Undeclared nuclear activity monitoring

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Outline

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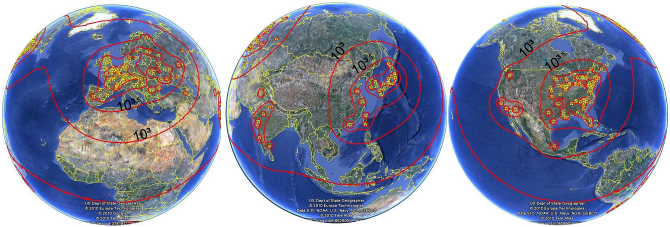
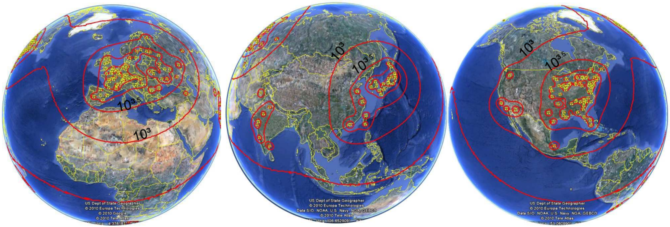
Introduction



Purpose

- Coast monitoring $\rightarrow$ rogue activity detection

Introduction



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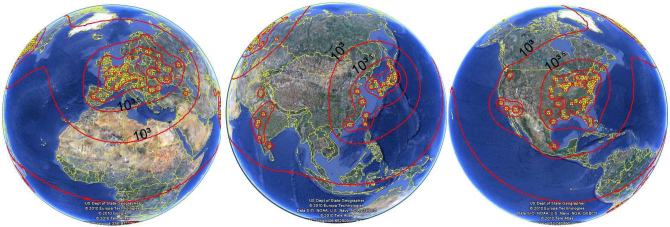


Purpose

- Coast monitoring $\rightarrow$ rogue activity detection
- Rogue reactor location
- Constraints : distances, detector position, regular reactor background, etc.

Outline

Regular reactor background

Antineutrino creation

Creation rate

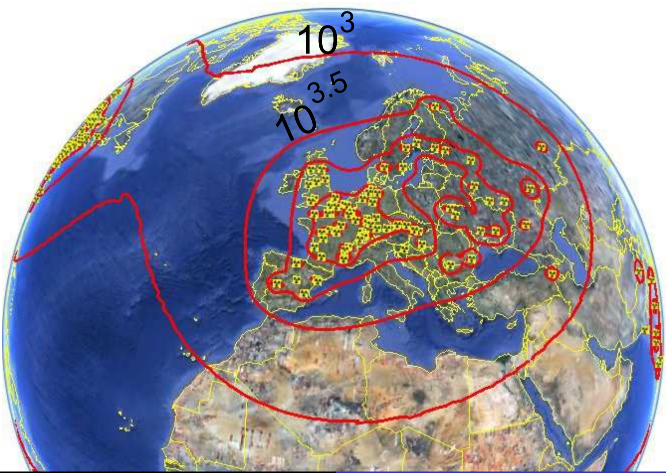
- 1 $GW_{th} \leftrightarrow 1.9 \times 10^{20}\ \overline{\nu}_e/s$
- World power reactors create $2.1 \times 10^{23}\ \overline{\nu}_e/s$

Induced background

1 year monitoring with a 10^{34} protons LS detector observes 150 events in the best case. Can rise up to a few 10^4 events. Non-reactor background are not accounted for.

Regular reactor background

Europe map



Regular reactor background

Simulation

Data

- 192 nuclear power stations
- Standard core composition (52% ^{235}U, 34%^{239}Pu)
- Average load factor (world mean : 0.8)

Simulation

- Simulation code from Saclay
- Neutrino oscillation included, with standard parameters

Outline

Rogue activity detection

Assumptions

Assumptions

- Rogue power P = 100 MW - 2 GW (classic : 500 MW)
- Exposure time T = 1 month - 2 years (classic : 3 months)
- Detector size N = 10^{33} - few 10^{34} protons (classic : 10^{34})
- Luminosity = PTN (10^{2} - 10^{5} rnu) (classic : 1250 rnu)
- Detector in an oil tanker, moving in the oceans
- Actual number of events in detector follows a Poisson law, λ = theoretical number of events.

Rogue activity detection

Likelihood ratio method

Method

- Data set *n*, theoretical value without rogue activity *b*
- Fitness probability : $p = \frac{L(b,n)}{L(b,b)}$
- L = likelihood function
- $L_{poisson}(b,n) = -b + n \times log(b) - log(\Gamma(n+1))$
- We take this value to detect rogue activity presence

Rogue activity detection

Monte Carlo simulation

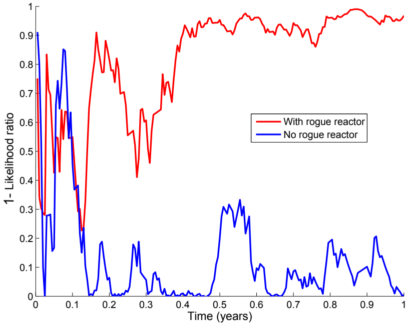


FIGURE: Monte Carlo simulation of likelihood ratio. Total experiment = 3000 rnu (10^{34} protons, 300 MW), distance = 300 km, low background

Rogue activity detection

Detection criterion

Chosen arbitrary criterion

- False alarm is set to 10%
- 90% probability
- $\rightarrow$ Likelihood ratio > 90% in at least 90% cases

Outline

Detection sensibility

Simulation

Simulation parameters

- 1 detector in a given luminosity $\mathcal{L}$
- Reactors randomly placed around the detector
- For each reactor, likelihood ratio method is applied
- We assume the reactor is detected when detection follows the previous criterion

Detection sensibility

Simulation

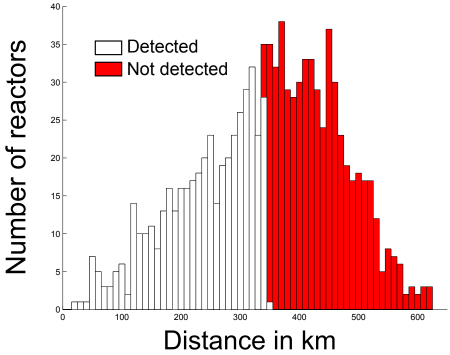


FIGURE: Detection sensibility for 5000 rnu luminosity.

Detection sensibility

Detection distance

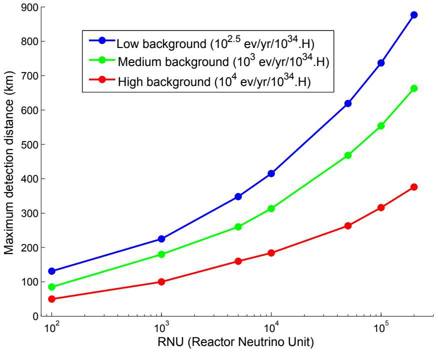


FIGURE: Detection distance for high, medium, and low background cases.

Detection sensibility

Detection law

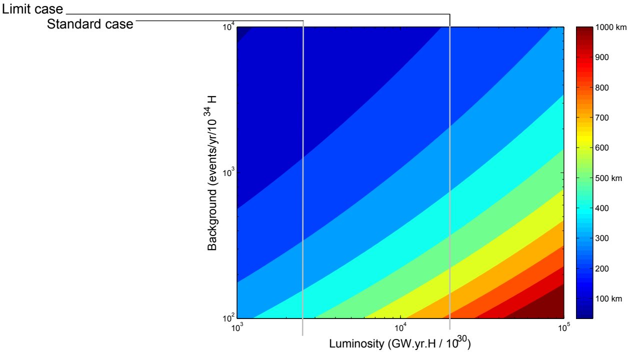


FIGURE: Detection distance as a function of luminosity and background level.

Outline

Localisation

Principle

Localisation steps

1. Detectors patrol around the world. One of them detects a rogue activity.
2. Several detectors move towards the area, and take data to determine a more accurate area to monitor.
3. Detectors get closer to accurately monitor the area, and give a possible location of the rogue reactor.

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Localisation

Algorithm

SNIF algorithm (single data set)

- SNIF maps the area with potential reactors, and reiterates around the 5 best fits of the previous mapping.
- We obtain a potential location, around which we draw confidence level contours

Localisation

Once user is convinced there is a rogue activity, SNIF is used for first and second localisation monitoring.

Examples

Examples

Disclaimer

These examples are arbitrary examples and were chosen for their pedagogic parameters.

Localisation

1^{st} example

Example 1 : West Africa.

- Low background
- 600 MW
- 10^{34} protons / detector

Localisation

1^{st} example - First step

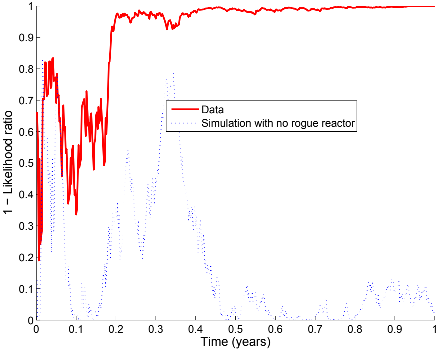

FIGURE: Rogue activity likelihood through time. 350 km - 6000 rnu/yr

Localisation

1^{st} example - Second step

FIGURE: 6 months observation

Localisation

1^{st} example - Second step

Detector	Events	BG(th)	R(th)	CL
1	233	226.26	6.52	0.11
2	257	217.59	37.93	0.97
3	232	227.19	16.89	0.06
4	228	239.68	6.75	0.23

Localisation

1^{st} example - Third step

FIGURE: 1 year observation

Localisation

1^{st} example - Third step

Detector	Events	BG(th)	R(th)	CL
1	500	442.2532	32.79	0.97
2	501	440.93	51.73	0.98
3	564	454.91	112.78	1
4	512	453.92	83.86	0.97

Localisation

2^{nd} example

Example 2 : Sri Lanka.

- Medium background
- 500 MW
- 10^{34} protons / detector

Localisation

2^{nd} example - First step

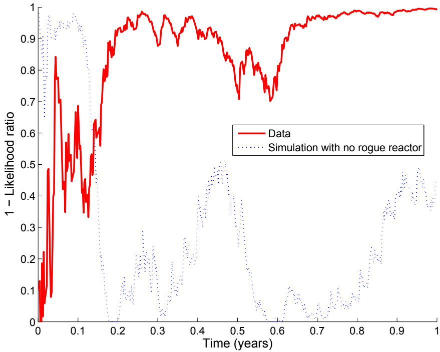

FIGURE: Rogue activity likelihood through time. 250 km - 5000 rnu/yr

Localisation

2nd example - Second step

FIGURE: 6 months observation

Localisation

2nd example - Second step

Detector	Events	BG(th)	R(th)	CL
1	329	272.75	66.39	1.0
2	364	239.57	52.52	1.0
3	433	226.34	200.61	1.0
4	304	211.79	84.90	1.0

Localisation

2^{nd} example - Third step

FIGURE: 1 year observation

Localisation

2^{nd} example - Third step

Detector	Events	BG(th)	R(th)	CL
1	790	468.18	340.16	1.0
2	21	424.39	364.57	1.0
3	934	439.81	574.27	1.0
4	913	499.19	424.62	1.0

Outlook

- Detection distance : few 100 km for 5000 rnu
- 1 detector gives good confidence after a few months
- Localisation possible but not always accurate
- Regular reactor background influence
- We are working on detector background handling, and design

Thank you for listening