Validation of single-particle test samples with SDHCal and comparison with AHCaL

ILD software & analysis meeting

C. Carrillo for the SDHCAL collaboration

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First look at the datasets for the SDHCAL validation and AHCAL comparison

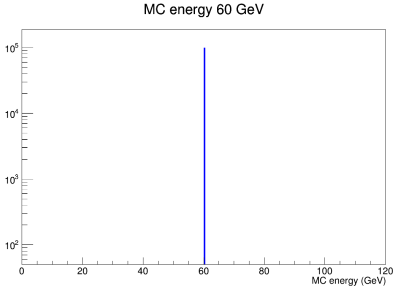
- Details about the ILD confluence production for the test production with the latest ilcsoft v02-01. `https://confluence.desy.de/display/ILD/Production+with+v02-01`
- The data (mostly single particles) are reconstructed with the AHCAL (scintillator) option ILD-l5-o1-v02 and few with SDHCal option ILD-l5-o2-v02.
- For the moment We have access to the high level objects in this dataset.

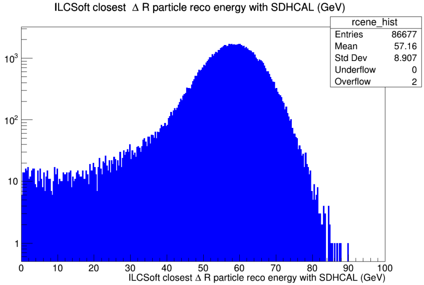
First look at the datasets for the SDHCAL validation and AHCal comparison, K_L^0

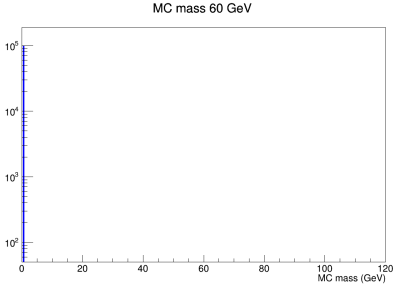
- Energy range: (1,2,5,10,20,30,40,50,60,70,80,90,100,110) GeV. **o1**
- Energy range: (1,2,5,10,20,30,40,50,70) GeV. **o2**
- We made a full copy of both datasets to our local cluster in CIEMAT dedicated to CALICE/ILD analysis by accessing the dataset via DIRAC[1]
- Using the same ilcsoft version (v02-01 → `/cvmfs/ilc.desy.de/sw/x86_64_gcc82_sl6/v02-01/init_ilcsoft.sh`) as for the central production we have produced the corresponding LCTuples.
- The resolution/linearity studies are now done with the total sum of the reconstructed enerygy in the event. Previous studies were done with the closest reco match in ΔR to the generated K_L^0.

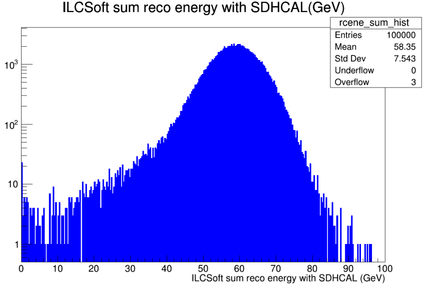
[1] We have solved certificate issues

SDHCAL validation, K_L^0 p=60 GeV


MC energy 60 GeV


ILCSoft closest Δ R particle reco energy with SDHCAL (GeV)


MC mass 60 GeV


ILCSoft sum reco energy with SDHCAL(GeV)

Crystalball fit

$$f(x;\alpha,n,\bar{x},\sigma) = N\cdot\begin{cases}\exp(-\frac{(x-\bar{x})^2}{2\sigma^2}), & \text{for } \frac{x-\bar{x}}{\sigma} > -\alpha\\ A\cdot(B-\frac{x-\bar{x}}{\sigma})^{-n}, & \text{for } \frac{x-\bar{x}}{\sigma} \leqslant -\alpha\end{cases}$$

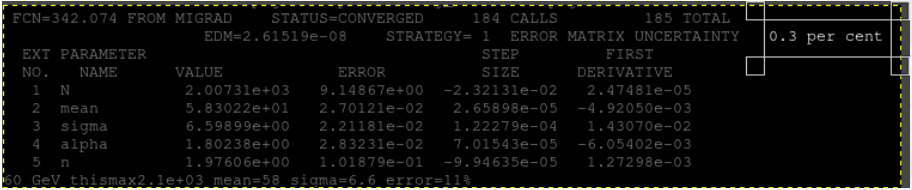
$$A = \left(\frac{n}{|\alpha|}\right)^n\cdot\exp\left(-\frac{|\alpha|^2}{2}\right),$$

$$B = \frac{n}{|\alpha|} - |\alpha|,$$

$$N = \frac{1}{\sigma(C+D)},$$

$$C = \frac{n}{|\alpha|}\cdot\frac{1}{n-1}\cdot\exp\left(-\frac{|\alpha|^2}{2}\right),$$

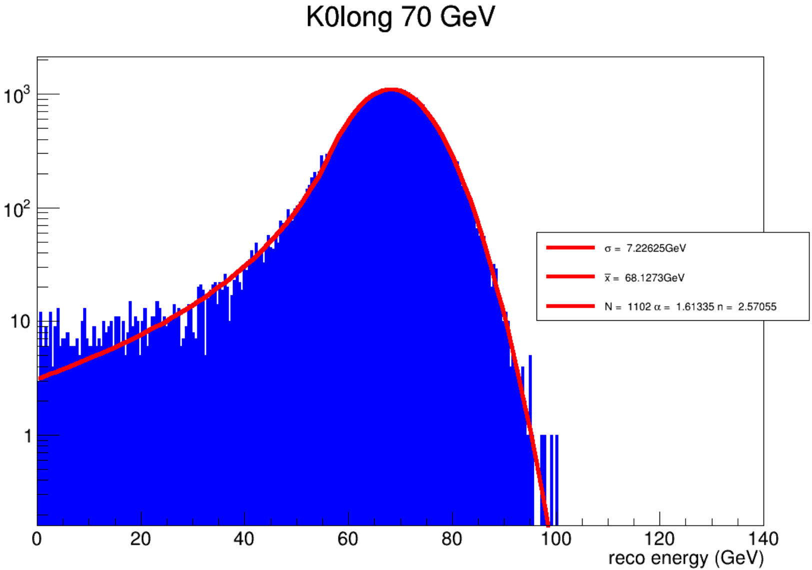
$$D = \sqrt{\frac{\pi}{2}}\left(1+\operatorname{erf}\left(\frac{|\alpha|}{\sqrt{2}}\right)\right).$$



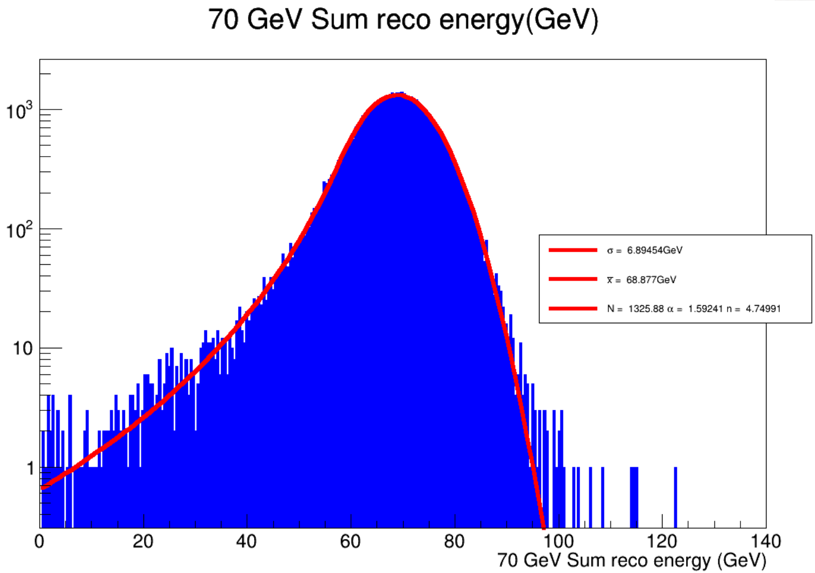
```
 FCN=342.074 FROM MIGRAD    STATUS=CONVERGED     184 CALLS         185 TOTAL
                     EDM=2.61519e-08    STRATEGY= 1  ERROR MATRIX UNCERTAINTY   0.3 per cent
  EXT PARAMETER                                   STEP         FIRST
  NO.   NAME      VALUE            ERROR          SIZE      DERIVATIVE
   1  N            2.00731e+03   9.14867e+00  -2.32131e-02   2.47481e-05
   2  mean         5.83022e+01   2.70121e-02   2.65898e-05  -4.92050e-03
   3  sigma        6.59899e+00   2.21181e-02   1.22279e-04   1.43070e-02
   4  alpha        1.80238e+00   2.83231e-02   7.01543e-05  -6.05402e-03
   5  n            1.97606e+00   1.01879e-01  -9.94635e-05   1.27298e-03
60 GeV thismax2.1e+03 mean=58 sigma=6.6 error=11%
```

https://en.wikipedia.org/wiki/Crystal_Ball_function

Crystalball fit, K_L^0 p=70 GeV, closest ΔR match, o2



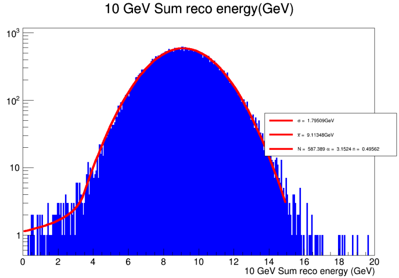
Crystalball fit, K_L^0 p=70 GeV, sum energy, o2

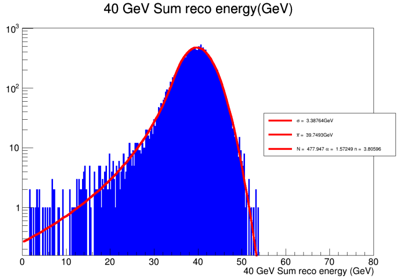


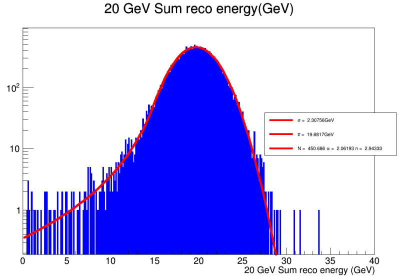
links with all results, please explore yourself:

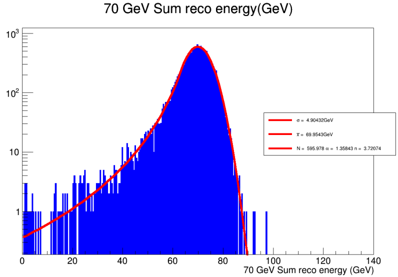
http:
//wwwae.ciemat.es/~carrillo/calice/indexk0o1.html
http:
//wwwae.ciemat.es/~carrillo/calice/indexk0o2.html

Crystalball fit, K_L^0, o1 sum reco energy

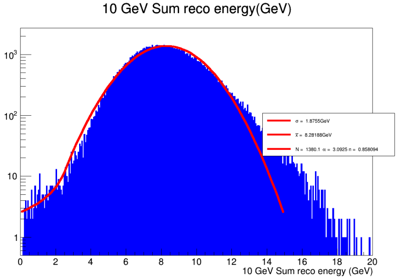


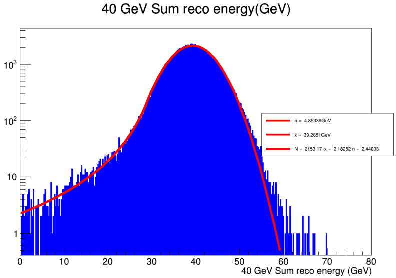


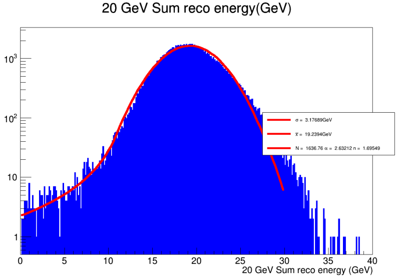


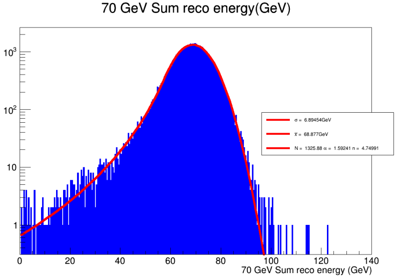


Crystalball fit, K_L^0, o2 sum reco energy

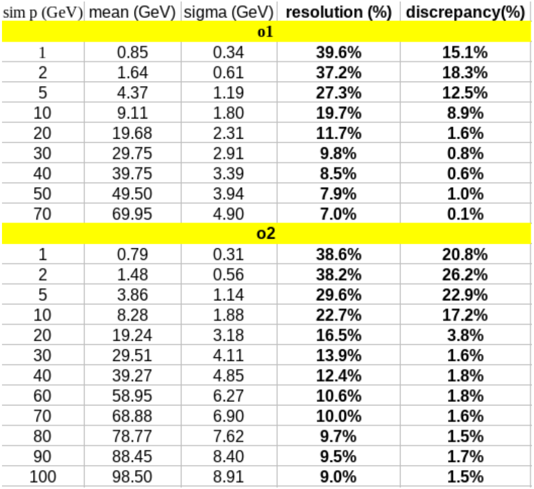

10 GeV Sum reco energy(GeV)


40 GeV Sum reco energy(GeV)


20 GeV Sum reco energy(GeV)


70 GeV Sum reco energy(GeV)

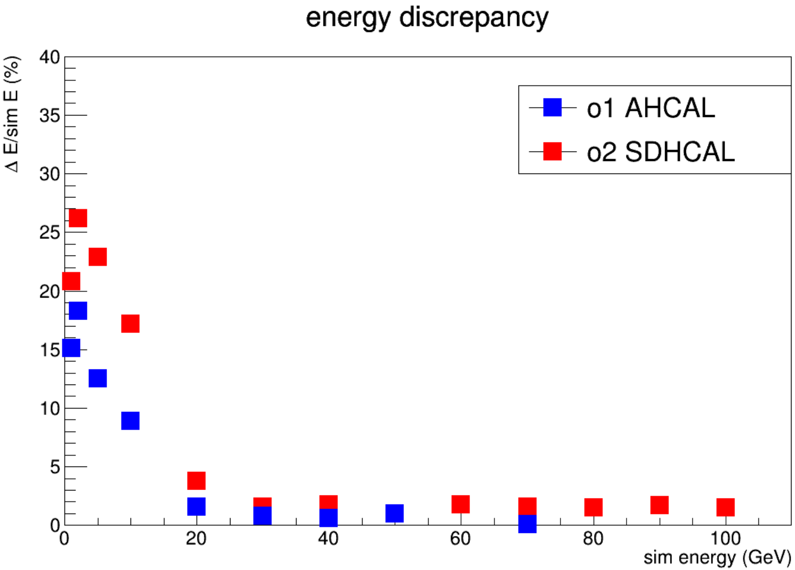
resolution and discrepancy for o1 and o2, fit results



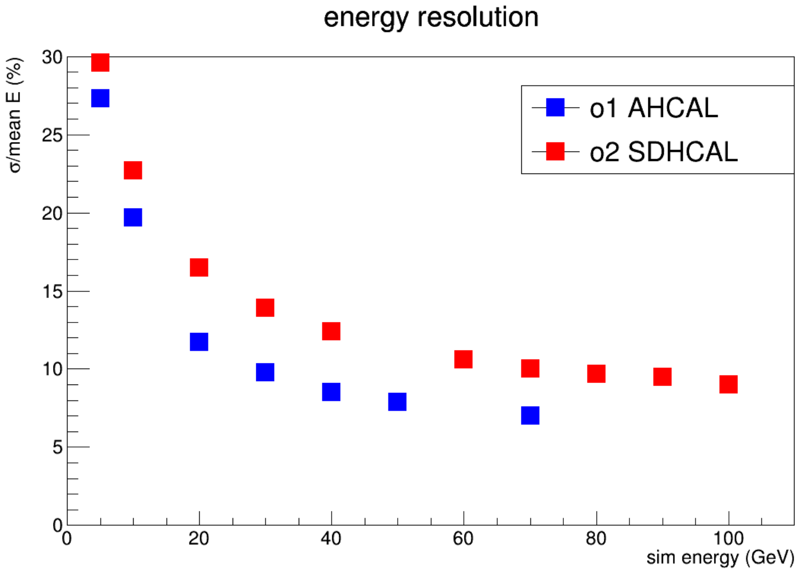
sim p (GeV)	mean (GeV)	sigma (GeV)	**resolution (%)**	**discrepancy(%)**
		o1		
1	0.85	0.34	**39.6%**	**15.1%**
2	1.64	0.61	**37.2%**	**18.3%**
5	4.37	1.19	**27.3%**	**12.5%**
10	9.11	1.80	**19.7%**	**8.9%**
20	19.68	2.31	**11.7%**	**1.6%**
30	29.75	2.91	**9.8%**	**0.8%**
40	39.75	3.39	**8.5%**	**0.6%**
50	49.50	3.94	**7.9%**	**1.0%**
70	69.95	4.90	**7.0%**	**0.1%**
		o2		
1	0.79	0.31	**38.6%**	**20.8%**
2	1.48	0.56	**38.2%**	**26.2%**
5	3.86	1.14	**29.6%**	**22.9%**
10	8.28	1.88	**22.7%**	**17.2%**
20	19.24	3.18	**16.5%**	**3.8%**
30	29.51	4.11	**13.9%**	**1.6%**
40	39.27	4.85	**12.4%**	**1.8%**
60	58.95	6.27	**10.6%**	**1.8%**
70	68.88	6.90	**10.0%**	**1.6%**
80	78.77	7.62	**9.7%**	**1.5%**
90	88.45	8.40	**9.5%**	**1.7%**
100	98.50	8.91	**9.0%**	**1.5%**

$$\text{resolution} = \frac{sigma}{mean}, \text{discrepancy} = \frac{sim\, p - mean}{sim\, p}$$

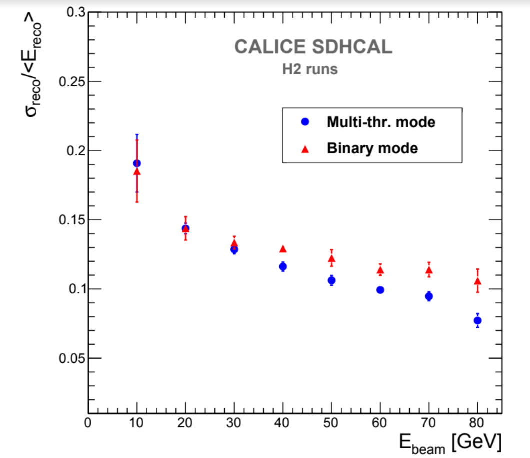
Comparison for the two scenarions, discrepancy.



Comparison for the two scenarions, resolution.



Only SDHCAL resolution observed in test-beams K_L^0



CALICE collaboration, First results of the CALICE SDHCAL technological prototype, JINST **11** (2016) P04001.

Conclusions

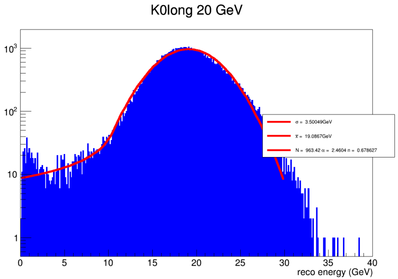
- Observed reconstructed p for the K_L^0 samples in **ilcsoft v02-01** test samples behave as expected with SDHCAL → ILD-l5-**o2**-v02.
- Studies with muon samples still to be done.
- Next steps:
  - extra variables to check the SDHCAL calibration are under scrutiny.
  - study the SDHCAL local reconstructed objects (cluster performance).
- key point about SDHCAL in ilcsoft[2]:
  - Geant4 physics model used in ilcsoft is QGSP-Bert which is not ideal to simulate SDHCAL.
  - FTF-BIC is the more appropriate for SDHCAL.

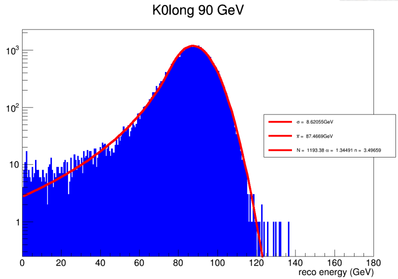
[2] `https://geant4.web.cern.ch/node/155`

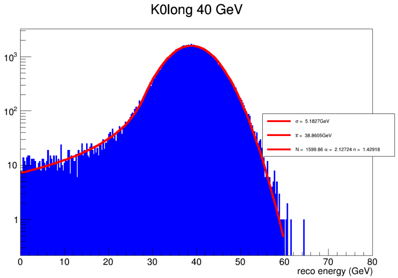
Backup

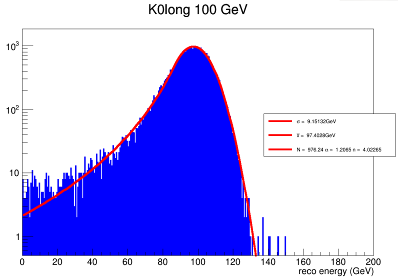
Backup

Crystalball fit, K_L^0, o2


K0long 20 GeV


K0long 90 GeV

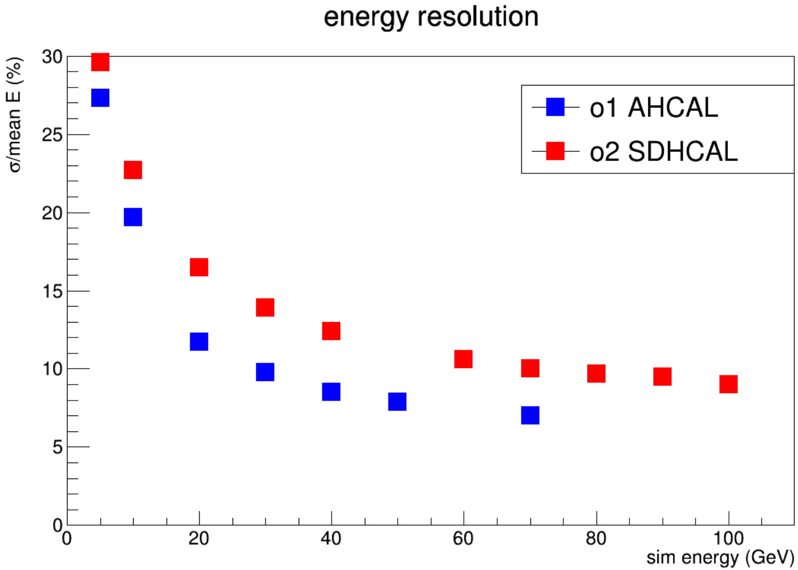

K0long 40 GeV


K0long 100 GeV

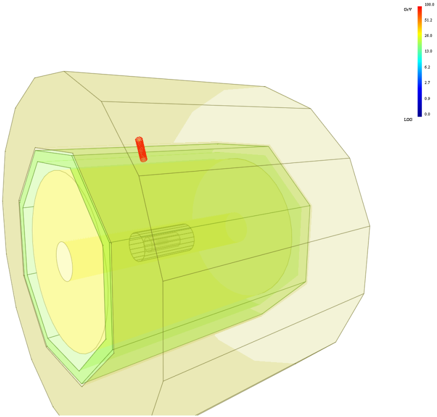
Summary, K_L^0, o2

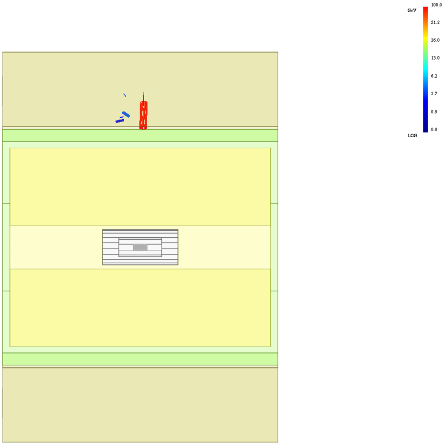
sim energy (GeV)	CB $\bar{x}$ (GeV)	CB σ (GeV)	$\frac{\sigma}{E}$ (%)
1	0.79	0.3	30
2	1.4	0.53	26
5	3.5	1.2	25
10	7.8	2.1	21
20	19	3.5	18
30	29	4.4	15
40	39	5.2	13
60	58	6.6	11
70	68	7.2	10
80	78	7.9	9.8
90	87	8.6	9.6
100	97	9.2	9.2

Summary Resolution, K_L^0

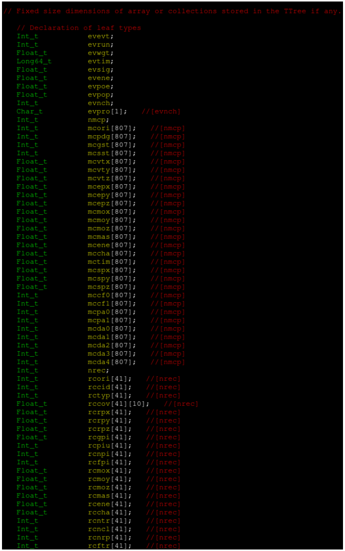


First look at the datasets for the SDHCAL validation, event display K_L^0 110 GeV, energy deposit in SDHCAL





List of variables available in the standard LCTuple



```
// Fixed size dimensions of array or collections stored in the TTree if any.

   // Declaration of leaf types
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   Int_t           evrun;
   Float_t         evwgt;
   Long64_t        evtim;
   Float_t         evsig;
   Float_t         evene;
   Float_t         evpoe;
   Float_t         evpop;
   Int_t           evnch;
   Char_t          evpro[1];   //[evnch]
   Int_t           nmcp;
   Int_t           mcori[807];   //[nmcp]
   Int_t           mcpdg[807];   //[nmcp]
   Int_t           mcgst[807];   //[nmcp]
   Int_t           mcsst[807];   //[nmcp]
   Float_t         mcvtx[807];   //[nmcp]
   Float_t         mcvty[807];   //[nmcp]
   Float_t         mcvtz[807];   //[nmcp]
   Float_t         mcepx[807];   //[nmcp]
   Float_t         mcepy[807];   //[nmcp]
   Float_t         mcepz[807];   //[nmcp]
   Float_t         mcmox[807];   //[nmcp]
   Float_t         mcmoy[807];   //[nmcp]
   Float_t         mcmoz[807];   //[nmcp]
   Float_t         mcmas[807];   //[nmcp]
   Float_t         mcene[807];   //[nmcp]
   Float_t         mccha[807];   //[nmcp]
   Float_t         mctim[807];   //[nmcp]
   Float_t         mcspx[807];   //[nmcp]
   Float_t         mcspy[807];   //[nmcp]
   Float_t         mcspz[807];   //[nmcp]
   Int_t           mccf0[807];   //[nmcp]
   Int_t           mccf1[807];   //[nmcp]
   Int_t           mcpa0[807];   //[nmcp]
   Int_t           mcpa1[807];   //[nmcp]
   Int_t           mcda0[807];   //[nmcp]
   Int_t           mcda1[807];   //[nmcp]
   Int_t           mcda2[807];   //[nmcp]
   Int_t           mcda3[807];   //[nmcp]
   Int_t           mcda4[807];   //[nmcp]
   Int_t           nrec;
   Int_t           rcori[41];   //[nrec]
   Int_t           rccid[41];   //[nrec]
   Int_t           rctyp[41];   //[nrec]
   Float_t         rccov[41][10];   //[nrec]
   Float_t         rcrpx[41];   //[nrec]
   Float_t         rcrpy[41];   //[nrec]
   Float_t         rcrpz[41];   //[nrec]
   Float_t         rcgpi[41];   //[nrec]
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   Int_t           rcnpi[41];   //[nrec]
   Int_t           rcfpi[41];   //[nrec]
   Float_t         rcmox[41];   //[nrec]
   Float_t         rcmoy[41];   //[nrec]
   Float_t         rcmoz[41];   //[nrec]
   Float_t         rcmas[41];   //[nrec]
   Float_t         rcene[41];   //[nrec]
   Float_t         rccha[41];   //[nrec]
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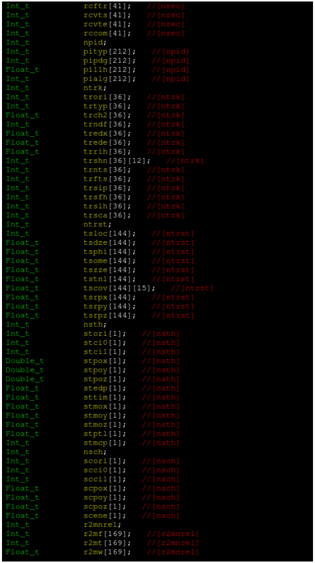

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 Int_t           pipdg[212];   //[npid]
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 Int_t           pialg[212];   //[npid]
 Int_t           ntrk;
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 Int_t           trtyp[36];   //[ntrk]
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 Int_t           trndf[36];   //[ntrk]
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 Float_t         trede[36];   //[ntrk]
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 Int_t           trslh[36];   //[ntrk]
 Int_t           trsca[36];   //[ntrk]
 Int_t           ntrst;
 Int_t           tsloc[144];   //[ntrst]
 Float_t         tsdze[144];   //[ntrst]
 Float_t         tsphi[144];   //[ntrst]
 Float_t         tsome[144];   //[ntrst]
 Float_t         tszze[144];   //[ntrst]
 Float_t         tstnl[144];   //[ntrst]
 Float_t         tscov[144][15];   //[ntrst]
 Float_t         tsrpx[144];   //[ntrst]
 Float_t         tsrpy[144];   //[ntrst]
 Float_t         tsrpz[144];   //[ntrst]
 Int_t           nsth;
 Int_t           stori[1];   //[nsth]
 Int_t           stci0[1];   //[nsth]
 Int_t           stci1[1];   //[nsth]
 Double_t        stpox[1];   //[nsth]
 Double_t        stpoy[1];   //[nsth]
 Double_t        stpoz[1];   //[nsth]
 Float_t         stedp[1];   //[nsth]
 Float_t         sttim[1];   //[nsth]
 Float_t         stmox[1];   //[nsth]
 Float_t         stmoy[1];   //[nsth]
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 Float_t         stptl[1];   //[nsth]
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 Int_t           scori[1];   //[nsch]
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 Int_t           scci1[1];   //[nsch]
 Float_t         scpox[1];   //[nsch]
 Float_t         scpoy[1];   //[nsch]
 Float_t         scpoz[1];   //[nsch]
 Float_t         scene[1];   //[nsch]
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 Int_t           r2mf[169];   //[r2mnrel]
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```
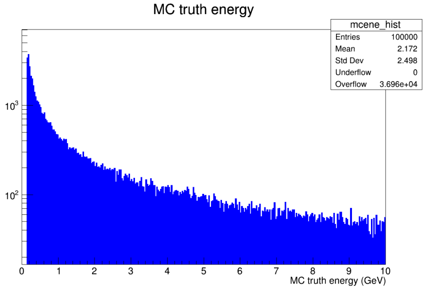
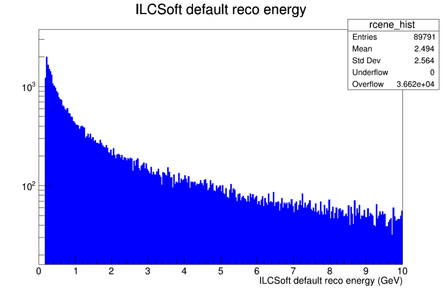
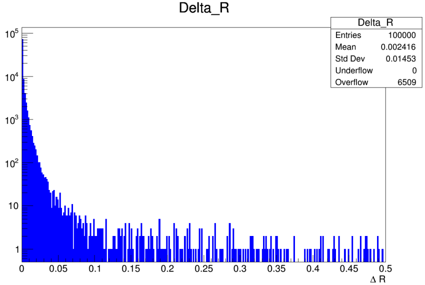

SDHCAL validation, μ sample


MC truth energy

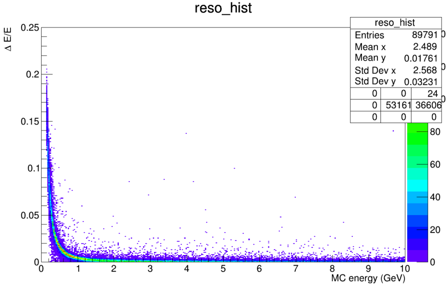
mcene_hist	
Entries	100000
Mean	2.172
Std Dev	2.498
Underflow	0
Overflow	3.696e+04


ILCSoft default reco energy

rcene_hist	
Entries	89791
Mean	2.494
Std Dev	2.564
Underflow	0
Overflow	3.662e+04

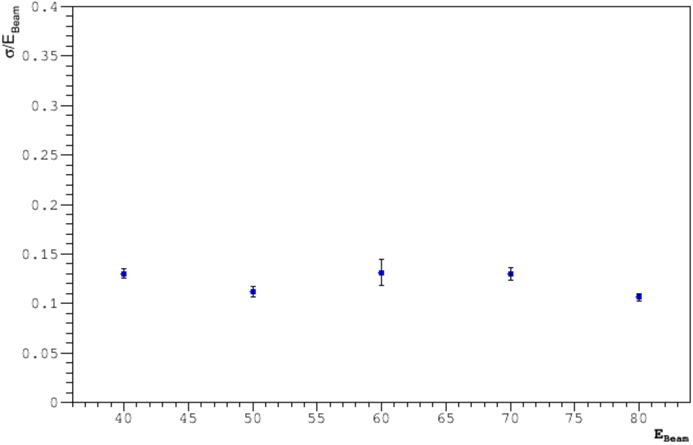

Delta_R

Delta_R	
Entries	100000
Mean	0.002416
Std Dev	0.01453
Underflow	0
Overflow	6509


reso_hist

reso_hist		
Entries		89791
Mean x		2.489
Mean y		0.01761
Std Dev x		2.568
Std Dev y		0.03231
0	0	24
0	53161	36606
0	0	0

SDHCAL validation, TB2018



The tools we have learned.

In the framework of the SDHCAL test-beams data analysis we have learned:

- How to work in the ILCSoft analysis framework. (Installed in CIEMAT running in dedicated nodes)
- Run from scratch a simulation using the standard sequences in the framework and switching from one scneario to another (large → small), (AHCAL → SDHCAL), etc.
- Navigate and run over the centrally produced datasets (DIRAC)
- Produce ntuples out of the samples for detector/physics analysis. (AIDA,REC,SIM)
- Use reconstructed physics objects and produce event cut flows for analysis.
- Event display, etc.

The tools we have learned

Private CIEMAT-SDHCAL pion gun simulation for comparison with TB-2018.