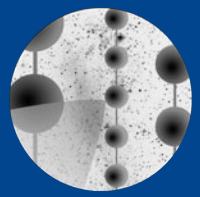


universitätbonn

RASTA
Radio Air-Shower Test Array

Sebastian Böser
on behalf of the radio air shower group

Radio Workshop

Madison

March, 15th 2010

Overview

universitätbonn

Motivation

- Composition
- Veto for IceCube
- UHE gammas

Large array

- Layout
- Trigger & Data flow

Simulation efforts

- LOPES based
- REAS2 based

RASTA

- Science goals
- Setup
- Modified DOM mainboards
- Event rate estimate

sboeser@physik.uni-bonn.de

Motivation

universitätbonn

IceCube

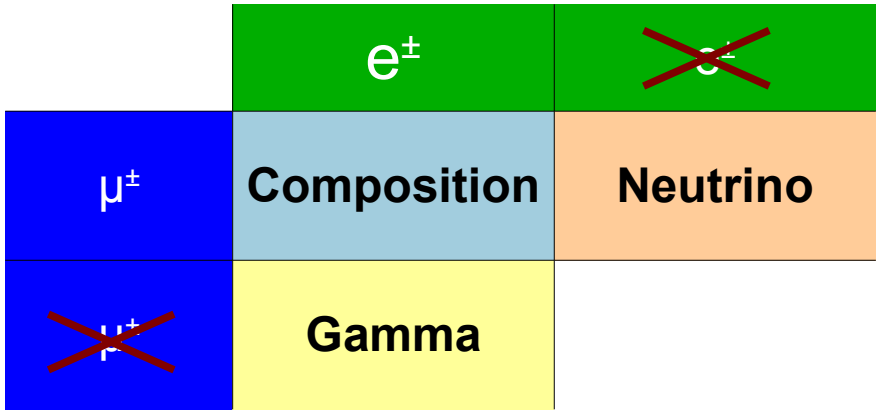
- measures muons (above ~TeV) in the ice

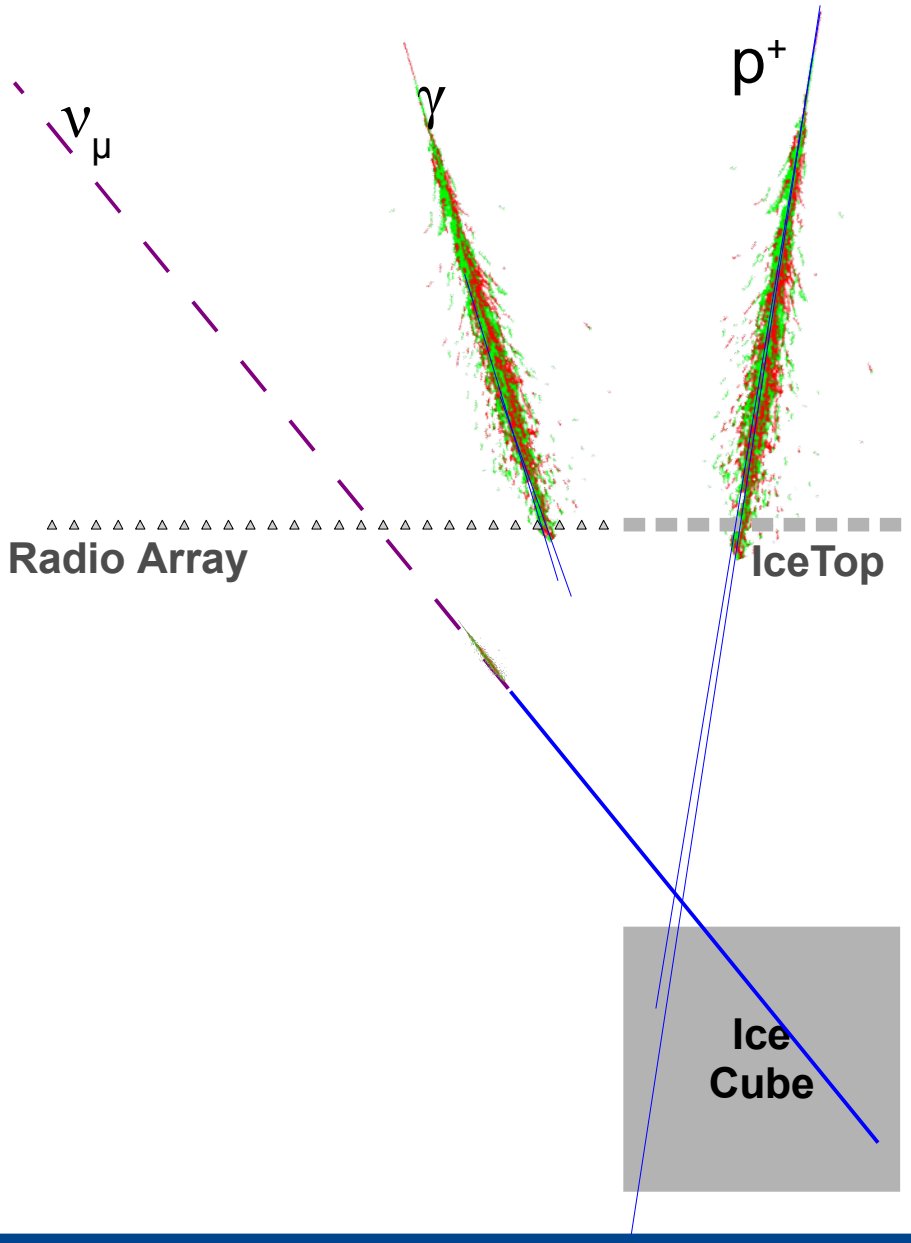
IceTop

- measures electron and muon population on the ground

Radio array

- measures total electron component (muon contribution negligible)





sboeser@physik.uni-bonn.de

Motivation: Composition

universitätbonn

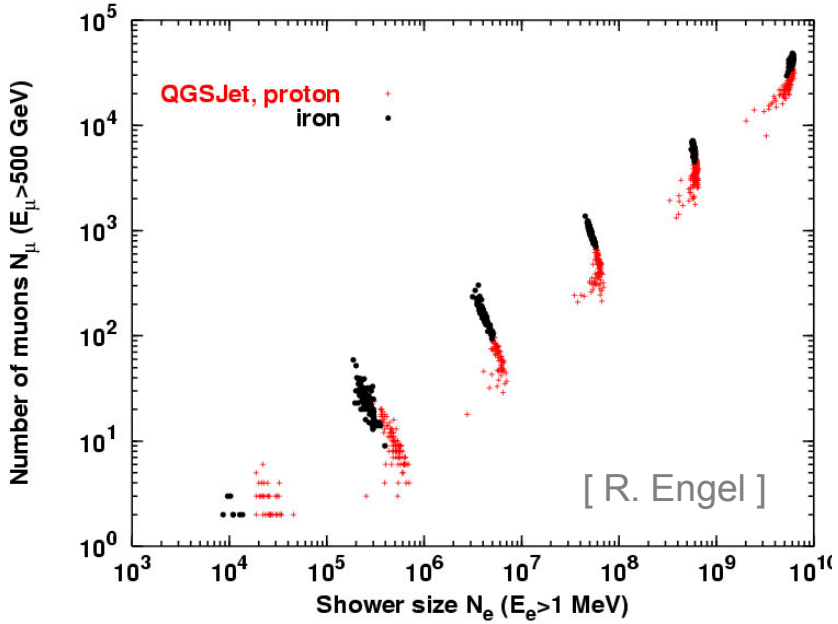
Composition measurement

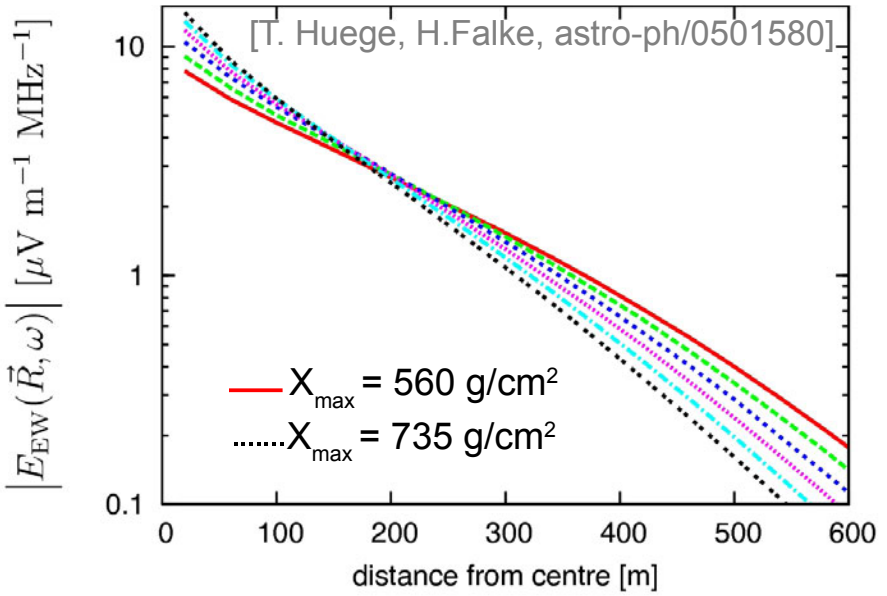
① from e-to-μ ratio

- heavy nuclei
  ➔ enhanced muon component
- IceTop: μ+e -Component
- IceCube: μ -Component
- Radio signal:
  - synchrotron emission ~ m^{-4}
    ➔ only e -Component

② from radial distribution

- steepness depends on distance to shower maximum
- will be enhanced at IceCube height (at ~750 g/cm²)





sboeser@physik.uni-bonn.de

Motivation: Neutrinos

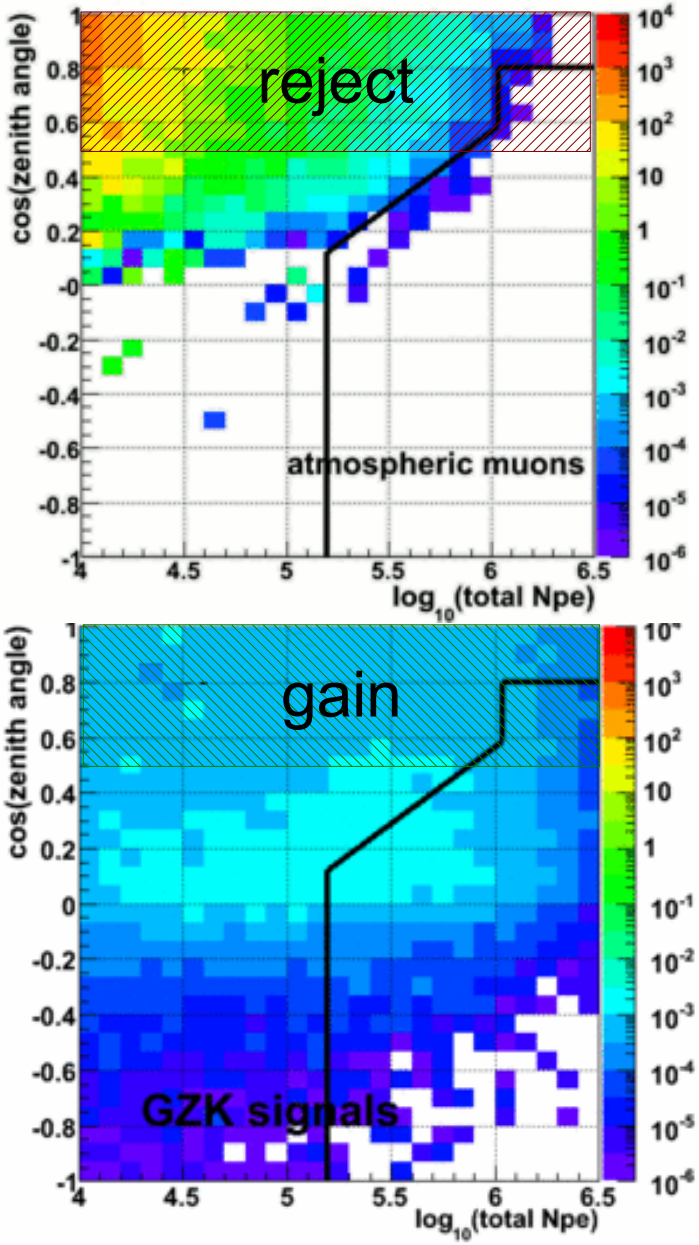
universitätbonn

Neutrino detection

- Provide a veto for air-showers above IceCube
  - ➔ increase the effective neutrino volume
  - ➔ reduce the muon bundle background for UHE analysis
- from IC22 UHE analysis
  - ➔ gain factor of ~3

Experiment	N_{events}(GZK)
ANITA	2 / flight
IceCube	0.7 / year
IceCube + veto	2 / year

- Provide a veto for an in-ice GZK radio array ?



sboeser@physik.uni-bonn.de

Motivation: Gamma rays

Idea

- search for muon-poor showers

photon induced showers

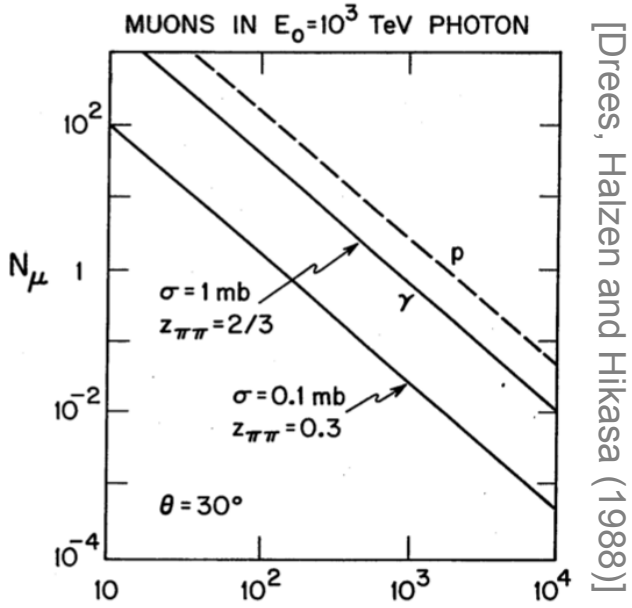
- contain 100x fewer energetic muons

➔ can be detected in radio array

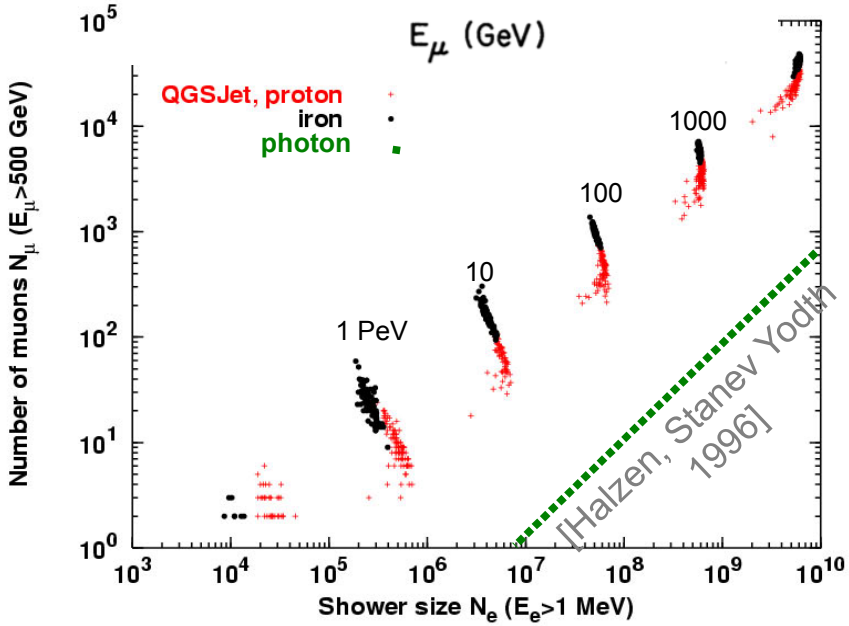
hadron induces showers

- will always contain some TeV muons
- will be detected in IceCube

➔ use as veto



[Drees, Halzen and Hikasa (1988)]



[Halzen, Stanev Yodh 1996]

sboeser@physik.uni-bonn.de

Motivation: Gamma sources

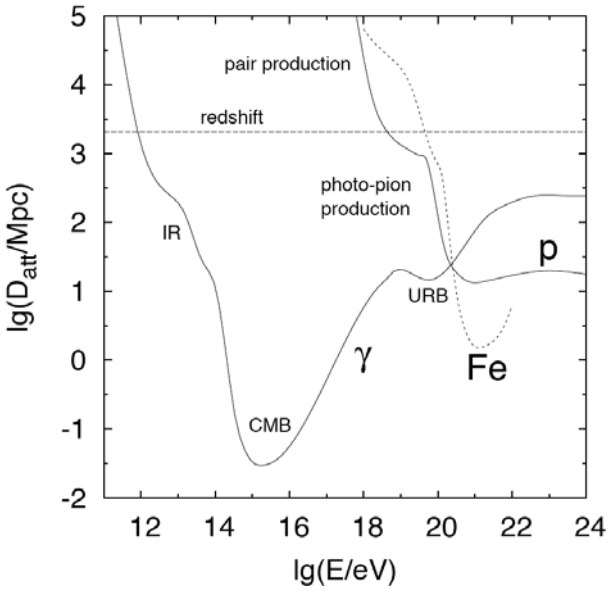
universitätbonn

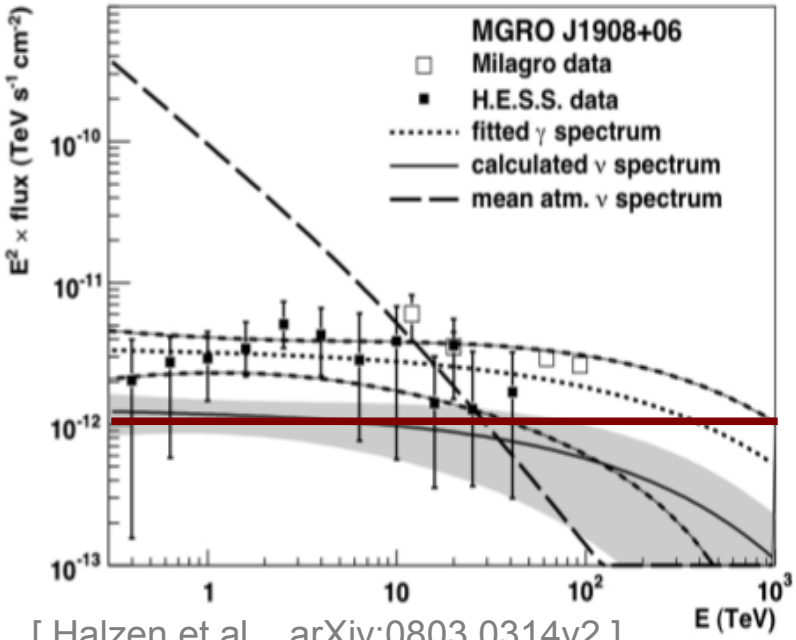
PeV photon sky

➔ largely unexplored

Extragalactic sources

- shielded by CMB absorption





[Halzen et al., arXiv:0803.0314v2]

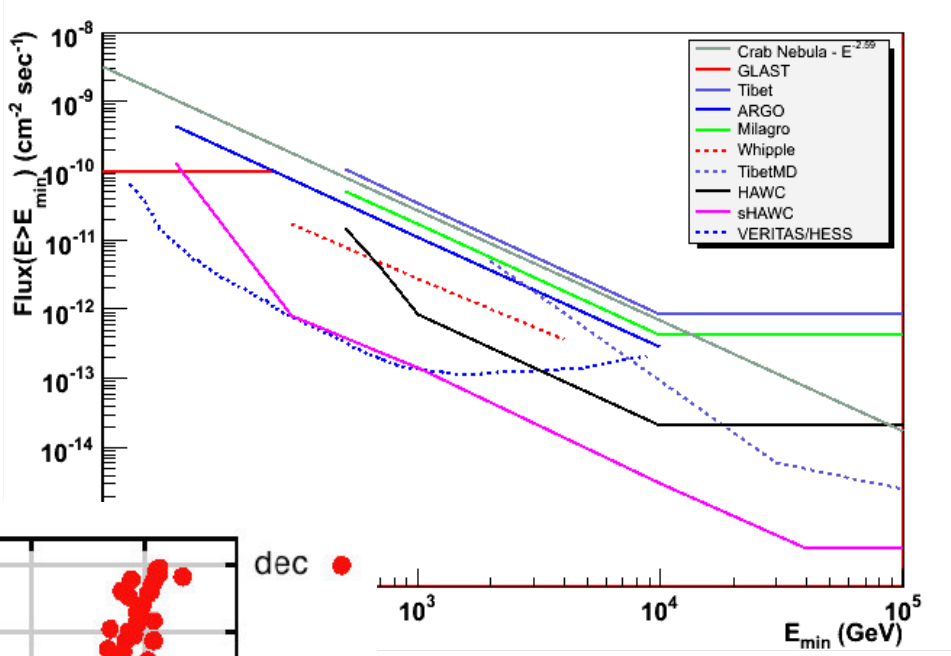
Galactic sources

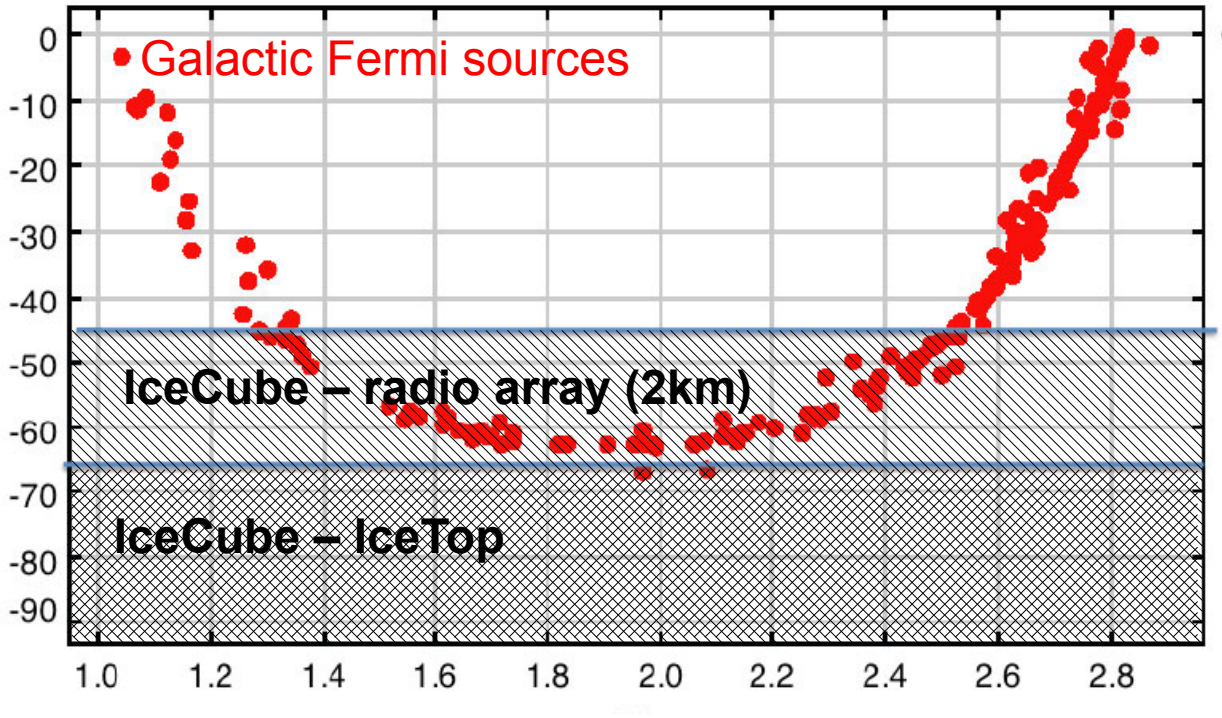
- Pevatron accelerators detected by Milagro
  - ➔ no sign of cutoff
    - expected at > 100 TeV for EM acceleration
- for unbroken E^{-2} at 10^{-12} TeV^{-1} s^{-1} cm^{-2}
  - ➔ Ø(10) events/year/km² with E > 1 PeV

sboeser@physik.uni-bonn.de

Motivation: Gamma sources

Experiment	A_{eff} [m^2]	FoV [sr]
Milagro	4 x 10^3	2π
HAWC	4 x 10^4	2π
Radio array	10^6	> 0.7





IceTop – IceCube:

- cover 25° from vertical

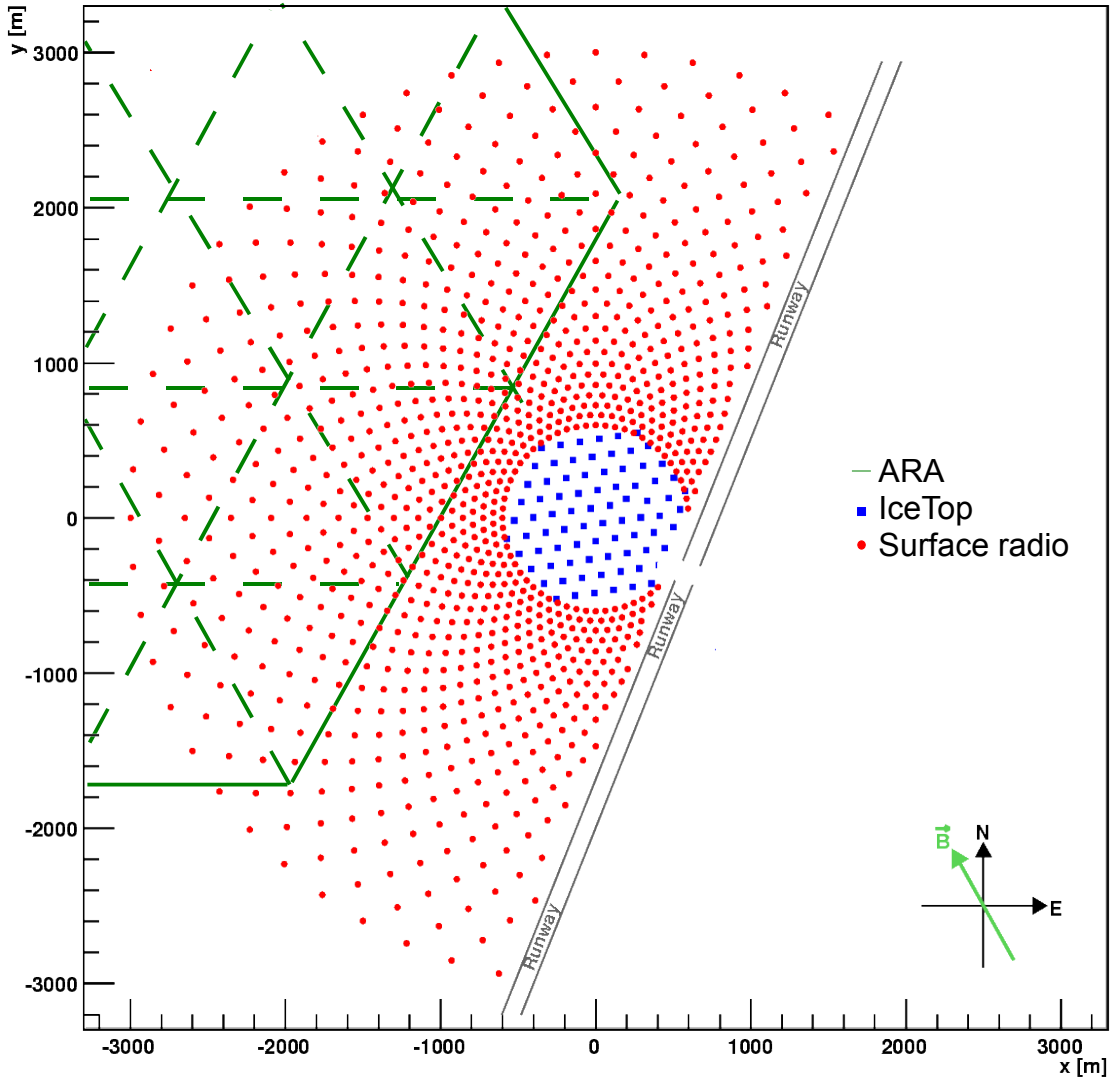
Radio array – IceCube:

- at 2km extension

  ➔ cover 45° from vertical

sboeser@physik.uni-bonn.de

Large scale array



Magnetic field

- -72.5° inclination (upwards)
- -29.2° declination

Constraints

- IceCube side of runway
- 3km radius (logistics)

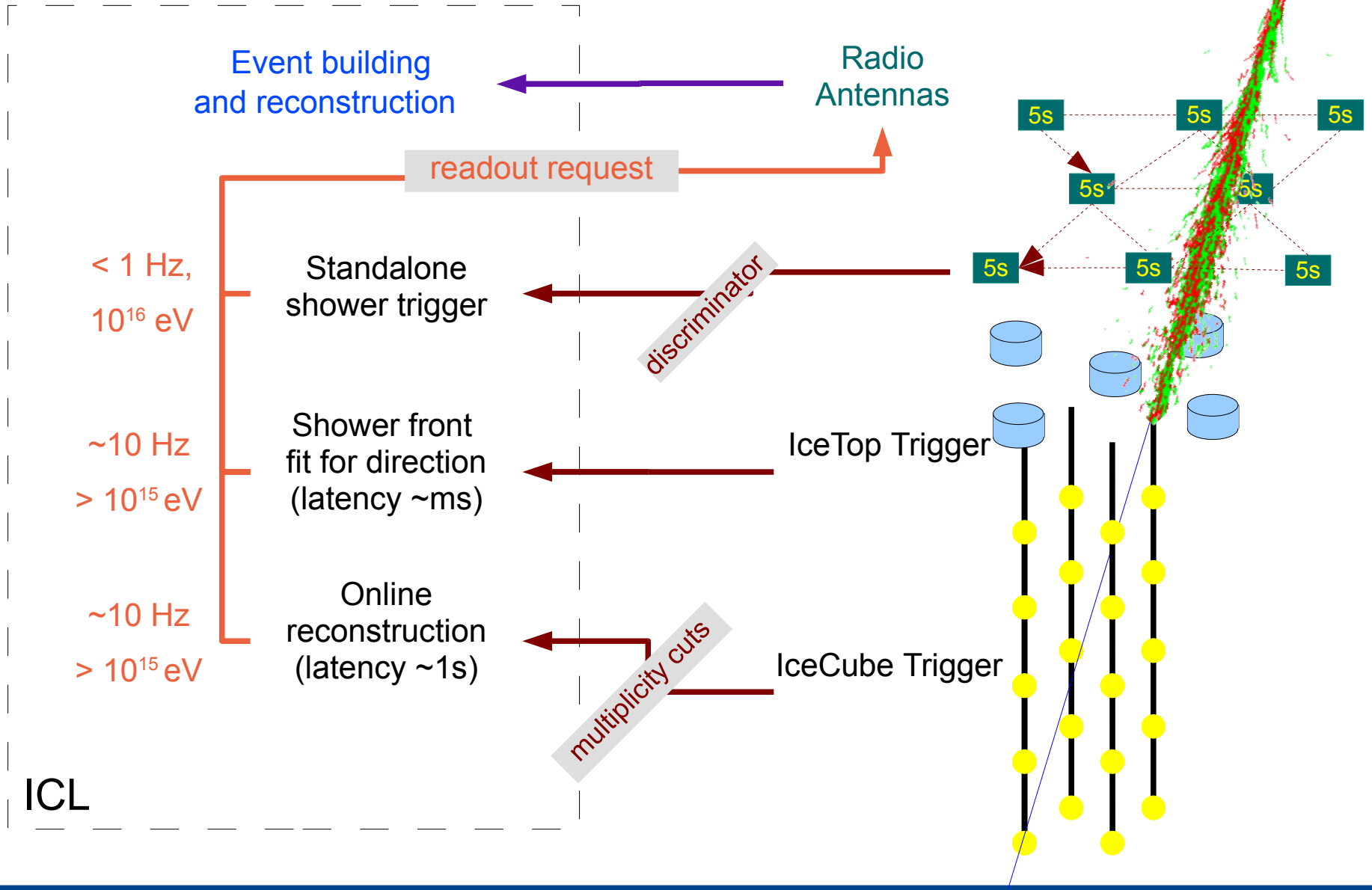
Configuration

- several hundred sensors
- increasing radial spacing

  ➔ compensate for signal strength

sboeser@physik.uni-bonn.de

Trigger and data flow



sboeser@physik.uni-bonn.de

Simulation I: LOPES parametrisation

universitätbonn

LOPES

- 30 radio antennas
- triggered by KASCADE
- 40-80 MHz bandwidth
- Calculate cross-correlation beam

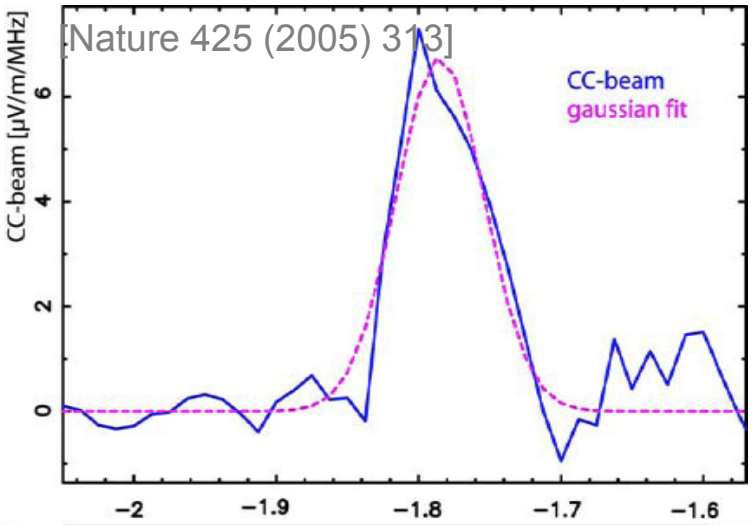
$$cc[t] = \pm\sqrt{\pm\frac{1}{N_{pairs}}\sum_{i}^{N-1}\sum_{j>i}^{N} s_i[t]s_j[t]}$$

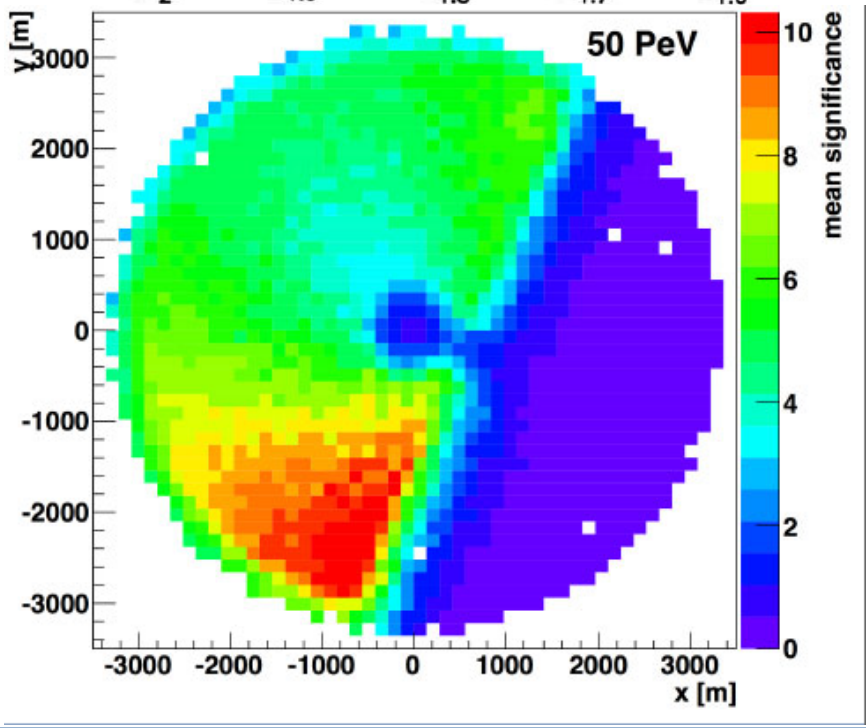
CC-beam parametrisation

$$\varepsilon_{EW} = A(1 + B - \cos\alpha)\cos\theta \; exp\left(-\frac{R}{R_0}\right)\left(\frac{E}{10^{17}eV}\right)^{\gamma}$$

Limited validity

- narrow frequency band
- close-to-vertical showers
  - ➔ **wrong angular description**
- **no pulse shapes**





sboeser@physik.uni-bonn.de

Simulation III: REAS2 – Jan Auffenberg

universitätbonn

REAS2

- full air shower simulation (CORSIKA)
- trace every particle and calculate radio emission
- very slow (Ø(hrs) per event)

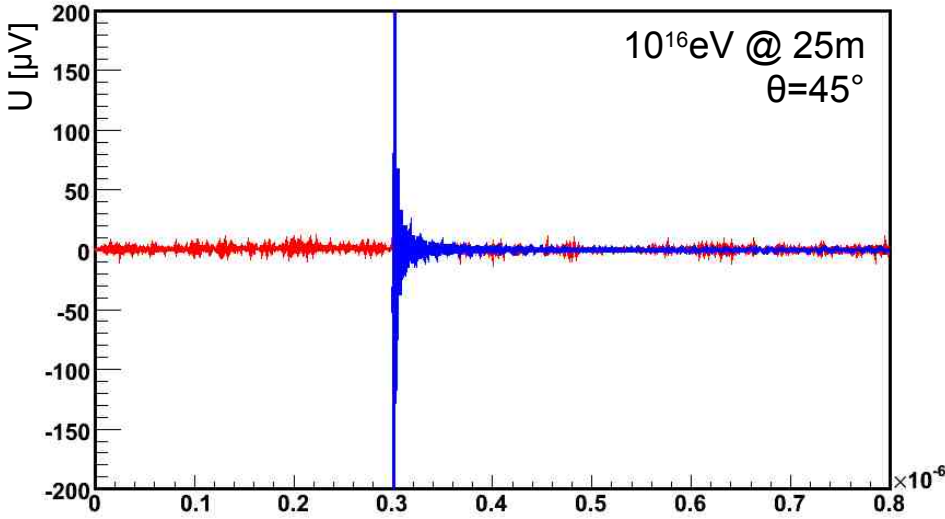
Dataset

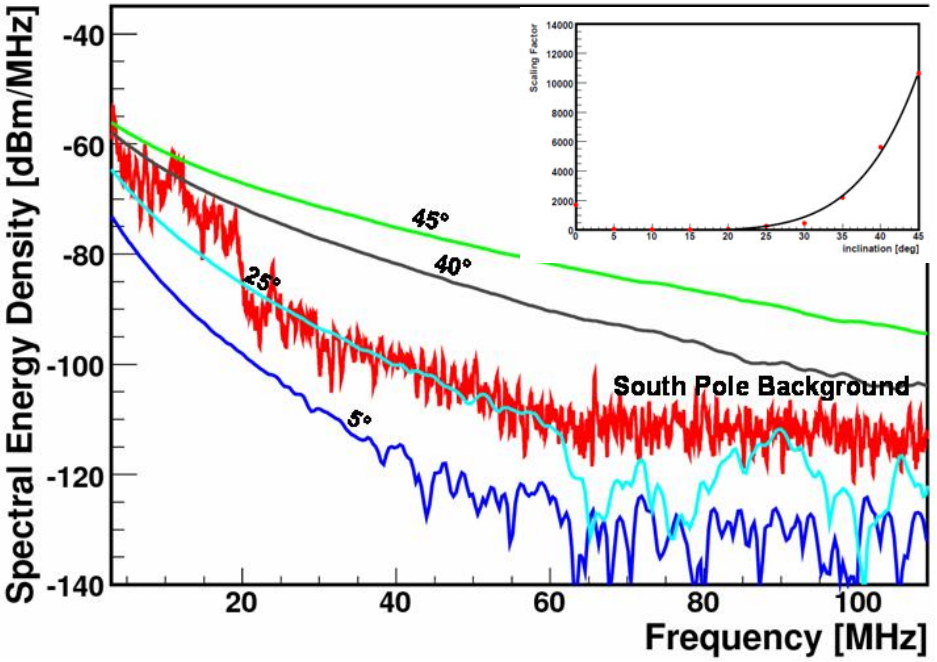
- few events at
  - PeV – EeV energies
  - 5º – 45º zenith angle
  - various azimuth angles

Results

- profit from lower noise level at low frequencies
- should get larger signal towards the horizon for proper antennas

➔ **severly CPU limited**





sboeser@physik.uni-bonn.de

Motivation

- can not trust existing simulations

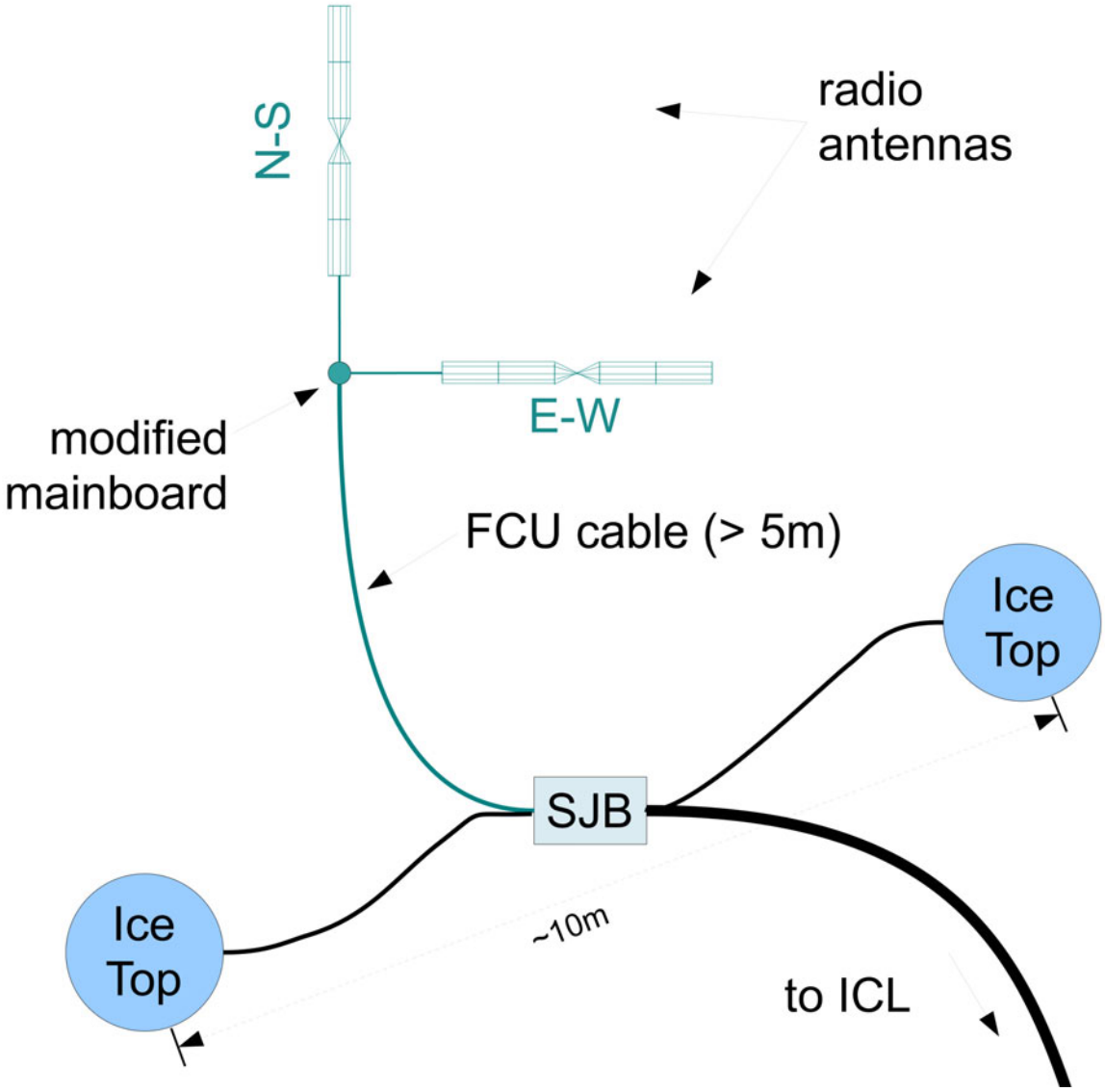
RASTA – Radio Air-Shower Test Array

Science goals

- show coincident detection of air-showers with IceTop
- measure air shower detection threshold
- measure transient background rates
- develop self-trigger strategies

sboeser@physik.uni-bonn.de

Setup



Limited resources

➔ reuse exisiting experience & infrastracture

Antennas

- fat wire dipoles

DAQ

- modified DOM mainboard

Cabeling

- IceTop freeze control

Software

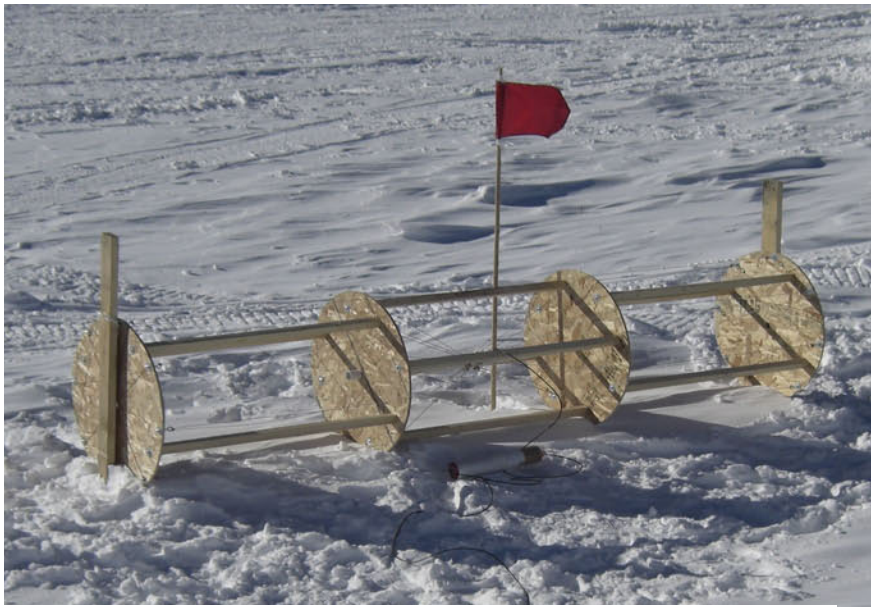
- AURA & SATRA or IceCube experience

sboeser@physik.uni-bonn.de

Antennas

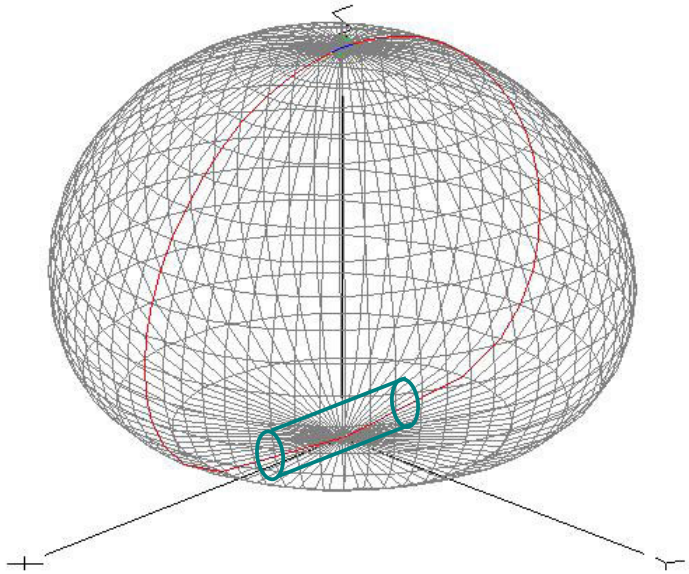
Fat wire-dipoles

- higher bandwidth than single dipoles
- smaller group delay than log-periodic dipole
- good acceptance in all directions
- successfully tested at South Pole



South Pole

- 4 (maybe 6) antennas available
- ship 12 more (18kg per antenna)

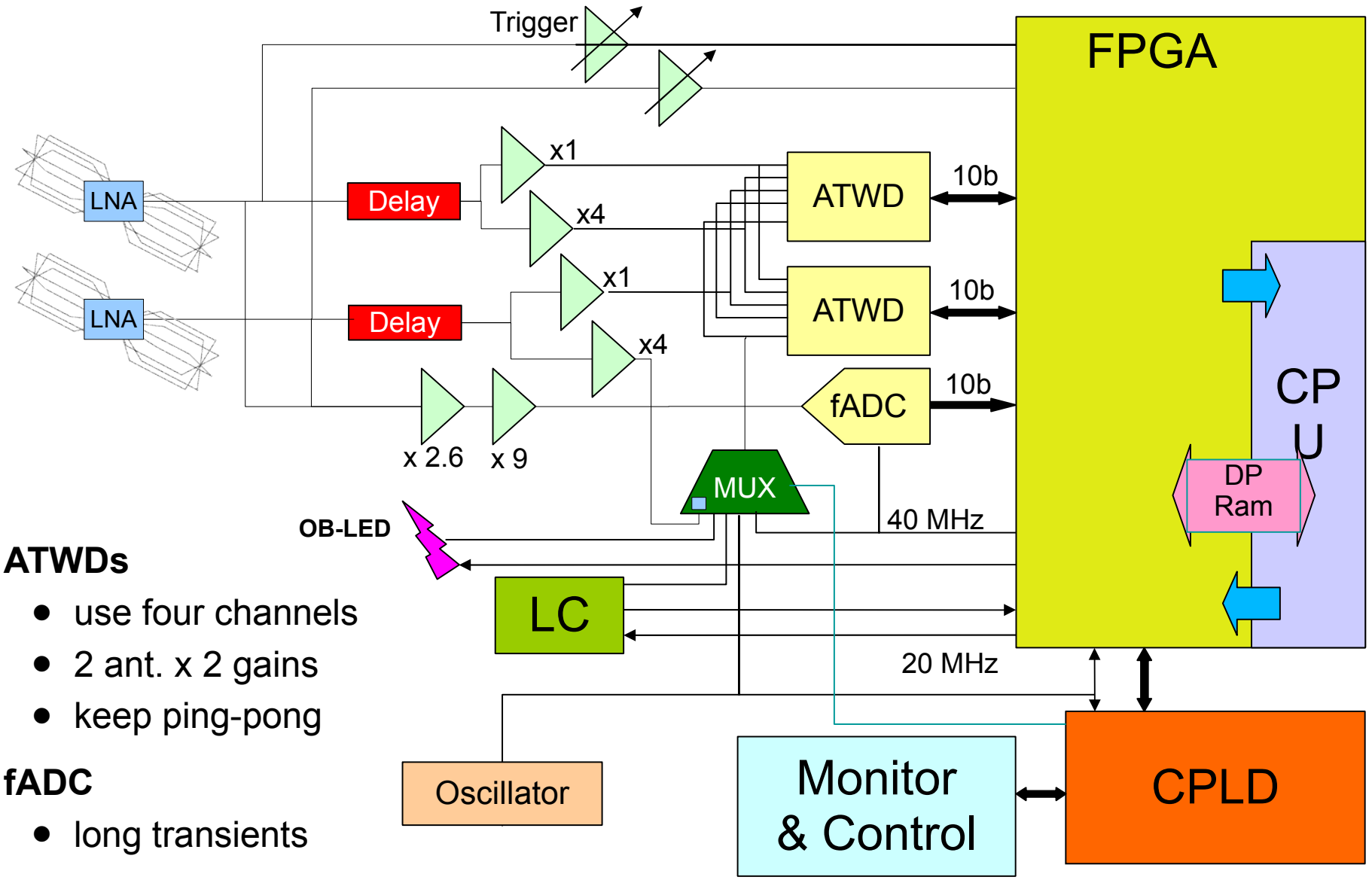


Deployment

- one E-W and one N-S per station
- in shallow ditch (1m deep)

sboeser@physik.uni-bonn.de

Modified DOM mainboard



ATWDs

- use four channels
- 2 ant. x 2 gains
- keep ping-pong

fADC

- long transients

sboeser@physik.uni-bonn.de

ICL & Software

universitätbonn

In ICL

- 2 DOR cards in one DOMHub
  (or 2 slots in existing hub)
- 1 DSB card

➔ standard IceCube

Software

- more questions than answers
  - can we use IceCube software ?
  - can we have a “radio multiplicity trigger” ?
  - can we get triggered by IceTop ?

Storage

- <10kB per event, 10Hz rate ➔ to tape
- 200MB/day (> 1k events) ➔ over satellite

sboeser@physik.uni-bonn.de

Layout and Event Rates

universitätbonn

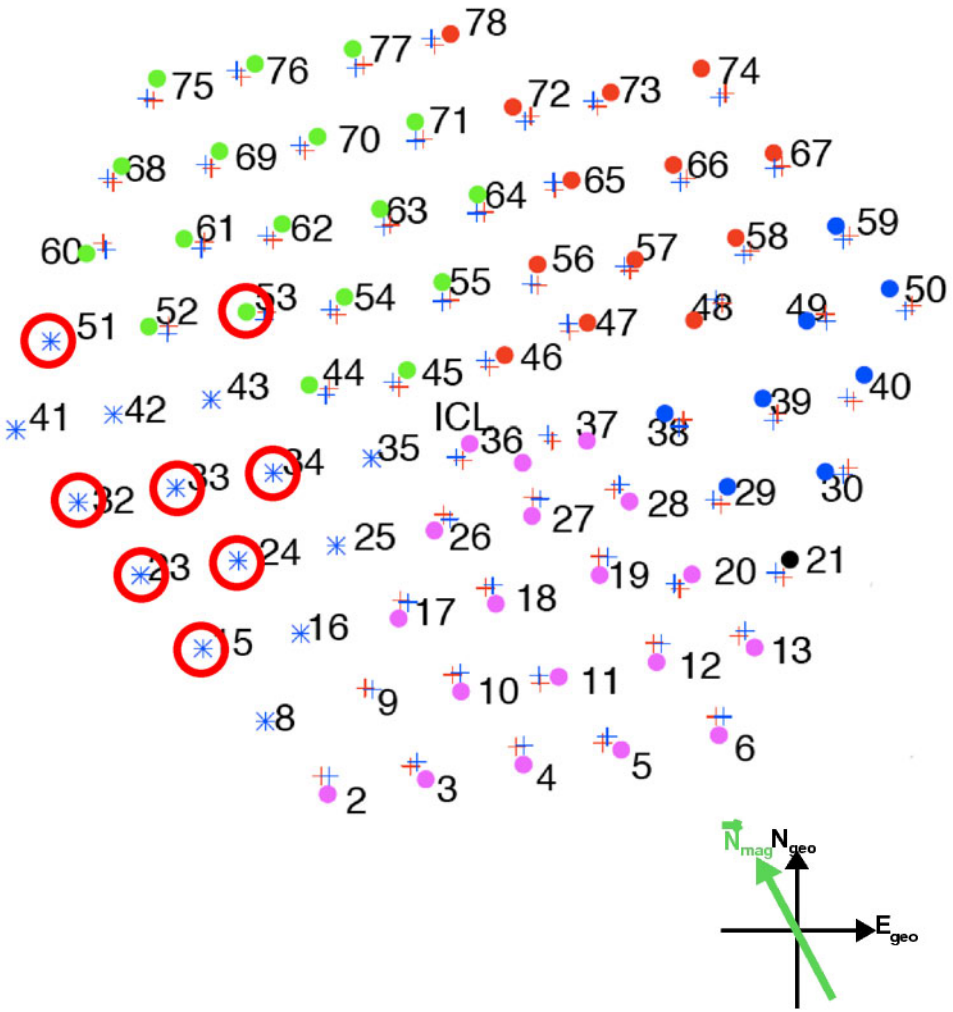
Layout

- 6 closely spaced for coincidence
- 2 further away
- can use any IceTop position

Event rate estimate

- single station triggers on 10^{17}eV at 125m
- 30°-60° to magnetic field
- $33 \cdot 10^3$ m^2 in dense part
- E^{-3} spectrum above 100 PeV

  ➔ Ø(1) event/day



sboeser@physik.uni-bonn.de