Explosive Detection Systems (EDS) based on Gamma Resonance Technology (GRT)

BNL: Lucian Wielopolski, Ph.D.

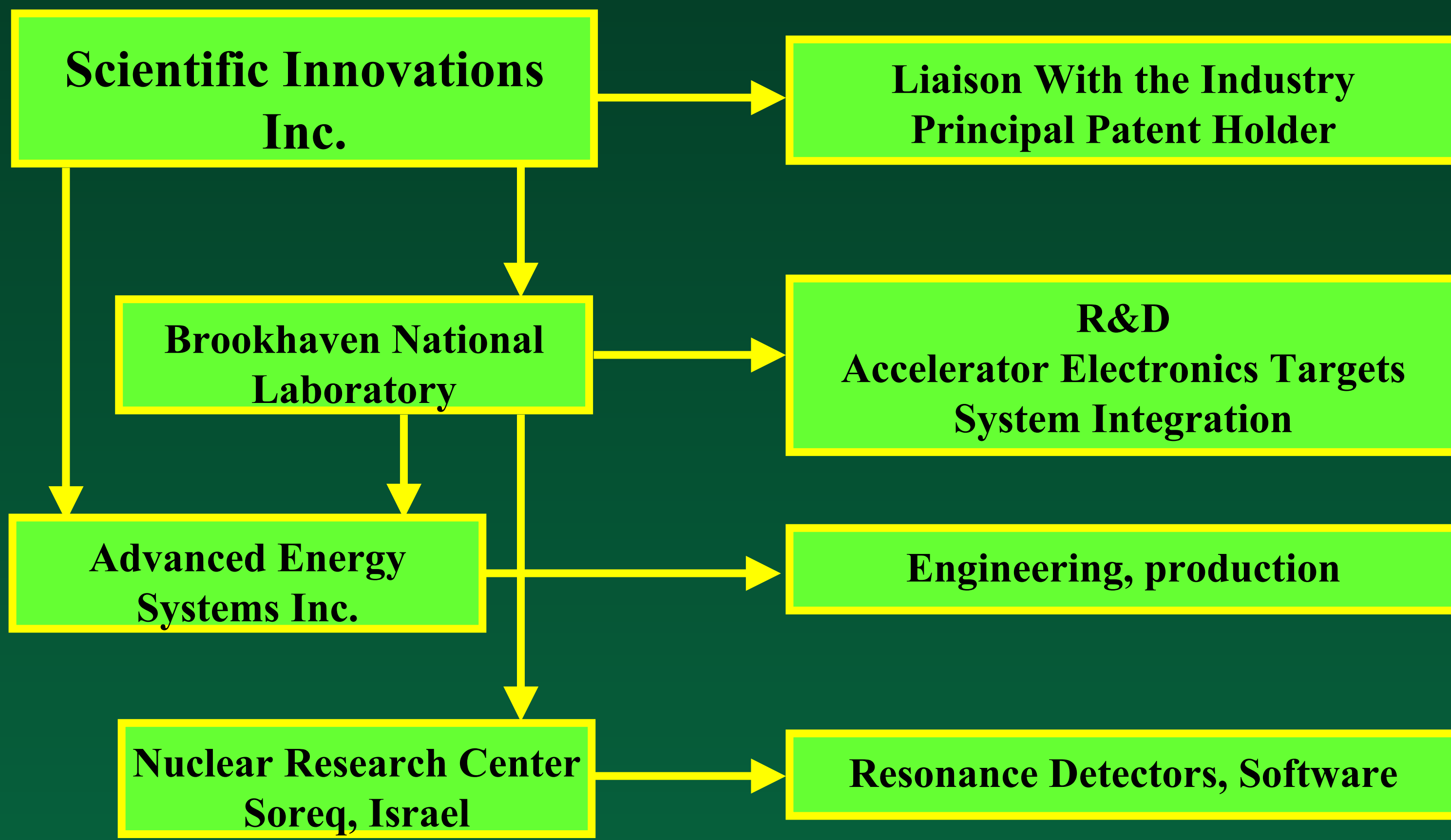
SII: Joseph Brondo, CEO

Collaborators

AES: Joseph Sredniawski, VP

NSNRC: David Vartsky Ph.D.

EDS-GRT: *Organization*



EDS-GRT: BNL Objective

A joint effort by Brookhaven National Laboratory (BNL), Scientific Innovations Inc. (SII), and Advanced Energy Systems (AES) for developing, testing and deploying explosive detection systems based on gamma resonance technology for bulk elemental analysis and imaging.

EDS-GRT: Explosives

Name	MW	C	H	N	O	N (%)	g/cm^3
TNT	227.13	7	5	3	6	18.5	1.65
RDX	222.26	3	6	6	6	38.0	1.83
HMX	296.16	4	8	8	8	37.8	1.96
Tetryl	287.15	7	5	5	8	24.4	1.73
PETN	316.20	5	8	4	12	17.7	1.78
NG	227.09	3	5	3	9	18.5	1.59
EGDN	152.10	2	4	2	6	18.4	1.49
AN	80.05	-	4	2	3	35.0	1.59
TATP	222.23	9	18	-	6	-	1.2
DNB	168.11	6	4	2	4	16.7	1.58
Picric Acid	229.12	6	3	3	7	18.3	1.76

EDS-GRT: Explosives

Where:

TNT – 2,4,6-Trinitrotoluene
RDX – Hexogen
HMX – Octogen
Tetryl –
PETN – Nitropenta
NG – Nitroglycerin
EGDN – Ethylene glycol dinitrate
AN – Ammonium Nitrate (NH_4NO_3)
TATP –
DNB – 1,3-Dinitrobenzene
Picric acid -

About 80% of the explosives contain N, those that do not contain N contain Cl. New explosive without N and Cl are rich in C, O.

EDS-GRT: Common Materials

Name	C%	H%	N%	O%	g/cm^3
Wool	37.5	4.7	21.9	5.1	1.32
Silk	39.5	5.3	28.8	26.3	1.25
Nylon	63.7	9.7	12.4	14.2	1.14
Orlon	67.9	5.7	26.4	0	1.16
Melamin Formaldehyde	43.6	5.5	50.9	0	1.48
Polyurethane	52.2	7.9	12.2	27.8	1.50
Meats	-	-	~3	-	1.10
Plants	-	-	~1	-	1.05

EDS-GRT: Goals

An ideal EDS system will

1) Detect directly presence of an explosive.

2) Identify the type of explosive.

3) Localize the explosive.

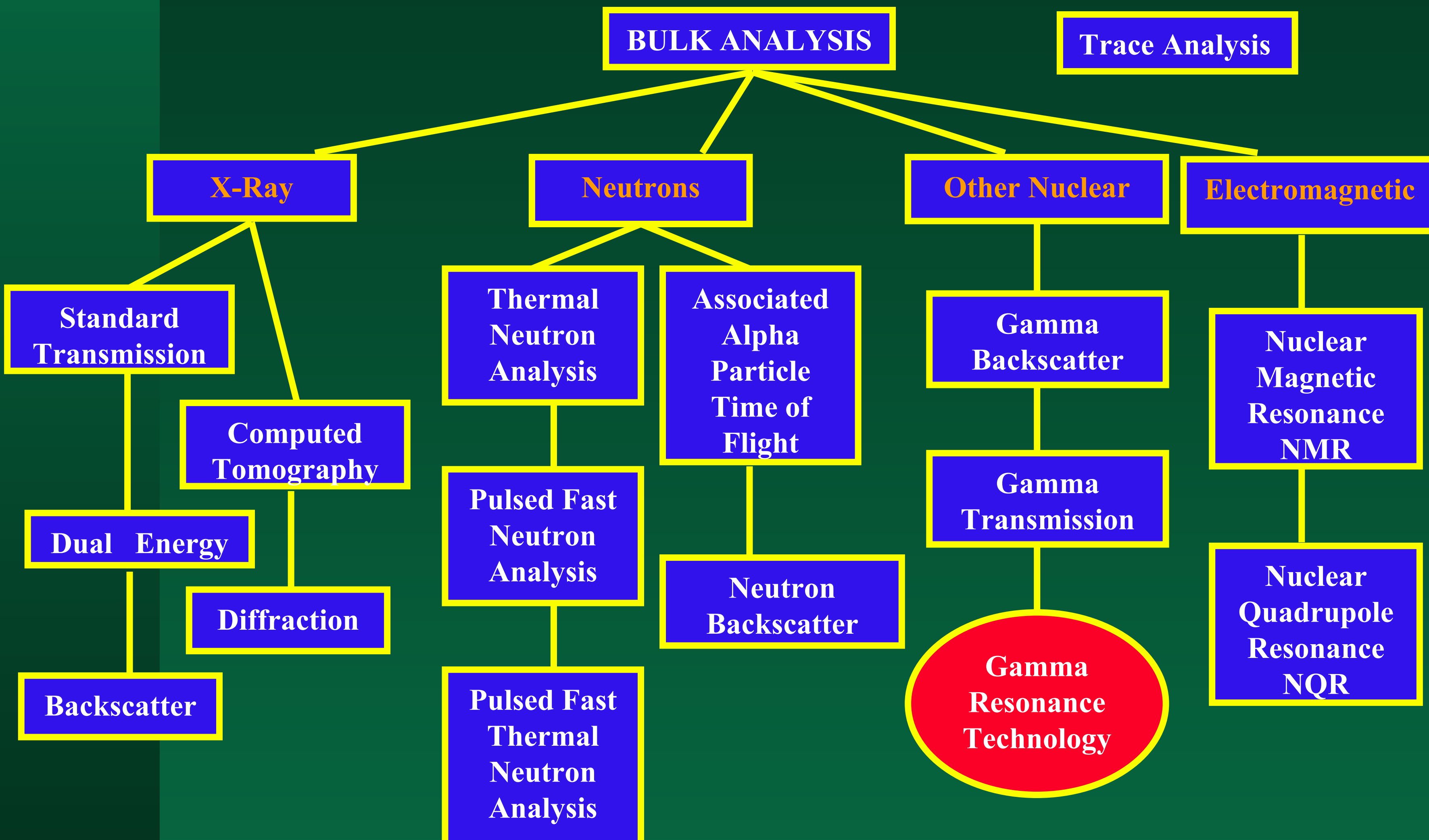
4) Minimize false positives.

5) Operate reliably in the field.

6) Provide high throughput.

7) Induce negligible amounts of residual activity.

EDS-GRT: Current Technologies



EDS-GRT: Key Advantages

- *High Detection Probability (>90%)
- * Low False Alarm Rate (<5%)
- * High Throughput (400 bags/hr/station,
  24 LD-3/hr/station)
- Specific Sensitivity to Explosives (N, Cl, O)
- No Induced Radioactivity

*Based on simulations to satisfy FAA requirements of sensitivity and throughput.

EDS-GRT: Basic Principle

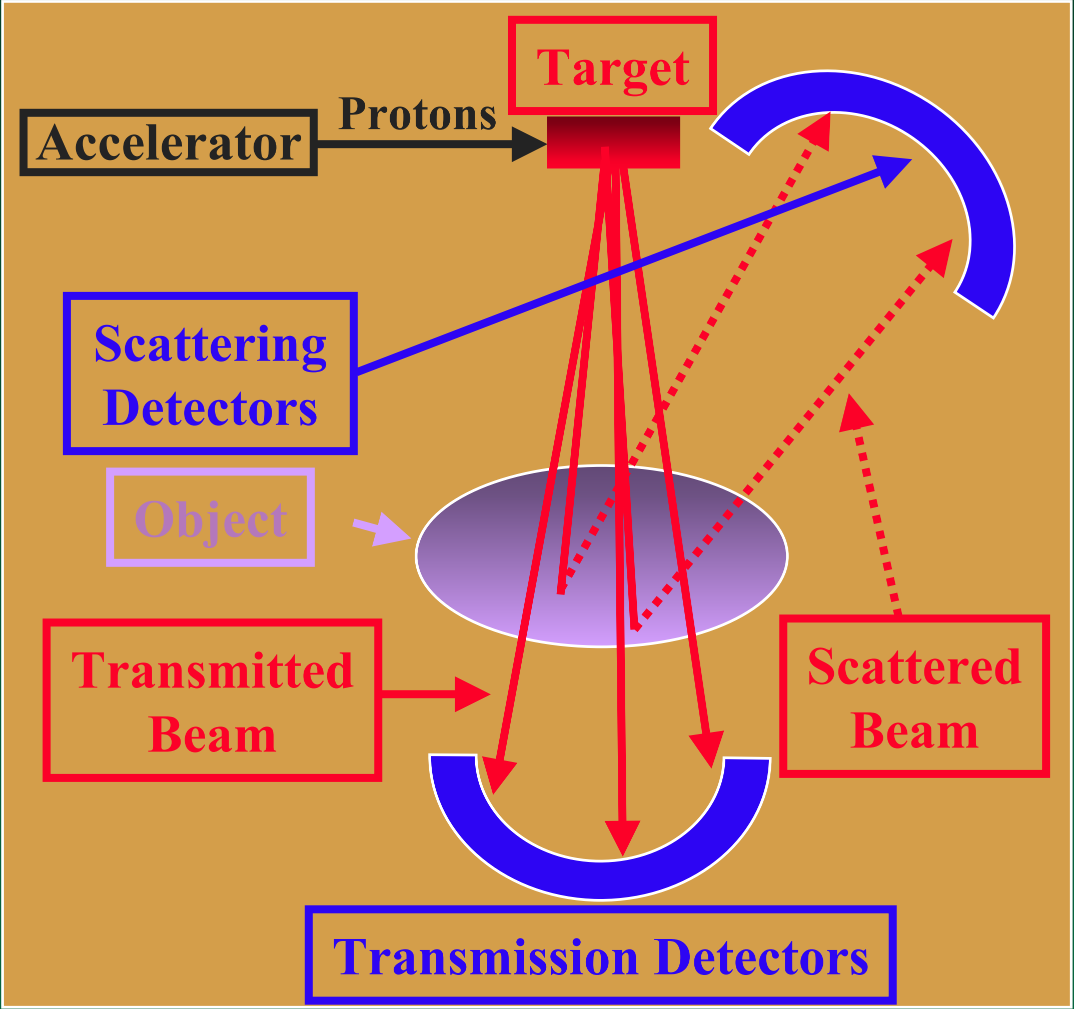
Gamma Resonance occurs when the energy of a gamma beam is precisely tuned to coincide with a nuclear excitation level in a nucleus of an element of interest.

GRT can be implemented in either absorption (transmission) or scattering mode.

EDS-GRT: Basic Configurations

A low energy proton beam hits a dedicated target and produces resonance gamma rays. These interact resonantly with N or Cl encountered in the explosive.

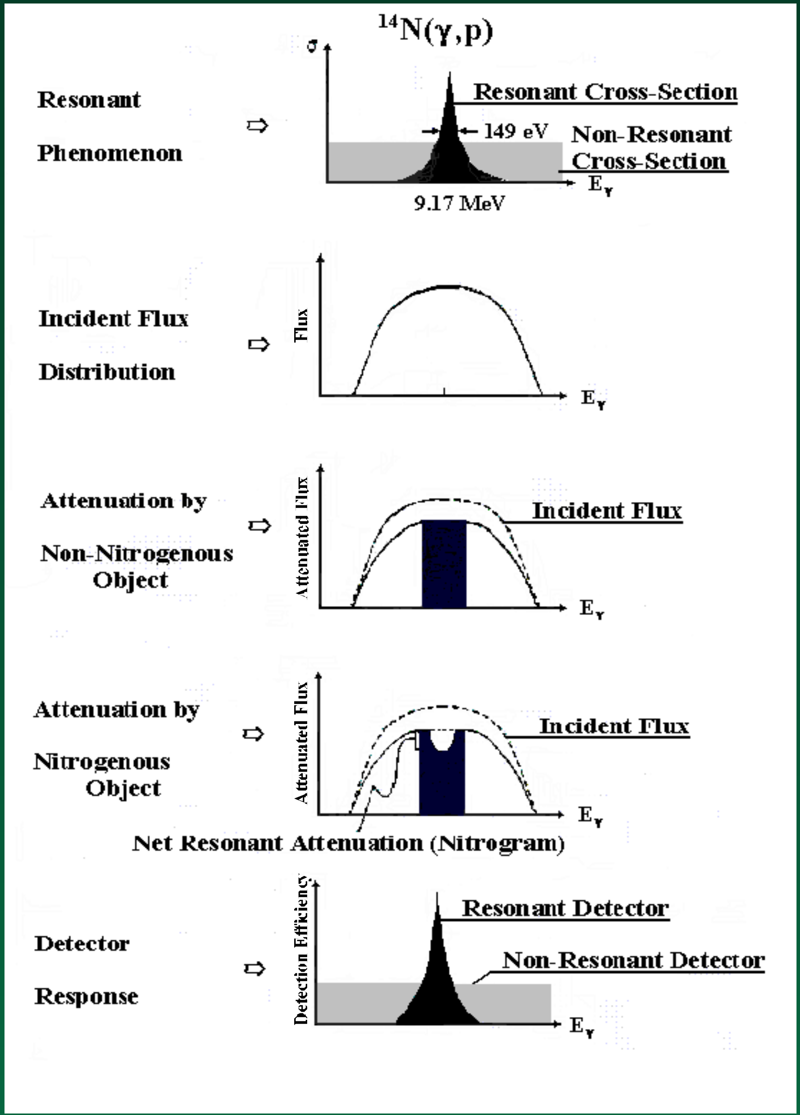
Monitoring the transmitted and the scattered beams, with the transmission and scattering detectors, respectively, allows analysis and imaging of the elements of interest.



EDS-GRT: Transmission

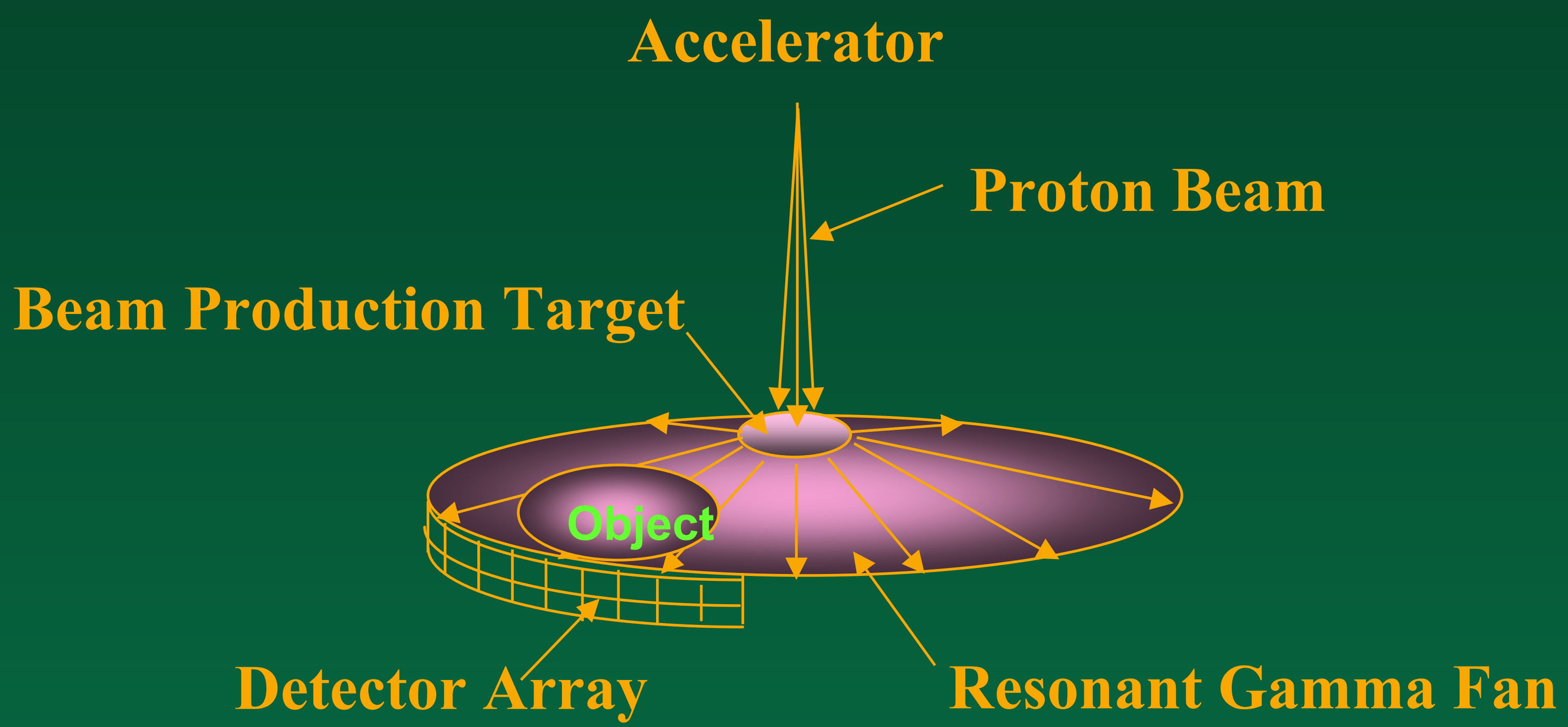
EDS-GRT measures the resonant and the non resonant gamma flux simultaneously. The ratio of the N density to total density identifies the explosive uniquely.

At 9.17 MeV gamma ray resonance attenuation is about four times higher than the attenuation of the non resonant radiation.

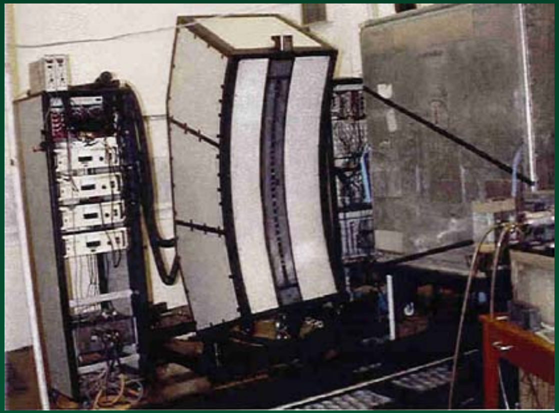


EDS-GRT: In a Transmission Mode

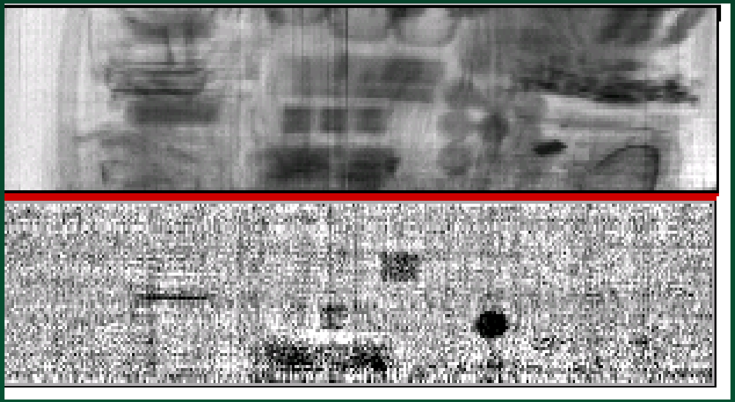
Gamma resonance radiation from accelerator based nuclear reactions



EDS-GRT: First Demonstration (1997)



Nahal Soreq group experimental set-up at Los Alamos inspecting LD-3 air cargo container

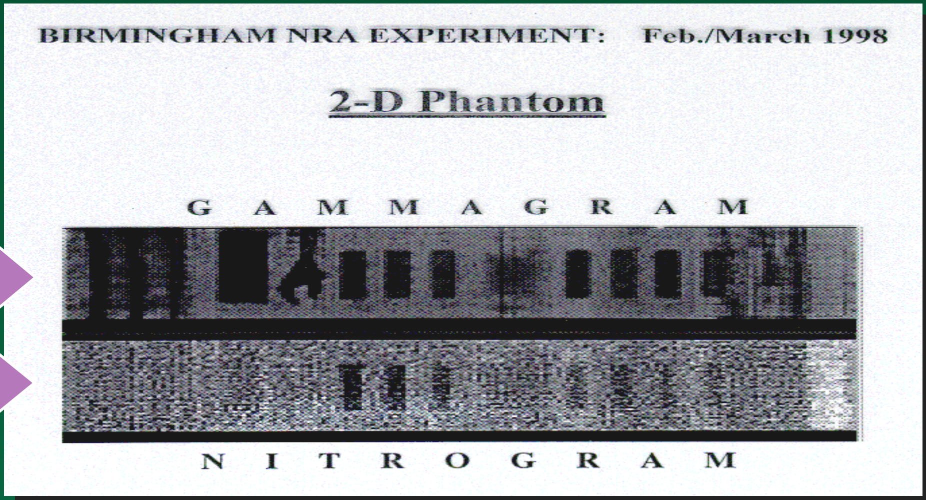


Two Projection images through an aircraft container loaded with mixed cargo containing six explosives. The nitrogen image clearly identifies the explosives.

EDS-GRT: Second Experiment (1998)

Nitrogenous and non-nitrogenous objects placed in a ☎ beam.

Nahal Soreq Group Experiment at Birmingham University

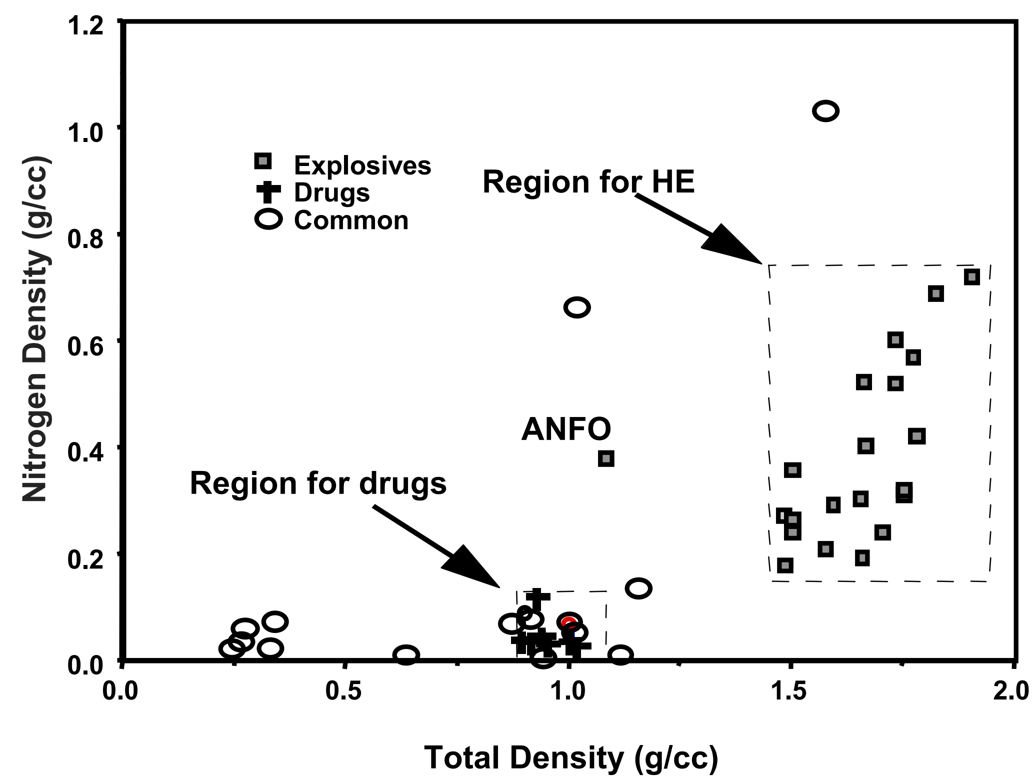


Out of resonance

In resonance

EDS-GRT: Explosives Identification

Nitrogen to total density ratio uniquely identifies explosives. → Can be implemented in an automatic Threat Algorithm.



HE are clearly separated

ANFO can be segregated

Items that will cause FAR with drugs include:
- Soybeans
- Barley
- Cheese
- Meat
- Leather

This may be statistically acceptable

EDS-GRT: *Current Location*

The System Has Been Located at BNL in Bldg. 945

EDS-GRT: Status of Proton Accelerator

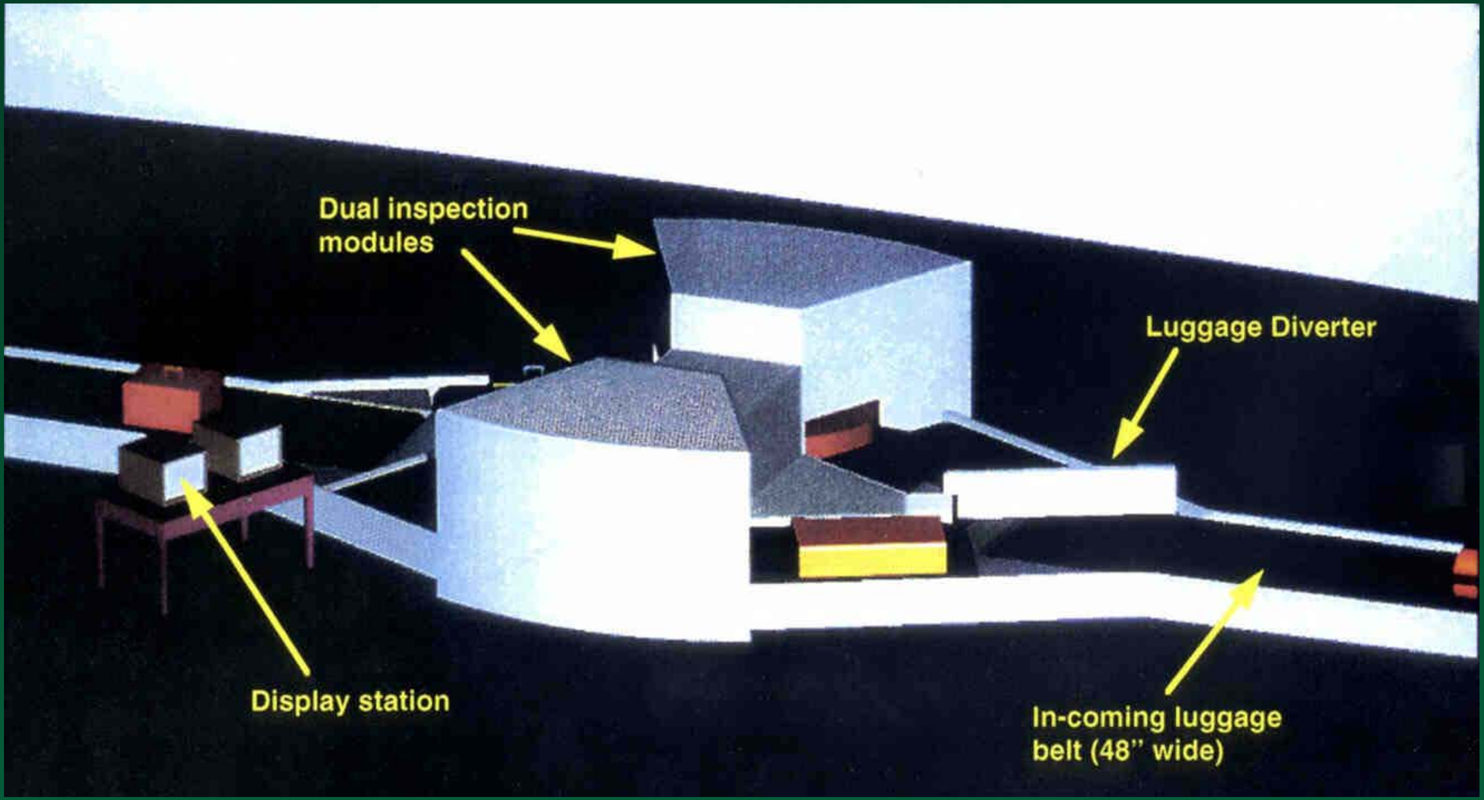
DC Tandem Accelerator Design Specifications

- Energy tunable up to ~ 1.9 MeV
- Beam current, ~2 mA, up to ~ 10 mA
- Total Emittance ~0.1 pi mm mrad
- Beam spread < 25 keV

Accelerator Area

Injector

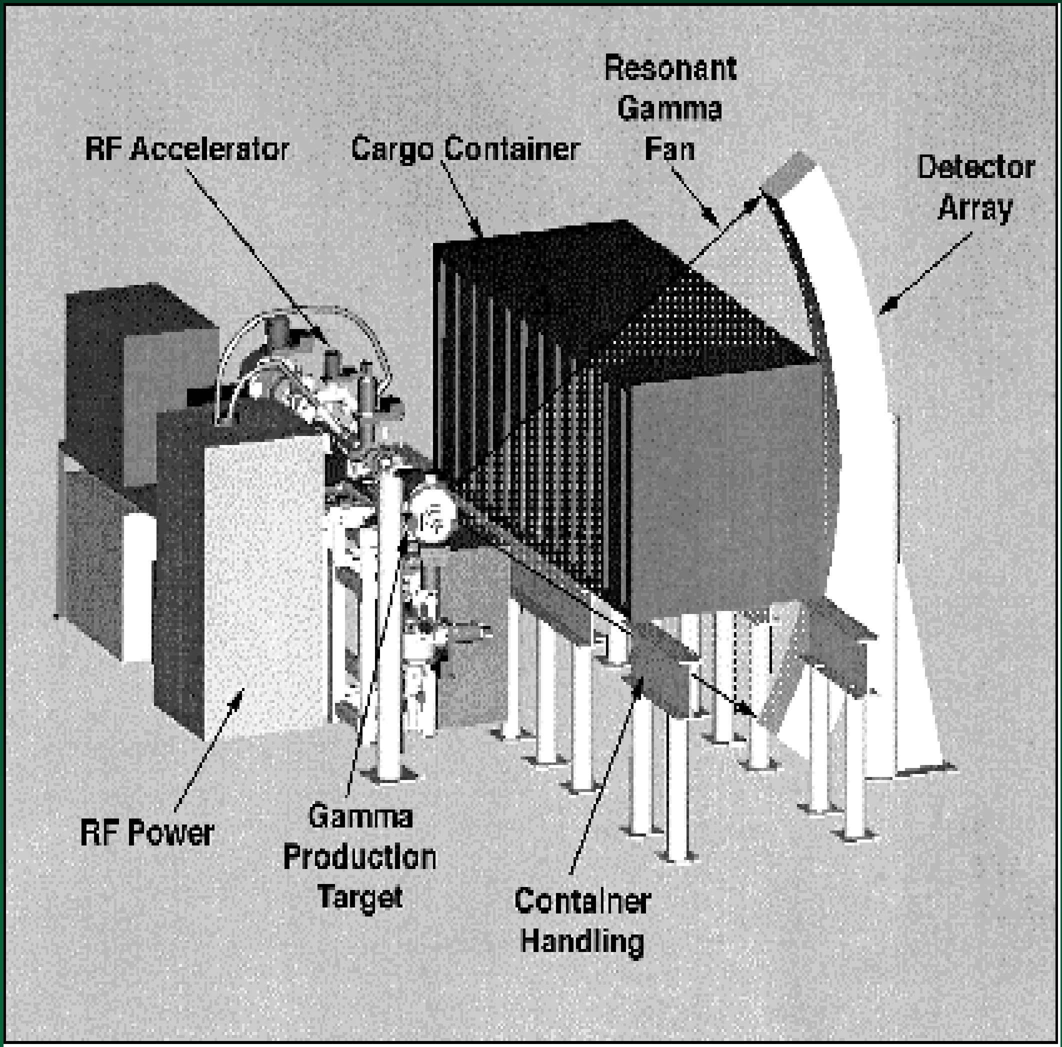
EDS-GRT: Small Cargo Screening



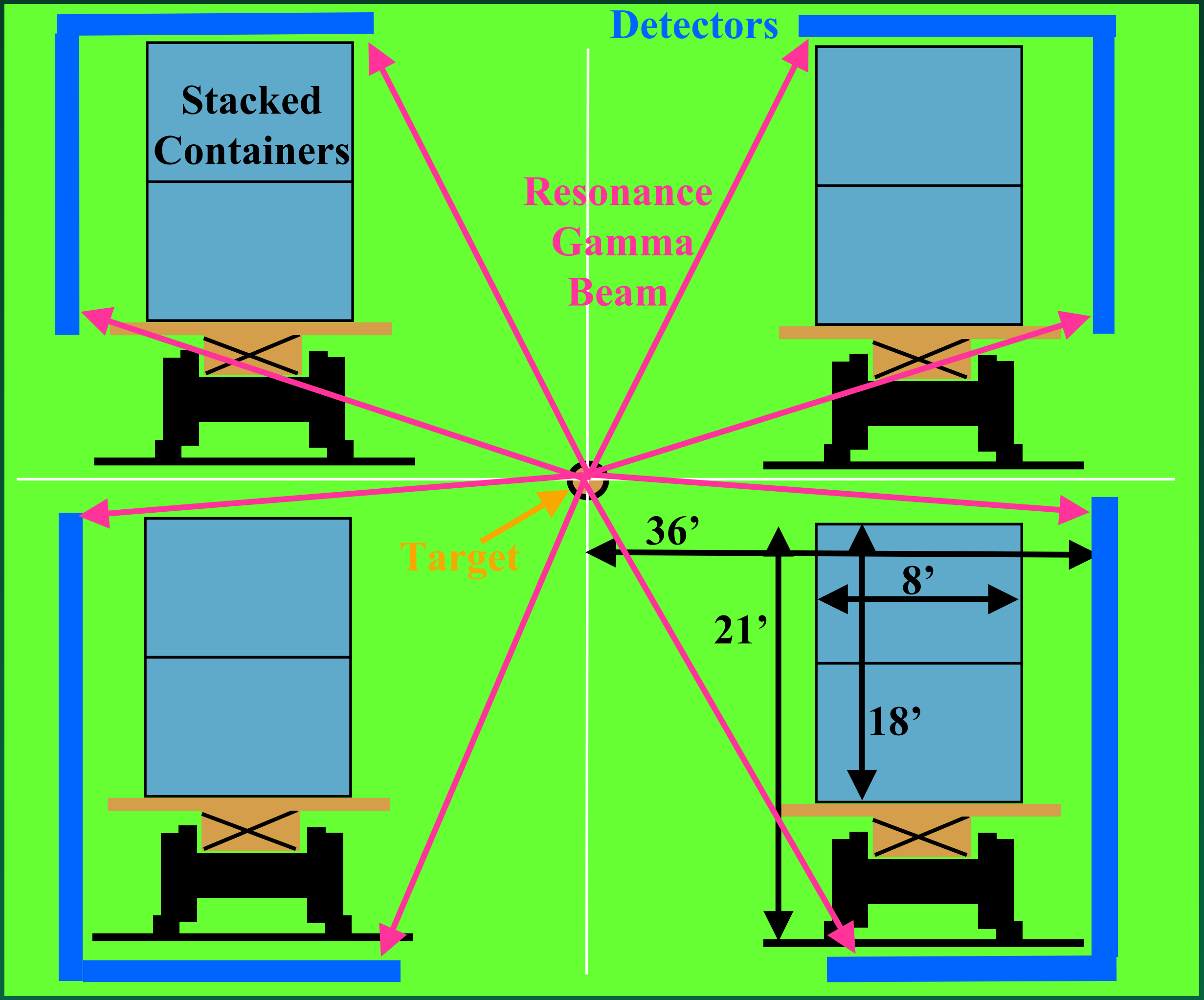
A configuration of a system in an airport feeding simultaneously two inspection stations for bags.

EDS-GRT: Large Cargo Screening

A possible configuration for scanning large containers

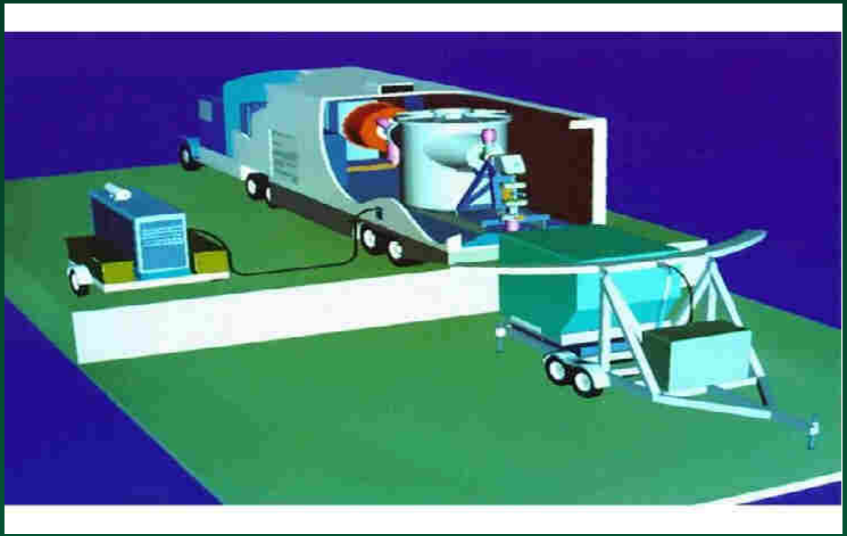


EDS-GRT: Large Cargo Screening

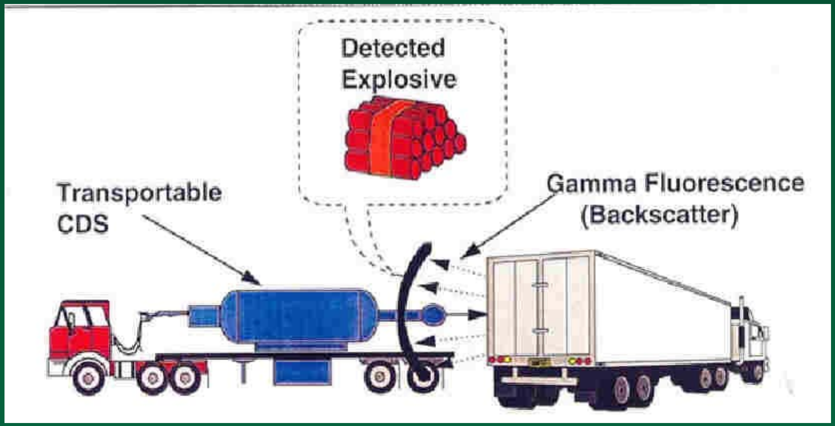


EDS-GRT: *Mobile Systems*

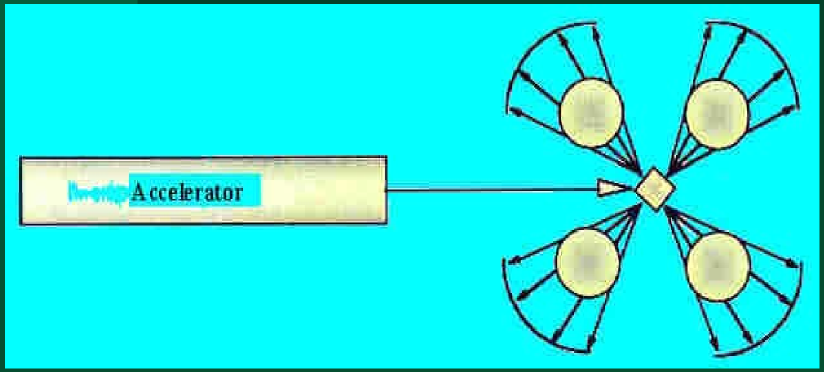
Can be engineered into
a transportable,
readily deployable system



Stand off use of the system
in a fluorescence mode

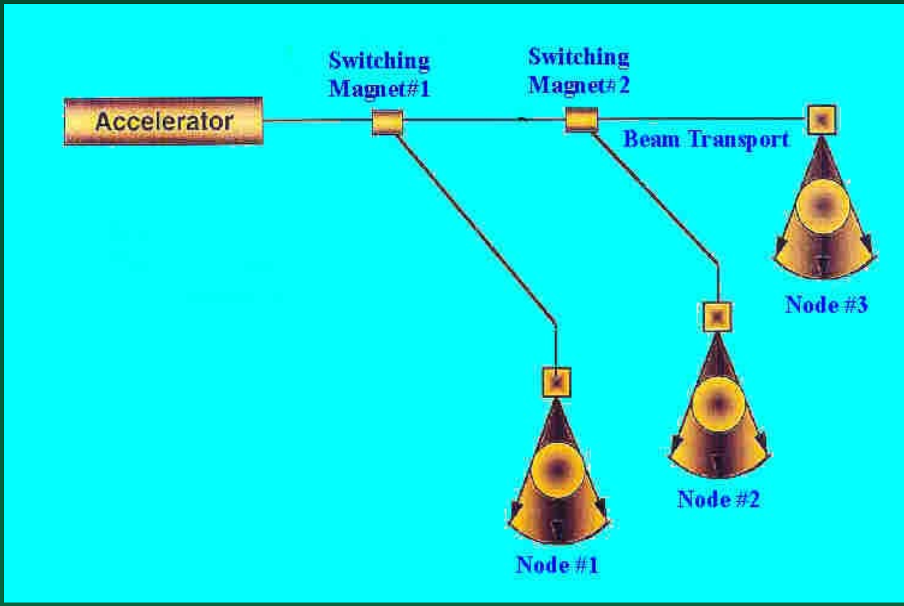


EDS-GRT: *Multi-Nodal Systems*



Single target feeding simultaneously four inspection stations.

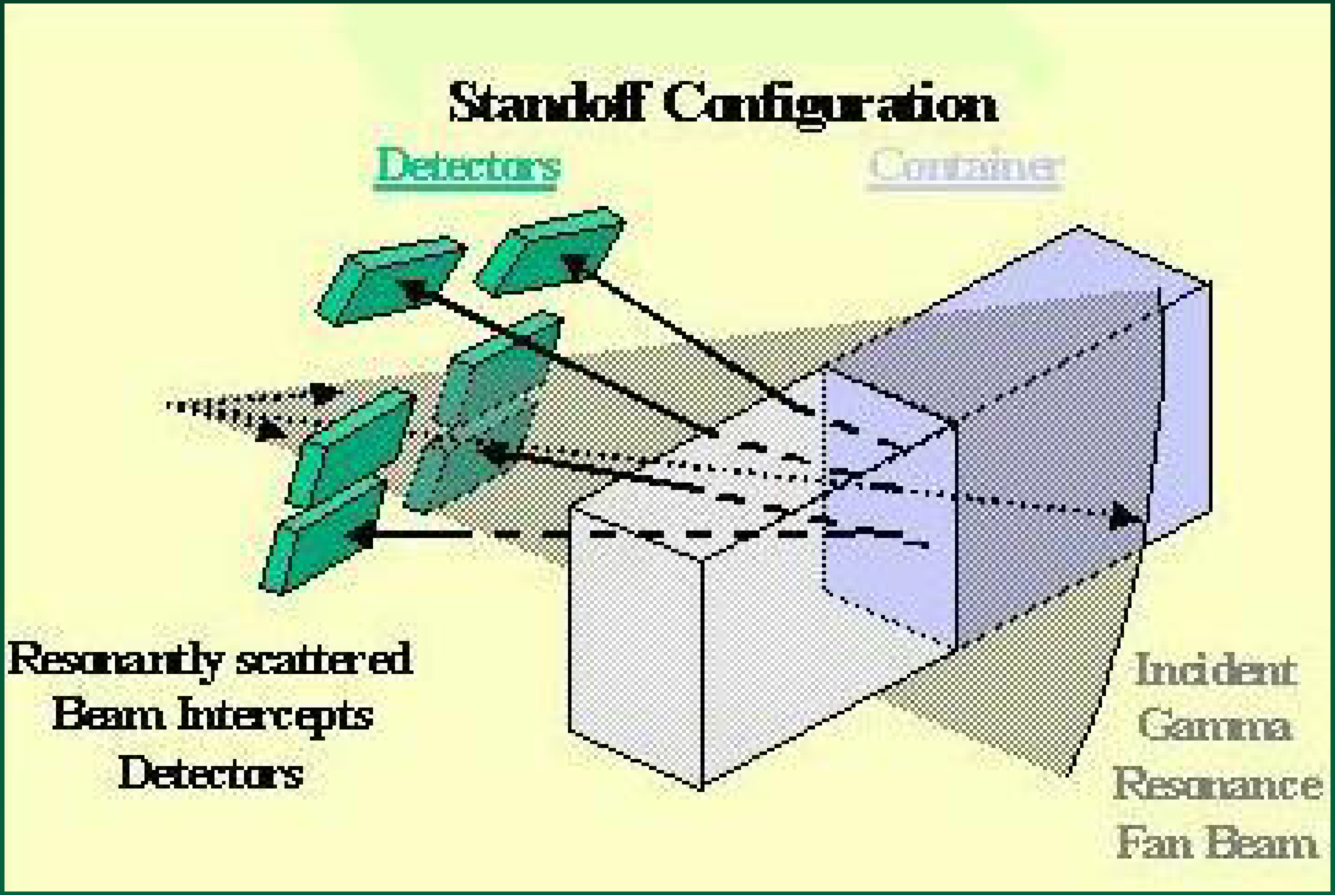
Single system feeds alternatively three targets.



EDS-GRT: *Processing Rates*

- *Each target can process about 4x400 bags/hr,*
- *24 LD-3 containers/hr*
- *4 conveyors simultaneously*
- *Interrogate 40 foot container in about 3 to 4 minutes, stacked containers will double the capacity. (Extrapolated from current measurements.)*

EDS-GRT: Unilateral System



EDS-GRT: Potential Users

Resonance Technology

Department of Transportation (DoT)

- FAA
- Explosives Detection in Cargo
- Checked baggage inspection
- Scanning trucks/vehicles/railroad cars

Force Protection (DoD)

- Military Bases
- Counter-terrorism
- Explosives Detection in Vehicles

Warhead/Rocket QC (DoD)

- Crack & Void Detection
- Mixture Quality
- 24% Rejection / Shelf Life

Environmental Cleanup (DoD)

- Unexploded Ordnance Detection
- Mine Field Clearance

US Customs

- Border Control
- Seaports
- Explosives / Drug Detection in Large Containers

Medical Research

- Neutron Capture Therapy
- Whole Body Composition

EDS-GRT: *Path Forward*

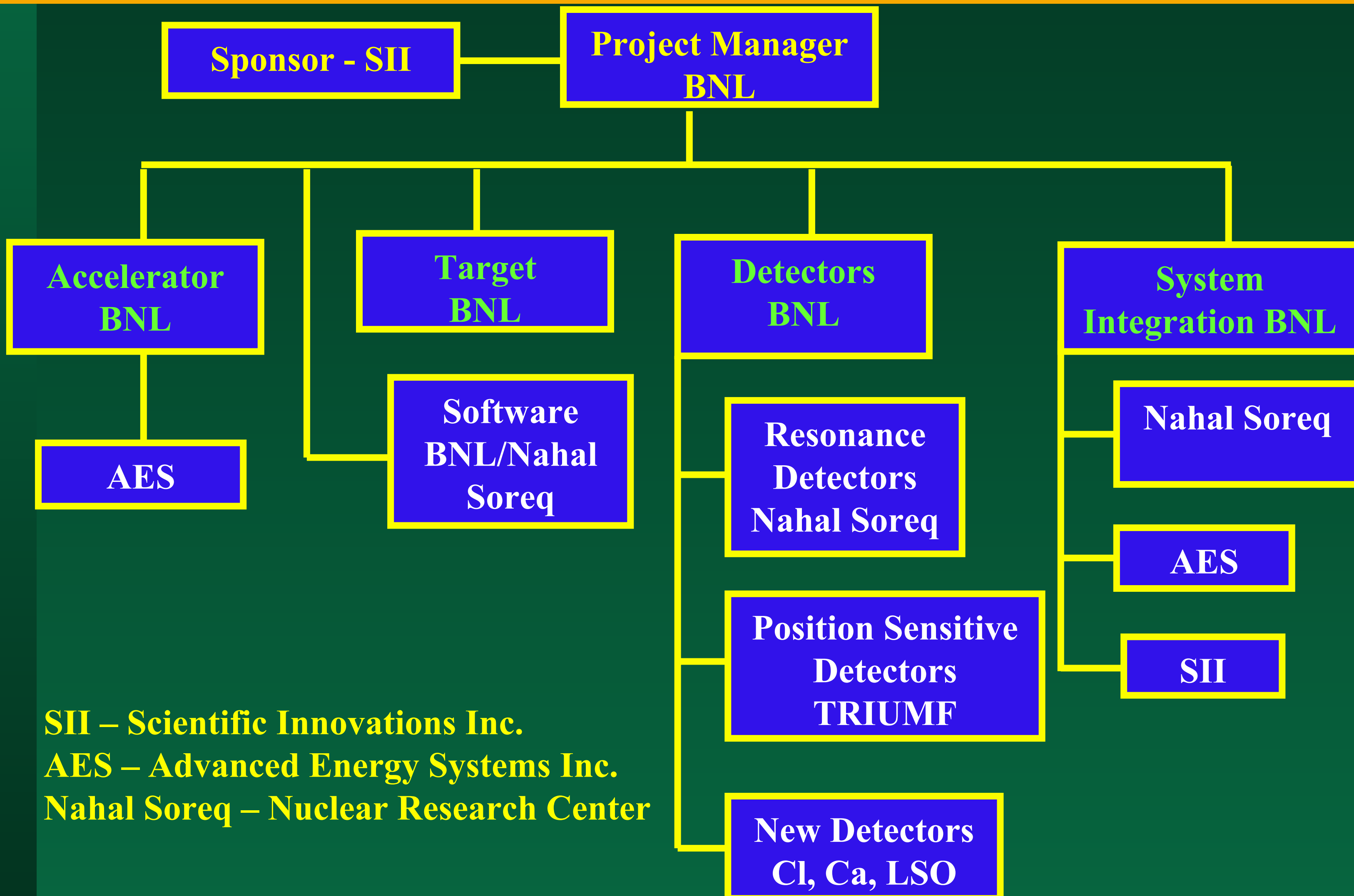
1. **Complete BNL Development and Test Facility (1y)**

   - Complete Facility
     - Target Development
       - Detectors Development
         - System Integration and Testing

2. **Setup a Low Rate System Production Facility (1-2y)**
   - Set Up Low Rate Production Facility
     - Production Engineering Design
       - Production of a Small and Large Cargo Inspection Systems
         - Field evaluation

3. **Setup High Rate System Production Facility (2-3y)**

EDS-GRT: R&D



SII – Scientific Innovations Inc.
AES – Advanced Energy Systems Inc.
Nahal Soreq – Nuclear Research Center

EDS-GRT: *Accelerators*

The Basic Requirements Are:

- Variable Energy In The Range 0.5 - 3MeV
- High Intensity > 3 mA.

Accelerator Types:

- DC Tandem Accelerators
- Electrostatic (6MeV, 60mA)
- Linear RFQ
- New Types

EDS-GRT: Targets

- **Single Element Targets**
  - **Multi-element (layered) Targets**

Element	Target	E_p (MeV)	☞$_{abs}$ (barns)	E_γ (MeV)	Reaction
^{14}N	^{13}C	1.75	2.6	9.17	$^{13}C(p,\gamma)^{14}N$
^{40}Ca	^{39}K	2.04	5.0	10.32	$^{39}K\ (p,\gamma)^{40}Ca$
^{35}Cl	^{34}S	1.89	1.0	8.21	$^{34}S(p,\gamma)^{35}Cl$
^{16}O	^{19}F	2.6	2.4	6.92	$^{19}F(p,\alpha\gamma)^{16}O$
^{12}C	^{15}N	2.6	1.1	4.43	$^{15}N(p,\alpha\gamma)^{12}C$

EDS-GRT: Targets

Layered Targets

CS_2 – Enriched in ^{13}C and ^{34}S
for detection of N and Cl.

Composite Targets

At E_p 1.94 MeV, ^{26}Mg & ^{30}Si to detect
^{14}N, ^{16}O, and ^{35}Cl

^{26}Mg & ^{30}Si (p,γ) → ^{27}Al → @ ~40° 7.117 MeV ^{16}O
^{27}Al → @ ~117° 9.082 MeV ^{35}Cl
^{26}Mg & ^{30}Si (p,γ) → ^{31}P → @ ~86° 9.173 MeV ^{14}N

EDS-GRT: Detectors

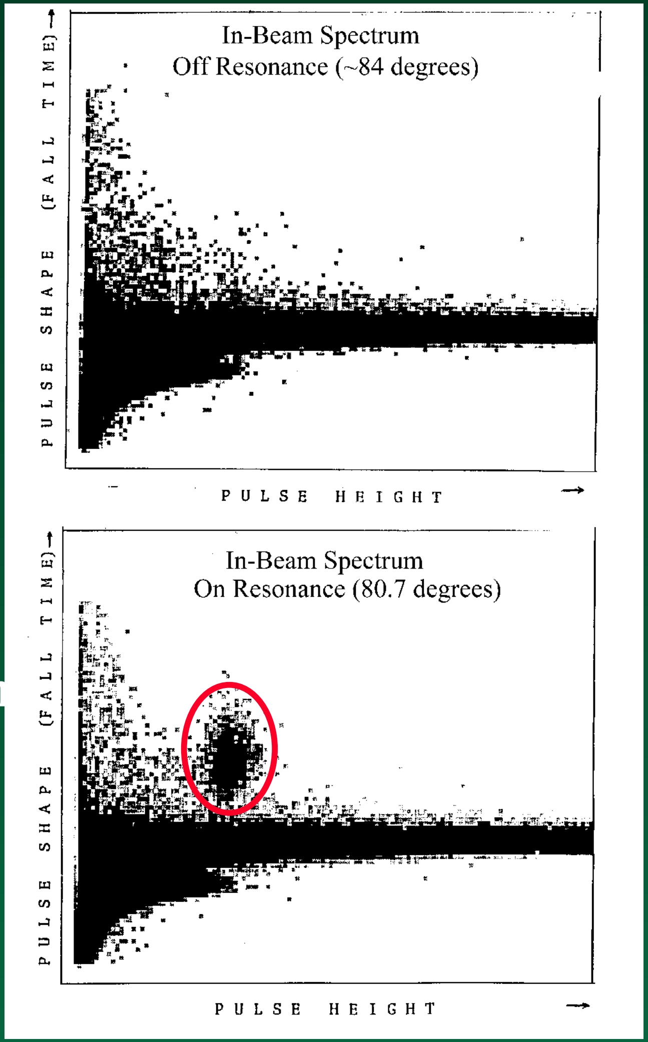
Type:
- Resonance
  - LS +N
- Non-resonance
  - HPGe, NaI
  - BGO, LSO, BaF
- Position sensitive
  - High Z sandwich

Optimization:
- Geometry
  - Number
    - Configuration
      - Electronics
        - Size

EDS-GRT: Resonance Detectors

Two dimensional pulse distribution from a resonance detector clearly separates proton pulses from electron pulses. Thus distinguishing resonance gamma radiation from non-resonant.

Proton pulses at 1.5 MeV are produced in the detector by the inverse (☎,p) reaction of the resonance radiation with the N in the detector.

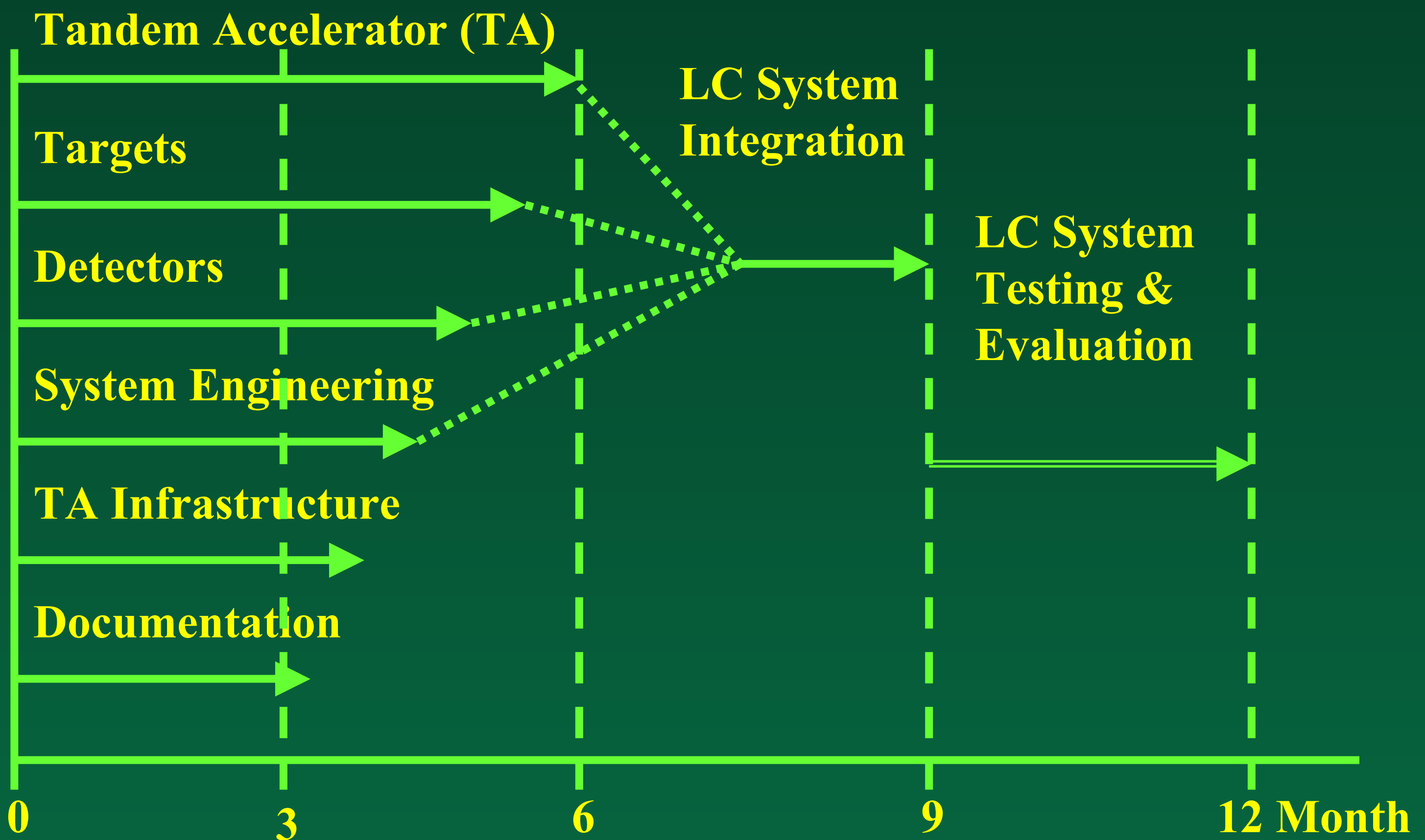


EDS-GRT: Public Safety

- Accelerator produces low energy x-rays.
- Target produces only gamma radiation, no neutrons.
- Shielded highly collimated beam.
- Dose to image N in human body 0.026 mrem.
- Dose to stowaway will be considerable lower.
- Gamma flux is two to three orders of magnitude lower than for VACIS or CT systems.

EDS-GRT: Time Schedule

Test facility can be ready within a year.



EDS-GRT: Budgets

Test Facility:	
Year 1	**$8M**
Year 2	**$3M**
Year 3	**$2M**
Cost of Deployed System	**~$3M**

SUMMARY

1. There is a need for new technology to meet future needs of national security.

2. Proof-of-principle of GRT for explosive detection and imaging has been demonstrated.

3. Gamma Resonance Technology is a viable method for detection of explosives and other elements in small and large shipping containers.

4. Life cycle of a unit is 10 to 15 years.

SUMMARY

5. The proposed GRT fills deficiencies of current x-ray scanners and other systems in use.

6. Extensive expertise at BNL in nuclear physics, particle accelerators, ☎ ray detectors and systems integration provide high probability for success.

7. A test facility ready for systems testing and prototype certification can be delivered within a year.

8. A field deployable system can be developed within two years.