$H \rightarrow \gamma\gamma$ measurement at 10 TeV with the MUSIC detector

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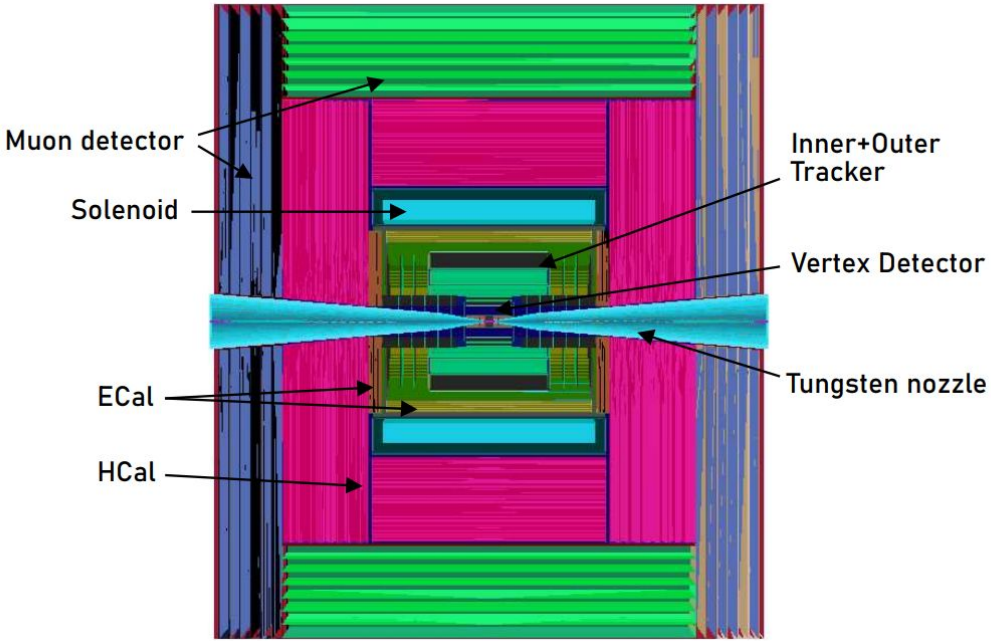
Objectives

- Investigate the $H \rightarrow \gamma\gamma$ decay channel using simulated data from 10 TeV muon collisions
    - Compare the photon reconstruction between Full Simulation (with beam-induced background) and DELPHES tuned for reproducing MUSIC performance
    - Determine the expected sensitivity of the $H \rightarrow \gamma\gamma$ cross section with the MUSIC detector

Procedures

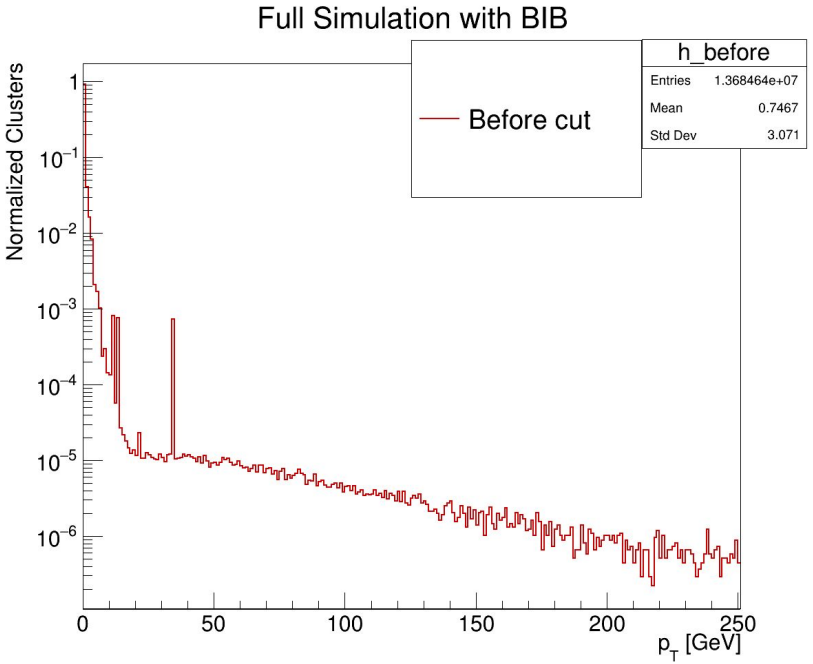
- Generation of Higgs and background events with WHIZARD/MADGRAPH
- MUSIC simulation with DDSIM
- Photon reconstruction with MARLIN:
    - Beam-induced background (BIB) overlay
- Analysis:
    - Apply Photon Energy Corrections
    - Apply pT cut, theta cut for cleaning the sample
    - Determination of the diphoton invariant mass distribution
- To speed up the analysis a DELPHES simulation is used
- Construction of a pseudo-dataset assuming 10 ab-1 of integrated luminosity
- Fit to the diphoton invariant mass distribution to determine the expected signal sensitivity

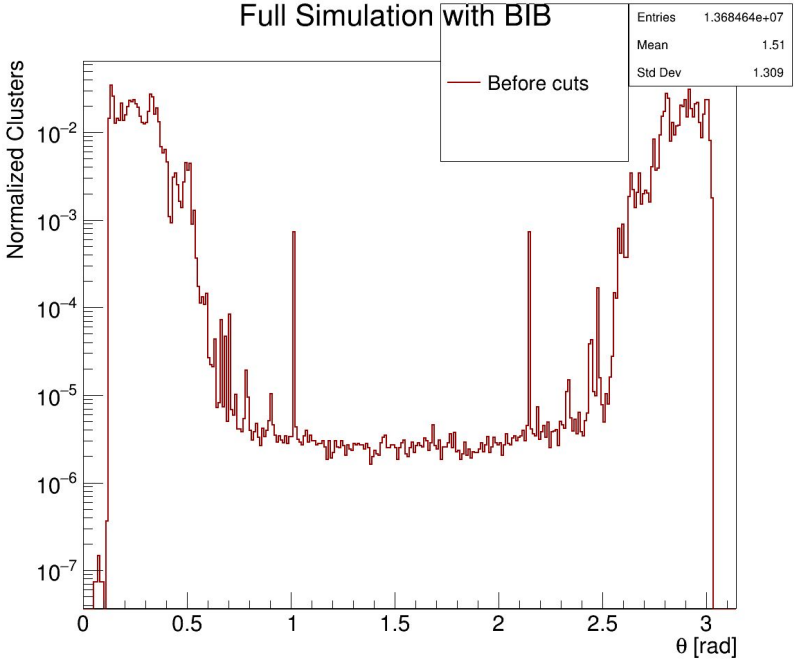
MUSIC detector



- Photons are reconstructed with CRILIN calorimeter
- The calorimeter reconstruction algorithm and energy corrections have been defined in Leonardo Palombini Thesis:
  https://thesis.unipd.it/retrieve/85415af8-64c3-4b21-a607-e3327da707b9/Palombini_Leonardo.pdf

Photon Pt/theta distributions and requirements





- The pT and theta distributions of $\mu^+\mu^- > \nu\nu H(\gamma\gamma)$ events are studied with the Full Simulation
- **Pt>20 GeV requirement removes the low energy BIB combinatorial**
- **An artifact around Pt=35 GeV corresponds to a spike at low theta**
- **Additional theta>0.2 requirement is applied to remove this spike**

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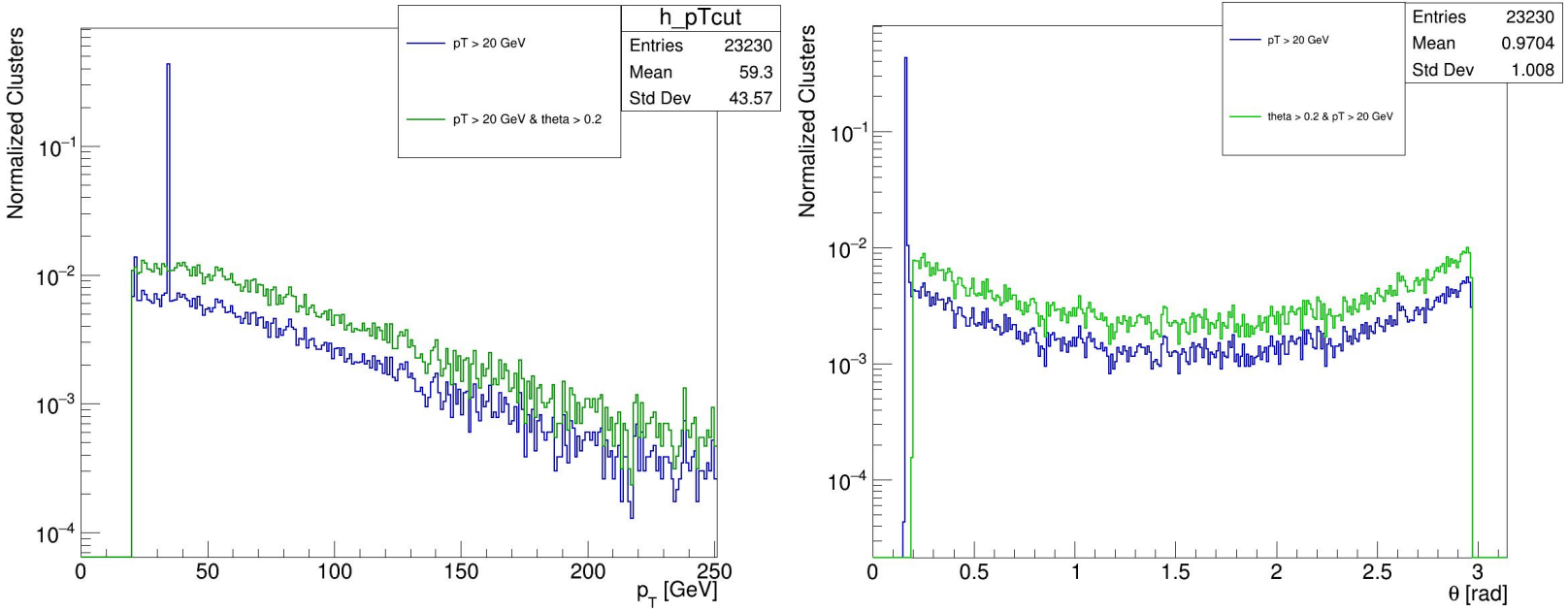

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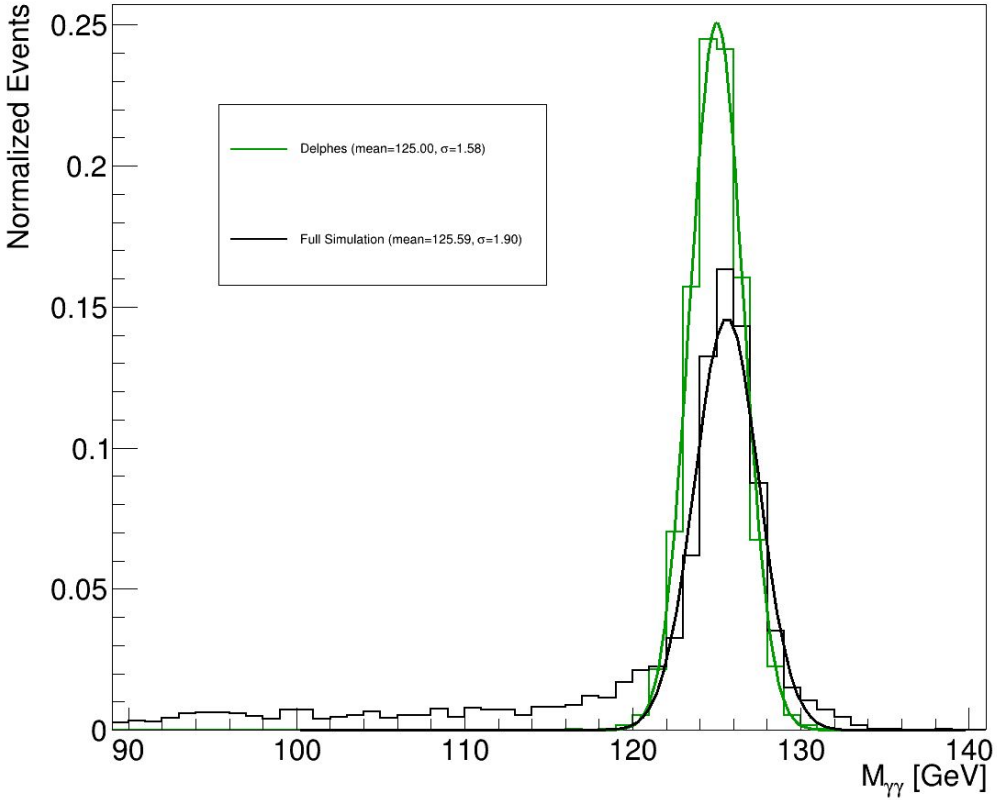
Comparison of Diphoton Invariant Mass between full and fast simulation



- DELPHES card prepared including MUSIC performance with BIB
- Signal width with full sim. = 1.90 GeV
- Signal width with fast sim. = 1.56 GeV (and no low mass tail)
- Fast/full sim. are close, but difference probably due to missing theta-energy correlations in DELPHES card

Expected number of events

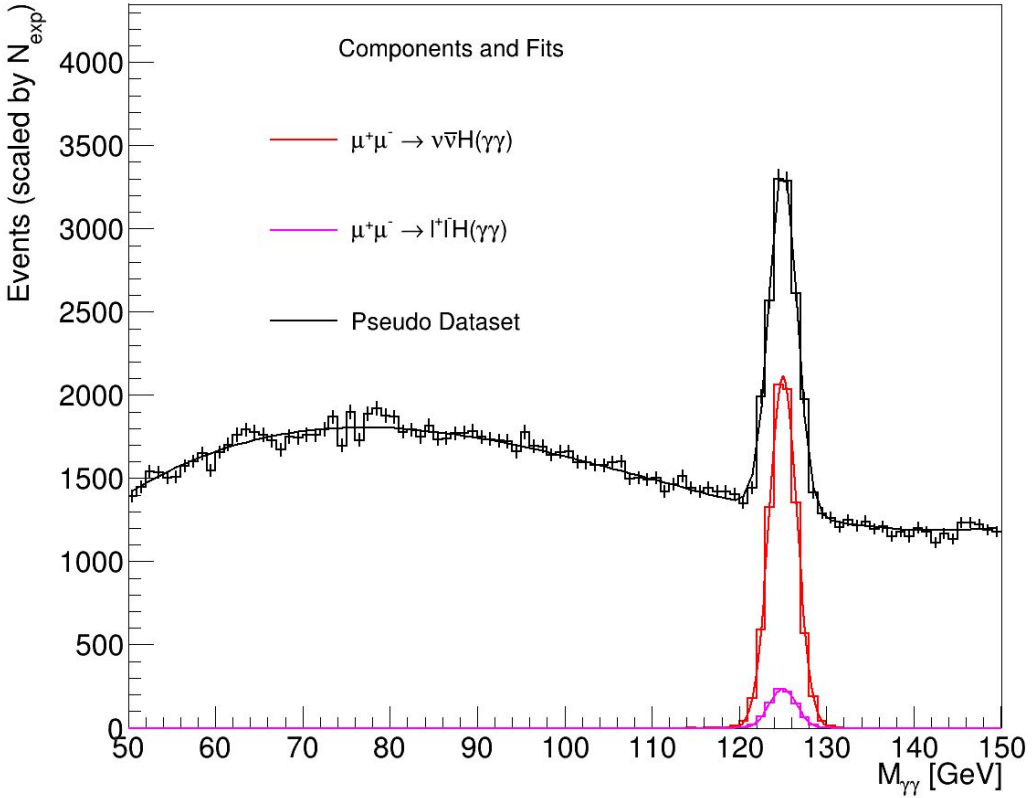
Simulations	σ(ab)	ε	N(exp)
μ+μ- > ν+ν-H(γγ)	1946	0.434	8425
μ+μ- > l+l-H(γγ)	210.6	0.44	926.85
μ+μ- > ν+ν-γγ	9125537	0.00177	161704
μ+μ- > l+l-γγ	1537	0	0
μ+μ- > l+l-γ	—	—	—
μ+μ- > γγ	30410	0	0

- **Generated from whizard and simulated by Delphes**
- N(exp) = $\mathcal{L}\sigma\varepsilon$ ($\mathcal{L}$=10 ab-1)
- **μ+μ- > l+l-γγ** and **μ+μ- > l+l-γ** : for these backgrounds, almost 0 events are selected, but electron mis-identification is not yet included in the DELPHES card

Applied Cuts

- **Theta > 0.2 rad**
- **pT > 20 GeV**
- **50 < Mgg < 150 GeV**

Diphoton invariant mass distribution fit



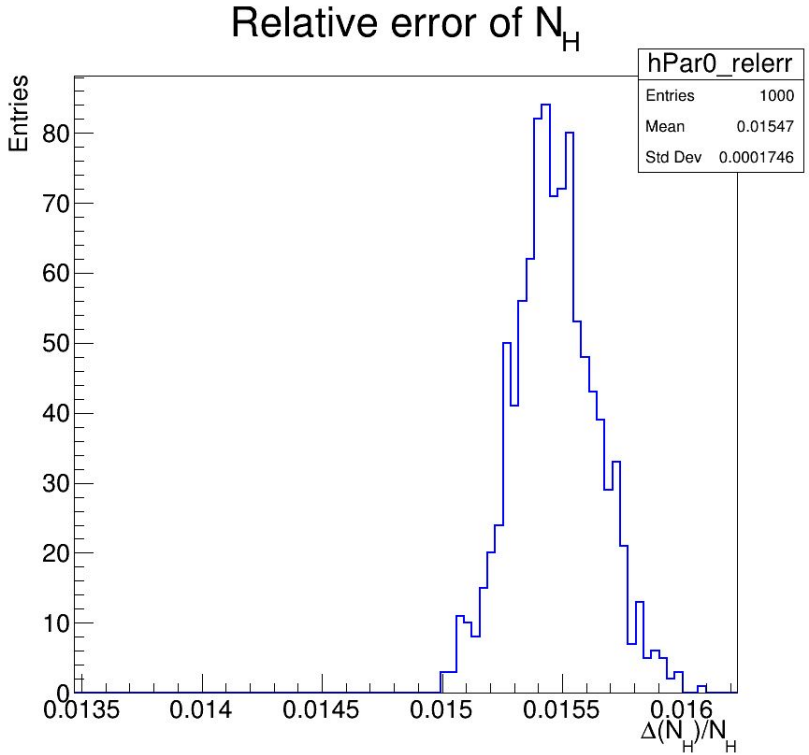
1. Background and signal models are obtained by fitting the mass distributions in the DELPHES simulation

2. Full data model obtained by normalizing the background and signal models to the number of expected events

3. Pseudo-dataset is obtained by sampling the full model

4. A fit to the diphoton invariant mass is performed to measure the number of signal events. In this fit the signal and background yields are floated

Relative Statistical Uncertainty Distribution



- Several pseudo-datasets are generated and fits are performed
- For each fit, the number of signal events (NH) is determined
- The distribution of the relative statistical uncertainty on NH is plotted
- **The average statistical uncertainty is 1.55%**

Conclusions

- The estimated statistical uncertainty on the measurement of the $H \to \gamma\gamma$ yield at 10 TeV with the MUSIC detector is 1.55%
- It is an improvement wrt the simulation study at 3 TeV where 7.6% was obtained
- The phenomenological study here (https://arxiv.org/pdf/2203.09425) predicts 1.6% at 10 TeV that is compatible with our result
- This is a preliminary result, few improvement are required:
  - Better modeling of the photon performance with the fast simulation
  - Evaluation of the mis-identification backgrounds from electrons

THANK YOU