Various tasks in data analysis (SiW ECAL at SPS, Nov 2015)

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Some introductory information

- ILC timing: bunches in 1 msec bunch trains, then 199 msec idle time
- In prototype, bunch trains are emulated by “spills” (eg. 4-5 Hz), every period is split into data taking (also called spill) and readout (“dead” time). Eg. for ILC scheme: 1 ms + 199 msec. To increase an event rate at SPS we used much higher duty cycles (eg. 50 msec instead of 199 msec). Note: spill signal is inverted: during data taking the spill generator signal = 0 V, “dead” when =4 V.
- One BX takes 400 nsec (2.5 MHz). BX counter in SKIROC has only 12 bits, after 4096 BX it is recycled to zero. Therefore, only about 1.6 msec can be coded uniquely. Also, the very first BXs are not sensitive. In some runs we were running with such “unique” very short spills.
- SPS spill signal was not used, so both data in AND out of SPS spills have been always accumulated.
- Acquisition number == spill number == spill counter. The spill frequency and duration is available in run configuration *.xml files.
- In SKIROC there are 15 memory slots, called SCA's (or columns), all are used and working well. They are filled in the following order: 1, 2, 3, … (up to 15). The memories are implemented as capacitors (analog memory). In the previous prototype it was checked, that there is no visible charge dissipation, the response to charge injection is linear with the same linearity slope for all SCAs (including the 1st, which keeps the charge the longest). The only “bad” effect which should always be taken into account: pedestals in different SCA's are different.

Some introductory information

- Sometimes, after trigger in BX, the retrigger occurs in BX+1 (sometimes in BX+2,3,4). This efect is related to noise conditions and not fully understood. Note, there may be no triggers in BX+1 (though, BX+1 event is digitized). This is known and expected when the trigger happens close to BX clock edge: the level of OR64 trigger is ON both in BX and BX+1, so both events are written out. Why the (re)triggers may be (re)generated in BX+1 and may continue in BX+2, … is not known. If retriggers continue, the number of triggered channels often grows as an avalanche (up to so-called “plane” events when big fraction of all channels is fired). Fortunately, this effect and noises in general, are small in the new prototype (may be no problem)
- Terminology used in R analysis (sorry, I've never used ROOT):
- event = something triggered within 400 nsec.
  Ie. spill (or acquisition) number + BX, if BX were coded with infinite number of bits. In reality, BX has only 12 bits and this may lead to confusions.
  Note: in some runs we reduced the spill duration on purpose, so that 12 bits are sufficient.
  For other runs: if BX in SCA n+1 drops compared to SCA n, this signals that BX was recycled (4095 → 0). In such cases it is corrected in the simplest way: BX->BX+4096. This is the best one can do, but may well be not correct (SCA n+1 may contain larger BX even in case of recycling, or one should add n*4096 with n>1).
- One file (of dif) == one layer == 16 chips == 16X64 channels == 4 sensors

Analysis tasks: Debugging

- Data corruption checks. Eg. some time ago I've written a C++ program to detect spill blocks corruption (it was used during TB a few times). It may be eg.
    - upgraded to check also an integrity of chip blocks,
    - run through all data to determine corruption rate in each run and add it to Dan's and Kostya's run summary tables.
- There were several variations of running conditions, eg. spill (not SPS) frequency scan, changes of spill duration and duty cycle. One can study the data integrity as a function of those parameters. Eg. it was observed (unexpectedly) that sometimes the last 16th chip and sometimes even the second half of all chips (9-16) were not readout. The other (known) effect is the data corruption when reading out of all chips takes longer than the "dead" (not data taking) time in the spill period (the part dedicated for the readout).
- One may study and compare the ECAL behavior during / out of SPS spills.
- Sometimes we had BX>4095, there may be other similar unphysical data. This requires some debugging..
- Pedestals, known effects: they depend on SCA, there is also a common baseline correlation with the total injected charge, anything else?
- Negative signals (ADC below pedestals)? – such events should normally be removed
- Comparison of continuous and power pulsing modes

Retriggers and noises

- The noise conditions were rather good, but they need to be systematically checked for all data taking period. If there will be any anomalies discovered or eg. any information on why dif2 was noisier than dif0,1, they should be reported to engineers. There may be retrigger / noise dependence on running conditions (frequency of particles, chip load etc.) which may be studied.

Calibration

- It may be interesting to measure nonuniformity of pixel responses (within one wafer and between wafers). Nonuniformity comes from variations of active (depleted) silicon thicknesses AND front-end electronics gains. The latter may be calibrated in the future in the lab with charge injection. With the previous prototype the electronic gain variation was measured at a few % level (around 4%). On the other hand, the thickness is expected to be very uniform (<1%) but unknown → the goal is to calibrate MIPs with an accuracy better than 1%
- Calibration may be done with muons and pions (pion showers should be removed). Do not forget about slight dependence on the particle energies due to logarithmic relativistic rise in Bethe-Bloch dE/dx formula. This can possibly be measured.
- Stability with time.
  Check also for day-night variations (temperature), other correlations?
- Double (second) MIP peak – extra tool for calibration and cross checks
- Uniformity and stability should be a big advantage of the Si detector, it greatly simplifies calibration and reduces all systematic errors. This should be demonstrated to full extent.

Efficiency

- There were several MIP measurements with different thresholds. One can plot the corresponding MIP spectra and see to which extent the thresholds cut left part of MIP signals. An example of such an analysis may be found in e-log (thresholds 200 and 230 for a few channels).
- The threshold scan was also done when Si sensors were turned by about 45 degrees and MIP increased by sqrt(2). In this case the MIP signal should be well above the minimal threshold. Using the threshold scan data, the trigger efficiency at higher thresholds may be measured, see an example of such an analysis (“S-curves”) in e-log.
- Using the same 45 degree data one can extrapolate to 500 um thick Si sensors. They may be used in the future prototypes (even 700 um is planned). Note, SKIROC is not optimized for such thick sensors, but signal is larger, capacitance is lower and sampling fraction is better.
- Efficiency measurement. This requires the track reconstruction in two layers (coincidence in space and time), then one can look at the efficiency in the third layer. Note:
    - BX in different layers may be different by 1. Normally, one layer may be slightly slower and one slightly faster. Ie. the faster layer may have BX or BX+1, the slower BX or BX-1, while the third has BX. This is to be checked.
    - SKIROC memory is limited to 15 slots (SCAs). When the memory is full, the chip is “dead”, but this should be distinguished from inefficiency due to trigger threshold.

Any other use of reconstructed tracks?

Data when beam is parallel to sensors

- In the end of the test beam the ECAL was turned by 90 degrees, so that the beam was passing through one layer parallel to the sensors plane.
  Note:
  - other layers were far from the beam in this configuration.
  - With pions there were hadronic showers due to Aluminum plate which was also parallel to the beam.
- However, in one layer there was a clear peak corresponding to MIPs passing through 5.5 mm of Si == pixel size. A preliminary analysis may be found in the e-log. I've even seen about 50 events when one particle passed in this way through all 16 pixels (ie. maximally, through 2 sensors == 16*5.5 mm of active Si).
- One can analyze this data and think about other possible measurements (eg. efficiency of 5.5 mm Si should be close to 100%)

e+/- showers

- With only 3 ECAL layers the number of measurements is rather limited, however, one can think of a few studies below and, for sure, there may be other ideas.
- Fractal dimension measurement, for e+/- and pi+/-. Here, one fully uses the transverse granularity. This may be a first measurement of the fractal dimensions in electromagnetic showers with data.
- There were scans in energy and in the absorber thickness. One may study and compare with MC:
  - total number of hits / energy versus e+/- energy at various points in longitudinal shower direction (absorber thickness);
  - radii of the transverse core / tails of the showers versus energy / absorber;
  - possibly: invent other (not so common) variables characterizing showers in the transverse plane; in the past the transverse description of the showers was not addressed at this level of details (this ECAL has a record granularity), so one may expect that new useful descriptions / variables may be invented;
  - correlations between layers, especially when there were no W in between

e+/- showers

- Saturation of front-end electronics at the highest e+/- energies – important for ECAL systematics; the question is to which extent the saturation curves are needed and may be calibrated (possibly, with charge injection in the lab).
- Characterization of guard ring “square events”, when large energy deposition at the sensor guard ring provoke triggering of all peripheral pixels due to capacitive coupling.
- A new effect, not known before: under high load (either big number of hits or large total energy deposition) the chip triggers not in BX but in BX+1. This results in lower occupancy in BX compared to surrounding chips. See the entry in the e-log about this effect. It should be studied in detail and characterized.
- Correlations between SKIROC channels

pi+/- showers

- Should be similar to e+/- except lower energy depositions and wider showers. Eg. measurement of hadron shower fractal dimensions, may be clearer correlations between the layers.
- Can we sometimes distinguish electromagnetic pi0→gamma gamma components in the transverse view?
- Comparison of the transverse shower cross sections with GEANT4 models?

Conclusions

- Contributions to MC prototype description and simulations are highly welcome
- (At least) two sets of tools for analysis: ROOT and R
  1. Cross-checks
  2. Competition?
- Proposal: to compare and x-check the results, it is advantageous (and even necessary) to provide full details on data set + selection + algorithm.
- Regular meetings / information exchanges.
- Common use of Twiki Analysis pages: everybody is encouraged to fill Twiki with full details of her/his studies.
- Common publication in the end.