

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

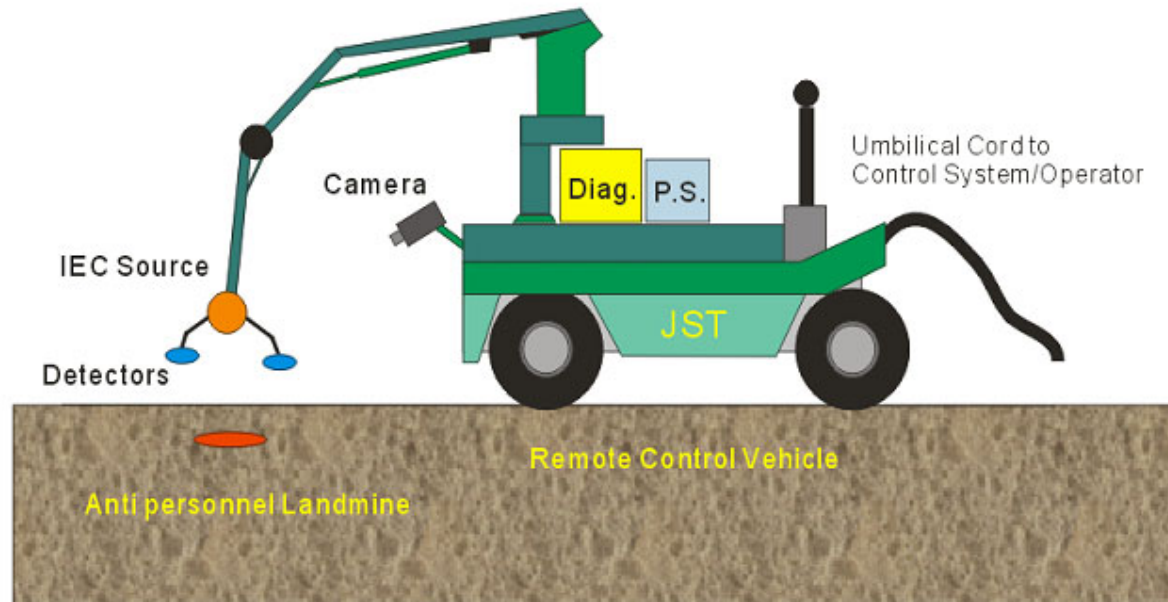
Sensing technique

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 ; $(n, \gamma), (n, n' \gamma)$
- 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	$\phi 66 \times 122$	1.70	0.10	1/25
TMA_3	AT	B	n	$\phi 260 \times 80$	6.50	6.50	
PMA_2	AP	B	n	$\phi 60 \times 33$	0.135	0.10	1/25
PMA_3	AP	B	n	$\phi 104 \times 40$	0.183	0.035	1/25
TMR_P6	AT	B, tilt rod on S	m	$\phi 290 \times 137$	7.20	5.10	
TMM_1	AT	B	m	$\phi 250 \times 85$	8.65	5.60	
PROM_1	AP	B, protruding assembly on S	m	$\phi 75 \times 329$	3.00	0.425	50/100
TMA_4	AT	B	n	$\phi 280 \times 65$	6.30	5.50	
TMA_5	AT	B	n	$300 \times 275 \times 113$	6.60	5.50	
PMA_1	AP	B	n	$142 \times 68 \times 35$	0.40	0.20	1/25
MRUD	AP	S	m	$231 \times 46 \times 89$	1.50	0.90	50/200
TMA_1	AT	B	n	$\phi 310 \times 100$	6.50	5.40	
TMA_2	AT	B	n	$330 \times 260 \times 100$	6.50	5.40	
PMR_3	AP	S	m	$\phi 80 \times 150$	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)

$H(n, \gamma) \cdots 2.22 \text{ MeV } \gamma \text{ ray emission}$

$N(n, \gamma) \cdots 10.83 \text{ MeV } \gamma \text{ ray emission}$

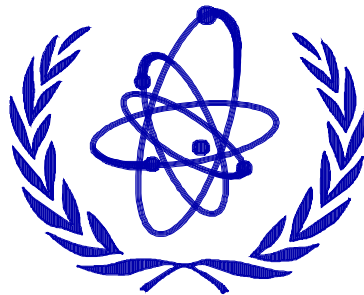
➤ back-scattered neutron (existence of LM)

$H(n, n') \cdots \text{scattering cross section of H large}$

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
<i>Methods to find buried objects</i>					
X-ray Backscatter	X-rays backscattered from 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)
<i>Methods to identify composition of buried objects</i>					
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.	Vourvopoulos (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) Kuznetsov (RUS) Hussein (CAN)

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



^3He 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.

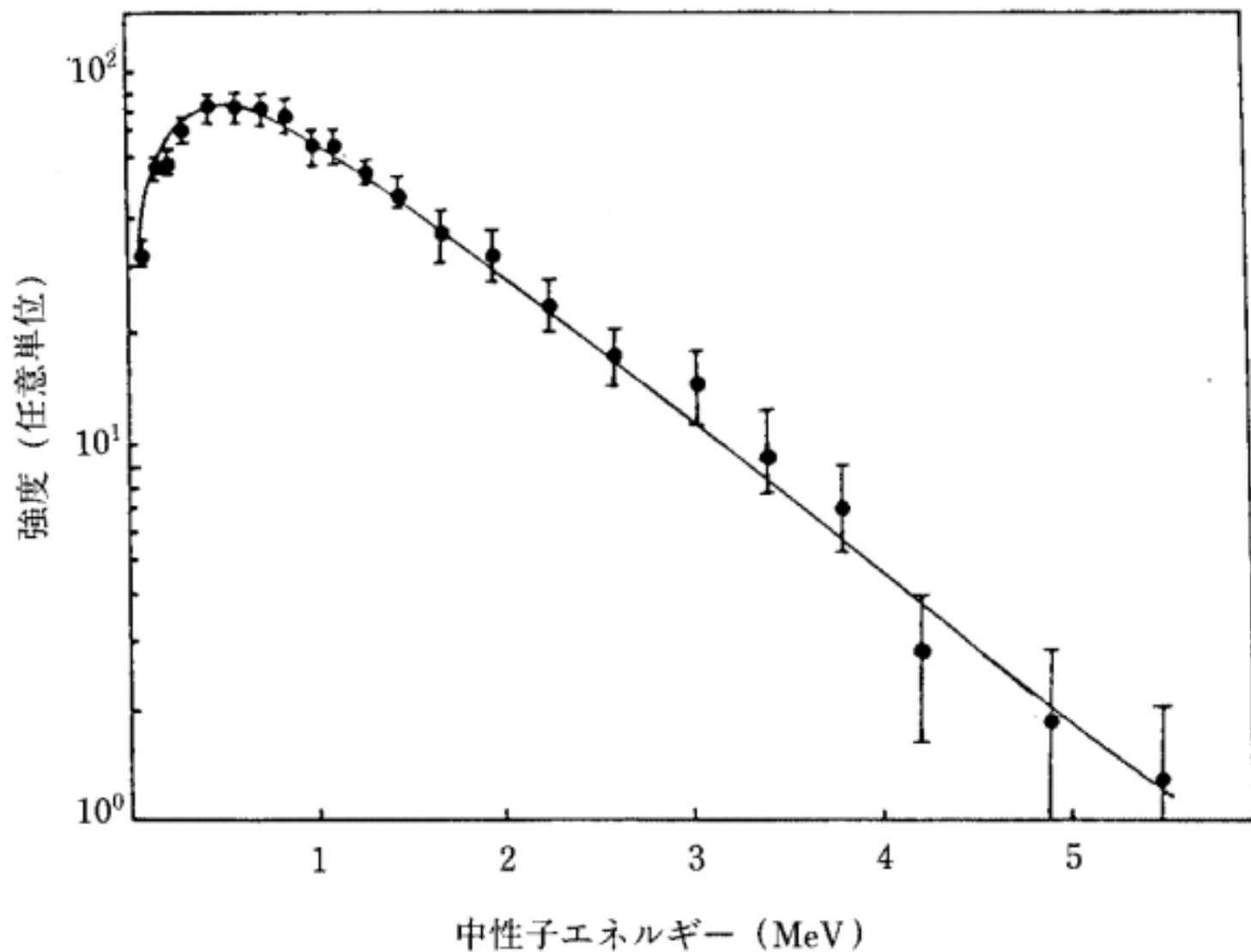
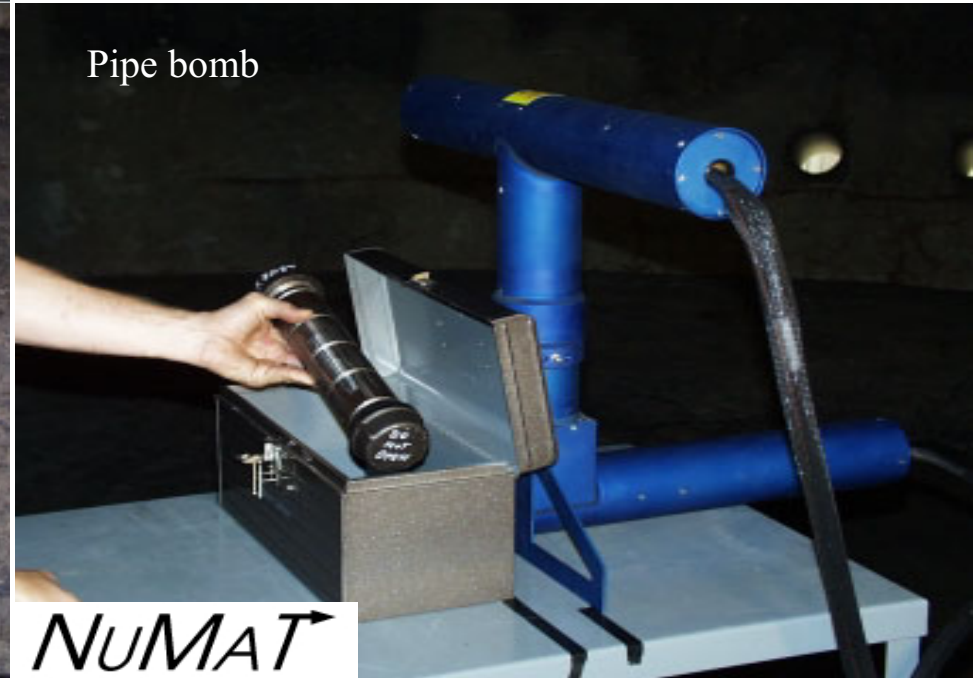
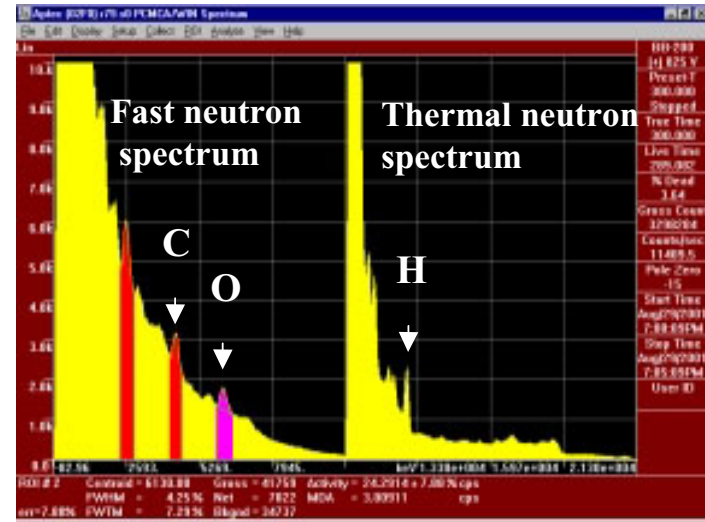


図 1.10 ^{252}Cf の自発核分裂で発生する中性子エネルギースペクトルの測定値 (Batenkov ほか¹²⁾ による)

PELAN TRIALS, 8/99, OHIO, Battle



Pipe bomb

NUMAT

PERAN III ; 10^8 n/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

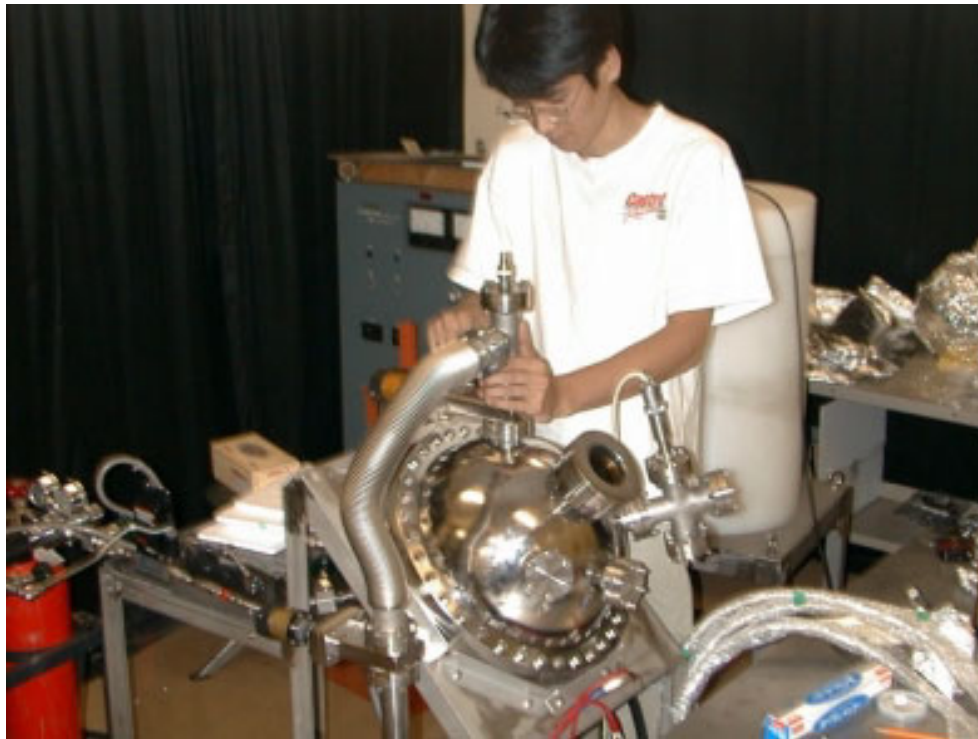
Kyoto

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)

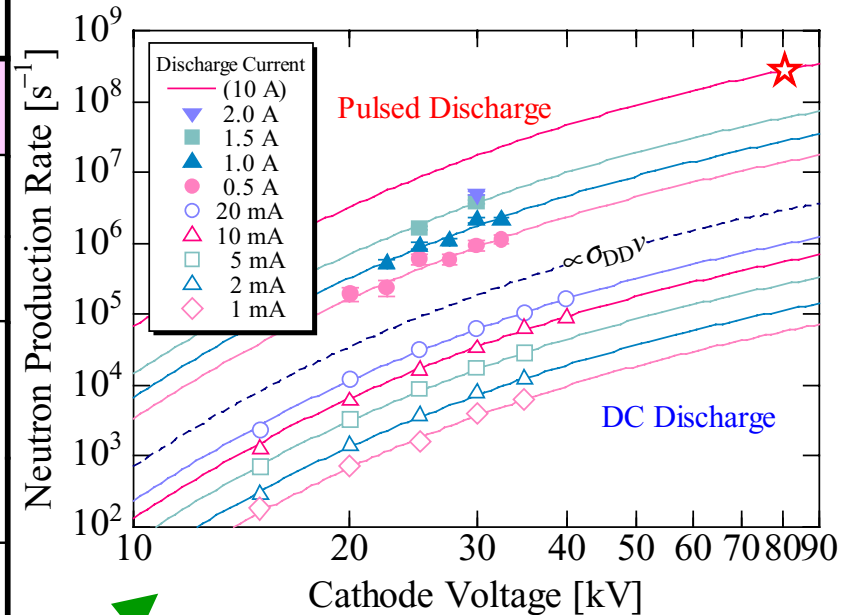


Achievement of neutron yield

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- ^3He)
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

($10^8 \text{ n/s} \rightarrow 80 \text{ kV}, 10 \text{ A}?$)

R&D Organization & Budget

① R&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