The "buzz" words since the European council meeting in Lisbon in 2000

- Innovation
- Science
- Technology
- Public awareness
- Education

However…

At the age of 15/16, majority of high-school students:

- Has not yet decided on future career
- Is highly susceptible to trends and gets easily bored
- Has 'basic' knowledge of math, chemistry, biology and physics
- Is comfortable with information technology and learns quickly

Challenge them…

…and change the image of science & technology…

Young talent, the Dutch perspective…

- In the Netherlands, high-school students (age: 12 – 18 years) may graduate in:
  - Humanities
  - Social sciences & Economics
  - Natural- & Health sciences
  - Natural science & Technology

- 40% of all high-school students selects a natural science profile

Young talent, the Dutch perspective…

Only 1% decides to study Physics or Technology (Math even less) at University level…

…so, for the best of Dutch (European) society, we have a ‘mission’!

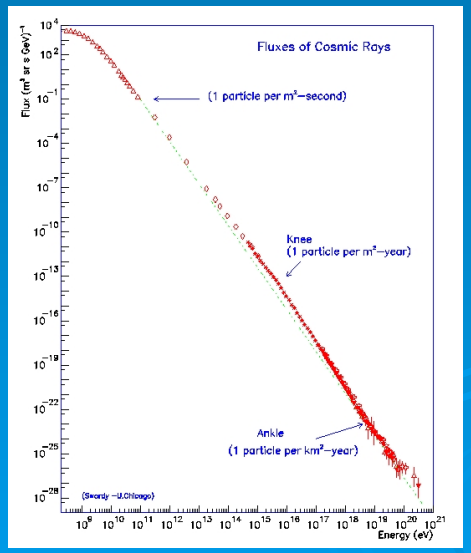
A new idea (2002), a new approach (2004)…

- Offer participation in a 'state-of-the-art', long-term, scientific experiment (> 10 yrs)
- Create collaboration among high-school students & teachers and scientists
- Present high-school students and teachers with appealing (modern) material & scientific questions
- Offer teachers support and options for post-academic education (part-time)

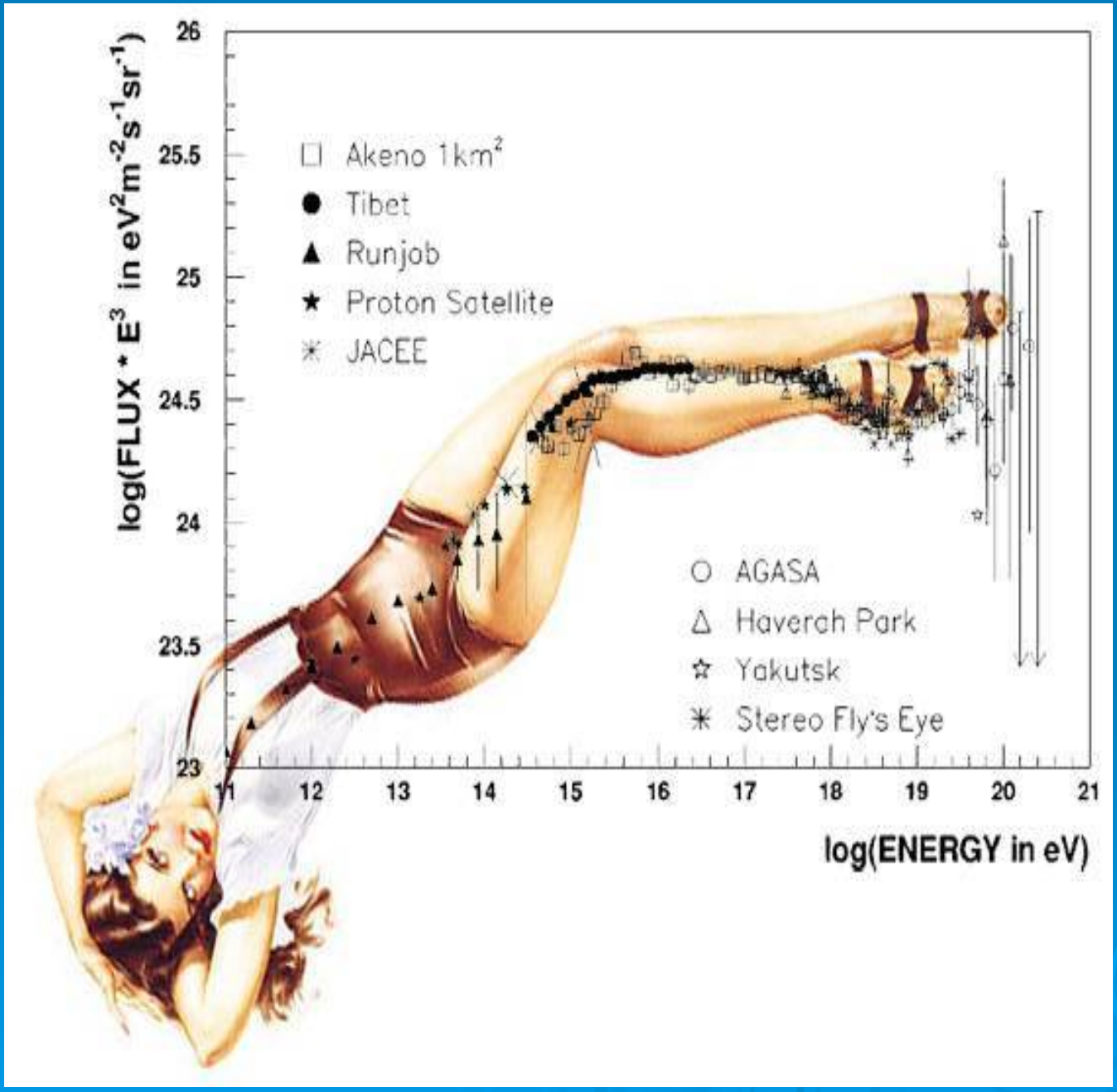
A modern scientific collaboration…with high-school student and teacher as researchers…

Some (ambitious) scientific questions:

- How many cosmic particles with an energy above 10^{15} eV reach our earth's atmosphere?
- Where do these extremely energetic particles come from?
- Direction?
- Are there 'nearby' sources (that is; within our milky way) ?
- Can one measure the GZK- cut-off?
- Are there long range correlations between showers (Zatsepin - Gerasimova effect) ?



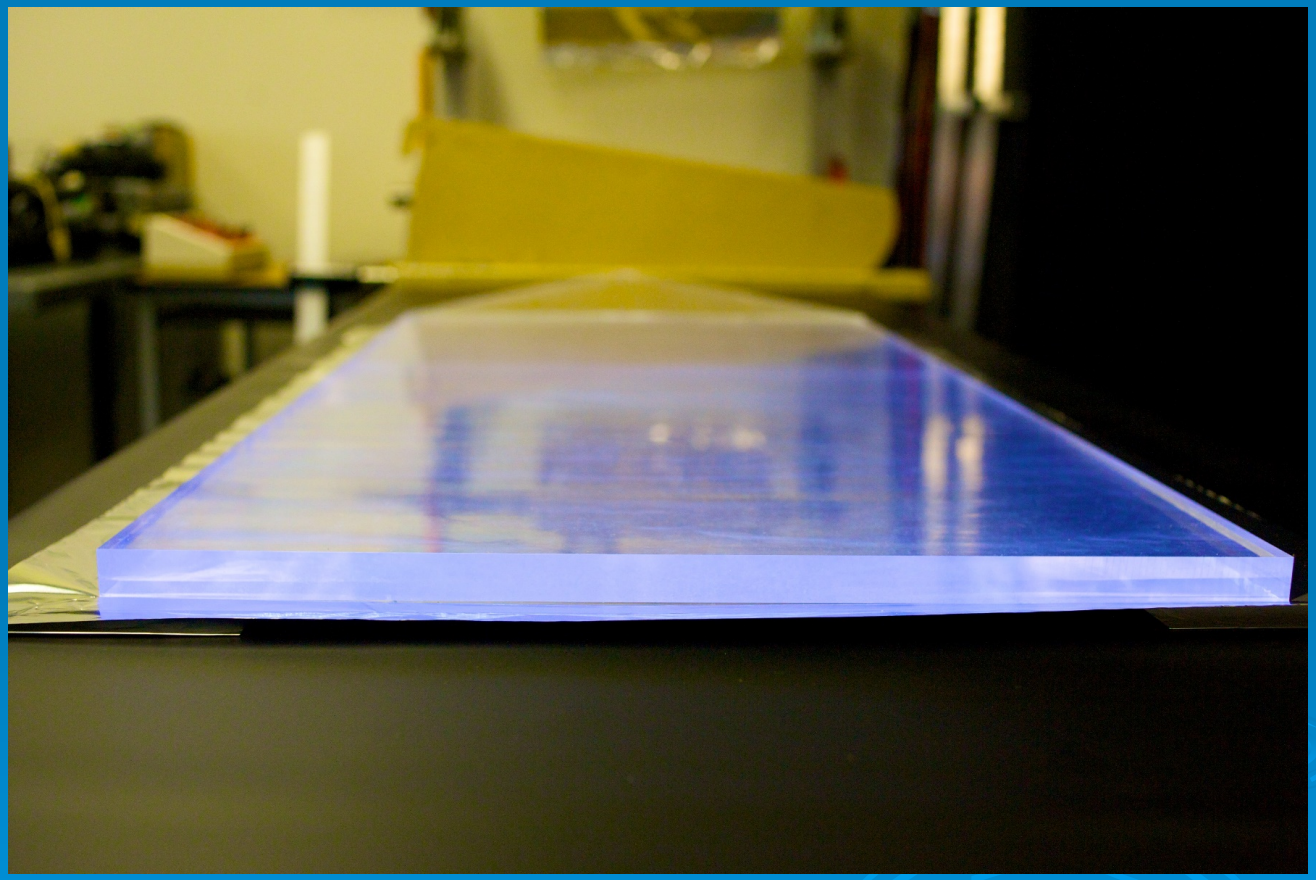
HiSPARC: Build high-school network for detection of cosmic ray air-showers…



HiSPARC detects showers beyond the knee' (~ 10^{15} eV)

HiSPARC single scintillator: 0.5 m^2

HiSPARC scintillator:
100 x 50 x 2 cm^3



Plastic scintillator: solution of organic scintillators (anthracene - fluor) in a solid solvent (polyvinyltoluene).

Single photomultiplier readout

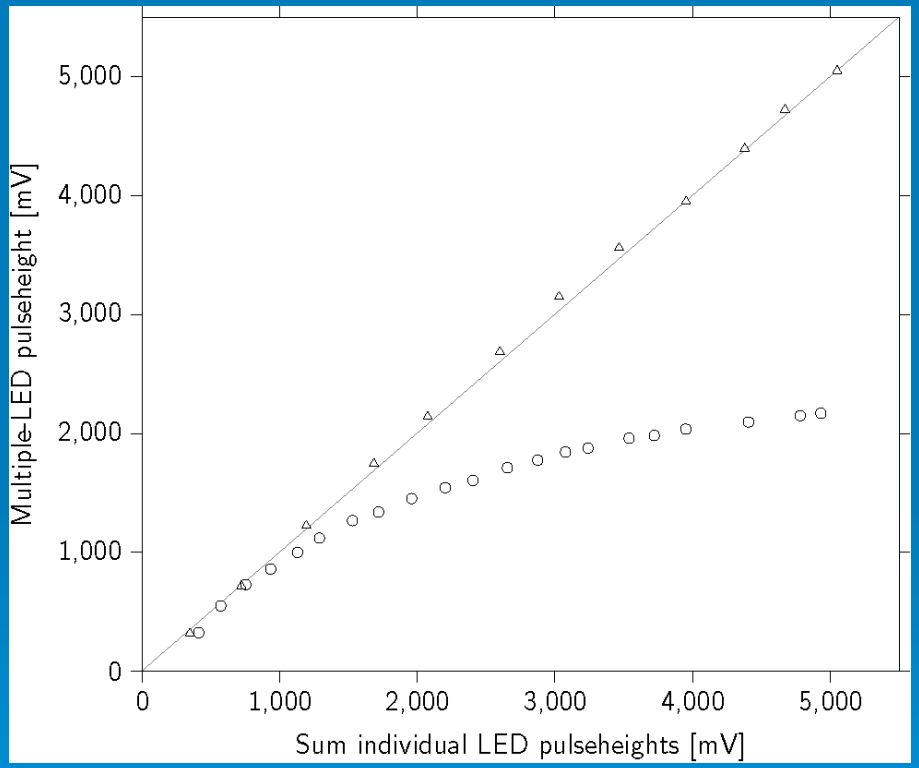
- Photocathode: bialkali, active diameter 25 mm
- Quantum efficiency (at peak wavelength 350 nm): 28%
- # of dynodes: 10 (11)
- Internal voltage converter ($12\,V \rightarrow 300 - 1800\,V$)

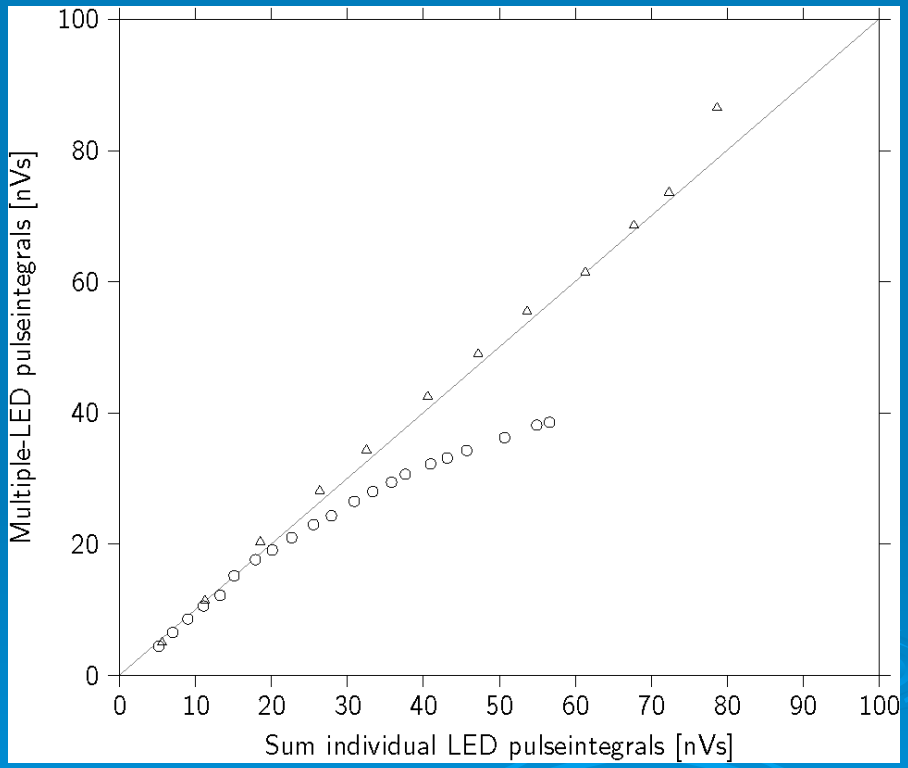
PMT in shielded enclosure

PMT glass tube removed

Photomultiplier response (pulse-height&integral)

- Commercial (Senstech) 'all-in-one' PMT vs Hamamatsu tube + Nikhef base:





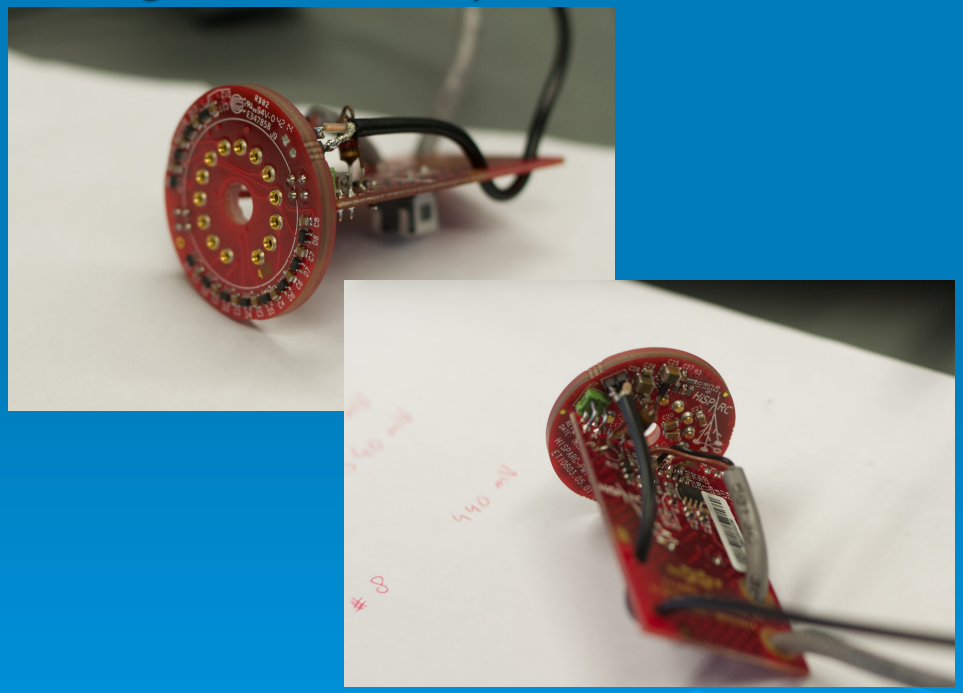
Sensetech (o):
Highly non-linear response!

Hamamatsu + Nikhef base (Δ):
Large range linear response!

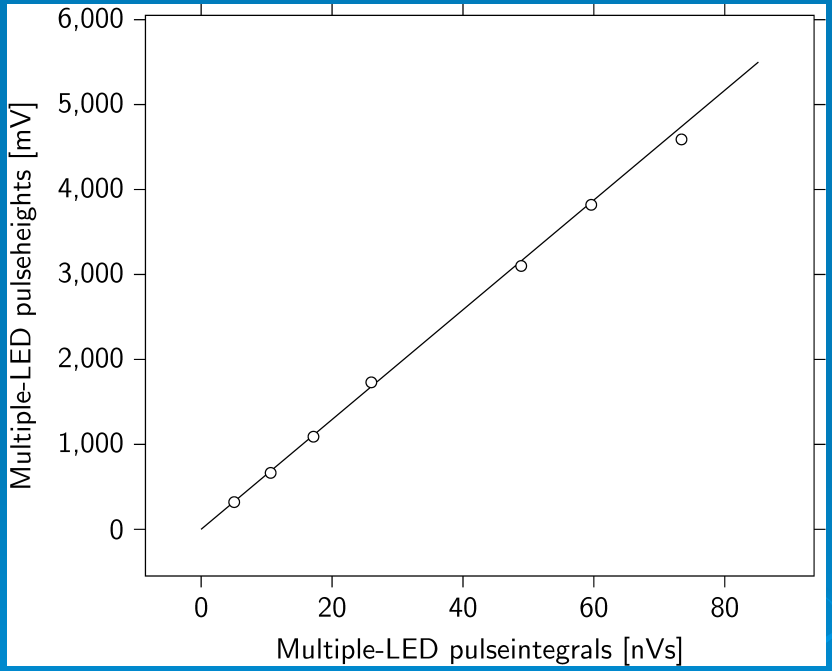
Photomultiplier response (pulse-height vs integral)

- Hamamatsu tube + Nikhef base:

High voltage converter using KM3NET-chip



Fast amplifier and 50 Ω impedance line-driver



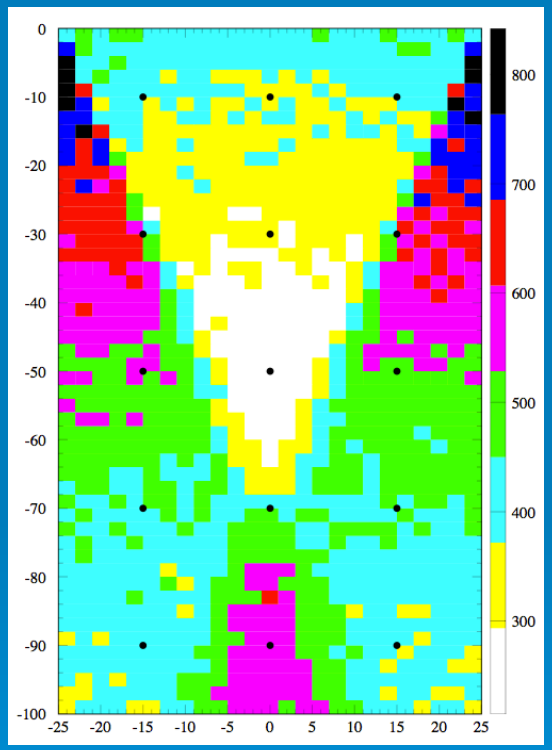
Hamamatsu + Nikhef base (o): Excellent linearity!

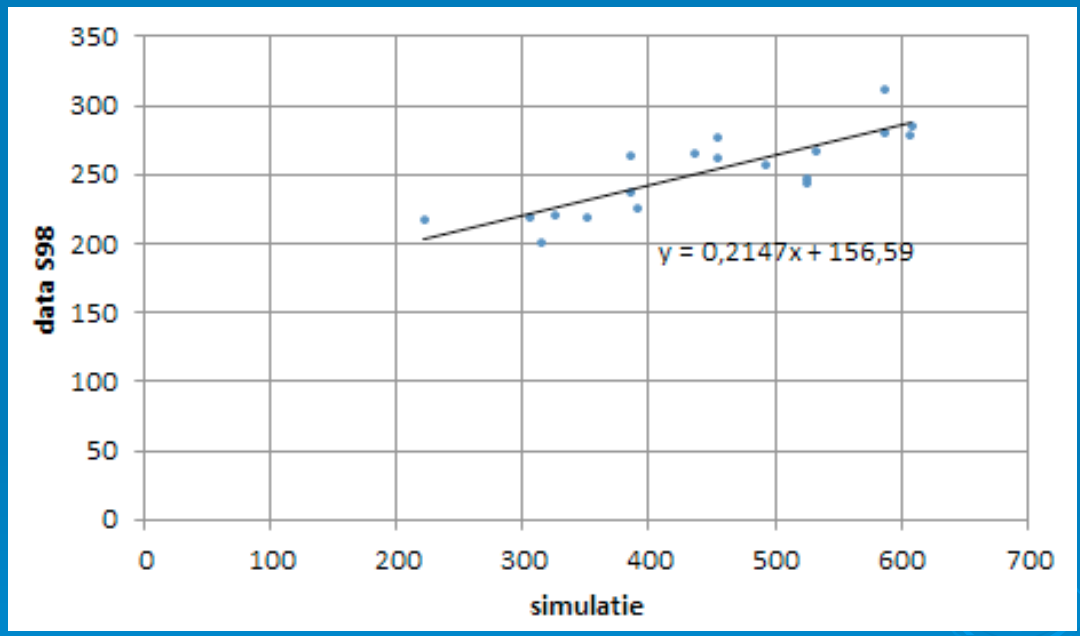
'Fish-tail' light guide and PMT-adapter

Plastic light-guide and PMT-adapter with same refractive index ($n = \frac{c}{v}, c_0^2 = \frac{1}{\varepsilon_0 \mu_0}$) as scintillator (and optical glue)

Scintillator signal response

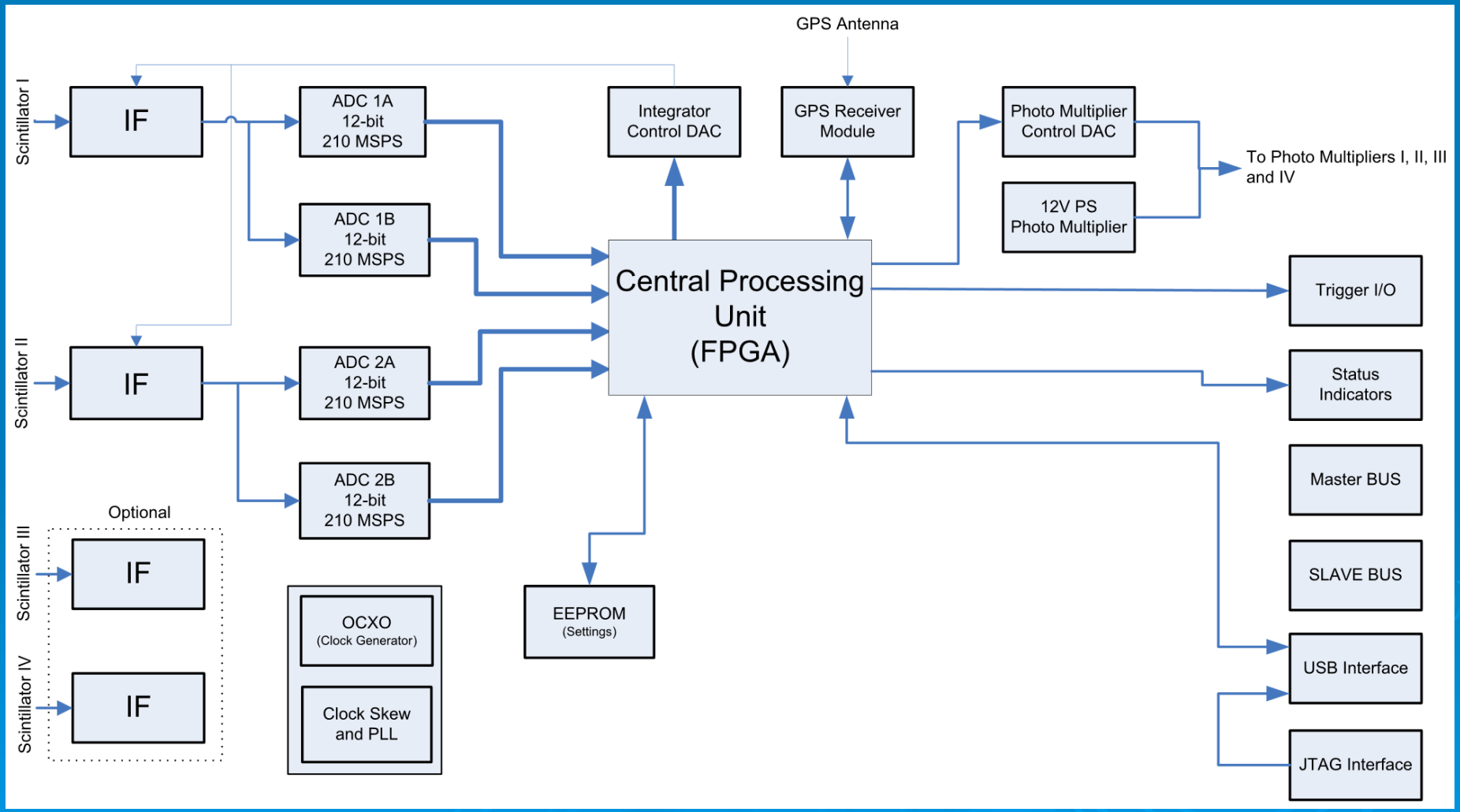
Simulation: # of photons arriving at PMT





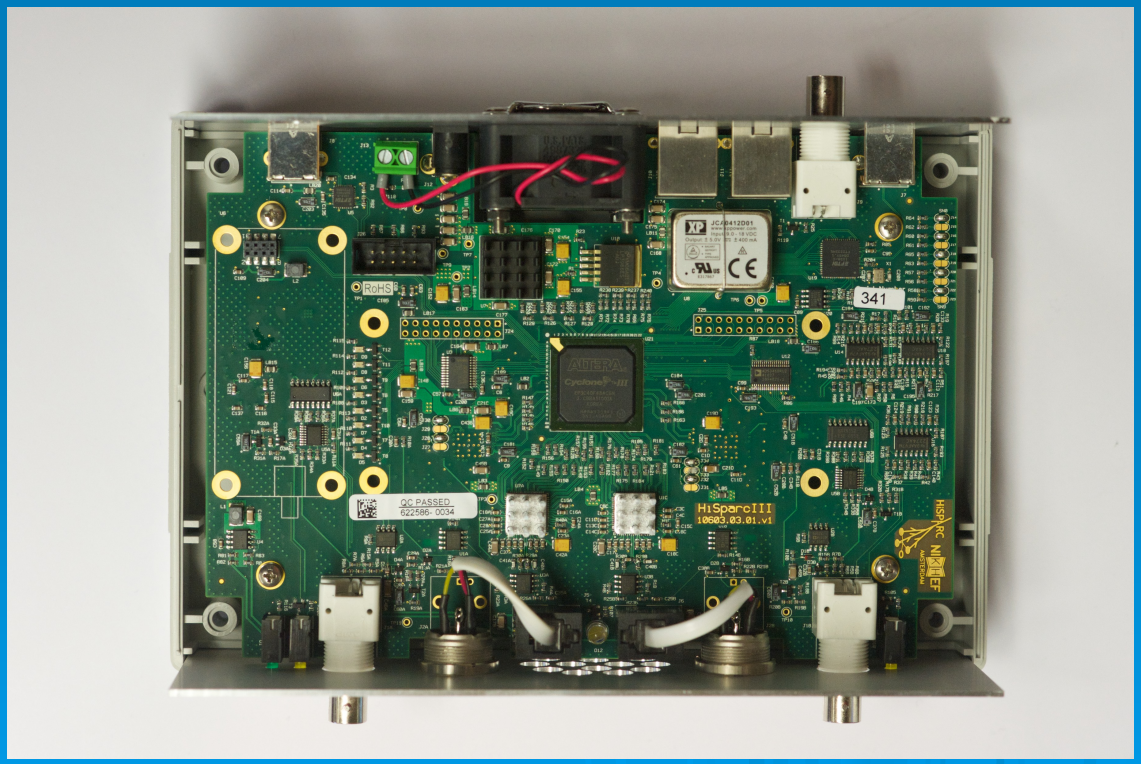
HiSPARC scintillator: 100 x 50 x 2 cm^3

DAQ electronics: 4-channel 400 MHz 12 bits oscilloscope



DAQ electronics units
('Master & Slave')

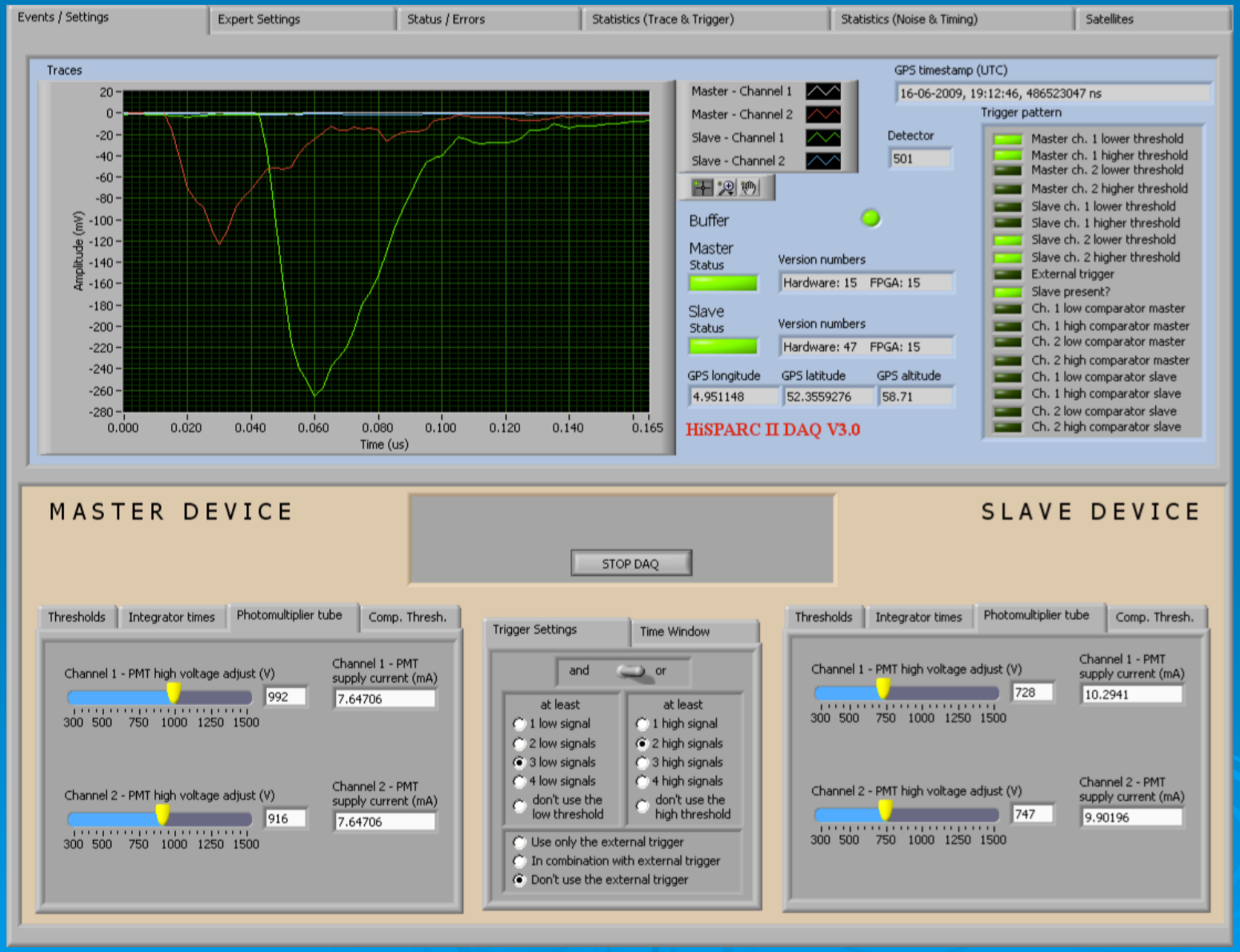
- 1 electronics unit has:
- FPGA
- 2 x 2.5 ns sampling 12 bits osc.
- power supplies & controls 2 PMTs
- 'piggy-back' GPS board (Master only; σ ~ 7 ns)



2 electronics units may run in Master/Slave configuration:

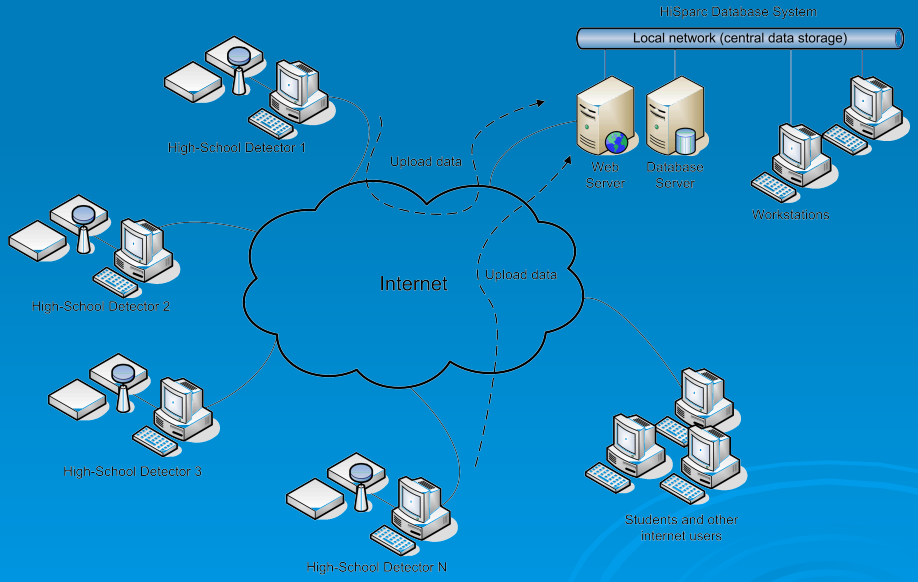
- 4 oscilloscopes
- drive & control 4 PMTs
- common GPS time-stamp
- 4-channel trigger matrix

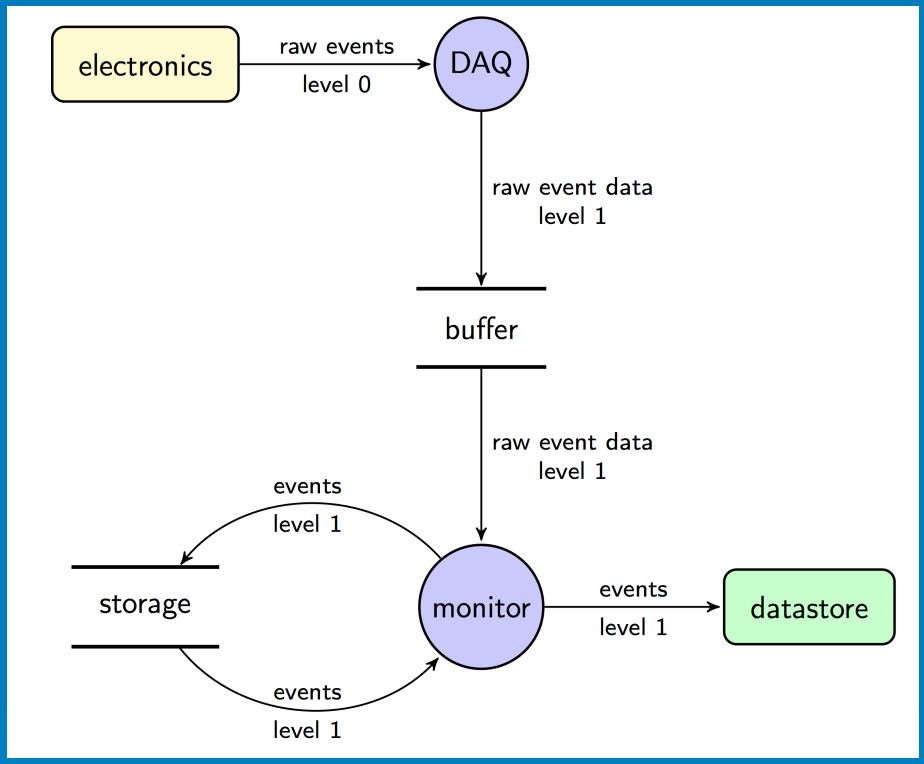
DAQ electronics control (LabView)
('Master & Slave')



Station steering software…

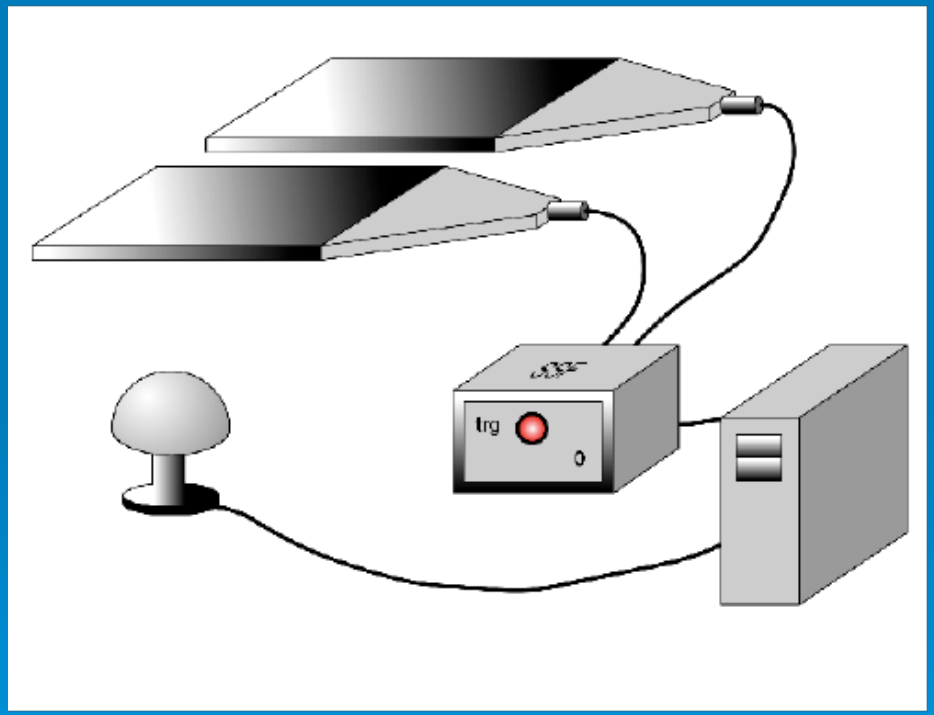
- local 'Monitor program' (Python)
- temporary local data storage
- internet service up? ship data 'real time' over internet to dataserver@Nikhef

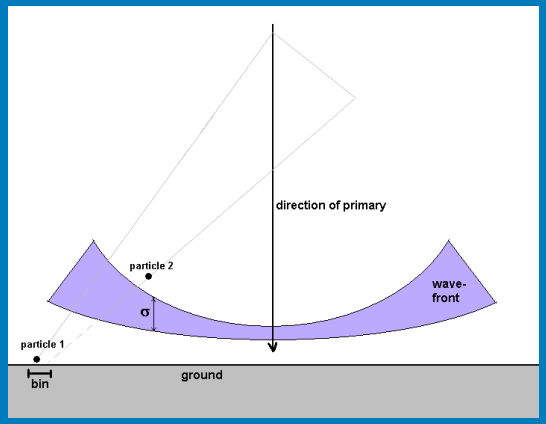


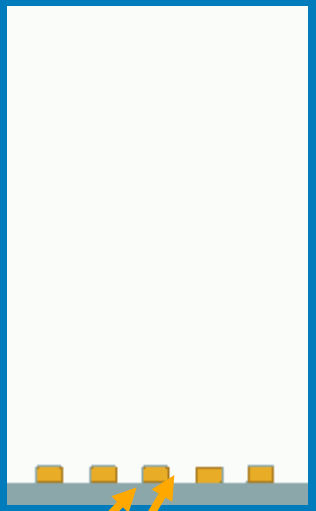


Grid of Cosmic Ray Detectors

Detect cosmic showers…

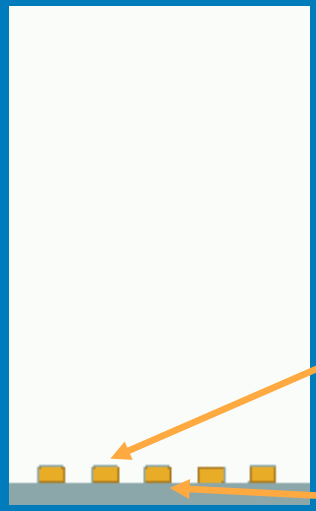


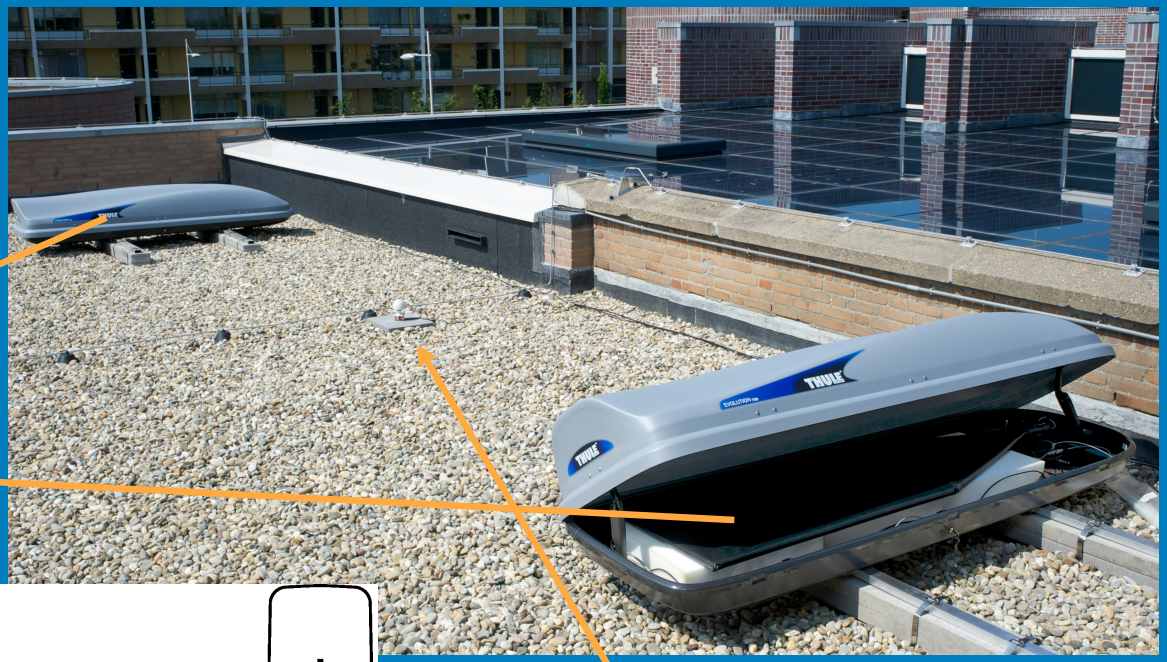


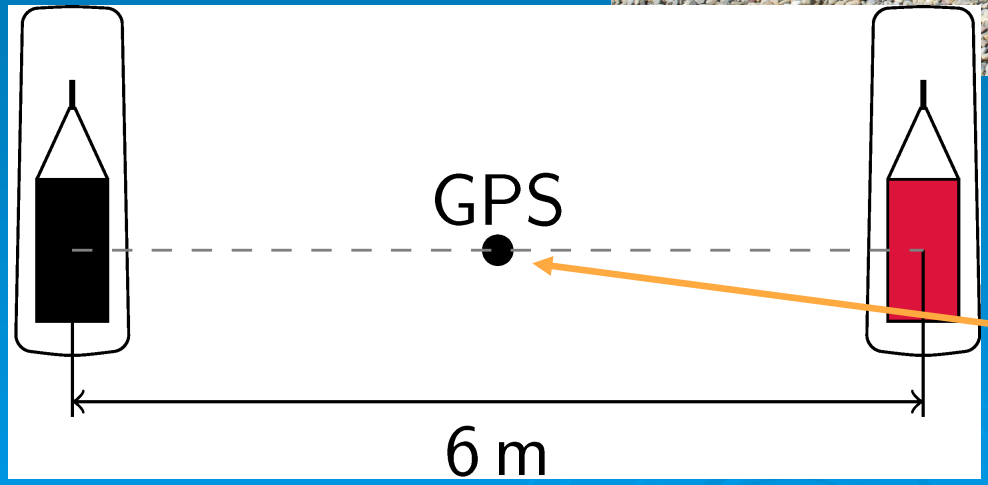


…with scintillator pairs and GPS'

HiSPARC Station with 2 scintillators
(minimum configuration)

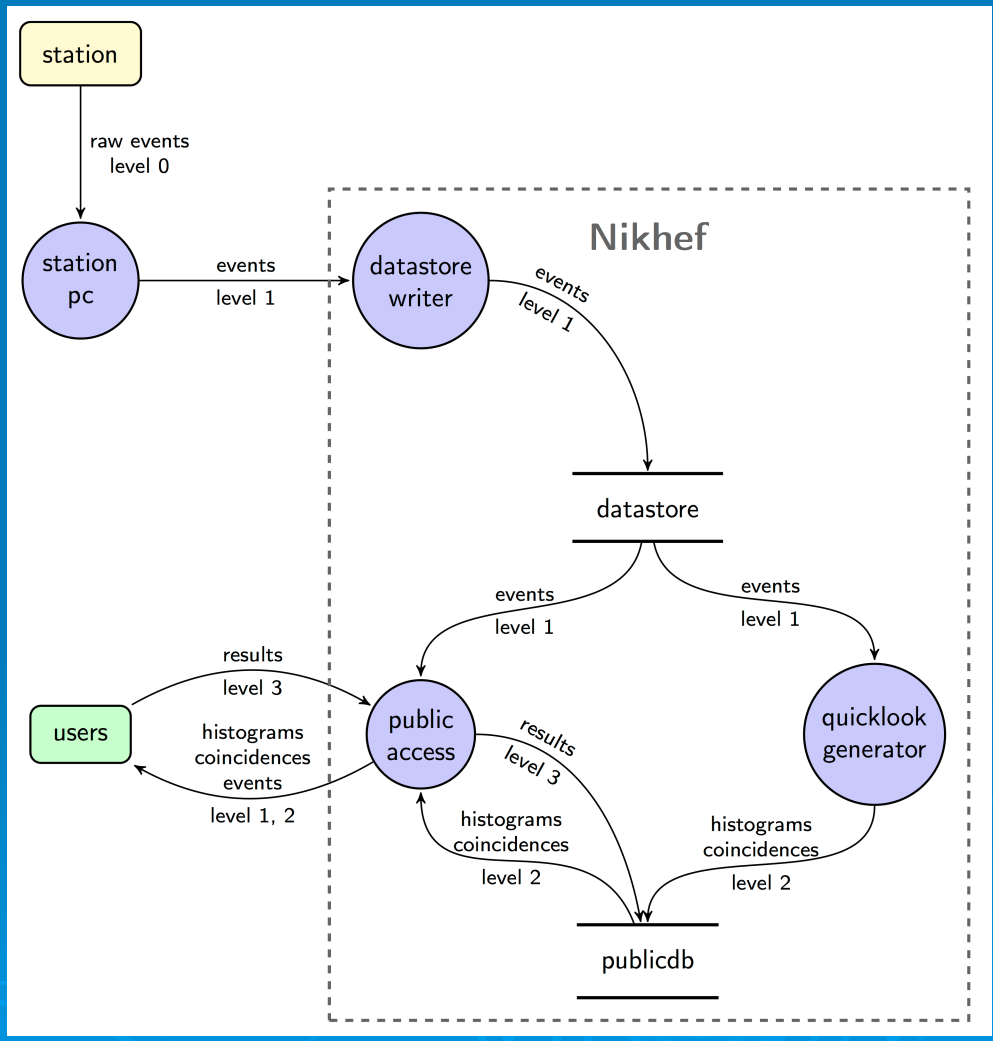






At the data store side…

- data 'arrival' server
- data store & backup (data raid)
- public (user) remote data access internet to 'derived' database with pre-processed data



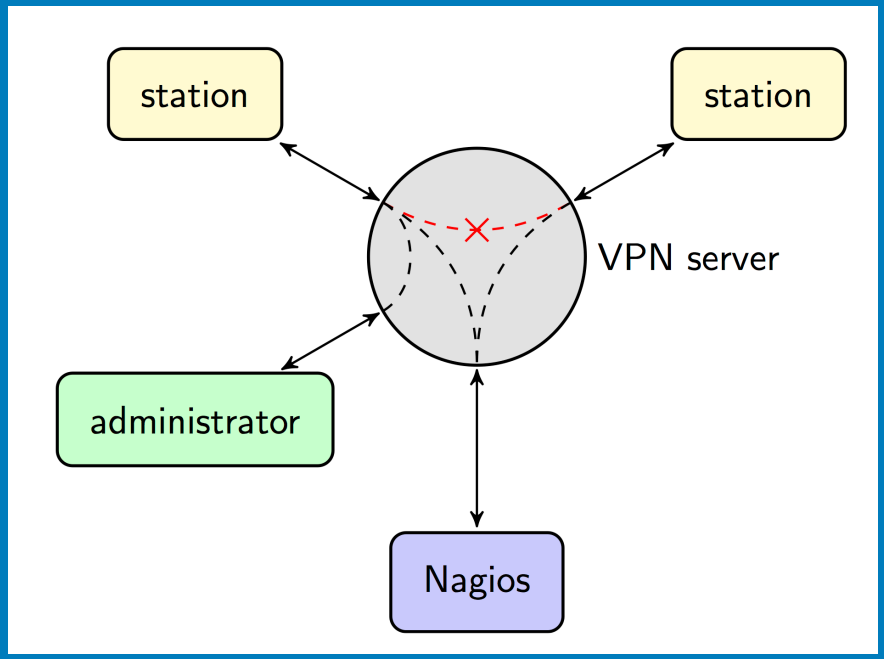
Remote monitor, access and control…

- NAGIOS monitoring (published on the Web)

- VPN (secure encryption)
- remote access to station

- access to LabView panel
- adjust settings
- analyse malfunctioning hardware/software

- remote software update (automatic)



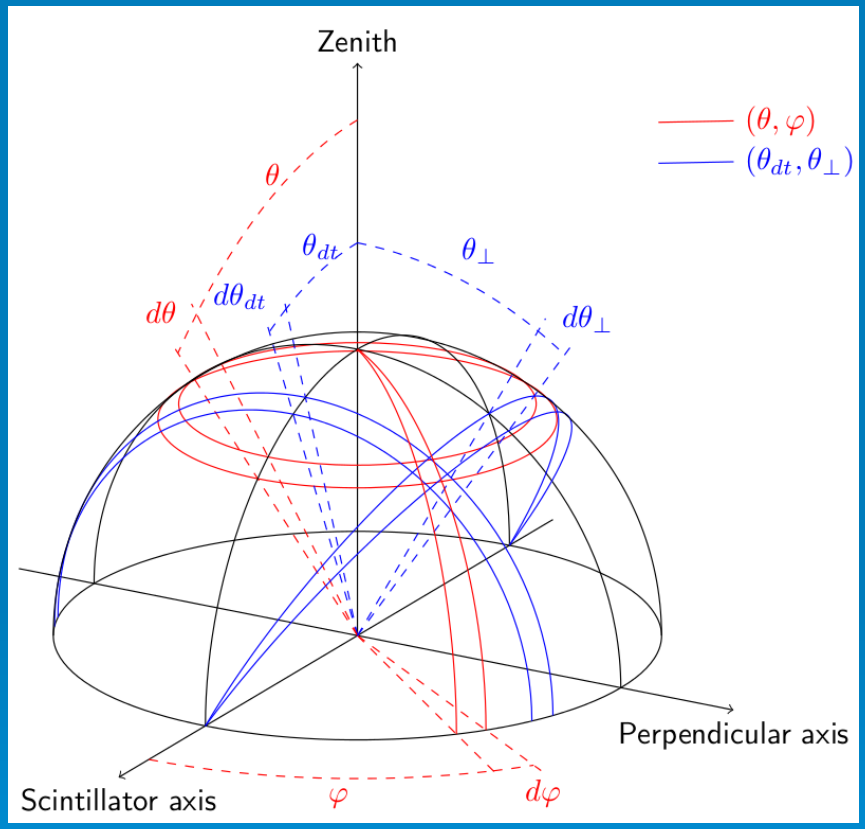
Service Status Details For Host 'sciencepark501'

Host	Service	Status	Last Check	Duration	Attempt	Status Information
sciencepark501	Buffer size	OK	10-30-2011 22:54:32	7d 18h 47m 40s	1/3	Buffer DB contains 251 events
	CPU Load	OK	10-30-2011 22:57:57	7d 16h 44m 15s	1/3	CPU Load 47% (5 min average)
	Drive Space C:	OK	10-30-2011 22:57:22	7d 18h 44m 50s	1/3	c: - total: 232.88 Gb - used: 13.83 Gb (6%) - free 219.05 Gb (94%)
	EventRate	OK	10-31-2011 15:51:32	18d 13h 23m 2s	1/3	Event rate for a period of 61.14 seconds is 0.95
	LabviewUsage	OK	10-30-2011 22:54:22	7d 17h 37m 50s	1/3	Memory usage: 39.3 Mb
	Memory Usage	OK	10-30-2011 22:56:22	7d 16h 35m 50s	1/3	Memory usage: total:2440.90 Mb - used: 771.87 Mb (32%) - free: 1669.03 Mb (68%)
	StorageGrowth	OK	10-31-2011 15:51:33	25d 3h 3m 1s	1/3	Storage growth: -0.716667 Hz
	StorageSize	OK	10-31-2011 15:51:31	25d 3h 3m 3s	1/3	Storage size: 5 events
	TriggerRate	OK	10-31-2011 15:51:11	0d 1h 0m 33s	1/3	Trigger rate: 0.58 Last update: 6 seconds ago
	Uptime	OK	10-30-2011 22:57:43	7d 16h 34m 29s	1/3	System Uptime - 17 day(s) 20 hour(s) 32 minute(s)

Searching for a cosmic ray source with a 2 scintillator HiSPARC Station…

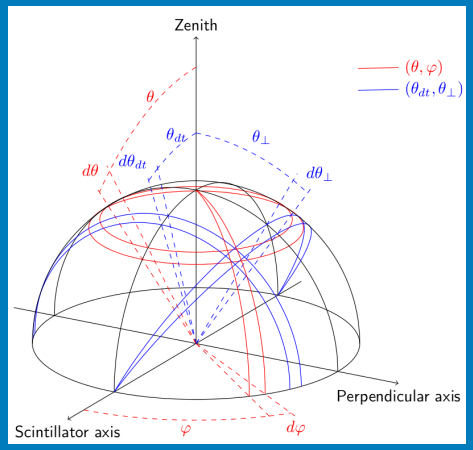
The stars are mapped on the celestial sphere in a Mollweide (equal bin area) view. Stella Polaris is the uppermost bright star [astronelson.wordpress.com].

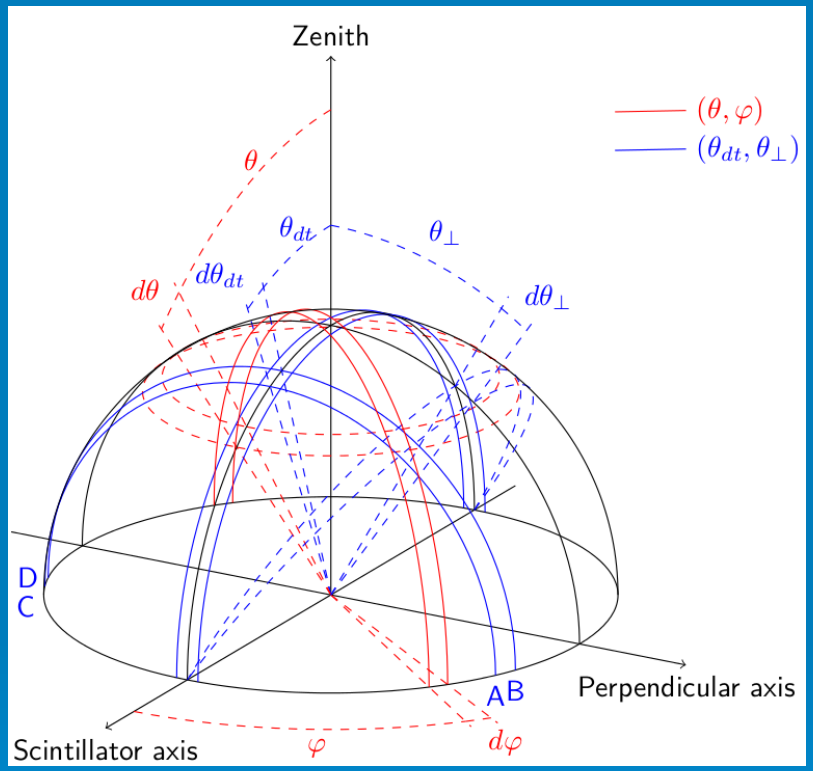
Introduce coordinate system to normalise cosmic ray flux on 2 scintillators…



The local coordinate system can be defined in two (amongst others) ways:
- The (θ, φ) coordinate system is symmetric around the zenith (red)
- The ($\theta dt, \theta_\perp$) coordinate system is symmetric around the axis through 2 scintillators (blue).

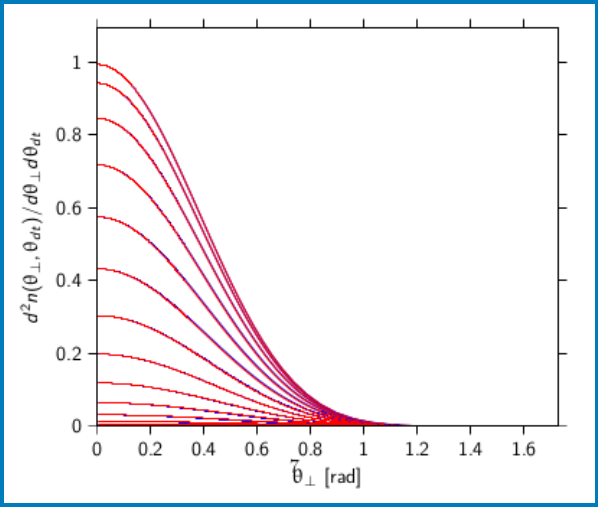
Introduce coordinate system to normalise cosmic ray flux on 2 scintillators…





Bands through the zenith have equal surface area. Other vertical bands are almost equal. The red and blue slices cross the zenith. The flux at these crossings is the same both blue and red systems.
The flux defined by Θ (red) must be equal to the flux defined by Θ_{dt} and $\Theta_\perp$ (blue). The sharpness of the band is determined by the angular resolution of the two scintillator combination.

2-scintillator particle detection



The exact perpendicular distribution is given in red. The blue distribution is the corrected perpendicular distribution using the distribution as function of θ_{dt} and $\theta_\perp$.

Local station-coordinate system by θ and φ (θ_{dt} and $\theta_\perp$). The earth rotates fromwest to east; thus sun and stars move (w.r.t. station) from east to west. The axis of a scintillator pair rotates with the earth as is there connecting axis.

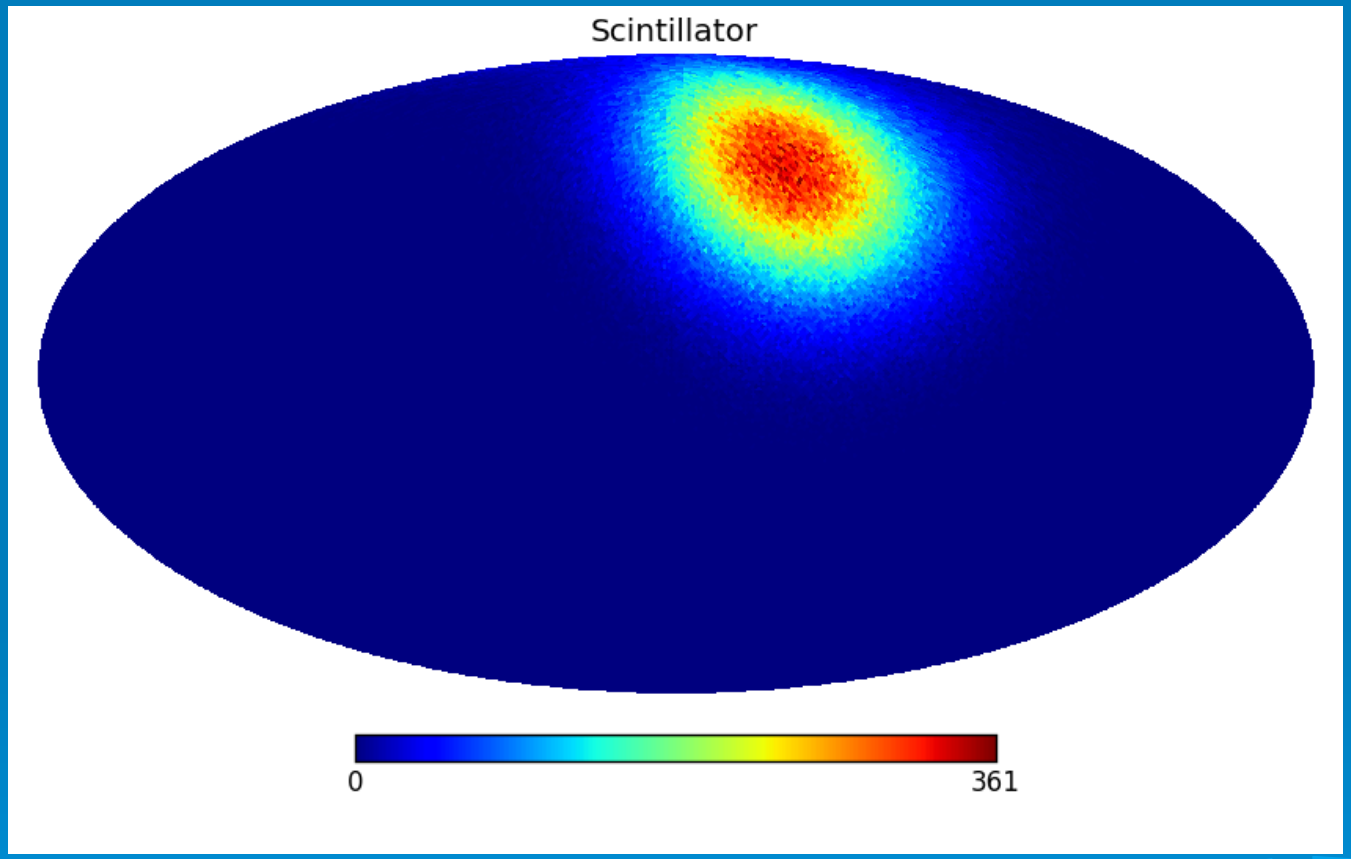
A transformation to a solar defined system can now be made. Points in the sky move 15 degrees per (solar) hour to the east. The earths rotation around the sun gives an additional (small) contribution.

When using stars as reference frame, the rotation is a bit faster. Therefore, the sidereal time, defined by the movement of the stars across the sky, is a bit faster too.

Conclusion:

- A pair of scintillators has a good resolution for angles with the axis through the scintillators.
- The resolution perpendicular on this axis is much lower, but can be derived.
- The axis through the scintillators turns -with the earth- around the earths axis in one sidereal day.
- The line of possible points of origin turns also in a sidereal day.
- A point source will lead to differences in the distribution across the celestial globe.

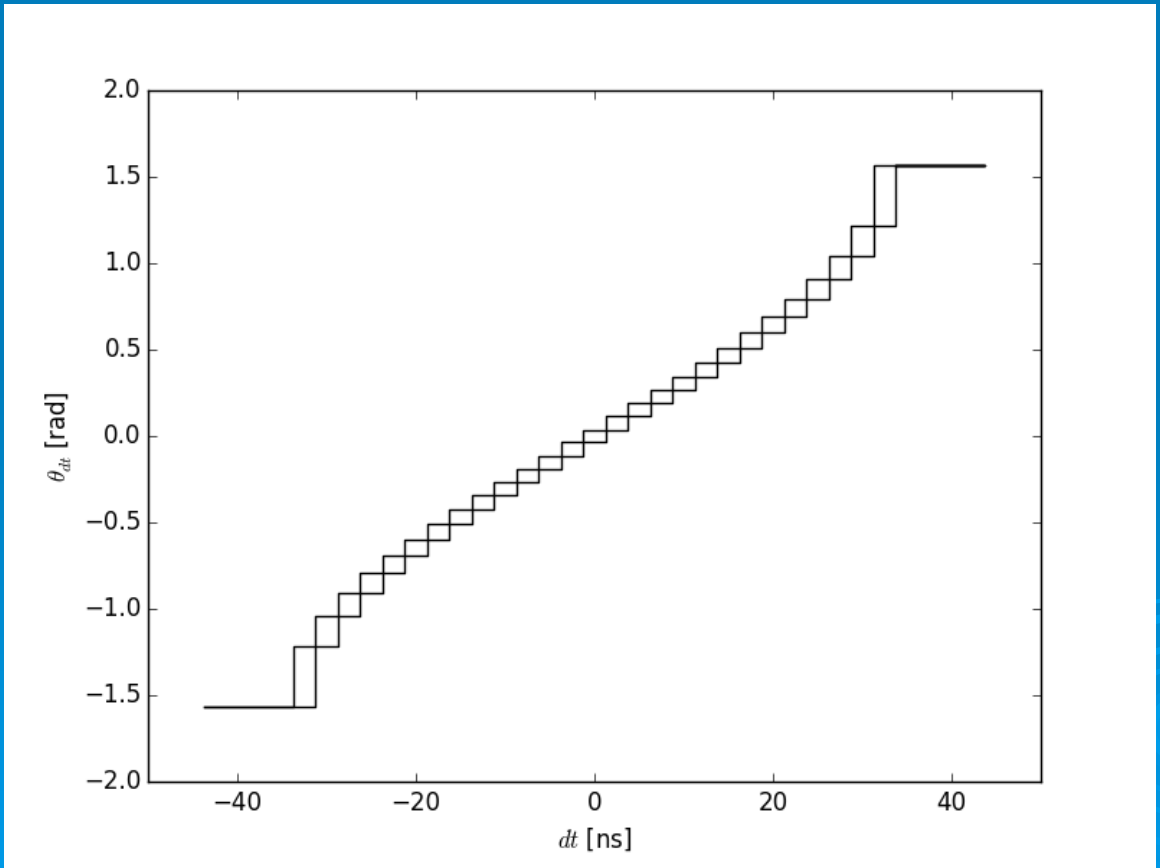
1-scintillator particle detection



10^6 simulated particle showers are hitting a single scintillator.
Points of origin are placed on the celestial sphere in a Mollweide view.

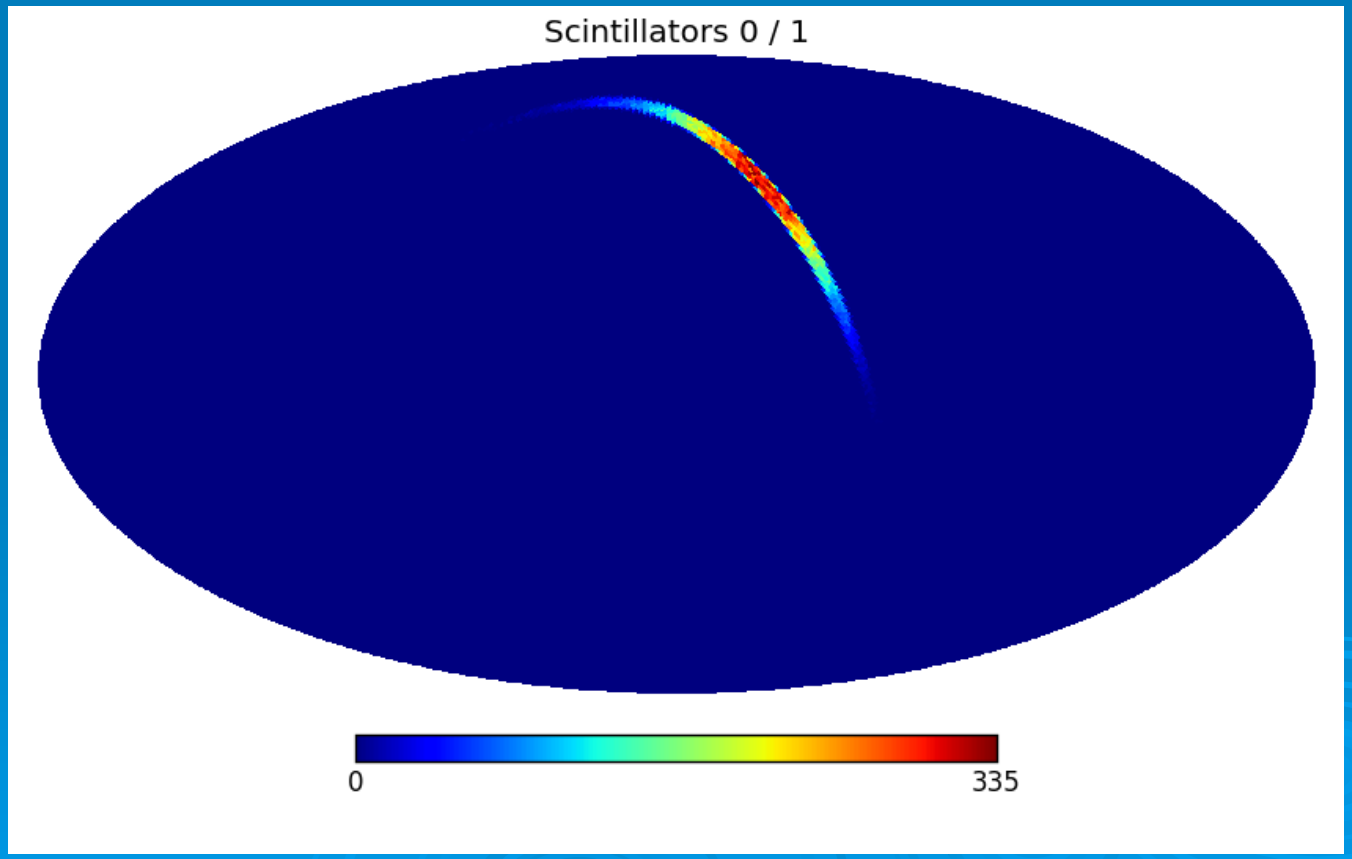
…2 scintillators…reconstruct 1 shower angle…

- HiSPARC signal sampling in 2.5 ns bins
- With two scintillators the difference in arrival time (assuming here a flat shower front) can be measured.
- The angle between the shower front and the axis through the scintillators is then derived from this time difference.

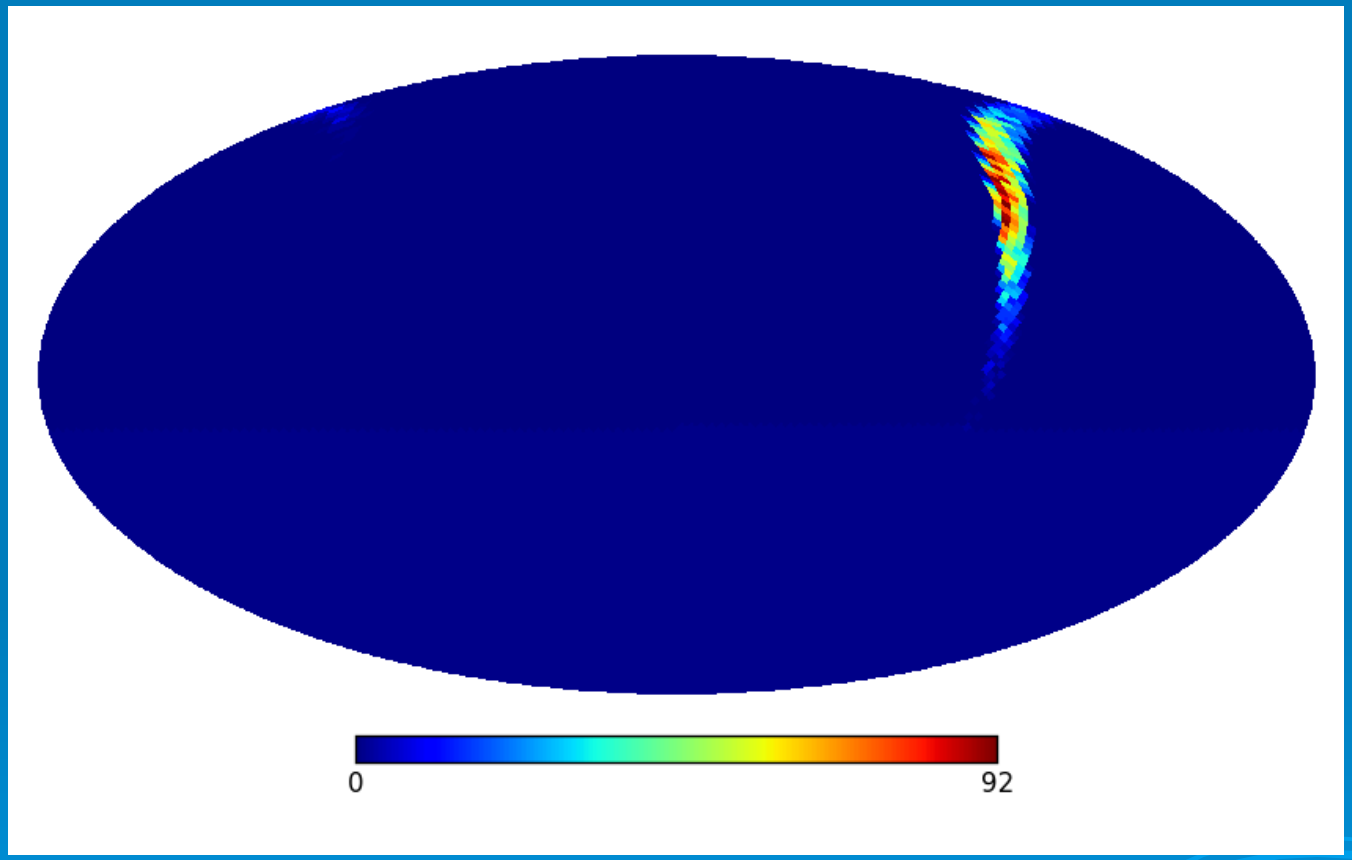


…of a possible source…

- The angle between the shower front and the axis through scintillators ‘0’ and ‘1’ is used to select possible origins (plane) for cosmic ray primaries.
- The sources are distributed over bin sizes of 10 m.



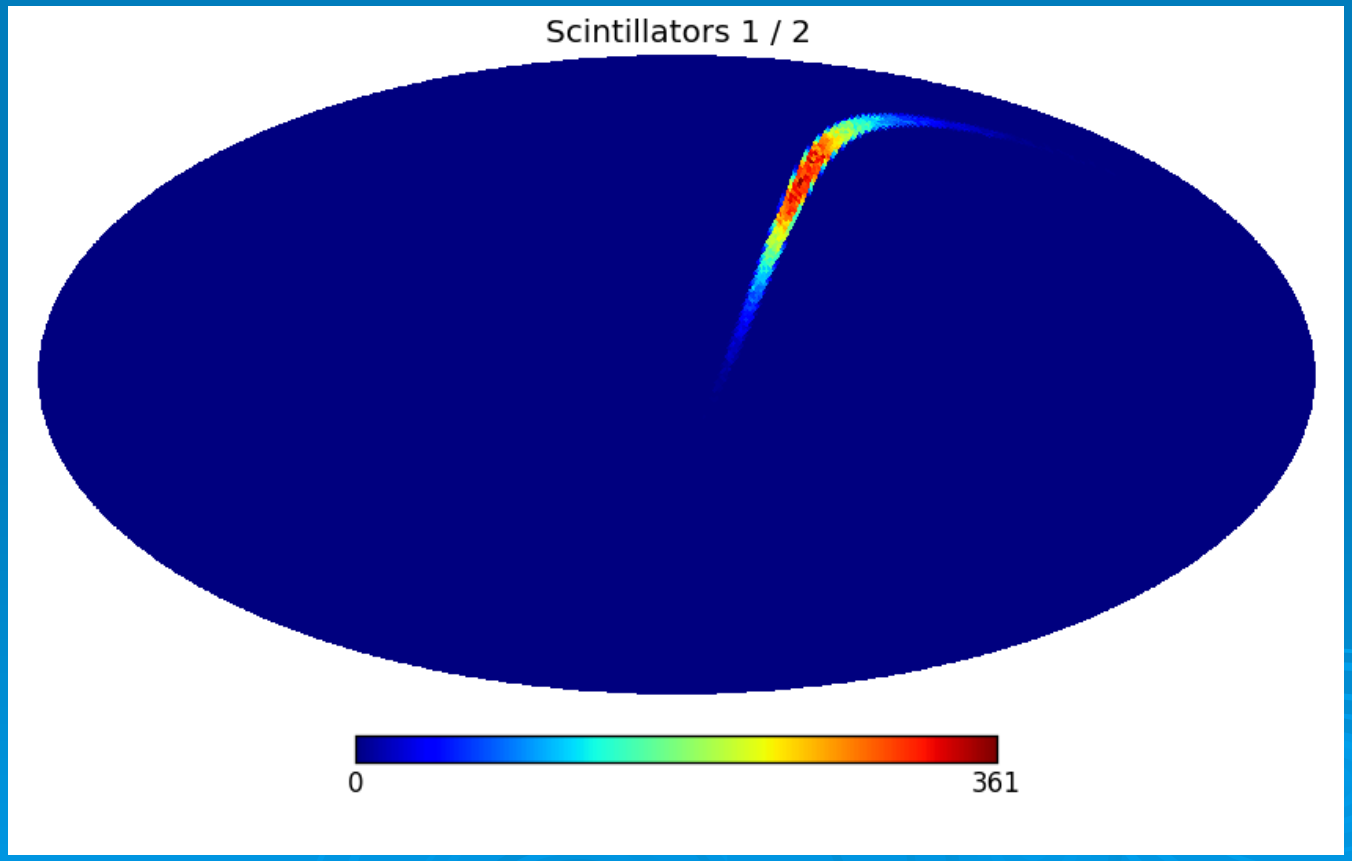
And as the world turns…
(period is 500 ns)



- The location of an ‘active’ source can be determined.

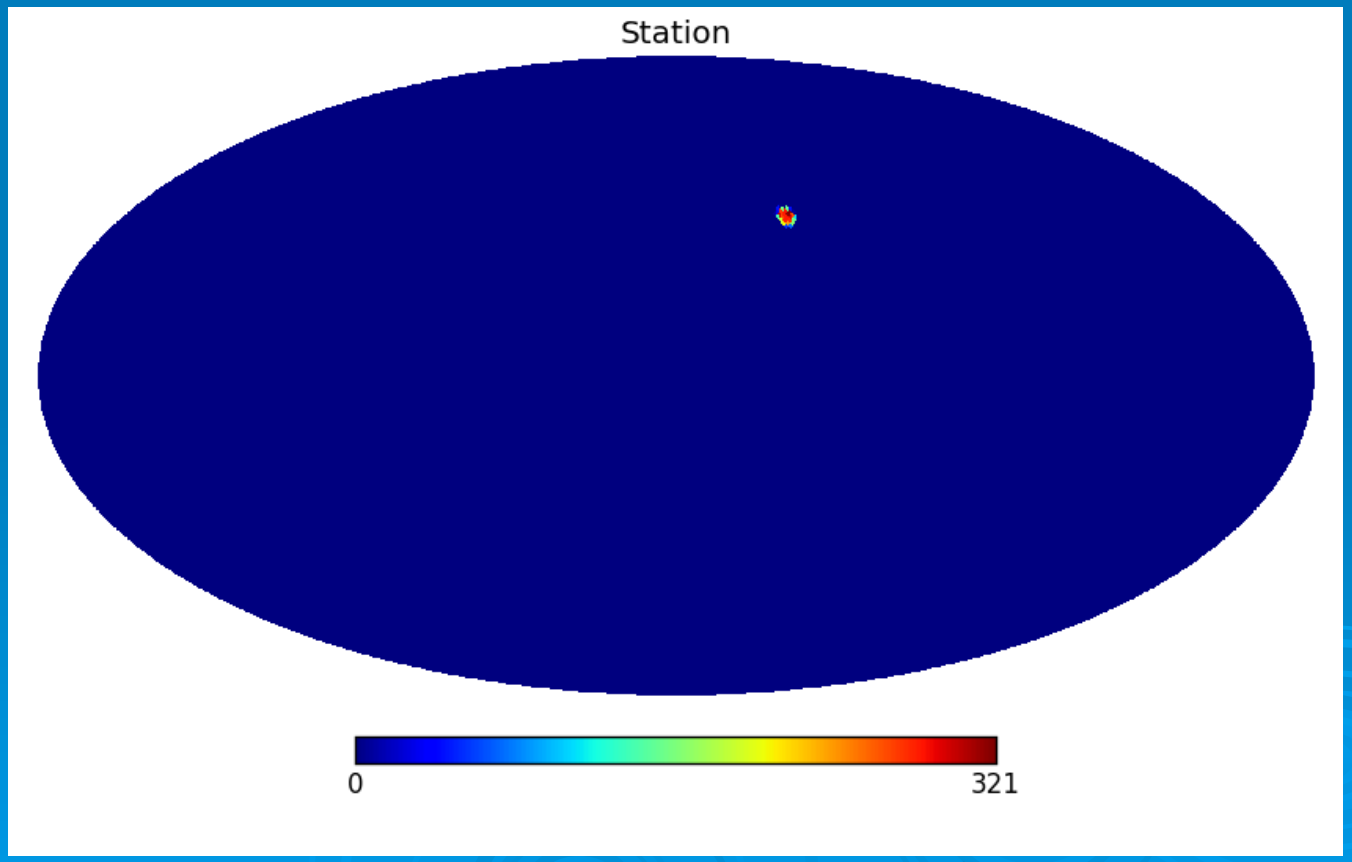
Extend to 3 scintillators in triangle…

- The angle between the shower front and the axis through the scintillators ‘1’ and ‘2’ is used to select possible origins for cosmic ray primaries as well.
- The angle between pair 0/1 and 1/2 is π/3 rad.

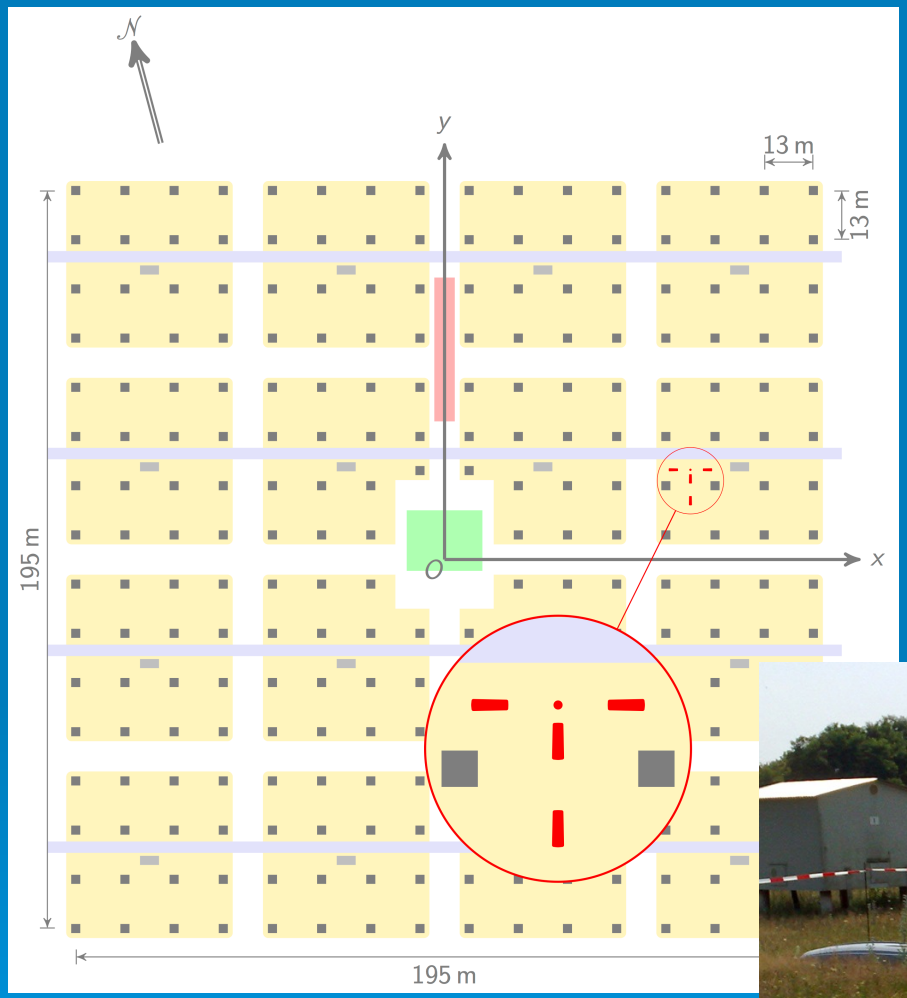


..and the direction can be determined per shower

- A station with three scintillators contains three scintillator pairs.
- This defines (within the exp. resolution) the origin of the cosmic ray primary.

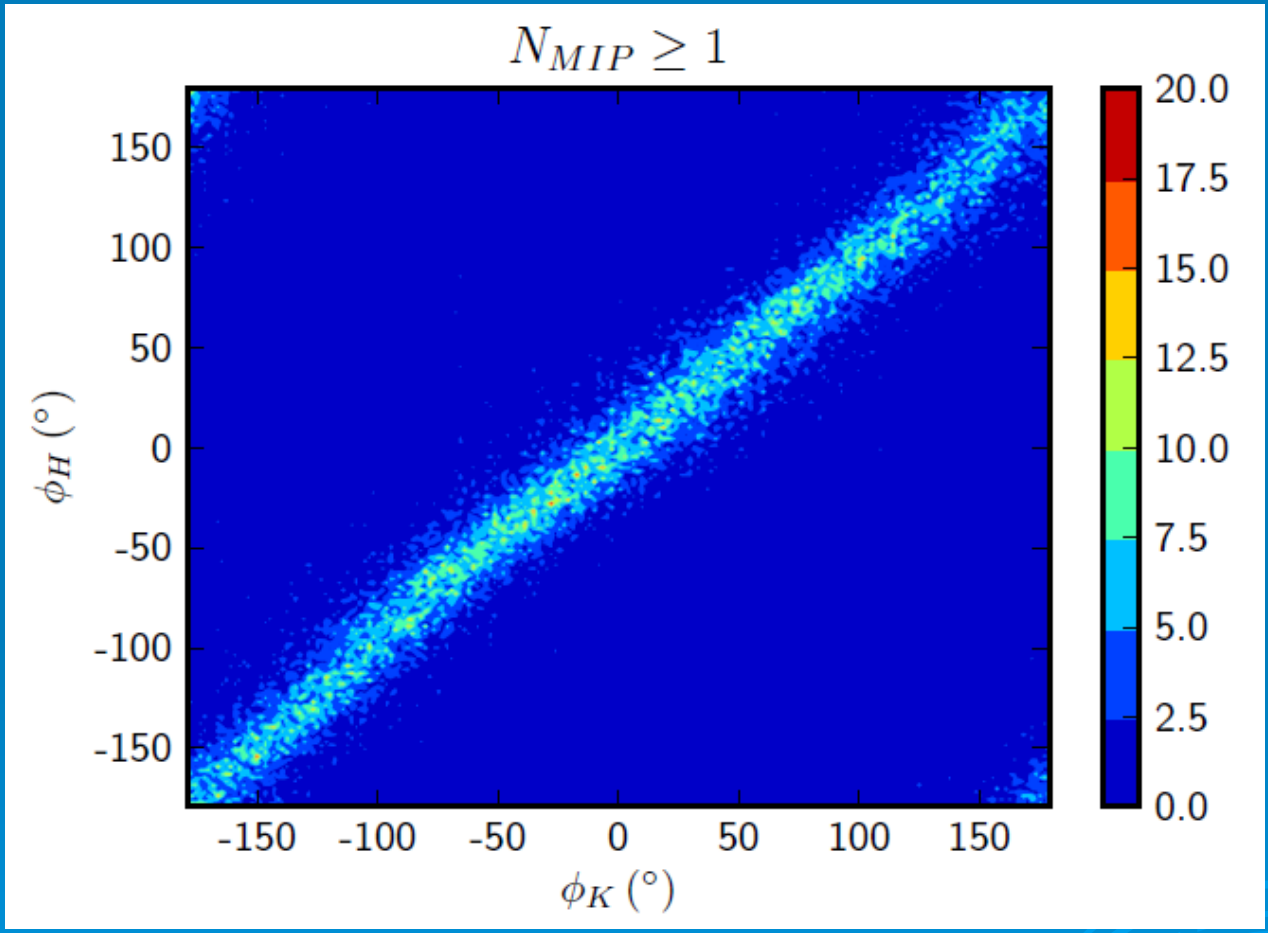


KASCADE experiment (Karlsruhe)



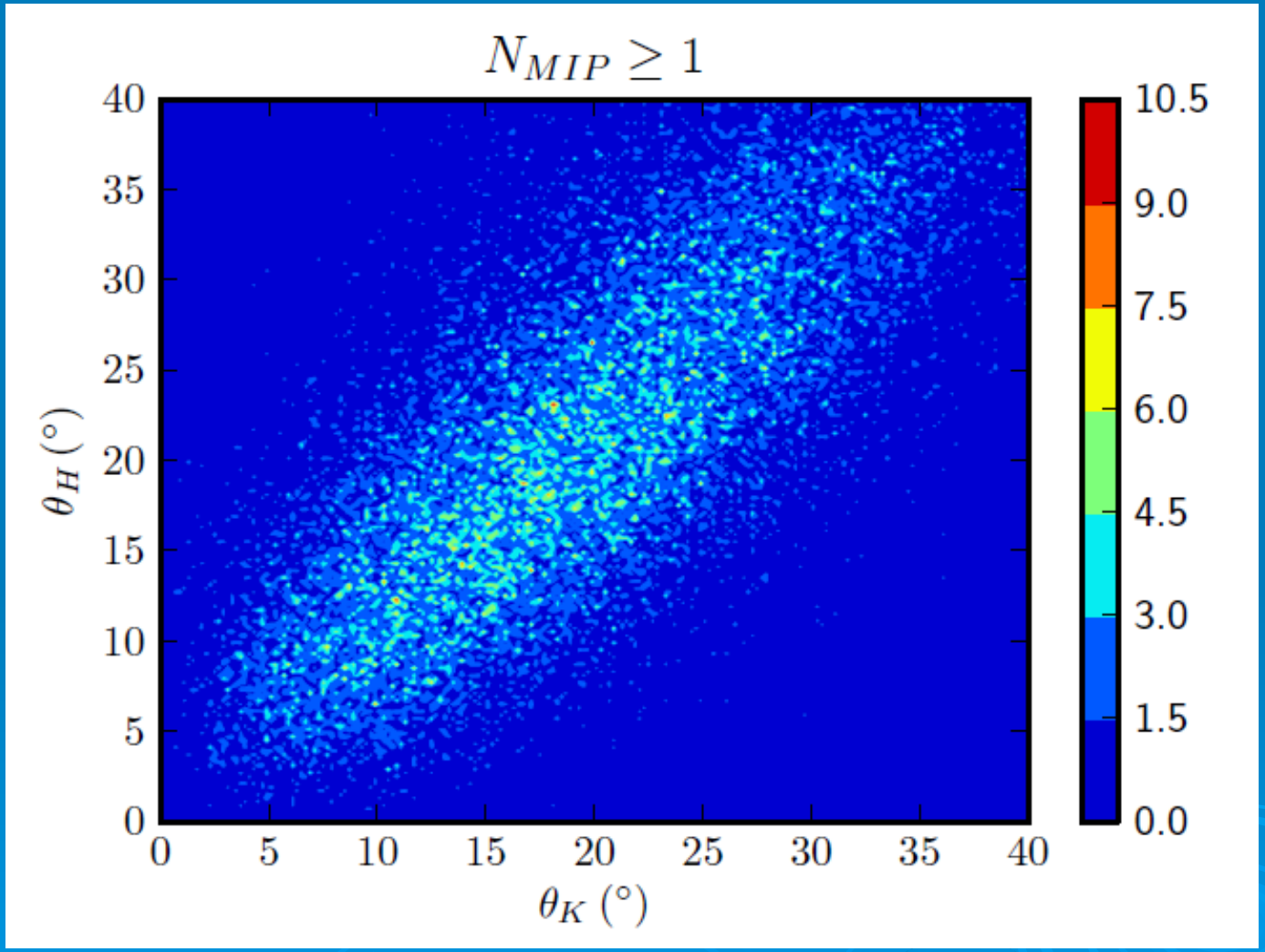
HiSPARC@KASCADE:
Kascade shower triggers
HiSPARC DAQ system

Angular resolution:



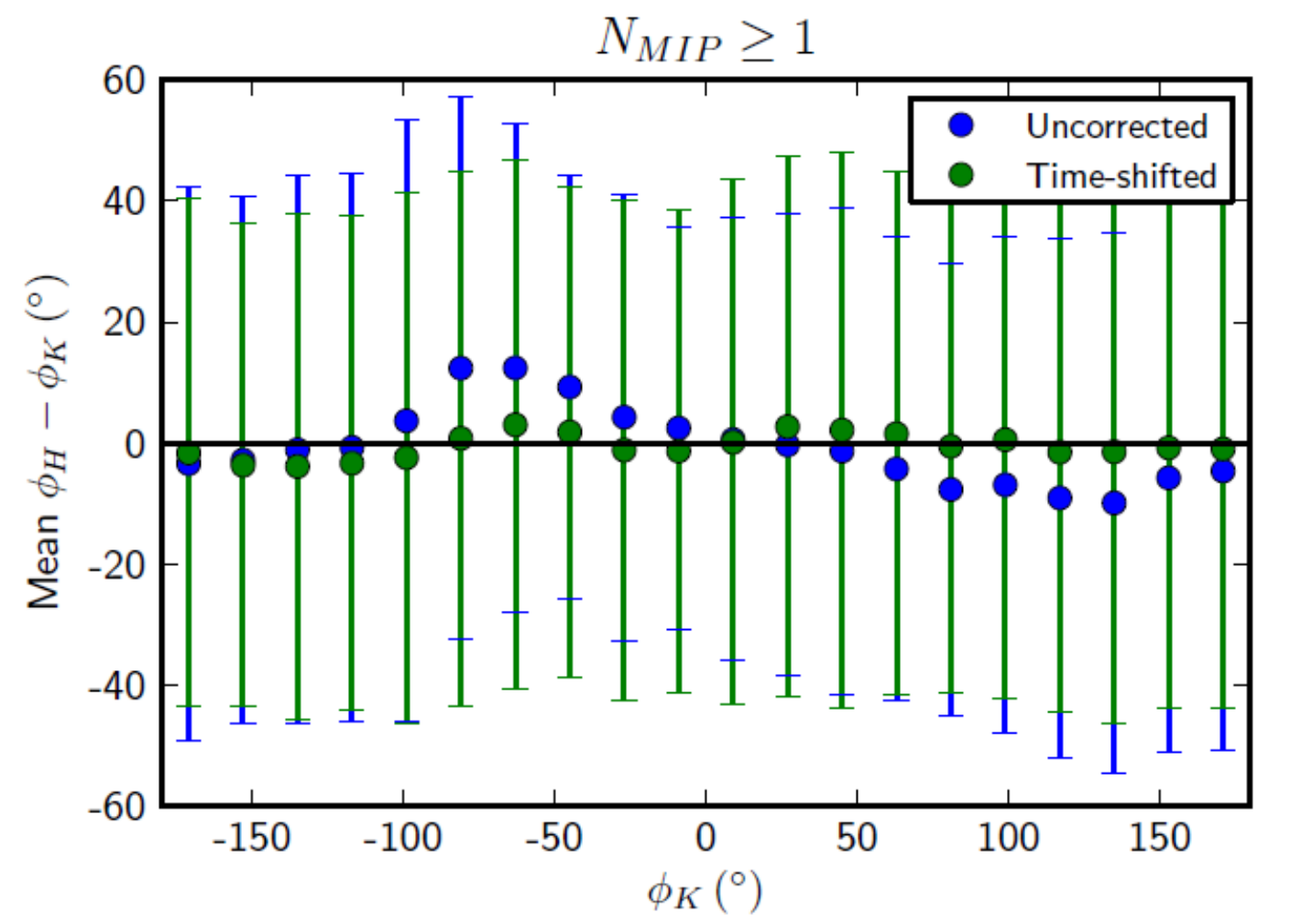
Azimuth: KASCADE vs HiSPARC

Angular resolution:



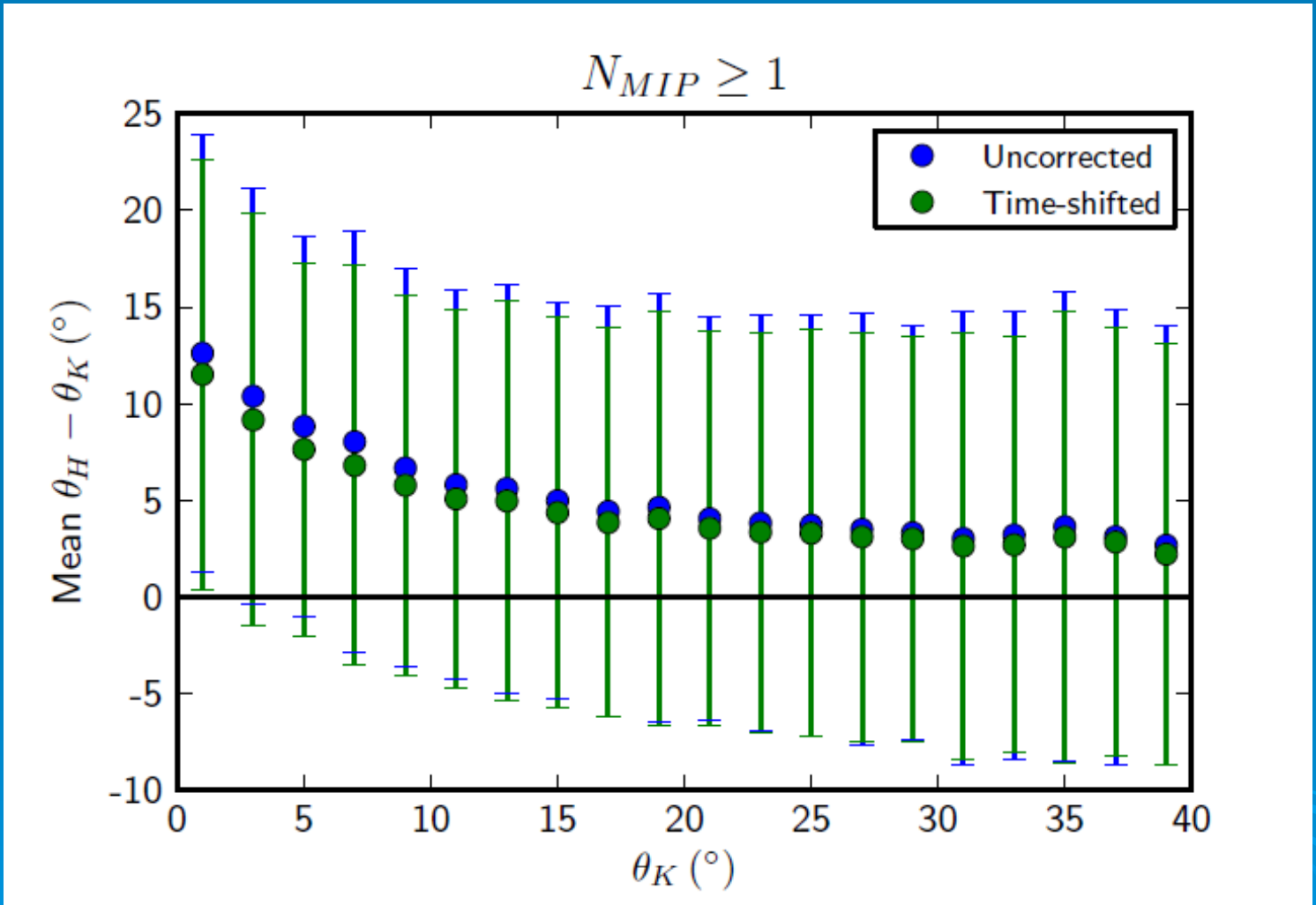
Zenith: KASCADE vs HiSPARC

KASCADE vs HiSPARC:



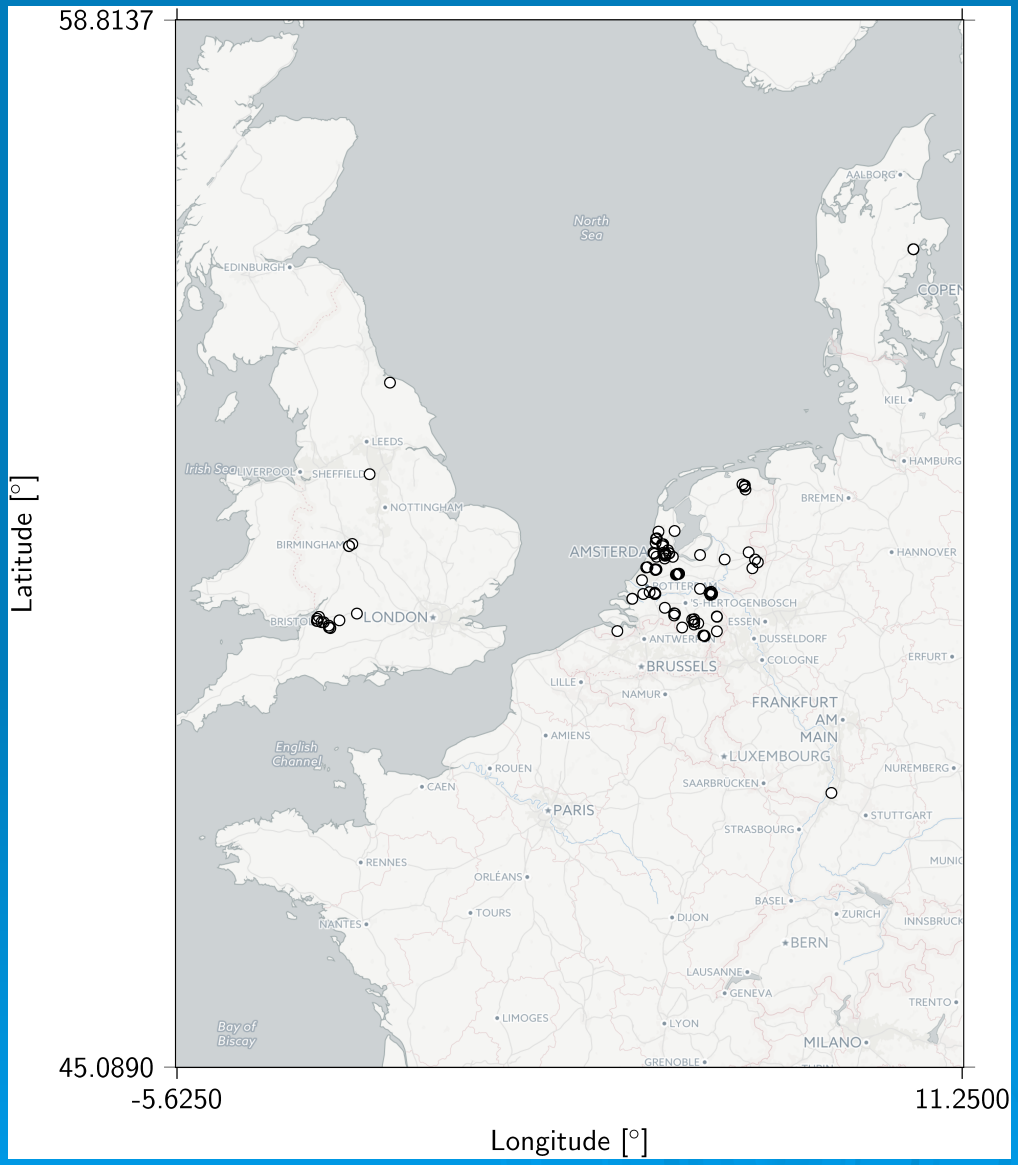
Azimuth angle

KASCADE vs HiSPARC:



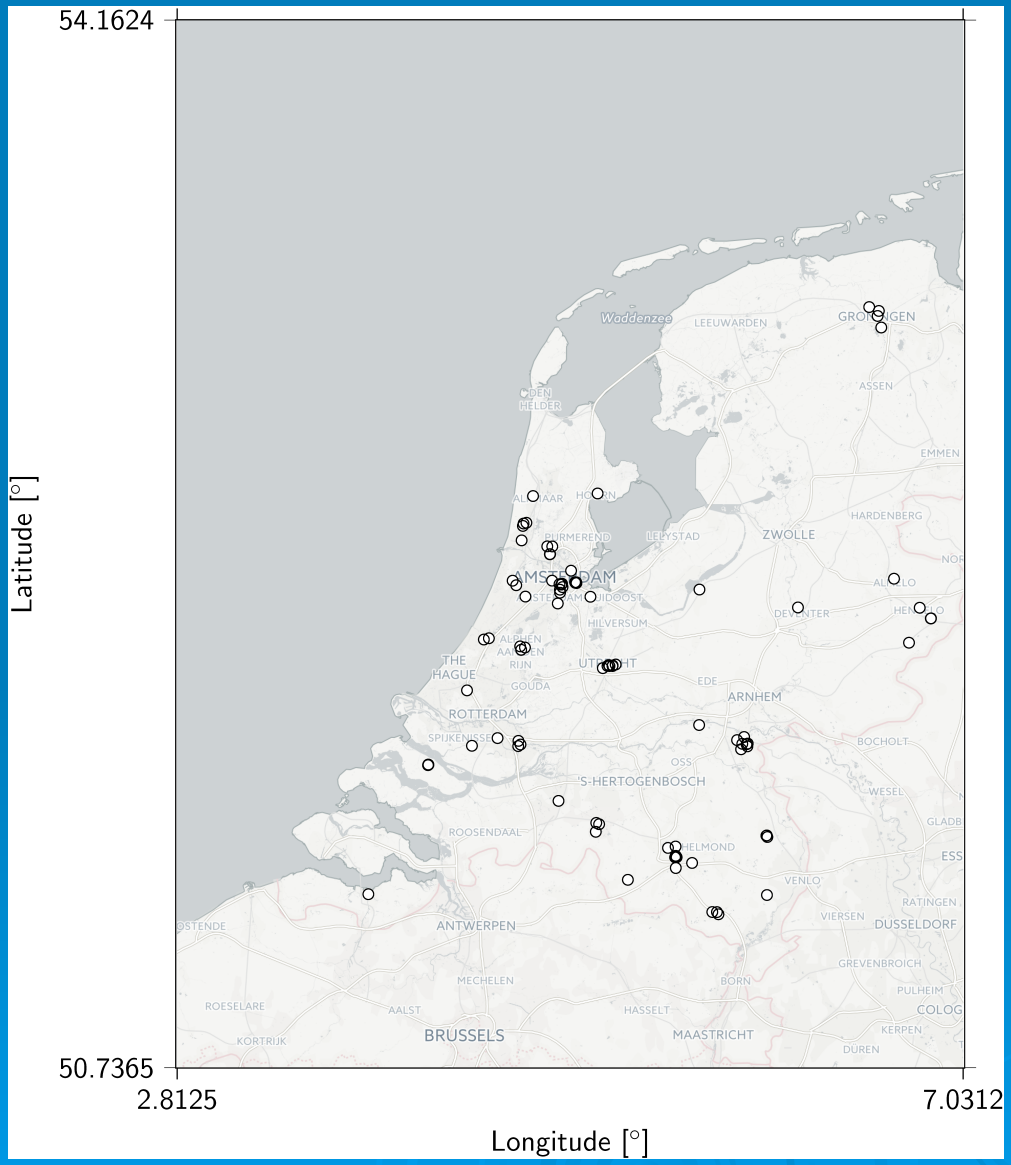
Zenith angle

HiSPARC today: the network



- 80 2-scintillator stations
- 25 4-scintillator stations

HiSPARC today: Netherlands

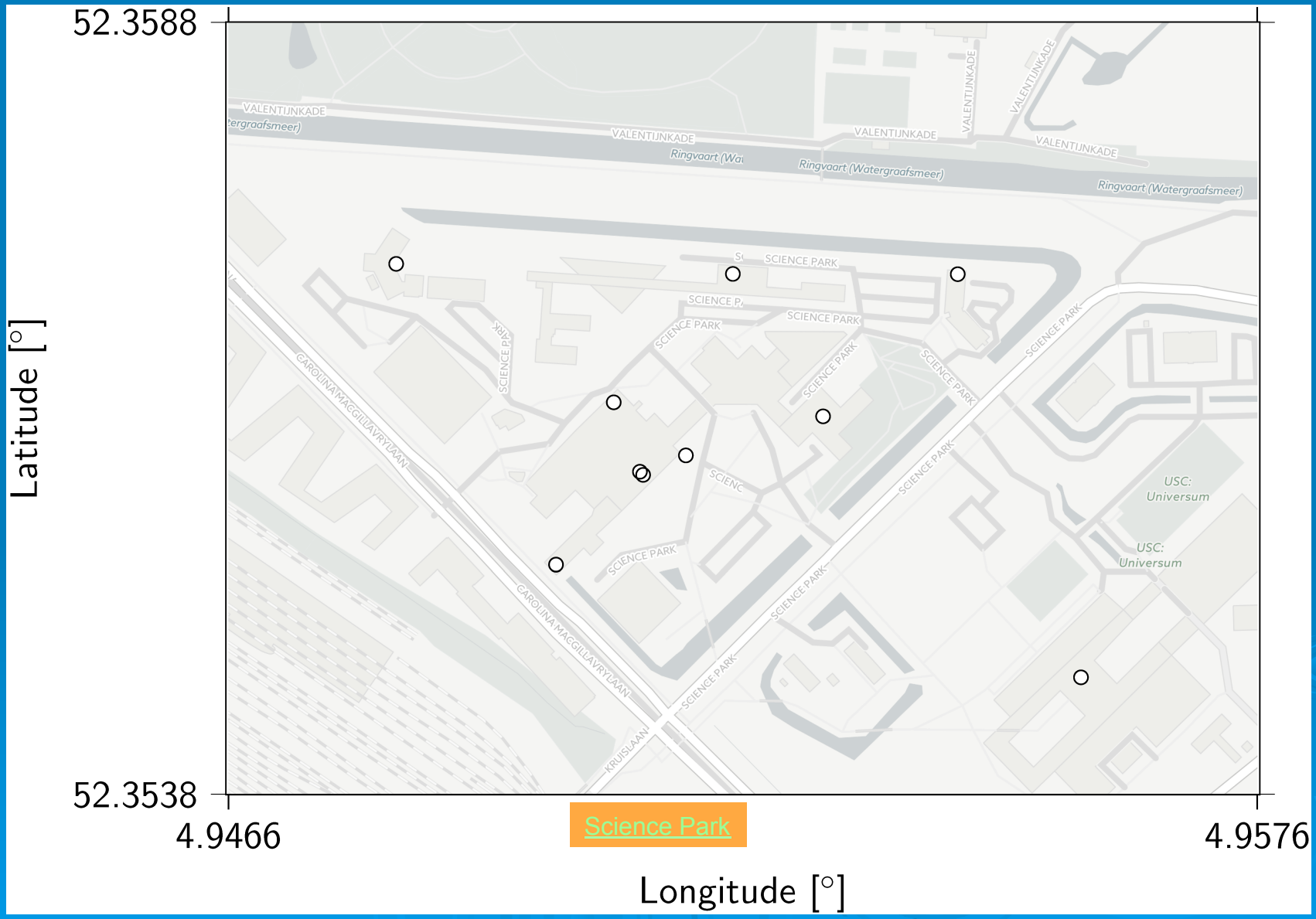


~ 100 stations

Science Park cluster

Stations 501 - 510

Science Park... with 'life display'



Public access to data…

- download data-sets
- data reconstruction
- analysis algorithms
- 'education letters'
- 'RouteNet'