

Particle Physics Experiments

Hi, my name is Teppei

- Experimental particle physicist
- BSc in Japan
- PhD in USA
- Lecturer in UK

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King's College London
June 8, 2021

Cryogenic photo-multiplier tube test
(photo by Reidar Hahn, Fermilab)

Particle Physics

Study matter, force, space-time with elementary particles

Origin of matter

Origin of space-time

Unification of matter, force, and space-time

etc



Particle Physics

Study matter, force, space-time with elementary particles

Origin of matter

→ Artificial beam experiment

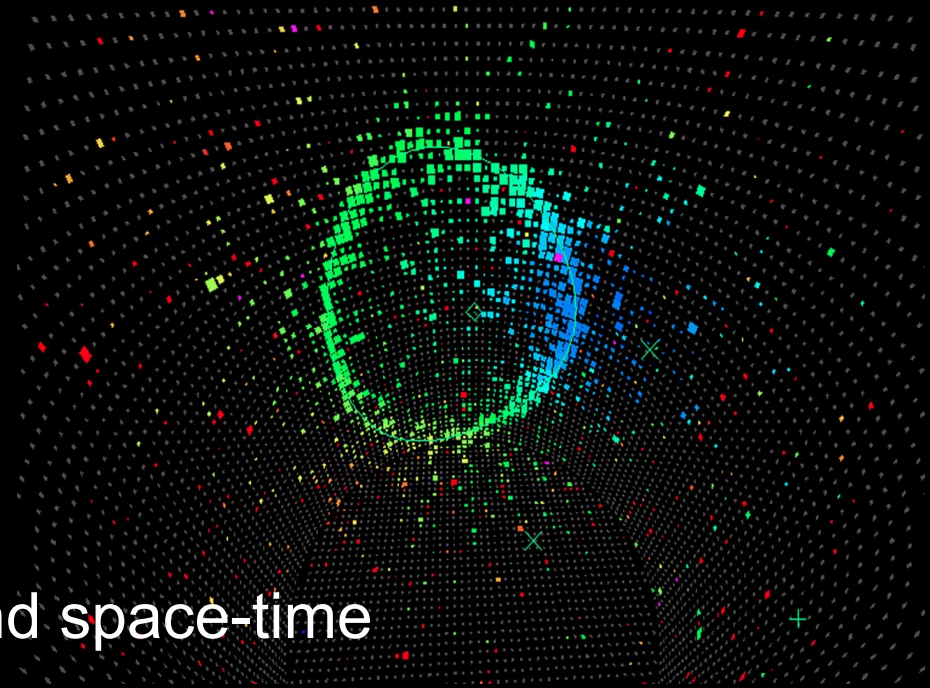
Origin of space-time

→ Cosmic ray measurement

Unification of matter, force, and space-time

→ Proton decay search

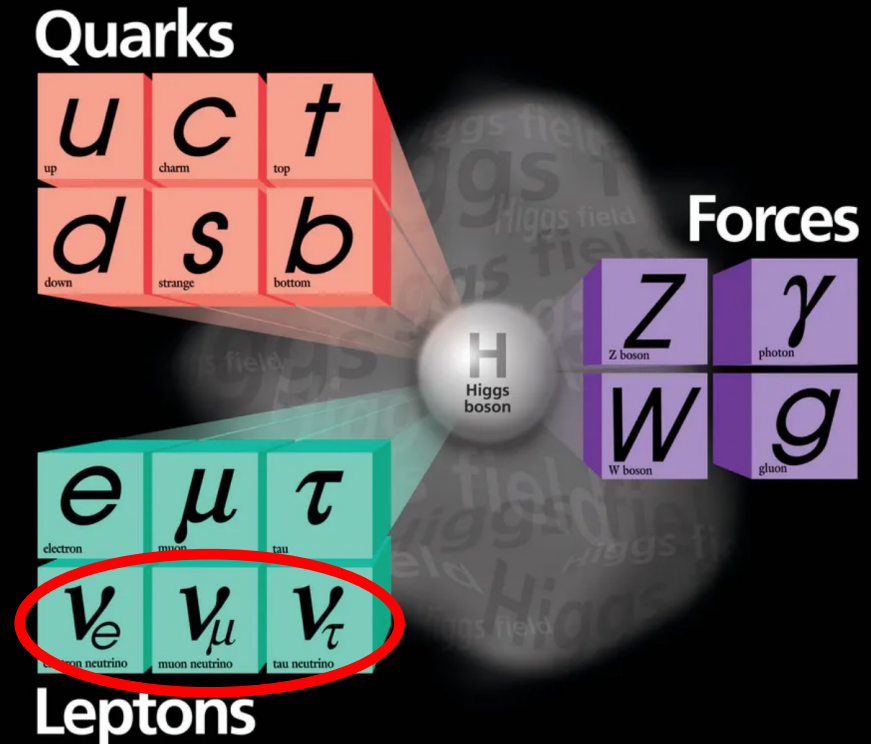
etc



Experimental evidence of the world beyond our world

The Standard Model, Elementary Particles of the Universe

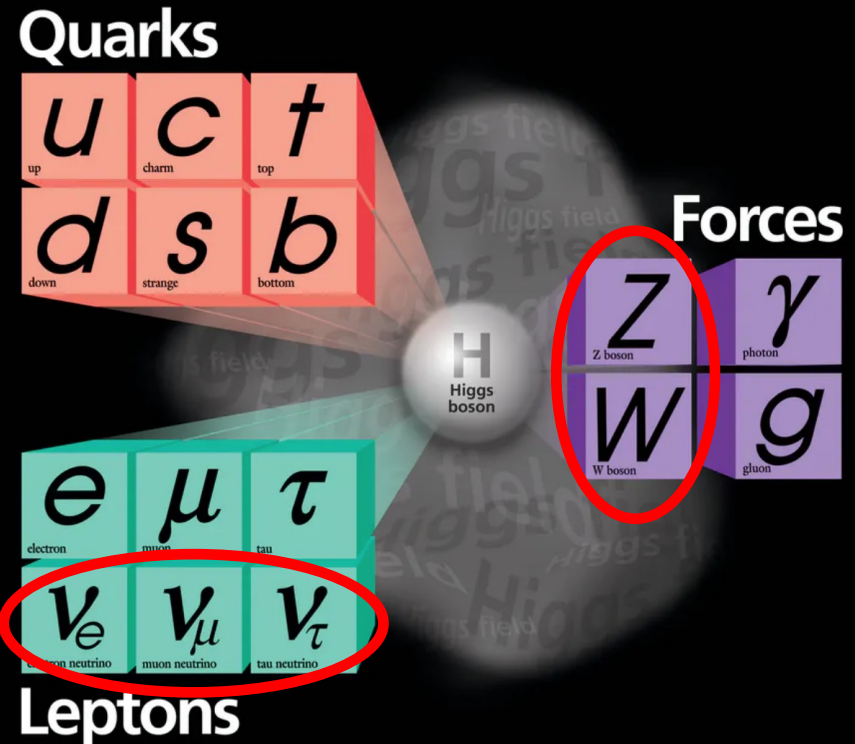
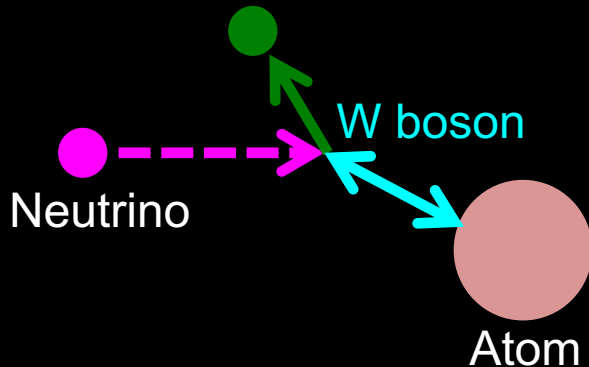
- 6 Quarks
- 6 Leptons
 - 3 neutrinos
- 3 Force carriers
- The Higgs boson



Neutrinos, Ghost particles

Neutrinos are everywhere, but very difficult to observe
→ You need extremely large detector

Neutrinos can exchange
only **W and Z bosons**
(Weak interaction)



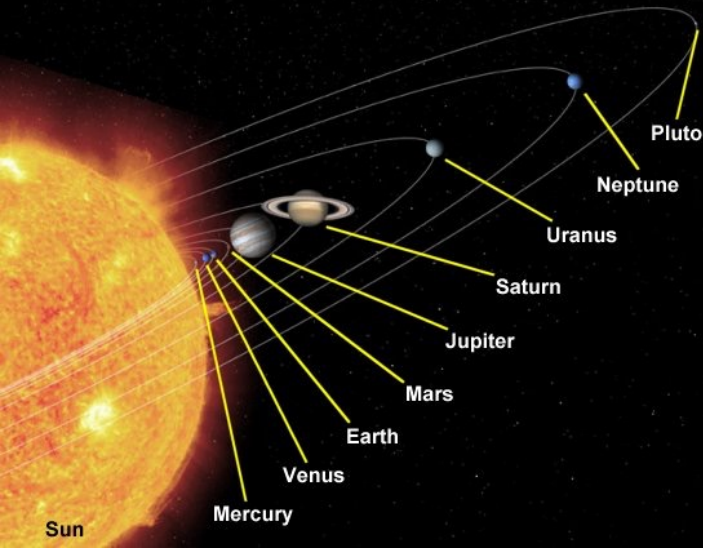
Neutrinos, Ghost particles

Neutrinos are everywhere, but very difficult to observe

→ You need extremely large detector

Neutrinos are produced by nuclear fusion in the Sun.

Around 1,000,000,000,000 (1 trillion) neutrinos from the Sun pass through your body every second.

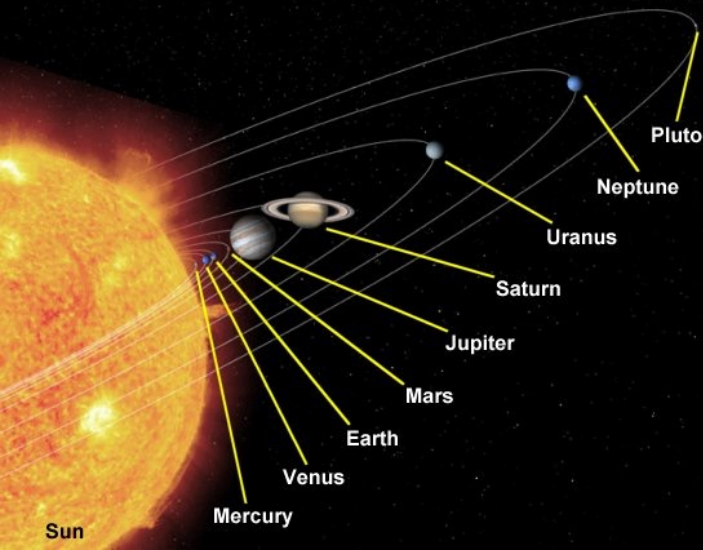


Neutrinos, Ghost particles

Neutrinos are everywhere, but very difficult to observe
→ You need extremely large detector

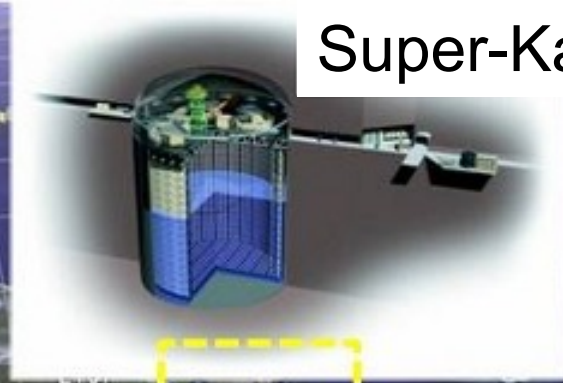
Neutrinos are produced by nuclear fusion in the Sun.

Around 1,000,000,000,000 (1 trillion) neutrinos from the Sun pass through your body every second.



However, you have a **small chance** to hit **1 neutrino** in your lifetime

Super-Kamiokande detector



T2K

T2K (Tokai to Kamioka)
experiment

295km

Neutrino beam

Strong artificial neutrino beam is sent over 300km underground



J-PARC

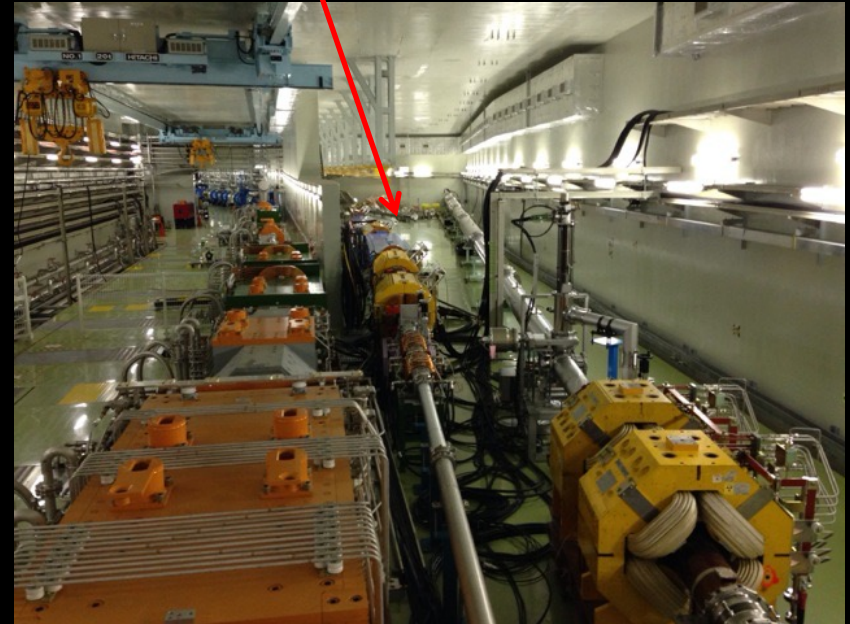
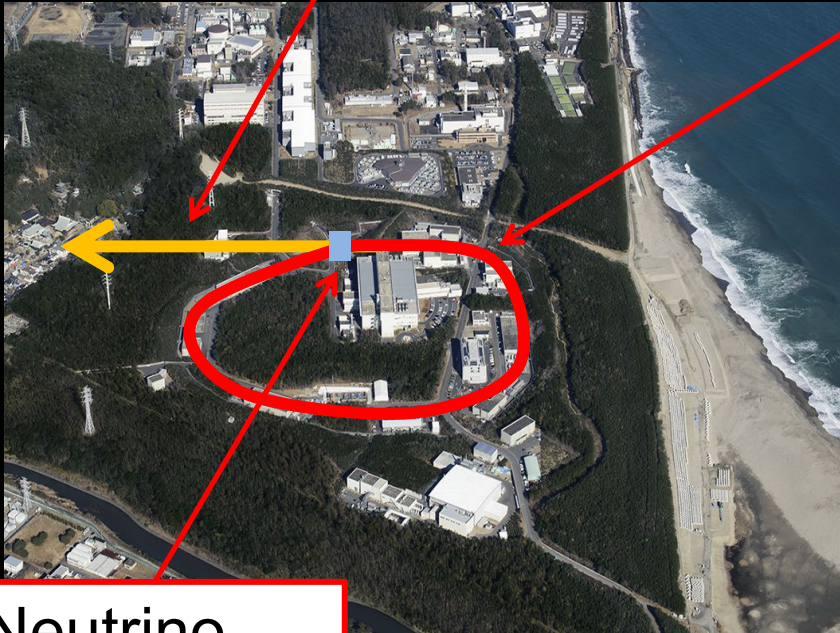
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Streaming 100%

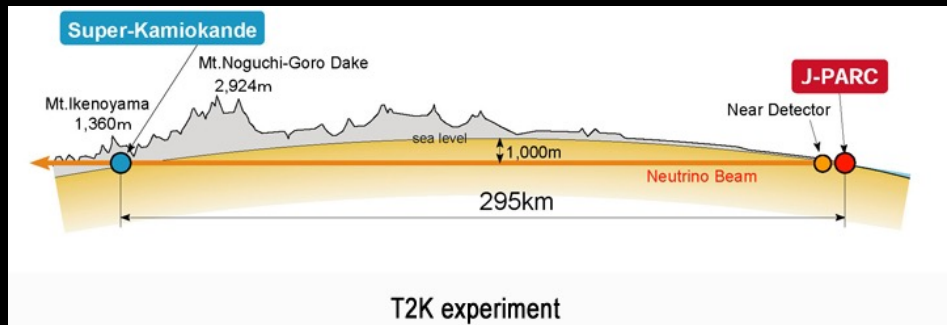
J-PARC neutrino beam

Neutrino beam

proton accelerator



Neutrino production target



40m height, 50k ton of pure water to observe neutrinos

Super-Kamiokande detector

40m



The Nobel Prize in Physics 2015
Takaaki Kajita, Arthur B. McDonald

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The Nobel Prize in Physics 2015



Photo © Takaaki Kajita
Takaaki Kajita
Prize share: 1/2



Photo: K. McFarlane,
Queen's University
/SNOLAB
Arthur B. McDonald
Prize share: 1/2

The Nobel Prize in Physics
Kajita and Arthur B. McDo
oscillations, which shows

The Nobel Prize in Physics 2002



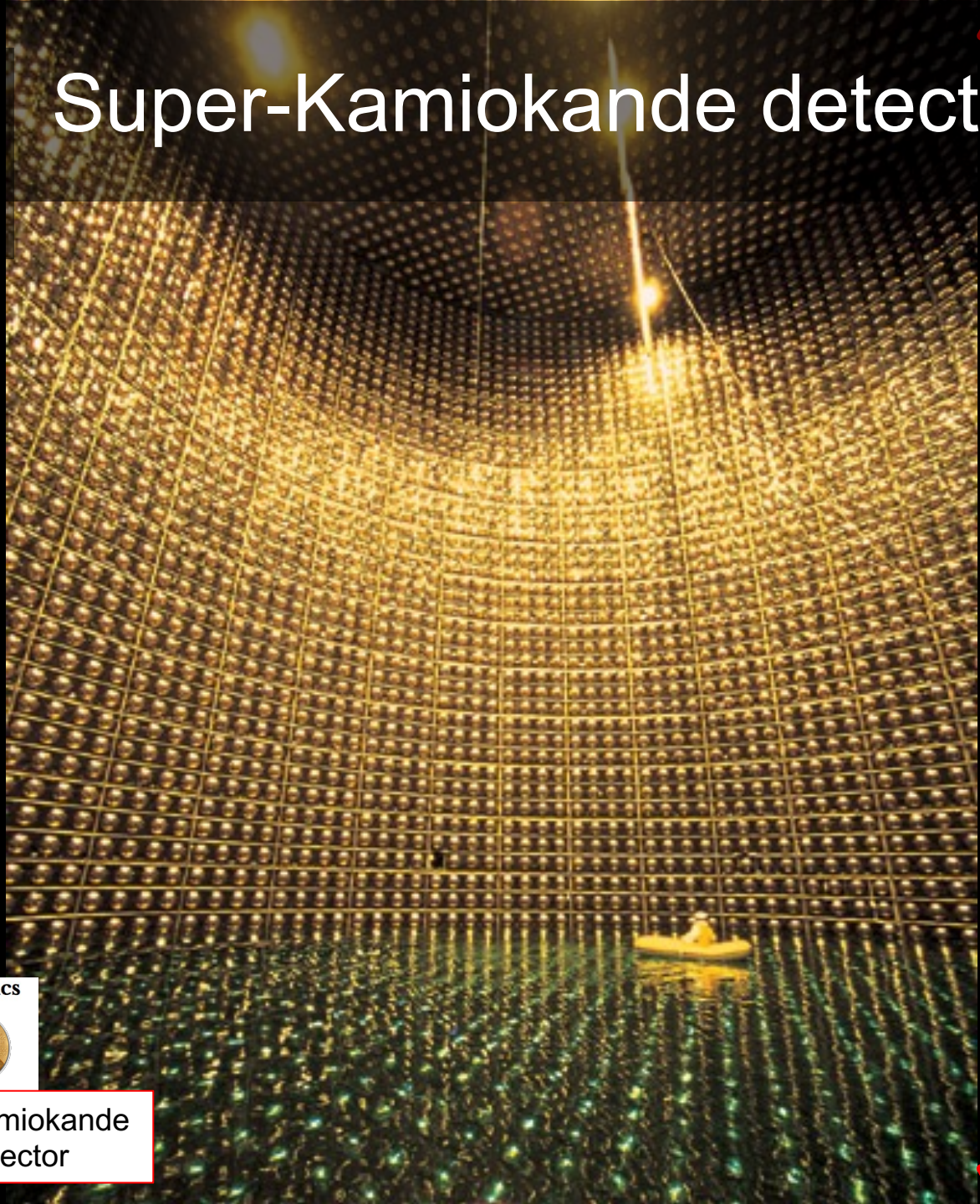
Raymond Davis Jr.
Prize share: 1/4



Masatoshi Koshiba
Prize share: 1/4



Kamiokande detector



40m height, 50k ton of pure water to observe neutrinos

Neutrinos hit with water atom, and produce photons

Photo-multiplier tubes (PMTs) covered on the wall to identify neutrinos

Super-Kamiokande detector

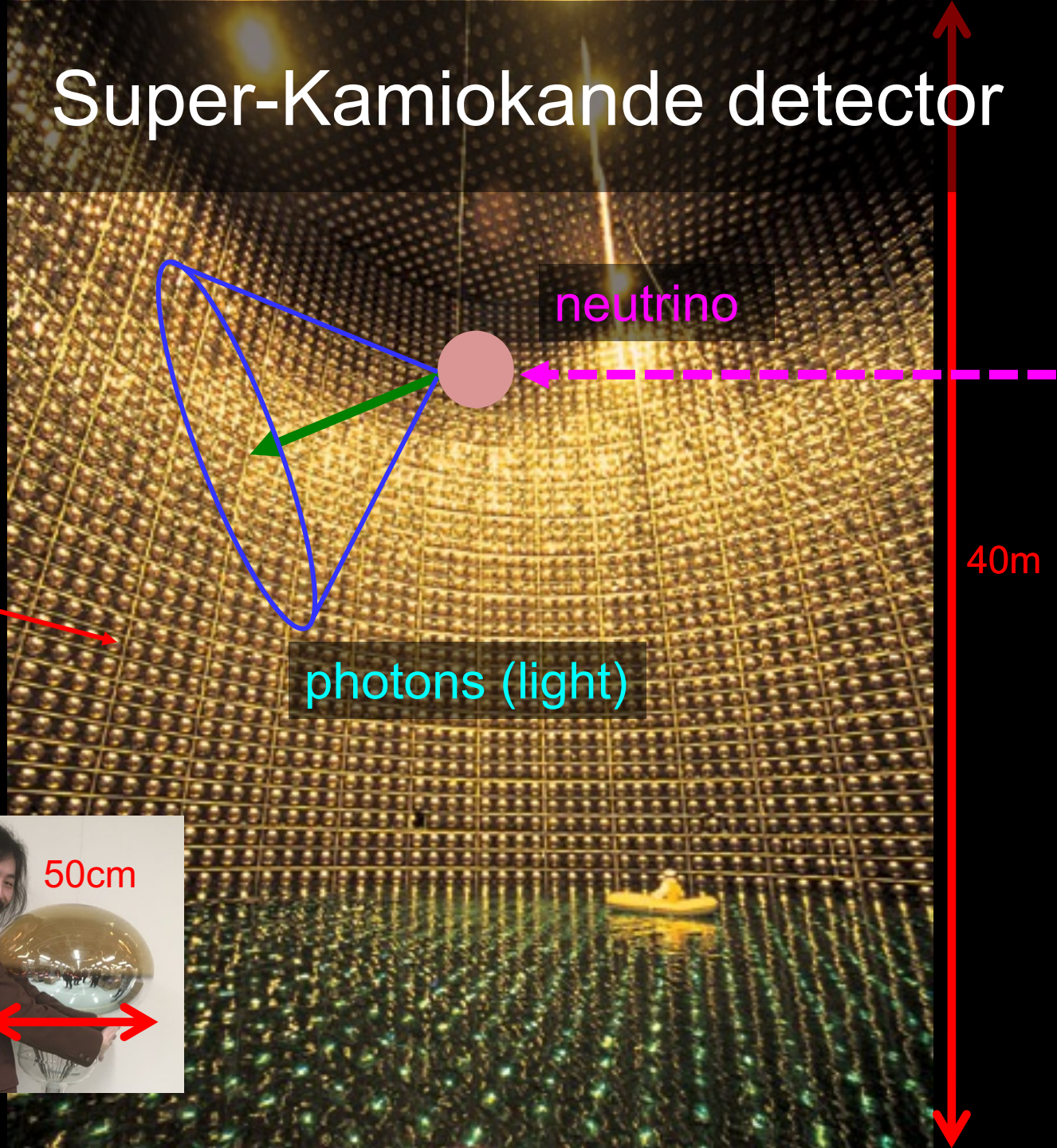
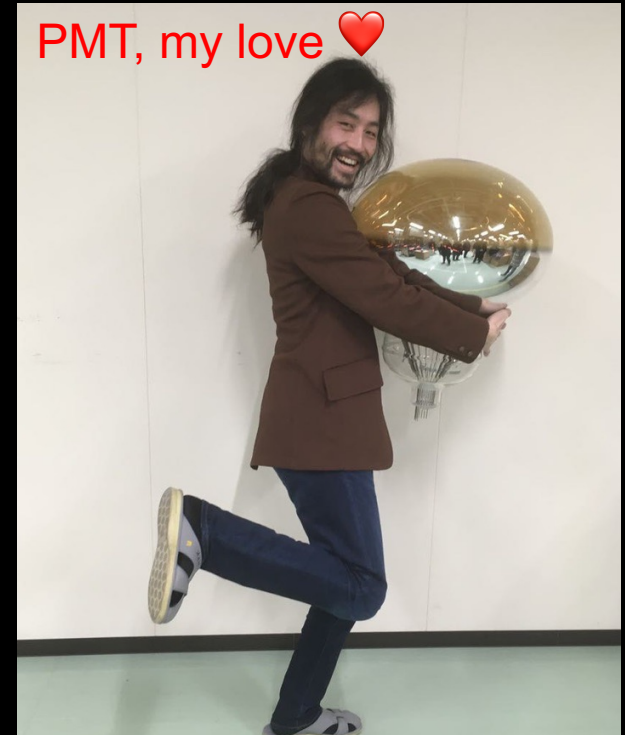


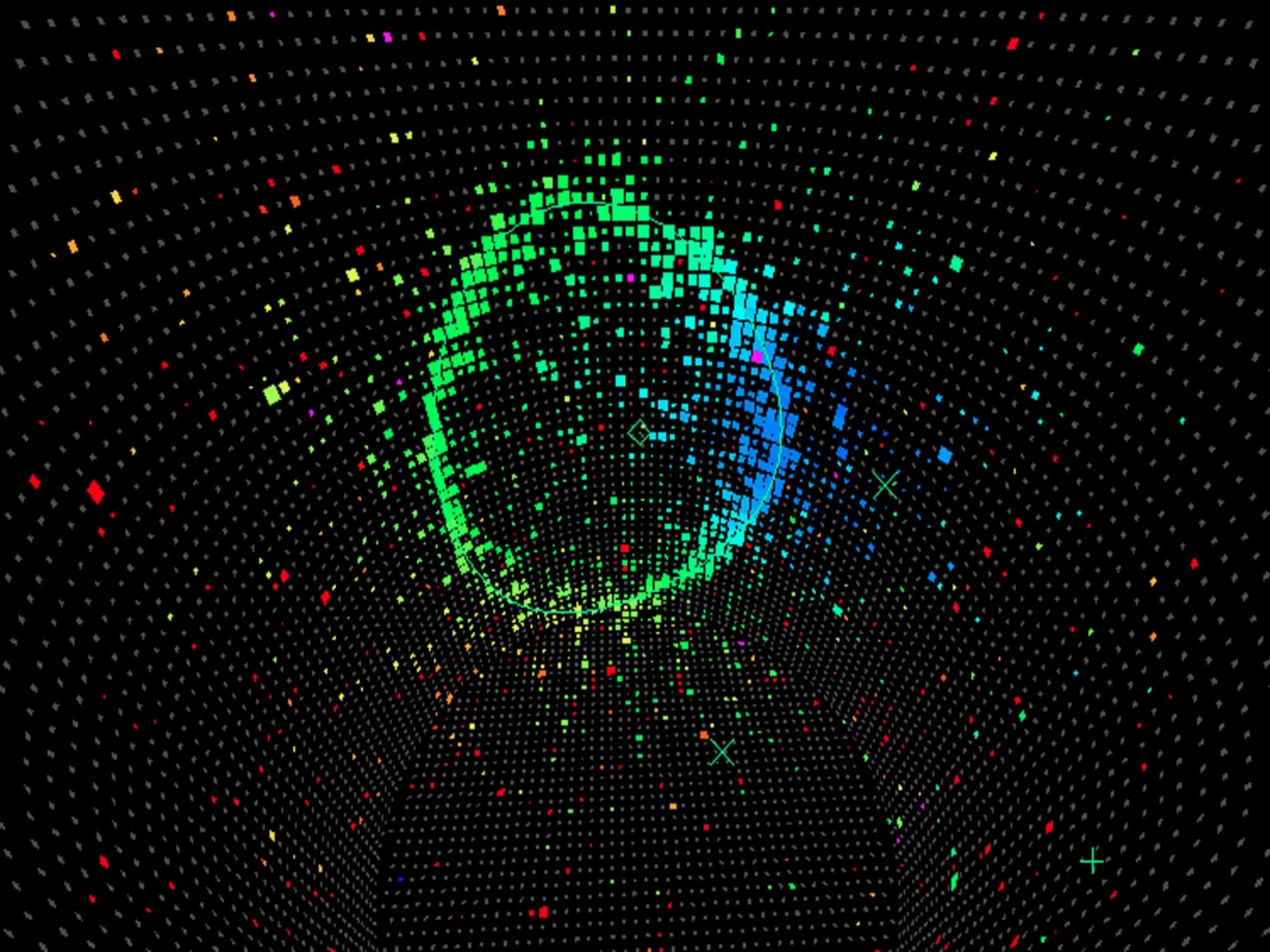
Photo-multiplier tubes (PMTs)

In bright room, 1,000,000,000,000,000,000 (10^{18}) photons are constantly hitting your hand

Neutrinos produce a few photons

PMT can detect one photon





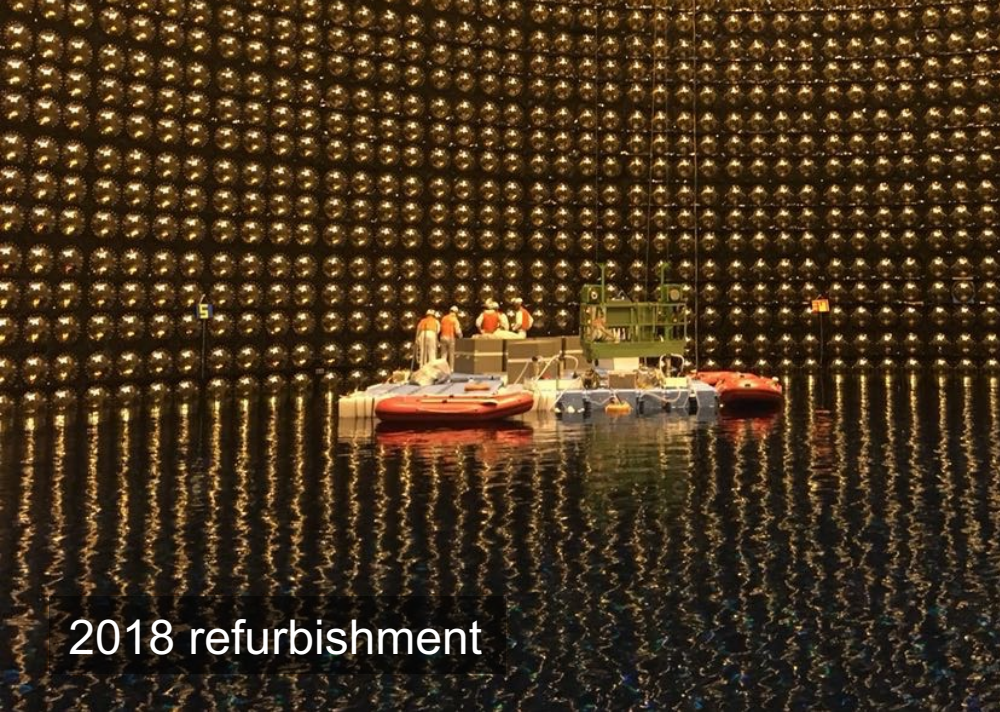
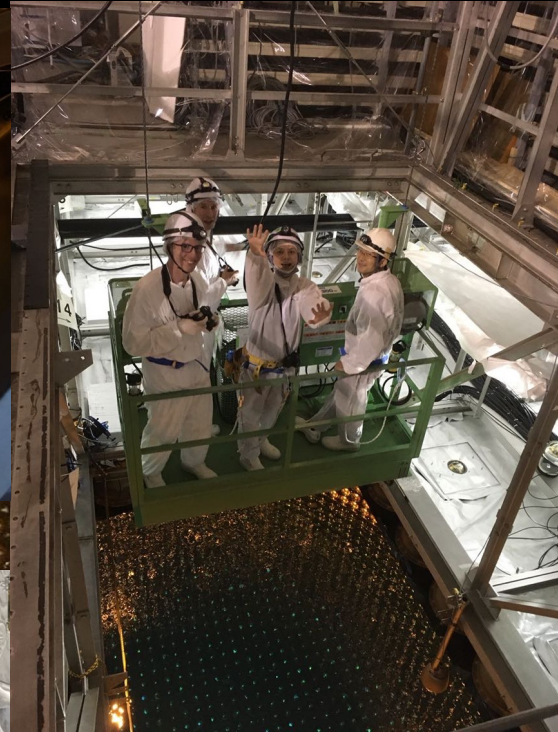
Super-Kamiokande detector

Kamioka (神岡), Japan

Deep mountain area, and the detector is located inside of a mountain



Super-Kamiokande detector

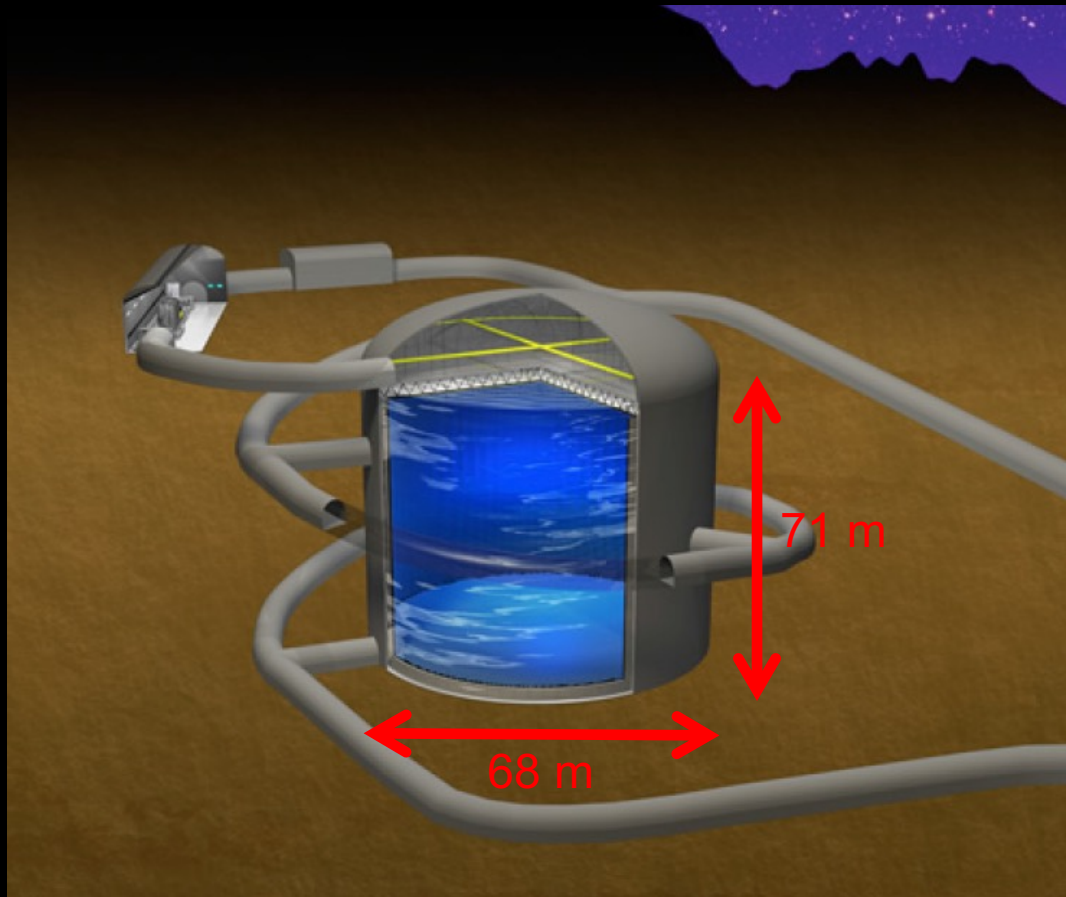


2018 refurbishment

Hyper-Kamiokande detector

We are building a new bigger water tank

- Detect more neutrinos from artificial beam, Sun, nuclear reactors, supernova, galaxies, etc



Daily life of particle physicists

Operation shift

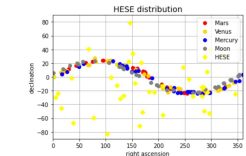


Programming

```

root_DUNE.cpp
TTree * gen1 = dynamic_cast<TTree*> (infile.Get("gst"));
gStyle->SetOptStat(0000);

int nbs=100;
int nbq=30;int nlq=0.0;int nhq=3.0;
int nbn=30;int nln=0.0;int nhn=3.0;
int nbw=30;int nlw=0.0;int nhw=3.0;
TH1F *h1q2 = new TH1F("h1q2","h1q2",nbq,nlq,nhq);
TH1F *h1nu = new TH1F("h1nu","h1nu",nbn,nln,nhn);
TH1F *h1w = new TH1F("h1w","h1w",nbw,nlw,nhw);
TH2F *h2qn = new TH2F("h2qn","h2qn",nbq,nlq,nhq);
TH2F *h2hn = new TH2F("h2hn","h2hn",nbn,nln,nhn);
TH2F *h2wn = new TH2F("h2wn","h2wn",nbw,nlw,nhw);
TH2F *h2qan = new TH2F("h2qan","h2qan",nbq,nlq,nhq);
TH2F *h2han = new TH2F("h2han","h2han",nbn,nln,nhn);
TH2F *h2wan = new TH2F("h2wan","h2wan",nbw,nlw,nhw);
TH2F *h2qnq = new TH2F("h2qnq","h2qnq",nbq,nlq,nhq);
TH2F *h2hnh = new TH2F("h2hnh","h2hnh",nbn,nln,nhn);
TH2F *h2wnw = new TH2F("h2wnw","h2wnw",nbw,nlw,nhw);
h1q2->SetLineWidth(1);h1q2->SetLineColor(1);
h1nu->SetLineWidth(1);h1nu->SetLineColor(1);
h1w->SetLineWidth(1);h1w->SetLineColor(1);
h2qn->SetLineWidth(1);h2qn->SetLineColor(1);
h2hn->SetLineWidth(1);h2hn->SetMarkerColor(2);
h2wn->SetLineWidth(1);h2wn->SetMarkerColor(4);
h2qan->SetLineWidth(1);h2qan->SetMarkerColor(8);
h2han->SetLineWidth(1);h2han->SetMarkerColor(6);
h2wan->SetLineWidth(1);h2wan->SetMarkerColor(6);
h1q2->GetXaxis()->SetTitle("#nu (GeV)");
h1nu->GetXaxis()->SetTitle("#nu (2) (GeV^{2})");
h1w->GetXaxis()->SetTitle("#W (GeV)");
h2qn->GetXaxis()->SetTitle("#nu (GeV)");h2qn->
(2)");
h2hn->GetXaxis()->SetTitle("#nu (GeV)");h2hn->
(2)");
h2wn->GetXaxis()->SetTitle("#nu (GeV)");h2wn->
(2)");
  
```



Writing

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TECHNICAL REPORT

Pulse shape particle identification by a single large hemispherical photomultiplier tube

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^e*Wisconsin IceCube Particle Astrophysics Center, Madison, WI 53706, U.S.A.*

lab work



Daily life of particle physicists

Many meetings

- double, triple bookings
- unusual time (1am,etc), almost all meetings are international

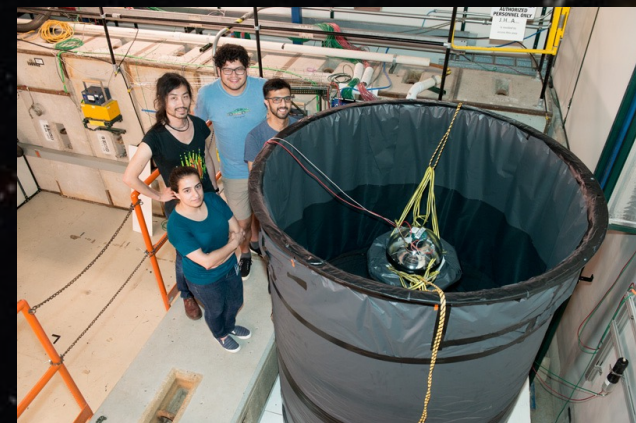


Daily life of particle physicists

IceCube Neutrino Observatory (Antarctica)

- 2 winter over operators at the South Pole right now





End

Particle physics is the subject to study matter, force, space-time with elementary particles.

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