Looking Past the Standard Model

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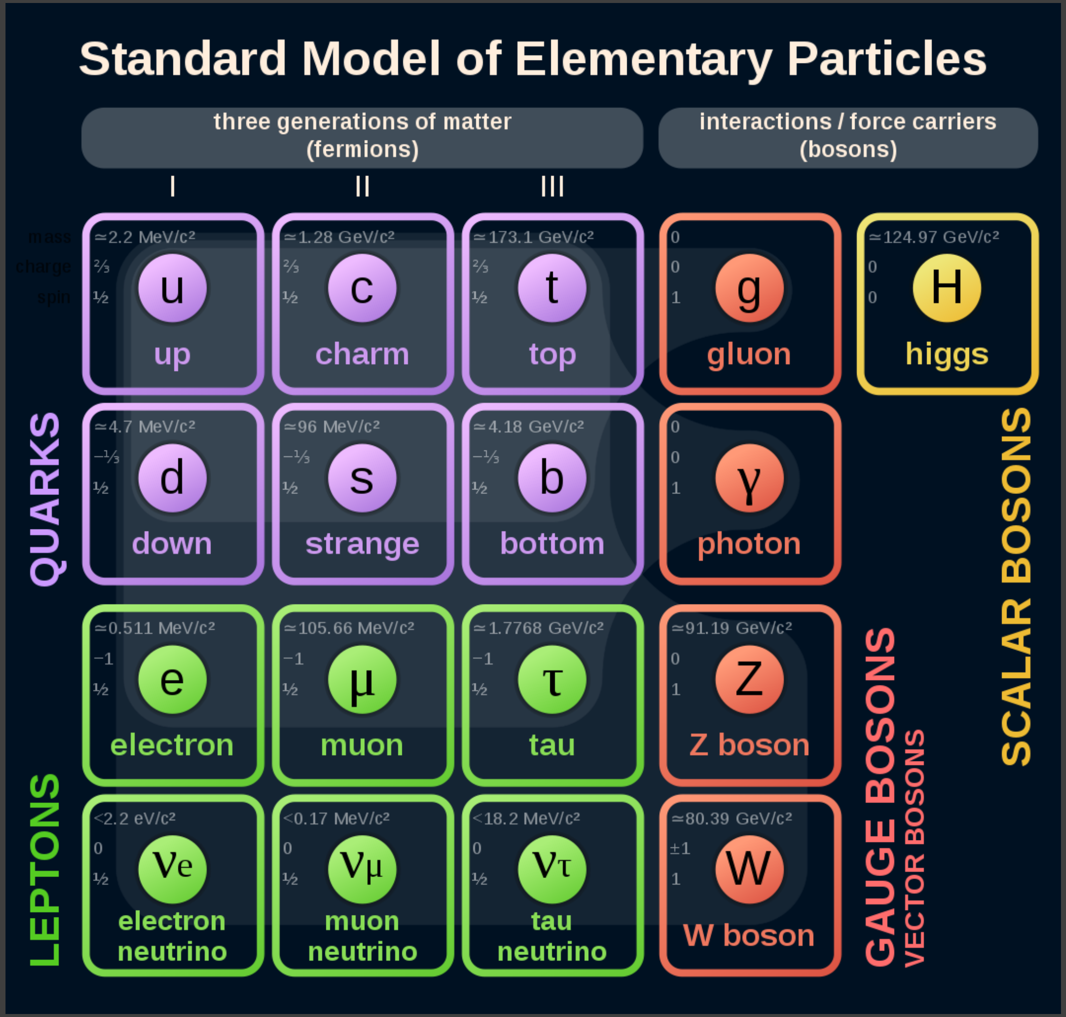
Standard Model

- Main interest are Z and W bosons (Gauge Bosons) force carriers of the weak force (Fermions)
    - Their ability to self couple
- Not many studies have been carried out on multi W and Z bosons



Few Problems With Standard Model

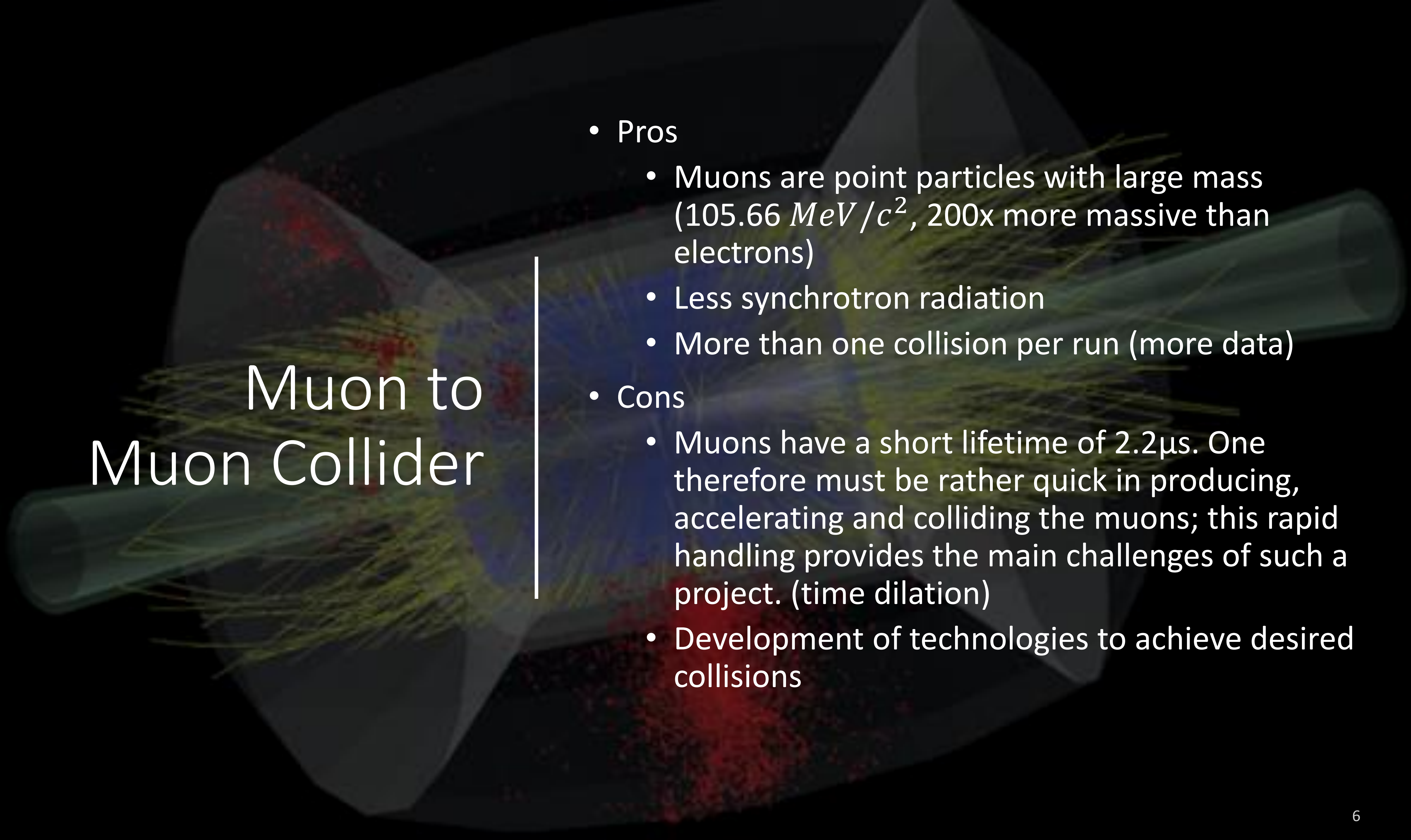
- Gravity: SM doesn't explain gravity. Current approach is adding a graviton to the SM doesn't recreate what is observed experimentally without other modifications. Moreover, SM is considered incompatible with the most successful theory of gravity to date, general relativity
- Dark matter: Cosmological observations tell us the SM explains ~5% of all energy present in the universe. Does not supply any fundamental particles that are good dark matter candidates
- Charge+Parity (CP) violation: Is in SM, particles and anti-matter symmetry of universe cannot be explained by SM

How to Test the Standard Model

- Make measurements different than the SM to see effects
- Look for new particles

What is the Best Collider Moving Forward?

- There are many different options for future colliders:
- e^+e^- (CLIC) – Linear accelerator
- Proton-Proton (LHC) – Circular
- Electron – >Proton (possible upgrade at the LHC->LHeC)
- Which has the best chance of discovering new physics?



Muon to Muon Collider

- Pros
  - Muons are point particles with large mass (105.66 MeV/c^2, 200x more massive than electrons)
  - Less synchrotron radiation
  - More than one collision per run (more data)
- Cons
  - Muons have a short lifetime of 2.2μs. One therefore must be rather quick in producing, accelerating and colliding the muons; this rapid handling provides the main challenges of such a project. (time dilation)
  - Development of technologies to achieve desired collisions

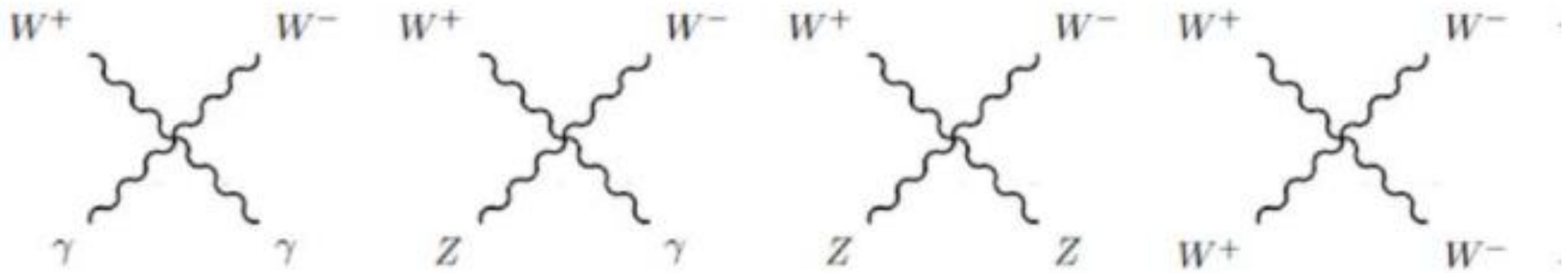
S: Pure Higgs field, pure longitudinal
M: Mixed Higgs-field-strength, mixed long-transverse
T: Pure field-strength tensor, pure transverse

	$WWWW$	$WWZZ$	$WW\gamma Z$	$WW\gamma\gamma$	$ZZZZ$	$ZZZ\gamma$	$ZZ\gamma\gamma$	$Z\gamma\gamma\gamma$	$\gamma\gamma\gamma\gamma$
$\mathcal{O}_{S,0}$, $\mathcal{O}_{S,1}$	✓	✓			✓				
$\mathcal{O}_{M,0}$, $\mathcal{O}_{M,1}$,$\mathcal{O}_{M,6}$,$\mathcal{O}_{M,7}$	✓	✓	✓	✓	✓	✓	✓		
$\mathcal{O}_{M,2}$,$\mathcal{O}_{M,3}$, $\mathcal{O}_{M,4}$,$\mathcal{O}_{M,5}$		✓	✓	✓	✓	✓	✓		
$\mathcal{O}_{T,0}$,$\mathcal{O}_{T,1}$,$\mathcal{O}_{T,2}$	✓	✓	✓	✓	✓	✓	✓	✓	✓
$\mathcal{O}_{T,5}$,$\mathcal{O}_{T,6}$,$\mathcal{O}_{T,7}$		✓	✓	✓	✓	✓	✓	✓	✓
$\mathcal{O}_{T,8}$,$\mathcal{O}_{T,9}$					✓	✓	✓	✓	✓

Allowed by SM

What Was My Project?

- I will be looking at $\mu\mu \rightarrow W^{+}W^{-}$
- There are 16 different parameters to choose from we chose to study T1 due to it being affected by all four couplings



Anomalous Quartic-Gauge Coupling (aqgc)

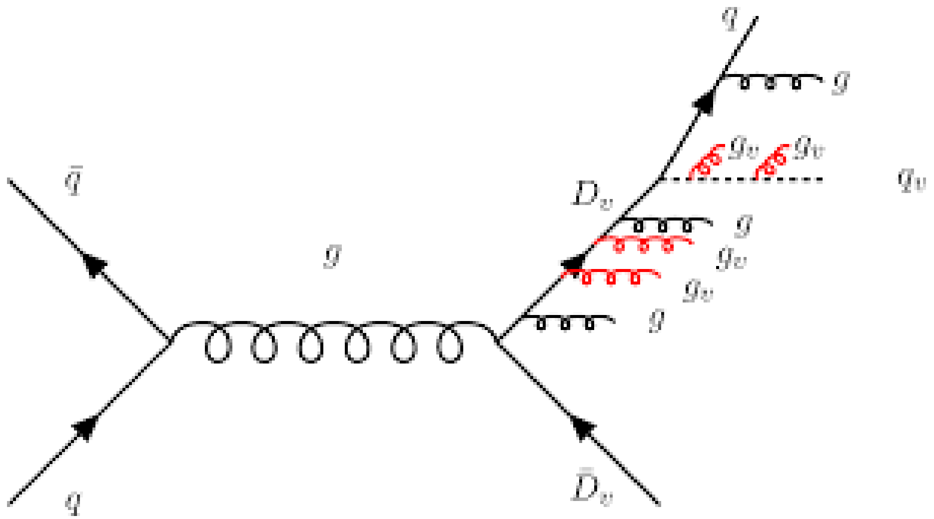
- Meaning: deviating or inconsistent with SM
  - For instance: $W^+W^-\gamma\gamma$, $W^+W^-Z\gamma, W^+W^-W^+W^-$
- We will be looking into all these vertices
- By changing parameters such as, $1x10^{-14}$, $1x10^{-13}$, $1x10^{-12}$, and $5x10^{-12}$ we can have increasing strength of coupling, which will dominate over SM couplings.

MadGraph

- Monte Carlo event Generator
- Generates types of decays, and it allows us to put in aqgc, calculate cross-sections at the parton level
  - Cross-Section refers to probability that two particles will collide and react in a certain way
- I ran 100,000 events at 3 TeV for each simulation (appox. 5 hours per)

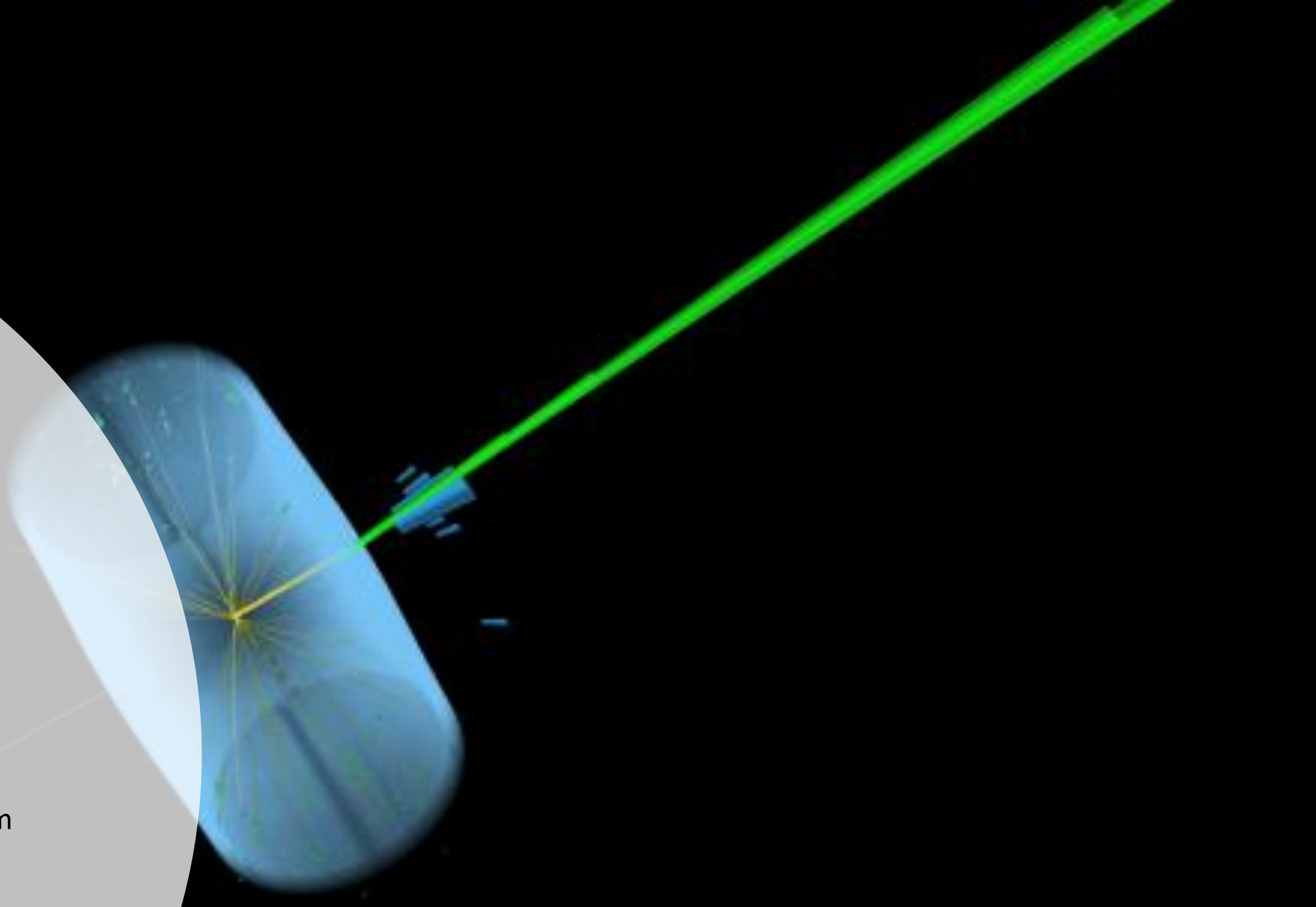
Pythia8

- Standard tool for the generation of high-energy collisions, comprising a coherent set of physics models for the evolution from a few-body hard process to a complex multihadronic final state.
- Decays unstable particles from MadGraph



Delphes

- Performs a fast multipurpose detector response simulation. Which includes a tracking system, embedded into a magnetic field, calorimeters and a muon system.
- Outputs observables such as isolated leptons, missing transverse energy, and collection of jets which can be used for dedicated analysis.
- After running delphes, we can generate plots and analyze cross-sections(We can compare the new physics model to the SM- in the model of a muon collider)



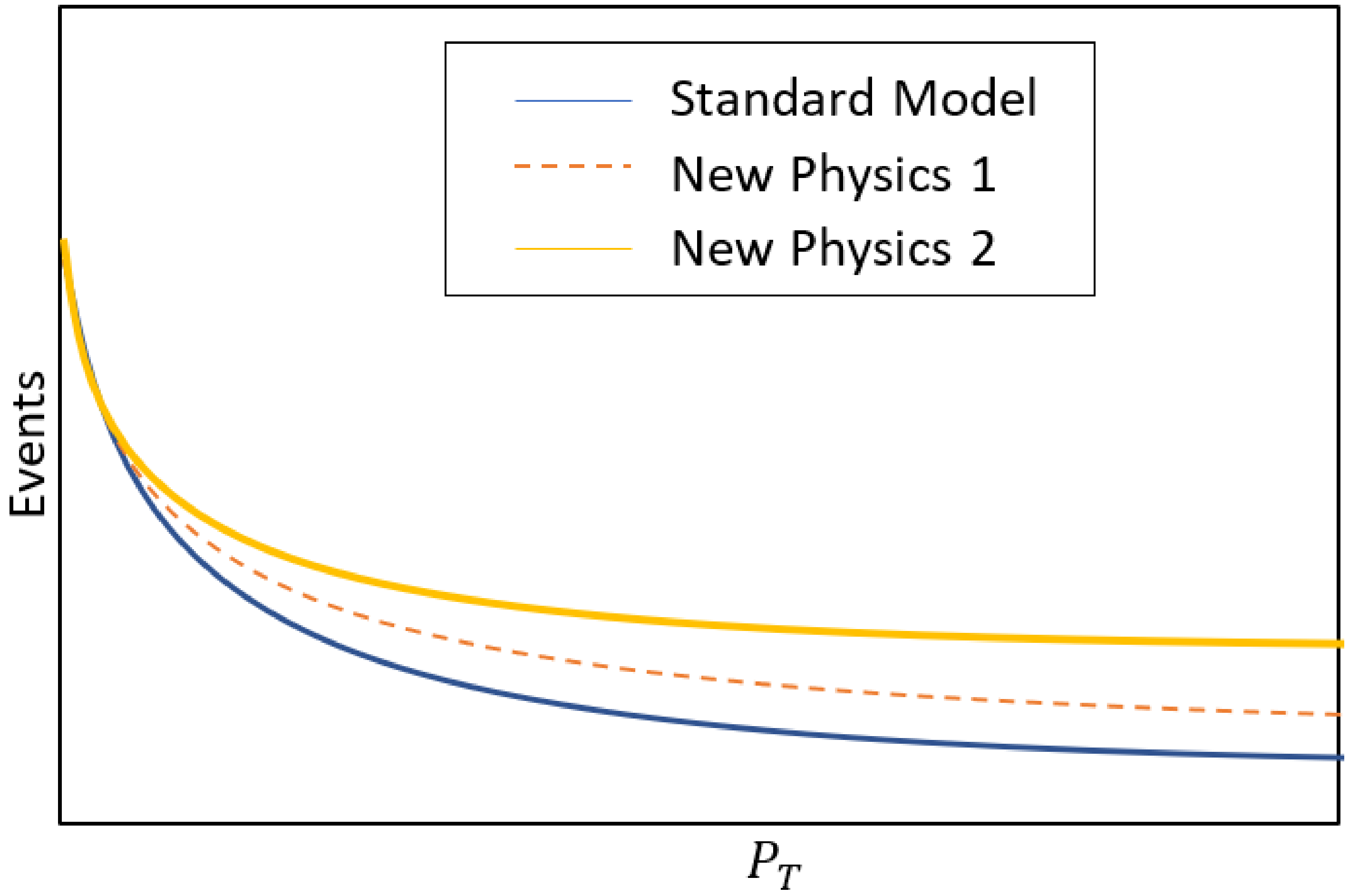
Transverse Momentum and Why it’s Important

- Transverse Momentum of a particle is defined by:

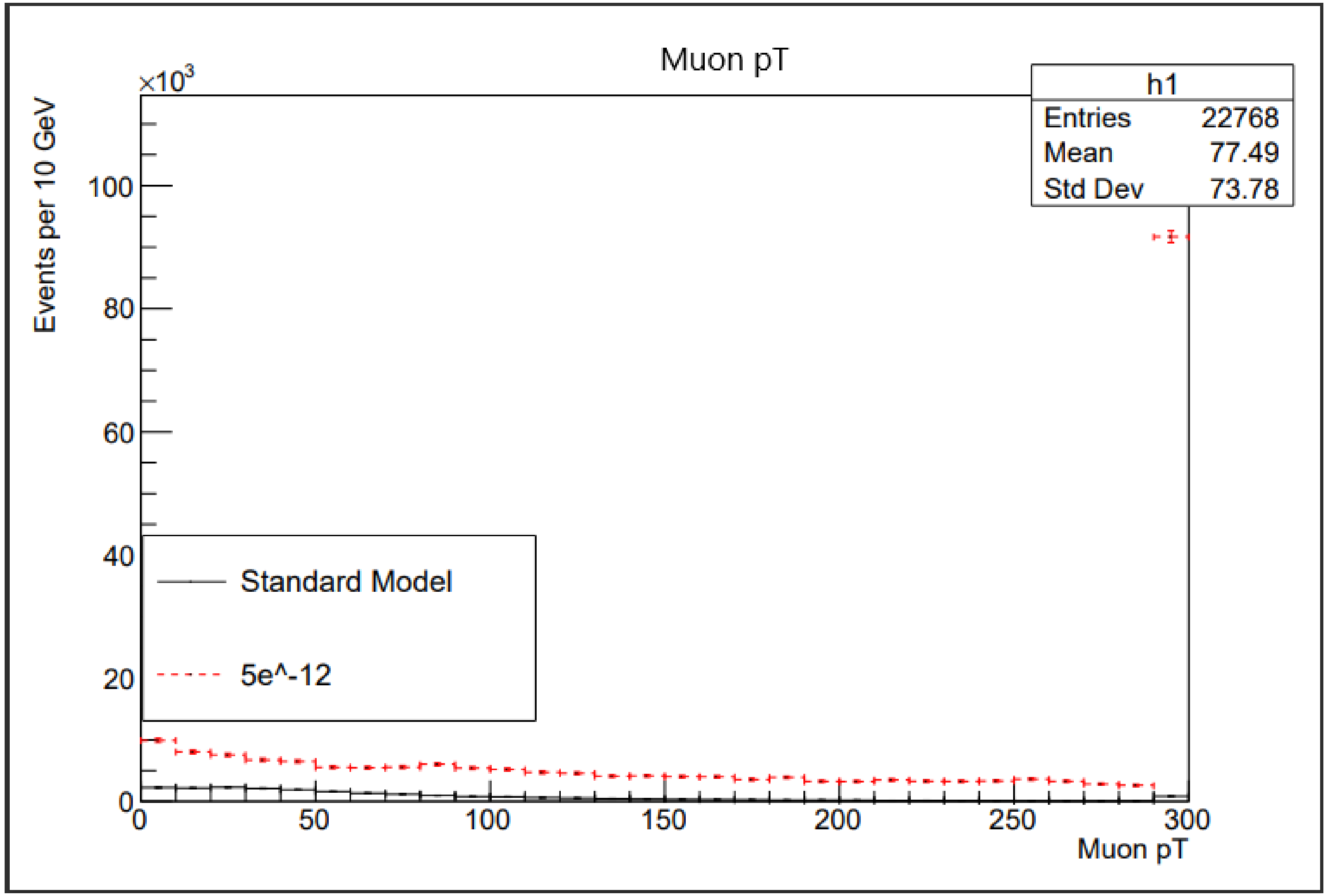
$$P_T = \sqrt{P_x^2 + P_y^2}$$

- Where P_x and P_y are the momentum components in the transverse momentum plane. The transverse momentum distributions of the final-state particles are called first observations in the high-energy experiments.
- At the greatest energies, measurements of transverse momentum help us to pin down the details of the Standard Model and discover new particles.
- $P_T \perp$ beam axis

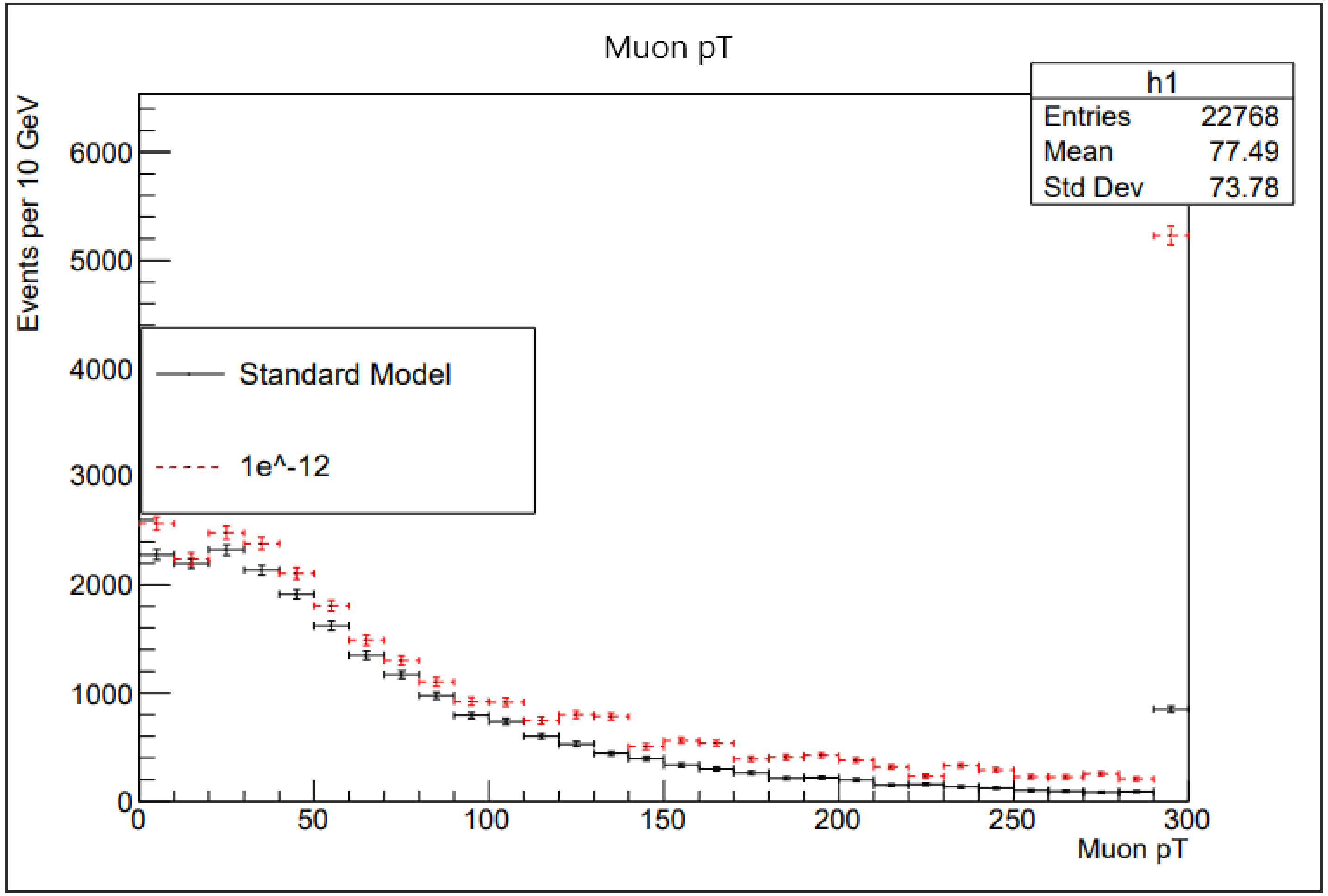
Big Picture



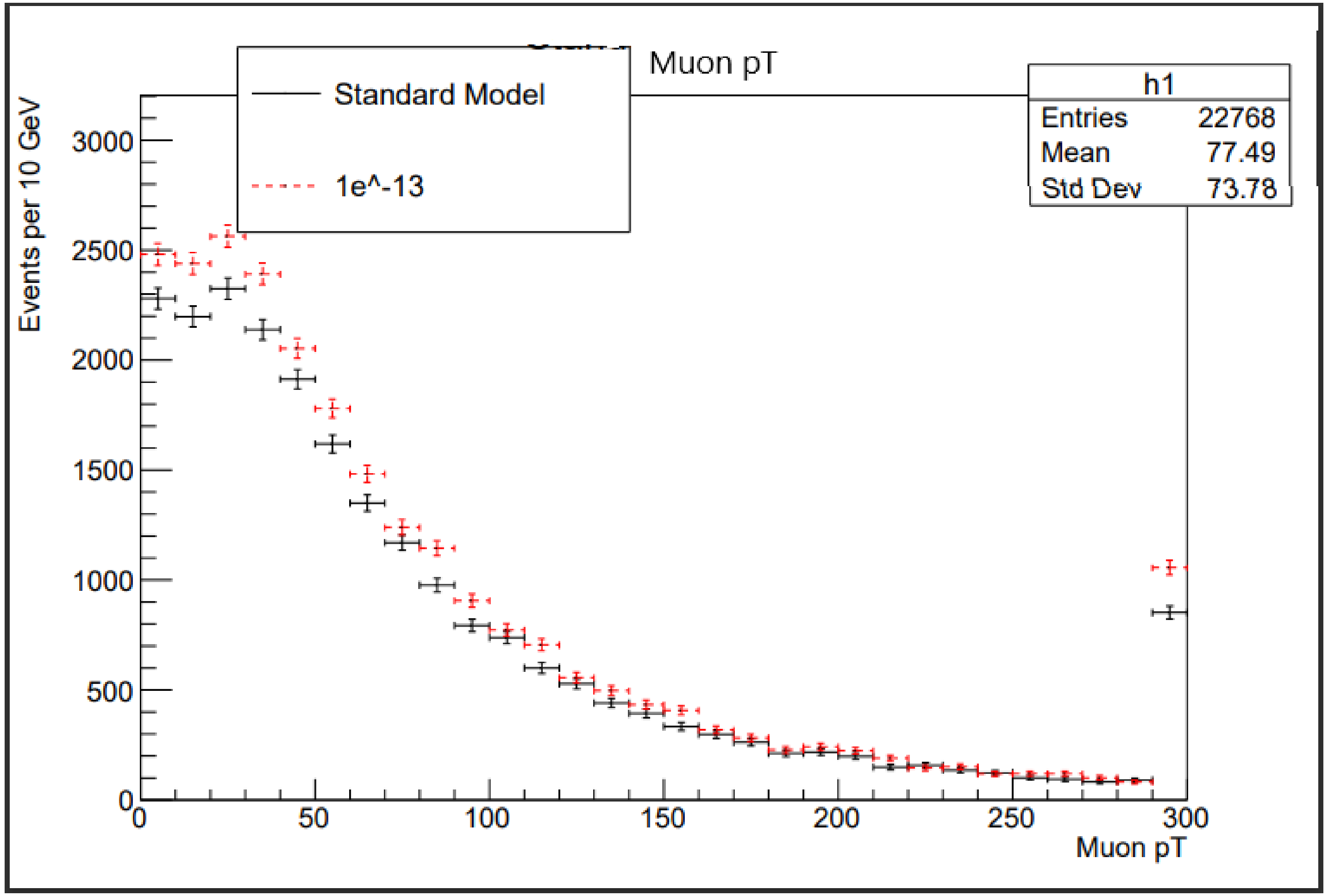
Parameter:
T1=$5x10^{-12}$



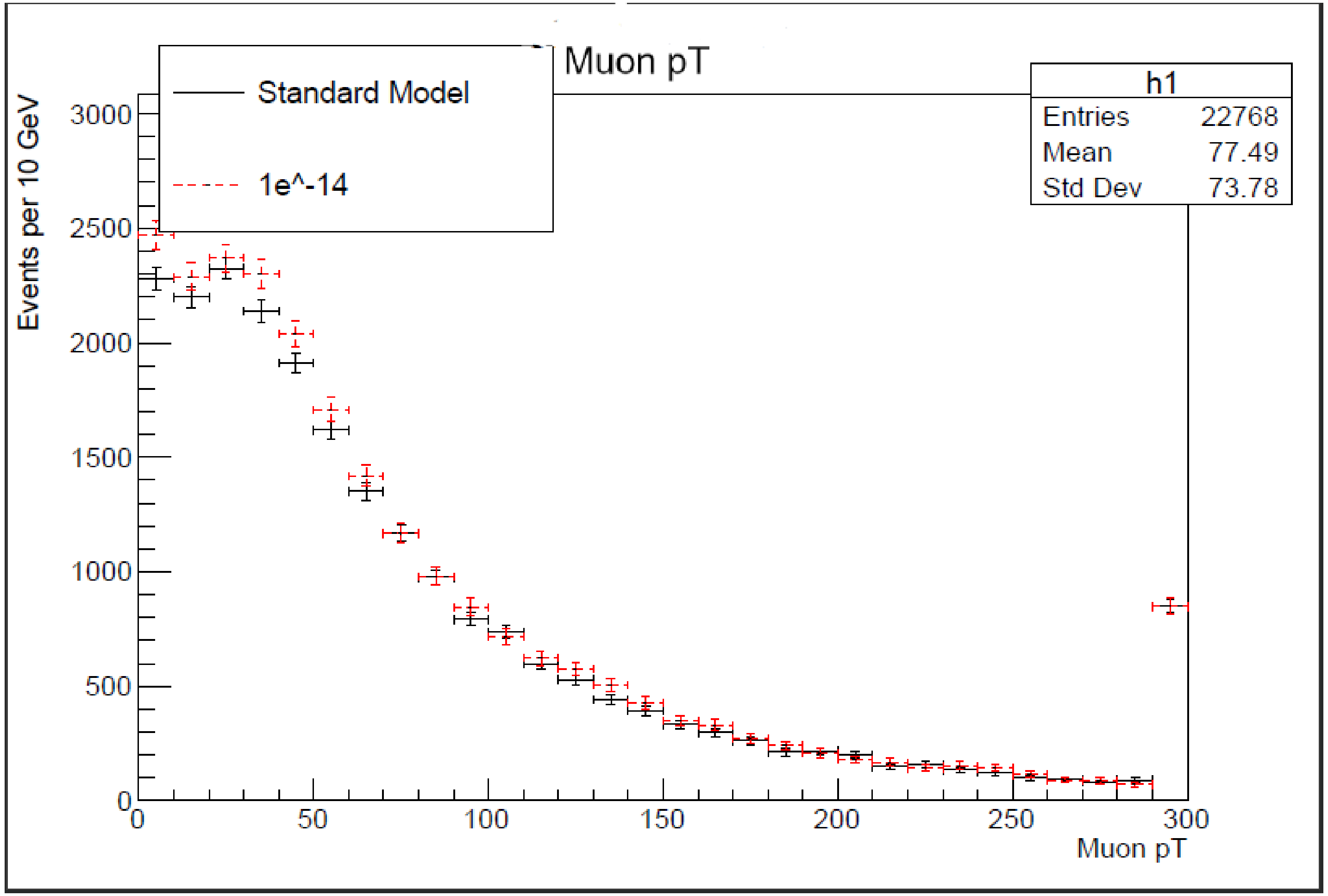
Parameter: $T1 = 1x10^{-12}$



Parameter: T1=$1x10^{-13}$



Parameter:
$T1=1x10^{-14}$



SnowMass

- The Particle Physics Community Planning Exercise (a.k.a. “SnowMass”)
- Provides an Opportunity for the entire high energy particle physics (HEP) community to come together to identify and document a scientific vision for the future HEP in the U.S. and its international partners.
- Will define the most important questions for particle physics and identify promising opportunities.
- Develop a strategic plan to be executed over a 10-year time scale, in the context of a 20-year global vision.

In Conclusion:

Collider at 3 TeV, should be able to observe new physics.

Allows us to compare with other colliders to decide which is the best option.

Now that the machinery is set, we can test all other parameters, then compare our results to expected results from CLIC, LHeC, etc..

To help the physics community to decide on next generation collider.

Any Questions?