“Who Ordered that?”: A Dimuon Analysis

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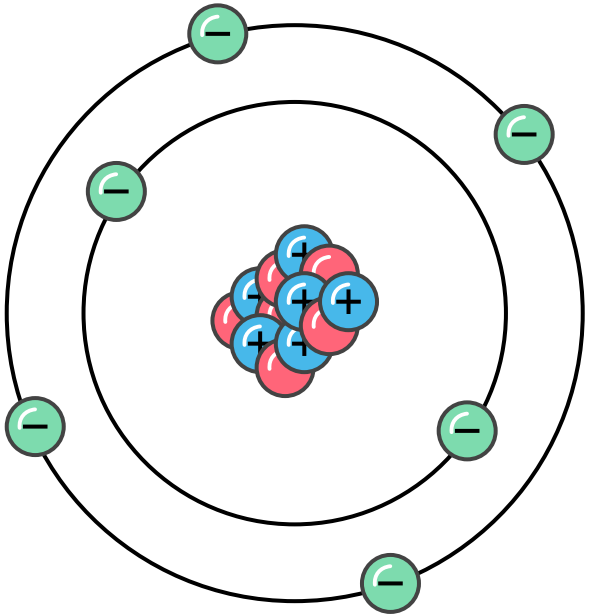
THE STRUCTURE OF THE ATOM

ELECTRON

PROTON

NEUTRON



Unexpected particles: Muons

Who ordered that?

Isaac Rabi, Nobel laureate

Muon μ^-

- Negatively charged particles
- 200 times more massive than electrons

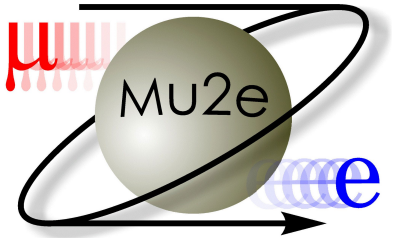
Dimuon

Anti muon μ^+

- Positively charged particles
- 200 times more massive than electrons

Count the number of muons in the presentation (the green ones)

Why do we care?



Testing fundamental physics : Mu2e experiment

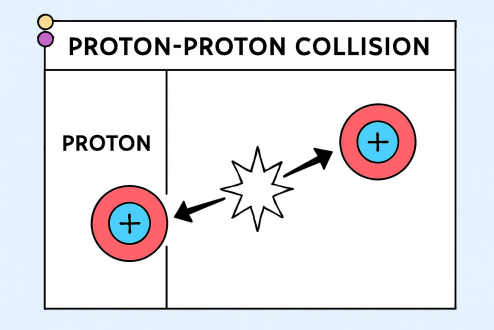
Physics beyond the standard model?

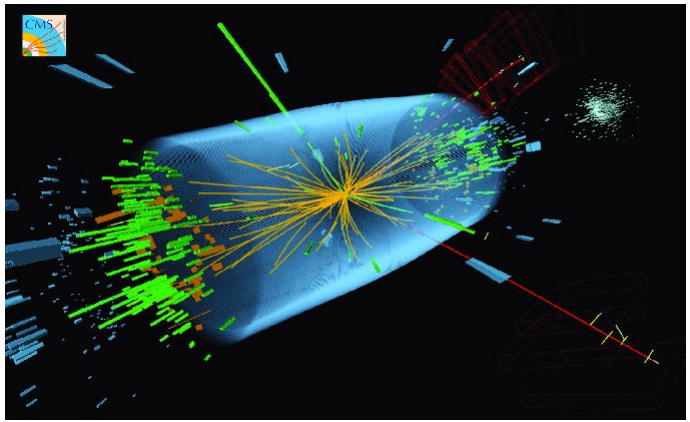
Muography : Imaging using cosmic muons

What can we image? e.g. the pyramids!

Fun fact: In 2023, "a corridor-shaped structure" was found in Khufu's Pyramid using the cosmic-ray muons.

Where do muons come from?



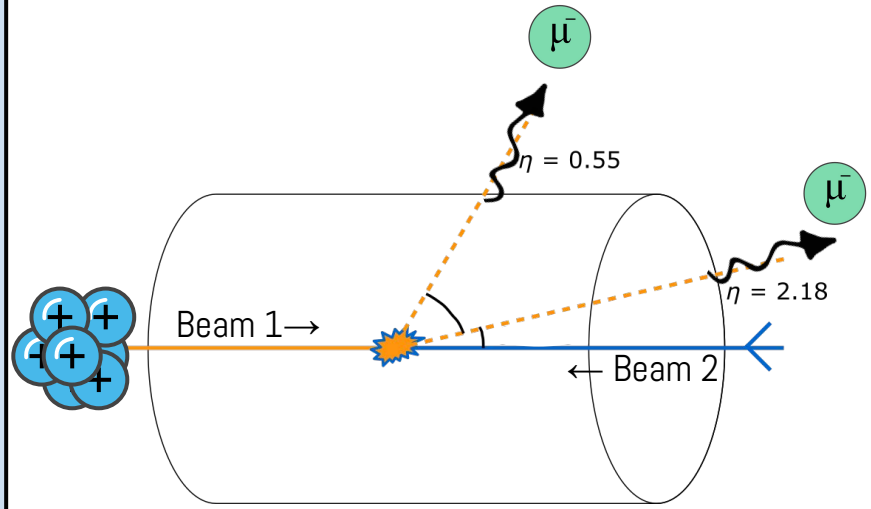


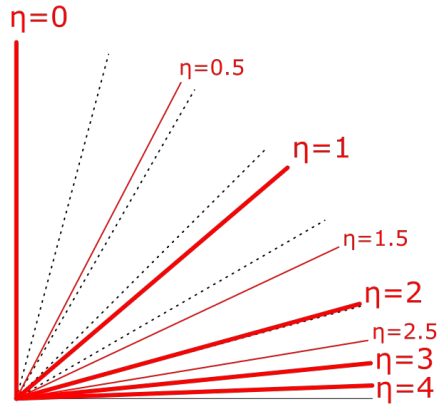
Hi! μ^- μ^+ Hi!

Z

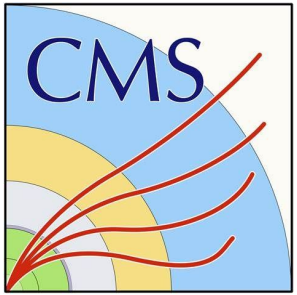
Source Particle
e.g. Z boson

What is the Pseudorapidity η?





About the dataset

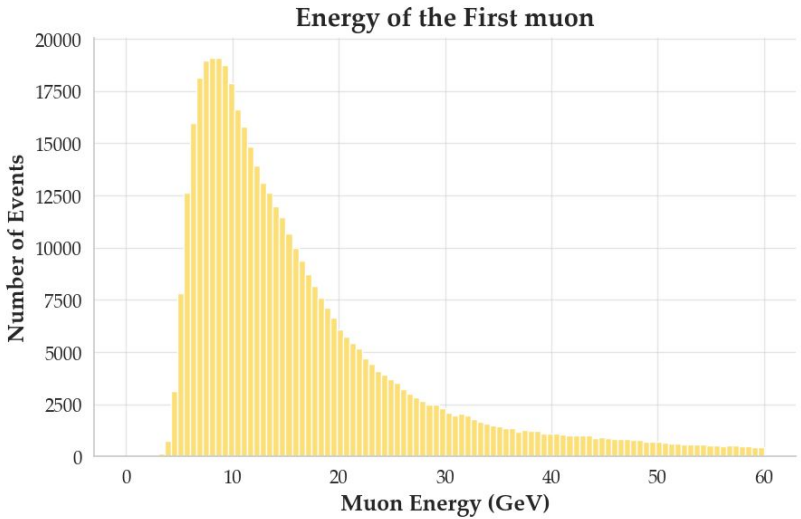


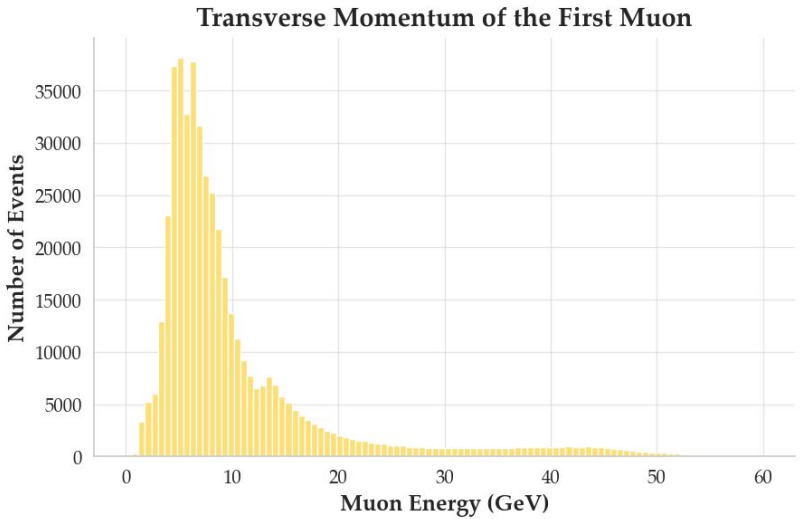
The **dimuon** dataset comes from high-energy physics experiments where pairs of muons (called dimuons) are produced in proton-proton collisions, such as those at the **CERN** Compact Muon Detector (CMS).

This dataset has 475,465 events with 21 features, which includes variables like:

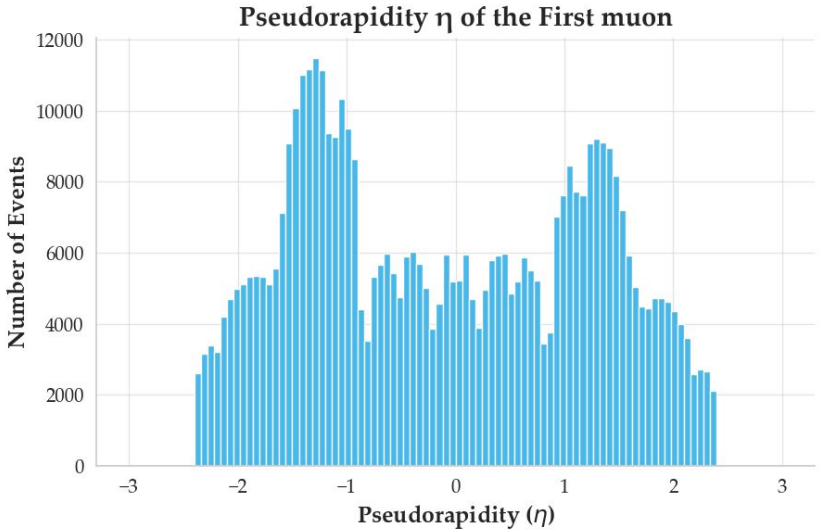
- **Momentum** and **energy** of each muon
- **Pseudorapidity** (η), which describes the angle of the muons relative to the beamline
- **Invariant mass** of the muon pair, useful for identifying possible particle resonances (like the J/ψ, ϒ, or Z boson)

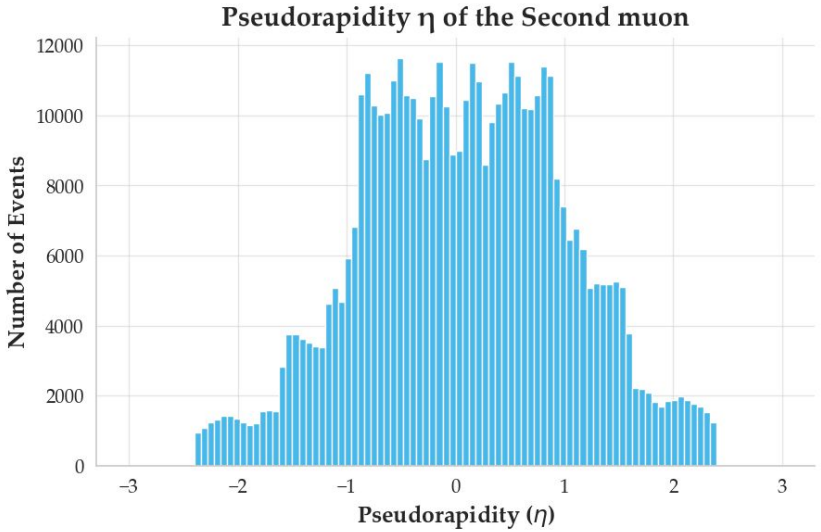
Energy vs. Transverse Momentum



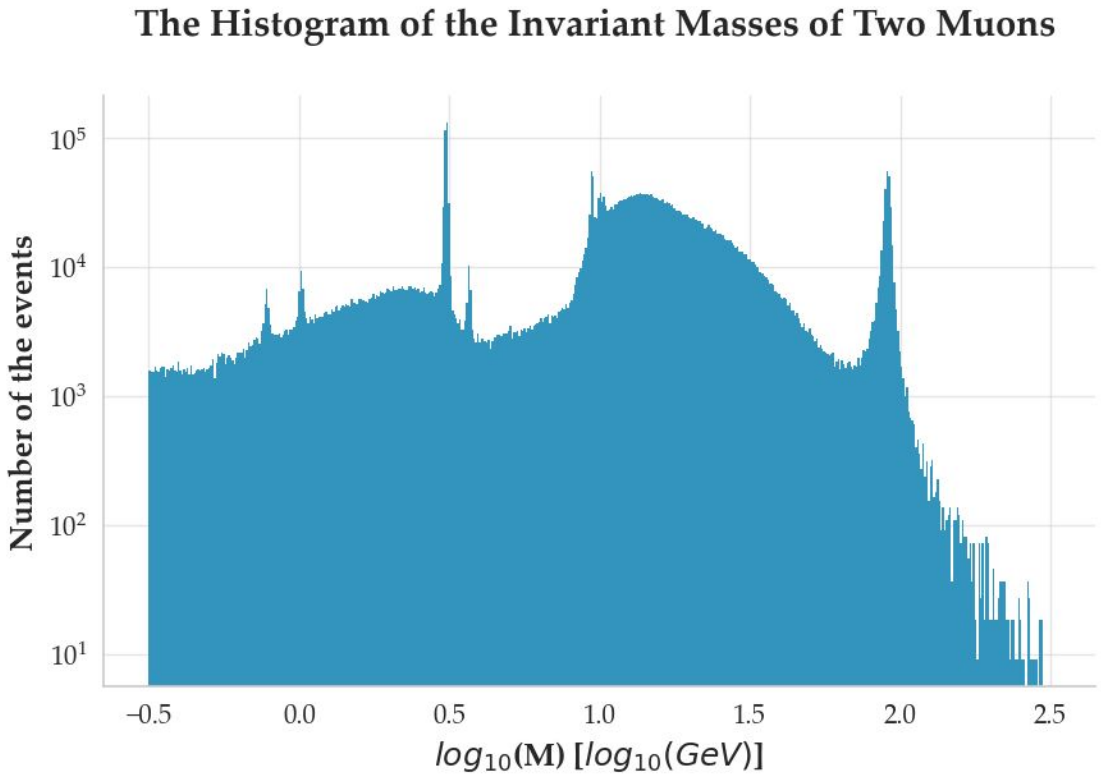


Pseudorapidity (η)

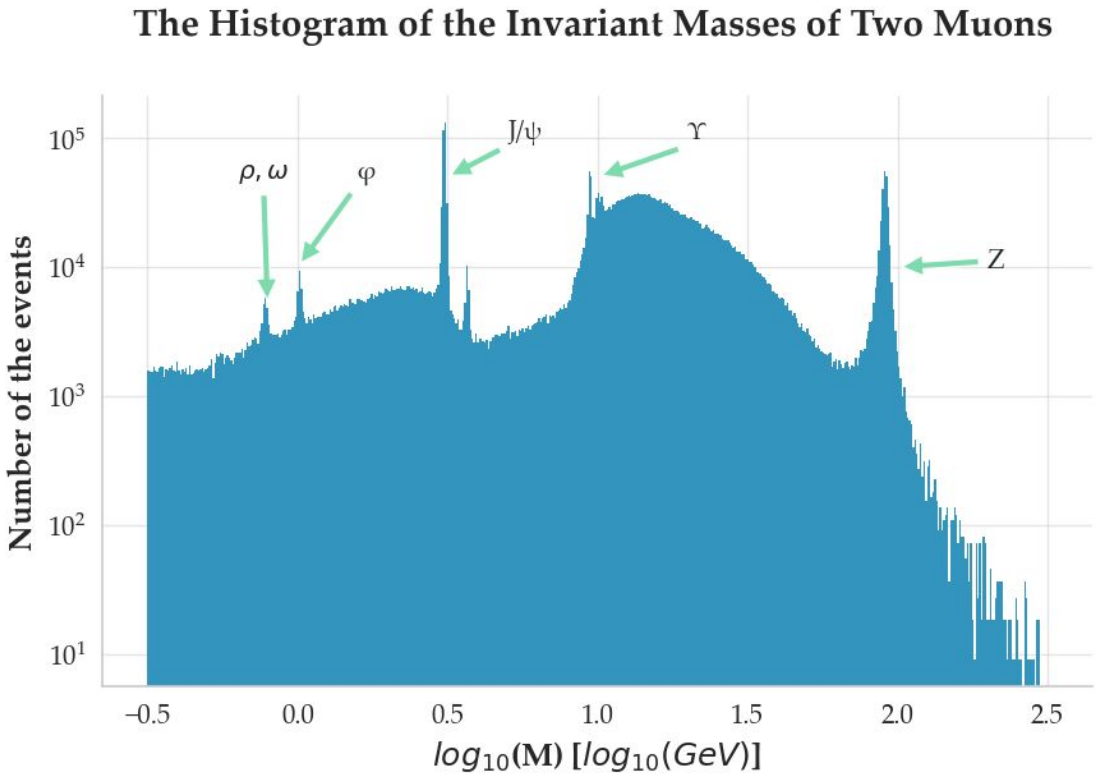




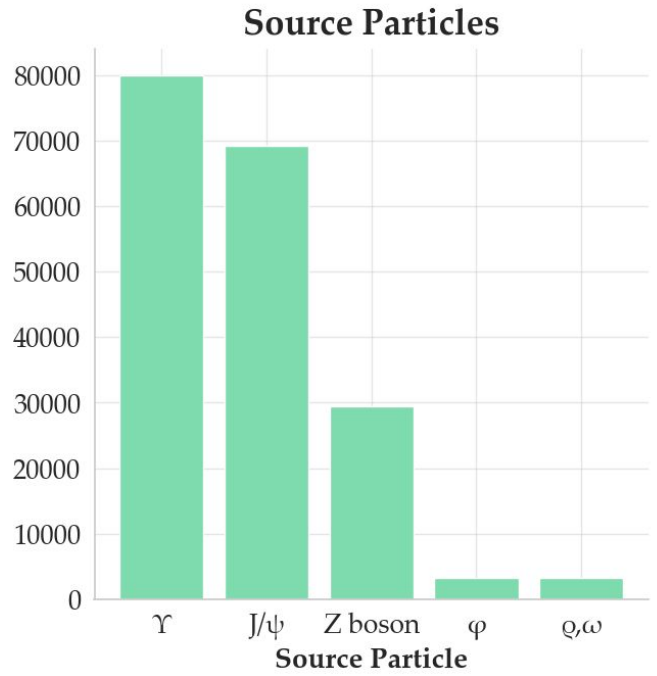
Invariant Mass

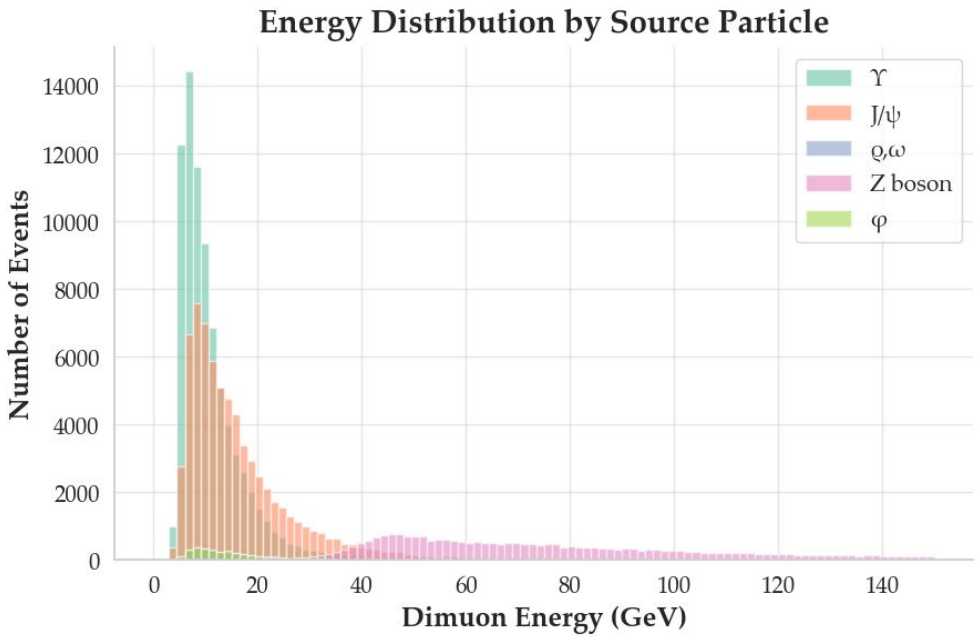


Identifying Source particles



Distribution of Source Particles across Events

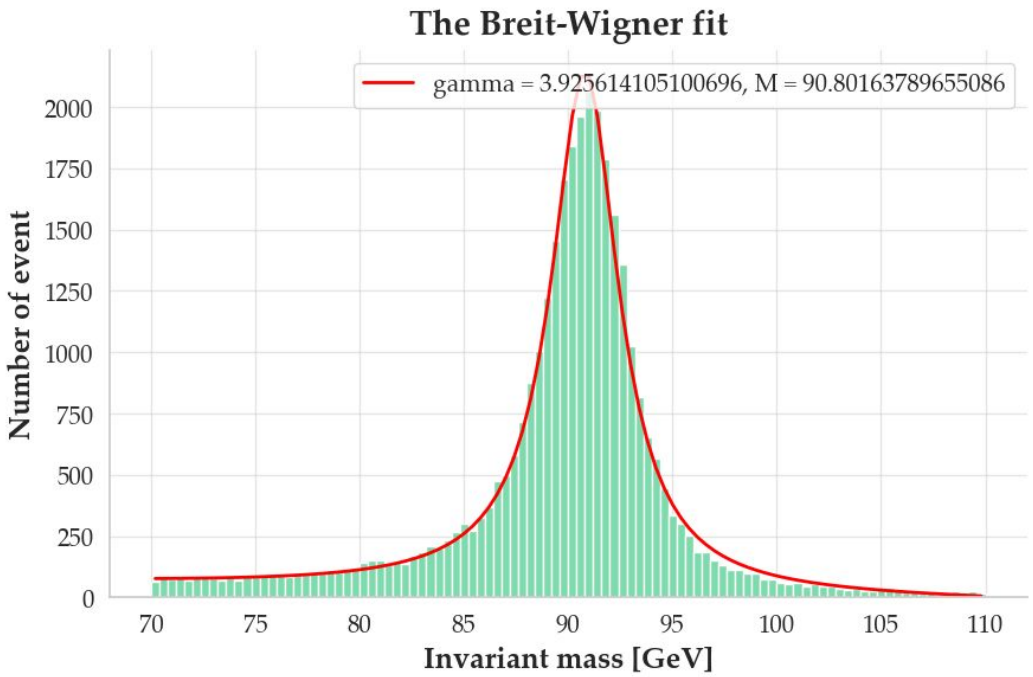




How can we get the exact invariant mass ? By Fitting!

M
90.8 GeV

Decay Width Γ
3.93

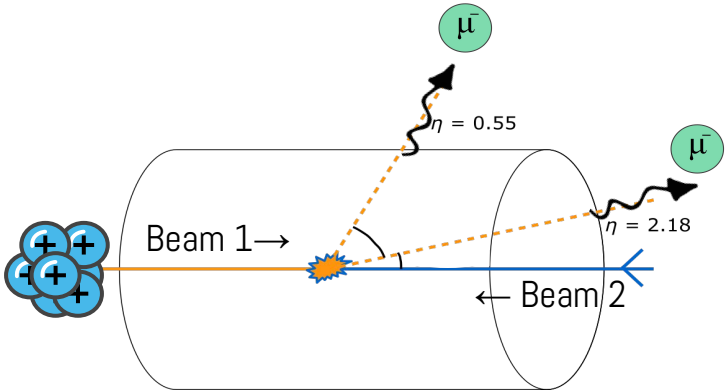


Pseudorapidity

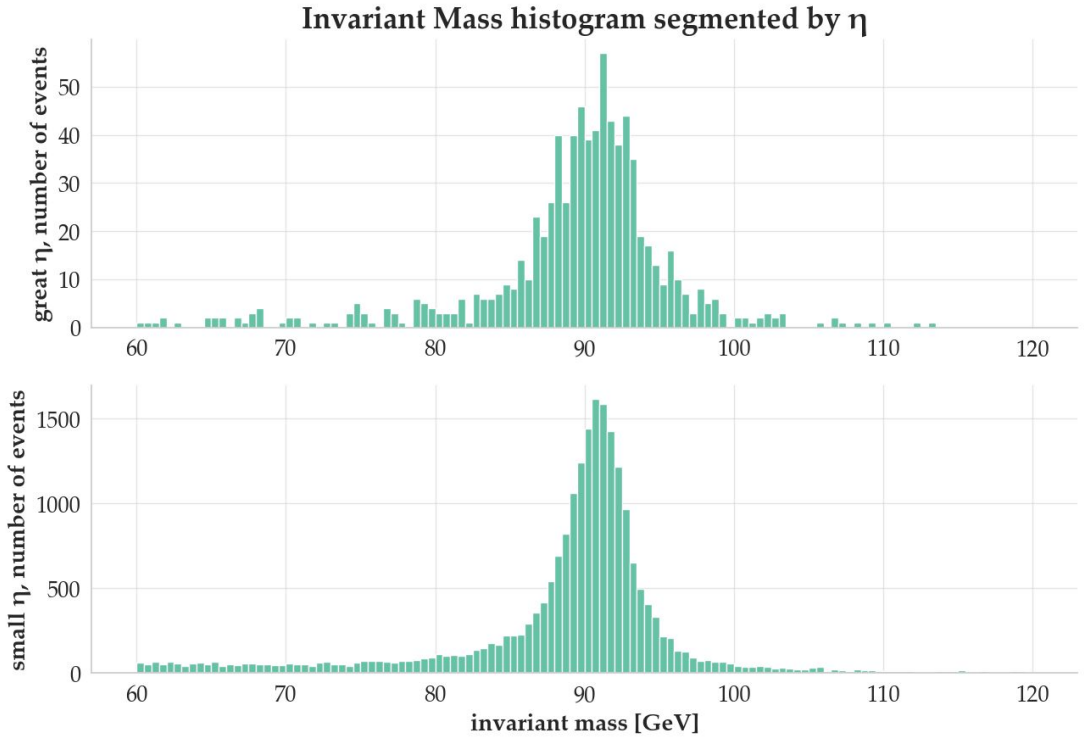
All Events
475,465

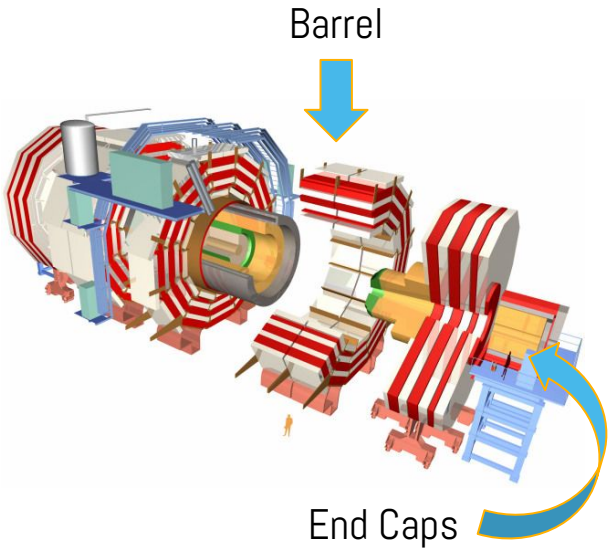
Small η
288,119

Large η
14,428

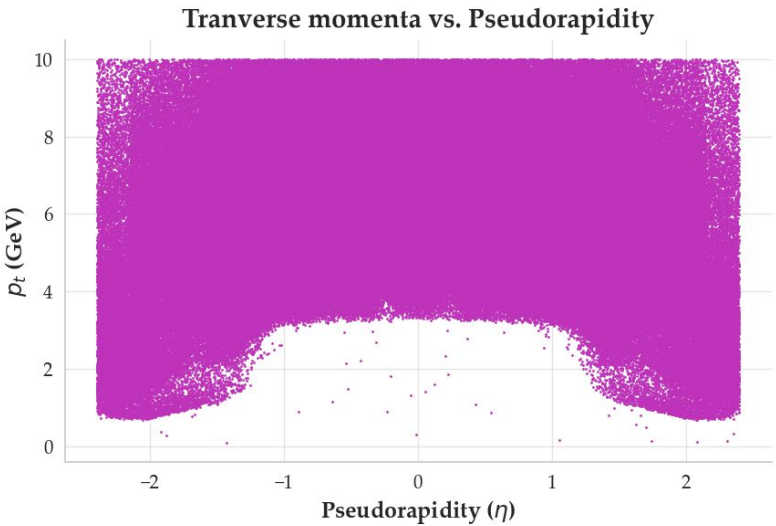


What is going on?

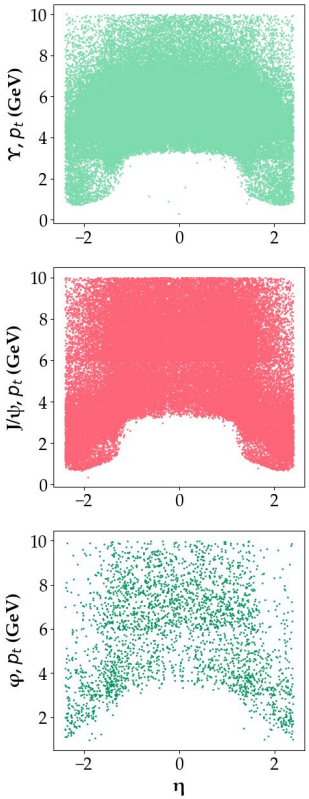




What is going on, again?



Invariant Mass



Global Muons vs. Tracker Muons

Muon Types

Global Muons

Detected in the tracker and the muon system

No. of G muons

34,742

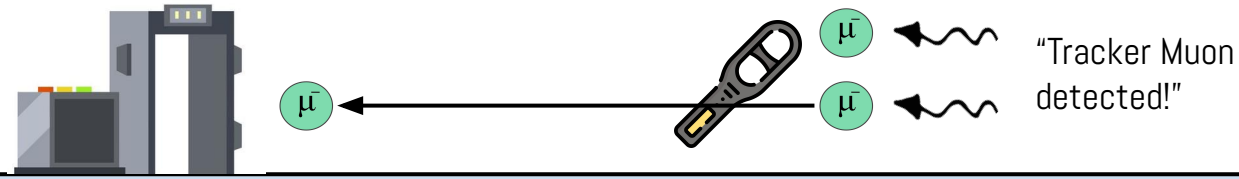
Tracker Muons

Detected in the inner tracker

No. of T muons

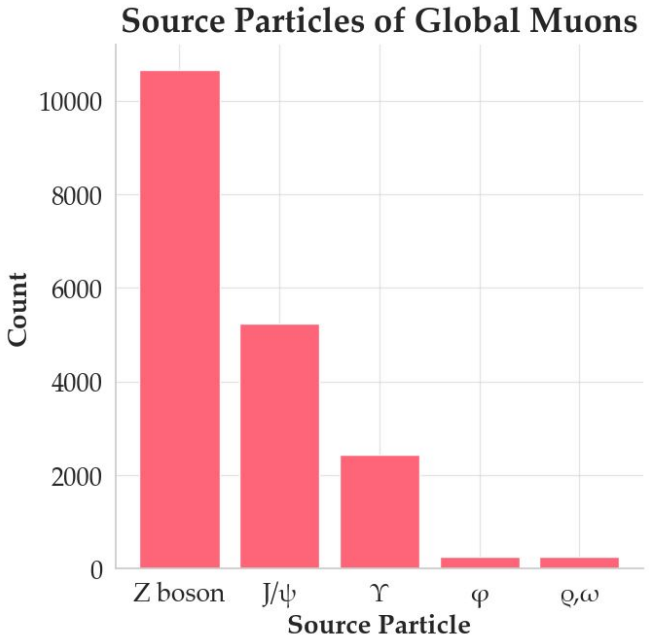
49,019

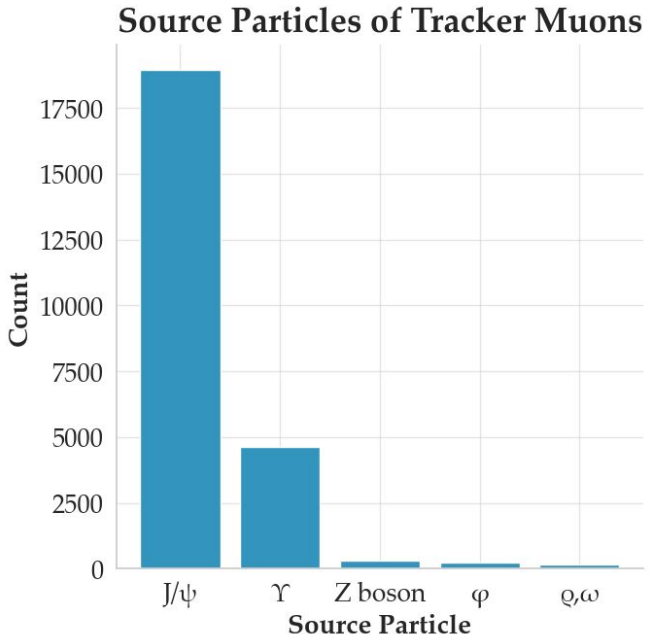
"Global Muon detected!"



"Tracker Muon detected!"

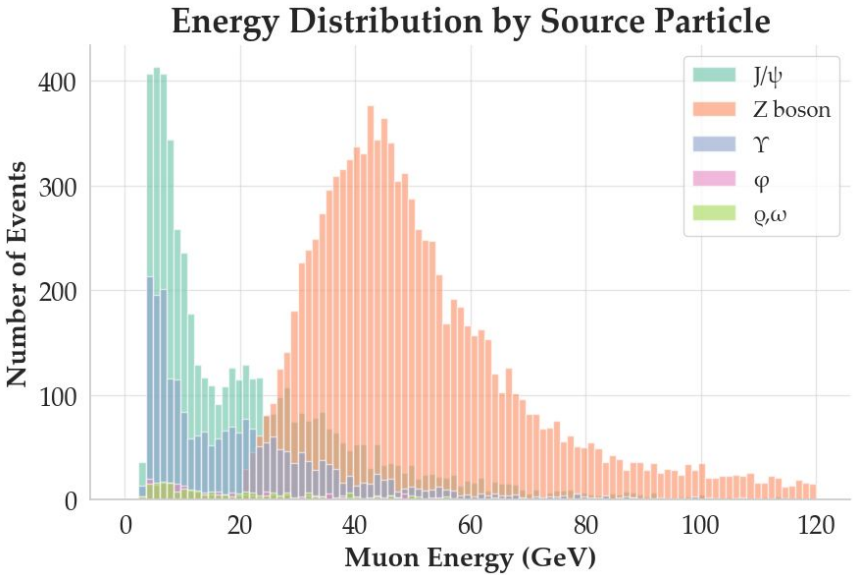
Distribution of Events by Source Particle



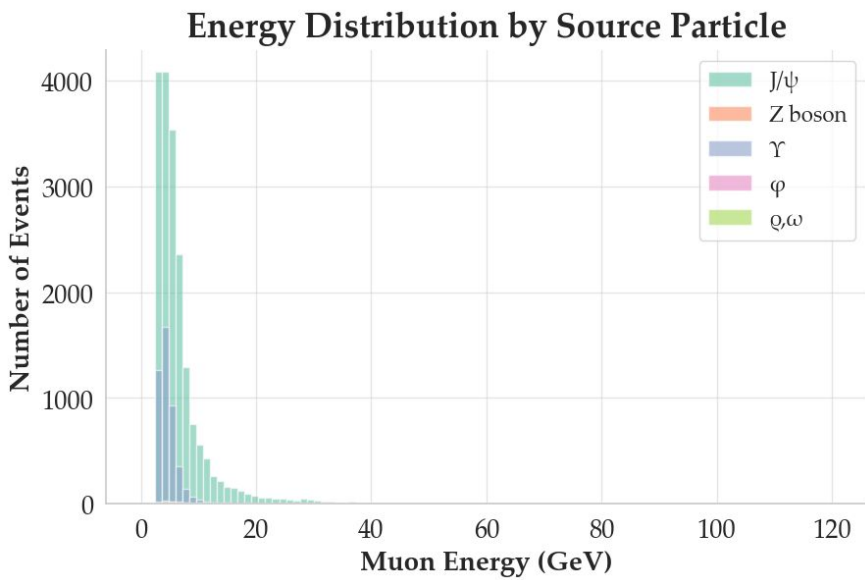


Energy Distributions

Global Muons



Tracker Muons



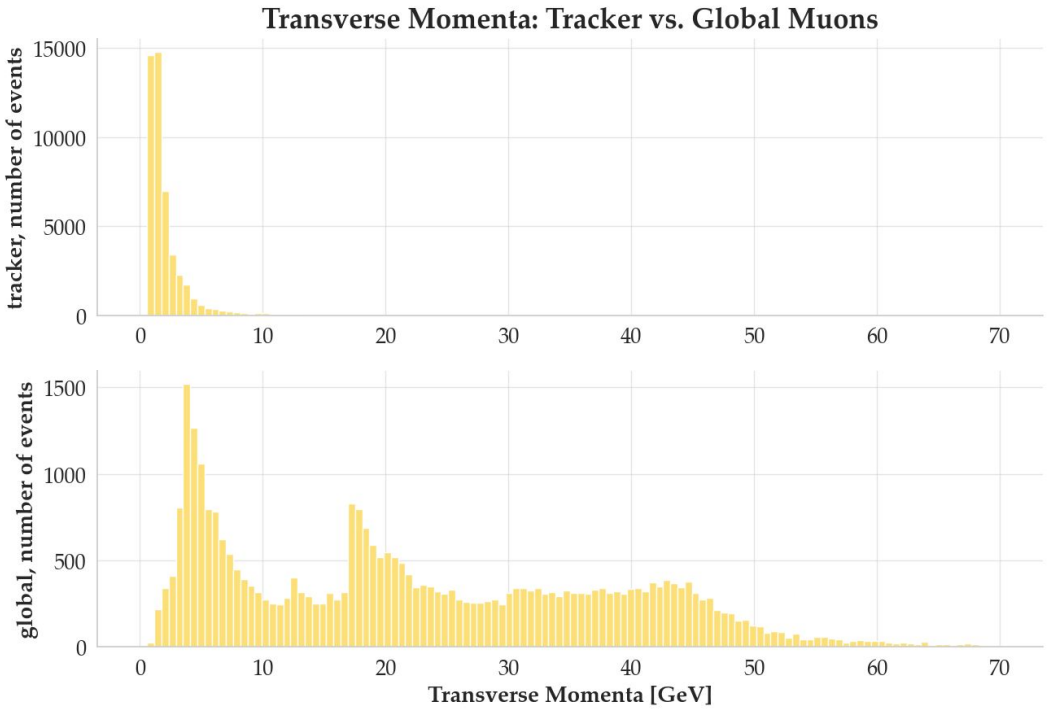
Transverse Momenta

T Muons

Lower Transverse momentum

G Muons

Wide range of Transverse Momentum



Summary: Global vs. Tracker Muons

Muon Type	Source Particle	Energy	Transverse Momentum
Tracker Muons	Z boson	Low energies (<4 GeV)	Low Momenta (<10 Gev)
Global Muons	J/ψ	Higher energies	Wide range

Dimuon Summary

Source Particle

- Most events come from Υ source particle.
- Heavier source particles produce dimuons with higher E and pt.

Pseudorapidity η

Most events have higher pseudorapidity

Detector Resolution

The resolution of the detector is lower at higher pseudorapidity (close to the beam axis).

Tracker vs. Global muons

- Global muons are good for low pT muons from J/ψ decays.
- Tracker muons are good for high pT

Future Work

φ	l	H
Study other properties like the azimuthal angle	Compare between dimuons and other leptons	Analyze Higgs decay to muons

Thank you!