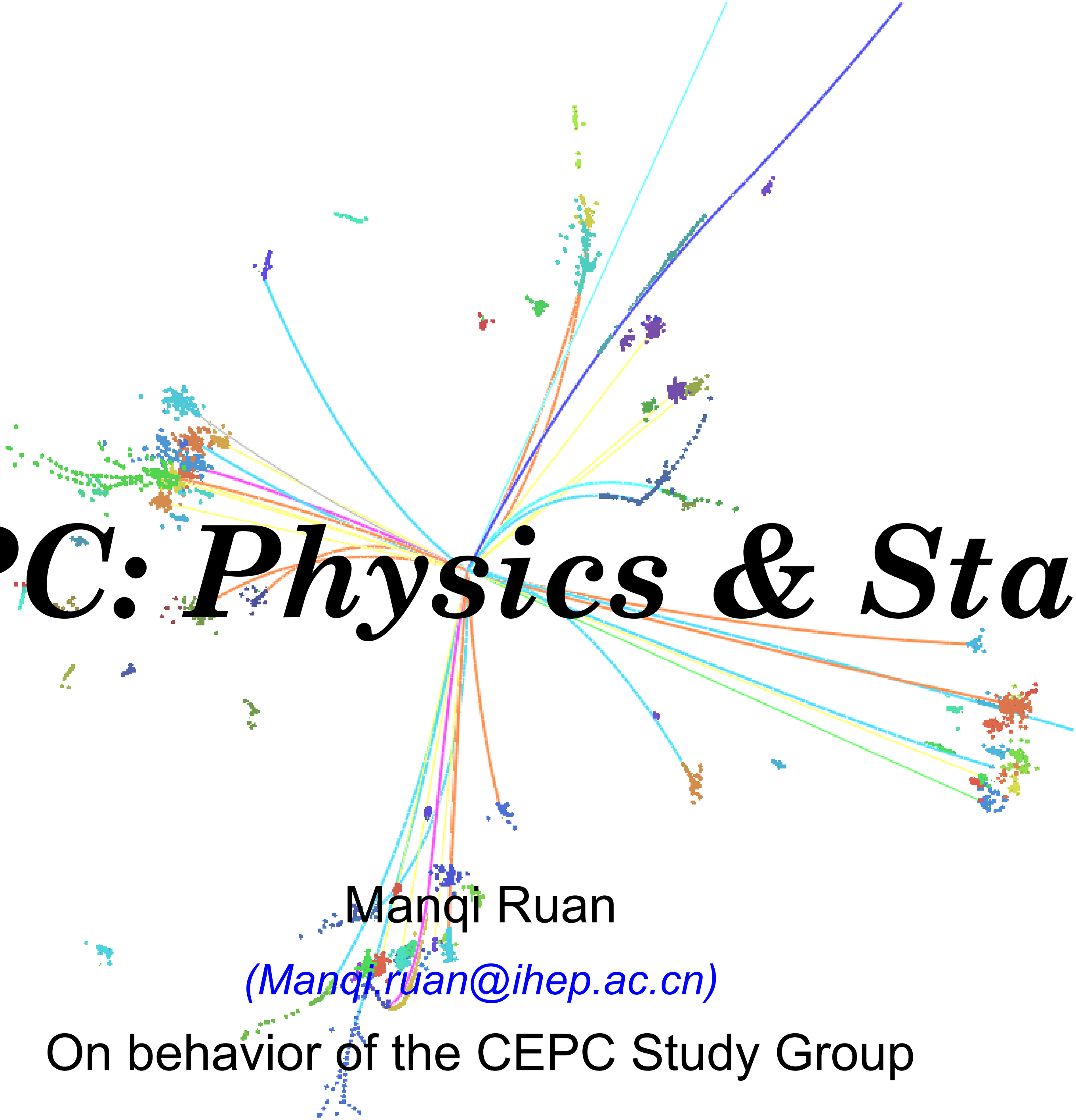
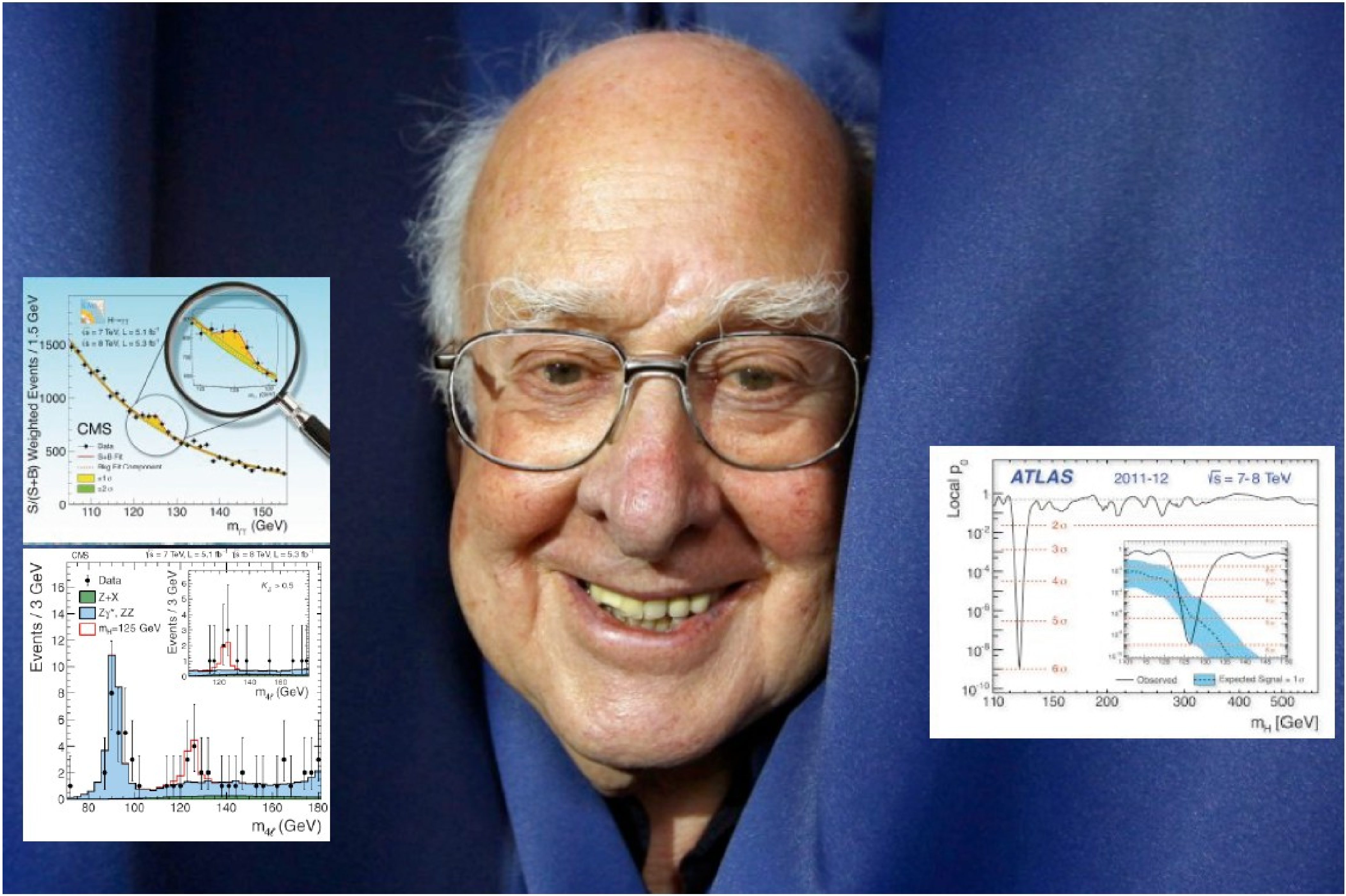


CEPC: Physics & Status

Manqi Ruan

(Manqi.ruan@ihep.ac.cn)

On behavior of the CEPC Study Group

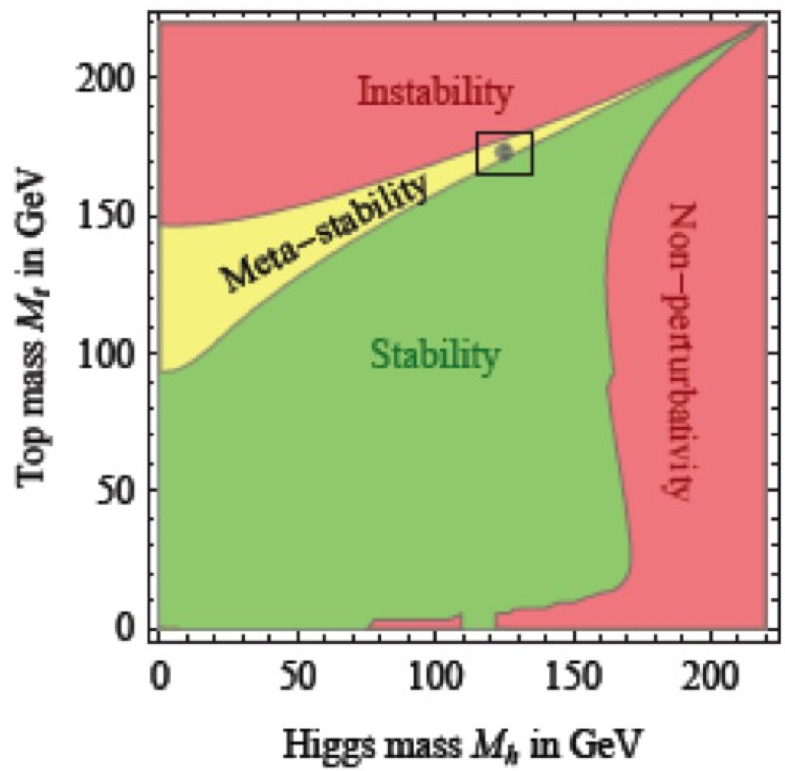

S/(S+B) Weighted Events / 1.5 GeV
CMS
Data
S+B Fit
Bkg Fit Component
±1σ
±2σ
m_γγ (GeV)
Events / 3 GeV
Data
Z+X
Zγ*, ZZ
m_H=125 GeV
m_4ℓ (GeV)
ATLAS
2011-12
√s = 7-8 TeV
Local p_0
2σ
3σ
4σ
5σ
6σ
Observed
Expected Signal ± 1σ
m_H [GeV]

SM is **NOT** the end of story...

- 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

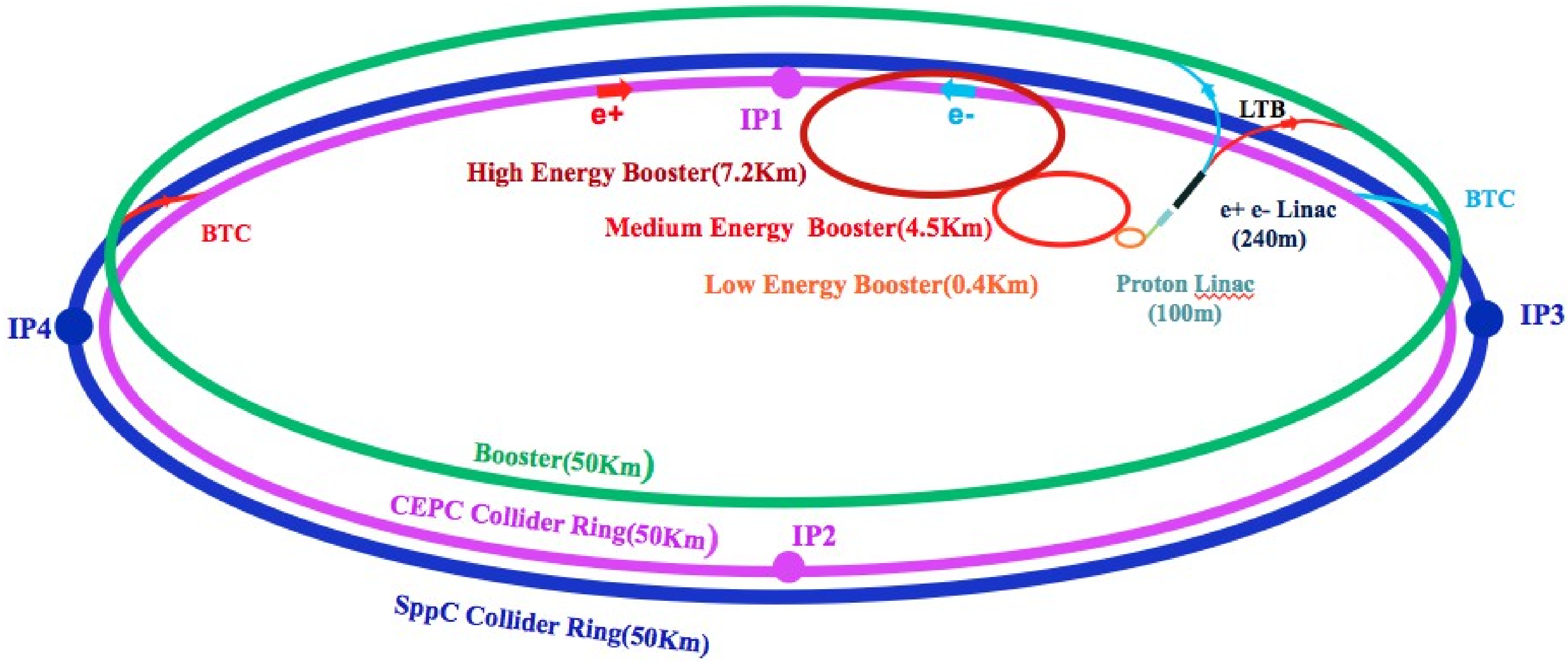
- **Most issues related to Higgs**

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



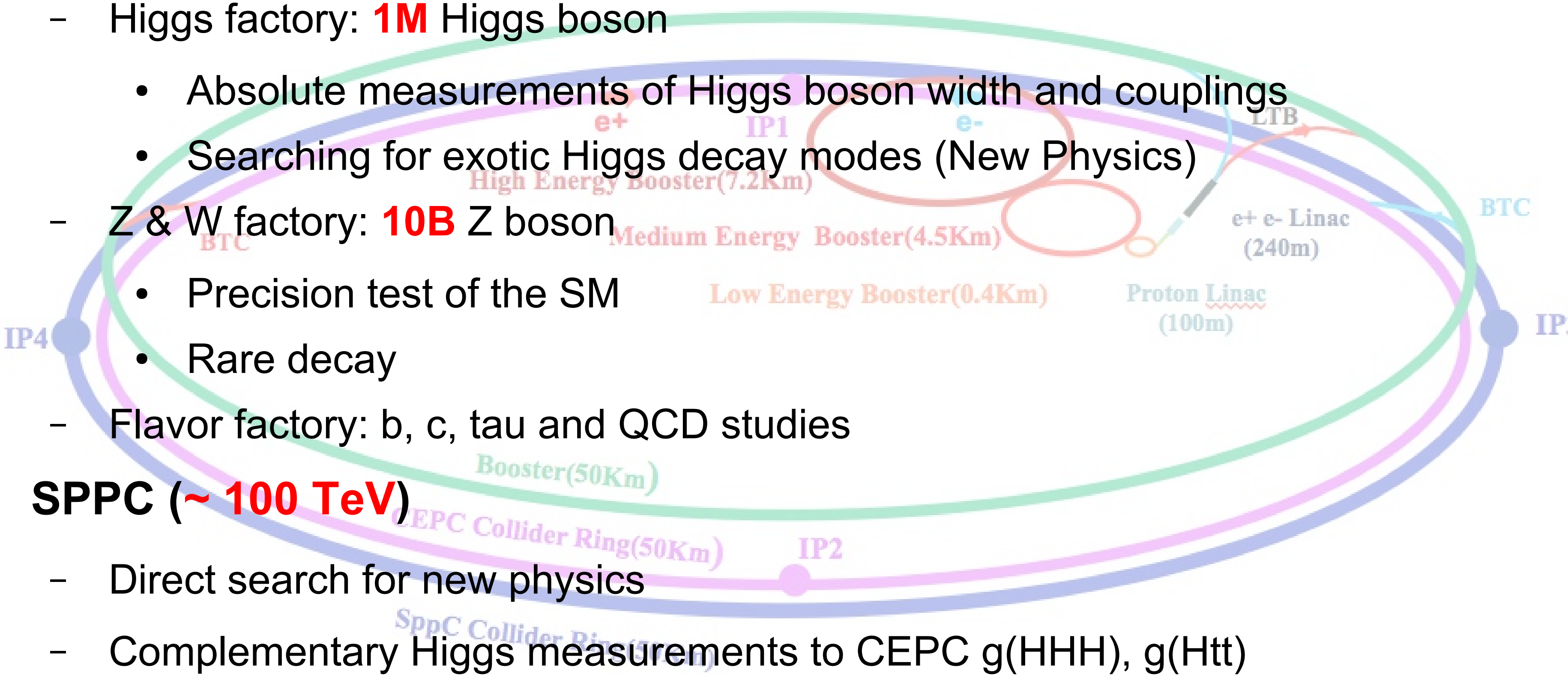
Key: a precise Higgs factory

- 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



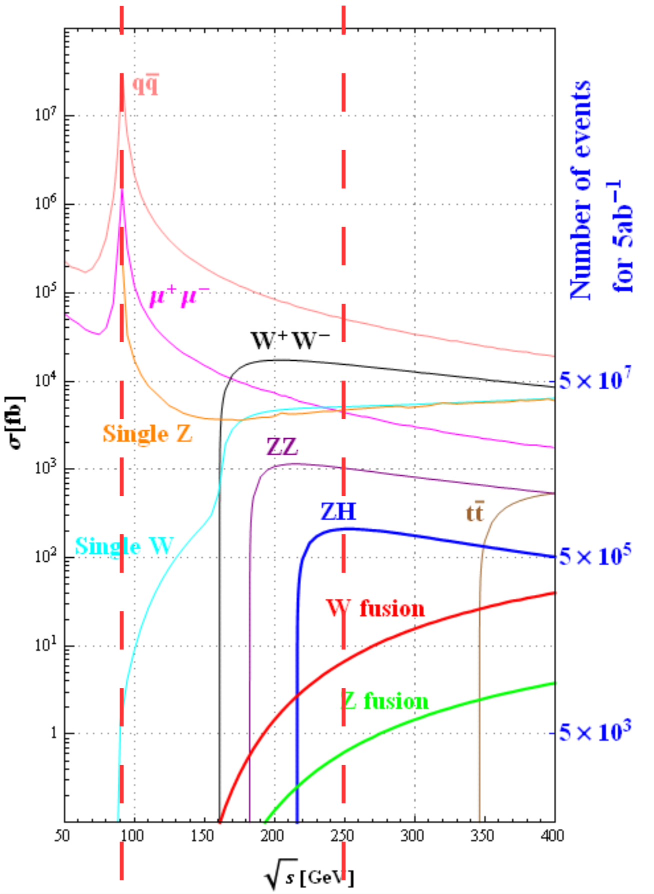
Science at CEPC-SPPC

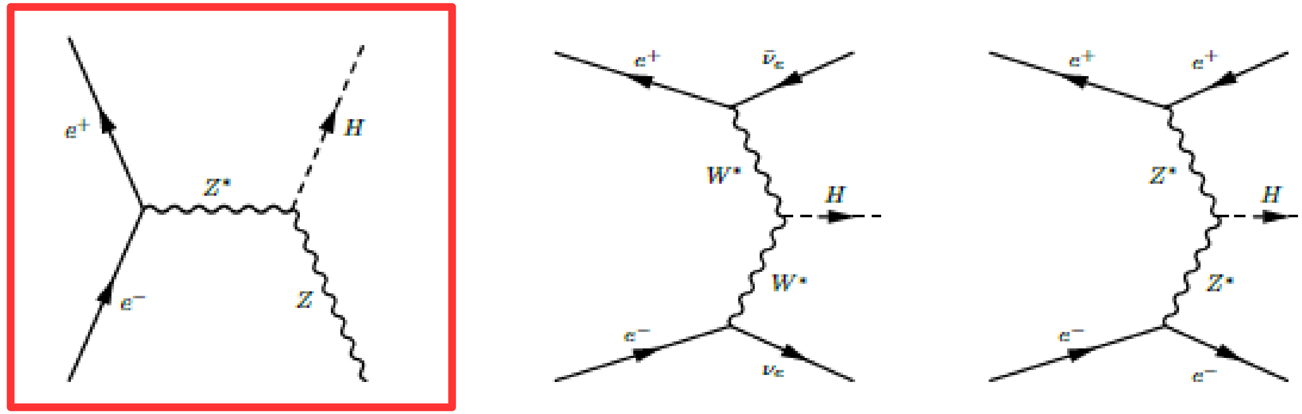
- **Tunnel ~ 100 km**
- **CEPC (90 – 250 GeV)**
  - Higgs factory: **1M** Higgs boson
    - Absolute measurements of Higgs boson width and couplings
    - Searching for exotic Higgs decay modes (New Physics)
  - Z & W factory: **10B** Z boson
    - Precision test of the SM
    - Rare decay
  - Flavor 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 @ CEPC





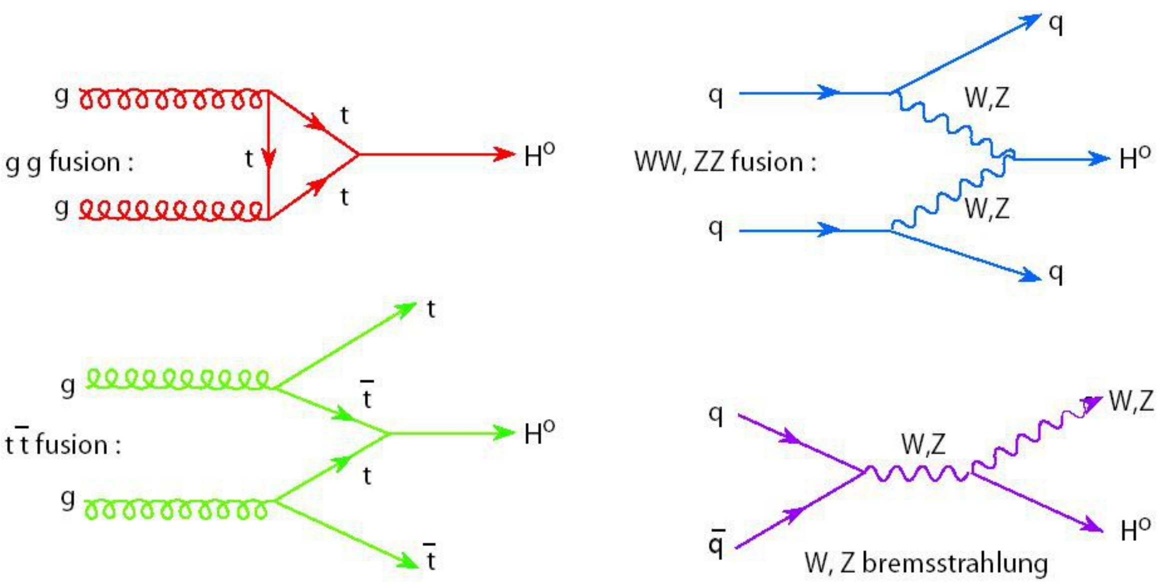
Process	Cross section	Events in 5 ab^{-1}
Higgs boson production, cross section in fb		
$e^+e^- \to ZH$	212	1.06×10^6
$e^+e^- \to \nu\bar{\nu}H$	6.72	3.36×10^4
$e^+e^- \to e^+e^-H$	0.63	3.15×10^3
Total	219	1.10×10^6

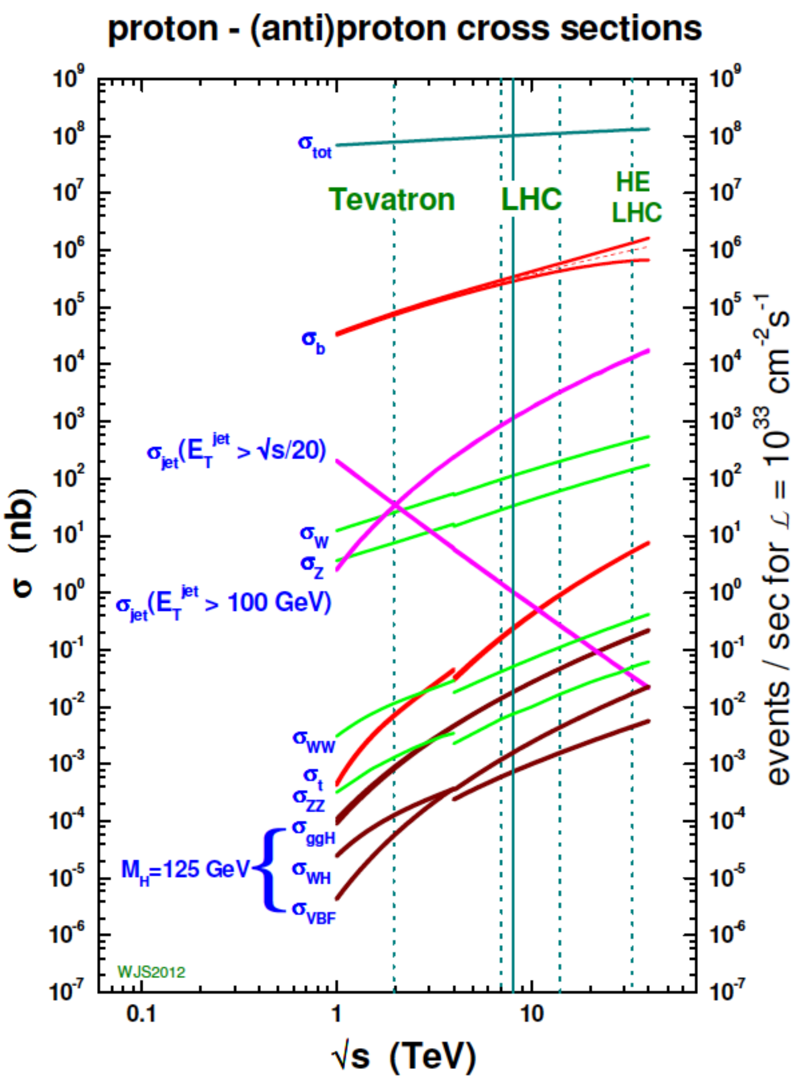
S/B ~ 1:100 - 1000

Observables: Higgs mass, CP, σ(ZH), event rates (σ(ZH, vvH)*Br(H→X)), Diff. distributions

Derive: Absolute Higgs width, branching ratios, couplings

Higgs @ LHC

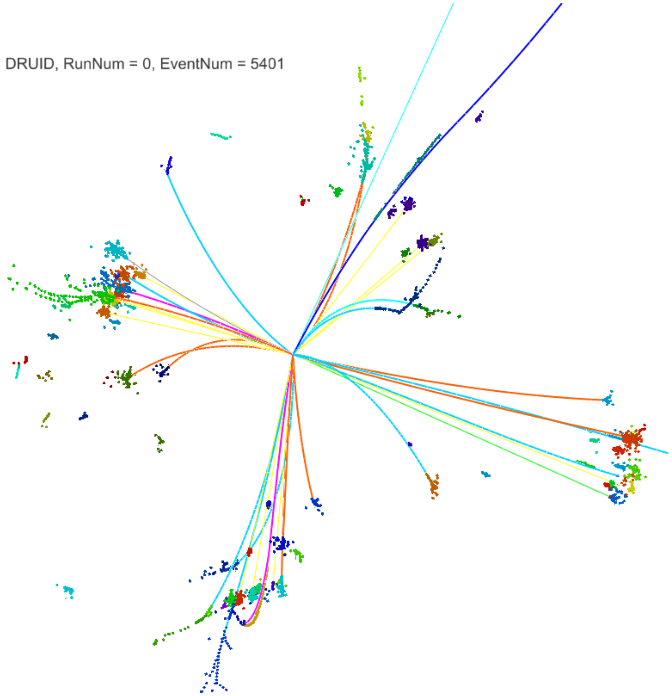


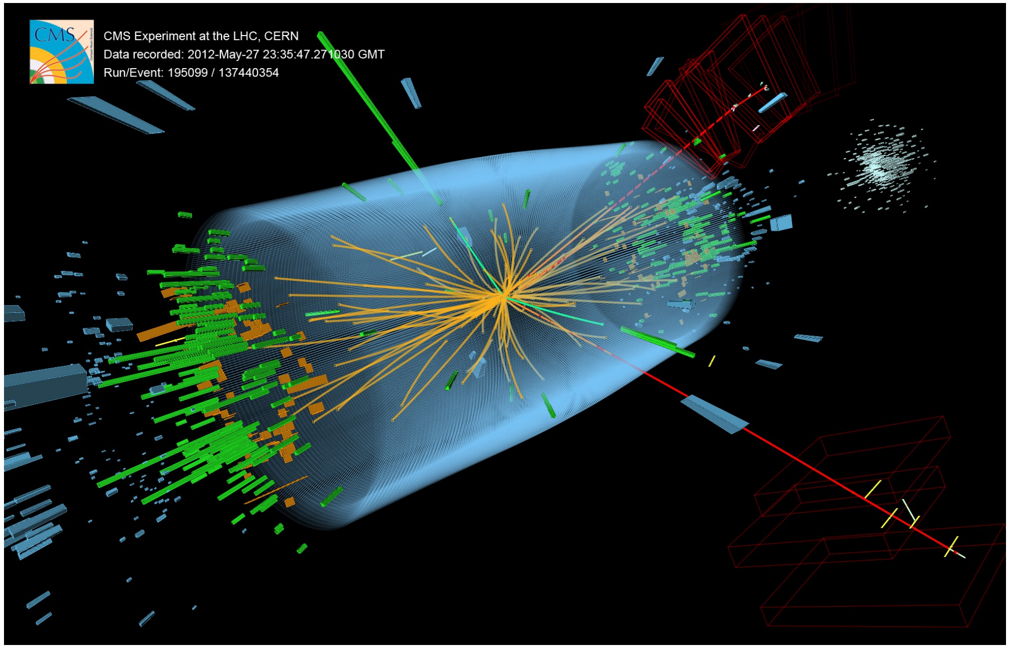


S/B ~ 1:1E10 !!!

$$\sigma(AA \rightarrow H \rightarrow BB) \sim g^2(HAA)g^2(HBB)/\Gamma_{total}$$

Higgs measurement at e+e- & pp

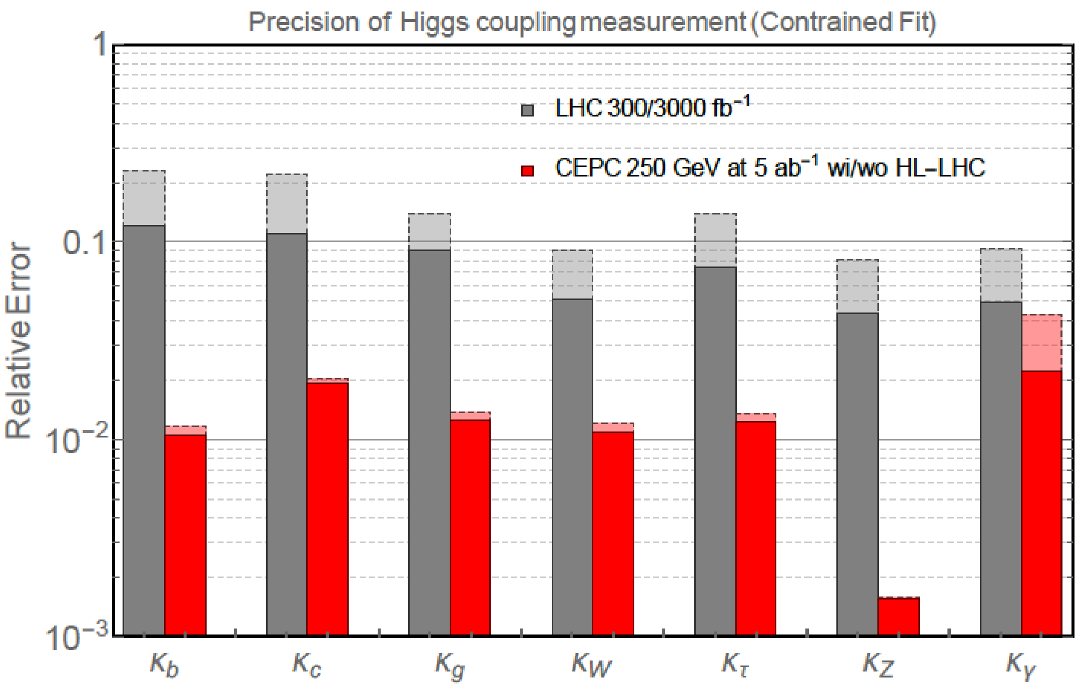


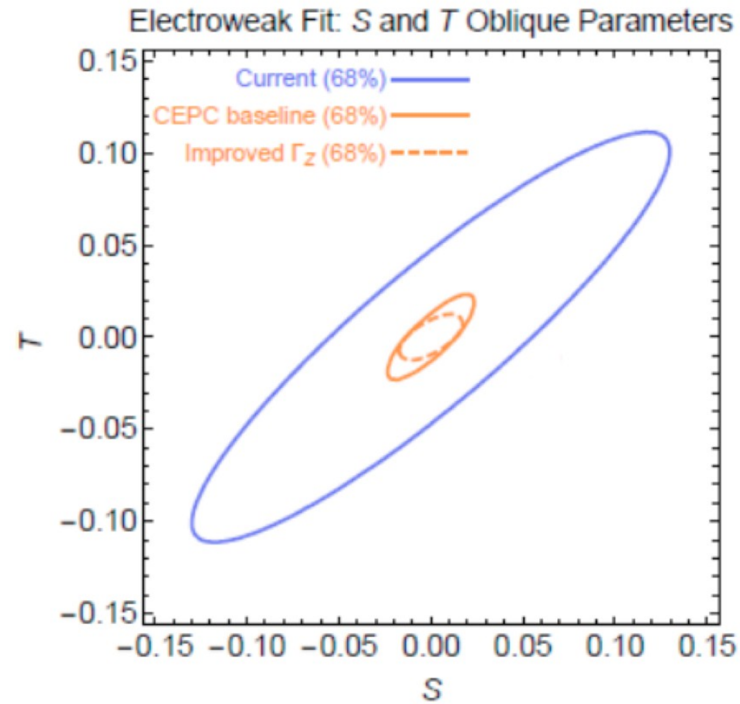


	Yield	efficiency	Comments
LHC	Run 1: 10^6 Run 2/HL: $10^{7\text{-}8}$	$\sim o(10^{-3})$	High Productivity & High background, Relative Measurements, Limited access to width, exotic ratio, etc, Direct access to g(ttH), and even g(HHH)
CEPC	10^6	$\sim o(1)$	Clean environment & Absolute measurement, Percentage level accuracy of Higgs width & Couplings

Complementary

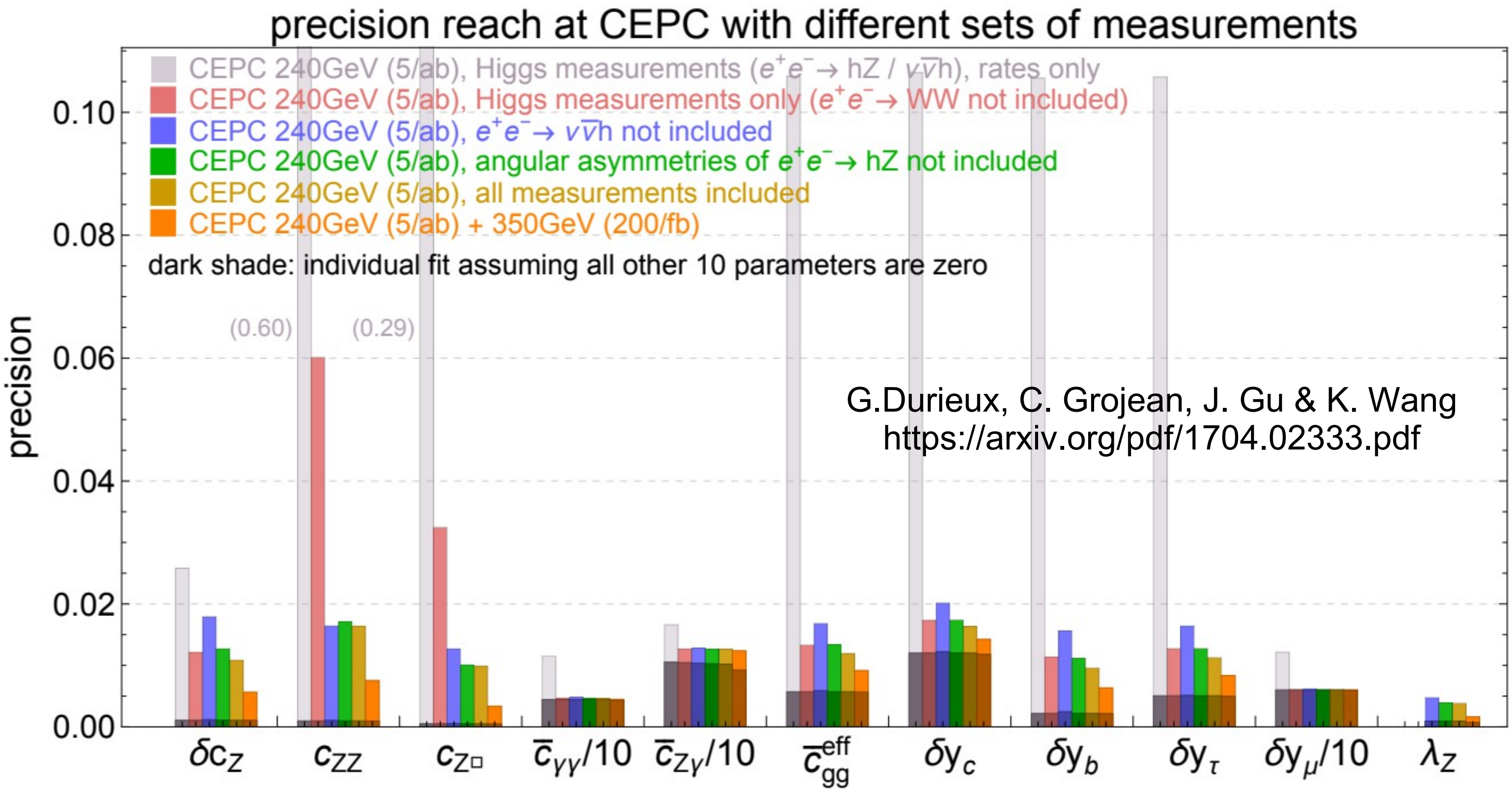
Physics Potential





- The nature of Higgs boson & EWSB, + flavor physics...
  - Higgs signal strengths (In kappa framework): expected accuracy roughly 1 order of magnitude better than HL-LHC
  - Absolute measurement to the Higgs boson: 2-3% level accuracy of Higgs boson width, 10^{-3} - 10^{-5} up limit to Higgs invisible/exotic decay modes (improved by at least 2 orders of magnitude comparing to HL-LHC)
  - Improve EW measurement precision by also 1 order of magnitude

Pheno-studies: EFT & Physics reach



The Physics reach could be largely enhanced if the EW measurements is combined
With the Higgs measurements (in the EFT)

Timeline

Milestones

1st, PreCDR (end of 2014)

2nd, R&D funding from MOST (Middle 2016, 35 M CNY/5yr for the 1st phase)

3rd, CDR ~~(end of 2017)~~ (Acc. Volume: July 2018)

4th, R&D funding from MOST (Middle 2018, 2nd phase)

...

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

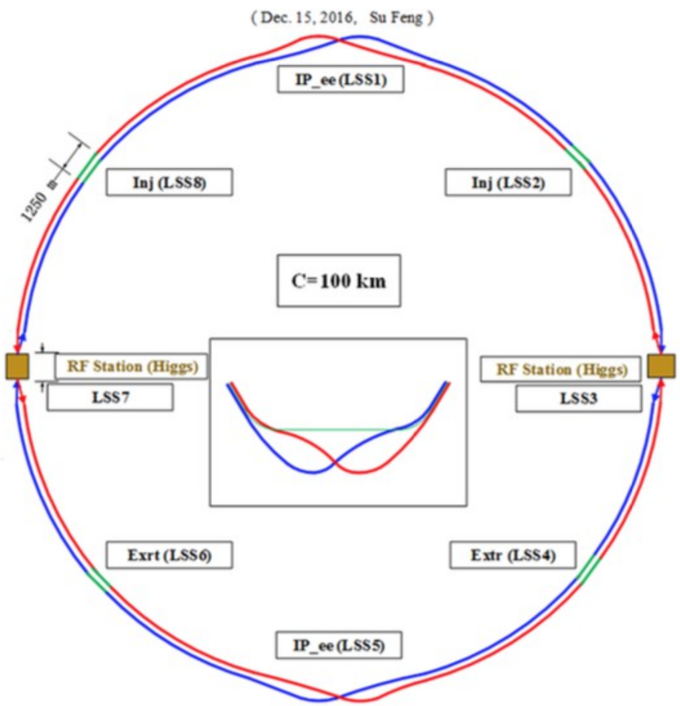
March 2015

Current Status and the Plan

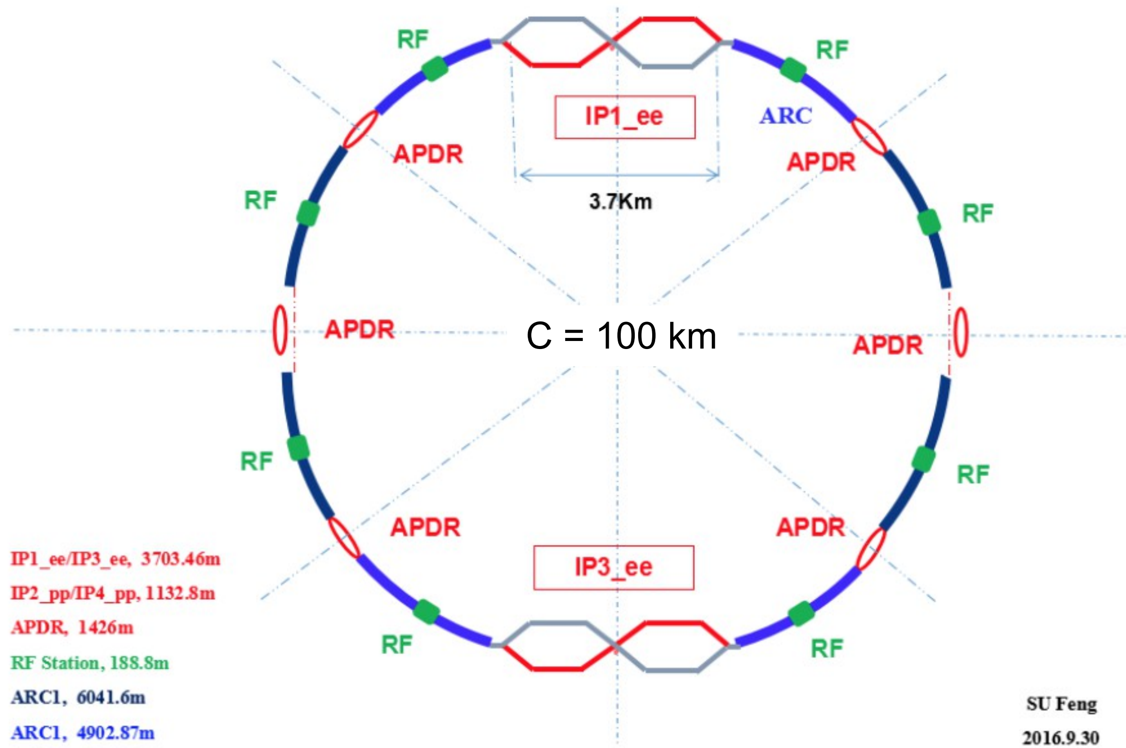
- Pre-CDR completed
  - No show-stoppers
  - Technical challenges identified → R&D issues
  - Preliminary cost estimate
- Working towards CDR
  - A working machine on paper
  - Ready to be reviewed by government at any moment
- R&D issues identified and funding request underway
  - Seed money from IHEP: 12 M RMB/3 yrs
  - MOST: 36 M/5 yr approved, ~40 M to be asked next year
  - NSFC: ~12M RMB approved/4 yrs → 6 M/yr to be approved
  - NCDR: ~0.8 B RMB/5 yr, failed in a voting process
  - CAS: ~ 8M/yr, more under discussion
  - CNSF: under discussion
  - Beijing Municipal Government: R&D platform

CEPC two shcemes towards CDR

Jie Gao



CEPC Advanced Partial Double Ring Option II



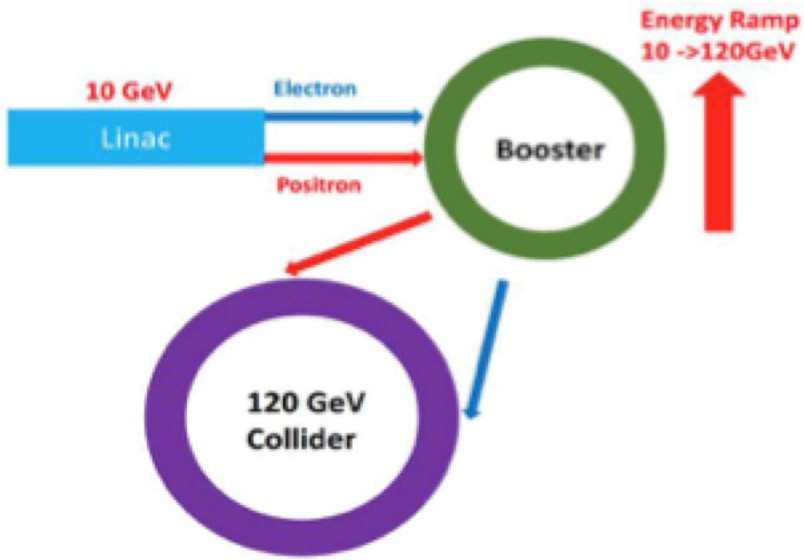
CEPC Baseline Design

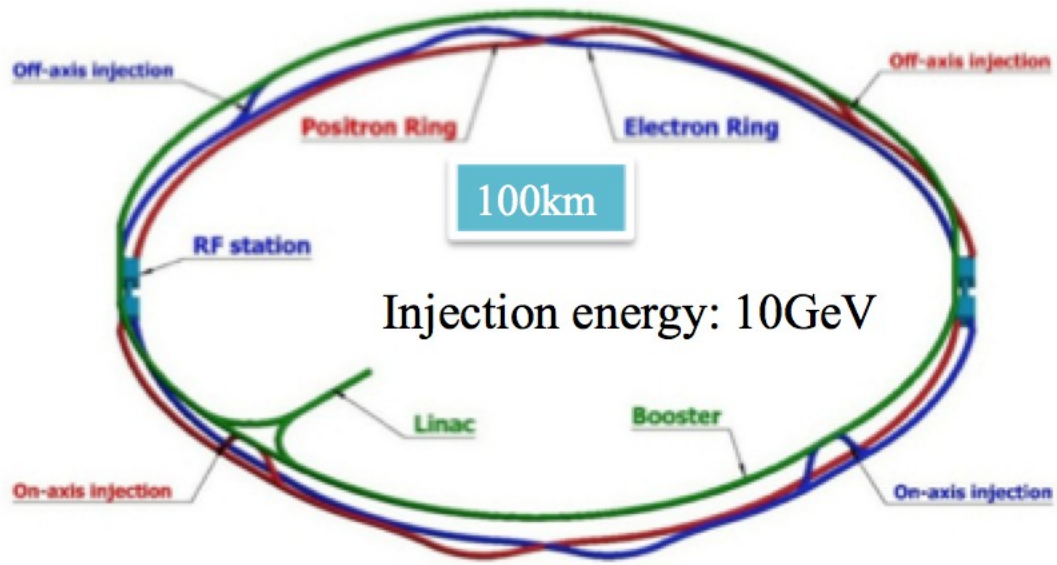
Better performance for Higgs and Z compared with alternative scheme, without bottle neck problems, but with higher cost

CEPC Alternative Design

Lower cost and reaching the fundamental requirement for Higgs and Z luminosities, under the condition that sawtooth and beam loading effects be solved

Accelerator Baseline for the CDR



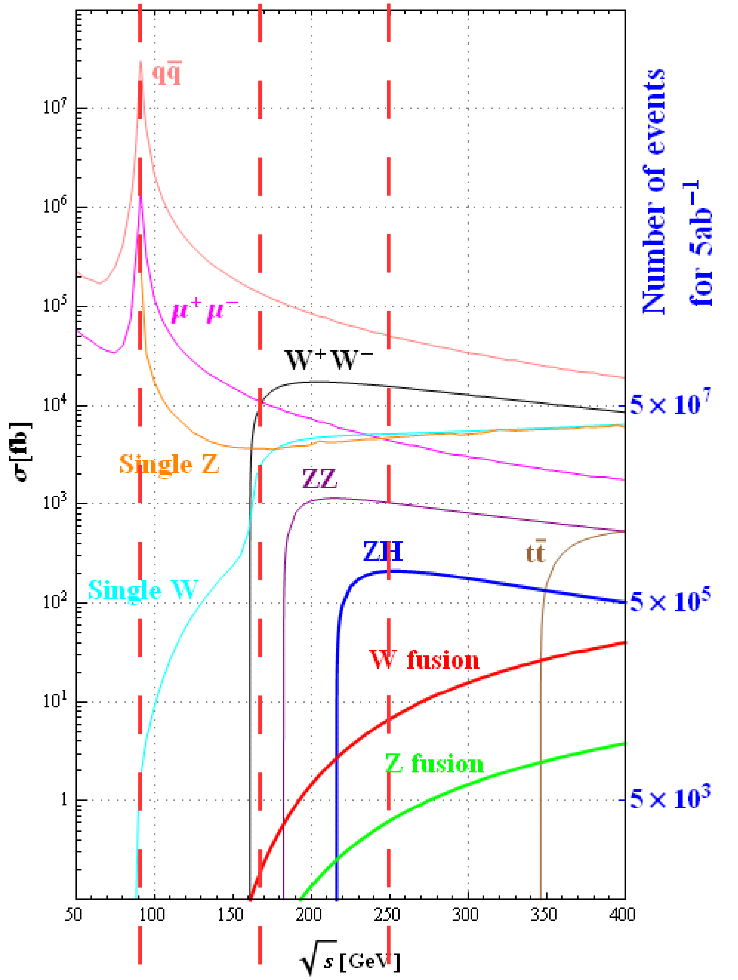


- 10 GeV linac provides electron and positron beams for booster.
- Top up injection for collider ring ~ 3% current decay
- Booster is in the same tunnel as collider ring, above the collider ring.
- Double ring collider with 2 IPs, crab-waist collision
- Collider ring adopt twin-aperture quadrupoles and dipoles in the ARC

CEPC Beam parameters

	Higgs	*W*	*Z (3T)*	*Z (2T)*
Number of IPs	2			
Beam energy (GeV)	120	80	45.5	
Circumference (km)	100			
Synchrotron radiation loss/turn (GeV)	1.73	0.34	0.036	
Crossing angle at IP (mrad)	16.5×2			
Piwinski angle	2.58	7.0	23.8	
Number of particles/bunch N_e (10^{10})	15.0	12.0	8.0	
Bunch number (bunch spacing)	242 (0.68μs)	1524 (0.21μs)	12000 (25ns+10%gap)	
Beam current (mA)	17.4	87.9	461.0	
Synchrotron radiation power /beam (MW)	30	30	16.5	
Bending radius (km)	10.7			
Momentum compact (10^{-5})	1.11			
β function at IP β_x^* / β_y^* (m)	0.36/0.0015	0.36/0.0015	0.2/0.0015	0.2/0.001
Emittance $\varepsilon_x/\varepsilon_y$ (nm)	1.21/0.0031	0.54/0.0016	0.18/0.004	0.18/0.0016
Beam size at IP σ_x/σ_y (μm)	20.9/0.068	13.9/0.049	6.0/0.078	6.0/0.04
Beam-beam parameters ξ_x/ξ_y	0.031/0.109	0.013/0.106	0.0041/0.056	0.0041/0.072
RF voltage V_{RF} (GV)	2.17	0.47	0.10	
RF frequency f_{RF} (MHz) (harmonic)	650 (216816)			
Natural bunch length σ_z (mm)	2.72	2.98	2.42	
Bunch length σ_z (mm)	3.26	5.9	8.5	
HOM power/cavity (2 cell) (kw)	0.54	0.75	1.94	
Natural energy spread (%)	0.1	0.066	0.038	
Energy acceptance requirement (%)	1.35	0.4	0.23	
Energy acceptance by RF (%)	2.06	1.47	1.7	
Photon number due to beamstrahlung	0.29	0.35	0.55	
Lifetime simulation (min)	100			
Lifetime (hour)	0.67	1.4	4.0	2.1
F (hour glass)	0.89	0.94	0.99	
Luminosity/IP *L* (10^{34}cm^{-2}s^{-1})	2.93	10.1	16.6	32.1

Boson yields @ CEPC



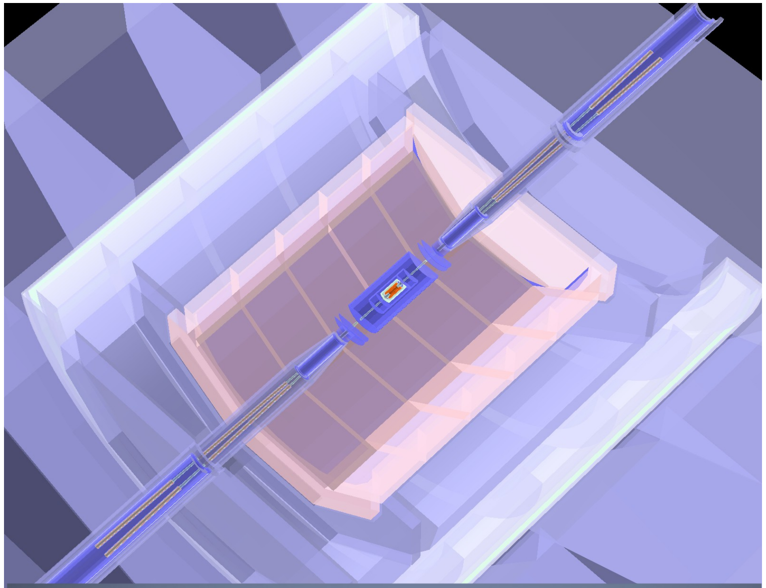
Operation mode	Z factory	W threshold scan	Higgs factory
$\sqrt{s}/GeV$	91.2	161	240
$L/10^{34}cm^{-2}s^{-1}$	16-32	10	3
Running time/year	1-2	1-2	8-10
Higgs yield	-	-	10^6
W yield	-	10^8	10^8
Z yield	10^{10-11}	10^9	10^9

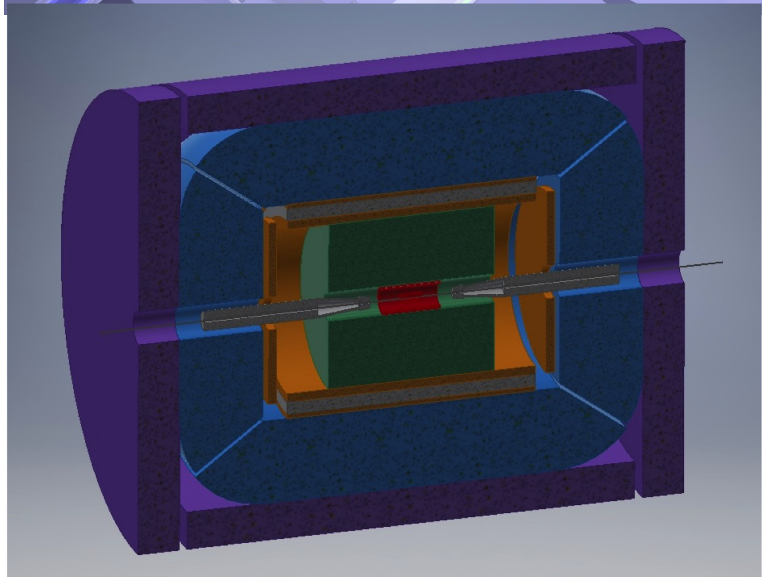
CEPC Baseline Accelerator design:

High productivity for all massive SM bosons.

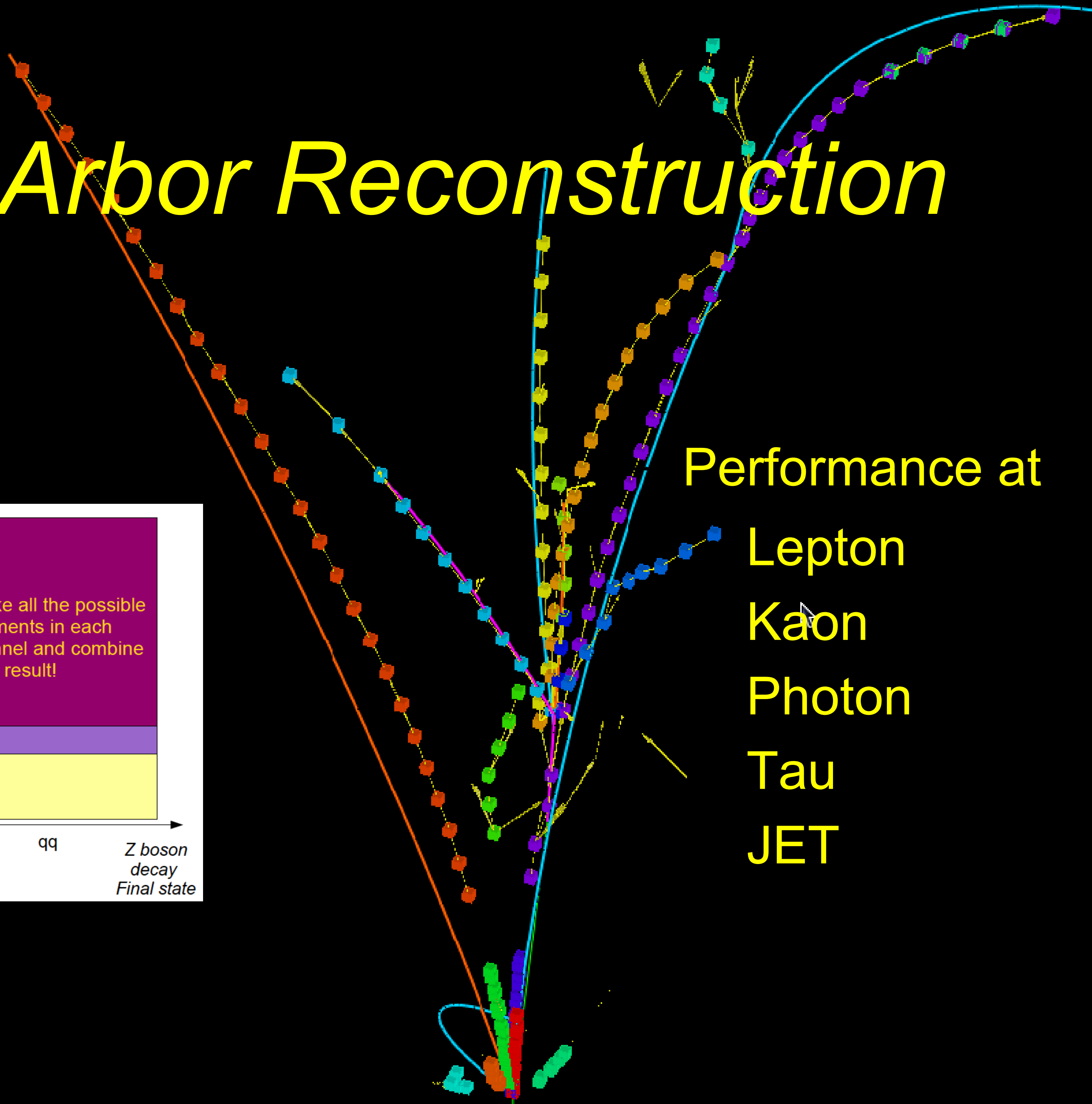
Detectors for the CDR

- APODIS (Baseline)
  - A PFA Oriented Detector for HIggS factory (Reference: ALEPH, SiD and **ILD**)
  - Low material tracker + ultrahigh granularity calorimeter (serve also as ToF) + large Solenoid
  - Dedicated MDI
  - Fully implemented into Geant 4 simulation and full reconstruction
  - Optimized versus Physics Benchmarks
- IDEA (Alternative)
  - Wire Chamber + Dual Readout based: implementing into full simulation
- Multiple detectors & New ideas are welcome!



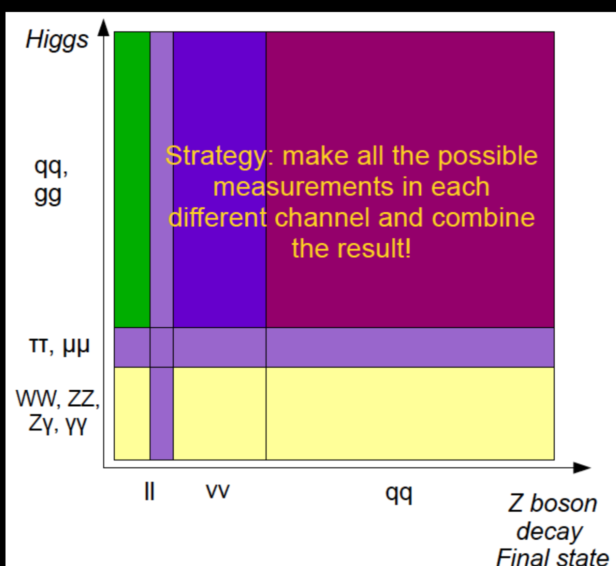


Arbor Reconstruction

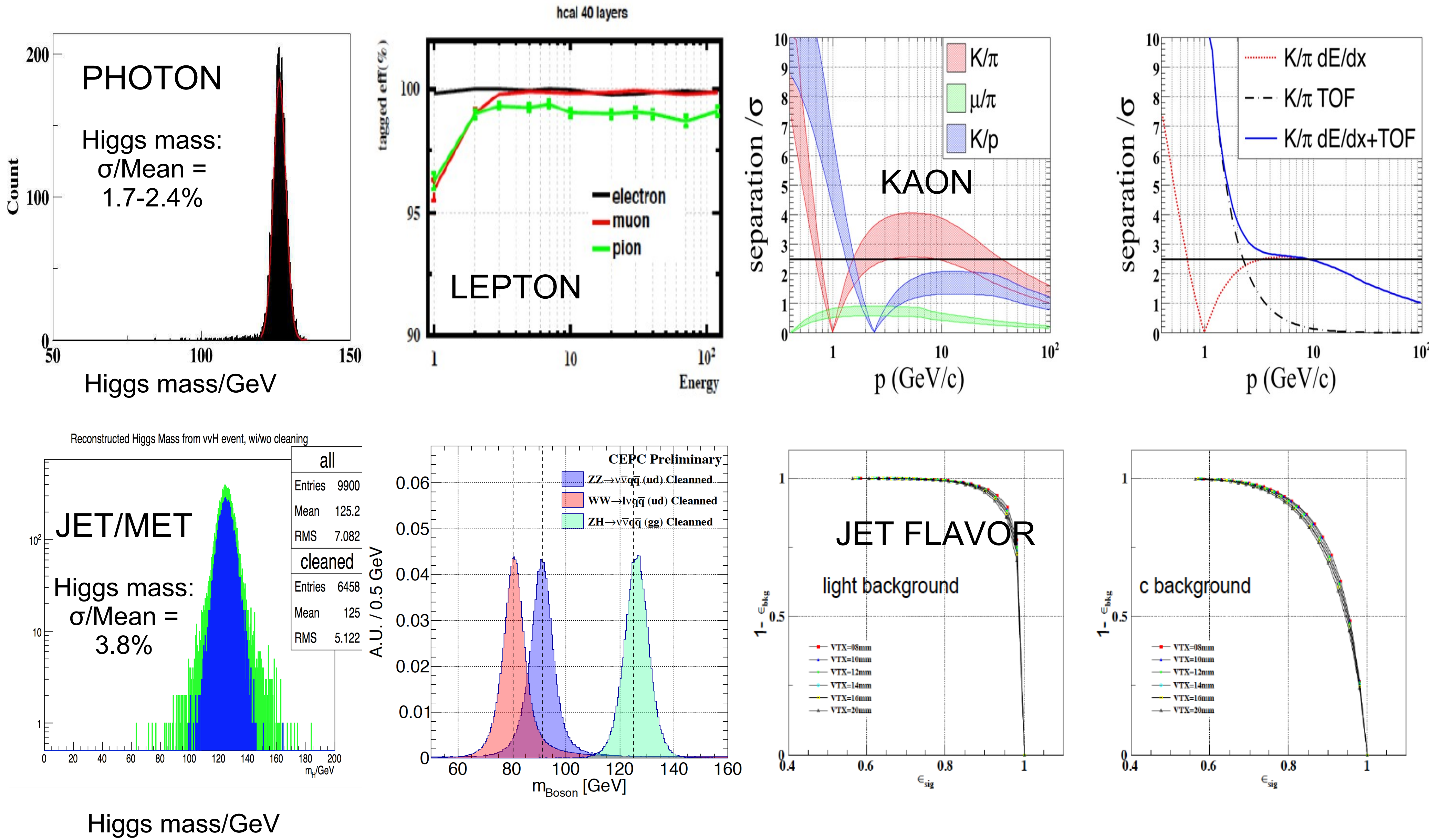


Performance at

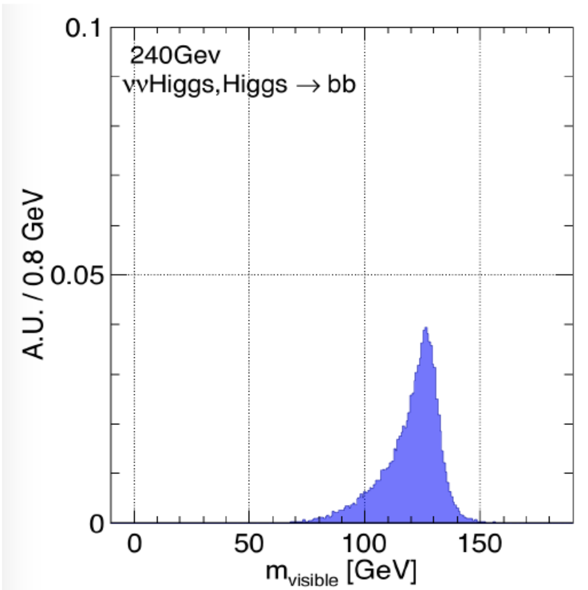
- Lepton
- Kaon
- Photon
- Tau
- JET

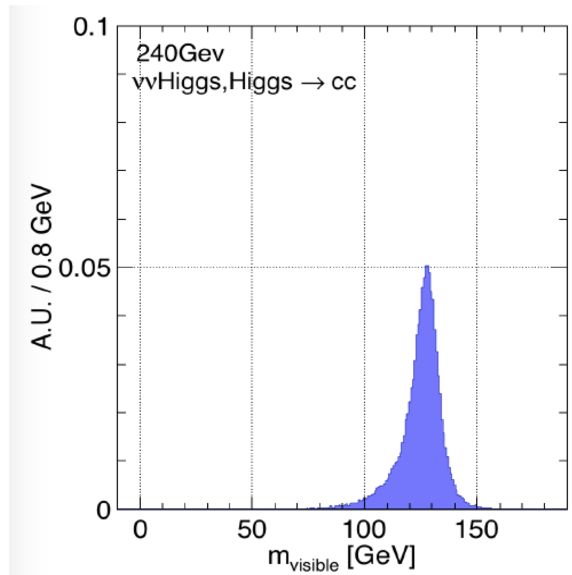


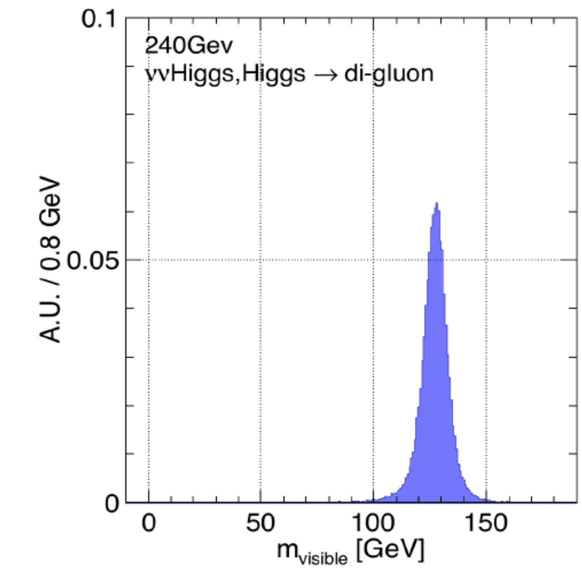
PFA Oriented Reconstruction

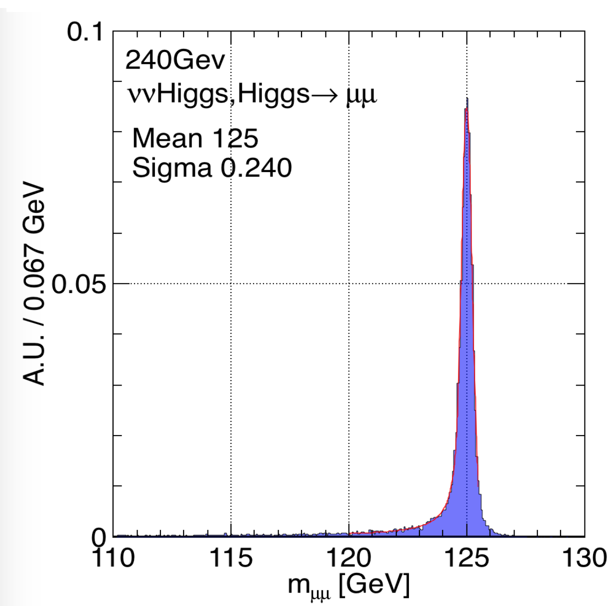


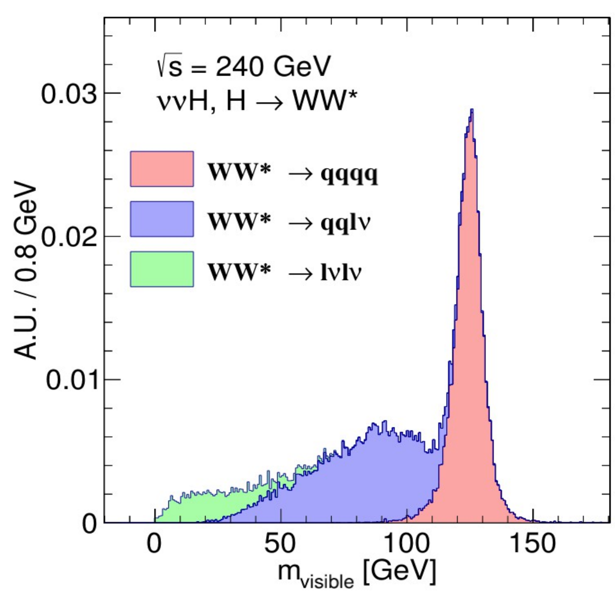
Higgs Signals at APODIS

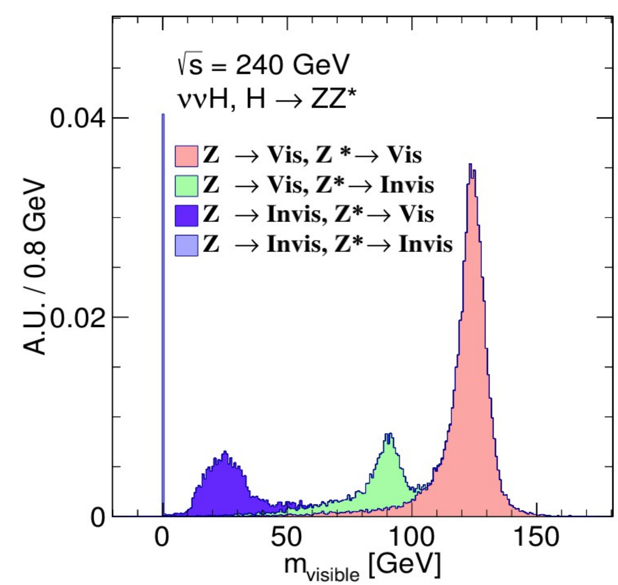






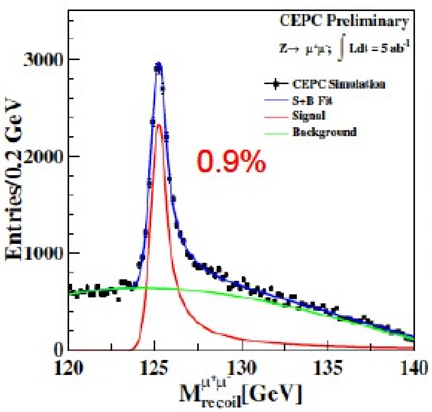


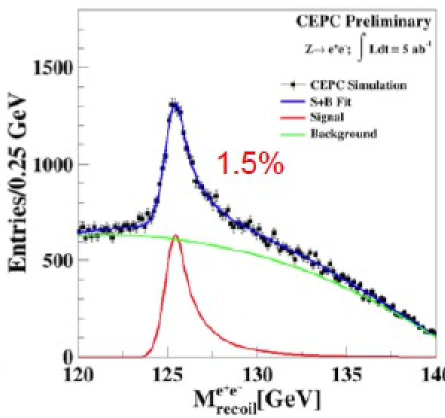




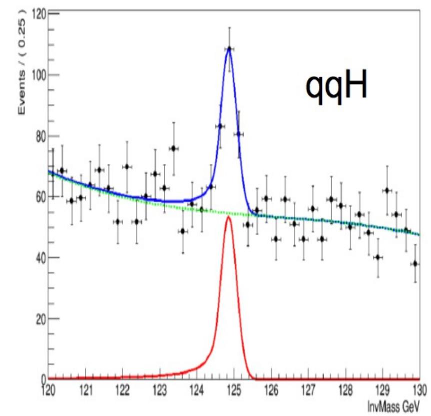
CEPC: absolute Higgs measurements

Zhenxing Chen & Yacine Haddad

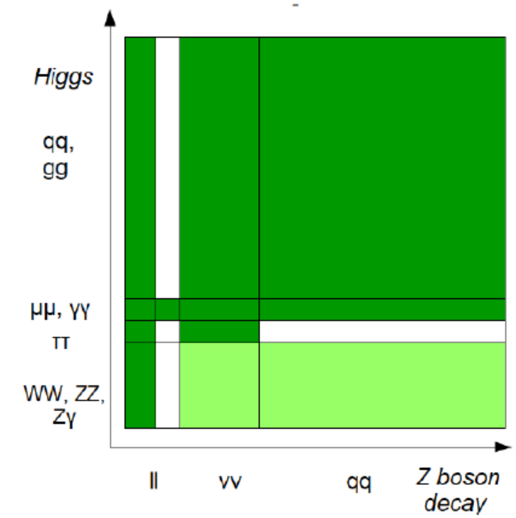




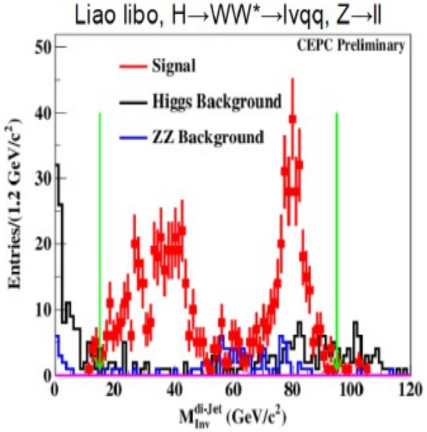
σ(ZH) measurements



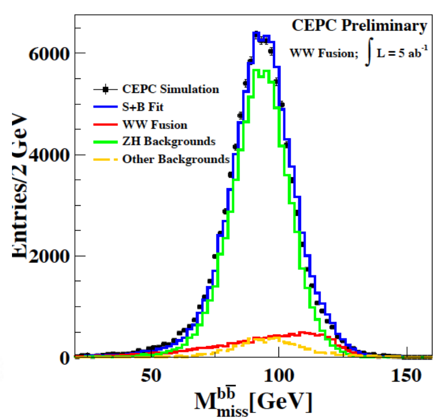
Br(H→μμ)



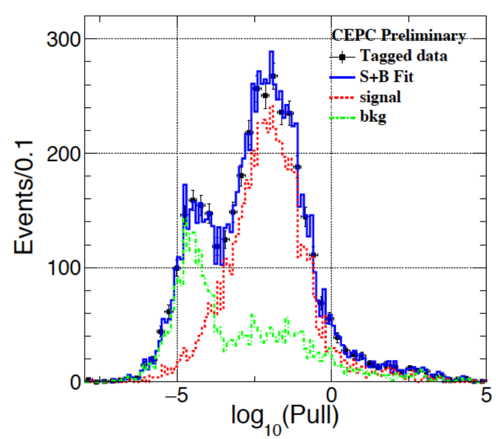
Liao libo, H→WW*→lνqq, Z→ll



Br(H→WW)



σ(ννH)*Br(H→bb)

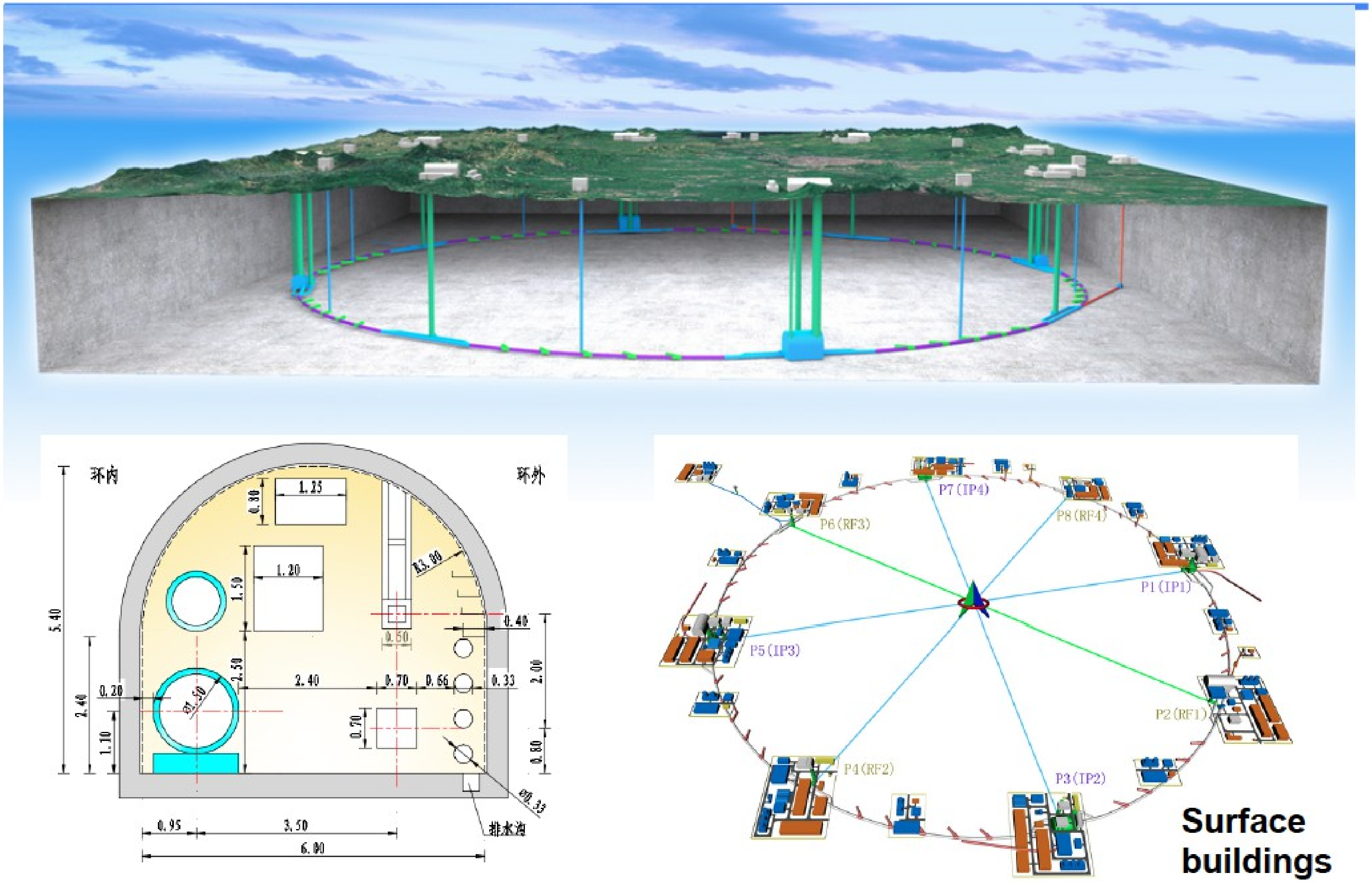


Br(H→ττ)

	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%	1.2%
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%	12%
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

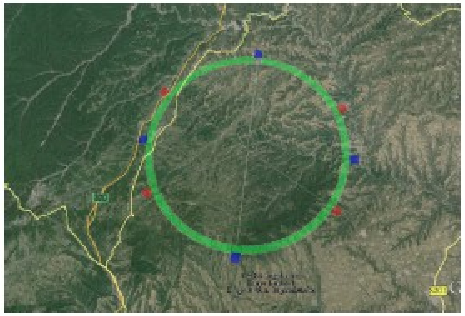
See Dan's talk for more detail

Civil Construction



Site selections (a few main candidates)

1)



2)

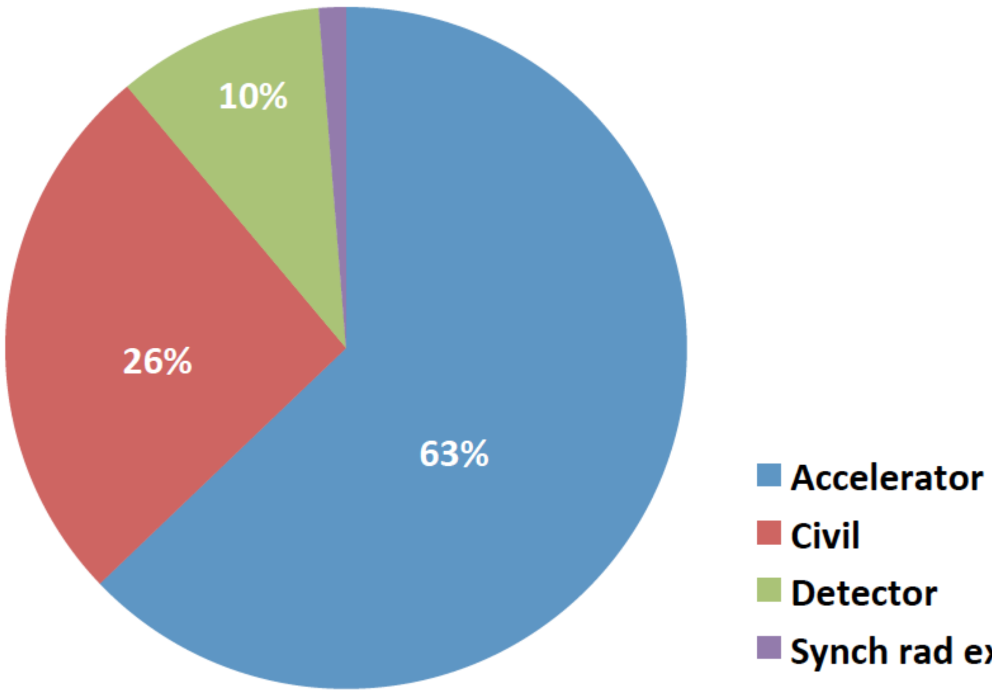
3)

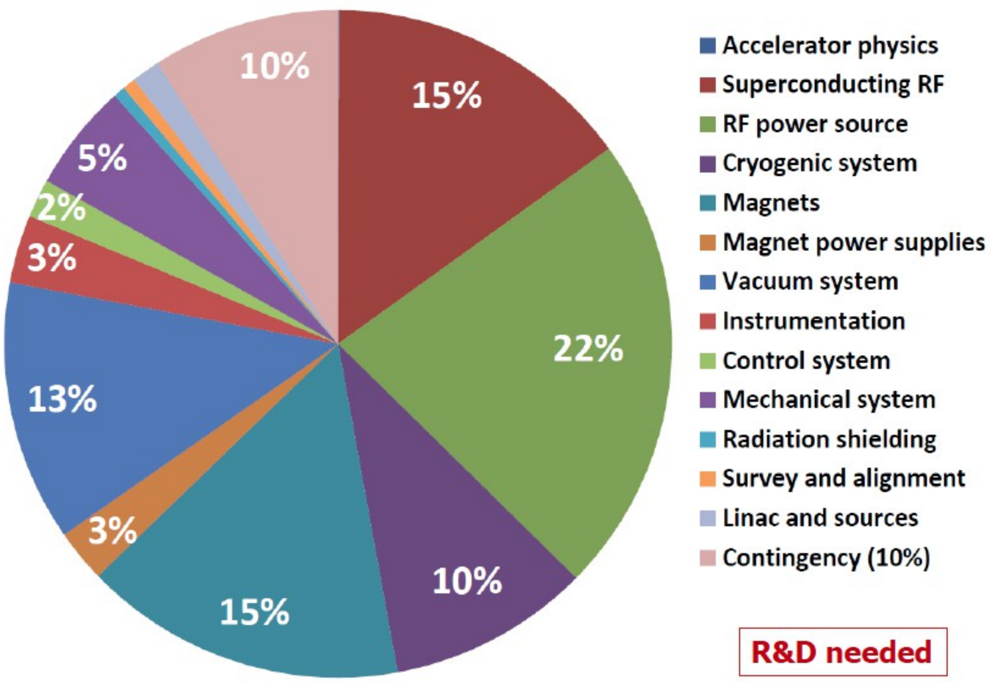
1) Qinhuangdao

2) Shanxi Province

3) Near Shenzhen and Hongkong

Cost estimation





- Preliminary: 25/36 Billion CNY at 50/100km Circumference

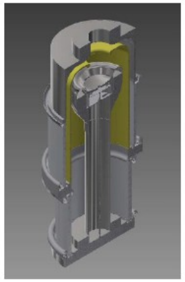
Progress in Key R&D

RF power source: Efficiency

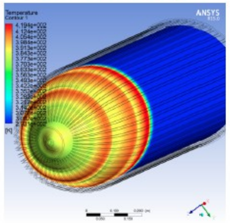
Key parameters of NEW klystron design

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

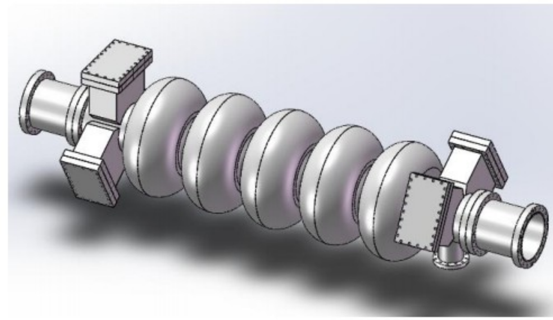
- Largest SRF system next to ILC
- Technically challenge
- Used by all future acclerators
- Key factors for the cost

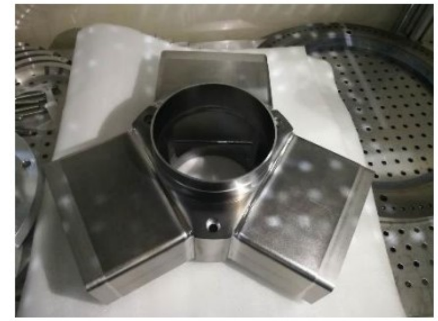
- Accelerator: Key technology development on going (budget + power)
  - *RF source (efficiency)*
  - *High Q SRF cavities*
  - High power Cryogenic system
  - Beam Monitoring and Diagnostics
  - High field SC magnets

…

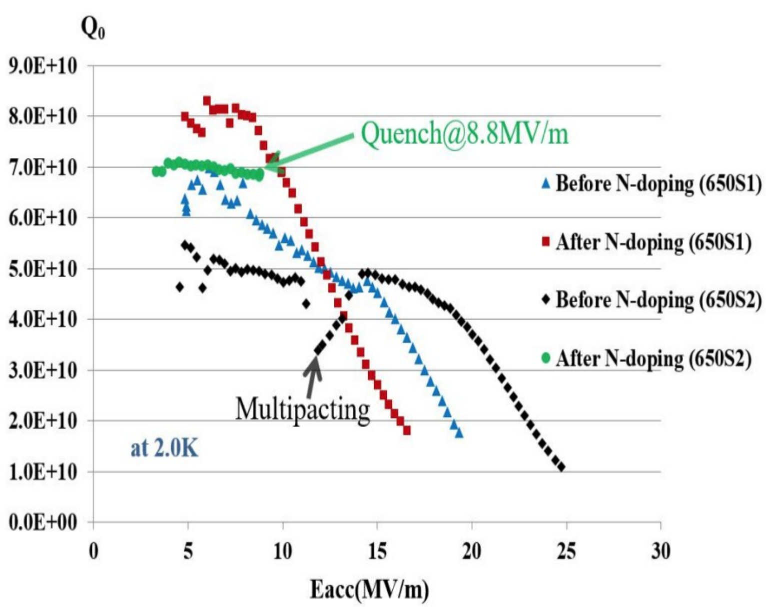
SRF prototyping & tests

650 MHz 2-cell cavity





650 MHz 5-cell cavity with waveguide HOM coupler



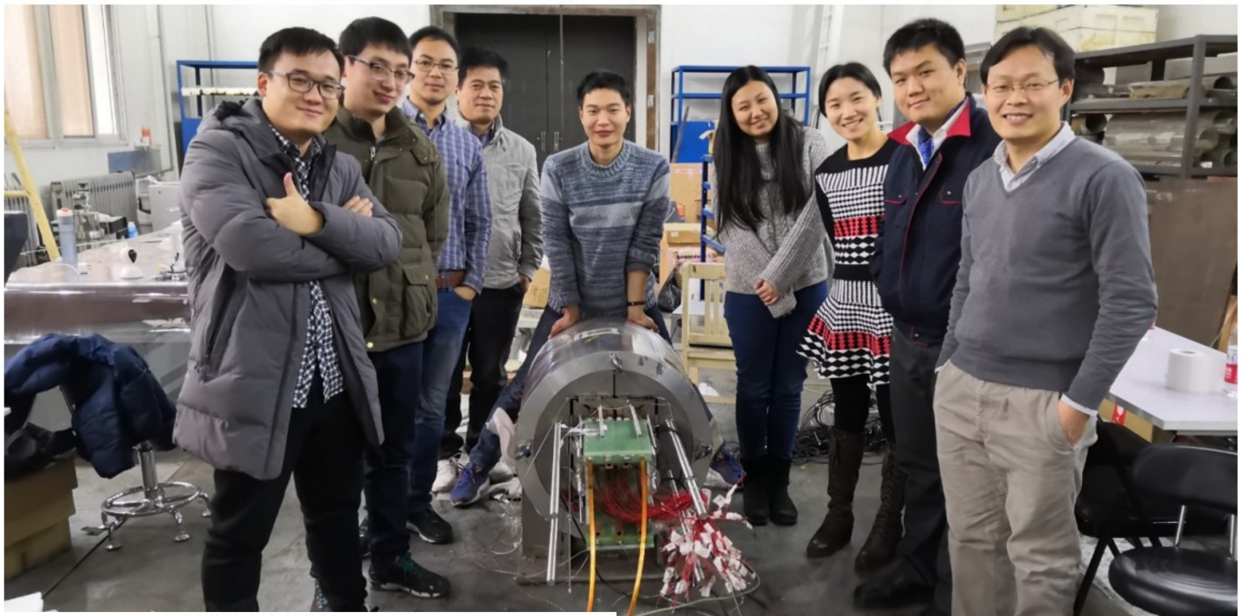
New furnaces for
N-doping and infusion study

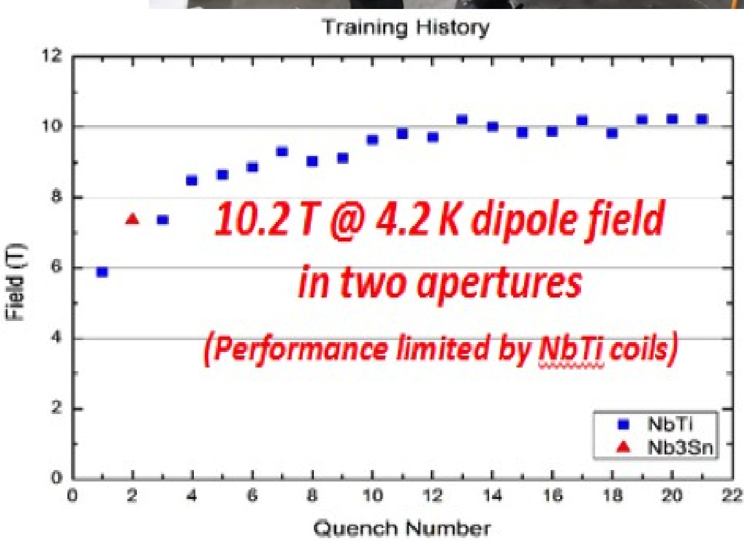
Helmholtz coil & flux gate
for high Q research

HTC Superconducting Cables

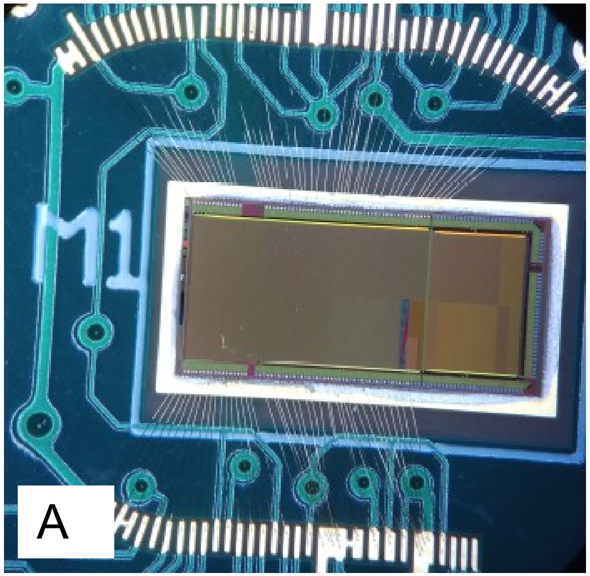
- Huge impact If magnet can be used at ~ 4.5K - 20 K
- Fe-based HTC cable
  - Metal, easy to process; Isotropic; Cheap in principle
- Background in CAS
  - World highest Tc Fe-based materials
  - World first ~ 115 m Fe-based SC cables: 12000 A/cm^2 @ 10 T
- A collaboration on “HTC SC materials” : Institute of Physics, USTC, Institute of electric engineering, IHEP, 3 SC cable companies in China
  - Iron based HTC cables
  - ReBCO & Bi-2212
  - Goal: ~ 3-5 \$ /kA·m
    - Current density: × 10
    - Cost/m: ÷10

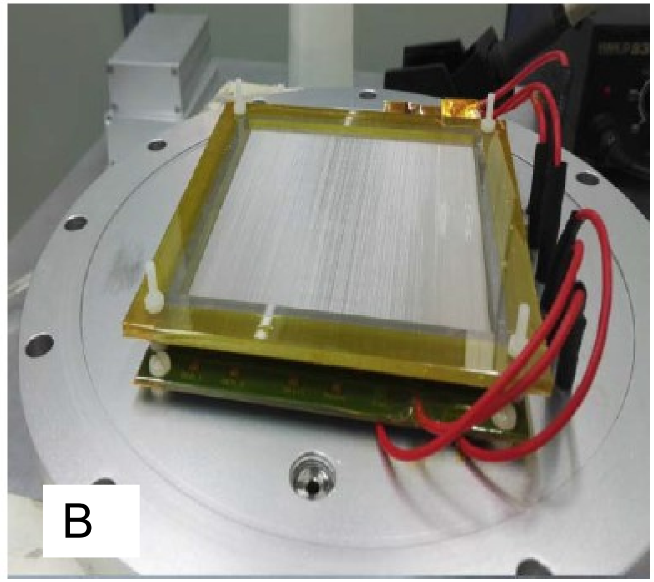
Dipole Prototype: B = 10.2T @ 4.2K

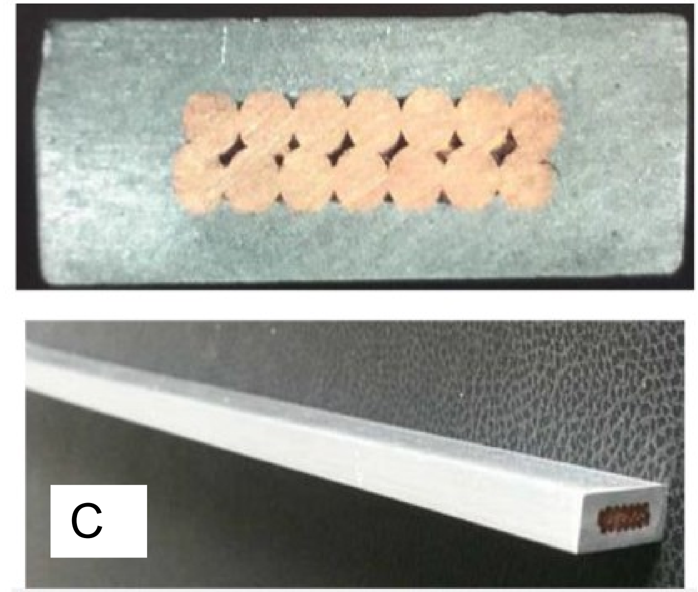


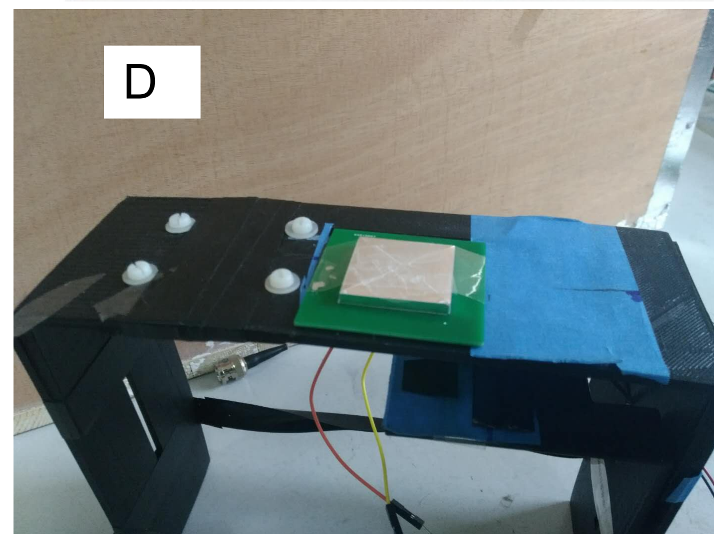


Detector studies









A: Silicon Sensor wire binding & test

B: TPC amplification module

C: Rutherford cable for the Solenoid

D: Calorimeter sensor test

Collaboration with industry

The CEPC Industrial Promotion Consortium (CICP) is established in Nov 2017. More than 50 companies joined CICP, with expertise on superconductor, superconducting cavities, cryogenics, vacuum, klystron, electronics, power supply, civil engineering, precise machinery, etc. The CIPC serves as a communication forum for the industrial and the HEP community.

Summary

- CEPC, a productive and clean Higgs/W/Z factory,
  - Boost our precision horizon by at least 1 order of magnitude w.r.t our current knowledge and the HL-LHC
  - Surprises
- CDR Studies
  - Accelerator: Baseline design secures high productivity for Higgs, Z and W bosons.
  - Detector: Baseline design exhibit high efficiency/accuracy reconstruction of all key physics objects + clear Higgs signal in every SM decay channel.
  - Alternative designs, New ideas are always welcome
- Key technology development: significant progresses & link to industrial

Significant Progress are made – challenges & interesting topics everywhere

Your ideas and participations are more than welcome!

The FCPPL is extremely helpful for the CEPC studies. Let's keep the momentum!

Thank you!

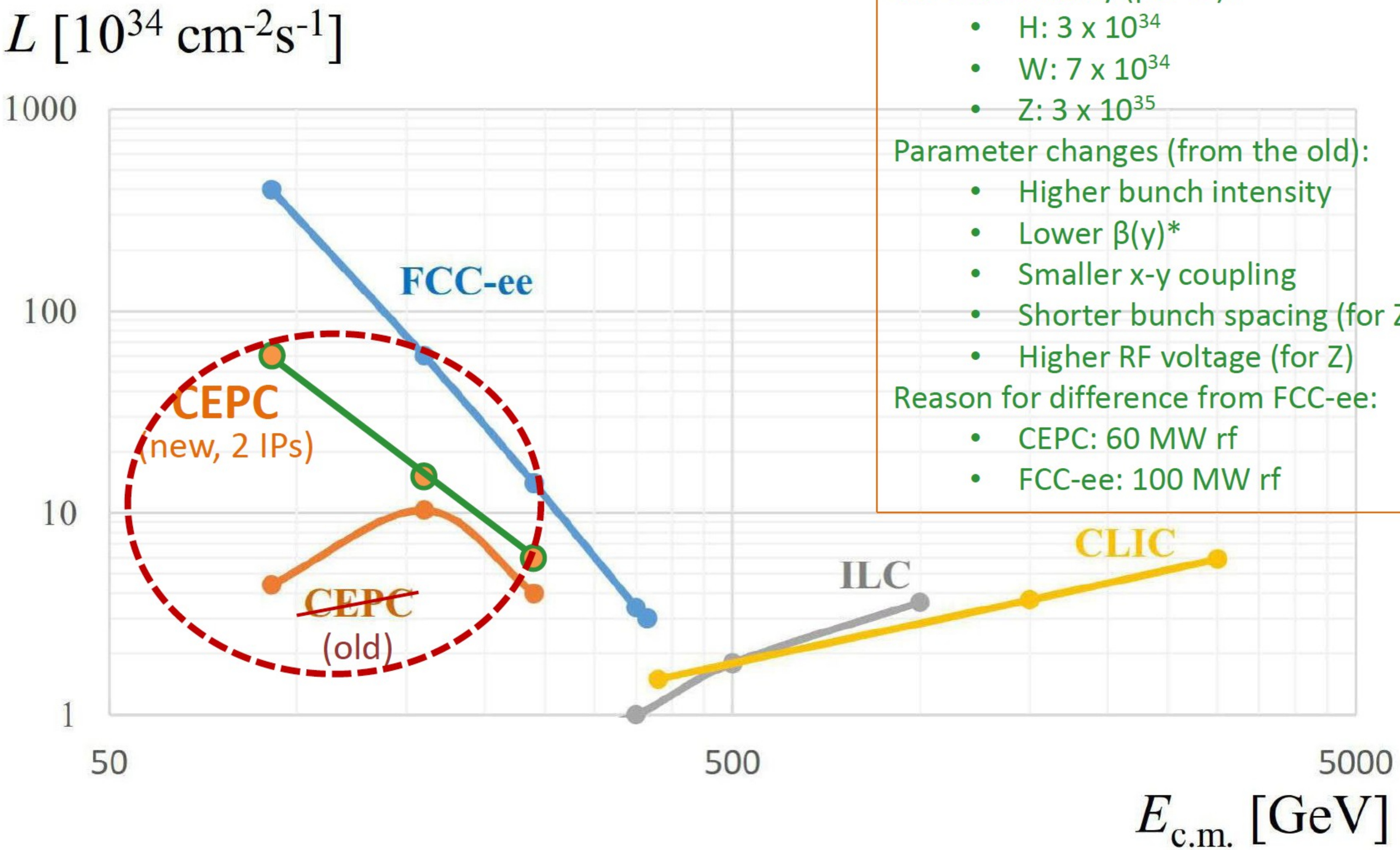
Critical Tasks for detector design

- MDI:
  - L* optimization, beam background analysis & detector protection
  - LumiCal, Luminosity monitoring study
- VTX: Critical R&D & Synergy with ATLAS upgrade
- Main Tracker
  - Feasibility of TPC: Maximal event rate, ion feedback (JINST 2017_12_P07005)
  - Large area silicon detector R&D
  - Stability & Alignment study
- Calorimeter
  - Digitization, development of Energy Estimation, Integration...
- Yoke & Muon System
  - Thickness: Outer B-Field Leakage & Inner B-Field Homogeneity

Example Working Points & Performance for Object identification (Preliminary)

	Efficiency	Purity	Mis-id Probability from Main Background
Leptons	99.5 – 99.9%	99.5 – 99.9% at Higgs Runs(c.m.s = 240 GeV), Energy dependent	$P(\pi^{\pm} \rightarrow leptons) < 1\%$
Photons*	99.3 – 99.9%	99.5 – 99.9% at Higgs Runs Energy Dependent	$P(\text{Neutron} \rightarrow \gamma) = 1\text{-}5\%$
Charged Kaons**	86 – 99%	90 – 99% at Z pole Runs (c.m.s = 91.2GeV, Track Momentum 2- 20 GeV)	$P(\pi^{\pm} \rightarrow K^{\pm}) = 0.3 - 1.1\%$
b-jets	80%	90% at Z pole runs $(Z \rightarrow qq)$	P(uds → b) = 1% P(c → b) = 10%
c-jets	60%	60% at Z pole runs	P(uds → c) = 5% P(b → c) = 15%

CEPC Luminosity



CEPC luminosity (per IP):

- H: 3×10^{34}
- W: 7×10^{34}
- Z: 3×10^{35}

Parameter changes (from the old):

- Higher bunch intensity
- Lower β(y)*
- Smaller x-y coupling
- Shorter bunch spacing (for Z)
- Higher RF voltage (for Z)

Reason for difference from FCC-ee:

- CEPC: 60 MW rf
- FCC-ee: 100 MW rf

CEPC CDR Baseline Parameters (Jan. 2018)

D. Wang

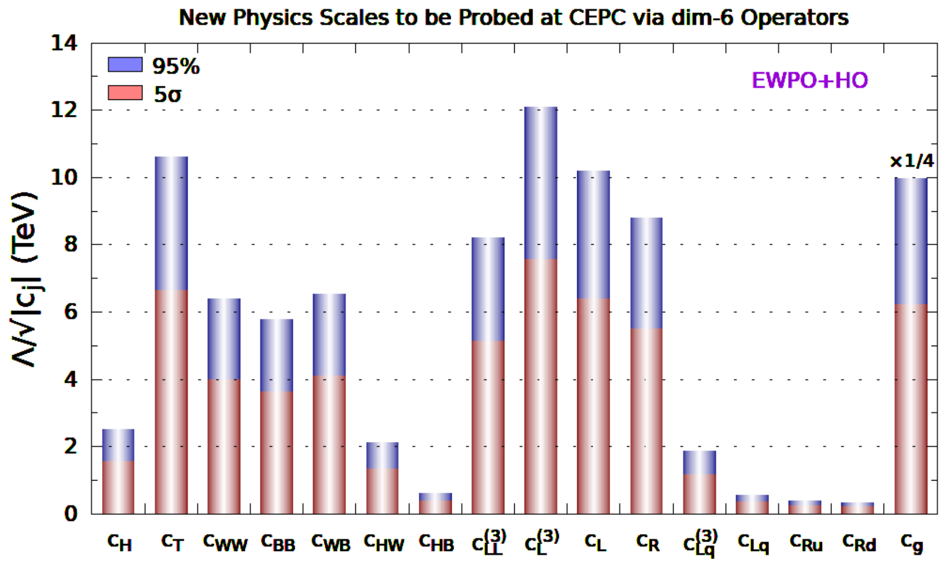
	Higgs	*W*	*Z*
Number of IPs		2	
Energy (GeV)	120	80	45.5
Circumference (km)		100	
SR loss/turn (GeV)	1.73	0.34	0.036
Half crossing angle (mrad)		16.5	
Piwinski angle	2.58	4.29	16.4
N_e/bunch (10^{10})	15	5.4	4.0
Bunch number (bunch spacing)	242 (0.68us)	3390 (98ns)	8332 (40ns)
Beam current (mA)	17.4	88.0	160
SR power /beam (MW)	30	30	5.73
Bending radius (km)		10.6	
Momentum compaction (10^{-5})		1.11	
β_{IP} x/y (m)	0.36/0.0015	0.36/0.0015	0.2/0.0015
Emittance x/y (nm)	1.21/0.0031	0.54/0.0016	0.17/0.004
Transverse σ_{IP} (um)	20.9/0.068	13.9/0.049	5.9/0.078
ξ_x/ξ_y/IP	0.031/0.109	0.0148/0.076	0.0043/0.04
V_{RF} (GV)	2.17	0.47	0.054
f_{RF} (MHz) (harmonic)		650 (216816)	
Nature bunch length σ_z (mm)	2.72	2.98	3.67
Bunch length σ_z (mm)	3.26	3.62	6.0
HOM power/cavity (kw)	0.54 (2cell)	0.47(2cell)	0.49(2cell)
Energy spread (%)	0.1	0.066	0.038
Energy acceptance requirement (%)	1.52		
Energy acceptance by RF (%)	2.06	1.47	0.76
Photon number due to beamstrahlung	0.29	0.16	0.28
Lifetime due to beamstrahlung (hour)	1.0		
Lifetime (hour)	0.67 (40 min)	2	4
F (hour glass)	0.89	0.94	0.99
L_{max}/IP ($10^{34}cm^{-2}s^{-1}$)	**2.93**	**7.31**	**4.1**

J. Gao, IAS2018

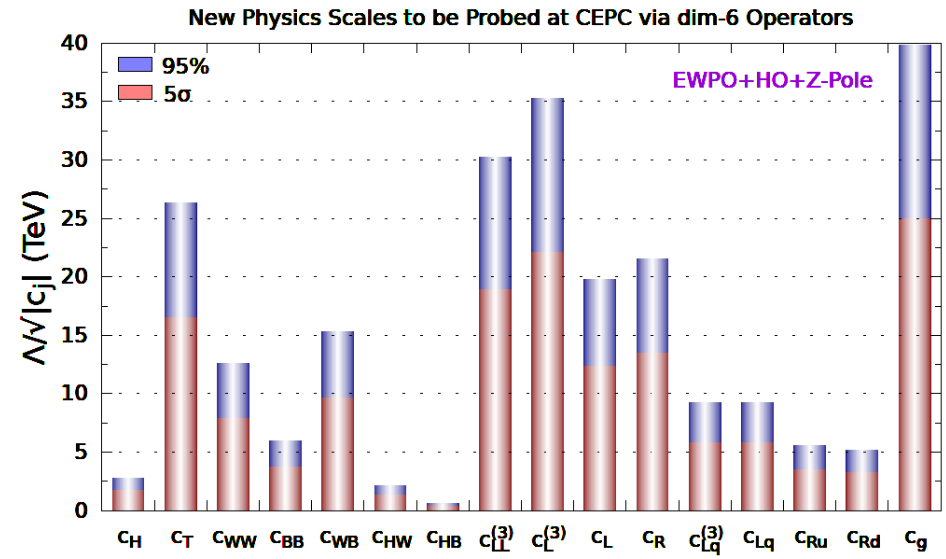
without bootstrapping

New Physics Reach via dim-6 operators

Sensitivities from Existing EWPO & Future HO



Sensitivity from EWPO+HO+Z-Pole

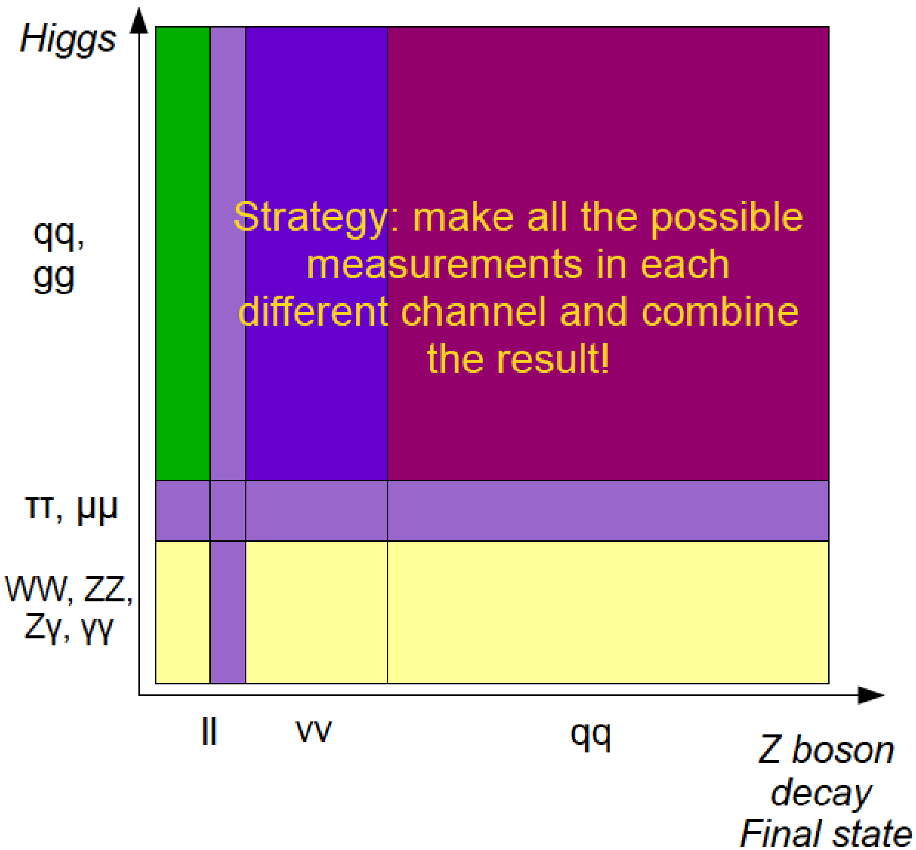


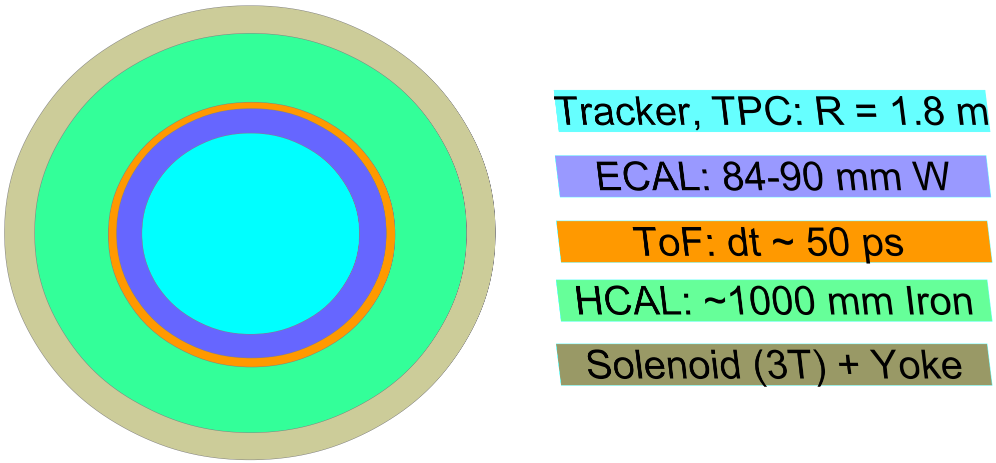
1603.03385

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

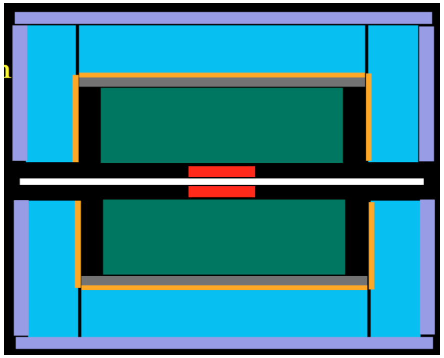
Higgs	EW Gauge Bosons	Fermions
$\mathcal{O}_H = \frac{1}{2}(\partial_\mu \lvert\mathbf{H}\rvert^2)^2$	$\mathcal{O}_{WW} = g^2 \lvert\mathbf{H}\rvert^2 W^a_{\mu\nu} W^{a\mu\nu}$	$\mathcal{O}_L^{(3)} = (i\mathbf{H}^\dagger \sigma^a \overleftrightarrow{D}_\mu \mathbf{H})(\bar{\Psi}_L \gamma^\mu \sigma^a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

Detector Designs





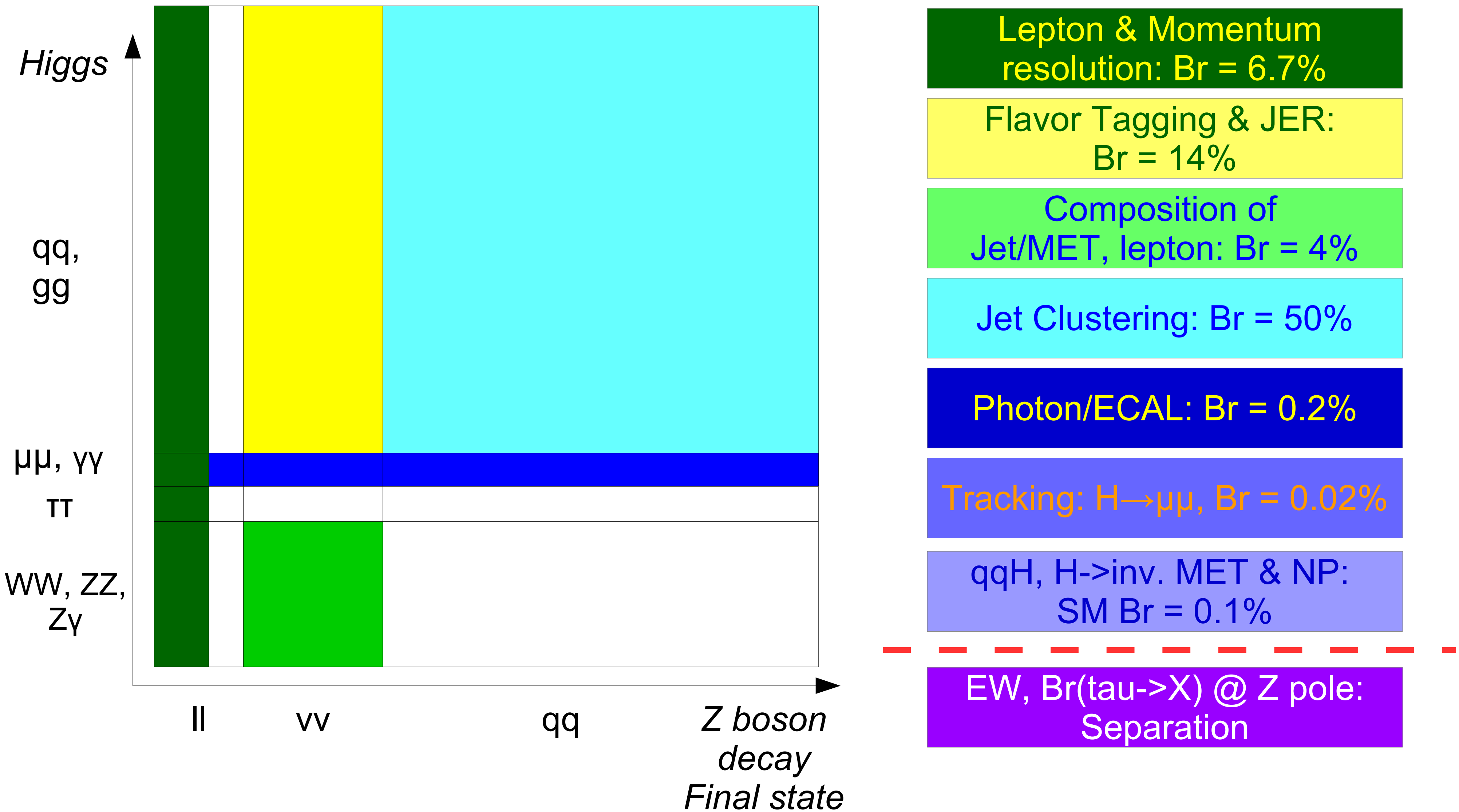
PFA Oriented:
TPC/Silicon + High Granularity Calorimeter



- Beam pipe (R~2 cm)
- VTX: 4-7 MAPS layers
- DCH: 4 m long, R 40-200 cm
- 2 T, R~2 m SC Coil
- Preshower (1-2 X_0)
- DR calorimeter (2 m/8 λ_{int})
- (yoke) muon chambers

Alternative:
Wire Chamber + Dual Readout Calorimeter

Optimization Benchmarks



Feasibility & Optimized Parameters

Feasibility analysis: TPC and Passive Cooling Calorimeter is valid for CEPC

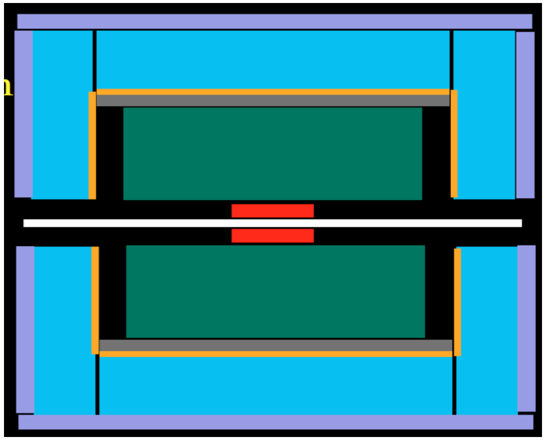
	CEPC_v1 (~ ILD)	Optimized (Preliminary)	Comments
Track Radius	1.8 m	>= 1.8 m	Requested by Br(H->di muon) measurement
B Field	**3.5 T**	**3 T**	**Requested by MDI**
ToF	**-**	**50 ps**	**Requested by pi-Kaon separation at Z pole**
ECAL Thickness	84 mm	84(90) mm	84 mm is optimized on Br(H->di photon) at 250 GeV; 90mm for bhabha event at 350 GeV
ECAL Cell Size	5 mm	10 – 20 mm	Passive cooling request ~ 20 mm. 10 mm should be highly appreciated for EW measurements – need further evaluation
ECAL NLayer	30	20 – 30	Depends on the Silicon Sensor thickness
HCAL Thickness	**1.3 m**	**1 m**	-
HCAL NLayer	**48**	**40**	Optimized on Higgs event at 250 GeV; Margin might be reserved for 350 GeV.

PFA Oriented Detector: Performance

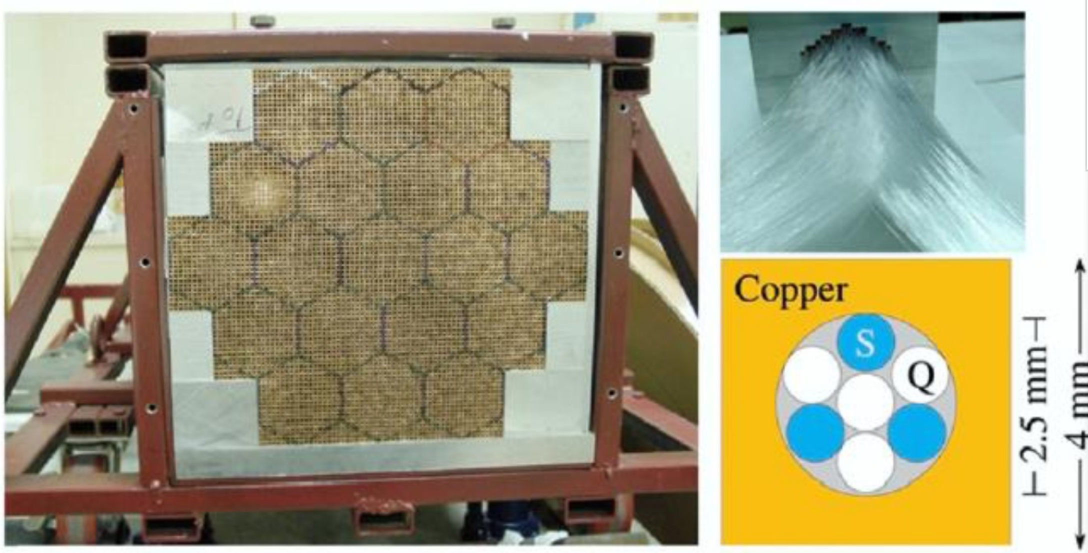
- Solid Angle Coverage : $|\cos(\theta)| < 0.99$
- Lepton id : eff > 99.5%, mis id < 1%
- Calorimeter Shower Separation : 9 – 16 mm
- Tracking: $\delta(1/P_t) \sim 2e\text{-}5\ \text{GeV}^{-1}$, 1 order of magnitude better than current status
- C-tagging is feasible
- Photon Energy resolution: σ/Mean ~ 1.7 – 2.4% for H->γγ events
- Jet Energy resolution: σ/Mean ~ 4% for H->gg events
- Pi-Kaon Separation: at 3-4 sigma level with E < 20 GeV

- Systematic control : ~ 1 order of magnitude better
  - Beam energy monitoring, Calibration, Alignments...

The "IDEA" detector concept



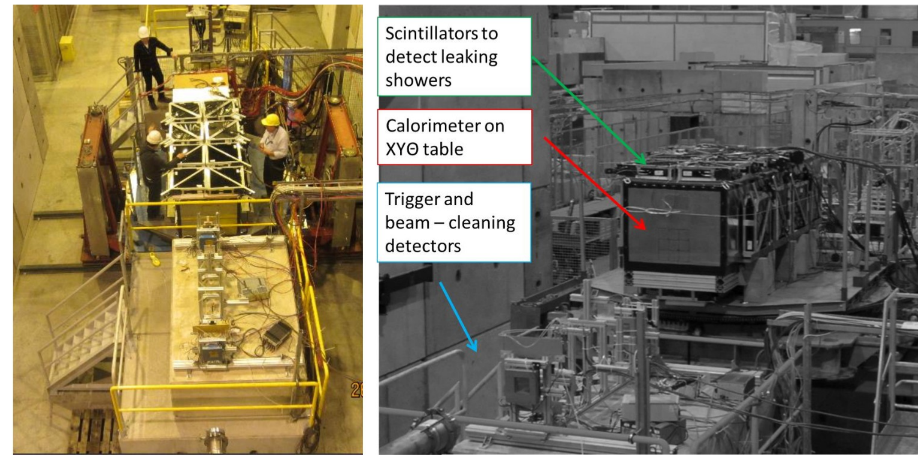
DREAM: Structure



Test beam @ SPS - CERN

RD52 DREAM

S. Franchino - Dual Readout Calorimetry - H.E.P.@ IAS, Hong Kong 2016



Used particles (both polarities): 4 – 180 GeV electrons, pion/protons, muons

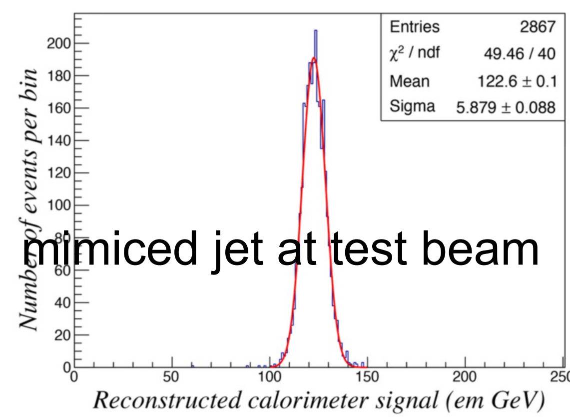
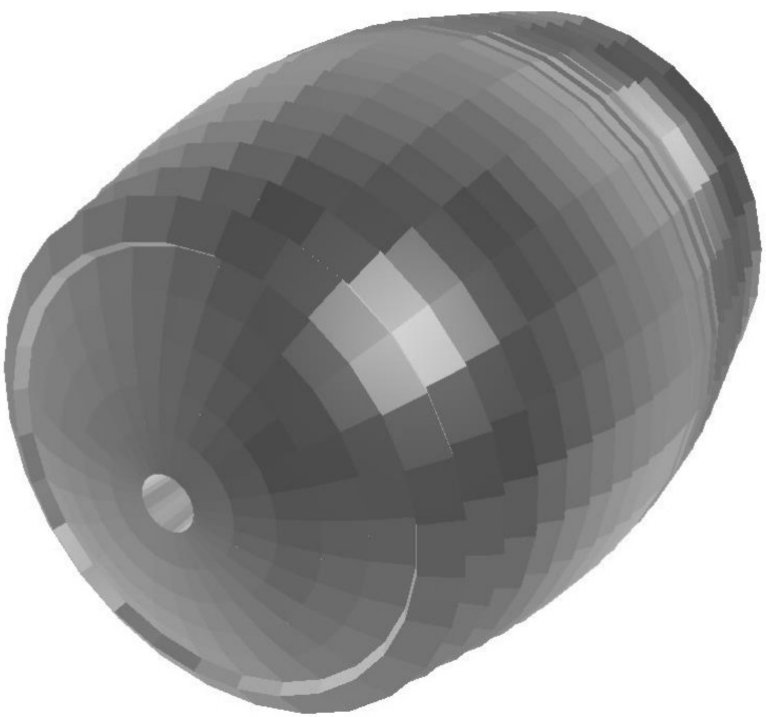
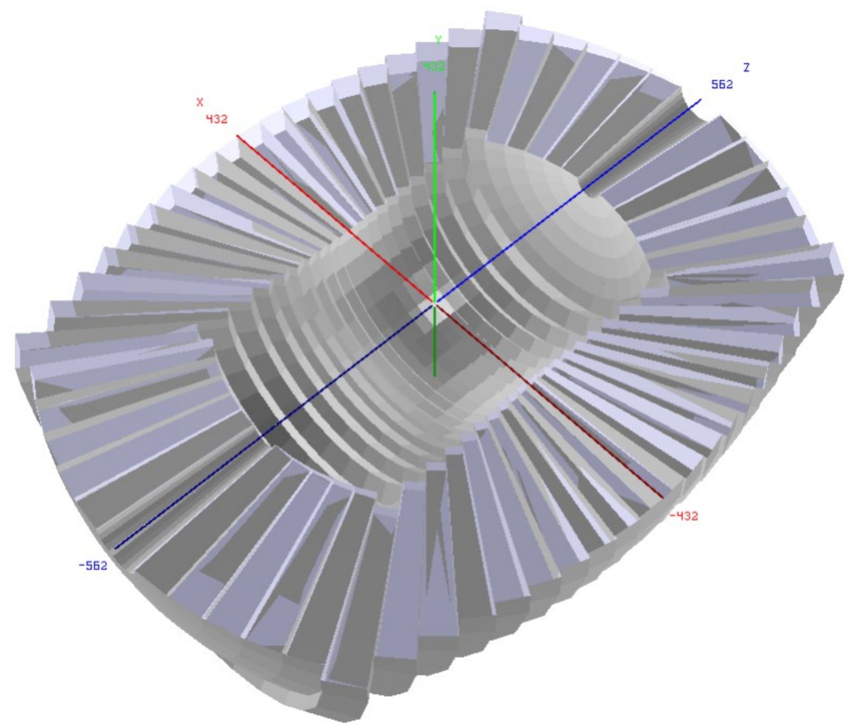


Fig. 18. Signal distribution for 125 GeV multiparticle events obtained with the rotation method described in the text. The energy scale is set by electrons showering in this detector.

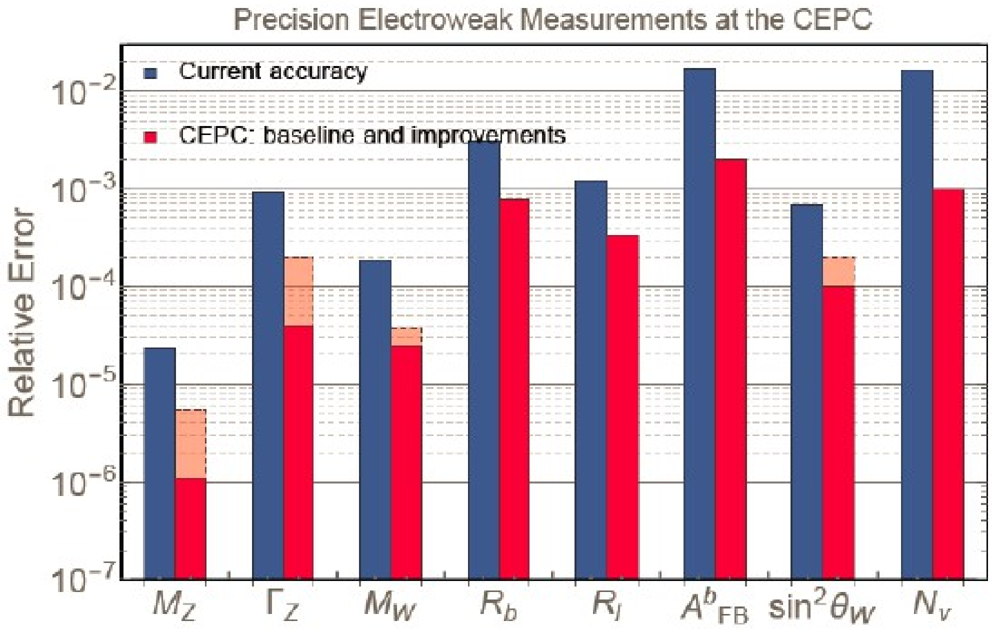
Simulation initialized

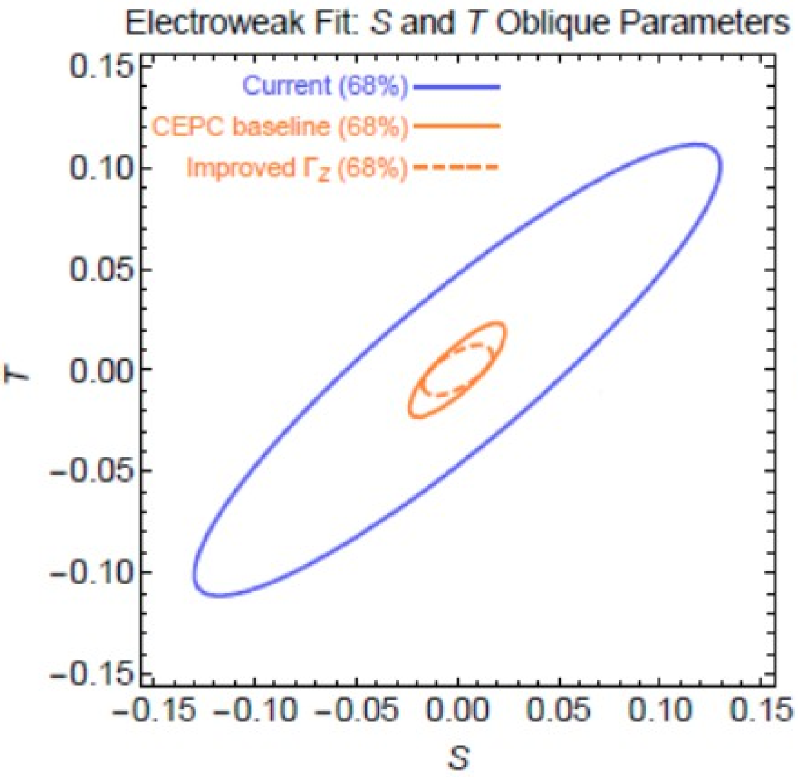
- $N\phi = 28$
- Nbarrel = 10
- Nencap = 5
- $\delta\theta = 0.1$





EW Physics





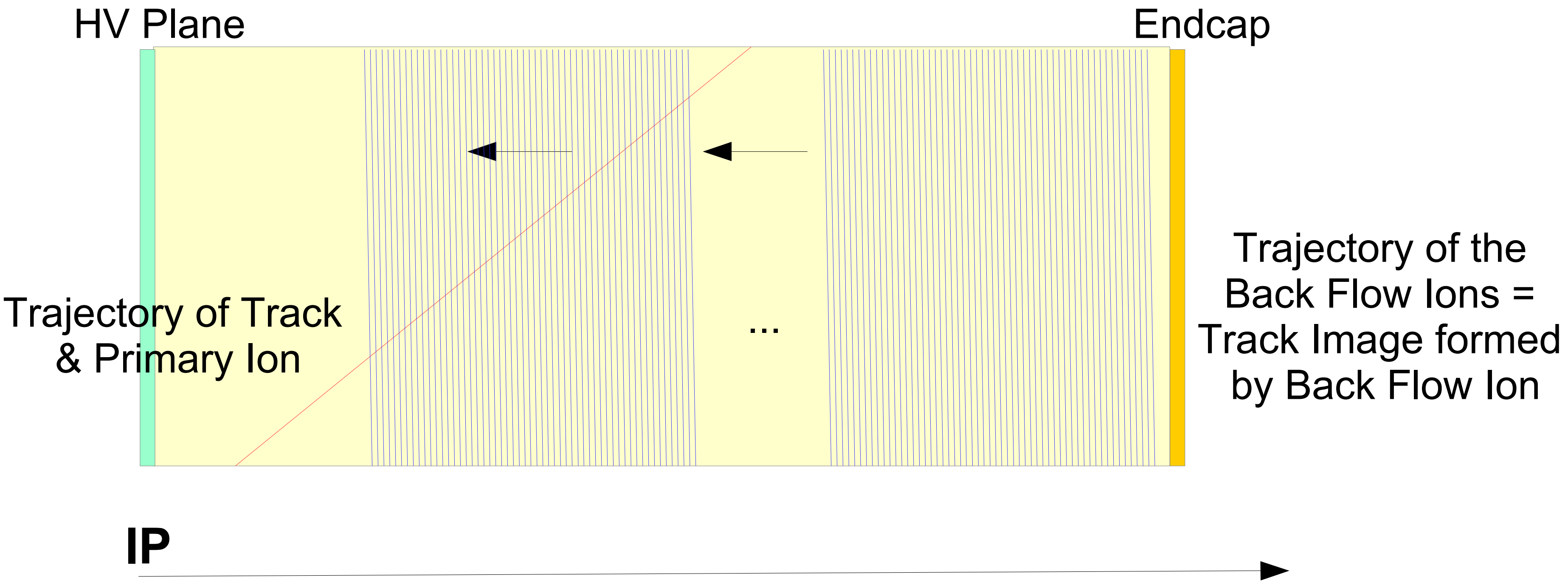
From 10 Billion Z bosons + the data at Higgs runs

TPC Usage

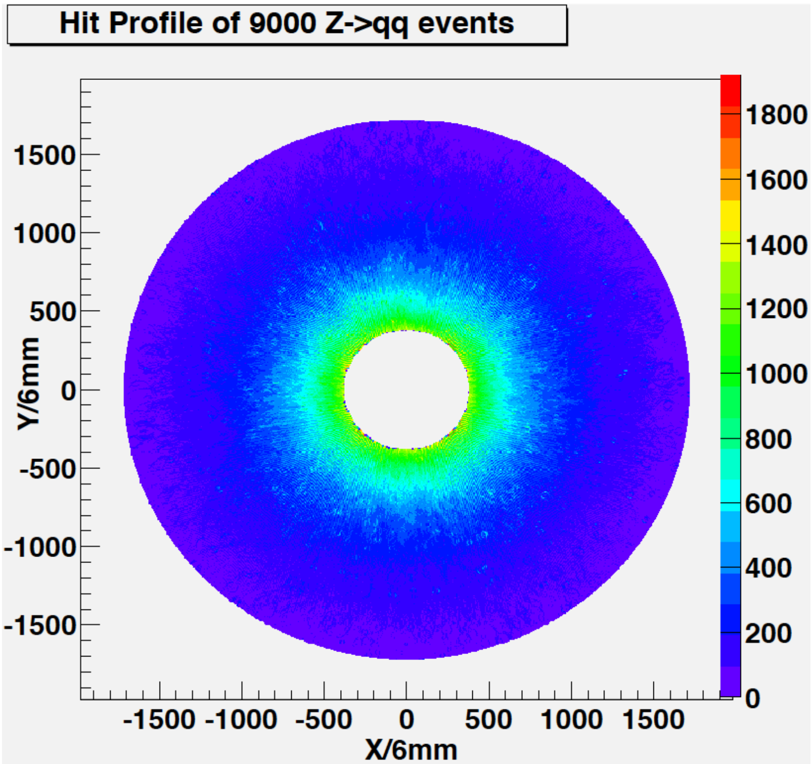
- Feasibility not limited by
  - Voxel occupancy (1E-4 - 1E-6)
  - IBF & Ion Charge Distortion
- Dedx: TPC +50 ps ToF: a full range pi-kaon separation at Z pole operation
- Tech. Difficulties to be further studied
  - Complex, unstable field maps
  - Stability & Homogeneity of Amplification/DAQ system, temperature/pressure monitoring & corrections
  - Radiation background: Working Gas selection is essential
    - Neutron Flux + Working gas with hydrogens
    - Delta Ray Noise
    - Gamma Ray Noise
- Be iterated with Hardware/Electronic Design & Test beam studies

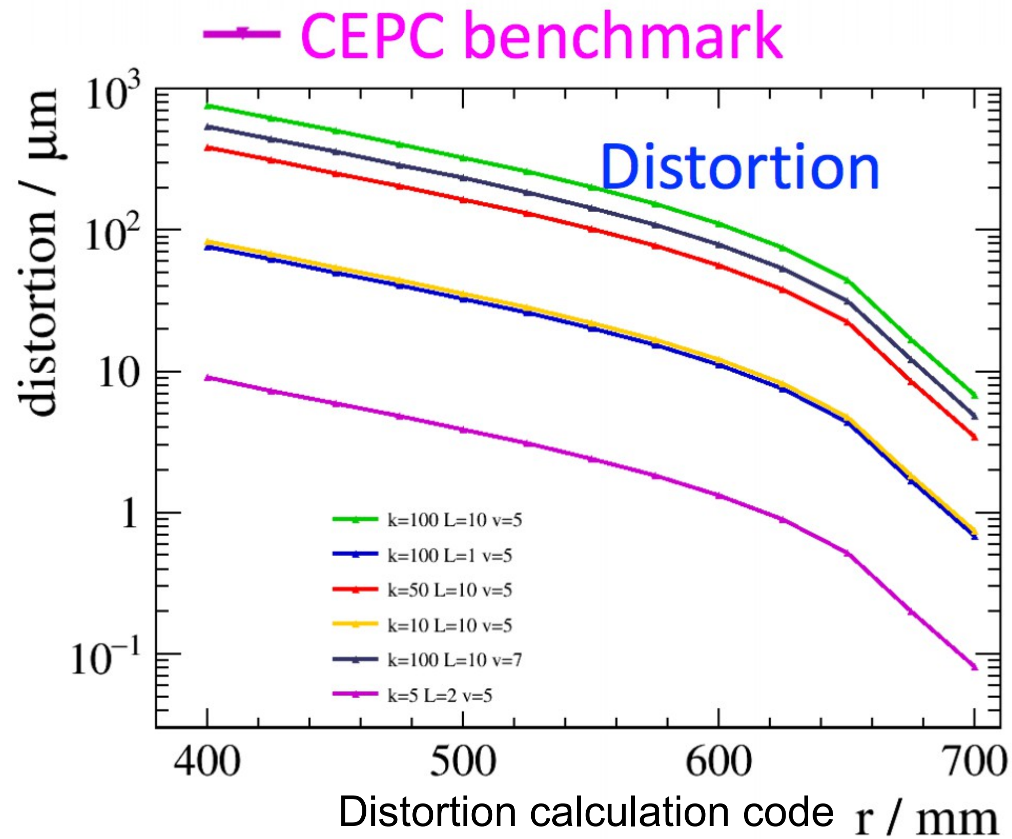
Feasibility of TPC at Z pole

- 600 Ion Disks induced from Z->qq events at 2E34$cm^{-2}s^{-1}$
- Voxel occupancy & Charge distortion from **Ion Back Flow** (IBF)
- Cooperation with CEA & LCTPC



TPC Feasibility (Preliminary)

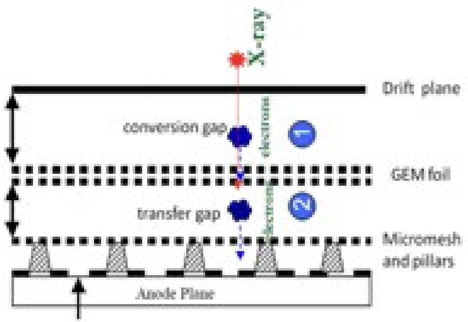


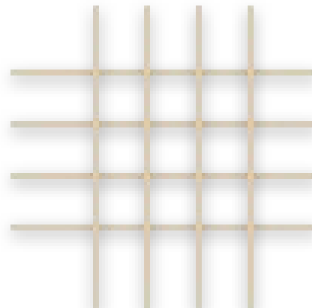


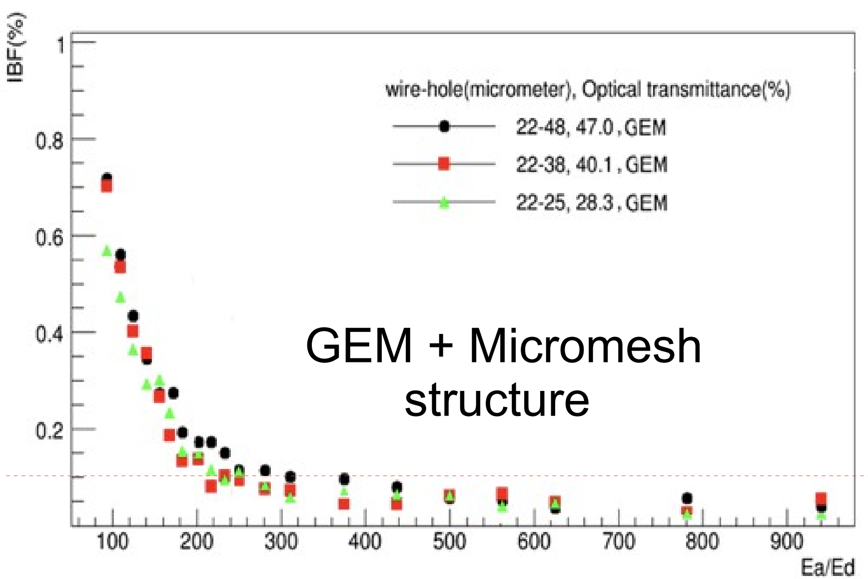
Distortion calculation code provided by KEK

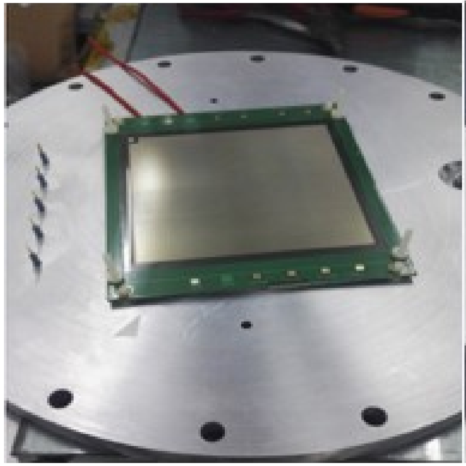
- Conclusion:
  - Voxel occupancy ~ (10^-4 – 10^-6) level, safe
  - **Safe for CEPC If the ion back flow be controlled to per mille level** - The charge distortion at ILD TPC would be one order of magnitude then the intrinsic resolution (L = 2E34 $cm^{-2}s^{-1}$)

R&D on the IBF control

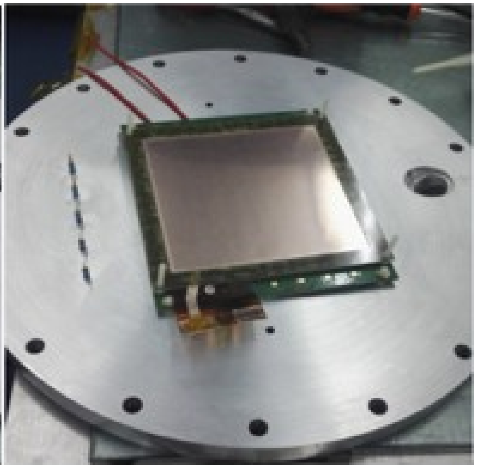




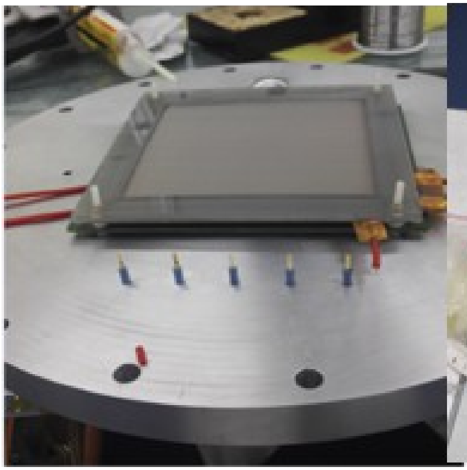




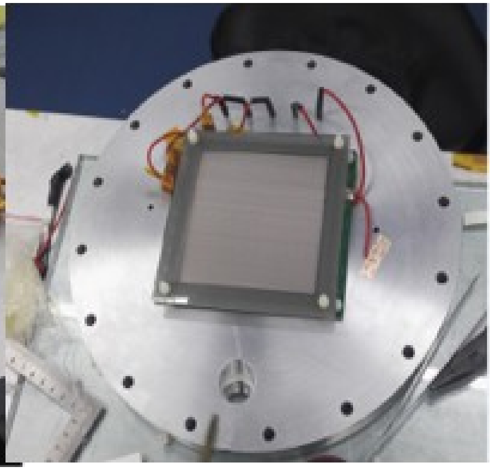
Micromegas(Saclay)



GEM(CERN)



Cathode with mesh



GEM-MM Detector