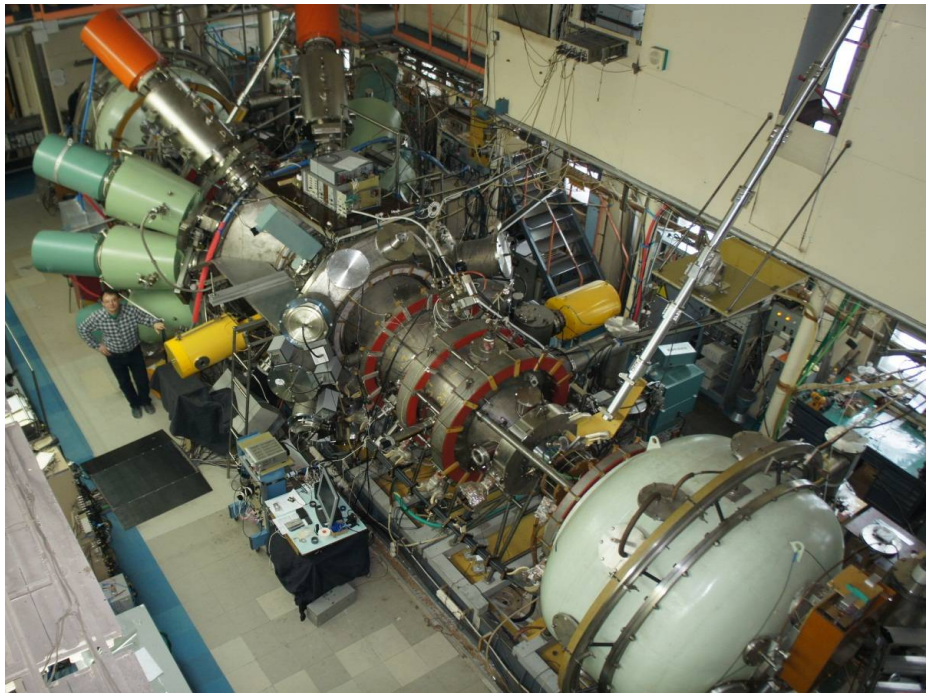
A Magnetic Mirror Path to Fusion Power



Gas Dynamic Trap (GDT) at BINP in Novosbirsk, Russia

Thomas C. Simonen (simonen42@yahoo.com)
Fusion Power Associates Meeting Washington D.C.
December 17, 2015

GDT Axisymmetric Magnetic Mirror

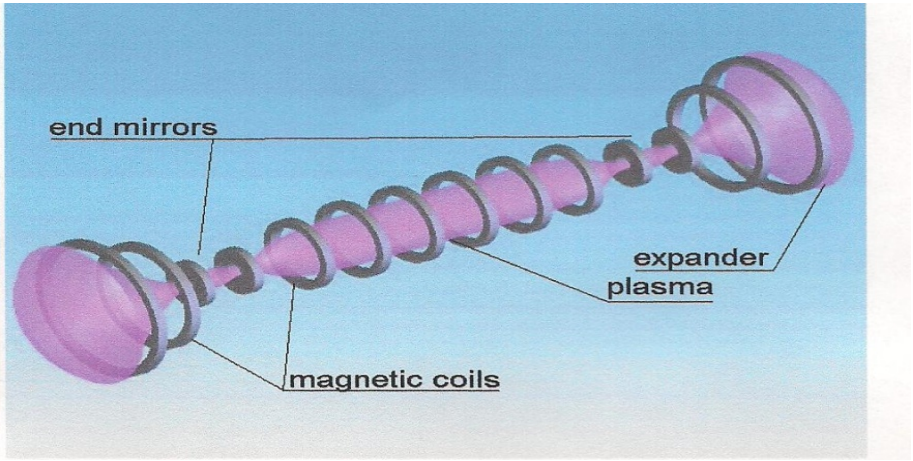
Enables High Field Magnets

No Neoclassical Transport

No current to disrupt or Divertor to melt

Geometry eases construction and maintenance

Low Fusion Power Development Path



GDT: 10T Mirror, R=30, 7m mirror-mirror, 30 cm dia.

Power & Particle Exhaust Guided to large Expander End Tanks

Achieved: Beta < 60%, E_i < 10 keV, T_e < 1 keV, n_e < 10^{20} m^{-3}

L > (mfp)lnR/R

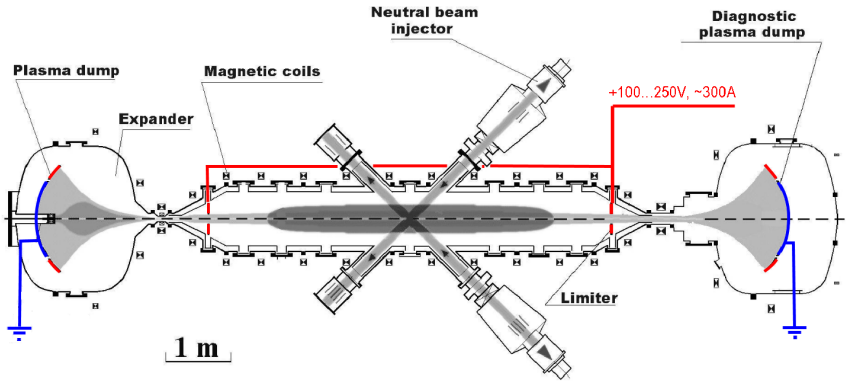
Four Hurdles Overcome by the GDT Axisymmetric Mirror

- 1. MHD Flute Instabilities
- 2. Ion Cyclotron Micro-Instabilities
- 3. Low Electron Temperature
- 4. Low Q (low electrical efficiency)
  - In the 1980's with severe cuts in fusion funding all US mirror research was terminated
  - Mirror Research continued in Japan and Russia

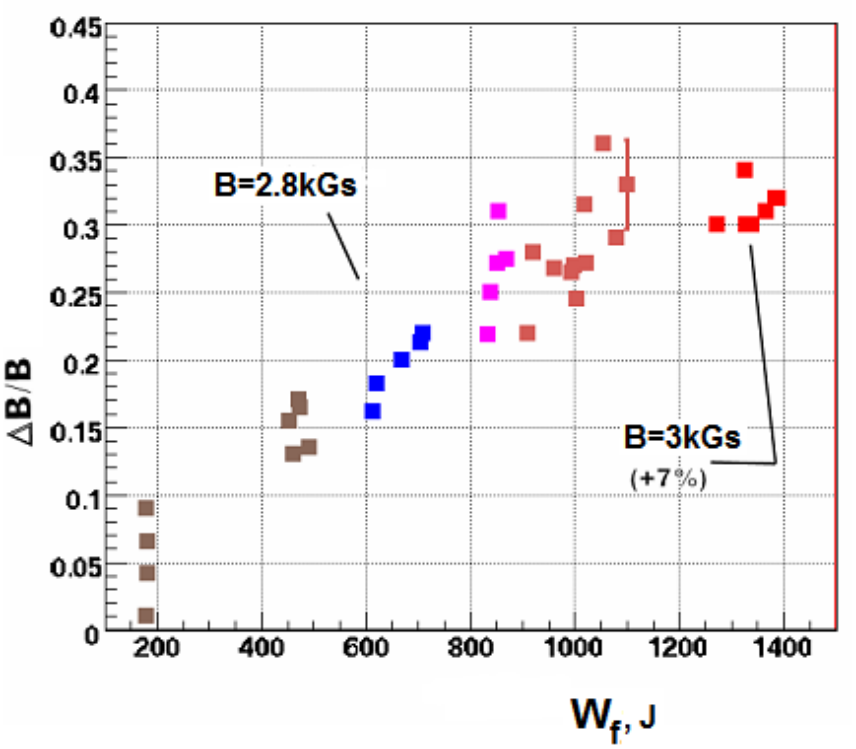
- **GDT Turned these 4 Stumbling Blocks into Stepping Stones and Building Blocks**

1. Vortex Stabilization: Radial Electric Shear Mitigates MHD Instability

Limiter or End Wall Bias

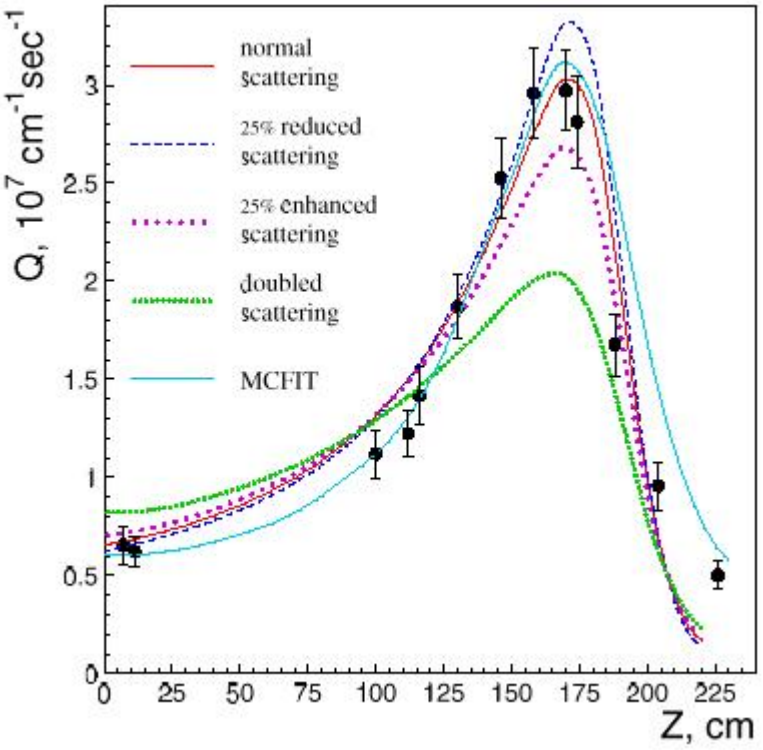


Plasma Beta 60% (MSE)

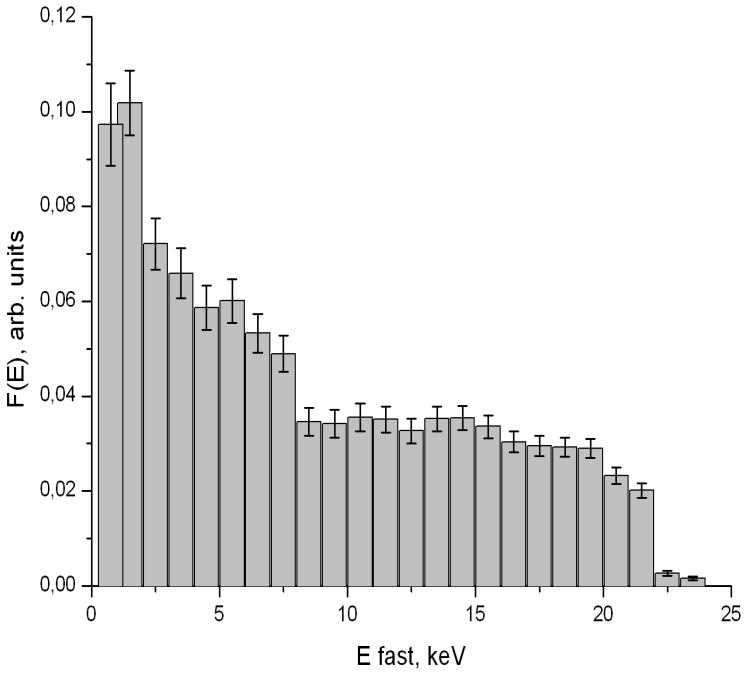


2. Skew Neutral Beam Injection Suppresses Micro-Instabilities

Hot Ion Density Peaks Off Mid-plane to Confine Warm Ions(Neutrons)

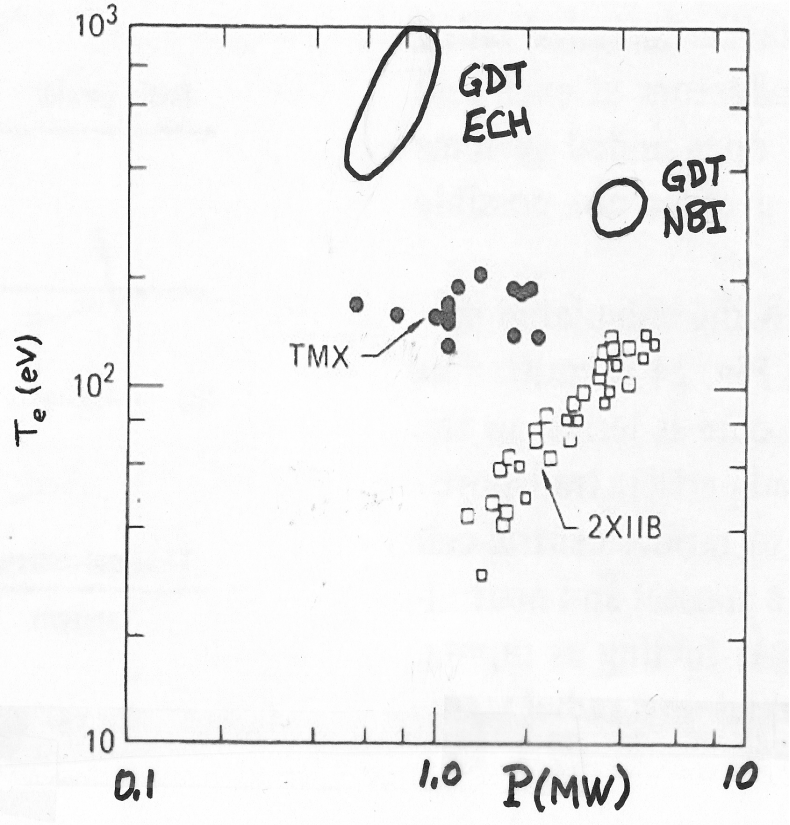


Confined Warm Ions Fill the Mirror Loss-Cone

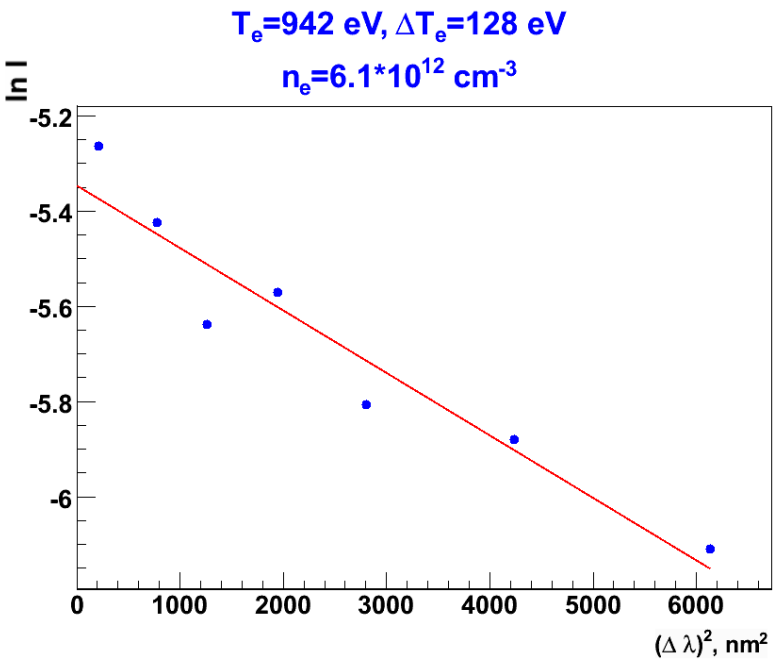


3. GDT Electron Temperature Reaches 1 keV with ECRF

Historical Data



50-700 eV Thomson Scattering Spectrum of Bulk Isotropic Electrons



4. GDT End Plug Reduces End Loss

Tandem Mirror End Plug

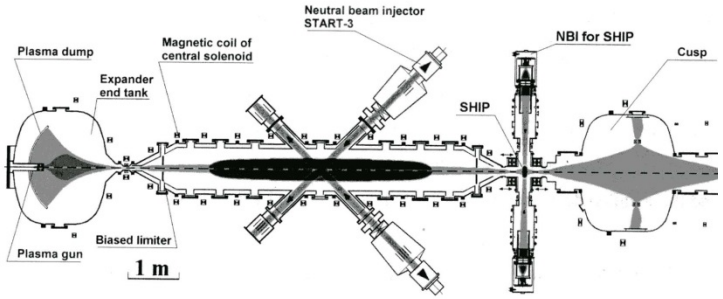
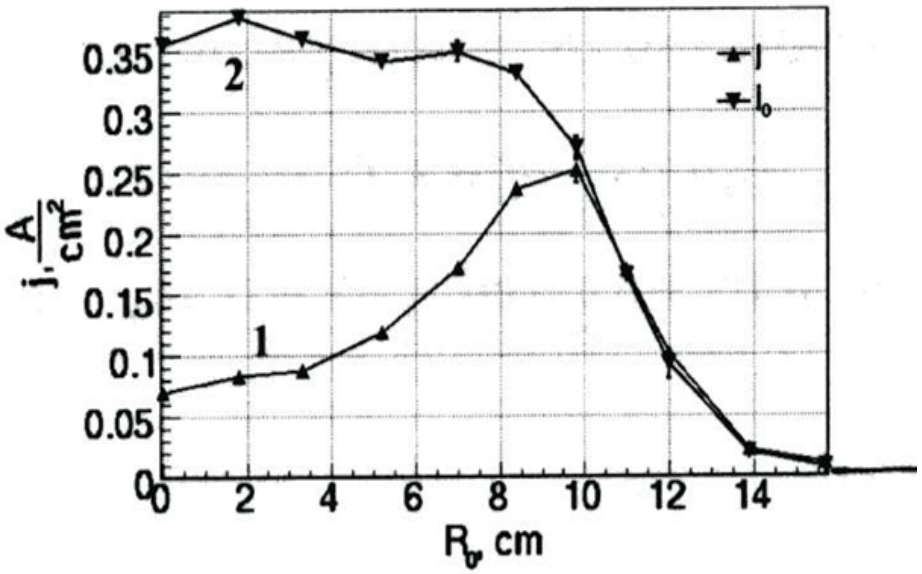


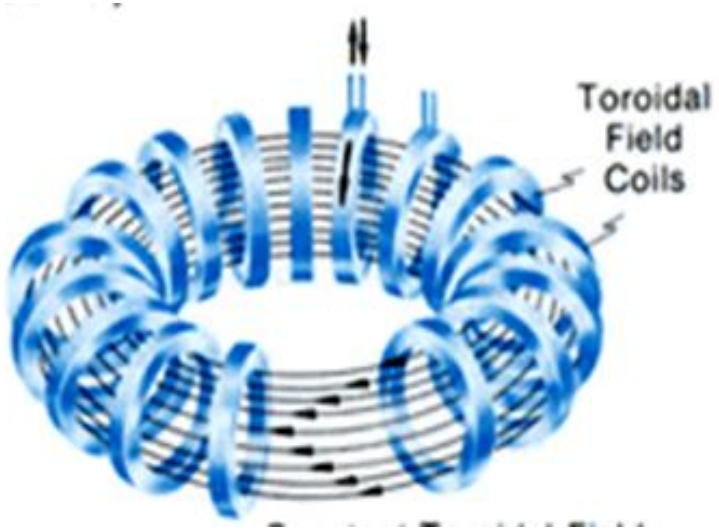
Fig.1. GDT experimental layout

End Loss Reduced x5



Imagine GDT Device as a Torus

R_p = 1.2 m, a_p = 0.15m



Features

- **Systems**
  - No Non-circular Coils
  - No Central Solenoid
  - No Poloidal Coils
  - No Plasma Current
  - No Current Drive Systems
  - No In-magnet Divertor
- **Achieved Plasma Parameters**
  - Beta(0) < 60%
  - E_i < 10 keV
  - T_e < 1 keV
  - $n_e < 10^{20}\ m^{-3}$

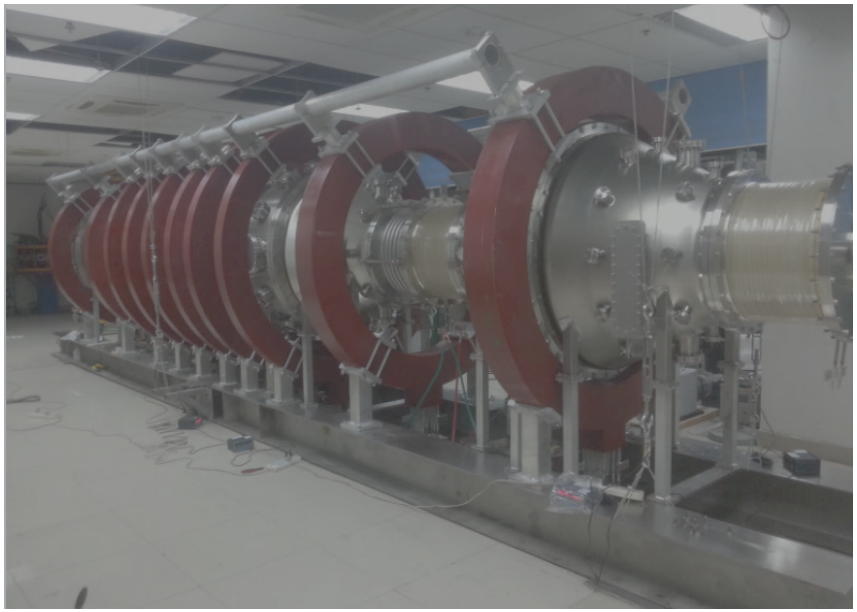
GDT's Game-Changing Advances Provides New Optimism about Axisymmetric Mirrors as a Fusion Power Source

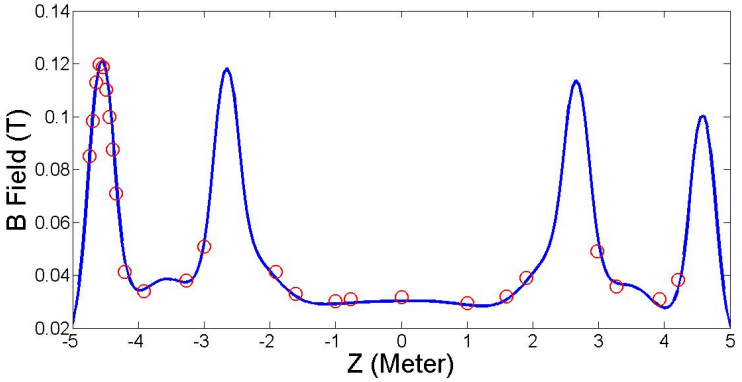
- **A Path to Fusion Power can be Envisioned (1 MW to 100's)**
  - **Medical Isotopes,**
  - **Fusion Materials Testing & Development,**
  - **Fission Fuel Production and/or Waste Burner**
  - **Fusion Electrical Power**
- **An Effort Should be Undertaken to Assess Implications of the GDT Accomplishments**
  - **Simulation**
  - **Collaboration**
  - **Extend Database**

KMAX Tandem Mirror
University Science Technology China

Axisymmetric RF Driven

B(z)





Recent GDT Publications

- A.A. Ivanov and V.V. Prikhodko, “Gas Dynamic Trap: an overview of the concept and experimental results”, Plasma Physics and Controlled Fusion 55, 063001 (2013).
- A.G. Shalashov, et.al., Auxiliary ECR heating system for the gas dynamic trap”, Physics of Plasmas 19, 052503 (2012).
- P.A. Bagryansky, et.al., “First results of auxiliary electron resonance heating experiment in GDT magnetic mirror”, Nuclear Fusion, 54, 082001 (2014).
- P.A. Bagryansky, et.al., “Overview of ECR plasma heating in the GDT magnetic mirror”, Nuclear Fusion 55, 053009 (2015).
- P.A. Bagryansky, et.al., “Threefold Increase of the Bulk Electron Temperature of Plasma Discharges in a Magnetic Mirror Device, Physical Review Letters 114, 205001 (1015).
- Physics Today, August 2015