Electroweak Physics in CEPC

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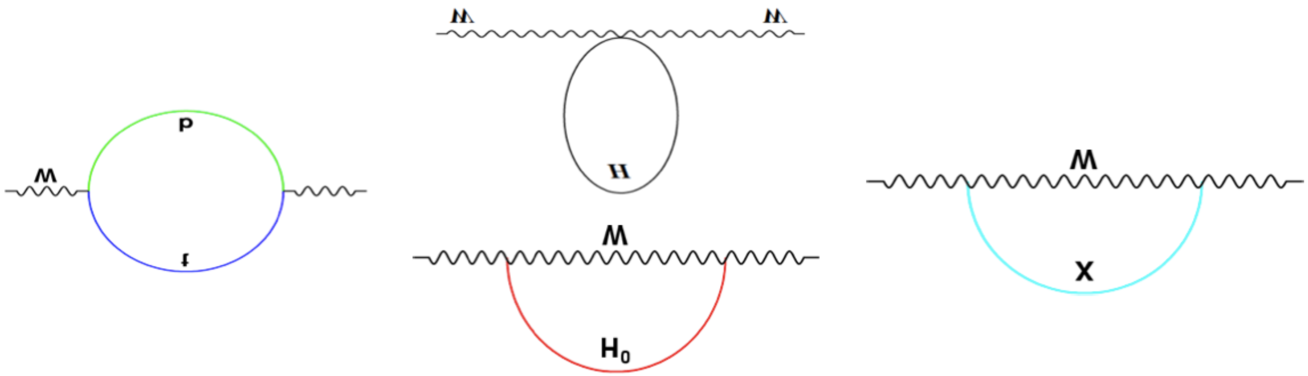
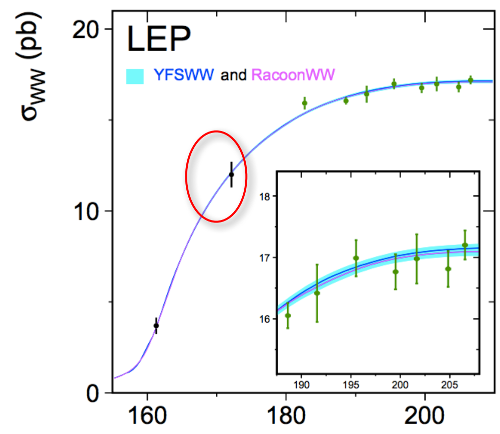
Introduction

- CEPC have good potential in electroweak precision physics.
- Precision measurement is important
  - Precision electroweak measurement constrain new physics beyond the standard model.
  - Eg: Radiative corrections of the W or Z boson is sensitive to new physics



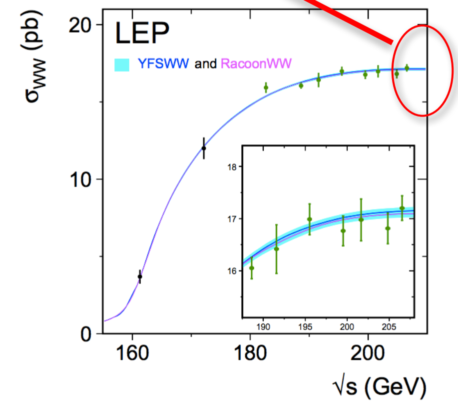
W mass measurement: threshold scan

- **Current PDG precision : 80.385±0.015 GeV**
  - Possible goal for CEPC : ~5 MeV
  - 1.Threshold scans of W+W- cross section (√s=160GeV)
    - **Disadvantage:**
    - Higher cost
      - Require dedicated runs 100fb^{-1} on WW threshold (~160GeV)
    - Low statistics: low cross section below threshold
    - high requirement on beam momentum uncertainty
      - LEP (~50ppm)
      - Require CEPC to be less than 10ppm
    - **Advantage:**
      - Very robust method, can achieve high precision.



	LEP	CEPC (100 fb^{-1})
Statistical error	200 MeV	2 MeV
Syst error	70 MeV	2~4 MeV

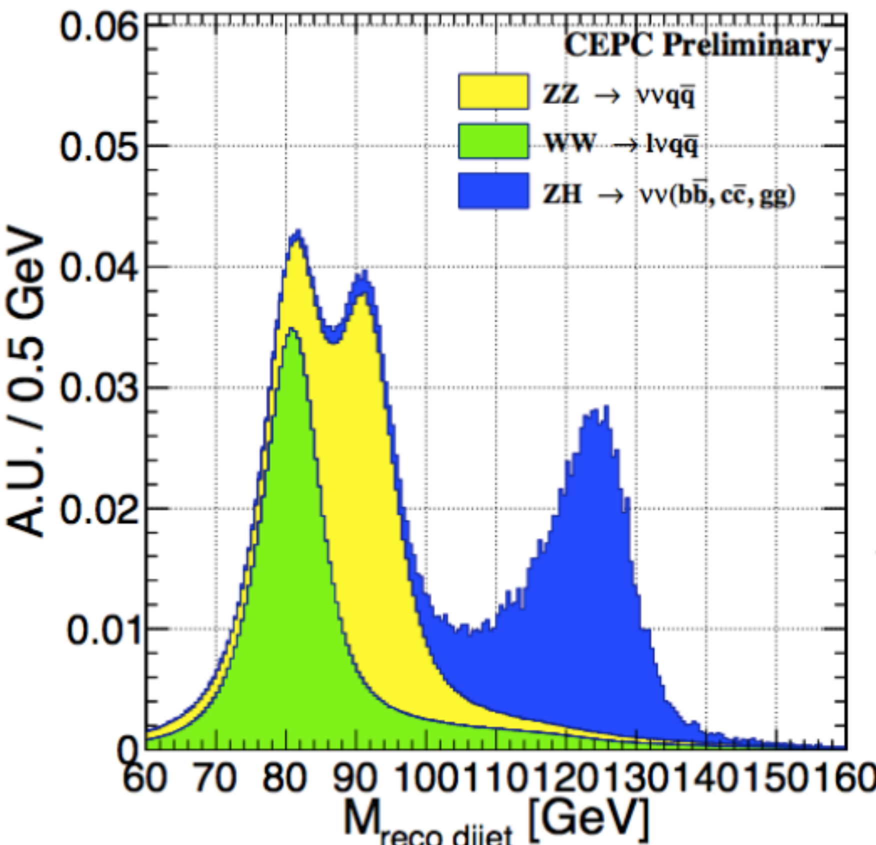
W mass measurement: direct reconstruction



- Method 2: direct reconstruction (√s=250GeV)
  - Decays model : WW-> lvqq , WW->lvlv
  - Advantage :
    - No additional cost :measured in ZH runs (sqrt(s)=250GeV)
    - Higher statistics: 10 times larger than WW threshold region
    - Lower requirement on beam energy uncertainty.
  - Disadvantage :
    - Larger uncertainty due to initial/final state photon radiation modeling

Some study on jet energy resolution in CEPC ZH runs

- Direct reconstruction Need to have very good jet energy resolution



- Use ee_KT as jet algorithm

Jet clustering algorithm at hadron collider

$$d_{ij} = \min(k_{ti}^{2p}, k_{tj}^{2p})\frac{\Delta y^2 + \Delta\phi^2}{R^2} \qquad d_{iB} = k_{ti}^{2p}$$

for CEPC, beam jets negligible

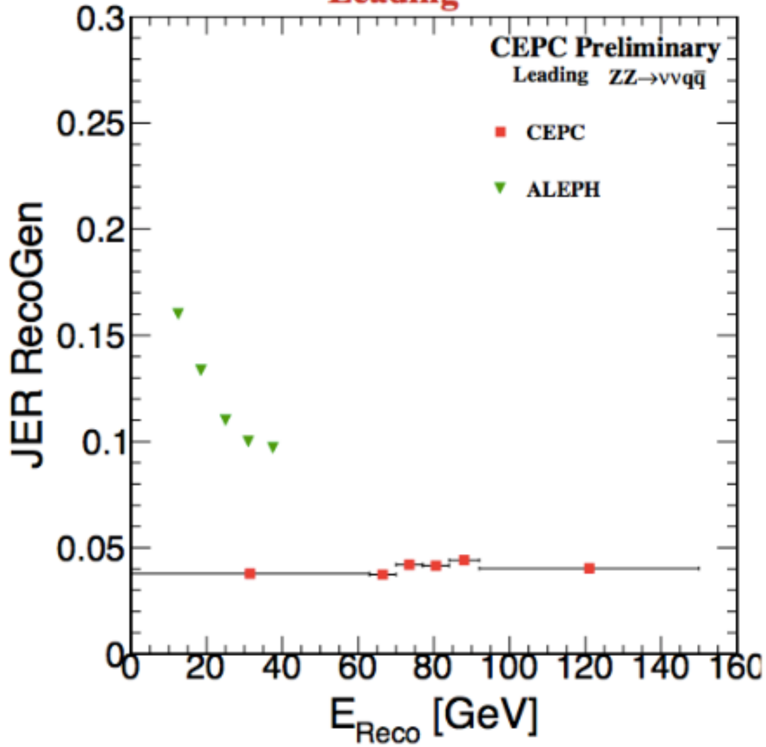
ee_kt_algorithm — S. Catani, Y. L. Dokshitzer, M. Olsson, G. Turnock and B. R. Webber, Phys. Lett. B 269, 432 (1991)

name	$d_{ij} =$	$d_{iB} =$	remark
ee_kt_algorithm	$2(1-\cos\theta_{ij})\frac{\min(E_i^2,E_j^2)}{s}$	-	also known as Durham
kt_algorithm	$\min(p_{t,i}^2, p_{t,j}^2)\frac{(y_i-y_j)^2+(\phi_i-\phi_j)^2}{R^2}$	$p_{t,i}^2$	y is pseudorapidity
cambridge-aachen	$\min(p_{t,i}^0, p_{t,j}^0)\frac{(y_i-y_j)^2+(\phi_i-\phi_j)^2}{R^2}$	$p_{t,i}^0$	no energy weighting
antikt_algorithm	$\min(p_{t,i}^{-2}, p_{t,j}^{-2})\frac{(y_i-y_j)^2+(\phi_i-\phi_j)^2}{R^2}$	$p_{t,i}^{-2}$	start with merging high energy particles

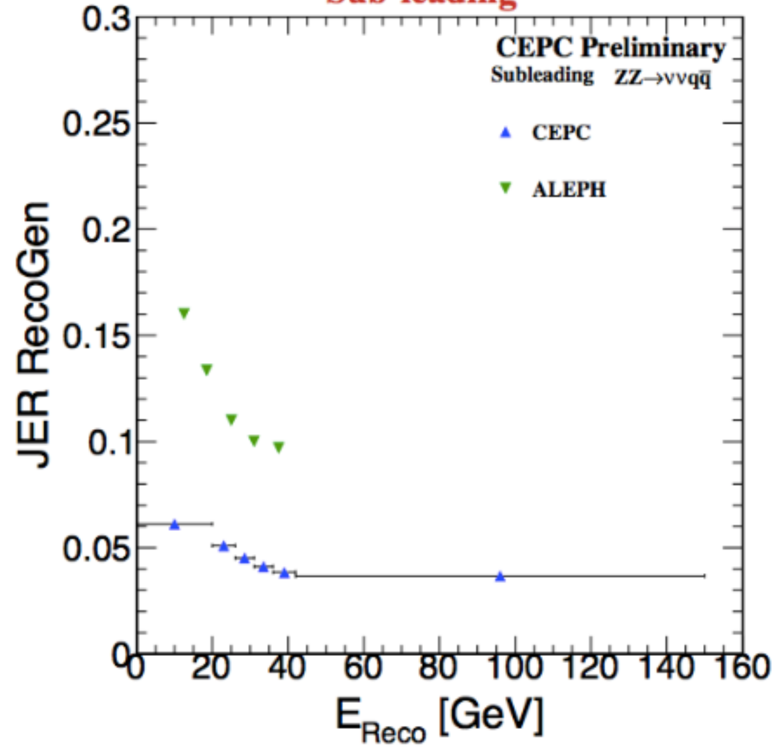
Some study on jet energy resolution in CEPC ZH runs (2)

- **Large uncertainty due to jet clustering algorithm**
- **4% jet**

Leading

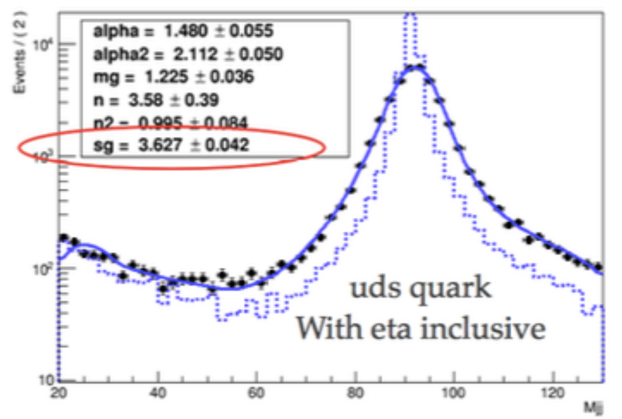


Sub-leading



Some study on jet energy resolution in CEPC ZH runs (3)

- **Another attempt: use PFA object directly**
  - No uncertainty due to jet clustering, works for lvqq channel
  - Main systematics is PFA object momentum scale
    - the neutral object energy scale in PFA algorithm



$$BW \otimes \boxed{DSCB(\mu, \sigma, n_1, n_2, \alpha_1, \alpha_2)}$$

Mean of DSCB quantifies the shift of peak due to sim/reco
Gives the JES/global PFA scale
Sigma of DSCB represents the detector resolution.

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Expected systematics in W mass measurement

	LEP	CEPC@240GeV (5ab-1)	CEPC@ 240GeV (5ab-1)
	lvqq	Lvqq (dijet mass)	Lvqq (kinematic fit)
Statistical error	30 MeV	<1 MeV	<1 MeV
Beam energy	17 MeV	-	1~2 MeV
Detector resolution	14MeV	2~3 MeV	<1 MeV
Hadronisation	19MeV	1~2 MeV	1~2 MeV
QED	20MeV	1~2MeV	1~2 MeV

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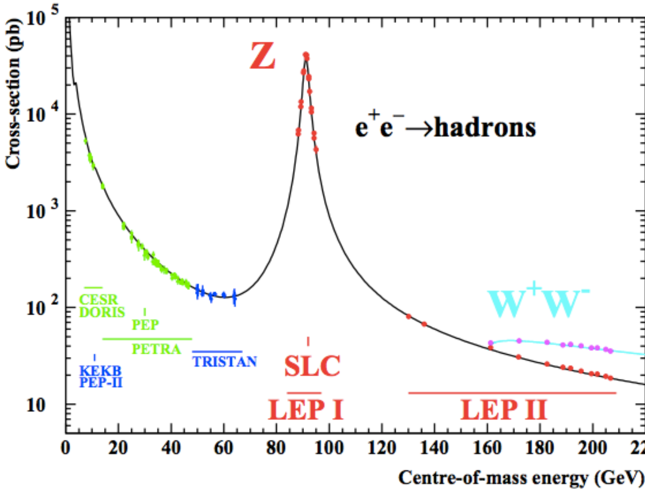
Summary on W mass

- No strong motivation to have dedicated WW threshold scan ($\sqrt{s}$=160GeV runs) in CEPC.
- Direct W mass measurement in ZH runs ($\sqrt{s}$=250GeV) have potential to reach less than 5 MeV level precision.
  - More detailed estimation need to be done in next month with MC simulation

m_Z measurement



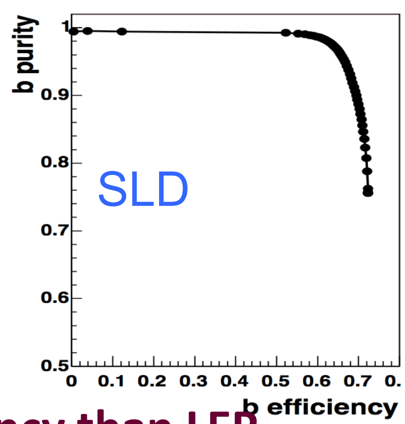
- LEP measurement : 91.1876±0.0021 GeV
  - Stat uncertainty : 1MeV
  - Syst uncertainty: ~1.5 MeV
    - beam energy uncertainty
    - lepton momentum scale uncertainty
- CEPC possible goal: 0.5~1 MeV
  - Stat uncertainty: 0.2 MeV , syst uncertainty: 0.5~1MeV
- Z mass threshold scan is needed to achieve high precision.
  - Precision in direct measurement in ZH runs is much lower
  - Z threshold scan is very important for energy scale calibration

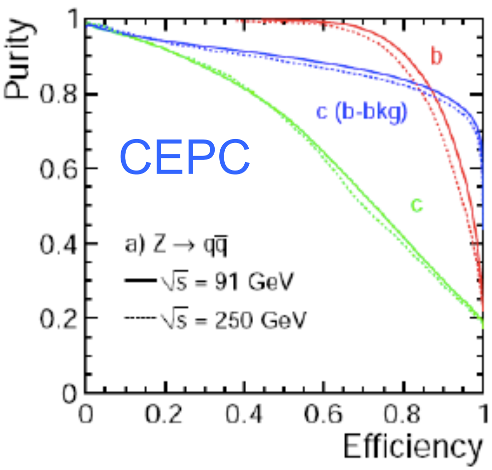
Branching ratio (R^b)

$$\frac{\Gamma(Z \to b\bar{b})}{\Gamma(Z \to had)}$$

- LEP measurement 0.21594 ±0.00066
  - Stat error : 0.44%
  - Syst error : 0.35%
    - Charm mistag (0.2%)
    - Light jet mistag rate (0.2%)
    - Gluon radiation (g->bb , g->cc) (0.15%)

B working point in SLD





- CEPC
  - Expect 10~15% higher B tagging efficiency than LEP
    - In 95% B jet purity working
    - Reduce charm mistag and light jet mistag and hemi corrections systematics
  - Stat error (0.04%)
  - Syst error (0.07%)
    - Charm mistag (0.05%)
    - Gluon radiation (g->bb , g->cc) (0.1%)

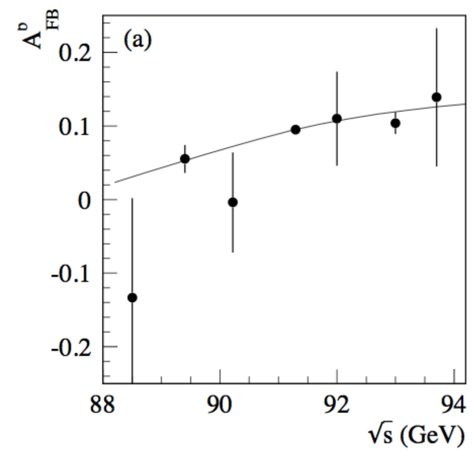
Backward-forward asymmetry measured from b jet

$$A_{FB}^{b\bar{b}}(0)$$

- **LEP measurement : 0.1000+-0.0017 (Z peak)**
  - **Stat error: ~1.2% (4 experiments)**
  - **Systematics: ~1.4% (combination of three methods)**
  - **Method 1: Soft lepton from b/c decay (~2%)**
    - Branching rate of b/c decay into lepton (1.5%)
    - B-tag and jet charge (1.1%)
    - Lepton pT and lepton Identification (0.9%)
  - **Method 2: jet charge method using Inclusive b jet (~1.2%)**
    - B-tag efficiency (0.4%)
    - charge correlations due to B tag/ jet charge (0.1%)
    - Sample statistics in light/heavy flavor jet sample (0.74%)
- **CEPC**
  - **Should focus on soft lepton method**
  - **Expected Stat error (0.1%) (>100 times of LEP stat)**
  - **Expected Systematics (0.12%) :**
    - Charge misID (0.1%)
    - Uncertainty in branching ratio (0.1%)

Weak mixing angle $\sin^2\theta_{eff}^{lept}$

- LEP/SLD measurement : 0.23153 ± 0.00016
  - 0.1% precision.
  - Stat error in off –peak runs dominated.
- CEPC
  - Stat error : 0.02% ;
  - systematics error : 0.01%
  - The statistics of off-Z peak runs is key issue.
    - Need at least 10 fb^{-1} for off-peak runs to reach high precision.



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Branching ratio (R^{mu})

- **LEP result: 0.2% total error**
  - **Stat : 0.15%**
  - **Syst : 0.1%**
- **CEPC : 0.05% total error expected**
  - **Better EM calorimeter is the key**
  - **Stat: 0.01%**
  - **Syst: 0.05%**

Systematics source	LEP	CEPC
Radiative events (Z->μμγ)	0.05%	0.05%
Photon energy scale	0.05%	0.01%
Muon Momentum scale	0.009%	0.003%
Muon Momentum resolution	0.005%	0.003%

Number of neutrino generation (N_ν)

- **LEP measurement :**
  - **Indirect measurement (Z line shape method): 2.984+-0.008**
  - **Direct measurement (neutrino counting method): 2.92+-0.05**
    - **Stat error (1.7%), Syst error (1.4%)**
- **CEPC measurement :**

$$e^+e^- \to \nu\bar{\nu}\gamma.$$

    - **Stat error (0.1%), Syst error (0.15%)**
  - **expected better granularity in calorimeter can help photon identification**
  - **Should focus on direct measurement**
    - **Need to consider photon trigger in early stage**
    - **Photon Trigger performance is key for this measurement**

Systematics source	LEP	CEPC
Photon Trigger efficiency	0.5%	0.1%
Photon Identification efficiency	0.5%	0.1%
Calorimeter energy scale	0.5%	<0.05%

Summary

- Still lots of work need to be done to understand the electroweak physics potential in CEPC
  - Especially W mass measurement
- Welcome to join the CEPC electroweak physics study

Branching ratio (R^{tau})

- LEP result: ~0.2% total error
  - Stat : 0.15%
  - Syst : 0.17%
    - Tau selection efficiency : 0.08%
    - Consistency of analysis cuts in different dataset: 0.11%
    - Background (Bhabha events ...): 0.08%
      - BG Modelling is not good
- CEPC result:
  - Stat (0.01%)
  - Syst (0.04%)
    - Expect better BG MC modelling , no consistency issue
    - Tau selection efficiency : 0.03%
    - Background (Bhabha events ...): 0.03%

Number of neutrino generation (N_ν)

- LEP measurement :
  - Indirect measurement (Z line shape method): 2.984+-0.008
    - Measured in Z peak region
    - No much room to improve
  - Direct measurement (neutrino counting method): 2.92+-0.05
    - Measured in 180~209 GeV runs
    - Using single photon + missing energy events
    - Stat error (1.7%)
    - Systematics (1.4%)
      - » Photon Trigger efficiency (0.5%)
      - » Photon Identification efficiency (0.5%)
      - » Calorimeter energy scale (0.5%)

$$e^+e^- \longrightarrow \nu\bar{\nu}\gamma.$$

- CEPC
  - focus on direct measurement
    - Need to consider Photon trigger in early stage
    - Trigger performance is key for this measurement
- Measured in ZH runs (cms~ 250GeV)
  - Stat error (0.1%)
  - Syst error (0.15%)
    - ~~expected better granularity in calorimeter can help photon identification~~
    - Photon Trigger efficiency (0.1%)
    - Photon Identification efficiency (0.1%)
    - Calorimeter energy scale (<0.05%)

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