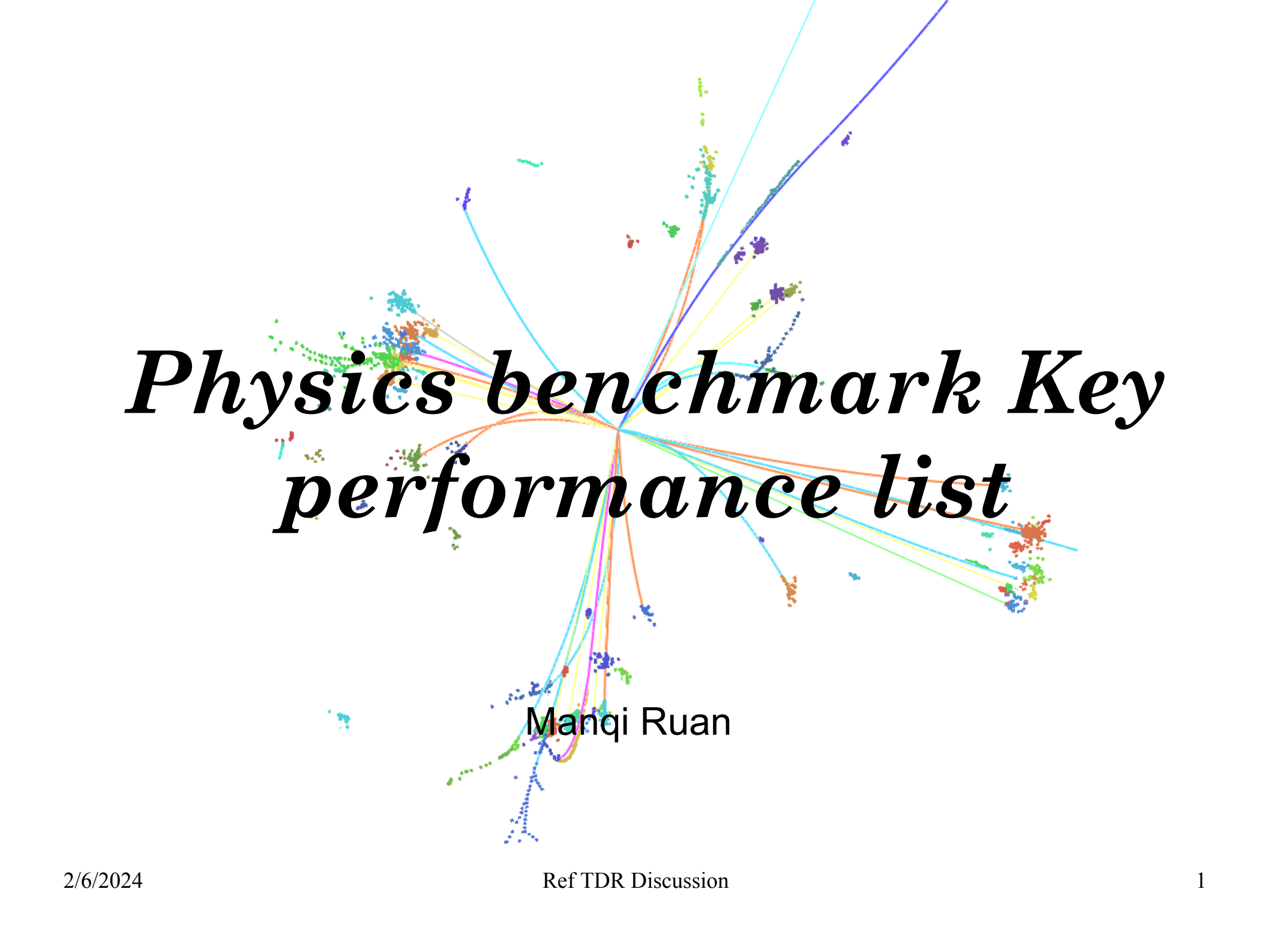


Physics benchmark Key performance list

Manqi Ruan

Benchmark

Feb 5th

	Processes @ c.m.s.	Domain	Object Performance	Sub-D
H->ss	vvH @ 240 GeV	Higgs	PFA (+ MET) + jet origin id	All sub-D, especially VTX, Pid
Vcb	WW@ 240/160 GeV	Flavor	Jet origin id, lepton id	All
W fusion Xsec	vvH @ 360 GeV	Higgs	PFA (+ MET) + jet origin id	All
Alpha_s via Z->tautau	Z->tautau @ 91.2 GeV	QCD	Tau id & Tau final state id	ECAL + Tracker material
Weak mixing angle	Z	EW	Inferred directly from jet origin id	All
Higgs recoil	llH	Higgs	Leptons, track dP/P	Tracker, All
H->bb, cc, gg	vvH	Higgs	PFA (+ MET) + jet origin id	All
	qqH	Higgs	PFA (+ MET) + CSI + jet origin id	All
H->inv	qqH	Higgs	PFA (+ MET)	All
H->di muon	qqH	Higgs	Leptons, PFA	Calo, All
H->di photon	qqH	Higgs	Photons, PFA	ECAL, All
W mass & Width	WW@160 GeV	EW	Beam energy	NAN
Top mass & Width	ttbar@360 GeV	EW	Beam energy	NAN
Bs->vvPhi	Z	Flavor	Object in jets; MET	All
Bc->tauv	Z	Flavor	-	All
B0->2 pi0	Z	Flavor	Pi0 in jets	ECAL

Red: Key benchmarks that need to be processed at Full Sim level.

Blue: secondary benchmarks.

Resources needed

- Well validated Samples (1 Billion ~ 1 M CPU*day)
  - 240 GeV ~ 1 Billion (Phy events ~ o(5) Billion)
  - Z pole ~ 1 Billion (Phy events ~ 4 Tera)
  - WW ~ o(10) M?
  - Top ~ o(10) M
  - 1 Billion ~ 1 M CPU*day ~ 10k CPU * 3 months.
  - // 1 CPU*day ~ 1k events

- Experienced Analysts: 2 months

Benchmark analysis timeline

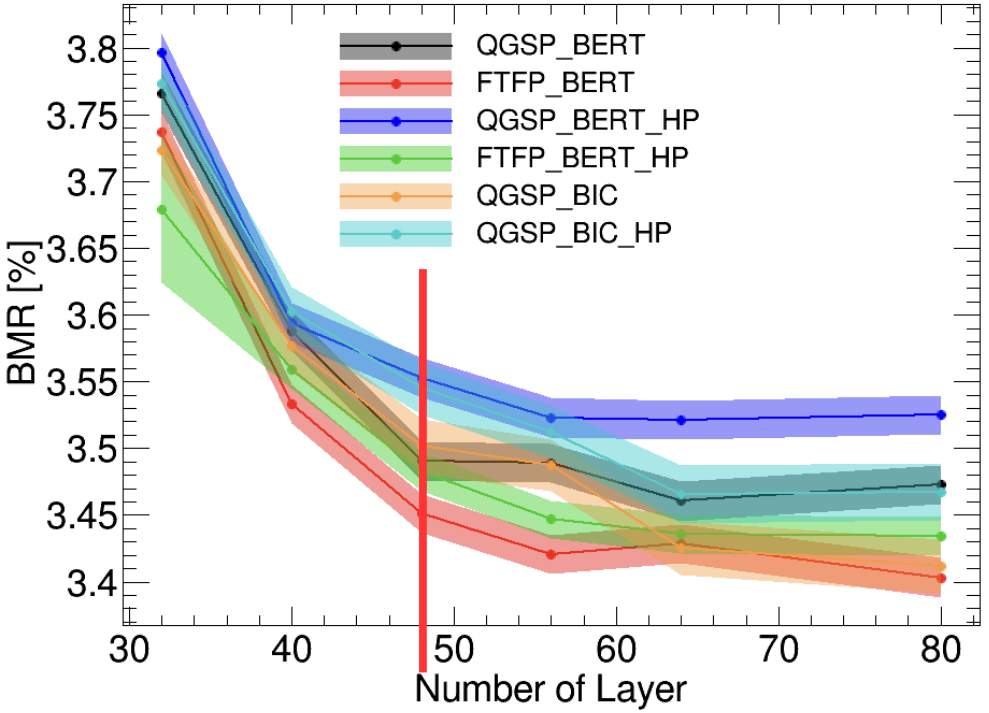
- 2024. now - May: Geo. Fix

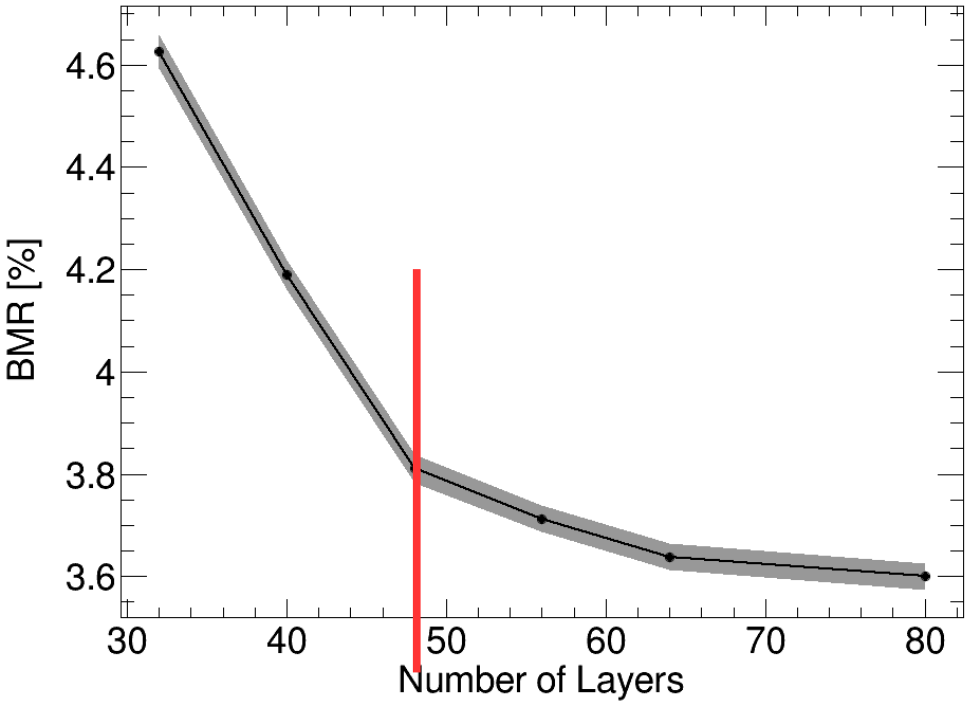
- 2024. May - Aug:
  - Reconstruction Fine tune & Optimization
  - Performance Validation: BMR + Jet Origin ID

- 2024. Aug – Nov: Sample massive Generation
  - Generator Level Validation & Analysis
    - Delphes: fast simulation level analyses and training.

- 2024. Nov – 2025. Jan: Benchmark analysis

HCAL Thickness





With ECAL ~ 1 lambda in the front.

Thus the current optimal setup: ECAL (1 lambda) + HCAL (6 lambda)

Sub-D key info.

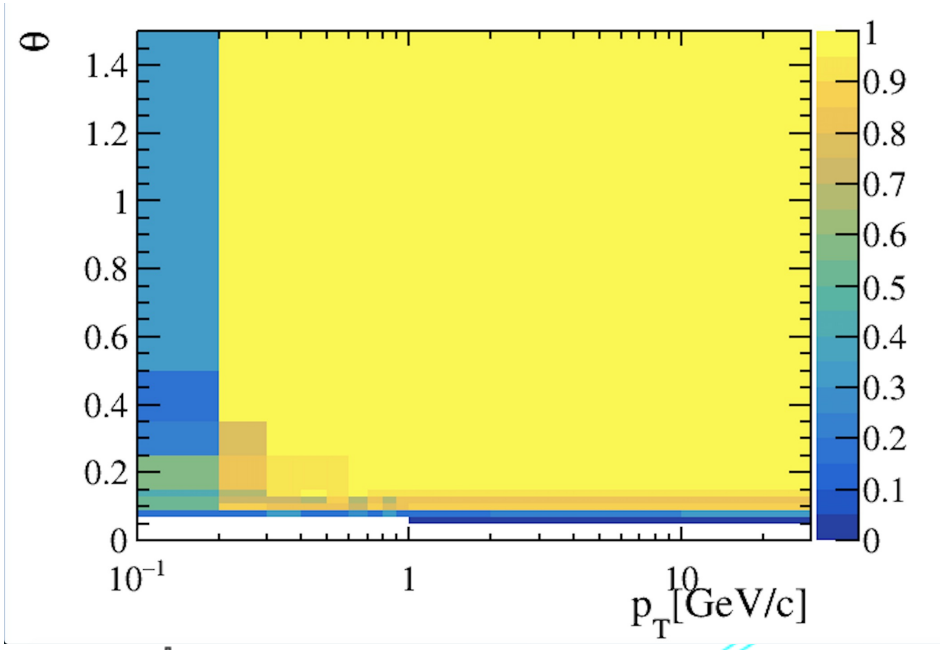
- Intrinsic performance
  - Tracker + VTX
    - Differential efficiencies
    - 5 resolution
    - Separation
  - Calorimeter
    - Intrinsic resolution
    - Separation Power
    - Hit Coll. Efficiency. (Cluster Splitting Chance...)
  - Digitization development, Validation from TB/Prototype experience
- Integration oriented -> input to Electronic + TDAQ, and to Mechanics
  - Mass, dimension,
  - Material budget & Distribution for Tracker & VTX
  - Power-cooling,
  - Noise rate: Intrinsic Noise, MIP Noise, Gamma-Bath relevant Noise
  - Noise dependency (temp. Radiation) -> MDI & Machine Protection
- Cost: Current, extrapolate ~ 1 decades, corr. with R&D.

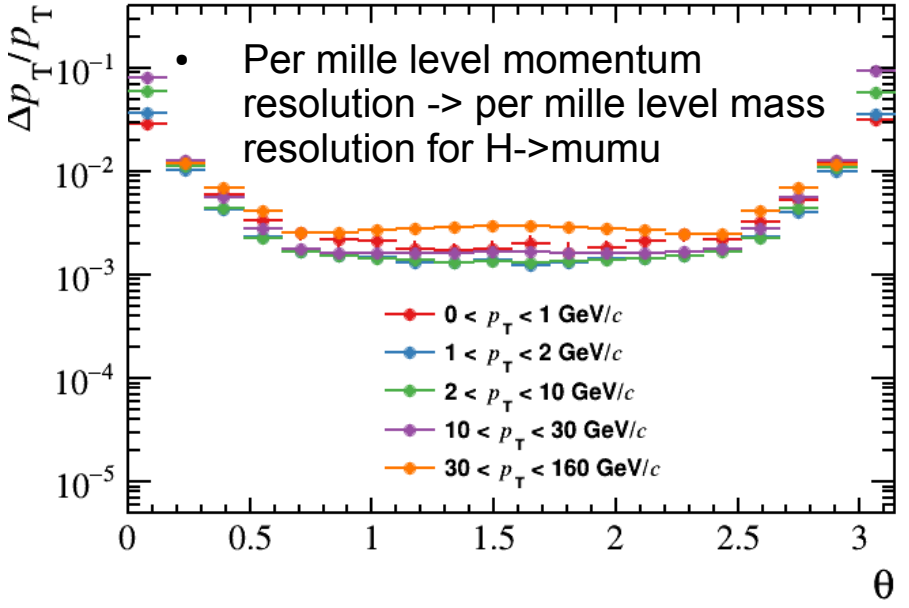
Global Performance

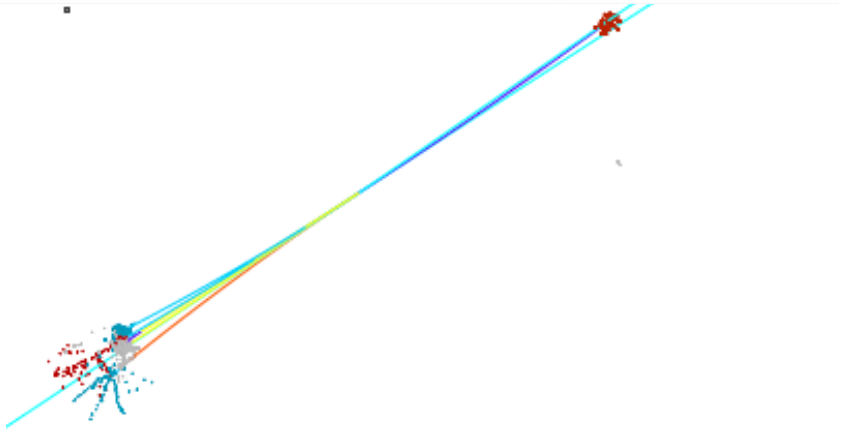
- PFA, etc Reconstruction
  - BMR
  - Jet origin id
  - Pid (differential), isolated & inside jet
  - Tau final State id

- Physics Benchmarks
  - 5 benchmarks... most relevant to the sub-d. Performance.

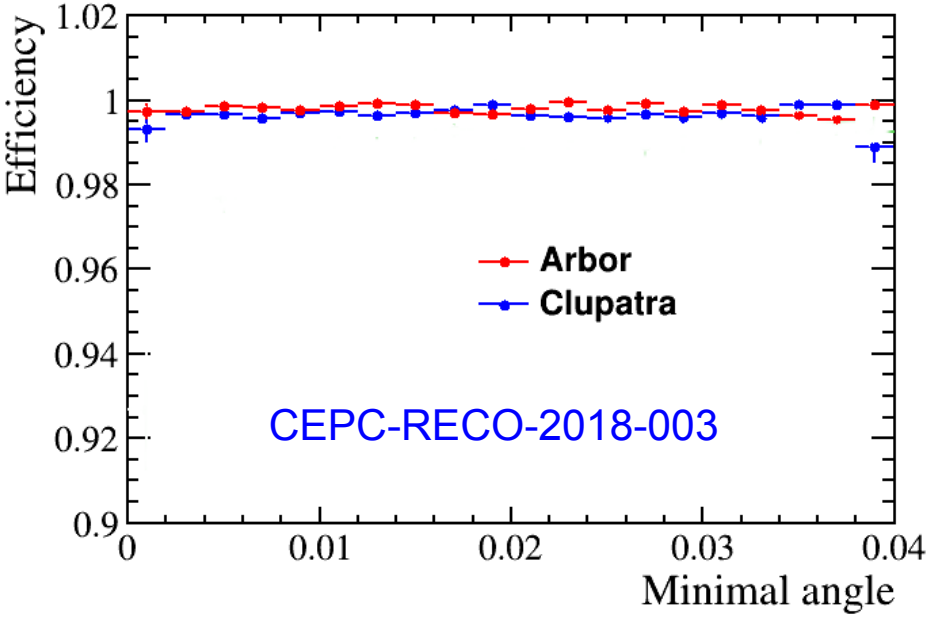
Tracking



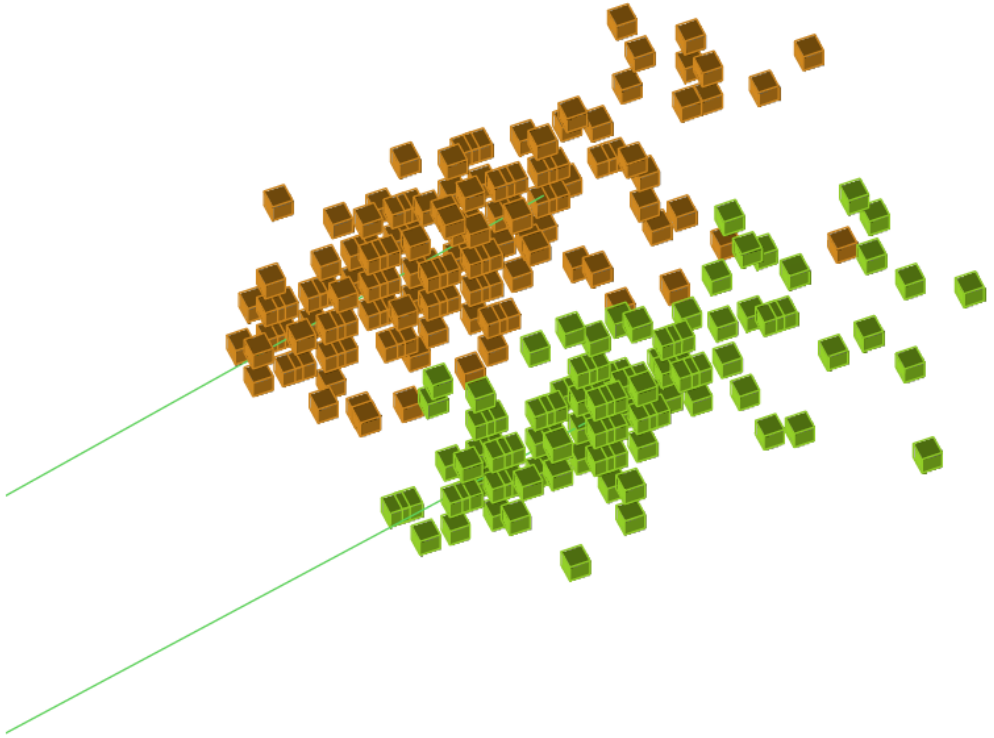


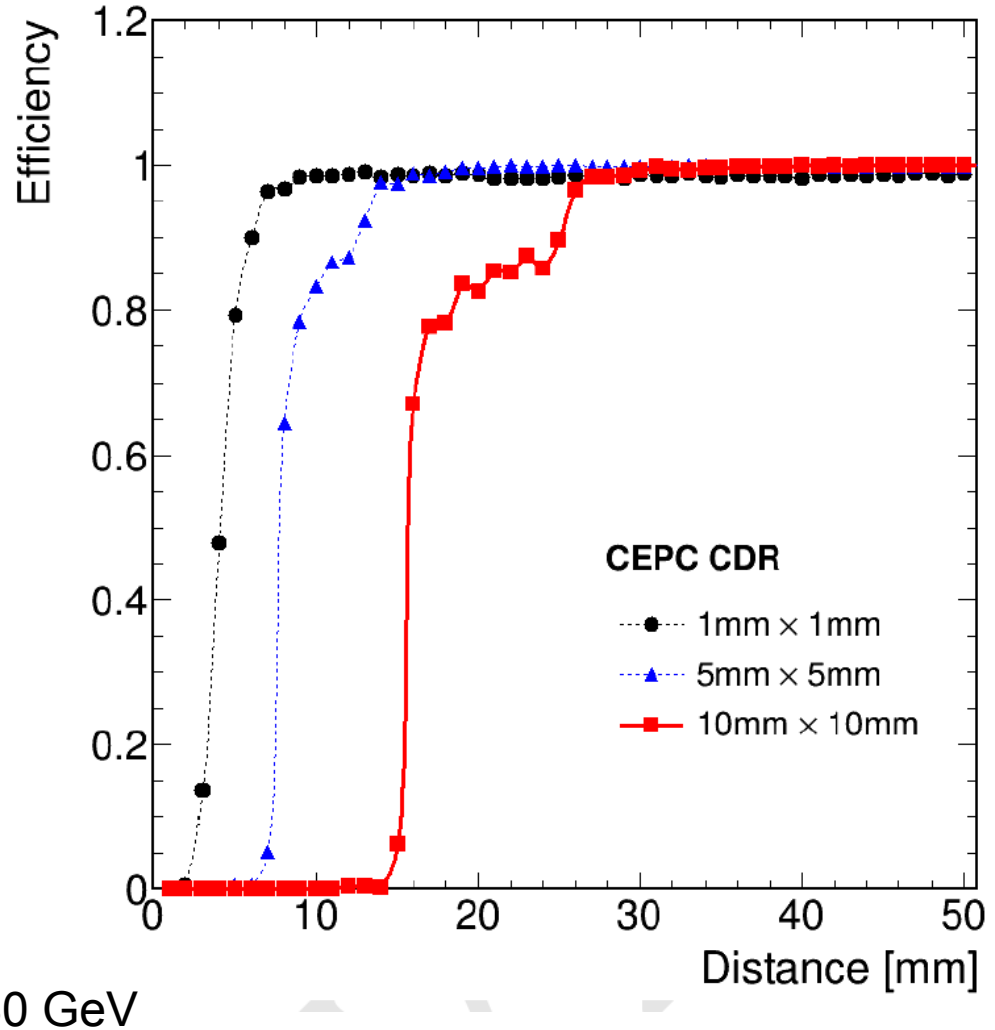


See Mingrui Zhao's talk



Clustering

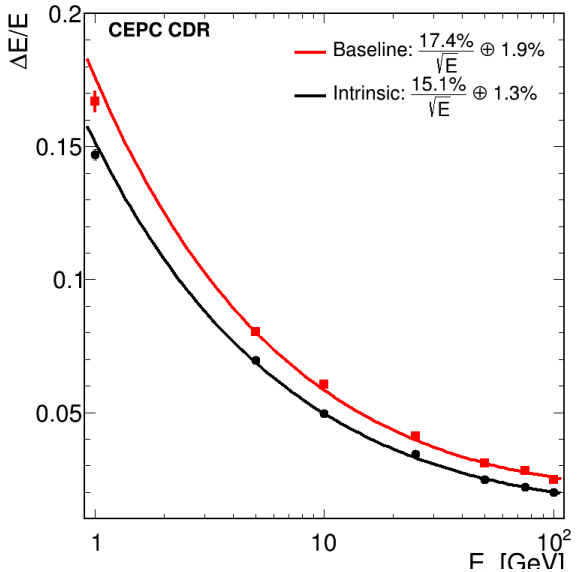


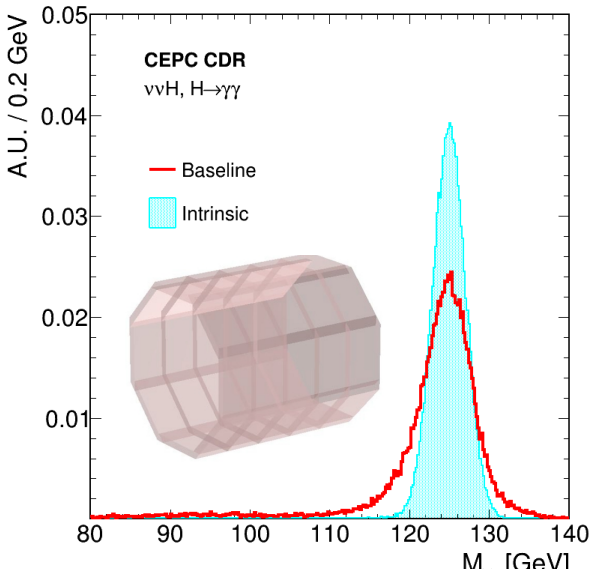


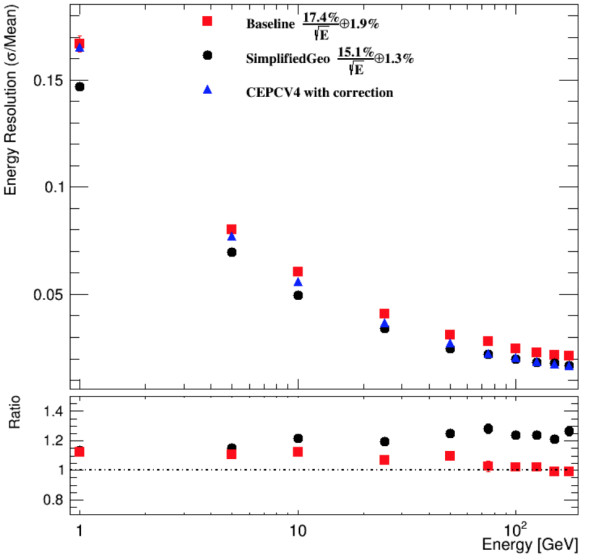
Critical energy to separate an evenly decay π_0: 30 GeV

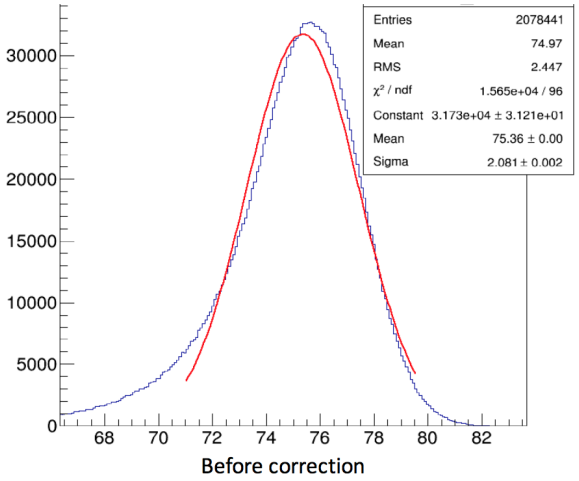
See Hang Zhao's talk

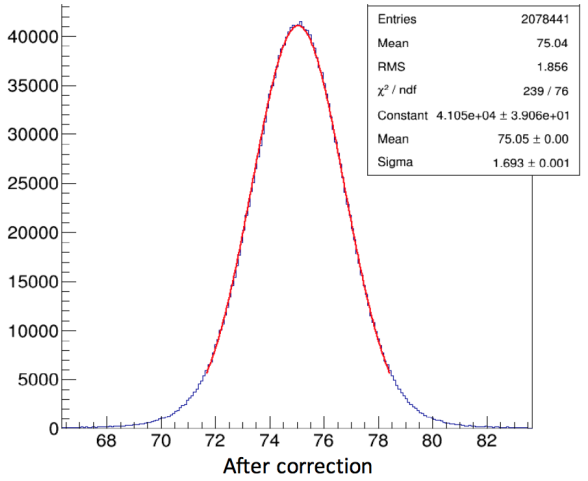
Photon: resolution







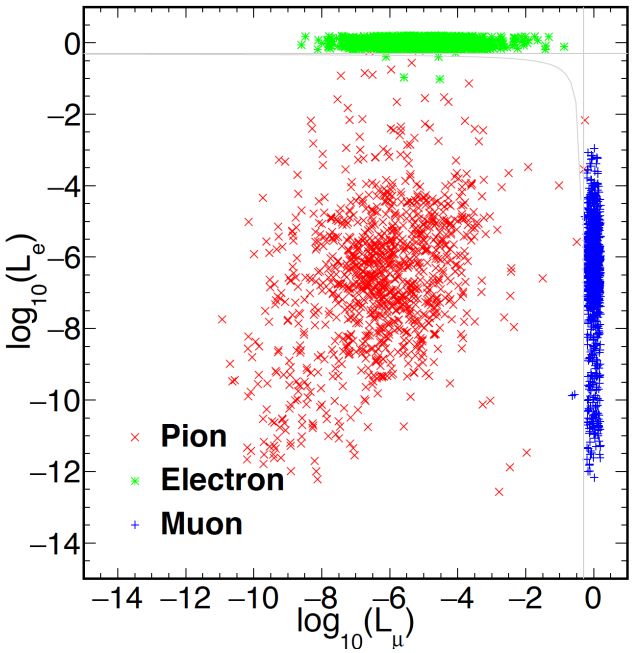


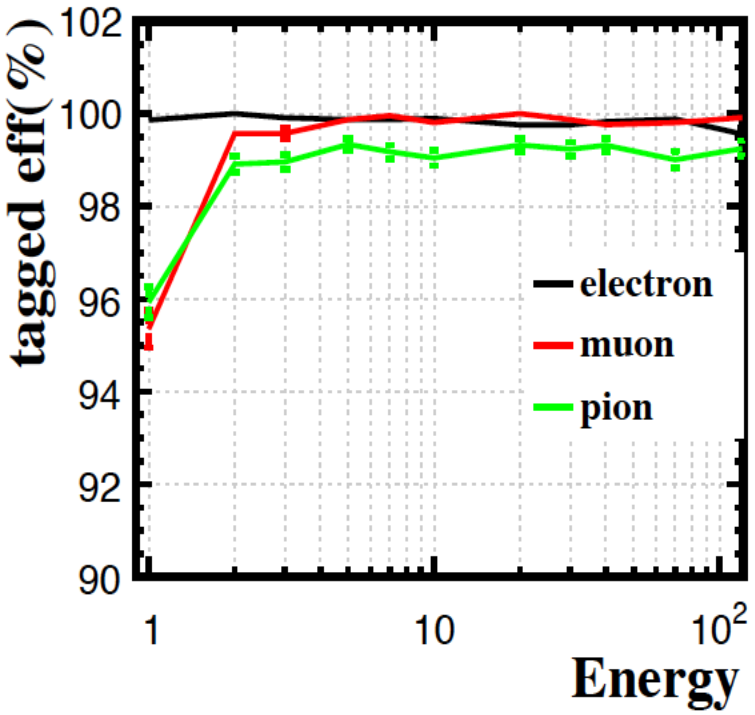


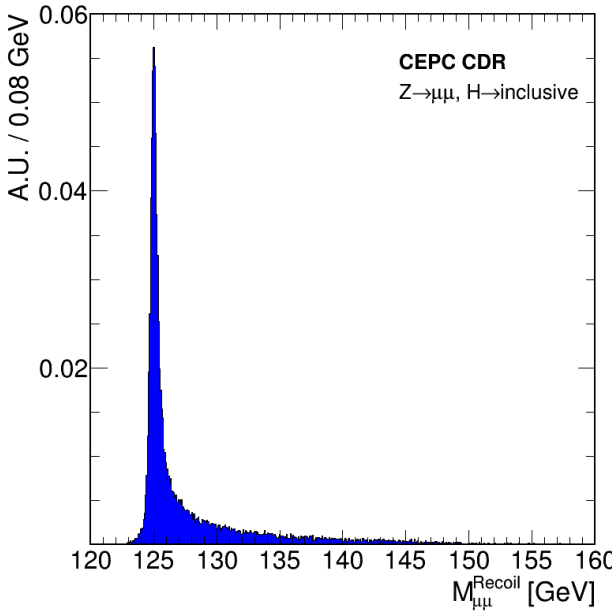
- A Higgs mass resolution of 1.7/2.5% is achieved in the Higgs to di-photon final states with simplified/baseline geometry
- The geometry defects correction could be efficiently corrected (Preliminary)

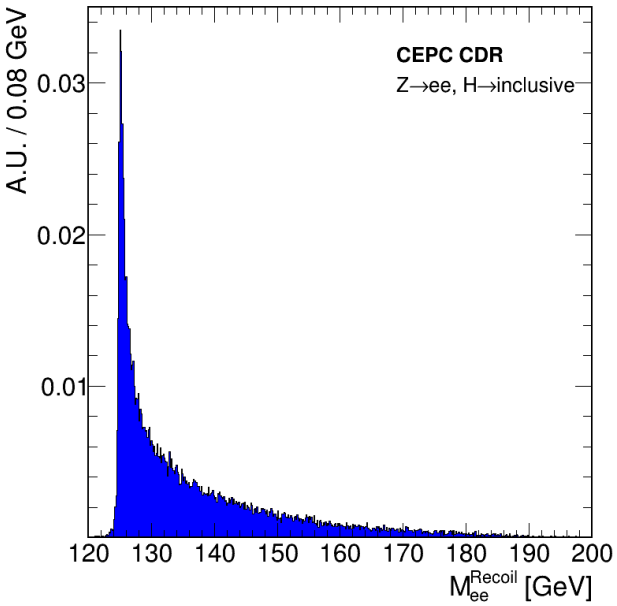
See Yuqiao Shen's talk

Leptons







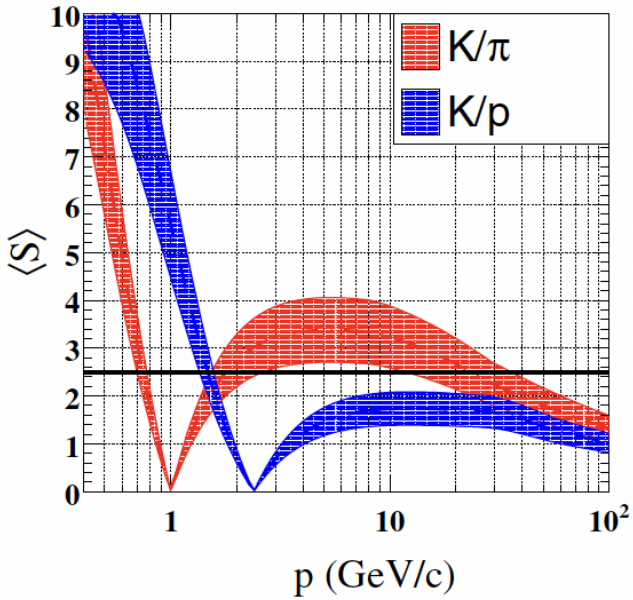


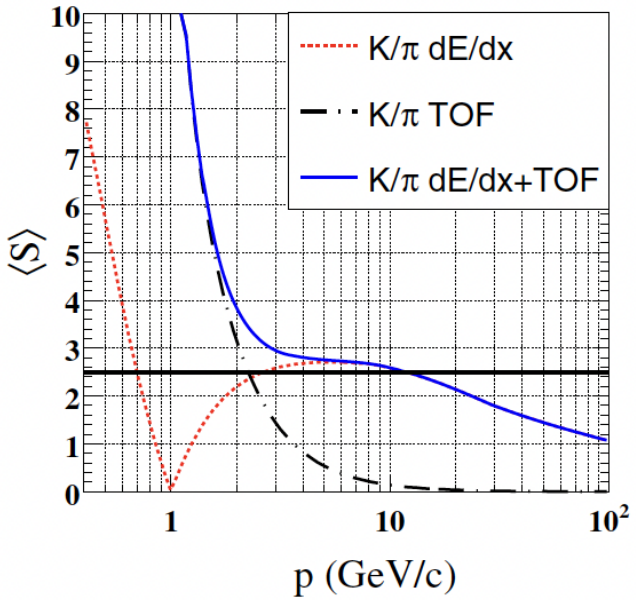
BDT method using 4 classes of 24 input discrimination variables.

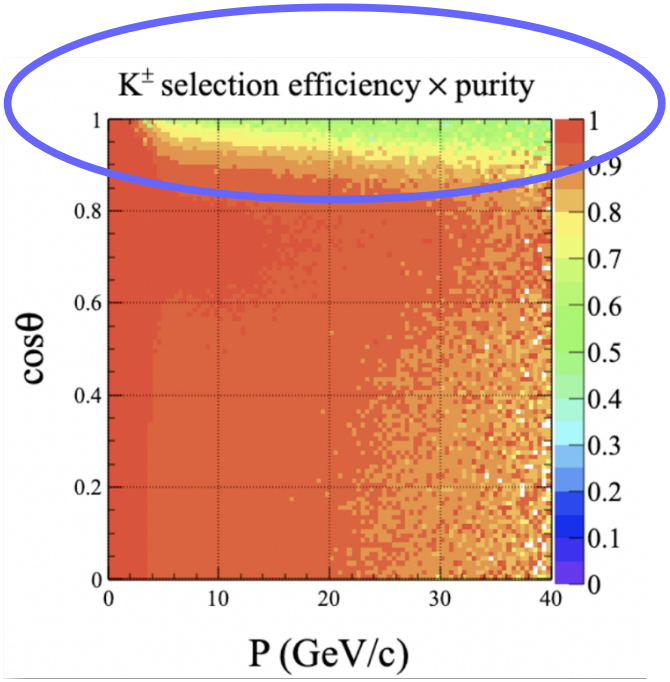
Test performance at: Electron = E_likeness > 0.5 ;
Muon = Mu_likeness > 0.5
Single charged reconstructed particle, for E > 2 GeV:
lepton efficiency > 99.5% && Pion mis id rate ~ 1%

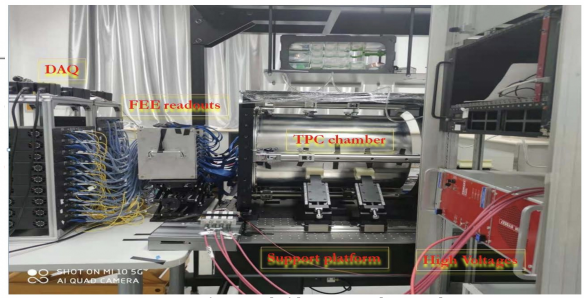
Eur. Phys. J. C (2017) 77: 591

Tracker: Pid









TPC prototype integrated with 266nm UV laser tracks

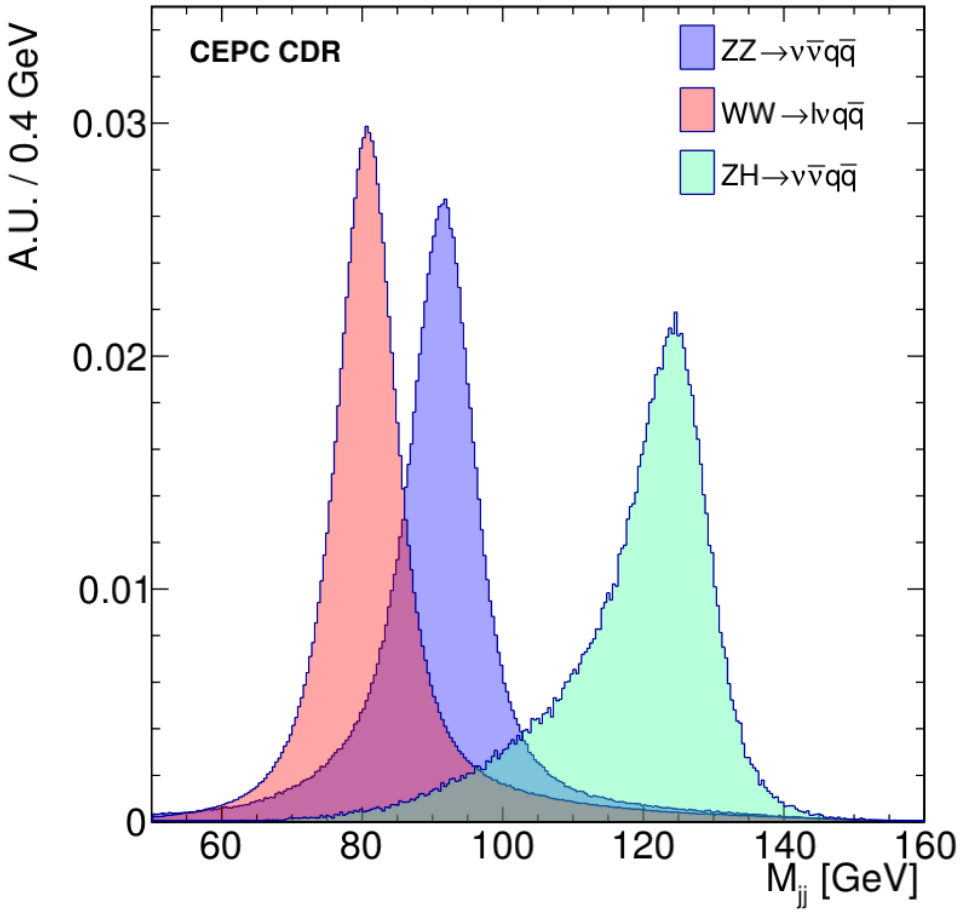
Table 3
The $K^{\pm}$ identification performance with different factors, $\sigma_{actual} = factor \cdot \sigma_{intrinsic}$, with/without combination of TOF information at the Z-pole.

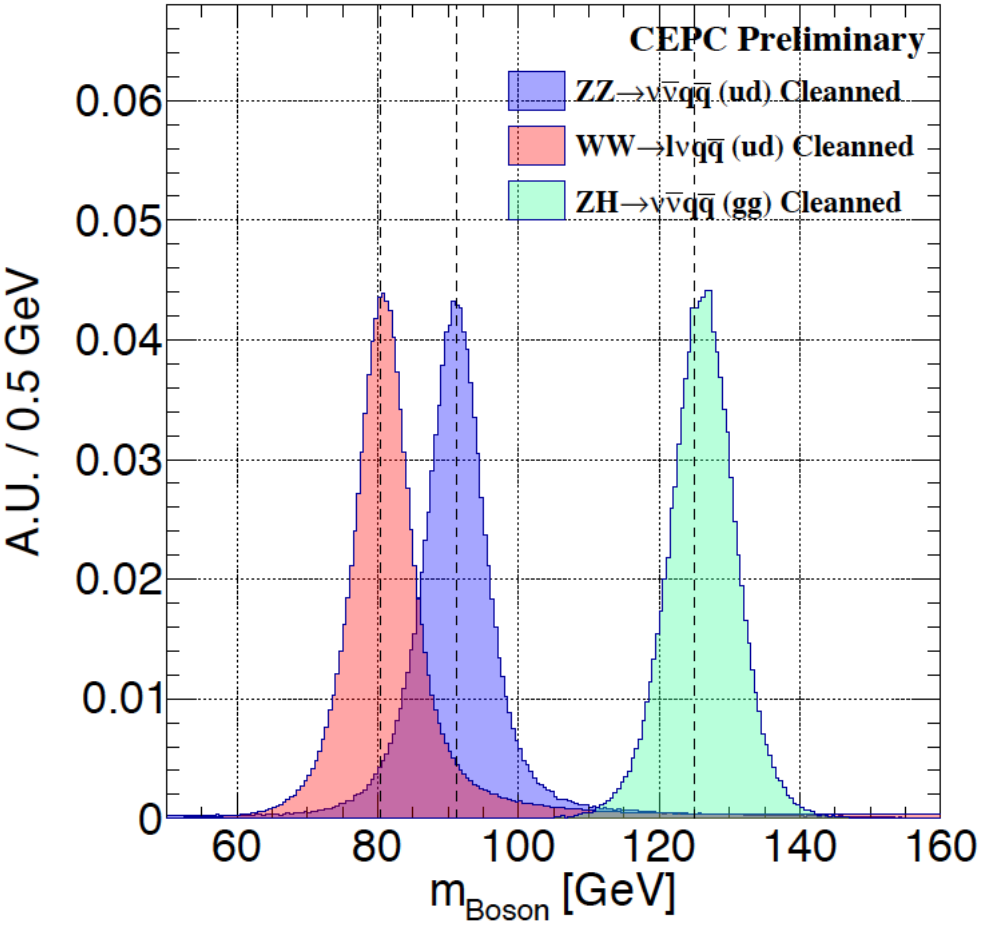
	Factor	1.	1.2	1.5	2.
dE/dx	ε_K (%)	95.97	94.09	91.19	87.09
	$purity_K$ (%)	81.56	78.17	71.85	61.28
dE/dx & TOF	ε_K (%)	98.43	97.41	95.52	92.3
	$purity_K$ (%)	97.89	96.31	93.25	87.33

- Pid via dEdx or dNdx: **< 3%**
- Current TPC studies using laser reaches 3.4%
- 50 ps Timing on Calo. Clusters

Ref TDR]

Massive Boson Separation





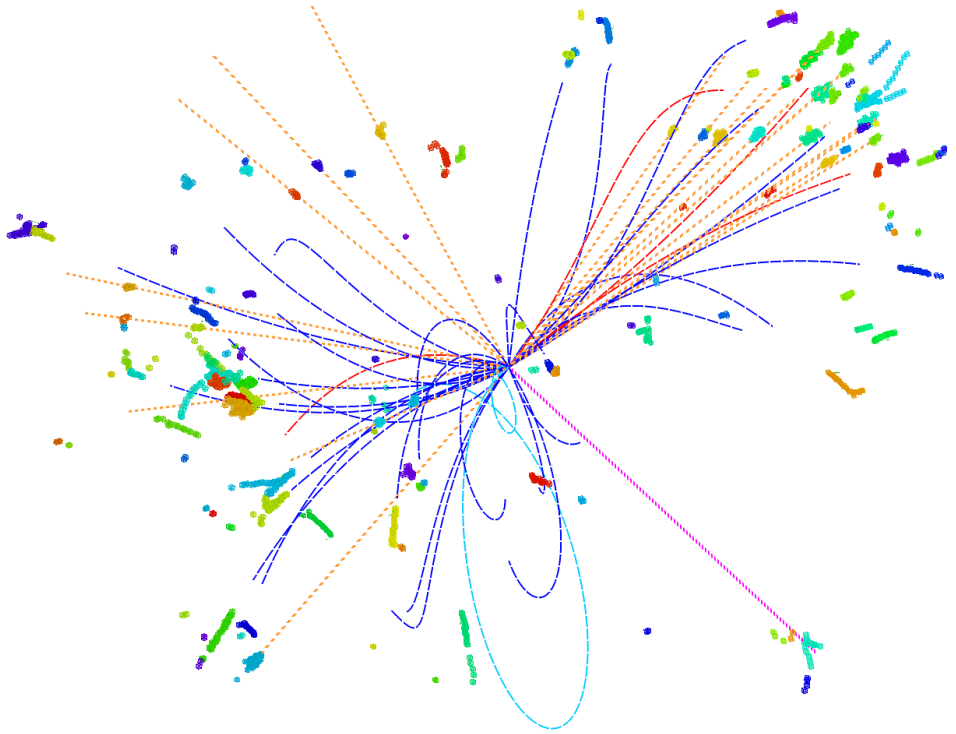
See Peizhu Lai's talk

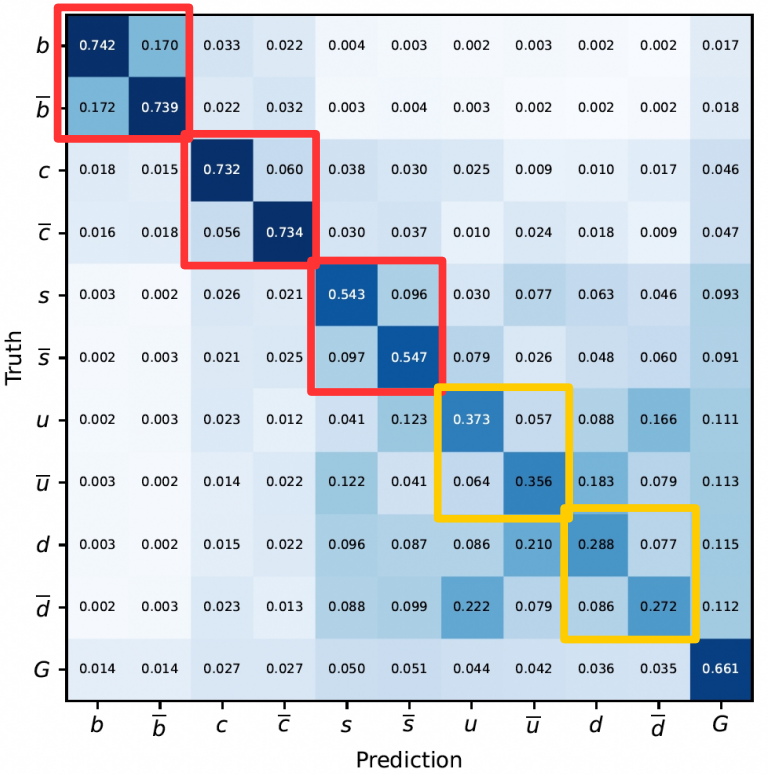
WW sample: using μνqq sample,
Plot: the visible mass without the muon

CEPC-RECO-2017-002 (DocDB id-164),
CEPC-RECO-2018-002 (DocDB id-171),

Eur. Phys. J. C78 (2018) no.5, 426

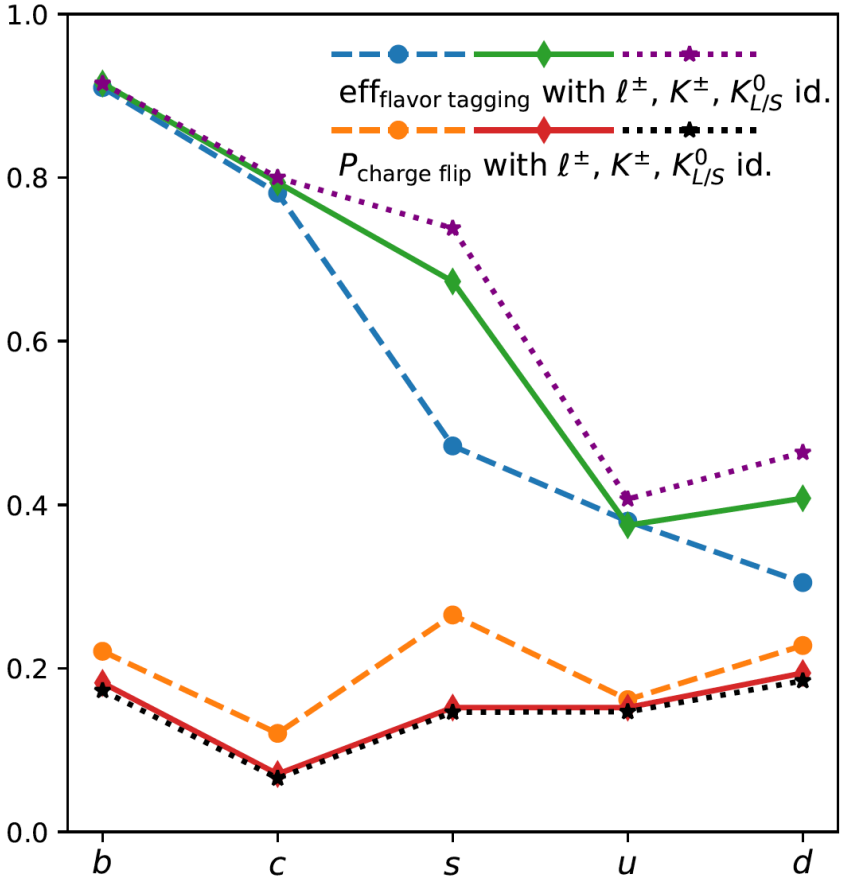
Recent HL: Jet Origin Identification

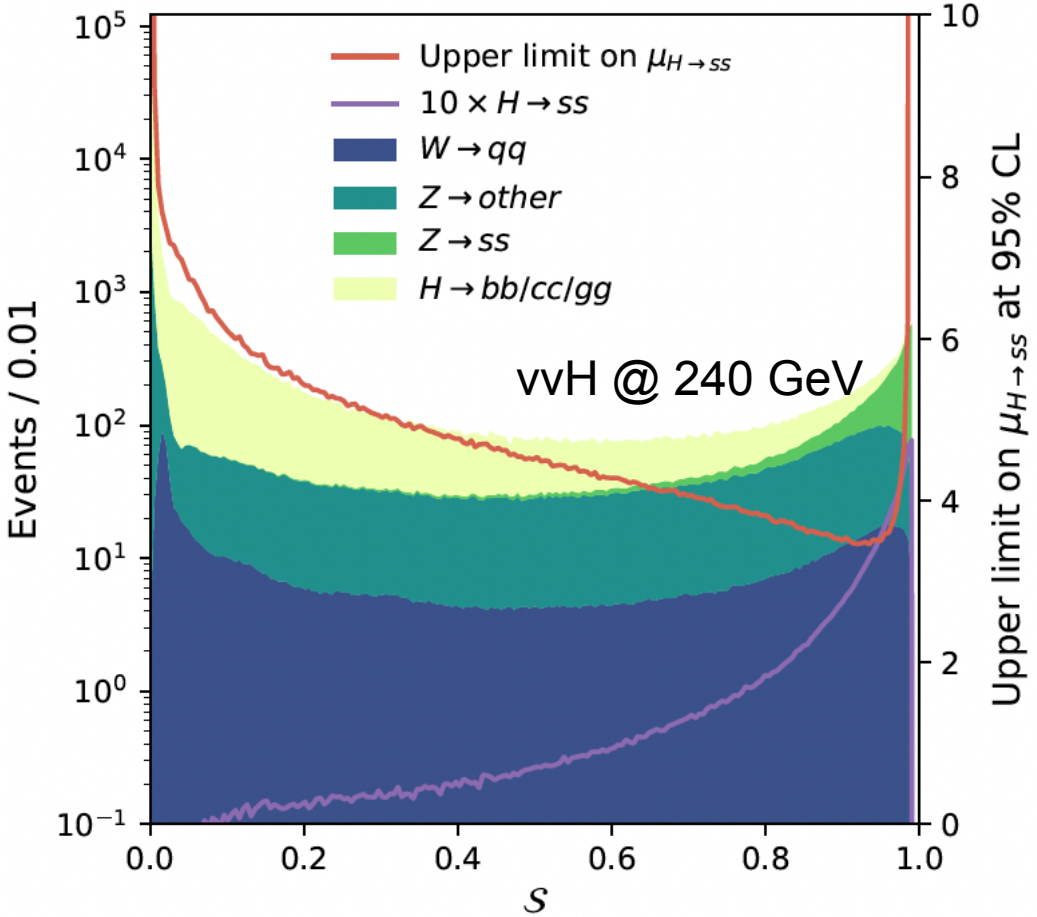




- **Jet origin identification: 11 categories (5 quarks + 5 anti quarks + gluon)**
  - Jet Flavor Tagging + Jet Charge measurements + s-tagging + gluon tagging...
- Full Simulated vvH, Higgs to two jets sample at CEPC baseline configuration: CEPC-v4 detector, reconstructed with **Arbor + ParticleNet (Deep Learning Tech.)**
- 1 Million samples each, 60/20/20% for training, validation & test

Performance with different PID scenarios & H→ss measurements





Flavor tagging: type that maximize {L_q + L_q_bar, L_g}

If quark jet: jet charge ~ compare {L_q, L_q_bar}

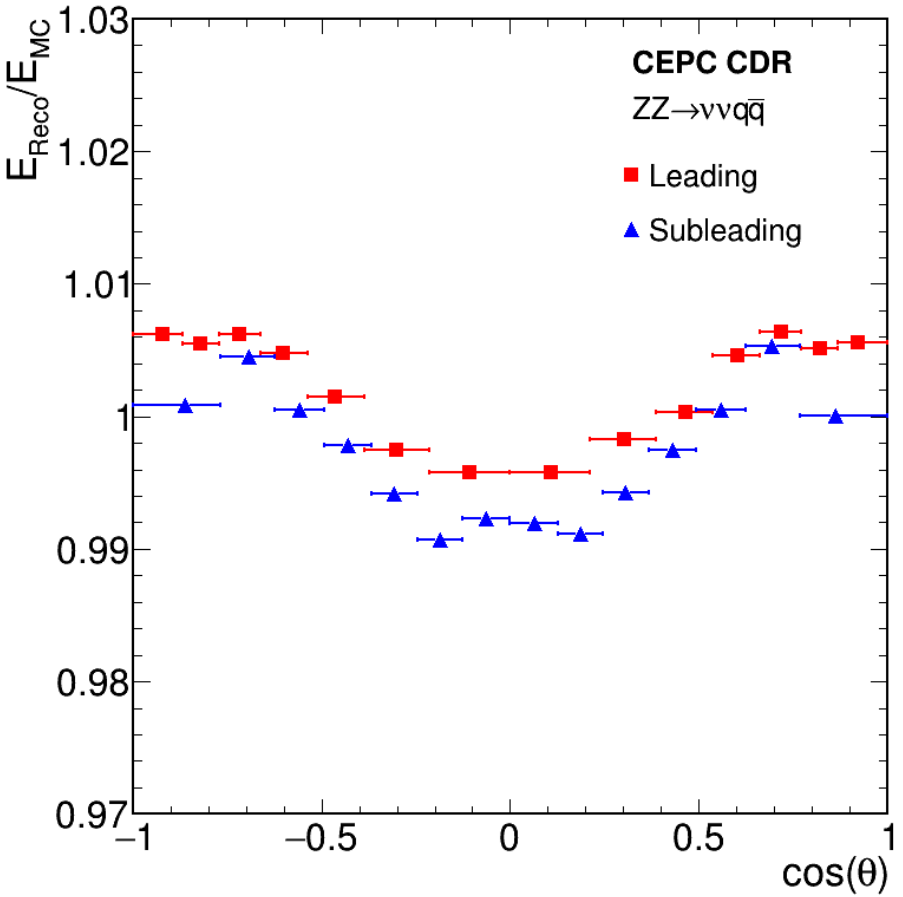
Key questions

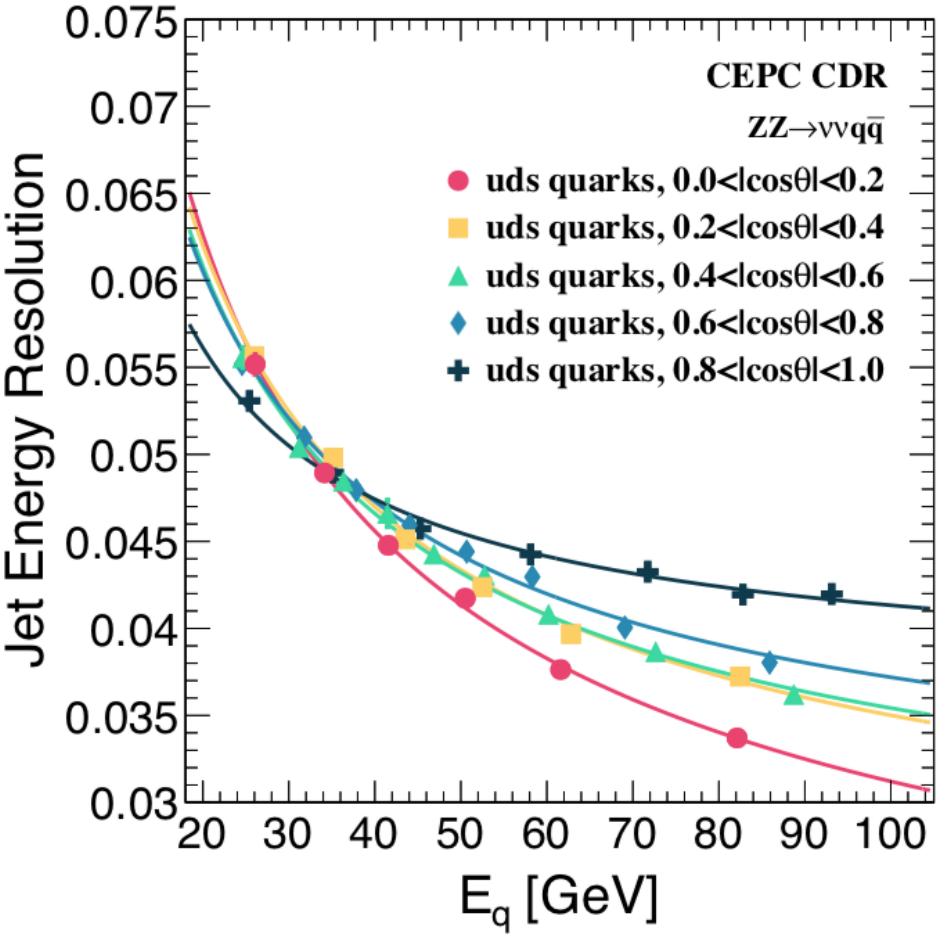
- How to address the manpower of reconstruction, especially PFA reco?

- Reconstruction =
  - Digitization (Need to validate on experimental data - SubD)
  - Tracking (Track finding + Fitting)
  - PFA (Calo. Clustering + Track Matching(1 FTE) + Pid(1 FTE))

- High level Reco.
  - Tau, Ks, Lambda, pi-0 finding, converted photon recon
  - Jet origin id (1 FTE), etc.

Jet Energy Scale & Resolution





- JES ~ with 1% of the unity (without correction)
- JER ~ 3.5% - 5.5% for E ~ 20 – 100 GeV Jets
- **Both Superior to LHC experiments by 3-4 times**

See Peizhu Lai's talk