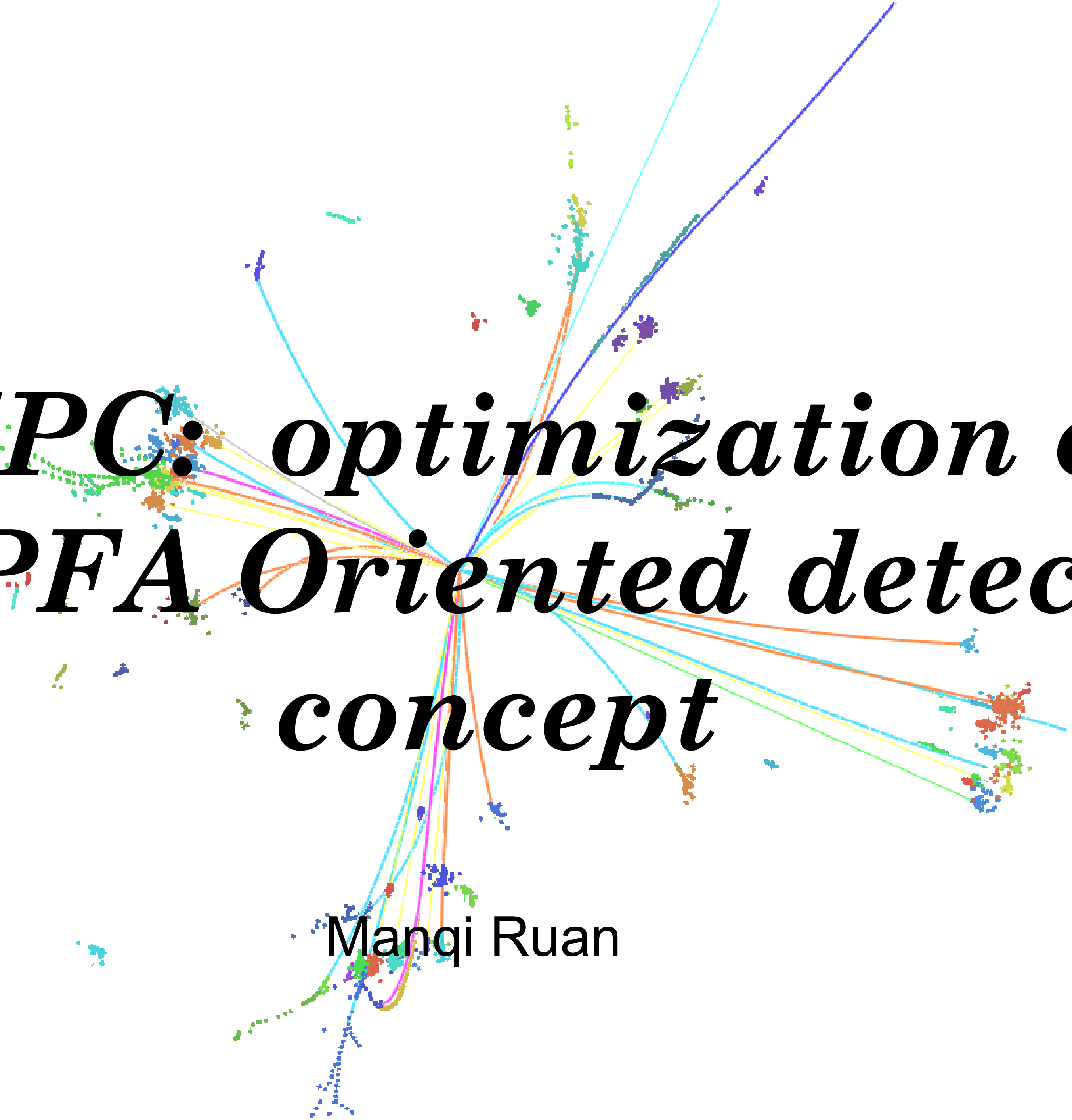
CEPC: optimization of the PFA Oriented detector concept



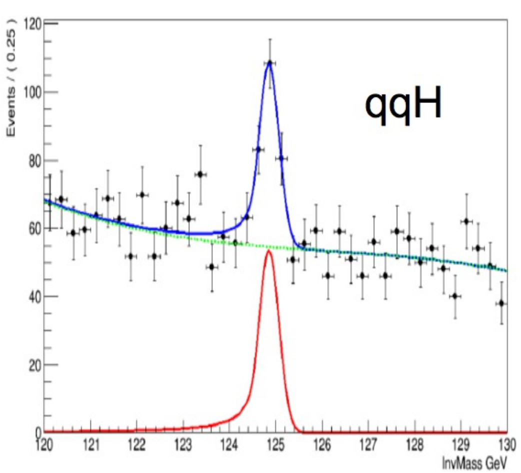
Manqi Ruan

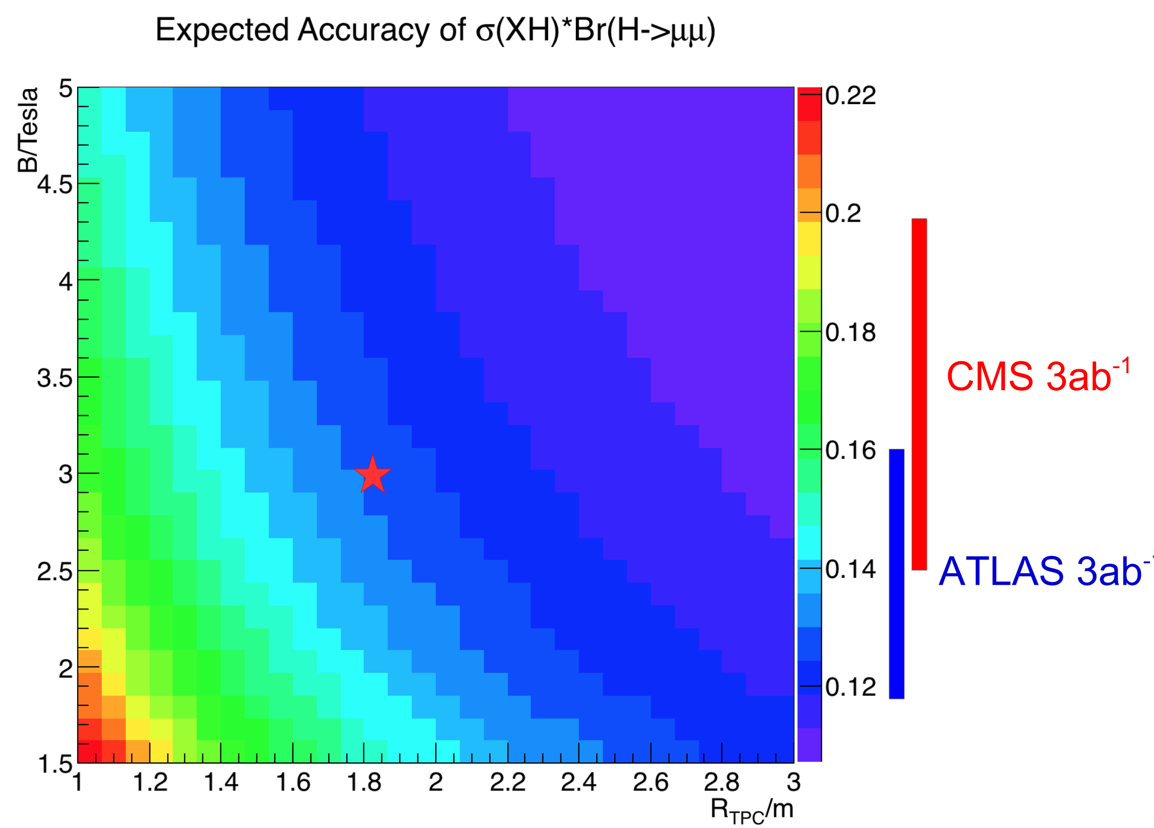
Parameters

	CEPC_v1 (~ ILD)	Optimized (Preliminary)	Comments
Track Radius	1.8 m	>= 1.8 m	Requested by Br(H->μμ) 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->γγ) at 250 GeV; 90mm for bhabha event at 350 GeV
ECAL Cell Size	5 mm	10 – 20 mm (5 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.

Tracker Radius & B-Field: the optimized value

- Detector cost is sensitive to tracker radius, however, I recommend TPC radius >= 1.8m:
  - Better separation & JER
  - Better dEdx
  - **Better (H->di muon) measurement**

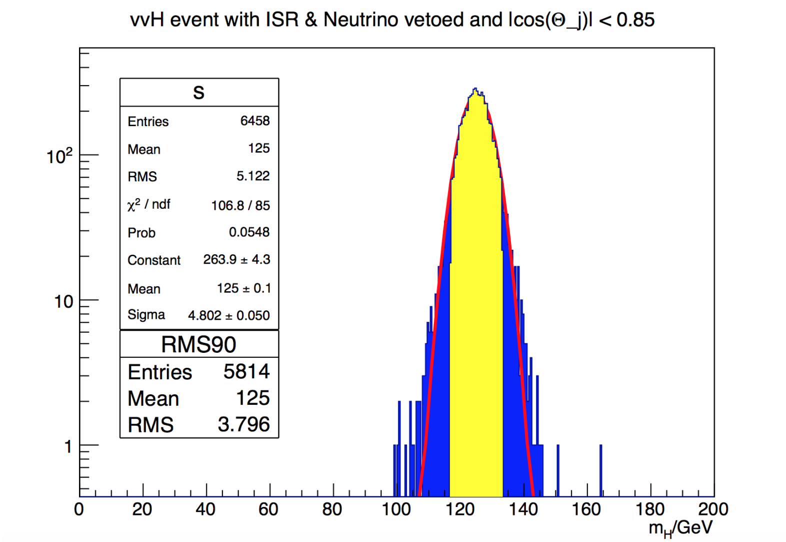


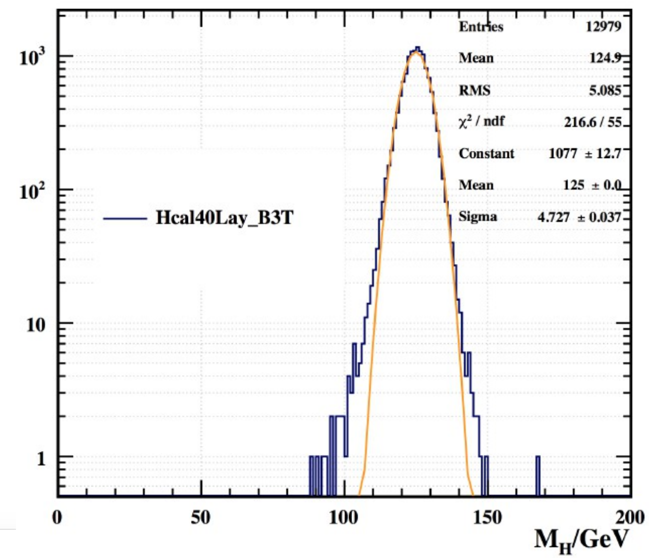


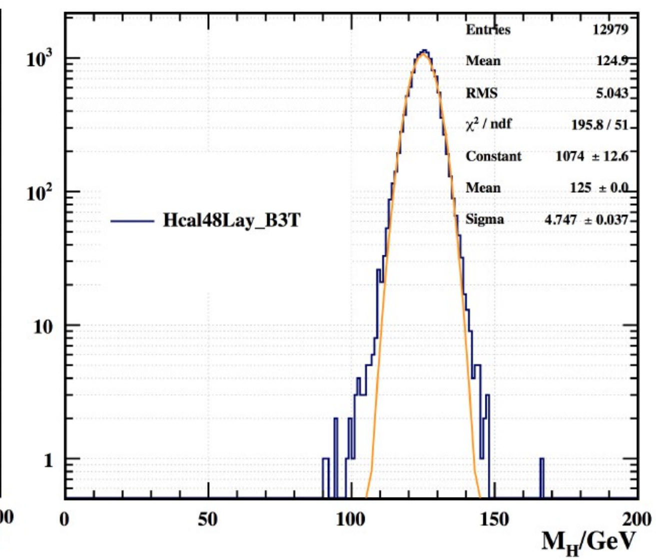
★ *Default TPC Setting: B = 3 T & R_{out} = 1.8*

B-Field VS JER

3.5T & 48 Layers	3T & 40 Layers	3T & 48 Layers

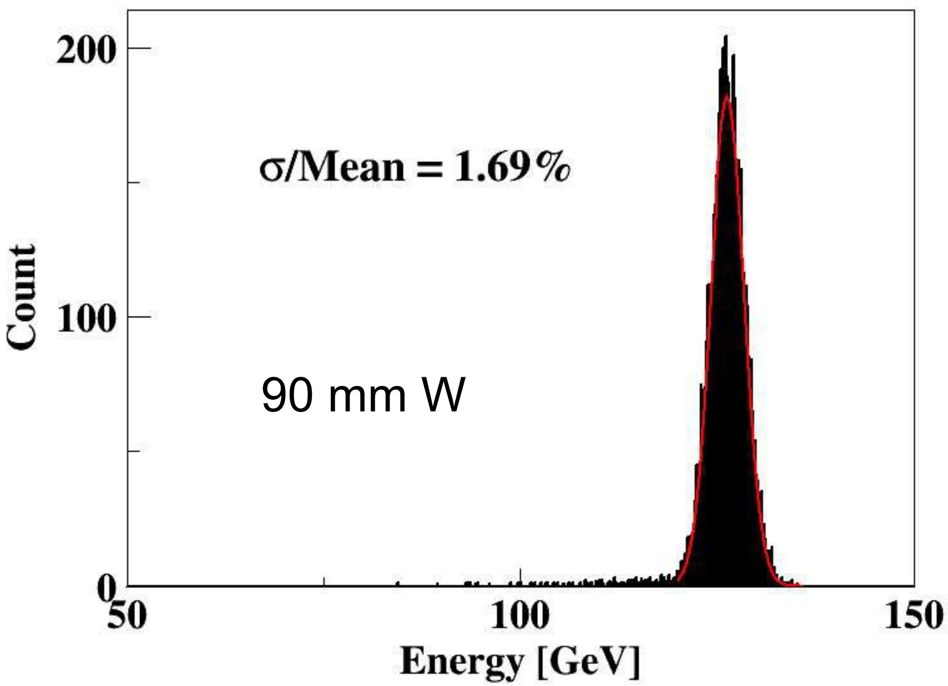


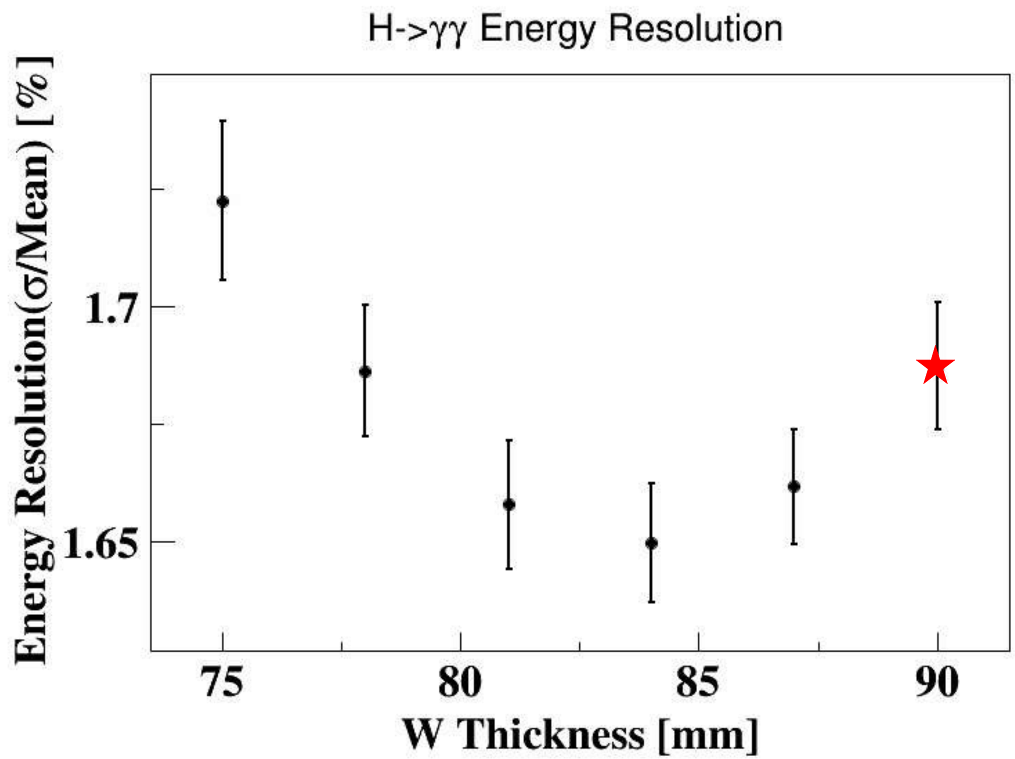




- Marginal Impact on JER (from 3.5T -> 3T)
- *3 Tesla even turns out to be better than 3.5 Tesla (~only 1 sigma)*
  - *At 5 mm Cell size*

ECAL Absorber (W) thickness Via H->γγ

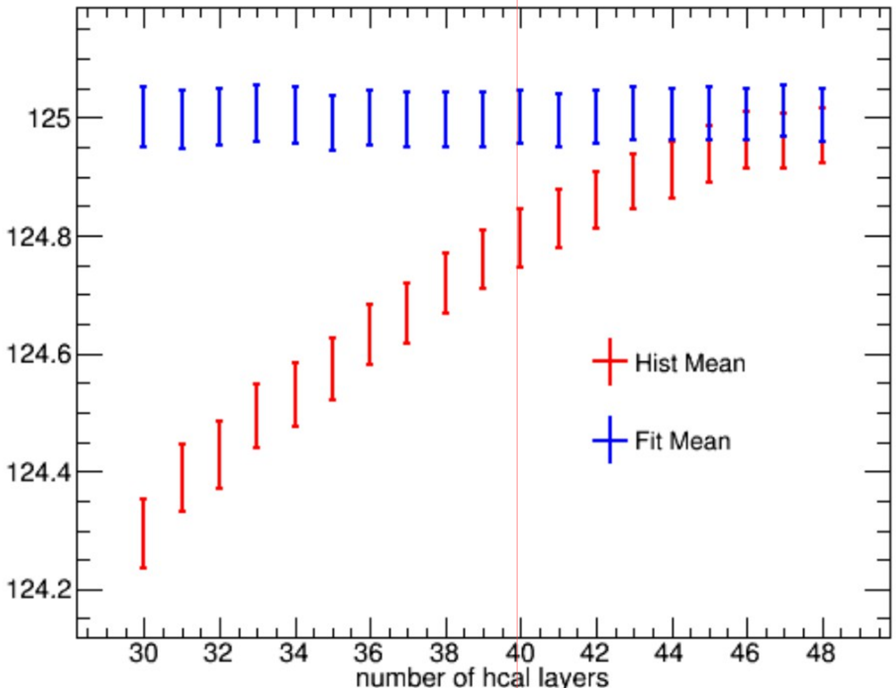


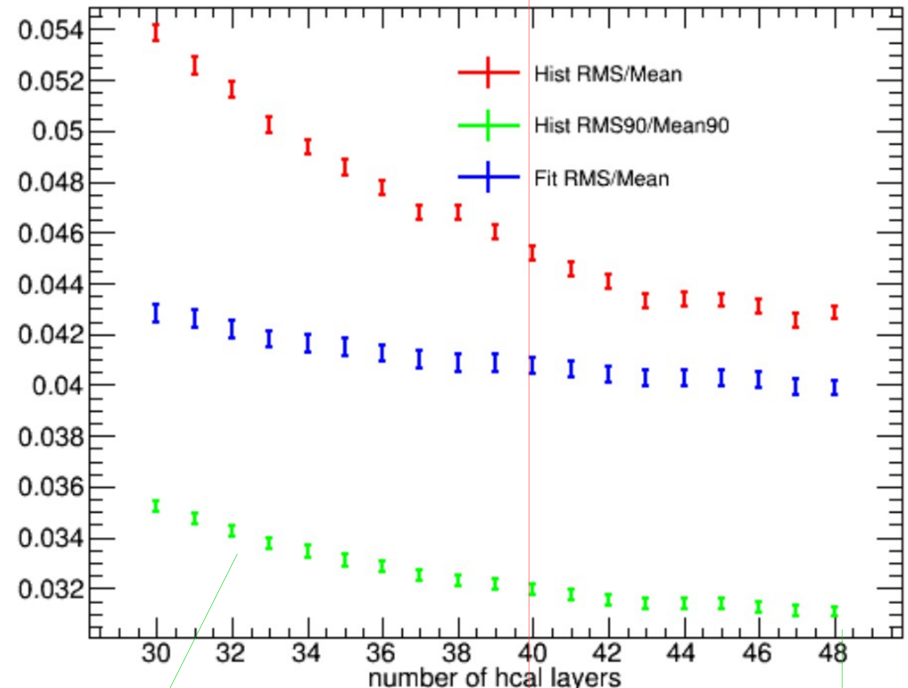


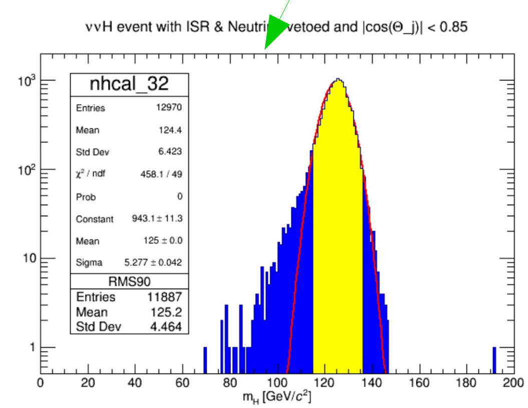
30 Layers, each layer with 0.5 mm Si + 2 mm PCB
ECAL only performance

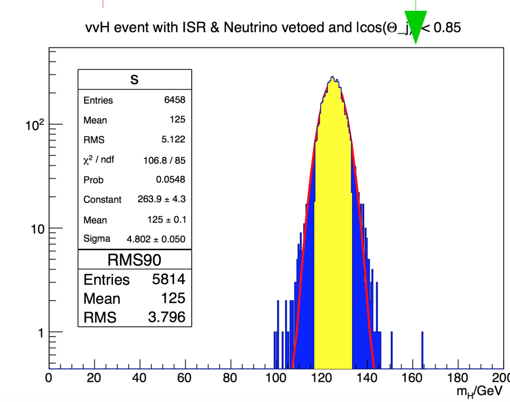
Optimization on the in-homogeneous longitudinal structure (i.e, Absorber thickness at different layer) not applied

HCAL thickness (#Layers) Via JER ~ vvH, H->gluons









Reducing the #Layers from 48 -> 40 (same layer thickness)
A degrading of 2% (relative) in JER

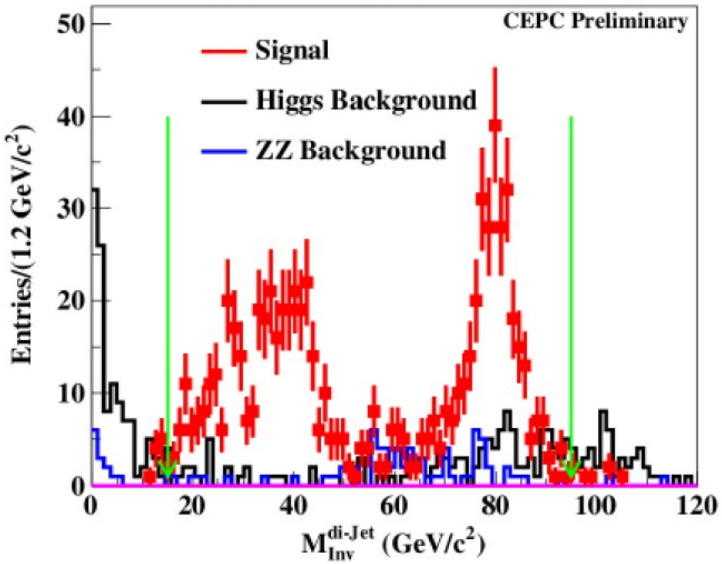
Performance depends on the version...

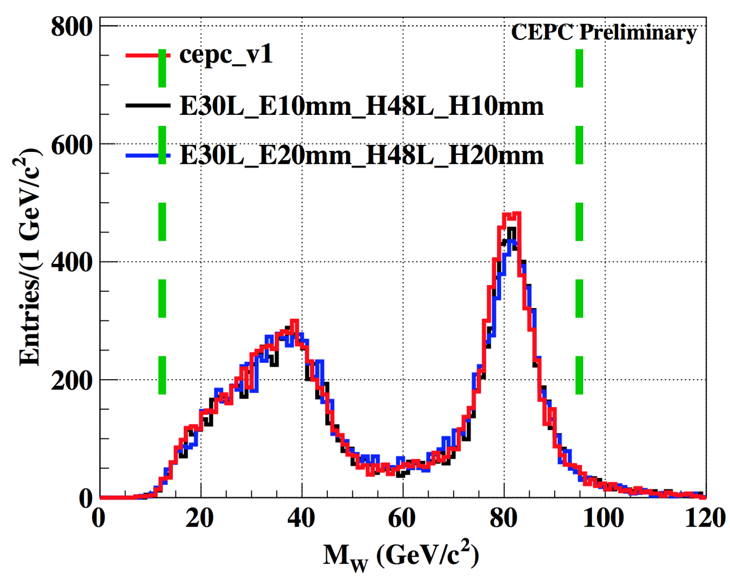
Calorimeter Optimization: Cell Size

- No Power Pulsing + Passive Cooling Calorimeter
  - Number of channels reduce by~10 times, test Geometries with 10-20 mm ECAL/HCAL Cell + reduced layers
  - Percentage level degrading in signal reco. efficiency on Higgs Benchmarks
    - Photon & H->photons
    - Lepton & Higgs recoil
    - Jets & H->gluons,
    - H->WW*

No lose in the object level efficiency: JER degraded, ~ 5/10% at 10/20 mm

Liao libo, H→WW*→lνqq, Z→ll





Key performance: Separation

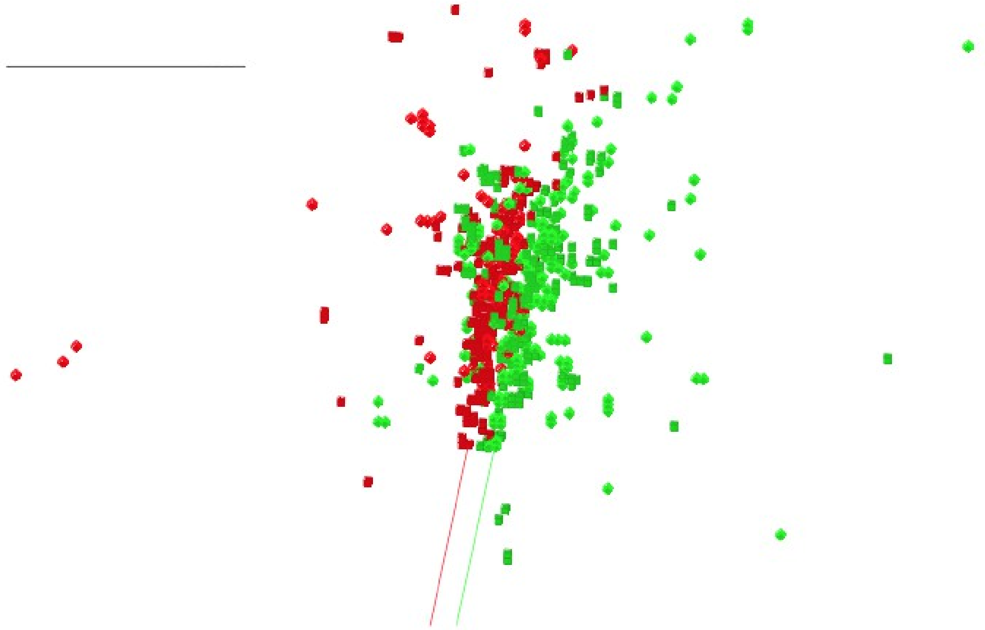
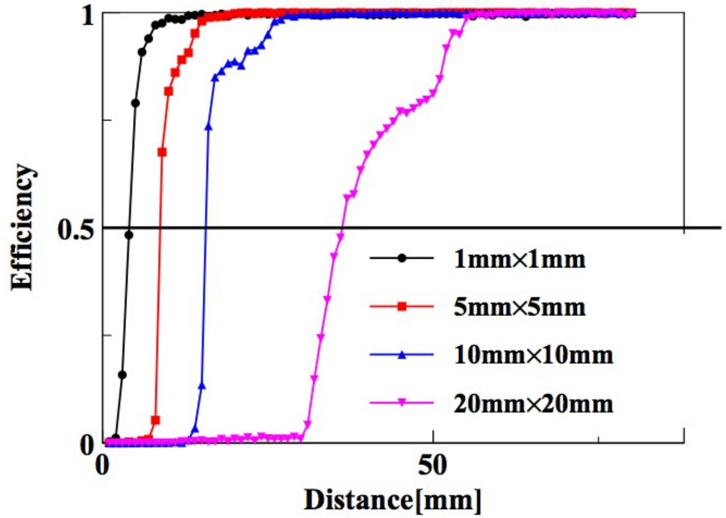
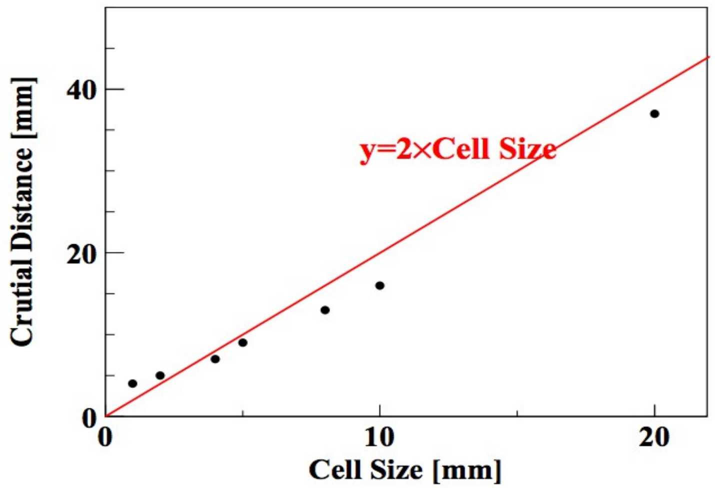


Figure 11. Event display of reconstructed di-photon.

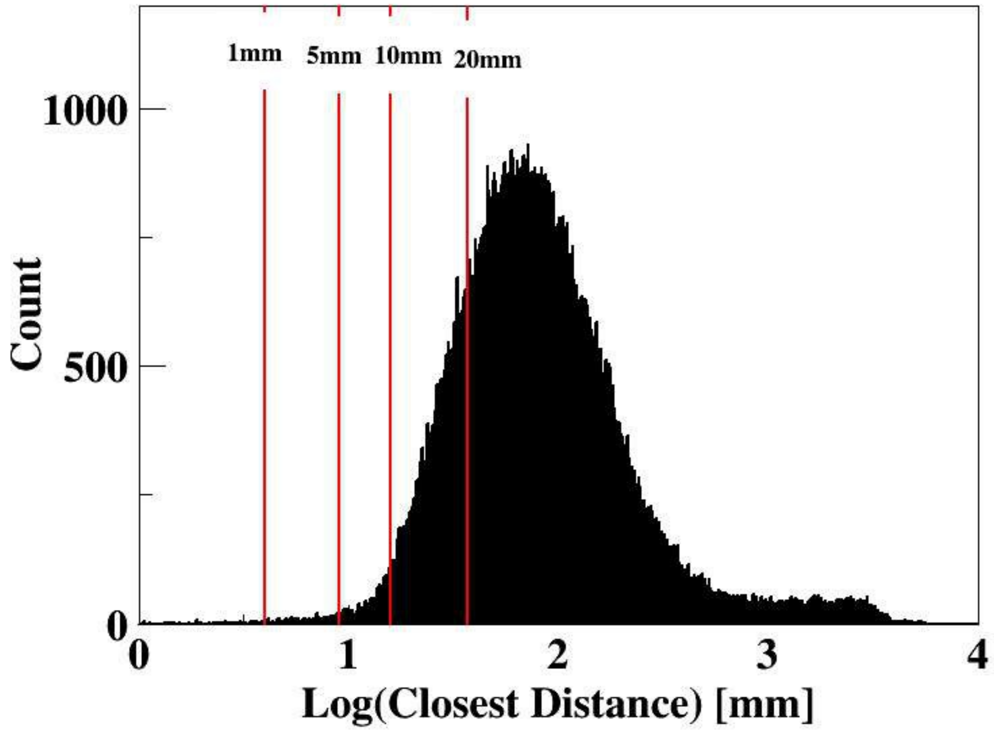


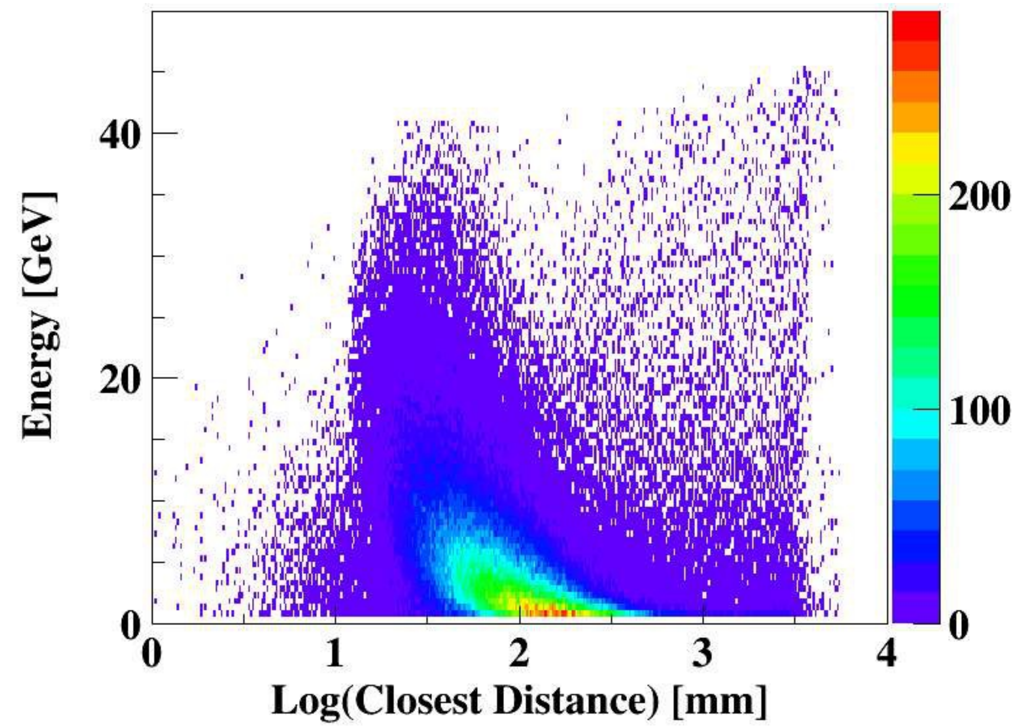


Separation power/Crucial Distance:

- ~ 2*Cell with Cell Size <= Moliere Radius;
- ~ 1 Cell with Cell Size > 1 Moliere Radius.

Impact of Separation: Z->tau tau @ Z pole





Cell Size/mm	1	5	10	20
Crucial Dis/mm	4	9	16	37
Percentage of potentially overlap photon	0.07%	0.4%	1.7%	18.6%

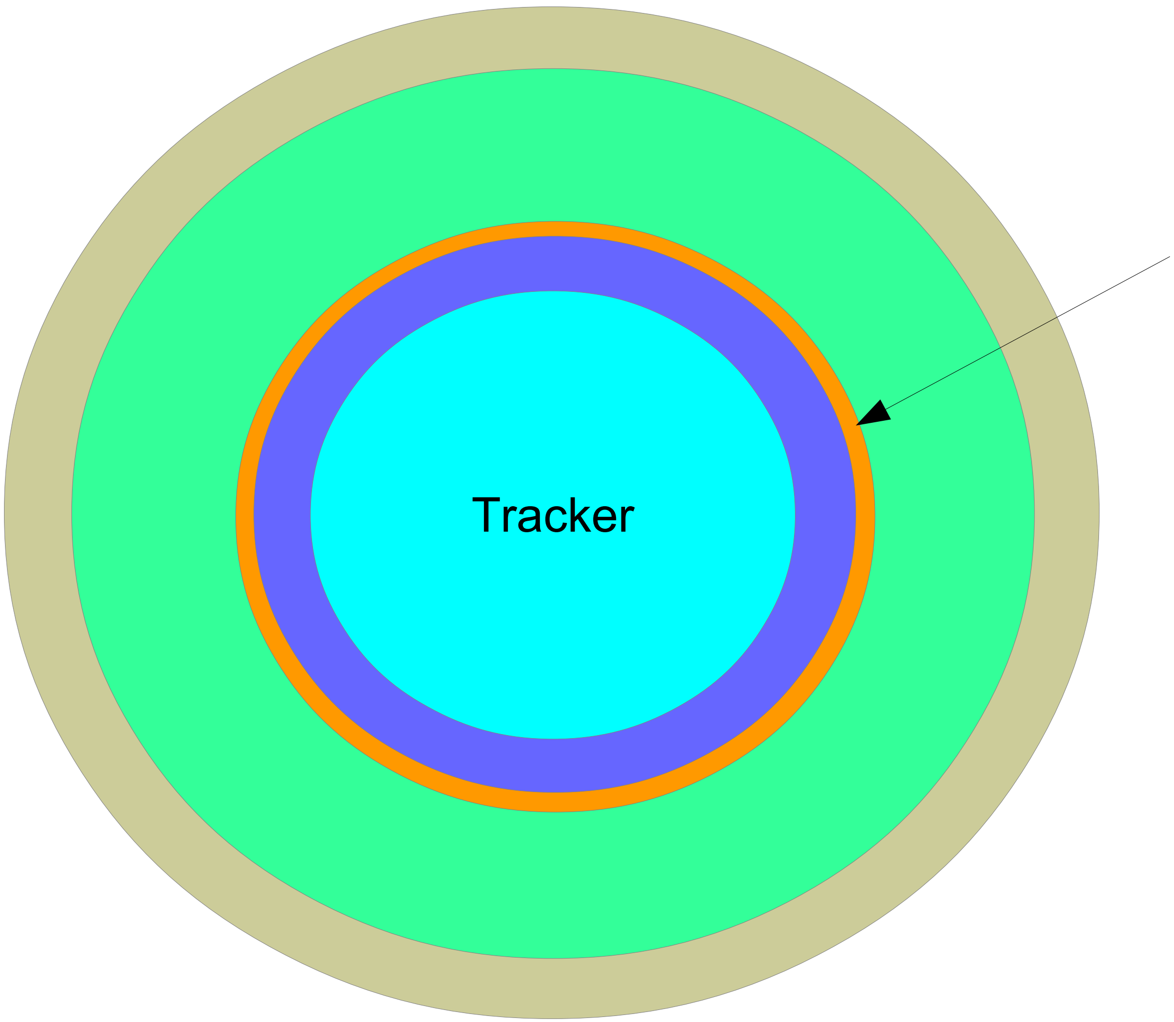
5 -> 20 mm: May severe degrade Tau physics performance
-> to be investigated

Conclusion & Todo

- PFA oriented detector design: OK at CEPC
  - 3 Tesla Solenoid
  - TPC is OK
  - Passive cooling Calo:
    - No significant impact on Higgs physics
    - EW Physics: to be further evaluated
- Several key R&D issue identified
- Converged to an set of reference number.
- To be covered at CDR
  - Converge the MDI/FWD concept design
  - **Full Sim Analysis on Physics Benchmarks at Conceptual geometry**
    - **Signal Sample is READY**
    - **Identify people to study them in details!!!**

Back up

PFA Oriented concept: A preliminary design



Dedicated ToF
Or
ECAL Layer with TDC
Equipped Chips

delta(T) ~ 50 ps

To balance the efficiency &
Purity of time measurement...

Tracker, TPC: R = 1.8 m

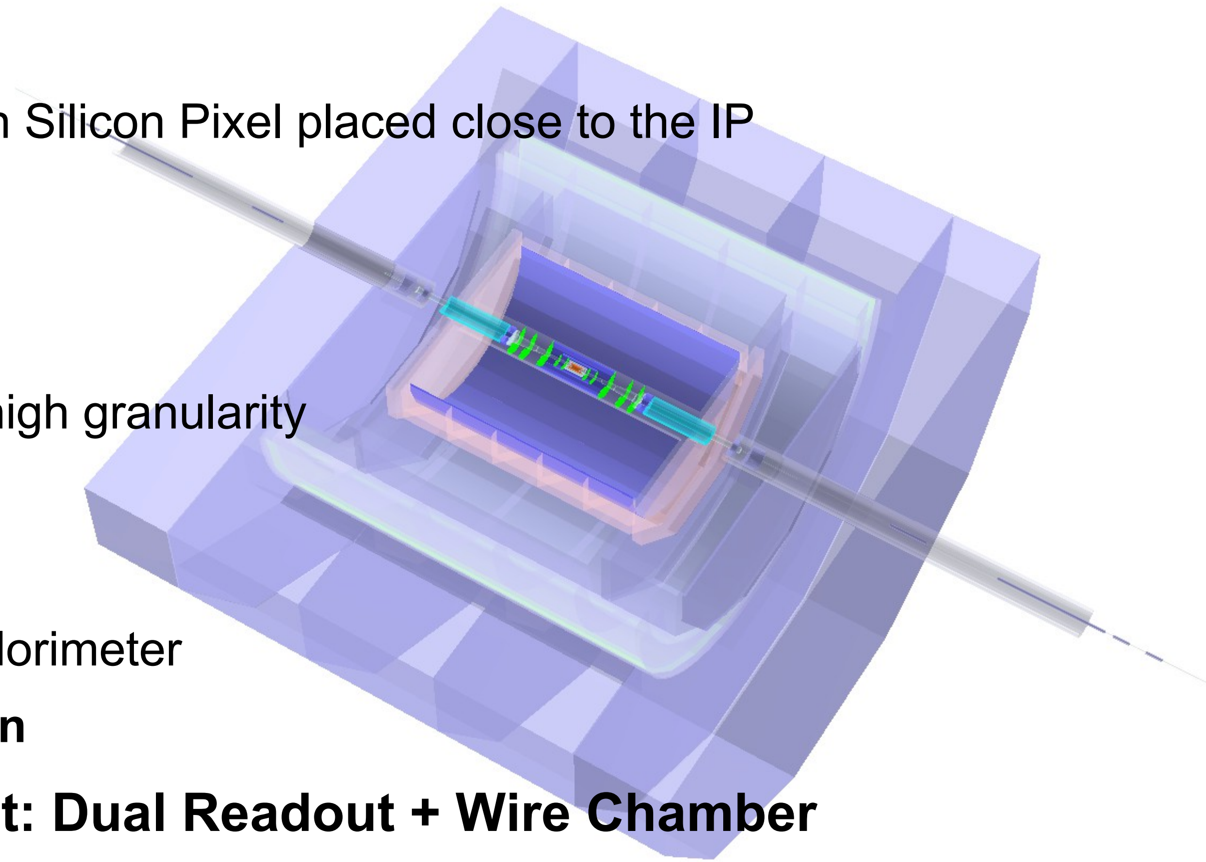
ECAL: 84-90 mm W

HCAL: ~1000 mm Iron

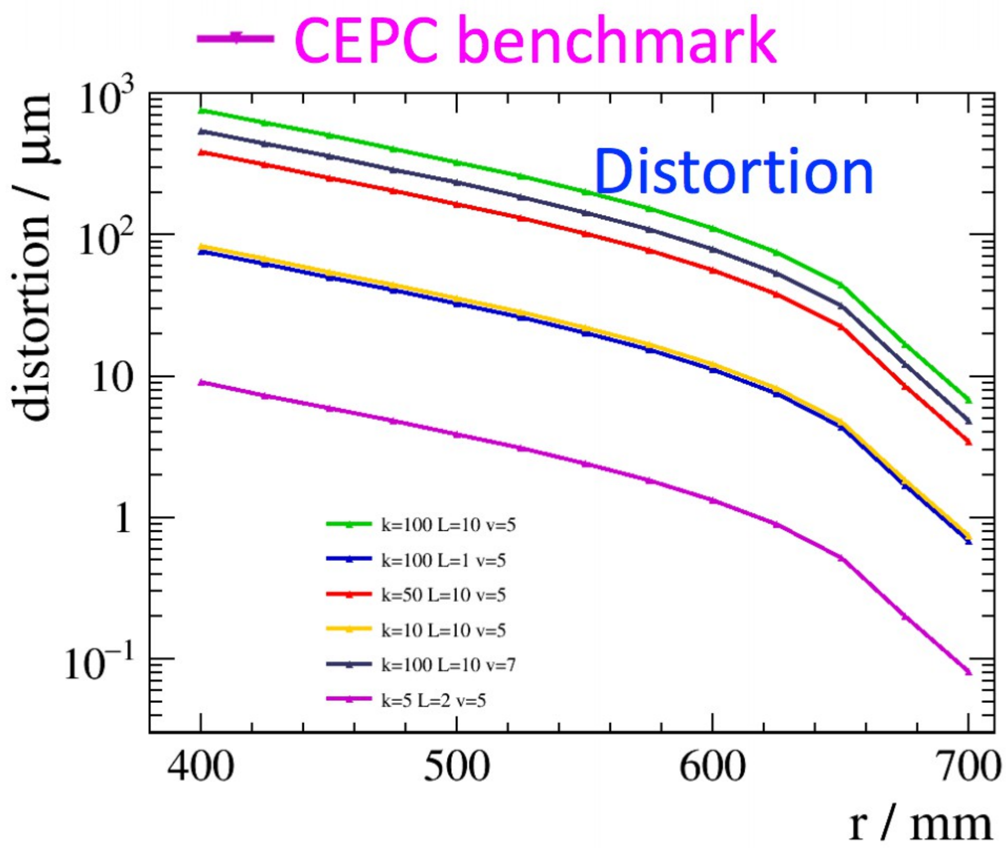
Solenoid (3T) + Yoke

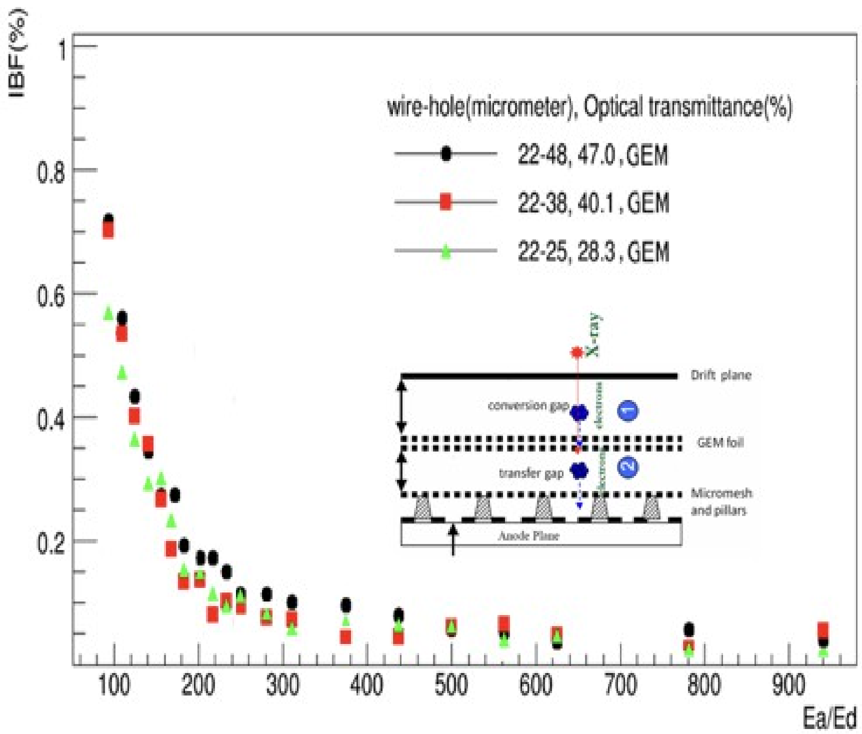
Optimization

- **PFA Oriented Concept: Optimizing Via Sim-Reconstructions**
  - Layout:
    - VTX: High precision Silicon Pixel placed close to the IP
    - Main Tracker:
      - Silicon Tracker
      - TPC
    - Calorimeter: Ultra-high granularity
  - **Feasibility Study**
    - TPC
    - Passive cooling Calorimeter
  - **Parameter optimization**
- **The Alternative Concept: Dual Readout + Wire Chamber**
  - To be implemented in Full Simulation &



TPC Feasibility

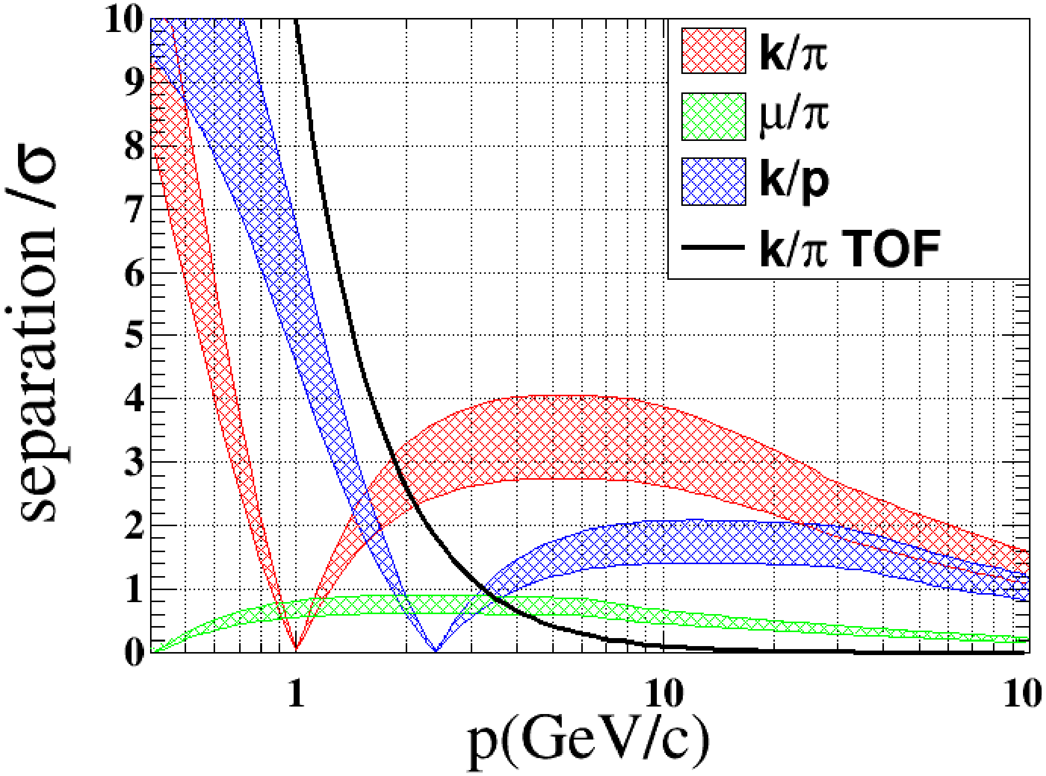


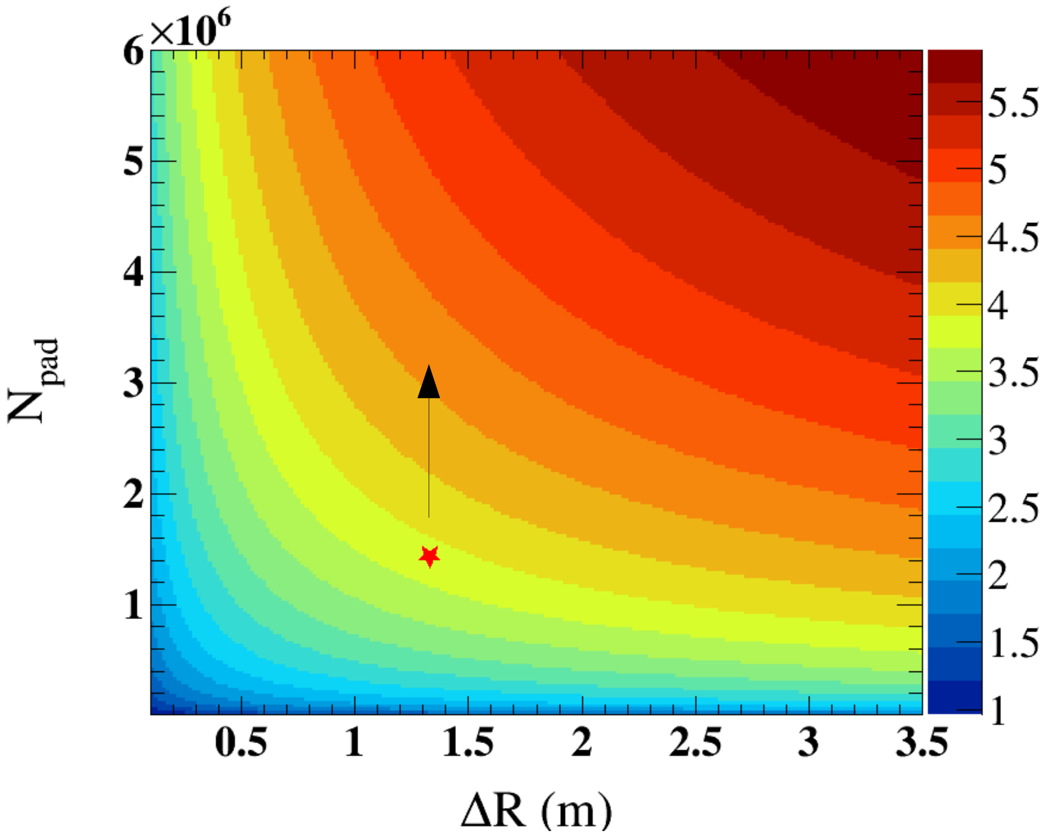


- Voxel occupancy: 1.0^{-4} – 1.0^{-6} level
- Distortion induced by Ion charge:
  - 1/10 of the intrinsic TPC resolution if k (IBF*Gain) = 5

OK

TPC dEdx & future optimizations





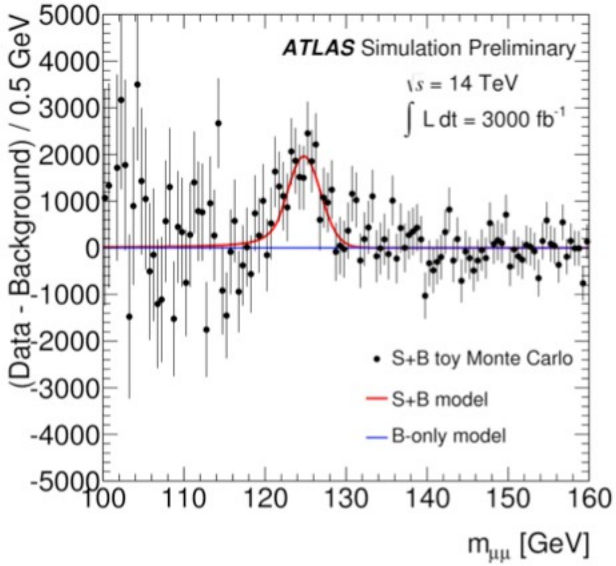
- TPC dEdx + ToF at dt ~ 50 ps: a full range of pi-kaon separation (3-4σ) at Z pole
- Be iterate with hardware study & Test beam: Quantify the hardware requirements
- TPC in general:
  - Stability & Homogeneity requirement
  - Radiation Background, Gas optimization (Neutron Flux, Delta/Gamma Ray)

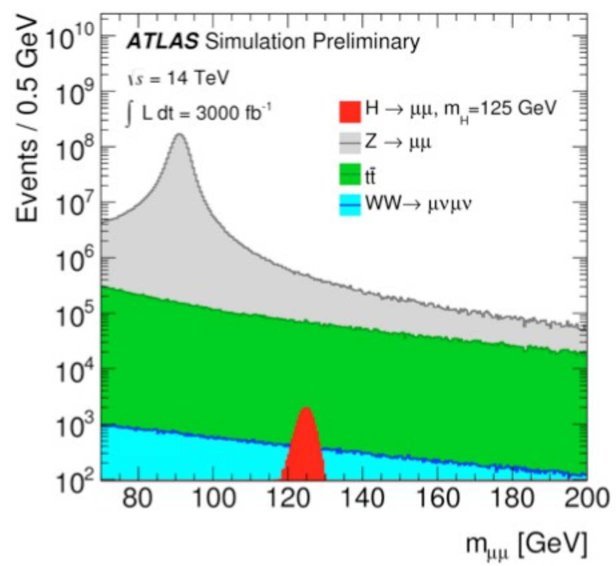
H→μμ

- BSM interest: models with Higgs decaying preferably to muons
- **ggF, VBF, VH, ttH** production
- Backgrounds: **Zjets, $t\bar{t}$, WW**

		μ-hat error	
	$\mathscr{L}$ (fb^{-1})	Scenario 1	Scenario 2
ATLAS	300	± 0.39	± 0.38
CMS	300	± 0.42	± 0.40
ATLAS	3000	± 0.16	± 0.12
CMS	3000	± 0.20	± 0.14

ATLAS scenarios: 1- full sys 2- no theory sys
CMS scenarios: 1- run-1 sys 2- reduced sys

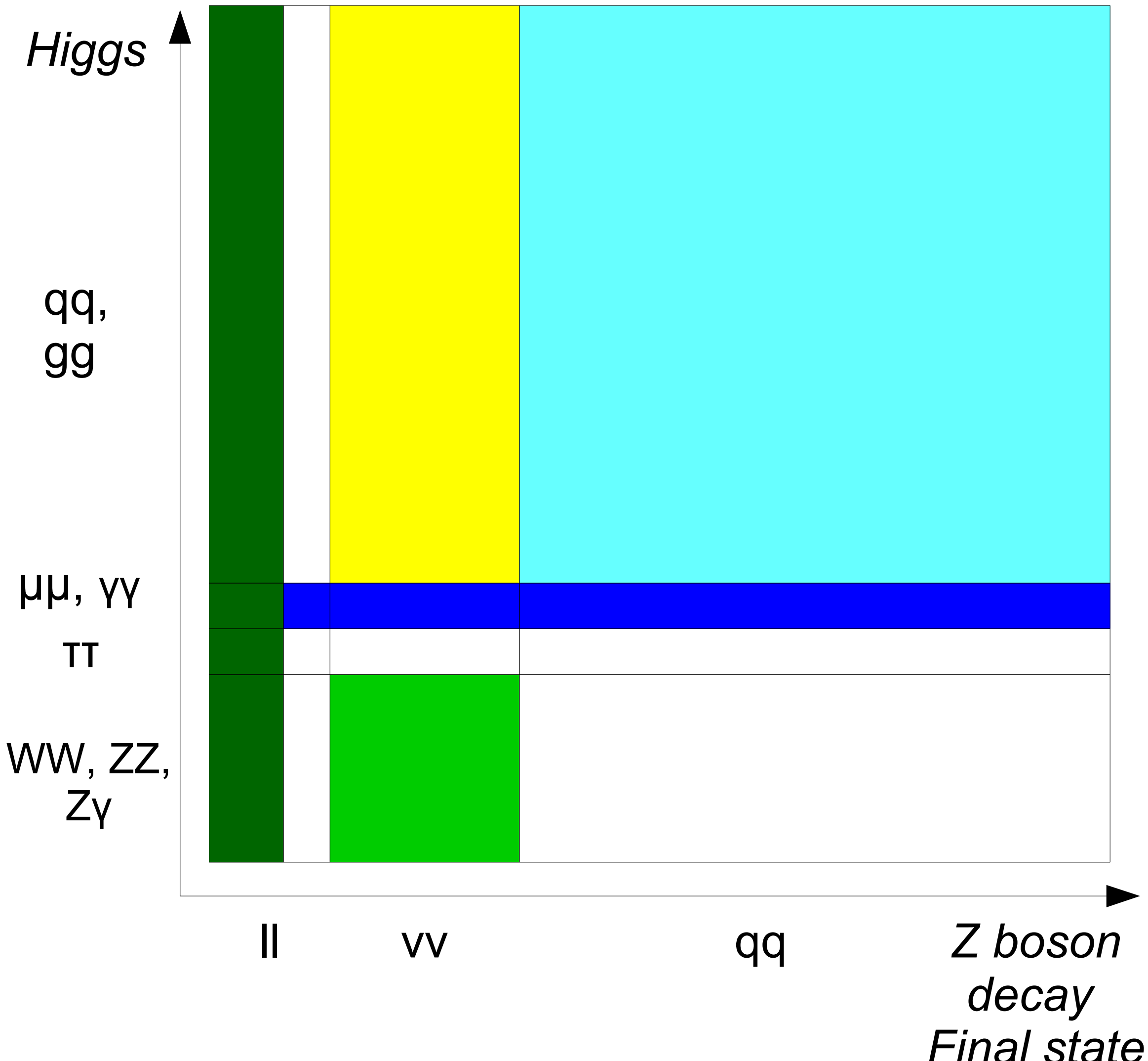




ATL-PHYS-PUB-2013-014

CMS NOTE-13-002

Benchmark measurements



Lepton & Momentum resolution: Br = 6.7%

Flavor Tagging & JER: Br = 14%

Composition of Jet/MET, lepton: Br = 4%

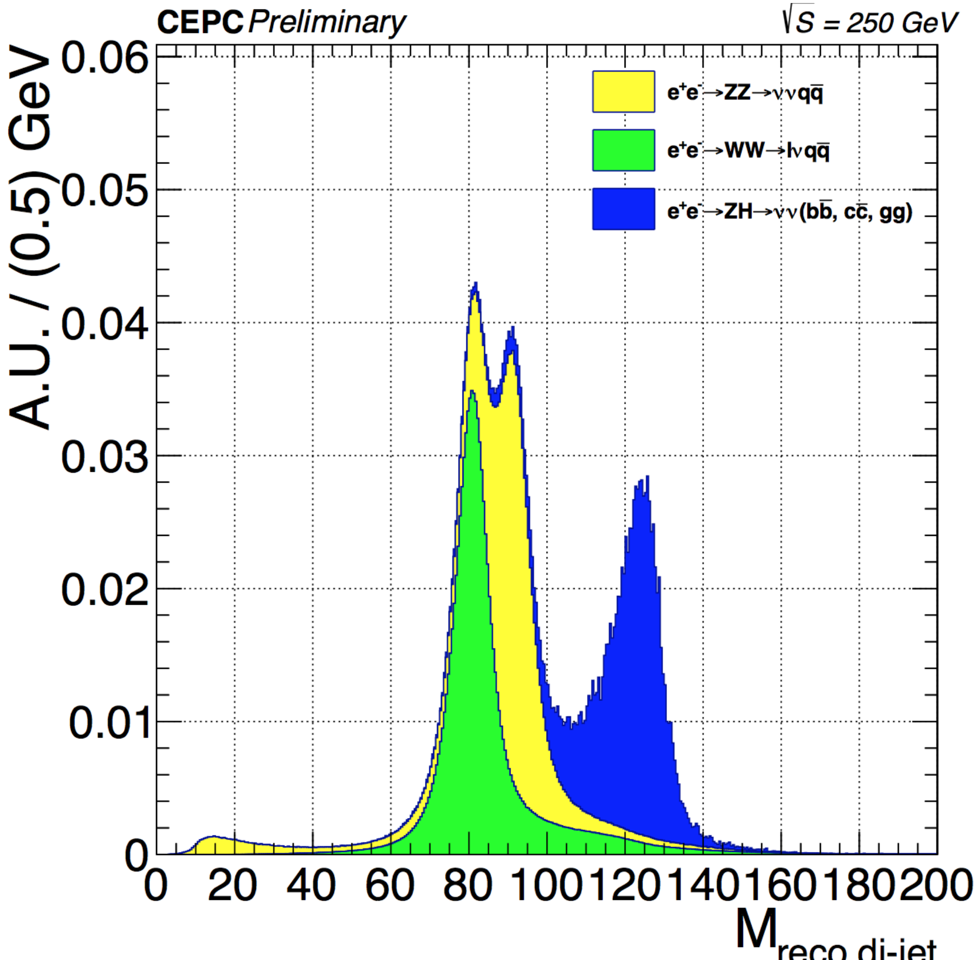
Jet Clustering: Br = 50%

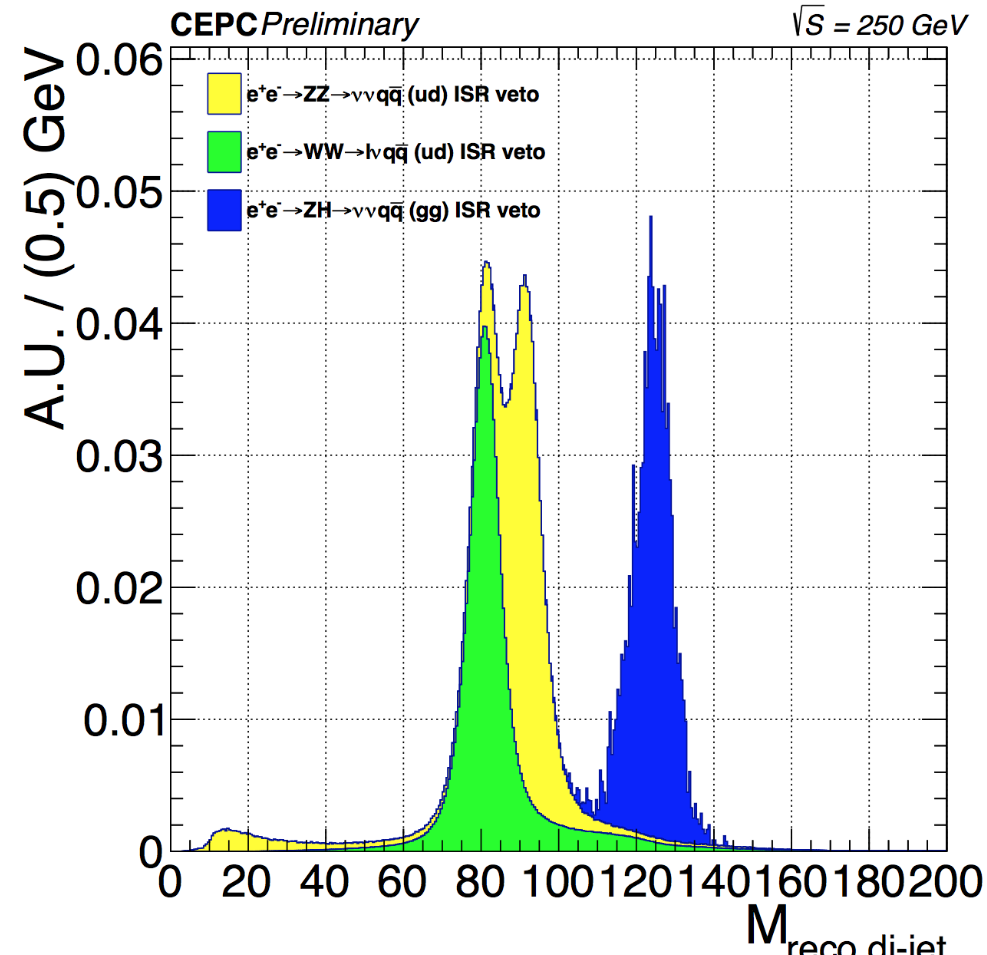
Photon/ECAL: Br = 0.2%

qqH, H->inv. MET & NP: SM Br = 0.1%

EW, Br(tau->X) @ Z pole: Separation

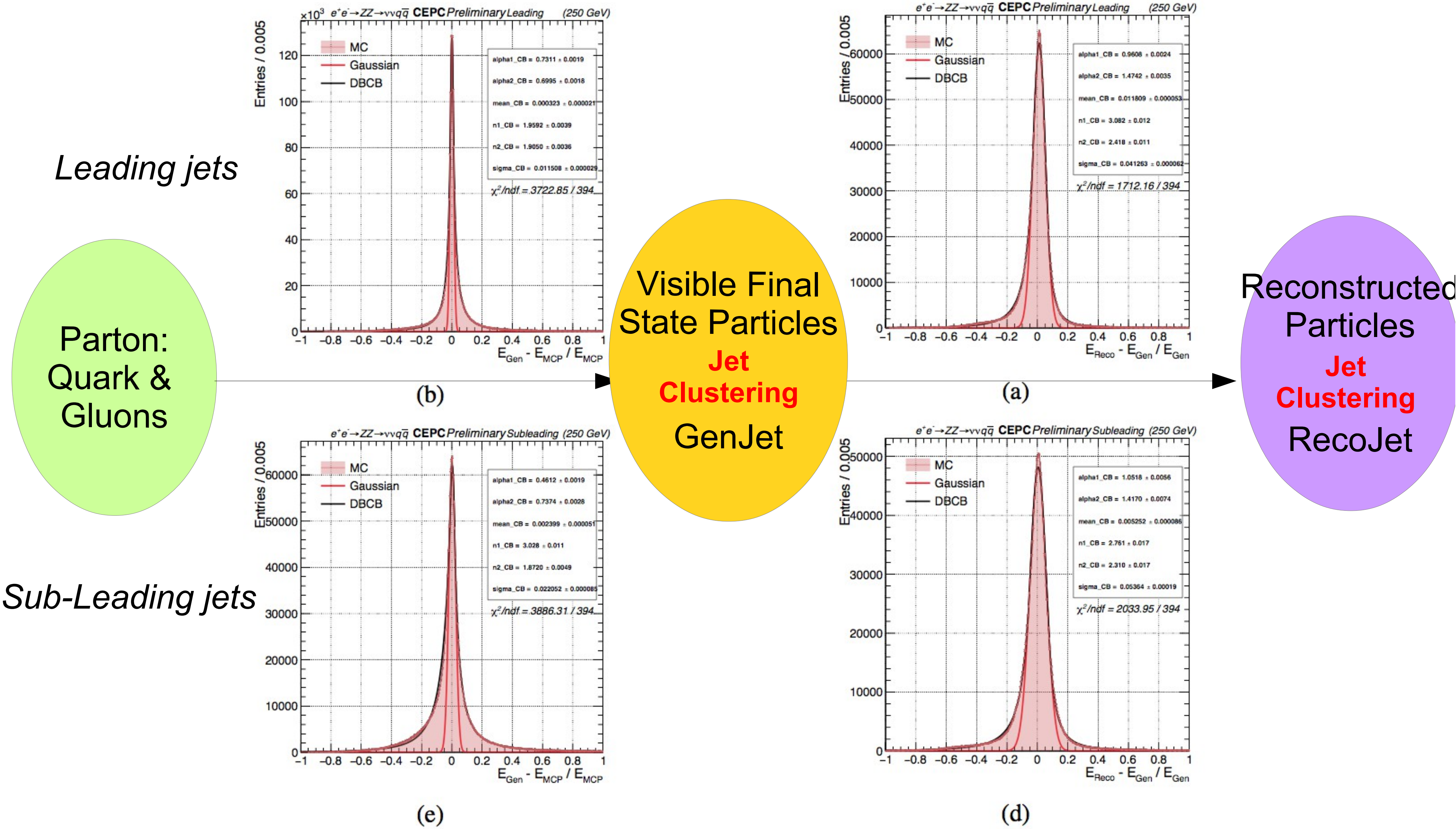
Separation





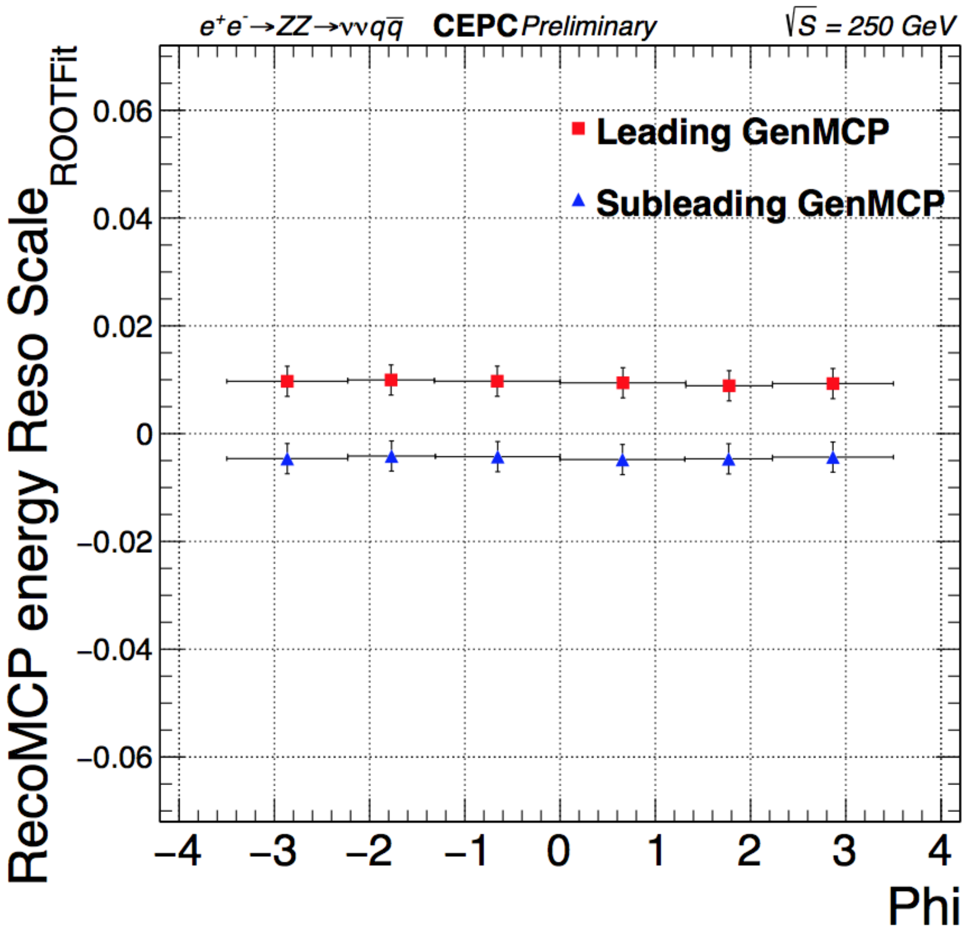
PDF Normalized to unit Area.
Left: Inclusive Samples
Right: Light flavor Sample with Visible ISR Photon Veto

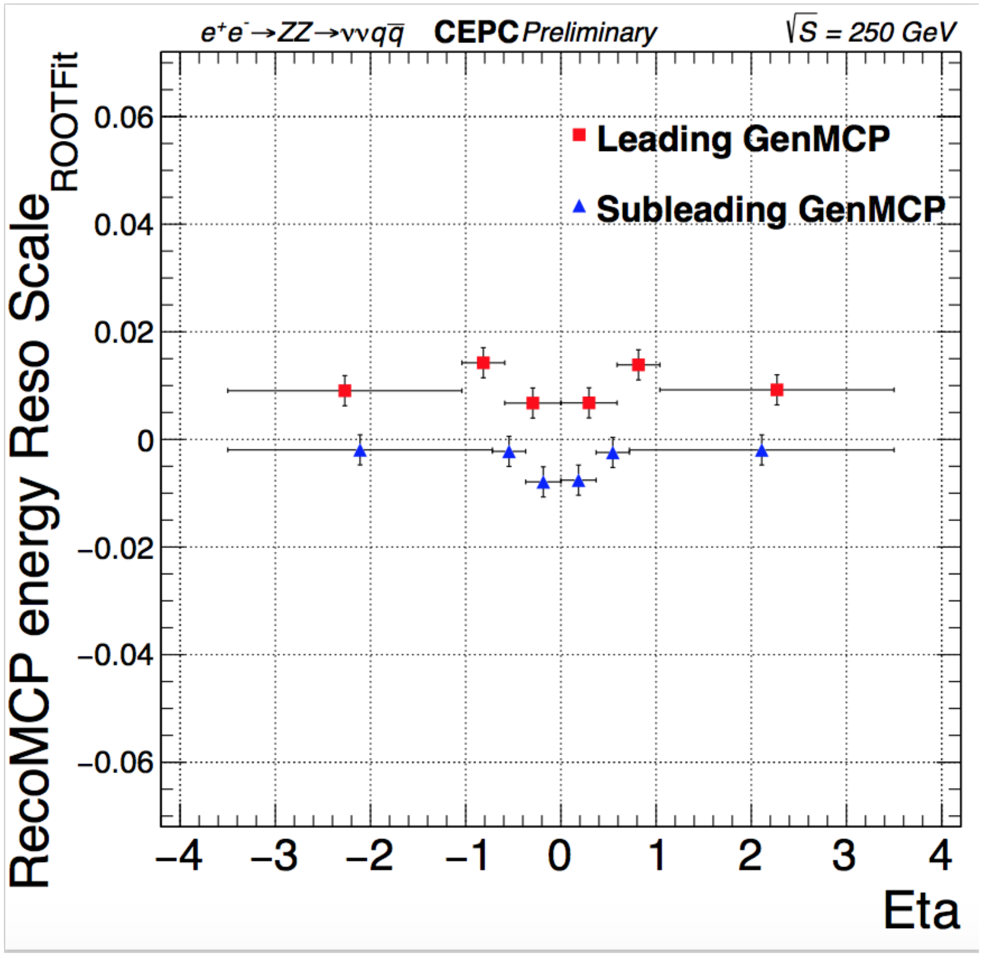
Impact of Jet Clustering: Significant



Jet Clustering is Mainly responsible for the tails

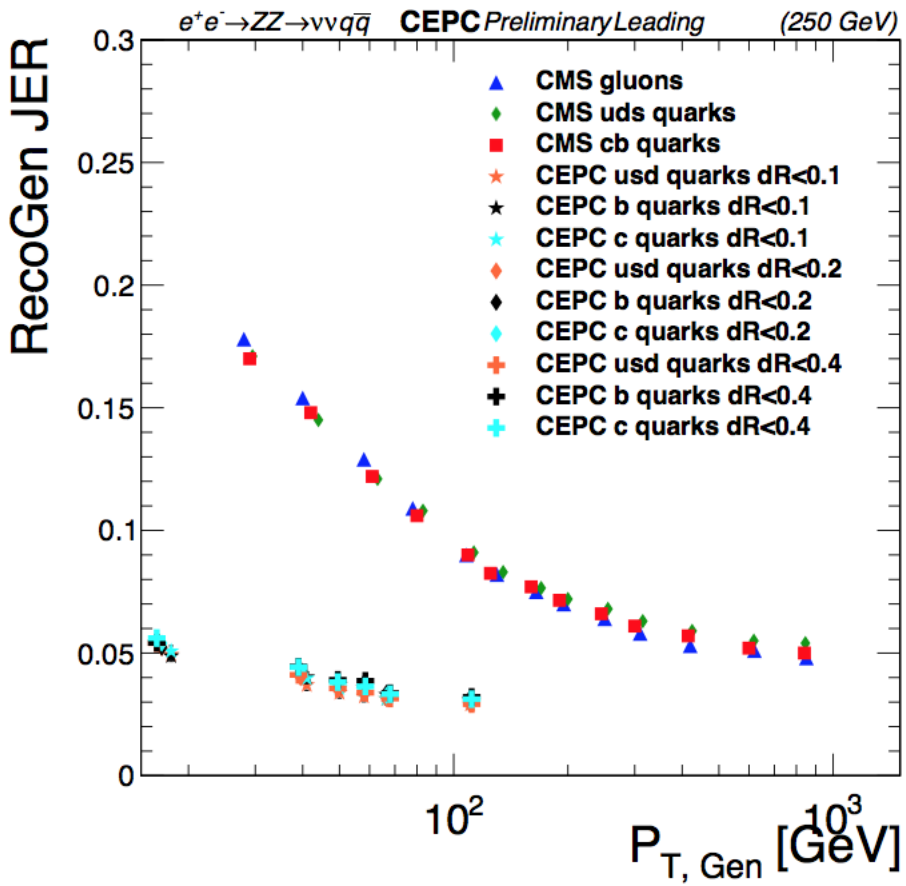
Jet energy Scale

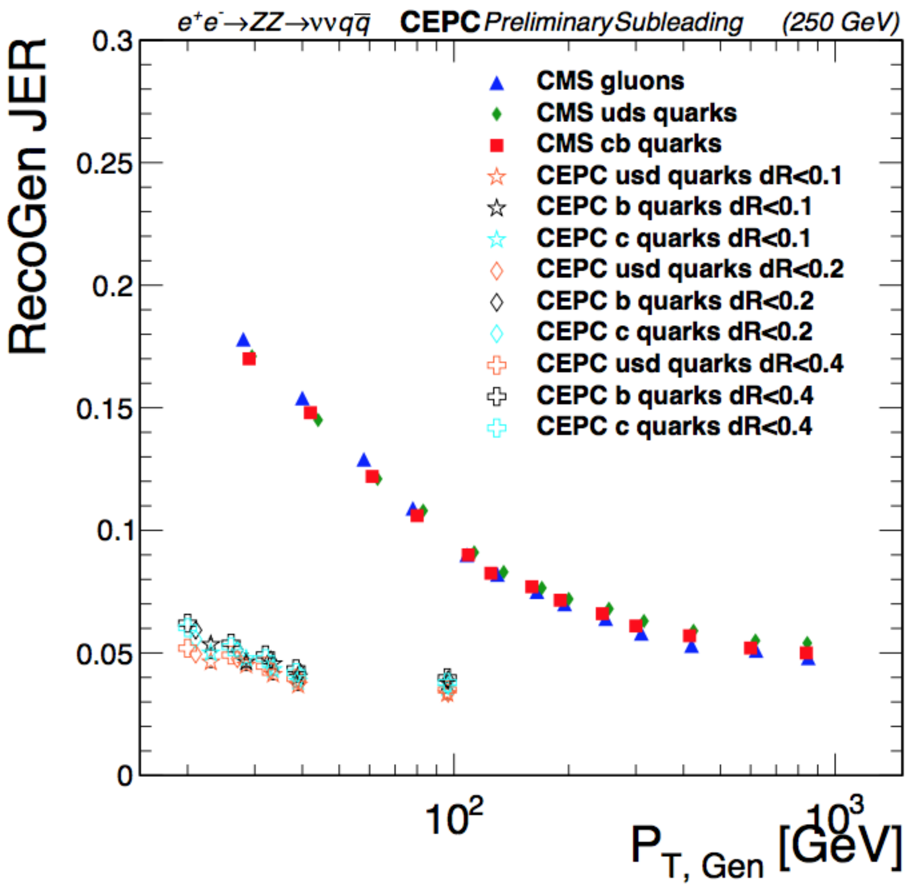




Amplitude ~ 1%
Large JES observed at Leading Jet (Correlated), and at overlap region (Increasing of Splitting)

Jet Energy Resolution





CMS Reference: CMS-JME-13-004,

Jet energy scale and resolution in the CMS experiment in pp collisions at 8 TeV