Fermilab

U.S. Department of Energy

Analysis of H and HH signals at a multi-TeV Muon Collider

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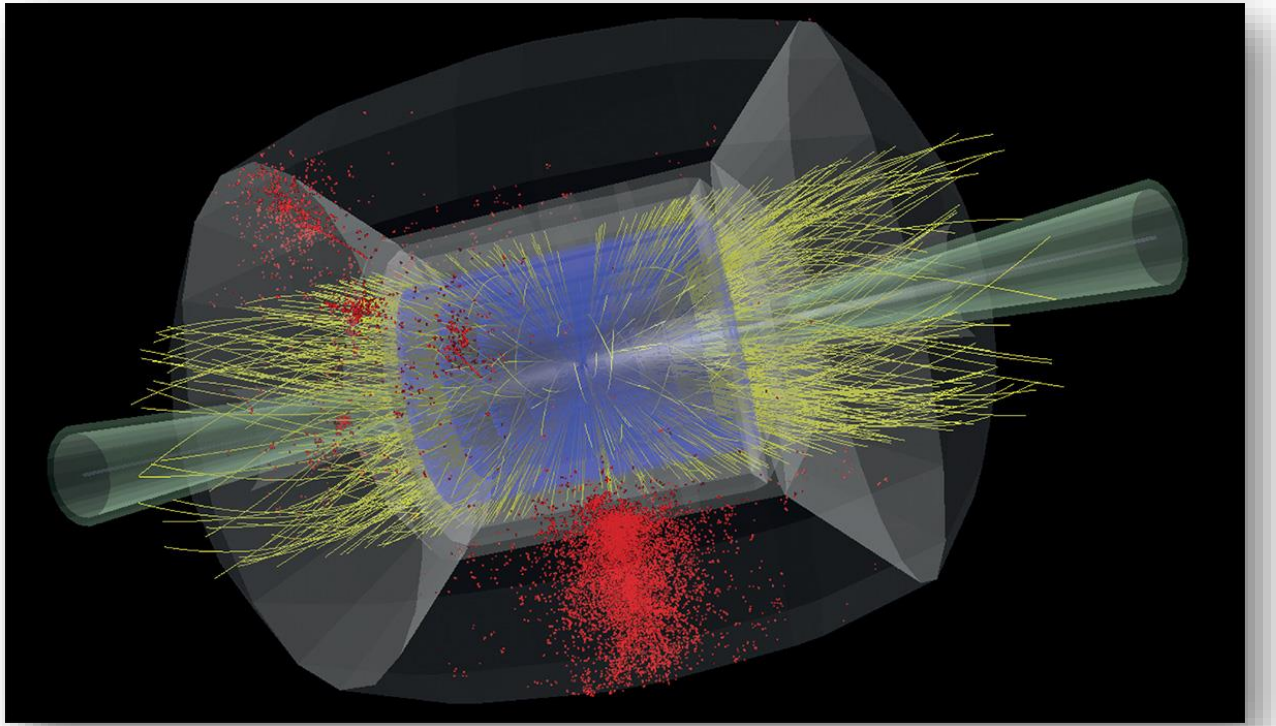
Muon Collider



- What:

Collision of $\mu^+\mu^-$
at $\sqrt{s} = 3\ TeV, \sqrt{s} = 10\ TeV$
To do precision measurements of H
and search for new physics

- Where:

Fermilab or CERN

- When:

2026 → Cost and Performance Estimation
2033 → Ready to Commit
2037 → Ready to Construct
2043 → Ready to Operate

- Who:

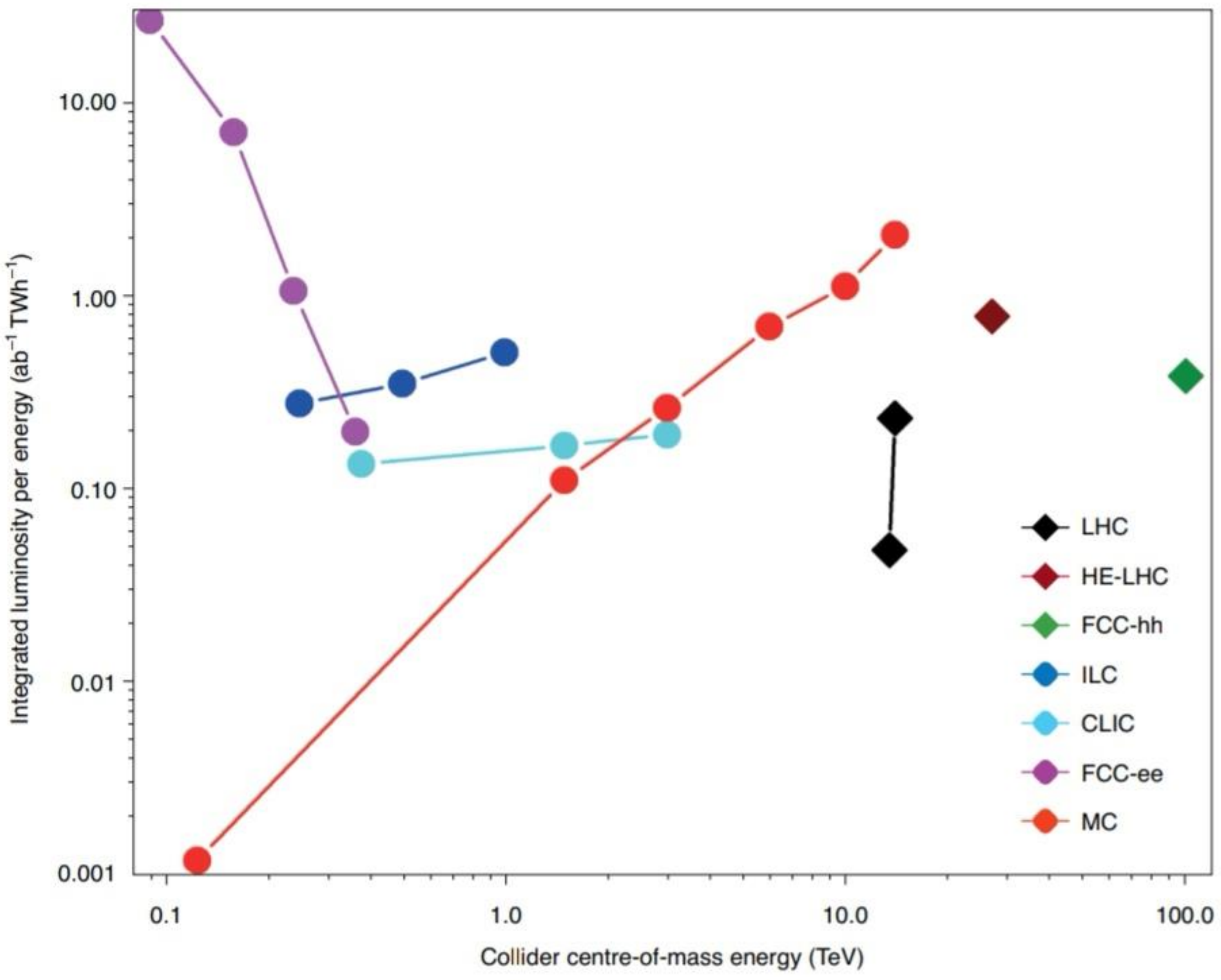
International Muon Collider Collaboration (IMCC) hosted by CERN

Benefits of Muon Collider

- ✓ Compared to circular e^+e^- accelerators, less synchrotron radiation thanks to the mass of the muons:

$$P = \frac{1}{6\pi\varepsilon_0}\frac{e^2}{c^2}\frac{v^2}{r^2}\left(\frac{E}{m}\right)^4$$

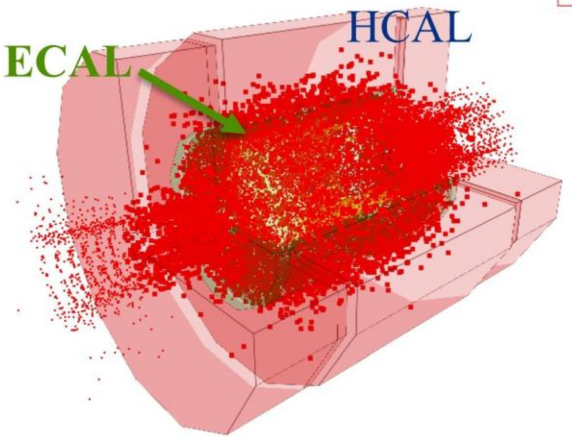
- ✓ Colliding elementary particles
- ✓ Compared to linear accelerators, elements can be used several times
- ✓ Luminosity per energy consumed

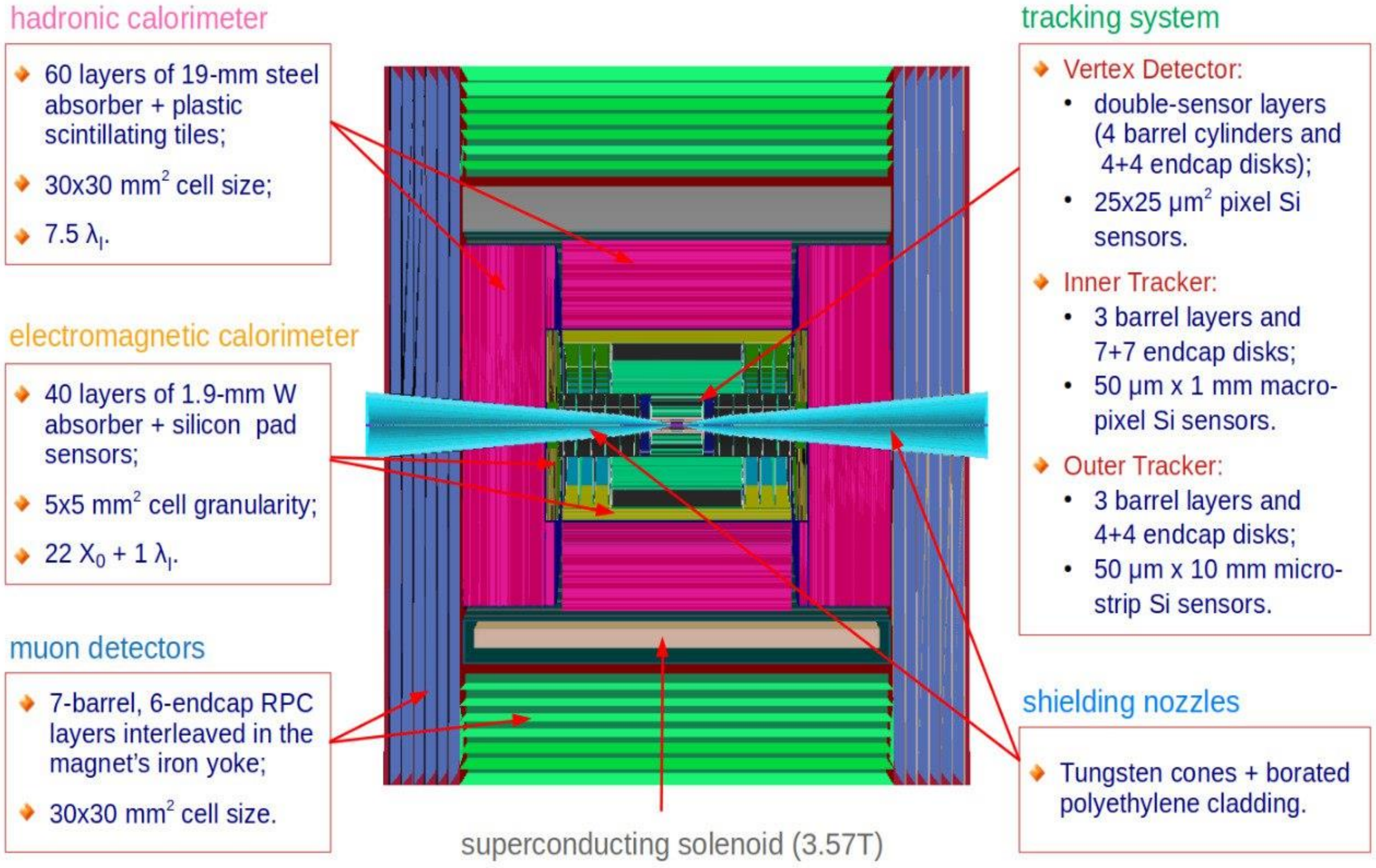


K. R. Long, Muon colliders to expand frontiers of particle physics, Nature Physics, VOL 17, Marzo 2021

BIB challenge

Muons decay with an average lifetime of $\tau_\mu = 2.2\ \mu s$ at rest. Decay products interact with machine elements and produce the Beam Induced Background (BIB) that degrades the performance of detector





DETECTOR, based on CLIC detector

Strategy of work

- Collisions are expected to happen at the maximum rate of 100 kHz, corresponding to the minimum time between crossings of 10 μs
- We need Trigger and Data Acquisition (TDAQ) systems to store not all events and select interesting physics events
- We want to study if we can have an efficient trigger based on the presence of one or more tracks above a certain PT threshold

➢ Study of physics signal

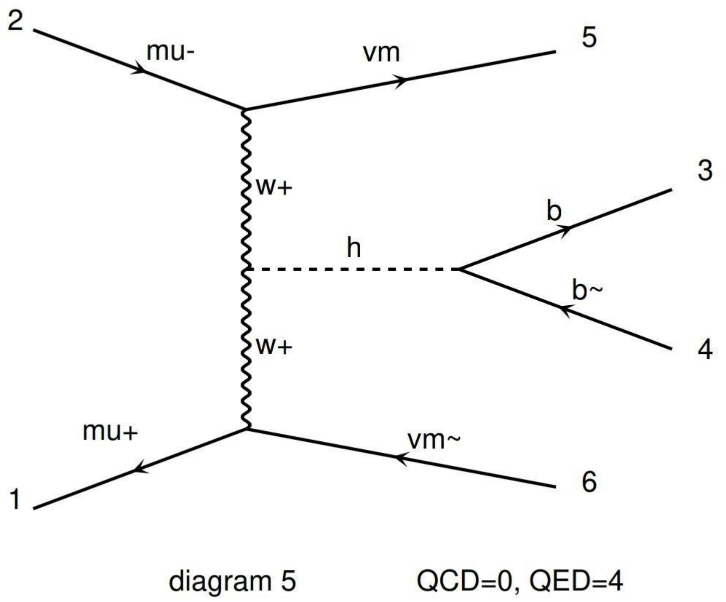
➢ Study of BIB properties

➢ Comparison between the two

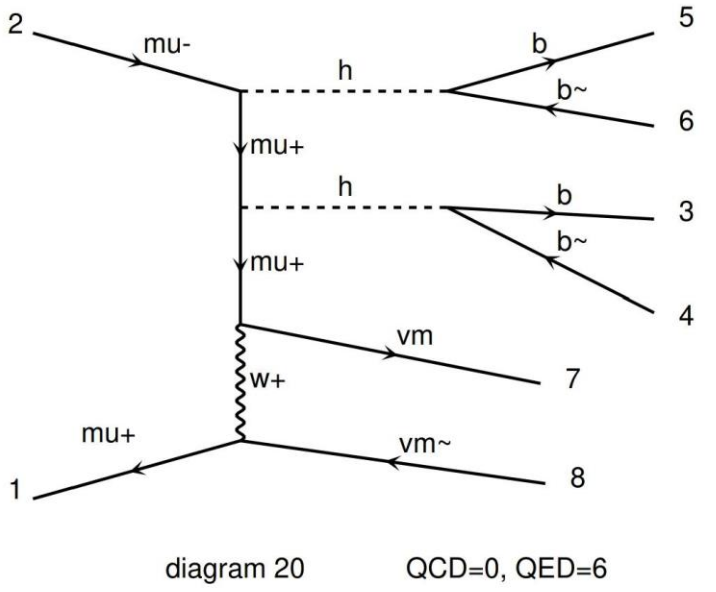
Monte Carlo simulations

Generation of 10000 events with Madgraph implemented with Pythia for adronization of b quarks and Delphes to obtain a Root file.

Samples are generated at $\sqrt{s} = 3\ TeV,\ L = 1ab^{-1}$, with the full standard model of



$\mu^+\mu^- \rightarrow H\nu_\mu\overline{\nu_\mu}\ , H \rightarrow b\bar{b}$



$\mu^+\mu^- \rightarrow HH\nu_\mu\overline{\nu_\mu}\ , H \rightarrow b\bar{b}$

Analyses with CERN-ROOT

- Selection of charged particles in the final state

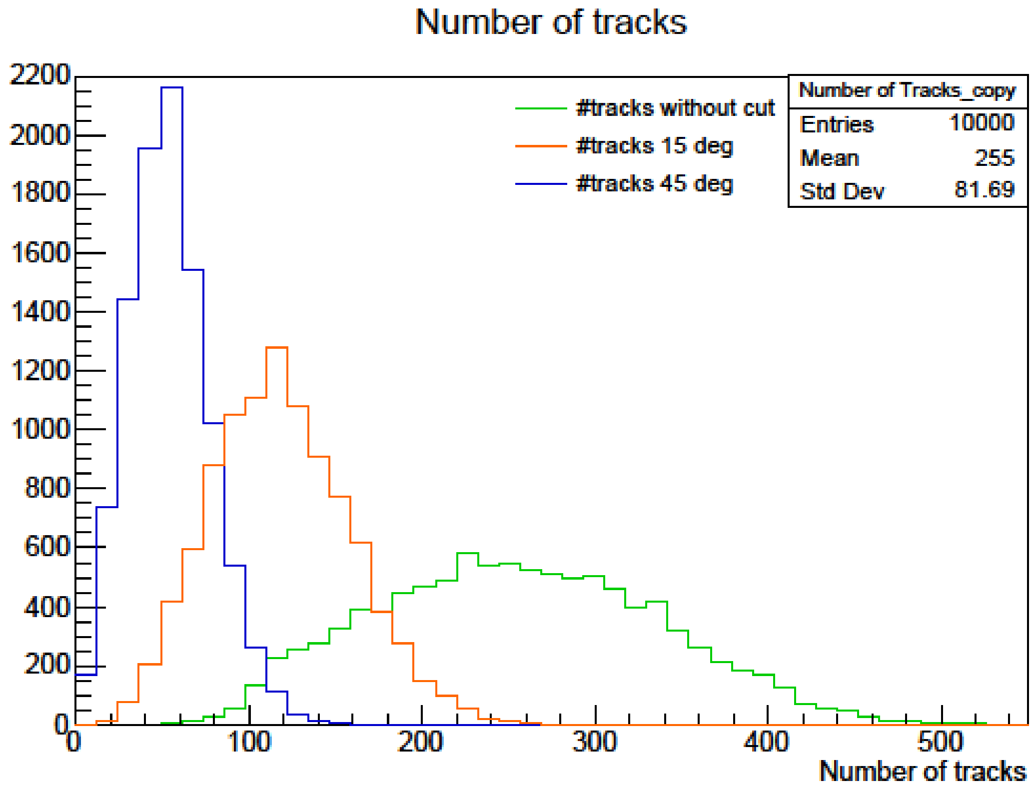
$$(K, \pi, p, e, \mu)$$

- Distributions analysed: P_T, θ, φ, E
- Different selections on *Theta*:

$$0 < \theta < 180°$$

$$15° < \theta < 165°$$

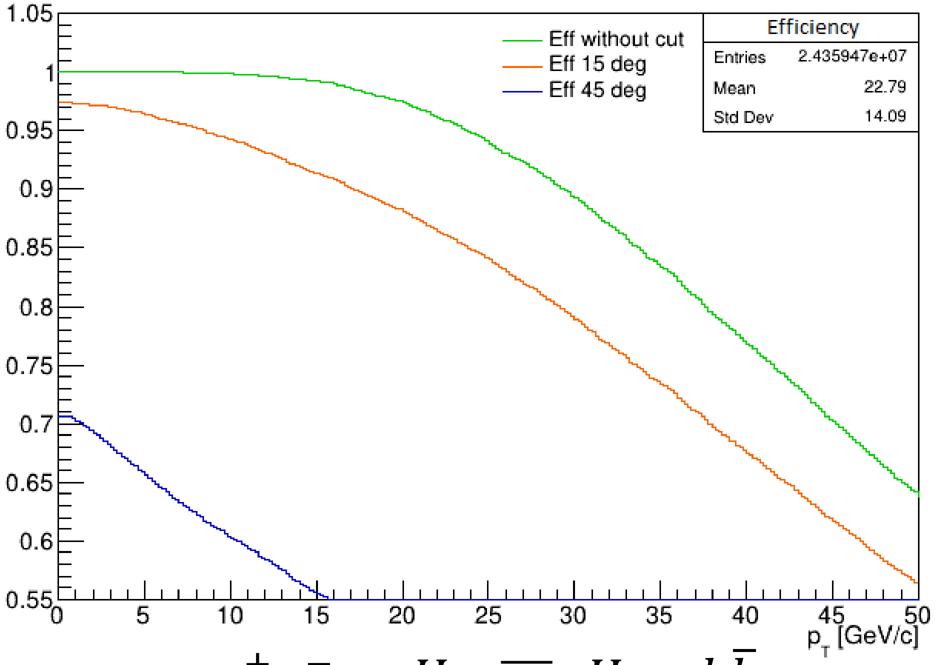
$$45° < \theta < 135°$$



Trigger strategy

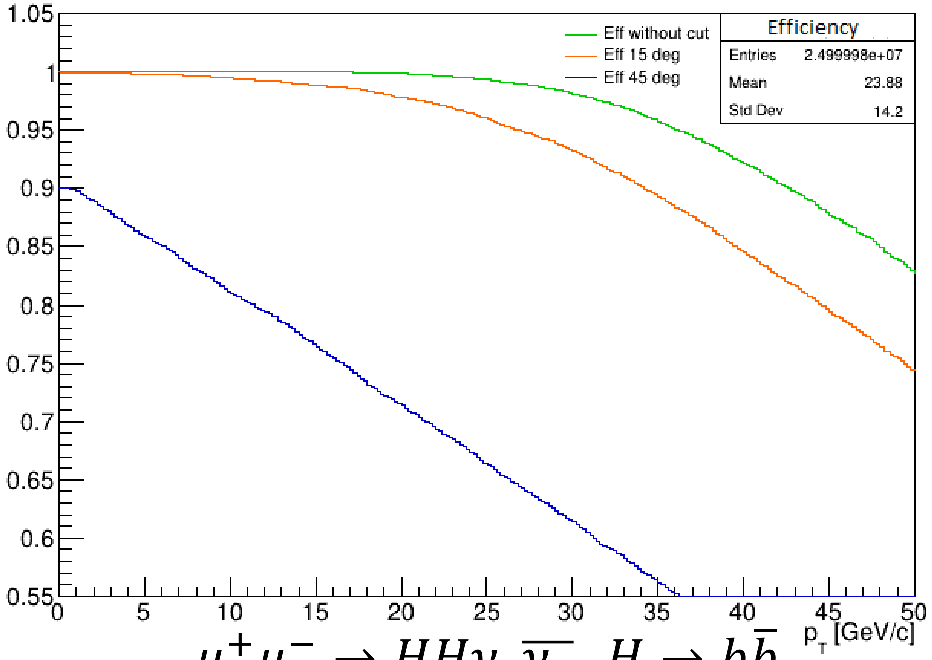
- A common trigger strategy is to look for one or more tracks with a large transverse momentum (PT)
- As a first step in this direction we plot the fraction of events containing at least one track with a PT above a certain threshold. This would represent the efficiency of a single track trigger for this particular process.
- We do this for different angular regions.
- The PT threshold is on the horizontal axis.

Efficiency for single Higgs



$$\mu^+\mu^- \to H\nu_\mu\overline{\nu_\mu}\,, H \to b\overline{b}$$

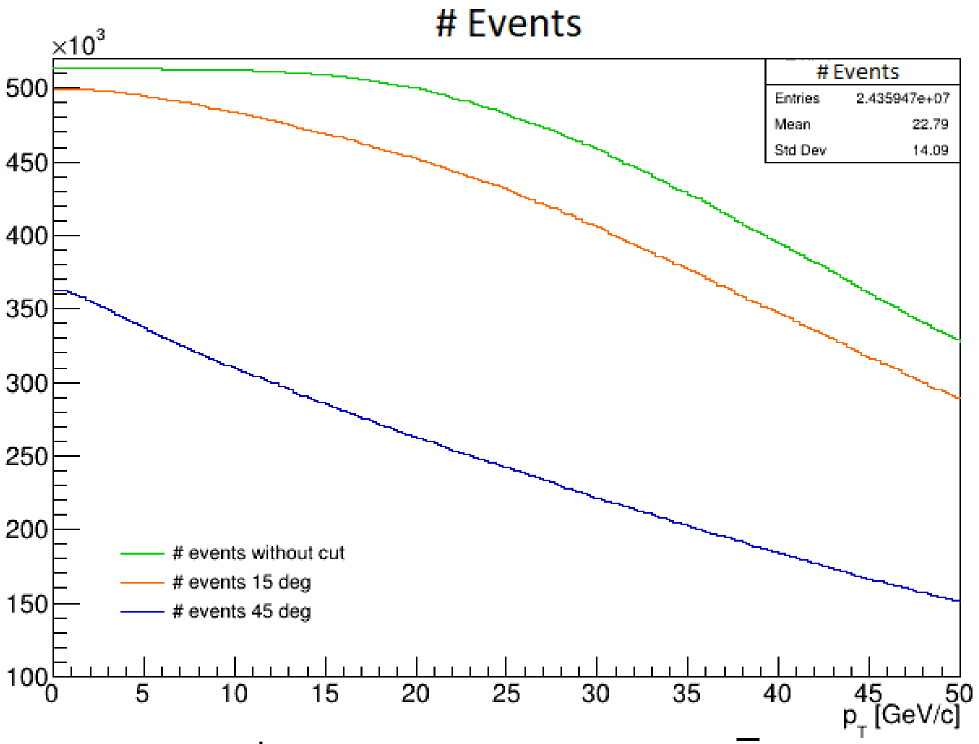
Efficiency for double Higgs



$$\mu^+\mu^- \to HH\nu_\mu\overline{\nu_\mu}\,, H \to b\overline{b}$$

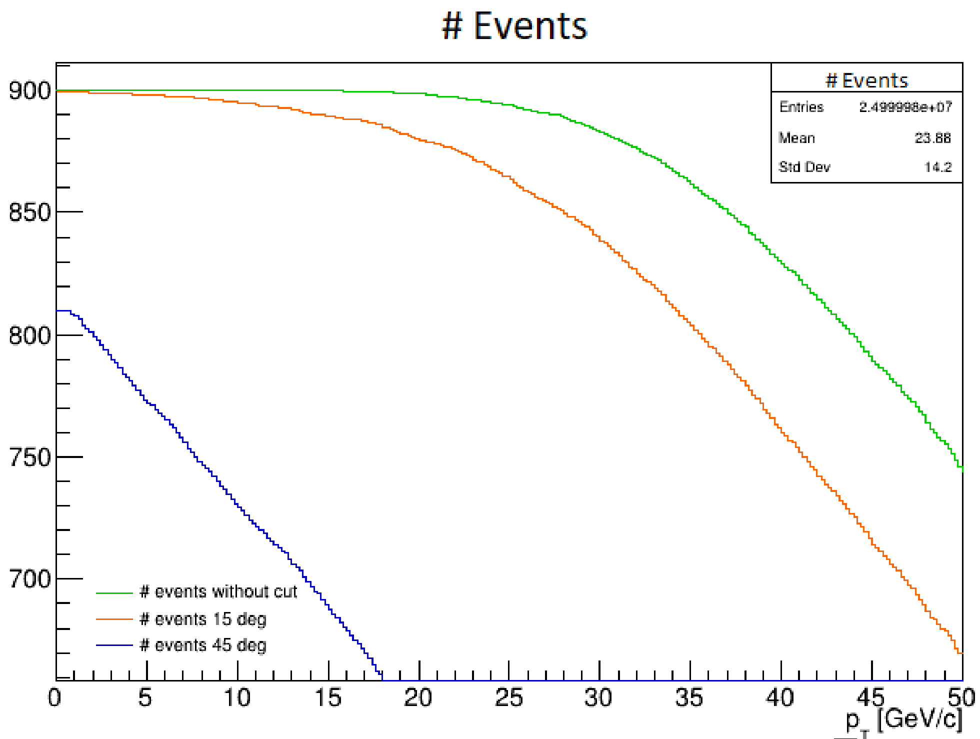
Number of events

- The number of events is calculated as the efficiency for a certain PT threshold multiplied by the cross section given by MadGraph and the integrated luminosity.
- The PT threshold is on the horizontal axis.
- $L = 1ab^{-1}\ (5\ years)$



$\mu^+\mu^- \rightarrow H\nu_\mu\overline{\nu_\mu}\,, H \rightarrow b\bar{b}$

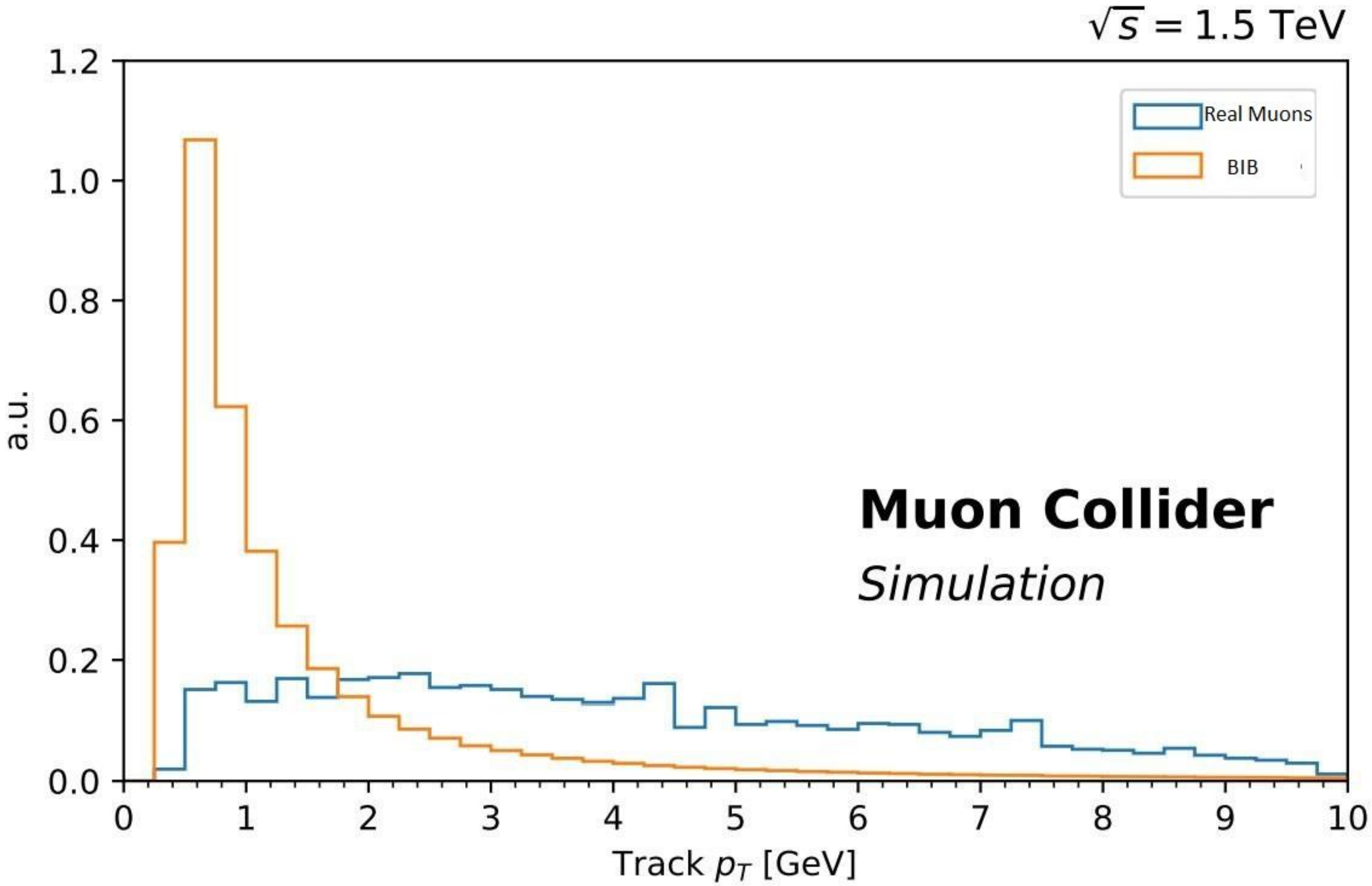
$\sigma = 0.5131\ pb$



$\mu^+\mu^- \rightarrow HH\nu_\mu\overline{\nu_\mu}\,, H \rightarrow b\bar{b}$

$\sigma = 0.0009\ pb$

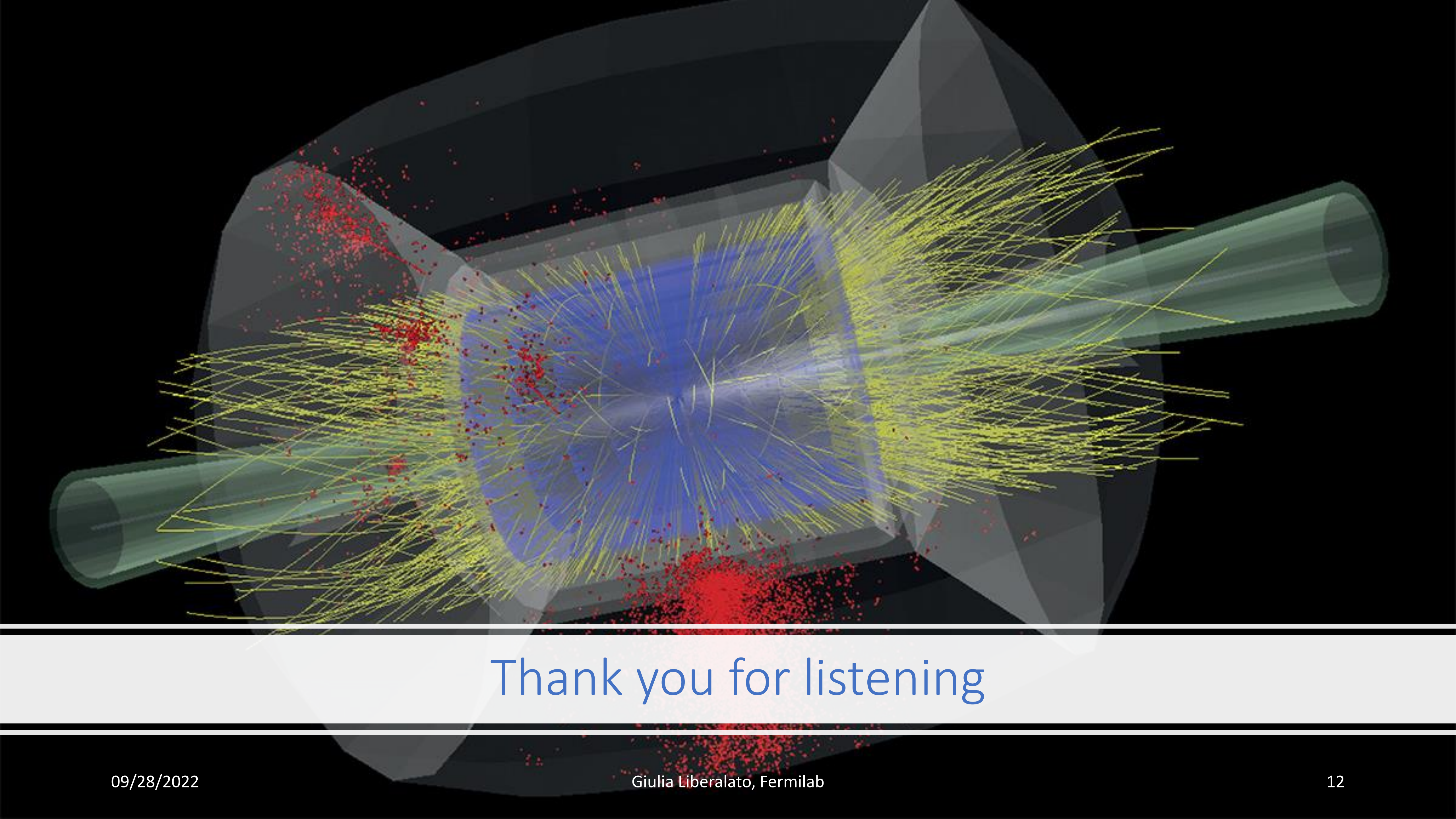
BIB properties



- It is important to study properties of background
- We can appreciate that BIB are low momentum particles
- This is the reason why I studied the efficiency as a function of the transversum momentum

Future prospects

- Study of BIB
- Analyses at $\sqrt{s} = 10\ TeV$
- Analyses of other tracks and how close they are



Thank you for listening