Modification of JAEA system code

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JAEA

Outline

- Outline of JAEA system code
- Modification of system code
  - TF coil design code
  - Bootstrap current calculation
- Summary

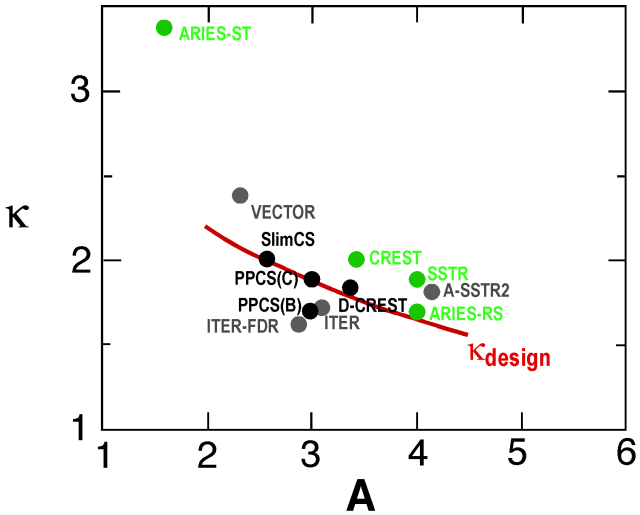
Outline of JAEA code

- Basic model is TPC code based on the TRESCODE and ITER physics design guideline.
- Recent code development focused on:

  minimize the weight of the reactor for reduced construction cost

Add constraints in systems code:

- **κ and β_N limits, especially in low A**
  - ◆κ (A): key parameter for high P_{fus}
  - ◆β_N (A, κ): GA formula with JAEA correction

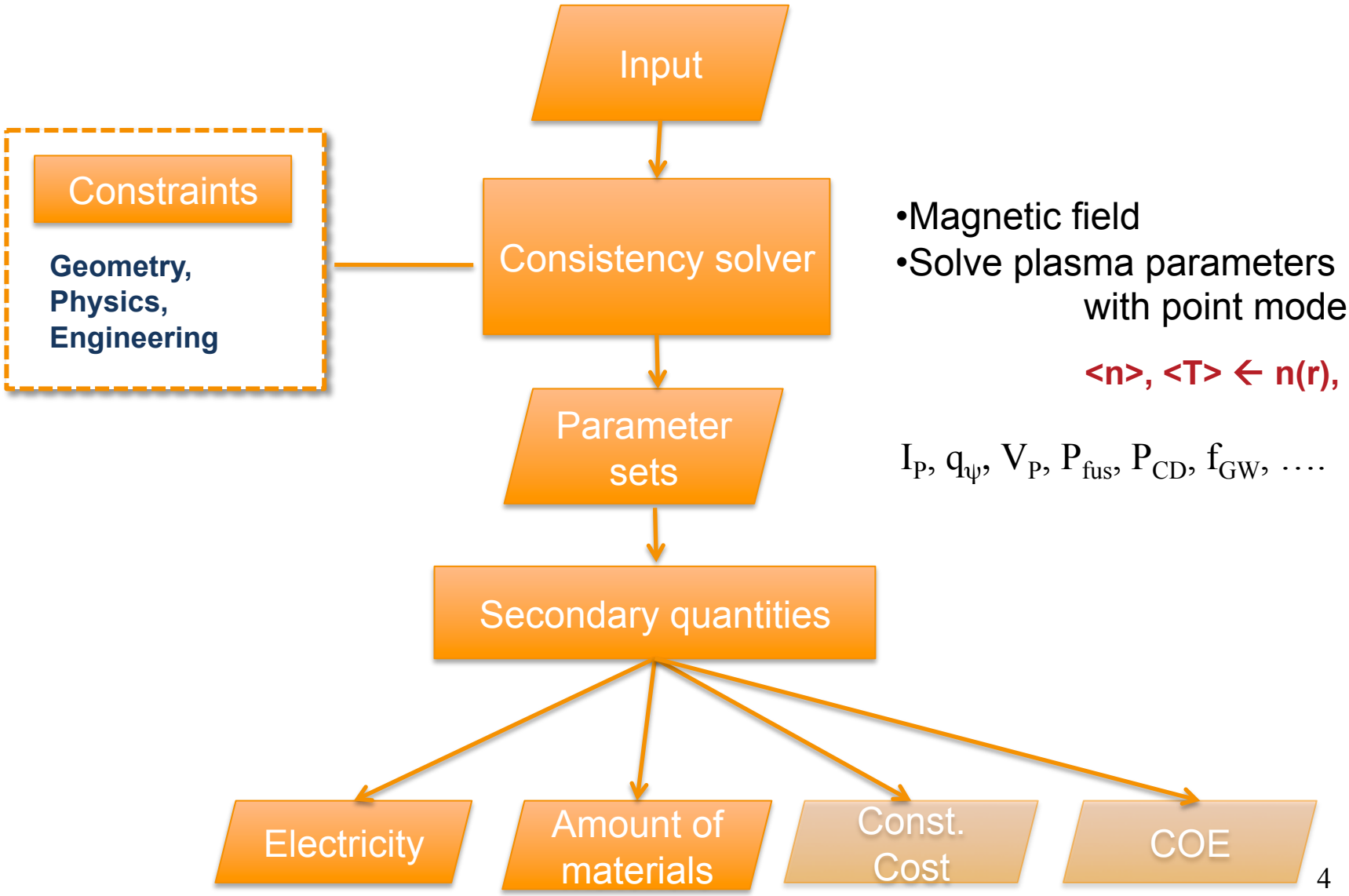


In this modification, to improve reliability of evaluated value,

1) Add TF coil design code SCONE

2) Add new BS current model

General structure of systems code

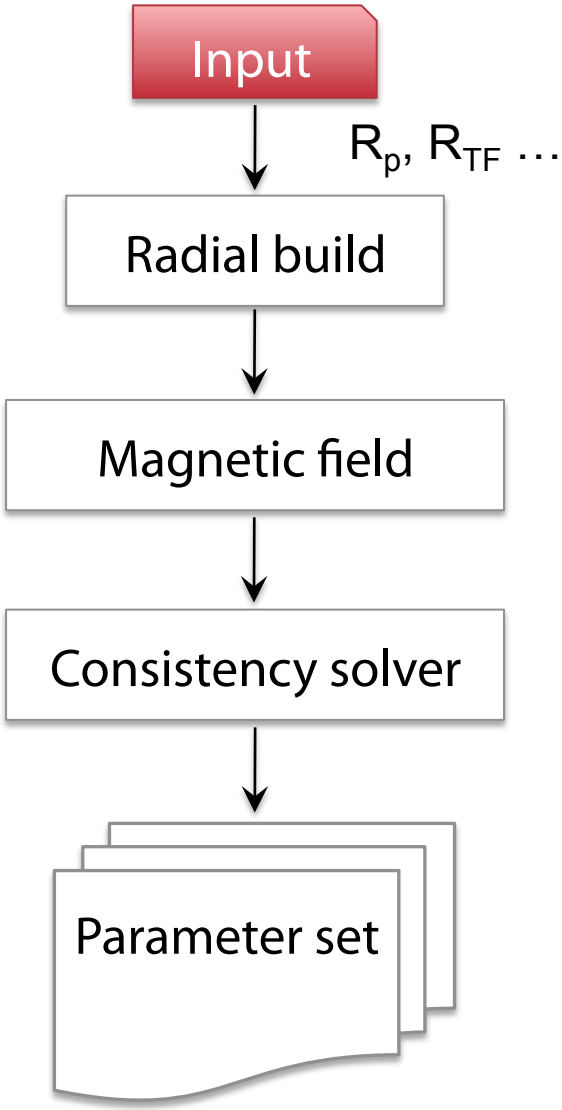


•Magnetic field
•Solve plasma parameters with point model

<n>, <T> ← n(r), T(r)

I_P, q_ψ, V_P, P_{fus}, P_{CD}, f_{GW}, ….

Flowchart of JAEA system code



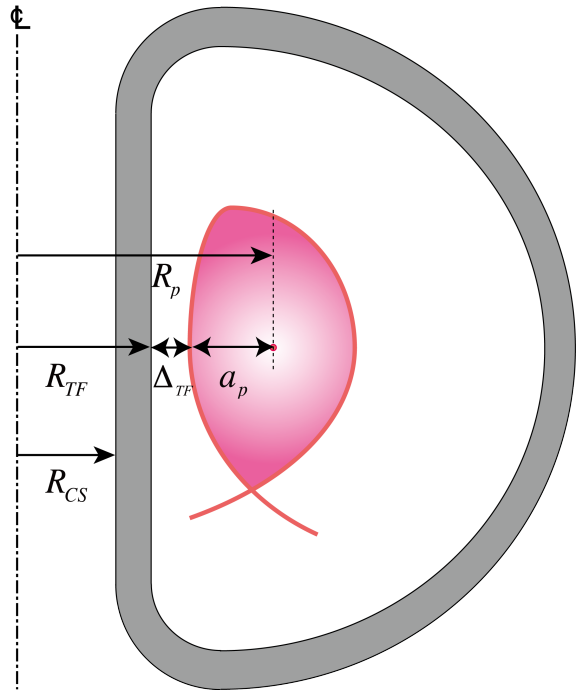
Input parameters

Scan parameters:

R_p & R_{TF}

Constant parameters:

δ	
HH_{y2}	
<T> (keV)	
z_{eff}	
R_{cs} (m)	
Δ_{TF} (m)	
B_{pmax}	
Current drive	NB or EC
SC strand	NbTi, Nb_3Sn, Nb_3Al



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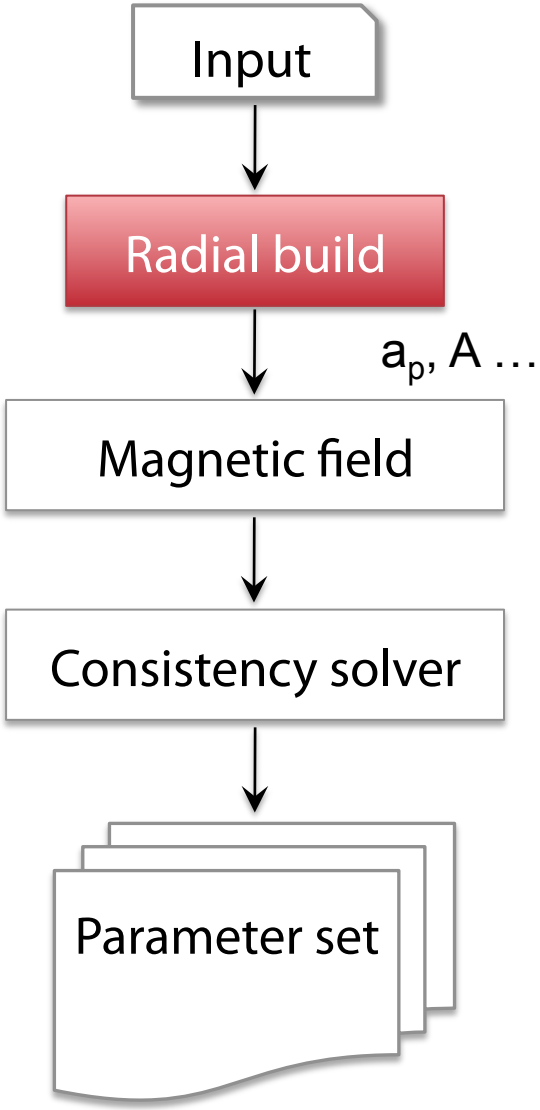


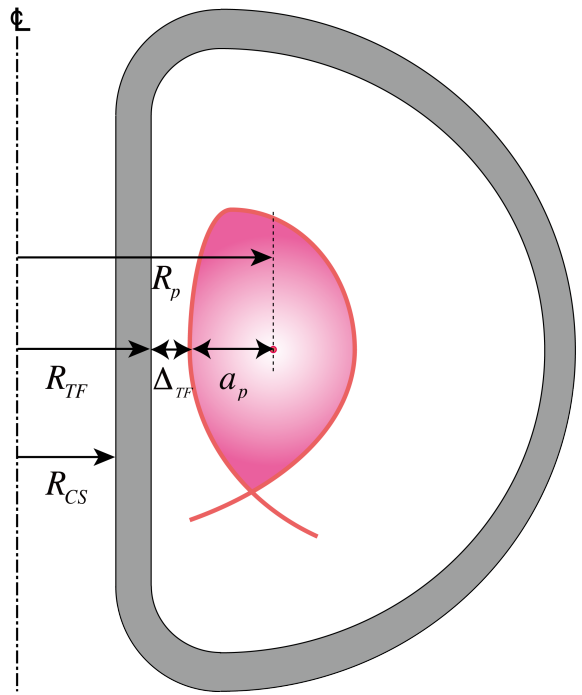
Radial build

given

$$a_p = R_p - \Delta_{TF} - R_{TF}$$

Scan parameter

$$\Delta_{TF} = \Delta_{BLK} + \Delta_{Shield} + \Delta_{SOL}$$



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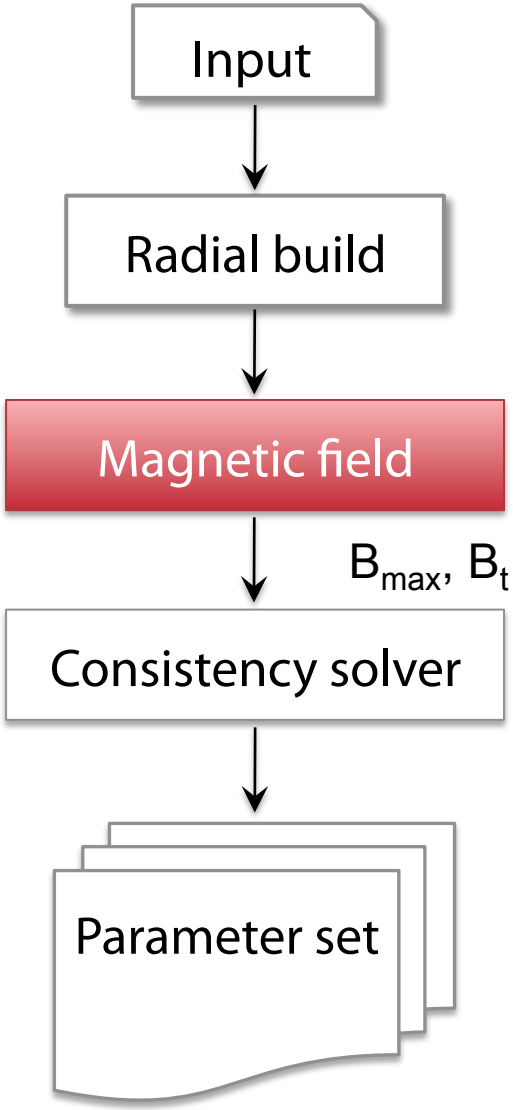
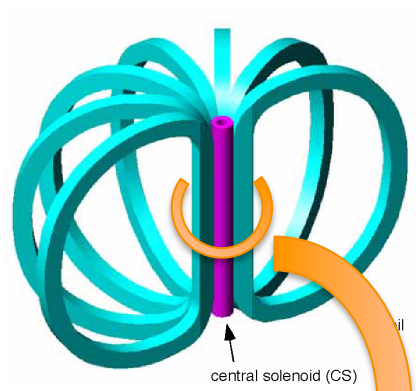
Magnetic field calculation

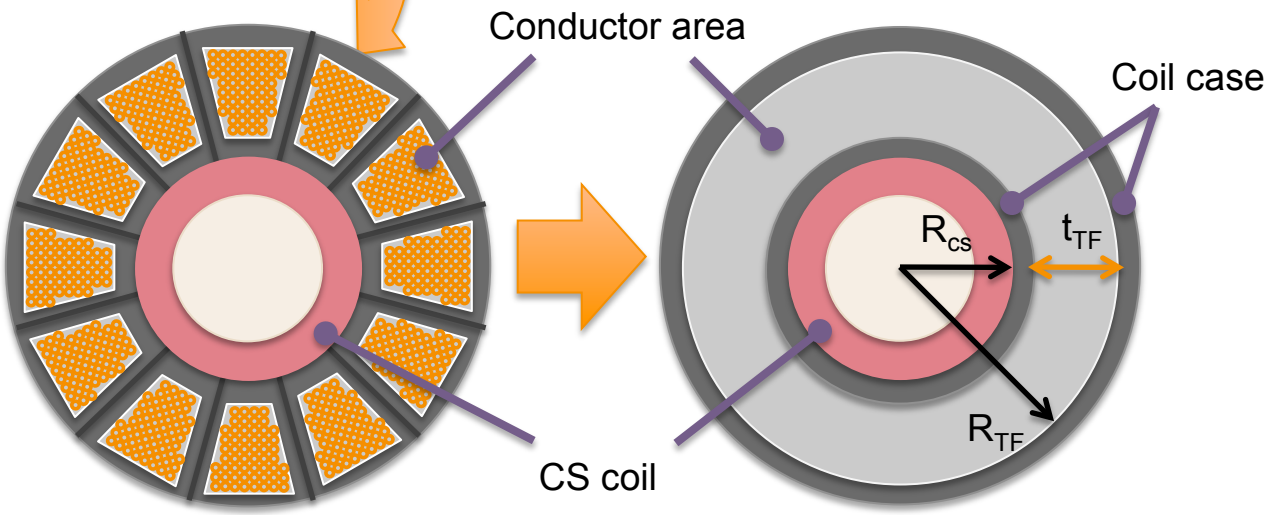


Magnetic field



B_{max} is given by *SCONE* code

(**S**uper**con**ductor coil **E**valuation: **SCONE**)



Uniformity in coil structure

TF coil design code: **SCONE**

✧maneuverable design tool of superconducting TF coils

Input parameters	
SC strand	Nb_3Sn, Nb_3Al …
Operation cond.	Conductor current
	Operation temperature
	Operation strain
Design cond.	Design stress, S_m
	Terminal voltage
Coil size	Conductor thickness
	Coil case thickness
	Width
	Height

From system code

- Geometry (R_p, a_p, R_{cs}, R_{TF}, Δ_{TF}, κ)
- Divertor (single or double)

TF coil design code: **SCONE**

SCONE consistently solves the key essentials;

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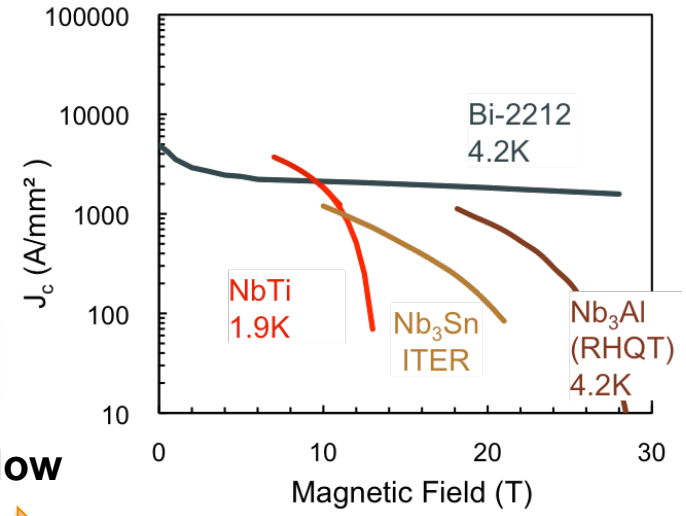

Operation current density

- **Scalling low**

B_{max}

Heat balance

- **Joule heating**
- **stabilizer**

EM forces

- **von Mises stress**

From system code

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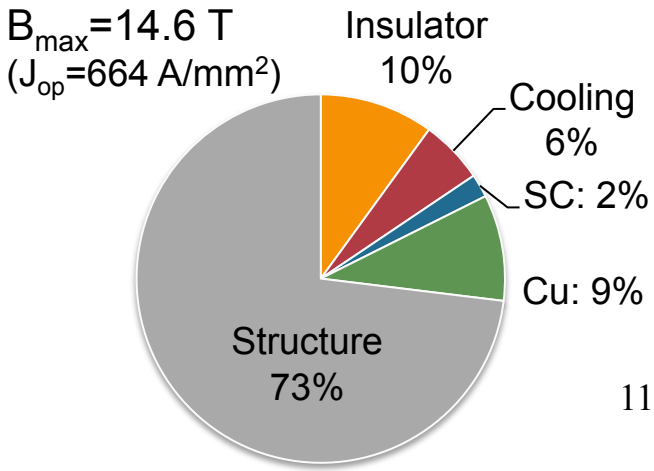
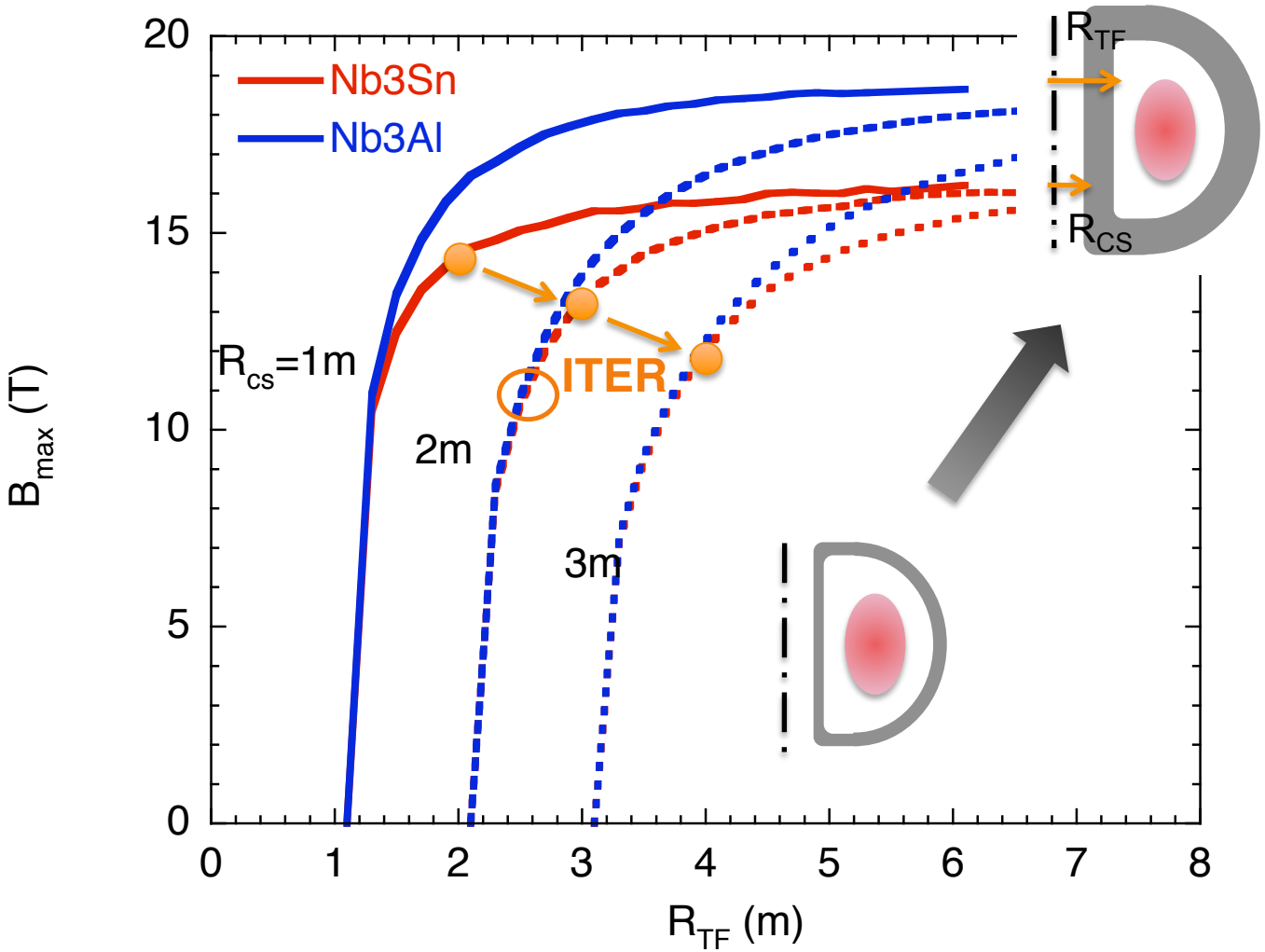
Output parameters
Maximum field in TF coils
Number of turns
Magnetic energy in TF coils
Total magneto motive force
Operation current density
Material composition amount
…



Example ~Evaluated B_{max} as a function of R_{TF}~

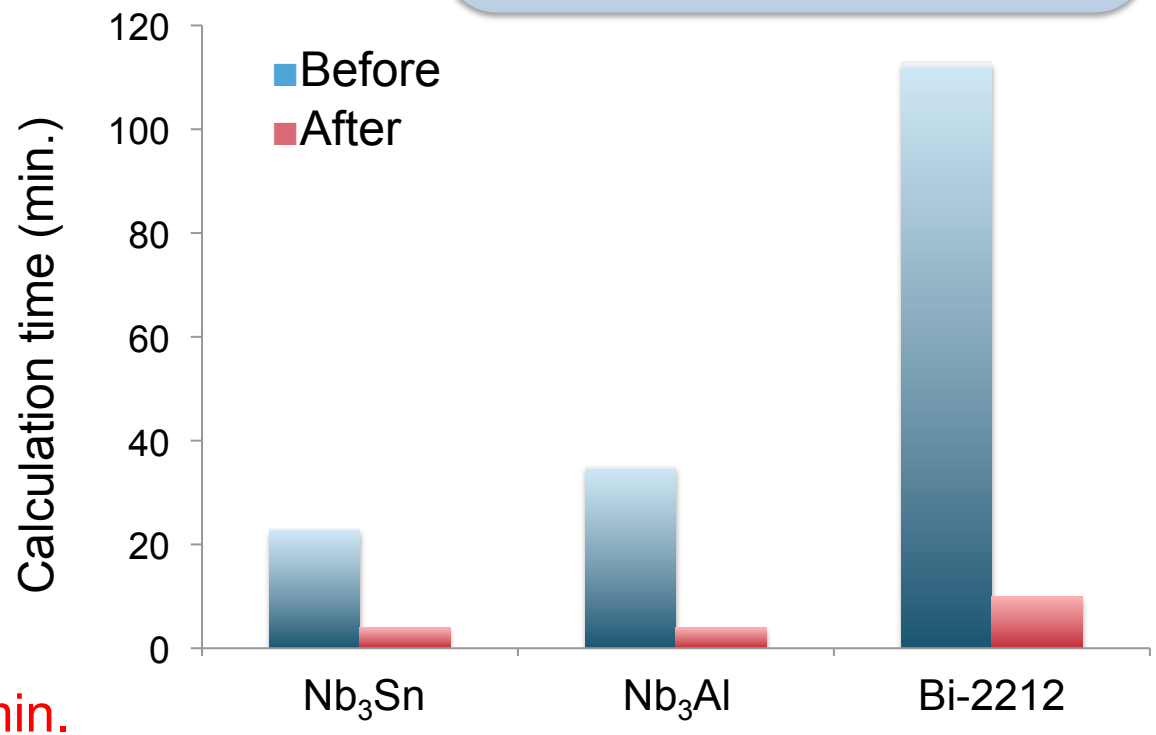


Integration to system code

Speed-up by modification of calculation algorithm

Calculation conditions:

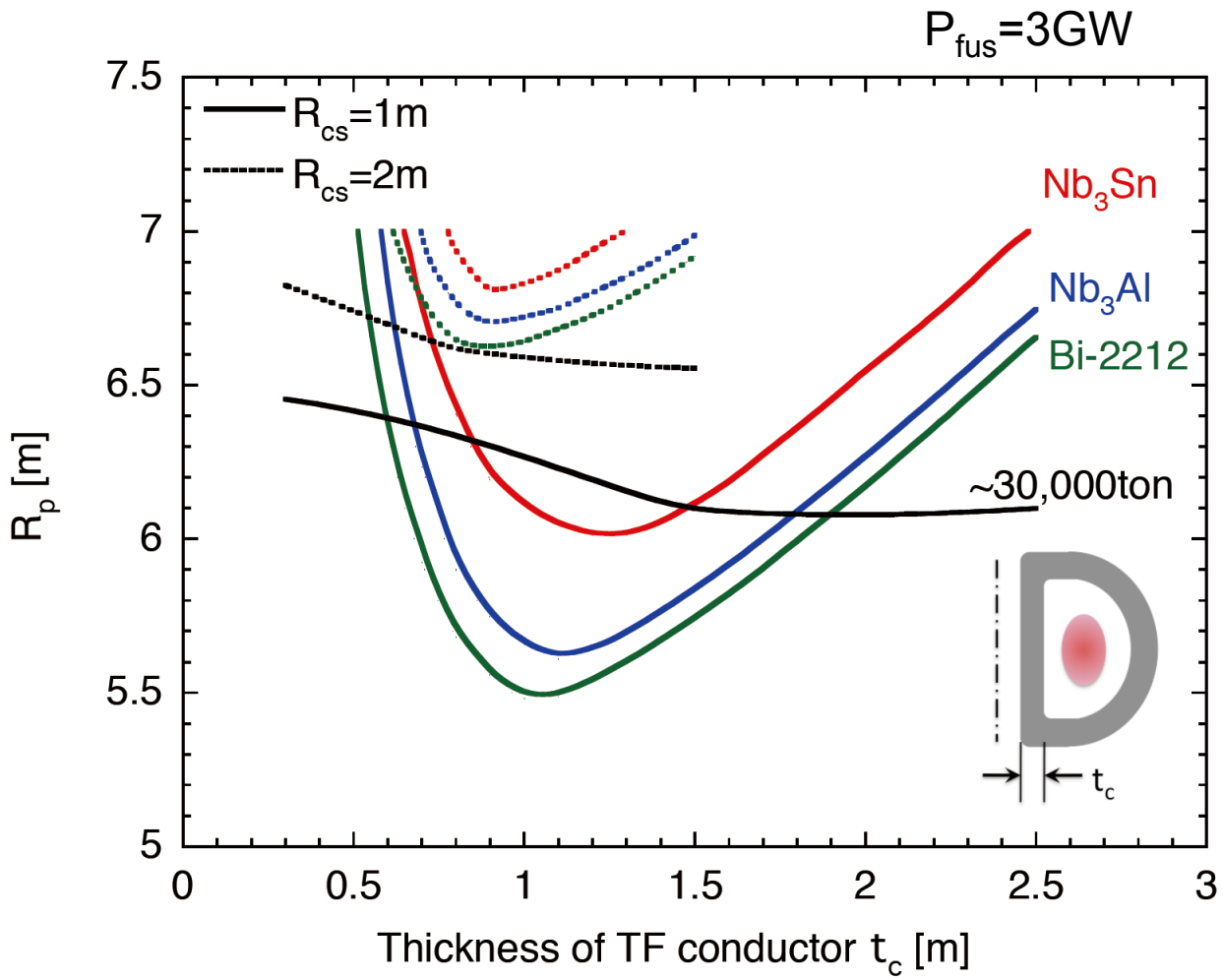
OS: Windows7 Virtual XP mode
CPU: Core 2 Quad 2.66 GHz
Memory: 3.0 GB
1000 case



Calculation time < 10 min.

Example on system code with SCONE

- Merit of high J_c of Nb_3Al reduced as CS coil size increase.
- Optimal t_c is ~1m under all conditions.



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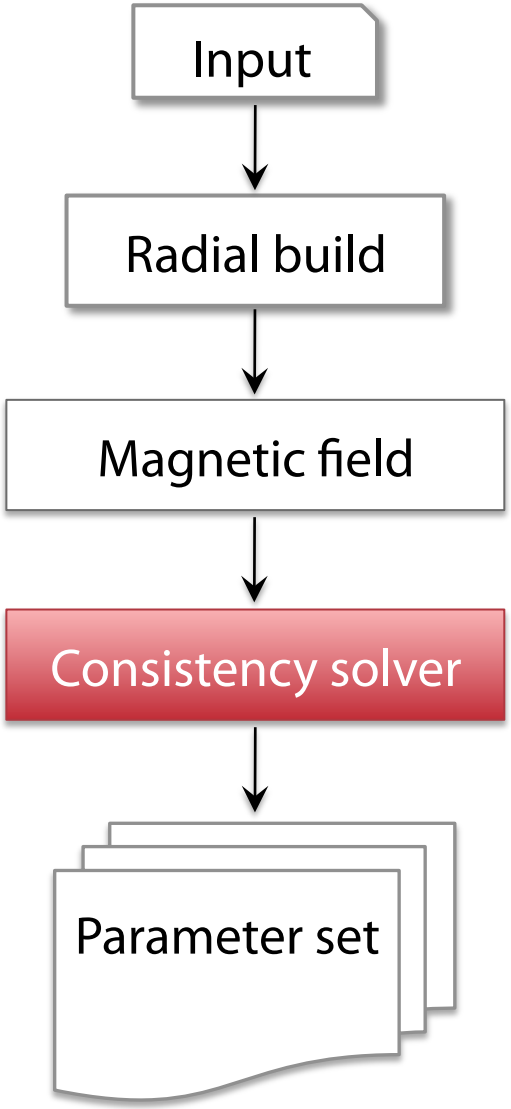
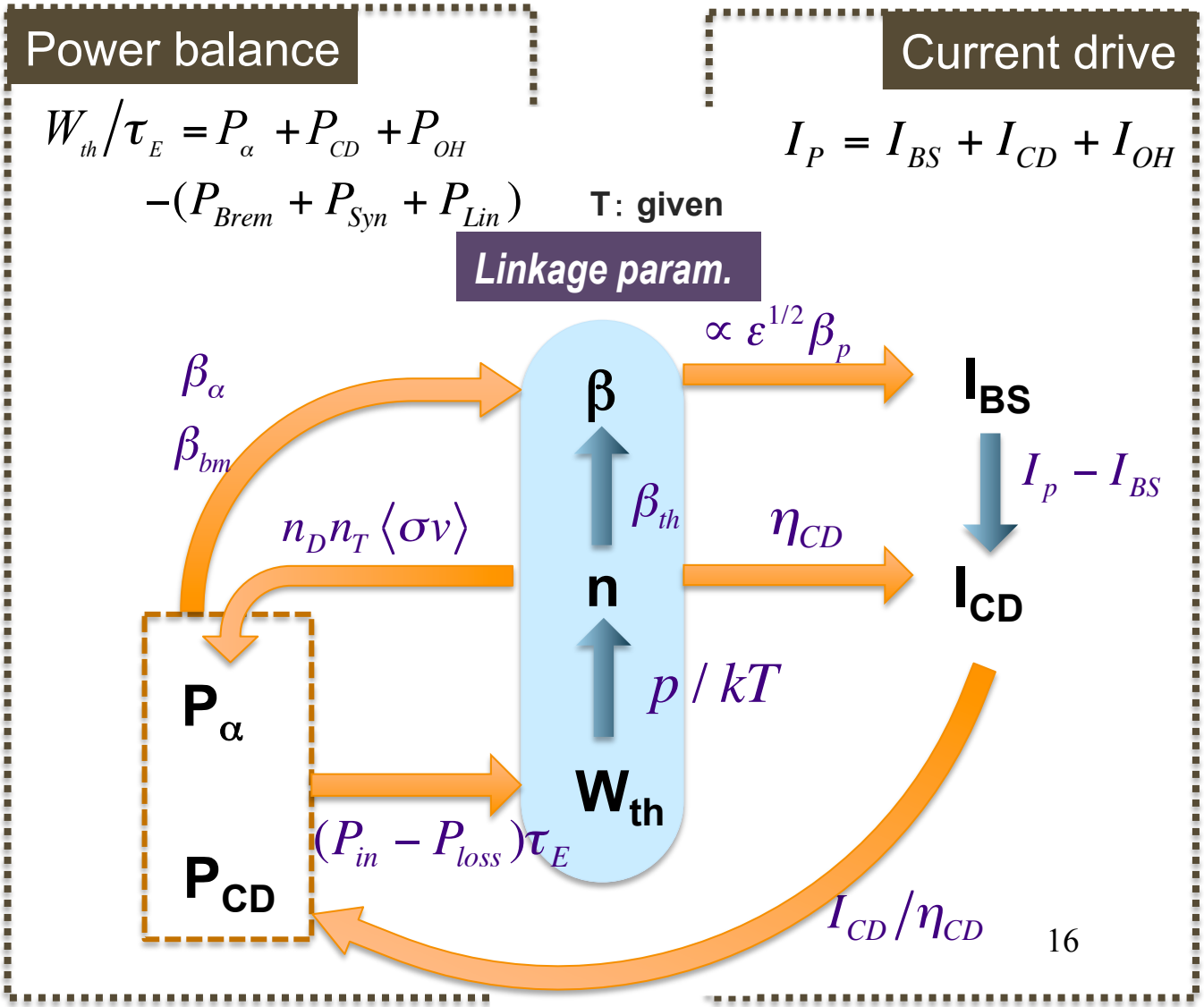
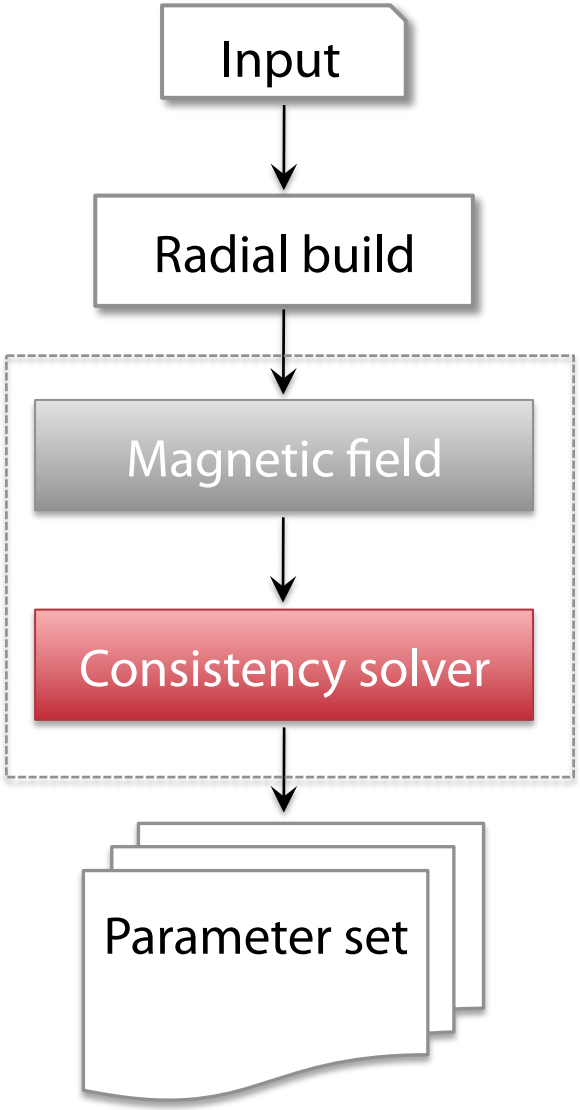
Consistency solver

Main formula ← ITER Phys. Design Guidelines





Problem of present system code: CD



P_{CD}: important parameter

To improve reliability of P_{CD}, modification of evaluation model of I_{BS}/I_p is required.

I_{BS}/I_p : ITER Physics Guideline

$$\frac{I_{BS}}{I_p} = C_{BS}\left(\frac{\beta_p^*}{A^{1/2}}\right)^{1.3}$$

where $$C_{BS} = 1.32 - 0.235\frac{q_\psi}{q_0} + 0.0185\left(\frac{q_\psi}{q_0}\right)^2$$

$$\beta_p^* = \beta_T\left(\frac{B_T}{B_a}\right)^2 = \beta_T\kappa\left(\frac{2\pi a}{\mu_0 I_p}\right)^2$$

I_{BS}/I_p, independent of profiles

➔Necessary to treat profile effects

I_{BS} calculation with profile effects

I_{BS} new formula with profile effects[2]

$$j_{BS} \approx -\frac{0.032 R_0 q}{B_0 \rho \kappa a^2}\left[L_{31} T \frac{\delta n}{\delta \rho} + \left(L_{31} + \frac{L_{32} + \alpha L_{34}}{2} \right) n \frac{\delta T}{\delta \rho} \right]$$

①assumption of q profile : q(ρ)

- Monotonic shear (Normal shear: NS)
- Weakly-Reversed-Shear (WRS)
- Strongly-Reversed-Shear (SRS)

②n, T profile calculation

$$n(\rho) = n_0 \left(1 - \rho^2\right)^{A_n}$$

$$T(\rho) = T_0 \left(1 - \rho^2\right)^{A_T}$$

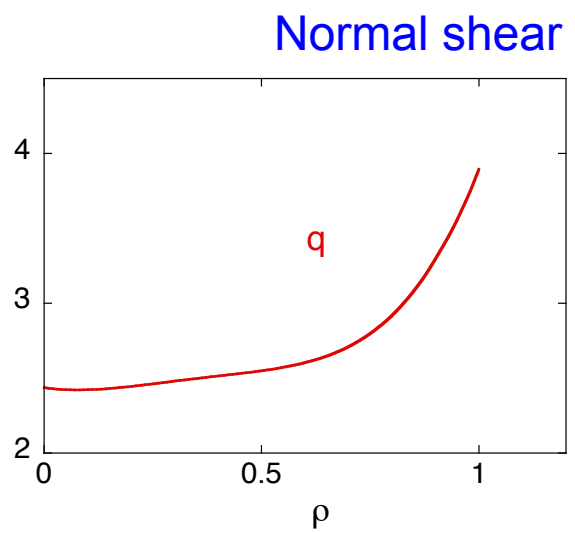
③I_{BS} calculation

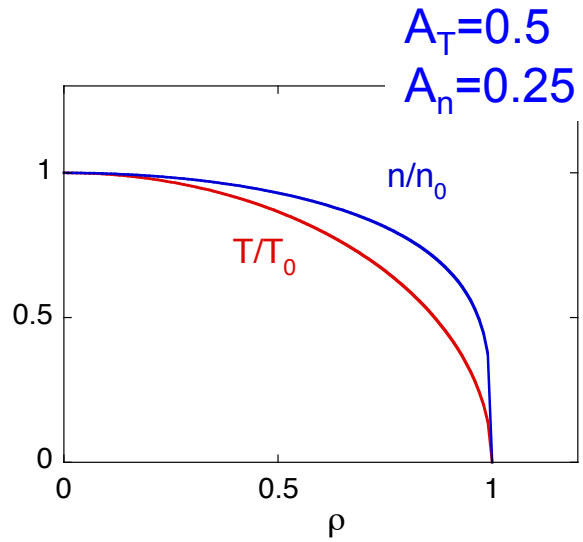
[2] M. Sengooku, PST-03-41, (2003).

Comparison with another code

Calculation conditions:

P_{fus}=2.95GW, β_N=4.3, f_{GW}~1, q_0=2.4





Code	System code (0D)	System code (1D)	ACCOME (1D)
I_{BS}/I_p	61.3%	66.8%	70.6%

Summary

❖JAEA system code (TOPPER) was modified.

- Improvements from previous code are as follows;
  1) Add TF coil design code SCONE
  2) Add new BS current model

<u>Future plans</u>

- Analysis of applicable range of BS current model (dependence of beta value and profile shape etc.)
- Improvement of BS current model