Corelation Between Neutron and X-ray Emission from Megajoule Plasma Focus

M. Scholz, B. Bieńkowska, I.M. Ivanova-Stanik, L. Karpiński, A. Kasperczuk, R. Miklaszewski, M. Paduch, T. Pisarczyk, K. Tomaszewski, E. Zielińska,

Institute of Plasma Physics and Laser Microfusion,
Hery, 23 Str, P.O. Box 49, 00-908 Warsaw, Poland

J. Kravarik, P. Kubes,

Czech Technical University, Technicka 2, 166 27 Prague 6, Czech Republic

A. Banaszak, L. Jakubowski, M. Sadowski, A. Szydłowski,

Soltan Institute for Nuclear Studies (IPJ), 05-400 Otwock – Świerk, Poland

H. Schmidt,

International Centre for Dense of Magnetised Plasmas
P.O. Box 49, 00-908 Warsaw, Poland

S. Vituli

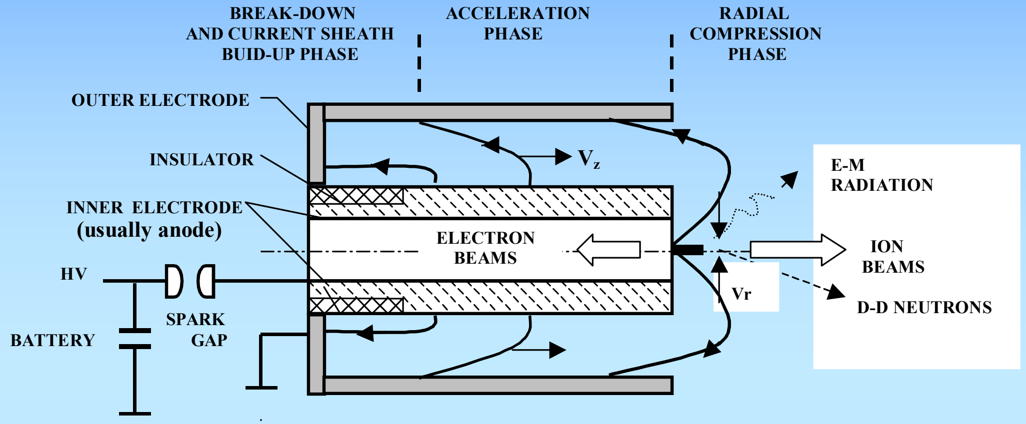
ENEA, Centro Ricerche Brasimone, 40032 Camugnano, Bologna.


COTTONFIELD

Outline

1. Introduction
   – Plasma focus discharge
2. Goals of the experiment: mechanism of neutron production
3. Experimental set-up
4. Results and discussion
   – X-ray measurements
   – Ion beam measurements
5. Summary

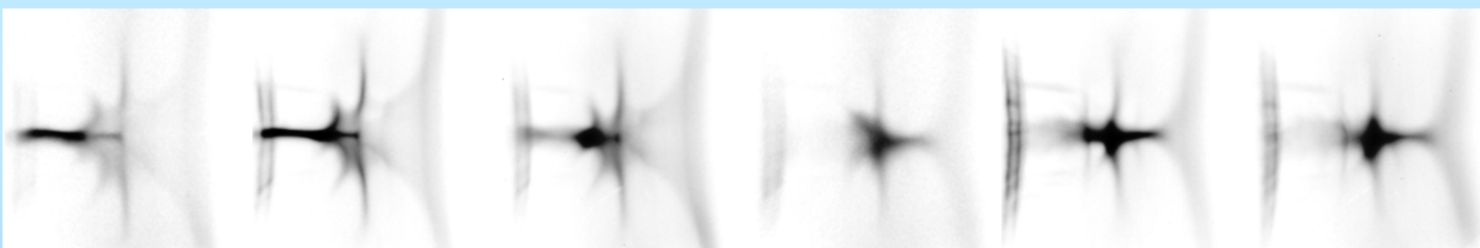
Three phases of plasma focus discharge



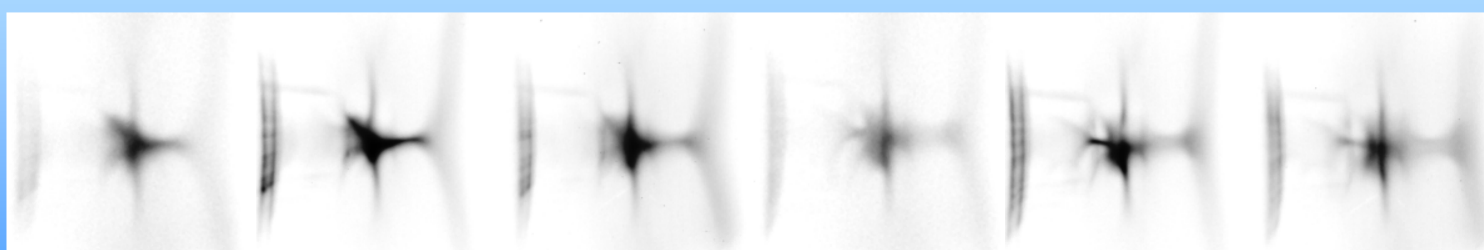
- Main plasma parameters
  - $n_{i\,max} = 10^{18} \div 10^{19}\ cm^{-3}$
  - $T_{i\,max} = 1 \div 5$ keV
  - $\tau_p = 50 \div 200$ ns
  - $Y_n = 10^8 \div 10^{12}$ neutrons/shot

A set of frame camera pictures of pinching dynamics in the implosion and post pinch phase (p_{D2} = 3 Torr; U_b = 33 kV; I_{max} = 1.7 MA)

-0.178 μs -0.168 μs -0.148 μs -0.079 μs -0.069 μs -0.049 μs



-0.005 μs 0.005 μs 0.025 μs 0.057 μs 0.067 μs 0.087 μs



0.107 μs 0.117 μs 0.137 μs 0.139 μs 0.149 μs 0.169 μs

Two mechanism of neutrons production

Thermonuclear

correlation of outputs of:

- soft X-ray
- neutrons
  - $Y_n \sim W^2 \sim I^4$
  - $Y_n \sim$ isotropic

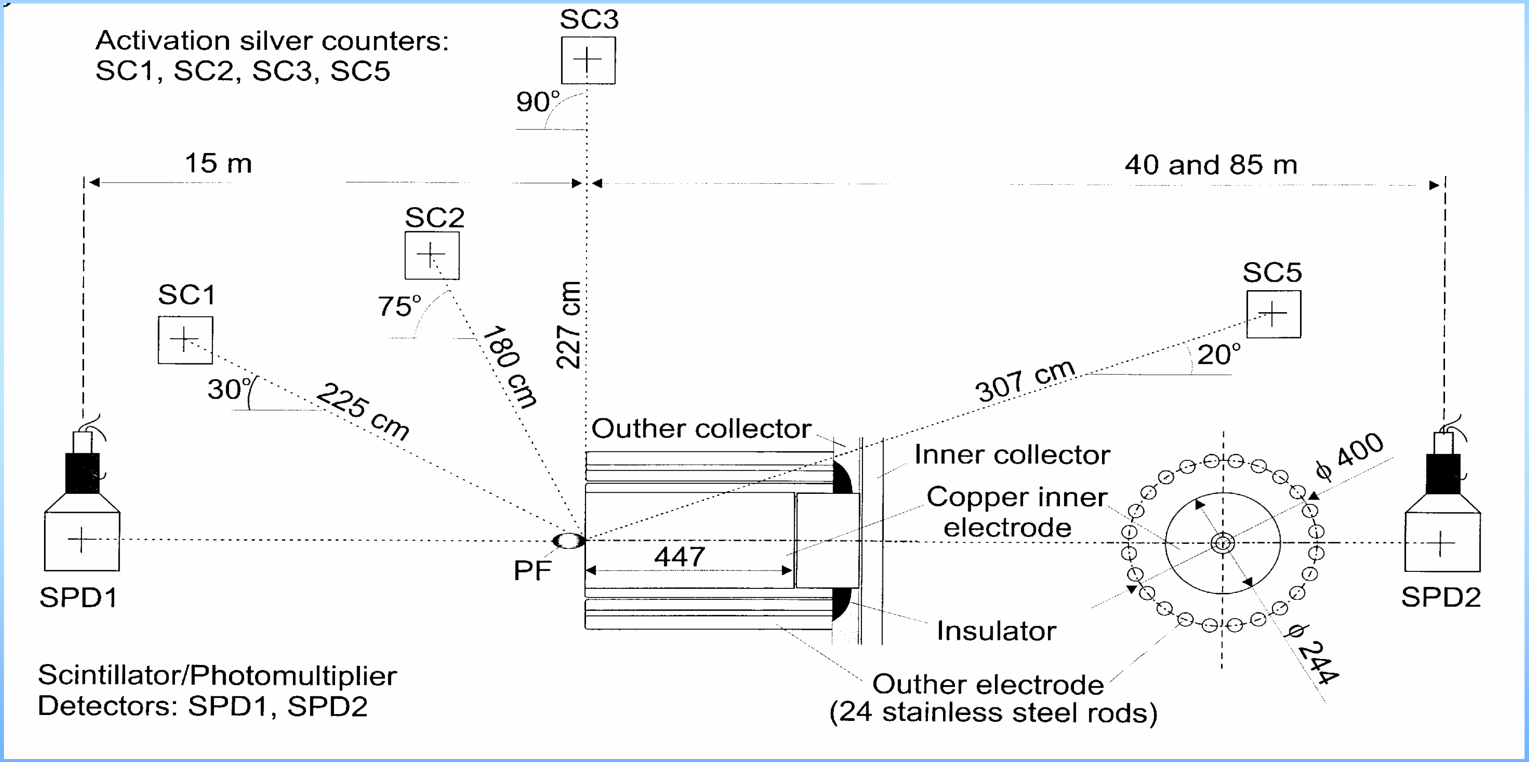
Beam-target

time correlation of emission of:

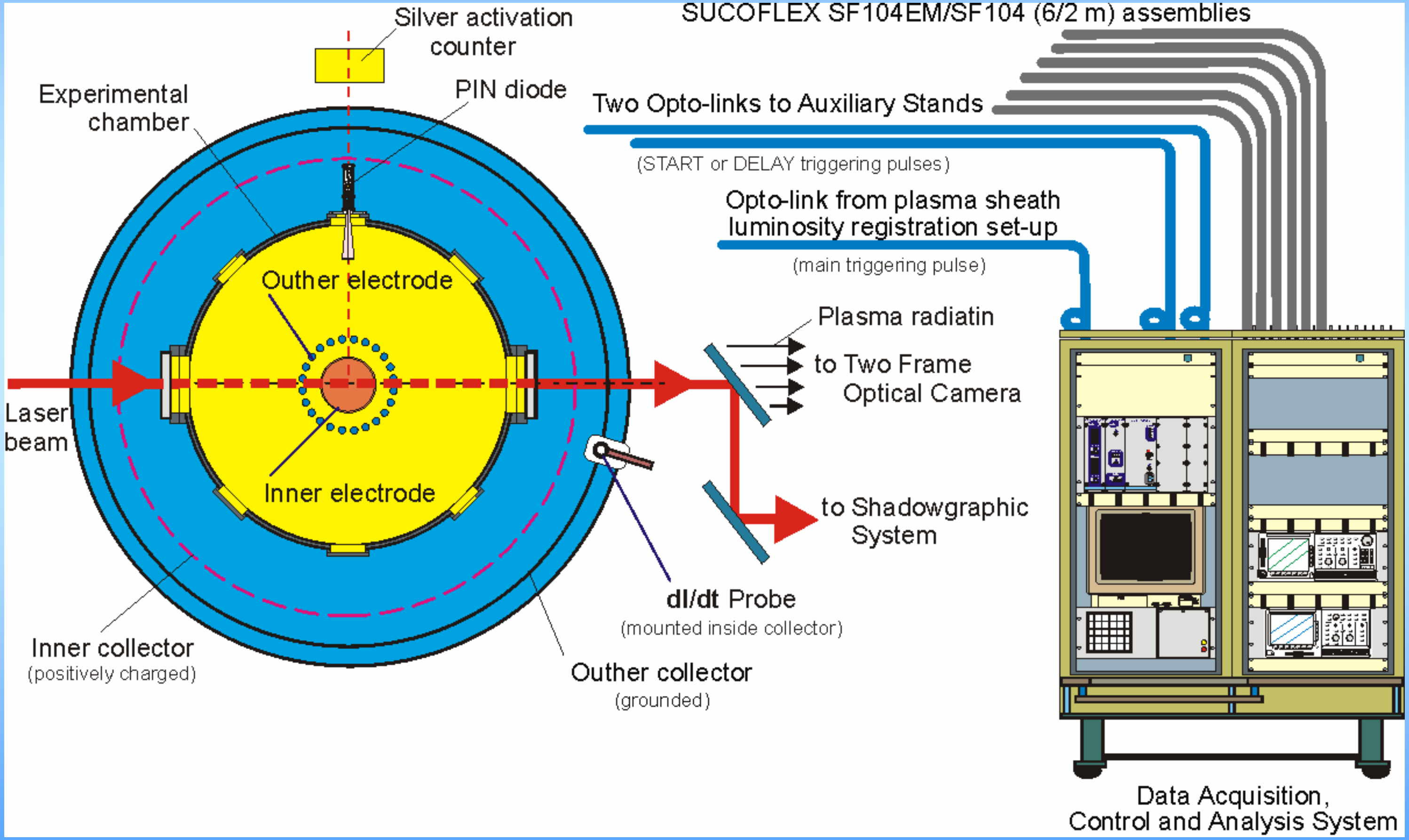
- e^- beams → hard X-ray
- i beams → neutrons
  - $Y_n \sim W \sim I^2$
  - $Y_n \sim$ anisotropic

It is important to find the contribution of each mechanism in the total neutron output (for various discharge conditions)

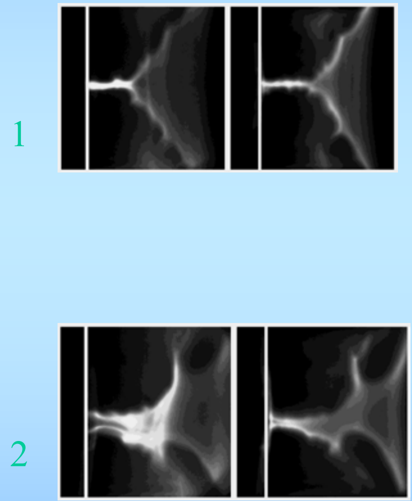
Experimental set-up

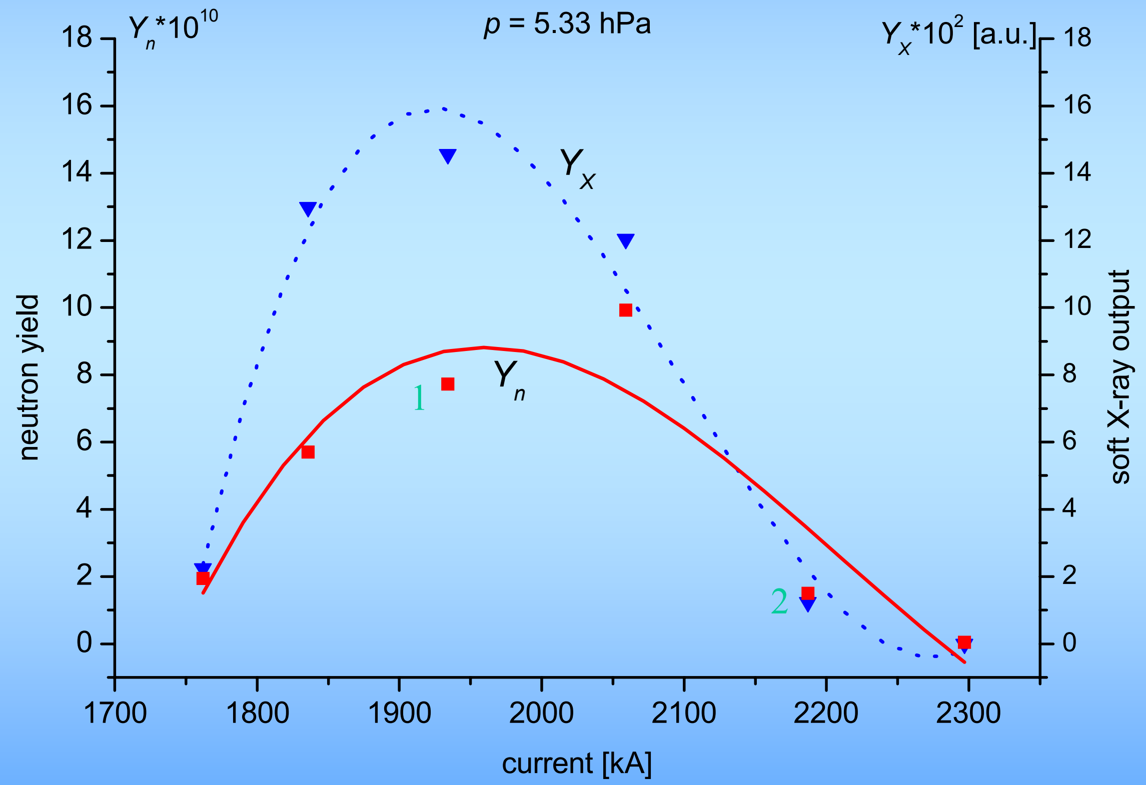


Experimental set-up



Neutron yield and the soft X-ray emission as a function of the discharge current value.

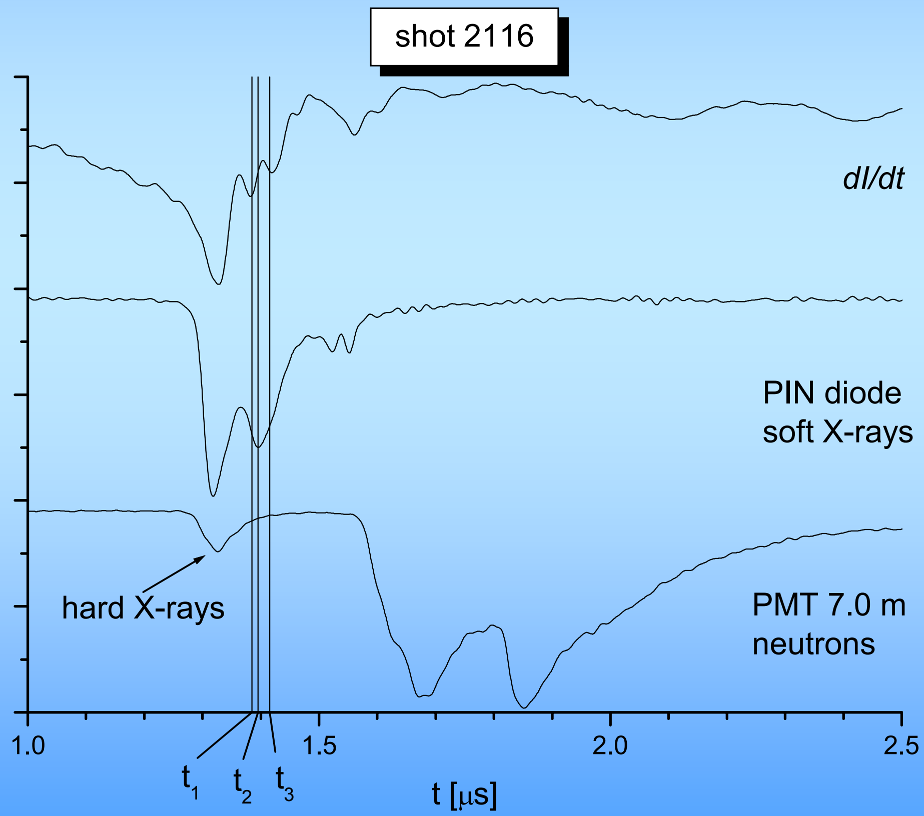


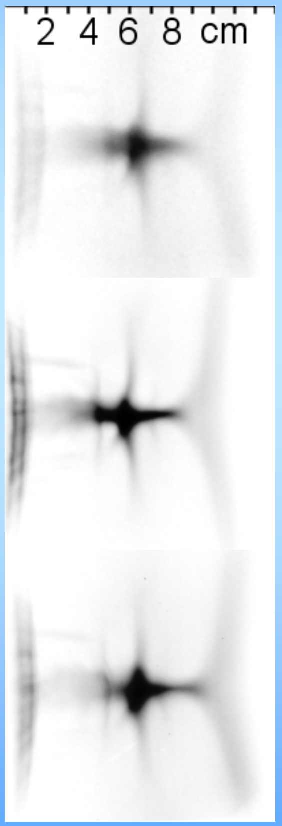


PF-1000 pinch structure registered on the frame picture at the moment after maximum compression (good shot)

Shot No 2116

$p = 3$ Torr, $U_b = 33$ kV, $I_{max} = 1.7$ MA $Y_n = 1.2 \cdot 10^{11}$





$t_1 = 0.057$

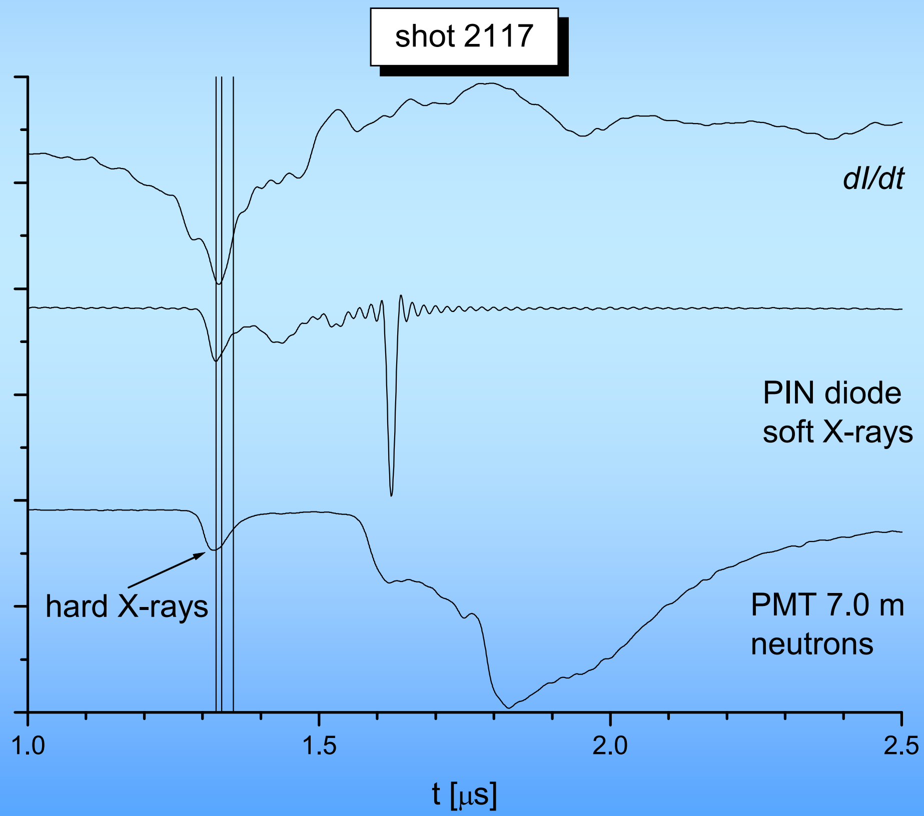
$t_2 = 0.067$

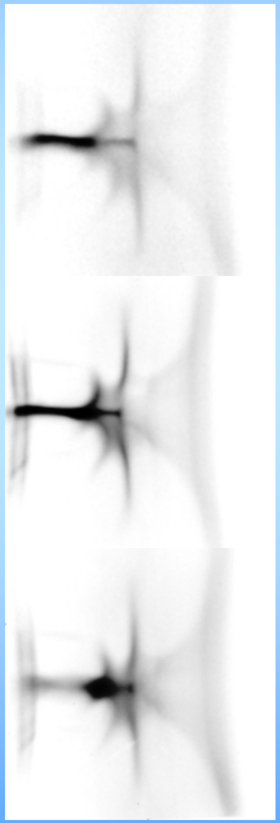
$t_3 = 0.087$

PF-1000 pinch structure registered on the frame picture at the moment of the first peak of neutron emission marked by a vertical line (good shot)

Shot No 2117

$p = 3$ Torr, $U_b = 33$ kV, $I_{max} = 1.7$ MA $Y_n = 1.4 \cdot 10^{11}$





$t_1 = -0.005$

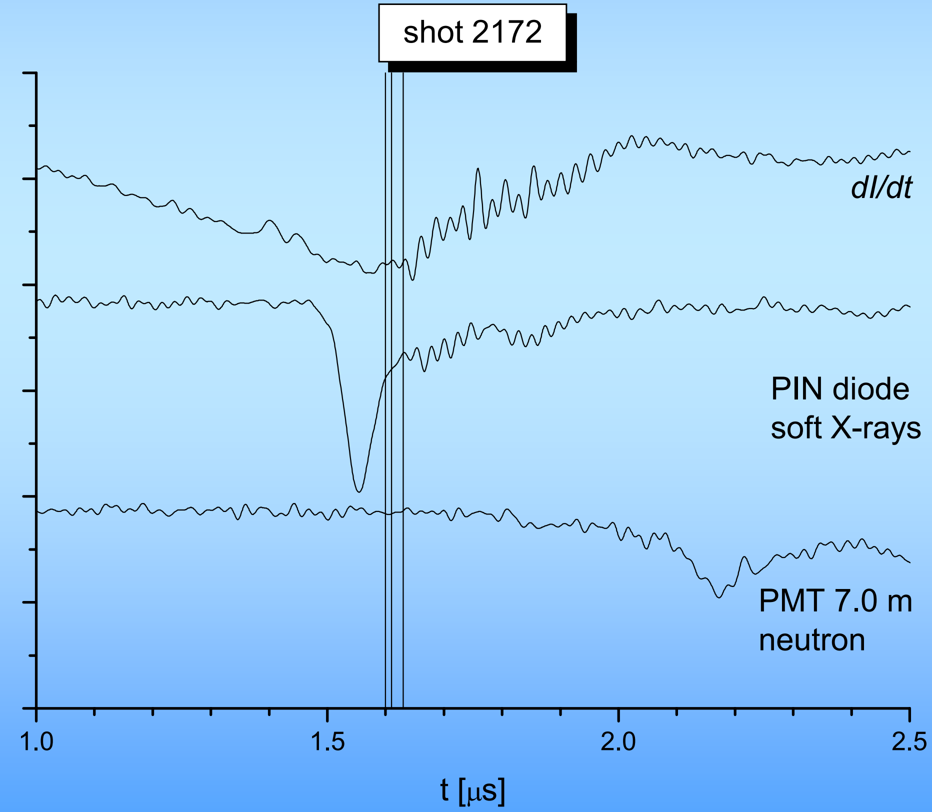
$t_2 = 0.005$

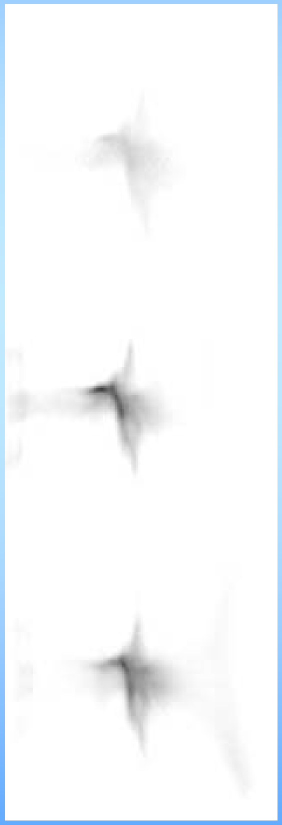
$t_3 = 0.025$

PF-1000 pinch structure registered on the frame picture at the moment after maximum compression (bad shot)

Shot No 2172

$p = 3$ Torr, $U_b = 33$ kV, $I_{max} = 1.7$ MA $Y_n = 6.02 \cdot 10^9$





$t_1 = -0.046$

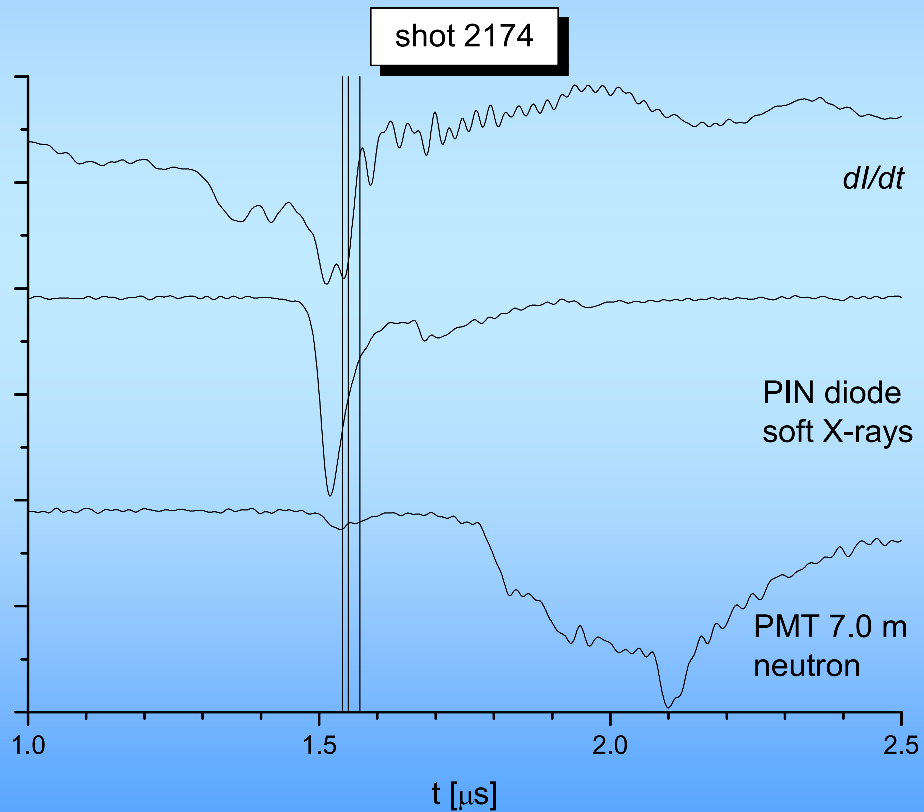
$t_2 = -0.036$

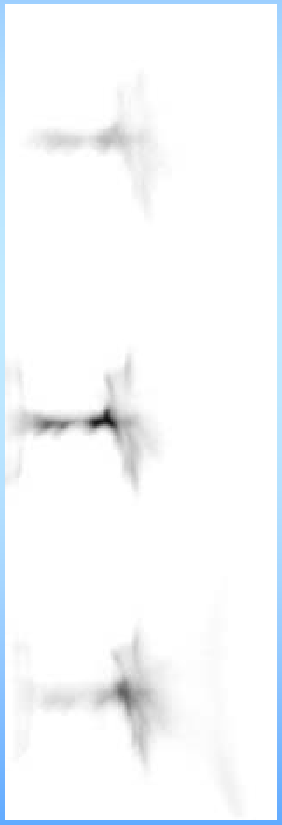
$t_3 = -0.016$

PF-1000 pinch structure registered on the frame picture at the moment after maximum compression (bad shot)

Shot No 2174

$p = 3$ Torr, $U_b = 33$ kV, $I_{max} = 1.7$ MA $Y_n = 8.96 \cdot 10^9$



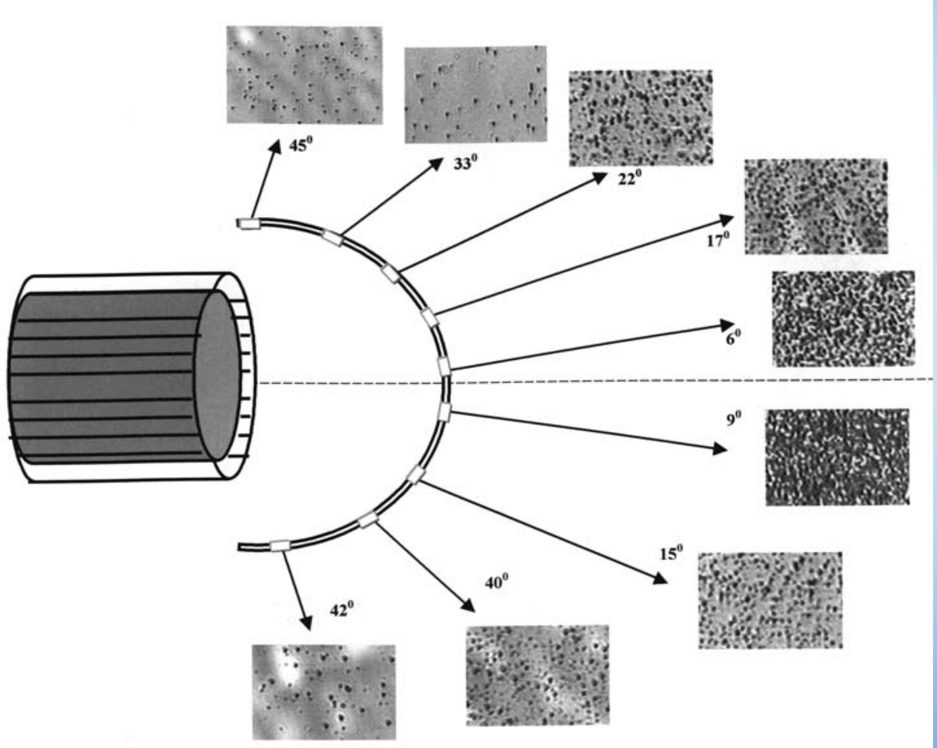


$t_1 = 0.027$

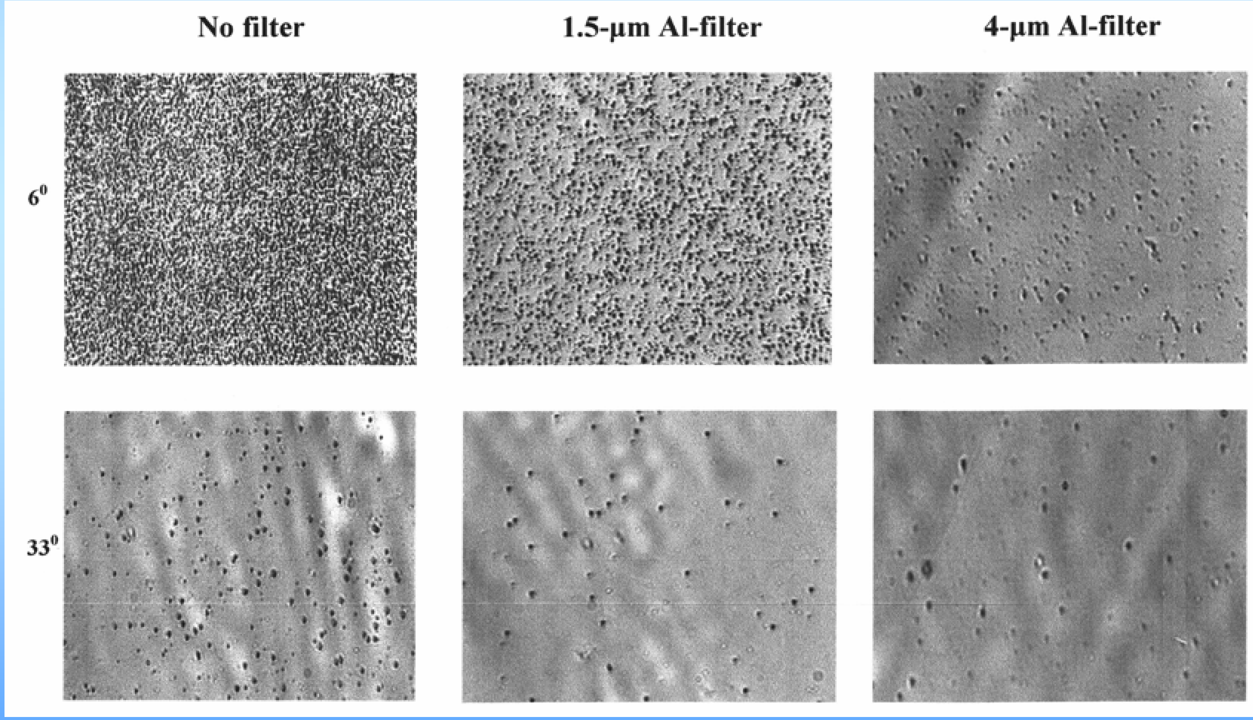
$t_2 = 0.037$

$t_3 = 0.057$

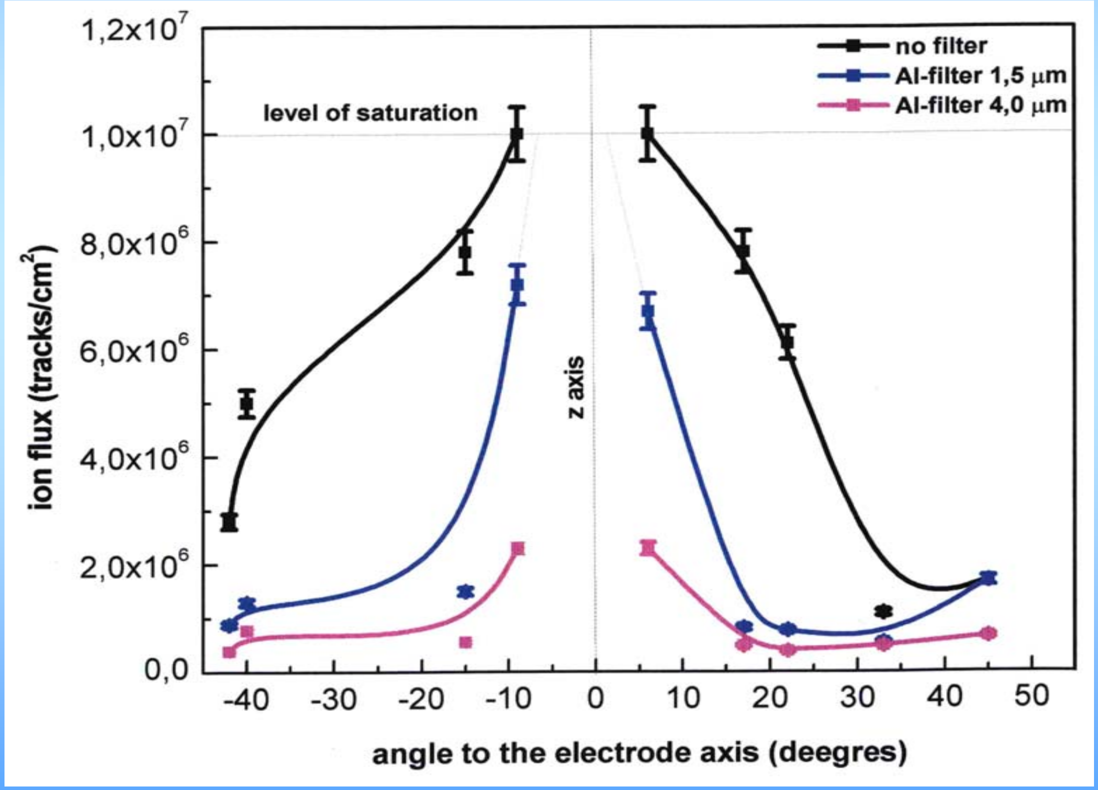
Ion track images, as recorded during angular measurements within PF-1000 facility.



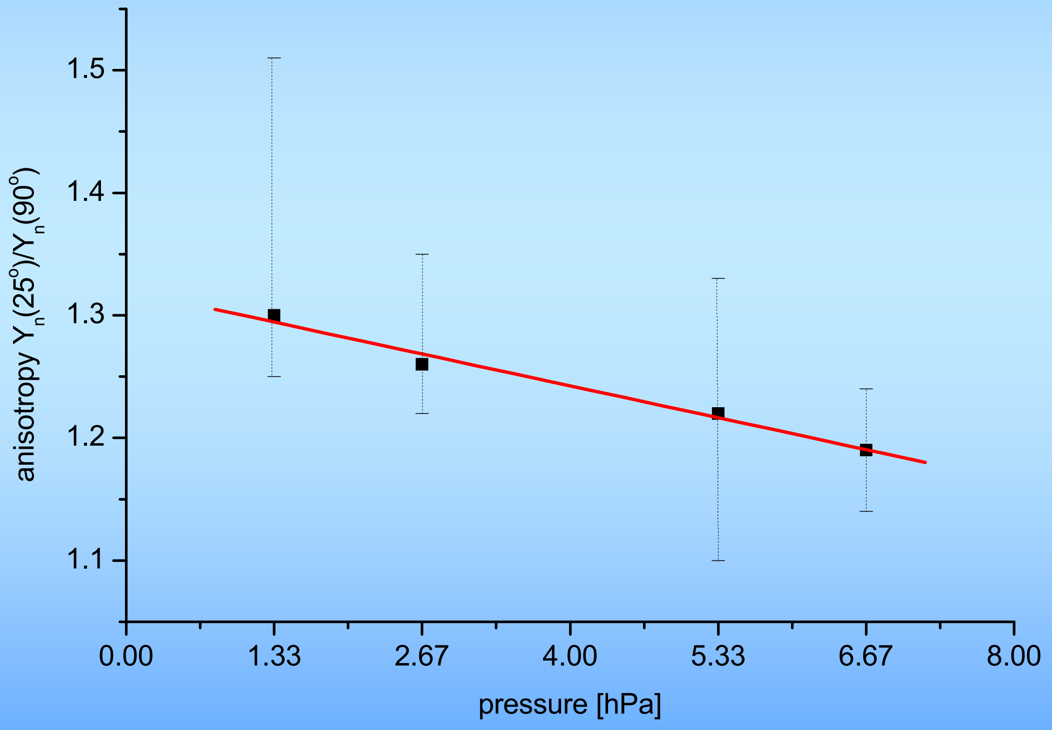
Examples of ion tracks, which were recorded upon SSNTDs without and with Al-filters, at different angles to the z-axis give evidence of the ion beam energy and anisotropy of ion emission



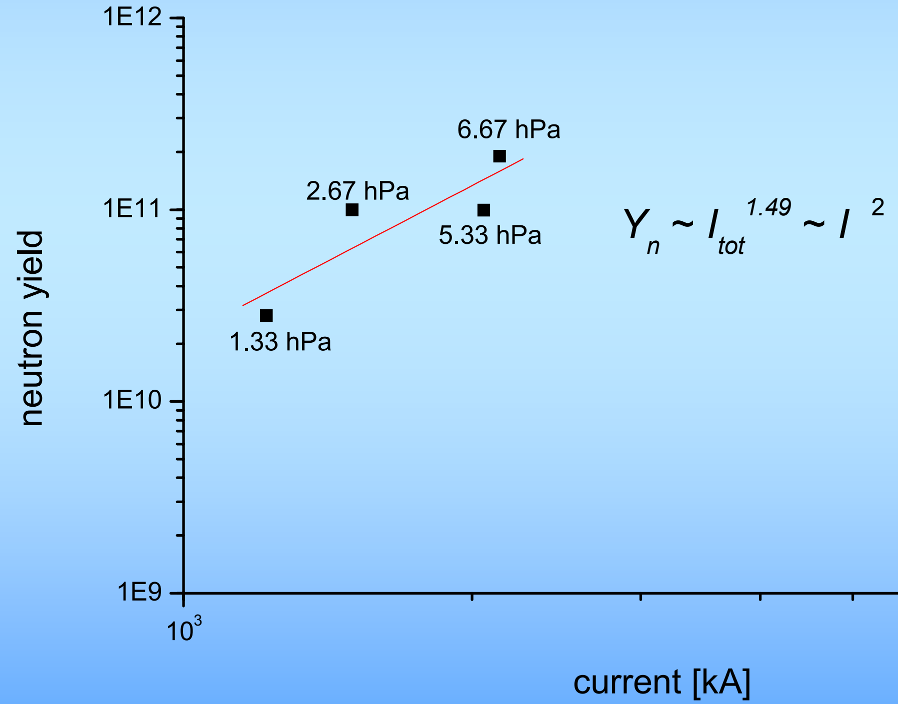
Angular distributions of fast deuterons decide about the beam-target mechanism contributions to the total neutron output.



Average value of the neutron emission anisotropy as a function of the D_2-filling pressure gives evidence of the contribution of beam-target mechanism.



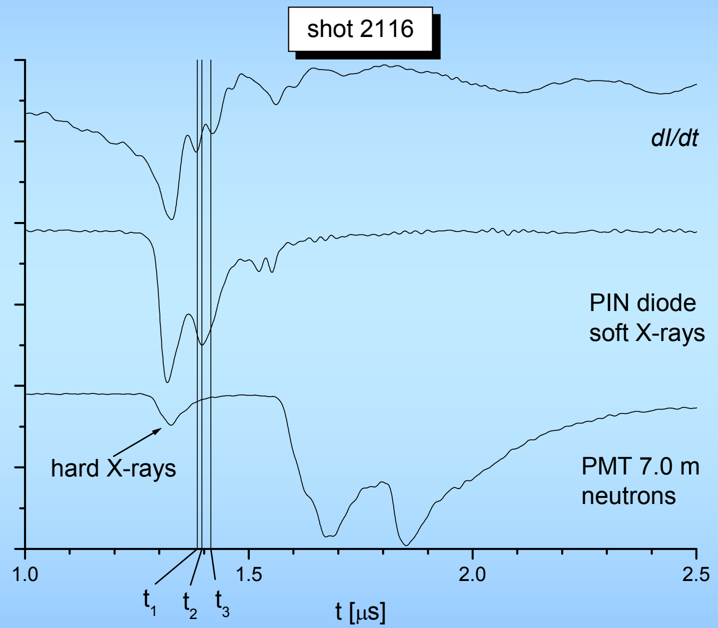
Neutron yield versus the discharge current as determined for the first series of shots performed with the modernized PF-1000 facility gives evidence of the beam-target mechanism in neutron production

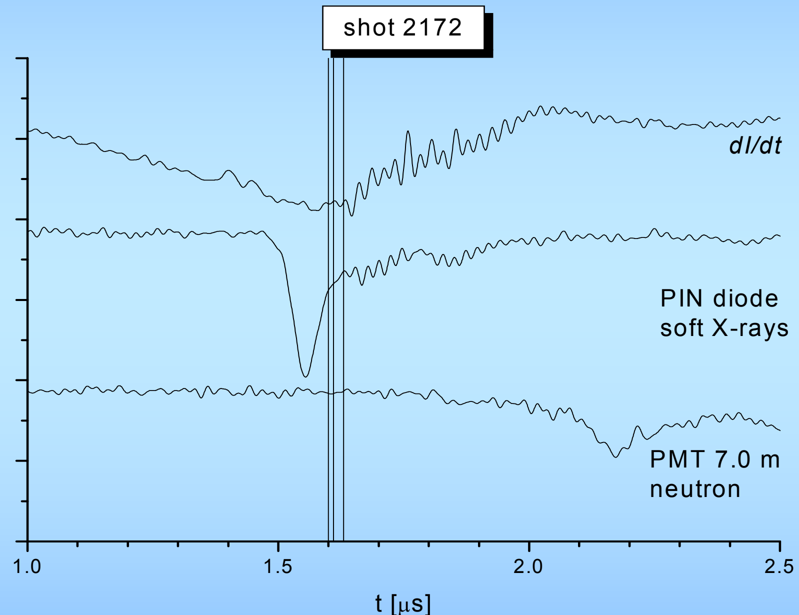


A comparison of time development of signals for a good shot and the bad shot

good shot $Y_n = 1.2 \cdot 10^{11}$

bad shot $Y_n = 6.02 \cdot 10^{9}$





dI/dt – lack of dip

soft X-ray – single peak

hard X-ray – lack of hard X-ray signal

neutron – small intensity, delayed emission

Conclusions

- Correlation between neutron and X-ray emission in megajoule PF: helps to identify the relative contribution of thermonuclear mechanism and beam target mechanism in the total neutron output
- In the case of a “good” shot the first neutron pulse shows a double structure, in which the second pulse is more intense than the first one. This result can be interpreted this way that the first pulse is generated by thermonuclear neutrons and second one by neutrons produced by the beam target reaction