- Role of low order rational surface : ZF generation **Lakhin** non resonant modes **Tokunaga, Sarazin**
- Derivation of GK equations with large ExB flows **Miyato, Scott**

Kim



Strong co-current parallel flow generated in ITB plasmas →open hysteresis curves.

Interaction between turbulence and MHD, electromagnetic turbulence

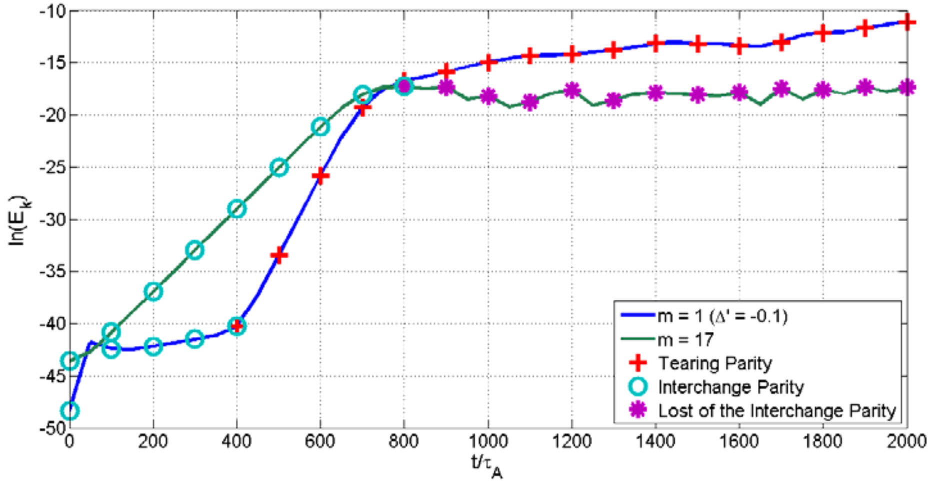
THC/P4-02 Bottino, THC/P4-16 Li, THS/P5-01 Agullo, THS/P5-07 Hao

- Stable tearing mode pumped by turbulence **Agullo**
- Interaction between a magnetic island and micro-turbulence:

  - effect of large scale flows **Bottino**

  - seesaw oscillation due to dynamo effect **Li**
- Turbulent viscosity lowers the critical toroidal velocity needed to stabilize RWM **Hao**

Agullo

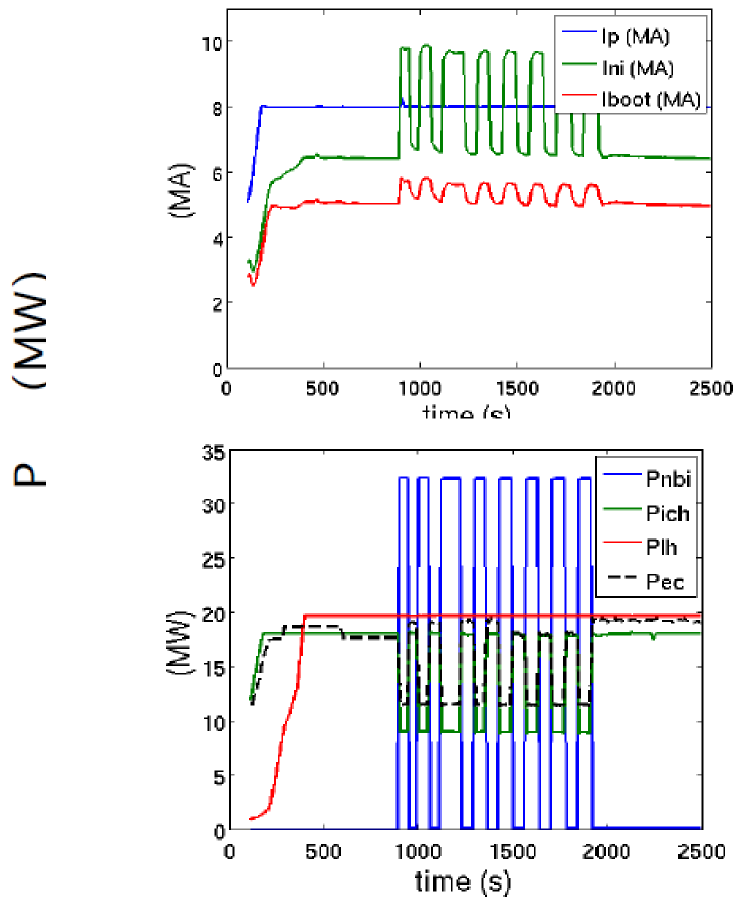


Integrated Tokamak Modelling

THC/3-3 Kinsey, THC/P2-01 Garcia, THC/P2-04 Kritz,THC/P2-03 Guo, THC/P2-05 Calabrò, THW/P2-02 Kim, THC/P3-02 Cary, THC/P4-23 Poolyarat, THC/P3-03 Kim, THS/P3-02 Hayashi, THC/P3-05 Pankin, THC/P3-06 Rozhansky, THS/P2-04 Na, THC/P4-29 Wakasa, THC/P2-02 Geiger, THW/P2-01 Fukuyama

- Confinement and scenarios for ITER **Kinsey, Garcia, Kritz, Kim** EAST **Guo,** FAST **Calabrò,**
- Core-edge coupling **Cary, Poolyarat**
- ELMs pacing with pellets **Kim, Hayashi,** pedestal **Pankin, Rozhansky**
- RT-control of NTMs **Na**
- Stellarators **Wakasa, Geiger**
- Heating **Fukuyama**

Garcia



Conclusions

- Trend : global description of the plasma
- multiscale: time and spatial scale separation
- full treatment

→ Cross-talk between various topics

- Increasing activity on integrated modelling.
- A number of papers related to ITER scientific programme. Some subjects are nearly absent :
- LH transition,
- disruptions,
- interaction MHD/turbulence,
- edge/core integration