Software Development for IceCube in Chiba

ICEPP in HAKUBA
Feb. 18, 2003
Kotoyo Hoshina
Chiba University

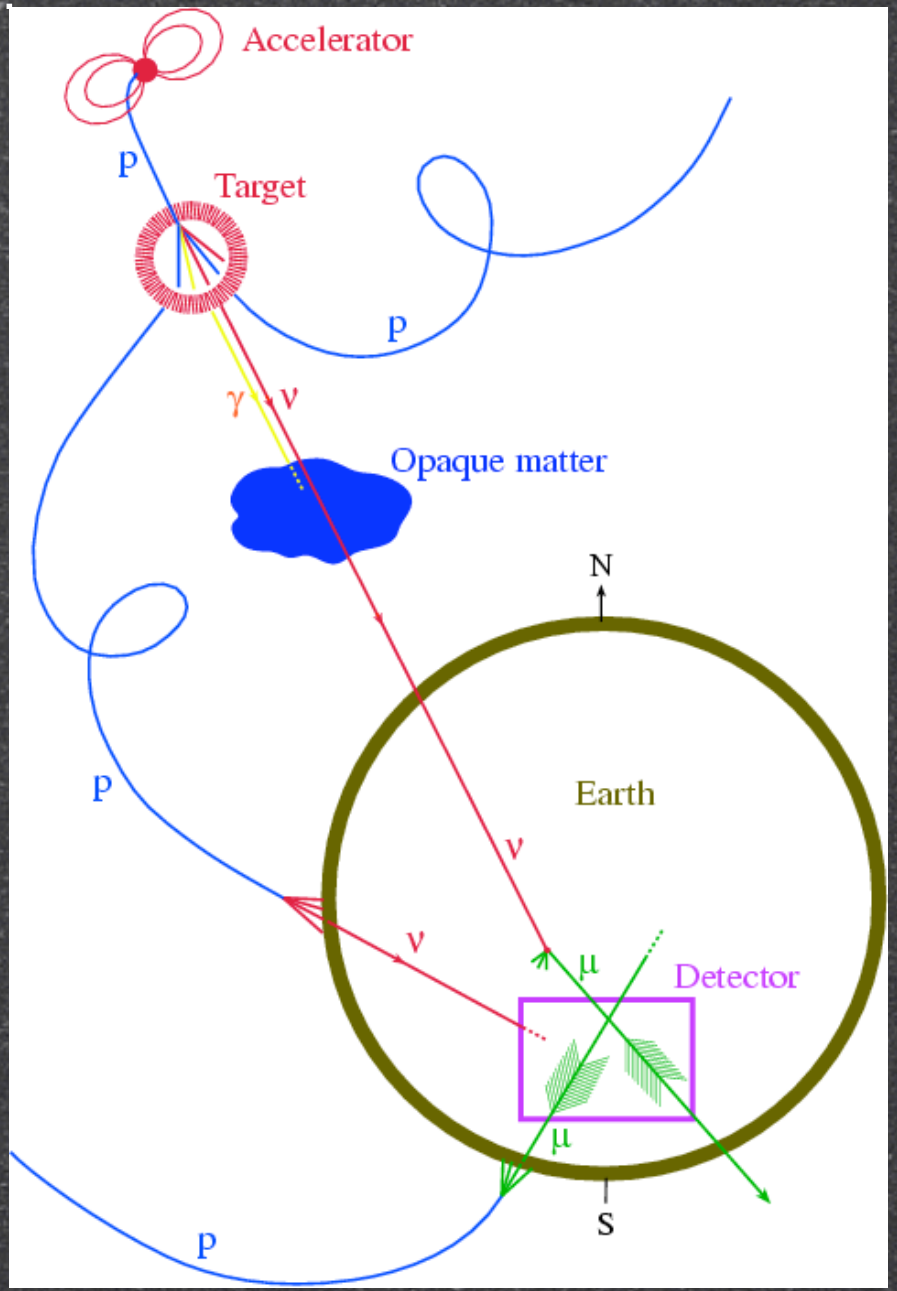
- Why neutrino astro-physics?
- What is IceCube?
- Activity in Chiba
- JULIeT - the UHE lepton transporter
- DOM simulator based on Geant4
- Summary

Collaborators

- Chiba University, Chiba, Japan
- Clark Atlanta University, Atlanta, GA, USA
- DESY-Zeuthen, Zeuthen, Germany
- Imperial College, UK
- Institute for Advanced Study, Princeton, NJ, USA
- Lawrence Berkeley National Laboratory, Berkeley, CA, USA
- Pennsylvania State University, Philadelphia, PA, USA
- South Pole Station, Antarctica
- Southern University and A & M College, Baton Rouge, LA, USA
- Stockholm Universitet, Stockholm, Sweden
- Universität Mainz, Mainz, Germany
- Universität Wuppertal, Wuppertal, Germany
- Université Libre de Bruxelles, Bruxelles, Belgium
- Université de Mons-Hainaut, Mons, Belgium
- University of Alabama, Tuscaloosa, AL
- University of California-Berkeley, Berkeley, CA, USA
- University of Canterbury, Christchurch, New Zealand
- University of Delaware, Newark, DE, USA
- University of Kansas, Lawrence, KS, USA
- University of Maryland, College Park, MD, USA
- University of Wisconsin-Madison, Madison, WI, USA
- University of Wisconsin-River Falls, River Falls, WI, USA
- Universidad Simon Bolivar, Caracas, Venezuela
- Uppsala Universitet, Uppsala, Sweden
- Utrecht University, Utrecht, Netherlands
- Vrije Universiteit Brussel, Brussels, Belgium

Why neutrino astro-physics?

Why neutrino astro-physics?

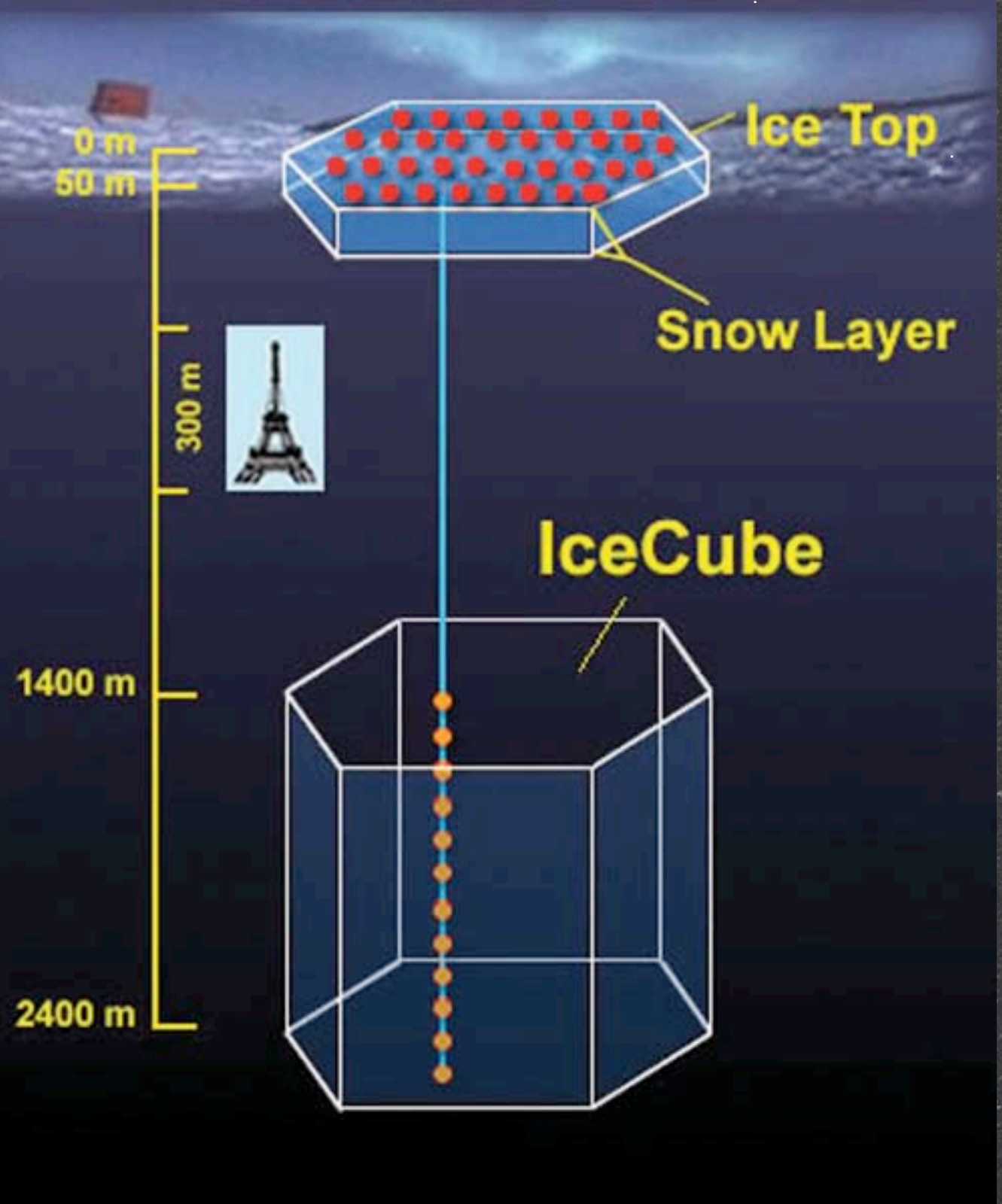


- Neutrinos can reach cosmological distance (=time) because they are not absorbed or deflected by:
  - Electro-Magnetic field
  - Opaque matter
- We can know the direction of the neutrino sources because the detected leptons are closely parallel to their origin

Target physics

- Gamma Ray Burst
- Super Novae
- Origin of high energy cosmic ray (e.g. Active Galactic Nuclei)
- Dark matter, WIMP, etc....

What is IceCube?

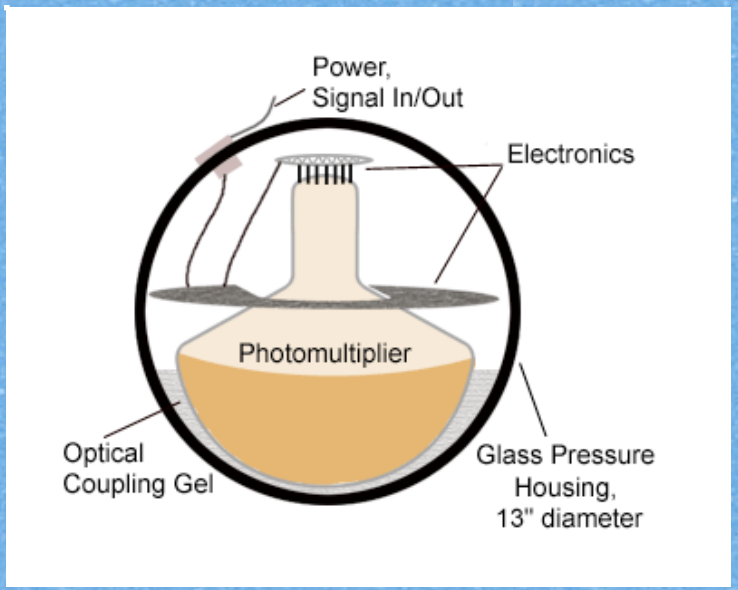


IceCube

- 1 cubic kilometer
- 80 strings
- 60 Optical Sensor /string
- Includes AMANDA inside the cube (AMANDA: 200x500m cylinder, completed in 2000)
- The first string to be deployed in the end of the year (up to 2008)

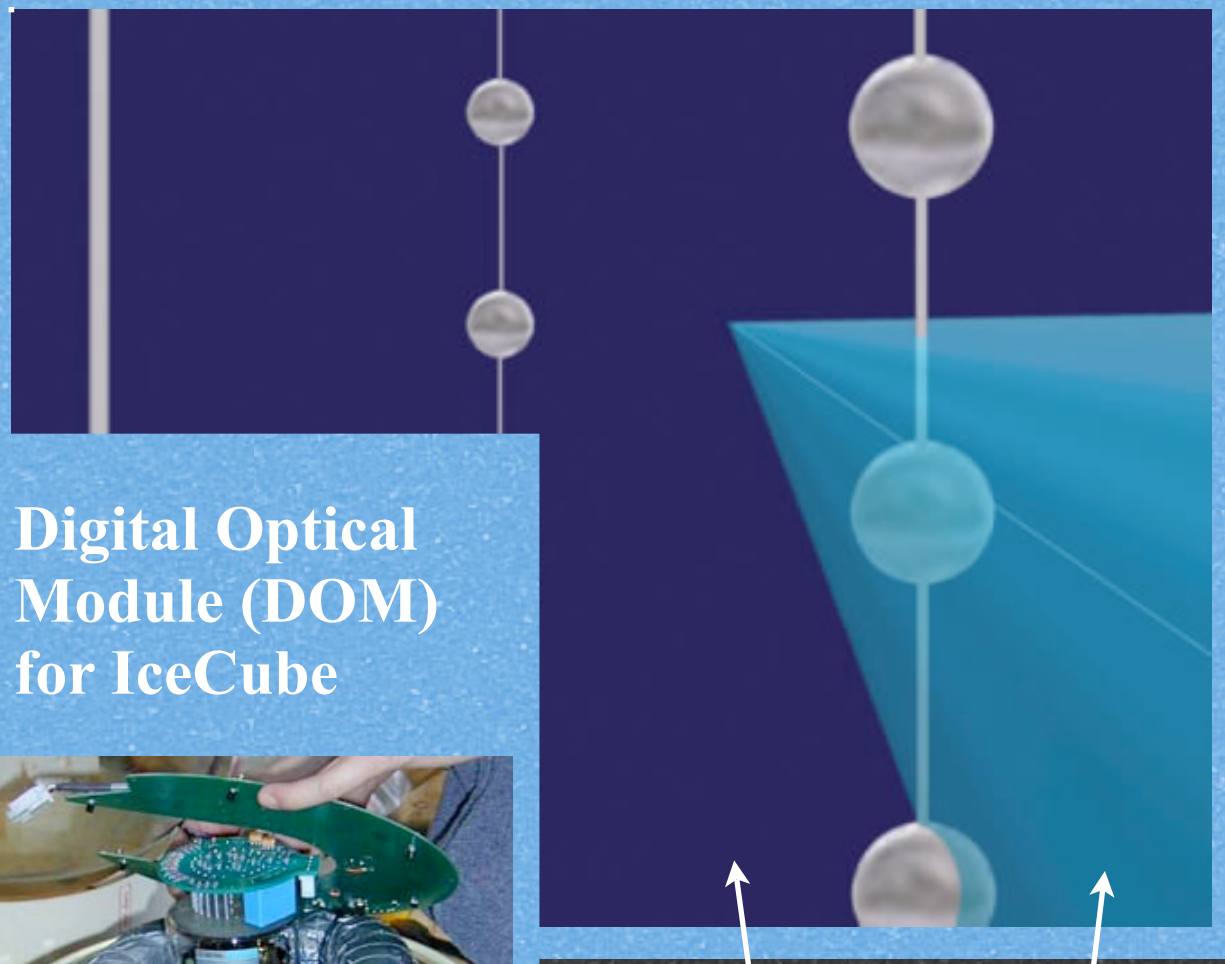
Detection Mechanism

- Construct OM Array in the deep Earth
- Reconstruct tracks using the maximum likelihood method of photon arrival times.



Optical Module (OM) for AMANDA

Digital Optical Module (DOM) for IceCube



South Pole

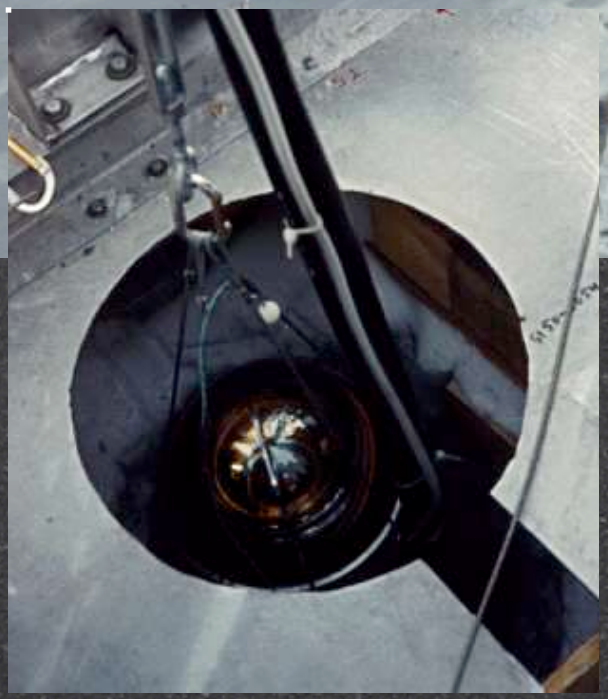
Dark sector

Skiway

AMANDA

Dome

IceCube



Activity in Chiba

R&D menu in Chiba

- Hardware work
  - Research property of DOM (see Hiroko's talk)
  - Calibrations
- Software work
  - Ultra High Energy(UHE) lepton propagator
  - Monte-Carlo simulator for DOM

JULIeT
the JAVA-based Ultra high energy Lepton Integral Transporter

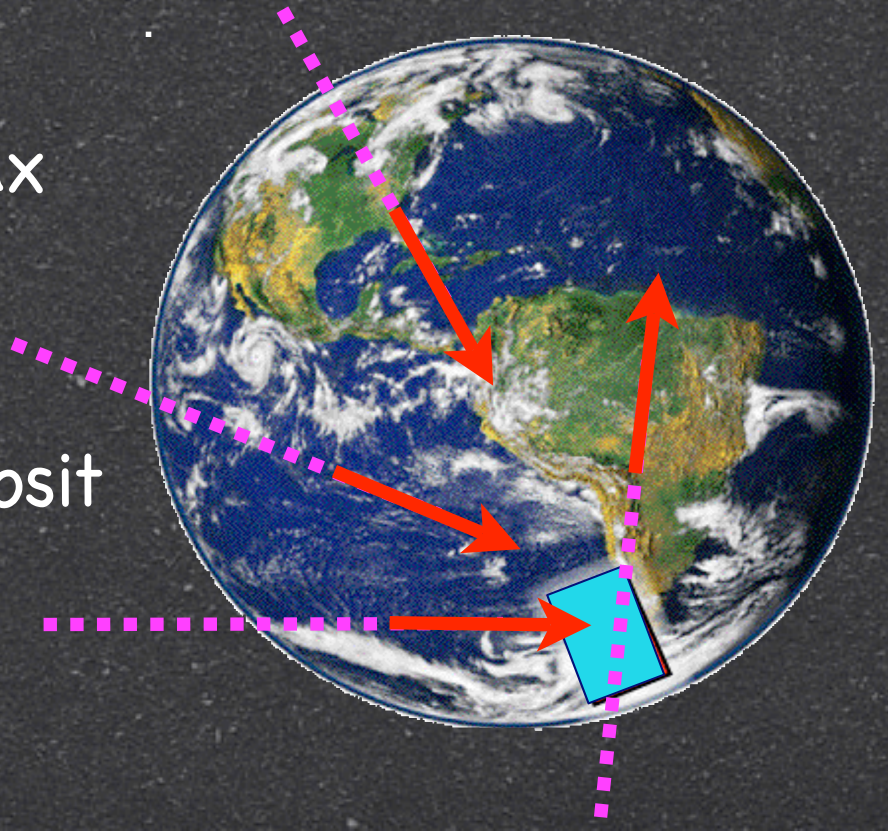
Motivation of development of JULIeT

- Target Energy range : > PeV (E > 10^{15}eV)

GZK mechanism:
UHEProton(~10^{20}eV) +
2.7K micro-wave background

$$
\begin{aligned}
p + \gamma &\rightarrow \pi^+ + [N] \\
&\rightarrow \mu^+ + \nu_\mu + [N] \\
&\rightarrow e^+ + \nu_e + \nu_\mu + [N]
\end{aligned}
$$

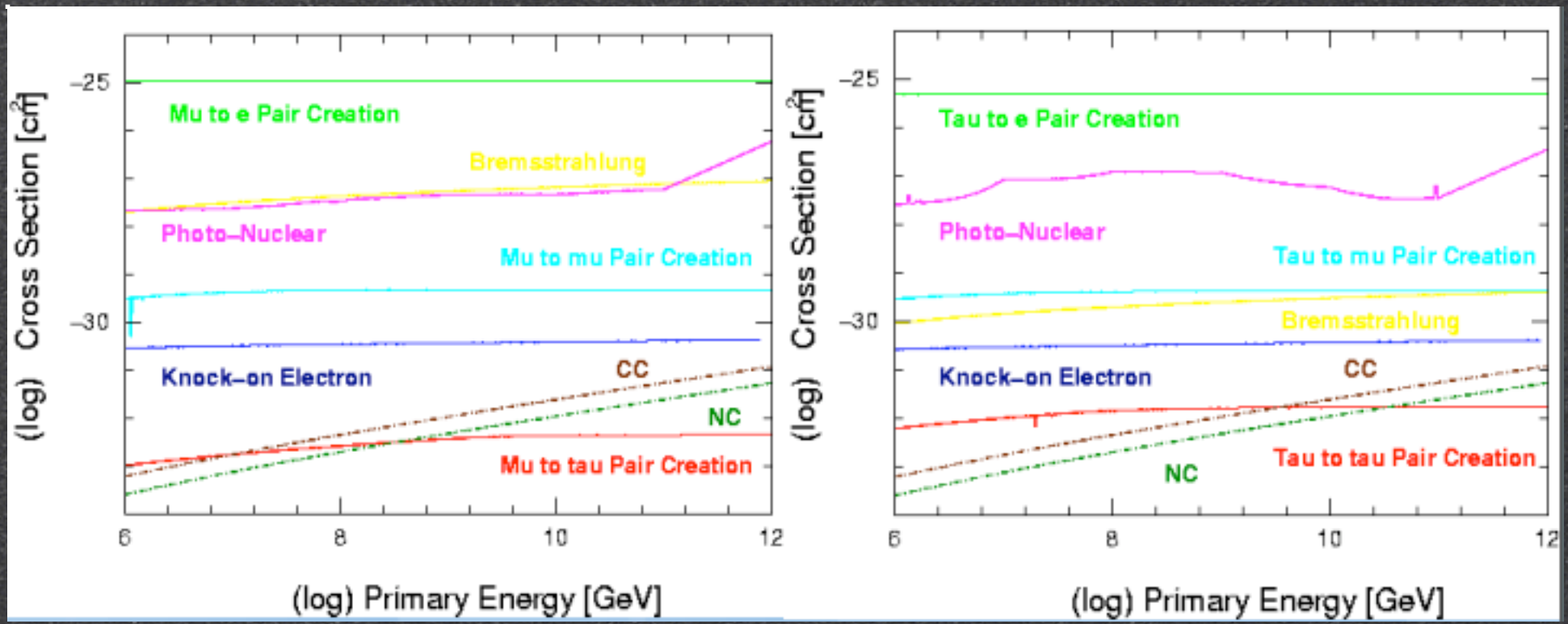
- The Earth is opaque even for the neutrinos!
- Estimate the neutrino flux AFTER propagate in the Earth (use Transport Equation)
- Estimate the energy deposit in the detector (Monte-Carlo simulation)



Cross Sections

At PeV energy range, muons and tauons live longer

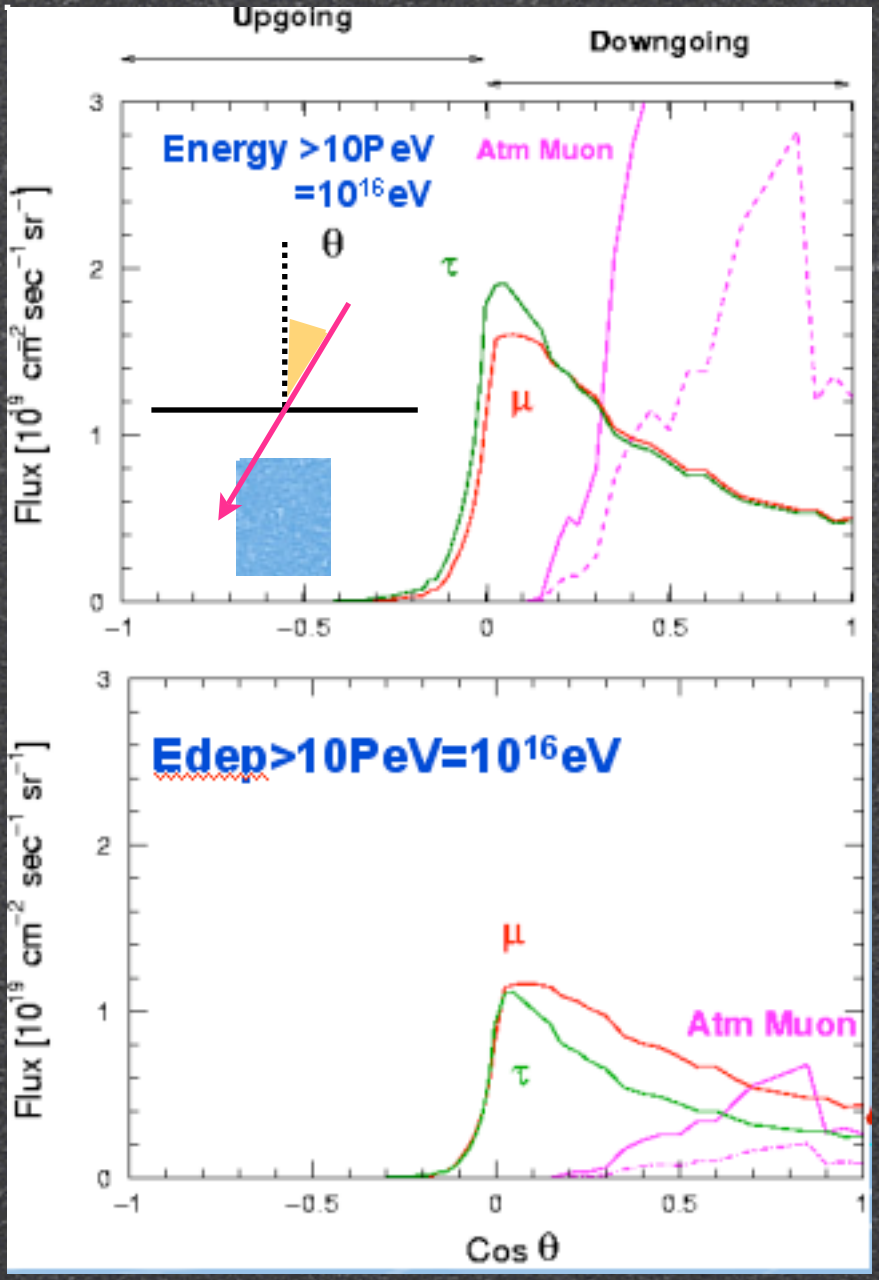
Take into account the propagation of leptons in the Earth BEFORE arrival to the IceCube!

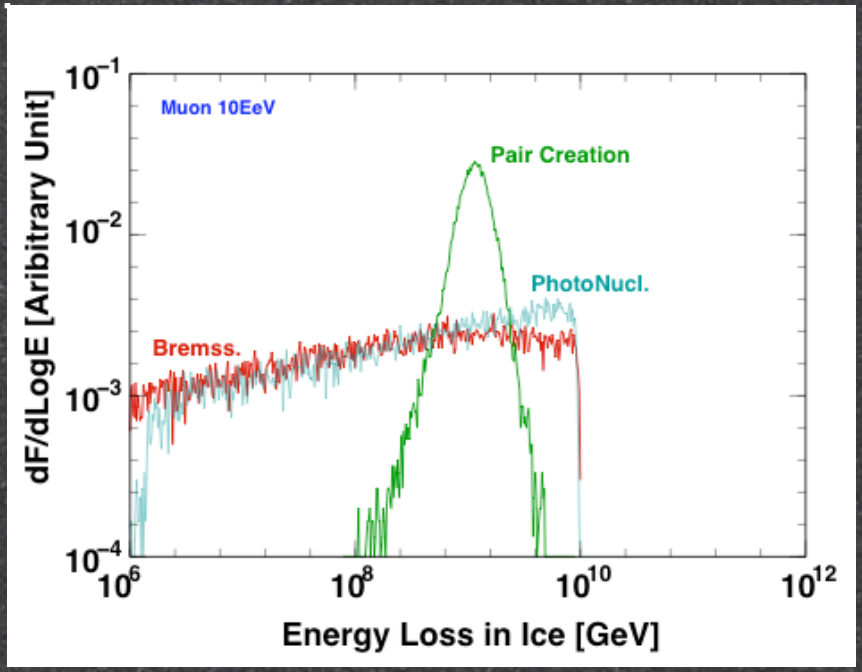


Muon

Tau

Angular Dependency of arrived charged-lepton flux



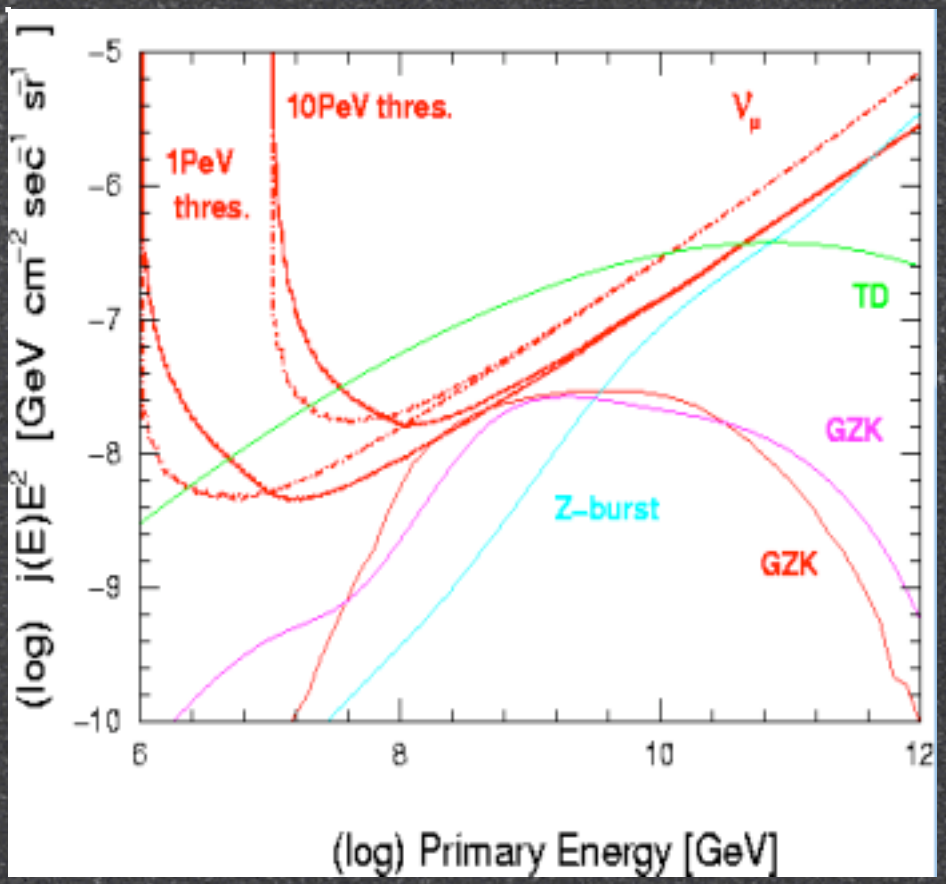


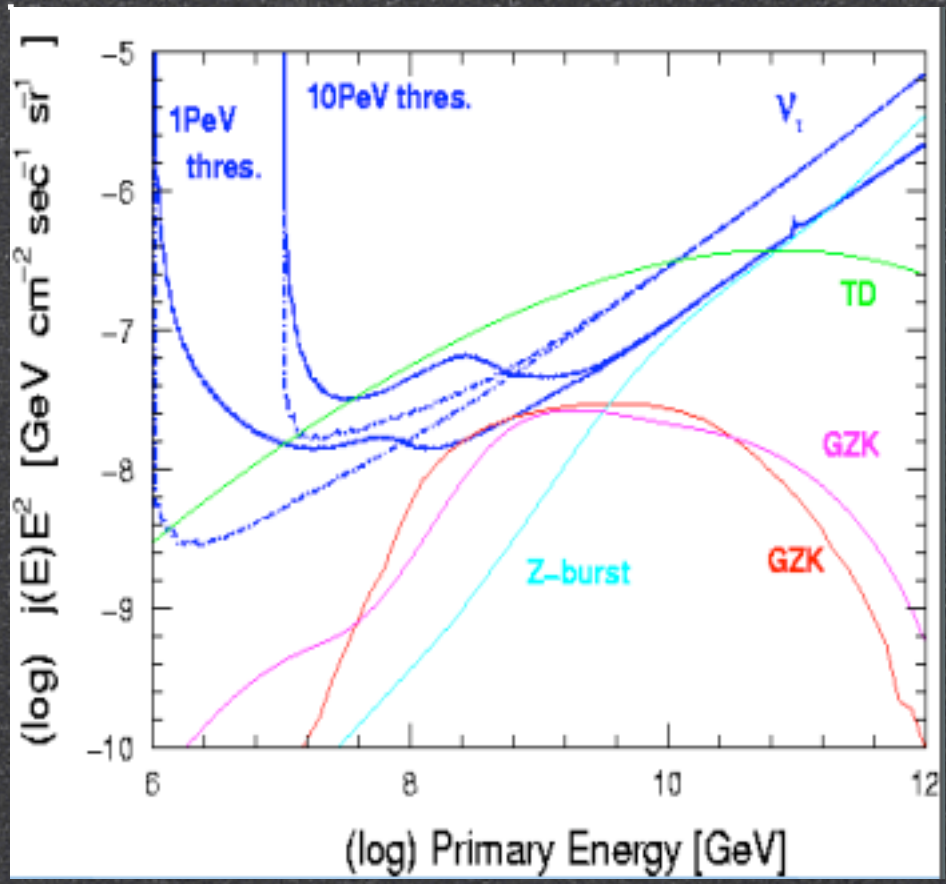
Energy loss of muons within 1km path length

Charged lepton flux at the IceCube

Energy deposit of charged leptons in the IceCube

IceCube Sensitivity





Mu-neutrino

Tau-neutrino

(dushed line: neutrinos interacting inside the IceCube)

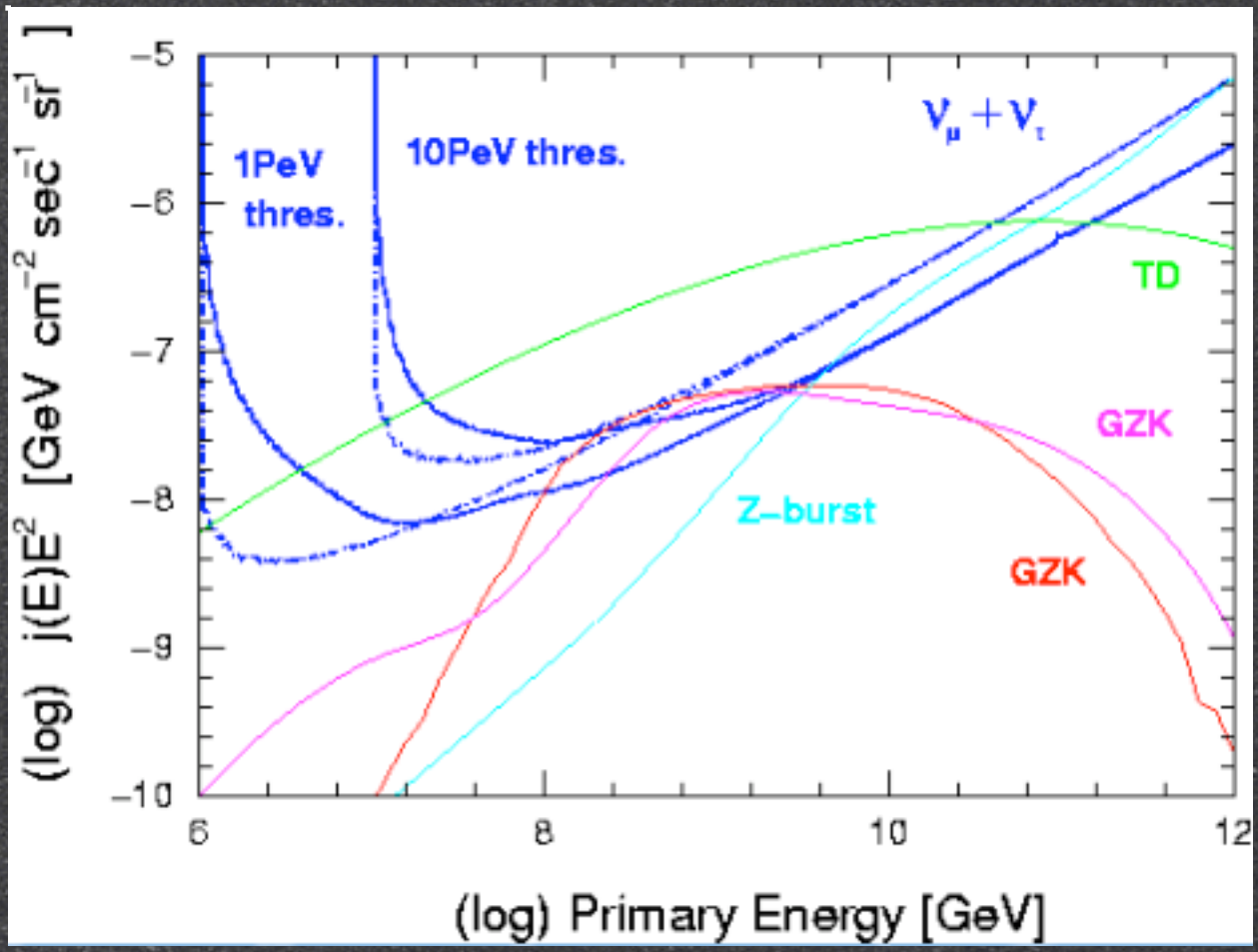
1km^2 detection area, 10years, 90%CL Upper Limit

3.7×10^{-8} at 10^9GeV

4.6×10^{-8} at 10^9GeV

IceCube Sensitivity

(1km^2 detection area, 10years, 90%CL)



Upper Limit:

4.6×10^{-8}

[GeV cm^{-2}s^{-1}sr^{-1}]

at 10^9GeV

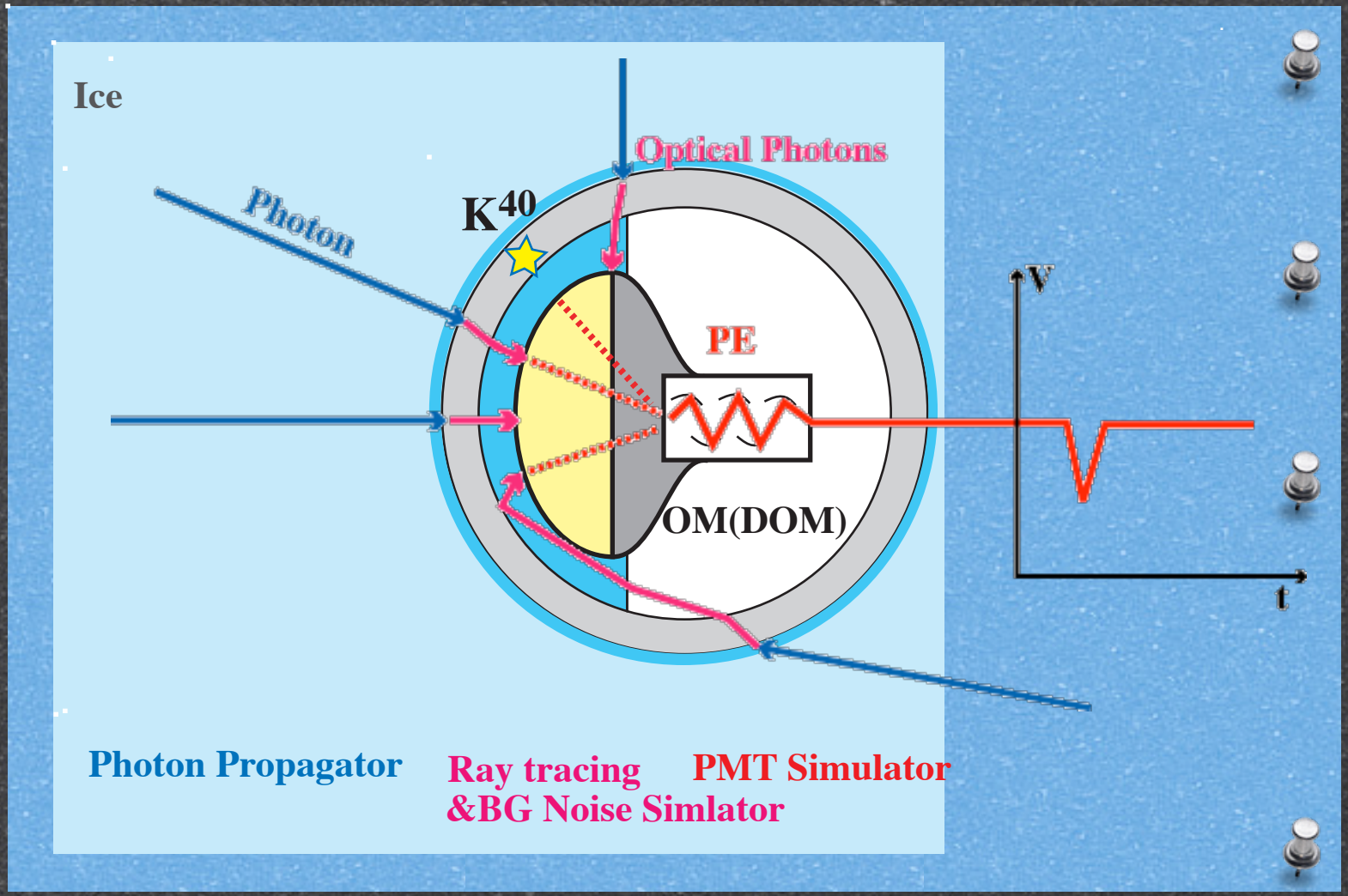
Detailed paper is Accepted Phys.Rev D

S.Yoshida, R.Ishibashi, H.Miyamoto

See also: http://www.ppl.phys.chiba-u.jp/reserch/IceCube/

DOM Simulator based on Geant4

Planned software spec



Ray tracing Simulator

BG Noise Simulator

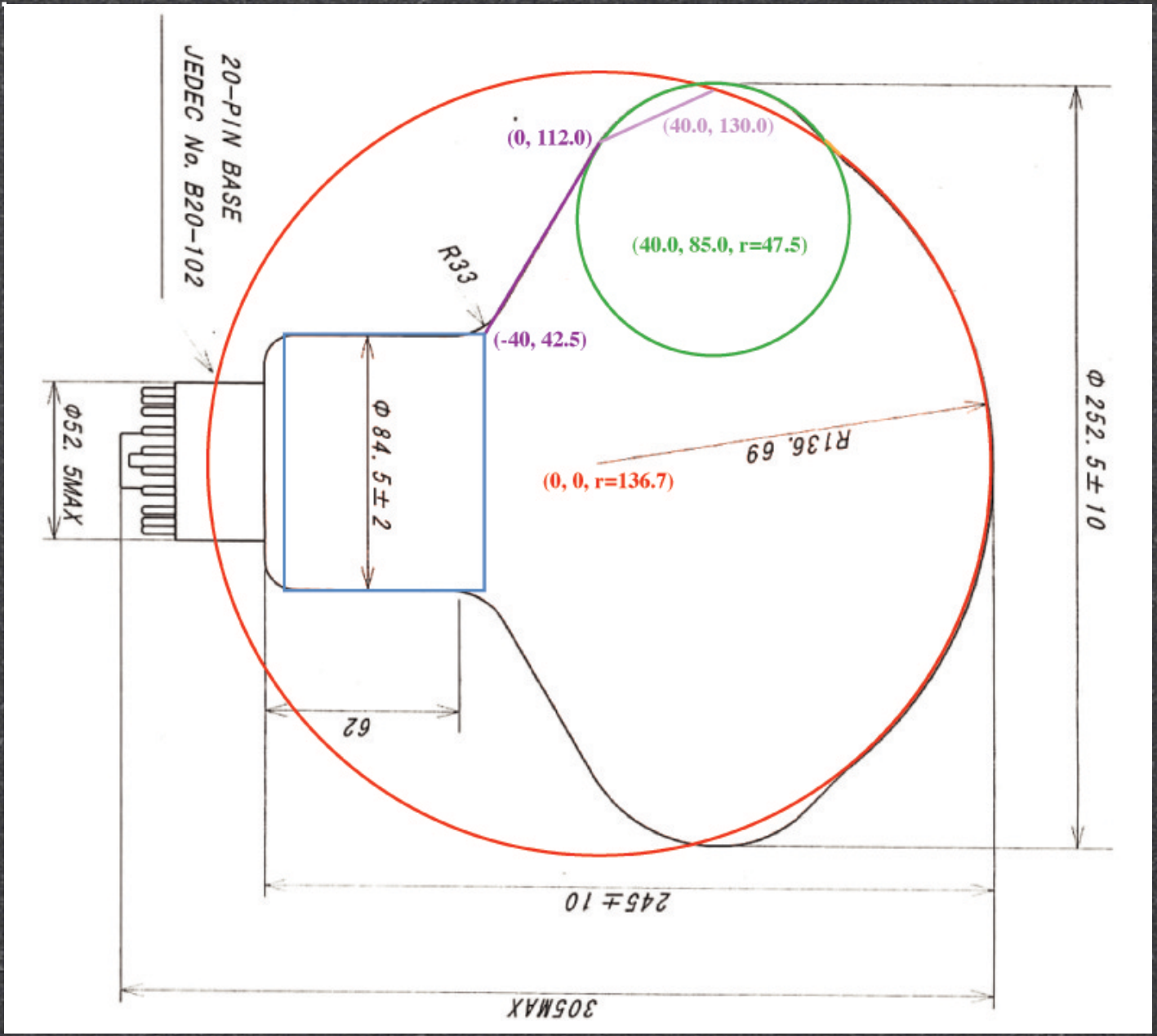
Wave Length Shifter Simulator

PMT Simulator

Use Geant4 except for PMT simulator

How can we get the PMT solid?

The PMT solid



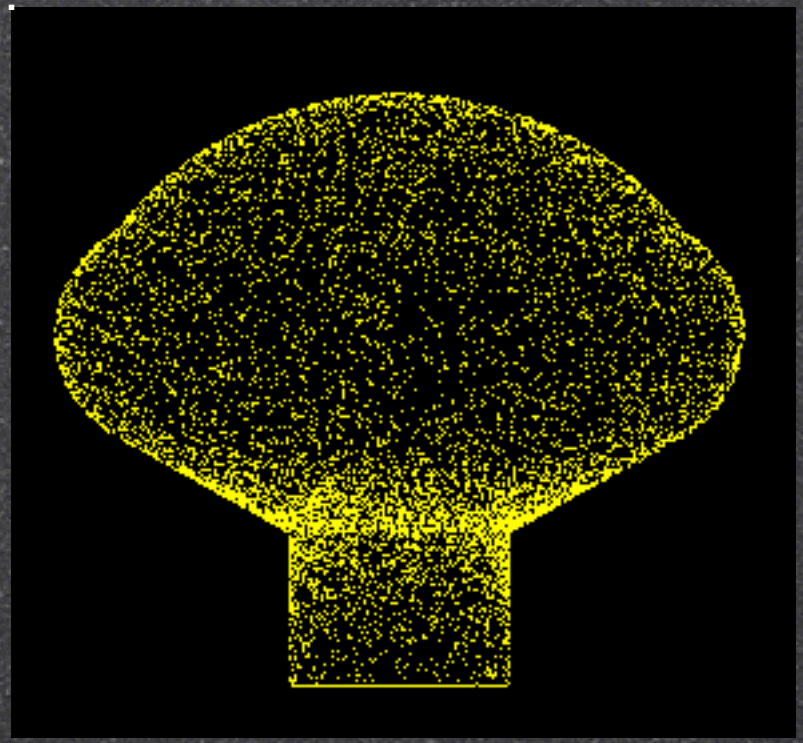
Use G4UnionSolid!

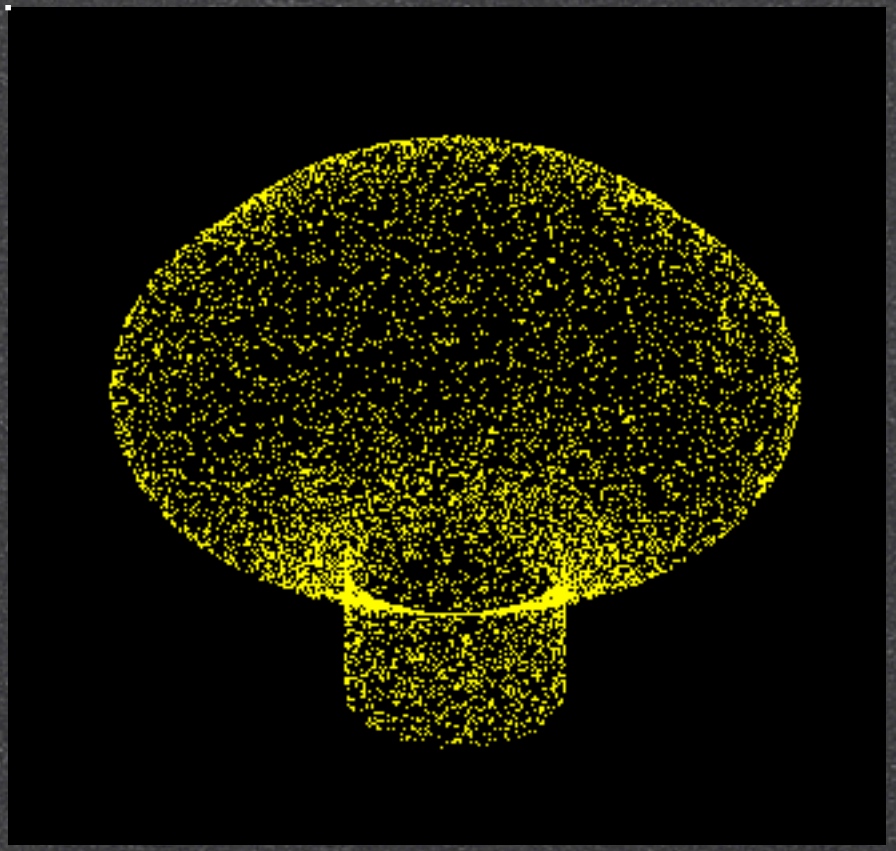
Problem:

- Complicated Boolean solids cannot be drawn correctly
- Computing time will be longer

Test of PMT solid

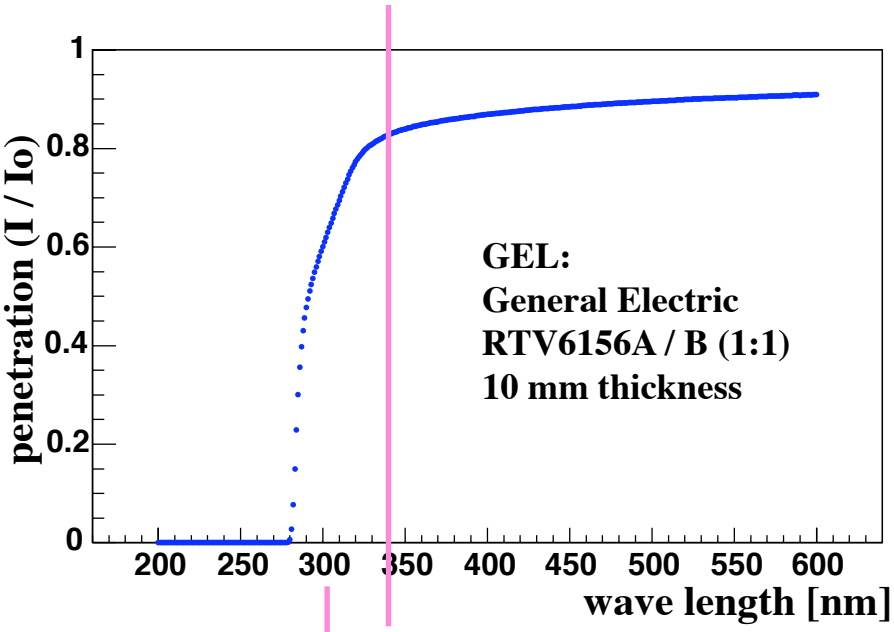
- Test the solid by geantino
- Kill tracks at the surface of PMT

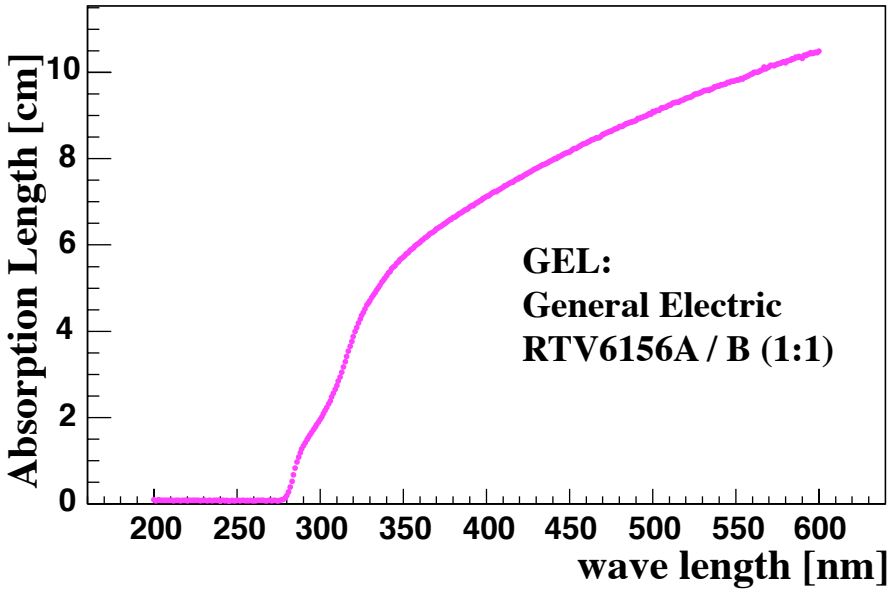


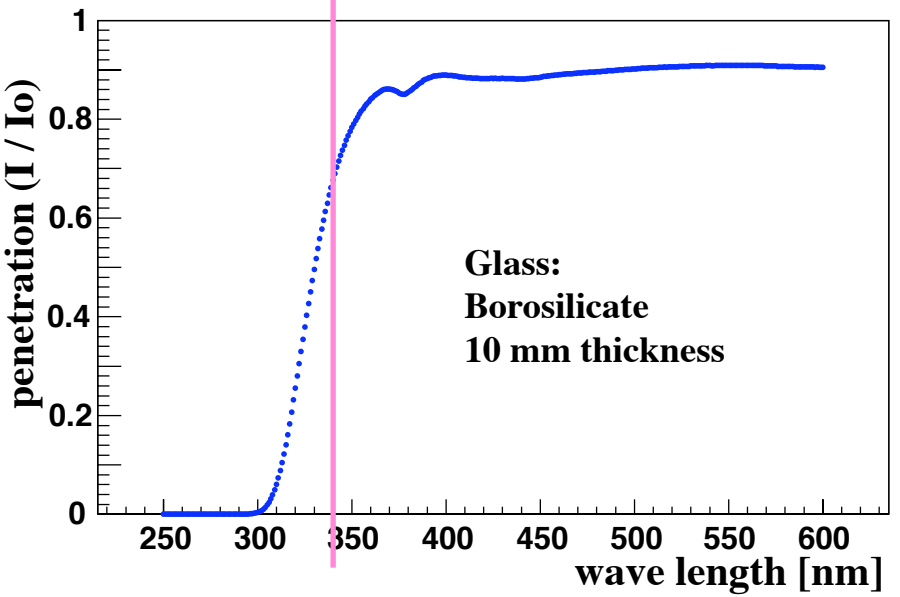


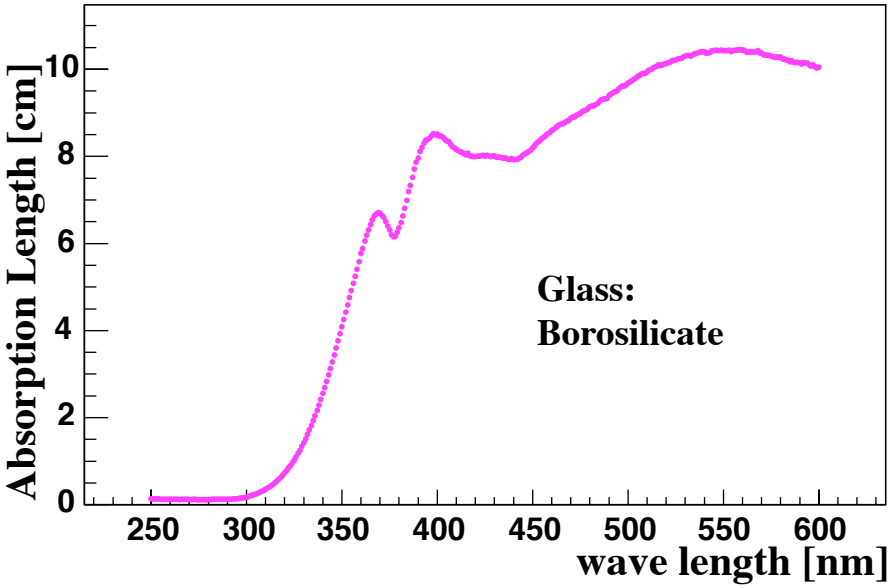
Next :
Install material properties!

Material properties



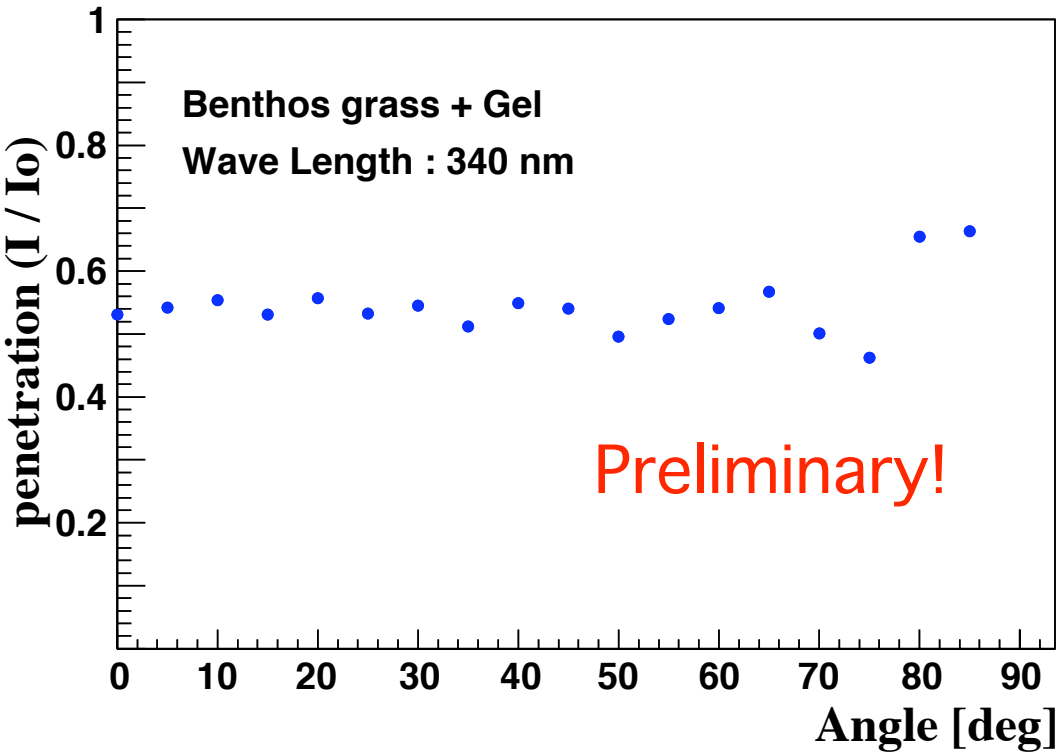


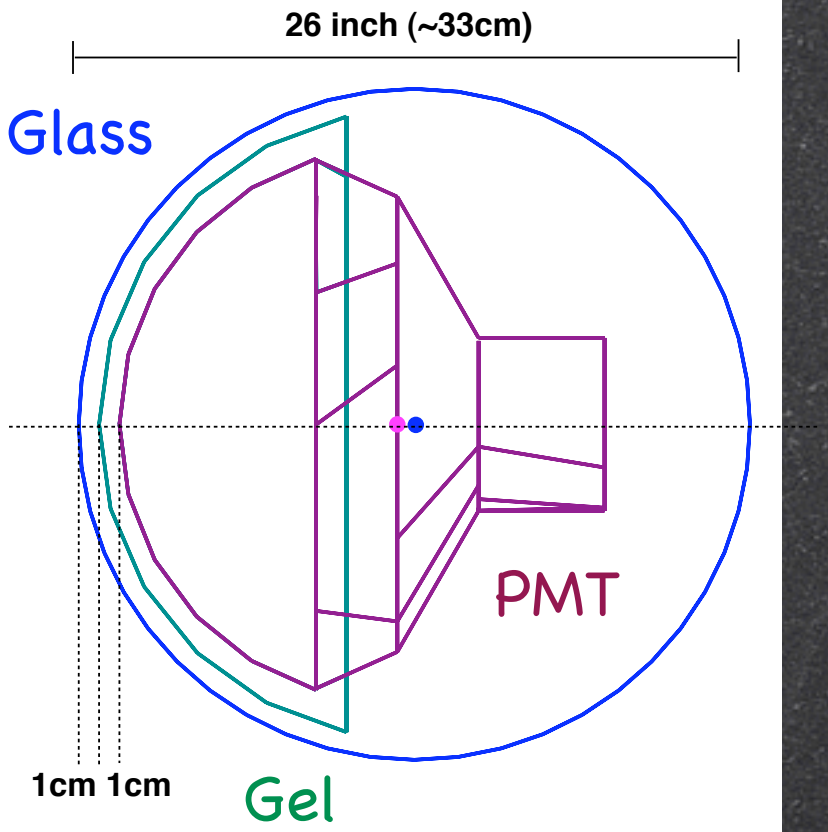




penetration data taken by Eliza Resconi

Material properties (DOM setup)





0.8(1cm Glass) x 0.7(1cm Gel) = 0.56(at PMT)

Summary

- IceCube construction start in the year
- From chiba university, the first version of UHE lepton propagation simulator (JULIeT) will be released in this march. The sensitivity of the IceCube detector for UHE leptons is estimated and its detailed paper is accepted Phys.Rev D.
- Started development DOM simulator based on Geant4.