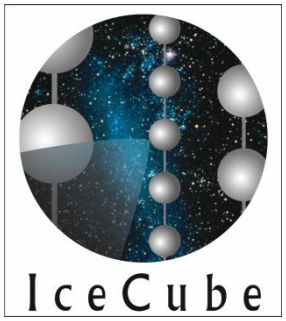
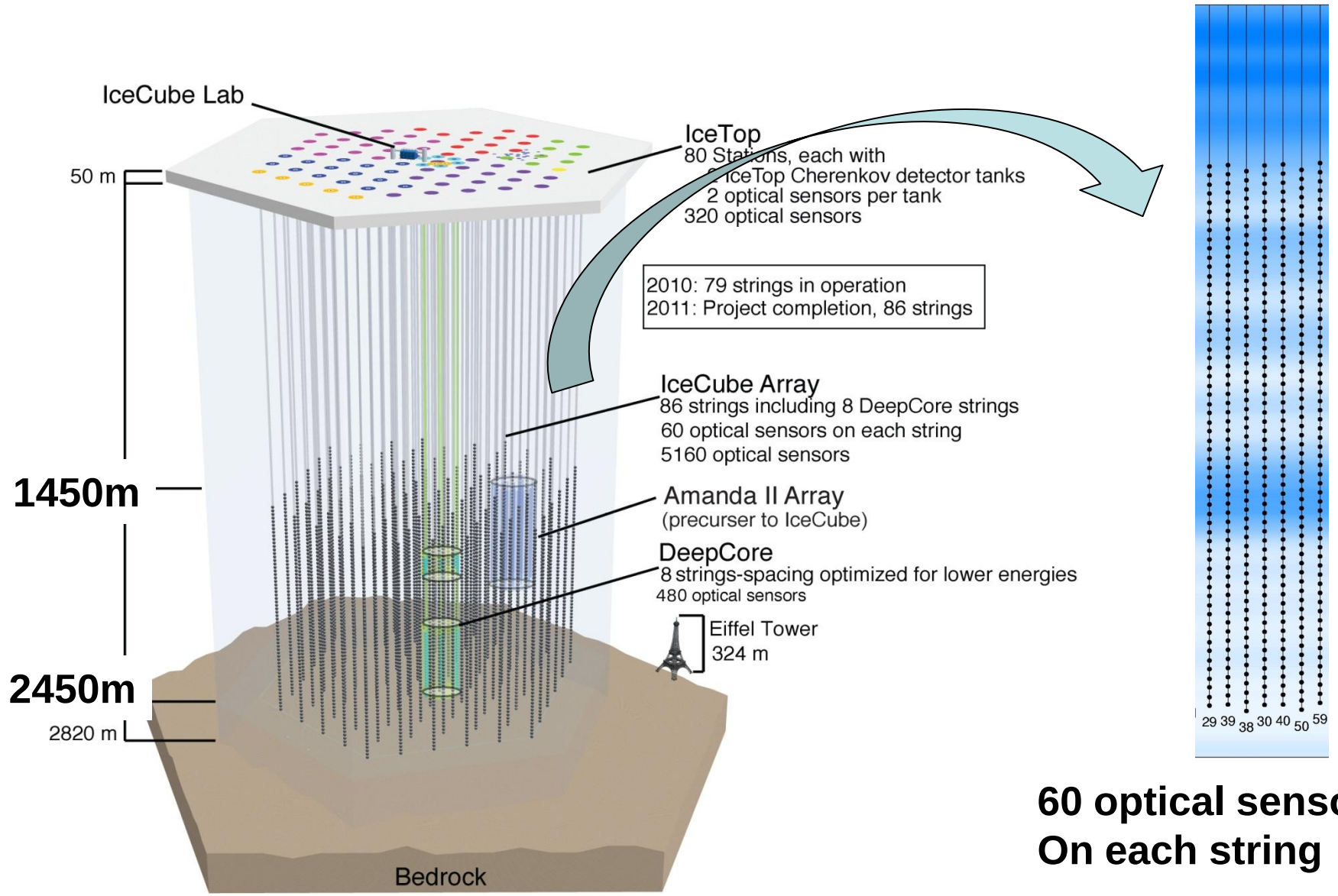


Calibrations in IceCube

Akiko Kawachi
Tokai Univ.
for IceCube Collaboration

1km Cubic Detector



60 optical sensors
On each string

Systematics ?

- ***Detector Uncertainties***
  - **Sensors**
    - absolute & relative efficiencies
    - charge response & waveforms
    - timing
  - **Geometry**
  - **Ice Property**
    - absorption /scattering

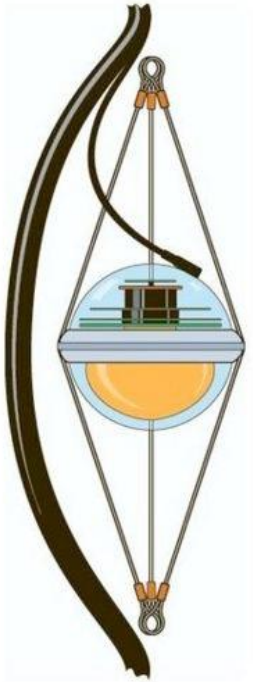
- ***Systematics in Analysis***
- ***Theoretical Uncertainties***

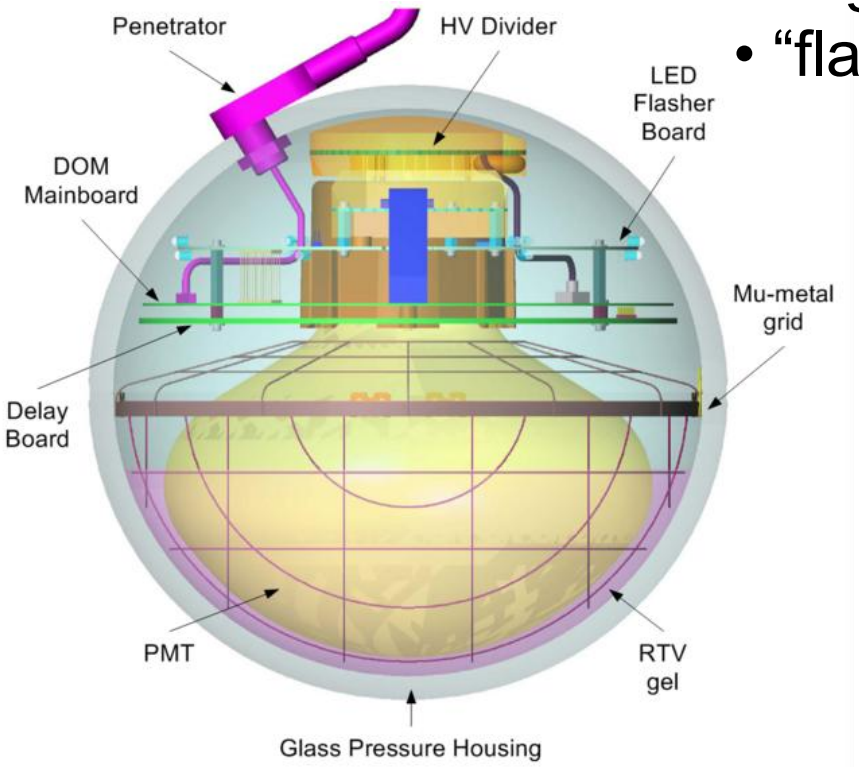
Detector Uncertainties and Calibrations

- ***Detector Uncertainties***
  - **Sensors** — ***Lab.***
    - absolute & relative efficiencies
    - charge response & waveforms
    - timing
  - **Geometry**
  - **Ice Property**
    - absorption /scattering

In Situ.

Sensors: Digital Optical Module

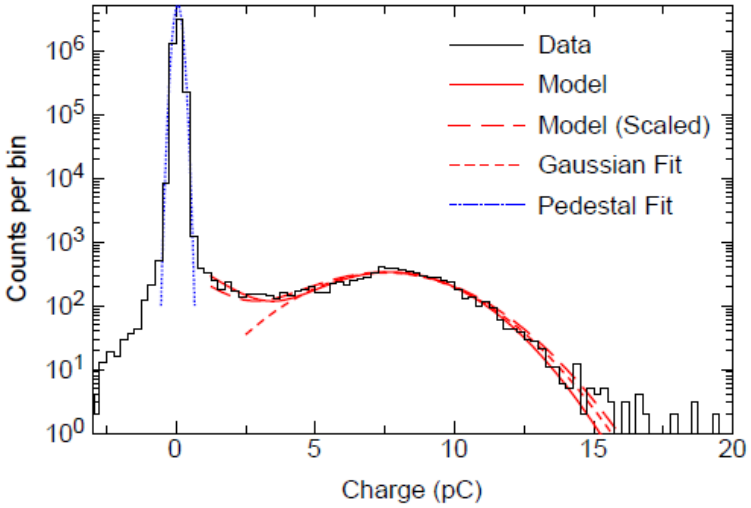




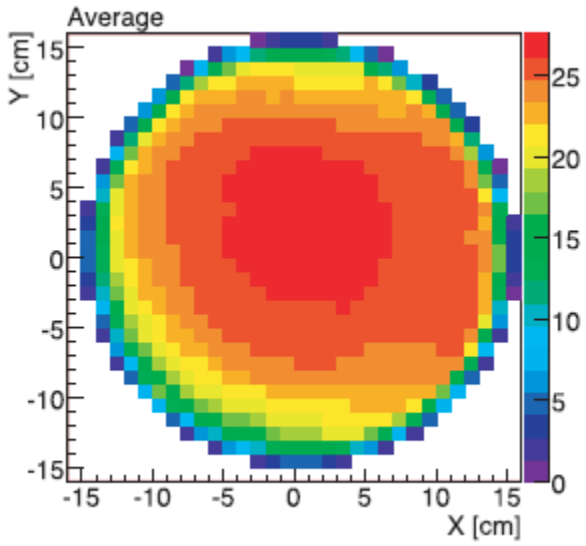
- local coincidence
- degitizers
- “flasher” Unit

- Hamamatsu R7081-02(10”)
- 10 dynodes, ~1.5kV : gain ~10^7
- single p.e. sensitivity

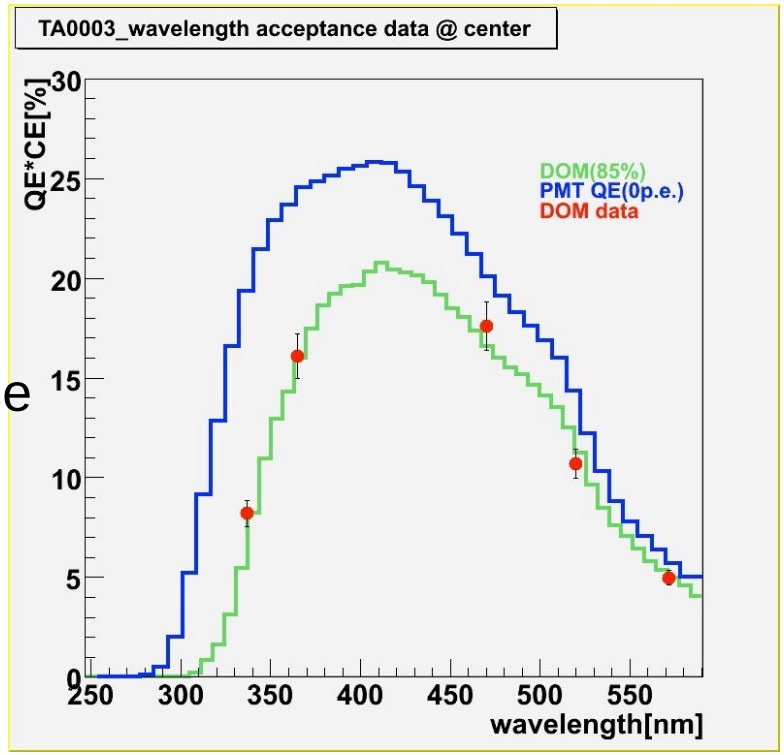
Lab. Calibrations for Modeling



Single p.e. response



2d cathode response



PMT & DOM acceptance vs wavelength

Abbasi et al., (2010)NIMPA 618 pp.139.

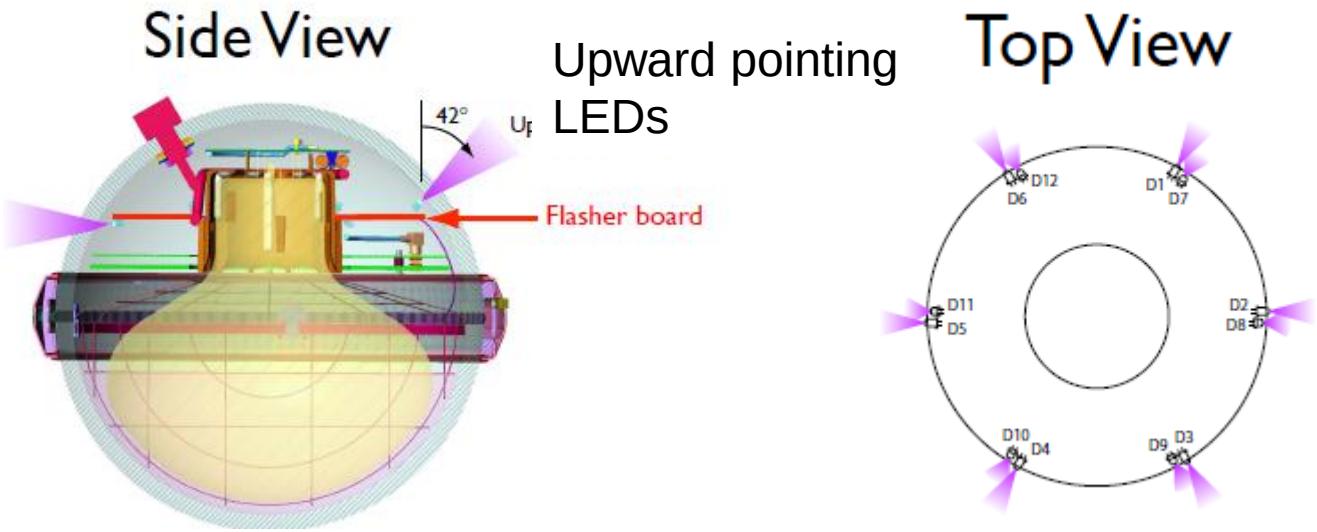
In Situ Calibrations & Light Sources

- **Sensors**
  - absolute & relative efficiencies
  - charge response & waveforms
  - timing
- **Geometry**
- **Ice Property**
  - absorption /scattering

In Situ.

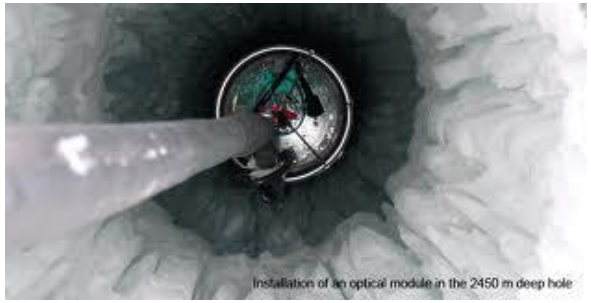
- ***Flashers***
- ***"Standard Candles"***
- ***Downgoing muons***

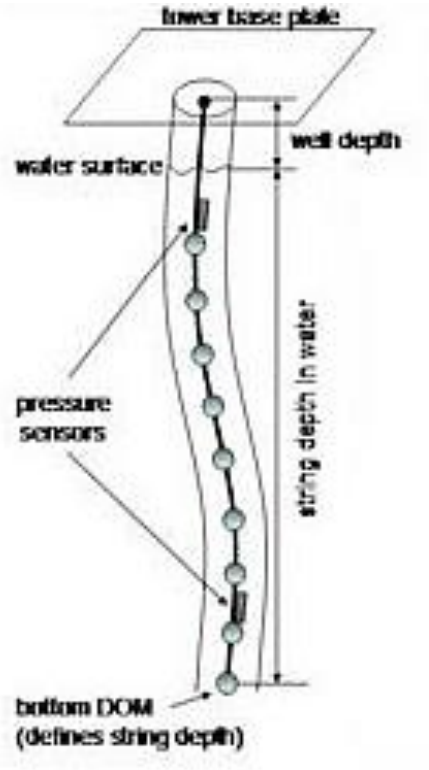
Flashers:

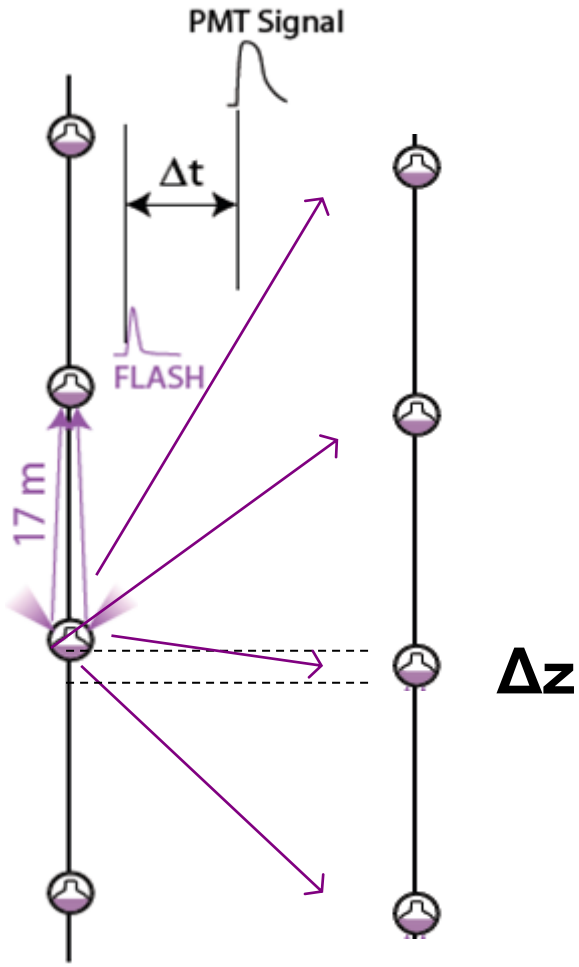


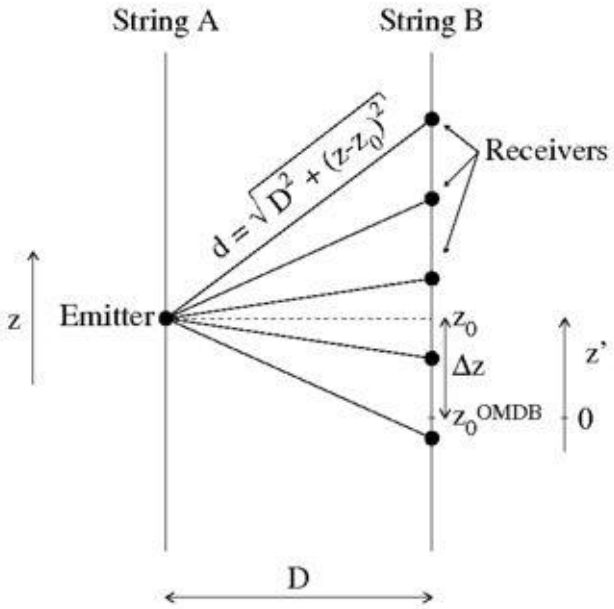
- **Twelve** violet (405nm) LEDs at each DOM
- brightness & width variable : max. ~9e10 photons
- flashing pattern variable

Flash and measure everywhere : (a) intra-string Geometry

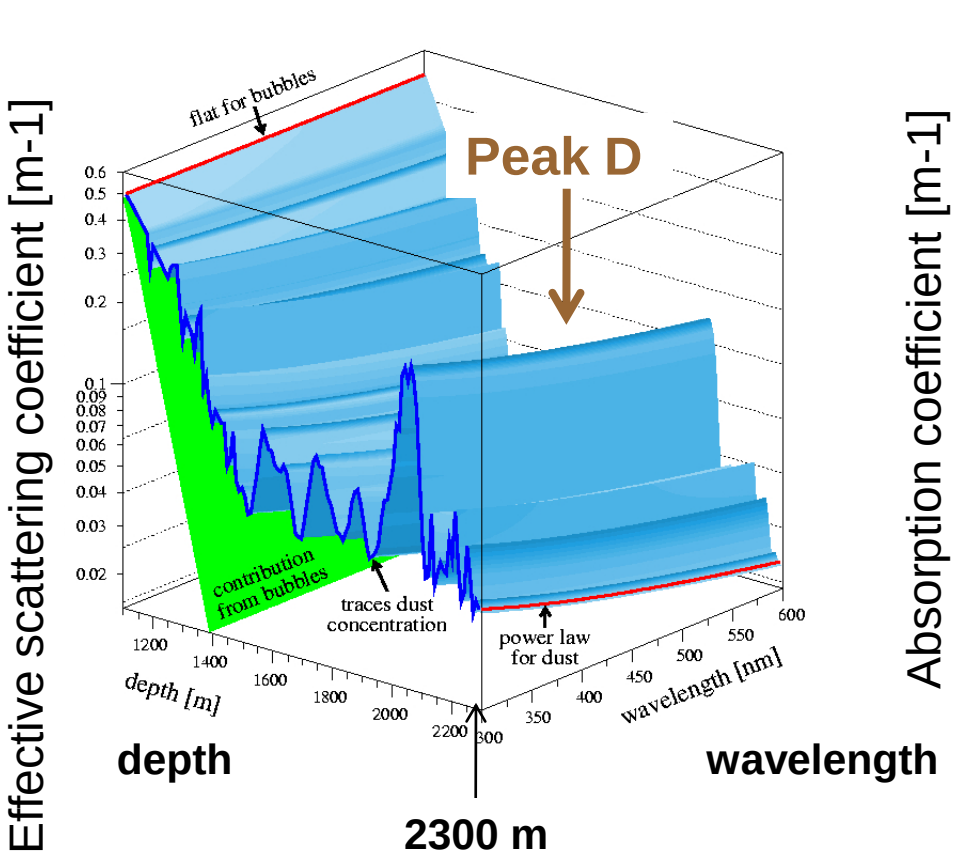


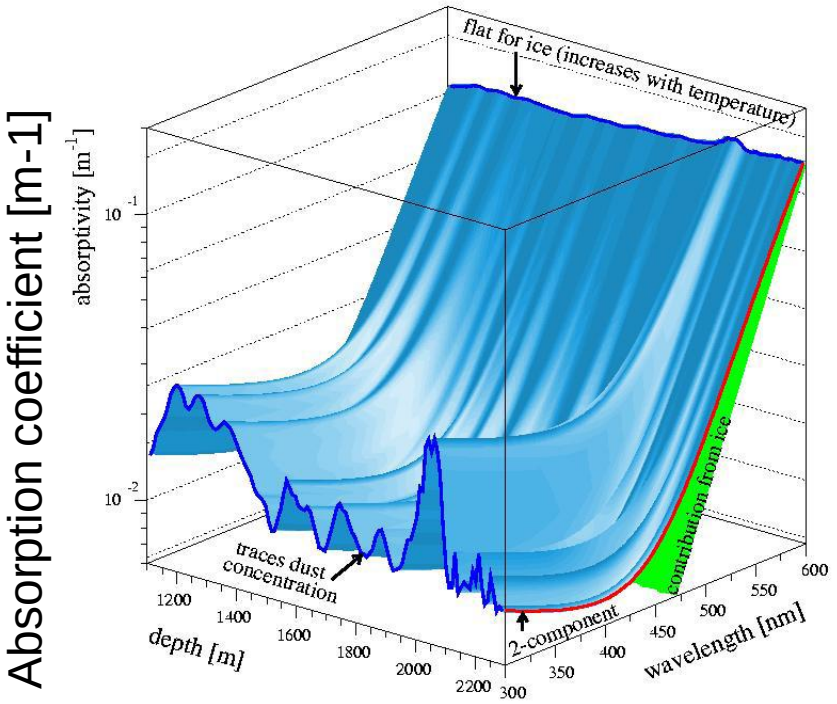






(b) Ice Property : AMANDA Result

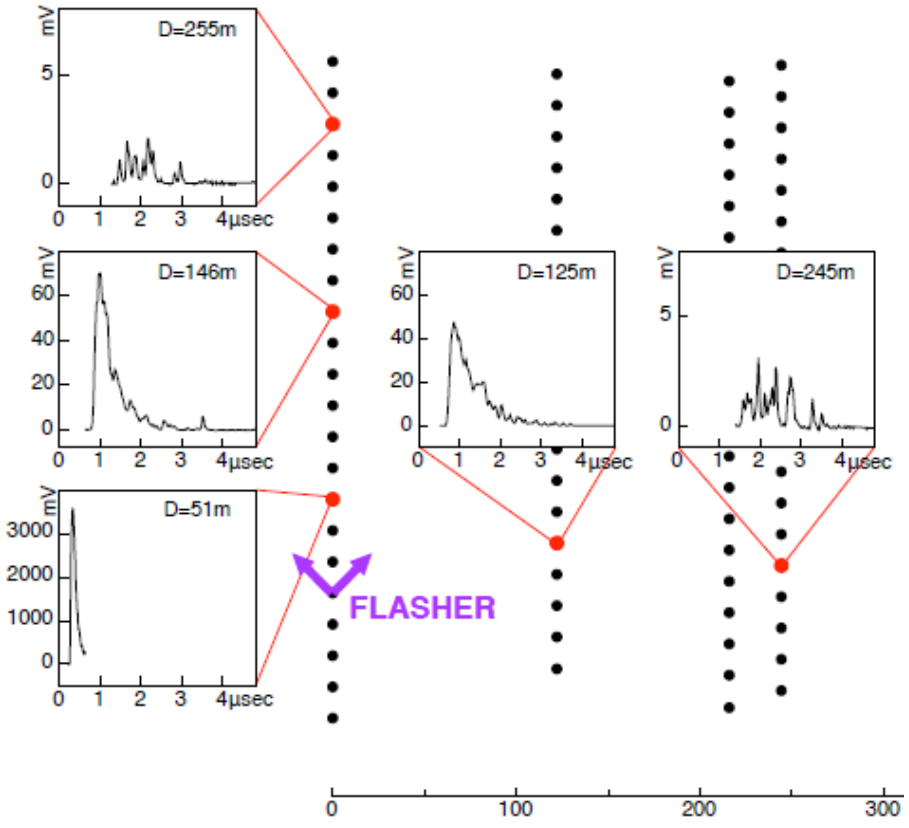




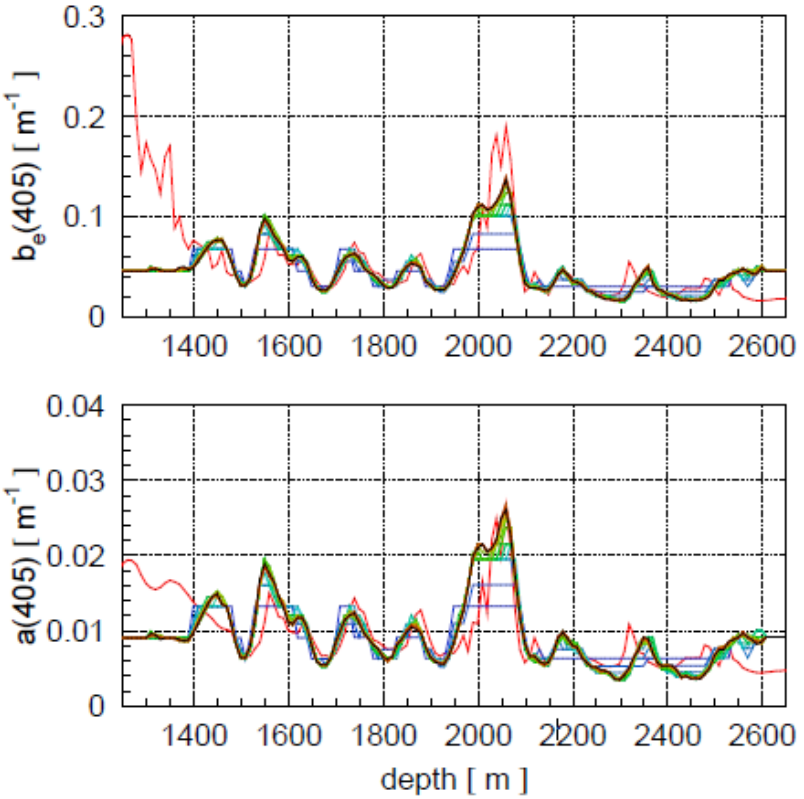
- scattering on bubbles, dust grains
- Absorption by ice, dust grains
- Layer structure

Ackerman et al., (2006), J.Geophys.Res.111,D13203

Flasher data: Likelihood minimization fits to get Ice parameters



→ "SPICE" model



Compare waveforms w/ simulation to iterate coef.

Based on the works of Dima Chirkin

In Situ Calibrations & Light Sources

- **Sensors**
  - absolute
  - charge
  - timing
- **Geometry**
- **Ice Property**
  - absorption /scattering

In Situ.

✓**Wide propagation of photons**

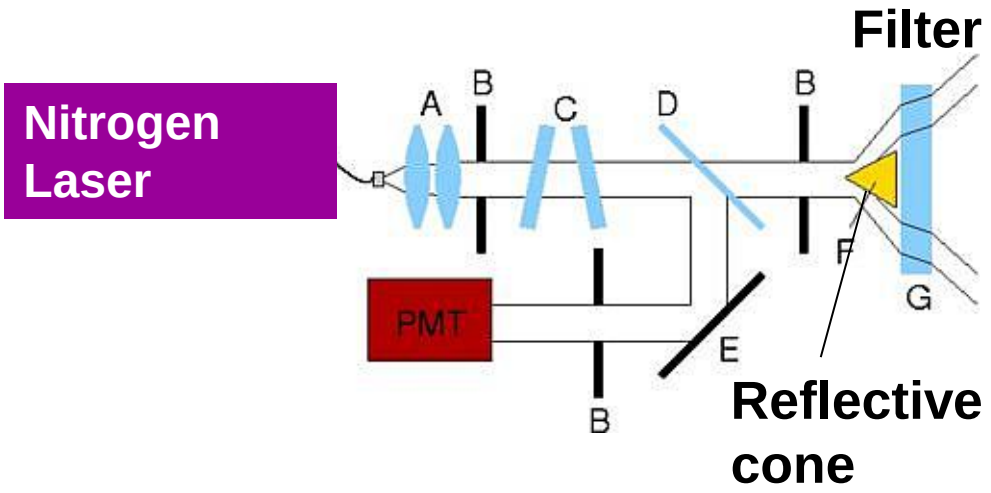
For UHE events

✓ **energy scale calibration**

✓ **saturation**

- ***Flashers***
- ***"Standard Candles"***
- ***Downgoing muons***

“Standard Candle”s:

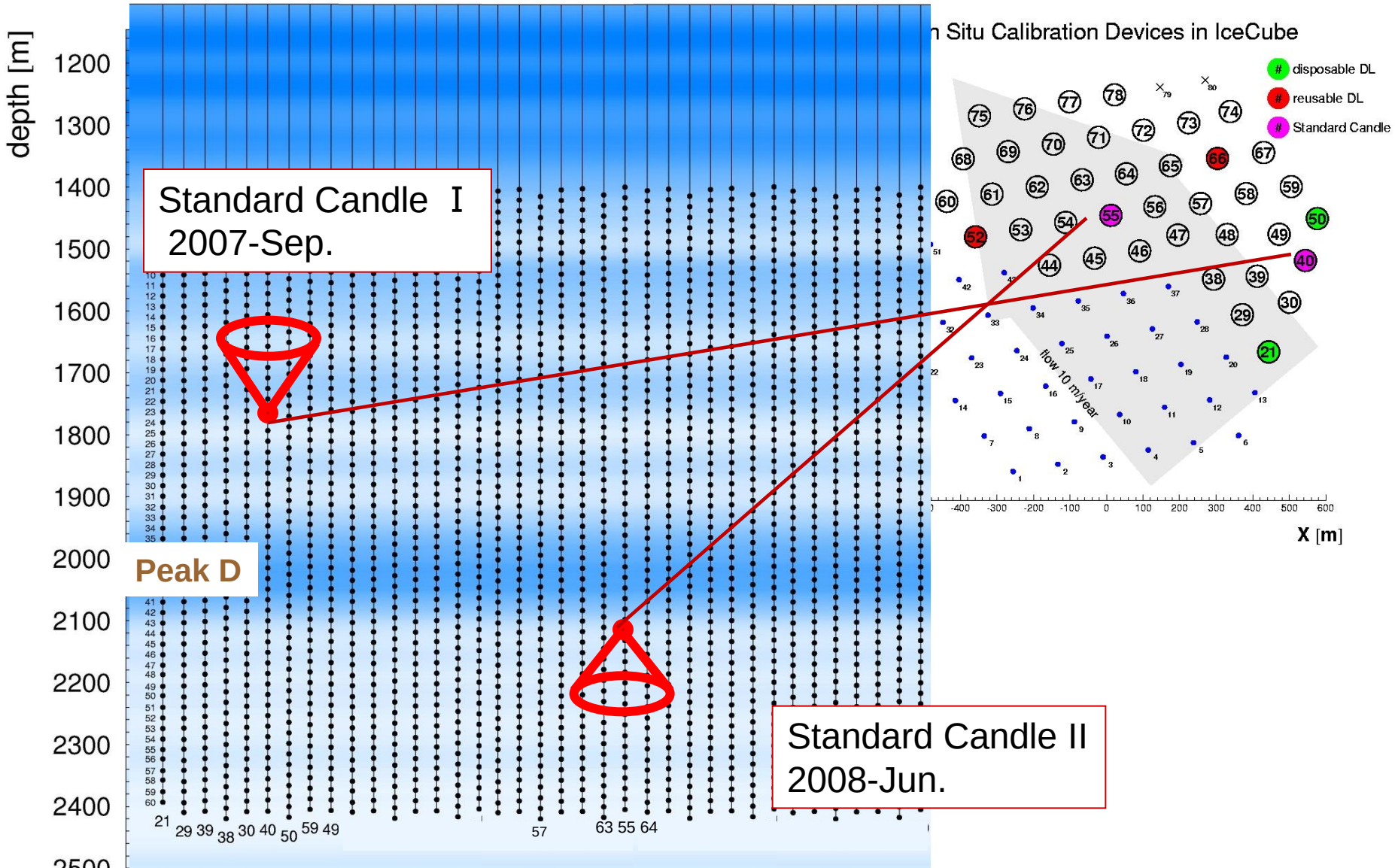


- **Nitrogen** (337nm) pulse lasers w/ optics & electronics
- Brightness absolutely calibrated and variable

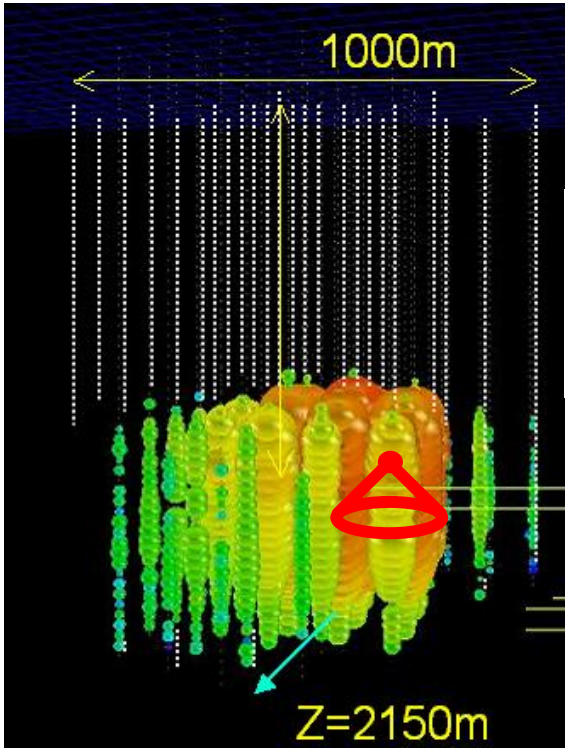
  input : 2e11- 4e12 ph (SC-I) / 1.7e10- 2.5e13 (SC-II)

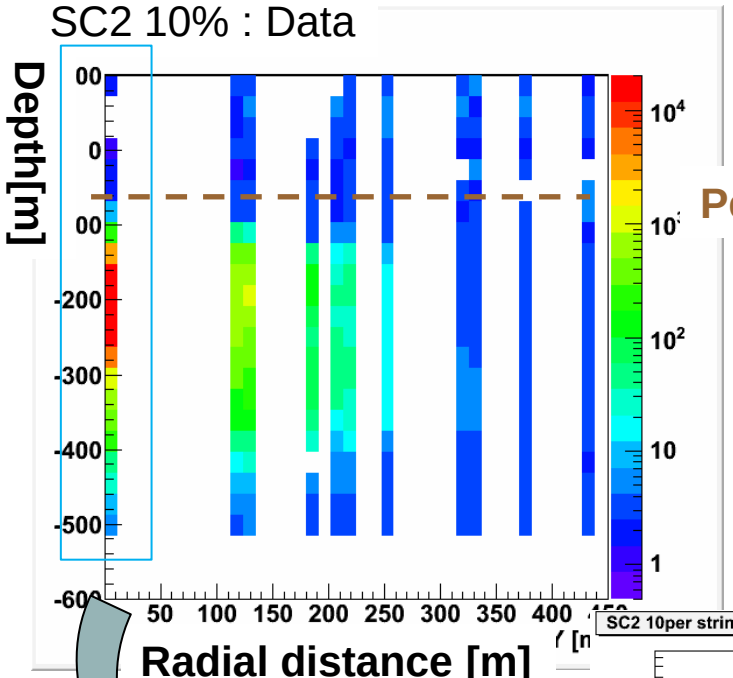
  ~ 1-100PeV ν_e cascade events

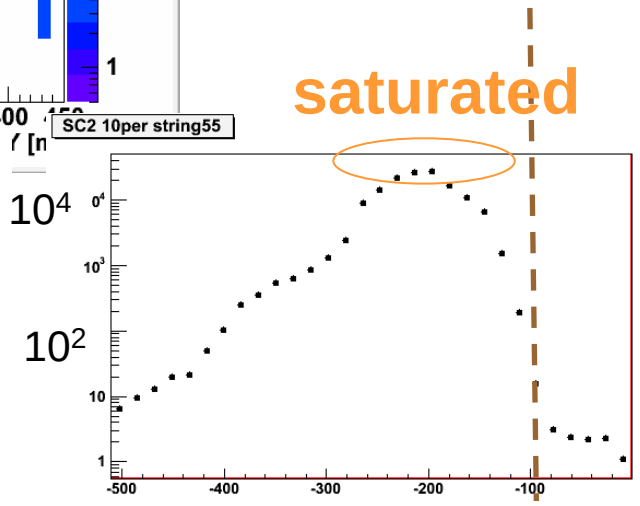
“Standard Candle” Runs



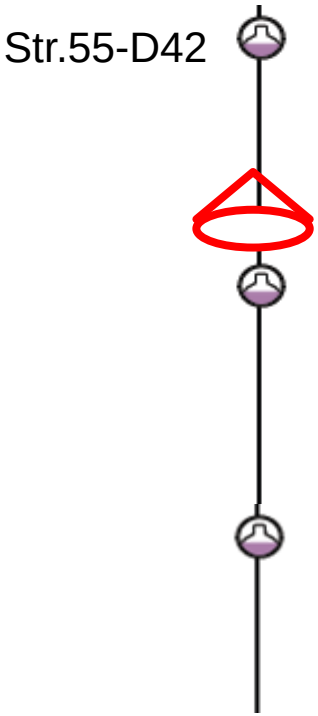
SC Events: How they look

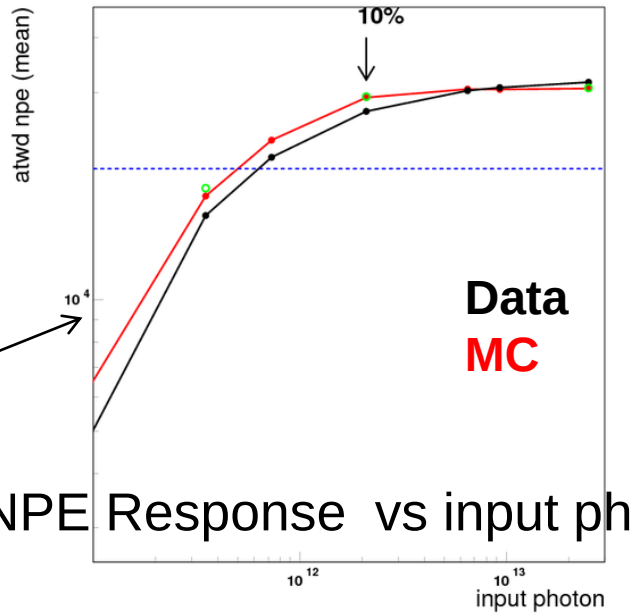




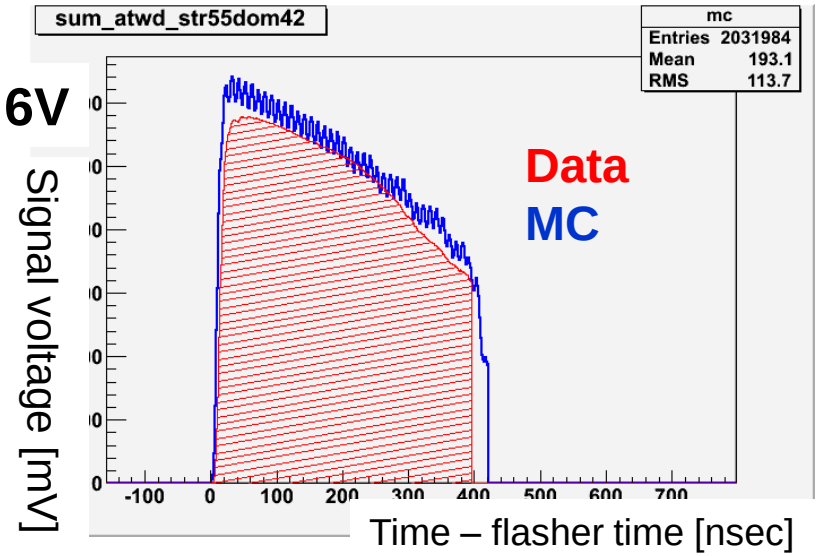


Response near saturation:

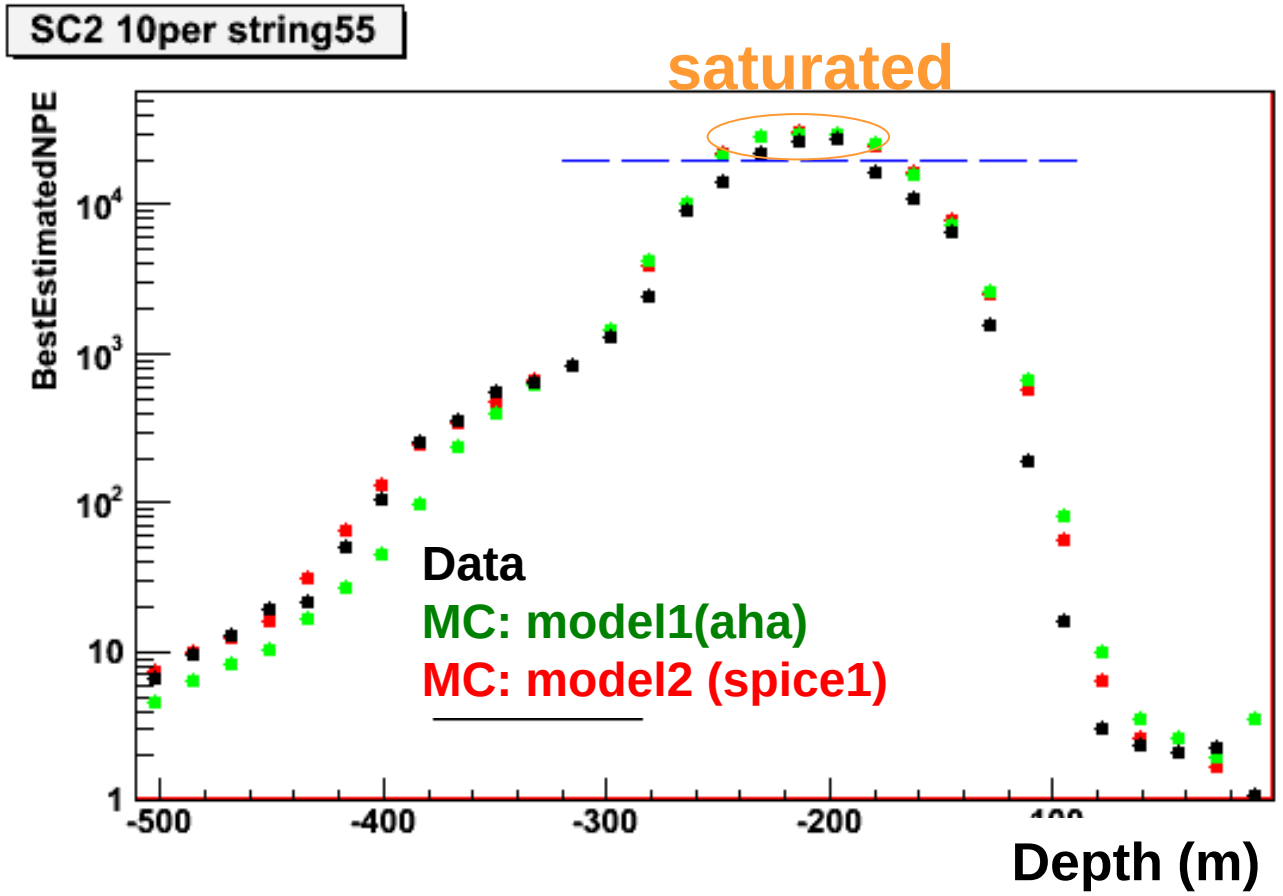




NPE Response vs input photon

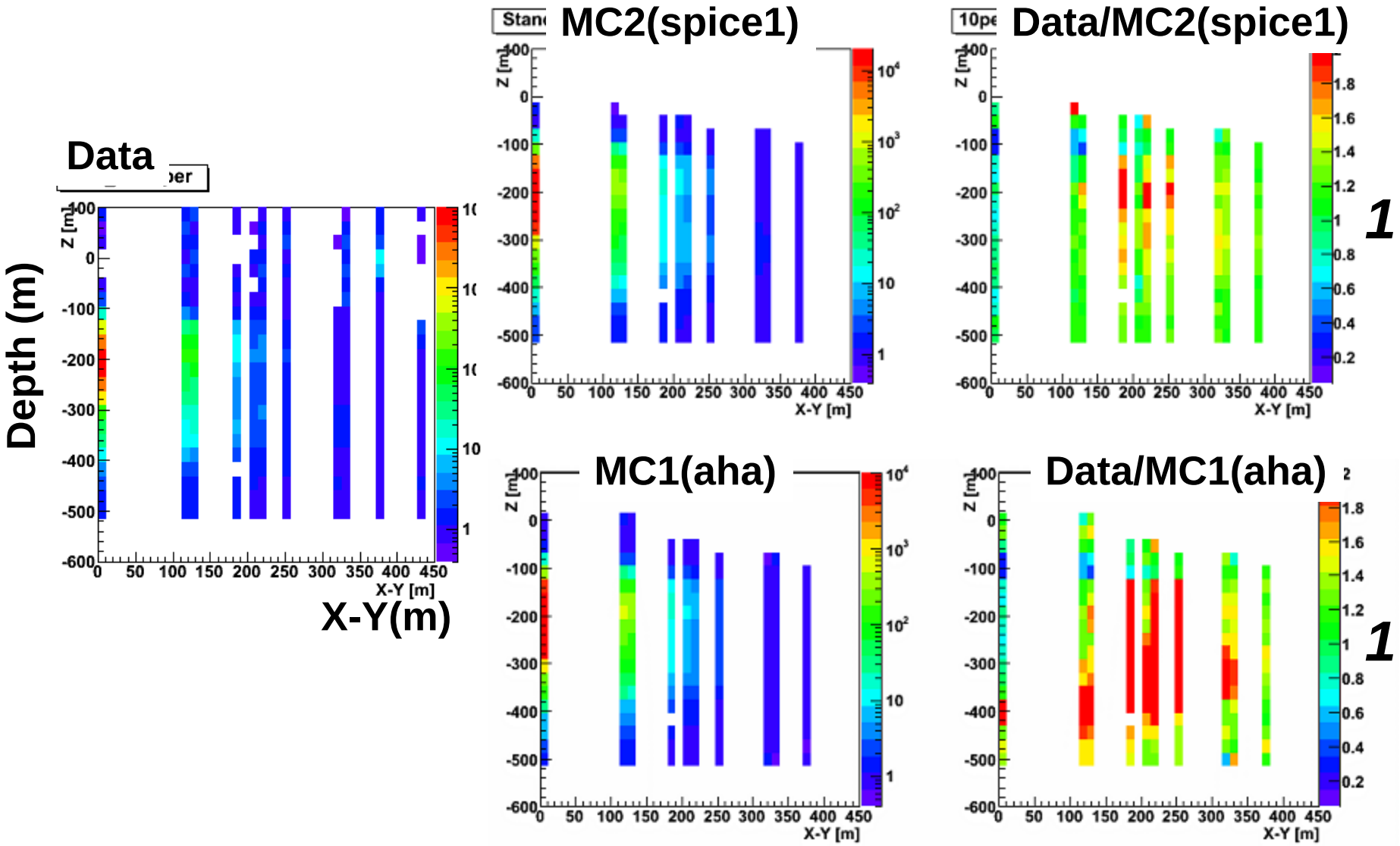


Sensitive to Ice property models(1):



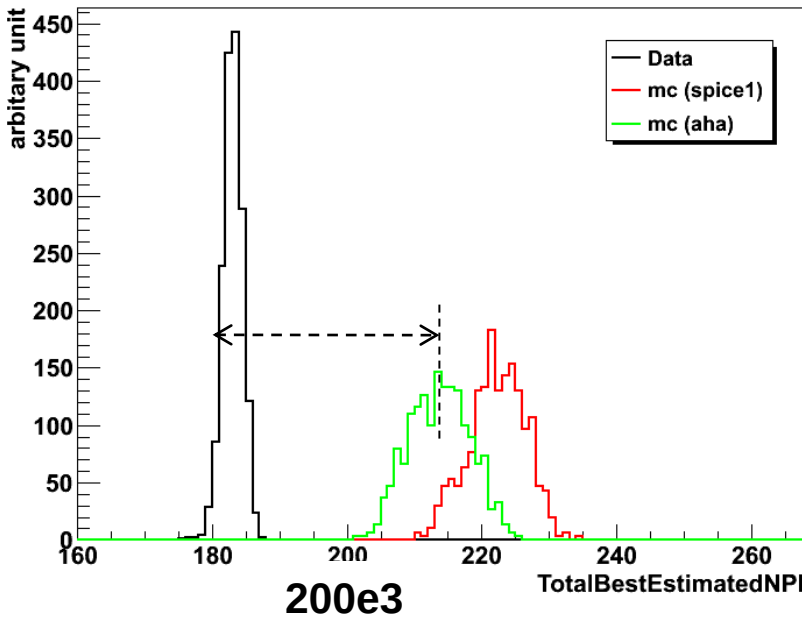
Deviation between models and data depends on layers.

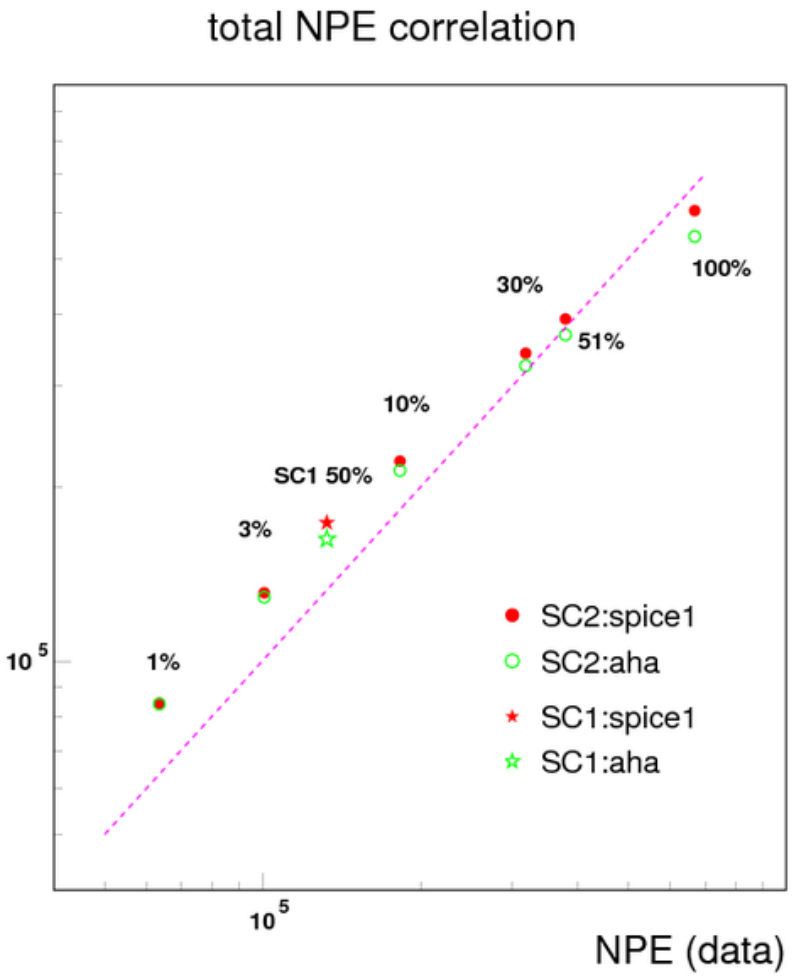
Sensitive to Ice Property Model(2)



Deviation of “Total NPE” estimation

SC2 10% 2.1e12ph:





(data-MC)/MC : -14.4% **(aha)**

: -17.6% **(spice1)**

Summary

In order to understand the detector uncertainty, lab and in-situ calibrations to obtain fundamental calibration quanta have been done by IceCube group.

Study with the known light sources are on-going and offer/examine more precise modeling of sensor s & ice.