Studies of granularity of a hadronic calorimeter for tens-of-TeV jets at a 100 TeV pp collider

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Abstract

Texts

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1. Introduction

Particle collisions at energies beyond those attained at the LHC will lead to many challenges for detector technologies. Future experiments, such as high-energy LHC (HE-LHC), future circular pp colliders of the European initiative, FCC-hh [?] and the Chinese initiative, SppC [?].

The studies of this paper are based on full Geant4 simulation and reconstruction as implemented in the detector described in [?]. This study included the discussion of the impact of the calorimeter granularity on the shape of hadronic showers in terms of the calorimeter hits for two particles separated by some angle. It was concluded that HCAL granularity is essential in resolving two close-by particles for energies above 100 GeV. This paper makes a new step towards understanding of this problem using high-level physics quantities used in physics studies.

2. Studies of effective jet radius

The effective radius is the average of the energy weighted radial distance in $\eta - \phi$ space of jet constituents. Recently, it has been studied for multi-TeV jets in Ref.[?].

New we sill study jet splitting the effect of granularity on jet splitting scales. A jet k_T splitting scale [?] is defined as a distance measure used to form jets by the k_T recombination algorithm [? ?]. This has been studied by ATLAS [?], and more

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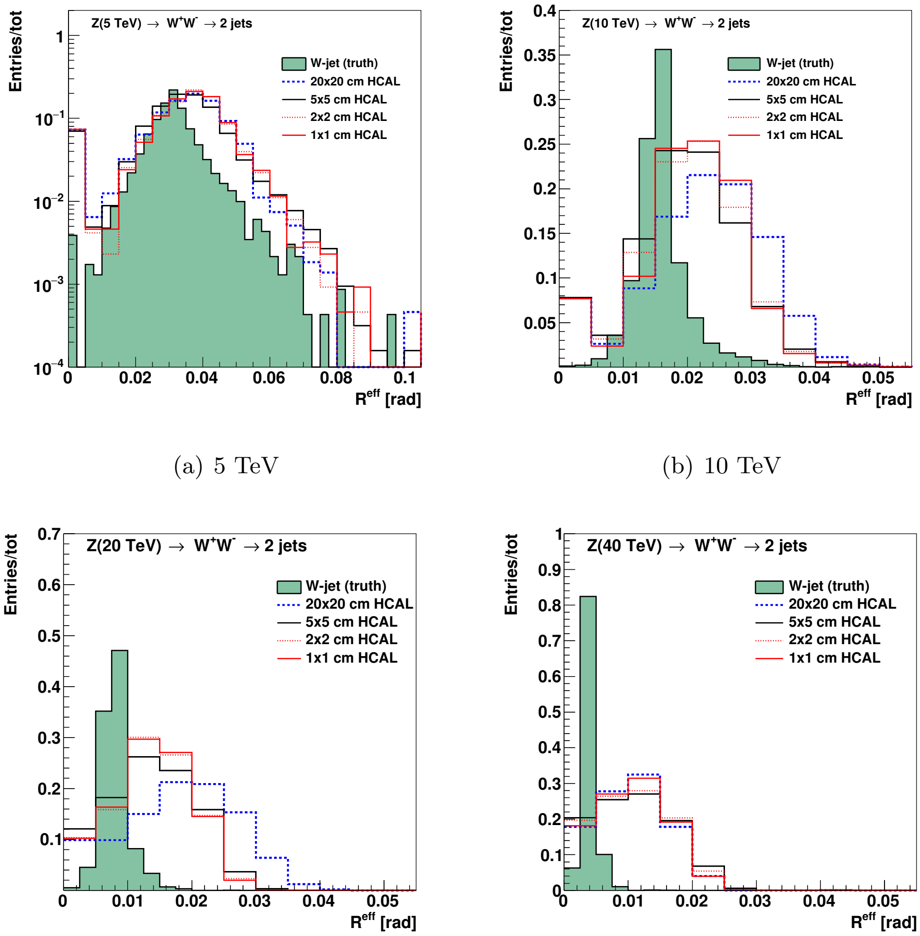


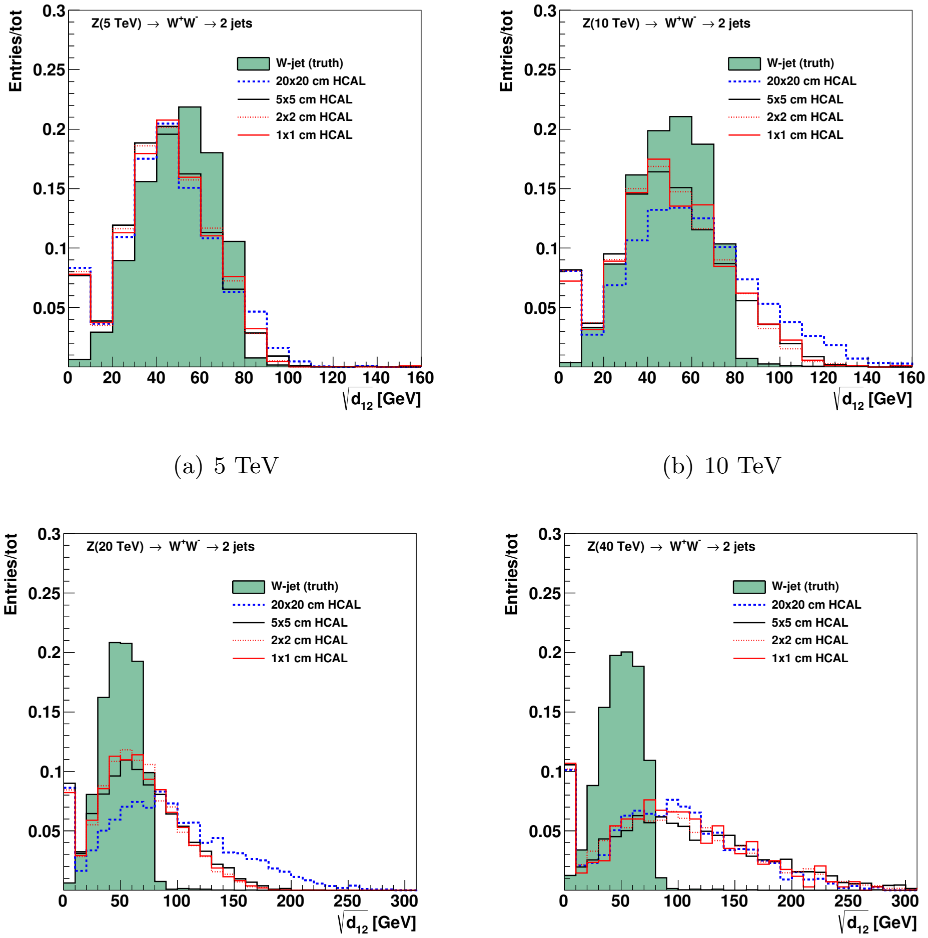
(a) 5 TeV

(b) 10 TeV

(c) 20 TeV

(d) 40 TeV

Figure 1: Jet effective radius for different jet transverse moment and HCAL granularity.



(a) 5 TeV

(b) 10 TeV

(c) 20 TeV

(d) 40 TeV

Figure 2: Jet splitting scale for different jet transverse moment and HCAL granularity.

recently in the context of 100 TeV physics [?]. The distribution of the splitting scale $\sqrt{d_{12}} = \min(p_T^1, p_T^2) \times \delta R_{12}$ [?] at the final stage of the k_T clustering, where two subjets are merged into the final one, is shown in Fig. 2.

3. Studies of signal and background separation using calorimeter clusters

In this section, we study different jet substructure variables and compare their ability to separate the signal and the background for different detector sizes using calorimeter clusters.

Figures 3–5 show the ROC curves of three variables, $c_2^{(1)}$ [?] , τ_{21} [?], and τ_{32} [?], respectively. Three different cell sizes of the HCAL are compared for four collision energies. For different cell sizes with the same signal efficiency, the one with the highest background rejection rate, namely (1-background efficiency), has the highest separate power.

In Figure 3 for the variable $c_2^{(1)}$, the ROC curves of the three detector cell sizes are close to each other for each collision energy. Therefore, this variable is not sensitive to the detector cell size.

For the τ_{21} variable in Figure 4, at 5 TeV, the smallest detector size (1×1 cm) can separate the background from the signal well. However, this is not the usual case as the ROC curves nearly merge together at higher collision energy. In addition, the detector with the bigger size tends to have higher separation power than the smaller detector size in 20 and 40 TeV collision energy.

Figure 5 shows the variable τ_{32}, where the smallest detector size has the best separation power for all collision energies.

In conclusion, in all the cases of energy and detector size, the variable $c_2^{(1)}$ has the best separation power compared to the other two variables. In addition, the variable τ_{32} follows the expectation that smaller detector size has better separation power.

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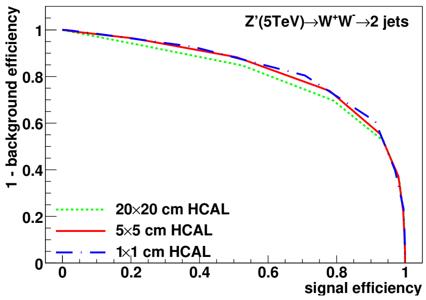
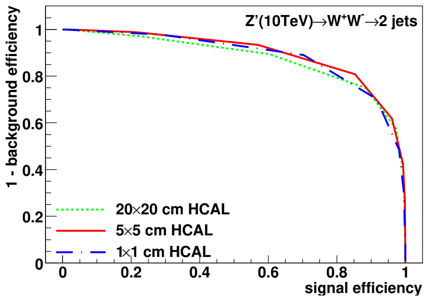
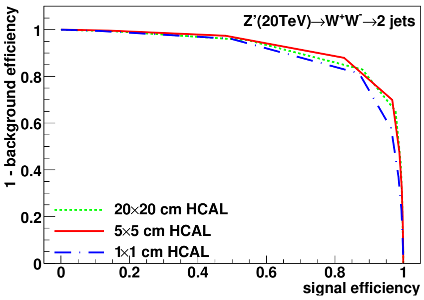


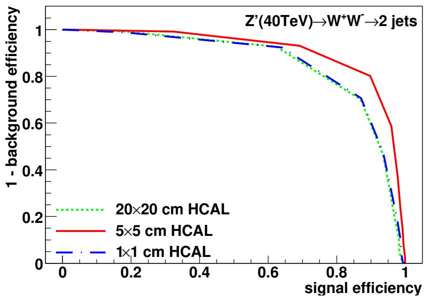
(a) 5 TeV



(b) 10 TeV

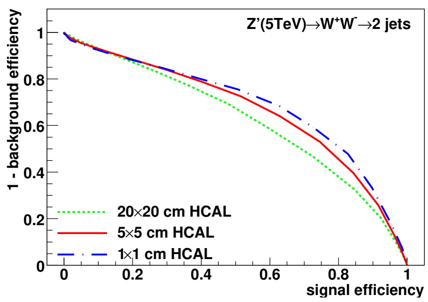


(c) 20 TeV

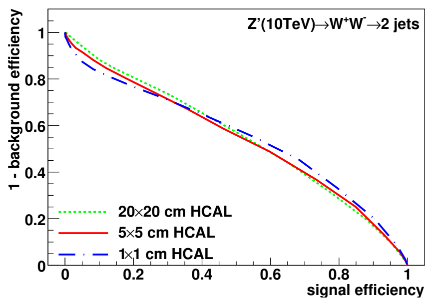


(d) 40 TeV

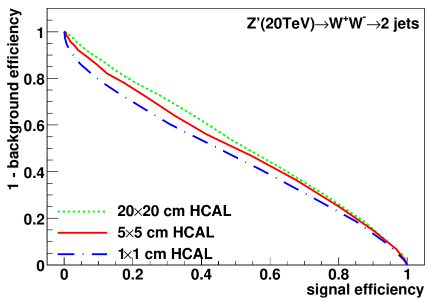
Figure 3: Signal efficiency versus background rejection rate using $c_2^{(1)}$.The energies of collision at (a)5, (b)10, (c)20, (d)40TeV are shown here. In each picture, the three ROC curves correspond to different detector sizes.



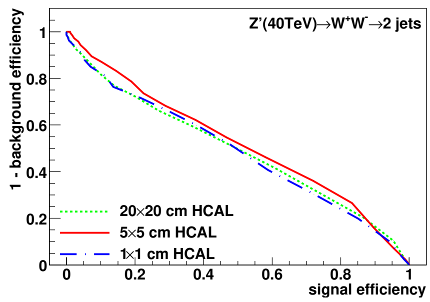
(a) 5 TeV



(b) 10 TeV



(c) 20 TeV



(d) 40 TeV

Figure 4: Signal efficiency versus background rejection rate using τ_{21}.The energies of collision at (a)5, (b)10, (c)20, (d)40TeV are shown here. In each picture, the three ROC curves correspond to different detector sizes.

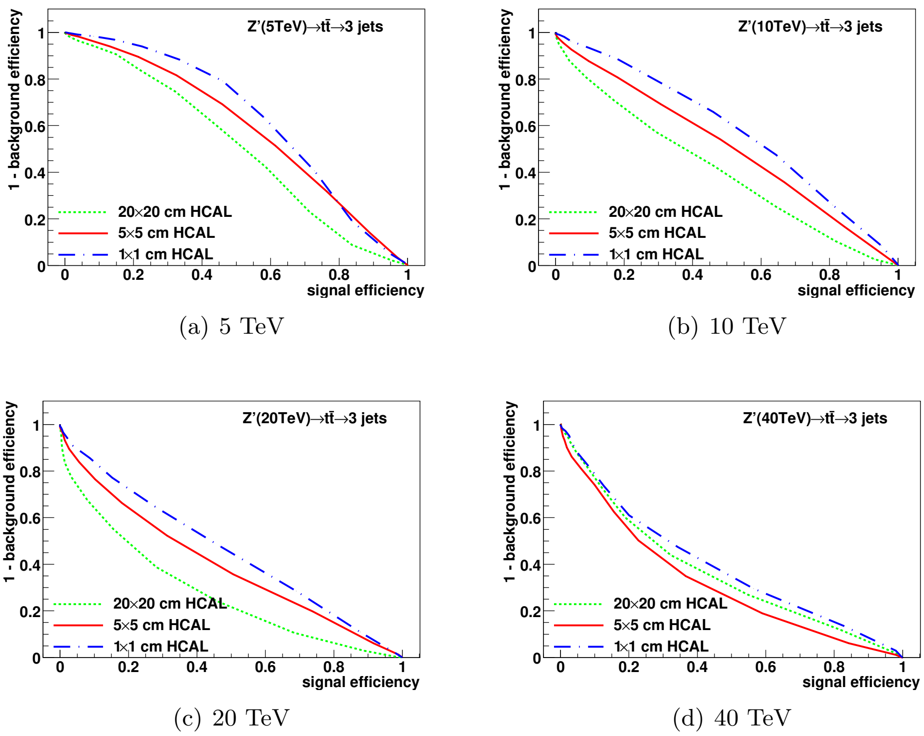


Figure 5: Signal efficiency versus background rejection rate using τ_{32}.The energies of collision at (a)5, (b)10, (c)20, (d)40TeV are shown here. In each picture, the three ROC curves correspond to different detector sizes.

References