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MATHUSLA FAQs

What is MATHUSLA?

It's a proposed detector for long-lived particles produced at the HL-LHC. It would take the form of basically an aircraft hanger on the surface, ~100m from ATLAS or CMS, with a tracking system at the top and a scintillator skin hermetically surrounding the air-filled decay volume.

Why would you look for long-lived particles?

LLPs show up in almost any theory you can think of -- after all, it just requires a small decay width. For example, RPV SUSY generically has such small RPV couplings that many of the superpartners can be long-lived, meaning more than ~100 microns or so. They are especially motivated in hidden sector theories, which can solve the Hierarchy Problem, Baryogenesis, Dark Matter, Neutrinos, ... The lifetime can easily exceed 100 meters, up to astrophysical length scales.

If the LLPs can be super long-lived, why would they decay near the LHC and not in another galaxy?

If you can produce an LLP at colliders, then it's produced in the hot plasma of the early universe. If they're too long lived, their late decay disrupts Big Bang Nucleosynthesis. A generic upper bound on the lifetime is about 0.1 - 1 seconds (with some caveats, but this is a very reliable rule of thumb).

That's still pretty big.

Yes it is, but if you produce LLPs in large numbers, then you only need to see one in a million to have a good chance at seeing a BBN-lifetime LLP. That's what MATHUSLA is trying to do.

Why not use intensity frontier experiments to make many LLPs, isn't that what they're good for?

It's true that intensity frontier colliders like B-factories etc are very good at producing many light particles < few GeV, including LLPs. However, the LHC is the only machine that can produce large numbers of LLPs near the electroweak scale, which is particularly motivated because they can easily be produced in exotic Higgs decays, and other theories the LHC looks for.

But why build a separate detector? Can't I see these decays at ATLAS or CMS?

While LLP decays are spectacular, there is some QCD background in the main detector, and that's enough to make it impossible to see just a few LLP decays in the main detector.

So how much better is MATHUSLA at seeing LLPs than ATLAS or CMS?

(That question is answered in the first MATHUSLA paper, figure 1.) MATHUSLA and ATLAS have roughly the same geometric acceptance for a long-lifetime LLP to decay within their volumes, but MATHUSLA is background-free, while backgrounds in ATLAS are sizable. In the end, MATHUSLA has 1000x better
sensitivity than ATLAS (in both long lifetime and low cross section).

**How do you know the ATLAS backgrounds?**

The best way to look for LLPs with very long lifetimes is in the ATLAS muon system, and public ATLAS data shows that the inclusive QCD background rate for a single DV to be in the 100fb-equivalent range.

**How is MATHUSLA background free? Don't cosmic rays kill you?**

There are indeed a lot of cosmic rays, about $10^{15}$ over the lifetime of the HL-LHC. However, MATHUSLA is so big that even ns timing resolution in the tracking system means that charged particle tracks are reconstructed not just geometrically but with sensitive timing and hence velocity information as well. Therefore, displaced vertices (DVs) can be reconstructed not just by converging the tracks in space, but also in time. This is a very hard signal criterion to fake for cosmic rays. Furthermore, cosmics mostly travel down, not up like LLP decay products, which can be sufficiently rejected with enough tracking layers.

**What about neutrino scatterings?**

Atmospheric neutrinos do scatter off the air in MATHUSLA and give DVs, but they can be rejected by vetoing narrow cones which don’t point back to the LHC interaction point, and also vetoing non-relativistic protons in the final state.

**What about stuff made at the LHC, doesn't that give MATHUSLA backgrounds?**

Hadrons are stopped in the rock. Muons do not give a DV, or if they do it's so few that they can be vetoed by the scintillator skin. Neutrinos are dominantly very soft and can be rejected by cutting on non-relativistic final states in the DV. You're left with almost no background at the end of the HL-LHC run.

-- DavidCurtinExternal - 2017-02-15