R&D of Technology for Humanitarian Landmine Detection by a Compact IEC Fusion Neutron Source

Oct.10-11, 2002

U. of Wisconsin, Madison

5th US-Japan Workshop on Inertial Electrostatic Confinement Fusion

IAE, Kyoto University

Kiyoshi Yoshikawa

Outline of Project

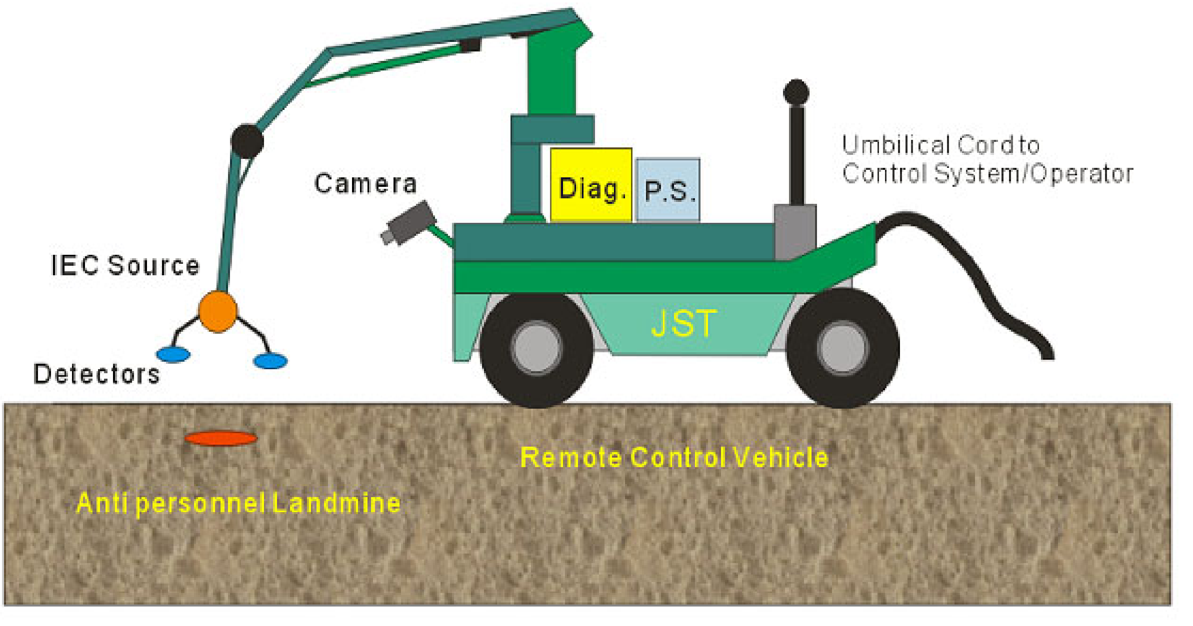
Sensing technique

In 5 years, develop techniques to be able to identify

- **Landmine exists?**
- **Plastic or LM? Then what kind ?**
- **Then, where is it?**

Detection thru neutron-related reactions, able to identify

- **Constituents ; (n, γ),(n,n' γ)**
- **Location; tomography, and by**
- **Innovative IEC neutron source;**
  $>10^8$n/s, in Pulse, CW modes



Requirements for Landmine Detection

>30g in depth of 20cm, 100% detection

Characteristics of the landmines found in Croatia

Mine	Type	Buried -B, Surface -S	Metal Content	Dimensions	Weight total	Weight explo.	Kill/ Casualty radius
				mm	kg	kg	m
PMR_2A	AP	S	m	φ66×122	1.70	0.10	1/25
TMA_3	AT	B	n	φ260×80	6.50	6.50	
PMA_2	AP	B	n	φ60×33	0.135	0.10	1/25
PMA_3	AP	B	n	φ104×40	0.183	0.035	1/25
TMR_P6	AT	B, tilt rod on S	m	φ290×137	7.20	5.10	
TMM_1	AT	B	m	φ250×85	8.65	5.60	
PROM_1	AP	B, protruding assembly on S	m	φ75×329	3.00	0.425	50/100
TMA_4	AT	B	n	φ280×65	6.30	5.50	
TMA_5	AT	B	n	300×275×113	6.60	5.50	
PMA_1	AP	B	n	142×68×35	0.40	0.20	1/25
MRUD	AP	S	m	231×46×89	1.50	0.90	50/200
TMA_1	AT	B	n	φ310×100	6.50	5.40	
TMA_2	AT	B	n	330×260×100	6.50	5.40	
PMR_3	AP	S	m	φ80×150	1.70	0.41	20/100

Principle of LM Detection

Atomic ratio of explosives fixed

explosives	Atomic number			
	H	C	N	O
TNT	3	7	3	6
Pentrite	8	5	4	12
Hexogen	2	1	2	2
Ammonium nitrite	4	-	2	3

- **neutron-captured γ ray（kind of LM）**

  H(n, γ)･･･ 2.22 MeV γ ray emission

  N(n, γ)･･･10.83 MeV γ ray emission

- **back-scattered neutron（existence of LM）**

  H(n, n')･･･scattering cross section of H large

IAEA ACTIVITIES IN HUMANITARIAN DEMINING

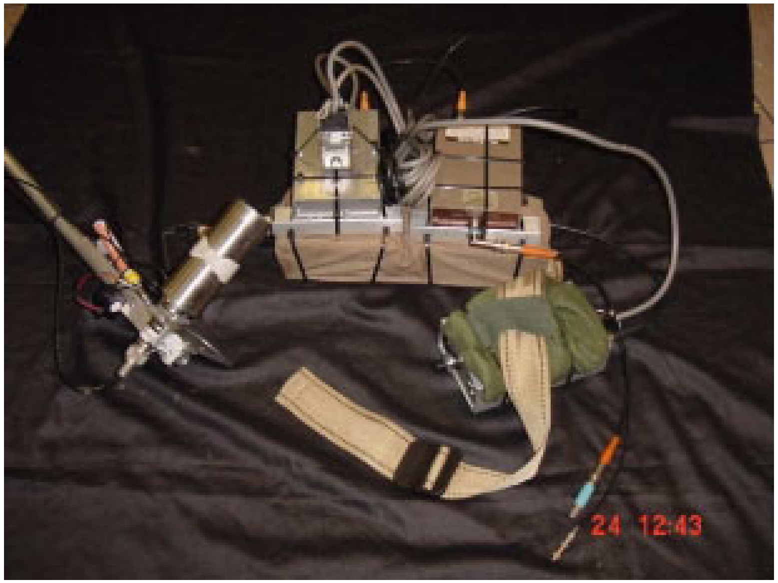
Ulf Rosengård
IAEA/Physics Section

September 6, 2002, Kyoto

Table 1. Nuclear methods under development

Name	Principle	Advantages	Issues	Status	CRP Groups
Methods to find buried objects					
X-ray Backscatter	X-rays backscattered form soil can be imaged using collimated detectors	Real time images sufficiently detailed to identify landmine size and type, independent of surface clutter.	Limited x-ray penetration depth into soil, speed of ground coverage, portability, cost (minimum $250K).	Tested with plastic and metal antitank mines as well as anti-personnel mines.	Shope (USA)
Neutron Backscatter	Quantity of neutrons backscattered from soil can indicate concentrations of hydrogen.	Focuses on plastic landmines, insensitive to metallic clutter, emulates a metal detector (simple to use), simple and low cost, portability (<$10K)	Sensitivity to hydrogen clutter, possible depth limitation, dependence of soil moisture stand off distance dependence.	Successful in laboratory	Brooks (SAF) Bom (HOL)
Positron annihilation Compton scatter imaging (PACSI)	Gamma rays backscattered from soil can indicate density of buried objects.	Simple and low cost method for forming 3D images to a depth of 20-30 cm. Potentially low cost (about 10 k$)	Experimental test needed.	Demonstrated in computer simulation.	Tickner (AUL)
Methods to identify composition of buried objects					
Neutron- induced gamma rays	Neutrons enter the soil and cause emission of gamma rays. Identify elemental compositions from the gamma ray energies.	Identify composition of buried objects to determine presence of explosives. Compact portable system. Easy operated training.	Speed limited by neutron source strength. Background gamma rays must be subtracted.	The PELAN method (Prof. Vourvopoulos) has been demonstrated successfully with unexploded ordnance and is ready for field testing in minefield.	Vourovoupolous (USA) Hussein (CAN) Valkovic (CRO) Viesti (ITA) Ringbom (SWE)
Backscattered neutrons	Measure the energies of backscattered neutrons.	Good penetration of neutrons into soil. High neutron cross sections.	Neutron energy measurement requires complex electronics & analysis.	Tested in laboratory. and verified by simulations	Csikai (HUN) Hlavac (SLV) Kuznetsof (RUS) Hussein (CAN)

The battery-powered, hand-held HYDAD-H landmine detector. (Univ. of Cape Town).



^{3}He proportional N counter with ^{252}Cf source.

Associated Particle Detection

Khlopin Institute St:Petersburg

Prototype of the mobile device with 2 mg ^{252}Cf source with various investigated objects: TNT imitators, metallic cylinder, wet root etc.

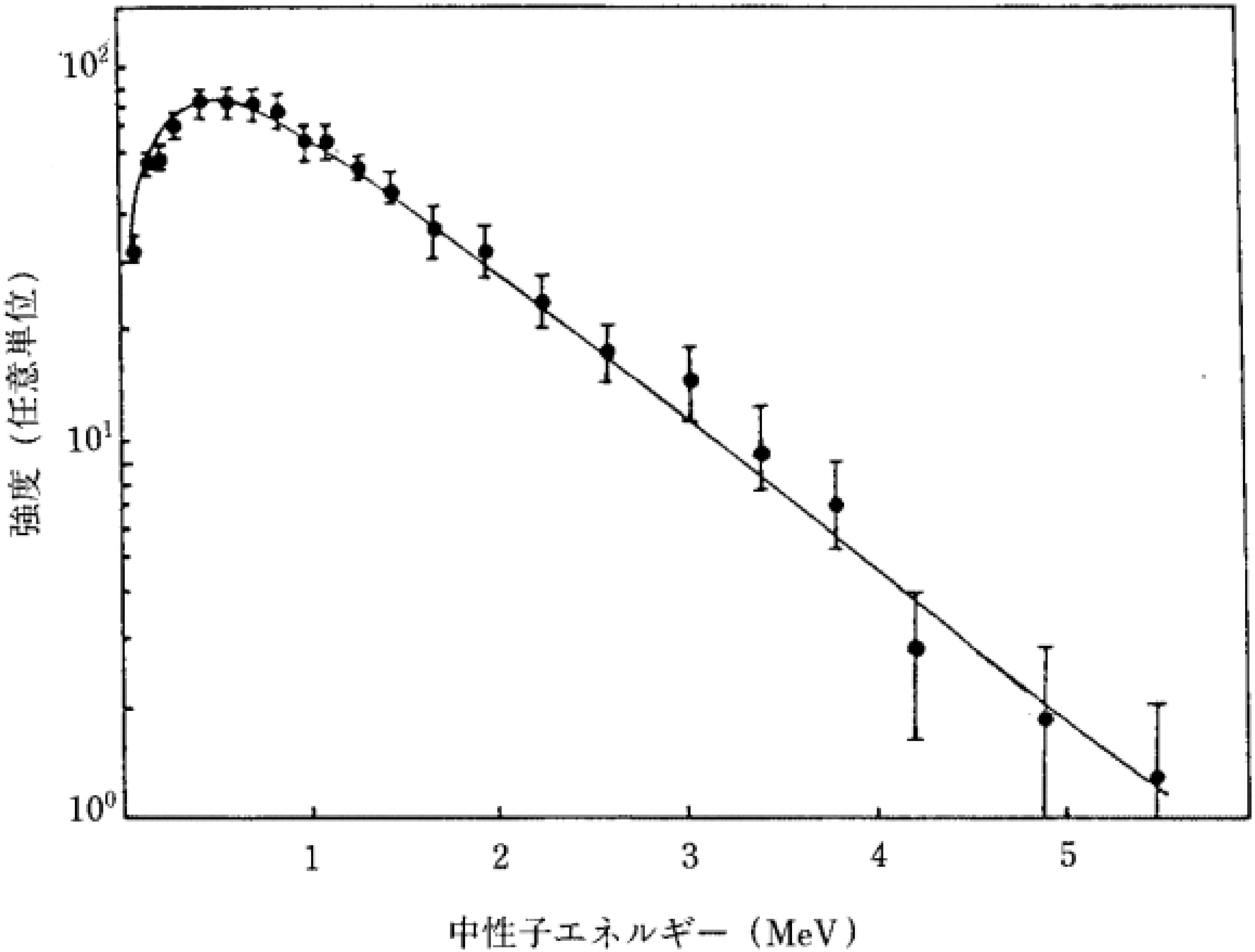
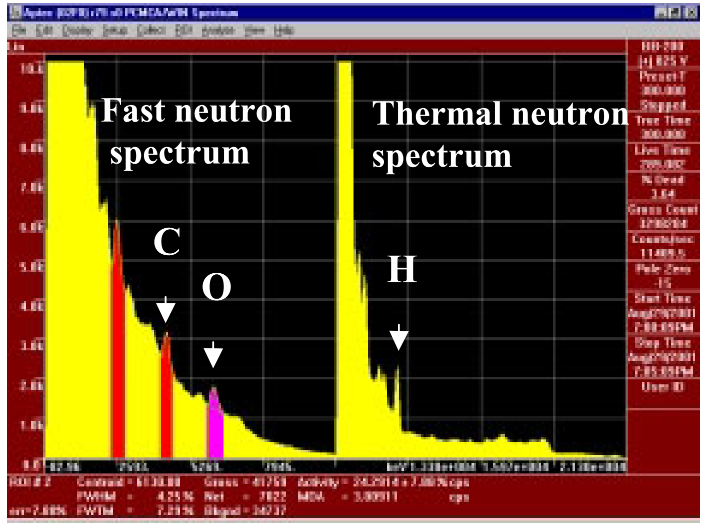
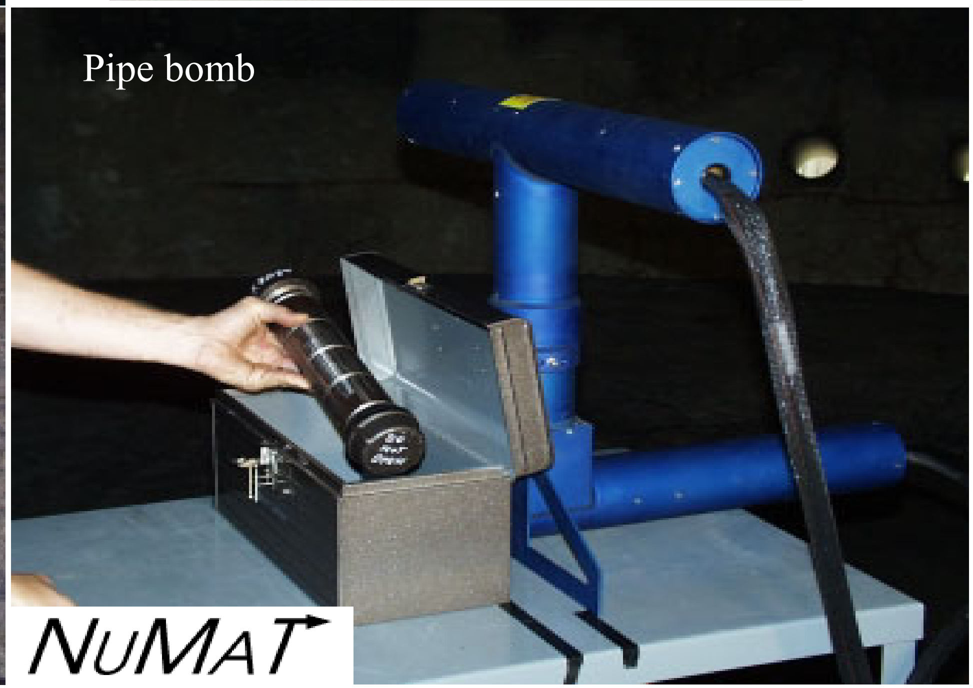


図 1.10　^{252}Cf の自発核分裂で発生する中性子エネルギースペクトルの測定値
(Batenkov ほか[12] による)

PELAN TRIALS, 8/99, OHIO, Battle





PERANⅢ ; 10^8n/s(D-T)

DEMO for Identification of explosives

Demonstration of the PELAN device in Vienna

February 2002

Sodern社製
NG(France)

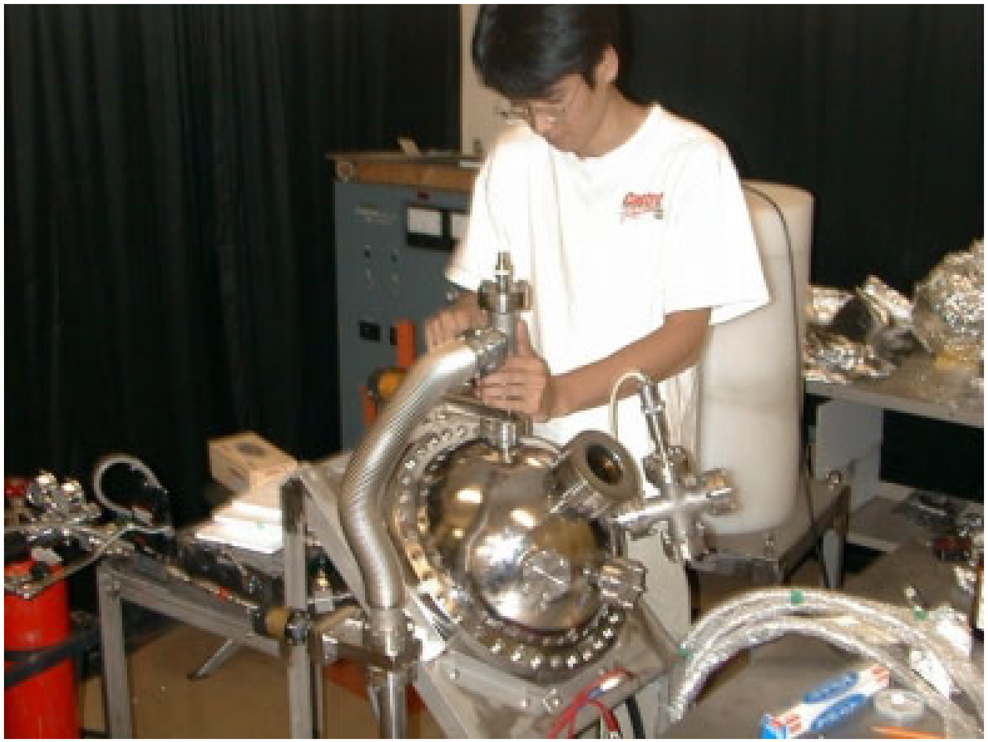
2002/9/8 Kyoto

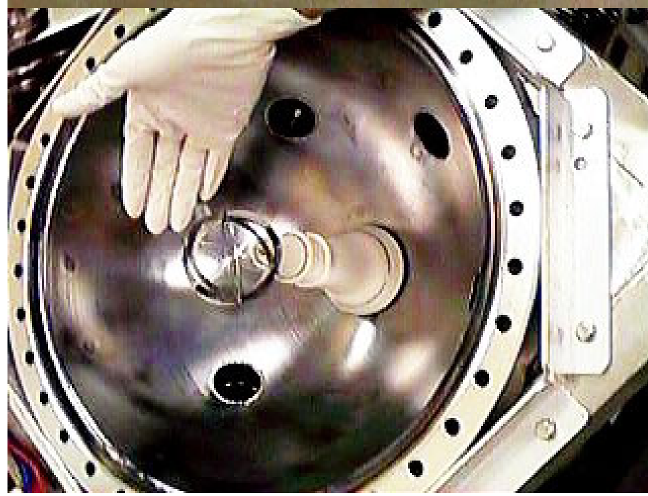
Sept.6, 2002, IAE., Kyoto U. , by Ulf Rosengard, IAEA

Compact Discharge-type Fusion Neutron Source

慣性静電閉じ込め核融合

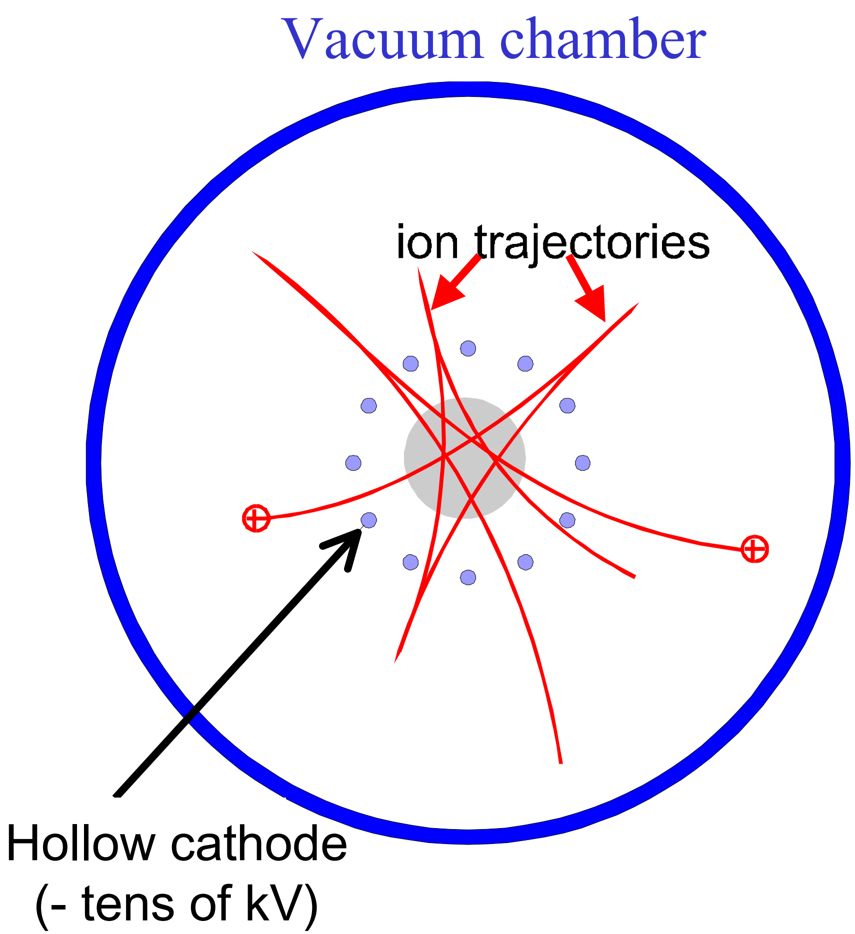
I E C F (Inertial Electrostatic Confinement Fusion)





Principle of Inertial Electrostatic Confinement Fusion

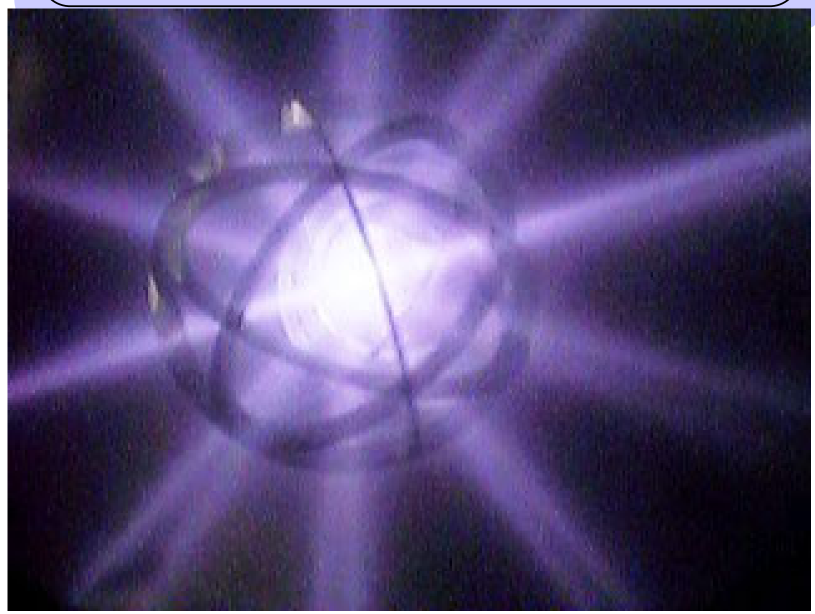
I E C F (Inertial Electrostatic Confinement Fusion)



D^+ accelerated to the center of hollow cathode

Fusion reaction

$$D + D \rightarrow T + \mathbf{p}\ (3.03\ \mathrm{MeV})$$
$$\rightarrow {}^{3}He + \mathbf{n}\ (2.45\ \mathrm{MeV})$$

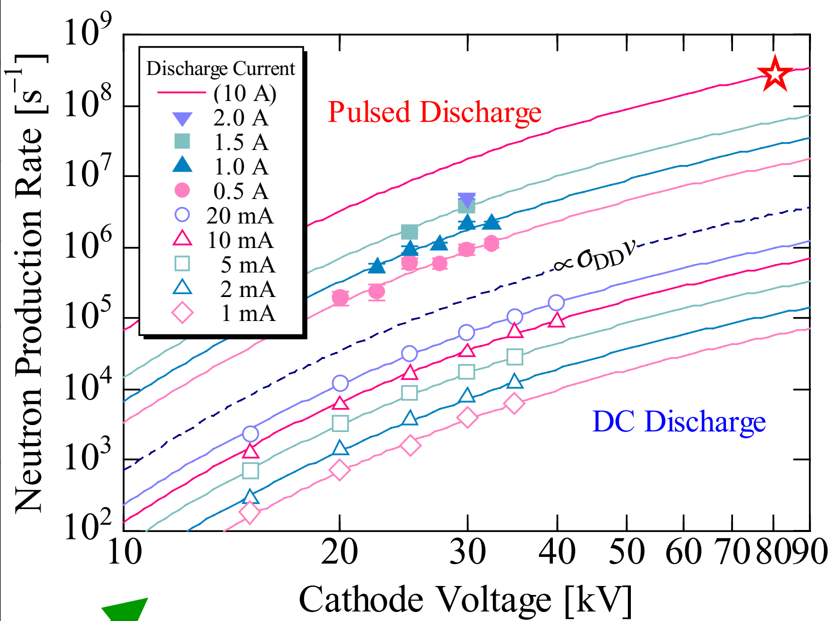


Achievement of neutron yield

As of March, 2002

	Neutron yield [n/sec]	
IAE, Kyoto U.	1.1×10^7	(CW;62kV30mA)
UIUC	2×10^6	(CW)
	7×10^8	(pulse)
UW, Madison	1.1×10^8	(CW, D-D, 135kV,58mA)
	1.6×10^8	(CW, D-^{3}He)
LANL	1×10^6	(CW)
TIT	5×10^5	(CW)
	2×10^6	(pulse;30kV,2A)
Hitachi	7.5×10^7	(CW)

V-I dependence of pulsed neutron yield (TIT)



Neutron yield

(10^8n/s → 80kV,10A?)

R&D Organization & Budget

①R&D of compact IEC

●CW/pulse IEC;

Kyoto-U, Kansai-U.

●CW/Pulse power supply ; TIT

② R&D of LM Detection

●Diagnostics;

Kyoto-U., TIT, Kyushuu-U.

●Tomography;

Kyoto-U., JAERI,Wakasa-bay Energy Res. Center,

●Total system;

Kyoto-U., Nikki Co.

Budget(2002.9-2006.3); about US$2〜2.5M