(version: 20161117.1)

Characters:

Mu2e Physicist (ERIC)

Friend (MARY ANNE)

MUON (Sophia)

ELECTRON (Tessa)

NEUTRINOS (Liana + Alexa)

ALUMINUM Nucleus (Danielle + Nolan + Emerson)

COP/DETECTOR (Tony)

Props:

Roll of aluminum foil

T-shirts (labels with “E”, “M”, and “N”)

Cop outfit, detector

Action Cues:

* All particles begin offstage to stage left.
* ERIC: “It’s too bad I don’t have some study aids…”
* Muon and electron appear from offstage
* ERIC: “Each one has an associated “neutrino””
* NEUTRINOS come on from Stage Left and wave. Stand behind Electron and Muon
* ERIC: “And when I say ‘fundamental’ I mean the smallest building blocks of matter. As far as we know, they can’t be broken apart”)
* TONY and DANIELLE try to pull each of the particles apart. Give up and walk away.
* MARY ANNE: “That sounds like death”
* Muon does death scene.
* ERIC: “In this case, the muon disappears and becomes an electron and two neutrinos”
* Electron and neutrinos push muon down and pose triumphantly. Neutrinos walk of, stage left.
* ERIC: “but we’re looking for something different: a case where the muon decays to an electron with no neutrinos”
* MUON stands back up. ELECTRON pushes her down and stands triumphantly. Both walk offstage to Stage Left. At this point NEUTRINO crosses to Backstage Right, staying out of sight.
* ERIC: “They go right through our detectors, like they’re not even there.”
* At “through the detector”, LIANA sneaks up and taps ERIC on the shoulder.

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* MARY ANNE: “Sounds like jail”
* MUON backs in from stage left, followed menacingly by TONY, dressed as cop
* ERIC: “No, no”
* Cop and MUON walk off Stage Left
* ERIC: “We actually catch the muons with a big clump of aluminum.”
* Aluminum nucleus goes onstage. Nucleus chases her around in slo-mo
* ERIC: “If you say so”
* The MUON is grabbed by the nucleus.
* ERIC: “Maybe an equation is in order”
* Clump shuffles offstage. Muon walks off
* MARY ANNE: “Sure, everyone loves equations”
* ELECTRON walks on stage and stands next to MUON
* ERIC: “If an electron decays just to an electron”
* Muon falls down and electron runs off stage
* ERIC: “We know exactly how much energy it has, since energy can neither be created or destroyed”
* Electron returns with two neutrinos
* ERIC: “On the other hand, if the muon decays to an electron and two neutrinos
* Muon tags the electron and neutrinos, and they all slowly shuffle off.
* A few moments later, the muon gets up and walks off
* Everyone except TONY crosses behind to Stage Right
* ERIC: “We’ve already started building it”
* TONY comes in with detector from Stage Left
* MUON approaches slowly from Stage Right
* ERIC: “Of course, we don’t send in just one muon”.
* A lot of particles run in from Stage Right and start running around
* ERIC: “All the grains of sand in the world”
* Particles move off.
* ERIC: “After all, sometimes great things come in small packages”
* LIANA picks up the mic and says “You don’t need to be big to be powerful.”)

**[slide 1-Title]**

ERIC

I appreciate you helping me out. This talk was written by Mariel, and I’ve never given it before. Hopefully, you can give me some advice

MARY ANNE

Sure. Why don’t you go through the talk, and I’ll interrupt with comments.

ERIC

OK, My name is Eric Prebys and I’m here to tell you about the Mu2e Experiment at Fermilab.

MARY ANNE

You might want to start with the name. It kind of sounds like a cat meowing

**[slide 2-Cats]**

ERIC

Good point, “Mu2e” means “Muon to Electron”

**[slide 3-muon to electron]**

ERIC

Muons and electrons are two flavors of what we call “leptons”

MARY ANNE

You might want to explain what “flavor” is, because it kind of sounds like ice cream.

**[slide 4 – ice cream]**

ERIC

OK, Right. In physics, we use “flavor” to mean different types of similar things. I wish I had some study aids….

**[slide 5 – muon and election]**

**(MUON and ELECTRON walk on from Stage Left. Ham it up a bit. ERIC and MARY ANNE pretend not to see them)**

ERIC

….but I’ll guess I’ll just have to make do without them.

I think most people know what an electron is. Along with protons and neutrons, they make up atoms. Muons are like electrons, but about 200 times heavier.

**[slide 6 – Standard Model]**

ERIC

In our “Standard Model” they are two different “flavors” of what we call “leptons”. Each one has an associated “neutrino”. They’re almost massless, and can go through almost everything.

***(NEUTRINOS come on from Stage Left and wave. Stand behind Electron and Muon)***

ERIC

Now we believe that these particles are all “fundamental”; that is, you can’t break them apart.

***(TONY and DANIELLE come on stage, try to pull on the arms of each one in turn, shrug, give up, and walk off stage)***

**[slide 7 – legos]**

ERIC

They aren’t made up of anything, as far as we know. Like the smallest piece of Legos that you use to build up the whole set. The fundamental particles are used to make up all of the matter around us.

**[slide 8 – muon decay]**

ERIC

Now ordinarily, when a muon decays…

MARY ANNE (interrupting):

“Decay” another one of those words that confuses people. It sounds like death.

**[slide 9 – muon headstone]**

***(MUON hams up death scene)***

ERIC

Oh, I suppose it does. Yeah, I guess we use the word “decay” differently within particle physics. In this case, the muon disappears and becomes an electron and two neutrinos.

[**slide 10 – muon decay again]**

***(MUON stands up. ELECTRON tags her. She falls down. ELECTRON and NEUTRINOS stand triumphantly)***

MARY ANNE

Oh, that sounds less sad.

ERIC

Now that’s what normally happens, but we’re looking for something different: a case where the muon decays to an electron with no neutrinos.

***(NEUTRINOS run offstage. MUON stands up again and the ELECTRON quickly pushes her shoulders down and stands in front of him again.)***

ERIC

Our current understanding of particle physics tells us that this kind of decay should be astoundingly rare.

**[slide 12 – probability]**

ERIC

It’s about the same odds as you becoming president, then shooting a hole-in-one in nine straight holes of golf, and then the White House getting hit by a meteor. I guess it’s possible, but it’s so rare that we can basically say it’ll never happen.

**[slide 13 – gravity]**

Butwe know that our current theory has problems. It can’t explain gravity, or dark matter, or many other things we see in nature. We have some new theories that could extend the Standard Model to explain mysteries like gravity. But we have to find a way to test whether any of these new theories are right.

That’s why the Mu2e experiment is so important. Because it turns out that many of these new theories say that this kind of decay isn’t actually as rare as we thought. Basically, if we see the muon going to just an electron, we’ll have taken a huge step forward in understanding the universe. And if we DON’T see it, we’ll have ruled out some of these new ideas. So either way it’s progress.

MARY ANNE

You should probably say something about how you tell whether there are neutrinos or not.

ERIC

**[Slide 14 – neutrino]**

Good point. The fact is that we can’t detect neutrinos, because they go through just about everything. They go right through our detectors, like they’re not even there.

***(One of the NEUTRINOS taps ERIC on the shoulder and she whips around, seeing nothing. She sprints offstage, giggling.)***

So that’s what we’re doing with the Mu2e experiment! Setting up the conditions so that we can tell if we’re seeing the kind of decay with neutrinos or without them, even though we can’t see the neutrinos! It turns out one of the best ways to do this is to first hold the muon still, so the first step is to capture it.

MARY ANNE

Sounds like jail.

***(MUON backs in from stage left, followed menacingly by TONY, dressed as cop)***

**[Slide 15 – jail]**

ERIC

No, no.

***(TONY and MUON walk offstage)***

ERIC

I guess when I say “capture” I really mean “stop.” We actually catch the muons with a big clump of aluminum.

***(CLUMP of people covered in aluminum foil shuffle awkwardly to center stage. MUON starts walking around it)***

**[slide 16 – Pokemon]**

ERIC

It’s kind of like….you know, the last time we did this, that Pokemon Go reference killed. I mean, what happened with that? You got anything? Maybe something about the World Series?

MARY ANNE

You could say that Aluminum is better at catching than the Indians were in Game 6.

ERIC

If you say so.

***(CLUMP shuffles around after the MUON on stage, MUON tries to escape in slow motion, then grabs her.)***

**[slide 17- MUON being captured]**

ERIC

Anyway… So we’ve stopped the muon. I think an equation would be helpful here. What do you think about equations?

MARY ANNE

Sure, everyone loves equations!

***(CLUMP shuffles off stage, maybe looking scared of equations)***

ERIC

Let’s start with E=mc^2.

**[Slide 18 – E=mc2]**

MARY ANNE

Good start. I’m guessing they’ve all heard of Einstein.

ERIC

Exactly. So as you might know, this equation tells us that mass and energy are basically the same thing, with a conversion factor of “c-squared.” The main idea is that if we start out with the muon standing still, captured by the aluminum, we can calculate the total energy that we’re starting with -- it’s just the mass of the muon. After the muon decays, we know that that energy has to be exactly equal to the total energy of all the things coming out of the decay, since energy can’t be created or destroyed,

***(ELECTRON walks to center stage.)***

**[SLIDE 19-MUON decays]**

ERIC

Because the electrons and neutrinos are so much lighter than the muon, almost all of the energy from the muon’s *mass* goes into the *motion* of the electrons and neutrinos. So if the muon decays to only an electron, we know exactly how fast it will fly away, because it just got all the muon’s energy at once…

***(MUON runs on, tags the ELECTRON, and the ELECTRON runs off)***

..*.*but if the muon decays to an electron and two neutrinos

***(ELECTRON and NEUTRINOS walk on again; the MUON runs towards them and tags them, but the ELECTRON just walks away)***

that initial energy will be split up among all the particles, so the electron will *always* have a lower energy. Since we can’t see the neutrinos, that electron is our *only* clue to tell us what type of decay really happened.

ERIC

And we’re building a detector that will let us measure the electron energy really precisely so that we can tell if any of our electrons have that one special energy that tells us that we didn’t have any neutrinos in the decay.

MARY ANNE

Maybe a little more detail on the detector?

**[Slide 20- Detector]**

ERIC

Well, you can think of it as kind of like a microscope, but a microscope the size of an NBA basketball court and tall enough for me to stand in! We make muons here, capture them here, and look for those special electrons here. It’s designed so lower energy electrons we don’t care about escape down the middle. We’ve already started building it.

***(TONY comes out with detector from Stage Left. MUON walks slowly toward it from Stage Right)***

Of course, we don’t send in just one

***(MUON stops)***

We need to send in a lot of muons at once. We send in about 10 billion muons every second, and in the end, we’ll have about a quintillion muons.

***(A lot of particles run in from Stage Right and start running around)***

MARY ANNE

You might want to explain how many that is

ERIC

Uh… 10^18. 1 with 18 zeroes.

**[Slide 21 – Once Quintillion]**

MARY ANNE

Not a big improvement

**[Slide 22 – beach]**

ERIC

OK, imagine the number of grains of sand on all the beaches in the world. We need to search through *that many* particles to even get close to discovering something this rare.

***(all the kids move off to Stage Left)***

MARY ANNE

That’s probably as well as you can do.

**[Slide 23 – Sensitivity]**

ERIC

Capturing so many muons will really increase the sensitivity. The previous best measurement was made in an experiment in Switzerland. They proved that this happens less than one in a trillion times. That’s a one followed by 12 zeros.

That’s the probability of your house getting hit by a meteor.

Today.

**[Slide 24 – Our sensitivity]**

ERIC

But our experiment will be able to see this if it happens 10,000 times less often than that, one time in 10 quadrillion, or one followed by 16 zeros. That’s the probability that your house will be hit by a meteor – in the next ten seconds.

Experiments almost never make that big an improvement in one step, so Mu2e is very special.

MARY ANNE

You might want to say something about how this fits in with the LHC at CERN

**[slide 25-LHC]**

ERIC

Good point. The LHC is a lot bigger bigger, and studies things at much higher energies, but by studying rare decays, Mu2e is very complementary, and might even be able to see some things that the LHC can’t.

**[slide 26-Mu2e + gift]**

ERIC

After all, sometimes great things come in small packages

***(LIANA grabs mic and walks onstage)***

LIANA

Just because you’re small doesn’t mean you can’t be powerful!

**[slide 27 – head shots]**

***(everyone takes a bow)***