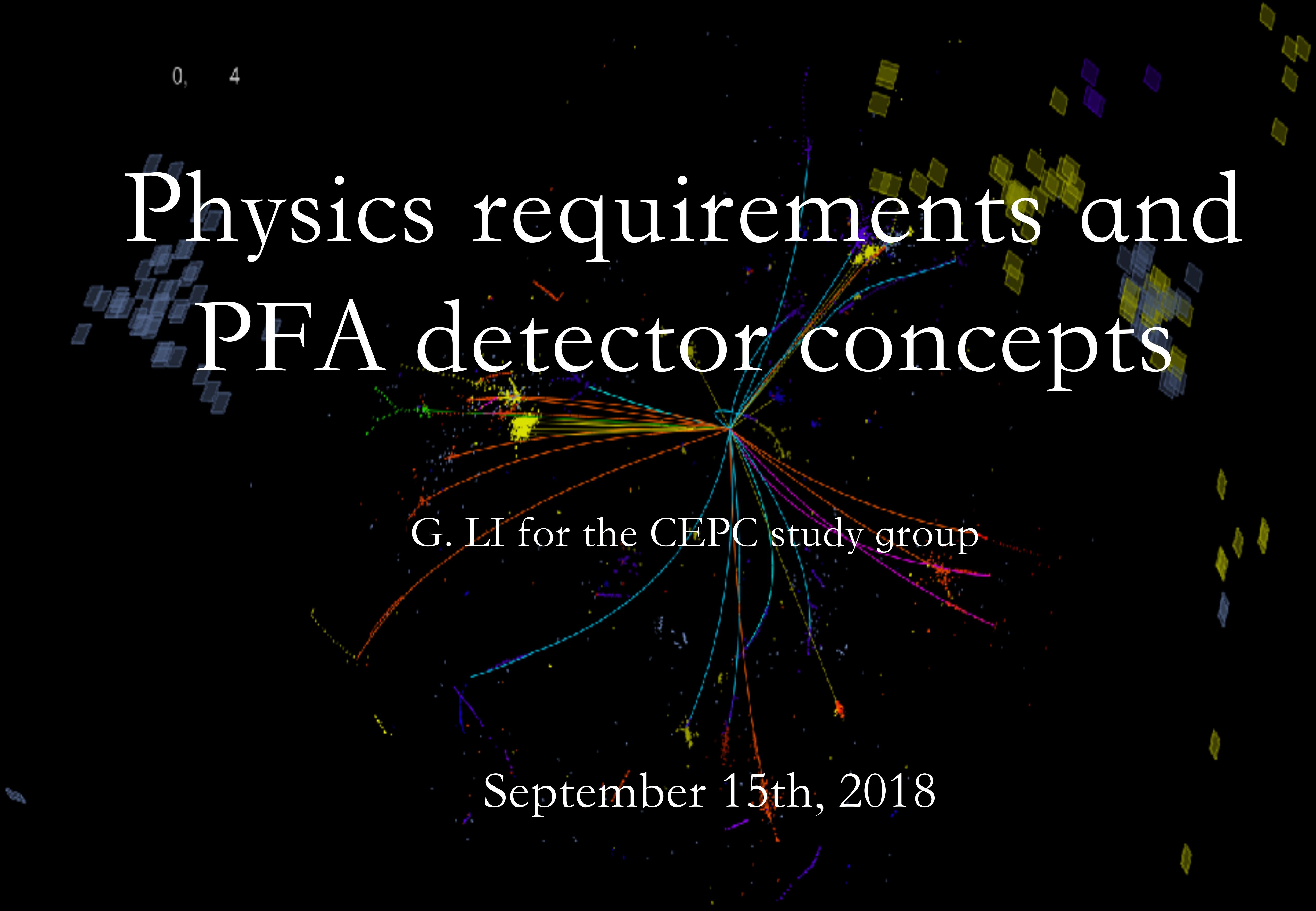
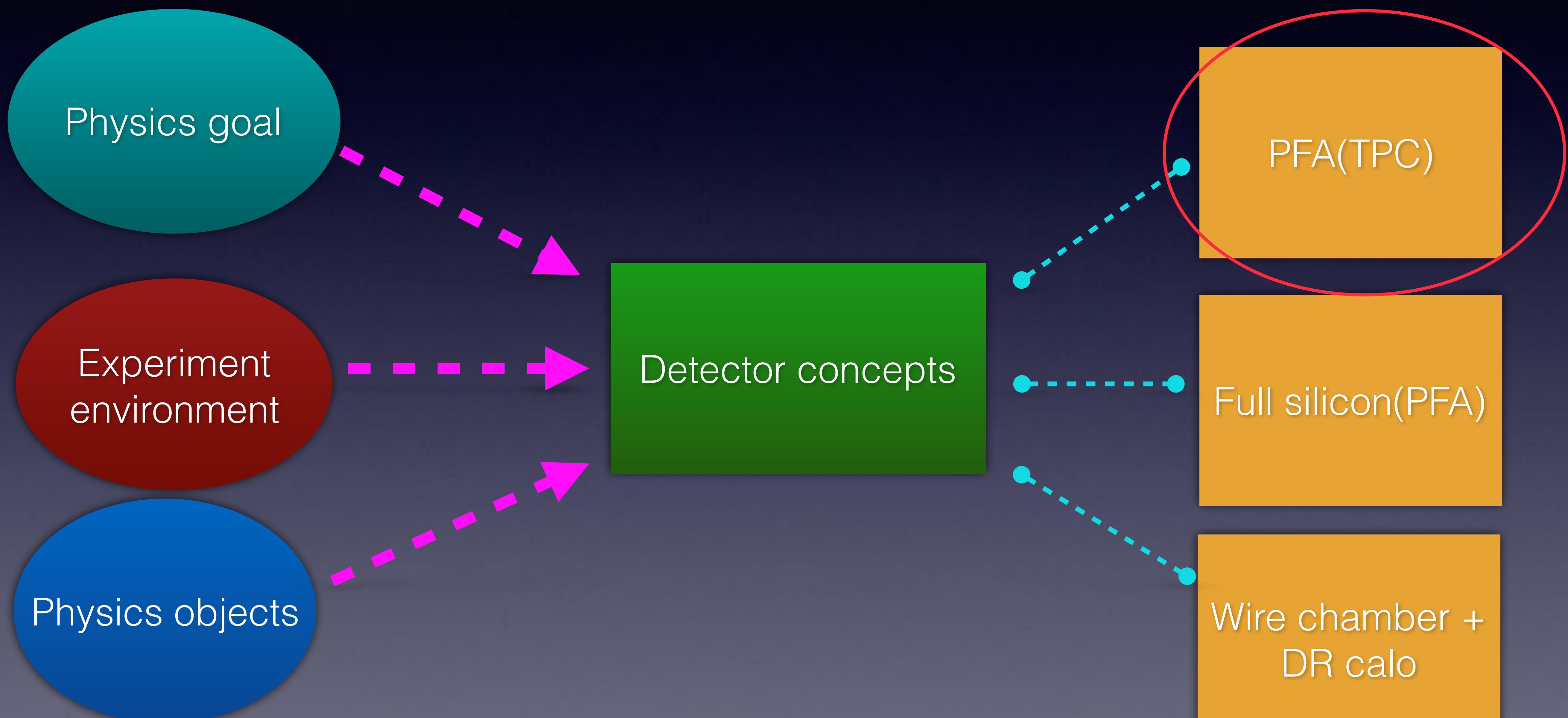


Physics requirements and PFA detector concepts

G. LI for the CEPC study group

September 15th, 2018

Schema

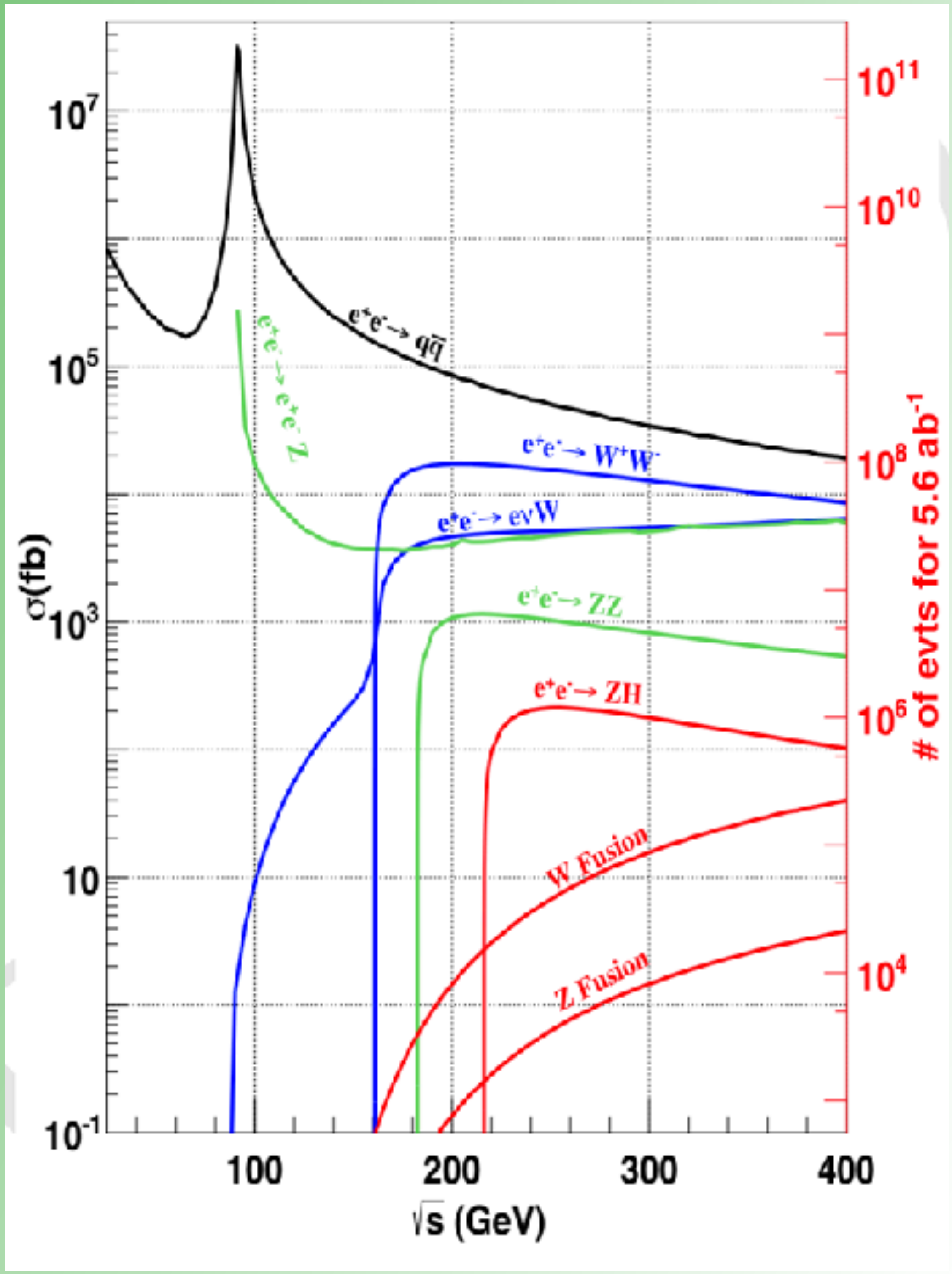


Physics goal
Experiment environment
Physics objects
Detector concepts
PFA(TPC)
Full silicon(PFA)
Wire chamber + DR calo

Physics of Z, W, and Higgs

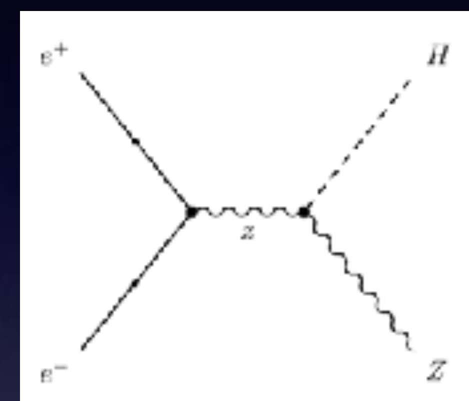
- ☑ CEPC dedicated to Higgs physics, as well as EW physics of W & Z
- ☑ Higgs still limited by statistics ~ $O(0.01)$, but
- ☑ W&Z physics extremely depends on the systematic uncertainty control

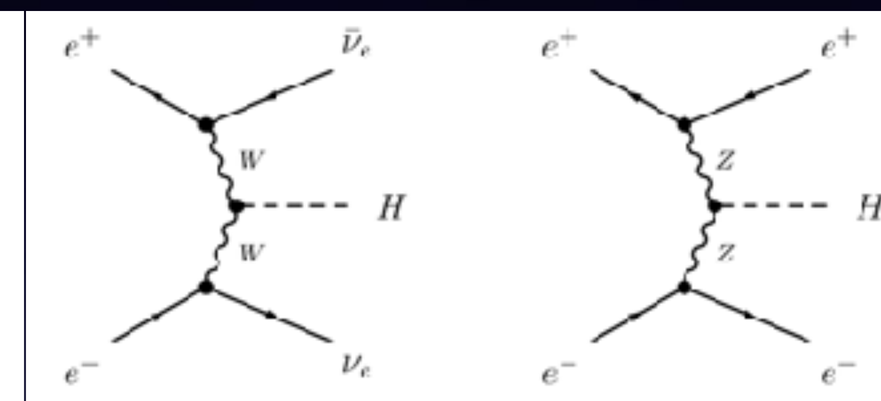
Operation mode	Z factory	W threshold scan	Higgs factory
$\sqrt{s}$ (GeV)	91.2	158 - 172	240
L ($10^{34}\mathrm{cm}^{-2}\mathrm{s}^{-1}$)	16-32	10	3
Running time (years)	2	1	7
Integrated Luminosity (ab^{-1})	8 - 16	2.6	5.6
Higgs yield	-	-	10^6
W yield	-	10^7	10^8
Z yield	10^{11-12}	10^9	10^9



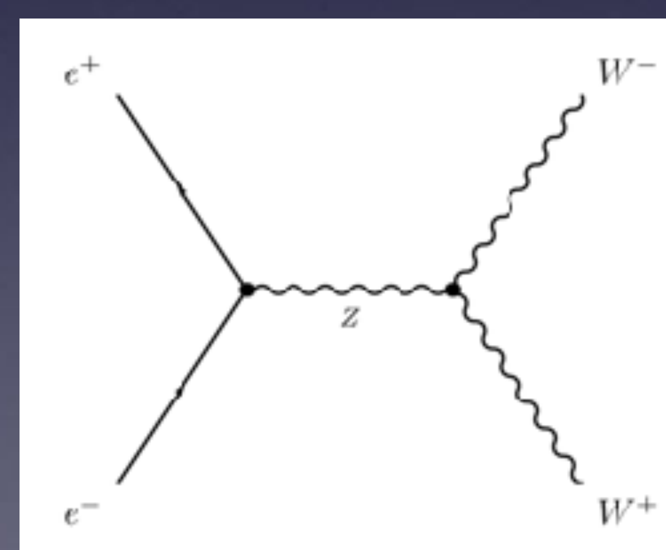
Physics goal
Precision measurements and direct searches

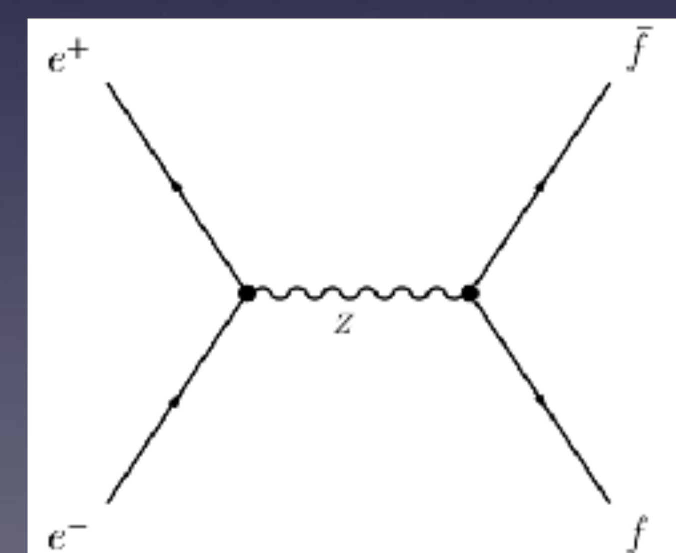
- Higgs : precision measurement the Higgs properties of its mass, width, production, decay couplings





- W: mass, width, and TGC
- Z: Rb, Afb, ···
- Flavor physics





See Liantao, Jianming, and Zhijun's talks

Physics requirements

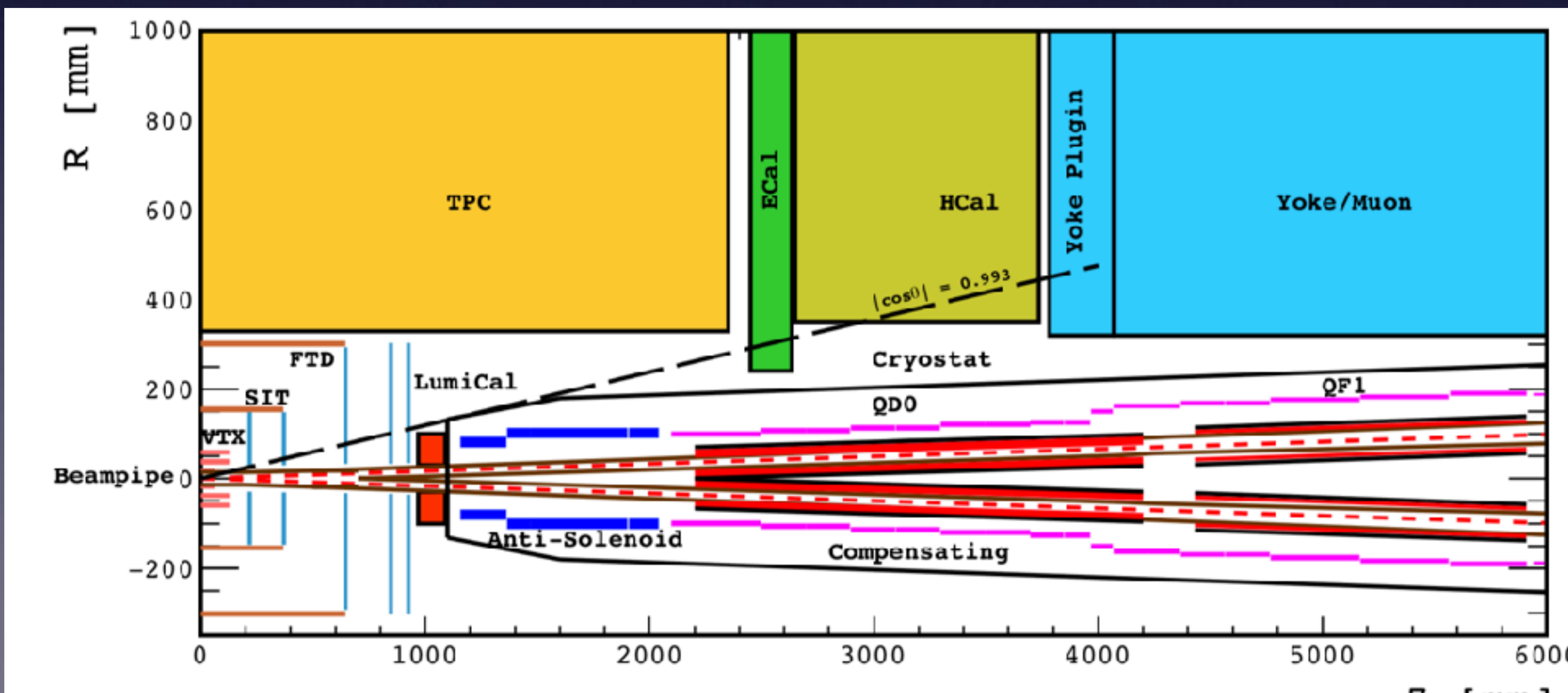
- Robustness and efficiency : record all physics events/objects in a noisy environment
- Excellent resolution and efficiency to reconstruction physics objects: poor resolution needs more statistics to compensate
- Luminosity/beam energy calibration to meet physics goal
- Highly hermetic coverage: better use of advantage of e+e- collider — initial state precisely defined.
- PID: lepton/jet/hadron identification with high efficiency and rejection power

Experiment conditions

More detail see Hongbo and Sha's talk

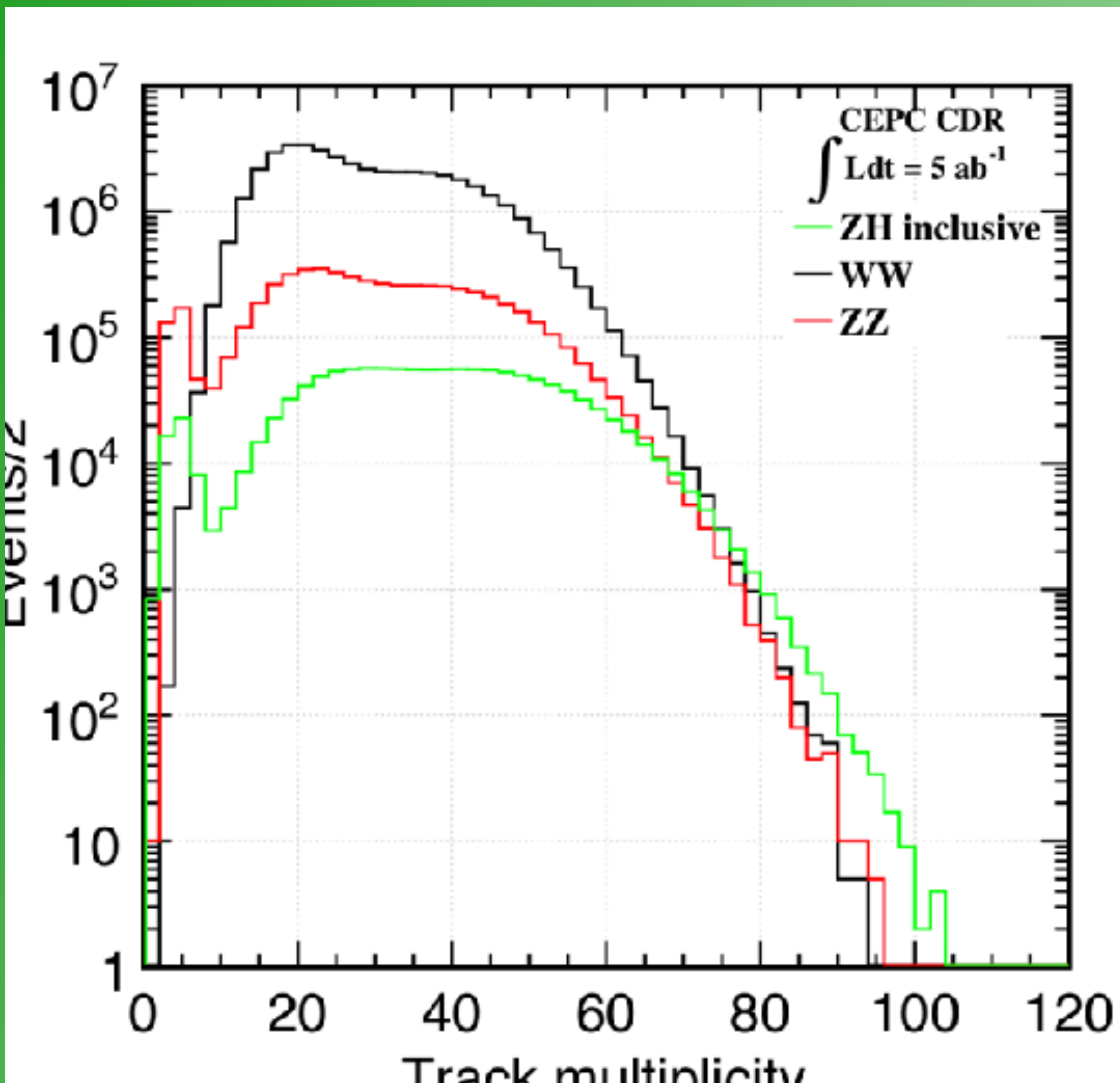
- CEPC design supposed to deliver more luminosities at all energies
- Baseline design of accelerator
  - double ring
  - cross angle: 33 mrad
  - L* = 2.2 m, QD0, QF1 inside detector
  - Backgrounds : pair production & off-beam particles
  - Luminosity measurement very challenge
- Stringent requirements on detector design

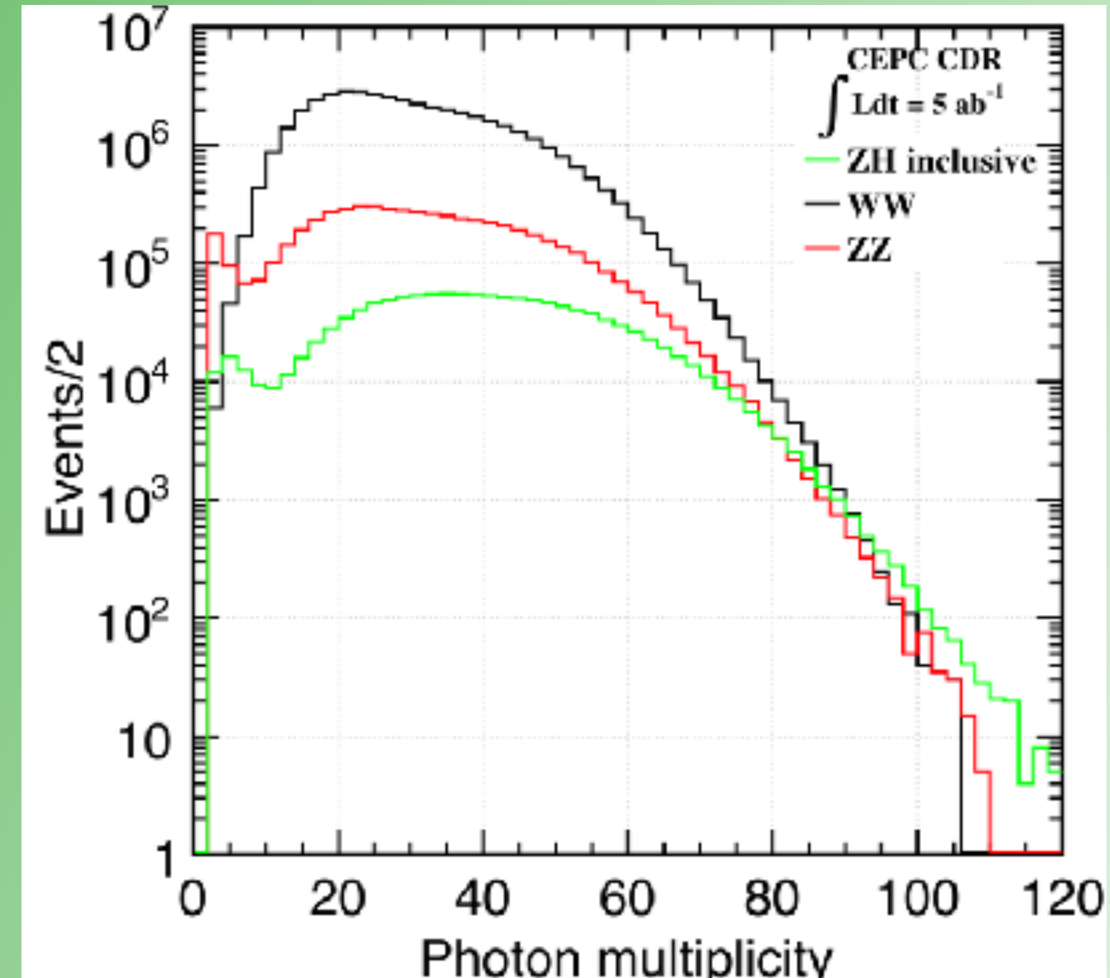
	H (240)	W (160)	Z (91)
Hit Density [hits/cm^2·BX]	2.4	2.3	0.25
TID [MRad/year]	0.93	2.9	3.4
NIEL [10^{12} 1 MeV n_{eq}/cm^2·year]	2.1	5.5	6.2

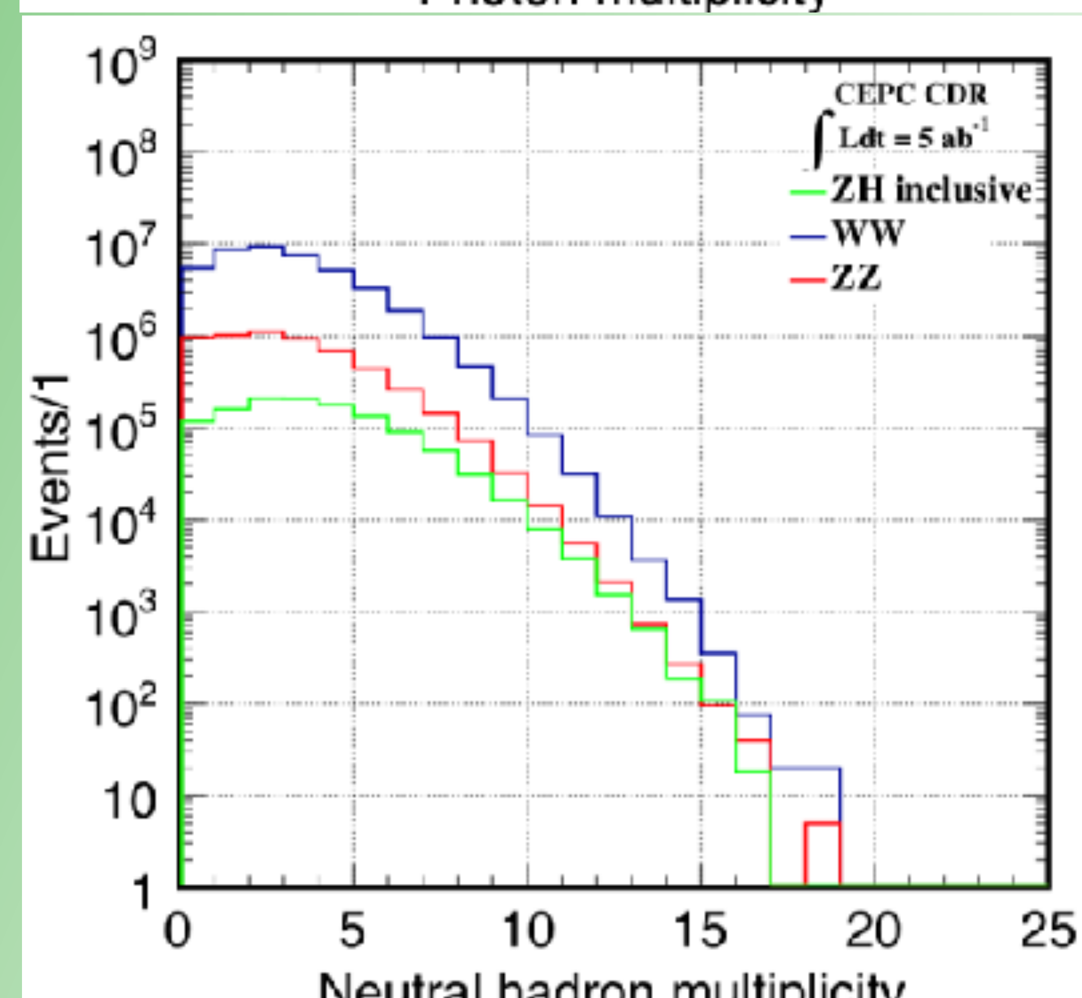


Physics objects: leptons, photons, jets, missing Energy, $\cdots$

Multiplicities

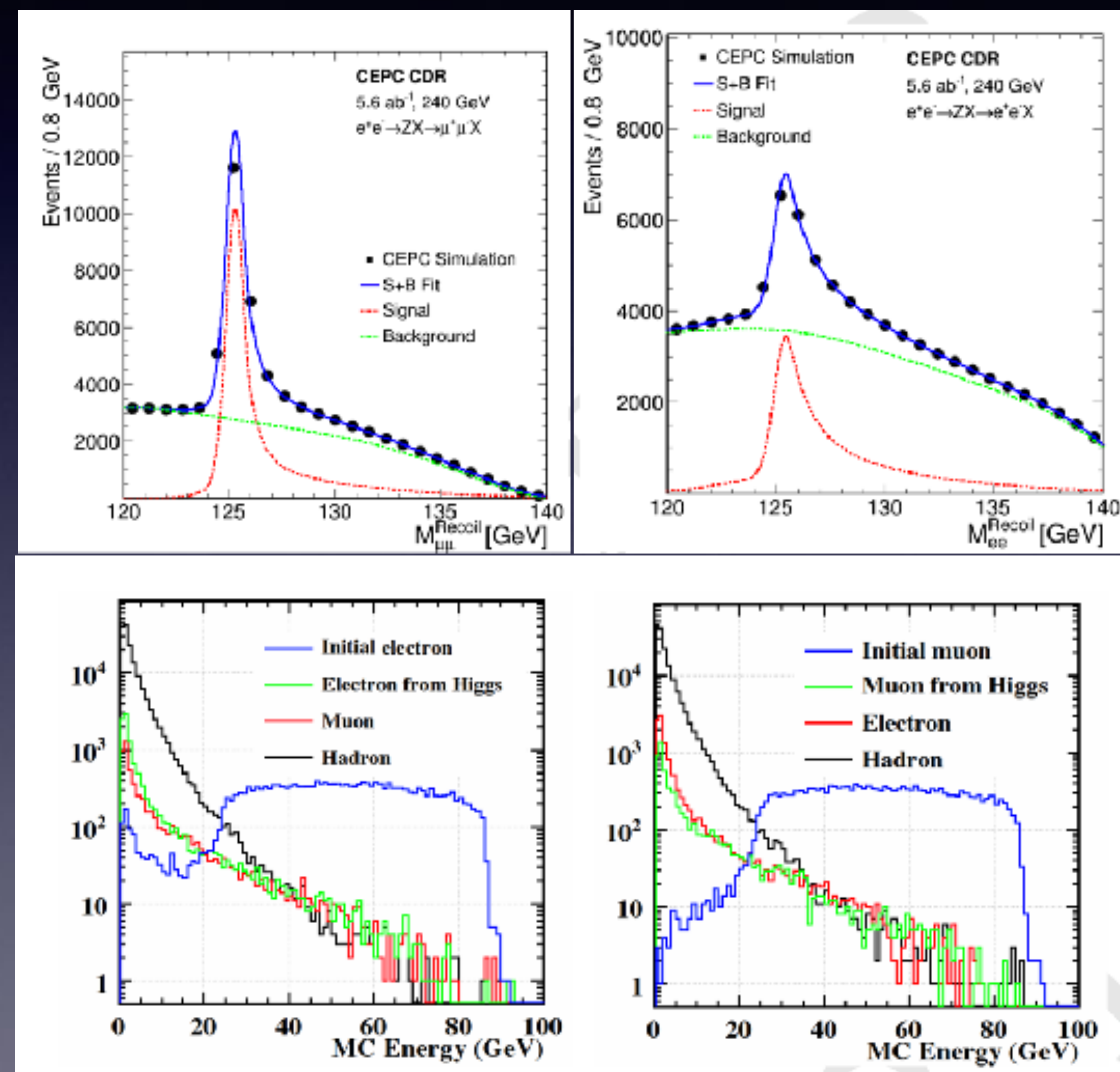






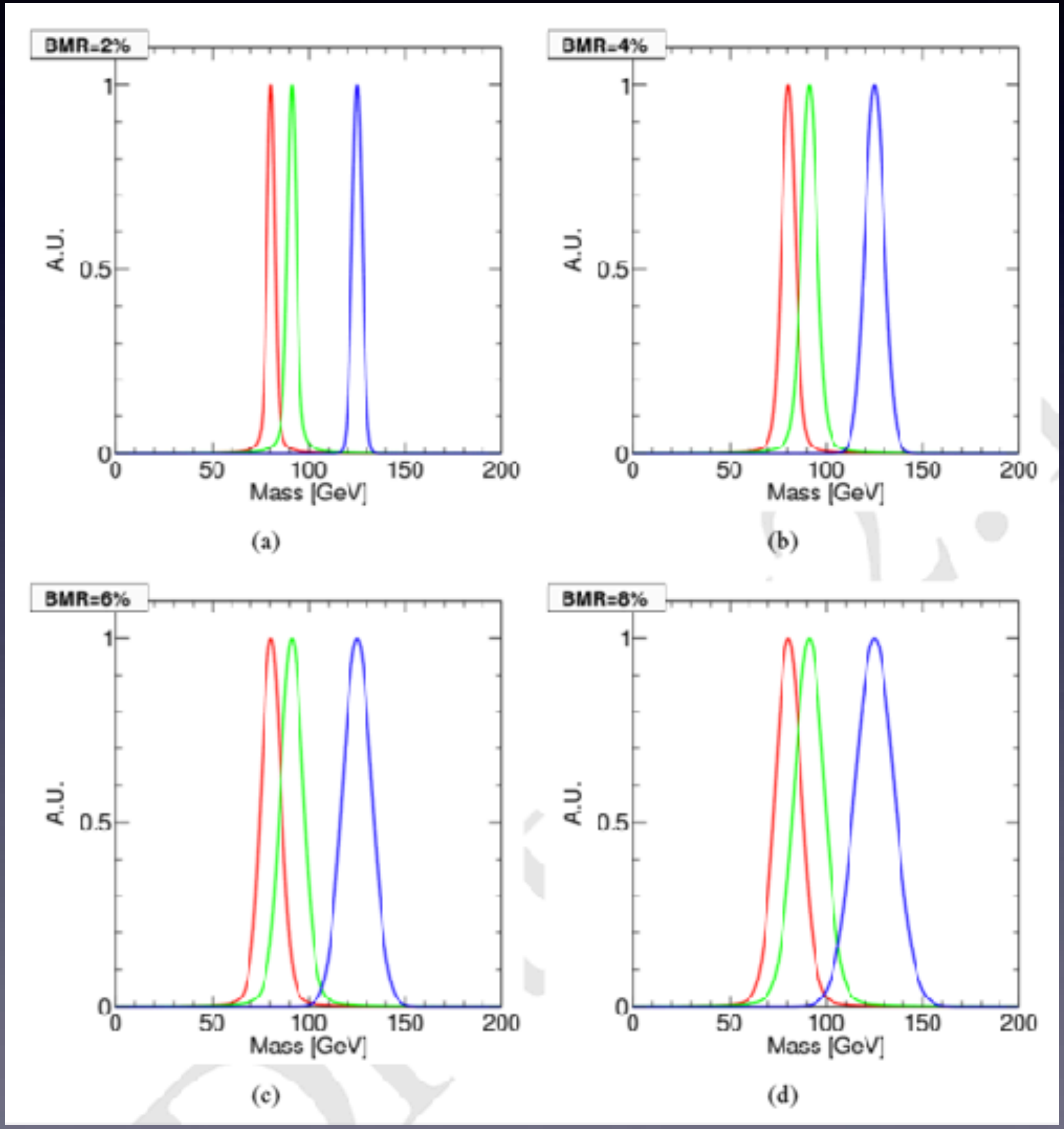
Leptons: tracking & ID

- Leptons extremely important for the model independent study of Higgs
- The momenta greater than 15 GeV
- High tracking efficiency, good lepton ID, and good resolution preferred
- Poor resolution needs more statistics to compensate



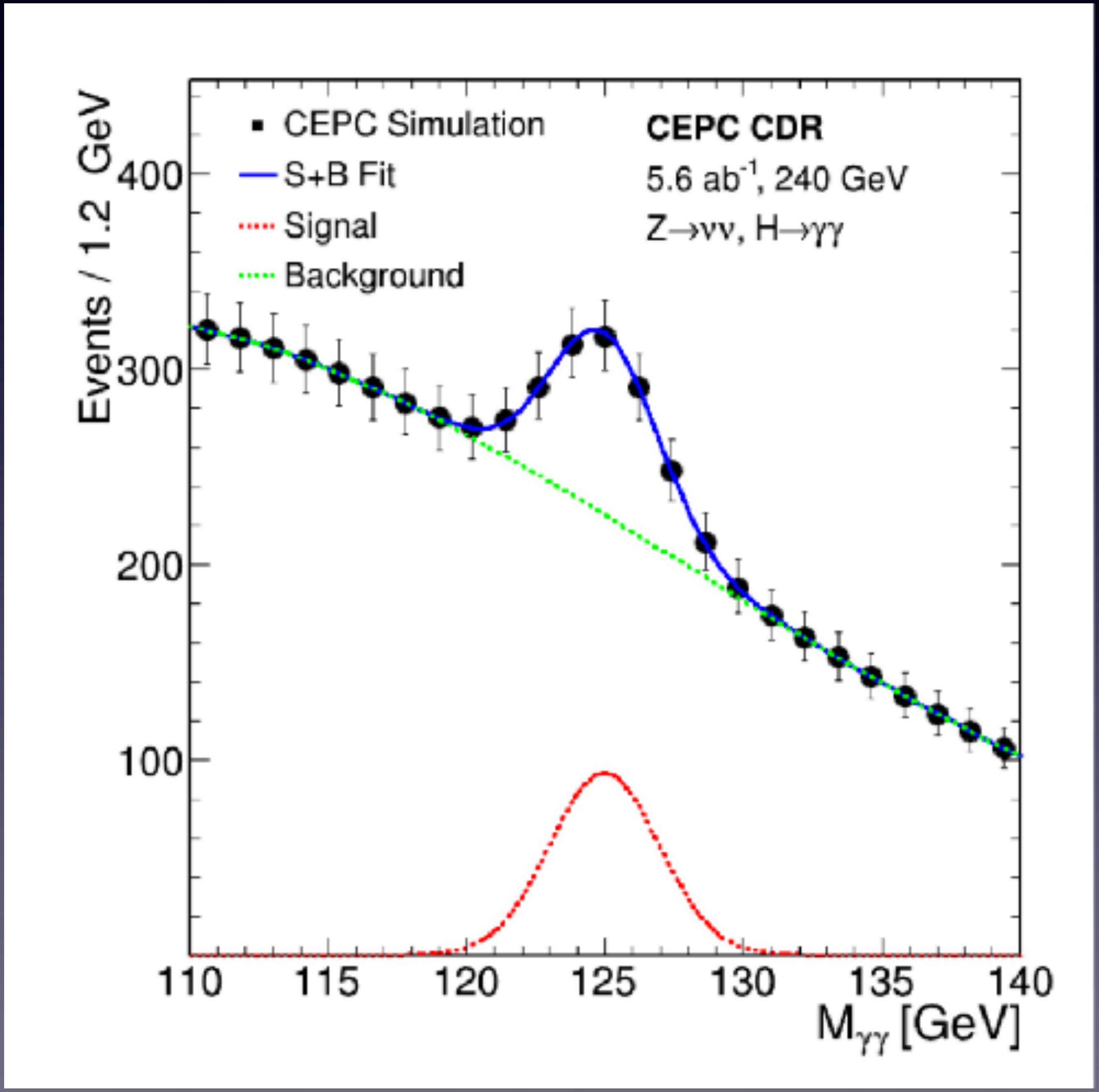
Jet energy resolution: PFA

- Jet energy resolution is essential for boson mass, which benefit a lot from PFA
- In the realistic case, it also depends on jet-clustering, isolated lepton/photon algorithm, initial state photon rejection, … more study should be done



Photons

- Photon energy resolution is key issue for Higgs di-photon measurement, as well as π^0 and ISR photon tagging
- For the photon energy resolution, there is still some room to improve, which has to compromise with separation power requested by PFA concept

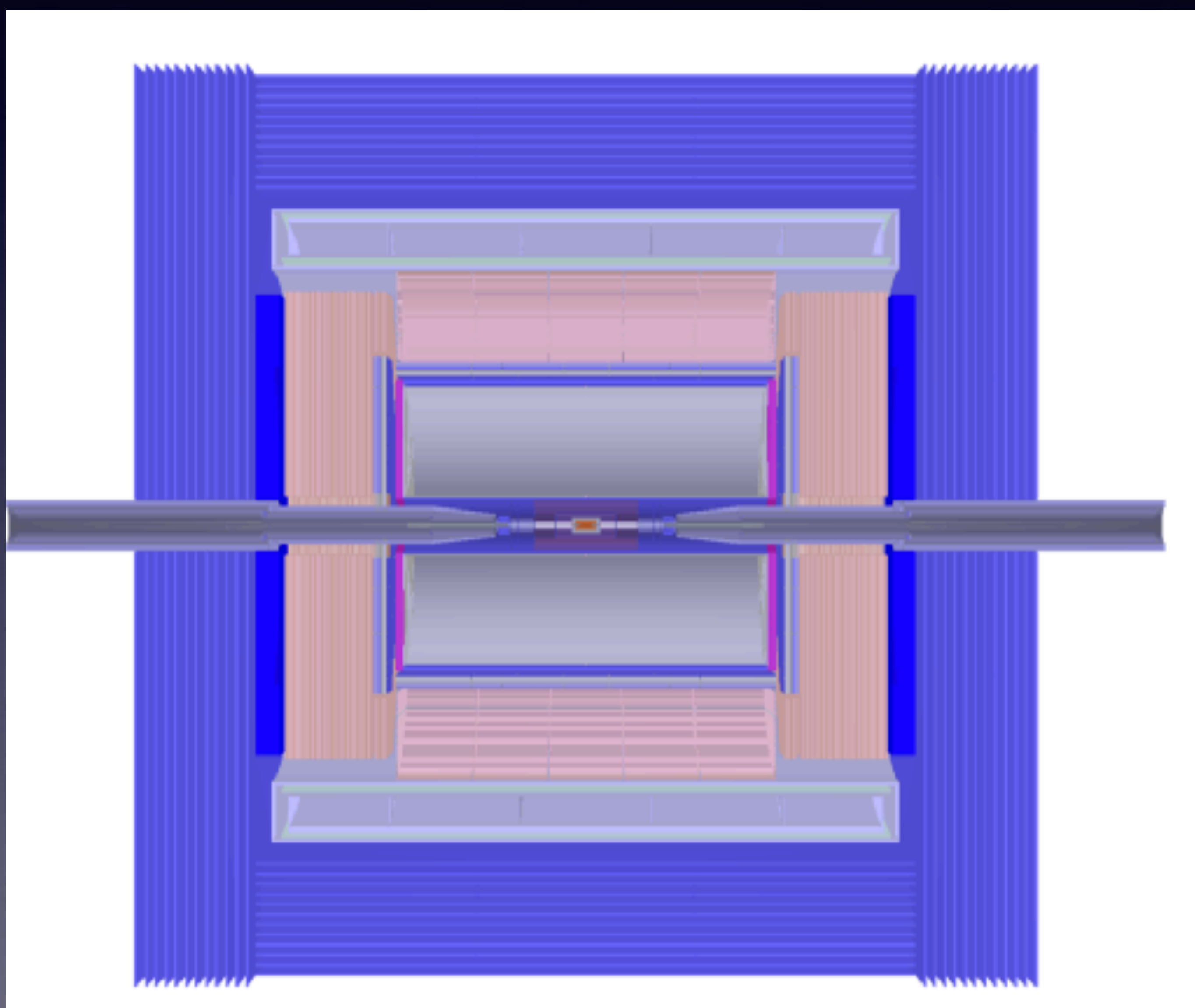


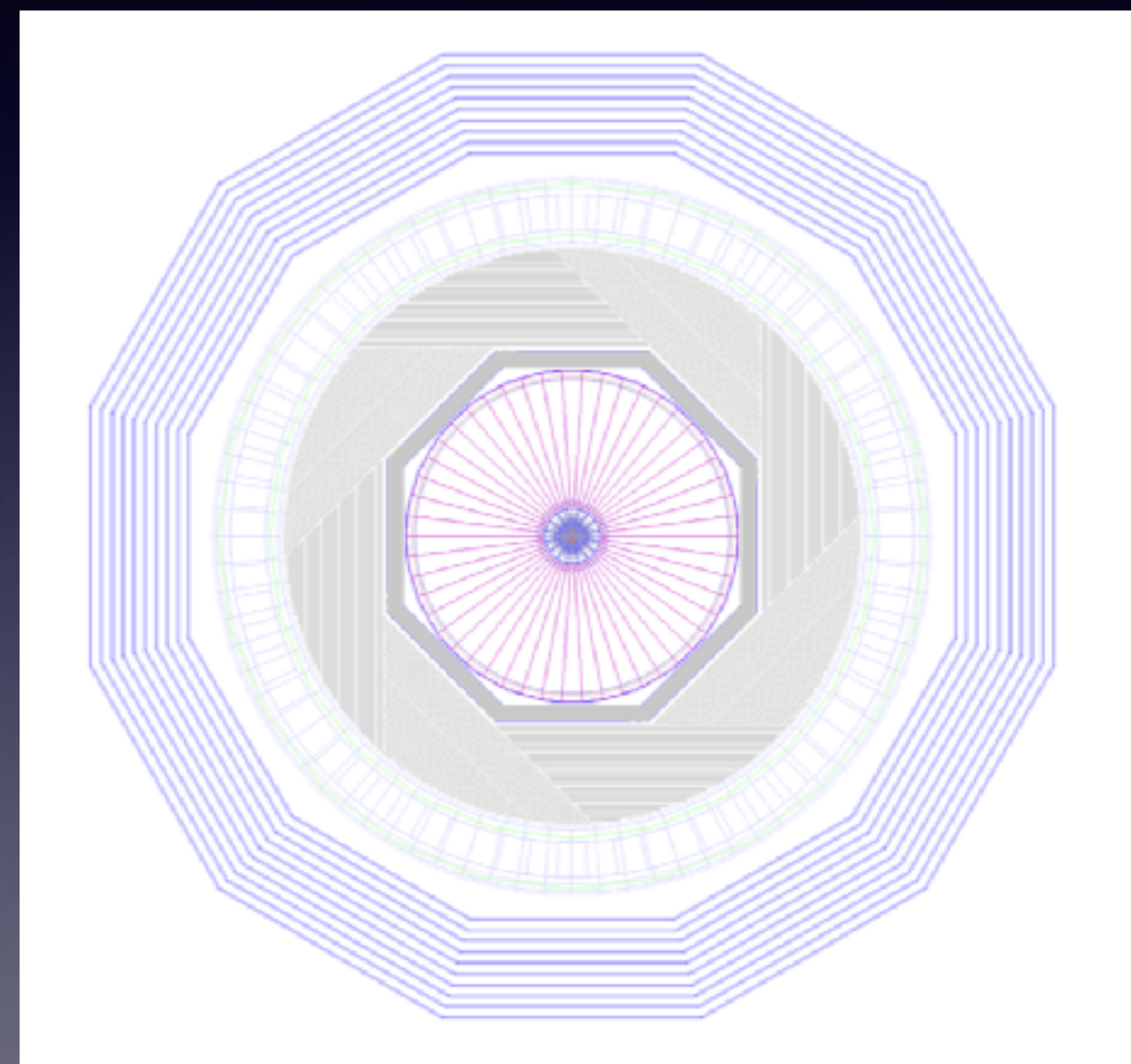
CEPC baseline detector concept

Particle flow: make use of the optimal sub-detector information in reconstruction and a high granularity calorimetry system

CEPC baseline detector

Take ILD as reference with intensive optimizations





Baseline design

Concept	ILD	CEPC baseline
Tracker	TPC/Silicon	TPC/Silicon or FST
Solenoid B-Field (T)	3.5	3
Solenoid Inner Radius (m)	3.4	3.2
Solenoid Length (m)	8.0	7.8
L* (m)	3.5	2.2
VTX Inner Radius (mm)	16	16
Tracker Outer Radius (m)	1.81	1.81
Calorimeter	PFA	PFA
Calorimeter λ_I	6.6	5.6
ECAL Cell Size (mm)	5	10
ECAL Time resolution (ps)	-	200
ECAL X_0	24	24
HCAL Layer Number	48	40
HCAL Absorber	Fe	Fe
HCAL λ_I	5.9	4.9
DRCAL Cell Size (mm)	-	-
DRCAL Time resolution (ps)	-	-
DRCAL Absorber	-	-
Overall Height (m)	14.0	14.5
Overall Length (m)	13.2	14.0

- L*: 2.2 m, required by accelerator final focusing
- Magnet field: 3 Tesla to achieve higher luminosity
- Impact parameter resolution:

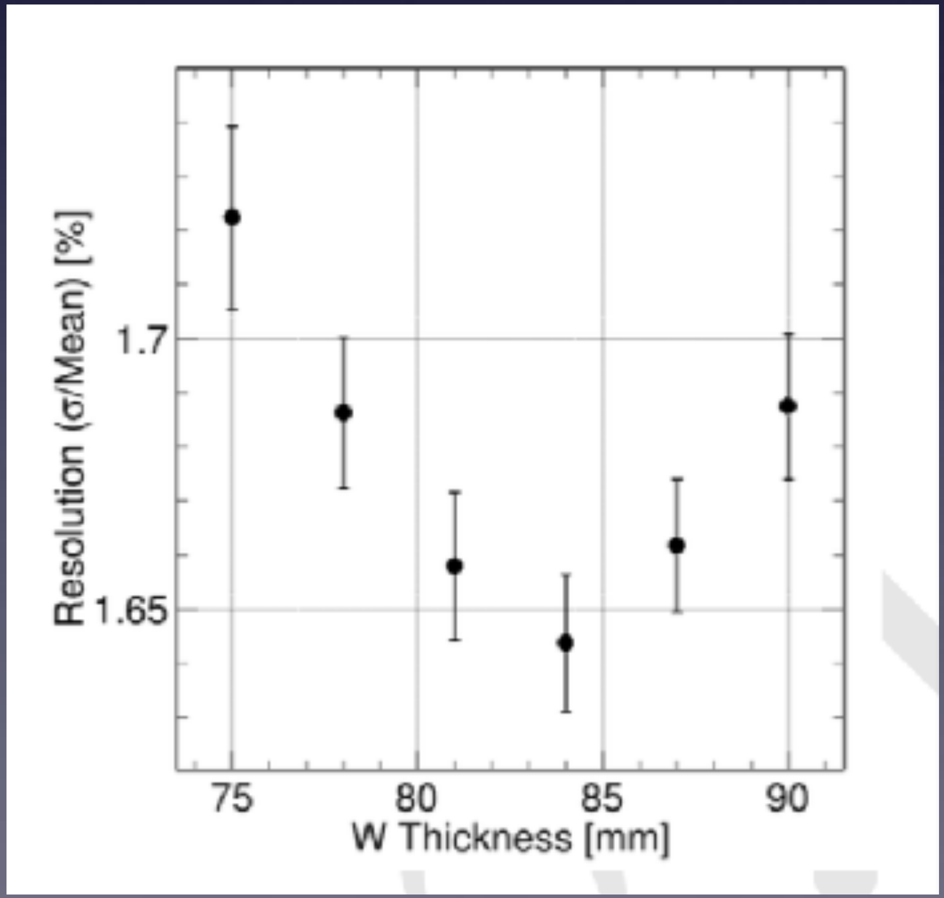
$$\sigma_{r\phi} = 5 \oplus \frac{10}{p(\text{GeV})\sin^{3/2}\theta}$$

- Momentum resolution : $\Delta(1/P_T) \sim 2 \times 10^{-5}\ \text{GeV}^{-1}$
- A double amplification layer technique for TPC for the Z pole high events rate environment
- Good performance on pi/K separation with TPC dE/dx and time information in ECAL
- Calorimetry system, see next page ···

Calorimetry optimizations

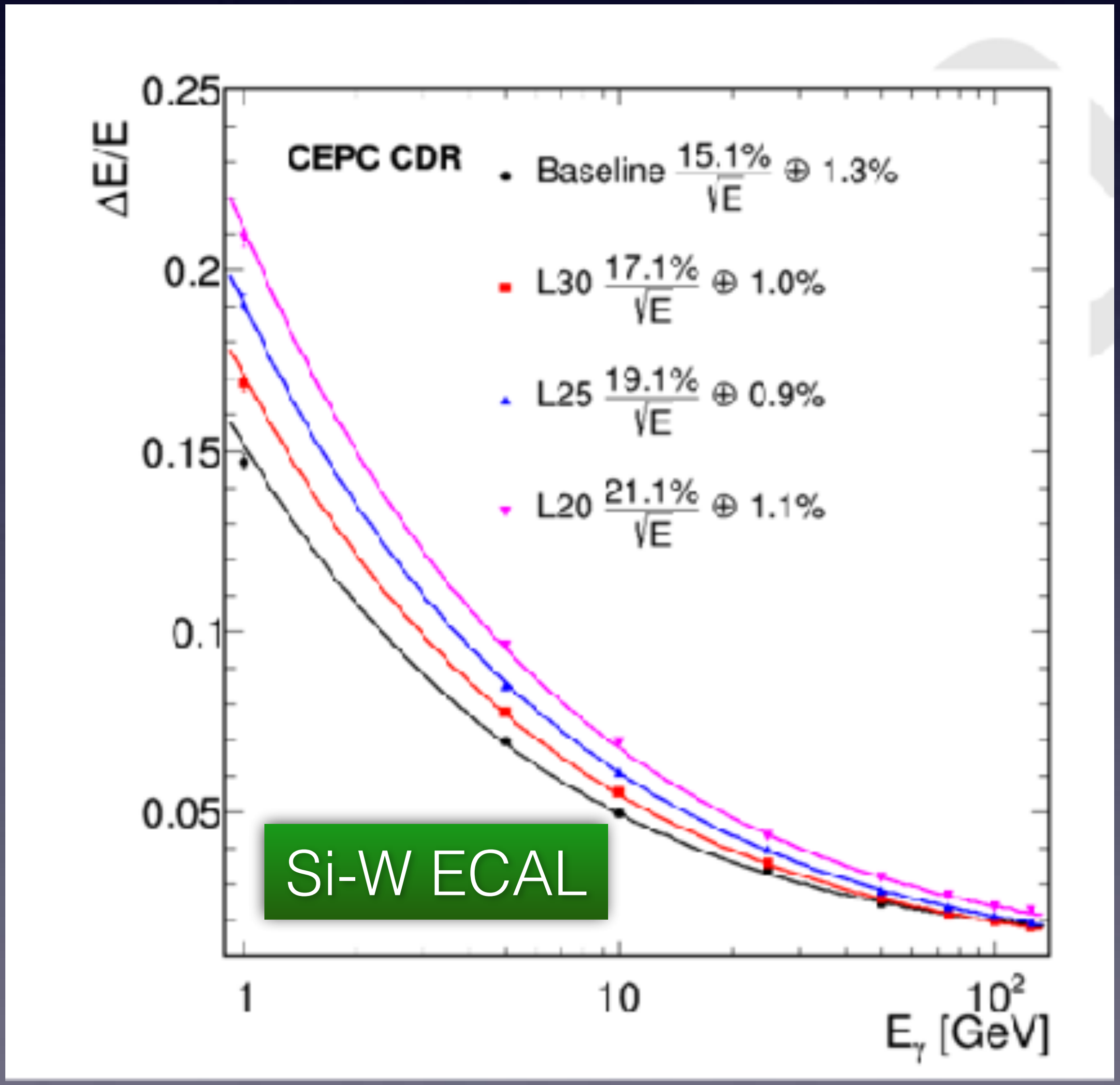
- High granularity calorimetry system suffers from cooling problem, but CEPC is not going to operate with push-pull mode
- The cell size and number of layers optimized with full simulation study, which is active-cooling free but with 5% resolution degrading.
- Optimized results
  - ECAL cell size: of 10x10 mm^2
  - ECAL absorber: 84 mm
  - HCAL #of layers: 40
  - Cost/weight/thickness reduced

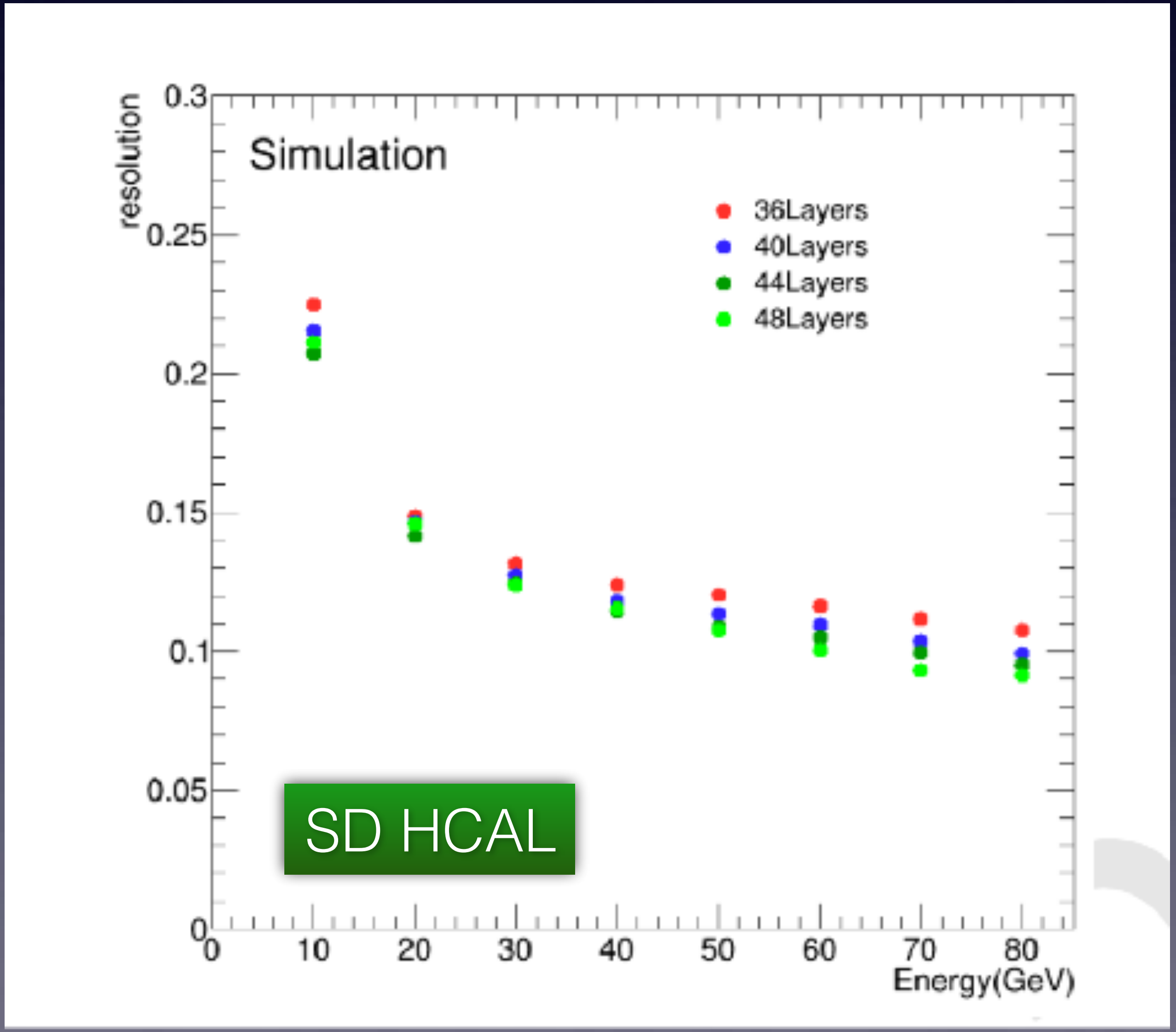
    25%/50%/20%



Calorimetry optimizations

- Number of layers vs. energy resolutions





Other issues

- Photon energy resolution could be improved
- Muon detector needs more investigation and to be optimized
- More details please refer to Manqi's performance talk

Summary

- CEPC focus on Higgs, EW precision and flavor physics also are important
- MDI and physics program put stringent requirements on detector design
- Silicon+TPC tracker with PFA calorimetry system detector concept is a reasonable design, which has been optimized with full simulation
- More validations and works still needed

Extras

The requirements
high tracking efficiency
Excellent tracking resolution
Jet energy (boson mass) resolution
Good separation power: pi0, tau, jets, …

Generally
High granularity means high efficiency
Potential application of modern development of machine learning/deep learning