

中国科学院高能物理研究所

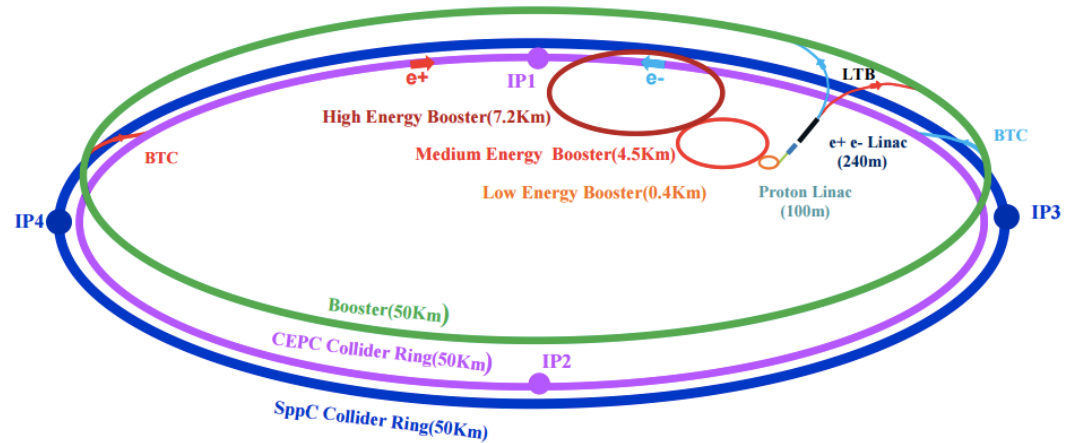
Institute of High Energy Physics Chinese Academy of Sciences

# ELECTROWEAK PHYSICS TOWARDS THE CDR

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Zhijun Liang (IHEP)

# CEPC accelerator



- Electron-positron circular collider
  - Higgs Factory ( $E_{\text{cms}}=250\text{GeV}$ ,  $10^6$  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 ( $E_{\text{cms}}=91\text{ GeV}$ ,  $10^{10}$  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

# 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

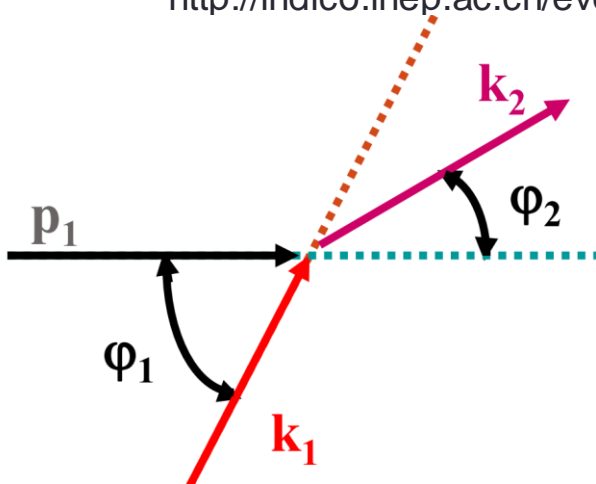
Observable	LEP precision	CEPC precision	CEPC runs
$m_Z$	2 MeV	0.5 MeV	$Z$ lineshape
$m_W$	33 MeV	3 MeV	$ZH$ ( $WW$ ) thresholds
$A_{FB}^b$	1.7%	0.15%	$Z$ pole
$\sin^2 \theta_W^{\text{eff}}$	0.07%	0.01%	$Z$ pole
$R_b$	0.3%	0.08%	$Z$ pole
$N_\nu$ (direct)	1.7%	0.2%	$ZH$ threshold
$N_\nu$ (indirect)	0.27%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

# Major systematics in EWK measurement

	Major systematics	Other systematics
$m_Z$	Beam energy ( $10^{-5} \sim 10^{-6}$ )	Luminosity measurement ( $10^{-4}$ )
$A_{FB}(\text{lepton})$	Beam energy ( $10^{-5} \sim 10^{-6}$ )	Track Alignment in forward region Track angular resolution ( $<0.05\%$ )
$R_b$	flavor tagging (light jet and c jet background).	Gluon splitting modeling
$A_{FB}(b)$	flavor tagging (light jet and c jet background).	Jet charge
$m_W$ (direct reconstruction )	Jet energy scale and resolution ( $<3\%$ JER)	Beam energy
$m_W$ (threshold scan)	Beam energy	Luminosity measurement
$\alpha_{QCD}, \alpha_{QED}$	To be study	

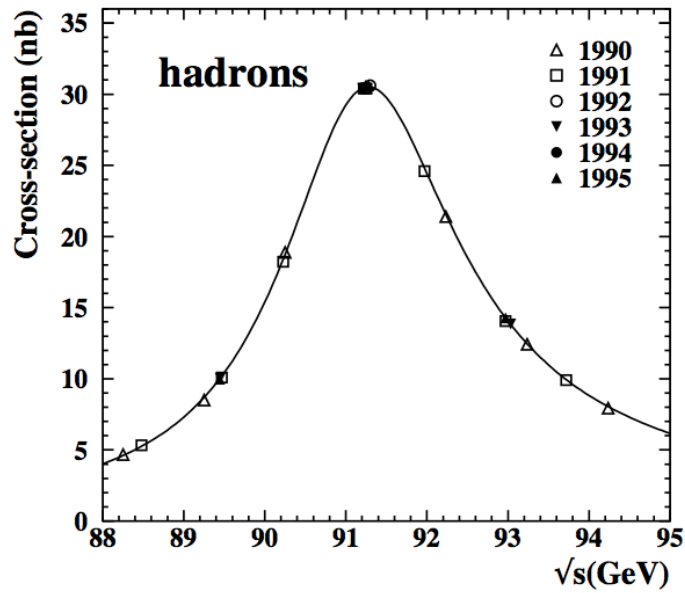
# Task 1 : Beam energy measurement

- **Resonant depolarization method.** (LEP approach)
  - Urgently need Beam polarization design in CEPC
  - Whether CEPC can have bunch with polarization and how long it lasts
  - Polarization fraction in Z and WW threshold
- **compton scattering approach**
  - **Whether it can reach 1MeV precision from this approach**
    - preliminary study in G-Y. Tang's talk  
<http://indico.ihep.ac.cn/event/6495/session/4/contribution/29/material/slides/0.pdf>

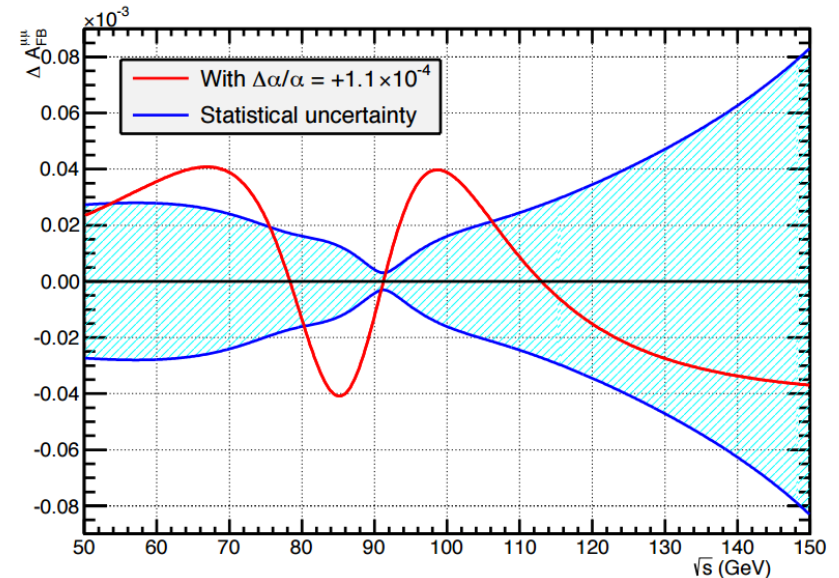


# Task 2: optimizing Z threshold scan

- Optimize off-peak runs statistics for Z line shape and  $\alpha_{\text{QED}}$  shape
  - Check event selection efficiency as a function of beam energy
- Fcc-ee colleague proposed to take more data around 87 and 94 GeV off-peak runs for  $\alpha_{\text{QED}}$  shape
- Need fastsim study to check  $\alpha_{\text{QED}}$  measurement



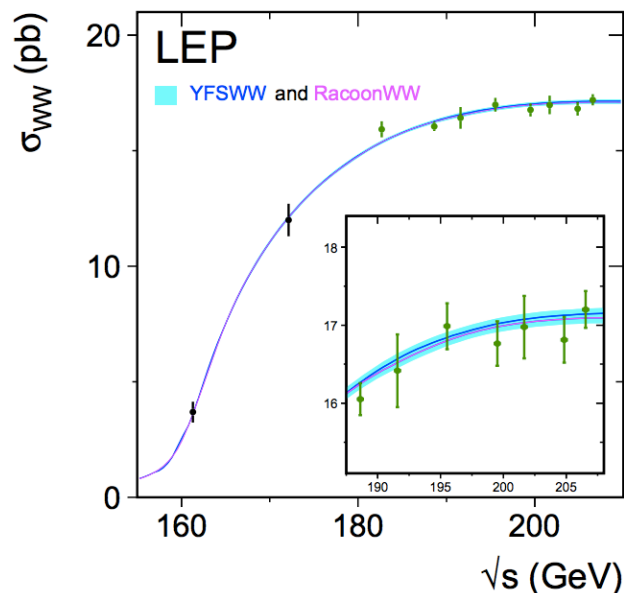
P. Janot, JHEP 1602 (2016) 053



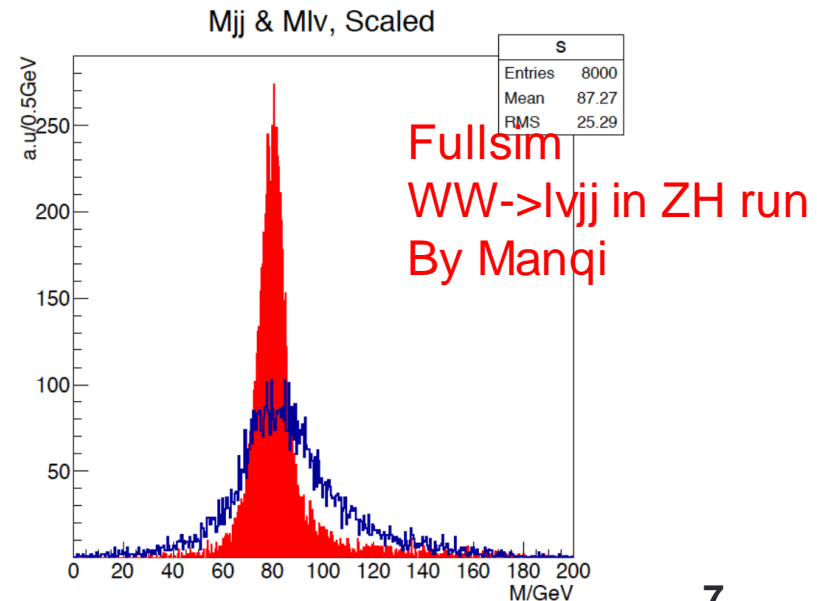
# Tasks in W mass measurement

- Threshold scan method
  - Optimize off-peak runs statistics
  - Check selection efficiency in different off-peak runs
- Direct measurement of the hadronic mass (method for pre-CDR)
  - Optimize W mass direct reconstruction method in ZH runs
  - Jet energy calibration

## Threshold scan



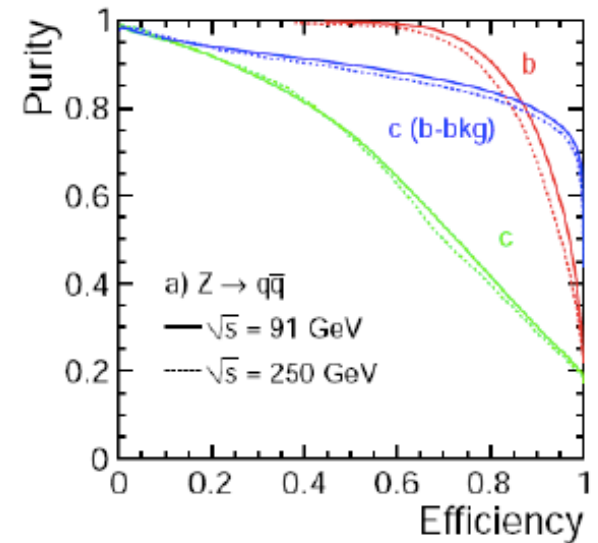
## Direct reconstruction



# B tagging performance in Branching ratio ( $R^b$ )

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

- Major systematics is from light jet and c jet background
- can be reduced by improving the b tagging performance
- Need fullsim to validate its performance



Uncertainty	LEP	CEPC	CEPC improvement
hemisphere tag correlations for b events	0.2%	0.1%	Higher b tagging efficiency



# Tasks in EWK measurements

	Task	samples
$m_Z$	Resonant depolarization and Compton scattering method on beam energy	
$m_Z$ , $\alpha_{QED}$	Optimize off-peak runs statistics and selection	<a href="#">fastsim</a>
$R_b$	Validate B/c tagging performance in $R_b$ Measurement	Fullsim
$A_{FB}(b)$ semi-leptonic	<b>Jet charge reconstruction</b>	Fullsim
$A_{FB}(b)$ leptonic	<b>Lepton reconstruction in jets</b>	Fullsim
$m_W$ (direct reconstruction )	Optimize W mass reconstruction and jet energy calibration	Fullsim
$m_W$ (threshold scan)	Optimize off-peak runs statistics and selection	<a href="#">fastsim</a>
$A_{FB}(lepton)$	<b>Detector acceptance , forward detector alignment precision</b>	<a href="#">fastsim</a>

# Manpower status

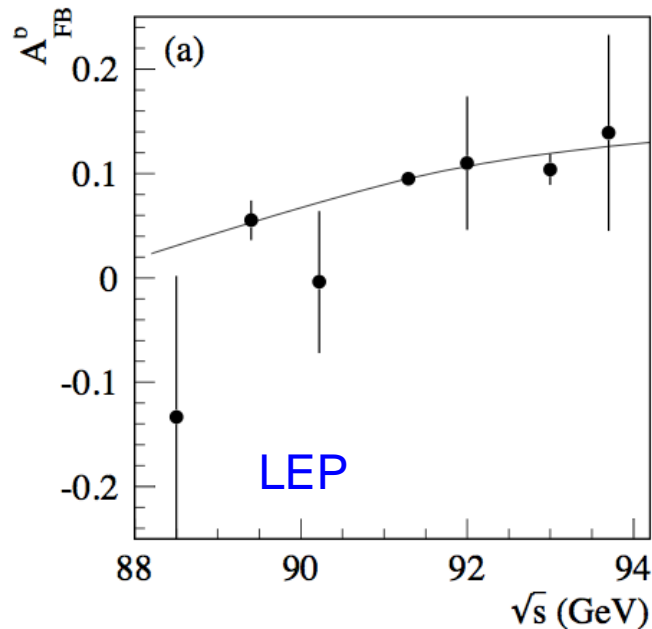
	manpower	Availability
Resonant depolarization and Compton scattering method on beam energy		
Optimize off-peak runs statistics and selection	-	
Validate B/c tagging performance in R_b Measurement	Bo Li	Just joint
Jet charge reconstruction	-	
Lepton reconstruction in jets	-	
Optimize W mass reconstruction and jet energy calibration	YanJun	Till middle of 2017
Optimize off-peak runs statistics and selection	-	
Detector acceptance , forward detector alignment precision	Mengran	Till middle of 2017

# Summary

- EWK study in Pre-CDR is mainly based on extrapolation from LEP
- Would like to do fast or full simulation study for CEPC CDR.
- Need more manpower to complete these study
- Welcome to join this effort

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

- LEP/SLD:  $0.23153 \pm 0.00016$ 
  - 0.1% precision.
  - Stat error is one of limiting factor.
- CEPC
  - systematics error : 0.01%
    - Input From Backward-forward asymmetry measurement
    - The precision mZ is another limiting factor ( uncertainty on  $P_{\text{beam}}$  )
  - If mZ is not well measured in CEPC ,
    - We need a large statistics of off-Z peak runs for weak mixing angle



CEPC off-peak runs stat

# Branching ratio ( $R^b$ )

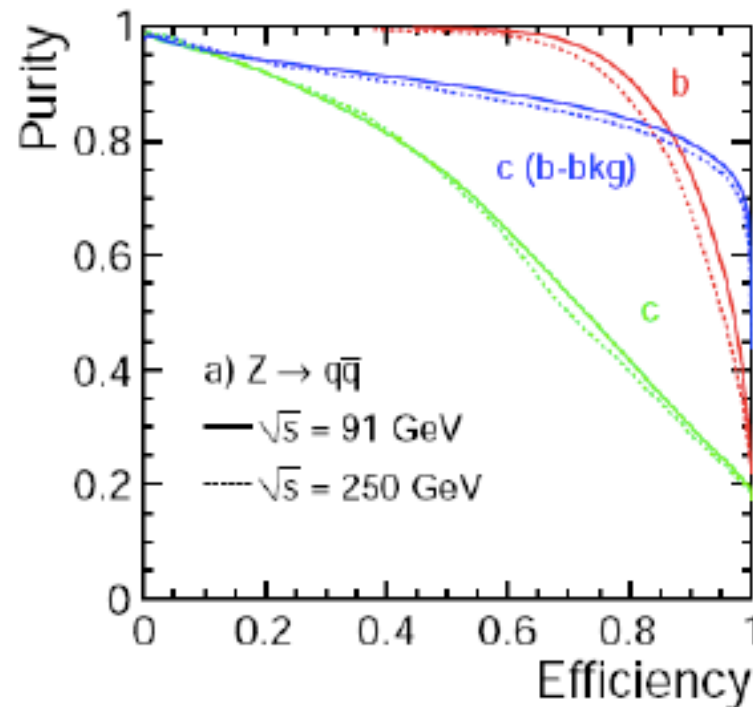
$$\frac{\Gamma(Z \rightarrow b\bar{b})}{\Gamma(Z \rightarrow \text{had})}$$

- LEP measurement  $0.21594 \pm 0.00066$

- Stat error : 0.44%
- Syst error : 0.35%
- Typically using 65% working points

- CEPC pre-CDR

- 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 :  $0.1000 \pm 0.0017$  (Z peak)
  - Method 1: Soft lepton from b/c decay ( $\sim 2\%$ )
  - Method 2: jet charge method using Inclusive b jet ( $\sim 1.2\%$ )
  - Method 3: D meson method ( $>8\%$ , less important method)
- CEPC pre-CDR
  - 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

# 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
    - $m_Z$
- Welcome to join this effort

# Urgent open task

- 1. W mass measurement
  - Try to understand the precision with direct measurement approach
  - Design dedicated runs for WW threshold scan approach
- 2. Detector optimization using  $Z \rightarrow b\bar{b}$   $R(b)$  measurement as benchmark model.
  - Pixel size optimization:
    - Baseline  $16 \times 16 \mu\text{m}$
    - Whether we need high resolution both direction
    - Is  $16 \times 32 \mu\text{m}$  OK ?
  - Momentum resolution requirement
  - Impact parameter requirement



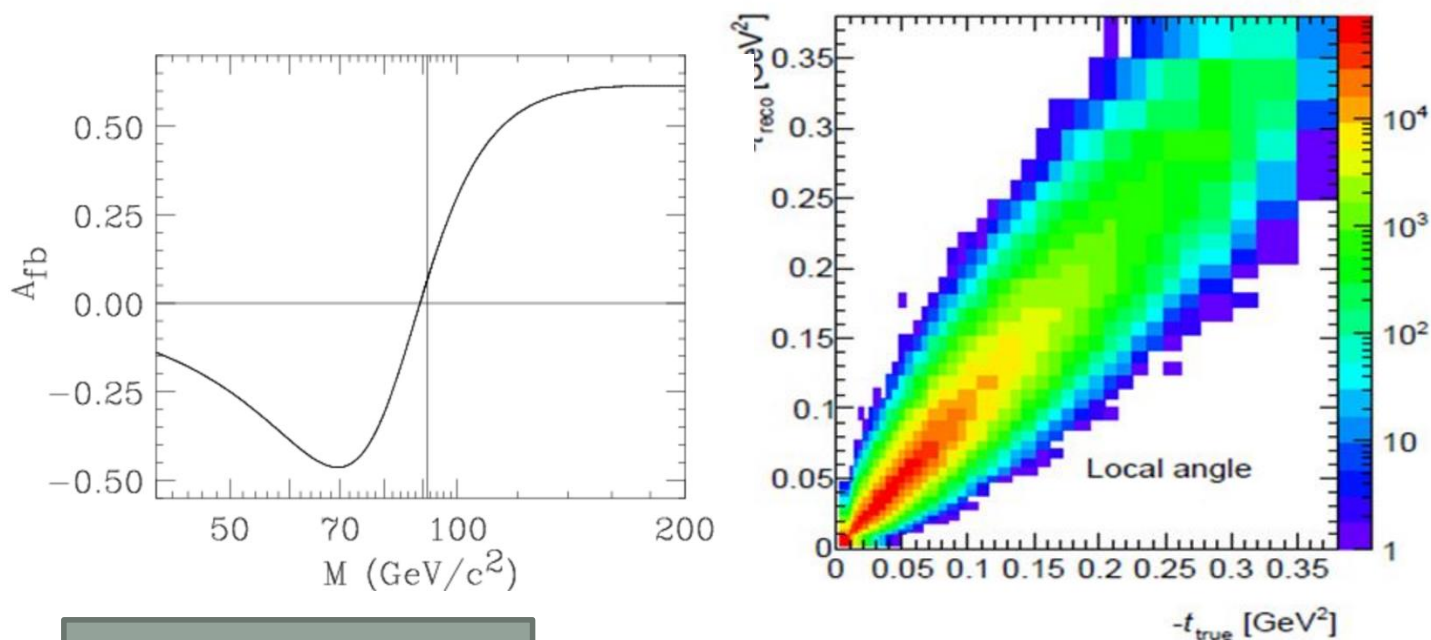
# From Pre-CDR to CDR

- Propagate beam momentum scale uncertainty to all EW measurement.
- Give a clear physics requirement to accelerator

		Correlations				
		$m_Z$	$\Gamma_Z$	$\sigma_{\text{had}}^0$	$R_\ell^0$	$A_{\text{FB}}^{0,\ell}$
$\chi^2/\text{dof} = 172/180$		ALEPH				
$m_Z$ [GeV]	$91.1893 \pm 0.0031$	1.000				
$\Gamma_Z$ [GeV]	$2.4959 \pm 0.0043$	0.038	1.000			
$\sigma_{\text{had}}^0$ [nb]	$41.559 \pm 0.057$	-0.092	-0.383	1.000		
$R_\ell^0$	$20.729 \pm 0.039$	0.033	0.011	0.246	1.000	
$A_{\text{FB}}^{0,\ell}$	$0.0173 \pm 0.0016$	0.071	0.002	0.001	-0.076	1.000

# Plan for Weak mixing angle

- More details in Mengran's talk

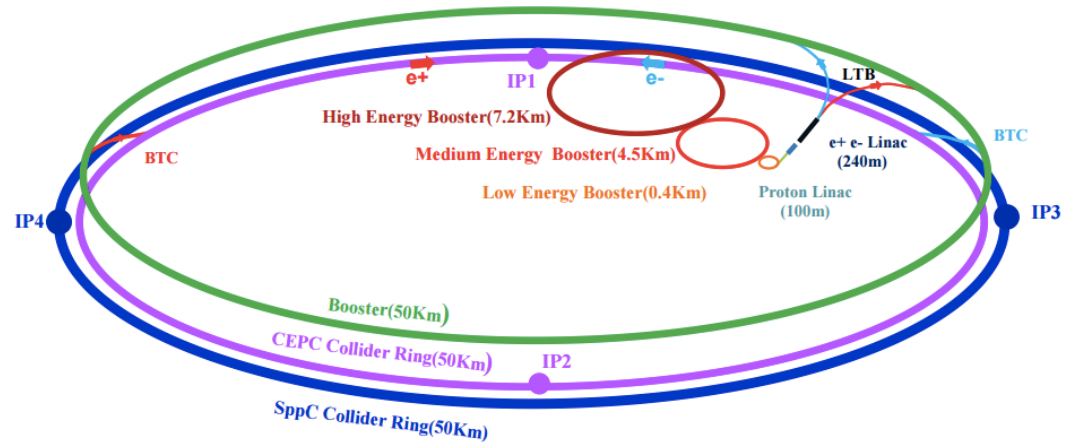


Truth  
distribution  
From Z fitter

unFolding matrix

Reco level  
distribution

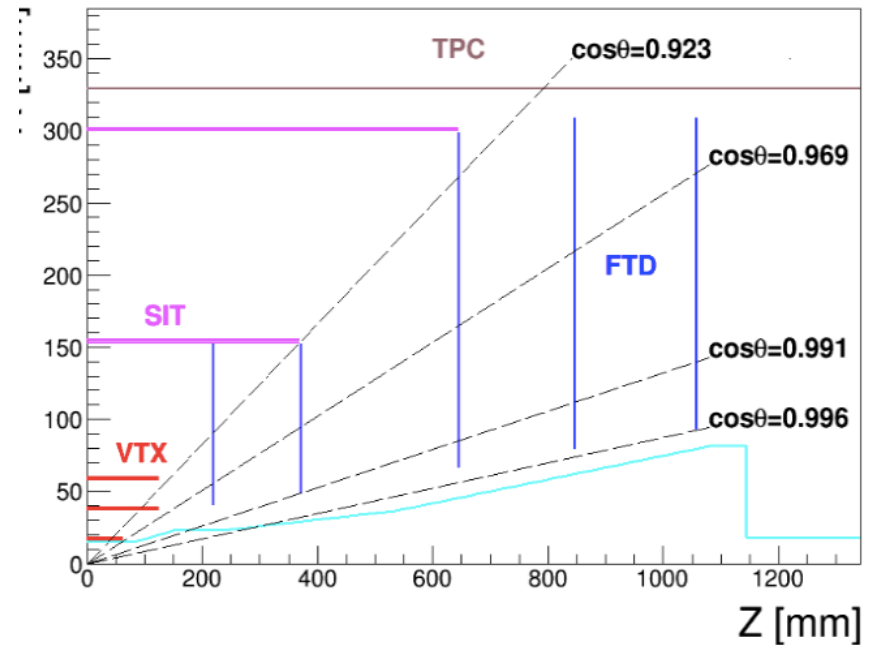
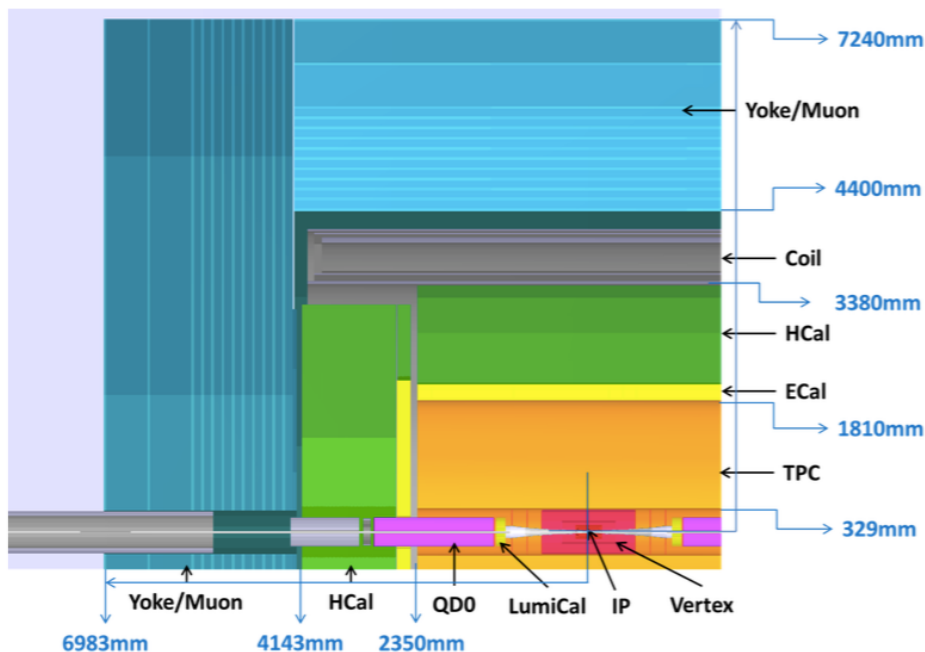
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# CEPC detector (1)

- 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  $16 \times 16 \mu\text{m}$
  - Expected Impact parameter resolution: less than  $5 \mu\text{m}$
  - Expected Tracking resolution :  $\delta(1/P_t) \sim 2 \cdot 10^{-5} (\text{GeV}^{-1})$



# CEPC detector (2)

- Calorimeters:

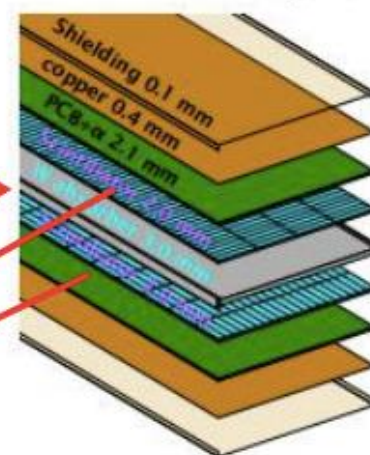
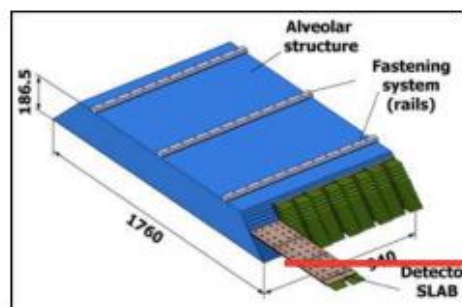
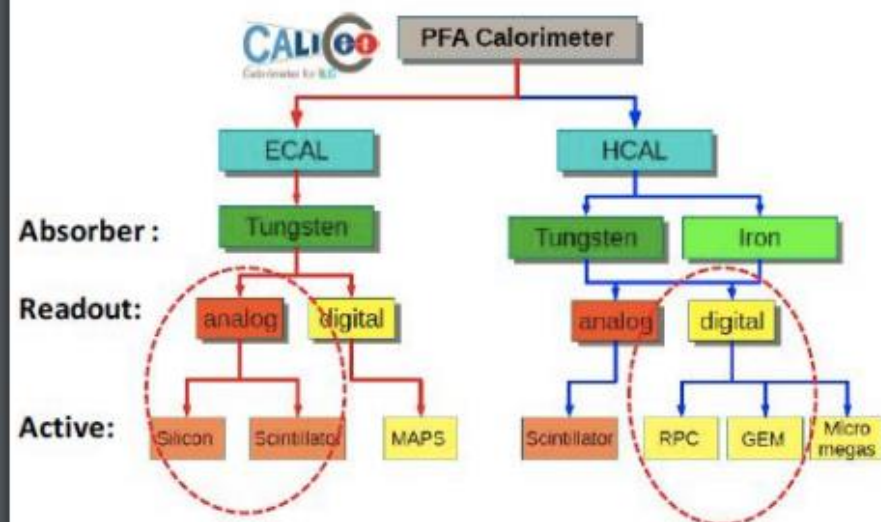
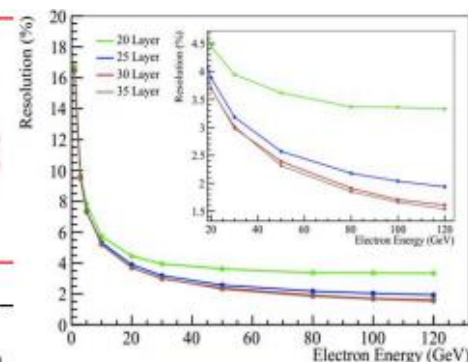
- Concept of Particle Flow Algorithm (PFA) based
- EM calorimeter energy resolution:  $\sigma_E/E \sim 0.16/\sqrt{E}$
- Had calorimeter energy resolution:  $\sigma_E/E \sim 0.5/\sqrt{E}$
- Expected jet energy resolution :  $\sigma_E/E \sim 0.3/\sqrt{E}$

- Jet energy (Higgs self-coupling, W/Z separation)

– ~1/2 resolution (wrt LHC)

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

less demanding  
at CEPC



ECAL: Scintillator + W + Scintillator