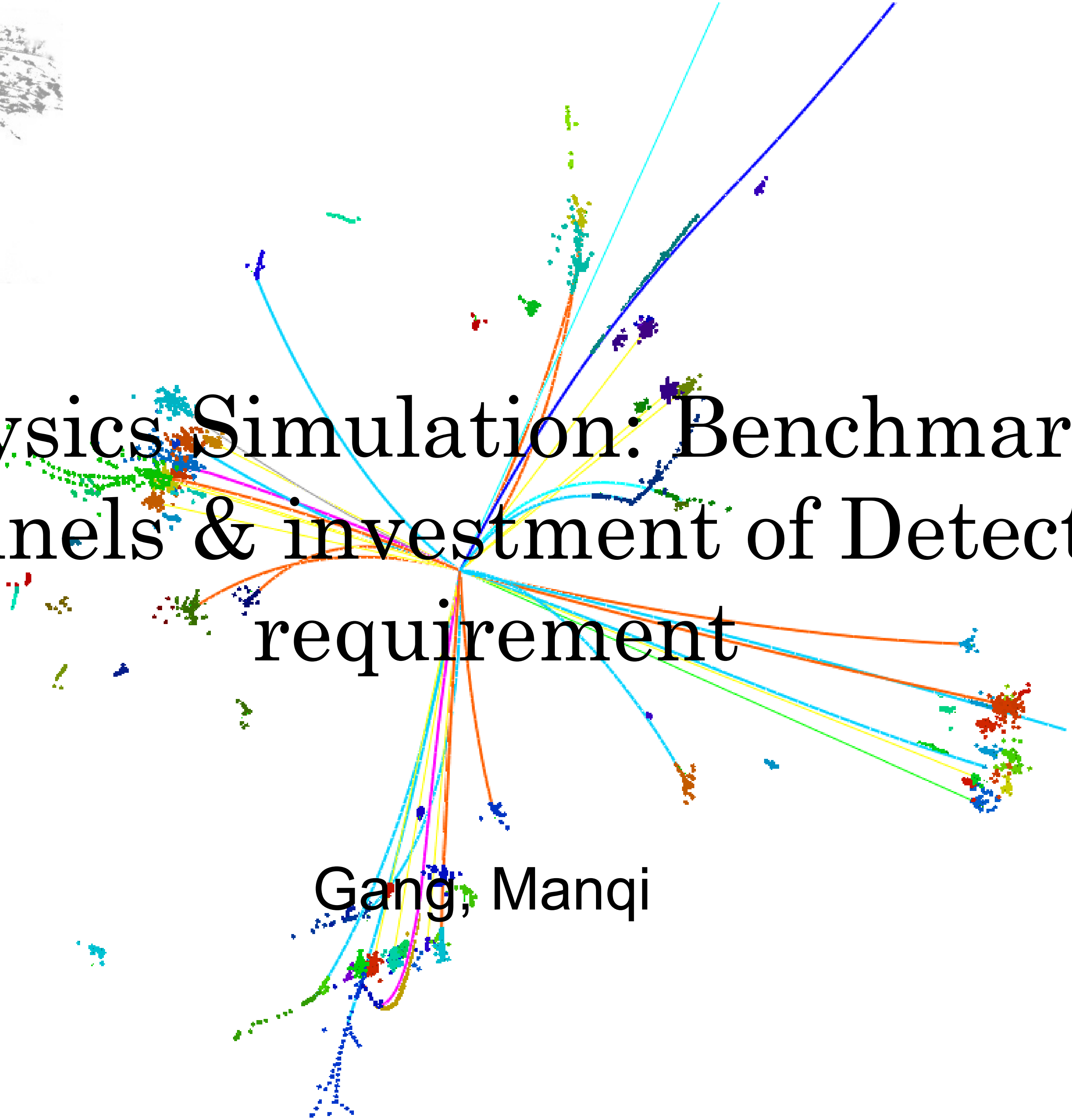


Physics Simulation: Benchmark channels & investment of Detector requirement

Gang, Manqi

Benchmarks for detector optimization

6 benchmark analyses for MOST

- Higgs mass/Xsec measurement with Z->ll, H->inclusive
  - Physics importance weight (PIW): 30%
  - Performance: PID (Calo) & Tracking
  - Requirement on Systematic error
- Br(H->ZZ) via ZH->ZZZ*->llvvqq or Br(H->WW) via Z->ll & H->WW*->lvqq
  - PIW: 25%,
  - Key to Higgs total width
  - Object reconstruction in complex environments: JER, LEPTON & MET
- Br(H->bb, cc, gg): *divergence from ILC extrapolation: need more careful study*
  - PIW: 20%, access to g(Hcc)
  - Performance:
    - Z->qq: Jet Clustering & Flavor tagging, 8%
    - vv + H->bb, cc, gg : Flavor tagging, key to Higgs width, 8%
    - Z->ll: Flavor tagging, 4%

Benchmark Physics Processes

- Br(H->exo)
  - PIW: 10%
    - H->inv: 5%, require JER.
    - H->leptonic: 5%
- Br(H->di photon)
  - PIW: 5%
  - Performance:
    - Materials budget (photon converting rate & recovery)
    - ECAL intrinsic resolution, which, strongly correlate with JER
- One Z/W measurement: for example $A_{FB}(b)$, $\sin^2(\theta_w)$, PIW = 10%
- *Personal Perspective: Comment & Suggestions?...*

Non-benchmark Higgs Processes

- Higgs:
  - Xsec measurement via Z->qq, H->inc. PIW = 25%
    - Very complex analysis. Not covered due to manpower & expertise
  - H->tautau: PI = 15%
    - ll, vv + tautau: covered, PI = 7%
    - Z -> qq: ongoing analysis, 8%
    - Goal: to flag every tau decay final states, need further study
    - Remark:
      - An excellent test bed for particle separations//PFA.
      - Key to tau-related physics measurements (bkg...).
  - Br(H->WW, ZZ) via non Benchmarks: PI = 10%
    - Covered: 5% (Br(H->WW/ZZ) via Z->ll, H->WW/ZZ->4q)
    - Non covered: 5%
  - Br(H->mumu): PI = 5%, covered
  - Br(H->exotic): with Jets in final states, PI = 5%, partially covered

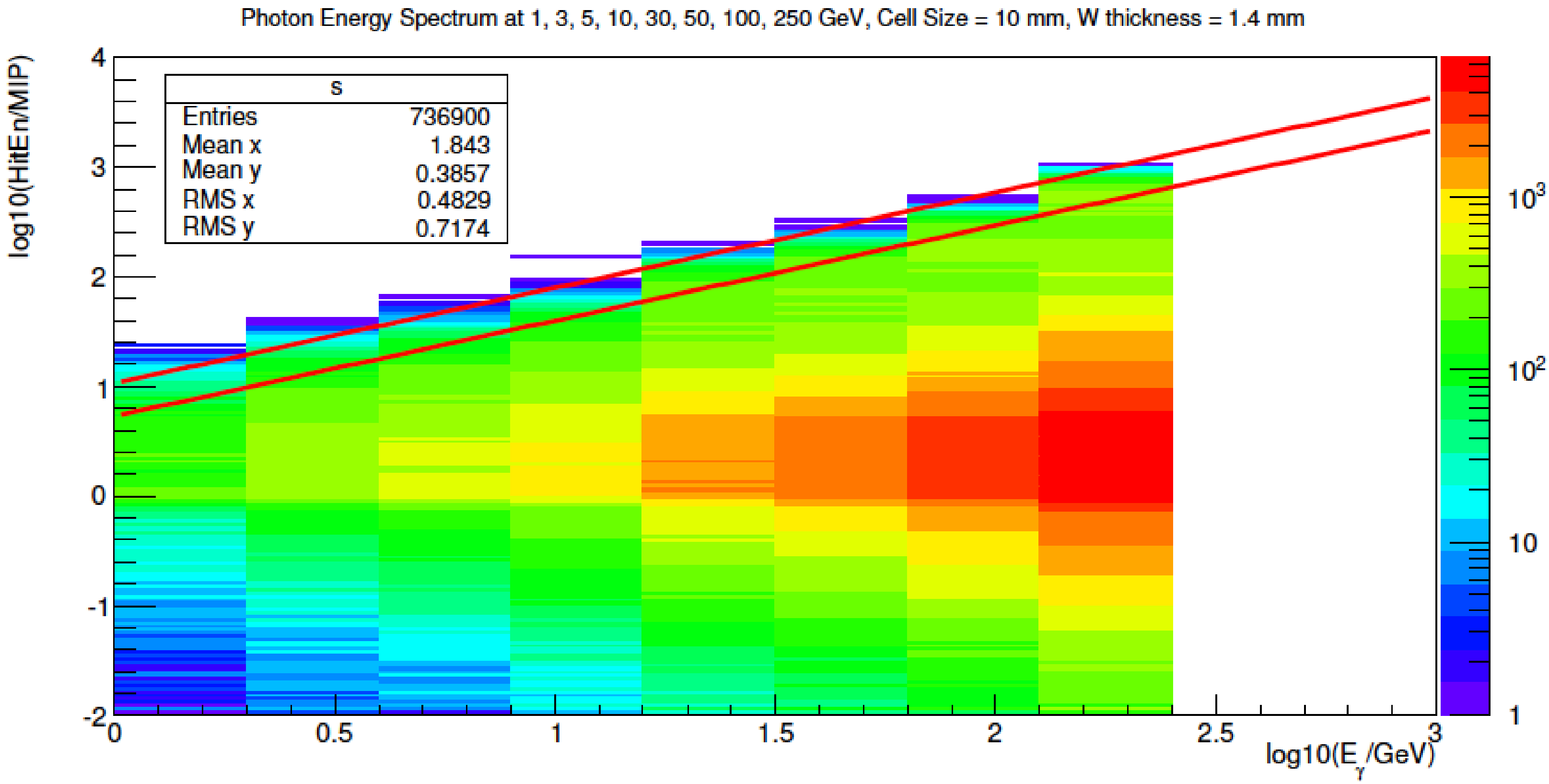
Physics analysis

	Physics importance	Coverage at cepc_v1	Consumed Manpower/Ph.D U	Future demands /Ph.D U
MOST Benchmarks	100%	70%	5.0	7.0
Higgs_non benchmark	60%	20%	1.0	6.0
Higgs_differential	20%			2.0
E/W	50%	10%		4.0
Flavor	20%	5%		2.0
Else (top, 750, ...)	20 - 40%			2.0 – 3.0

- Remarks:
  - A Ph.D Unit: analysis work for 1 Ph.D 50% of his/her thesis
    - Yu Dan, Analysis: Br(H->tautau), Service: Reconstruction (PID) + TB analysis
  - Manpower: Analysis at cepc_v1 = analysis for further iterations
  - PIW != Efforts Needed.
    - EW/Flavor needs extra manpower from experienced Staffs...
    - Data driven analysis and combination requires at least 3 Ph.D U

Saturation

On Silicon...



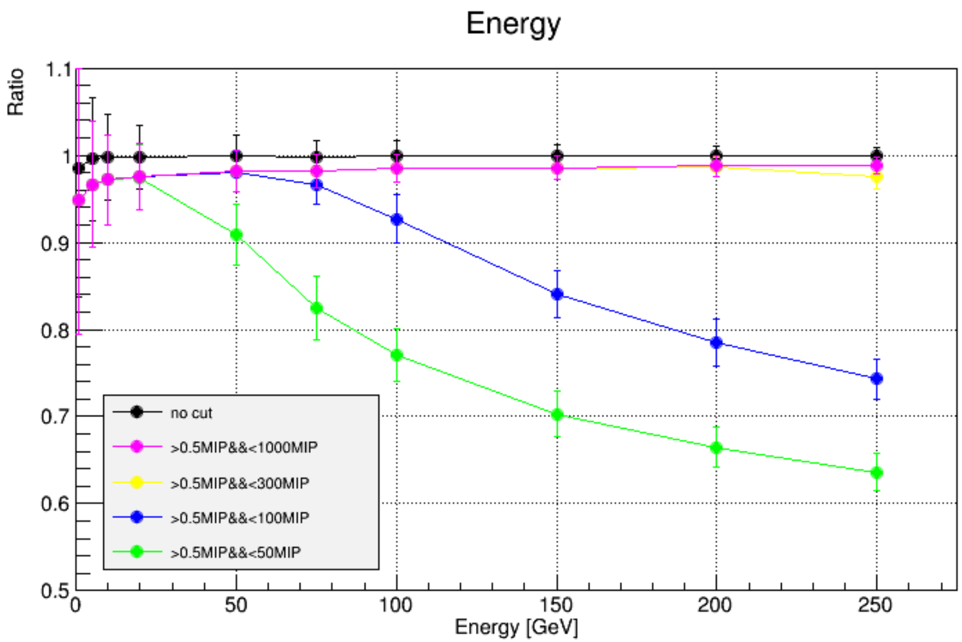
$$L\ 1\text{sigma value} = 0.87x - 0.24yy + 0.97y - 0.43z + 0.82$$

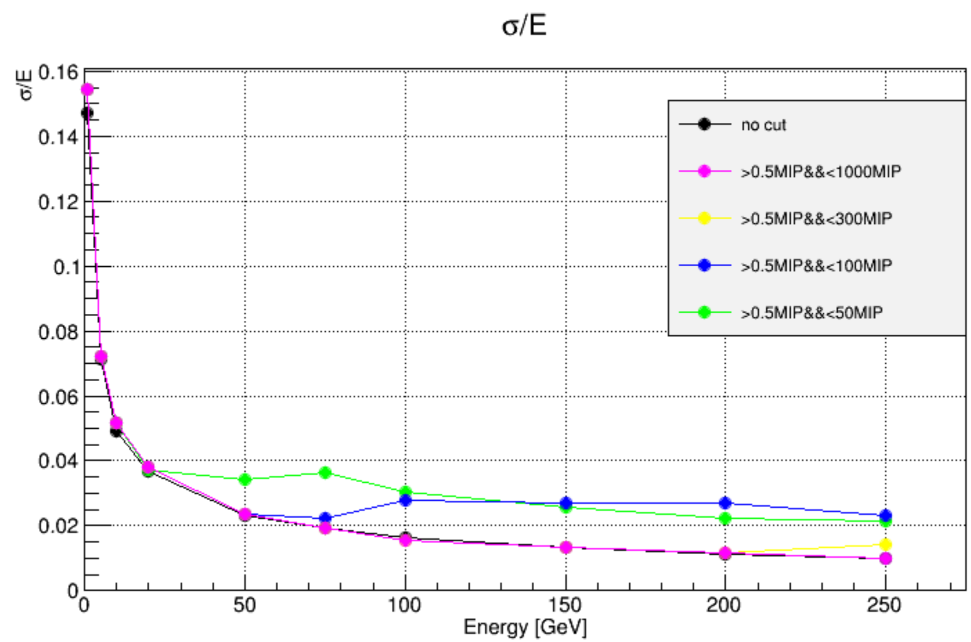
$$x = \log 10(\text{energy})\ y = \log 10(\text{cell size})\ z = \log 10(\text{angle})$$

Saturation = 2 * L_1sigma

eg, 175 GeV photon at 20mm ECAL cell size: 2500 MIP

On Scintillator...





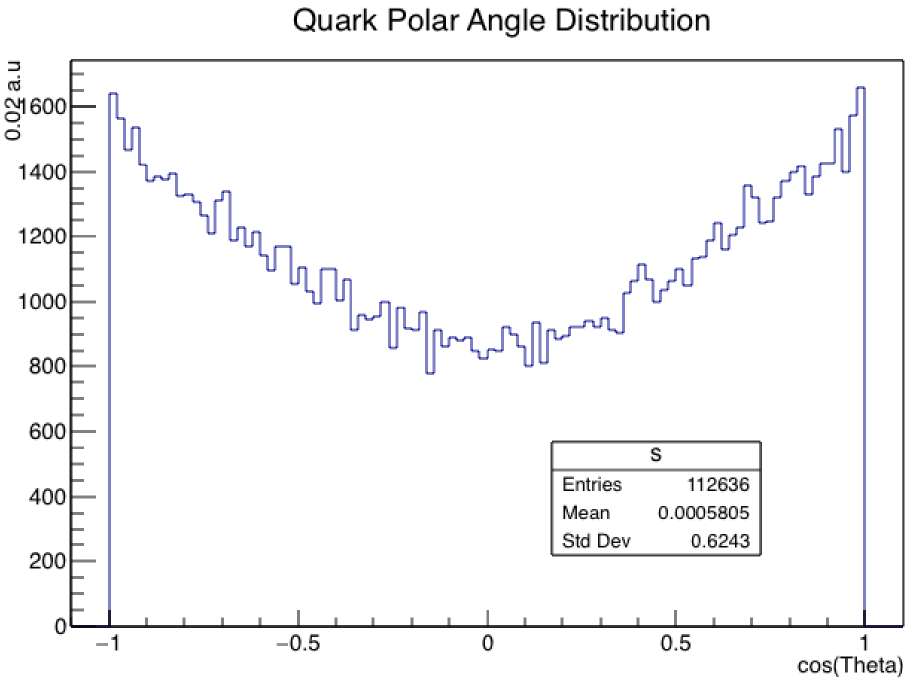
photon, Cell Size 5x5mm
(W:3,Air:0.5,Scintillator:2,Air:0.5,PCB:2,Air:0.5)*50

Rate & Occupancy

Physics event rate at Z pole ~ 2 orders of magnitude higher than Higgs runs (assume same luminosity)

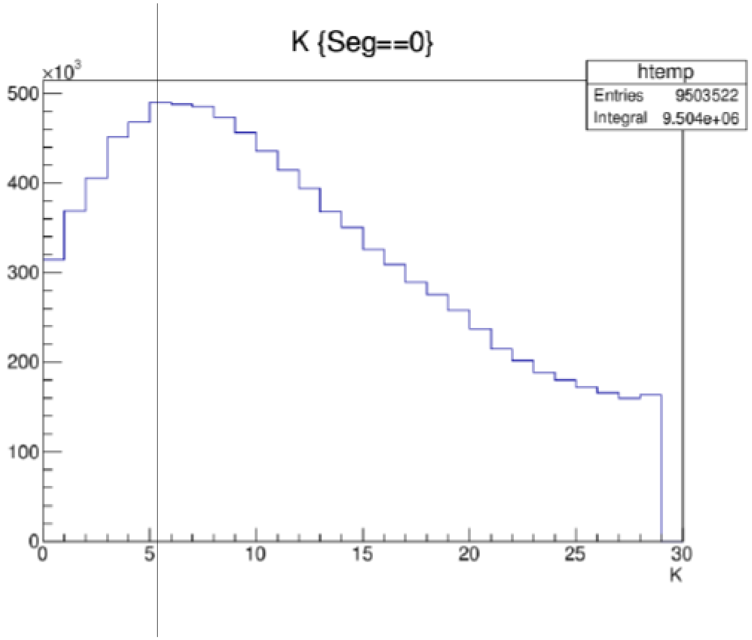
- Should be studied on Z->qq, Bhabha & Irradiation samples
- Z pole Luminosity ~ Higgs Run:
  - 250 fb^{-1}/year*IP (2E34)
  - 1.25E7 sec/year
  - 1E10/IP Z event year;
  - z->qq: ~500 Hz/IP

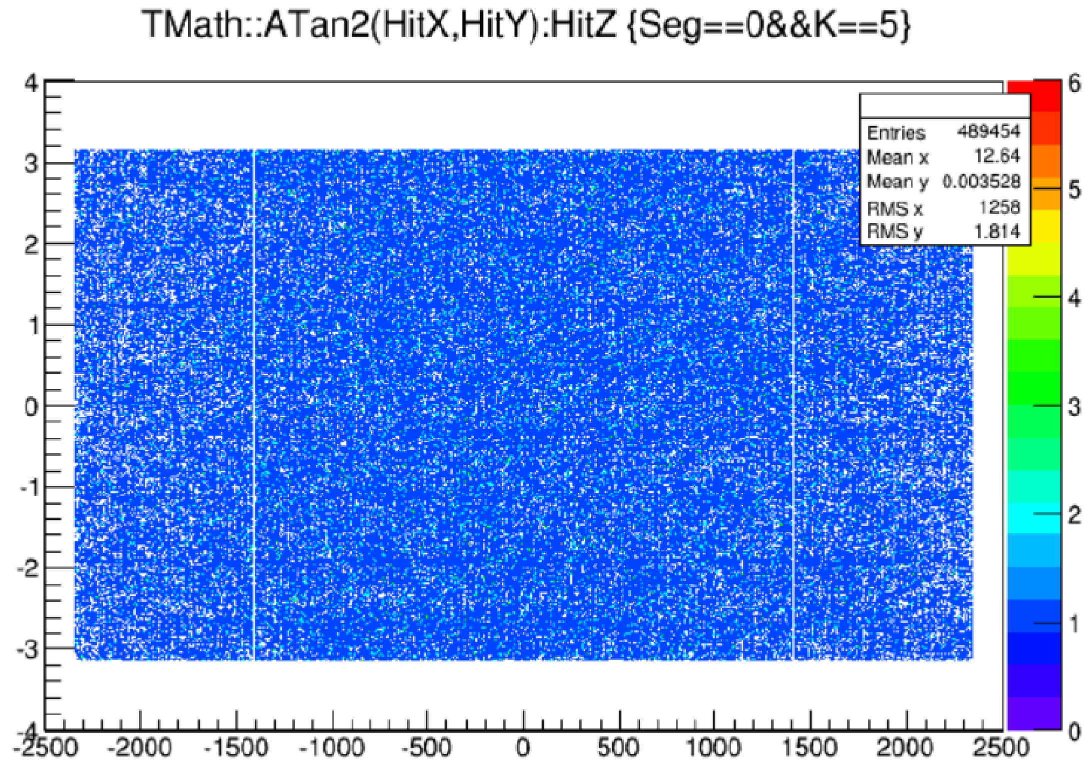
- Test on 5k Z->qq events



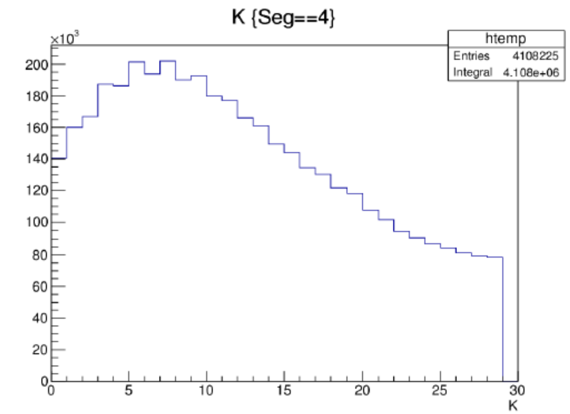
Zqq

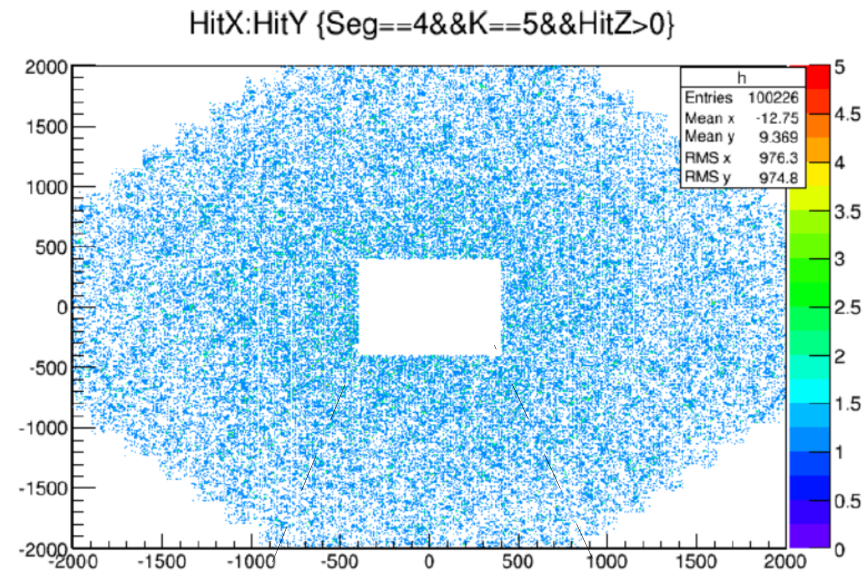
5K Events



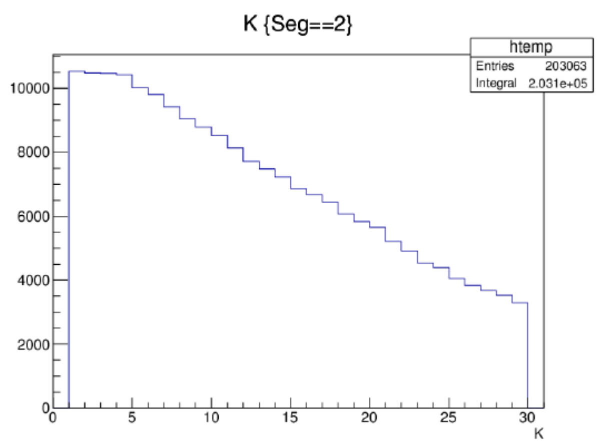


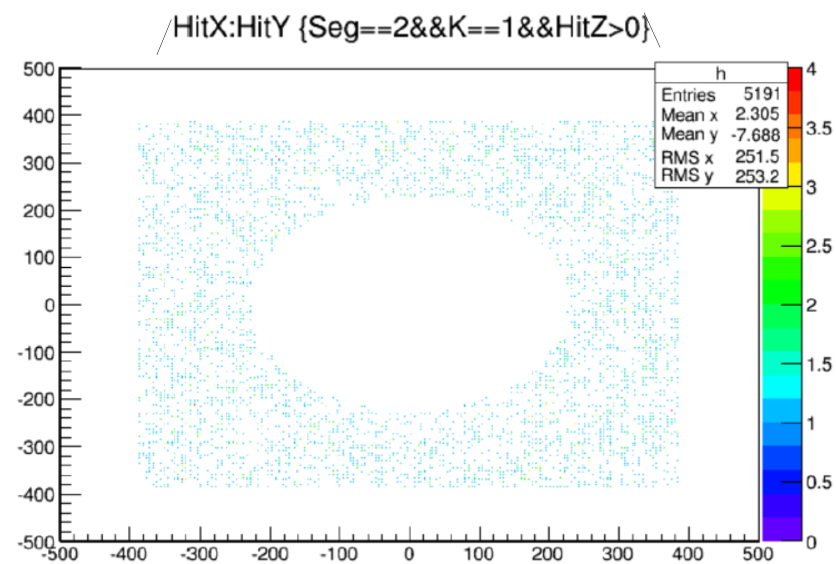
EcalBarrel





EcalEndcap

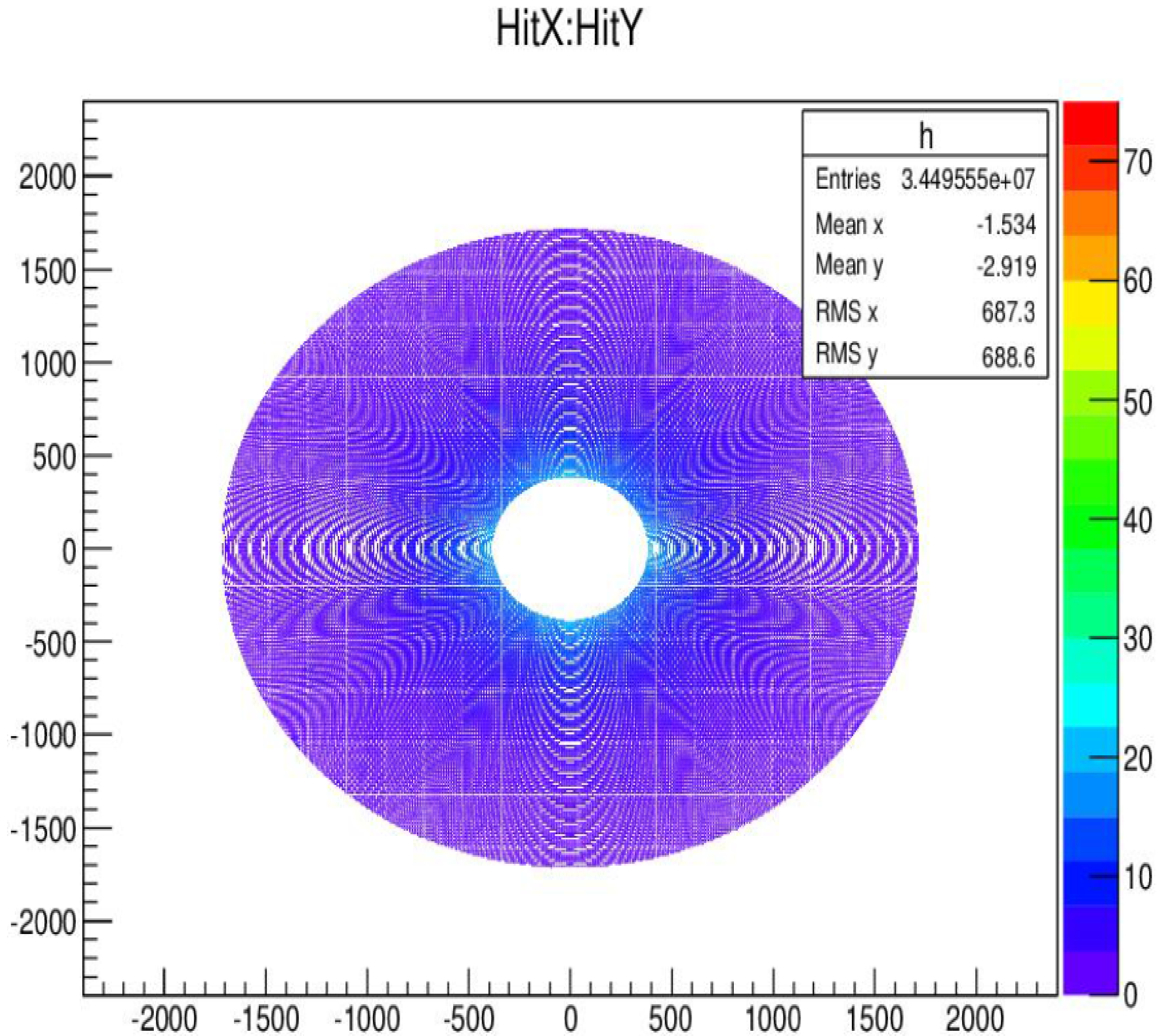




EcalEndcapRing

	Longitudinal Max	Max Rate (Hz) @ Longitudinal Max	Average occupancy @ Longitudinal Max
ECAL Barrel	5	6	0.2
ECAL Endcap	5	5	0.21
ECAL Endcap Ring	1	4	0.3
HCAL Barrel	0	4	0.015
HCAL Endcap	0	4	0.03
HCAL Endcap Ring	0	2	-
LumiCal	0	8	-

Average occupancy = Nhit/Total Cells



TPC

Hit Map at 5k zqq event

Time resolution required for pi-K separation

Fast calculation

- For a straight line:
  - $\Delta t = 0.5*L/c*(\gamma_1^{-2} - \gamma_2^{-2}) = 0.5*L/c*E^{-2}(m_1^2 - m_2^2)$
  - mass(pion) = 139 MeV; mass(Kaon) = 493 MeV;

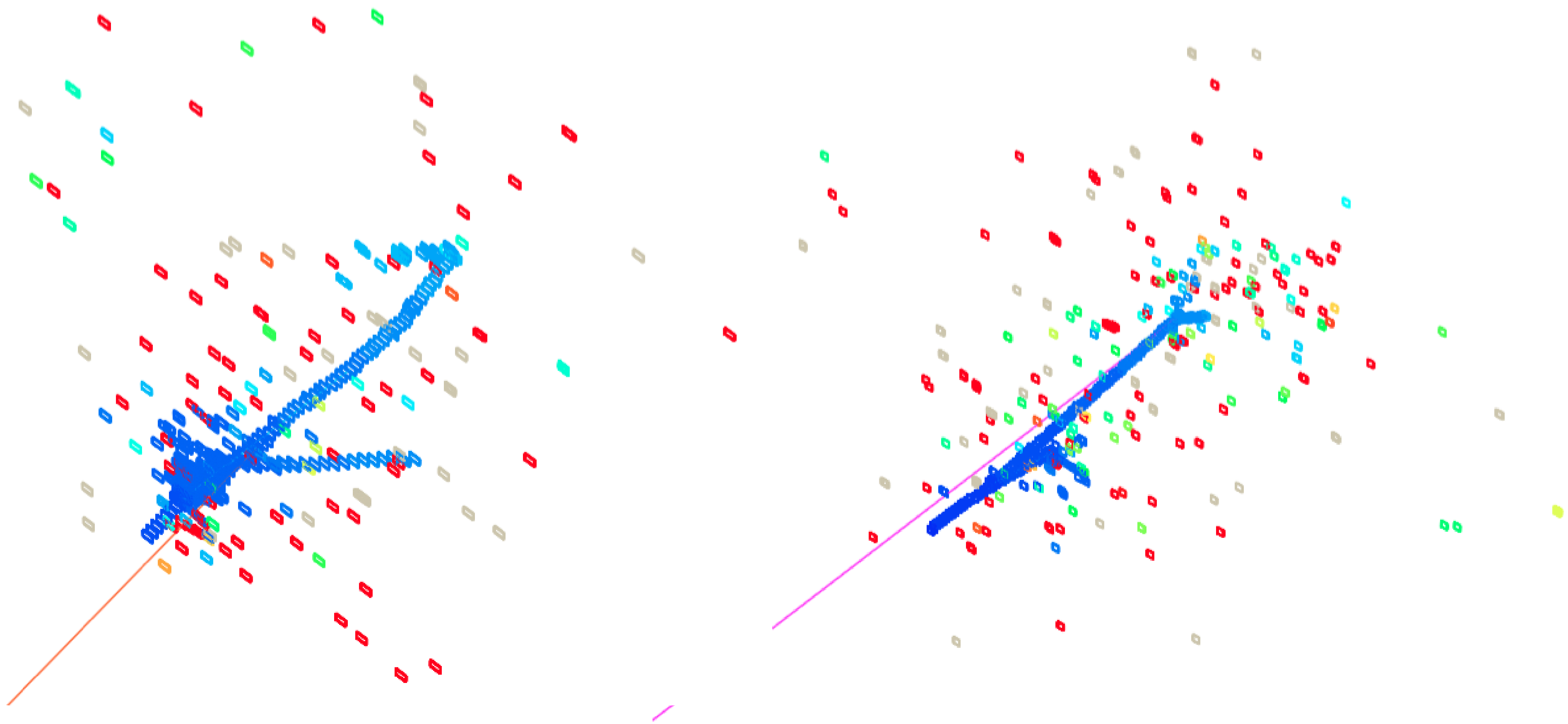
$$\Delta t = k*LE^{-2} = 380*L/m*(E/GeV)^{-2}\ \mathrm{ps}$$

- In CEPC_v1: L varies from 1.8 meter to 3 meter at the Calorimeter entrance.
  - Helix != Straight line
  - Deeper layers has larger L
  - Take 2.6 meters as average: $\Delta t = E^{-2}$ ns
  - To separate 10 GeV pions from kaons at 3-sigma: 3 ps time resolution required.

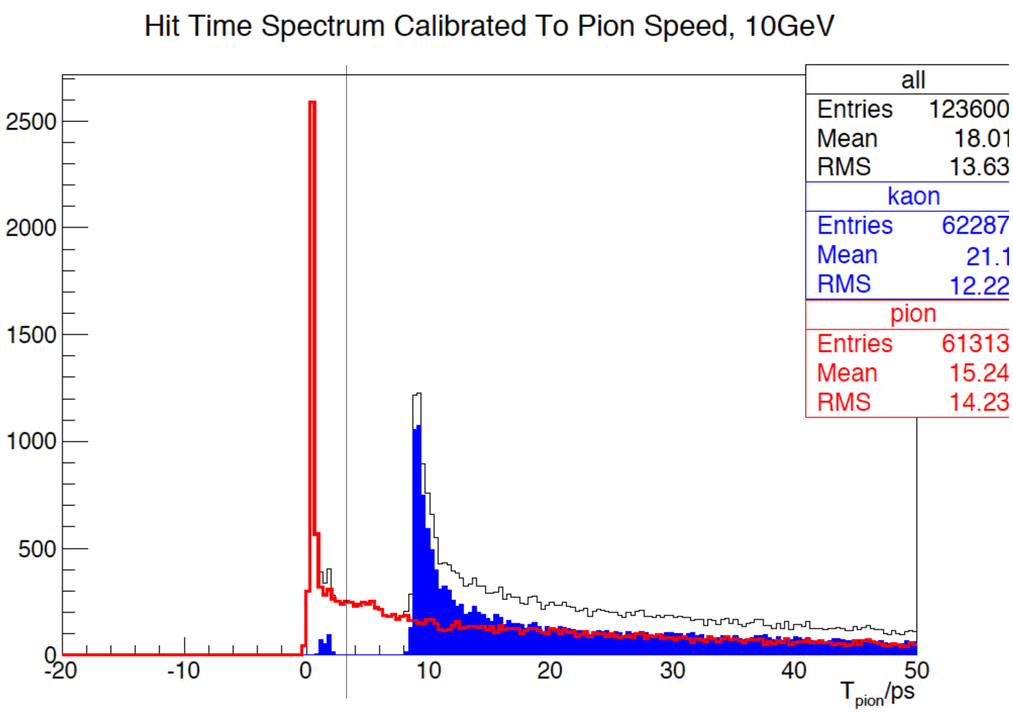
Effective number of Hits

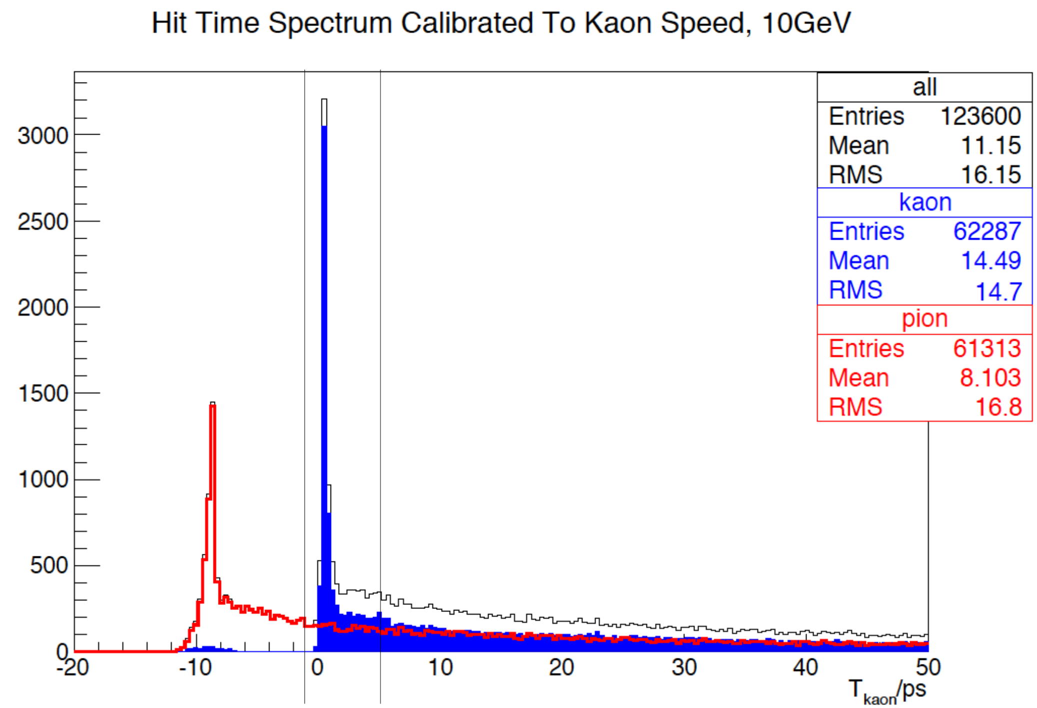
- Suppose each cell is equipped with high precision TDC and synchronized to ps level accuracy.
- Each hadronic shower is composed of fast and slow component; only the fast component could be used for ToF measurement.
  - Fast component ~ component with Time
- Need to know the average Fast Cell Per Shower at a given energy.
  - Required resolution = 3ps*sqrt(N_{fast})
- N_{fast} = N_{fast} * Hit collection Efficiency ~ 25 for 10 GeV.
  - Required resolution = 15 ps per channel

Pion(Left) – Kaon(Right) @ 10 GeV



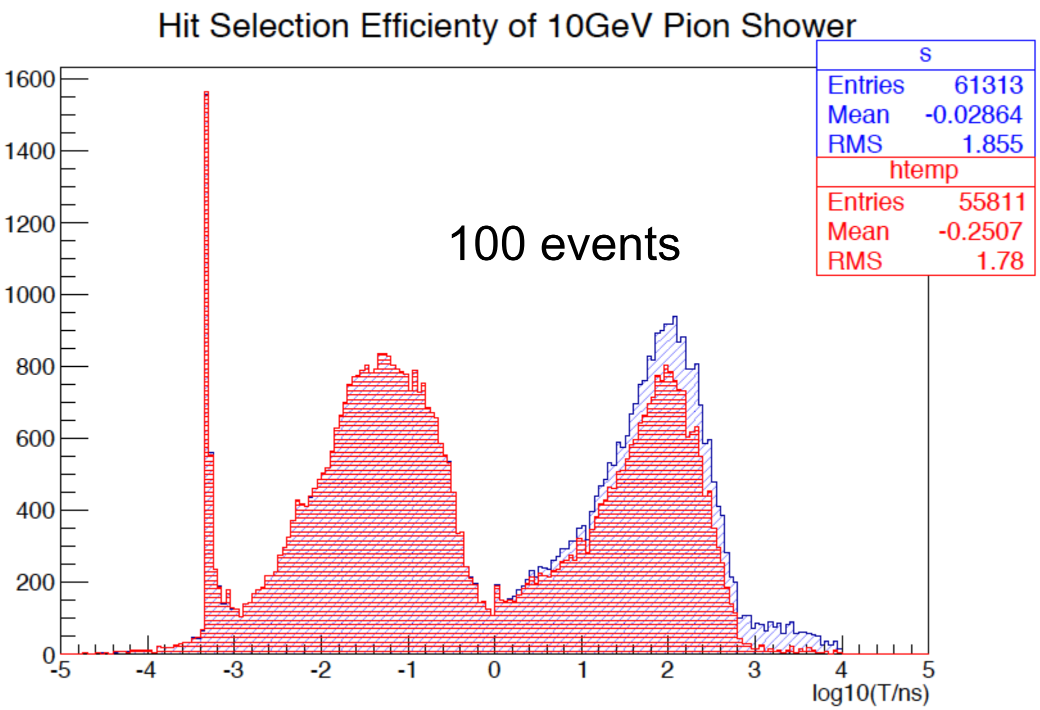
100 events

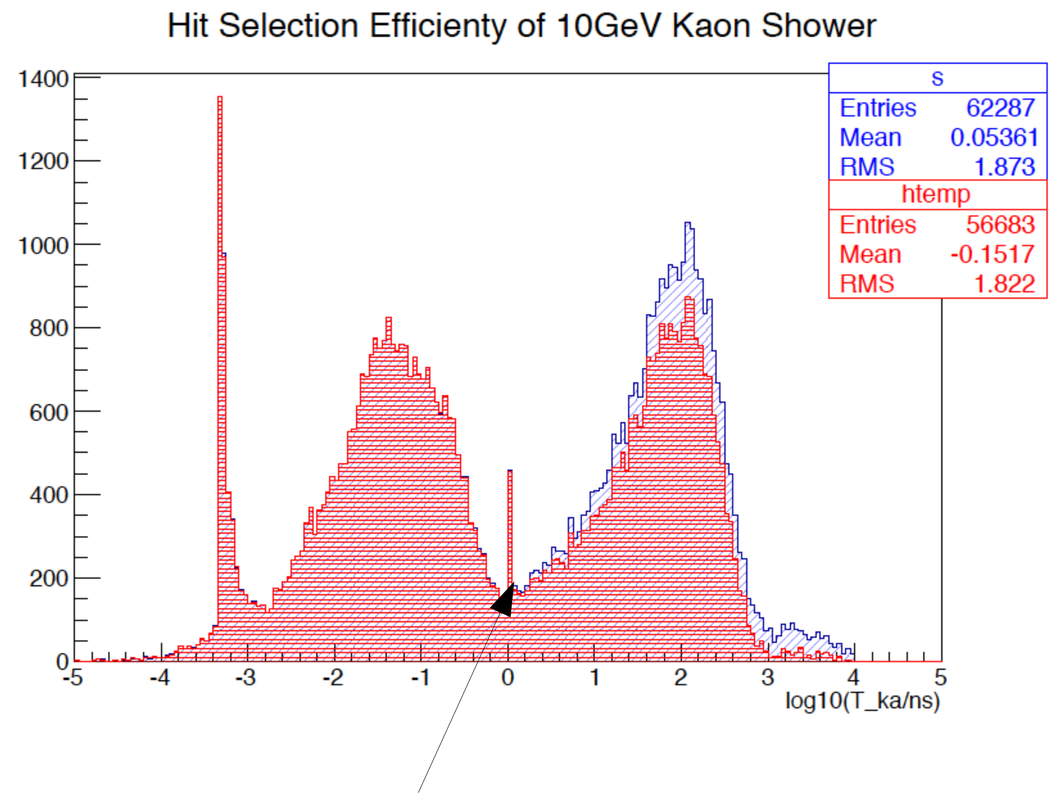




	T < 5 ps	T < 5ps && Nlayer < 30	T < 2ps	T < 20s && Nlayer < 30
Pion	64.6	38.3	43.6	27.3
Kaon	68.3	34.8	50.2	26.3

Arbor Clustering: Hit Collection Efficiency





Arbor Core Parameter dependent.

Kaon decay...

Efficiency ~ 100% for Fast component.
Thus, ~ 25 fast hits for each shower. Located at the beginning of the shower
Estimation Only. Algorithm need to be developed & polished.
Better align algorithm might increase the Number by ~ 2...

Effective number of Hits

- Suppose each cell is equipped with high precision TDC and synchronized to ps level accuracy.
- Each hadronic shower is composed of fast and slow component; only the fast component could be used for ToF measurement.
  - Fast component ~ component with Time
- Need to know the average Fast Cell Per Shower at a given energy.
  - Required resolution = 3ps*sqrt(N_{fast})
- N_{fast} = N_{fast} * Hit collection Efficiency ~ 25 for 10 GeV.
  - Required resolution = 15 ps per channel

Detector requirement

- Saturation:
  - ECAL: ~ 1000 – 2500 MIP
  - HCAL: ~ 100 MIP @ Scintillator HCAL
- Max Rate:
  - Z->qq event at Z pole: 5k event sample
    - Max Hit Rate - o(10)Hz
    - Occupancy -o(0.1)
  - *Bhabha?*
  - *Beam Irradiations? ...*
- Time resolution:
  - ~15 ps for 3-sigma pi-K separation (10 GeV)

Processing: Calorimeter Digitization

Calo - Digi

	Saturation	MIP Energy Response	Time response	Efficiency	Multiplicity	Noise Rate	Homogeneity & Dead region
Scintillator ECAL							
Si ECAL							
GRPC HCAL							
THGEM				R	R		

Modeling module validated.

Efforts/Time needed, for the students to get familiar with software tool, valid the parametrization and get the preliminary result