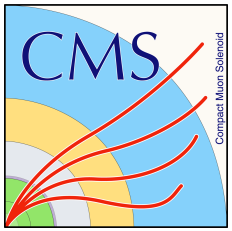
Reference telescope and first detector tests at the 25 MeV proton cyclotron CYRCé at Strasbourg



Clément Grimault,
on behalf of the IPHC team (J. Andrea, C. Bonnin, J.-M. Brom, L. Charles, C. Collard, T. Goeltzenlichter, U. Goerlach, L. Gross, C. Haas, M. Krauth, E. Nibigira, N. Ollivier-Henry, S. Veeramootoo + several people from CYRCé)
With the participation of Demokritos (Patrick Asenov, Dimitris Loukas)
And significant help from Nikkie Deelen, Danek Kotlinski, Jory Sonneveld

IPHC, Strasbourg

29/01/2020

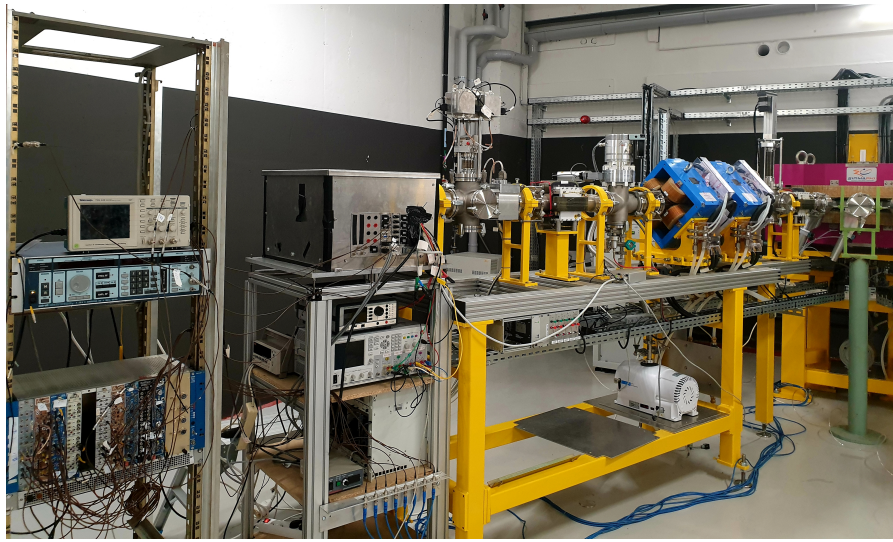
Outline

CYRCé cyclotron at Strasbourg

Cyclotron : initially installed for production of radionuclides and radiobiology experiments

Beam characteristics :

- 25 MeV protons (low energy beam , large energy deposition → 10-15 times higher than MIP)
- High rates : up to 100 nA (6×10^{11} protons per second)
- Low rates : 1 fA (6×10^{3} protons per second)
- Beam structure : 85 MHz



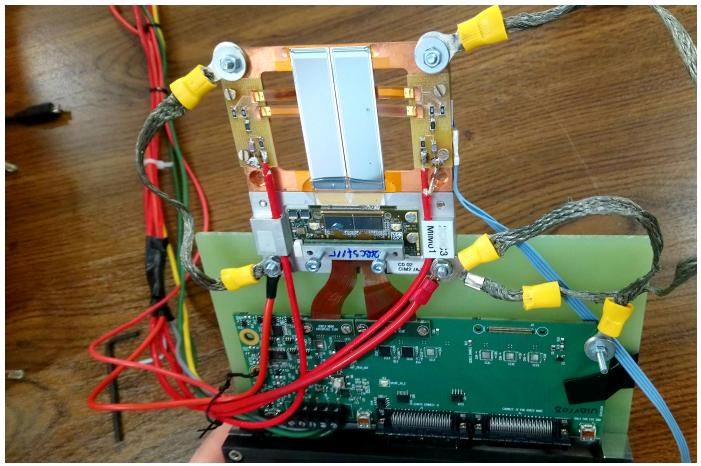
Electronics can be synchronised with beam at 42.5 MHz (close to the 40 MHz LHC frequency). See Ulrich Goerlach presentation on Monday to more details.

New beam line, dedicated to CMS Phase-2 Tracker Upgrade : rate studies , irradiation of sensors

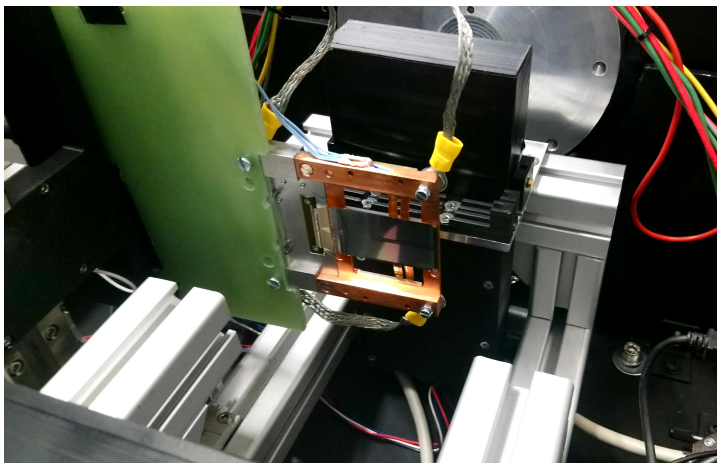
2S mini-module

DUT (provided by KIT group) :

- 2S mini-module prototype with 2 CBC3
  CBC3 : **C**MS **B**inary **C**hip including logic for detecting high momentum tracks
- 2 different pairs of sensors, one for each CBC (CBC#0 and CBC#1)
- CBC#0 with a 240 μm-thickness sensors
- CBC#1 with a 290 μm-thickness sensors



front sensors

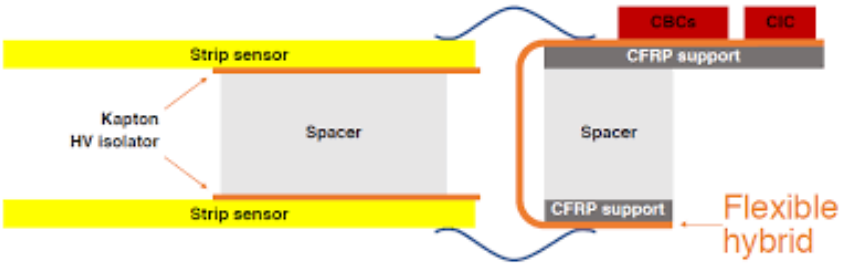


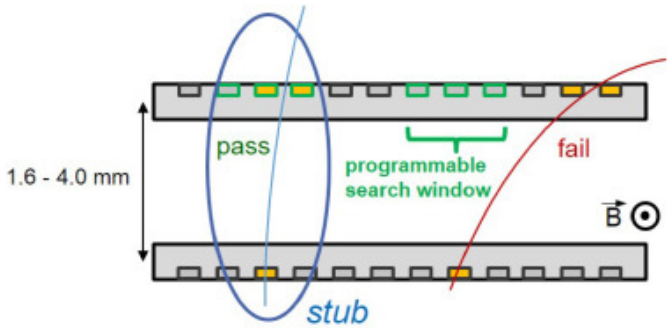
back sensors

Trigger provided by 2 plastic scintillators with a NIM logic for coincidence
Selected one bunch of proton over two : 42.5 MHz

Selection of high p_T track : stub

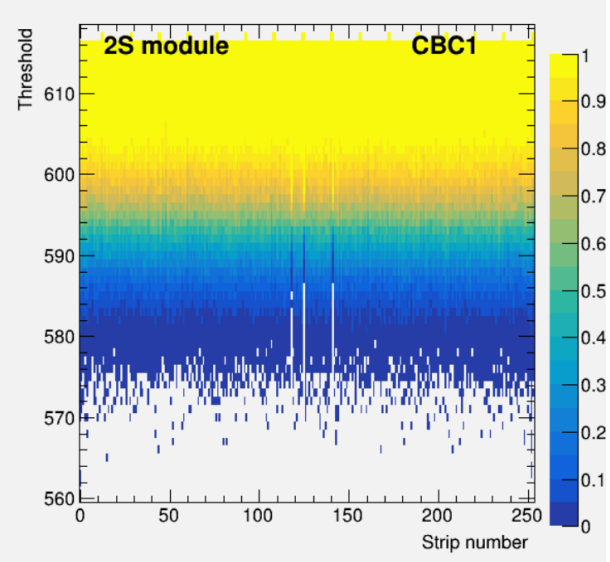
High Luminosity LHC (HL-LHC) : need to reduce events rates in Level-1 trigger
The new outer tracker will provide data to the trigger.
The 2 silicon microstrip planes separated by a few mm and on-chip logic selecting correlated hit in the 2 sensors to identify high transverse-momentum tracks, called stub

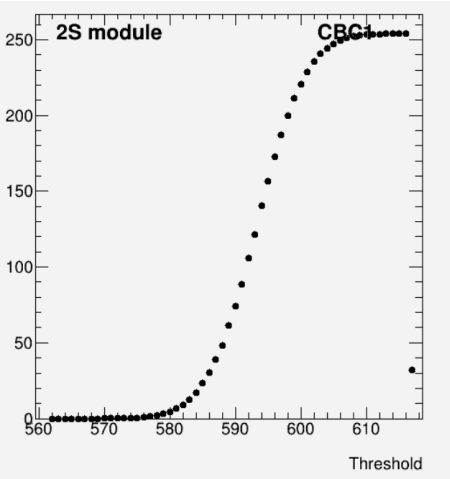




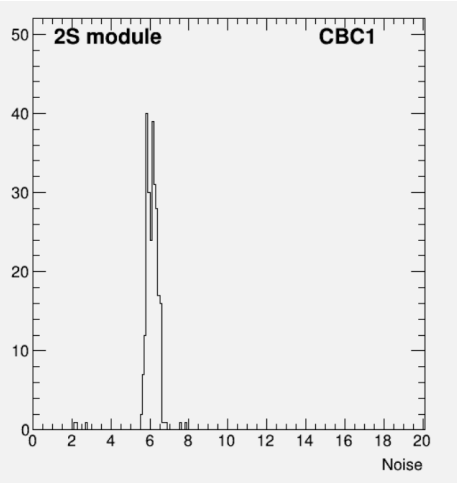
Calibration of the 2S module

Threshold (Vcth) scan : Determination of the pedestral and the noise



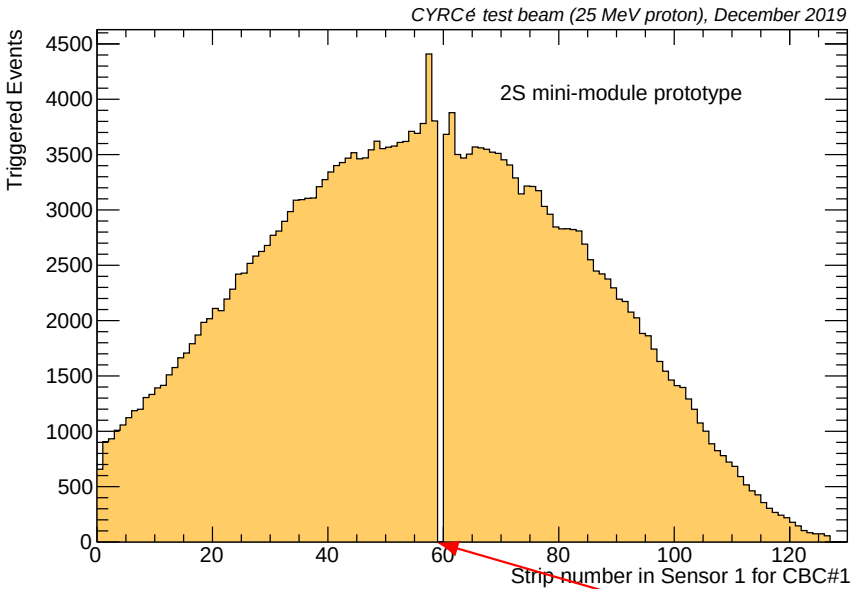


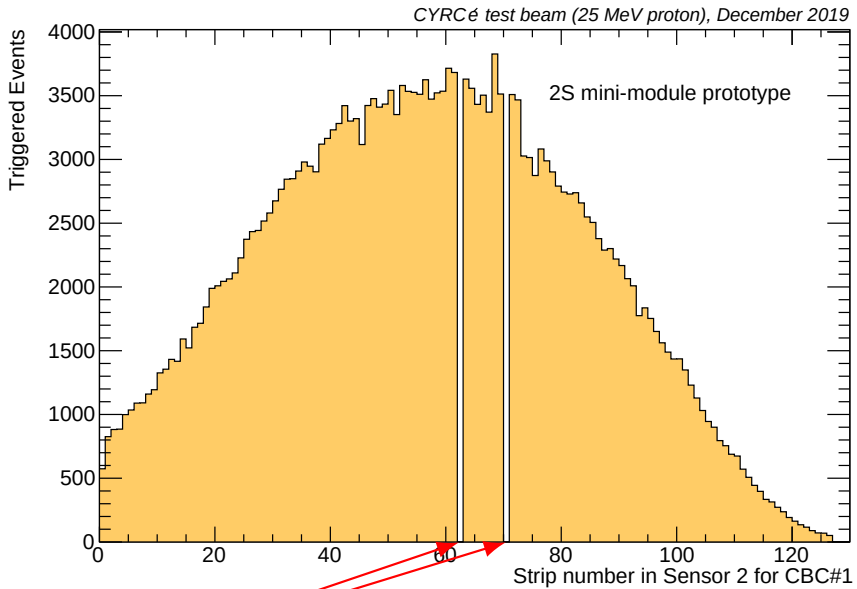
S-curve



Noise in Vcth unit

Beam profiles for the front and back sensors

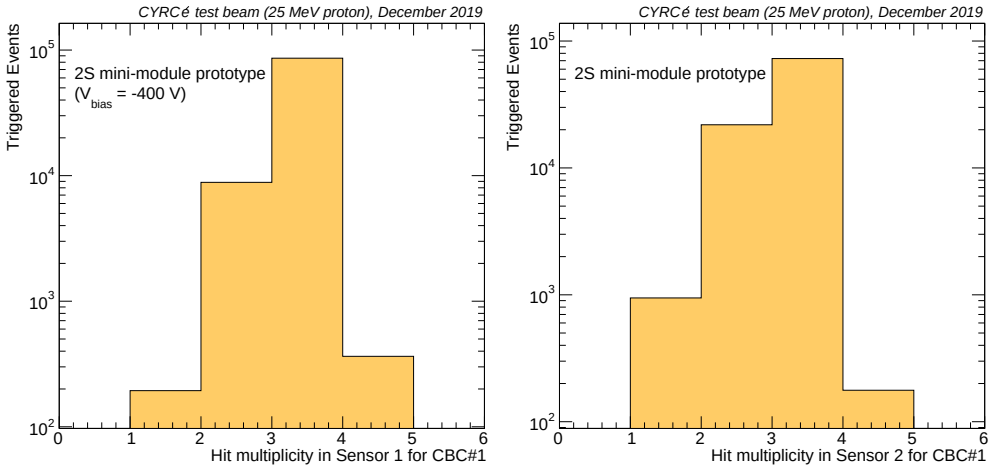




Dead channels (broken wire bounds)

The beam is relatively well positioned for the sensors of CBC#1
but a part misses the module

Strip multiplicity

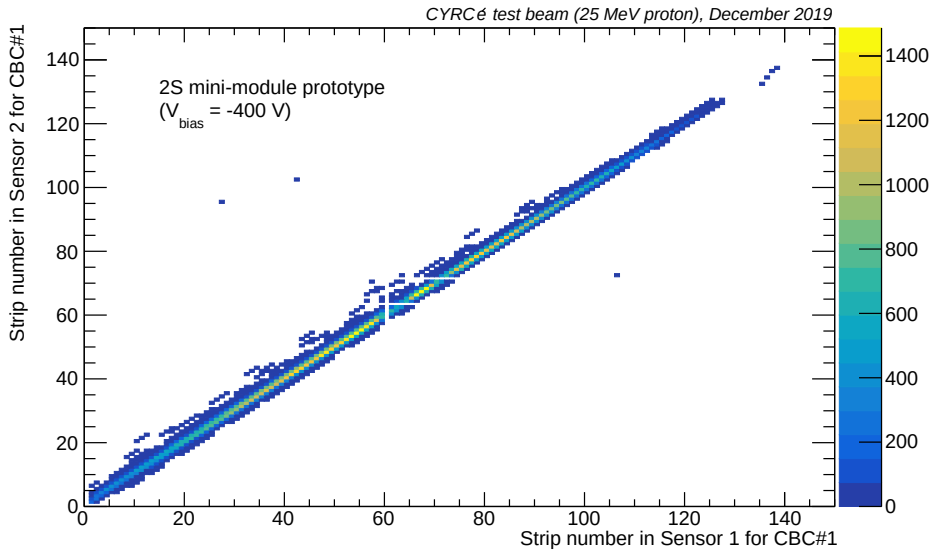


Only events with at least 1 hit in sensor

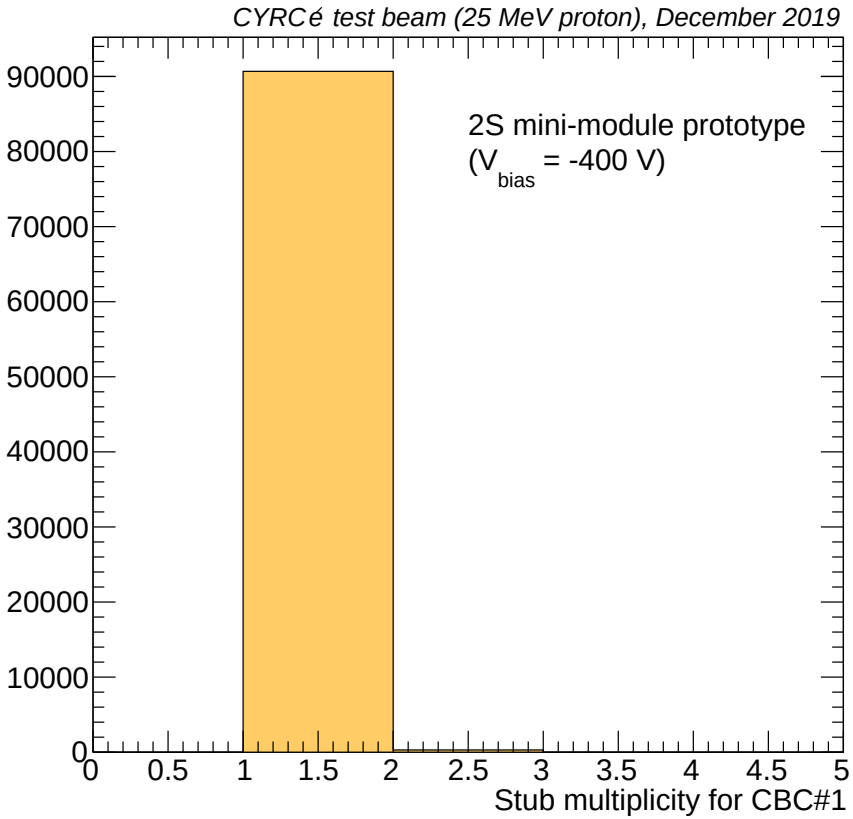
On average **3 strips** are hit
due to a large energy deposition

Very high correlation between the hits in the front and the back sensors

The width of the distribution comes from large clusters



Reconstructed stub for the 2S mini-module



Events with at least 1 hit

In the majority of events, **1 single stub** is reconstructed (in accordance with the perpendicular orientation of the module relative to the beam)

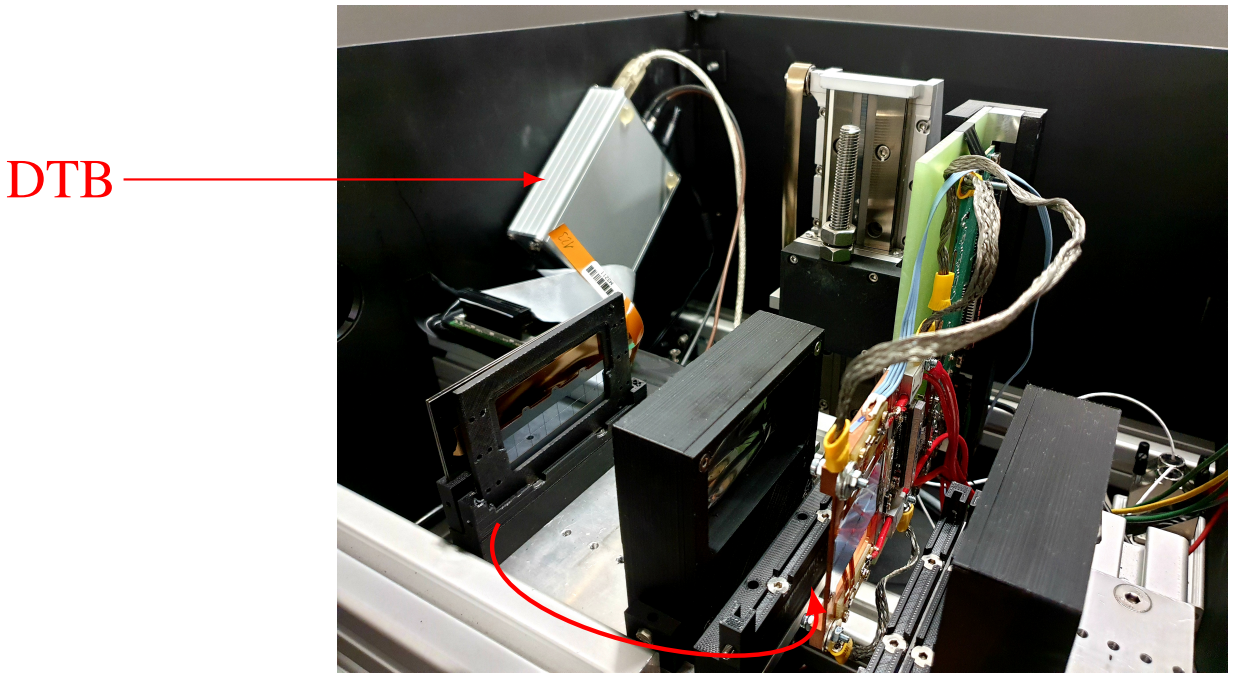
Limited impact of the large clusters on stub reconstruction

Calibration and Test of CMS Phase-1 Pixel

Telescope is not yet operational $\Longrightarrow$ Use of a **D**igital **T**est **B**oard (DTB) for calibration and taking data

DTB is readout electronics designed for laboratory tests during the production of Phase-1 Pixel module. It can also operate detector in beam environment.

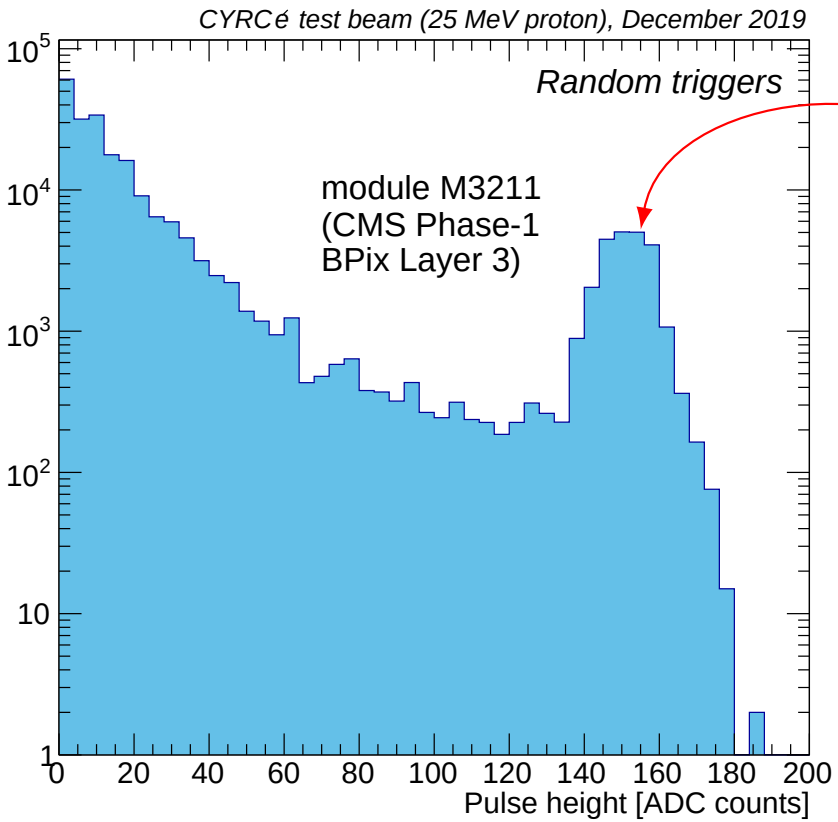
Working with **random triggers**



Picture of the box for illustrating, pixel module is not in the right place (just behind the DUT)

Saturation of the Front End electronics

Each pulse height is digitized by an **8-bit** ADC (enabling values from 0 to 255)



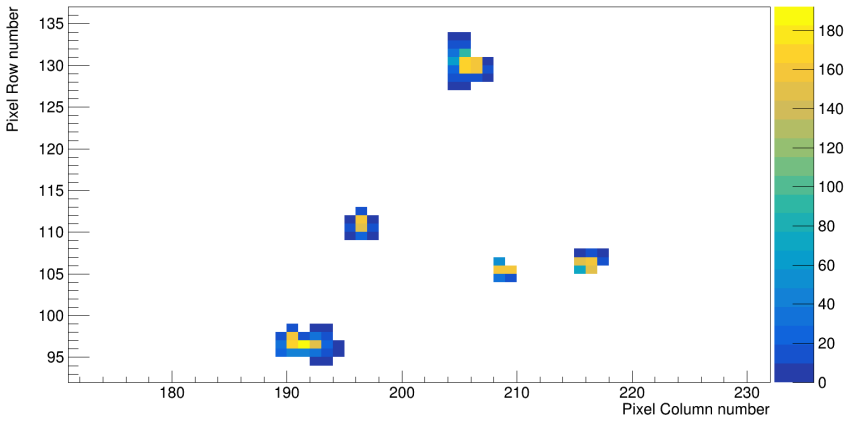
Pixels saturate around 155 ADC counts $\Longrightarrow$ saturation of the Front-End electronics (pre-amplifier) due to large signals (15 x MIP)

random triggers $\Longrightarrow$ continuous spectrum

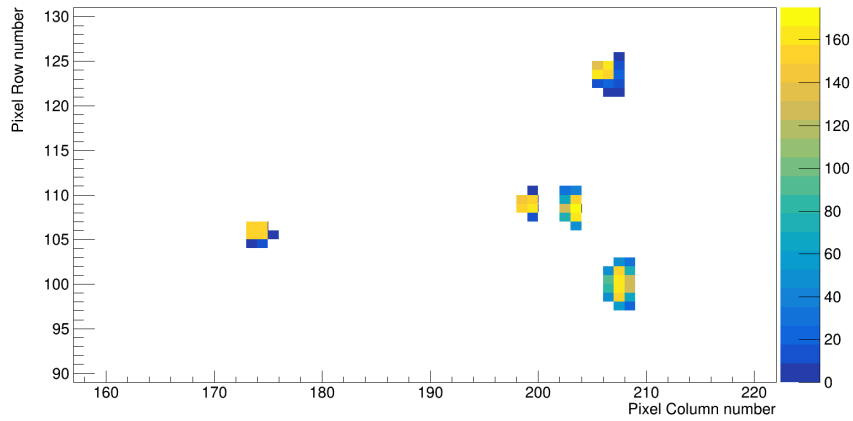
From 1 to 3 neighboring pixels of cluster are in the saturation peak depending on the random trigger

Events displays

Overlaid events (for each event, every hit pixel is plotted)
for different signal categories :



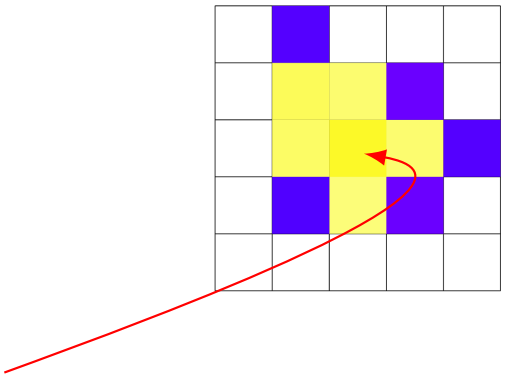
high signals : 2 central pixels with
pulse height > 150 ADC counts



very high signals : 3 central pixels with
pulse height > 150 ADC counts

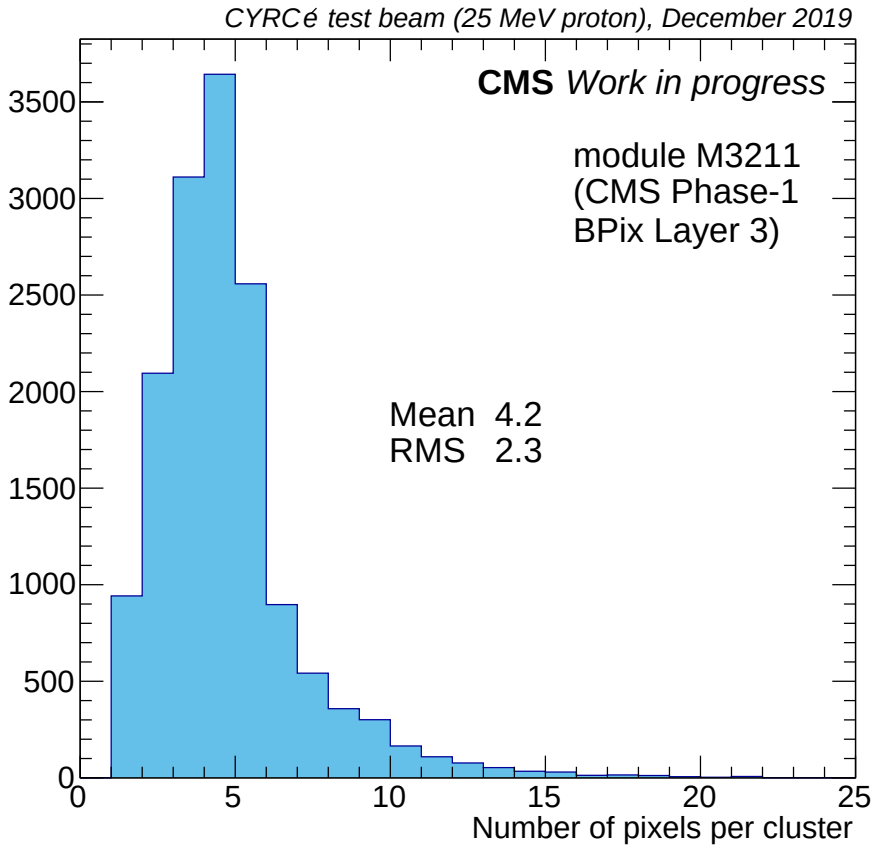
$\Longrightarrow$ Large clusters (as for the 2S module)

Clustering method



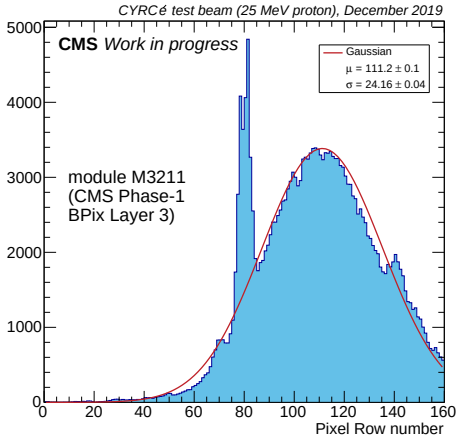
cluster seed : pixel with the highest pulse height and above 150 ADC counts

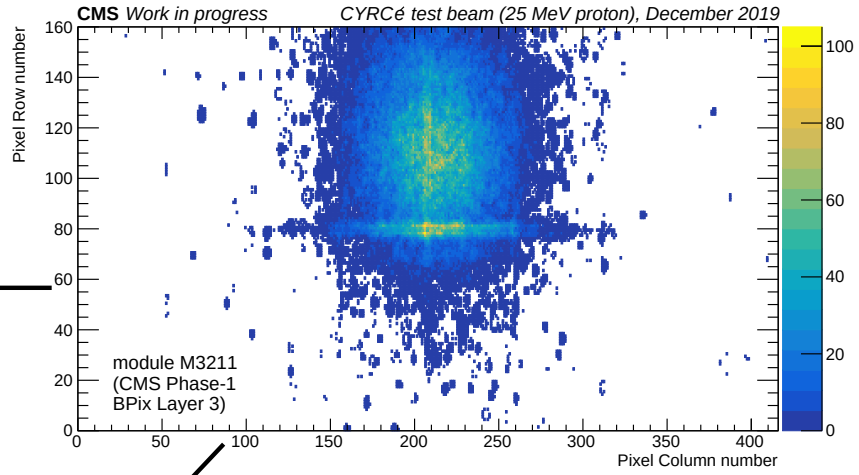
other pixels are clustered if they are not more than 2 pixels away from the seed and if PH > 20 ADC counts



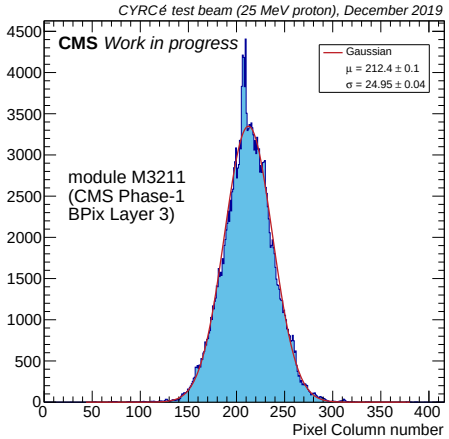
One single cluster reconstructed per event

Beam profiles (events weighted by the pixel size)



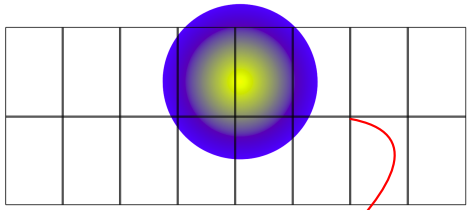


projections along axis

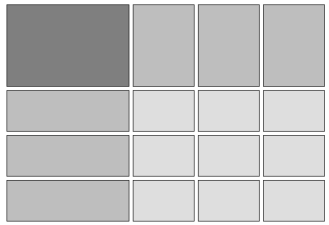


pixels with higher occupancy corresponds to pixels of larger sizes, located at the edges of ROC

16 **R**ead**O**ut **C**hip (ROC) per module



zoom



pixels at the left corner of a ROC

Summary and Next Step : Telescope Commissioning

Future mini-telescope : CHROMini

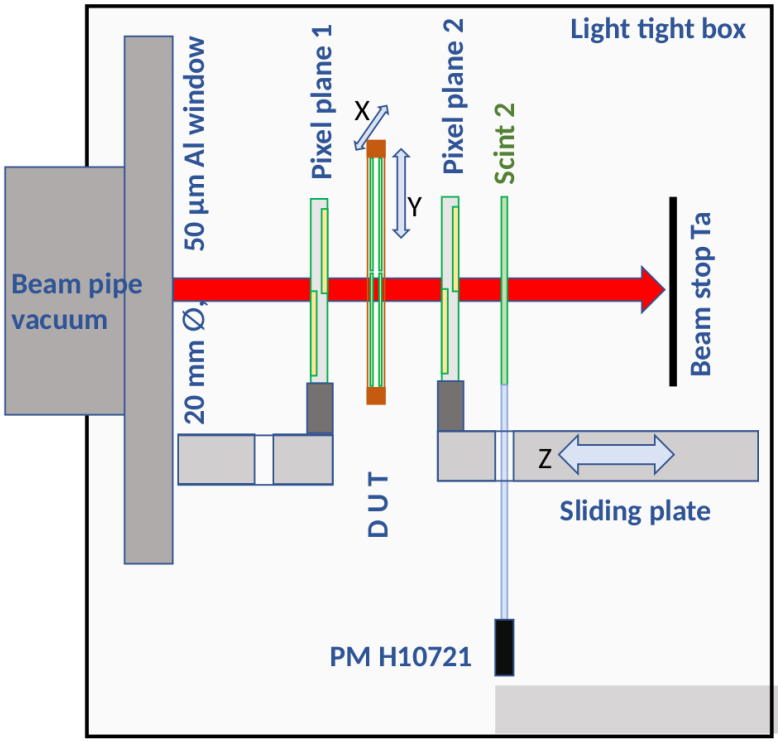
- Design inspired of CHROMIE telescope. See Nikkie Deelen presentation today.
- 2 reference planes of CMS Phase-1 Pixel modules (each plane contains 2 modules)

Last test beam have demonstrated that the reconstruction of clusters is possible under CYRCé beam despite the saturation of the electronics

Thank you for your attention !

Planned set-up

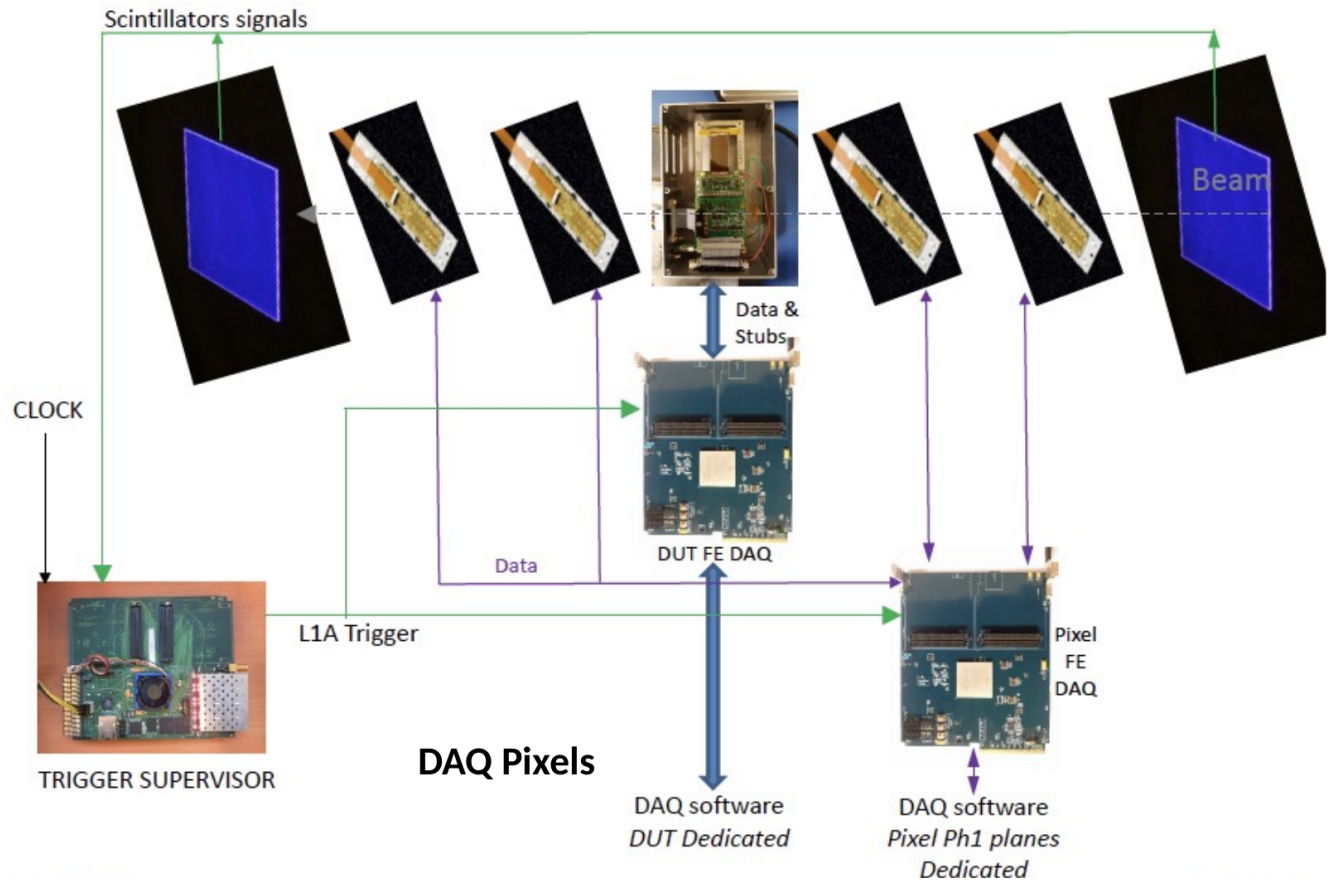
Planned set up



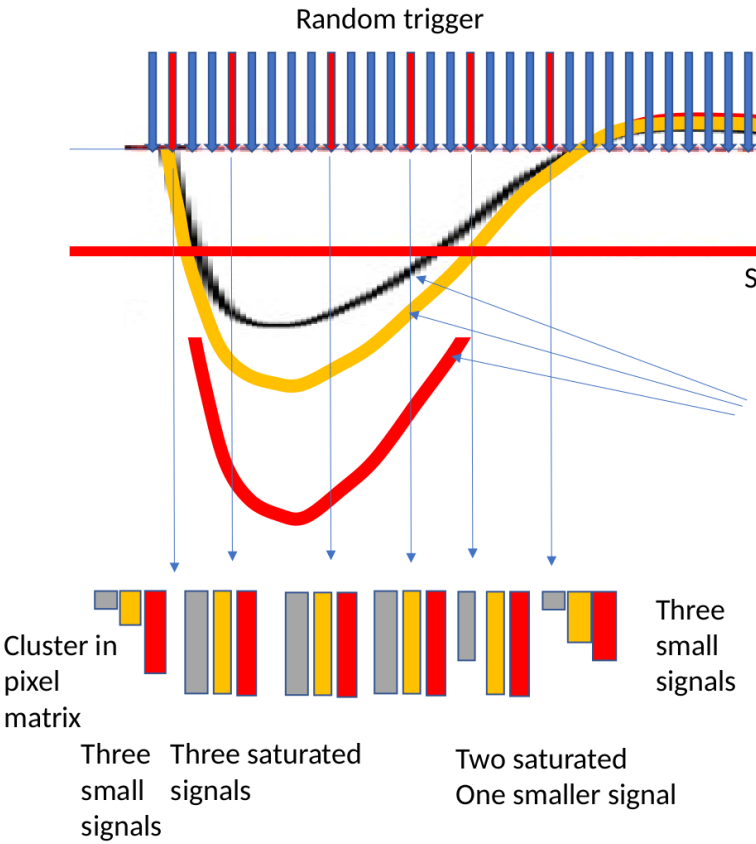
- 1 scintillators (2mm thick) for trigger in NIM logic
- 8 channel WaveCatcher for monitoring of scintillators. (Analysis still ongoing)
- 42.5 MHz synchronisation signal with beam
- X-Y precision table, remote control for DUT (Detector Under Test) and cooling
- Used a mini 2S CMS-module of KIT (Karlsruhe)
- *2 reference planes of Pixels foreseen; (CMS phase I upgrade modules)*
- *Electronics and DAQ "copy" of CHROMIE-telescope *)*
- All in a fairly light and air tight box

*) https://publikationen.bibliothek.kit.edu/1000100329

DAQ Pixel

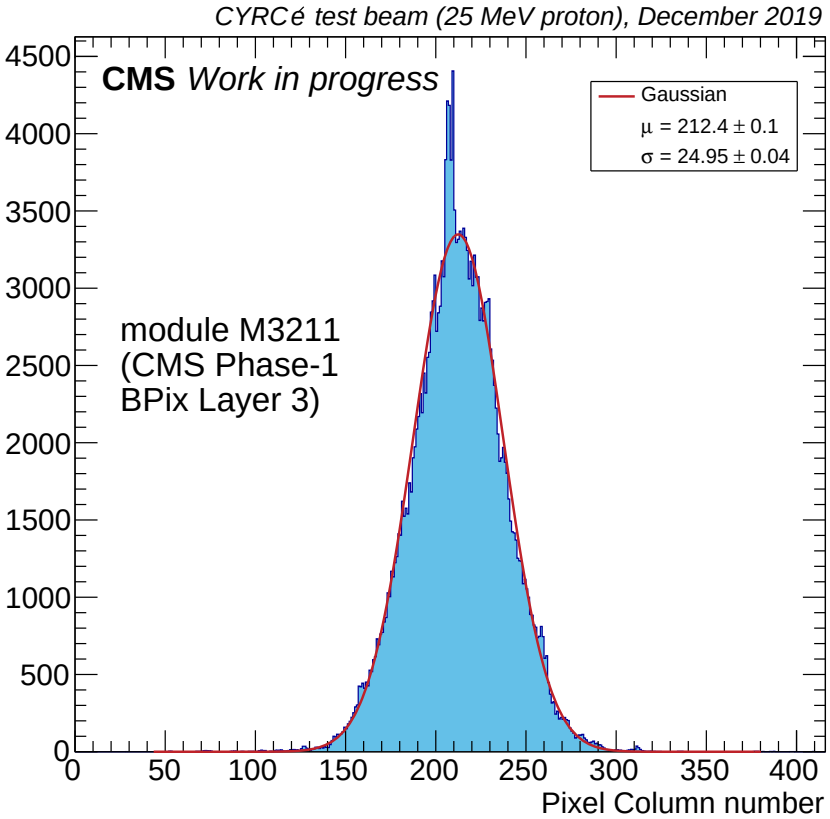

Scintillators signals
Beam
Data &
Stubs
CLOCK
DUT FE DAQ
Data
L1A Trigger
Pixel
FE
DAQ
TRIGGER SUPERVISOR
DAQ Pixels
DAQ software
DUT Dedicated
DAQ software
Pixel Ph1 planes
Dedicated

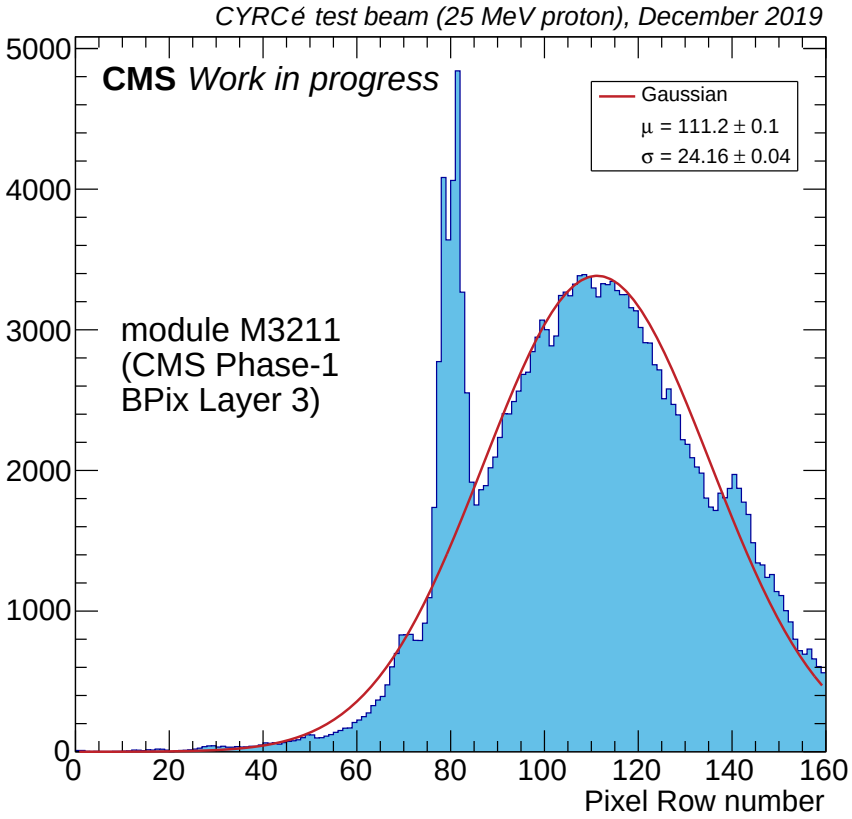
Effect of random triggers



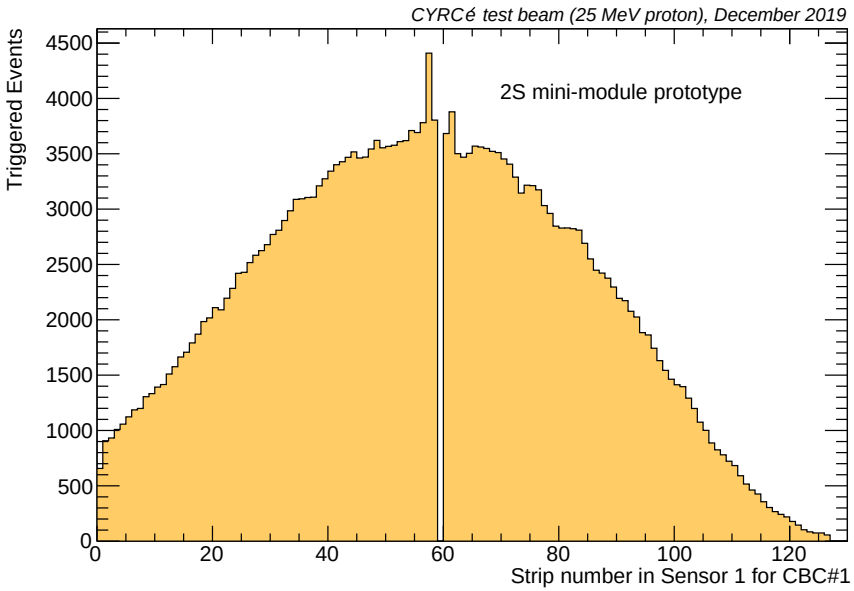
In read largest charge in central pixel
In this example all three signals are above the saturation of the pixel amplifier.
Depending on the relative timing of the random trigger we find one, two or three pixels in saturation, or three small signals.
That is about what Clement finds.

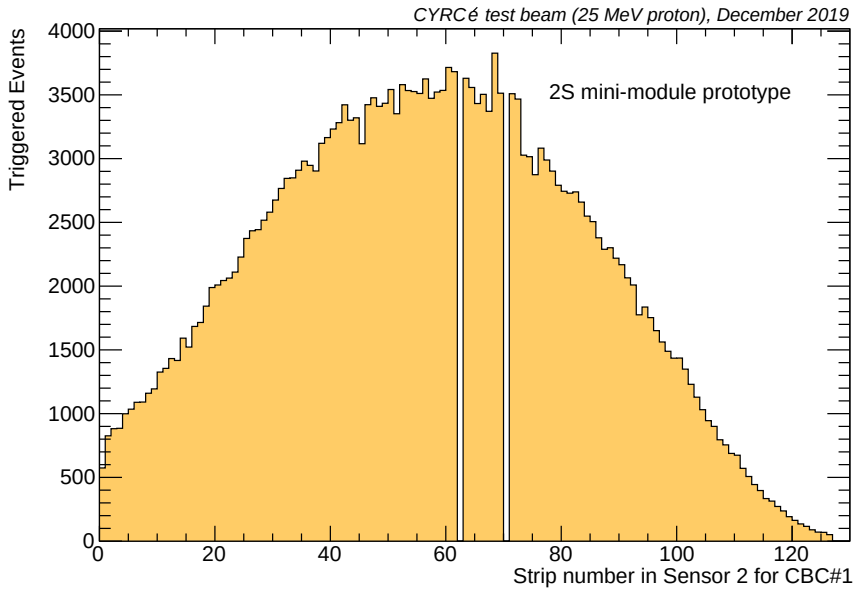
Projected hit map for columns and rows



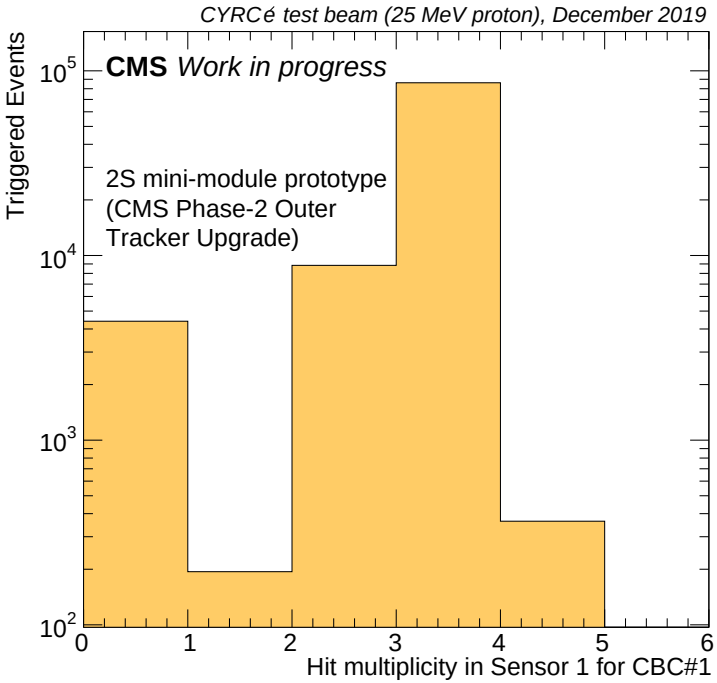


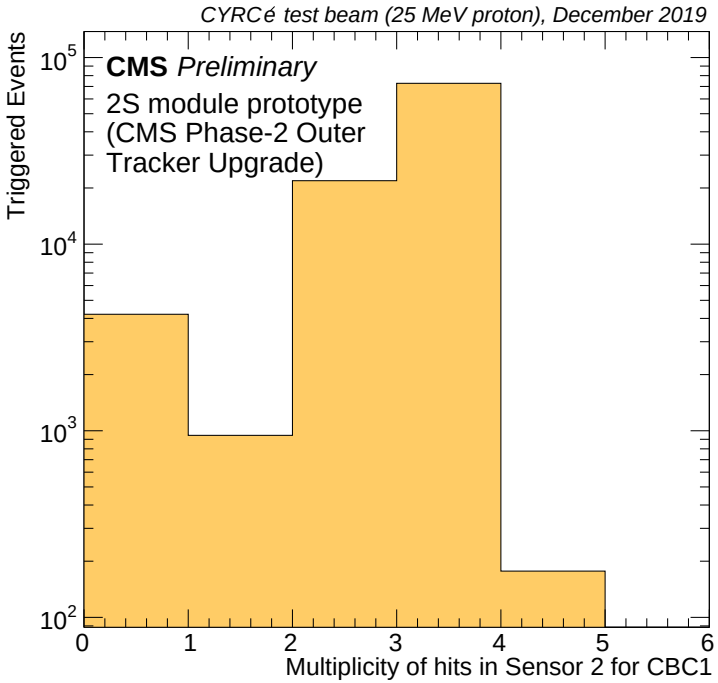
Occupancy plots



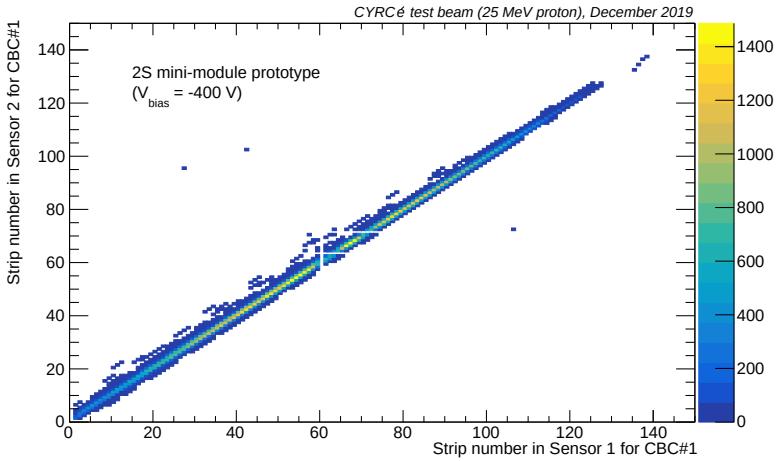


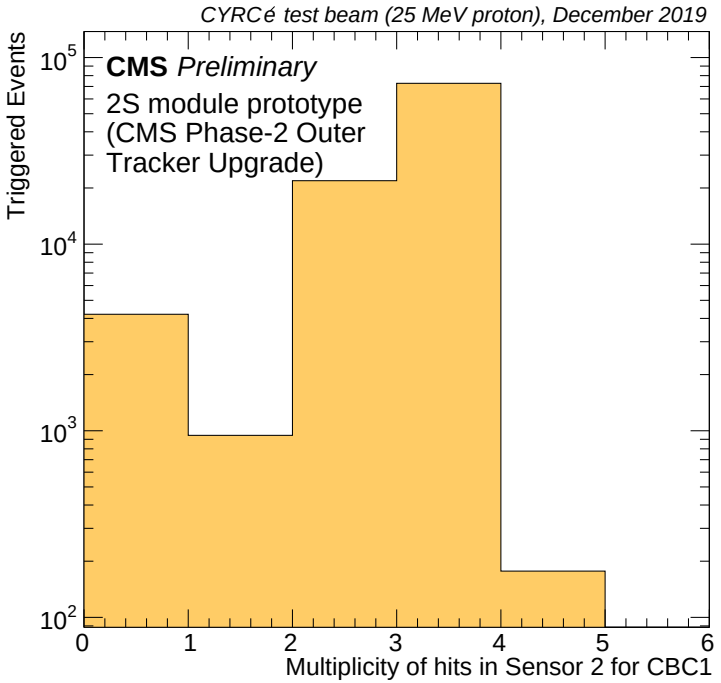
Hit multiplicity



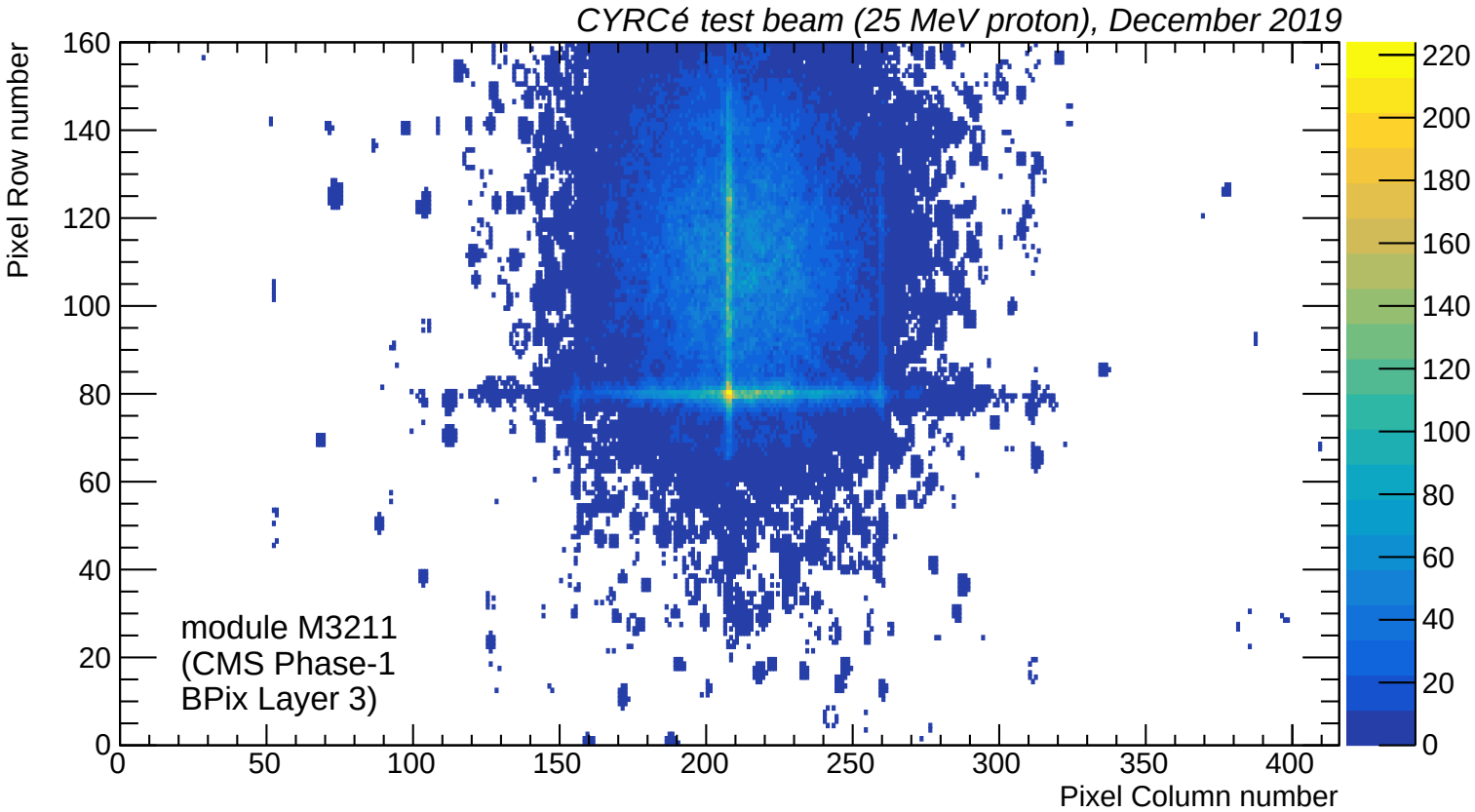


Hit correlation

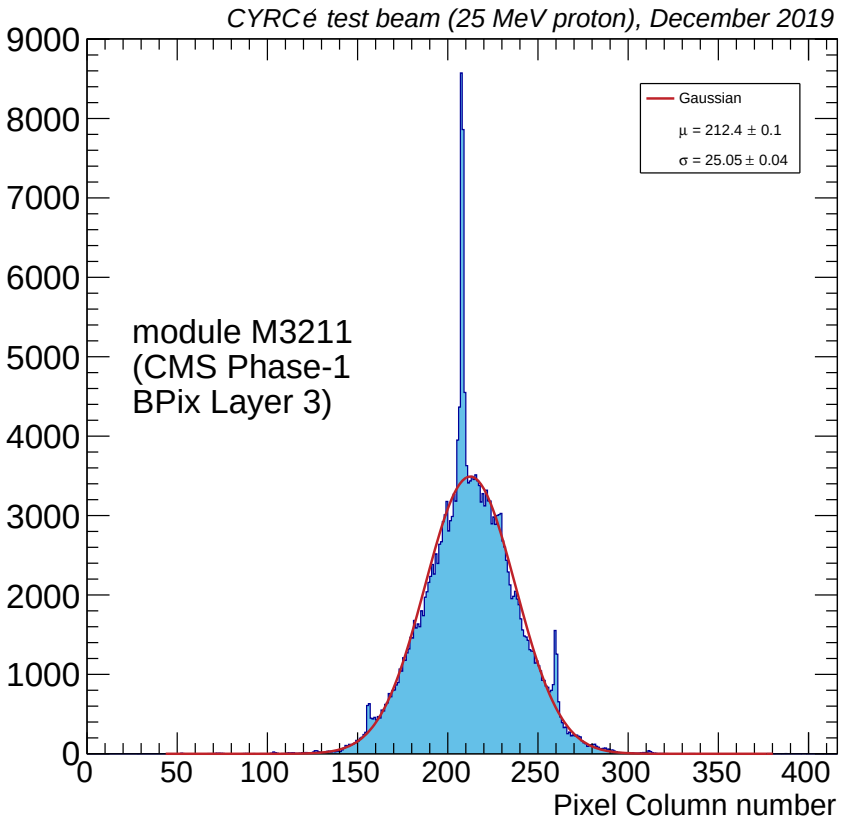


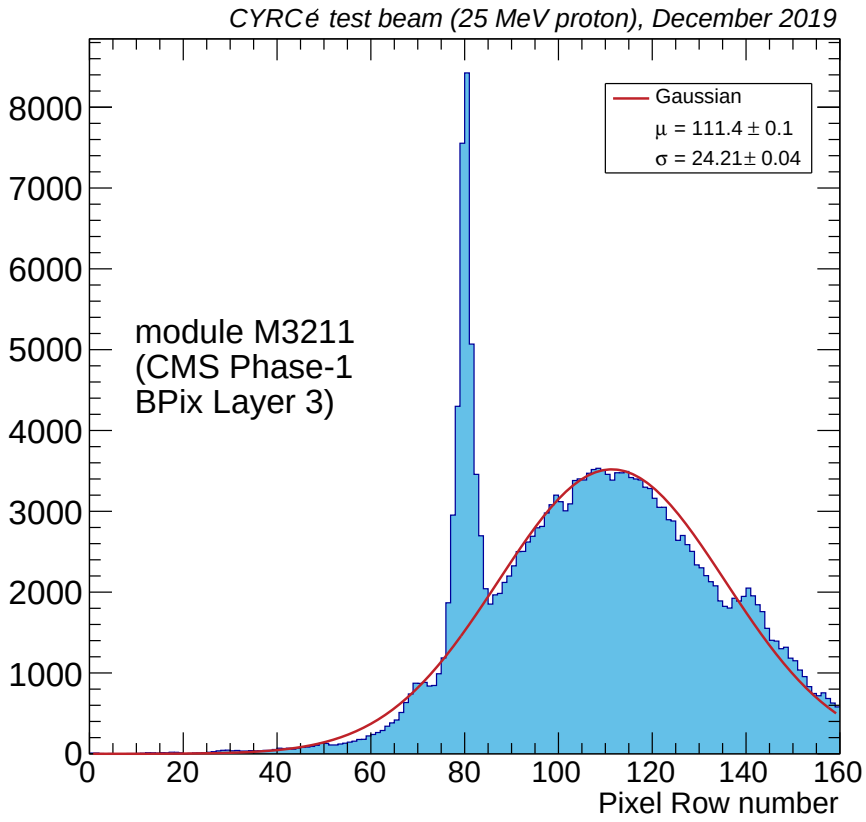


2D hit occupancy map (raw output , unweighted events)

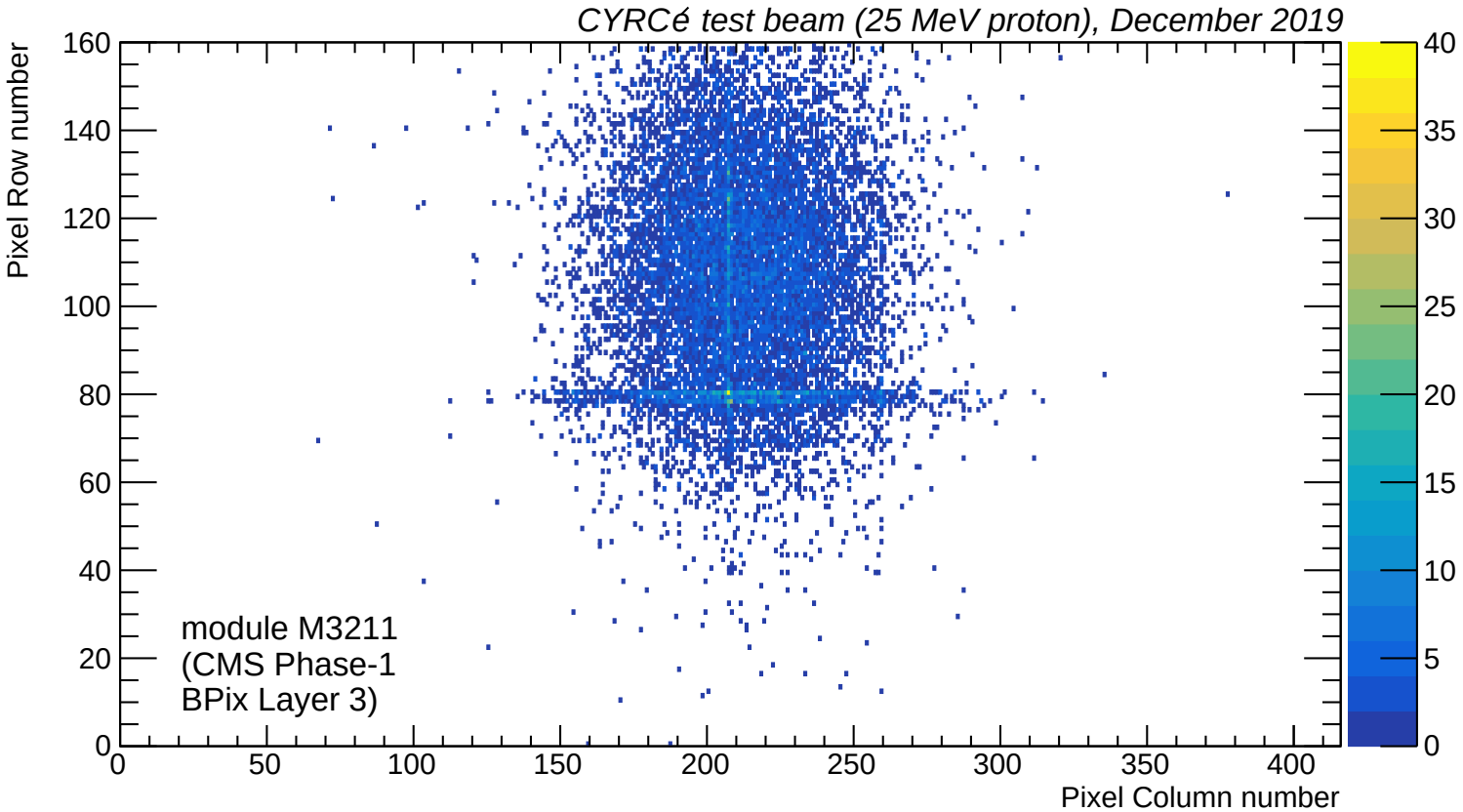


Projected hit map occupancy for columns and rows (raw output , unweighted events)

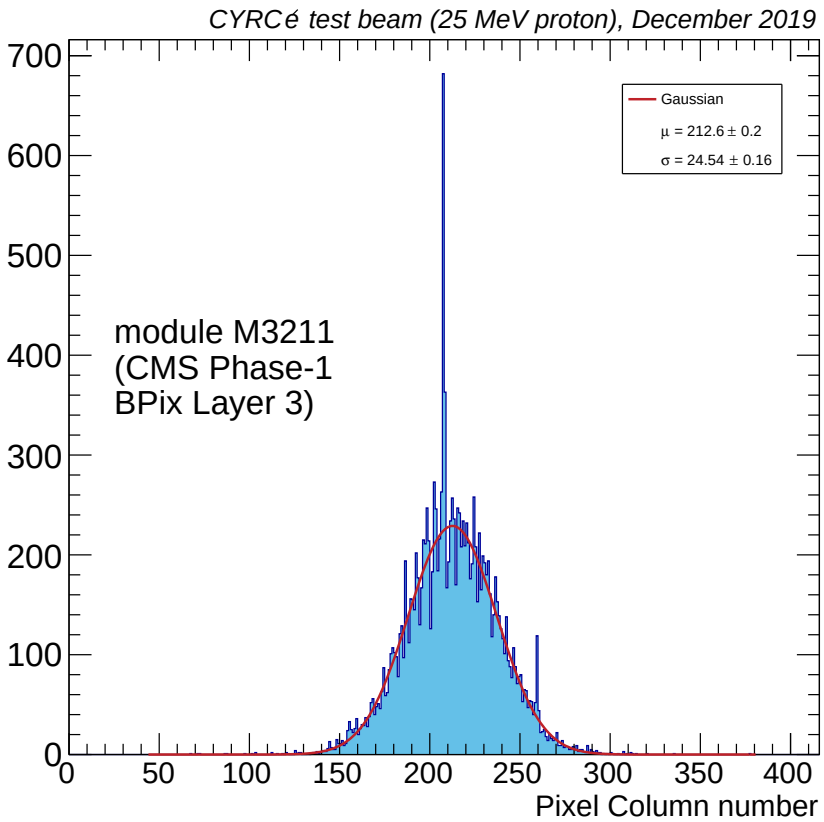


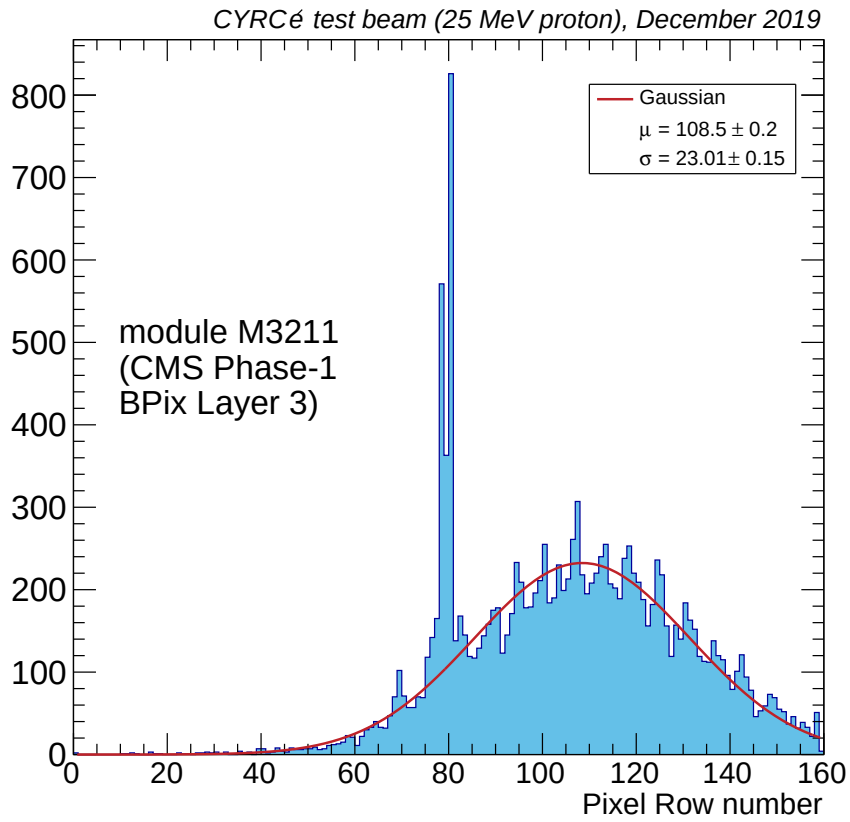


2D cluster barycenter map

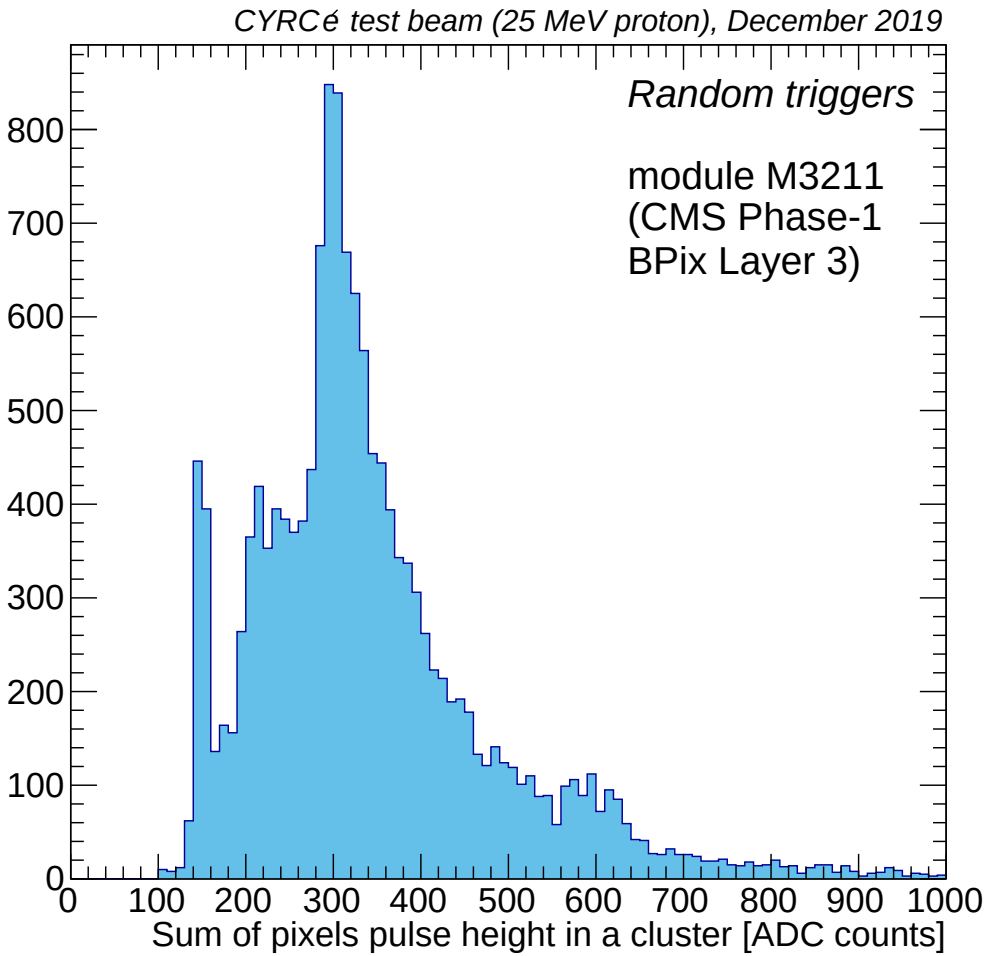


Projected cluster occupancy for columns and rows

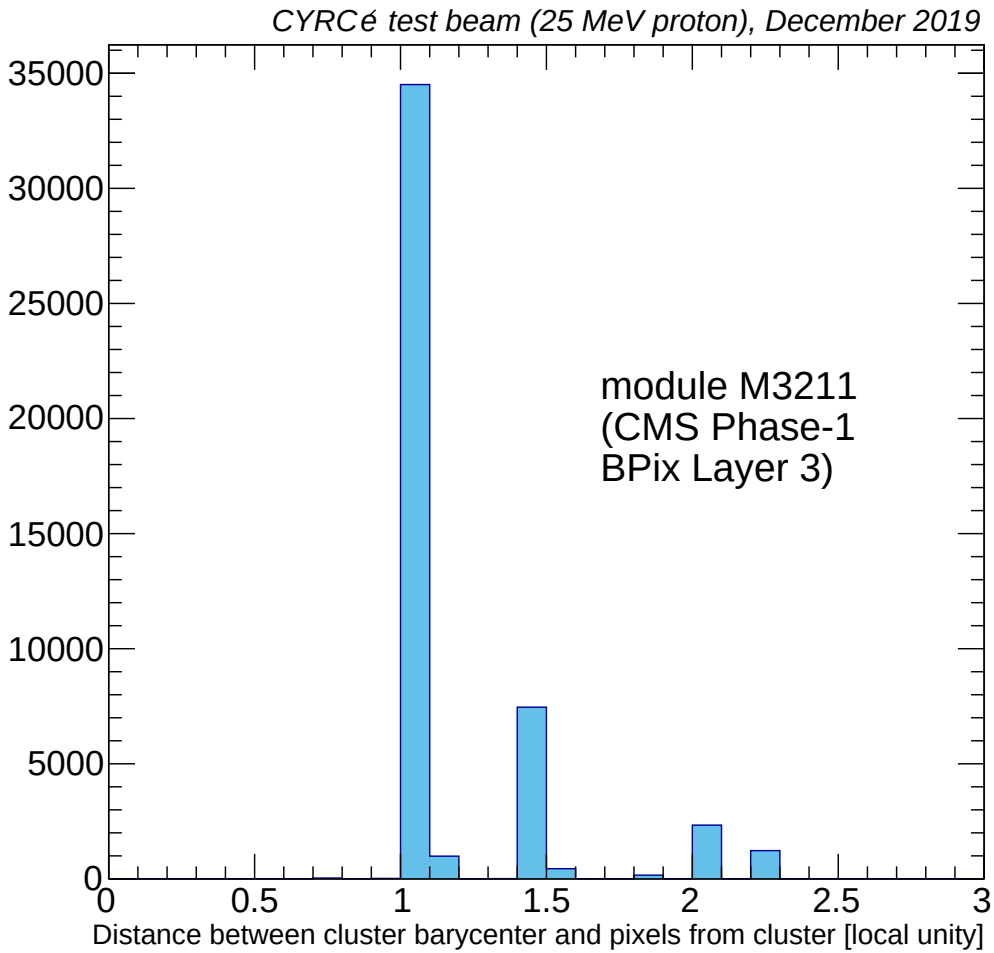




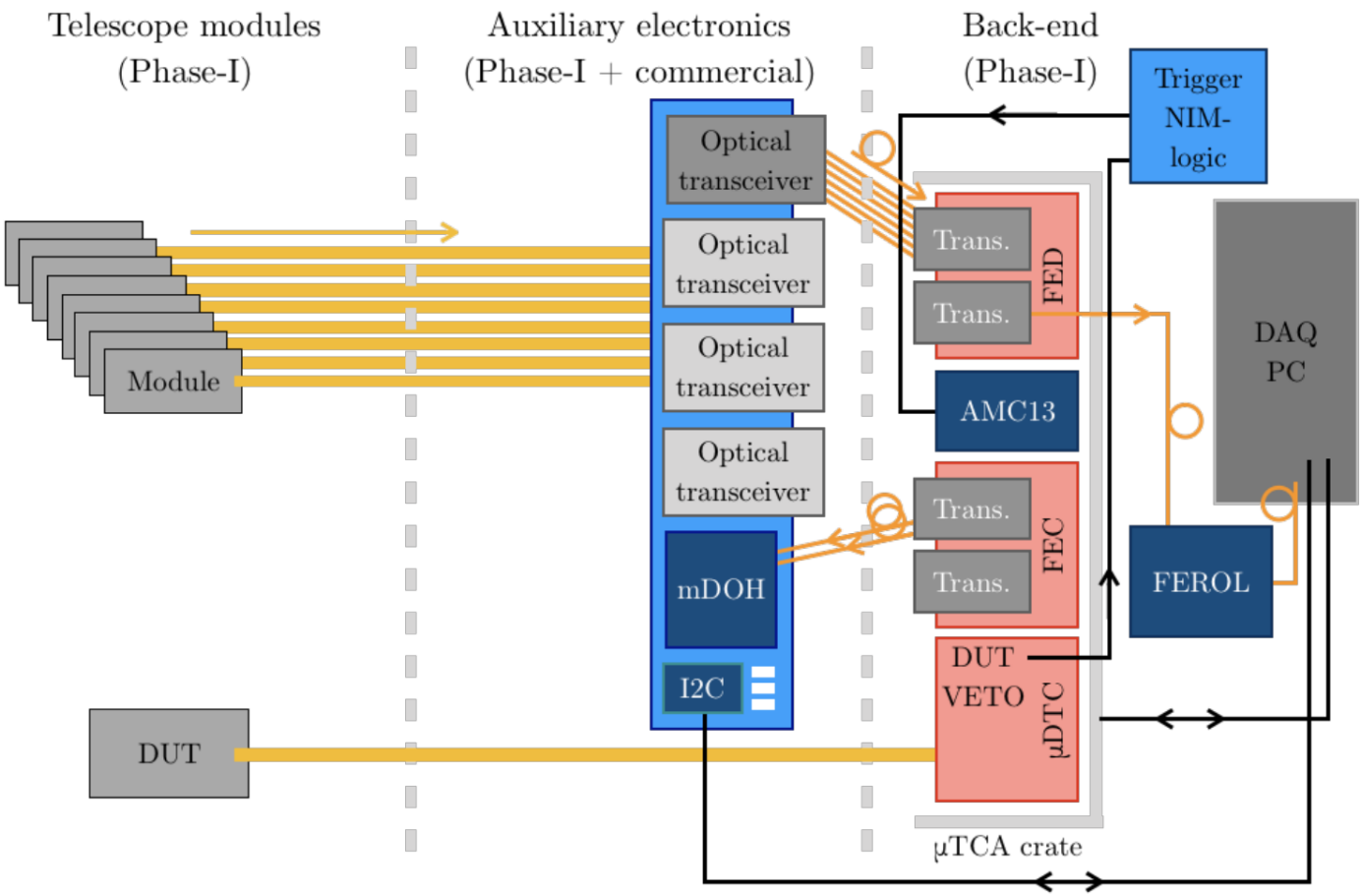
Cluster charge



Cluster radius



DAQ of CHROMIE and the CBC3 mini-module



from Nikkie Deelen thesis : Characterizing detector modules for the Upgrade of the Silicon Tracker of the Compact Muon Solenoid experiment