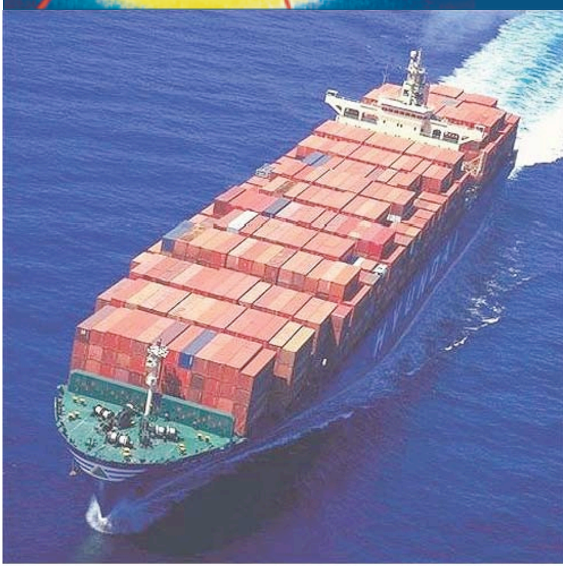
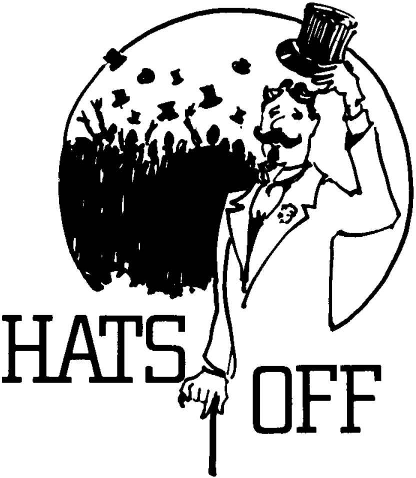
Scientists and Home Land Security

Moshe Gai
UConn and Yale
http://astro.uconn.edu



- The Problem
- SNM
- History HLS
- Past Solutions
- Future Solutions…
- From Basic Science Home Land Security
- The Yale/UConn Collaboration

Avery Point, September 29, 2011

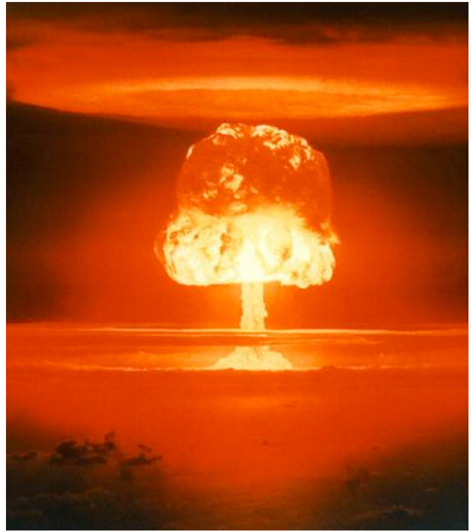


Congressman
Joe Courtney

(aka “Landslide Joe”; elected by 83 votes)

Terrorists' Dream
(Our Reality)

→ ?



SNM = Special Nuclear Material

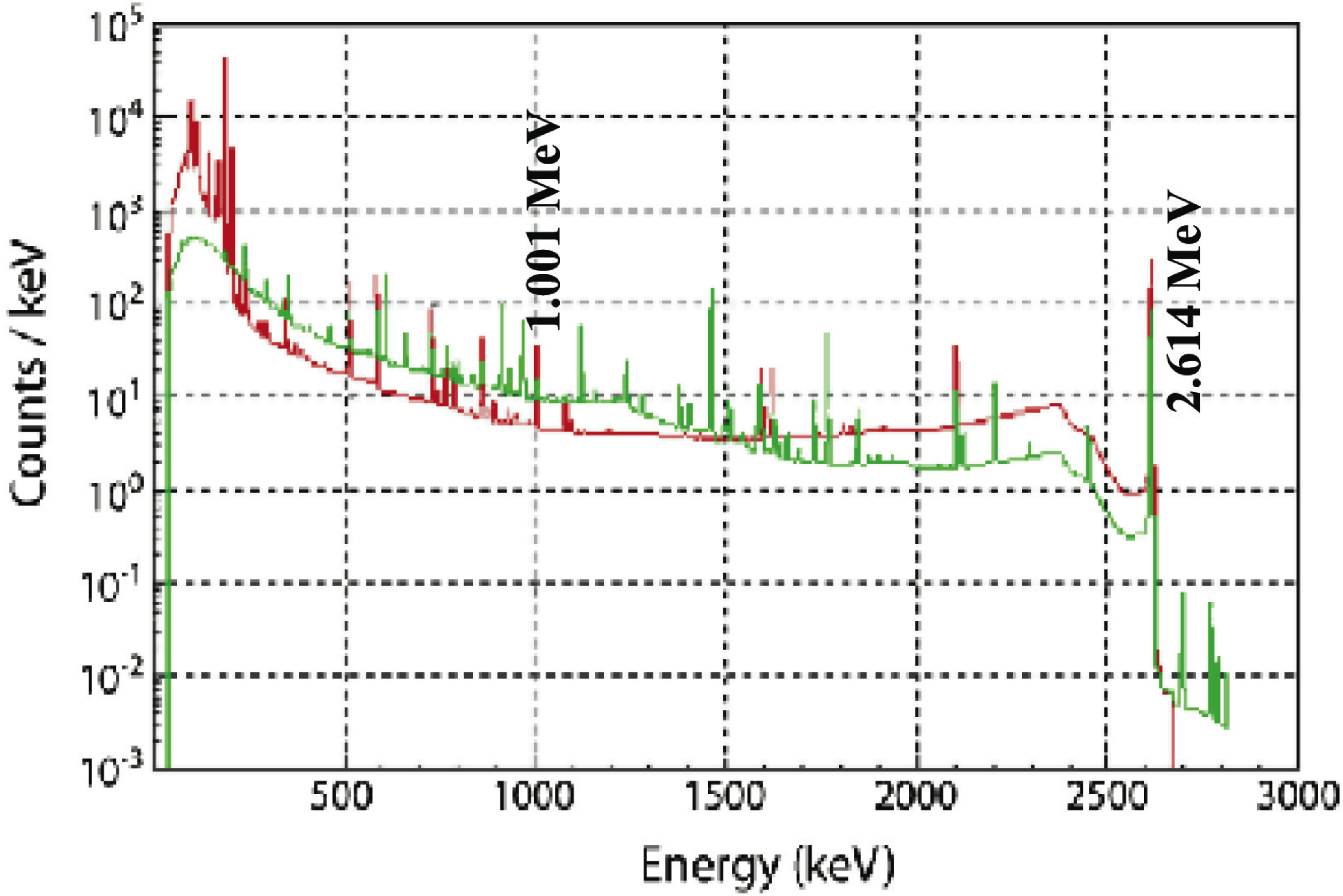
Defined by the International Atomic Energy Commission (IAEC)
Act of 1954:

plutonium, uranium-233, 235
uranium enriched in the isotopes uranium-233, 235.

SNM is radioactive (gamma rays and neutrons).

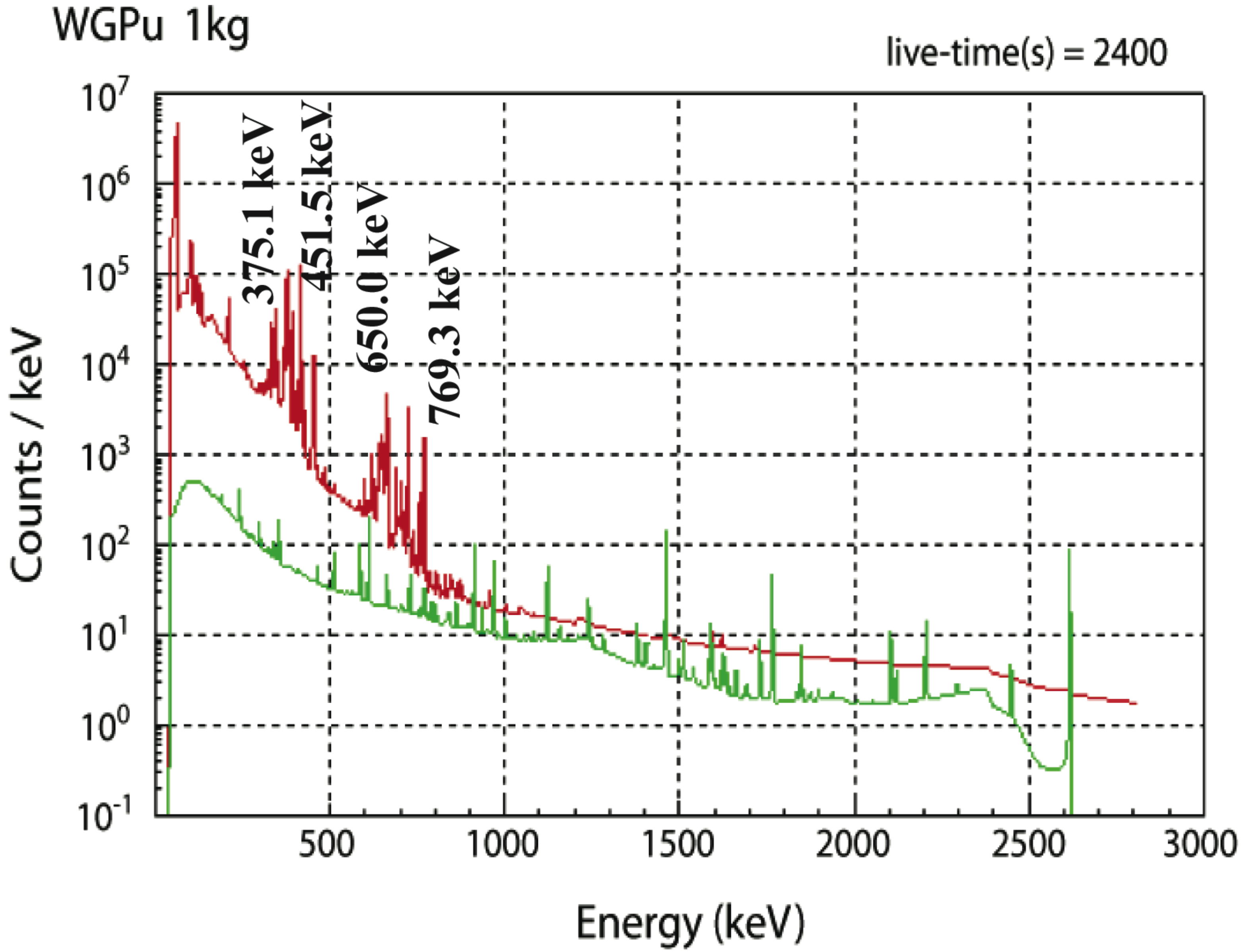
It includes fissile material—uranium-233, uranium-235, and plutonium-239—that, in concentrated form, can be the primary ingredients of nuclear explosives.

1 kg of HEU (90% ^{235}U) at 1.0 meter, 2400 sec vs background



Source: 2 kg HEU (~100 ppT 232U) = 60,000 γ/sec at 2.6 MeV
(from 238U) = 8,000 γ/sec at 1.001 MeV

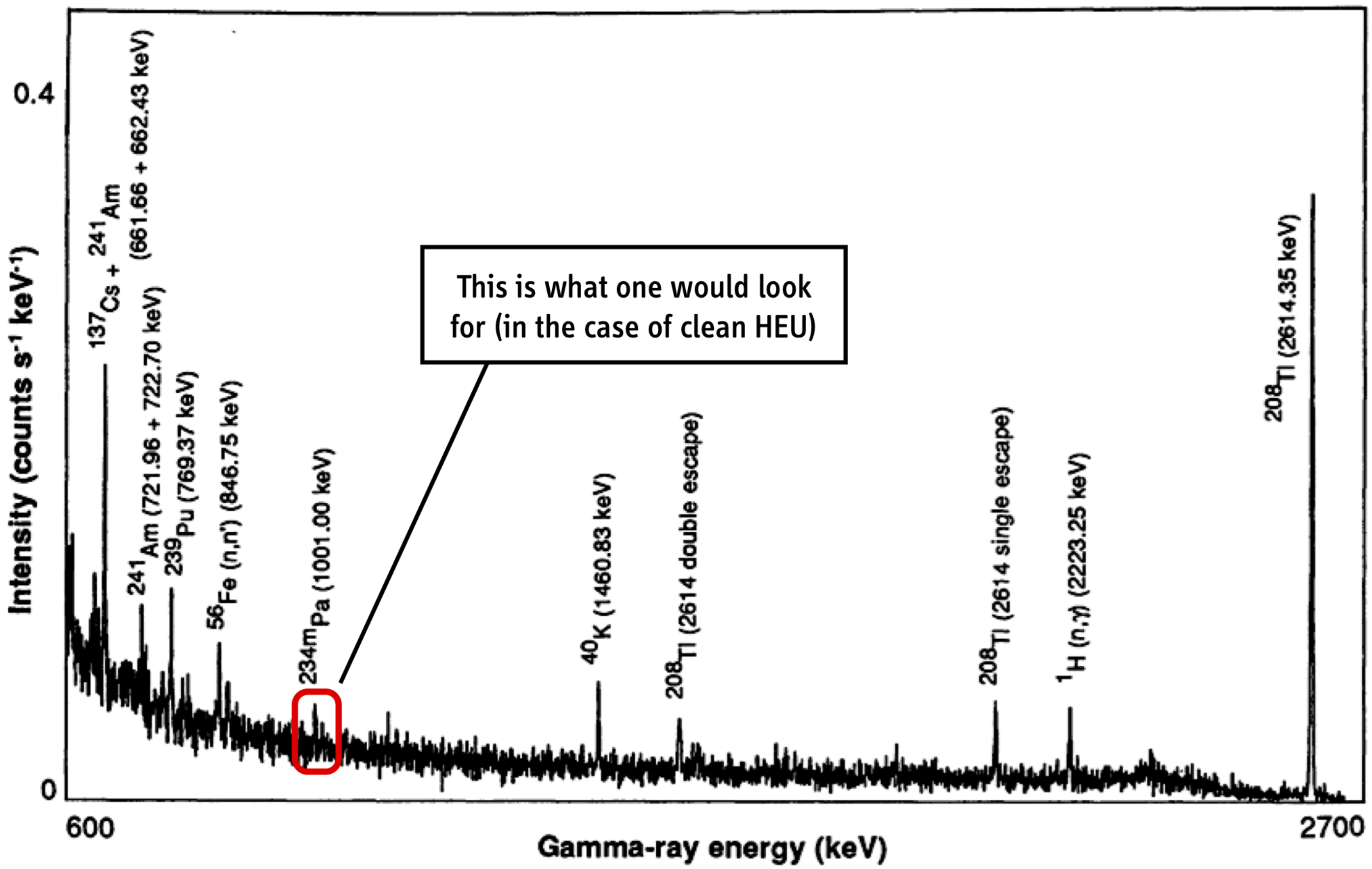
1 kg of WGPu at 1.0 meter, 2400 sec vs background



- WGPu emits 300,000 γ/sec above 1.0 MeV
- WGPu emits 1,860,000 γ/sec between 0.6 – 0.8 MeV
- WGPu emits 60,000 neutrons/sec (from 240Pu)

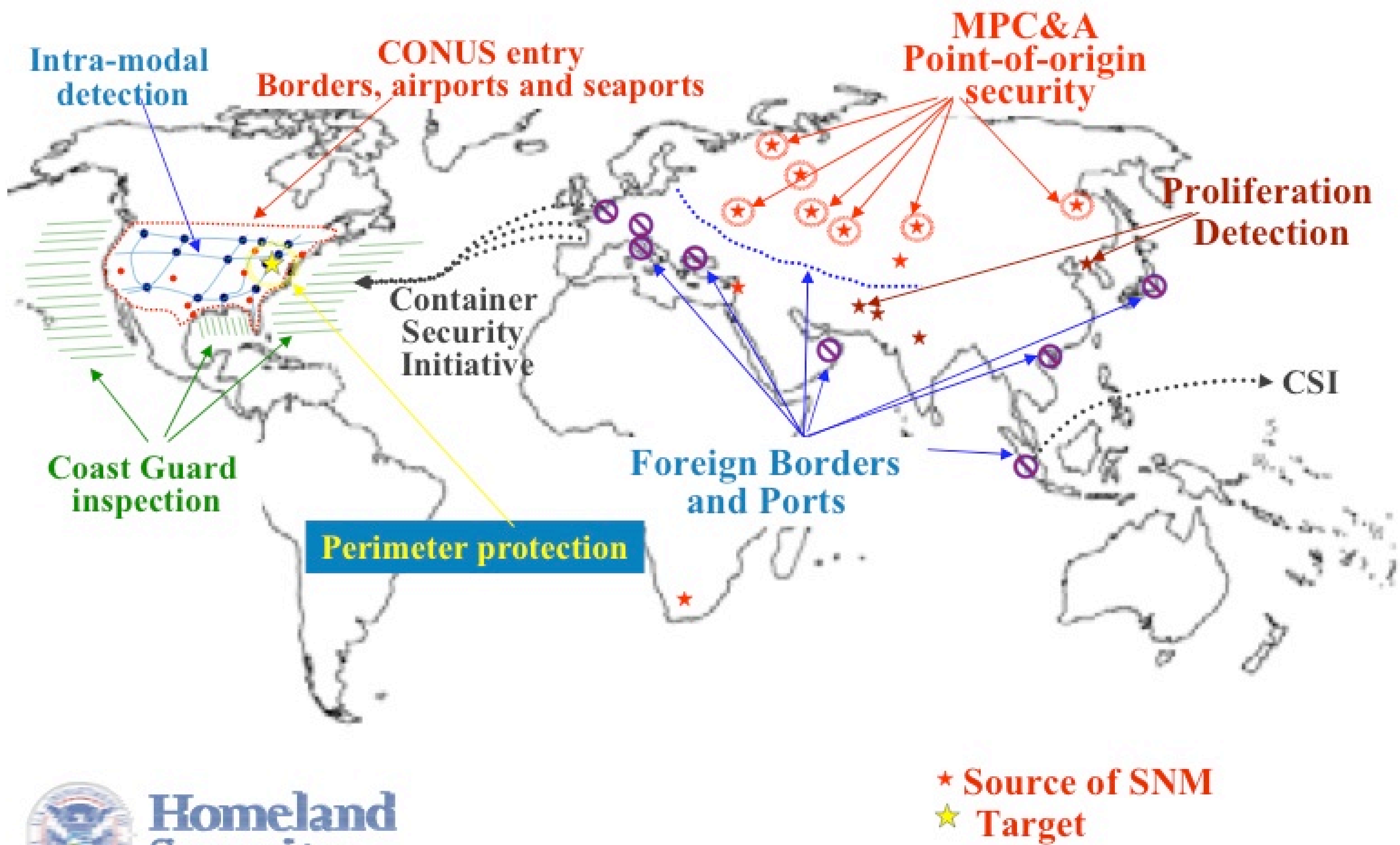
Looking for Niddle in a Hay Stack
(Much Like Looking for Dark Matter)

The Usual Suspects



etter, T. B. Cochran, L. Grodzins, H. L. Lynch, and M. S. Zucker, "Measurements of Gamma Rays from a Soviet Cruise Missi
Science, 248, 18 May 1990, pp. 828-834

Layered Defense Concept



Homeland Security

3

J. Kammeraad et al., *Radiological and Nuclear Countermeasures*
Department of Homeland Security, Briefing, 9 March 2004

Stuxnet Worm:

First Cyber Warfare, June 2010.

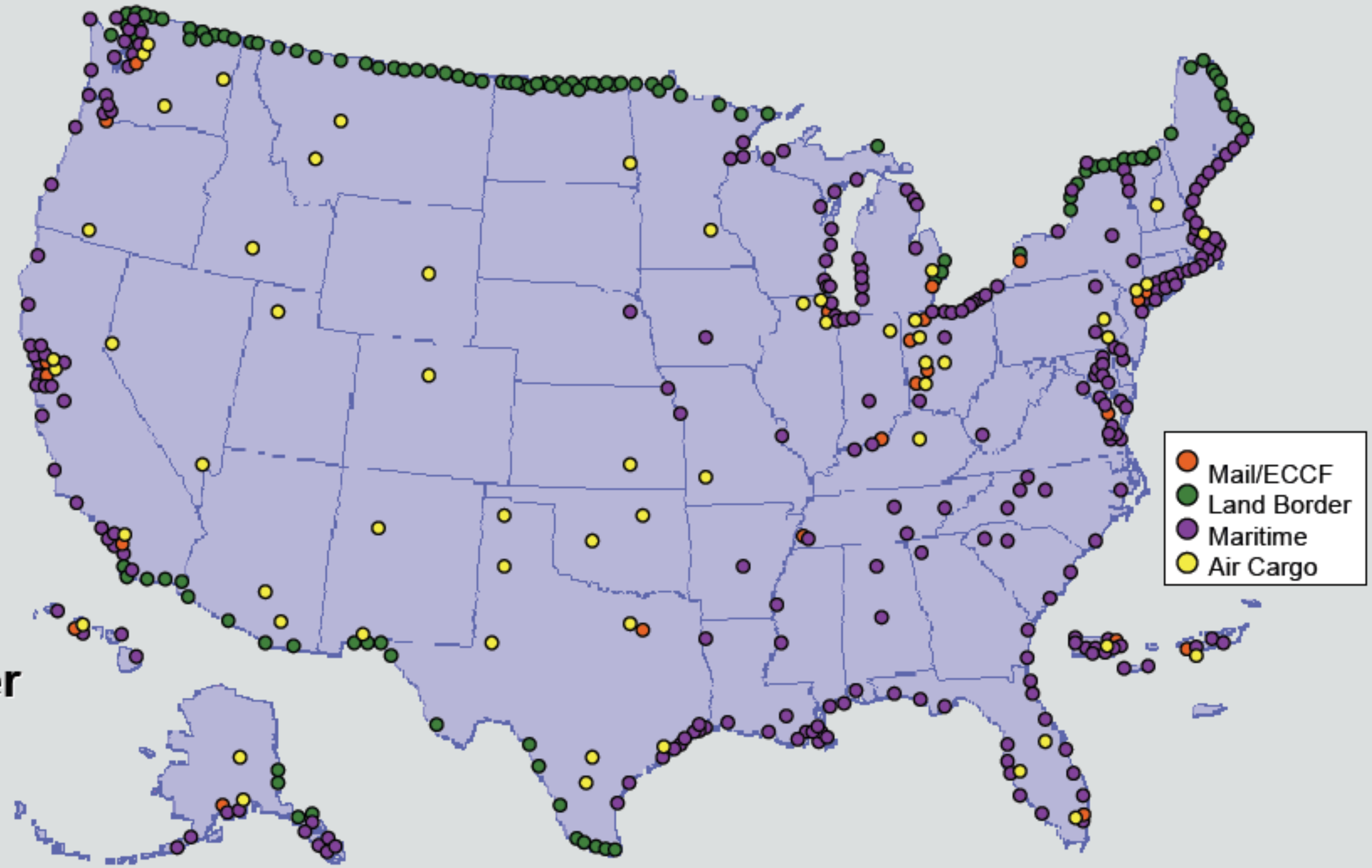
Siemens' 986 centrifuges demolished in Iran (without a single bullet fired)

The Global View

20-foot Shipping Container Traffic Per Year

<u>Credit:</u> James Ely
Pacific North West National lab
June 2006

The Challenge: U.S. Ports of Entry



307 Ports of Entry representing 621 border sites to protect

332,622 vehicles per day
57,006 trucks/containers per day

2,459 aircraft per day
580 vessels per day

- **Early Days of Home Land Security**
- **2001 – 2004: Unmitigated Disaster**
- **2004 NYT: $4B spent without deliverable(s)**
- **2005: Katrina; Communication Failure of First Responder**
- **Politics Dominated Science**

U.S. SENATOR • ARIZONA

JOHN McCAIN

http://mccain.senate.gov

PRESS RELEASE

Wednesday, July 24, 2002
FOR IMMEDIATE RELEASE
CONTACT:
Rebecca Hanks 202/224-2182

McCain Voices Opposition to FY'02 Supplemental Appropriations Bill

Washington, DC – U.S. Senator John McCain (R-AZ) today entered the following statement into the Congressional Record regarding the FY'02 Supplemental Appropriations Bill:

Other questionable provisions regarding the TSA should also be mentioned. For example, in the Statement of Managers, the appropriators have earmarked money for the field testing of a particular security technology referred to as Pulsed Fast Neutron Analysis (PFNA). There is only one company that has developed this technology: Ancore Corporation of Santa Clara, California. Unfortunately, earlier this month, the National Research Council (NRC) concluded that PFNA is not ready for airport deployment or testing. Even though the main role for PFNA is the detection of explosives in full cargo containers, the appropriators are directing money for field testing on checked bags. This earmark could be a total waste of critical research money that should be contributing to our effort to increase aviation security.

DIANA HI-TECH

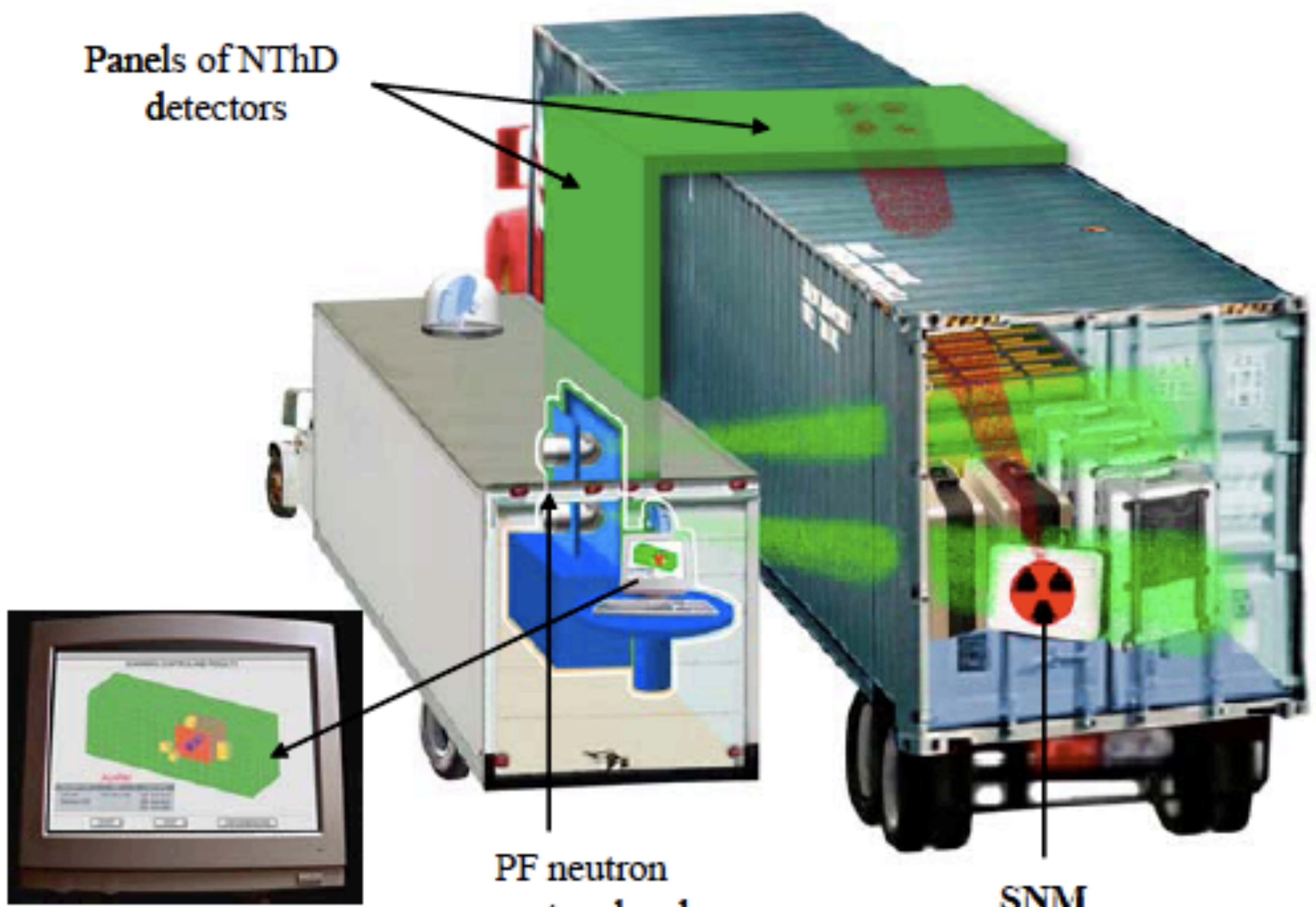
NORTHROP GRUMMAN Mission Systems

BOEING

BAA Number: 04-02
TTA: 6:AAISS Part: B

DIANA HI-TECH LLC
5/03/2004

Title: Direct Detection of Special Nuclear Materials with Single Pulses of Fast Neutrons



Parameter	AFNIT	BAA 04-02 requirements
M_{SNM}: Mass of detected ^{235}U, ^{239}Pu,... [% of Nuc. WMD]	< 5%	"limited quantities"
Direct elemental detection and position	yes	required
Chemical form of SNM	any	not adressed
Volumetric dilution of M_{SNM} within inspected slot	any	not adressed
Type of cargo load	any	not adressed
Sensitivity to clandestine shielding	none	none
Total cost of one container inspection	$80	low
Scan time for 8x10x40 ft cargo container [s]	20	20
Detection rate per SNM [%]	99.9	70
Nuisance & false alarm per container [%]	0.01	?????
Operation from mobile platform	yes	yes
Architecture open for upgrade and integr.	yes	yes
Decision and data transmission	automatic	automatic

Operational Capability:

Comments:
1. Nuisance & false alarm reduction is due to immediate second inspection of container slot when SNM is detected. Present systems (and TTA-3 solutions) have no detection capacity for shielded SNM.
2. Inspection cost includes capital investment and 2 years of operation costs.
3. SNM mass is indicated vaguely for security reason.
4. Architecture is open for adding high energy γ-detectors to detect chemical explosives and an advance high energy X-ray radiology for 3D imaging

Proposed Technical Approach: Active inspection for SNM occurs in steps. Neutrons from Plasma Focus PF) source (~10^{13} n/pulse; $\Delta\tau \leq$ 50ns) are aimed at a volumetric slice of the cargo container (2'×6'). Neutrons are moderated by the content of the cargo container, absorbed by cargo nuclei and re-emitted fast neutrons from prompt-fission. Neutron threshold detector, NThD, (property of scintillator, not an electronic) is set outside of the container walls and gives unique information about presence of SNM. DIANA has already built PF-sources operating in lab. conditions and cross-checked with Monte Carlo simulations (LLNL and DIANA effort) that the fast-fission-neutrons information can be selectively recorded in a strong field of gamma and thermal neutrons and that PF-source has sufficient yield to support fast inspection. Phase-IA: Definition of system parameters and feasibility evaluation of: PF-source, threshold detectors. Phase-IB: Experimental feasibility of PF pre-prototype and NThD fragment performance and PDR. Phase-II: Construction of complete prototype in lab. technology (PF, NThD, decision software) and validate SNM signature, accuracy, throughput, safety and CDR. Phase-III: Convert technology from laboratory to field prototype. Construct and test in field full system ready to go for serial production.

ROM Cost and Schedule:

Phase	Task	Main Activity	month	COST in M$	DELIVERABLE
Ph-IA&B	1	Monte Carlo (MC) simulation of SNM signature	6 & 12	0.36 & 0.45	Signature & source yield
Ph-IA&B	2	Simulation/design of the PF engineering	6 & 12	0.27 & 0.35	Conceptual design
Ph-IA	3	Concept devel./design of the NThD engineering	7	0.98	3 options of concept. design
Ph-IA	4	Techn. concept of eng. Devel., pricing, suppliers	7	0.55	Final Report
Ph-IB	5	MC simulation/design of radiation safety for tests	15	0.45	Safety procedures
Ph-IB	6	Build and test PF meeting Ph-IA definitions	18	1.7	PF source; (not rugged)
Ph-IB	7	Build and test NThD meeting Ph-IA definitions	18	1.15	1 segment of detecting panel
Ph-IB	8	PDR, exp. concept validation, Ph-II eng. Program	19	1.38	Final Report
Ph-I	1-8	Feasibility studies; A- concept, B- experiment	7 & 19	2.16 & 5.5	*Prove of principles & scaling*
Ph-II	9-16	Prove of performance, eng.param. for field	31	7	*Lab. prototype*
Ph-III	17-2	Field prototype: constr., tests, documentation	43	7-10	*Complete field prototype*

Corporate Information:

- For DIANA Hi-Tech LLC, 1109 Grand Ave., North Bergen, NJ 07047,
  POC: Dr. Jan S. Brzosko, CTO, (201)223-9930 ext 2#; Email: brzoskoj@diana-hitech.com
- For Boeing Co. Program Manager: Ted Ralston (714)896-3312; ted.ralston-iii@boeing.com
- For Northrop Grumman Program Manager: Neil Siegel; (310)764-3003; Neil.Siegel@ngc.com

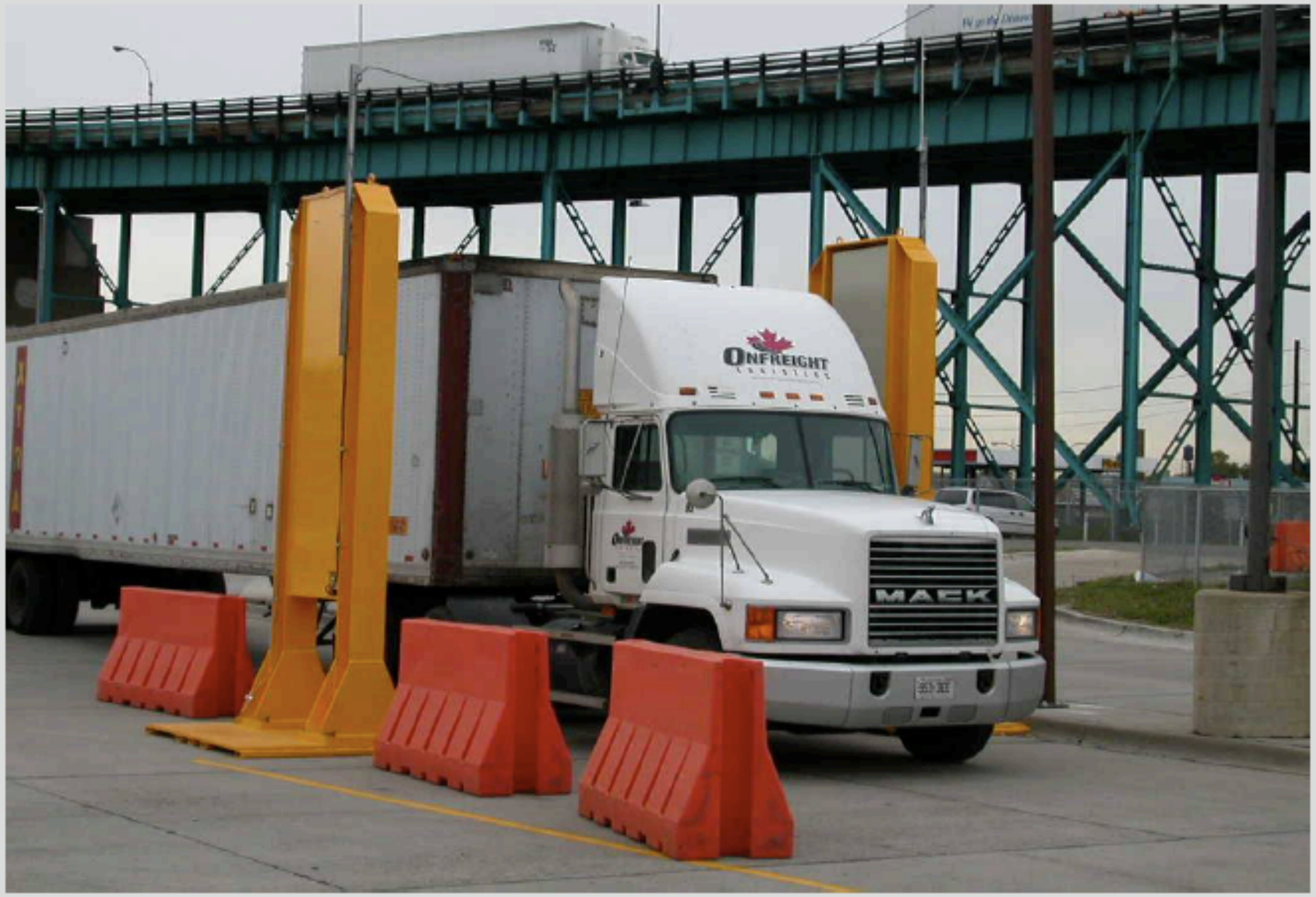
Primary (Tripwire) Screening

- Rapidly release the majority of vehicles
- Survey all vehicles/containers
- Facilitate the flow of commerce
- High throughput is an operational necessity
    - 5 mph drive through → ≤20 sec/vehicle

Primary Portal for Each Lane

Secondary Screening

- Evaluate all suspect vehicles/items
- Confirm primary alarm was not an anomaly
- Identify any real threats within a smaller population
- Resolve cross-talk alarms (multiple-vehicle alarms)
- More measurement time available per vehicle



Secondary Portal

Border Security Examples

Border Security Examples

Rapiscan, Torrance, CA (Formerly Ancore...)

Rapiscan Systems / Products / Cargo and Vehicle Inspection / Air Cargo - Eagle A Series / Air Cargo / Rapiscan Eagle® A1000 Print This Mail This

Rapiscan Eagle® A1000

Powerful 1 MV X-ray screening of air cargo pallets and containers.

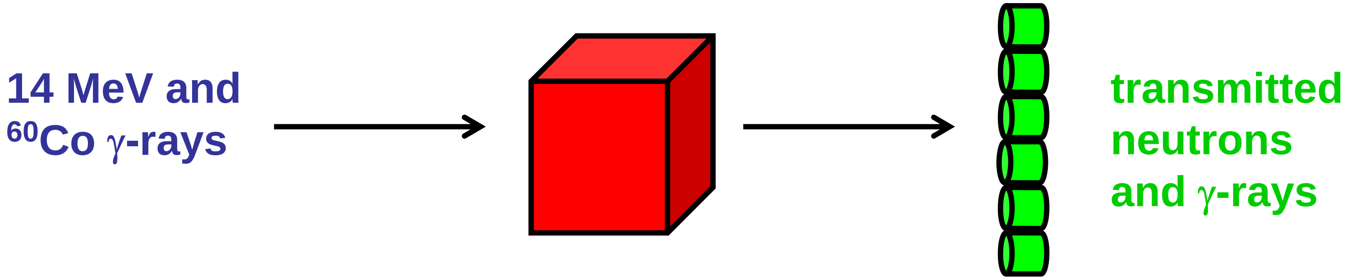
1

Rapiscan, Torrance, CA (Formerly Ancore...)

Rapiscan Eagle® M45

Multiple scan modes on a mobile platform for flexible 4.5 MV X-ray inspection at any location.

CSIRO Fast Neutron and Gamma Radiography Technique

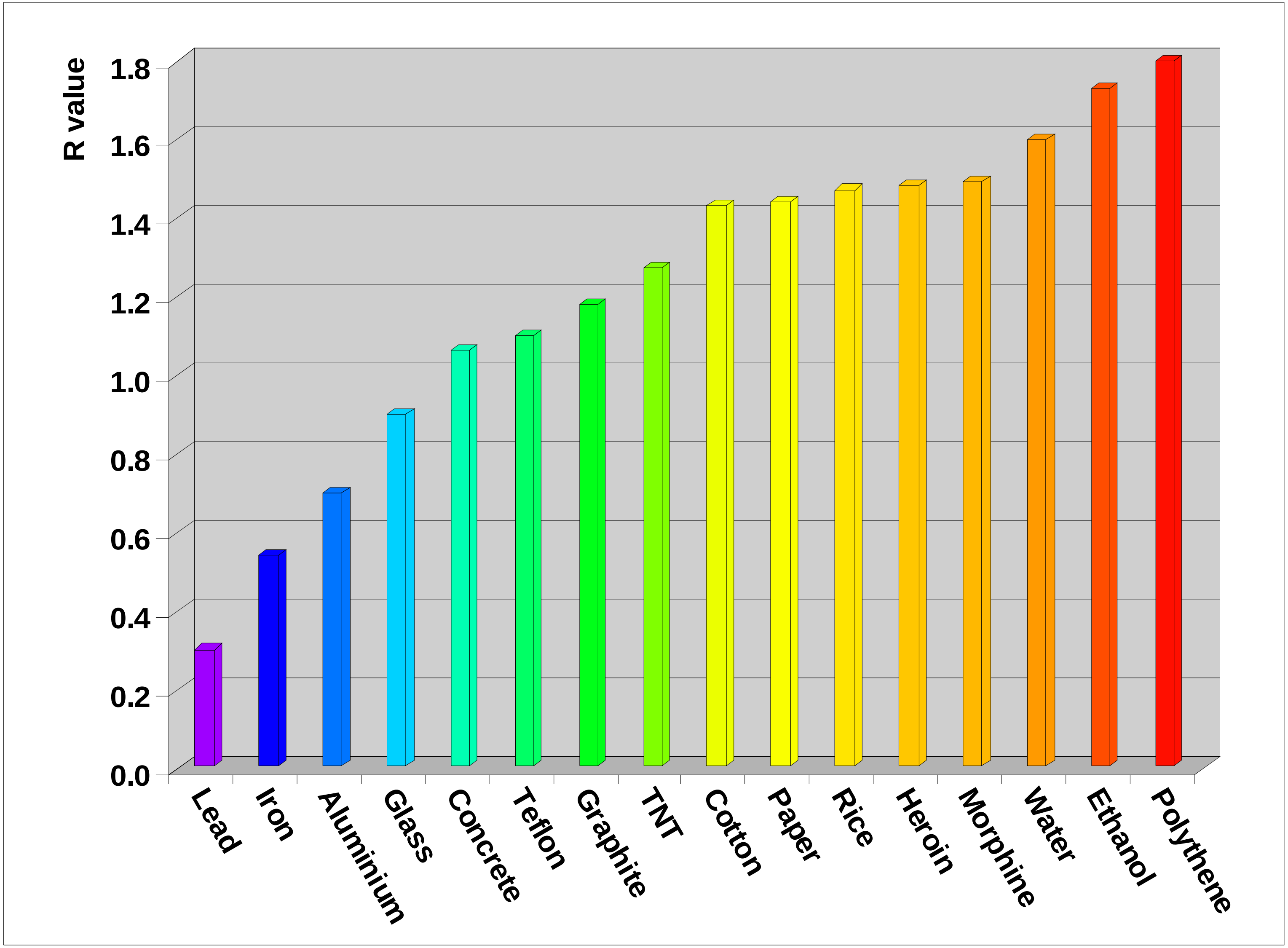


- Collect images (radiographs) using fast neutrons and high-energy gamma-rays
- Neutron attenuation: $I_n/I_{on} = \exp(-\mu_{14}\,\rho\, x)$
- Gamma attenuation: $I_g/I_{og} = \exp(-\mu_g\,\rho\, x)$
- Form ratio of mass attenuation coefficients:

$$R = \mu_{14}/\mu_g = \ln(I_n/I_{on}) \,/\, \ln(I_g/I_{og})$$

- From the radiographic images and the calculated R values, form a 2D composite image showing average density and composition

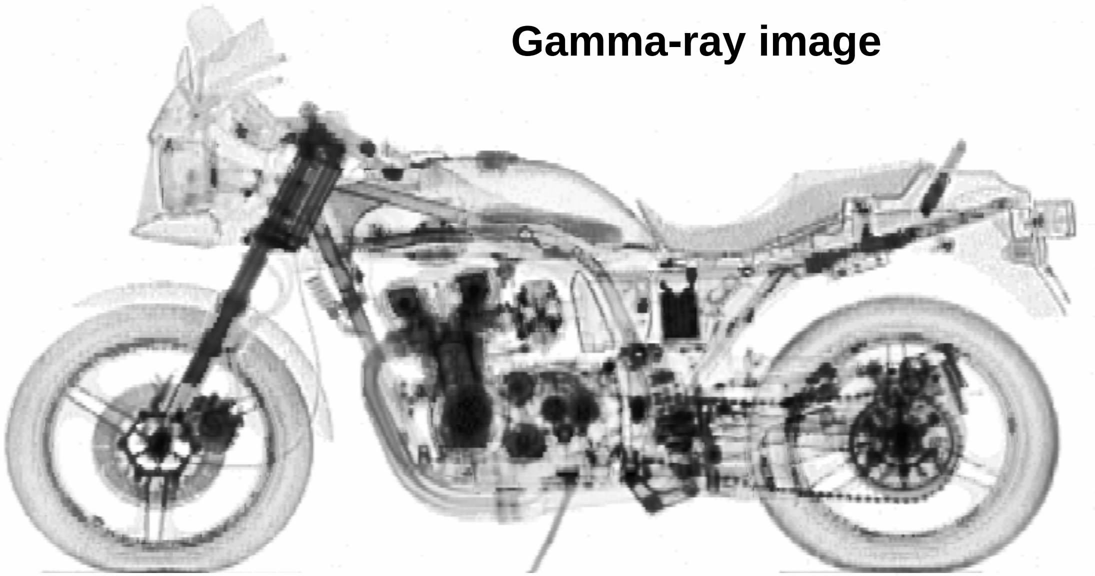
R-Values : 14 MeV Neutrons & ^{60}Co Gamma Rays



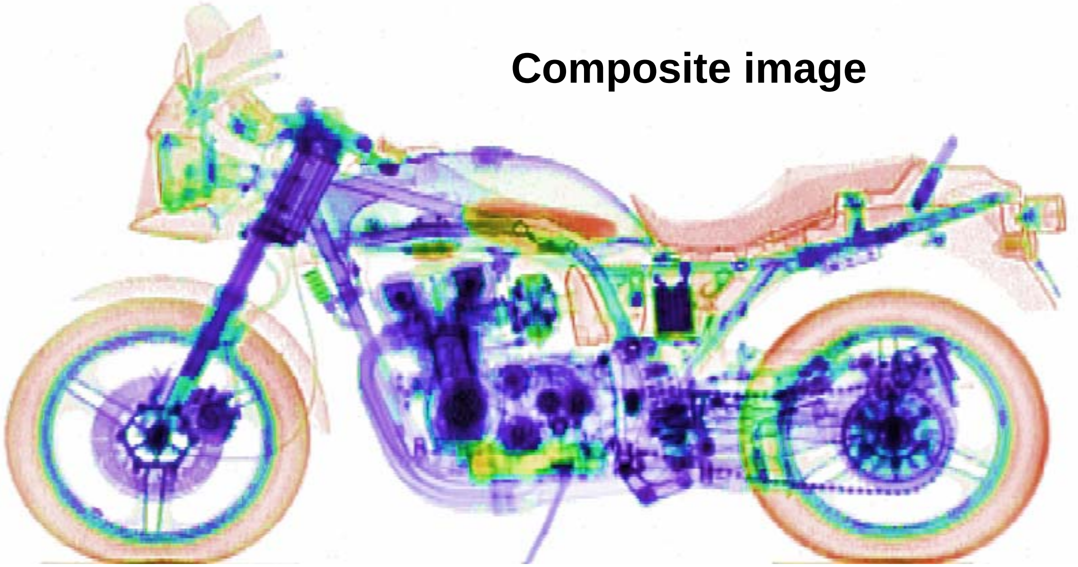
Detector System

- **High efficiency**
  - Plastic scintillator neutron detectors
  - CsI(Tl) gamma-ray detectors
- **Small detector size**
  - High spatial resolution
  - Neutron detectors 20x20x75mm
  - Gamma detectors 10x10x50mm
- **Modular**
  - 704 neutron and 352 gamma detectors in modules of 16 or 32
  - Similar channel-to-channel performance
- **Low cost**
  - Less than US$200 per channel

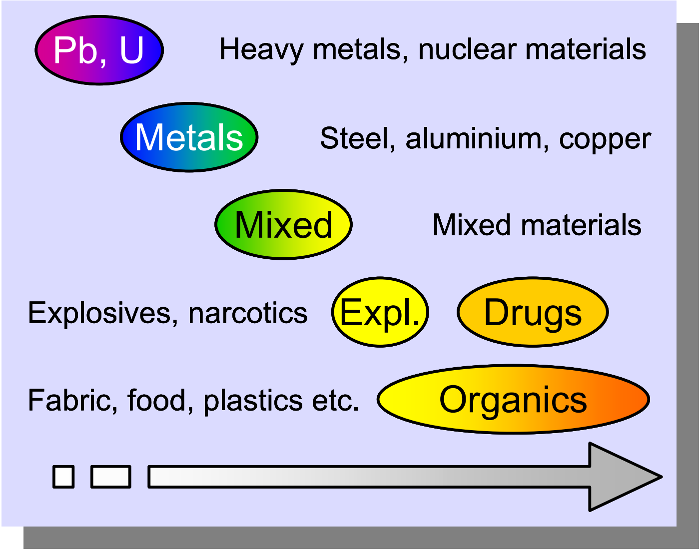
Reference Scanner: Motorbike



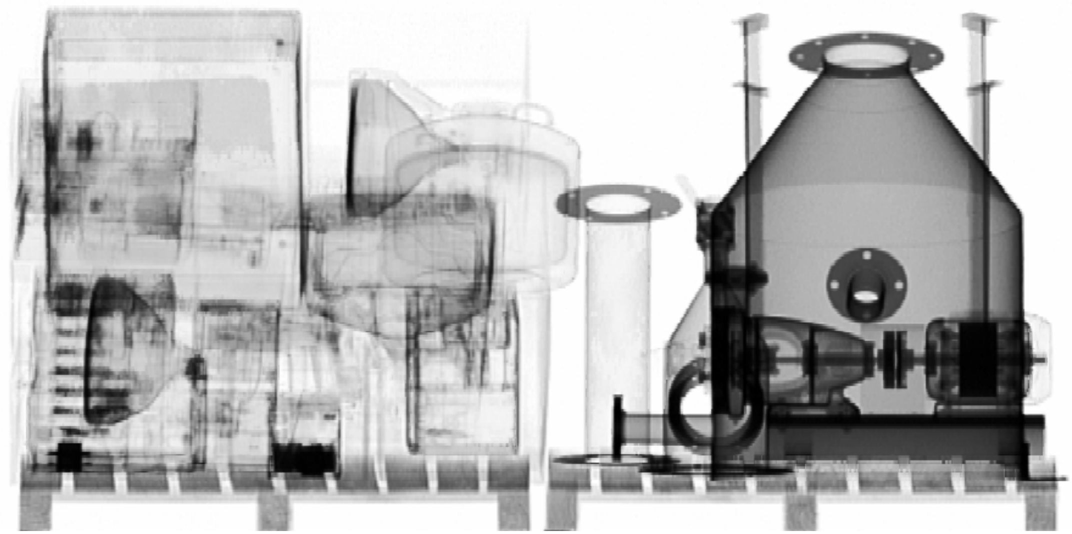
Gamma-ray image

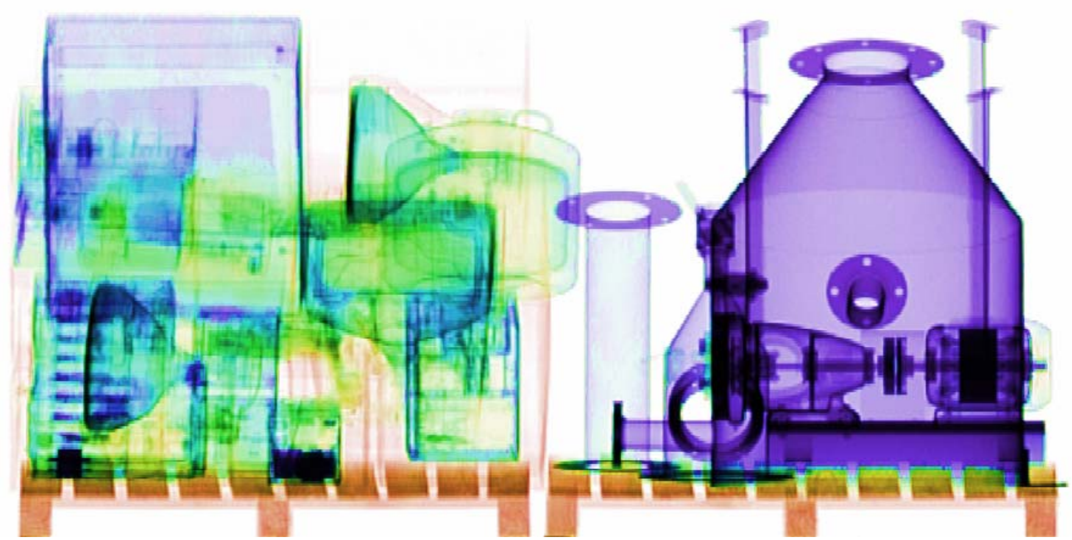


Composite image



Reference Scanner: Pallets with Computer Equipment (left) and Mixed Metal Parts (right)





CSIRO/Australian Customs Collaboration

- CSIRO Minerals **first approached** by Customs in December 2001
- CSIRO initiated a **feasibility study**: Stage 1 (Completed September 2002)
- **Full scale demonstration** of FNGR at CSIRO using consolidated ULDs with contraband: Stage 2 (Completed June 2003)

- Federal Government allocated $8.4 million to Australian Customs to construct and test a **commercial-scale CSIRO Air Cargo Scanner** in Brisbane: Stage 3 (Mar 2004 - present)
- **Reference scanner** commissioned at CSIRO (2005) for trials, R&D

Future Directions in Radiation Detection for Homeland Security

Domestic Nuclear Detection Office (DNDO)

- Near Term (Circa 2006)
  - Spectroscopic portal monitors
  - Enhanced imaging systems
  - Enhanced radioisotope identifiers
  - Networked systems – global architecture
- Mid to Long Term
  - Transformational R&D

2005 Nevada test Site

Spectroscopic Portal Monitors

- DNDO tested 10 prototype spectroscopic portal monitors under the Advanced Spectroscopic Portal program

- DNDO currently in the process of selection for contract of production units

In March 2006, the Government Accountability Office (GAO) expressed concern that "in tests performed during 2005, the detection capabilities of the advanced technology prototypes demonstrated mixed results—in some cases they worked better, but in other cases, they worked about the same as already deployed systems."[5] The GAO recommended that the Secretary of Homeland Security work with the Director of DNDO to prepare a cost-benefit analysis for the deployment of ASPs.

In May 2006, DNDO reported on a cost-benefit analysis that it said supported the proposed ASP procurement. In July 2006, it awarded contracts to three companies—Raytheon Company, Thermo Electron Corporation (now known as Thermo Fisher Scientific), and Canberra Industries—to further develop and manufacture ASP systems. The Raytheon and Thermo systems used medium-resolution detectors made of sodium iodide (NaI); the high-resolution Canberra system used high-purity germanium (HPGe).[6] The DHS stated that it planned to procure and deploy 80 systems quickly and ultimately to deploy a total of about 1,400 at land and sea ports of entry.[7]

In October 2006, GAO reported that the DNDO cost-benefit analysis did "not provide a sound analytical basis for DNDO's decision to purchase and deploy new portal monitor technology."[8] The GAO's concerns involved both the cost of ASPs and their performance relative to existing radiation detection systems.

In the Department of Homeland Security Appropriations Act, 2007 (P.L. 109-295, signed October 4, 2006), Congress prohibited DHS from obligating FY2007 funds for full-scale procurement of ASPs "until the Secretary of Homeland Security has certified ... that a significant increase in operational effectiveness will be achieved." The act did not define or explain the phrase "significant increase in operational effectiveness."

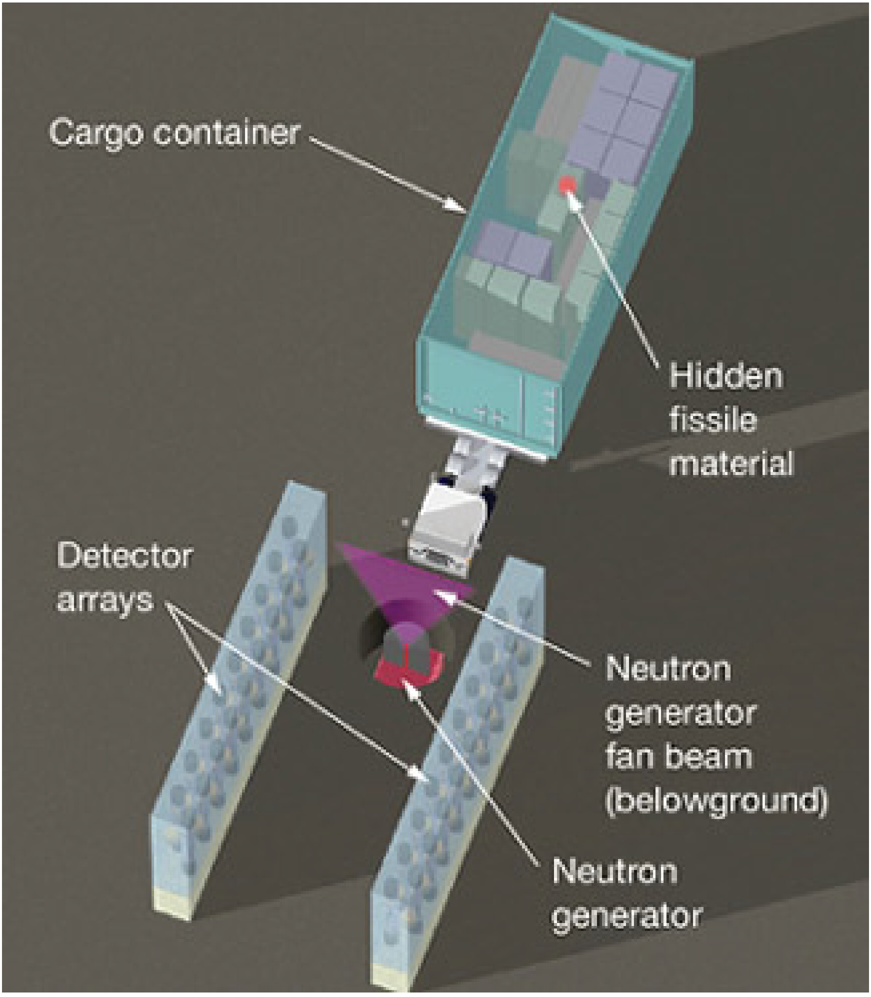
The Advanced Spectroscopic Portal Program: Background and Issues for Congress
December 30, 2010 - RL34750

Download Report

Add to Folder

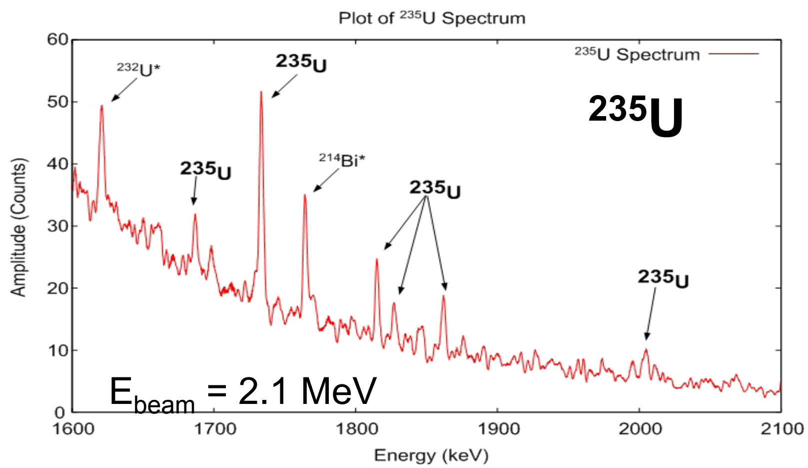
The Domestic Nuclear Detection Office (DNDO) of the Department of Homeland Security (DHS) is charged with developing and procuring equipment to prevent a terrorist nuclear or radiological attack in the United States. At the forefront of DNDO's efforts are technologies currently deployed and under development whose purpose is to detect smuggled nuclear and radiological materials. These technologies include existing radiation portal monitors and next-generation replacements known as advanced spectroscopic portals (ASPs). Customs and Border Protection officers use radiation portal monitors to detect radiation emitted from conveyances, such as trucks, entering the United States. When combined with additional equipment to identify the source of the emitted radiation, radiation portal monitors provide a detection and identification capability to locate smuggled nuclear and radiological materials. The ASPs currently under testing integrate these detection and identification steps into a single process. By doing this, DHS aims to reduce the impact of radiation screening on commerce while increasing its ability to detect illicit nuclear material. The speed of ASP development and deployment, the readiness of ASP technology, and the potential benefits of the ASP program relative to its cost have all been topics of extensive congressional interest. Congress has held oversight hearings on the ASP ...

Active Interrogation
Lawrence Livermore National Lab
(Car Wash Style)

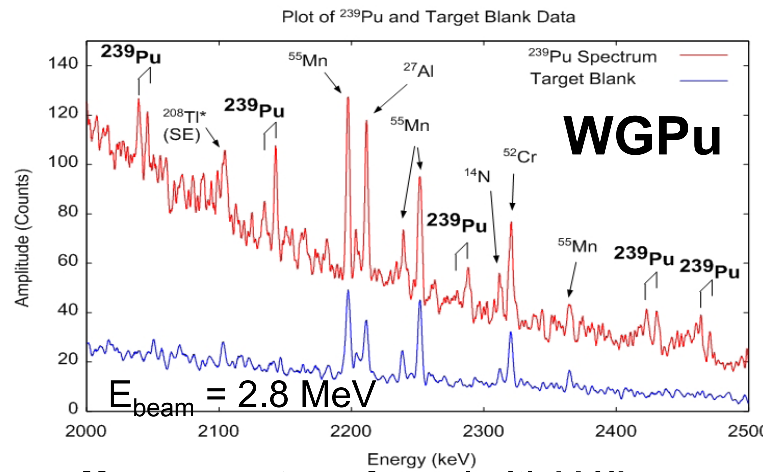


Acton (MIT), Boston, MA

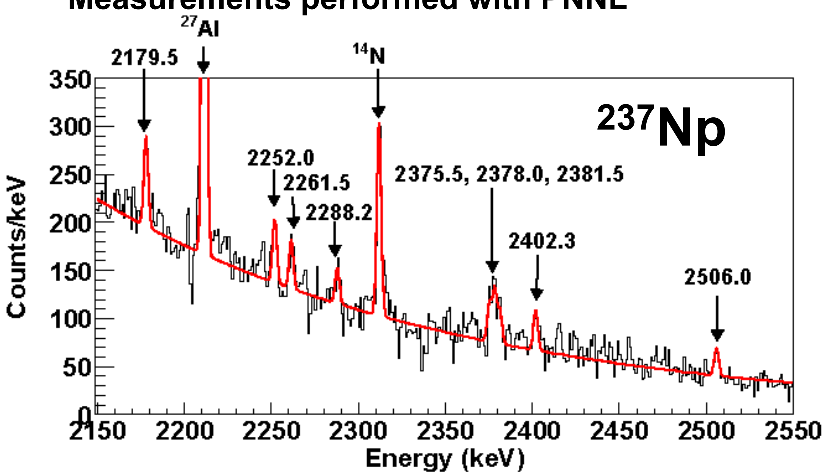
Actinide NRF Signatures



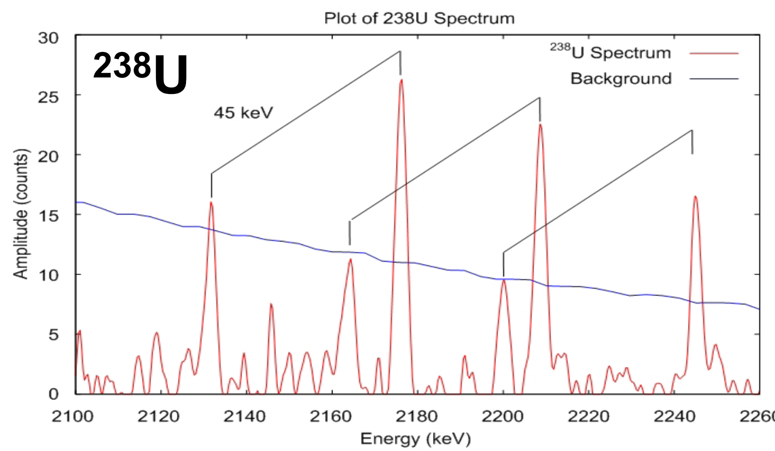
Measurements performed with PNNL



Measurements performed with LLNL



Measurements performed with UC-Berkeley

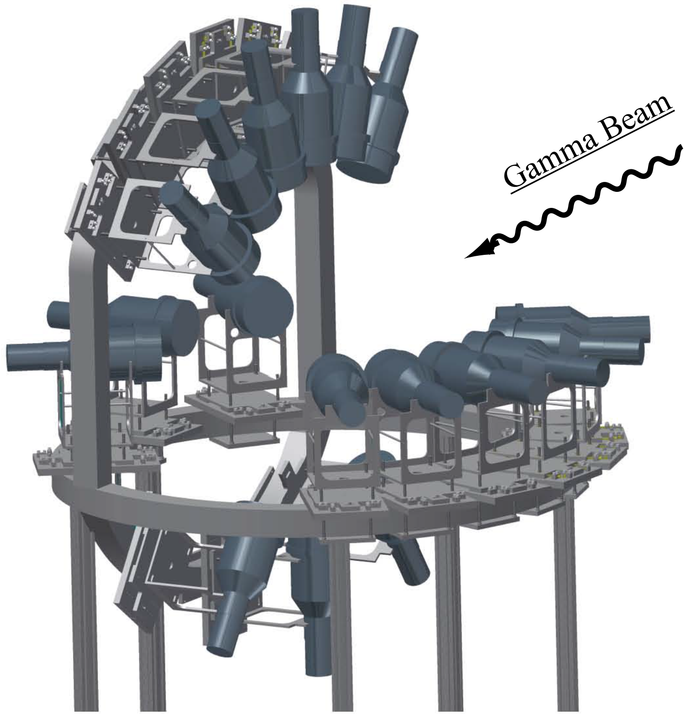


- Unambiguous signature for SNM isotopes and other Actinides
- NRF states in SNM < 3 MeV

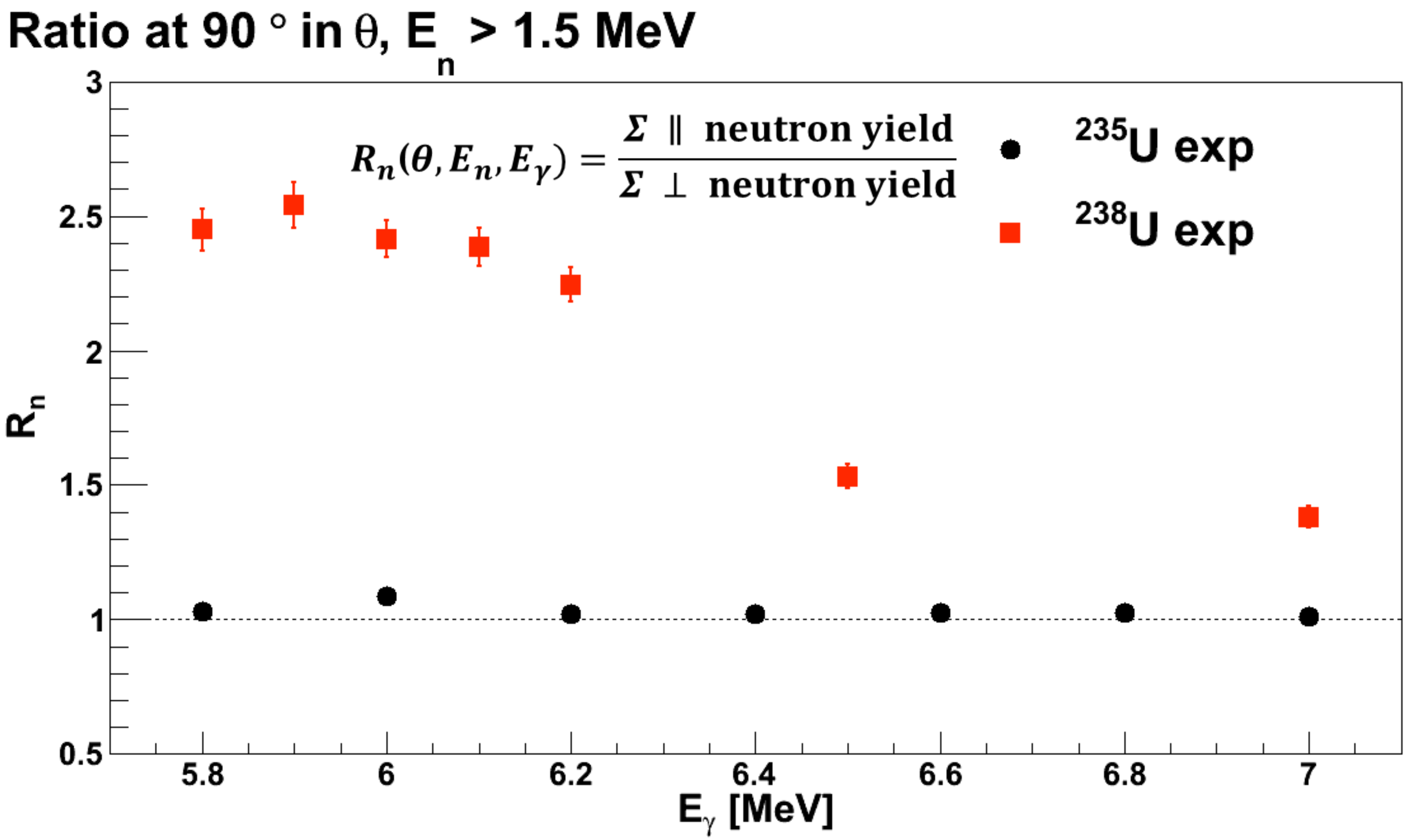
DNDO/ARI Project, Duke University

Neutron Detectors

- 18 BC-501A neutron detectors
- Time of flight used to measure E_n
- PSD used to distinguish γ rays from neutron counts

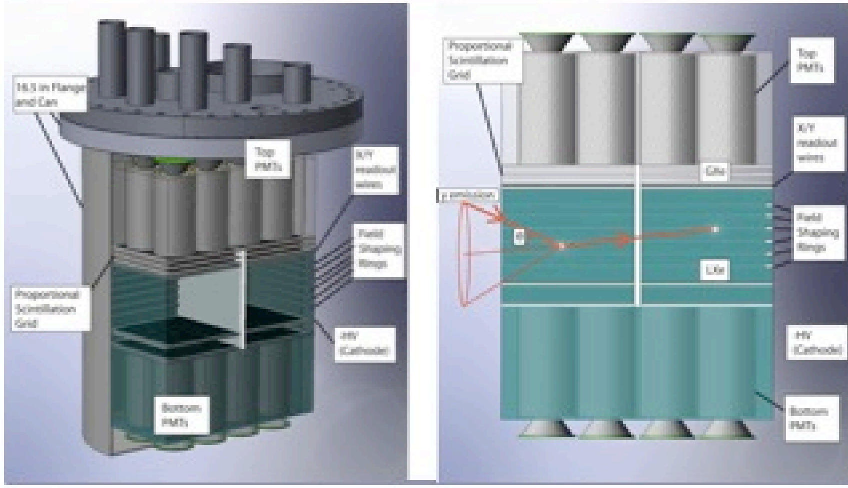


Experimental Results



Title: *ARI-MA: Gamma Ray Imaging of Special Nuclear Materials with a Liquid Xenon Time Projection Chamber*

Org/PI: *Yale University / Prof. Dan McKinsey*



Technical Progress

- Year 1: Commissioning of cryogenic and xenon handling systems. Monte Carlo studies of geometry optimization for best energy and angular resolution.
- Planned accomplishments for Year 2: Full design and construction of Compton Imaging prototype.
- Planned accomplishments for Year 3: Collection of Compton Imaging data. Demonstration of radioactive source imaging and identification.

Technical Merit

- A successful development would enable accurate γ-ray imagers based on Liquid Xe (LXe), allowing passive imaging and detection of kg quantities of SNM in seconds.
- Superior energy and position resolution, uniform response, and scalable to hundreds of kilograms.

Schedule/Cost:

- Duration: 60 months

FY10: $380K	FY##: $292K
FY11: $332K	FY##: $287K
FY12: $301K	Total: $1,592K

Team

- Co-PI: Moshe Gai, University of Connecticut

Broader Impact

- Total students sponsored: 1 undergraduate student at Yale. Total # students involved: 3 at Yale (+2 at U Connecticut)
- Dissemination of research results to the community: 0 papers published, 3 presentations, 4 posters
- Equipment infrastructure and nuclear science program development in radiation detection at Yale and University of Connecticut. Advisory partnership with LLNL.
- Use in PET medical imaging, double beta decay, and dark matter detection.

Homeland Security

Last updated on: 08/25/2011

Title: *ARI-MA: Gamma Ray Imaging of Special Nuclear Materials with a Liquid Xenon Time Projection Chamber*

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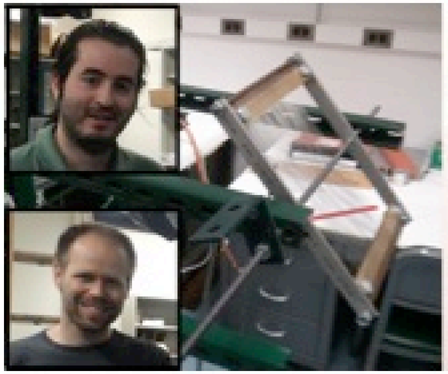
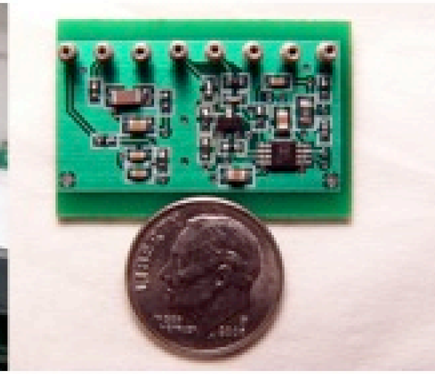




Technical Progress

- Significant accomplishments in Year 1: Design and testing of preamplifier for wire readout, design and construction of wire grid tensioning system.
- Current status: Wire grid construction under way.
- Planned accomplishments for Year 2: Testing of wire grid and wire readout system, installation in liquid xenon time projection chamber.
- Planned accomplishments for Year 3: Use of wire grid system to read event positions, and thereby image gamma rays.

Technical Merit

- A successful development would enable accurate γ-ray imagers based on Liquid Xe (LXe), allowing passive imaging and detection of kg quantities of SNM in seconds.
- Superior energy and position resolution, uniform response, and scalable to hundreds of kilograms.

Schedule/Cost:

- Duration:
  60 months

FY10: $17K	FY##: $100K
FY11: $64K	FY##: $103K
FY12: $97K	Total: $381K

Team

- PI: Dan McKinsey, Yale University

Homeland Security

Broader Impact

- Total students sponsored: 1 graduate student at U Connecticut. Total # students involved: 2 at U Connecticut (+3 at Yale)
- Dissemination of research results to the community: # 0 papers published, 3 presentations, 4 posters
- Equipment infrastructure and nuclear science program development in radiation detection at Yale and University of Connecticut. Advisory partnership with LLNL.
- Use in PET medical imaging, double beta decay, and dark matter detection.

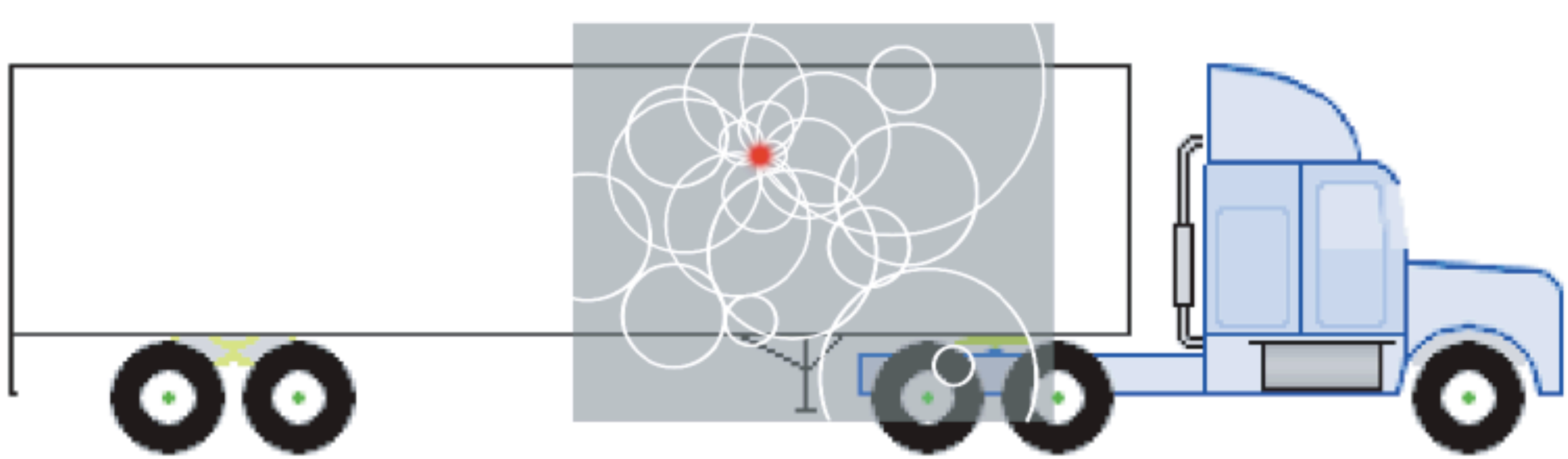
Last updated on: 08/25/2011

Concept: A liquid Xenon detector system that has multiple uses, including:

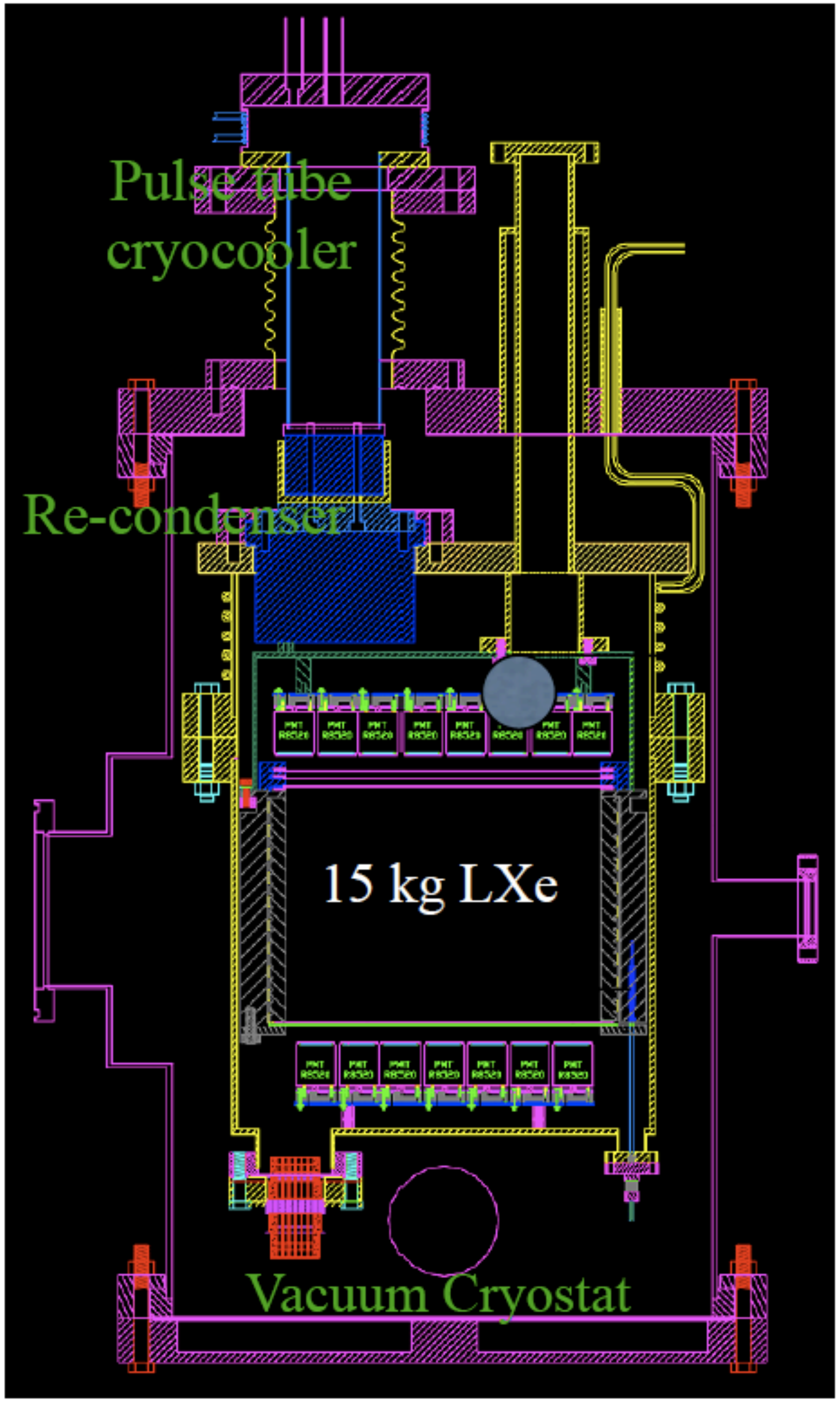
Passive imaging
- High signal-to-noise imaging of gamma rays
- Low false alarm rates

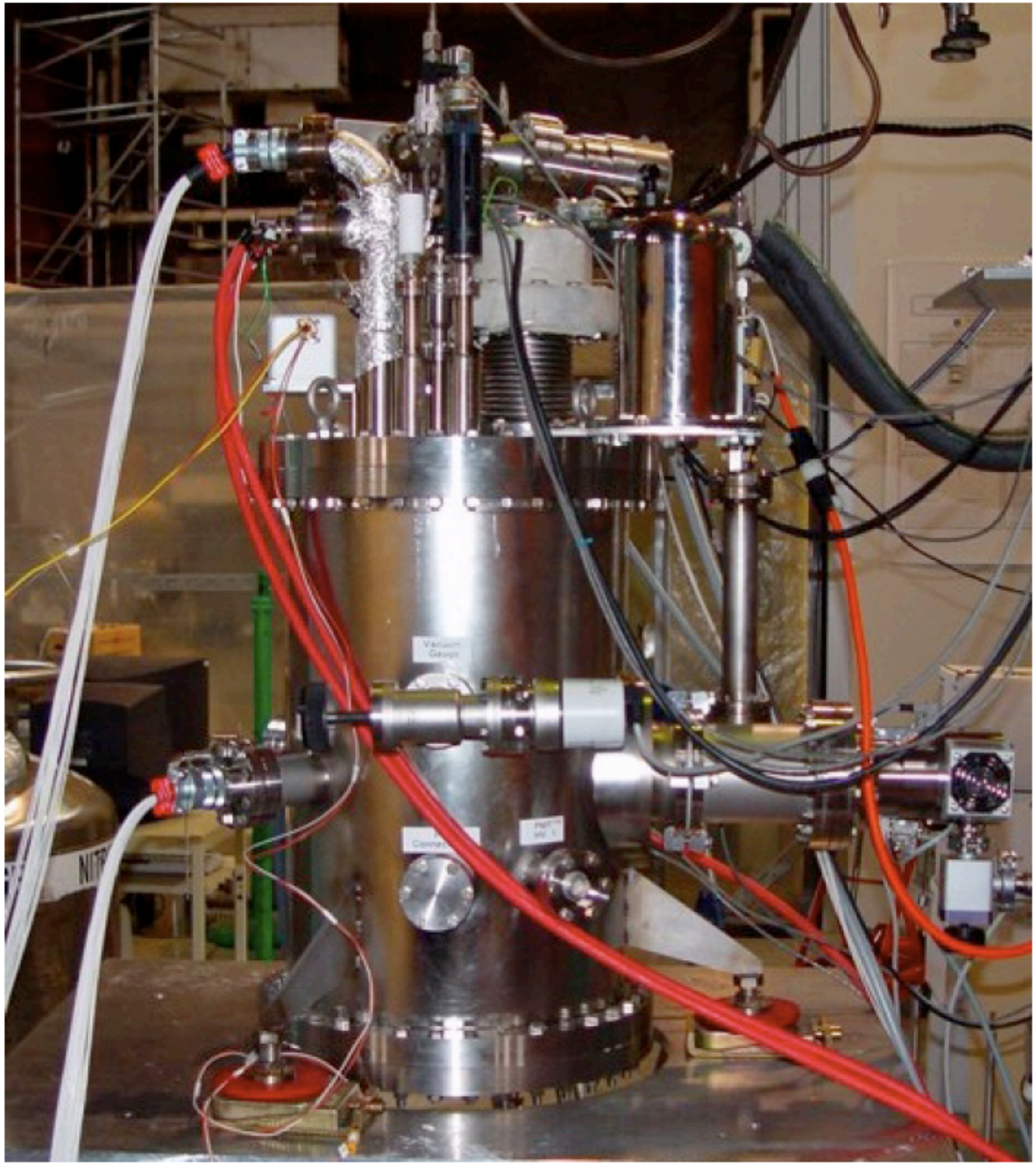
Active interrogation
- Efficient collection of gamma rays and neutrons
- Neutron/gamma ray identification

Liquid Xenon is a recently devoped technology
- Modest refrigeration needs
- Robust high-gain signal collection

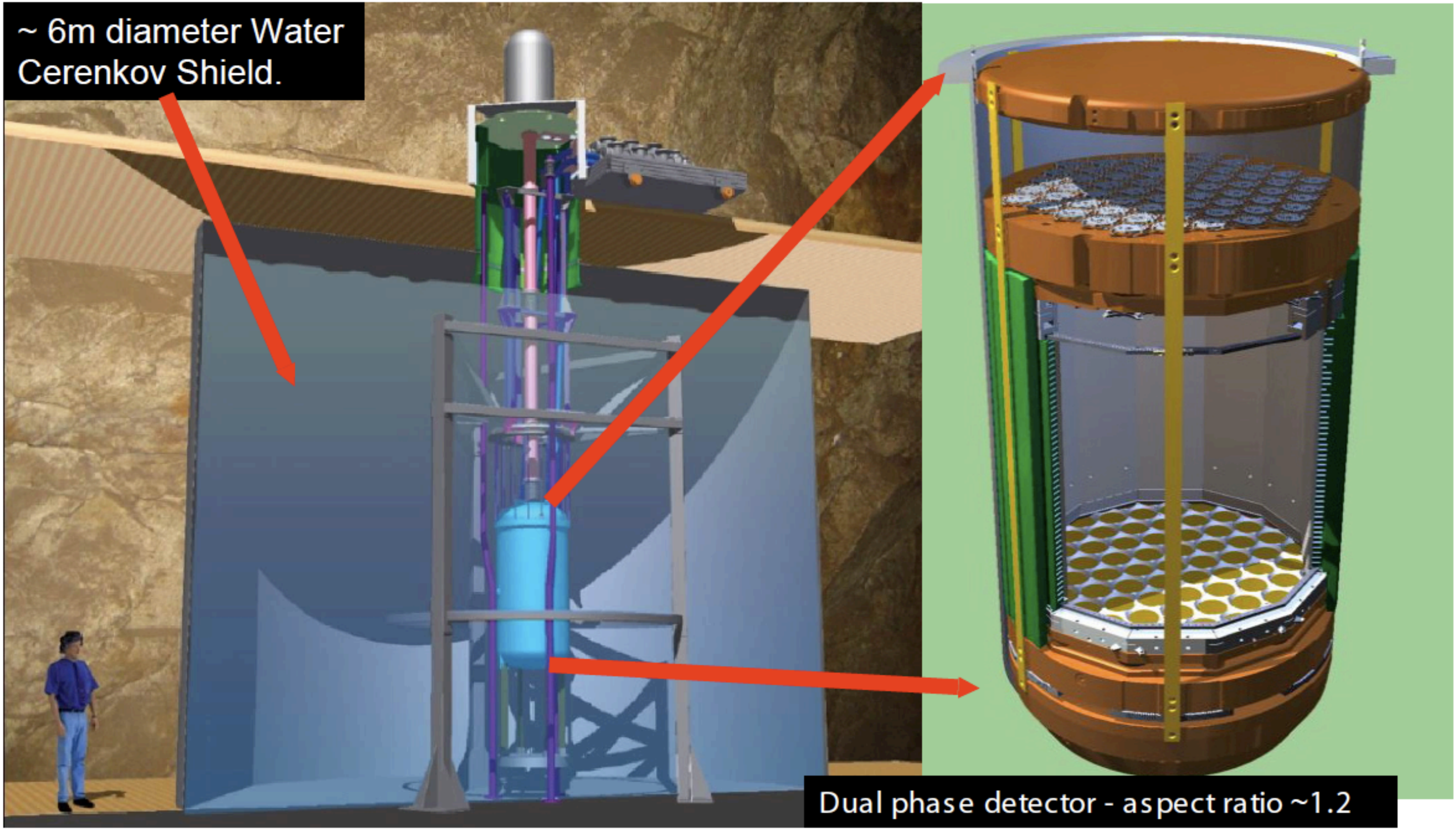


The XENON10 Detector

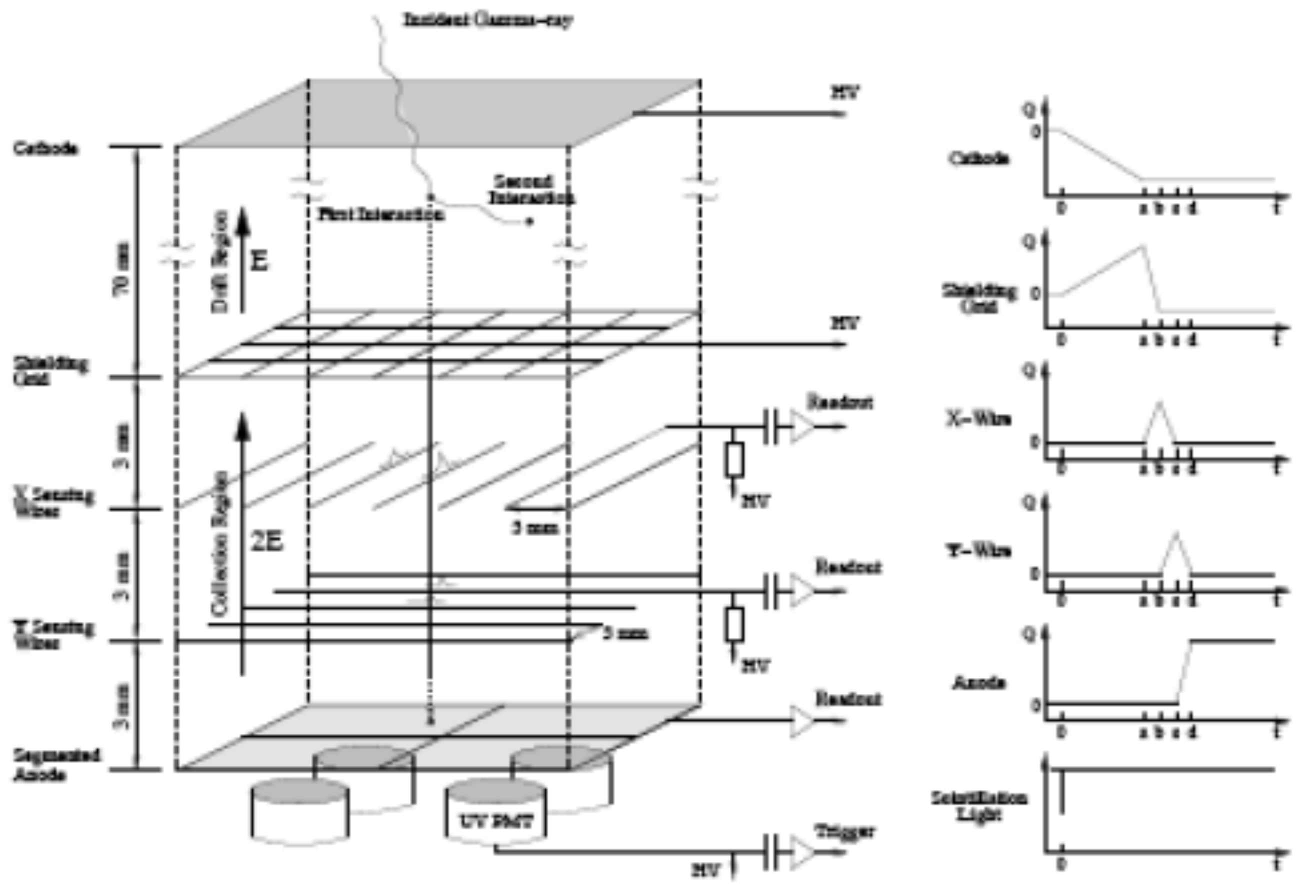


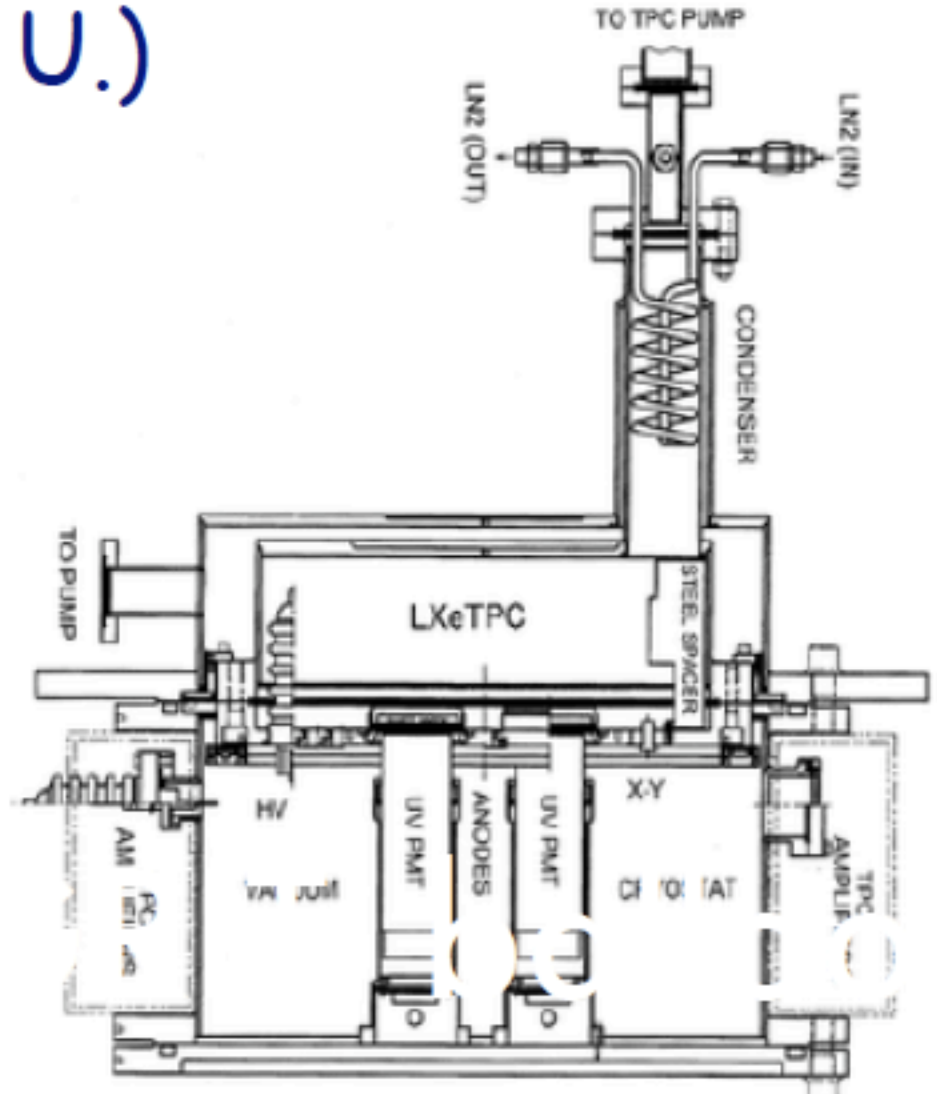


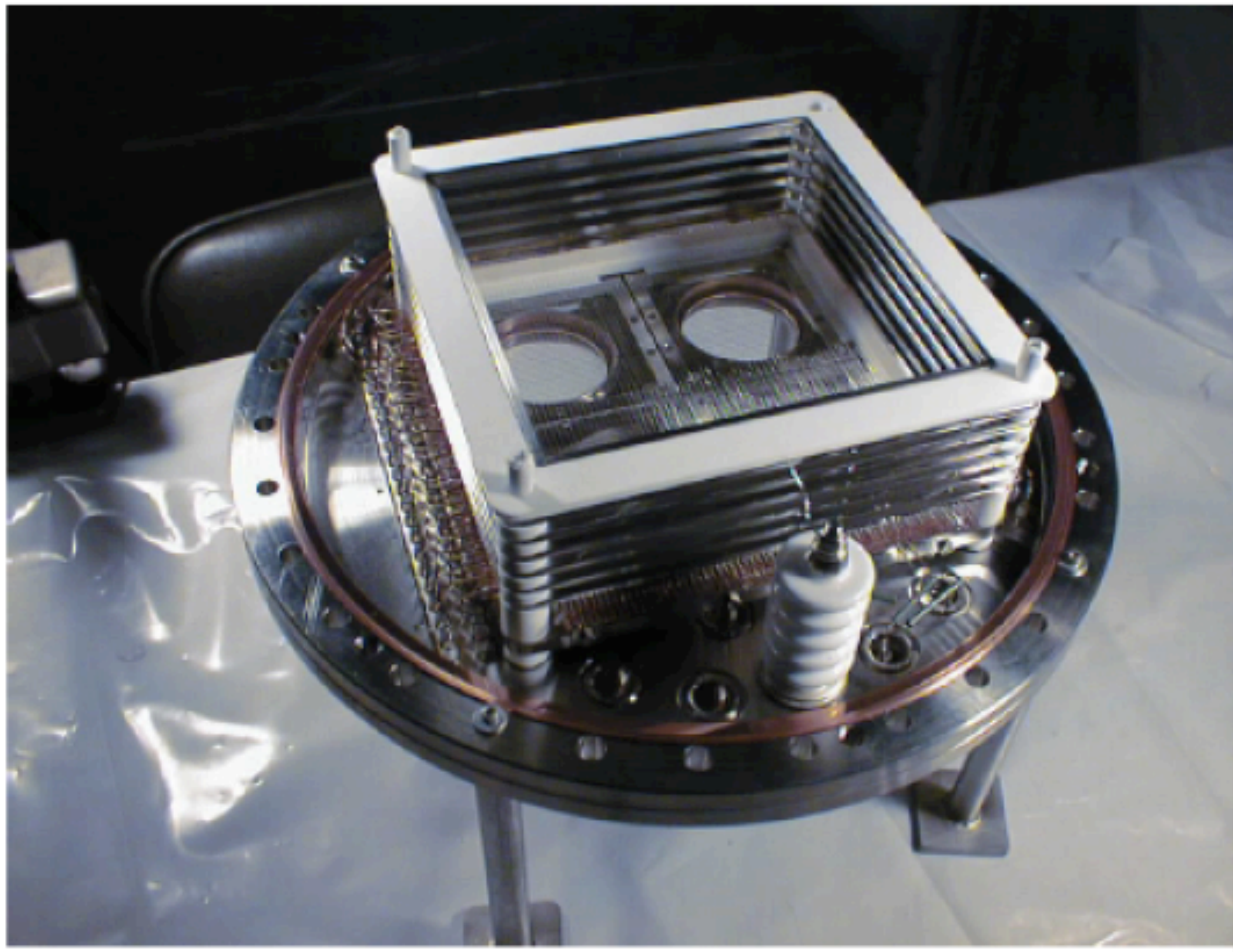
The LUX Detector



LXeGRIT gamma ray imager (Columbia U.)

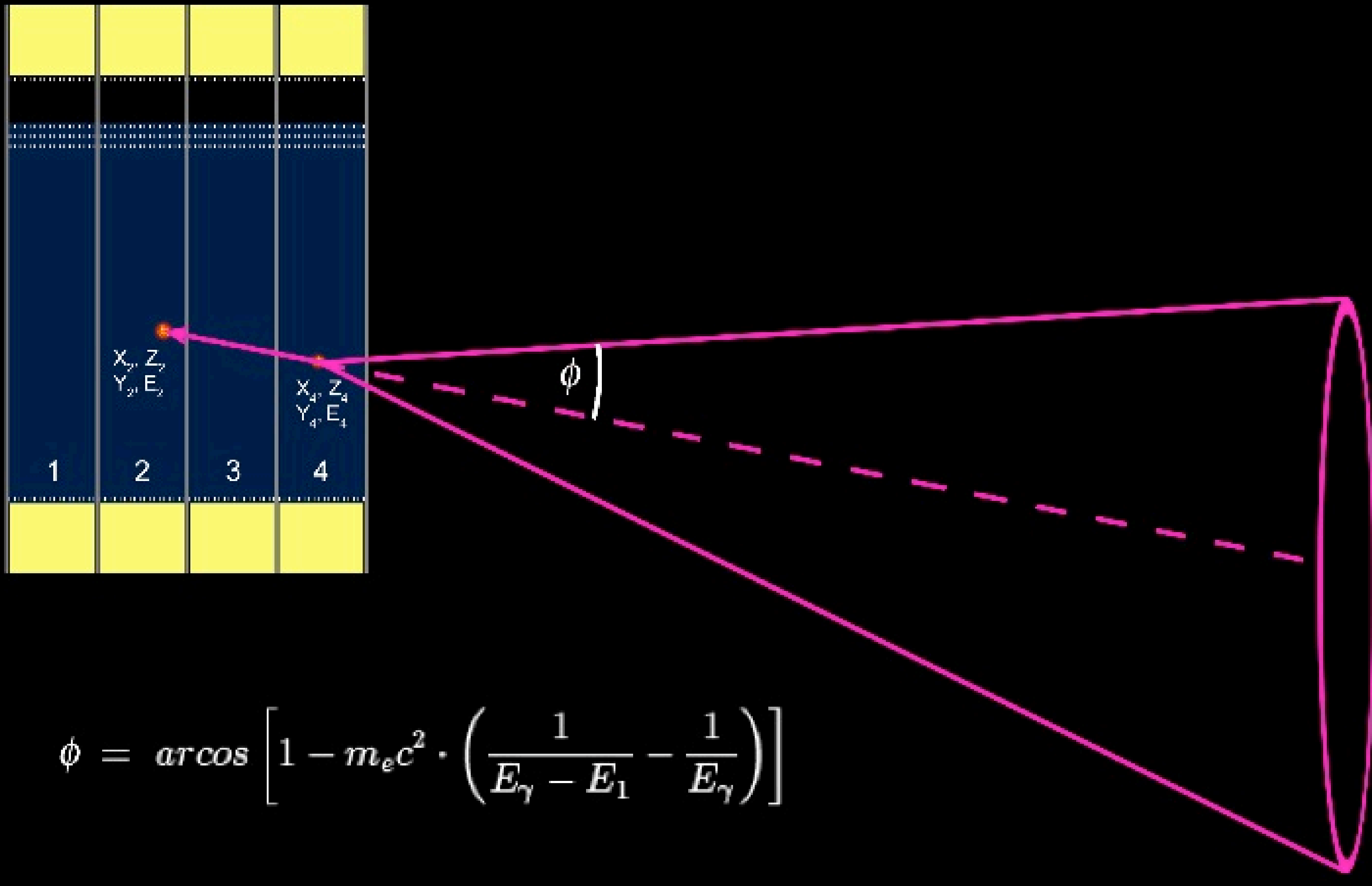






PIXeY – Particle Identification in Xenon at Yale

- Independent control of drift and proportional scintillation fields.
- Test neutron/gamma discrimination at high field.

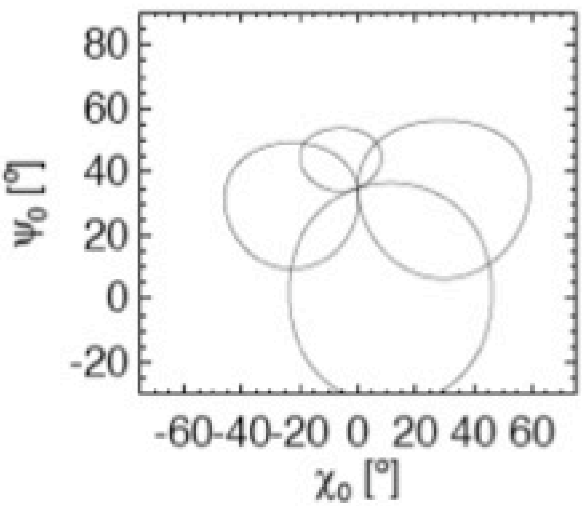


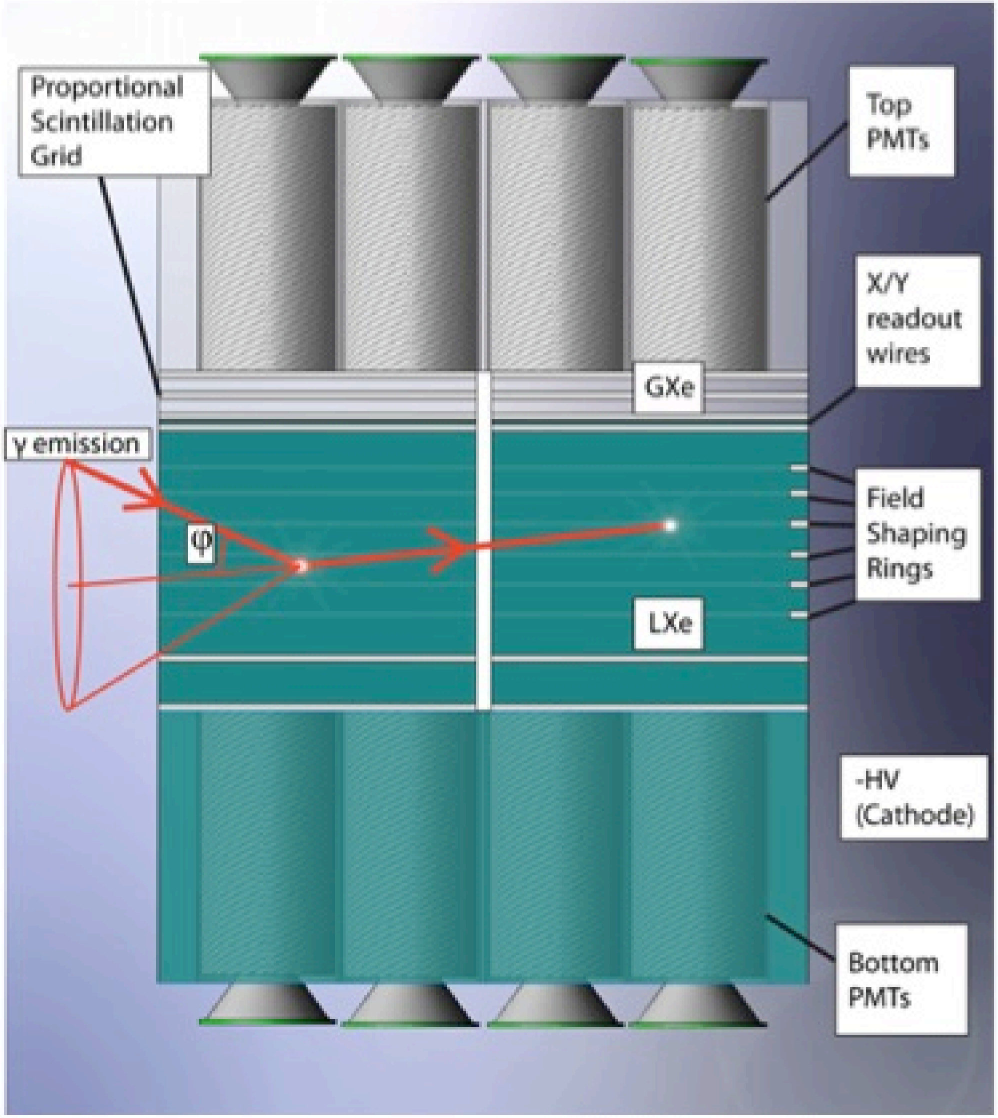
$$\phi = arcos\left[1 - m_e c^2 \cdot \left(\frac{1}{E_\gamma - E_1} - \frac{1}{E_\gamma}\right)\right]$$

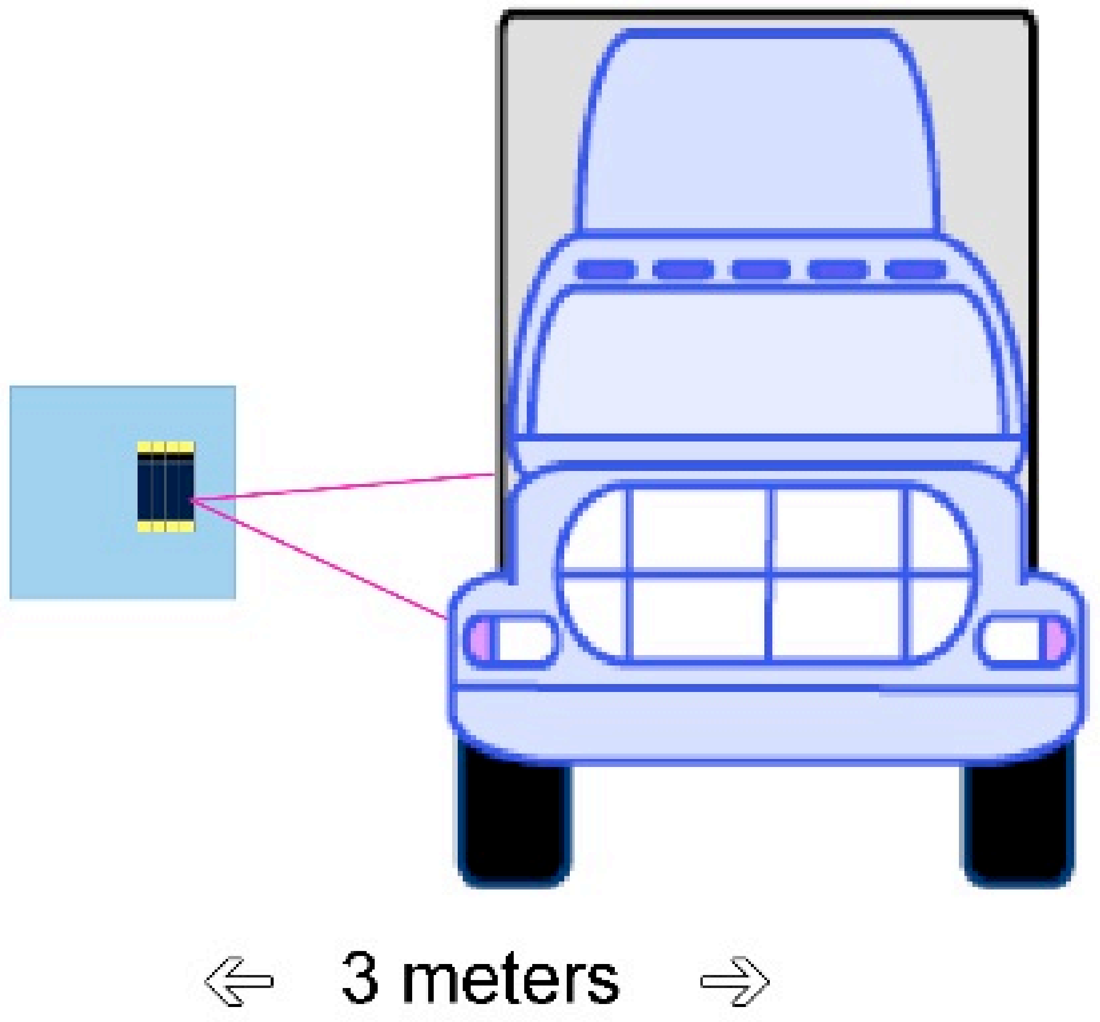
Compton Imaging

$$E'_\gamma = \frac{E_\gamma \cdot m_e c^2}{E_\gamma \cdot (1 - cos\bar{\varphi}) + m_e c^2}$$

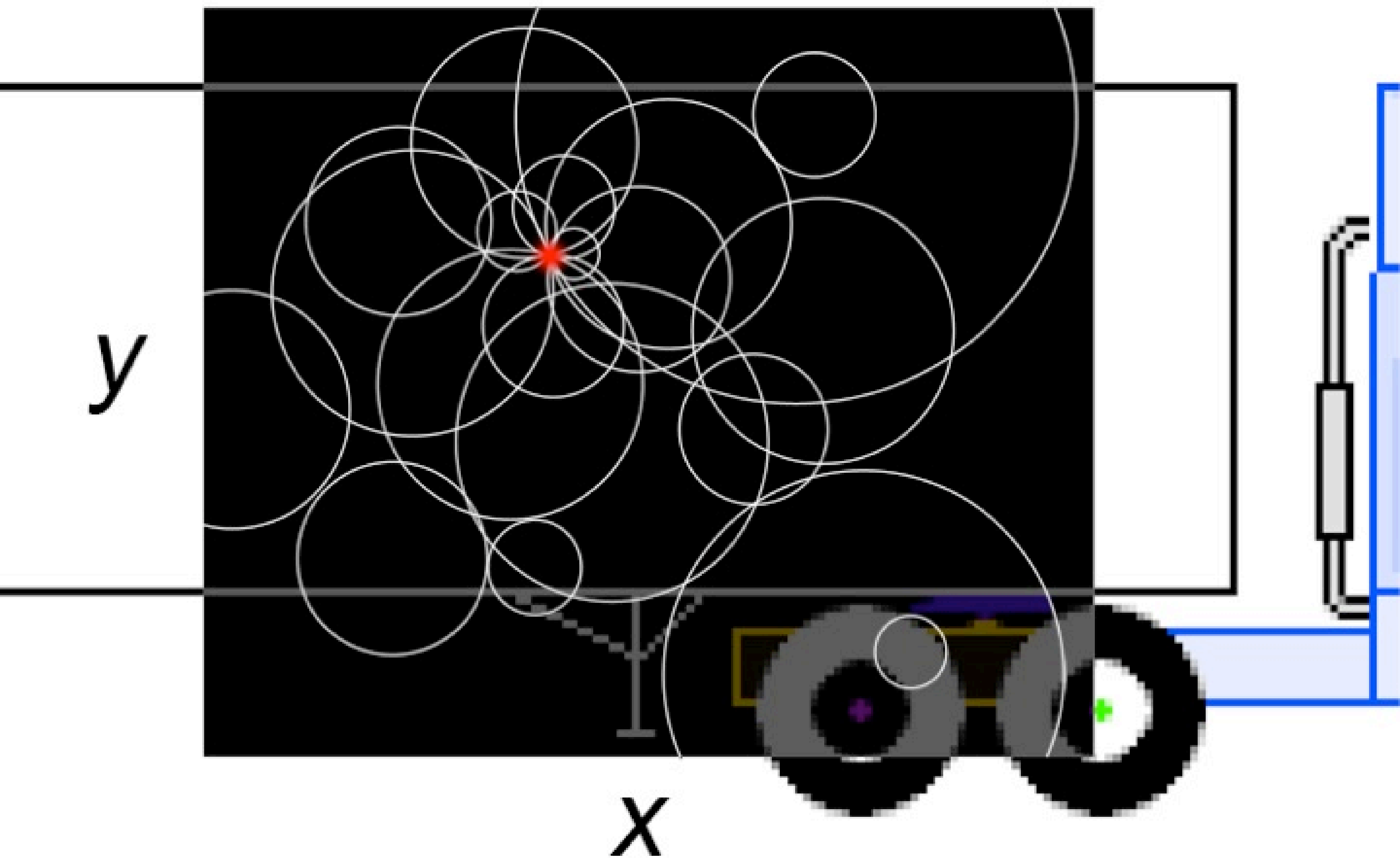
$$\bar{\varphi} = arcos\left[1 - m_e c^2 \cdot \left(\frac{1}{E_\gamma - E_1} - \frac{1}{E_\gamma}\right)\right]$$







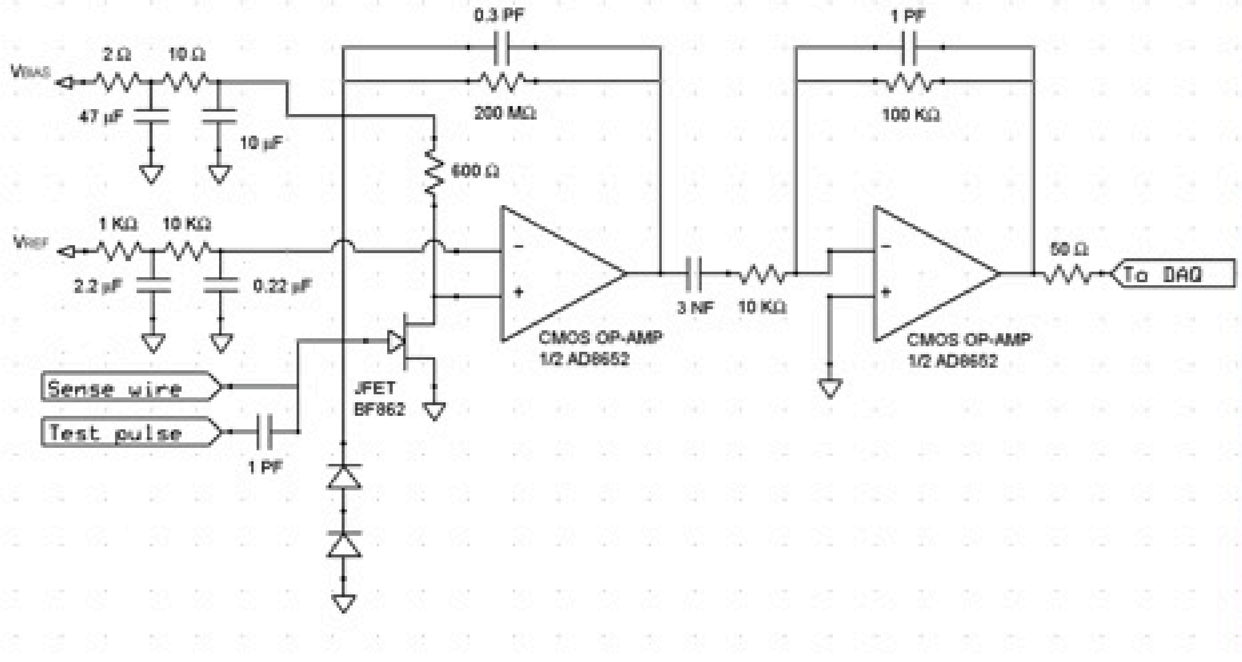
3 meters

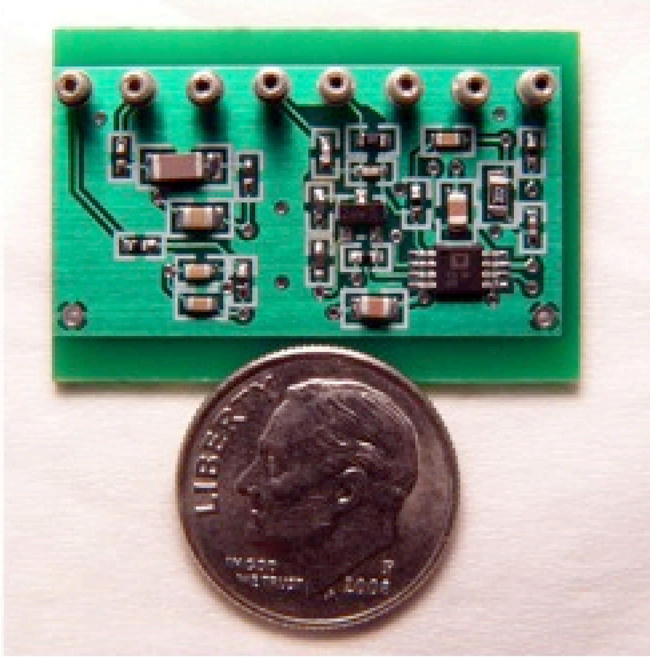


y
x

Low noise wire readout charge preamplifiers

- Used to read out individual wires in LXe
- With 3 mm wire pitch, expect < 1 mm position resolution.
- Preamplifiers planned to be mounted inside detector, at LXe temperature.
- Design used for GERDA germanium double beta decay experiment
- Testing underway





Scientists and Home Land Security

Moshe Gai
UConn and Yale
http://astro.uconn.edu

Conclusions:

- **The Home Land is Secured Against SNM With Passive Interrogation (10M Cars, 2M Cargo Containers /Month)**
- **Application of Basic Science (Search for Dark Matter)**
- **R&D Advances Spectroscopic Portal (ASP)**
- **R&D Transformational Technologies**
- **Yale/UConn Collaboration**
  Liquid Xenon Technology
  First Year of a Five-Year Project

Avery Point, September 29, 2011