The ARA-experiment The Search for cosmogenic neutrino at the South Pole

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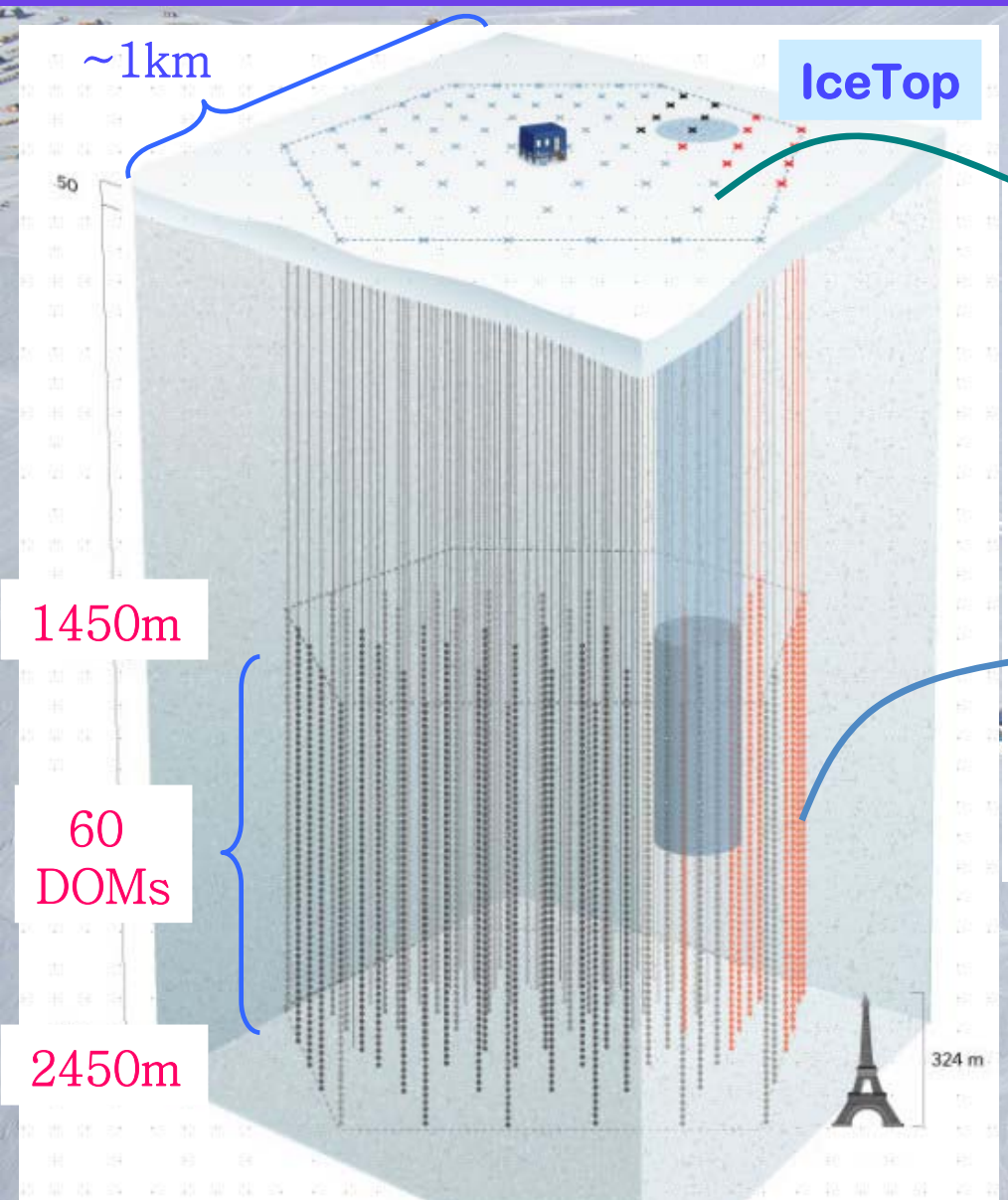
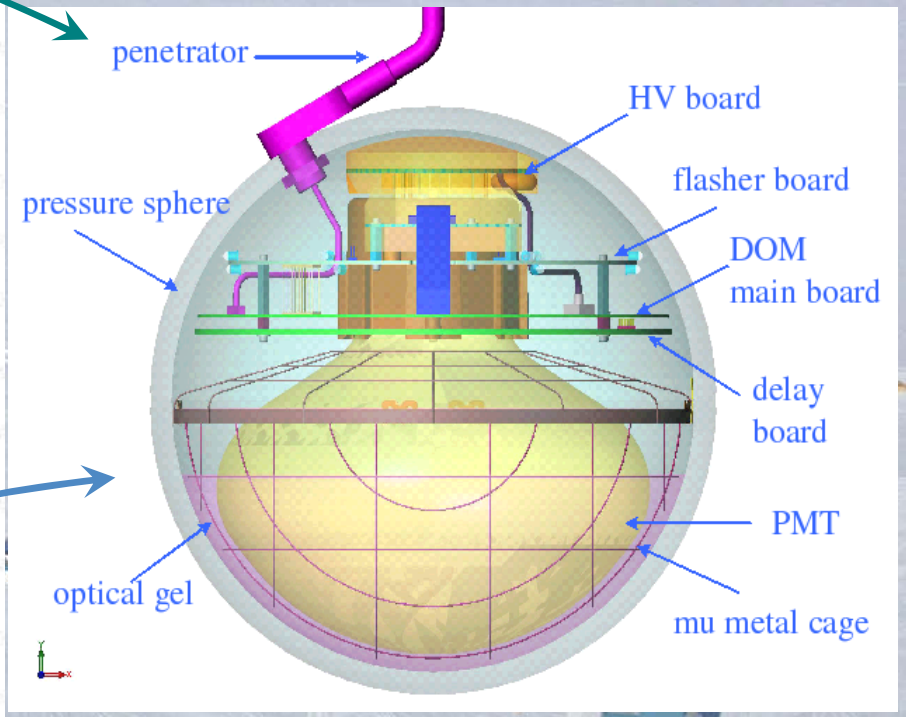
CRC Future Project Symposium 2010.9.16

Outline

- Status of the IceCube detector
  - Expected EHE (>10^6 GeV) neutrinos
- From the IceCube to the ARA (Askaryan Radio Array) experiments
  - What shooting for
  - Where we are now

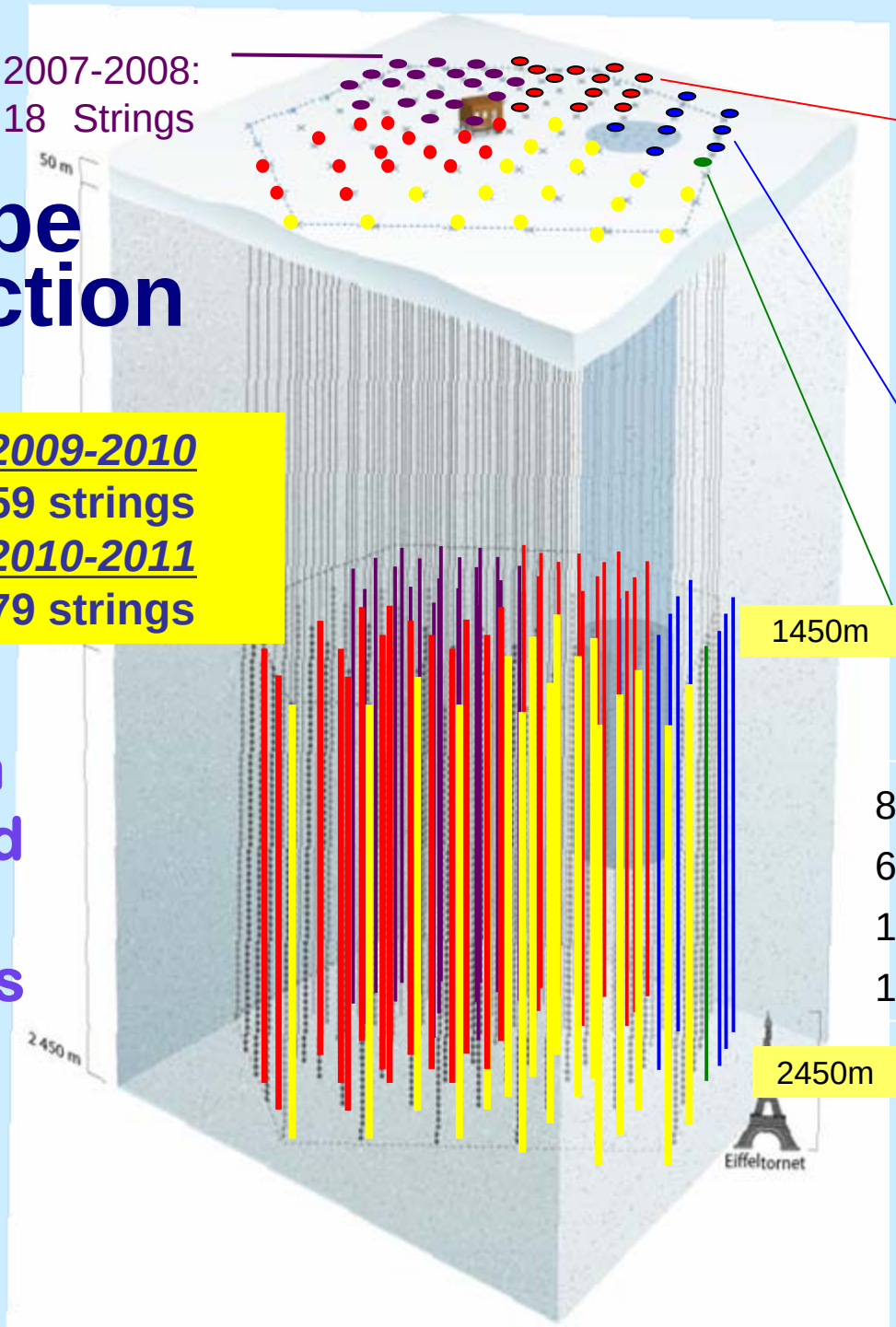
The IceCube Detector





- measure individual photon arrival time
- 400 photoelectron/15ns
- 400ns/6.4μs time range
- 1~2ns time resolution

IceCube Construction



2007-2008:
18 Strings

2006-2007:
13 Strings

2008 -2009 Data
40 strings
80 IceTop tank

2005-2006: 8 Strings

2009-2010
59 strings
2010-2011
79 strings

1450m

2004-2005 : 1 String

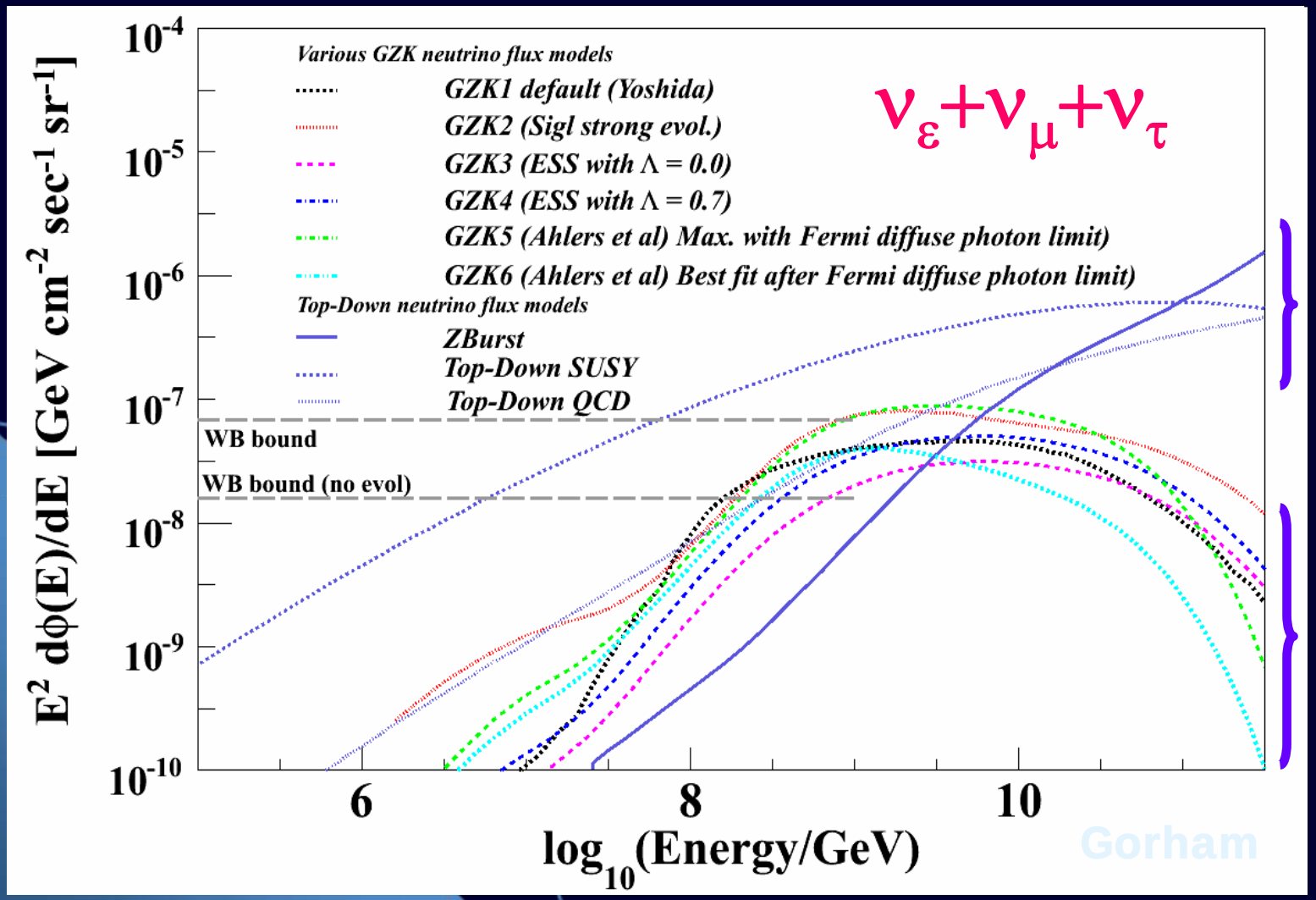
2450m

80+6 Strings
60 Optical Modules
17 m between Modules
125 m between Strings

Construction > 90% finished

7 more strings to complete!

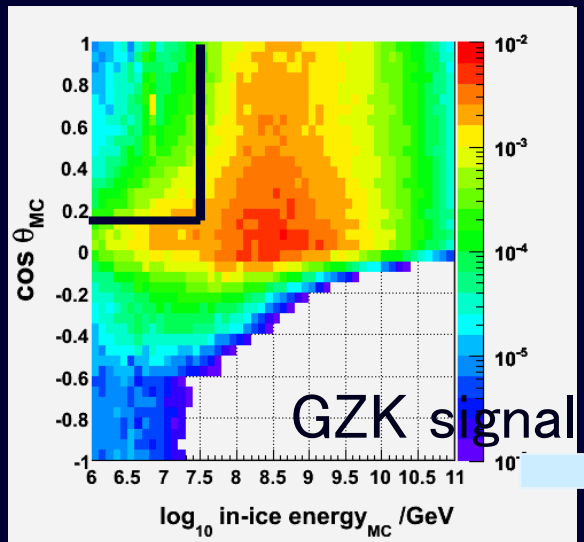
Extremely High Energy Neutrino Targets

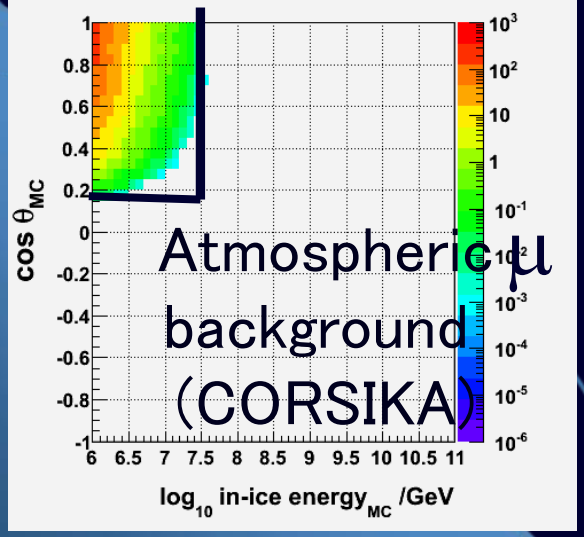


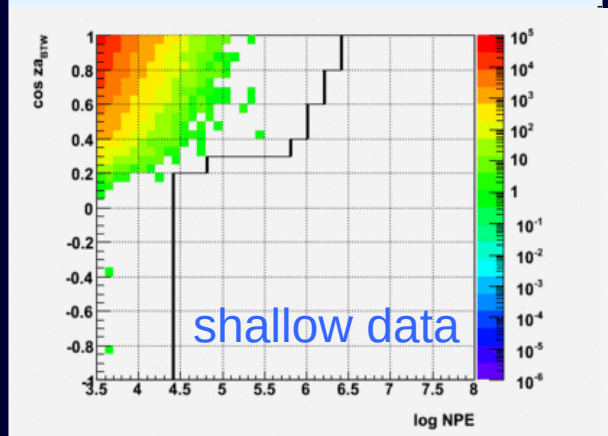
Top-down

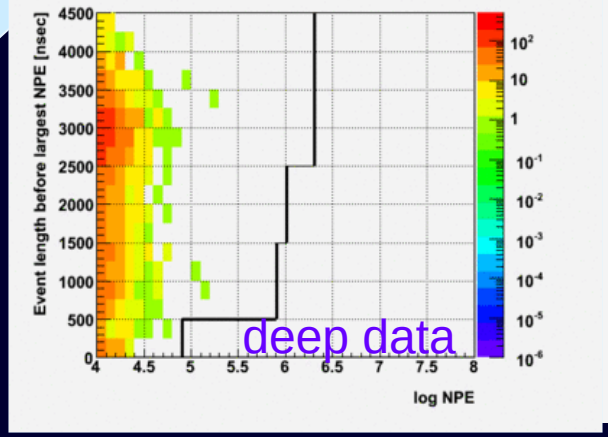
Various GZK models consistent within a factor of 2-3

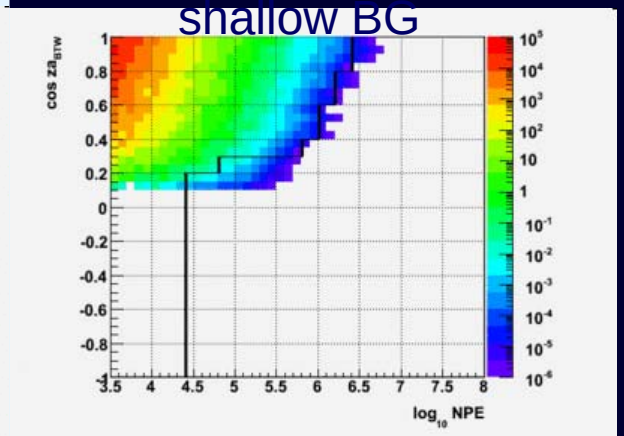
Simple Detector – Simple Analysis

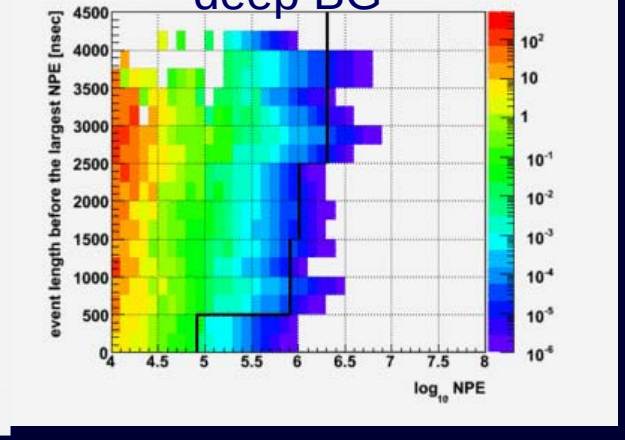










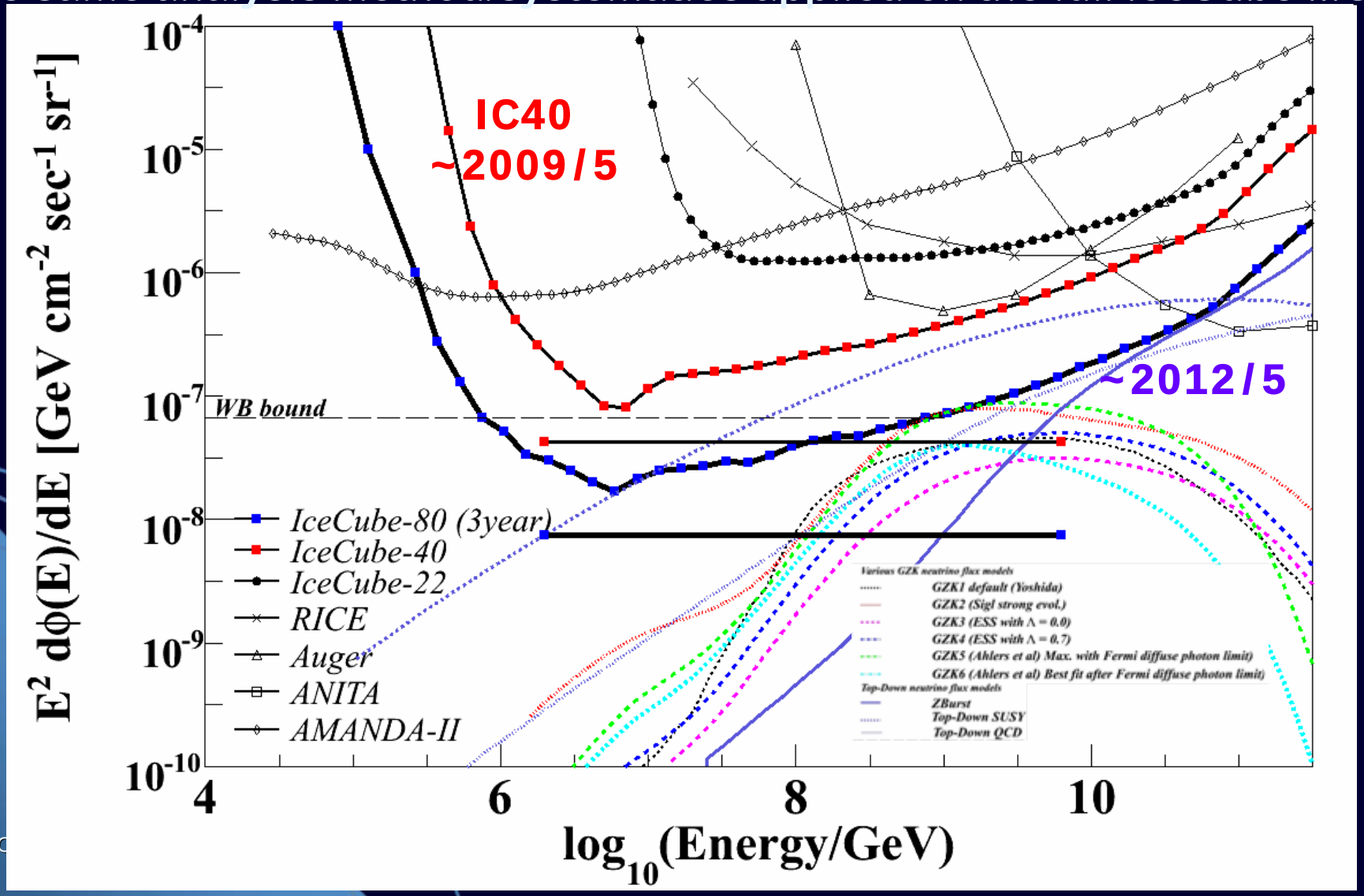


Cuts are decided without looking at data sample

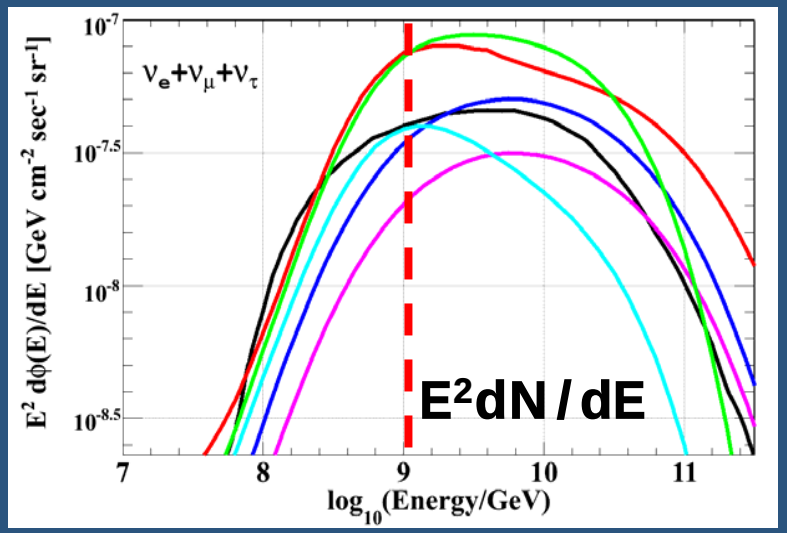
background 0.1 per full livetime

IceCube baseline Sensitivity

The same analysis method/systematics applied on the full IceCube MC



Signal Event Distributions



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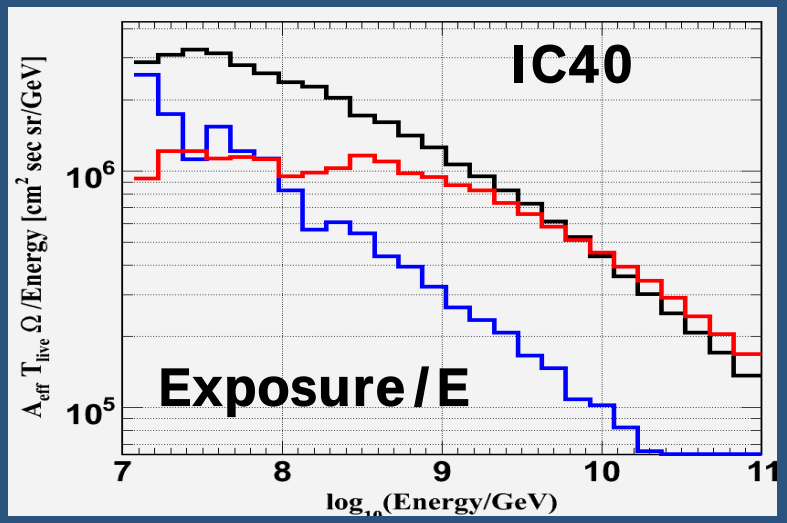

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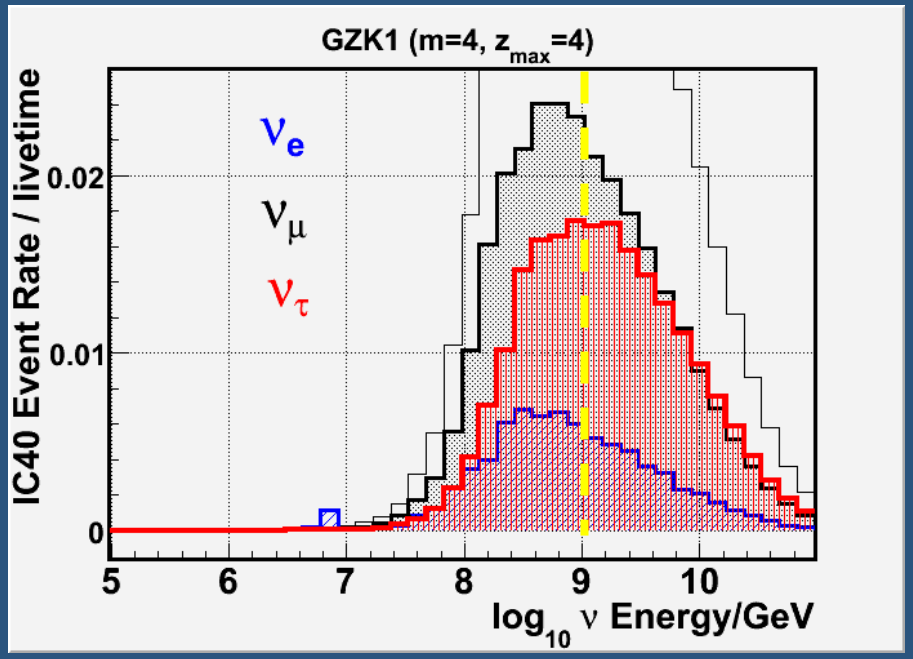
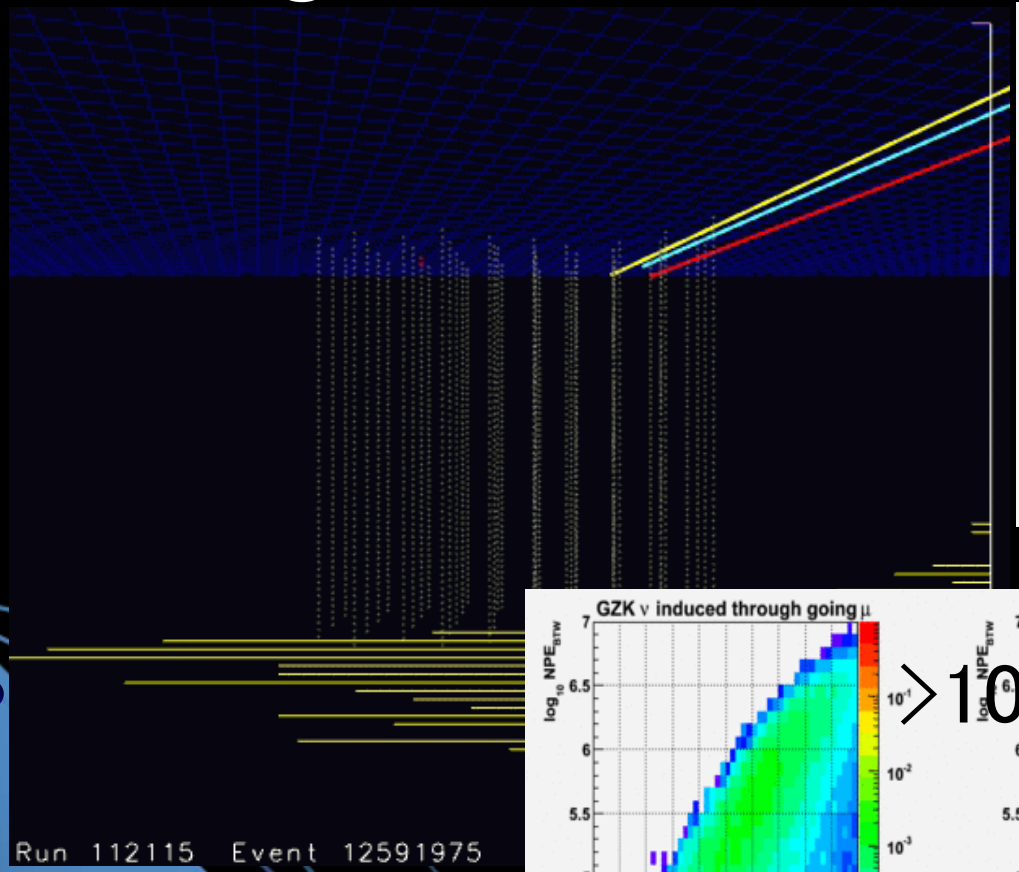
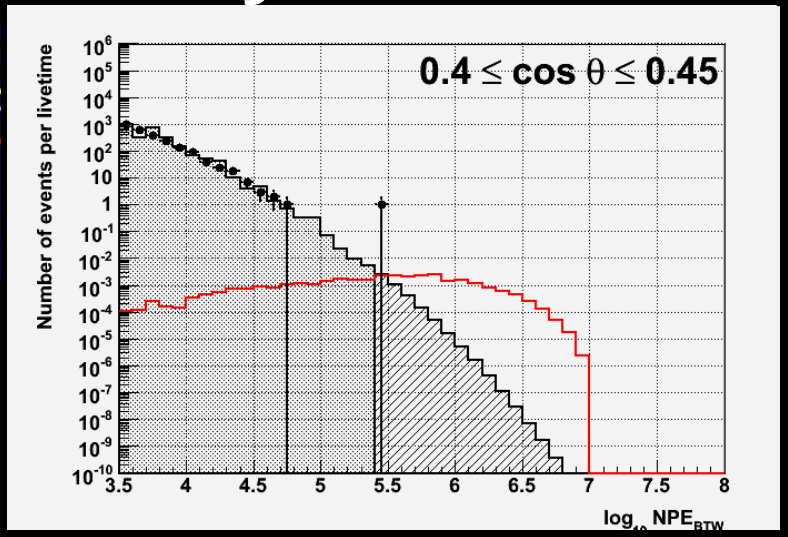


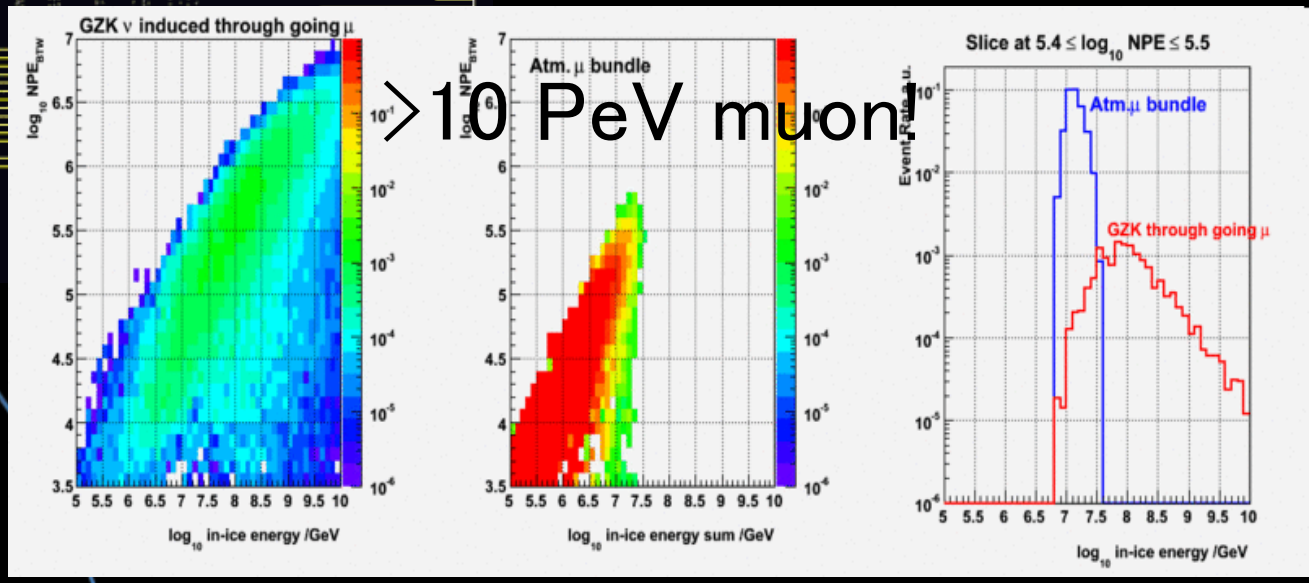
Expected # of EHE signal events

Models	IC40 # of events (333days)	IC80(full) # of events (3 years, by 2012/5)
GZK1 (Yoshida et al)	0.57	**3.1**
GZK2 Strong Evol. (Sigl)	0.91	**4.9**
GZK3 (ESS with W_L=0.0)	0.29	**1.5**
GZK4 (ESS with W_L=0.7)	0.47	**2.5**
GZK5 (Ahlers max)	0.89	**4.8**
GZK6 (Ahlers best fit)	0.43	**2.3**
Z-Burst	1.03	**5.1**
Top Down(SUSY)	5.68	**31.6**
Top Down(QCD)	1.19	**6.3**
W&B(evol)	3.7	**24.5**
W&B(no evol)	1.1	**5.5**

The highest NPE event by 2009/5







- >10 PeV muon!

How to Cook *the Best*-Physics with the IceCube EHE ??

Primary Ingredients:

Wants to know the Highest E CR sources!

- GZK models are solid – if the highest CR is proton
- IceCube sees them in a couple of years

New Recipe Needed for

- Enlarge detection volume by x10 (~10 GZK events/year)
- In a cost effective way
- Still reliable

The Largest yet a Sparse Detector

No new recipe needed, old cook books tell us -

【エアレイション】英語 aeration
空気を抱き込ませること。振るったり、かき混ぜて、材料や生地に空気を充分に抱き込ませること。または、発酵において、生地を膨らませること。

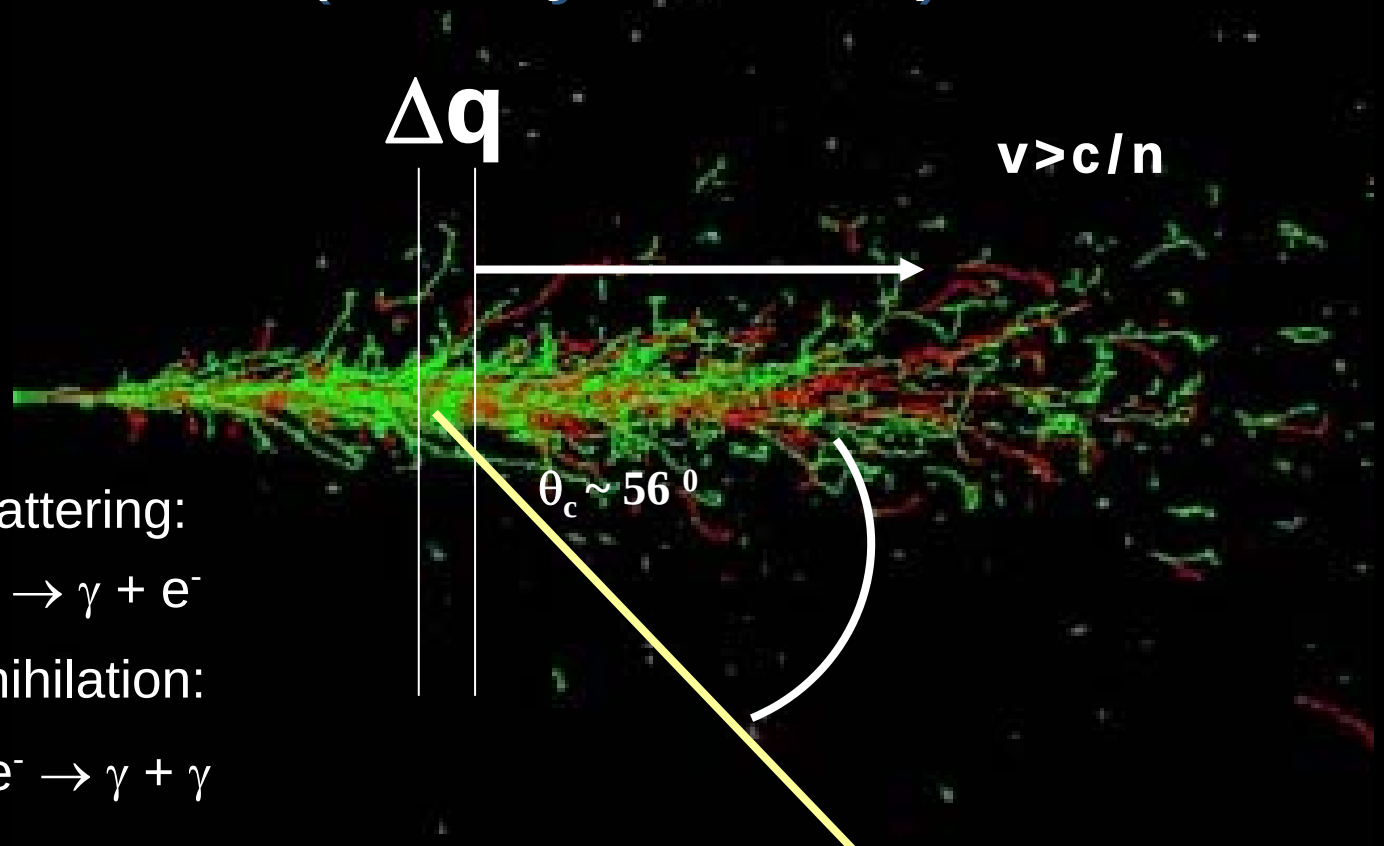
Detector density is decided by photon's scattering and absorption lengths

IceCube@380nm: Scatt. ~25m, Abs. 100 ~150m
Vertical 17m, Horizontal 125m

@380GHz: Attenuation length >~1500m
Thus detector separation as large as ~1.5km!

Radio Pulses from Neutrino

EM cascade resembles a large negative excess charge moving exceeding speed of light (Askaryan effect)



Compton scattering:

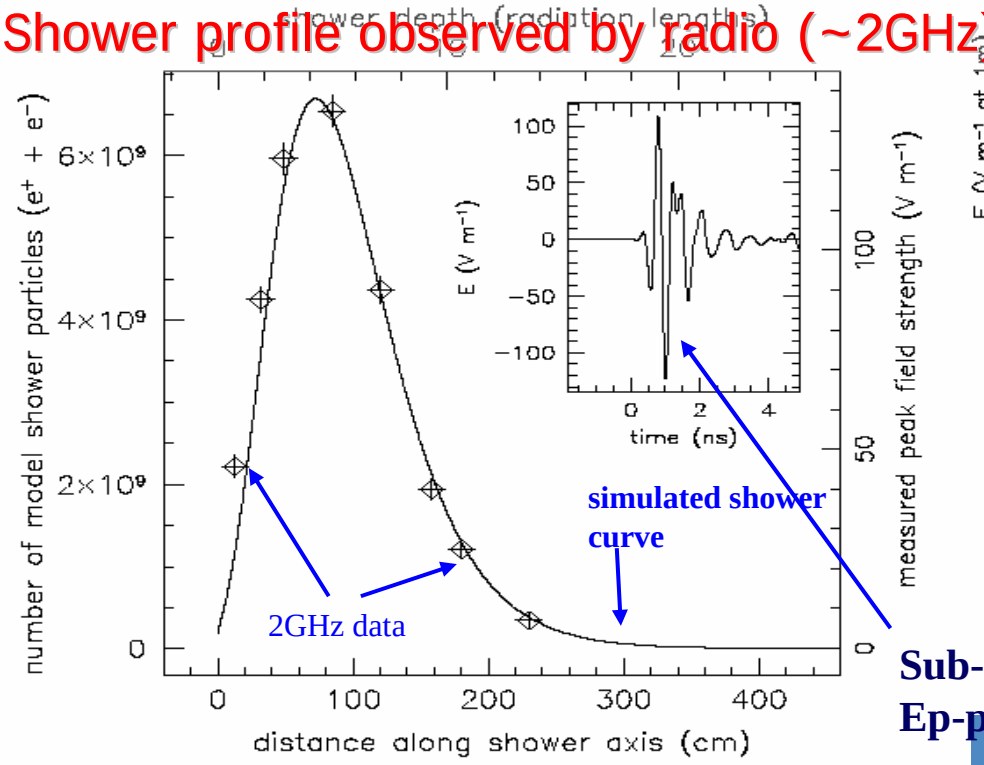
$$\gamma + e^- \rightarrow \gamma + e^-$$

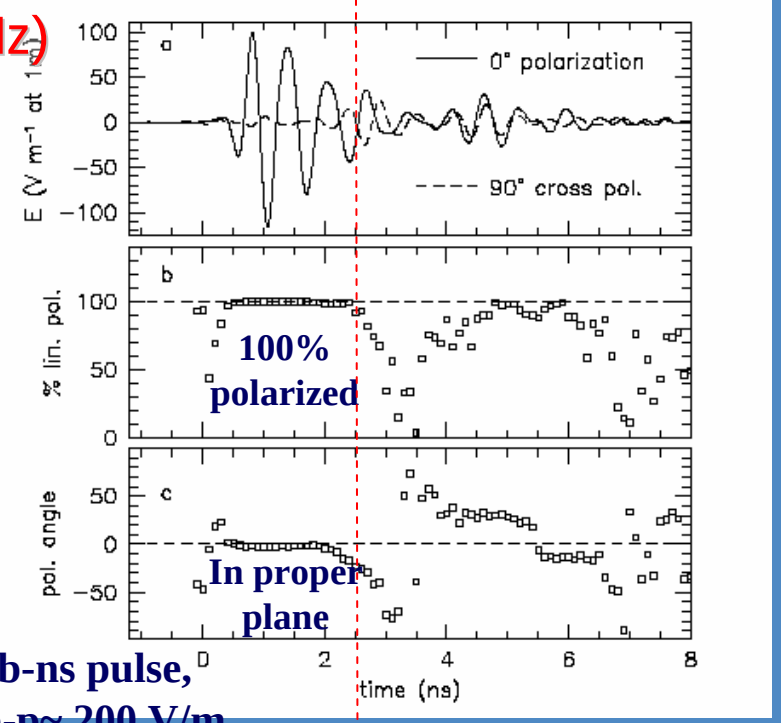
Positron annihilation:

$$e^+ + e^- \rightarrow \gamma + \gamma$$

Cherenkov Radio Pulse measurement

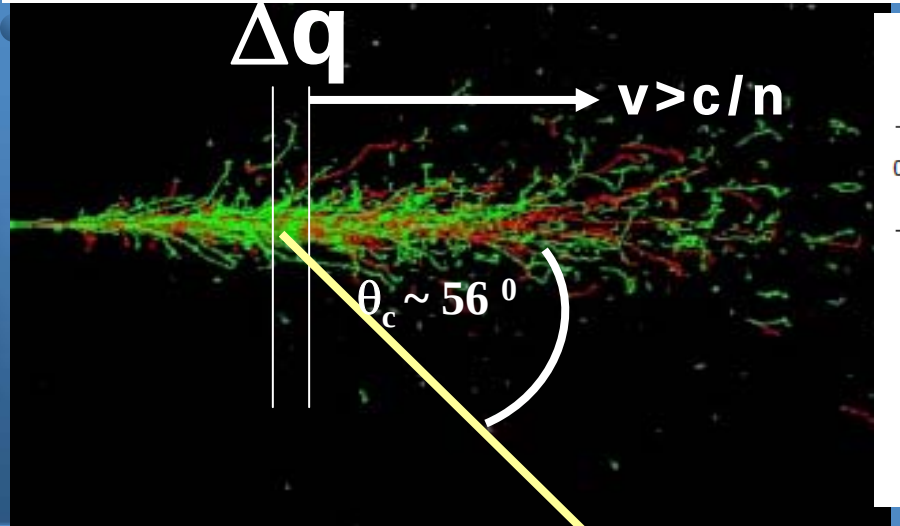
Shower profile observed by radio (~2GHz)

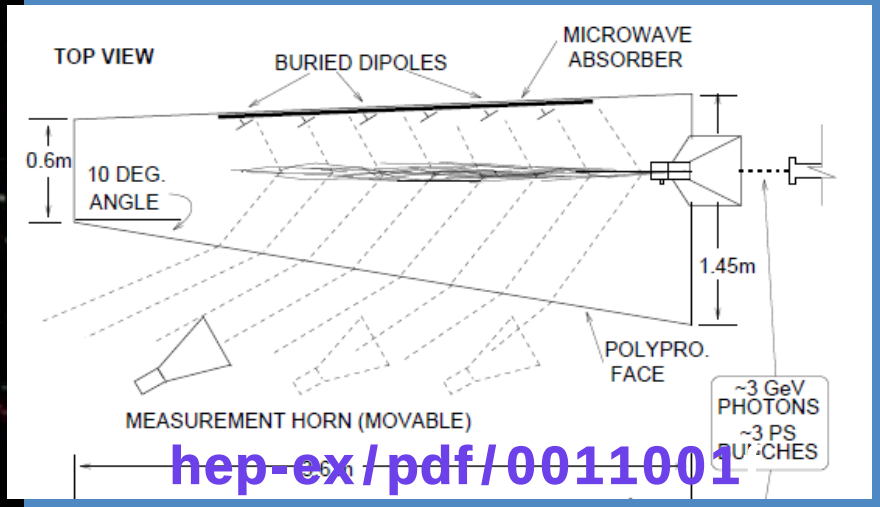




Sub-ns pulse,
Ep-p~ 200 V/m

←Reflection from side wall





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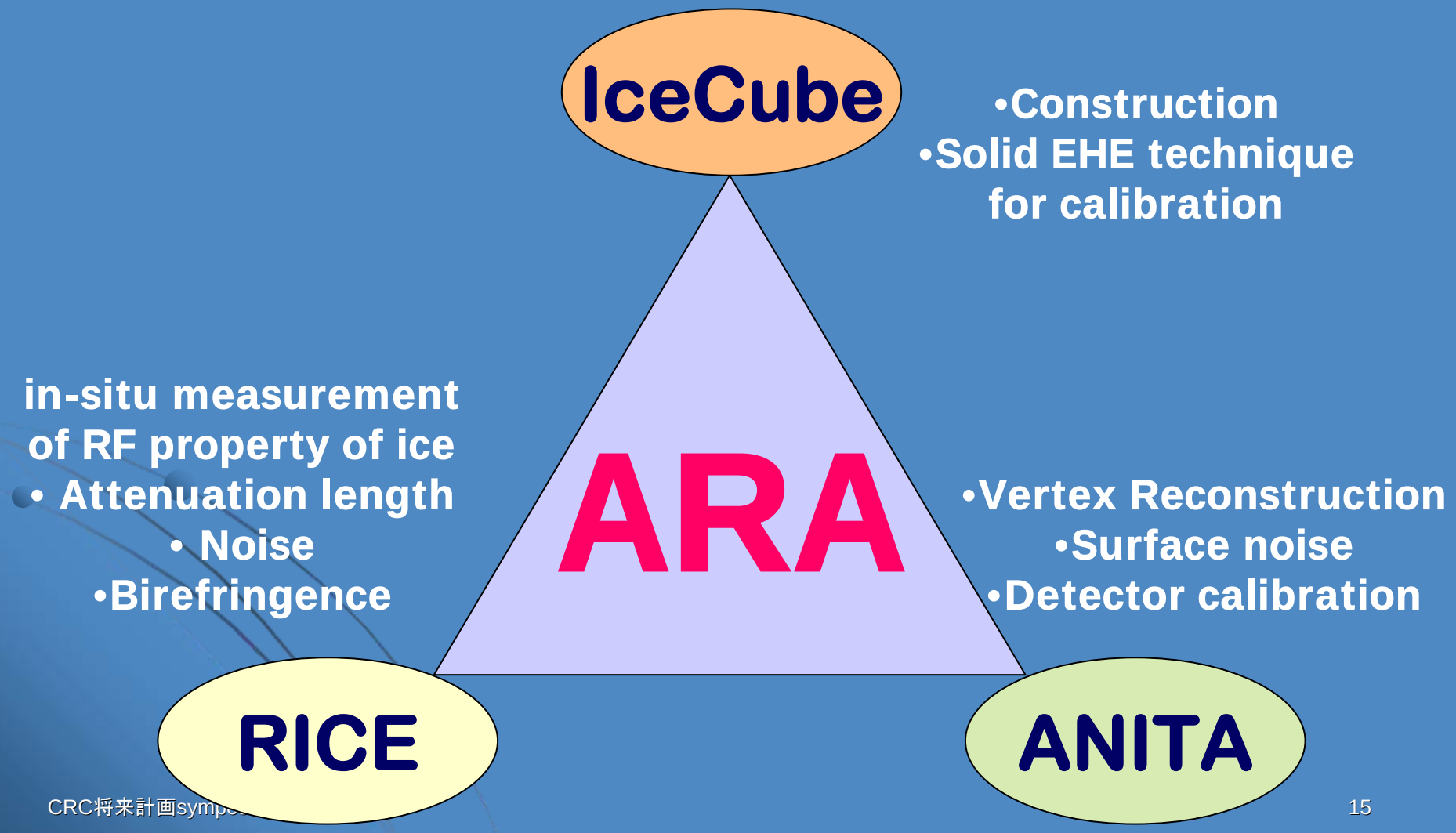
Collaborating Experiments with Experiences



The ARA collaboration

The IceCube collaboration

Universite Libre de Bruxelles
Vrije Universiteit Brussel
Université de Mons-Hainaut
Universiteit Gent University Utrecht

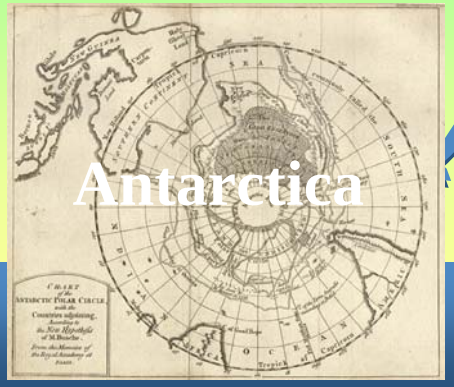
University of Oxford

Universität Mainz
Humboldt Univ., Berlin
DESY, Zeuthen
Universität Dortmund
Universität Wuppertal
MPI Heidelberg
RWTH Aachen
Uppsala University
Stockholm University

Chiba University

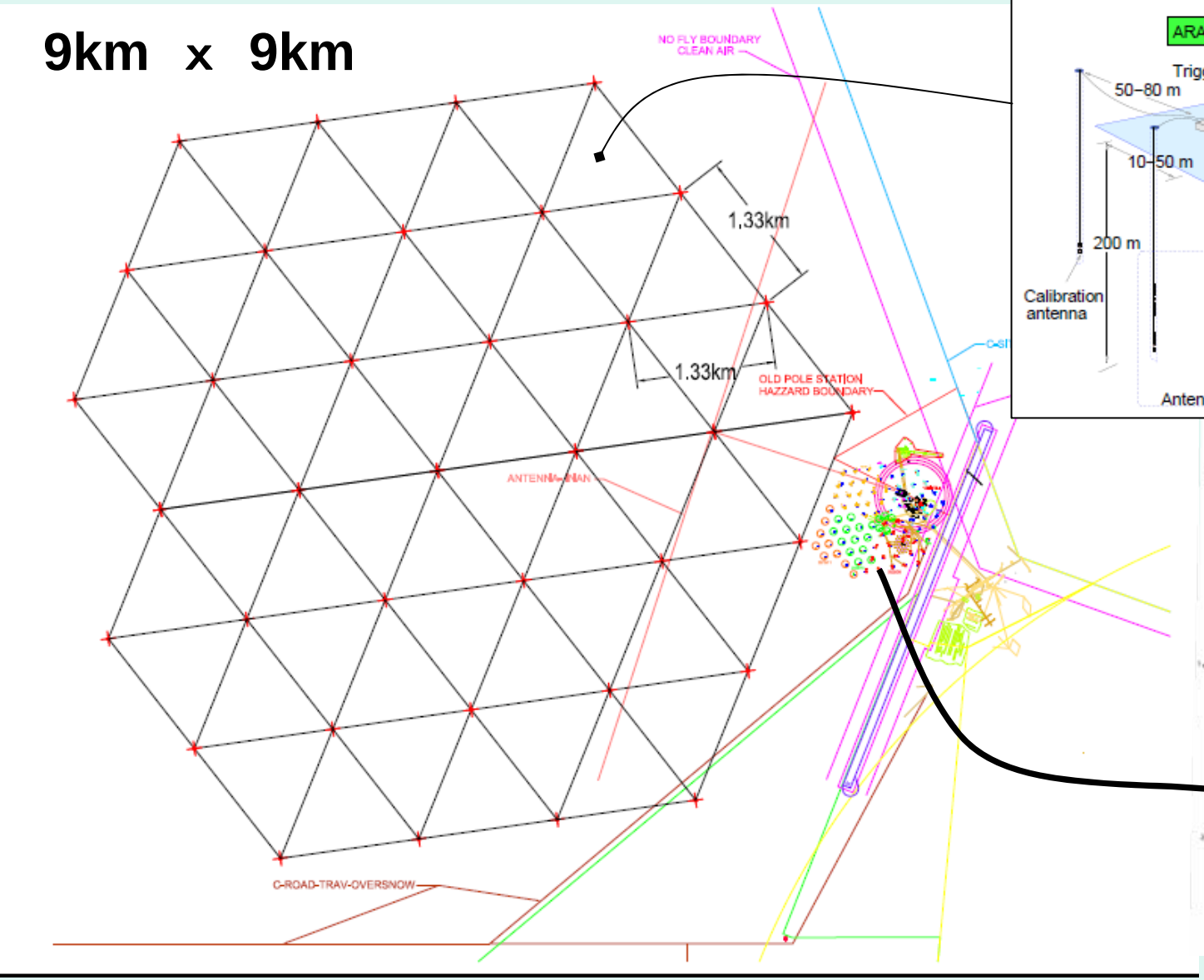
Univ. of Canterbury, Christchurch

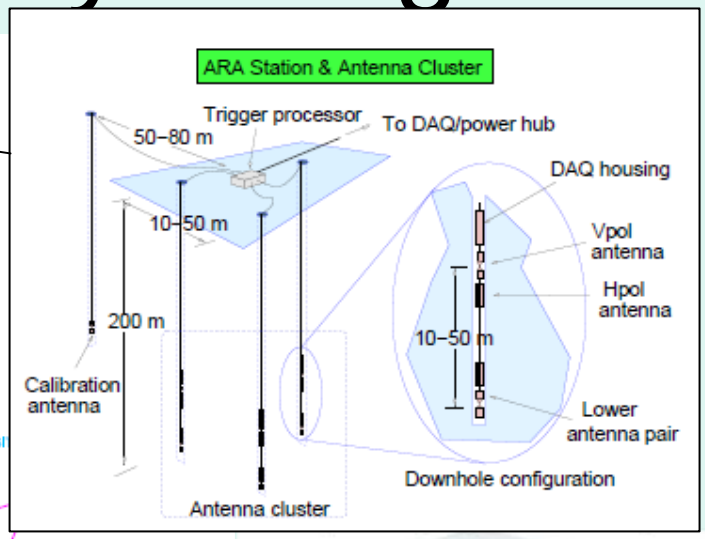
Univ Alaska, Anchorage
UC Berkeley
UC Irvine
Clark-Atlanta University
U Delaware / Bartol Research Inst
University of Kansas
Lawrence Berkeley National Lab
University of Maryland
Pennsylvania State University
University of Wisconsin-Madison
University of Wisconsin-RiverFalls
Southern University, Baton Rouge

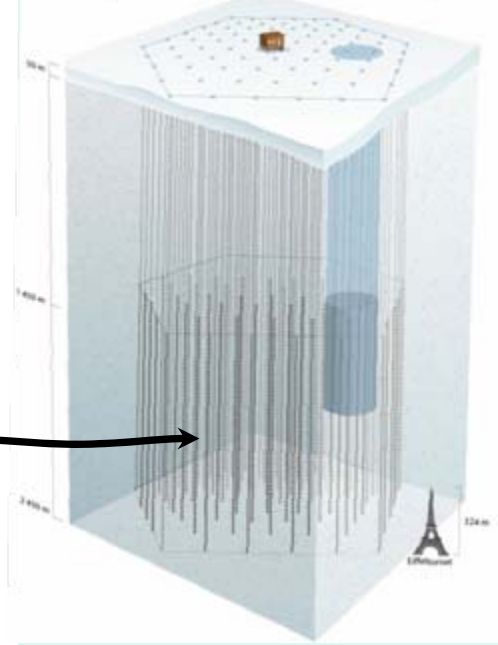


Askaryan Radio Array Design

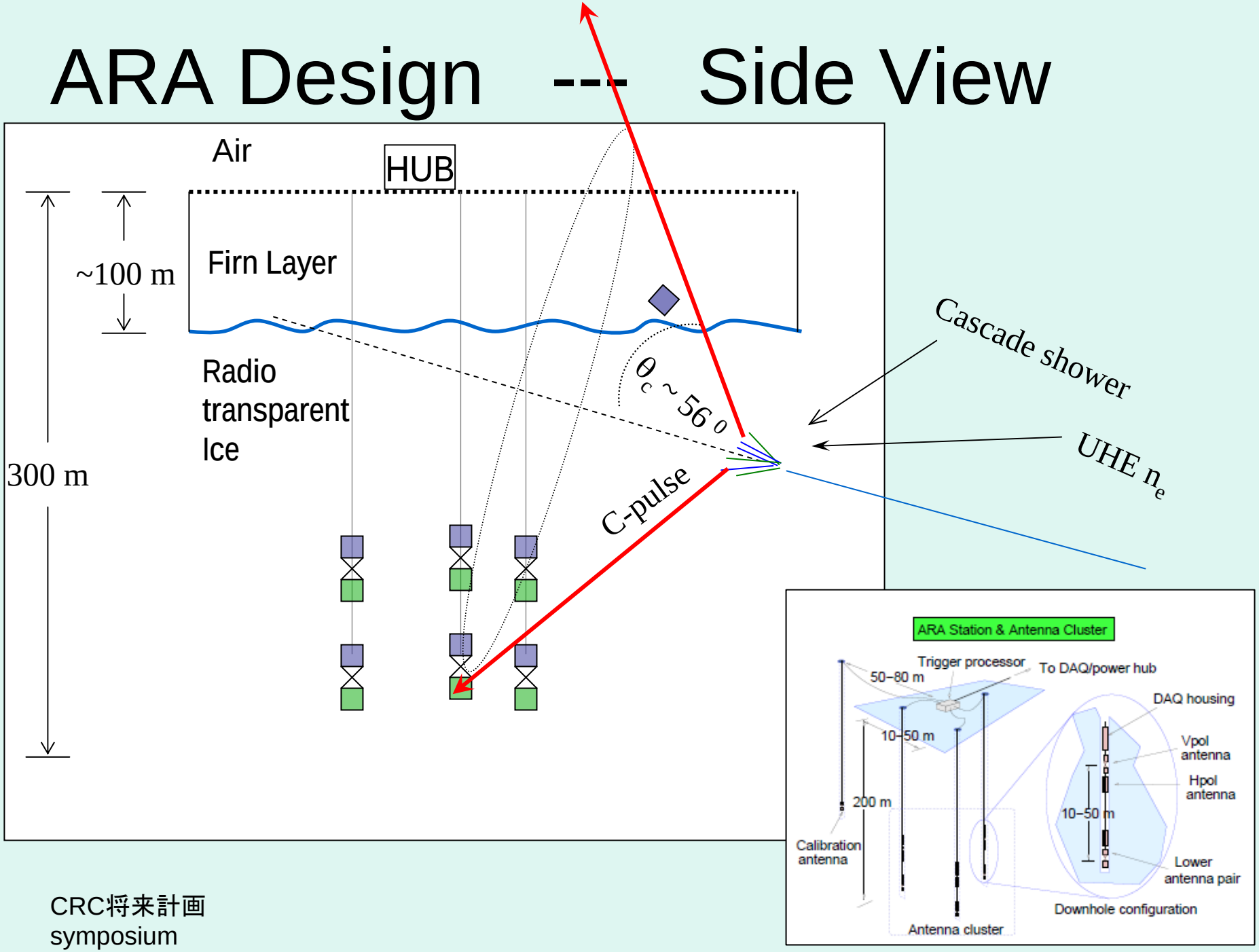
9km x 9km







ARA Design --- Side View

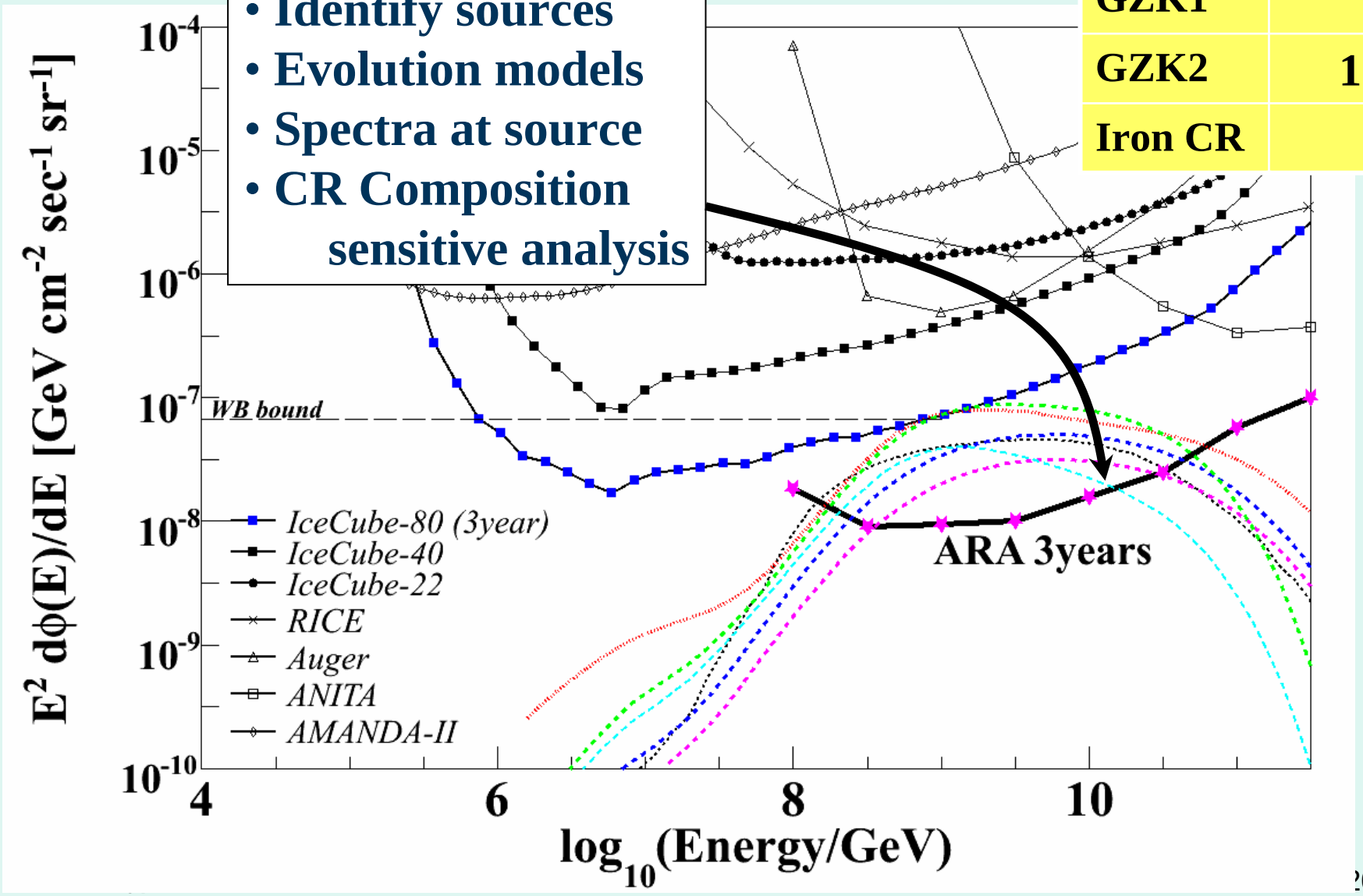


CRC将来計画
symposium

ARA到達予想感度

Model	#/year
GZK1	7.0
GZK2	11.1
Iron CR	~1

- Identify sources
- Evolution models
- Spectra at source
- CR Composition sensitive analysis



Current Status

Ongoing projects by Japan

- Inter-site synchronization
- Wireless LAN for comm.
- Antenna response function calibration
- IceCube ARA coincident event detection

and

working hard to find the first EHE neutrino with IceCube!

Phase II: ~10 km^2 Radio Antenna Array (2011-2013)

Testing communication + DAQ, Turbine, Inter-station sync.

finalize the antenna + front-end readout

Phase III: ~2014

~100 km^2 Radio Antenna Array

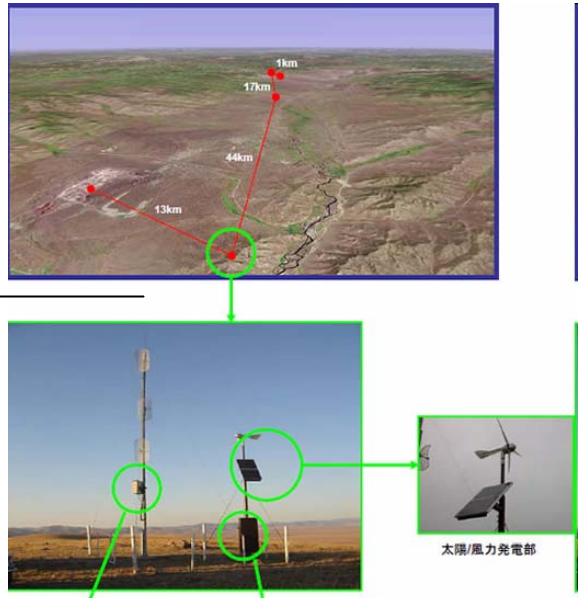
Working projects / Budget schedule

Full Scale Request　2011~2012

Wireless communication
Inter string synchronization
Antenna response function calibration
Antenna + Readout

→ **$1M**

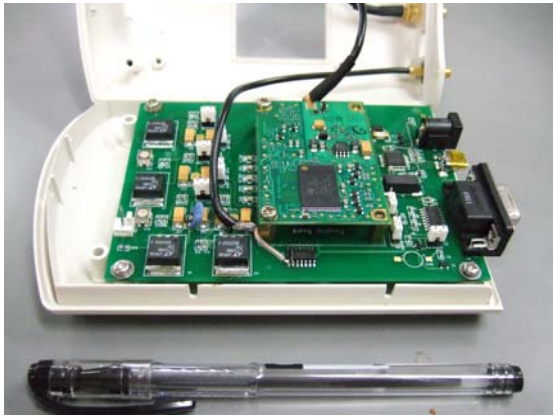
Wireless communication system
The experimental set-up



power system

Bridge, controller, shield box

▪GPS clock sync calibration



Summary

- ARA project has been started – Test bed system (2010-2011), initial phase (~2013)
- Sensitivity reaches to the level that ARA distinguishes various GZK models and even the most pessimistic iron composition case with ~0.2millon$/km^2
- IceCube 3year expects to see a few GZK events by mid-2012
- IceCube's solid optical Cherenkov method calibrate ARA detector