Study of Jet Substructure Variables for the Future Detector

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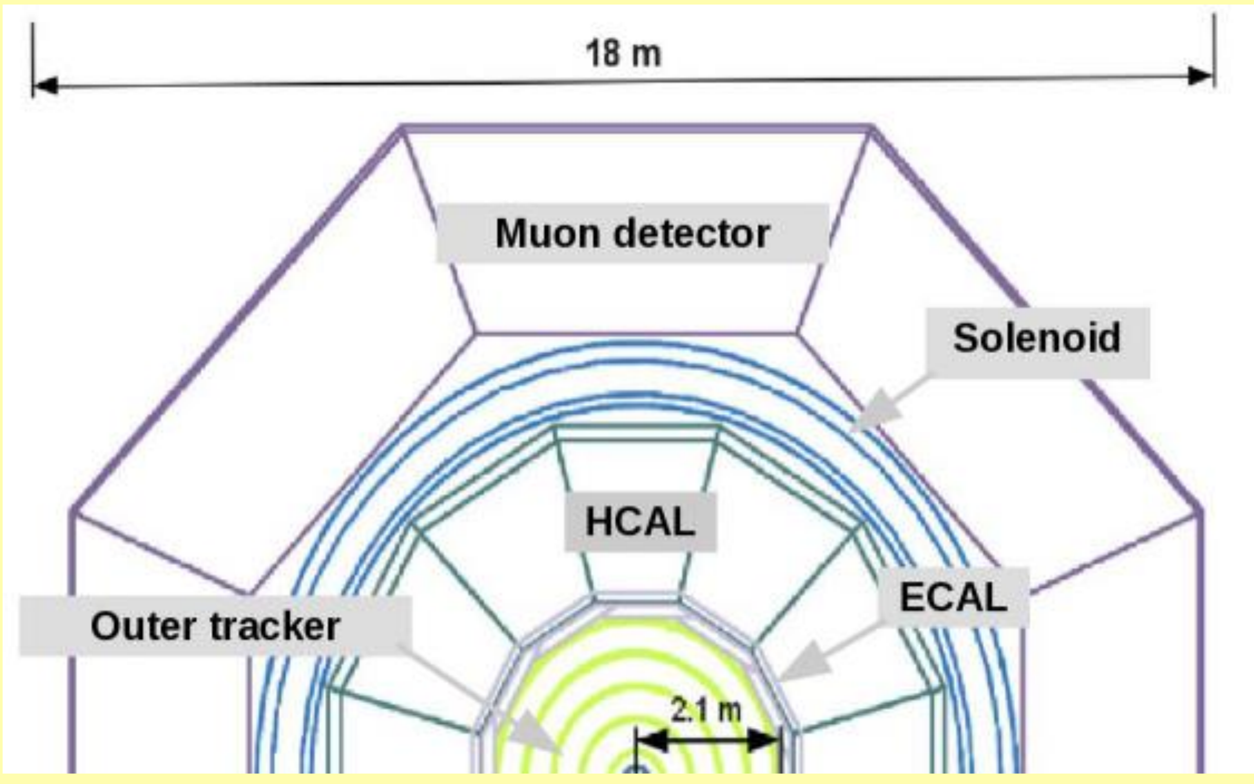
Abstract:

In this poster, we study the performance of hadron calorimeter in SiFCC for the future √s=100 TeV pp collider. The GEANT4 full simulation includes calorimeters with different cell sizes. We aim to efficiently separate signal Z'->ww or Z'->tt and background Z'->qq. Various jet substructure variables and Z' masses from 5 to 40 TeV are also compared.

Geant 4 Simulation of Future Detector SiFCC



Barrel	Technology	pitch/cell	radii (cm)	$\lvert z\rvert$ 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

$$d_{ij} = \min(k_{ti}^{2p}, k_{tj}^{2p})\frac{\Delta_{ij}^2}{R^2} \qquad \Delta_{ij}^2 = (y_i - y_j)^2 + (\phi_i - \phi_j)^2$$

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

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

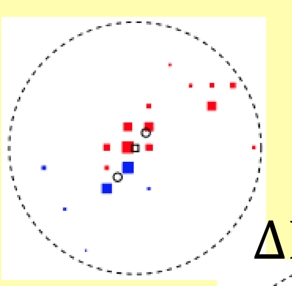
(2)k_{ti}, k_{tj}: the transverse momenta of particles i and j

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

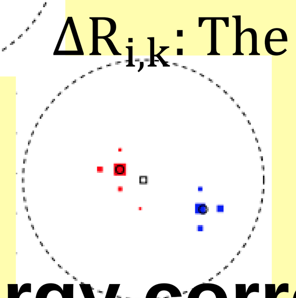
Jet Substructure Variables

1.N-subjetness:



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

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

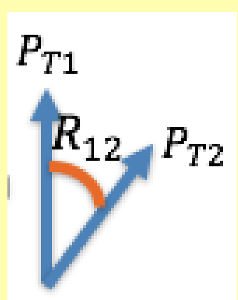


$\Delta R_{i,k}$: The distance between constuient in the eta − phi plane

R_0: The cone size we want to cluster

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

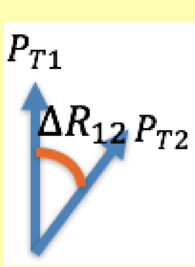
2.Energy correlation function:



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

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

3.Soft drop:

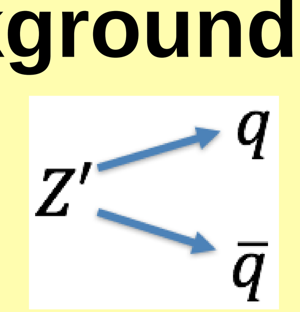


$$\frac{\min(P_{T1},P_{T2})}{P_{T1}+P_{T2}} < Z_{cut}\left(\frac{\Delta R_{12}}{R_0}\right)^{\beta}$$

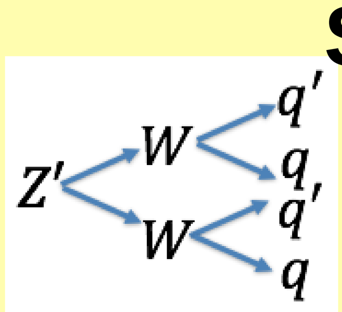
$\beta > 0$: Remove both soft and wide − angle
$\beta = 0$: Depend on the cut of pT asymmetry
$\beta < 0$: Remove both soft and collinear

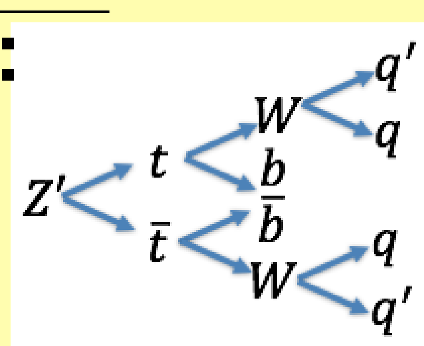
Signal and Background Process:

Background:



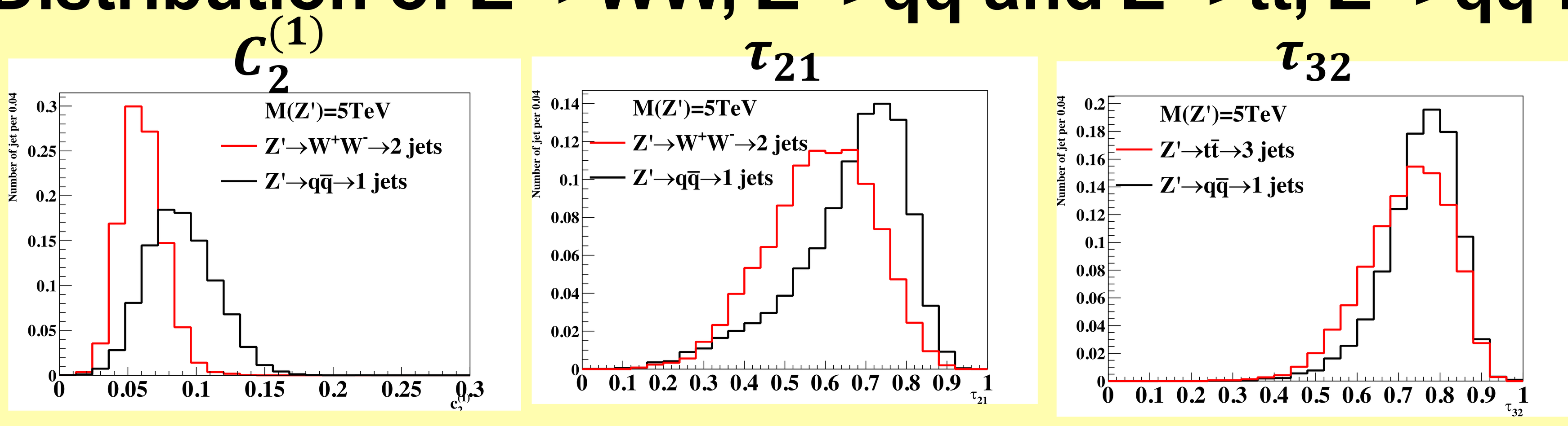
Signal:



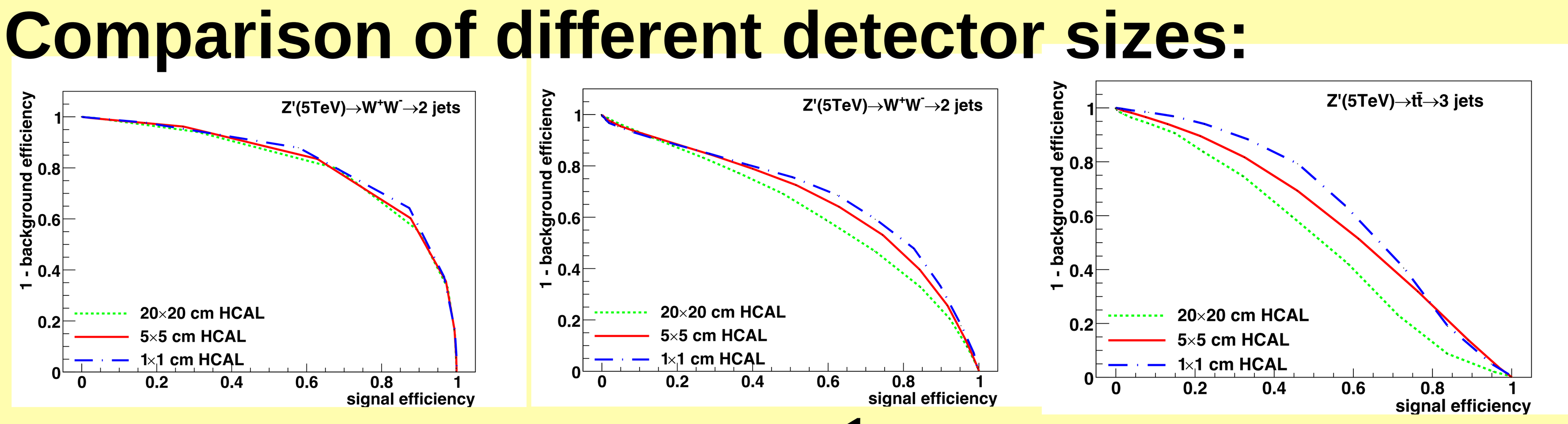


Variables Study in $C_2^1, \tau_{21}, \tau_{32}$:

Distribution of Z'->WW, Z'->qq and Z'->tt, Z'->qq :



Comparison of different detector sizes:

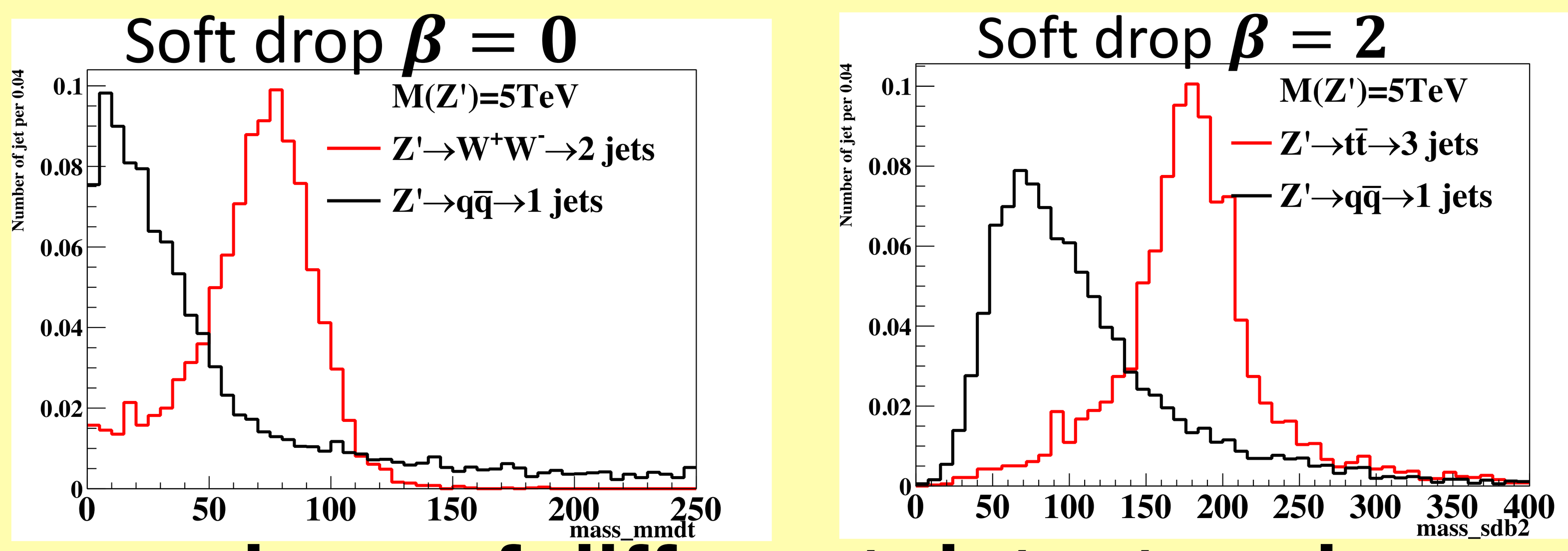


Summary for C_2^1, τ_{21}, τ_{32}:

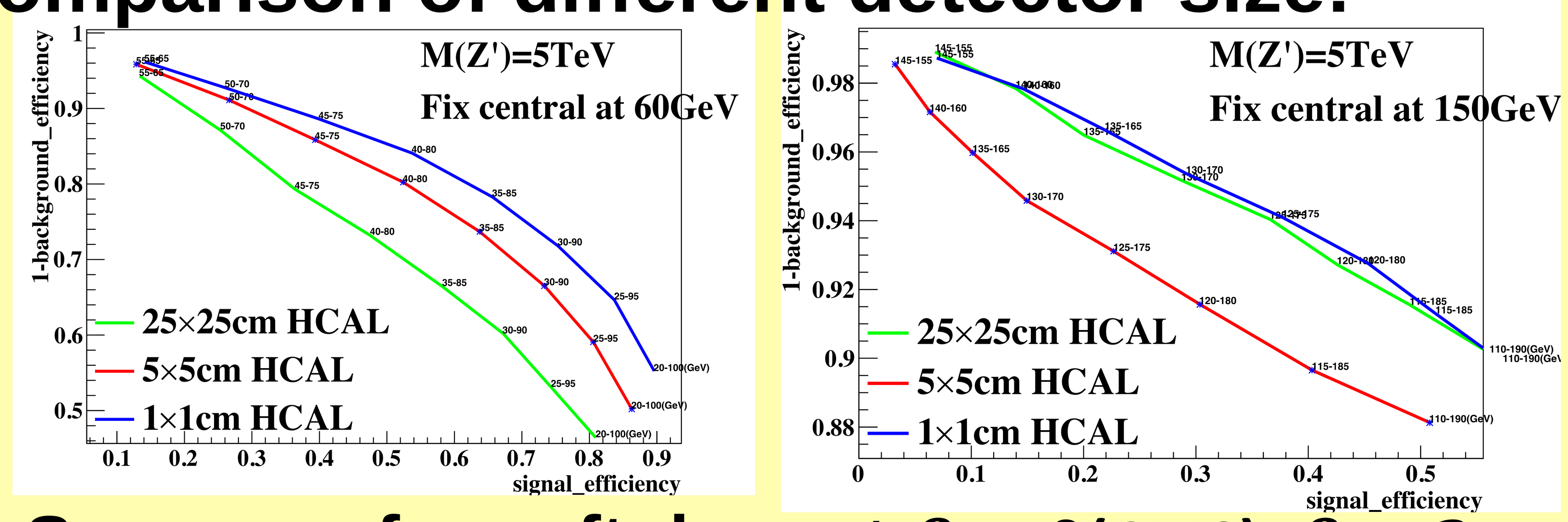
Is it the best for smallest detector cell size?

	$\sqrt{s} = 5TeV$	$\sqrt{s} = 10TeV$	$\sqrt{s} = 20TeV$	$\sqrt{s} = 40TeV$
C_2^1	X	X	X	X
τ_{21}	O	X	X	X
τ_{32}	O	O	O	O

Study of Soft Drop at $\beta = 0$(CMS), $\beta = 2$:



Comparison of different detector size:



Summary for soft drop at $\beta = 0$(CMS), $\beta = 2$:

Is it the best for smallest detector cell size?

Fix central (from near highest)	$\sqrt{s} = 5TeV$	$\sqrt{s} = 10TeV$	$\sqrt{s} = 20TeV$	$\sqrt{s} = 40TeV$
$\beta = 0$ Signal=WW	O	O	X	X
$\beta = 2$ Signal=WW	X	X	X	X
$\beta = 0$ Signal=tt	X	O	O	X
$\beta = 2$ Signal=tt	X	X	X	X

Reference

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