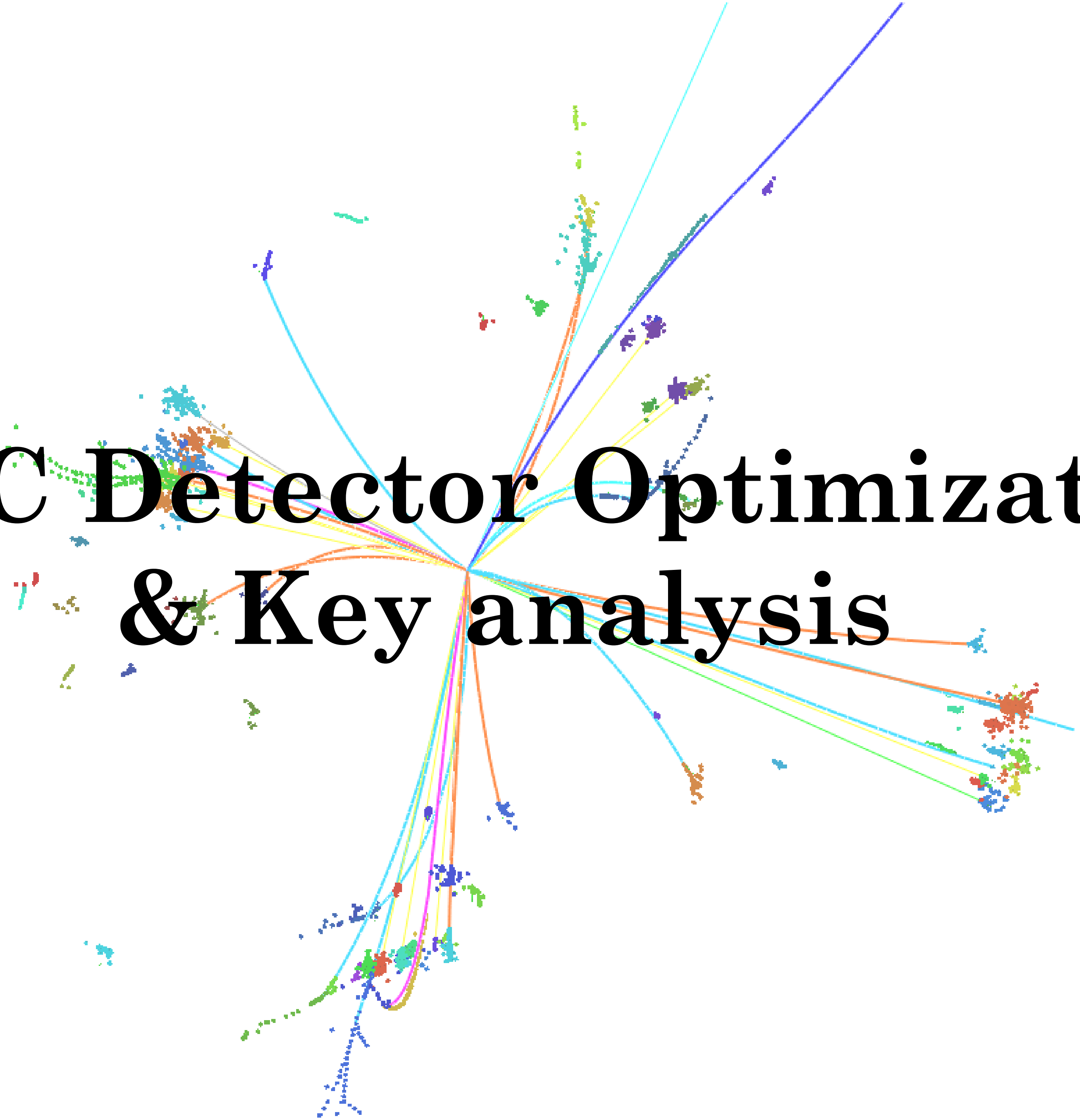


CEPC Detector Optimization & Key analysis

Outline

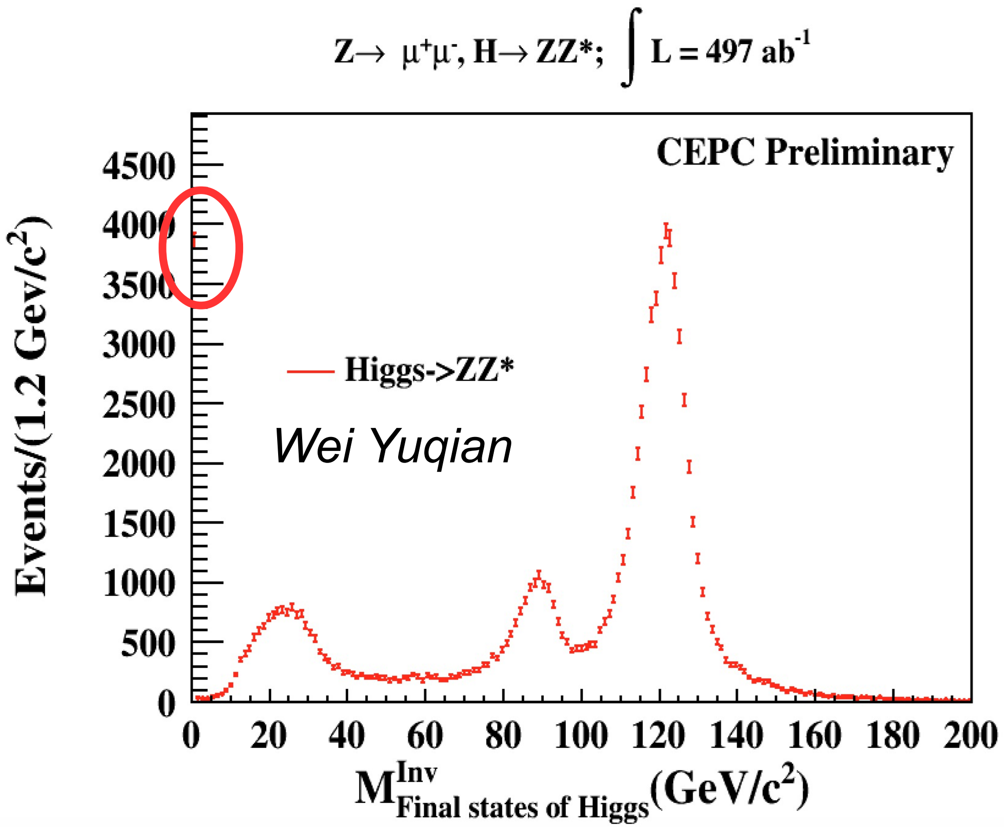
- Key Analysis: Br(H->WW/ZZ)

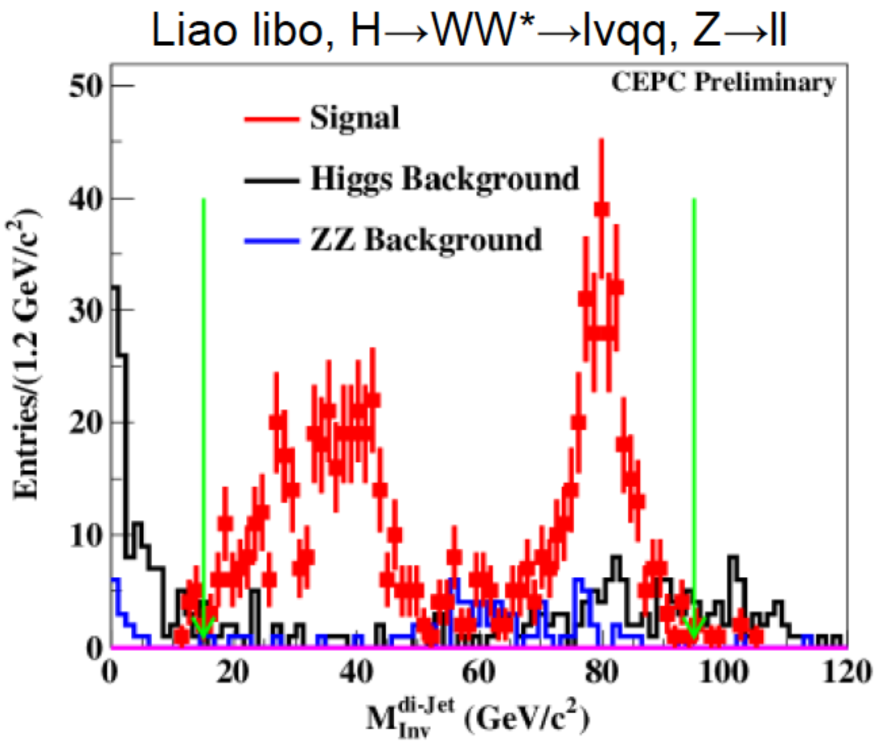
- Optimization:
  - VTX:
    - Inner most radius, flavor tagging & Br(H->bb, cc, gg) measurements
  - Calorimeter:
    - Performance wi/wo active cooling
      - PID
      - Higgs recoil analysis, Br(H->ZZ)
    - ECAL Dynamic Ranger & Br(H->di photon)

Key analysis

Higgs to ZZ/WW

Portal to Higgs width & perfect test bed for detector/reconstruction performance...





Br(H→ZZ)

Expected Number of events with different objects

	Z→ll	tautau	vv	qq
H→ZZ*→4q	888	444	3.10k	9.24k
2v + 2q	508	254	1.77k	5.29k
2l + 2q	170	85	596	1.8k
4v	73	36	254	756
2l + 2v	49	24	170	508
4l	8	4	28	86
X + tau	120	60	418	1246

YQ. Wei

- More than 2 jets, Await for sophisticated Jet Clustering
- Await for tau finder
- limited accuracy ~ > 50%
- Explored by H->invisible analysis -> Accuracy ~ 40%
- Promising channels
- Unexplored

Br(H→ZZ)

ZZZ*	Yield	Object reconstructed	Signal Efficiency(%)	Main Background	Accuracy (%)	Comments
μμvvqq	128	118	63.3	h->ww&zz_sl	**12.9**	Tau finder would be highly appreciated Reconstructed efficiency of electron need to be improved
μμqqvv	128	125	-	h->bb&zz_sl	>25	
eevvqq	132	91	53.8	h->ww&sze_sl	**15.8**	
eeqqvv	132	88	-	h->bb&zz_sl	>25	
vvμμqq	158	144	61.4	h->t,w&zz_sl	**11.0**	
vvqqμμ	158	149	51.9	h->w,b&zz_sl	**12.9**	
vveeqq	151	118	43.1	h->w&sze_sl	**21.3**	
vvqqee	151	134	-	h->bb&sze_sl	>25	
qqμμvv	135	115	-	h->tt&zz_sl	>25	Compare to ll recoil, qq recoil mass has much worse distinguishing power to SM background
qqvvμμ	135	122	-	h->t,w&zz_sl	>25	
qqeevv	127	107	-	h->tt&sze_sl	>25	
qqvvee	127	123	-	h->t,w&sze_sl	>25	
μμμμqq/qqμμ	43	39	69.8	h->tt&zz_sl	**19.9**	Tau finder & Electron Reconstruction
μμeeqq/qqee	43	39	60.5	h->tt&zz_sl	**21.2**	
eeeeqq/eeqqee	43	33	-	h->tt&sze_sl	>25	
eeμμqq/eeqqμμ	43	41	58.2	h->tt&sze_sl	**19.9**	

Full Simulation analysis performed on 16 independent channels.
8 Channels acquire accuracy better than 25%.

Combined accuracy: **5.4%**

If electron id efficiency ~ muon id: ***4.8%***

TLEP extrapolation**: 4.3%**

Br(H→WW)

Expected Number of events with different objects

	Z→ll	tautau	vv	qq
H→WW*→4q	6.91k	3.45k	19.74k	69.1k
μvqq	2.27k	1.14k	6.47k	22.7k
evqq	2.27k	1.14k	6.47k	22.7k
eevv	186	93	527	1.9k
μμvv	186	93	527	1.9k
eμvv	372	186	1154	3.7k
X + tau	3.2k	1.6k	9.14k	32.0k

LB. Liao

Purple	Extrapolated from ILC results
Cyan	Await for tau finder
Yellow	Await for the SM Background simulation
Dark green	Full Simulation
Light green	Preliminary result acquired
White	Unexplored

Br(H→WW)

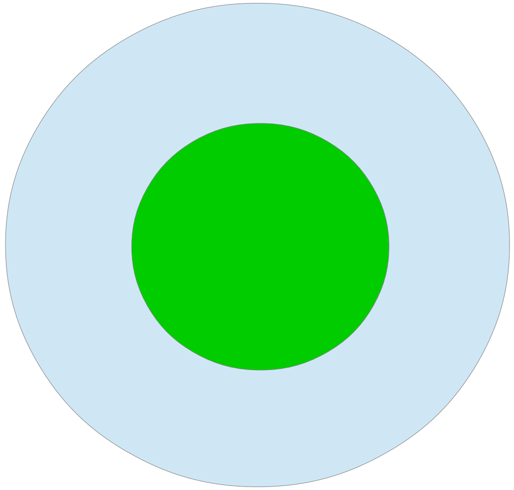
ZH, H->WW*	Yield	Object reconstructed	Isolation	Signal Efficiency	Main Background	Accuracy	Combined
Z(μμ)H(evev)	88	76(86.36%)	61(80.26%)	36(40.91%)	4(ZH)	17.57%	2.68%
Z(μμ)H(μvμv)	89	80(89.89%)	77(96.25%)	52(58.43%)	6(ZH&ZZ)	14.65%	
Z(μμ)H(evμv)	174	157(90.23%)	147(93.63%)	105(60.34%)	0	9.76%	
Z(μμ)H(evqq)	1105	1042(94.30%)	864(82.92%)	663(60.00%)	45(ZH)	4.02%	
Z(μμ)H(μvqq)	1110	1056(95.14%)	988(93.56%)	717(64.59%)	159(ZH&ZZ)	4.13%	
Z(μμ)H(qqqq)	Preliminary						3.0%
Z(ee)H(evev)	91	62(68.13%)	60(96.77%)	22(24.16%)	16(SZ)	28.02%	2.87%
Z(ee)H(μvμv)	82	63(76.83%)	63(100%)	44(53.66%)	24(SZ)	18.74%	
Z(ee)H(evμv)	178	132(74.16%)	124(93.94%)	82(46.07%)	25(ZH&SZ)	12.61%	
Z(ee)H(evqq)	1182	1041(88.07%)	916(87.99%)	621(51.78%)	188(SZ&ZH)	4.62%	
Z(ee)H(μvqq)	1221	1194(97.79%)	1048(87.77%)	684(56.02%)	49(ZH&SZ)	3.96%	
Z(ee)H(qqqq)	Preliminary estimation						3.2%

- Full Simulation on 12 independent channels
  - Very high object reconstruction efficiency
  - Combined result: 1.45%
- Extrapolation from other ILC channels: 1.59%
- Combined: 1.07%

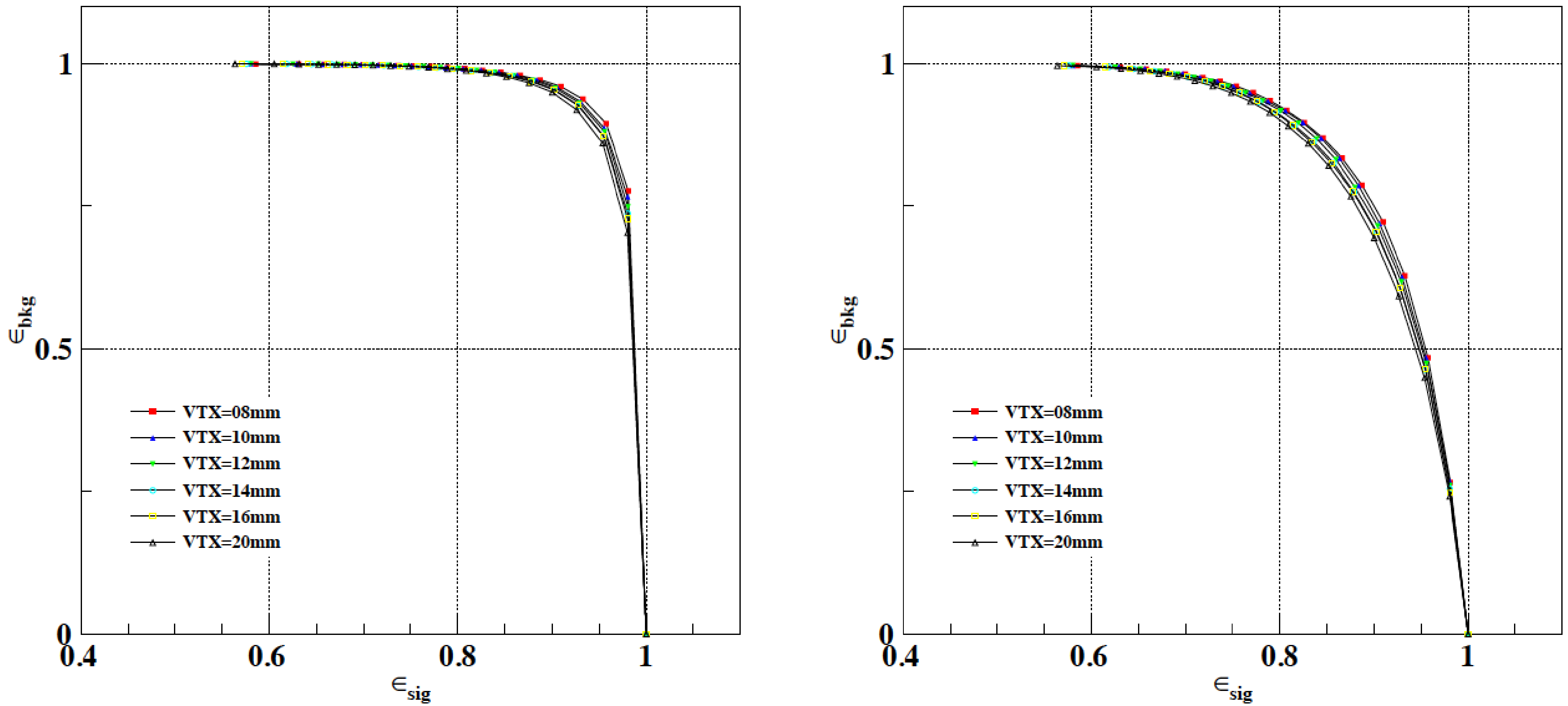
	Z→ll	tautau	vv	qq
H→WW*→4q	1.45%	3.45k	2.3%	69.1k
μvqq		1.14k	6.47k	2.2%
evqq		1.14k	6.47k	
eevv		93	527	1.9k
μμvv		93	527	1.9k
eμvv		186	1154	3.7k
X + tau	3.2k	1.6k	9.14k	32.0k

Optimization: VTX

- Foreword:
  - The design of MDI is not finalized yet.
  - Simply scan over different inner radius of VTX...
    - 16 mm -> 8 mm

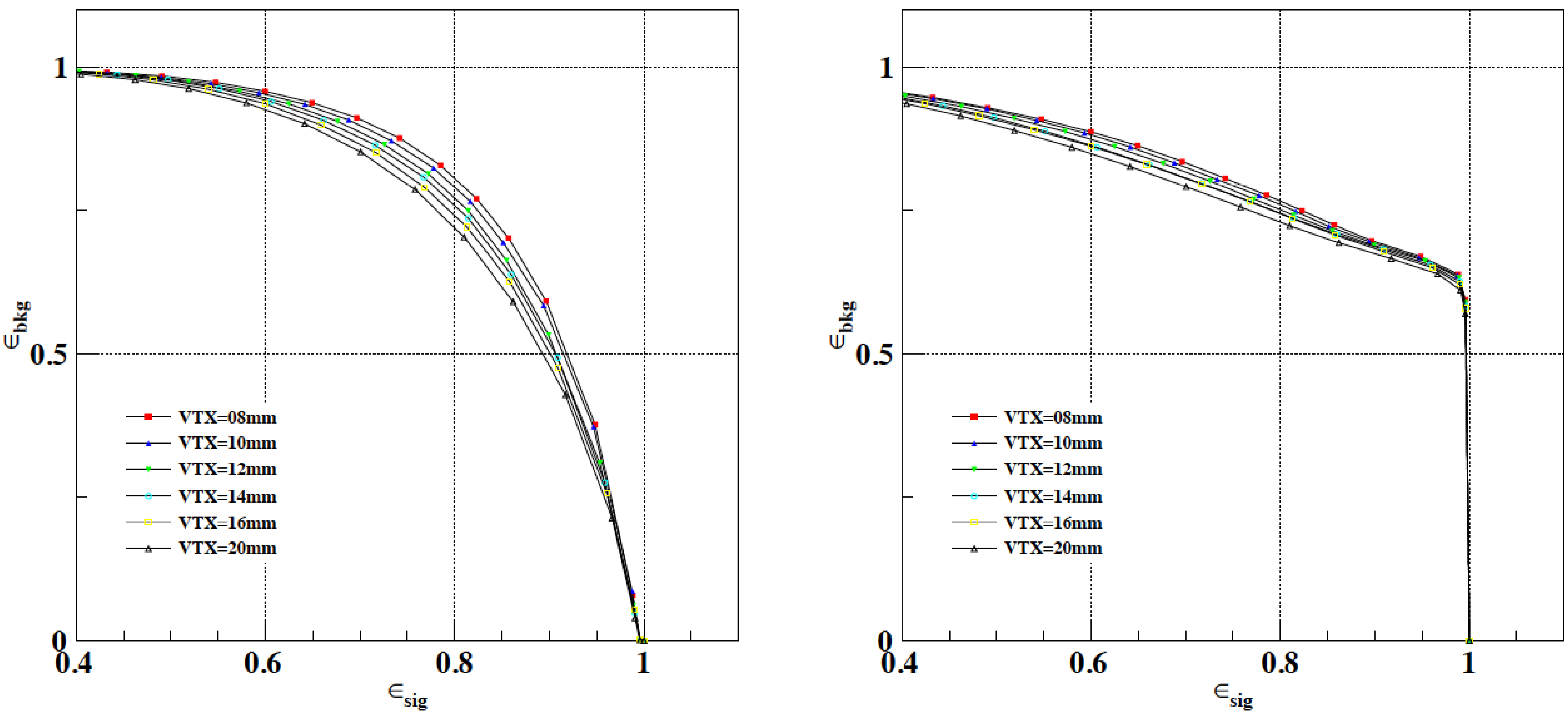


RoC Curve @ different radius



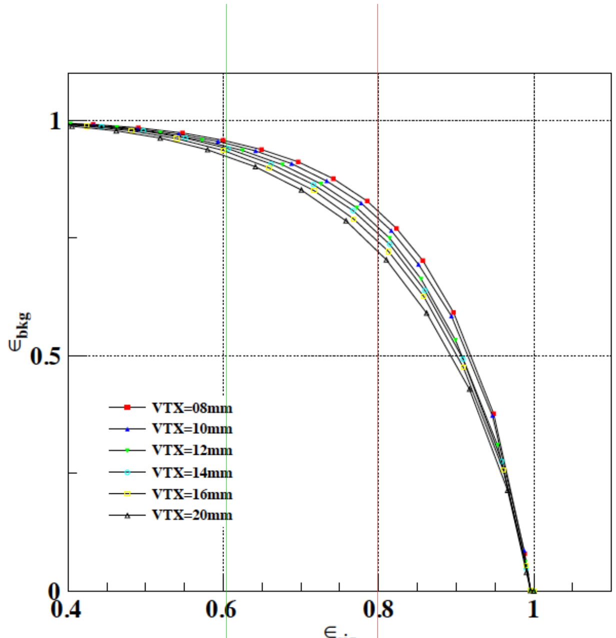
- B-tagging (Left: light background & Right: c-background)

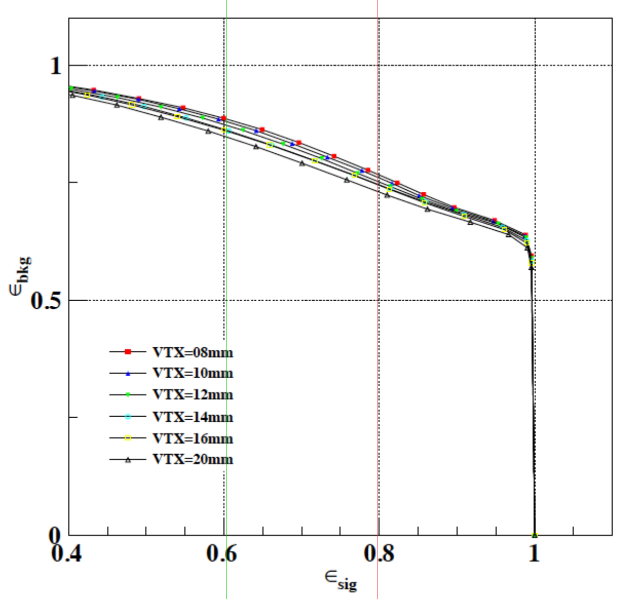
RoC Curve @ different radius



- C-tagging (Left: light background & Right: b-background)

RoC Curve @ different radius





- Z decay Branching ratio
  - Br(Z->uc): 11.6%
  - Br(Z->dsb): 15.6%
- In Z->qq sample
  - 16.6% Z->cc
  - 22.3% Z->bb
  - 61.1% Z->uds
- At Efficiency = 60% (Green Line)
  - P(uds->c) = 0.045/0.08
  - P(b->c) = 0.12/0.16
    - Purity = 0.6*16.6/(0.6*16.6 + 0.045(0.08)*61.1 + 0.12(0.16)*23.3) = 64%(53%)
- At Efficiency = 80% (Red line)
  - Purity = 44%(36%)

Optimization: Calorimeter

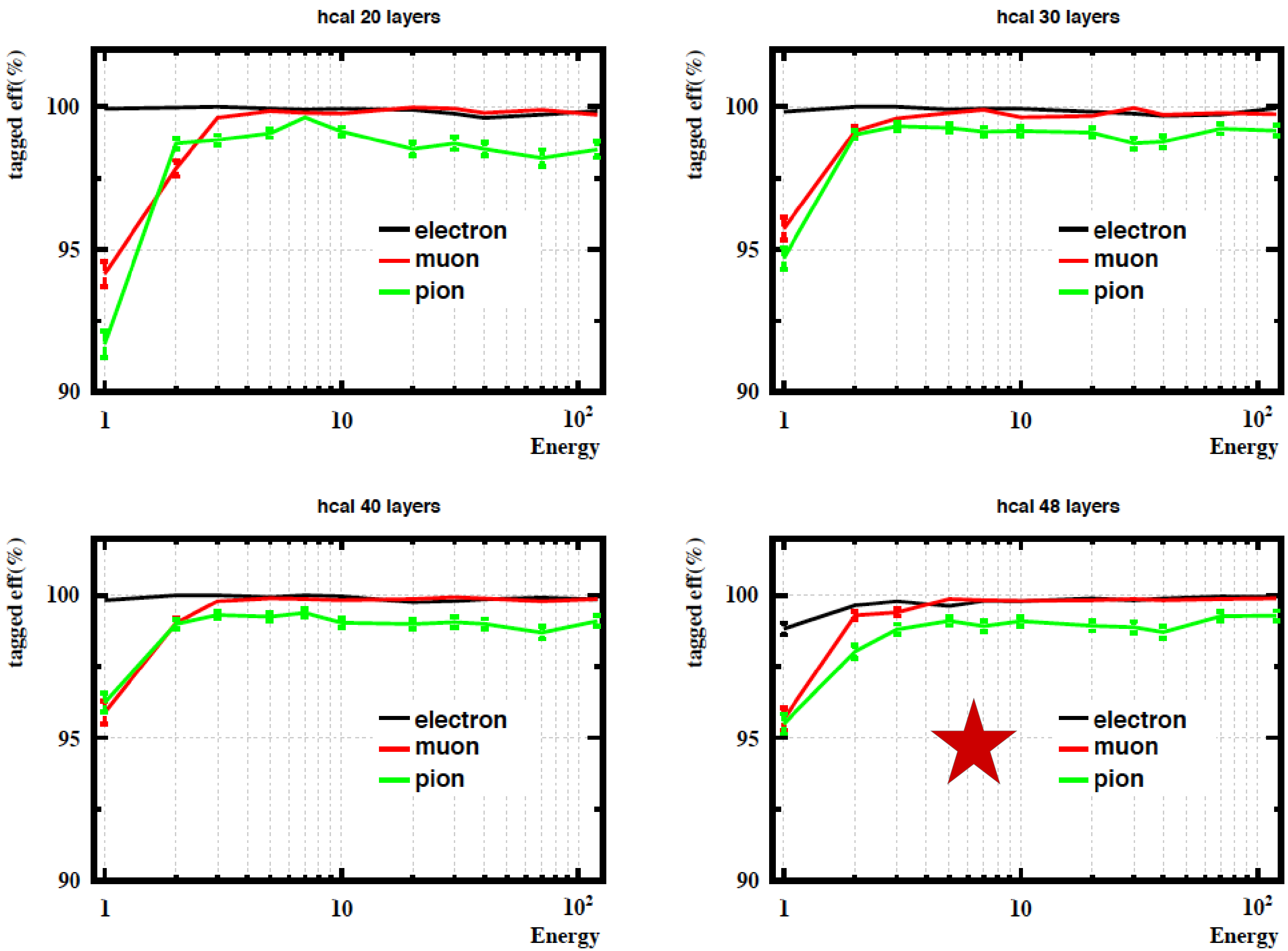
- Granularity: Wi/wo active cooling
  - Setting:
    - Active cooling in simulation: + 2mm thick cooper per active layer (reference to CMS HGC)
    - Wo: Reduce the granularity by more than 1 order of magnitude
  - Performance:
    - PID;
    - Separation & JER
    - Physics benchmark:
      - Z->di muon, Higgs to inc;
      - Z->di muon, vv; H->ZZ->llqq;
- ECAL Saturation studies: H->di photon

PID @ Different Granularity:

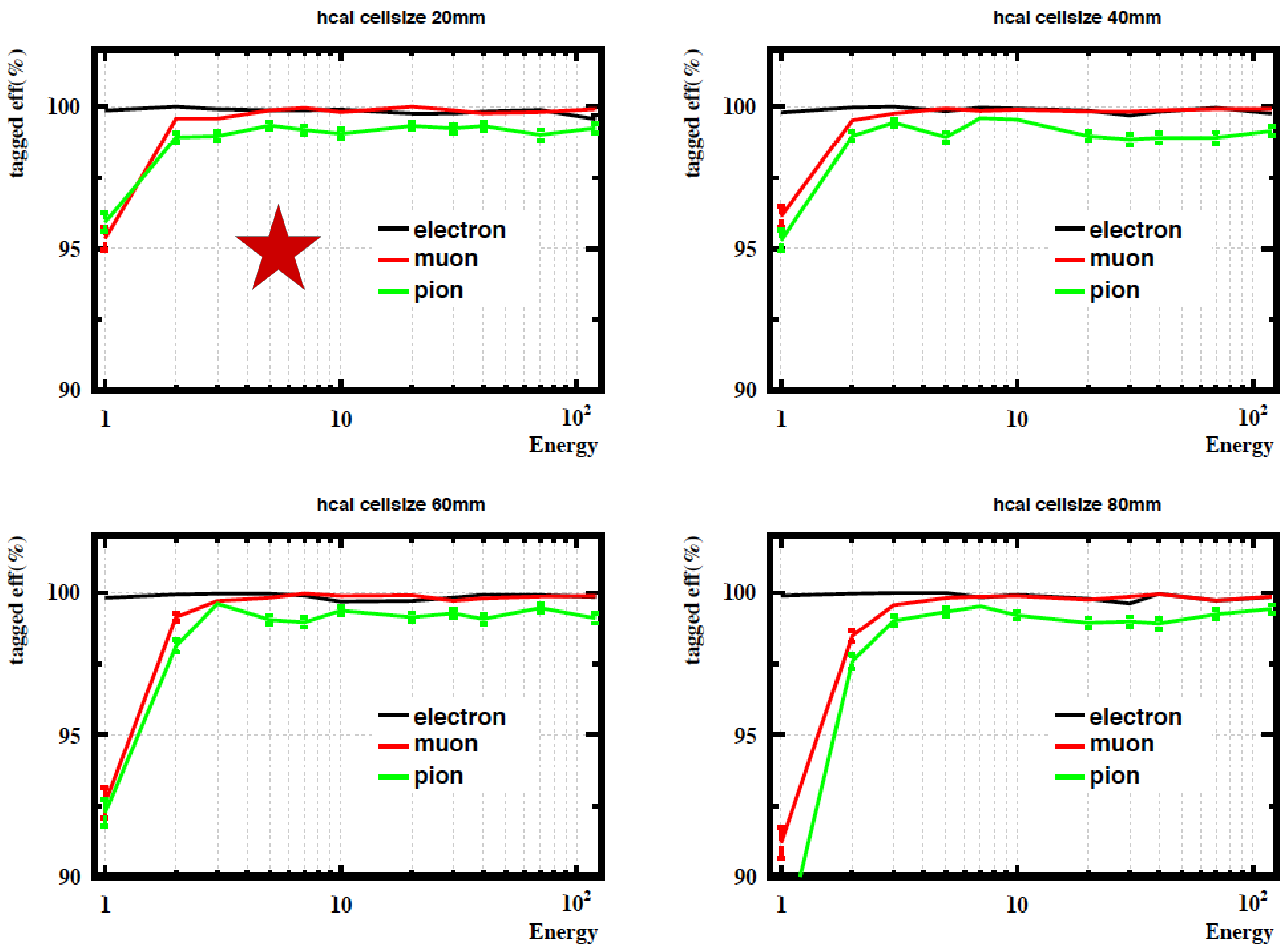
Solved By Dan

Varies from standard:
ECAL 30 layer & 5 mm cell size
HCAL 48 layers & 10 mm cell size

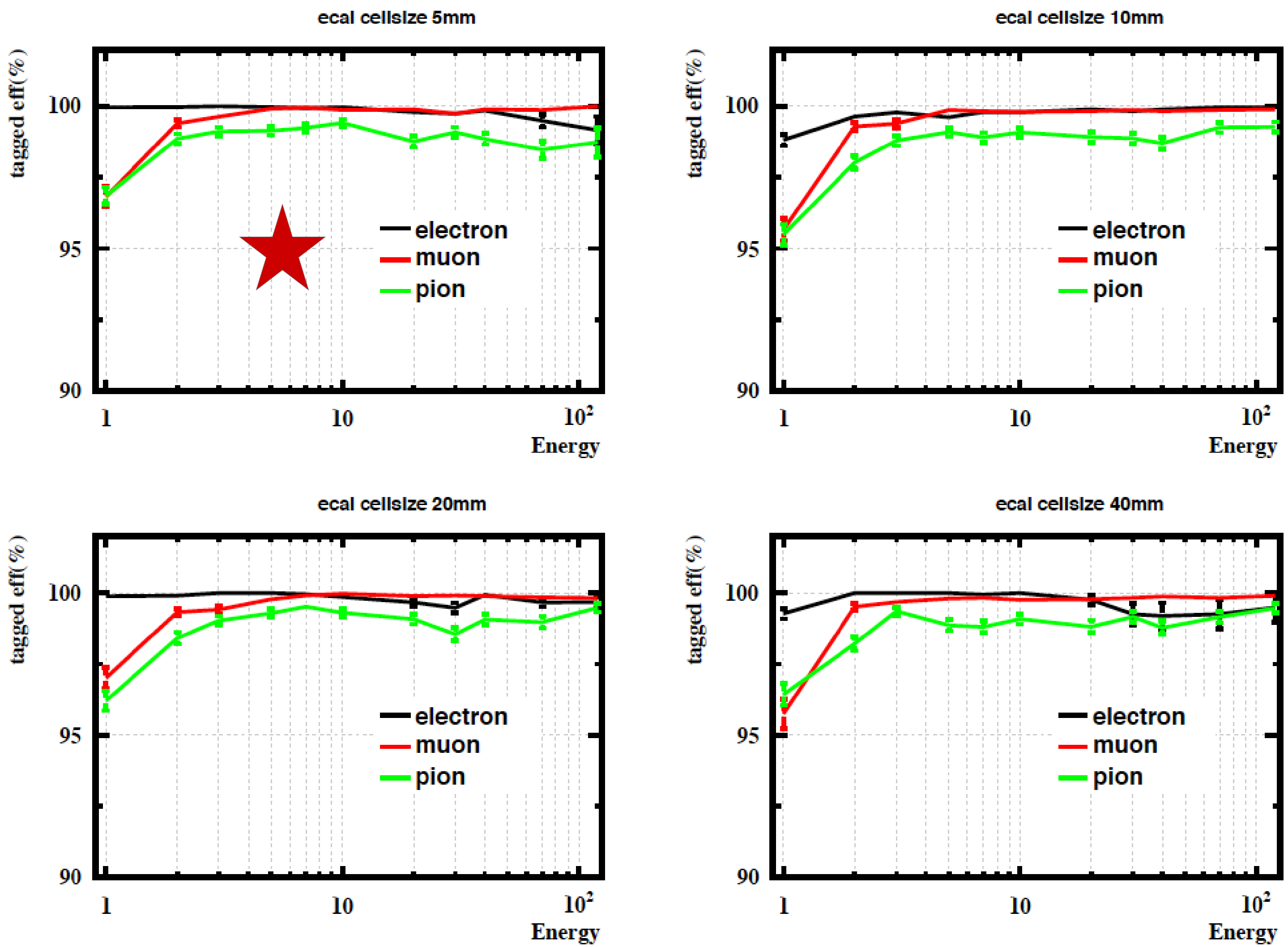
LICH: different HCAL layer



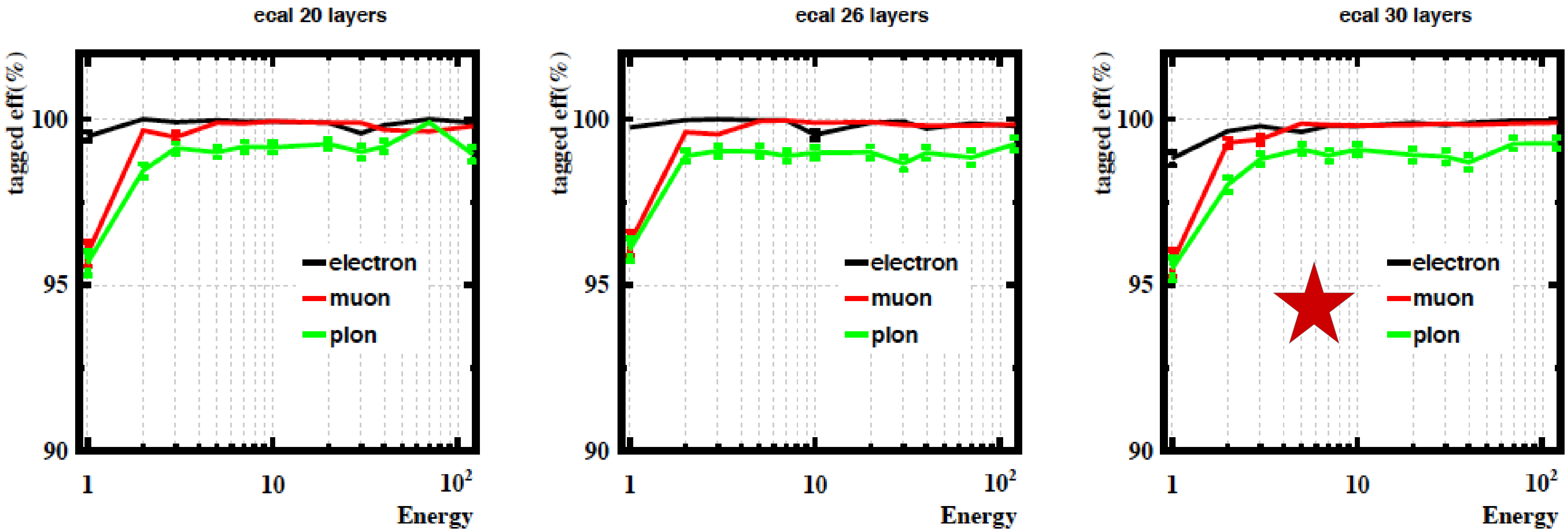
LICH: different HCAL cell size



LICH: different ECAL Cell size



LICH: different ECAL Layers



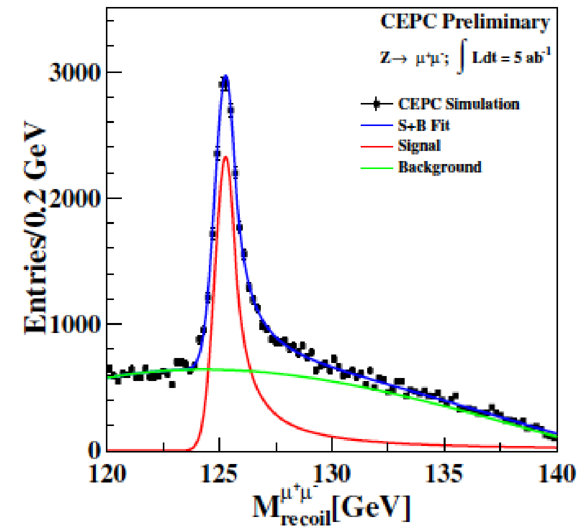
@Physics: Z->μμ, H->inc

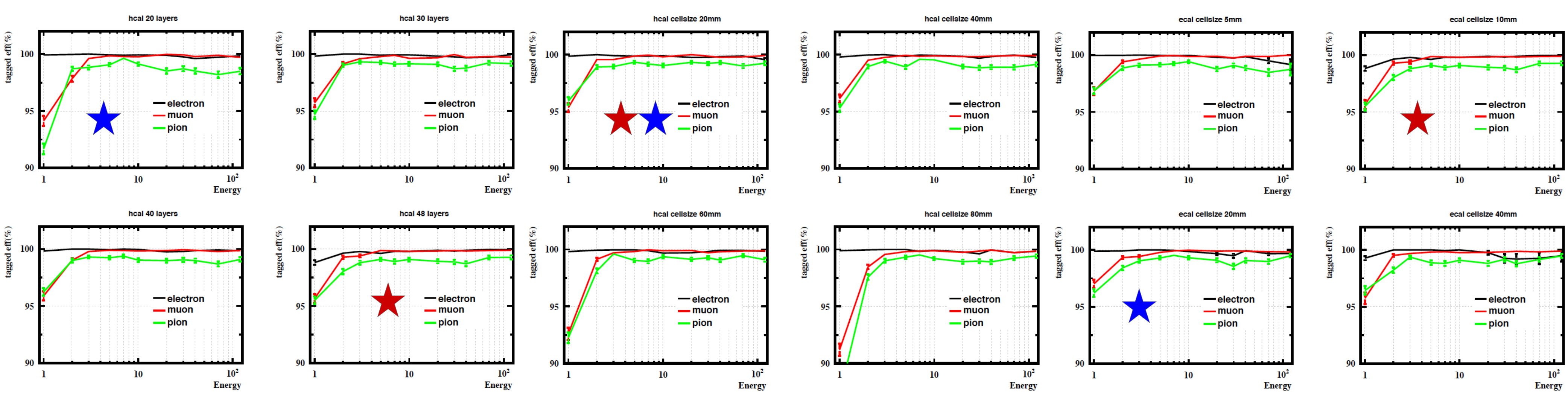
Table 3 $\mu\mu H$ events muon pid efficiency

	Geom 1	Geom 2	Geom 3
ECAL N layers	30	30	20
ECAL cell size	10	20	20
HCAL N layers	48	48	20
HCAL cell size	10	20	20
$\mu\mu H$ efficiency (%)	97.99 ± 0.44	96.48 ± 0.58	95.17 ± 0.73

channels compare to ILD:

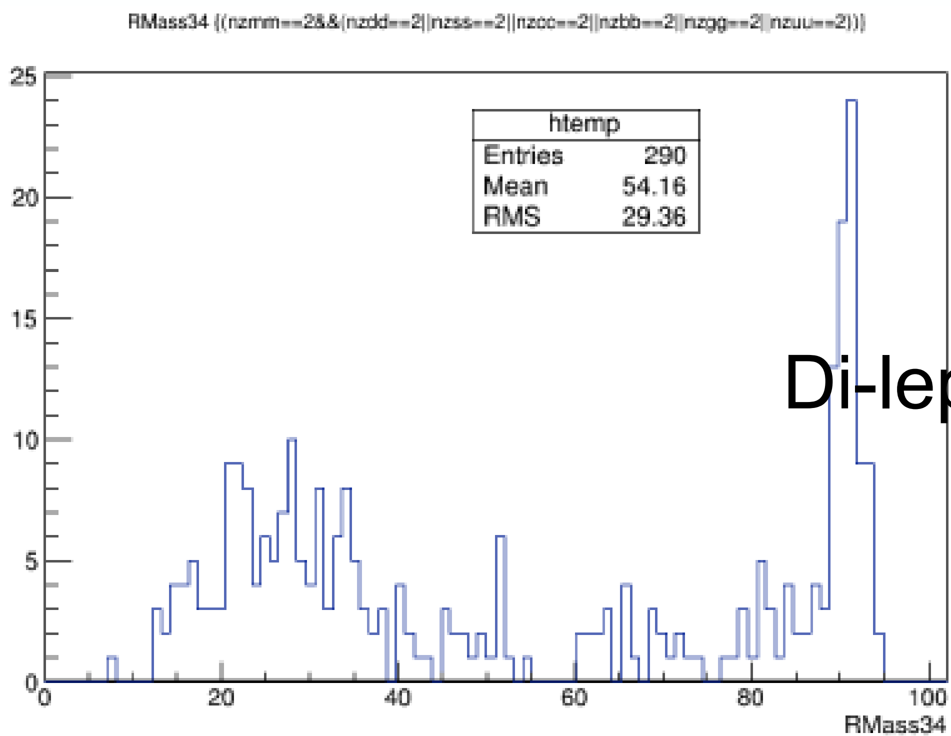
	Geom 1	Geom 2	Geom 3
ECAL	1/4	1/16	1/24
HCAL	1	1/4	1/10



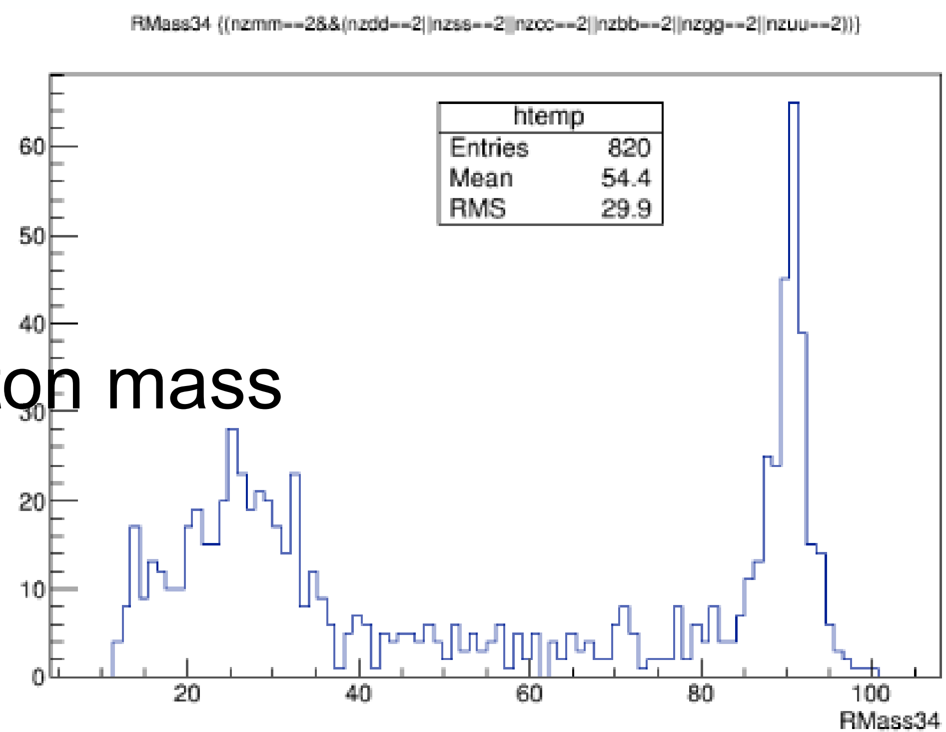


@Physics: Z->μμ/νν, H->ZZ->llqq

CEPC_v1
ECAL: 5mm * 30L
HCAL: 10mm * 48L



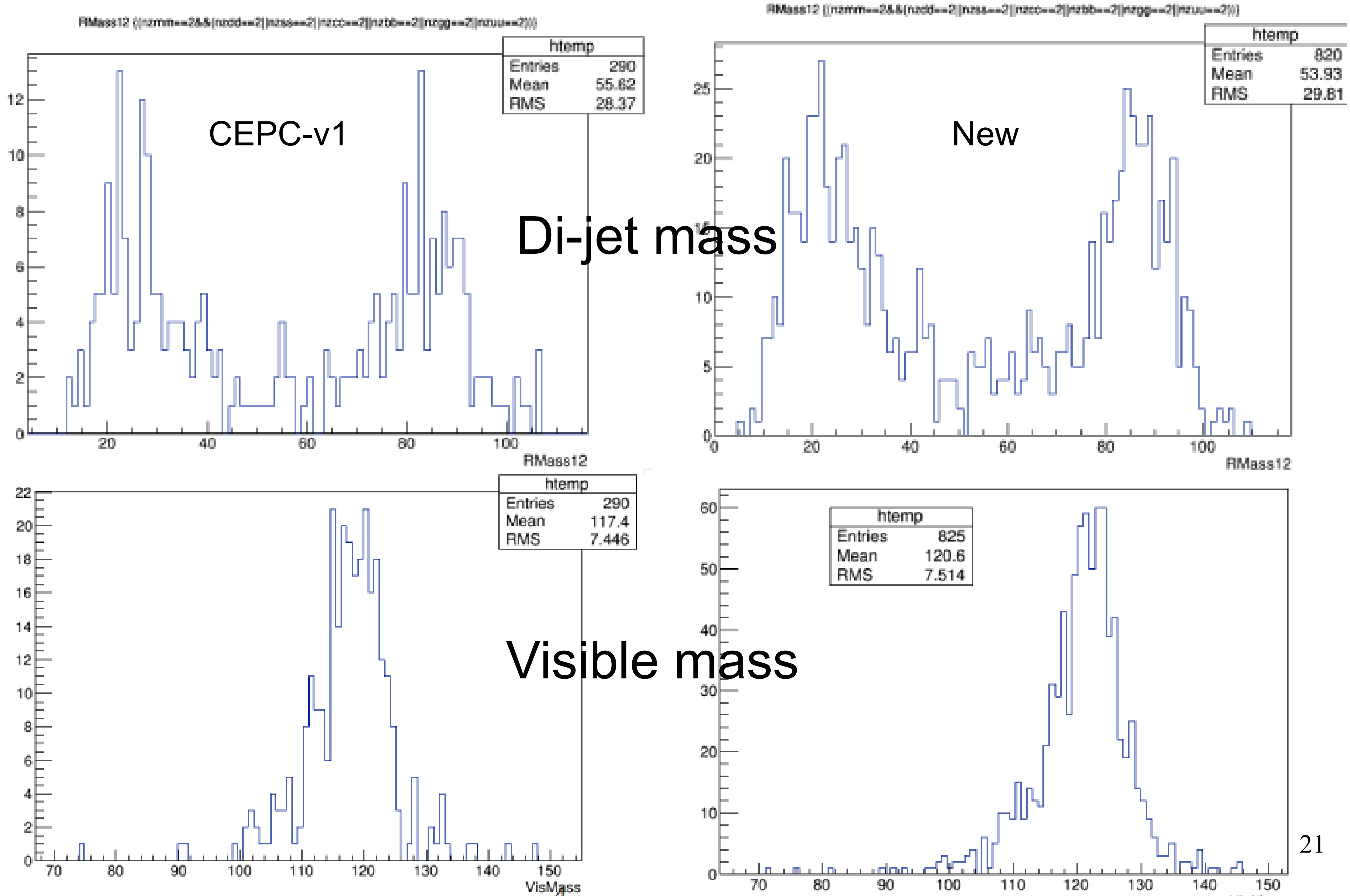
New
ECAL: 20mm * 30L
HCAL: 20mm * 48L



Di-lepton mass

Efficiency of finding all objects: 95% (CEPC_v1) -> 93% (New)

@Physics: Z->μμ/νν, H->ZZ->llqq

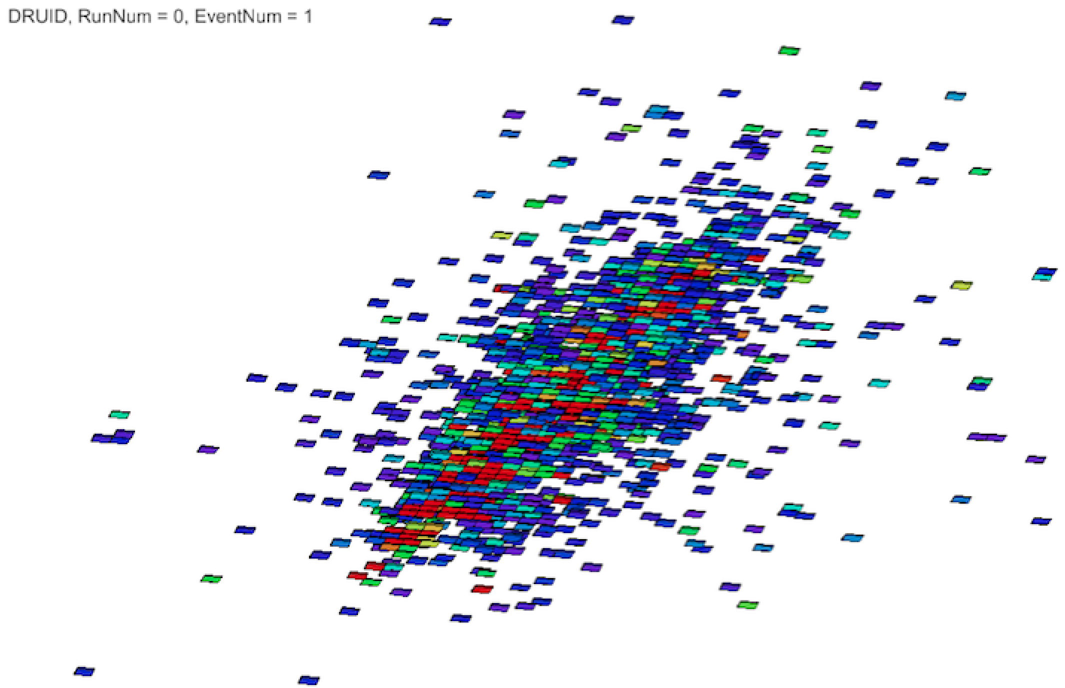


At Physics Benchmark

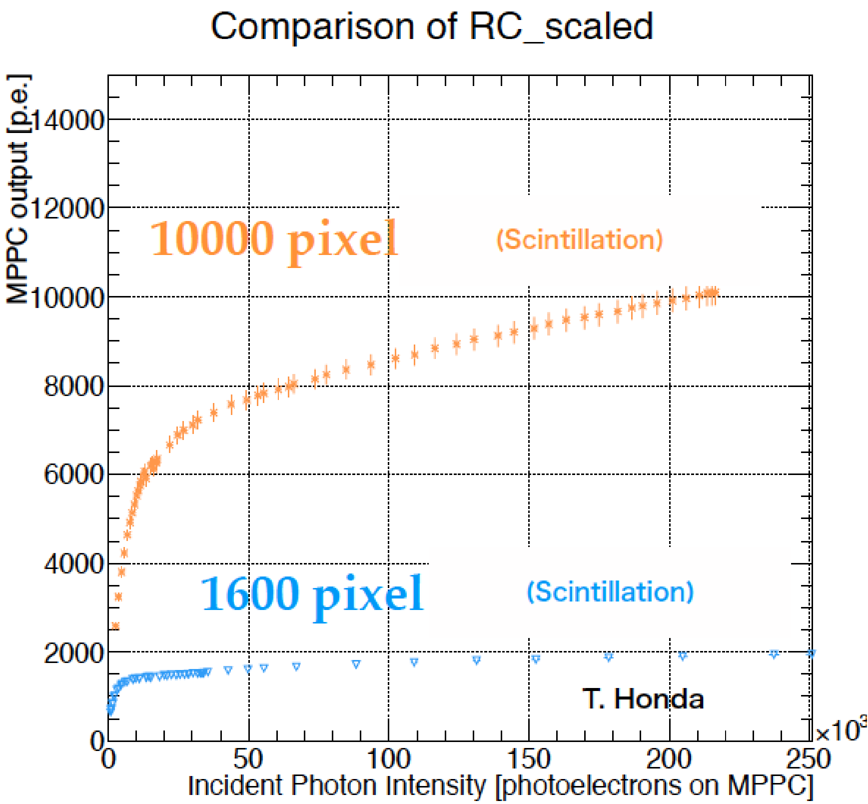
- From CEPC_v1 -> Active Cooling Free Module...
- Efficiency reduced by ~ 1-2%, Jet Mass distributions very similar.
  - Z->di muon, H->inc
  - Z->di muon/vv, H->ZZ->llqq

- Physics Object of Low Energy Leptons & Jet Leptons is not yet tested
- Electron ID at different Geometry need to be fine tuned (to overcome the complexity induced by Bremsstrahlung, etc)

ECAL Saturation/Linear Range Study

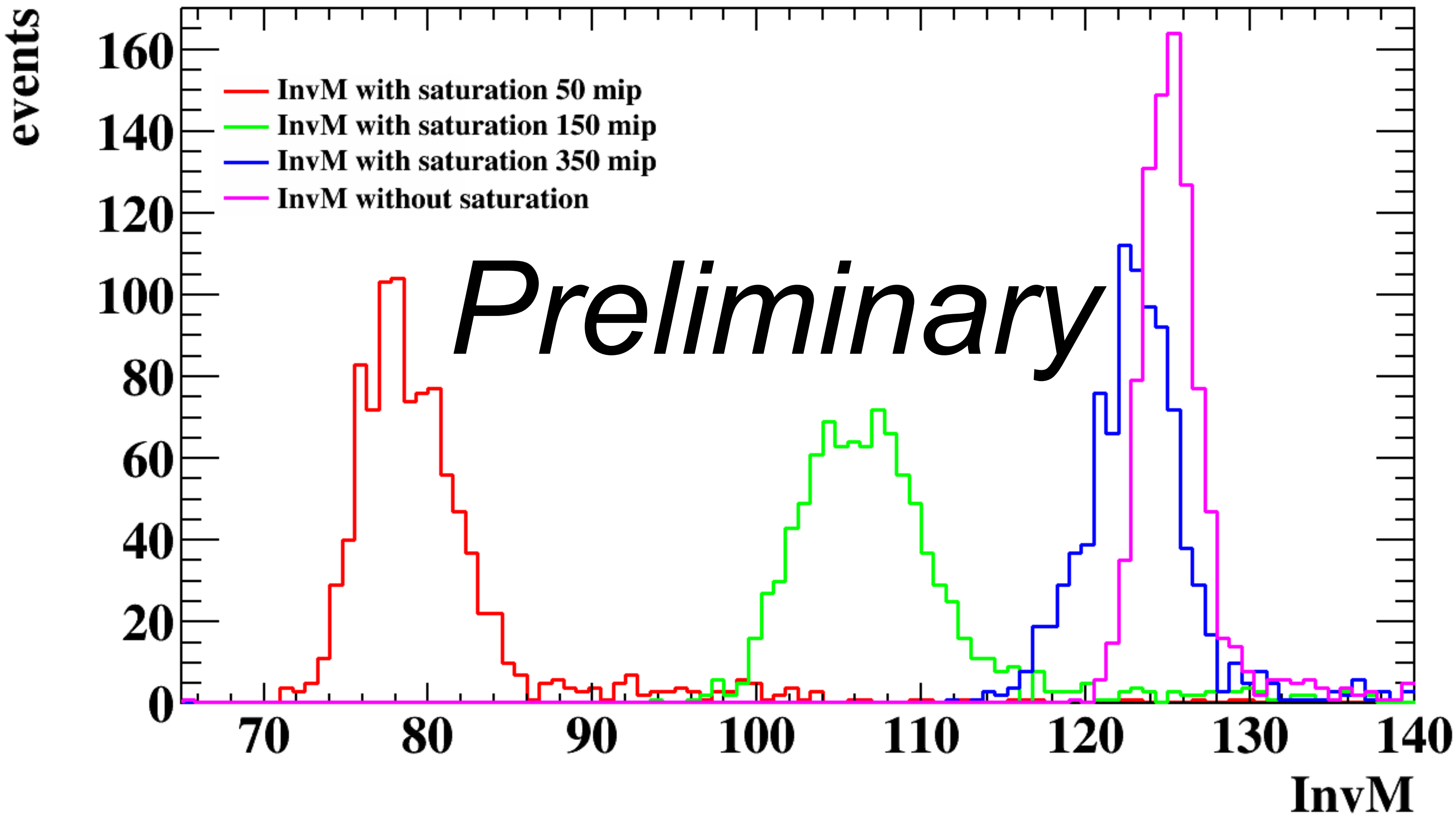


100 GeV Photon Cluster
At 5 mm Cell Size ECAL
(30 layer)

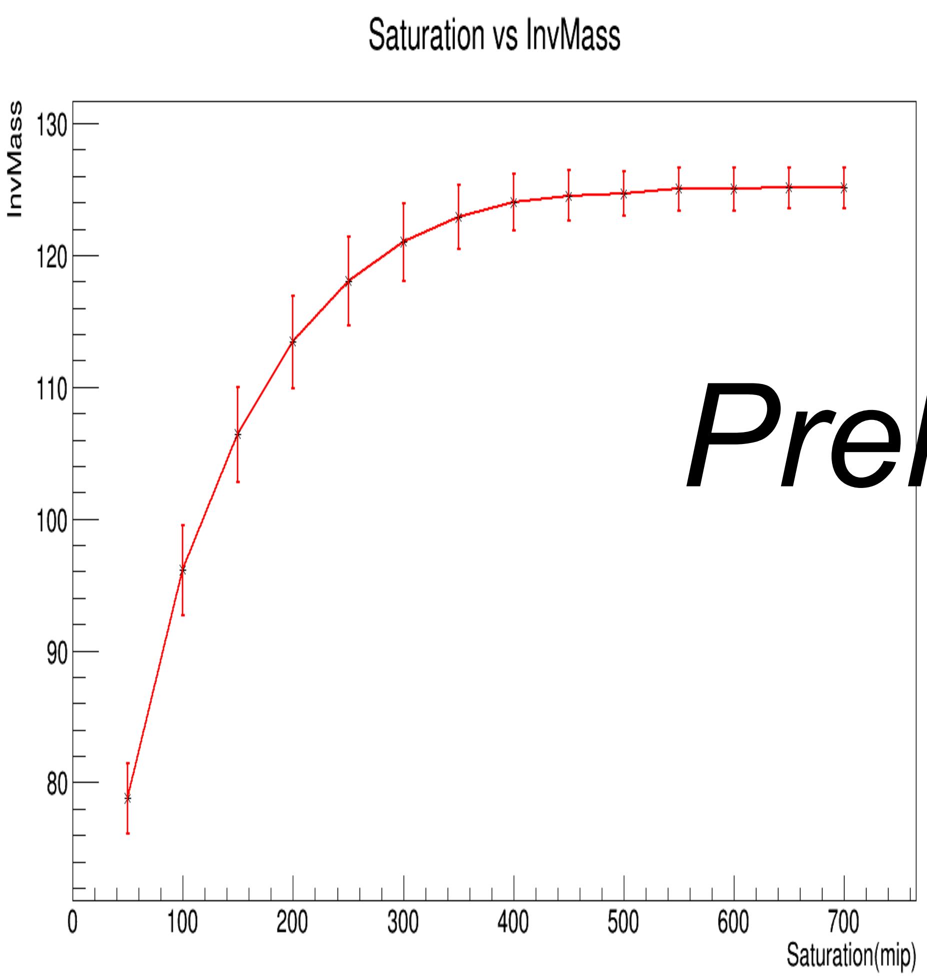


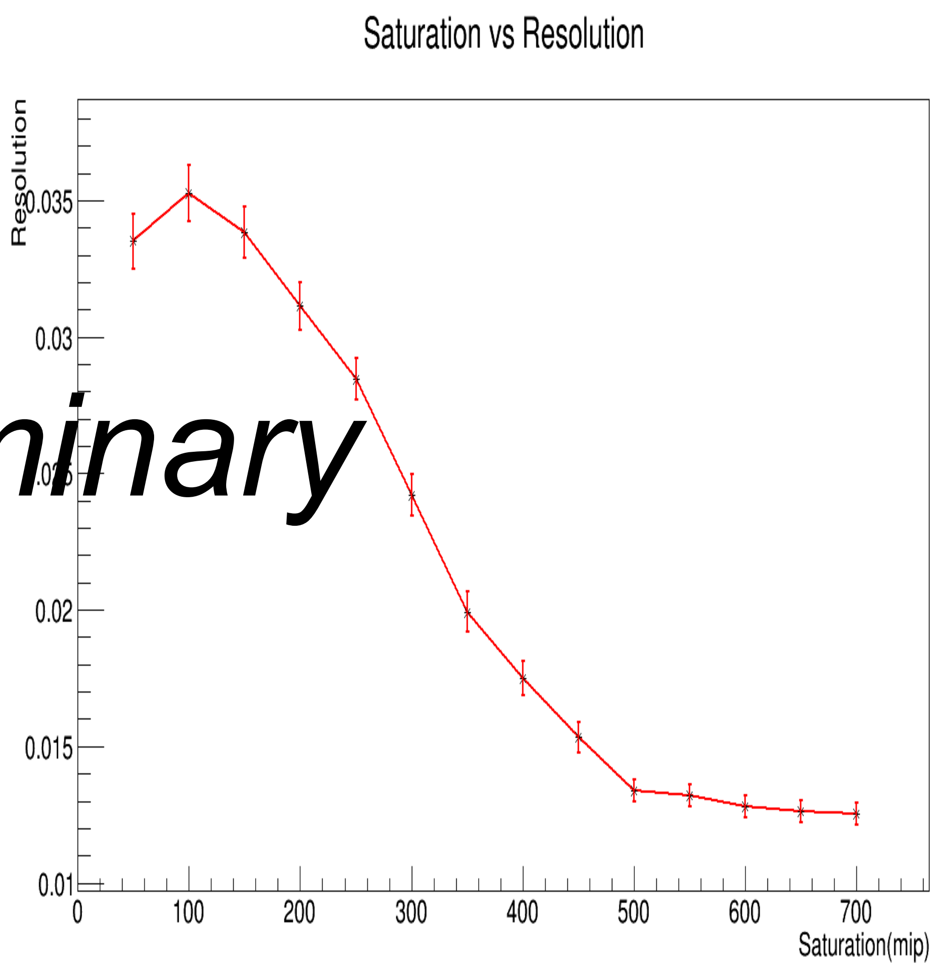
T.Takeshita, ILDDET@KEK

ECAL dynamic range: H→di photon measurement



ECAL dynamic range: H→di photon measurement





Preliminary

At 10 mm Cell Size: Require the Dynamic range of at least 1k MIP...

Summary

- Analysis:
  - Profound understanding to H->WW/ZZ measurement. Will cover the remaining channels.

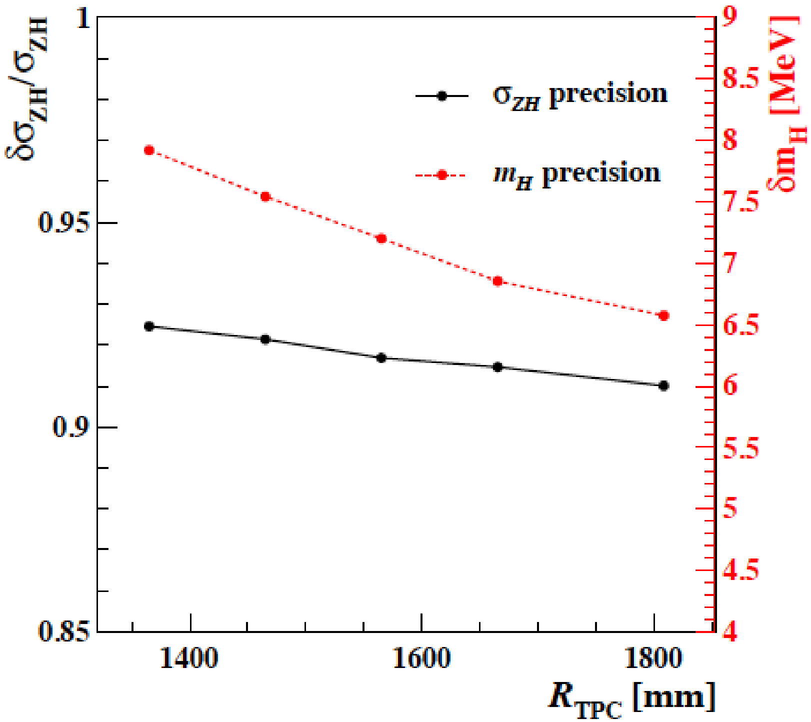
- Optimization:
  - Impact of VTX inner radius identified & studied.
  - Tracker: Separation is the main issue.
  - Calorimeter:
    - Active cooling free geometry studied.
      - For benchmarks with high energy leptons, no significant impact observed
      - **NOT YET TO CONCLUDE: low energy objects, etc...**
    - ECAL Saturation confirmed to be > 1k MIP

Backup

Reference Physics Channels

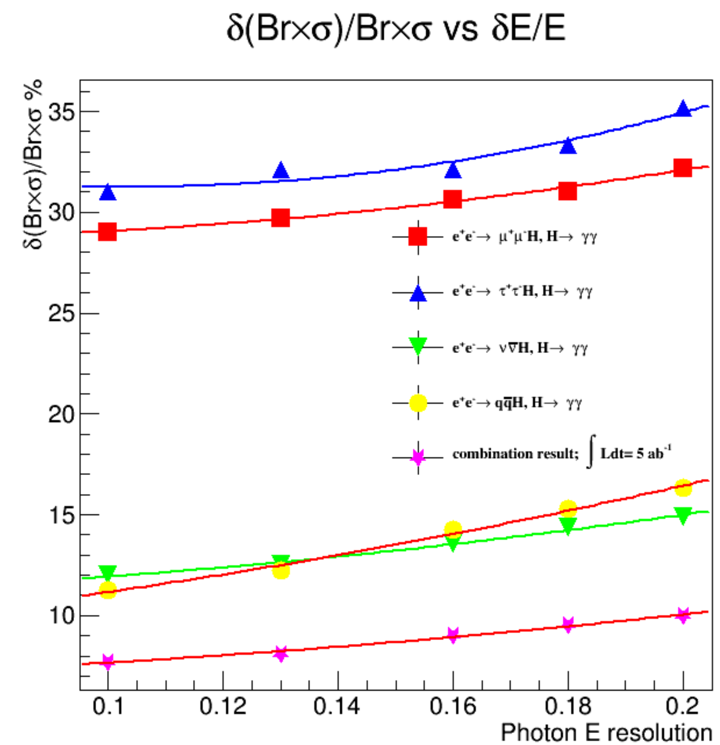
- VTX:
  - Br(H->bb, cc, gg) via Z->di muon channel
  - Br(H->di tau) via Z->di muon channel
- Tracker:
  - Higgs recoil mass analysis via Z->di muon
  - Br(H->di muon)
- Calorimeter
  - Br(H->di photon) (for ECAL intrinsic resolution & dynamic range)
  - Higgs recoil mass
  - Br(H->inv) via Z->di quark
  - Br(H->WW/ZZ) (Higgs width)

TPC Radius & ECAL resolution



$$\delta m_H = 36.286 \times (1 + 0.092 \times e^{-1.820 \cdot R_{TPC}})\text{MeV}.$$

$$\frac{\delta\sigma_{ZH}}{\sigma_{ZH}} = 0.485 \times (1 + e^{-0.094 \cdot R_{TPC}})$$



H->di photon branching ratio measurement