Summer program project at DESY

Studies of the front-end electronic of the AHCAL

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LAL Meeting

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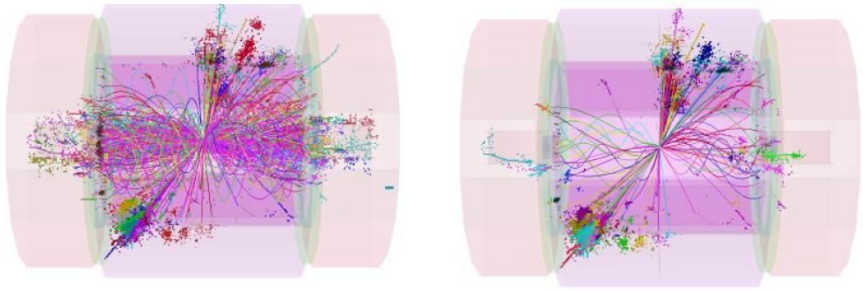
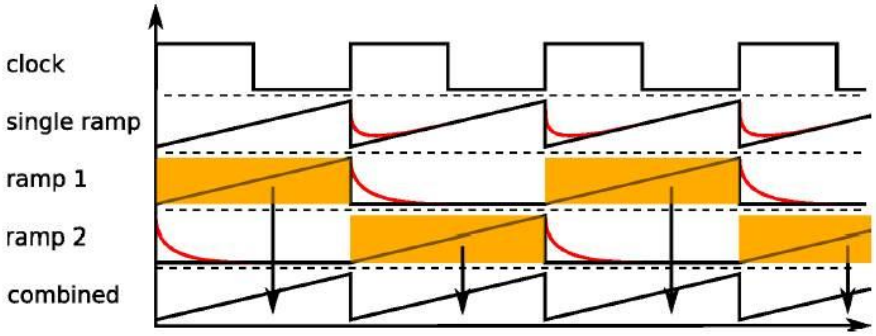
Contents

TDC Measurements

Goal of time measurement and working principle

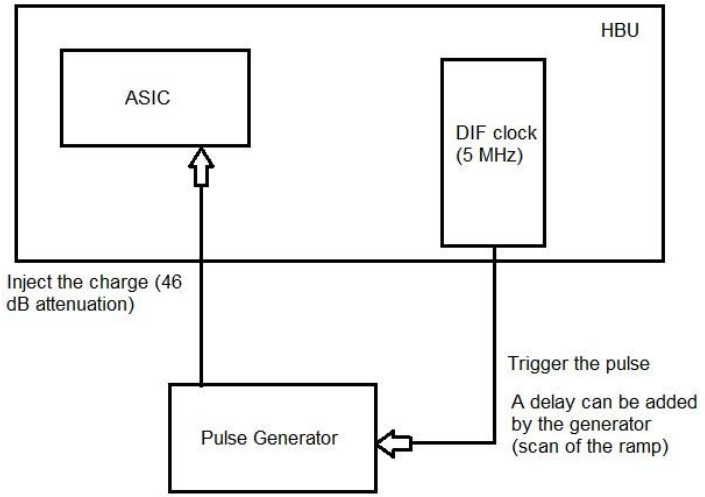
- Improve the resolution of the detector
- Time cut for overlapping showers
- Working principle :
  - Dual TDC ramp in SPIROC switch by a multiplexer





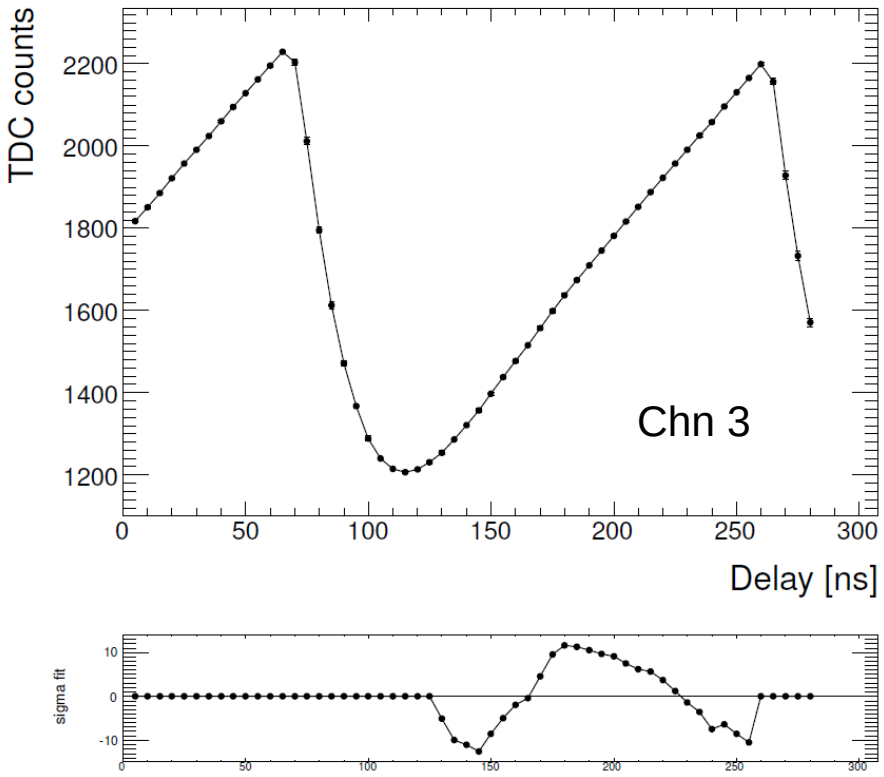
Setup

- One HBU with DIF board, Calib board and Power board
- Charge injection : pulse generator synchronize to the clock
- LED : use of LCS by Labview software
- Measurements : 100 cycles and 16 triggers (for good statistics)



ILC mode

- 5 MHz clock cycle = 200 ns ramp length
- Design resolution : 100 ps
- Scan of the ramp by variation of the delay between trigger and pulse output (done by step of 5-10 ns)
- Comparison between channel 3 and 4

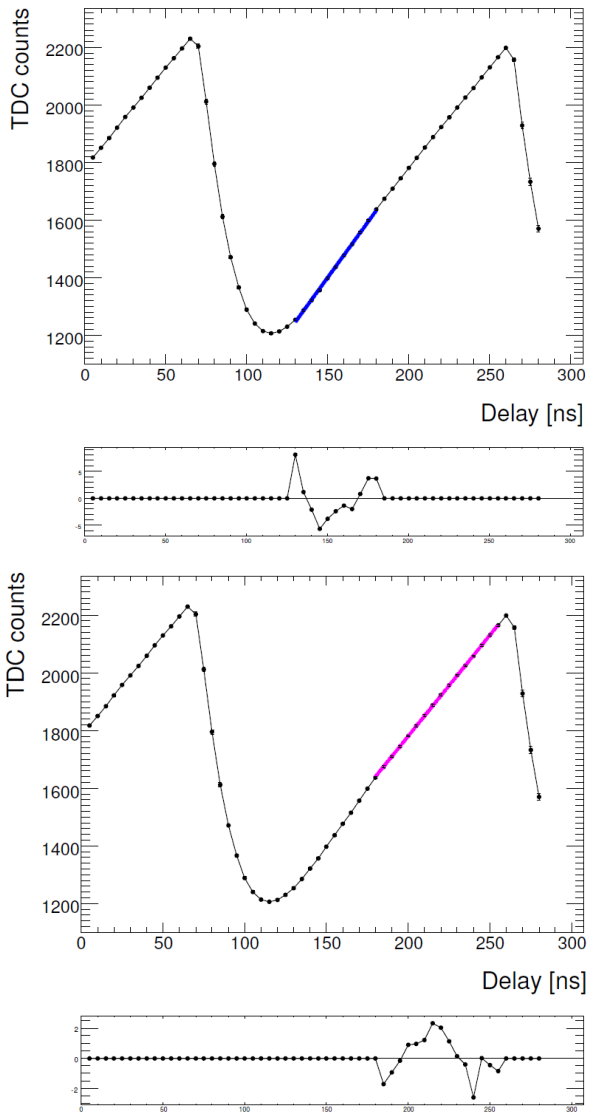


ILC mode

- Fitting by a 1st polynomial function
- Resolution :

$$\sigma_{tot} = \frac{\sqrt{\sigma^2_{histo} + \sigma^2_{fit}}}{slope_{fit}}$$

- Several method : middle of the ramp :
  - Lower part
  - Upper part
  - All the ramp



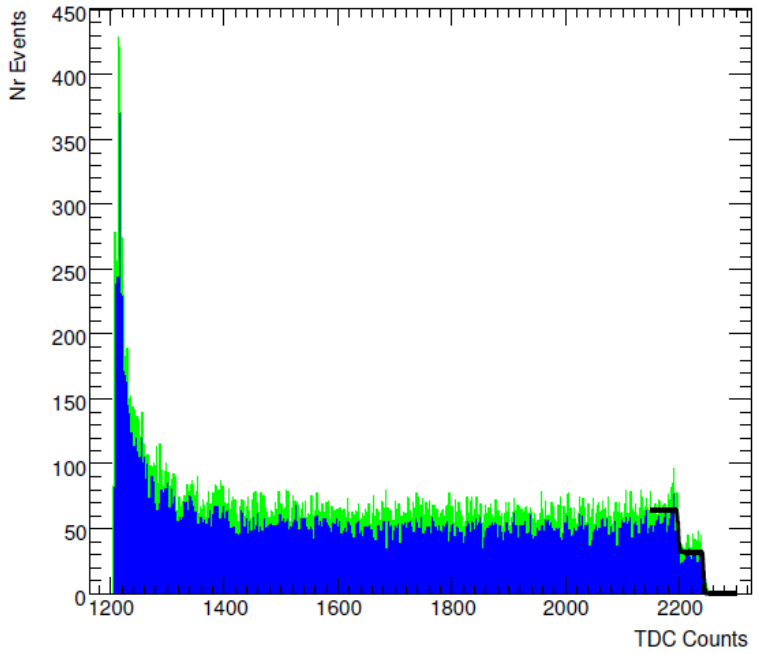
Results Table

- Average Resolution : 150-350 ps
- Far from design
- Need to improve by increasing the ramp slope

Channel	Ramp	Part	σ_{fit}	Slope	σ_{tot} [ns]
3	1	lower	1.60	7.65	0.21
3	1	upper	1.12	7.03	0.16
3	2	lower	0.87	7.42	0.12
3	2	upper	0.54	6.80	0.08
3	1	all	3.20	7.35	0.436
3	2	all	2.52	7.14	0.354
4	1	all	0.67	6.91	0.1
4	2	all	3.15	7.33	0.43
4	2	lower	2.6	7.75	0.34
4	2	upper	0.76	7.01	0.11

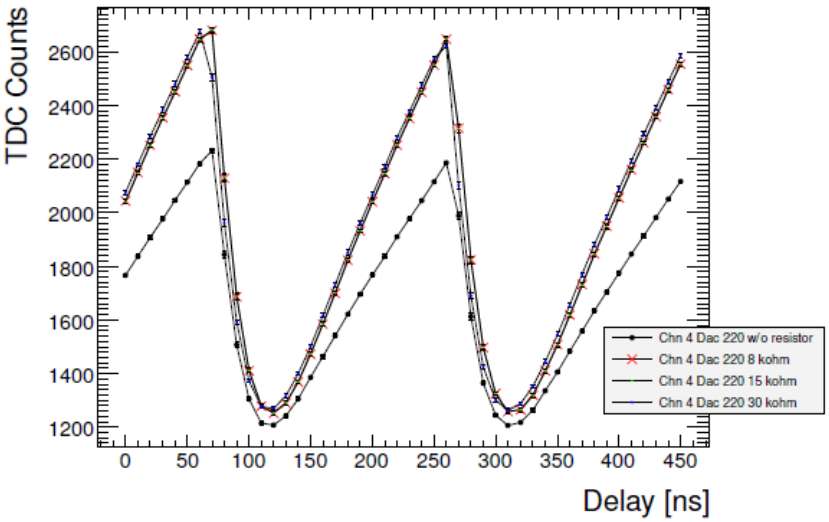
Spectrum

- Fire random pulse with the pulse generator give a TDC Spectrum
- Characterize the ramps : height and deadtime
- Deadtime : 35% of the ramp length
- Height difference : 45 TDC tics



Improvement of the resolution

- Soldering resistor on the slope bias point
- Range from 30 kΩ to 8 kΩ
- Improvement by factor of 1.2-1.5
- Results Table : 8 kΩ (left) and 30 kΩ (right)

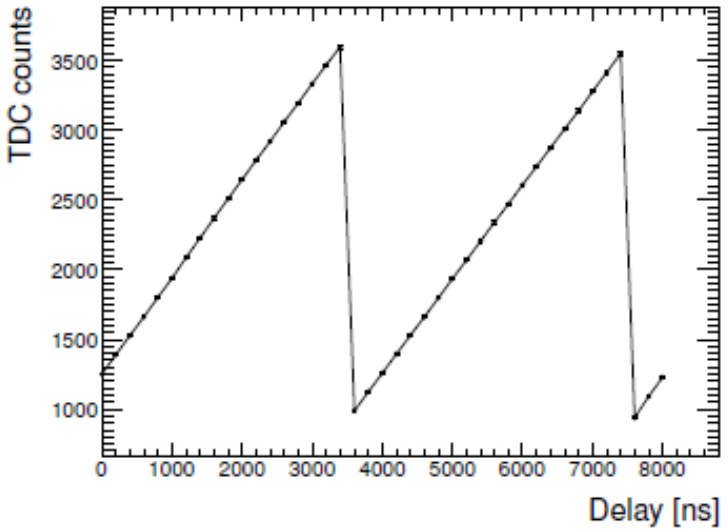


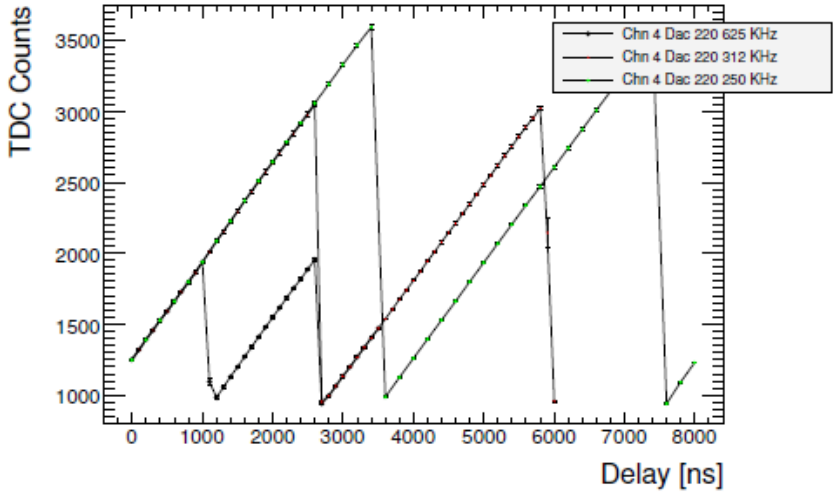
Channel	*Ramp*	*Part*	σ_{fit}	*Slope*	$\sigma_{tot}[ns]$
4	1	*lower*	0.13	11.33	0.018
4	1	*upper*	1.87	10.38	0.18
4	2	*lower*	0.2	10.30	0.02
4	2	*upper*	2.36	10.24	0.23
4	1	*all*	2.00	10.84	0.19
4	2	*all*	3.44	10.46	0.33

Channel	*Ramp*	*Part*	σ_{fit}	*Slope*	$\sigma_{tot}[ns]$
4	1	*lower*	2.5	11.32	0.22
4	1	*upper*	2.01	10.22	0.19
4	2	*lower*	2.95	10.63	0.28
4	2	*upper*	1.58	10.08	0.16
4	1	*all*	4.03	10.79	0.37
4	2	*all*	2.65	10.43	0.25

Testbeam mode

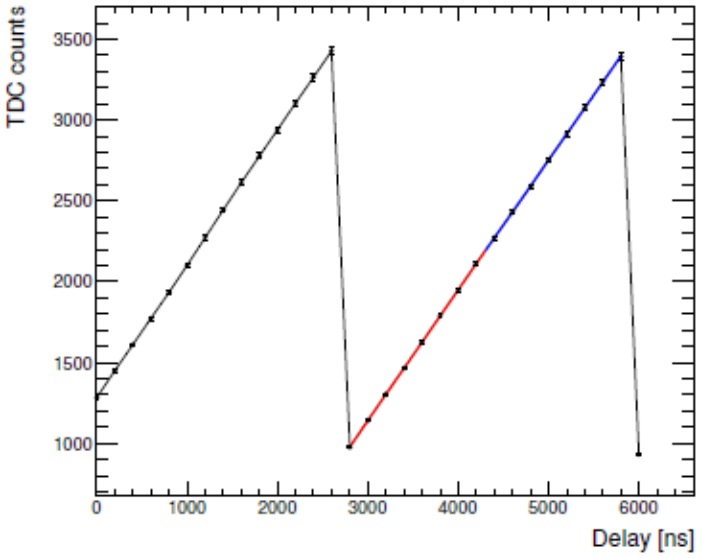
- Different clock frequency (can be chosen – 200 kHz to 625 kHz)
- Step of 200 ns
- Comparison function of the frequency :
  - Dynamic range (2000 TDC tics at 250 kHz against $<$1000 TDC tics at 625 kHz)
  - Deadtime (relative to the frequency – less deadtime at low frequency)

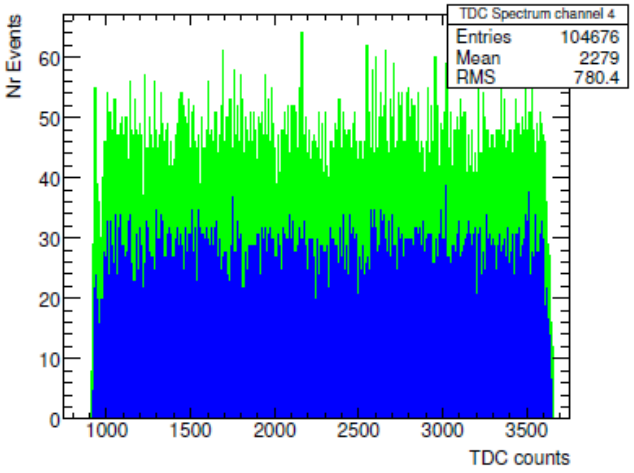




Testbeam mode

- Same fitting as in ILC mode
- Problem with the pulse generator at 2 μs – decrease the resolution
- Spectrum : flat distribution – no deadtime apparent and no height difference
- Improvement of the resolution :
  - Soldering a 120 kΩ resistor at 312 kHz (to avoid a saturation of the TDC)
  - Results : Better dynamic range and resolution roughly increased





Results

- Table results :
  - 250 kHz

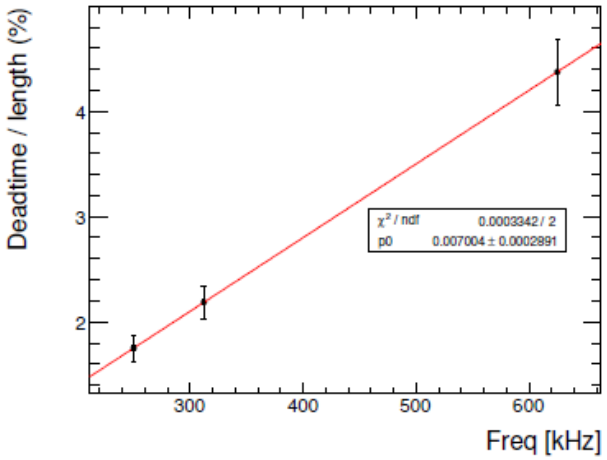
Channel	Ramp	Part	σ_{fit}	Slope	σ_{tot} [ns]
4	1	lower	1.06	0.698	1.53
4	1	upper	0.39	0.682	0.61
4	2	lower	0.59	0.674	0.91
4	2	upper	0.51	0.671	0.79
4	1	all	2.92	0.695	4.21
4	2	all	0.49	0.673	0.78

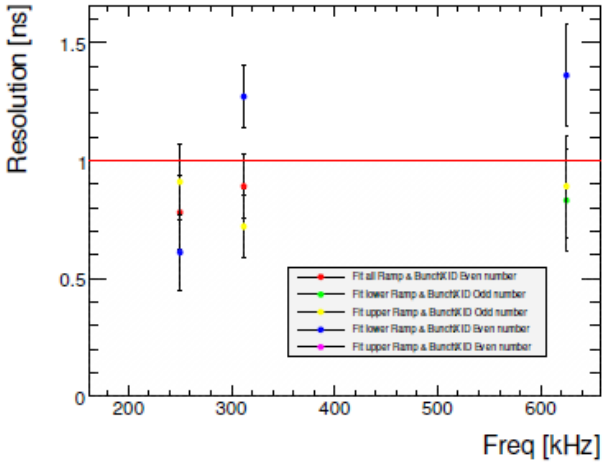
  - 625 kHz

Channel	Ramp	Part	σ_{fit}	Slope	σ_{tot} [ns]
4	1	lower	0.52	0.685	0.83
4	1	upper	0.91	0.687	1.36
4	2	lower	0.60	0.711	0.89
4	2	upper	0.40	0.681	0.67
4	1	all	0.91	0.683	1.37
4	2	all	1.59	0.694	2.31

Resolution

- Focusing on compromise between dynamic range, relative deadtime and resolution
- Deadtime roughly constant : 70 ns
- Best compromise (without increasing slope) :
  - 250 kHz (or lower than 312 kHz)
  - Deadtime : 2-2.5 %
  - Resolution : 1 - 1.5 ns
  - Dynamic range : 1500 – 2000 TDC tics





Conclusion

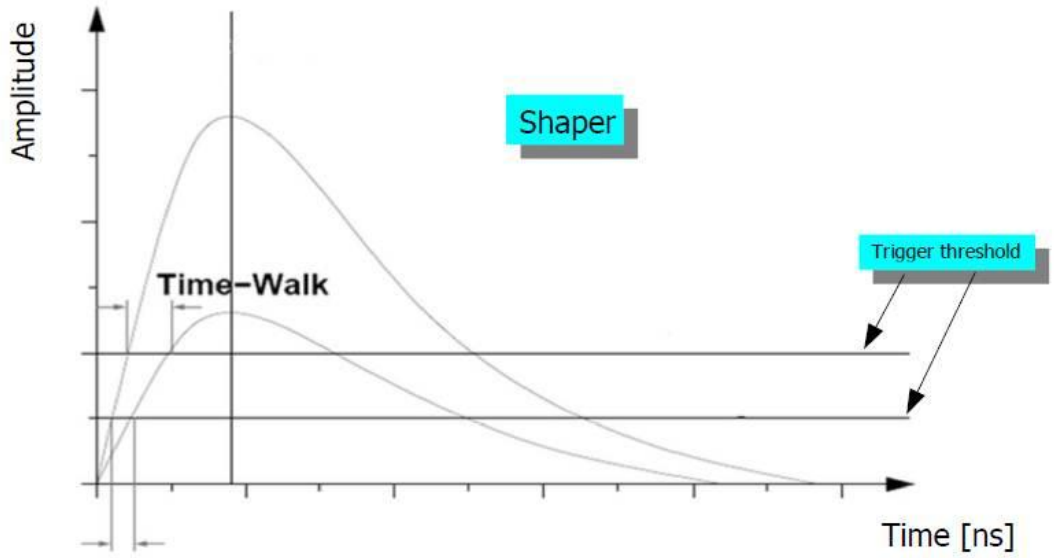
- ILC mode :
  - 100 – 250 ps resolution achieved
  - Spectrum measurement : ~50 TDC tics of height difference
  - Deadtime too big (35%)
  - Fail of distinguishing the ramp by BXID

- Testbeam mode :
  - 1 – 1.5 ns resolution achieved
  - Frequency comparison (250 kHz to 625 kHz)
  - Spectrum measurement : no visible height difference
  - Compromise between resolution, deadtime and dynamic range
  - Could improve the resolution (< 1 ns) by increasing the slope

The Time walk effect

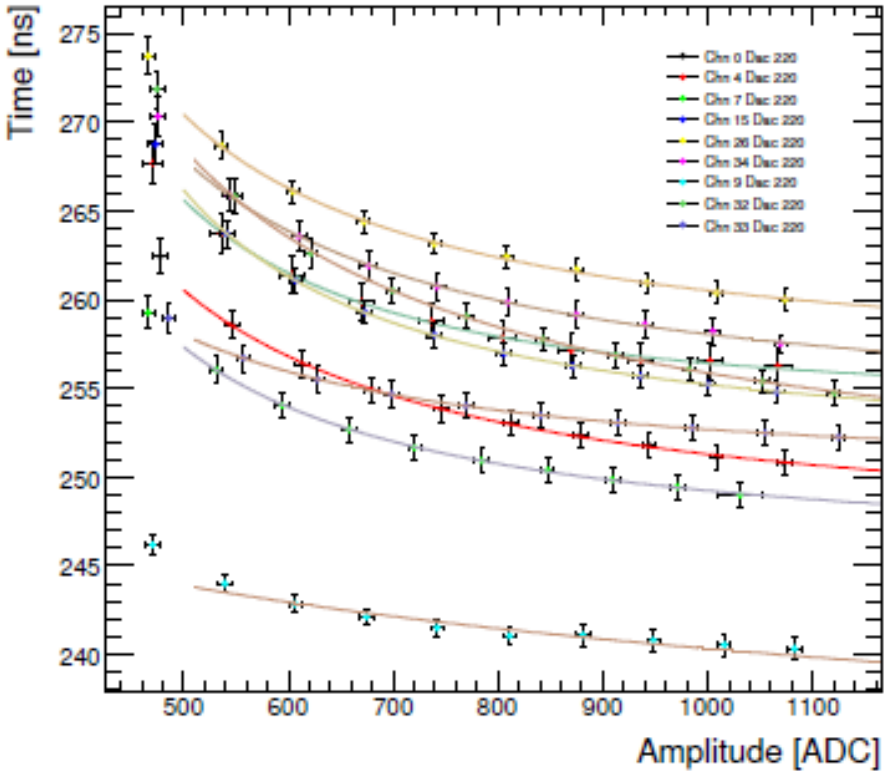
Explaining of the effect

- Dependence of the trigger with the amplitude of the signal
  - High amplitudes trigger before small amplitudes
  - Imply a time difference between the trigger



Charge injection measurements

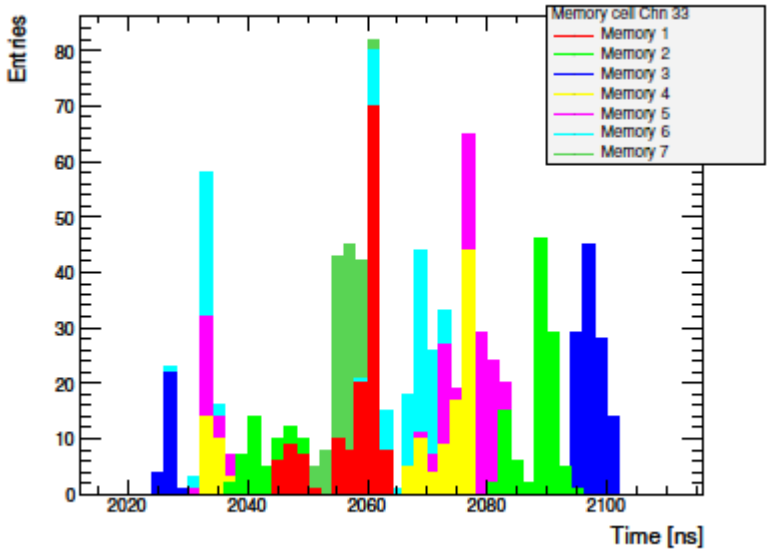
- ILC mode :
  - Same setup used
  - Variation of the voltage (Amplitude) and plotting the time (TDC) function of the Amplitude (ADC)

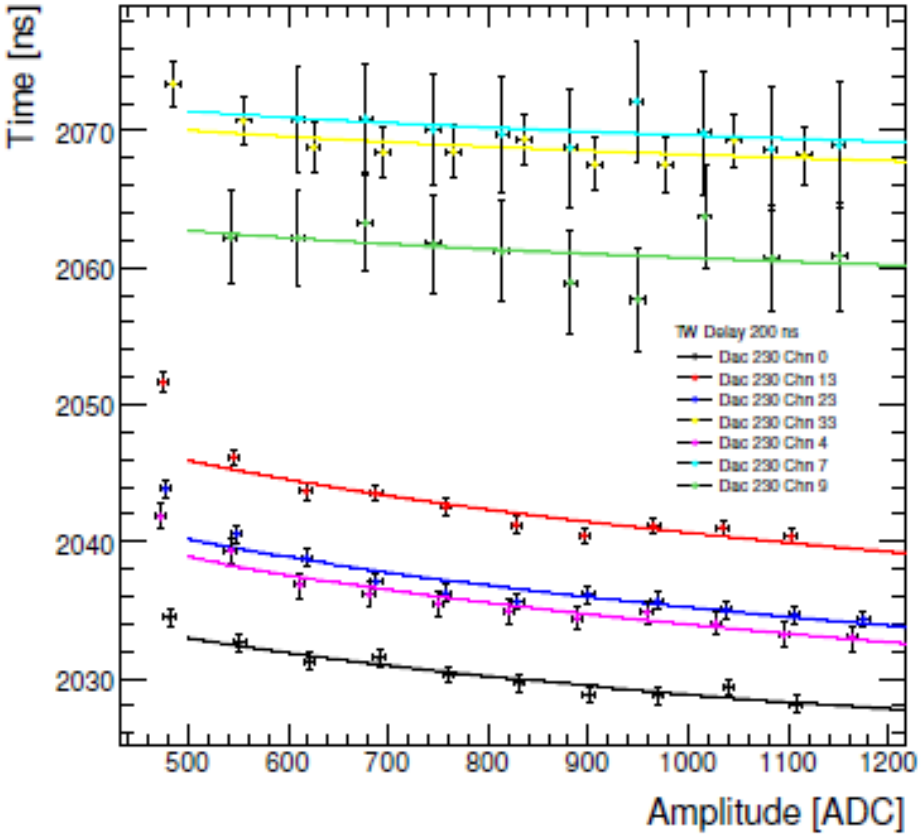


- Fitting function [1]/(x ^ [3]-[2]) + [0]
- Different shapes
- Offset channel to channel
- Channel can't be compared

Charge injection measurements

- Testbeam mode :
  - Same effect as in ILC mode
  - Error bar bigger (divided by 10 on the plot)
  - Investigation of this – reveled TDC memory cell offset





Calculated offsets : ILC mode

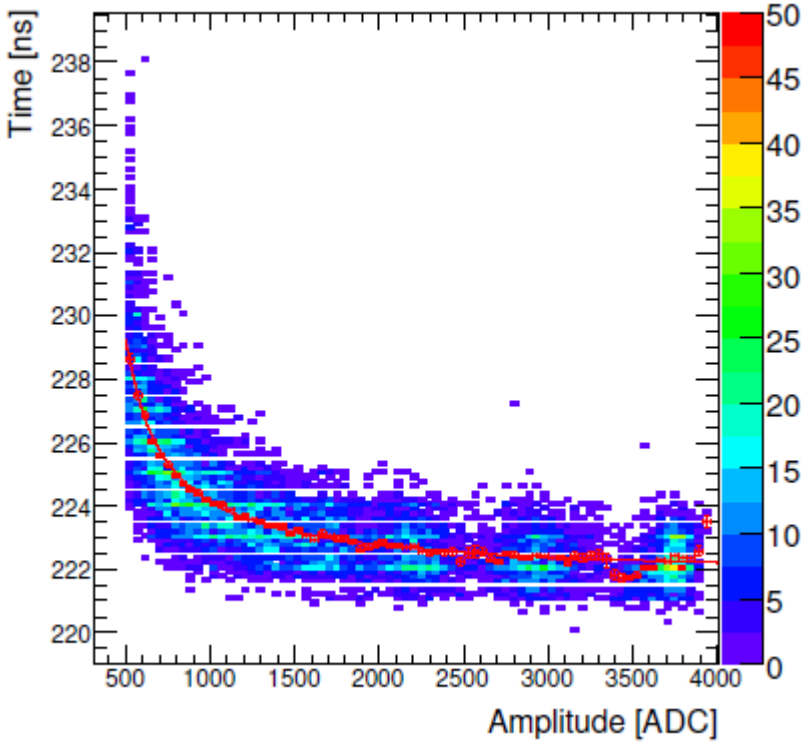
Channel	[0] (ns)	[1] (ADC.ns)	[2] (ADC)	[3]	Chi²
0	246.074	6520.56	283.892	1.06	0.09
4	254.109	5.66e6	84320.1	2.13	0.11
7	245.258	8154.71	472.471	1.13	0.06
15	251.018	31010	1532.75	1.32	0.02
26	255.386	5324.38	292.758	1.04	0.18
34	252.865	9199.02	390.991	1.11	0.12
9	141.225	116.531	0.18	0.04	3.18
32	246.138	518.118	30.72	0.64	0.05
33	250.281	182357	1342.51	1.63	0.06

Calculated offsets : Testbeam mode

Channel	[0] (ns)	[1] (ADC.ns)	[2] (ADC)	[3]	Chi²
0	1032.16	1025.52	0.013	0.006	4.35
13	1042.9	1034.43	0.016	0.007	11.63
23	1039.19	1031.02	0.015	0.007	9.86
33	1042.43	1032.63	0.010	0.002	1.56
4	1037.96	1013.96	0.03	0.007	3.17
7	1044.39	1032.97	0.009	0.002	0.43
9	1040.84	1027.92	0.011	0.003	1.87

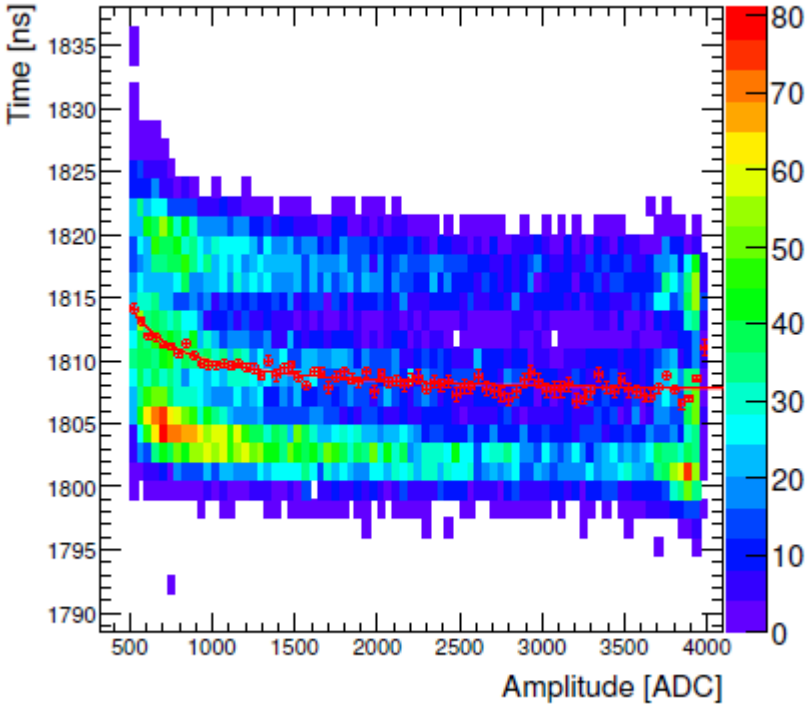
Light Calibration System measurements (LED)

- ILC mode :
  - Same behavior as charge injection
  - Projection of the 2D histogram
  - Spread around the mean – certainly due to the LED trigger system and the fact that the LED has not always the same amplitude (fluctuations)



Light Calibration System measurements (LED)

- Testbeam mode :
  - Same setup
  - Spread much more larger than in ILC mode – consequence of the memory offset and slope < 1 TDC tics/ns induces more sensibility to noise

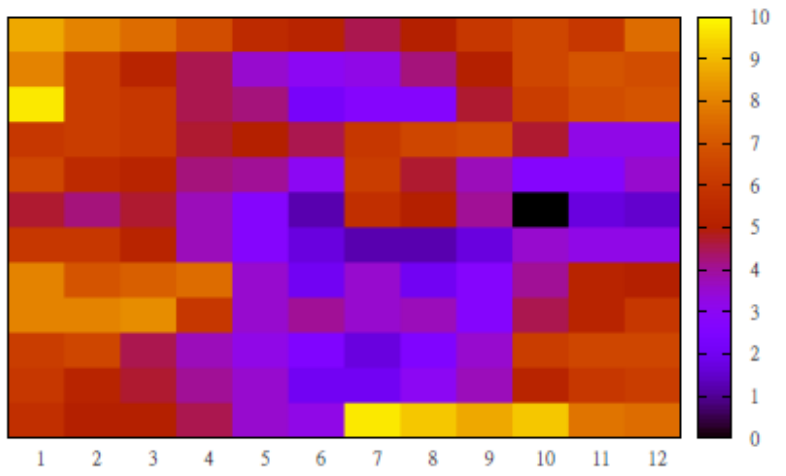


Timing Correction Procedure

- Procedure to calculate offset channel to channel in any mode
- Extend to a whole HBU
- Calculate offset using LED data
- Take into account : memory cell offset (need to check the reproducibility) and LED jitter (difference between trigger and pulse of the LED)

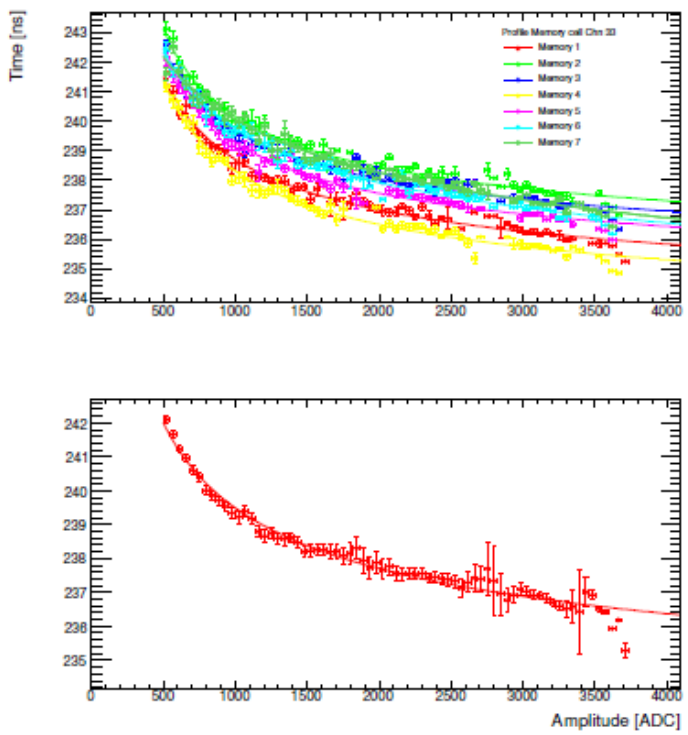
Vcalib=10V. Timing in ns. View on TILE side of HBU. CIF on right side

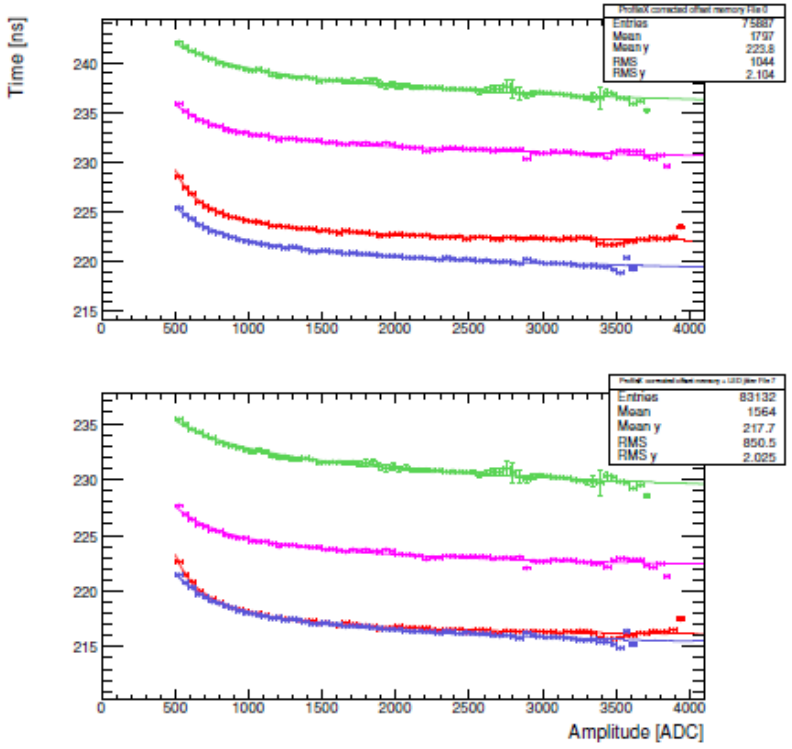
	1	2	3	4	5	6	7	8	9	10	11	12
12	8.7	8	7.5	6.7	5.5	5.2	4.5	5	6	6.5	6	7.5
11	8	6.2	5.2	4.5	3.5	3	3.2	4.2	5	6.5	6.9	6.7
10	9.7	6.2	6	4.5	4.2	2.2	2.7	2.7	4.7	6.2	6.7	6.9
9	6	6.2	6	4.7	5	4.5	6	6.5	6.7	4.7	3.2	3.2
8	6.5	5.5	5.2	4.2	4	3	6.2	4.7	3.7	2.7	2.7	3.5
7	4.7	4.2	4.7	3.7	2.7	1.2	5.7	5	4	0	1.7	1.5
6	6	6	5.2	3.7	2.7	1.7	1.2	1.2	1.7	3.5	3.2	3.2
5	8	6.9	7.2	7.5	3.5	2	3.5	2	2.7	4	5.2	5
4	8	8	8.2	6	3.5	4	3.5	3.7	2.7	4.5	5.2	6
3	6.2	6.5	4.5	3.7	3.2	2.5	1.7	2.5	3.5	6.2	6.5	6.5
2	6	5.2	4.7	4	3.5	2	2	3	3.7	5.2	6	6.2
1	5.7	5	5	4.5	3.5	3.2	9.7	9.2	8.7	9.2	7.7	7.5



Preliminary results

- Procedure applied to LED data in ILC mode
- Only 4 channels presents good data
- Give a lookup table





Preliminary results

Chip	Channel	Moy_offset	LED_Jitter	Offset_corrected
0	0	221.585	6	215.606
0	23	228.006	8.3	219.634
0	33	229.488	6.7	221.523
0	9	217.145	4	212.586

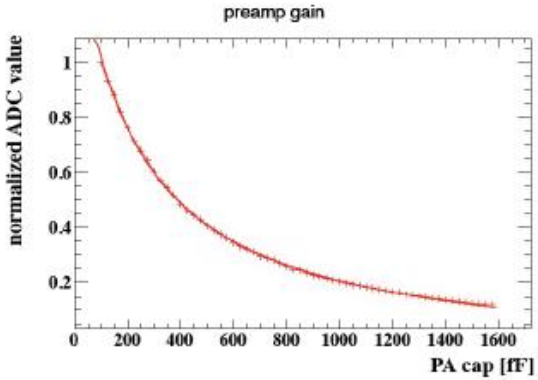
- Results (offset channel to channel) can be compared between charge injection and correction (check if match)
- Need to take more data

Conclusion

- Measurements performed on the linearity and resolution of the TDC in SPIROC and time walk effect analyzed
- TDC measurements :
  - ILD mode : resolution around 150-200 ps, ramp height differs up to 50 TDC tics, huge deadtime, improvement can be made by increasing the slope
  - Testbeam mode : resolution around 1-1.5 ns, choice of 250 kHz frequency – deadtime ~1%, good dynamic range (2000 TDC tics), improvement can be made also by increasing the slope (achieve a resolution < 1ns)
- Time walk effect :
  - Inverse function : [1]/(x^[3]-[2]) + [0]
  - Calculate offset channel to channel using LCS
  - Timing correction procedure has to be performed in order to compare channel timing (needed for testbeam in November at CERN)

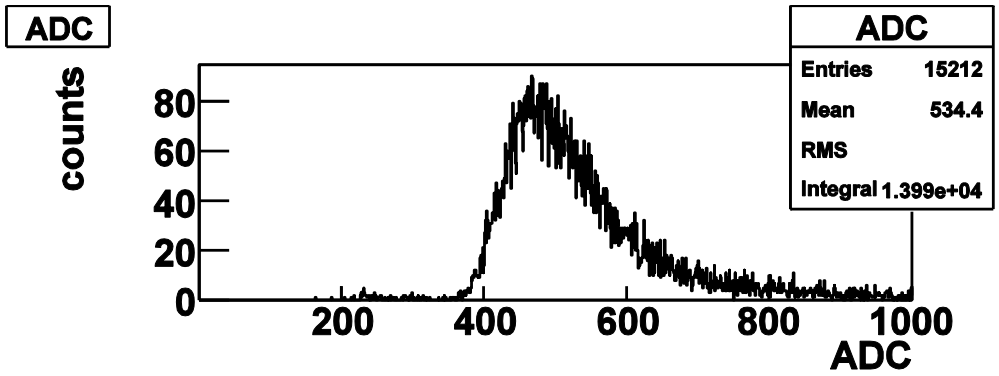
Outlook

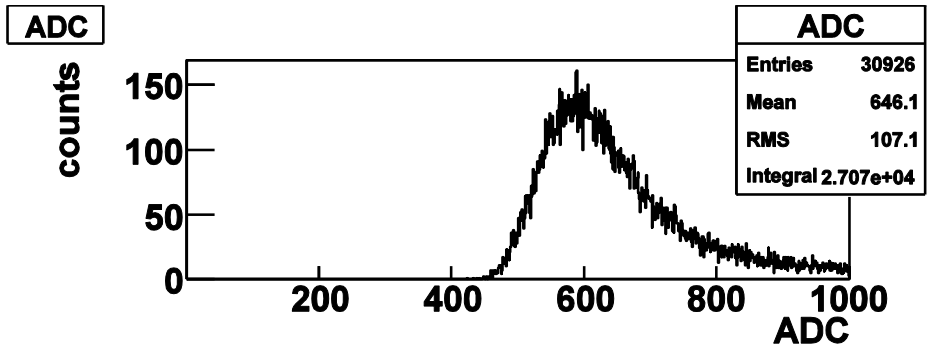
- Commissioning of the 4 HBU for testbeam at CERN in November
  - Calculate Input DACs for each SiPM
  - Pre-Amplifier equalization
  - Noise measurement (Set Trigger threshold)
  - ADC to MIP Calibration
  - Timing correction (lookup table for each HBU)
  - Timing measurement (study the timing of em shower)
  - Playing around with Temperature
  - …



Testbeam @ DESY

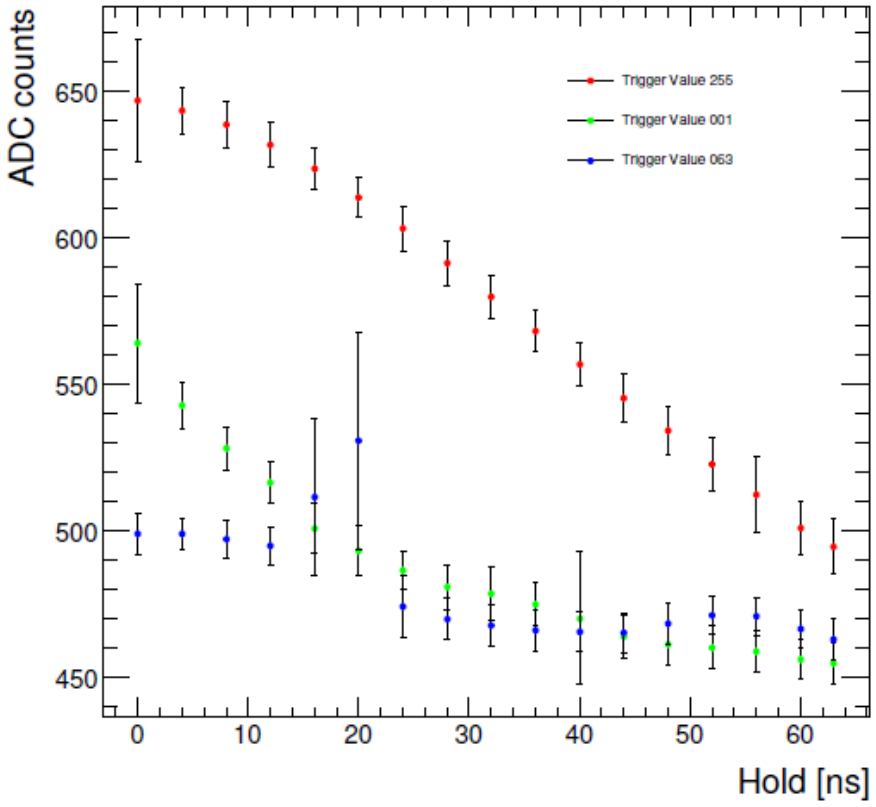
- Testbeam at the end of my inturnship
  - Begin to take data
  - Results not so long ago
- What we do :
  - Determine where the beam is hitting
  - Determine a threshold to have a correct MIP Spectrum
  - Acquire MIPs on some channels
- Some results :





A new prototype : SPIROC2c

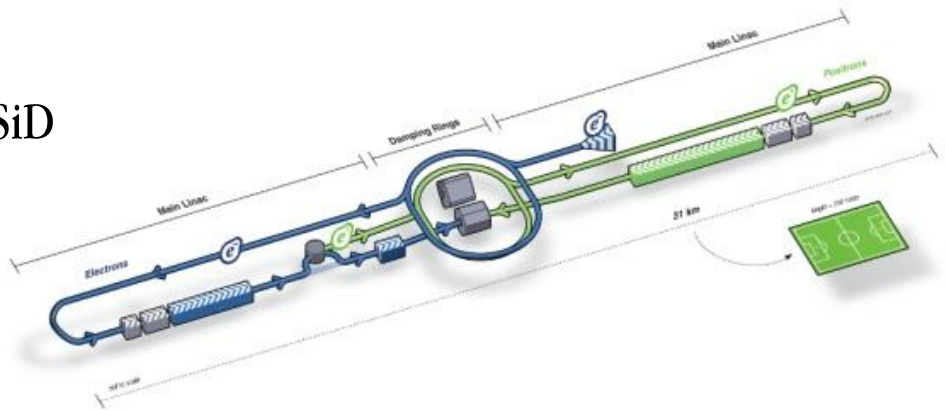
- New prototype arrived beginning of August : SPIROC2c
- Holdscan performed in external trigger
- Studies ongoing : holdscan, pedestal shift, zero event…



Backup Slides

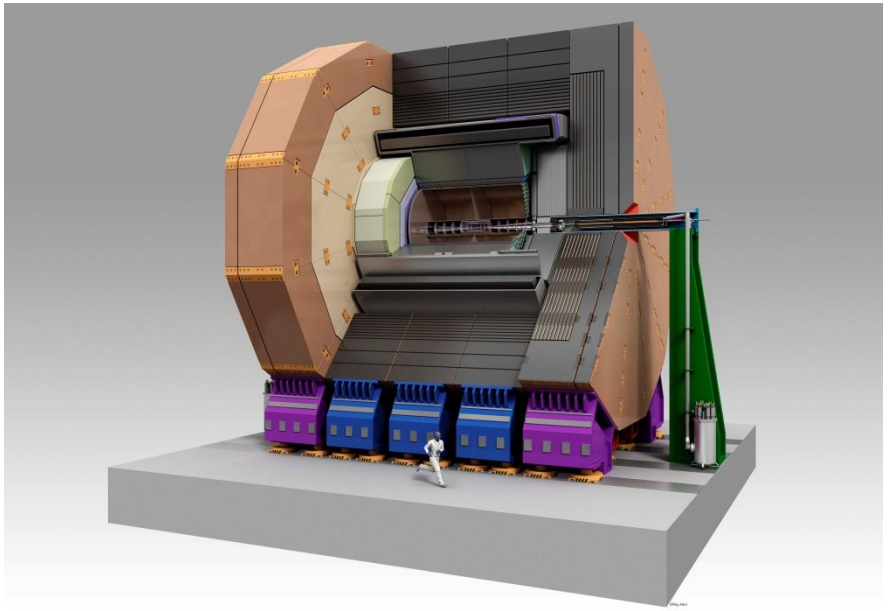
The International Linear Collider

- 30 km long
- e^+e^- linear collider at 500 GeV (upgrade to 1 TeV)
- Precision Measurements (low background)
- 2 complementary detectors technologies (SiD and ILD)
- Planned for ~2020



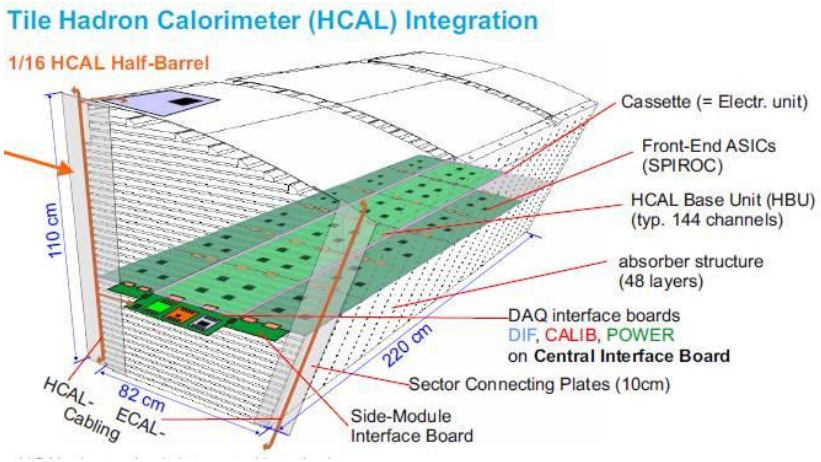
The ILD (International Linear Detector)

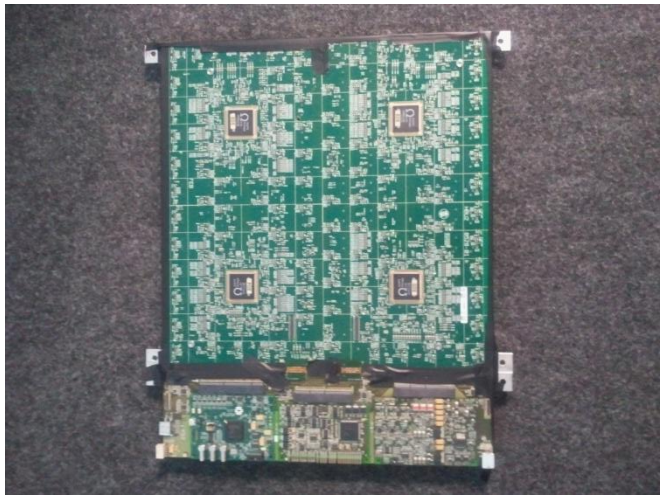
- One of the detector prototype
- High granularity – Particle Flow Algorithms to trace single particles in jets
- Composed by :
  - Vertex Detector (scintillator strips)
  - Time projection chamber (trace charge particles – up to 224 points)
  - ECAL (silicon pixels or scintillator strips with W or Fe)
  - HCAL (scintillator tiles + SiPM or gas detector as active medium)
  - Cole and Yoke (channel magnetic field and tracking muons)



The AHCAL prototype

- Analog readout using scintillator tiles ($3*3\ cm^2$) and SiPM
- 18 mm thick (10 mm W or Fe, 3 mm tiles, 5 mm electronics)
- Front-end : SPIROC
- 36 channel, auto-trigger, 2 gain modes, time measurement (TDC)
- HBU : 4 chips = 144 tiles
- Slab : 6 HBU = 24 chips = 864 tiles
- Power consumption : 40 μW/channel





SPIROC : Silicon PM Integrated Read Out Chip

- 2 Gains possible : Haut Gain (75) et Bas Gain (7,5)
- 36 voies par gain
- Déclenchement intégré (Trigger)
- Mesure : 1 pe (160 fC) -> 2000 pe