NSD-Fusion

# Applications for Gas-Plasma Target Neutron Generators

**presented to**

**International Topical Meeting on Nuclear Research Applications and Utilization of Accelerators**

**7 May 2009, Vienna, Austria**

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www.nsd-fusion.com

*Prepared with OpenOffice - Linux*

# Topics

NSD-Fusion

- History
- Technology
- Innovative Applications Examples

# History – since 1996

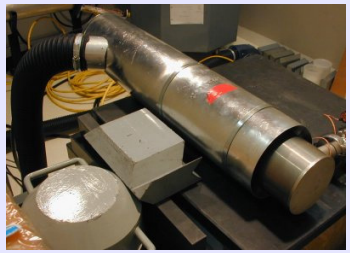
NSD-Fusion


1996-2001

Q3 2001

Q4 2001-2004

2005



2006-2008

NOW

# Innovation

NSD-Fusion

The neutron generator is like a new light source.

To sell it, there have to be **applications** where it:

Either enables further innovation.

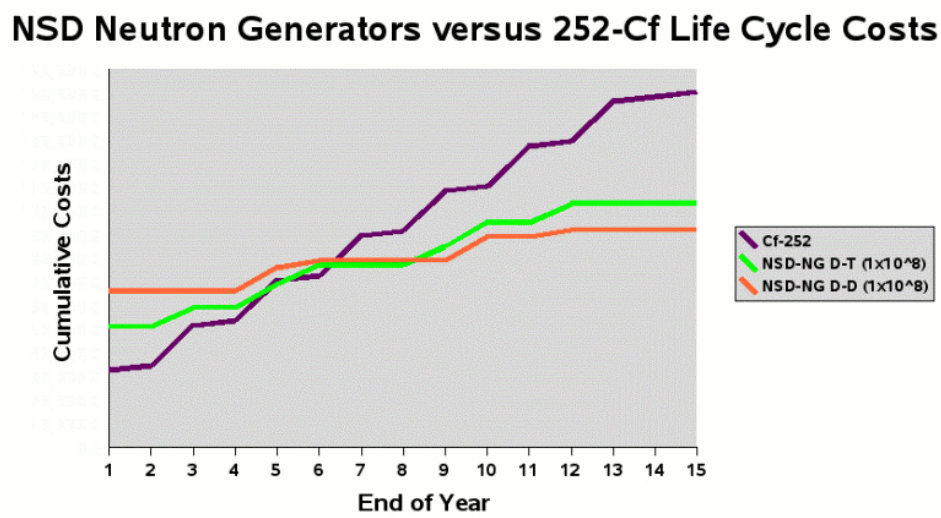
Or replaces obsolete neutron source technologies.

Replace $^{252}Cf$ (“Unaffordium”)

Overcome short endurance of solid target NGs.

# Life Cycle Cost Comparison

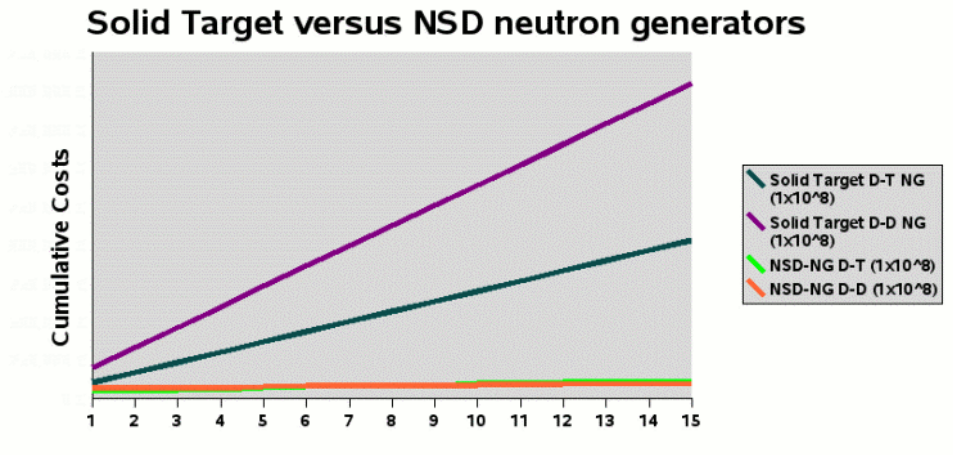
NSD-Fusion




**This is an old chart.**

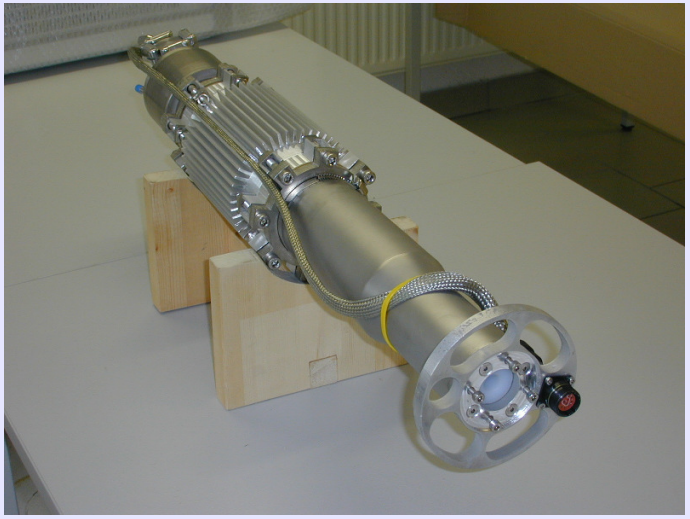
**<u>Price</u> of $^{252}$Cf is increasing to <u>6 times</u> ! (off the chart)**

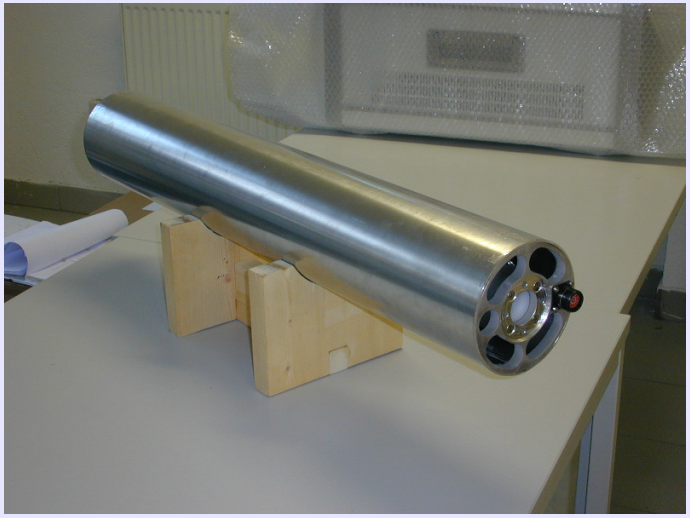
- Longest life at full power (years)
- No solid target
- No thermal fatigue
- Long service interval
- Higher output
- Lower price



# Sealed Tube Reaction Chamber

NSD-Fusion

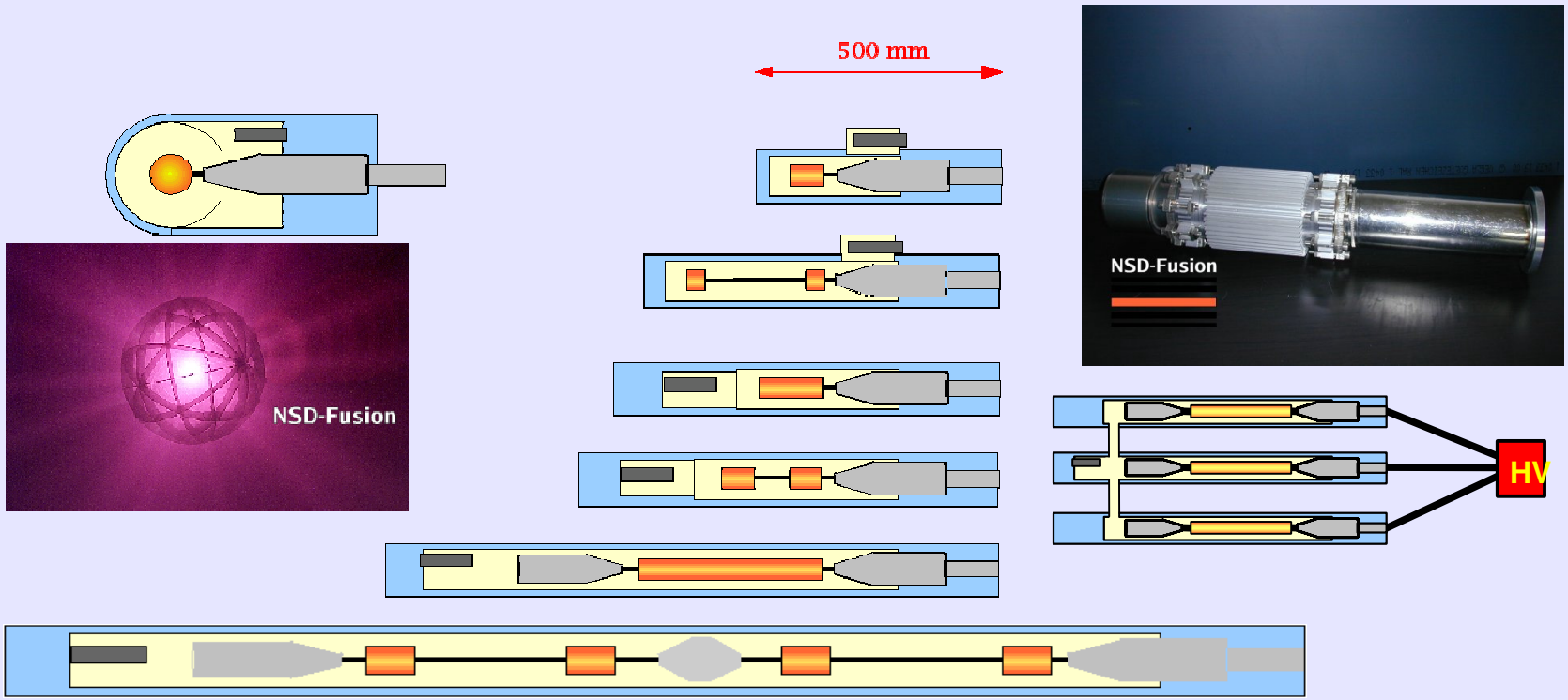




O.D. 135 mm
Length depends on configuration of electrode

# Versatile

NSD-Fusion



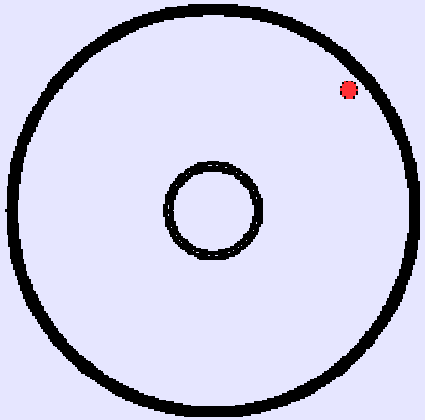

http://www.nsd-fusion.com/

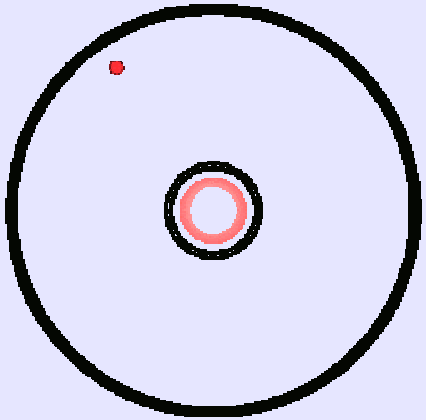
# Technology

NSD-Fusion

## Inertial Electrostatic Confinement IEC Fusion

Inventor: Philo Farnsworth (Television)





a) ${}_1D^2 + {}_1D^2 \rightarrow {}_2He^3$ (0.82 MeV) + ${}_0n^1$ (2.45 MeV)
b) ${}_1D^2 + {}_1D^2 \rightarrow {}_1T^3$ (1.01 MeV) + ${}_1p^1$ (3.02 MeV)
c) ${}_1D^2 + {}_1T^3 \rightarrow {}_2He^4$ (3.5 MeV) + ${}_0n^1$ (14.1 MeV)
d) ${}_1D^2 + {}_2He^3 \rightarrow {}_2He^4$ (3.6 Mev) + ${}_1p^1$ (14.7 Mev)
e) ${}_2He^3 + {}_2He^3 \rightarrow {}_2He^4 + 2\,{}_1p^1$ + 12.86MeV

# Pulse Performance

NSD-Fusion

Solid target NGs

N/sec ⊠ fusion particle flux onto target

IEC plasma-gas target NGs

beam-beam and beam-background collisions
electrostatic confinement increases fusion probability
destabilizing effects in high pressure (poor vacuum)
limits scaling

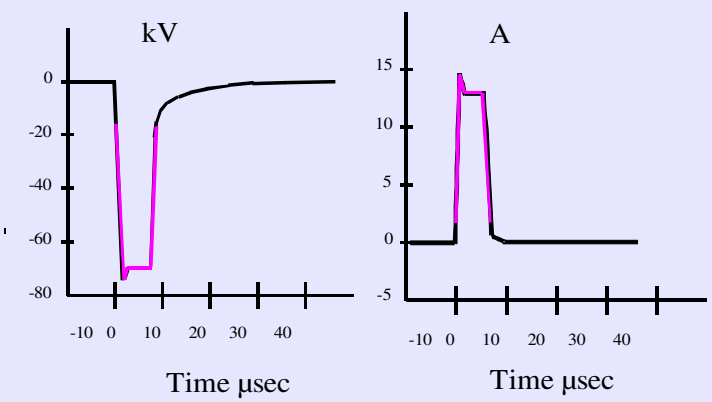
NSD-NG highest specific DC performance

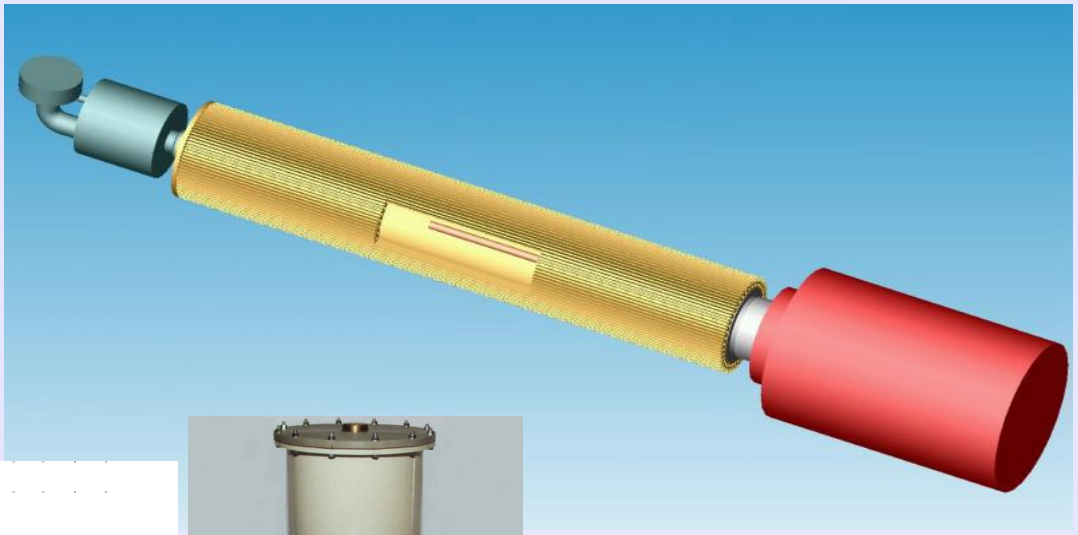
Pulsing experiments in USA (UI & UW), Japan (Kyoto)

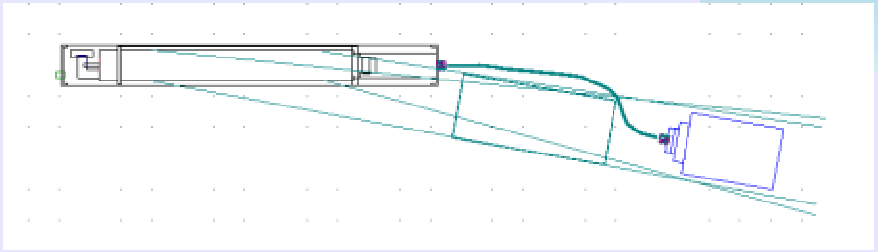
Super linear scaling with current
Linear n/s □ $I^{1.0}$
Super-linear □ $I^{1.x}$ **x > 0** $I^{1.5}$ **=> ~10X gain**

# Pulsed Power

NSD-Fusion



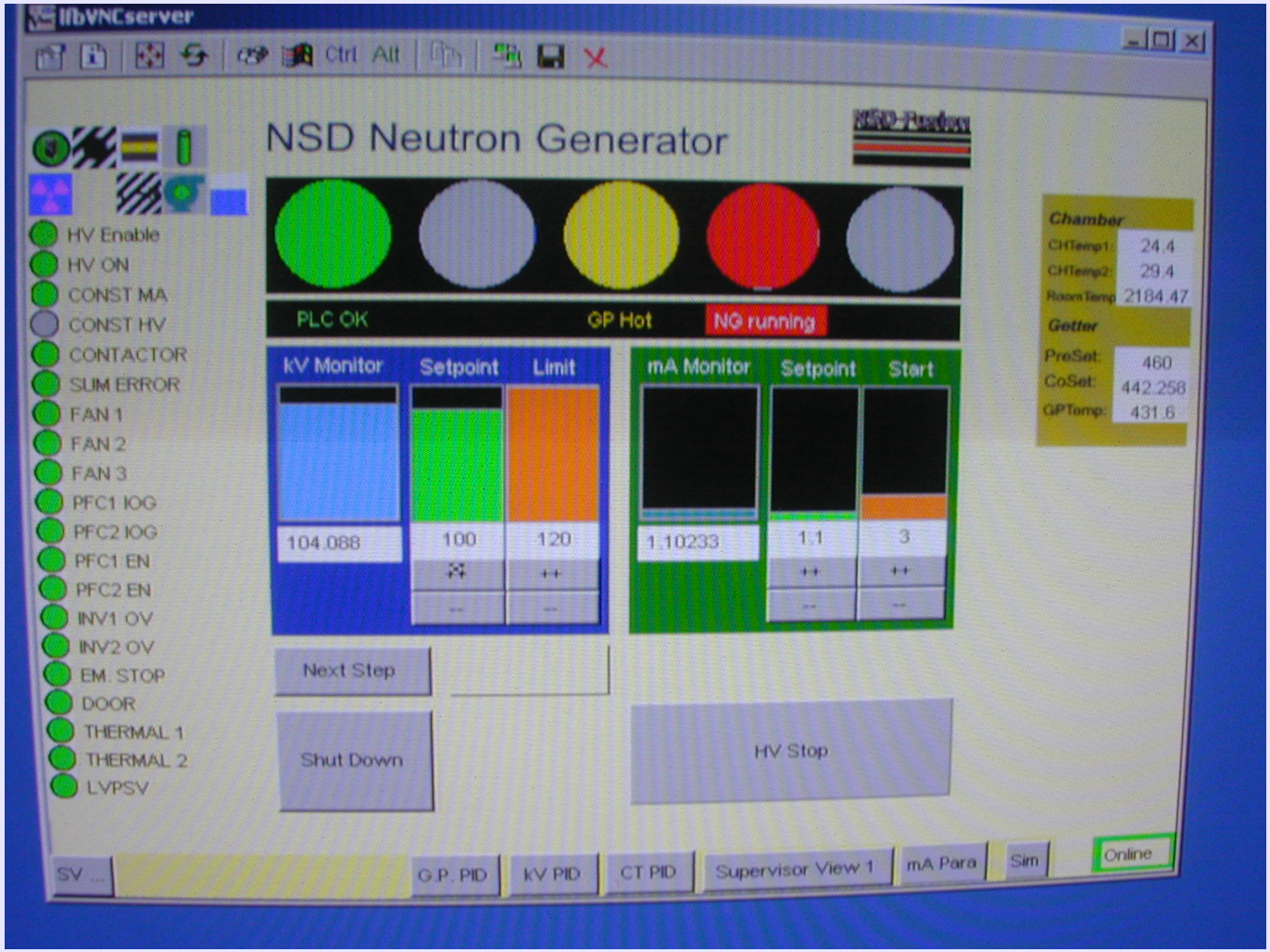






- Pulsed power allows much higher performance
- Compact pulsed High Voltage Power Supply
- 3% duty cycle
- Maximum input power ~15 kW (3 phase power)
- NSD-Fusion measurement in preparation

# Automated Control

NSD-Fusion



# Markets for Neutron Generators

NSD-Fusion

**Neutron Generator output neutrons / sec**

$10^{10}$

Sub-critical fission power
BNCT cancer treatment
P.E.T. Isotope production
Medical n-gamma imaging
**Neutron radiography**

$10^{9}$

Land Mine detection
On-line letter and parcel inspection
**ContainerProbe**
Industrial on-line and off-line solids and fluids PGNAA

$10^{8}$

Car, Parcel and Letter Bomb IED detection
**Baggage inspection explosives detection PGNAA**
**Online mineral quality monitoring PGNAA**
Exploration bore hole / mobile PGNAA assay

$10^{7}$

Mobile Safeguards inspection (nuclear and chemical weapons)
**Material sorting NiCd/NiMH battery PGNAA**
Radiochemistry laboratories (analytical labs)
Online Moisture in coal and coke measurement
**Industrial Gauges**

# Collaborative Research

NSD-Fusion

Proposed example (N. Menduev NSD-Fusion):

**Gamma Release End Time**

What is the Gamma release end time of irradiated sample by PGNAA ?

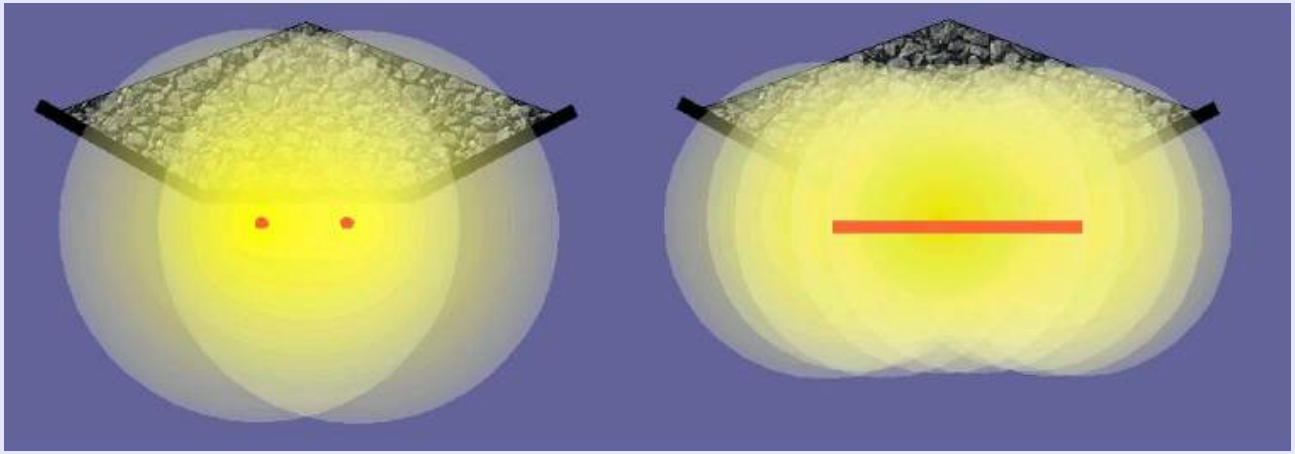
What is the PGNAA parameters of activation ?

We need to know the “gamma release end time of many elements activated by PGNAA.

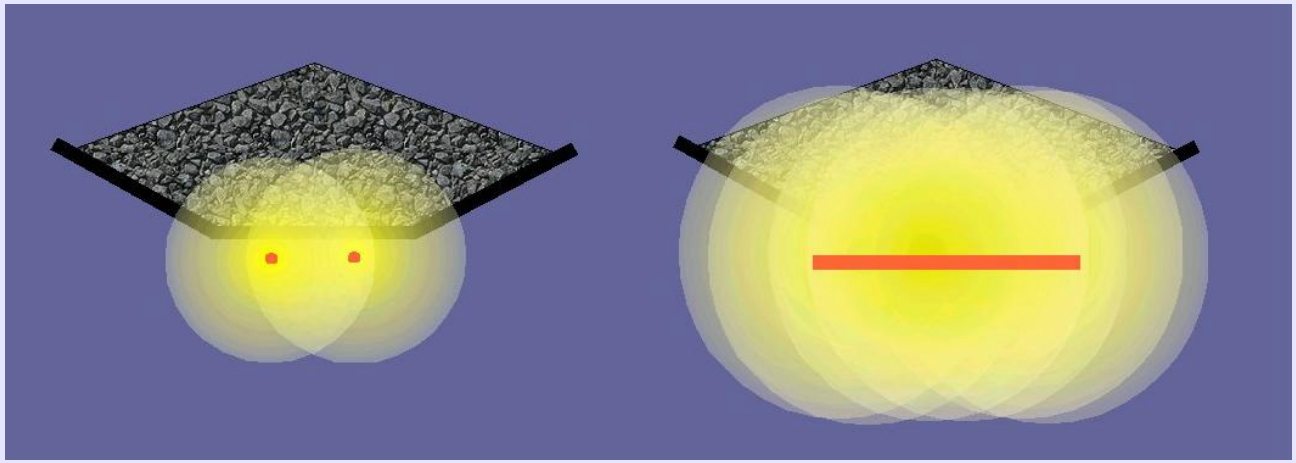
Create Function GET(f,T,t,d,m)= gamma end time after termination of PGNAA.
f(neutron flux),
E(neutron energy ),
t(irradiation time ),
d(distance) and
m(sample mass) dependent function database .

# On-Line Minerals PGNAA

NSD-Fusion



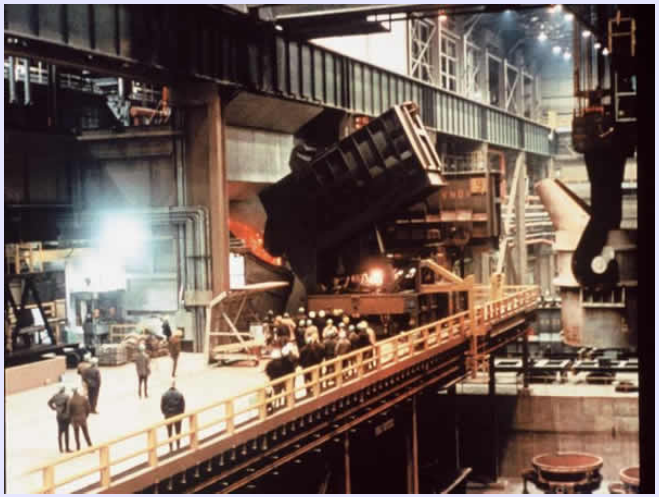
Beginning of $^{252}Cf$ life



2.65 years later

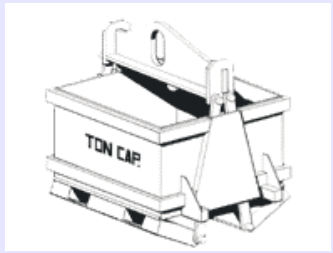
# SCRAP-PROBE

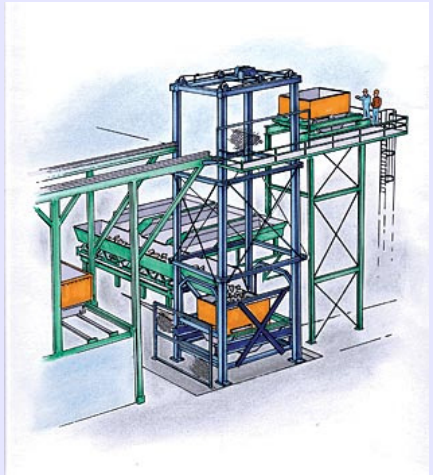
NSD-Fusion



EC Research Fund for Coal and Steel wanted a resubmission of proposal for neutron interrogation Prompt Gamma Neutron Activation Analysis PGNAA of scrap in scrap charge buckets for **increased recovery of scrap**. “Strategic importance”.

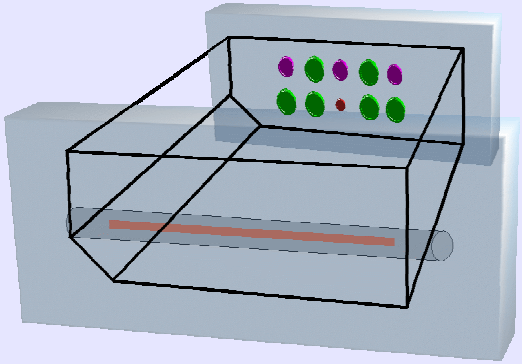
Scrap-Probe project started – end 2011
Arcelor Mittal (ES), University Liverpool (GB)
Centre de Rescherches Metallurgique (BE)
Cetto project coordinator (DE)
NSD-Fusion (system integrator) (DE)



# SCRAP-PROBE

NSD-Fusion



Alloy elements %
Carbon % content option.
Water % content option.

**Scrap Bucket Probe**

**ContainerProbe** variants in portals ->
**TruckProbe** for non-ferrous recyclers
**RailWagonProbe**
**Small BucketProbe replaces hand assay**

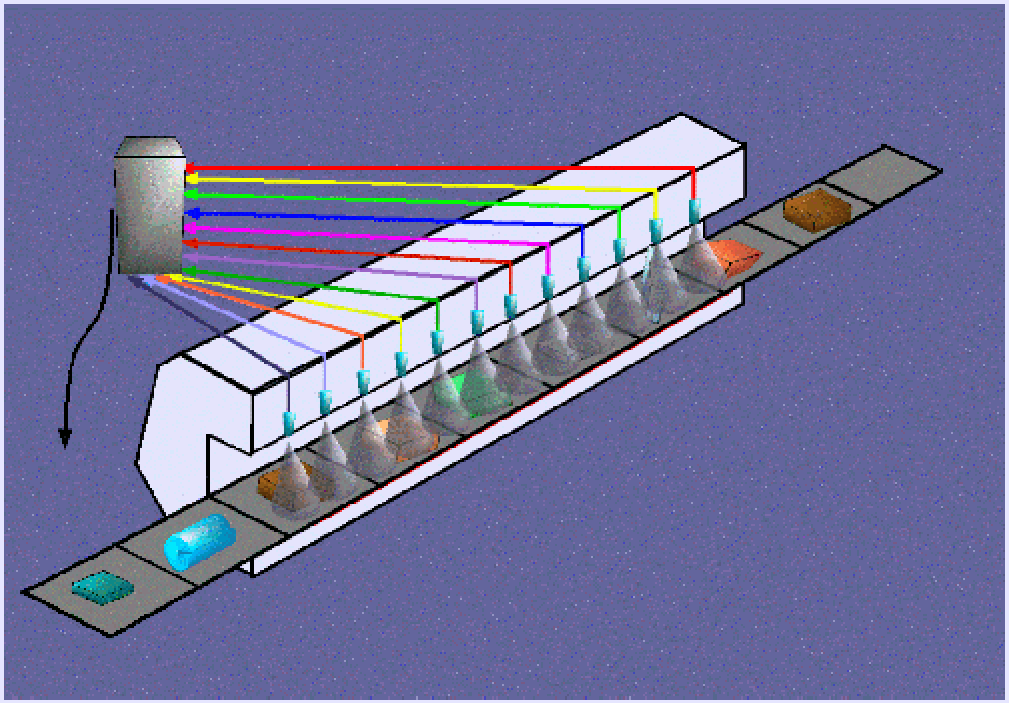
# Benefits to Society

NSD-Fusion

- ✓ Energy Saving
- ✓ Environmental Protection
- ✓ Recycling of Materials
- ✓ Civil Security
- ✓ Safety
- ✓ Industrial Quality Assurance  incl. nuclear power
- ✓ Scientific Research

# Tunnel Baggage Neutron Interrogation

NSD-Fusion



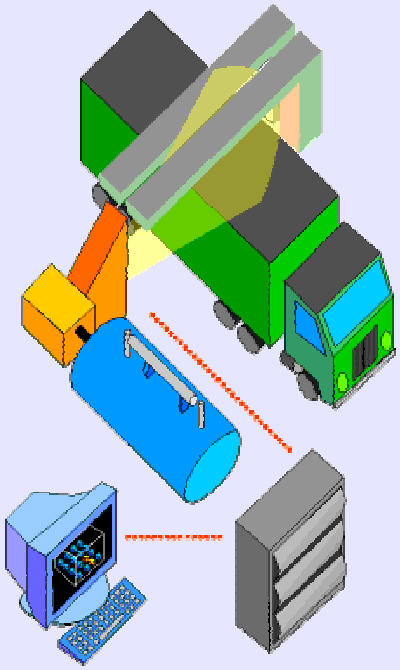
Continuous Motion of Conveyor

NSD-NG makes it economic

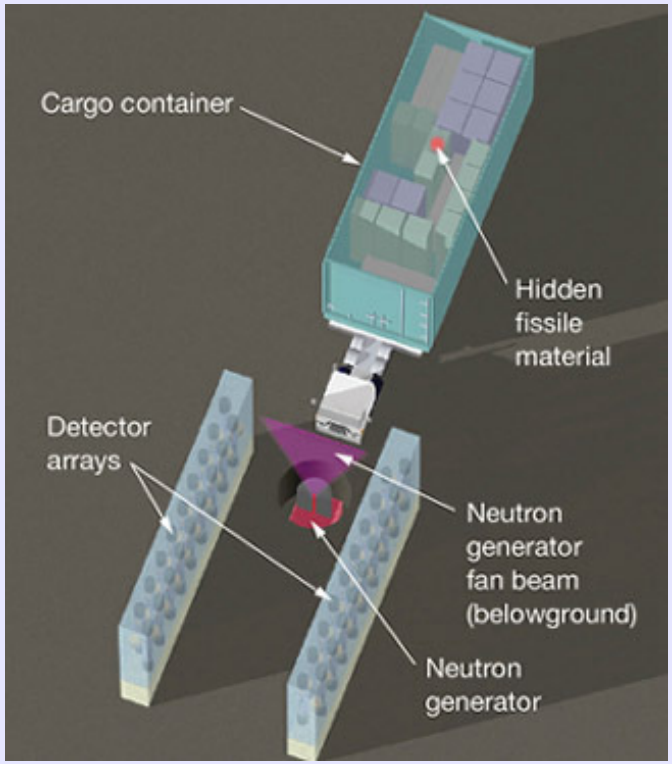
http://www.nsd-fusion.com/bag-screen.php

# Container Scanners

NSD-Fusion



Rapiscan:
large (expensive)
neutron generator (accelerator)



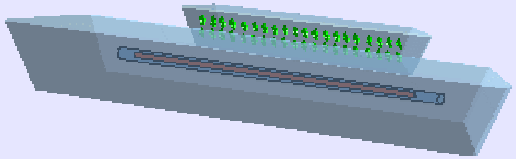

Livermore Labs
R&D project
shows that a
moderate output
neutron generator
can support
30 second scan
detection of
fissile material.

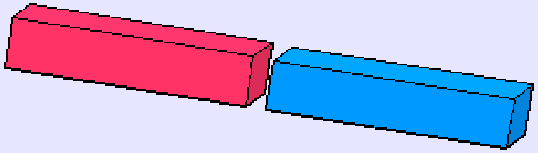
NSD-NG
long segmented line
neutron source
can deliver more
neutrons to probe
the container
without scanning.

Scanning past a source and detector gives position information and takes time

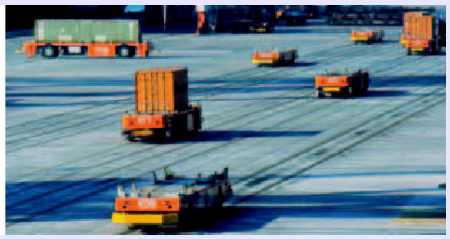
# ContainerProbe Portal

NSD-Fusion









# Stakeholders

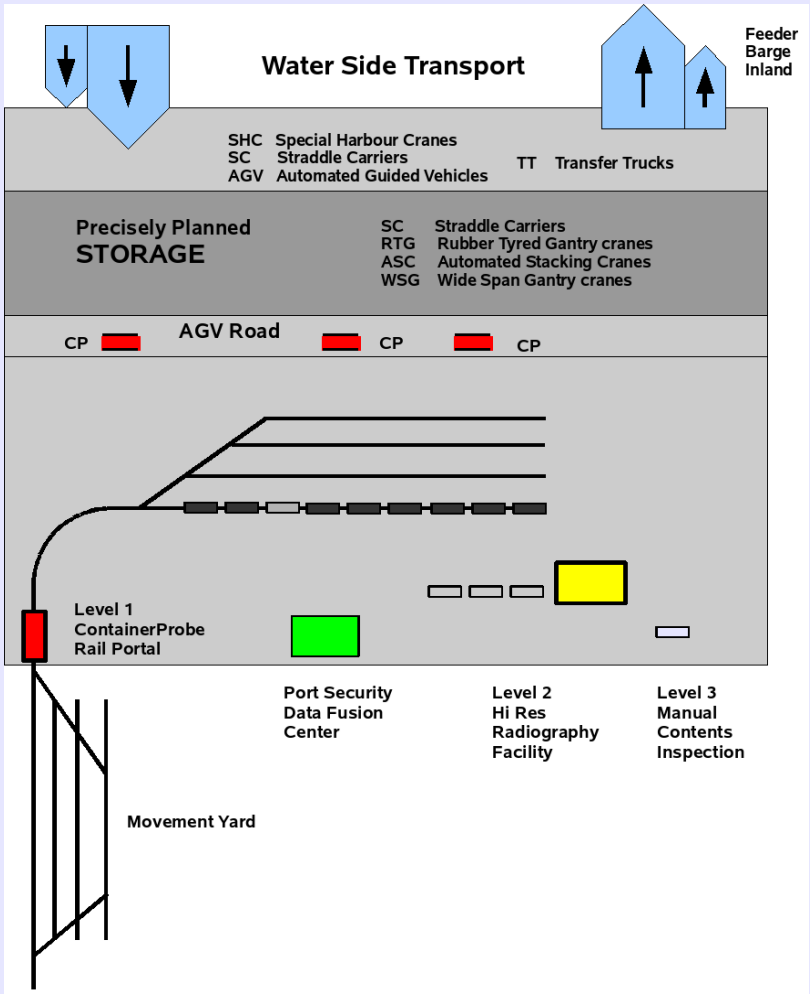
NSD-Fusion

Promoted to DHS (USA)
for 100% Risk Screening of containers
(USA Safe Ports Act 2006)

Not financially eligible for EU FP7 Security Research

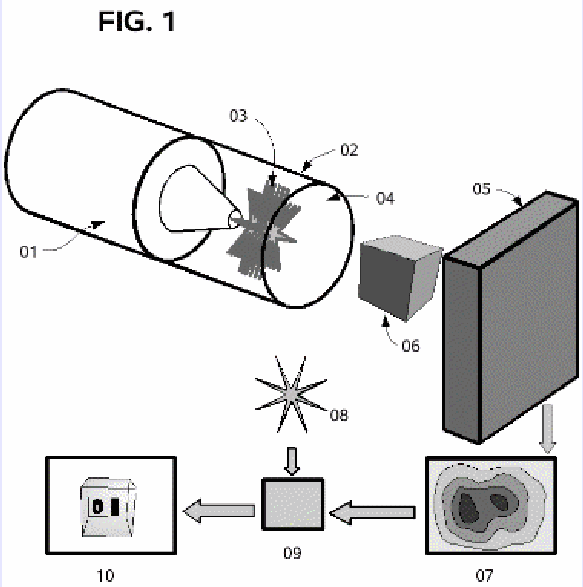
Since April 2009
U.S.A. - Germany security technology research funding

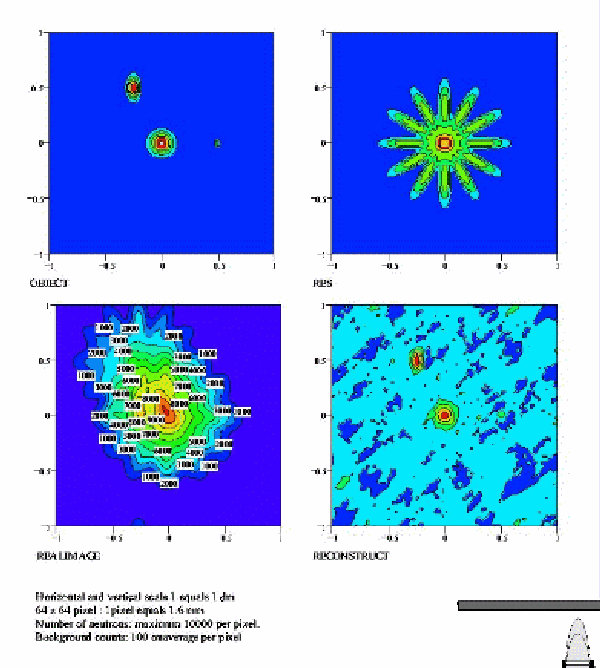
ConsortiumNeutron Systems

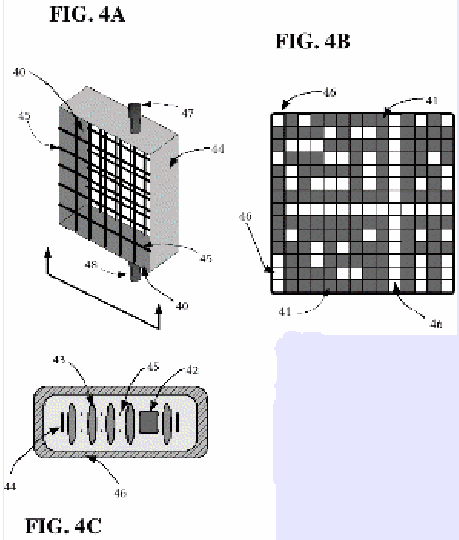


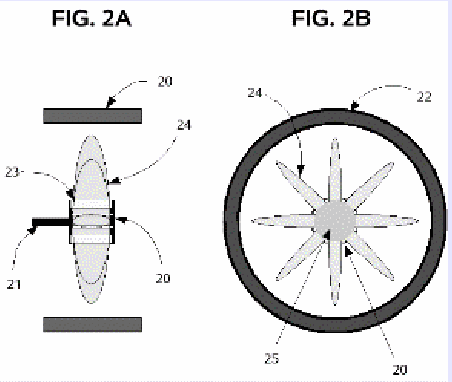
# Fast Neutron Radiography

NSD-Fusion

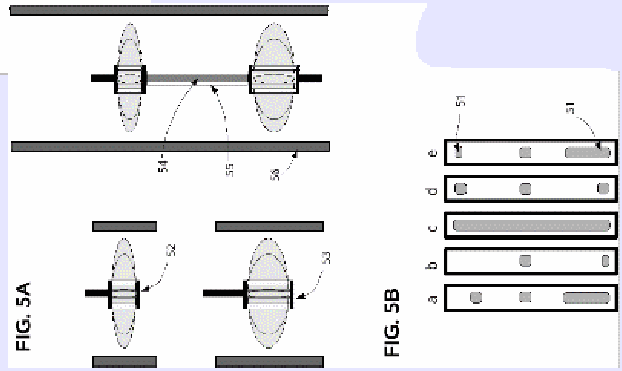





Deconvolution of neutron source structure.



# Discussion

NSD-Fusion

Further discussion at Poster Paper

or please visit our exhibit booth