STS/MUCHxyter as alternative for Nxyter?

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Chapter 1

Basic Characteristics

Due to problems with nxyter and CBM switching to STS / MUCH xyter we had some discussions already if we should also switch to STSxyter for the next generation of boards. The "killing argument" was so far always the internal 5bit flash ADC. Idea is to investigate if STSxyter might be sufficient for us.

Remark: since STSxyter has a completely new 'data protocol' FPGA code of 'GEMEX' development could not be simply used.

The basic Characteristica of STS / MUCH ASIC are:

1. UMC 180nm CMOS
2. as a consequence the radiation tolerance is increased compared to the nxyter
3. 5-bit Flash ADC + digital peak detector.
   one can set 31 thresolds, see Fig. 1.1
   Thus one can e.g. put this to log scale.
4. Charge Sensitive Amplifier (CSA) gain is configurable
   STS 7.5mV/fC (other publication says 40 ...) and MUCH 1.32 mV/fC
   dynamic range 0-12fC (STS mode) 0-100fC (MUCH mode)
   dynamic range increases compared to nxyter!
5. ASIC designed for detector-capacitance of approx 30 pF
6. 250kHits/s/channel
7. time resolution, not yet fully clear
   CLARIFICATION NEEDED !

   - "few ns"
   - 14bit timestamp (3.125 ns bin)
     ASIC running on 160MHz clock? would mean 6.25 ns bins

where does value 3.125 ns come from?

- if i remember correctly from discussions with Christian the time 'resolution' is supposed to be the same as for the nxyter
  Only time i checked this was before beam time june 16 with time calibrator. Result was 1 bin = 1ns, so it would be better by a factor of 3!? Resolution of peaks was approx. $\sigma = 3.5$ns but this was with signals injected via old ATTENIX (might make measurement noisy), see MAIN-GEMEX-Logbook page 220.
  From nxyter manual:
  `256 MHz clock is used to generate time stamp of 1 ns resolution.`
  256MHz means steps of 3.9 ns, 1ns binning is achieved with phase shifts of the clock and 2 additional bits
  14-bit time stamp = 12-bit counter + 2-bit 'fine counter'

- Requirement for SuperFRS tracking detector is < 3ns to achieve y resolution.

8. switch off every 2nd ch. in MUCH mode!?
9. internal ADC calibration is possible
10. CBM needs 14k chips
11. for final FEE 8 ASICs on one PCB
12. power consumption 10mW/ch. Nxyter has a 2.5 times higher power consumption. Relaxes cooling requirements.
13. chip size: approx. 10×6.7 mm^2
14. CBM DAQ (triggerless) based on GTBx exists, but no real solution for us
15. ASIC can be operated in 'semi triggered' acquisition mode.
    operation via 'global gate' could make GEMEX like application much easier (there we had artifitial trigger window on the FPGA) However, statement in the manual is 'needs to be checked and verified'
    mostlikely not usable for us. gate can not be placed in past, but trigger decission takes time.
    virtual gate in GEMEX always included events which happend 'before' the trigger.
16. time to stream out data can be up to 100 μs
    if noisy chip would be to slow to be used!
    in NX is the max 16 μs.

literature e.g.:

- Analog front-end design of the STS/MUCH-XYTER2-full size prototype ASIC for the CBM experiment
  `http://iopscience.iop.org/article/10.1088/1748-0221/12/01/C01053/pdf`

- Back-end and interface implementation of the STS-XYTER2 prototype ASIC for the CBM experiment
`http://iopscience.iop.org/article/10.1088/1748-0221/11/11/C11018/pdf`
- Offset correction system for 128-channel self-triggering readout chip with in-channel 5-bit energy measurement functionality
`http://www.sciencedirect.com/science/article/pii/S0168900215000790?via%3Dihub`
- GBT based readout in the CBM experiment
`http://iopscience.iop.org/article/10.1088/1748-0221/12/02/C02061/pdf`

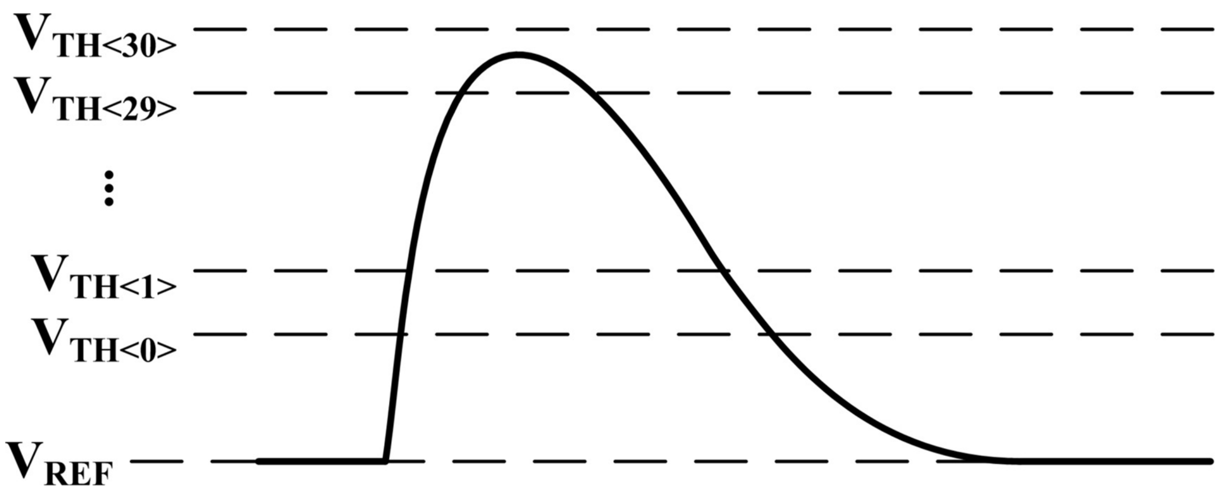


Figure 1.1: STSxyter 5bit flash ADC. thresolds for each bit can be tuned seperately.

Chapter 2

ADC BITs

Idea is to perform very basic MonteCarlo Simulation to learn how much ADC bits are needed to get a reasonable tracking resolution.

2.1 Results from Andrej

Andrej did this excercise already some time ago.

```
generate Gaussian signal with width corresponding to
the electron cloud width at pad plane.

assumed ideal gaussian, so ideal detector energy resolution,
a lot of electron, no noise etc.

The mean, or position of the Gaussian was generated
randomly (uniform distribution)  along several strips.

Then assuming pitch and ADC bit resolution I sampled Gaussian
function at the center of strips and then I fit the Gaussian
to the sampled data and compared with original Gaussian.
So what I call position resolution is the RMS of the mean
of the original Gaussian and "fitted" Gaussian.

This I did for P10 gas and ArCO2 gas, both 4cm drift and for
different signal height compared to the total dynamic range.

As you can see from the attached plots the contribution coming
from this procedure and ADC bit resolution is much below other
effects like detector energy resolution and position straggling
of the electron cloud passing GEM foils. This is true for 5bit
or 10bit ADC. So if its true you should not see any position
```

`resolution degradatioin if you resample measured data to 5 bit.`

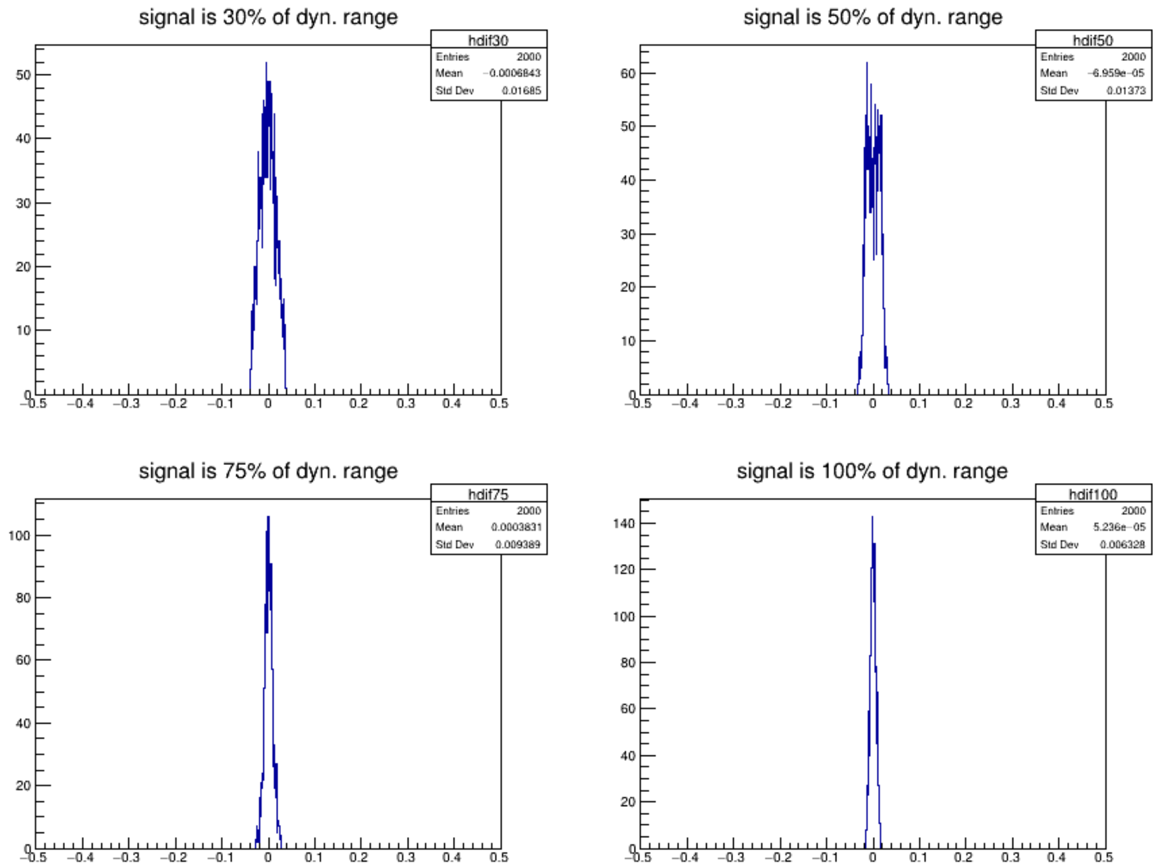


Figure 2.1: Andrejs results: P10-gas Tracking example histograms

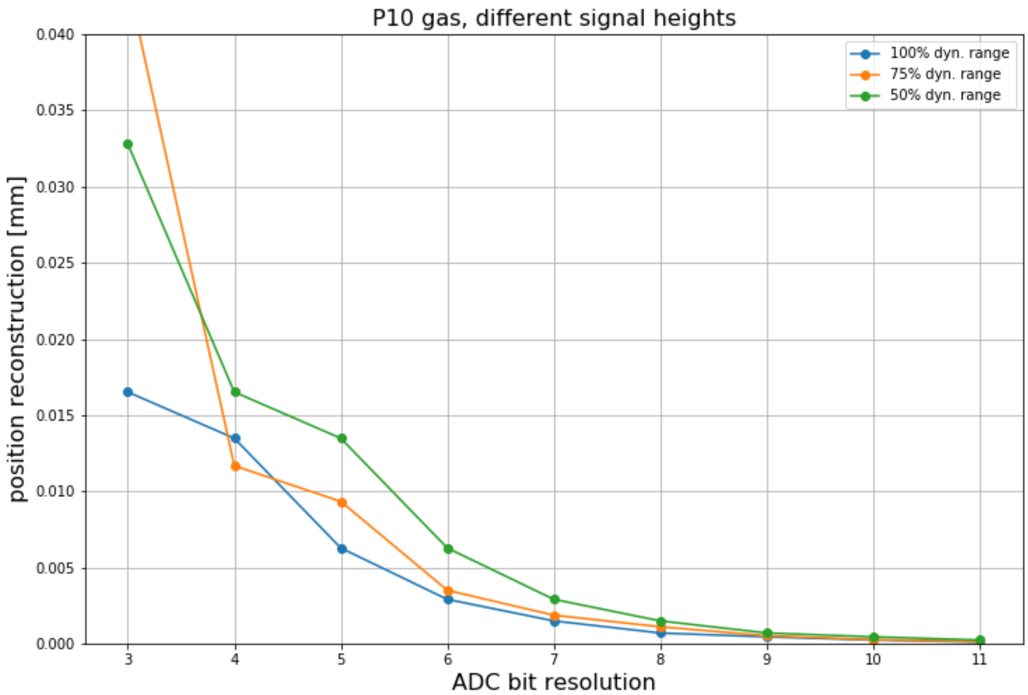


Figure 2.2: Andrejs results: P10 gas. Tracking resolution as function of ADC bits for several signal heights

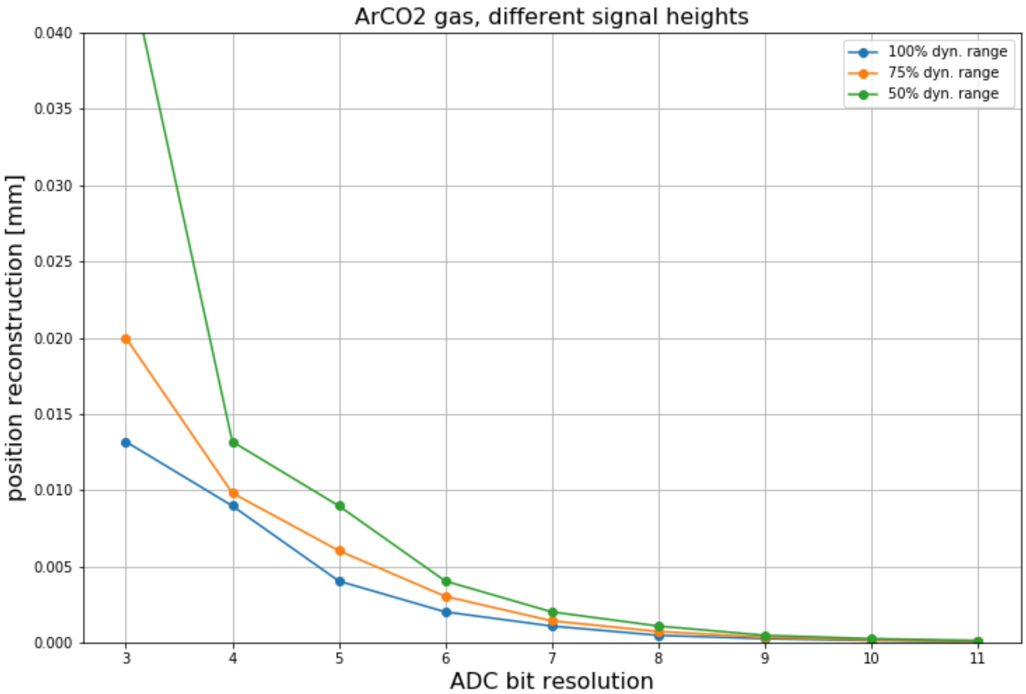


Figure 2.3: Andrejs results: $ArCO_2$ gas. Tracking resolution as function of ADC bits for several signal heights

2.2 Christophs Results

Independent of Andrejs Results i finished my work of course ;-)

Steps used in simulation to generate event

1. x_{in}: get position from flat disribution (0,204800)
   512×0.4 mm = 204800 μm

2. $q_{in;max}$: get height of deposited charge from flat distribution (0,1024)
   i simply sart with assuming that 10bit is the full dynamic range.
   nominal we do have 12bit ADC on the GEMEX. 0 to 2047 for neg charges and 2048 to 4095 for pos ones
   However, s-curve scans indicate that max usable range is approx between 1000 to 2500

3. put gaussian of this height with σ_{CD}=1248 μm as charge distribution on PadPlane
   σ_{CD} is obtained from Andrejs formula from Pre-Design Report
   $\sigma_{CD} = \sqrt{0.359 * y + 0.1225}$ $y = 4$cm, result is mm [1]
   neglect all effects of higher order (in this first apporach MonteCarlo), e.g. dependence:

   - on Z e.g. if fragment setting
   - on GEM GAIN
   - on Gas

   etc ... since i take $q_{in;max}$ from a flat distribution covering the full range i have in principle a similar effect as e.g. different Z. For a primary beam this distribution should be a 'sharp gaussian' ... see e.g. pumps in Fig, 2.9 top

4. charge on each Pad = $q_{in;Pad_i}$ this is determined from gaussian given above.
   Remark: now i go from x in μm to pad

5. $q_{in;Pad_i}$ and the resolution of the charge measurement $\sigma_{cm;nxyter} = 5$ ch. define a gaussian, from this i obtain $q_{measured;Pad_i}$
   Remark on charge resolution of nxyter:
   for internal test pulses best values are approx. 3 ch (see GEMEX Logbook page 198 Fig 10.5)
   for external 4.5 ch (see GEMEX Logbook page 144 Fig 9.38)
   so i use 5 here as a starting point, however, i think this is a rather optimistic value.

6. Use $q_{measured;Pad_i}$ values and rebin to e.g. 5bit (STS flash ADC) to obtain $q_{STS;Pad_i}$
   remark: Rebinning is of course done later in analysis.

7. obtain $x_{tracked}$ from fit of $q_{measured;Pad_i}$.

8. $x_{tracked}$ - x_{in} defines tracking resolution.

[1] width of charge cloud was also checked from last year data see section 2.4

In principle i could simply decrease resolution of real data/events. But it might well not be possible to observe effect of 'ADC binning' alone since e.g different nxyter behave so differently and each channel adds even more fluctuations ...

For the simulation here i use always linear bins
To optimize for STSxyter later on one could maybe individual thresholds.

Results are shown in Fig. 2.4. Iuse the root peak finder (TSpectrum) to init mean for gaussian fits.

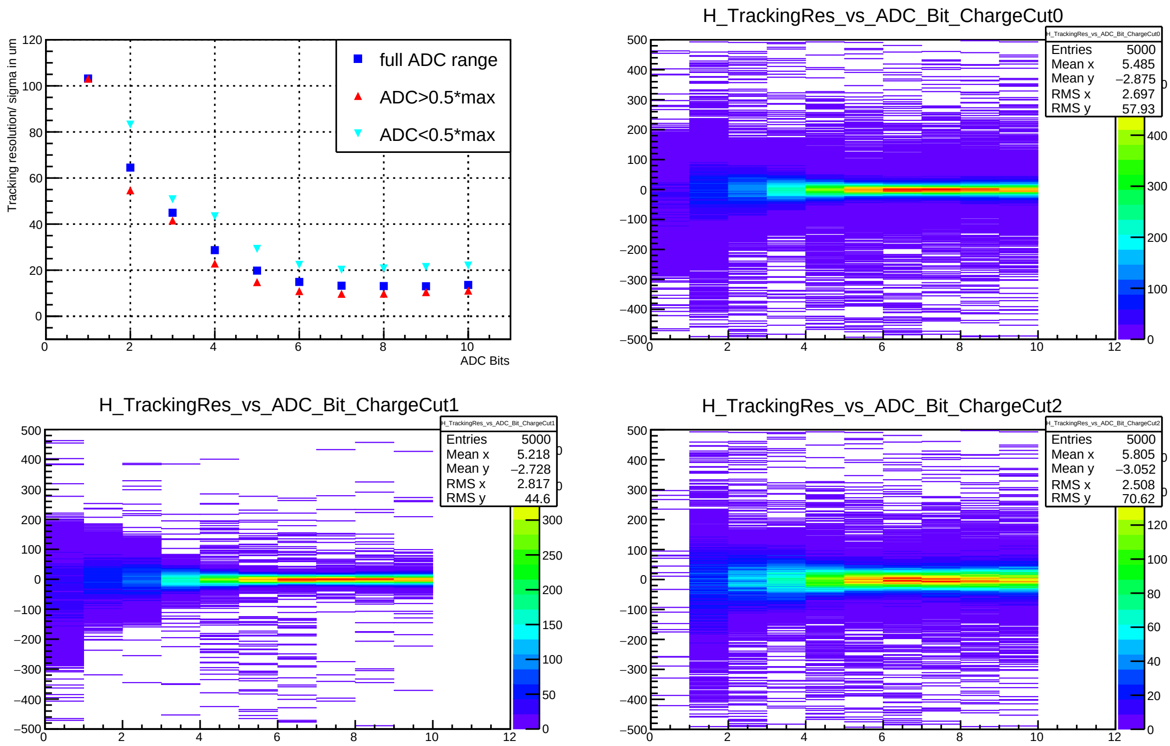


Figure 2.4: Tracking Resolution vs ADC-Bits. left top shows the σ of $x_{tracked}$ - x_{in} as a function of the number of ADC Bits. The 3 different graphs represent different peak heights (charges). The other 3 histograms correspond to those charge cuts.

Conclusion: in this very basic simualtion going from a 10bit to a 5bit ADC decreases the tracking resolution by about 5 μm. (Andrej obtains a very similar value) Which means it is negligible, what is at least for me quite surprising ...

2.3 Put 2 Ions

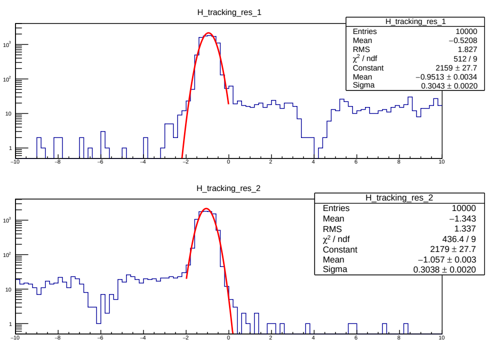
The above shown results are all for one charge cloud at the time. What happens if i have two overlaping ones?

i simply use 2 gaussians for each event now. How to treat overflow? At the moment i simply cut if the 'charge' is larger than 1023

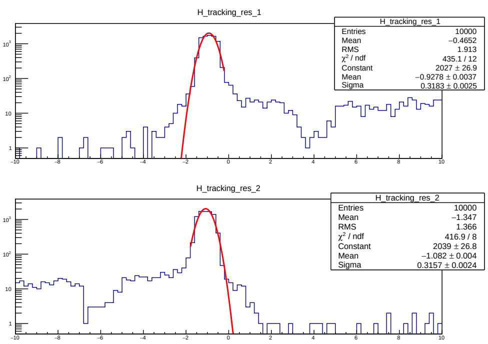
I simulate 'overlaping' events only, meaning 2nd gaussian is 'randomly' taken close to 1st.

```
x_in[1] =x_in[0]+10+rnd.Integer(10);
```

This results are from older simulations here i use as input x-position in Pad Number (integer). From the analysis i get the mean from the gaussian fit (float).



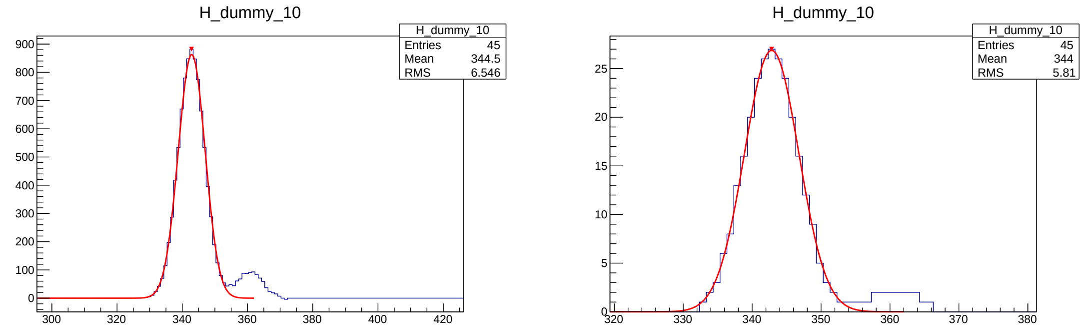
(a) Two Charge distributions on Pad Plane 10bit ADC (NX)



(b) Two Charge distributions on Pad Plane 5bit ADC (STS)

Figure 2.5: (color online) Shown is the x position from the fit (float) minus the input to the simulation (integer (Pad Number)). Top for the first and Bottom for the second Charge distributions. No real difference between NX and STS is visible.

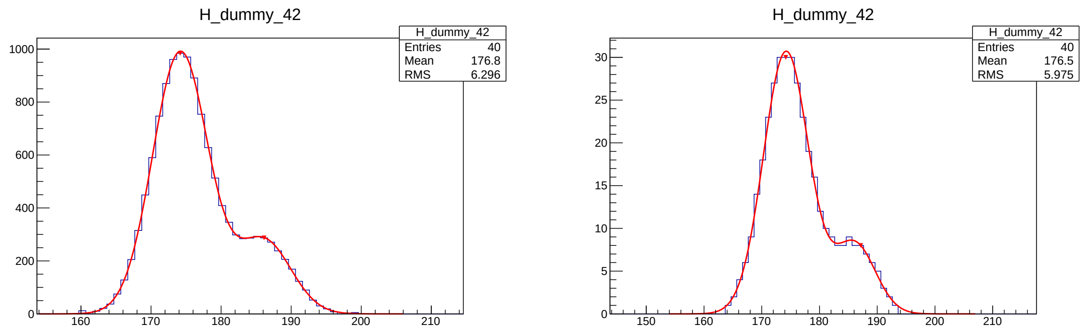
Going from 10 to 5 ADC BITs does not seem to have a major impact.



(a) Two Charge distributions on Pad Plane 10bit ADC (NX)

(b) Two Charge distributions on Pad Plane 5bit ADC (STS)

Figure 2.6: (color online) Peak finding and fitting does not work. For 'all' cases those problems occur for both STS/NX meaning it is not connected to the resolution at all. Obvoiusly here one could easily improve the procedure ...



(a) Two Charge distributions on Pad Plane 10bit ADC (NX)

(b) Two Charge distributions on Pad Plane 5bit ADC (STS)

Figure 2.7: (color online) For this event with overlapping charge distributions peak finding and fitting is no problem, independent if NX or STS

2.4 Charge Distributions from data taken June 2016 with nxyter

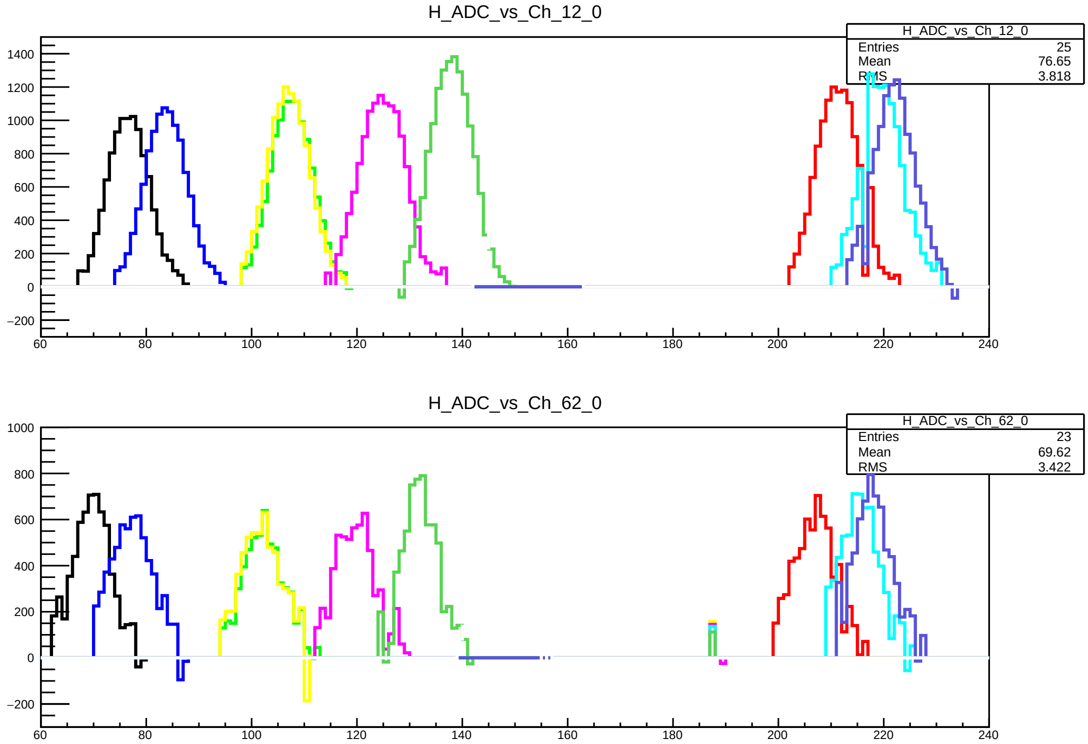


Figure 2.8: ADC vs Ch. for a few events. each color represents one event. fit those distributions. use parameters for 'event generator' later

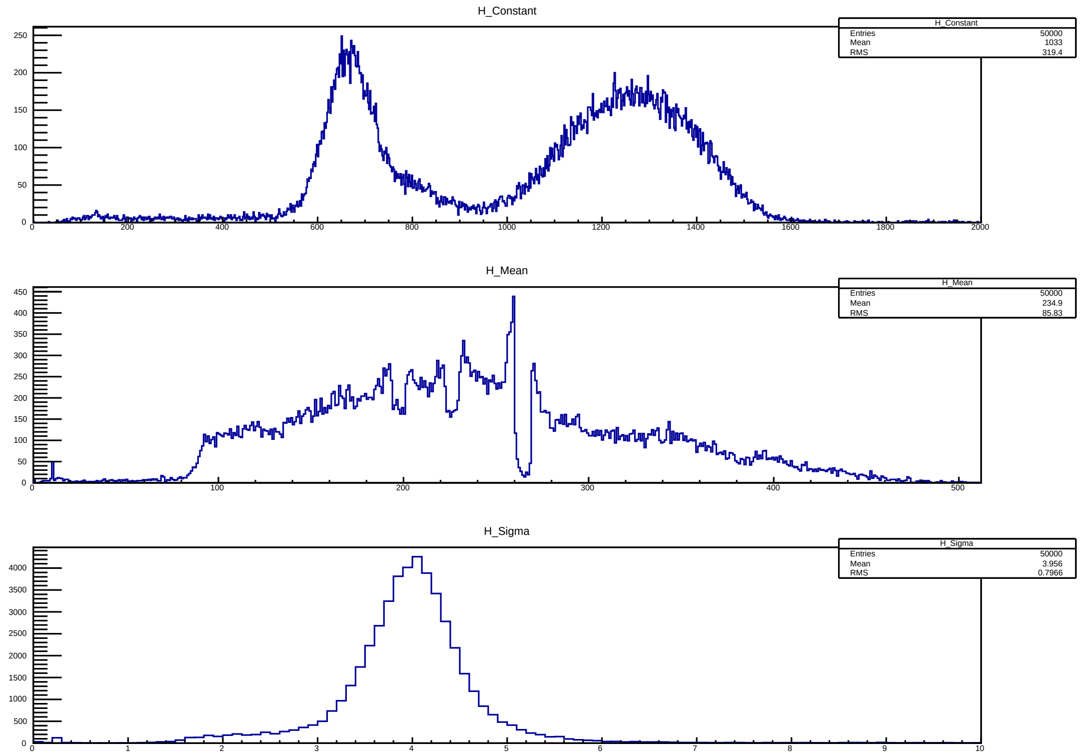


Figure 2.9: Characteristica of Charge Distr on PadPlane.Only data from one half of the TWIN detector has been used. I fitted 50k events. Shown are the paramters obtained from those fits: constant(max ADC), mean(x position) and sigma(width of charge distribution) from top to bottom. sigma looks ok. mean/x distribution looks strange. Data is mostlikely with 'broken' card. Constant shows clearly the 2 completely different gains of the two cards