Performance of Jets at the Higgs Factory, CEPC

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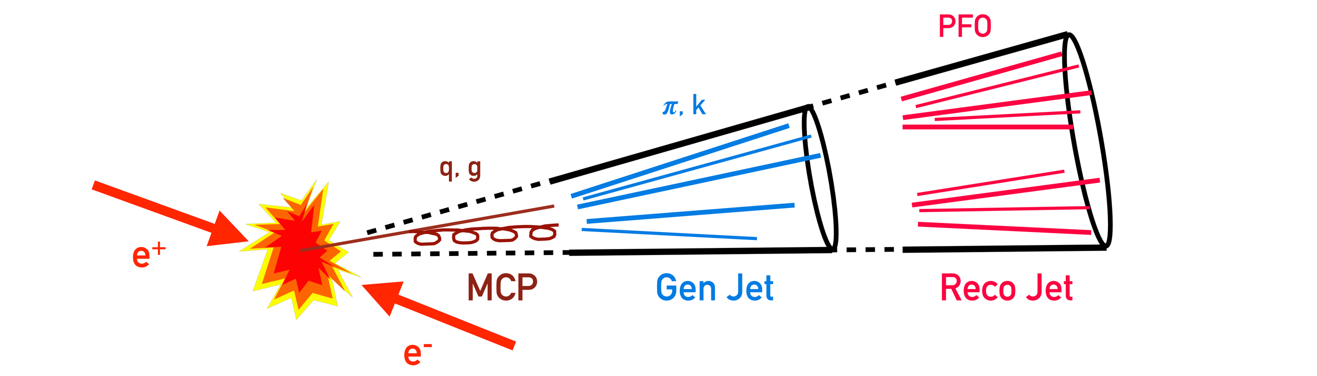
Introduction

The understanding of both the energy scale and resolution of the jet is crucial for many physical analyses at Circular Electron-Positron Collider (CEPC). The study of them are performed using the simulation at $\sqrt{s}$ = 240 GeV with the conceptual detector.

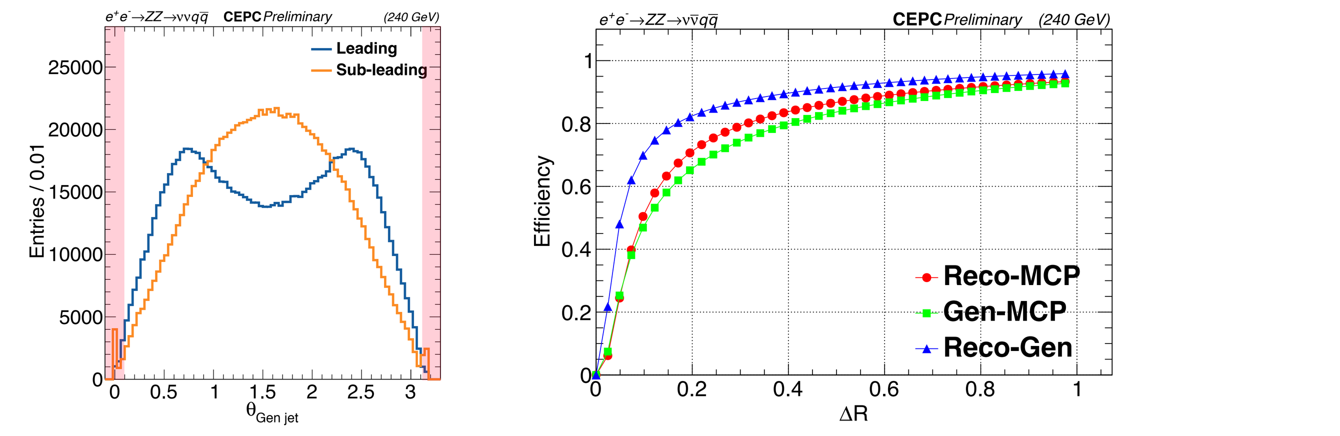
Definition of Simulation Stages

To study the performance of the jet reconstruction at CEPC, we look at the simulation which contains MC particles (MCP), MC final state particle jet (Gen jet), and particle flow objects jet (Reco jet). Both Gen jet and Reco jet are clustered by the ee_kt jet clustering algorithm.



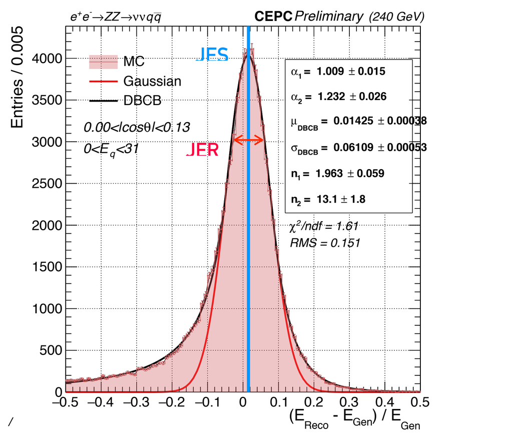
Event Selection

- Events in forward region are excluded. ➡ To remove the ISR photon(s) contamination.
- ΔR(Reco-MCP) < 0.1. ➡ Select jets with good clustering quality.



Approach

Double-sided crystal ball function (DBCB) is used to extract energy resolution and scale.



Results

JER & JES between each simulation stage

- Gen jet - MCP : Represent jet clustering algorithm performance.
- Reco jet - Gen jet: Represent detector response.
- Reco jet - MCP : The total effects of jet final state will bring.

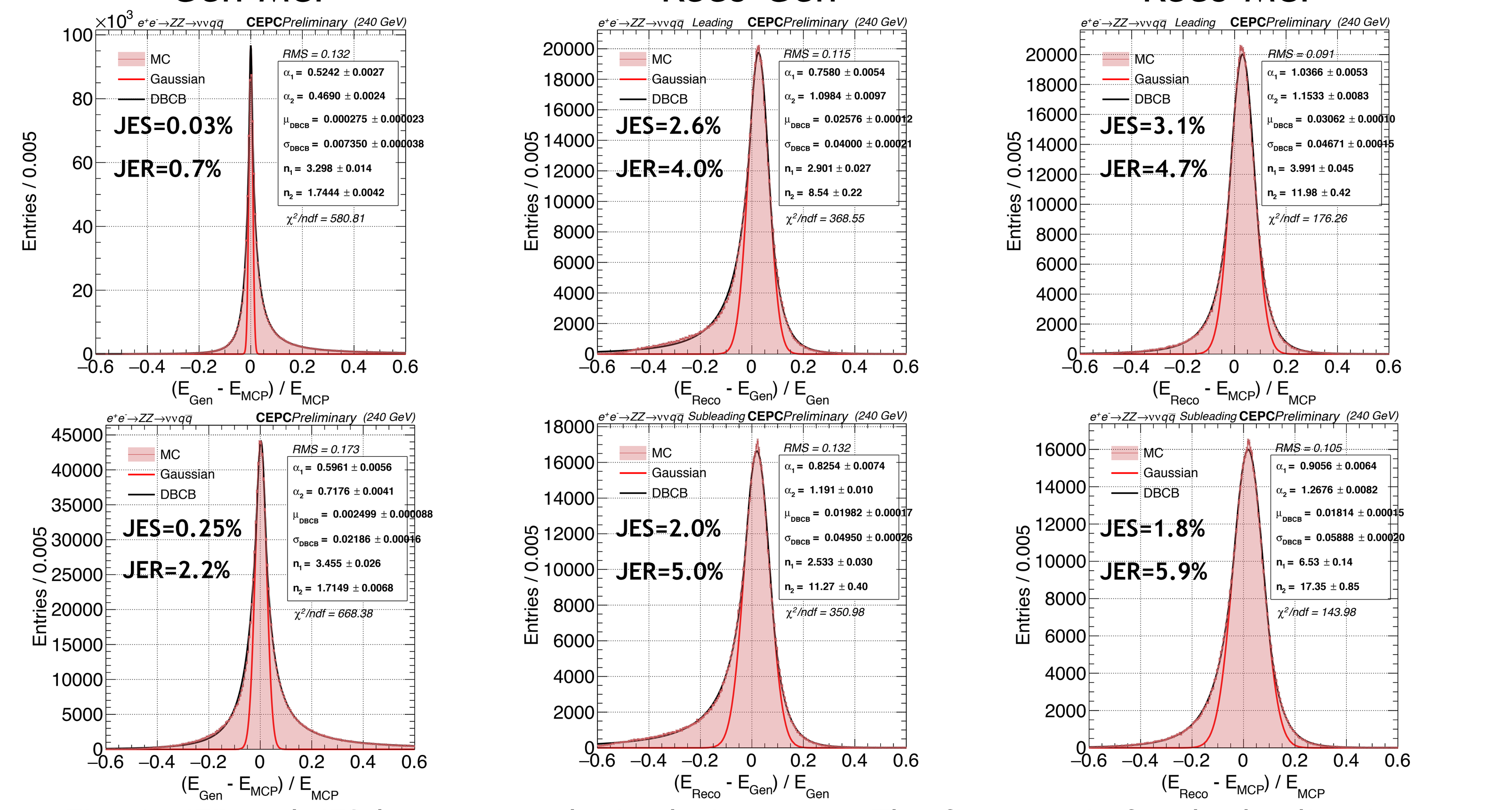
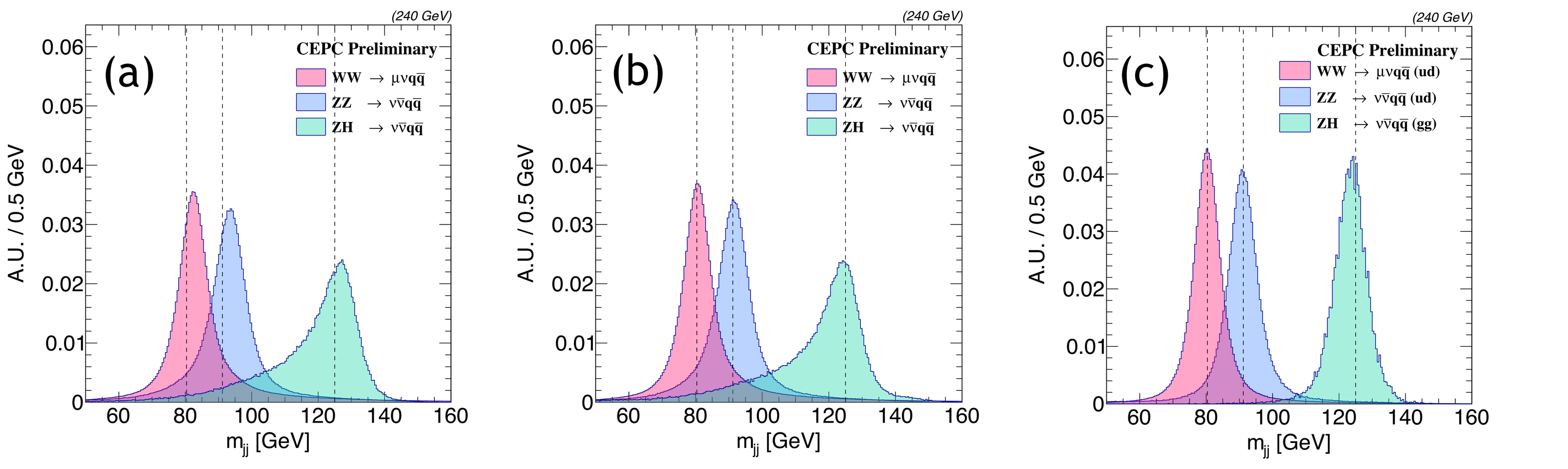


Fig. 1. JER and JES between each simulation stage. The first row is for the leading jet performance and the second row is for the sub-leading.

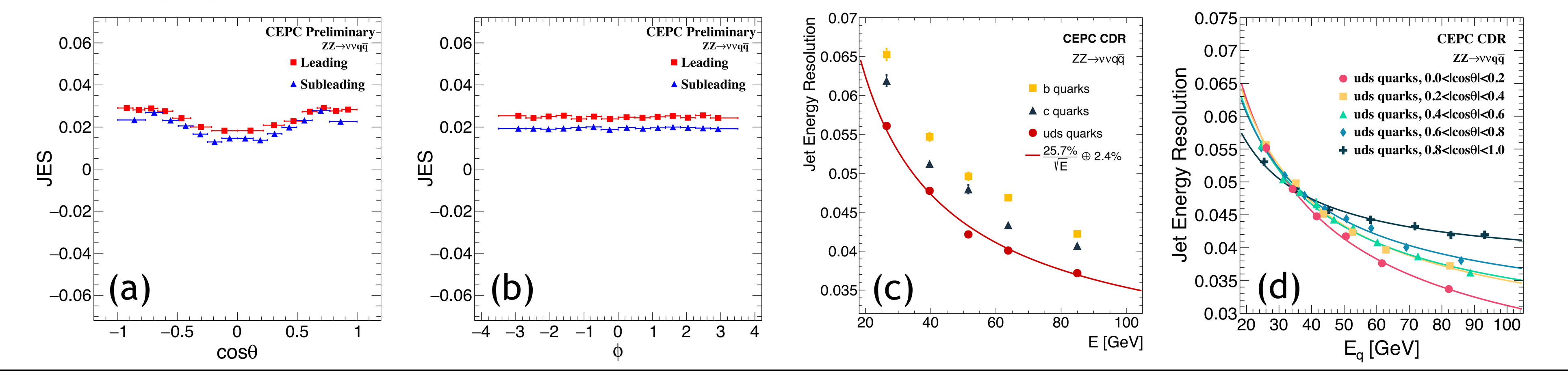
Boson mass resolution & Jet energy calibration

(a) shows the reconstructed dijet invariant mass distribution from $WW\rightarrow\mu\nu q\bar{q}$, $ZZ\rightarrow\nu\bar{\nu}q\bar{q}$, and $ZH\rightarrow\nu\bar{\nu}(b\bar{b}/c\bar{c}/gg)$ processes, respectively. H->$b\bar{b}$ and H->$c\bar{c}$ decay expect a long low mass tail because these two channels have major branching ration and neutrinos produced in semi-leptonic decays of b- and c-quarks. The mass resolutions for $W\rightarrow q\bar{q}$ and $Z\rightarrow q\bar{q}$ are 4.4%, leading to an average separation of 2σ or better for the hadronically decaying W and Z bosons. After applying JES calibration, each resonance is calibrated to its expected position, as shown in (b). To decouple the detector response from these physics effects, a dedicated set of event selections, including light flavor jet selection, detector acceptance as well as with low energy ISR photon(s) and neutrino, is applied in (c).



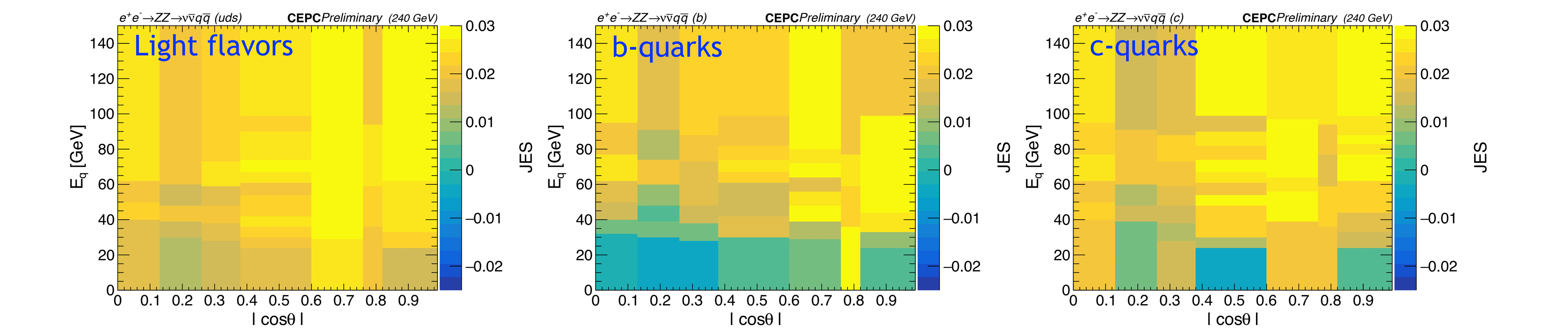
Dependence of JER & JES

(a) shows JES between the reconstructed jets and MC particle jets for different polar angles derived from the simulated $ZZ\rightarrow\nu\bar{\nu}q\bar{q}$ events. The JES is close to 2% and the variation is < 1%, and keeps homogeneous in the Φ direction which is shown in (b). The jet energy resolution is shown in (c) as a function of jet energy for different jet flavors. For light jets, the resolution ranges from 6% at 20 GeV to 3.6% at 90 GeV. The resolutions for heavy-flavor are poorer as expected because of neutrinos in their decays. The JERs for light jets in different range of cosθ is shown in (d).



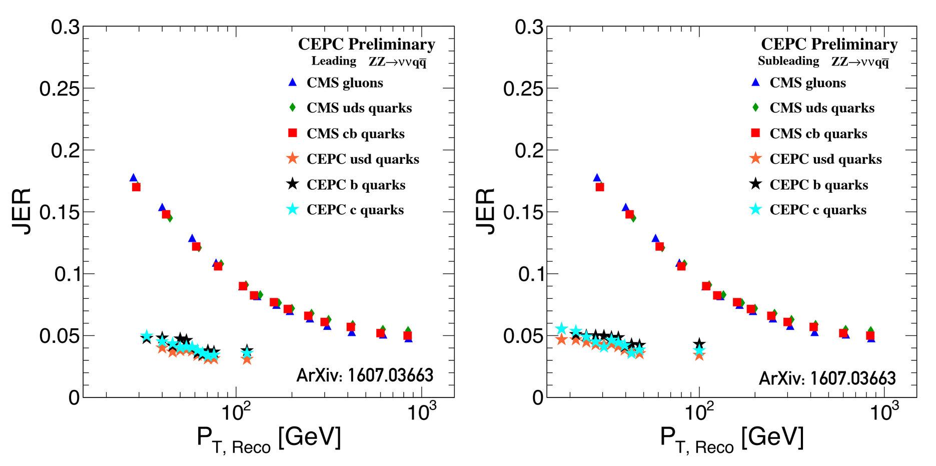
Dependence of JES in 2D (energy, angle and jet flavor)

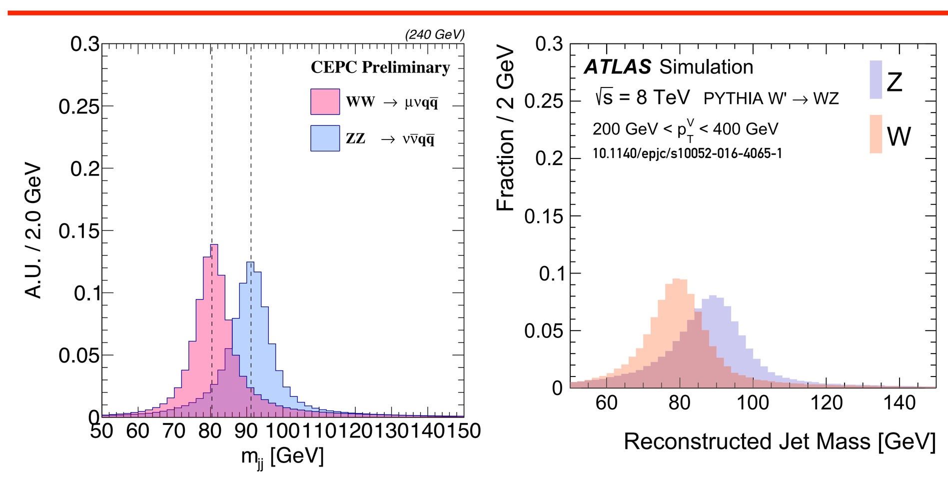
Major factors affecting the JER and/or JES are jet flavor composition, shower fluctuations, clustering algorithm, as well as the stability and uniformity of the detector responses. Their impacts can be mitigated by detailed studies and calibrations.



JER comparison with CMS at LHC

The performances of JER are compared with CMS at LHC. CEPC conceptual detector is expected to obtain 2-4 times better jet energy resolution than CMS within the same energy range.



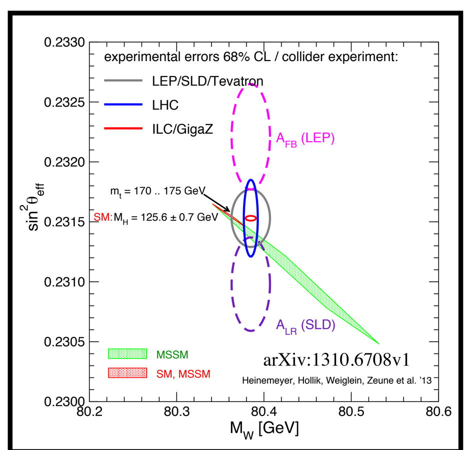


Massive boson separation

Good separation of W- and Z-boson reconstructed dijet invariant mass in CEPC benefits from excellent jet energy resolution.

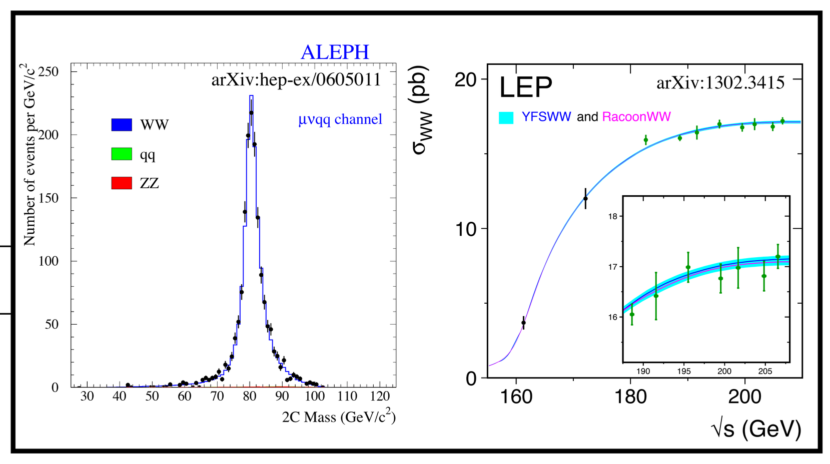
Motivation of W-boson Mass Measurement

- Developing important tools for indirect information to probe new physics.
- It is important in testing the internal consistency of the standard model (SM).(e.g. mixing angle)
- Any new particle or interaction that gives a contribution to the quantum loop corrections to the W-boson mass will not result in the consistency between SM prediction and experimental data.

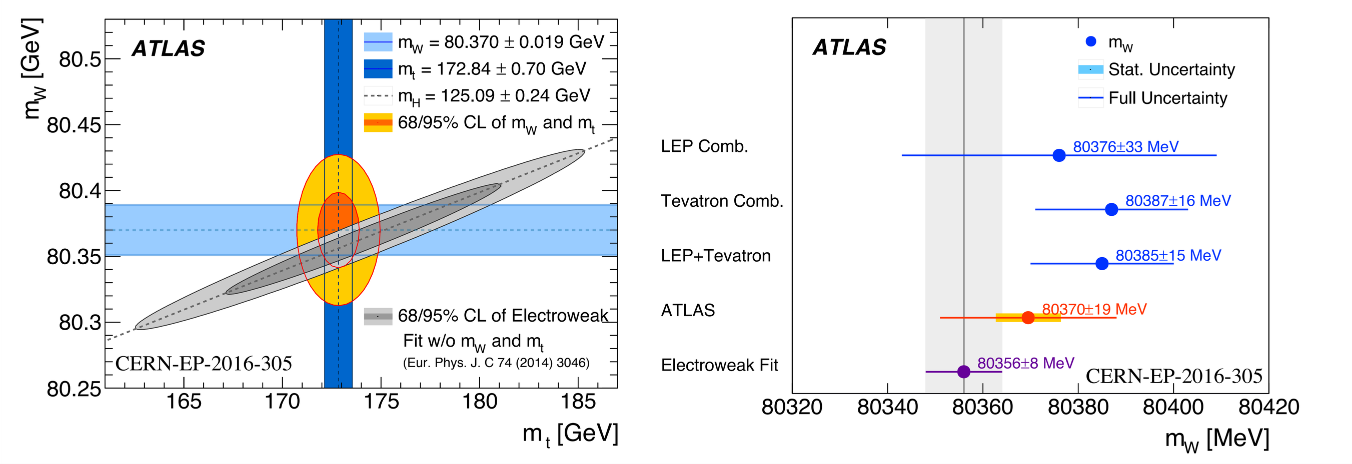


Operation Plan

Operation mode	$\sqrt{s}$ (GeV)	L per IP (10^{34} $cm^{-2}s^{-1}$)	Years	Total ∫L (ab^{-1}, 2 IPs)	WW Event yields
ZH	240	3	7	5.6	9.4 x 10^7
W^+W^-	158-172	10	1	2.6	1.5 x 10^7

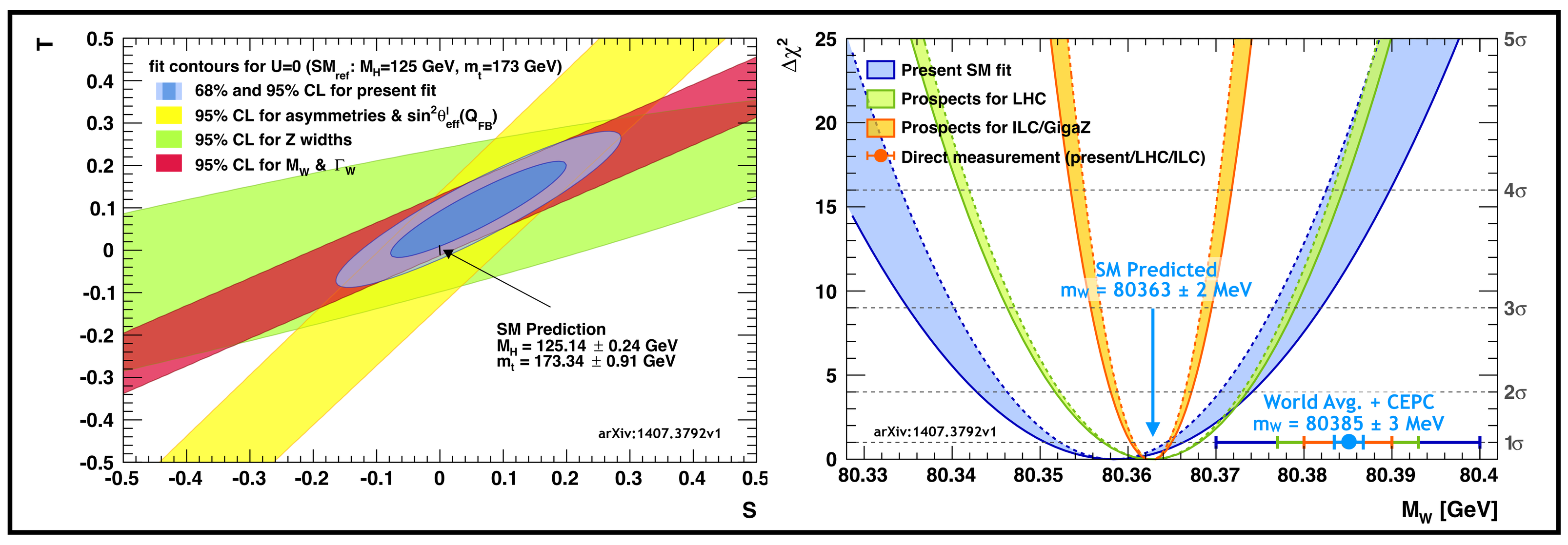


Latest Results of W-boson Mass Measurement



Uncertainties

Collider	LEP	CEPC
$\sqrt{s}$ (GeV)	180-203	240
∫ Ldt	2.6 fb^{-1}	5.6 fb^{-1}
Channels	$l\nu q\bar{q}$, $q\bar{q}q\bar{q}$	$l\nu q\bar{q}$
Source	Uncertainty (MeV)	
Statistics	25	1.0
Beam energy	9	1.0
Hadronization	13	1.5
Radiative corrections	8	1.0
Detector effects	10	1.5
Total	33	3.0

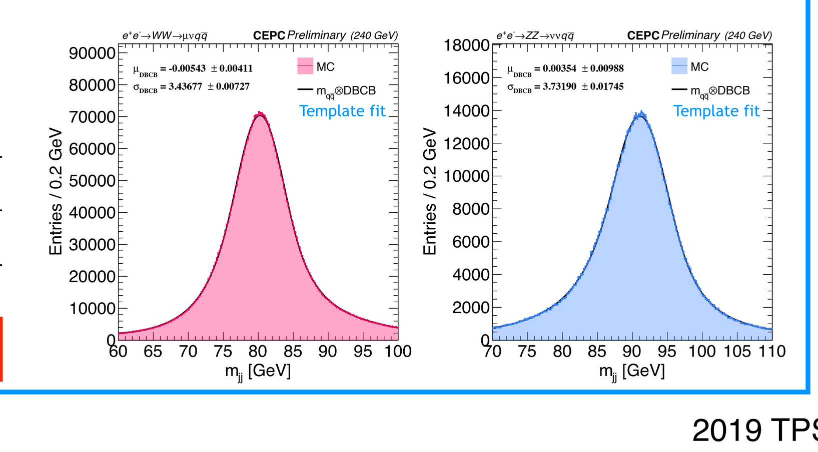


Summary

- Preliminary results of JER and JES with CEPC using simulated are presented.
- Excellent JER(~4%) and JES(~1%) can be obtained.
- Good jet energy resolution leads to good massive boson separation.
- Applying JES to calibrate W- and Z-boson mass can reach up to 10^{-3} GeV precision level.
- Using the kinematic reconstruction approach, a total uncertainty for W-boson mass measurement at the level of 3 MeV seems reachable.
- These results are accepted for publication by EPJC (DOI: 10.1140/epjc/s10052-018-5876-z) and/or included in CEPC Conceptual Design Report (CDR).

Resutls

Inclusive	Δm_W (GeV)	Δm_Z (GeV)
Nominal	2.18988 ± 0.00450	2.40783 ± 0.01382
Global Calibration	0.06806 ± 0.00436	0.00783 ± 0.01024
JES (All MC phase space)	0.02683 ± 0.00409	0.00395 ± 0.01034
JES (All Reco phase space)	-0.00543 ± 0.00411	0.00354 ± 0.00988



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