

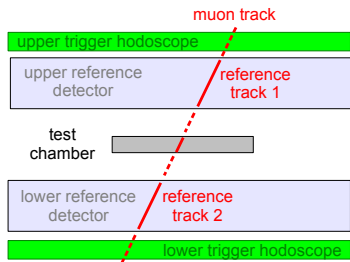
SM2 Micromegas Modules in the Cosmic Ray Facility

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Ludwig-Maximilians-Universität München - Lehrstuhl Schaile

Muon Week 12.05.2020

Validation using Cosmic Muons - Cosmic Ray Facility



trigger

track reconstruction

active area

angular acceptance

energy cut

readout (full module)

readout rate

scintillator hodoscope

resolution ~ 10 cm

Monitored Drift Tubes (MDTs)

resolution ~ 0.2 mm

$2.2 \text{ m} \times 4 \text{ m}$

$\pm 30^\circ$

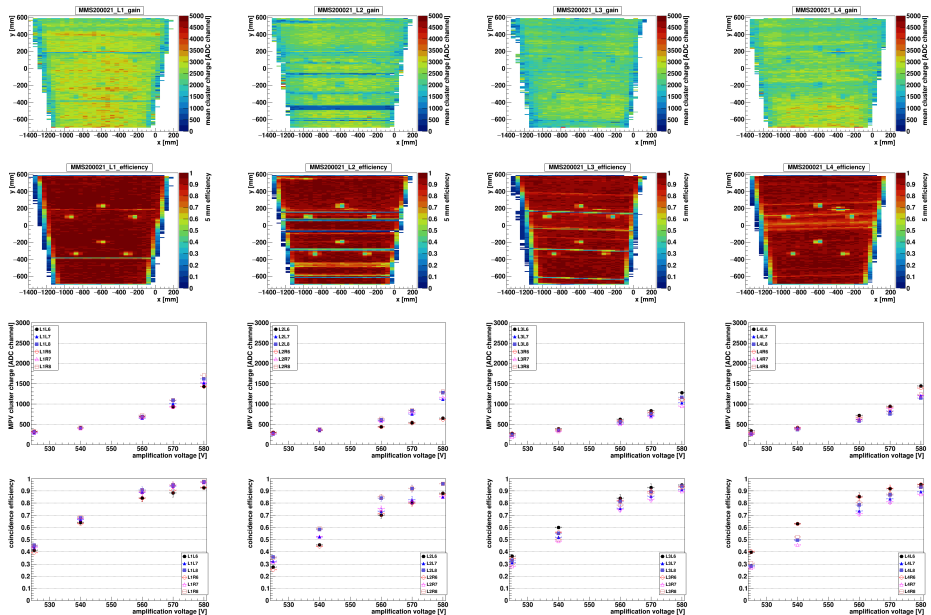
iron plate $\rightarrow E_\mu > 600 \text{ MeV}$

12288 channels

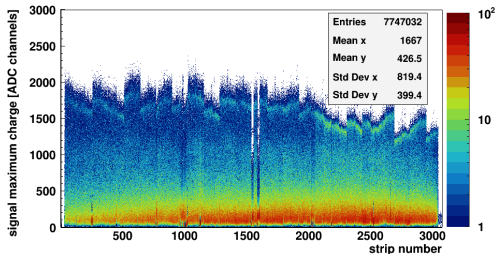
100 Hz (online zerosuppression)



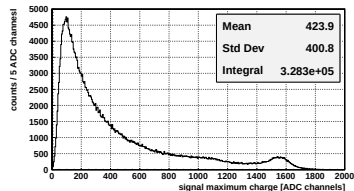
Pulse Height and Efficiency (Ar:CO₂ 93:7 vol%) Module 21



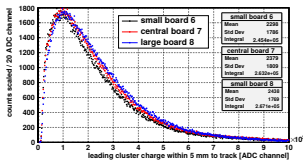
Typical Pulse-Height Distributions (M27)



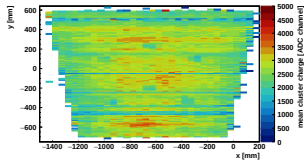
single APV (128 strips)



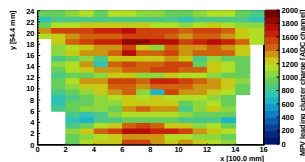
efficient cluster



mean map



MPV map



CRF measurements for Pulse-Height Comparisons

module	before			after		modification
	voltage [V]	measurement events (10^6)		measurement events (10^6)		
12	570	19.06.-20:09	4.8	30.08.-11:29	9.8	passivated
13	570	28.08.-09:32	3.9	02.10.-16:34	7.0	taped
17	570	18.09.-08:12	3.9	12.10.-18:26	0.5	taped
18	580	09.09.-20:01	N/A	07.10.-19:52	4.6	taped

problems :

m12 : upside down (before) , flushing (after) , other mesh on outer layers

m13 : slowcontrol stopped (after)

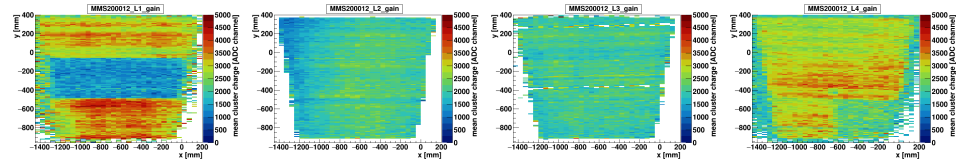
m17 : not all sectors at nominal voltage (before)

m18 : wrongly connected $\Rightarrow$ mapping has to be adjusted (before)

for all measurements : pressure yet not considered

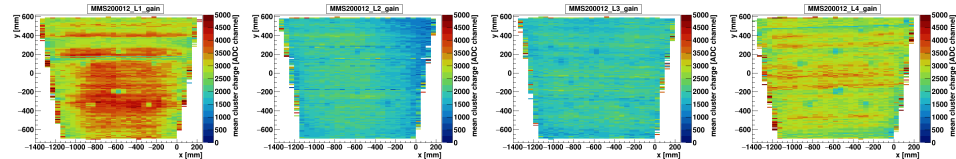
M12 @ 570 V

before passivation



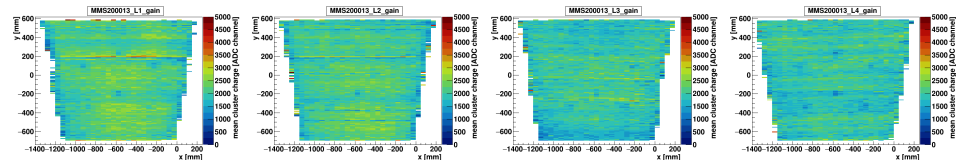
918 - 920 mBar

after passivation



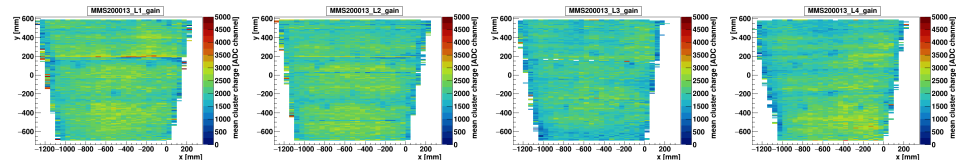
927 - 933 mBar

M13 @ 570 V before taping



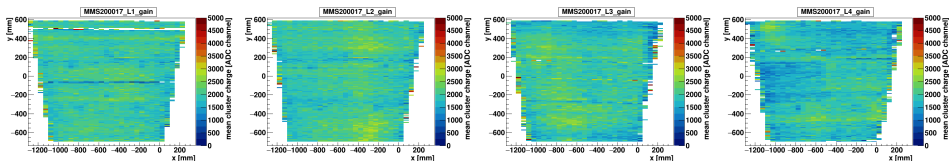
927 - 929 mBar

after taping



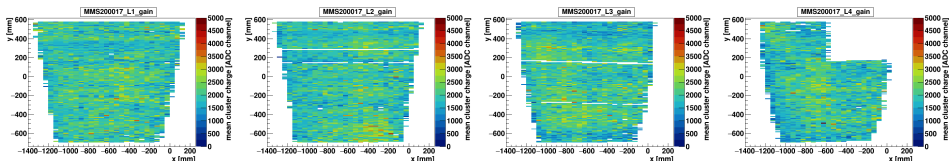
922 - 931 mBar

M17 @ 570 V before taping



934 - 936 mBar

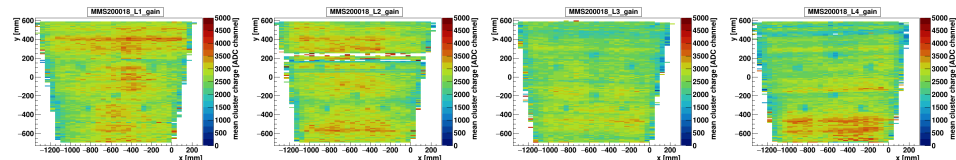
after taping



926 - 927 mBar

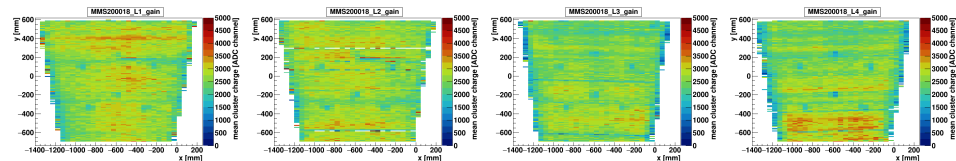
stereo_out board8 right repaired after this measurement

M18 @ 580 V before taping



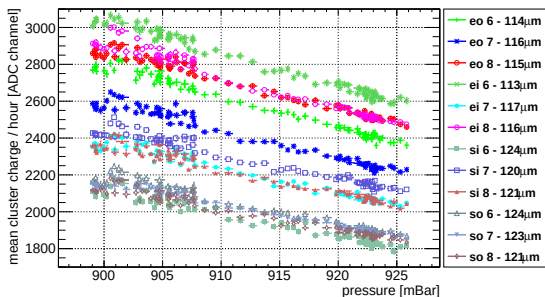
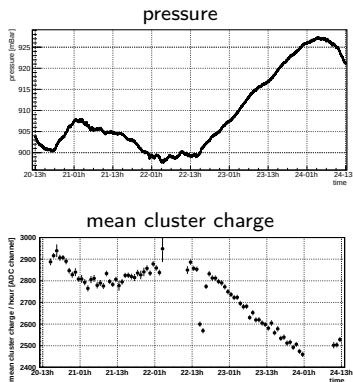
N/A

after taping



925 - 929 mBar

Pulse-Height Pressure Dependence (M3 long term test)



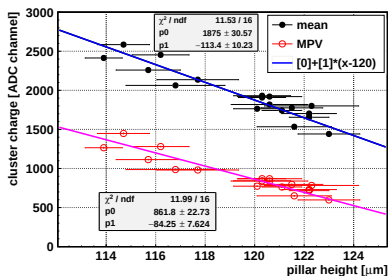
⇒ clear pressure dependence, as expected

⇒ dependence on pillar-height NOT straight forward

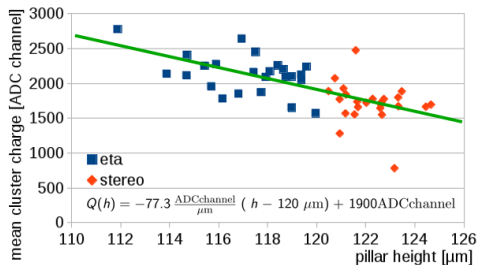
(pressure biased: offset about 30 mBar)

Pulse-Height Amplification-Gap Dependence

M8 and Eta3-Doublet
(same measurement period)



modules 1,3,6,7



⇒ for a single measurement period a good correlation is given

⇒ comparison of different periods require pressure compensation

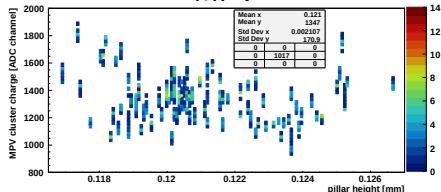
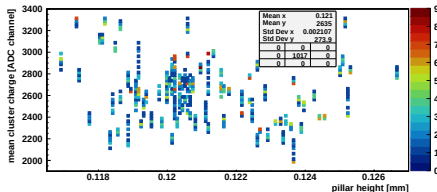
cluster charge @ 580 V

(modules 4 , 13 , 14 , 15 , 17 , 18 , 20 - 25)

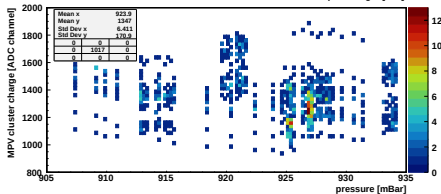
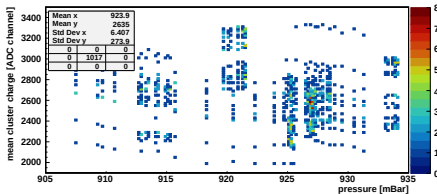
mean

MPV

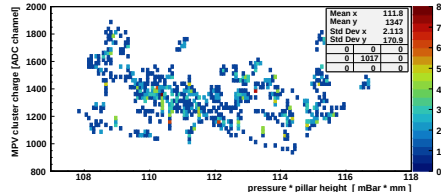
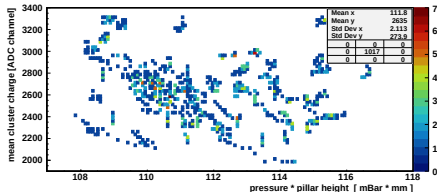
pillar height



pressure

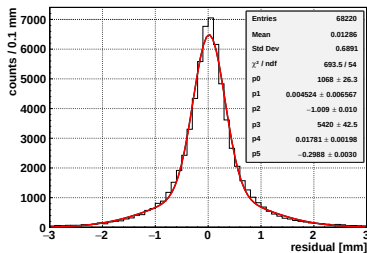


product

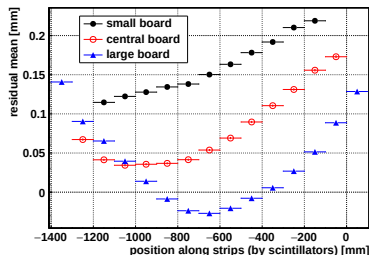


Alignment Reconstruction Using Cosmic Muon Tracks

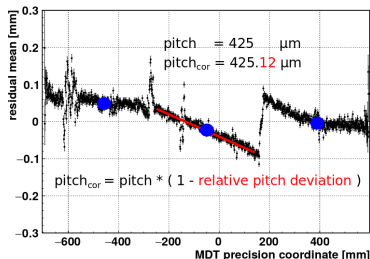
difference of reconstructed hit
and reference track interpolation



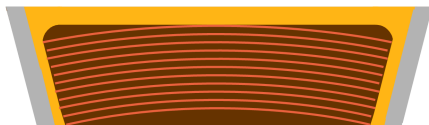
board rotation and strip deformations



deviations of inter-strip distance



bend strip shape



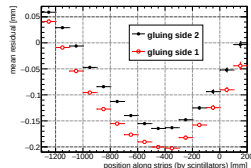
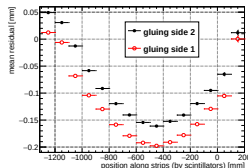
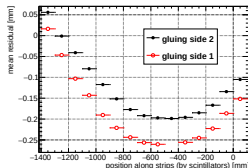
Alignment Investigation Eta-panel 3 $\Rightarrow$ Consistent Reconstruction

September 2018,
in M3

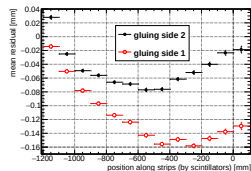
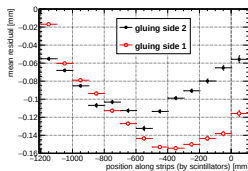
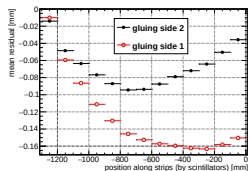
January 2019,
as doublet

May 2019,
as doublet

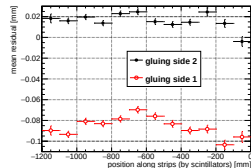
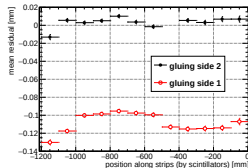
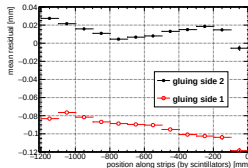
board 8



board 7

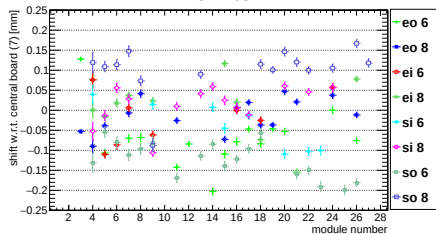


board 6

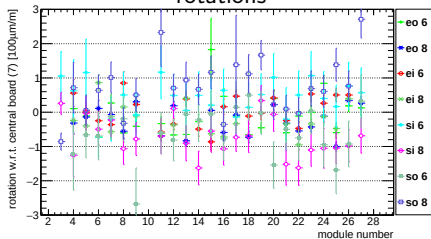


Alignment Comparison Production Modules

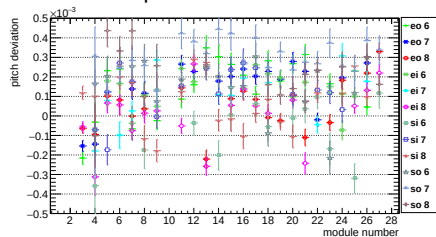
shifts



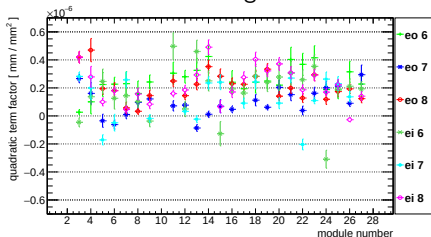
rotations



pitch deviations

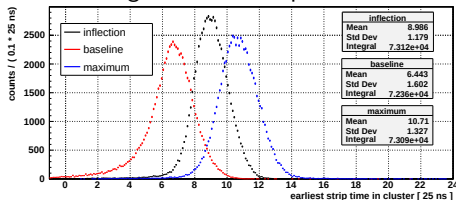


bendings

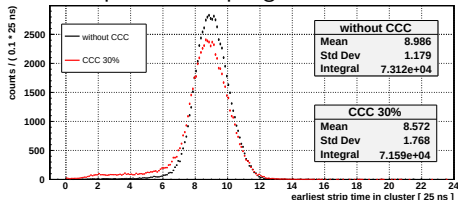


Timing Investigation using FEC-APV-Readout

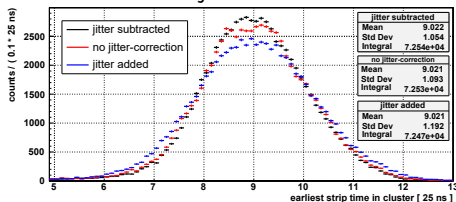
signal evaluation points



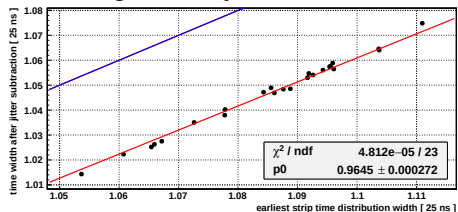
capacitive coupling correction



effect of jitter correction



magnitude of jitter correction



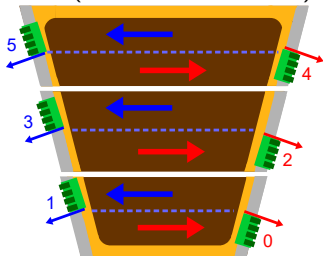
⇒ narrowest time distribution : inflection , without CCC , jitter subtracted

⇒ jitter correction : about 3% or about $0.039 \cdot 25 \text{ ns}$

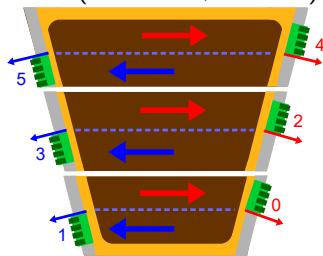
Timing Investigation using FEC-APV-Readout

layer cabeling

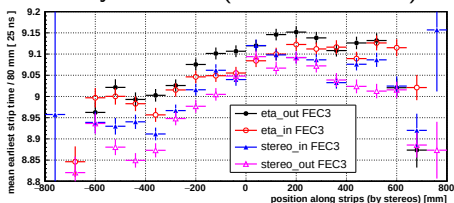
odd (stereo_out , eta_in)



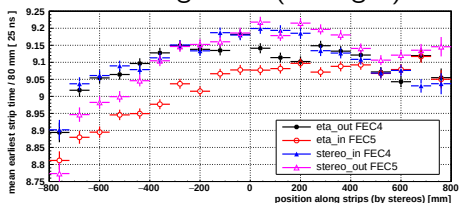
even (stereo_in , eta_out)



all layer FEC3 (same direction)

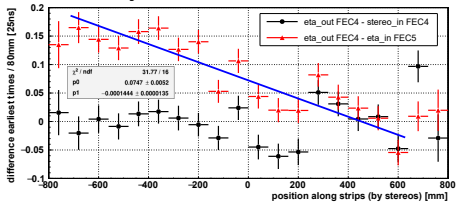


alternating FECs (left-right)

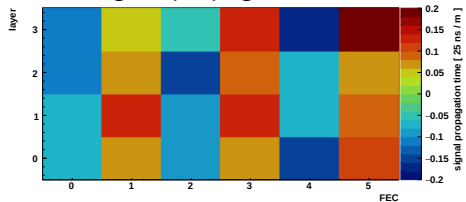


expected : $6 \text{ ns/m} = 0.24 \cdot 25 \text{ ns/m}$
 opposite readout $\Rightarrow$ **0.48** $\cdot 25 \text{ ns/m}$

layer time difference



signal propagation time

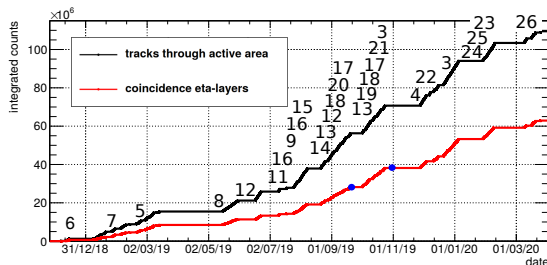


$\Rightarrow$ mean reconstructed : **(0.10 $\pm$ 0.03)** $\cdot 25 \text{ ns/m}$

Summary

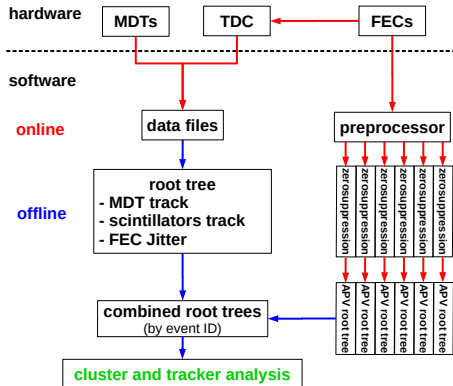
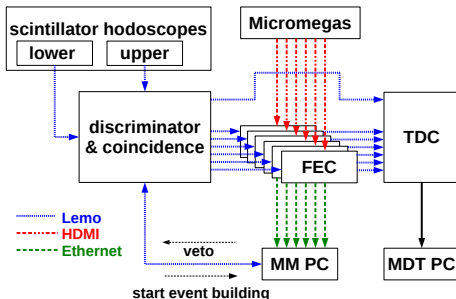
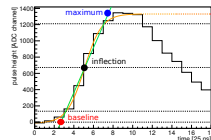
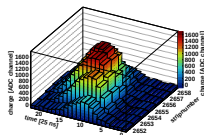
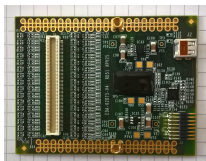
investigation of the full active area using reference tracker for cosmic muons

- information about pulse-height and efficiency send together with modules to CERN
- comparison of measurements for same modules show
 - similar features $\Rightarrow$ consistent reconstruction
 - inhomogeneities arise mainly due to pillar-height variations
- pulse-height dependence:
 - amplification gap size (pillar-height)
 - pressure
 - micro-mesh
- timing-evaluation difficult using local setup
 $\Rightarrow$ systematic effects under investigation



Backup

SRS-based Data-Acquisition

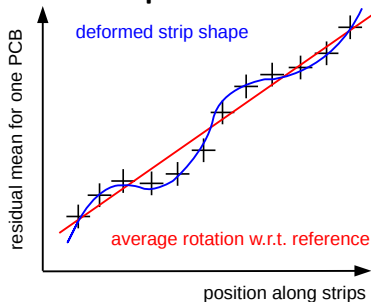


Precision Reconstruction of Geometrical Properties

Boards of the Readout Anode can have:

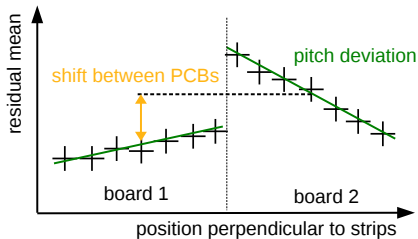
- ⇒ **rotations** and **shifts** w.r.t. each other
- ⇒ **non-straight strip shape** and **pitch deviation**

**residual mean VS
non-precision direction**



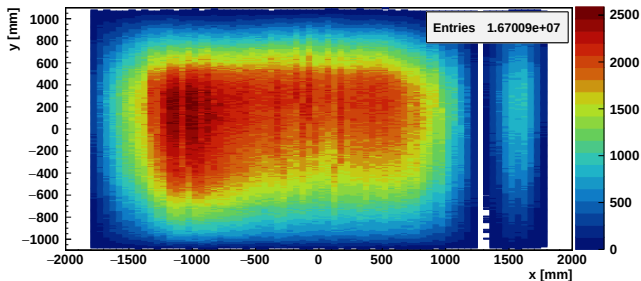
- ⇒ slope indicates rotations
- ⇒ strip shape is given by deviation from straight line

**residual mean VS
precision direction**

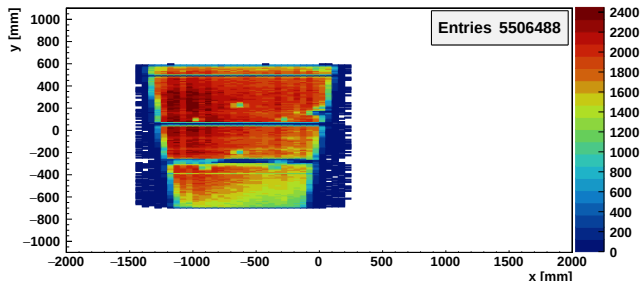


- ⇒ shift between boards is given by difference of the centers
- ⇒ slope indicates deviation to nominal pitch

CRF hit distribution



M3 eta_out, 5 mm efficient



Theoretical Gain Description

Gain by Townsend (1910) :

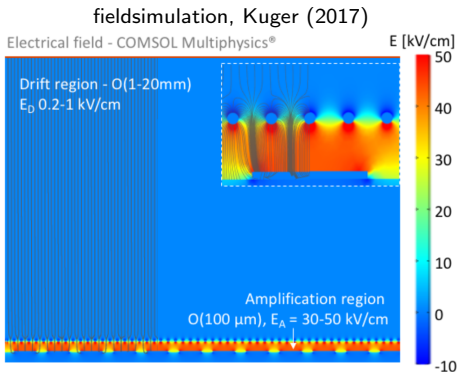
$$G = \exp [d \cdot \alpha]$$

α by Rose and Korff (1941) :

$$G = \exp \left[d \cdot \frac{pA}{T} \cdot \exp \left(-\frac{dpB}{TU} \right) \right]$$

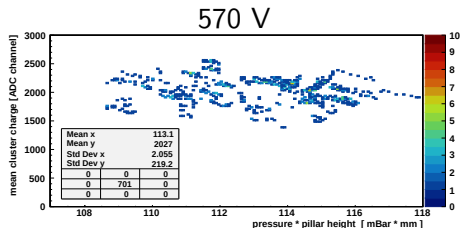
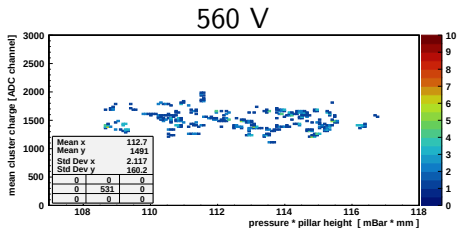
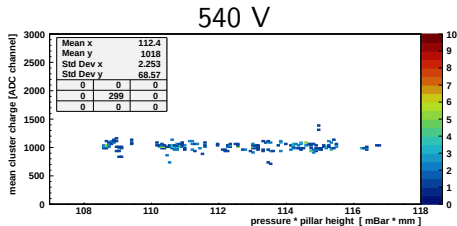
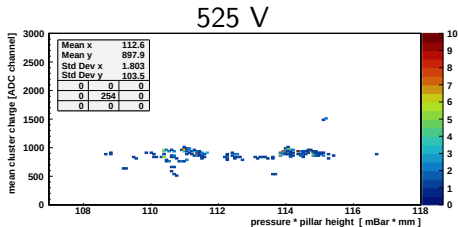
effective description :

$$G = f(dp; U)$$



paper by Giomataris mentioning the prospects of a large sample of gap widths ($d \hat{=}$ pillar heights):

<https://www.slac.stanford.edu/pubs/icfa/fall99/paper1/paper1.pdf>



CRF measurements with module 3 (high statistics)

measurement	events (10^6)	remark
20.12.19-15:21	19.2	
22.12.19-11:32	20.0	
24.12.19-10:19	20.0	slowcontrol stopped
26.12.19-18:26	18.0	
28.12.19-13:30	8.8	
29.12.19-10:47	19.6	
31.12.19-10:06	20.0	
02.01.20-14:07	8.7	
03.01.20-10:54	20.0	

⇒ in total **154** $\cdot 10^6$ events

⇒ usable after MDT-analysis **70** $\cdot 10^6$ events

CRF measurements with module 16 (drift scan @ $U_{\text{amp}} = 570 \text{ V}$)

drift voltage [V]	measurement	events (10^6)
125	02.08.-08:55	4.1
150	02.08.-19:53	6.5
175	03.08.-13:20	2.5
200	03.08.-20:03	5.2
300	31.07.-19:46	4.7
450	04.08.-10:06	2.5