Application of the parameterized EPED1 model to time-dependent transport simulation

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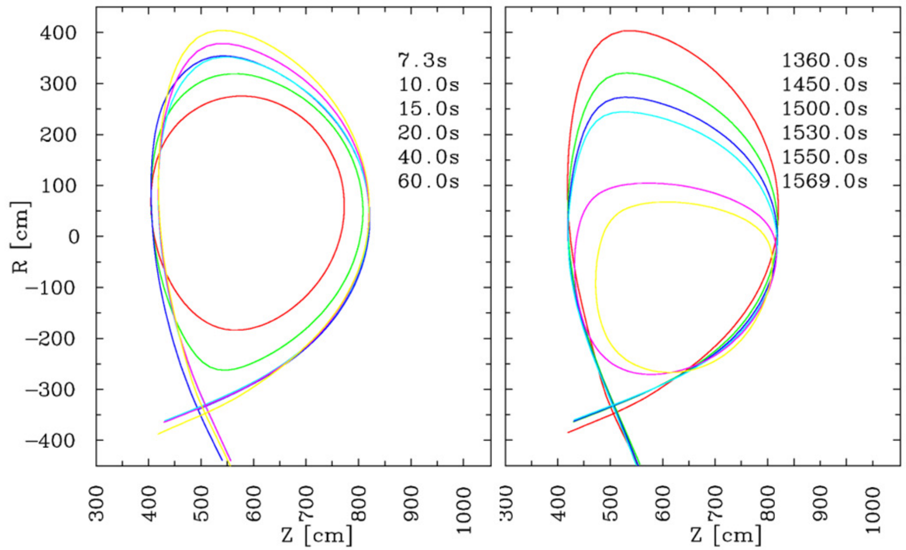
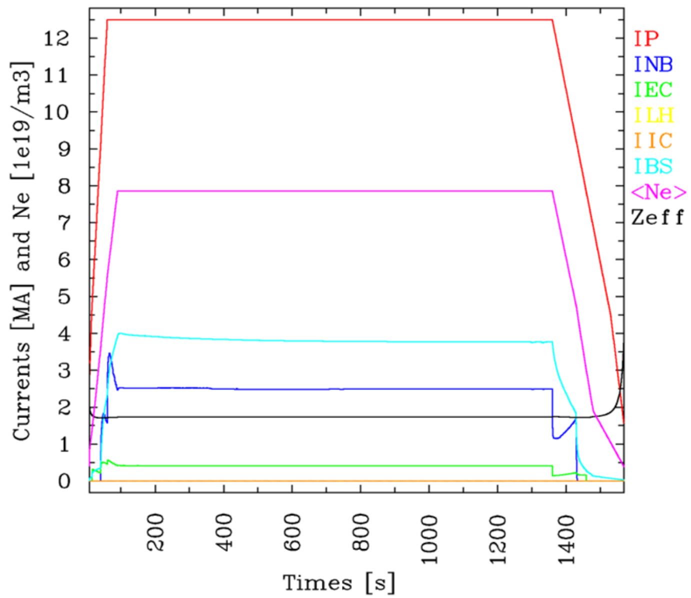
ISM(EU) and P. Snyder (GA) – EPED1 results

ITER hybrid mode with a parabolic density shape

1. 12.5MA scenario, large bore startup
3. 1300s of current flat-top & n_{GW}~9.9e19 m^{-3}
4. n_e(0,flat-top)=8.5e19 m^{-3} & parabolic shape
5. Coppi-Tang transport model
6. Te(ped) ~ 3-4keV, ρ_{tor}(ped) ~0.95
7. Effective sawteeth when q_{min}<0.97
8. Be and Ar impurities, self-consistently with Zeff(t)=1.7+2.3*(ne0(t0)/ne0(t))^2.6 (V. Lukash)
9. 33MW of NB (off-axis) & 20MW of EC (2 co-ELs and 1 UL-LSM)
10. 60s ramp-up (XPF at about 15s and L-H transition at 40s)
11. 210s ramp-down (H-L transition 70s after EOF)





At t=1359s (tEOF = 1360s)

1. Q ~ 9.6 & P_α ~ 101MW → high Q (>5.0) with P_{aux}=53MW
2. H_{98} ~ 1.24 & l_i(3) ~ 0.75 → improved confinement
3. β_N ~ 2.5 & β_p ~ 0.82 → high betas
4. I_{BS} ~ 3.8MA, I_{NB} ~ 2.5MA & I_{EC} ~ 0.4MA → f_{NI} ~ 0.54

Parameterized EPED1 model

- EPED1 results on ITER H-mode and hybrid mode scenarios are provided by P. Snyder (ISM working session in JET Nov. 2011)
- 9 inputs : (I_p, $n_{e,ped}$, Z_{eff}, β_N, R, a, κ, δ, B_t)
- 4 outputs : (Δ_{ped}, P_{ped}, Δ_{top}, P_{top})

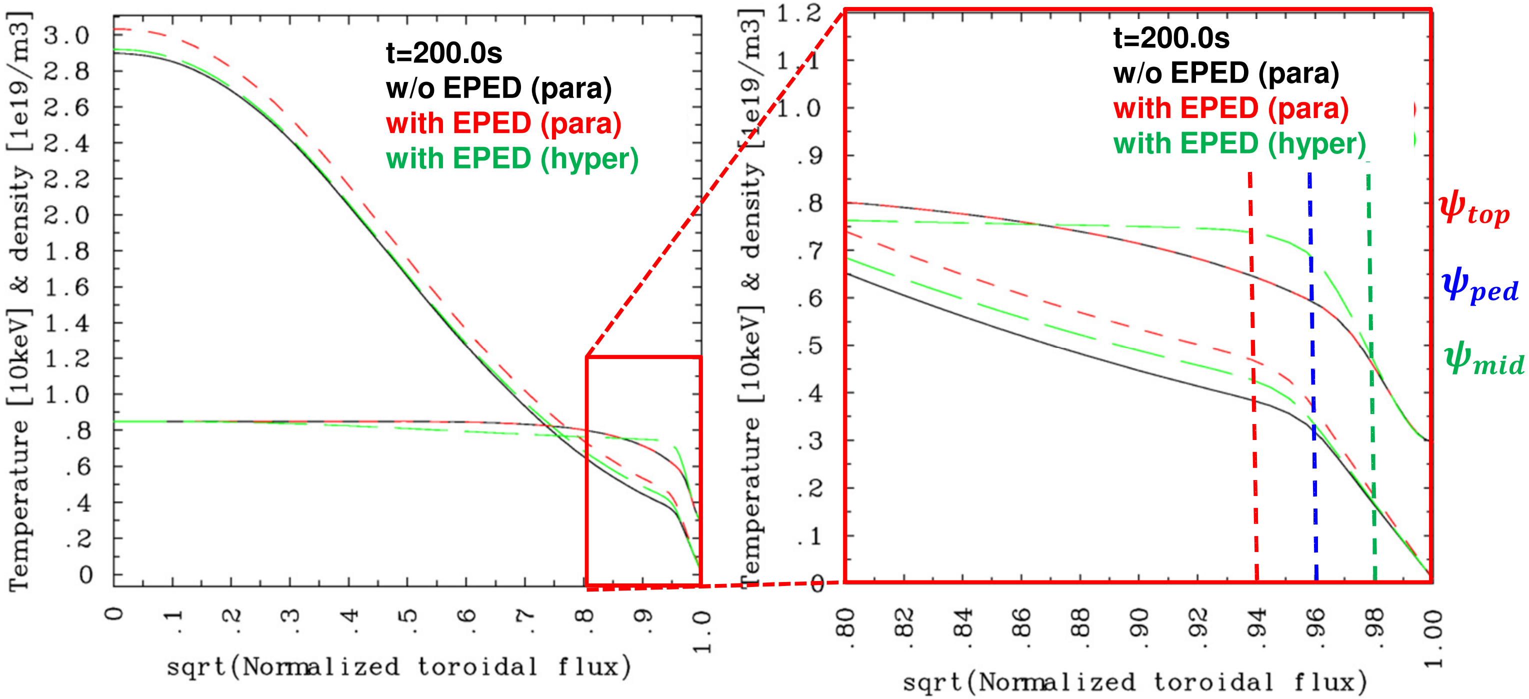
- When the density profile is prescribed in time-dependent transport simulations, the input $n_{e,ped}$ need to be determined either
  - assuming a constant value, $n_{e,ped} = r_1 * n_{e,0}$, then allowing the prescribed density profile to vary.
  - or using iterations, $n_{e,ped} = n_e(\Delta_{ped}^{(k+1)})$ =EPED1 { $n_e(\Delta_{ped}^{(k)})$, ….}, with a fixed density profile

- The pedestal height ($T_{e,top}$, not $T_{e,ped}$) can be feedback controlled
  - ✓ using X_e & X_i to satisfy $n_{e,top} * T_{e,top} + n_{i,top} * T_{i,top} = P_{top}(1- \Delta_{top})$

Hyperbolic pedestal density profile

- A hyperbolic tangent shape pedestal density profile [PPCF**46**, P. Snyder] is modified to have only 4 control parameters for entire density profile (also for density peaking).
- 2 exponents (α, β) and 2 density ratios at the pedestal and edge (r1, r2).

$$n_e(\psi) = n_{e0}\left\{(1-r_2)\left(c_1\left[H\left(1-\frac{\psi}{\psi_{ped}}\right)\left(1-\left(\frac{\psi}{\psi_{ped}}\right)^{\alpha}\right)^{\beta}\right]+c_2\left[tanh\left(2\frac{1-\psi_{mid}}{1-\psi_{ped}}\right)-tanh\left(2\frac{\psi-\psi_{mid}}{1-\psi_{ped}}\right)\right]\right)+r_2\right\}$$



$$\alpha = \beta = 1.0$$

$$r_1 = 0.80$$

$$r_2 = 0.35$$

$$n_e(0) = n_{e0}$$

$$n_e(\psi_{ped}) = r_1 n_{e0}$$

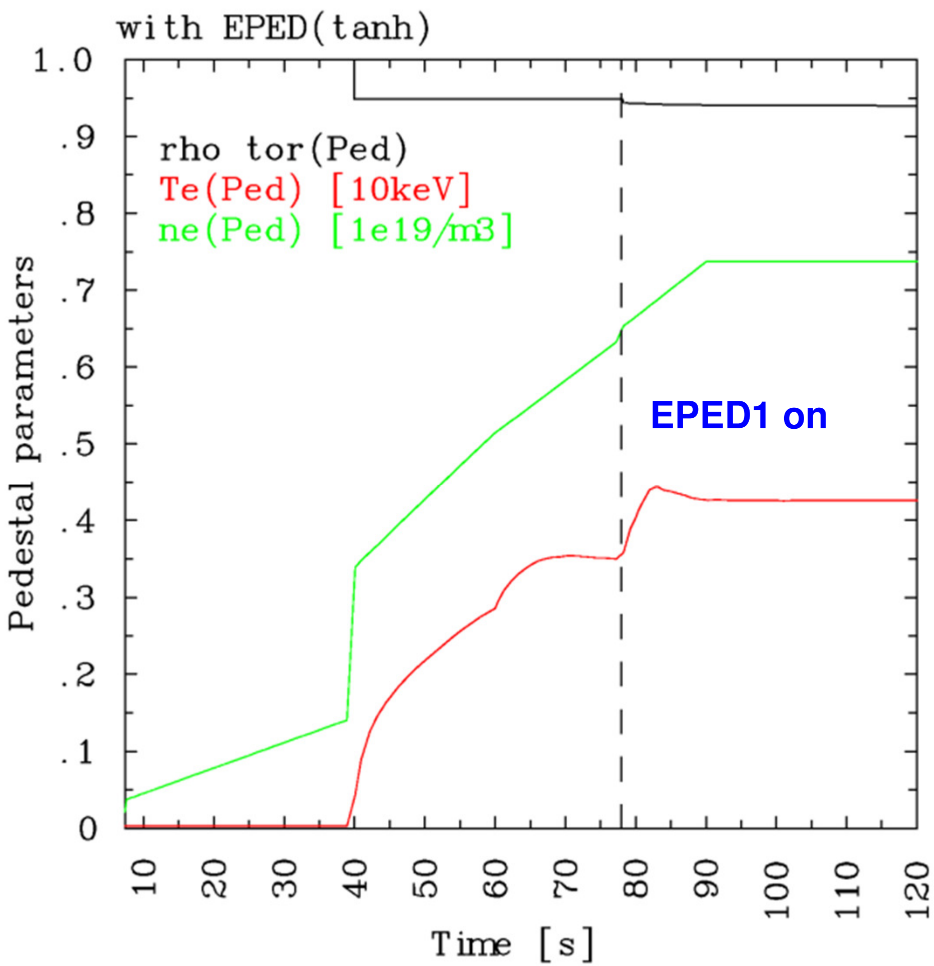
$$n_e(1) = r_2 n_{e0}$$

$$c_2 = \left(\frac{r_1-r_2}{1-r_2}\right)\frac{1}{2tanh(1)}$$

$$c_1 \cong 1 - c_2(1+\tanh(1))$$

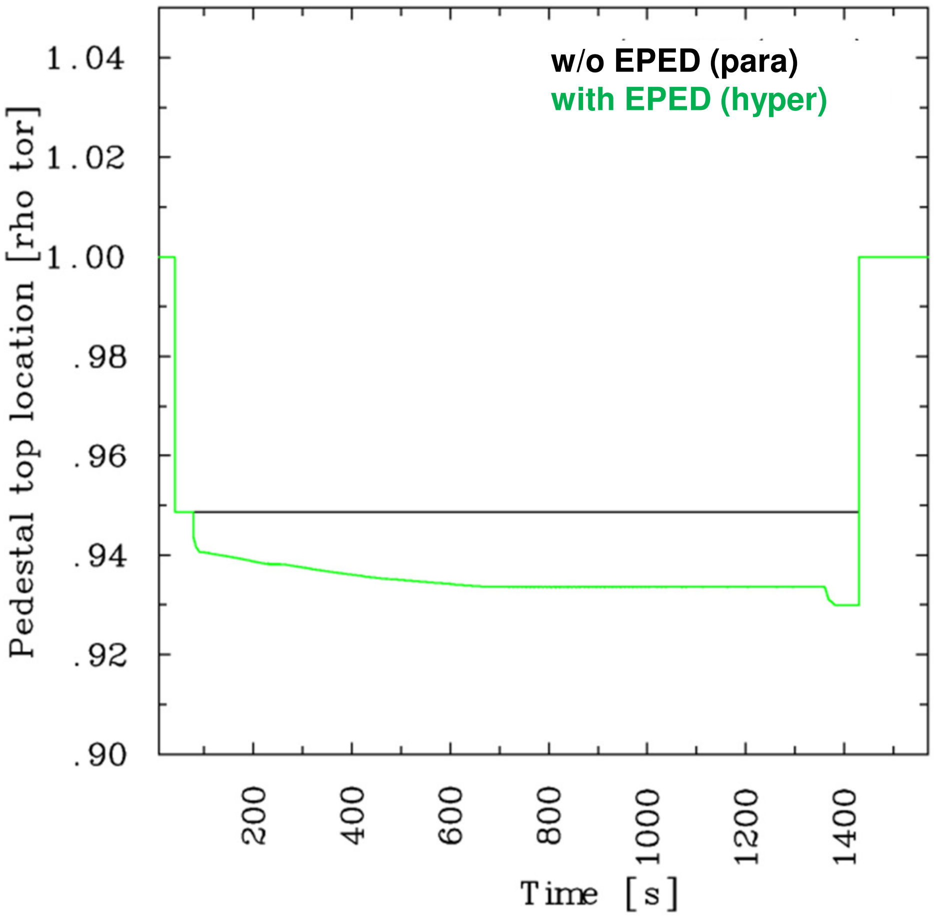
Application to CORISCA simulation

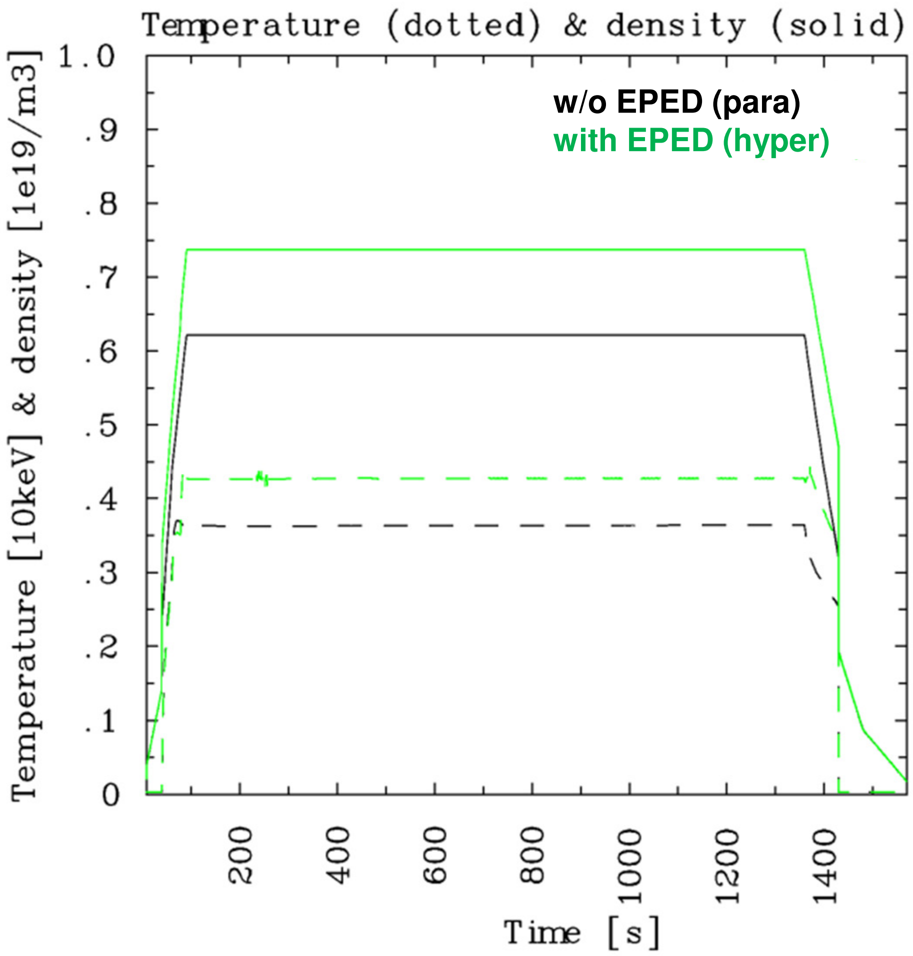
- Multi-dimensional linear interpolation / extrapolation
  - ✓ up to 9 input dimensions
  - ✓ extrapolation up to several tens %
  - ✓ switched on only when it can work properly.
  - ✓ Indexing for fast 1 dimensional calculation (2^m instead of $n_1 * n_2 * \ldots * n_m$)
- Feedback control
  - ✓ $X_{e,i}\ (\rho > 1-\Delta_{top},\ t^{k+1})$
    $= f_{mult} * X_{e,i}\ (\rho > 1-\Delta_{top},\ t^{k})$
  - ✓ f_{mult} is determined by measuring P_{top}/P_{top}^{EPED}



Evolution of the pedestal width & height

- The EPED1 pedestal width & height are larger & higher than previously used settings.





Bootstrap current density profile

- Total bootstrap currents are similar, although their profile shapes are different

For the same ne0 (= 8.5e19 /m^3)

- **w/o EPED (para) : IBS = 3.759 MA**
- **with EPED (hyper) : IBS = 3.776 MA**