

Hisparc cosmic ray detector's response to heavy rain.

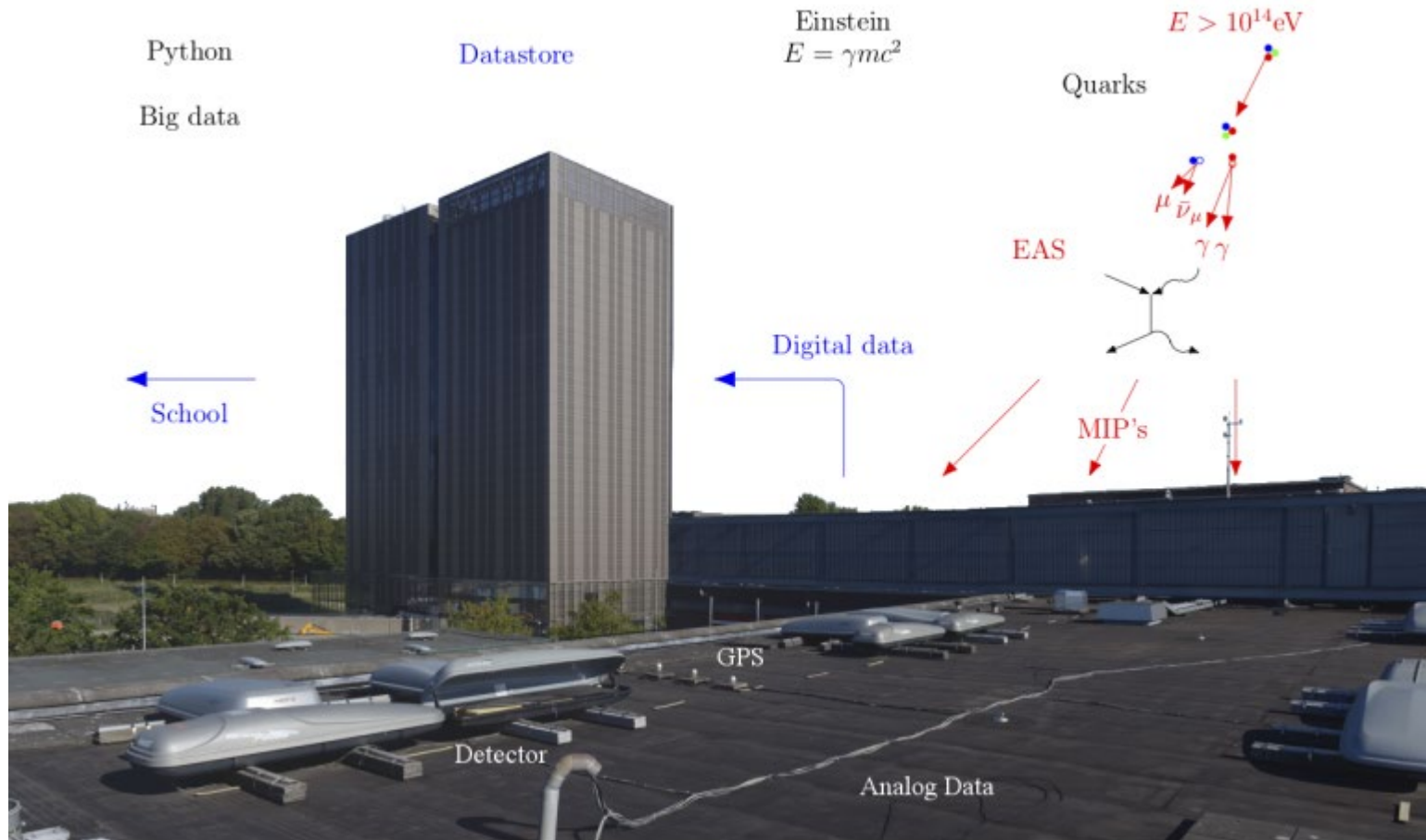
Alexander.P.J. van Deursen, David Fokkema¹,
Kasper van Dam¹, Bob van Eijk¹

¹ Nikhef, Amsterdam



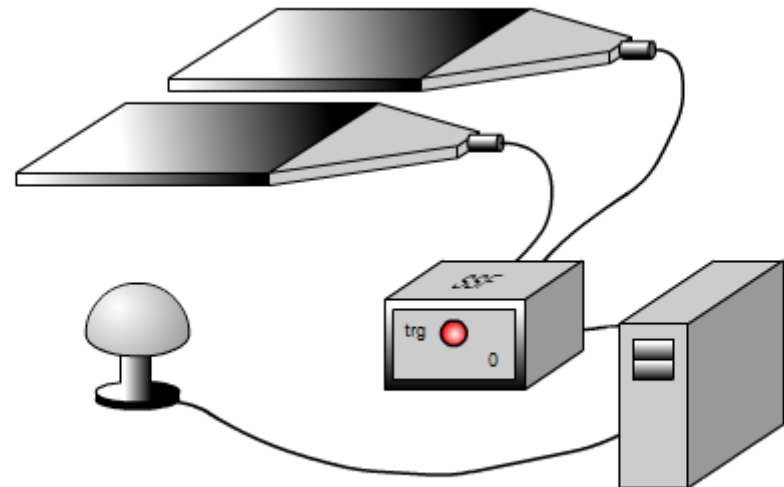
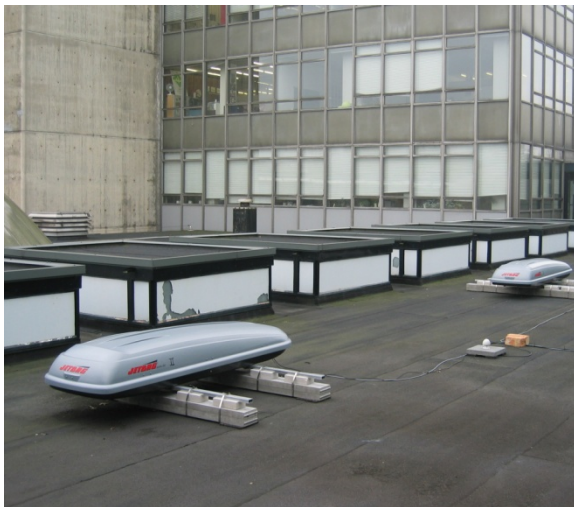
High School Project on Astrophysics Research with Cosmics

From www.hisparc.nl



Hisparc

- Cosmic ray detectors built by high-school pupils, installed on school roofs. Hardware parts & software provided by Nikhef
- Set of 2 or 4 plastic scintillators (0.5 m² x 2 cm thickness) with photomultipliers in roof boxes, signals recorded on coincidence (trigger matrix), with GPS timing
- Over 100 stations, majority in NL, other countries as well
- All data storage at Nikhef, open access for participants



See: <https://doi.org/10.1016/j.nima.2020.163577>

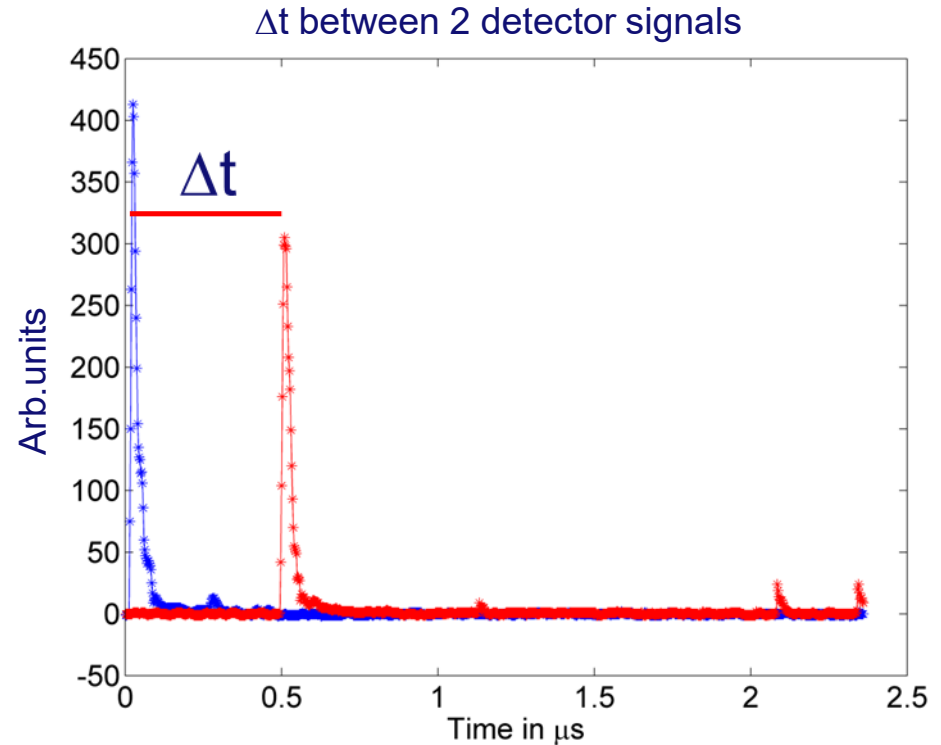
Hisparc, 2 detector system

Each scintillator detector PMT sensitivity set for about $n = 300$ hits/s

Coincidences of 2 detectors within $\Delta t = 1.5 \mu\text{s}$ saved as event

Averaged event rate about of 10^3 per hour

Cosmic air showers: majority with $\Delta t \leq 0.2 \mu\text{s}$



Two stations in Eindhoven, 14-15 July 2010

Response to heavy rain*:

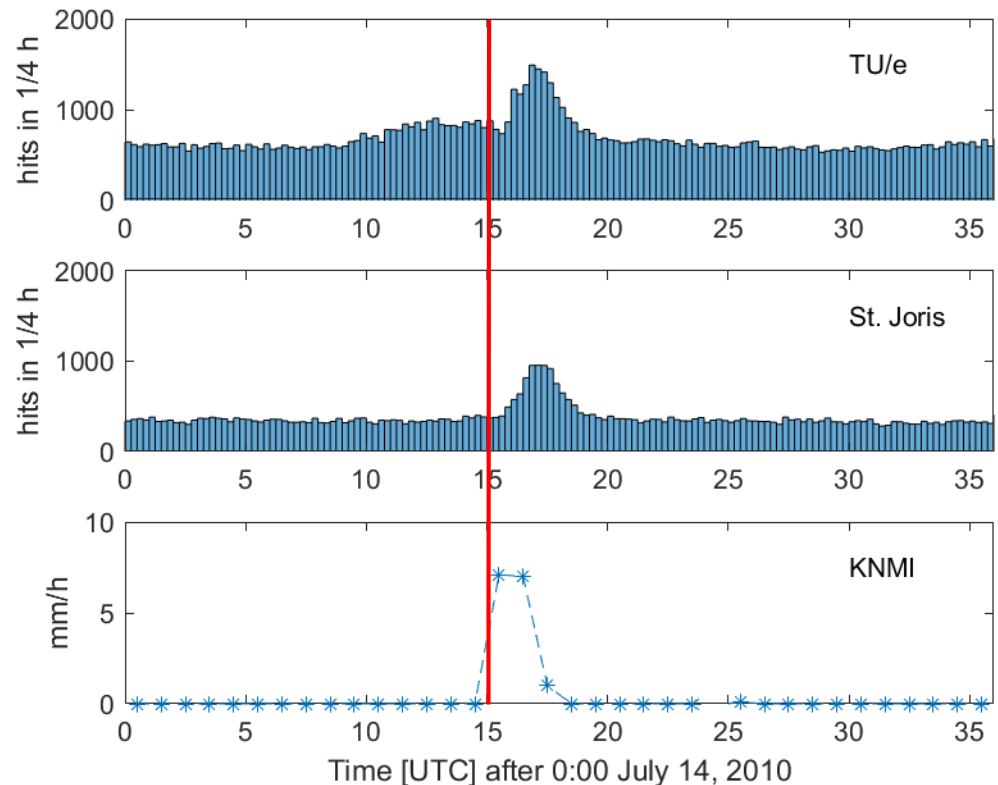
TU/e North of St. Joris,
4.5 km apart

Hisparc normal event rate up
to about 15:30

KNMI weather station at
airport (W), hourly records

Rain starts between 15:00
and 16:00 (red line)

Hisparc event rate increase
strongly correlates to rain
after 16:00



KNMI: Koninklijk Nederlands Meteorologisch Instituut

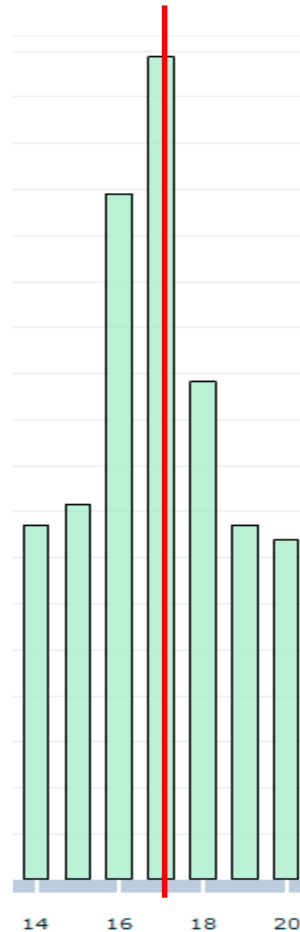
*) See e.g. Martijn Westerink rolwolk <https://www.youtube.com/watch?v=qyWSKgpfF7U>

Severe weather sweeps 220 km from SW to NE in about 2.5 hours

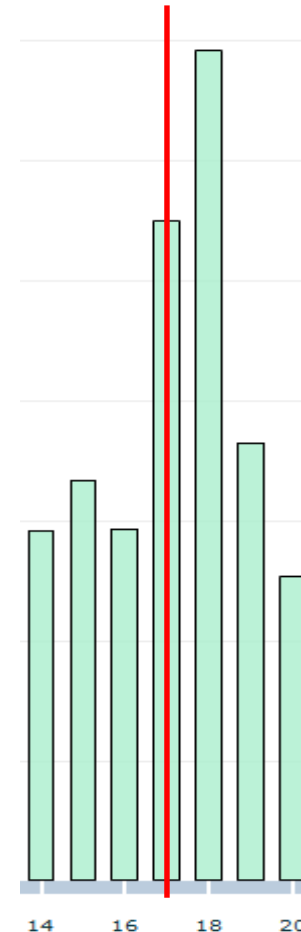
Cosi fan tutte



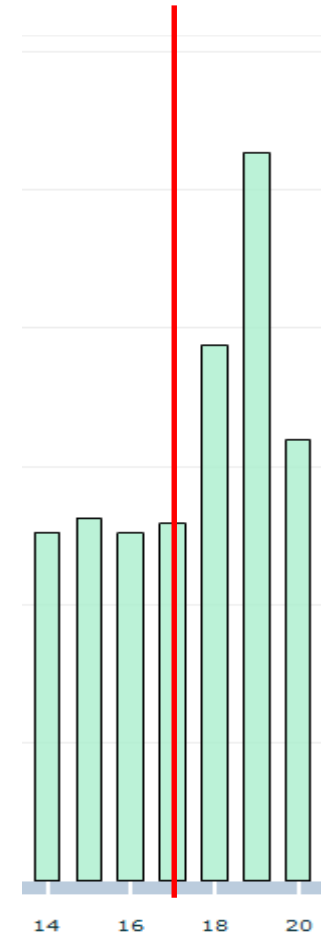
wikipedia.org



Eindhoven



Enschede



Groningen

Lightning gamma photons involved?

Base hisparc event rate:
approx. 1.3k per 30 min

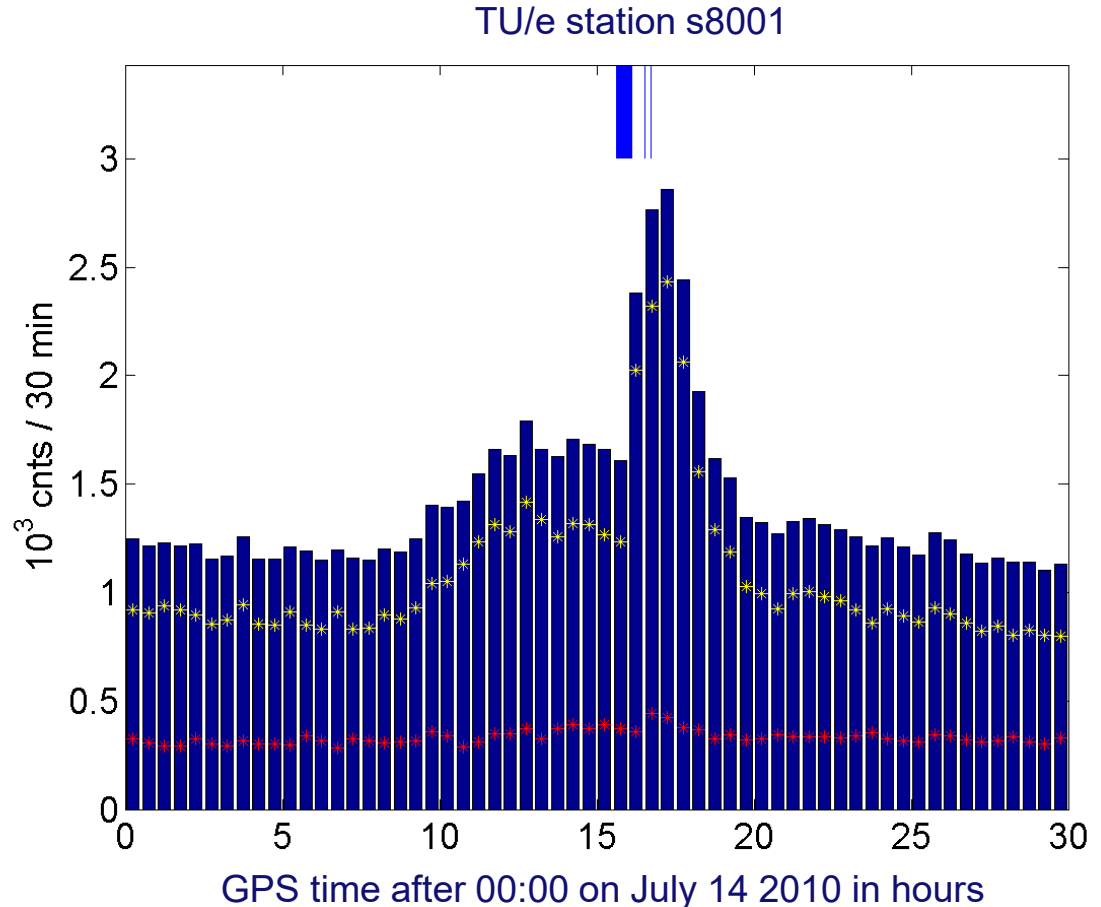
Lightning produces γ s, near to
instantaneous bursts, which
could cause event in Hisparc.

KNMI lightning within 4 km
from TU/e (s8001) indicated
by blue markers on top

Conclusion:

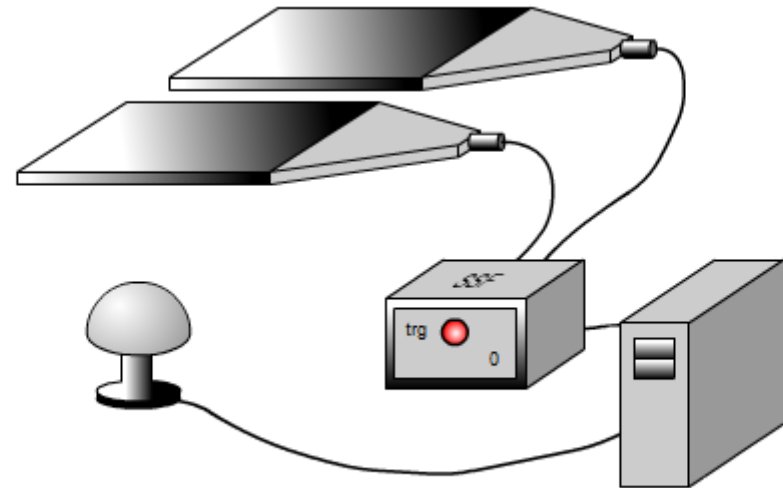
If lightning then

- hit-frequency too high
- decay time too long
- unrealistic photon energy required



Hisparc response?

A hisparc event record requires coincidence of both detectors within $\tau = 1.5 \mu\text{s}$



Assume n_1 & $n_2 \approx 300$ hits/s on each plate, uncorrelated

Random coincidences within $\tau = 1.5 \mu\text{s}$:

$$C = 2 n_1 n_2 \tau \quad \text{or} \quad \approx C = 0.27/\text{s} \text{ or } 10^3/\text{h}$$

In 2010 $n_{1,2}$ not in database yet!

Hisparc TU/e data detail

Determine Δt between both detectors & divide $1.5 \mu\text{s}$ in 15 blocks of 100 ns

Show Δt distribution over hisparc events (in number per half hour) after 0:00 July 14 2010

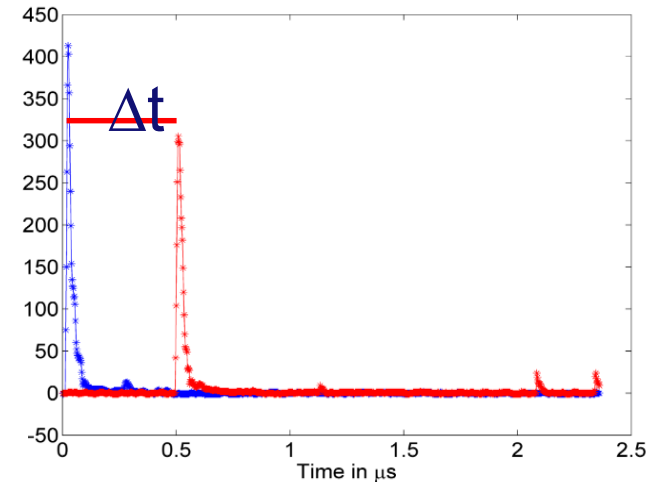
No thunderstorm:

$\frac{1}{4}$ fraction occurs in $\Delta t < 100 \text{ ns}$,
 $\frac{3}{4}$ in $\Delta t > 100 \text{ ns}$

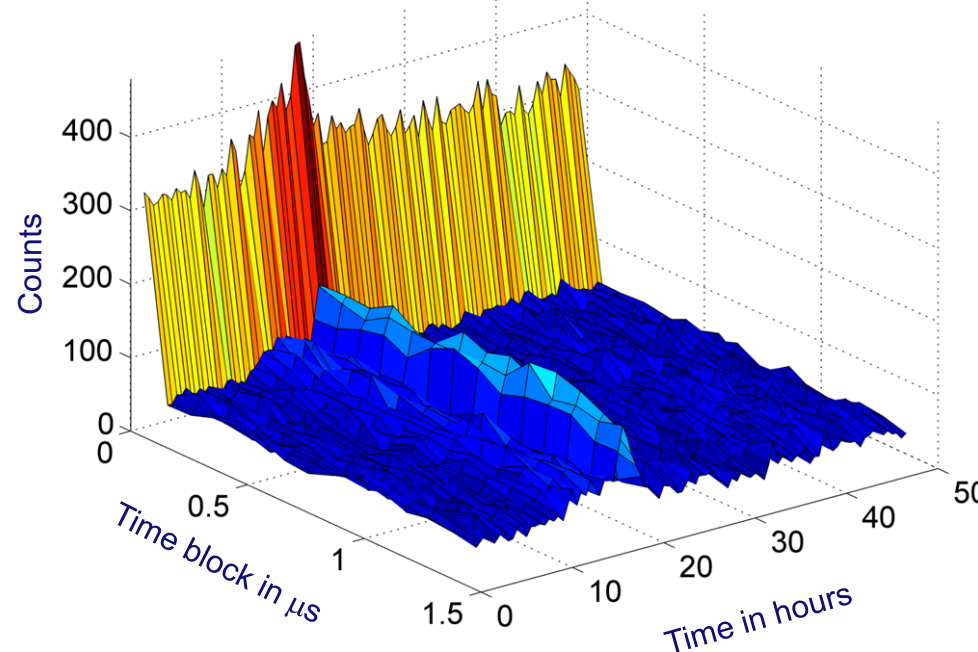
This storm @ TU/e:

Factor 1.6 / 2.5 increase event rate
for $\Delta t > 100 \text{ ns}$

Similar rise in block $\Delta t < 100 \text{ ns}$



Δt distribution variation over time



Radioactive decay of radon daughters

Thesis R. Blaauboer & R. Smetsers:

“Variations in outdoor radiation levels in the Netherlands”

Sources: Rn daughters rain-out and wash-out of the atmosphere

Two isotopes with approx. 20 min. decay time

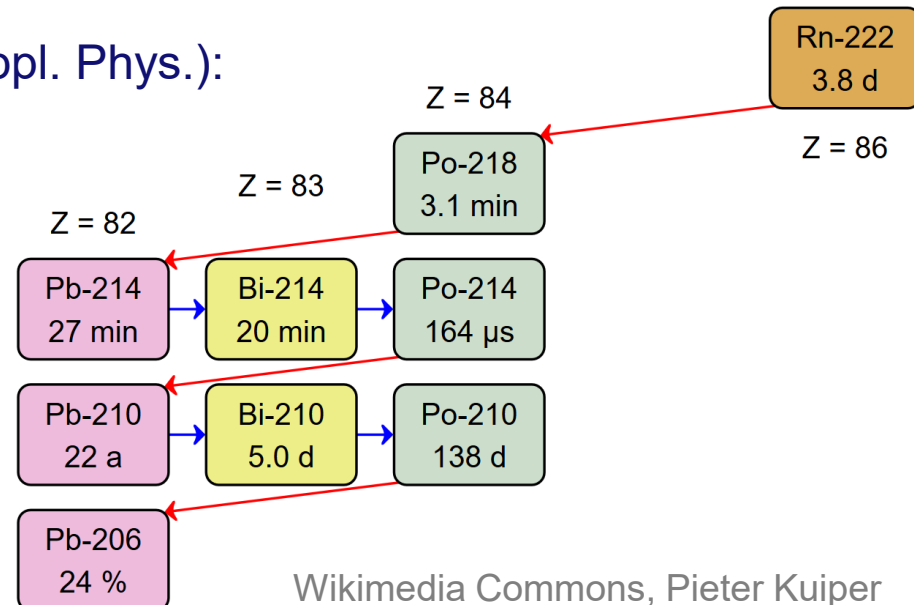
Papers by M.B. Greenfield (J. Appl. Phys.):

In 2003 C, N, O, Ar

In 2008 Rn daughters

α : He^{2+}

β : e^{-}



R.O. Blaauboer & R.C.G.M. Smetsers, Thesis University Groningen 1996

Greenfield 2009: γ -spectrum of fresh rain

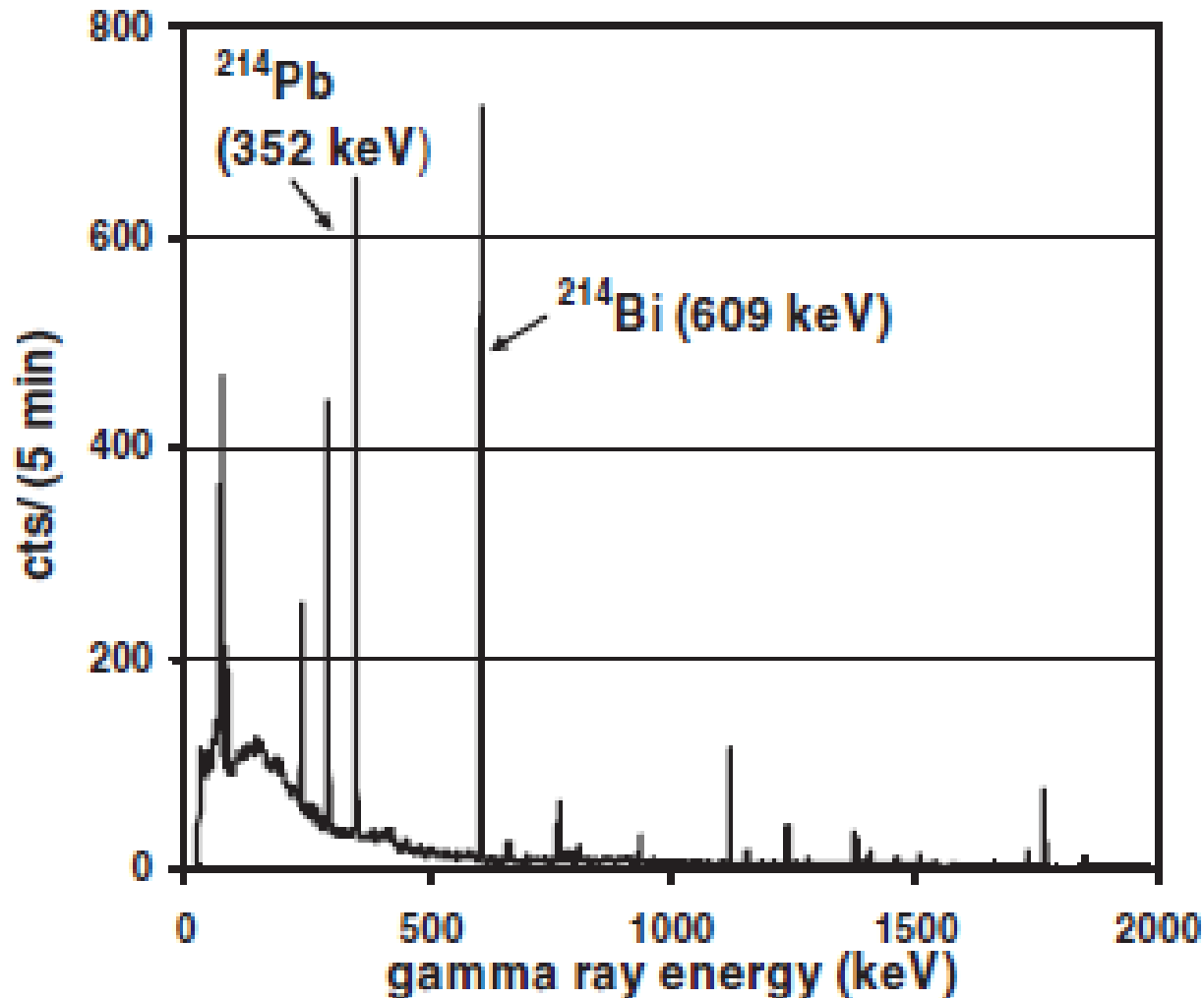
γ -radiation from:

^{214}Pb $t_{1/2}$ 26.5 min

^{214}Bi $t_{1/2}$ 19.9 min

Records by hisparc due to
Rn daughters in rain
water.

Duration of increased
event rate determined by
decay times and by
stagnation time of water
on roofs after shower



And then something special

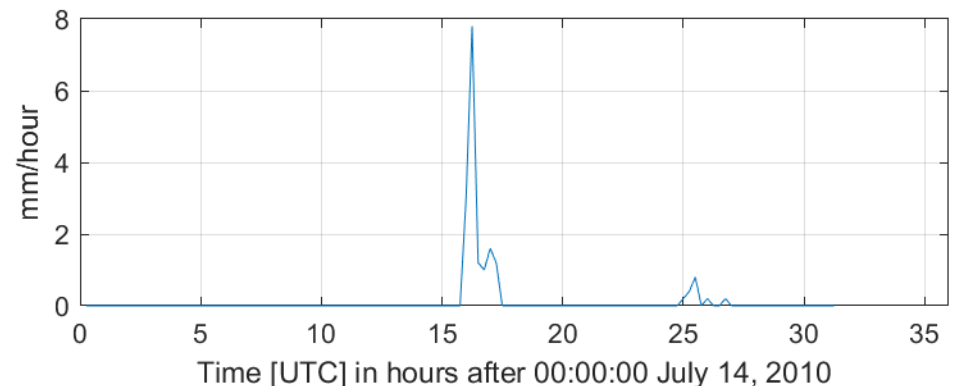
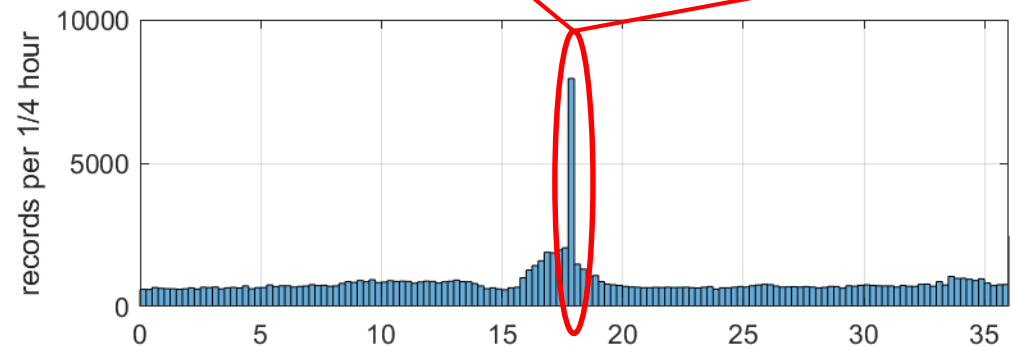
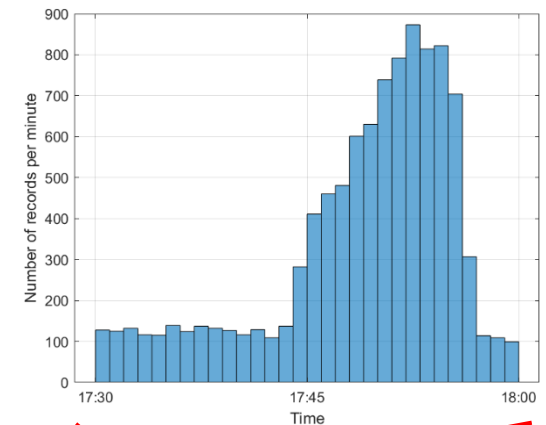
Tilburg KWII (s8101) with weather station:

Records increase at 15:45, start with rain as in other stations.

Sudden huge increase at 17:44 after rain, on top of behavior similar to other stations

Rise time approx. 5 min., fast decay in 3 min

Not explained yet



Result of analysis

Background due to random events, in part of cosmic origin

Within first 100 ns: $\frac{1}{4}$ of hisparc events are predominantly of cosmic origin

Increased background due to rain-out and wash-out goes with increase in hisparc response

TU/e: increase by a factor of 1.6 / 2.5

KW II: a factor of 2.7 / 7

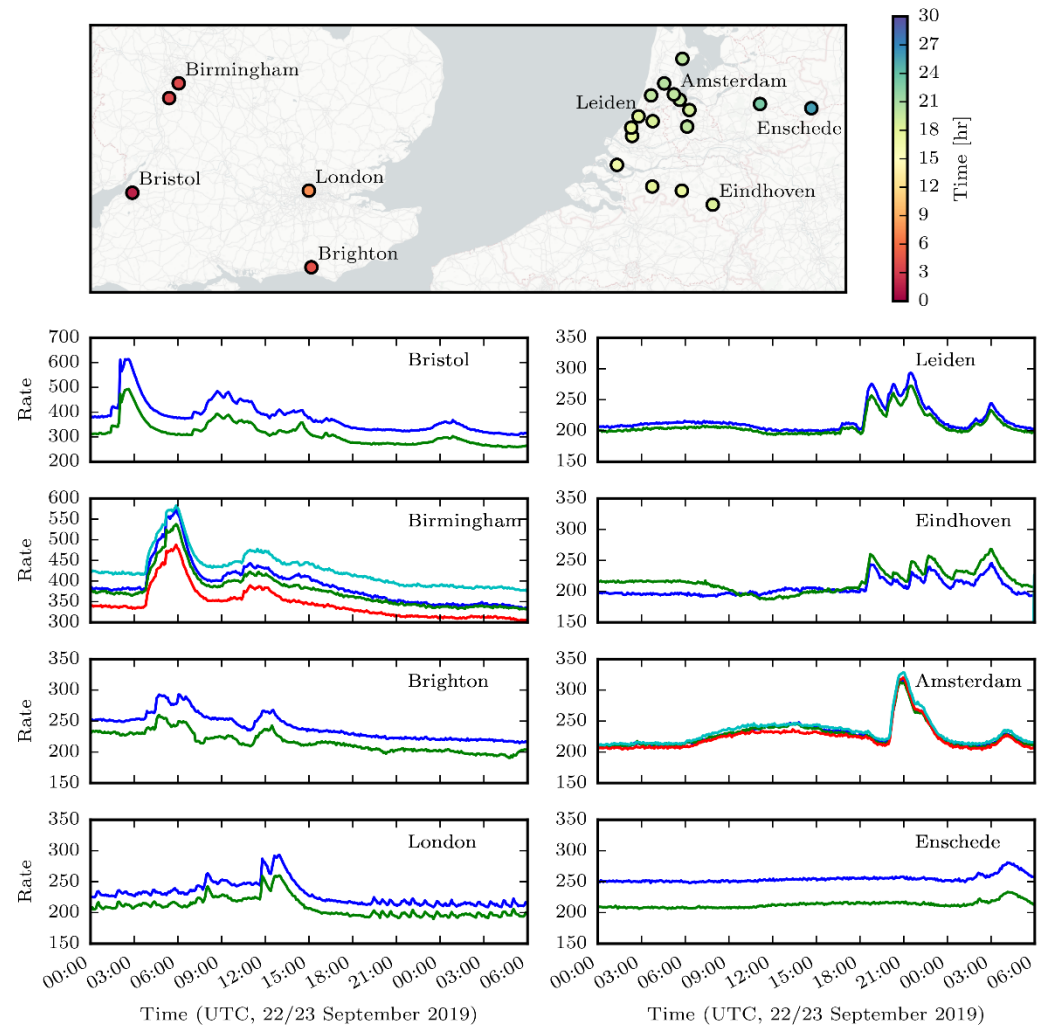
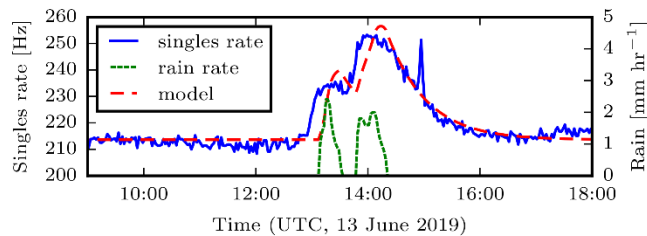
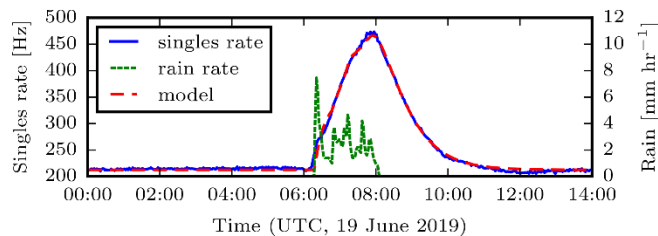
Decay consistent with $t_{1/2}$ of ^{214}Pb en ^{214}Bi

A modern analysis with known single rates

(Kasper van Dam, under review)

Right: Single rates for 8 stations during the passing over of a weather front from the West.

Below: **rain rate** and **fitted single rate** (dashed) model with ^{214}Pb and ^{214}Bi collected by rain (Amsterdam data)



Conclusion

- Increased response of hisparc can be explained by rain-out and wash-out of ^{214}Pb and ^{214}Bi isotopes
- Other similar applications of hisparc?
- Analysis can be extended to other days, all detectors. Suitable for hi-school pupils?
- Gamma spectrum is not measured (yet).
- n_1 and n_2 now in database
- What happened in Tilburg KWII 14/07/2010?

The authors thank all schools involved in the hisparc project.

For a list see: https://data.hisparc.nl/show/stations_by_country/