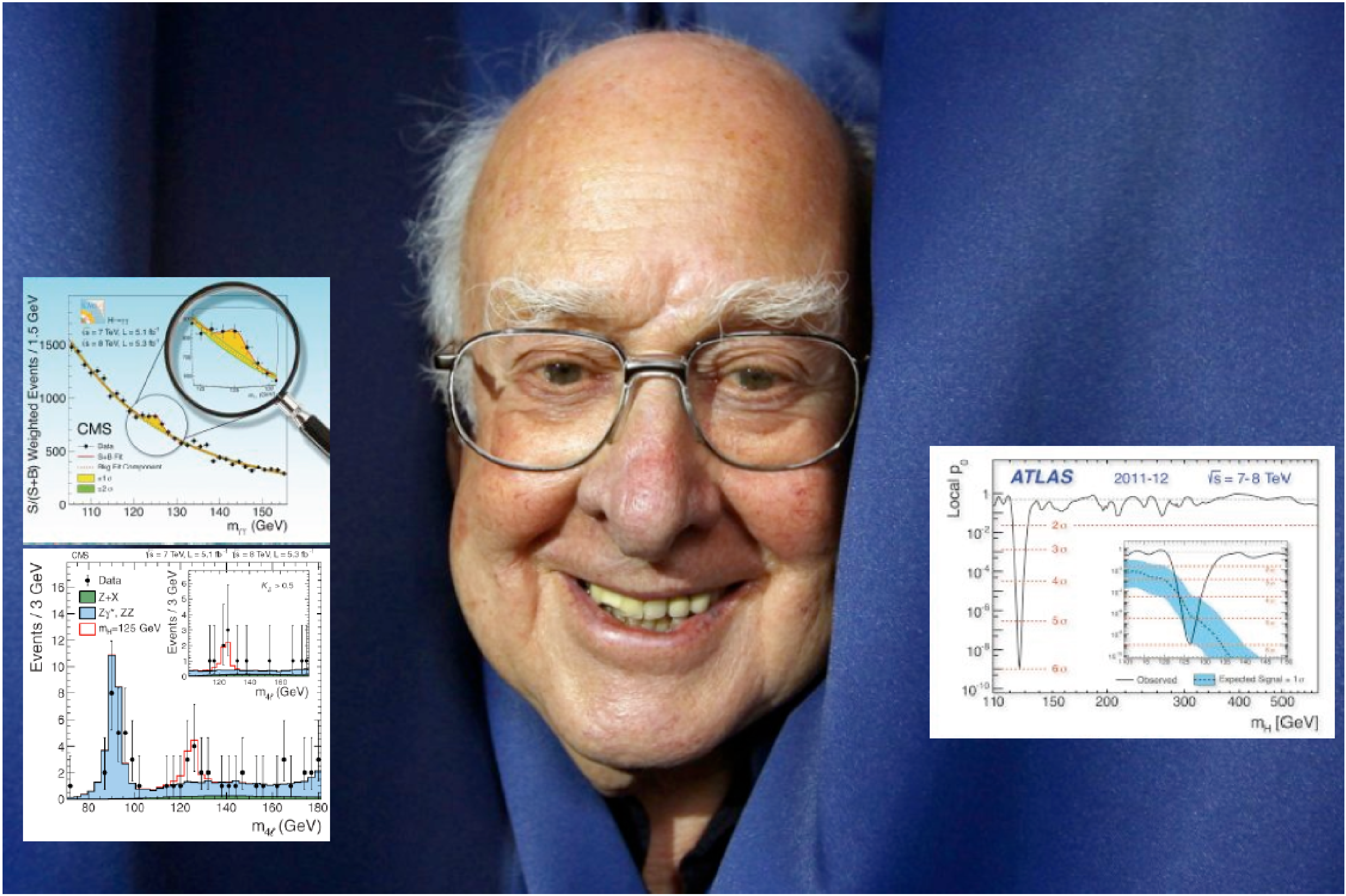
CEPC-SPPC, a future high energy facility in China

Manqi RUAN

On behavior of the CEPC-SPPC Study group

Outline

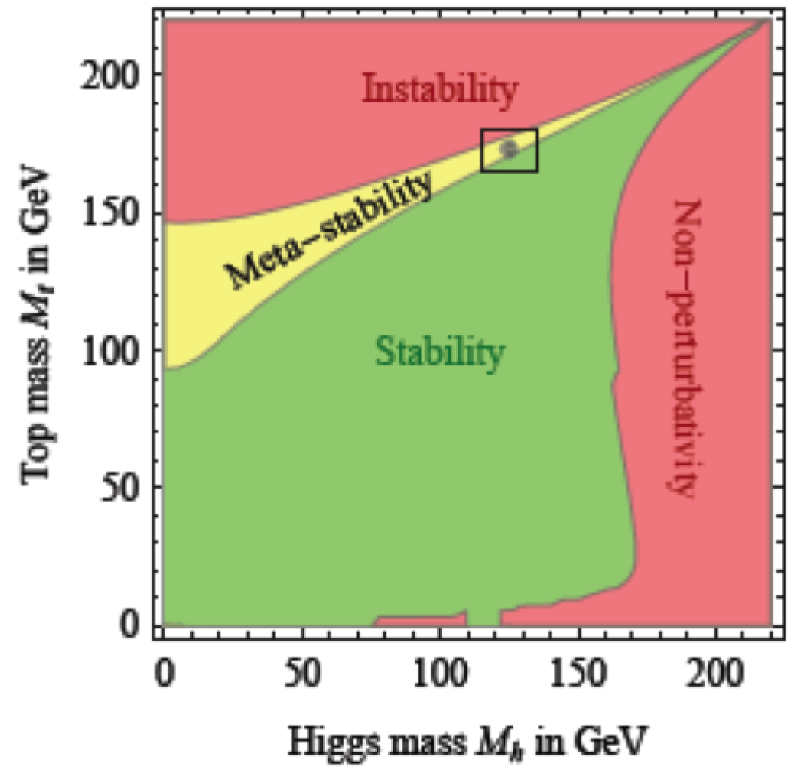
- Science
- Accelerator
- Detector
- Site & Civil design
- Status & Funding request
- Summary


CMS
S/(S+B) Weighted Events / 1.5 GeV
Data
S+B Fit
Bkg Fit Component
m_γγ (GeV)
CMS
√s = 7 TeV, L = 5.1 fb⁻¹ √s = 8 TeV, L = 5.3 fb⁻¹
Events / 3 GeV
Data
Z+X
Zγ*, ZZ
m_H=125 GeV
m_4ℓ (GeV)
ATLAS
2011-12
√s = 7-8 TeV
Local p_0
m_H [GeV]
Observed
Expected Signal ± 1σ

SM is **NOT** the end after the Higgs

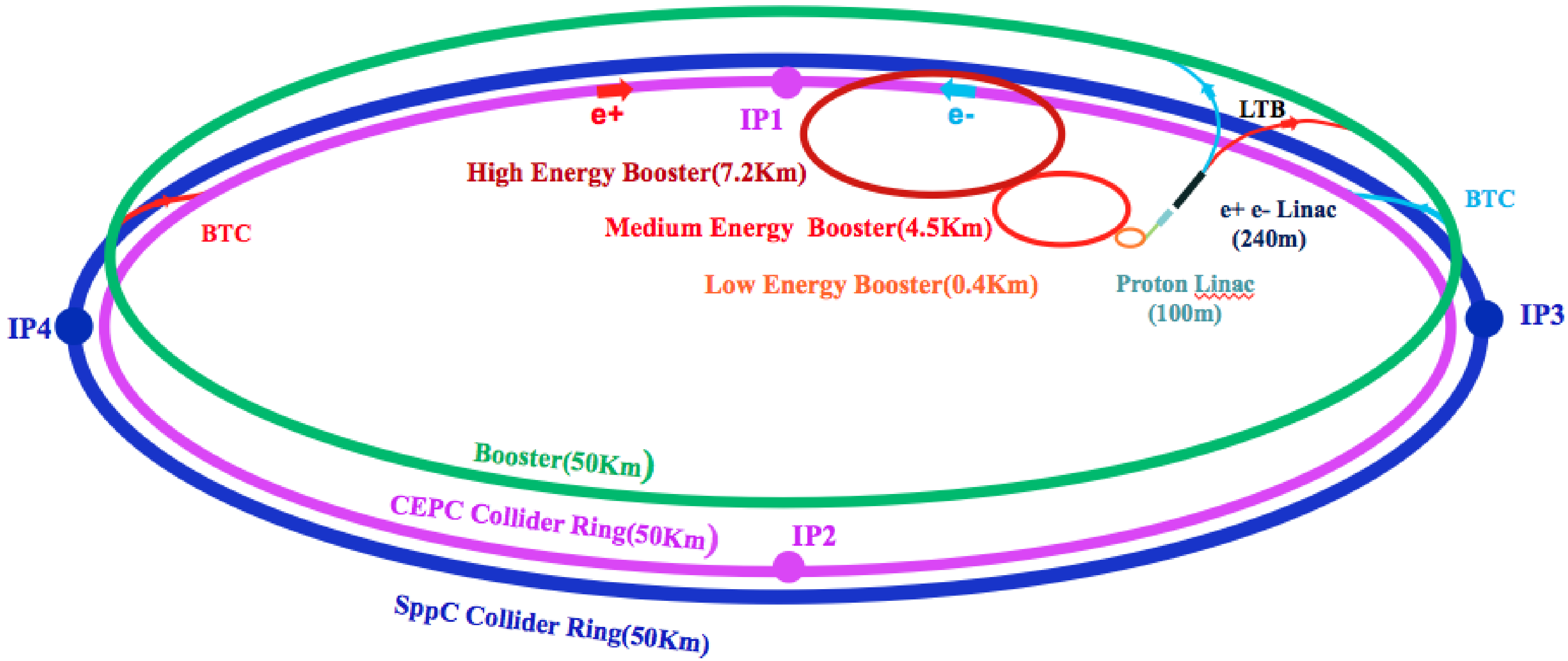
- Hierarchy: From neutrinos to the top mass, masses differs by 13 orders of magnitude
- Naturalness: Fine tuning of the Higgs mass
- Masses of Higgs and top quark: meta-stable of the vacuum
- Unification?
- Dark matter candidate?
- Not sufficient CP Violation for Matter & Antimatter asymmetry
- **Most issues related to Higgs**

$$m_H^2 = 36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}933{,}023 - 36{,}127{,}890{,}984{,}789{,}307{,}394{,}520{,}932{,}878{,}928{,}917{,}398 = (125\ \mathrm{GeV})^2\ !\ ?$$



Key: a precise Higgs factory

- Higgs mass ~ 125 GeV, it is possible to build a Circular e+e- Higgs factory (CEPC), followed by a proton collider (SPPC) in the same tunnel
- Looking for Hints (from Higgs) at CEPC → direct search at SPPC



Science at CEPC-SPPC

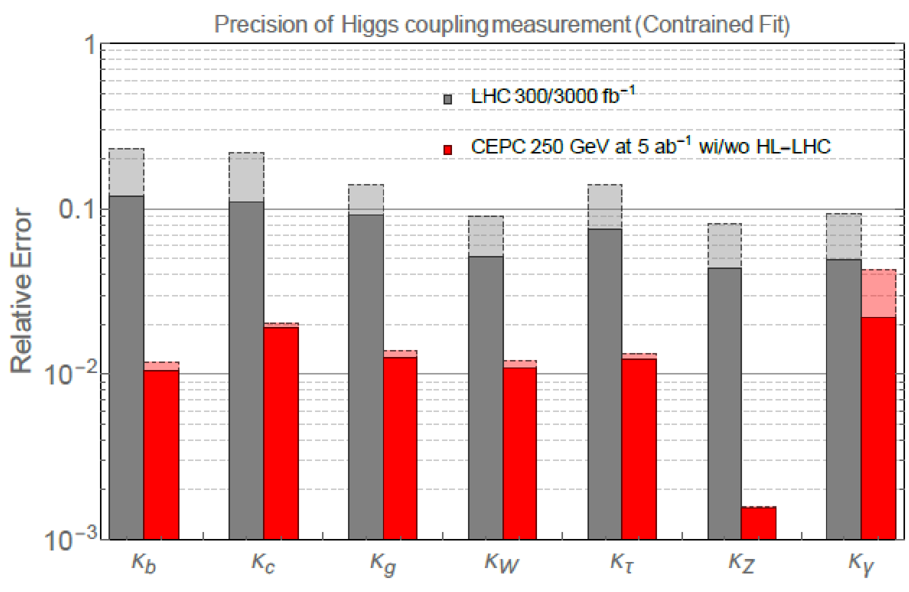
- **CEPC (90 – 250 GeV)**
  - Higgs factory: 1M Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: 10B Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor factory: b, c, tau and QCD studies
- **SPPC (~ 100 TeV)**
  - Direct search for new physics
  - Complementary Higgs measurements to CEPC g(HHH), g(Htt)
  - ...
- **Heavy ion, e-p collision...**

Complementary

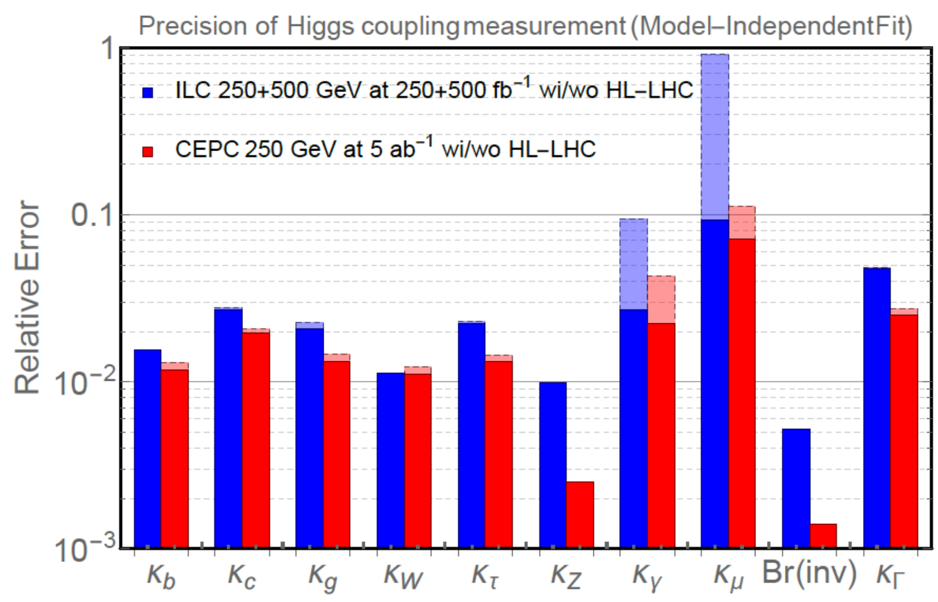
Higgs Physics

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_i \frac{c_i}{M^2}\mathcal{O}_{6,i} \qquad \delta \sim c_i \frac{v^2}{M^2}$$

% precision ➔ M ~ 1 TeV
to new physics ➔ ~ × 10 over LHC

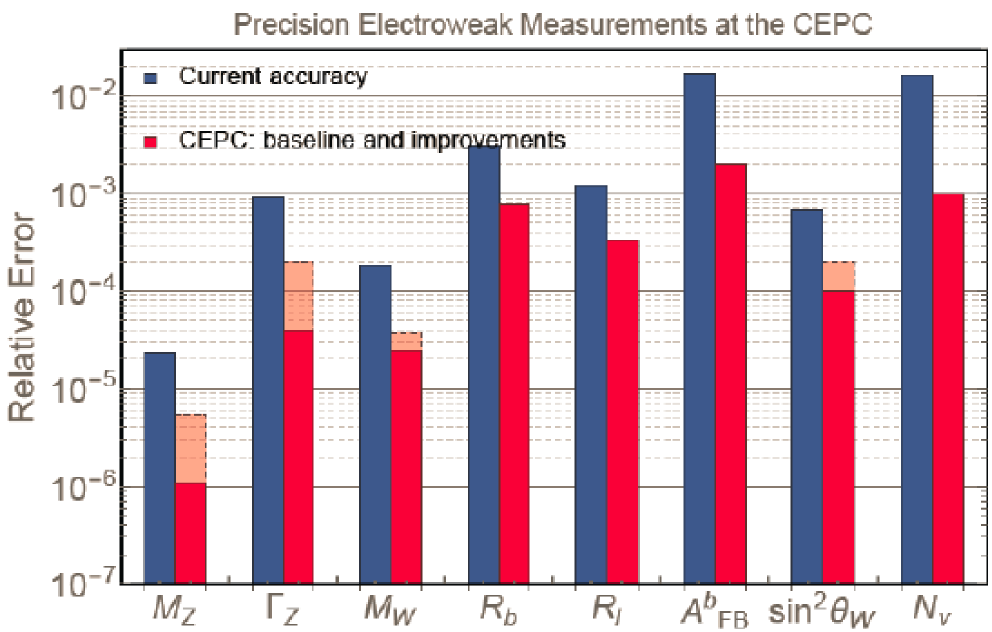


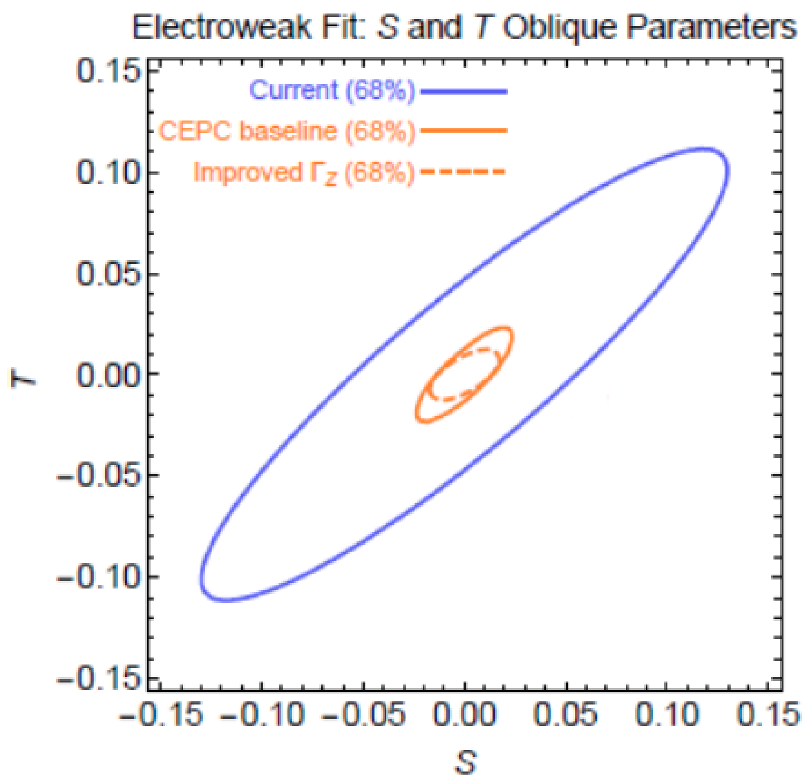
Kappa-framework
model-dependent measurements



Absolute measurements

EW Physics

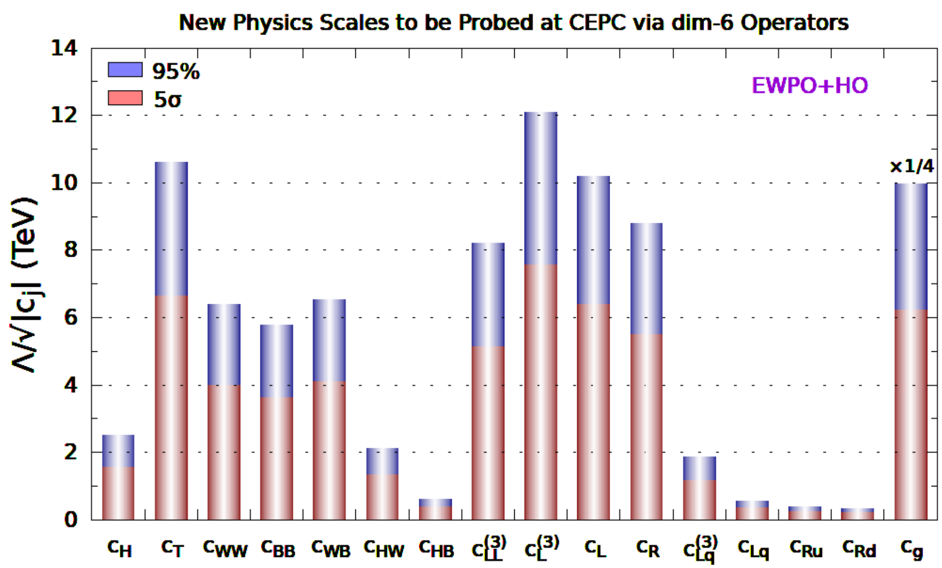




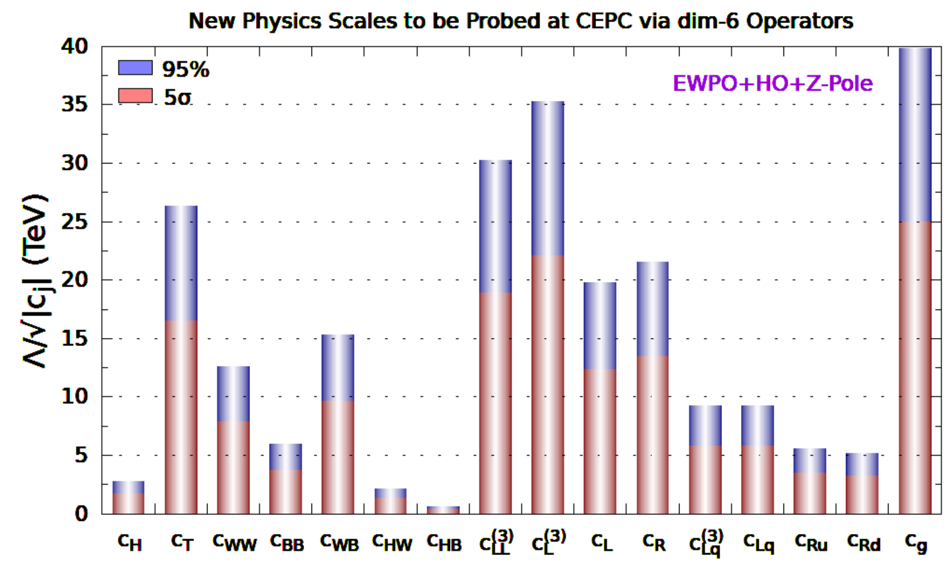
From 10 Billion Z bosons + the data at Higgs runs

New Physics Reach via dim-6 operators

Sensitivities from Existing EWPO & Future HO



Sensitivity from EWPO+HO+Z-Pole



1603.03385

$$\mathcal{L} = \mathcal{L}_{SM} + \sum_{ij} \frac{y_{ij}}{\Lambda \sim 10^{14}\text{GeV}} (\overline{L}_i \tilde{H})(\tilde{H}^\dagger L_j) + \sum_i \frac{c_i}{\Lambda^2} \mathcal{O}_i \,.$$

Higgs	EW Gauge Bosons	Fermions
$\mathcal{O}_H = \frac{1}{2}(\partial_\mu \lvert H\rvert^2)^2$	$\mathcal{O}_{WW} = g^2 \lvert H\rvert^2 W^a_{\mu\nu} W^{a\mu\nu}$	$\mathcal{O}^{(3)}_L = (iH^\dagger \sigma^a \overleftrightarrow{D}_\mu H)(\overline{\Psi}_L \gamma^\mu \sigma^a \Psi_L)$
$\mathcal{O}_T = \frac{1}{2}(H^\dagger \overleftrightarrow{D}_\mu H)^2$	$\mathcal{O}_{BB} = g^2 \lvert H\rvert^2 B_{\mu\nu} B^{\mu\nu}$	$\mathcal{O}^{(3)}_{LL} = (\overline{\Psi}_L \gamma_\mu \sigma^a \Psi_L)(\overline{\Psi}_L \gamma^\mu \sigma^a \Psi_L)$
	$\mathcal{O}_{WB} = gg' H^\dagger \sigma^a H W^a_{\mu\nu} B^{\mu\nu}$	$\mathcal{O}_L = (iH^\dagger \overleftrightarrow{D}_\mu H)(\overline{\Psi}_L \gamma^\mu \Psi_L)$
Gluon	$\mathcal{O}_{HW} = ig(D^\mu H)^\dagger \sigma^a (D^\nu H) W^a_{\mu\nu}$	$\mathcal{O}_R = (iH^\dagger \overleftrightarrow{D}_\mu H)(\overline{\psi}_R \gamma^\mu \psi_R)$
$\mathcal{O}_g = g_s^2 \lvert H\rvert^2 G^a_{\mu\nu} G^{a\mu\nu}$	$\mathcal{O}_{HB} = ig'(D^\mu H)^\dagger (D^\nu H) B_{\mu\nu}$	

Time Window

- CEPC (90 – 250 GeV)
  - Pre-Study, R&D
    - Pre-Study: 2013 – 2015
      - **Pre-CDR Delivered**
    - R&D & Engineering Design: 2015 - 2020
  - Construction: 2021 - 2027
  - Data taking: 2028 - 2035
- SPPC (~ 100 TeV)
  - Pre-Study, R&D
    - Pre-Study: 2013-2020
    - R&D, Engineering Design:2020-2035
  - Construction: 2035 - 2042
  - Data taking: 2042 -

IHEP-CEPC-DR-2015-01

IHEP-EP-2015-01

IHEP-TH-2015-01

Can be downloaded from

http://cepc.ihep.ac.cn/preCDR/volume.html

CEPC-SPPC

Preliminary Conceptual Design Report

Volume I - Physics & Detector

403 pages, 480 authors

The CEPC-SPPC Study Group

March 2015

IHEP-CEPC-DR-2015-01

IHEP-AC-2015-01

CEPC-SPPC

Preliminary Conceptual Design Report

Volume II - Accelerator

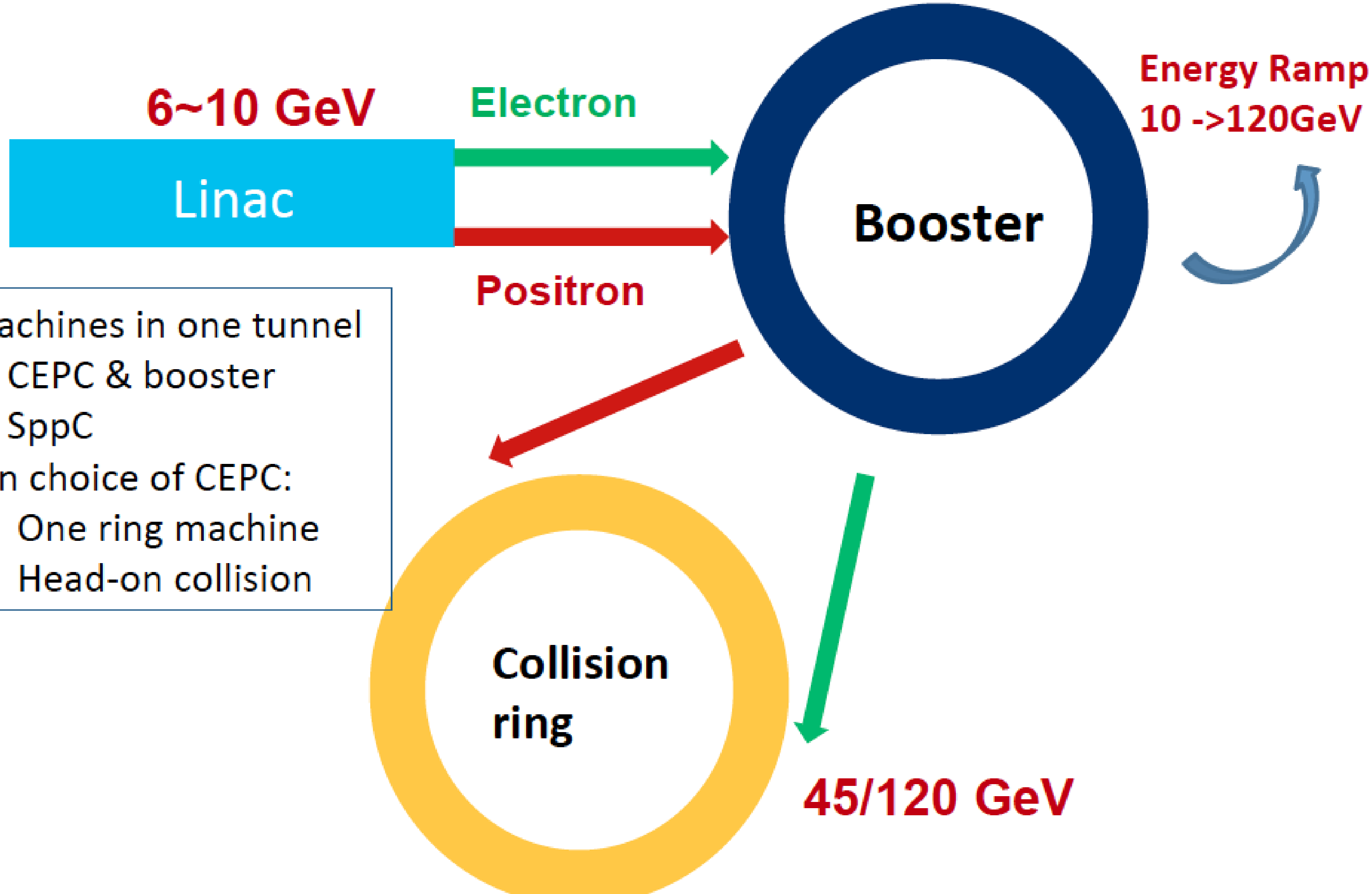
328 pages, 300 authors

The CEPC-SPPC Study Group

March 2015

Accelerator Design

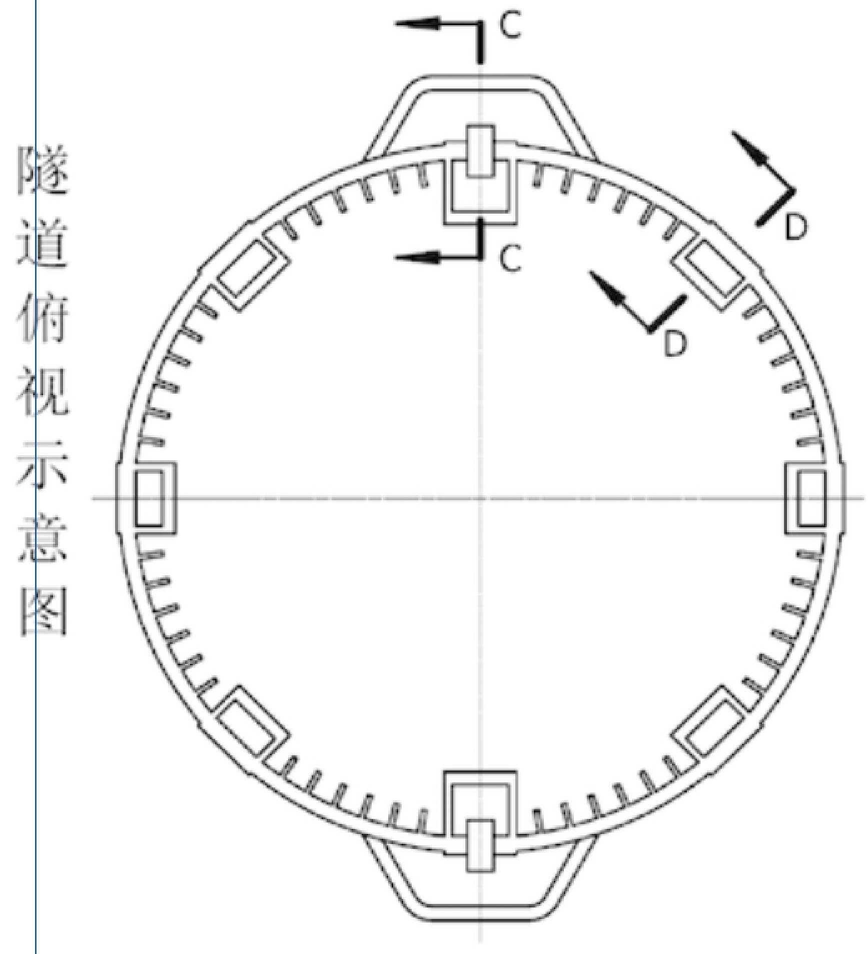
CEPC Accelerator



- 3 machines in one tunnel
  - CEPC & booster
  - SppC
- Main choice of CEPC:
  - One ring machine
  - Head-on collision

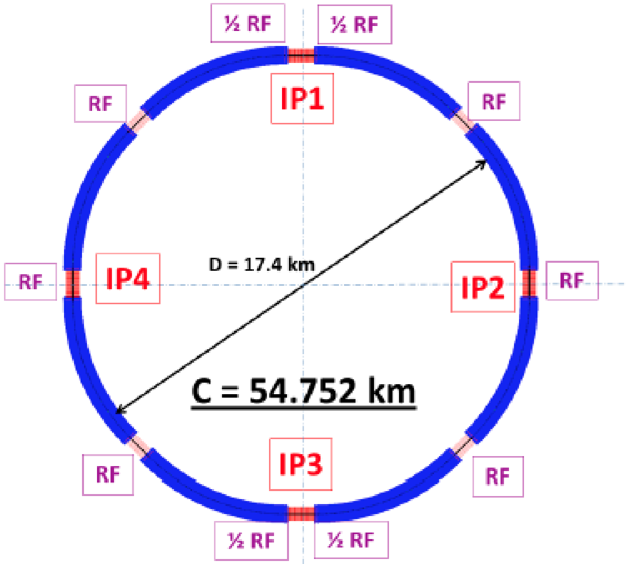
Compatibility: The Key Issue

- CEPC Injector
- SPPC injector
- Beam pipe detour for detectors
  - CEPC booster avoid storage ring
  - CEPC avoid SPPC detectors
  - SPPC avoid CEPC detectors
- SR beamlines
- Predict what SPPC needs
  - Collimators
  - Straight sections
  - Tunnel dimensions
  - Access tunnel
  - ....
- To be fully understood in the next 5 years



CEPC Design

- Critical parameters:
  - SR power: 51.7 MW/beam
  - 8*arcs, 2*IPs
  - 8 RF cavity sections (distributed)
  - RF Frequency: 650 MHz
  - Filling factor of the ring: ~70%



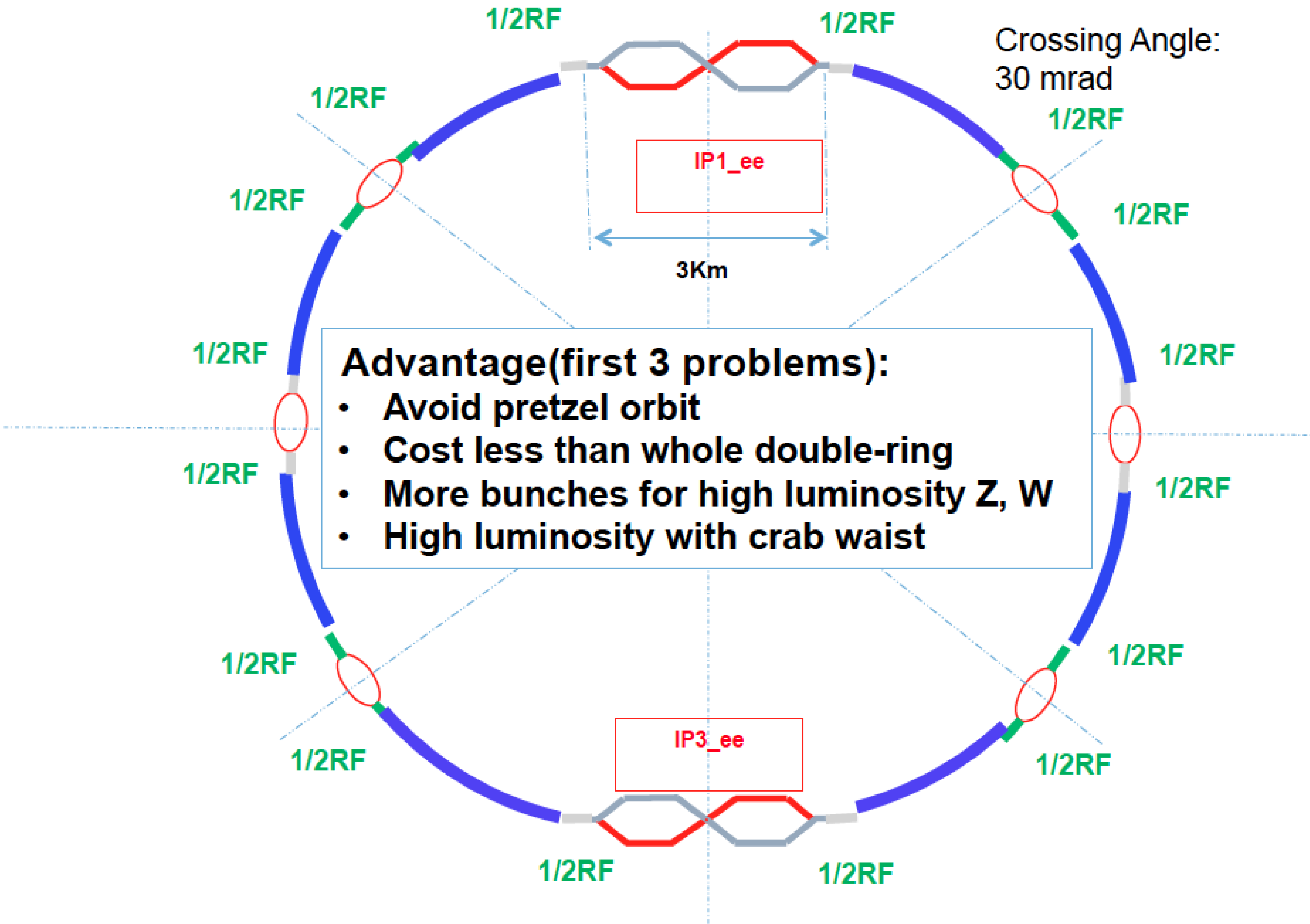
Parameter	Unit	Value	Parameter	Unit	Value
Beam energy [E]	GeV	120	**Circumference [C]**	m	54752
Number of IP[N_{IP}]		2	**SR loss/turn [U_0]**	GeV	3.11
Bunch number/beam[n_B]		50	**Energy acceptance RF [h]**	%	5.99
SR power/beam [P]	MW	51.7	**Beam current [I]**	mA	16.6
emittance (x/y)	nm	6.12/0.018	**β_{IP}(x/y)**	mm	800/1.2
Transverse size (x/y)	μm	69.97/0.15	**Luminosity /IP[L]**	$cm^{-2}s^{-1}$	2.04E+34

Main Problems left in Pre-CDR

1. Pretzel scheme is difficult to design and operate, with little flexibility and stability
2. Too high AC power consumption (~ 500 MW)
3. Very low luminosity for Z
4. Booster with very too low magnetic field (30 Gauss for 6GeV injection in a background field of 3 Gauss, say in the BEPCII tunnel) and too small dynamic aperture
5. Very small Dynamic Aperture at 2% energy spread with beam-beam effects and magnetic errors

- **Goal of CEPC CDR:** a "design" working on paper

New Idea: Partial Double Ring

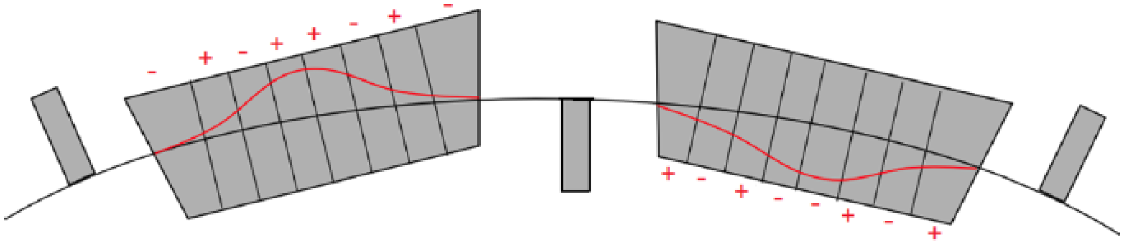


CEPC Booster Design

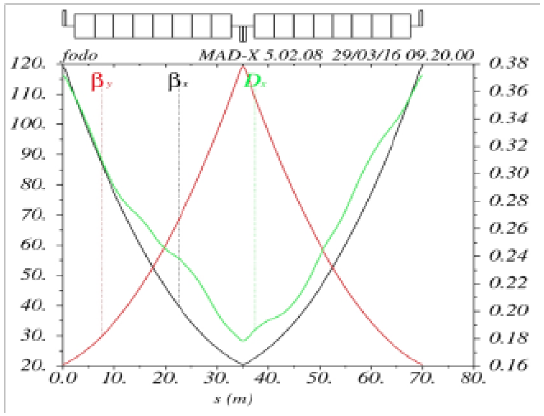
1) Normal Low field Bend Scheme

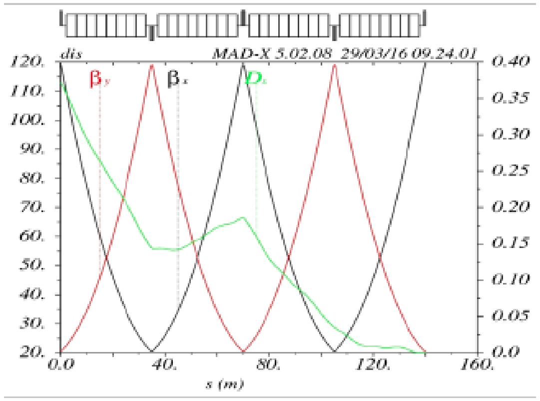
Solution to the 4th problem

2) Wiggling Bend Scheme



- **90 degree FODO**
- **FODO length:70 meter**





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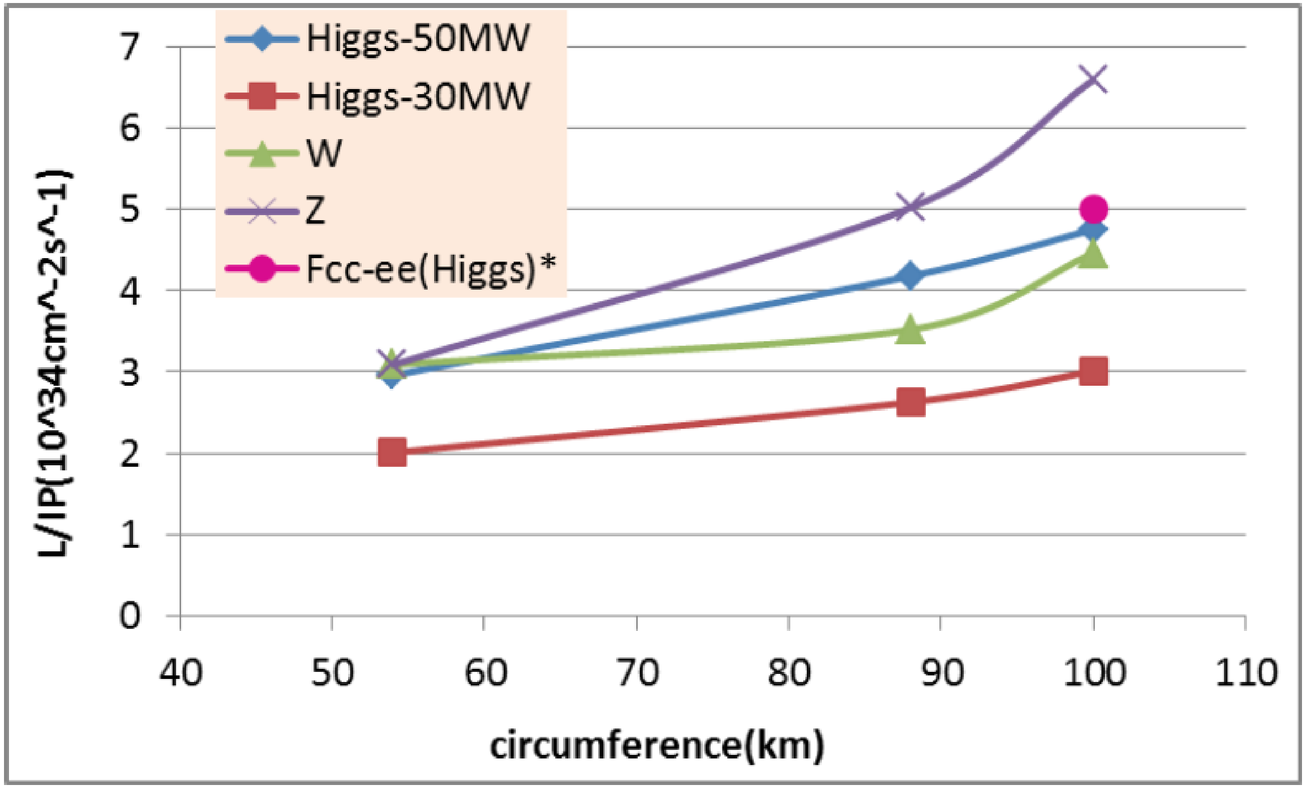
Addressed by PDR	Addressed by Wiggler	Progressing

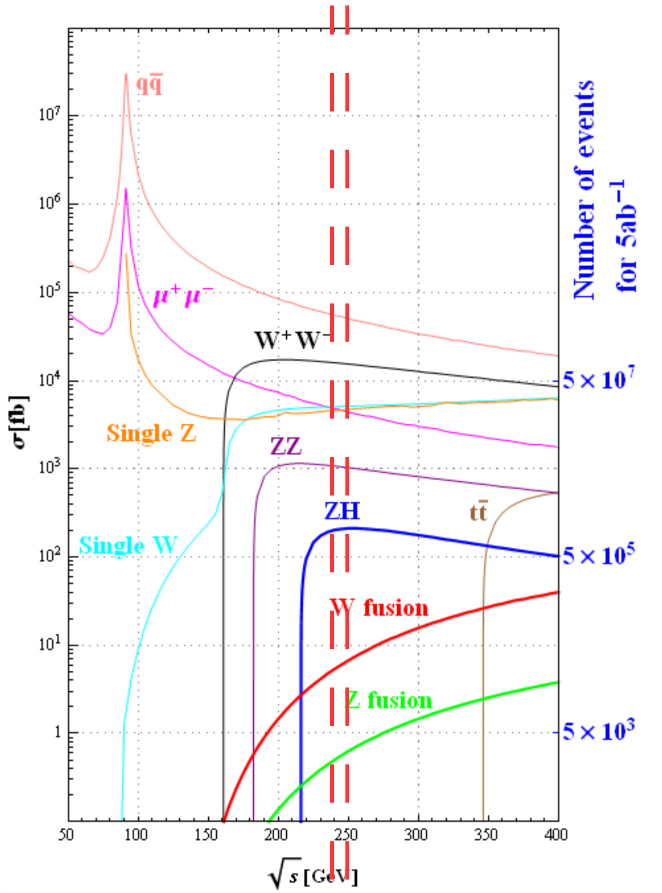
Partial Double Ring Luminosity

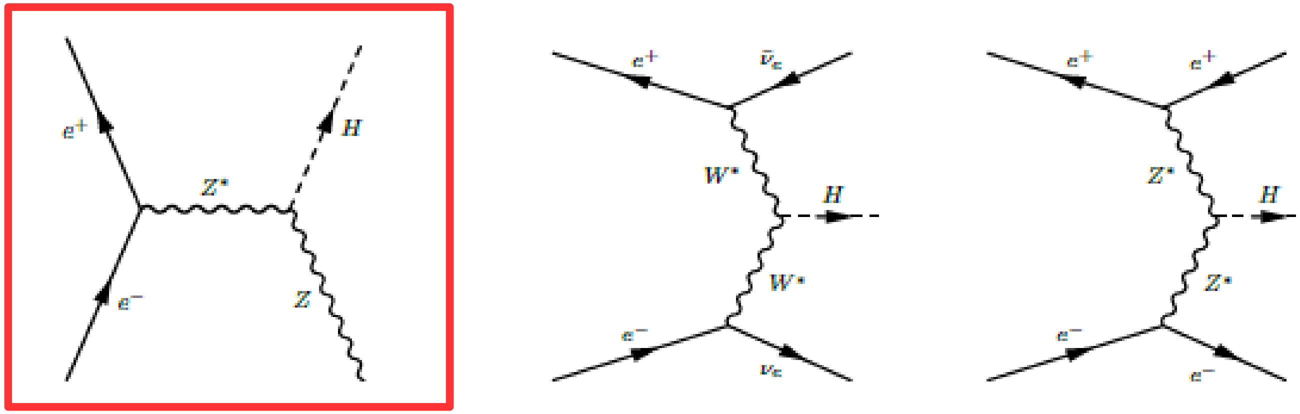


* Fabiola Gianotti, Future Circular ColliderDesign Study, ICFA meeting, J-PARC, 25-2-2016.

Detector Design

Higgs program at CEPC



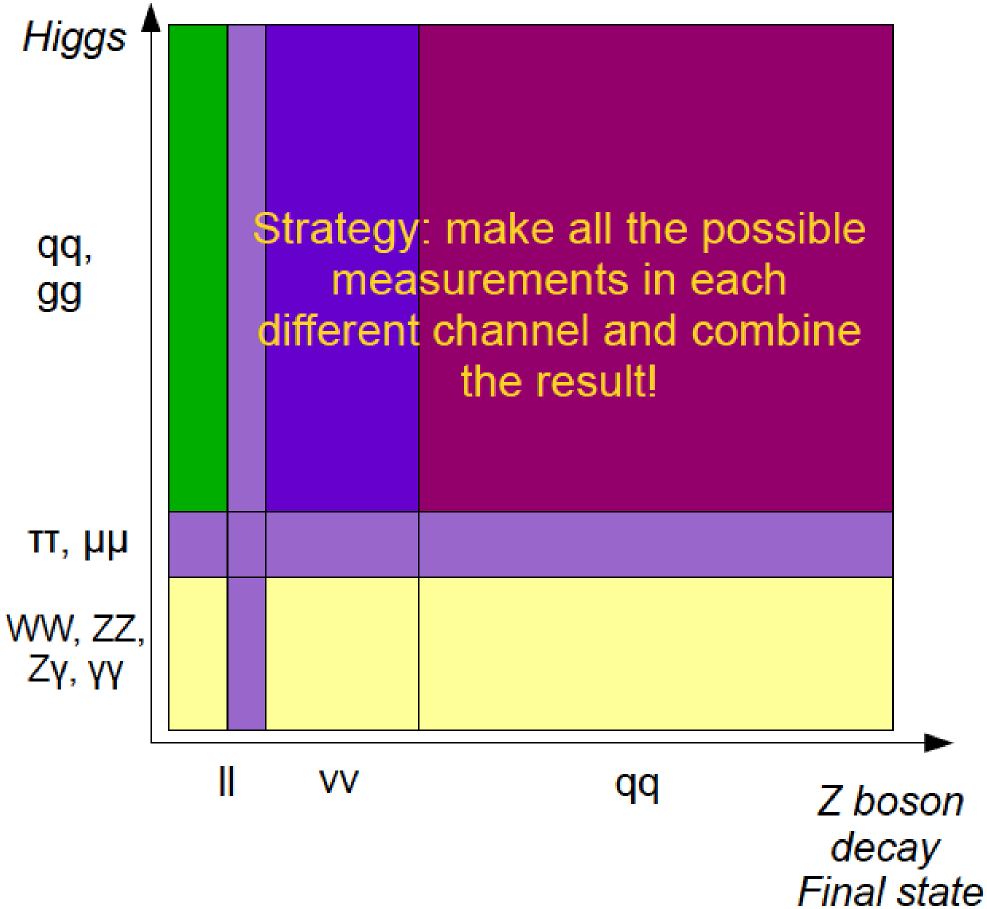


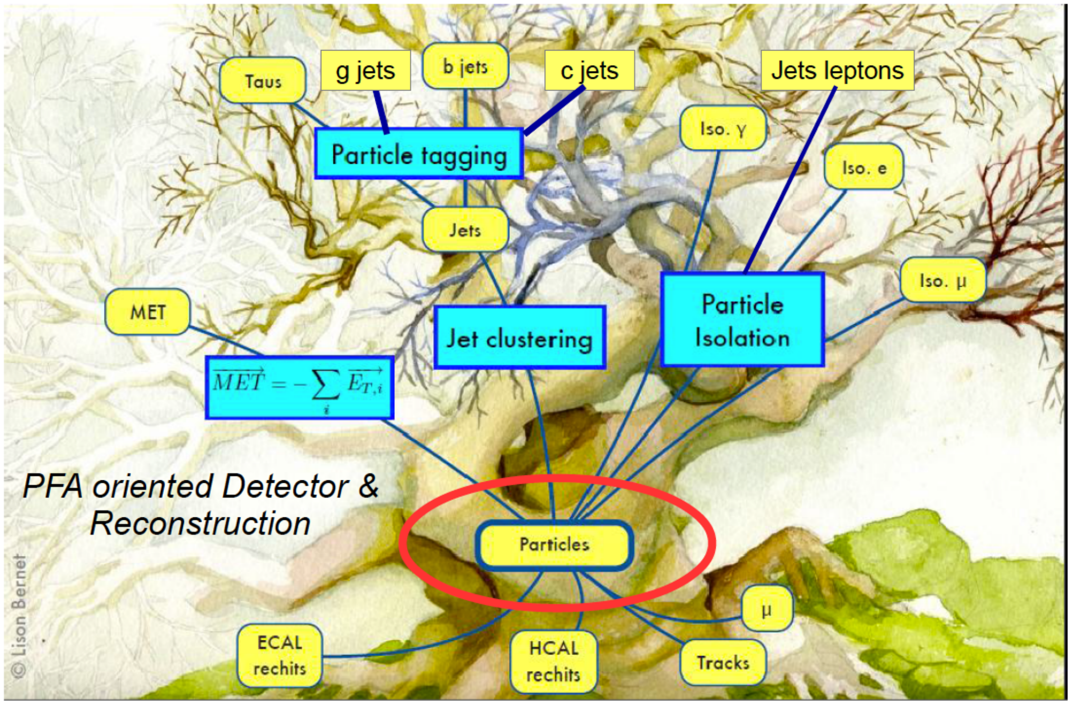
Process	Cross section	Events in 5 ab^{-1}
Higgs boson production, cross section in fb		
$e^+e^- \to ZH$	212	1.06×10^6
$e^+e^- \to \nu\bar{\nu}H$	6.72	3.36×10^4
$e^+e^- \to e^+e^-H$	0.63	3.15×10^3
Total	219	1.10×10^6

Observables: Higgs mass, CP, σ(ZH), event rates (σ(ZH, vvH)*Br(H->X))

Derive: Higgs width, branching ratios & absolute value of coupling constants

CEPC detector: PFA oriented

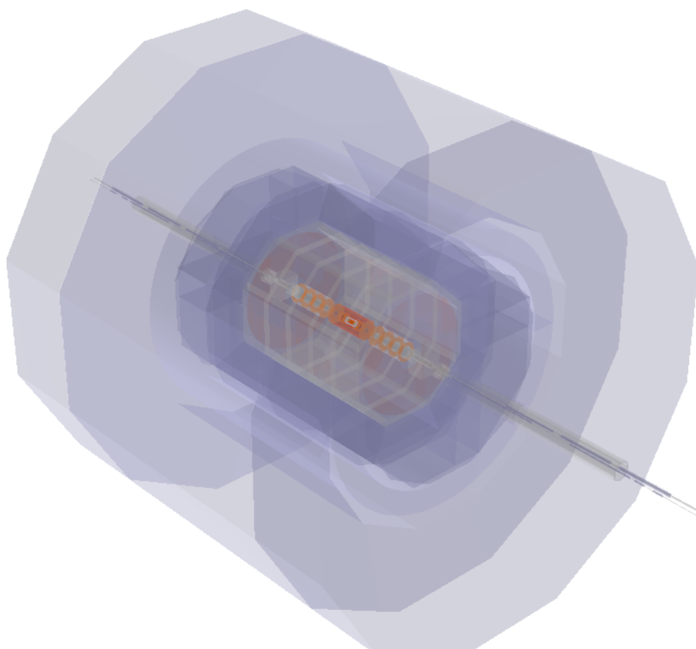


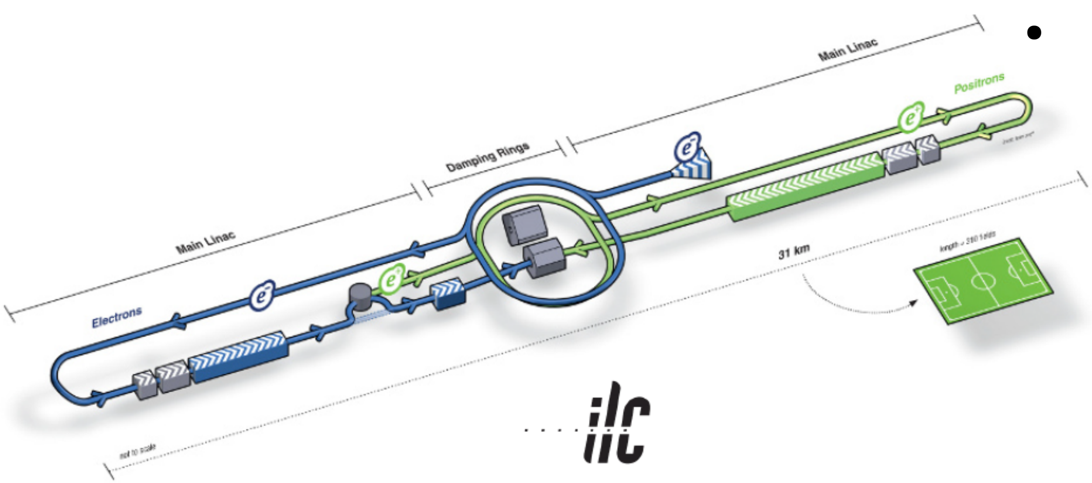


Reconstruct **ALL** the physics objects (lepton, γ, tau, Jet, MET, ...) with high efficiency/precision

High Precision VTX close to IP: b, c, tau tagging
High Precision Tracking system:
***PFA** oriented Calorimeter System:*
Tagging, ID, Jet energy resolution, etc

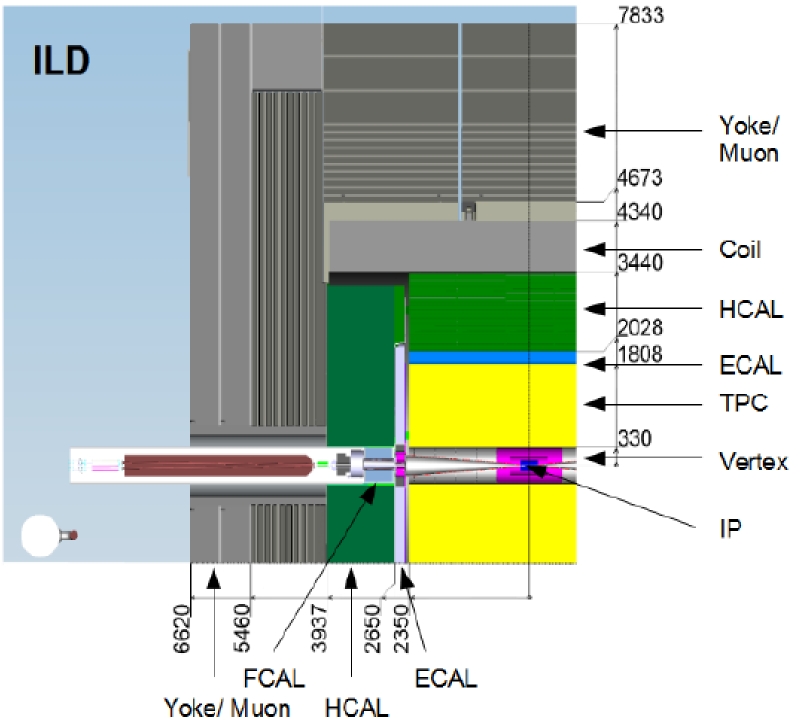
ILD, reference for CEPC detector

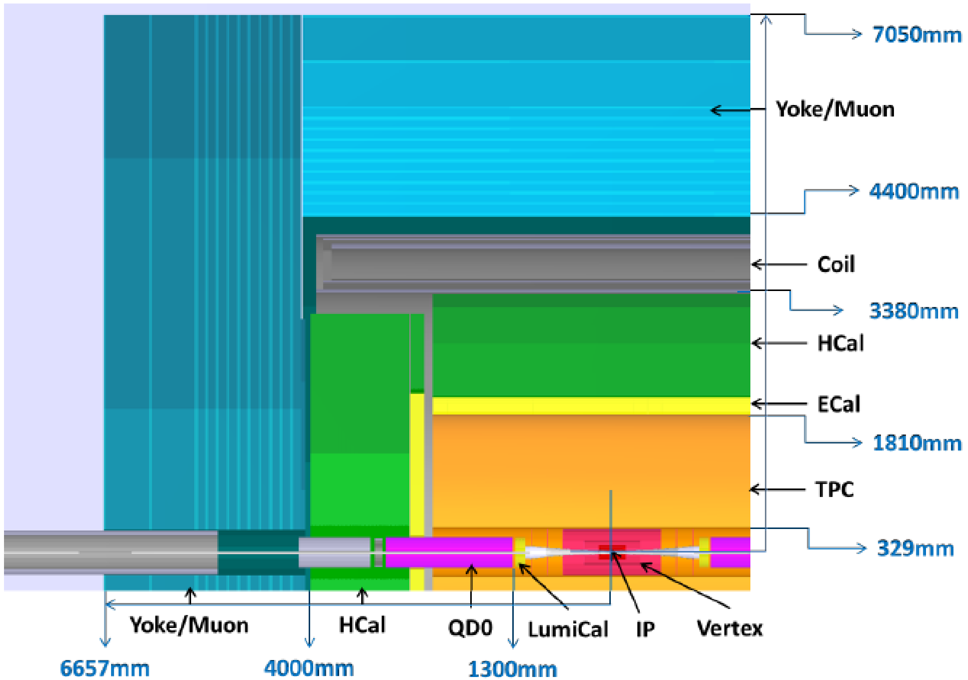




- ILD: Benchmark detector for linear collider studies (ILC, CLIC)
- Layout:
  - Scale: 7.3 meters radius & 6.6 meter Half Z
  - VTX (Silicon Pixel)
  - Main Tracker: TPC + Silicon System
  - Sampling Calorimeter with Ultra High Granularity (~o(10^8) channels)
- Performance:
  - Flavor Tagging: b, c
  - Tracking: $\delta(1/Pt) \sim 2*10^{-5}(GeV^{-1})$
  - *PFA: JER ~ 4%*

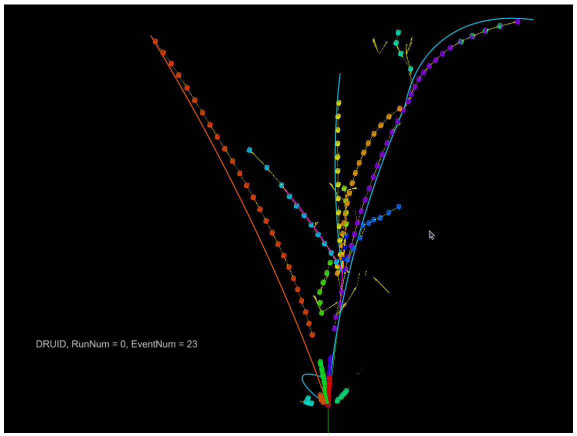
Baseline detector

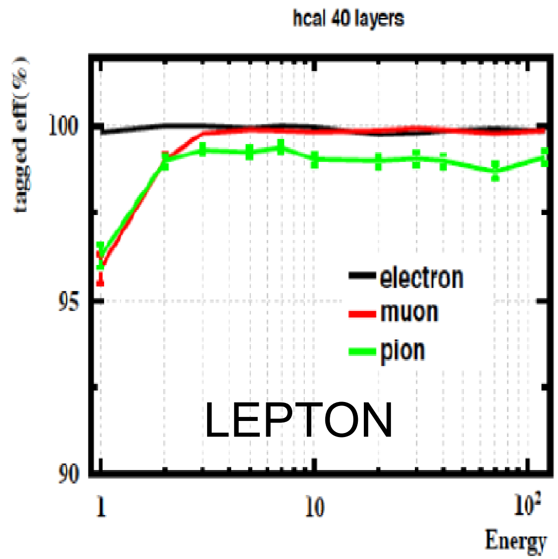


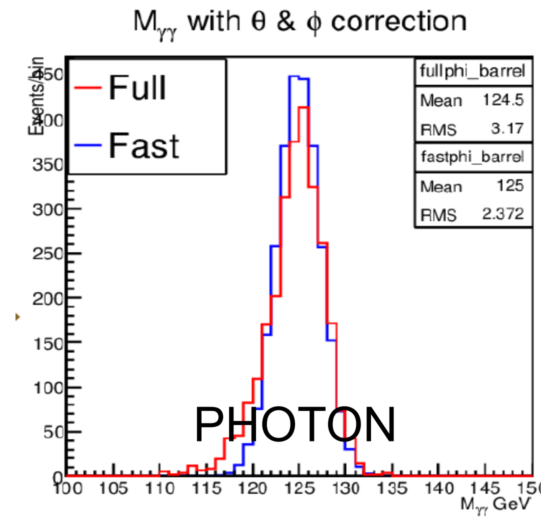


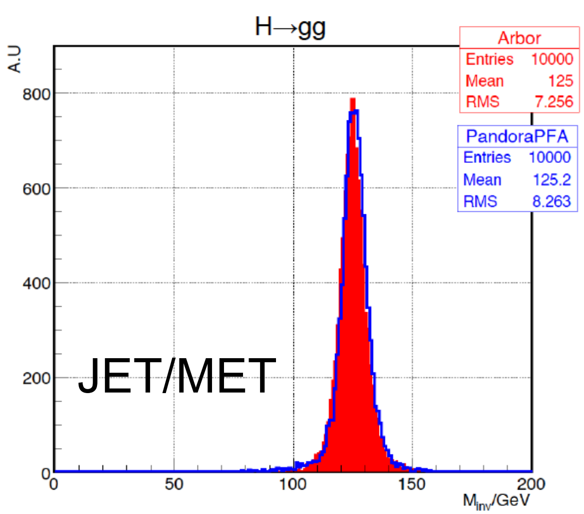
- Modifications to ILD
  - Less Yoke (no push-and-pull for CEPC)
  - Machine Detector Interface (MDI)
  - *Power pulsing* not possible
- Efforts on optimizing the size/geometry not implemented in the baseline detector, to make the comparisons easier

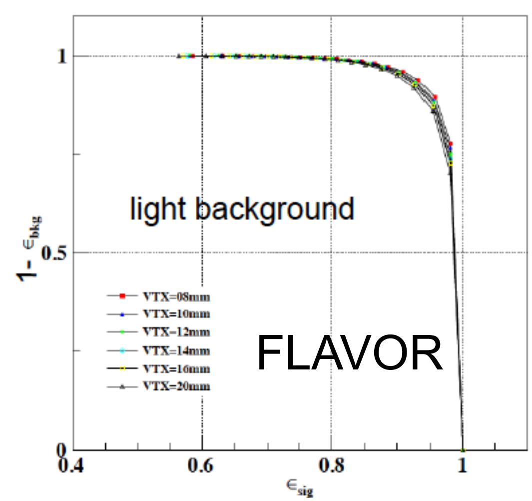
Simulation & Software

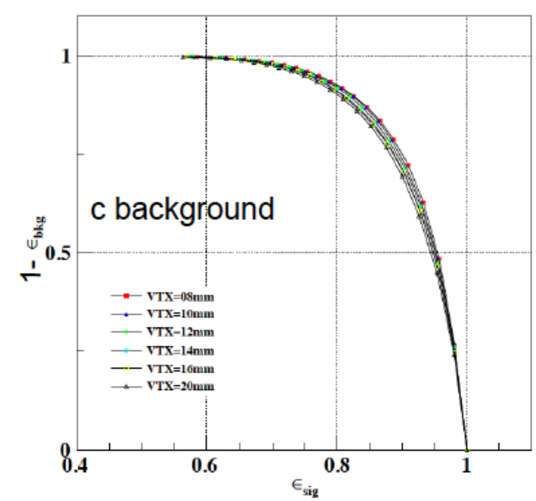




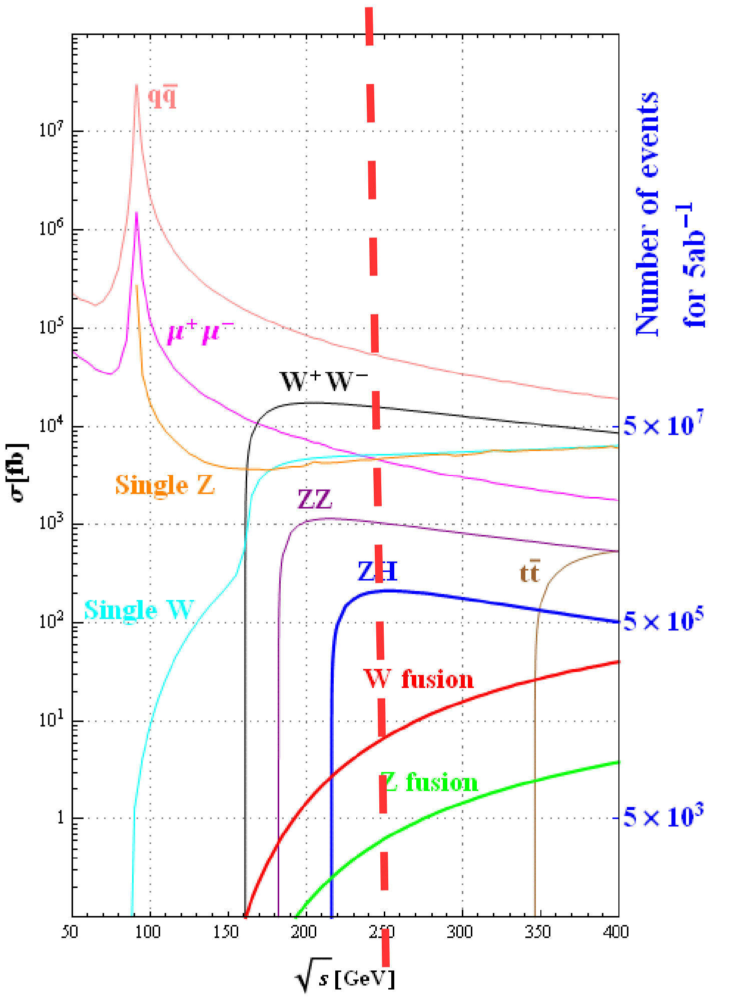






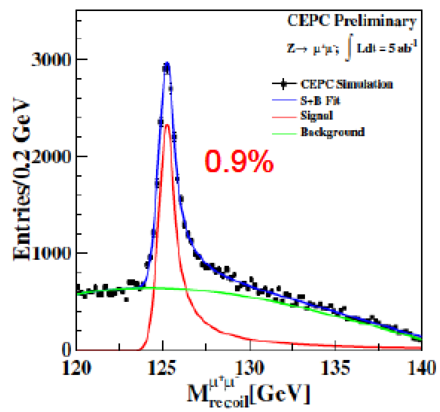


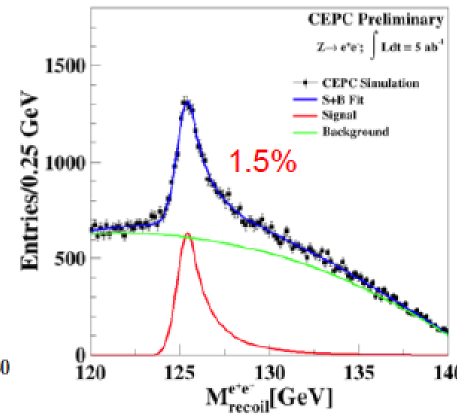
CEPC: absolute Higgs measurements

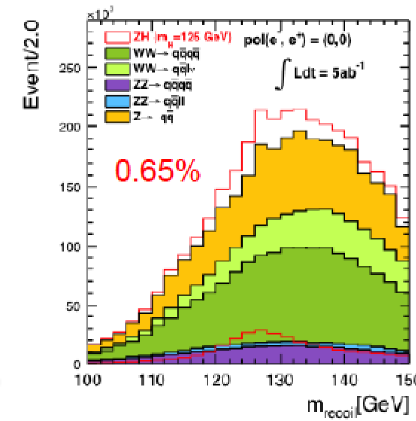


Zhenxing Chen & Yacine Haddad

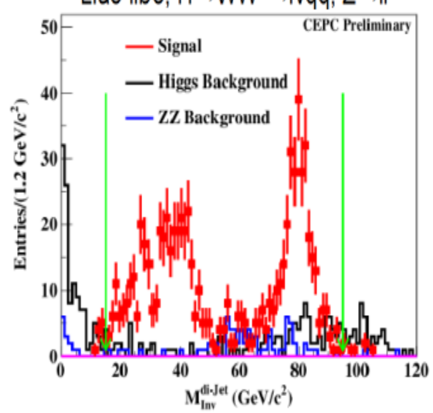
σ(ZH) measurements



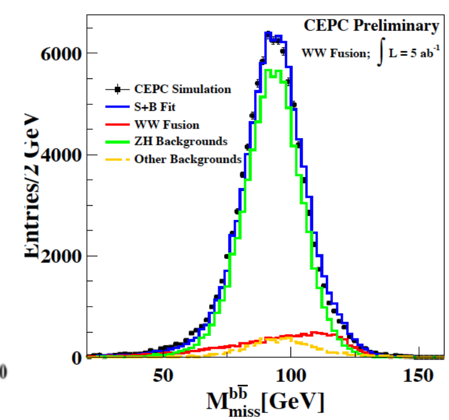




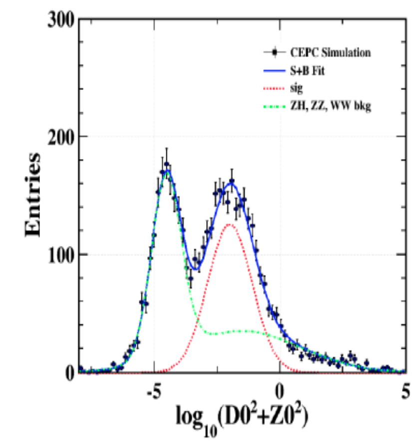
Liao libo, H→WW*→lνqq, Z→ll



Br(H→WW)

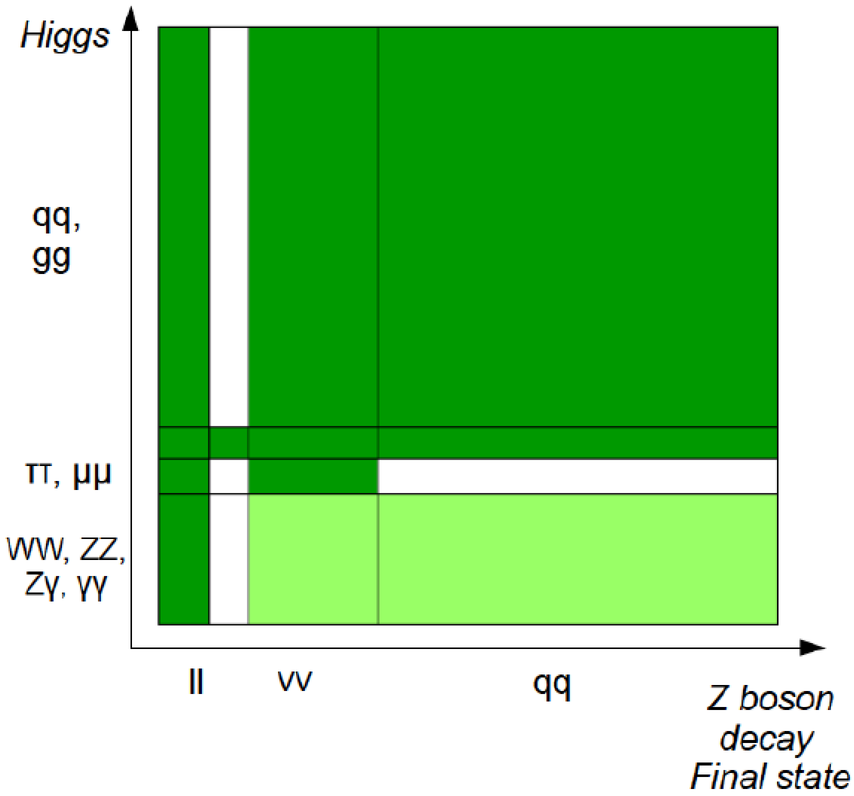


σ(ννH)*Br(H→bb)



Br(H→ττ)

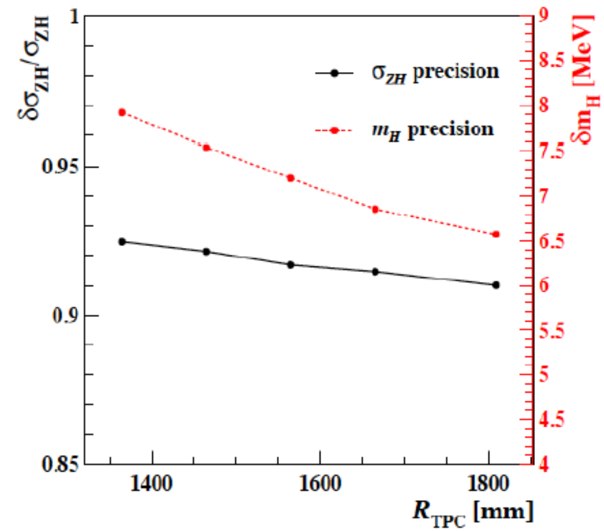
CEPC: Simulation Studies

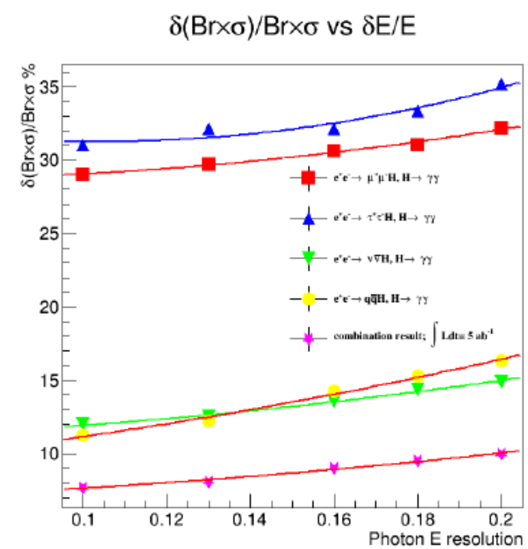


	PreCDR (Jan 2015)	Now (Aug 2016)
σ(ZH)	0.51%	0.50%
σ(ZH)*Br(H→bb)	0.28%	0.21%
σ(ZH)*Br(H→cc)	2.1%	2.5%
σ(ZH)*Br(H→gg)	1.6%	1.3%
σ(ZH)*Br(H→WW)	1.5%	1.0%
σ(ZH)*Br(H→ZZ)	4.3%	4.3%
σ(ZH)*Br(H→ττ)	1.2%	1.0%
σ(ZH)*Br(H→γγ)	9.0%	9.0%
σ(ZH)*Br(H→Zγ)	-	~4 σ
σ(ZH)*Br(H→μμ)	17%	17%
σ(ννH)*Br(H→bb)	2.8%	2.8%
Higgs Mass/MeV	5.9	5.0
σ(ZH)*Br(H→inv)	95%. CL = 1.4e-3	1.4e-3
Br(H→ee/emu)	-	1.7e-4/1.2e-4
Br(H→bbχχ)	$<10^{-3}$	3.0e-4

Main question: optimization

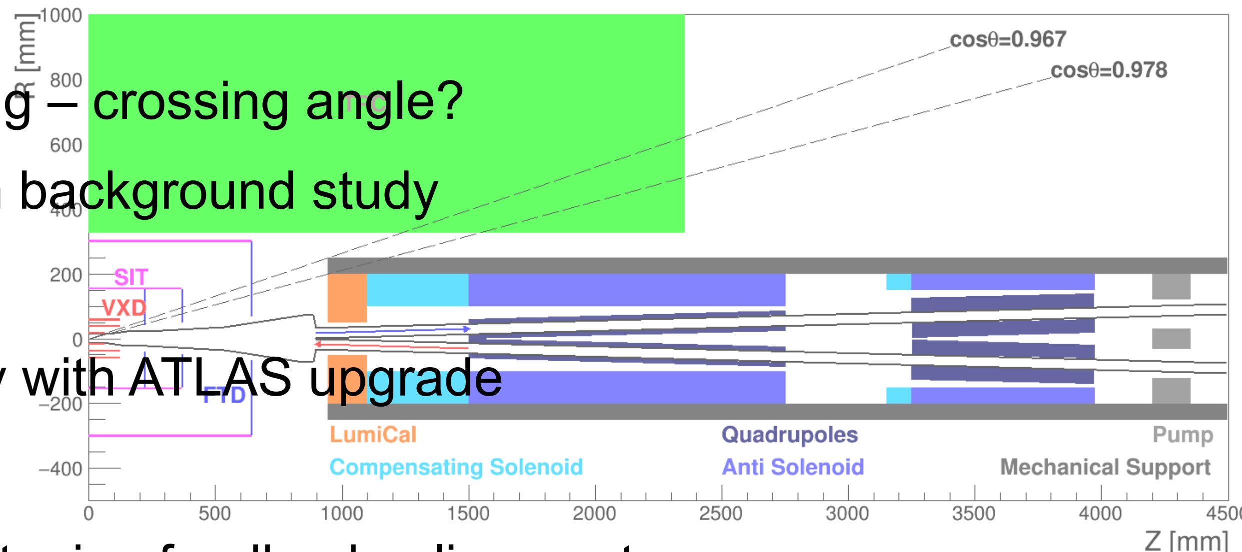
- Performance
  - Smaller Detector Size & B Field:
    - Higgs mass & σ(ZH) accuracy at μμH channel: *accuracy reduced by 20%/3% with 25% smaller TPC radius*
    - *Separation at different configuration*
  - Without Active Cooling:
    - Br(H->WW/ZZ) studies: *event selection efficiency reduced by ~2%*
  - Different technology options:
    - Br(H->di photon): *options compared (Scintillator – Silicon Sensor)*
    - Tracking: Full Silicon Tracker - TPC



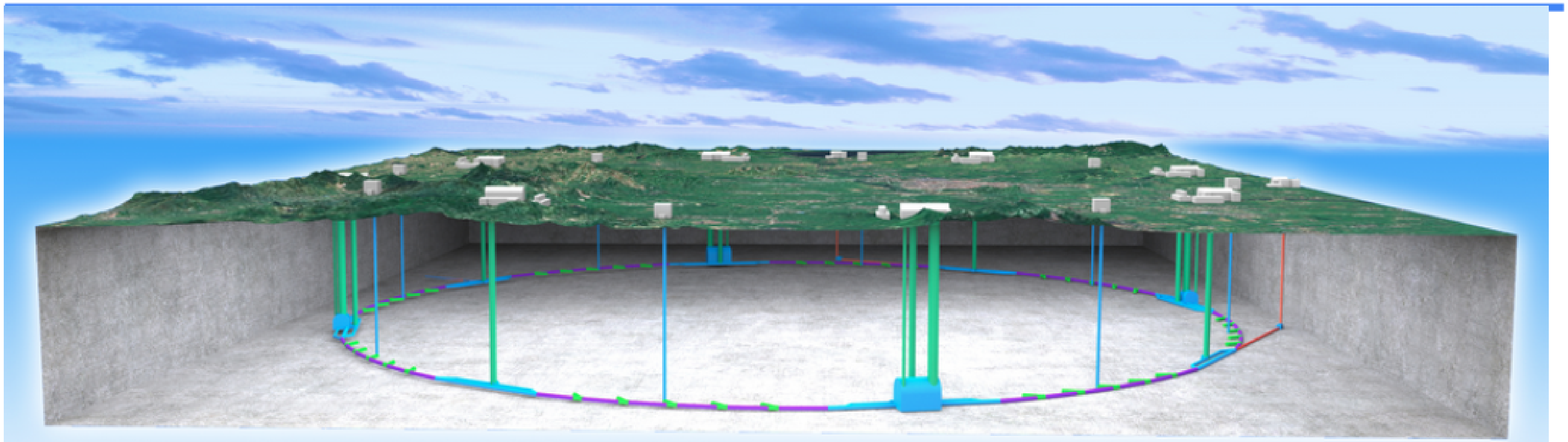


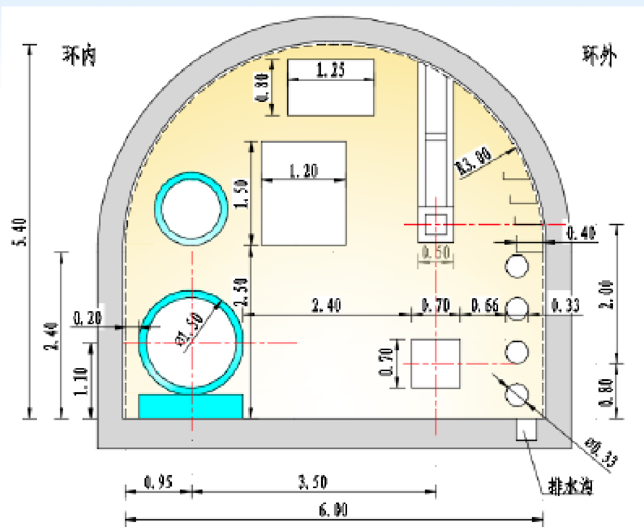
Critical Tasks

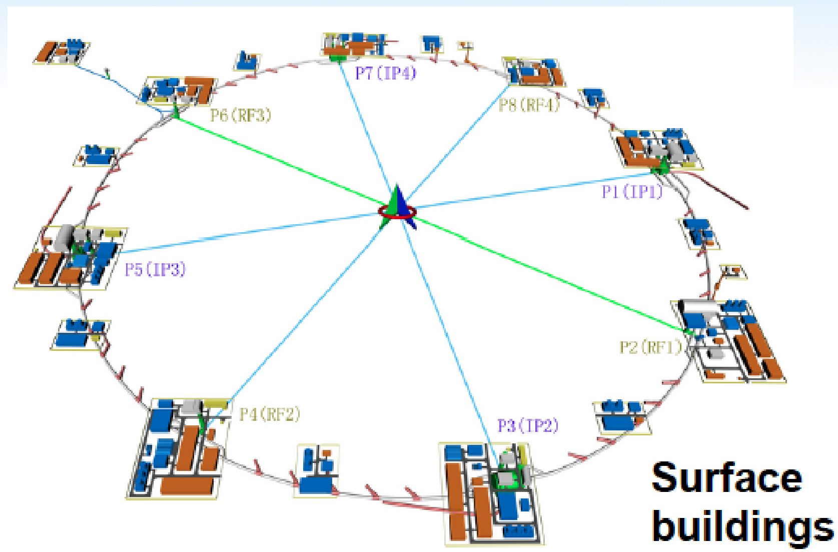
- MDI:
  - single partial double ring – crossing angle?
  - L* optimization & beam background study
- VTX:
  - Critical R&D & Synergy with ATLAS upgrade
- Main Tracker
  - TPC: Maximal event rate, ion feedback, alignment
  - Large area silicon detector R&D
- Refine the requirement for calorimeter
  - Less demanding in Jet Energy Resolution + no power pulsing
- ...



Civil Construction

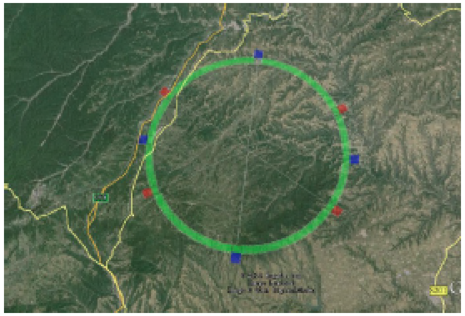






Site selections (a few main candidates)

1)



2)

3)

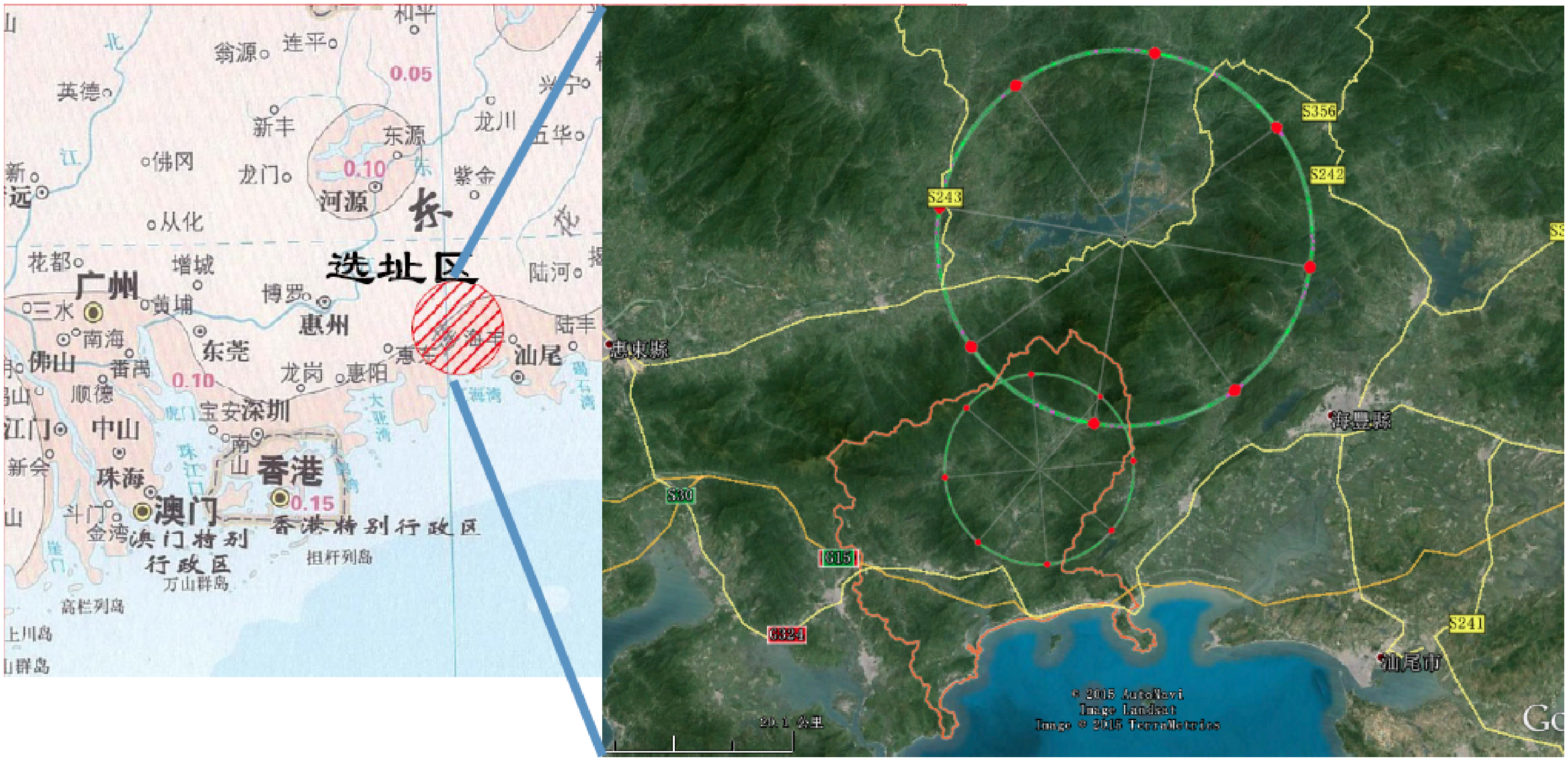
1) Qinhuangdao

2) Shanxi Province

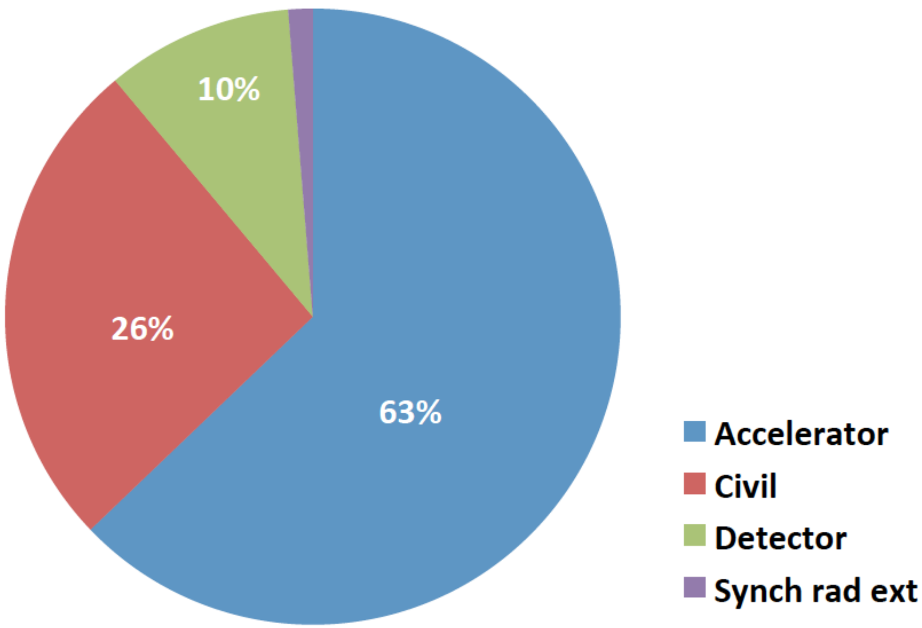
3) Near Shenzhen and Hongkong

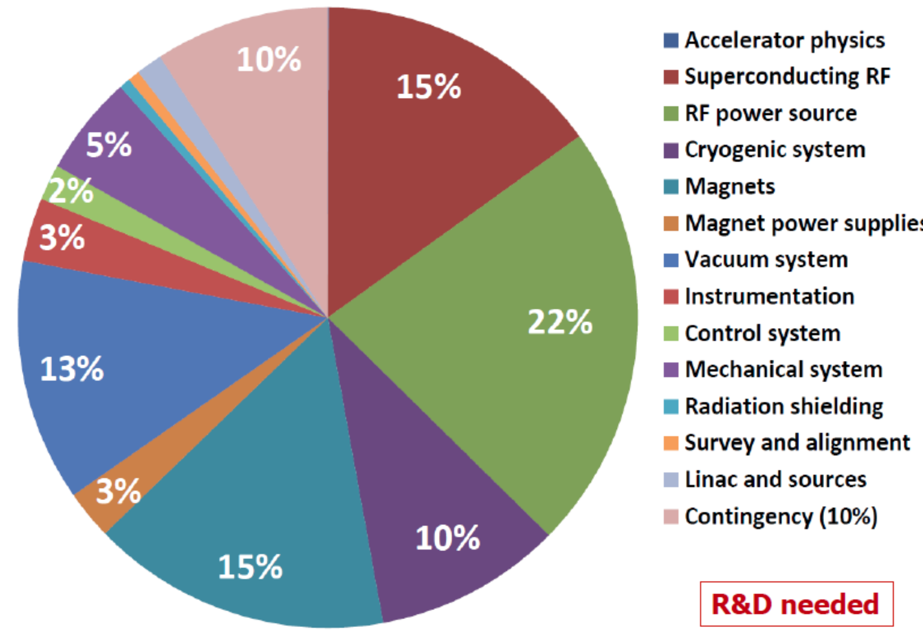
Site Selection

- Continue to work on site selection
- Previously investigated: 300 km north-east of Beijing
- A new possibility close to Hong Kong, invited by the local government



Cost estimation





- Preliminary: 25/36 Billion CNY at 50/100km Circumference
- Accelerator: Key technology development on going (budget + power)
  - *RF source (efficiency)*
  - *High Q SRF cavities*
  - *...*

Status & plan

- Pre-CDR delivered
  - No show-stopper
  - Technical Challenges identified
  - Preliminary cost estimate
- Towards CDR
  - Working machine on paper
  - Get ready to be reviewed by government at any moment

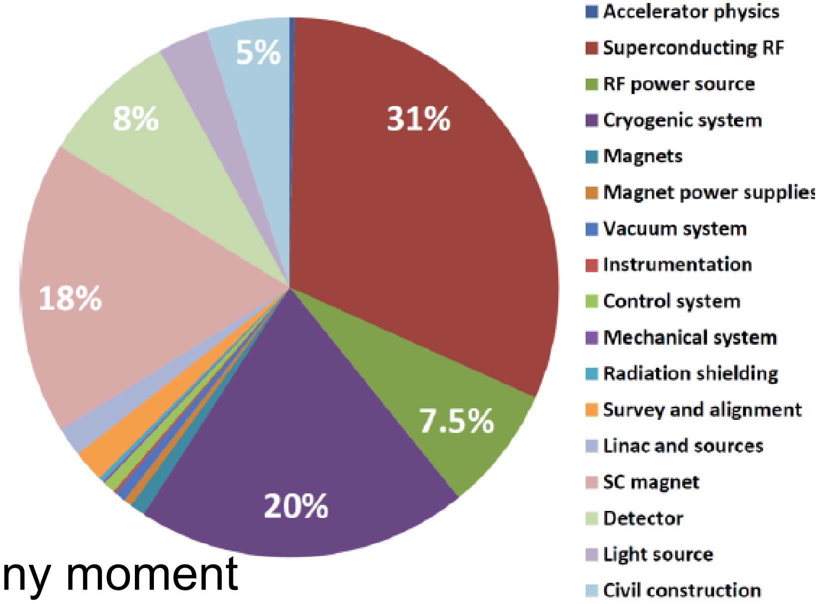
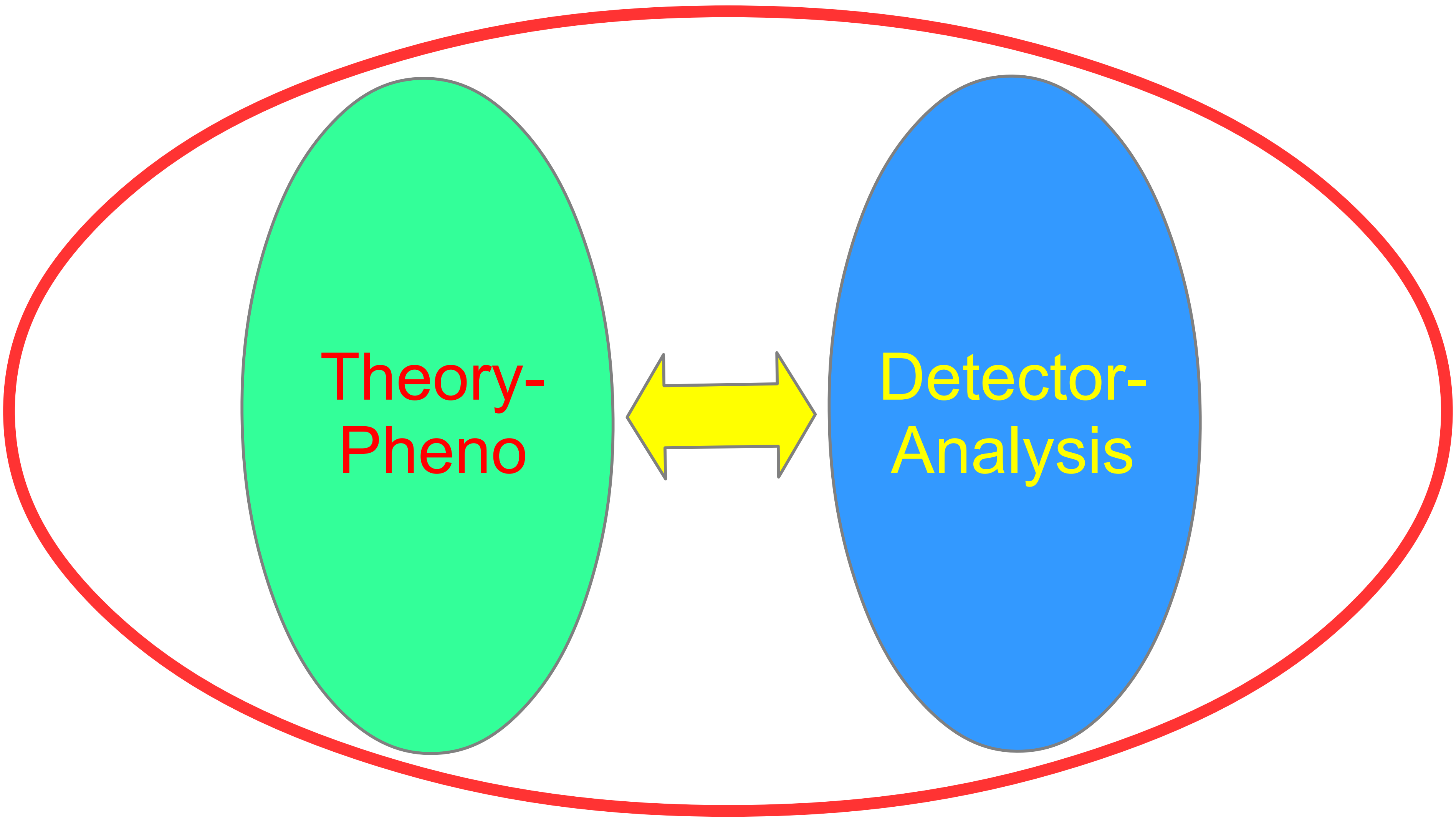
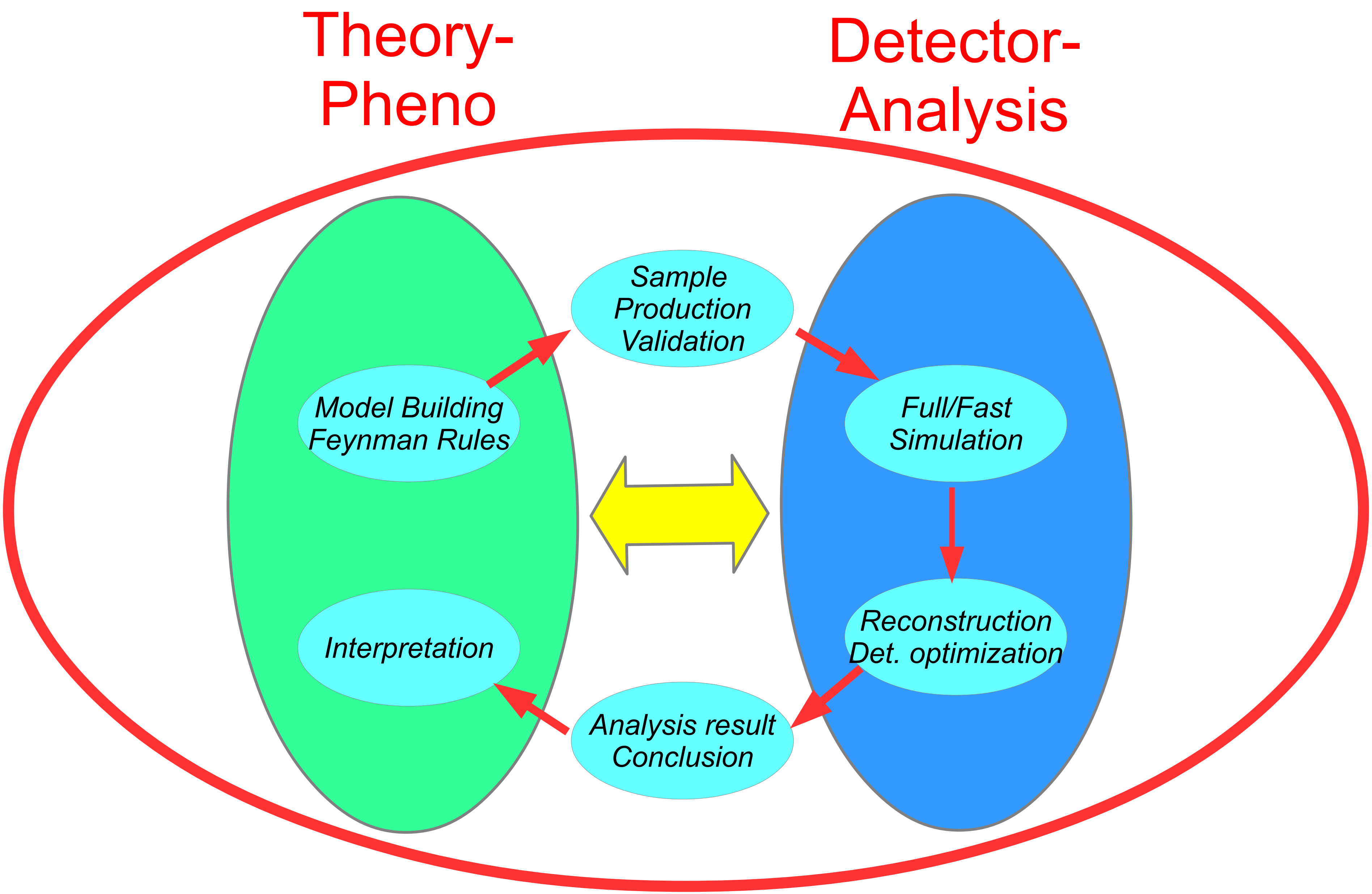


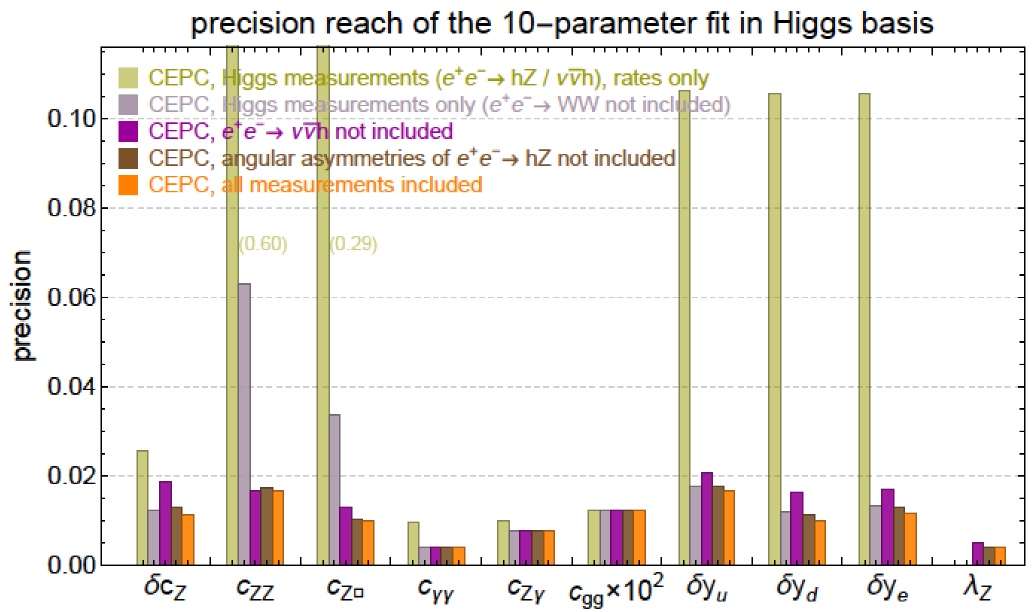
Figure 12.4: Breakdown of the R&D budget of each system.

- R&D issues identified & funding request underway
  - IHEP **seed** money: 12 M CNY/3 years
  - MOST: 35 M/5 yr **approved**, ~ 40 M to be asked next year
  - NCDR (13^{th} 5 year plan): ~ 0.8 B/5 yr, **failed** in voting process
  - CAS & CNSF: **under discussion**, hopefully ~ 50 M/y


Theory-
Pheno
Detector-
Analysis


Theory-
Pheno
Detector-
Analysis
Sample
Production
Validation
Model Building
Feynman Rules
Full/Fast
Simulation
Interpretation
Reconstruction
Det. optimization
Analysis result
Conclusion

Recent high light 1: Impact of TGC & Differential measurements



The "10-parameter" framework in the Higgs basis

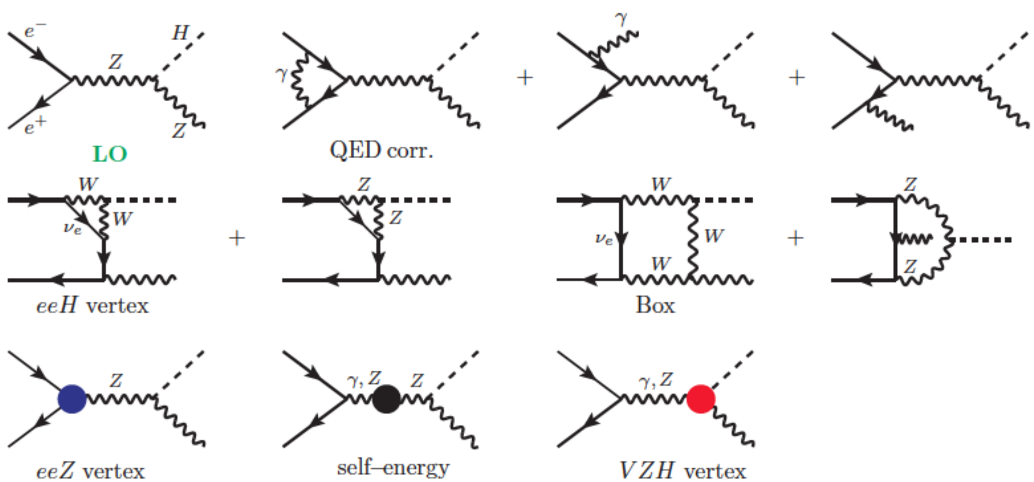
- Starting with all the D6 operators that can contribute to the above measurements.
- Assuming new physics is CP-even, flavor universal.
- Assuming no corrections to Z-pole observables and W mass. (More justified if the machine will run at Z-pole.)
- We are left with 10 operators, parameterized in the Higgs basis by:

$$\delta c_Z\,,\quad c_{ZZ}\,,\quad c_{Z\Box}\,,\quad c_{\gamma\gamma}\,,\quad c_{Z\gamma}\,,\quad c_{gg}\,,\quad \delta y_u\,,\quad \delta y_d\,,\quad \delta y_e\,,\quad \lambda_Z\,.$$

- Strong independent constraints can be obtained for all 10 coefficients!
- [1505.00046] Falkowski
  [1508.00581] Falkowski, Gonzalez-Alonso, Greljo, Marzocca

Jiayin Gu (顾嘉荫) G. Durieux, C. Grojean, K. Wang

Recent high light 2: High Order Feynman Diagram to ZH production



arXiv:1609.03995 Qingfeng SUN

In collaboration with Feng Feng(CUMT), Yu Jia(IHEP), Wen-long Sang(SWU)

Numeric Results in $\alpha(0)$ scheme

$\sqrt{s}$ (GeV)		LO (fb)	NLO Weak (fb)		NNLO mixed EW-QCD (fb)				
		$\sigma^{(0)}$	$\sigma^{(\alpha)}$	$\sigma^{(0)} + \sigma^{(\alpha)}$	$\sigma_{eeZ}^{(\alpha\alpha_s)}$	$\sigma_{Z}^{(\alpha\alpha_s)}$	$\sigma_{\gamma}^{(\alpha\alpha_s)}$	$\sigma^{(\alpha\alpha_s)}$	$\sigma^{(0)} + \sigma^{(\alpha)} + \sigma^{(\alpha\alpha_s)}$
240	Total	**223.14**	6.90	230.03	0.83(7)	1.58(14)	0.008(1)	2.42(21)	232.45(21)
	L	88.67	3.29	91.96	0.33(3)	0.63(5)	0.003(1)	0.96(8)	92.92(8)
	T	134.46	3.61	138.07	0.50(4)	0.95(8)	0.005(1)	1.46(13)	139.53(13)
250	Total	**223.12**	6.34	229.46	0.83(7)	1.57(14)	0.009(1)	2.41(21)	231.87(21)
	L	94.30	3.42	97.72	0.35(3)	0.66(6)	0.004(1)	1.02(9)	98.74(9)
	T	128.82	2.92	131.74	0.48(4)	0.91(8)	0.005(1)	1.39(12)	133.13(12)
500	Total	**53.22**	1.23	54.45	0.18(3)	0.15(2)	−0.003(1)	0.33(3)	54.78(5)
	L	41.50	1.52	43.02	0.14(2)	0.12(2)	0.001(1)	0.26(4)	43.28(4)
	T	11.72	−0.29	11.43	0.04(1)	0.03(1)	−0.004(1)	0.07(1)	11.50(1)

The (un)polarized Higgsstrahlung cross sections at $\sqrt{s} = 240$ GeV, 250 GeV and 500 GeV. We enumerate the NLO weak corrections, together with the NNLO electroweak-QCD $\mathcal{O}(\alpha\alpha_s)$ corrections.

Summary and outlook I

- We revisit the $\mathcal{O}(\alpha)$ NLO correction with modern accuately measured parameters and and find the NLO correction is about 3.1% at 240 GeV.
- We calculate the $\mathcal{O}(\alpha\alpha_s)$ NNLO corrections and find the NNLO corrections sizable, about 1.1% at 240 GeV, well above the projected experimental sub-percent accuracy for the $\sigma(ZH)$ measurement.
- To meet such an exquisite experimental precision, it might even be relevant to further address the two-loop $\mathcal{O}(\alpha^2)$ NNLO corrections or even the three-loop $\mathcal{O}(\alpha\alpha_s^2)$ NNNLO corrections.
- The ISR(Initial State Radiation) effects have to be considered carefully to meet the experimental requirements.

Key question & Wish lists

- Physics potential & requirement on the detector design & Accelerator Parameters
- Motivation
  - New ideas
  - Data-driven method
  - Differential distributions
- Detector optimization
  - Solid angle coverage
  - Sensitive Volume of the detector
- Interpretation
  - Theoretical error control

Summary

- CEPC is the first Chinese effort for a Science project at such scale → challenges every where
- Tremendous progresses up to now, but still long way to go
  - Detector Design, Optimization..
- Given the importance of Higgs, we expect that at least one of them, FCC-ee, ILC, or CEPC, can be realized.

- **Profound understanding of the physics motivation, interpretation and requirement on these facilities is essential – Need your participation!!**

Backup

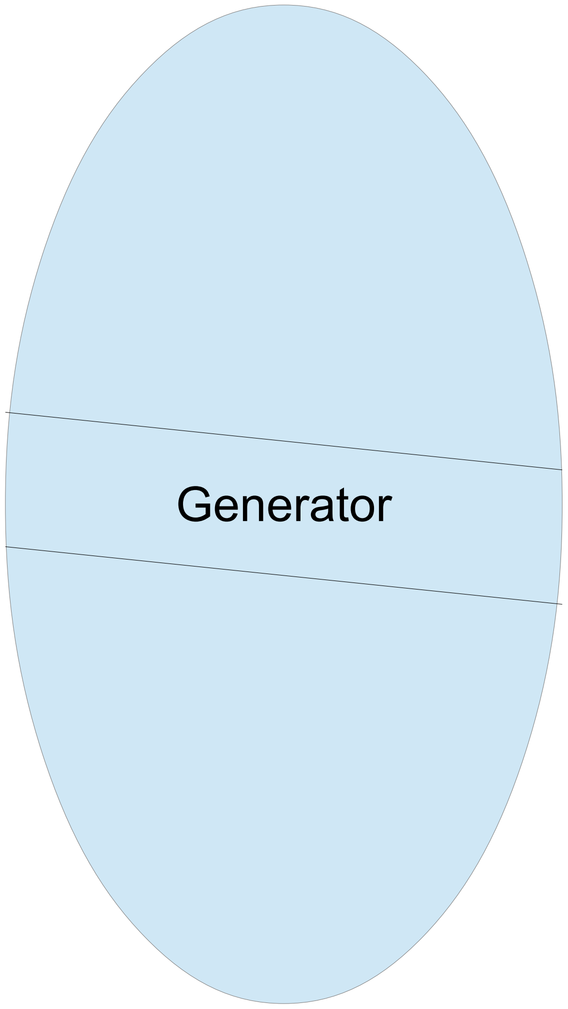
Theory-Pheno: Physics motivation

- Unique/distinguishable advantage of electron-positron Higgs factory
- Higgs:
  - Event Number Counting
    - Absolute Higgs measurements
      - Total generation Xsec
      - Higgs width, Decay branching ratio & absolute couplings
    - Exotic decay mode searching via recoil mass method
  - Differential distribution measurements
    - Higgs CP
    - O5, O6 Higgs interaction operators
- EW:
  - Z pole observables, etc

Generator Studies

- For any Pheno-expoloration, the Sim Group can provide **Full Set of SM Bkgrd** (on the same footing) & **more realistic detector simulation.**
- Generator: interface between Theory-Pheno And Detector Studies
- Cooperations Interactions with Madgraph & Whizard
  - Madgraph: ISR
  - Whizard 2.0: VTX position missing ...
  - MC4BSM WS
- Our own generator development is more than welcome
- Validation @ precision measurement is essential
- **A fully operation chain**, still need lots of efforts

  MM → Feynman Rule → UFO → Samples → Validation→Sim/Reco/Analysis... → result & documentations.



International Collaboration

- A new international organization for CEPC will be organized after (at least some) funding is available
  - A new format: not ITER, CERN, ILC, …
- An international advisory board is formed to discuss in particular this issue, together with others
- Many MOU and meeting minutes signed with collaborating institutions/organizations:
  - UChicago, BNL, SLAC, BINP, Oxford, INFN, …
  - More will be signed
- Seeking international coordination

ICFA Statements

- **ICFA meeting of Feb. 2014 at DESY, Hambourg, stated:**

> **ICFA supports studies of energy frontier circular colliders and encourages global coordination**

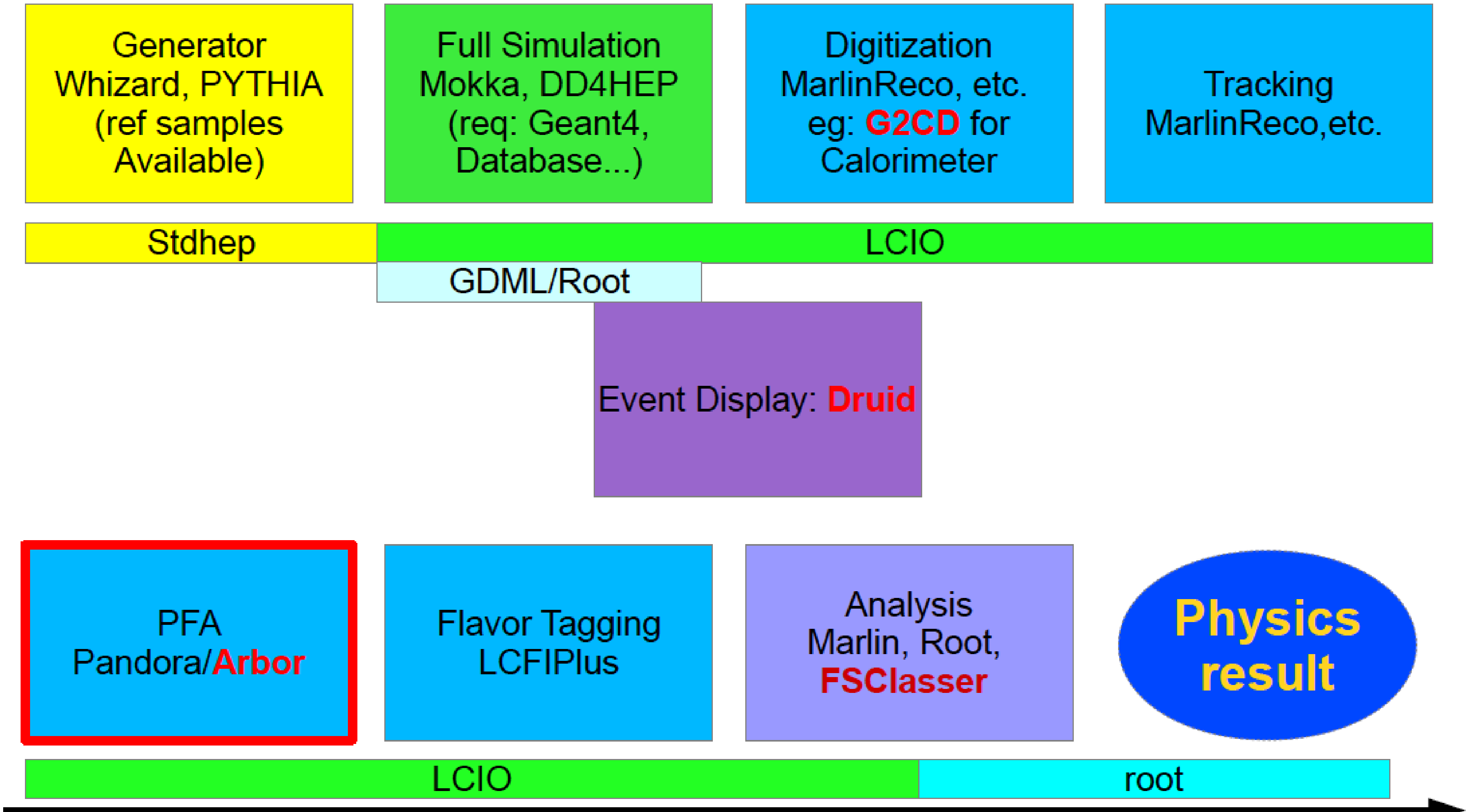
- **ICFA meeting of July 2014 in Spain, stated:**

> **… ICFA continues to encourage international studies of circular colliders, with an ultimate goal of proton-proton collisions at energies much higher than those of the LHC.**

AsiaHEP/ACFA Statement on ILC + CEPC/SPPC

AsiaHEP and ACFA reassert their strong endorsement of the ILC, which is in a mature state of technical development. The aim of ILC is to explore physics beyond the Standard Model by unprecedented precision measurements of the Higgs boson and top quark, as well as searching for new particles which are difficult to discover at LHC. The Higgs studies at higher energies are especially important for measurement of WW fusion process, to fix the full Higgs decay width, and to measure the Higgs self-coupling. In continuation of decades of world-wide coordination, we encourage redoubled international efforts at this critical time to make the ILC a reality in Japan. The past few years have seen growing interest in a large radius circular collider, first focused as a "Higgs factory", and ultimately for proton-proton collisions at the high energy frontier. We encourage the effort lead by China in this direction, and look forward to the completion of the technical design in a timely manner.

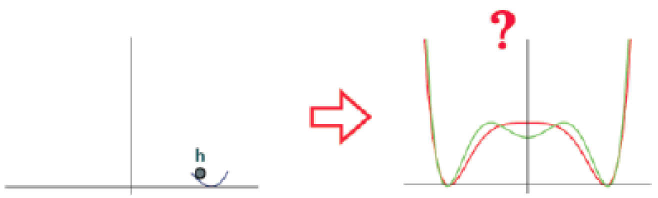
SCRAC

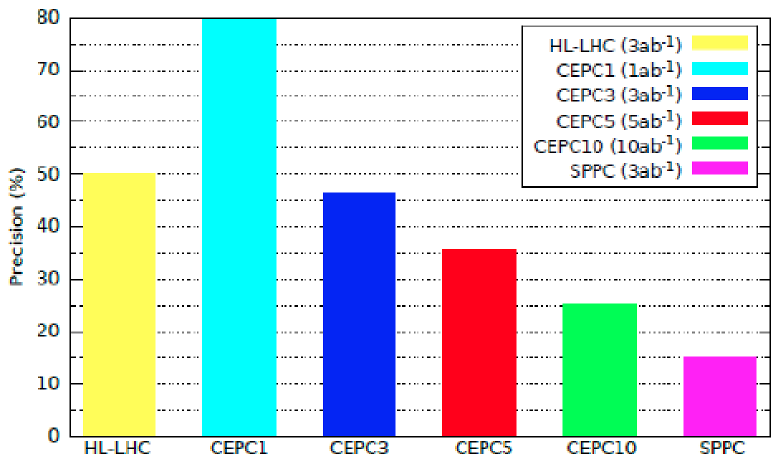


07/04/2016 *Simulation Calibration Reconstruction Analysis Chain* 3

Nature of EW Phase Transition ?

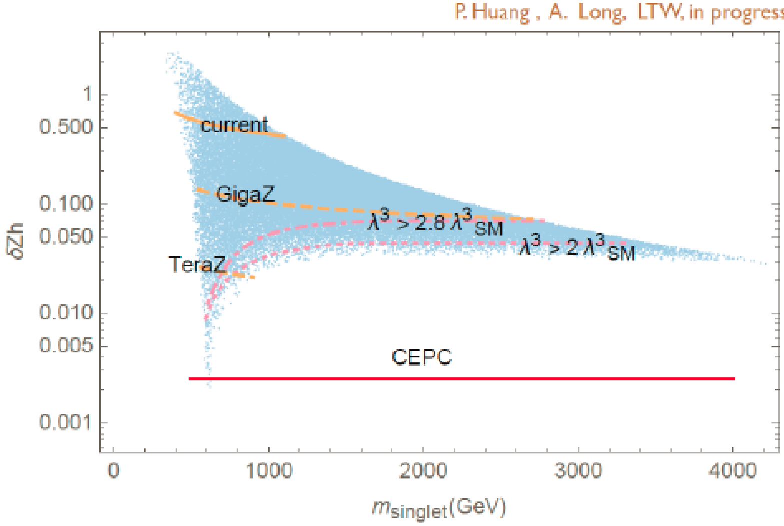
- 1^{st} or 2^{nd} order ➔ Huge implications
  - O(1) deviations in h^3 coupling
  - O(1%) shift in h-Z coupling
- CEPC can determine it:
  - h^3 coupling at CEPC： 20-30%
  - h-Z coupling at CEPC： < 0.2%





M. McCullough, PRD 90(2014)015001

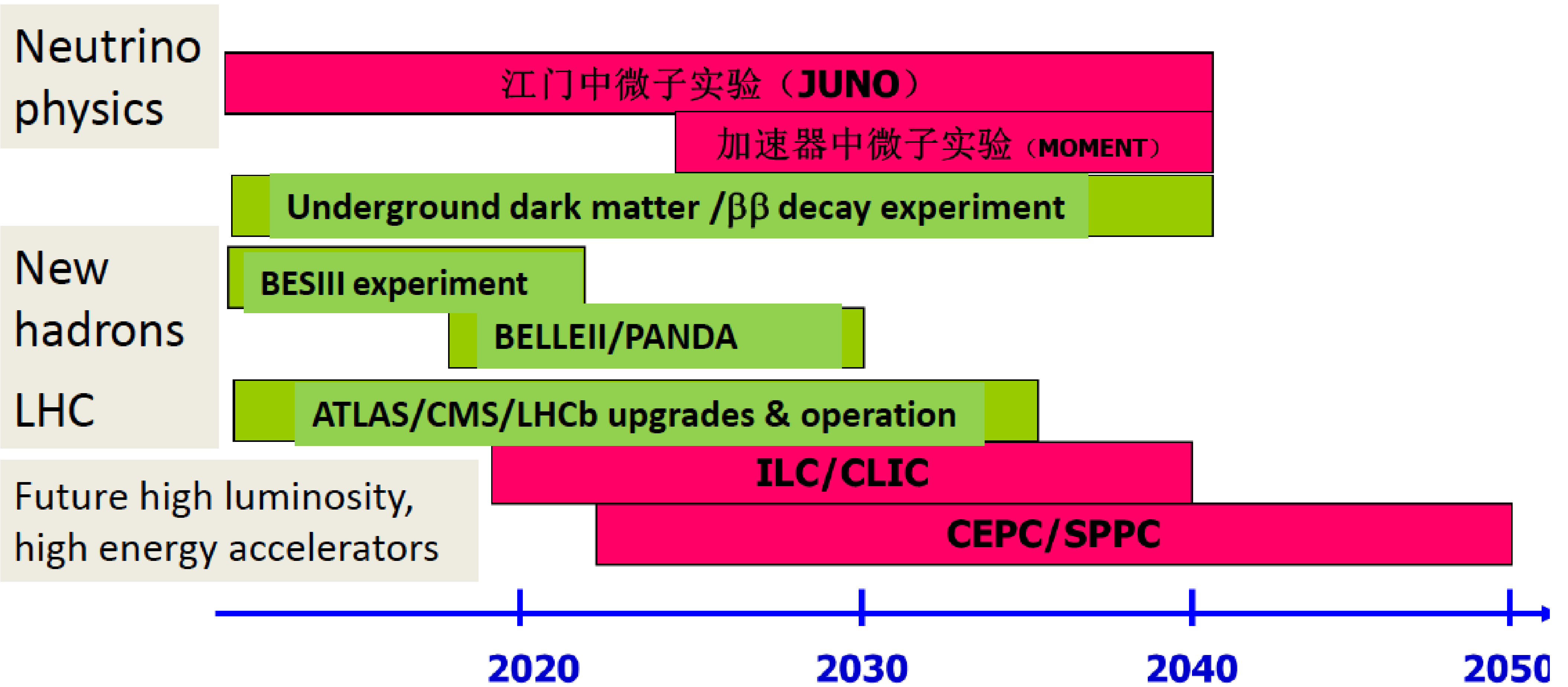
P. Huang , A. Long, LTW, in progress



Particle Physics Program in China

a variety of experiments ongoing or planned

CEPC-SppC the very long term future



Higgs measurements at PreCDR

	di-muon	di-electron	di-neutrino	di-jets
σ(ZH)			-	
M_H				
σ(ZH)*Br(H→bb)				
σ(ZH)*Br(H→cc)				
σ(ZH)*Br(H→gg)				
σ(ZH)*Br(H→WW)				
σ(ZH)*Br(H→ZZ)				
σ(ZH)*Br(H→ττ)				
σ(ZH)*Br(H→γγ)				
σ(ZH)*Br(H→μμ)				
σ(ννH)*Br(H→bb)	-	-		-
Br(H→invisible)			-	
Br(H→exotic)				

Signal with CEPC Full Simulation, Bkgrd with Fast Simulation

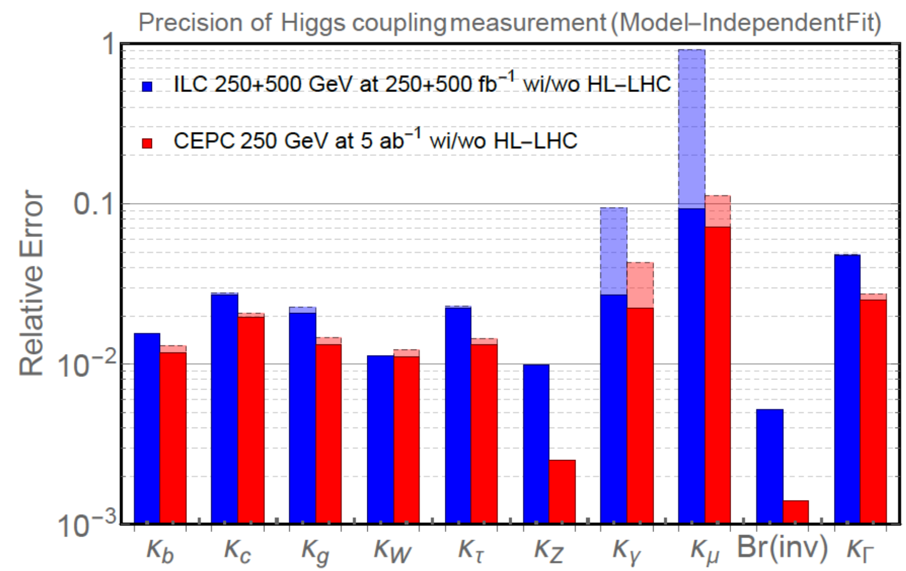
CEPC Fast Simulation

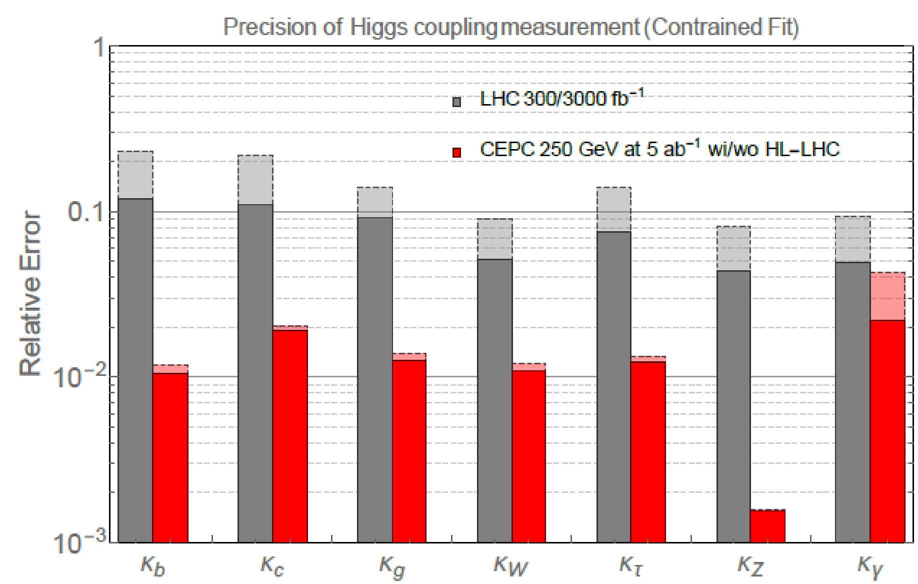
Extrapolated from ILC/FCC-ee results

Table 3.12 Estimated precisions of Higgs boson property measurements at the CEPC. All the numbers refer to relative precision except for M_H and BR($H \to$ inv) for which ΔM_H and 95% CL upper limit are quoted respectively.

ΔM_H	Γ_H	$\sigma(ZH)$	$\sigma(\nu\nu H) \times$ BR($H \to bb$)
5.9 MeV	2.8%	0.51%	2.8%

Decay mode	$\sigma(ZH) \times$ BR	BR
$H \to bb$	0.28%	0.57%
$H \to cc$	2.2%	2.3%
$H \to gg$	1.6%	1.7%
$H \to \tau\tau$	1.2%	1.3%
$H \to WW$	1.5%	1.6%
$H \to ZZ$	4.3%	4.3%
$H \to \gamma\gamma$	9.0%	9.0%
$H \to \mu\mu$	17%	17%
$H \to$ inv	–	0.28%

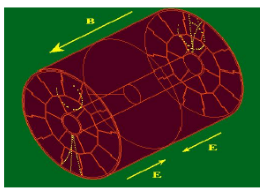




TPC, VTX, Calorimetry

Performance/Design goals

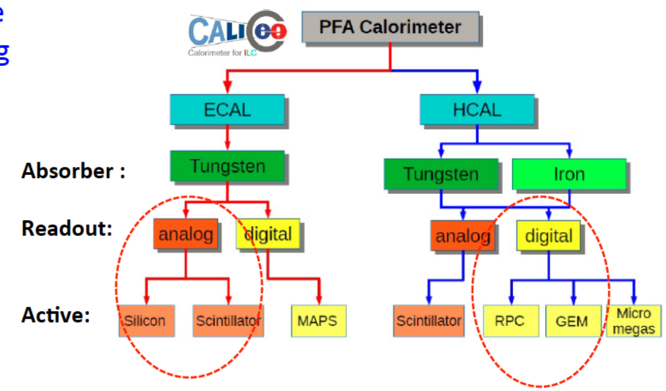
- ILD TPC Design adopted for the baseline detector at CEPC



Momentum resolution at B=3.5T	$\delta(1/pt) \approx 10^{-4}$/GeV/c TPC only
δ_{point} in rΦ	<100μm (avg for straight-radial tracks)
δ_{point} in rz	≈0.4~1.4mm (for zero – full drift)
Inner radius	329mm
Outer radius	1800mm
Half length	2350mm
TPC material budgt	≈0.05X_0 including the outer field cage in r <0.25X_0 for readout endcaps in z
Pad pitch/no. padrows	≈1mm×4~10mm/≈200
2-hits resolution in rΦ	≈2mm (for straight-radial tracks)
Performance	>97% efficiency for TPC only (pt > 1GeV/c) >99% all tracking (pt > 1GeV/c)

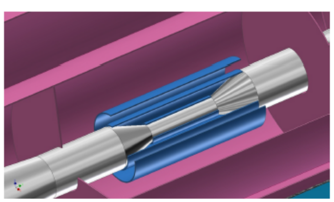
Global R&D of Imaging Calorimeters

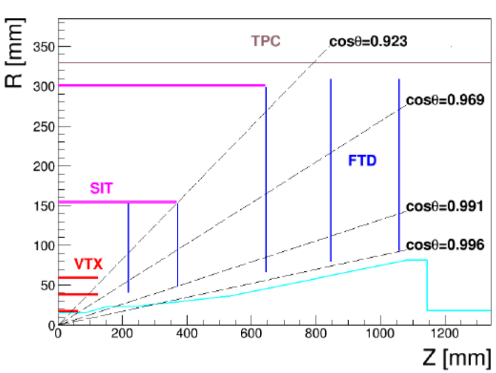
- Concept of Particle Flow Algorithm
  -> calorimeters with very fine granularity
- The calorimetry system at CEPC should be allowed to consider:
  - easier (less challenging) options
  - cost effective
  - active cooling



Vertex Detector and Silicon Trackers

Qun Ouyang's talk





Vertex detector:

- 3 cylindrical and concentric double-layers of pixels

Silicon Internal Tracker (SIT)

- 2 inner layers Si strip detectors

Forward Tracking Detector (FTD)

- 5 disks (2 with pixels and 3 with Si strip sensor) on each side

Silicon External Tracker (SET)

- 1 outer layer Si strip detector

End-cap Tracking Detector (ETD)

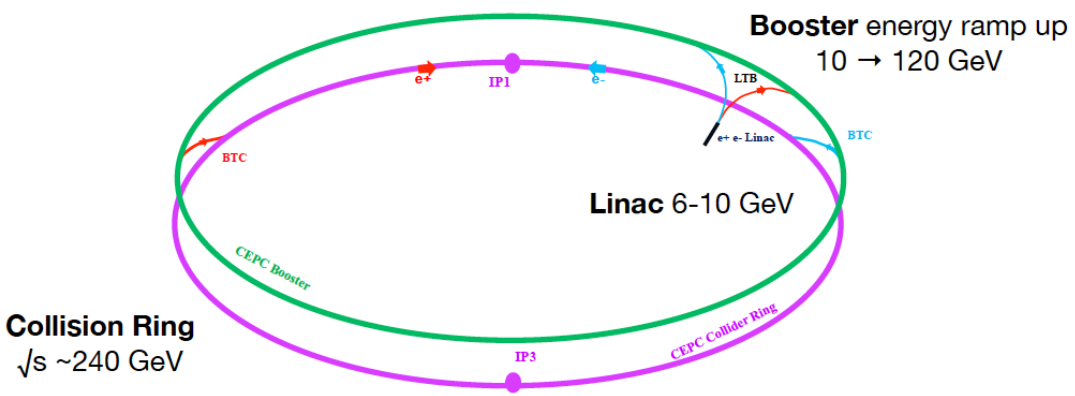
- 1 end-cap Si strip detector on each side

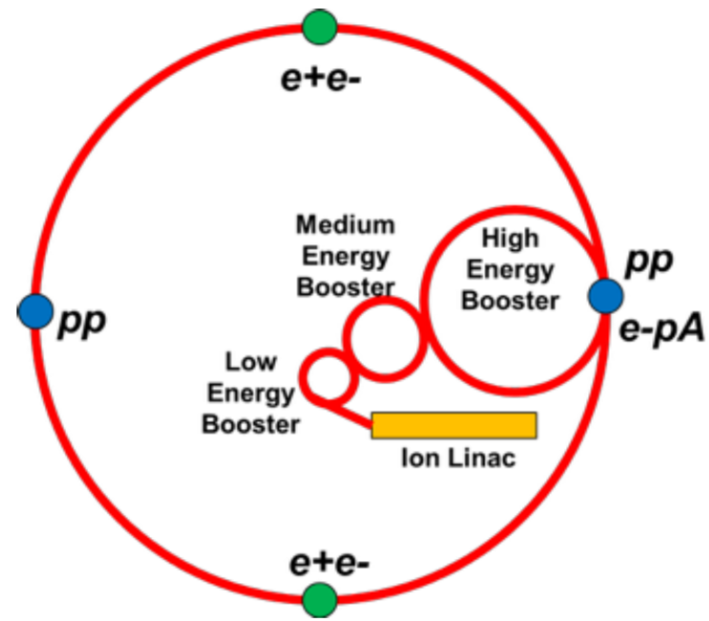
- Explore the physics potential: thanks to 20+ years' world-wide efforts from ILC/CLIC and from Fcc-ee recently

- Focus on feasibility studies for the PreCDR
  - keep in mind the tight schedule !
  - clarify performance requirements
  - skeletonize a baseline detector design
  - availability of technologies
  - identify items for future R&D

Critical R&D target identified...

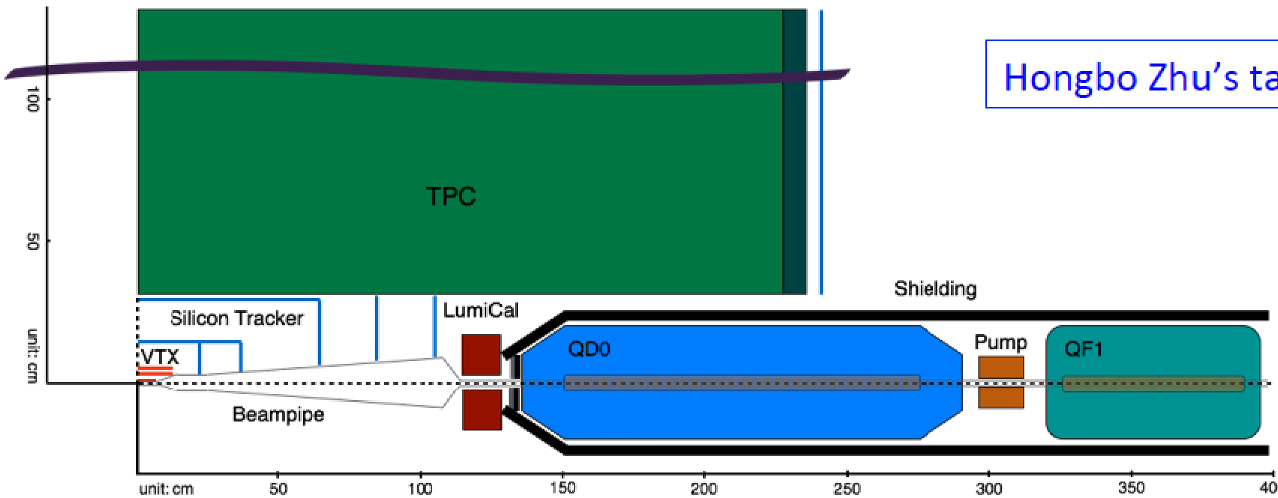
CEPC-SPPC



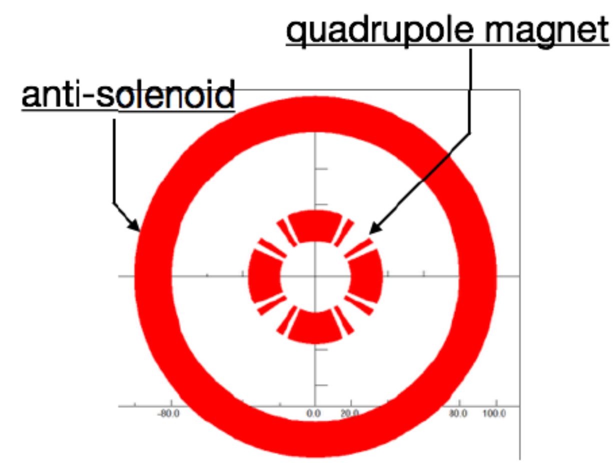


- Electron-positron collision phase
  - Higgs factory: collision at ~240 - 250 GeV center-of-mass energy, Instant luminosity ~ $2*10^{34}$ $cm^{-2}s^{-1}$, 1M clean Higgs event at 2 IP over 10 years
  - Z pole operation for precise EW measurement
- Proton-Proton collision phase
  - center-of-mass energy constrained by tunnel circumference and high-field dipole
  - Peak luminosity ~ $1*10^{35}$ $cm^{-2}s^{-1}$ (*ArXiv: 1504.06108, discussion on needed Luminosity*)
- Tunnel circumference: 54 km in the baseline design. Longer tunnel to be evaluated.

MDI



Hongbo Zhu's talk



coil layout

- Short focal length of L* = 1.5 m (cf. ~3.5m at ILC)
- Final focusing magnets inside the detector →→ constraints on the detector design + QD0/QF1 design
  - No. of FTD's reduced to 5 (cf. 7 for ILD)
  - redesign of offline/online luminosity instrumentation
  - design of QD0/QF1

QD0 Parameters

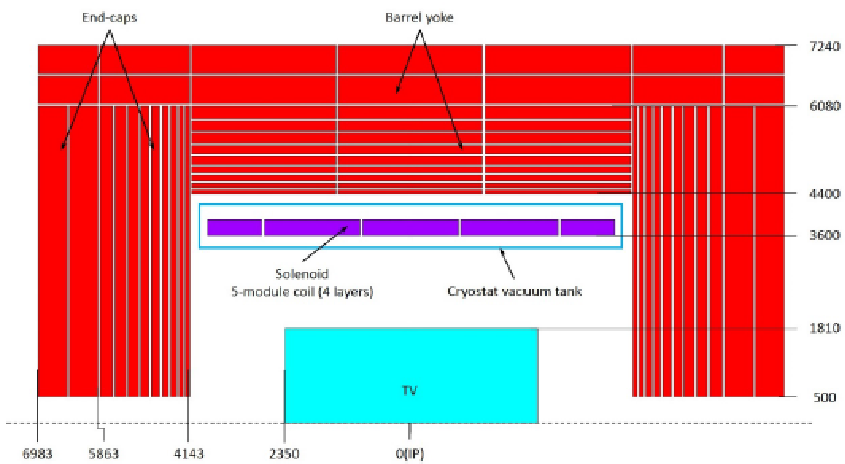
Parameter	Unit	Value
Length	m	1.25
Field gradient	T/m	300
Coil inner radius	mm	20
Beampipe radius	mm	16
Cryostat diameter	mm	400

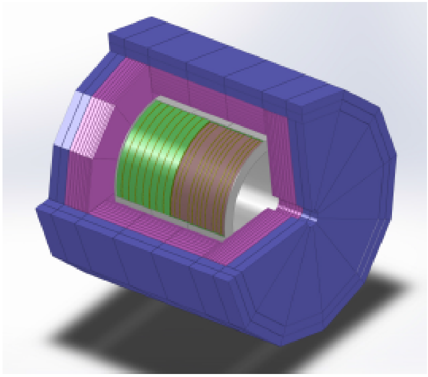
Beam background estimated...

- Anti-solenoid (3.5 T) and quadrupole focusing magnet (6 T) → with superconducting magnet: NbTi/Nb3Sn

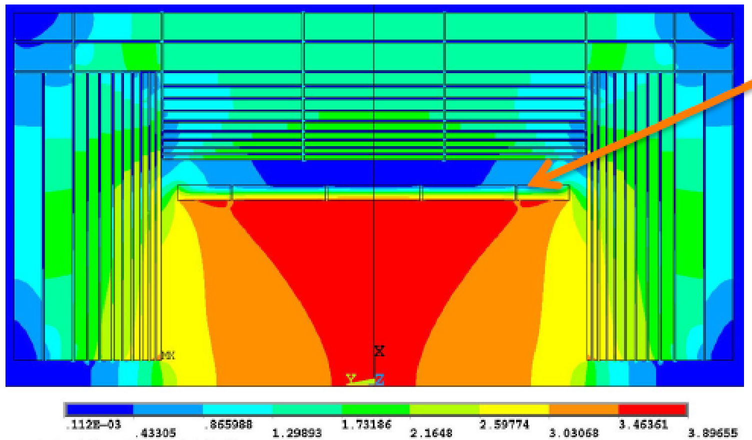
Magnet

- A new design for baseline detector at CEPC

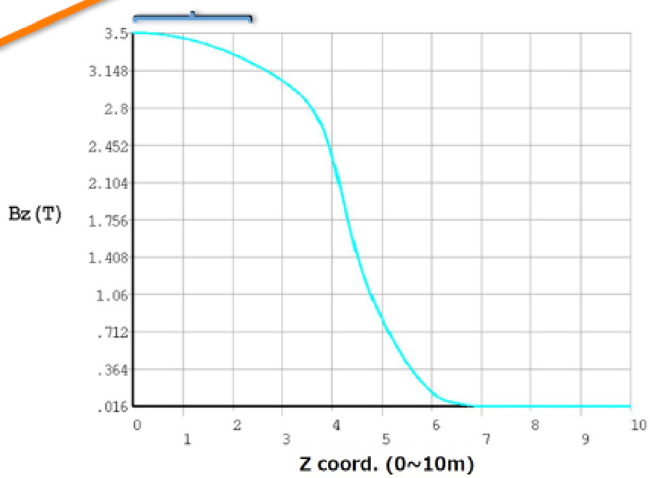




- Simulated field distributions



correction/fine tuning possible



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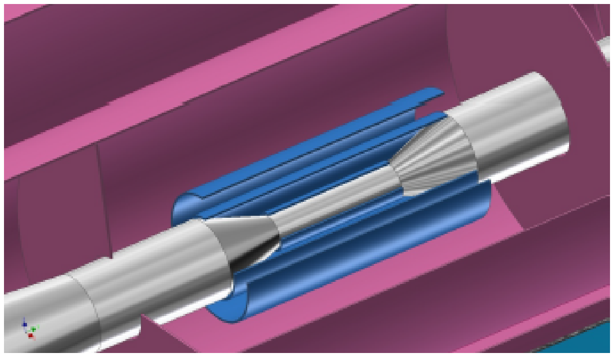
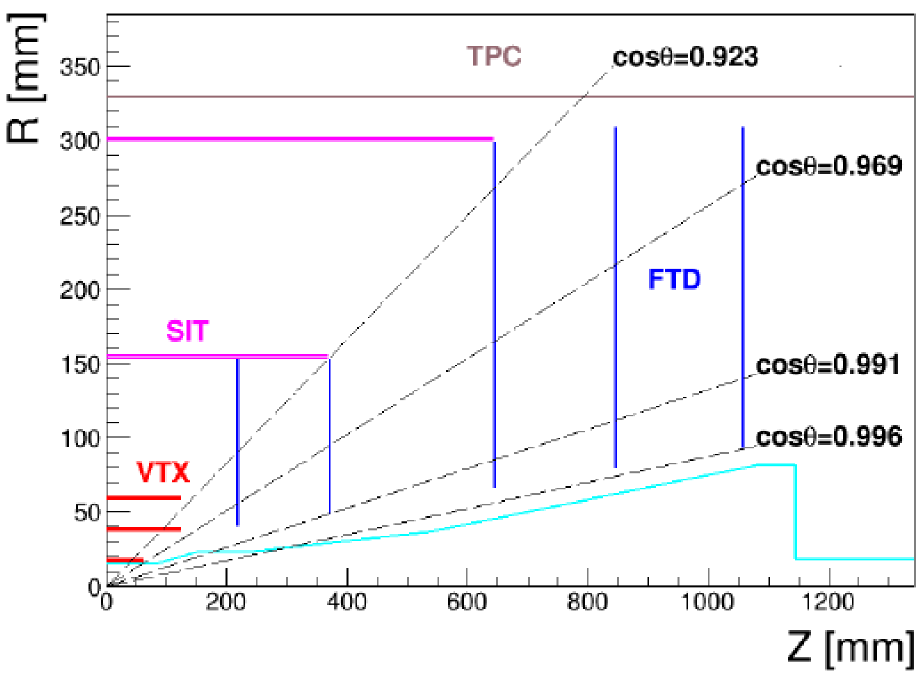
Qun Ouyang's talk





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End-cap Tracking Detector (ETD)

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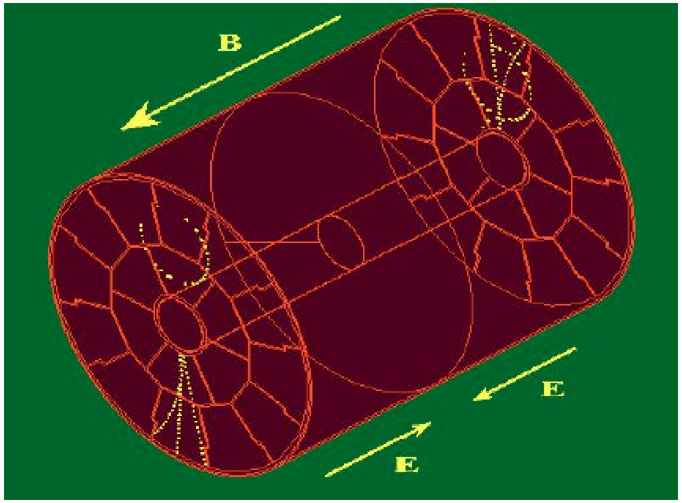
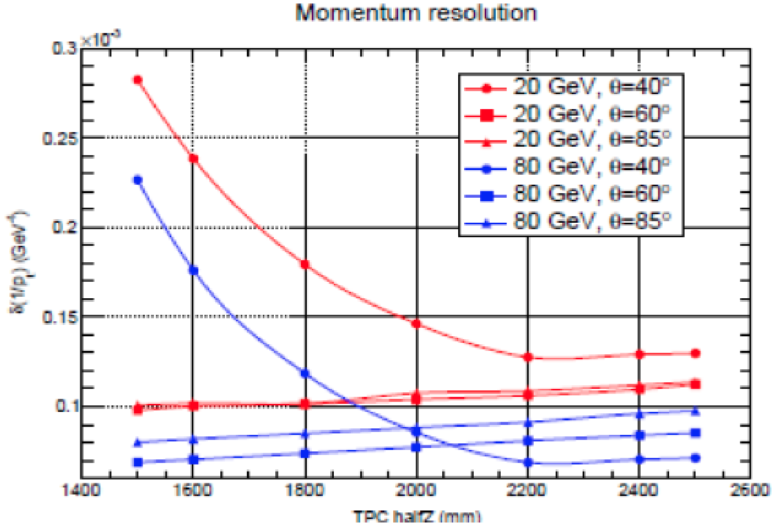
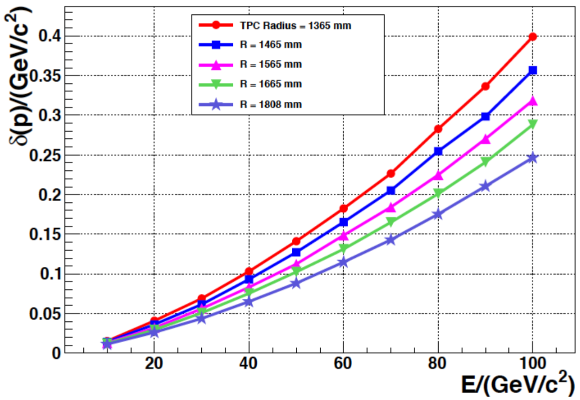
TPC Design







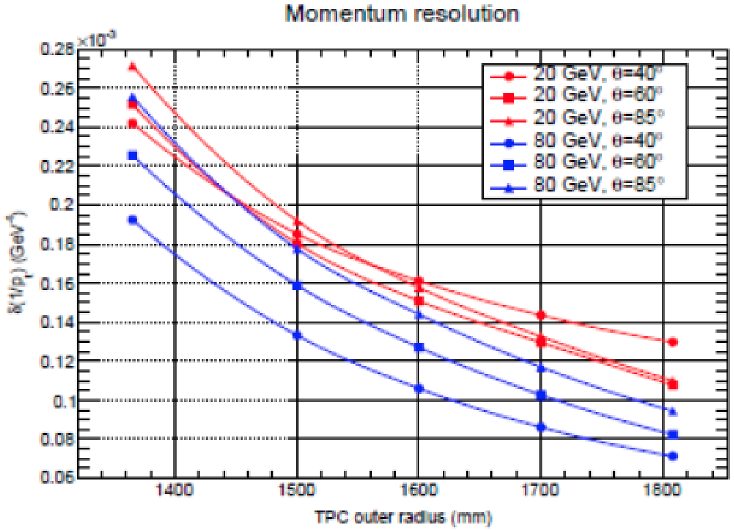
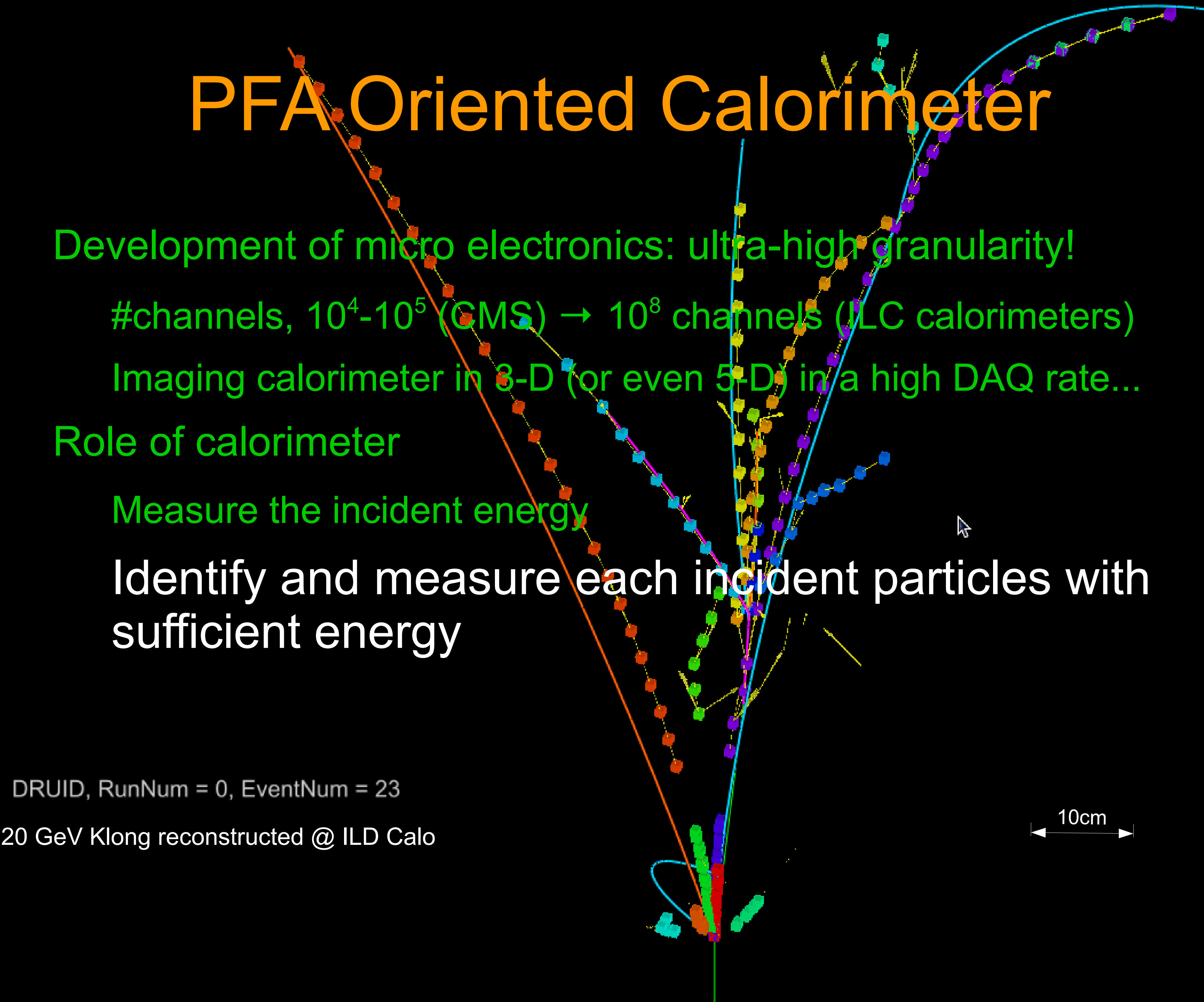


Fig. 6. Tracker Performance at different TPC Radius

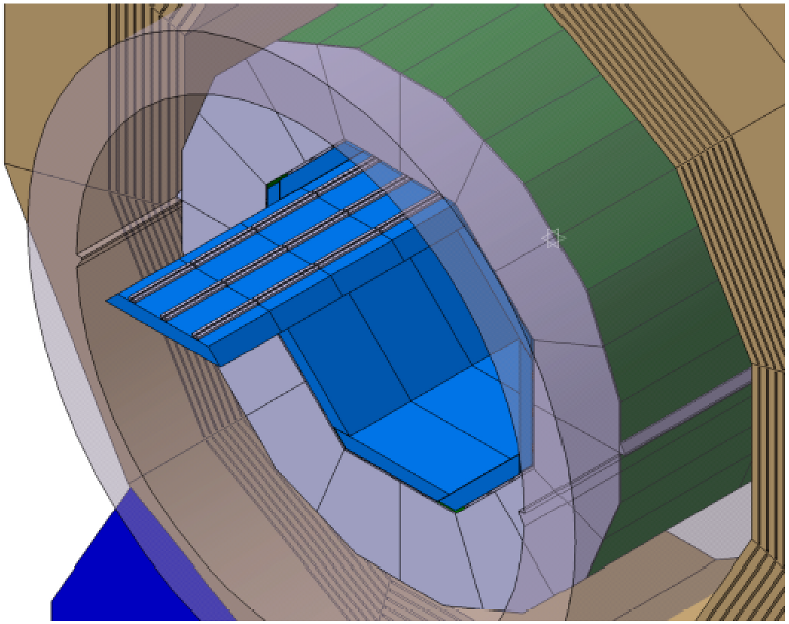
PFA Oriented Calorimeter

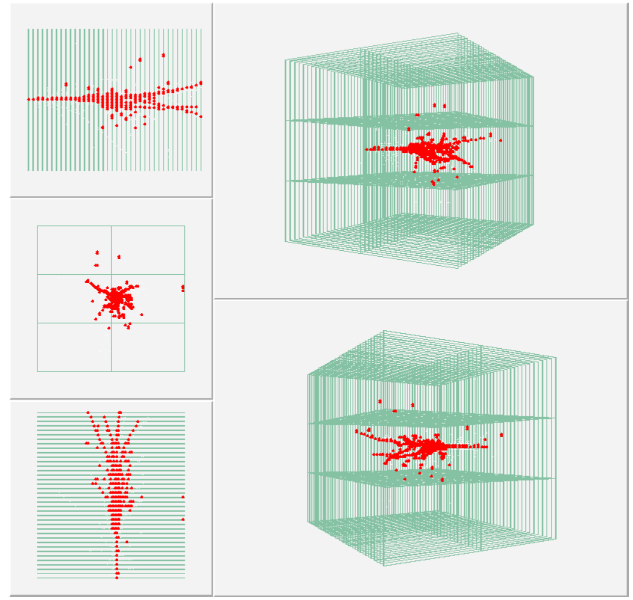
- Development of micro electronics: ultra-high granularity!
  - #channels, 10^4-10^5 (CMS) → 10^8 channels (ILC calorimeters)
  - Imaging calorimeter in 3-D (or even 5-D) in a high DAQ rate...
- Role of calorimeter
  - Measure the incident energy
  - Identify and measure each incident particles with sufficient energy

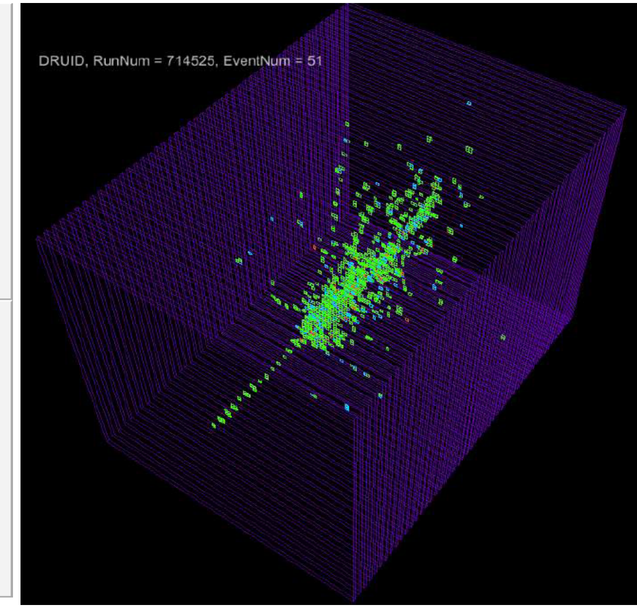


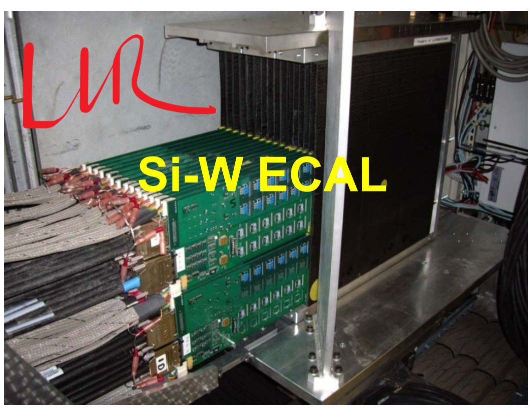
20 GeV Klong reconstructed @ ILD Calo

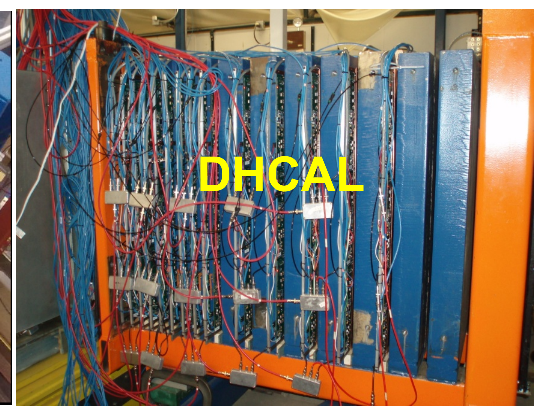
Calorimeter R&D for ILD











Ultra high granularity ~ 1 channel cm^{-3}. 3d, 4d or 5d image...

Given the state of the accelerator technology and interests in particle physics going beyond the discovery of the Higgs boson, new proposals for hadron and heavy-ion colliders at tens of TeV center of mass energy per nucleon pair have been envisioned [14, 15]. One can address many important questions in future heavy-ion collision experiments in the energy range from tens to hundreds of TeV. These include:

(a) What is the equation of state (EoS) for the strongly interacting matter at high temperatures? Do effects of charm quarks start to become significant in the EoS?

(b) What is the thermalization mechanism, and how does the thermalization time depend on the colliding energy?

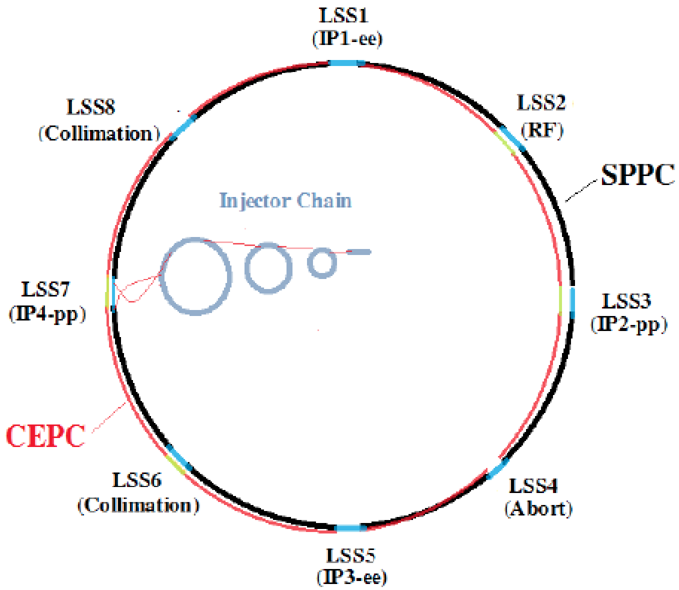
(c) What are the transport properties of strongly interacting matter at the highest temperatures probed by high-energy jets and collective phenomena? Are they approaching the weak coupling values as predicted by perturbative QCD?

(d) What is the nature of the initial state and its fluctuations in nuclear collisions?

(e) Can we find other exotic hadrons or nuclei such as light multi-Λ hyper-nuclei, bound states of $(\Lambda\Lambda)$ or the H di-baryon?

(f) What are the fundamental symmetries of QCD at high temperatures? How does the restoration of the spontaneously broken chiral symmetry manifest itself in the electromagnetic radiation from the medium? Is the axial $U_A(1)$ symmetry effectively restored and what are the possible consequences in the hadron yields?

SppC General design



- 8 arcs (5.9 km) and long straight sections (850m*4+1038.4m*4)

Parameter	Value
Circumference	54.36 km
Beam energy	35.3 TeV
Dipole field	20 T
Injection energy	2.1 TeV
Number of IPs	2 (4)
Peak luminosity per IP	**1.2E+35 $cm^{-2}s^{-1}$**
Beta function at collision	0.75 m
Circulating beam current	1.0 A
Max beam-beam tune shift per IP	0.006
Bunch separation	25 ns
Bunch population	2.0E+11
SR heat load @arc dipole (per aperture)	56.9 W/m

Key R&D Issues

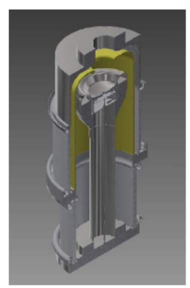
- Accelerator & Detector design
- Site selection, civil design
- Key technology development
  - High Q_0 SRF cavities and high efficiency thermal power removing SRF accelerating unit
  - High efficiency RF power sources(Klystron, solid state, …)
  - High power Cryogenic system
  - Beam monitor and diagnostice
  - Silicon detectors
  - High field SC magnets

RF power source: Efficiency

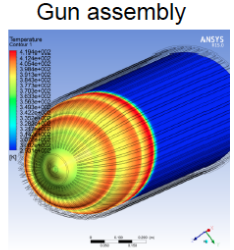
Key parameters of NEW klystron design

Parameters mode	Now	Future
Centre frequency (MHz)	650+/-0.5	650+/-0.5
Output power (kW)	800	800
Beam voltage (kV)	80	70
Beam current (A)	16	15
Efficiency (%)	65	80

- ➢ **Key factors for the cost and the power consumption**
- ➢ **Used by radar, radio and television broadcasting, …**



Gun assembly



Collector design

SRF System: three key issues

- Extremely high Q_0 cavities
  - New technology: N-doping to improve Q_0 by a factor ~ 4
- Efficient thermal power extraction
  - SR power
  - HOM power
- Mass production

- ➢ **Largest SRF system next to ILC**
- ➢ **Technically challenge**
- ➢ **Used by all future acclerators**
- ➢ **Key factors for the cost**