Report on IOS JA-9: Optimisation of Operational Space (OS) for Long-pulse Scenarios

= Contributors (Potential contributors):

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= Contact Person:

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= Relation to the ITER Physics Operation Workprogram:

DT baseline long-pulse scenarios Δt_{FT} > 1000 s, P_{fus} > 250 MW, Q > 5

= Basic goal:

To find the OS and optimal parameters (I_p, n, etc.) for long pulse operation and TBM program (There is no systematic scan on I_p, n yet)

= Scope of the task (general):

Assessment of operational space (OS) for long-pulse scenarios by 1.5D modelling

- **fixed boundary equilibrium at current flat-top is sufficient,**
- **ICCD is not necessary (?) (the least efficient, mainly reduces Q [Murakami et al])**
- **q_{min}> 1 is not required (EC can be redirected from EL to UL to q=1.5, 2 at ST ?)**

Phase I (mid-term)

Assessment of the OS with validated models by plasma current and density scan,

I_p = 8 - 15 MA, n = $n_{NBI,shine}$ - n_G; ($n_{NBI,shine}$ ~ 3 $10^{19} m^{-3}$)

Choice of optimal parameters comfortably far from the operational boundaries

β_N < 4 l_{i3}, n < n_G, P_{SOL} < 120 MW, P_{SOL} > 1 (~ 1.5?)

Phase II (long term)

Sensitivity studies for modelling assumptions (pedestal, Z_{eff}, n(0)/<n>, etc)

Plan for 2011(see Appendix for motivation)

A) **Density scan n = $n_{NBI,shine}$ - n_G for each of the models: for I_p =15 MA with basic set of CD: 16.5 MW on- + 16.5 MW off-axis NBCD+ 20 MW of the outermost EL ECCD keeping the same assumptions (pedestal, etc) as for inductive baseline scenario with P_{fus}= 500 MW**

B) **Gathering of available modelling data I_p, n (for data list see attached Exel file) If assumptions are different from the reference case, I_p=15 MA then comment what and why is modified**

= Scope of the task (2011):

A. For those who plan new modelling for long-pulse:

(0) Start from ITER inductive base line scenario I_p=15 MA, P_{fus} =500 MW, Q = 10, Δt_{FT} =400 s with your model (CDBM, MMM, GLF23, BgB, etc) with 16.5 MW innermost + 16.5 MW outermost NBI + 20 MW outermost ECCD (EL)):

(1) Keep the same input and assumptions you used to simulate 500 MW baseline scenario:
I_p=15 MA, P_{aux} = 50 MW (53 MW?), geometry, pedestal, etc;

(2) Scan (reduce) density (lower limit n > $n_{NBI,shine}$ ~ 3 10^{19}m^{-3})

- **keeping pedestal parameters, nT_e~35 keV*10^{19}m^{-3} , Δ_{ped}/ρ_a ~0.04)**
- **keeping boundary conditions, $n_{e,edge}$ = 3 10^{19}m^{-3}, T_{edge} ~ 0.2 keV at the level of saturation predicted by SOLPS with P_{SOL} ~ 100 MW**

(3) For each point of the scan provide the output listed in attached EXEL file (just fill it?)

Expected results:

- P_{fus} and Q will drop but pulse length will increase due to increase of the CD efficiency (~T/n) and increase of current conductivity (1/Res~ $T^{3/2}$). P_{FUS} = 250 MW and Q =5 are still acceptable for hybrid long pulse operation.

= Scope of the task (2011):

B. For those who already have data for long-pulse:

- **Please just fill the attached EXEL file (including the following comments below)**

- **Specify the model used for core transport, (T_i,T_e,n_{He},n_e, impurities…?) and pedestal**

- **Describe plasma configuration if different from full bore baseline case:**
  BxR = 5.3x6.2 Tm; a/R=2/6.2 m, k_a=1.76 ($k_a = S/\pi a^2$), triangularity ~ 0.5,

- **Describe of the set and configuration of the H&CD (power and location) if different from proposed in (A):**

- **If assumptions are different from the reference case, I_p=15 MA then comment what and why is modified**

= Present status:

Data provided by October 20, 2011

- **F. Koechl (BgB, GLF23 with JINTRAC, new modelling: I_p = 15 MA density scan)**
- **A. Polevoi (Scaling Based with ASTRA, new modelling: I_p = 15 MA density scan)**
- **N. Hayashi (CDBM with TOPICS, new modelling: I_p = 15 MA density scan)**
- **V. Leonov (Scaling Based with ASTRA, new modelling: I_p = 15 MA density scan)**
- **A. Pankin (MMM71, Weiland with ASTRA, new modelling: I_p = 15 MA density scan)**
- **J. M. Park (GLF23 with FASTRAN, new modelling: I_p = 15 MA 33 NBI + 20 IC)**
- **M. Murakami (GLF23, CDBM with FASTRAN, new modelling: I_p = 15 MA, Sensitivity studies to ST model, heating mix, EC location)**
- **J. Citrin (GLF23 with CRONOS, available data analysis: I_p = 11.5-12.2 MA, sensitivity studies)**

Potential contributors:

J. Garcia (CRONOS), S-H. Kim (CORSICA), Y.S. Na ???

Present status summary for 2011

(1) 15 MA, Q=10, P_{fus} = 500 MW

Done by FK, NH, VL, AP, APn full bore plasma inductive

Done by JMP, MM for slim SS geometry (P_{fus} > 500 MW, Δt_{FT}> 400 s)

NB: Potentially interesting area for others for later optimization?

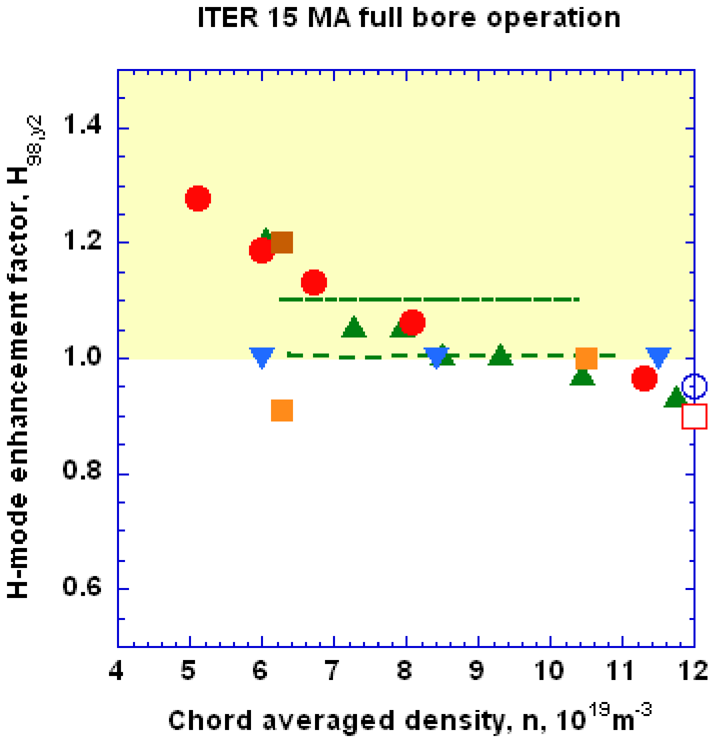
(2) Density scan for one slice: I_p = 15 MA

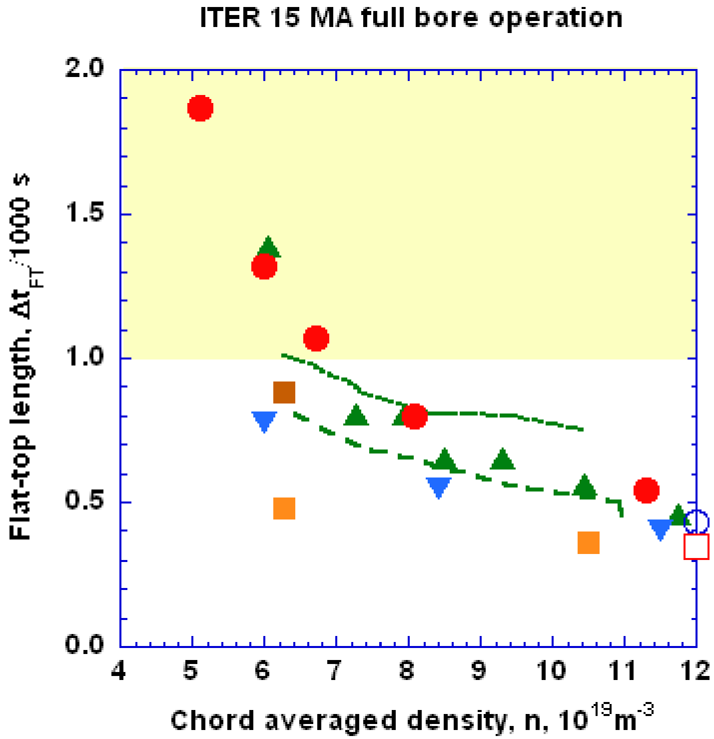
Done by FK, NH, VL, AP

- **Long pulse operation Δt_{FT} ~1000 s becomes possible for 15 MA at low densities, n/n_G ~0.5 for all models with $H_{y2,98}$ ~ 1.1 even with day-1 mix: 33 MW NBI + 20 MW EC for BgB, GLF23, SB(AP), SB(VL)**
- **Fusion gain factor Q drops with density reduction. For SB(VL) and CDBM(NH) it drops below Q=5.**
- **Load to divertor drops with density reduction**
- **Fluence increases for BgB and GLF23 with density reduction**

Would be the next step for JMP, MM, APn (plan for 2012??)

(2) I_p=15 MA density scan-I: Same assumptions as for 500 MW, 15 MA, Q =10



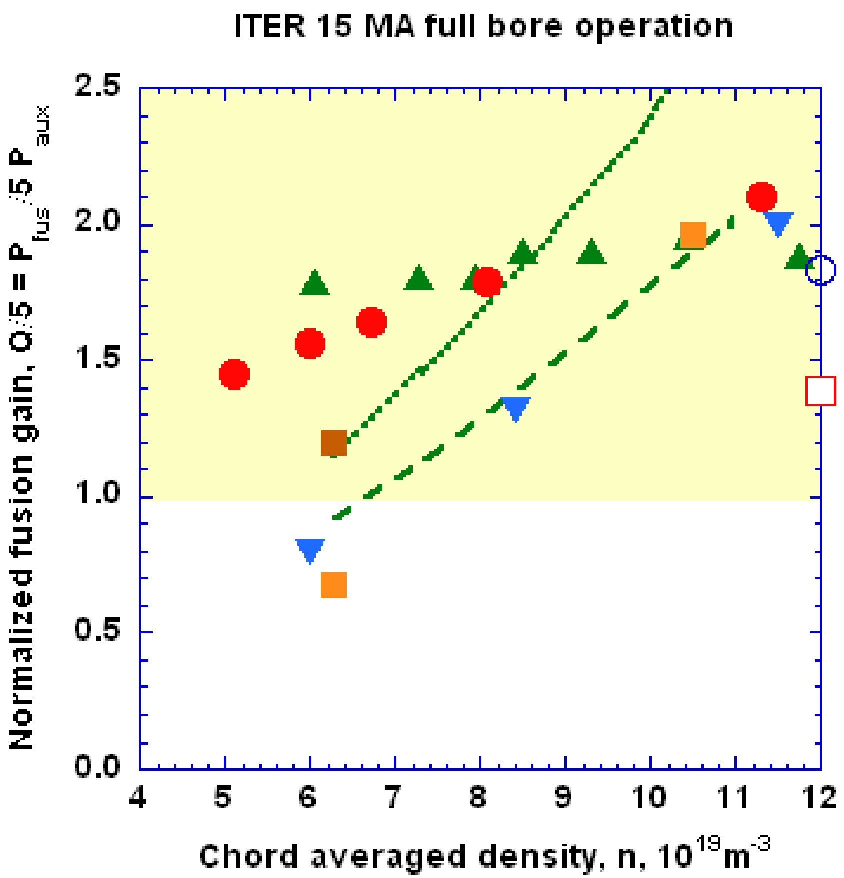


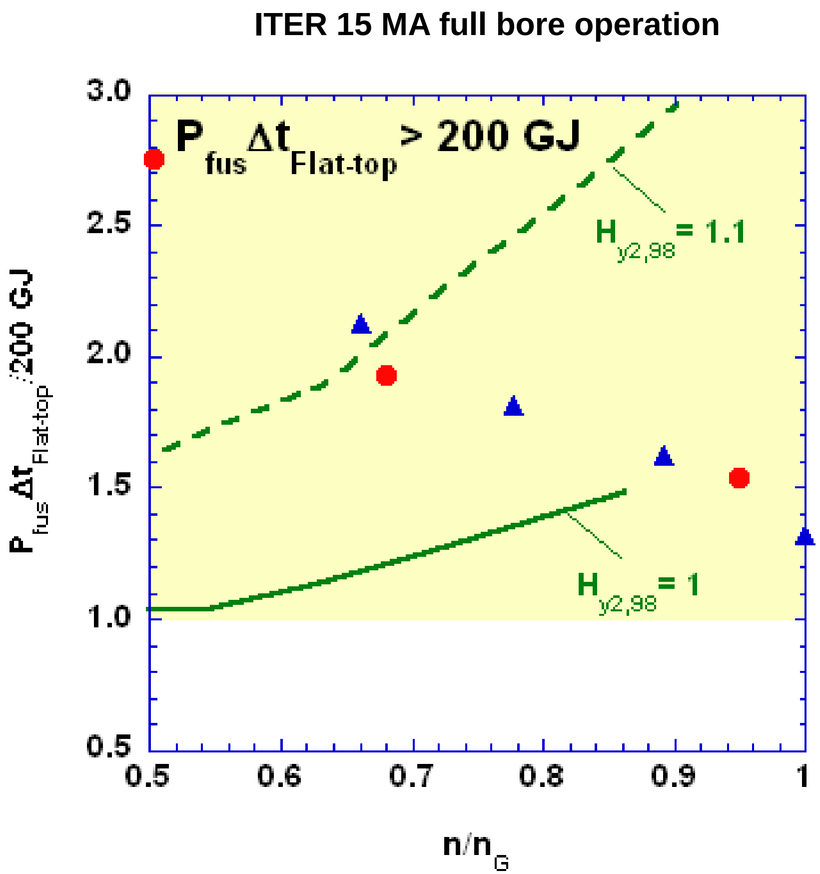
Density reduction increases $H_{y2,98}$ ~ 1 -> 1.1 for BgB, GLF23, and reduces for CDBM (NH)

Density reduction to n/n_G ~ 0.5 increases flat-top length to 800-1000 s (~500 s CDBM (NH))

BgB, GLF23, SB: Δt_{FT} ~1000 s becomes possible for 15 MA at low densities, n/n_G ~0.5 with $H_{y2,98}$ ~ 1.1 with the same model assumptions used for Q=10

(2) I_p=15 MA density scan-I: Same assumptions as for 500 MW, 15 MA, Q =10





For BgB and GLF23 Q drops with density reduction, but remains high Q> 5,

For BgB and GLF23 Fluence per shot remains higher than for baseline: $P_{fus}\Delta t_{FT}$ > 200 GJ. Fluence reduces for SB(VL) and CDBM (NH).

(3) Density scan for the range I_p = 10-15 MA (I_p-n OS):

(see Basic goal and Phase-I above)

done by VL with SBM by ASTRA **V. Leonov 7th IOS TG Meeting 18-21 Oct. 2011, Kyoto, Japan**
A.R. Polevoi, et al 37th EPS. (Dublin, Ireland, 2010) P2.187

Motivation of plasma current and plasma density choice is presented:

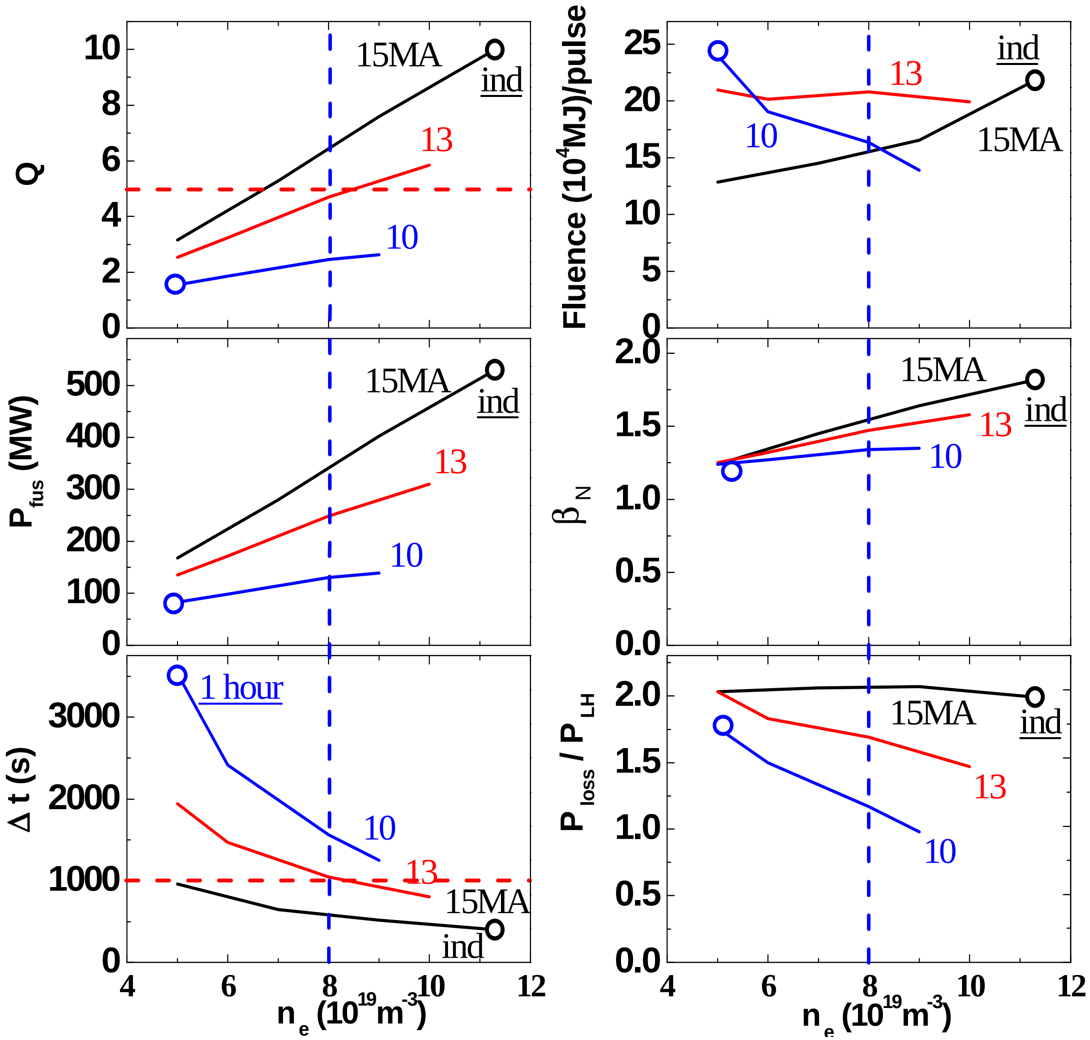
I_p and n for 1000 s operations are the solution of the set of equations:

$$Q(I_p,n) = 5,$$

$$\Delta t(I_p,n) = 1000 \text{ s}$$

Will be a natural next step for FK, NH

(Plan for 2012??)



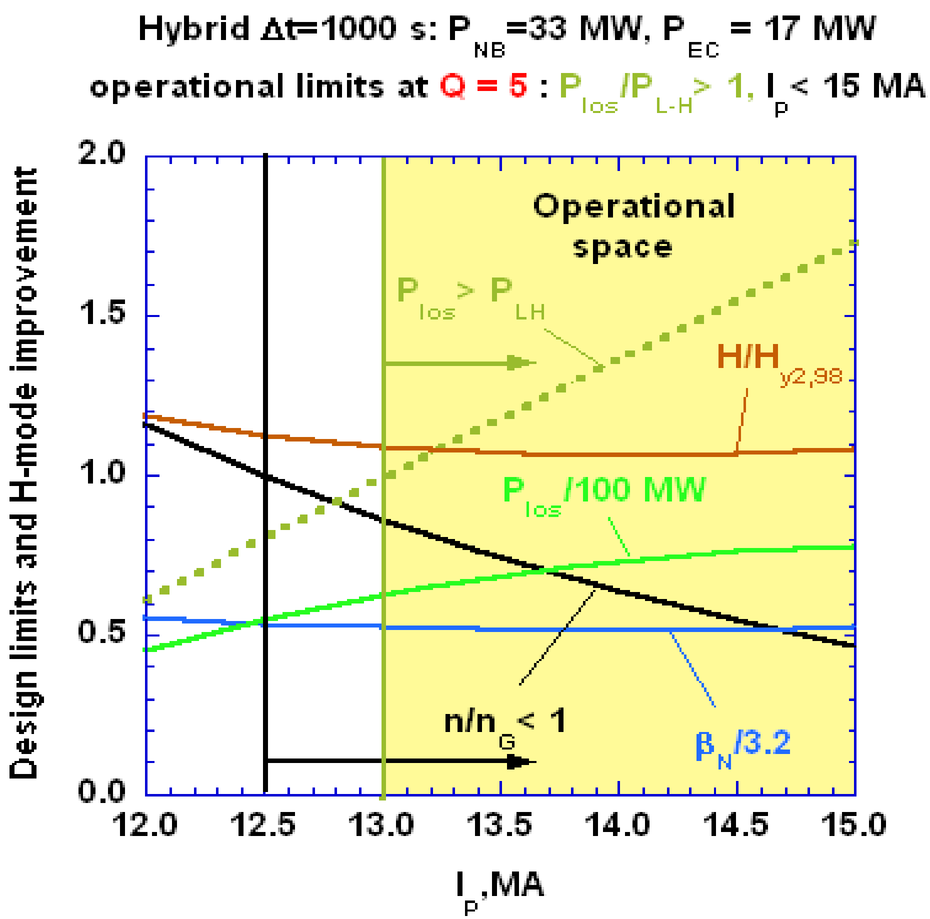
(3) Density scan for the range I_p = 10-15 MA (I_p-n OS):

(see Basic goal and Phase-I above)

done by AP (2010)

A.R. Polevoi, et al 37th EPS. (Dublin, Ireland, 2010) P2.187

So, VL already has sufficient information to draw I_p,n OS similar to this one =====➔



Hybrid operational space for P_{aux} = 50 MW

=> Plans:

(1) General : JA9 to be continued (2012)

(2) Different contributors are at different phases. Thus they follow an individual plan for 2012:

a) For those, who plan to join: choose way of contribution (A, B) (Potential contributors)

b) For those, who chosen A: start with step 1 doing density scan starting from 500 MW, I_p=15 MA (JMP, MM, APn)

c) For those, who passed step 1: continue with Phase-I doing I_p-n scan for other currents similar to step 1 (FK, NH)

d) For those, who passed Phase – I: continue with sensitivity studies near the chosen optimum (VL, AP), draw the I_p,n OS