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Electroweak physics at CEPC

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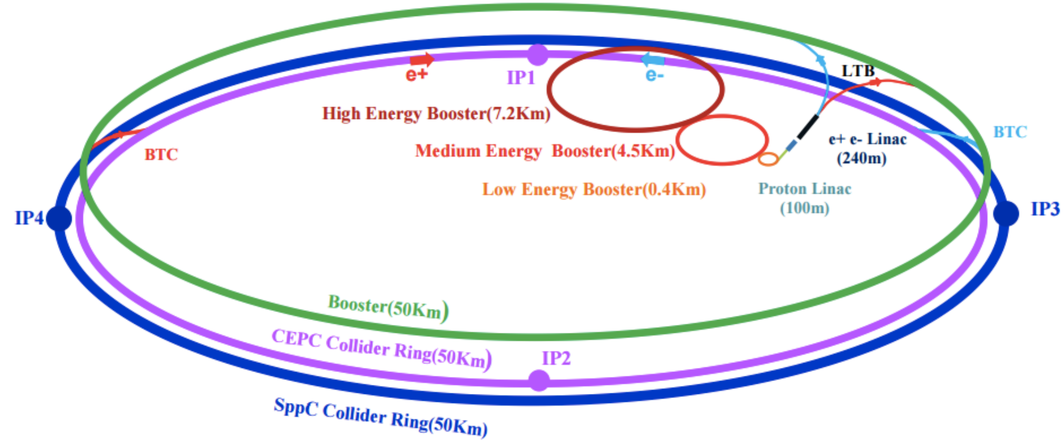
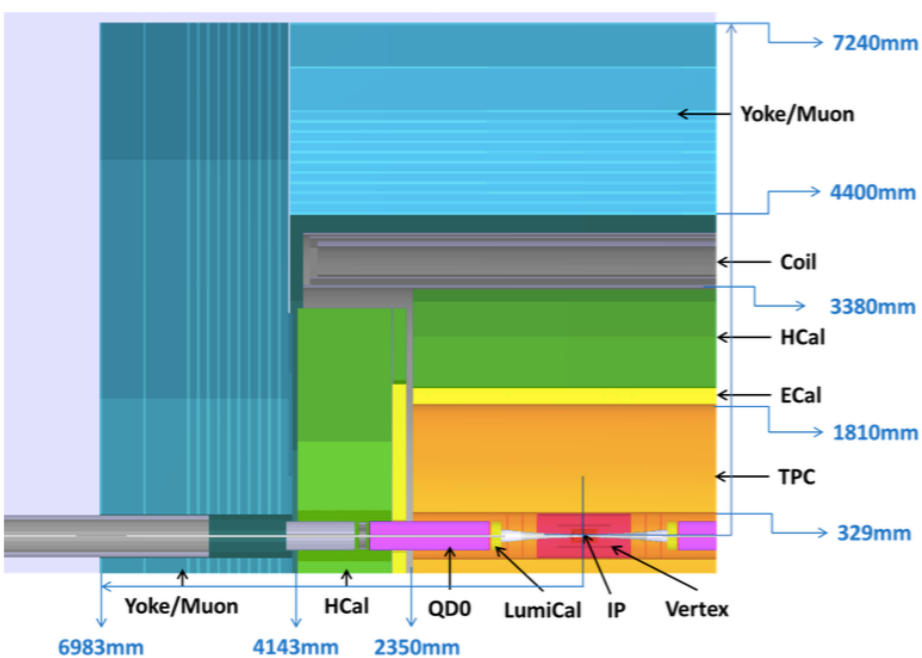
CEPC accelerator

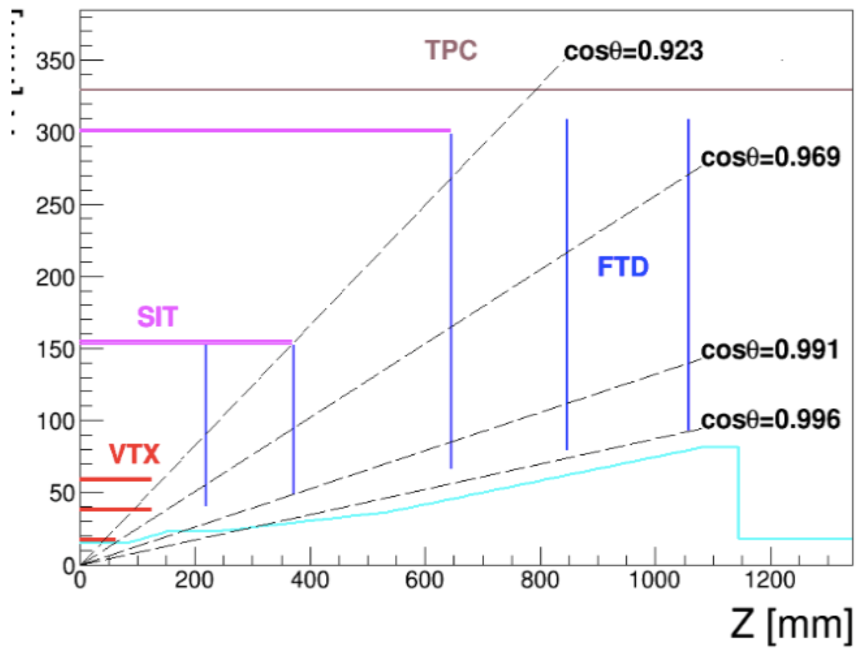


- Electron-positron circular collider
  - Higgs Factory（E_{cms}=250GeV , 10^6 Higgs)
    - **Precision study of Higgs coupling in ZH runs**
    - **complementary to ILC**
    - **See Manqi and Gang's talk this morning in Higgs section for more details**
  - Z factory（E_{cms}=91 GeV, 10^{10} Z Boson）：
    - **Precision Electroweak measurement in Z pole running**
    - **Major focus of this talk**
- Preliminary Conceptual Design Report(Pre-CDR) available :
  - http://cepc.ihep.ac.cn/preCDR/volume.html
- Aiming to finalize Conceptual Design Report (CDR) next year

CEPC detector (1)

- ILD-like design with some modification for circular collider
  - No Power-pulsing
- Tracking system (Vertex detector, TPC detector , 3.5T magnet)
  - Expected Pixel size in vertex detector : less than 16x 16μm
  - Expected Impact parameter resolution: less than 5μm
  - Expected Tracking resolution : $\delta(1/Pt) \sim 2*10^{-5}(GeV^{-1})$





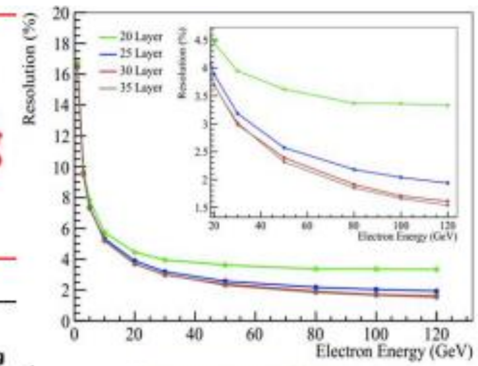
CEPC detector (2)

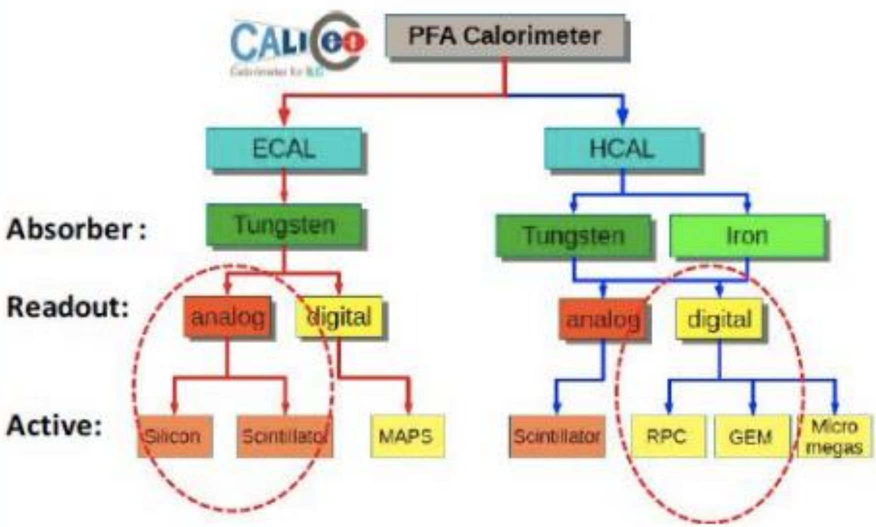
- Calorimeters:
  - Concept of Particle Flow Algorithm (PFA) based
  - EM calorimeter energy resolution: $\sigma_E/E \sim 0.16/\sqrt{E}$
  - Had calorimeter energy resolution: $\sigma_E/E \sim 0.5/\sqrt{E}$
  - Expected jet energy resolution : $\sigma_E/E \sim 0.3/\sqrt{E}$

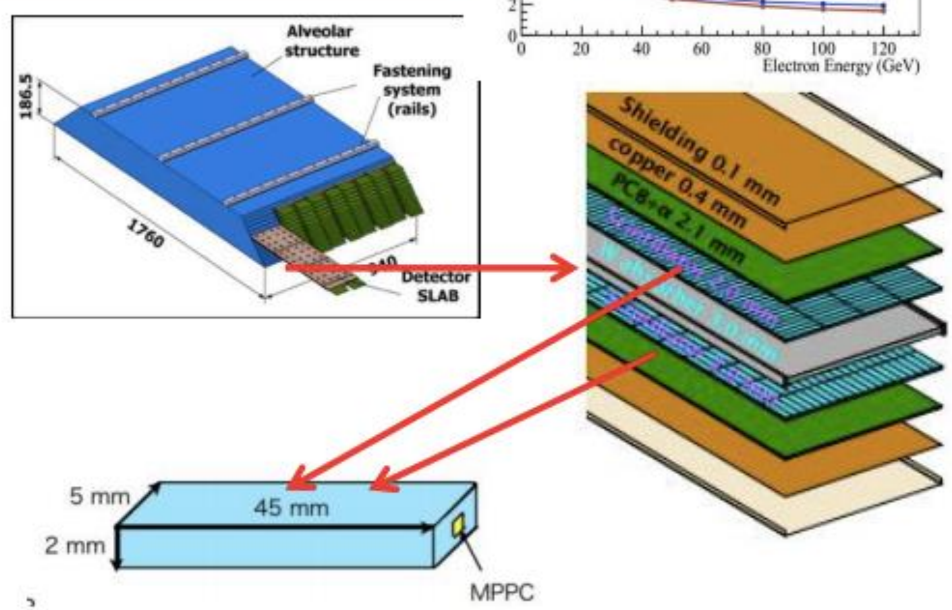
- Jet energy (Higgs self-coupling, W/Z separation)
  - ~1/2 resolution (wrt LHC)

$$\sigma_E / E = 0.3/\sqrt{E(GeV)}$$

less demanding at CEPC



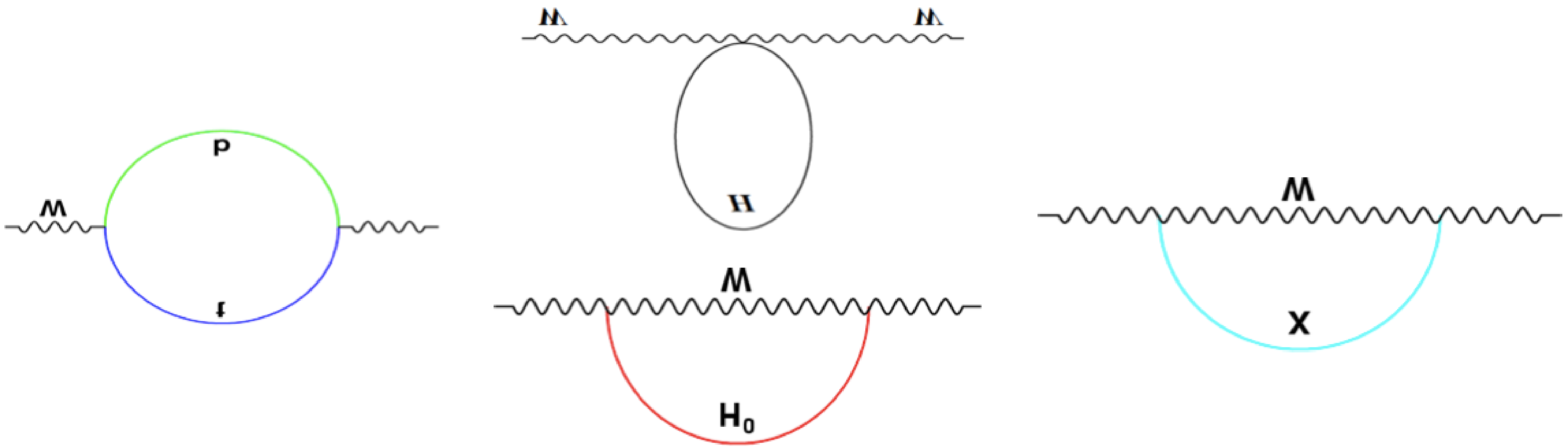




ECAL: Scintillator + W + Scintillator

Motivation

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



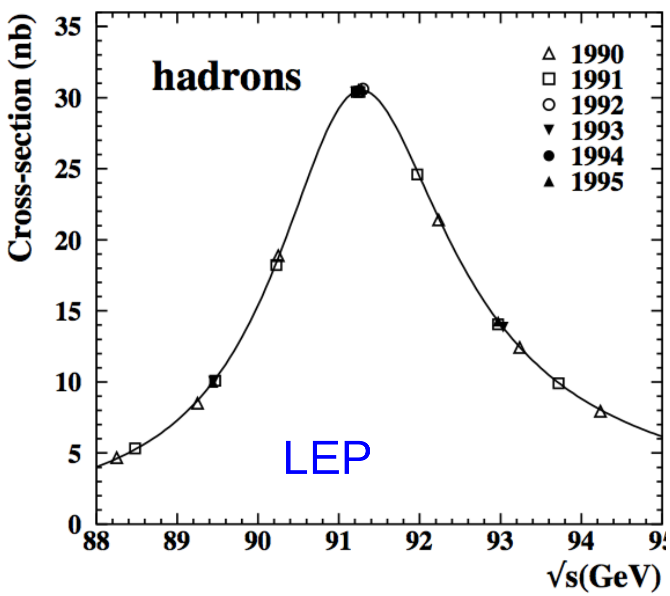
The prospect of CEPC electroweak physics in pre-CDR study

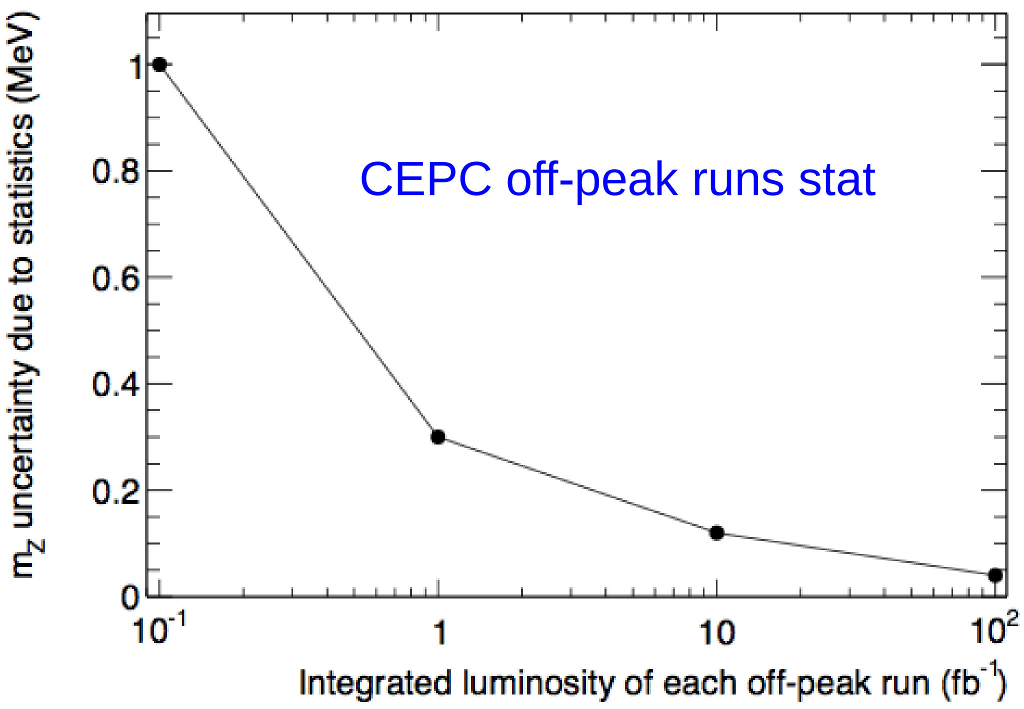
- Expected precision on some key measurements in CEPC Pre-CDR study based on projections from LEP and ILC.
  - http://cepc.ihep.ac.cn/preCDR/volume.html
- From now to next year, plan to update the study for Conceptual Design Report (CDR) with full detector simulation

Observable	LEP precision	CEPC precision	CEPC runs
m_Z	2 MeV	0.5 MeV	Z lineshape
m_W	33 MeV	3 MeV	ZH (WW) thresholds
A_{FB}^b	1.7%	0.15%	Z pole
$\sin^2\theta_W^{\mathrm{eff}}$	0.07%	0.01%	Z pole
R_b	0.3%	0.08%	Z pole
N_ν (direct)	1.7%	0.2%	ZH threshold
N_ν (indirect)	0.27%	0.1%	Z lineshape
R_μ	0.2%	0.05%	Z pole
R_τ	0.2%	0.05%	Z pole

Z mass measurement

- LEP measurement : 91.1876±0.0021 GeV
- CEPC possible goal: 0.5 MeV
  - Z threshold scan runs is needed to achieve high precision.
  - Stat uncertainty : 0.2MeV
    - Better to have more than 10fb^{-1} for off-peak runs (6 off-peaks runs)
  - Syst uncertainty: ~0.5 MeV
    - Beam energy uncertainty need to be better than 5ppm
    - start to Establishing a accelerator model relating the measured beam energy
    - Study of the resonant depolarization technique to measure beam energy (LEP approach)

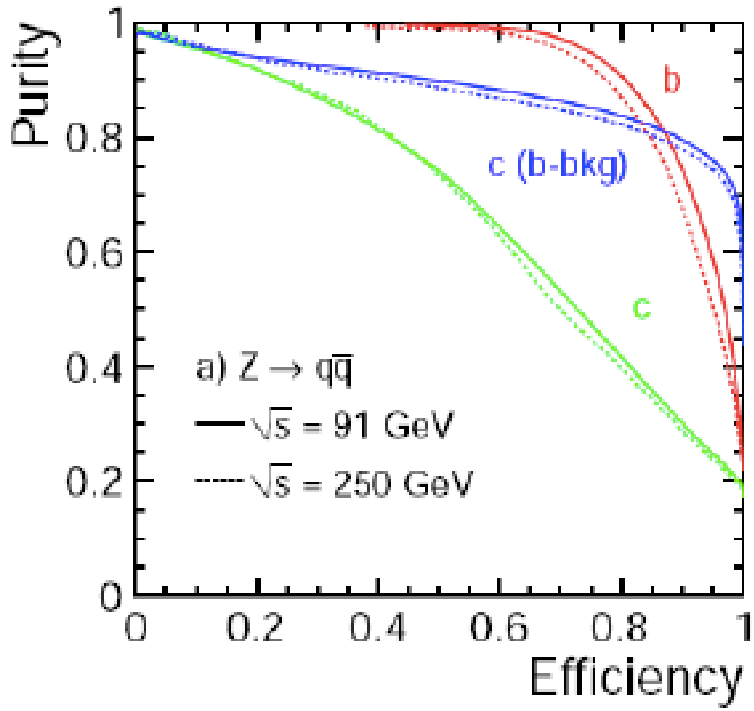




Branching ratio (R^b)

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

- LEP measurement 0.21594 ±0.00066
  - Stat error : 0.44%
  - Syst error : 0.35%
  - Typically using 65% working points
- CEPC
  - Expected Stat error (0.04%)
  - Expected Syst error (0.07%)
  - Expect to use 80% working points
    - 15% higher efficiency than SLD
    - 20-30% higher in purity than SLD



Uncertainty	LEP	CEPC	CEPC improvement
charm physics modeling	0.2%	0.05%	tighter b tagging working point
hemisphere tag correlations for b events	0.2%	0.1%	Higher b tagging efficiency
gluon splitting	0.15%	0.08%	Better granularity in Calo

Backward-forward asymmetry measured from b jet

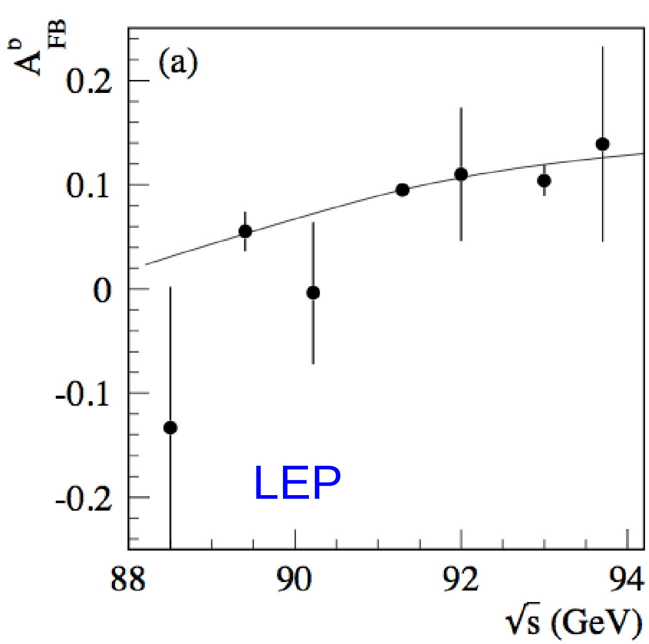
$A_{FB}^{b\bar{b}}(0)$

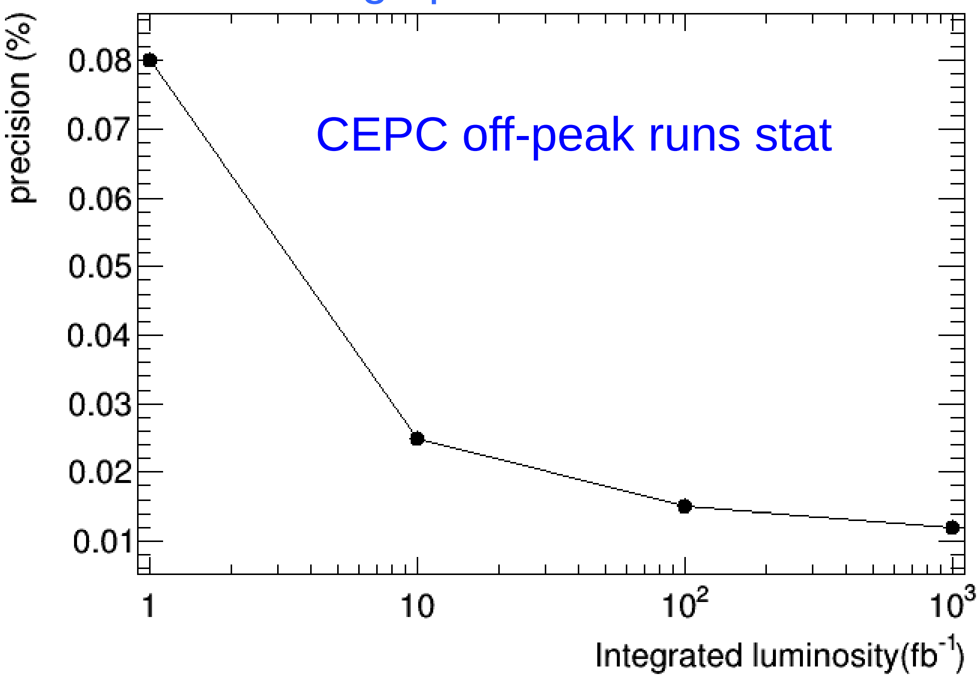
- LEP measurement : 0.1000+-0.0017 (Z peak)
    - Method 1: Soft lepton from b/c decay (~2%)
    - Method 2: jet charge method using Inclusive b jet (~1.2%)
    - Method 3: D meson method (>8%, less important method)
- CEPC
  - Focus more on method 2 (inclusive b jet measurement)
    - Expected Systematics (0.15%) :

Uncertainty	LEP	CEPC	CEPC improvement
charm physics modeling	0.2%	0.05%	tighter b tagging working point
tracking resolution	0.8%	0.05%	better tracking resolution
hemisphere tag correlations for b events	1.2%	0.1%	Higher b tagging efficiency
QCD and thrust axis correction	0.7%	0.1%	Better granularity in Calo

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

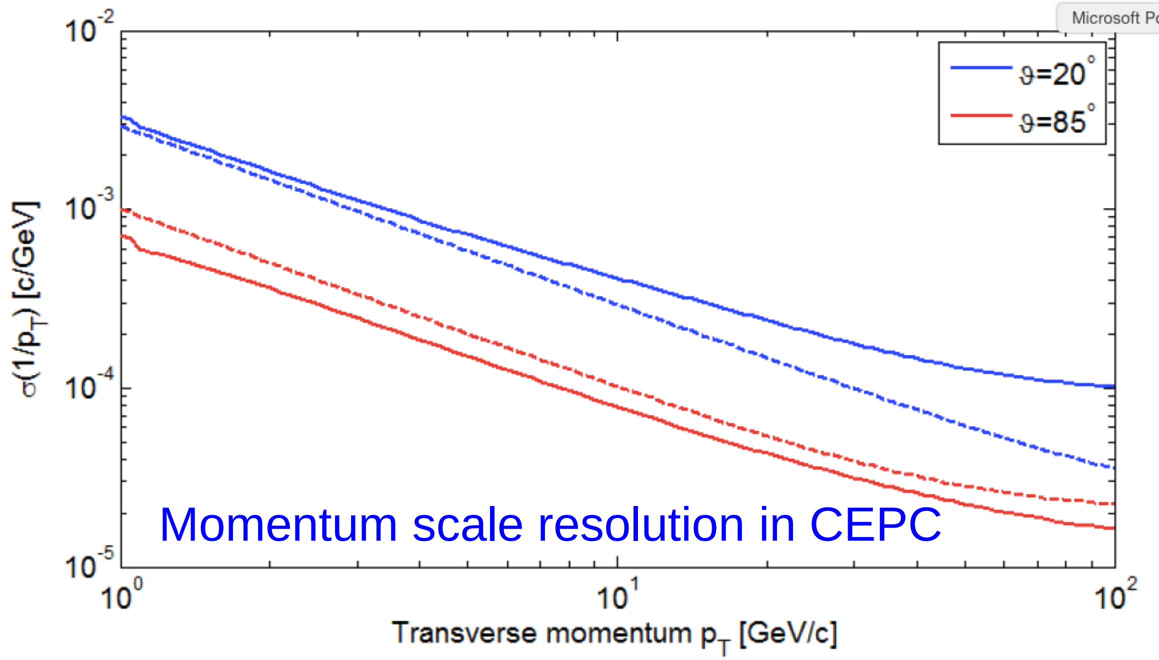
- LEP/SLD: 0.23153 ± 0.00016
  - 0.1% precision.
  - Stat error in off –peak runs is one of limiting factor.
- CEPC
  - Stat error : 0.02% ;
  - systematics error : 0.01%
    - Input From Backward-forward asymmetry measurement
  - The statistics of off-Z peak runs is one of the important issue.
    - Need at least 10 fb^{-1} for off-peak runs to reach high precision.





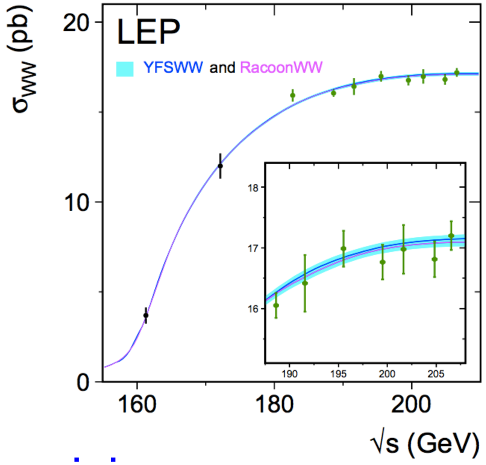
Branching ratio (R^{mu})

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



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%

W mass measurement



- Current PDG precision : 80.385±0.015 GeV
  - Possible goal for CEPC : 3 MeV
- Three methods for W mass measurements:
  - 1.WW Threshold scan (√s=160GeV):
    - Advantage: Very robust method, can achieve high precision.
    - Disadvantage
      - Beam polarization design has not finished.
      - Higher cost , Require dedicated runs >100fb^{-1} on WW threshold(~160GeV)
  - 2.Kinematic Reconstruction
    - Need good understanding of ISR
  - 3.Direct measurement of the hadronic mass (major method for CDR)
    - Based on 10^{10} Z->hadrons sample to calibrate jet energy scale (< 3MeV)
    - 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.
- For CEPC CDR next year,
  - Plan to compare these three methods with full simulation study
  - Major questions : whether we need WW threshold scan and beam polarization

Summary

- CEPC electroweak physics in Preliminary Conceptual Design Report.
  - Expected precision based on projections from LEP and ILC.
- Aim for more realistic study with full simulation for CDR next year.
  - Mainly focus on a few key measurements.
    - m_W
    - Weak mixing angle

- Welcome to join this effort