

# Validation of single-particle test samples with SDHCAL and comparison with AHCaL

ILD software & analysis meeting

SDHCAL group meeting

09/10/20

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**Ciemat**

Centro de Investigaciones  
Energéticas, Medioambientales  
y Tecnológicas



# The second test-dataset for the SDHCAL validation and AHCAL comparison

- This presentation is a follow up of our previous report  
<https://agenda.linearcollider.org/event/8559/>
- Details about the ILD confluence production for the **second** test production with the latest ilcsoft v02-01-02.  
<https://ild.ngt.ndu.ac.jp/eelog/dbd-prod/323>
- We are interested again in  $K_L^0$  particles
- For the first test production we presented results using high level objects (Physics objects). Now we have a working recipe that give us access to the low level objects (SDHCAL hits).

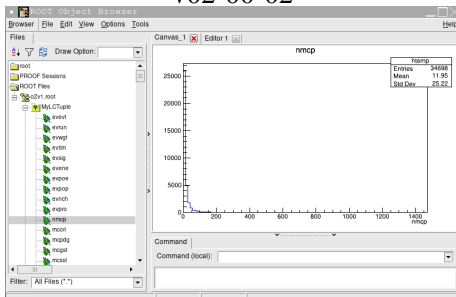
# First look at the second test-dataset for the SDHCAL validation and AHCAL comparison, $K_L^0$

- **o2** Energy range: (1,2,5,10,20,30,40,50,60,70,80,90,100,110) GeV.  
/ilc/prod/ilc/mc-opt/ild/dst-merged/1-calib/single/ILD\_15\_o2\_v02\_nobg/v02-01-02
- **o1** Energy range: (1,2,5,10,20,30,40,50,**60,70,80,90,100,110**) GeV.  
(single particle dataset, in blue new datasets wrt first test sample)  
/ilc/prod/ilc/mc-opt/ild/dst-merged/1-calib/single/ILD\_15\_o1\_v02\_nobg/v02-01-02
- 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.
- Using the same ilcsoft version v02-**01**-02 → /cvmfs/ilc.desy.de/sw/x86\_64\_gcc82\_sl6/v02-01-02/init\_ilcsoft.sh as for the central production we have produced the corresponding LCTuples.
- /pool/calice3/data/MonteCarlo/sdhcal\_validation/second\_test\_production/o1/dstm

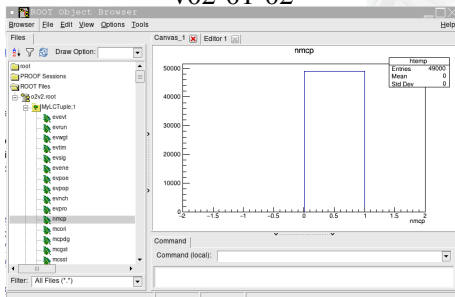
# DST-merged datasets look different

First a remark about the LCTuples:

v02-00-02



v02-01-02



The nmcp variable accounts for the number of MC particles in a given event. In the default LCTuple this variable appears always at zero in this second test-production.

# links with all results, please explore yourself:

- first test production

- `http://wwvae.ciemat.es/~carrillo/calice/indexk0o1.html`
- `http://wwvae.ciemat.es/~carrillo/calice/indexk0o2.html`

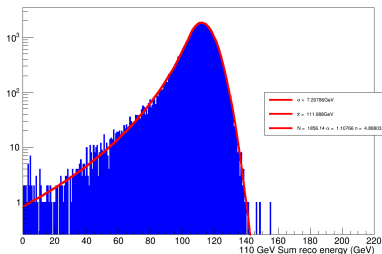
- second test production

- `http://wwvae.ciemat.es/~carrillo/calice/indexk0o1v2.html`
- `http://wwvae.ciemat.es/~carrillo/calice/indexk0o2v2.html`

Comparison o1/o2  $\otimes$  1<sup>st</sup>/2<sup>nd</sup> Test Production,  $K_L^0$  110 GeV2<sup>nd</sup>TP

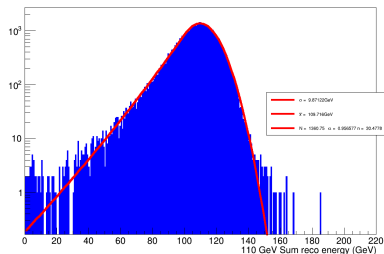
## AHCAL(o1)

110 GeV Sum reco energy(GeV)



## SDHCAL(o2)

110 GeV Sum reco energy(GeV)

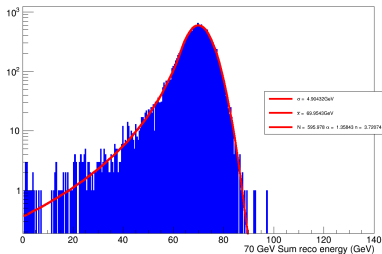


# Comparison o1/o2 $\otimes$ 1<sup>st</sup>/2<sup>nd</sup> Test Production, $K_L^0$ 70 GeV

1<sup>st</sup>TP

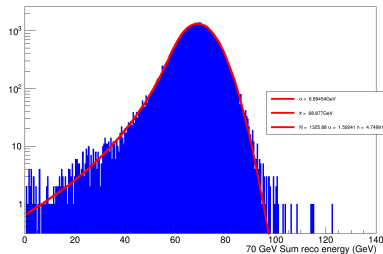
AHCAL(o1)

70 GeV Sum reco energy(GeV)



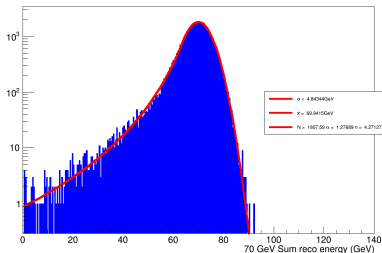
SDHCAL(o2)

70 GeV Sum reco energy(GeV)

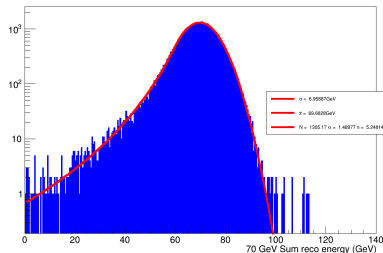


2<sup>nd</sup>TP

70 GeV Sum reco energy(GeV)



70 GeV Sum reco energy(GeV)

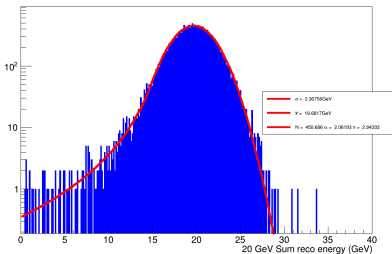


# Comparison $\alpha_1/\alpha_2 \otimes 1^{st}/2^{nd}$ Test Production, $K_L^0$ 20 GeV

1<sup>st</sup>TP

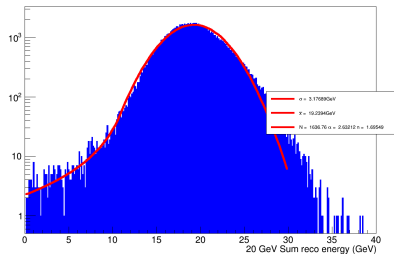
AHCAL( $\alpha_1$ )

20 GeV Sum reco energy(GeV)



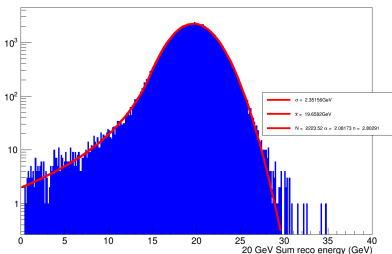
SDHCAL( $\alpha_2$ )

20 GeV Sum reco energy(GeV)

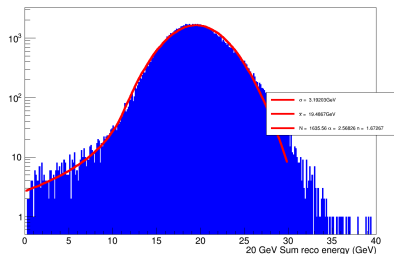


2<sup>nd</sup>TP

20 GeV Sum reco energy(GeV)



20 GeV Sum reco energy(GeV)





# resolution and discrepancy for o1 and o2, fit results

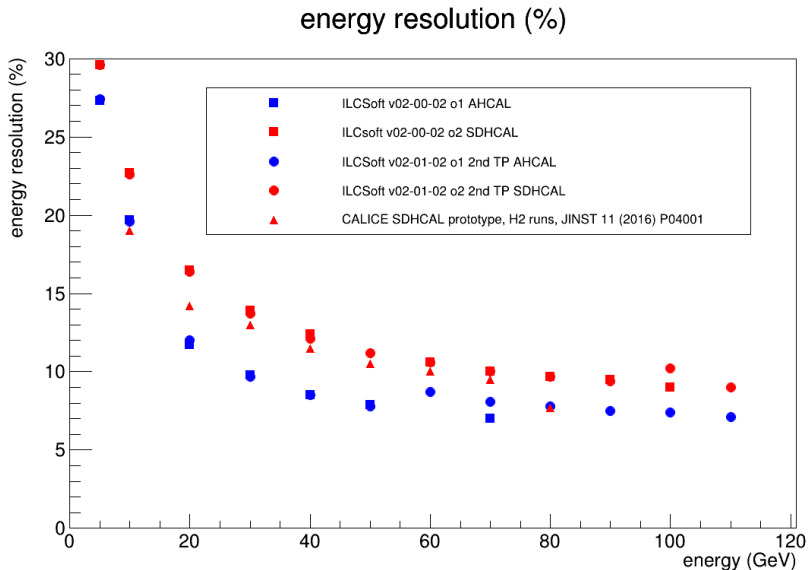
## 1<sup>st</sup>TP

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

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

## 2<sup>nd</sup>TP

sim p (GeV)	mean (GeV)	sigma (GeV)	resolution (%)	discrepancy(%)
<b>o1</b>				
1	0.66	0.23	<b>34.9%</b>	<b>34.0%</b>
2	1.63	0.62	<b>37.9%</b>	<b>18.5%</b>
5	4.37	1.19	<b>27.4%</b>	<b>12.7%</b>
10	9.12	1.79	<b>19.6%</b>	<b>8.9%</b>
20	19.66	2.35	<b>12.0%</b>	<b>1.7%</b>
30	29.73	2.90	<b>9.7%</b>	<b>0.9%</b>
40	39.76	3.37	<b>8.5%</b>	<b>0.6%</b>
50	49.71	3.90	<b>7.8%</b>	<b>0.6%</b>
60	59.82	4.33	<b>8.7%</b>	<b>17.2%</b>
70	69.94	4.84	<b>8.1%</b>	<b>14.5%</b>
80	80.13	5.46	<b>7.8%</b>	<b>12.6%</b>
90	90.63	6.02	<b>7.5%</b>	<b>11.0%</b>
100	101.20	6.71	<b>7.4%</b>	<b>9.4%</b>
110	112.00	7.21	<b>7.1%</b>	<b>8.0%</b>
<b>o2</b>				
1	0.81	0.31	<b>38.4%</b>	<b>19.1%</b>
2	1.51	0.56	<b>37.2%</b>	<b>24.5%</b>
5	3.92	1.16	<b>29.6%</b>	<b>21.7%</b>
10	8.40	1.90	<b>22.6%</b>	<b>16.0%</b>
20	19.49	3.19	<b>16.4%</b>	<b>2.6%</b>
30	29.86	4.09	<b>13.7%</b>	<b>0.5%</b>
40	39.74	4.80	<b>12.1%</b>	<b>0.6%</b>
50	49.64	5.56	<b>11.2%</b>	<b>0.7%</b>
60	59.63	6.31	<b>10.6%</b>	<b>0.6%</b>
70	69.68	6.96	<b>10.0%</b>	<b>0.5%</b>
80	79.63	7.70	<b>9.7%</b>	<b>0.5%</b>
90	89.66	8.40	<b>9.4%</b>	<b>0.4%</b>
100	98.50	10.09	<b>10.2%</b>	<b>1.5%</b>
110	109.70	9.87	<b>9.0%</b>	<b>0.3%</b>

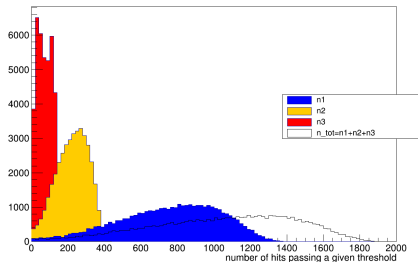
Resolution for the four scenarios: o1/o2  $\otimes$  1<sup>st</sup>/2<sup>nd</sup> TP

## SDHCAL Hit Level Analysis

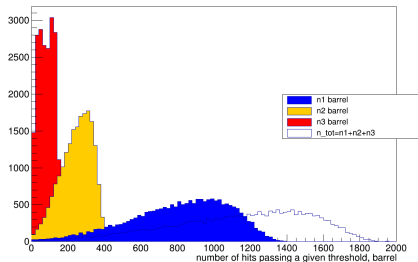
- For the single-hit level analysis, the dst datasets are not enough. The hit information is skimmed.
- An analysis of the rec dataset was needed.
- A copy of the rec dataset to CIEMAT was done.
- `/pool/calice3/data/MonteCarlo/sdhcal_validation/second_test_production/rec/o2v2`
- A customized LCTuple was produced out of rec dataset including the single hit information.
- As a reminder each hit in the SDHCAL tell us if the read energy on a given pad has passed one, two or three pre-set threshold.

## SDHCAL Hit Level Analysis 110 GeV

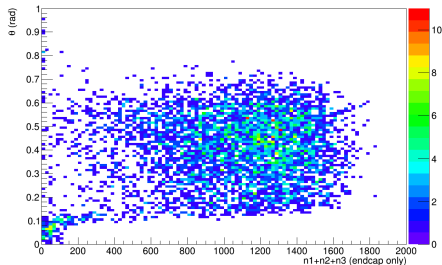
SDHCAL hits per threshold distribution



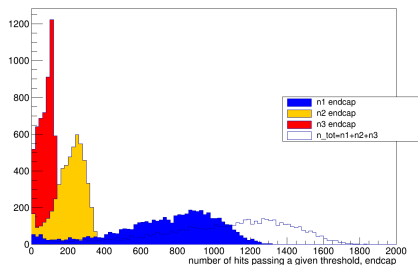
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

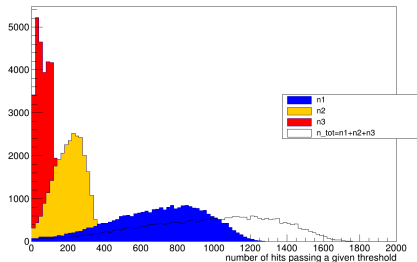


SDHCAL hits per threshold distribution, endcap

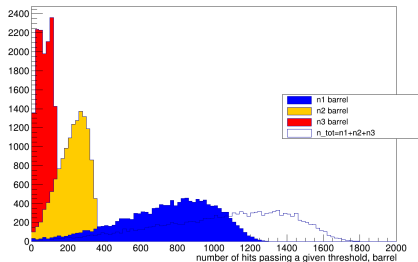
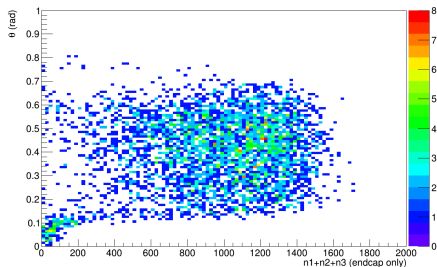


## SDHCAL Hit Level Analysis 100 GeV

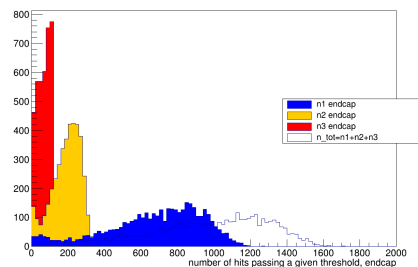
SDHCAL hits per threshold distribution



SDHCAL hits per threshold distribution, barrel

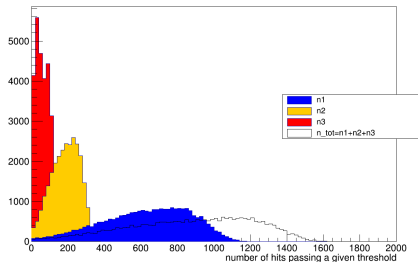
 $n_{hits}$  vs theta (endcap only)

SDHCAL hits per threshold distribution, endcap

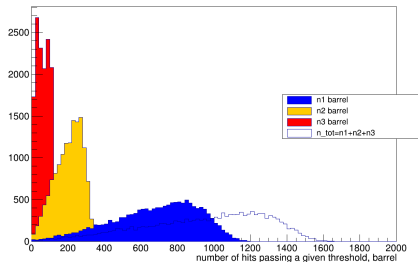


## SDHCAL Hit Level Analysis 090 GeV

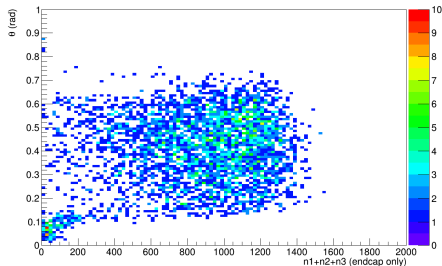
SDHCAL hits per threshold distribution



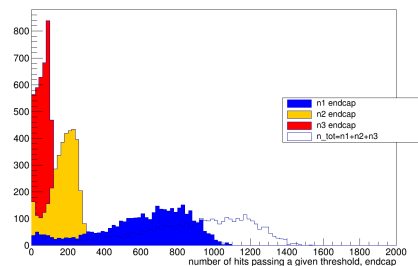
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

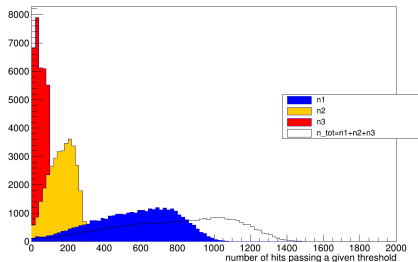


SDHCAL hits per threshold distribution, endcap

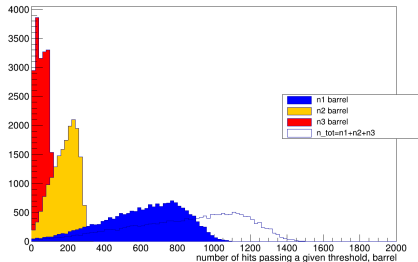


## SDHCAL Hit Level Analysis 080 GeV

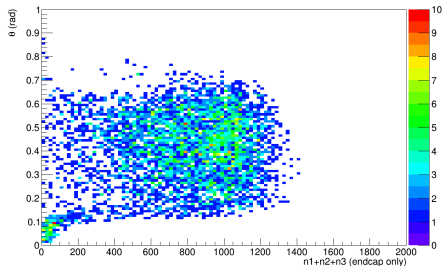
SDHCAL hits per threshold distribution



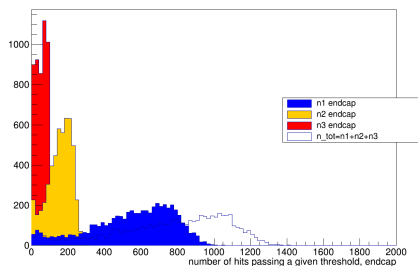
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

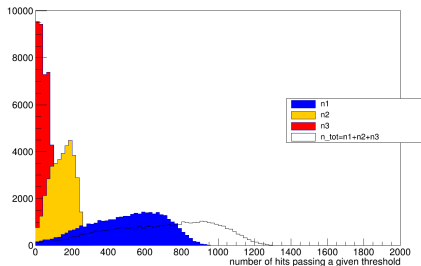


SDHCAL hits per threshold distribution, endcap

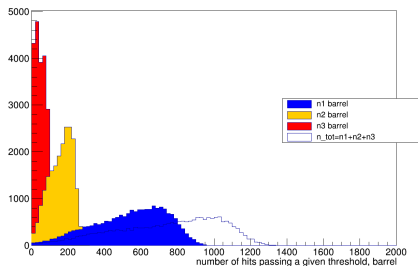


## SDHCAL Hit Level Analysis 070 GeV

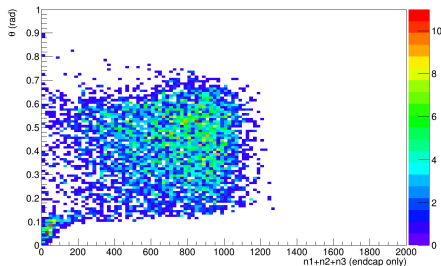
SDHCAL hits per threshold distribution



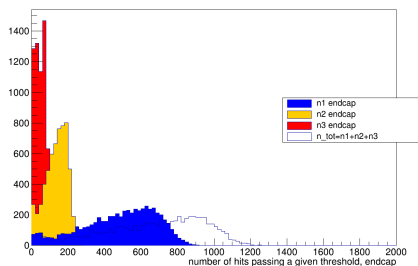
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)



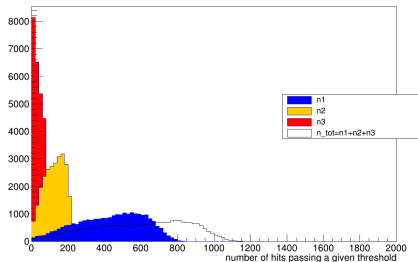
SDHCAL hits per threshold distribution, endcap



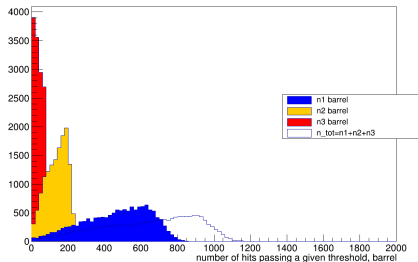


## SDHCAL Hit Level Analysis 060 GeV

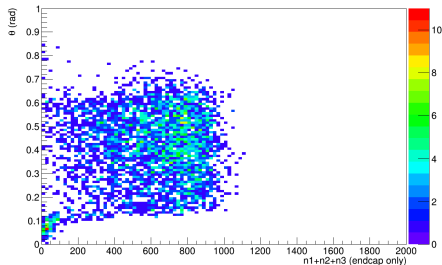
SDHCAL hits per threshold distribution



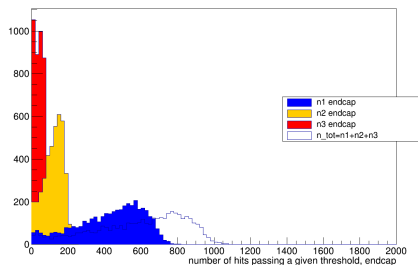
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

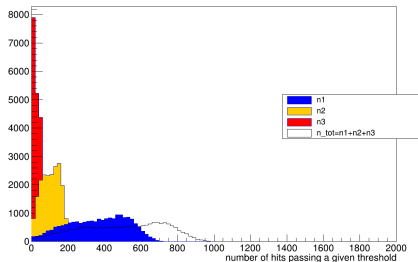


SDHCAL hits per threshold distribution, endcap

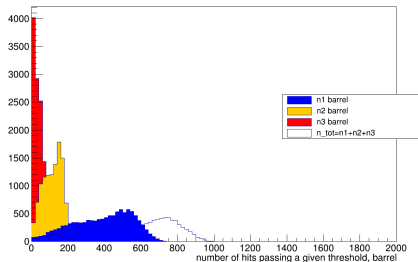


## SDHCAL Hit Level Analysis 050 GeV

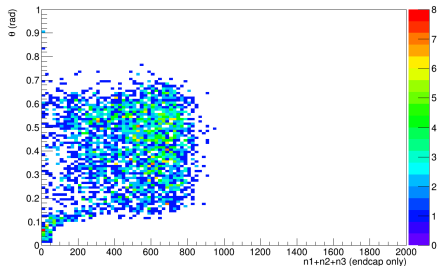
SDHCAL hits per threshold distribution



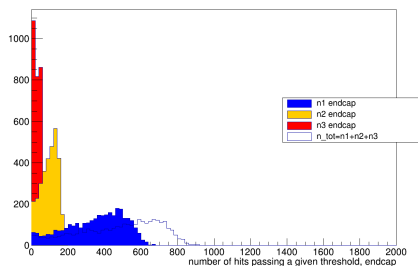
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

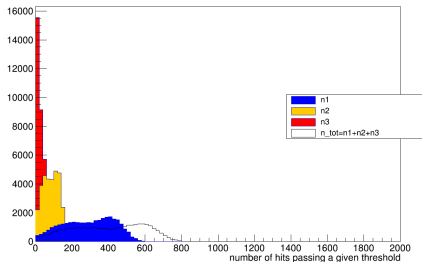


SDHCAL hits per threshold distribution, endcap

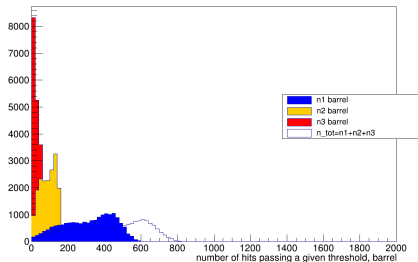
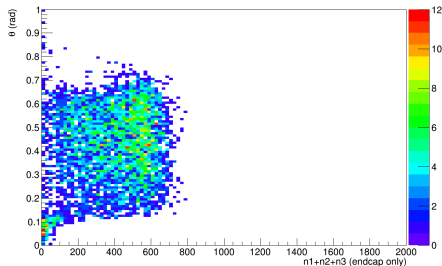


## SDHCAL Hit Level Analysis 040 GeV

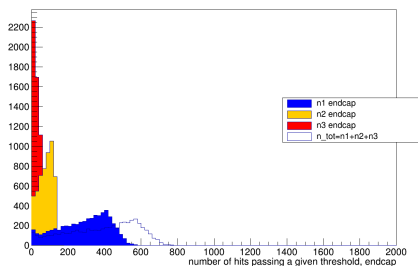
SDHCAL hits per threshold distribution



SDHCAL hits per threshold distribution, barrel

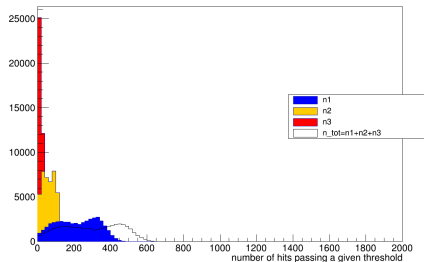
 $n_{hits}$  vs theta (endcap only)

SDHCAL hits per threshold distribution, endcap

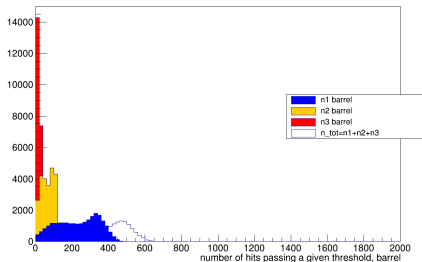


## SDHCAL Hit Level Analysis 030 GeV

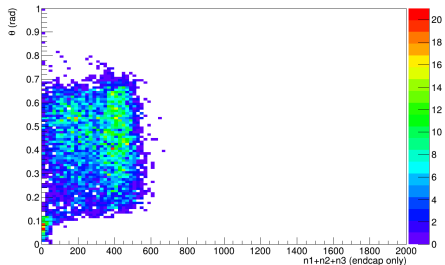
SDHCAL hits per threshold distribution



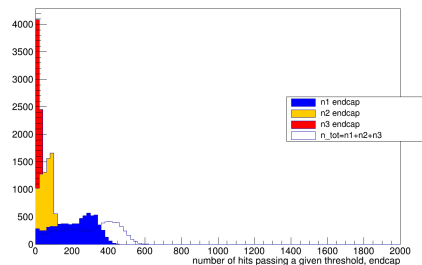
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

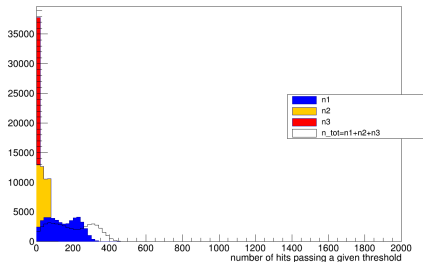


SDHCAL hits per threshold distribution, endcap

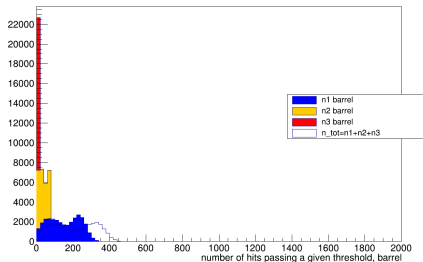


## SDHCAL Hit Level Analysis 020 GeV

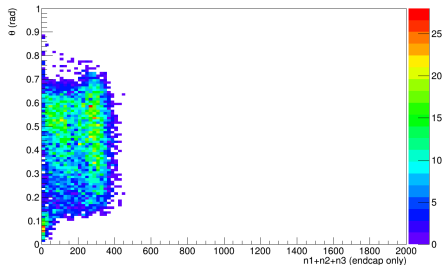
SDHCAL hits per threshold distribution



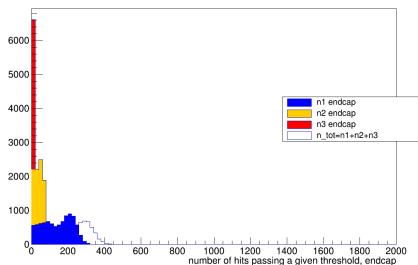
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

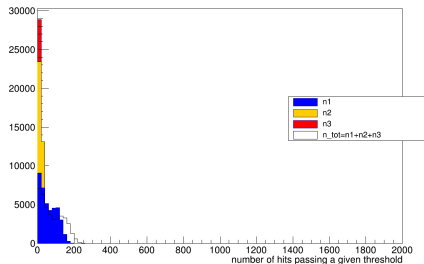


SDHCAL hits per threshold distribution, endcap

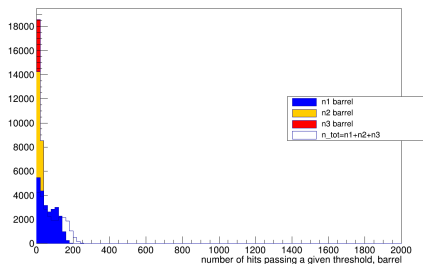


## SDHCAL Hit Level Analysis 010 GeV

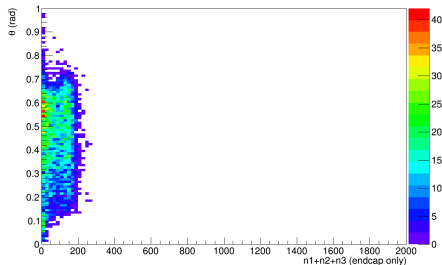
SDHCAL hits per threshold distribution



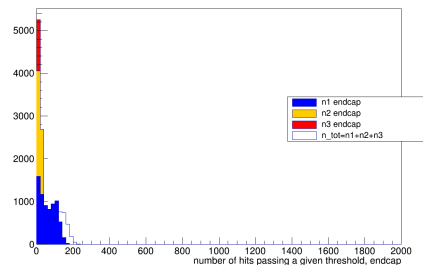
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

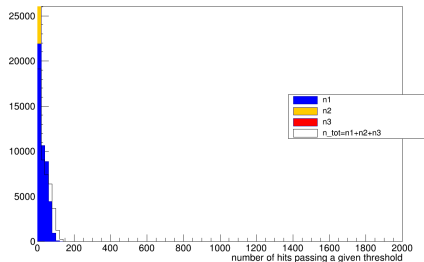


SDHCAL hits per threshold distribution, endcap

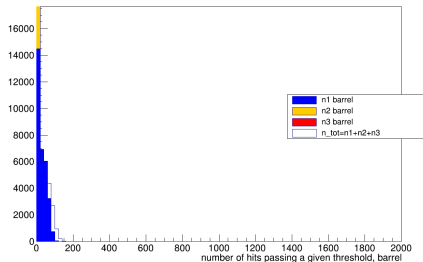


## SDHCAL Hit Level Analysis 005 GeV

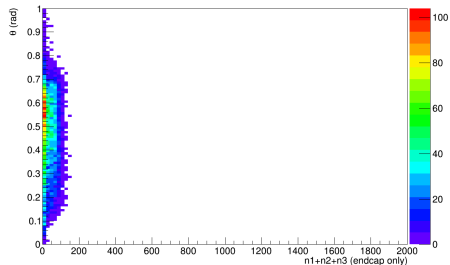
SDHCAL hits per threshold distribution



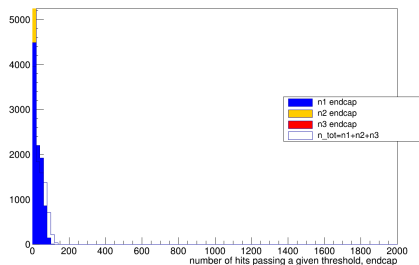
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)

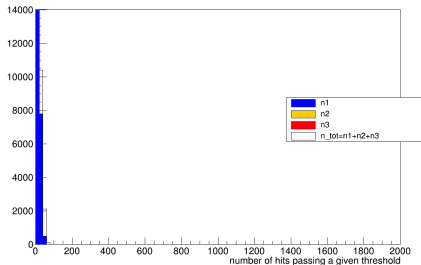


SDHCAL hits per threshold distribution, endcap

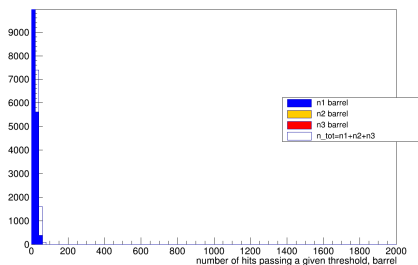


## SDHCAL Hit Level Analysis 002 GeV

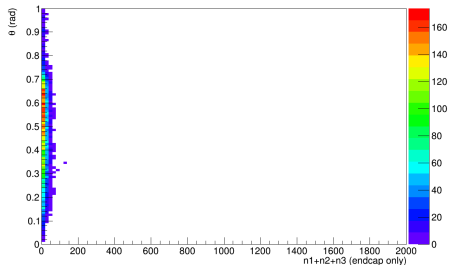
SDHCAL hits per threshold distribution



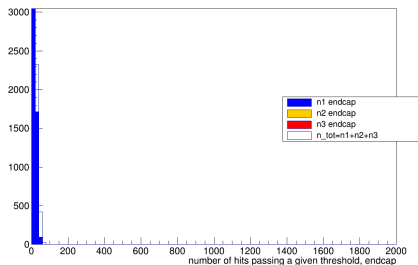
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)



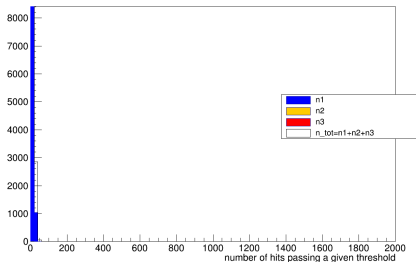
SDHCAL hits per threshold distribution, endcap



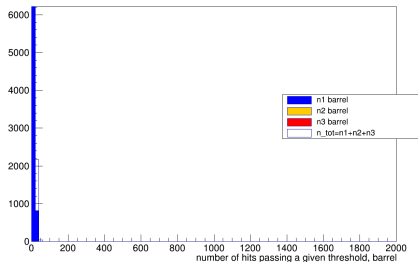


## SDHCAL Hit Level Analysis 001 GeV

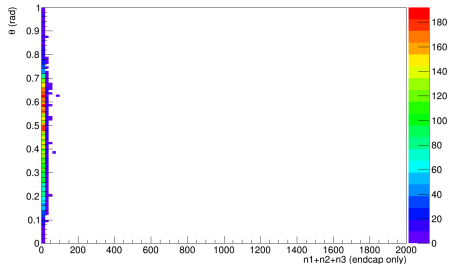
SDHCAL hits per threshold distribution



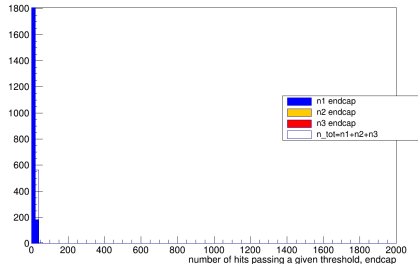
SDHCAL hits per threshold distribution, barrel



n\_hits vs theta (endcap only)



SDHCAL hits per threshold distribution, endcap



# Conclusions

- No relevant difference has been observed with the new test-sample for the SDHCAL/AHCAL performance.
- 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<sup>1</sup>:
  - Geant4 physics model used in ilcsoft is QGSP-Bert which is not ideal to simulate SDHCAL.
  - FTF-BIC is the more appropriate for SDHCAL.

---

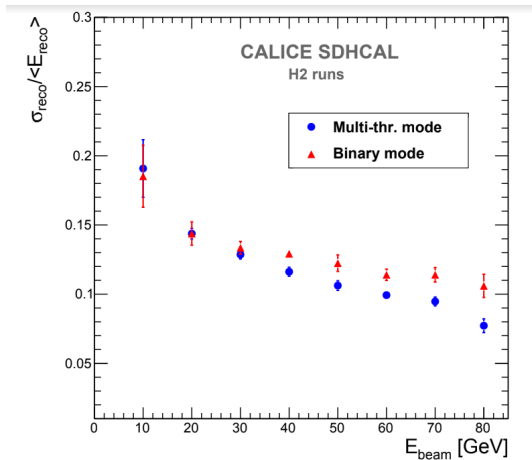
<sup>1</sup><https://geant4.web.cern.ch/node/155>

# Backup

# Backup



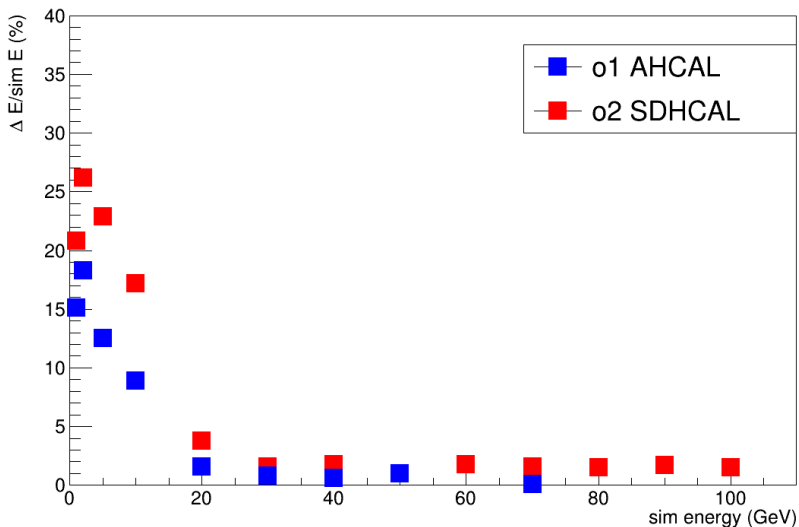
# Only SDHCAL resolution observed in test-beams



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

# Comparison for the two scenarios, discrepancy.

energy discrepancy



# Crystalball fit

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

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

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

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

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

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

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

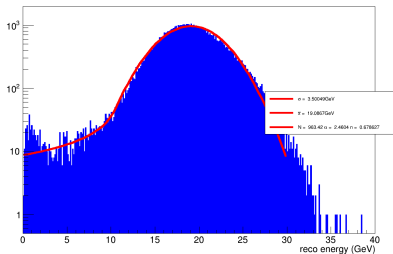
FCN=342.074 FROM MIGRAD STATUS=CONVERGED 184 CALLS 185 TOTAL  
EDM=2.61519e-08 STRATEGY= 1 ERROR MATRIX UNCERTAINTY 0.3 per cent

50 GeV thismax2.1e+03 mean=58 sigma=6.6 error=11%

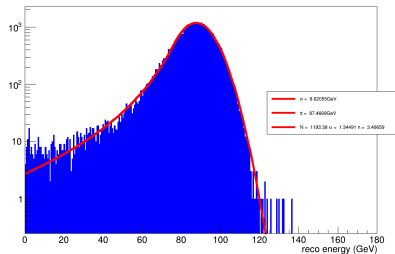
[https://en.wikipedia.org/wiki/Crystal\\_Ball\\_function](https://en.wikipedia.org/wiki/Crystal_Ball_function)

# Crystalball fit, $K_L^0$ , o2

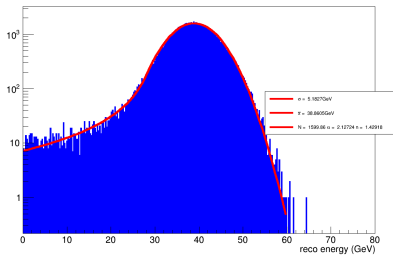
K0long 20 GeV



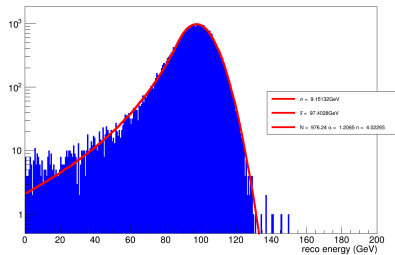
K0long 90 GeV



K0long 40 GeV



K0long 100 GeV



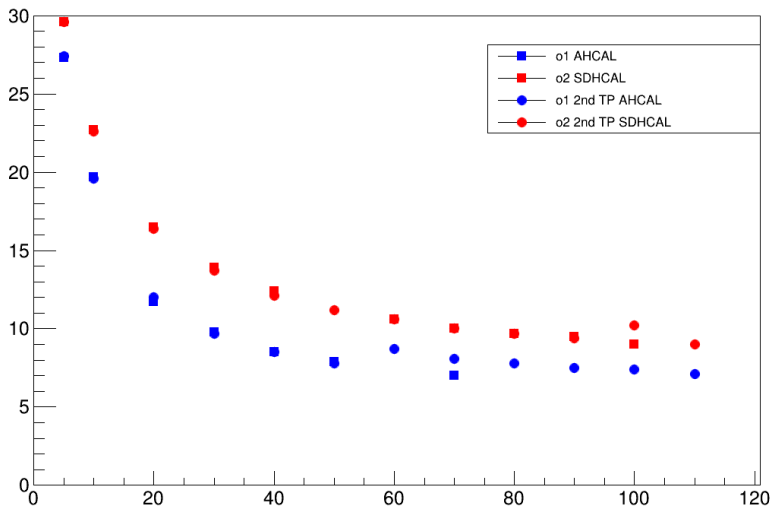
# Summary, $K_L^0$ , o2

sim energy (GeV)	CB $\bar{x}$ (GeV)	CB $\sigma$ (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

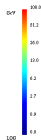
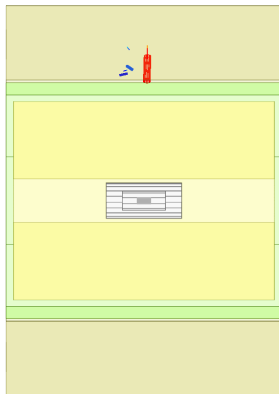
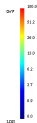
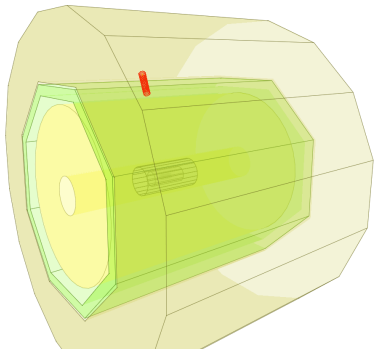


# Summary Resolution, $K_L^0$

## energy resolution



# 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 Tree if any.

// Declaration of leaf types
Int_t      ewevt;
Int_t      ewrun;
Float_t    ewepz;
Float_t    ewlxy;
Float_t    ewair;
Float_t    ewenez;
Float_t    ewpox;
Float_t    ewpzy;
Float_t    ewvtx;
Char_t     ewprb[1]; // (ewvtx)
Int_t      nmcps;
Int_t      ncpdg[807]; // (nmcps)
Int_t      ncpqt[807]; // (nmcps)
Int_t      nccat[807]; // (nmcps)
Float_t    nccvt[807]; // (nmcps)
Float_t    ncvtx[807]; // (nmcps)
Float_t    nmcps[807]; // (nmcps)
Float_t    nmcpy[807]; // (nmcps)
Float_t    nmcpx[807]; // (nmcps)
Float_t    nmmsx[807]; // (nmcps)
Float_t    nmopy[807]; // (nmcps)
Float_t    nmox[807]; // (nmcps)
Float_t    nmmsz[807]; // (nmcps)
Float_t    mceue[807]; // (nmcps)
Float_t    mchua[807]; // (nmcps)
Float_t    mci_in[807]; // (nmcps)
Float_t    mcapk[807]; // (nmcps)
Float_t    mcapy[807]; // (nmcps)
Float_t    mcapz[807]; // (nmcps)
Int_t      mccf0[807]; // (nmcps)
Int_t      mccf1[807]; // (nmcps)
Int_t      mcpas[807]; // (nmcps)
Int_t      mcpas1[807]; // (nmcps)
Int_t      mnda0[807]; // (nmcps)
Int_t      mnda1[807]; // (nmcps)
Int_t      mnda2[807]; // (nmcps)
Int_t      mnda3[807]; // (nmcps)
Int_t      nzea;
Int_t      rcori[41]; // (nrec)
Int_t      rcori0[41]; // (nrec)
Int_t      rcotyp[41]; // (nrec)
Float_t    rconv[41][10]; // (nrec)
Float_t    rcpst[41]; // (nrec)
Float_t    rcppy[41]; // (nrec)
Float_t    rcrpt[41]; // (nrec)
Float_t    rcppi[41]; // (nrec)
Float_t    rcpil[41]; // (nrec)
Int_t      rcpml[41]; // (nrec)
Int_t      rcfpi[41]; // (nrec)
Float_t    rcmex[41]; // (nrec)
Float_t    rcmoy[41]; // (nrec)
Float_t    rcmox[41]; // (nrec)
Float_t    rcmaz[41]; // (nrec)
Float_t    rcme1[41]; // (nrec)
Float_t    rcoch[41]; // (nrec)
Int_t      rcont[41]; // (nrec)
Int_t      rconcl[41]; // (nrec)
Int_t      rncpp[41]; // (nrec)
Int_t      rctfr[41]; // (nrec)
```

```
Int_t      rcrtz[41]; // (nrec)
Int_t      rcvtx[41]; // (nrec)
Int_t      rcvtxe[41]; // (nrec)
Int_t      rconv[41]; // (nrec)
Int_t      npid;
Int_t      pityp[212]; // (npid)
Int_t      pipdq[212]; // (npid)
Float_t    pillh[212]; // (npid)
Int_t      pinlp[212]; // (npid)
Int_t      ntrk;
Int_t      trori[36]; // (ntrk)
Int_t      trtyp[36]; // (ntrk)
Float_t    trchz[36]; // (ntrk)
Int_t      trmd[36]; // (ntrk)
Float_t    trred[36]; // (ntrk)
Float_t    trede[36]; // (ntrk)
Float_t    trrih[36]; // (ntrk)
Int_t      trshh[36][12]; // (ntrk)
Int_t      trst[36]; // (ntrk)
Int_t      trfta[36]; // (ntrk)
Int_t      trrip[36]; // (ntrk)
Int_t      trafh[36]; // (ntrk)
Int_t      trslh[36]; // (ntrk)
Int_t      trscn[36]; // (ntrk)
Int_t      ntrst;
Int_t      tsloc[144]; // (ntrst)
Float_t    tsdze[144]; // (ntrst)
Float_t    tsphi[144]; // (ntrst)
Float_t    tszoe[144]; // (ntrst)
Float_t    tszre[144]; // (ntrst)
Float_t    tstnl[144]; // (ntrst)
Float_t    tszov[144][15]; // (ntrst)
Float_t    tszpa[144]; // (ntrst)
Float_t    tszpy[144]; // (ntrst)
Float_t    tszsp[144]; // (ntrst)
Int_t      nath;
Int_t      atori[1]; // (nath)
Int_t      atci0[1]; // (nath)
Int_t      atci1[1]; // (nath)
Double_t   Dgmb;
Double_t   stpov[1]; // (nath)
Double_t   stpos[1]; // (nath)
Float_t    stedp[1]; // (nath)
Float_t    atrim[1]; // (nath)
Float_t    atmos[1]; // (nath)
Float_t    atmov[1]; // (nath)
Float_t    atmos1[1]; // (nath)
Float_t    stpt1[1]; // (nath)
Int_t      stsep[1]; // (nath)
Int_t      nscr;
Int_t      scori[1]; // (nscr)
Int_t      sccl0[1]; // (nscr)
Int_t      sccl1[1]; // (nscr)
Float_t    scpx[1]; // (nscr)
Float_t    scpy[1]; // (nscr)
Float_t    scpz[1]; // (nscr)
Float_t    scene[1]; // (nscr)
Int_t      r2mre1;
Int_t      r2mf[169]; // (r2mre1)
Int_t      r2m[169]; // (r2mre1)
Int_t      r2mw[169]; // (r2mre1)
```