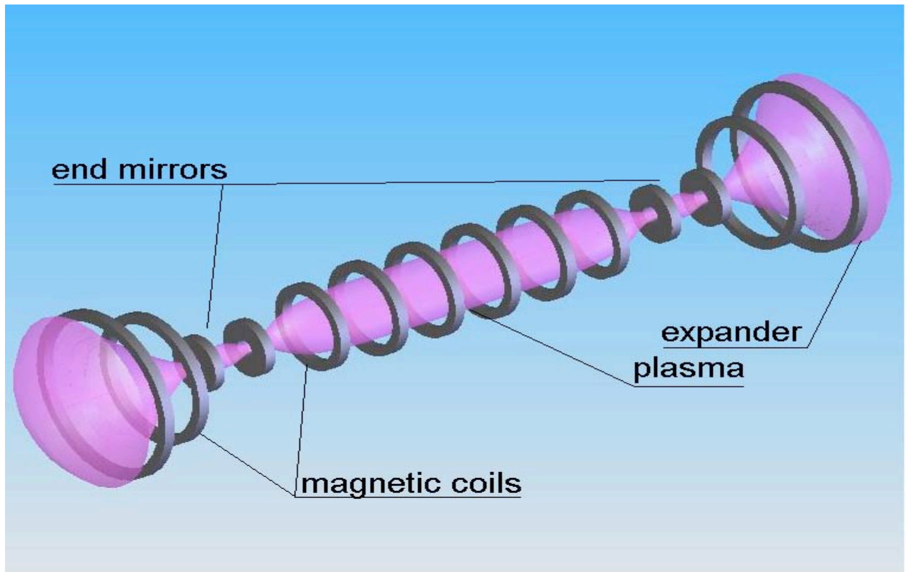
The Status of Mirror Research

Based on a Workshop in
Berkeley, CA. Sept. 8-9, 2008

25 Participants - 6 Labs. and 5 Universities - Japan & Russia

T. C. Simonen
FPA Meeting 12/4/08

The Axisymmetric Tandem Mirror



- **Simplified Physics, Engineering, and Technology**
  - **No Thermal Barriers**
  - **No Minimum-B Magnets**
  - **No new Technology Development**
  - **Old & New Ideas + New Data (Russia & Japan)**

ATM Improves Construction, Confinement, and Power Balance

- Circular coils enable smaller end plugs and higher fields
- Smaller end plugs eliminates need for thermal barriers
- Higher fields reduce end losses
- Axisymmetry eliminates neoclassical radial transport
- Large end expansion enables high electron temperature
- Central plasma suppresses loss cone and Alfven modes.
- ITER technologies are adequate.

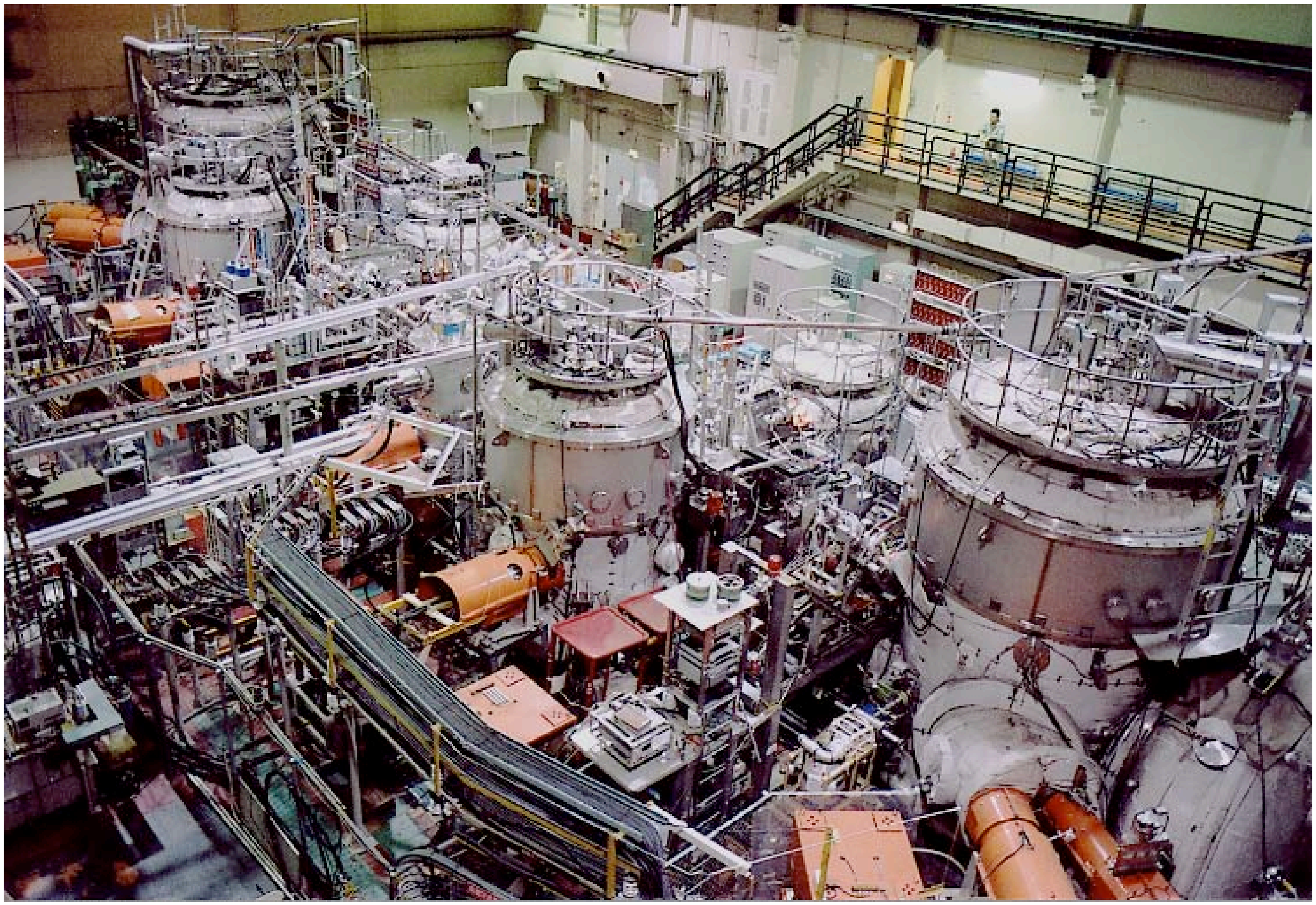
How Can a Simple Mirror be MHD Stable?

- Five Demonstrated Methods
  1. Expander plasma Outflow (GDT)
  2. Plasma Rotation (MCX)
  3. Divertor(Tara)
  4. Pondermotive (Phadrus & Tara)
  5. End Wall Funnel Shape (Nizhni Novgorod)

- Five Untested Methods
  1. Expander Kinetic Pressure (Post)
  2. Pulsed ECH Dynamic Stabilization (Post)
  3. Wall Stabilization & Feedback (Berk)
  4. Non-paraxial End Plugs (Ryutov)
  5. Cusp End Plugs (Kesner)

Gamma 10 Tandem Mirror at Tsukuba U. Japan

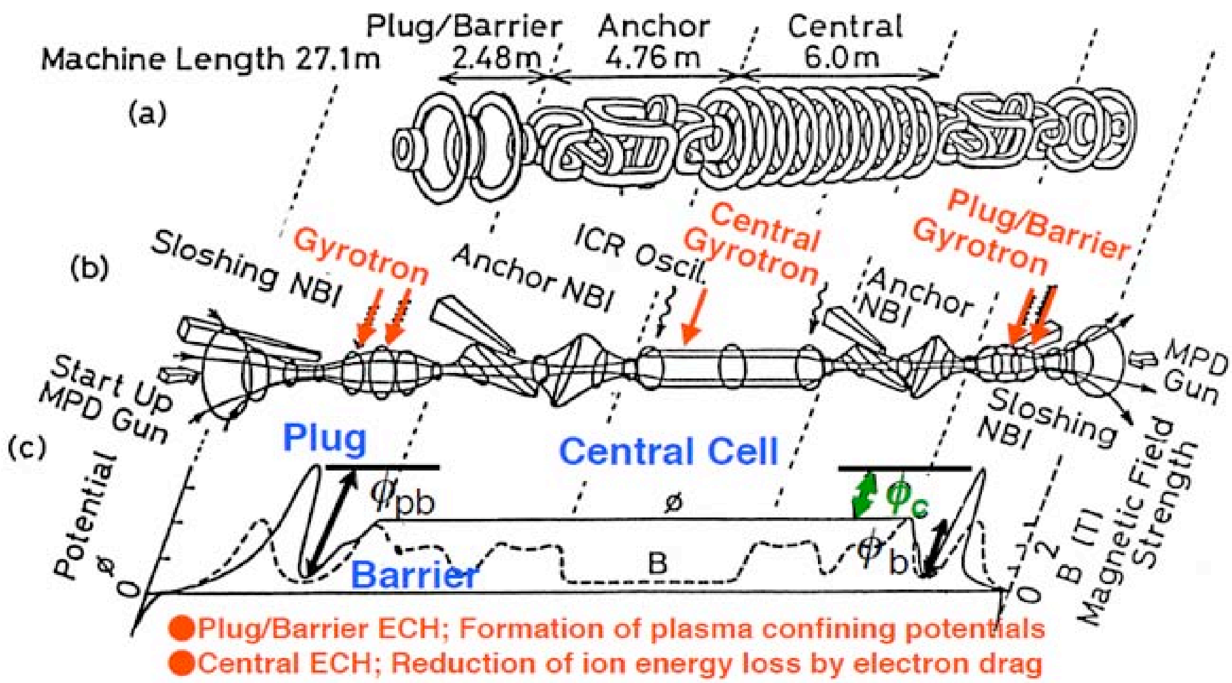
27 m Long with Large End Tanks



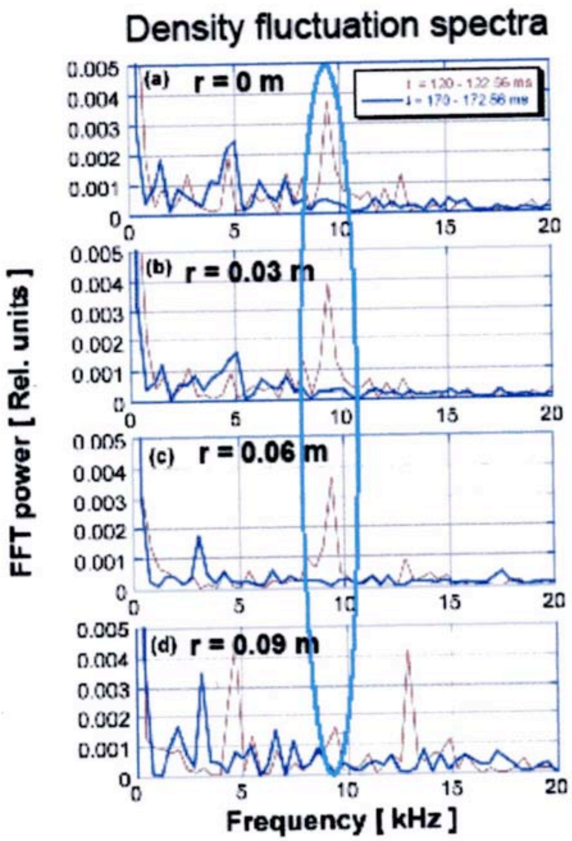
Gamma 10 Magnet Geometry

Powered by ICRF and ECH

Gamma 10 also develops LHD Gyrotrons



Suppression of Gamma 10 Turbulence with ECH



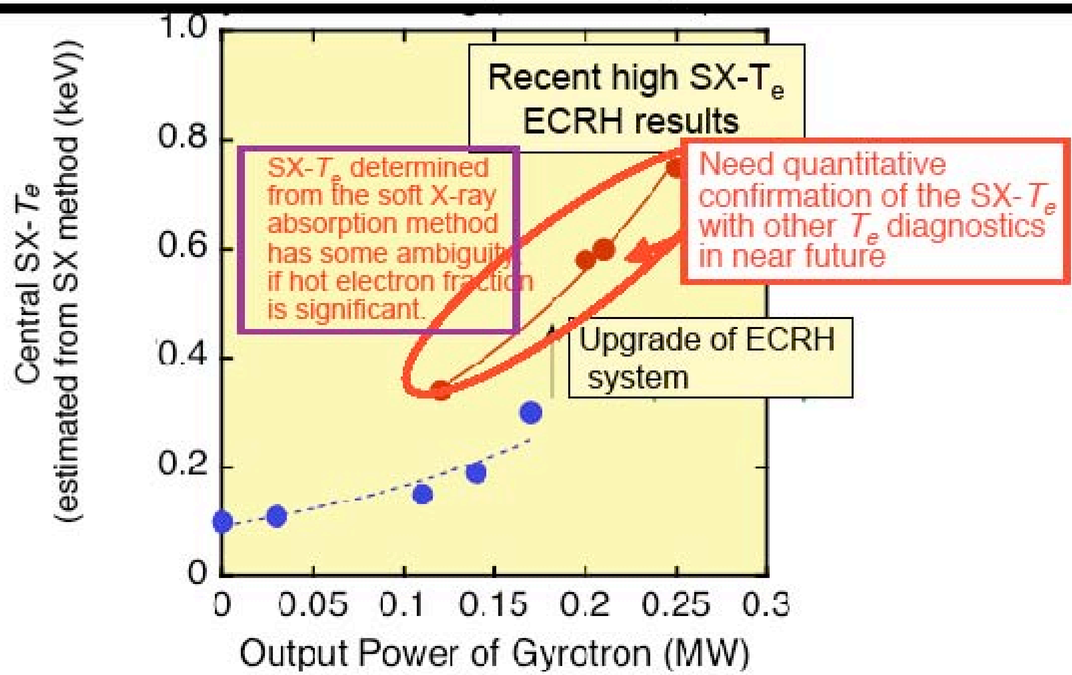
- Red without ECH
- Blue with ECH

- ExB Rotation Shear
- Like H-mode & ITB
- Possible Tokamak Application?

5. Efficiency Enhancement of ECRH System

Power Scalings of Soft X-ray estimated T_e (SX-T_e) with ECH Power (Tentative)

PRC

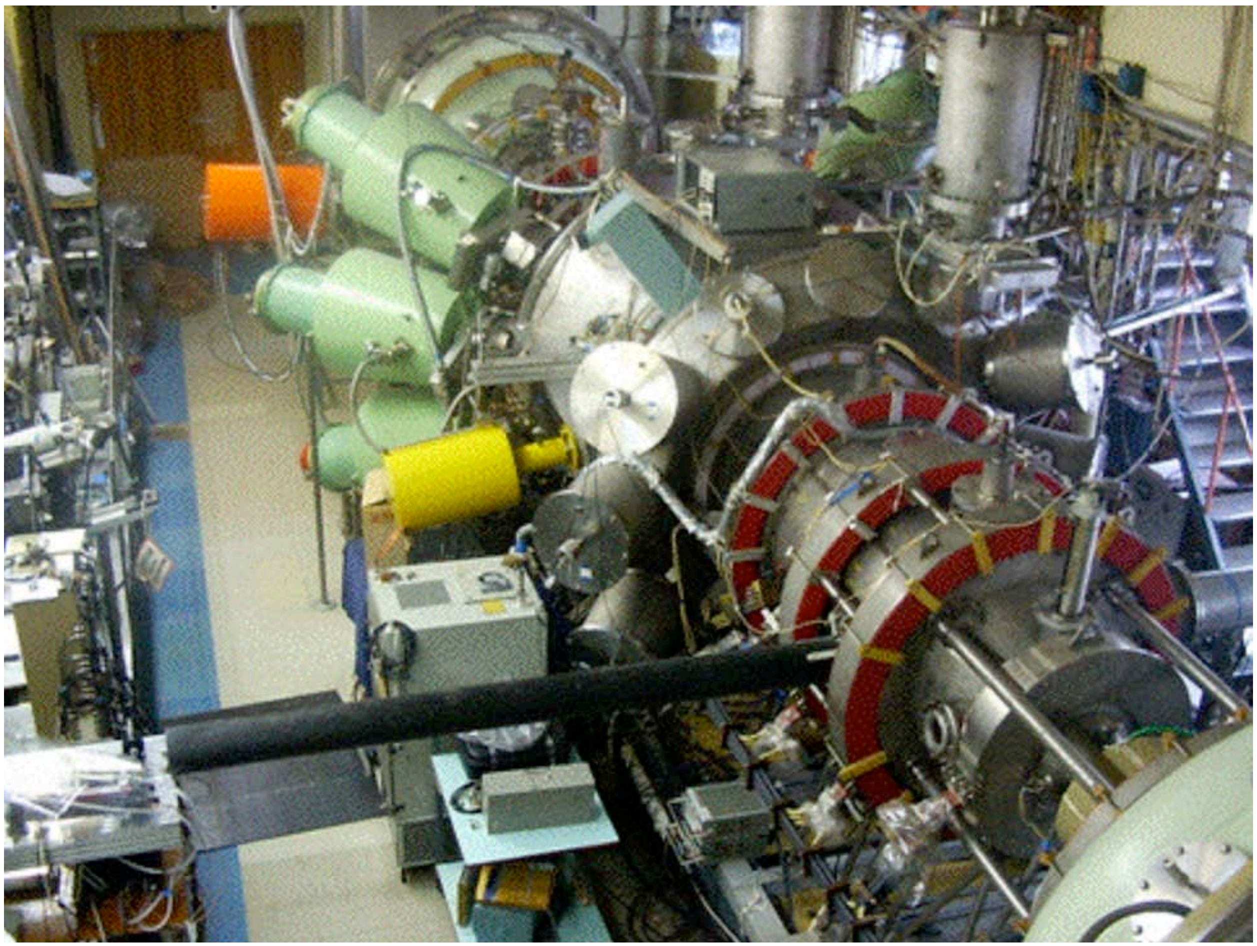


No saturation of power scaling of SX-T_e

Highest SX-T_e estimated from Soft X-ray seems to be 0.5 ~ 0.75 keV, but its confirmation must be done by other diagnostics like Thomson Scattering.

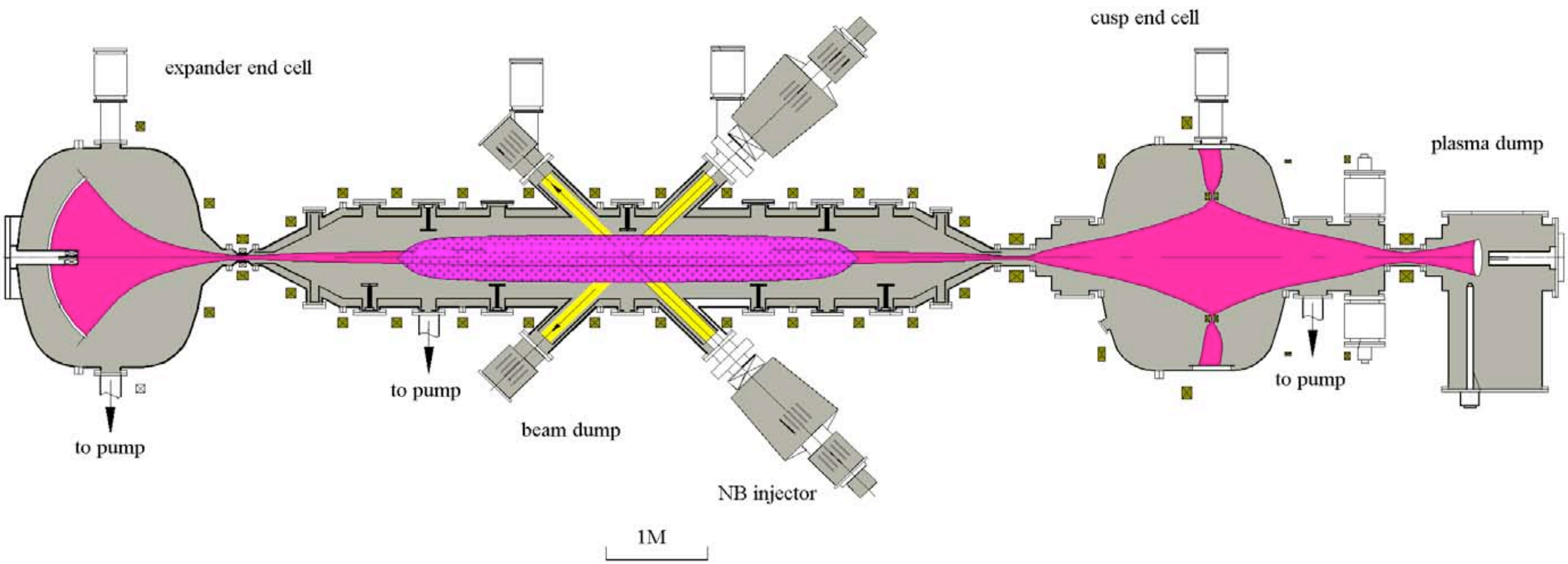
GDT at Novosibirsk, Russia

12 m Long with Large End Tanks



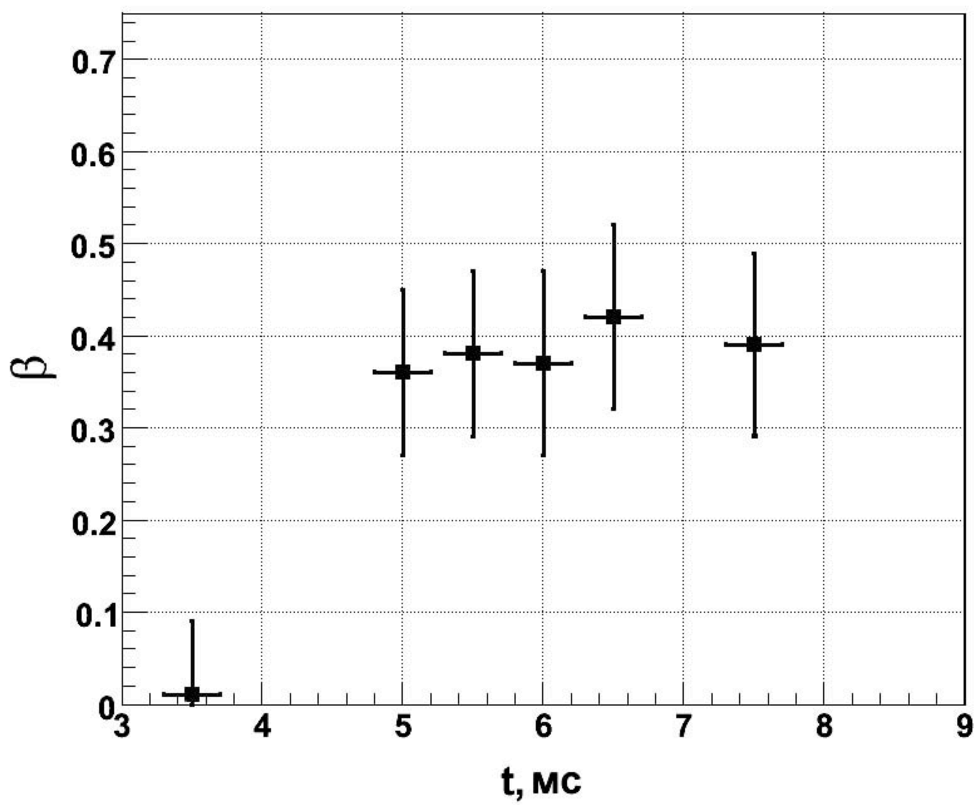
GDT Experimental Set-up

Powered by Deuterium Neutral Beams



GDT Central Beta Reaches 60%

Design level for Neutron Source

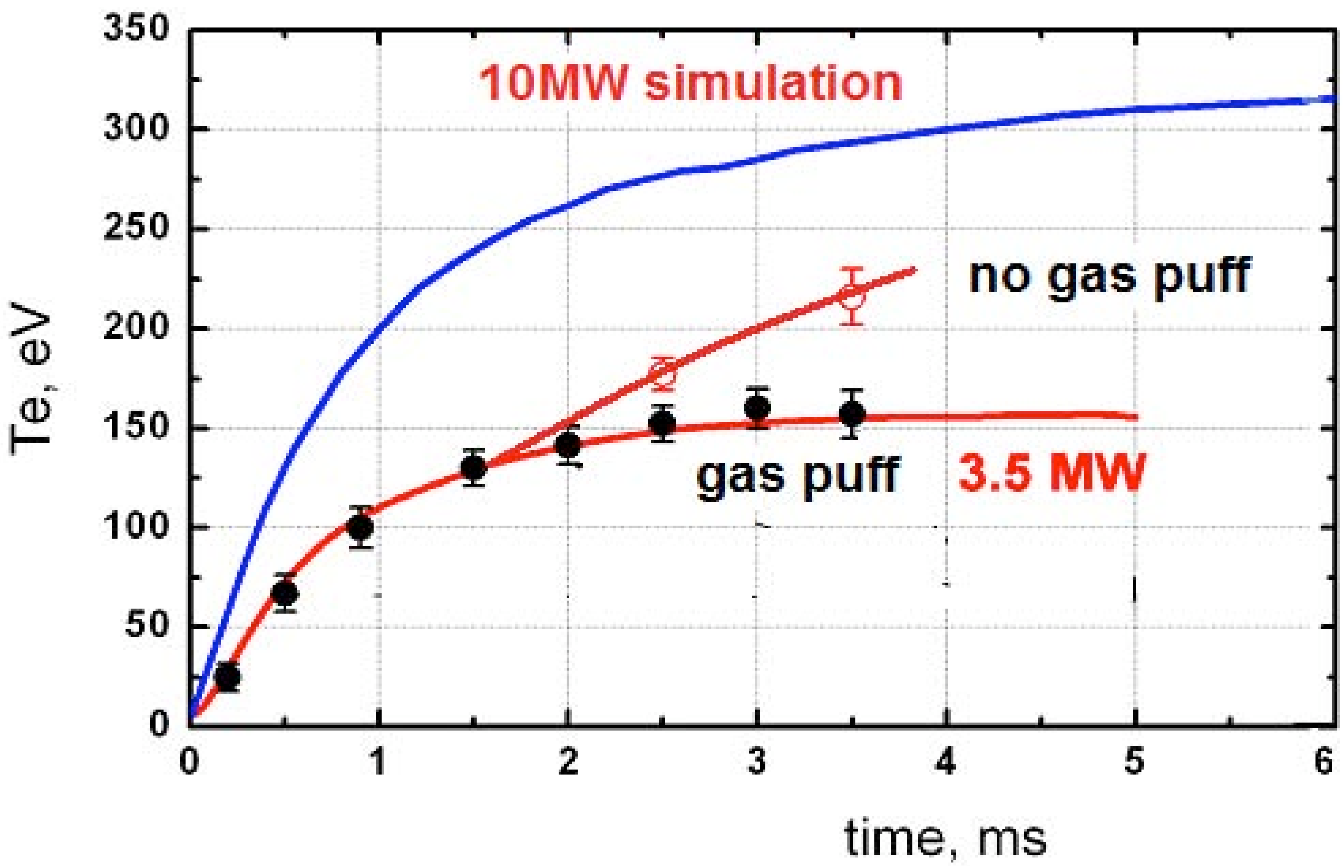


recent achievements

$\beta_{max} \approx 60\%$

$n_f \approx 5x10^{19}\ m^{-3}$

GDT Electron Temperature
(Thomson Scattering)



System Studies Summary

		Neutron Source[1]	Hybrid Reactor [2]	Power Plant[3]	Advanced Power Plant [4]
L	m	10	30	30	95
a	m	0.08	1.5	1.5	0.42
B-min	T	1.3	3.0	3.0	3.0
B-max	T	20	18	-	26
NBI	keV	70	70	1000	
NBI	MW	30	70		30
Ne	1e20 m-3	2.0	1.0		2.2
Ti	keV	-	30-60	22	30
Te	keV	0.75	50-150	66	
Beta	%		30	40	60
P-neut	MW	2	100-500	-	960
Flux	MW/m2	2	2.7		
Area	m2	1.5x0.6			
Q		0.07	1.5 to 5	10	40

- [1] D.D. Ryutov, et.al., J. Fusion Energy, 17, p253 (1998)
- [2] J. Pratt & W. Horton, Phys. Plasmas, 13,042513 (2006)
- [3] D.D. Hua & T.K. Fowler, LLNL Report UCRL-ID-204783 (June 14, 2004)
- [4] R.W. Moir & T.D. Rognlien, Fusion Sci. & Tech 52, p408 (2007)

The ATM is Suited for Many Applications

- Q ~ 10 for electric power with ignited central cell
- Q ~ 3 to 5 for Fission-Fusion Applications
- Q < 1 for nuclear subcomponent and materials testing with low tritium consumption

Further evaluation is warranted

Neutron Flux vs Electron Temperature