EFDA
EUROPEAN FUSION DEVELOPMENT AGREEMENT
Task Force
INTEGRATED TOKAMAK MODELLING

Remote meeting, 27 April 2011

INTEGRATED SCENARIO MODELLING, Introduction meeting 27 April 2011

Presented by X LITAUDON & I VOITSEKHOVITCH

TF Leader : G. Falchetto
Deputies: R. Coelho, D. Coster

EFDA CSU Contact Person: D. Kalupin

Agenda

- **X. Litaudon & I. Voitsekhovitch, Introduction & report from ITPA-IOS meeting**
- **D. Hogeweij Modelling of ITER ramp-up**
- **J. Citrin modelling for hybrid scenario at JET & Asdex-U**

Remote meeting

Regular remote meeting on Wednesday morning 10h30-12h00 CET (09h30-11h00 GMT) :

- **Wed 11 May**
  - Status of benchmark exercise using the JET hybrid pulse #77922 (ETS, JETTO, CRONOS, ASTRA)
  - Preparation of next ITM code camp at Helsinki, 16-27 May
- **Wed 25 May**
- **Wed 8 June**
  - EPS rehearsals
- **Wed 22 June**
  - preparation of ISM working session July 4-8

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ISM Working session & related meeting [2/2]

- First ISM working session 07 March - 11 March
- ITPA- TC : 5-8 April
- ITPA-IOS : JET culham 11-15 April
- **EPS: 27 June - 01 July**
- **Second ISM 04-08 July FOM**
- **ITM general meeting 12-16 sept**
- **ITPA- TC : 5-7 October Cadarache**
- **13th international Workshop on H-mode Physics & Transport Barriers: 10-12 October**
- **Third ISM, Culham**
  - **7-11 Nov (before JET General Planning meeting) ?**
  - **or 21-25 Nov ?**

2011 -Participation to conferences, Workshop , ITPA

- **ITPA-TC April**
  - Current ramp-up modelling Irina Voitsekhovitch
- **ITPA – IOS April**
  - DIII-D modelling Irina Voitsekhovitch
  - J. Garcia Hybrid modelling
  - X. Litaudon ISM activities
- **EPS: Strasbourg du 27 june to 1 july 2011 : http://www-fusion-magnetique.cea.fr/eps2011/index.html**
  - Invited talk: integrated modelling G. Giruzzi
  - Determination of the requirements for the sustainment of hybrid scenarios on JET : J. Garcia et al
  - JET / ASDEX hybrid transport modelling: J. Citrin
  - ITER Hybrid current ramp up: D. Hogeweij
  - JET ramp-down modelling: P. Belo
- **EFTC & APS**
  - Core/Edge ITER modelling (baseline) S. Wiesen

EU mobility for ISM activities

- **J. Garcia: April 14-21 2011 & J. Ferreira: April 14-21 2011 at JET/culham to work with I. Voitsekhovitch (CCFE) for ASTRA & TRANSP and JM Park (ORNL) for ONETWO**
- **Modelling of JET and DIII-D current ramp-up including plasma rotation using GLF23**
  - **Use of ITPA TC database**
  - **Benchmark GL23 model for rotation using ASTRA, CRONOS, ETS & JETTO and ONETWO & TRANSP**

- **In future, exercice to be extended to JET - DIII-D similarity experiments on Hybrid regimes**

JT-60SA EU physics activities

- **EFDA activity within the ITER physics department (D. Borba as head of department)**
- **Coordination physics activity: G. Giruzzi (letter of F. Romanelli to HRU 20 April) in liaison with P. Barabaschi (F4E)**
- **2011 activity : revision of the research plan for JT-60SA by nov. 2011**
- **dedicated meeting 23-24 May 2011 at Frascati**
- **May 13 : express interest indicating which chapter on which you plan to contribute**
- **WP-2011: ISM is involved in the scenario modelling : Define operational space : 0-D senario modelling**

Chapter of JT-60SA reseach plan

- **Ch.1 Research Strategy of JT-60SA**
- **Ch.2 Theoretical models and simulation codes**
- **Ch.3 Operation Regime Development**
- **Ch.4 MHD Stability and Control**
- **Ch.5 Transport and Confinement**
- **Ch.6 High Energy Particle Behavior**
- **Ch.7 Pedestal and Edge Characteristics**
- **Ch.8 Divertor, SOL and PMI**
- **Ch.9 Fusion Engineering**
- **App. A: Heating and Current Drive Systems**
- **App. D: Plasma Diagnostics Systems**

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JET / JT-60U modelling

- **At last ITPA-IOS meeting, we have agreed with Ide on a collaboration agreement on "Comparison and modeling of JT-60U and JET plasmas in typical operational domains"**
  - **Establish plasma modeling Standard H-mode, Advanced Inductive and Steady State**
  - **select typical discharges in each domains among the JT-60U and JET discharges, compare the plasma performance and characteristics and benchmark with codes and models developed in Japan & EU.**

- **List of EU Participants to be finalised : G. Giruzzi, V. Parail, J. Garcia, M. Schneider, X. Litaudon etc**

ITPA-IOS report on modelling

- SWIM Integrated Plasma Simulator on ITER D. Batchelor
- Status of ITER Scenario Modeling group in EU X. Litaudon
- Predictive modeling of ITER scenarios in EU, requested by ITER IO V. Parail
- ITER scenario modeling by PTRANSP R. Budny
- Update of Steady-State scenario modeling C. Kessel
- Hybrid scenarios on JET and extrapolation to ITER J. Garcia
- Modelling of DIII-D current ramp up discharges and JET I.Voitsekhovitch
- ITER EC top launcher study M. Murakami
- Pedestal and core confinement in JET hybrid plasmas and comparison with EPED1 pedestal model M. Beurskens
- + discussion/definition on IOS-Joint modelling activities
- **NEXT MEETING: Kyoto University, Kyoto, 18 – 21, October, 2011**

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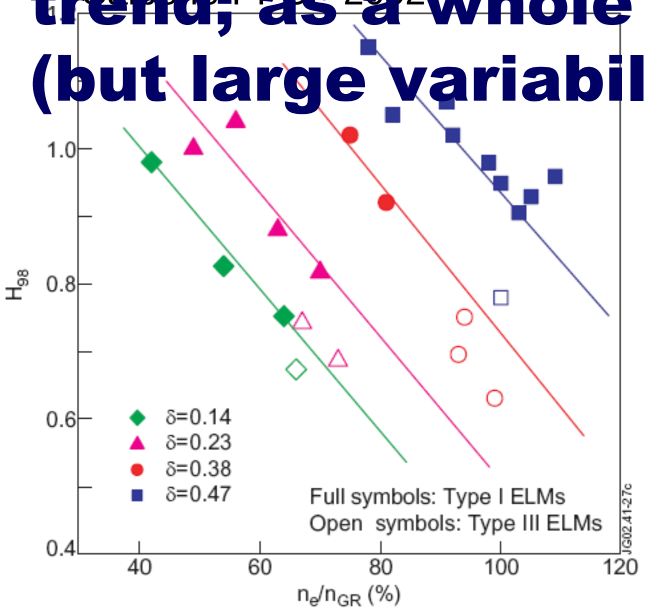
On-going discussions

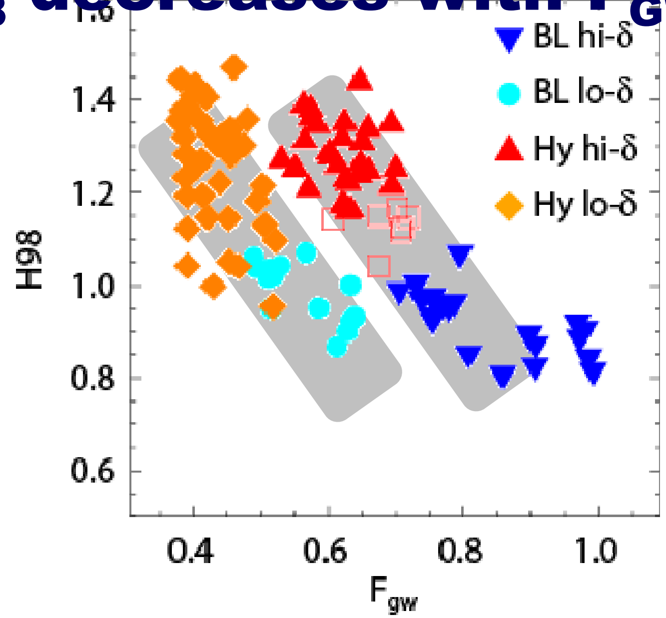
- **q-profile evolution in hybrid regimes : Neo-classical diffusion ?**
- **density peaking in hybrid regimes**
  - New ITER steady-state and hybrid with density peaking (EU- F4-E grant)
  - Issues related to the density modelling , peak density with GLF23 ?
- **EPED1 pedestal model validation on JET database**
- **ECCD optimisation for ITER**
  - Upgrade of upper ECH launcher (USM20) for current profile control was considered. Increase toroidal angle from 20-deg to 26-(or 30-) degree results in :
  - ncreasing CD by ~50% (calculated with CQL3D/TORAY)
  - filling in the previous gap between on axial CD (ELs and off-axis NBI) and the upper launchers
  - 9-MA SS scenarios with the ECH upgrade was examined using GLF23 Masanori Murakami

Plasma Density dependence of confinement

- **Low d plasmas operate at lower density than high d plasmas at a given H_{98}**
- **In baseline plasmas: confinement degrades with F_{GW} [SaibenePPCF-2002]**
- **New database is consistent with such a trend; as a whole H_{98} decreases with F_{GW}, (but large variability)**

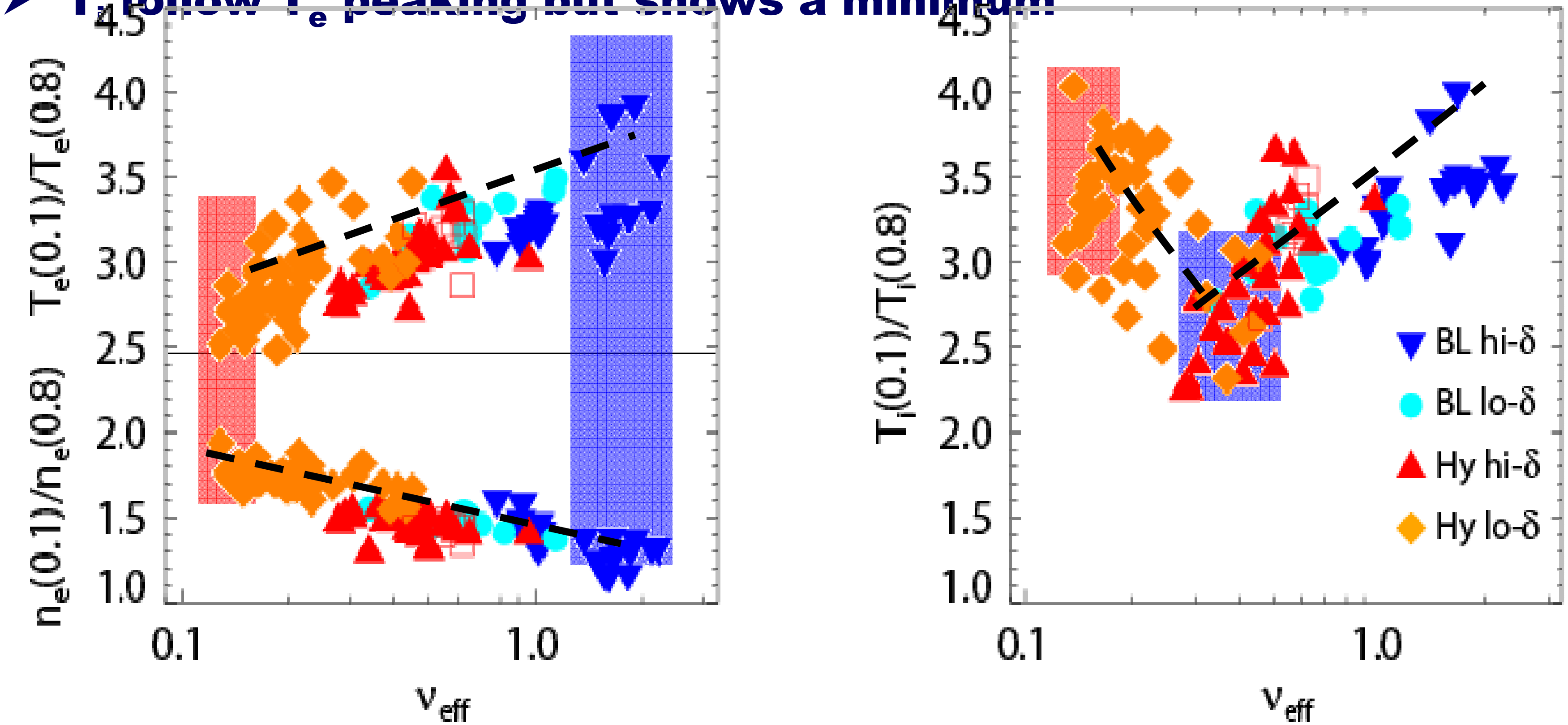
Saibene-PPCF-2002



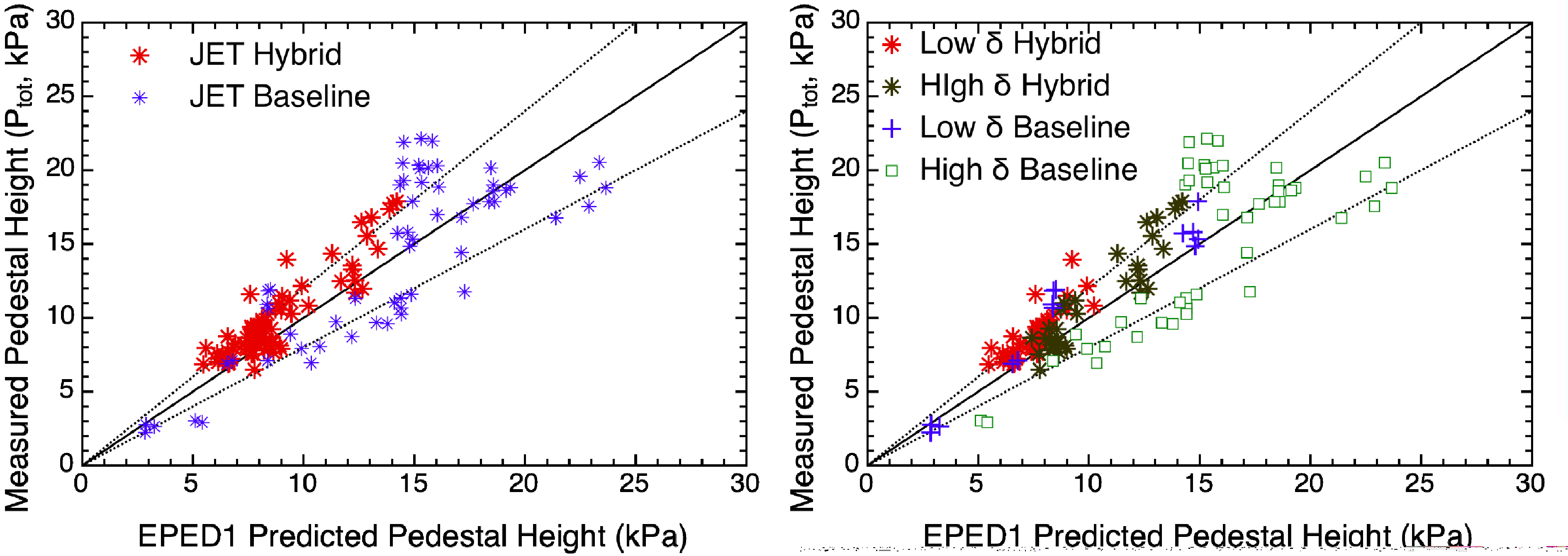


What do the profiles look like?

- **n_e peaking varies with n_{eff} as found in [Maslov,Weisen,Angioni]**
- **Now found that T_e peaking compensates this**
- **Pressure peaking no strong trend with n_{eff}**
- **T_i follow T_e peaking but shows a minimum**



Comparison of Hybrid vs Baseline Discharges: Comparison with EPED1 pedestal model



- **Pedestal model EPED1 produces predictions for BL and hybrid plasmas that are in agreement with experimental data within both the model and measurement uncertainties of ~15% each.**

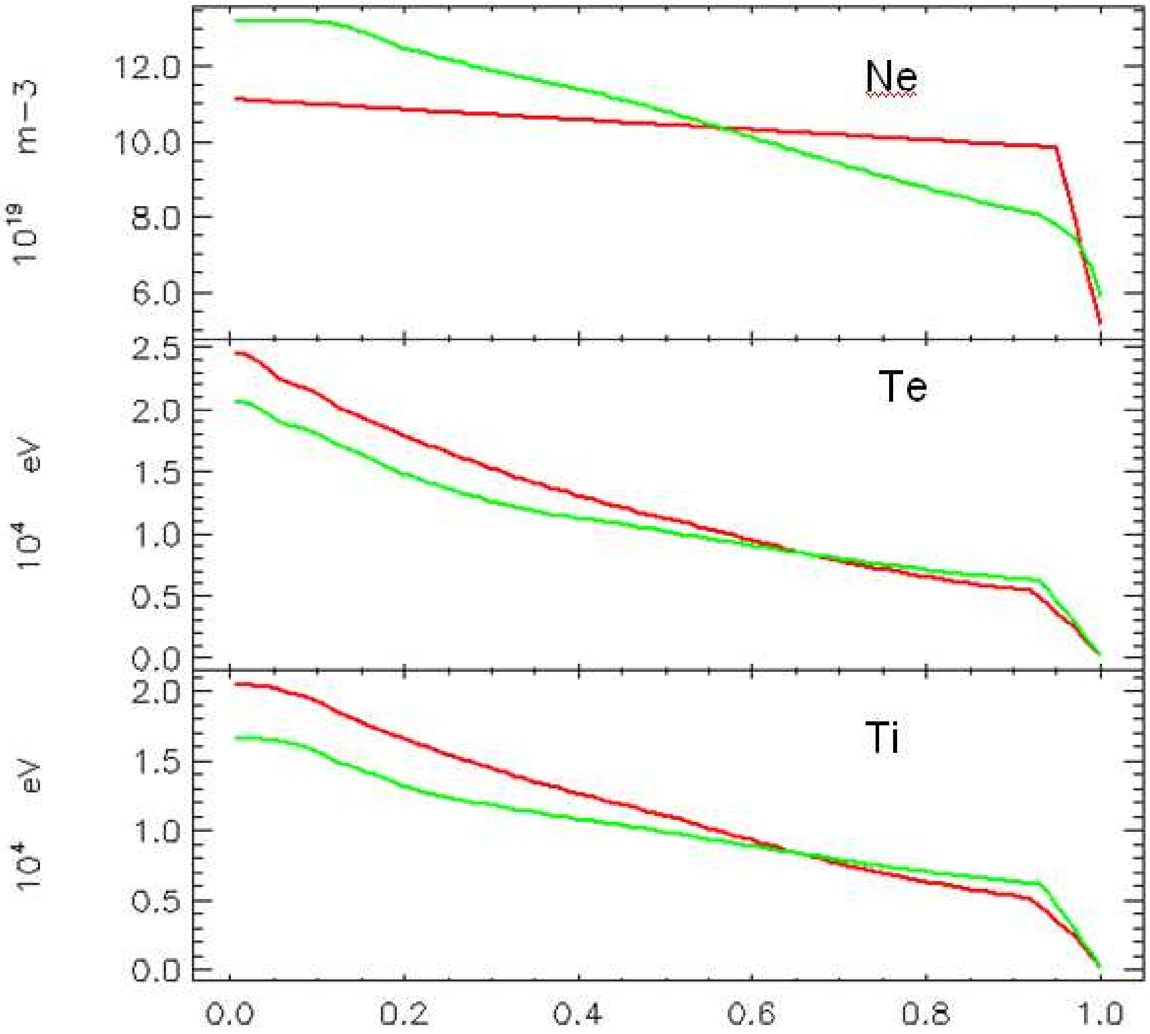
Phil Snyder TTF 2011

ITER-baseline modelling

Main findings- flat top (4)

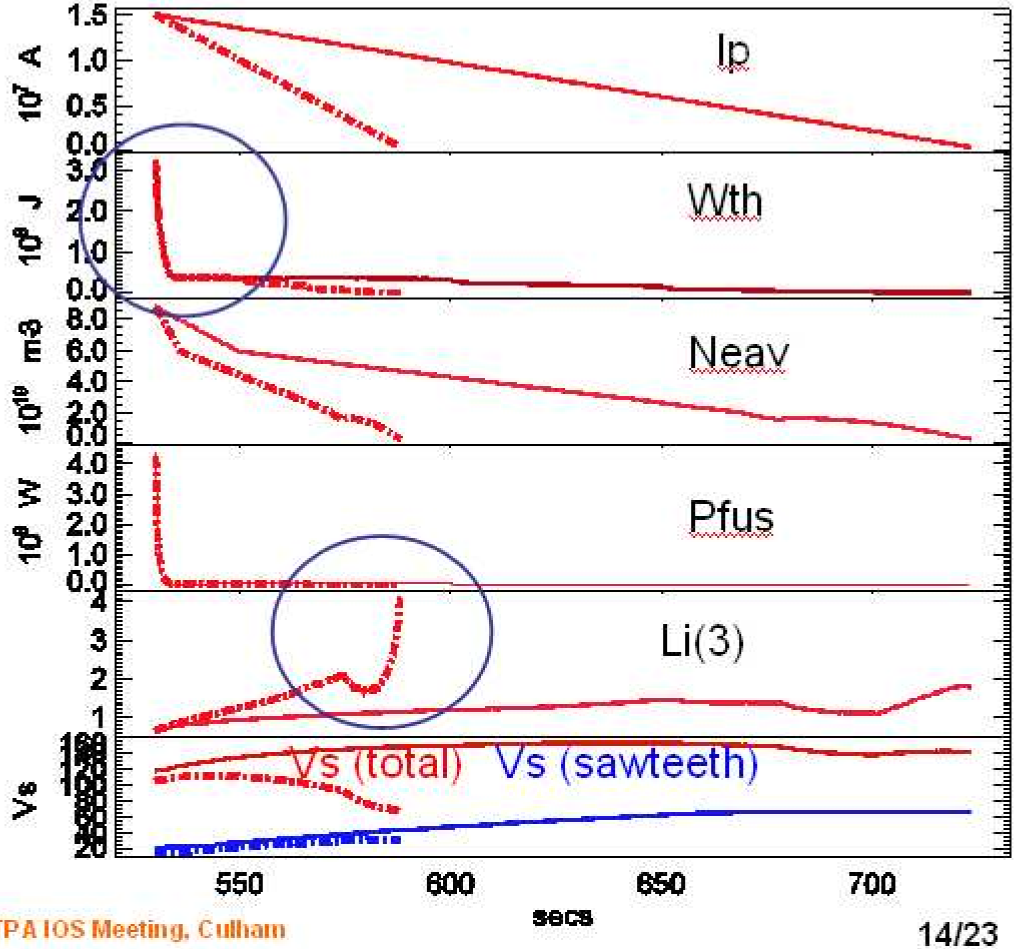
Comparison between cases with prescribed, flat density (red) and simulated density (green)

Note: plasma performance is almost identical in two cases



Main findings- ramp down (1)

Note two critical issues: 1)very fast loss of plasma energy after H-L transition and 2) strong increase in Li(3) at the later stage of ramp down



CCFE V. Parail et al, ITPA IOS Meeting, Culham 14/23 12 Apr 2011

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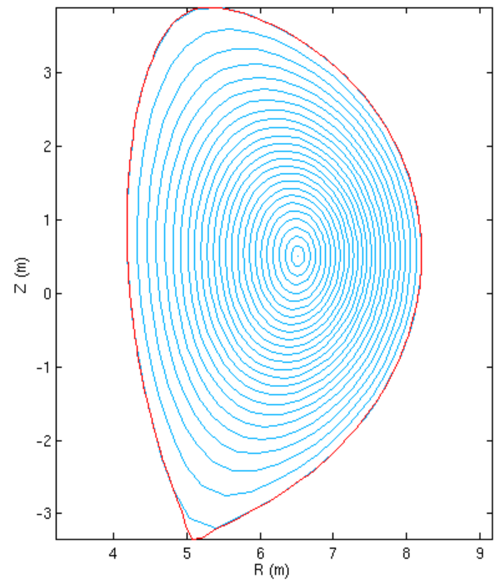
Joint modelling on Predictive modelling of current ramp down in ITER and present day tokamaks V. Parail

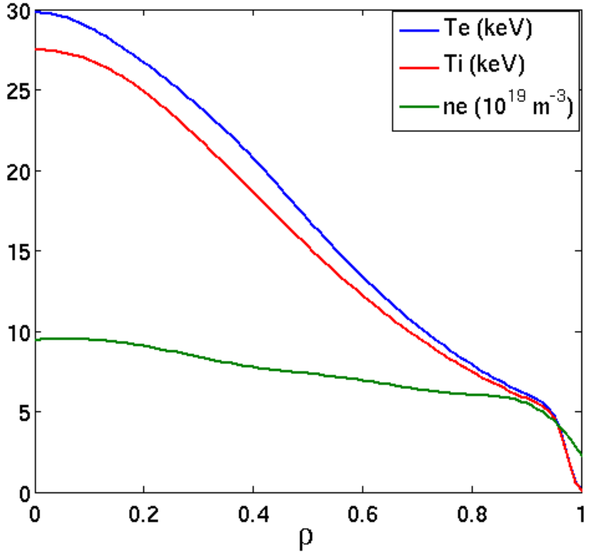
- **Short-term plan (for 2011)**
  - Select two ITER scenarios of current ramp down (reference and "the most dangerous") in consultation with ITER IO and agree on the way to proceed with the modelling (May-June 2011);
  - Exchange preliminary results (September 2011);
  - Summarise results and present it on the next IOS meeting (October 2011).
- **ISM participation**
  - Vassili Parail, Paula Belo, others ?

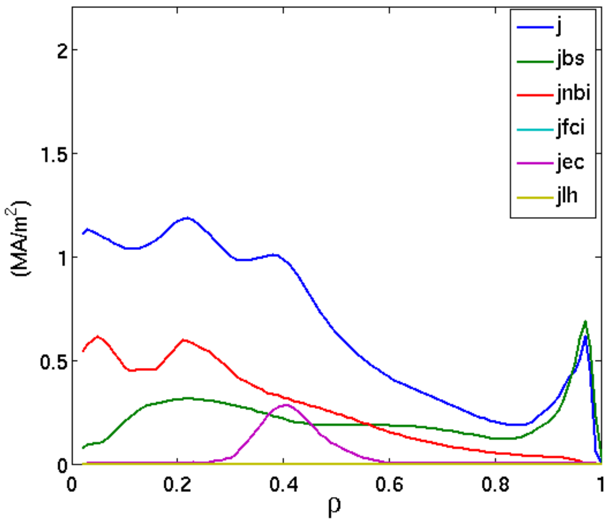
Simulations of ITER hybrid scenario with the same scheme as in JET

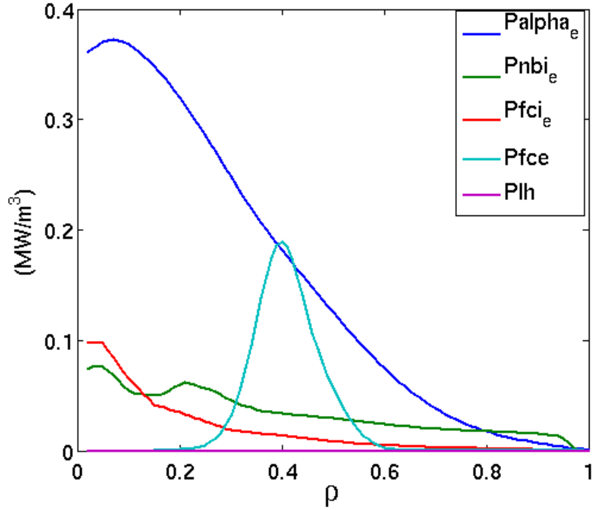
- **I_p = 11 MA**, B_T = 5.3 T
- **dI_p /dt= 0.18 MA/s**, B_T = 5.3 T, f_G=0.4 during ramp-up. f_G=0.85 flat-top phase
- **EC wave launch**: top launchers, 8MW during ramp-up, 20MW flat-top
- **ICRH:** 20 MW, **NBI:** 33MW (off-axis and on-axis)
- n_e profile fixed, picked profile, $n_e(0) \approx 0.95\ 10^{20}\ m^{-3}$
- $r_{ped} \approx 0.95$, $n_{ped} \approx 0.55\ 10^{20}\ m^{-3}$, **$T_{ped}$ □ 4.5 keV**
- **Bohm-GyroBohm transport model during ramp-up**
- **H_{98}=1.3 with Bohm-GyroBohm shape for flat-top phase**

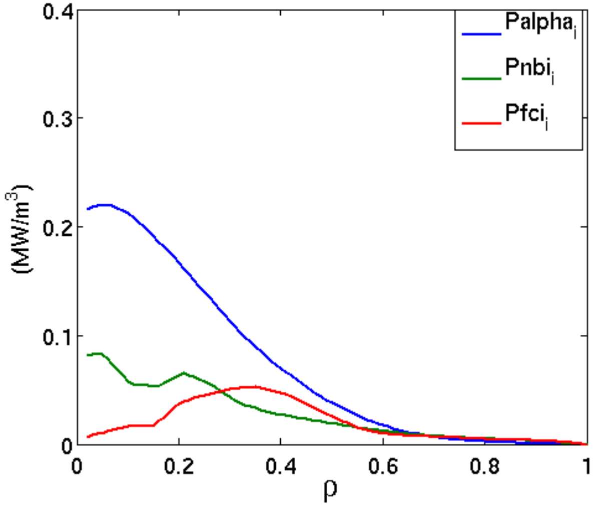


ITER simulations with the same current scheme



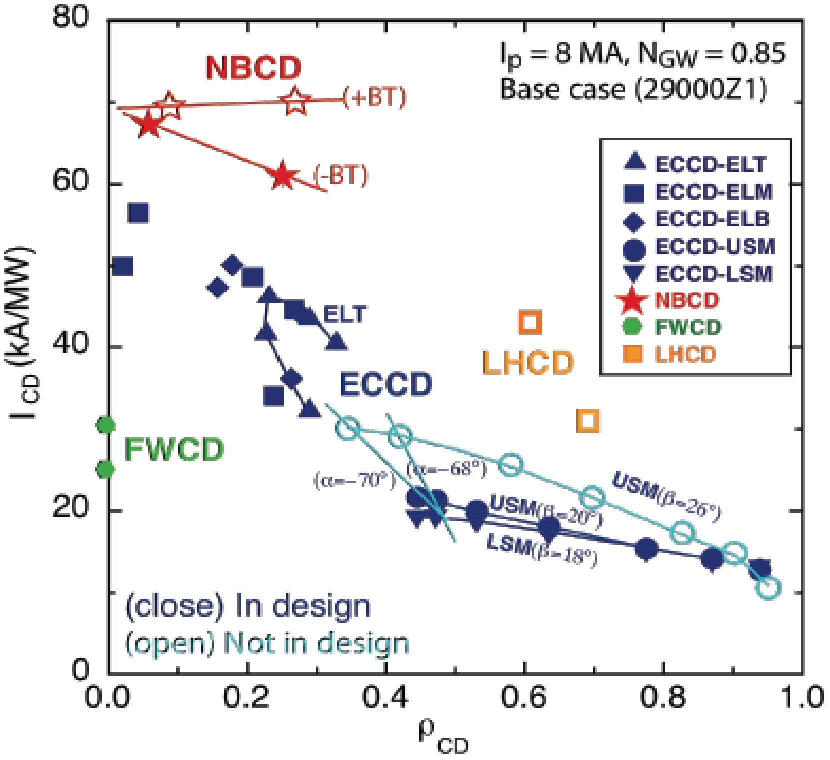






- The current configuration is nearly the same one used for JET.
- Peaked density profile, checked with GLF23
- The on-axis NBI power helps to peak the pressure profile
- The ICRH power is on-axis for the electrons and off-axis for the ions
- **β_N=2.7, β_p=1.6, Q=7**

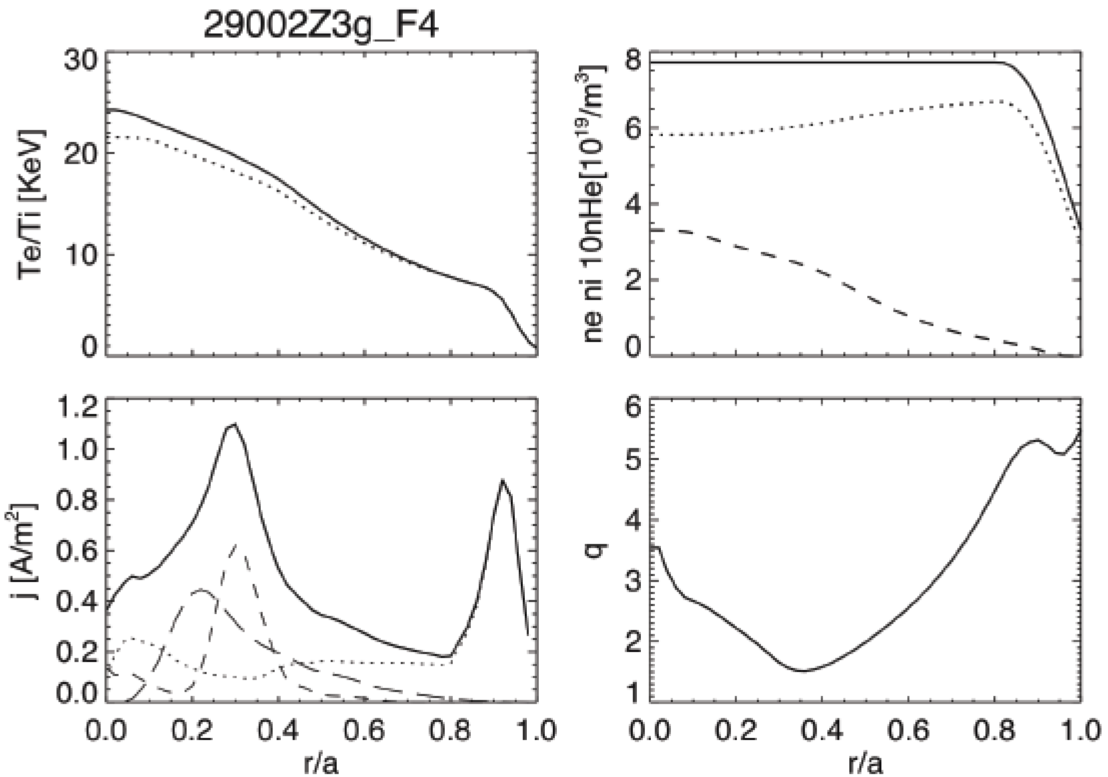
Increase in toroidal angle in USM increases the CD and fills in the CD gap around ρ = 0.35



- **The previous UL design was optimized only for NTM feedback which requires narrow CD**
  - **Hopefully LSM18 system is sufficient for it**
- **Current profile control for SS operation needs**
  - **Broader CD profile preferred**
  - **High efficiency**

M. Murakami

Optimization of 9-MA SS scenarios using the ECCD upgrade is in progress, approaching close to the goal of Q=5 and f_{NI}=100%



NBI: 33 MW off-axis(1)
On-axis(3/4)
ECH: ELT(20MW)+USM26 (17MW)
ICH: 3MW
Q=5.65
fNI = 97%
fBS = 61%
fNB = 21%
fEC = 14%
fFW = 1%
H98 = 1.46
NGW = 0.90

In this case somewhat larger negative central sheer is created by spreading two NBIs overlapping with ECCD

4/13/11

M. Murakami

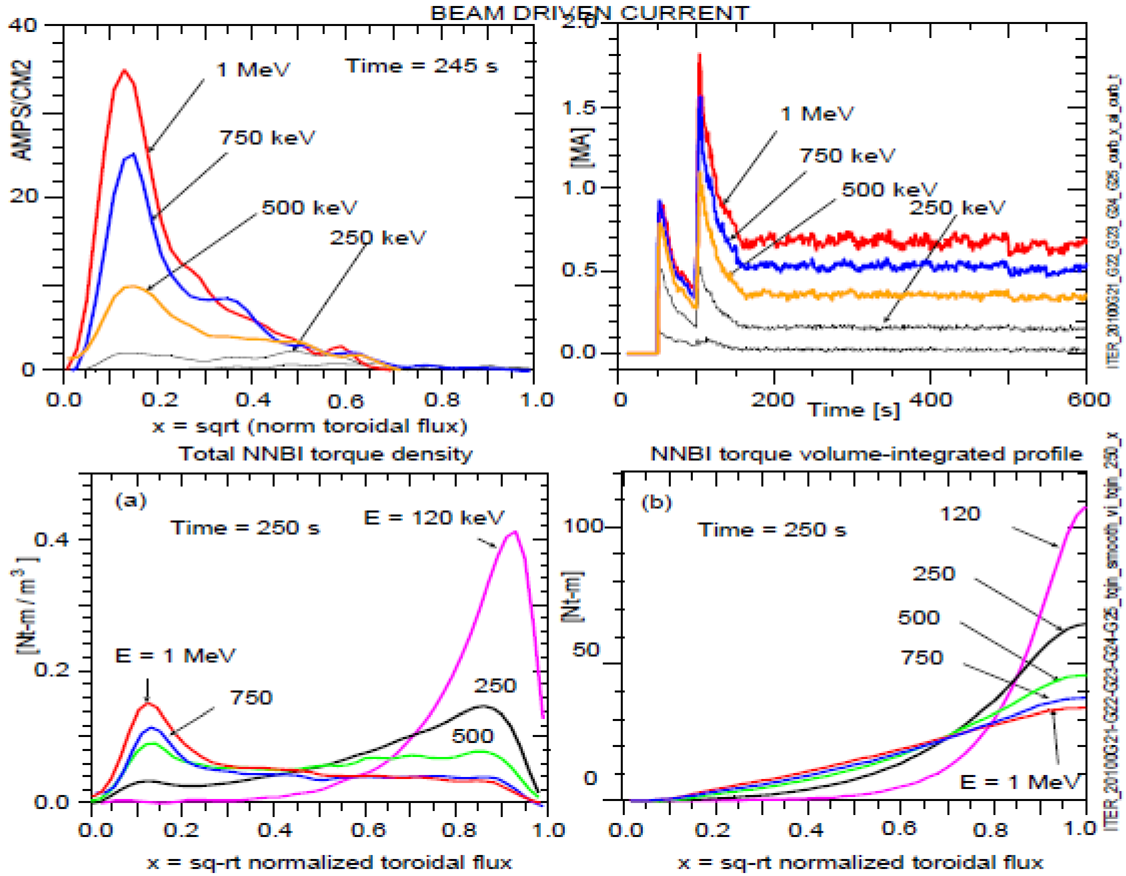
PTRANSP simulations for ITER

R.V. Budny, ITPA-IOS, Culham, April 12, 2011

- Meanings of PTRANSP:
  - PTRANSP = TRANSP (same distribution; P signifies extensive upgrades for predictions)
  - PTRANSP = manually iterating between TRANSP + TSC
- Papers with PTRANSP simulations for ITER:
  - Kessel NF <47> (2007) 1274 - Hybrid and steady state
  - Budny NF <48> (2008) 075005 - H-mode with GLF23
  - Halpern PP <15> (2008) 062505 - H-mode
  - Budny NF <49> (2009) 085008 - comparison of heating schemes
  - Budny PP <17> (2010) 042506 - current control in SS
  - Budny (submitted) - alpha heating in L-mode and H-mode
  - Kritz draft in prep - Hybrid and SS

More examples of results for lowering NNBI voltage

- Keep P_{NNBI}=33MW



- NBCD decreases, total torque increases with decreasing E_{NNBI}

Using the SWIM Integrated Plasma Simulator for ITER Simulations (and other things)

ITPA – IOS meeting
Culham, England
April, 2011

D. B. Batchelor, L. A. Berry, E. F. Jaeger, D. A. Spong – *ORNL Fusion Energy*

D. E. Bernholdt, E. D'Azevedo, W. Elwasif, S. Foley (NCCS) – *ORNL Computer Science*

S. C. Jardin, E. Feibush, D. McCune, J. Chen, L. P Ku, M. Chance, J. Breslau – *PPPL*

G. Abla, M. Choi, D. P. Schissel – *General Atomics*, R. W. Harvey – *CompX*

R. Bramley– *Indiana University*, D. Keyes – *Columbia University*, D. Schnack – *U. Wisconsin*

P. T. Bonoli, J. Ramos, J.Wright – *MIT*, S. Kruger, T. Jenkins – *TechX*, G. Bateman – *Lehigh University*

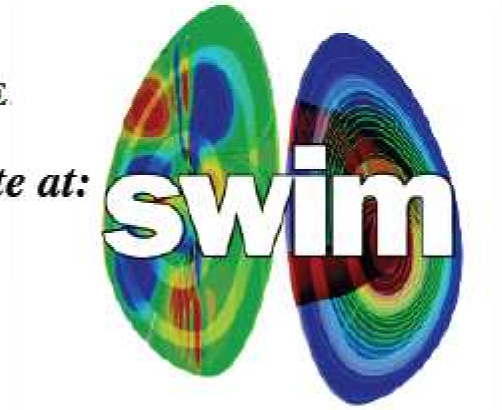
Unfunded participants:

L. Sugiyama – *MIT*, J. D. Callen, C. C. Hegna, C. Sovinec – *University of Wisconsin*, E.

H. St. John – *General Atomics*, A. Kritz – *Lehigh Univ*.

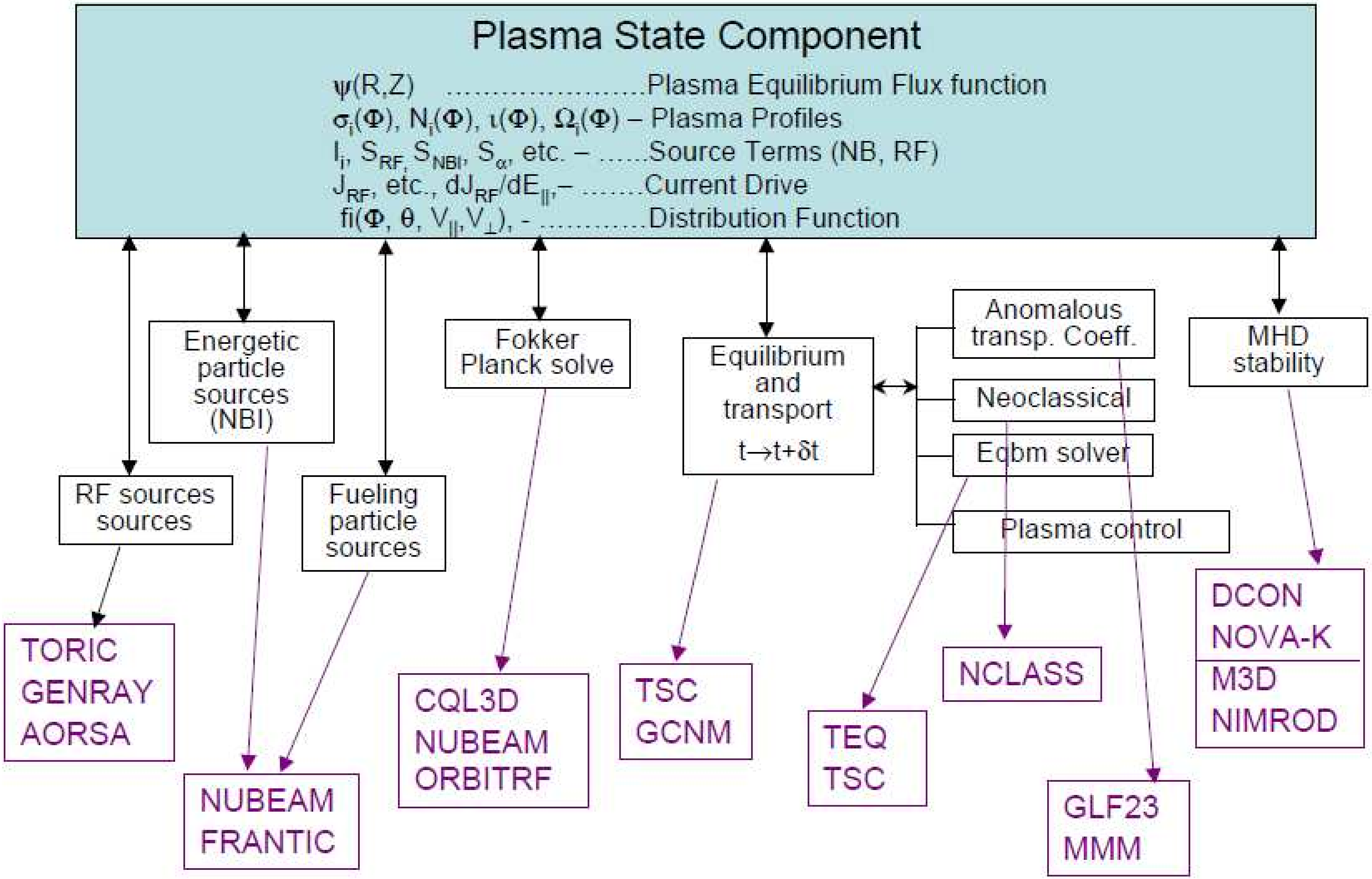
See our fun website at:

www.cswim.org



SciDAC
Scientific Discovery through Advanced Computing

Integrated Plasma Simulator design – Component are implemented by mature, well-validated codes



Summary of ITER simulations with IPS

Simulations at very high resolutions to show capability of massive parallelism

- TSC +AORSA + NUBEAM (1,000,000 particles/species)
- TSC + TORIC (255 poloidal modes) + NUBEAM (1,000,000 particles/species)
- *running times ~ 30 hr on 1600 cores*

Simulations at resolutions more typical of present practice for comparison

- ITER hybrid scenario
- TSC (1 core), TORIC (31 poloidal modes, 4 cores), NUBEAM (5,000 particles/species, 16 cores)
- Typically ramp-up from 1.5 sec into flattop 550 sec

- TSC alone – using TSC internal (analytic) models for NBI and ICRF
  - *No parallelism, 1 core, running time ~ 11 hr*
- TORIC + NUBEAM + TSC – sequential execution of parallel components
  - *One level of parallelism, 16 cores, running time ~ 28 hr*
- TORIC + NUBEAM + TSC – concurrent execution of parallel components
  - *Two levels of parallelism, 24 cores, running time ~ 12 hr*
- Parameter study – pedestal location, pedestal height (chi pedestal)
  - Nine concurrent simulations run simultaneously
  - *Three levels of parallelism, 128 cores, running time ~ 16 hr*