EXPERIMENTS IN TOKAMAK T-11M WITH LITHIUM CAPILLARY-PORE LIMITER

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The communication concerns several questions.

First - usage in T-11M tokamak a lithium material basing on capillary - porous systems as a material of rail limiter, working in conditions of considerable thermal (~10MW/m^2, exposition duration 0.1-0.05sek) and electromechanical loads caused by interaction with a tokamak plasma.

The second - the influence of deuterium and helium recycling drop as result of lithium sputtering and deposition to discharge conditions.

The third - the deuterium retention in tokamak lithium experiment.

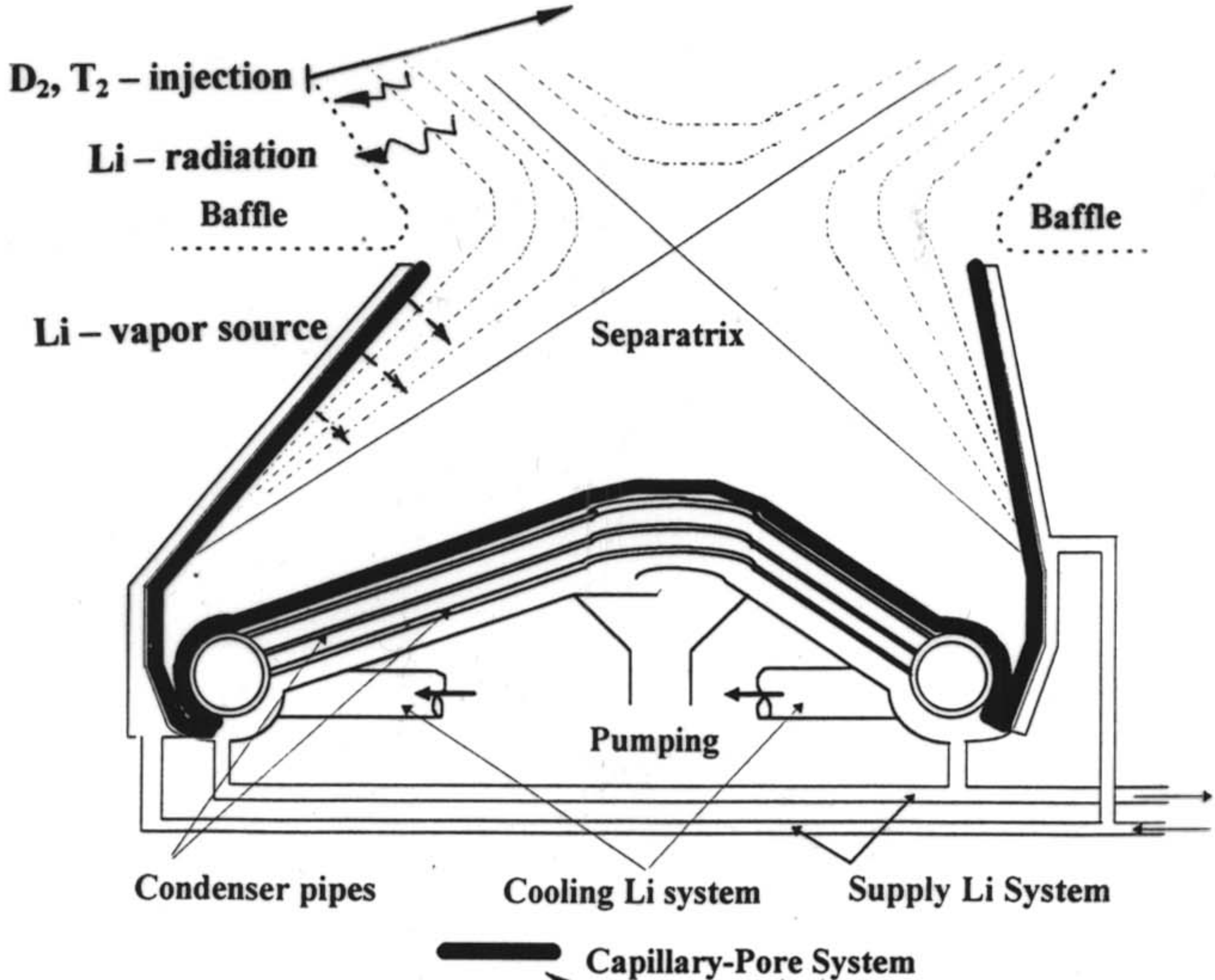
Our experience of liquid metal (Ga and Li) using, as limiters in small tokamaks Ga in T-3M (Shatura) and Li in T-11M (TRINITI):

a) the free metal mirrors or moving films can not be used - they gave the reach metal flux to wall during disruptions ,
b) it can be used : droplet stream near plasma boundary or Capillary Porous System (CPS) – suggested early by V.Evtikhin ea ("Red Star" Moscow) and tested in T11M (TRINITI). Most realistic for tokamak-reactor can be CPS limiters and divertor plates.
c) during the T-11M experiments (1kW/cm ^{2} duration 0,1sec, He or H plasma) we suppressed by choosing of CPS design the Lithium pellets (droplets) emission to the wall after disruption,
d) we wasn't see in stationary stage of discharge the excessive Lithium emission events (arcs, blooms ea.), the total Li-emission coefficient [4] was approximately equal Lithium spattering coefficients (D^++Li, Li^++Li , 0,5-1), which was measured in laboratory modeling experiments,
e) as early in TFTR experiments, we saw the deep gettering effect, but not only of D_2 and for He- too. The real gettering temperature threshold for He was near 50-100C, but for D_2 it was 350-400C. May by we can make in future the Tritium separator for lowering of Tritium inventory by using of this effect,
f) It will be very important to transform the main heat flux to divertor into radiation and avoid it by all chamber. In T-11M we have the first success in this direction. We decrease to 2 times the energy flux to T-11M limiter by increasing of Lithium emission in He – experiment (EXP4/21.). That is way to RI-regime. For such experiments is needed the long pulse tokamak.
We have plans to make this experiment in T-10.
g) very important feature of CPS is high resistant opposite disruption, as result of vapor shielding. It was shown in modeling experiments in TRINITI .

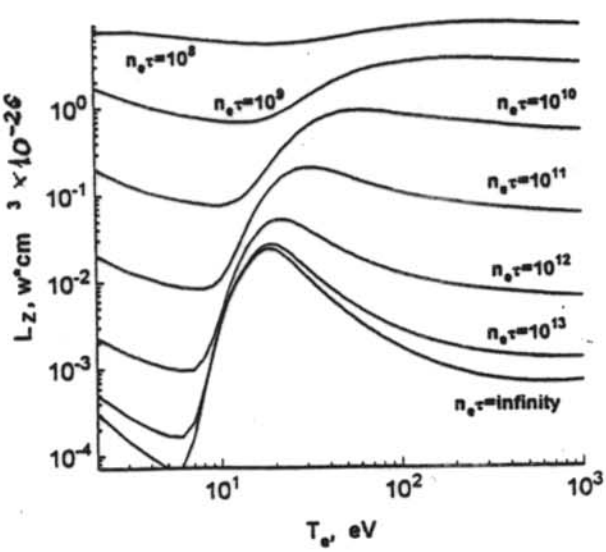
Stationary regime:
The schema of two Li-circuit cooling of divertor plate was presented by Dr. V.Evtikhin (IAEA Sorrento FTP1/24), the group from NFI (Kurchatov Inst.) made successfully the (CPS)Li-target experiment with stationary energy removal up to 20MW/m^2 of thermal load.

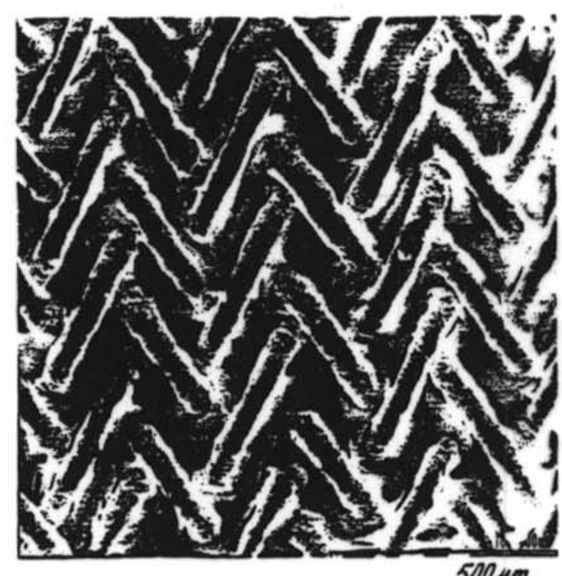
"Prana-Red Star", NFI RRC KI, TRINITI - Suggestion :

Li – Liquid Metal Divertor Alternative Design



Li – radiation in low $n_e\tau_{Li}$ conditions





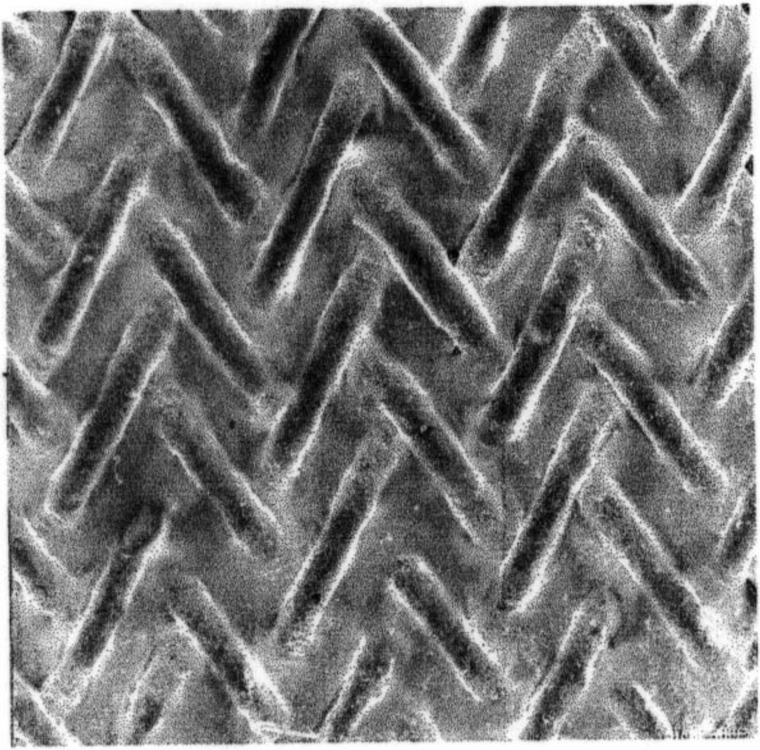
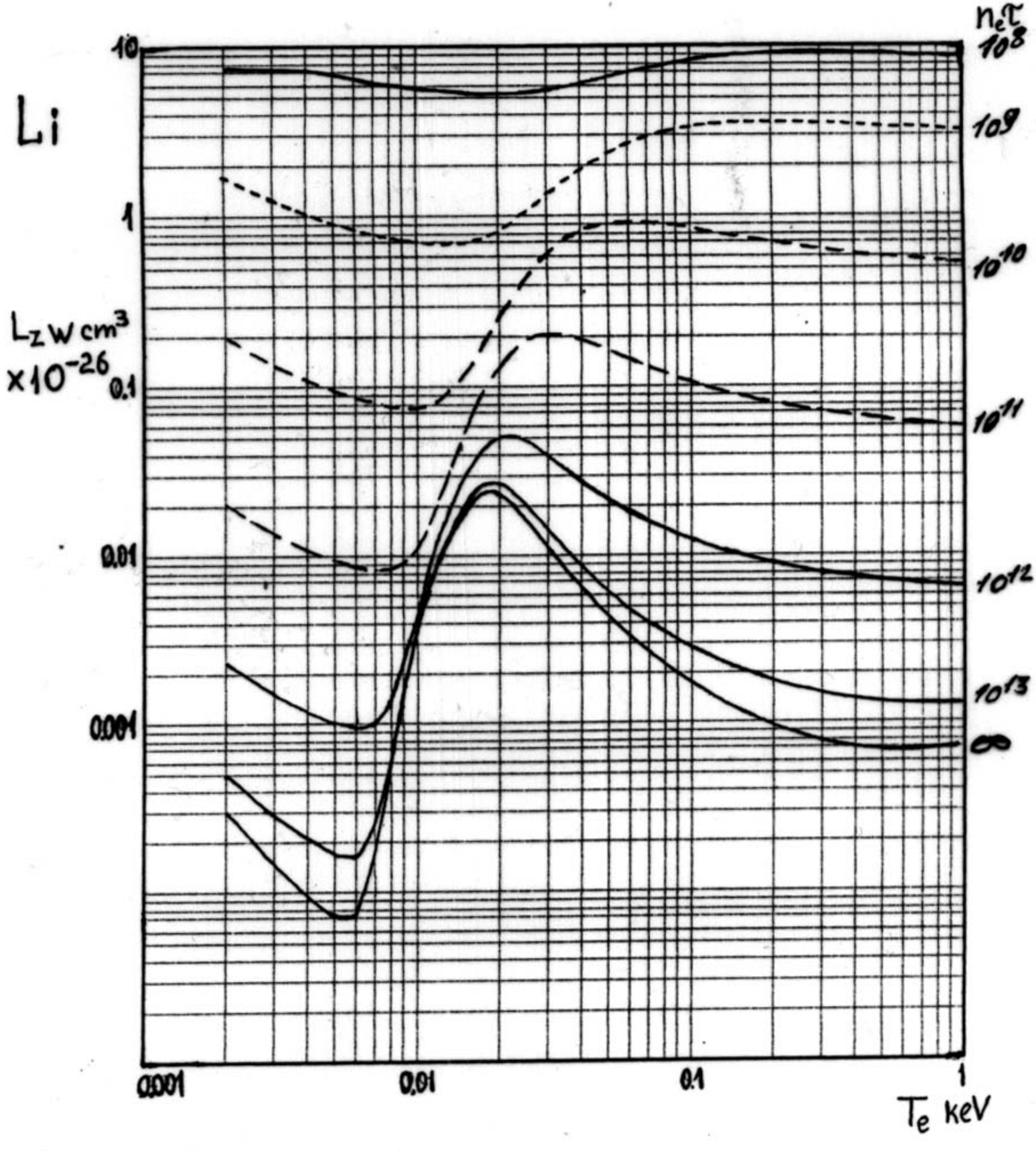


Fig.3A



Li
L_z w cm³ ×10⁻²⁶
10
1
0.1
0.01
0.001
0.001
0.01
0.1
1
T_e keV
$n_e\tau$
10⁸
10⁹
10¹⁰
10¹¹
10¹²
10¹³
∞

Experimental conditions

Experiments were performed on the tokamak T-11M with R=0.7m, a=0.2m, B_T=1T, I_p=70…100 kA.

The multi-channel radiation loss measuring system (MRLMS) with 16-element absolute extreme UV (AXUV) detector array was installed into the tangential port of T-11M for the monitoring of rapid impurity penetration into the plasma core. An AXUV detectors could be regarded as electromagnetic radiation bolometers in 1…5000 eV photon energy range, with high temporal resolution (~2 μs). The tangential direction touching toroidal axis, with vertical orientation of the detector field-of-view (FOV) plane was chosen, contrary to traditional poloidal FOV. It provides an opportunity to watch the vertical diameter of the poloidal plane (toroidal angle φ=0°), in the vicinity of Li limiter.

After impurity injection due to plasma-limiter interaction during the disruption, cold peripheral Li ions need 70…100 μsec to move around the torus. In this period, the variation of emission profile over MRLMS view chords could be roughly considered as qualitatively representing the vertical movement of Li impurity transverse the toroidal magnetic field. Thus we eliminated the necessity of Abel inversion procedure, being the main source of errors in the absence of cylindrical symmetry of XUV-emission in plasma column.

The main part of the total XUV emission was provided by Li ions, since our experiments were performed in general with the Li limiter.

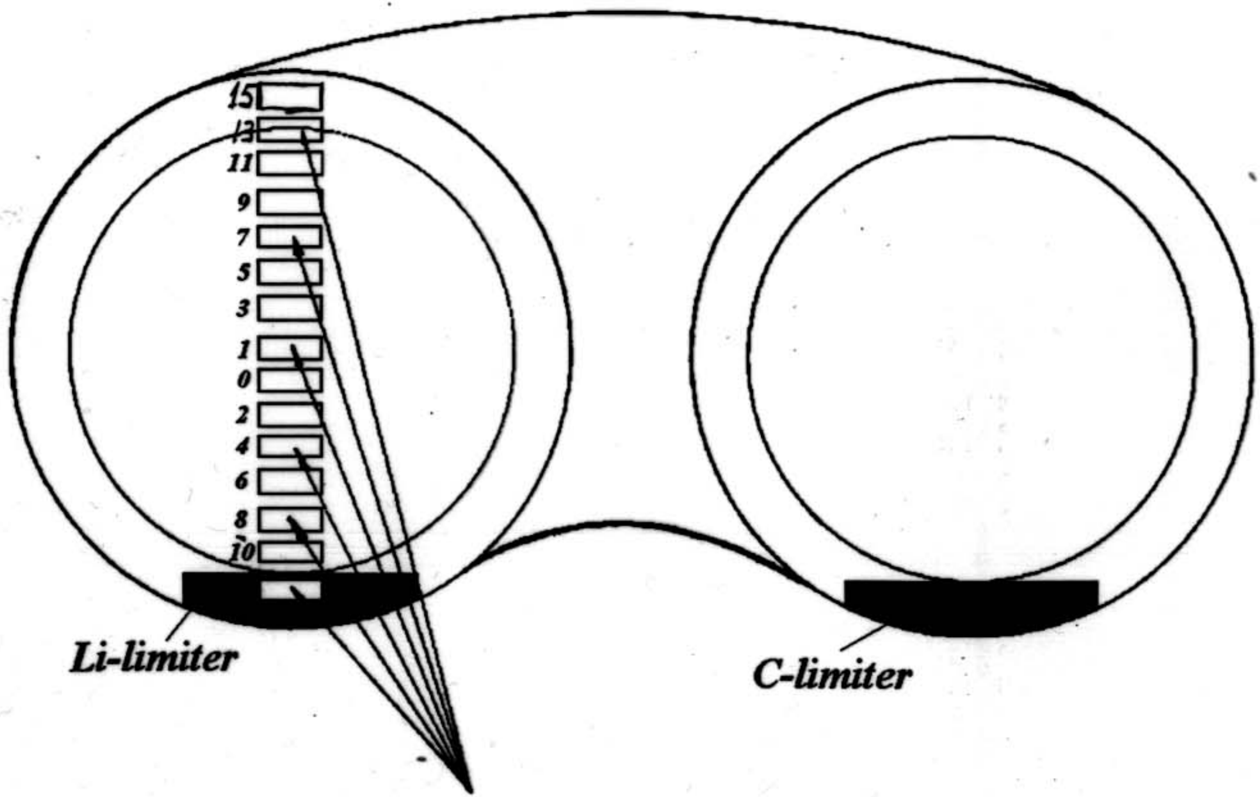
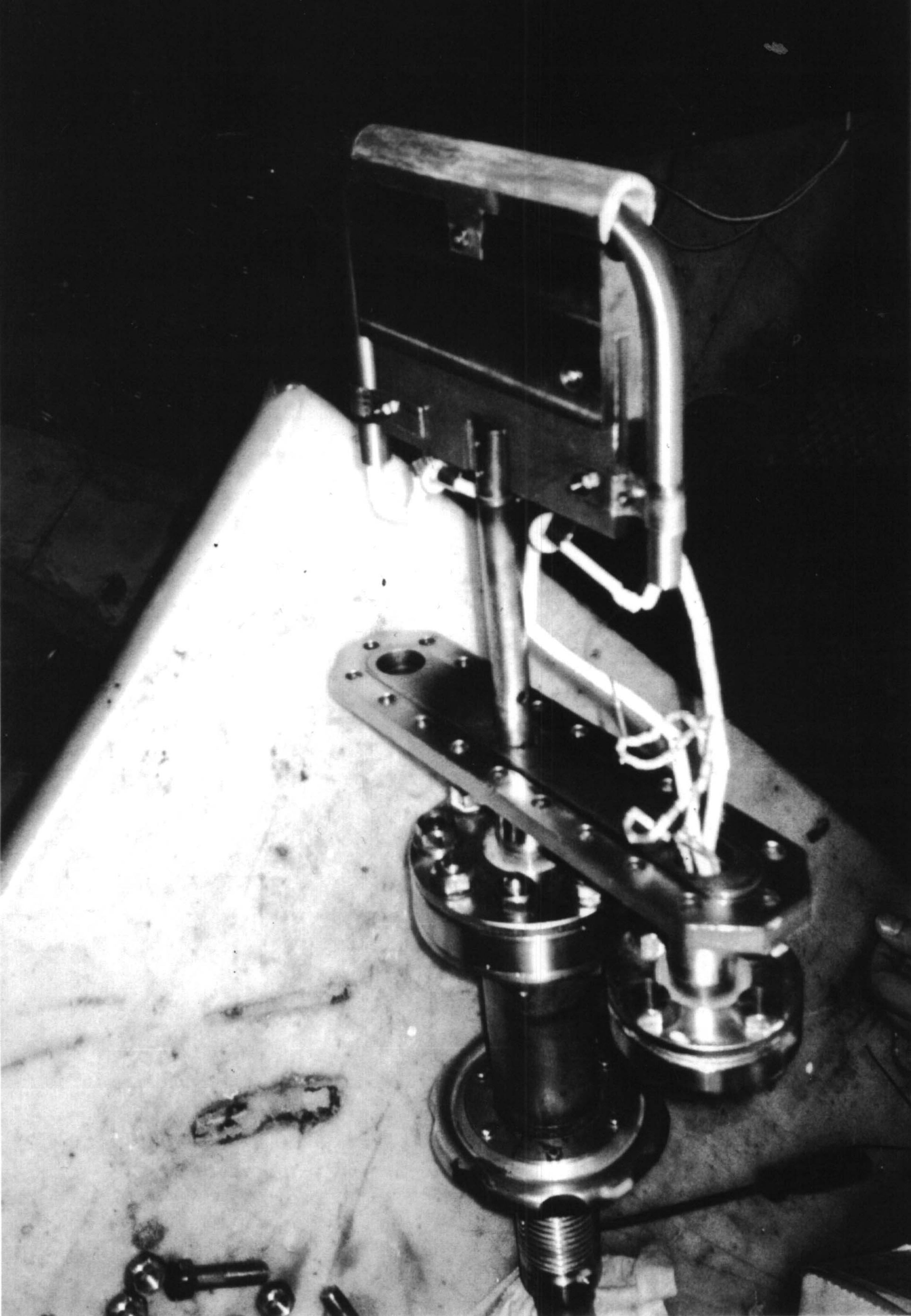
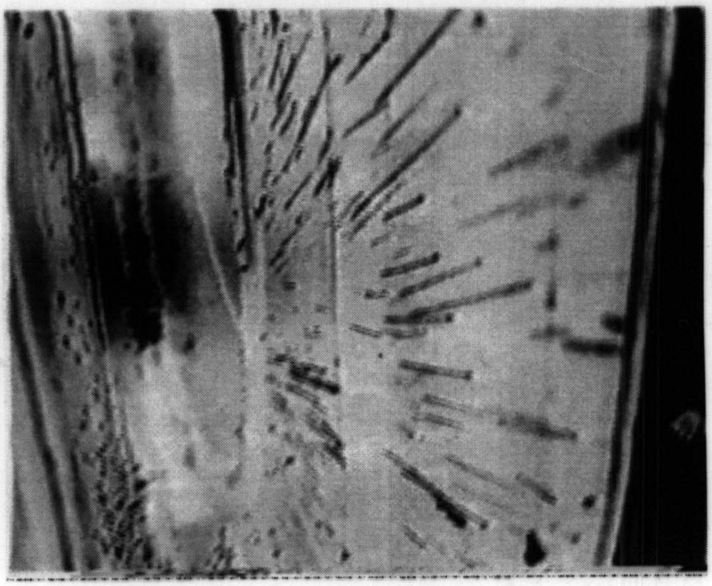
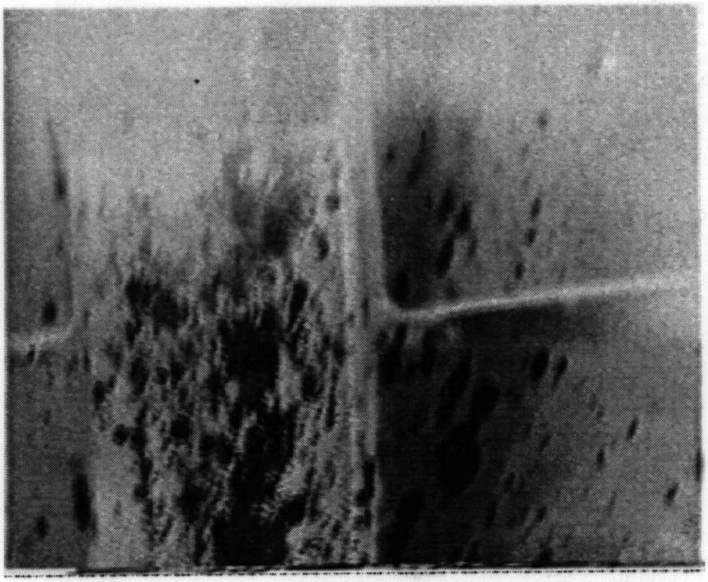


Fig. AXUV photodiode array FOV setup: arrows – detector view directions. Li or C limiter.

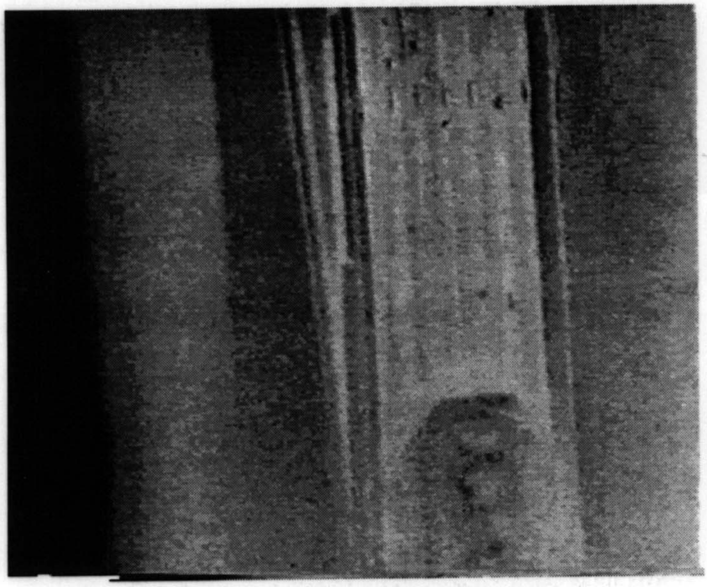




Патрубок Т-11М
после работы с
первым вариантом
диафрагмы (негатив).



Задняя стенка Т-11М
после работы с
первым вариантом
диафрагмы (негатив).



Задняя стенка Т-11М
после работы со
вторым вариантом
диафрагмы (негатив).

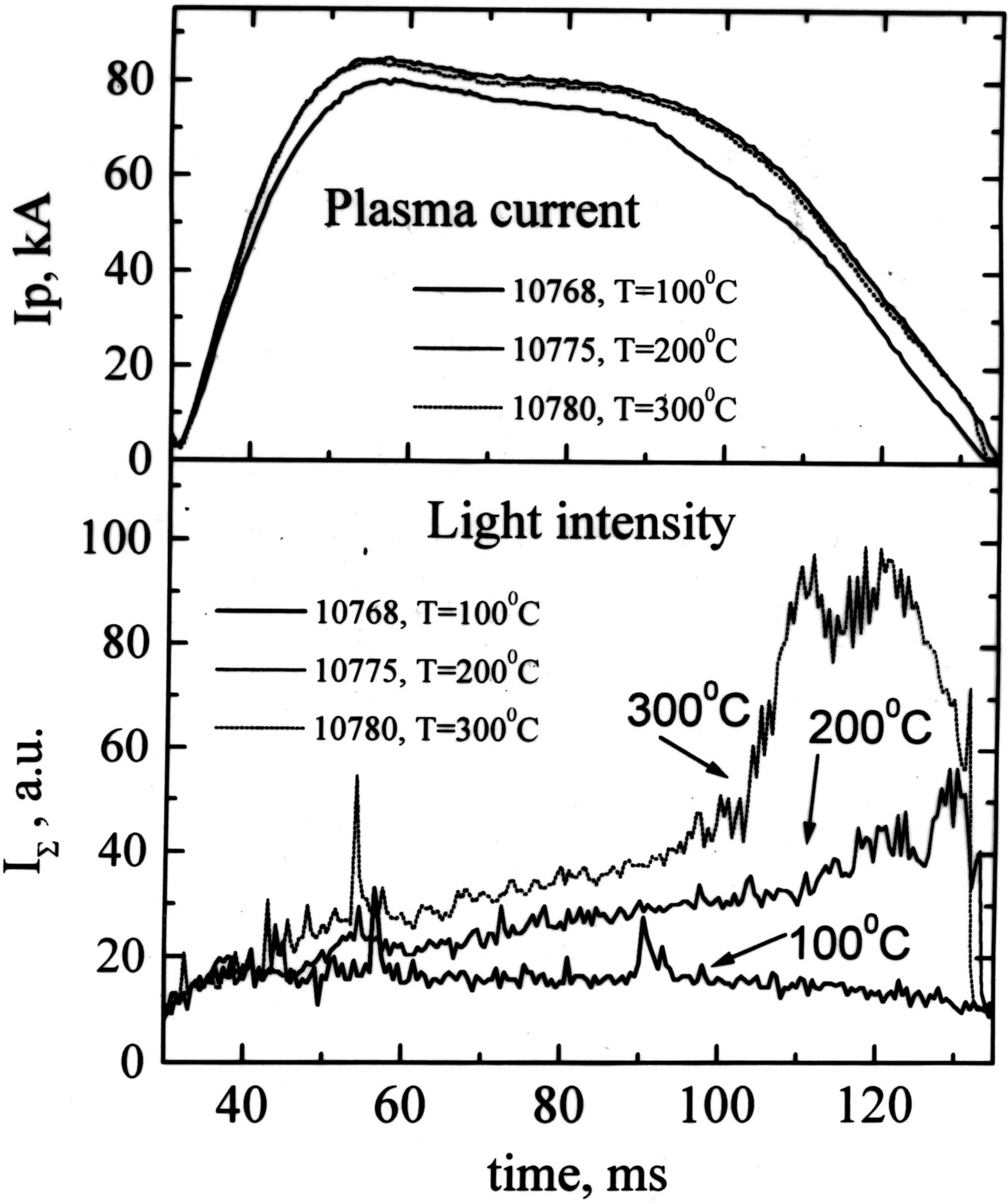


Fig. 2. Light intensity near the limiter during same shots for different initial lithium temperatur 100^0 - 300^0 C.

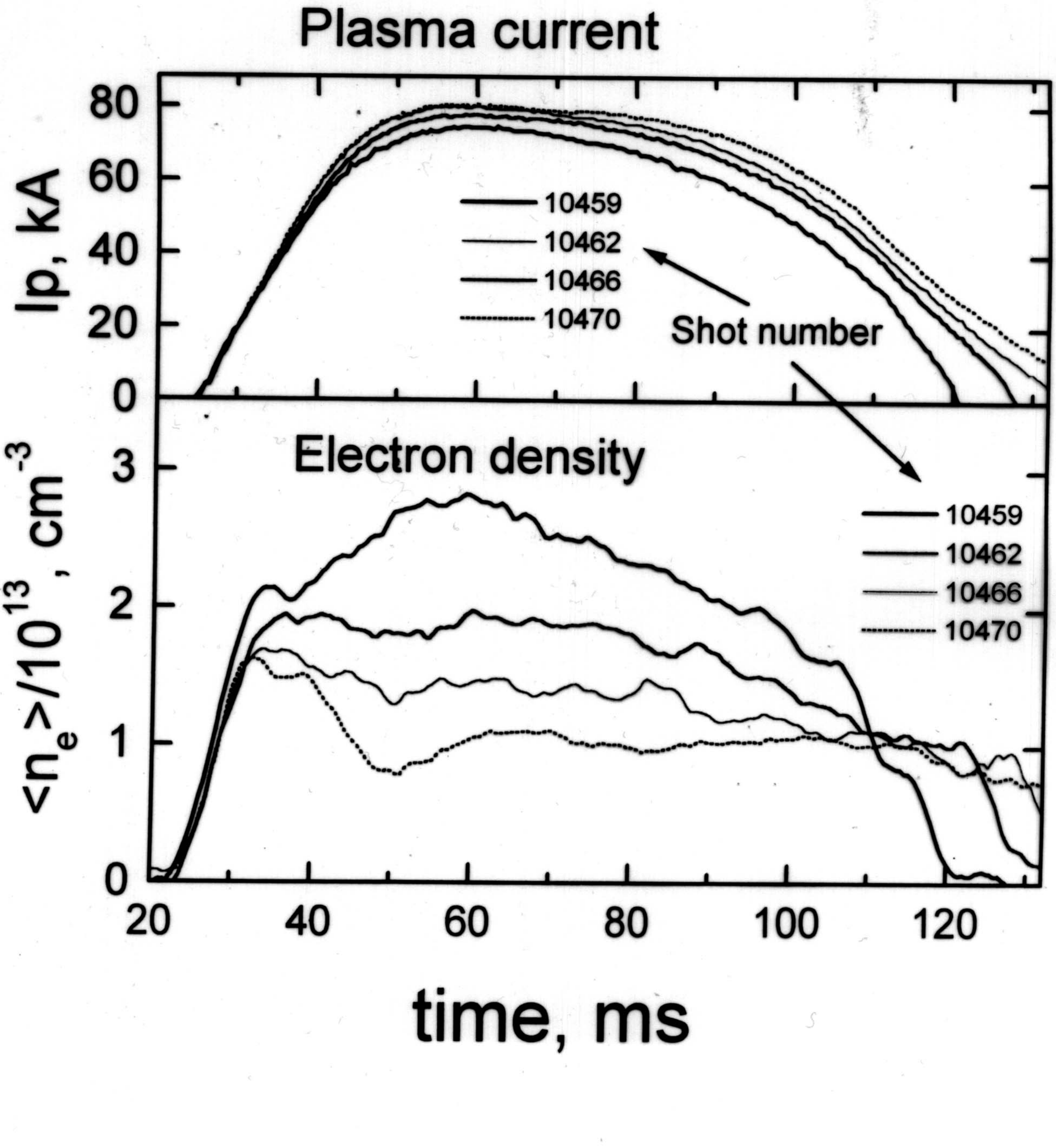
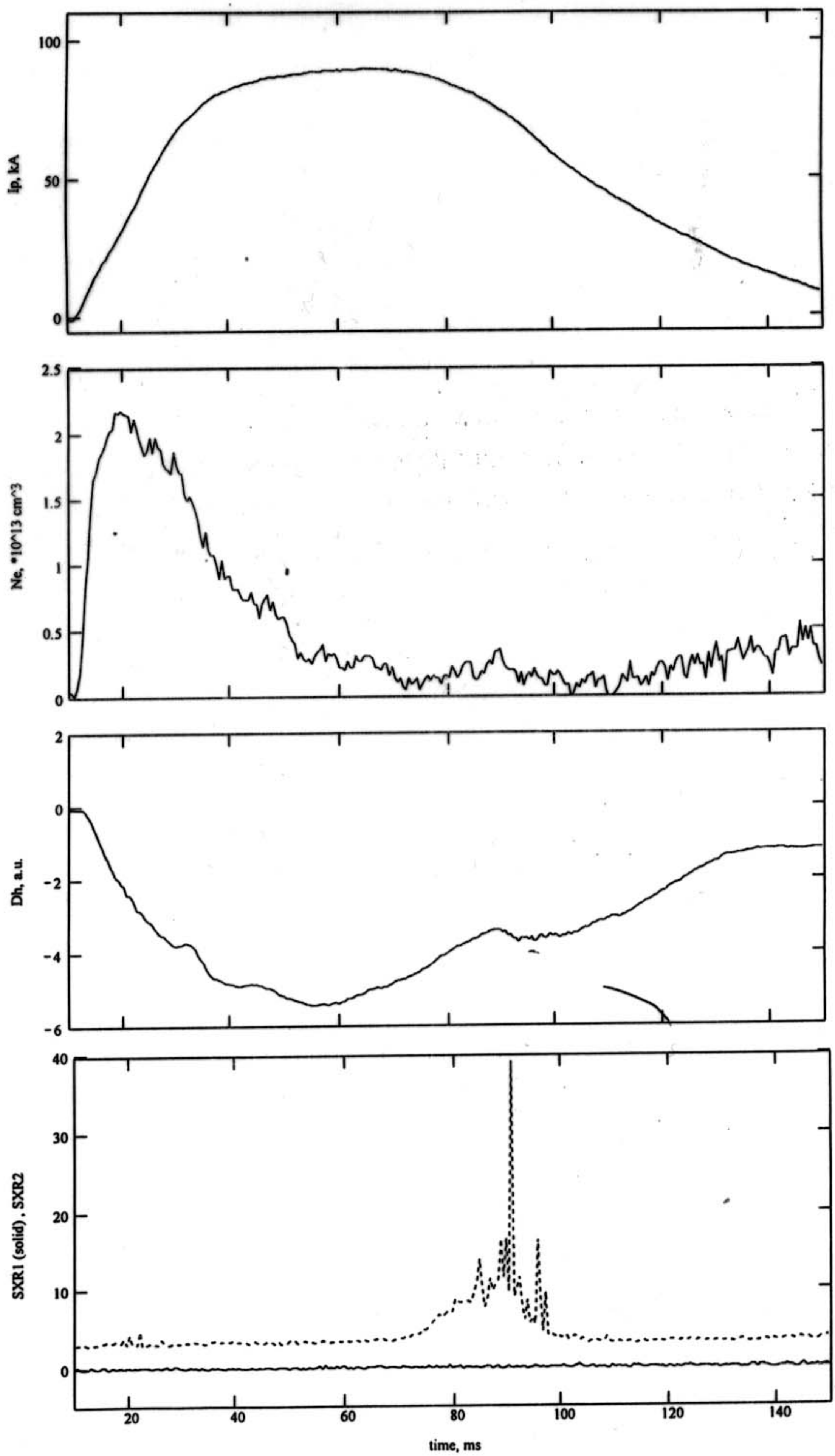
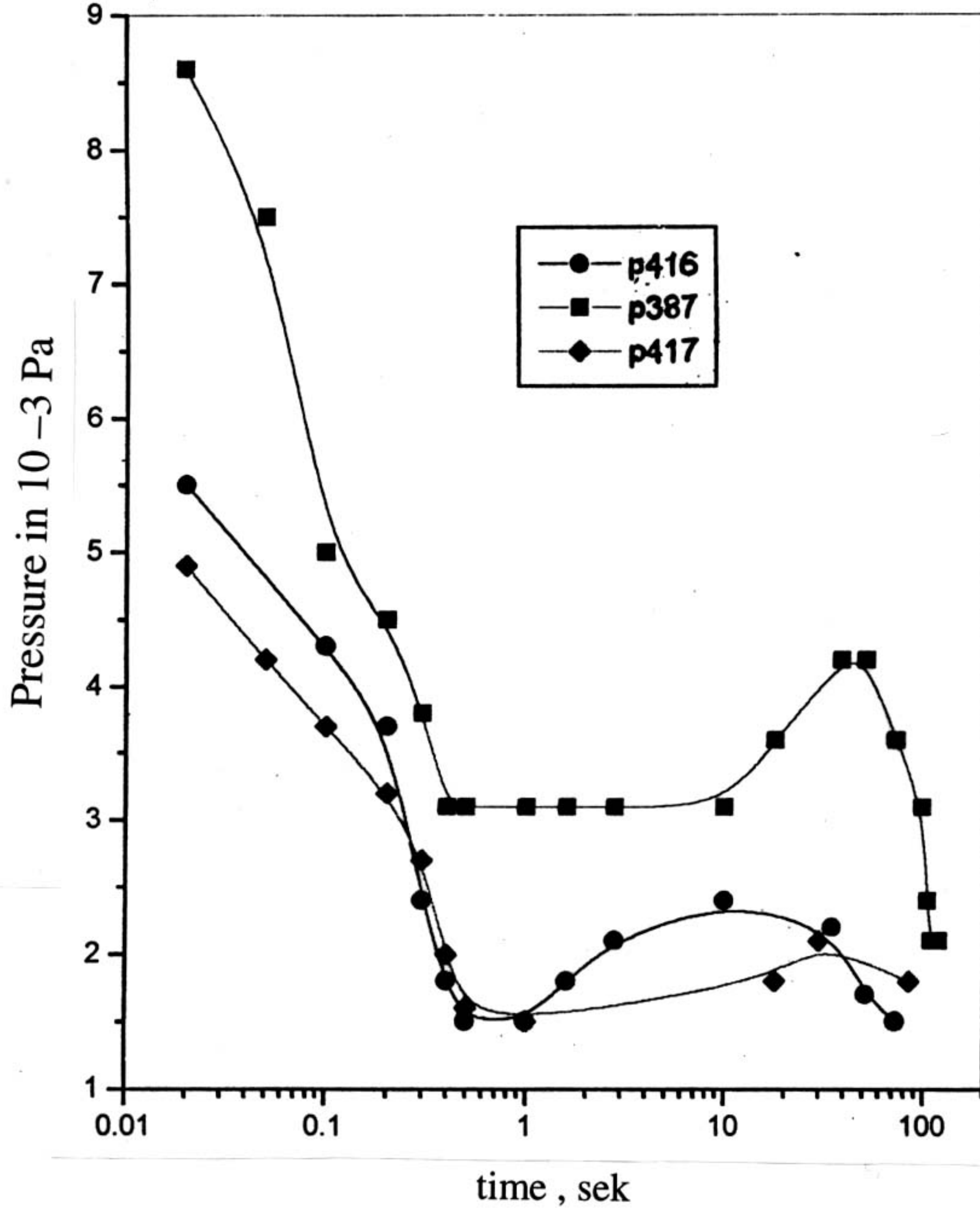


Fig.9. Elecron density evolution from shot to shot in dischages with high temperature (approx. 500^0C) Lithium limiter. Operational gas - He.

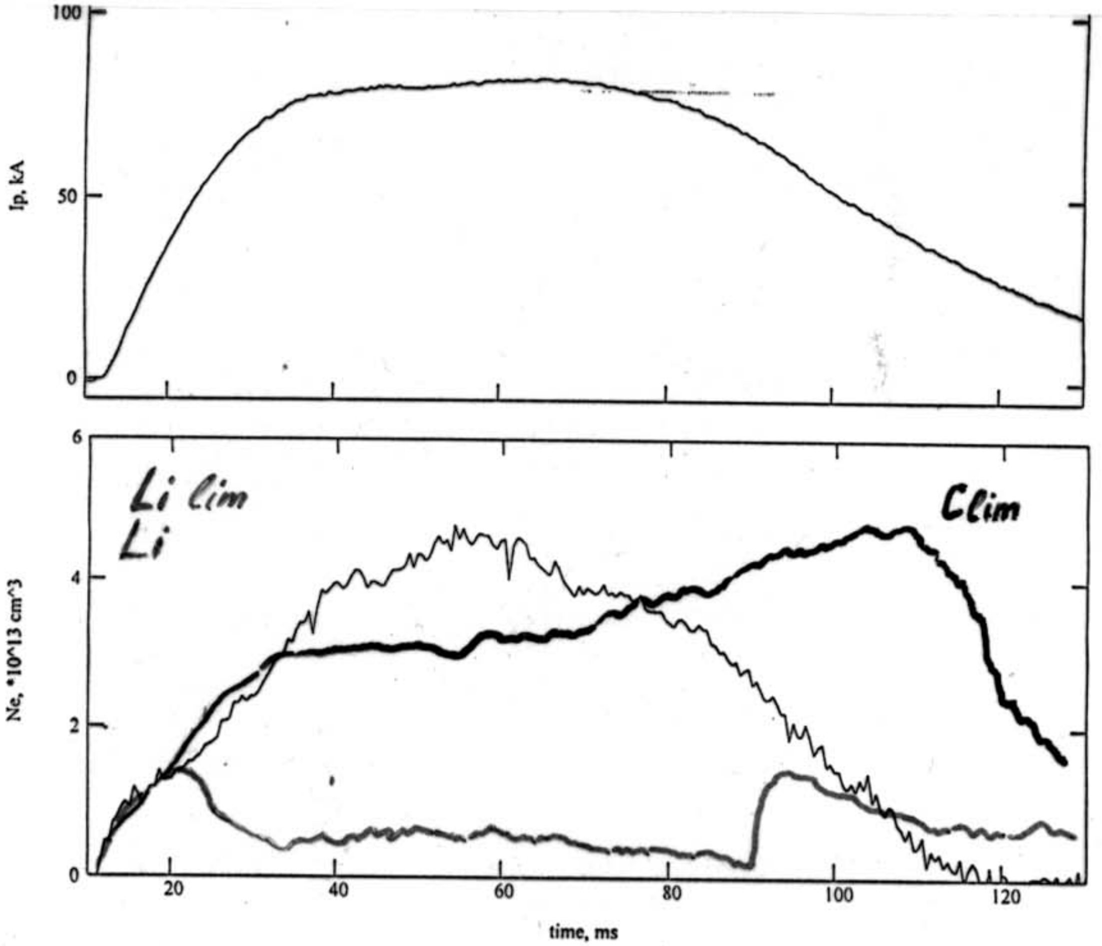
Раб. газ. He $P_0 = 7 \cdot 10^{-5}$ Тор
C_{Lim}, Li_{Lim} = 25см.

T-11M #12328 26/11/99

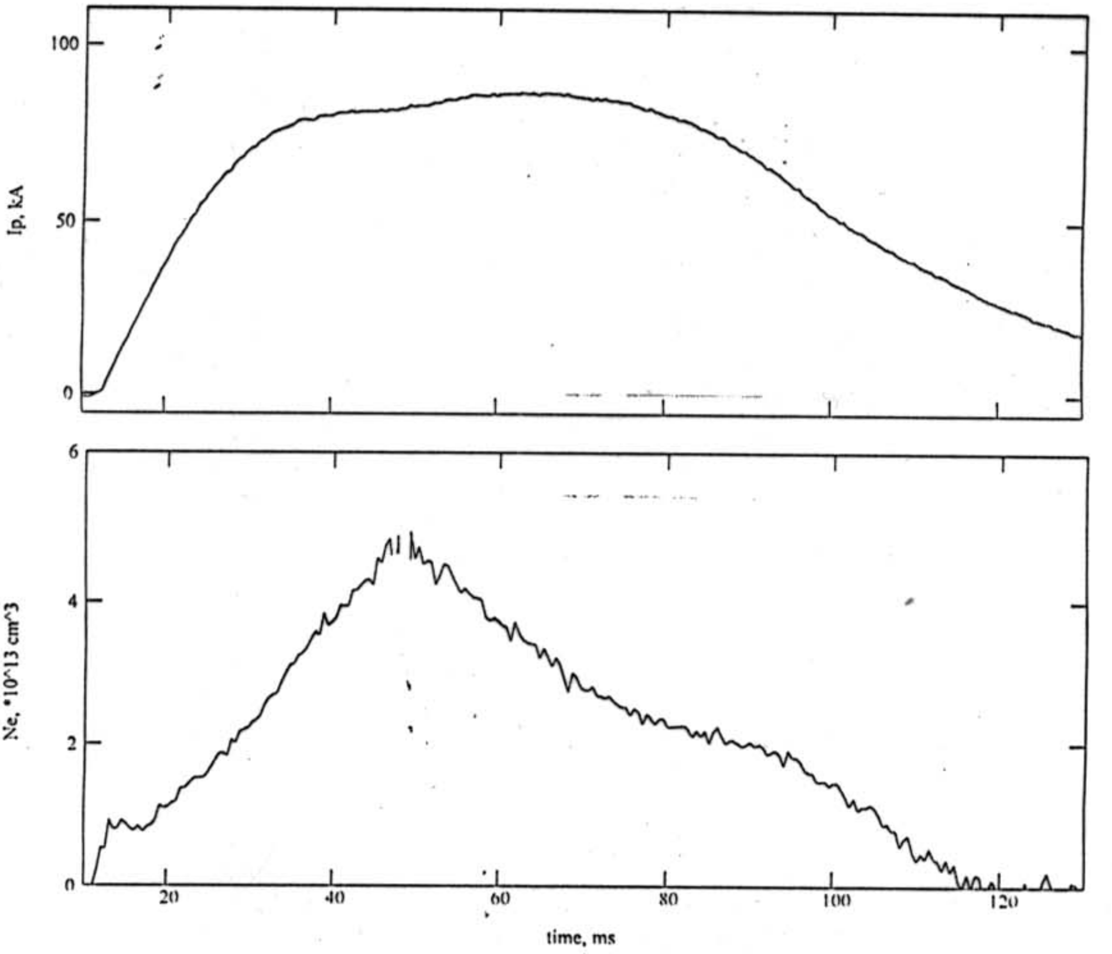


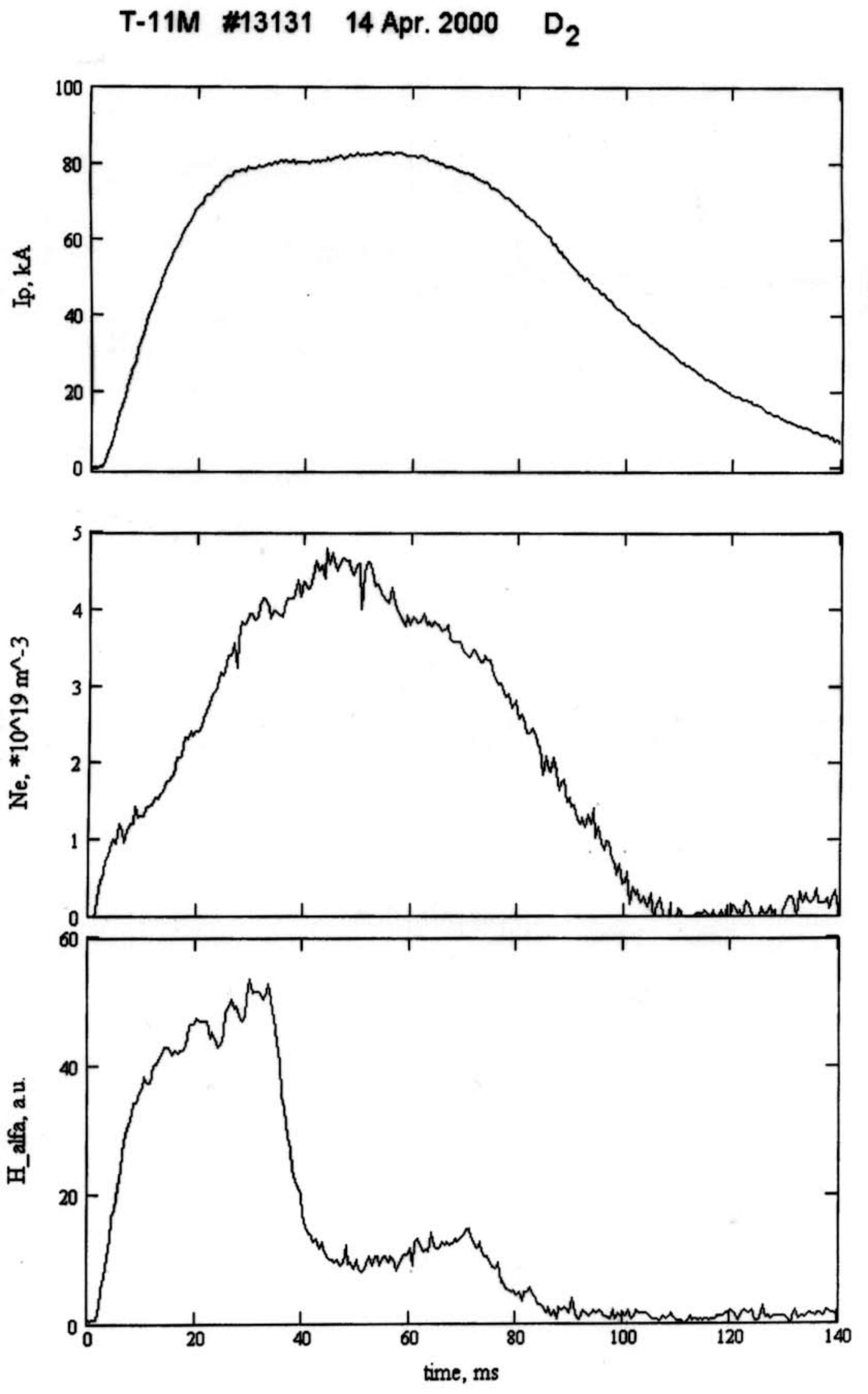


The temporal behavior of He pressure after discharge in T-11M chamber for different initial pressure.



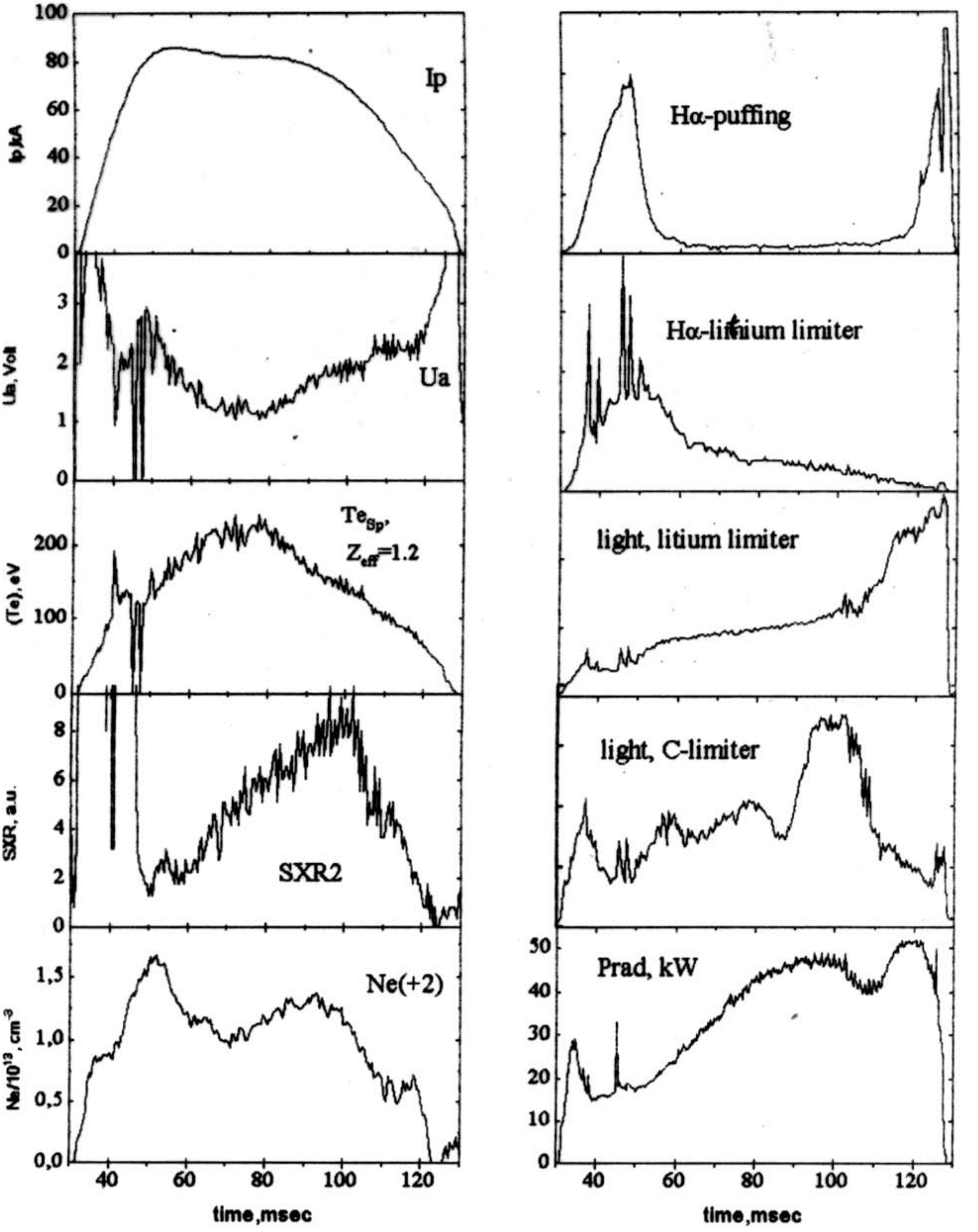
T-11M #13128





T-11M #13131 14 Apr. 2000 D2
Ip, kA
Ne, *10^19 m^-3
H_alfa, a.u.
time, ms
0
20
40
60
80
100
1
2
3
4
5
120
140

02.02.99, T-11M, H_2-puffing, Litium limiter, T=350C, shot 11113.



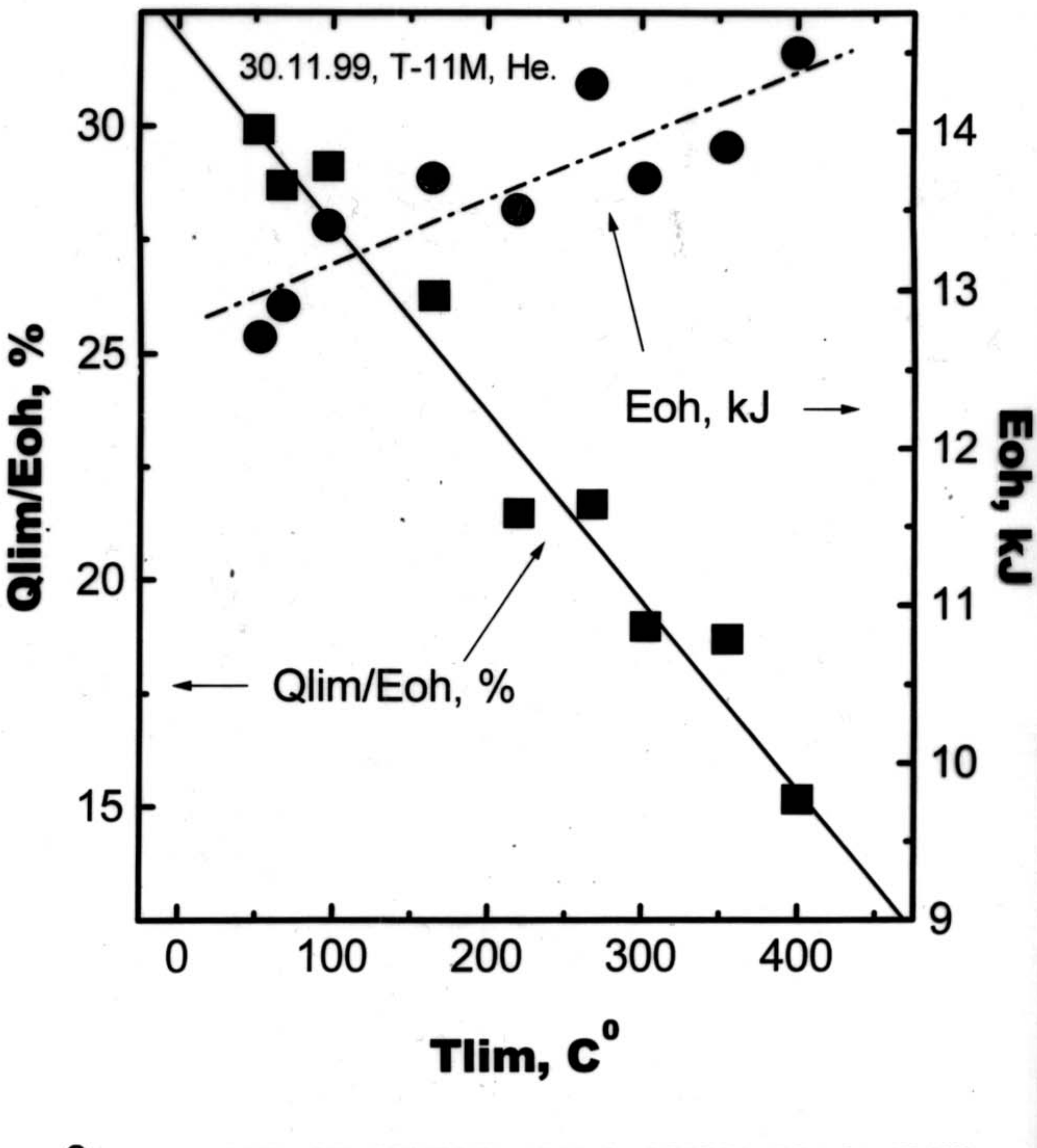
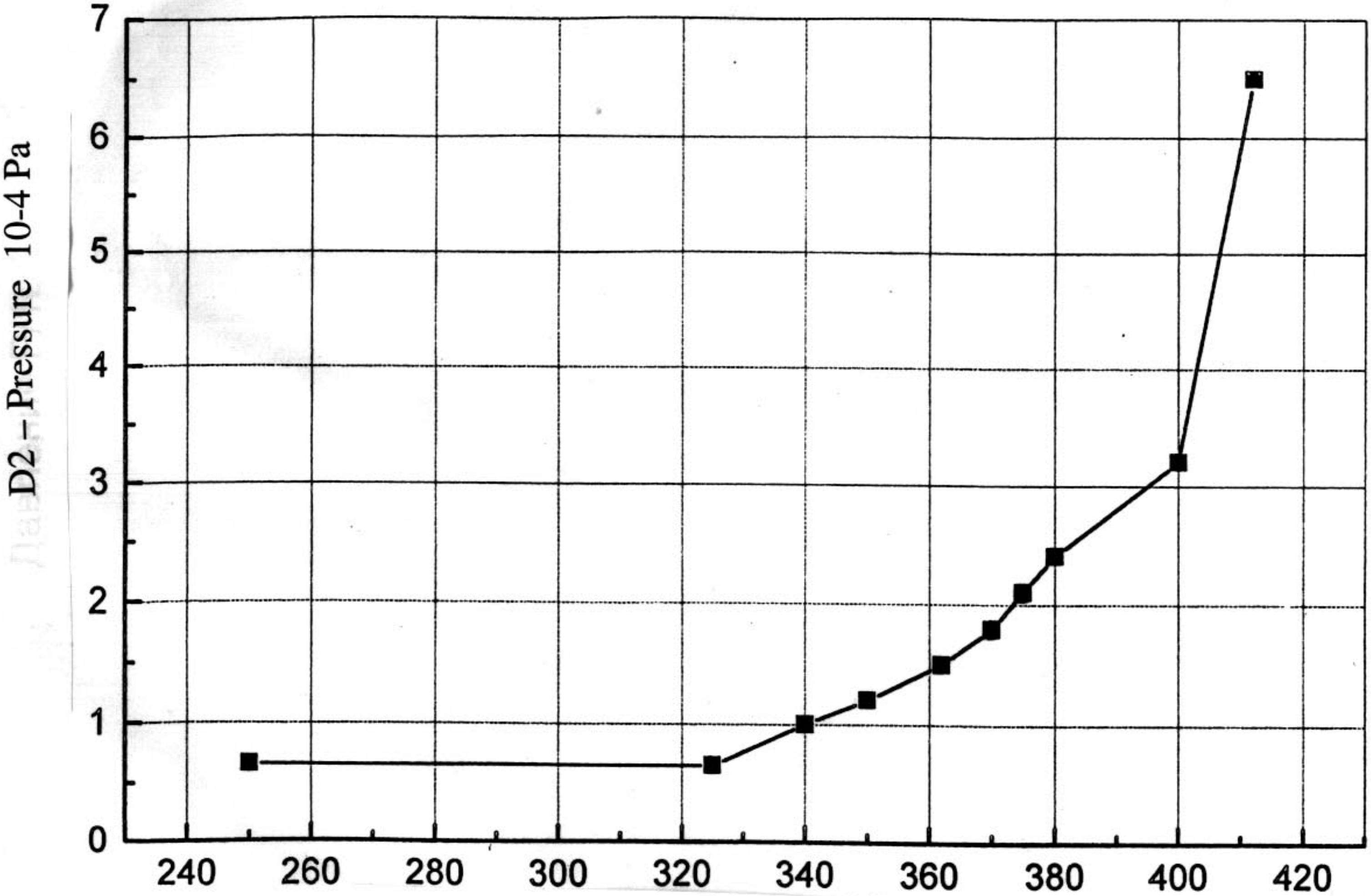


Рис. .Зависимость относительного энерговыделения на литиевой диафрагме Qlim/Eoh от ее начальной температуры. Eoh - полная энергия омических потерь в плазме изменяется не змачительно.

18.04.00, T-11M.

The back deuterium flux versus limiter temperature.



Limiter temperature , C grads.