Noise analysis of the 1m^3 DHCal test beam

Qingmin Zhang

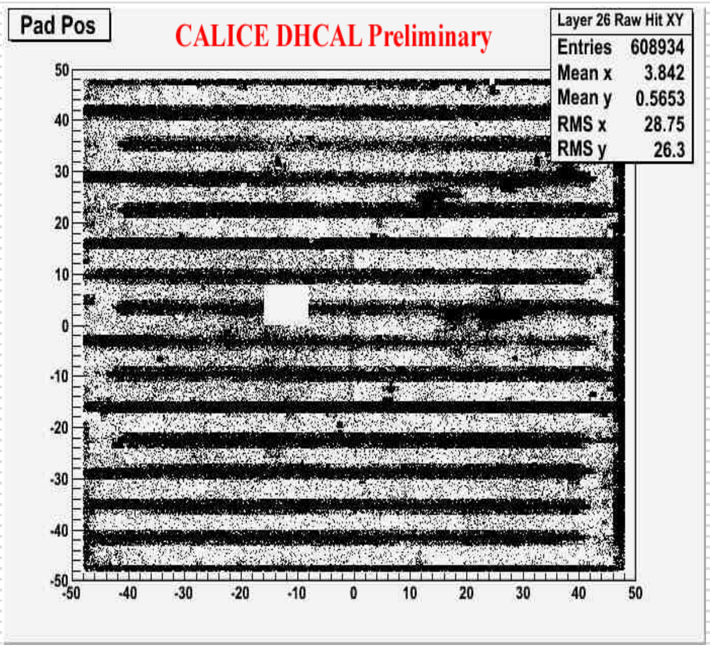
Lei Xia

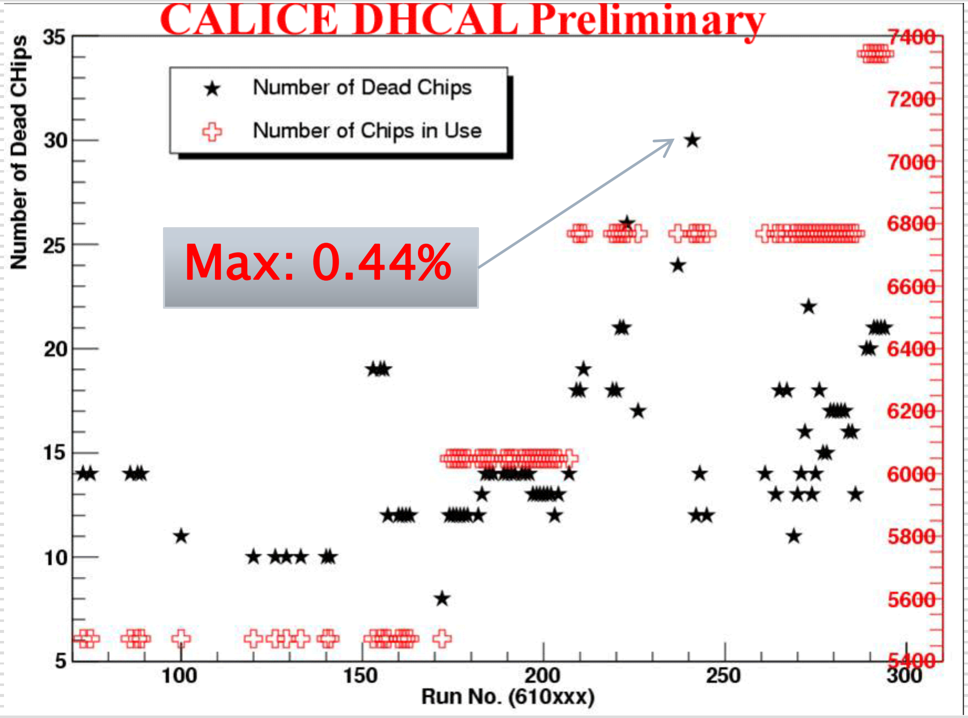
Outline

- ‘Dead’ ASIC’s
- Noise rate monitoring from self-triggered runs
- Noise comparison between self-triggered and randomly triggered runs (just started)
- Noise ‘hot’ spot study

'Dead' ASIC's

- A tiny fraction of the FE asic's will not give any data in any run type: appear to be 'dead'
  - Reason is not clear at the moment
  - Average fraction is only 0.27%
  - They are not 'really' dead (most of them)
  - Their status can change with time and power cycle

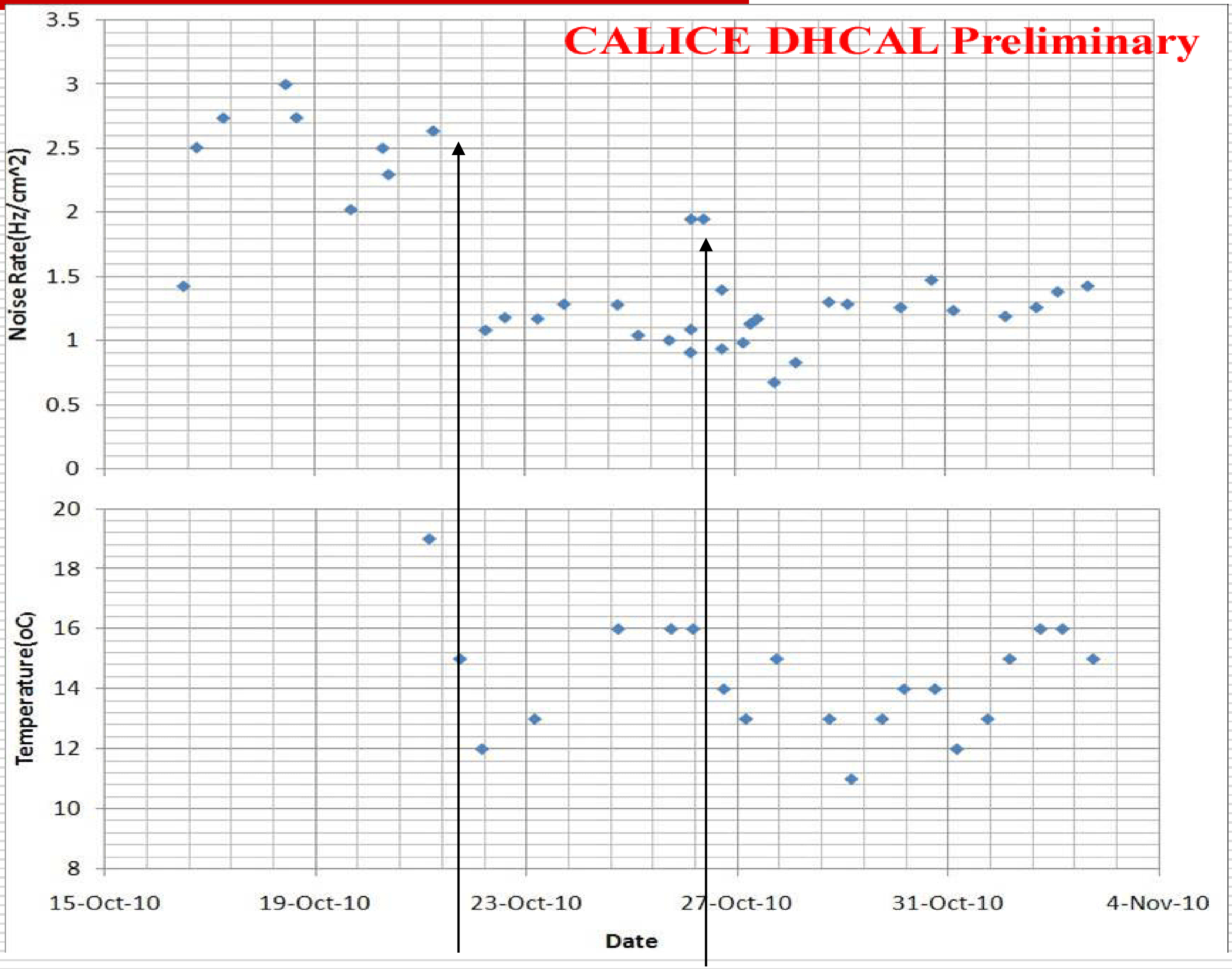




Noise monitoring

- The $1m^3$ DHCal prototype is capable of setting the FE freely running (self-trigger)
  - All FE signals are recorded, up to a certain rate limit (not likely reached without beam)
  - Perfect running mode to record RPC noise
- We use this running mode to monitor RPC noise during test beam campaigns
  - 2+ noise runs per day
  - They monitor the 'health' of the RPC's

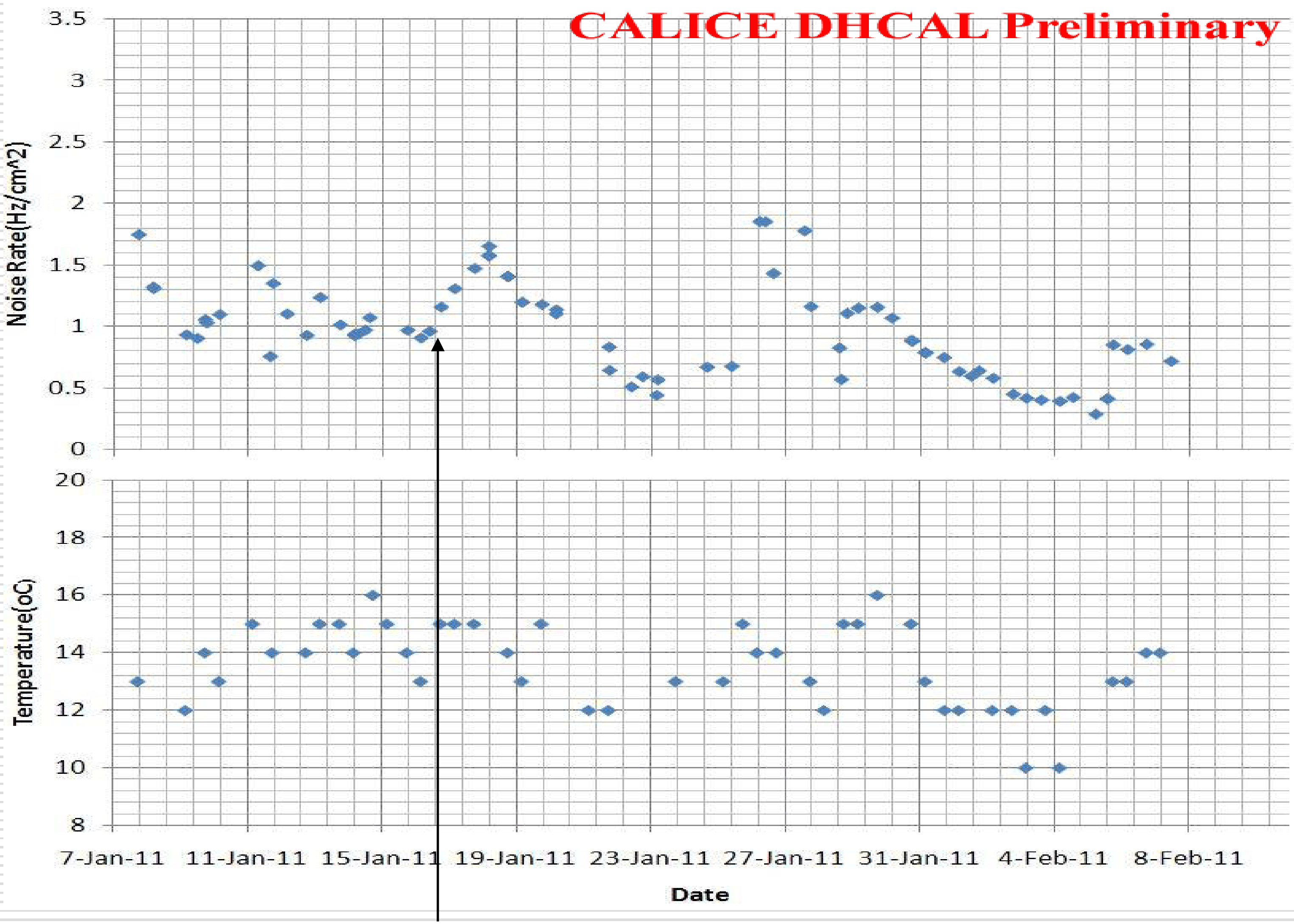
1^{st} run period: 10/2010



Air conditioning fixed

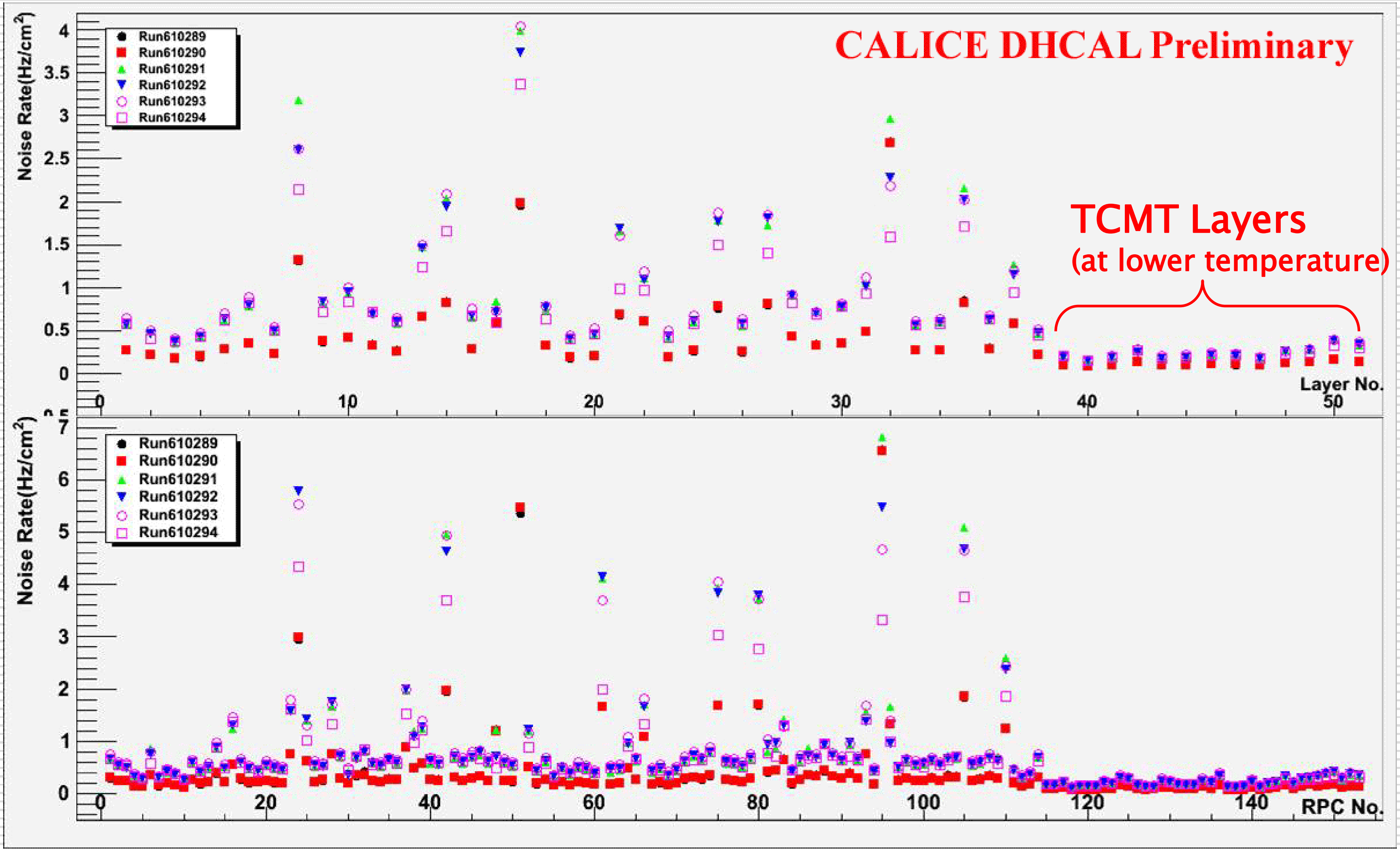
Air conditioning briefly down

2nd run period: 1/2011



Gas flow reduced to 150cc/min, from 300cc/min

Noise rate vs. layers/RPCs



Spikes are due to noisy regions on some RPC's (see later slides)

Noise hit estimate

- Using the measured noise rate, we can estimate the expected noise level in triggered beam data
  - Assume all measured noise in self-triggered runs is from RPC's themselves (not exactly true)
  - Total number of channels in 1m3 + TCMT (51 layers) is 96x96x51 = 470K
  - Method excludes possible correlated noise from other sources
- Noise contribution to triggered beam events is extremely small (almost negligible), even with unexpected high temperature

Table: noise contribution / event for entire system (DHCAL + TCMT)

RPC Noise rate (Hz/cm^2)	0.1	0.5	1.0	2.0	4.0
N_{noise}/evt 200ns gate	0.0094	0.047	0.094	0.19	0.38
N_{noise}/evt 700ns gate	0.033	0.165	0.33	0.66	1.32

Expected noise level for current test beam analysis (→ 0.094)

Expected for a 'cool' DHCal stack (→ 0.0094)

Noise analysis: consistency check

- To study possible correlated noise, we compare self-triggered noise run with randomly triggered noise run
  - Uncorrelated (RPC) noise should behave in the same way in the two run types
  - Noise related to trigger/readout may show up differently in these run types
- Use (time wise) close by runs to avoid effects from temperature change, etc.

	Triggerless Noise run	Random Trigger Run
1st (Monday, 10/25)	610085 (10/25 04:00am) 610086 (10/25 18:10pm)	600047 (started at 10/25 7:31am, ended at 10/25 9:49am)
2nd (Thursday, 1/13)	610179 (1/13 18:06pm) 610183 (1/14 4:26pm)	610180 (started at 01/13 18:20,overnight)

Self-triggered noise run

↓

Noise rate on each pad

↓

Expected hits on each pad: λ_i in a radomly triggered run

⟷ compare ⟷

Randomly triggered noise run

↓

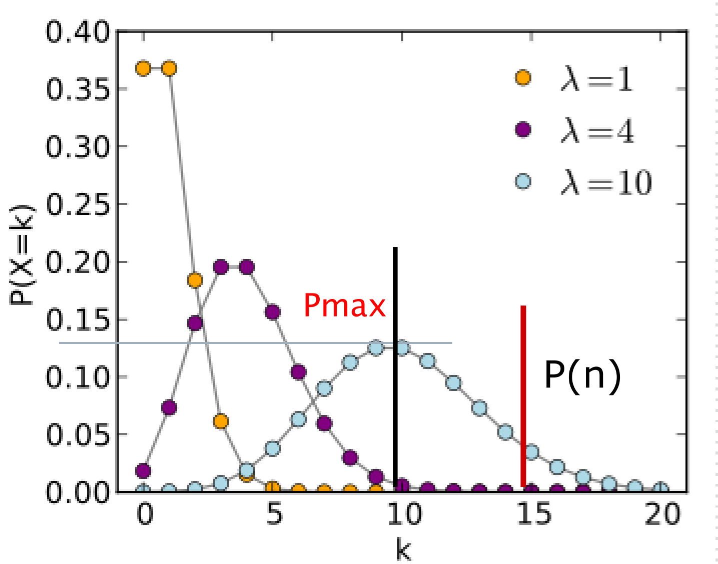
$\mathbf{N_i}$: observed number of hits

Consistency check

- P(n, λ) is the probability of observing n hits when expect λ in a Poisson distribution, as determined from triggerless runs
- Pmax(λ) is the peak value of the same Poisson distribution with a mean of λ
- Define R
  - If $n < \lambda$, $R = -(1 - P(n, \lambda)/P_{max}(\lambda))$
  - If $n \geq \lambda$, $R = +(1 - P(n, \lambda)/P_{max}(\lambda))$

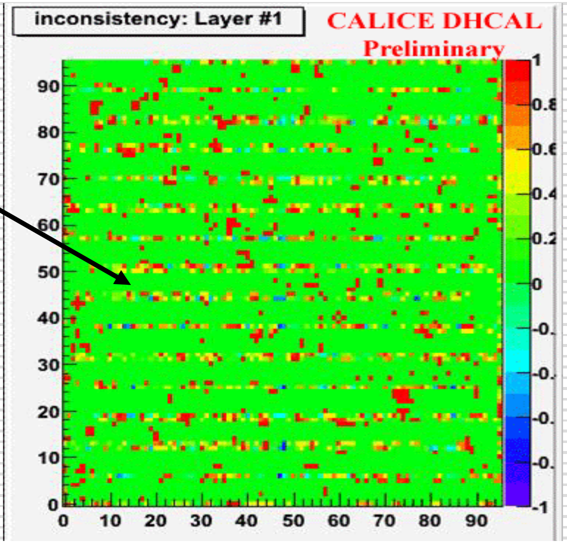
To see the inconsistency explicitly

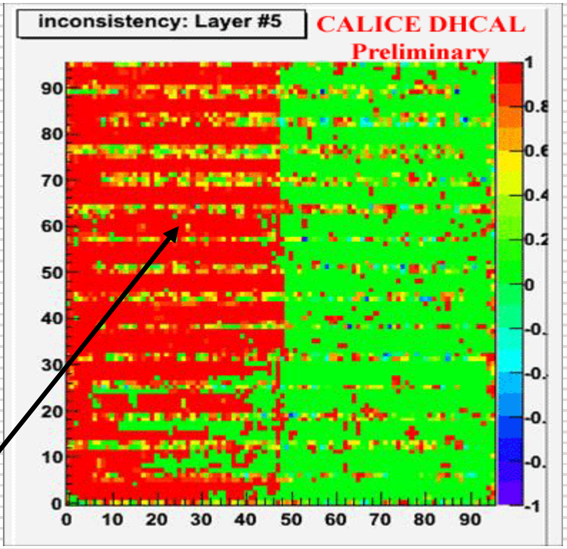
1)If R is close to 0.0, it means n is consistent withλ
2)If R is approaching 1.0, n is too large compare to λ
3)If R is approaching -1.0, n is too small compare to λ



Consistency check

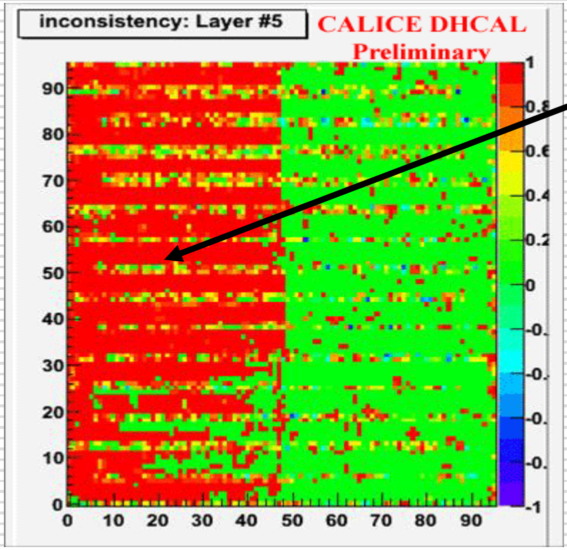
- For most of the layers, the noise levels are consistent
- Several layers show signs of a small correlated noise component
  - Inconsistent regions between two run types
  - Exact mechanism of correlated noise not well understood yet
    - it is grounding related
    - Often contain hits at the ground connector and edges on FE board
    - Often fire a lot of pads
  - Contribution to triggered beam data is at most 'tiny' (and can be easily identified)
- Try to eliminate correlated noise in the randomly triggered runs
  - Filter out events with hits on the boundary between two FE boards
  - Filter out events with hits on the HV ground connector





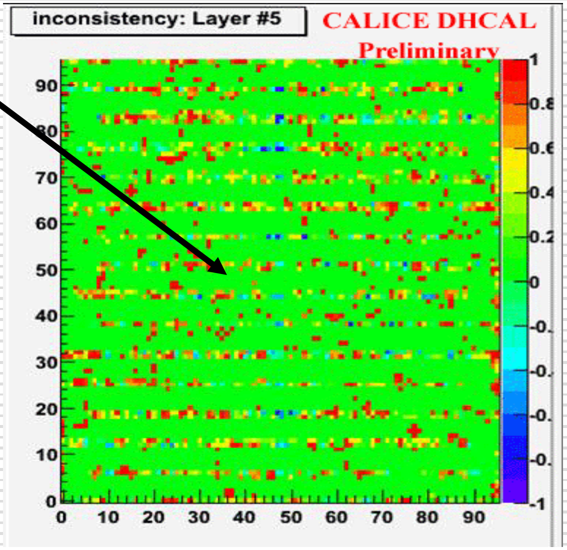
Noise hits in random-triggered run exceeded expectation from self-triggered run

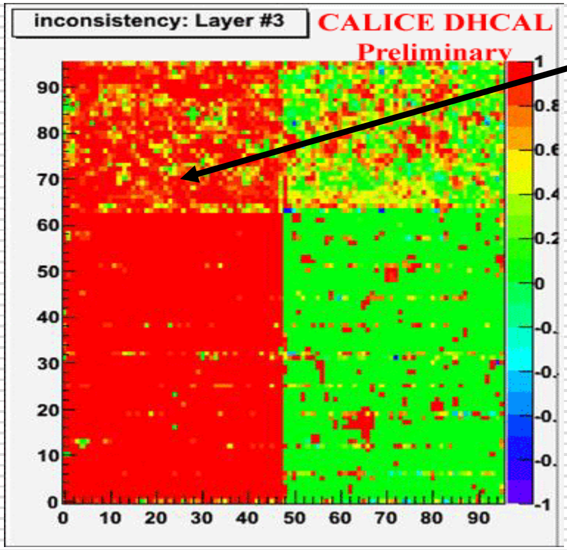
Consistency check: before and after filtering



Suggest correlated noise only in randomly triggered run for these FE boards

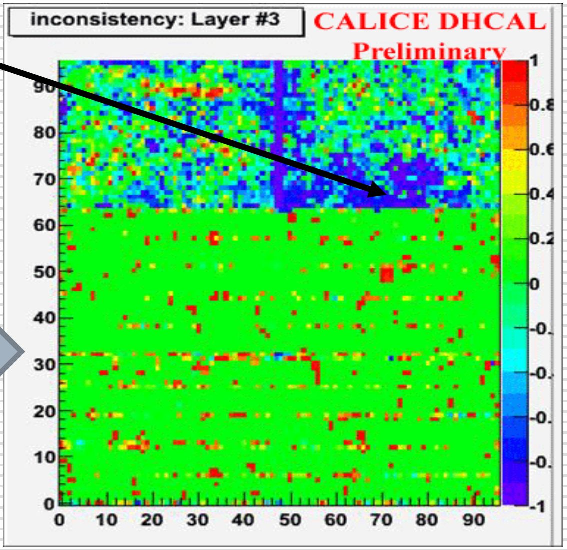
After Filtering



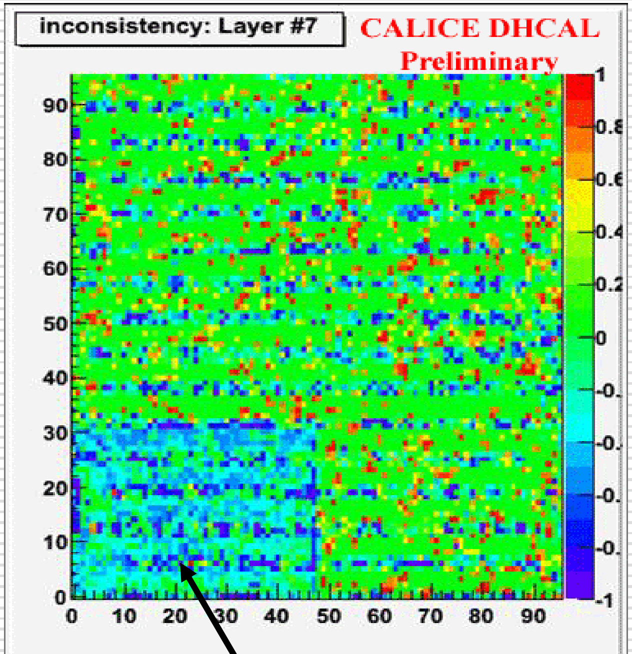


Suggest correlated noise in both run types, but more in randomly riggered runs

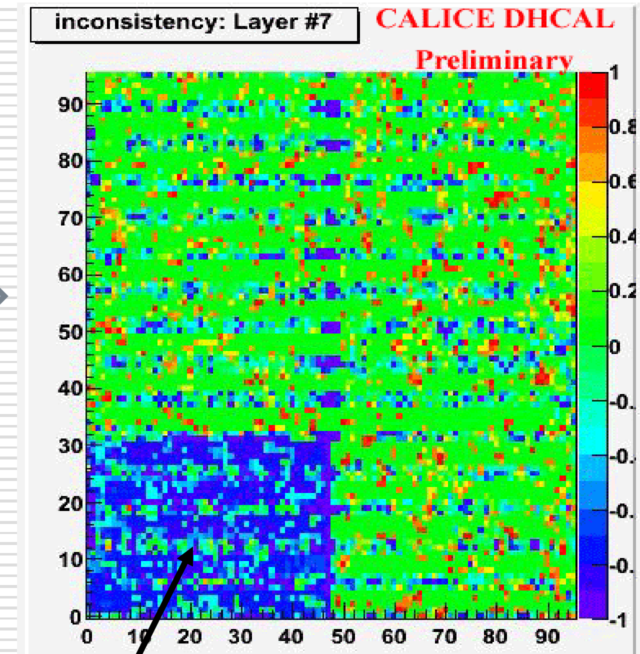
After Filtering



Consistency check: before and after filtering



After Filtering



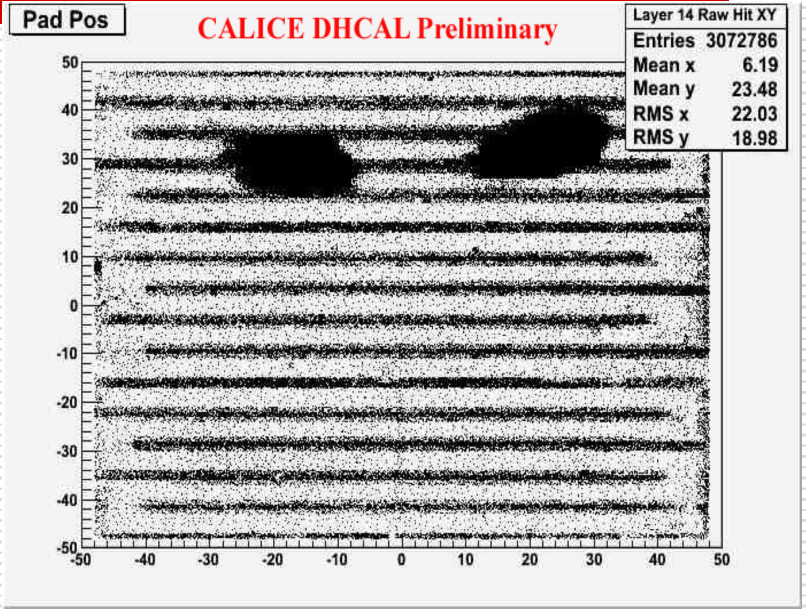
Suggest more correlated noise in self-triggered run

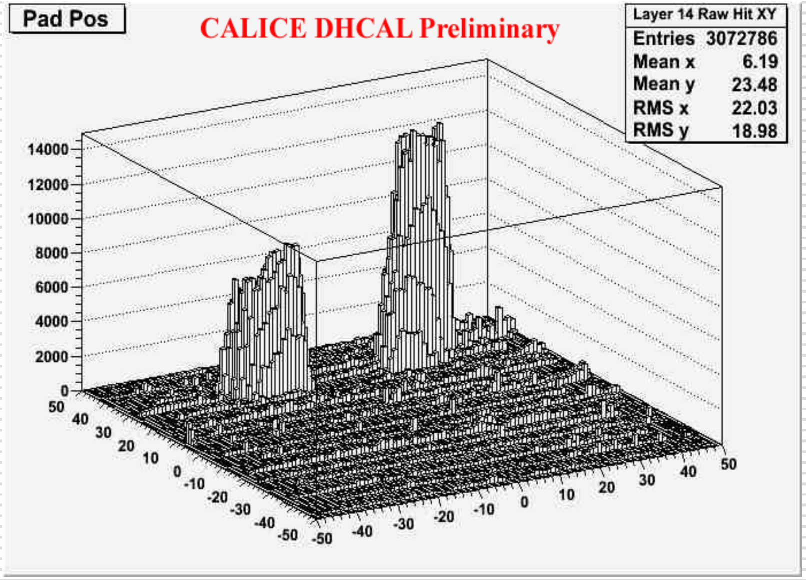
Conclusion

- The study has just started…
- More careful study of different noise categories is ongoing
- The contribution of correlated noise is very small (if not negligible)
- We will set a limit on correlated noise contribution on beam data

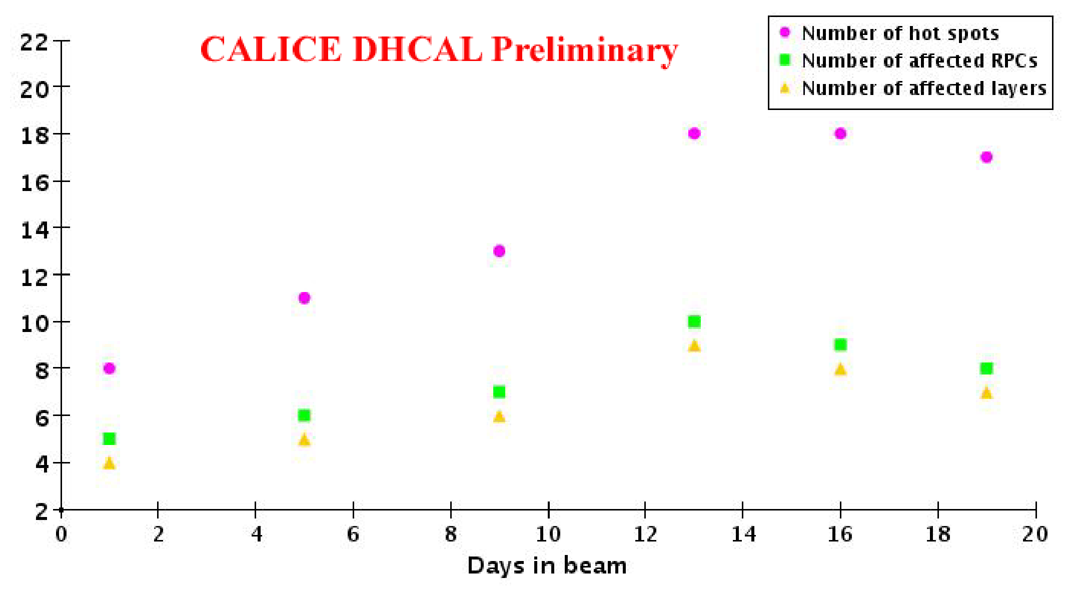
Noise ‘hot’ spot

- Noise ‘hot’ spots are seen in both test beam periods
  - Nearly no visible effect on beam data (a little bit on multiplicity)
  - Significantly worse in 2nd test beam period
  - Varies with time, temperature, gas flow rate, etc.
  - NOT seen in the ‘cooler’ tail catcher
  - (mostly) not seen in cosmic ray test at ANL
- In the worse case, affected 33% of RPC’s during a noise run in $1m^3$



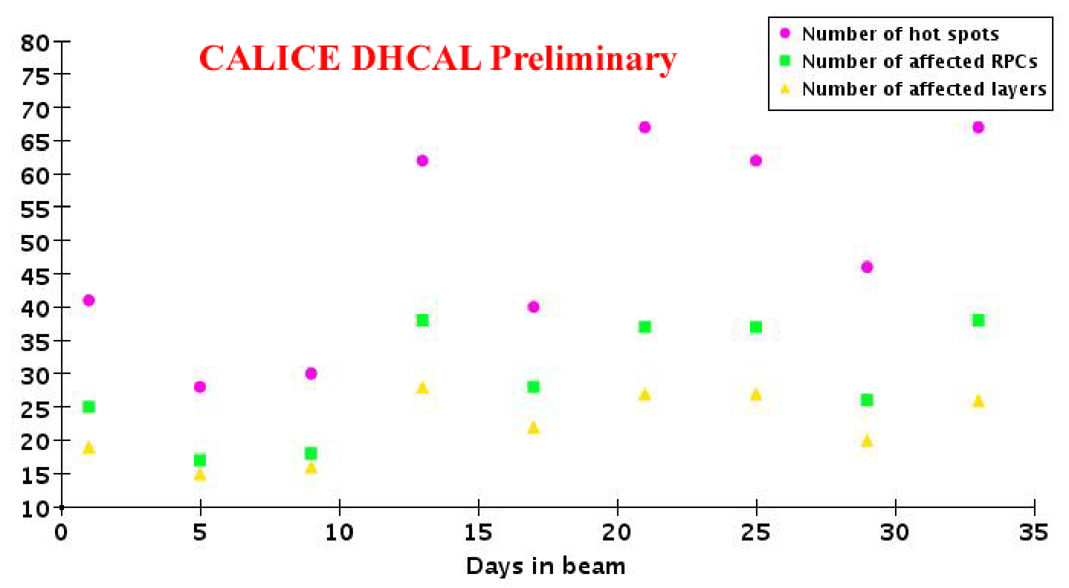


Run history plot



1^{st} run period

2^{nd} run period



Digging into the log books…

- Use one noise run close to the end of 2nd run period
  - Layer affected: 19/38
  - RPCs affected: 27/114
  - RPC positions: top (14), middle (4), bottom (9)
- Track down the producers of the RPCs

	Producer A	Producer B	Producer C	unknown
Affected RPC	14	2	7	4
Total produced	53	39	40	
Fraction	0.26	0.05	0.18	

Conclusion

- This is due to inadequate surface cleaning
- It only shows up with elevated temperature

Summary

- Number of 'dead' asics is very small
- RPC's are in good shape after two beam tests
  - Average noise level is stable
  - Absolute noise level is high due to high temperature
- However, noise contribution to triggered beam data is still extremely small (~0.1 hit/event for entire DHCAL+TCMT)
  - This noise level corresponds to ~6MeV/event
  - RPC contribute negligible noise hits to beam data
  - Correlated noise level needs more study
- Noise 'hot spots' are due to unclean surface
  - Not a problem if temperature is low

Consistency check (alternative)

$n < \lambda$, $P(x<=n)$ --> $R = -P(x<=n)$

$n > \lambda$, $P(x>=n)$ --> $R = P(x>=n)=1-P(x<n)$

1)If $|R|$ close to 0.0, it means n is far from λ

2)If $|R|$ close to 0.5-1.0, it means n is close to λ