Updates from the GP group

Pietro Grutta
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Padua, 11/03/24

Updates from the GP group

- Mini-workshop on sapphire detectors (https://agenda.infn.it/event/38681/) – Padua 11/01/24.
- *'Dependence on laser intensity of the number-weighted angular distribution of Compton-scattered photon beams'* paper (https://arxiv.org/abs/2402.03454) submitted to PRL A.
- Abstract on sapphire detectors (experimental) submitted for 16th PISA Meeting on Advanced Detectors May 26th -June 1st 2024. Paper collecting experimental campaign results expected for June '24.
- Test beam - Q3 '24 at CLEAR (CERN)
  - latest FBK sensors
  - Nicomatic flat flex cables
  - Improved YAG:Ce-camera system as beam monitor reference for GBP
  - EUDAQ2-based daq with CAEN A5202 FERS cards integration

Sensors developed

- Three main type of sensors developed so far
  - Thin pad sapphire sensors, with low-noise charge amplifiers for **initial assessment of CCE**
  - 4-strip sensors, to measure **radiation hardness** (no amplification) with an intense electron beam
  - 192-strip sensors prototypes, with multi-channel CAEN FERS A5202 readout electronics (**LUXE GBP detector setup**).

- Different sapphire wafers tested, from
  - Germany (SITUS Technicals GmbH, Wuppertal) – 110um thickness
  - US (UnivesityWafers Inc.) – 150um thickness
  - Russia (Monocrystal) – 150um thickness

- Characterization of sapphire detectors with
  - Sources (alpha)
  - Electron beam at low (1-8000 e/bunch) and high intensity (up to 300pC/train)

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  - Sources (alpha)
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TB4-192 update
Analysis

Pietro Grutta
University of Padua, INFN-Padua

Padua, 13/12/23

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Experimental setup

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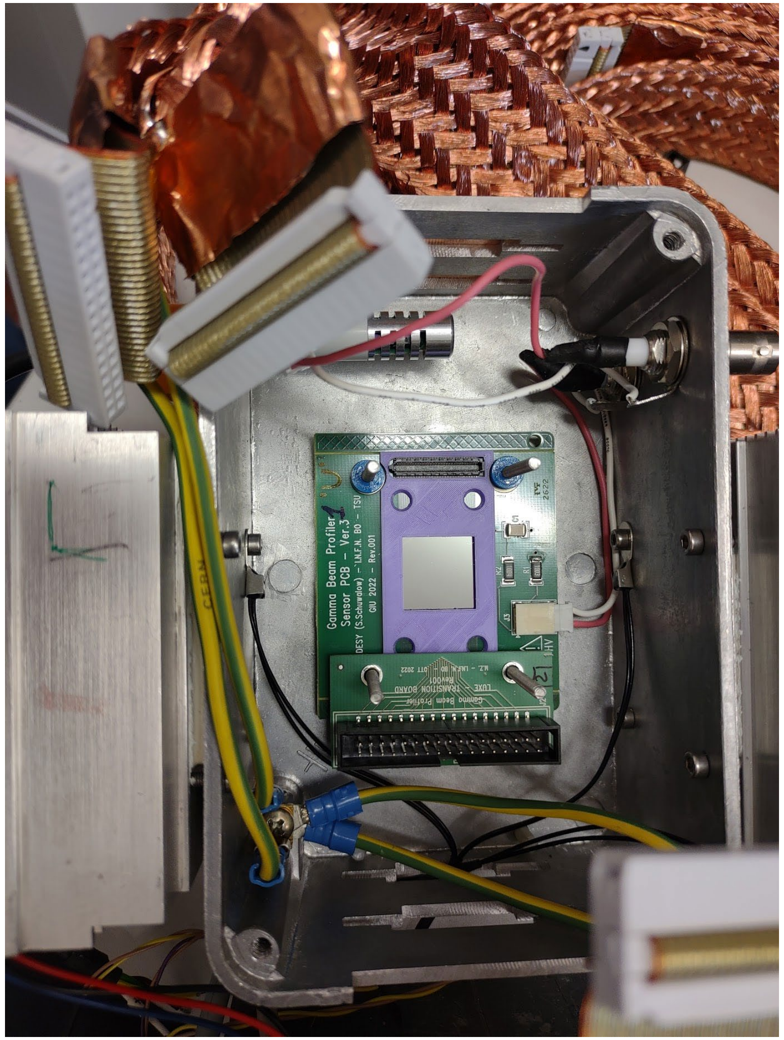
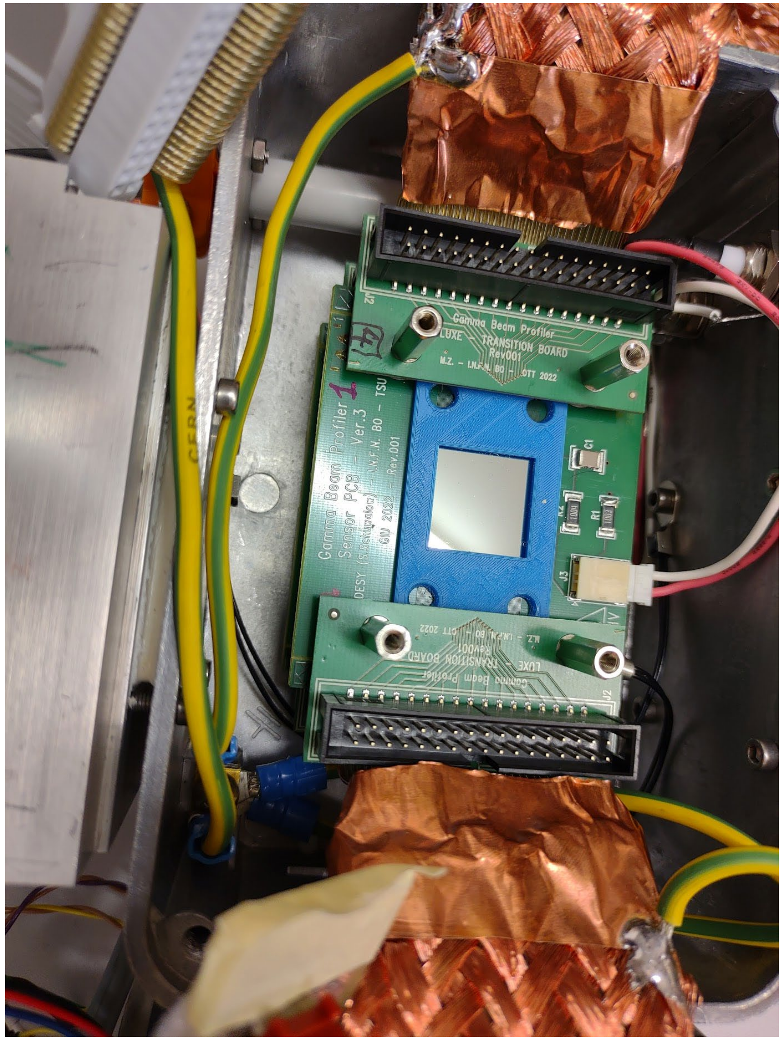
Experimental setup

- Content of the box showing
  - the two sensors,
  - ground connections,
  - the transition boards (id),
  - humidity and thermocouple sensors (unused).
- **Upstream**
  - detector **1' Monocrystal (110um)**
  - connected to **HV ch0** (2901709A)
  - connected to **FERS det1** (pid24990)
- **Downstream**
  - detector **1' UniversityWafersInc. (150um)**
  - connected to **HV ch1** (2901710A)
  - connected to **FERS det0** (pid22096)



- downstream



- upstream

Experimental setup

- The detector box is 150x100x65 mm Zn-Al alloy of thickness 3mm. A square window opening of 2x2cm is at beam entrance (front) and exit (rear).

- Sensors inside the detector box are
  - **Upstream**
    - detector **1’ Monocrystal (110um)**
    - connected to **HV ch0** (2901709A)
    - connected to **FERS det1** (pid24990)
  - **Downstream**
    - detector **1’ UniversityWafersInc. (150um)**
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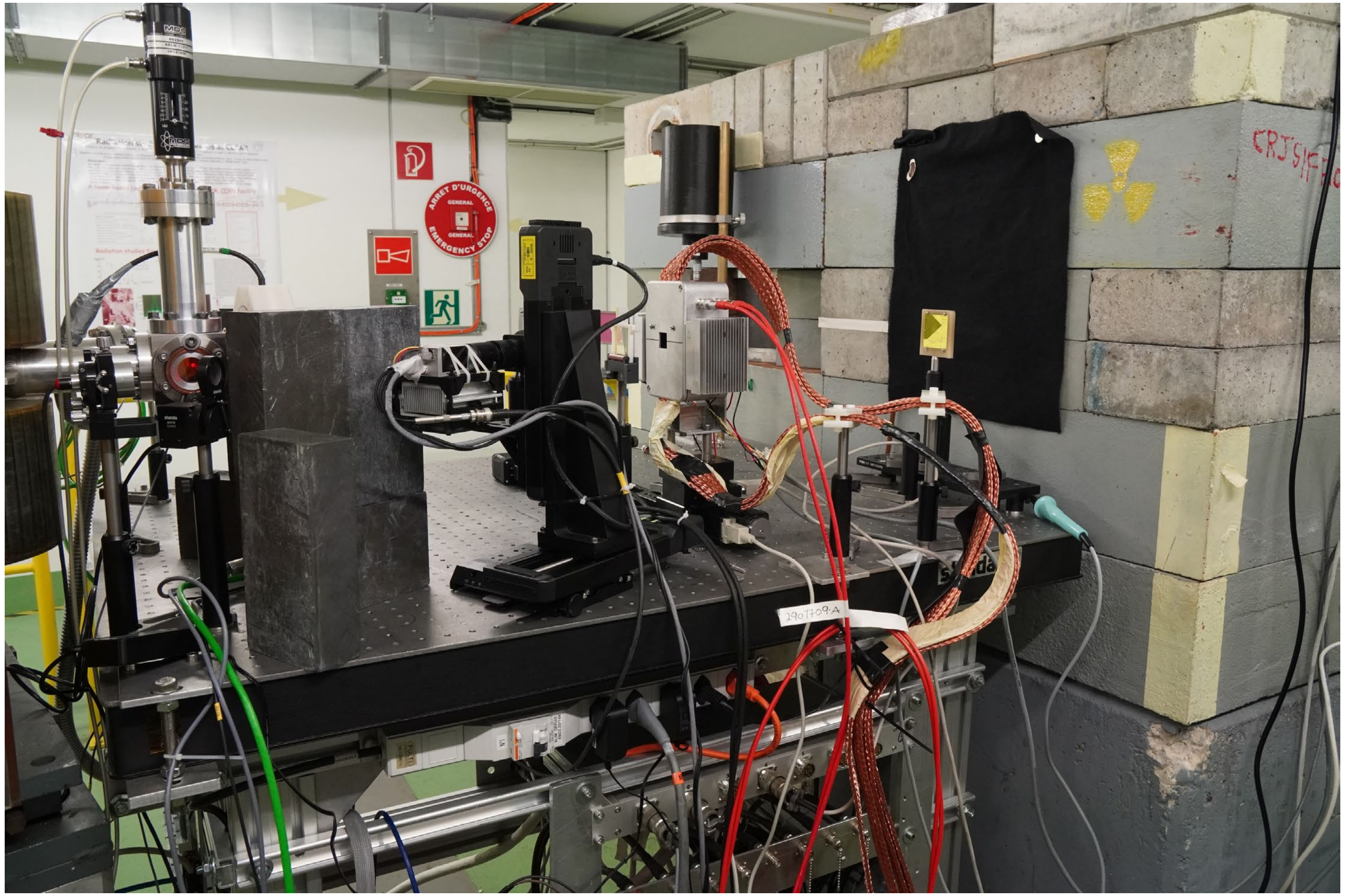
    - connected to **FERS det0** (pid22096)

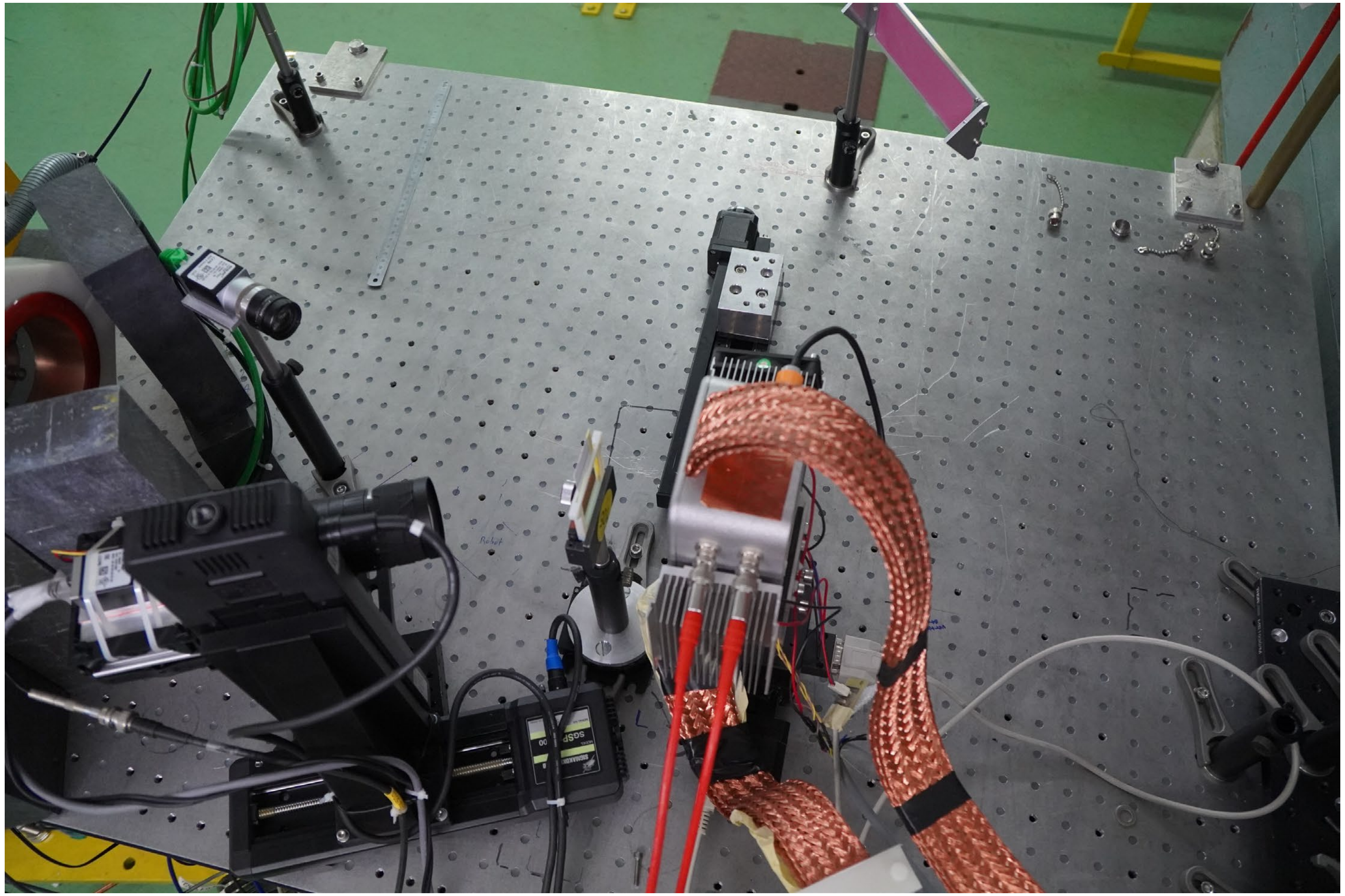
- Cable shielding is **electrically insulated** from the table.

- The odd-strips are extracted from the cables exiting the box from the bottom, the even-strips from cables exiting from the top.z



Experimental setup

- Camera setup
  - area of NxMmm of the YAG screen visible
  - lens aperture
  - magnification
  - mounted on XY stage
    - ► focus controllable
- Scintillator screen of thickness Xum **fixed position** w.r.t. table (static) at 2cm upstream the detector box.
- Another CLEAR camera (fixed) looking at the screen with wider field of view imaging the full YAG screen.



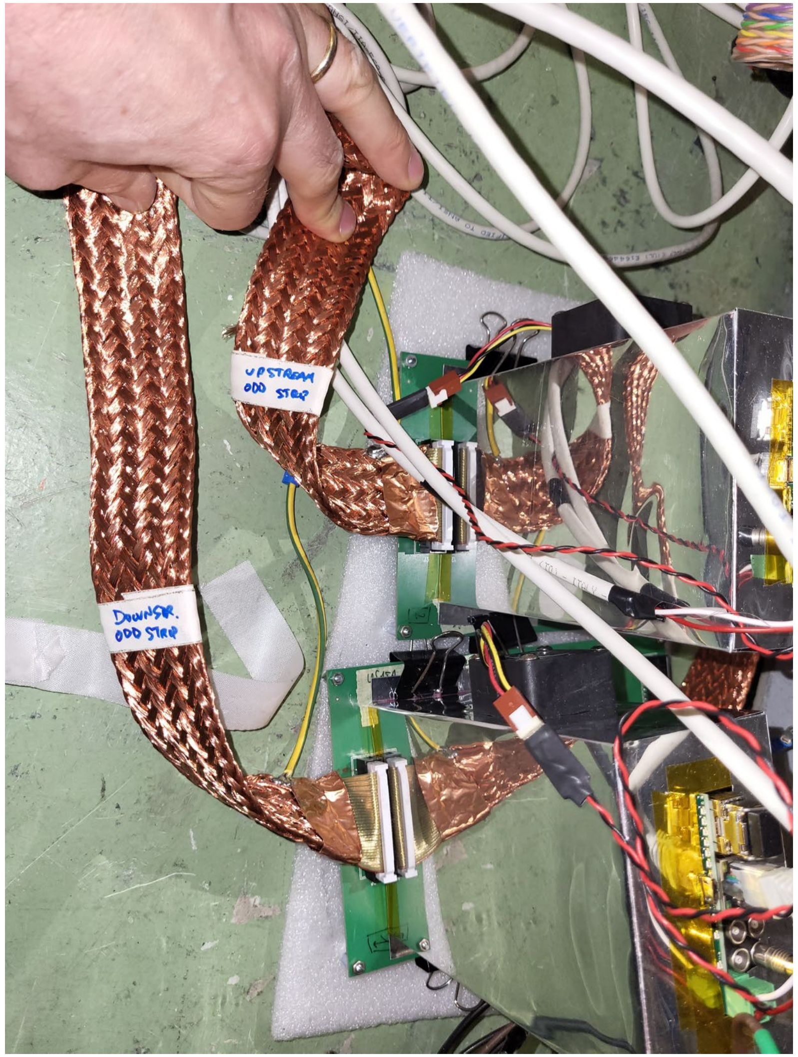
Experimental setup
Connections

FERS ch-strip table

FERS ch.	Strip no.	FERS ch.	Strip no.
A0	128	A32	65
A1	126	A33	67
…	…	…	…
A31	66	A63	127

CLEAR March 27-31st test beam map

- Cables from the box to the FERS carrier boards are connected in the same way of Vesper.
- Mistake in the labels
  - Odd and even must be exchanged – meaning that the cable with the *‘upstream even strip’* label brings upstream odd strip signals, and analogously for the downstream even/odd case.



28th March

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Summary of the day

- First day of TB
  - General tests of the acquisition systems (DT5730, FERS)
  - Test of the connections, powering of the detector
  - Empty FERS runs (no beam) with internal trigger, external trigger, internal pulser on
  - Early optimization of the FERS trigger point with 5pC beam on device
  - Determination of FERS optimal gain setting, with HV=100V and beam charge [8-100] pC
  - Evaluation of the RF background with 20pC 10Hz trg. (5Hz gun) rate LG=40 (looking external strips)
  - Detector XY acceptance with 50pC 5Hz gun rate by
    - ► Horizontal scan
    - ► Vertical scan

    Repeated the day after

Data collected

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    - ~~Horizontal scan~~
    - ~~Vertical scan~~

    Repeated the day after

Legend

Data not saved, Data ok , Difficult to localize files, due to badly written logbook

Empty runs with internal trigger and pulser

Run N	Gain LG/HG	Shaping Time	Pulse dest.	Pulse Ampl. (ADC)	Events saved
9	1/1	37.5ns	NONE	600	99
10			ALL	0	59
11				200	112
12				400	39
13				800	39
14				1600	66

Description

- Signal from FERS recorded without beam on device, with internal trigger and PTRG (fers pulse generator) scanning the internal impulse amplitude from [0,1600] in the steps (0,200,400,800,1600).
- Run control was manual, typical number of points per run is ~ 100. Internal trigger period of 1ms.
- No data from PSU or other instruments.

Analysis

- Time trace plots for det 0/1 for strip 65/96/128 in the LG/HG.
- Average value as a function of the PTRG pulse amplitude for
  - Strips 65, 96, 182 – det0, det1
  - Sum signals from ASIC I and ASIC II – det0, det1

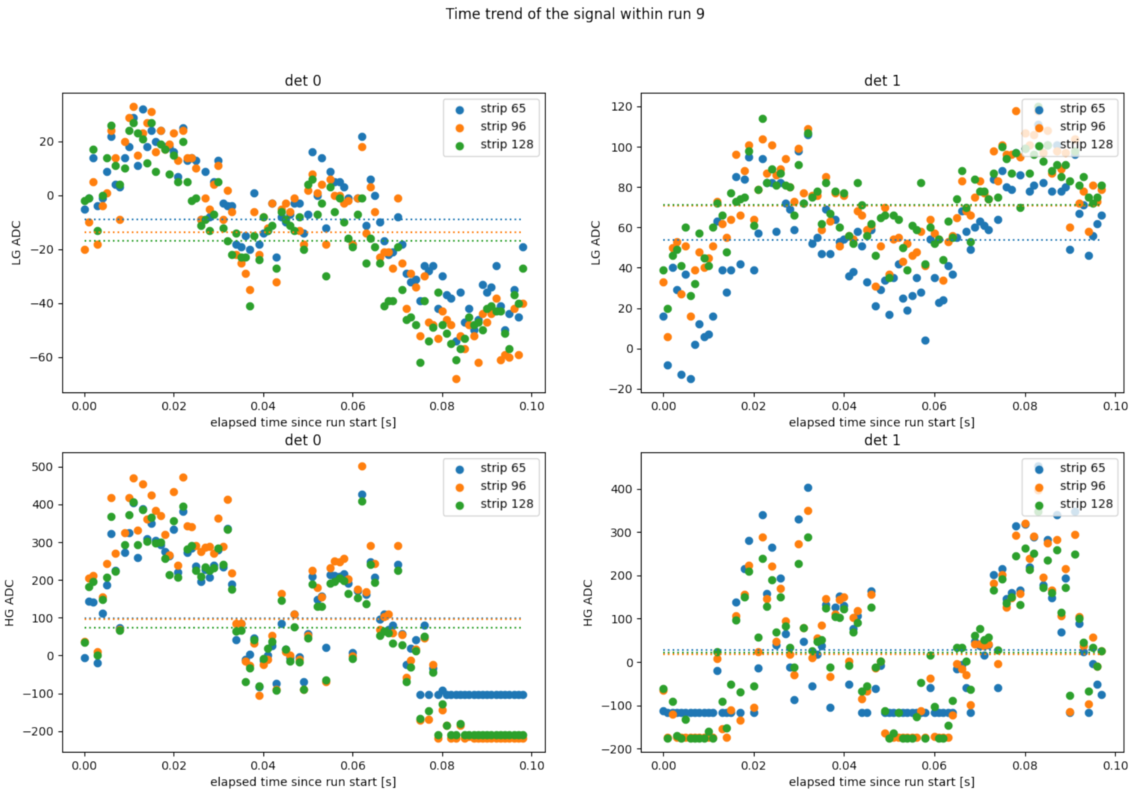
Challenges

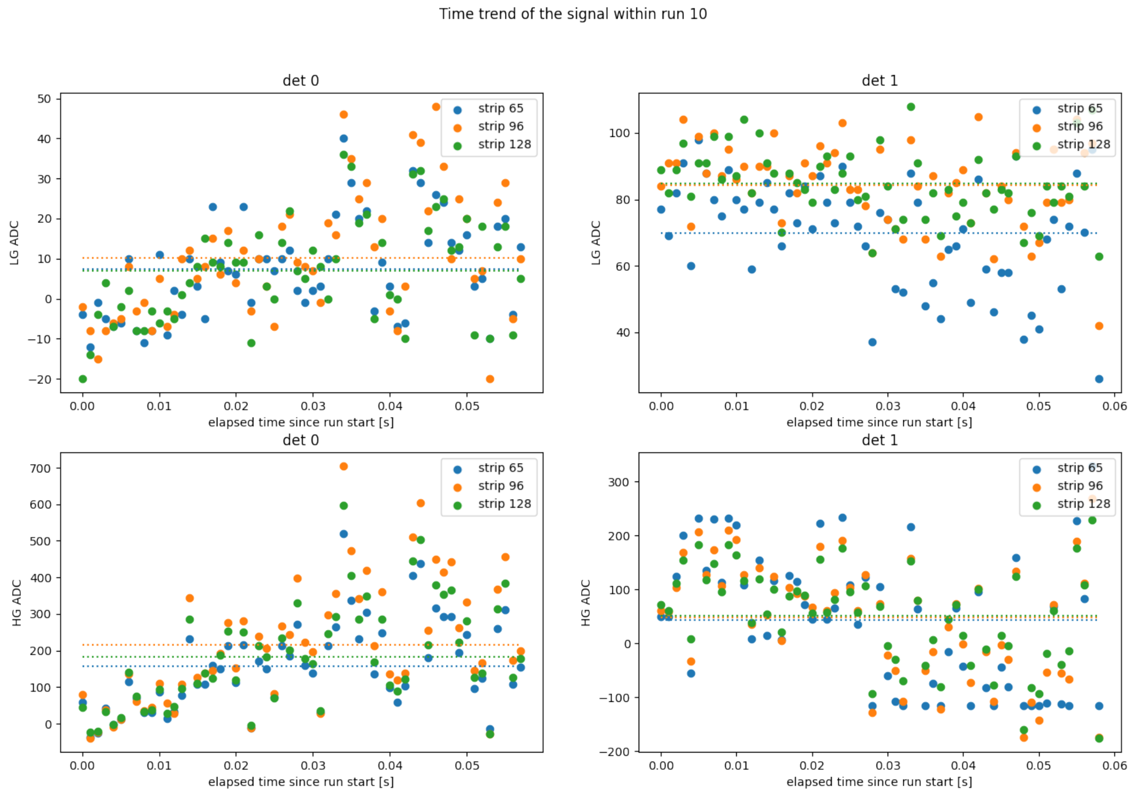
- **Difficulty** in reading the logbook: incomplete information, poor referencing to run number and conditions.
- Low number of events acquired for the PTRG period: structured noise visible.

Conclusions

- Linear response with PTRG internal gen.
- Slopes consistent between the ASICs, pedestal values within 2% for LG/HG.
- **Unclear** stick-behaviour observed (slide11).

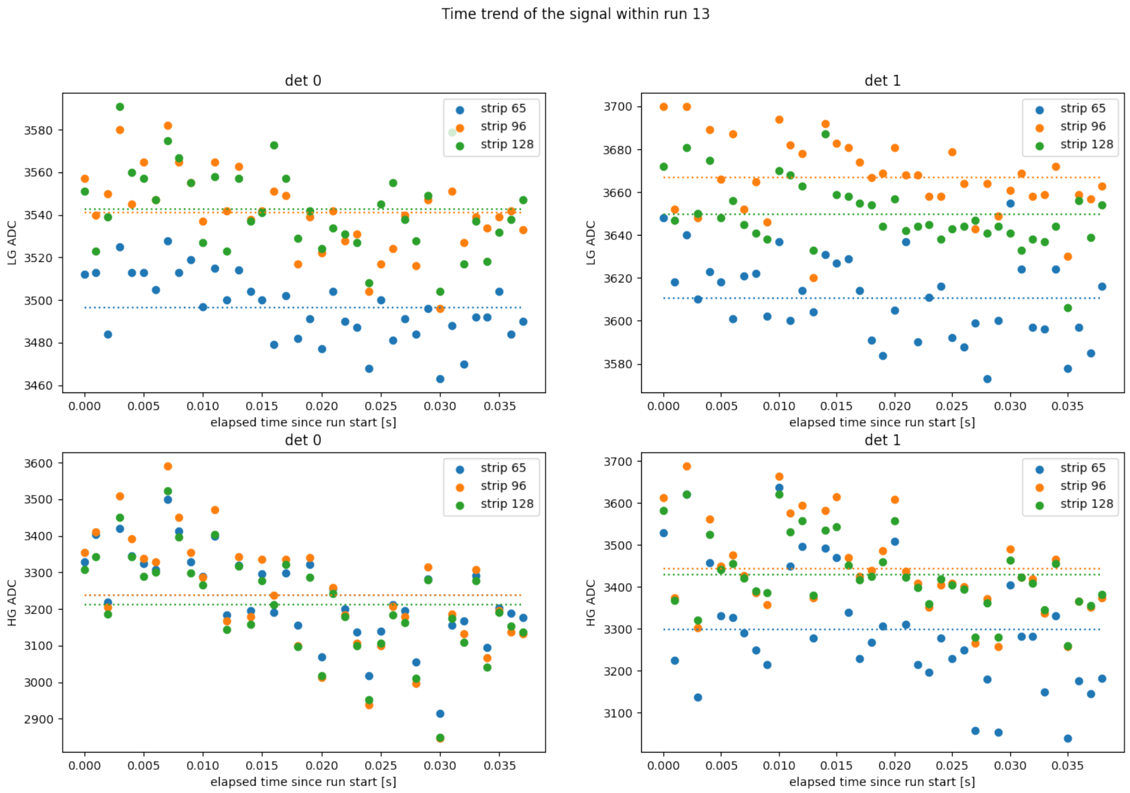
Run 9: pulsing at 600 without injection to LG+HG (99 events)
Run 10: pulsing at 0 with injection to LG+HG (59 events)





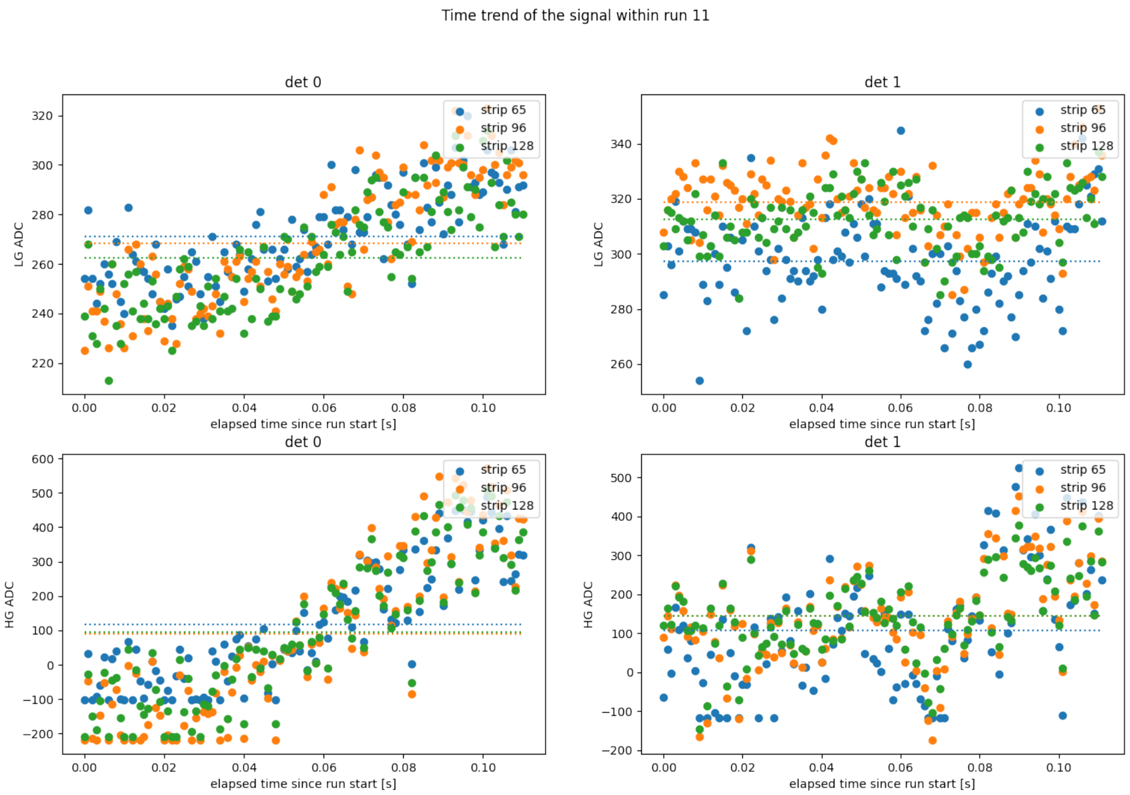
- Without attaching to pulse the preamp, the time dependent plot suggests external noise pickup of both positive/negative polarities.
- Unknown behaviour observed in both the cards at different times causing HG ‘sticking’ to same two values (one for each ASIC) for all the strips connected to them.
- Pulse redirection to LG+HG removes correlation between the two cards, suggesting that switching to ground (ADC=0) eliminates the pickups

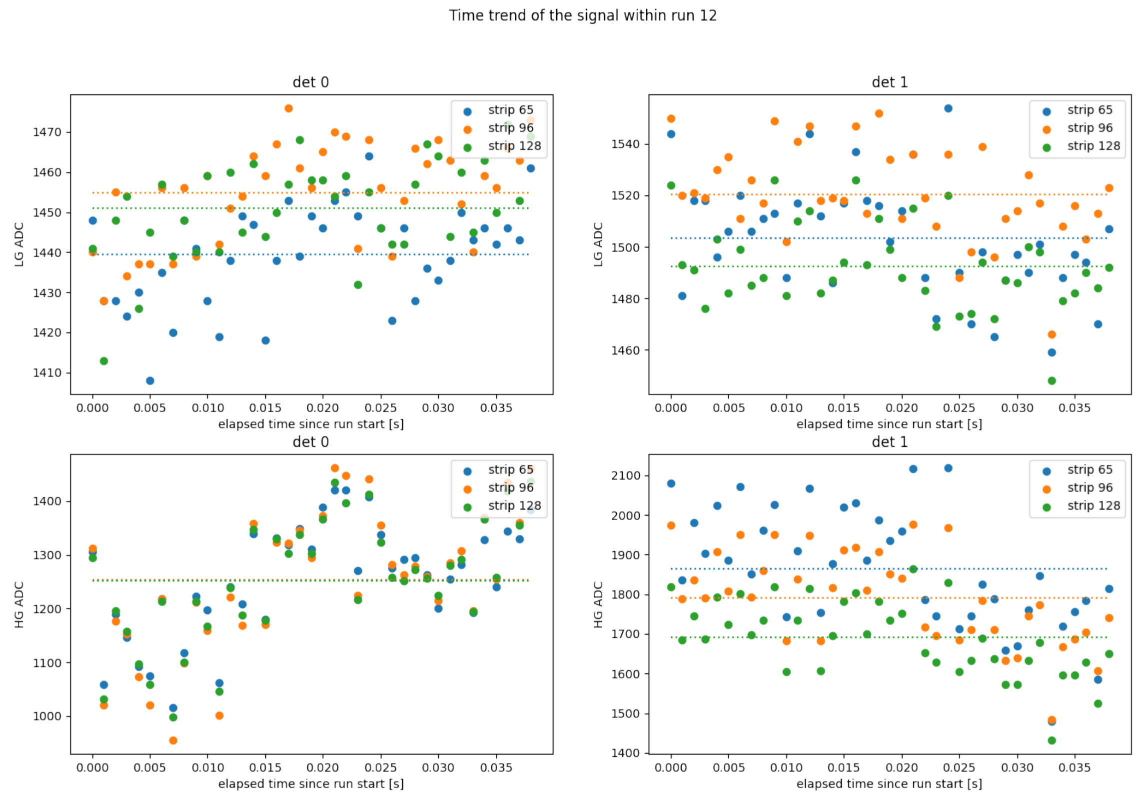
Run 13: pulsing at 800 (39 events)
Run 14: pulsing at 1600 (66 events)



- No appearance of patters in the time trends, **too few** events for Run13. Separation of mean values in det1 brd may be due only to low statistics
- Trend in ASIC I (strip 65 odd) of having lower response to pulse amplitude, as observed in mean values of both the two cards

Run 11: pulsing at 200 (112 events)
Run 12: pulsing at 400 (39 events)





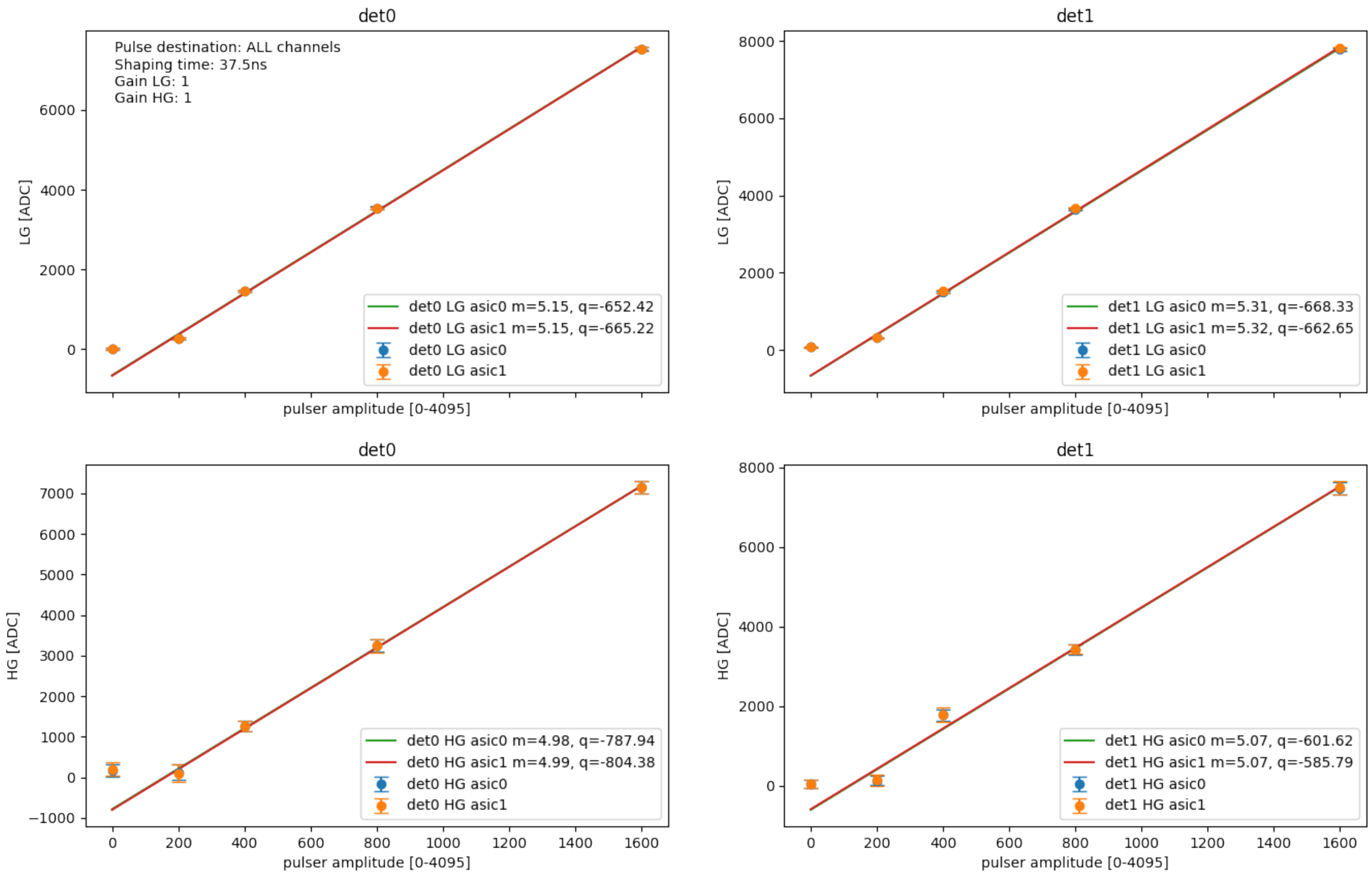
- Clear time drift observed in det0 card, possibly due to the ADC pulse amplitude drift (since observed both in LG/HG)
- **Same** constant values (-100, -200) at early time observed in the HG amp. but lasting for less time

- Not enough datapoints (39) to draw conclusions, **but non-linear response** with pulse amplitude (200→400 corresponds 270→1440) when injecting to **BOTH** LH/HG preamps

Empty runs with internal trigger and pulser.

Summary

Average signal per ASIC as a function of the internal pulser amplitude (in DAC units)



The plot shows the mean value, over the run, of the sum of channels 0-31 (asic0) and 32-63 (asic1) as a function of the run number/internal pulser amplitude. The uncertainty is the standard deviation.

- Data is presented separating each card in the columns, while in the row there are LG and HG
- The fit curve is a straight line, and the fit is performed for points $x \geq 200$ excluding the point at 0

Comments

- Slopes consistent between the ASICs, pedestal values within 2% for LG/HG
- **Unclear** stick-behaviour observed (slide11)

Outlook

- Suggested to perform the same scan in the present ground configuration, with longer run to minimize time-drift dependent effects.

29th March

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Summary of the day

- Second day of TB
  - Horizontal and vertical XY scans with 10-50pC beam charge **[15:45 - 17:45]**
  - Hold time scan to investigate dependence of profile's tails baseline value pt.1/2 **[17:59 - 18:12]**

Data collected

- Horizontal and vertical XY scans with 10-50pC beam charge
  - Continuous beam charge / xy-stage positions (from Timber)
  - Continuous beam position and shape on the YAG:Ce (from Basler)
  - Continuous voltage / current monitors (from PSU)
  - (Manual) Detector signal from FERS
  - Partial 10Hz beam charge (15% covered) logged (from DT5730)
- Hold time scan to investigate dependence of profile's tails baseline value pt.1/2
  - All data acquired at 10Hz continuously
  - Manual FERS run control

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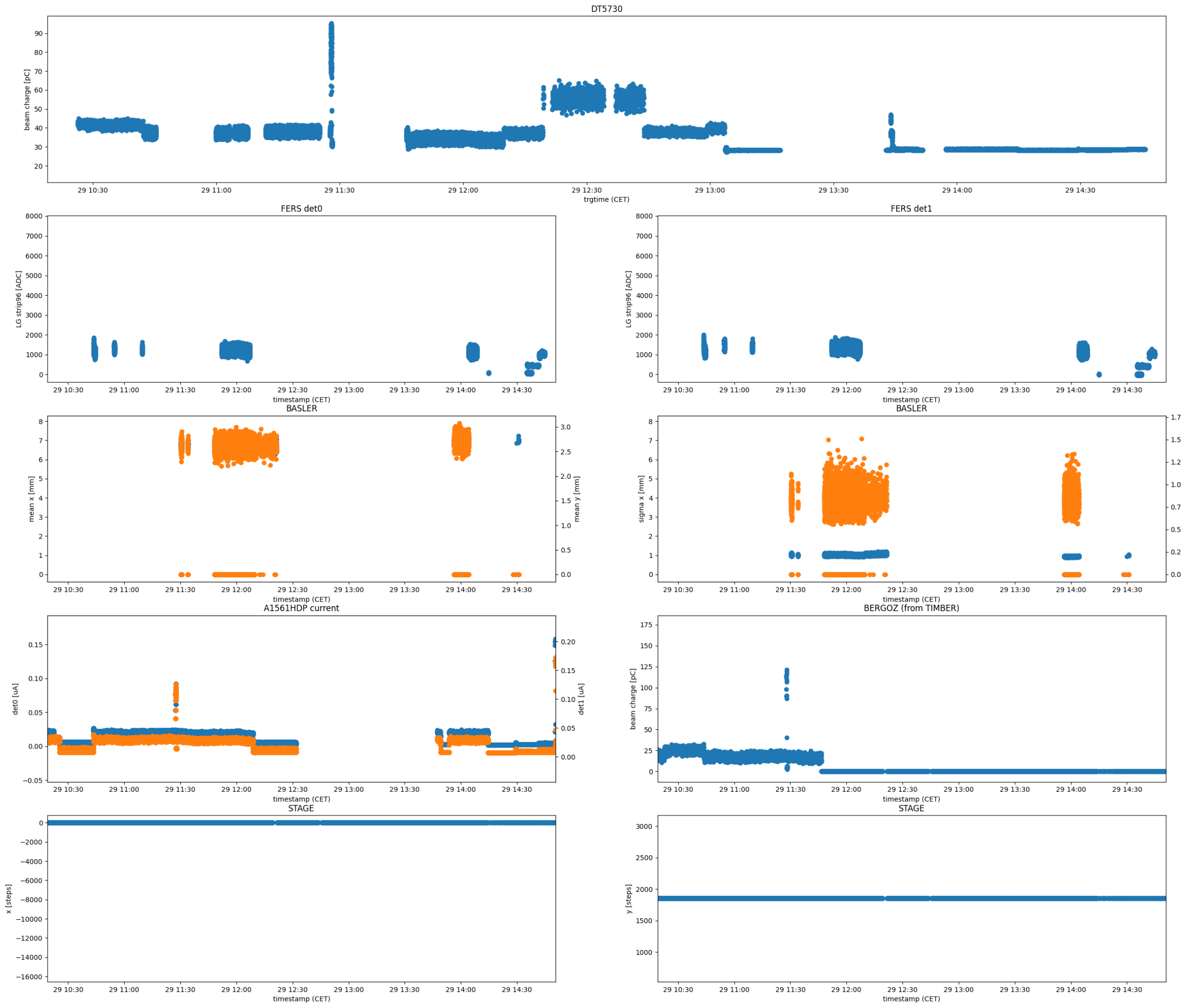
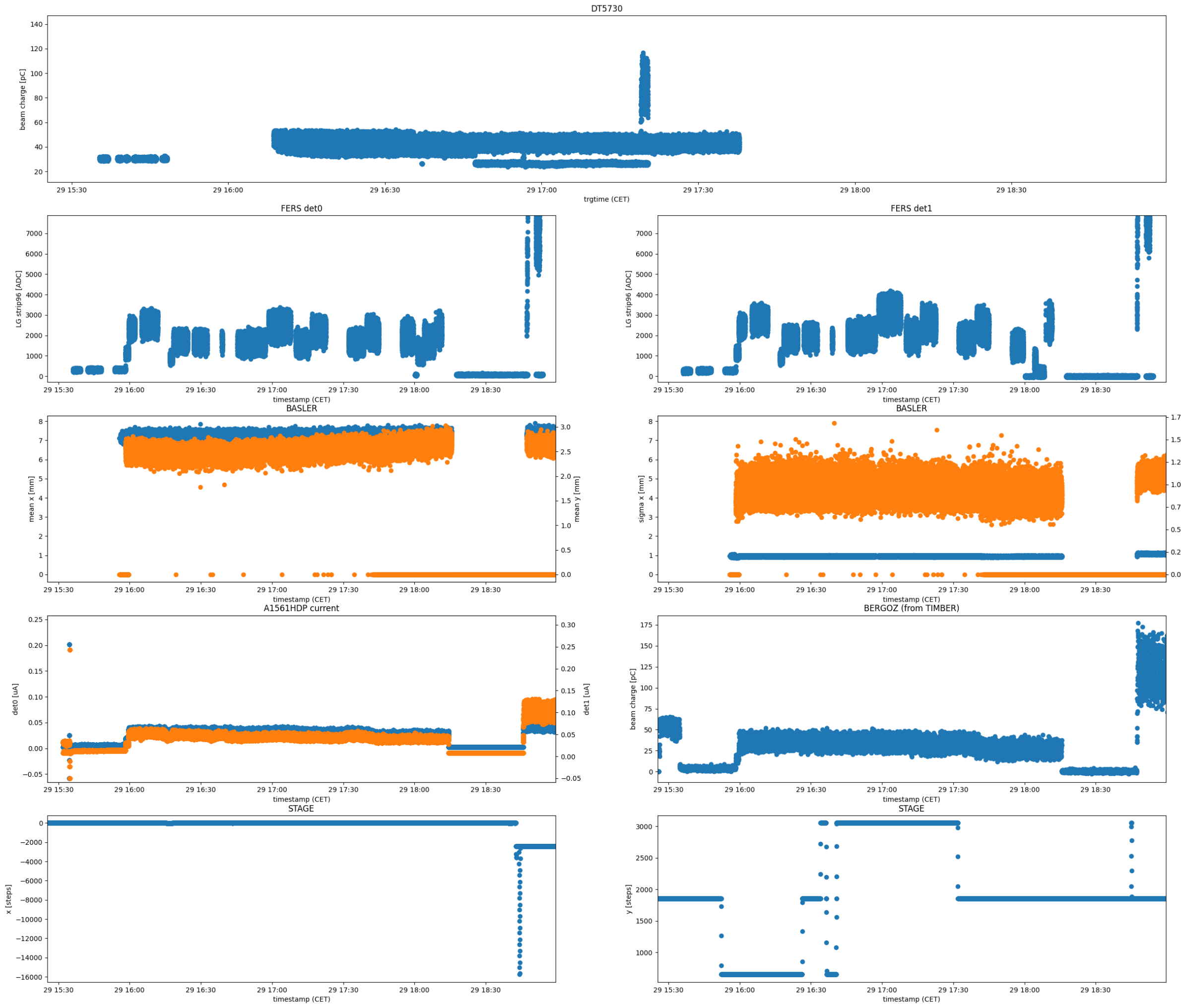
Summary of the day (the period is split in two parts)





Horizontal and vertical scans at 30pC/train

Detector response uniformity

Horizontal and vertical XY scans with 10-50pC beam charge
Summary

Description

- The horizontal and vertical position of the XY stage - where the detector assembly is mounted - has been changed to investigate the different response of the strips (horizontal displacements) and with respect to the vertical position of the beam within the strip.

Conditions

- Detectors supply voltage fixed to **100V**
- FERS settings fixed for both cards during the entire run to

LG/HG	Shaping time	MUX clock T	Hold time
1/1	37.5ns	300ns	100ns

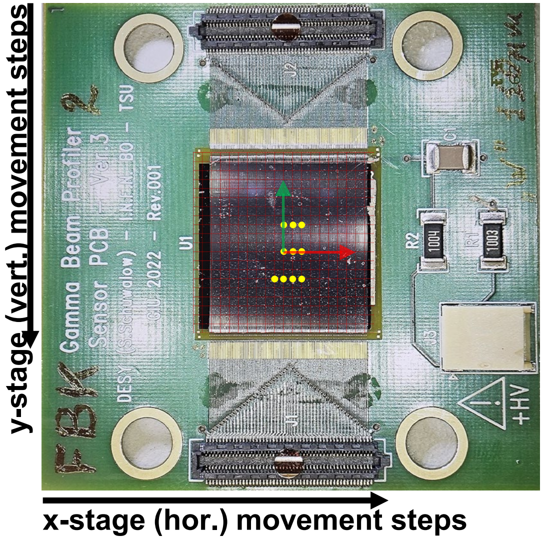
- Beam operated in **1 bunch/train** at rep. rate **10Hz** with typical train charge of **30-40pC** and beam shape of **1x1 mm**
- The XY-table is moved in $\pm$1mm ($\pm$3mm) horizontally (vertically) around the initial point

Analysis

1. Camera data is used to investigate the beam conditions over time for the period under consideration. The systematic uncertainties associated with beam position/width change are evaluated.
2. The detector response as a function of the table positions (x,y) is evaluated using the power supply current, the readout charge, and camera beam normalization.

Conclusions

- Uniform sensor response over the XY positions scanned.
- Observed the effect of the strip high-resistivity on the BP reconstruction in the asymmetry between even/odd profiles.

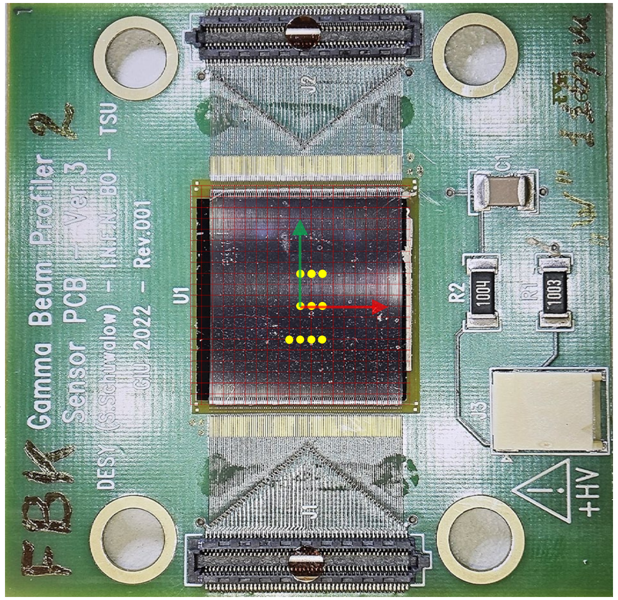


Horizontal and vertical XY scans with 10-50pC beam charge
Data used

Legend for the *data* field

- (timber, digitizer, fers, camera)
- The meaning is:
  - 1 – present
  - 0 – not present
  - p – partly present

y-stage (vert.) movement steps



x-stage (hor.) movement steps

Time start	Time stop	BEAM X [mm]	BEAM Y [mm]	Stage X	Stage Y	data
-	~~15:52:10~~	~~-1~~	~~0~~	~~-4~~	~~653~~	~~1pp0~~
15:59:42	16:02:15	-1	-3	-4	653	1011
16:05:00	16:12:30	0	-3	-6	653	1011
16:14:10	16:15:20	-1	-3	-4	653	1001
16:15:40	16:18:00	+2	-3	-10	653	1011
16:18:30	16:24:30	+1	-3	-8	653	1011
16:26:30	16:33:00	+1	**0**	-8	1853	1011
16:34:15	16:36:20	+1	+3	-8	3000	1001
16:38:30	16:39:30	+1	-3	-8	653	1011
16:41	16:43	+1	+3	-8	3000	1001
16:46:30	16:57:24	+1	+3	-8	3000	1011
16:58:30	17:08:00	0	+3	-6	3000	1011
17:10:00	17:15:30	+1	+3	-8	3000	1011
17:16:45	17:23:00	-1	+3	-4	3000	1011
17:25:00	17:31:30	+1	+3	-8	3000	1001
17:32:20	17:39:30	+1	0	-8	1853	1p11
17:39:52	17:45:04	0	0	-6	1853	1111

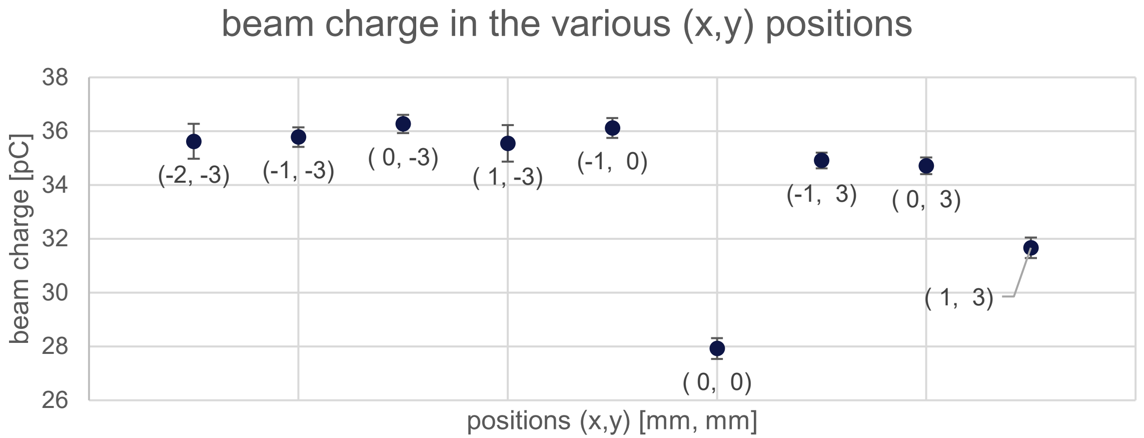
BEAM X – hor. beam pos on det
BEAM Y – vert. beam pos on det

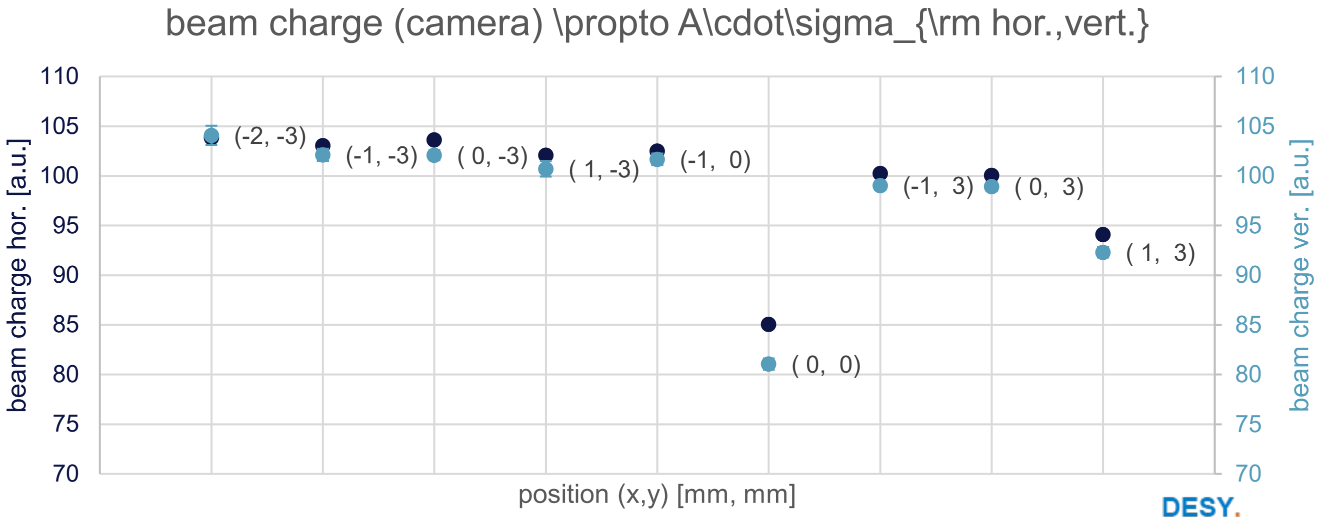
Horizontal and vertical XY scans with 10-50pC beam charge

Beam-related systematics

Charge

- Beam charge at 10Hz unavailable.
- Typical CLEAR's BCM variation is 2%
- Beam charge can be inferred from the camera too, by taking the area of the (gaussian + const.) fit
  - $Q_{beam} \propto V \equiv 2\pi(A_{hor} \cdot \sigma_{hor})$





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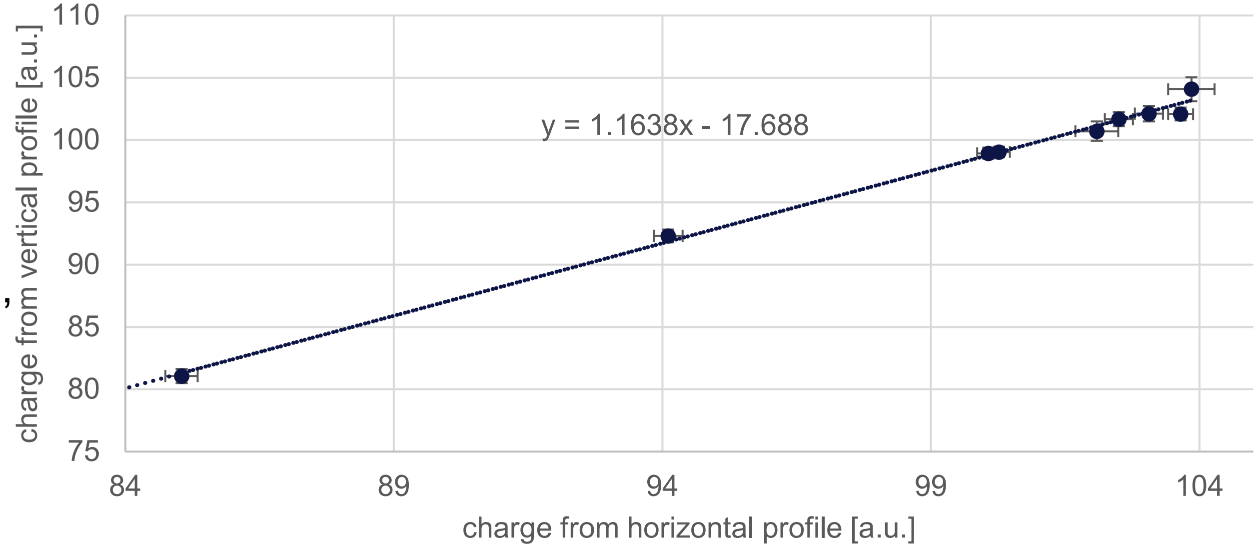
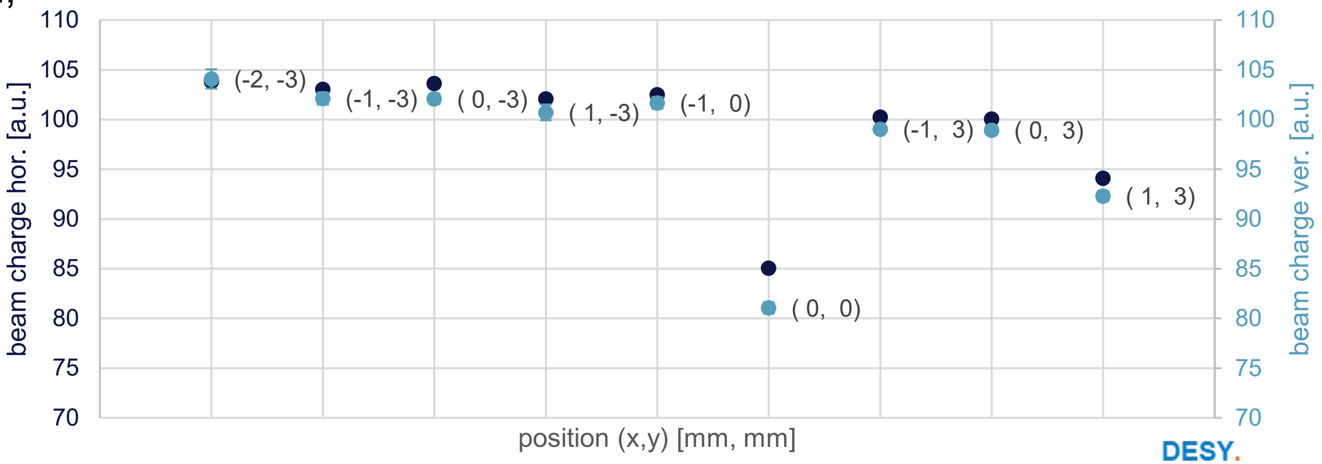
- Typical CLEAR's BCM variation is 2%
- Beam charge can be inferred from the camera too, by taking the area of the (gaussian + const.) fit
  - $Q_{beam} \propto V \equiv 2\pi(A_{hor} \cdot \sigma_{hor})$
  - This can be done using the fit from either the horizontal or the vertical profile projection.
  - The two quantities are expected to be **identical**, because they are the total sum of pixel intensities in the 2D image.
  - Indeed, they are correlated but the $Q_{ver.}(Q_{hor.})$ has (a) non -zero intercept and (b) slope ≠ 1. ***Why?***

Horizontal vs vertical integrated charge from camera (with std err)



$$beam\ charge_{camera} \propto (A \cdot \sigma_{hor.,vert.})$$



Horizontal and vertical XY scans with 10-50pC beam charge

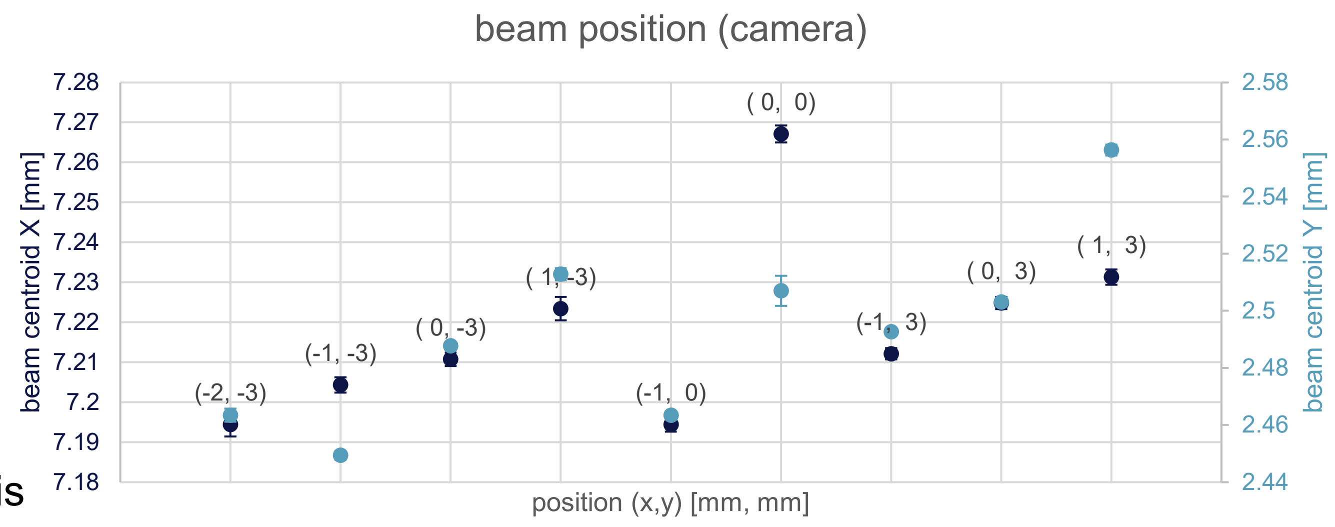
Beam-related systematics

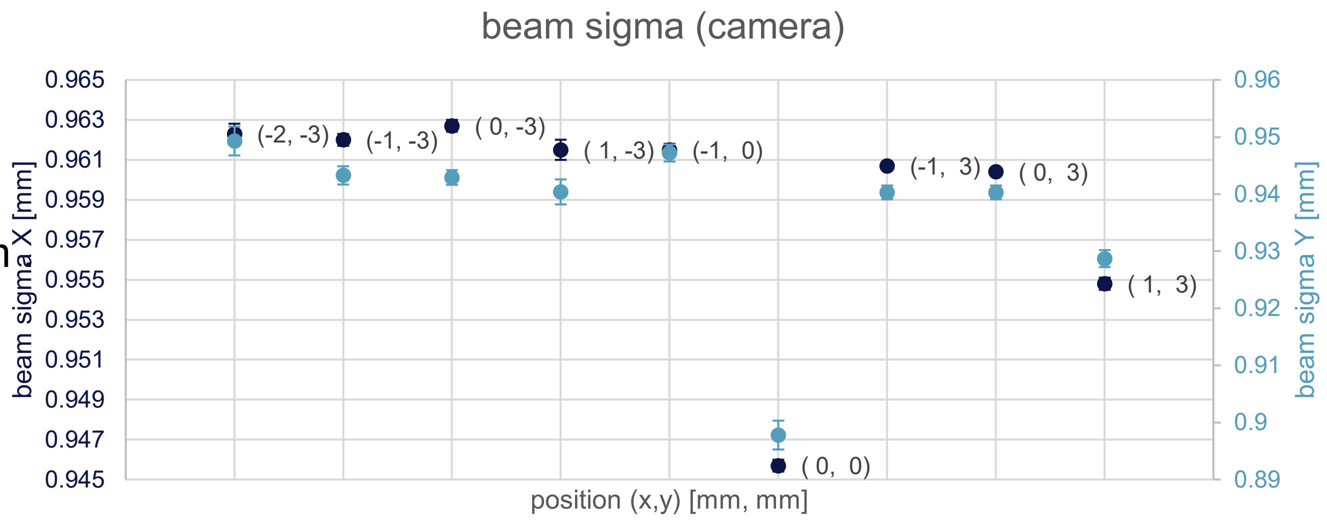
Position

- For a given position (x,y) of the table, the beam centroid is very stable (1%)

Width

- Also, the horizontal/vertical beam sigma can be considered constant to a good approximation: for example, during the time the detector position is (-1,3):
  - the average value for sigma horizontal is 0.96mm;
  - the standard deviation is 0.02mm;
  - the uncertainty of the mean value is 0.0003mm





Horizontal and vertical XY scans with 10-50pC beam charge

Analysis and Results

Conditions

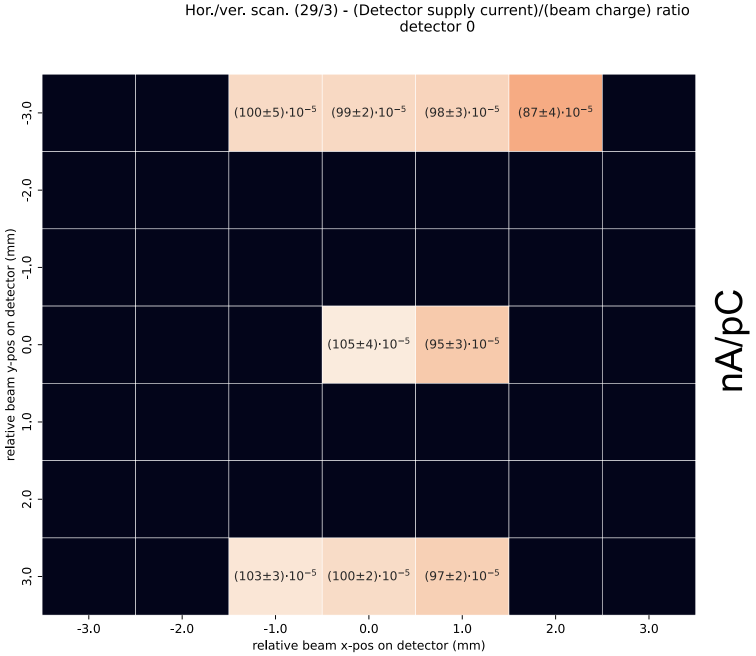
1. The beam in entirely contained within the 192-strip sensor area: the sensor is a square 2cm by 2cm and the beam is a spot with radius (3σ) of 0.3cm;
2. For beam aiming at (-1, X), the BP is centred horizontally.
3. No information on the absolute vert. position of the beam on the BP.

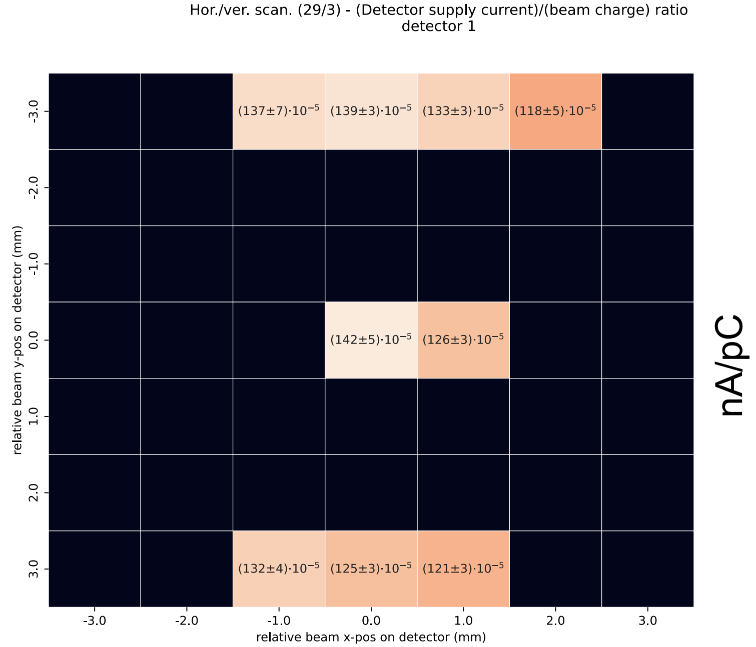
Analysis

- If we assume the ps current being proportional to CCE, then the ratio between I_det/Q_beam is a measurement of the sensor response as a function of the (x, y) coordinate of the beam on the sensor.
- The averages of ps currents and beam charge are taken over the (~3.7k) events for periods of 2-4 minutes. The error on the average is used. The ratio's uncertainty is the quadratic sum of the uncertainties.

Results

- Overall consistency in the ratio. Uncertainties are very likely underestimated, due to the nature of PS and TIMBER data sources.
- Consistent decrease with pos. x-displacements between the two sensors due to the BCM (being imprecise at such low charges)





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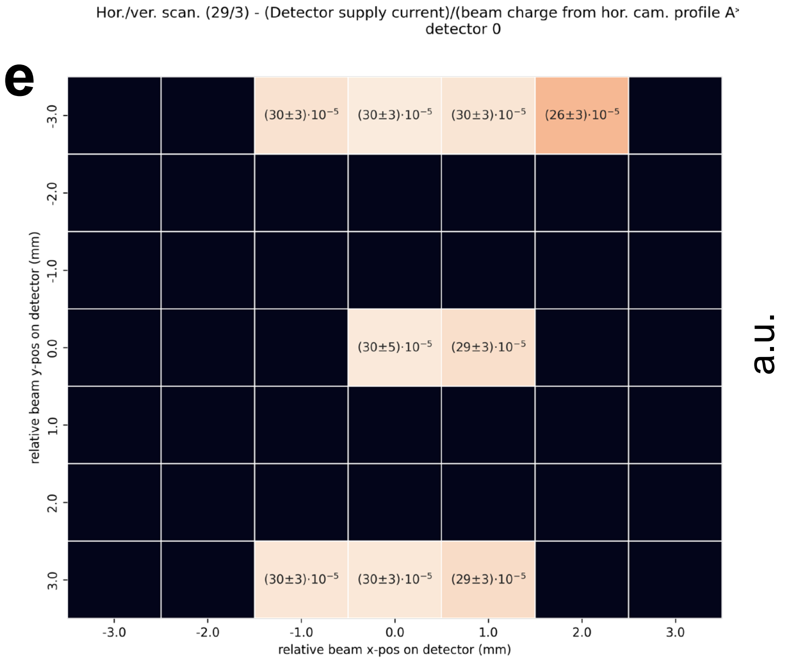
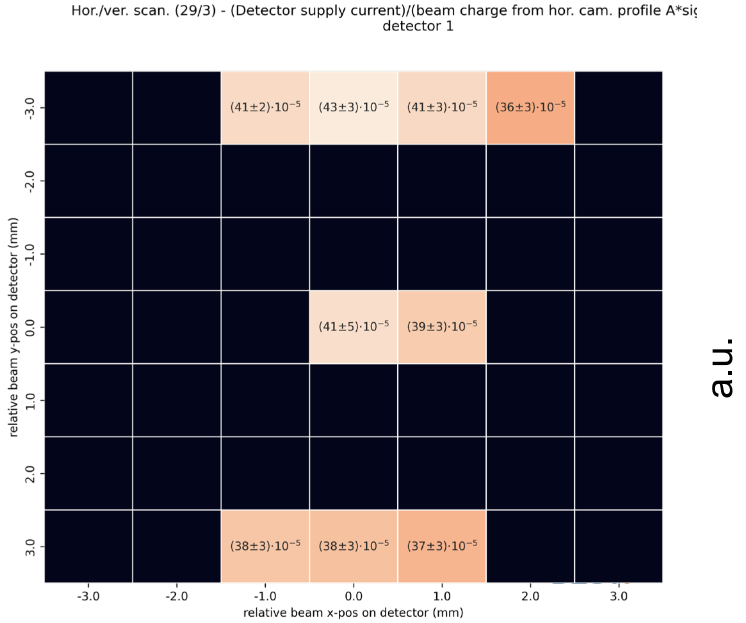
Results

- Overall consistency in the ratio. Uncertainties are very likely underestimated, due to the nature of PS and TIMBER data sources.
- Consistent decrease with pos. x-displacements between the two sensors due to the BCM (being imprecise at such low charges)
- Uniform response when using the beam charge inferred from camera-scintillator setup.





Horizontal and vertical scans at 30pC/train

Strip resistivity and vertical scan

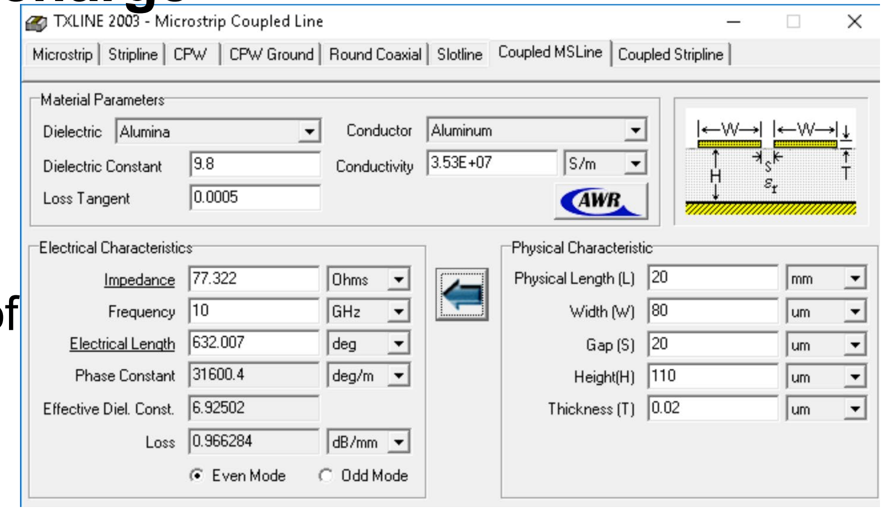
Horizontal and vertical XY scans with 10-50pC beam charge

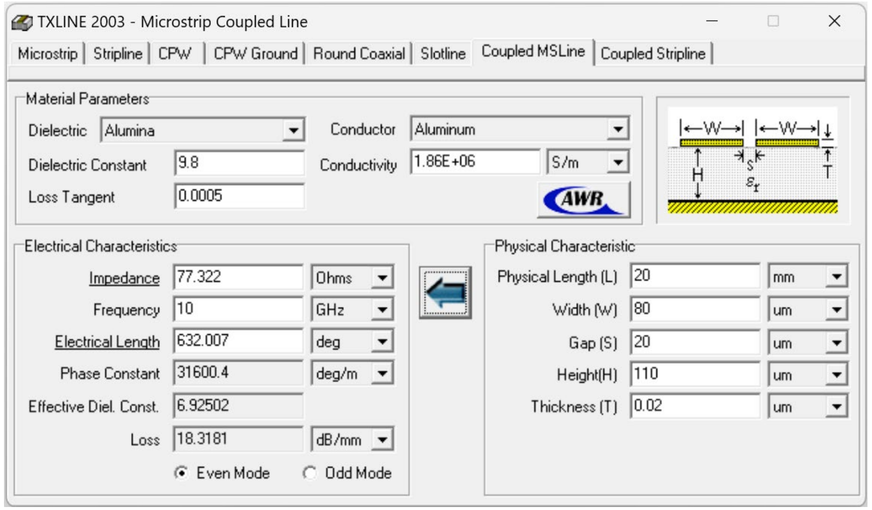
High strip resistivity and beam profile reconstruction

- Typical strip resistance (l=20mm) for **Tomsk** sensors is measured to be **6.7kΩ** for a strip, while **60Ω** for the **FBK** sensors.

- Typical strip even-mode impedance, assuming a signal rise time of 100ps, is approx. **77Ω** (93Ω) for the 110um-thick (150um) sensor.

- **Two key-points**
  1. high-strip resistivity implies signal attenuation (**loss**), whose intensity depends on the beam vertical position on the strip;
  2. lossy-line ($6.7k\Omega \gg 77\Omega$) means frequency-dependent termination: unproper matching and sig. **reflections.**





Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction

Description

- The test consists in moving the detector vertically and measure the effect looking at the asymmetry between the beam charge from the reconstructed beam profile (gaus+const fit) by either the even or the odd strips.

Theory

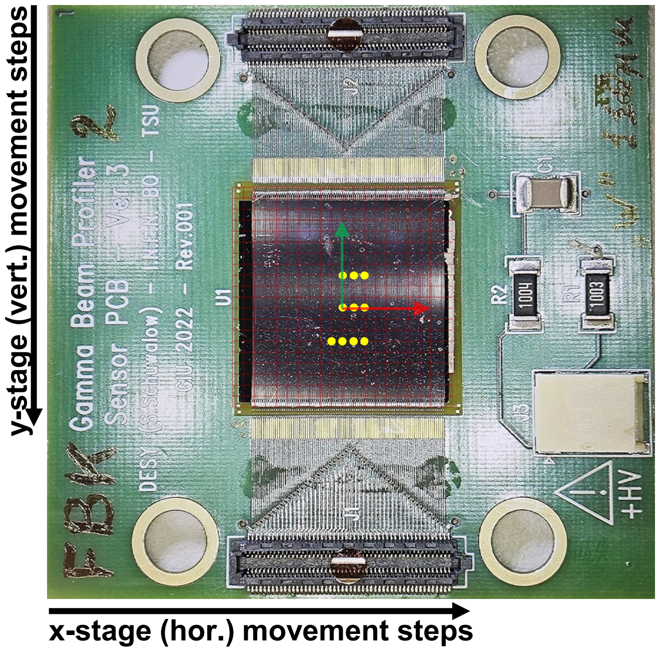
- If we assume the signal attenuation depending on the path length $e^{-loss\,\Delta y}$, there is a difference between signals which are readout from even and odd strips.
- With **y** the position of the beam on the sensor (as in the image on the right), we have
  - $Q_{even\ strip} \propto e^{-\alpha\left(\frac{d}{2}-y\right)}$
  - $Q_{odd\ strip} \propto e^{-\alpha\left(\frac{d}{2}+y\right)}$
- Therefore, the asymmetry

$$\frac{Q_{even} - Q_{odd}}{Q_{even} + Q_{odd}} = \tanh(\alpha y) = \alpha y - \frac{(\alpha y)^3}{3} + O\left((\alpha y)^5\right)$$

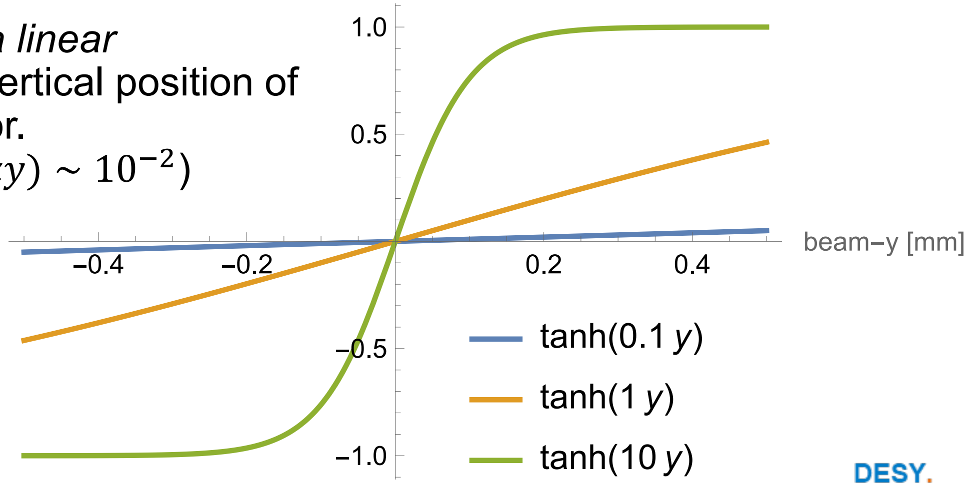
Expected

- That is, *it is expected a linear dependence* with the vertical position of the beam on the sensor.
  - (notice we have $(\alpha y) \sim 10^{-2}$)

even



odd



Horizontal and vertical XY scans with 10-50pC beam charge

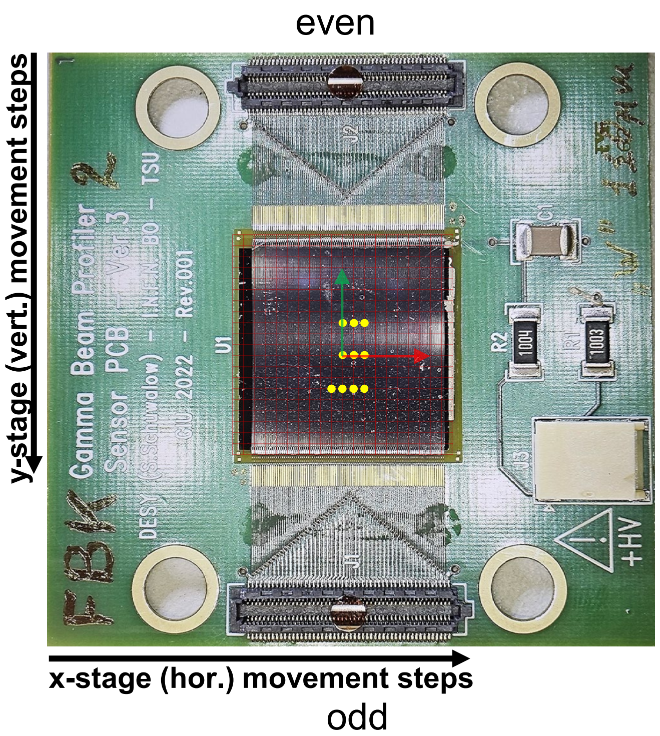
High strip resistivity and beam profile reconstruction

Conditions

- Beam (1,1)mm @40pC/train.
- Both detectors at 100V.

Analysis

- The calibrated GP profiles (w. *pedestalA* subtraction) are fitted with a gaussian + constant separately for even and odd strips in the range [65,128].
- A few quantities (asymA, asymB, …) are calculated for every event. At a given (x,y) beam position, for each of them the two plots are generated:
  - graph asym(time),
  - histogram of asym.
- Mean and sigma of the histogram’s gaussian fit are plotted in the chart asym(y).
- The (graph, hist) of other quantities (fit amplitude, sigma, mean, background) are plotted for inspection.



Data used

Dataset	BeamX [mm]	BeamY [mm]	From	To
One	1	-3	16:18:30	16:24:30
		0	16:26:30	16:33:00
		3	16:46:30	16:57:24
Two	0	-3	16:05:00	16:12:30
		0	17:39:52	17:45:04
		3	16:58:30	17:08:00

Horizontal and vertical XY scans with 10-50pC beam charge

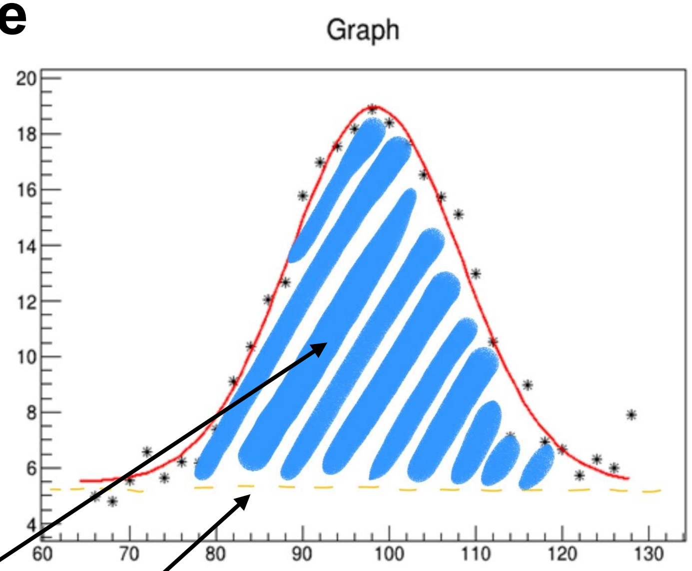
High strip resistivity and beam profile reconstruction

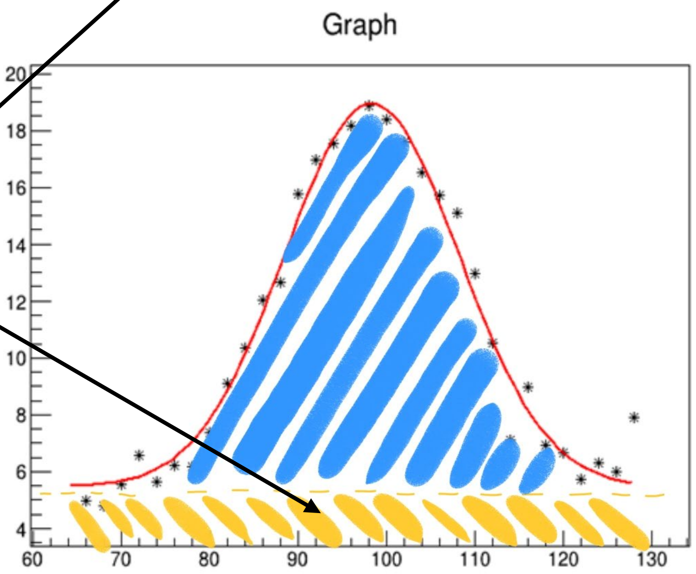
Variables

- Asymmetry A - $asymA \equiv \frac{(A\sigma)_{even} - (A\sigma)_{odd}}{(A\sigma)_{even} + (A\sigma)_{odd}}$
- Asymmetry B - $asymB \equiv \frac{(A\sigma+baseline*6.4)_{even} - (A\sigma+baseline*6.4)_{odd}}{(A\sigma+baseline*6.4)_{even} + (A\sigma+baseline*6.4)_{odd}}$
- Asymmetry C - $asymC \equiv \frac{(baseline*6.4)_{even} - (baseline*6.4)_{odd}}{(baseline*6.4)_{even} + (baseline*6.4)_{odd}}$
- Asymmetry D - $asymD \equiv \frac{\sum_{2i} Q_{strip} - \sum_{2i+1} Q_{strip}}{\sum_{2i} Q_{strip} + \sum_{2i+1} Q_{strip}}$
- Asymmetry E - $asymE \equiv \frac{\sigma_{even} - \sigma_{odd}}{\sigma_{even} + \sigma_{odd}}$

The product by 6.4mm is to compare asymB with asymD.

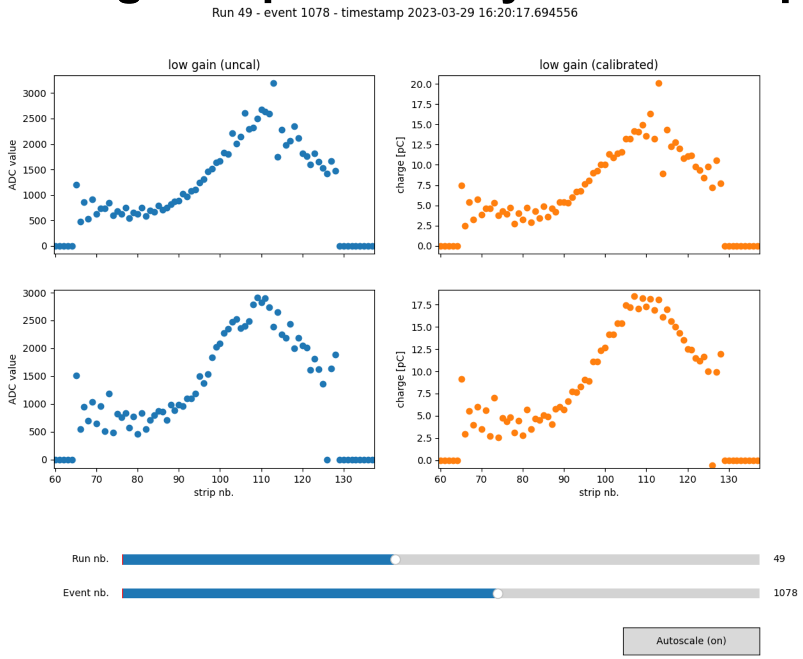
- $A\sigma$
- baseline curve
- baseline*6.4mn



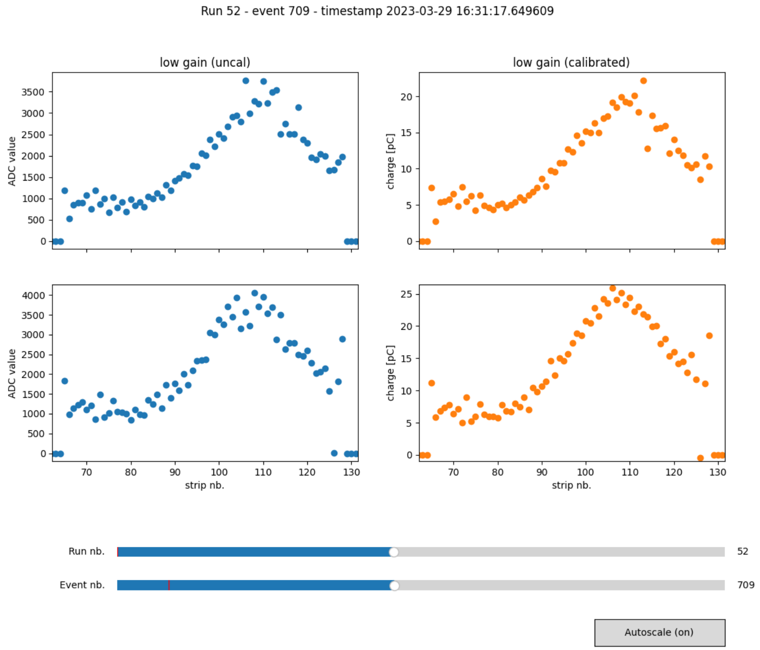


Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction. Vertical scan profiles.

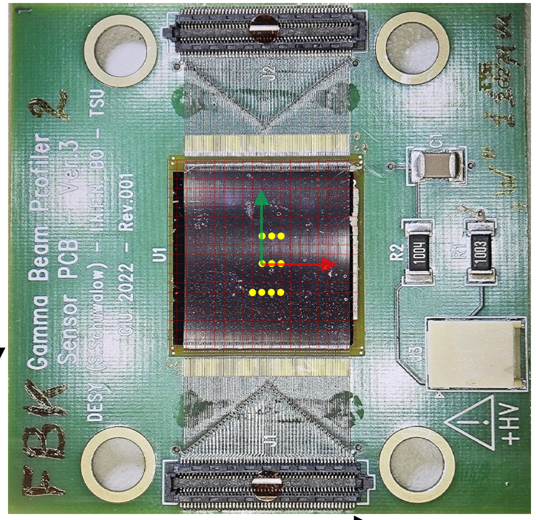


Pos (1, -3) mm

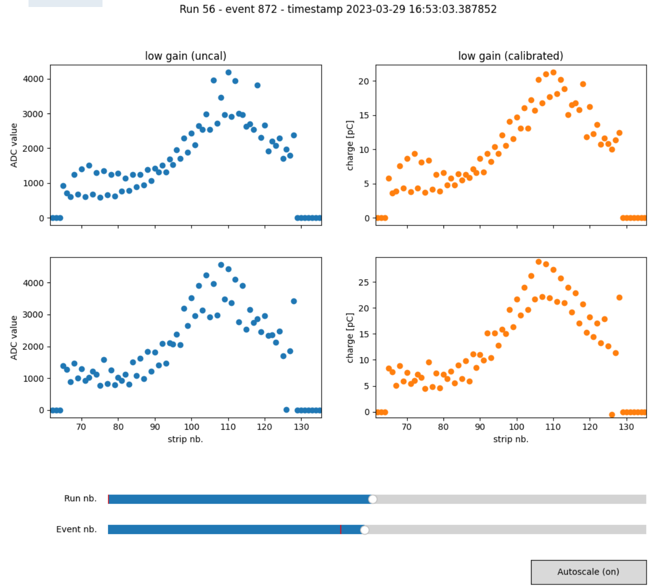


Pos (1, 0) mm

y-stage (vert.) movement steps



x-stage (hor.) movement steps

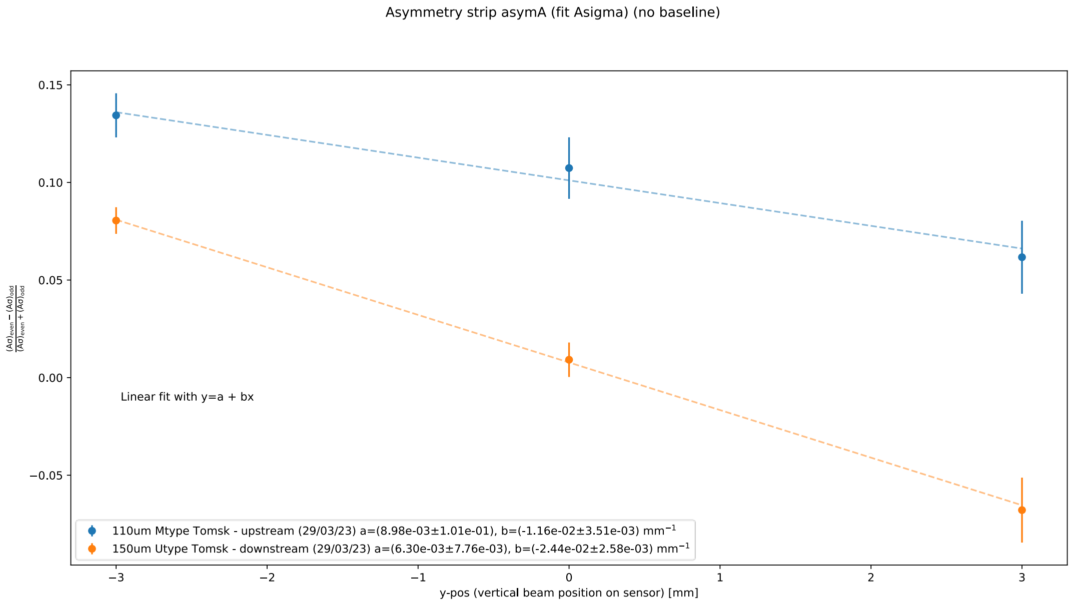


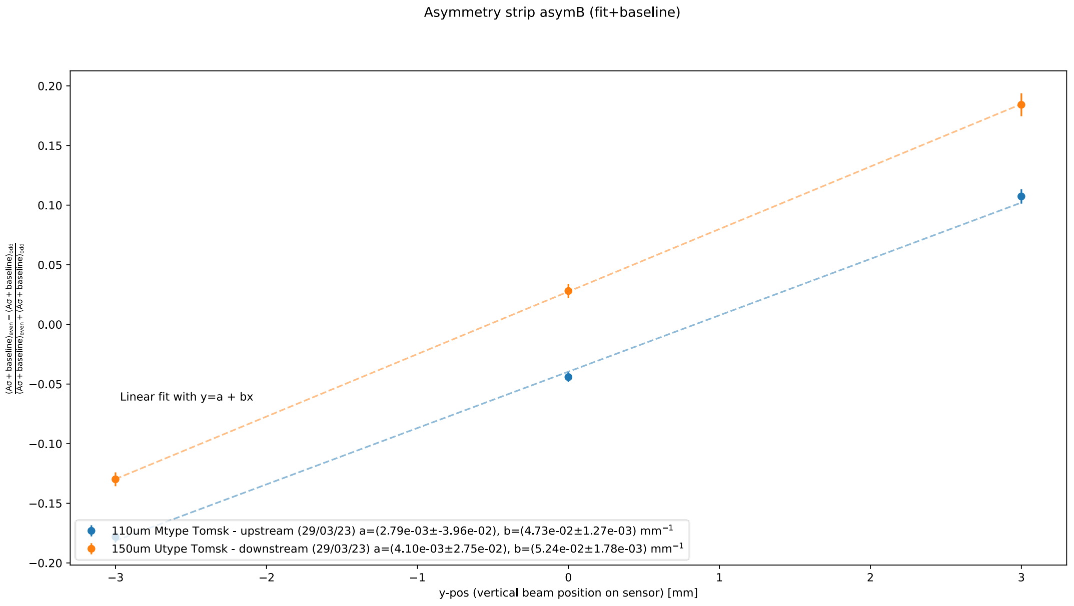
Pos (1, 3) mm

- Observed an increase of odd-even signals as a function of vertical beam position in the sensor.
- Separation is consistent within the events in the same run (as the three events represented above).
- Largest separation for pos. (1,3) in the even strips, with higher signals than odd, **as expected.**

Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction





asymA

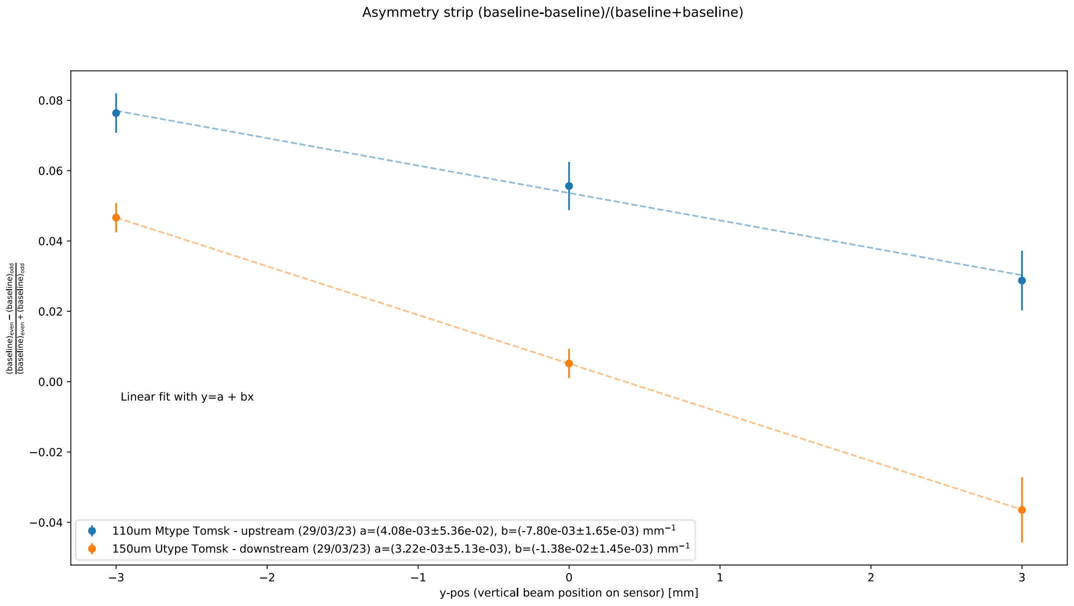
$$asymA \equiv \frac{(A\sigma)_{even} - (A\sigma)_{odd}}{(A\sigma)_{even} + (A\sigma)_{odd}}$$

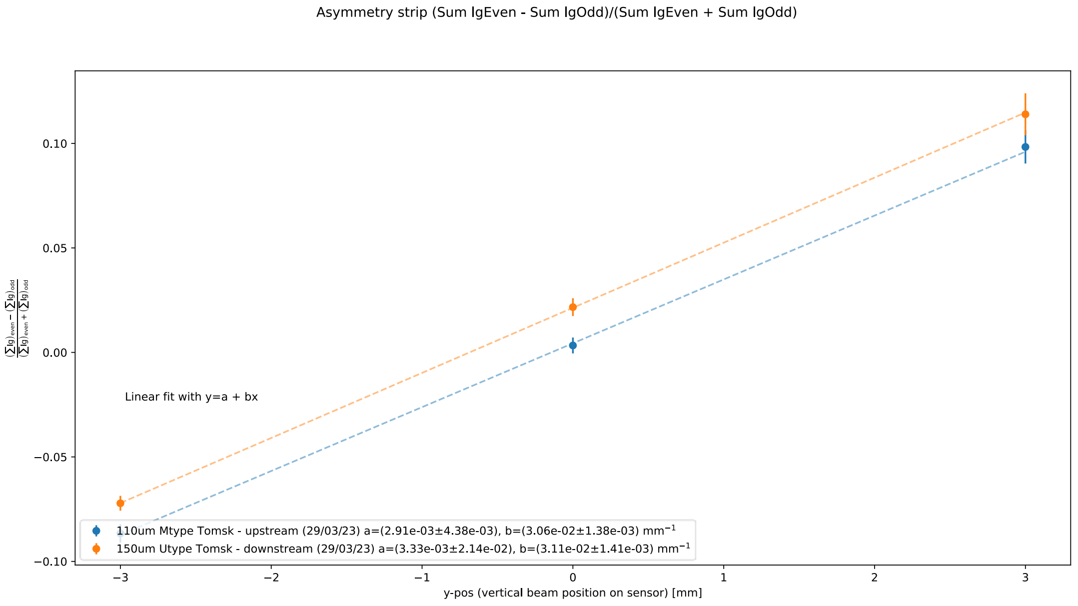
asymB

$$asymB \equiv \frac{(A\sigma + baseline * 6.4)_{even} - (A\sigma + baseline * 6.4)_{odd}}{(A\sigma + baseline * 6.4)_{even} + (A\sigma + baseline * 6.4)_{odd}}$$

Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction





asymC

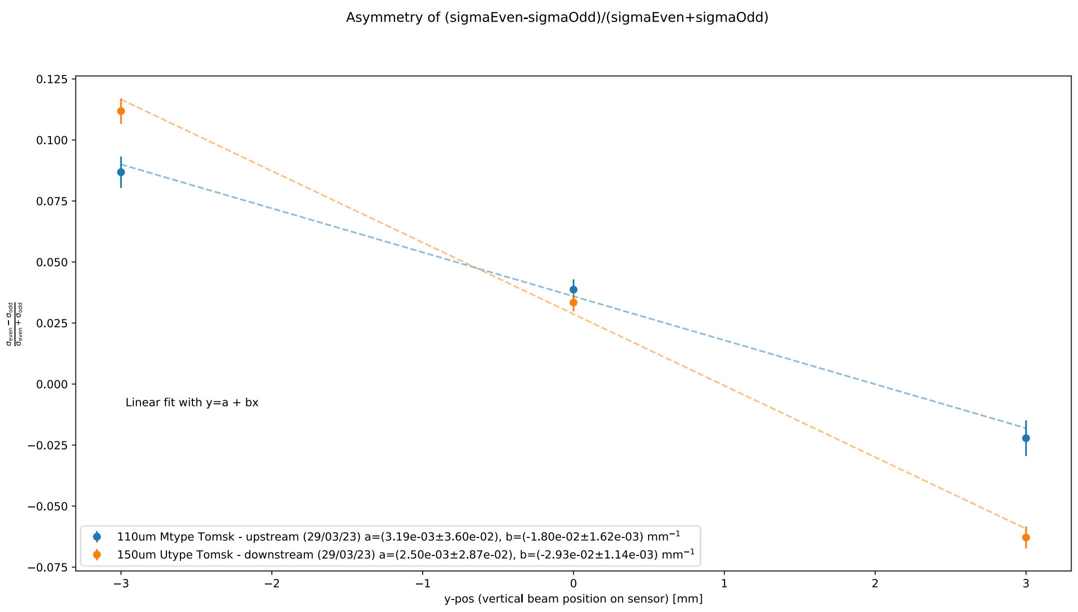
$$asymC \equiv \frac{(baseline * 6.4)_{even} - (baseline * 6.4)_{odd}}{(baseline * 6.4)_{even} + (baseline * 6.4)_{odd}}$$

asymD

$$asymD \equiv \frac{\sum_{2i} Q_{strip} - \sum_{2i+1} Q_{strip}}{\sum_{2i} Q_{strip} + \sum_{2i+1} Q_{strip}}$$

Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction

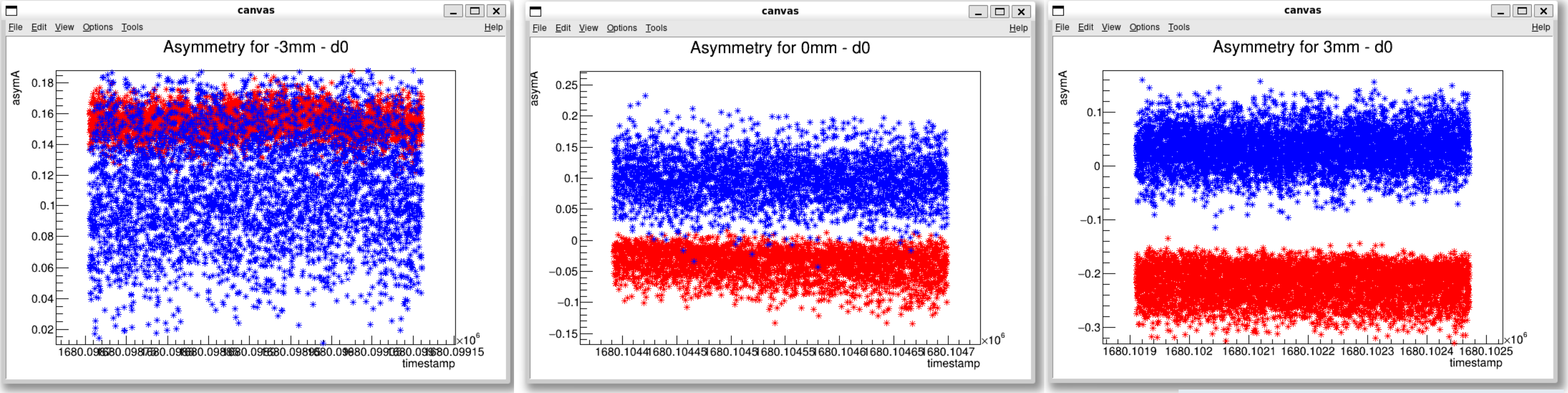


asymE

$$asymE \equiv \frac{\sigma_{even} - \sigma_{odd}}{\sigma_{even} + \sigma_{odd}}$$

Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction. Asymmetry vs time



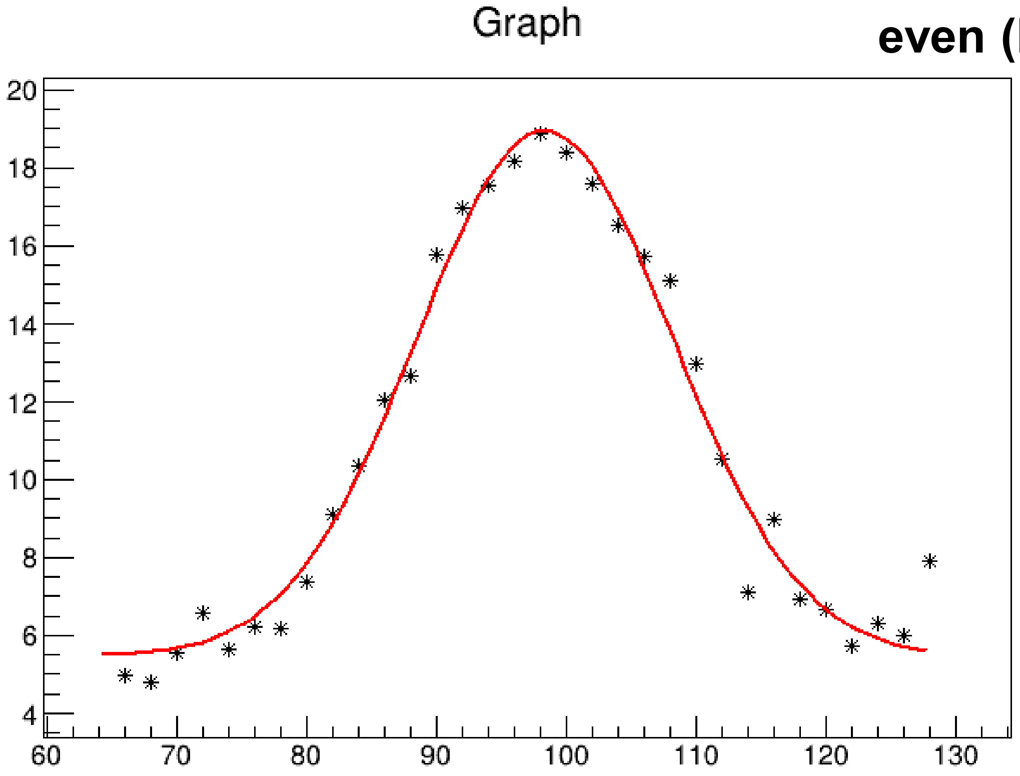
Detector 0 and detector 1

- No drift observed in asymA during the period under consideration (recall that these covers many runs).
- Analogously, beam charge very stable during the measurement (but no 10Hz info available).

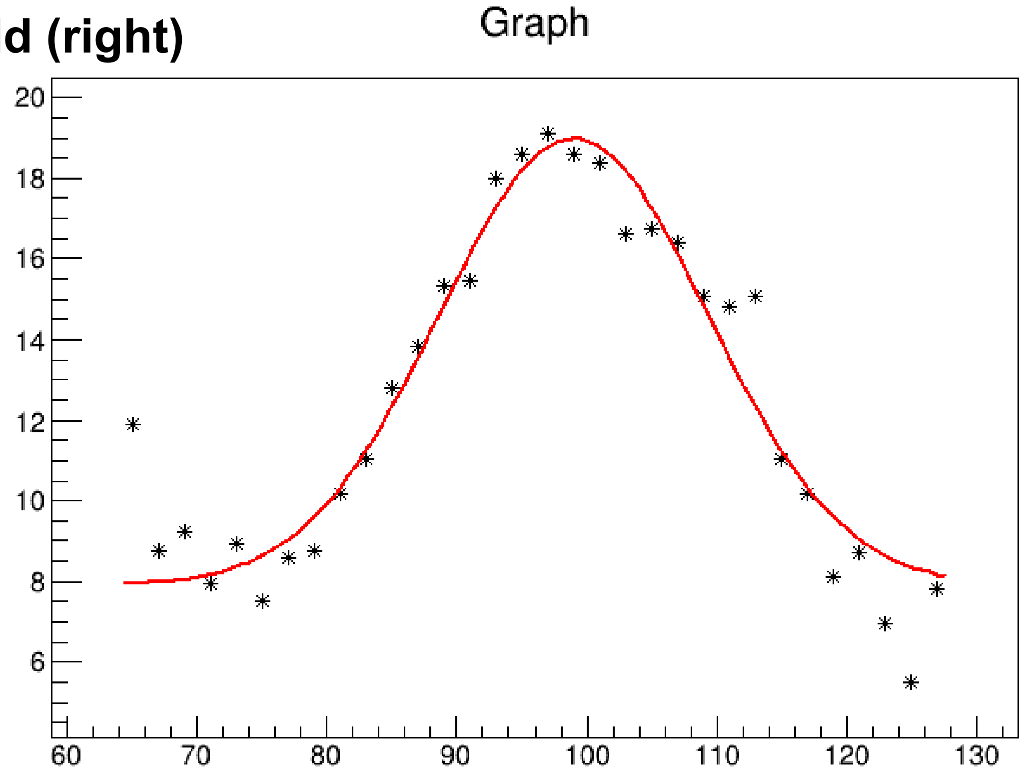
Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction. Fit result for run45 (0, -3) – det0 - event0

- Constraining fit to central region (e.g., say from strip 85 to 110) worse the result due to the lower points number. Tails do not seem to affect the gaussian fit.



even (left) | odd (right)

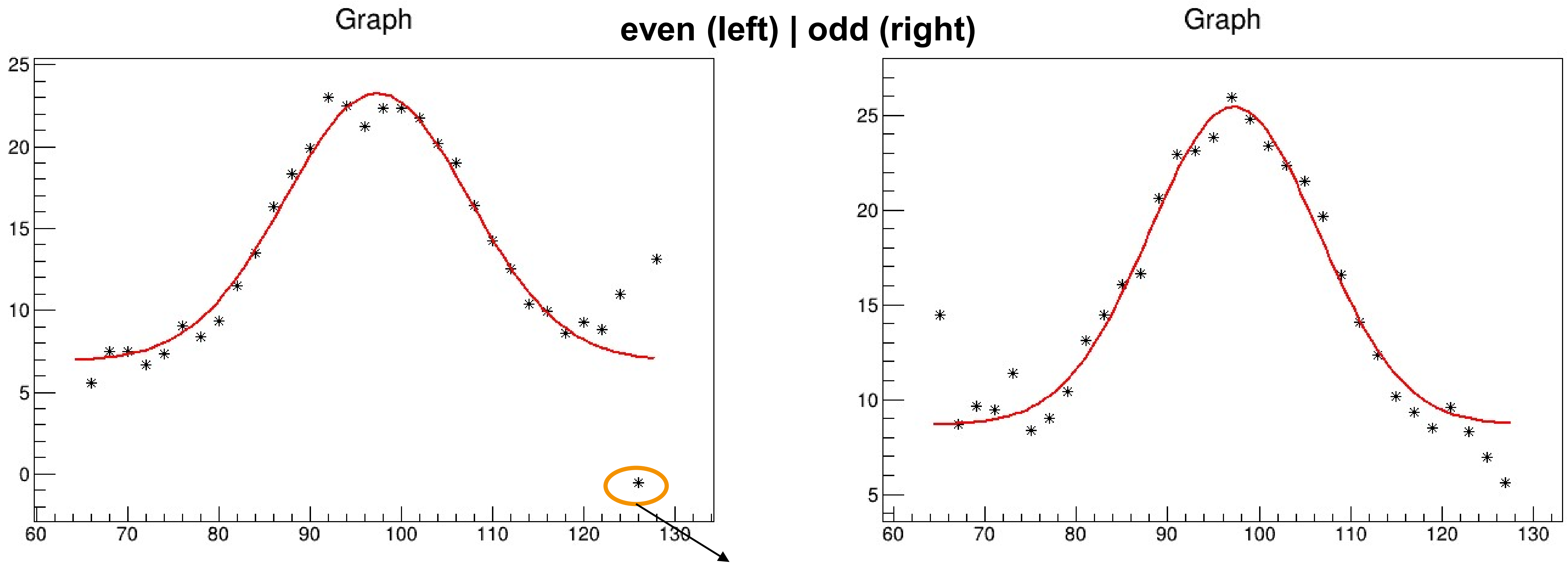


Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction. Fit result for run45 (0, -3) – det1 - event0

- Constraining fit to central region (e.g., say from strip 85 to 110) worse the result due to the lower points number. Tails do not seem to affect the gaussian fit.

even (left) | odd (right)



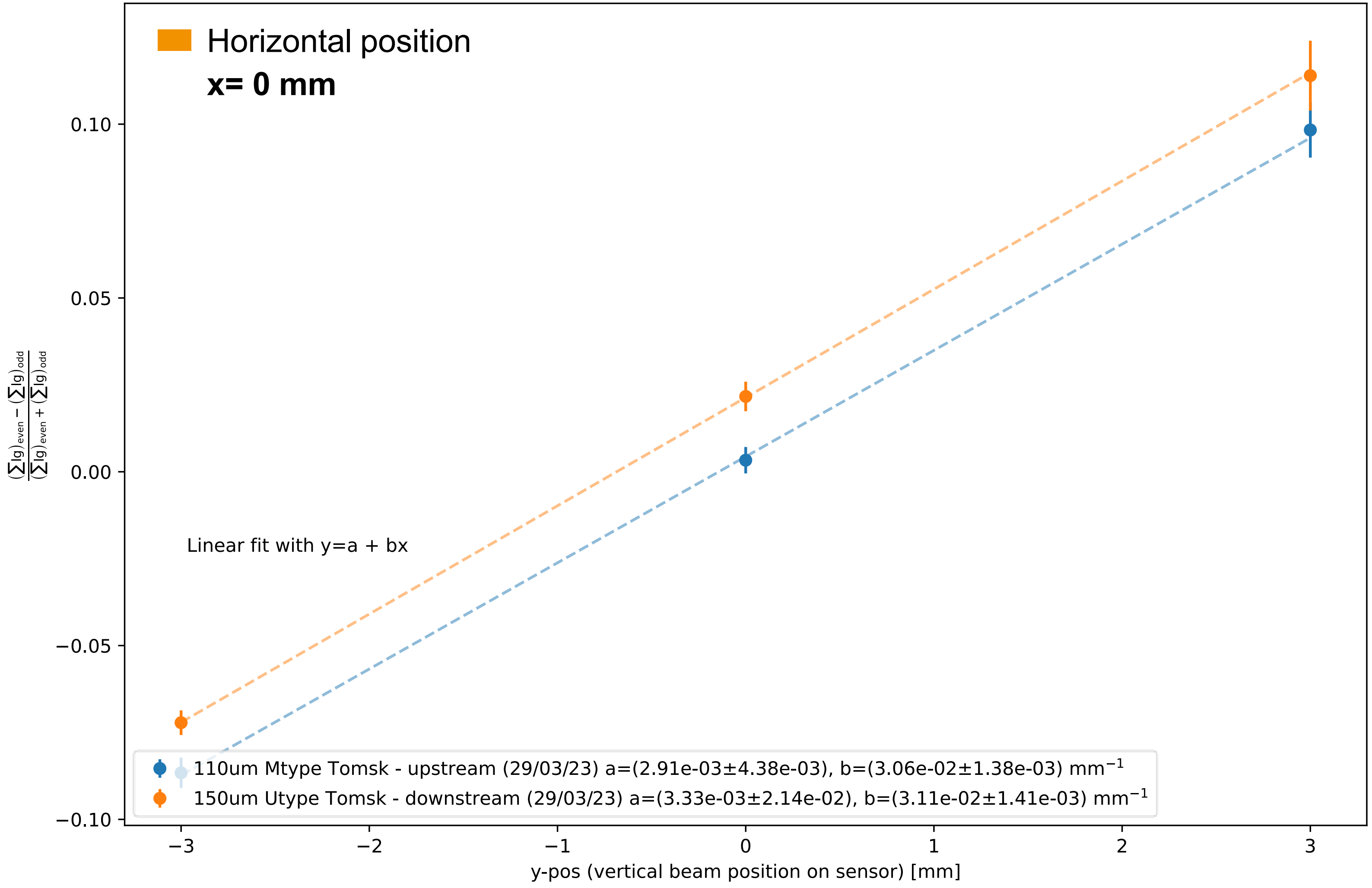
- Strip 126 (fers_ch A1 board pid24990) not connected / fers_ch not working.

Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction

Results from March 29th

- Positive correlation with the vertical beam position observed, as expected.

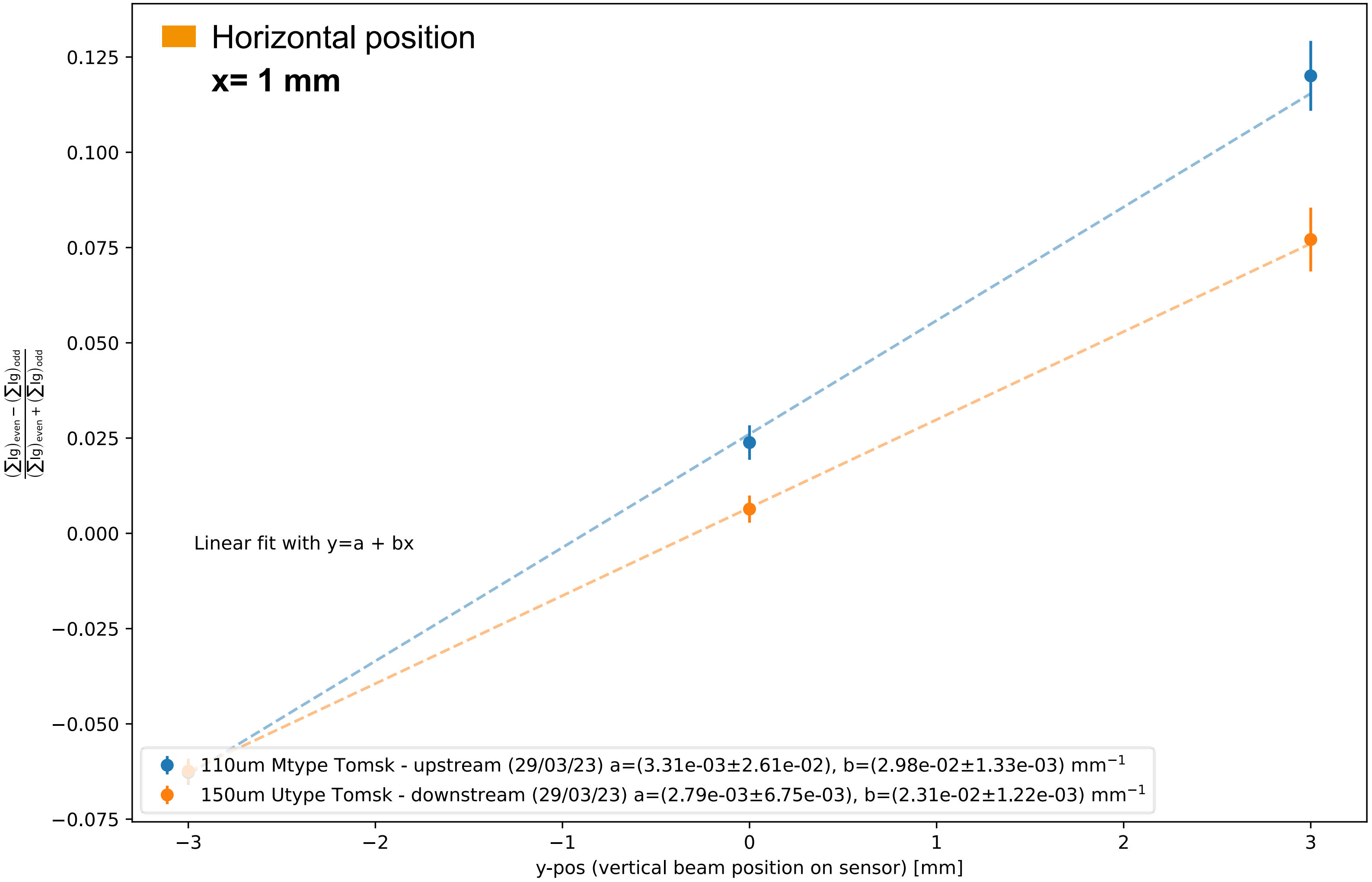


Horizontal and vertical XY scans with 10-50pC beam charge

High strip resistivity and beam profile reconstruction

Results from March 29th

- Positive correlation with the vertical beam position observed, as expected.
- Same effect at the two horizontal positions x=0 and x=1mm (this slide).



Horizontal and vertical XY scans with 10-50pC beam charge

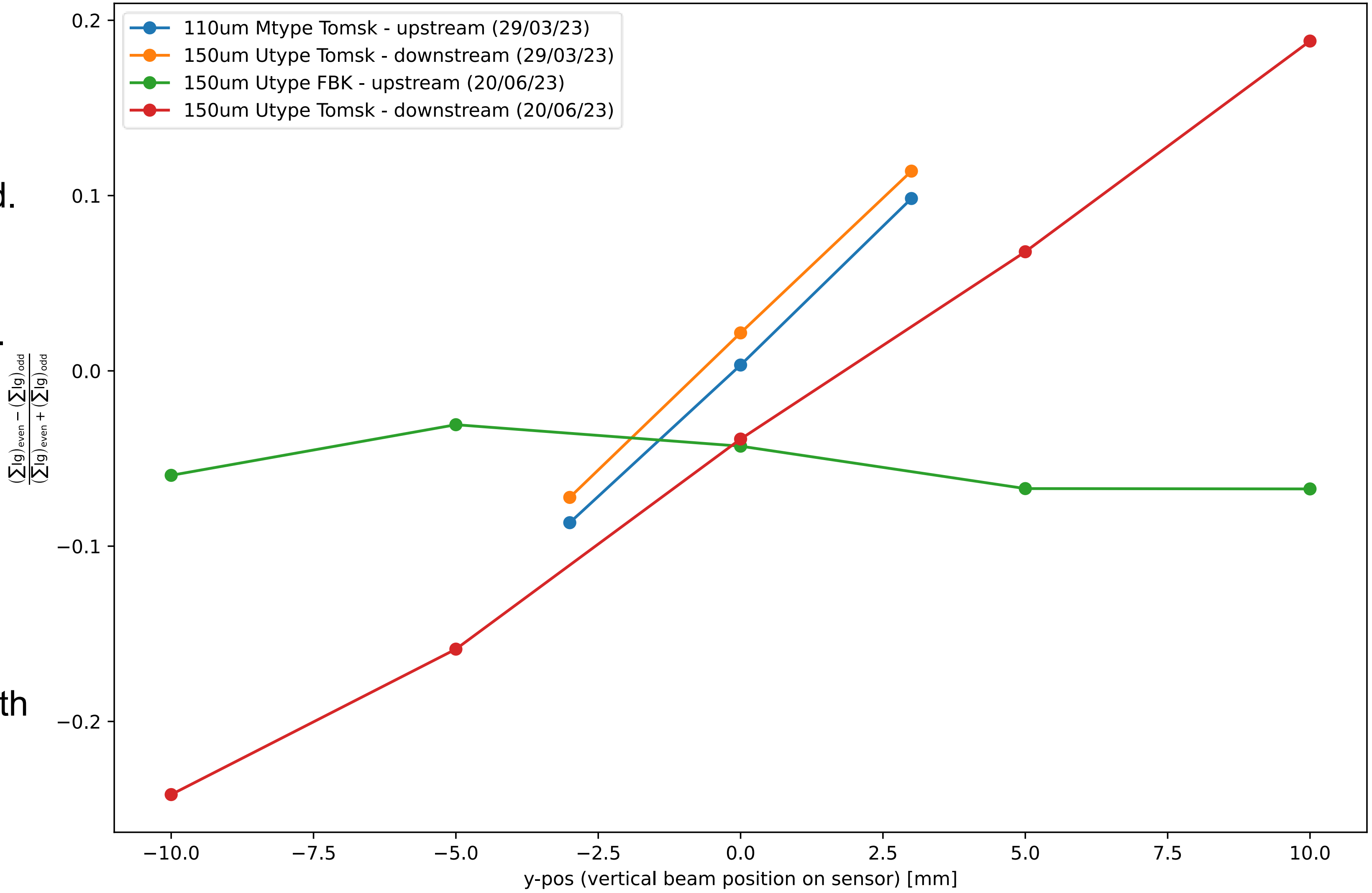
High strip resistivity and beam profile reconstruction

Results from March 29th

- Positive correlation with the vertical beam position observed, as expected.
- Same effect at the two horizontal positions x=0 and x=1mm (this slide).
- Small differences in offset can be caused by slightly different beam conditions during the run.

Results from 20/06/23 @ Vesper

- An analogous measure at Vesper (with FBK 150um) showing that with lower strip resistivity the effect disappears.



Horizontal and vertical XY scans with 10-50pC beam charge

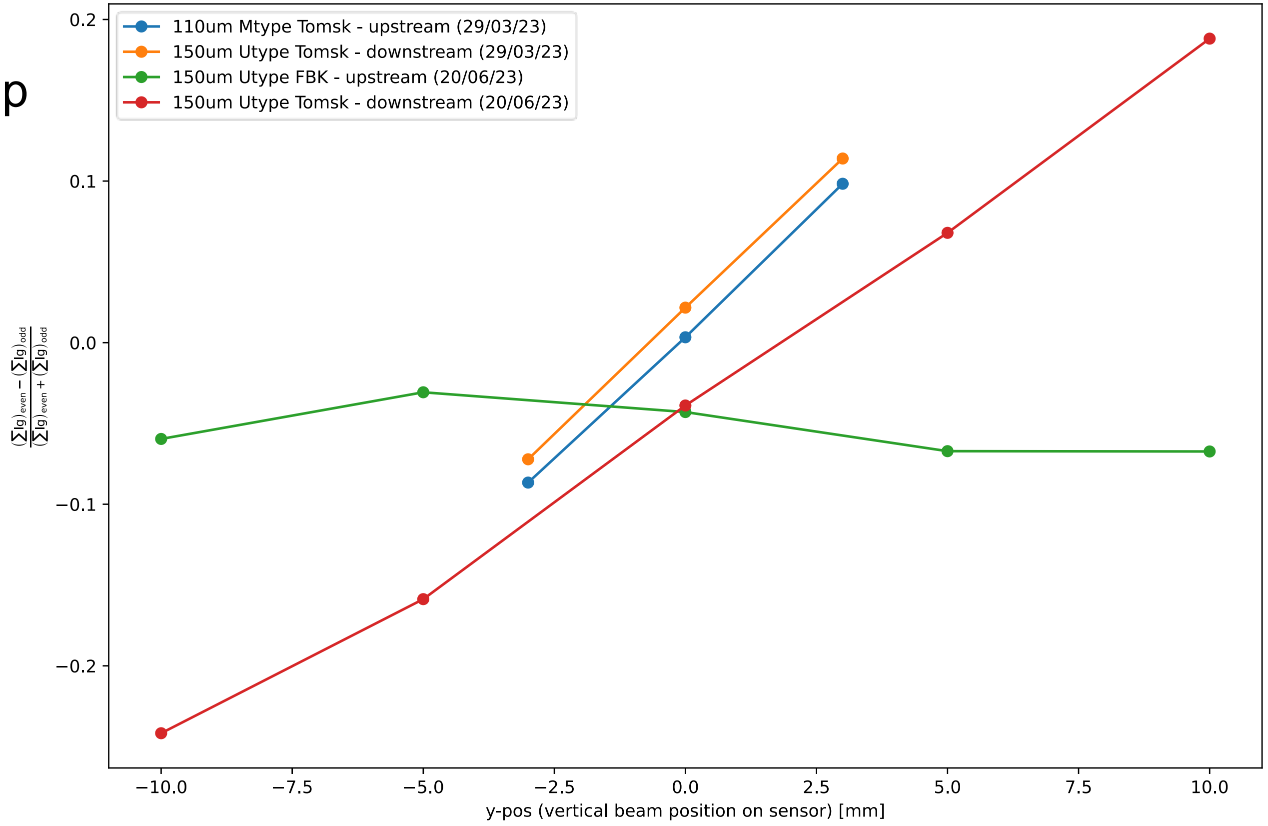
High strip resistivity and beam profile reconstruction

Conclusions

- High strip resistivity – i.e., much bigger than strip impedance – should be **avoided**.
- Early sapphire sensors (UniversityWafers-Inc. sapphire crystal + strip metallization by Tomsk-University) are affected by such issue
  ► FBK sensors OK

Open points

- Why the baseline charge 'matters' that much?
- What is the physical origin of this baseline?



Horizontal and vertical scans at 30pC/train

GP resolution. Preliminary

Horizontal and vertical XY scans with 10-50pC beam charge
Extra. GP resolution

Description

- The GP resolution is estimated from the difference between the detectors BP sigma
  $$var \equiv (\sigma_{d0} - \sigma_{d1})$$
  $$\delta var = \sqrt{\delta\sigma_{d0} + \delta\sigma_{d1}} \simeq \sqrt{2}\,\delta\sigma_{GP}$$
  - at controlled beam conditions (with same charge and beam shape).
  - The even/odd strips are treated separately.

Data used and Conditions

- Run45 and Run69 at same hor. Coordinate with vert. beam position at -3 and 0, respectively.
- Beam operated at 30pC/train and single bunch with approx. (1,1)mm beam shape.

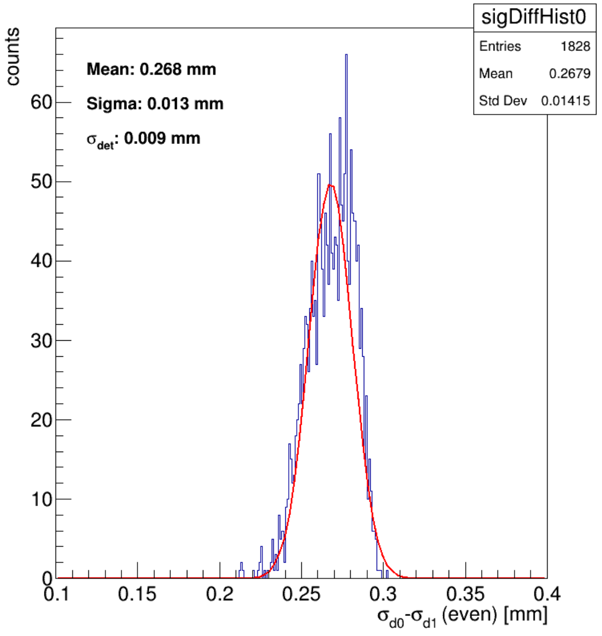
Analysis

- FERS data is synchronized with camera using the correlation between signals (d1s96 and profile_amp_hor)
- For each event, it is calculated:
  - charge profile on GP → (Gaussian + constant) fit of odd/even/full profiles → $(A, x_0, \sigma)_{odd,even,full}$
  - the scatter plot between the beam charge $Q \propto A\sigma$ of detector and camera → inspect synchronization
  - the ratio between σ_{det} and σ_{camera}

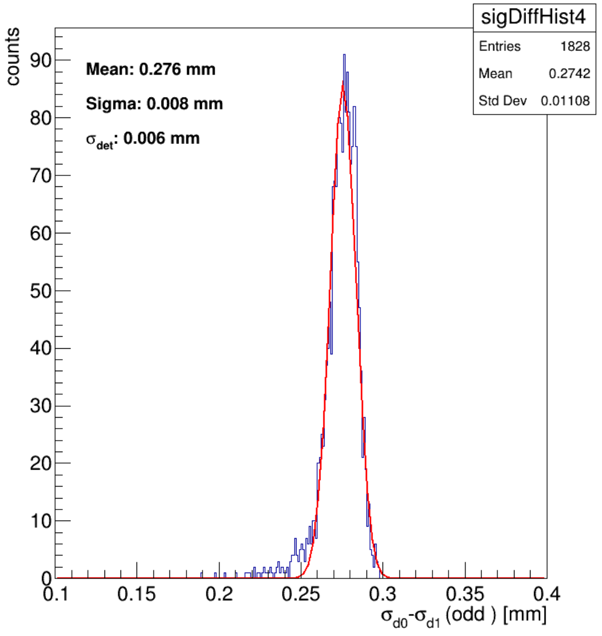
GP resolution. Preliminary

Resolution from run45 - assuming $\delta\sigma_{det0} = \delta\sigma_{det1} = \delta(\sigma_{d0} - \sigma_{d1})/\sqrt{2}$

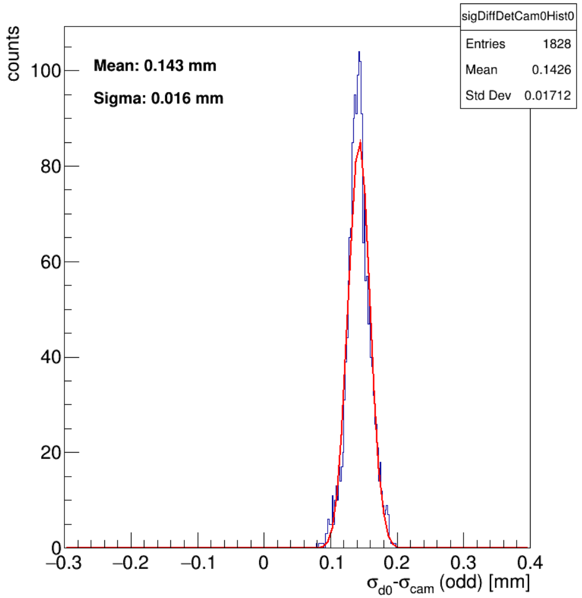
Difference between sigma d0-d1



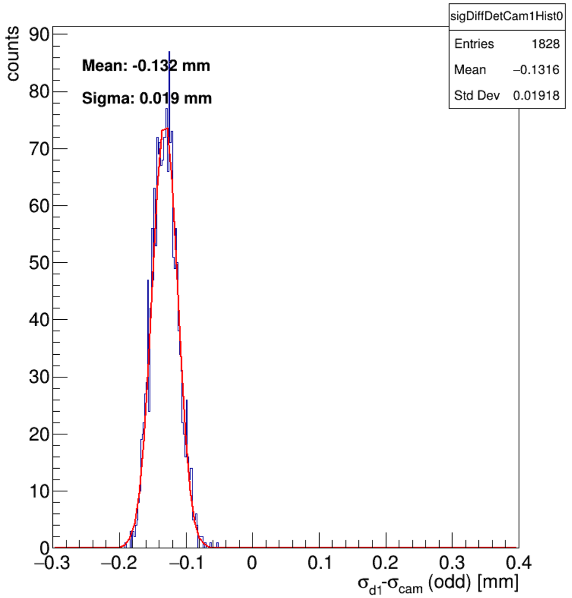
Difference between sigma d0-d1



Difference between sigma d0-cam



Difference between sigma d1-cam



- Unclear the very large systematics (270um) in the upstream/downstream detector's sigma
- **Standalone resolution** (d0-d1) is of the order of **6-10 um**

$$
\begin{aligned}
A &\equiv \delta\left(\sigma_{up} - \sigma_{cam}\right) && (1)\\
B &\equiv \delta\left(\sigma_{do} - \sigma_{cam}\right) && (2)\\
C &\equiv \delta\left(\sigma_{do} - \sigma_{up}\right) && (3)
\end{aligned}
$$

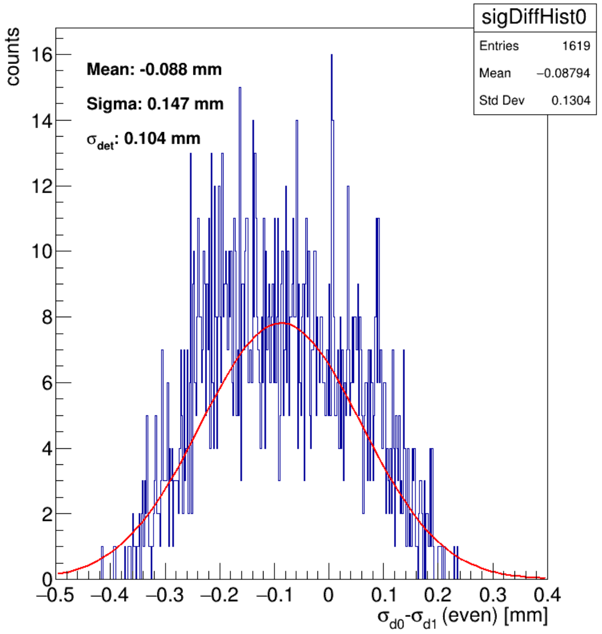
$$
\begin{aligned}
\delta\sigma_{cam} &= \sqrt{\frac{1}{2}\left(A^2 + B^2 - C^2\right)} && (4)\\
\delta\sigma_{up} &= \sqrt{\frac{1}{2}\left(A^2 - B^2 + C^2\right)} && (5)\\
\delta\sigma_{do} &= \sqrt{\frac{1}{2}\left(-A^2 + B^2 + C^2\right)} && (6)
\end{aligned}
$$

- Camera-detector comparison allows to estimate the resolution, solving out the system of equations
  - $\delta\sigma_{cam} = 0.017$ um
  - $\delta\sigma_{up} = 0.010$ um
  - $\delta\sigma_{do} = 0.004$ um

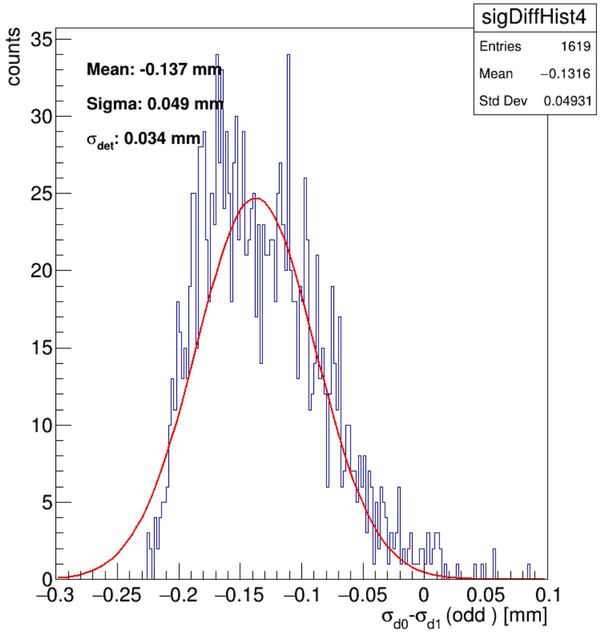
GP resolution. Preliminary

Resolution from run69 - assuming $\delta\sigma_{det0} = \delta\sigma_{det1} = \delta(\sigma_{d0} - \sigma_{d1})/\sqrt{2}$

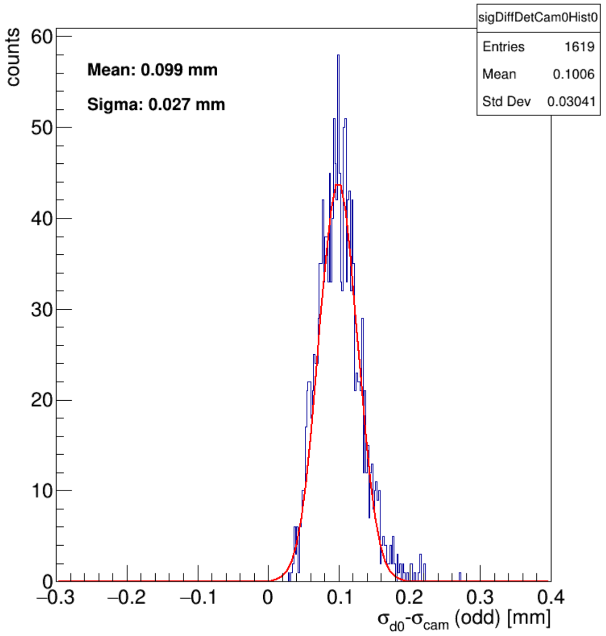
Difference between sigma d0-d1



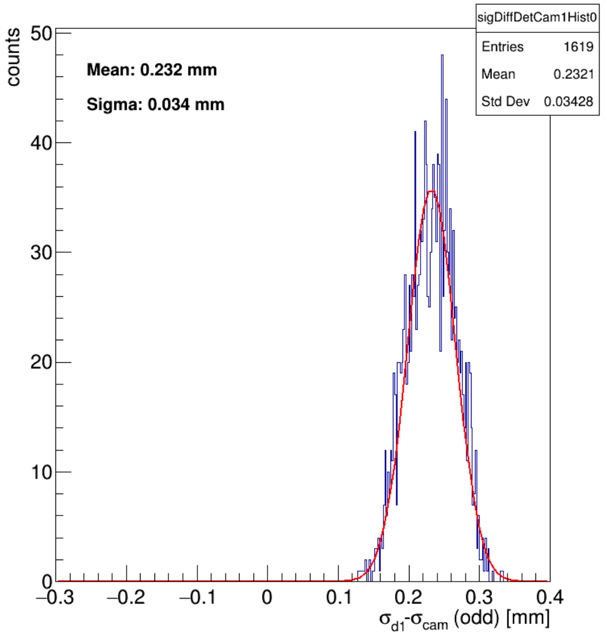
Difference between sigma d0-d1



Difference between sigma d0-cam



Difference between sigma d1-cam

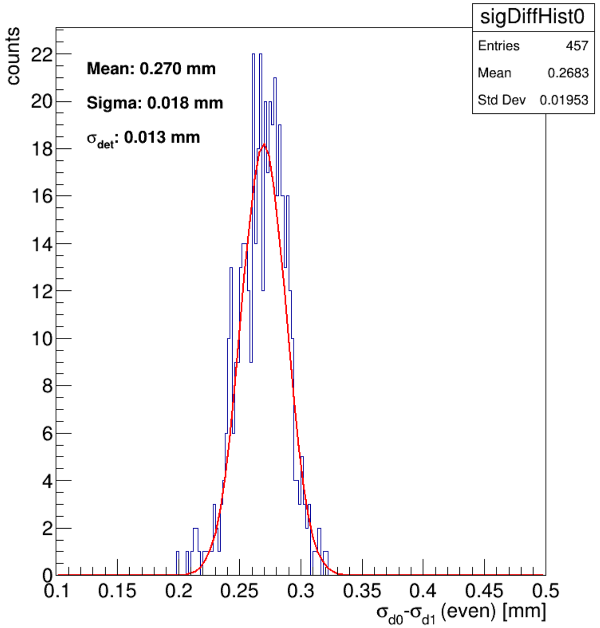


- Unclear the large systematics in the upstream/downstream detector's sigma, with **sign flip** with respect to Run45 (the vertical position from 0 to -3).
  - behaviour is due to ***d1*** but profiles seems ok!
- **Standalone resolution** (d0-d1) is of the order of **30 um, this time**
- Camera-detector comparison is reported for completeness, but analysis from this Run is inconclusive and these effects (sign flip, negative d0-d1) did not appear in other runs.
  - $\delta\sigma_{cam} = 0.019$ um
  - $\delta\sigma_{up} = !$ um
  - $\delta\sigma_{do} = 0.024$ um

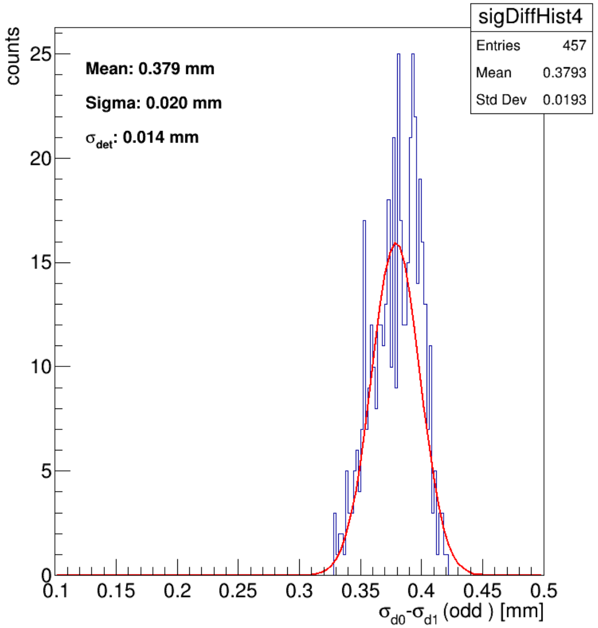
GP resolution. Preliminary

Resolution from run91 - assuming $\delta\sigma_{det0} = \delta\sigma_{det1} = \delta(\sigma_{d0} - \sigma_{d1})/\sqrt{2}$

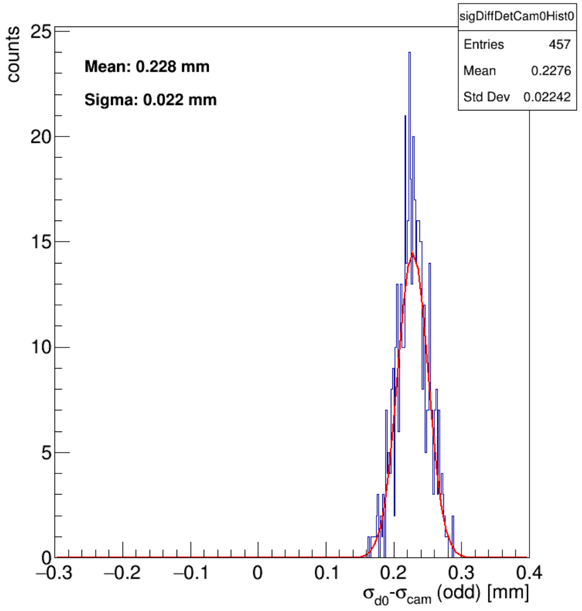
Difference between sigma d0-d1



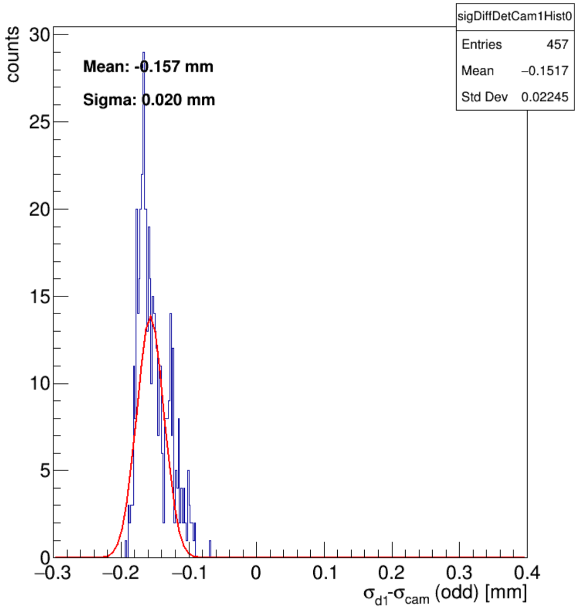
Difference between sigma d0-d1



Difference between sigma d0-cam



Difference between sigma d1-cam



- Unclear the large systematics in the up/down detector's sigma. Beam charge is 100pC/train. Some saturation in d1, so we cut on non-sat. profiles (457 events).
- **Standalone resolution** (d0-d1) is of the order of **14 um**

- Camera-detector comparison is reported for completeness, but analysis from this Run is inconclusive and these effects (sign flip, negative d0-d1) did not appear in other runs.
  - $\delta\sigma_{cam} = 0.019$ um
  - $\delta\sigma_{up} = 0.014$ um
  - $\delta\sigma_{do} = 0.010$ um