

Single Event Laser Fusion with 10-MJ Laser Pulses

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Laser ICF in physics solved with today's technology by

- **using NIF-like lasers producing ns-10MJ pulses (red!)**
- **direct drive**
- **adiabatic self similarity compression**
- **volume ignition**

The fusion gain per energy E_0 in the compressed core at *self-similarity* compression

$$G = (\text{fusion energy})/E_0 \quad (1)$$

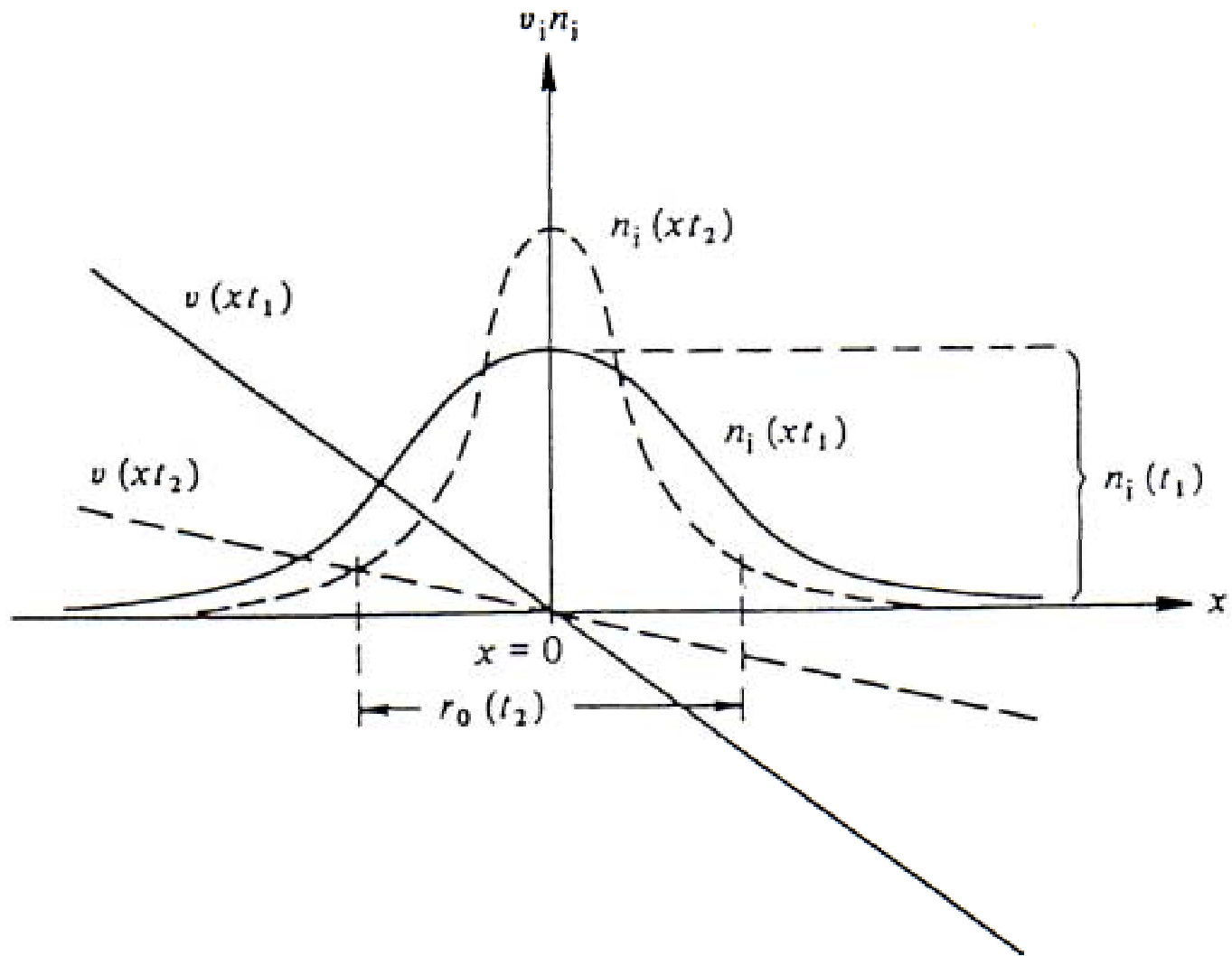
$$G = (E_0/E_{BE})^{1/3} (n_o/n_s)^{2/3} \quad (\text{Hora 1964, 1970}) \quad (2)$$

Where E_{BE} is the break-even energy for DT of 6.3 MJ defining the incorporated laser energy E_0 for solid-state density ($n_o = n_s$) where the gain $G = 1$. The numerical result is that the initial temperature at this optimum condition has to be

$$T_o = T_{opt} = 17 \text{ keV} \quad (3)$$

Expressing E_0 by T_o and R_o ($E_0 = 4\pi kT_o n_o R_o^3$), Eq. (2) results in

$$G = \text{const} \times n_o R_o \quad (\text{Kidder 1974}) \quad (4)$$



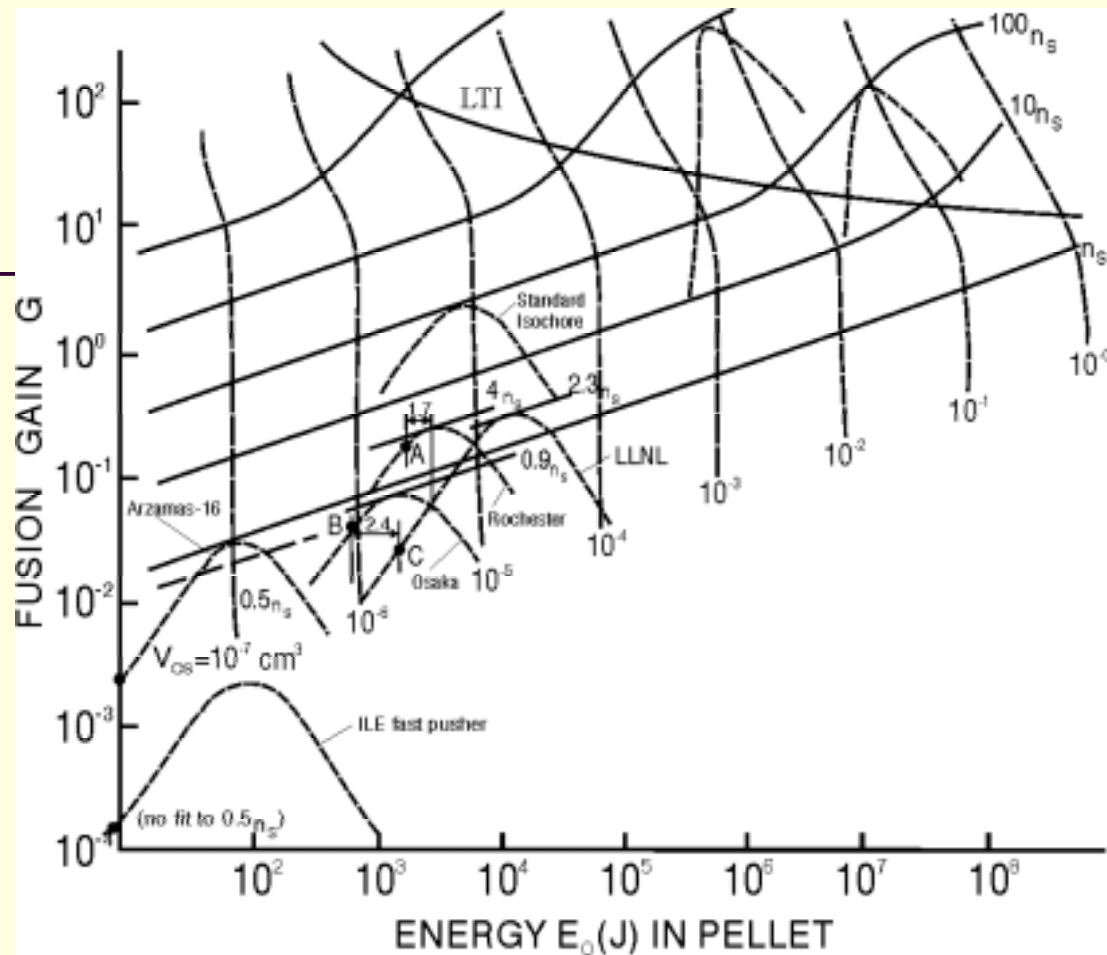


Fig. 1 Optimised core fusion gains G (full lines) for the three-dimensional self-similarity hydrodynamic volume compression of simple burn ($G < 8$) (sometimes called quenching: Atzeni [35]) and volume ignition for $G > 8$ with low temperature ignition above LTE line. The measurements of Rochester (Soures et al 1996, point A), Osaka (Takabe et al 1988 point B), Livermore (Storm 1986 point C) and Arzamas-16 (Kochemasov 1996 point D) agree with the isentropic volume burn model, while the earlier fast pusher (Kitagawa 1984 point E) with strong entropy-producing shocks does not fit [13].

Eq. (2) extended by including

1. re-heat of the DT fuel due to the generated reaction products as alpha particles (and neutrons),
2. reduction of radiation losses by partial re-absorption of the bremsstrahlung, and
3. depletion of fuel during the reaction.

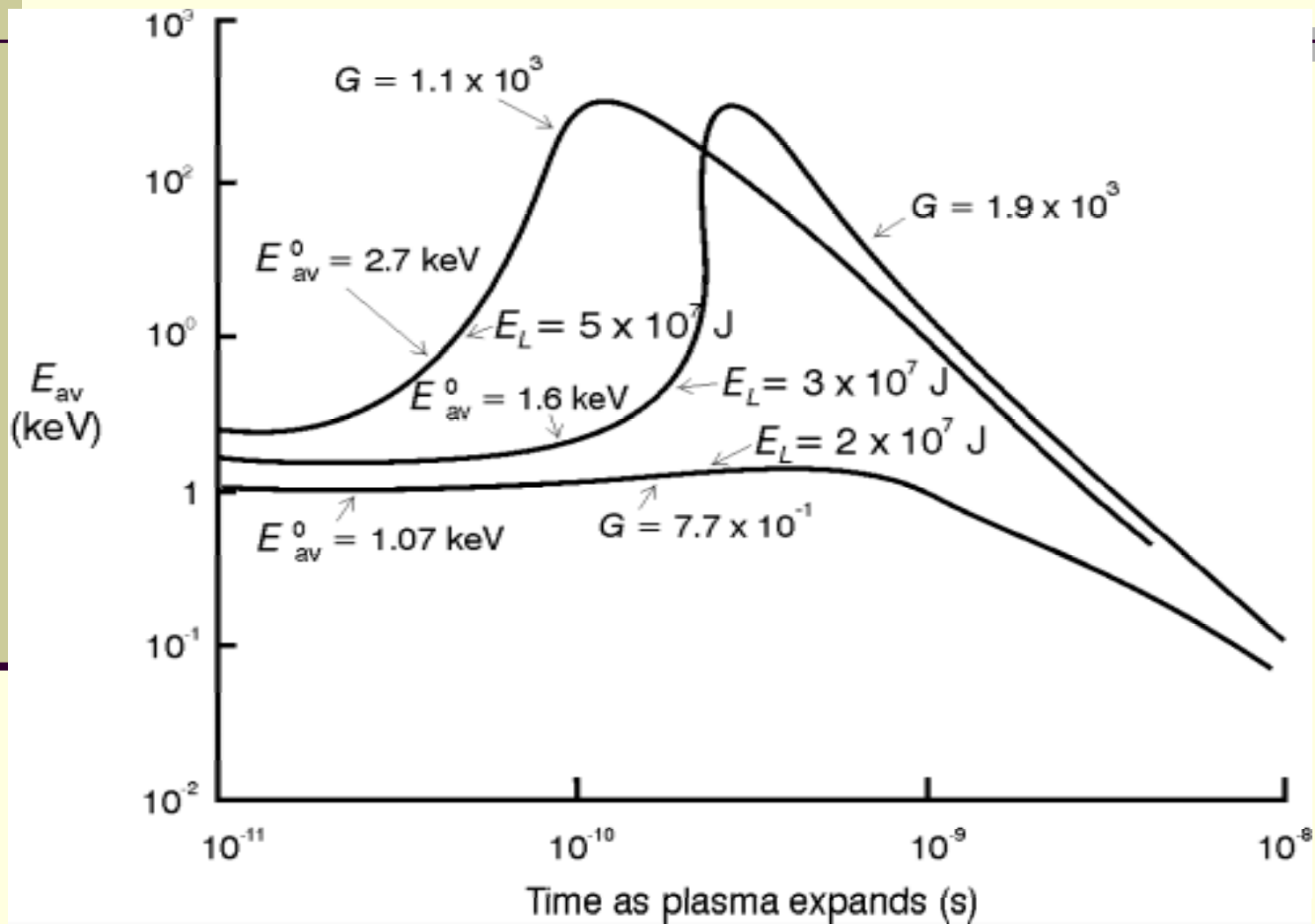
stopping lengths for the alphas compared with the collective interaction first derived by Gabor and reproduced by quantum electrodynamic modification of the Fokker-Planck collision term. For the re-absorption of the bremsstrahlung: Kramers spectra

Discovery of the volume ignition process

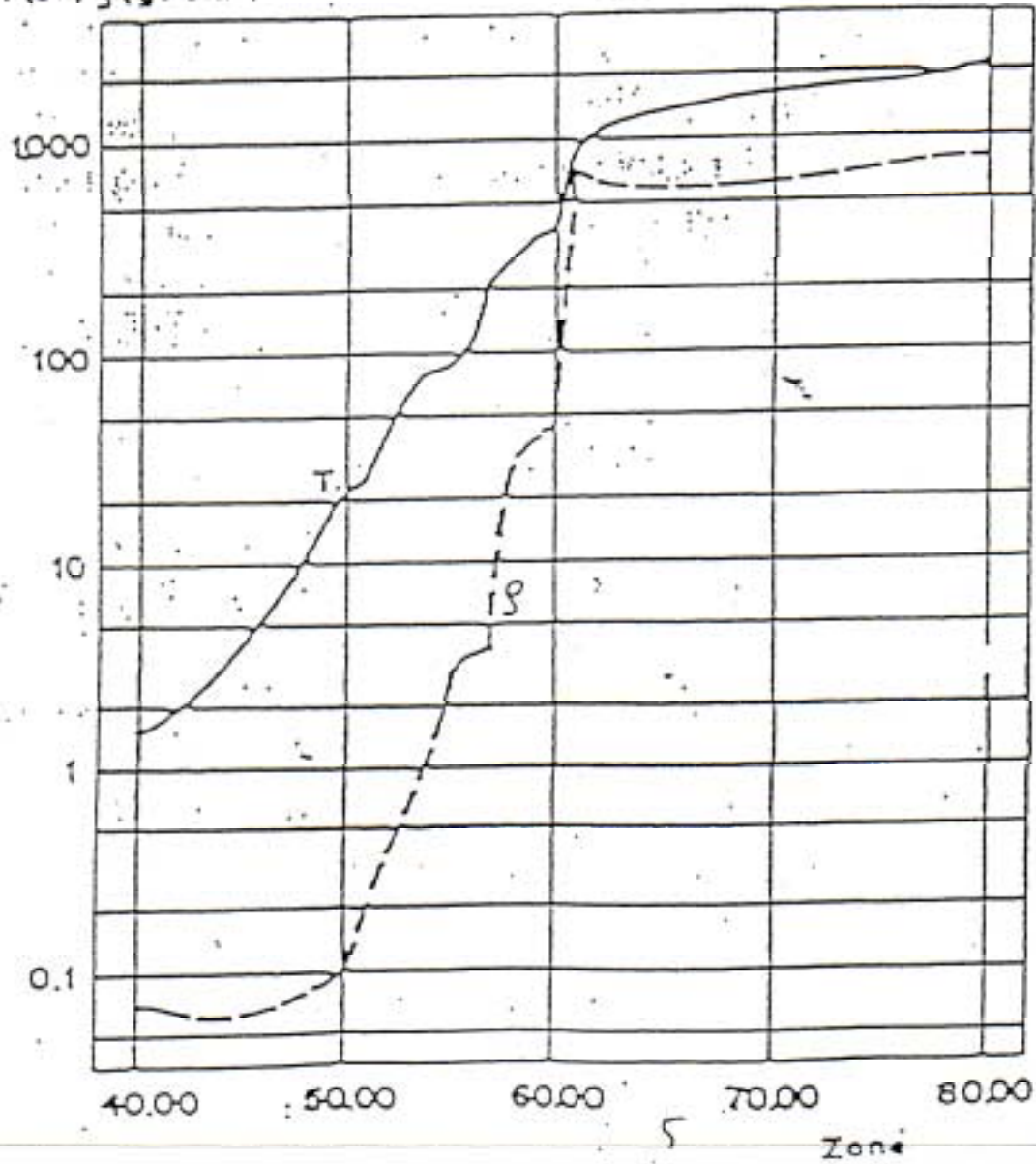
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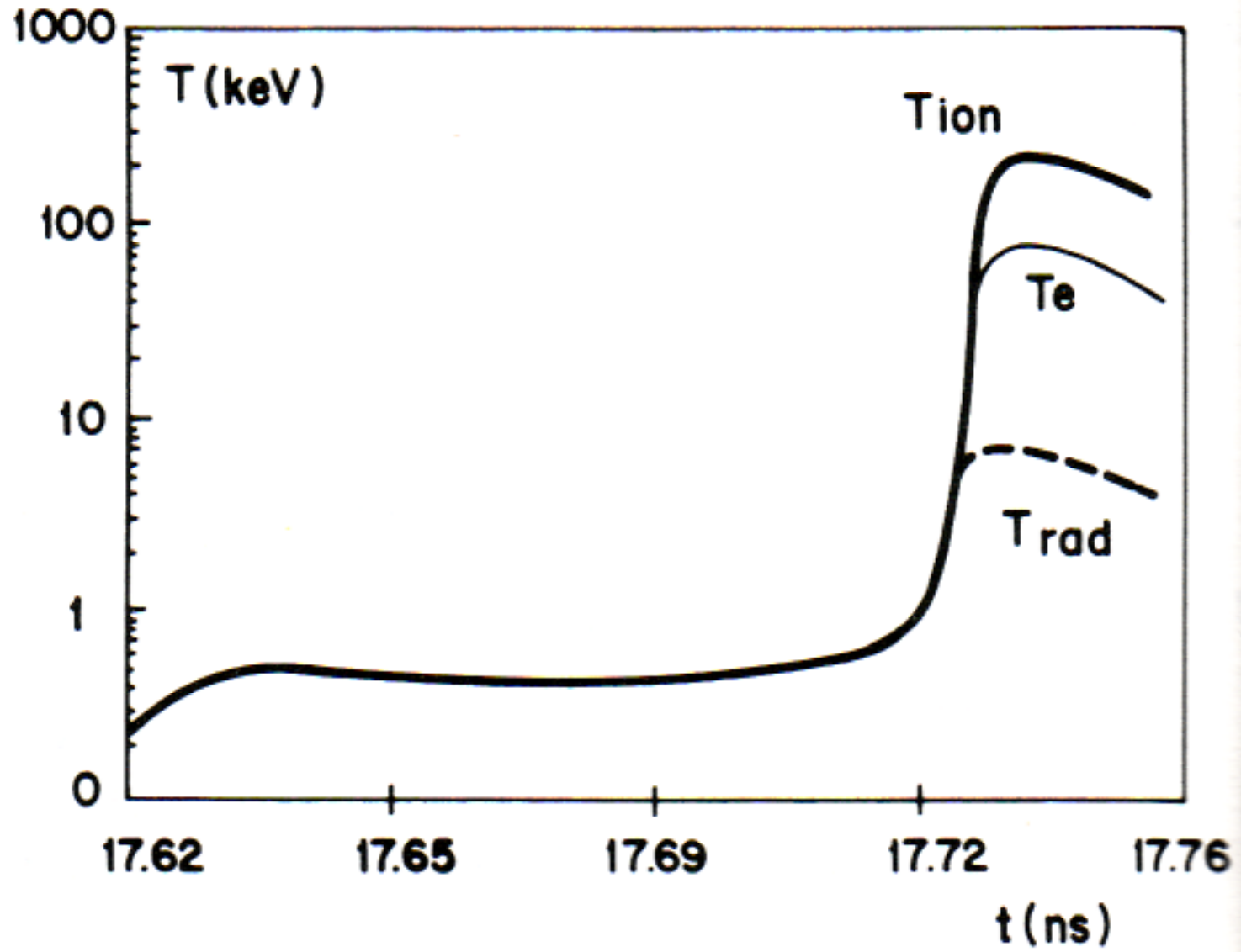
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$T(\text{eV}) \rho(\text{g/cm}^3)$





VOLUME IGNITION vs. CENTRAL SPARK IGNITION

VI: 78% gain of SI,

but VI is ROBUST AGAINST INSTABILITIES and ASYMMETRY

and is NATURAL ADIABATIC

form Spark Ignition (E. Strom et al 1988) we deduce:

$$E_{\text{spark}} = 1.62 \times 10^9 \text{ J/cm}^2. \quad (6)$$

This *energy triggers the fusion detonation wave* which travels into the surrounding cold outer plasma shell.

Close to other references, (Chu, Bobin, Kidder, Bodner, Ahlborn, Babykin, and Shvartsburg [44])

$$E_{\text{ign}} = 10^7 \text{ J/cm}^2. \quad (7)$$

Ignition by irradiation of the cold plasma by fast ions requires a current density of

$$j = 10^{10} \text{ A/cm}^2. \quad (8)$$

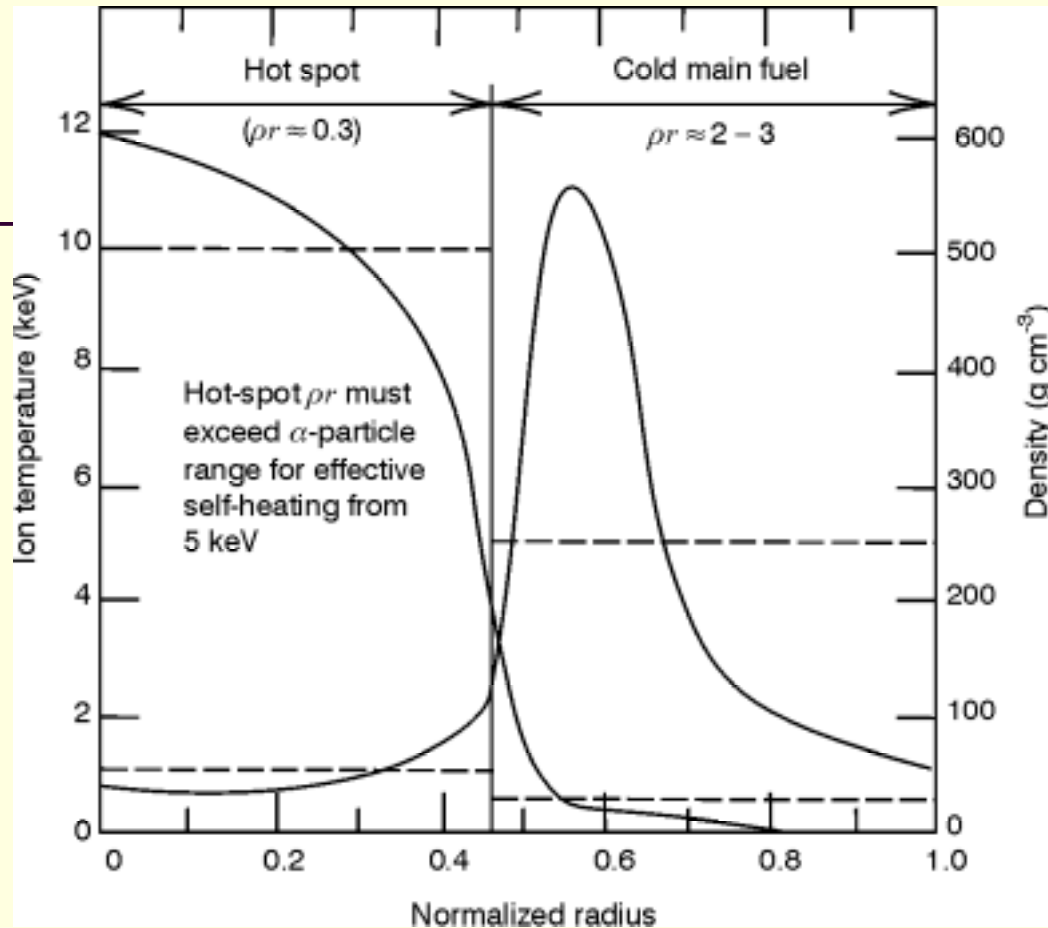


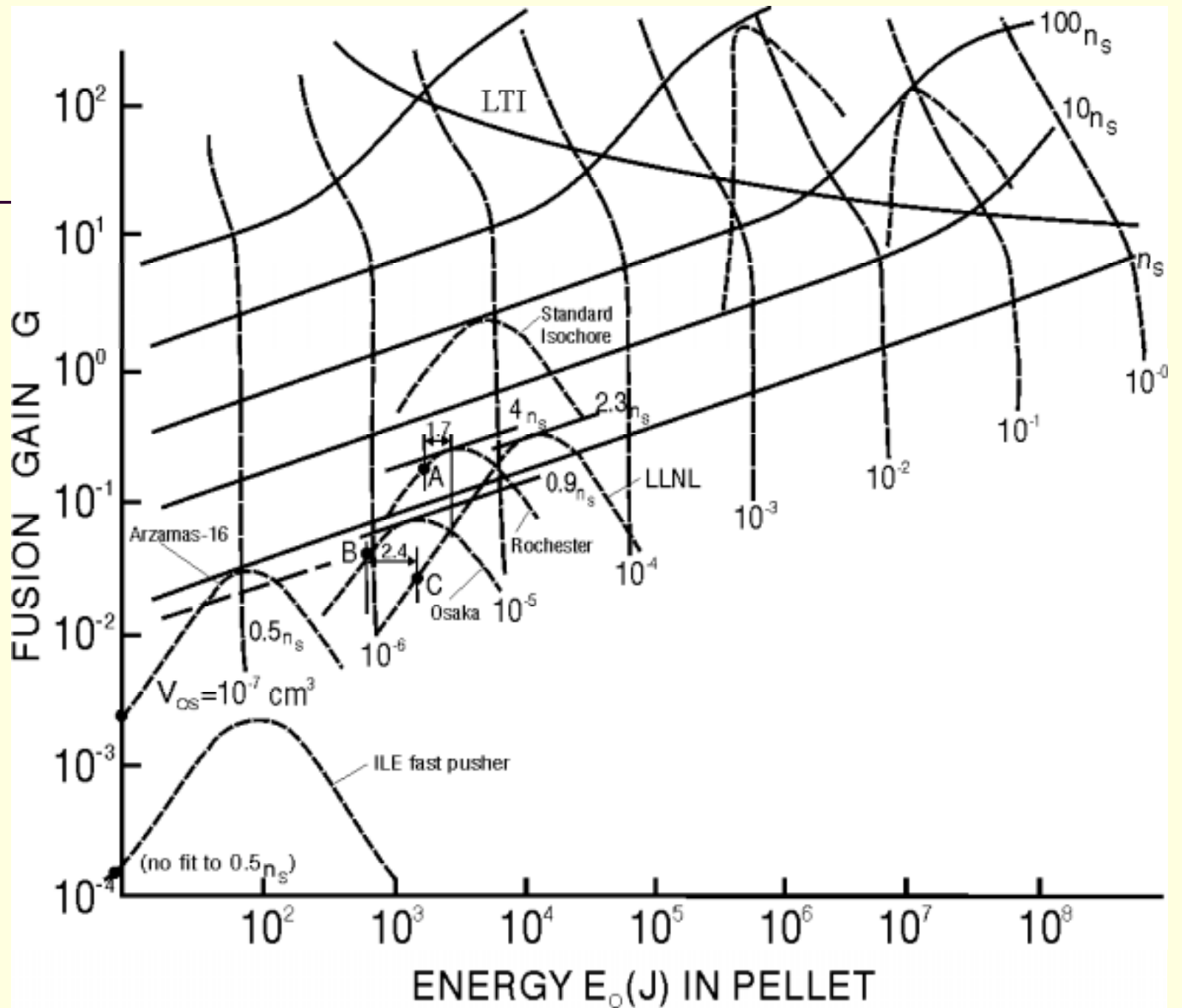
Fig. 3 Radial profiles of the ion temperature and density in a DT pellet computed at highest compression for an isobaric spark ignition [13] case according to Storm et al [41]. The radius of the fusion detonation wave is at 0.47 of the actual plasma radius and the dashed lines are the average temperature of inner and outer parts and the dashed-dotted lines are the averages of the densities respectively.

Triumph: Volume Ignition

Adiabatic compression resulted in highest DT fusion gains following the self-similarity computations.

Stagnation-free compression (Yamanka-compression).

Fast pusher: too much shock- and turbulence generation

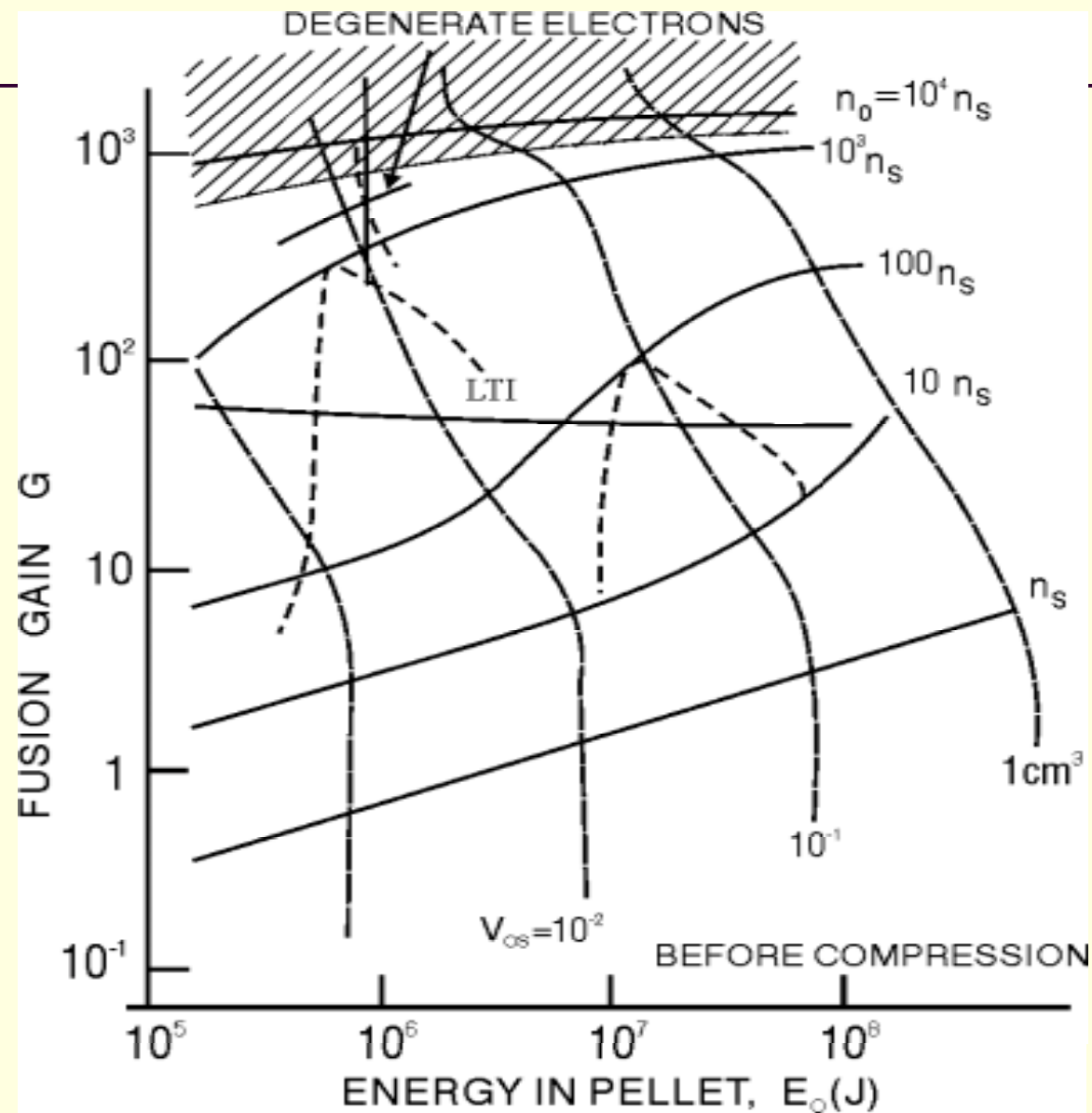


Problem after measurement of compression of Polyethylene to 2000 times solid state density (Azechi et al Laser and Particle Beams 1991):

Too low temperature of 300eV only.

Way out

- 1. E.M. Campbell: add up heating by fast ignition FI**
- 2. H.Hora: take single step volume ignition direct drive with smoothed red light at higher than 5 MJ laser pulses and higher than 4000ns compression where the ignition temperature is not much above 500 eV.**



Summary:

Solution of laser fusion with present days technology using ns laser pulses (NIF-like)

One step interaction direct drive, volume ignition gain per laser energy 130 at laser pulses of 10 MJ, compression above 5000n_s.

Gain for electricity: 40 vs ~ for ITER-like systems

END

- Thank you for your interest.
- Questions – contact G. H. Miley
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