

GSI Colloquium

Bastian Löher

October 2017

What does it take to find a dirty bomb?



Bastian Löher

GSI Kolloquium October 2017

What does it take to find a dirty bomb?

Find





dirty bomb

Google-Suche

Auf gut Glück!

10.300.000 results

dirty bomb

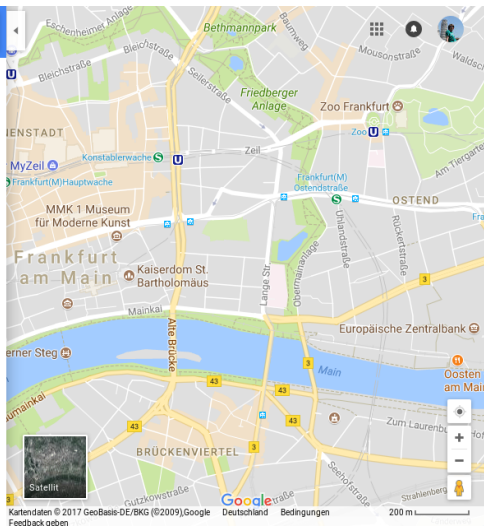
dirty bomb nicht in Maps gefunden

Achte bei deiner Suchanfrage auf die korrekte Schreibweise. Versuche, eine Stadt, ein Bundesland oder eine PLZ hinzuzufügen.

[Im Web suchen](#)

Sollte dieser Ort in Google Maps verzeichnet sein?

[Fehlenden Ort hinzufügen](#)



Finding means discovering

Bomb



An explosive device used or intended as a weapon
– *Wikipedia*

Damage types

- Shock

Damage types

- Shock
- Heat

Damage types

- Shock
- Heat
- Fragmentation

Finding a bomb

With Contact

- Colorimetric tests
- Ion Mobility spectrometry

Very accurate

Close range

- Dogs with special training
- X-ray inspection
- Neutron activation

Accurate, but usually expensive

Remote sensing

???

Very difficult

Dirty



Make it radioactive!

- Five grams of cesium - mixed with a few kg of explosives*
- are enough to cause damage in the range of billions*
- W. Koch, FKIE*

Dirty bomb – An Explosive Radiological Dispersal Device (ERDD)

- Not a nuclear device

Make it radioactive!

*Five grams of cesium - mixed with a few kg of explosives
- are enough to cause damage in the range of billions
- W. Koch, FKIE*

Dirty bomb – An Explosive Radiological Dispersal Device (ERDD)

- Not a nuclear device
- energy release from common chemicals

Why?

Fragmentation of radioactivity

- Same immediate damage

Fragmentation of radioactivity

- Same immediate damage
- Long-term health damage

Fragmentation of radioactivity

- Same immediate damage
- Long-term health damage
- Area Contamination

Fragmentation of radioactivity

- Same immediate damage
- Long-term health damage
- Area Contamination
- Psychological effects



Wikipedia (public domain)

How to find a dirty bomb?

How to find a radioactive source?

Related problems

- Dirty bombs

Related problems

- Dirty bombs
- Illegal transportation

Related problems

- Dirty bombs
- Illegal transportation
- Area monitoring

Related problems

- Dirty bombs
- Illegal transportation
- Area monitoring
- Area inspection

Dirty bombs



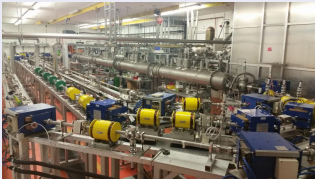
commons.wikimedia.org

Illegal transport



commons.wikimedia.org

Area monitoring

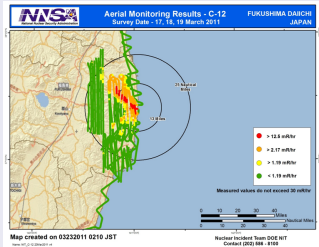


commons.wikimedia.org

Area inspection



commons.wikimedia.org



Building a detector

Key Requirements

- highly sensitive

Key Requirements

- highly sensitive
- fast

Key Requirements

- highly sensitive
- fast
- mobile

Key Requirements

- highly sensitive
- fast
- mobile
- easy to use

Key Requirements

- highly sensitive
- fast
- mobile
- easy to use
- rugged

Key Requirements

- highly sensitive
- fast
- mobile
- easy to use
- rugged
- (cheap)

What's on the market

- handheld

What's on the market

- handheld
- vehicle based

What's on the market

- handheld
- vehicle based
- stationary

What's on the market

- handheld
- vehicle based
- stationary
- one-off prototypes

Handheld devices

Ecotest SPECTRA



FLIR Identifinder



GammaScout



Rapiscan PRM470



detect rad-ID



Capabilities (handheld)

Property	SPECTRA	identiFINDER	Scout	Rapiscan	rad-ID
Gamma	yes	yes	yes	yes	yes
Neutron	yes	yes	no	yes	yes
Dose	yes	yes	yes	yes	yes
Histogramming	yes	yes	no	no	yes
Identification	yes	yes	no	no	yes
GPS	yes	yes	no	no	no
Material	CsI / Lil	NaI / GM / 3He	GM	plastic / 3He	CZT / NaI / 3He / GM

Car-based solutions

Canberra MOVERS



ORTEC Nal-SS



Thermo Fisher ARIS

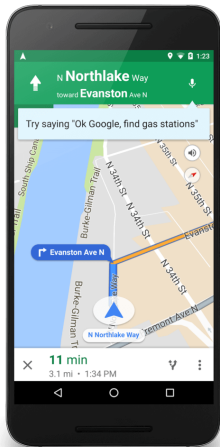


Capabilities (car based)

Properties	Canberra	Ortec	Thermo Fisher
Gamma	yes	yes	yes
Beta	yes	no	no
Neutron	no	yes	yes
GPS	yes	yes	yes
Dose	yes	yes	yes
Identification	no	no	yes
Histogramming	no	yes	?
Mapping	yes	yes	yes
Material	plastic / GM	Nal / 3He	Nal / plastic / 3He
Extra	Weather	Compact	Modular

What's missing?

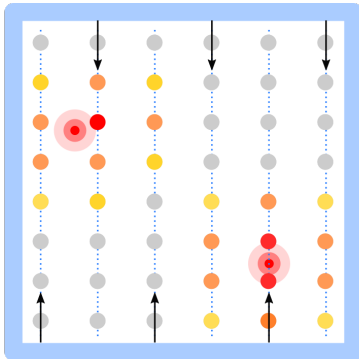
- Directional sensing



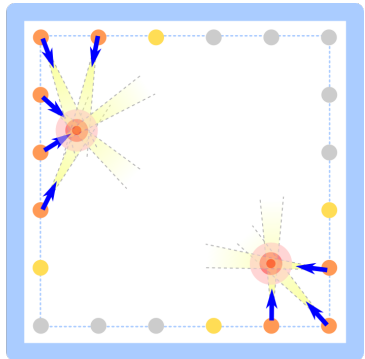
searchengineland.com

Grid search vs. Compass

a)



b)



Faster

Greater distance

Less exposure

Validation of an innovative handheld concept detector for gamma source location

Specifications

- Gamma detection
- Dose / Intensity
- Histogramming / ID
- Mapping
- Directional sensing

Design decisions

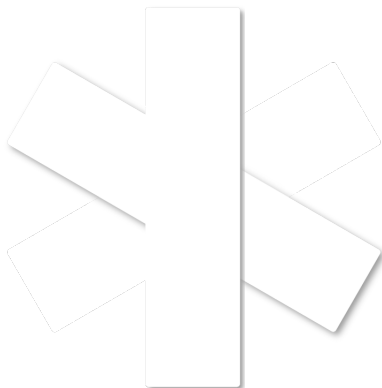
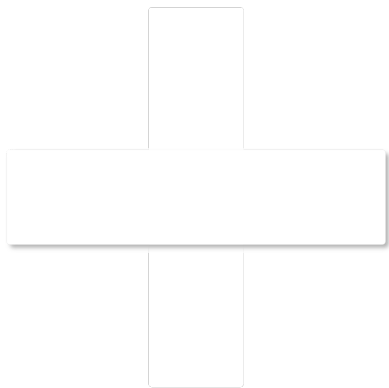
- Geometry
- Material
- Electronics

Geometry

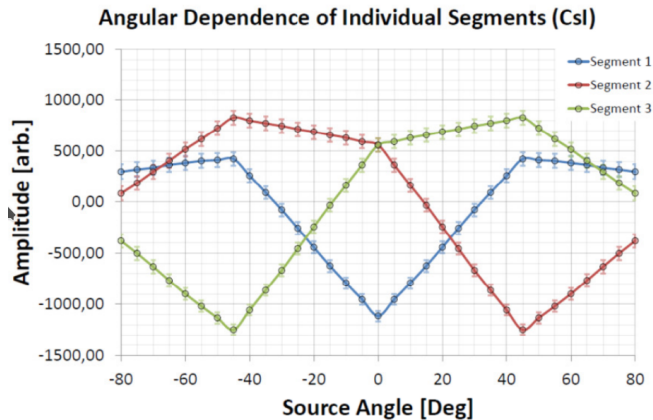




Detection efficiency depends on angle of incidence



Asymmetry



Material

Requirements

- Fast: High detection efficiency

Requirements

- Fast: High detection efficiency
- Histogramming: Good energy resolution

Requirements

- Fast: High detection efficiency
- Histogramming: Good energy resolution
- Easy to use: Reliable and stable

Requirements

- Fast: High detection efficiency
- Histogramming: Good energy resolution
- Easy to use: Reliable and stable
- Scintillator (CeBr)

Electronics

- Photo-multiplier tubes

Electronics

- Photo-multiplier tubes
- Off-the-shelf desktop digitizers with HV

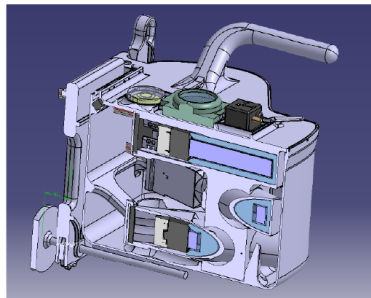
Electronics

- Photo-multiplier tubes
- Off-the-shelf desktop digitizers with HV
- High quality GPS receiver

Electronics

- Photo-multiplier tubes
- Off-the-shelf desktop digitizers with HV
- High quality GPS receiver
- Car battery as power source

ViDeO 1 prototype



Software

ViDeO – Demonstrator-Software

Datei Einstellungen Hilfe

Messung_1

Messung_2

Messung_3

...

Detektordaten:

SZ1 || 15 597 SZ2 || 14 389
X SZ3 12 107
19 461 SZ4 X

Verhältnis:

|| SZ1 und SZ2 1,084
X SZ3 und SZ4 0,622

Moving Average:

☒ autoscale
☐ manuel [sec]: 5

Konfig wechseln

Starten / Pausieren / Stoppen

Umgebungsdaten:

Datum: 2014-05-20
Uhrzeit: 08:55:59
GPS
- Länge: 55,691240 ° N
- Breite: 13,505720 ° O
Kompass: 23,54 °
Neigung
- längs: 15,86 °
- quer: 3,91 °
Beschleunigung: 3,2 m/s²
Temperatur: 24,5 °C



Infoberich

Systemstatus: bereit
Modus: Gesichtsfeld
Akkustand: 100%

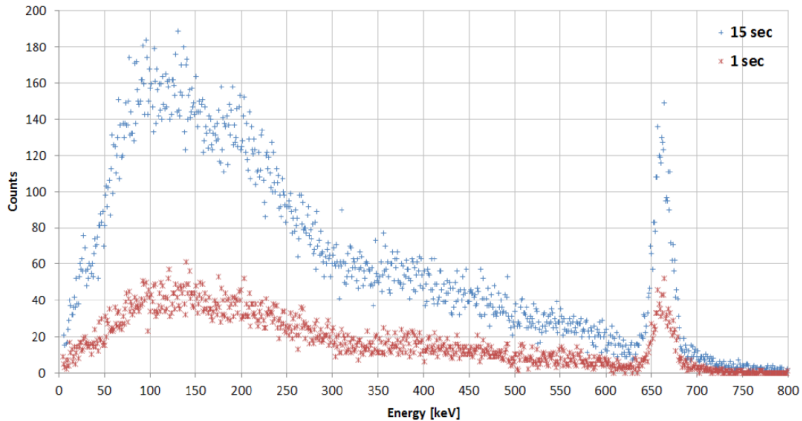
Aktivität:

2014-05-20 08:52:32:152 StartUp-Check gestartet
2014-05-20 08:53:54:182 StartUp-Check erfolgreich abgeschlossen
2014-05-20 08:54:15:254 System bereit

Fehlermeldungen:

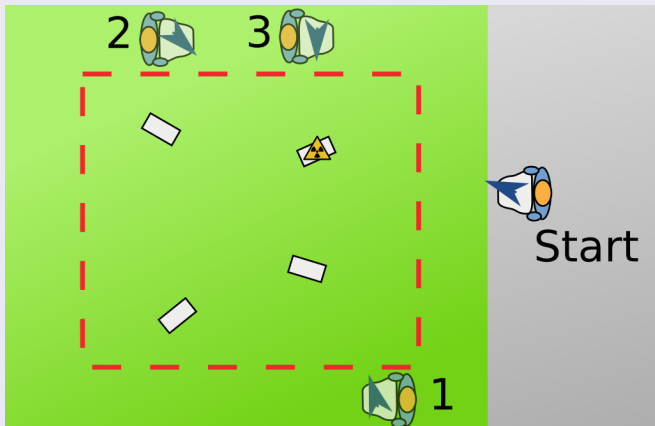
2014-05-20 08:54:04:013 keine Fehlermeldungen

Histogramming



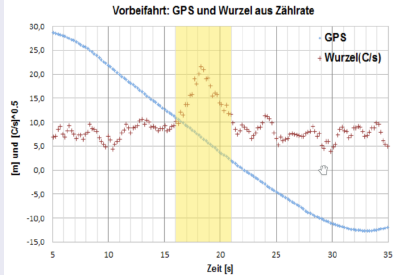
- Resolution $\sim 3\%$ at 662 keV

Field Test



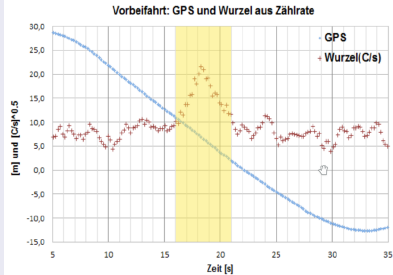
- 30 MBq gamma source at 10 m distance

Field Test 2



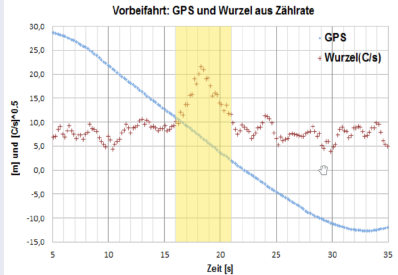
- 300 MBq gamma source at 12 m minimum distance

Field Test 2



- 300 MBq gamma source at 12 m minimum distance
- driving speed 30 km/h

Field Test 2



- 300 MBq gamma source at 12 m minimum distance
- driving speed 30 km/h
- 5 seconds of exposure

ViDeO results

- Basic concept validated

ViDeO results

- Basic concept validated
- More development needed

ViDeO 2

- Refine concept into a finished product

ViDeO 2

- Refine concept into a finished product
- Investigate new concept for a car-based detector

Main objectives

- Reduce system size

Main objectives

- Reduce system size
- Reduce system cost

Main objectives

- Reduce system size
- Reduce system cost
- Improve usability

Changes

- Tighter crystal geometry

Changes

- Tighter crystal geometry
- SiPM instead of PMT

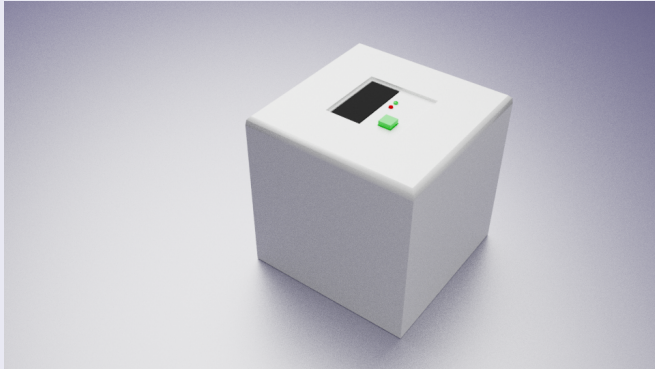
Changes

- Tighter crystal geometry
- SiPM instead of PMT
- ASIC based electronics

Changes

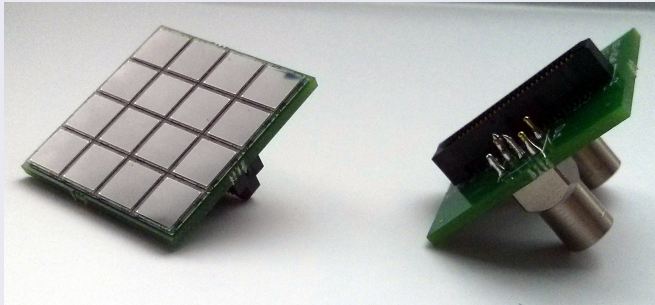
- Tighter crystal geometry
- SiPM instead of PMT
- ASIC based electronics
- Integrated CPU + wireless

New design study



- Dimensions: 20x20x16 ccm
- Weight: 2 kg
- Main control via external device

Silicon Photomultipliers

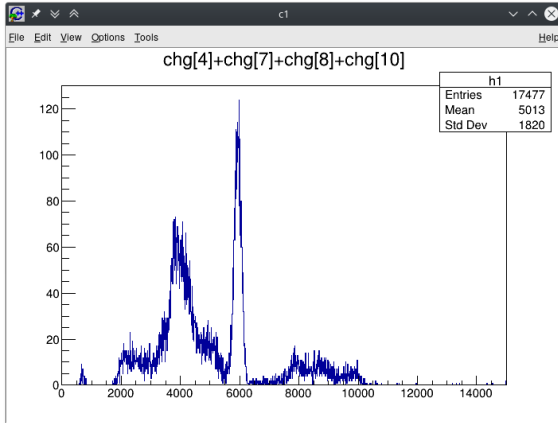


- Much smaller than PMT assembly
- Low voltage and low power
- Similar energy resolution

New readout electronics



- Up to 32 ch ASIC based readout (CITIROC)
- Integrated bias voltage for SiPM
- Raspberry Pi as readout controller
- 8h power supply via standard power bank

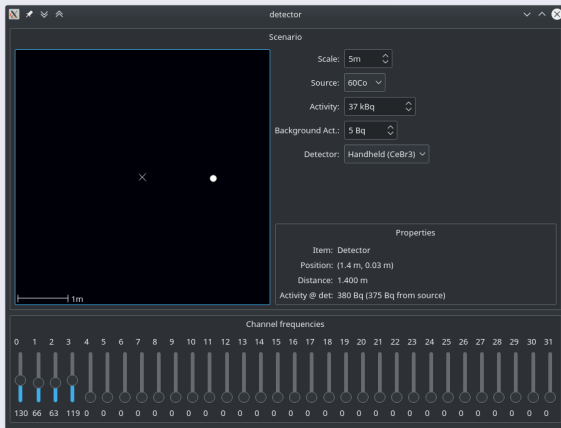


- LaBr3 background spectrum
- Four 16 pixel SiPM arrays (SensL B)
- 4.7% energy resolution without gain matching

A scalable and reliable DAQ

- Linux based
- Each component (readout / analysis / output ...) is independent
- Coupling via message passing interface (zeroMQ) -> data driven
- Monitoring / control using Linux systemd

Detector simulator



- Example of modularity - same data as from real detector
- Allows quick testing of algorithms

Current Status

- New electronics are working

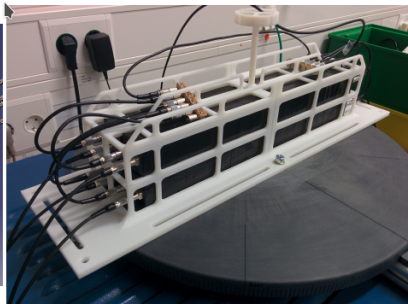
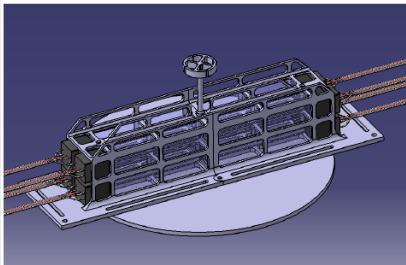
Current Status

- New electronics are working
- Waiting for new crystals

Current Status

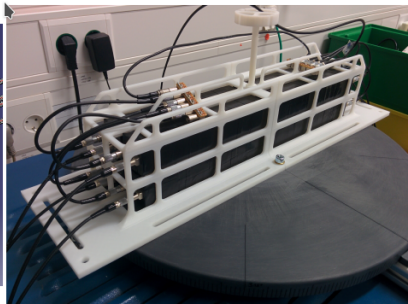
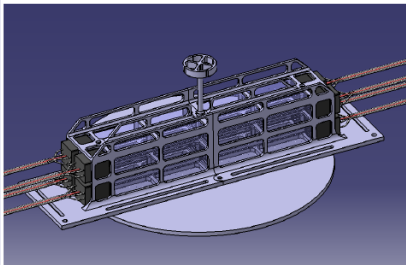
- New electronics are working
- Waiting for new crystals
- Software is in progress

Car based prototype



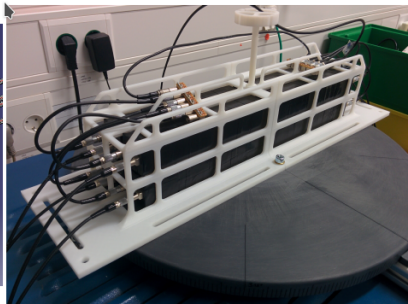
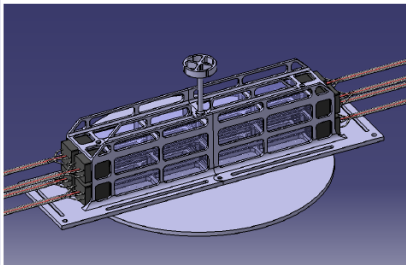
- one of 3 arms complete

Car based prototype



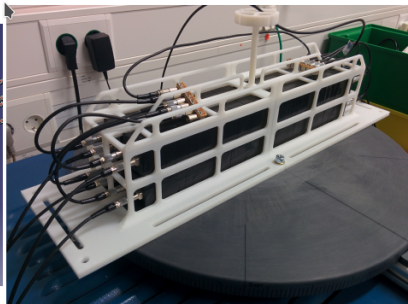
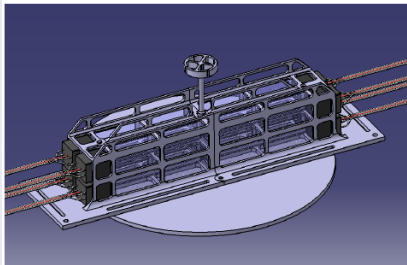
- one of 3 arms complete
- higher angular resolution

Car based prototype



- one of 3 arms complete
- higher angular resolution
- higher sensitivity

Car based prototype



- one of 3 arms complete
- higher angular resolution
- higher sensitivity
- longer range

Why develop this technology at GSI?

Expertise

- Detector construction

Expertise

- Detector construction
 - Scintillators & HPGe

Expertise

- Detector construction
 - Scintillators & HPGe
- High resolution spectroscopy

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- 3D position reconstruction

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 - AGATA

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- Particle ID (neutron / gamma)

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- Electronics department

Expertise

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- Complex detector systems

Expertise

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- Data acquisition / analysis
- Electronics department
- Complex detector systems
 - DESPEC / R3B / CBM

Sneak peak

Multiple source detection

- So far only a single radiation source

Multiple source detection

- So far only a single radiation source
- More complex

Multiple source detection

- So far only a single radiation source
- More complex
- Several concepts are being investigated

RAPID

Highly modular detection platform

- Scalable to demand

RAPID

Highly modular detection platform

- Scalable to demand
- Neutron & gamma detection

RAPID

Highly modular detection platform

- Scalable to demand
- Neutron & gamma detection
- Directional sensing

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Highly modular detection platform

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- Imaging

RAPID

Highly modular detection platform

- Scalable to demand
- Neutron & gamma detection
- Directional sensing
- Imaging
- Sensor fusion

Closing remarks



Summary

- Finding a dirty bomb means finding radiation
- Overview of available radiation finders
- We are adding direction sensing
- ViDeO 1 project successfully validated the concept
- ViDeO 2 aims at a finished product
- New concepts are evaluated for future systems



Gefördert durch:



Bundesministerium
für Wirtschaft
und Energie

GEFÖRDERT VOM

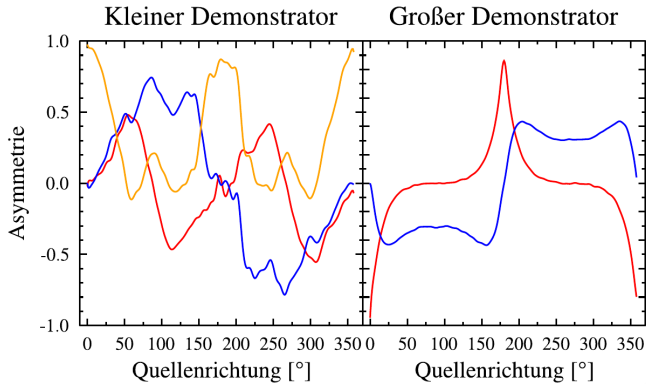


Bundesministerium
für Bildung
und Forschung

aufgrund eines Beschlusses
des Deutschen Bundestages

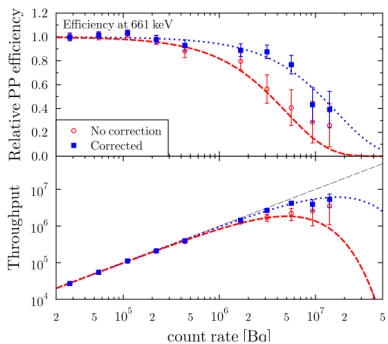
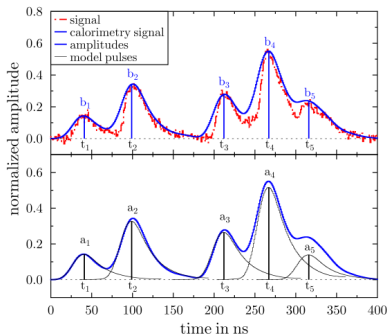
Backup

Asymmetry



1

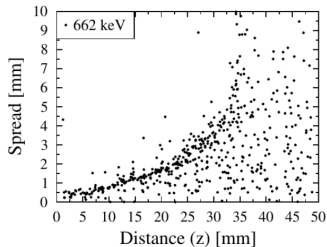
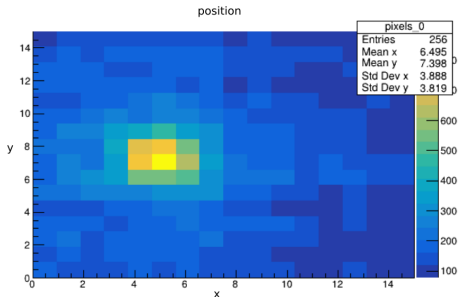
Pile-up correction



B. Löher NIM A 686 (2012)

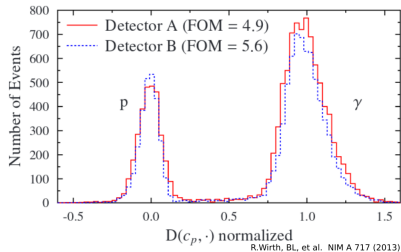
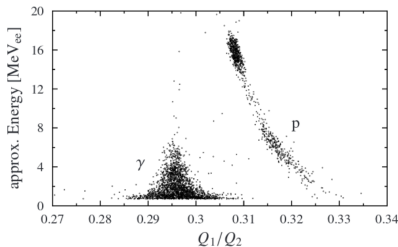
- LaBr3 detector and strong ^{60}Co source
- Pile-up alters measured energies
- Subtraction of contribution from neighboring signals
- Ensures correct operation in strong radiation fields

Position reconstruction



- Simulation of monolithic LaBr₃ and SiPM pixels
- Reconstruction of z coordinate from light spread
- Allows to construct position sensitive detectors from large crystals

Unsupervised particle ID



- CsI scintillator, mixed proton and gamma events
- Standard charge comparison \rightarrow detector dependent values
- Fuzzy clustering algorithm \rightarrow detector independent values
- Also investigated for neutron / gamma discrimination
- Allows efficient calibration of neutron detectors

Large array of large crystals

- High detection efficiency

Large array of large crystals

- High detection efficiency
- Position sensitive readout

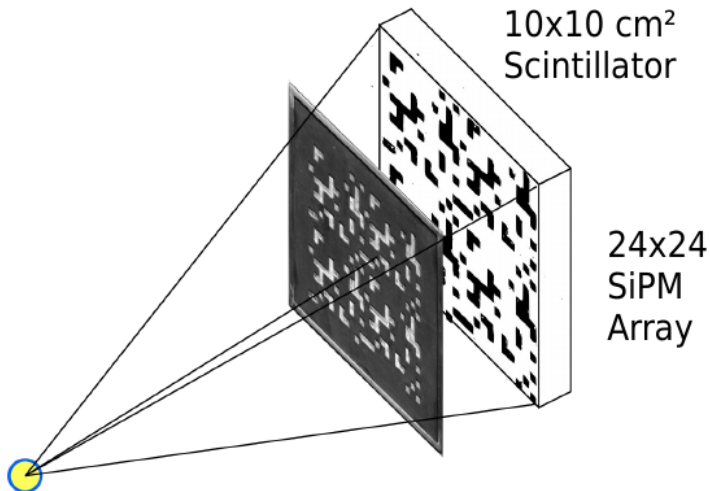
Large array of large crystals

- High detection efficiency
- Position sensitive readout
- 3D position information

Large array of large crystals

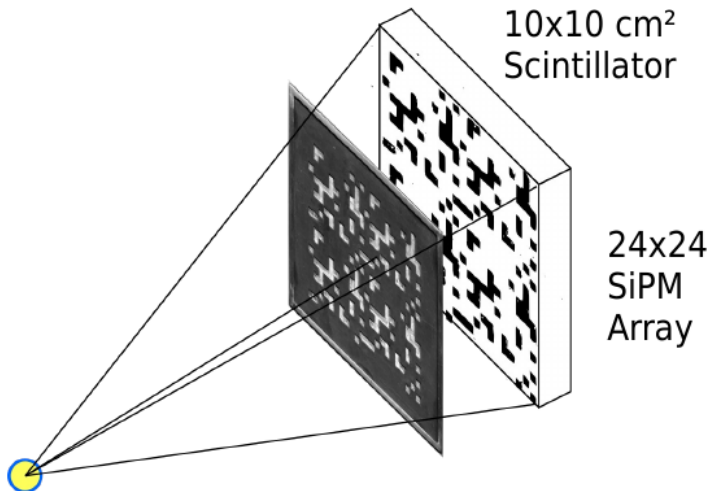
- High detection efficiency
- Position sensitive readout
- 3D position information
- Multiple source detection

Coded aperture



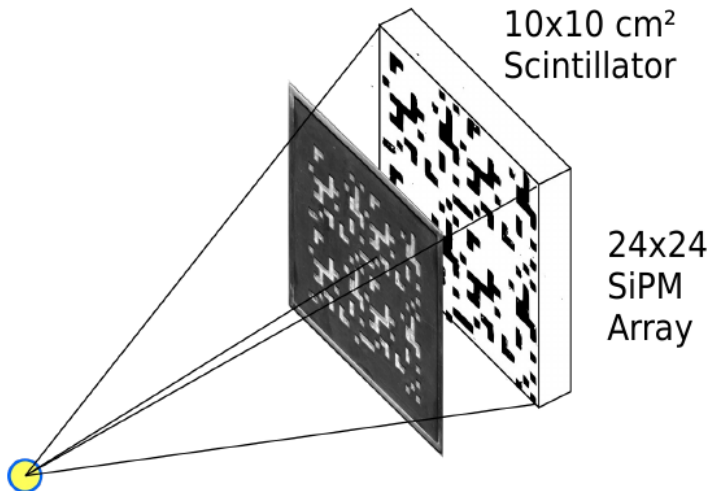
- Commonly used for gamma-ray telescopes

Coded aperture



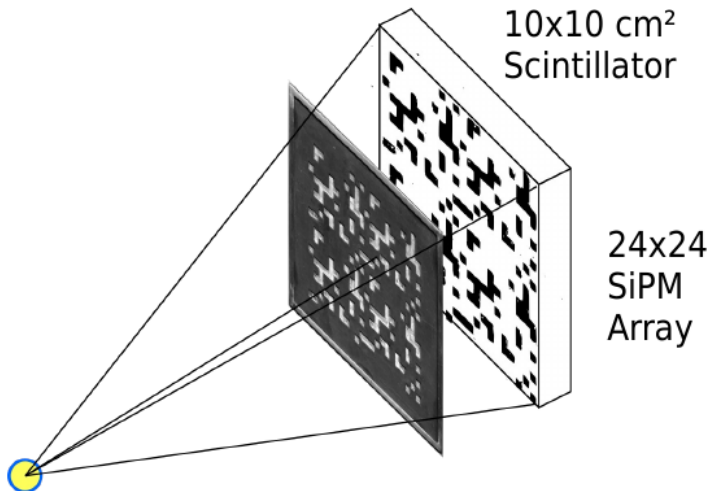
- Commonly used for gamma-ray telescopes
- Applicable for photons and neutrons

Coded aperture



- Commonly used for gamma-ray telescopes
- Applicable for photons and neutrons

Coded aperture



- Commonly used for gamma-ray telescopes
- Applicable for photons and neutrons

Compton Camera

- Low efficiency due to coincidence condition

Compton Camera

- Low efficiency due to coincidence condition
- High spatial resolution