ИСЭ СО РАН

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ZABABAKHIN SCIENTIFIC READINGS – 2023

SNEZHINSK, RUSSIA

Optimization of Double Shell Hybrid Gas-Puff with Outer Plasma Shell for Efficient Generation of K-Shell Radiation in the Microsecond Implosion Regime

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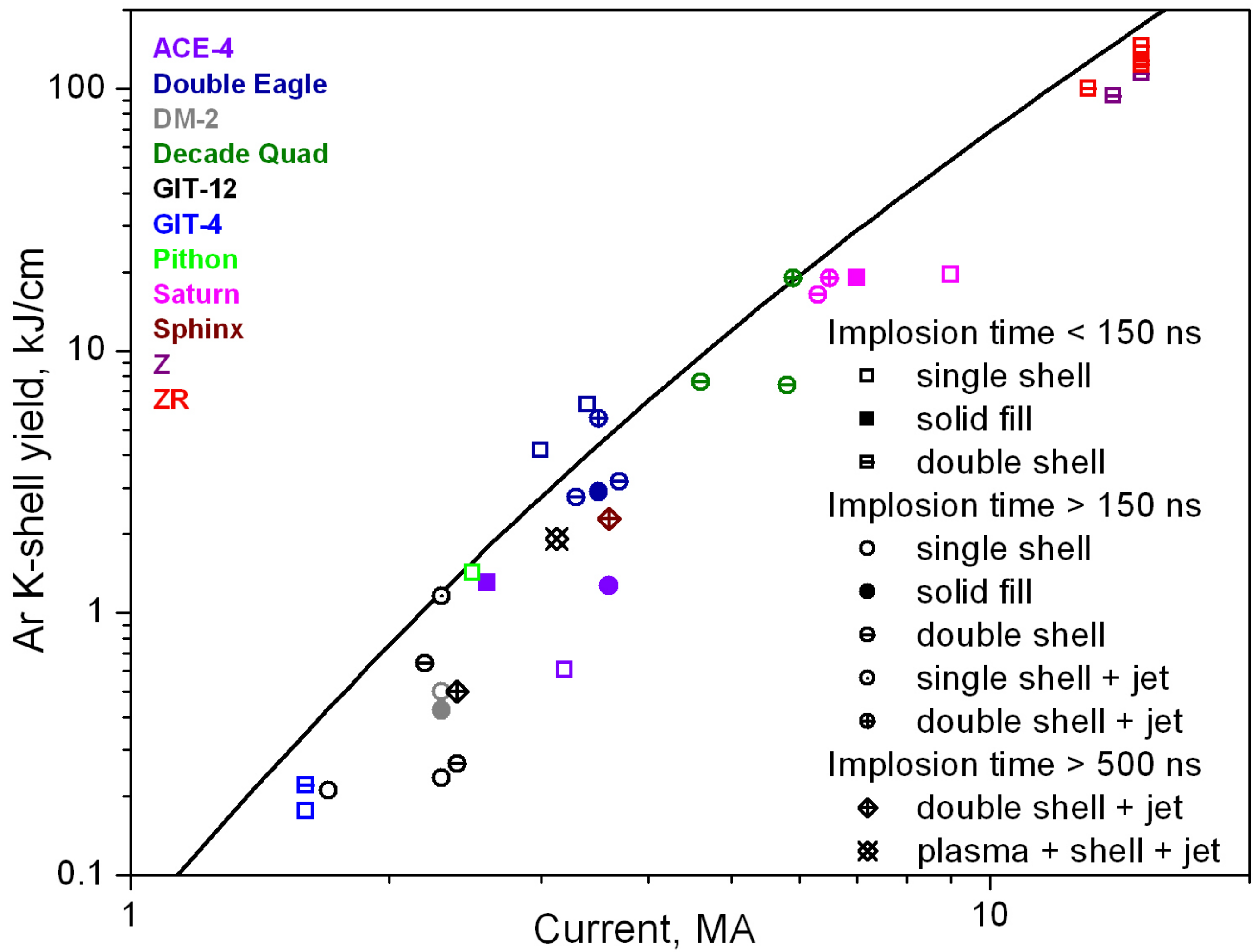
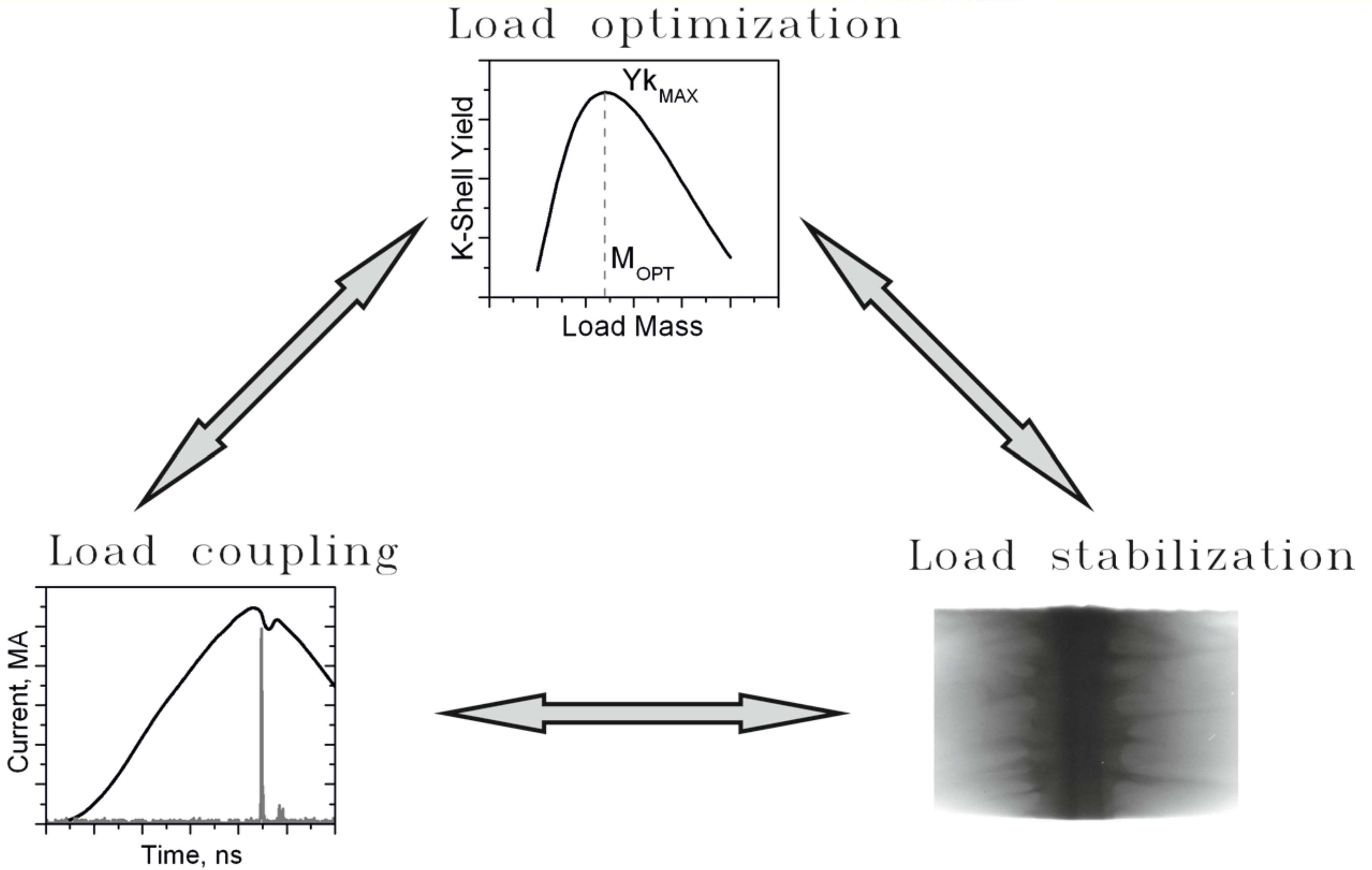
Ar K-shell plasma radiation sources



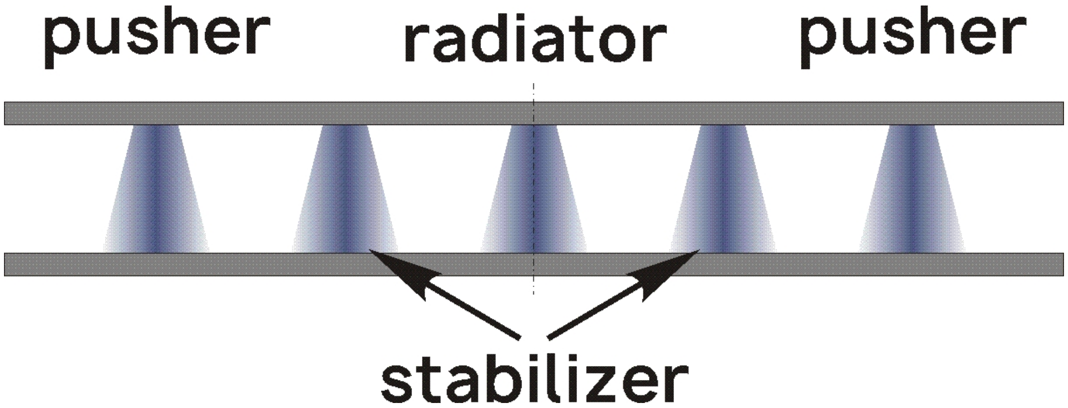
Ar K-Shell radiation yield scaling for different loads and implosion times

Three problems of the K-shell plasma radiation source



In the general case, all three problems must be solved altogether. The solution of one problem often interferes with the solution of another problem.

Triple gas puff: double shell + jet

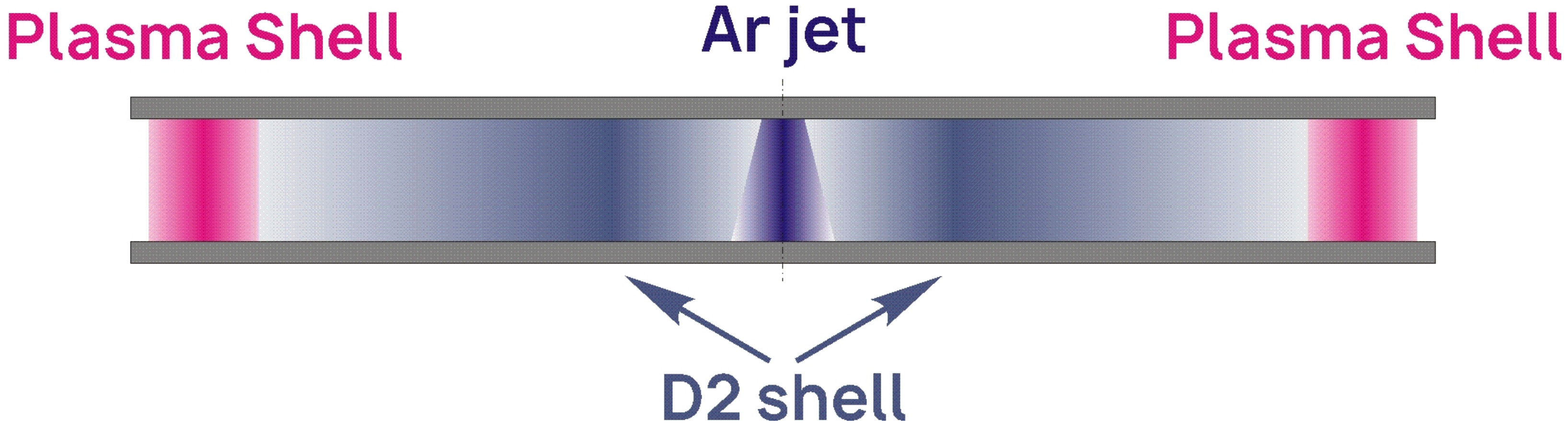


H. Sze et al., Phys. Rev. Lett., vol. 95, pp. 105001-1–105001-4, Sep. 2005.
J.S. Levine et al., Phys. Plasmas, vol. 13, no. 8, pp. 082702-1–082702-11, 2006.
R.J. Commisso et al., in Proc. 16th IEEE Pulsed Power Conf., Albuquerque, NM, USA, Jun. 2007, pp. 1773–1779.
A.V. Shishlov et al., Plasma Devices and Operations, vol. 13, No. 2, June 2005, 81–85.

"The jet-inner profile demonstrated that in implosions driven by slower current pulses the pusher does not necessarily have to start from a larger radius… to maintain high η; rather, the pusher can rapidly deliver the required thermal energy to the radiator via shock and quasiadiabatic compression, effectively amplifying η in the radiator, as in our jet-inner case."

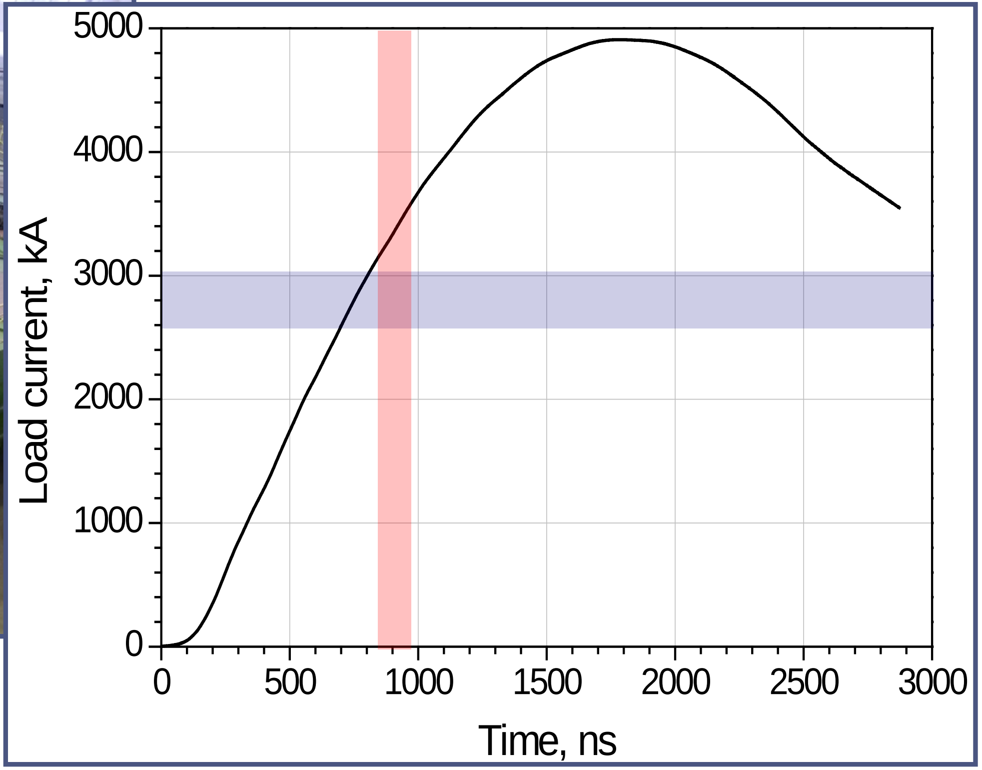
The load worked perfectly at long implosion times, but failed at microsecond implosion times.

Hybrid load as Ar K-shell plasma radiation source



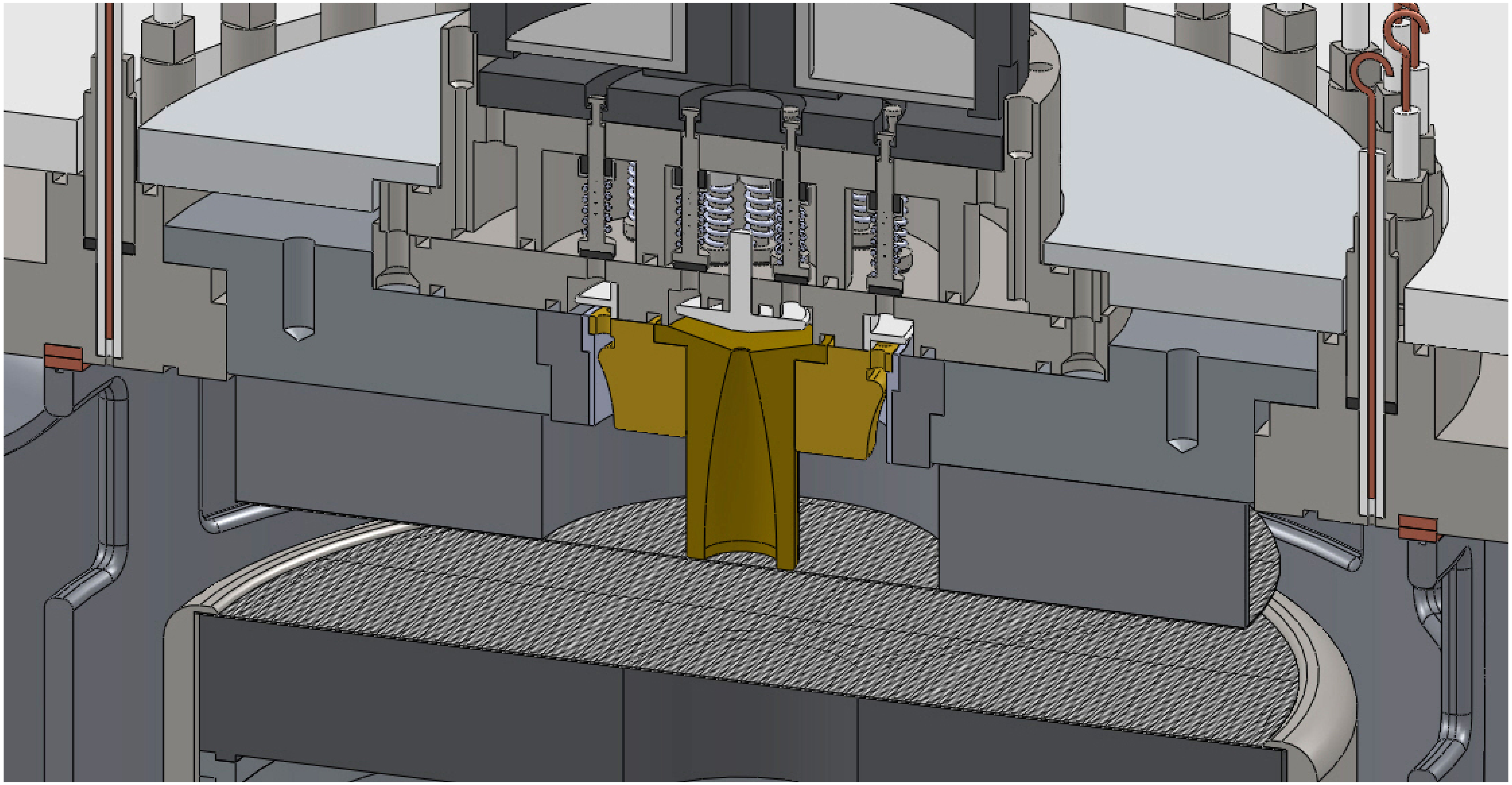
Ar jet: radiator, D2 shell + Plasma Shell: stabilizer and pusher.

Generator GIT-12



Charging voltage: 50 kV Stored energy: 2.6 MJ
Operation regime w/o POS: 4.7 MA, 1.7 ms, 3 kA/ns

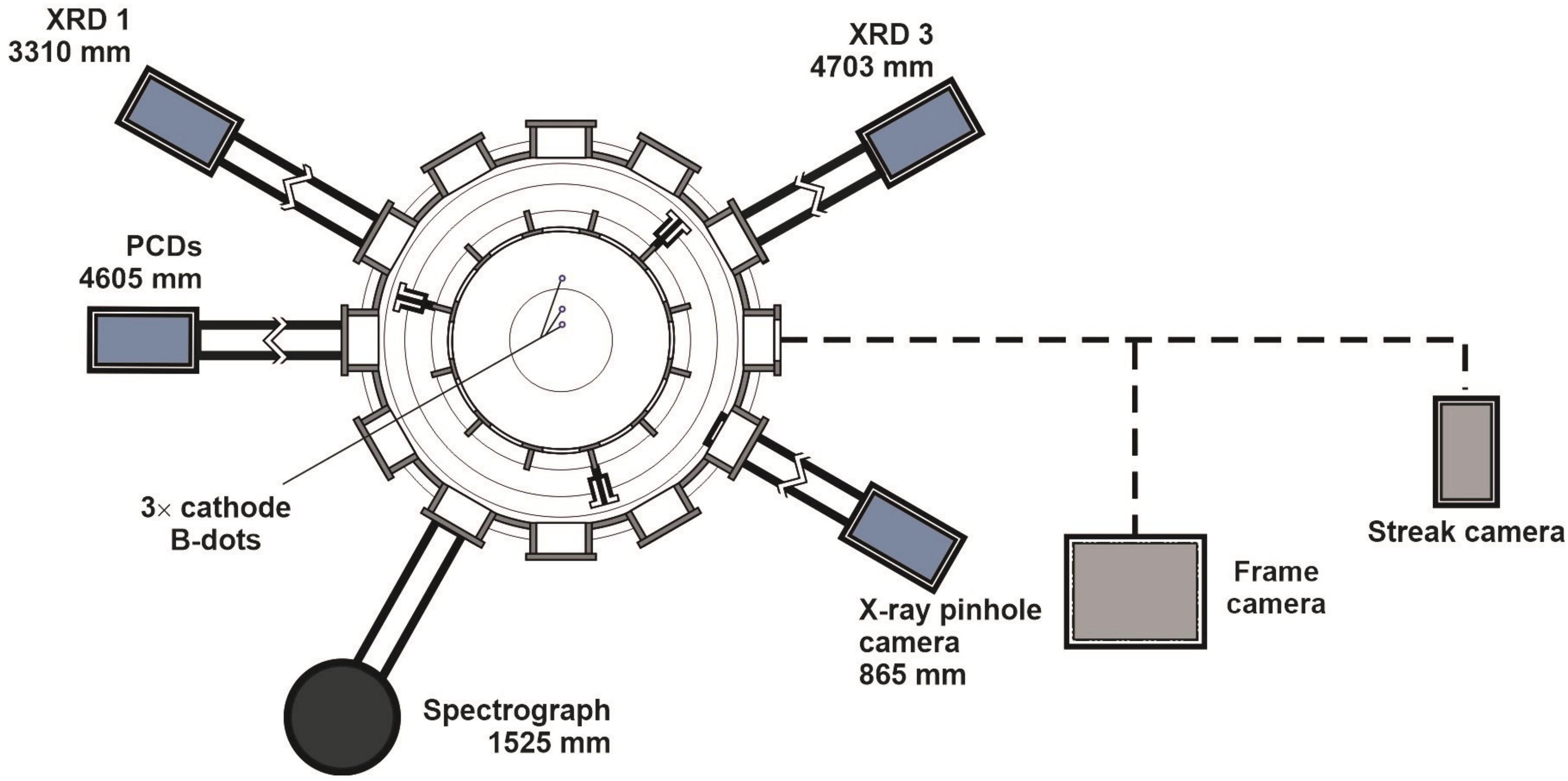
Load unit of the GIT-12 generator



- plenum pressure
- injection time
- nozzle cross-section
- grid transparency

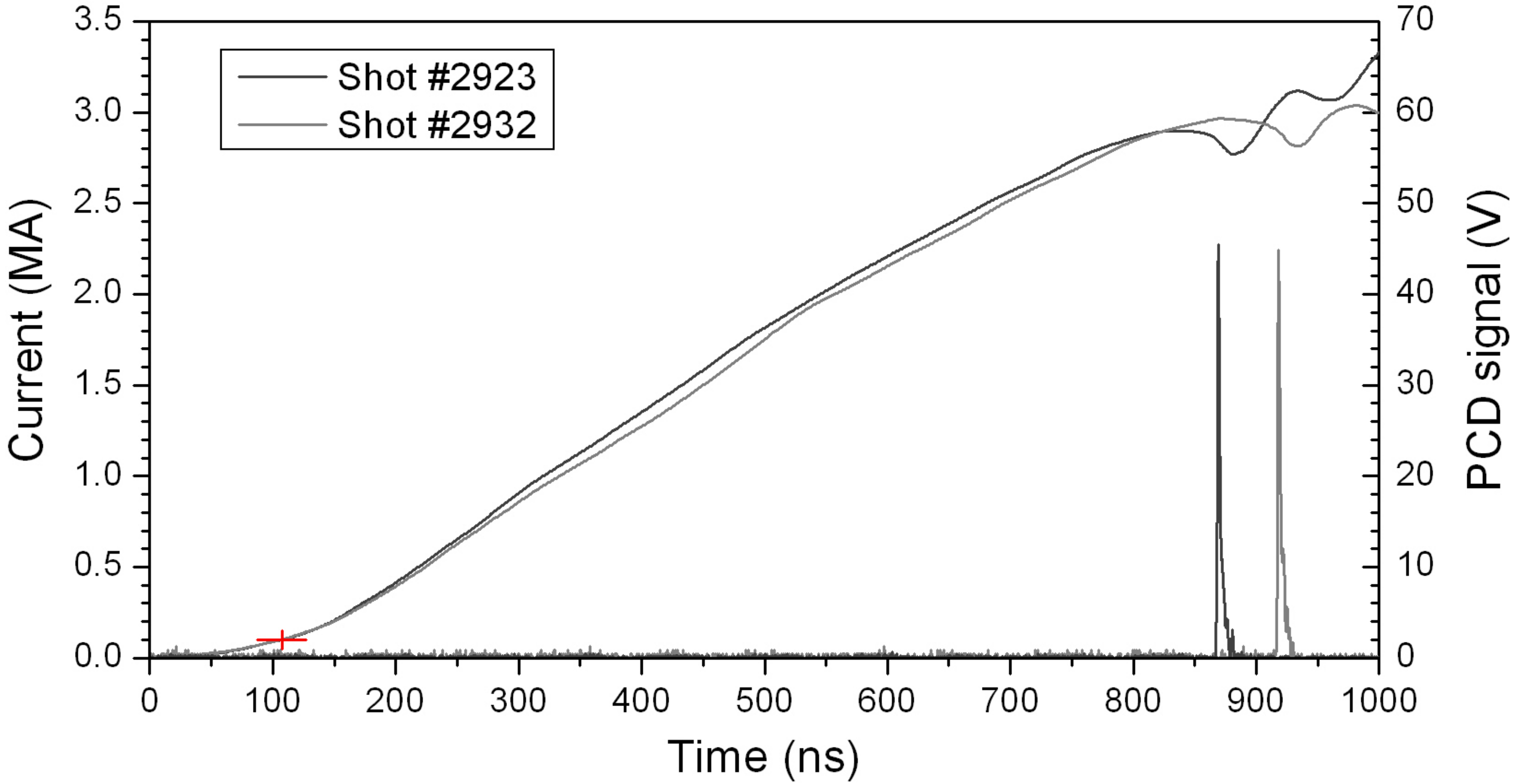
We can vary the total load mass and the gas density profile.
However, it is impossible to vary them independently.

Diagnostic set-up



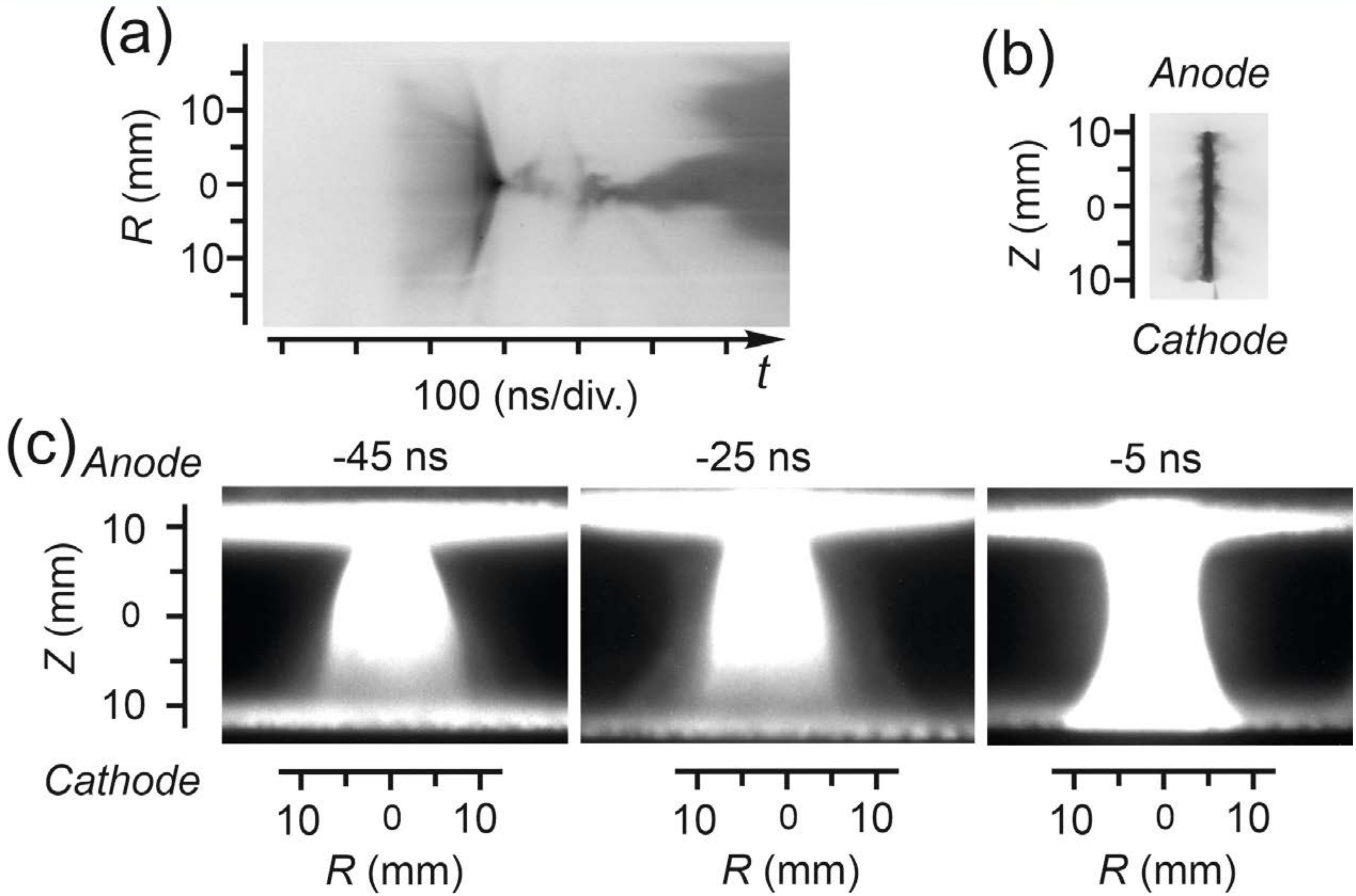
PCD 1: Ti 6.35 μ + Polypropylene 10 μ;   PCD 2: Teflon 30 μ + Polypropylene 20 μ
XRD 1: Cu cathode, Teflon 20 μ + Polypropylene 20 μ; XRD 3: Al cathode, Mylar 3 μ

Peak currents and implosion times



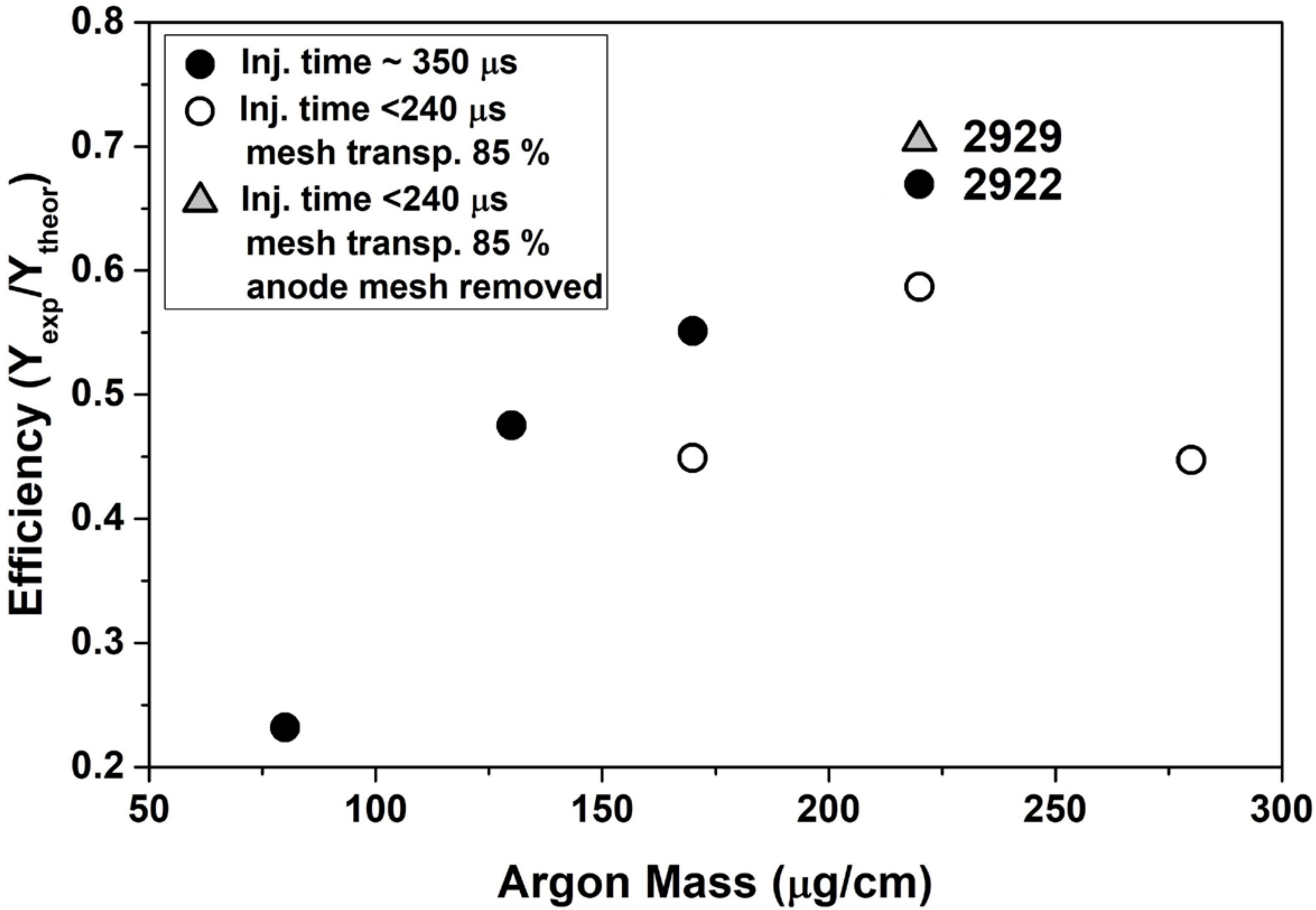
Peak currents and implosion times are mostly determined by the parameters of deuterium and plasma shells

Implosion dynamics



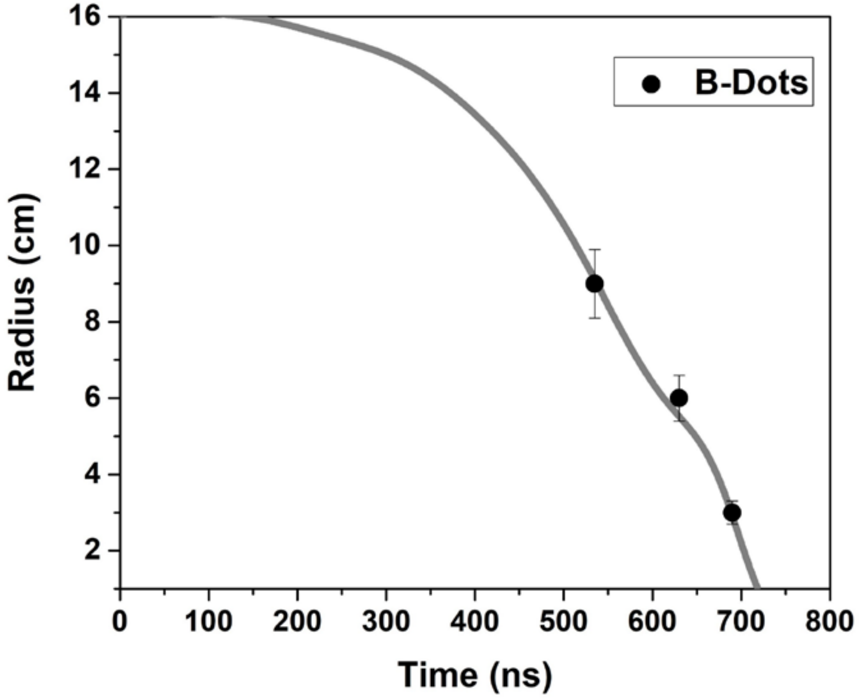
The hybrid gas puff with an outer plasma shell is capable of providing stable compression at implosion times of the order of a microsecond

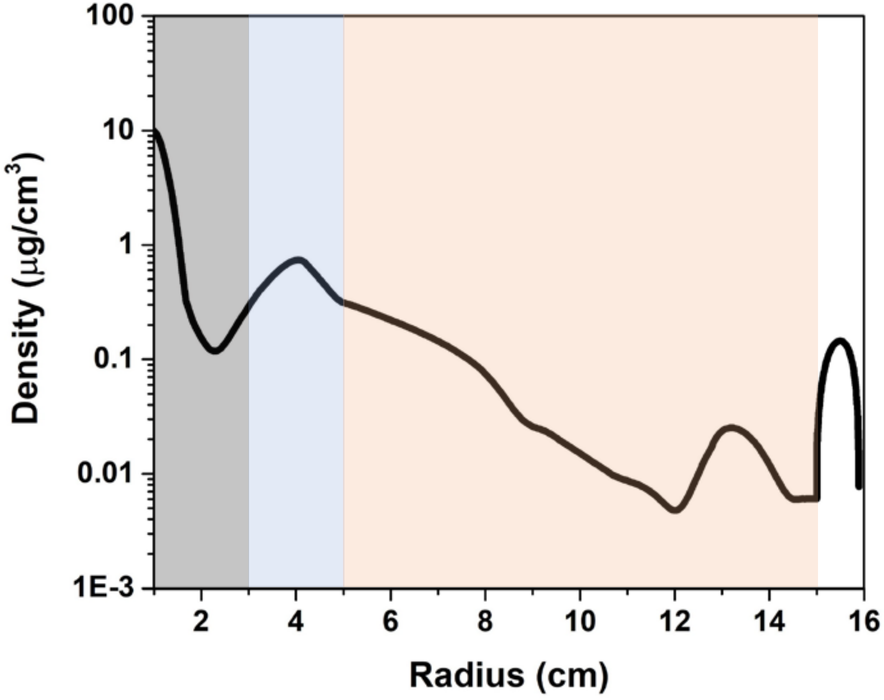
Optimization of double shell hybrid gas-puff



The maximum PRS efficiency was observed in a shot with a minimum spread of argon in the radial direction. Maximum K-shell yield was 1.66 kJ/cm.

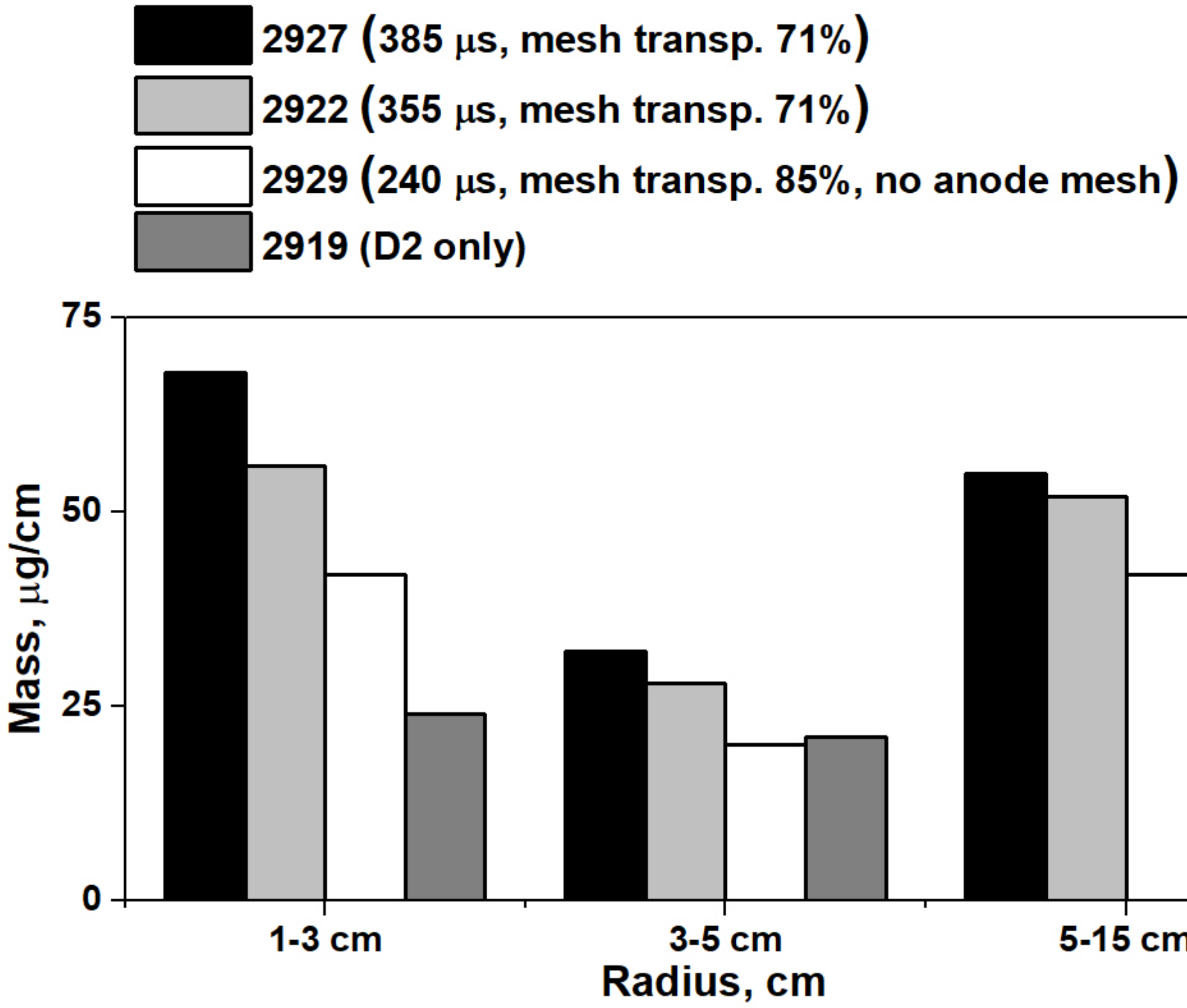
Density profile reconstruction





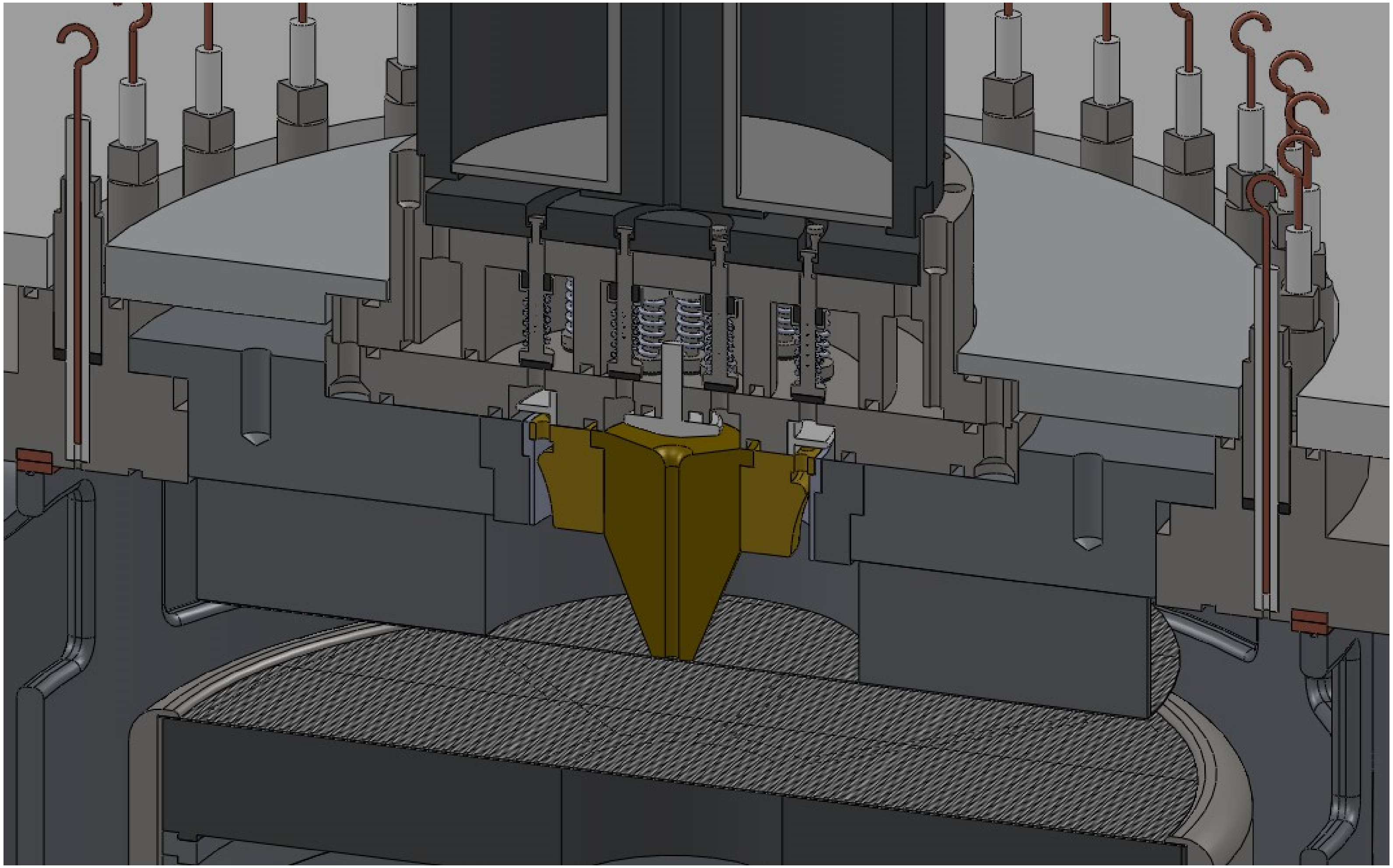
A.G. Rousskikh, et al., Technical Physics, **61**, 676–682, 2016
R.K. Cherdizov, et al., Plasma Phys. Control. Fusion **64,** 015011, 2022

Masses at different radii



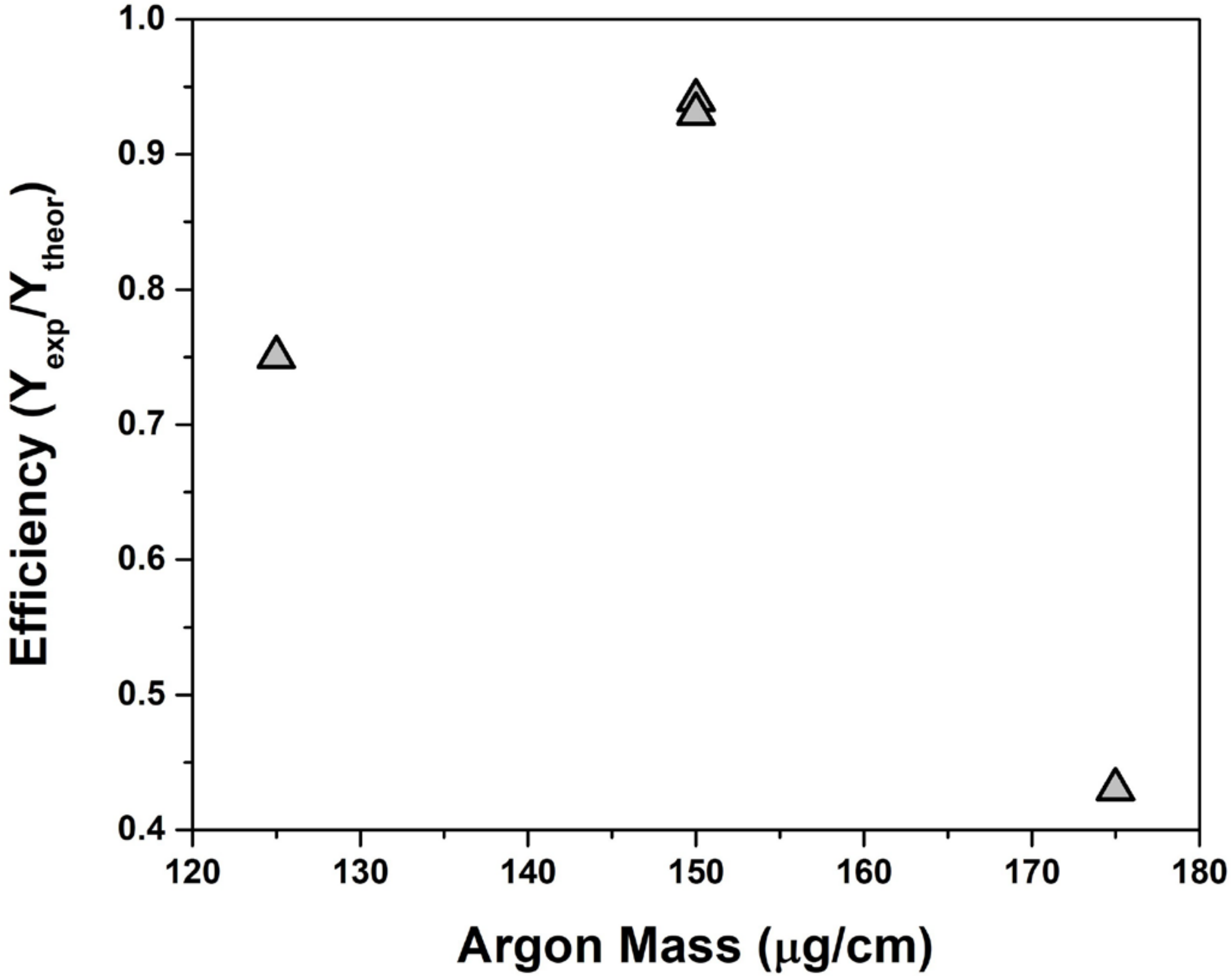
The injection time and the presence of grids determine the spread of argon in the radial direction.

New inner nozzle design



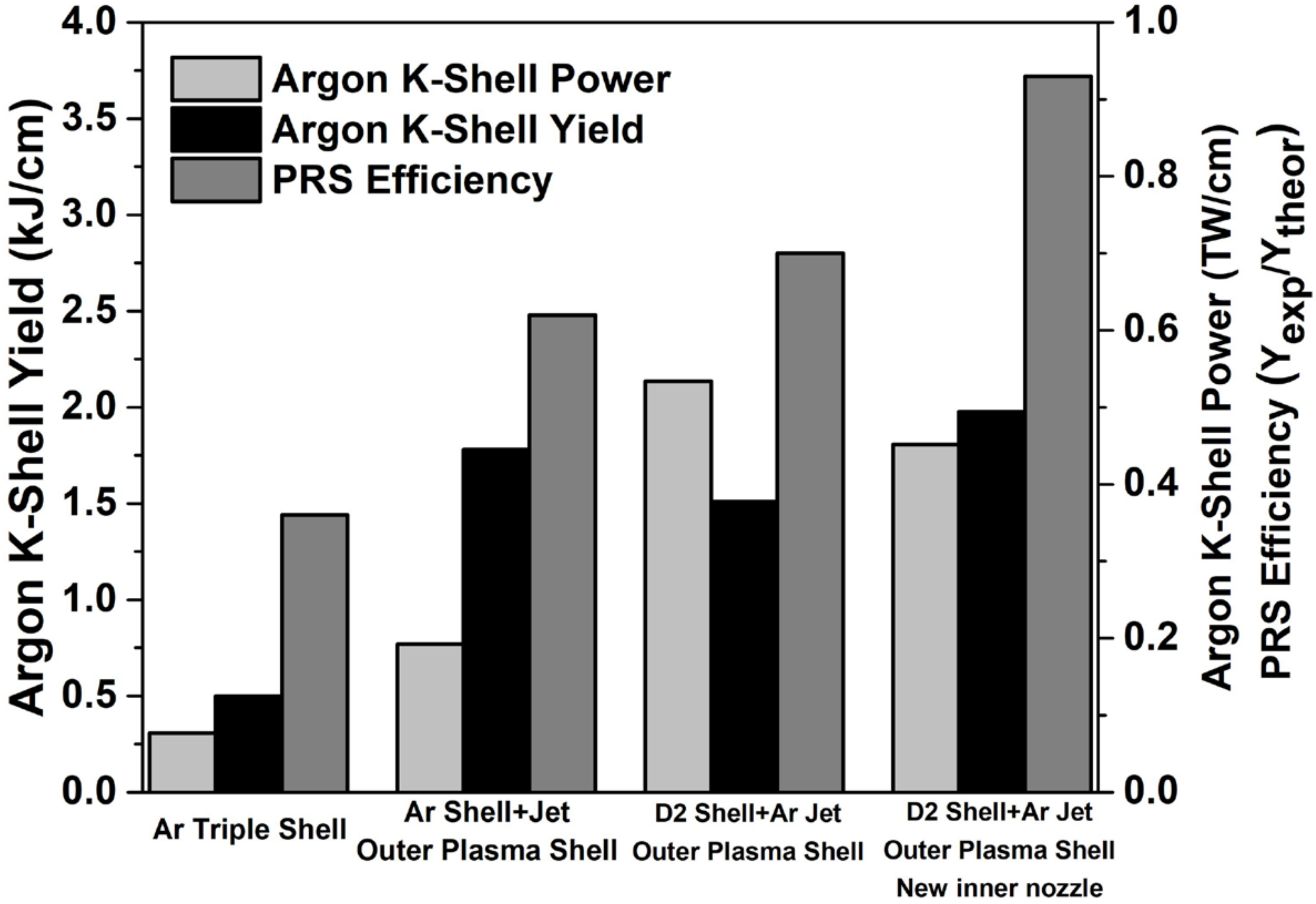
Reducing the nozzle opening should have led to an even greater localization of the emitter substance in the center of the load unit.

Optimization of double shell hybrid gas-puff



The new design of the inner nozzle allows for even greater K-shell radiation yield and PRS efficiency. Maximum K-shell yield was 1.98 kJ/cm.

Progress of K-shell PRS loads



The hybrid gas puff has demonstrated its advantages in implosion stability, duration and power of the radiation pulse, and the PRS efficiency.

Summary

- In comparison with other types of Z-pinch loads studied earlier, the hybrid gas puff has demonstrated its advantage in many important parameters, such as implosion stability, duration and power of the radiation pulse, and the efficiency of the plasma radiation source.
- The results of the experiments showed how the distribution of the gas-puff matter affects the K-shell radiation yield and the efficiency of plasma radiation source. By changing the density profile of the gas-puff, it was possible to achieve the K-shell radiation yield of 1.5-1.6 kJ/cm at a current level of 2.8–2.9 MA with the PRS efficiency up to 70 %.
- Using a new design of the central nozzle, which provides a localization of the emitter substance in the center of the load unit, it was possible to achieve a K-shell radiation yield of 1.9 – 2.0 kJ/cm at a current level of 2.75 MA, which corresponds to an PRS efficiency of more than 90%.
- A further increase of the radiation yield can be ensured by refurbishing the load unit by increasing the initial implosion radius. The hybrid load ensures effective suppression of instabilities, which will allow, by increasing the initial radius, to increase the current and implosion time, and hence the radiation yield.