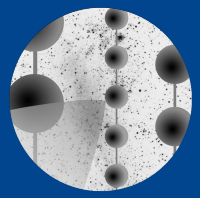

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A Radio Air-Shower Test Array (RASTA) for IceCube

Sebastian Böser
for the IceCube collaboration

ARENA

Nantes

June, 30th 2010

Overview

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Motivation

- Composition
- Veto for IceCube
- UHE gammas

Vision for large array

- Layout
- Trigger and data flow
- Items to be addressed

South Pole program

- Current setup
- RASTA proposal

Summary

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Motivation

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IceCube

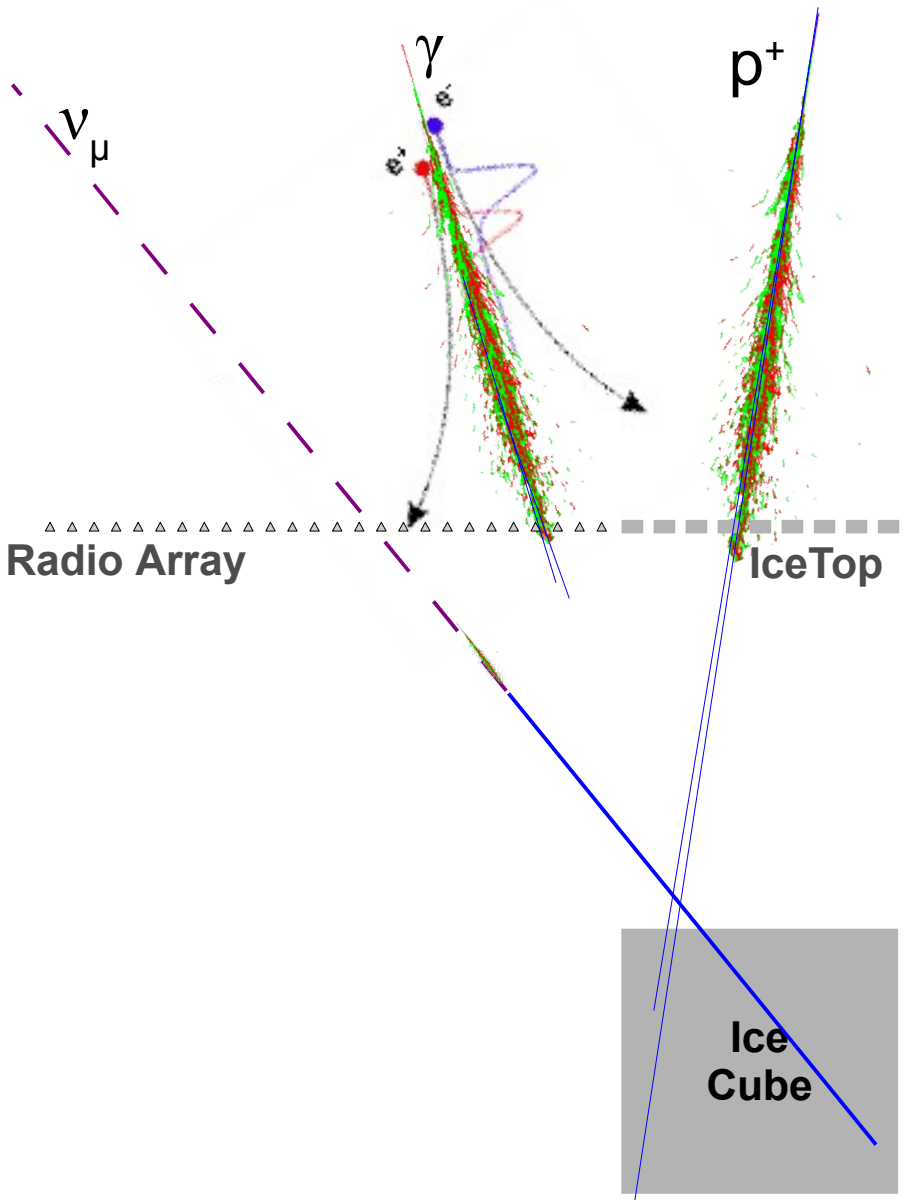
- measures muons (above ~TeV) in the ice

IceTop

- measures electron and muon population on the ground

Radio array

- measures total electron component (muon contribution negligible)



	$e^{\pm}$	~~$e^{\pm}$~~
$\mu^{\pm}$	**Composition**	**Neutrino**
~~$\mu^{\pm}$~~	**Gamma**	

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Motivation: Composition

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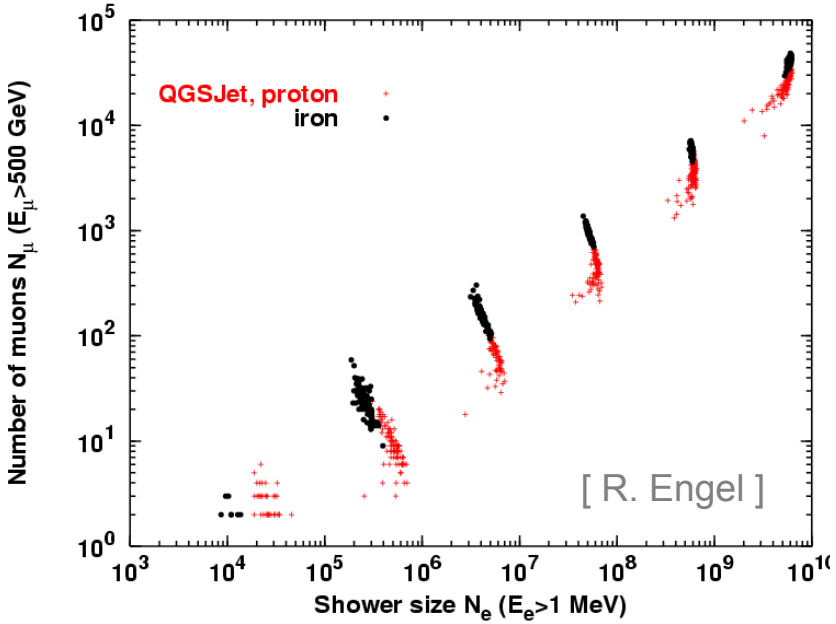
Composition measurement

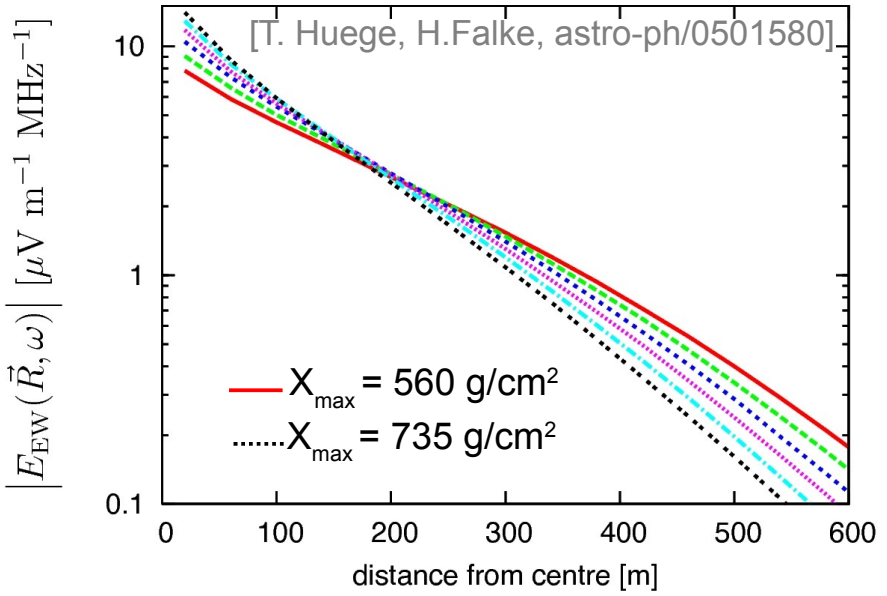
① from e-to-μ ratio

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

② from radial distribution

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





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Motivation: Neutrinos

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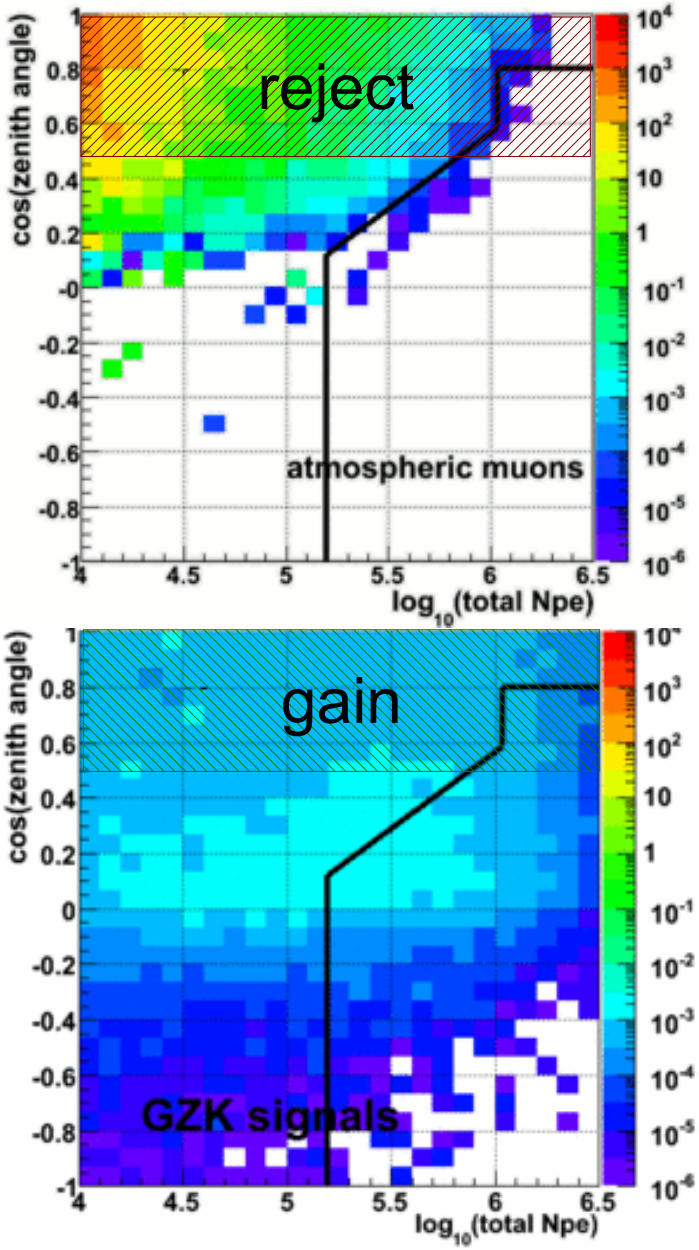
Neutrino detection

- 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 ?



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Motivation: Gamma rays

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Idea

- search for muon-poor showers

photon induced showers

- contain 100x fewer energetic muons

➔ can be detected in radio array

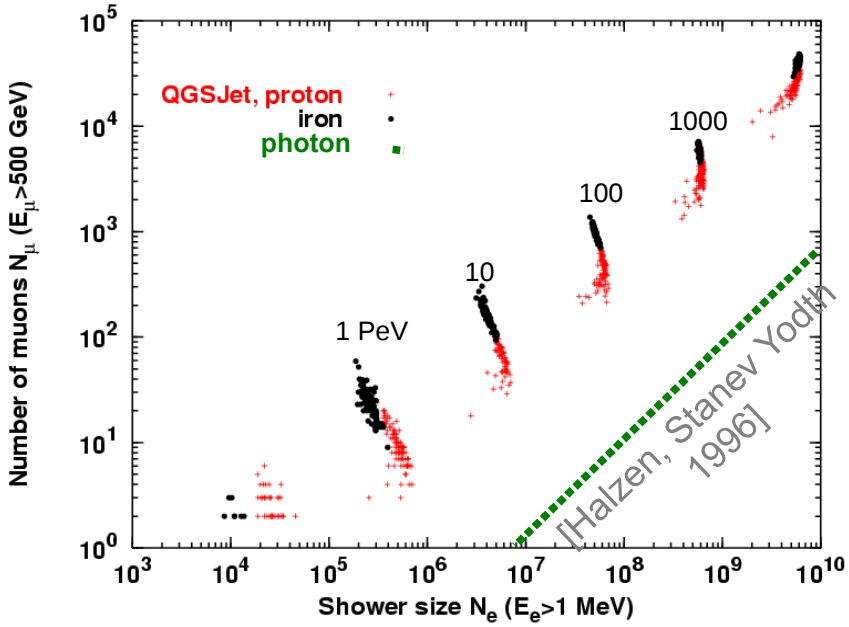
hadron induces showers

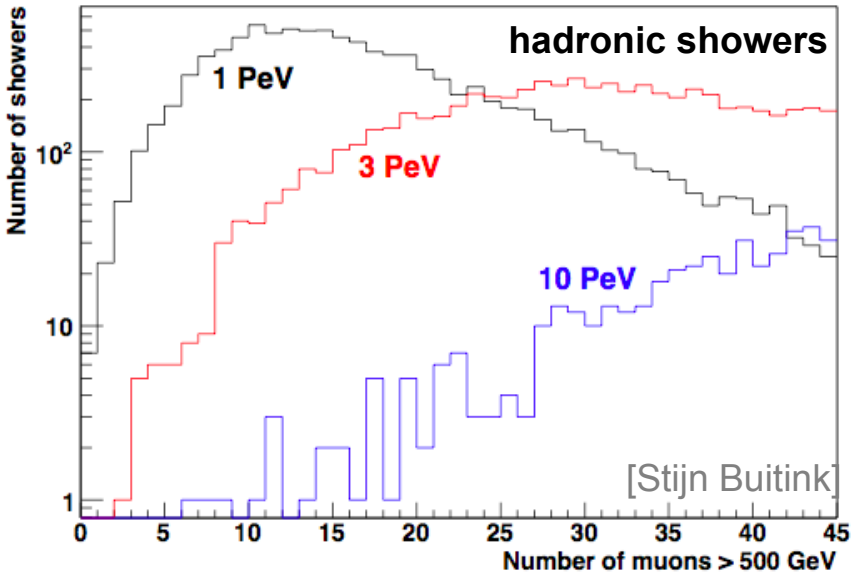
- will always contain some TeV muons
- will be detected in IceCube

➔ use as veto

Efficiencies

- false positives (CR w/o muons)
  - $< 10^{-3}$ for $E_{CR} > 1$ PeV
- false negatives (γ with muons)
  - estimated: %-level for E^{-2}





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Motivation: Gamma sources

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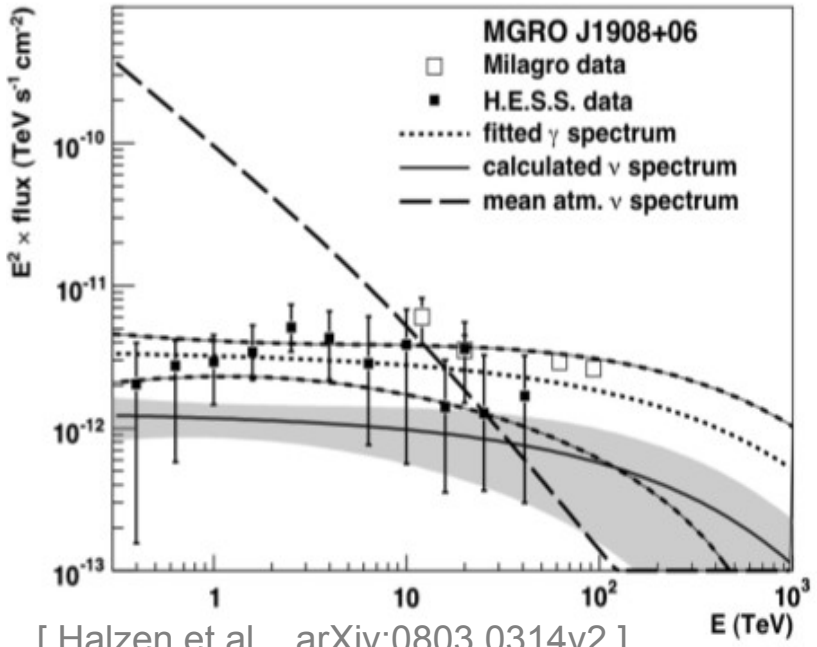
Photon limits

- Auger: $E_{CR} > 10^{17.5}$ eV
- KASCADE, CASA-MIA: $E_{CR} < 10^{16}$ eV

➔ energy range
not very well explored

Experiment	A_{eff} [m^2]	FoV [sr]
Milagro	4×10^3	2π
HAWC	4×10^4	2π
IceTop	10^6	0.25π
Radio array	10^6	1π



[Halzen et al., arXiv:0803.0314v2]

Extragalactic sources

- absorption on CMB
  ➔ attenuation length Ø(100kpc)

Galactic sources

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

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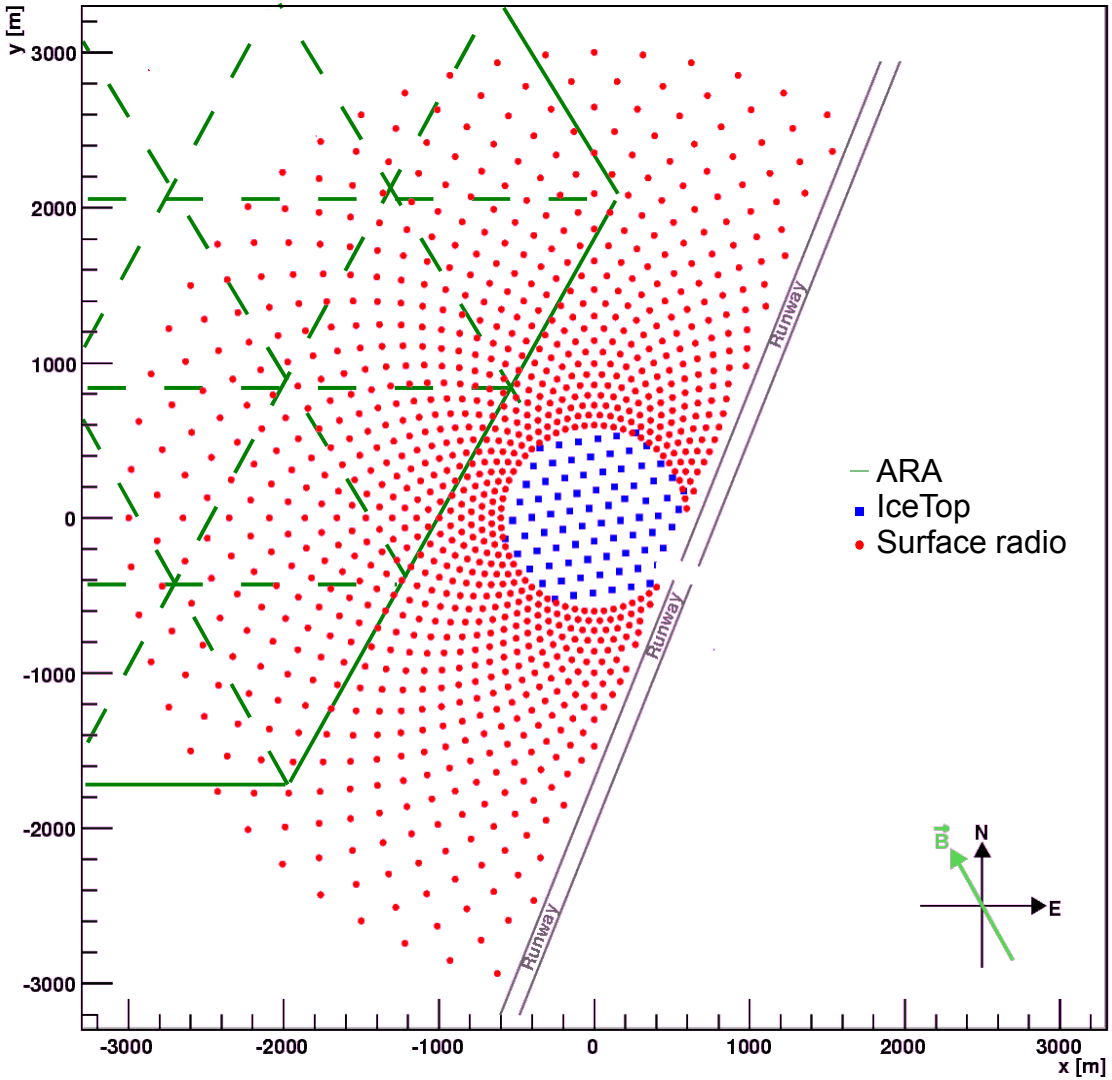
Vision: large scale array



Magnetic field

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

Constraints

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

Configuration

- several hundred sensors
- increasing radial spacing (60m - 300m)

  ➔ compensate for signal strength

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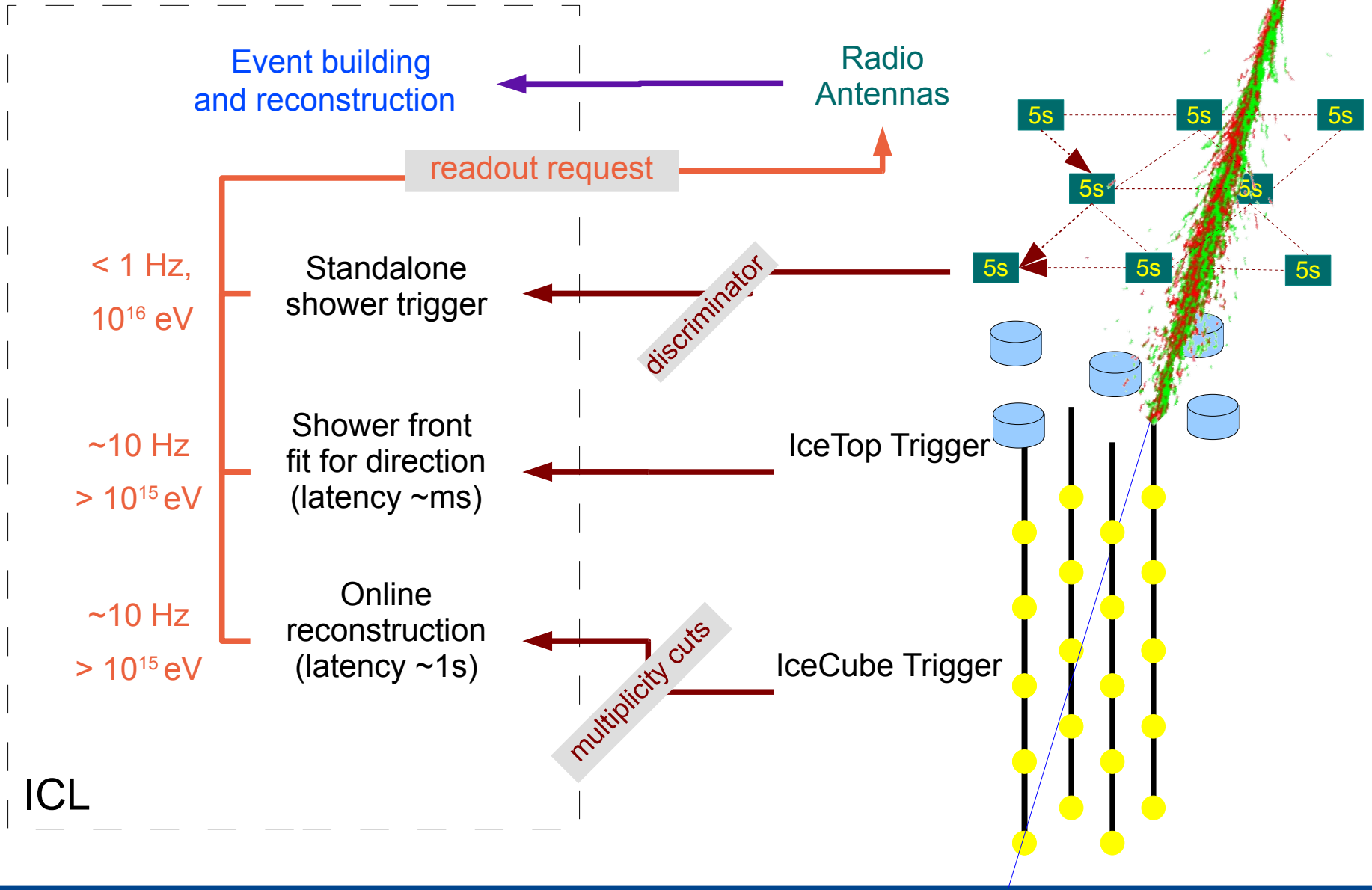
Trigger and data flow



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Items to resolve I

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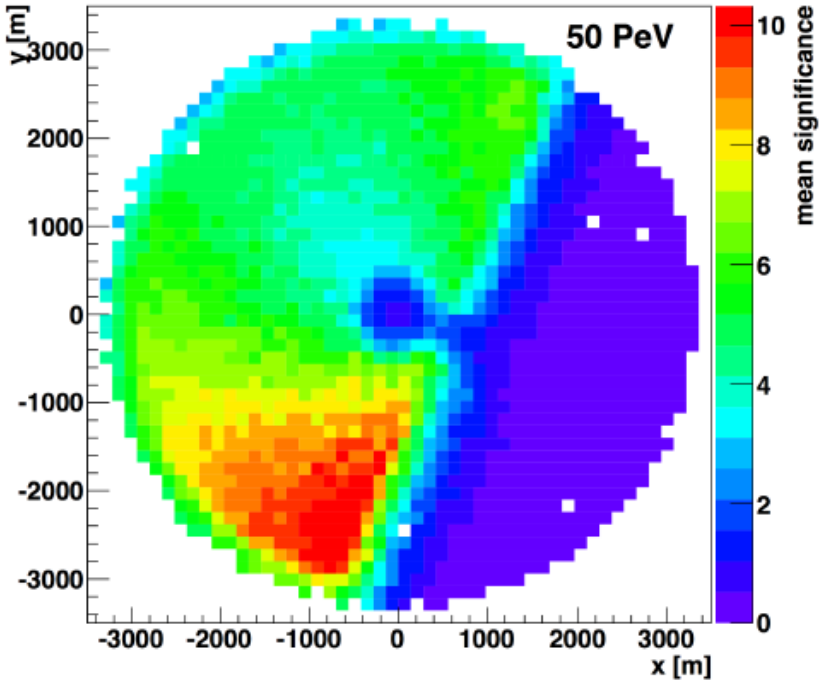
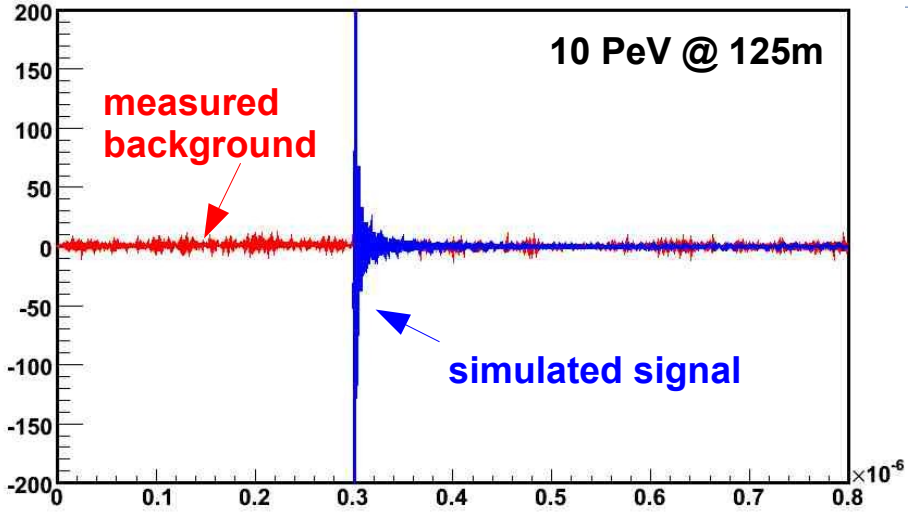
Simulation

- **LOPES Parametrization** ✓
  - based on measured data
  - different noise, antenna, digitization, altitude, geometry
    - ➔ can not be scaled reliably
- **REAS2/3 simulation** ✓
  - based on full shower simulation
  - in agreement with LOPES data
  - 8 hrs per event at 10 PeV!

➔ **need a fast(er) simulation**

[➔ talk by D. Seckel]





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Items to resolve II

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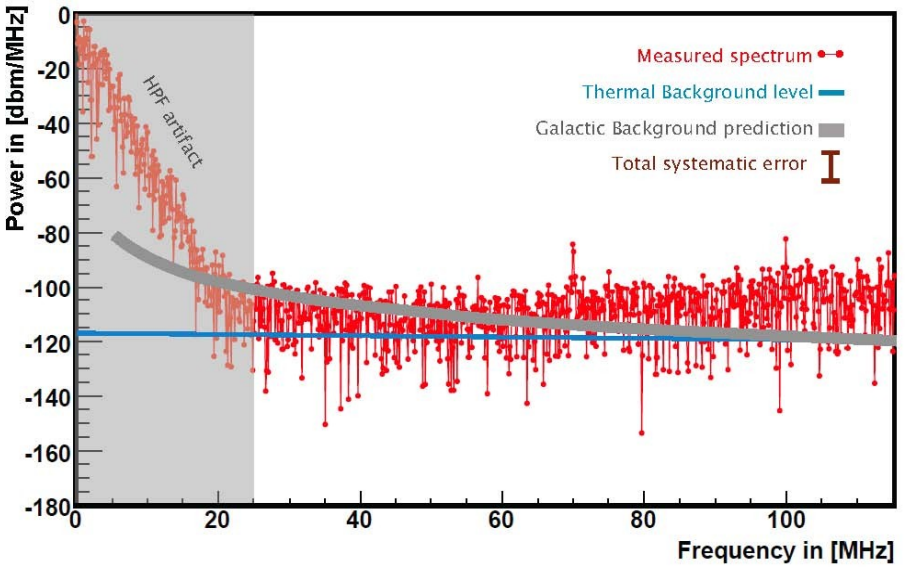
Background

- measured spectrum ✓
- no dedicated trigger with more than two identical antennas

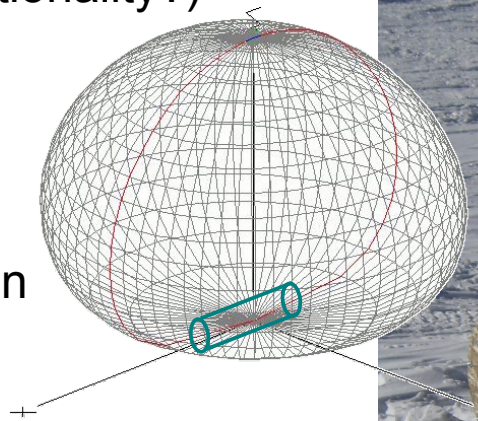
➔ **transients study**



Antennas

- fat-wire dipole ✓
- directed antennas (size?)
- LPDA antennas (directionality?)

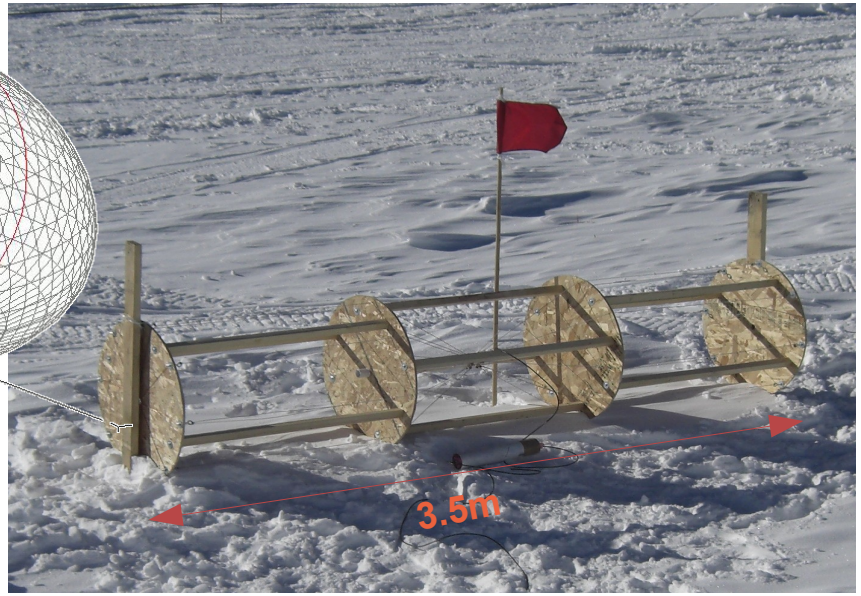
➔ **antenna studies**



DAQ/Electronics

- A/D at antenna
- timing with ns-precision
- trigger
  - self-triggered
  - IceCube&IceTop (latency)

➔ **multi-level buffered trigger**



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Current setup

Original plan

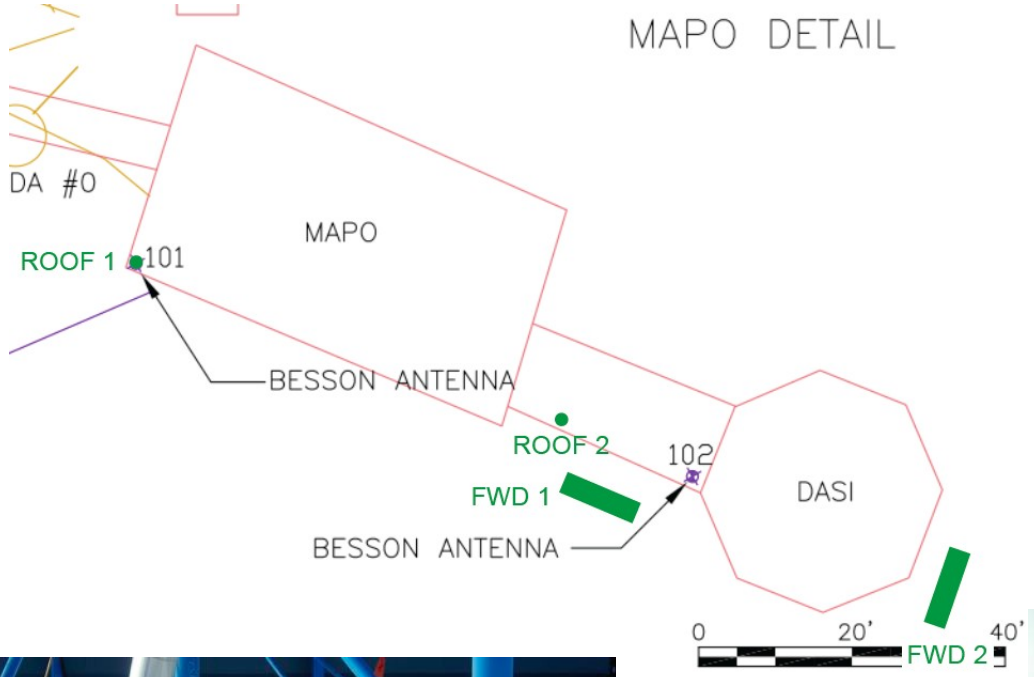
- 8 fat wire-dipoles
- threshold ~10PeV@125m
  - ➔ Ø(1) events/day (before trigger eff.)

Actual 2009/2010 installation

- no trenches
  - two fat wire-dipole antennas next to MAPO
  - two (crossed) dipoles on roof of MAPO
- RICE DAQ (scope based)
  - dedicated trigger
  - 3 of 4 over threshold
  - GPS timing

➔ **transient studies difficult**

➔ **expect < Ø(1) cosmic ray evts/week**



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RASTA proposal

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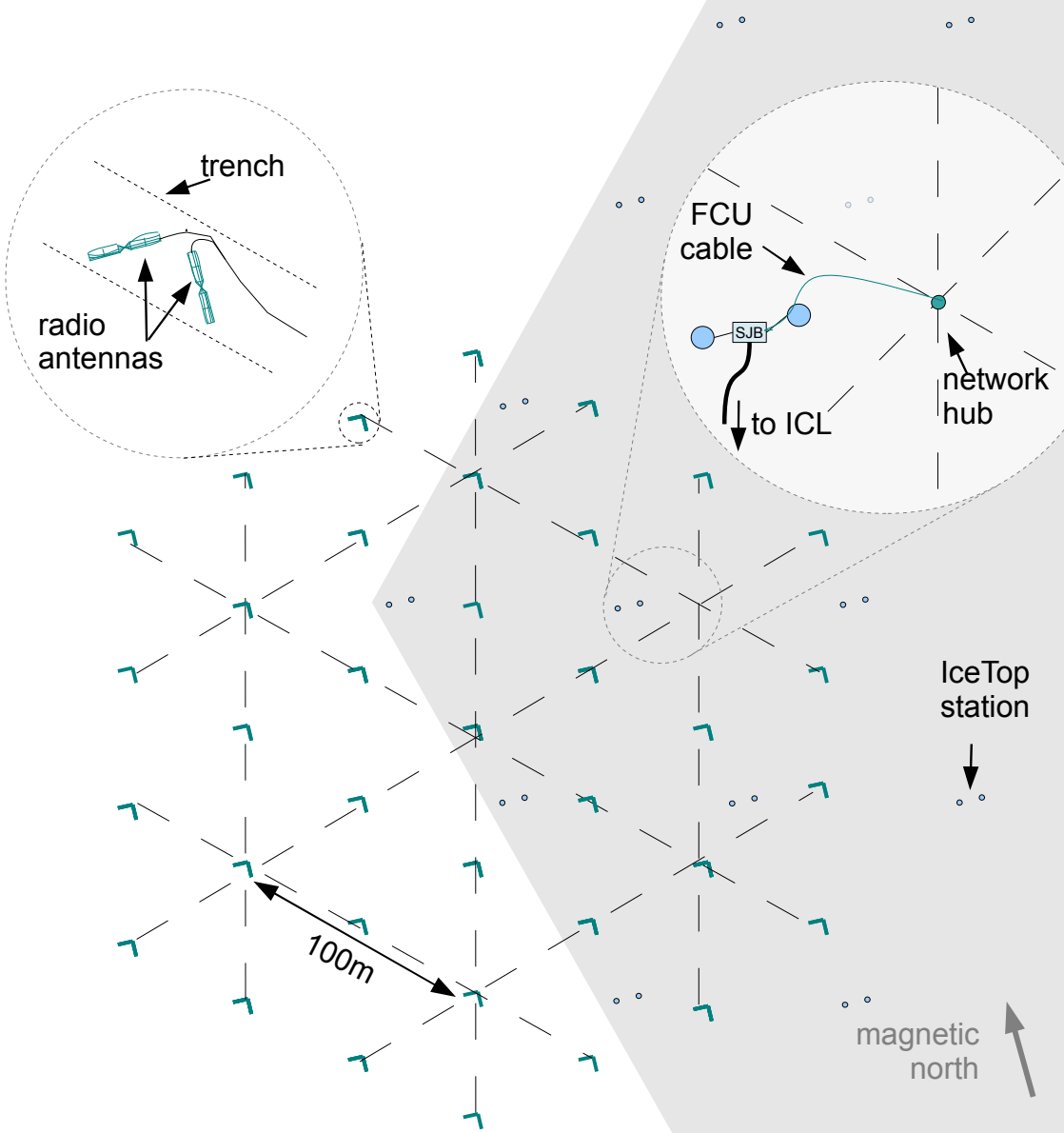
Aim

- provide all prerequisites for a large scale array

Multi-staged setup

- use existing infrastructure for first steps
  - commercial *central* DAQ
  - cabling
  - networking
- develop new technologies in parallel
  - buffered *local* DAQ
  - self-triggering
  - precision timing



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Timeline

Fast simulation development effort

DAQ electronics development

Analysis of first year data

Analysis of second year data

2011/2012 season:

- detect air-showers
- different antenna types
- dedicated transients study
- Ø(16) antennas

➔ proof of viability

2012/2013 season:

- demonstrate key technologies
- collect enough data for dummy analysis
  - Ø(70) antennas

➔ reliable sensitivity estimate

2013/2014 season:

- refinement of trigger logic
- calibration with source

May 2014: Proposal for large array

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Summary

Radio geosynchrotron detection can

- enhance the IceCube observatory by
  - an extended air shower detector
  - with complementary sensitivity to electrons
  - covering larger fraction of galactic plane

Radio Air-Shower Transients Array (RASTA)

- 3-year proposal targeting
  - proof-of-principle (air shower detection)
  - systematic background studies
  - proof of technology

➔ enables final sensitivity estimate and proposal for large array

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