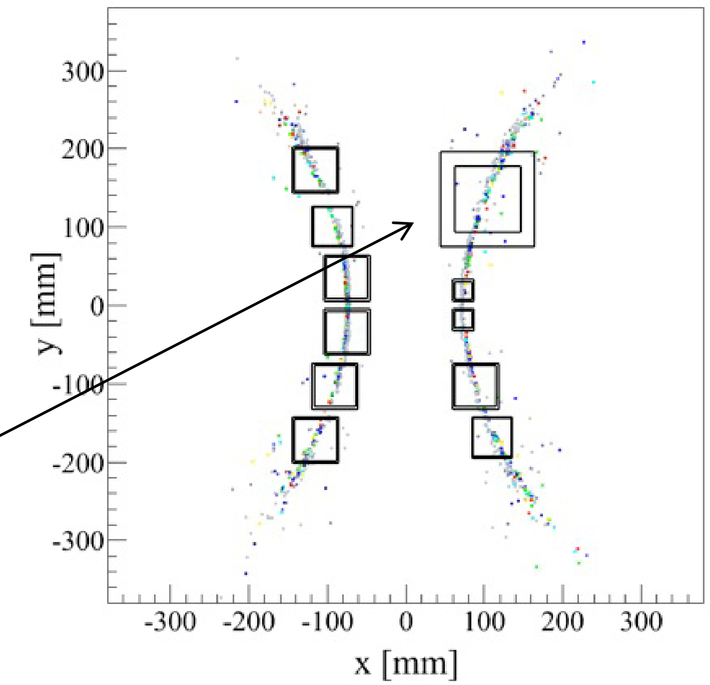
Status of the CERN test beam data analysis for the SiPM prototype

Austrian Academy of Sciences

T9 test beam at CERN

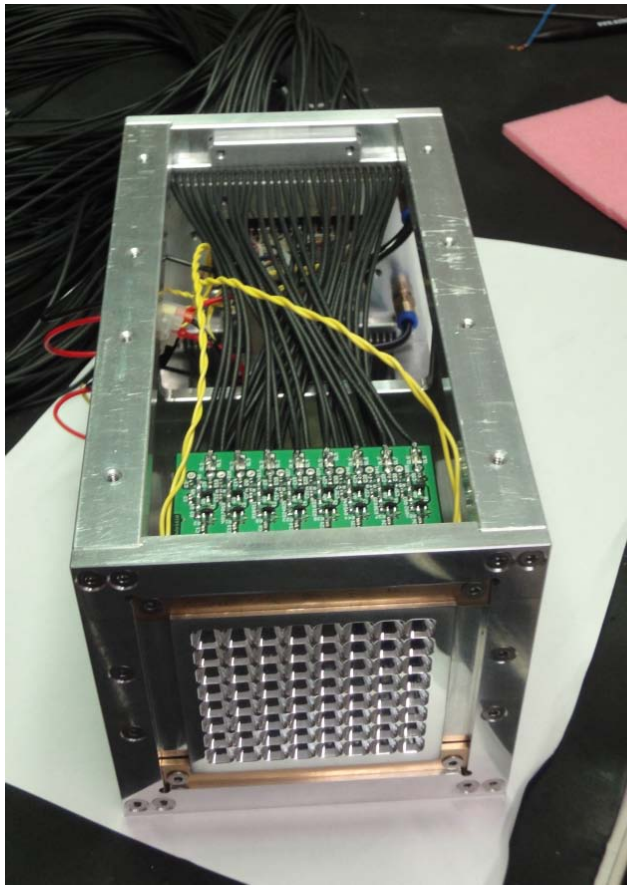
- Setup
  - Photo sensors are attached to an expansion volume (oil tank)
  - Our prototype sitting on the right upper corner



- SiPM prototype
  - 8 x 8 SiPM array (5.6 x 5.6 cm² detection area)
  - 64 Hamamatsu MPPCs (3 x 3 mm², 100 x 100 µm² pixel size)
  - 4 preamplifier boards with 16 preamplifiers each
  - Water- and Peltier cooling
  - Light concentrator on top of the sensors

Table 1. Main parameters of the light concentrator.

Parameter	Design value
Dimensions (L x W x H)	65 mm × 65 mm × 4.5 mm
Detection area	56 mm × 56 mm
Number of cells (funnels)	64
Funnel entrance aperture	7 × 7 mm^2
Funnel exit aperture	3 × 3 mm^2
Funnel height	4.5 mm
Fill factor (incuding rim)	69 %
Fill factor	93 %
Basic material	Brass
Coating	Aluminum, Chromium



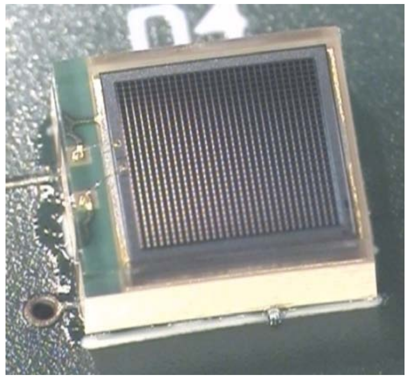
SiPMs for DIRC

		PMT	MCP-PMT	SiPM
PDE	Blue	20%	20%	50%
	Green - Yellow	40%	40%	40%
	Red	≤ 6 %	6%	30%
Time precision		100 ps	≤ 100 ps	130 ps
Gain		10^6	10^6	10^5 - 10^6
Threshold sensitivity		1 p.e.	1 p.e.	1 p.e.
Dark count rate		Hz - kHz	Hz/cm²	MHz/cm²
Operation in magnetic fields		< 10^{-3} T	< 2 T	Yes
Operation voltage		1 kV	3 kV	< 100 V

• Facts

- SiPMs have many advantages
- The main drawbacks of SiPMs are the small active area and the high dark count rate of several MHz at room temperature (for 3 x 3 mm² MPPCs)
  → challenge for single photon application like DIRC
- However, cooling and precise time information helps to reduce the dark count rate dramatically

MPPC S10931-100P



• Our approach for the test beam

- Since we had a combined setup (MCPs and SiPM) we had to find a compromise for the operating parameters (temperature, threshold)
- We cooled the detectors to ~10-15 °C and used nitrogen to avoid condensation inside the box
- Light concentrator on top
  → increased detection area
  → increased signal to noise (dark counts) ratio
- Rather low operating voltage to minimize dark count rate
- Eventuelly use timing from other detectors/simulation to improve S/N
- Since the prototype was assembled only a few days before the tests, we didn‘t have time for extensive tests in the lab and therefore our first goal is to see a Cherenkov signal/ring in the large background

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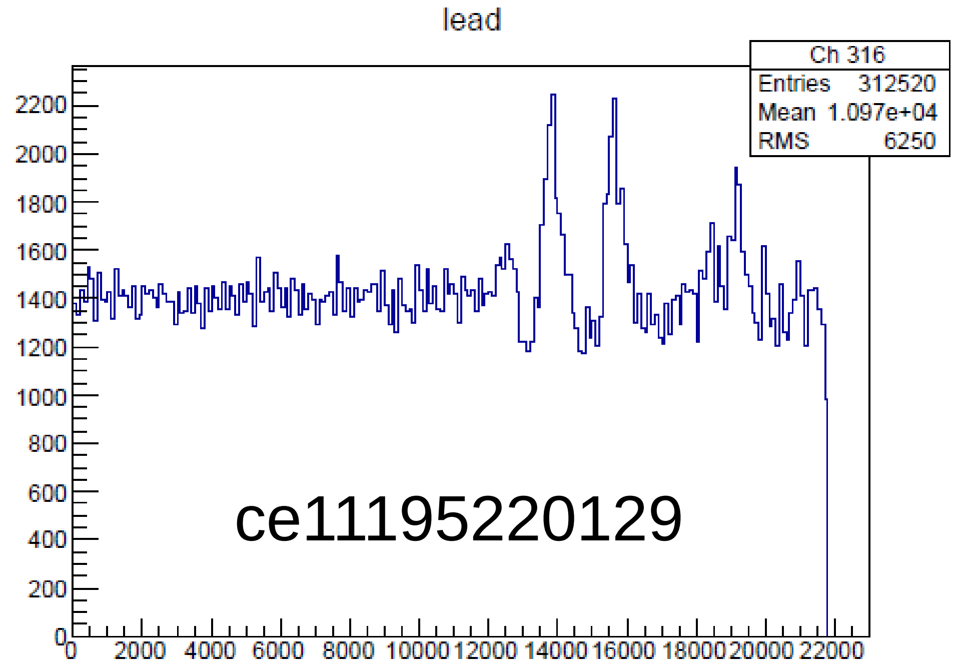
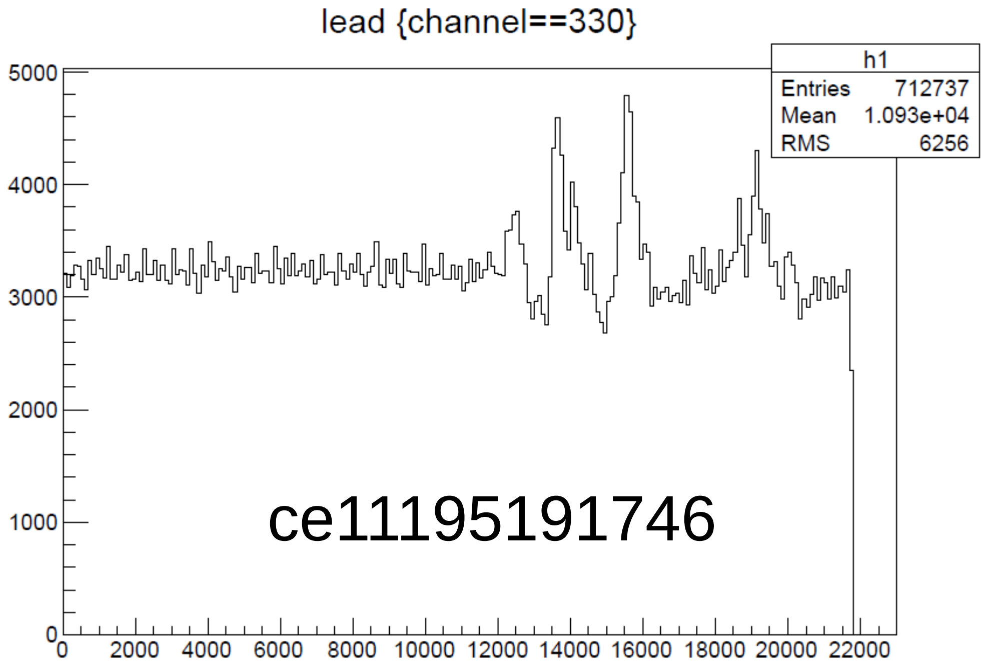
Data analysis results

- Timing histograms
  - When looking at specific runs we see peaks in the timing histograms
  - Timing seems to be more or less correct (compared to MCPs)
  - Why do we see two or more peaks?





  - Peaks could be real
  - Peaks could be crosstalk (from channels on same NINO, TDC, TRB)
  - Peaks could be some noise (electronics noise, we saw noise from preamp)

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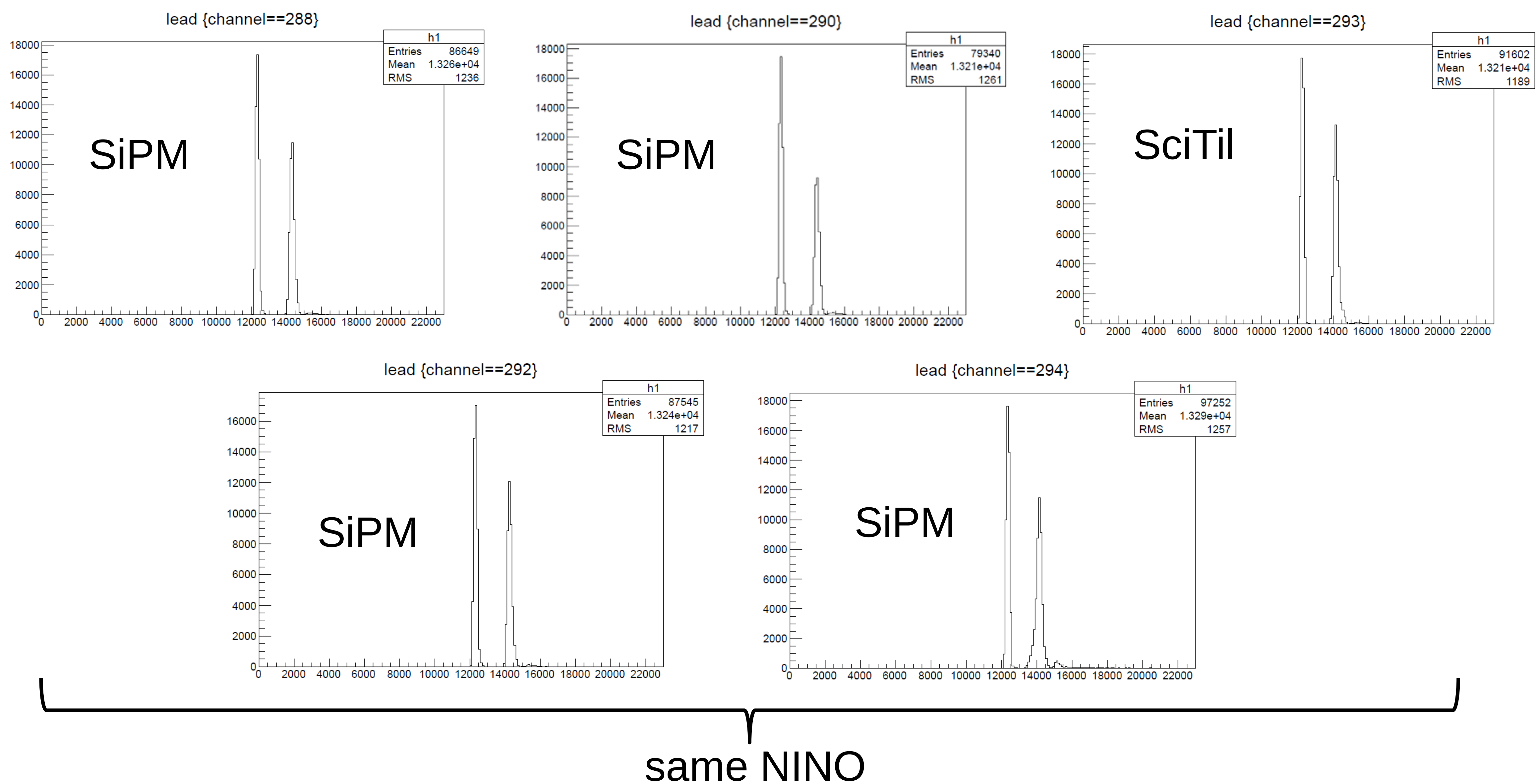
Crosstalk check

- Crosstalk within NINO chip
  - There is crosstalk within a NINO
  - Looking at run ce11195120115: our preamp off, SciTils connected to TRB2
  - We see SciTil signal although our voltage is off



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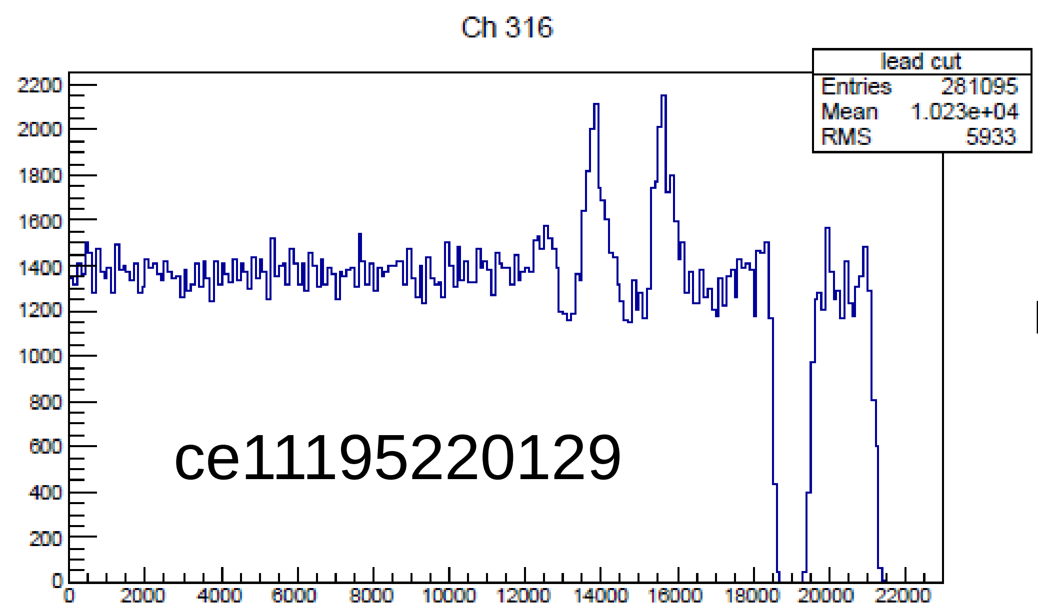
Crosstalk check

- Crosstalk within NINO chip
  - Since we shared TRB2 with MCPs, our peaks could be crosstalk
  - This could be checked by applying a cut saying: Only one hit per NINO per event, or only one hit per NINO per event within a specified time window

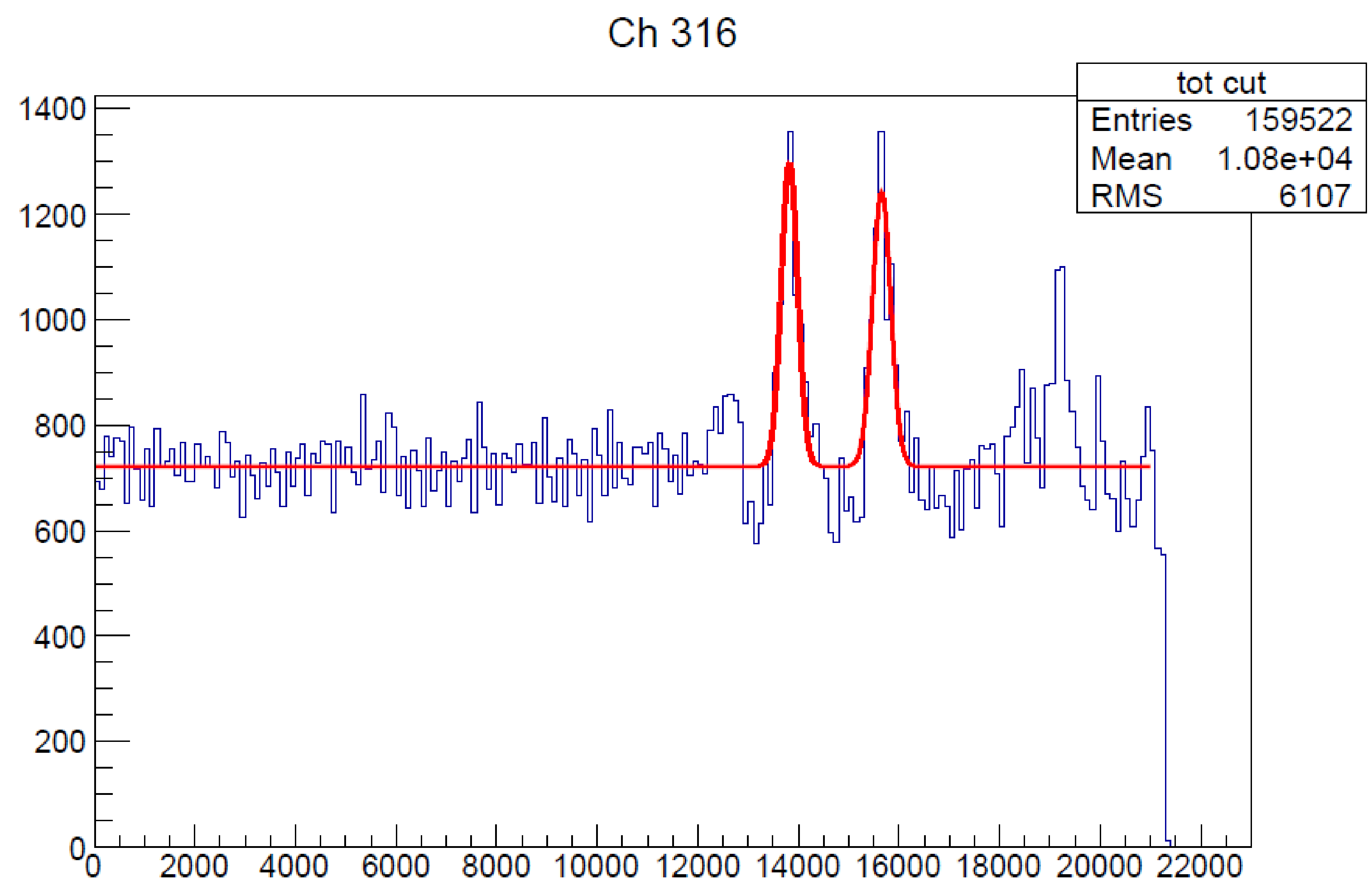


➡ Peaks remain

- Crosstalk within TDC/TRB
  - Rather unlikely, since we don‘t see crosstalk from SciTils on neighbouring NINOs

Data analysis results

- Occupancy plots
  - Try to produce occupancy pattern of the detector to see if the peaks are real
  - Subtracting continuous background coming from dark counts



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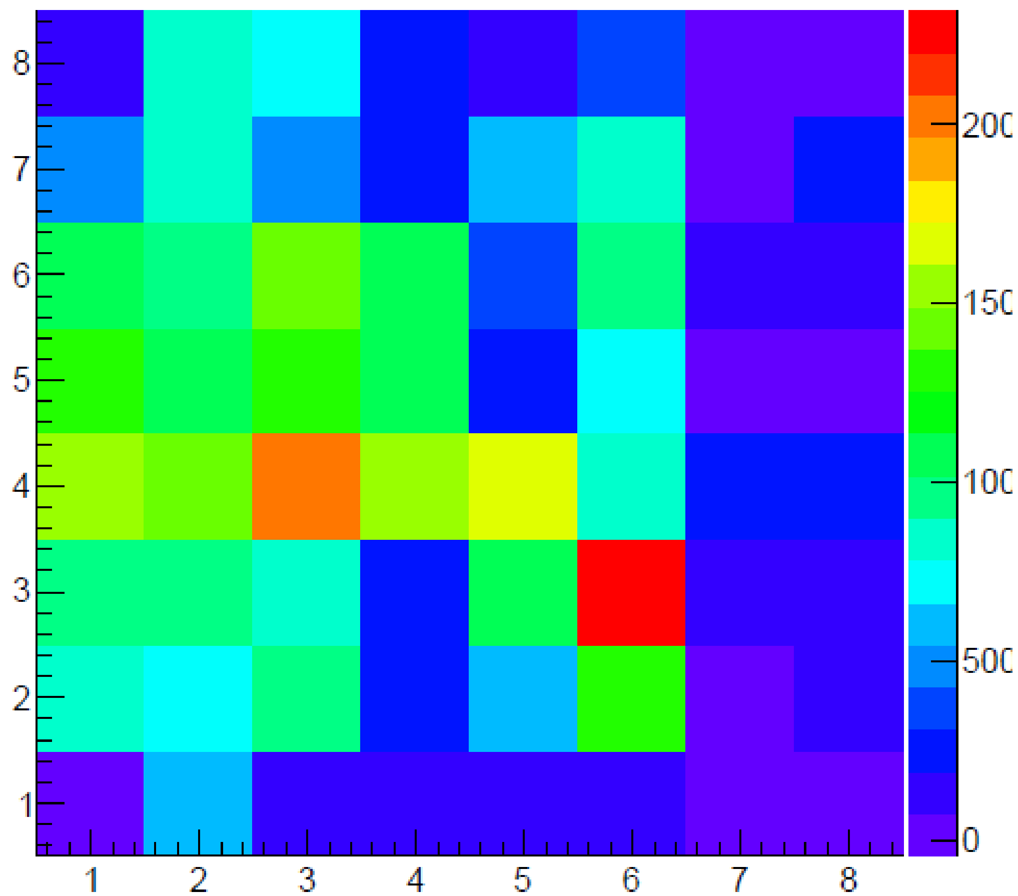
Occupancy plots



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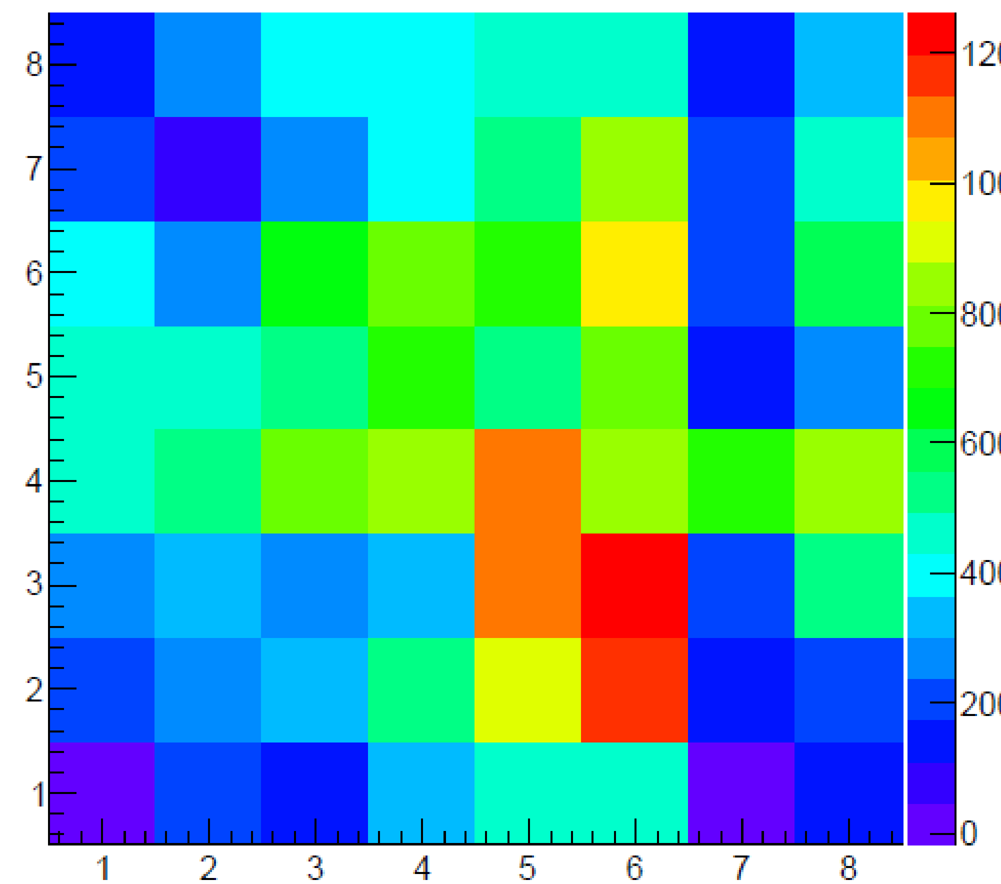

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- We might see a ring, but ....
- Still not 100% sure

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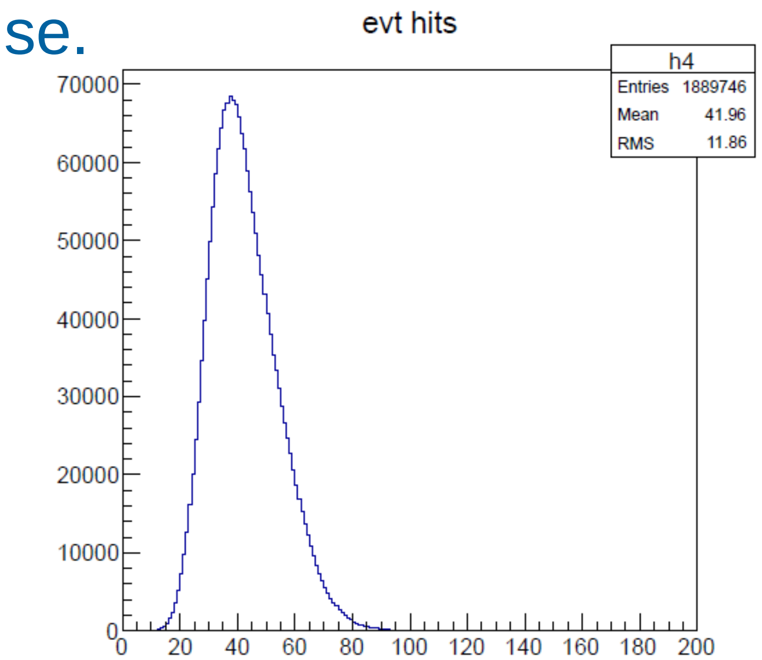
Summary

- Our first goal is to see the Cherenkov light within the large background coming from dark counts, crosstalk, electronics noise.

- This is challenging since we expect on average only a few (2-3) photons per event (0.2-0.3 per event on our detector), while we have 40-50 background hits per event on our detector.



- There‘s a clear evidence for crosstalk within a NINO chip. This problem is understood and should be worked out. The peaks we see still remain after applying a cut.

- The noise situation was unfortunately rather bad and we couldn‘t solve it completely during the beam time.

- We might see a Cherenkov ring on the detector, but we still cannot be a 100% sure since there are several open issues, namely
  - Why are there two or more peaks?
  - Unknown crosstalk

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Outlook

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- Data analysis
  - The signal we see is a sum of “real“ signals and background. The background dominates and comes from dark counts, crosstalk and electronics noise. We need to understand the single contributions and get a better feeling how much they contribute to answer open questions.
  - A precise prediction of the photon arrival time for each pixel (simulation by Roland, Carsten) could help to increase the signal to noise ratio and see a clear ring.
  - We still have the data we took with our waveform digitizer that are not yet analysed.

- Things to improve (for future measurements)
  - We have to further reduce the dark count rate (go to lower temperature).
  - Stable operating conditions (temperature, operating voltage) must be established. A system that controls and regulates the bias voltages would help. Cooling is crucial. A stable cooling system is mandatory. We had problems with our water pump during beam time which led to failures of the cooling system.
  - Noise from electronics has to be reduced to a minimum and should be smaller than the 1 p.e. signal of 2-3 mV (proper grounding and shielding).