Study of Jet Substructure Variables with the SiFCC Detector at 100 TeV

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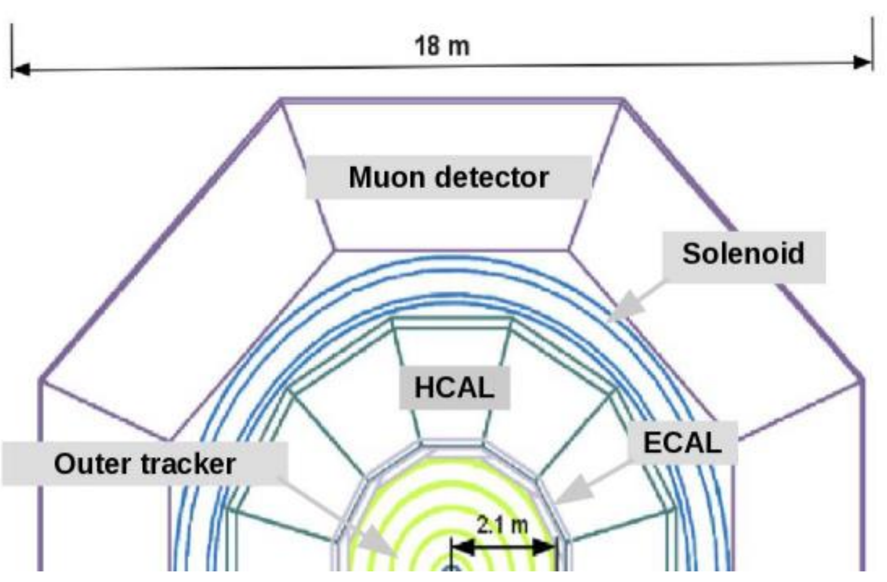
Abstract:

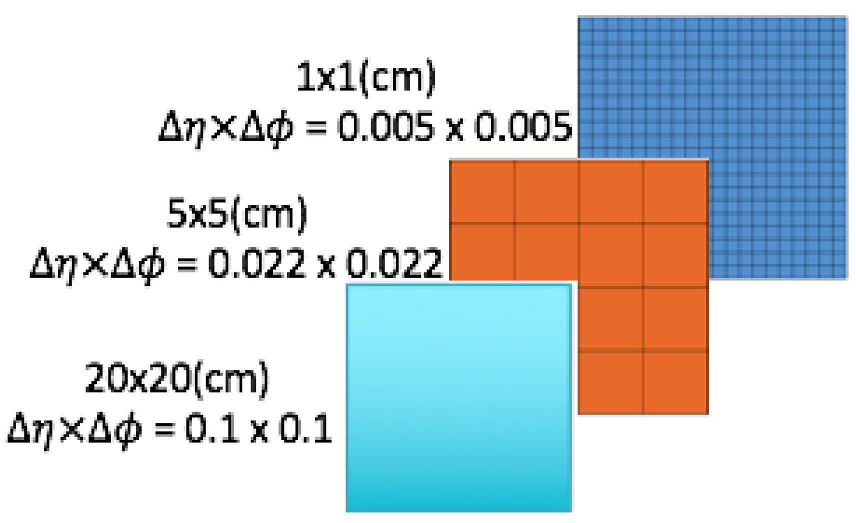
We study the performance of jet substructure variables with a detector designed for very high energy proton collisions, the SiFCC detector. The two-prong jets from Z'->WW and three-prong jets from Z'->ttbar are compared with the background from light quark jets at the same energy. The calorimeter geometry is benchmarked in various configurations in order to understand the impact of granularity on variables such as groomed jet mass, Njettiness and energy correlations within the jets. We present results on signal efficiency and background rejection using full GEANT simulations.

GEANT 4 Simulation of Future Detector



From[1]

HCAL cell sizes



Barrel	Technology	pitch/cell	radii (cm)	$\|z\|$ size (cm)
Vertex detector	silicon pixels/5 layers	25 μm	1.3 - 6.3	38
Outer tracker	silicon strips/5 layers	50 μm	39 - 209	921
ECAL	silicon pixels+W	2×2 cm	210 - 230	976
HCAL	scintillator+steel	5×5 cm	230 - 470	980
Solenoid	5 T (inner), -0.6 T (outer)	-	480 - 560	976
Muon detector	RPC+steel	3×3 cm	570 - 903	1400

Basic Jet Reconstruction Algorithm

$$d_{ij} = \min(k_{ti}^{2p}, k_{tj}^{2p})\frac{\Delta_{ij}^2}{R^2}$$

$$d_{ib} = k_{ti}^{2p}$$

$\Delta_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$

(1)i, j: the i and j particle

(2)k_{ti}, k_{tj}: the particle i and j transverse momenta

If $d_{ij} < d_{ib}$, i and j particle will be merged into one particle

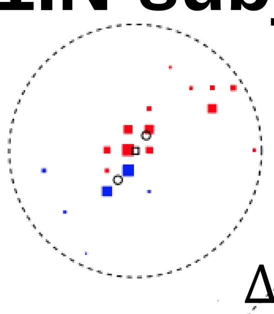
1.p=0 : Cambridge/Aachen algorithm

2.p=1 : kt algorithm

3.p=-1 : anti-kt algorithm

Jet Substructure Variables

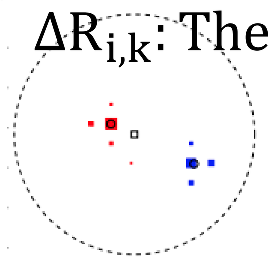
1.N-subjetness[2]:



$$\tau_N = \frac{1}{d_0}\sum_k P_{t,k} \min\{\Delta R_{1,k}, \Delta R_{2,k} \dots \Delta R_{N,k}\}$$

$$d_0 = \sum_k P_{t,k} R_0$$

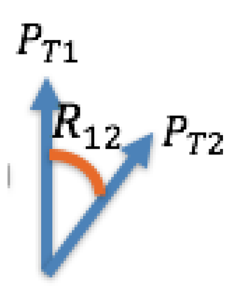
$\Delta R_{i,k}$: The distance between constuient in the eta − phi plane



R_0: The cone size we want to cluster

$$\tau_{21} = \frac{\tau_2}{\tau_1}, \tau_{32} = \frac{\tau_3}{\tau_2}$$

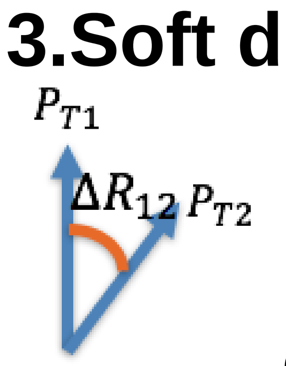
2.Energy correlation function[3]:



$$ECF(N,\beta) = \sum_{i_1<i_2<..<i_N\in J}\left(\prod_{a=1}^{N} PT_{ia}\right)\left(\prod_{b=1}^{N-1}\prod_{c=b+1}^{N}\Delta R_{ibic}\right)^\beta$$

$$C_N^{(\beta)} \equiv \frac{ECF(N+1,\beta)ECF(N-1,\beta)}{ECF(N,\beta)^2}$$

3.Soft drop[4]:



$$\frac{\min(P_{T1}, P_{T2})}{P_{T1} + P_{T2}} < Z_{cut}\left(\frac{\Delta R_{12}}{R_0}\right)^\beta$$

$\beta > 0$: Remove both (soft) and (wide angle)

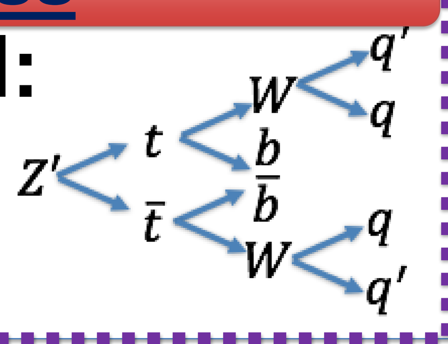
$\beta = 0$: Depend on the cut to select the asymmetry

$\beta < 0$: Remove both (soft) and (collinear)

Signal and Background Process

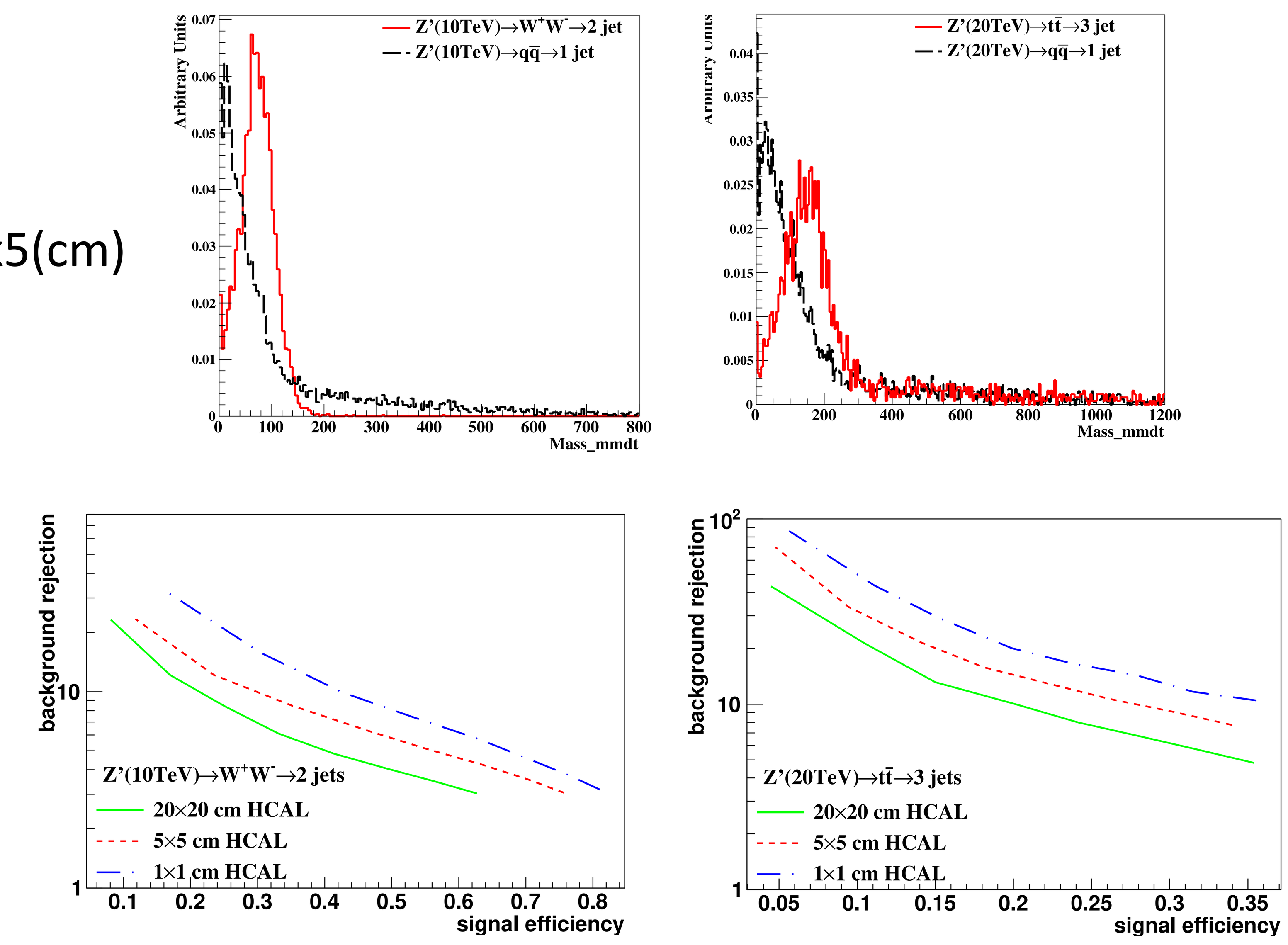
Background:

Signal:



Results: Soft drop mass at $\beta = 0$

5x5(cm)



Conclusion

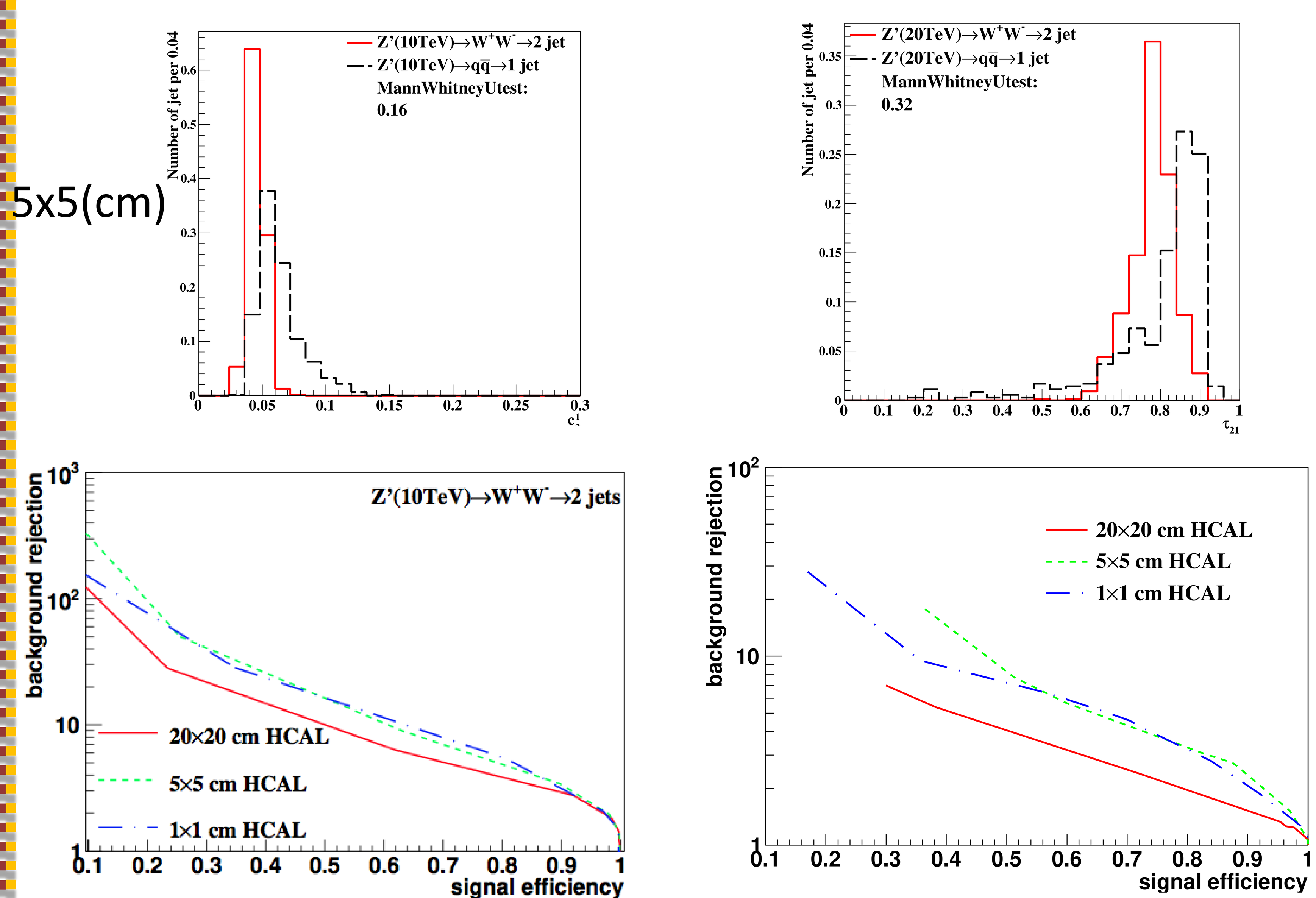
Improvements in signal identification using small cell sizes

	$\sqrt{s} = 5TeV$	$\sqrt{s} = 10TeV$	$\sqrt{s} = 20TeV$	$\sqrt{s} = 40TeV$
Signal=WW	V	V	V	X
Signal=tt	X	V	V	X

Results: C and Tau variables

C_2^1 τ_{21}

5x5(cm)



Conclusion

Overall, the best separation power is observed in the 5x5 cm cell size

Reference

[1]Initial performance studies of a general-purpose detector for multi-TeV physics at a 100 TeV pp collider, JINST 12 (2017) P06009

[2]Identifyling Booseted Objects with N-subjettiness, JHEP03(2011)015

[3]Energy correlation Functions for Jet Substrcture, JHEP06(2013)108

[4]Soft drop, JHEP05(2014)146

[5]Recursive soft drop, arxiv:1804.03657