Z AND W PHYSICS AT CEPC

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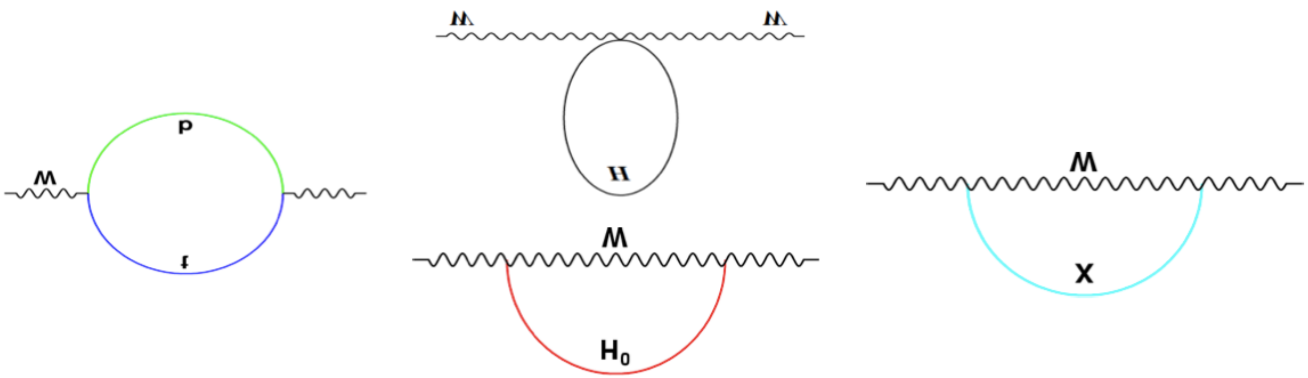
Introduction

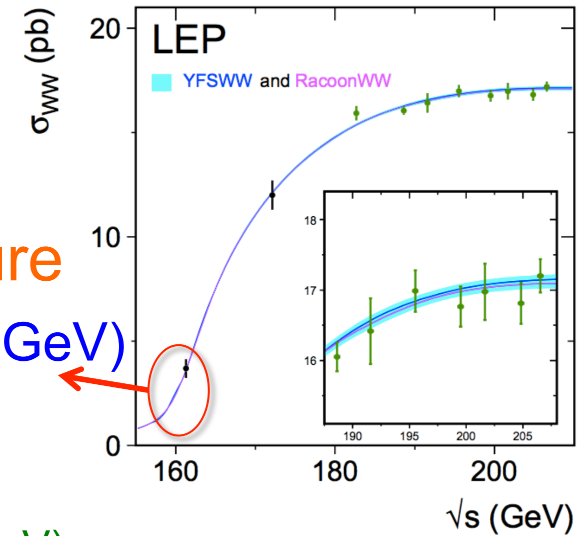
- CEPC have very good potential in electroweak precision physics.
- Precision measurement is important
  - Precision electroweak measurement constrain new physics beyond the standard model.
  - Eg: Radiative corrections of the W or Z boson is sensitive to new physics



- This talk summarize the existing precision measurement
- Estimate the expected precision in CEPC

W mass measurement

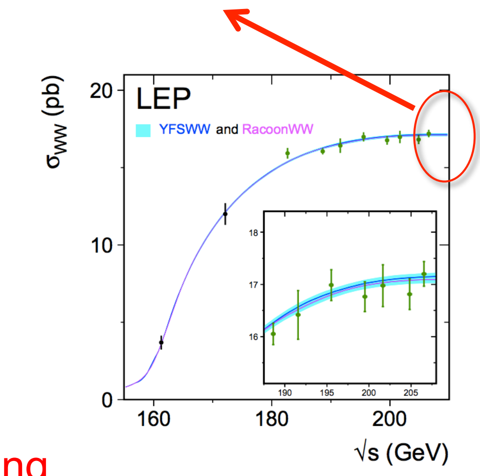
- Current PDG precision : 80.385±0.015 GeV
  - Possible goal for CEPC : ~5 MeV
- Two methods: Threshold scan, direct measure
  - 1.Threshold scans of W+W- cross section (√s=160GeV)
    - Disadvantage:
    - Higher cost
      - Require dedicated runs 100fb^{-1} on WW threshold (~160GeV)
    - Low statistics: 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 (100fb^{-1})
Statistical error	200 MeV	2 MeV
Syst error	70 MeV	2~4 MeV

W mass measurement

- Method 2: direct measurement ($\sqrt{s}$=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



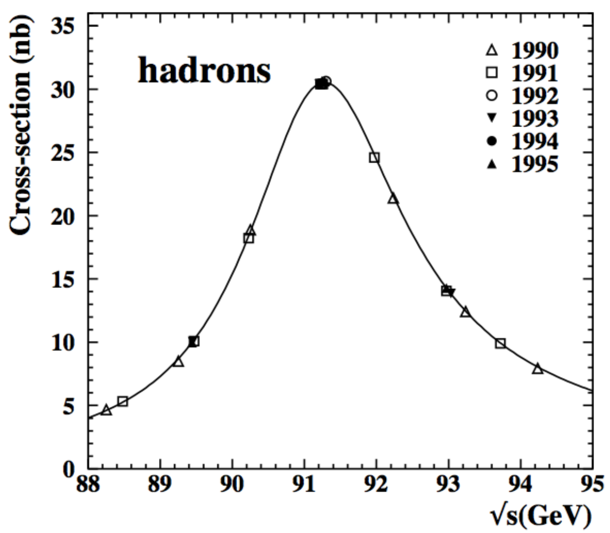
	LEP	CEPC (100fb^{-1})	CEPC (100fb^{-1})
	lvqq	lvqq	lvlv
Statistical error	30 MeV	1.5 MeV	~3MeV
Beam energy	17 MeV	0.5 MeV	0.5MeV
Detector resolution	14MeV	3~4 MeV	2~4 MeV
Hadronisation	19MeV	2~3 MeV	-
QED	20MeV	1MeV	2~3 MeV

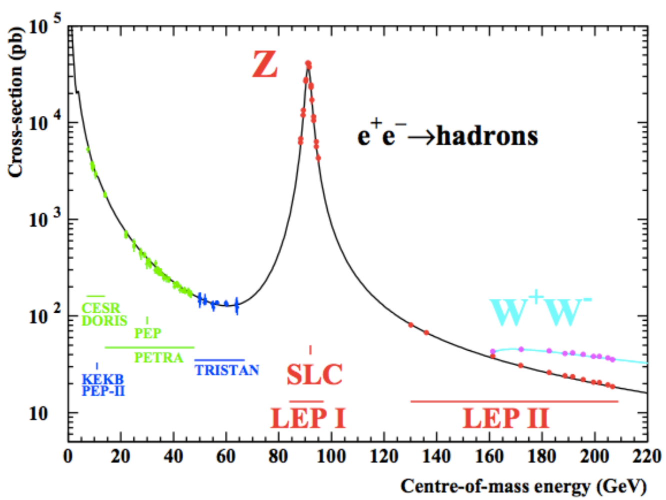
Summary on W mass

- 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

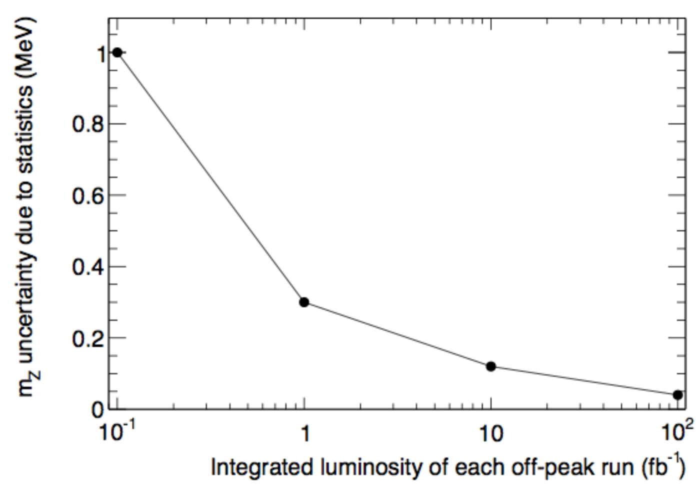




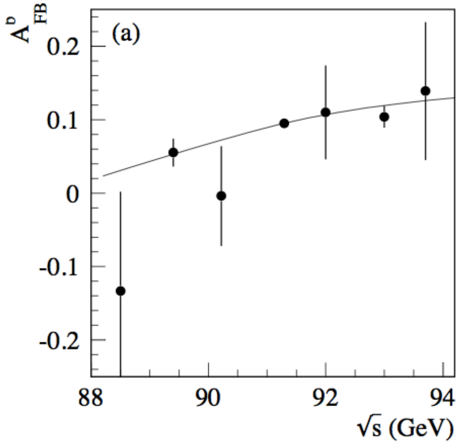
Proposal for Z Mass scan

- The statistics in Off-peak runs was the bottleneck
- Propose 10 fb-1 integrated luminosity for off-peak runs in CEPC
- 7 mass scan runs

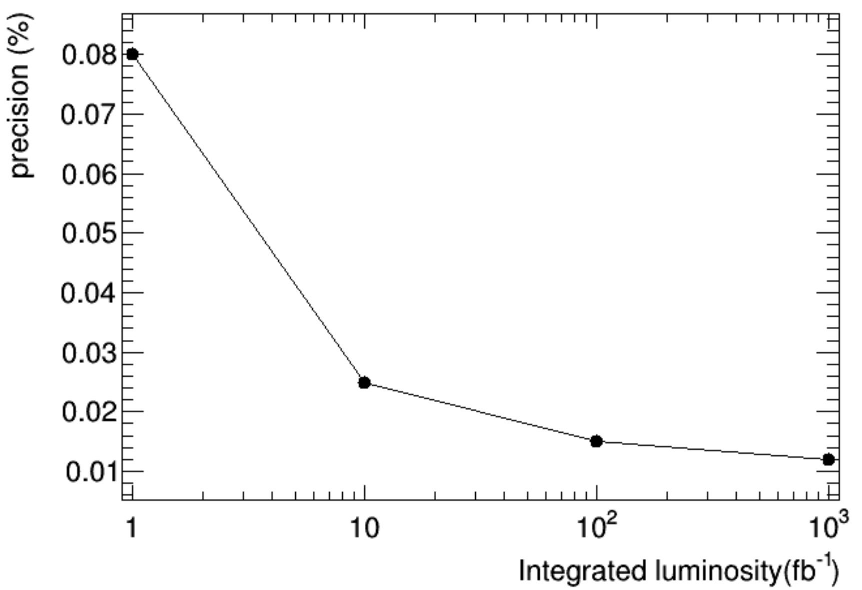
Sqrt(s) GeV	LEP lumi (fb-1)	Proposed CEPC lumi
88.2	0.05fb-1	10 fb-1
89.2	~0.4fb-1	10 fb-1
90.2	0.05fb-1	10 fb-1
91.2	~4 fb -1	100~1000fb-1
92.2	0.05fb-1	10 fb-1
93.2	~0.4fb-1	10 fb-1
94.2	0.05fb-1	10 fb-1



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



- 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.

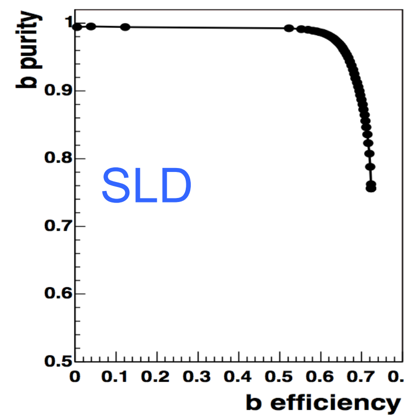


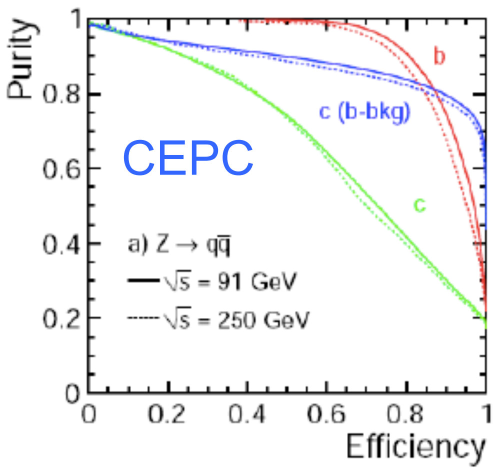
Branching ratio (R^b)

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

- 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 ex
    - 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%)
    - Light jet mistag (0.05%)
    - Gluon radiation (g->bb , g->cc) (0.1%)

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

- A comparison of LEP and CPEC precision
- To Do :
  - WW coupling limits
  - W and Z boson width measurement
  - QCD alpha_S measurement ….

Observable	LEP precision	CEPC precision
Z mass	2 MeV	0.5~1 MeV
W mass	33 MeV	3~5 MeV
$A_{FB\ (b)}$	1.7%	0.15%
$Sin^2\theta_W$	0.1%	0.01%
R^b	~0.3%	0.08%
N_ν (direct measurement)	1.7%	0.18%
R^{mu}	0.2%	0.05%
R^{tau}	0.2%	0.05%

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%)
    - Method 3: D meson method (>8%, less important method)
- CEPC
  - Should focus on inclusive b jet measurement
    - Expected Stat error (0.1%) (>100 times of LEP stat)
    - Expected Systematics (0.12%) :
      - B-tag efficiency (0.1%)
      - charge correlations due to B tag/ jet charge (0.05%)

Backup: Branching ratio (R^e)

- LEP result :
  - Syst error (0.17%)
    - t channel subtraction (0.11%)
    - Electron and momentum scale (0.06%)
    - Tau background (0.08%)

- CEPC
  - Dominated by t channel background and tau background
  - No much room to improve on R^e

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%)

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

- 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%)