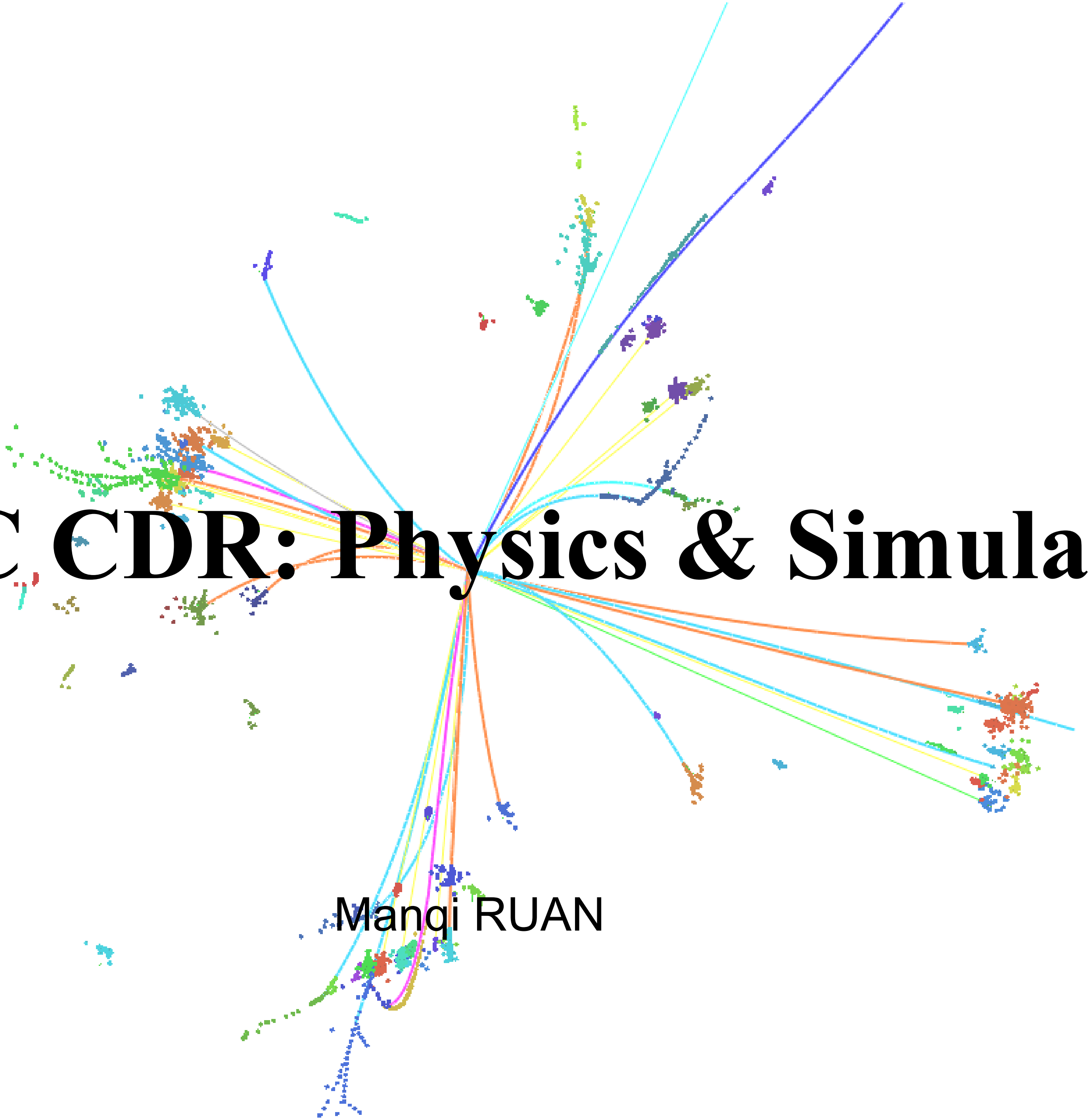


CEPC CDR: Physics & Simulation

Manqi RUAN

Personal Perspective to CDR

- Clear description of the physics goal/potential

- Demonstrate detectors
  - Adapted to the CEPC collision environment
  - Achieves excellent reconstruction efficiency for Higgs events
  - Address key systematic control, such that it could fully appreciate the huge statistic of EW data

- Detector Hardware & Integration level
  - No show stopper
  - Proof of Principle: Validation with the cosmic/TB data and/or reference designs applied else where
  - Technology Readiness Level, identify the crucial R&D issues

Personal Perspective to CDR

- Workable, Optimization & COST are important issues but not essential
- Not exclusive, any self-consist new concepts are welcome, as far as following questions could be concluded
  - Feasibilities:
    - How to adapted to collision environment (DAQ & Working Rate)
    - Be Integrated: Material budget (tracker) & Geometry layout
  - Systematic:
    - Systematic break up (Mainly EW measurements) & requirements on sub-detectors, at different benchmark luminosities
  - Performance: Physics Object & Full event level
    - How will the separation at Dual readout affect Jet/Tau reconstruction...
- Higgs Physics needs full demonstration (many materials are available @ CEPC_v1). However, EW measurement is posing more stringent requirement, to which I hope we have a better understanding at CDR

CDR Outline: Physics-Detector Volume (version 2)

CDR Outline: Physics-Detector Volume (version 2)

0. Executive Summary (1 - 5)

1. CEPC Physics Potential (5 - 40)
   1. Introduction
   2. Key Physics objectives
   3. Productivities @ Z, WW, Higgs, (top)
   4. Complementary of EW & Higgs measurements
   5. SPPC (? not necessary)

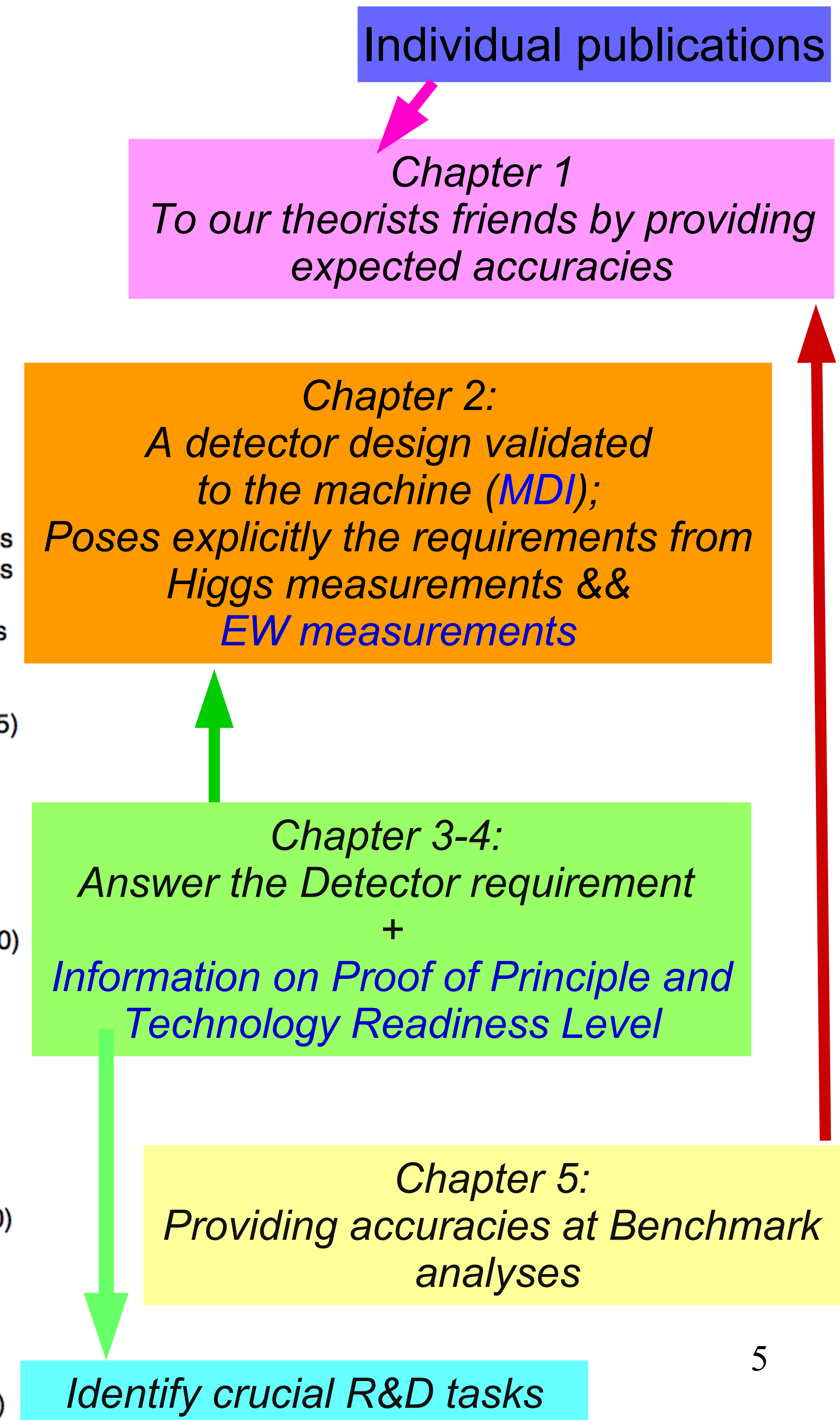
2. CEPC Collision Environment & Detector requirements (40 - 90)
   - 2.1. Introduction — 2 pages
   - 2.1. Beam Parameters & Constrain on the detector MDI — 5 pages
   - 2.2. Detector Requirements at
     - 2.2.1. Benchmark Physics channels & Requirements on Sub Systems — 3 pages
     - 2.2.2. General detector layout: Size, Coverage & B-Field — 10 pages
     - 2.2.3. Systematic Level (Luminosity, Beam Energy, etc) — 10 pages
     - 2.2.4. Power budget, DAQ requirement — 5 pages
     - 2.2.5. Physics Objects Level — 15 pages
     - // We need at least one detector that can do perfect tau-related physics

3, Detector Concepts (90 - 125)
   - 3.1. Introduction
   - 3.2. PFA Oriented (ILD/SiD), concept + optimization issues
   - 3.3. Italian (Wired + Dual)
   - 3.4. SPPC Conceptual
   - // Should Cost Estimation be included?

4, Detector Sub Systems: (125 - 240)
   - 4.1. VTX
   - 4.2. Tracker
   - 4.3. Calo
   - 4.4. MDI
   - 4.5. Very forward, Lumi Cal for Z pole?
   - 4.6. Muon & Solenoid
   - 4.7. Integration, Timing Structure, Electronic System & DAQ

5, Physics Performances + Detector optimization (240 - 280)
   - 5.1. Introduction
   - 5.2. Software & Reconstruction
   - 5.3. Physics Analysis at Benchmark Channels
   - // Key question: how would separation affect the performance

6, Future Plan & Crucial R&Ds (280 - 300)
   - // Optimization + Crucial R&Ds issue to be covered.



Leading questions

- Physics potential and simulation studies concerning CEPC Higgs measurement is relatively mature for the CDR (see Gang's talk)

- 0^{th} order
  - Machine adaptation & MDI design
  - EW Systematic break down & requirement on detector performance
  - SPPC Description, both for the physics motivation and detector concepts

- 1^{st} order
  - Level of details on simulation, optimization, validation studies

Simulation Status

Geometry Concept	Full Sim	Software & reconstruction	Fast Sim	Analysis	Optimizations
CEPC_v1 (ILD-like)	100%	90%	Delphes card implemented	~ 50 Higgs full sim/Analysis; A few EW studies initialized	Feasibility of TPC, active cooling free calo, calo geometry, etc
SiD-like	Tracker implemented	30%	-	-	-
Italian Proposal (Wired Chamber + Dual readout calo)	-	-	-	-	-

The majority of Analyzers, trained in Pre-CDR rushes, are now either leaving or only partly Available

We are short of computing resources as always. Not even a full SM samples in CEPC_v1

Final State	expected	generated	sim/reced	Arbor Version	Sim/Rec Ratio(%	Path
2 Fermions						
leptonic				***	***	***
zz_l_4tau	22119	100000	100000	v1	1.000	/cefs/higgs/weiyq/E250.Pzz_l.e0.p0.whizard195_bkg
zz_l_4mu	73578	100000	100000	v1	1.000	/cefs/higgs/weiyq/E250.Pzz_l.e0.p0.whizard195_bkg
zz_l_taumu	88577	100000	100000	v1	1.000	/cefs/higgs/weiyq/E250.Pzz_l.e0.p0.whizard195_bkg
zz_l_mumu	91758	100000	100000	v1	1.000	/cefs/higgs/weiyq/E250.Pzz_l.e0.p0.whizard195_bkg
zz_l_tautau	46460	100000	100000	v1	1.000	/cefs/higgs/weiyq/E250.Pzz_l.e0.p0.whizard195_bkg
ww_l	1984448	1984437	1982800	v1	0.999	/cefs/higgs/yant/E250.Pww_l.e0.p0.whizard195_bkg
zzorww_l_mumu	1084790	1084777	1083400	v1	0.999	/cefs/higgs/yant/E250.Pzzorww.e0.p0.whizard195_bkg
zzorww_l_tautau	1039492	1039510	1038400	v1	0.999	/cefs/higgs/yant/E250.Pzzorww.e0.p0.whizard195_bkg
sznu_l_mumu	218816	218824	218200	v1	0.997	/cefs/higgs/yant/E250.Psznu_l.e0.p0.whizard195_bkg
sznu_l_tautau	73578	100000	99600	v1	0.996	/cefs/higgs/yant/E250.Psznu_l.e0.p0.whizard195_bkg
sze_l_mu	4303527	4303528	4290400	v1	0.997	/cefs/higgs/weiyq/E250.Psze_l.e0.p0.whizard195/200k_sze_l_mu
sze_l_nunu	149581	149583	18600	v1	0.124	/cefs/higgs/weiyq/E250.Psze_l.e0.p0.whizard195_bkg_nu_add
sze_l_tau	758207	758206	220600	v1	0.291	/cefs/higgs/weiyq/E250.Psze_l.e0.p0.whizard195_bkg_tau_add
sw_l_mu	2167466	2167447	2149200	v1	0.992	/cefs/higgs/weiyq/200k_sw_l
sw_l_tau	2168556	2168556	2157600	v1	0.995	/cefs/higgs/weiyq/200k_sw_l
szeorsw_l	1259167	1259165	718000	v1	0.570	/cefs/higgs/weiyq/E250.Pszeorsw_l.e0.p0.whizard195_bkg_add
Semi-leptonic				***		***
zz_sl_nu_up	412686	412709	412000	v1	0.998	/cefs/higgs/yant/E250.Pzz_sl.e0.p0.whizard195_bkg
zz_sl_nu_down	681043	681041	678600	v1	0.996	/cefs/higgs/yant/E250.Pzz_sl.e0.p0.whizard195_bkg
zz_sl_mu_up	416019	416008	413800	v1	0.995	/cefs/higgs/yant/E250.Pzz_sl.e0.p0.whizard195_bkg
zz_sl_mu_down	646198	646181	642400	v1	0.994	/cefs/higgs/yant/E250.Pzz_sl.e0.p0.whizard195_bkg
zz_sl_tau_up	200889	200882	200600	v1	0.999	/cefs/higgs/yant/E250.Pzz_sl.e0.p0.whizard195_bkg
zz_sl_nu_up	324715	324709	323200	v1	0.995	/cefs/higgs/yant/E250.Pzz_sl.e0.p0.whizard195_bkg
ww_sl_muq	11911394	11911396	11900000	v1/v2_1	0.999	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/200k_ww_sl_*
ww_sl_muq	11911394	11911396	11832000	v1/v2_1	0.993	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/200k_ww_sl_*
sze_sl_uu	989093	989109	412600	v1	0.417	/cefs/higgs/weiyq/E250.Psze_sl.e0.p0.whizard195_bkg_uu_add
sze_sl_dd	650036	649940	193400	v1	0.298	/cefs/higgs/weiyq/E250.Psze_sl.e0.p0.whizard195_bkg_dd_add
sznu_sl_nu_up	283254	283254	282400	v1	0.997	/cefs/higgs/yant/E250.Psznu_sl.e0.p0.whizard195_bkg
sznu_sl_nu_down	460964	460961	459400	v1	0.997	/cefs/higgs/yant/E250.Psznu_sl.e0.p0.whizard195_bkg
sw_sl_qq	13025535	13025535	0	v1	0.000	/cefs/higgs/yant/E250.Psw_sl.e0.p0.whizard195_bkg
Hadronic				***		***
zz_h_utut	419604	419584	419200	v1	0.999	/cefs/higgs/yant/E250.Pzz_h.e0.p0.whizard195_bkg
zz_h_dtdt	1142310	1142270	1135600	v1	0.994	/cefs/higgs/yant/E250.Pzz_h.e0.p0.whizard195_bkg
zz_h_uu_nodt	483032	483045	481000	v1	0.996	/cefs/higgs/yant/E250.Pzz_h.e0.p0.whizard195_bkg
zz_h_cc_nots	485002	485016	482800	v1	0.995	/cefs/higgs/yant/E250.Pzz_h.e0.p0.whizard195_bkg
ww_h_cuxx	17147189	17147188	1709400	v1	0.100	/cefs/higgs/weiyq/E250.Pww_h.e0.p0.whizard195/200k_ww_h_cuxx/01
ww_h_uubd	252	100000	100000	v1	1.000	/cefs/higgs/weiyq/E250.Pww_h.e0.p0.whizard195/E250.Pww_h.e0.p0.whizard195_uubd_bkg
ww_h_uusd	837997	838010	205800	v1	0.246	/cefs/higgs/weiyq/E250.Pww_h.e0.p0.whizard195/uusd
ww_hccbs	28987	100000	100000	v1	1.000	/cefs/higgs/weiyq/E250.Pww_h.e0.p0.whizard195/E250.Pww_h.e0.p0.whizard195_ccbs_bkg
ww_h_ccds	836128	836128	60600	v1	0.072	/cefs/higgs/weiyq/E250.Pww_h.e0.p0.whizard195/ccds
zzorww_h_udud	7930514	7930514	5551400	v2_1	0.700	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/200k_zzorww_h_*
zzorww_h_cscs	7923141	7923140	5546200	v2_1	0.700	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/200k_zzorww_h_*
4 Fermions						
qq	250284565	250283714	10000	v2_2	0.000	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/qq_low_sta
signal						
e1e1h	38357	99938	100000	v2_2	1.001	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/e1e1h_151107
e2e2h	35849	99952	100000	v2_1	1.000	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/e2e2h_615
nnh	247237	247167	247600	v2_2	1.002	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/nnh_151110
qqh	724097	723755	724200	v2_2	1.001	/cefs/tmp_storage/yant/gridfs/cepc/user/w/weiyq/qqh_151112

Realistic Strategy

- Merge SiD & ILD into PFA oriented detector
  - Compare the tracking performance of TPC + Full Silicon: (2 FTE*month)
    - Track finding efficiency: eff(Theta, Energy)
    - Pre-interaction Rates
    - Track momentum resolution
    - dEdx
  - Develop an Delphes card for SiD like geometry and compare the Benchmark performances (1 FTE*month)
  - Delphes cannot model PFA Confusions: Valid if Confusion penalty can be ignored
  - Push further Optimization study, Full Sim, etc

- Providing necessary help to implement the Italian geometry
  - Extra manpower (mainly from ppl interested in this concept) is needed, to provide analysis results

Sets of key questions

- Feasibility:
  - TPC
  - Energy Budget for sub systems & active cooling free design
  - Trigger-free design? & DAQ structure...   (? FTE * year)
  - ...
- Systematic: – towards EW measurements
  - Common Systematics (@ Oblique parameters – 0.3 FTE*year (??))
    - Luminosity measurement
    - Alignment control
    - Beam energy measurement
    - Acceptances
  - Specialized Systematic: Mis-id rates of leptons, jet flavors & jet charges
- Performance: at Benchmarks

Benchmarks

Benchmarks	Main observables	Key performances	Status	
llH, H->X	Higgs recoil spectrum	Lepton Id efficiency, Tracker intrinsic momentum resolution	Well understood	90%
H+X, H->di photon	Event reconstruction efficiency, Higgs invariant mass peak width	Tracker Material, Intrinsic ECAL energy Resolution		
ZH->4 jets,	Br(H->bb, cc, gg)	Jet clustering, PFA: Jet Energy Resolution, Jet Flavor Tagging	Studied at CEPC conceptual Detector (CEPC_v1)	50%
vvH, H->2 jets (optional)	Br(H->bb, cc, gg)	Jet Energy Resolution & Flavor Tagging		
H+X, H->di muon	Event reconstruction efficiency, Higgs invariant mass peak width	Lepton Id efficiency, Tracker intrinsic momentum resolution		
vvH, H->di tau	Efficiency of Tau reconstruction with different tau decay mode	PFA separation, Impact parameter resolution		
qqH, H->invisible	Higgs recoil spectrum	PFA: Jet Energy Resolution		
vvH, H->WW->lvqq	Event Reconstruction Efficiency di-jet mass distribution	PFA, Simultaneous reconstruction of Lepton, Jets and Missing Energy	Studied at different Calorimeter Granularity	80%
WW->lvqq	W mass	Jet Energy resolution & Systematic controls	Full simulation analysis not accomplished yet	
Z->tautau	V/A, spectrum function, Branching ratios	Separation & Tracking efficiencies	not started yet	

Physics with taus would be essential for the detector optimization...
Lots of works remains to converge the optimization of PFA-based detector

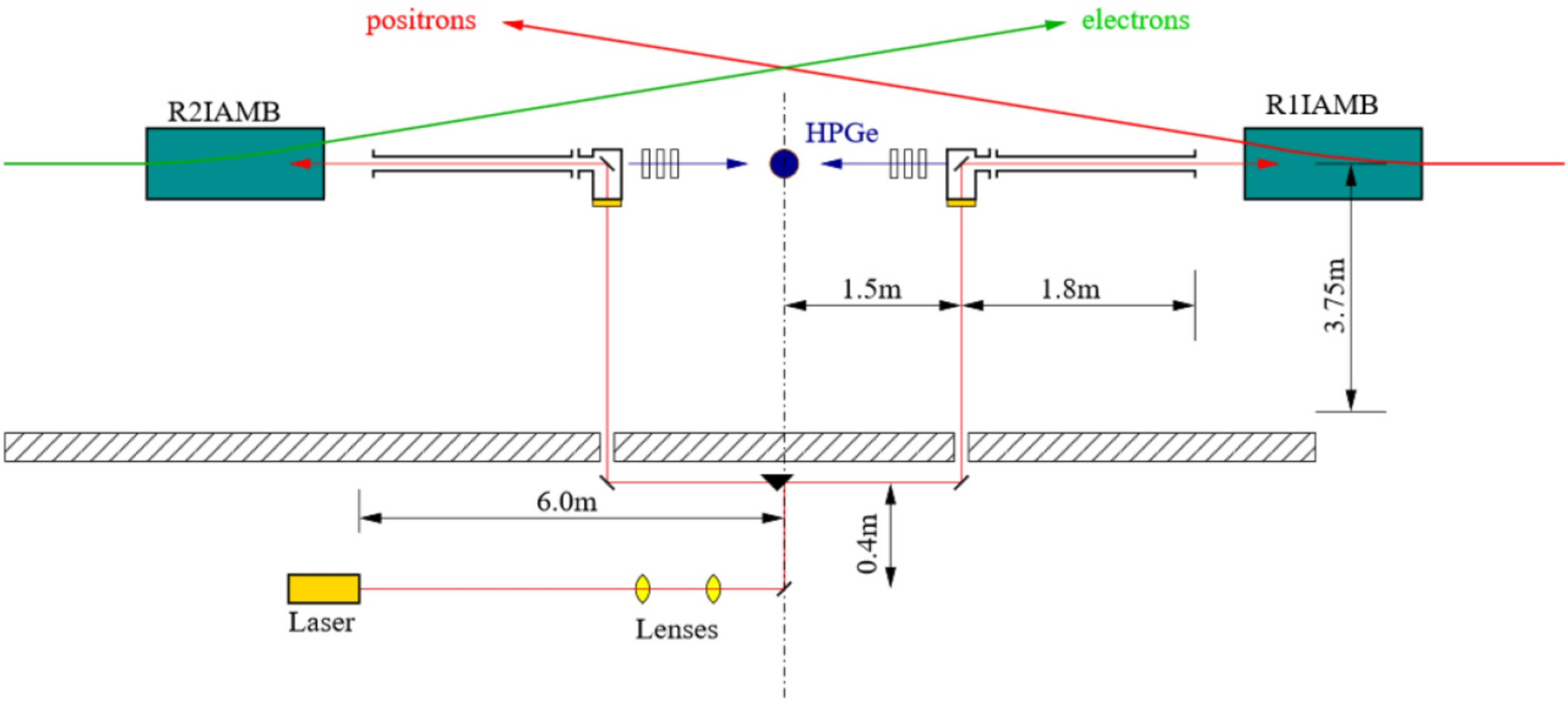
Luminosity monitoring

- 1E-3 for Higgs measurements
  - Better be 5E-4
- 1E-4 or better of Z line shape scan
  - Z mass, width & Neutrino generation
- ?? for WW/top measurements

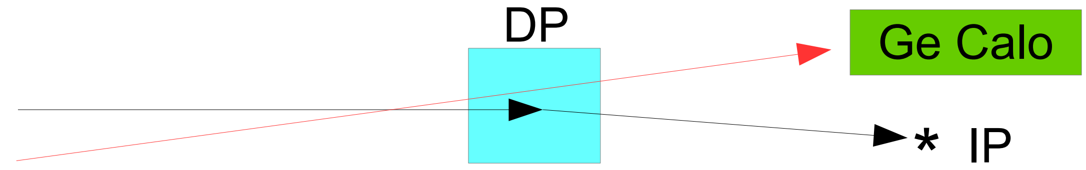
Beam energy monitoring

- Physics requirement
  - 1/100 MeV @ Higgs runs wi/wo recoil mass method
  - 0.1-1 MeV @ Z pole operation && WW mass operation
- Key issue: Beam energy stability (1 FTE*month)
- Resonant depolarization
- ISR return event
  - 10-100 MeV could be achieved if the beam stability maintains at 1E-4 level for 1 hour data taking...
- Compton scattering based

Laser based Beam Energy Monitor at BEPC



Based on Compton scattering

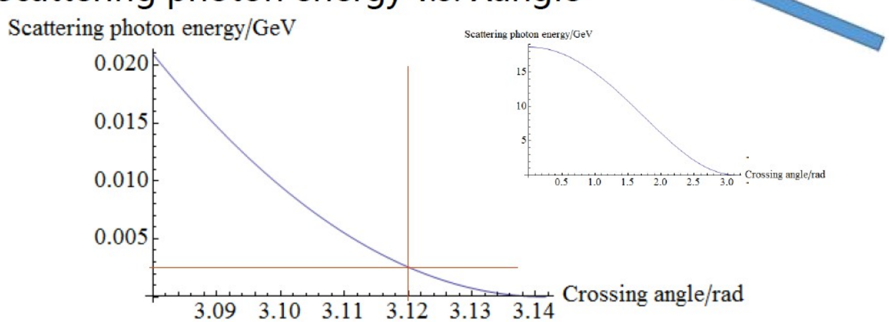


For 1 MeV accuracy (1E-5)
Recommend to place in the last Dipole

Photon Energy range	**OK**
Angular uncertainty of laser & emittance of beam	**OK**
Calibration	**OK**
Photon productivity	1E7/s
Separate from SR background:	Pretty Challenge
Device stability	?

CHANGE CROSSING ANGLE

- Crossing angle [0, π]
- Scattering photon energy v.s. Xangle



- When Xangle is 3.12 rad, maximum scattering photon energy is 2.815 MeV.
- Tl208: 2.614MeV.

SCATTERING PHOTON NUMBER

- From ref. CPC32, 995 (2008),
  - $N_\gamma = \frac{PI\sigma_T}{\omega_\gamma\, c\, e\, \pi^2} \iiint \frac{1}{\sigma^2(z)\sigma_x\sigma_y} f_\gamma f_e\, dxdydz \sim 2.7\times 10^8 s^{-1}$, @BEPCII
  - $\sigma(z) = \pi r^2\sqrt{1+\frac{z^2}{f^2}}$
  - $\frac{\sigma_{T\_CEPC}}{\sigma_{T\_BEPC}} \sim 0.016$. ($\sigma_T$ denotes the Compton scattering cross section.)

	Laser power	Photon energy	I	σ_x	σ_y
BEPCII	50W	0.117eV	9.8mA	1.6mm	0.16mm
CEPC			16.6mA	69.97μm	0.15μm

- $\frac{N_{\gamma\_CEPC}}{N_{\gamma\_BEPC}} \sim 0.023$, $N_{\gamma\_CEPC} \sim 6.3\times 10^6 s^{-1}$.

Key issues in each chapter: break down of 1st order questions

Physics Performance

- Detector Geometry & Layout

- Reconstruction performance at Objects
  - Single Particle level and Physics event level (i.e, vvH event):
    - Intrinsic efficiency/accuracy for Leptons, Photons, Pion, Kaon, Neutral Hadron;
    - Identification performance of Leptons and Particles
  - Tau reconstruction efficiency/purity
    - Efficiency matrix for tau decay modes
  - b, c, light, gluon quark ROC curves at Z pole sample
  - JET/MET at vvH, ZZ->vvqq, WW->lvqq events

- Physics Analysis Performance at Benchmark channels

Tracker

- Layout & Material budgets:
  - Photon converting rate, Pion pre-interaction rate, Electron/Positron bremsstrahlung rate
- Performances, as a function of polar angle and Pt:
  - Track finding: at sub-detector level (fragments finding), and at full tracker level
  - Momentum, dEdx, Impact parameter resolution
  - Separation of 3-prong decay tau at maximal energy (0.5*c.m.s)
- Power budget & Noise rates (beam induced & electronic)
  - Is active cooling needed
- Track energy scale stability (linearity)
- Alignments, stability-homogenous requirement of the B-Field and/or the HV system
- Dedicated:
  - VTX: Intra-layer clustering & noise veto performance, impact of off-time pile up
  - TPC: Ion back flow
  - Silicon: cooling & Track finding at low energy
  - Wired: Tension control, Mechanism Stability of the full system, homogeneity, aging

Calorimetry

- Layout, Leakage & Dead-zone:
- Performances, as a function of polar angle (Impact angle) and Energy:
  - Cluster Finding efficiency
  - Response to Charged/Neutral particle:
    - Linearity
    - Intrinsic resolution to visible particles
  - Separation of di-photon & photon-pion
- Power budget & Noise rates (beam induced & electronic)
  - Is active cooling needed
- Alignments, Calibration & stability requirements
- Dedicated:
  - PFA: homogeneity, energy budget & optimized layout
    - Scintillator – linear range
    - Calibration
  - Dual readout:
    - SiPM dynamic range, feasibility of usage at B-Field upto 3.5 Tesla
    - Cluster Separation. i.e, Jet lepton identifications

B-Field, MDI & Forward, DAQ

- Layout,
  - Mechanism design
- Beam induced background:
  - Boundaries
  - Hit rate in each sub-detector – impact of off-time pile up from beam induced background
- Coverage: Polar angle coverage Vs event reconstruction efficiency
- Compensating magnet layout
- Luminosity Measurement
  - How to reach 1E-4 for Z line shape measurements?

- DAQ: data stream & data handling
  - Beam induced background
  - Large size data process at Z pole

Conclusion

- Support functionalities, shortage of manpower & resources
  - Massive sample production
  - Reconstruction software validation
  - Computing power, in shortage
- Key tasks break ups, i.e:
  - Higgs measurements iteration at different geometry (optimization)
  - EW systematic breaks down, i.e, for Z line shape measurements
  - Beam energy calibration: stability - Compton Based method exploration
  - Luminosity measurement
  - Sub system wise: Sort and attack these key questions
    - Silicon/Wired tracking: track finding – track separation performance, mechanism stability, alignment
    - Dual readout: SiPM linear range, cluster separation performance

Please echo your feedback:

Content of the CDR

Comments, sort order of the topic breakdown, and your interests/availability...

Backup

CDR Outline: Physics-Detector Volume

1. Physics Potential;
   - Productivities @ Z, WW, Higgs, top
   - Key physics objectives

2, Collision Environment;
   - Beam Parameters & Constrain on the detector MDI

3, Detector Requirements;
   - // We need at least one detector that can do perfect tau-related physics
   - 1, Physics Objects Level;
   - 2, Systematic Level (Luminosity, Beam Energy, Coverage, etc)
   - 3, Power budget, DAQ requirement

4, Sub Systems:
   - VTX
   - Tracker
   - Calo
   - MDI
   - Very forward
   - Muon & Solenoid
   - Electronic System & DAQ
   - Integration + Cost (??)

5, Individual Concept 1:
   - PFA Concept -
     - ILD_CEPC_v1, SiD_CEPC_v1
     - Optimization toward the choice of parameters.
   - Dual Readout - Italian (Tracker + 4th)
     - General layout
   - SPPC Conceptual detector and its Delphes card??

6, Physics Performances
   - Benchmark physics channels
   - Performance @ Hit, Object (Single Particle) & Physics benchmark events

7, Crucial items to be covered in the future
   - // Feasibility issues should be answered in CDR.
   - // Optimization issue to be covered.

Systematic Uncertainties for the Luminosity Measurement

List of sources of systematic uncertainties, the value of the parameter and the impact on the luminosity measurement. Some depend on centre-of-mass energy, others on the LumiCal geometry, some on the accelerator

Source	Value	$\Delta L/L$
Bhabha cross-section [9]	$5 \cdot 10^{-4}$	$5 \cdot 10^{-4}$
Uncertainty in the reconstruction of the angle [10]	0.02 mrad	$2 \cdot 10^{-4}$
Bias in the reconstruction of the angle [10]	0.003 mrad	$2 \cdot 10^{-4}$
Position uncertainty of the LumiCal (OPAL) [11]	few μm	$\approx 10^{-4}$
Position of the interaction point [10]		$\approx 10^{-4}$
Energy resolution bias (ILC) [10]		$\approx 10^{-4}$
Energy scale (ILC) [10]		$\approx 10^{-3}$
Physics background (four-fermion, ILC) [12]		$\approx 10^{-3}$
Luminosity spectrum (ILC) [10]		$\approx 10^{-3}$
Polarisation (ILC) [10]		$\approx 10^{-4}$
Electromagnetic Deflection (ILC) [12]		$\approx 10^{-3} / \approx 10^{-4}$

References

[1] L. Linssen, A. Miyamoto, M. Stanitzki, and H. Weerts, eds. *Physics and Detectors at CLIC: CLIC Conceptual Design Report*. CERN, 2012. CERN-2012-003, arXiv:1202.5940.

[2] M. Aicheler, et al., eds. *A Multi-TeV Linear Collider based on CLIC Technology: CLIC Conceptual Design Report*. CERN, 2012. JAI-2012-001, KEK Report 2012-1, PSI-12-01, SLAC-R-985, https://edms.cern.ch/document/1234244/.

[3] P. Lebrun, et al., eds. *The CLIC Programme: towards a staged e^+e^- Linear Collider exploring the Terascale*. CERN, 2012. ANL-HEP-TR-12-51, KEK Report 2012-2, MPP-2012-115, https://edms.cern.ch/document/1234246/.

[4] D. Schulte. *Study of Electromagnetic and Hadronic Background in the Interaction Region of the TESLA Collider*. Ph.D. thesis, University of Hamburg, 1996.

[5] S. Poss and A. Sailer. Luminosity spectrum reconstruction at linear colliders. *The European Physical Journal C*, vol. 74(4) 2833, 2014.

[6] I. Sadeh, H. Abramowicz, R. Ingbir, S. Kananov, and A. Levy. A Luminosity Calorimeter for CLIC. LCD-Note-2009-002, 2009.

[7] I. Sadeh. *Luminosity Measurement at the International Linear Collider*. Master's thesis, Tel Aviv University, 2008.

[8] R. Schwartz. *Luminosity Measurement at the Compact Linear Collider*. Master's thesis, Tel Aviv U., 2012. Presented 17 Dec 2012.

[9] A. Stahl. Luminosity measurement via bhabha scattering: Precision requirements for the luminosity calorimeter, 2005. LC-DET-2005-004.

[10] H. Abramowicz et al. Forward instrumentation for ilc detectors. *Journal of Instrumentation*, vol. 5(12) p. P12002, 2010.

[11] G. Abbiendi et al. Precision luminosity for z^0 lineshape measurements with a silicon-tungsten calorimeter. *The European Physical Journal C*, vol. 14(3) pp. 373–425, 2000.

[12] I. Bozovic Jelisavcic, S. Lukic, G. Milutinovic Dumbelovic, M. Pandurovic, and I. Smiljanic. Luminosity measurement at ilc. *Journal of Instrumentation*, vol. 8(08) p. P08012, 2013. ArXiv:1304.4082.