GEM Detectors for SoLID

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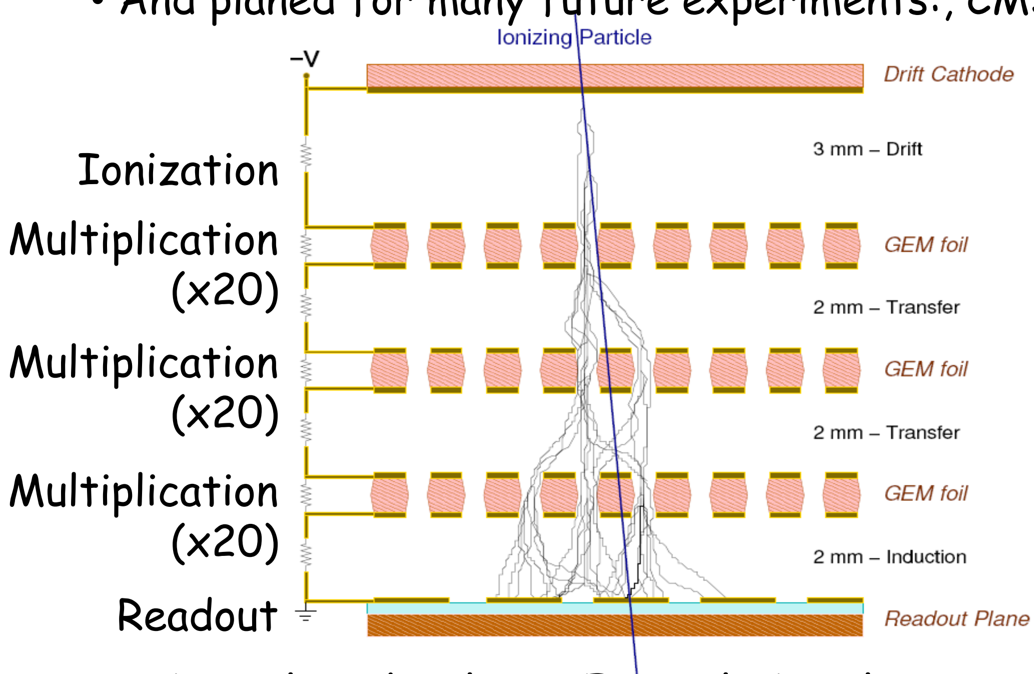
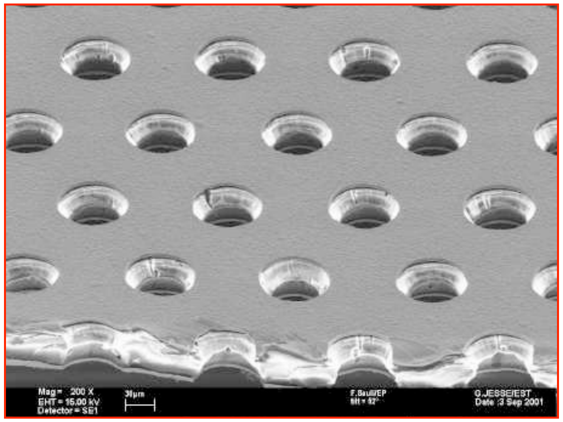
Why GEMs ?

- SoLID concept leads to high rate in trackers: and requires good resolution.
- Gas Electron Multiplier (GEM) detectors provide a cost effective solution for high resolution tracking under high rates over large areas.

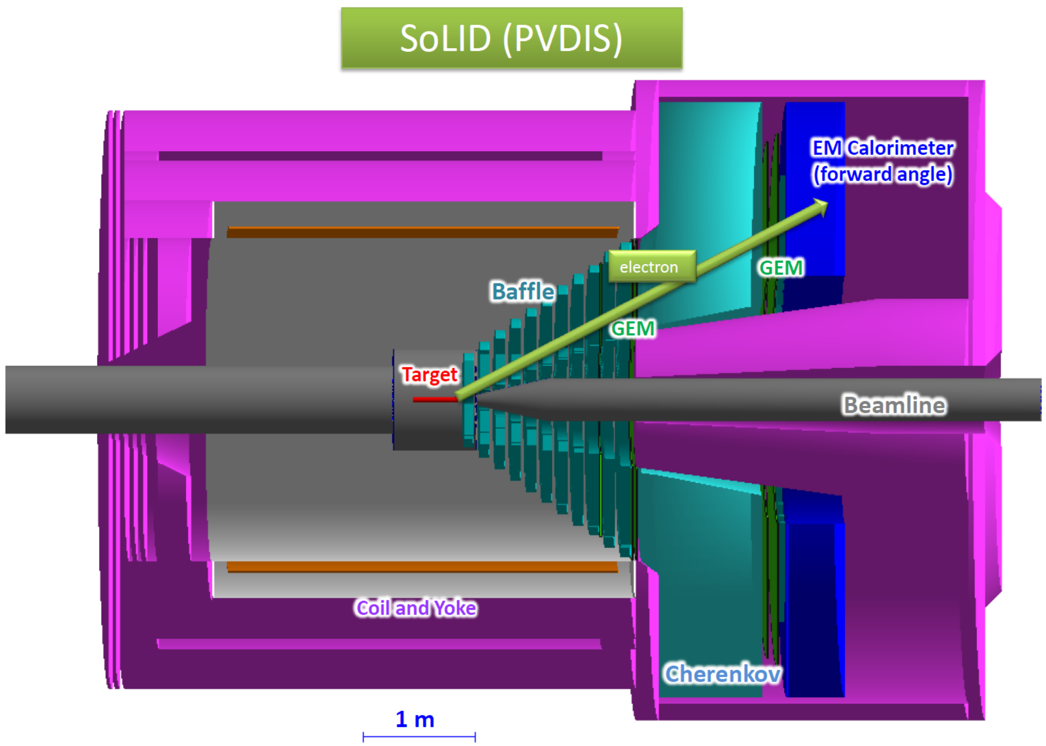
- Rate capabilities higher than many MHz/cm^2
- High position resolution (< 75 μm)
- Ability to cover very large areas (10s – 100s of m^2) at modest cost.
- Low thickness (~ 0.5% radiation length)
- Already Used for many experiments around the world: COMPASS, Bonus, KLOE, TOTEM, STAR FGT, ALICE TPC, pRad etc.
- And planed for many future experiments:, CMS upgrade, SoLID, Moller, P2 @ Mainz

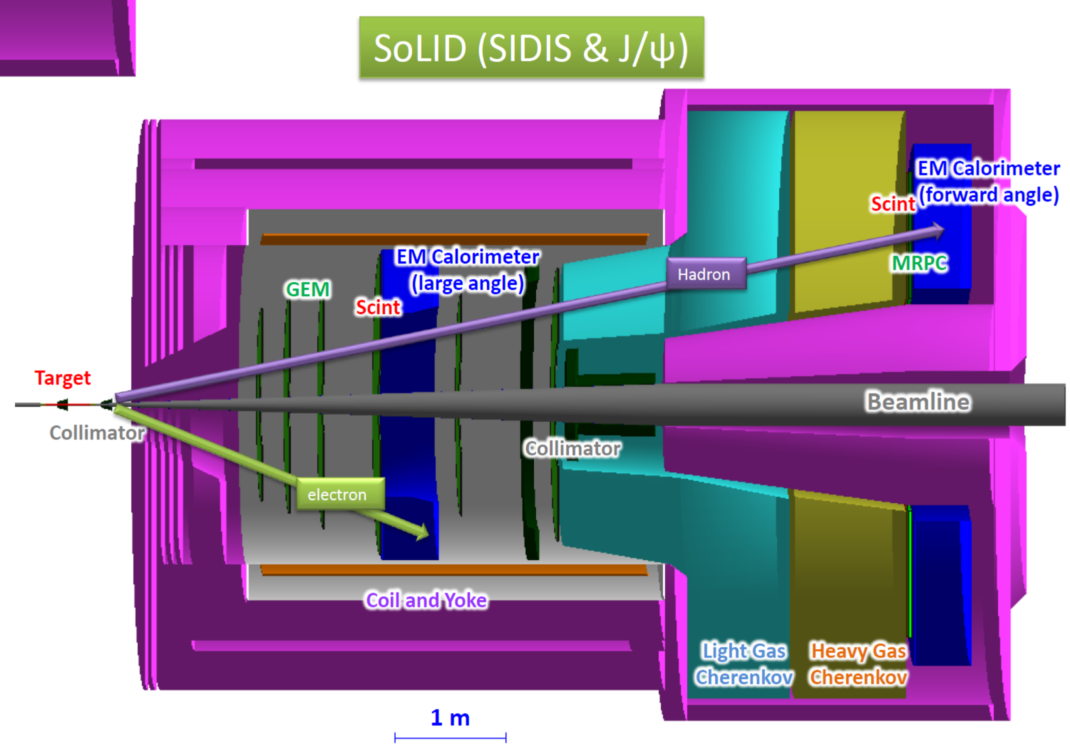


GEM foil: 50 μm Kapton + few μm copper on both sides with 70 μm holes, 140 μm pitch

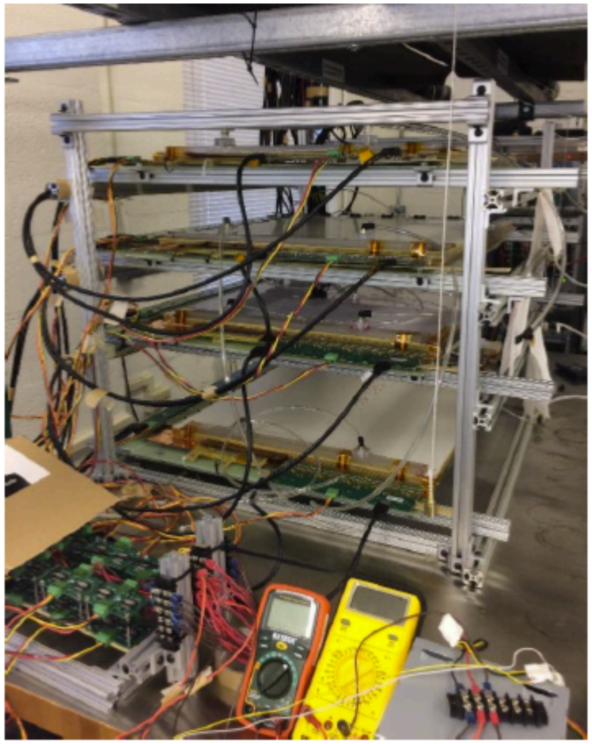


Novel technology: F. Sauli, Nucl. Instrum. Methods A386(1997)531


SoLID (PVDIS)
EM Calorimeter
(forward angle)
electron
GEM
Baffle
GEM
Target
Beamline
Coil and Yoke
Cherenkov
1 m


SoLID (SIDIS & J/ψ)
EM Calorimeter
(forward angle)
Scint
MRPC
Hadron
EM Calorimeter
(large angle)
GEM
Scint
Target
Collimator
Beamline
Collimator
electron
Coil and Yoke
Light Gas
Cherenkov
Heavy Gas
Cherenkov
1 m

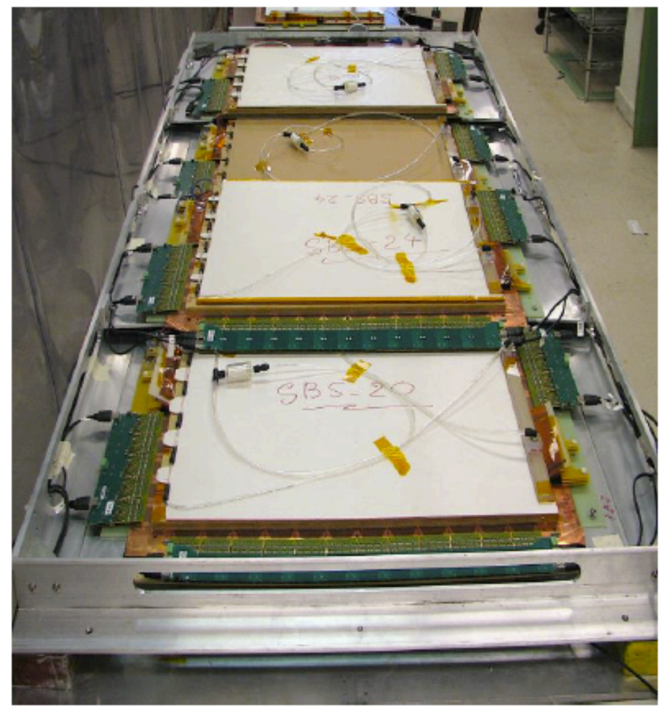
SBS Back Tracker module Production: almost complete



Production status

- 42 modules built and tested so far
  - ⇨ 40 modules 100% operational
  - ⇨ 2 modules have one bad sector ⇨ (97% active area operational)
  - ⇨ **Six spare modules in the queue for assembly, Expected by Aug 2017**
- UVa Comic stand with full MPD electronics for 4 modules
  - ⇨ Use to test newly built modules
  - ⇨ Additional test of the modules before shipment to JLab to define working HV
- Prototype of mounting frame for BT GEM layers assembled and tested

[H. Nguyen's Talk @ MPGD2017: https://indico.cern.ch/event/581417/contributions/2556718/attachments/1464747/2263931/HuongNguyen_MPGD2017.pdf](https://indico.cern.ch/event/581417/contributions/2556718/attachments/1464747/2263931/HuongNguyen_MPGD2017.pdf)



Migration of UVa modules to JLab

- 5 modules currently at JLab since 2016
  - ⇨ Danning's high rate tests in Hall A
  - ⇨ Probably for another high rate test team this fall in Hall C for
- Planning to move 4 more modules in June 2017
  - ⇨ Test the chamber on the cosmic stand in June-July
- Migration of all modules to JLab will start August 2017
  - ⇨ Modules will stored at in the GEM clean room space

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Lessons Learned for large Production

- Need a period of ~ 1-2 years for R & D
- Build several pre-production modules, test under realistic conditions and apply needed modifications to the design.
- Foil QA at every step extremely important
- Once the production line established, can do 1 module every 2 weeks; could be faster with more resources.

Next Steps for SBS GEMs (with direct befit to SoLID)

- Data volumes at high rates a serious issue due to bandwidth limitations.
- Must implement hardware level data reduction.
  - common mode correction
  - pedestal subtraction
  - zero suppression
  - filter out background not correlated with trigger time.
- Getting major help from electronics group to implement these at the SSP level
- Will be solved by the time SoLID need it.
- Plus, more powerful hardware becoming available (VTP etc.)

PVDIS GEM configuration

- Instrument five locations with GEMs:
- each module with a 12-degree angular width: need 1-2 cm for frame width: active angular width of a module limited to ~ 10-degrees.

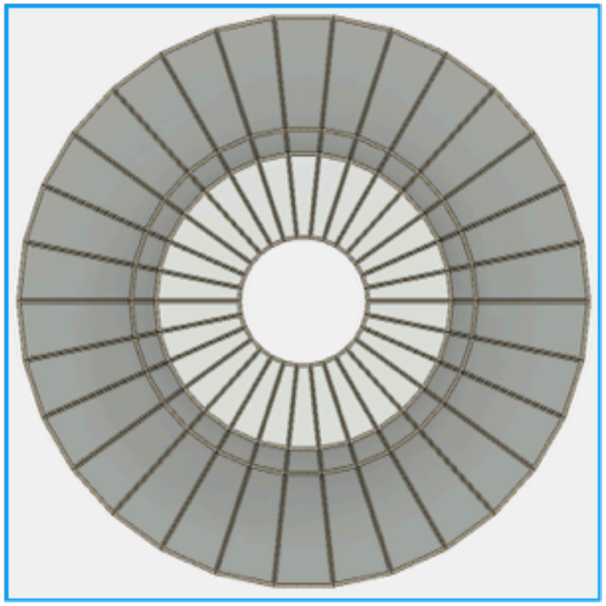
GEM Layer	Z(cm)	Rmin(cm)	Rmax(cm)	# Chan (.04/.06)	# Chan (.04/.04)
5	315	115	228	39773	59660
4	306	111	221	38552	57828
3	190	65	140	36633	36633
2	185.5	62	136	35587	35587
1	157.5	51	118	30877	30877
	Total			181422	220585

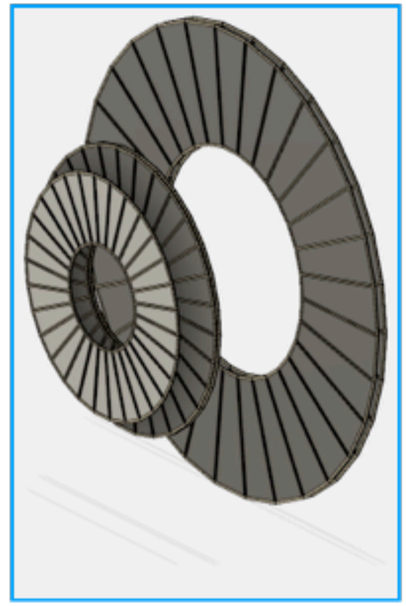
- are these outer radii reasonable ? (need room for rails, electronics etc.)
- New rail configuration looks much better
- Re-locating electronics with flex cct. adapters will help
- Will work with Whit Seay to fit come up with realistic active sizes

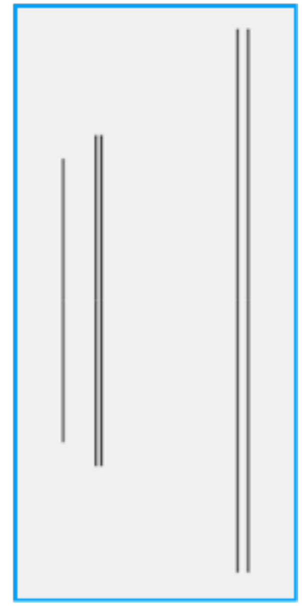
Starting on the CAD model of SoLID GEM modules

- Work by John Matter at UVa:

ombined



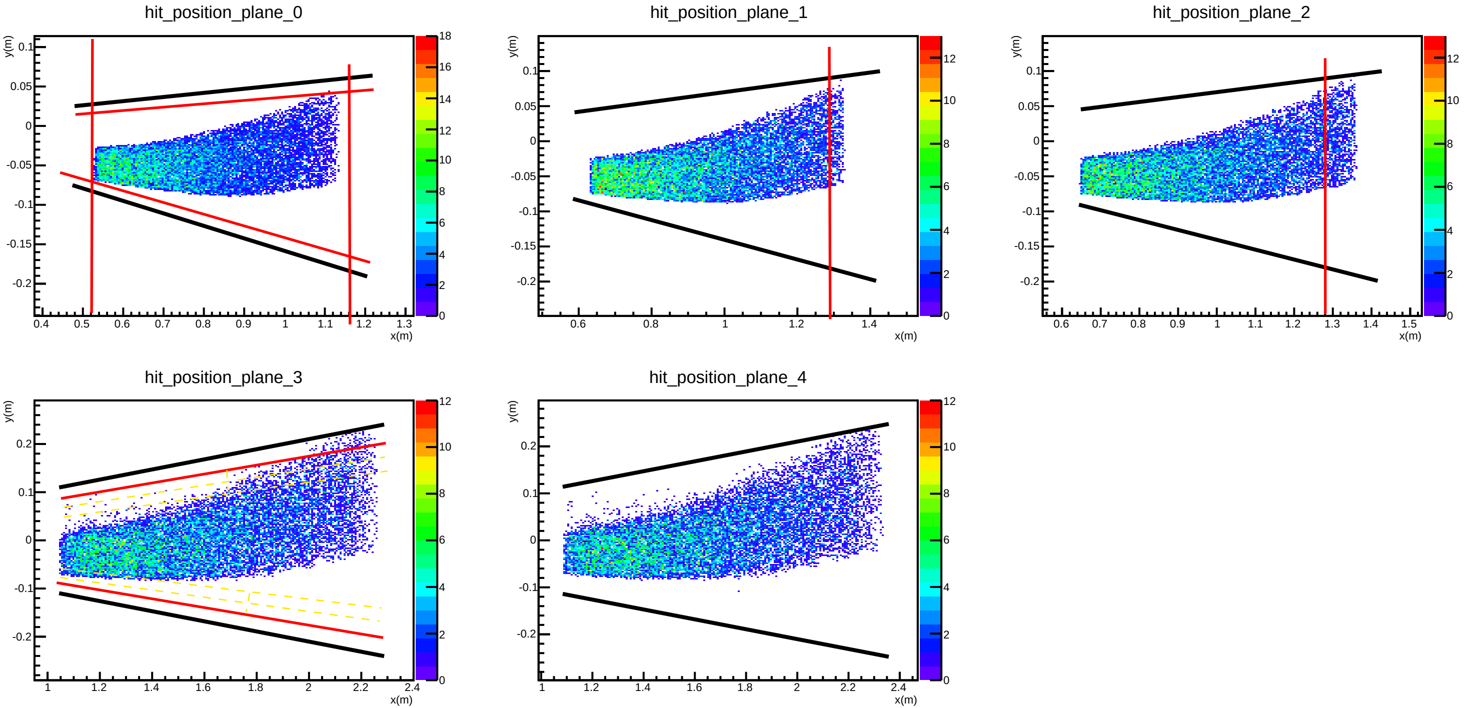




- Next steps: adding electronics, cables, gas lines
- Coordinate with Whit for installation in SoLID.

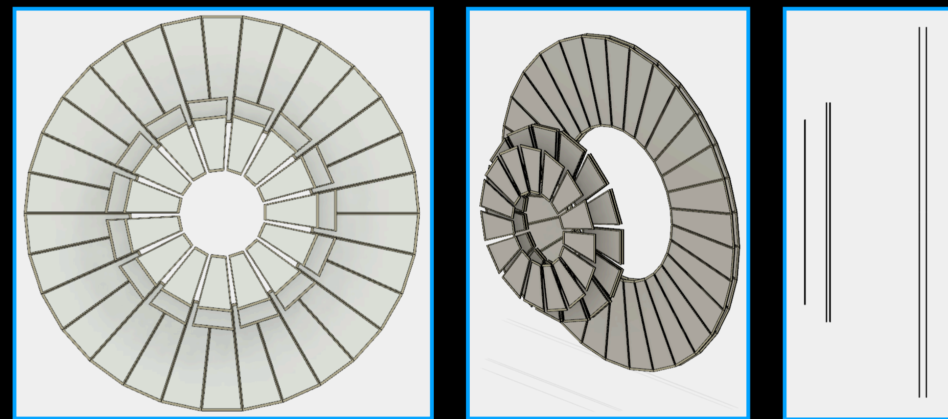
Challenges for SoLID GEM production

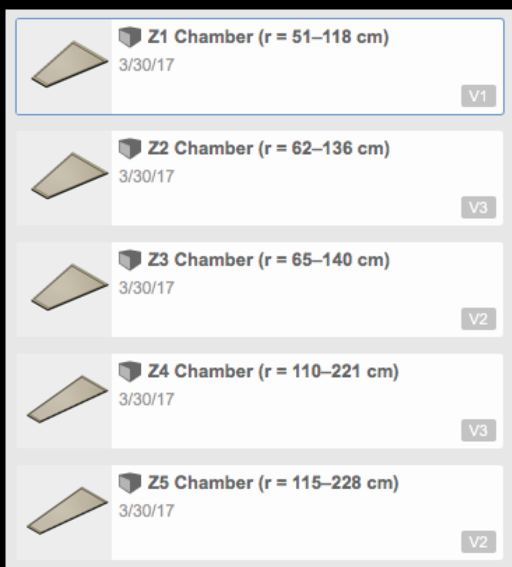
- ✓ Technology for Large area GEM foils > 1 m long.
- ✓ Establishing techniques for large area module construction
- Establishing large area GEM foil production in China
- Coordinated parallel production in multiple locations
- Untested R&D issues needing more work:
  - Segmented readout strip layers
  - High density readout at the outer radius
  - Relocation of readout cards away from the module edge.
  - …………..
- Effect of module edges in the active area of SIDIS ??
  - Combining modules: 2 - > 1 difficult.

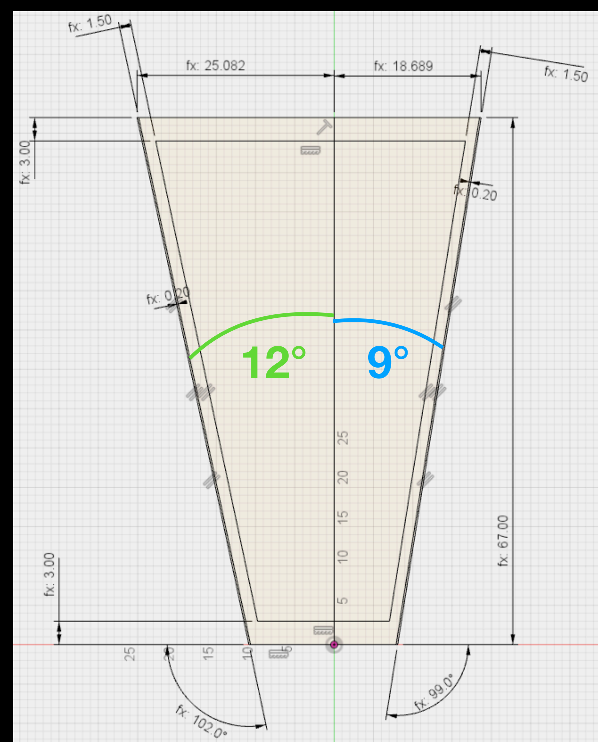

hit_position_plane_0
hit_position_plane_1
hit_position_plane_2
hit_position_plane_3
hit_position_plane_4
y(m)
x(m)

SoLID PVDIS (20170629)

Location	Z (cm)	R_{min} (cm)	R_{max} (cm)	Surface (m^2)	# chan
1	157.5	51	118	3.6	24 k
2	185.5	62	136	4.6	30 k
3	190	65	140	4.8	36 k
4	306	111	221	11.5	35 k
5	315	115	228	12.2	38 k
Total				≈ 36.6	≈ 164 k







R_{max}

Values in table currently define edge of frame, not active area

R_{min}

Angles on left/right are adjustable, of course

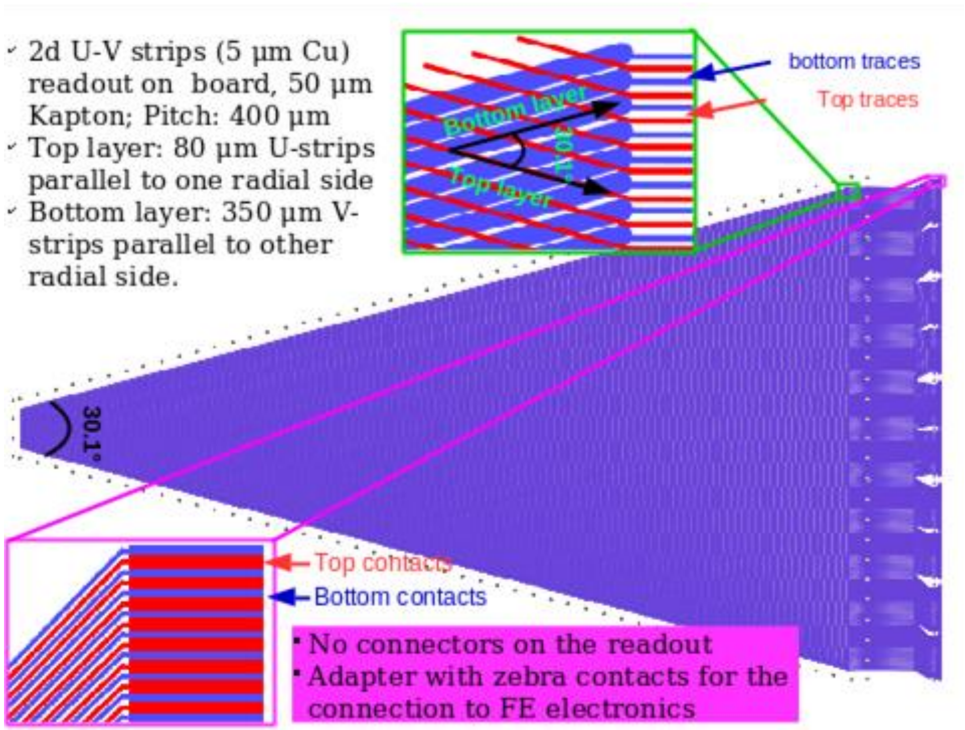
Ongoing work supported by EIC R&D etc.

Common GEM foil design:

✓ (Univ. of Virginia, Florida Tech, and Temple U.)

✓ All connections (HV, gas flow structure and FE cards) are made on outer radius end.

✓ We received 4 common GEM foils from CERN



2D U-V strips readout (R/O)

✓ Spatial resolution improvement

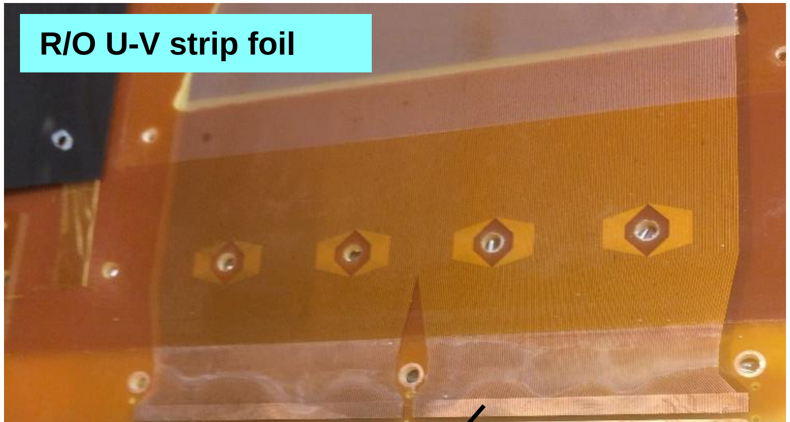
✓ No electronics on active area of the chamber

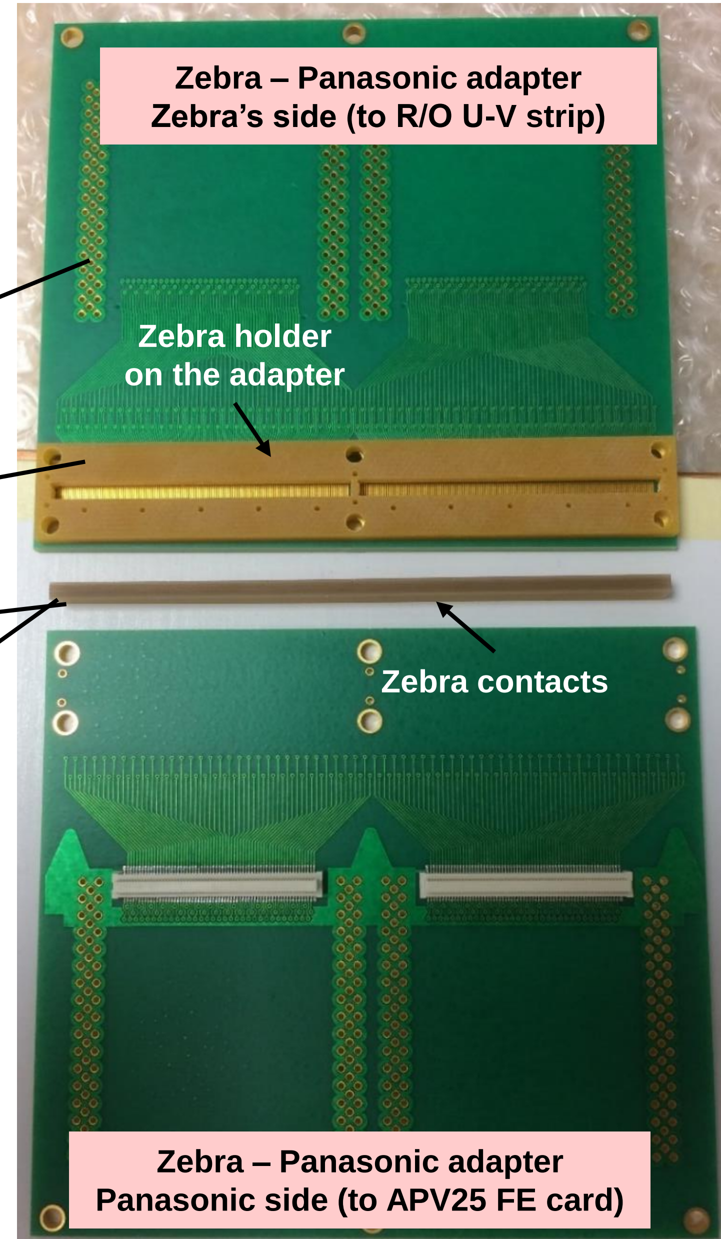
✓ No connectors or metallized vias on R/O

✓ Zebra connection for the FE electronics

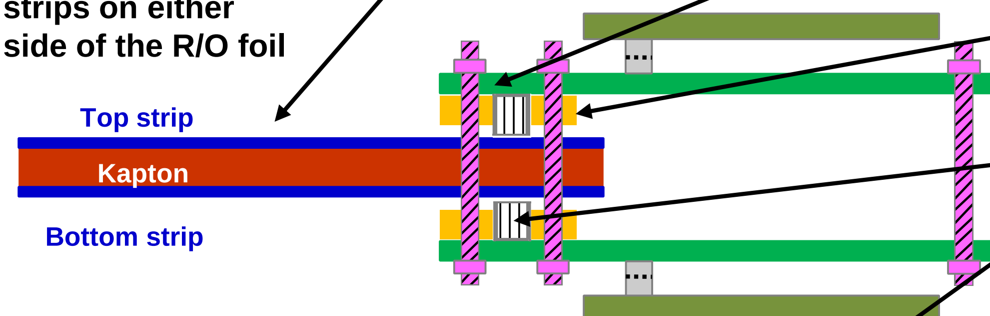
✓ Zebra-Panasonic adapter board

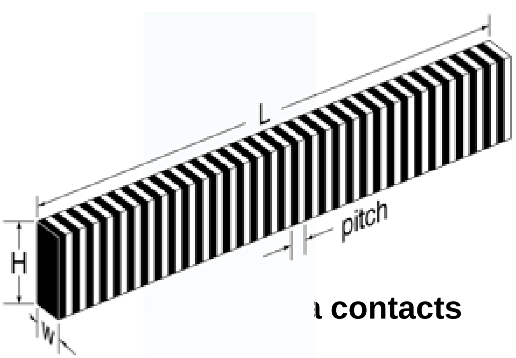
Zebra Connection for EIC-FT GEM Readout

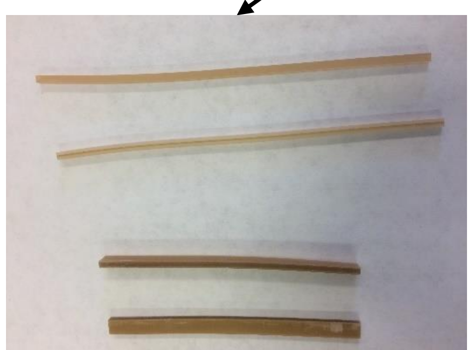




Contact of U and V strips on either side of the R/O foil

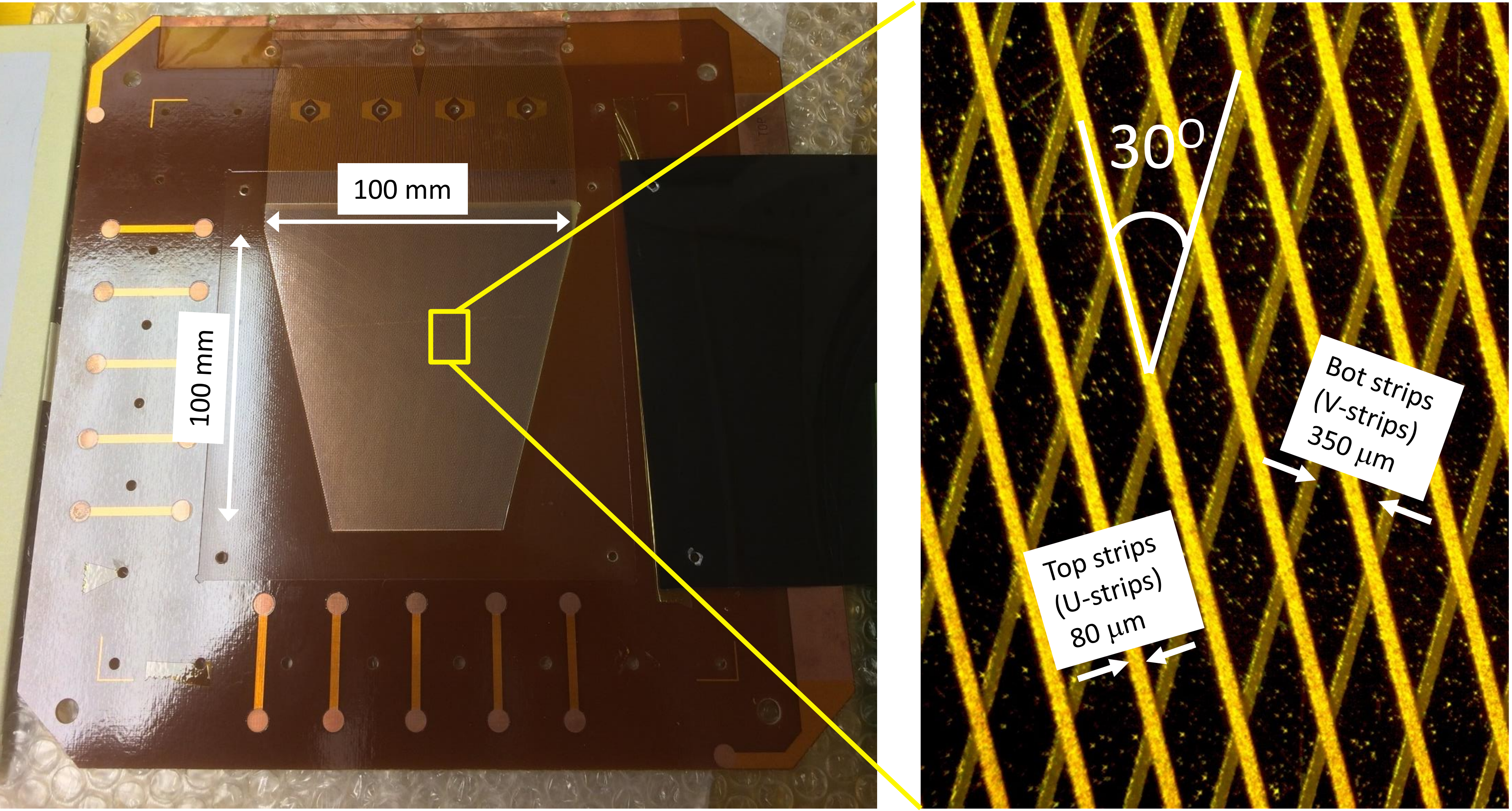






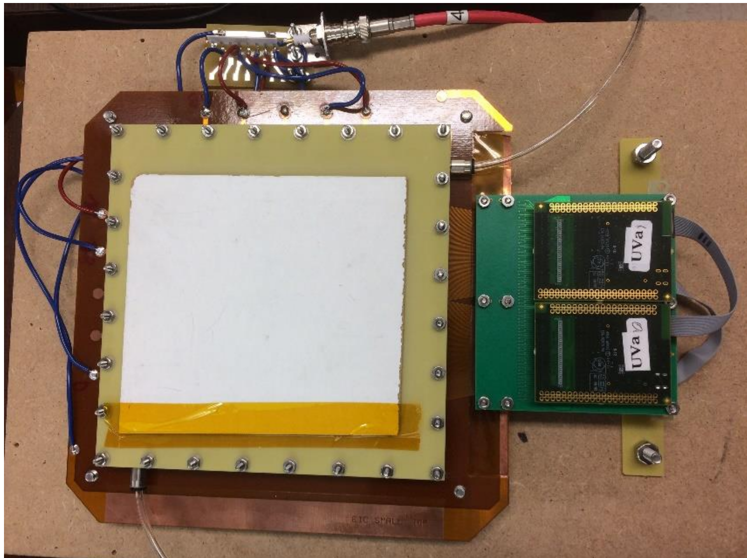
Small 2D U-V strips readout prototype

- 10 cm x 10 cm triple GEM,
- 2D flexible readout a la COMPASS with U-V strips,
- **double side zebra contact**

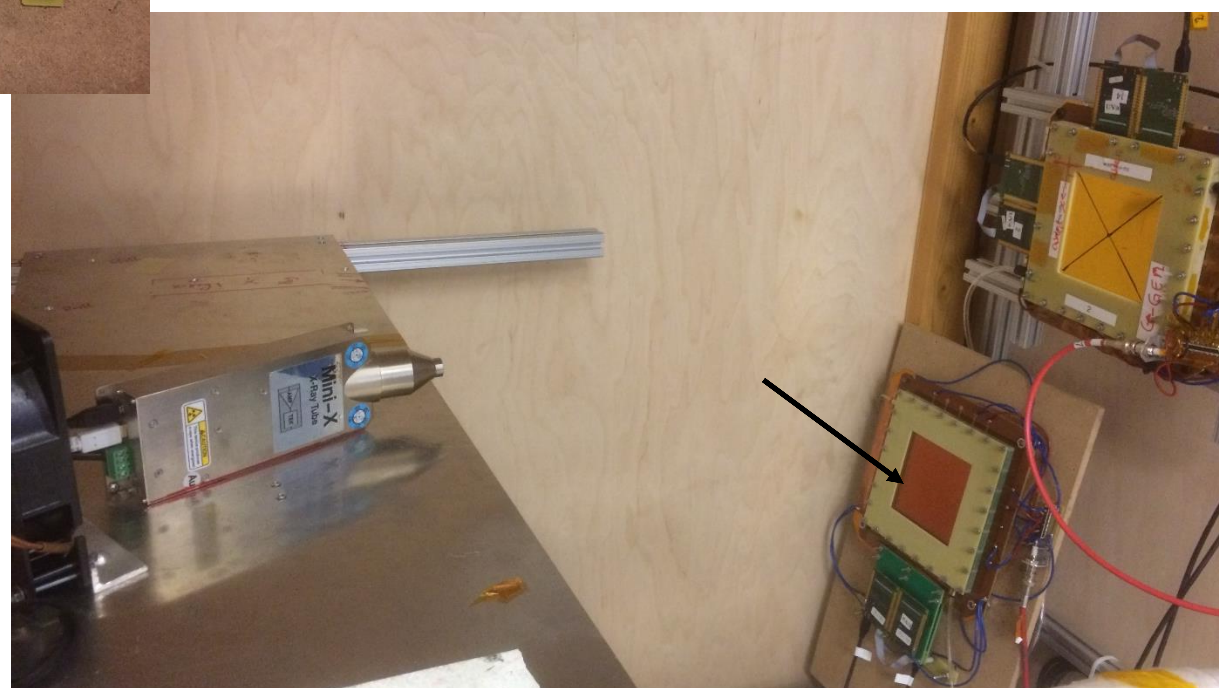


Characterization of U-V readout GEM proto with X-ray and Cosmic

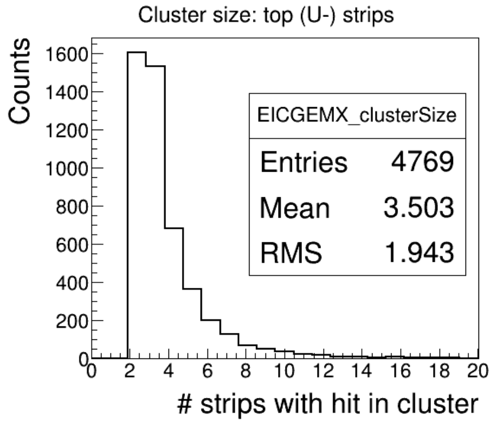
Cosmic



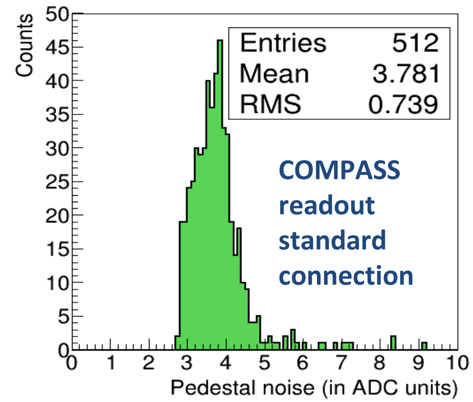
X-Ray box

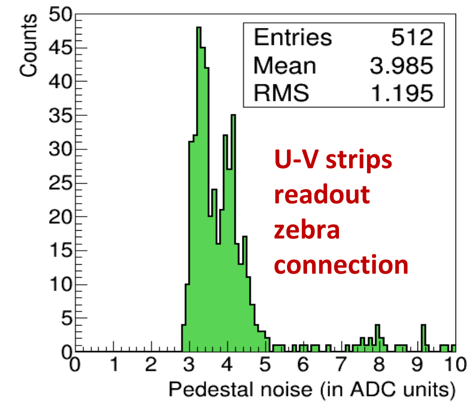


Characterization of U-V readout GEM proto with X-ray and Cosmic



Distribution of pedestal rms (noises) over 512 APV25 chs

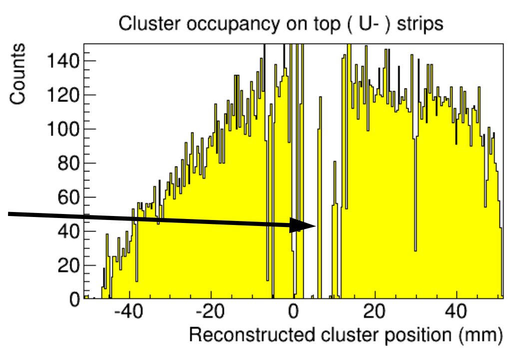


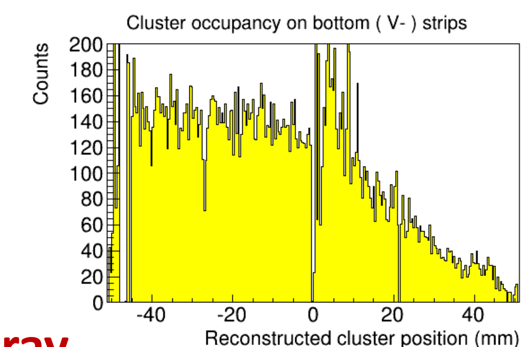


- Pedestal noise level comparable to standard COMPASS 2D readout
- No effect of the zebra connection on noise level

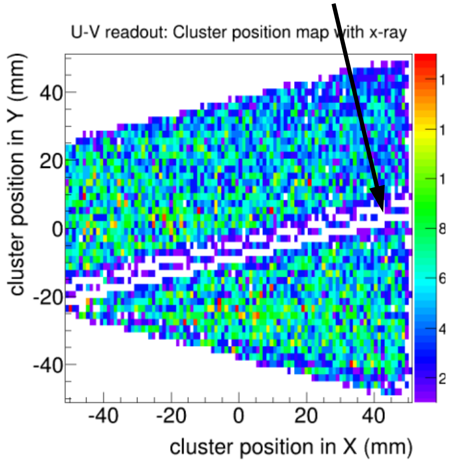
Cluster size > 3.5 ⇨ improvement in spatial resolution

bad zebra contact

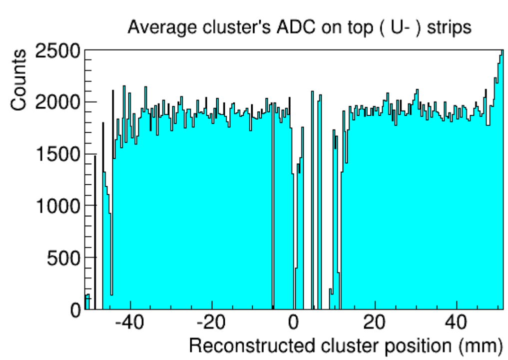


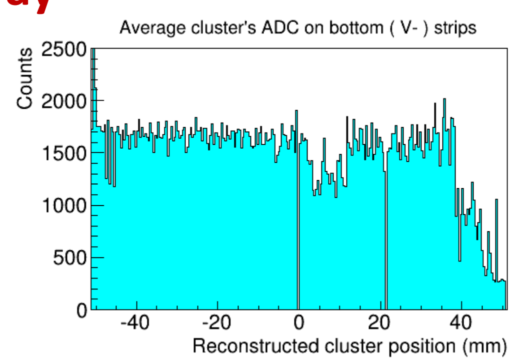


Occupancy for U and V strips: Linear dependence with strip length is shown



X-ray





Uniformity of the gain uniformity: (accumulated ADC / numbers of hits)