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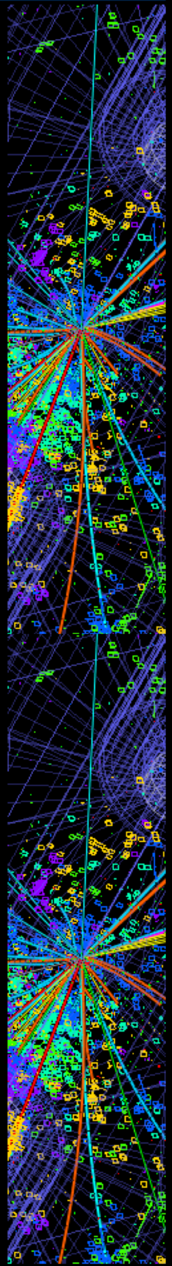

KAIST-KAIX workshop on Future Collider

The International Workshop on the Circular Electron Positron Collider EU EDITION 2019

Oxford, April 15-17, 2019

http://www.physics.ox.ac.uk/confs/CEPC2019/

Scientific Committee:
Franco Bedeschi – INFN, Italy
Marica Biagini – INFN, Italy
Alain Blondel – University of Geneva, Switzerland
Daniela Bortoletto – University of Oxford, UK
Joao Guimaraes da Costa – IHEP, China
Jie Gao – IHEP, China
Hong-Jian He – SJTU, China
Eric Kajfasz – CPPM, France
Eugene Levichev – BINP, Russia
Shu Li – TDLI and SJTU, China
Jianbei Liu – USTC, China
Nadia Pastrone – INFN, Italy
Jianming Qian – University of Michigan, USA
Manqi Ruan – IHEP, China
Felix Sefkow – DESY, Germany
Chris Tully – Princeton University, USA
Liantao Wang – University of Chicago, USA
Meng Wang – Shandong University, China
Marcel Vos – IFIC (UV/CSIC) Valencia, Spain

Local Organizing Committee:
D. Bortoletto – University of Oxford
P. Burrows – University of Oxford
B. Foster – University of Oxford
Y. Gao – University of Liverpool
B. Murray – University of Warwick/RAL
I. Shipsey – University of Oxford
G. Viehhauser – University of Oxford

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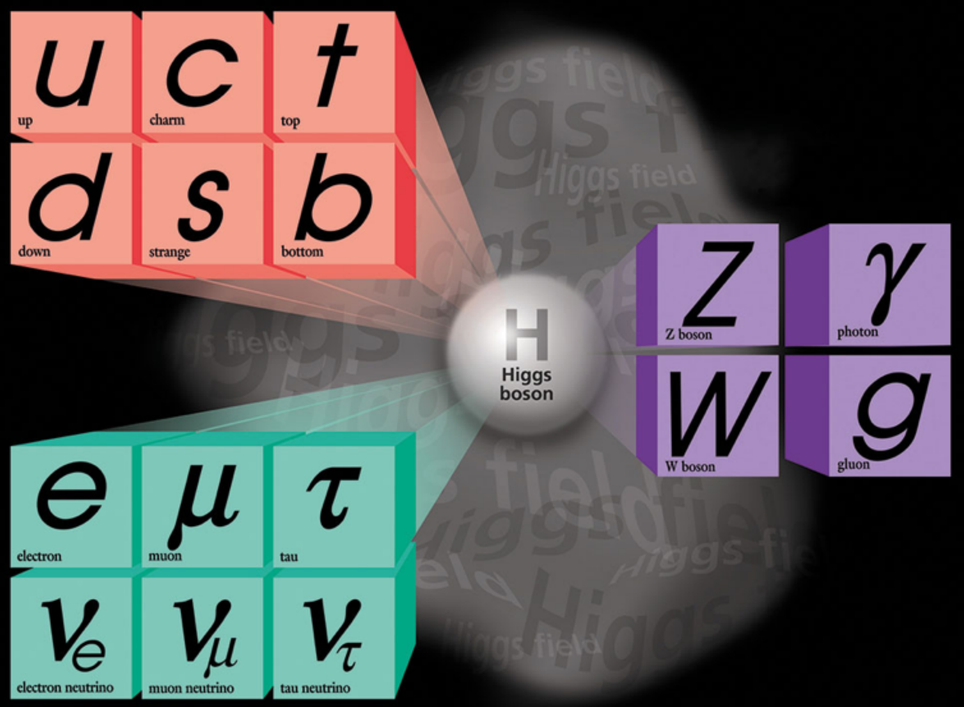
Daniela Bortoletto, University of Oxford

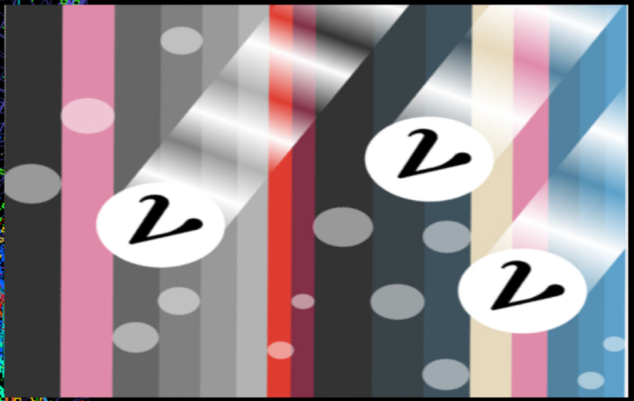
The completion of the Standard Model



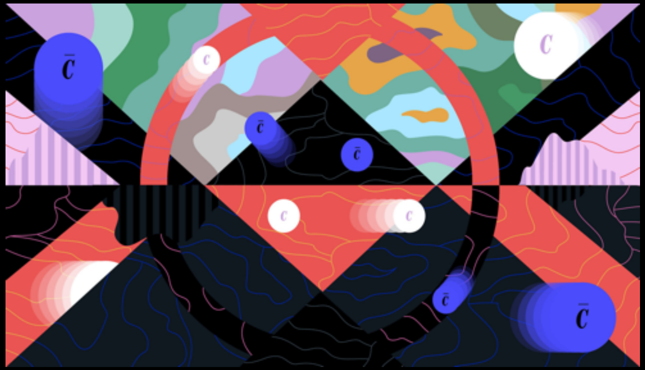
July 4th 2012

The discovery of the Higgs boson does not close the book but opens a whole new chapter of exploration in Particle Physics

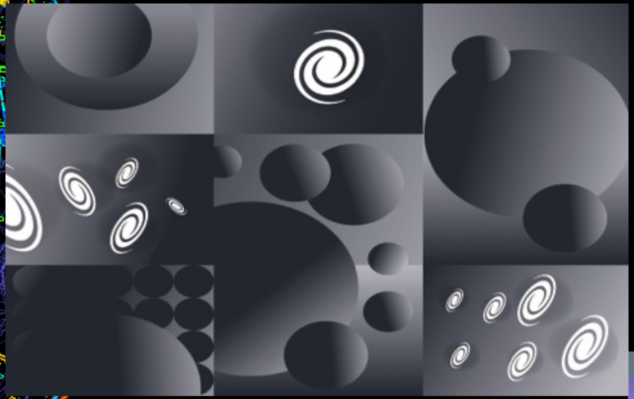
Many Open Questions Remain



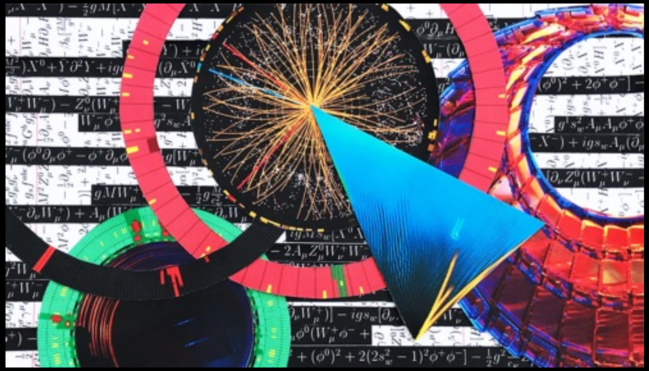
Pursue the physics associated with neutrino mass



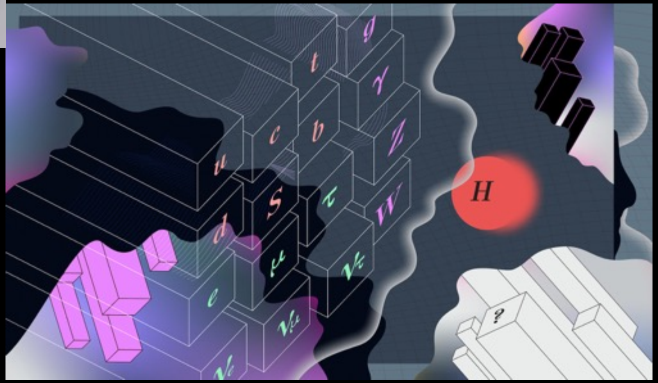
Understand the matter antimatter asymmetry of the Universe



Identify the new physics of dark matter



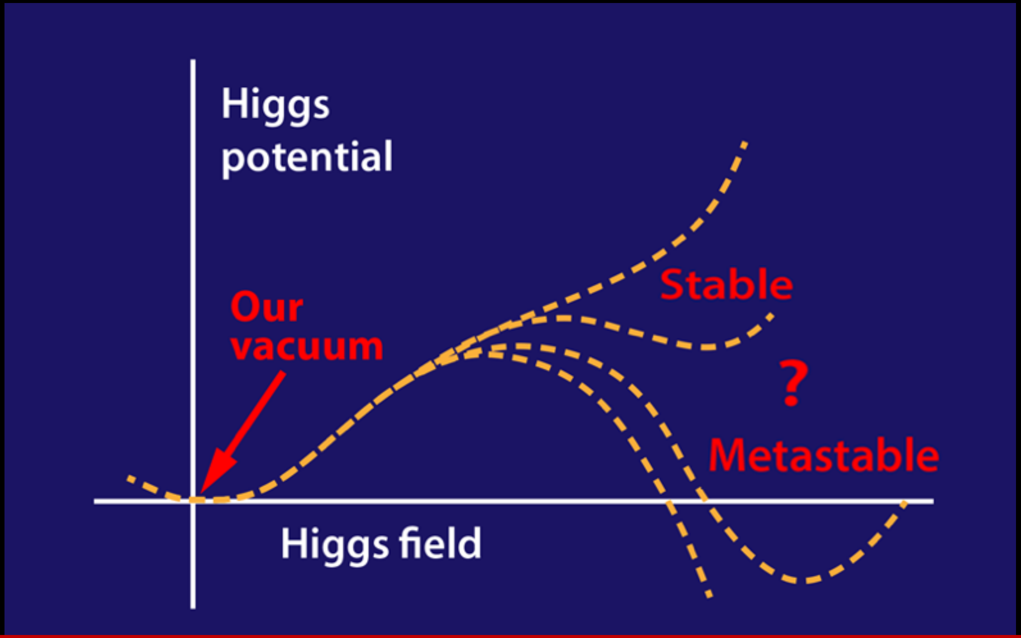
Explore the unknown: new particles, interactions, and physical principles



Use the Higgs boson as a new tool for discovery

The answers require different experiments

- The surprising neutrinos:
  - Mass hierarchy
  - CP violation
  - Majorana or Dirac nature
  - Neutrino masses could originate anywhere between the EW and the GUT scale
- DM could be anything:
  - O(TeV) WIMPs
  - multi-$M_{\odot}$ primordial BHs
  - Fuzzy 10^{-22} eV scalars
  - Axion

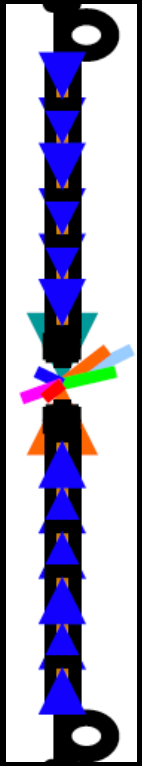


- Is M_H natural or fine tuned ? The Higgs dynamics is sensitive to scale larger than the Higgs mass
- Is Higgs is a composite object or elementary?
- Is there a TeV-scale solution to the hierarchy problem?
- Is it alone or are there other Higgs boson
- What is the origin of the coupling to fermions?
- Does the Higgs couple to DM and neutrinos ?

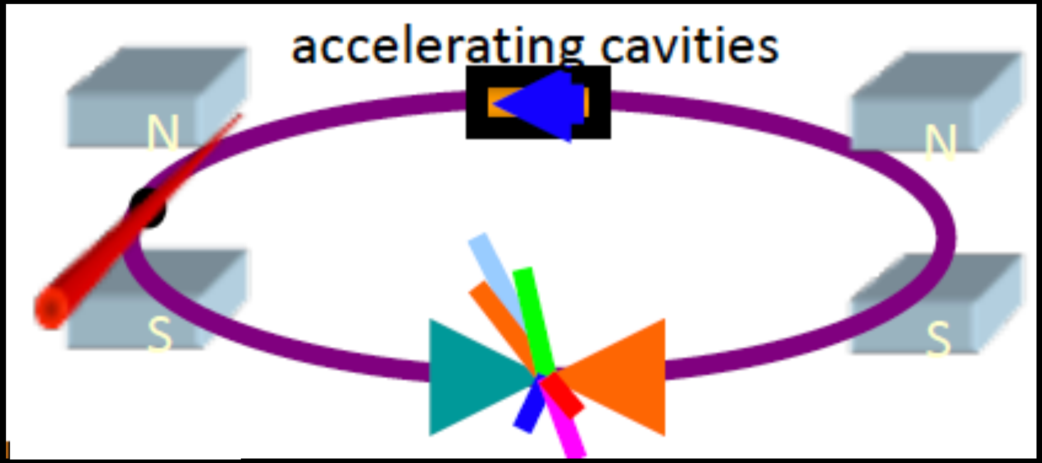
IMPACT of 125 GeV on Energy Frontier

- The low mass of the Higgs boson makes e^+e^- Higgs factories both linear and circular possible

- Linear accelerator can reach high energies ~ multi-TeV with high luminosity
  - Can avoid synchrotron radiation
  - High accelerating field to achieve high energy
  - High beam current and quality to achieve the luminosity

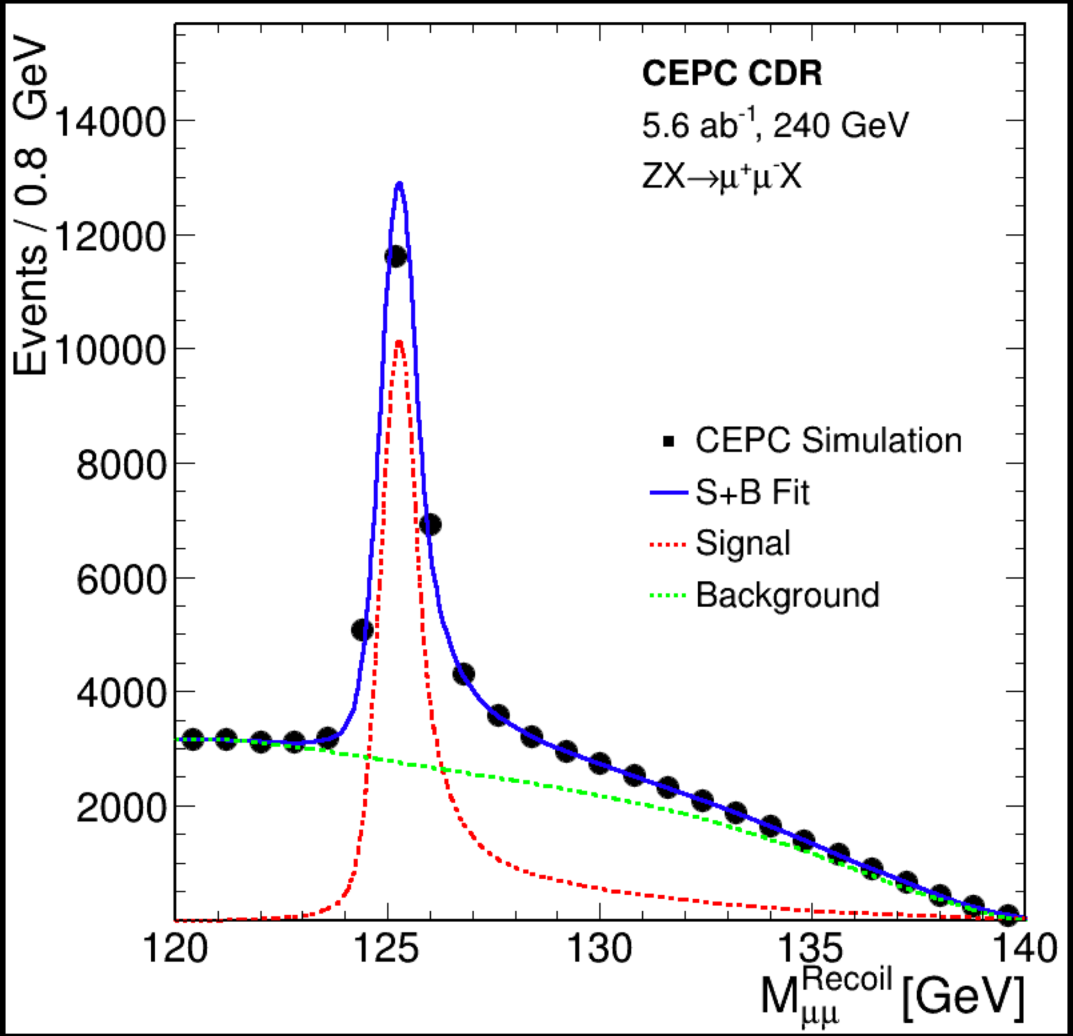


- Circular accelerator can reach high luminosity at lower energies
  - Can store and re-collide the beams
  - Experience
  - Synchrotron radiation limits the energy and beam quality

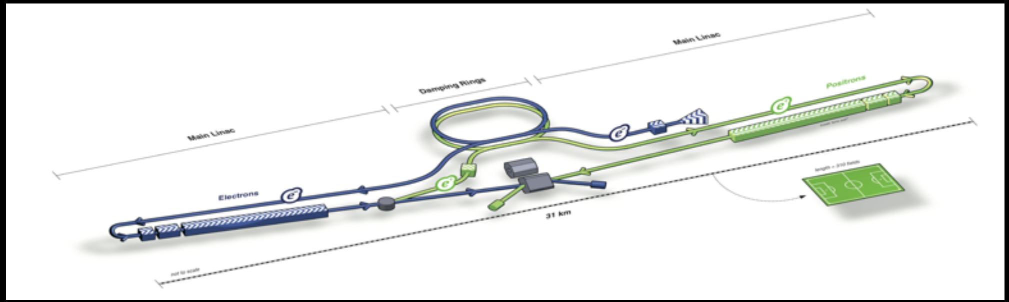


Advantages of e^+e^-

- Higgs events are readily isolated from background
- All standard Higgs decay modes are visible
- Measurement accuracies O(1%) are feasible
- The absolute cross section for $e^+e^- \to ZH$ can be measured and therefore there is no model dependence in BR measurements
- At 250 GeV any Z boson with E_{lab}=110 GeV is recoiling against a H boson



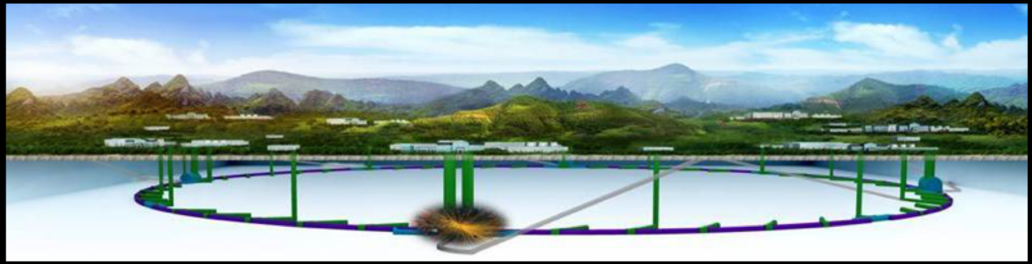
The e^+e^- options



ILC 250: 2032

CLIC 350: 2035

FCC-ee: 2039

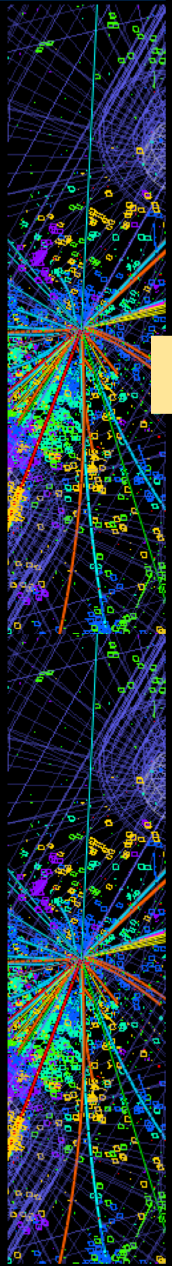


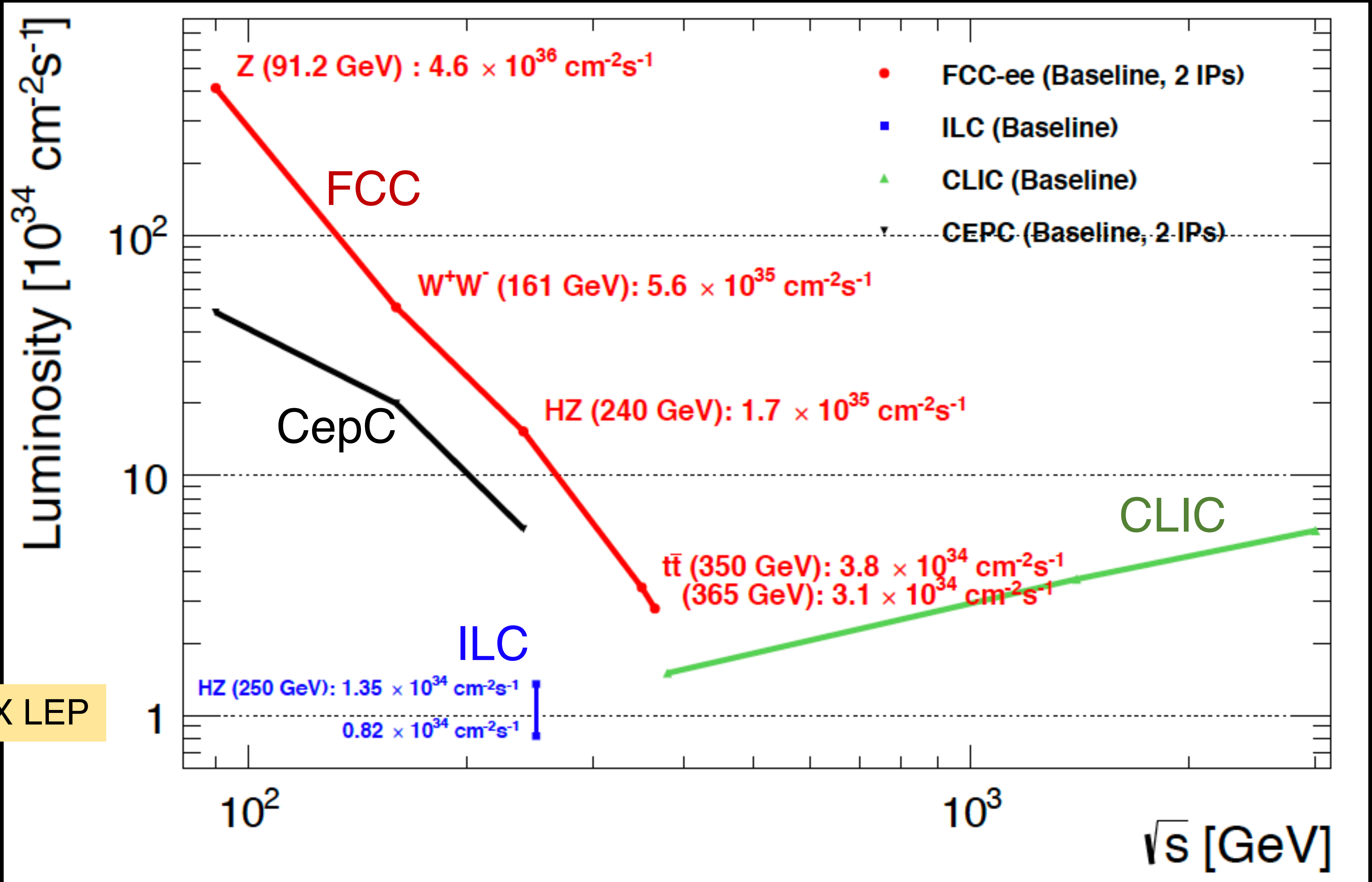
CEPC: 2030

Luminosity Comparison

10,000X LEP

100X LEP





e^+e^- collider potential

FCC

Z pole

Observable	Measurement	Current precision	FCC-ee stat.	FCC-ee syst.	Dominant exp. error
m_Z (keV)	Z Lineshape	91187500 ± 2100	5	< 100	Beam energy
Γ_Z (MeV)	Z Lineshape	2495200 ± 2300	8	< 100	Beam energy
R_l ($\times10^3$)	Z Peak ($\Gamma_{had}/\Gamma_{lep}$)	20767 ± 25	0.06	0.2 – 1	Detector acceptance
R_b ($\times10^6$)	Z Peak (Γ_{bb}/Γ_{had})	216290 ± 660	0.3	< 60	$g \rightarrow bb$
N_ν ($\times10^3$)	Z Peak (σ_{had})	2984 ± 8	0.005	1	Lumi measurement
$\sin^2\theta_W^{eff}$ ($\times10^6$)	$A_{FB}^{\mu\mu}$ (peak)	231480 ± 160	3	2 – 5	Beam energy
$1/\alpha_{QED}(m_Z)$ ($\times10^3$)	$A_{FB}^{\mu\mu}$ (off-peak)	128952 ± 14	4	< 1	Beam energy
$\alpha_s(m_Z)$ ($\times10^4$)	R_l	1196 ± 30	0.1	0.4 – 1.6	Same as R_l

- Higgs factory
- Z pole, WW: one-two orders of magnitude statistical precision than LEP, dominated by systematics
- tt: one order of magnitude better than LHC (mass, width, Yukawa)
- With m_{top}, m_H and m_W known, the standard model will be extremely constrained
- Theoretical calculations need to be brought to higher orders
- Discovery potential for very weakly coupled particles: dark photons, RH neutrinos

FCC CRD

International collaboration publishes concept design for a post-LHC future circular collider at CERN

Date Issued
January 15th, 2019

Source
CERN

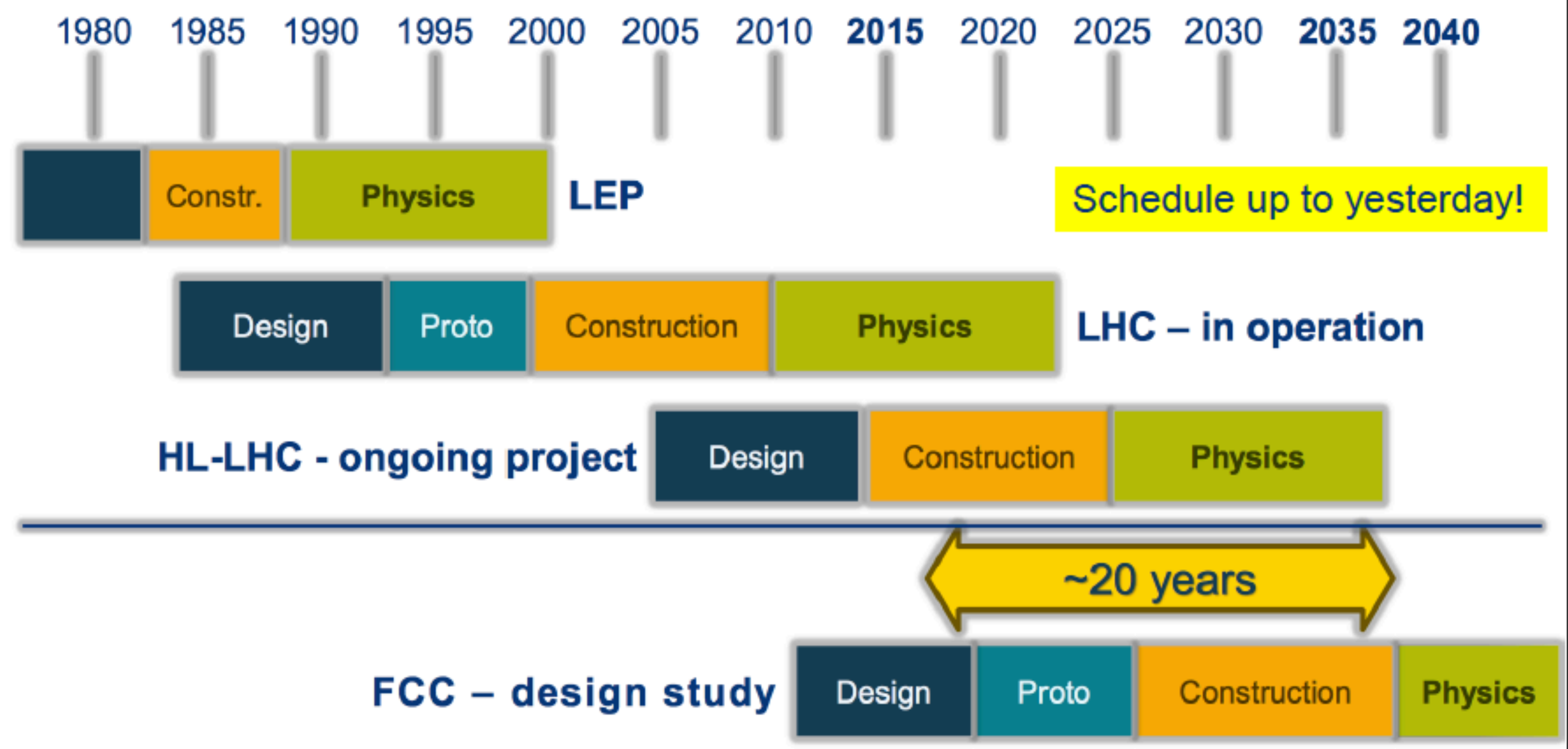
The proposed layout of the future circular collider (Image: CERN)

Geneva, 15 January 2019. Today, the Future Circular Collider (FCC) collaboration submitted its Conceptual Design Report (CDR) for publication, a four-volume document that presents the different options for a large circular collider of the future. It showcases the great physics opportunities offered by machines of unprecedented energy and intensity and describes the technical challenges, cost and schedule for realisation.

15/01/2019 (press release)
The FCC Conceptual Design Reports have been released with an updated time schedule and approx. cost estimate

Tunnel:	5000 MCHF
e^+e^- machine in tunnel:	4000 MCHF
hh machine in tunnel:	15000 MCHF
Possible e^+e^- starting date	~ 2040
Possible hh starting date	~ late 2050's

FCC-ee Schedule



CEPC CDR

IHEP-CEPC-DR-2018-01

IHEP-AC-2018-01

CEPC

Conceptual Design Report

Volume I - Accelerator

The CEPC Study Group

August 2018

IHEP-CEPC-DR-2018-02

IHEP-EP-2018-01

IHEP-TH-2018-01

CEPC

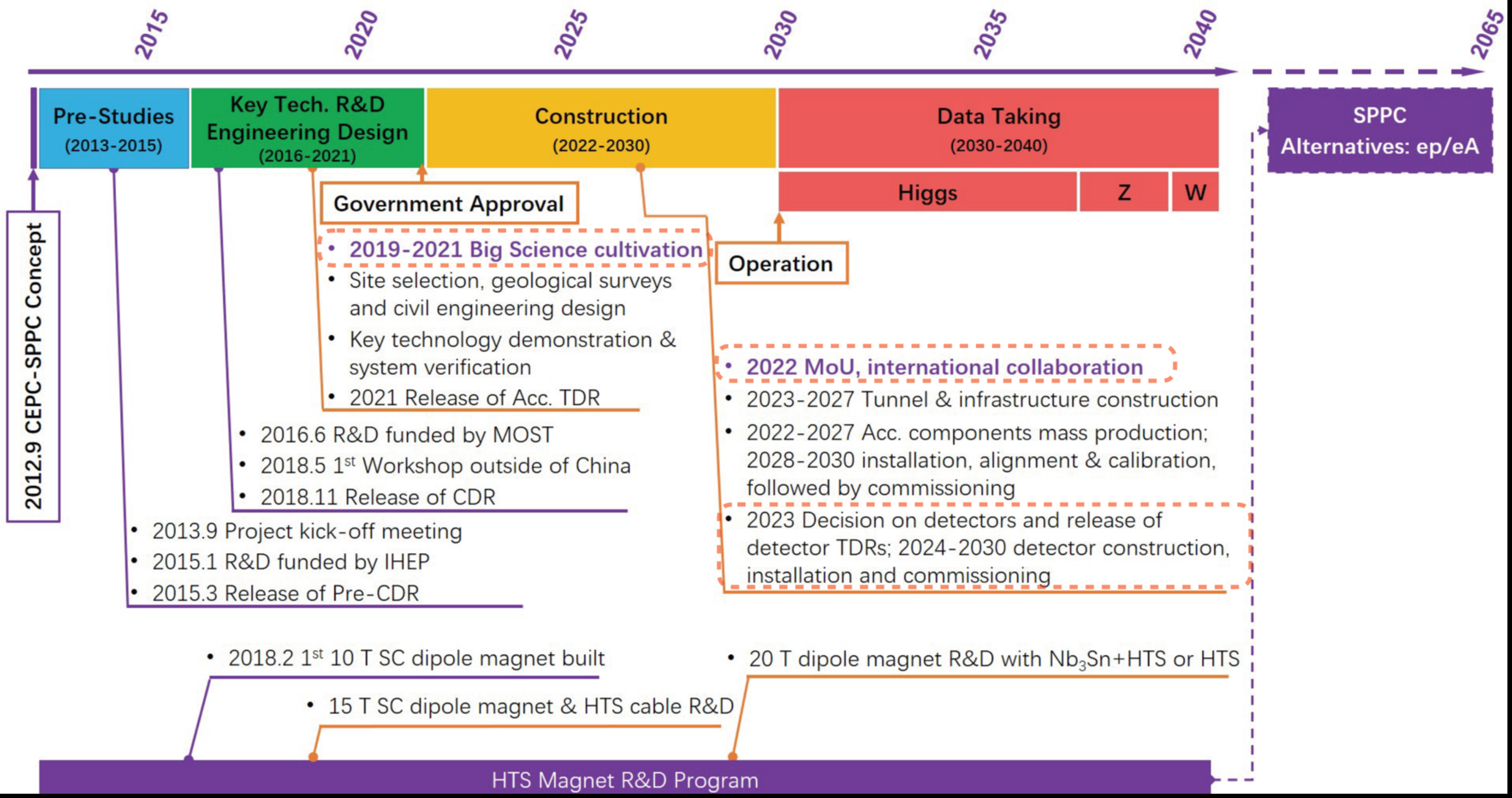
Conceptual Design Report

Volume II - Physics & Detector

The CEPC Study Group

October 2018

CEPC Project Timeline



Goal of the Oxford Meeting

- We are in the excellence position of having different regions of the world interested in fundamental physics and considering that the outstanding questions in particle physics are worth building the next generation particle collider.
- The LHC has shown us that while competition can be energizing, global cooperation is often critical to realize at least one machine.
- Let us find the optimal level of coopetition

Bringing the communities together

Workshop agenda & goals

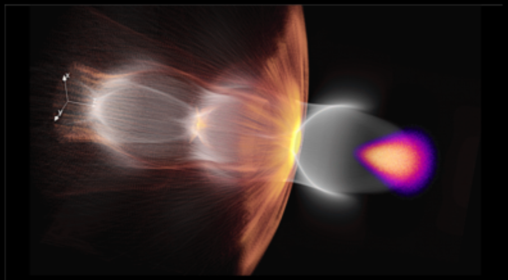
- Day 1: Status of all e^+e^- options for the post-LHC era & Physics
- Day 1 & 2: Parallel session on Physics, Detector R&D, Accelerator R&D, Tools & Performance
  - Looking at the plans for the CEPC TDR
  - Examining the potential for joint developments between FCC and CEPC (including joint EW TH efforts)
  - Understanding synergies with solutions designed for ILC/CLIC
  - Bringing together communities interested in similar physics and detector technologies
- Day 3:
  - Summaries of the Parallel sessions
  - Panel with representatives from many regions to discuss the path to the realization of at least one of these projects
  - Final motivational talk

CEPC Machine Development

- Conventional linac

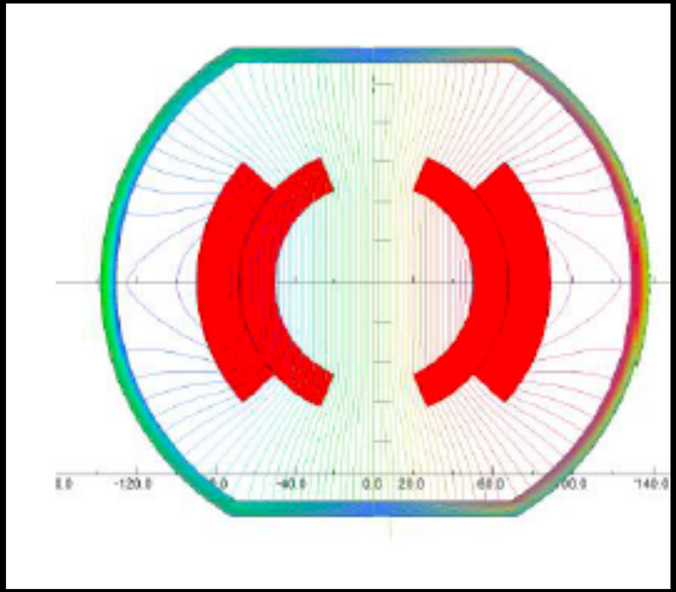
High power test bench @ IHEP

- R&D PWFA Linac replacement



CEPC Booster Magnets

The CEPC booster accelerates the electron and positron beam from 10 GeV to 120 GeV or 175 GeV. 16320 dipole magnets with min. field of 29 Gs, and max. field is 492 Gs.

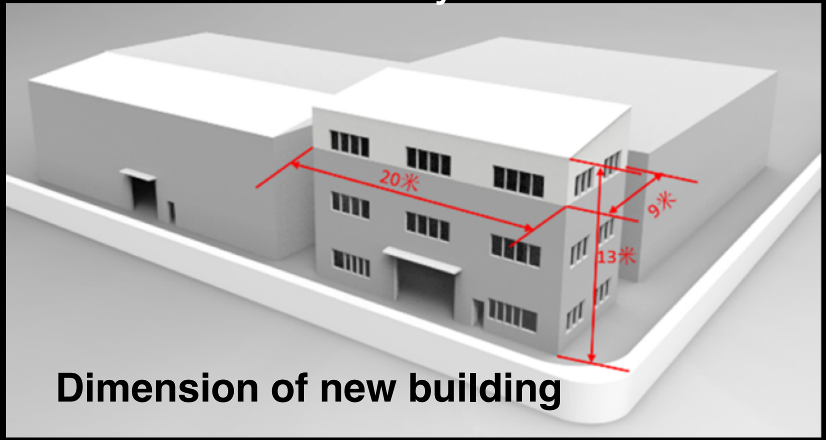


RF system

After N-doping of two 650 MHz single cell cavities (BCP treated),
Very close to achieving the goal of $Q_0 > 4E10$ @ 20 MV/m.

Klystron R&D

650MHz/800kW meets CEPC project demands 80% efficiency



Dimension of new building

1st prototype tube

Mechanical design and manufacture

Plant and infrastructure preparation

Dec. 29, 2018

Jan. 10, 2019

Jan. 28, 2019

Mar. 3, 2019

Mar. 27, 2019

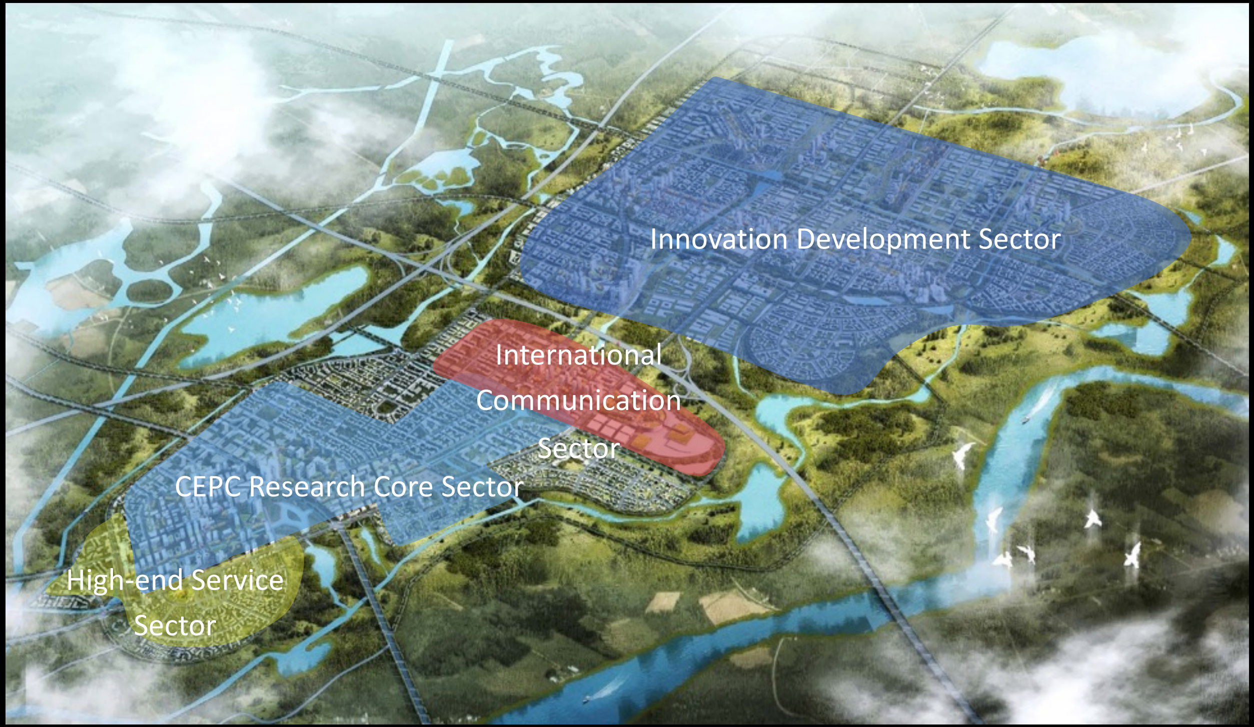
Apr. 12, 2019

High efficiency design 2nd prototype optimization Multi-beam klystron consideration

CEPC Civil Engineering & Site Selection

International Science City

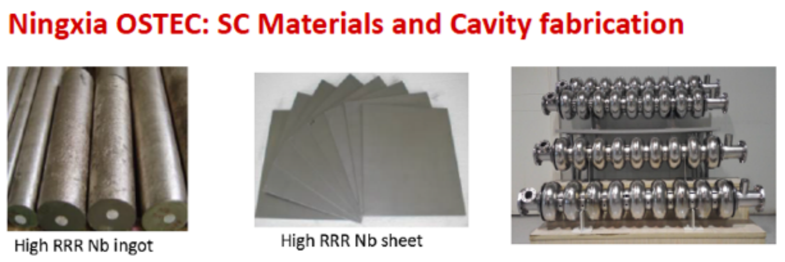
Overall Scale : 3.3 km² of construction area for short-term use & 6.7 km² for future use.



CEPC Industrial Promotion Consortium

- Superconducting materials (for cavity and for magnets)
- Superconducting cavities
- Cryomodules
- Cryogenics
- Klystrons
- Vacuum technologies
- Electronics
- SRF
- Power sources
- Civil engineering
- Precise machinery.....
- But also new vendors to fabricate SiPMs, LGAD detectors

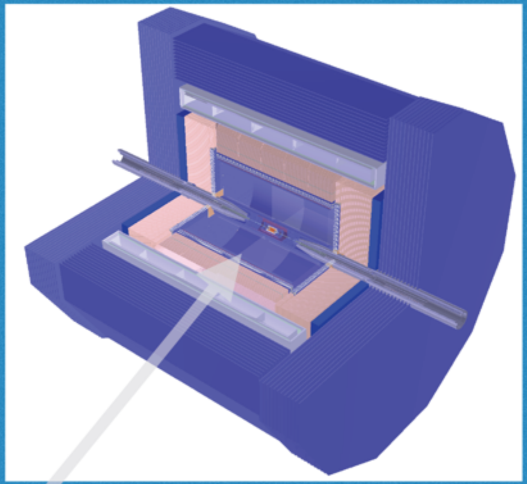
More than 50 companies have joined the CIPC

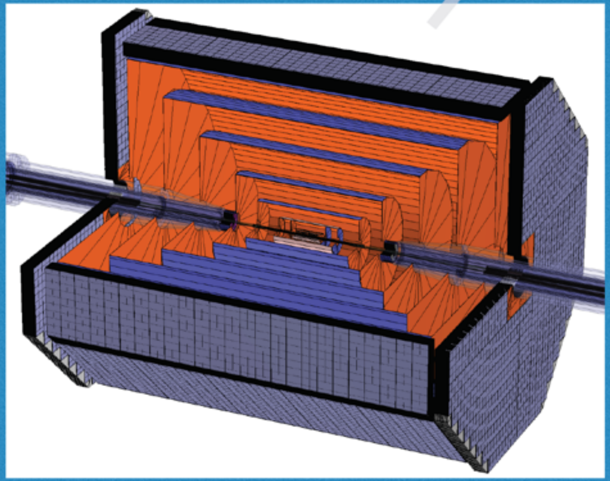


Detector Concepts for the CEPC

Particle Flow Approach

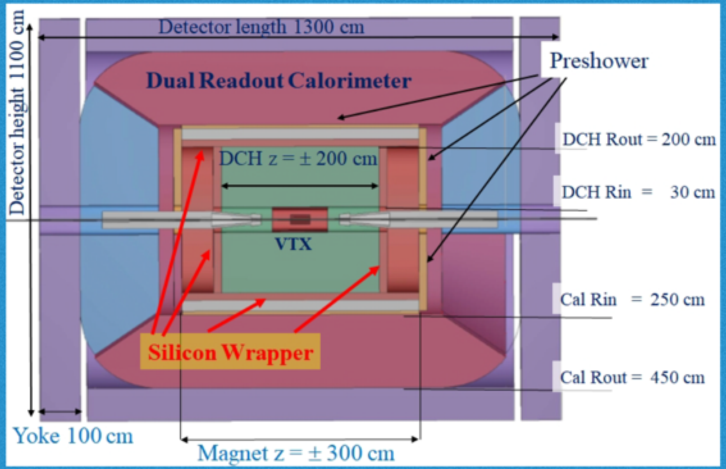
Baseline detector ILD-like (3 Tesla)





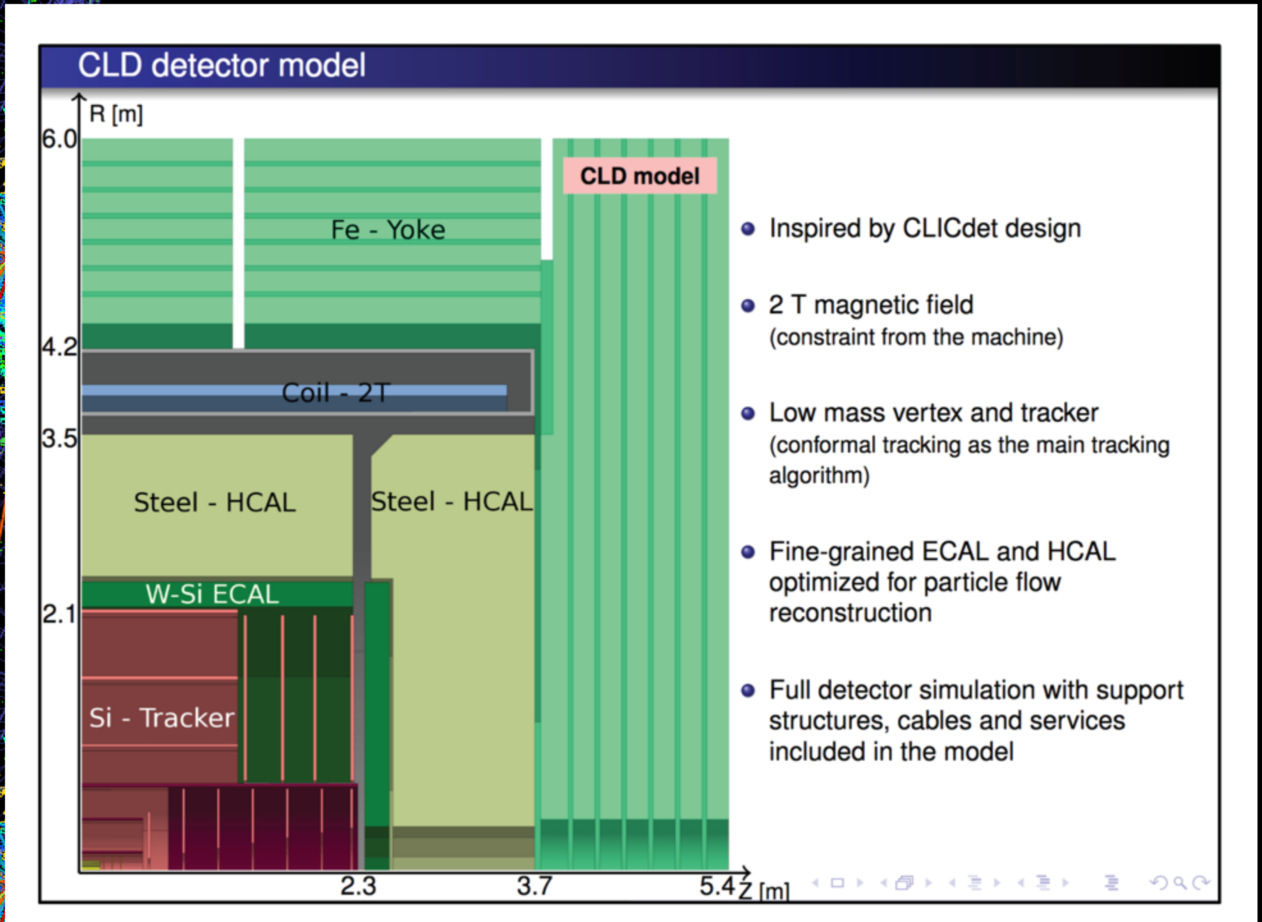
Full silicon tracker concept

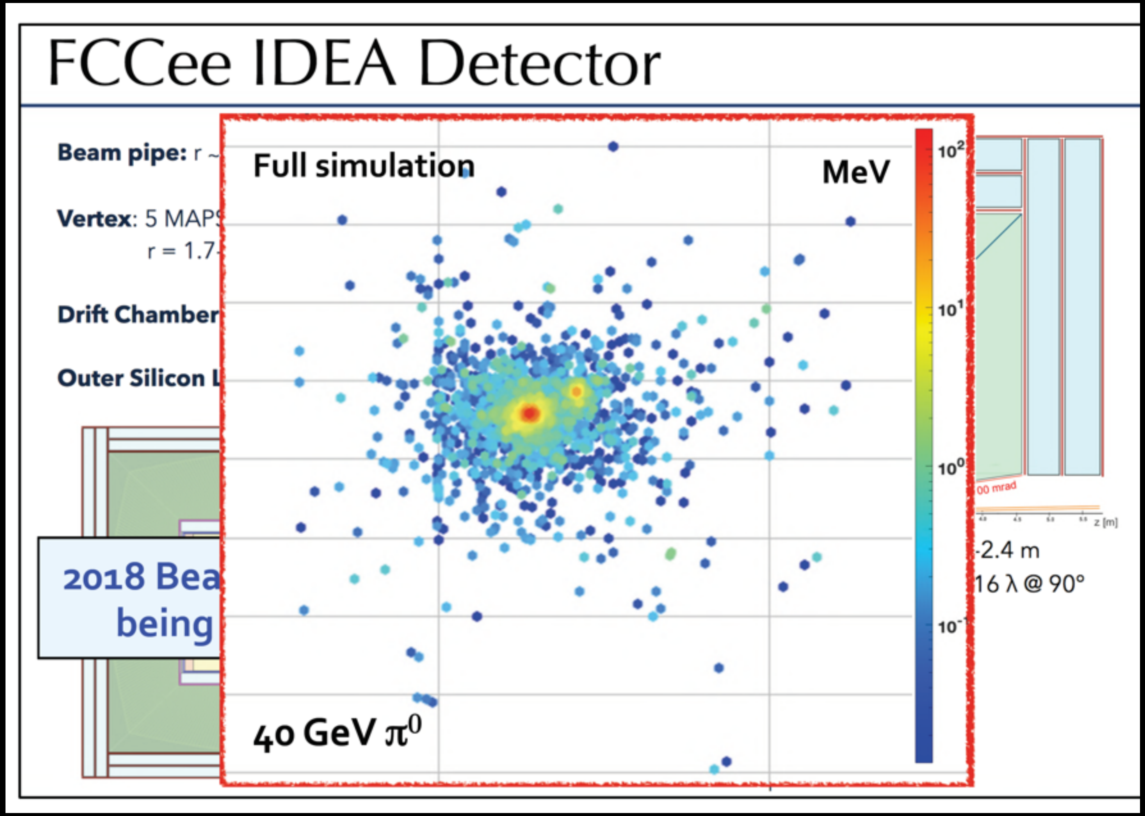
Low magnetic field concept (2 Tesla)



IDEA Concept
also proposed for FCC-ee

Detector concepts for the FCCee

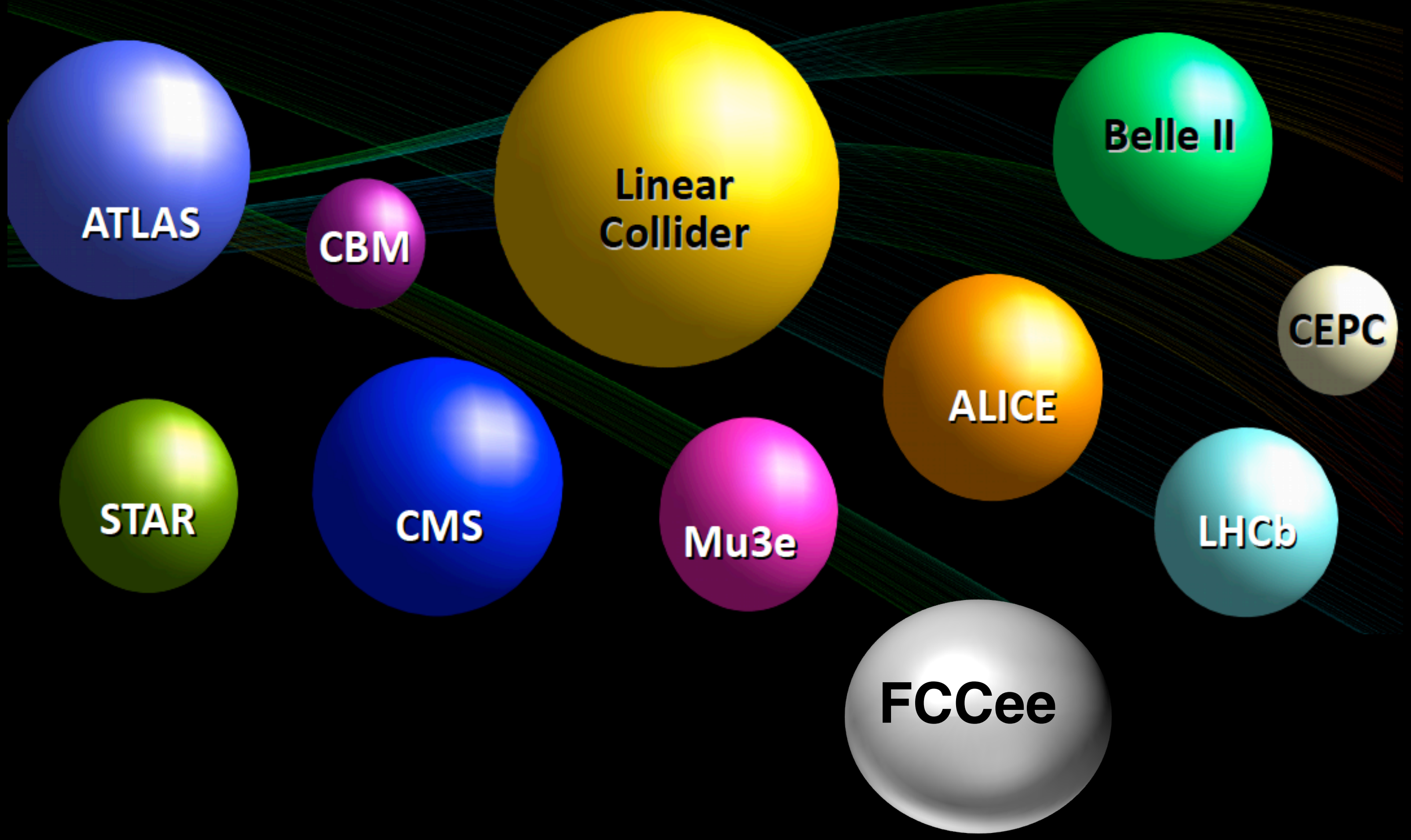




R&D for the CepC and the FCC-ee

- Benefits from a decade of Linear Collider R&D
- But also from:
  - ATLAS
  - ALICE
  - BELLE II
  - Mu3e
  - ……

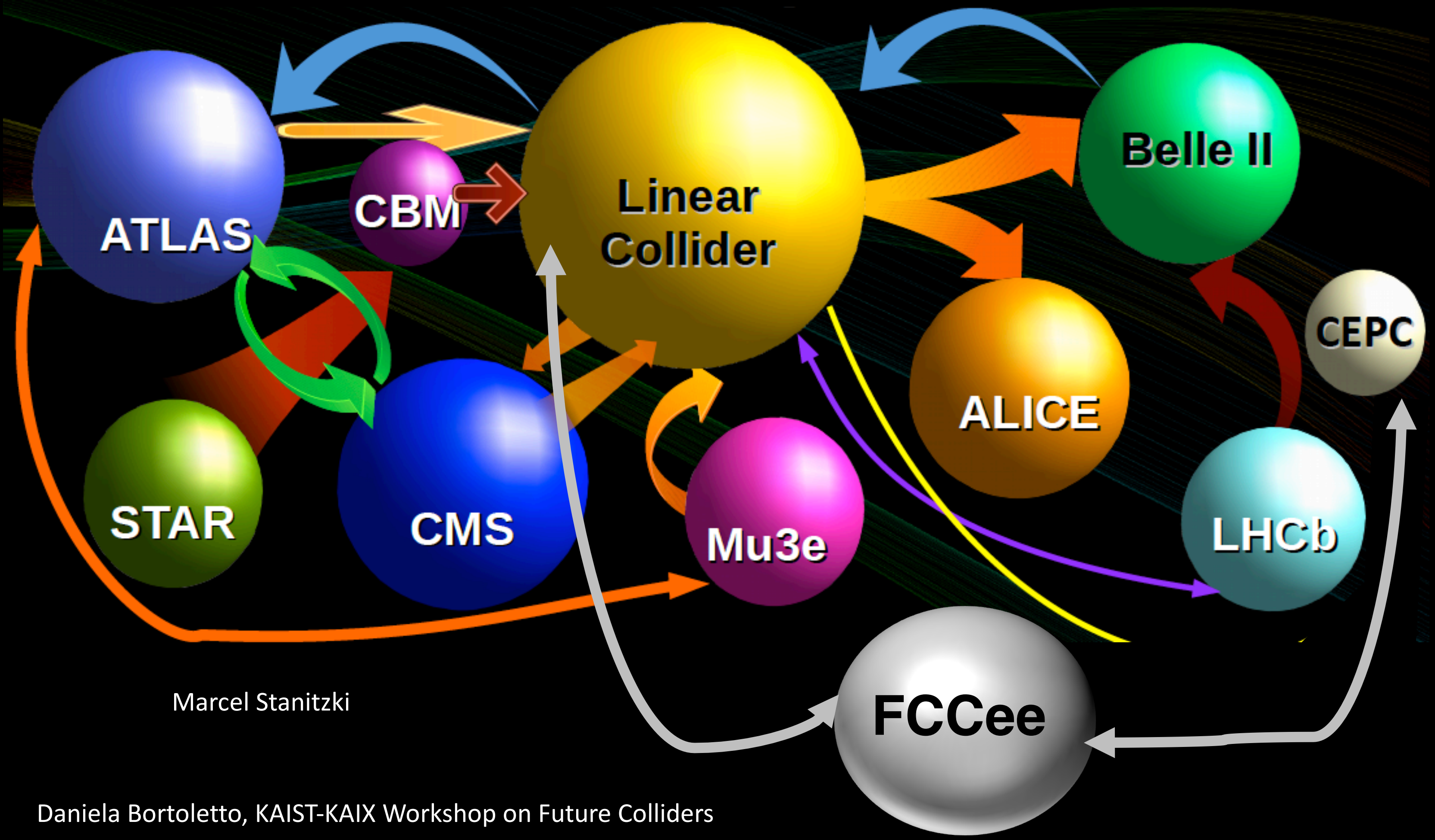
How we perceive R&D



R&D for the CepC and the FCC-ee

- Benefits from a decade of Linear Collider R&D
- But also from:
  - –ATLAS
  - –ALICE
  - –BELLE II
  - –Mu3e
  - –…..

In reality there are many interconnections



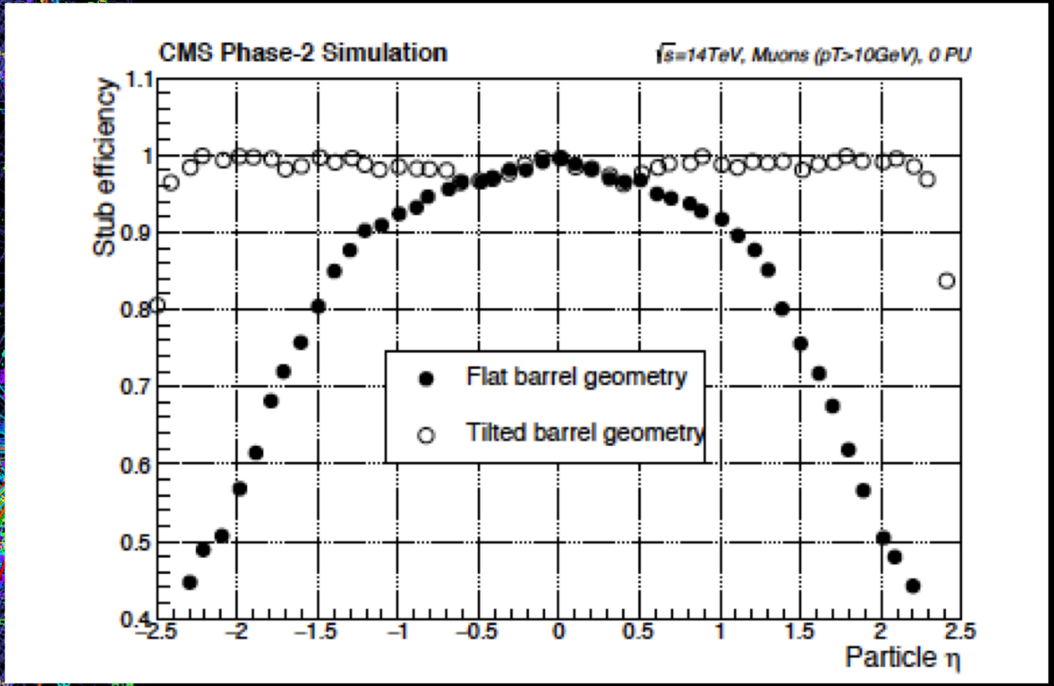
Marcel Stanitzki

Detector Development

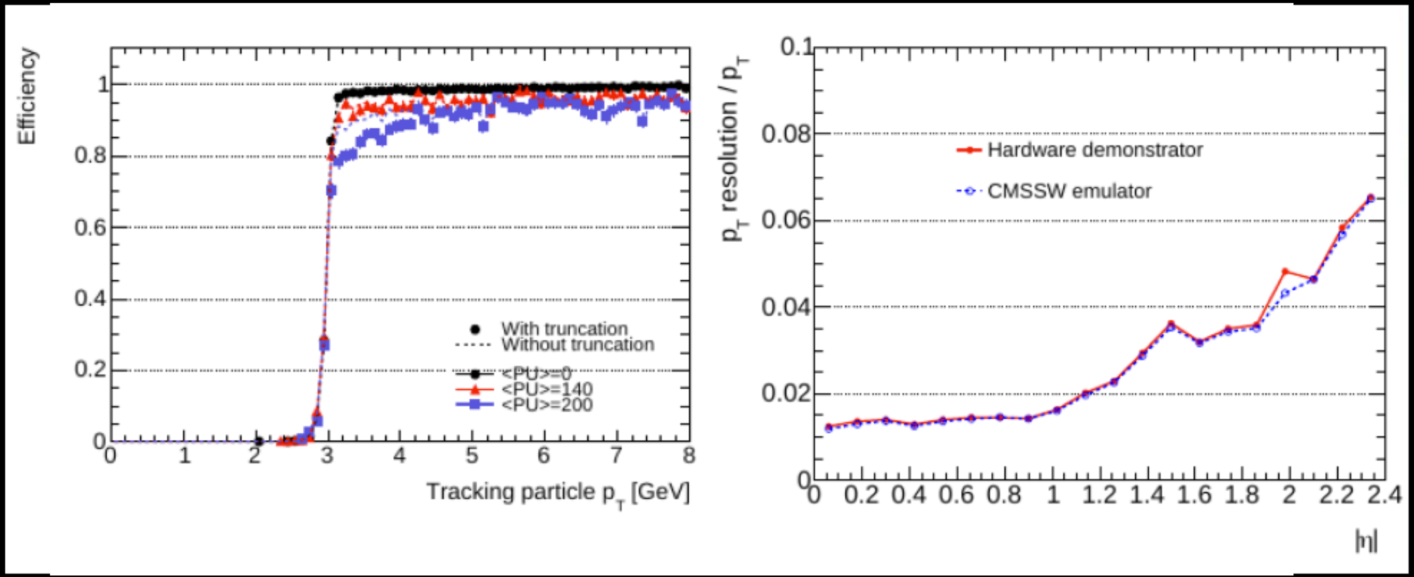
- Included many several talks from CMS and ATLAS tracker upgrades

Novel mechanics concepts

Tilted mechanics brings a large reduction in: number of modules, mass and large cost saving



Intelligent tracking

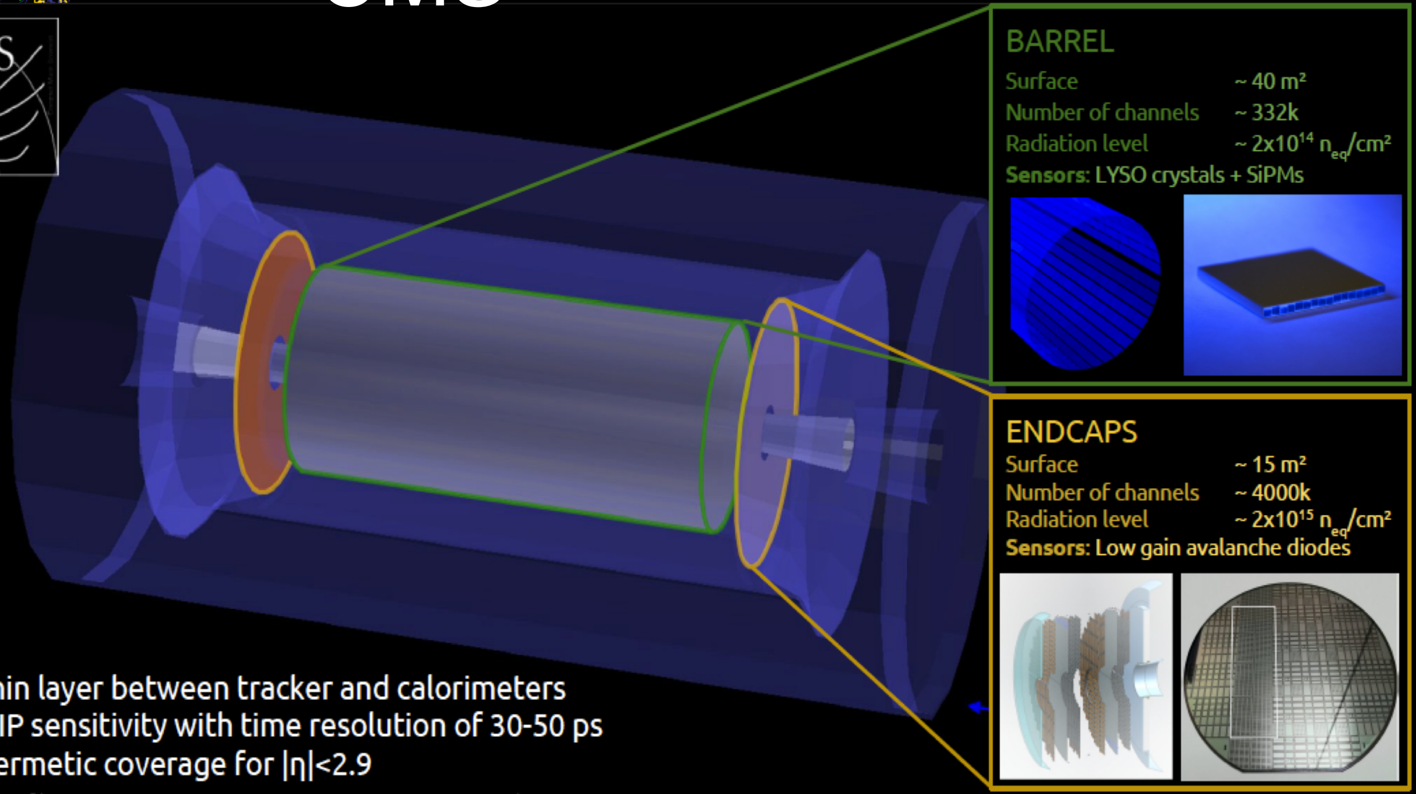


- Provide on-module data reduction for L1 tracking
- Effective way to collect two coordinate on a track
- Share electronics, support and cooling
- Lighter and cost-effective
- Potential for offline tracking (by reducing fake rate)
- Provides extra handles for detector calibration

New paradigm: tracking and vertexing in 4D

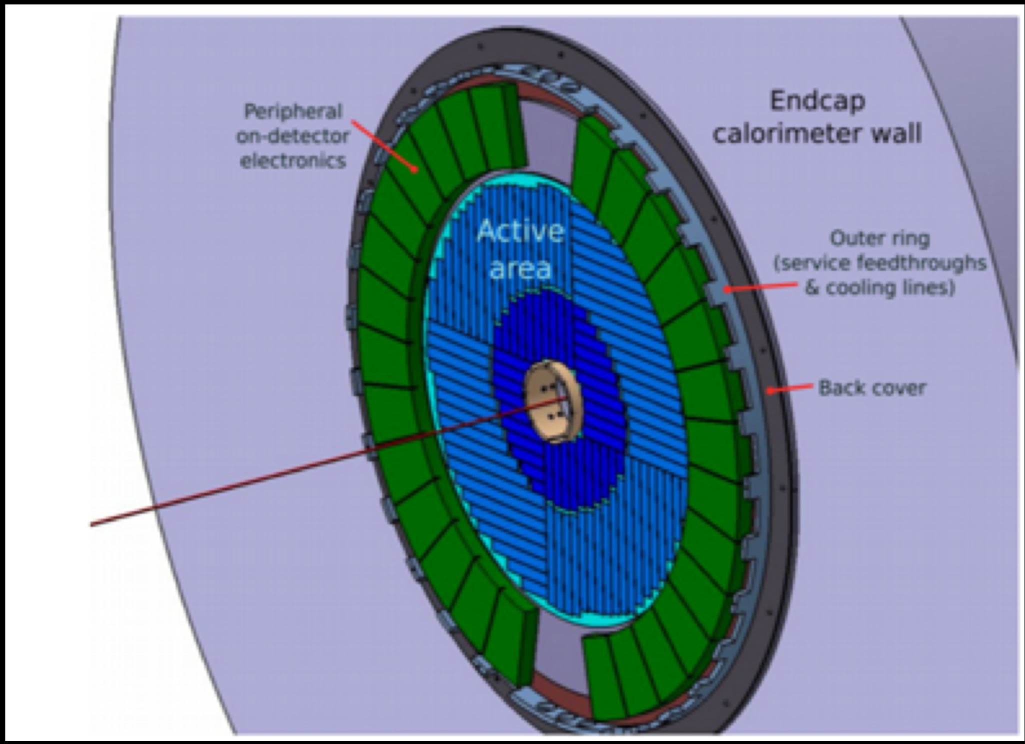
With detectors achieving ≈ 30 ps timing

CMS



- Thin layer between tracker and calorimeters
- MIP sensitivity with time resolution of 30-50 ps
- Hermetic coverage for |η|<2.9

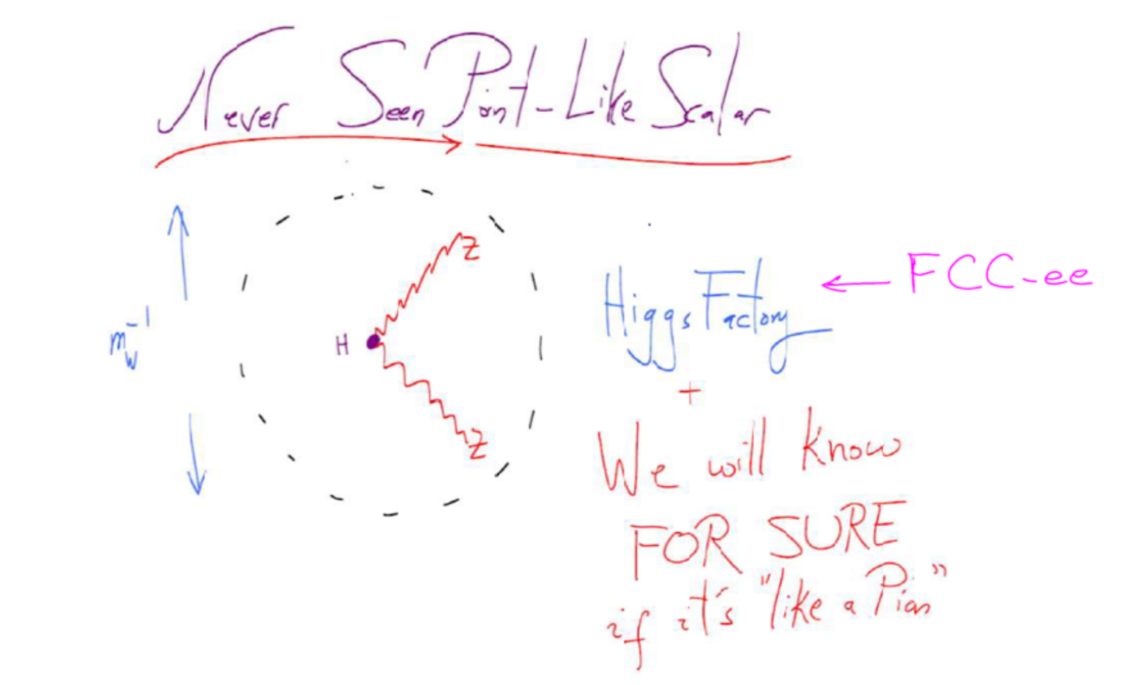
ATLAS

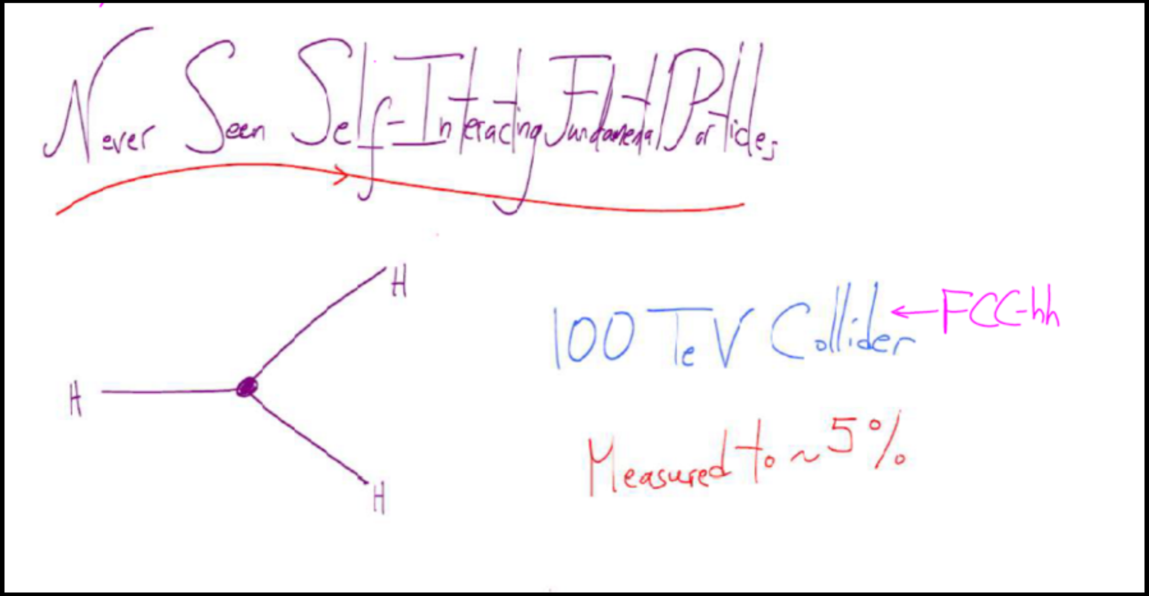


Physics

Higgs is Really New Physics!

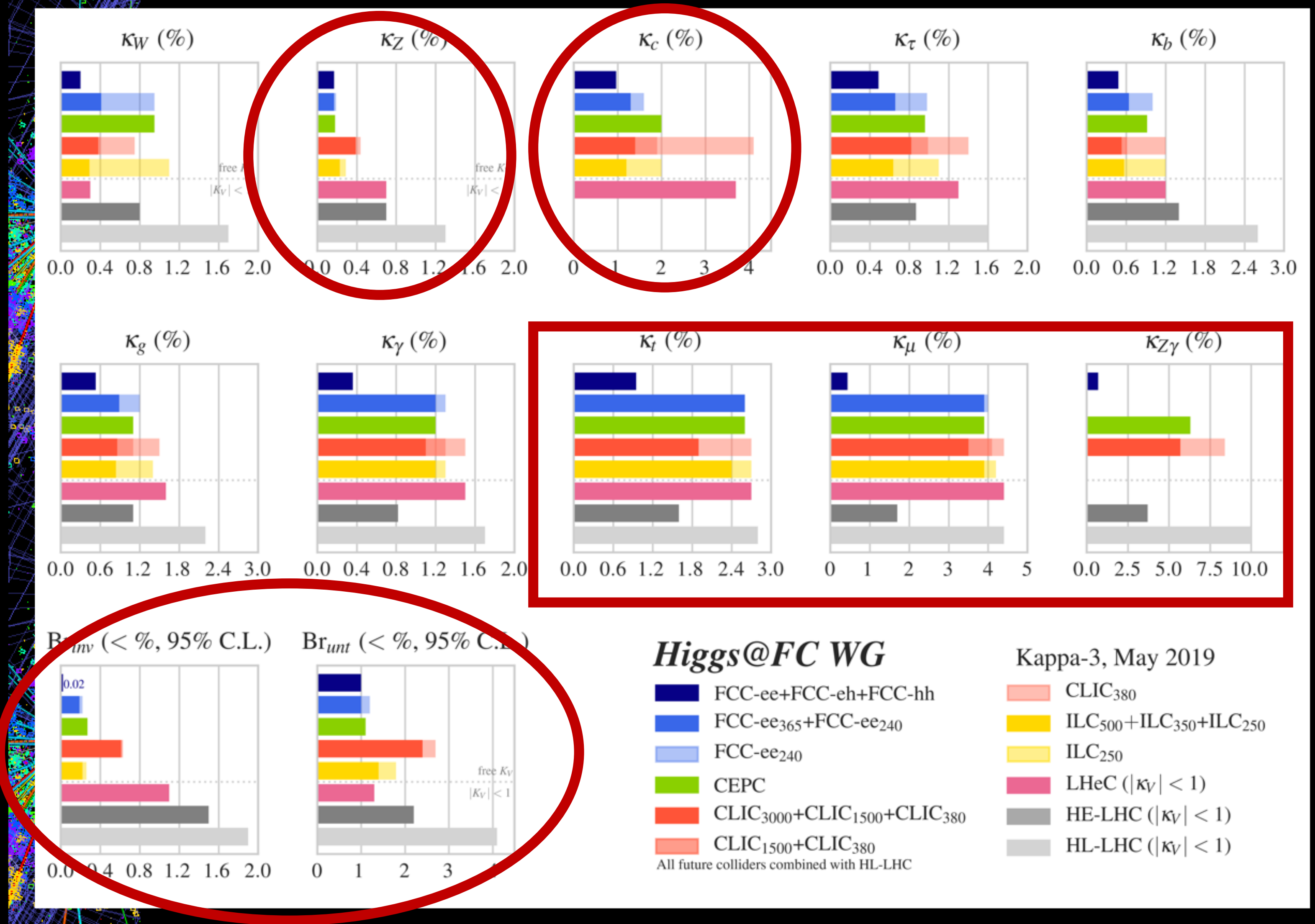
* We've never seen anything like it
* Harbinger of Profound New Principles at work in quantum vacuum
* MUST LOOK AT IT CLOSELY!





Nima Arkani Hamed

Higgs Physics – Kappa Framework



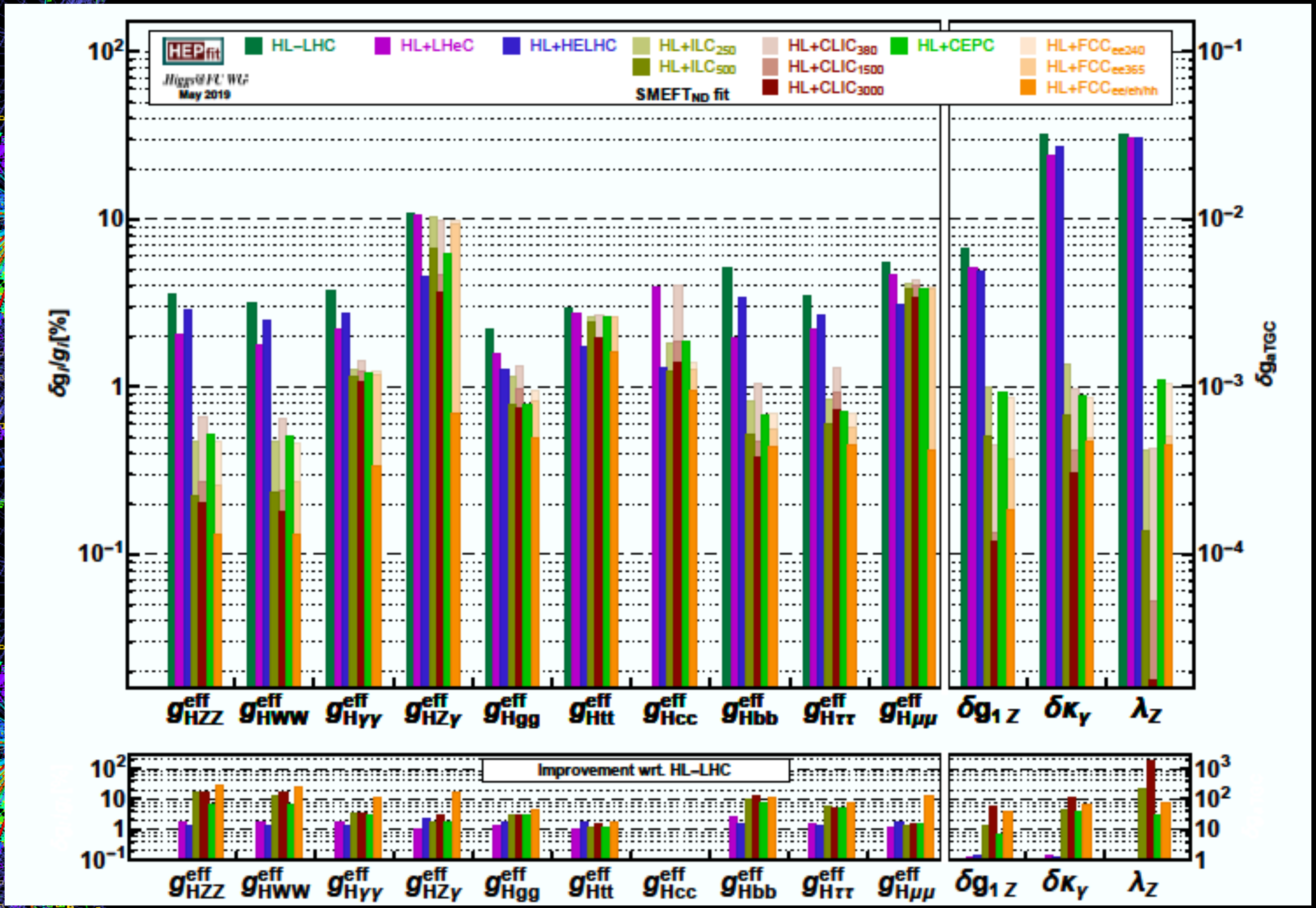
$$(\sigma \cdot BR)(i \to H \to f) = \frac{\sigma_i \cdot \Gamma_f}{\Gamma_H}$$

$$(\sigma \cdot BR)(i \to H \to f) = \frac{\sigma_i^{SM} \kappa_i^2 \cdot \Gamma_f^{SM} \kappa_f^2}{\Gamma_H^{SM} \kappa_H^2}$$

$$\kappa_H^2 \equiv \sum_j \frac{\kappa_j^2 \Gamma_j^{SM}}{\Gamma_H^{SM}}$$

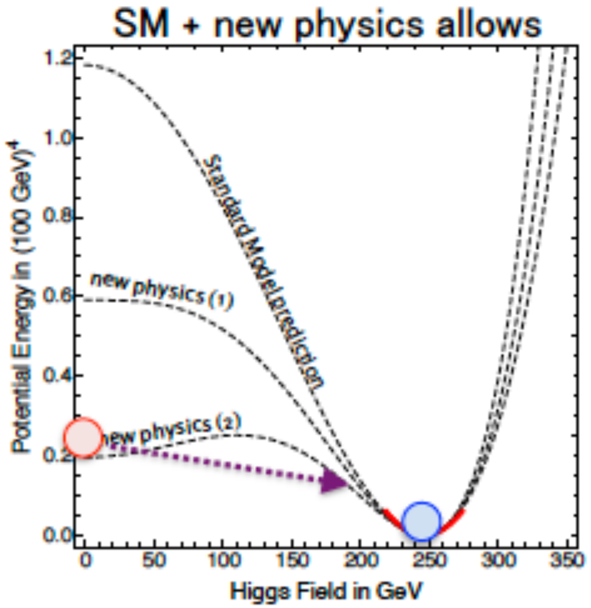
$$\Gamma_H = \frac{\Gamma_H^{SM} \cdot \kappa_H^2}{1 - (BR_{inv} + BR_{unt})}$$

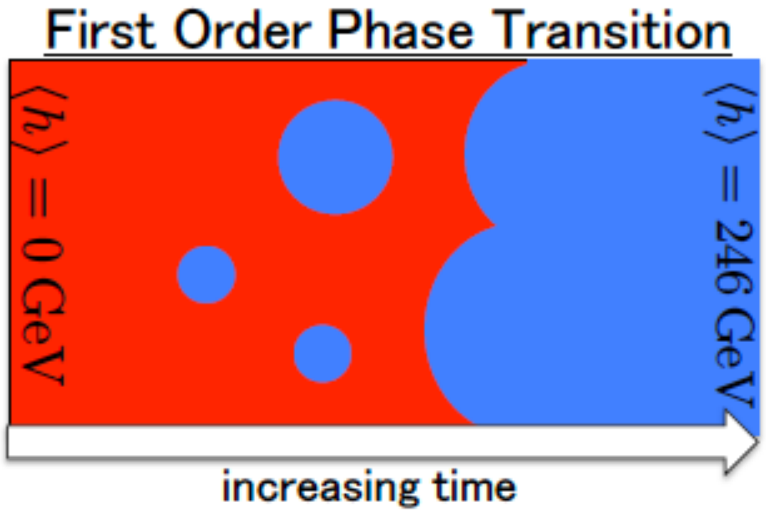
Higgs Physics: EFT framework



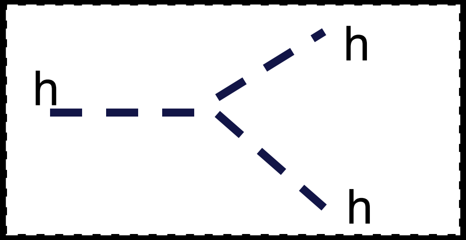
- Effective Higgs couplings
  - Constraints approach 0.1% precision for gauge bosons
  - Major improvement w.r.t. HL-LHC for many colliders for fermions
- Trilinear gauge couplings
  - Will achieve precision 10^{-3}-10^{-4}
  - About 2-3 orders of magnitude better than LEP

Higgs Field Phase Transition

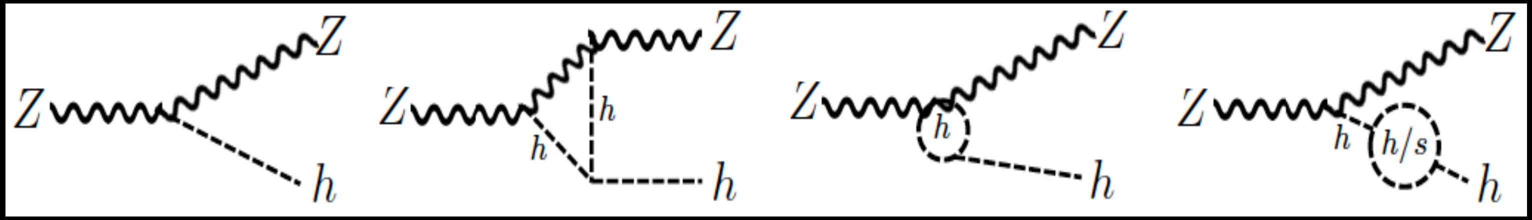




Higgs self coupling

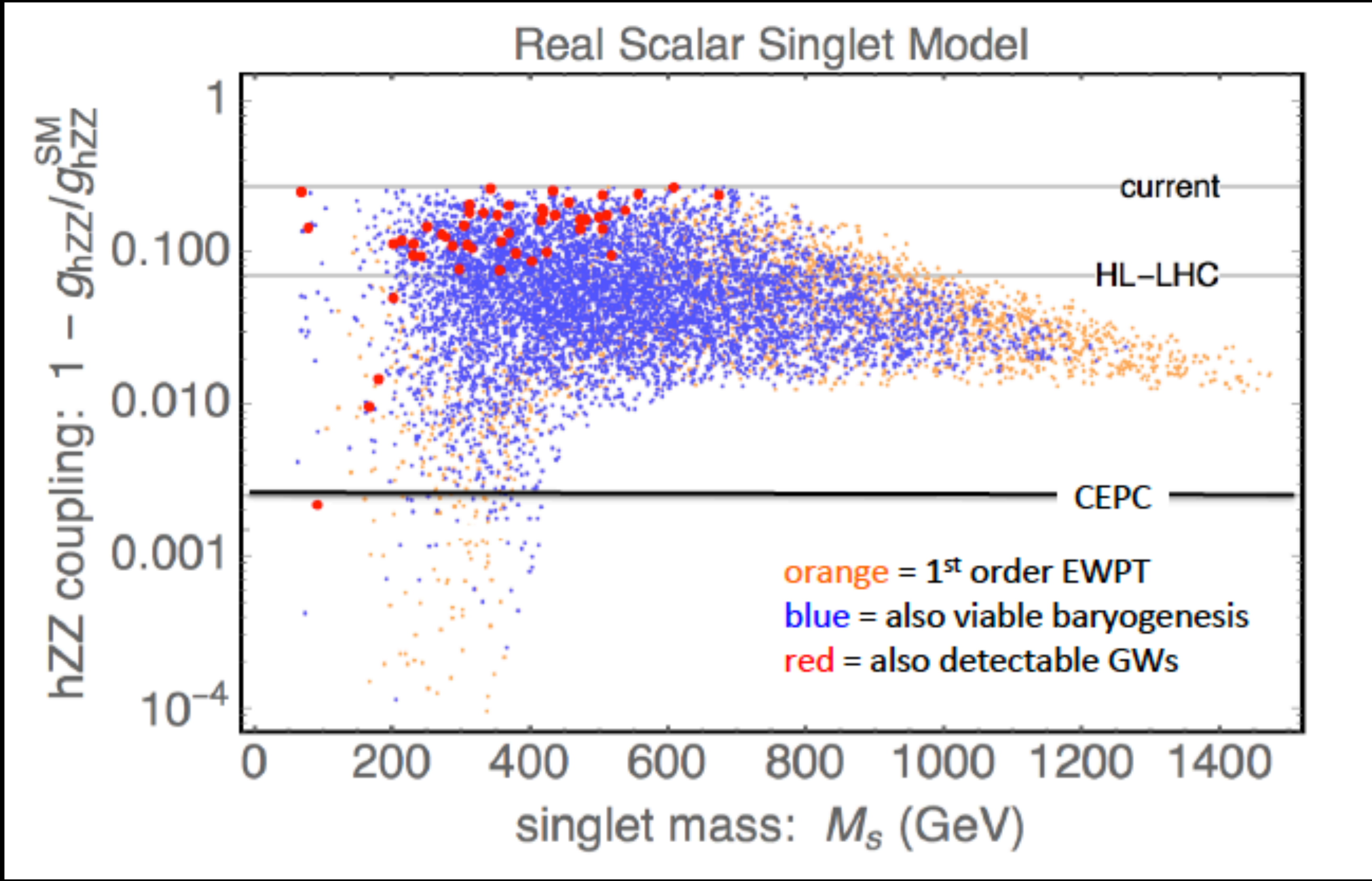


Higgs coupling to the Z boson



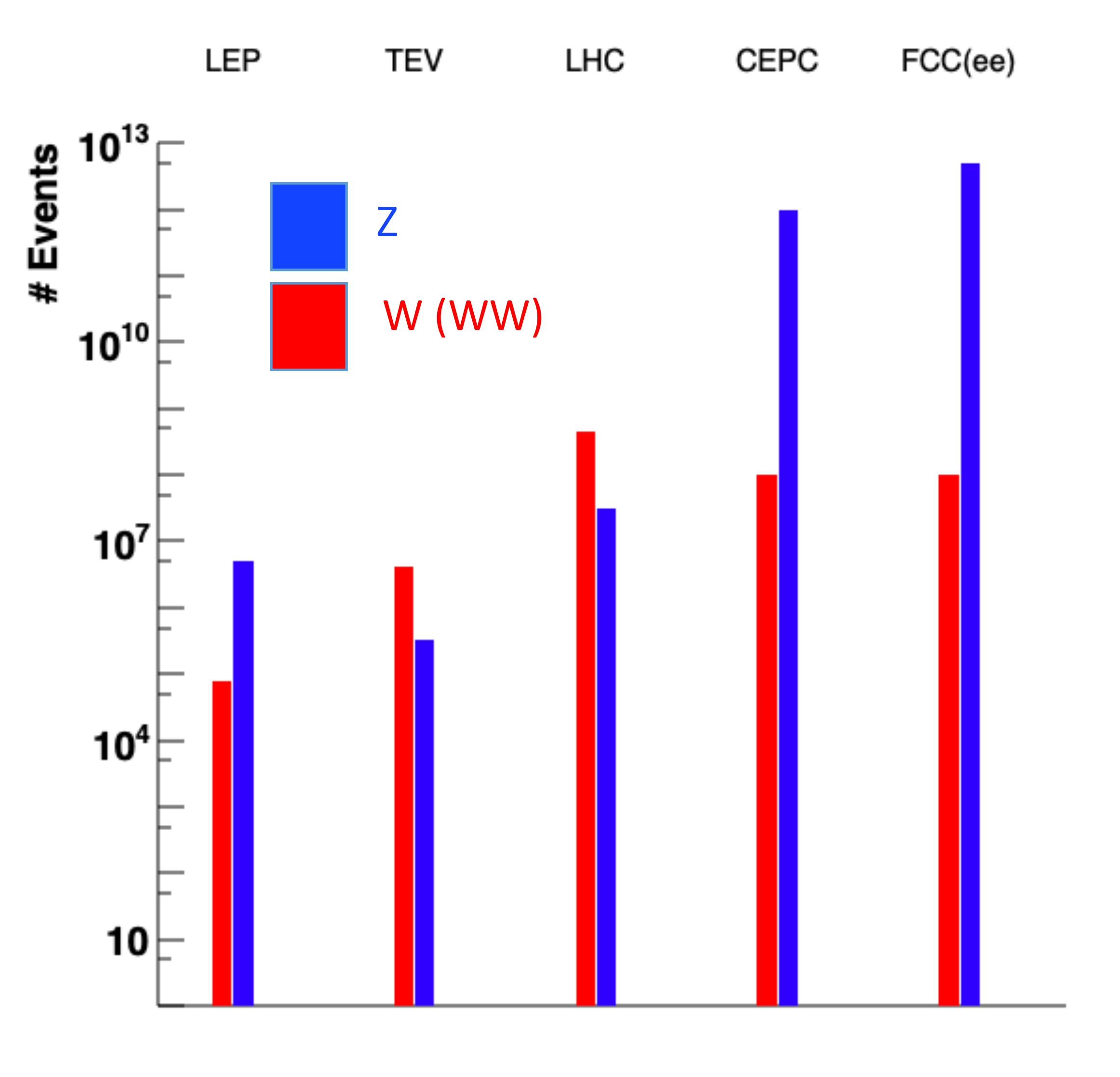
- Lepton colliders provide precision measurements of Higgs-ZZ coupling at the sub-percent level (0.25% at CEPC and 0.15% at FCCee)

Higgs Field Phase Transition



[Huang, AL, & Wang (2016)]

Electroweak Physics

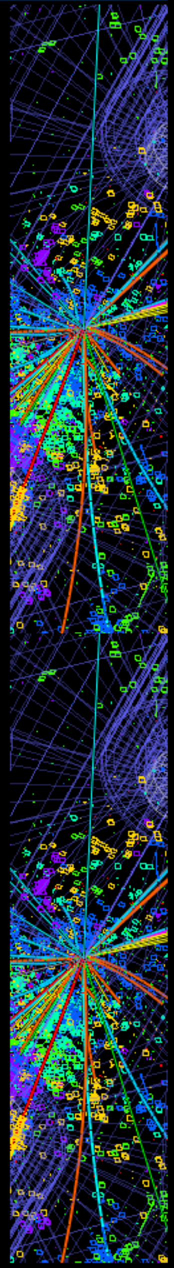


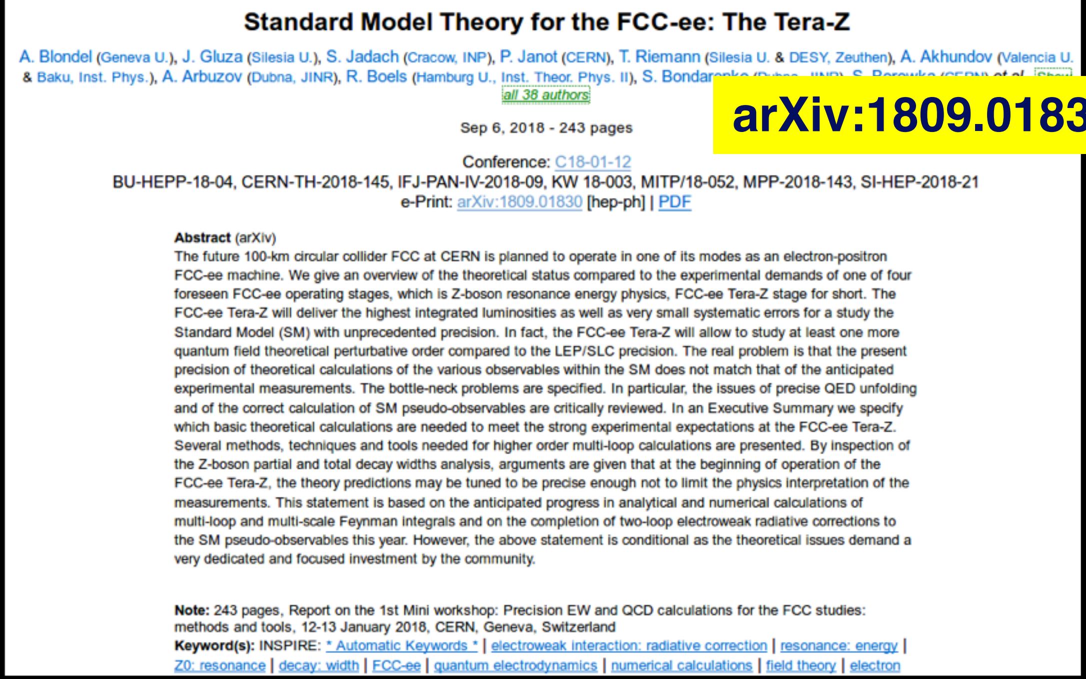
High-precision (better than 100 keV) absolute determination of the centre-of mass energies at the Z pole and WW threshold with transverse polarization and resonant depolarization

EWPO	Current	CEPC	FCC (ee)
M_Z [MeV]	2.1	0.5	0.1
Γ_Z [MeV]	2.1	0.5	0.1
N_ν [%]	1.7	0.05	0.03
M_W [MeV]	12	1	0.67
$A_{FB}^{0,b}$ [x10^4]	16	1	< 1
$\sin^2\theta_W^{\rm eff}$ [x10^5]	16	1	0.6
R_b^0 [x10^5]	66	4	2–6
R_μ^0 [x10^5]	2500	200	100

The Challenge to Theorists

- Series of FCC-ee workshops on "Methods and Tools" has started
- It has gathered a rapidly growing community of theorists thrilled by the challenge
  - –38 contributors in January 2018
  - –83 contributors in January 2019
- Report in Oxford by Janusz Gluza





Standard Model Theory for the FCC-ee: The Tera-Z

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all 38 authors

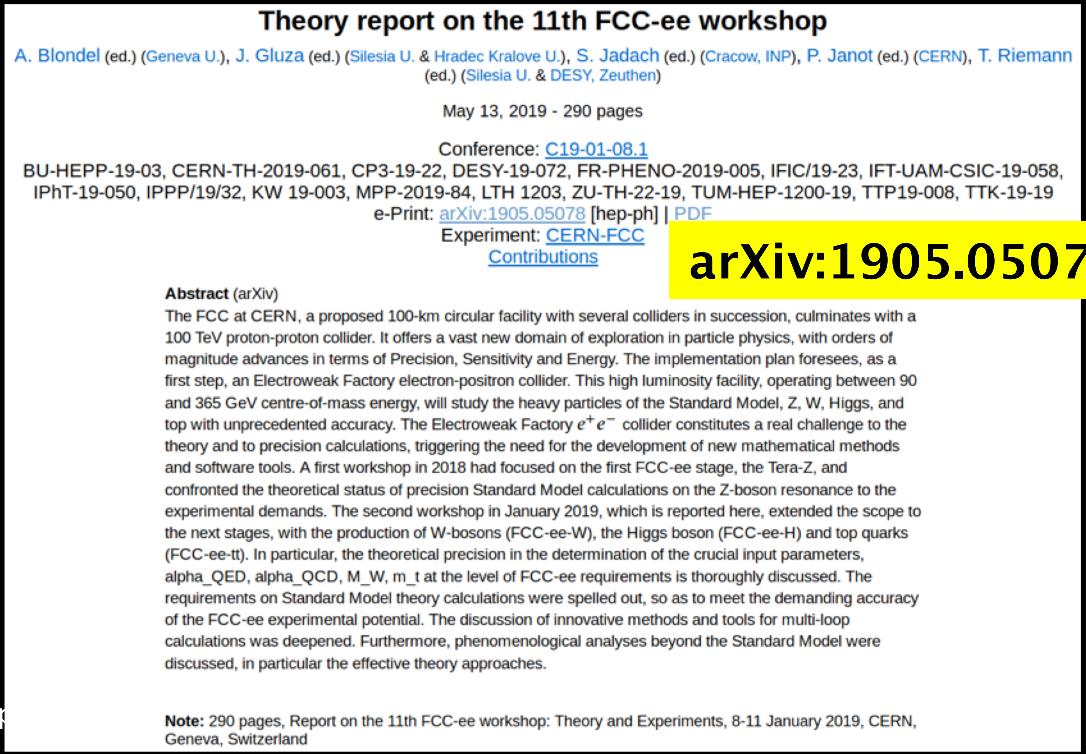
arXiv:1809.01830

Sep 6, 2018 - 243 pages

Conference: C18-01-12
BU-HEPP-18-04, CERN-TH-2018-145, IFJ-PAN-IV-2018-09, KW 18-003, MITP/18-052, MPP-2018-143, SI-HEP-2018-21
e-Print: arXiv:1809.01830 [hep-ph] | PDF

Abstract (arXiv)
The future 100-km circular collider FCC at CERN is planned to operate in one of its modes as an electron-positron FCC-ee machine. We give an overview of the theoretical status compared to the experimental demands of one of four foreseen FCC-ee operating stages, which is Z-boson resonance energy physics, FCC-ee Tera-Z stage for short. The FCC-ee Tera-Z will deliver the highest integrated luminosities as well as very small systematic errors for a study the Standard Model (SM) with unprecedented precision. In fact, the FCC-ee Tera-Z will allow to study at least one more quantum field theoretical perturbative order compared to the LEP/SLC precision. The real problem is that the present precision of theoretical calculations of the various observables within the SM does not match that of the anticipated experimental measurements. The bottle-neck problems are specified. In particular, the issues of precise QED unfolding and of the correct calculation of SM pseudo-observables are critically reviewed. In an Executive Summary we specify which basic theoretical calculations are needed to meet the strong experimental expectations at the FCC-ee Tera-Z. Several methods, techniques and tools needed for higher order multi-loop calculations are presented. By inspection of the Z-boson partial and total decay widths analysis, arguments are given that at the beginning of operation of the FCC-ee Tera-Z, the theory predictions may be tuned to be precise enough not to limit the physics interpretation of the measurements. This statement is based on the anticipated progress in analytical and numerical calculations of multi-loop and multi-scale Feynman integrals and on the completion of two-loop electroweak radiative corrections to the SM pseudo-observables this year. However, the above statement is conditional as the theoretical issues demand a very dedicated and focused investment by the community.

Note: 243 pages, Report on the 1st Mini workshop: Precision EW and QCD calculations for the FCC studies: methods and tools, 12-13 January 2018, CERN, Geneva, Switzerland
Keyword(s): INSPIRE: * Automatic Keywords * | electroweak interaction: radiative correction | resonance: energy | Z0: resonance | decay: width | FCC-ee | quantum electrodynamics | numerical calculations | field theory | electron



Theory report on the 11th FCC-ee workshop

A. Blondel (ed.) (Geneva U.), J. Gluza (ed.) (Silesia U. & Hradec Kralove U.), S. Jadach (ed.) (Cracow, INP), P. Janot (ed.) (CERN), T. Riemann (ed.) (Silesia U. & DESY, Zeuthen)

May 13, 2019 - 290 pages

Conference: C19-01-08.1
BU-HEPP-19-03, CERN-TH-2019-061, CP3-19-22, DESY-19-072, FR-PHENO-2019-005, IFIC/19-23, IFT-UAM-CSIC-19-058, IPhT-19-050, IPPP/19/32, KW 19-003, MPP-2019-84, LTH 1203, ZU-TH-22-19, TUM-HEP-1200-19, TTP19-008, TTK-19-19
e-Print: arXiv:1905.05078 [hep-ph] | PDF
Experiment: CERN-FCC
Contributions

arXiv:1905.05078

Abstract (arXiv)
The FCC at CERN, a proposed 100-km circular facility with several colliders in succession, culminates with a 100 TeV proton-proton collider. It offers a vast new domain of exploration in particle physics, with orders of magnitude advances in terms of Precision, Sensitivity and Energy. The implementation plan foresees, as a first step, an Electroweak Factory electron-positron collider. This high luminosity facility, operating between 90 and 365 GeV centre-of-mass energy, will study the heavy particles of the Standard Model, Z, W, Higgs, and top with unprecedented accuracy. The Electroweak Factory e^+e^- collider constitutes a real challenge to the theory and to precision calculations, triggering the need for the development of new mathematical methods and software tools. A first workshop in 2018 had focused on the first FCC-ee stage, the Tera-Z, and confronted the theoretical status of precision Standard Model calculations on the Z-boson resonance to the experimental demands. The second workshop in January 2019, which is reported here, extended the scope to the next stages, with the production of W-bosons (FCC-ee-W), the Higgs boson (FCC-ee-H) and top quarks (FCC-ee-tt). In particular, the theoretical precision in the determination of the crucial input parameters, alpha_QED, alpha_QCD, M_W, m_t at the level of FCC-ee requirements is thoroughly discussed. The requirements on Standard Model theory calculations were spelled out, so as to meet the demanding accuracy of the FCC-ee experimental potential. The discussion of innovative methods and tools for multi-loop calculations was deepened. Furthermore, phenomenological analyses beyond the Standard Model were discussed, in particular the effective theory approaches.

Note: 290 pages, Report on the 11th FCC-ee workshop: Theory and Experiments, 8-11 January 2019, CERN, Geneva, Switzerland

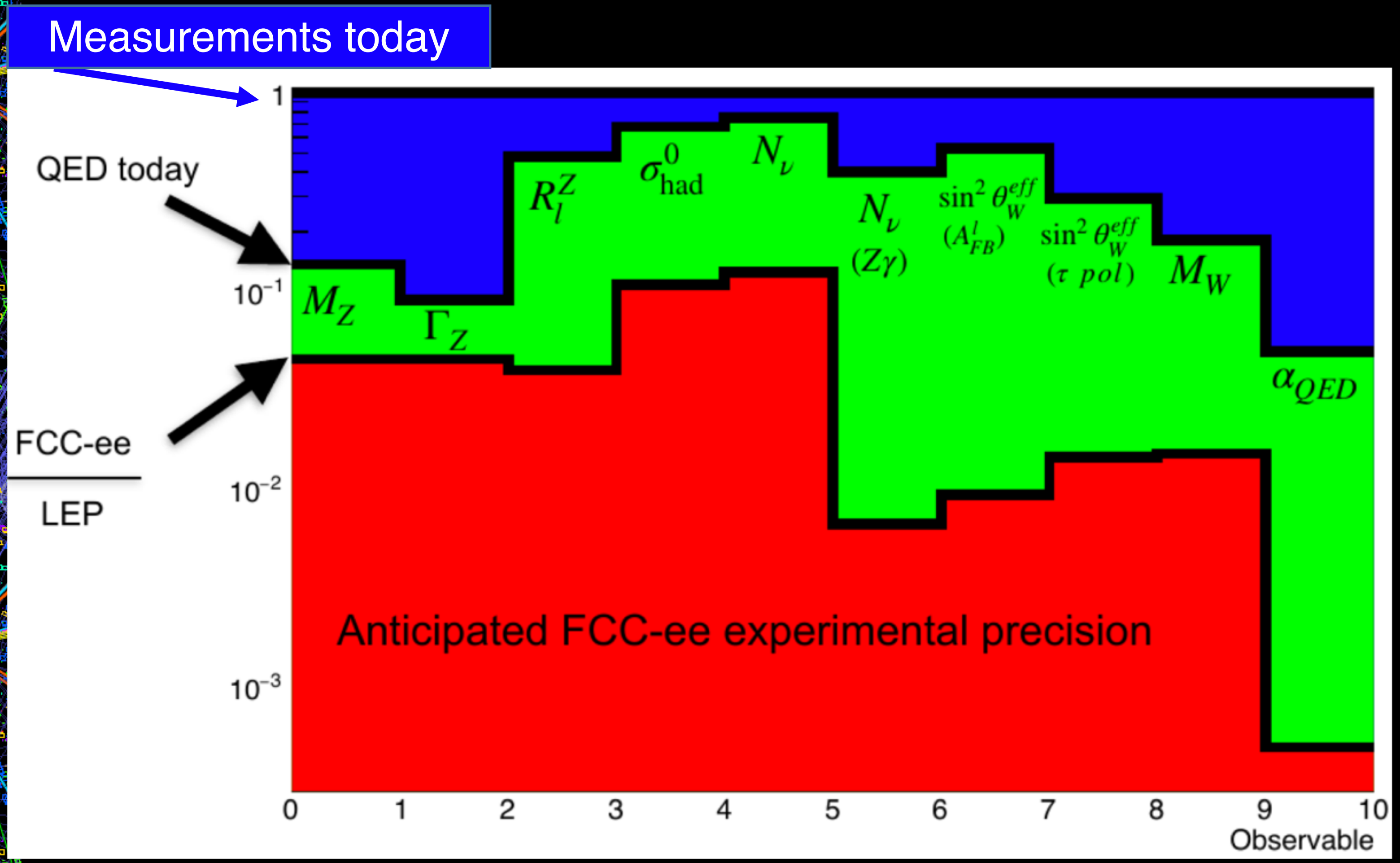
Expected precision in 2040

- 500 person-years needed over 20 years
- Recognized as strategic priority

	$\delta\Gamma_Z$ [MeV]	δR_l $[10^{-4}]$	δR_b $[10^{-5}]$	$\delta \sin^{2,l}_{eff} \theta$ $[10^{-6}]$
Present EWPO theoretical uncertainties				
EXP-2018	2.3	250	66	160
TH-2018	0.4	60	10	45
EWPO theoretical uncertainties when FCC-ee will start				
EXP-FCC-ee	0.1	10	$2 \div 6$	6
TH-FCC-ee	0.07	7	3	7

Improvements in QED and QCD

- Current QED uncertainties >> FCC-ee experimental precision

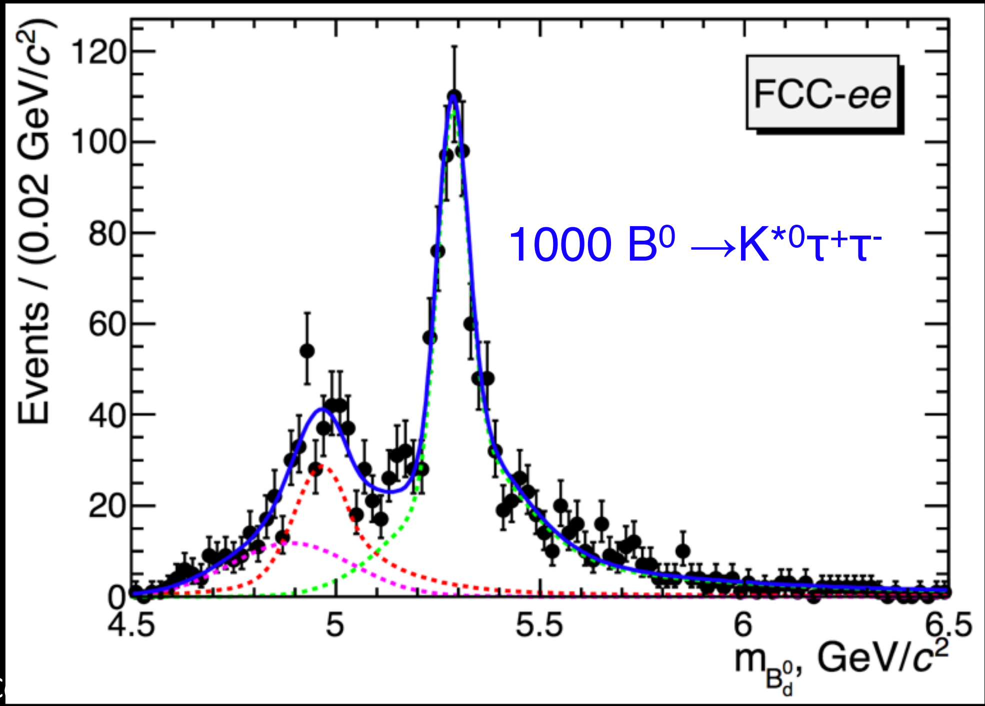


- Sophisticated MC event generators with Multi-loop EW and QCD corrections
- Soft-photon resummation
- Decrease α_{QED} error by a factor 5 to 10
- Permille precision extractions of the α_s coupling.

B Physics

	CEPC (10^{12} Z)	Belle II (50 ab^{-1} @$\Upsilon(4S)$ & 5 fb^{-1} @$\Upsilon(5S)$)	LHCb (50 fb^{-1})
$B^{\pm}/B^0$	6×10^{10}	3×10^{10}	3×10^{13}
B_s	2×10^{10}	3×10^{8}	8×10^{12}
B_c	10^{8}	-	6×10^{10}
b baryons	10^{10}	-	10^{13}

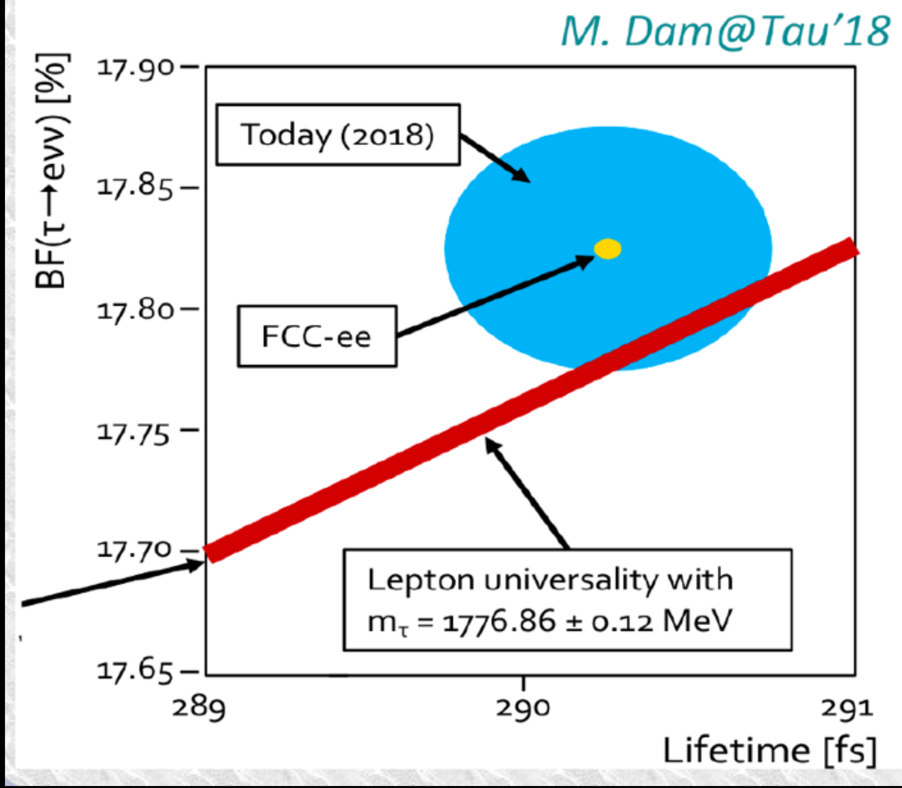
- Yield matches or exceeds Belle but is below LHCb
- Advantages:
  - B's are produced back to back and with predictable momenta
- Tau decay modes might be accessible
  - B→Kττ with 3-prong tau decays allows 4 vertex positions and thus full mass reconstruction
  - $B_c \to \tau\nu$



Physics with 1.7×10^{11} tau pairs

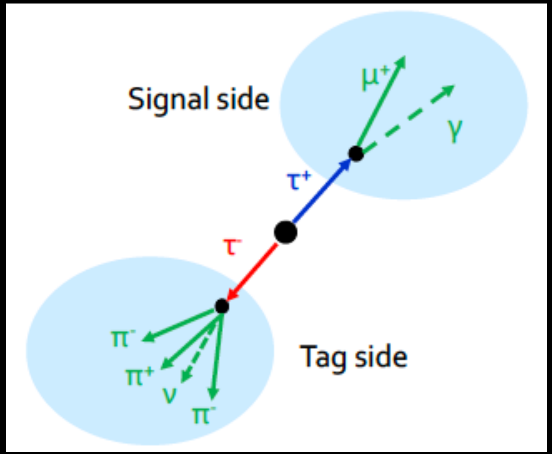
Tau leptonic br fractions with enormous statistics (at least a factor of 10 better than Aleph)

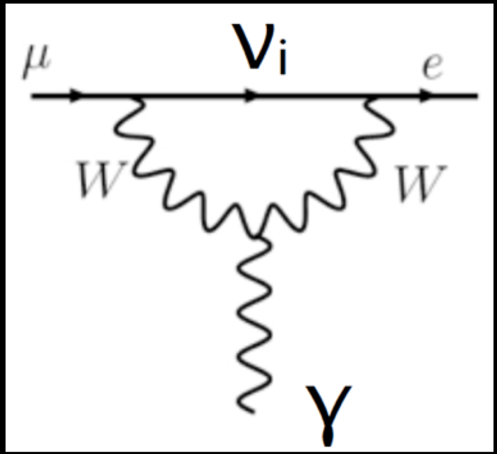
Lepton Universality

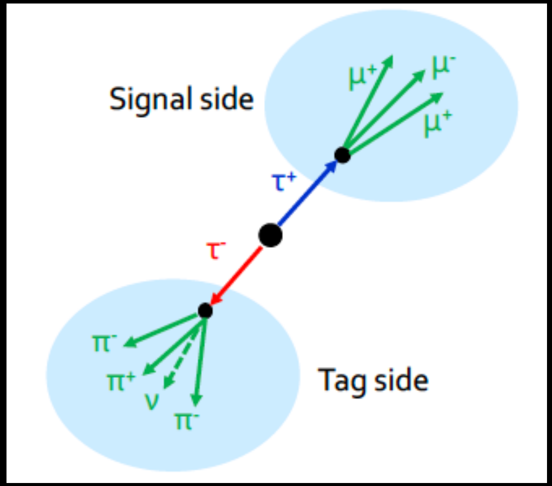


Emilie Passemar

Charged Lepton Flavour Violation



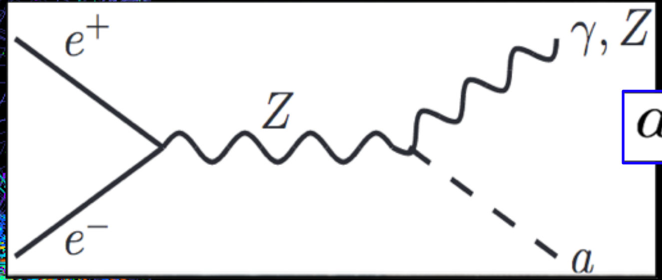




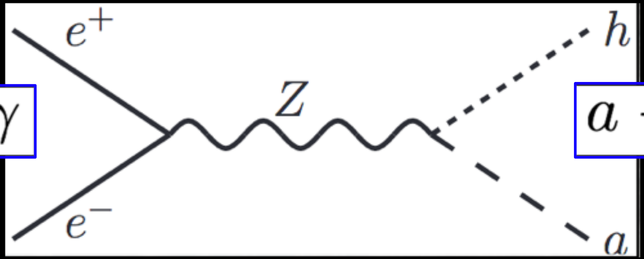
- Similar sensitivity for CEPC and FCC-ee as Belle II for $\tau \to \mu\gamma$: $Br(\tau \to \mu\gamma) \sim 2 \times 10^{-9}$
- Better sensitivity for $\tau \to 3\mu$: $Br(\tau \to 3\mu) \sim 10^{-10}$

New physics: Portal to Dark Matter

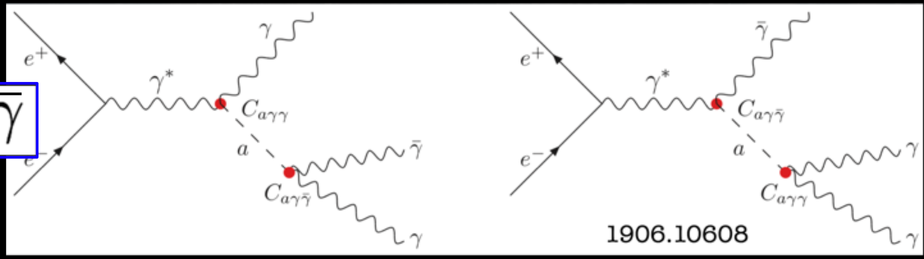
M. McCullough

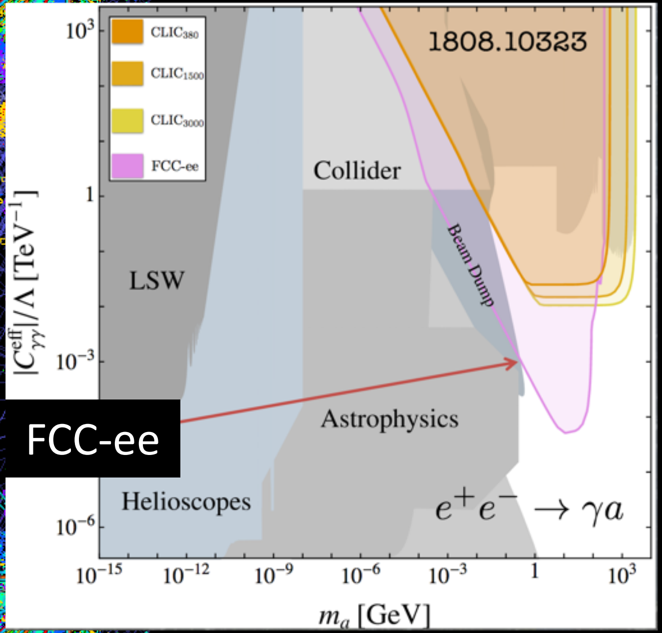


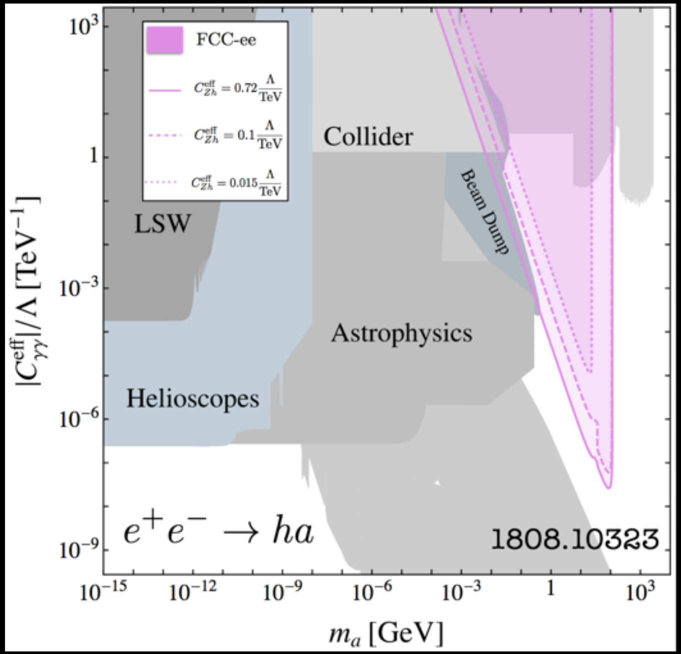
$a \to \gamma\gamma$

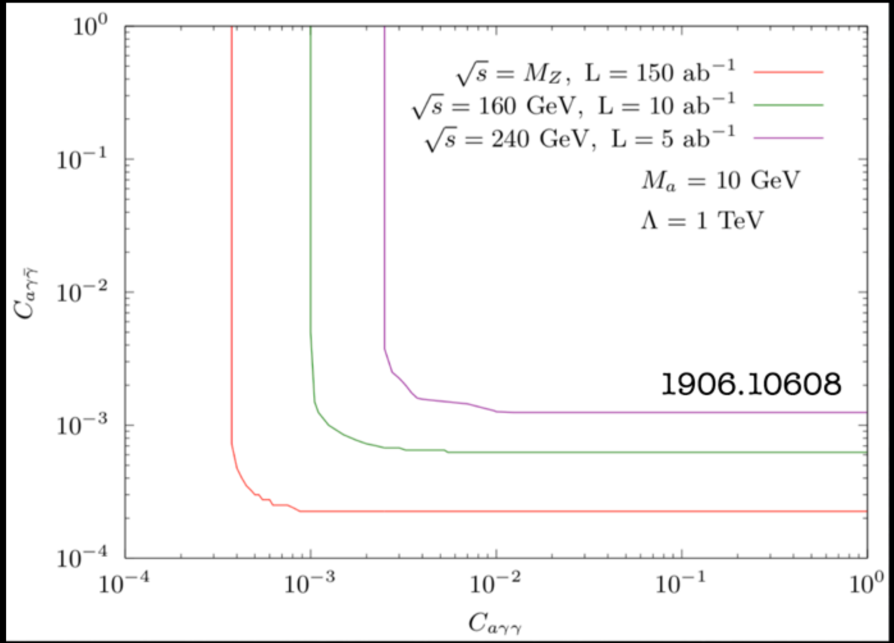


$a \to \gamma\bar{\gamma}$







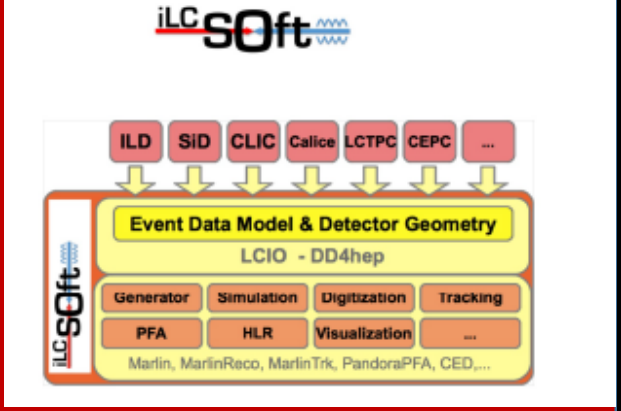


- FCC-ee can probe very small couplings for Axion-Like Particles (ALPS)

Tools and Performance

- Software needs to be modular, scalable, multi-threading, efficient for GPU and HPC computing
- Need both full and fast simulation
- Need both classical algorithms (as baseline) and ML based algorithm (as cutting-edge)
- Future developments huge benefit from collaboration with existing projects and LHC expertise

Linear Colliders: Both ILC and CLIC are using ILCSoft



- Full simulation for detector performance and Physics studies
- Realistic simulation aided by common software

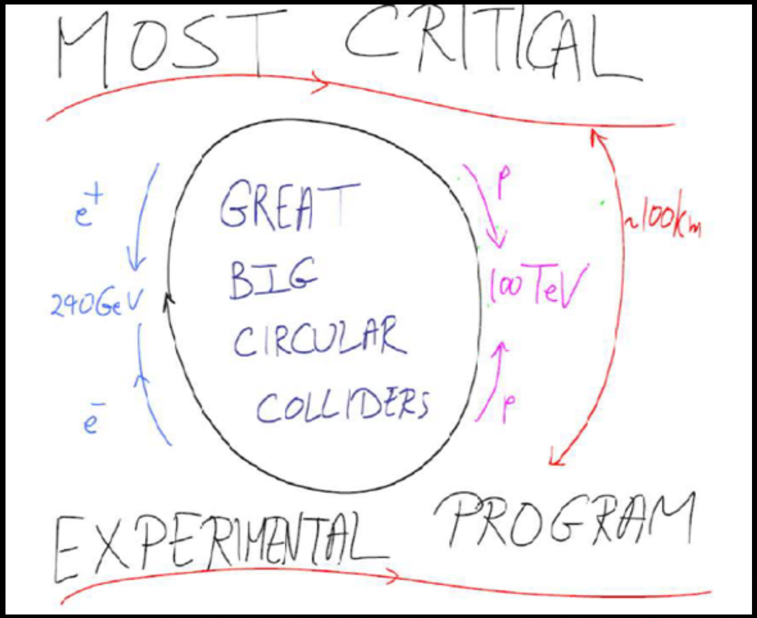
Circular Colliders

CEPC SW
Based on ILCSoft

FCC SW

Conclusions

- Much impressive work has been done but now both the FCC-ee and CEPC have to move beyond CDRs
- The conceptual designs must be taken to the technical design (TDR) stage and this requires that the viability of key technologies be demonstrated in large-scale prototypes.
- Truly international collaborations must be formed to do this
- Many activities from detector and accelerator R&D to the studies necessary to achieve the physics goals need support and would benefit from co-operation between FCC-ee & CEPC
- Training and coordinated R&D is essential. There are plans for:
  - EU ITNs on Precision calculations, Physics & Data Analysis Tools
  - AIDA++ (extension of AIDA2020)
  - A training program in instrumentation would also be useful
  - What can be done in Korea/Asia?

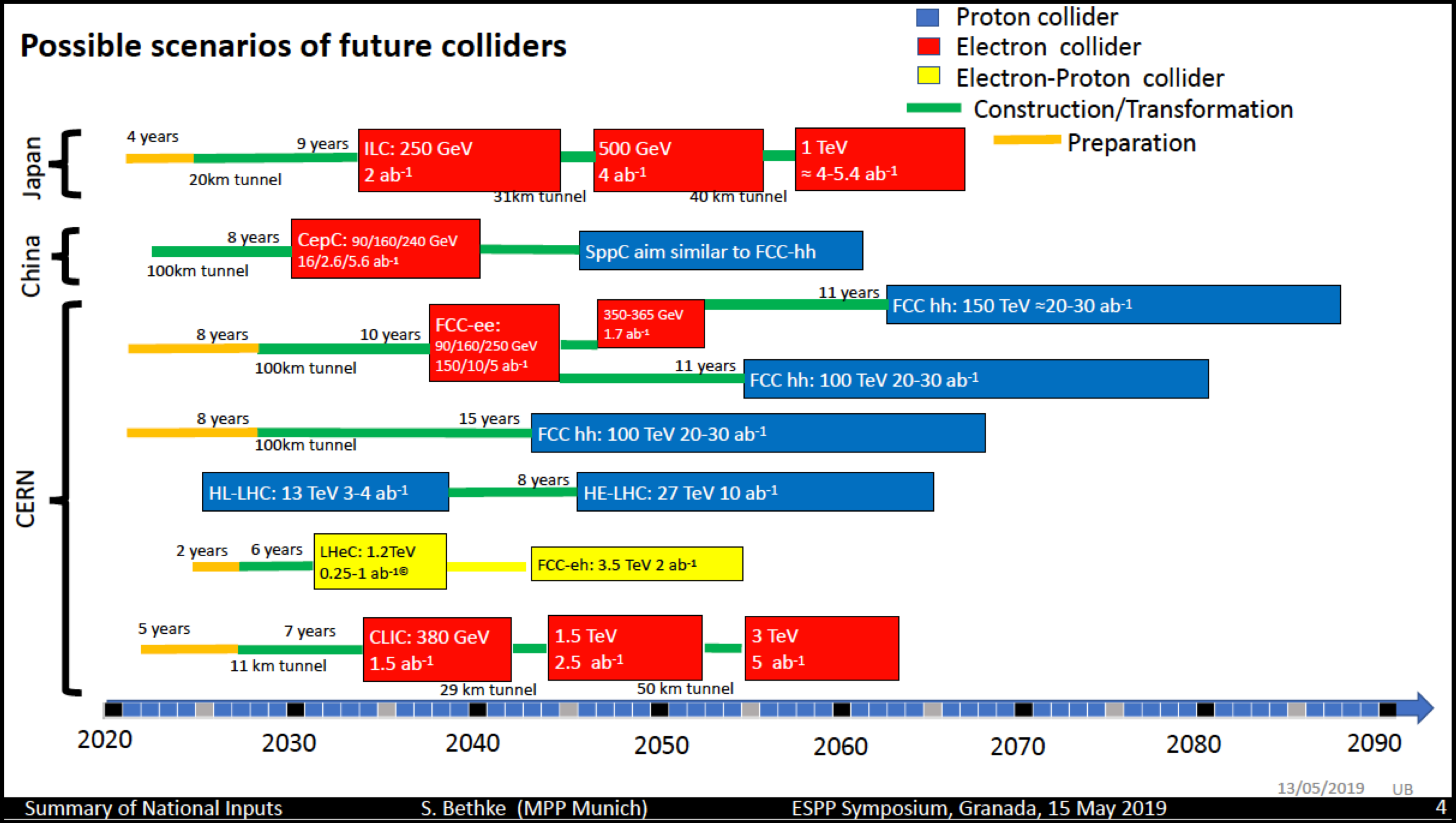


"One Ring to rule them all" - J.R.R. Tolkien

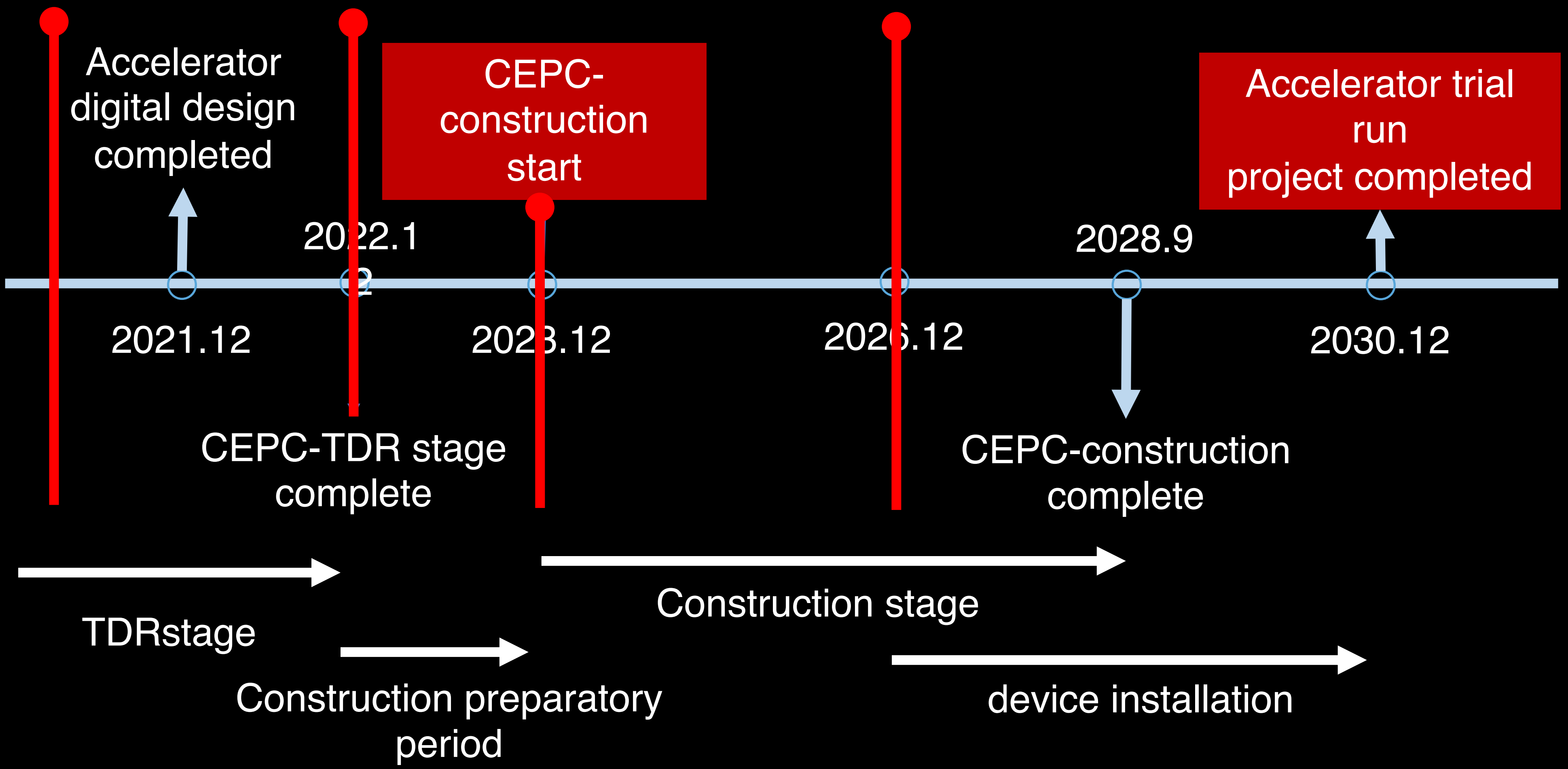
Thanks

- For this talk I have used input from Nima Arkani Hamed, Patrick Janot, Beate Heinemann, Joao Guimaraes da Costa, Michele Selvaggi, Andrew Long, Bill Murray, Brian Foster, Hongbo Zhu and others…

- Upcoming Meetings dedicated to Circular $e^+ e^-$ colliders
  - FCC Physics and Detectors Workshop 9-12 Sept. 2019 (CERN)
  - FCC-ee Workshop January 13-17, 2020 (CERN)
  - 2019 International Workshop on the High Energy CEPC, 18-20 Nov. 2019 (IHEP)


Possible scenarios of future colliders
Proton collider
Electron collider
Electron-Proton collider
Construction/Transformation
Preparation
Japan
4 years
9 years
20km tunnel
ILC: 250 GeV
2 ab-1
31km tunnel
500 GeV
4 ab-1
40 km tunnel
1 TeV
≈ 4-5.4 ab-1
China
8 years
100km tunnel
CepC: 90/160/240 GeV
16/2.6/5.6 ab-1
SppC aim similar to FCC-hh
CERN
8 years
10 years
100km tunnel
FCC-ee:
90/160/250 GeV
150/10/5 ab-1
350-365 GeV
1.7 ab-1
11 years
FCC hh: 150 TeV ≈20-30 ab-1
11 years
FCC hh: 100 TeV 20-30 ab-1
8 years
15 years
100km tunnel
FCC hh: 100 TeV 20-30 ab-1
HL-LHC: 13 TeV 3-4 ab-1
8 years
HE-LHC: 27 TeV 10 ab-1
2 years
6 years
LHeC: 1.2TeV
0.25-1 ab-1©
FCC-eh: 3.5 TeV 2 ab-1
5 years
7 years
11 km tunnel
CLIC: 380 GeV
1.5 ab-1
29 km tunnel
1.5 TeV
2.5 ab-1
50 km tunnel
3 TeV
5 ab-1
2020
2030
2040
2050
2060
2070
2080
2090
13/05/2019 UB
Summary of National Inputs
S. Bethke (MPP Munich)
ESPP Symposium, Granada, 15 May 2019
4

CEPC Construction Schedule



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FCC and CEPC CDRs

International collaboration publishes concept design for a post-LHC future circular collider at CERN

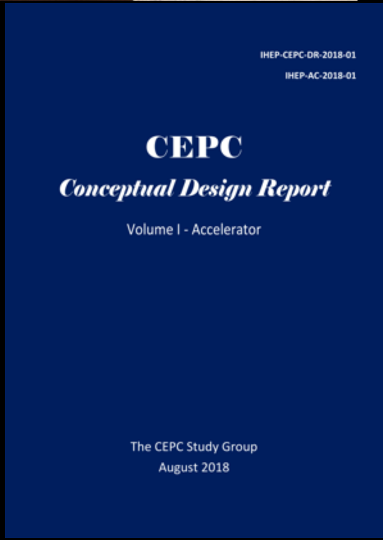
Date Issued
January 15th, 2019

Source
CERN

The proposed layout of the future circular collider (Image: CERN)

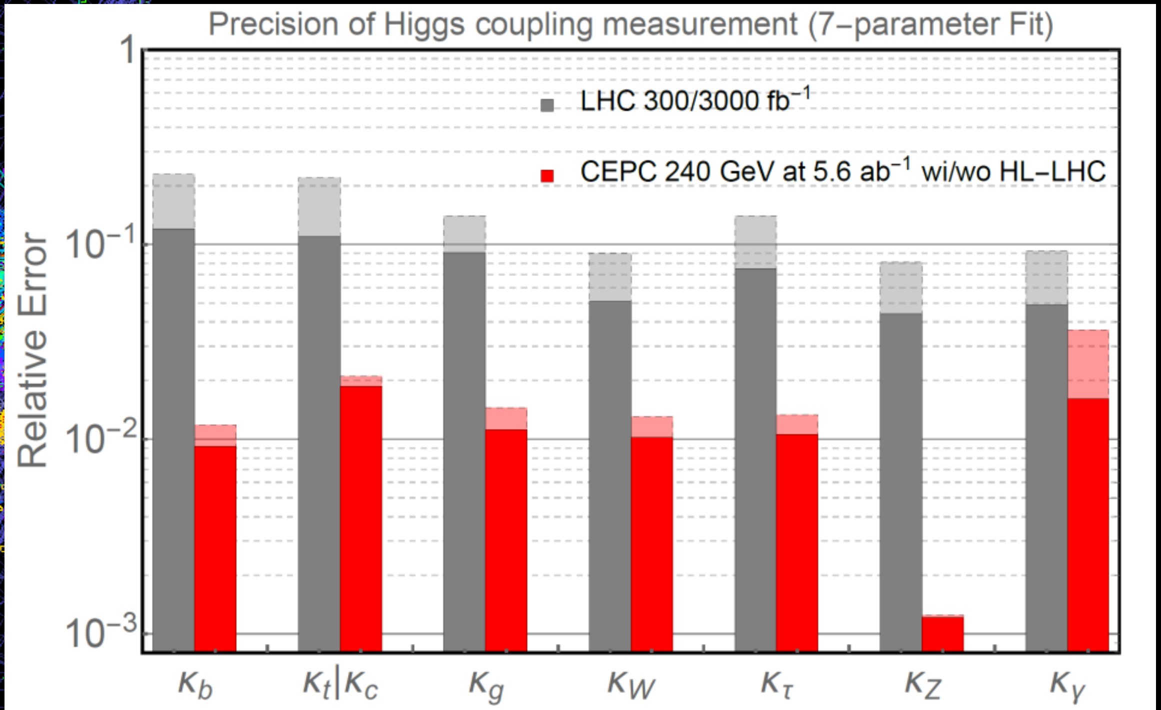
Geneva, 15 January 2019. Today, the Future Circular Collider (FCC) collaboration submitted its Conceptual Design Report (CDR) for publication, a four-volume document that presents the different options for a large circular collider of the future. It showcases the great physics opportunities offered by machines of unprecedented energy and intensity and describes the technical challenges, cost and schedule for realisation.

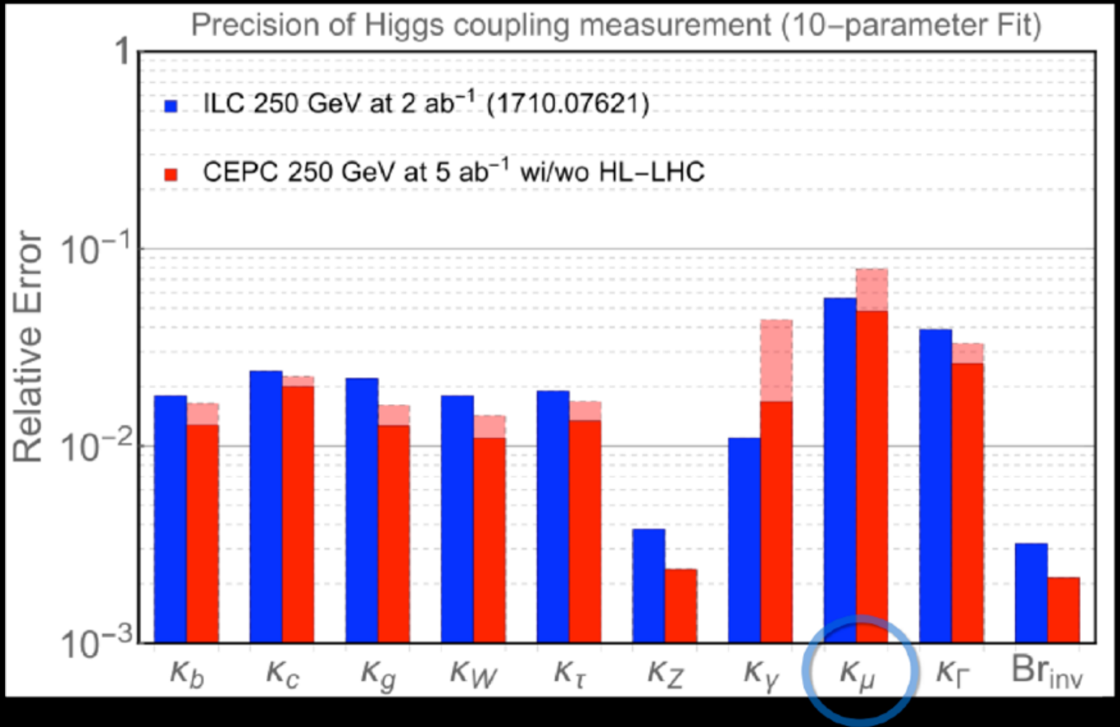
The Group photo of the CEPC Team at the CDR release ceremony 14-11-2018



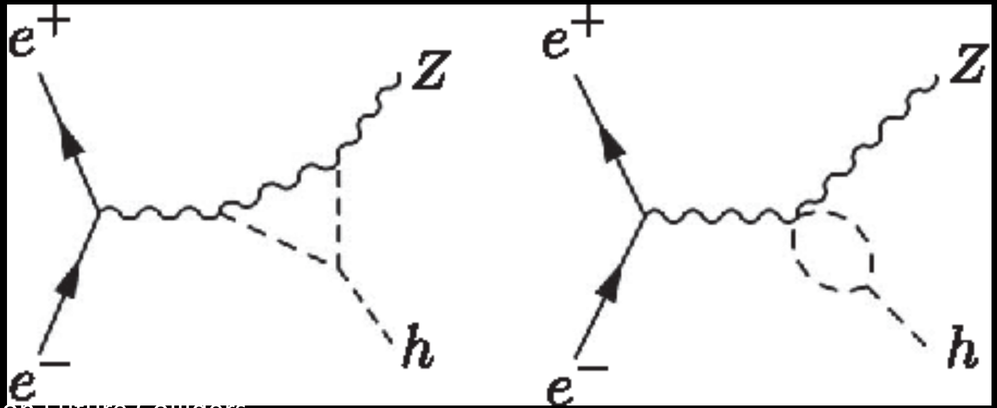
e⁺e⁻ collider potential

CepC





- Coupling measurements at the % level
- Model independent Higgs width
- 3 σ, possibly 5, discovery of Higgs boson self coupling from vertex corrections



European Strategy