CONGRATS EVERYONE!!!!!

AWESOME WORK!!!!!

[S1]

- **Interviewer:** 42![S2] that's the percentage of Americans that believe in ghosts. Do you believe in ghosts? Well, you should because they exist. Today, we'll discuss the real ghosts in nature. The neutrinos. A neutrino is a fundamental particle, like electrons as you may be used to, but it is also a ghost particle that does not behave like any other. They were first postulated by a physicist, Pauli, to solve a problem in nuclear physics. He later regretted that by saying that whatever he postulated cannot be found[s3]. Fortunately, Pauli was slightly wrong. It took more than 20 years, but finally neutrinos were discovered in an experiment near a nuclear plant. The first experiment needed a massive amount of neutrinos. The idea was to have an atomic bomb explosion[s4]. So today, we have a special invisible guest in our program: Mr neutrino. Hello, welcome to our studio.[s5]
- **Neutrino:** Hi everybody. Sorry for my weak russian accent, I have studied the human language in Moscow.
- **Interviewer:** So, where do you come from?
- **Neutrino: [s6]**We come from everywhere. Some of us come from a billion light years away, from very distant galaxies in a supernova explosion. Other come from stars, like the Sun. I even have some friends that originate in the earth's atmosphere. And we really travel large distances. Every second 10 billion neutrinos born in the Sun pass through each square sm of human bodies.
- **Interviewer:** But wait, I don't feel blasted by this many neutrinos every second. In fact, I haven't felt any of them. How is that?
- **Neutrino: [s7]**That because we interact only via the weak force that, as you may guess, is one of the weakest between all those currently known. You could interact with one of us. Is just very unlikely. During your lifetime only one neutrino will give you high five on average.
- **Interviewer:** So if you are everywhere, how can you be detected?
- **Neutrino:** Well, if you were to use humans, you will need 700'000 people to detect 1 neutrino in an hour. That is like 4 times the number of people that attend the Super Bowl. [s8]
- **Interviewer:** That doesn't sound feasible
- **Neutrino:** Yeah, it's not. Scientists have built big detectors instead. They usually use big tanks of something transparent. Like water for example.
- **Interviewer:** How big?**[s9]**
- **Neutrino**: The SuperKK for example weights 50000 tons that is approx 630000 men,
- **Interviewer**: I think I've heard about this. Isn't it there something similar in the antarctic?

- **Neutrino: [s10]**That's right, but they use ice instead. When neutrinos pass through ice or water, they hit water atoms. The debris of this collision interacts with water and produces light which is detected usually with photomultipliers, that are like big cameras.
- **Interviewer:** But if any interaction is so unlikely, you don't affect our daily lives. Why should we care about you?
- **Neutrino:** [s11] For different reasons, mainly related to the fact that we don't like to interact with anything during our trip along the Universe. You can think of the following analogy: for the luminous signals the universe is opaque, like a glass of milk, but, for us it is as transparent as a glass of water! You can then study us in many different ways. For example:
    - [s12] Tons of us were produced during the Big Bang so we can give some hints about the beginning of the Universe
    - We are also perfectly suited as messengers from far away places like distant galaxies and supernovas, the explosion of a star, which not only are the largest explosion that takes place in space but also play a key role in distributing elements throughout the universe itself: many of the elements we find here on Earth are made in the core of stars!
    - [s12p1]We can then bring information directly from the cores of the stars so you can study the processes happening there. LIKE WHY SUN IS SHINING
    - [s12p2]We come from the interaction of cosmic rays with Earth's atmosphere.
    - [s12p3]We steal a bit of your energy produced at nuclear power plants. But we can reveal if anybody on the Earth is playing with nuclear weapons in return.[s12p4]
    - [CHANGE SPEAKER] We can even tell you about processes in your planet, The Earth!!! Your planet produces neutrino!!!! And that's not the end of the story…
- **Interviewer:** Wait what happened to your voice?
- **Neutrino:** Oh sorry I just changed flavour, it happens.
- **Interviewer:** What do you mean?
- Neutrino: [s13] We come in three different types: the electron neutrino, the muon neutrino and the tau neutrino. And to each of these types we call them flavours. When we are produced in interactions (e.g. in the sun) we start to travel as one of these flavours. However, as time goes by, we can change from one flavor to another, and back, in a periodic process. Which flavor you find depends on the time that passed after we were produced.
- **Interviewer:** [s14]Oh! This sort of oscillation reminds me of ice cream flavours: When I was a kid my brother and I used to go for ice cream but he could never made up his mind between vanilla and chocolate. Thus, whenever we left home, I asked my brother what flavour he'd go for today. He'd start with a definite *'It's chocolate day'*, but after a minute he'd mumble something. Then it was *'Maybe vanilla'*, then *'No, chocolate'*, then again *'Better vanilla'*... When we arrived at the store, he was caught somewhere between vanilla and chocolate!

- **Neutrino**: thats a funny comparison but yeah we think of ourselves as identity thieves. And guess what: study our flavor changing properties can help physicists to understand new phenomena.
- **Interviewer:** You convinced me, studying the characteristics of neutrinos sounds really interesting...
- **Neutrino**: ...Absolutely, you should be excited! [s15] Did you know that FOUR nobel prizes have been awarded to neutrino lovers physicists? The neutrino is like the Meryl Streep of particles! [s16] Also, did you ever wonder about the internal composition of the planet Earth? Some scientists have started using the detector in the Antarctic to take a "neutrino tomography" of the Earth! And what is even more weird, the detector could stay hidden down there for centuries! Like a time-capsule! Bottom line is there are many more discoveries are yet to come and YOU [s16p2] could be the person to uncover them.
- **Interviewer:** I'm sure I will! Thank you so much for coming!

SLIDES
https://docs.google.com/presentation/d/1C0sMSelTSrnDchERhK6YkV3kON7Osxafq_Ad4k55xHk/edit?usp=sharing

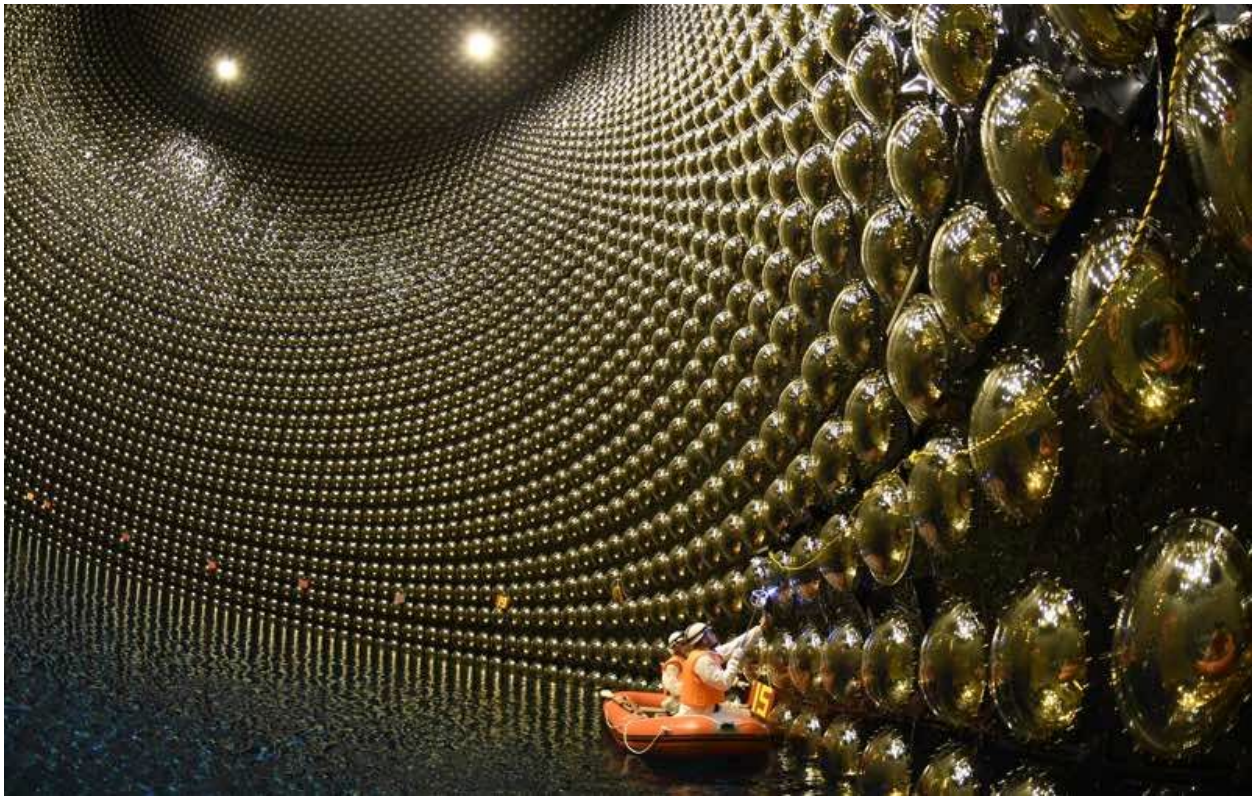
1. **Why do we care about them? -> Why do we care about you?**
    - You should care about us, because we are everywhere, we have been here, in this universe since the Big bang.
    - We can bring the information directly from distant galaxies, because a lot of us produced in Supernovae explosions.
    - We can bring the information directly from the cores of the stars. So you can study the properties of processes happening there.
    - We come from the interaction of cosmic rays with Earth's atmosphere.
    - We steal a bit of your energy produced at power plants. But we can reveal it if anybody on the Earth is playing with nuclear weapons.
    - We can tell about processes in your planet The Earth!!! Your planet produces neutrino!!!!

- Your bodies emitting neutrino Every human produces 1 million of neutrinos per second!

2. **Fun facts**

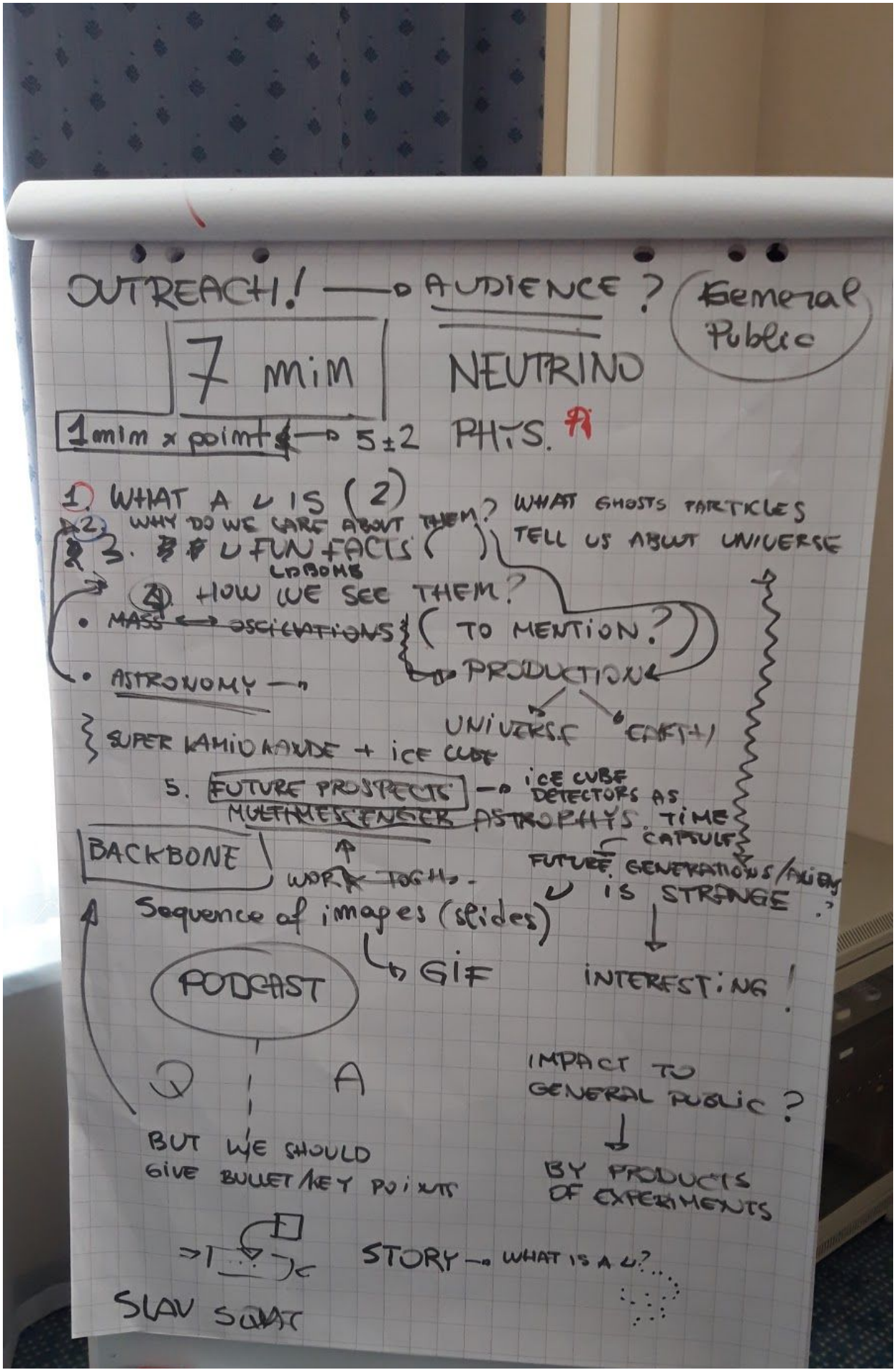
- Neutrinos detected from icecube can reach energies of the order of few PeV > 1000 * LHC
- The Neutrino is a 4 time Nobel prize winner particle
- The Neutrino is a transgender particle
-

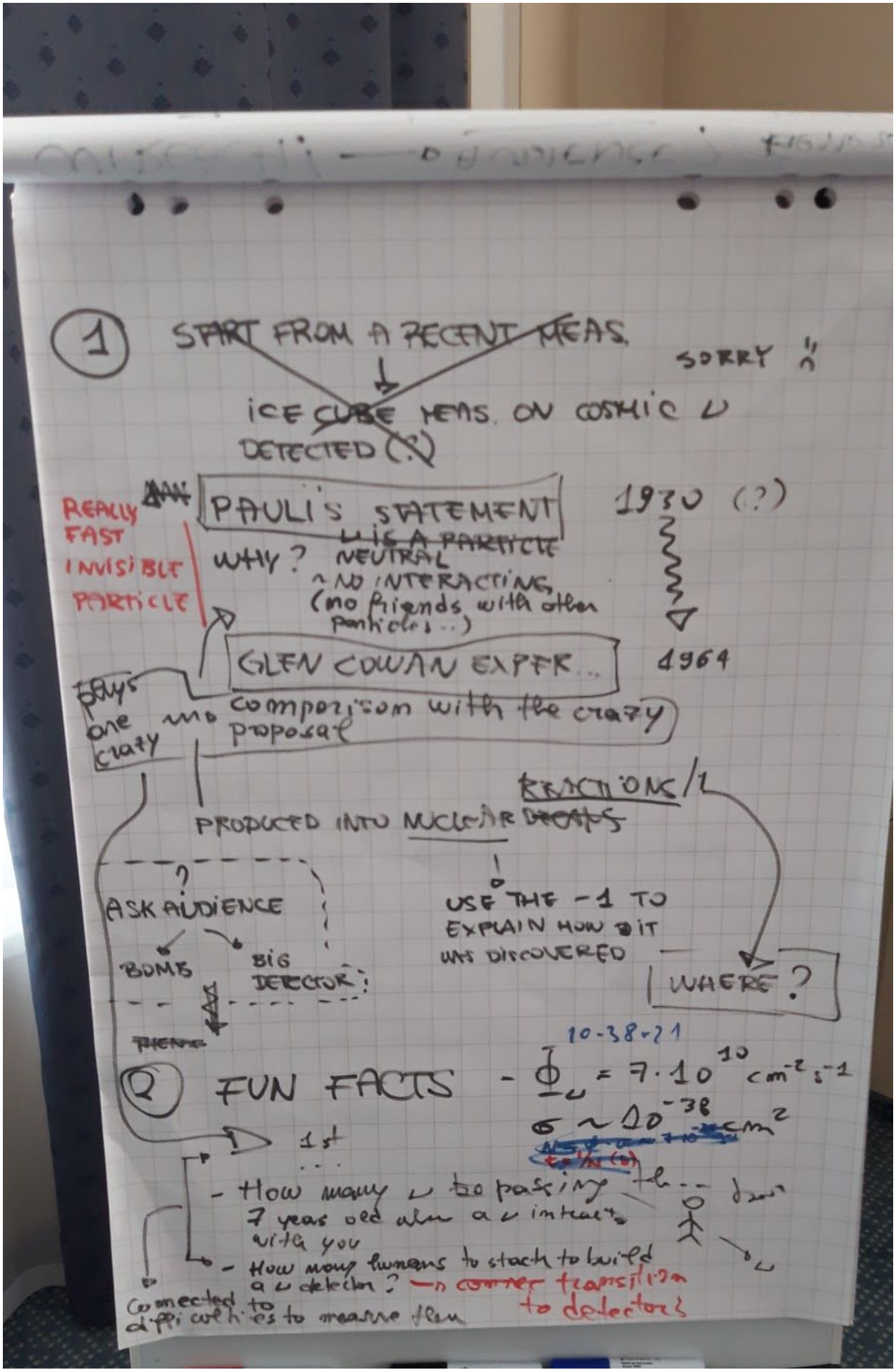
3. **How we see them?**
   - Nu don't interacts very much
   - 4 every 10e13 nu passing the thickest part of the earth 1 of them interacts somewhere (time?)
   - Detectors are not so big obviously. Basic principle:
     - Big tank of water as interaction media (SuperKK weight 50000 tons that is approx 630000 men, DUNE experiment @ fermilab even bigger)
     - Most nu will pass through them undetected!
     - Nu interacts only via the weak force that, as you may guess, is the weakest force when we consider interactions between particles (example how much weak -> Distance of closest approach of a neutrino to atom to interact is < 0.001 size of an atom = 10e-18m like the distance from the earth to the nearest galaxy Proxima Centauri)
     - Nu entering water into detector interacts (Prob approx zero) with atom nuclei in water smashing it -> smashing debris interacts with water ending up into photons that are detected through photomultipliers, basically cameras
   - The Super-K is located 1,000 m (3,300 ft) underground in the Mozumi Mine in Hida's Kamioka area. It consists of a cylindrical stainless steel tank that is 41.4 m (136 ft) tall and 39.3 m (129 ft) in diameter holding 50,000 tons of ultrapure water. Mounted on the superstructure are 11,146 photomultiplier tubes (PMT).
   - Most neutrino experiments must address the flux of cosmic rays that bombard the Earth's surface.
     - The higher-energy (>50 MeV or so) neutrino experiments often cover or surround the primary detector with a "veto" detector which reveals when a cosmic ray passes into the primary detector, allowing the corresponding activity in the primary detector to be ignored ("vetoed").
     - For lower-energy experiments, the cosmic rays are not directly the problem. Instead, the spallation neutrons and radioisotopes produced by the cosmic rays may mimic the desired signals. For these experiments, the solution is to place the detector deep underground so that the earth above can reduce the cosmic ray rate to acceptable levels.



4. **Future Prospects**
- Earth tomography with neutrinos

SPARES
http://www.astro.wisc.edu/~larson/Webpage/neutrinos.html
https://en.wikipedia.org/wiki/List_of_neutrino_experiments
https://www.quora.com/Why-are-neutrinos-so-hard-to-detect


OUTREACH! → AUDIENCE ? General Public
7 min
1 min x point → 5±2
NEUTRINO PHYS.
1. WHAT A ν IS (2)
WHY DO WE CARE ABOUT THEM?
WHAT GHOSTS PARTICLES TELL US ABOUT UNIVERSE
3. ν FUN FACTS
LABOMB
4. HOW WE SEE THEM?
• MASS ↔ OSCILLATIONS
(TO MENTION. ?
• ASTRONOMY →
PRODUCTION
UNIVERSE
EARTH
SUPER KAMIOKANDE + ICE CUBE
5. FUTURE PROSPECTS → ICE CUBE DETECTORS AS ASTROPHYS. TIME CAPSULE
MULTIMESSENGER
BACKBONE
WORK TOGH.
FUTURE GENERATIONS/ALIENS
IS STRANGE ?
Sequence of images (slides)
GIF
INTERESTING !
PODCAST
Q
A
IMPACT TO GENERAL PUBLIC ?
BUT WE SHOULD GIVE BULLET/KEY POINTS
BY PRODUCTS OF EXPERIMENTS
STORY → WHAT IS A ν?
SLAV SOMT


1
START FROM A RECENT MEAS.
SORRY !!
ICE CUBE MEAS. ON COSMIC ν
DETECTED (?)
REALLY FAST INVISIBLE PARTICLE
PAULI'S STATEMENT
1930 (?)
WHY? NEUTRAL
~NO INTERACTING
(no friends with other particles..)
GLEN COWAN EXPER..
1964
comparison with the crazy proposal
PRODUCED INTO NUCLEAR REACTIONS
ASK AUDIENCE
BOMB
BIG DETECTOR
USE THE -1 TO EXPLAIN HOW IT WAS DISCOVERED
WHERE ?
2 FUN FACTS
$\Phi_\nu = 7 \cdot 10^{10}\ cm^{-2} s^{-1}$
$\sigma \sim 10^{-38}\ cm^2$
1st
- How many ν to passing th... dow...
7 years old alm a ν interac... with you
- How many humans to stack to build a ν detector? → in correct transition to detectors
Connected to difficulties to measure them

DISCUSSION : HUMAN Vs ν (?)

(2.) WHY DO WE CARE 'BOUT THEM?

BIG
- ASTRONOMY → WHAT GHOST PARTICLES TELLS US ABOUT UNIVERSE
  ATMOSPHERE COMP.
- ENERGY CONSERVATION
- "PORTALS" EVEN TO THE SMALL MICROSCOPIC WORLD (OSCILLATIONS)

MACRO (ν) MICRO

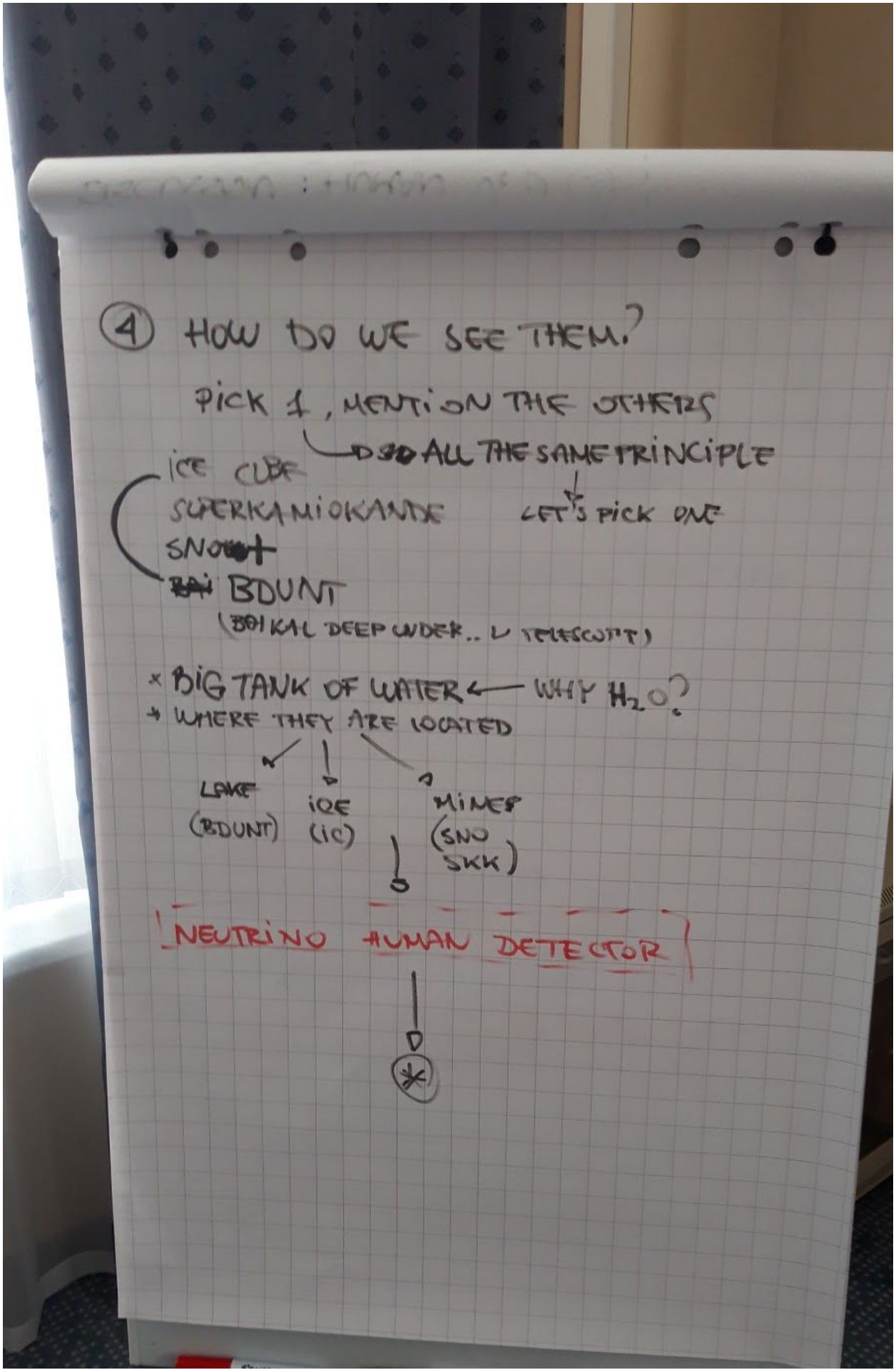
FORCES

[CALORIMETER (THERMAL) EXAMPLE
  - >E SUPERNOVAE FROM ν — DO WE ARE MISSING SOMETHING...
  - ☆ PRODUCES (ν DURING THEIR LIFETIME; OR MOMENTUM (?)
    ↓ NUCLEAR REACTIONS → CHILDREN OF ☆
  - HIGH PENETRATION
  - ↯ LIGHT UNIVERSE IS A BOTTLE OF MILK
    ↓ ν " WATER

[EARTH TOMOGRAPHY WITH NEUTRINOS

[ν LINKED ALSO TO MICROSCOPIC WORLD
  HELPS US TO UNDERSTAN FUNDAMENTAL
  PARTICLES (EVEN IF THEY ARE SO UNFRIENDLY)

NEUTRINO SAILBOAT


④ HOW DO WE SEE THEM?
PICK 1, MENTION THE OTHERS
DO ALL THE SAME PRINCIPLE
ICE CUBE
SUPERKAMIOKANDE
SNO
BAI BDUNT
(BOIKAL DEEP UNDER.. U TELESCOPE)
LET'S PICK ONE
× BIG TANK OF WATER ← WHY H_2O?
→ WHERE THEY ARE LOCATED
LAKE (BDUNT)
ICE (IC)
MINES (SNO SKK)
NEUTRINO HUMAN DETECTOR

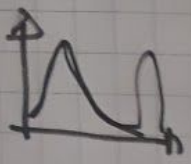
⑤ FUTURE PROSPECTS (OUTLOOK)

⊕

SUMMARY

⊕

CONCLUSIONS



* ONE OF THE MOST ENERGETIC PARTICLES ACCESSIBLE TO HUMANS

n m
n m n

OPEN

ICE CUBE DETECTORS WILL REMAIN IN ICE 4EVER

→ timyurl.com/y653e7w2 ←

↑
N

INTRODUCTION (< 2 min)

- Ghosts
- Beta decay
- Postulation
- How many they are
- Hard to detect them -> 1st nuclear explosion then RC experiment (1957)

First question: so, neutrino, where do you come from?

WHERE DO YOU COME FROM? (??? min)

- Big bang, supernovas, sun, nuclear plants and even our bodies

Fun fact: how many neutrinos pass through human body x sec

Why I