Ladder Classification

Milan Stojanovic
Purdue University

Overview

❑ Goal: Classification of ladders based on number of good (bad) channels

❑ Using data from bench test
  ❑ Combining data from N and S, making total number of bad channels for each ladder

❑ Based on the code developed by Cheng-Wei and Han-Sheng

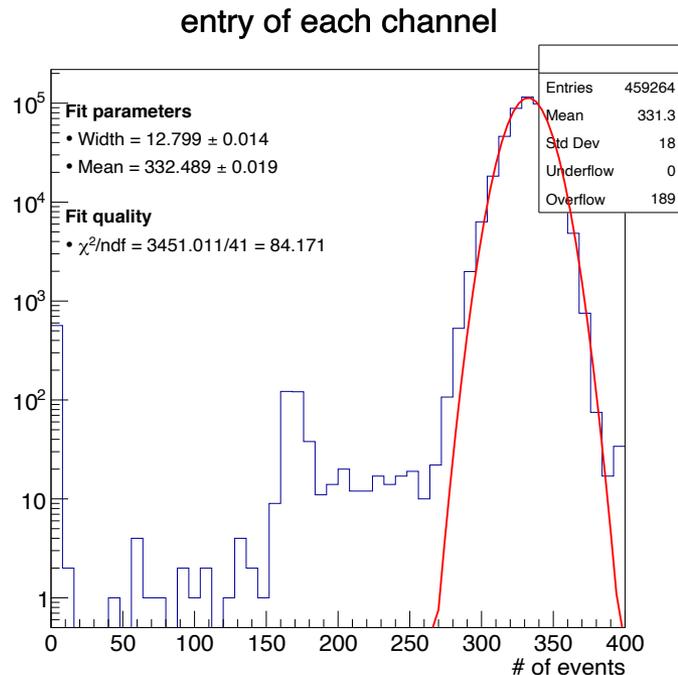❑ 82 ladders classified (out of 84 ladders at BNL)

Methodology

Criteria

❑ Using the established scheme which consist out of 7 criteria:
1) # of entries in each channel
   o To count the number of dead, hot and abnormal channels
2) Width of amplitude distribution from all partial inclusive amplitude distribution
   o To quantify the overall noise at all comparators
3) Threshold for each individual comparator
   o To check the threshold position of each individual comparator are correctly set.
4) Width of amp distribution vs. comparator (linearity)
   o To quantify the variation of noise vs. comparator
5) mean of amplitude of adc0
   o To check the offset of ADC response
6) Linearity of amplitude mean vs. ADC
   o To check the linear response of amplitude mean vs. ADC
7) Slope of amplitude mean vs. ADC
   o To check the gain of ADC. Note: can be corrected via calibration in principle

1) # of entries in each channel

Purpose: To quantify the overall noise at all comparators

Method:
- Making 1-D histogram of the channel entry distribution from all channels of all ladders
- Fit with a Gaussian and define the boundary for good channels
- Good channels within 5-sigma of the Gaussian distribution

entry of each channel

Fit parameters
- Width = 12.799 ± 0.014
- Mean = 332.489 ± 0.019

Fit quality
- χ^2/ndf = 3451.011/41 = 84.171

Entries	459264
Mean	331.3
Std Dev	18
Underflow	0
Overflow	189

# of events

2) Width of amplitude distribution

Purpose: To quantify the overall noise at all comparators

Method:

➢ Fit the following amplitude distributions with error function.

- ○ ADC0 || ADC1 || ADC2....||ADC7
- ○ ADC1 || ADC2 ||.... ADC7
- ○ ...
- ○ ADC7

width_sum of each channel

Entries	1837056
Mean	2.782
Std Dev	0.7352
Underflow	0
Overflow	2105

Fit parameters
- Width = 0.688 ± 0.000
- Mean = 2.786 ± 0.001

Fit quality
- χ^2/ndf = 28256.791/76 = 371.800

Width from all ladders

➢ The mean and width correspond to the threshold and its noise at each comparator

➢ <u>Good channels have width within 5-sigma of the all-ladders mean value</u>

chip_id=1, chan_id = 2, ADC0
turn on : 28.4688
width : 3.108
height : 10.025

chip_id=1, chan_id = 2, ADC1
turn on : 36.0492
width : 4.245
height : 10.140

chip_id=1, chan_id = 2, ADC2
turn on : 42.8464
width : 2.275
height : 9.900

chip_id=1, chan_id = 2, ADC3
turn on : 50.2629
width : 3.302
height : 10.132

PB1-L001
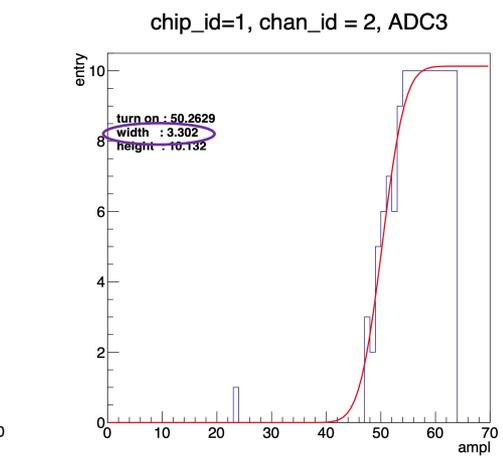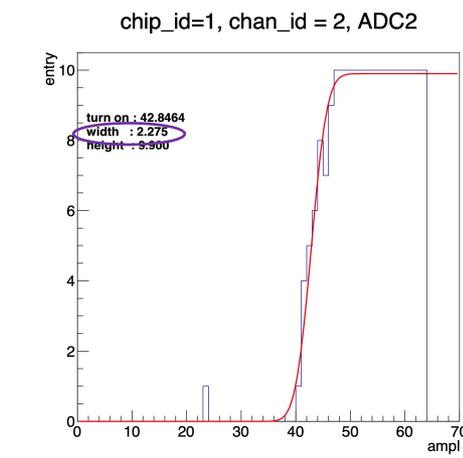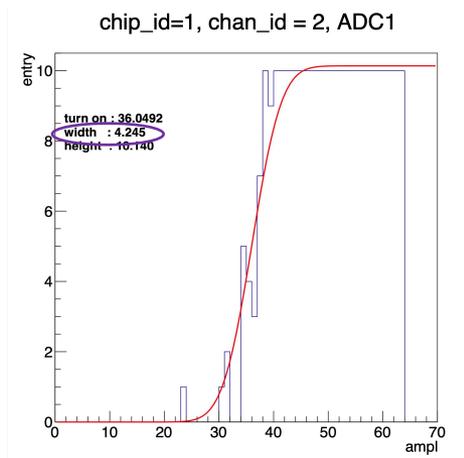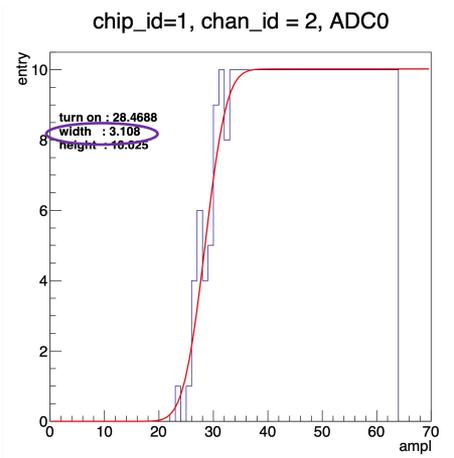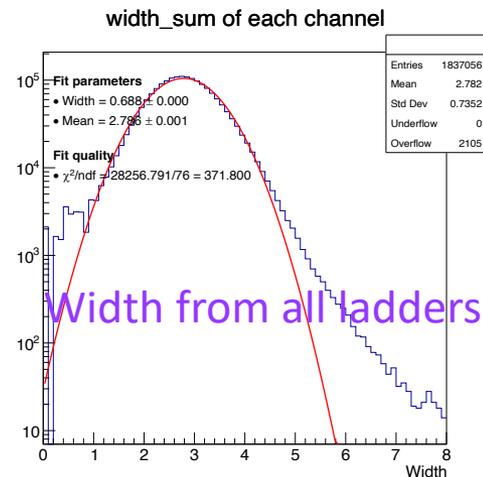
3) Threshold of each individual comparator

Purpose: To check the threshold position of each individual comparator are correctly set

Method:

➤ obtained threshold distribution via fitting partial inclusive amp distribution
  ○ Similar as on previous slide
➤ If any of the 4 threshold beyond boundary, this channel is bad
  ➤ Boundary determined by all-ladders distribution threshold for each competitor
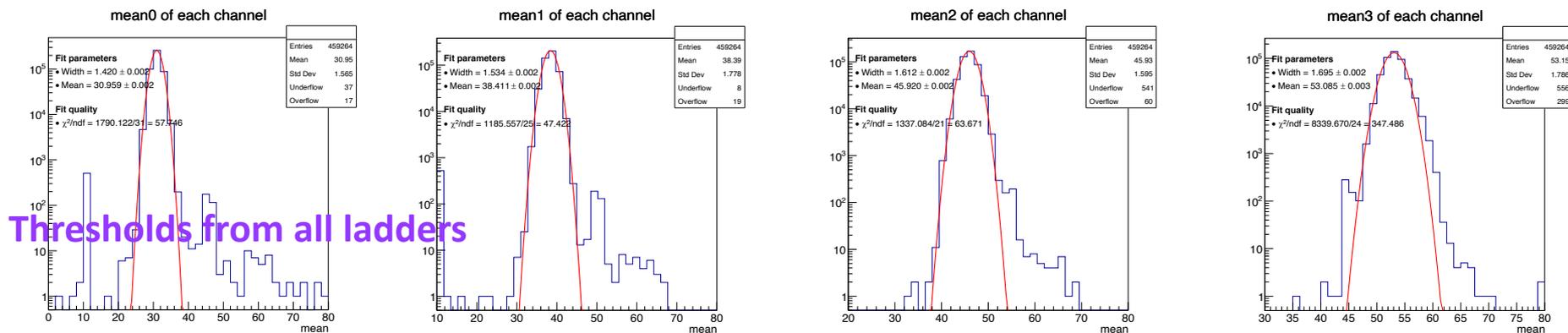
Thresholds from all ladders

PB1-L001

ic, IN
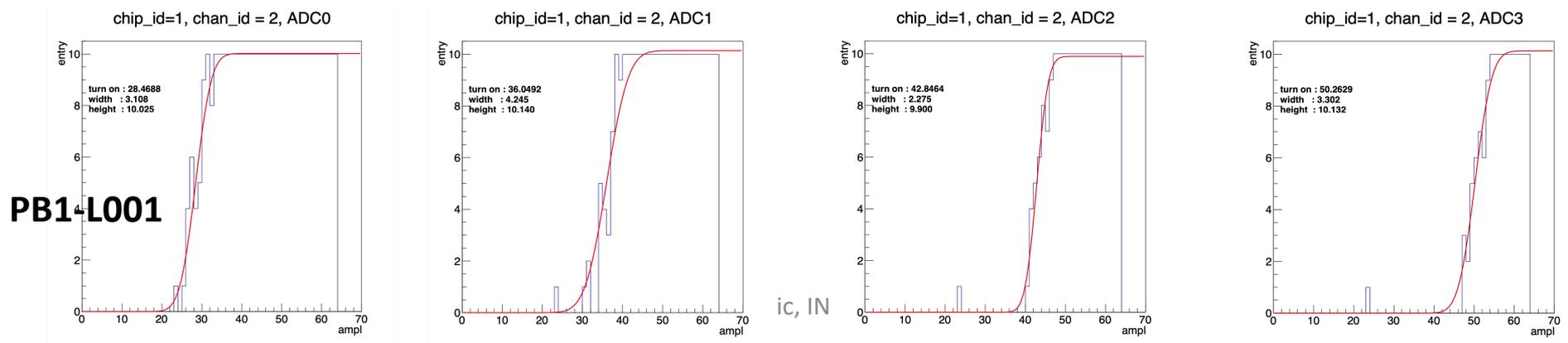
4) Width of amp distribution vs. comparator

Purpose: To quantify the variation of noise vs. comparator

Method:

➢ plot "width vs. comparator ID",
  ➢ width is the error function width of the amplitude distribution.
➢ Chip is bad if the probability that the function is not constant is less than 0.0000006 (more than 5 sigma)

p value = (Chi2,NDF) = 0.65

PB1-L001

chip_id=1, chan_id = 2

fit : 2.997
χ^2 : 1.66, NDF : 3, χ^2/NDF : 0.55
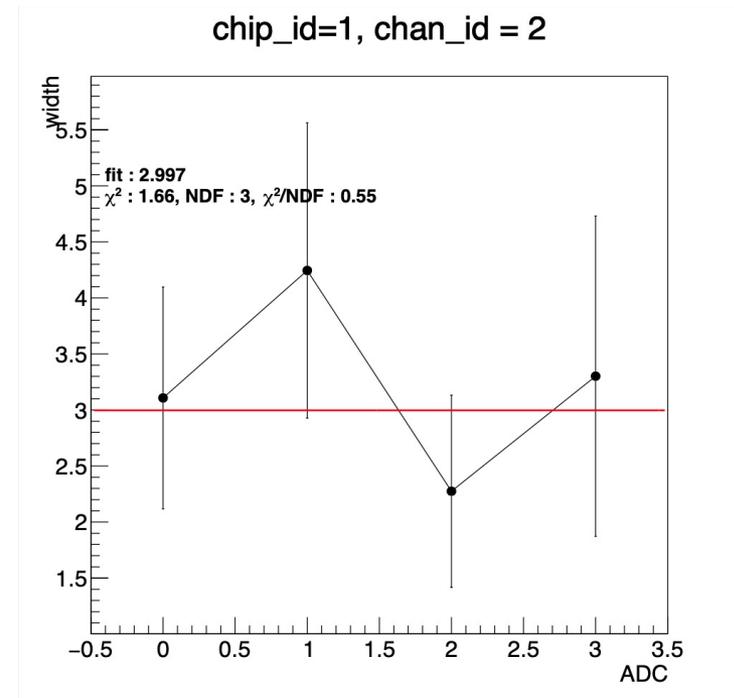
5) Mean of amplitude of adc0

Purpose: To check the offset of ADC response

Method:
- ➢ Make a 1-D distribution of the amplitude mean of adc0 from all channels of all ladders.
- ➢ The channel is bad if fails more than 5 sigma away of the all-ladders average value

PB1-L001

Single channel ADC0 distribution
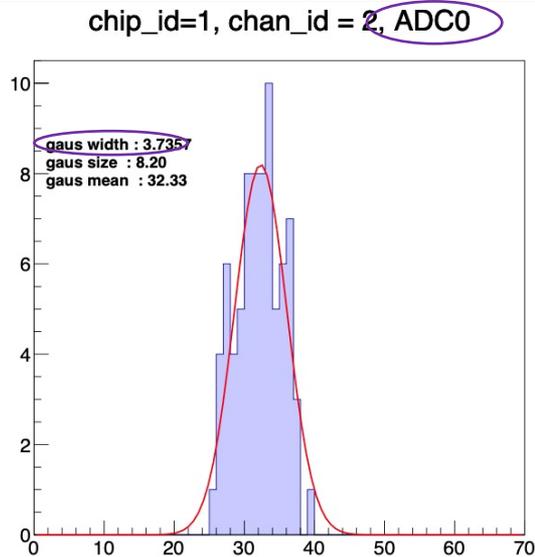
Distributions of ADC0 means, from all ladders
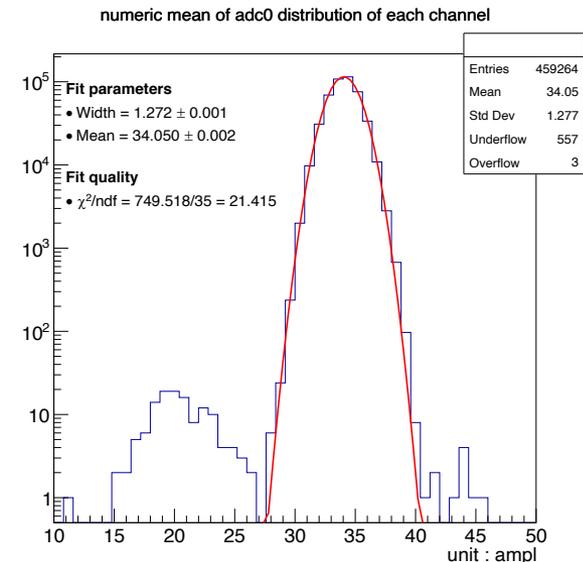
6) Linearity of amplitude mean vs. ADC

Purpose: To check the linear response of amplitude mean vs. ADC

Method:
- plot "mean amplitude vs. ADC",
  - mean is the error function mean of the amplitude distribution.
- Chip is bad if the probability that the function is not linear is less than 0.0000006 (more than 5 sigma)

chip_id=1, chan_id = 2

p value = (Chi2,NDF) = 0.9

PB1-L001

fit : 7.220 * x + 32.218
χ^2 : 0.20, NDF : 2, χ^2/NDF : 0.10

mean of ampl

ADC
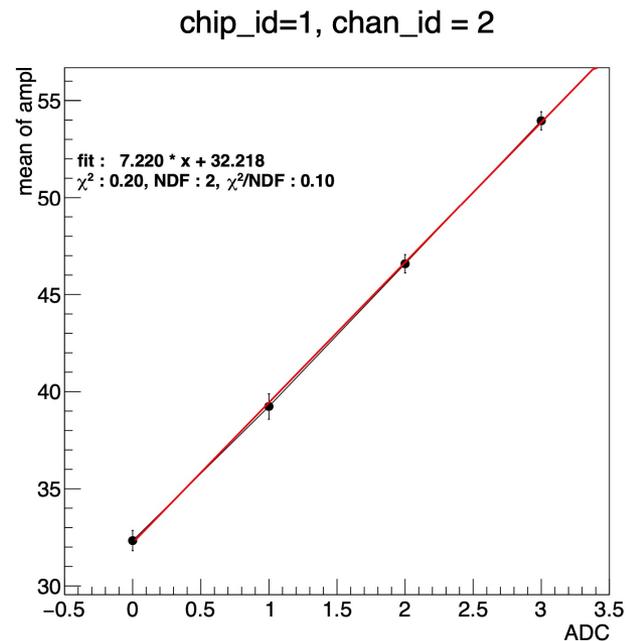
7) 7.Slope of amplitude mean vs. ADC

Purpose: To check the linear response of amplitude mean vs. ADC

Method:
- plot "mean amplitude vs. ADC",
  - mean is the error function mean of the amplitude distribution.
- Do the calibration of slope vs. chip ID
  - to remove the signal attenuation in different path length.
- The chip is bad if the slope is more than 5 sigma of all-ladders average value

chip_id=1, chan_id = 2
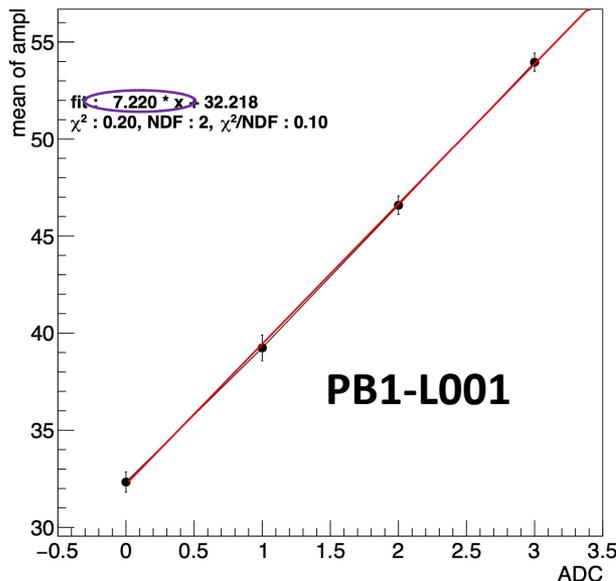
slope value of each channel after correction
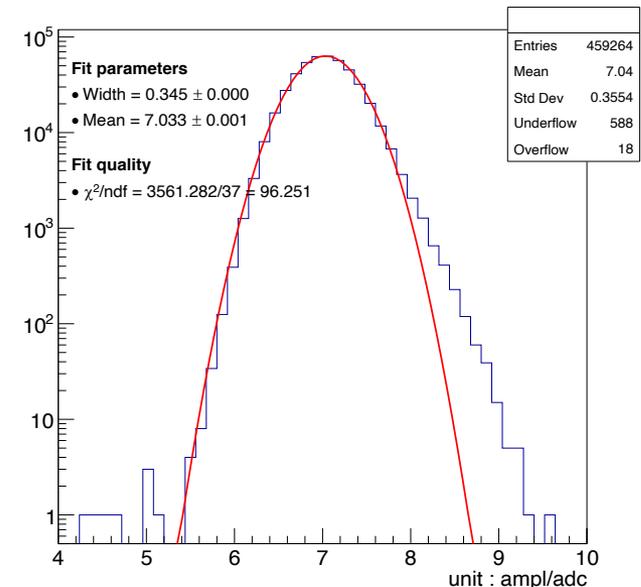
Results

Classification table

❑ Totally analyzed 82 ladders
❑ Most of them are class 1 (<0.5% of bad chips)

Classification	Barrel 1 (24 needed)	Barrel 2 (32 needed)
Class 1 (<= 0.5%)	26	40
Class 2 (> 0.5% && <= 1.0%)	5	2
Class 3 (> 1.0% && <= 2.0%)	0	1
Class 4 (> 2.0% && <= 3.0%)	3	5

Details for each ladders: link

Check with bench test

Count	82	Total	Stave Batch-ID	South Chips/HDI Status															North Chips/HDI Status												
		Barrel Type HDI/Stave Glued		U26	U25	U24	U23	U22	U21	U20	U19	U18	U17	U16	U15	U14	Data File	U26	U25	U24	U23	U22	U21	U20	U19	U18	U17	U16	U15	U14
	New Name		HdI ID	U13	U12	U11	U10	U9	U8	U7	U6	U5	U4	U3	U2	U1	Name	U13	U12	U11	U10	U9	U8	U7	U6	U5	U4	U3	U2	U1
3	PB2_L003	2	Batch 1	2	2	2	2	2	2	2	2	2	2	2	0	2	20210329-1036_0_2	2	2	2	2	2	2	2	2	2	2	2	2	2
				2	2	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	2	2	2	2	2	2	2
8	PB1_L003	1	Batch 1	2	2	2	2	2	2	2	2	2	2	2	2	2	20210325-1915_0_2	2	2	2	2	2	2	2	2	2	2	2	2	2
				2	2	2	2	2	2	2	2	2	2	2	2	2		2	2	2	2	2	2	3	2	2	2	2	2	2

Ladder	Bench test	Classification
PB2-L003	One bad chip (U15)	138 bad channels (2.07%) Class 4
PB1-L003	Half entries issue (U7)	149 bad channels (2.2%) Class 4
PB1-L018	No issues spotted	39 bad channels (0.6%) Class 2

❑ Ladder classification algorithm can quantify issues observed during the bench test
❑ It can also detect unusual behavior of chips, that cannot be seen with bench test only

Status

Status

HDIs/Chips

	0	Chip is Missing
	1	Chip is Mounted
	2	Chip is Good
	3	Chip/HDI has Half Entries

Chips/Sensors

	0	Sensor is Missing
	1	Sensor is Mounted
	2	Sensor is Good

Ladder Encapsulated

	0	Red
	1	Ready For Enc
	2	Good

Live Channels / Classes

- Class 1 = 100 %
- 99 % =< Class 2 < 100 %
- 98 % =< Class 3 < 99 %
- 96 % =< Class 4 < 98 %
- Class 5 < 97%

Production Ladders

34	Barrel 1
49	Barrel 2
83	Total

South Chips/HDI Status / North Chips/HDI Status / South Sensor Status / North Chips/HDI Status / Encapsulation / Ladder Class

Count	New Name	Barrel Type HDI/Stave Glued	Stave Batch-ID / Hdl ID	Data File Name	File Name	Sensor A	Leakage Current nanoAmp	Sensor B	Leakage Current nanoAmp	File Name Vb<100V	Sensor A	Leakage Current nanoAmp	Sensor B	Leakage Current nanoAmp	File Name	Survey File	South File Name	North File Name	1 to 5	Bad Channels	Source Test File
42	PB2-L024	2	BH2-90 / S-316/N-317	20210927-1218_0.5	20210927-1217_0.5	2	126	2	238	20211007-1210_0.5	2	157	2	138	20211007-1200_0.5	2	2	20211014-1252_0.5	20211014-1233_0.5		
43	PB2-L025	2	BH2-82 / S-289/N-290	20210813-1042_0.8	20210813-1035_0.8	2	120	2	152	20210909-1026_0.5	2	152	2	132	20210909-1018_0.5	2	2	20210915-1601_0.5	20210915-1540_0.5		
44	PB2-L026	2	BH2-84 / S-291/N-292	20210810-1703_0.8	20210810-1656_0.8	2	175	2	130	20210826-1427_0.5	2	220	2	140	20210826-1416_0.5	2	2	20210916-1242_0.5	20210916-1228_0.5		
45	PB2-L027	2	BH2-85 / S-293/N-294	20210810-1723_0.8	20210810-1715_0.8	2	143	2	120	20210830-1312_0.5	2	161	2	134	20210830-1259_0.5	2	2	20210916-1334_0.5	20210916-1323_0.5		
46	PB2-L028	2	BH2-87 / S-157/N-181	20210813-1050_0.8	20210813-1108_0.8	2	153	2	130	20210908-1011_0.5	2	173	2	300	20210908-0948_0.5	2	2	20210920-0950_0.5	20210917-0941_0.5		
47	PB2-L029	2	BH2-88 / S-183/N-184	20211221-1126_0.5	20211221-1133_0.5	2	111	2	97	202201-1417_0.5	2	116	2	103	20220112-1406_0.5	2	2	20220114-1030_0.5	20220114-1020_0.5		
47	PB2-L030	2	BH2-91 / S-185/N-186	20210811-1013_0.8	20210811-1041_0.8	2	148	2	115	20210830-1332_0.5	2	149	2	127	20210830-1322_0.5	2	2	20210921-1403_0.5	20210921-1354_0.5		
48	PB2-L031	2	BH2-93 / S-187/N-188	20210811-1104_0.8	20210811-1053_0.8	2	189	2	130	20210831-1314_0.5	2	190	2	210	20210831-0952_0.5	2	2	20210921-1506_0.5	20210914-1459_0.5		
49	PB2-L032	2	BH2-94 / S-190/N-191	20210730-1405_0.1	20210730-1427_0.1	2	160	2	110	20210831-1416_0.5	2	160	2	110	20210831-1408_0.5	2	2	20210921-1511_0.5	20210921-1505_0.5		
50	PB1-L019	1	BH3-75 / S-205/N-295	20210913-1638_0.5	20210913-1625_0.5	2	174	2	129	20211018-0924_0.5	2	170	2	114	20211018-0917_0.5	2	2	20211025-1054_0.5	20211025-1045_0.5		
51	PB1-L020	1	BH3-76 / S-282/N-283	20210909-1006_0.5	20210909-0952_0.5	2	133	2	126	20211012-1042_0.5	2	120	2	144	20211012-1034_0.5	2	2	20211021-1108_0.5	20211021-1049_0.5		
52	PB1-L021	1	BH3-78 / S-284/N-285	20210830-1246_0.5	20210830-1236_0.5	2	155	2	156	20211012-0939_0.5	2	137	2	147	20211012-0911_0.5	2	2	20211020-1128_0.5	20211020-1103_0.5		
53	PB1-L022	1	BH3-79 / S-286/N-287	20210908-1209_0.5	20210908-1157_0.5	2	149	2	333	20211012-1109_0.5	2	331	2	221	20211012-140_0.5	2	2	20211021-1201_0.5	20211020-1146_0.5		
54	PB1-L023	1	BH3-80 / S-271/N-272	20210913-1700_0.5	20210913-1648_0.5	2	157	2	202	20211018-1021_0.5	2	162	2	149	20211012-1009_0.5	2	2	20211020-1445_0.5	20211020-1437_0.5		
55	PB1-L024	1	BH3-87 / S-273/N-274	20210917-0944_0.5	20210917-0907_0.5	2	183	2	111	20211018-0940_0.5	2	130	2	113	20211018-0934_0.5	2	2	20211025-0954_0.5	20211025-0947_0.5		
56	PB1-L025	1	BH3-88 / S-275/N-276	20210917-1006_0.5	20210917-0957_0.5	2	138	2	129	20211014-1314_0.5	2	138	2	330	20211014-1308_0.5	2	2	20211025-1443_0.5	20211025-1436_0.5		
57	PB1-L026	1	BH3-89 / S-277/N-278	20210917-1025_0.5	20210917-1018_0.5	2	158	2	119	20211018-0810_0.5	2	128	2	220	20211018-0803_0.5	2	2	20211027-1019_0.5	20211027-1011_0.5		
58	PB1-L027	1	BH3-90 / S-279/N-280	20211007-1140_0.5	20211007-1125_0.5	2	133	2	107	20211021-1500_0.5	2	101	2	101	20211021-1454_0.5	2	2	20211029-1129_0.5	20211029-11122_0.5		
59	PB1-L028	1	BH3-81 / S-296/N-297	20210908-1230_0.5	20210908-1224_0.5	2	165	2	118	20211018-0907_0.5	2	150	2	600	20211018-0853_0.5	2	2	20211027-1041_0.5	20211027-1029_0.5		
60	PB1-L029	1	BH3-83 / S-298/N-299	20210910-0955_0.5	20210910-0947_0.5	2	138	2	5500	20211020-1204_0.5	2	129	2	95	20211020-1141_0.5	2	2	20211105-1130_0.5	20211105-1114_0.5		
61	PB1-L030	1	BH3-84 / S-300/N-301	20211029-1159_0.5	20211029-1151_0.5	1	10	1	10	20211021-1151_0.5	1	10	1	10			1		1		
62	PB1-L031	1	BH3-85 / S-281/N-288	20210920-1124_0.5	20210920-1120_0.5	2	143	2	111	20211021-1138_0.5	2	133	2	100	20211021-1130_0.5	2	2	20211027-1148_0.5	20211027-1140_0.5		
63	PB1-L032	1	BH3-77 / S-303/N-304	20210922-1102_0.5	20210922-1048_0.5	2	121	2	99	20211103-1103_0.5	2	118	2	98	20211103-1048_0.5	2	2	20211109-1524_0.5	20211109-1517_0.5		
64	PB1-L033	1	BH3-82 / S-305/N-306	20210922-0925_0.5	20210922-0909_0.5	2	137	2	116	20211025-1214_0.5	2	178	2	389	20211025-1206_0.5	2	2	20211109-1416_0.5	20211109-1431_0.5		
65	PB1-L034	1	BH3-86 / S-302/N-307	20211014-1226_0.5	20211014-1216_0.5	2	199	2	164	20211109-1459_0.5	2	129	2	91	20211109-1448_0.5	2	2	20211116-1114_0.5	20211116-1103_0.5		
66	PB2-L033	2	BH3-97 / S-308/N-309	20211029-1216_0.5	20211029-1207_0.5	2	194	22	107	20211117-1507_0.5	2	259	2	1120	20211117-1500_0.5	2	2	20211122-1201_0.5	20211122-1151_0.5		
67	PB2-L034	2	BH3-98 / S-310/N-311	20211103-1149_0.5	20211103-1125_0.5	2	122	2	105	20211115-1154_0.5	2	141	2	184	20211115-1147_0.5	2	2	20211123-1117_0.5	20211123-1110_0.5		
68	PB2-L035	2	BH3-99 / S-312/N-313	20211103-1117_0.5	20211103-1111_0.5	2	462	2	4400	20211117-1447_0.5	2	153	2	1300	20211117-1424_0.5	2	2	20211207-1630_0.5	20211207-1622_0.5		
69	PB2-L036	2	BH3-100 / S180/N-318	20211108-1056_0.5	20211108-1047_0.5	2	319	2	130	20211123-1548_0.5	2	340	2	97	20211123-1542_0.5	2	2	20211202-1134_0.5	20211202-1117_0.5		
70	PB2-L037	2	BH3-101 / S-384/N-385	20211108-1542_0.5	20211108-1532_0.5	2	159	2	87	20211129-1641_0.5	2	118	2	84	20211129-1634_0.5	2	2	20220106-1011_0.5	20220106-0952_0.5		
71	PB2-L038	2	BH3-102 / S-386/N-387	20211122-1434_0.5	20211122-1426_0.5	2	801	2	105	20211207-1651_0.5	2	142	2	325	20211207-1645_0.5	2	2	20220106-1018_0.5	20220106-1033_0.5		
72	PB2-L039	2	BH3-103 / S-54/N-355	20211108-1558_0.5	20211108-1552_0.5	2	144	2	151	20211206-1525_0.5	2	184	2	257	20211206-1518_0.5	2	2	20220106-1108_0.5	20220106-1100_0.5		
73	PB2-L040	2	BH3-105 / S-356/N-357	20211109-1540_0.5	20211109-1534_0.5	2	128	2	94	20211123-1055_0.5	2	1800	2	169	20211123-1047_0.5	2	2	20211202-1207_0.5	20211202-1144_0.5		
74	PB2-L041	2	BH3-106 / S358/N-359	20211130-1110_0.5	20211130-1103_0.5	2	407	2	202	20211208-1542_0.5	2	227	2	143	20211208-1536_0.5	2	2	20220118-1041_0.5	20220118-1031_0.5		
75	PB2-L042	2	BH3-107 / S360/N361	20211117-1626_0.5	20211117-1619_0.5	2	1700	2	92	20211123-1434_0.5	2	3900	2	3800	20211123-1427_0.5	2	2	20211201-1109_0.5	20211201-1055_0.5		
76	PB2-L043	2	BH3-108 / S362/N363	20211130-1132_0.5	20211130-1126_0.5	2	117	2	103	20211208-1559_0.5	2	1000	2	183	20211208-1551_0.5	2	2	20220110-1010_0.5	20220110-1000_0.5		
77	PB2-L044	2	BH3-109 / S364/N365	20211201-1559_0.5	20211201-1547_0.5	2	133	2	588	20211214-1801_0.5	2	118	2	94	20211214-1713_0.5	2	2	20220111-1001_0.5	20220111-0948_0.5		
78	PB2-L045	2	BH3-110 / S366/N367	20211201-1613_0.5	20211201-1606_0.5	2	112	2	100	20211214-1814_0.5	2	103	2	103	20211214-1807_0.5	2	2	20220111-1018_0.5	20220111-1010_0.5		
79	PB2-L046	2	BH3-111 / S368/N369	20211130-1534_0.5	20211130-1526_0.5	2	691	2	154	20211214-1831_0.5	2	184	2	274	20211214-1822_0.5	2	2	20220112-1335_0.5	20220112-1326_0.5		
80	PB2-L047	2	BH3-112 / S370/N371	20211130-1554_0.5	20211130-1548_0.5	2	121	2	408	20211214-1600_0.5	2	109	2	118	20211214-1553_0.5	2	2	20220112-1358_0.5	20220112-1343_0.5		
	PB2-L048		BH3-104	20211122-						20211220-					20211220-						

Status

Summary

Ladder classification based on bench test data

81 ladders classified

Final results once we have all ladders

Backup

Tests	Purpose	Method	Bit position of the Criteria
1.Number of channel entries	To count the number of dead, hot and abnormal channels	• 1-D histogram of the channel entry distribution from all channels of all ladders • Fit with a Gaussian and define the boundary for good channels. • Good channels within around 5-sigma of the Gaussian distribution	2nd bit
2.Width of amp distribution from all partial inclusive amp distribution	To quantify the overall noise at all comparators.	• Obtain the threshold of each comparator (CR). Fit the following amp distribution with error function. The mean and width correspond to the threshold and noise at each comparator. o ADC0 || ADC1 || ADC2.....||ADC7 o ADC1 || ADC2 ||.... ADC7 o ADC2 || ADC3 ||.... ADC7 o ADC3 || ADC4 ||.... ADC7 o ADC4 || ADC5 ||.... ADC7 o ADC5 || ADC6 || ADC7 o ADC6 || ADC7 o ADC7 • Combine all width into a single width distribution. • Good channels within around 5-sigma of the Gaussian distribution	10th bit
3.Threshold of each individual comparator.	To check the threshold position of each individual comparator are correctly set.	• obtained threshold distribution via fitting partial inclusive amp distribution. o In calibration we can see 4 ADC values, i.e. 4 threshold can be checked. • Set criteria for each threshold and reject outliers. o If any of the 4 threshold beyond boundary, this channel is bad.	1st bit
4.Width of amp distribution vs. comparator	To quantify the variation of noise vs. comparator.	• plot "width vs. comparator ID", where width is the error function width of the amplitude distribution. • fit the plot with a constant line, i.e. "pol0" in ROOT, and obtain chi2/NDF from the ROOT. • Calculate p-Value, i.e. TMath::Prob(chi, NDF) • Set cut based on the distribution. o e.g. ▪ p-Value = 0.006%--> 5 sigma	11th bit

5.Linearity of amplitude mean vs. ADC	To check the linear response of amplitude mean vs. ADC	• plot "mean of the amplitude vs. ADC", where the mean is the Gaussian mean of the amplitude distribution. • fit the plot with a straight line, i.e. "pol1" in ROOT, and obtained chi2/NDF from the ROOT. • Calculate p-Value, i.e. TMath::Prob(chi, NDF) • Set cut based on the distribution. o e.g. ▪ p-Value = 0.006%--> 5 sigma	5th bit
6. mean of amplitude of adc0.	To check the offset of ADC response.	• Make a distribution of the amplitude mean of adc0 from all channels of all ladders. • 5-sigma as boundary.	4th bit
7.Slope of (amplitude mean vs. ADC)	To check the gain of ADC. Note: can be corrected via calibration in principle	• first do the calibration of slope vs. chip ID o to remove the signal attenuation in different path length. • plot the distribution of the (slope of amp mean vs ADC) from all channels of all ladders. • set boundary accordingly o 5-sigma	9th bit
8.Unbounded channel	Source test		To be added
Classification	To classify a ladder	• remove double counting on bad channels from all above criteria • plot "number of single ladders" vs. "number of bad channels" • printout the ladder information for each class.	classification based on the percentage of bad channels in a full ladder • 1: 1.0% • 2: 2.0% • 3: 3.0% • 4: 4.0%