The non-destructive measurement of soil water content of upper part of the cave using soft component of air shower

~How I became a friend with our enemy

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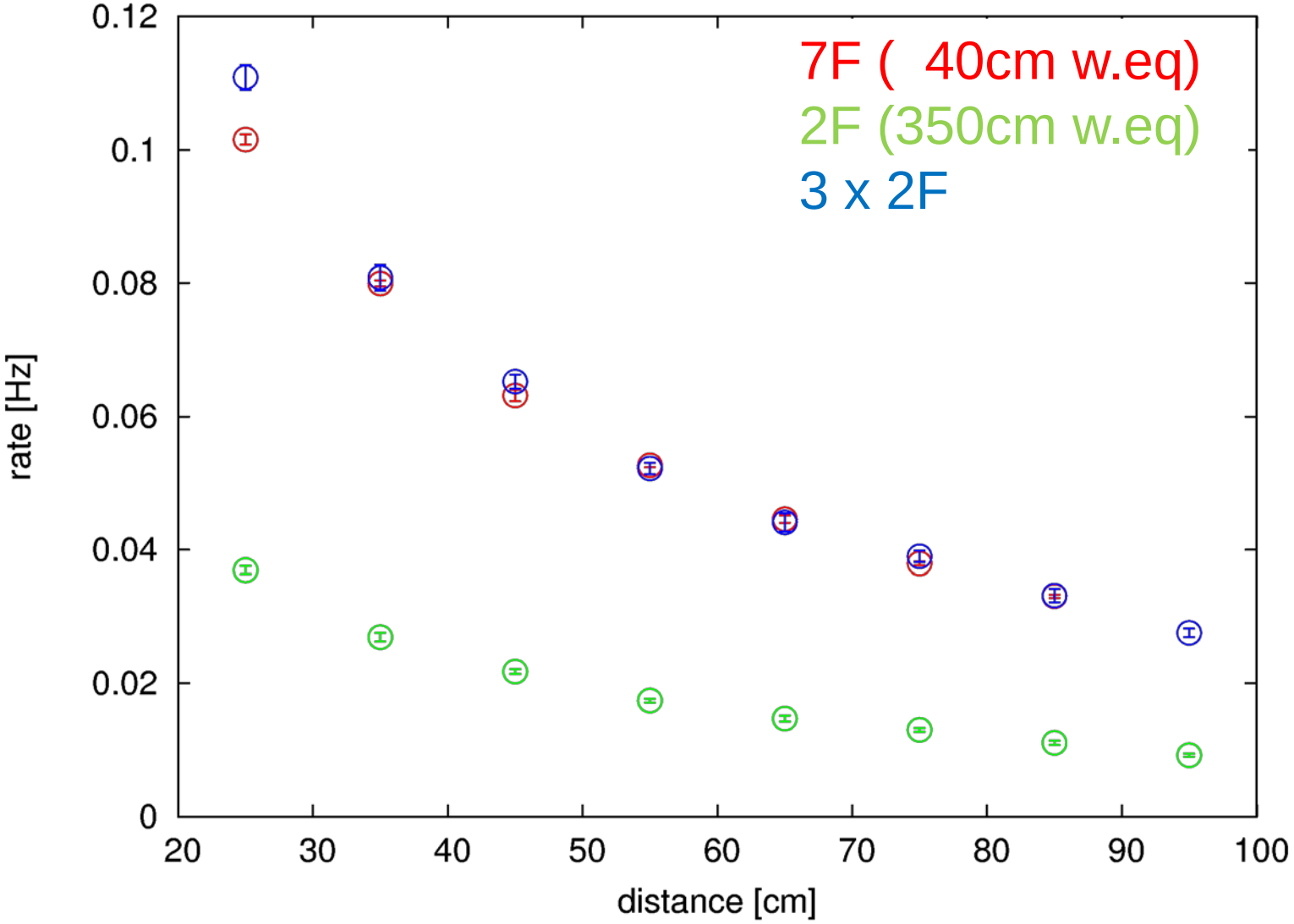
@NMR2012, Clermont Ferrand, April 2012.4.19

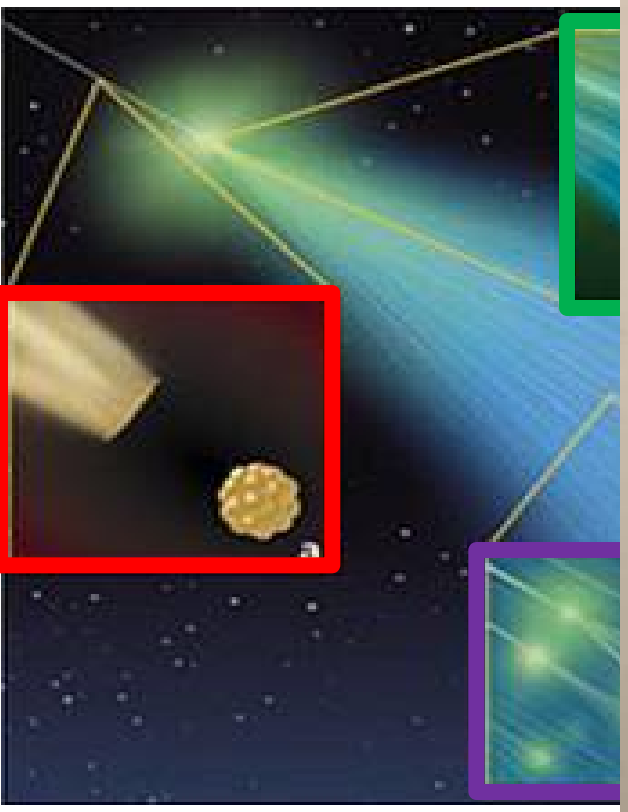
Lateral distribution of air shower particles

(measured by scintillator strips)

~We have to know about enemy, to beat them



What is the air shower? The entrance of the factory?



ray collides to
oheric nuclei

ates secondaries

laries collide to
oheric nuclei

secondaries are
as “air shower”

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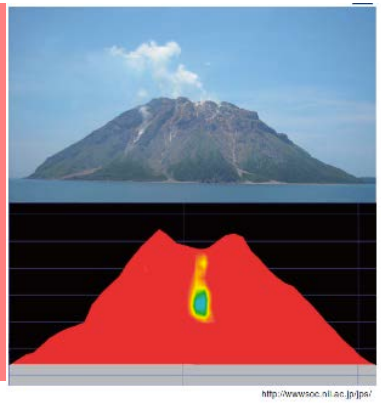
tic)

Possible scale of radiographies

There is missing ranges!

X-ray

muon



neutrino

My talk

The Holy Grail of geophysics

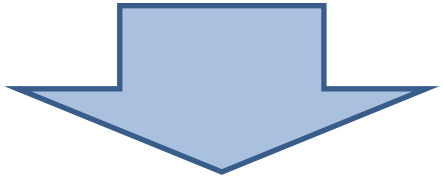
0.1 1 10 10^2 10^3 10^4 10^5 10^6 m

Radiography using cosmic rays

- Hard component (muon)
  - more penetrative → large scale
  - From ~20m to ~5000m structure
- Soft component (electron, positron and photon)
  - Less penetrative → small scale
  - From ~0.2m to ~30m structure
- neutrino
  - much more penetrative→ Earth scale
- neutron
  - Different sensitivity
  - Used for snow depth meter etc. (M. Kodama, more than 30 years ago)

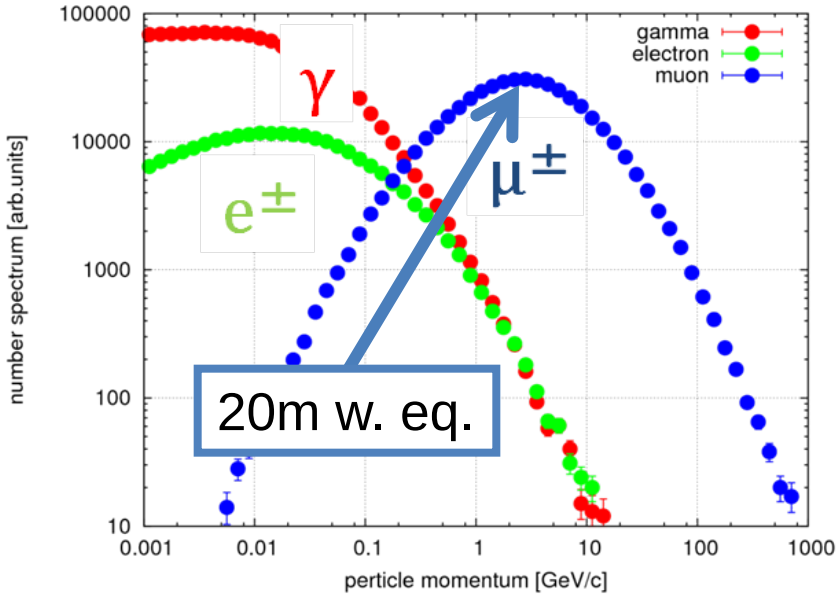
Before soft component radiography …

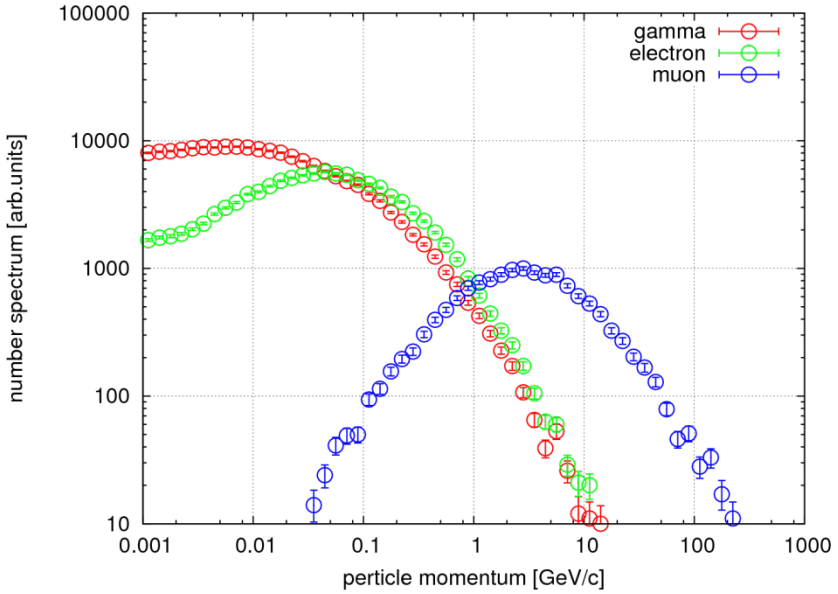
- Particle identification required
- It's difficult for each particle, we need CMS or ATLAS
- 90% particles in air shower is the soft component
- Lateral distribution of soft component and of hard component are different

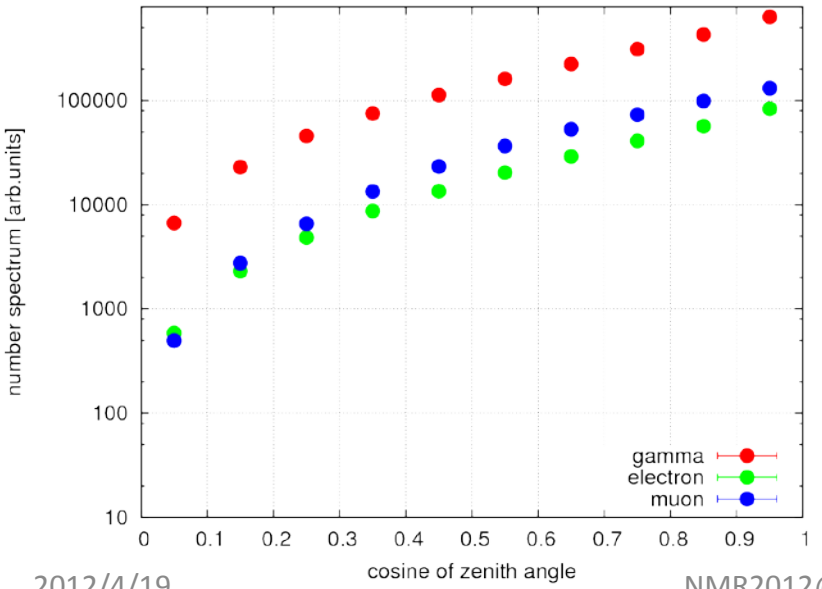


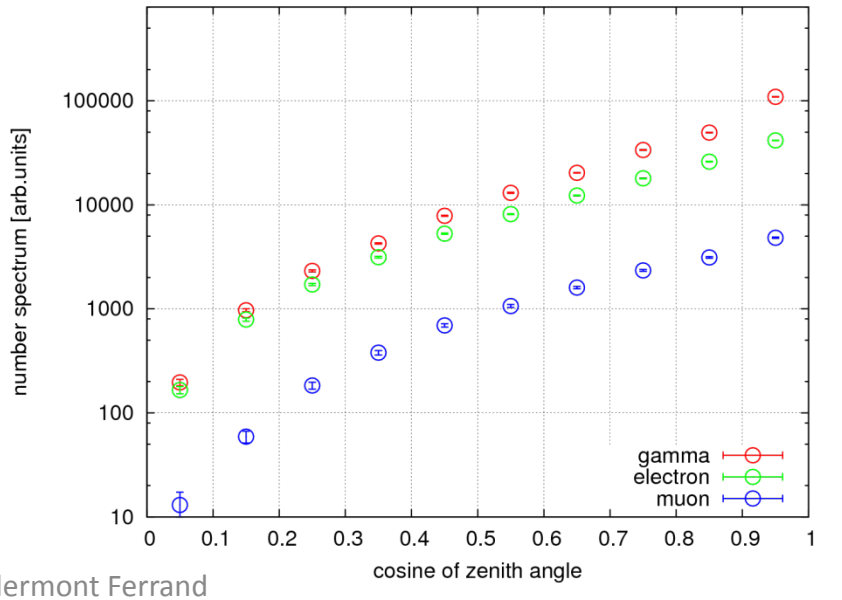
- Take coincident particle → 90%
- Measure lateral distribution → 99% (statistically)

Discrimination power (MC result, ΔT<100ns, r<1m)





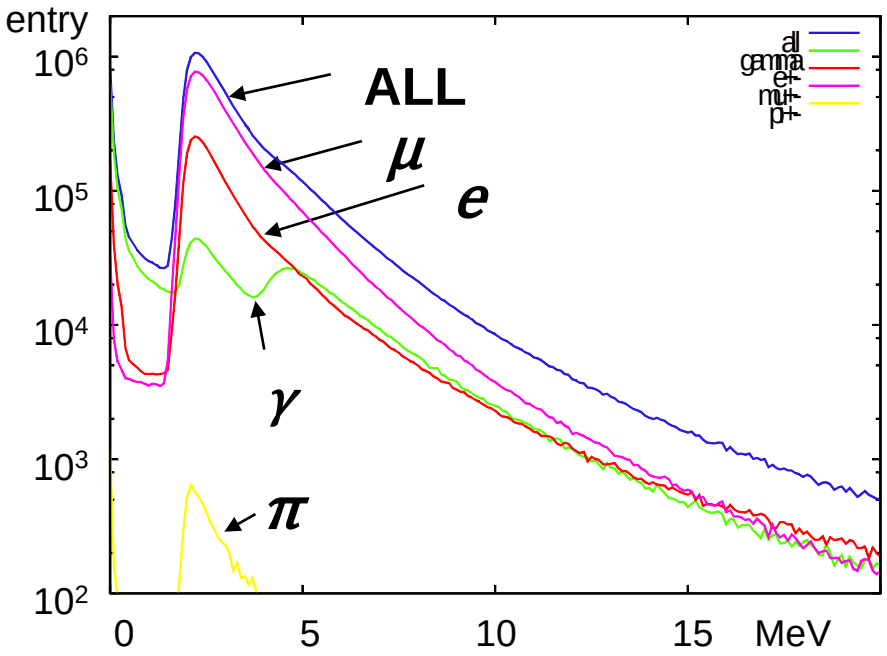


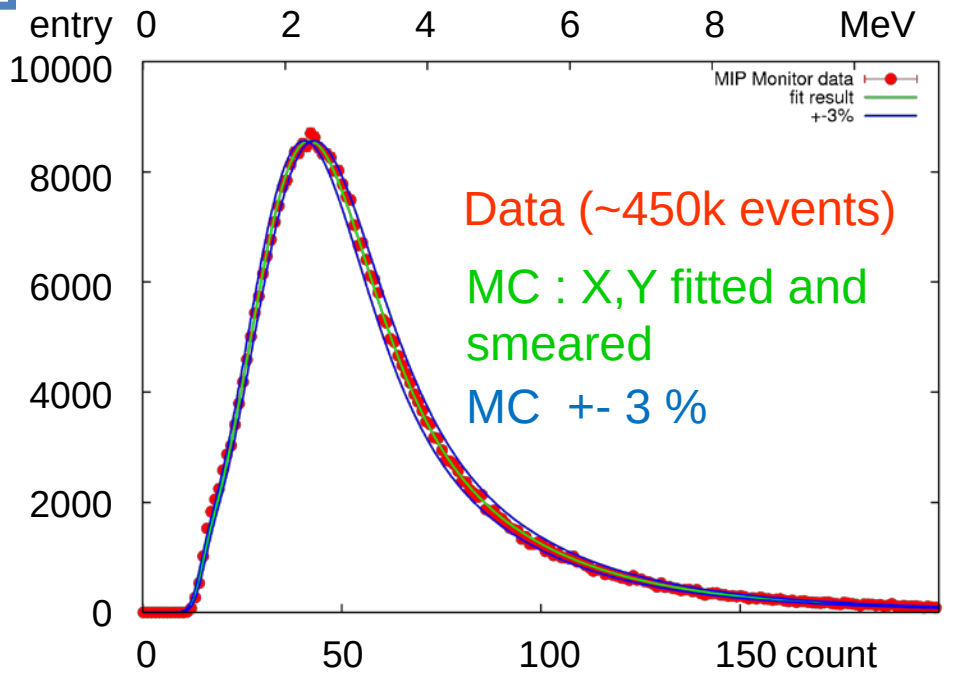


Air shower and detector MC

Primary spectra(AMS01, p,He,CNO),
Interaction model (dpmjet3+qgsjet2),
Air shower MC (COSMOS),
Detector simulator (GEANT4),
Ideal detector

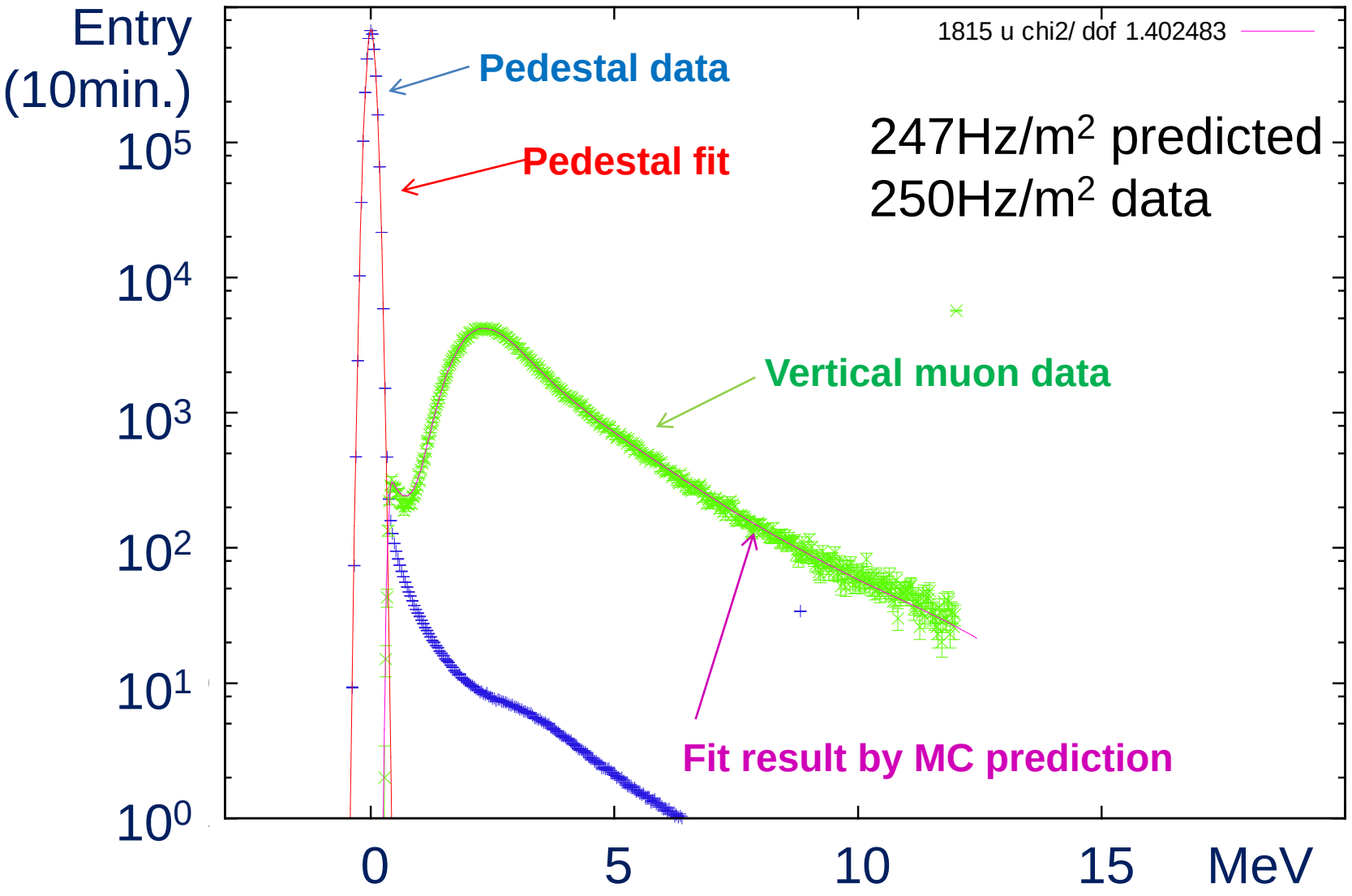
Get detector parameters by comparing data and MC





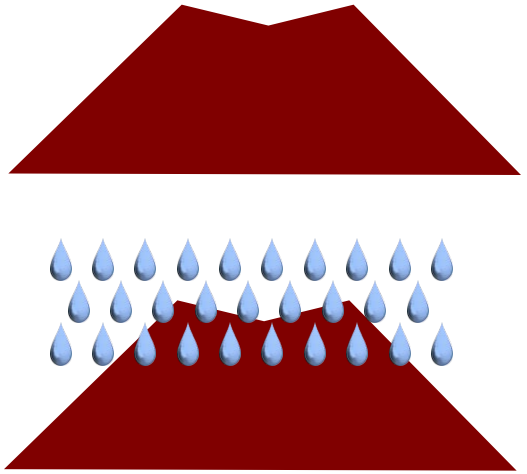
If you want to know more about COSMOS, see :
M. Honda, et al, Phys. Rev. D83, 123001 (2011)

muon spectrum in 10min (3m^2 detector)

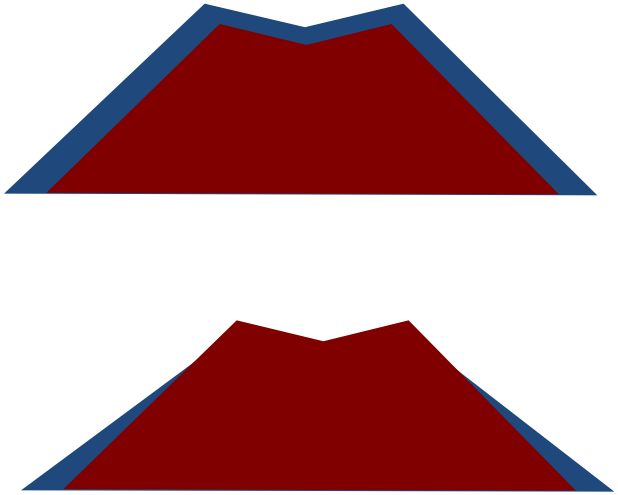


What we can do : underground water content

- Rainfall disturbs gravitymeter and tiltmeter
  - Variation of the total mass of the mountain
  - Underground water stream

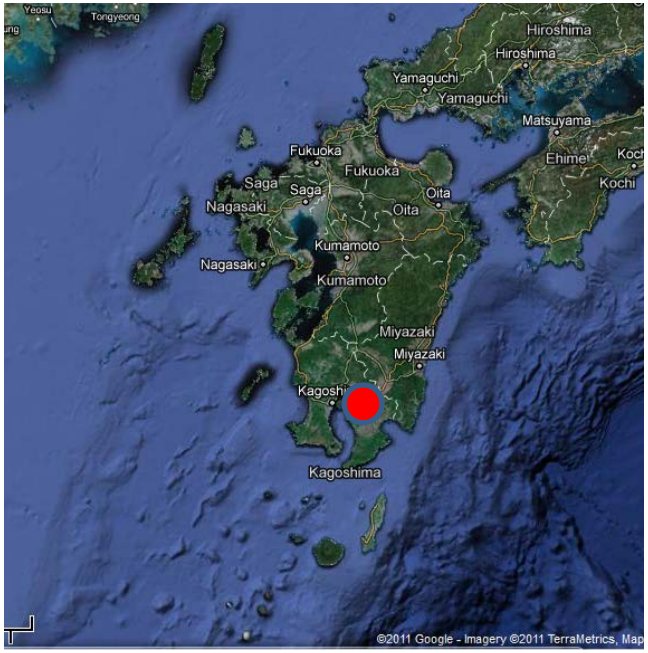


- How can we calibrate it?
  - Difficult for muon radiography (10m scale)
  - Soft component is suitable for this range
  - Observation pit

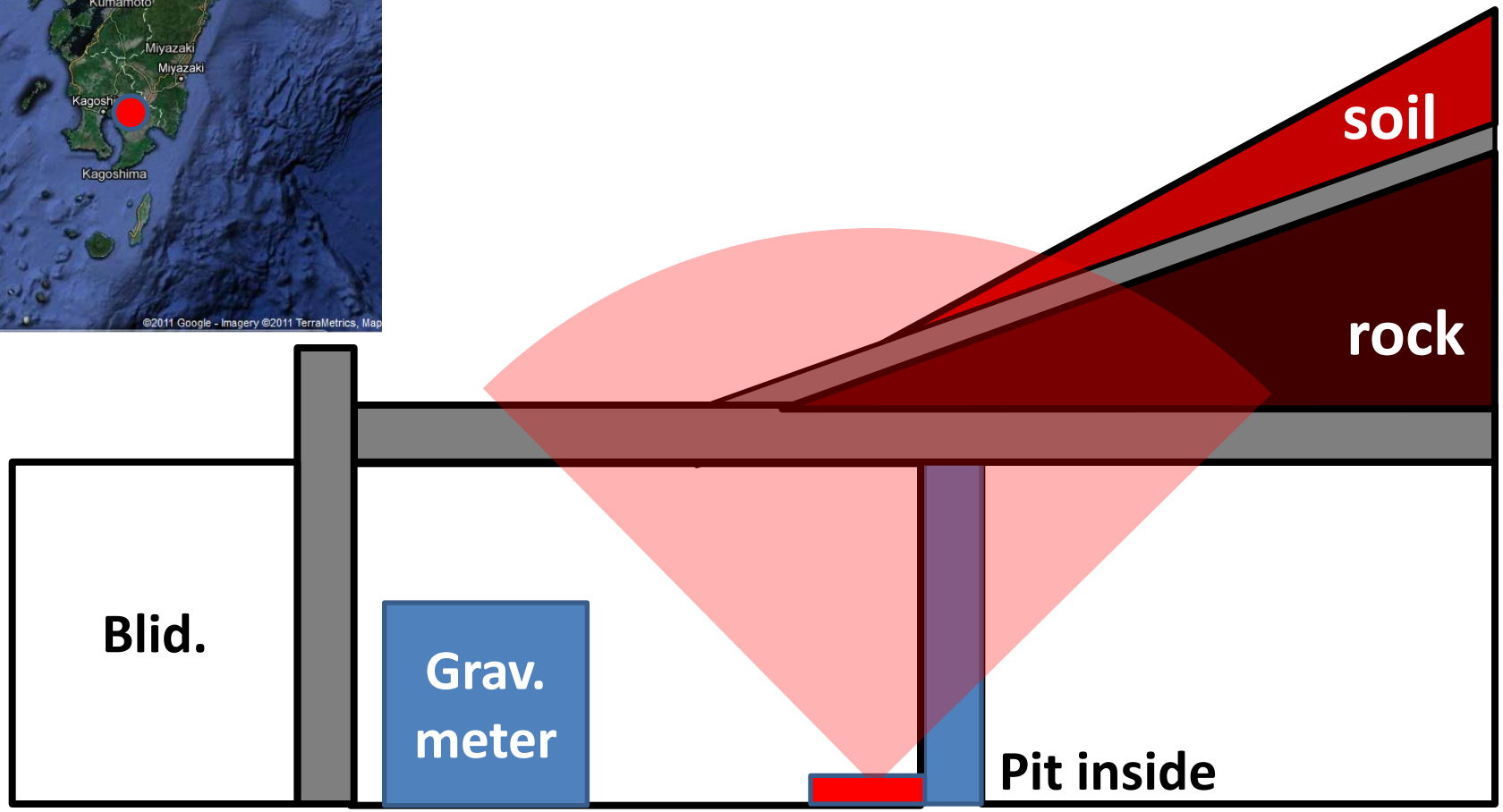


Observation point

Mt. Sakurajima, Kagoshima Prefecture



Soil (ash) ~ 0.3 m
rock ~ 4.0 m
Concrete ~ 0.3 m



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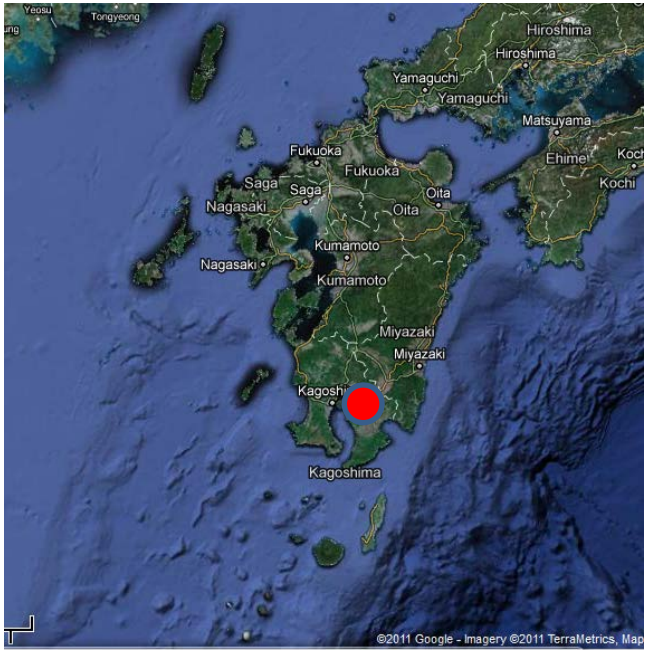

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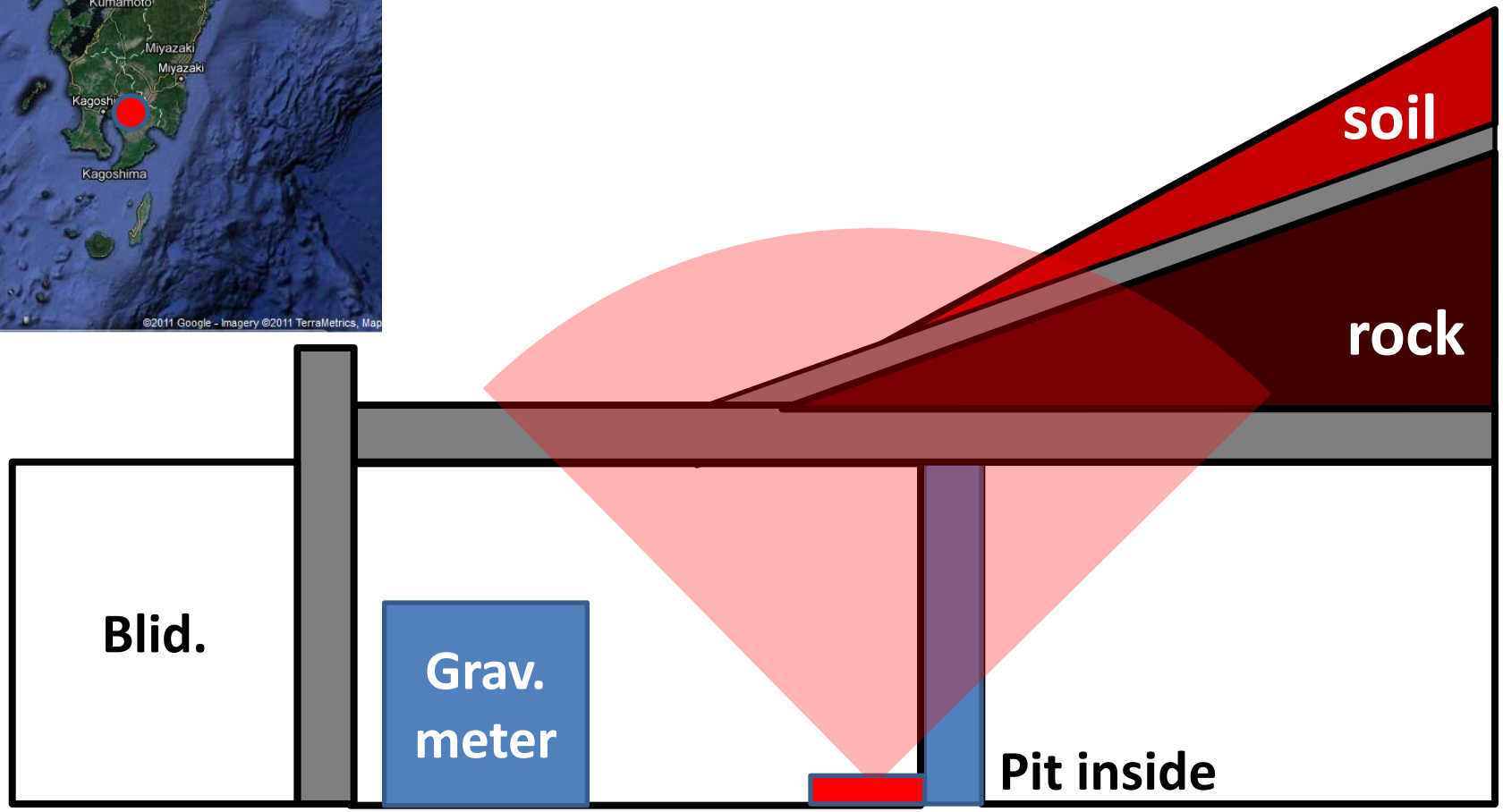
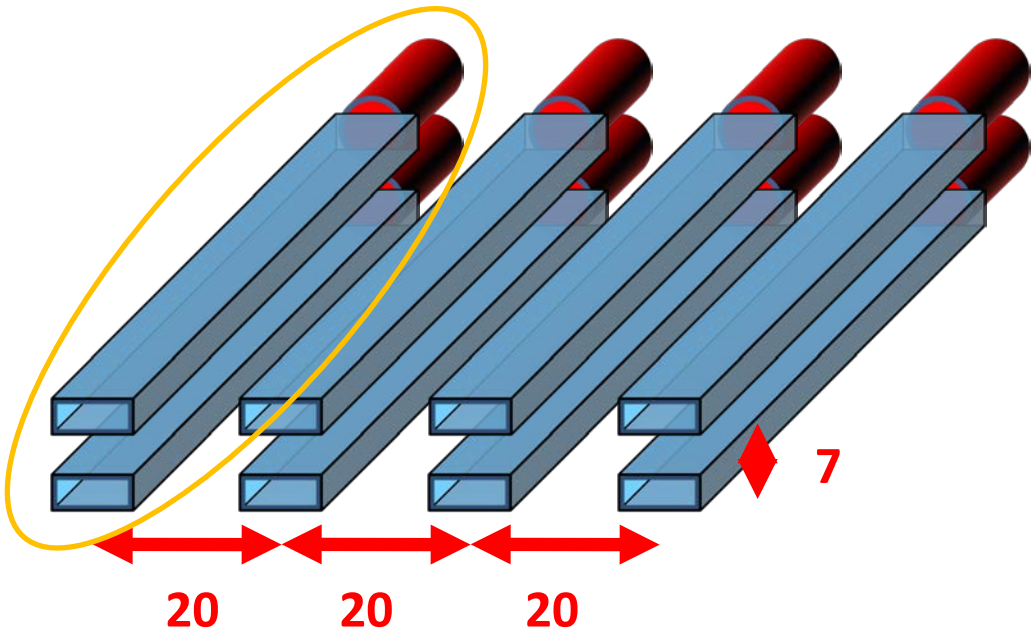
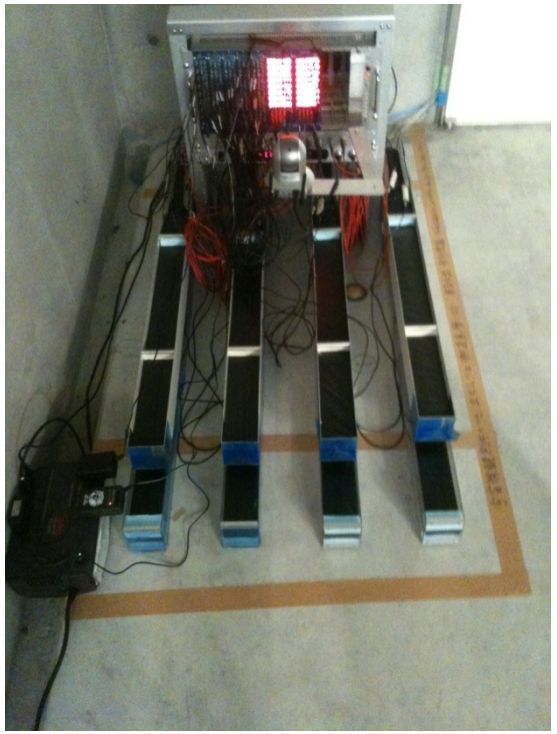


Detector arrangement

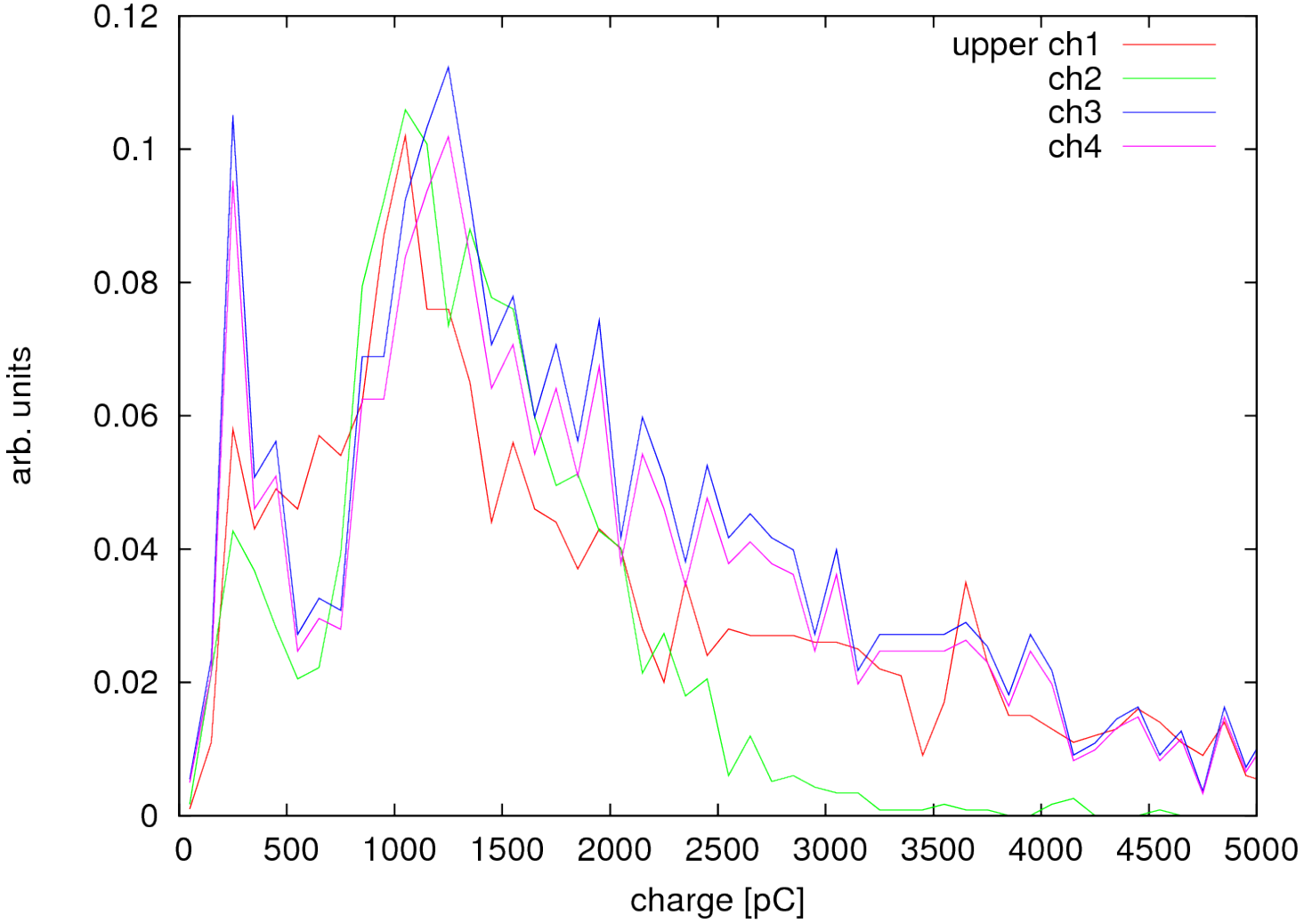




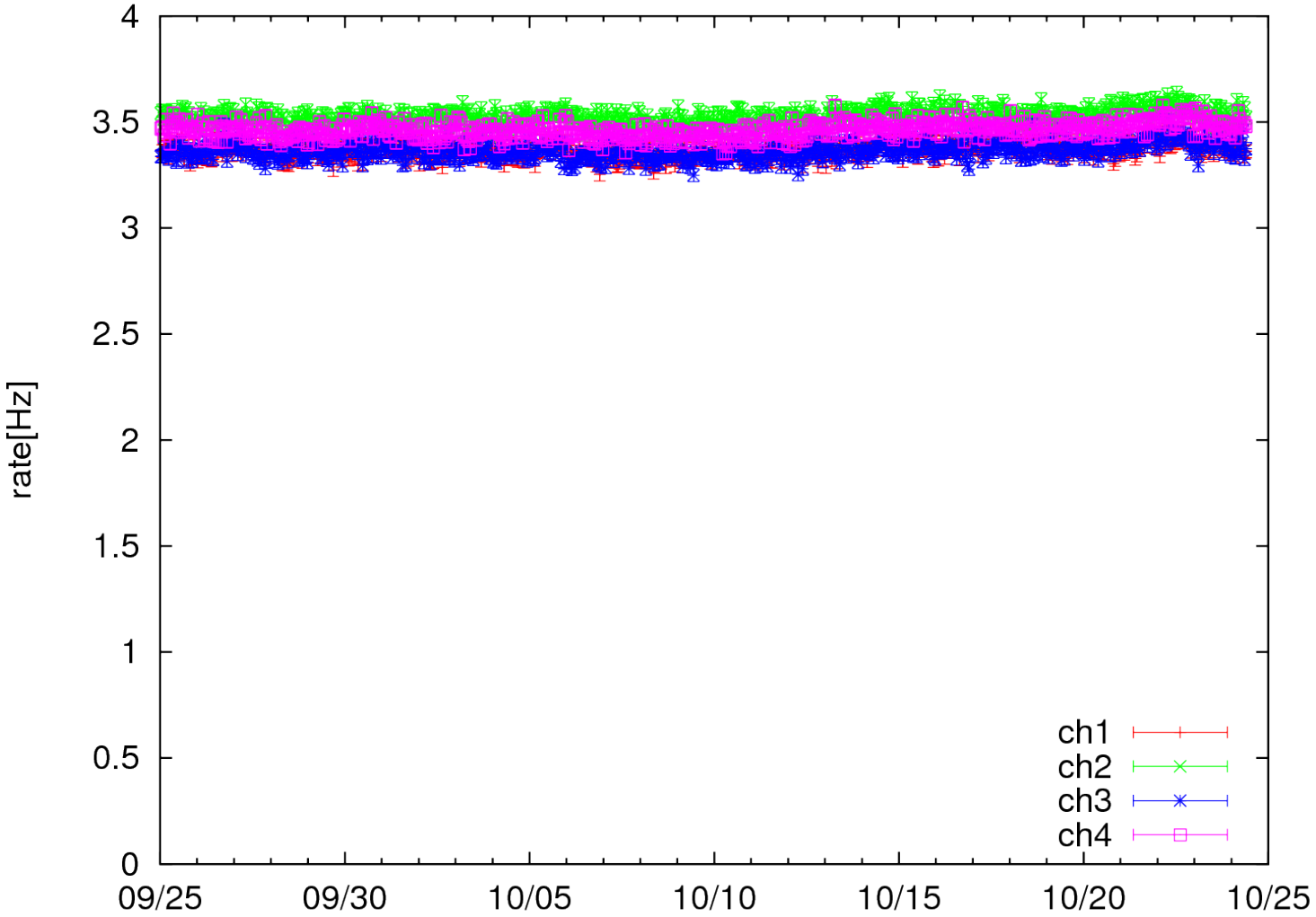
1 unit consists of
- 2 Scintillator (100 x 7 x 2)
- 2 PMT + attenuator
- coincidence upper and lower

→ Take coincidence of any 2 units

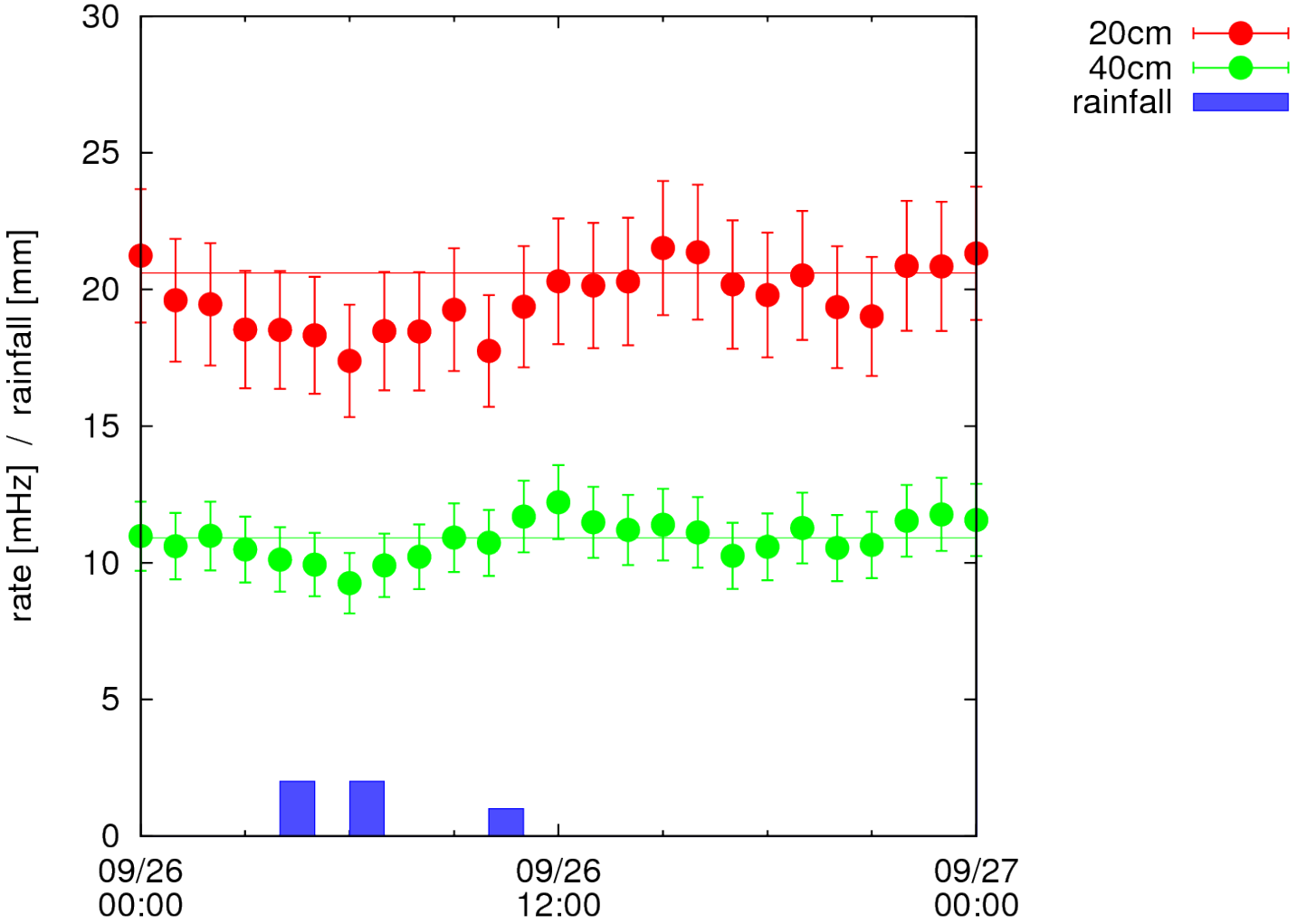
Detector gain calibration



Single unit count rate



Typical permutation effect (6 hour moving average)



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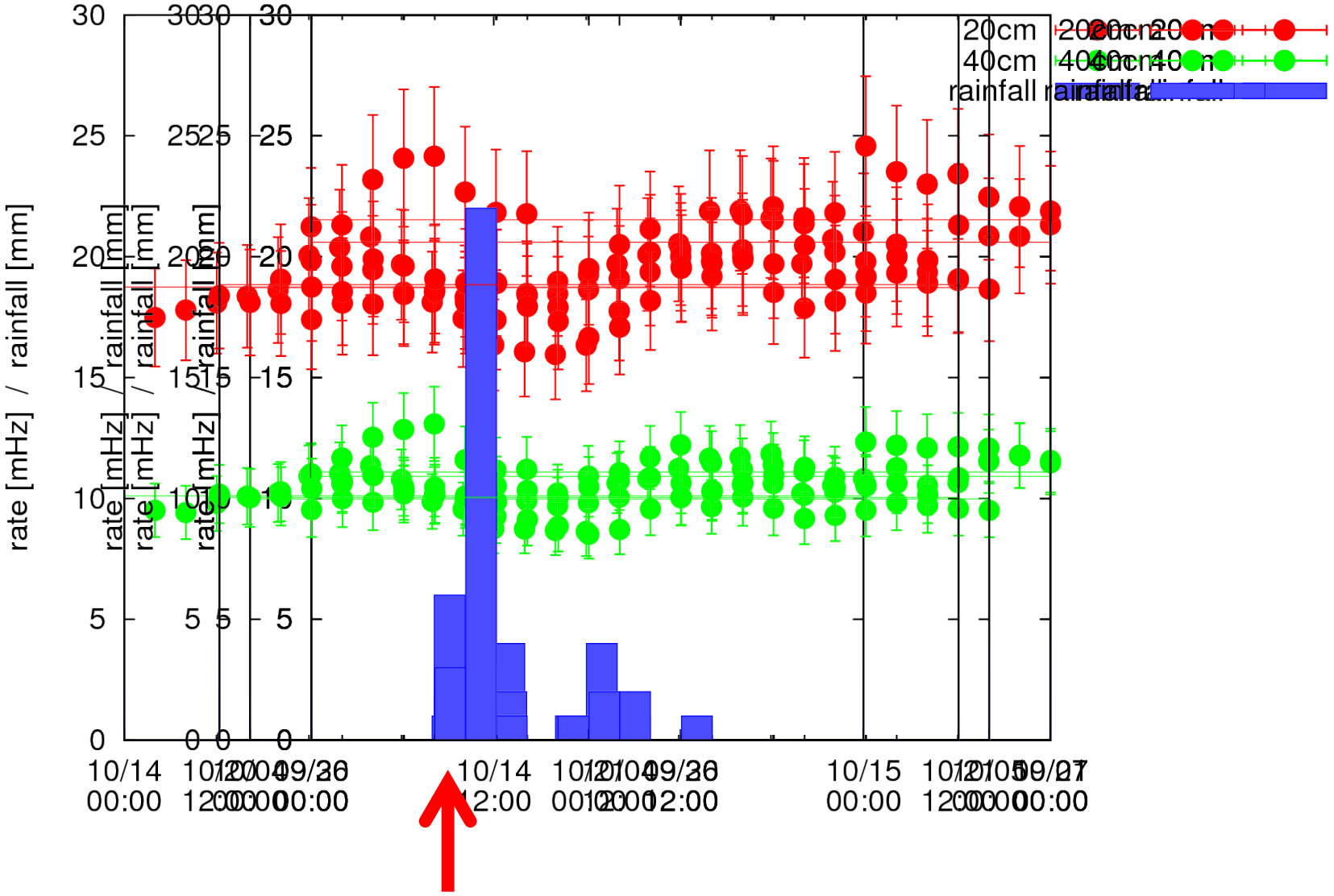
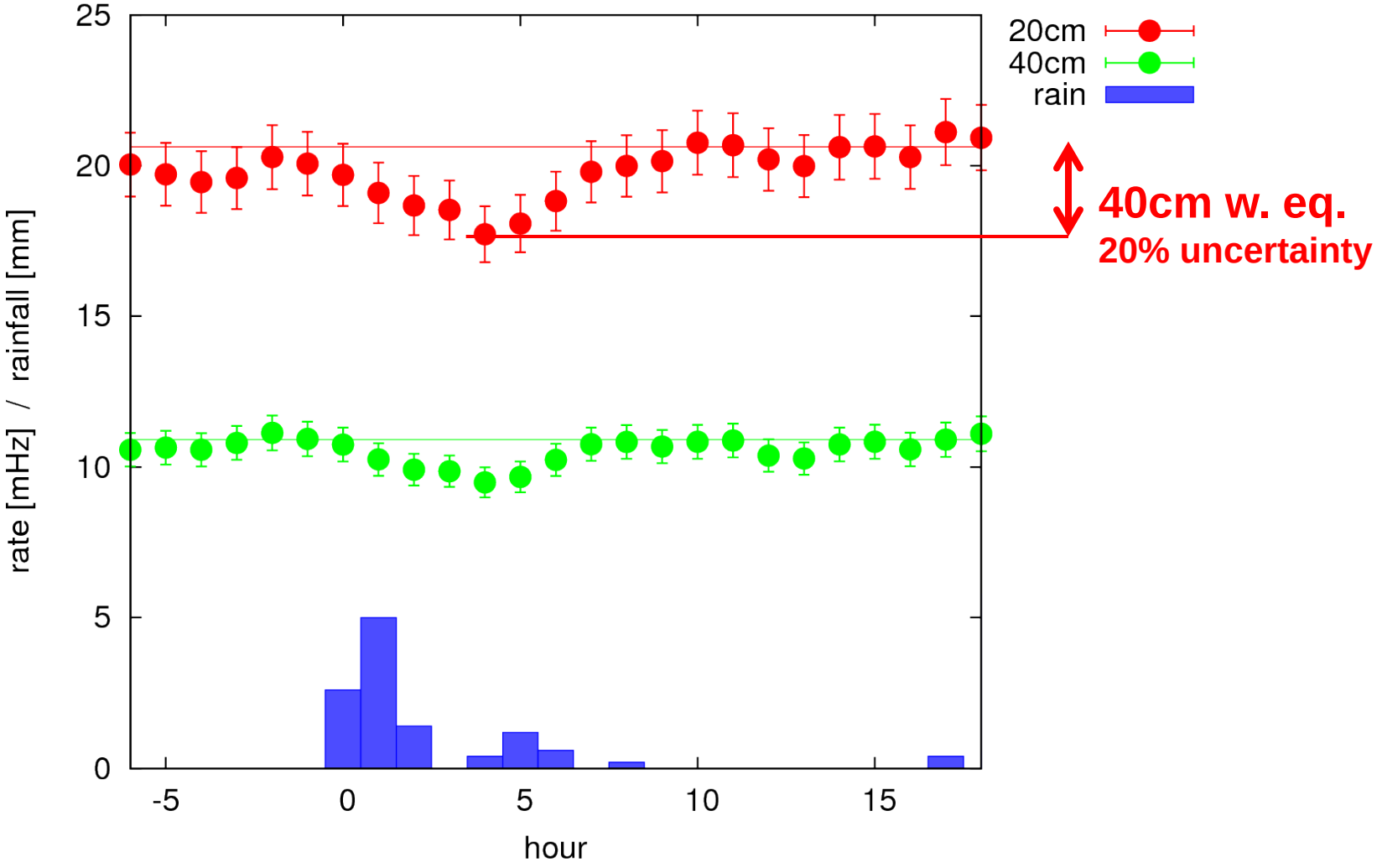
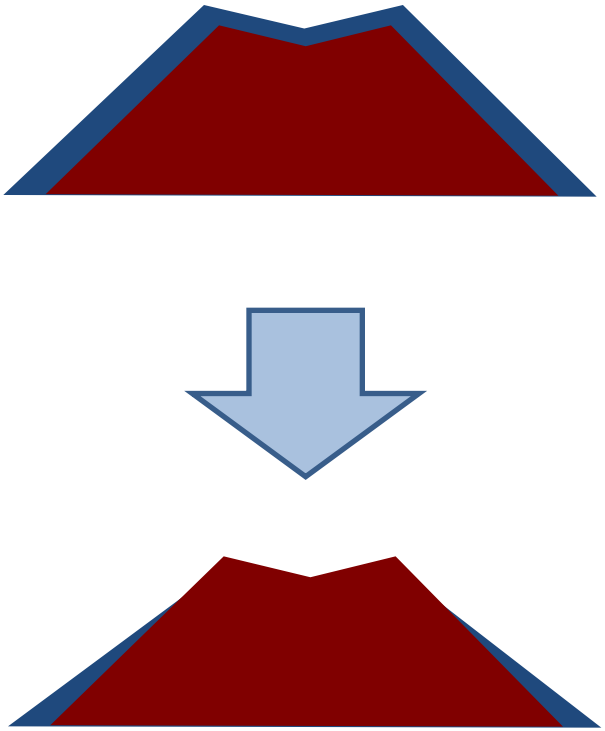


Average permutation effect (6 hour moving average)



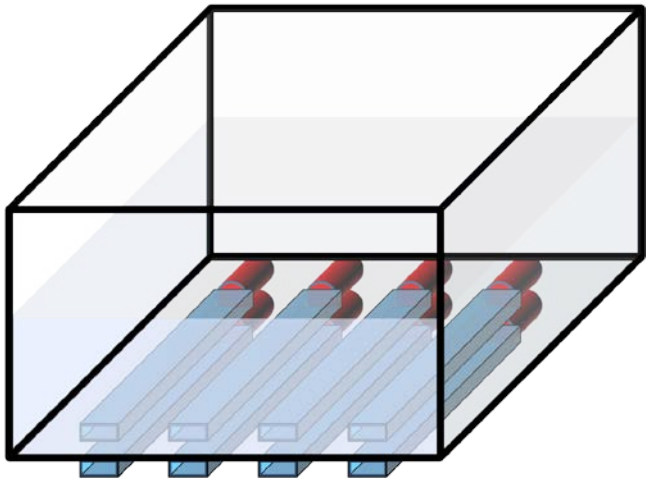
Result of the observation

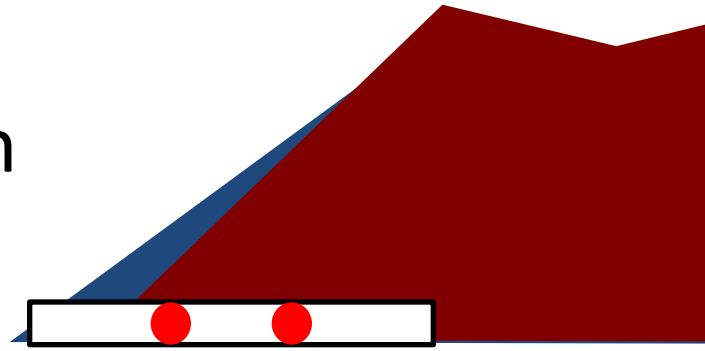
- There is clear anti-correlation between rainfall and soft component flux
  - After taking average, not real-time
- Maximum water level was 40 cm
  - Hydrologist says “It’s possible”
  - Need to confirm
- 5 hours delay from rainfall to flux decreasing
  - Underground water stream?
- Short recovery time ~ 5 hours
  - More sensitive to underground water stream than water content of soil ?



Near future prospect

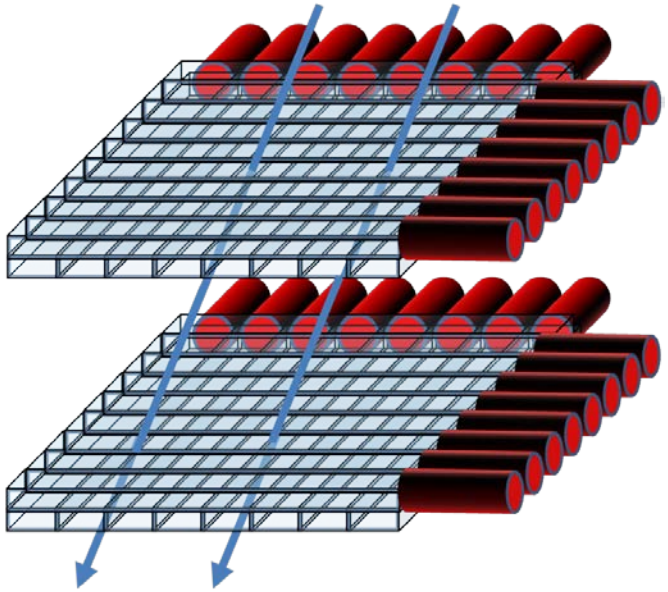
- Enlarge detector effective area
  → 3 times larger
- Detector calibration using water tank above detector
- Simultaneous observation from another point in same pit
  – To measure the speed of underground water stream
- Simultaneous observation from different pit
  – To know the locality



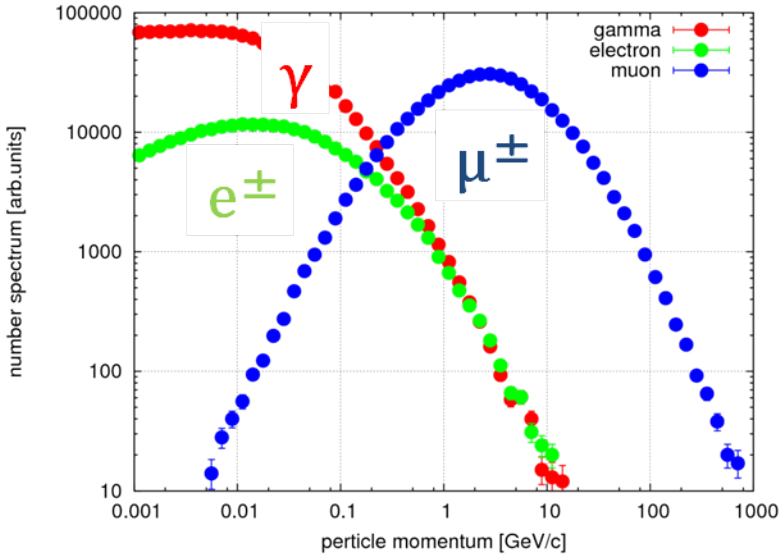


Future prospect

- 2+1D radiography
- 2+1+1D radiography with superconductive gravitymeter
- Emulsion based measurement



- Study for hydrology
  - Calibrator for geophysical measurements
  - Landslide alert
- Remote sensing of the water level in the building



Conclusion :

Air shower is not only for physics, but also for application

- ***Now our enemy become my friend !***
  - I hope it will also be your friend
- We have developed a novel radiography method for small scale structure
  - Enlarged CR radiography observable range
  - A lot of ***possible*** applications
  - Disaster prevention (landslide etc)
- Hydrology study by **air shower**
  - Accuracy improvement of magma head movement and magma chamber pressure variation

Thank you very much for your attention