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# **COMPACT DT FUSION SPHERICAL TORI AT MODEST FIELD**

***Preliminary Assessments Suggest That  
Ignition Spherical Torus(IST) Has  
High Potential but Requires  
New Physics Data Base***

***Y-K. Martin Peng  
and***

<b><i>S. K. Borowski</i></b>	<b><i>G. T. Bussell</i></b>
<b><i>G. R. Dalton</i></b>	<b><i>J. D. Galambos</i></b>
<b><i>G. E. Gorker</i></b>	<b><i>J. R. Haines</i></b>
<b><i>W. R. Hamilton</i></b>	<b><i>S. S. Kalsi</i></b>
<b><i>M. H. Kunselman</i></b>	<b><i>D. C. Lousteau</i></b>
<b><i>V. D. Lee</i></b>	<b><i>J. B. Miller</i></b>
<b><i>R. L. Reid</i></b>	<b><i>B. W. Reimer</i></b>
<b><i>E. C. Selcow</i></b>	<b><i>D. J. Strickler</i></b>
<b><i>N. A. Uckan</i></b>	

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**MASTER**

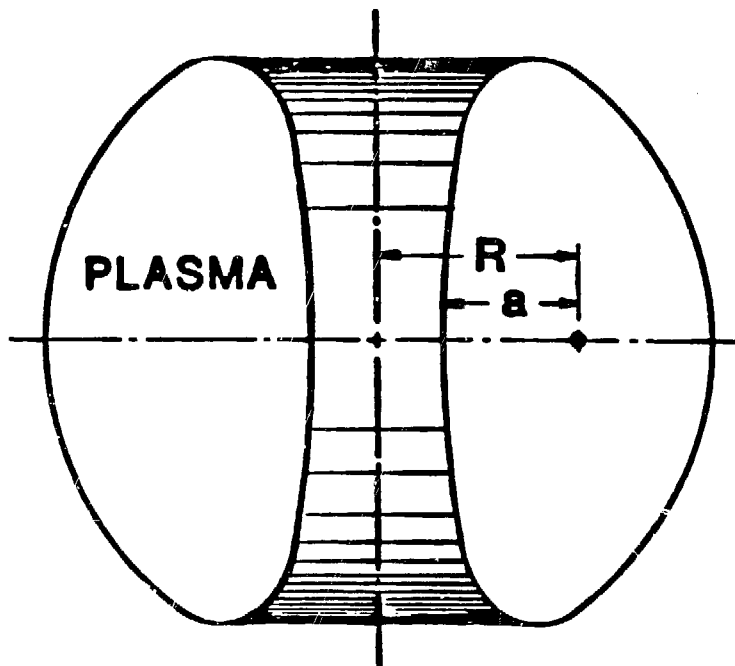
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*JSW*

# SPHERICAL TORUS

*A spherical torus is obtained by retaining only the indispensable components on the inboard side of a tokamak plasma. It features an exceptionally small aspect ratio (around 1.5), a naturally elongated, D-shaped plasma cross section (2 to 1 elongation), and ramp-up and maintenance of the plasma current primarily by advanced methods. It takes on the spherical shape with a modest hole through the center, suggesting the name.*

ORNL-DWG 84-3421 FED



## ***PURPOSE OF THE ASSESSMENT***

- ***Quantify its potentials and challenges***
- ***Characterize its critical issues***
- ***Highlight its data base needs***

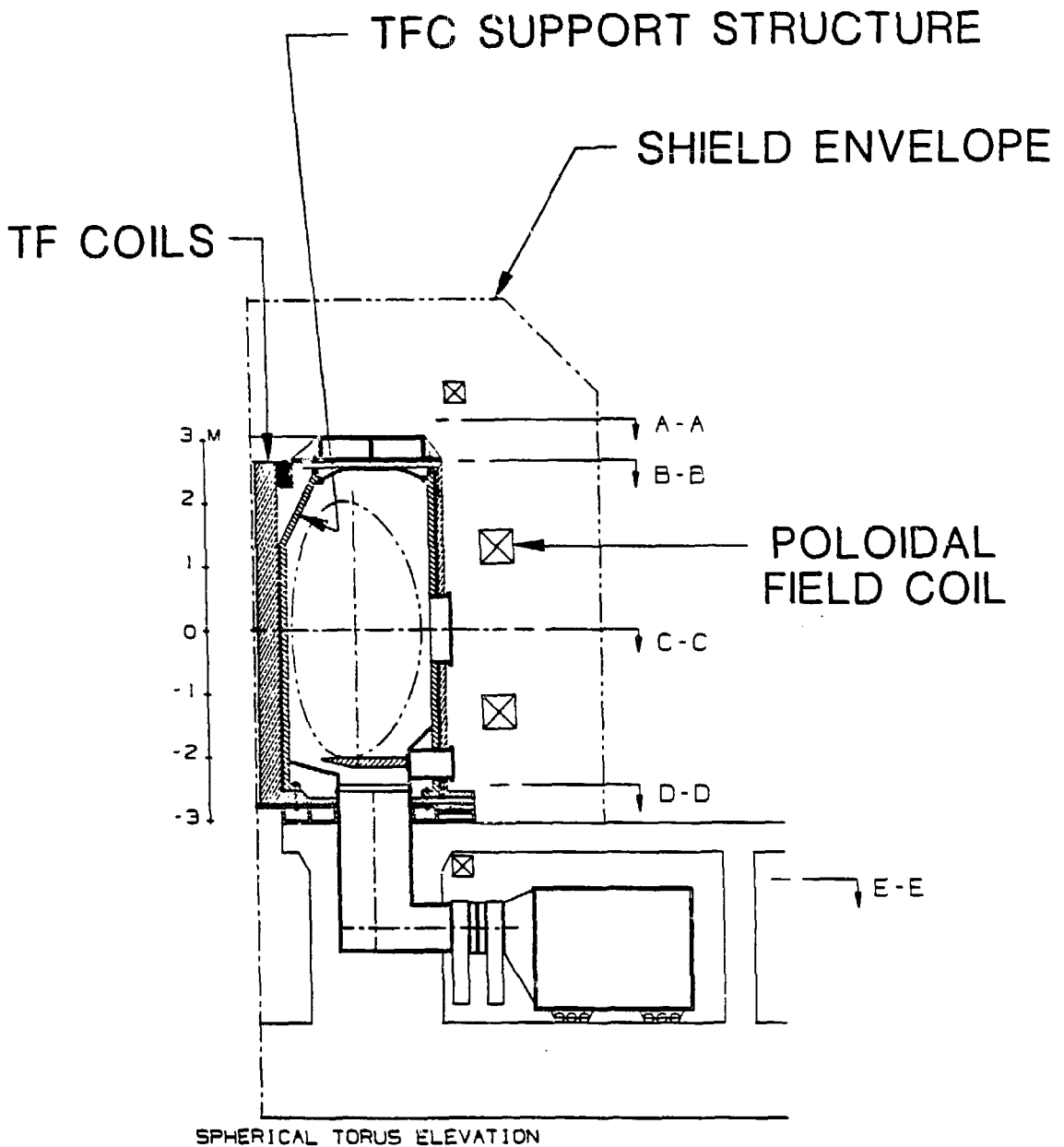
## ***MISSION OF AN IST***

- ***Achieve ignition***
- ***Pulse length for 10's of seconds***
- ***Enough cycles for repeatability***
- ***Achieve lowest overall cost***

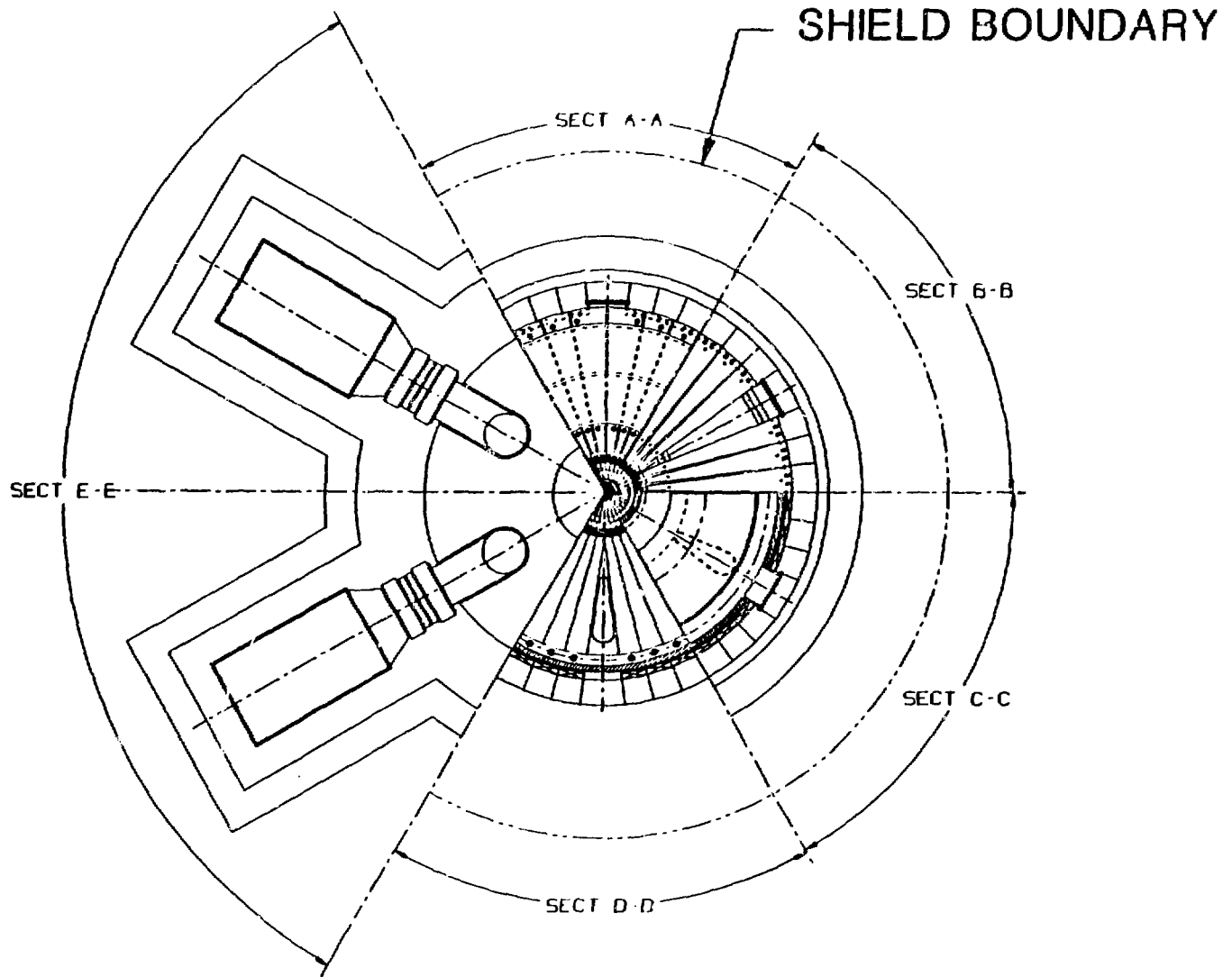
## **MAJOR ASSUMPTIONS OF A FUSION IGNITION SPHERICAL TORUS**

- ***Plasma Assumptions And Features***
  - ***Troyon beta scaling, coef = .035, 77 DT***
  - ***neo-Alc. or Mirnov confinement scaling***
  - ***naturally large plasma elongation, b/a=2***
  - ***strong paramagnetism, B/Bo = 1.7***
  - ***Murakami density limit***
  - ***RF wave current rampup, 50-sec burn***
- ***Engineering Assumptions***
  - ***conventional engineering***
  - ***C-17510 alloy option for center conductor  
(hi-vel pressurized water at 300 deg. C)***

# NOMINAL IGNITION SPHERICAL TORUS



# PLAN VIEW

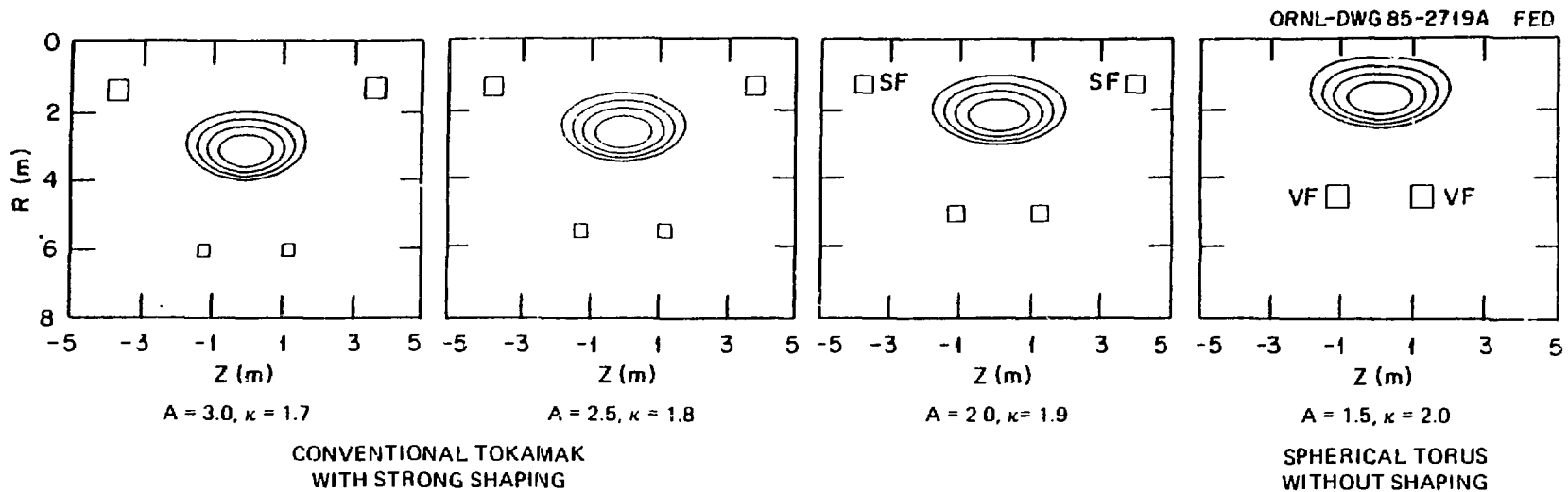


**THE SIZE AND PERFORMANCE OF IST  
DEPEND STRONGLY ON PLASMA PHYSICS  
EXTRAPOLATIONS AND TOROIDAL FIELD  
COIL TECHNOLOGY**

	<u>Nominal TF Coils</u>	<u>High-Tech TF Coils</u>
<i>Vacuum field(T)</i>	2.0	3.0
<i>Plasma field(T)</i>	3.4	5.1
<i>Coil J(kA/cm )</i>	3.3	10
<i>Elongation, b/a</i>	2	2
<i>Major radius(m)</i>	1.6	1.0
<i>Minor radius(m)</i>	1.0	0.61
<i>Plasma current(MA)</i>	14	12
<i>TF Amp-turn(MA)</i>	16	15
<i>Beta</i>	0.24	0.23
<i>RF rampup power(MW)</i>	8	5
<i>Fusion power(MW)</i>	55(160)	56(160)
<i>Wall load(MW/m )</i>	0.26(0.76)	0.69(2.0)
<i>IM(Mirnov)</i>	1.0(2.0)	1.0(1.9)
<i>IM(neo-Alc)</i>	0.27(1.3)	0.22(1.2)

*The values in parentheses assume favorable  
effects of the enhanced plasma field,  
plasma paramagnetism of the spherical torus*

## SPHERICAL TORUS HAS A NATURAL ELONGATION OF ABOUT 2

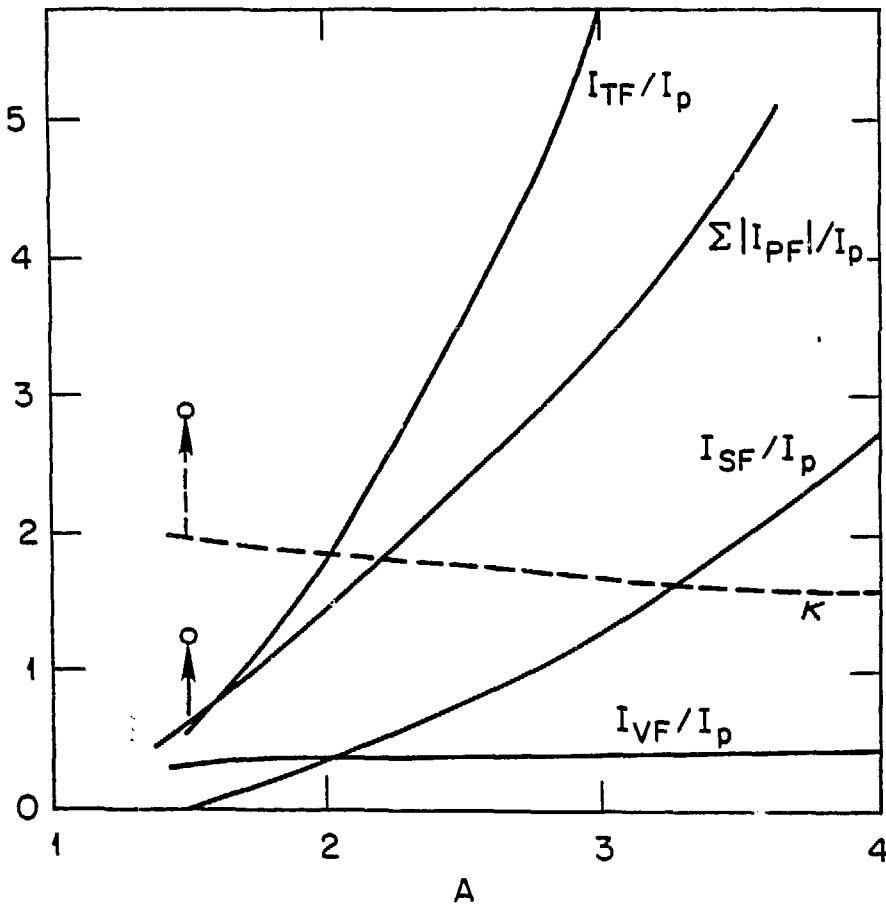


$$\left( a = 1 \text{ m, } B_{t0} = \text{CONST. } q_{\psi} = 2.4, I_p \propto \frac{\epsilon(1.22 - 0.68\epsilon)}{(1 - \epsilon^2)^2} (1 + \kappa^2), \right)$$

AND COIL CROSS SECTION PROPORTIONAL TO COIL CURRENT

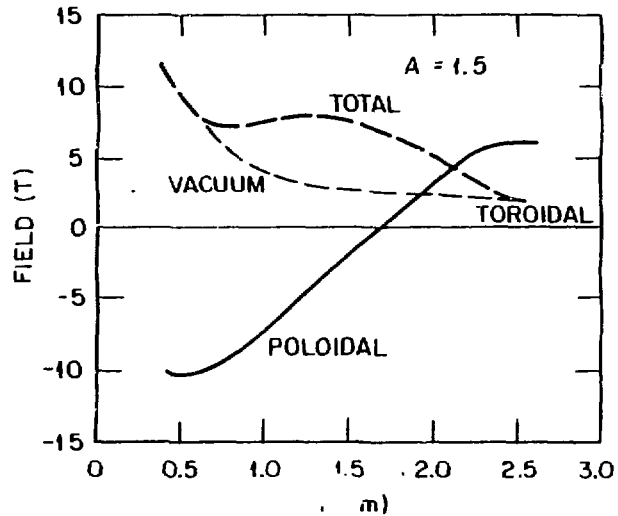


**SPHERICAL TORUS REQUIRES ONLY  
MODEST COIL CURRENTS IN  
COMPARISON WITH CONVENTIONAL  
TOKAMAKS**

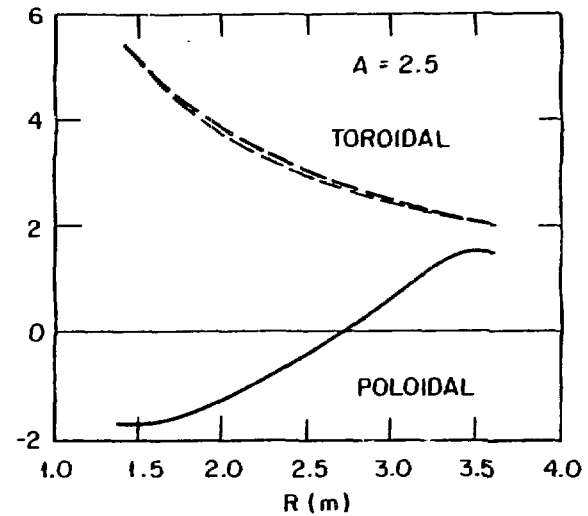


***Spherical Torus is a NATURAL  
Plasma Configuration***

**SPHERICAL TORUS DISTINGUISHES  
ITSELF WITH STRONG PLASMA  
GENERATED MAGNETIC FIELD --  
PLASMA PARAMAGNETISM**



SPHERICAL TORUS



CONVENTIONAL TOKAMAK

**SIGNIFICANT PARAMAGNETISM SETS IN WHEN  $A$  BECOMES LESS THAN 2**

**COMPARED WITH HIGH-FIELD COMPACT  
IGNITION TOKAMAK CONCEPTS, IST HAS  
SIMILAR SIZE, LOWER ENGINEERING RISK  
BUT HIGHER PHYSICS RISK**

	<u>IST</u>	<u>ISP(PPPL)</u>
<i>Major radius(m)</i>	<b>1.6</b>	<b>1.6</b>
<i>Aspect ratio, R/a</i>	<b>1.6</b>	<b>3.1</b>
<i>Elongation, b/a</i>	<b>2.0</b>	<b>1.6</b>
<i>Vacuum field(T)</i>	<b>2.0</b>	<b>9.0</b>
<i>Plasma field(T)</i>	<b>3.4</b>	<b>9.0</b>
<i>Plasma current(MA)</i>	<b>14</b>	<b>8</b>
<i>Safety factor</i>	<b>2.4</b>	<b>2.6</b>
<i>Beta</i>	<b>0.24</b>	<b>0.05</b>
<i>Current rampup</i>	<i>rfw</i>	<i>induction</i>
<i>Fusion power(MW)</i>	<b>160</b>	<b>300</b>
<i>Ignition margin</i>	<b>1.3</b>	<b>1.3</b>
<i>Coil J(kA/cm<sup>2</sup>)</i>	<b>3.3</b>	<b>5.5</b>
<i>TF Amp-turn(MA)</i>	<b>16</b>	<b>73</b>
<i>PF Amp-turn(MA)</i>	<b>9</b>	<b>23</b>
<i>Pulse length(s)</i>	<b>50</b>	<b>5</b>
<i>Coil cooling</i>	<i>s.s.</i>	<i>inertial</i>

# ***FOR COMPACT FUSION AT LOW FIELD, SPHERICAL TORUS HAS HIGH POTENTIAL BUT REQUIRES NEW PHYSICS DATA BASE***

## ***ATTRACTIVE FEATURES***

- ***Compact, Low Field and Conventional Engineering***
- ***Can Benefit From High Technology Toroidal Field Coils***
- ***Has Free-Standing TFC Configuration***

## ***PHYSICS DATA BASE NEEDS***

- ***New Physics Regime in spherical torus***
- ***Uncertainties in Plasma Physics Have Strong Effects on IST Size and Performance***
- ***ORNL Will Propose a Small ( $R = 0.45$  m) and Low Field (0.5 T) Spherical Torus Experiment - STX***

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