ITPA Divertor/SOL group report

- Revision of priorities
- Report on meeting participation
- New results & plans
  - ELMs
  - Transport
  - Materials/T codepostion
  - Modelling
  - Disruptions
- Physics basis work
- Summary

Presented by N. Asakura for

The Divertor/SOL group

ITPA CC meeting, Garching Germany, Oct 24-25, 2002

Revision of priorities

- High Priority:
  - Understanding the effect of ELMS/disruptions on divertor and first wall structures,
  - Tritium retention & the processes that determine it,
  - Improve understanding of SOL plasma interaction with the main chamber
  - Better prescription of transport coefficients and boundary conditions for input to BPX modelling
- Medium-Term
  - SOL transport (parallel and drift)
  - High-Z materials - operational experience,
  - Improve our understanding of processes that determine the core impurity level,
  - The impact of the simultaneous use of different materials (e.g. tritium retention)
- Possible Items for Joint Work with other TGs
  - Disruption physics at the plate (shielding) and mitigation.
  - Design divertor diagnostics (measurement and FB control) for BPX experiments
  - Helium exhaust or transport in ITB plasma
  - ELMs & understanding pedestal gradient
  - Density limits

Meeting participation

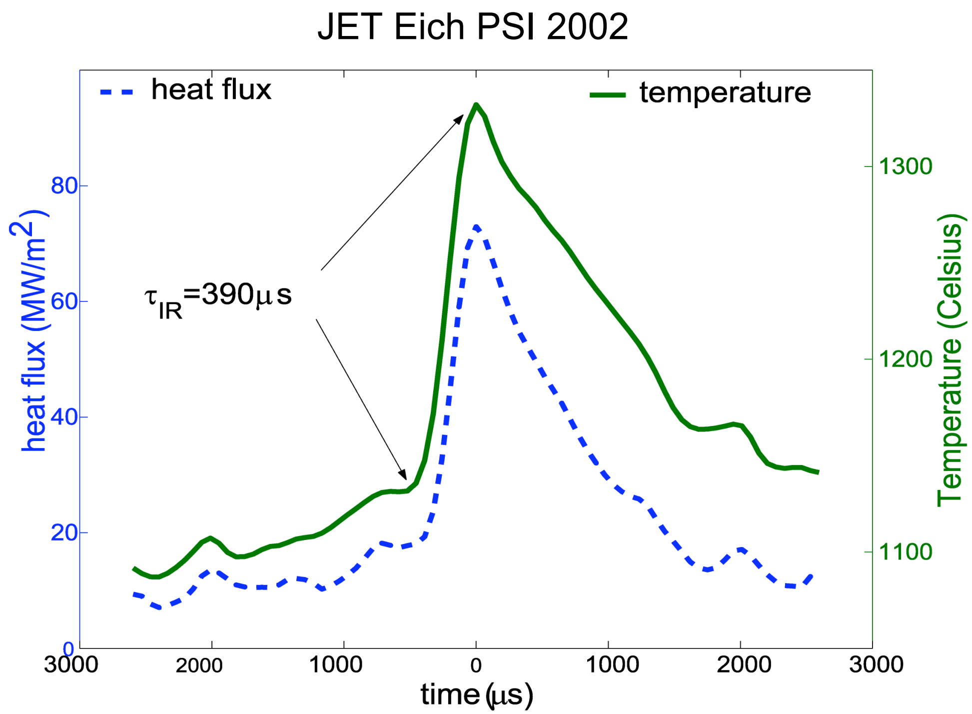
- Participation in PSI 2002/Gifu
  - A. Loarte, et al. ‘ELM energy and particle losses and their extrapolation to burning plasma experiments’.
  - V. Phillips, et al. ‘Chemical erosion behaviour of carbon materials in fusion devices’
  - G. Porter, et al., ‘Simulation of the effect of plasma flows in DIII-D, JET and JT-60U’
- IAEA 2002/Lyon
  - N. Asakura, et al., ‘Studies of ELM heat load, SOL flow and carbon erosion from existing tokamak experiments and projections for ITER’.

2nd ITPA SOL/divertor meeting in Lausanne, Oct, 21-23, 2002

Next ITPA SOL/divertor meetings

- July 2003 (after EPS) – planned for St. Petersburg, fallback – Europe
- November 2003 – potentially Naka

New measurements of ELM Divertor Power Flux pulse

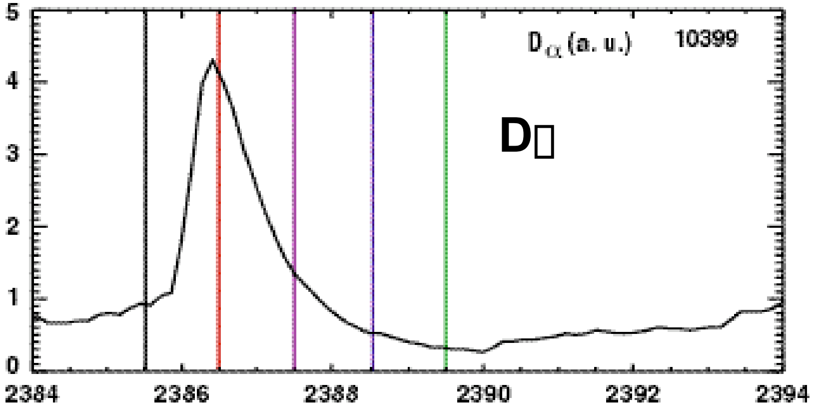


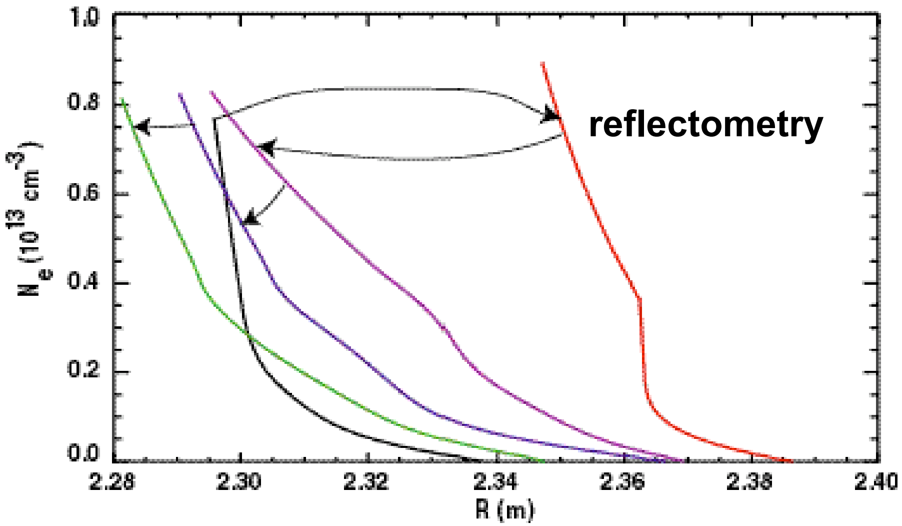
- Duration of Divertor ELM energy pulse correlated with ||B ion transport <u>not</u> with $□_{MHD}^{ELM}$
- Divertor ELM energy pulse is <u>not</u> rectangular 0.25-0.5□□W_{ELM}^{div} before peak

Both Findings provide a very favourable extrapolation of Type I □W_{ELM}^{div} for ITER

Further experimental characterisation of q_{ELM}^{div} and modelling is in progress.

ELM Energy Losses accounting still under investigation



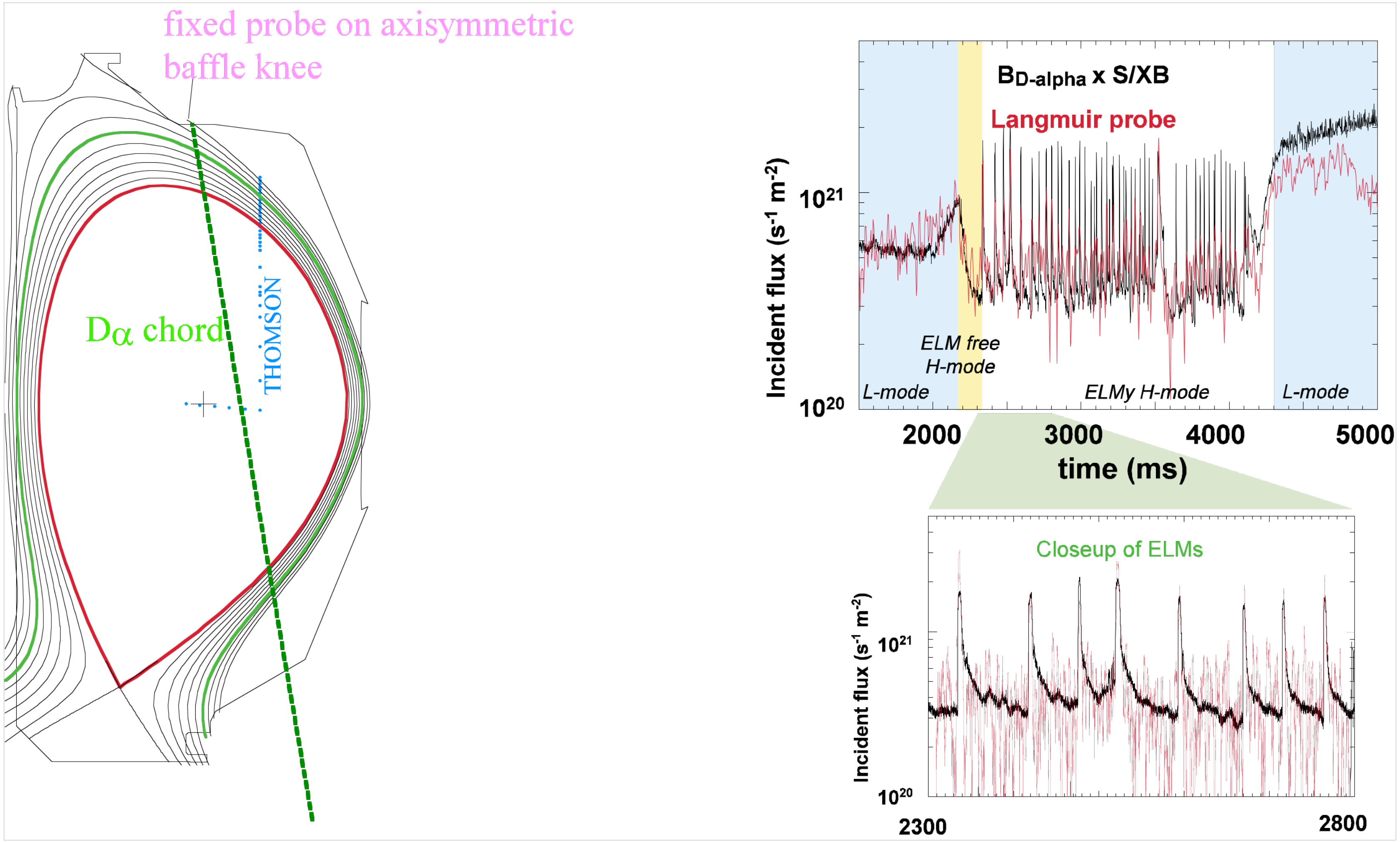


- JET & ASDEX results indicate

ΔW_{ELM}^{div} ~ 50 – 80 % of ΔW_{ELM}^{dia}

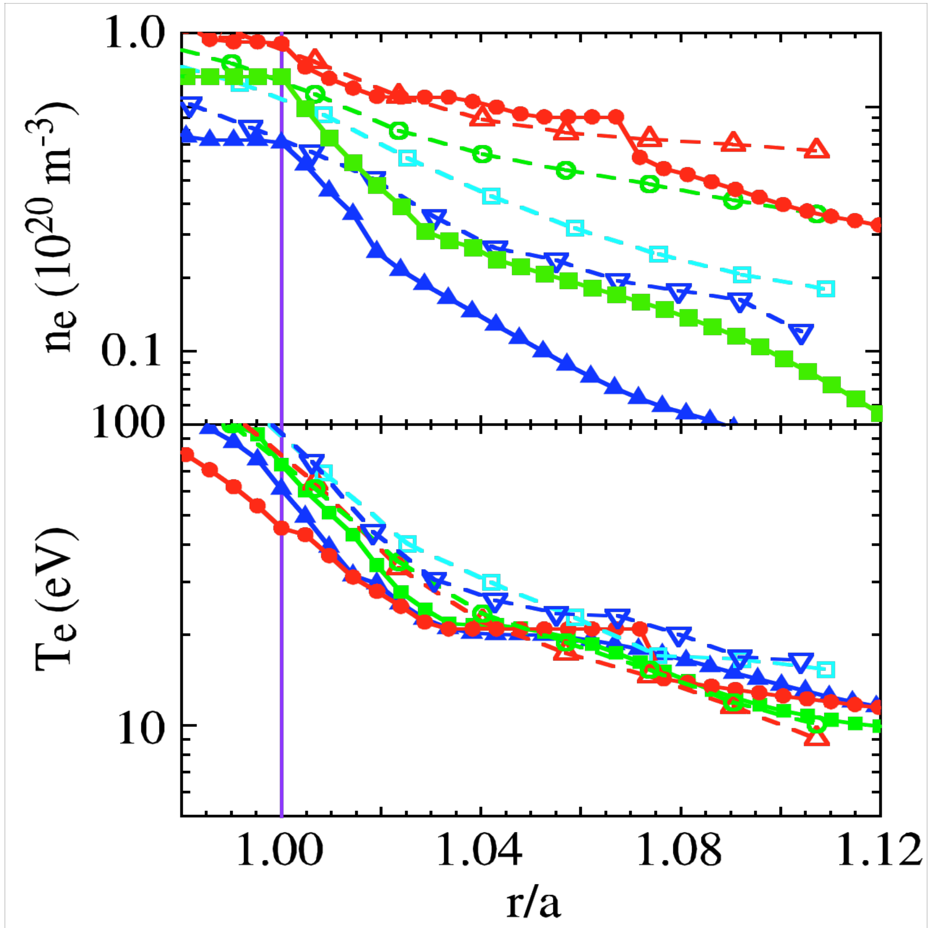
- Significant Density Rise seen at outer mid-plane Limiter within 500 μs @ ELM
- D+-e- Equilibration Time of $>$ 400 μs implies that significant Fraction of ΔW_{ELM}^{ion} may reach Main Chamber wall.
- This would help divertor ELM problem but raises concern for first-wall.
- We plan emphasis on diagnosis of ELM fluxes to wall.

Main chamber D and ion fluxes show strong ELM interaction with walls



DIII-D - Whyte

Dimensionlessly scaled SOL of DIII-D and C-Mod are surprisingly similar



- Scaled the data from DIII-D to C-Mod
  - $n_e a^2$, $T_e a^{1/2}$ held constant
  - Use normalized radius (r/a)

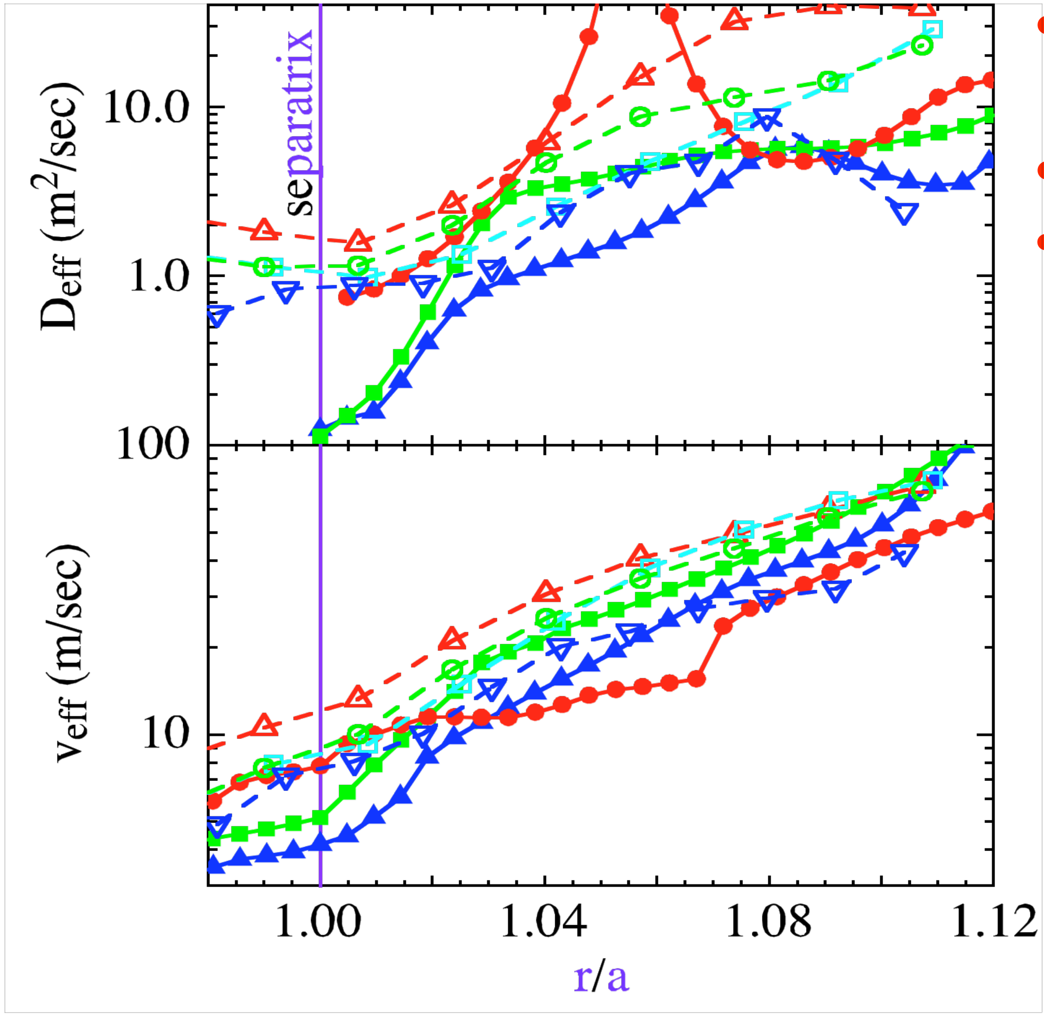
DIII-D	$\bar{n}_e$ (10^{19} m^{-3})	$\bar{n}_e/n_{Greenwald}$
- -▽- -	2.69	0.26
- -□- -	3.6	0.38
- -○- -	4.32	0.45
- -△- -	5.53	0.58

C-Mod	$\bar{n}_e$ (10^{19} m^{-3})	$\bar{n}_e/n_{Greenwald}$
—▲—	11.0	0.16
—■—	16.2	0.23
—●—	25.6	0.36

- Profiles are similar
  - Steeper profile ‘near’ separatrix
  - Flatter profile ‘far’ from separatrix
  - Profiles flatten w/increasing n_e
  - Density profile inflection point

C-Mod – B. Lipschultz
DIII-D - Whyte

The derived radial transport coefficients are very similar



- Same analysis technique applied to both experiments.
- $D_{eff} \equiv$ □/gradn, $v_{eff} \equiv$ □ /n
- Scaled the data from DIII-D to C-Mod
  - D_{eff} x $a^{+3/4}$, v_{eff} x $a^{-1/4}$ held constant
  - Use normalized radius (r/a)

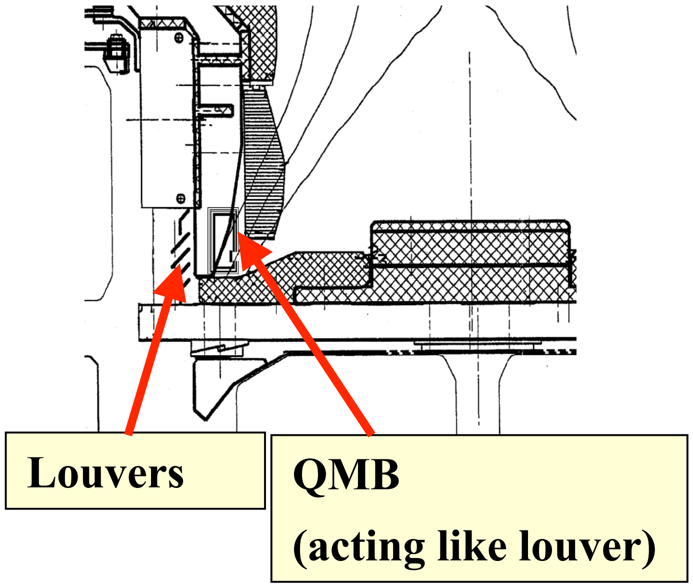
DIII-D	$\bar{n}_e/n_{Greenwald}$
–▽–	0.26
–□–	0.38
–○–	0.45
–△–	0.58

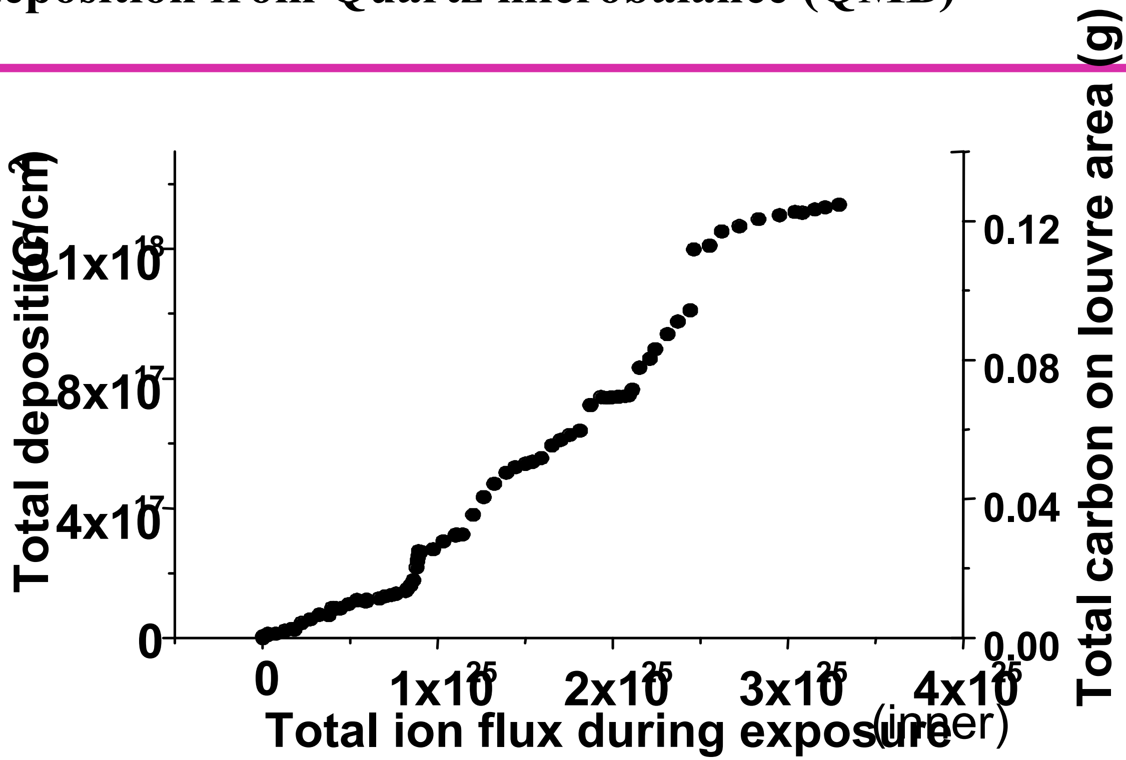
C-Mod	$\bar{n}_e/n_{Greenwald}$
–▲–	0.16
–■–	0.23
–●–	0.36

- Similar
  - Magnitude of transport
  - Radial variation
- Differences in the ‘near’ SOL
- Expanding such comparisons to JET, JT-60U AUG, and TCV.

C-Mod – B. Lipschultz
DIII-D - Whyte

New data on JET louver deposition from Quartz microbalance (QMB)





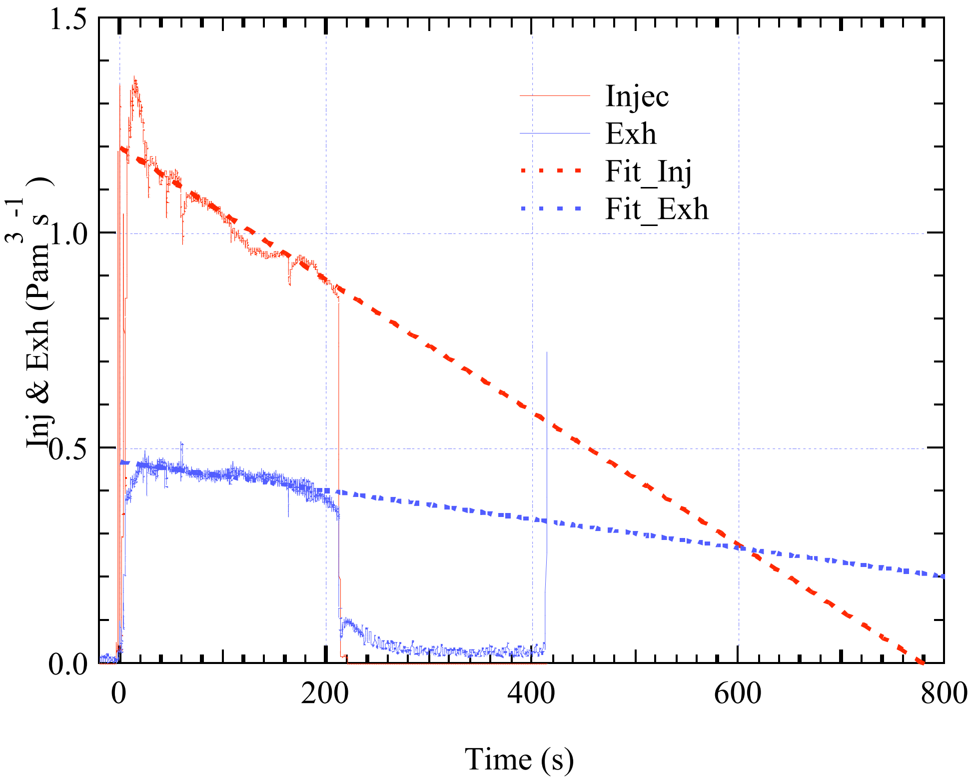
- **Analysis of 83 shots (C5-campaign), L& H-mode, various divertor geometries**
- **Louvre C flux/inner divertor ion flux ≈ 1.9 10^{-4} C/ion**
- **Estimate from previous DT1-tritium campaign ≈ 5 x 10^{-2} C/ion**
- **Modelling and further experiments planned to reduce uncertainty**

Extrapolations of tritium retention results to ITER

Extrapolation from experiments	D,T flux (#/s)	T-retention rate (T/ion)	ITER retention gT/s extrapolation (flux: $1.8\ 10^{24}$/sc)	shots /T-limit (400 sec)
TEXTOR	$5\ 10^{20}$/s	$6.4\ 10^{-4}$	0.0064	136
JET T experience	$1.2\ 10^{22}$/s (inner only)	$1.75\ 10^{-2}$ (only louver)	0.10g	9
JET GB on tiles	$2\ 10^{22}$/s	$2.7\ 10^{-3}$	0.024	36
JET C5 on louver from QMB	$1.9\ 10^{22}$/s	2.9 10-4	0.0026	340
Modelling				
ERO-code (2% CxHy er.)			0.006	145
WBC code			0.007	125

- All experimental results imply T retention too large for ITER graphite operation
- It is possible, but not likely, that the mixture of materials in ITER may help this.
- Our opinion is that amelioration/removal techniques must be emphasized
    - example – trap the T on cold surface, remove surface to remote location
- This has also forced us to review the choice of C divertor material for ITER

Long pulse: No saturation in wall retention so far



- Four minute shot on Tore Supra
- 60% wall retention
- At t~600s Wall retention --> 220 Pam^3 of D_2 (1.1 10^{23}D).
- Plasma content ~ 3.5 x 10^{20}D
- Important implications for density control and T inventory
- Could be due to codeposition of C and D.

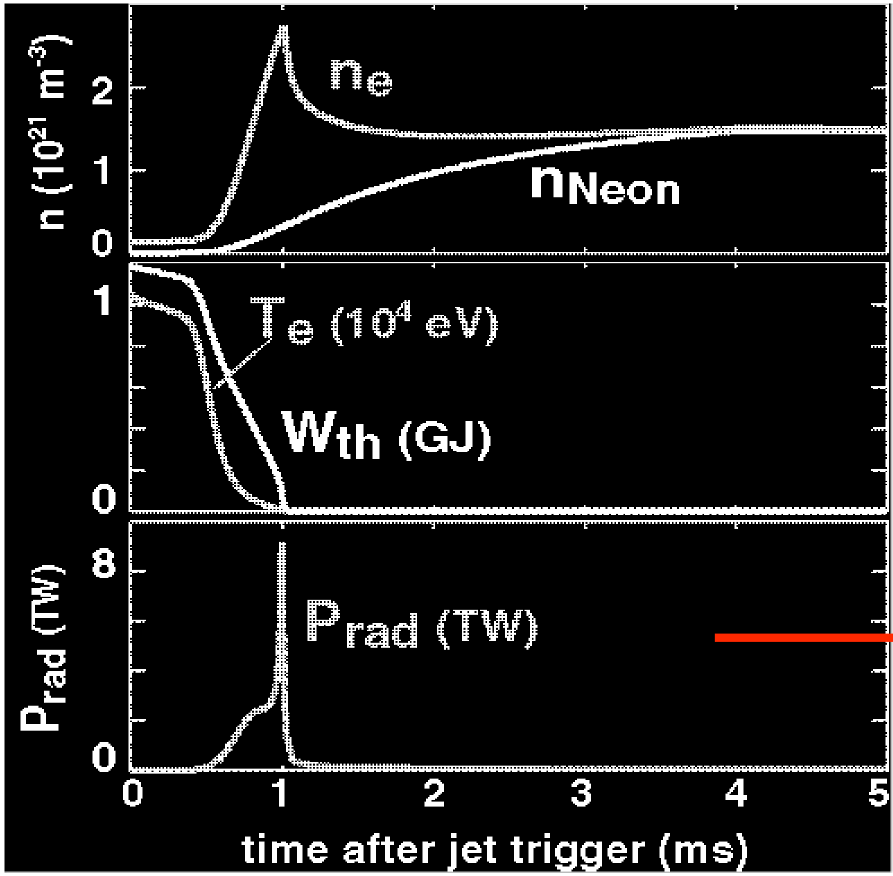
T. Loarer, Cadarache

Euratom cea

TORE SUPRA

KPRAD model used to extrapolate disruption mitigation results to ITER

Neon gas jet into example burning plasma device: ITER-EDA (R~8m)



- Neon gas jet into DIII-D disruption
  - Reduces heat loads, halo currents
  - Removes runaways
- KPRAD model matches key features

First wall heating:

ITER-EDA → 33 MJ $m^{-2}s^{-1/2}$

ITER-FEAT → 21 MJ $m^{-2}s^{-1/2}$

Melt/ablate limits:

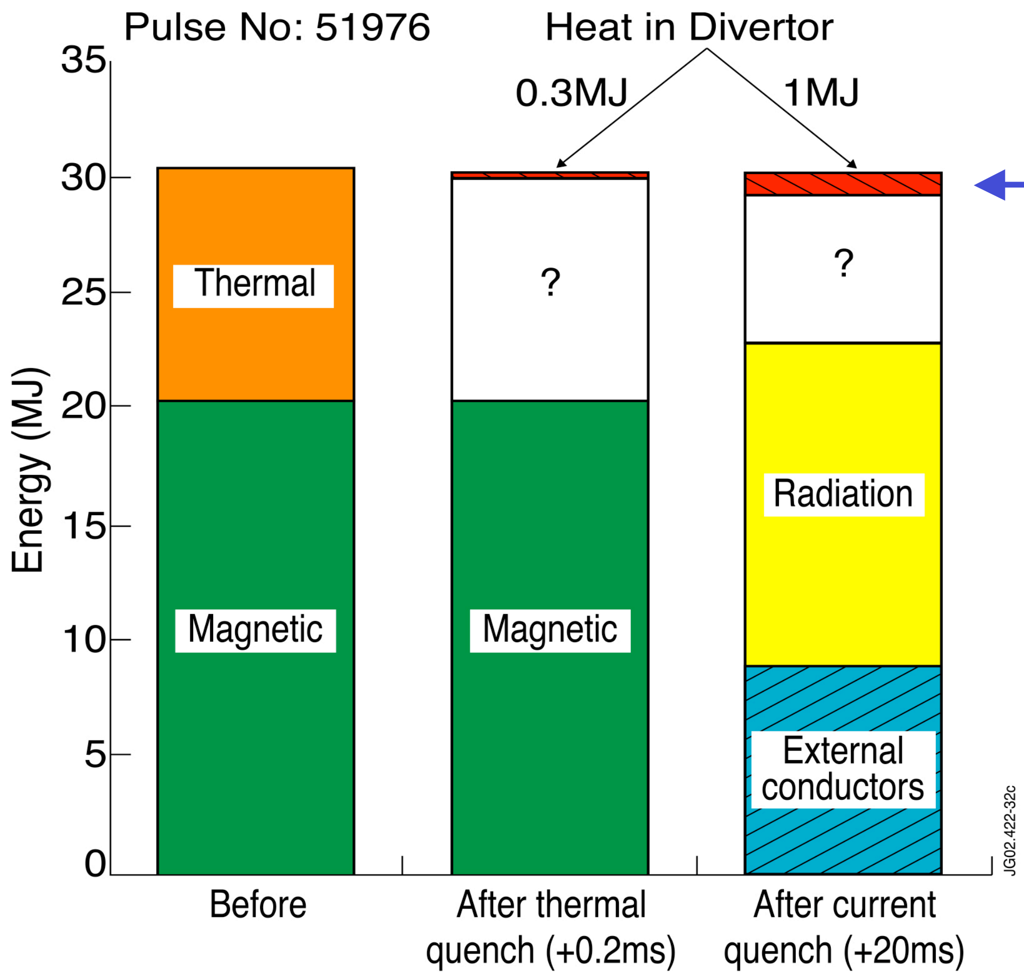
Beryllium ~ 25 MJ $m^{-2}s^{-1/2}$

Tungsten ~ 45 MJ $m^{-2}s^{-1/2}$

Carbon ~ 40 MJ $m^{-2}s^{-1/2}$

- Disruption mitigation very beneficial
- BUT, not good for Be wall
- →rethink Be choice for first wall (also because of ELMS).

Energy balance in JET disruptions



Only 3% of disruption energy is observed in the divertor!

A general result for JET (TC and IR data)

At odds with other tokamaks

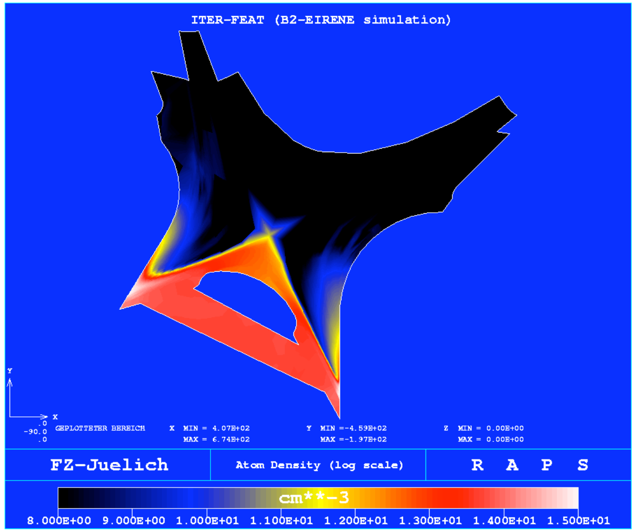
We need to understand where the power is going in JET!

More comparisons are needed

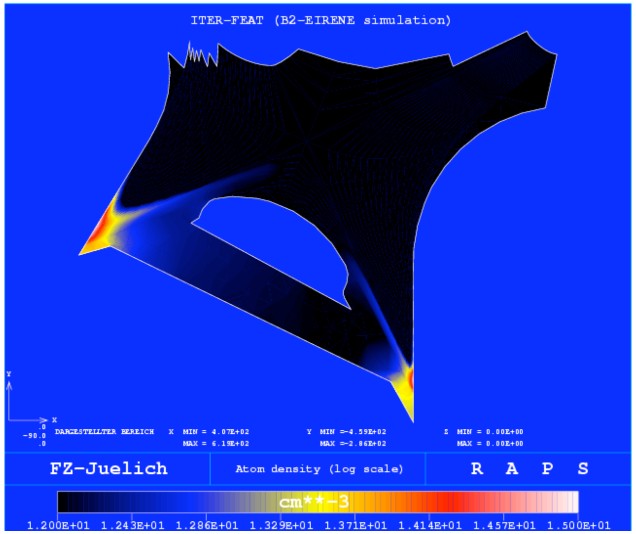
G. Matthews, JET

Inclusion of opacity effects important for prediction of ITER divertor operation

Optically thin



Consistent neutral particle
and radiation field



- Reduces ion source rate by factor of 5!
- This causes the plasma to reattach (no detachment).
- A number of effects still have to be included:
  - Zeeman-Splitting (in strong B-field, C-Mod, ITER)
  - Stark broadening (at high electron densities)
  - isotope effects in D-T mixture

D. Reiter, Julich

ITER physics basis update planning

- After long discussion we propose the following schedule
  - Dec 2002 title/section outline and responsible persons assigned.
  - July 2003 (next meeting) responsible persons present outlines of sections for discussion
  - July – November 2003, draft sections written, collected by cochairs, circulated
  - December 2003 (next meeting) review chapter and resolve issues
  - January-February 2004, draft divertor/SOL section to ITPA coordinating committee
- Our proposed topics
  - ELMs and their effect on wall/divertor structures
  - Disruptions and their effect on wall/divertor structures
  - SOL transport and effect on the core, impurities, heat loads and recycling
  - T retention and dependence on material, type of operation, and codeposition
  - Operational experience – steady state and High-Z issues and mitigation techniques
  - Progress in ITER modelling
  - Would not match original physics basis sections

Summary

- First-wall ELMs and disruptions
  - ELMs and disruptions appear to deposit particles and energy on first-wall
    - Better measurements of radial transport during ELMs and disruptions planned
    - Is Be the proper choice for first-wall?
  - New measurements of divertor ELM energy pulse indicate reduction in predictions for ITER
- T retention very variable but still too much
    - continue to reduce experimental uncertainties
    - amelioration/removal techniques must be emphasized
    - Use of C in BPX will be reviewed
- Initial dimensionless SOL comparisons fruitful
  - Similarities seen in transport description,
  - plans for more comparisons to be done

Comment and response by chair in CC meeting

- Proposal of joint meetings

  (1) With MHD group (in next year):

  Heat load to wall and divertor, and power accountability in disruption.

  (2) With pedestal (after summarizing more ELM scalar and profile database):

  Understand parallel and perpendicular transport ELM heat and particle in SOL.