The Ignitor Fast Pellet Injector

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Density Peaking for Burning Plasmas

- Ignition, the condition where the nuclear plasma heating equals the rate of plasma energy loss, can be attained at relatively low peak temperatures in a high magnetic field experiment, such as Ignitor [i] (R_0=1.32 m, $a \times b$ = 0.47×0.86 m^2, B_T= 13 T, I_p= 11 MA), designed to explore the physics of burning plasmas.

  The most accessible conditions to reach ignition involve relatively peaked density profiles (e.g., $n_0/\langle n \rangle \cong 2$) as they are beneficial for fusion burning plasmas from several perspectives, and in particular can provide a stability edge against the so-called η_i modes that enhance the ion thermal transport.

- [i] B. Coppi, A. Airoldi, F. Bombarda et al, *Nucl. Fusion* **41**, 1253 (2001).

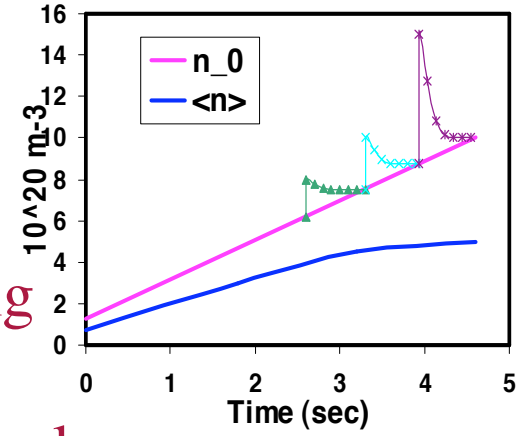
The Fast Pellet Injector Program

- In order to control density peaking, a high speed, multiple pellet injector [i] is planned as an integral part of the Ignitor facility.
- The ENEA Laboratory at Frascati and the Fusion Technology Group of Oak Ridge are jointly developing a multiple injector capable of shooting pellets of variable sizes for Ignitor.
- A 4 barrel, double stage gun able to reach speeds up to 4 km/s is being developed and built.

- [i] A. Frattolillo, S. Migliori, et al., http://www.aps.org/meet/DPP03/baps/abs/S2080045.html .

Accessibility

The compact size of the Ignitor machine favors the injection from the low field side, for which very positive results have been obtained on the FTU machine [i], in terms of density profile peaking and good energy confinement.



Simulations indicate that speeds of 3-4 km/s would allow a sufficient particle penetration within the plasma column, particularly during the initial current rise, when the plasma temperature is lower but density profile control is more desirable.

[i] D. Frigione at al., *Nucl. Fusion* **41**, 1613 (2001).

Ongoing Activities (ORNL Side)

I. Design/fabrication of pellet vacuum chamber and four gun barrel assemblies

II. Design/fabrication of pellet injector diagnostics (four light gates and a microwave cavity mass detector)

III. Develop control and data acquisition systems including digital pellet photography and integration with ENEA systems

IV. Prepare test stand to accommodate ORNL and ENEA equipment; this includes a ballast tank at the end of the injection line for measuring pellet size and dispersion

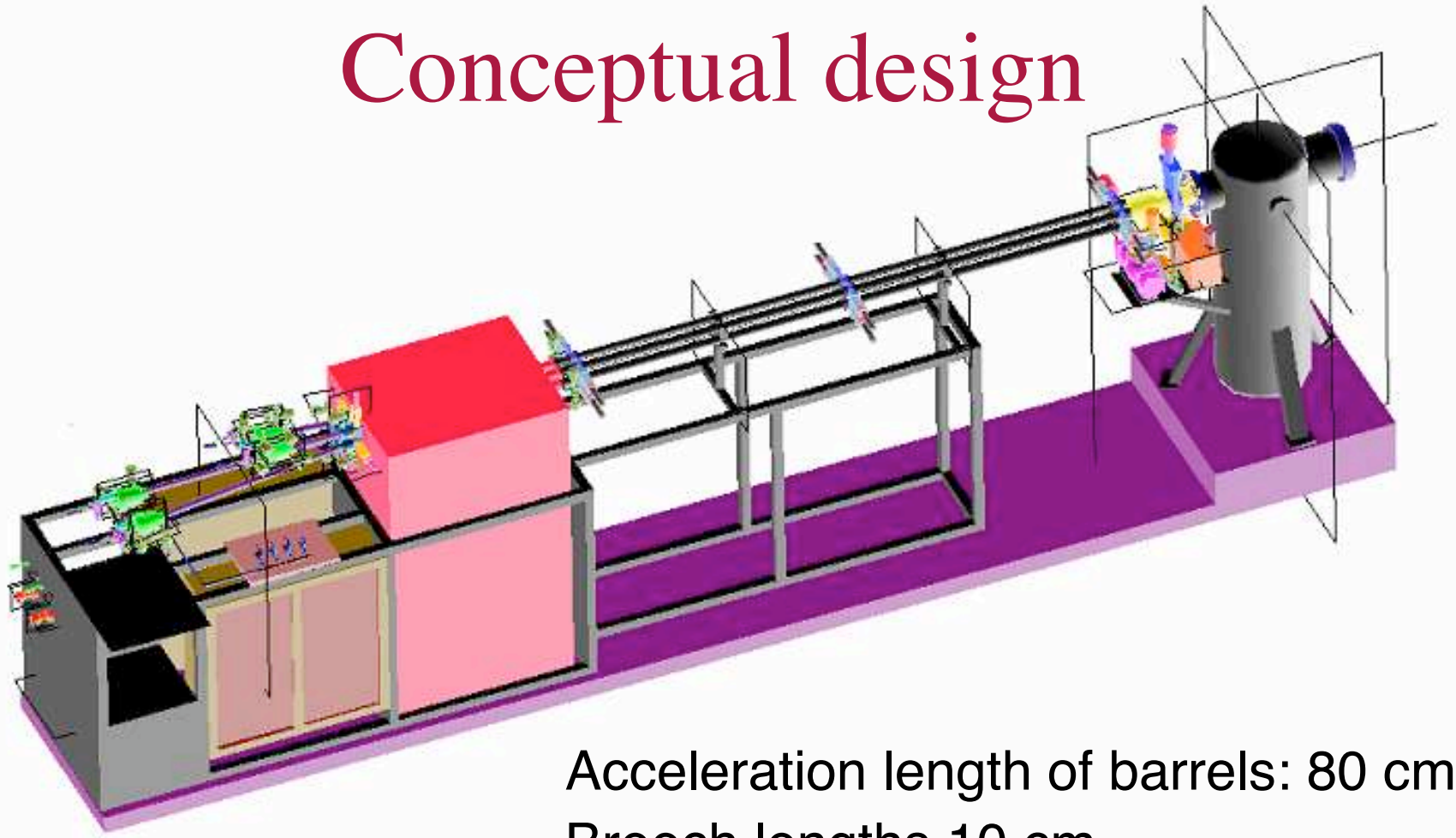
V. Assemble ORNL equipment and test with deuterium pellets and propellant valves

VI. Install ENEA two-stage gun systems on ORNL test stand and start initial experimental campaign

Ongoing Activities (ENEA side)

- Design and construction of the gun by ENEA and Criotec.
- Development of a new fast valve that considerably reduces the requirements on the expansion volumes necessary to prevent the propulsion gas to reach the plasma chamber.

Conceptual design



Acceleration length of barrels: 80 cm

Breech lengths 10 cm.

The design can accommodate acceleration lengths

of 70 to 110 cm and breech lengths of 5 to 10 cm

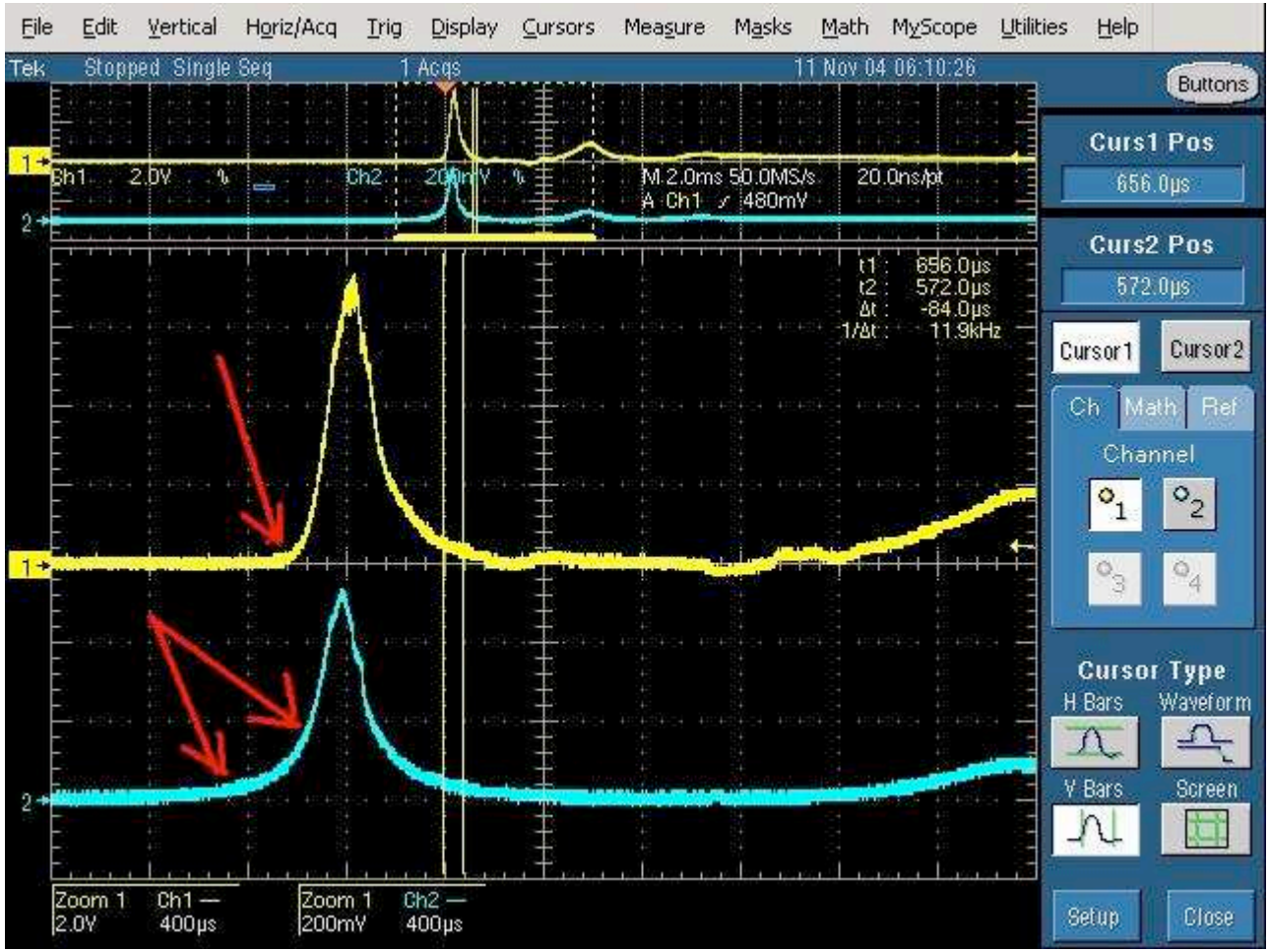
Present Status

- The conceptual design of the 4 barrel injector has been defined, detailed project in progress (Criotec, ORNL)
- Tasks 1 through IV are proceeding with everything coming together early in 2005. Tasks V and VI to follow.
- New fast valve successfully tested.

Fast Valve

- A special fast valve is being developed to reach the required pellet speed
- The valve serves the purpose of properly shaping the pressure pulse needed to accelerate the pellet
- The pulse before the valve (blue line, Fig. 1) increases gradually, while that after the valve (yellow line) rises linearly without the initial phase.
- This is an essential part of the acceleration process, as the initial (slow) pulse would push the pellet outside the acceleration tube before being accelerated

Fast Valve Tests



Fast Valve