The COMPASS experiment gets its new hybrid pixelized Micromegas detectors for high particle flux

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MicroPattern Gaseous Detectors conference 2015

13/10/2015

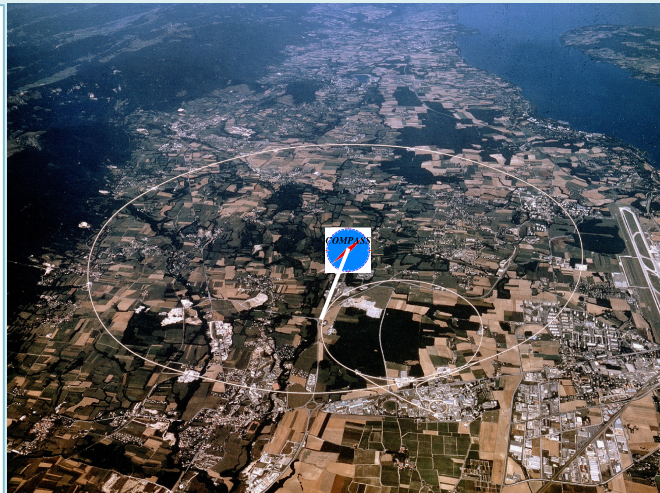
New pixelized Micromegas detector project

Pixelized read-out and discharge impact reduction

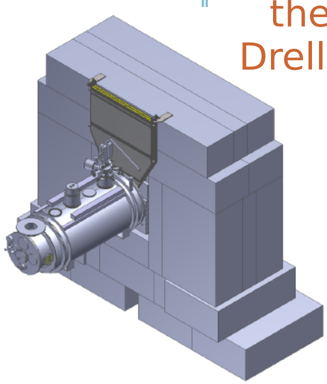
Preliminary performance during 2015 run

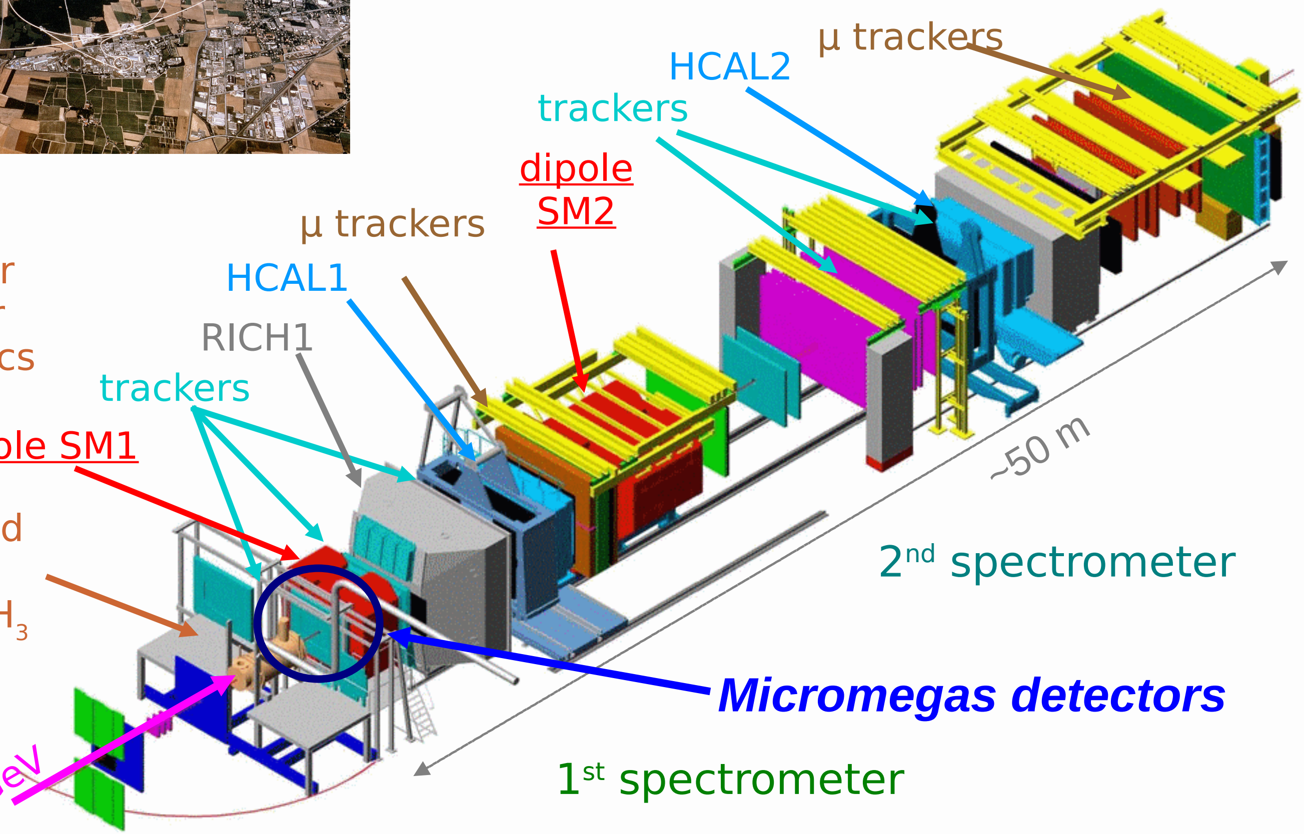
The COMPASS experiment at CERN

Irfu cea saclay



- Muon or hadron beams on fixed target
- 2 spectrometers for small and large angles
- Taking data from 2002 for nucleon structure studies
- High statistic experiment (30kHz trigger rate)
- Micromegas just after the target





Old COMPASS Micromegas detectors

COMPASS Micromegas detectors

First Micromegas detectors installed in particle physics experiment (since 2001-2002)

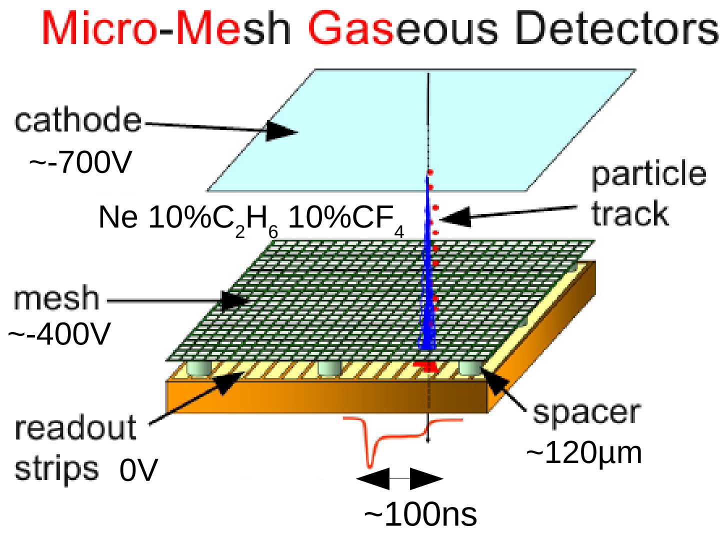
Light board sandwich with 40x40 cm² active area

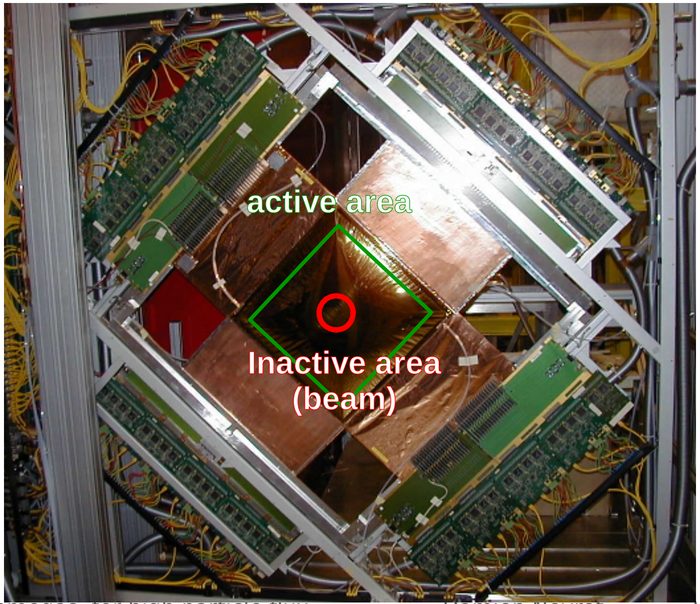
Good performance: 70-100 µm and 10 ns resolutions

Light gas mixture Ne + 10% C_2H_6 + 10% CF_4 to limit discharge rate

Blind center to reduce electronics occupation

Low-noise electronics using SFE16 chips (threshold ~ 4000 e^-)





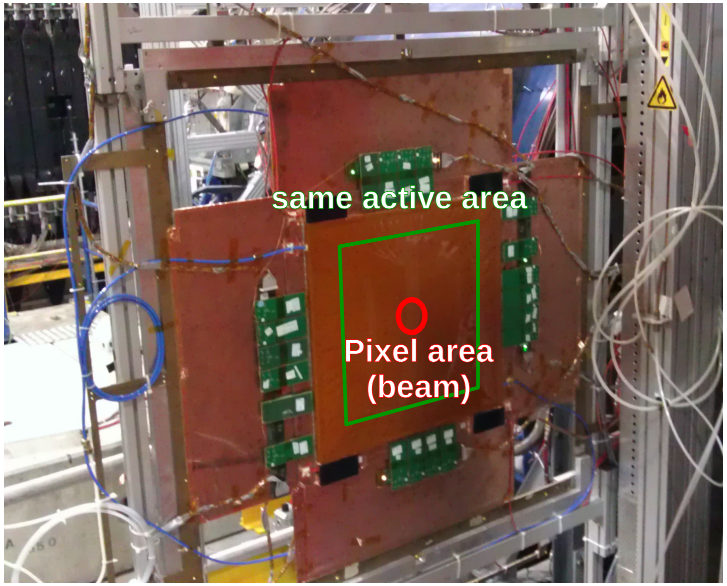
New pixelized Micromegas project

Motivations

New COMPASS study phase in 2015-2018 with high flux muon (DVCS) and hadron beams (Drell-Yan)

Tracking at very small angle with same material budget

Discharge impact reduction at high beam flux



Main objectives of the project

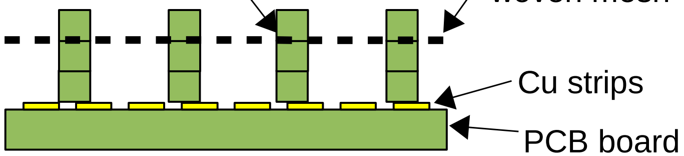
Detectors active in beam area with pixel read-out

Less discharge → stand 5 times higher flux

Integrated electronics (APV25 chips)

Robustness improved with bulk technology

Same active area (40x40cm²) as present MM



bulk technology

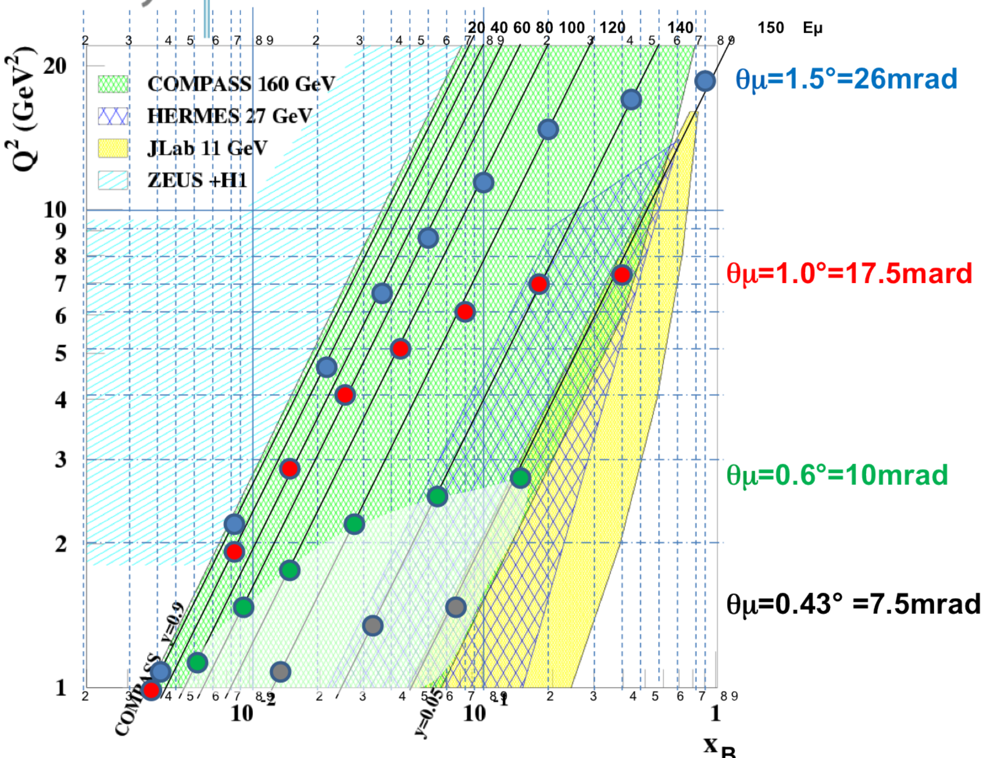
Impact of low angle tracking on DVCS measurement

Deep Virtual Compton Scattering (2016-2017)

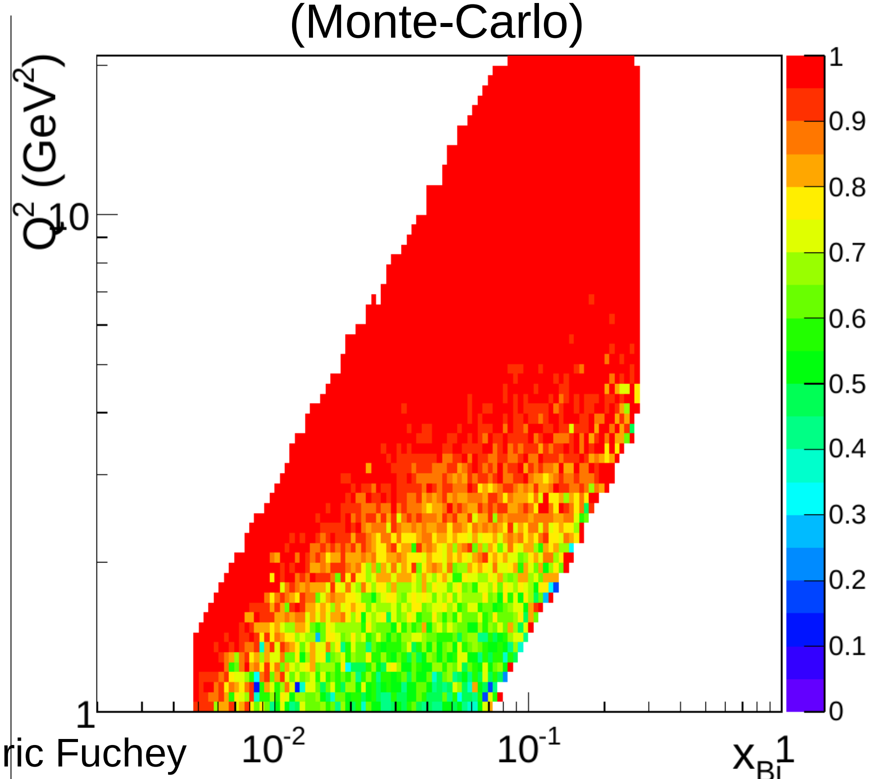
Study on large kinematic domain in particular at low muon scattering angle

Insufficient track detection at low angle would lead to loose statistic in important part of the domain

DVCS kinematic domain



DVCS event number ratio without/with active pixel area (Monte-Carlo)



Study by Eric Fuchey

Pixels read-out in the detector center

Too high flux for strips

Expected particle flux > 100kHz/mm²

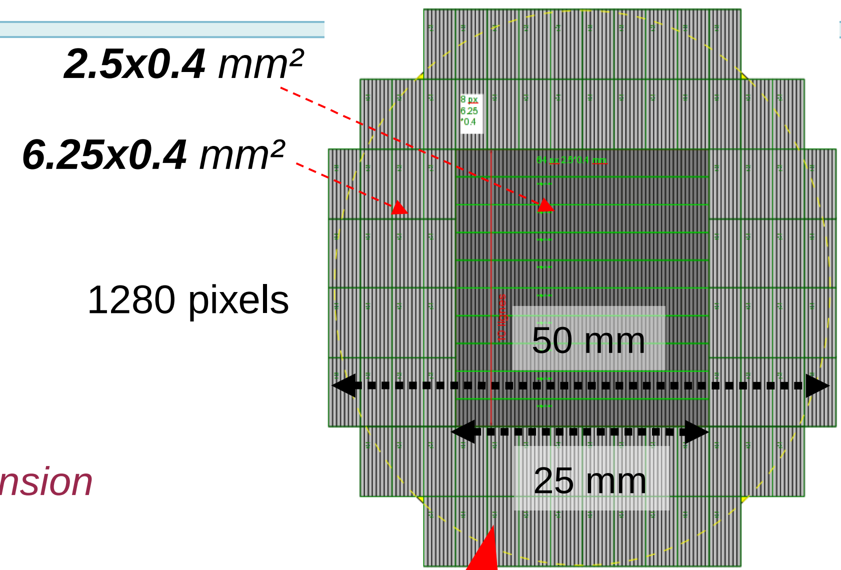
→ > 500kHz/channel if strip read-out

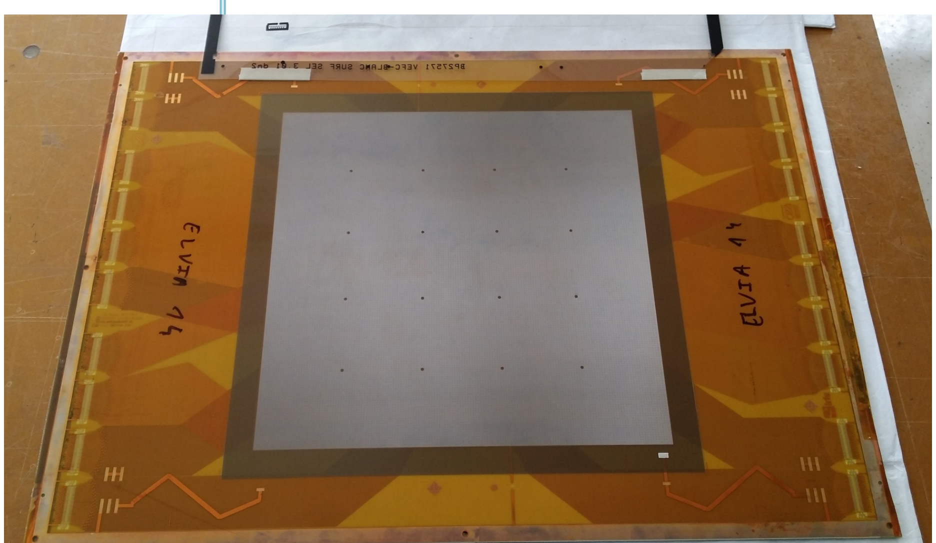
→ > 10% electronics inefficiency

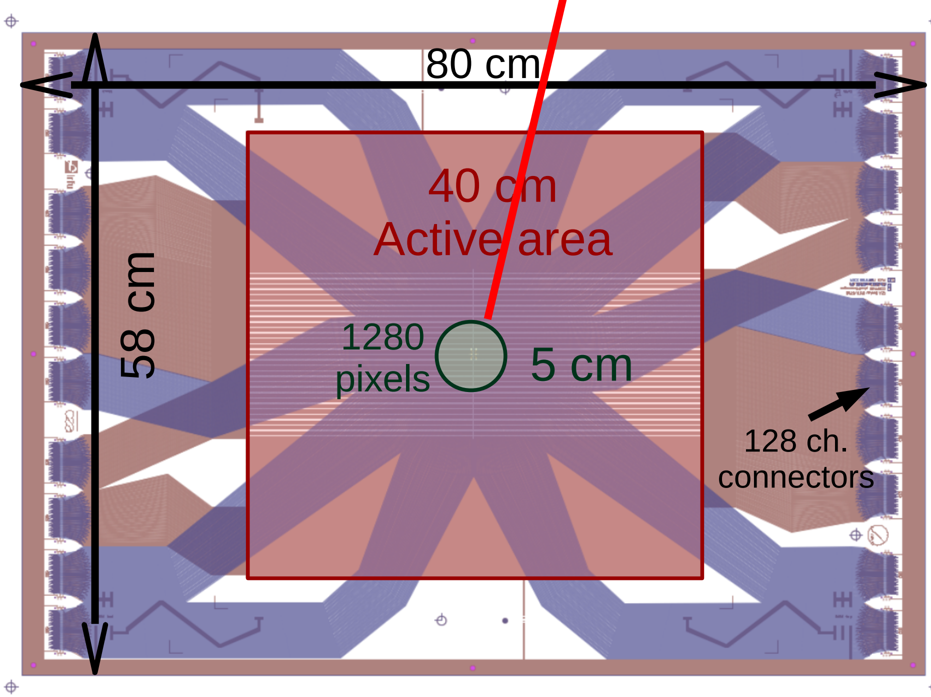
Rectangular pixels

Keep spatial resolution in perpendicular dimension (400µm pitch like strips)

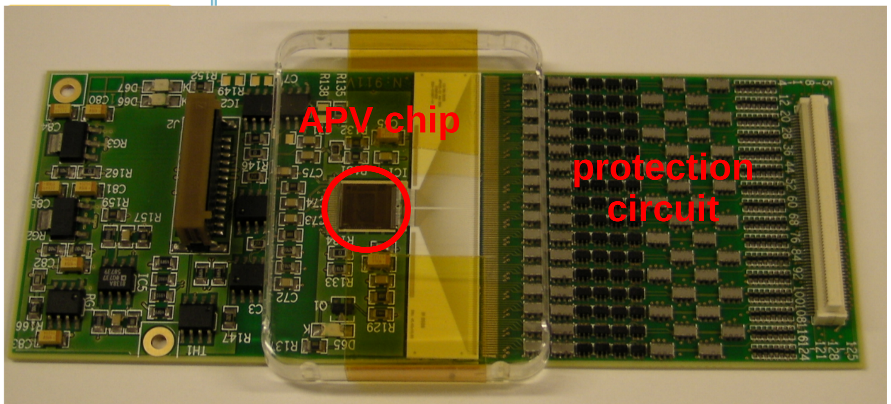
1280 pixels + 1280 strips

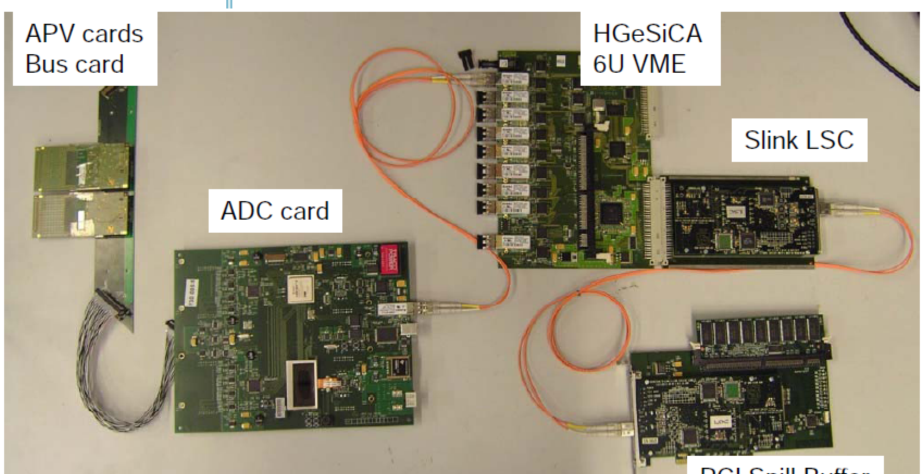






APV front-end electronics for pixelized MM





Design from TUM Munich

Used in other COMPASS detectors (RICH, pixelGEMs,...)

APV cards

APV25-S1 chips for amplification and analog multiplexing

Very integrated, 128 channels/chip

Specific changes done for MM read-out (protection circuit)

ADC boards

Digitalize analog signals from APV chips

HGeSiCa VME cards

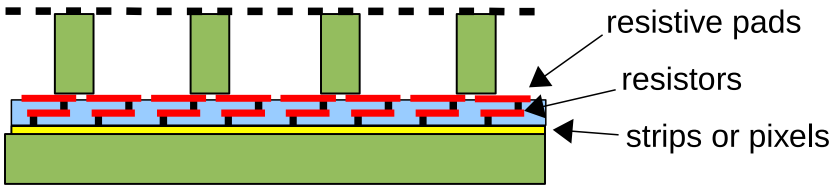
Data concentration and trigger distribution

Selected solutions to reduce the impact of discharges

Resistive Micromegas

Other resistive schemes not fully adapted for pixels

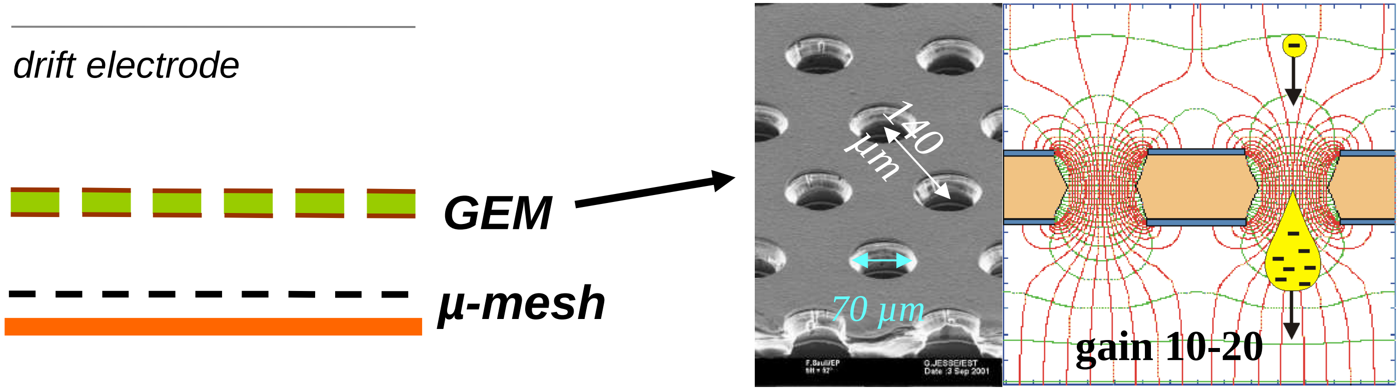
***Buried resistors** scheme proposed in 2010 by R. de Oliveira et al.*



Hybrid Micromegas with 1 GEM foil

Preamplification with a GEM foil (gain 10-20)

Micromegas stage at lower gain → fewer discharge

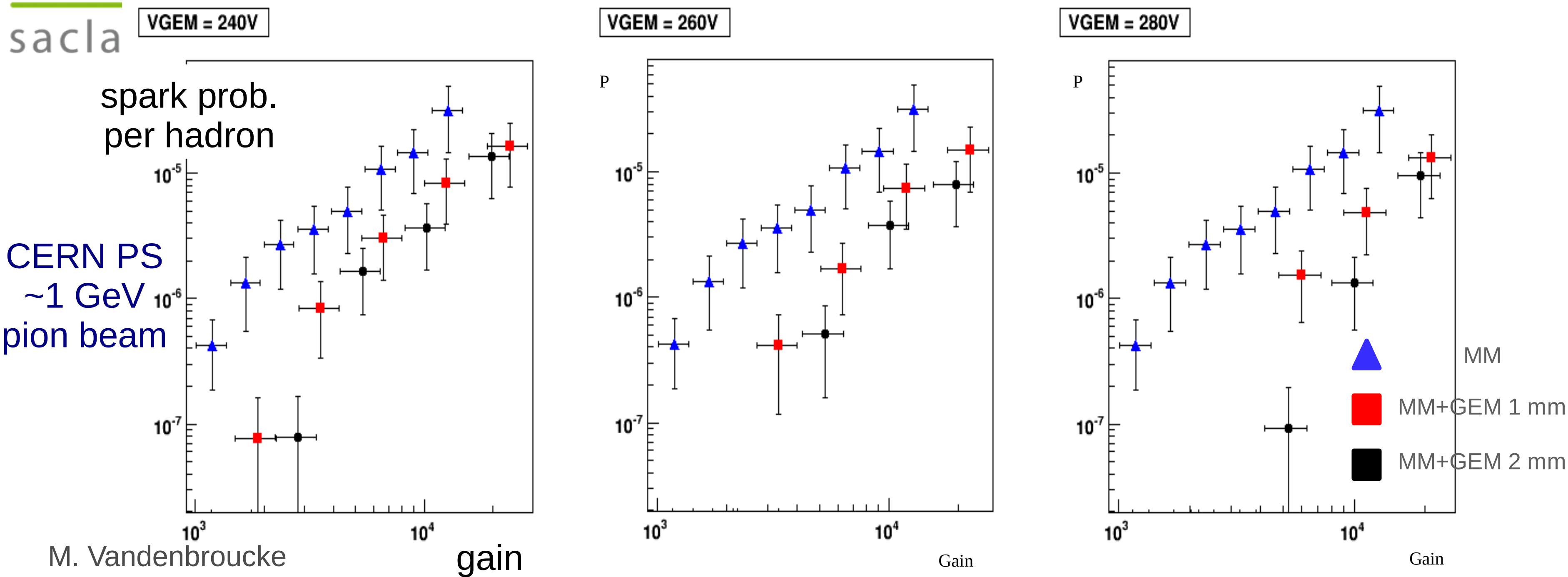


R&D on spark impact reduction

Common studies in 2009-2010 on small size detectors (6x10 cm² active area) with CLAS12 Saclay group in the framework of the RD51 collaboration

Hybrid detectors

Important reduction (>10) of discharge probabilities compared to standard MM



M. Vandenbroucke
G. Charles

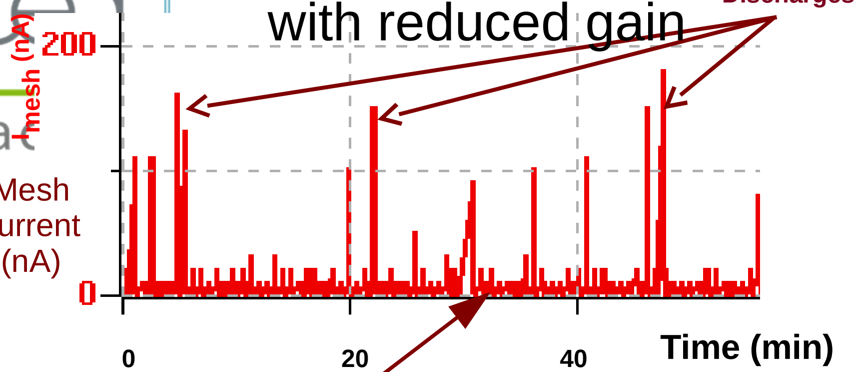
Resistive detector

No visible discharge as their amplitude are too small to be detected

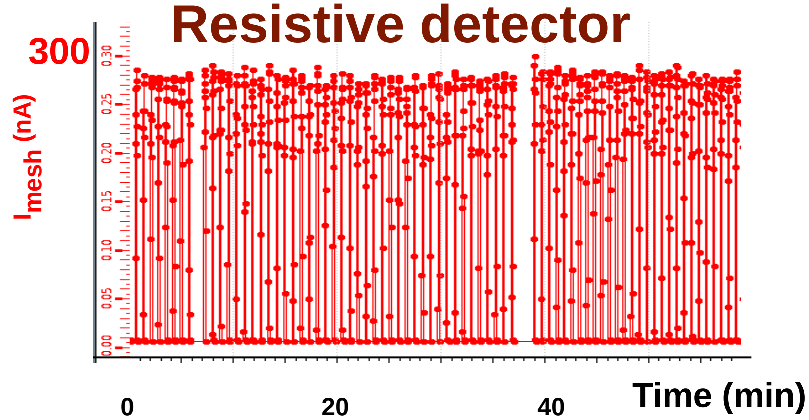
Discharge rates with high flux hadron beam

Hadron 2012 data taking at COMPASS, pion beam

Standard MM
with reduced gain

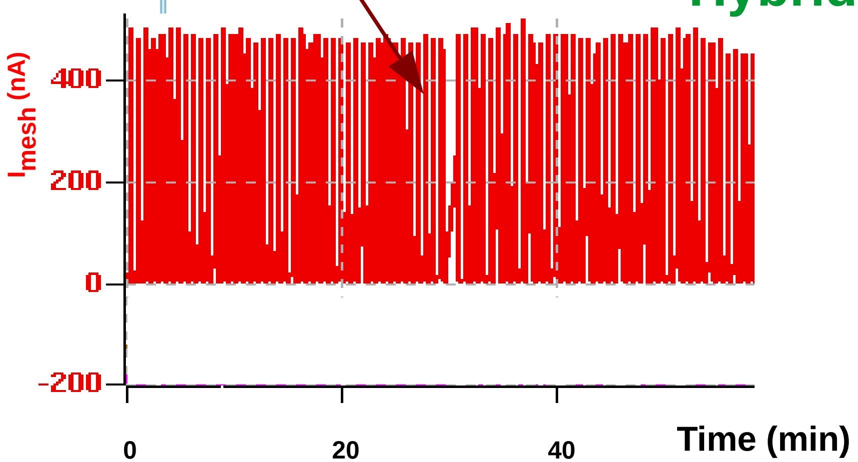


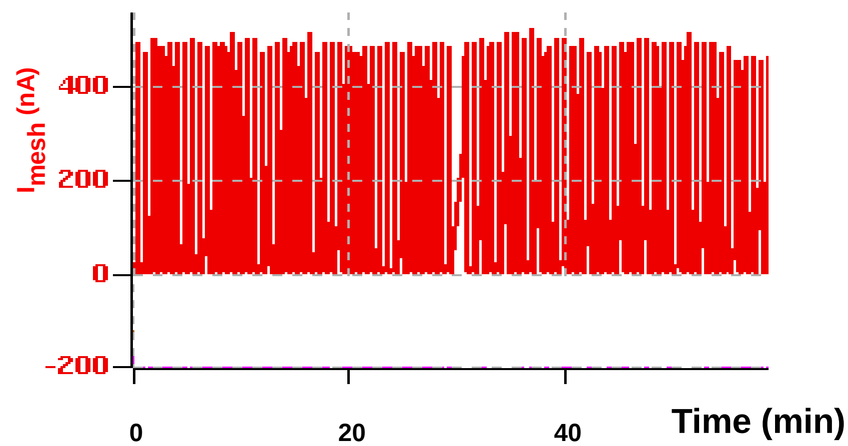
Resistive detector



Beam « spills »

Hybrid detectors





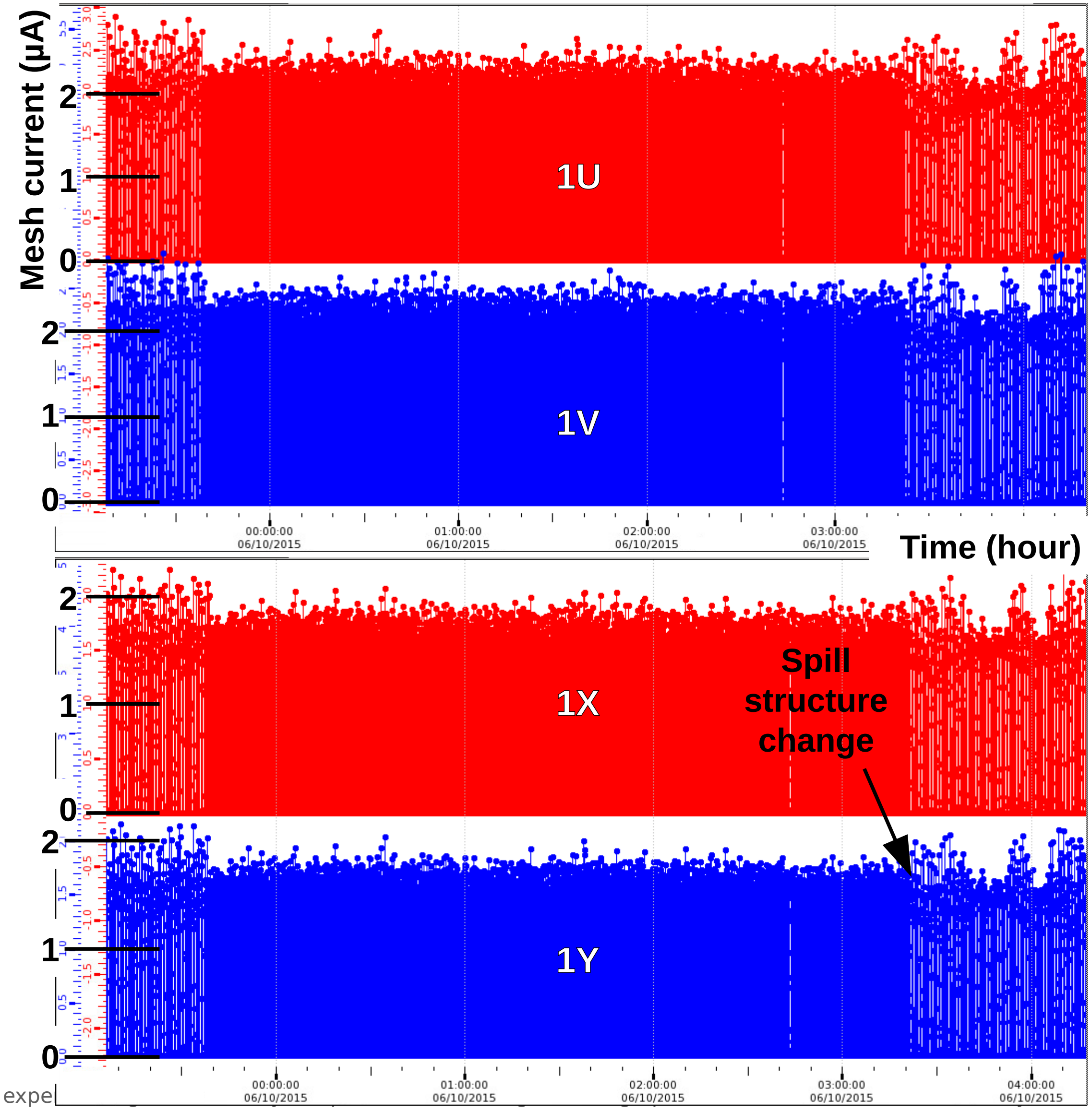
Discharge rates with high flux hadron beam

Drell-Yan 2015 data taking, pion beam

Mesh current on station 1 placed just after target + absorber

High current due to amplification of low momentum particles

No large discharge visible on new detectors



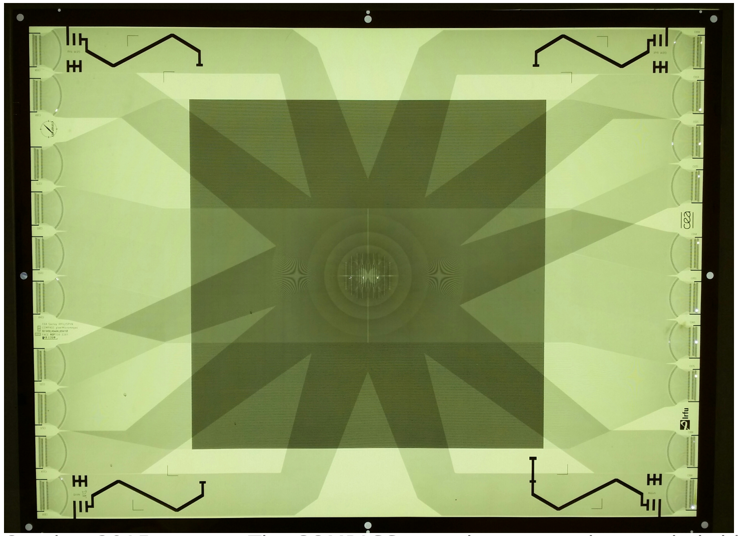
MM board production

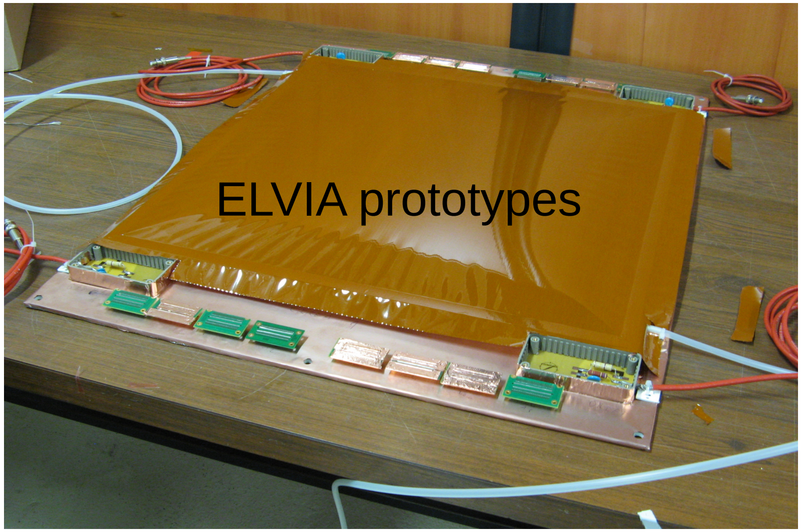
Choice of MM+GEM hybrid detection

- *Better spatial and time resolutions than for resistive detector*
- *No solution yet for serial production of buried resistor boards*

MM technology transfer to industry

- *Collaboration between IRFU and CIREA / ELVIA group (french PCB producer) since 2011, partner on « SPLAM » ANR agency funding*
- *ELVIA masters bulk technology since mid-2012, producing 40x40 cm² active area prototypes since then*





Production and installation of 12 detectors + spares

Challenges for the production

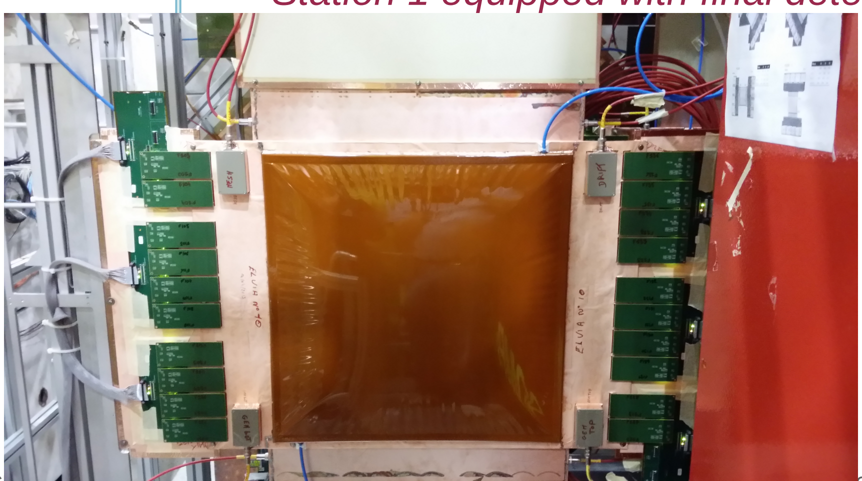
- *Large size PCB with very thin design in the pixel area (60µm thin strips with 60µm insulation)*
- *Gluing of 200 µm thin PCB – 4 mm Rohacell foam sandwich*

Production of bulk boards at ELVIA company

- *Took place from end 2014 to September, peak production 2 boards every 2 weeks*
- *Cf. poster*

Installation at CERN

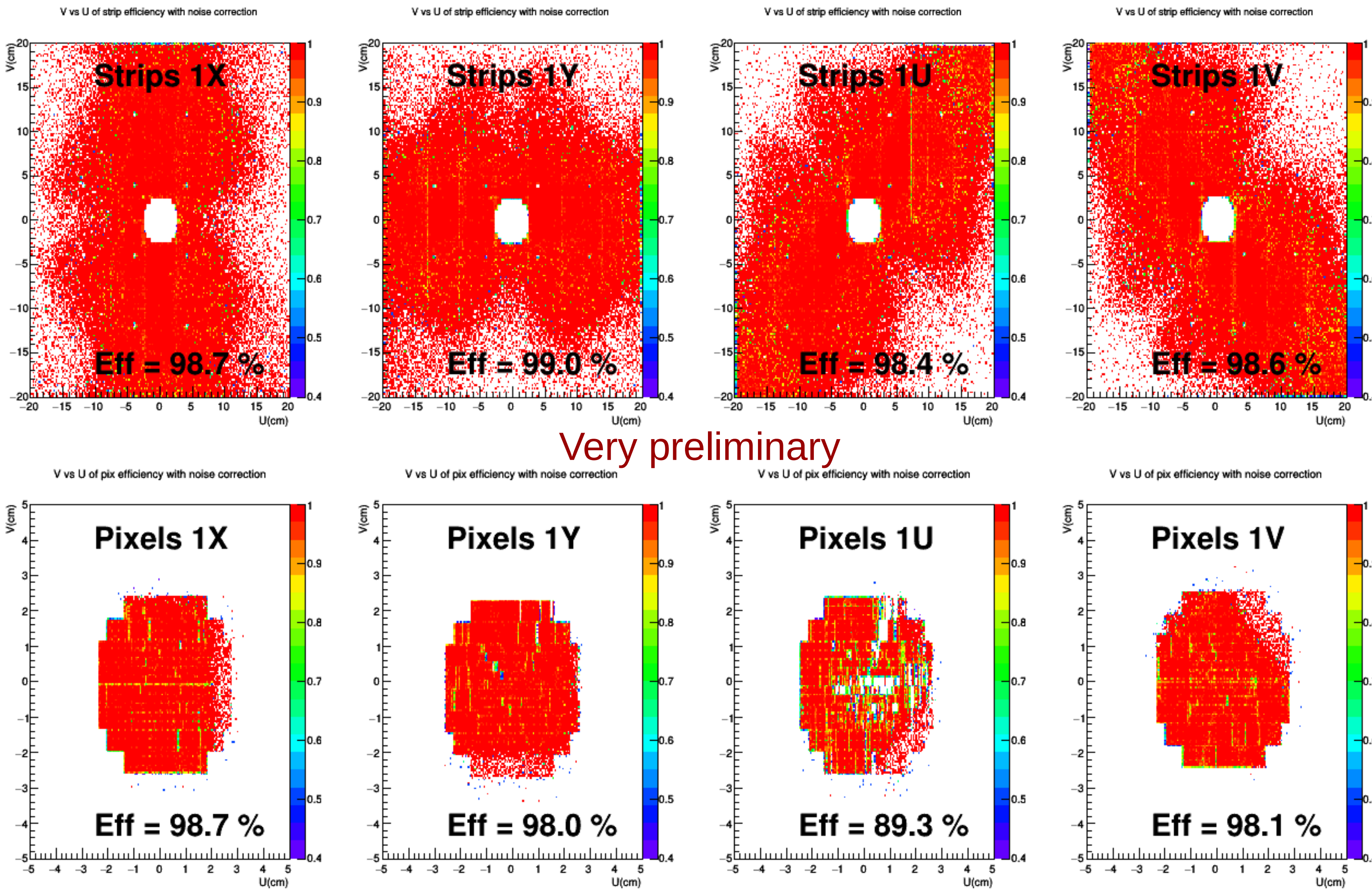
- *3 stations of 4 planes (X, Y, U, V), station 1 was already equipped in 2014 with prototypes of pixelized MM*
- *Station 2 installed in April, station 3 in May*
- *Station 1 equipped with final detectors in June*



PixelMM efficiencies at low μ flux

All magnets on

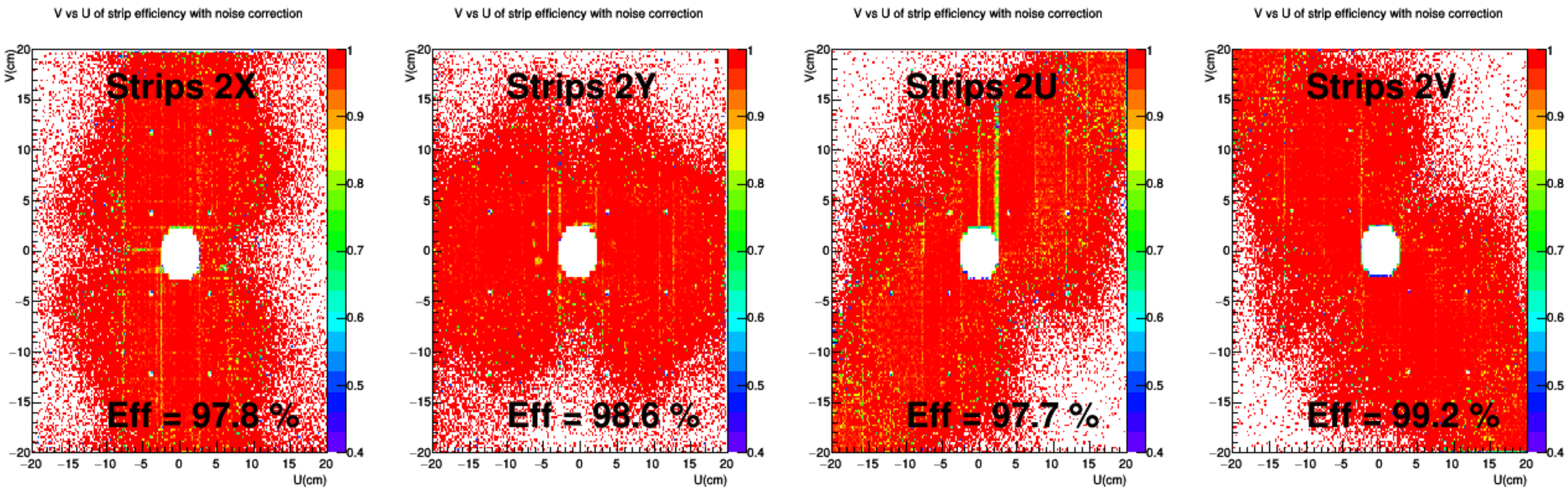
Station 1



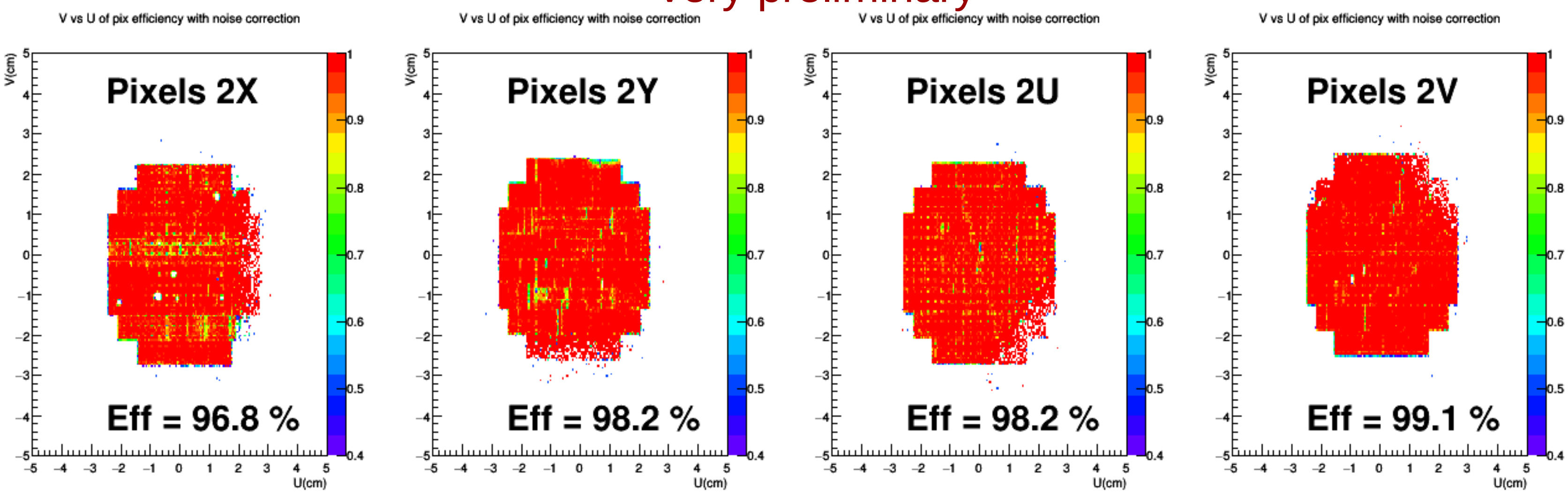
PixelMM efficiencies at low μ flux

All magnets on

Station 2



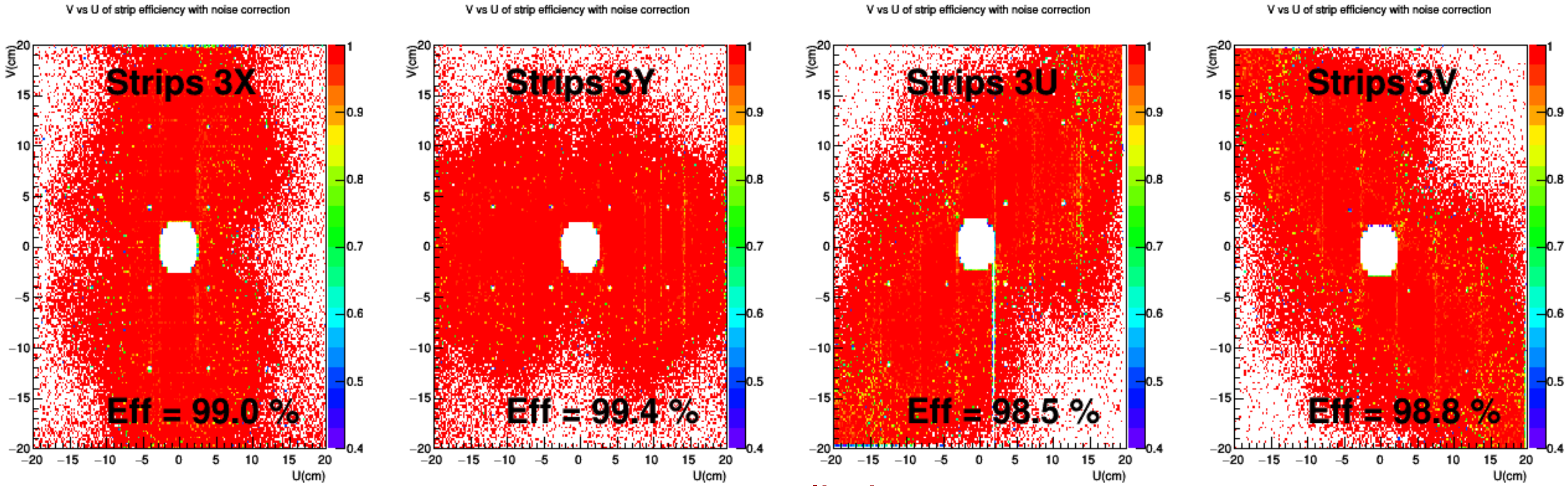
Very preliminary



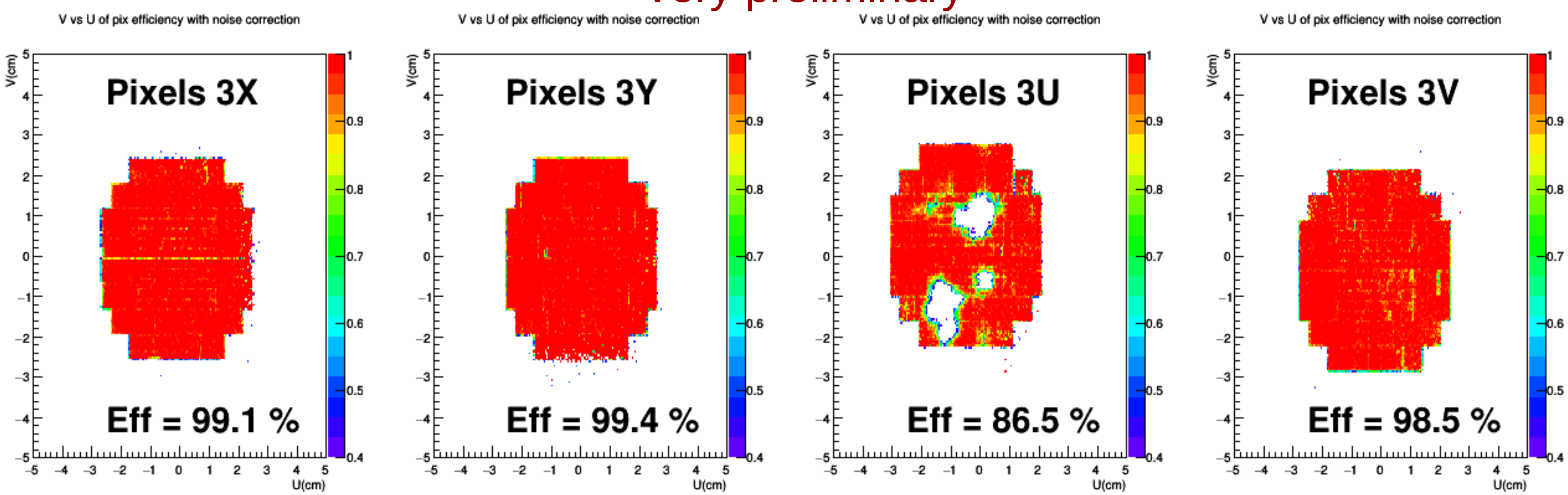
PixelMM efficiencies at low μ flux

All magnets on

Station 3

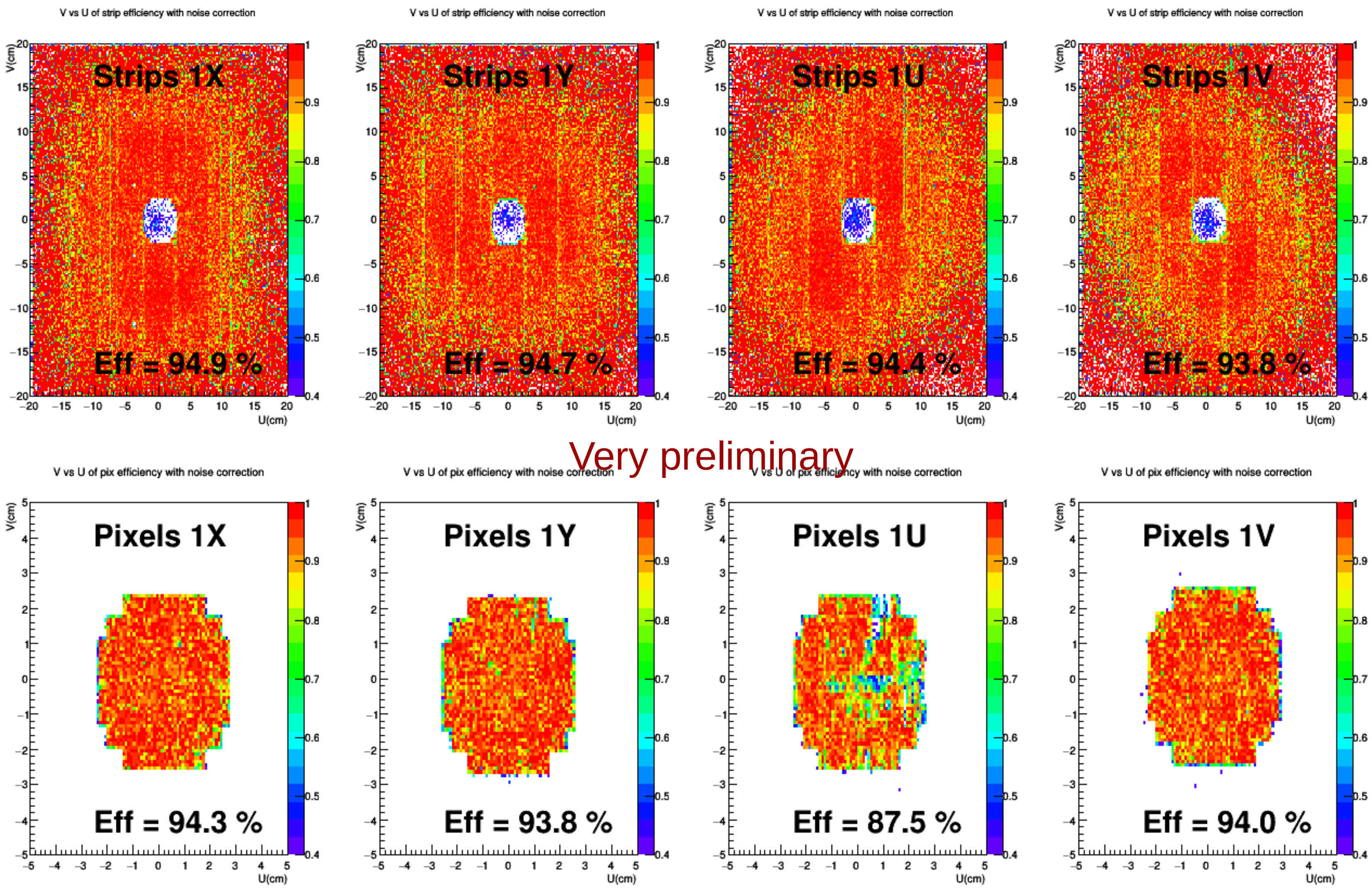


Very preliminary



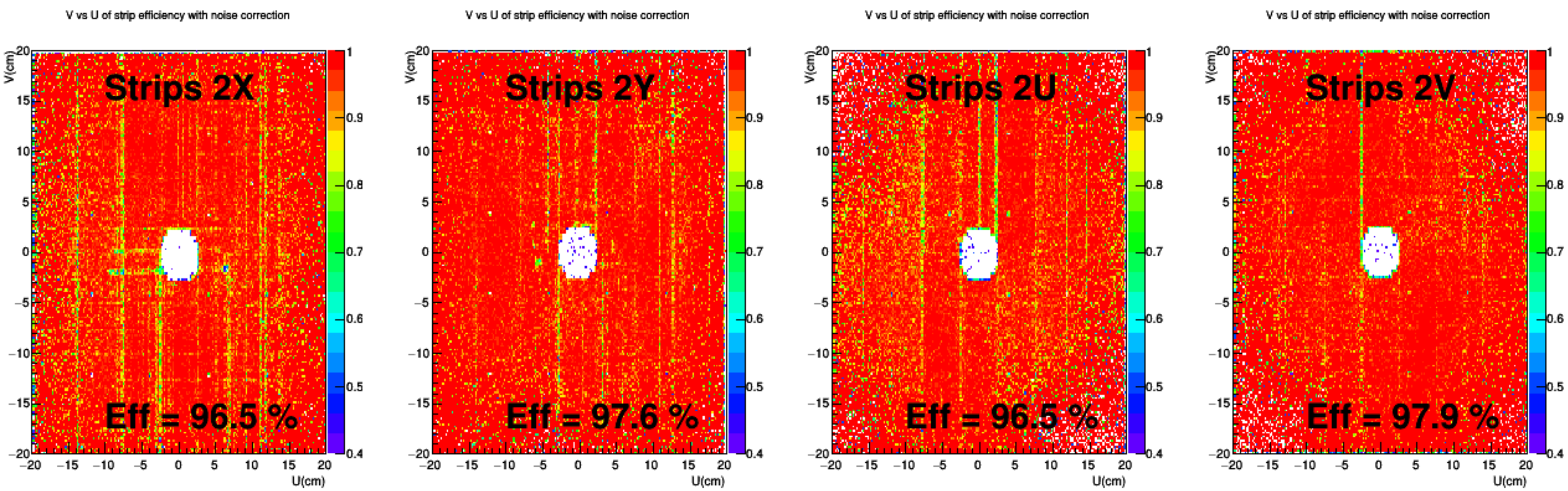
PixelMM efficiencies at high intensity hadron beam

Station 1

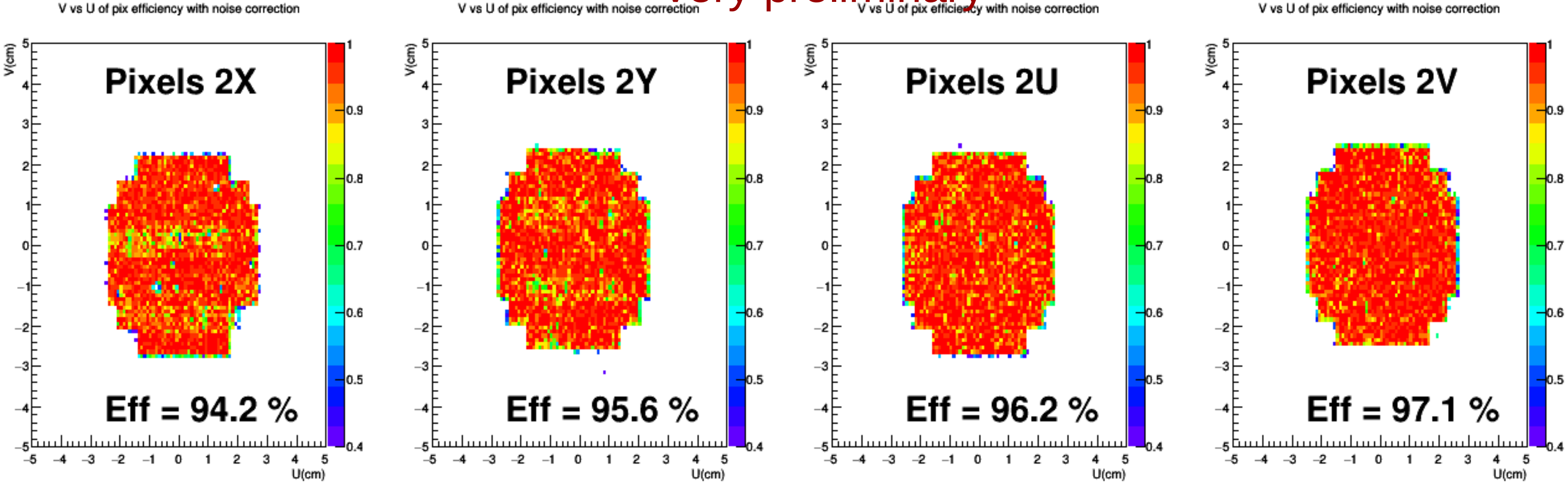


PixelMM efficiencies at high intensity hadron beam

Station 2

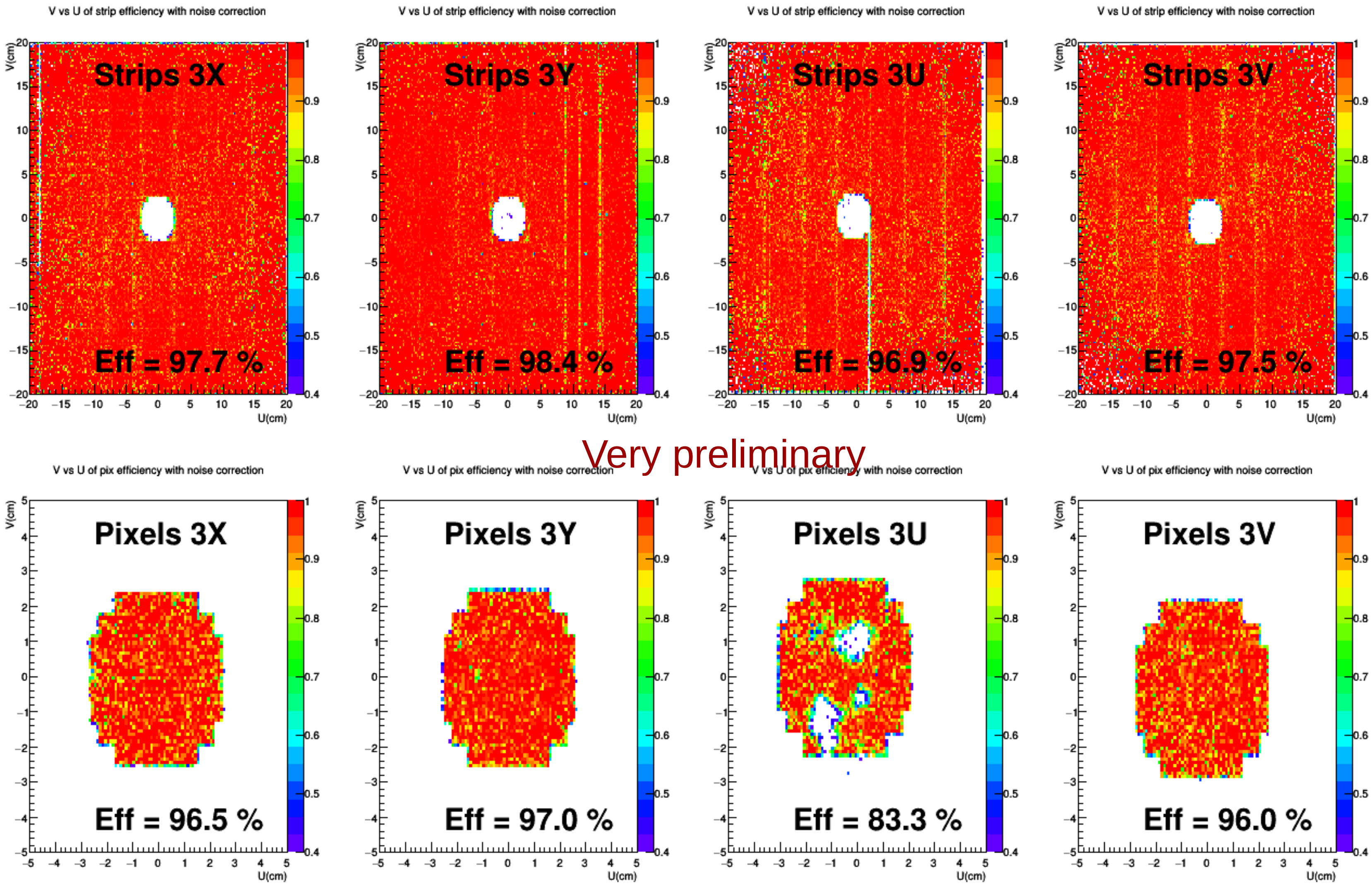


Very preliminary



PixelMM efficiencies at high intensity hadron beam

Station 3

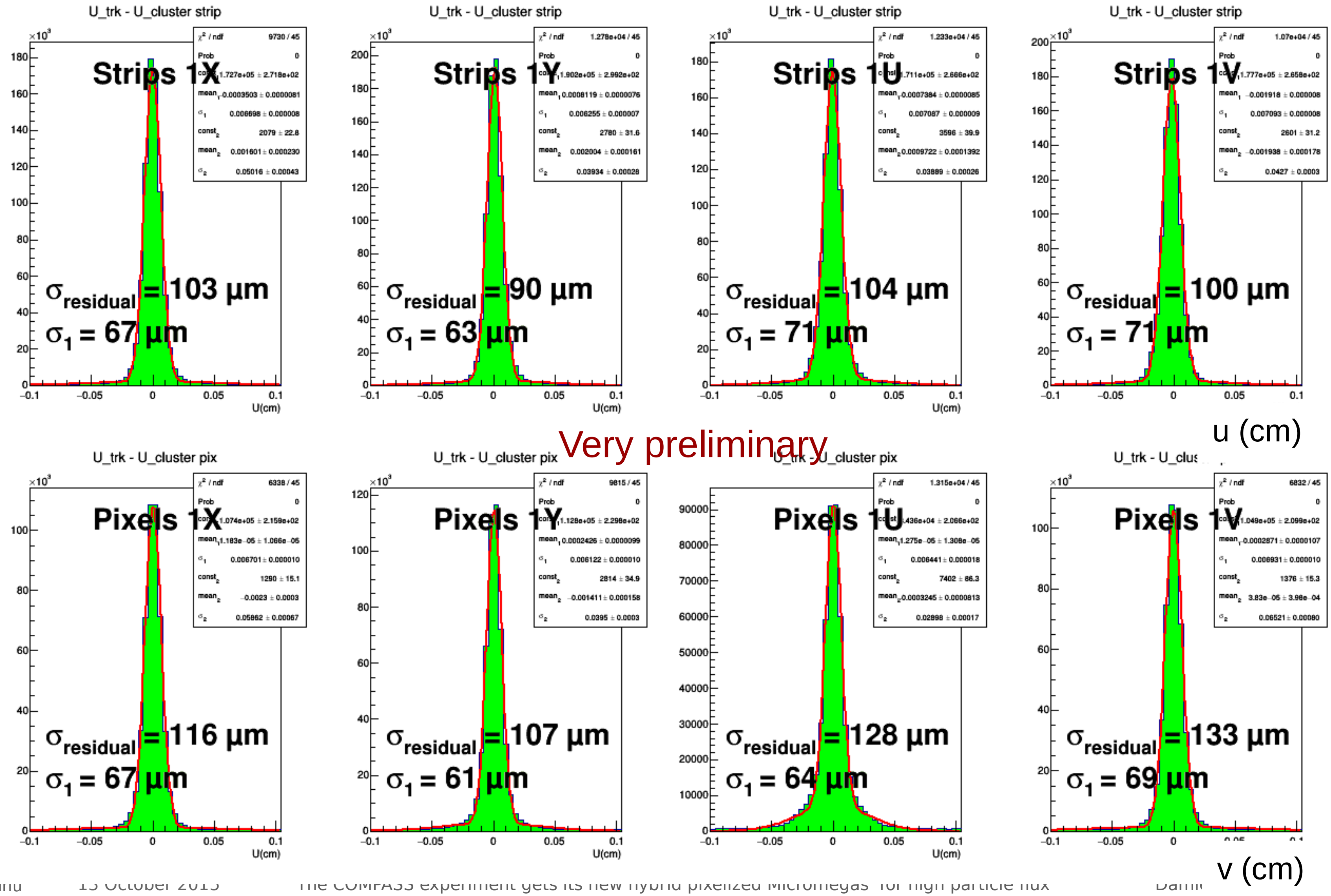


Very preliminary

Pixel MM spatial residuals at low μ flux

All magnets on

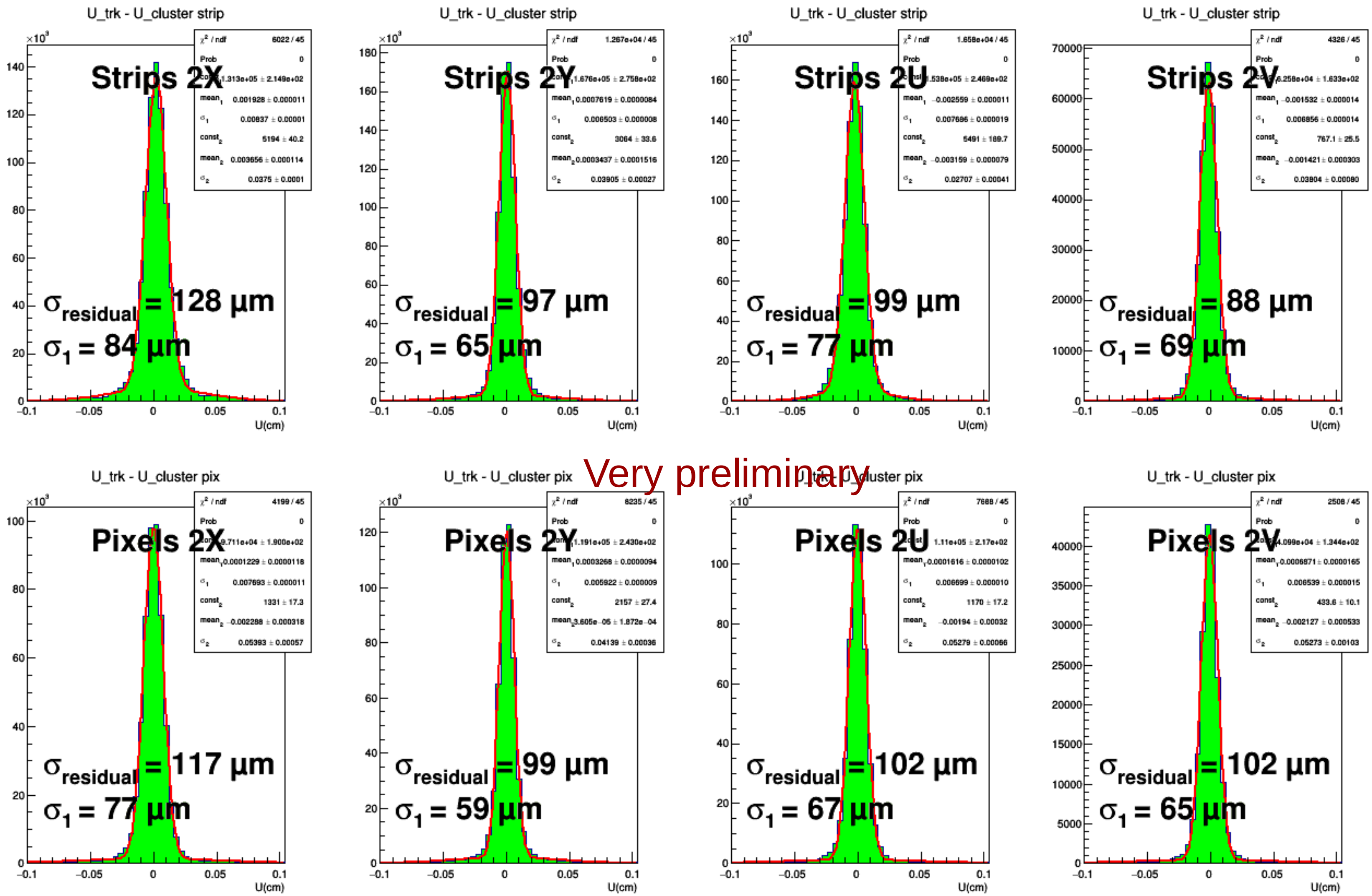
Station 1



Pixel MM spatial residuals at low μ flux

All magnets on

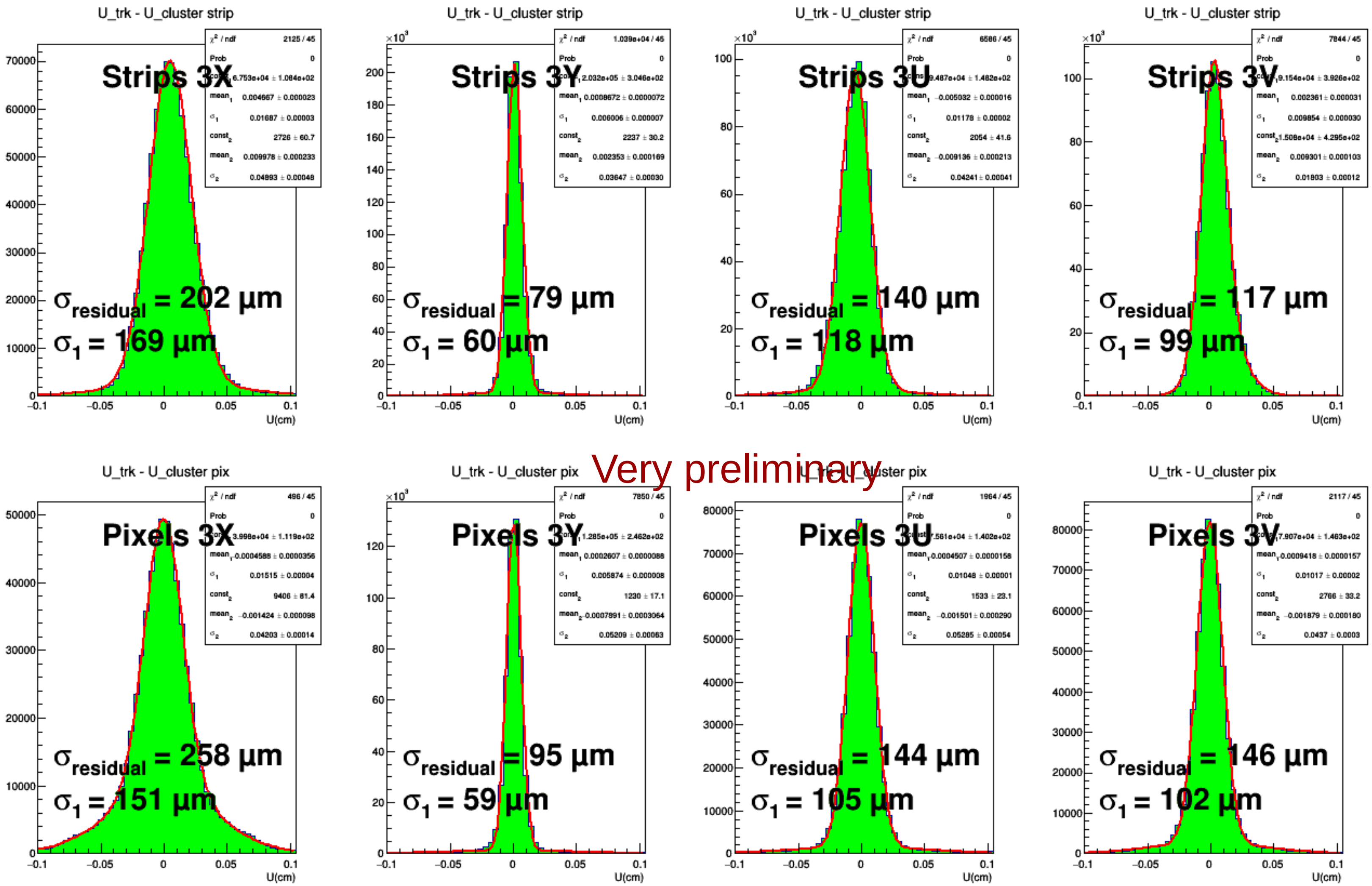
Station 2



Pixel MM spatial residuals at low μ flux

All magnets on

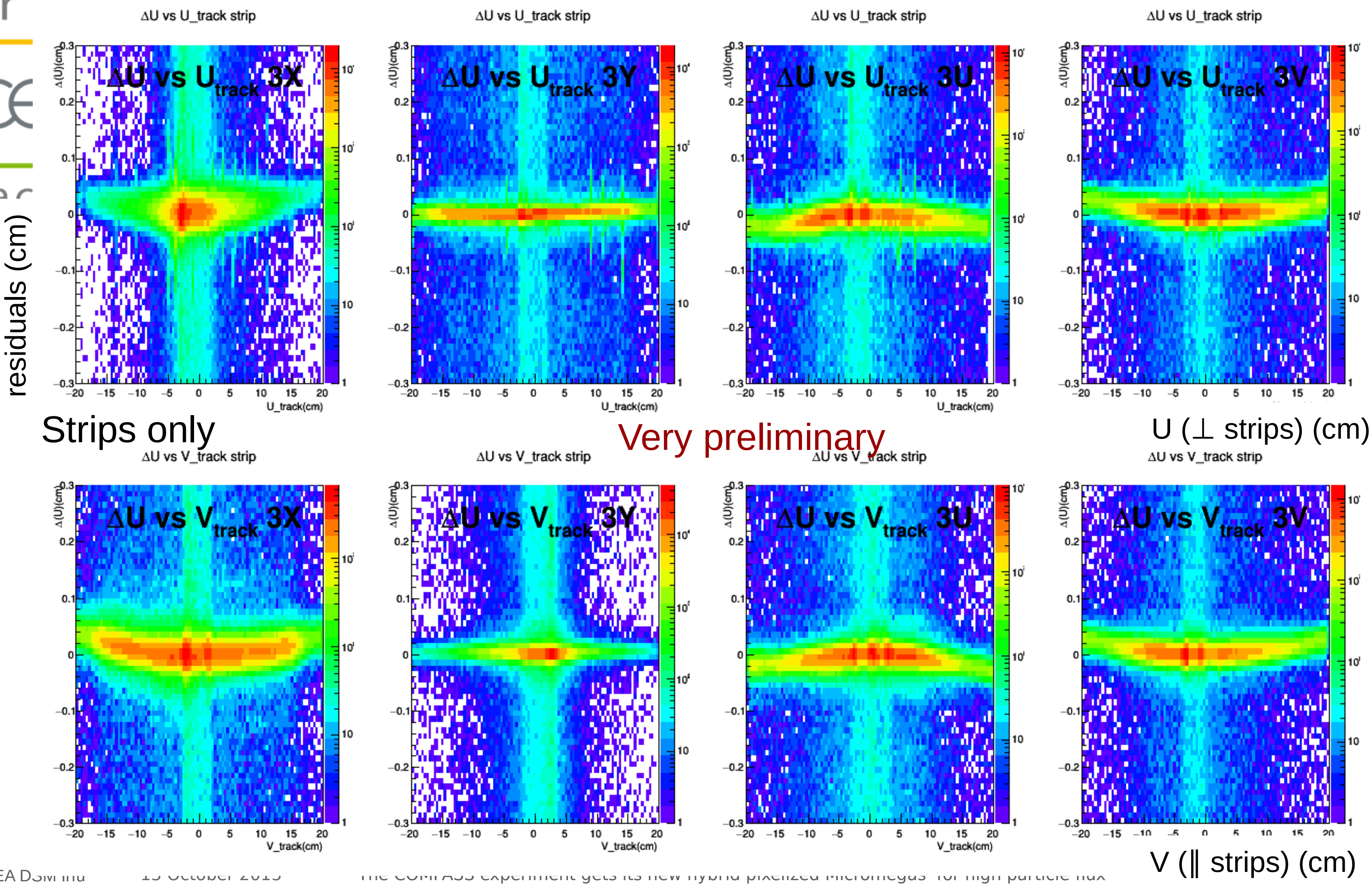
Station 3



PixelMM spatial residuals vs position at low μ flux

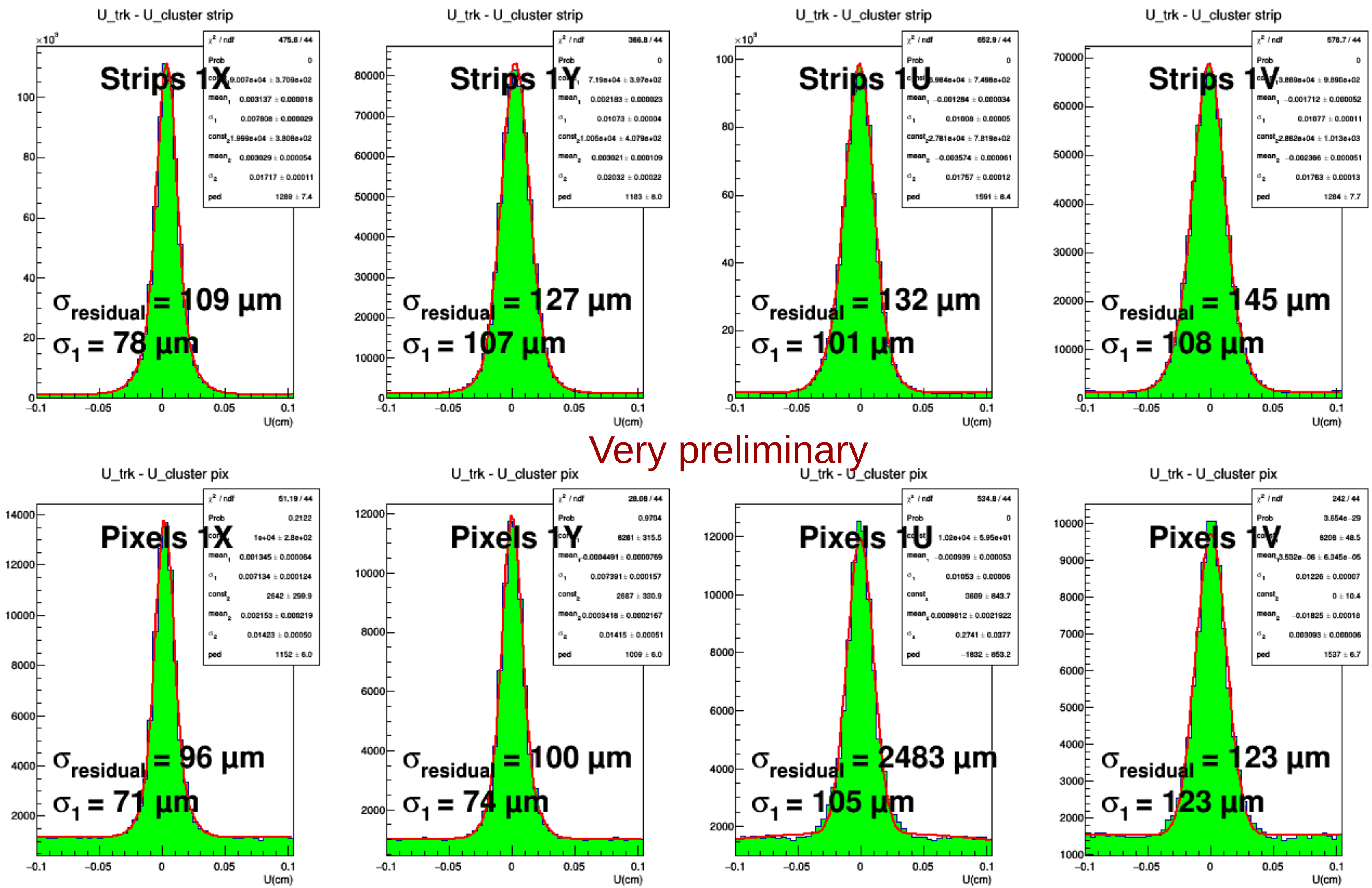
All magnets on

Station 3



Pixel MM spatial residuals at high hadron flux

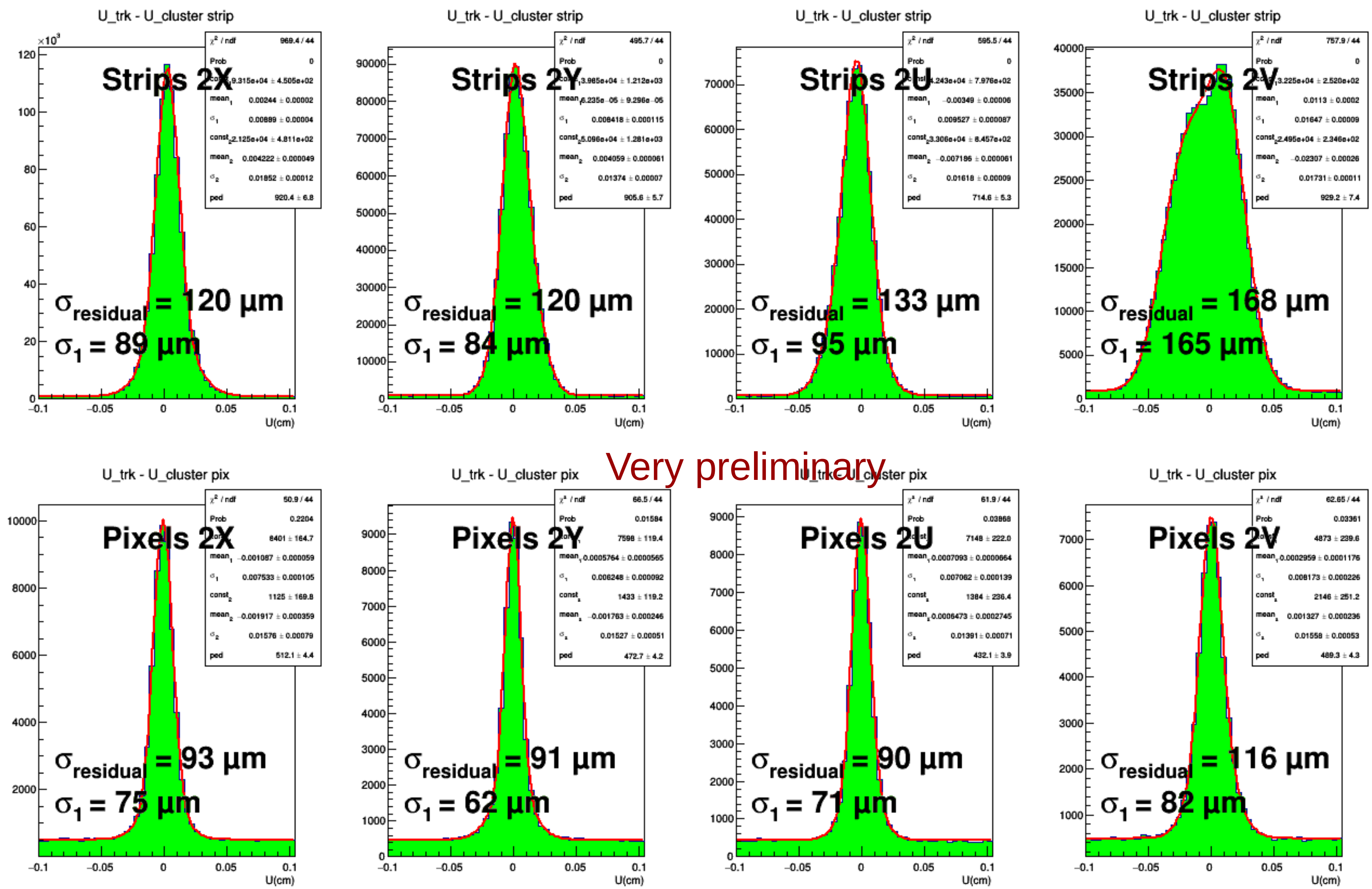
Station 1



Very preliminary

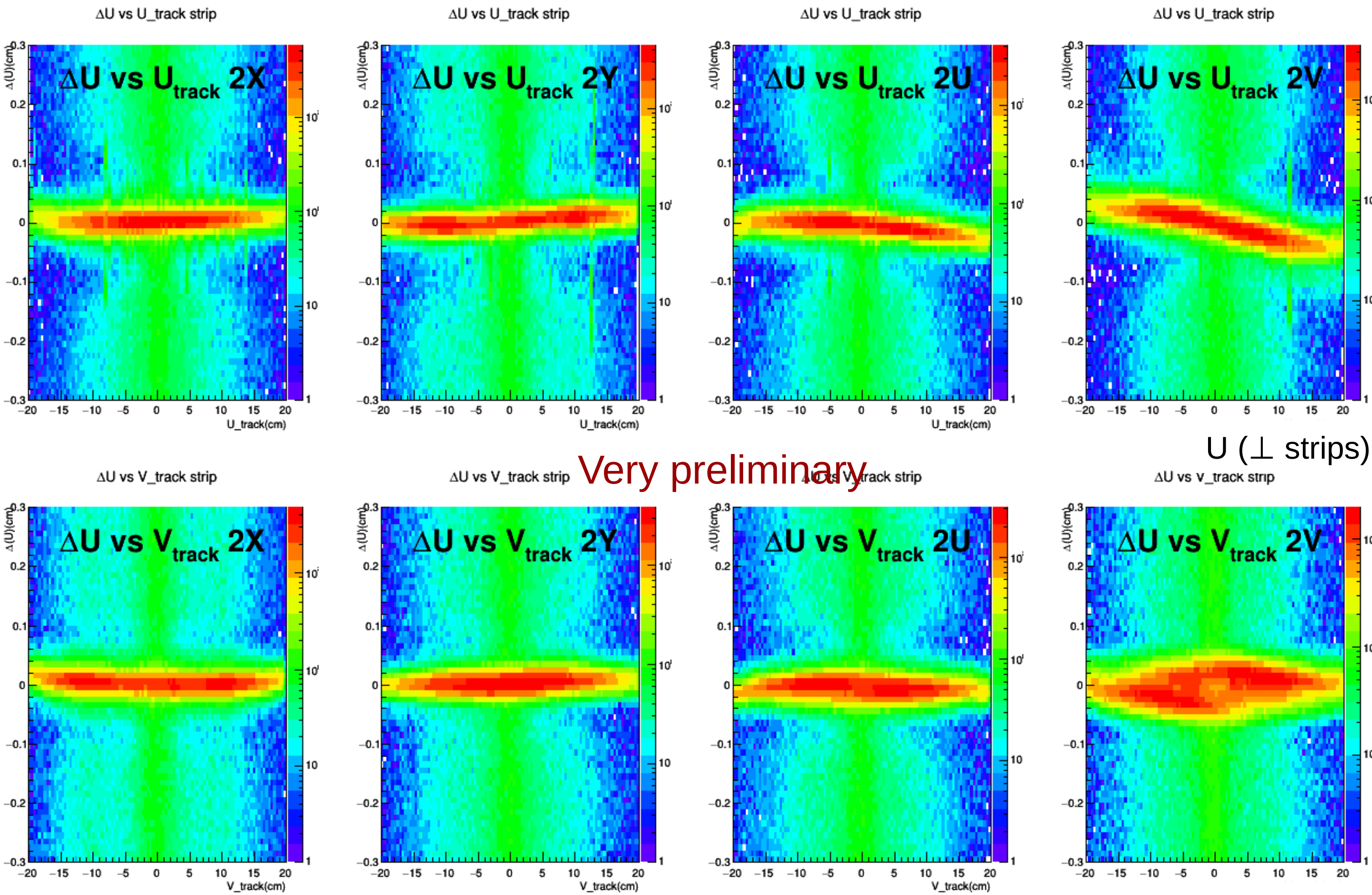
Pixel MM spatial residuals at high hadron flux

Station 2



PixelMM spatial residuals vs position at high hadron flux

Station 2



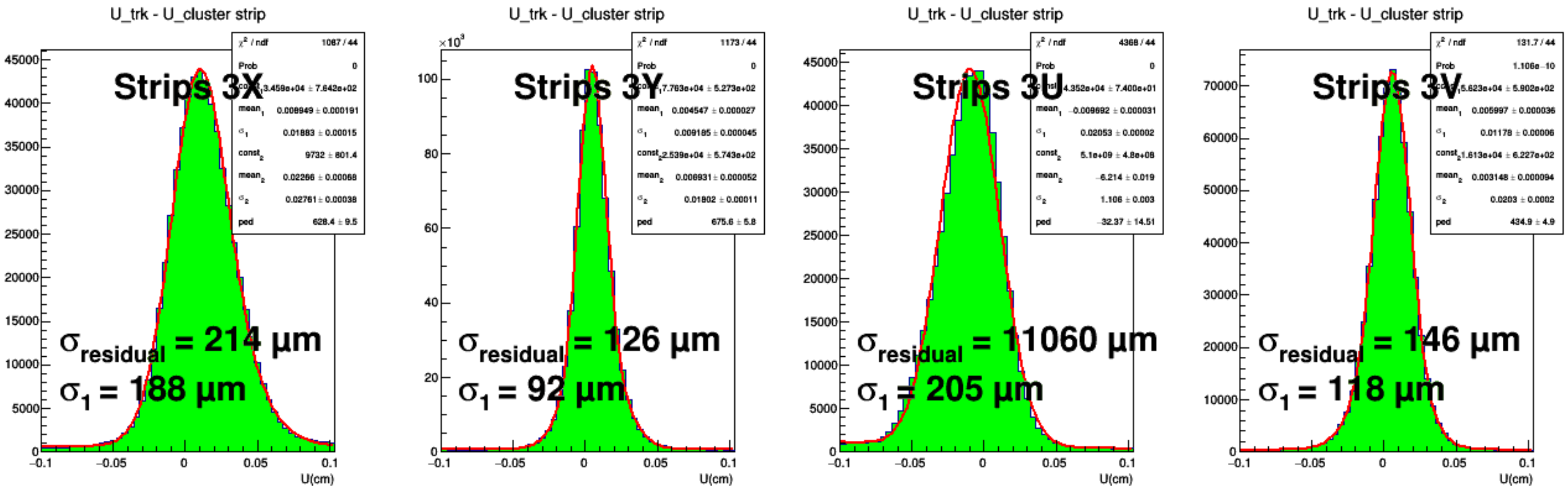
U (⊥ strips)

Very preliminary

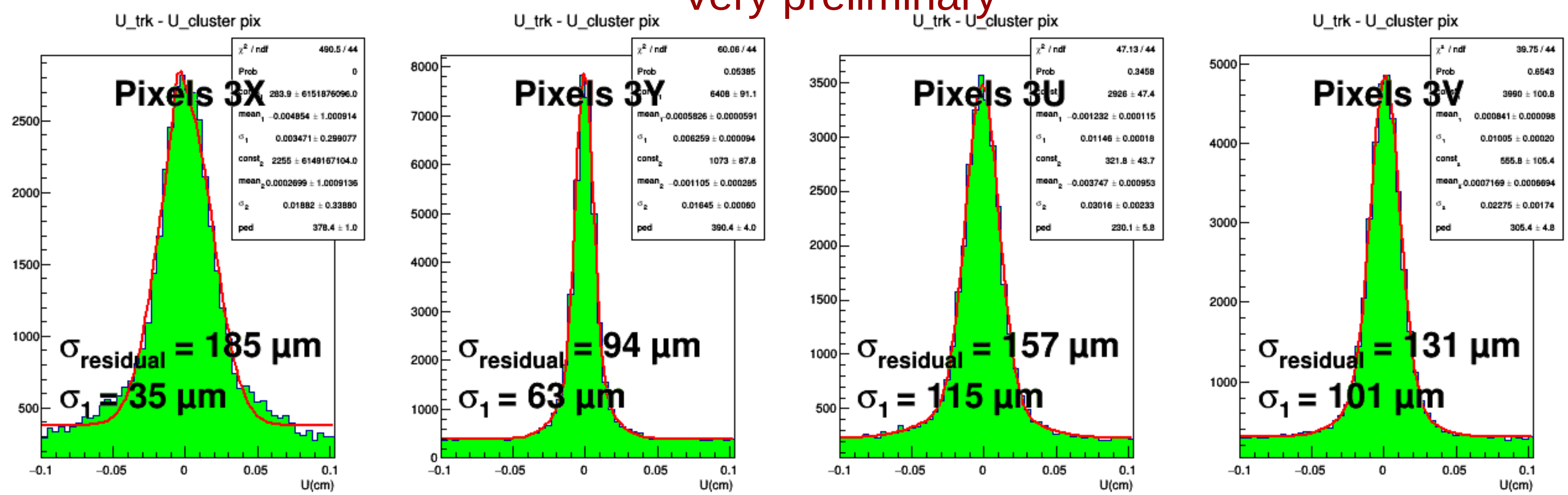
V (∥ strips)

Pixel MM spatial residuals at high hadron flux

Station 3

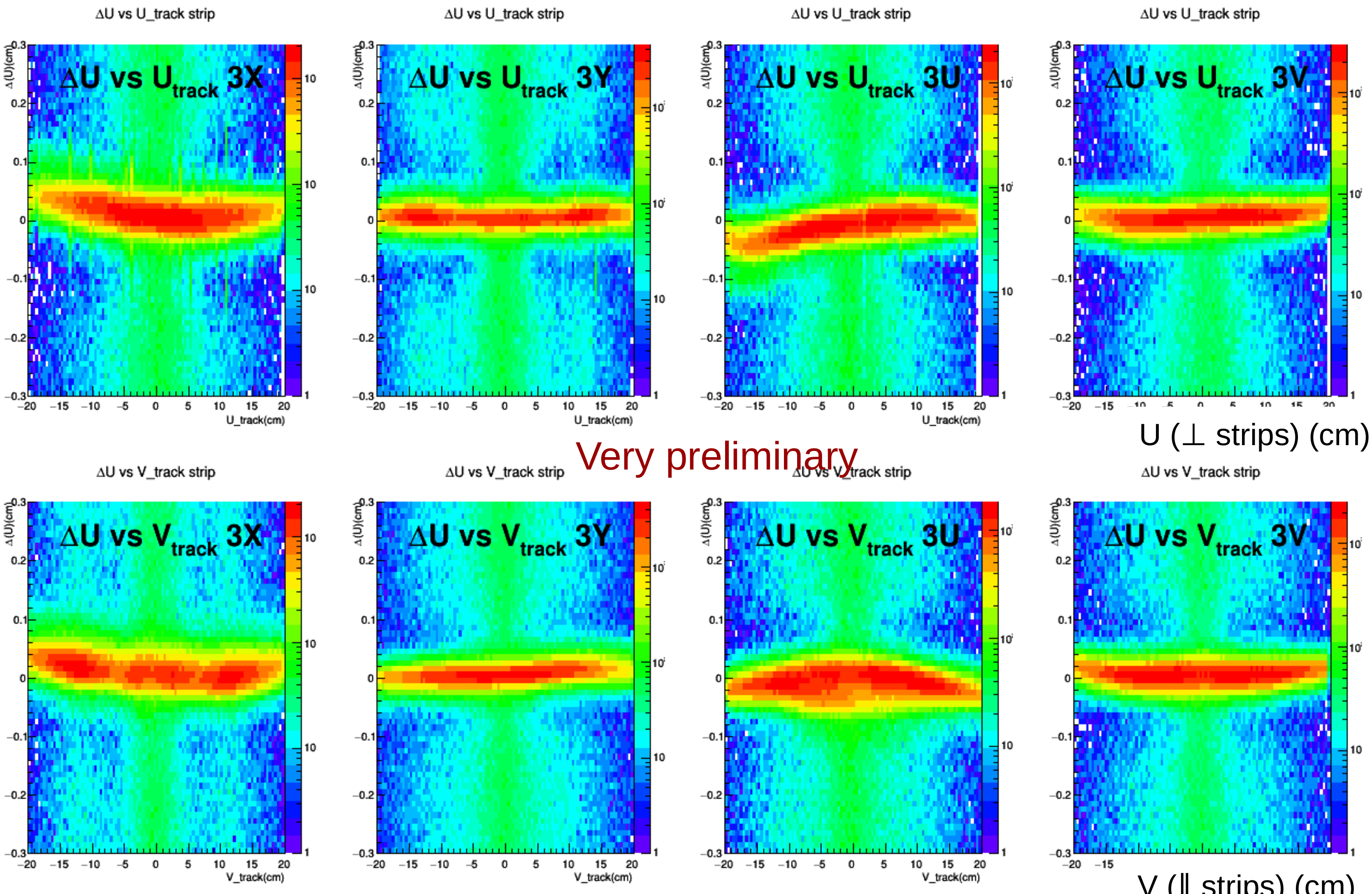


Very preliminary



PixelMM spatial residuals vs position at high hadron flux

Station 3



Conclusions

New COMPASS detectors installed and working

- *Good performances: efficiencies and spatial resolutions*
- *Preliminary results, further works to be done to complete them*
- *No result on time resolution yet for 2015 run, require more calibration work*

Hybrid Micromegas+GEM detectors proven to be very promising concept

- *Discharge rate strongly decreased at high intensity hadron beam, without efficiency loss*
- *Performance as good as or better than old classic Micromegas*

Buried resistor MM boards promising but further studies required

- *Complicated structure, R&D necessary for serial production of such boards*
- *Good efficiency and spatial resolution, but bad time resolution, origin not understood*