A Rationale for Fusion Energy Development in Japan

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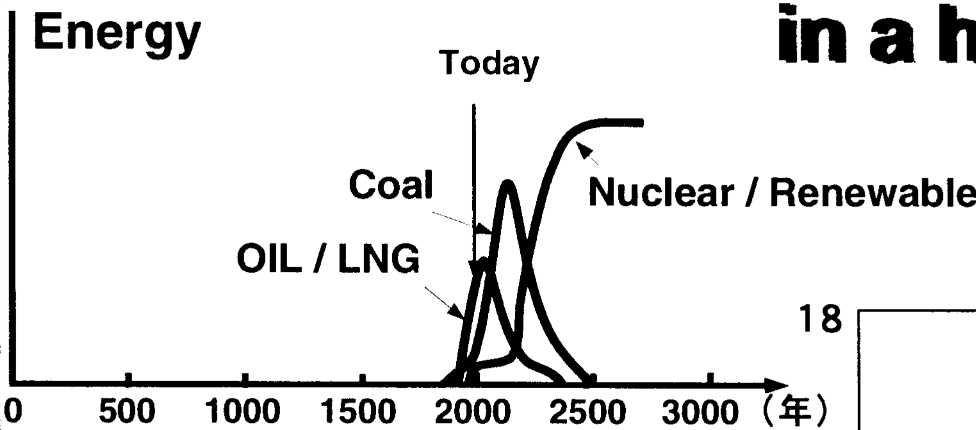
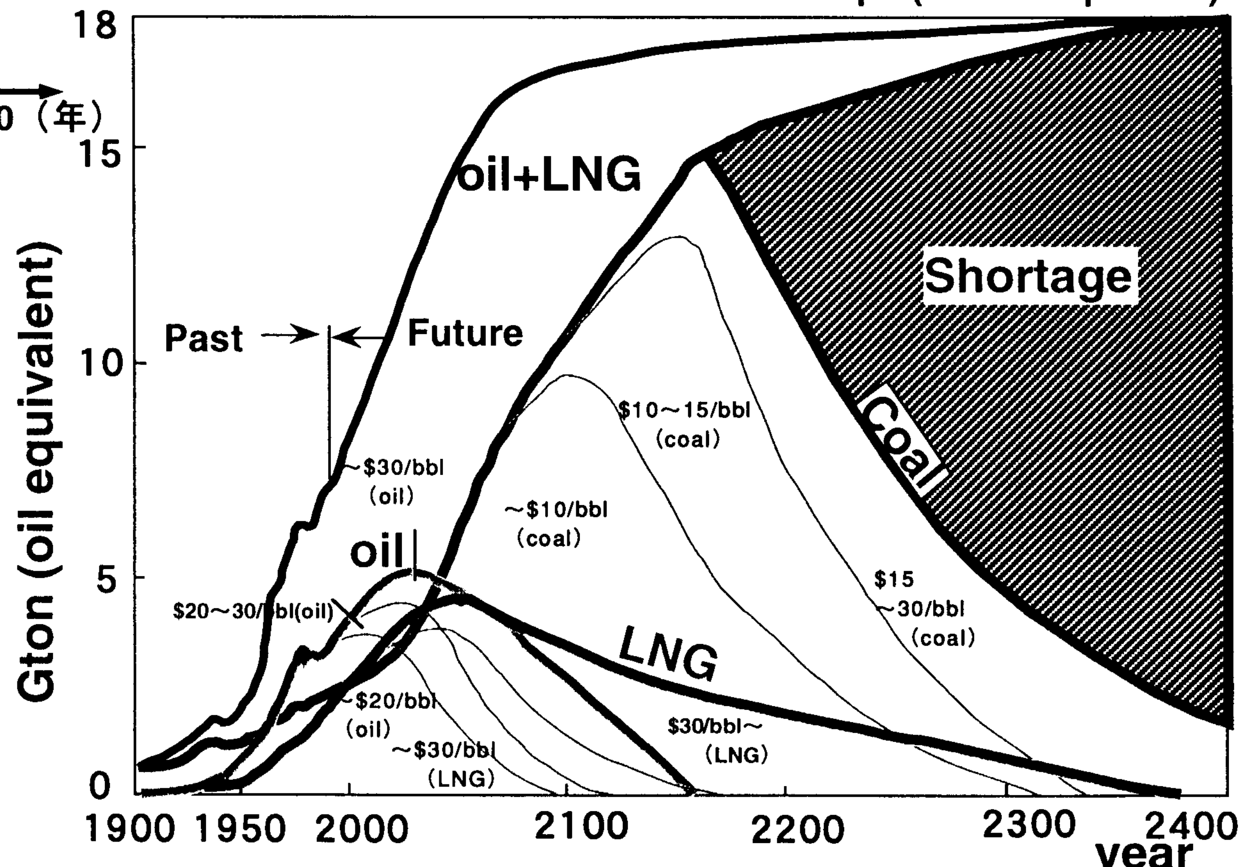
JAERI

Plenary Session July 12
" Fusion Summer Study "
Snowmass, Aspen, Cololad

We are experiencing very short Fossile Era in a history of human kind



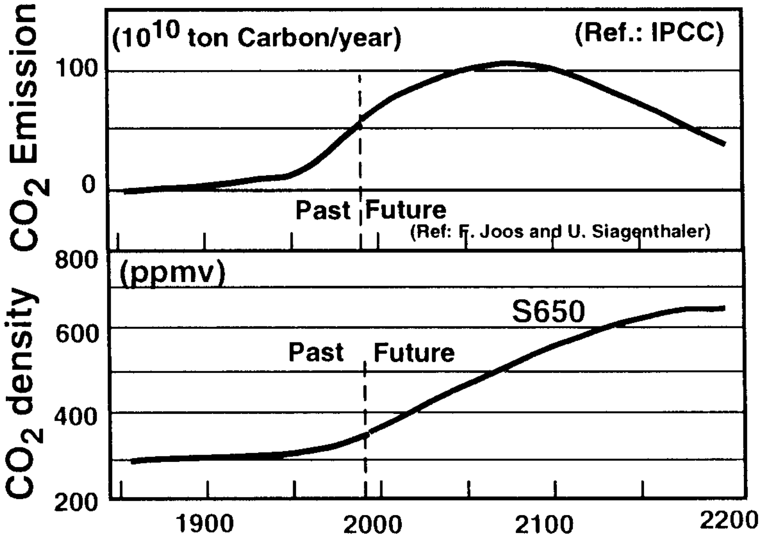
Assume world population saturates at 12 Billion People(1.67TOE/person)

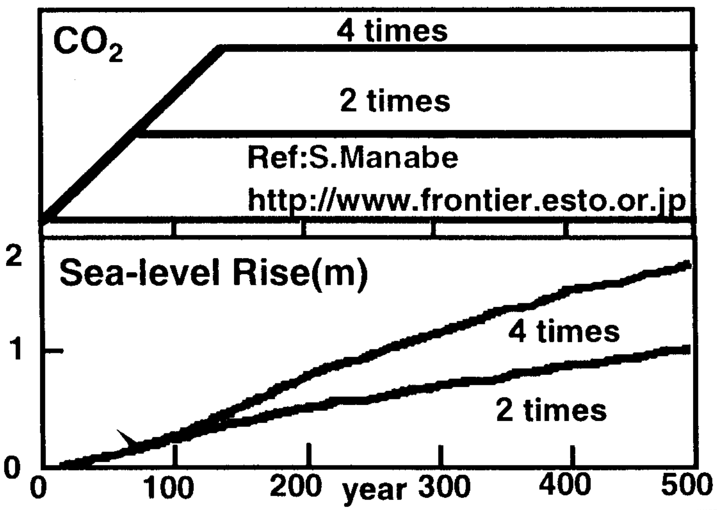


Ref. "TRI-LEMMA"
Three Major Problems Threatening World Survival , Susumu Yoda, General Editor,1998

Global Warming and Sea-level Rise

1m Sea-level rise would produce serious influence in Japan





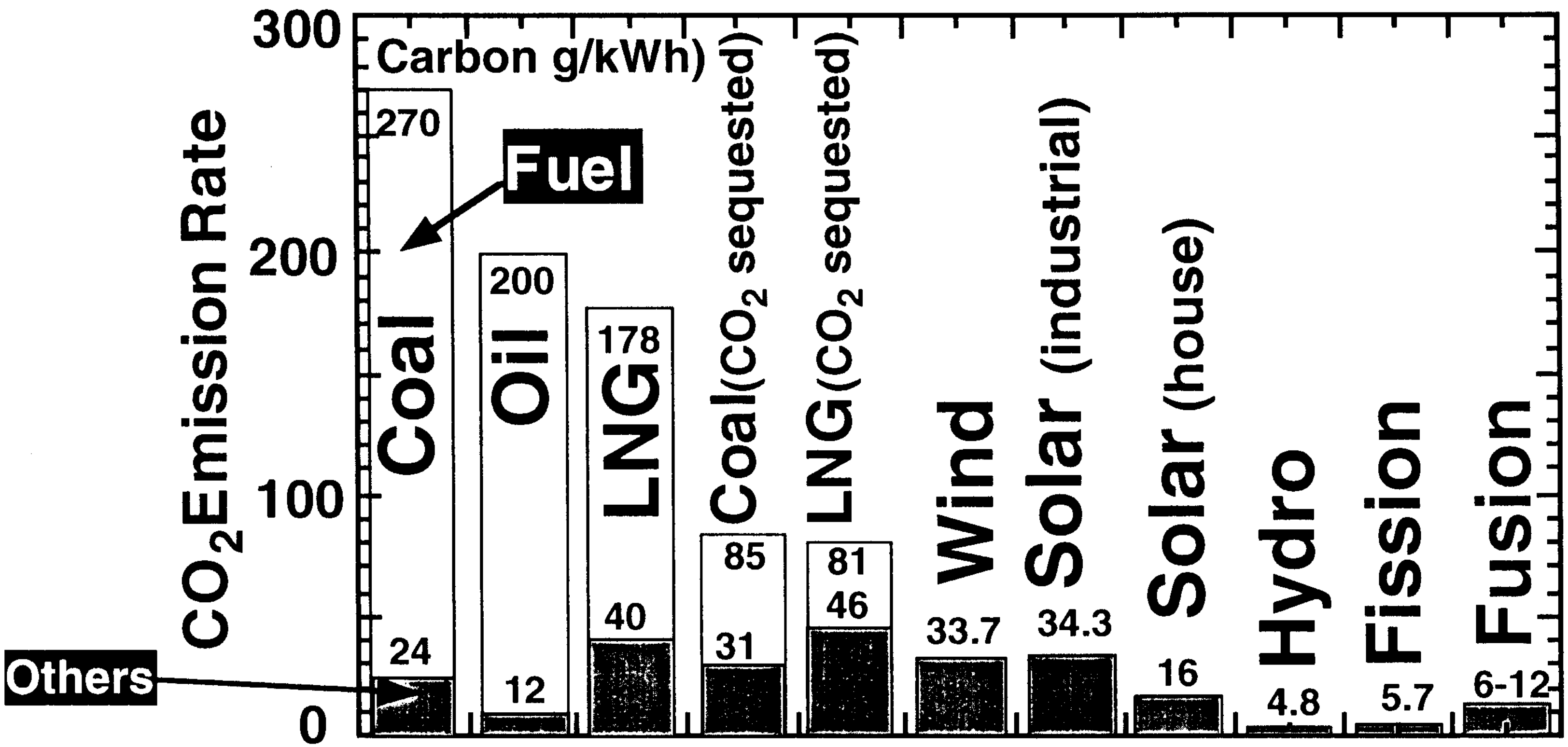
Effect in Japan (Case of 1m rise)

Estimated protection costs of Coastal infrastructures ~11.5 trillionYen (~100B$).

(White Paper of Enviroment, 1997)

CO_2 Emission Rates

Low CO_2 emission rate is an advantage of Fusion.

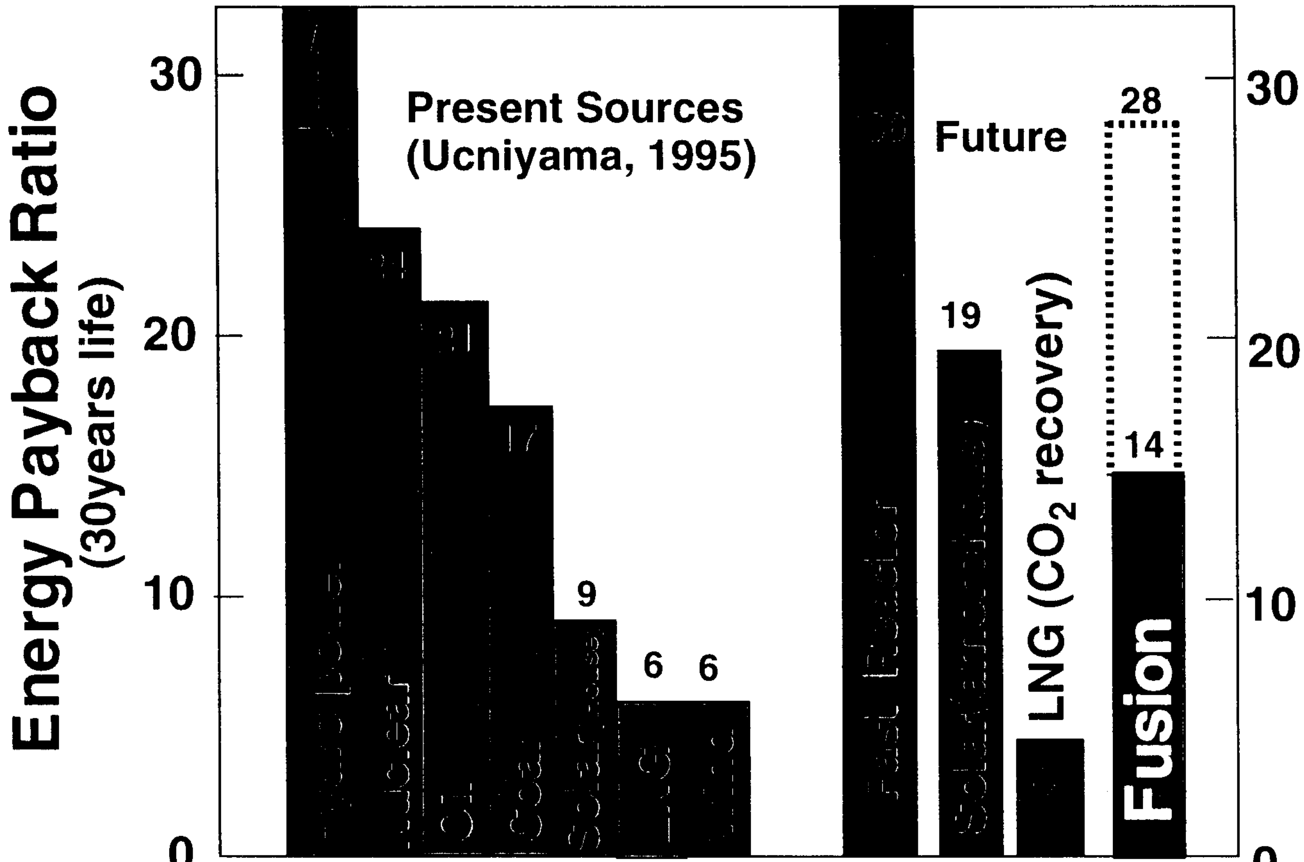


$$CO_2 \text{ Emission Rate} = \frac{CO_2 \text{ (Const/Ope/}CH_4 \text{ leak+Fuel)}}{\text{Electric Power Production}}$$

Ref. : Fusion : Tokimatsu, 1998
Others : Y. Uchiyama, 1994

Energy Payback Ratios

Estimated energy payback ratio for Fusion Reactor is large enough compared with other energy sources.

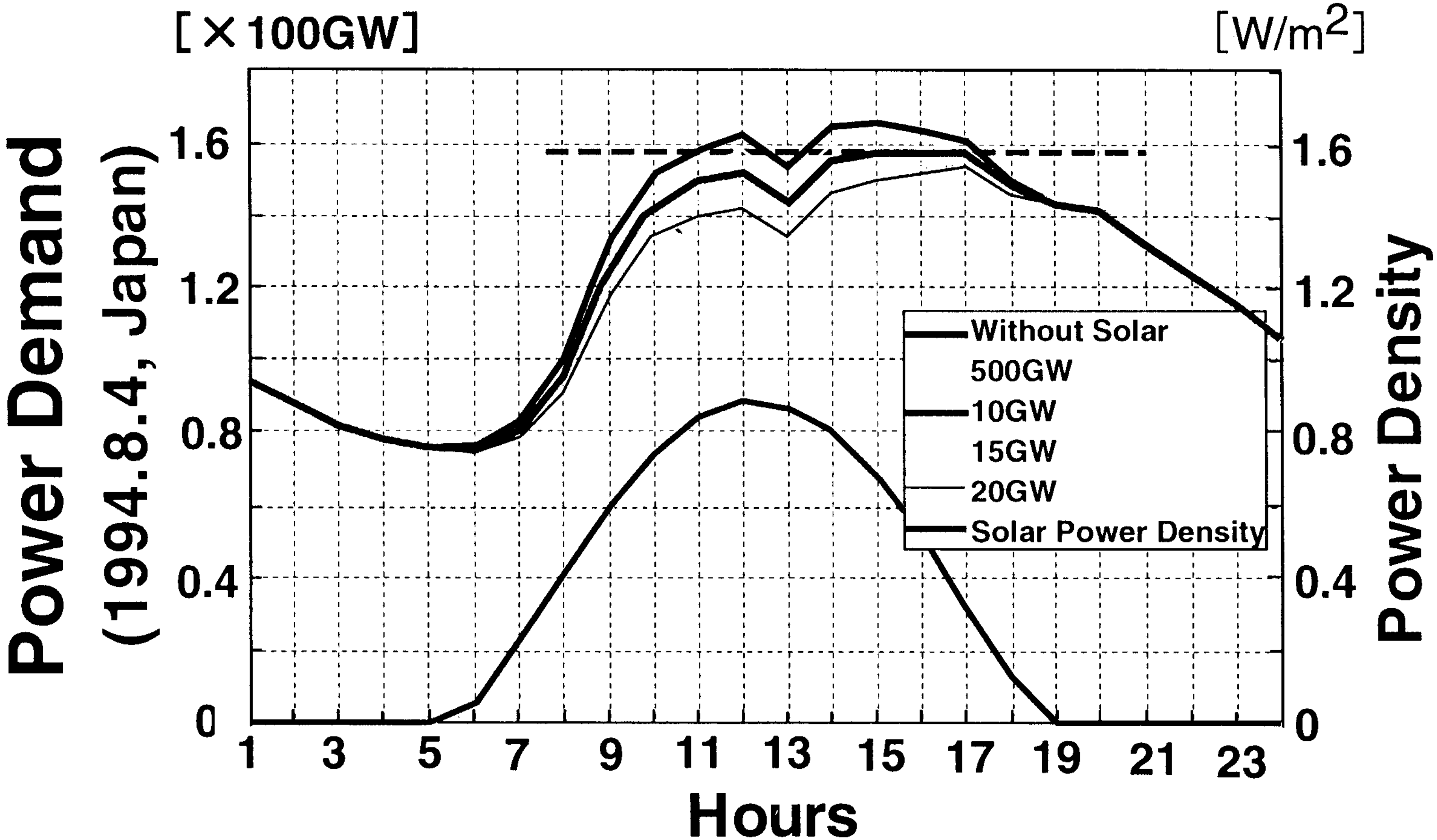


Fusion : Tokimatsu 1998 (IAEA-TCM)
Others : Uchiyama 1995

Solar Power is expected for Peak Cut

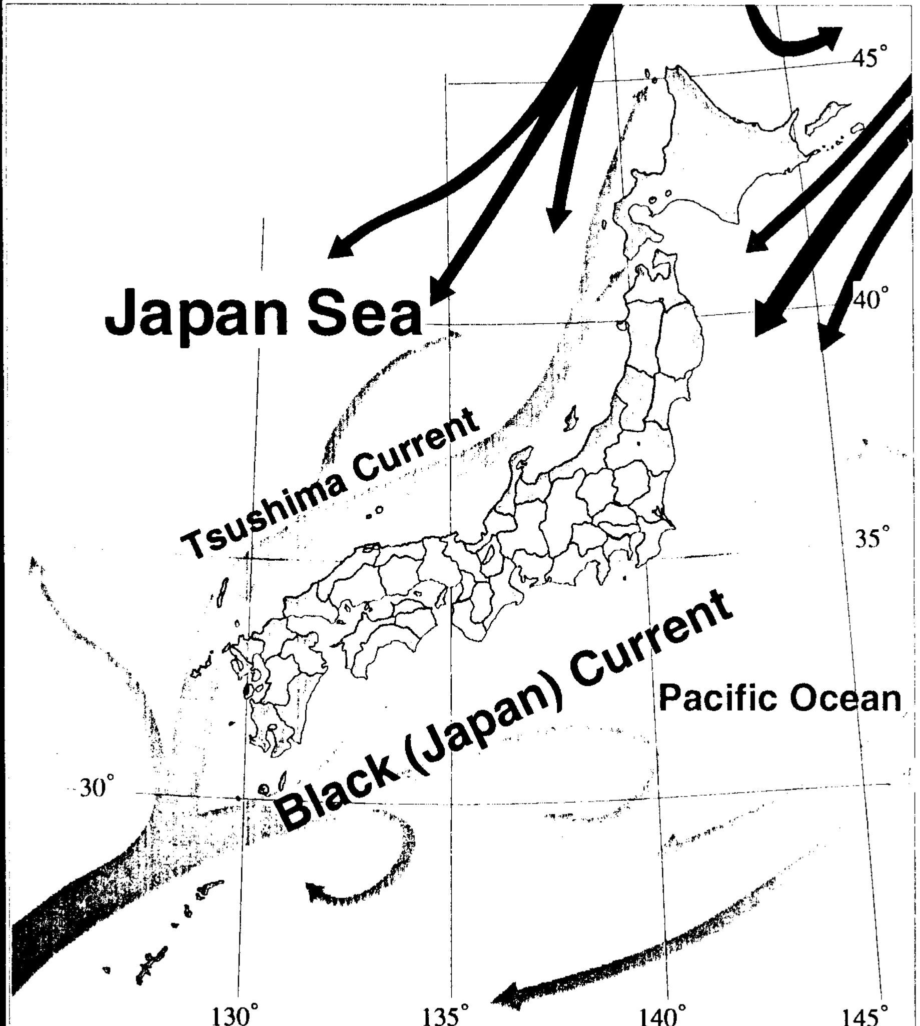
- **Solar power > 10GWe does not contribute to peak cut .**

- 10GW solar power ×12% availability ~ a 1.5GW fission ×80% availability -

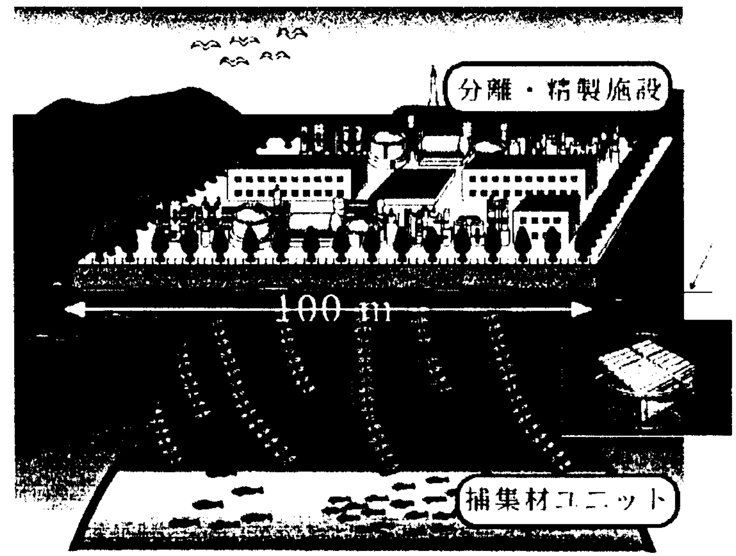


Ref. : Y. Uchiyama, CRIEPI

Lots of Resources in the Black (Japan) Current



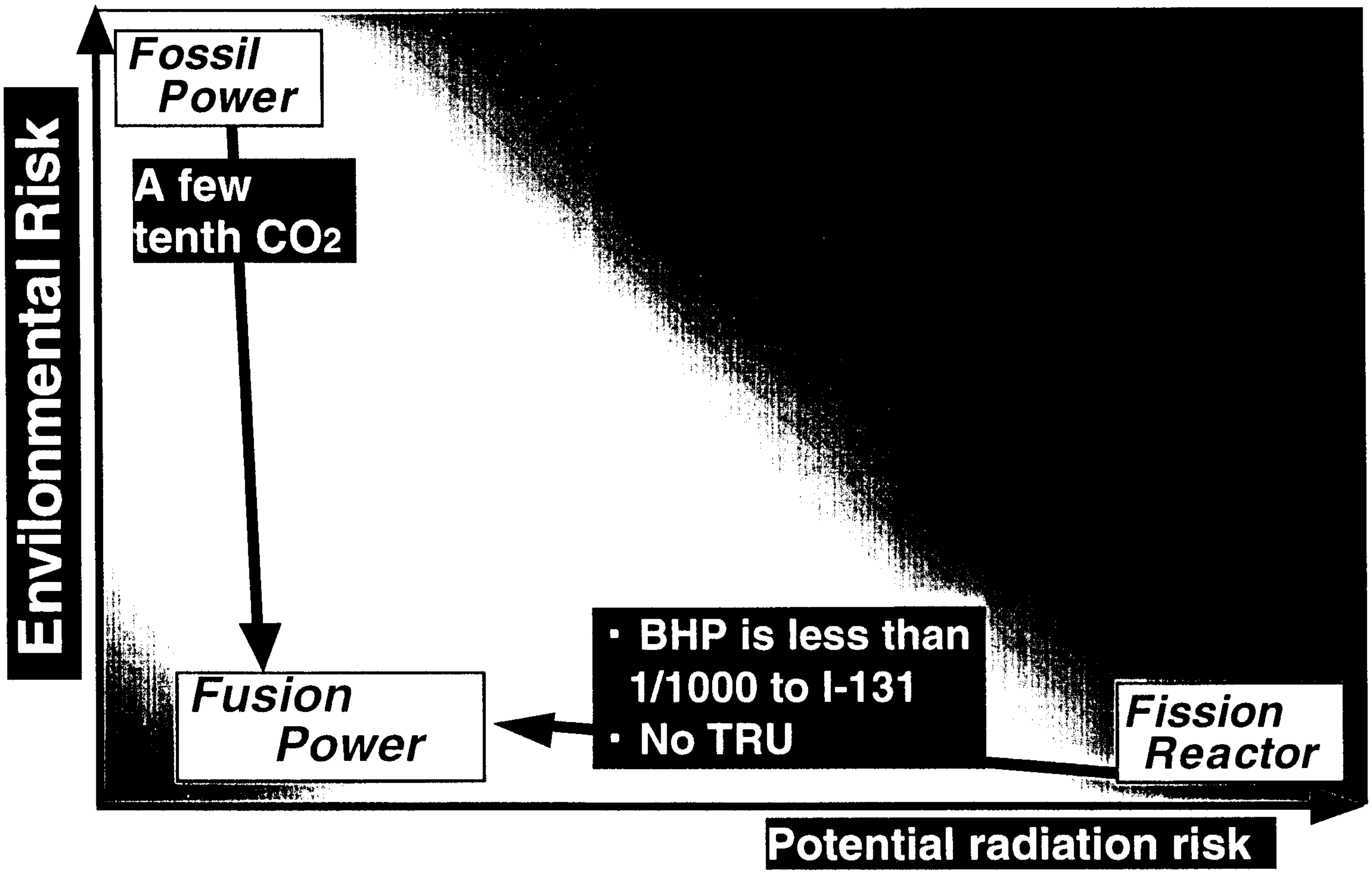
	Density	Resources carried by Black Current	Mass flowdensity $/m^2/year$
Li	170ppb	268ton/year	8.5 ton
U	3.3ppb	5.2ton/year	0.16ton
V	1.9ppb	3.0ton/year	0.09ton



Concept developed for U collection from Sea (Dr. T. Sugo, JAERI, Takasaki)

Advantage of Fusion Power

Fusion Power can reduce risks for environmental deterioration and potential radiation damage, simultaneously.

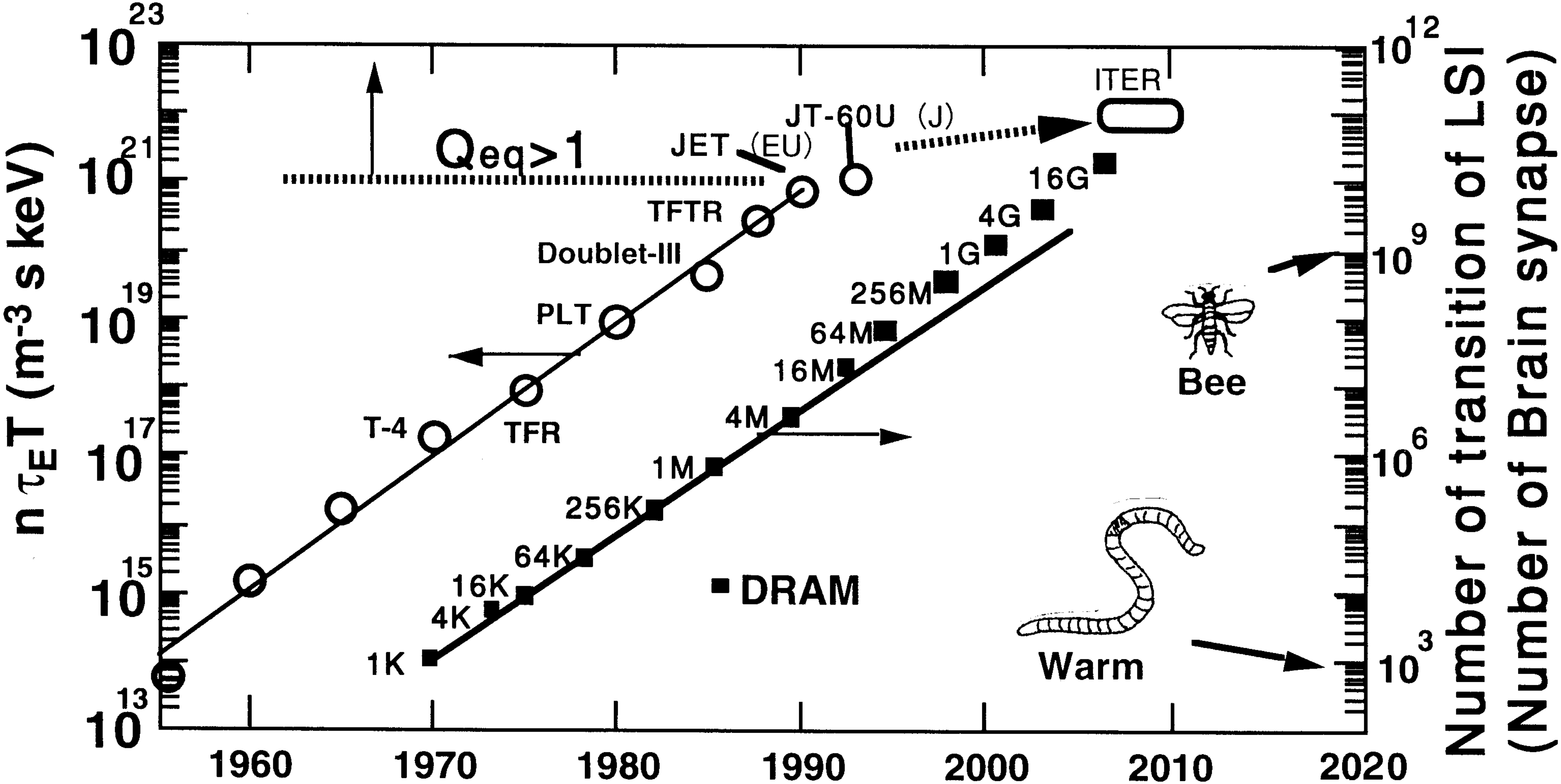


Energy Options for 21 Century

1) Fossil energy should be reduced if Global Warming is serious.
2) Renweable energy has issues of Supply inflexibility and lack of large sunny(windy) land in Japan.
3) Fission must improve Public Acceptance, and should be increased to improve Global Warming Problem.
4) Fusion has many potential advantages while cost effort is stringent.

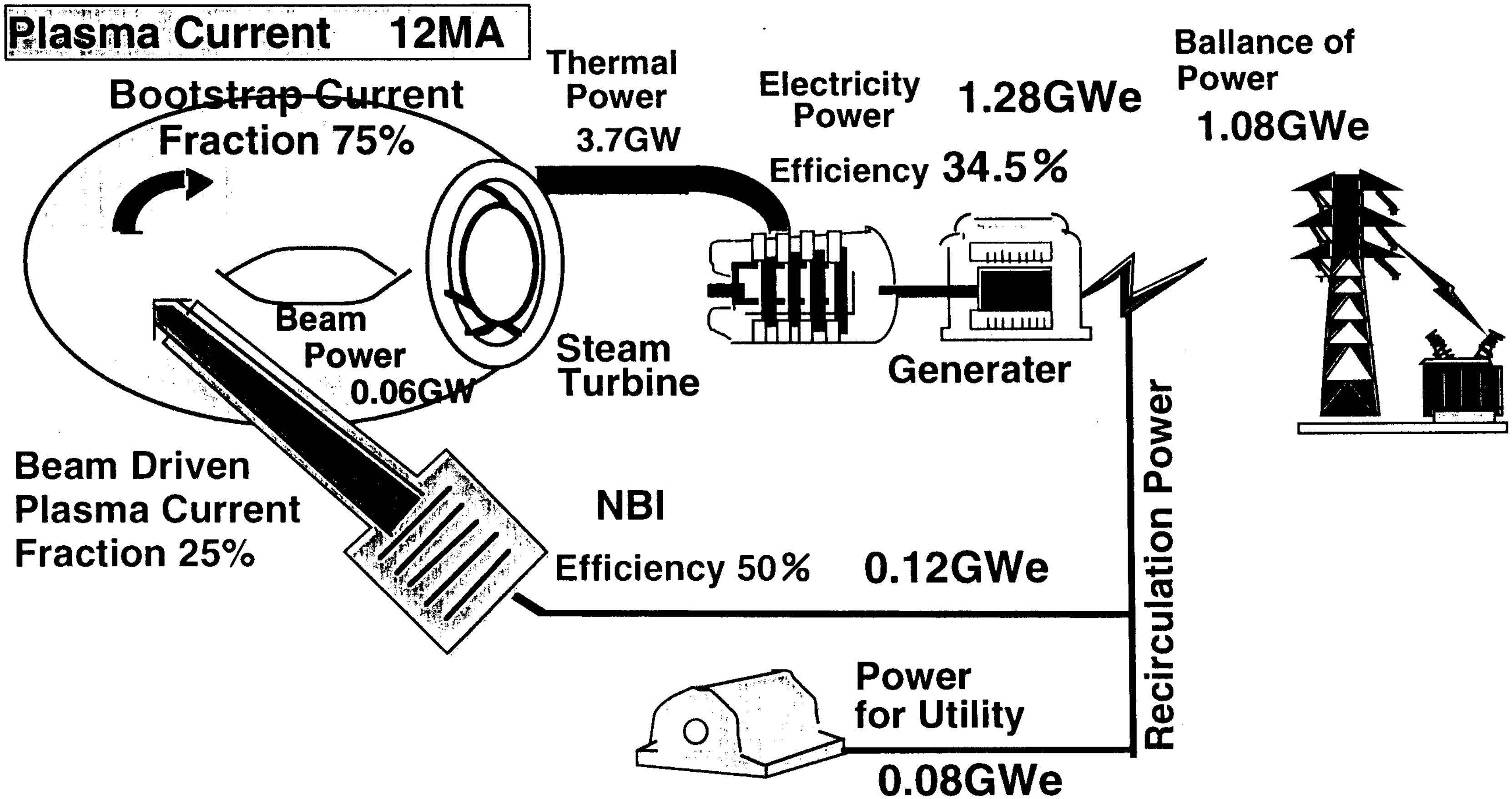
	Fossil	Fission	Renewable	Fusion
Supply Stability	◎	◎	×	◎
Large Scale Supply	◎	◎	△	◎
Resource	○	◎	◎	◎
CO_2 Emission	×	◎	◎	◎
Waste	○	△	◎	○
Siting	◎	△	△	○
Safety(1/BHP)	○	△	◎	○
Cost	◎	○	△	△

We must proud of our scientific progress which is as rapid as that of IC.

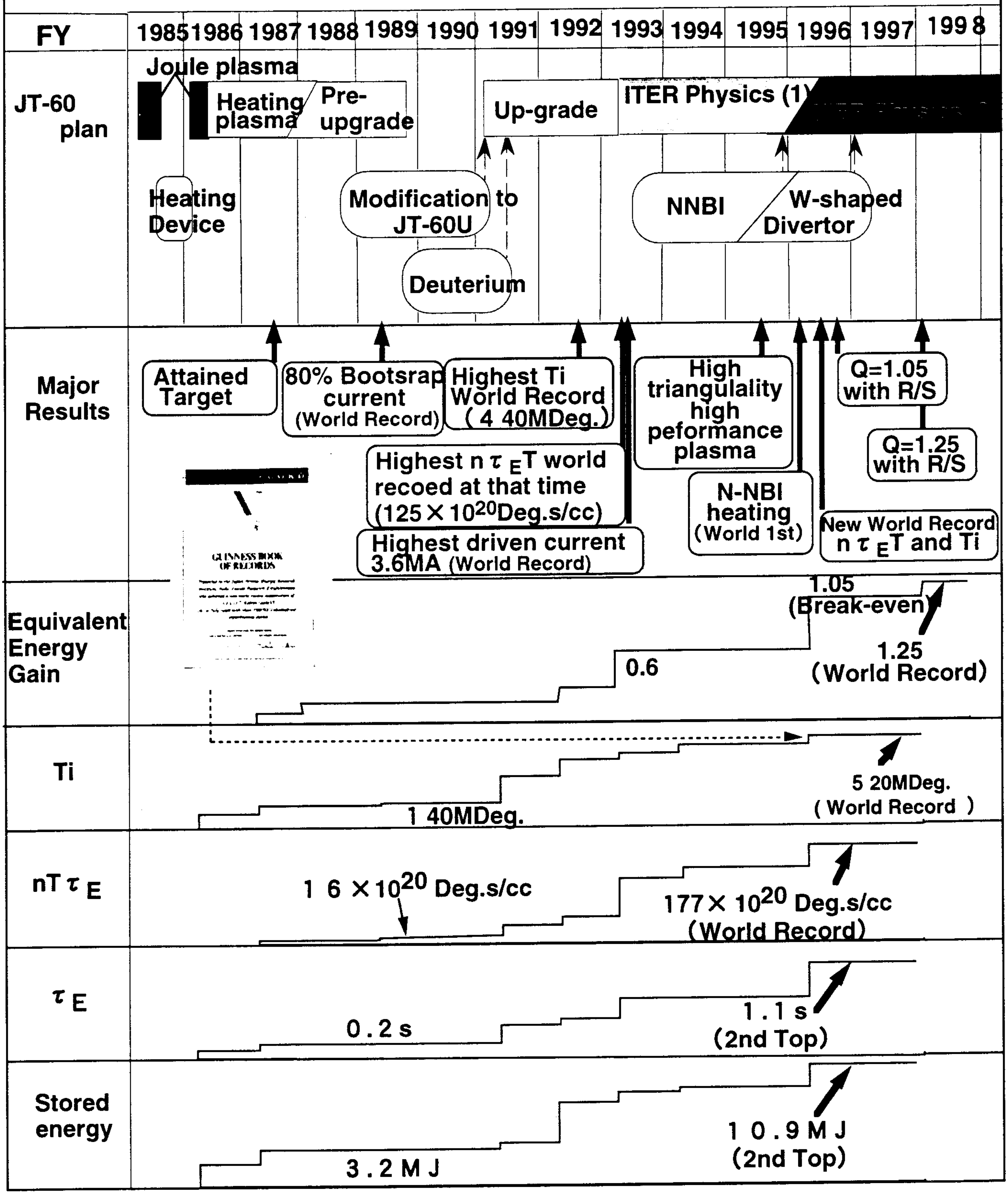


Principle of SSTR

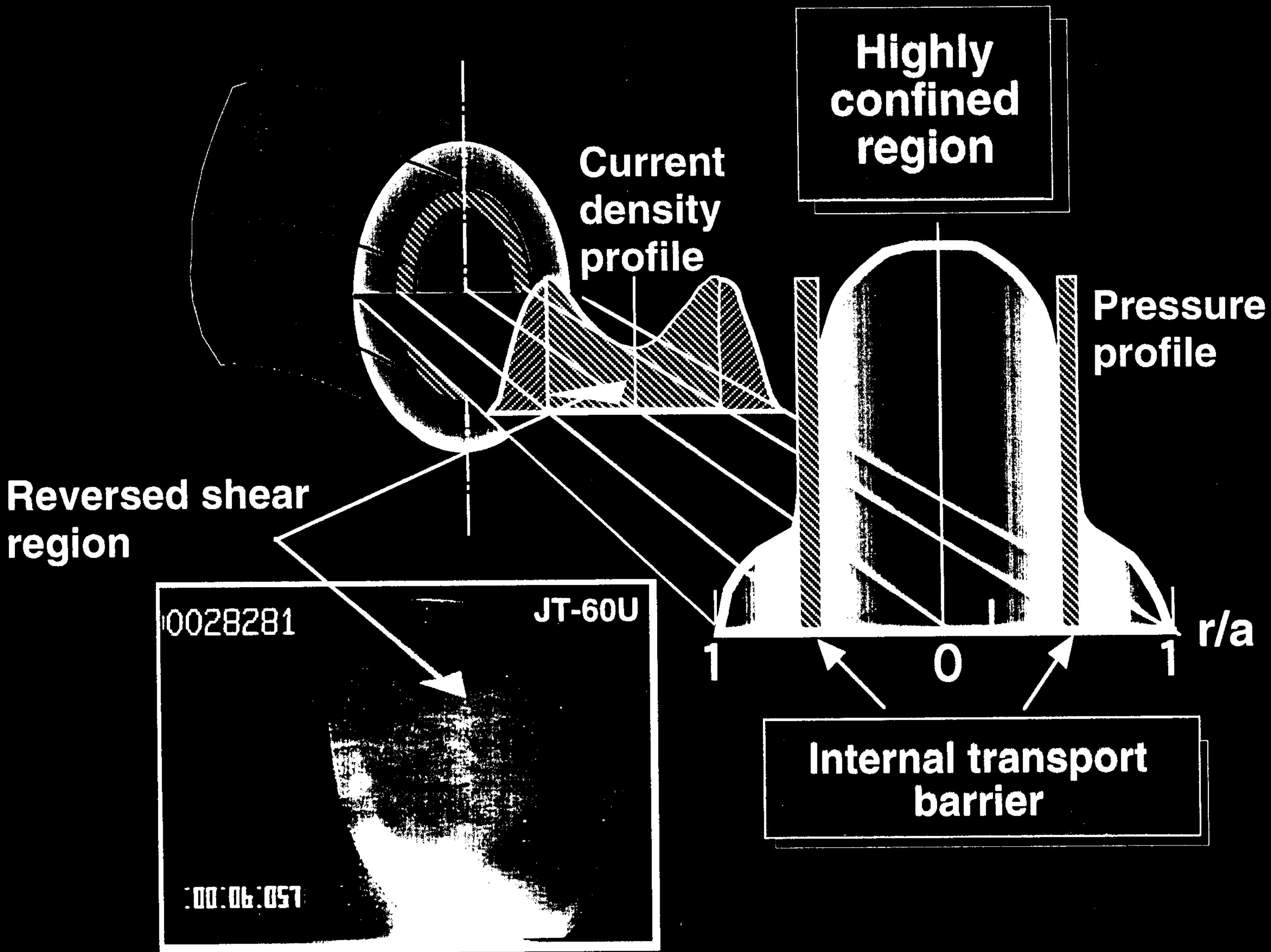
A low Ip with a large Bootstrap Current fraction allows reduction of re-circulation power.



JT-60 Progress and Achievement



Confinement improvement in reversed shear discharge

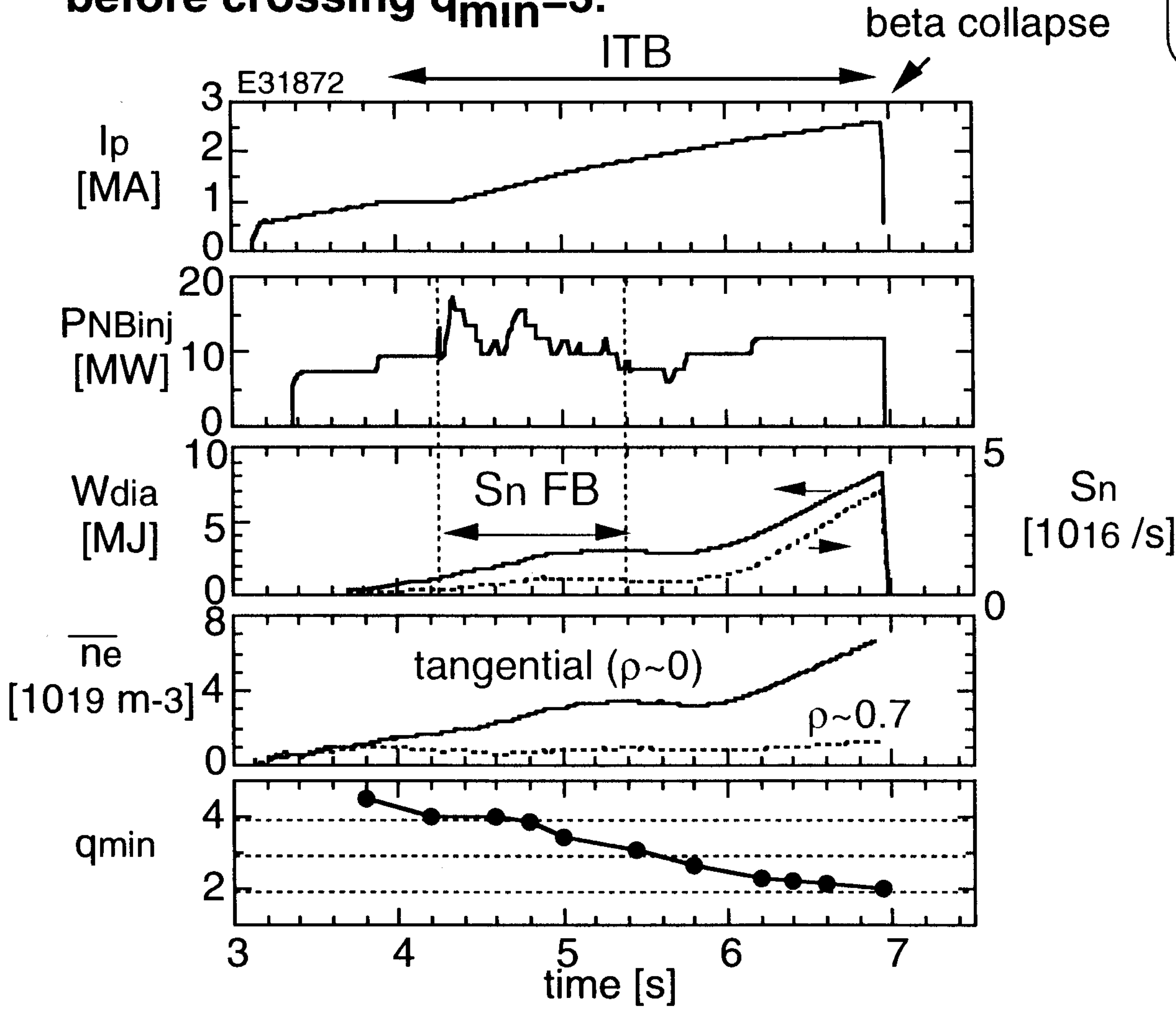


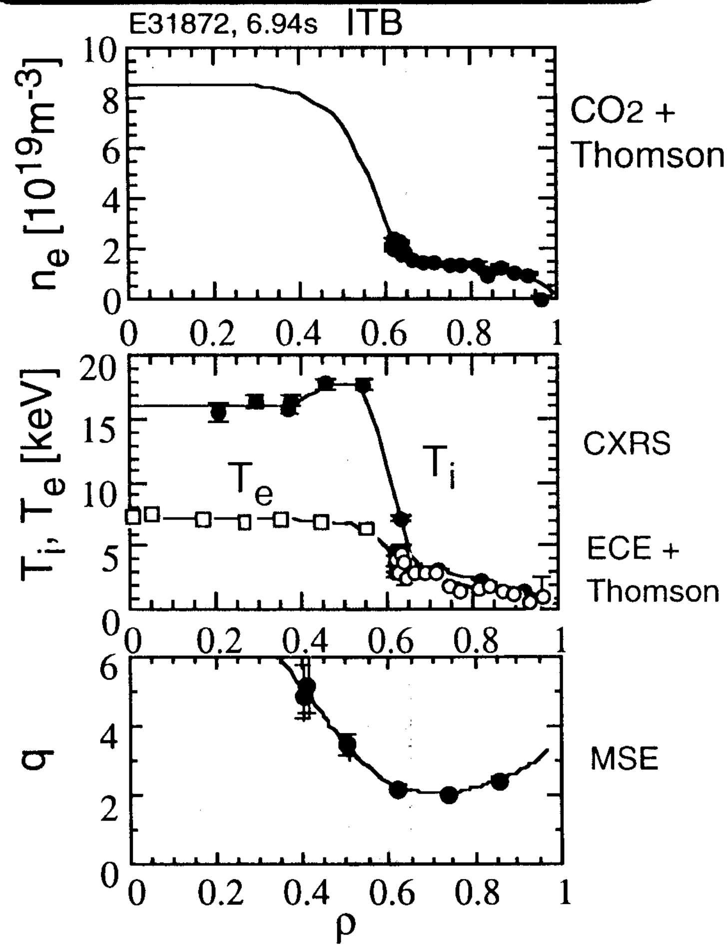
Reversed shear operation significantly improves fusion amplification factor

JT-60U

- Current ramp-up with persistent ITB.
- Sn feedback with NB power before crossing $q_{min}=3$.

$Q_{DT}^{eq}=1.25$, $S_n = 3.6 \times 10^{16}$ /s
$W_{dia} = 8.2$ MJ, $\tau_E = 1.07$ s
$H_{ITER89P} = 3.2$, $\beta_N = 1.53$

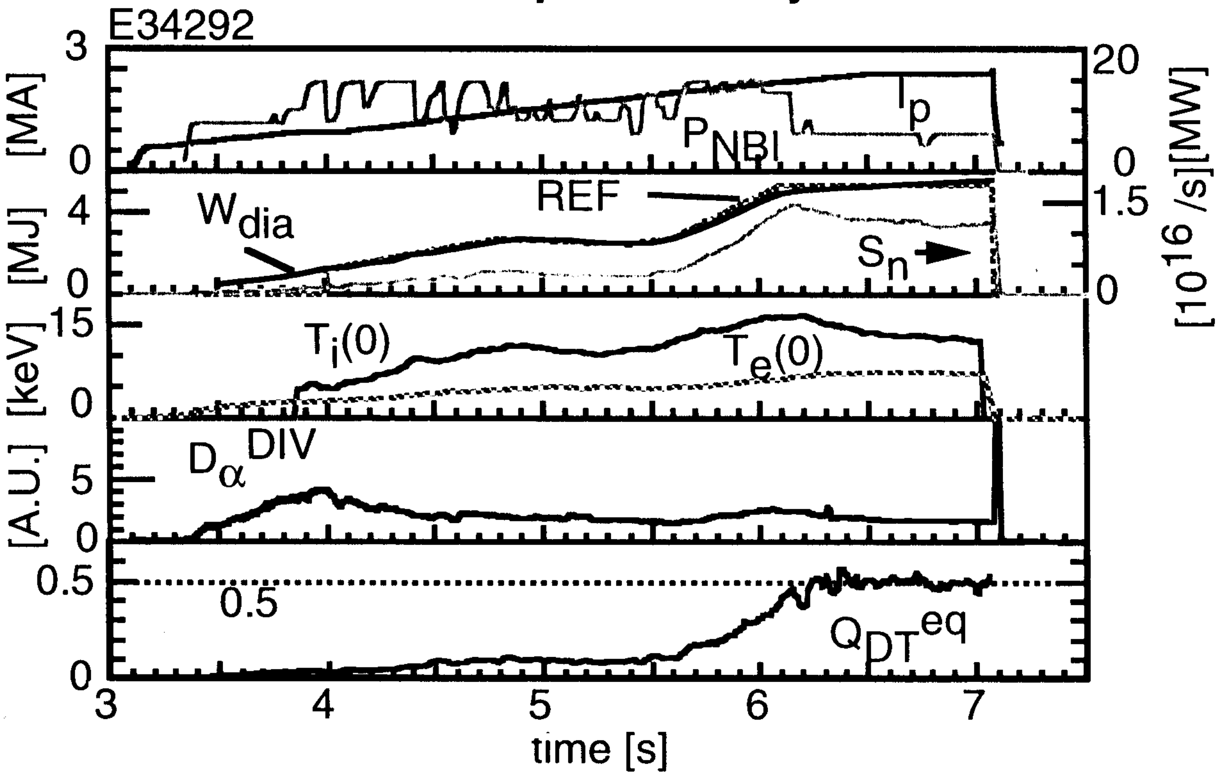




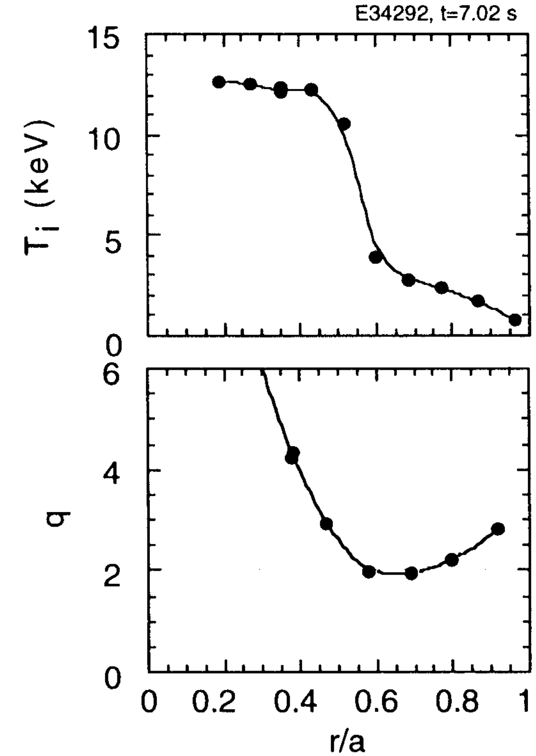
Sustainment of high performance reversed shear

JT-60U

Feedback control:
to avoid a collapse at q_{min}~3
to achieve quasi-steady state



- **q_{min} decreasing due to current penetration**



Termination: Collapse at q_{min}~2, β_N~1.2

- **Sustained performance with I_p=2.4MA, B_t=4.3T;**

  Q_{DT}^{eq} ~0.5 and H-factor~2.7 for ~0.8 s (τ_E ~0.9s) ,

  $n_D(0)\tau_E T_i(0)$~3.9x10^{20} m^{-3}•s•keV

Extension of quasi-steady high- β_N discharge region toward low q_{95}

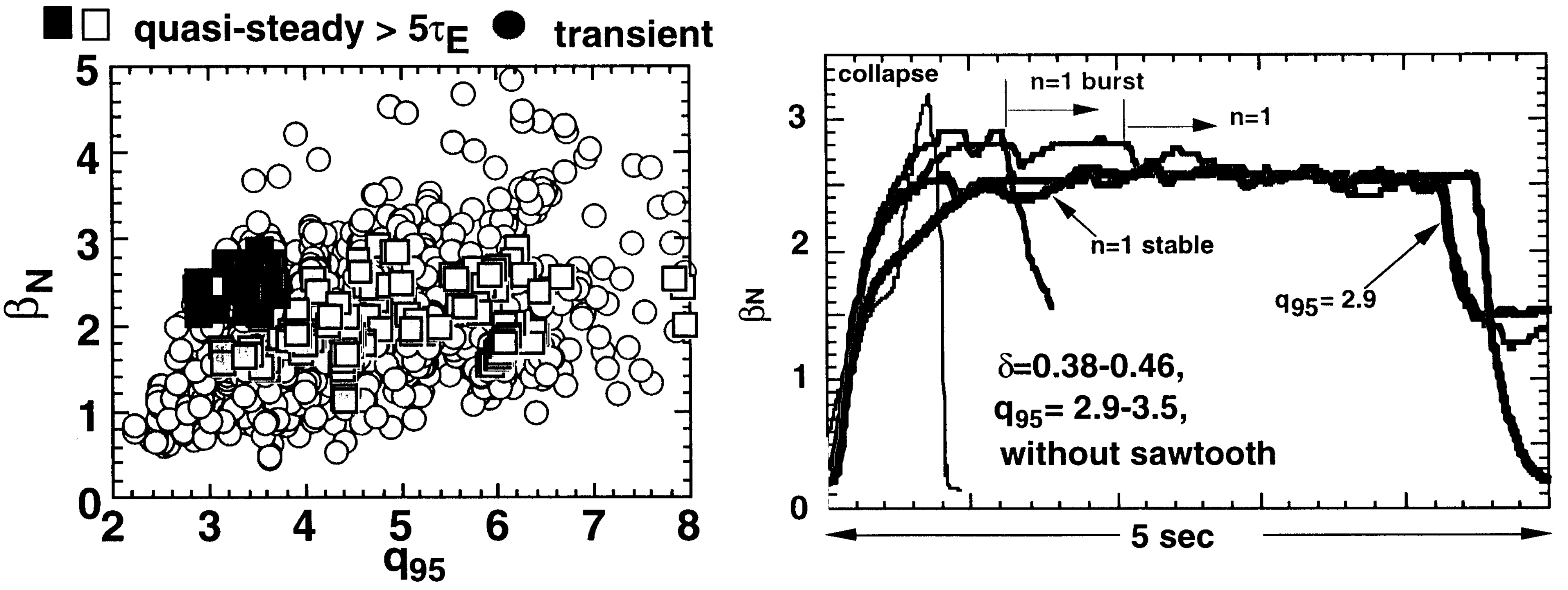
JT-60U

High β_p ELMy H-mode with high δ (=0.46) & q(0)>1

Medium p0/<p> maximizes β-limit (kink-balloon. + ELM).
At q_{95}~3, β_N=2.5-2.7 can be sustained for 3.5s (1.7-2.1T)

ν_e^* (r=a/2) ~ 0.04 - 0.05 (~ ITER-FDR)

If β_N>2.8, n=1 mode: ~ neoclassical tearing mode



quasi-steady β_N ~2.7 at 3.6T

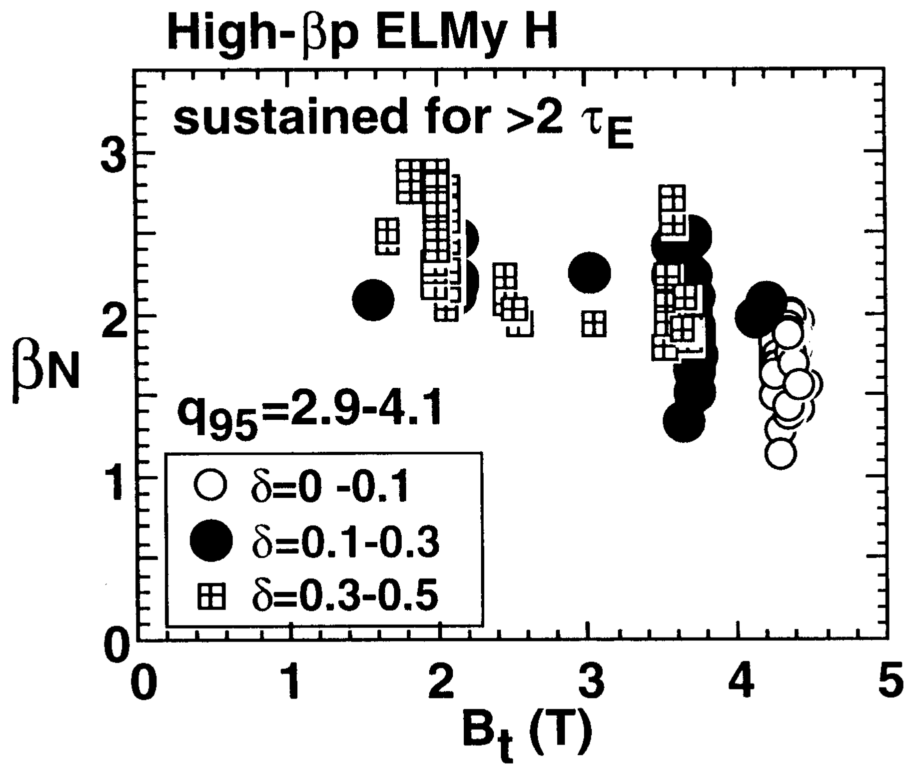
JT-60U

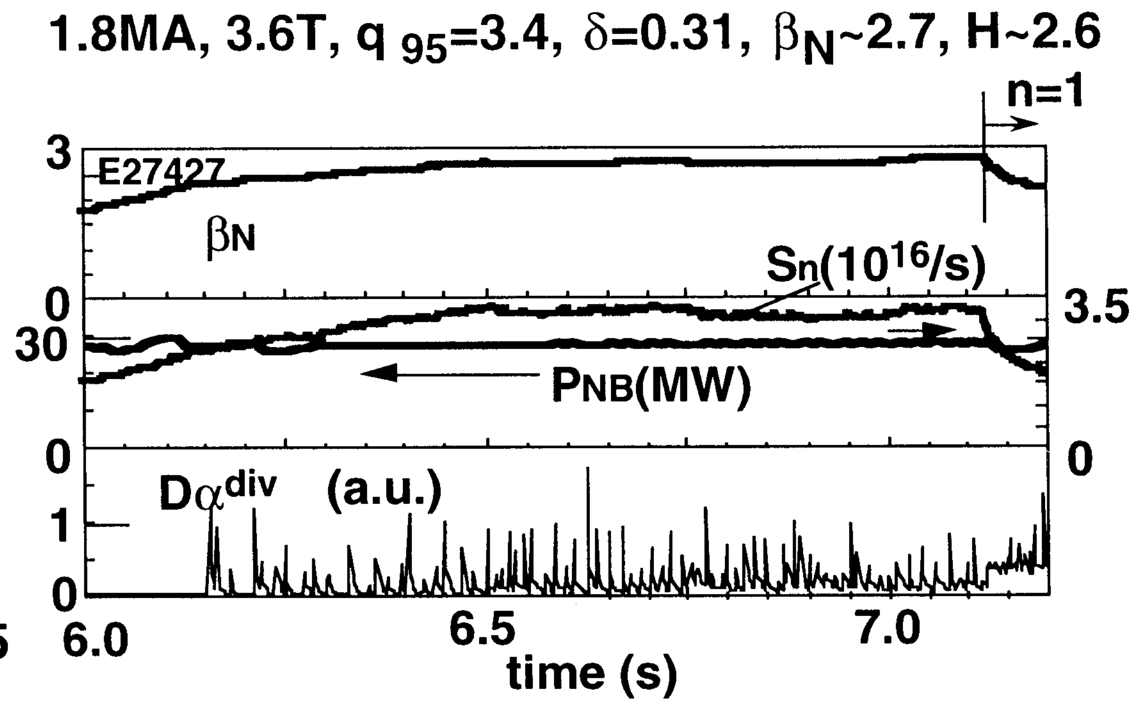
Suatainable β_N increases with triangularity.

β_N~2.5-2.7 was sustained for 3.5s (>15τ_E) at 1.7-2.1T/ 1MA (q_{95}~2.9-3.5): δ~0.46

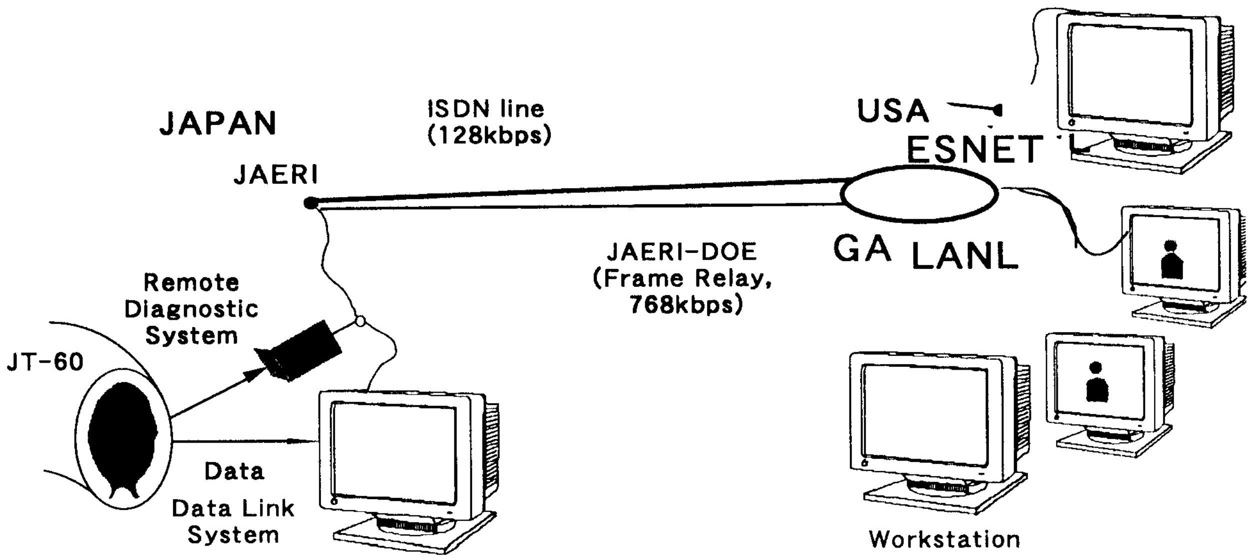
β_N~ 2.7 was sustained for 0.7s (~2τ_E) at Bt=3.6T / Ip=1.8MA (q_{95}~3.4): δ~0.31

Low sustainable β_N at ~4.4T : small δ <0.1





Remote Collaboration is essential for world fusion community



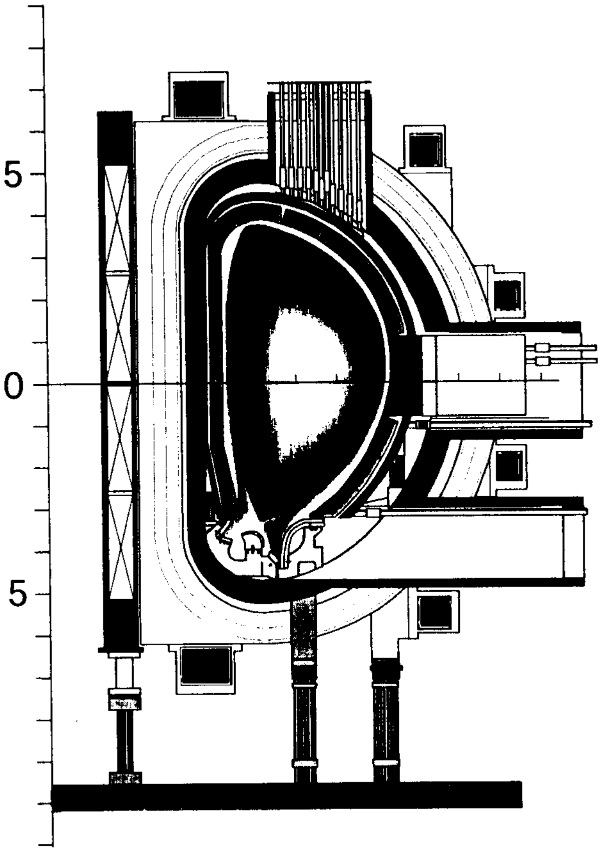
ITER oparation range –pulse operation–

Features : Based on FDR scenario.

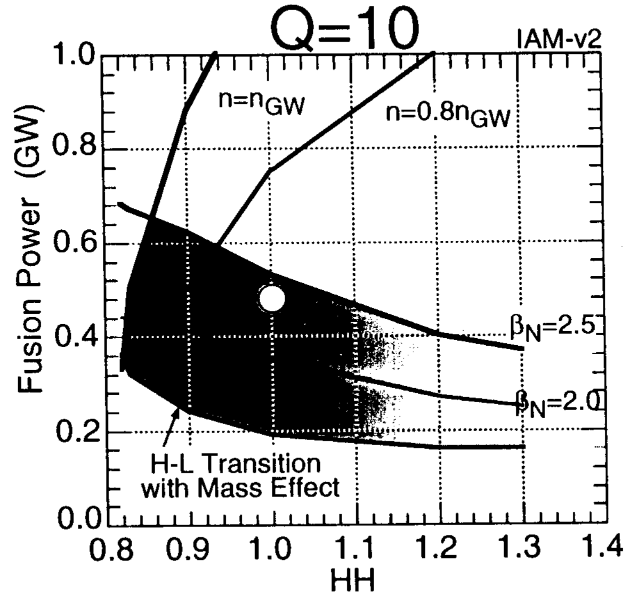
- Back Plate.
- Double shell VV.
- High non– circular plasma.

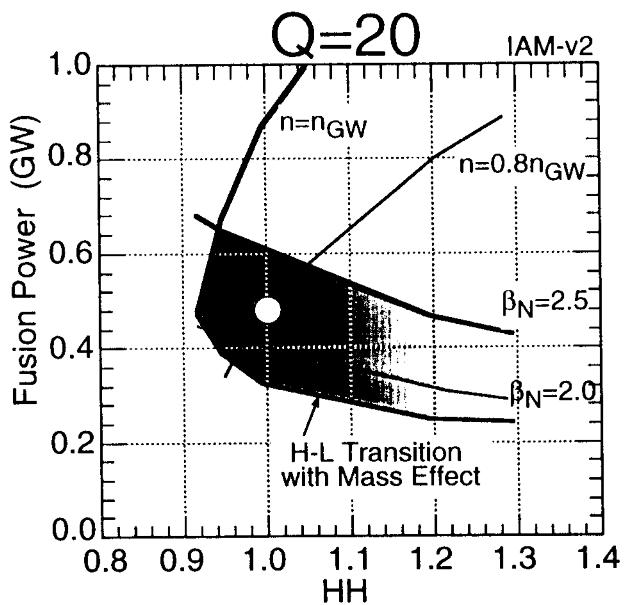
IAM-v2

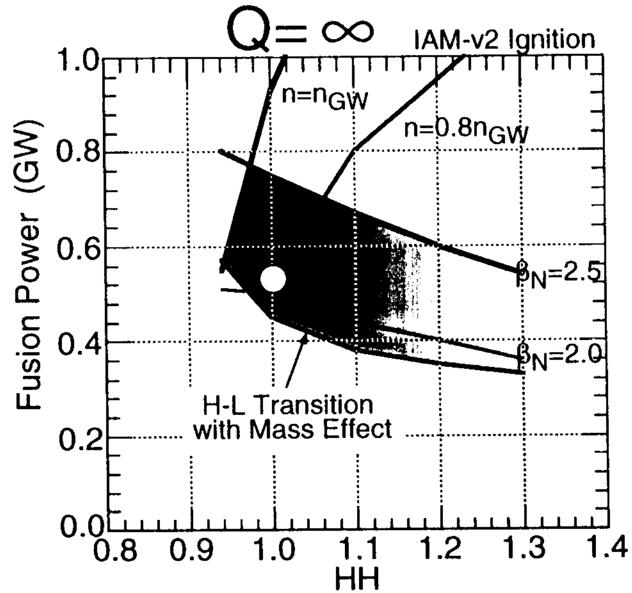
	Q=10	Q=20	Q= ∞
R(m)	6.2	6.2	6.2
a (m)	1.9	1.9	1.9
Bt (T)	5.51	5.51	5.51
Ip(MA)	13.3	13.3	14.0
Z_{eff}	1.8	1.8	1.5
κ_{95}	1.7	1.7	1.7
τ_{pHe}/τ_E	7	7	5



IAM-variant 2



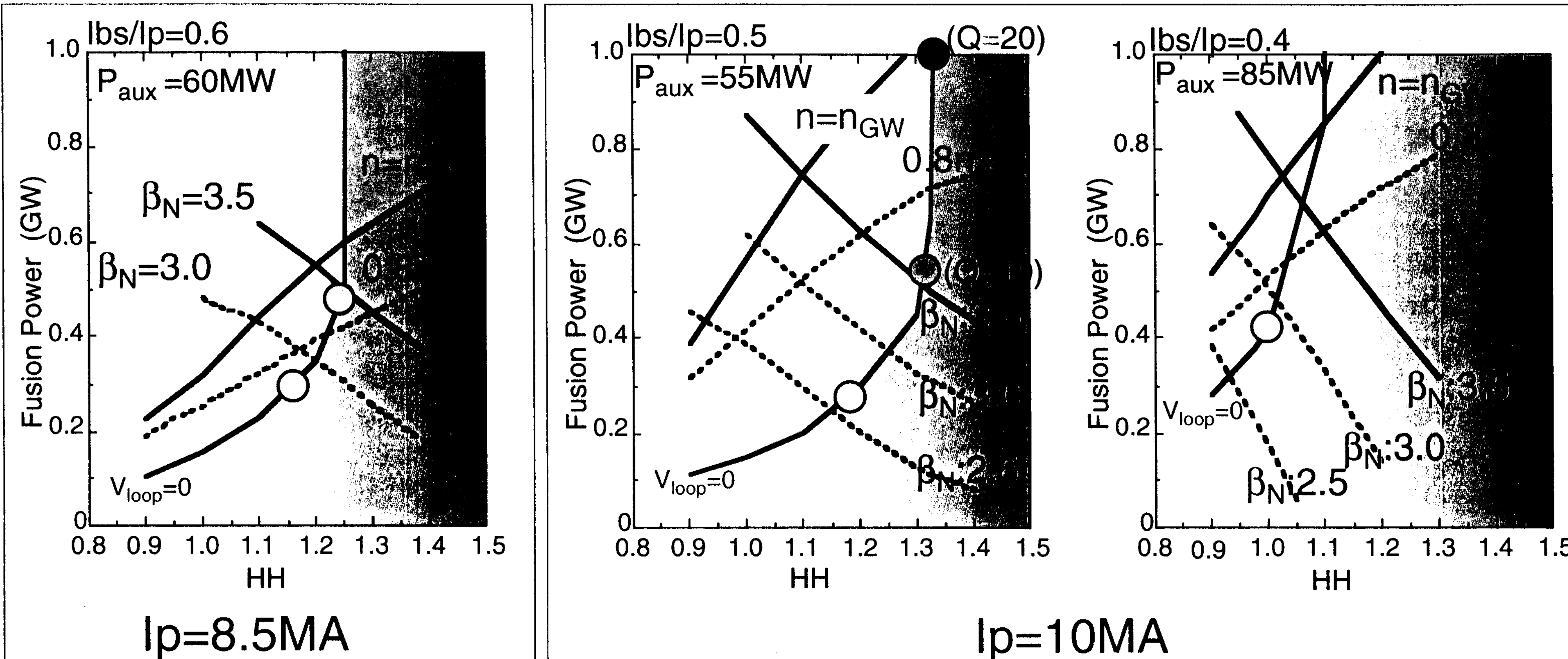




ITER Steady-state operation

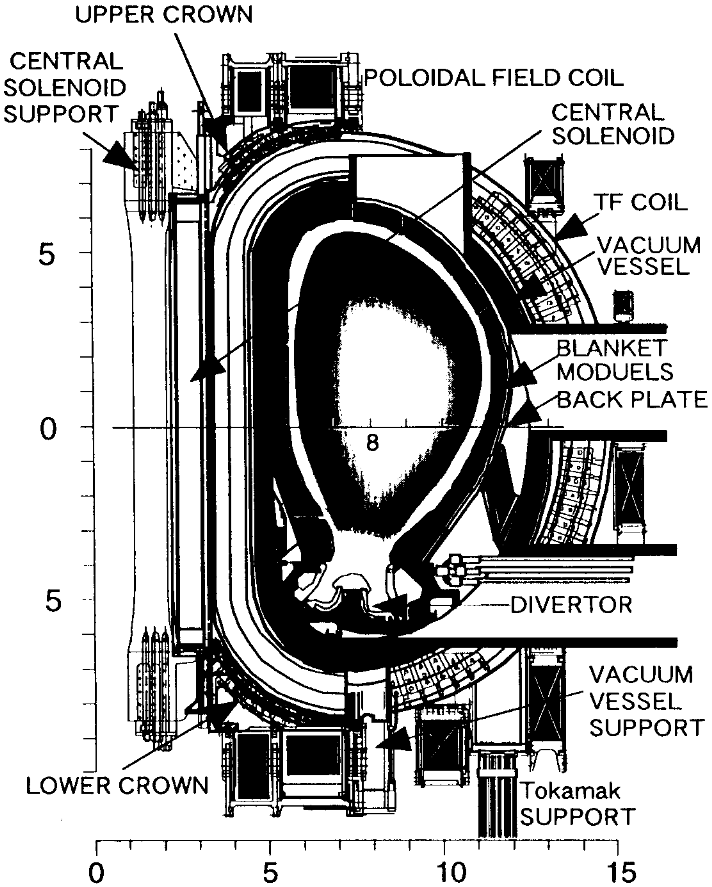
$Q \geqq 5$ possibility

with HH=1～1.3, P_{heat}=50～85 MW.



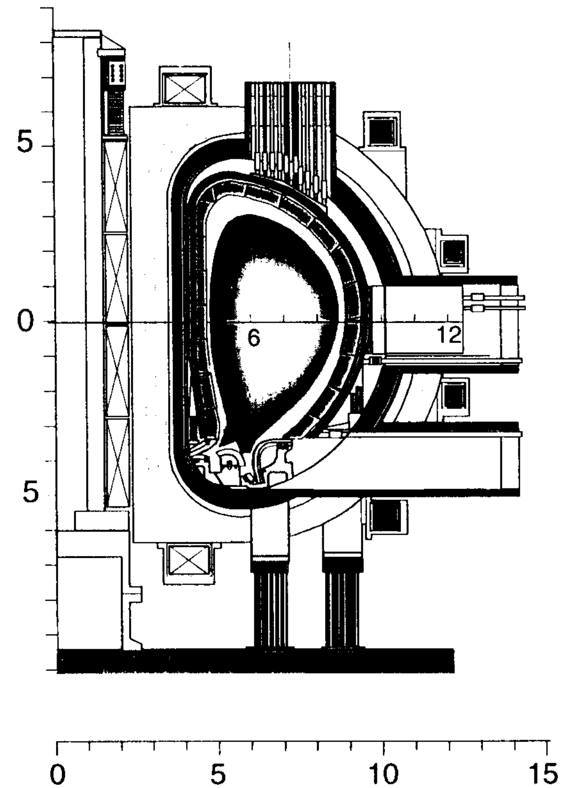
R/a=6.15m/1.75m、B=5.55T、κ_{95}=1.9、δ_{95}=0.47, Z_{eff}~1.5, τ_{pHe}/τ_E=6

From RC-ITER to DEMO (SSTR)



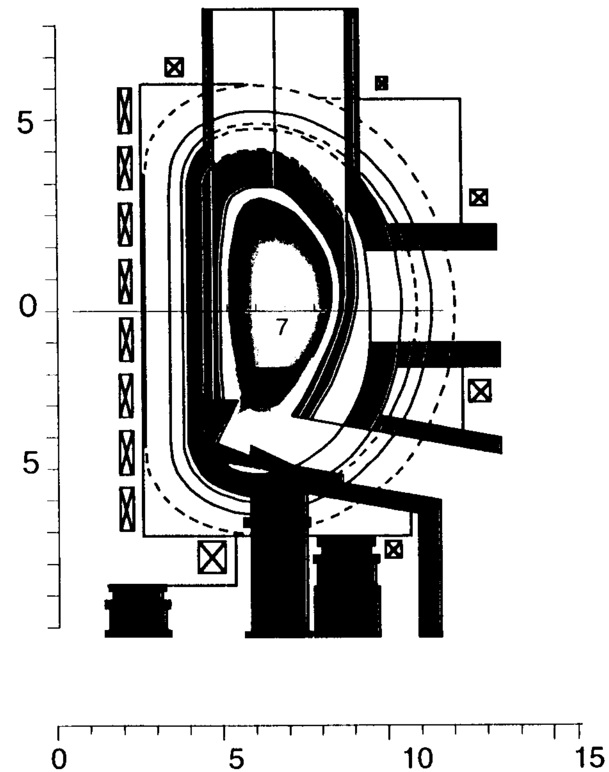
CURRENT ITER

Fusion Power 1500MW
Major Radius 8.1m
Weight 55,000 TONS



REDUCED COST ITER

Fusion Power 500～600MW
Major Radius 6.0～6.5m
Weight ～17,000 TONS



SSTR

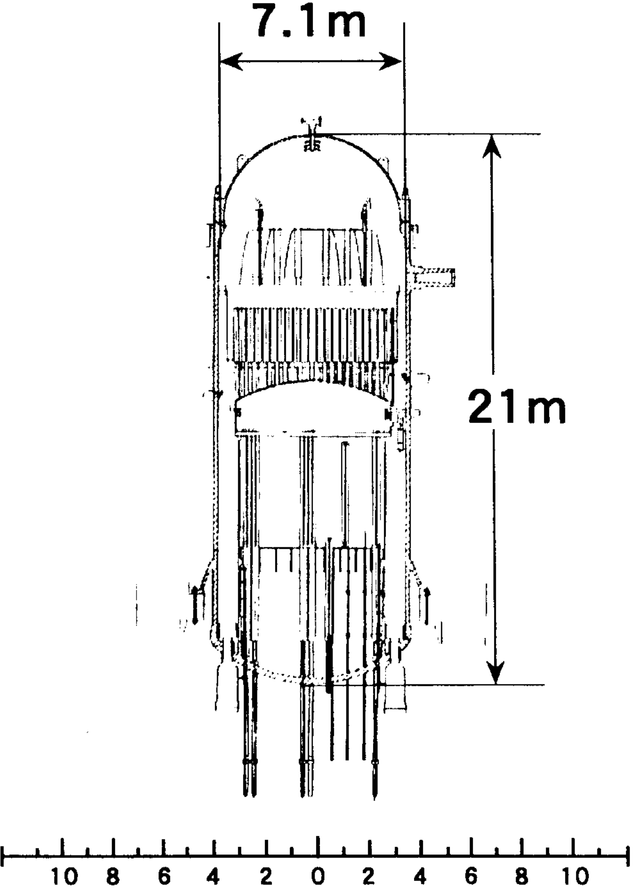
Fusion Power 3000 MW
Major Radius 7 m
Weight 30,000 TONS

From ITER to SSTR

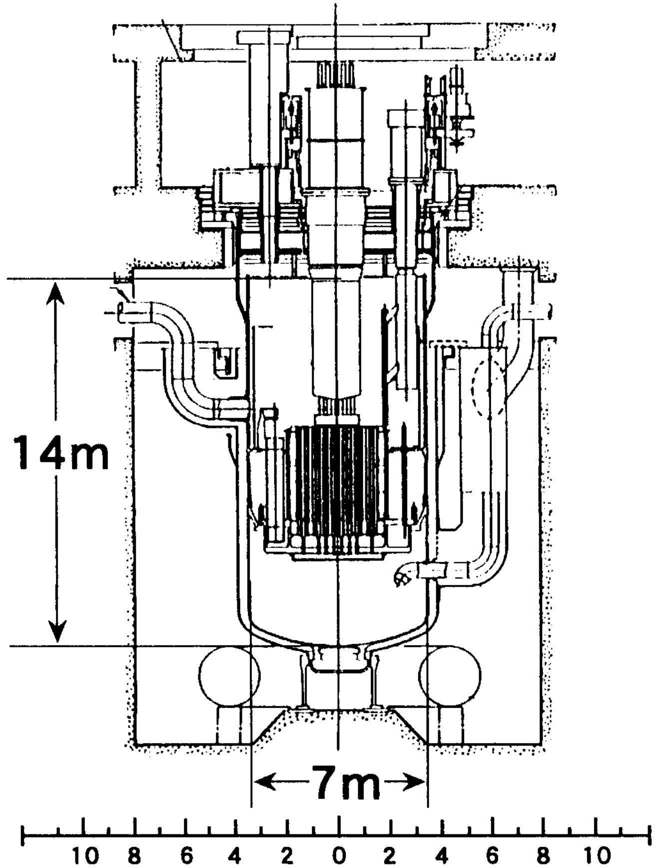
ITEM	ITER	SSTR
Burning Plasma	Q=10-20	Q=50
Steady State Operation	Q ≧ 5	Q=50
Plasma Plessure	A few atm.	~10 atm.
B_{max} of SC Coil	12T	16T
Normalized beta β_N	2.2~3(3.5)	3.5
Blanket	Module Test	Water /solid beeder
Structure Material	Stainles Steel	RAF(F82H)
Neutron Fluence	~0.3 MWy/m^2	~7MWy / m^2

Comparison between BWR, FBR and ITER

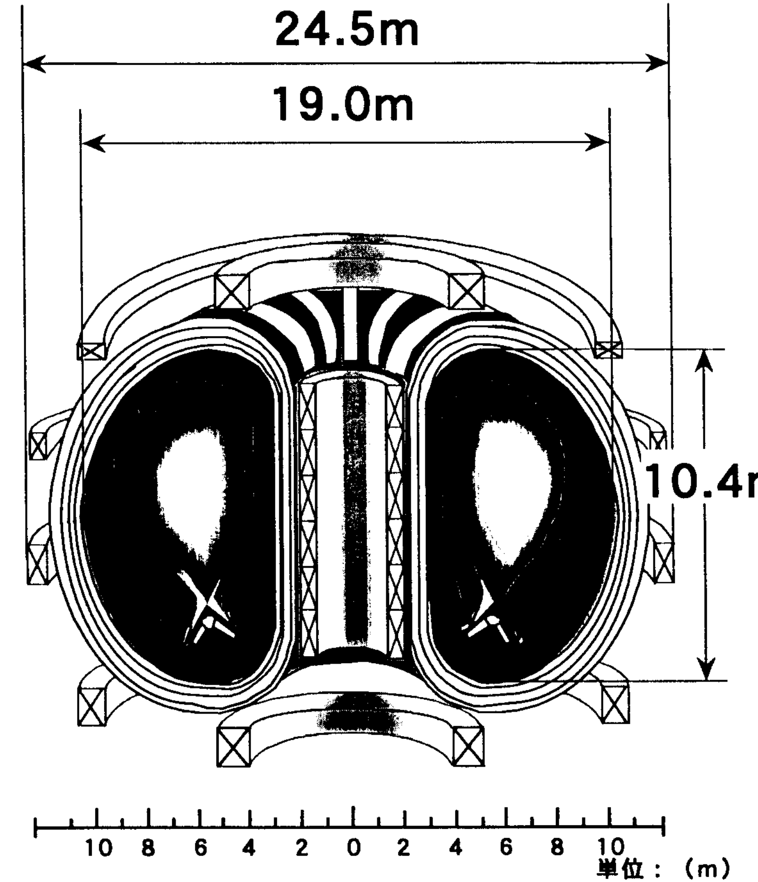
(M. Seki , JAERI)



A-BWR



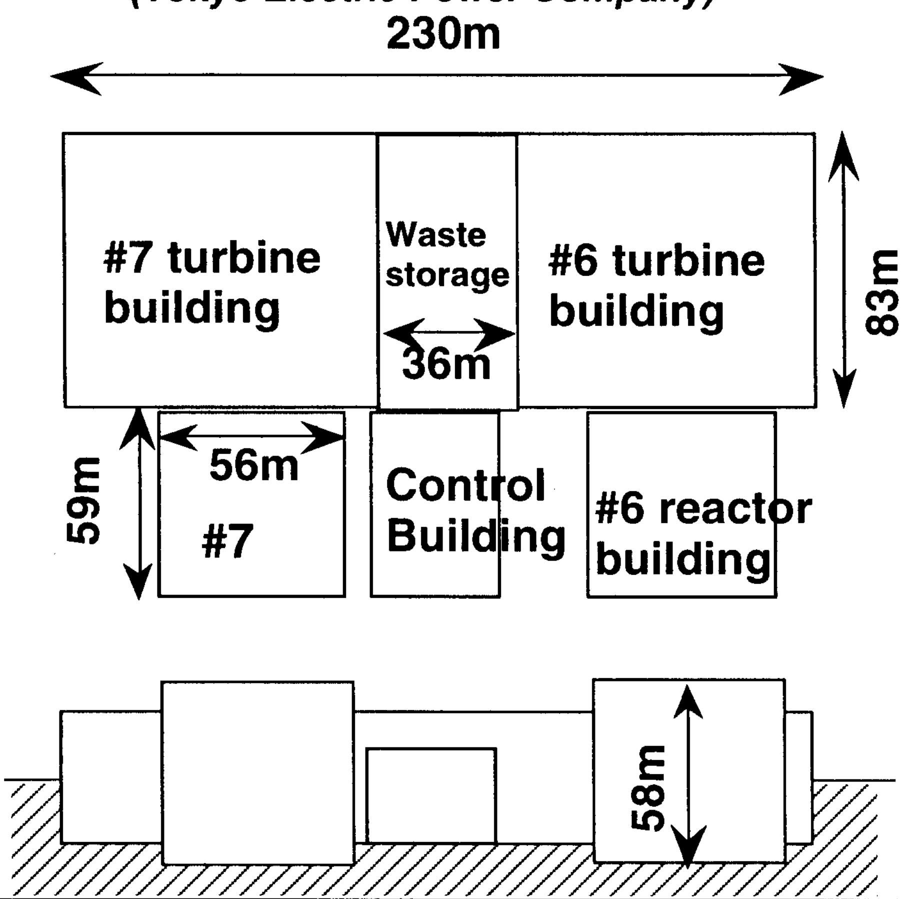
FBR (Monjyu)



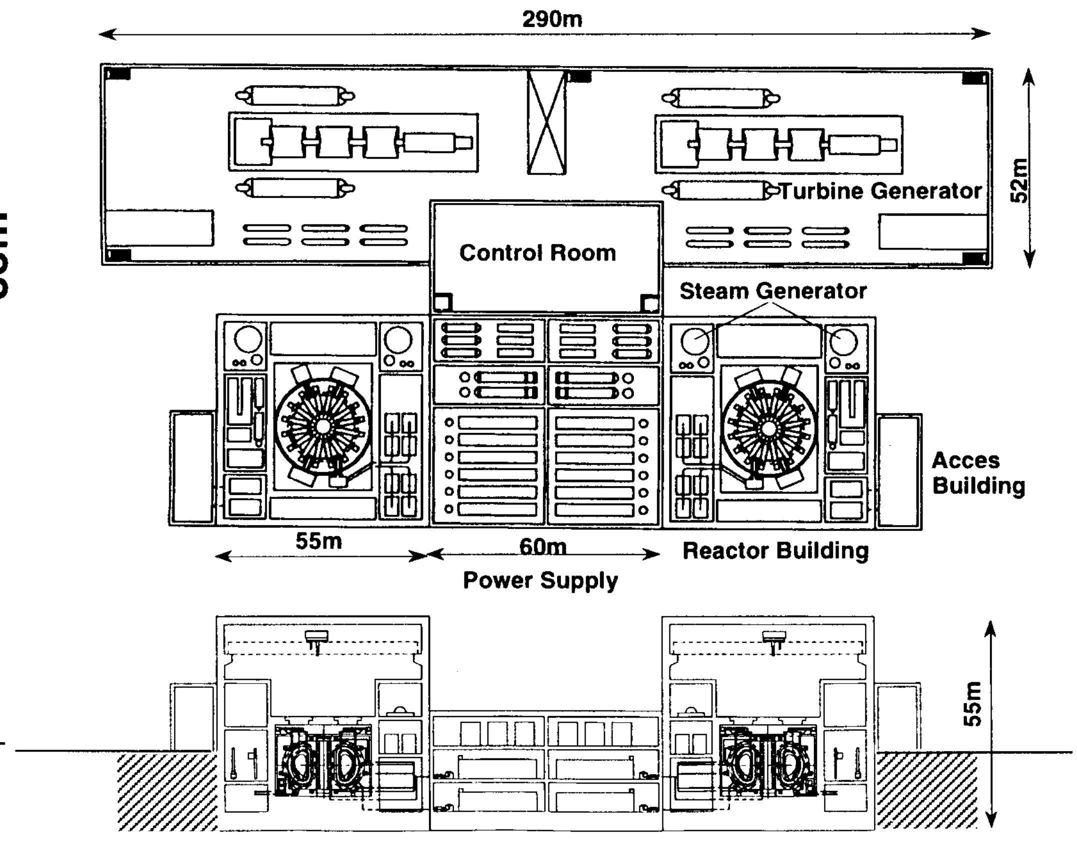
RC-ITER
Magnet/VV/Plasma

We must develop Economically Viable Fusion Reactor

The Advanced BWR
(Tokyo Electric Power Company)



The Advanced SSTR



Summary of my talk

[1] Energy market will be uncertain by Global Warming.
[2] Fusion still have some advantages over other sources.
[3] Tokamak progress is quite remarkable.
[4] Low cost ITER is worth investment.
[5] High β, AT research is crucial for tokamak reactor.
[6] Cost effort is also crucial.