Di-photon Separation Study and the Higgs Signals at CEPC

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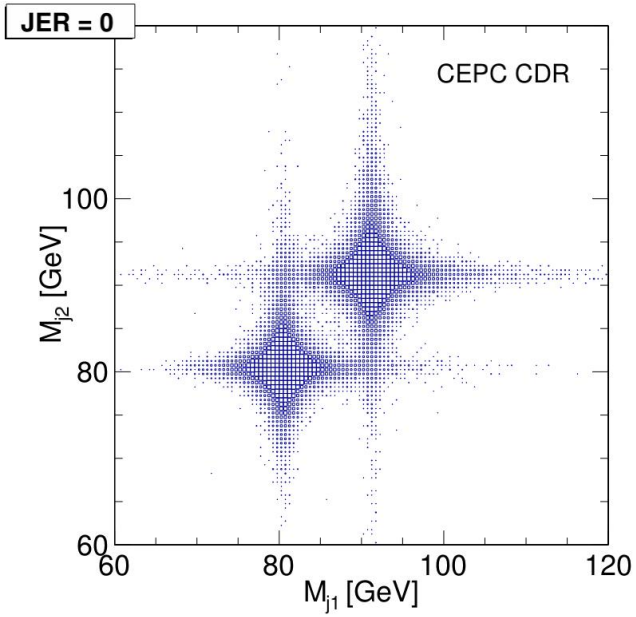
Outline

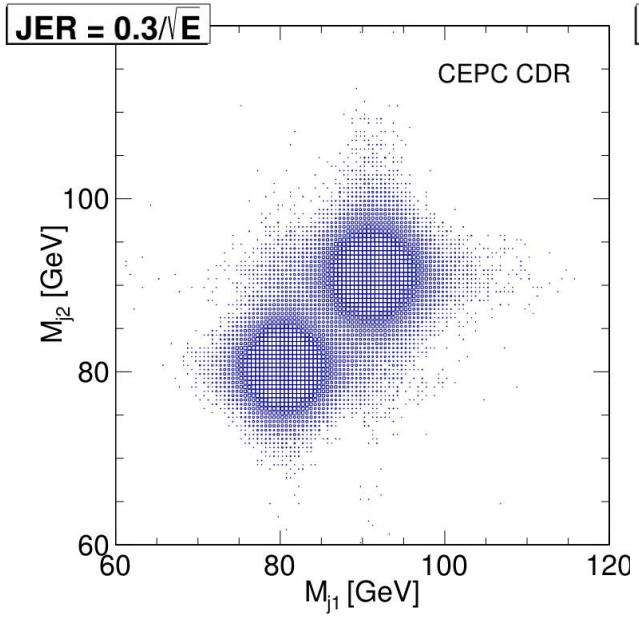
- Di-photon Separation Study

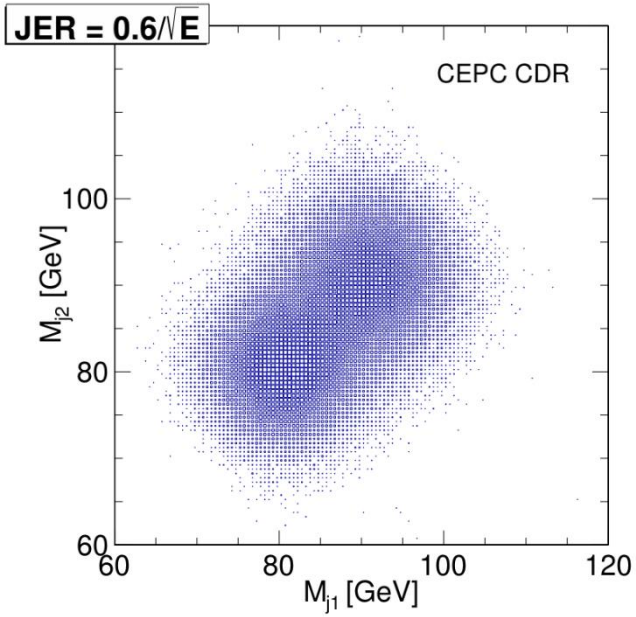
- Higgs Signals at CEPCv4 Geometry (APODIS, Baseline Geometry at CDR)

Jet Energy Resolution

Separation of W/Z bosons in their hadronic decays translates into a jet energy resolution requirement of ~ 30% /√E (E<100GeV).





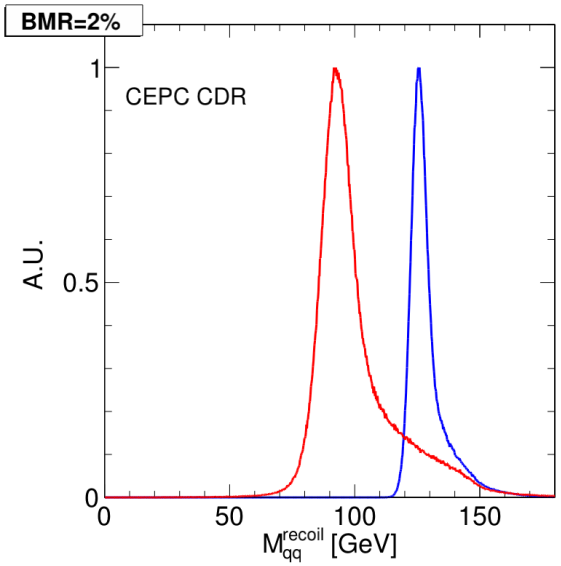


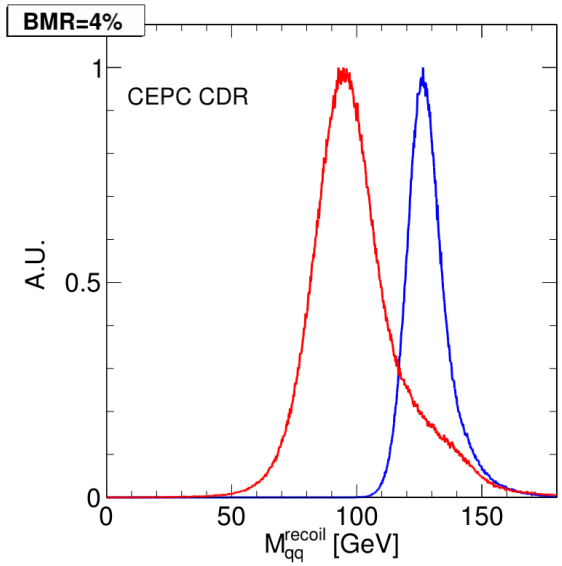
WW→4j and ZZ→4j

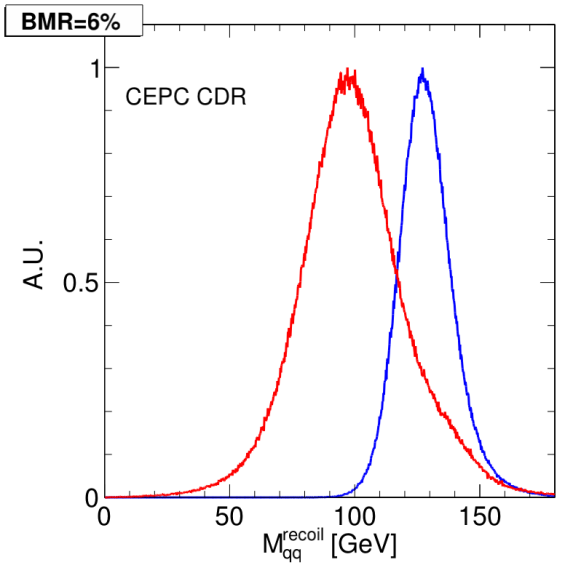
Jet Energy Resolution

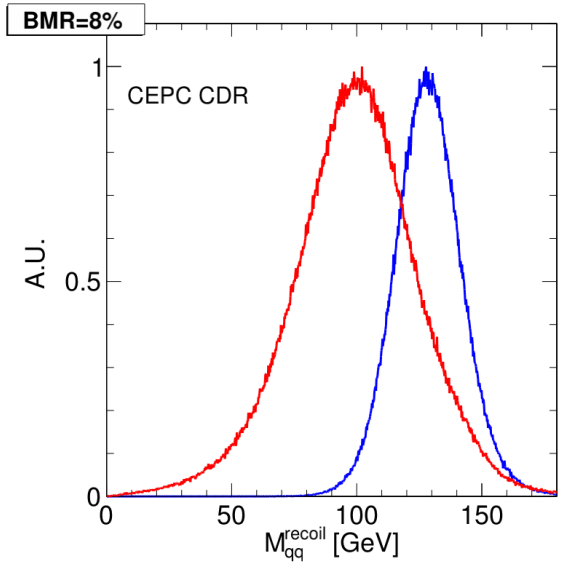
e+e→ZH, ZZ
Z->qq
H or Z ->invisible

a BMR of ~4% or better will be needed.



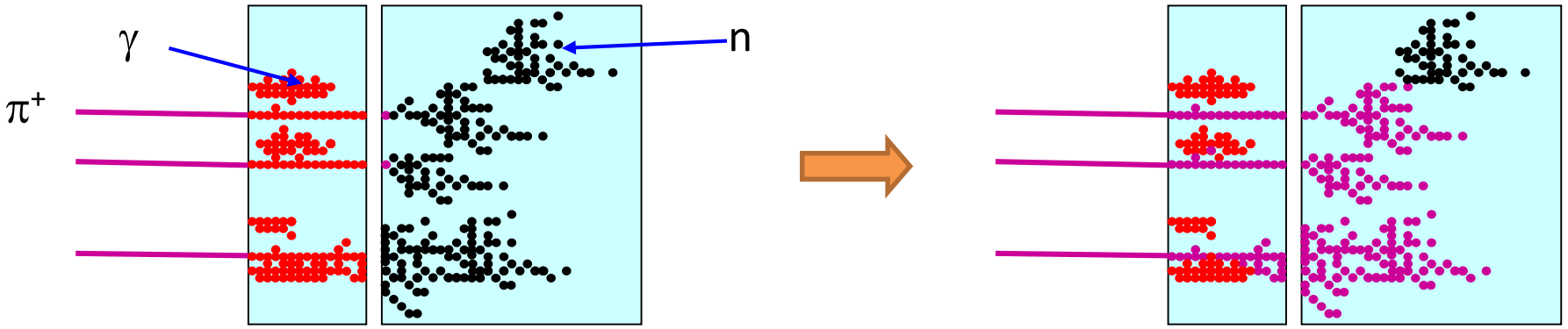






BMR: Boson Mass Resolution at di-jet final states
BMR*sqrt(2) = Jet Energy Resolution

Particle Flow Algorithm



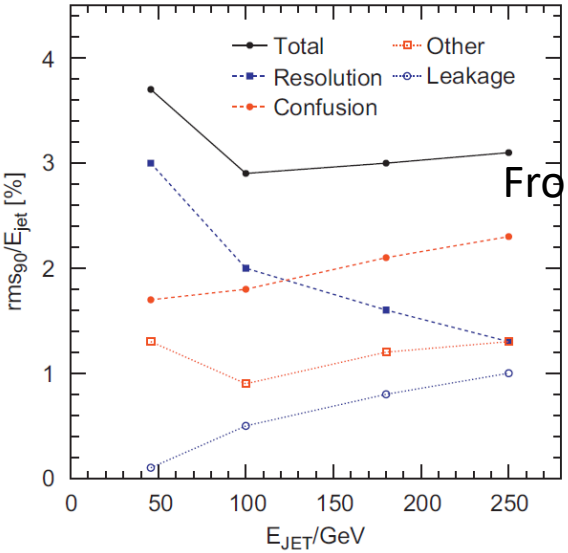
$E_{JET} = E_{ECAL} + E_{HCAL}$

$E_{JET} = E_{TRACK} + E_{\gamma} + E_{n}$

Particle Flow Calorimetry paradigm:

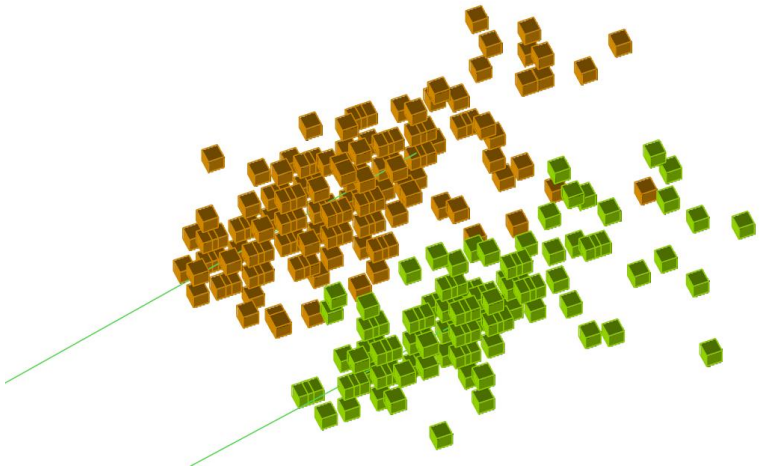
- Charged particle momentum measured in tracker (essentially perfectly)
- Photon energies measured in ECAL:
- Only neutral hadron energies (10% of jet energy) measured in HCAL: **much improved resolution**

$$\sigma^2_{jet} = w_{trk}\sigma^2_{trk} + w_{\gamma}\sigma^2_{\gamma} + w_n\sigma^2_n + \sigma_{confusion}$$



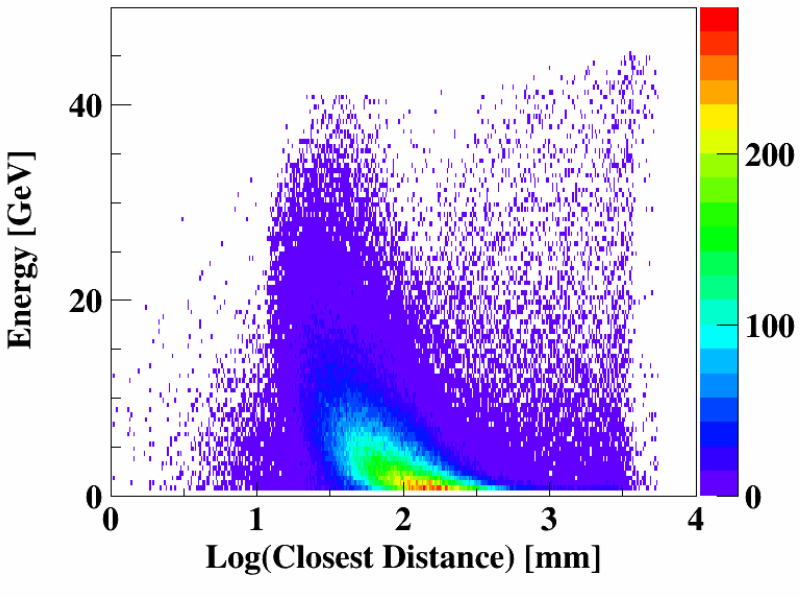
From Pandora

π_0 -> $\gamma\gamma$



Critical energy to separate an evenly decay π_0 : 30 GeV

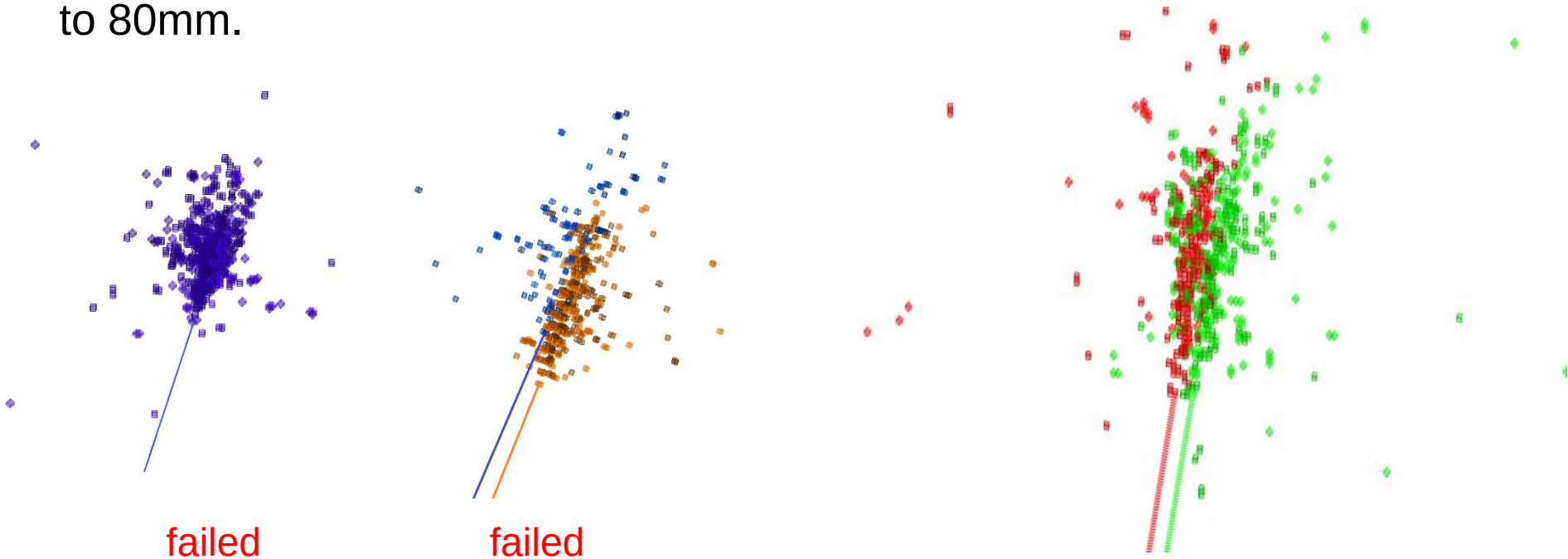
Z->tau tau
(at Zpole Energy)



Nearby EM-Shower Separation

Lots of nearby EM-showers exist in jets, the separation and reconstruction of them are important for some physics objects.

The reconstruction efficiency of two parallel 5 GeV photons was studied. The distance between these two photons ranges from 1mm to 80mm.



failed

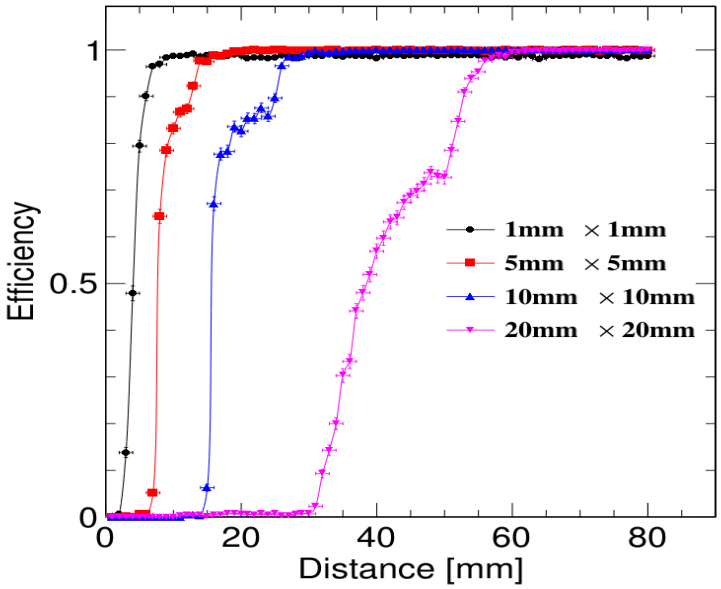
failed

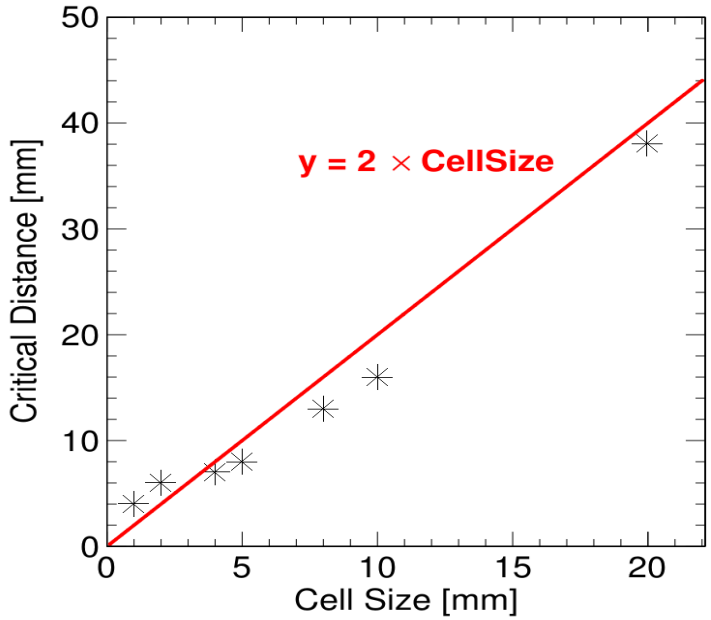
($E_{blue\ cluster} \approx 1/6 E_{orange\ cluster}$)

succeeded

$1/3E_{All}<E_{photon1}<2/3E_{All}$ && $1/3E_{All}<E_{photon2}<2/3E_{All}$: succeeded

Nearby EM-Shower Separation





Efficiency with different cell size was checked
At large distance, the reconstruction efficiency converges to 100%
At very closed by distance, the reconstruction efficiency drops significantly

The critical separation distance is defined as the distance with which the successful reconstruction efficiency is 50%.

Nearby Photon Showers in Physics Objects

Z->tau tau

(at Zpole Energy)

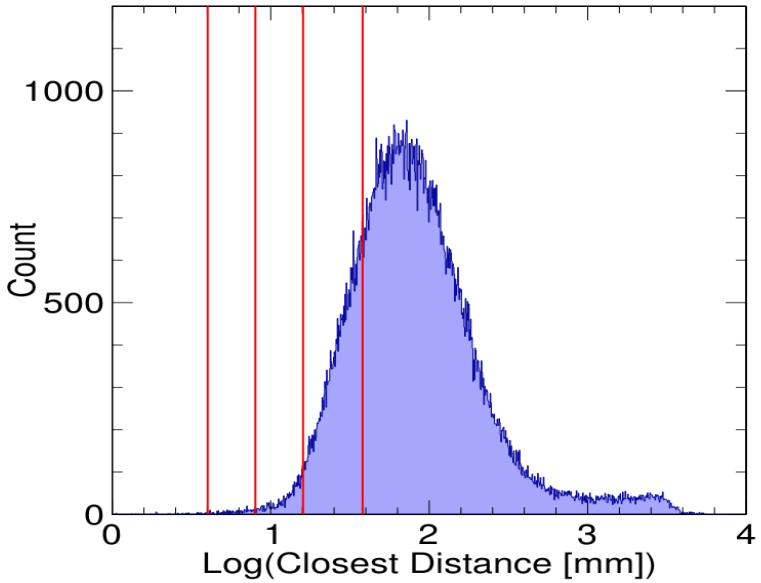
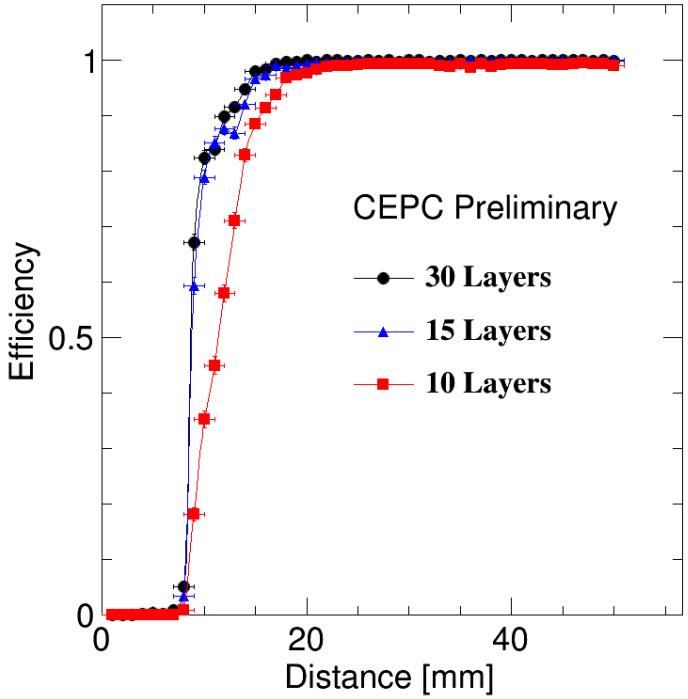


Table 2. Percentages of photons that would be polluted by neighbor particles

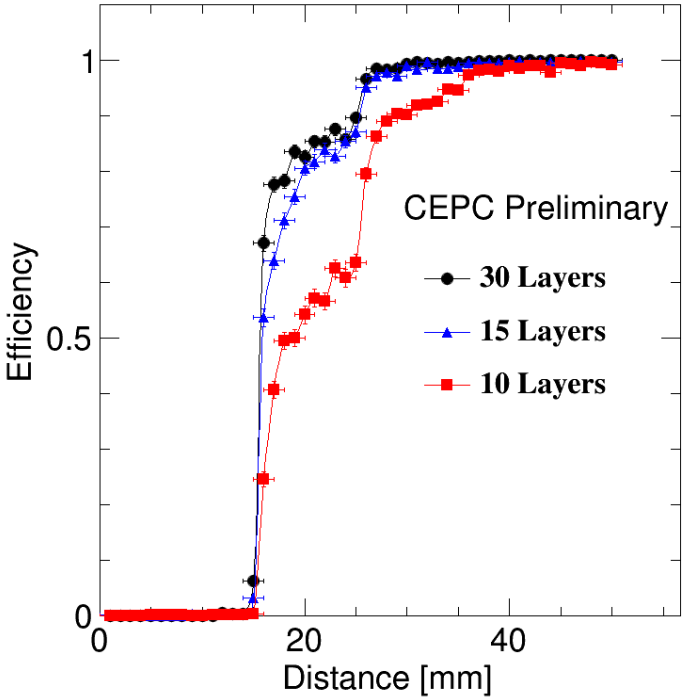
Cell Size	Critical Separation Distance with Arbor	Percentage of $Z \rightarrow \tau^+\tau^-$
1 mm	4 mm	0.07%
5 mm	8 mm	0.30%
10 mm	16 mm	1.70%
20 mm	38 mm	19.6%

At least ~10mm×10mm effective cell size

Separation Eff VS. ECAL Layer Number

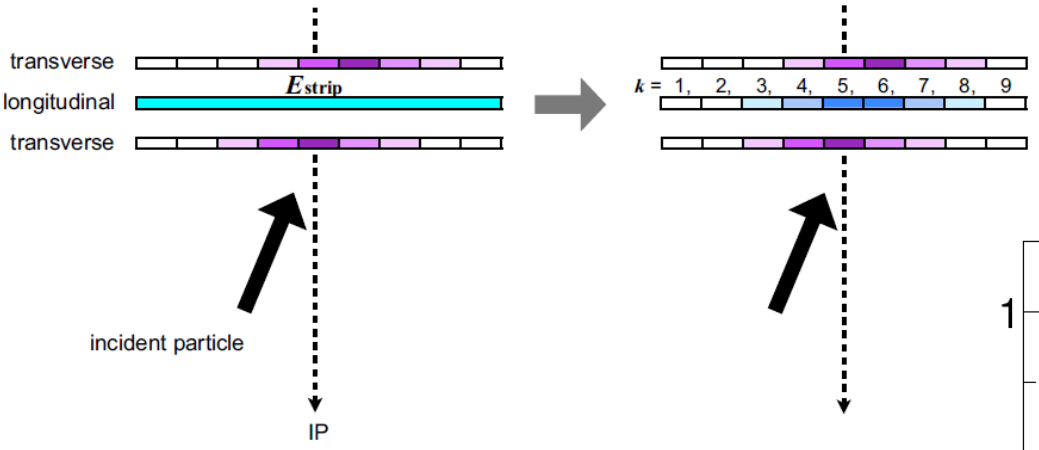


Cell Size = 5mm*5mm



Cell Size = 10mm*10mm

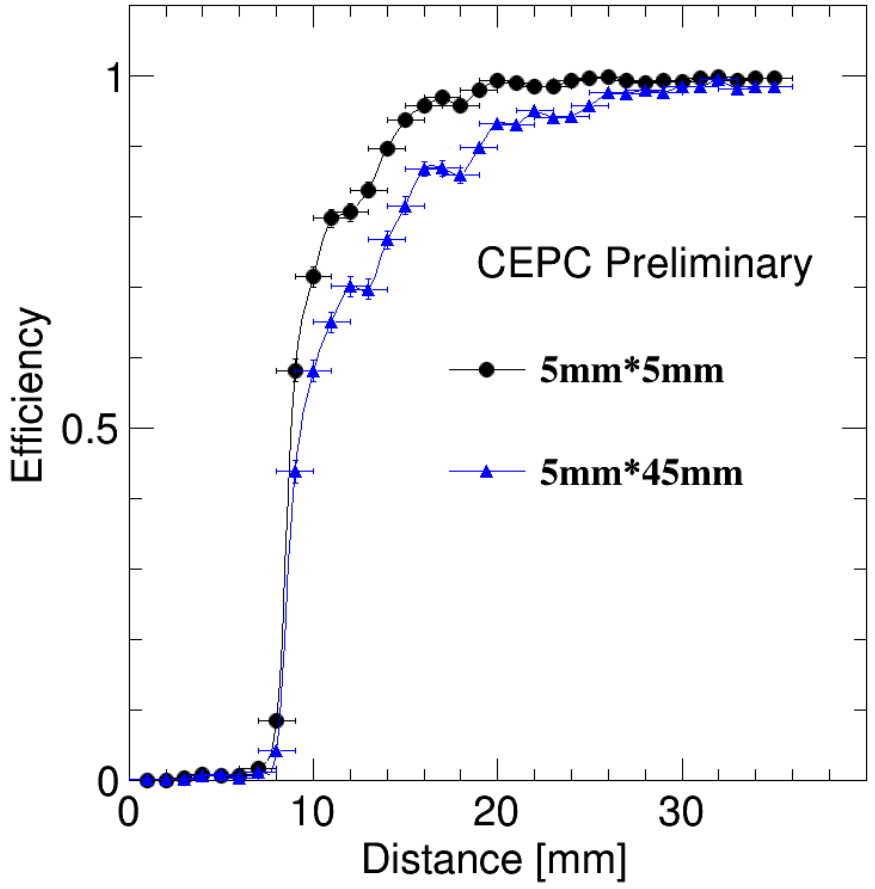
Separation at Strip Readout



5*45mm Cell -> 5*5mm Cell

Energies of Neighbor Layer Strips (2*9) are used to calculate the energy splitting weights

Next: further study at jet reconstruction



Summary for Di-photon Separation

- ~10mm*10mm or smaller cell size is needed for EM shower separation in tau jets.

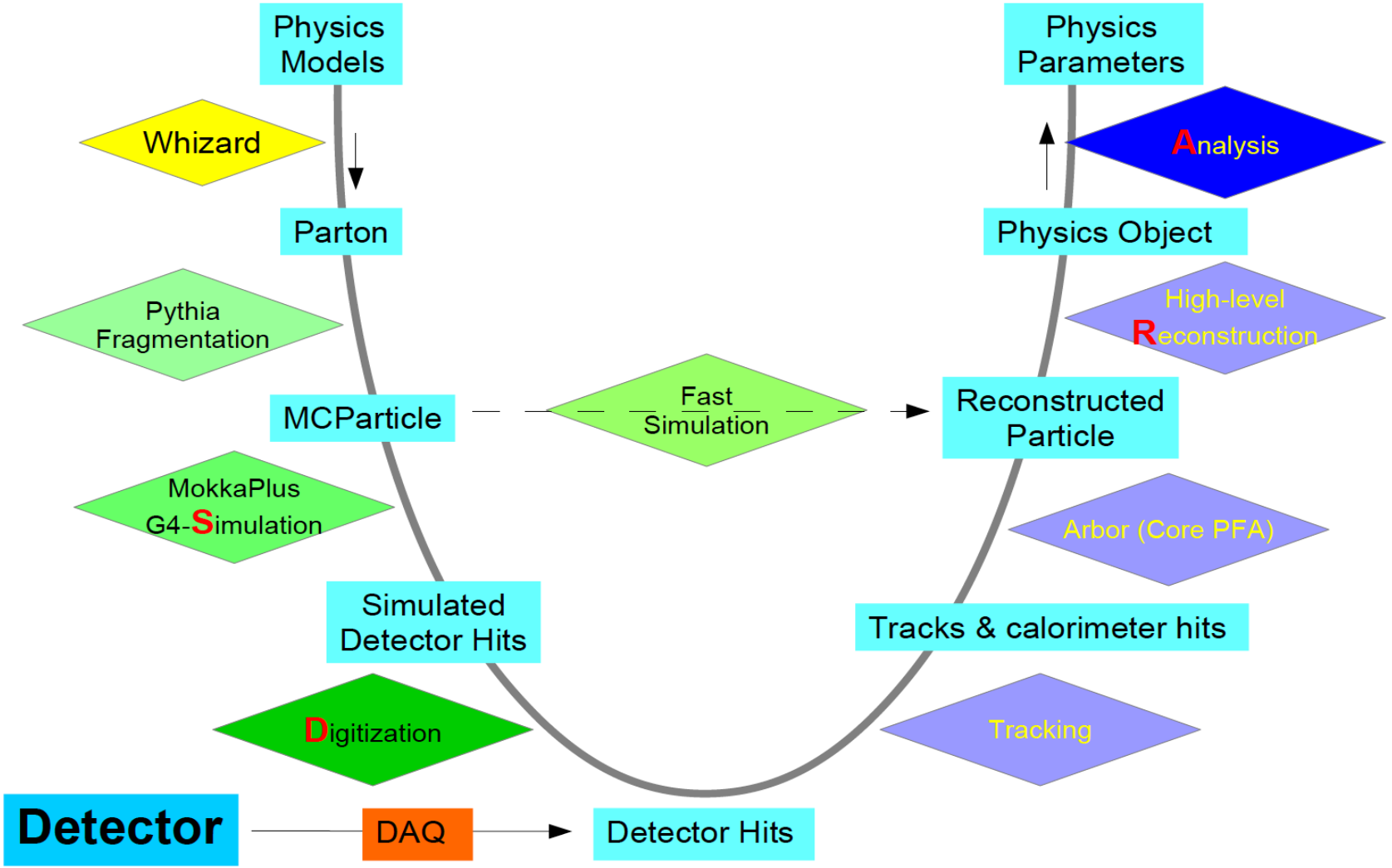
- Less readout layer or Strip readout method will slightly decrease the separation performance

Outline

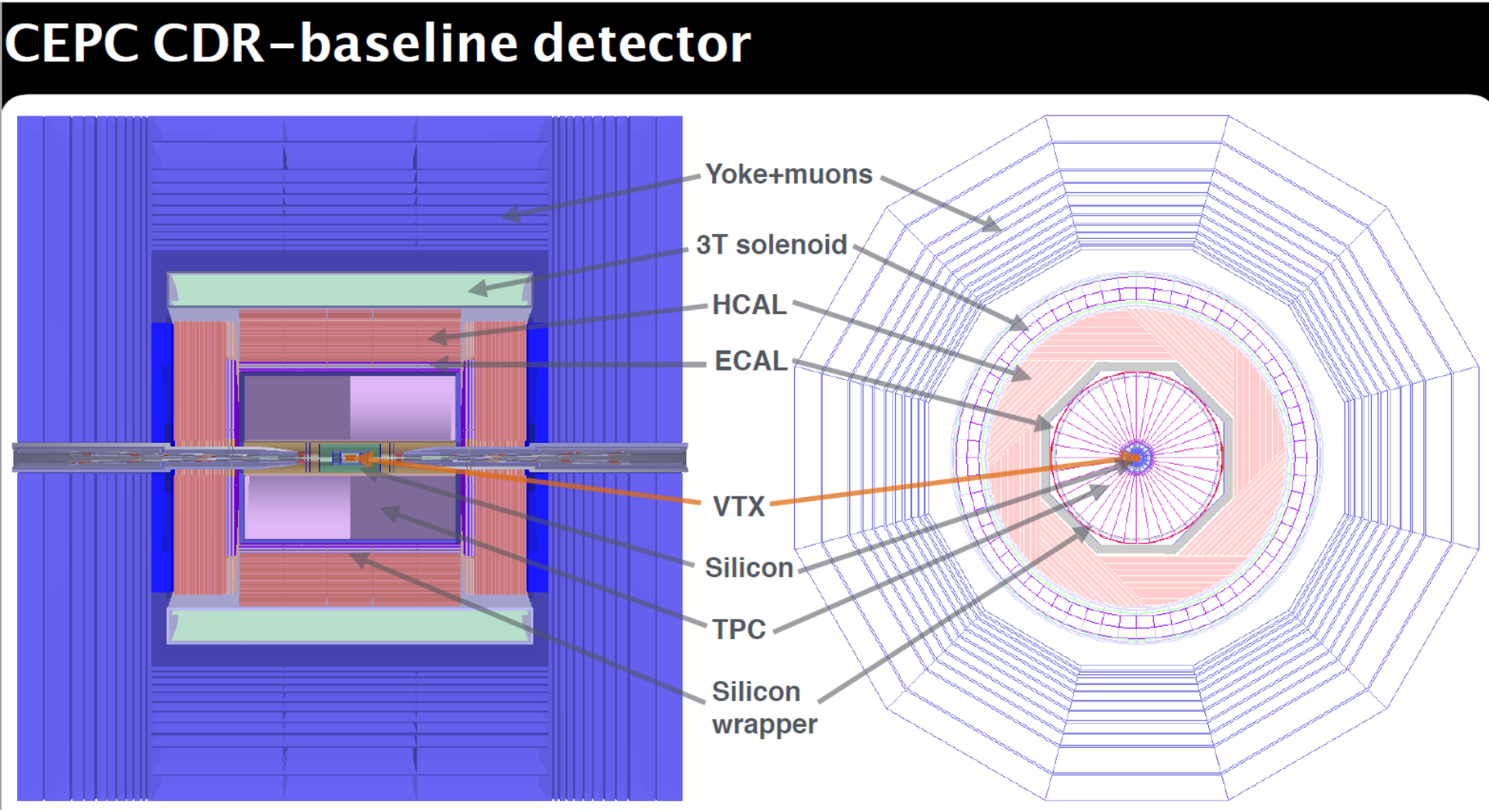
- Di-photon Separation Study

- Higgs Signals at CEPCv4 Geometry (APODIS, Baseline Geometry at CDR)

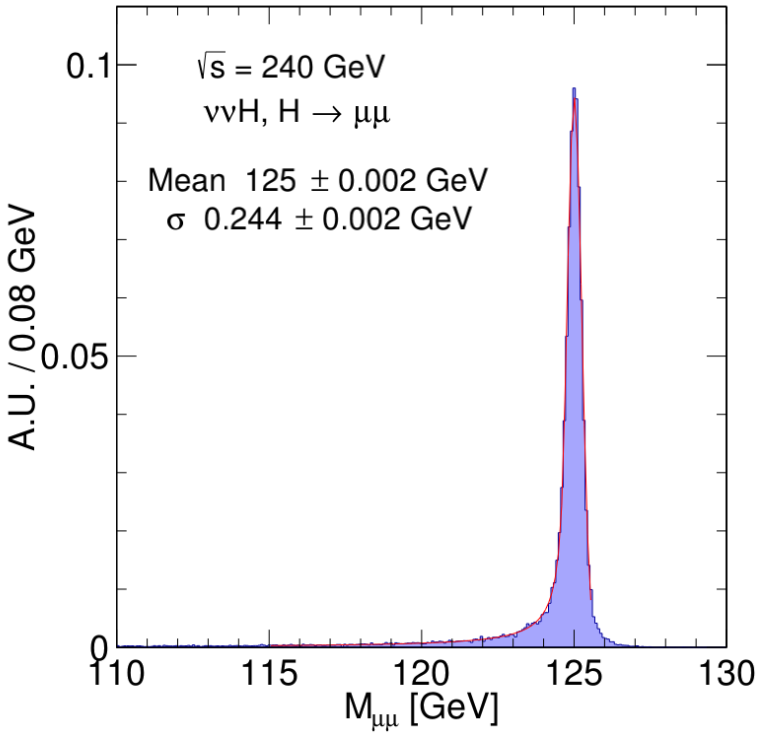
CEPC Full Simulation Software

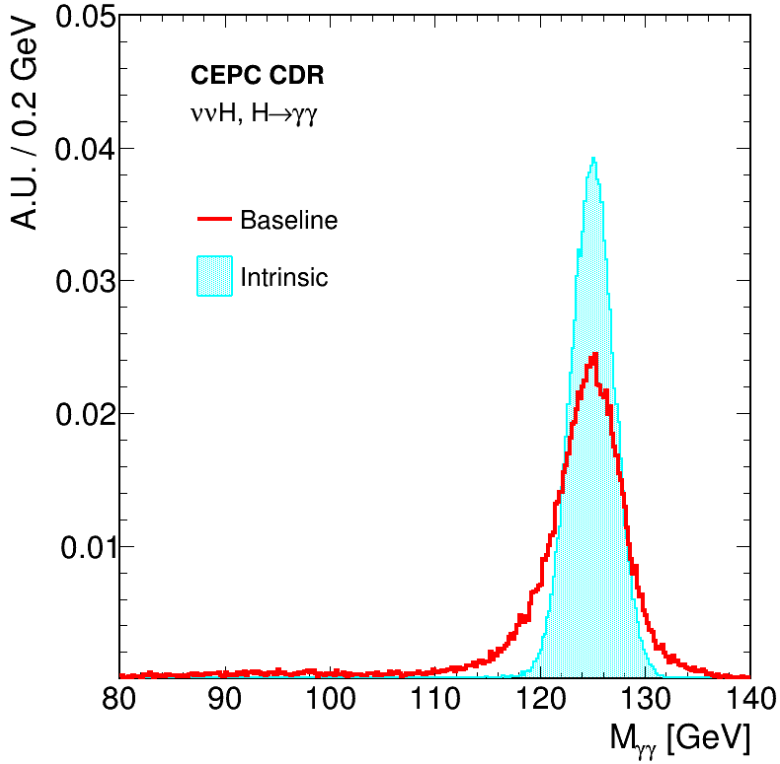


APODIS Geometry



Higgs Signals at APODIS



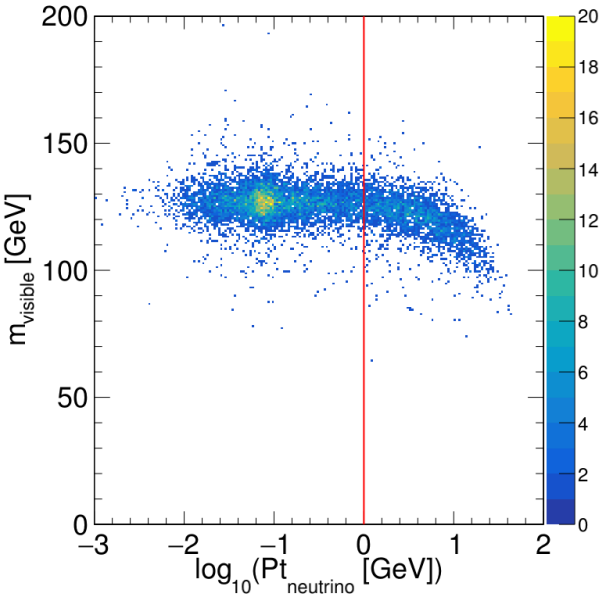


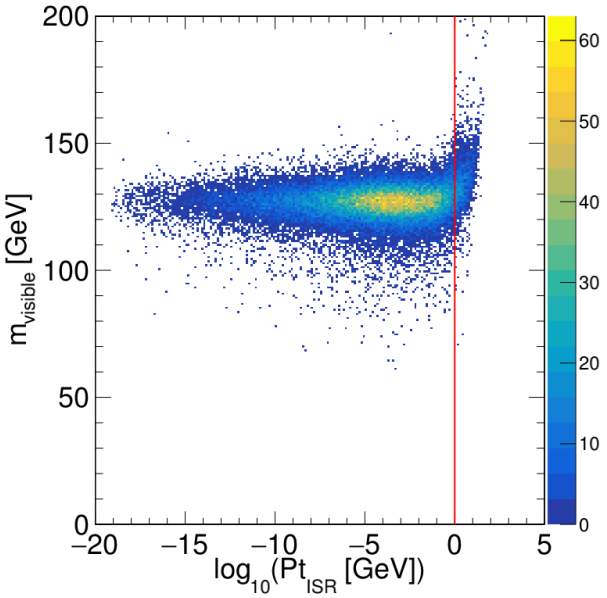
CEPC-RECO-2018-002
CEPC-Doc id 174, 175

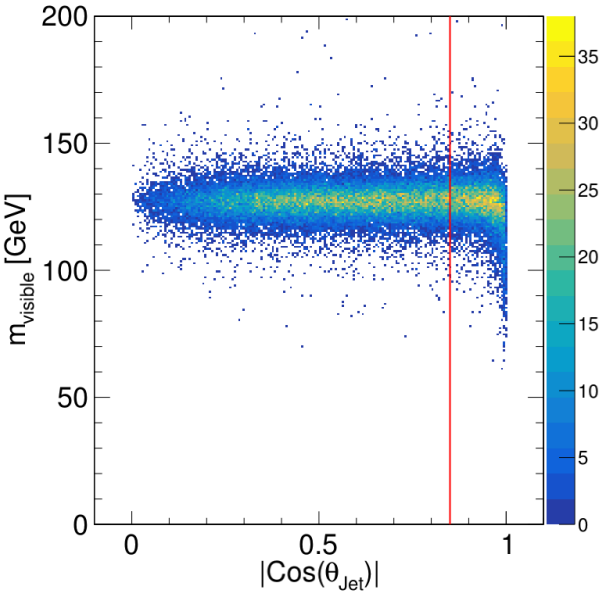
Lepton tracks & Photon Clusters

Event Selection for jet final states

- The ISR (initial state radiation) photons.
- The neutrinos generated by the Higgs boson decay products.
- The direction of the jets, for Higgs->di-jets events.

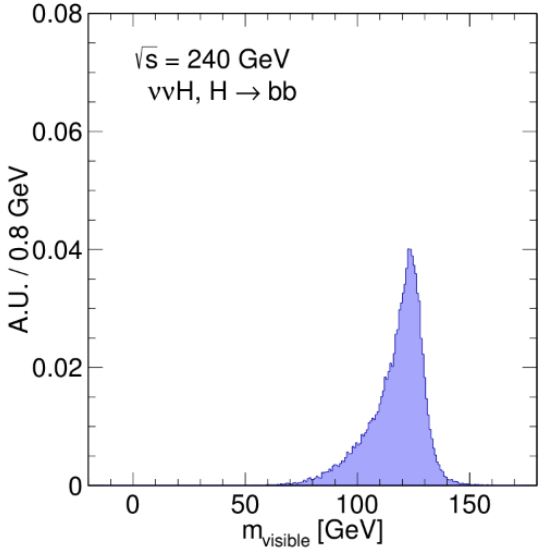


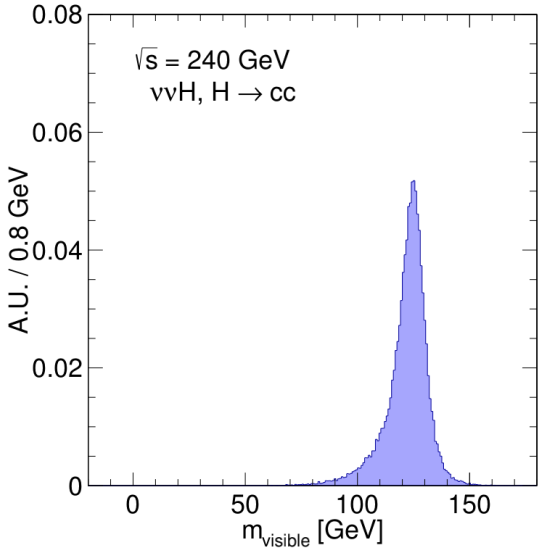


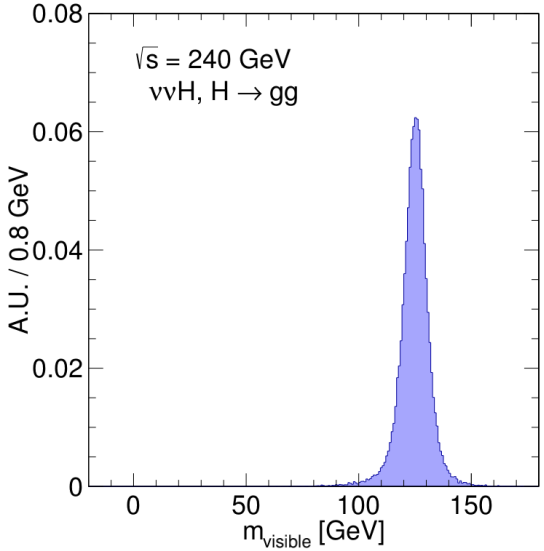


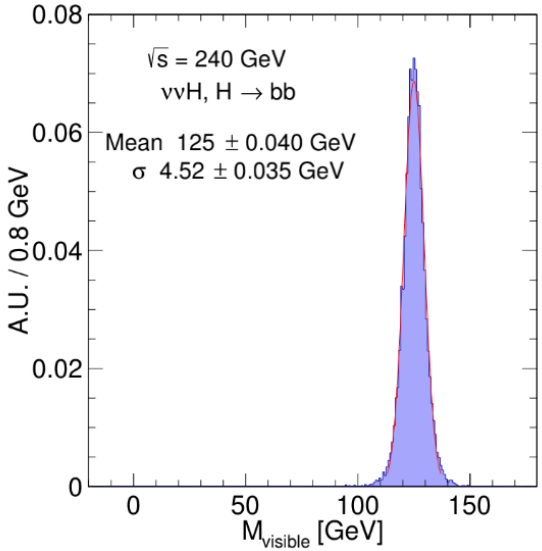
Higgs -> gg events

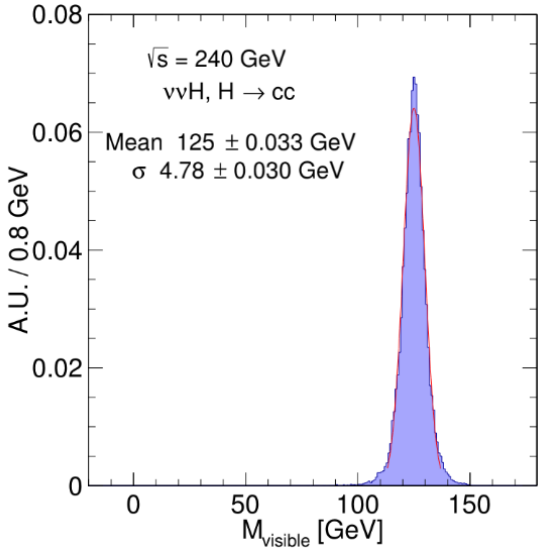
Higgs decaying to two jets

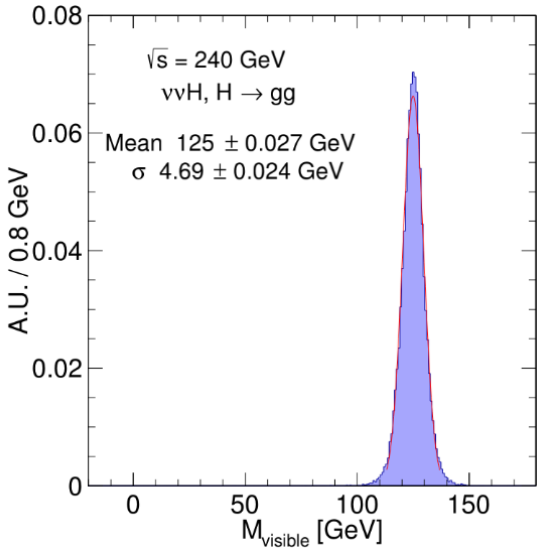




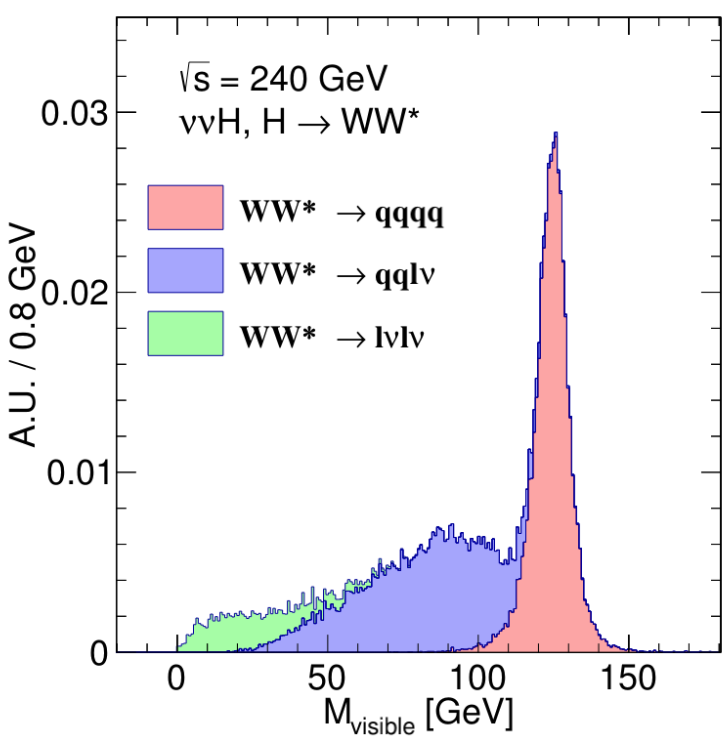




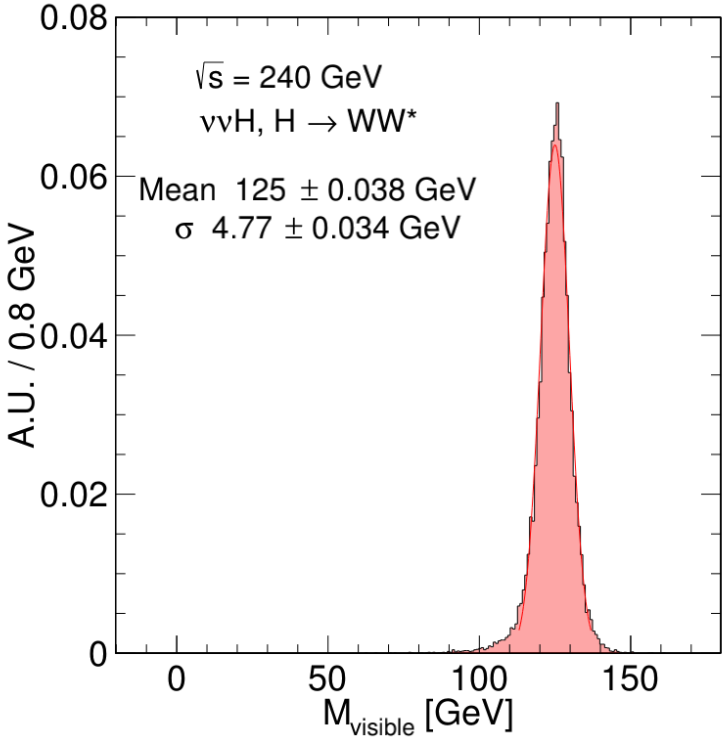




Higgs -> WW*

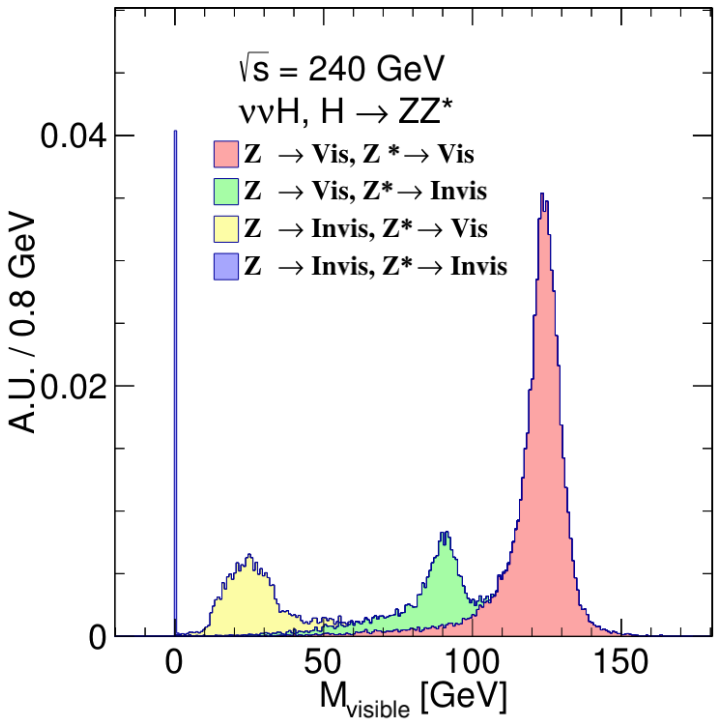


Before event selection

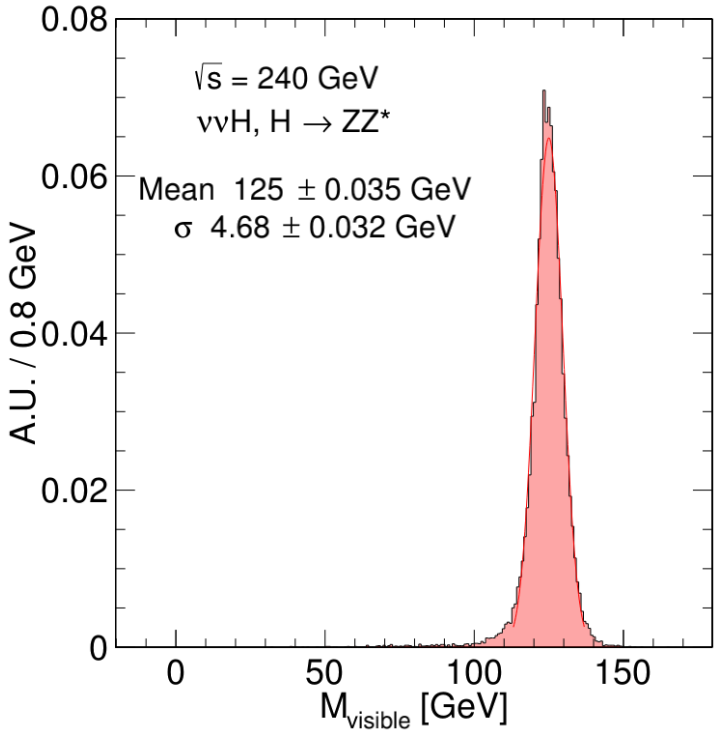


After event selection

Higgs -> ZZ*



Before event selection



After event selection

Higgs Signals at APODIS

Higgs boson mass resolution (sigma/Mean) at different decay modes with jets as final state particles, after event cleaning.

H->bb	H->cc	H->gg	H->WW*	H->ZZ*
3.63%	3.82%	3.75%	3.81%	3.74%

Benchmark resolutions (sigma/Mean) of reconstructed Higgs boson mass, comparing to LHC results.

	H->μμ	H->γγ	H->bb
CECP (APODIS)	0.20%	2.59%	3.63%
LHC (CMS, ATLAS)	~2%	~1.5%	~10%

- CEPC has much better resolution for charged particles and jets.
- Geometry based corrections and fine-tuned calibrations are needed for photons, see Yuqiao's talk

Arxiv: 1806.04992

Thanks!

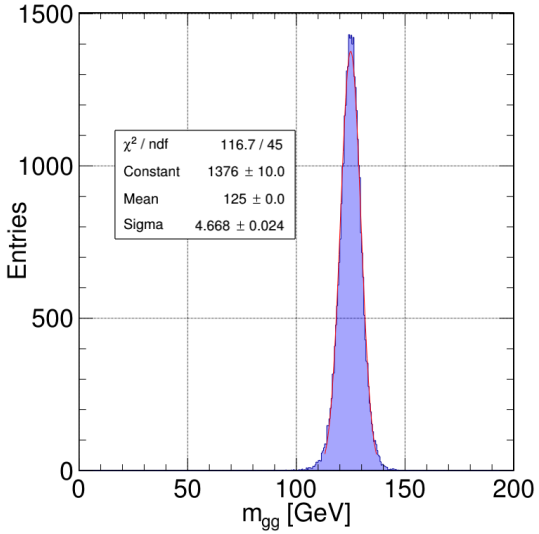
Back up

APODIS Geometry

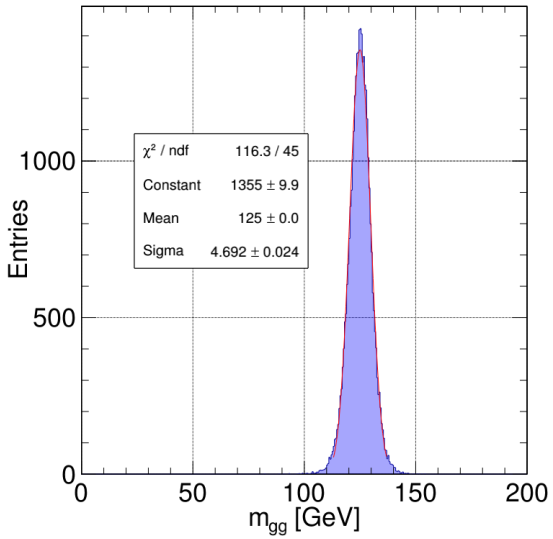
Physics process	Measurands	Detector subsystem	Performance requirement
$ZH, Z \to e^+e^-, \mu^+\mu^-$ $H \to \mu^+\mu^-$	$m_H, \sigma(ZH)$ $\mathrm{BR}(H \to \mu^+\mu^-)$	Tracker	$\Delta(1/p_T) =$ $2 \times 10^{-5} \oplus \frac{0.001}{p(\mathrm{GeV}) \sin^{3/2}\theta}$
$H \to b\bar{b}/c\bar{c}/gg$	$\mathrm{BR}(H \to b\bar{b}/c\bar{c}/gg)$	Vertex	$\sigma_{r\phi} =$ $5 \oplus \frac{10}{p(\mathrm{GeV}) \times \sin^{3/2}\theta}(\mu\mathrm{m})$
$H \to q\bar{q}, WW^*, ZZ^*$	$\mathrm{BR}(H \to q\bar{q}, WW^*, ZZ^*)$	ECAL HCAL	$\sigma_E^{\mathrm{jet}}/E =$ $3 \sim 4\%$ at 100 GeV
$H \to \gamma\gamma$	$\mathrm{BR}(H \to \gamma\gamma)$	ECAL	$\Delta E/E =$ $\frac{0.20}{\sqrt{E(\mathrm{GeV})}} \oplus 0.01$

CEPC Detector Model Results

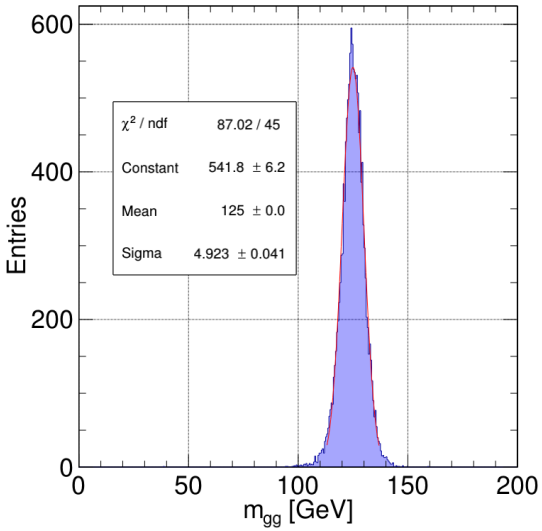
vvHiggs->gluon gluon



5mm*5mm



10mm*10mm



20mm*20mm

Cell Size (mm^2)	5 x 5	10 x 10	20 x 20
Boson Mass Resolution (sigma/mean)	3.74%	3.75%	3.93%