The spark measurement for the validation of low-resistive anode Micromegas

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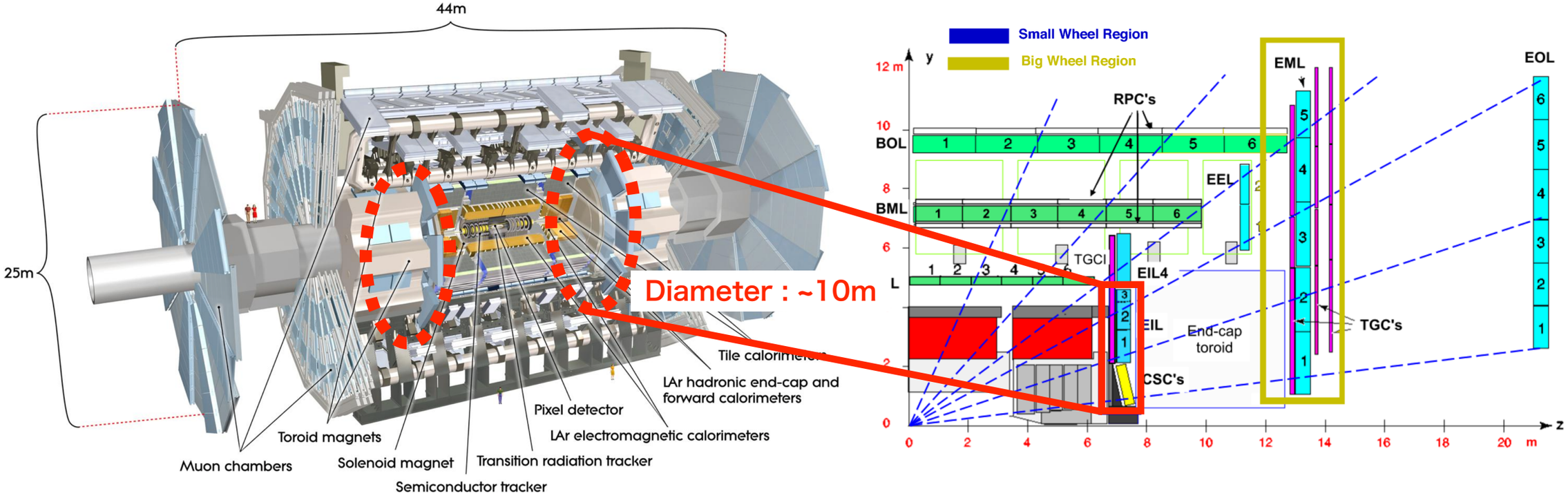
New Small Wheel upgrade

Motivation for the upgrade

- The peak luminosity of the LHC will be increased up to a factor of 5-7.5 with respect to the design value
- Severe limitation on the ATLAS performance in the forward region
  → Tracking efficiency, Level-1 muon trigger rate

Replacement of inner most muon end cap system

- Small Wheel (SW) → **New Small Wheel (NSW)**



- Two detector technologies: small Thin Gap Chambers and **MicroMegas** (MM)

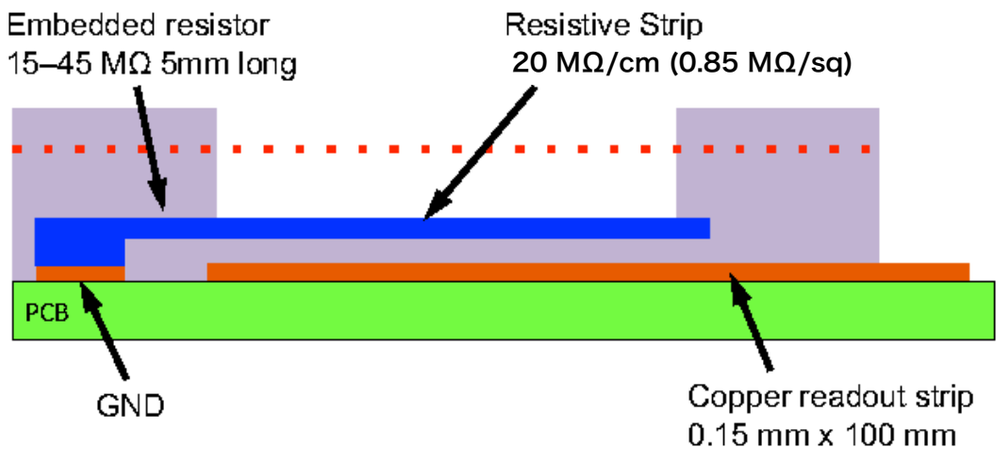
Resistive MicroMegas for NSW

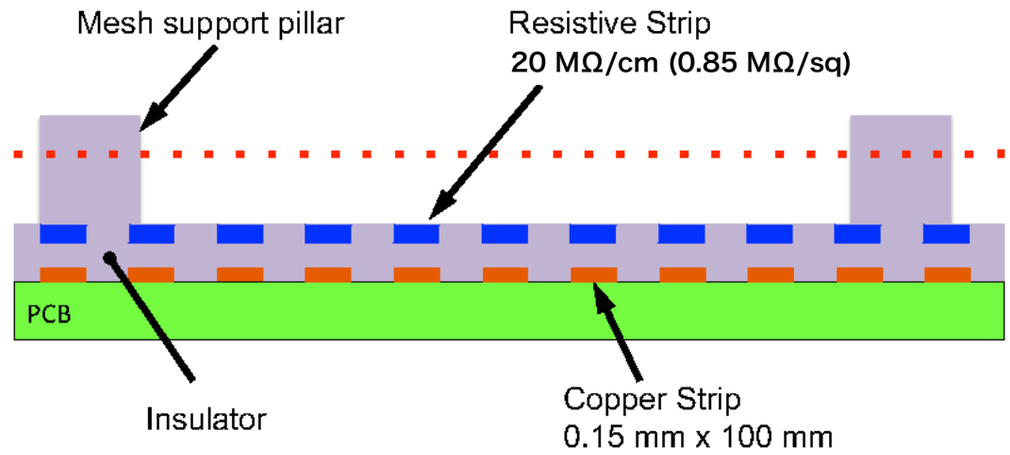
Spark tolerance is crucial for NSW MicroMegas

- Classical MM is vulnerable to spark when number of electrons in the avalanche reaches ~10^7

Resistive strip anode added on top of readout strips

- Separated by a thin insulator layer (50um)
- AC coupling to readout strips
- Can operate chamber at higher voltage (gain) due to the spark protected readout
  → Reduction in spark intensity by 3 orders of magnitude



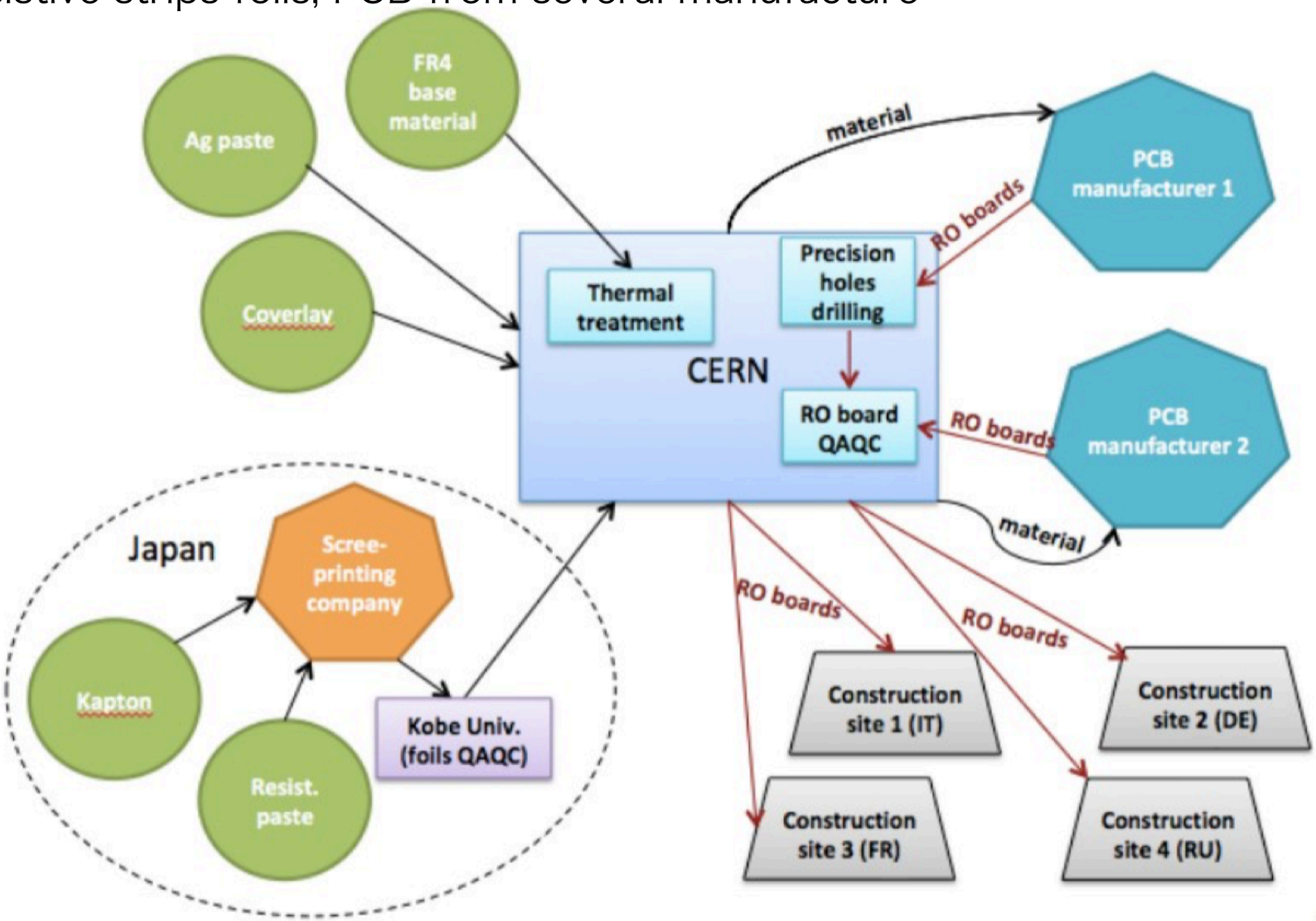


- Resistive strip width : ~300um, pitch : 425um, 450um

Micromegas Construction

The mass production is on-going

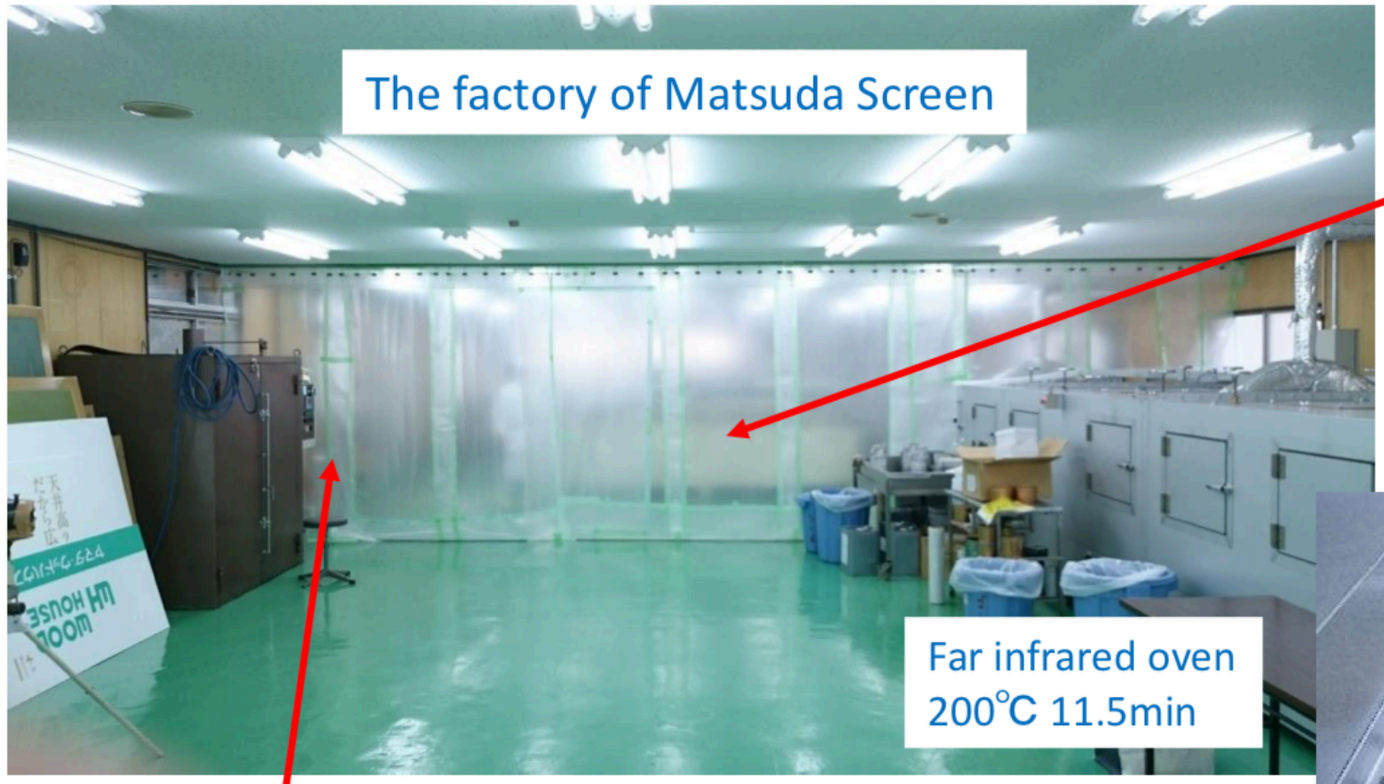
- Base materials delivered to CERN
- Four construction sites
- Resistive strips foils, PCB from several manufacture

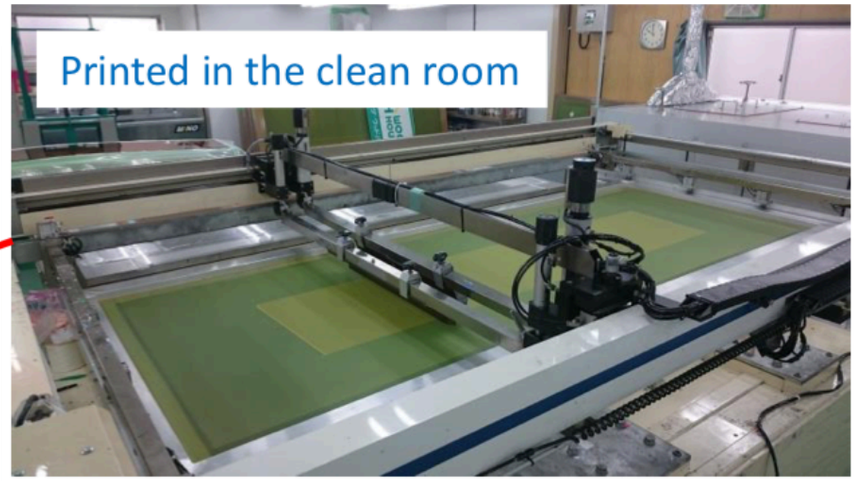


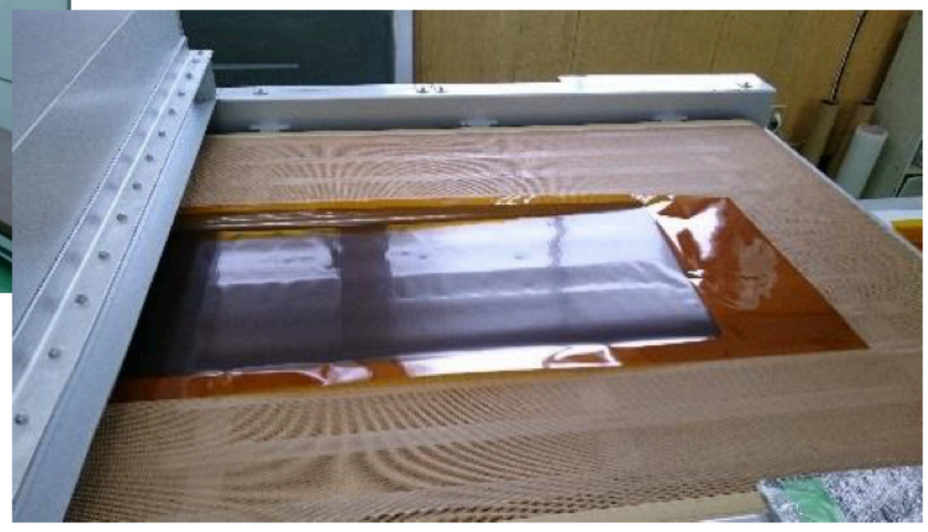
Resistive anode foil production

Production of resistive strips foils by Matsuda

- Screen printing on kapton sheet (50um)
- Carbon ink for resistive anode strips







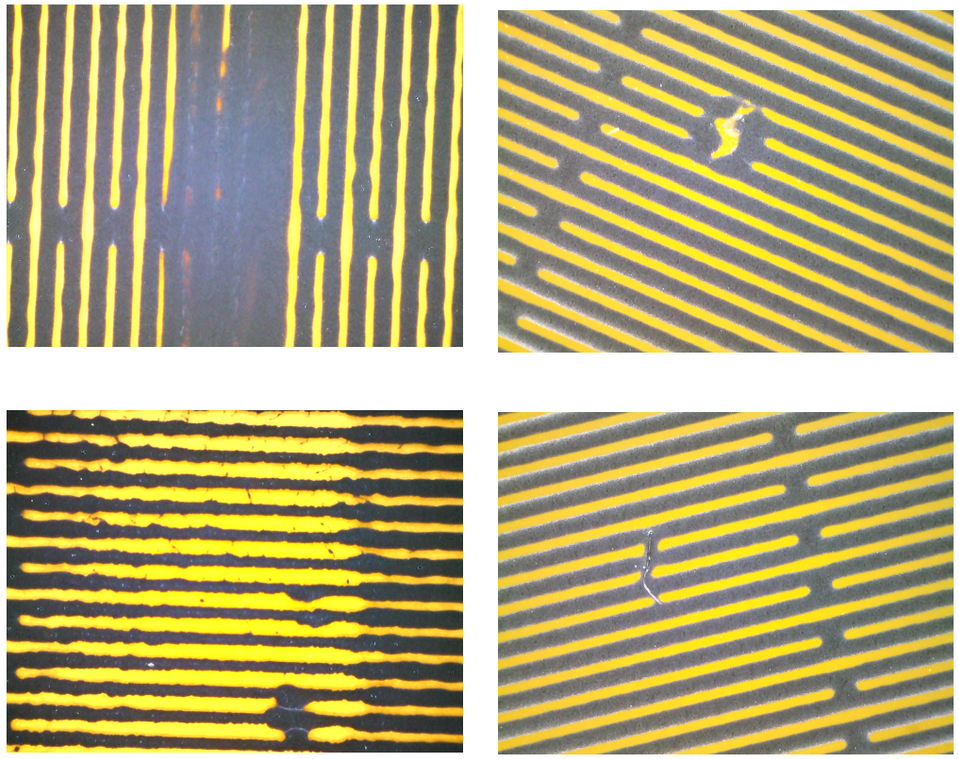
- ~ 2500 (including spare) foils were produced
- QA/QC at Kobe university
- Only accepted foils delivered to CERN

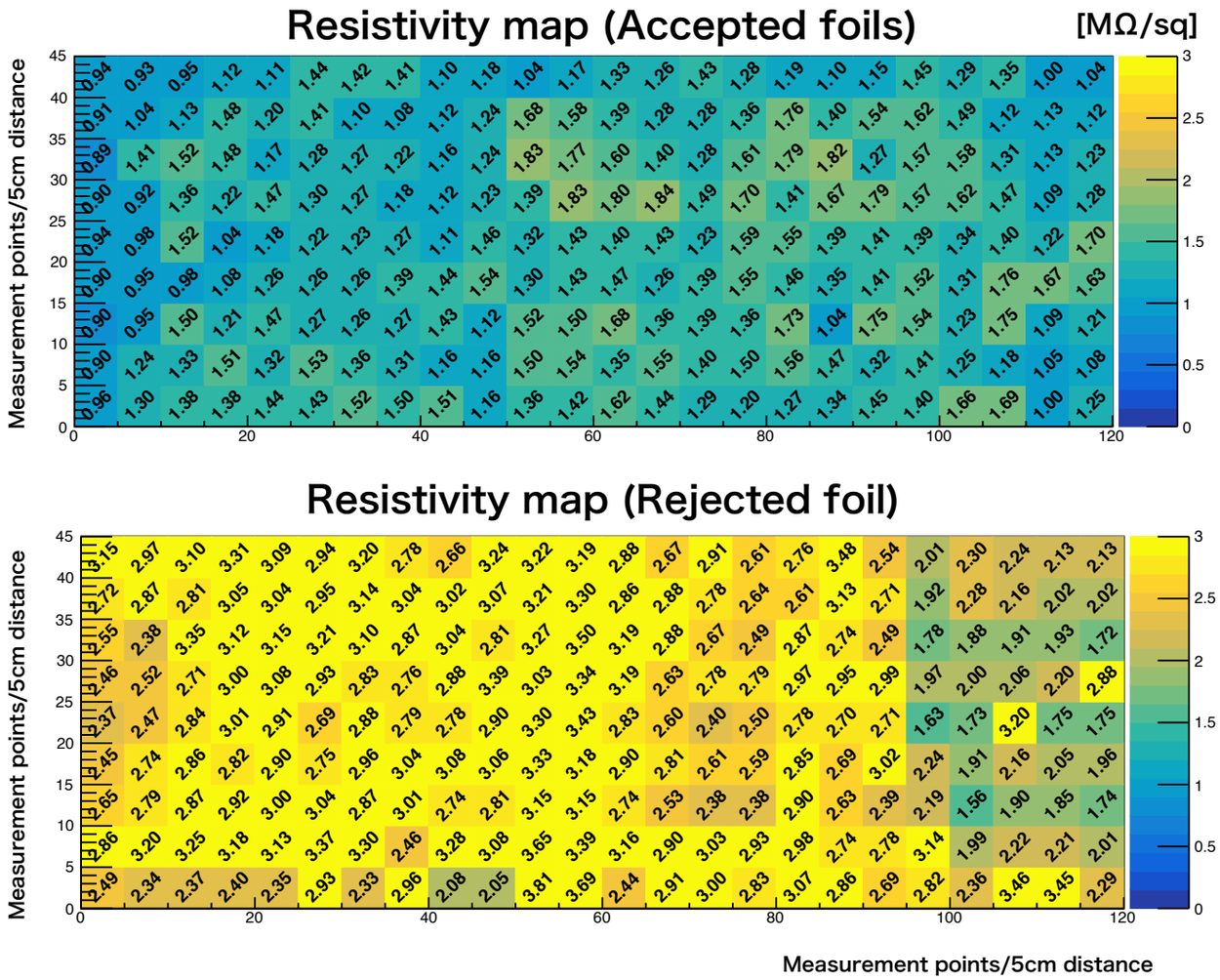
QA & QC for resistive foils

Quality check with several criteria

- Resistivity
  - Bulk check : Mean resistivity
  - Tails/Outlier check : % of measurements points within a target range
- Strip pattern
  - Strip width, pitch
  - Dust, damage on strips

Defects on rejected foils





Only accepted foils are used for the mass production due to the criteria

Low-resistivity issue

The mass production of resistive foils had been done about one year ago..

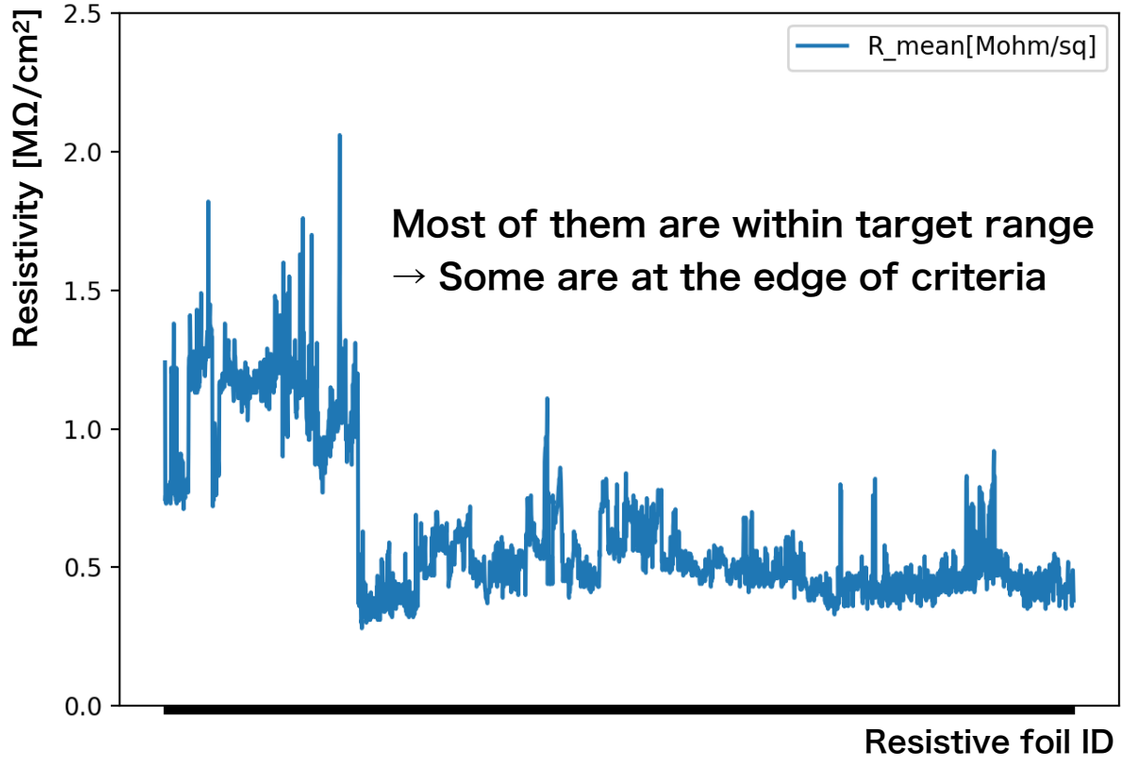
→ About ~5% foils were rejected due to the low resistivity (by Tail/Outlier check)

Tail/Outlier check

Target range : $R_{target}/3 < R_{target} < R_{target} \times 3$ [MΩ/sq], $R_{target} = 0.85$ [MΩ/sq]

Accept : >95% measurement points within the target range

Reject : <95% measurement points within the target range

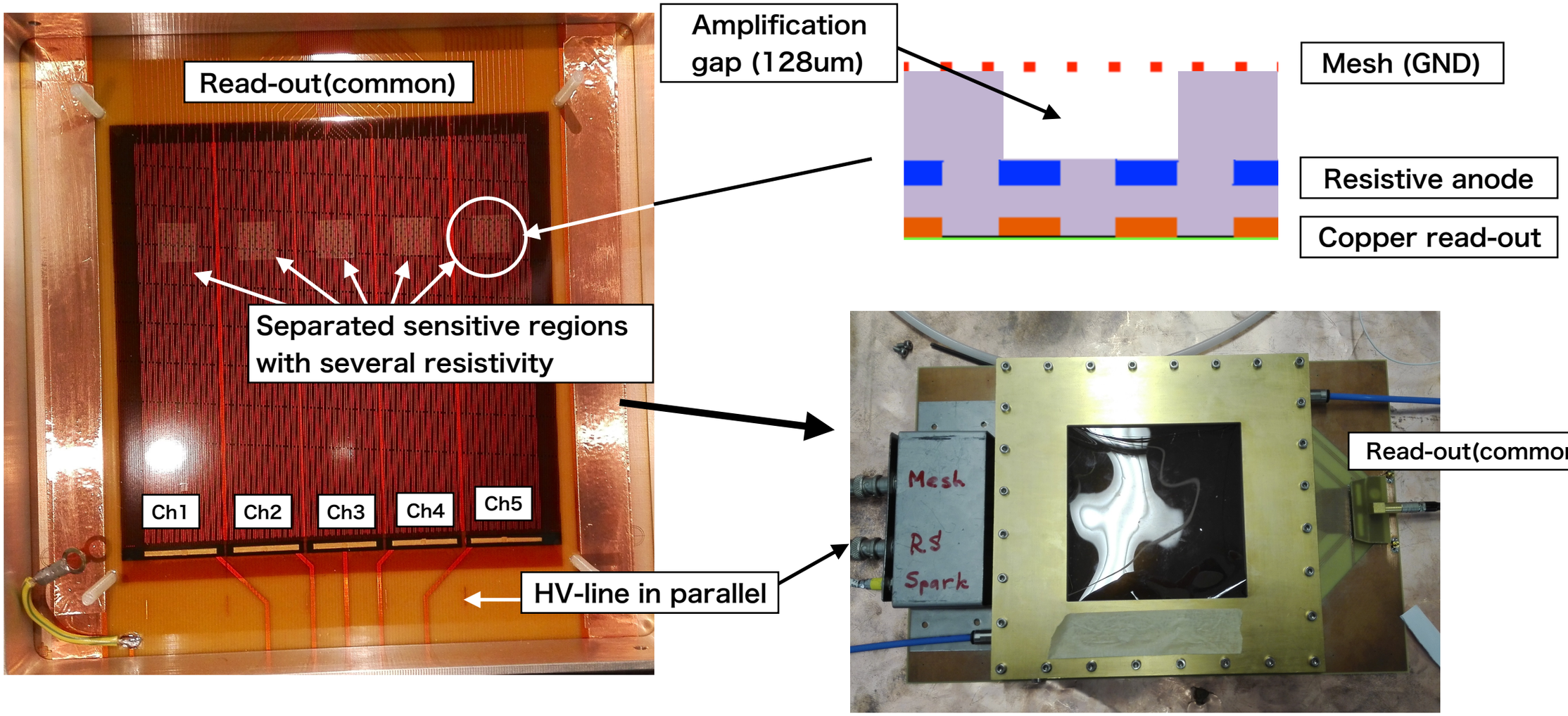


- Some of rejected foils could be good for the mass production
- Checked the difference between accepted and rejected foils
  → In terms of spark tolerance

Test chamber for spark tolerance study

To see the differences between accepted and rejected foils …

- Prepared a Micromegas test chamber (10cm × 10cm) designed and built @ CERN
- Separated sensitive regions with different resistivity (accepted and rejected)



Compared spark rate & shape amplitude to see the spark tolerance

- Spark rate : Possibility of spark
- Shape amplitude : Proportional to total charge induced by one spark

→ Applying HV (550~630V) without radiation source @CERN Lab

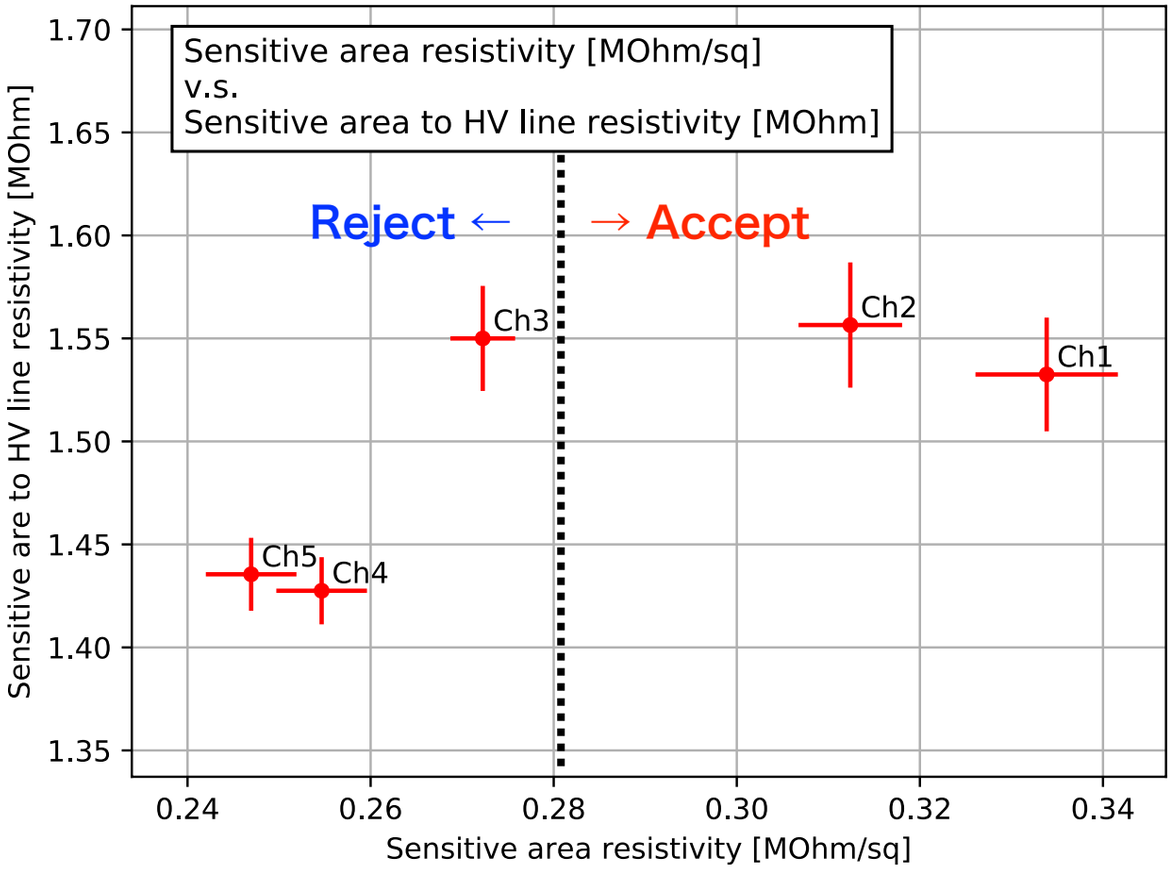
Resistivity of each sensitive region

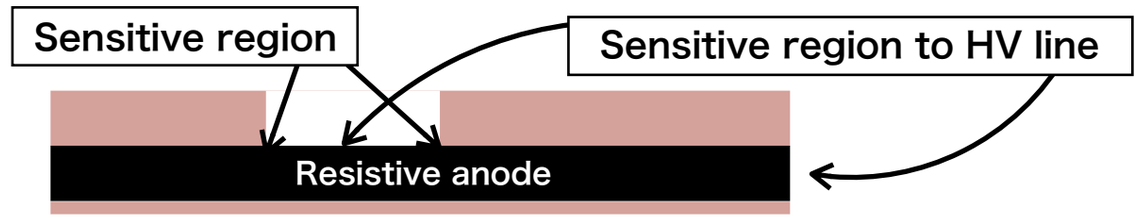
Two kind of resistivity measurements for each separated channel (Ch1~5)

① Resistivity of sensitive region [MΩ/sq]

② Resistance between sensitive region and HV line [MΩ]

→ For checking unexpected resistivity between sensitive region to HV line





	Region [MΩ/sq]		to HV line [MΩ]	
Ch1 (Accept)	0.327	0.339	1.513	1.552
Ch2 (Accept)	0.316	0.308	1.578	1.535
Ch3 (Reject)	0.275	0.270	1.568	1.532
Ch4 (Reject)	0.251	0.258	1.439	1.416
Ch5 (Reject)	0.243	0.251	1.448	1.423

※ **Two measurements for each column**

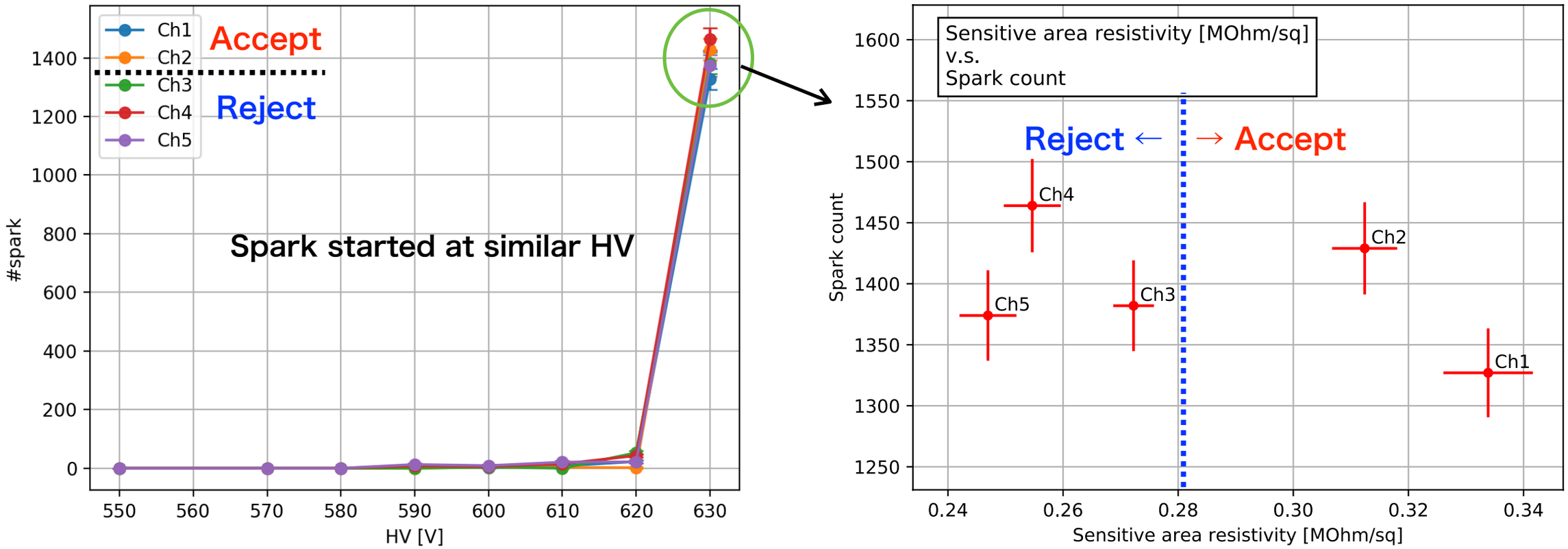
- No unexpected resistivity observed between sensitive region to HV line
- Accepted foil : Ch1, Ch2
- Rejected foil : Ch3, Ch4, Ch5

→ Measured spark count and shape amplitude with each channel @CERN Lab

Spark rate

Measurement of spark counts for each channel

- Measurement time : 2 minutes
- Scanned HV : 550, 570, 580, 590, 600, 610, 620, 630
- 5 channels × 8 HV → 40 measurements
- Spark signals from copper read-out
  → Preamplifier + Fast Filter Amp (ORTEC®)
  → Oscilloscope (TEREDYNE LECROY®)



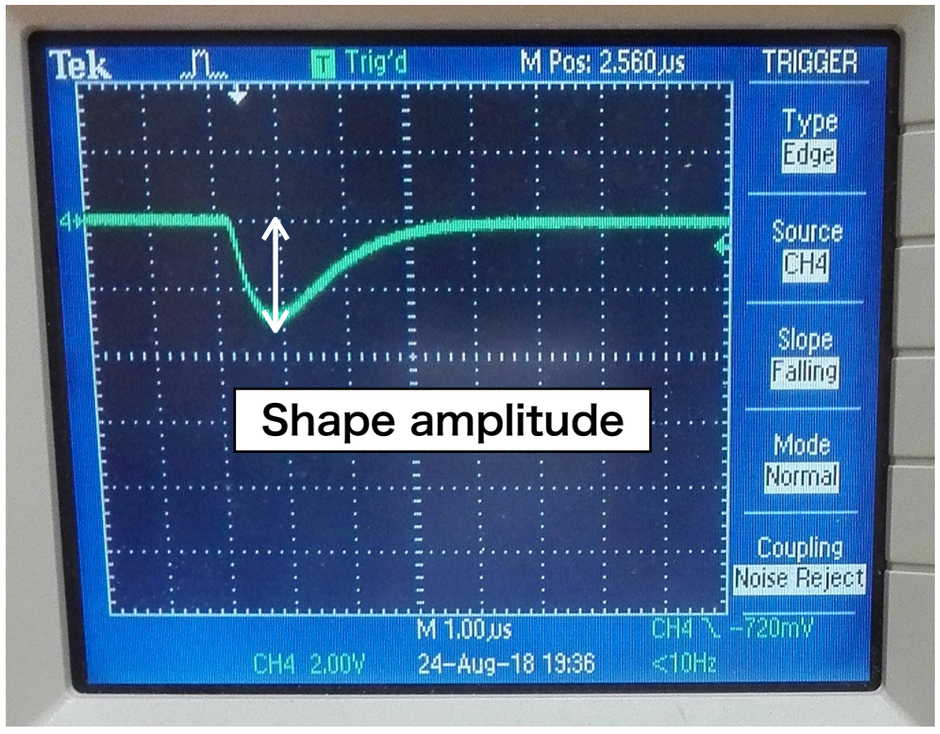
- Similar HV dependency observed (left plots)
- No significant differences by sensitive region resistivity (right plots)

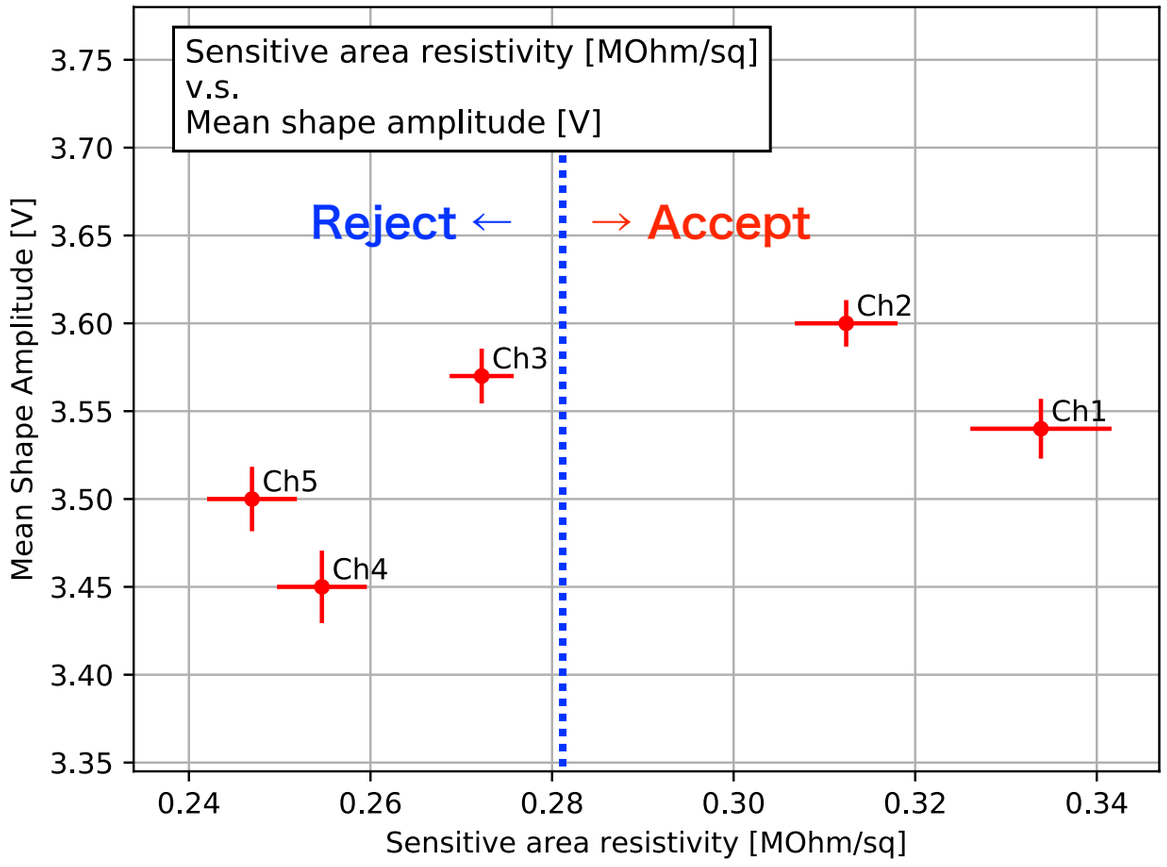
Shape amplitude

Measurement of mean shape amplitude for each channel

- Assuming shape amplitude is proportional to the total charge
  → Total charge (∝ spark size) depends on resistivity of anodes
- Measured at the same time width to the spark count measurement
- Compared the mean amplitude at HV 630 [V]

Typical spark signal





- No significant differences observed by sensitive region resistivity

Conclusion

Resistive anode strips are key components in the NSW construction

- Read-out protection from sparks
- The mass production of them is on-going

Spark test for the low resistivity strips foils

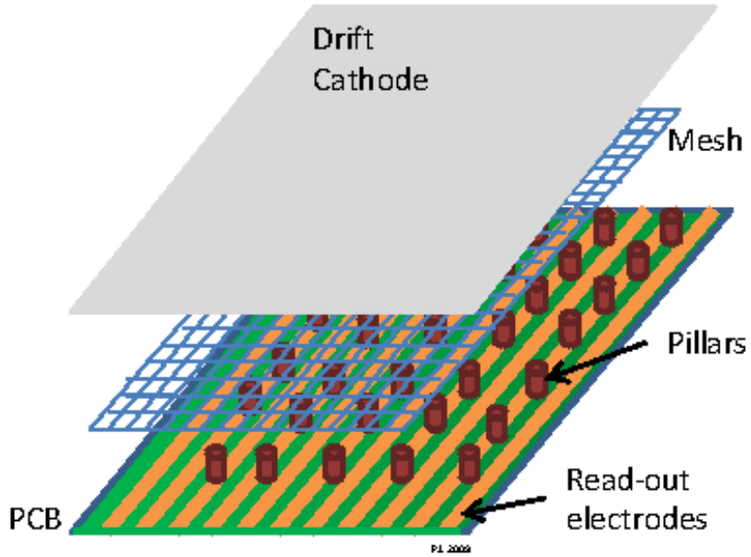
- Some resistive foils were rejected due to the low-resistivity
  → Only ~5% of all resistive foils
  → Around the edge of criteria
  → Could be good for the production
- Measured number of spark and shape amplitude to see the spark tolerance
- No significant difference observed between accepted and rejected foils

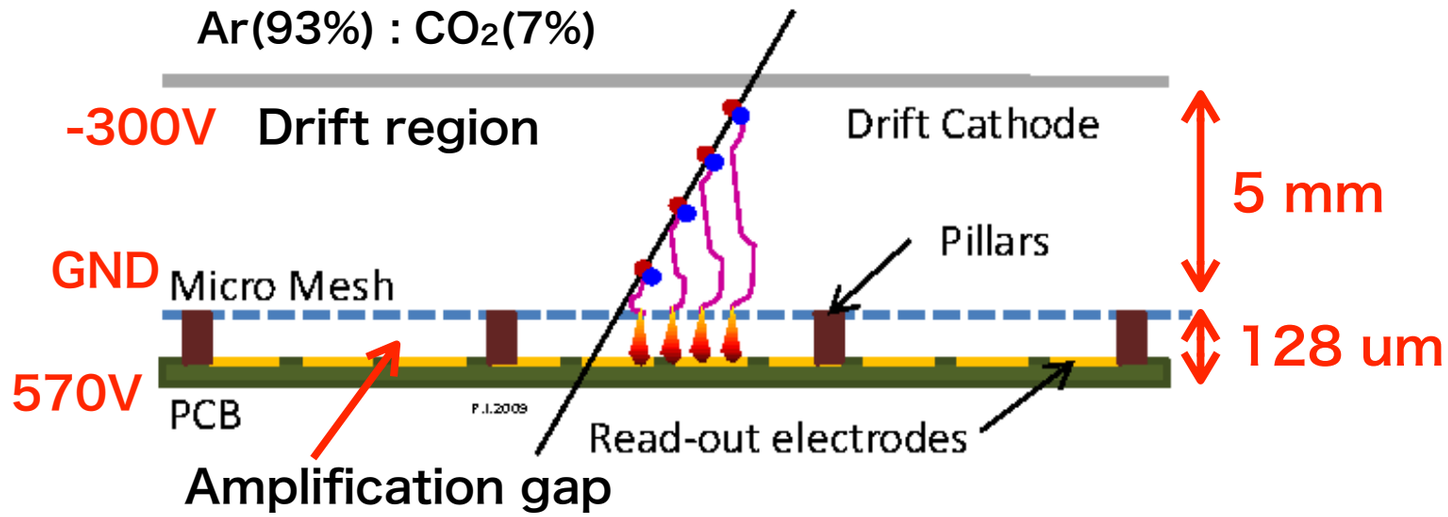
Backup

MicroMegas (MM)

Micro-Mesh Gaseous Detectors

- Parallel-plate chamber
- Consists of drift cathode, ground mesh, readout, PCBs
- Drift region (drift cathode ↔ ground mesh : 5mm)
- Thin amplification gap (ground mesh ↔ readout : 128um)
  → Short drift times (~5cm/us) and fast absorption of the positive ions (100ns)

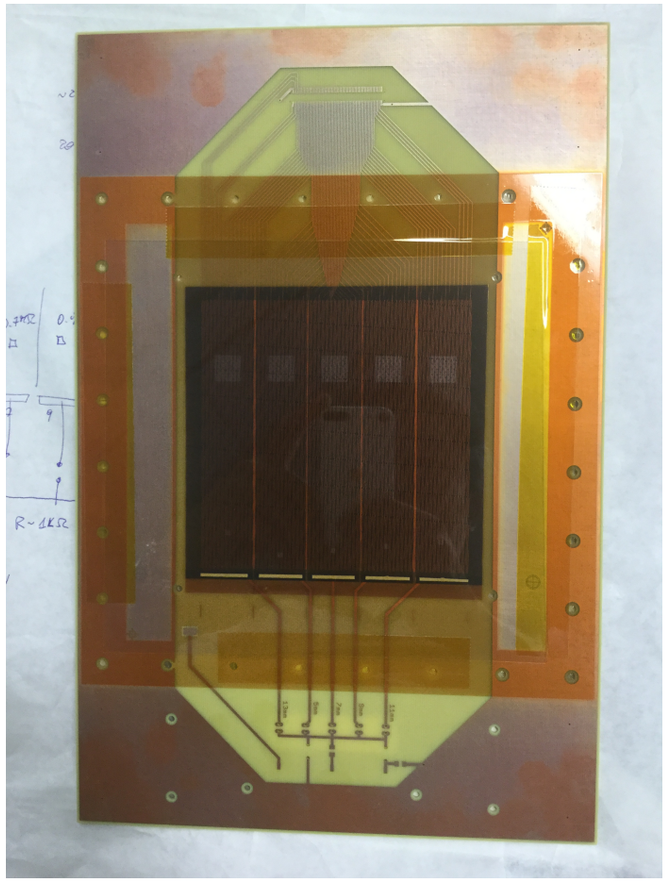


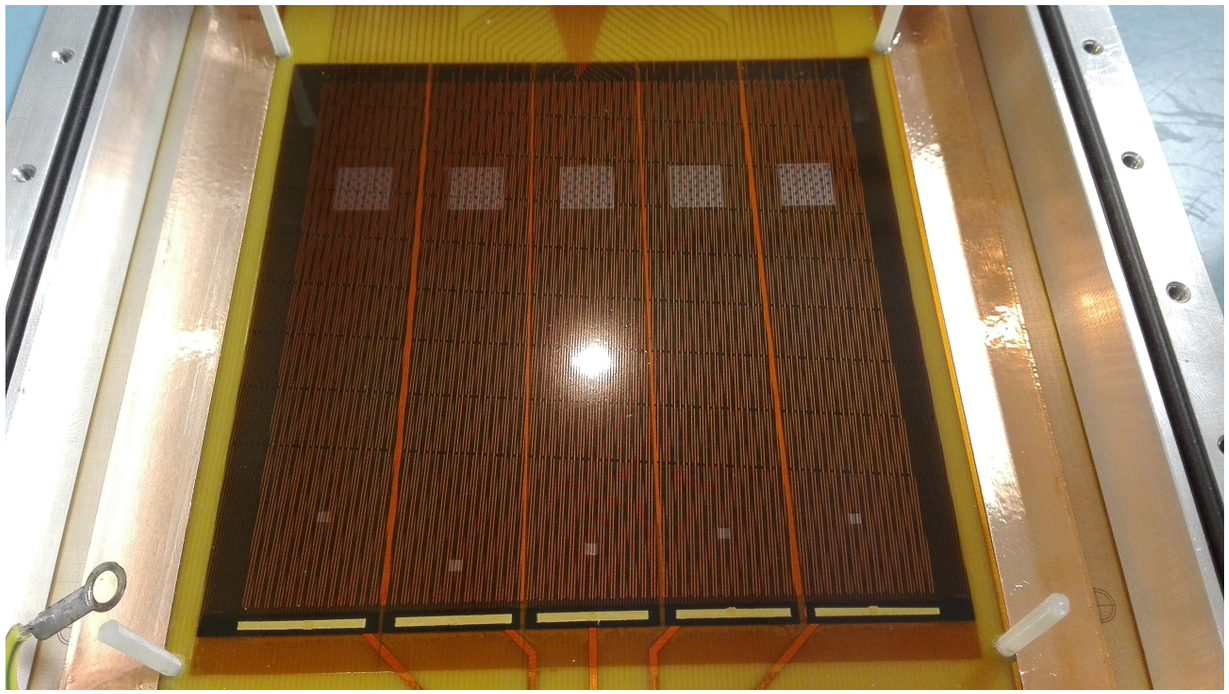


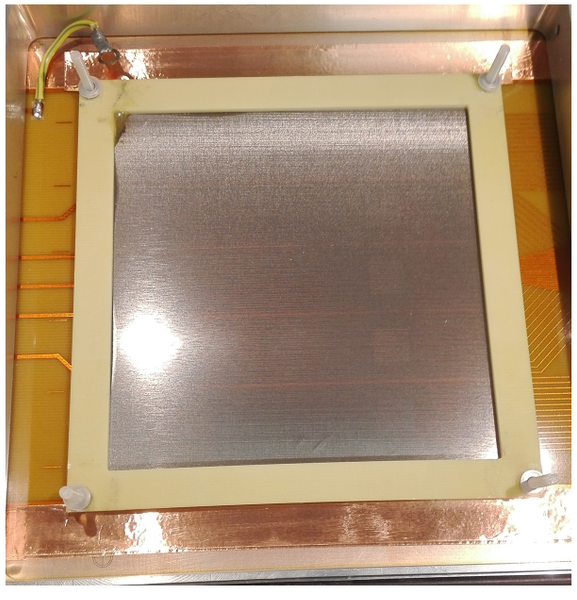
- Large area can be achieved simply
- Mass production
- High rate capability (~15kHz/cm^2)

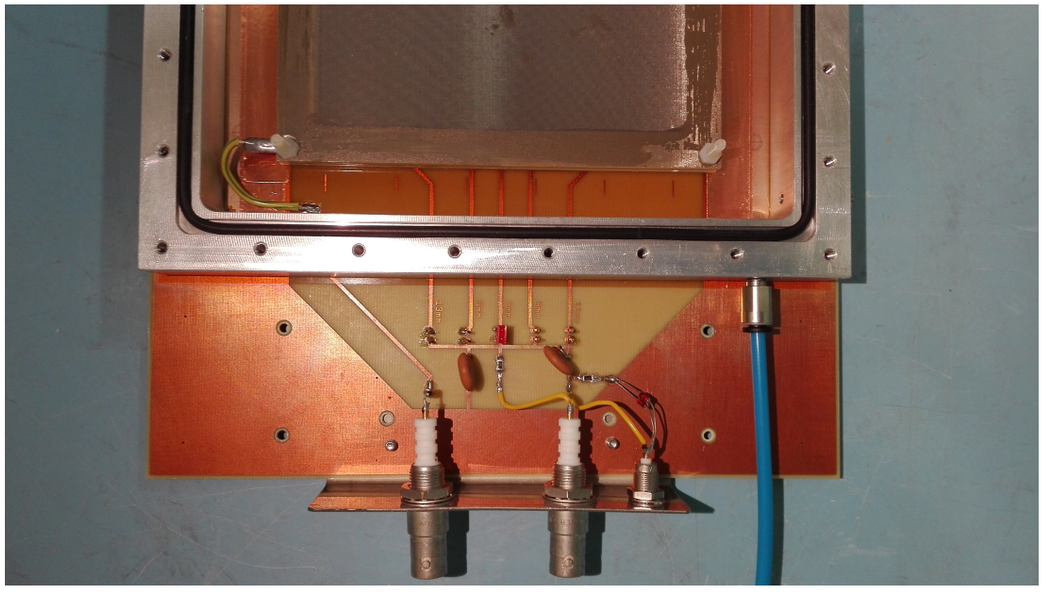
→ Suited for high-rate applications like LHC !!

Test chamber

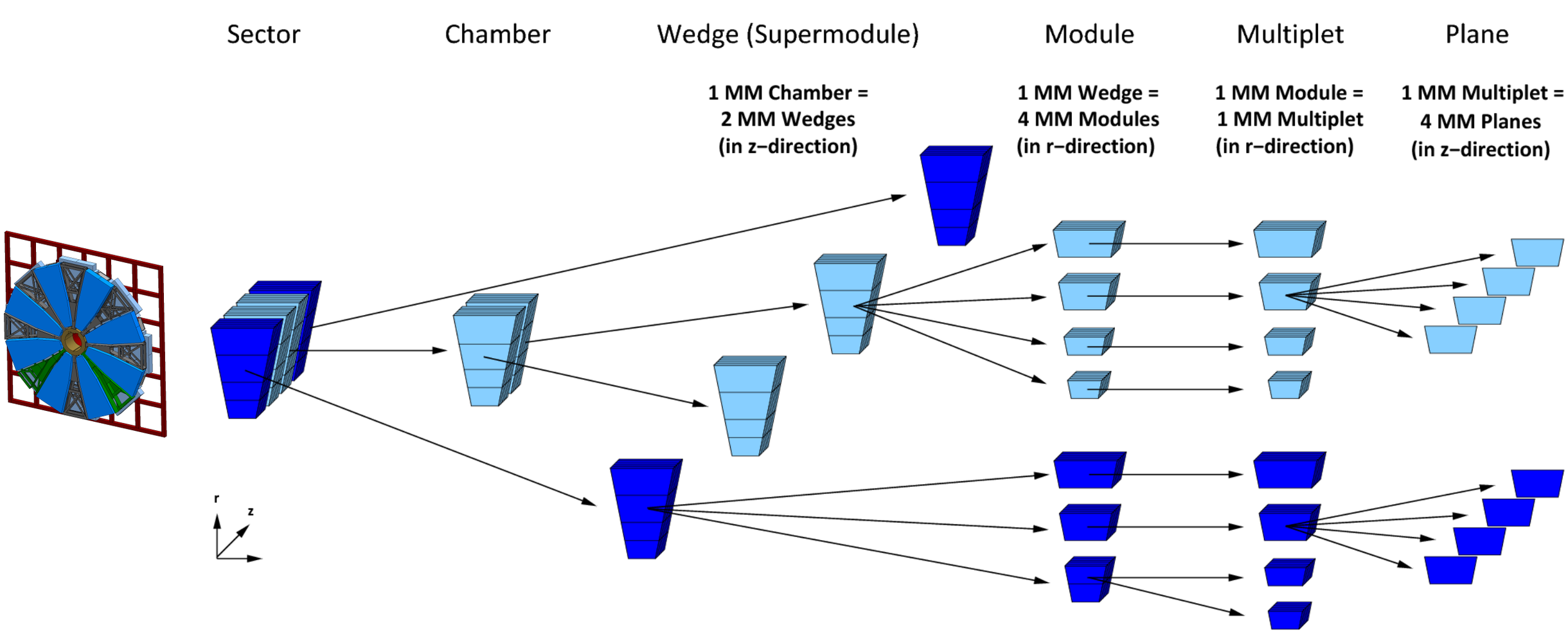




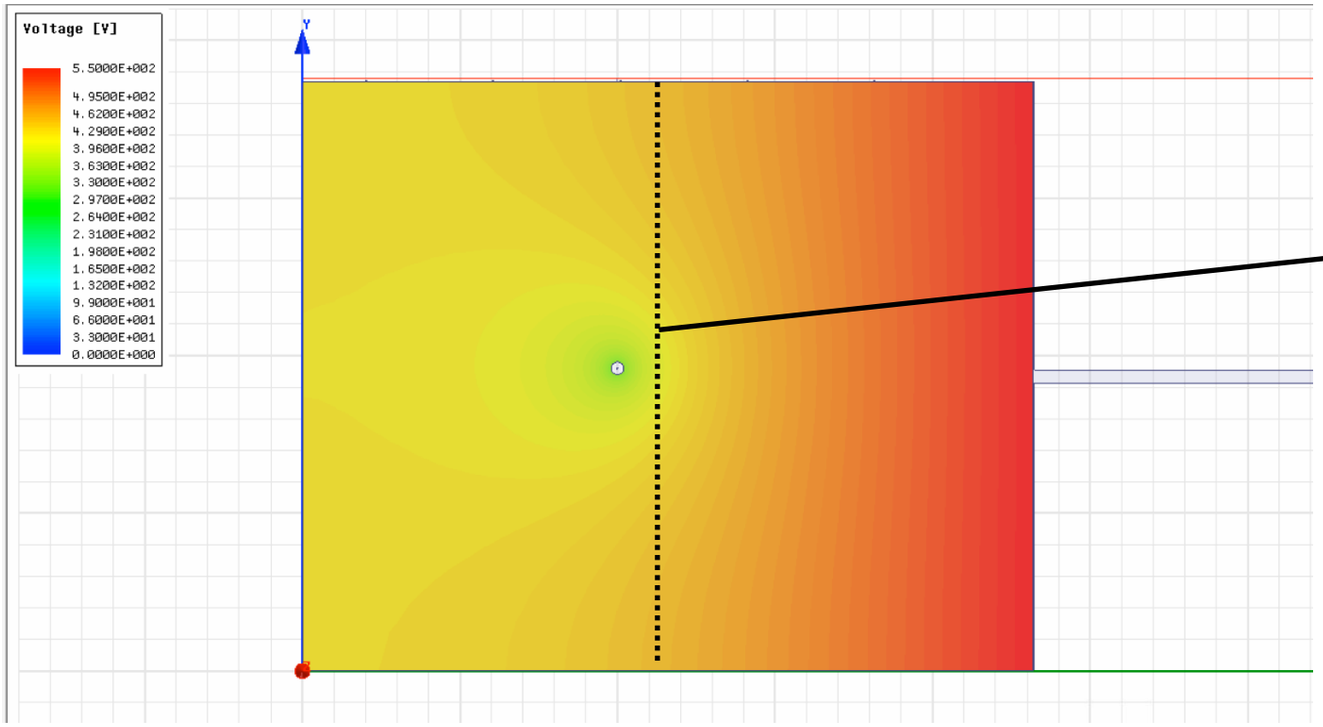


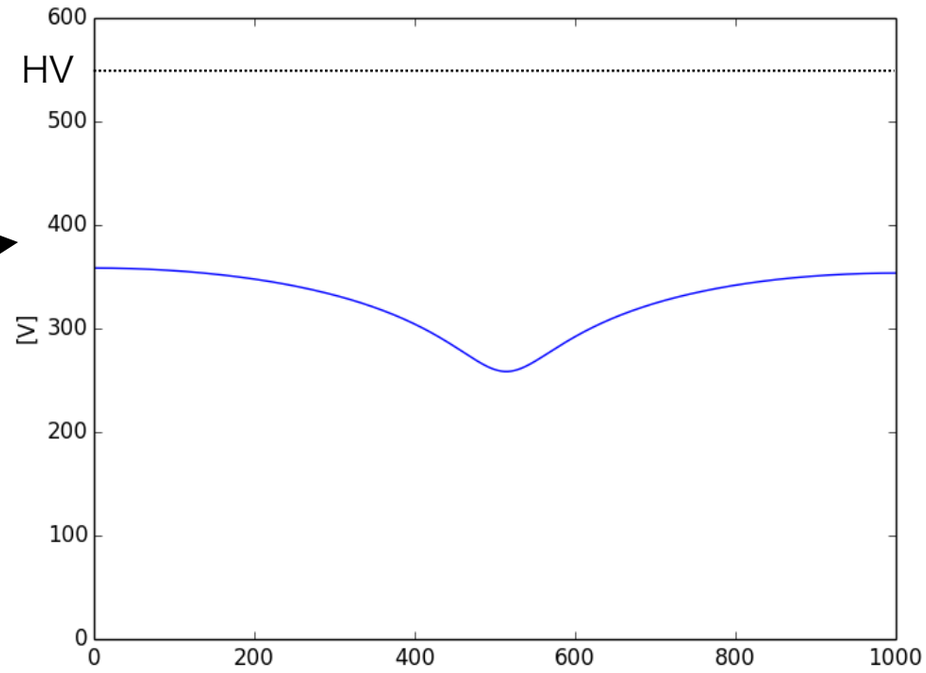


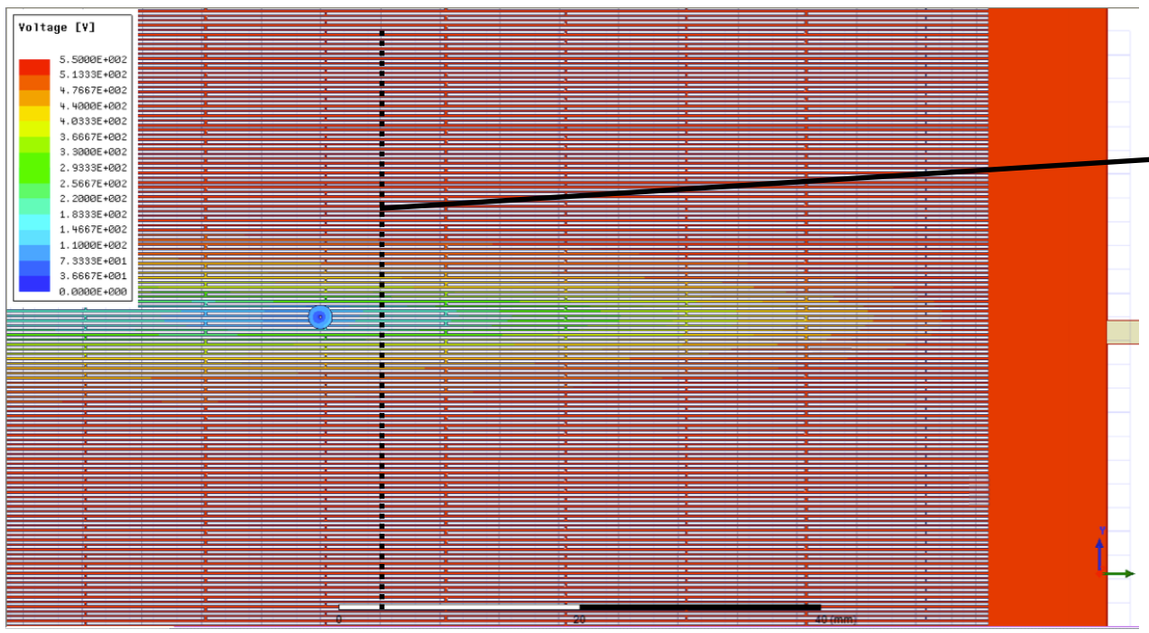
NSW structure

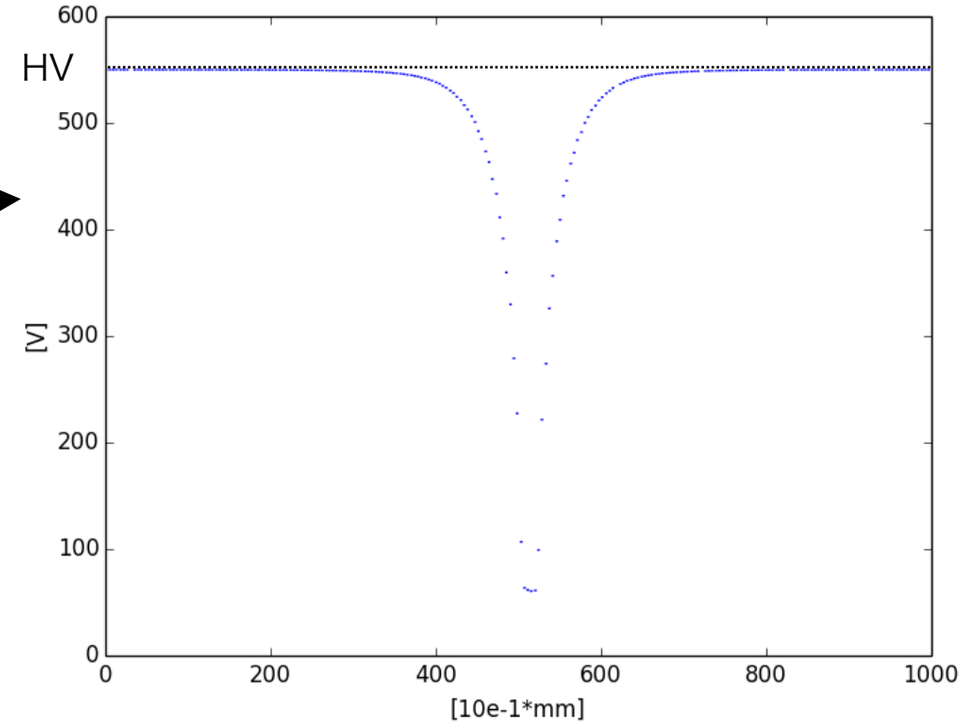


HV drop comparison by anode structure









- HV dropped area can be restricted by ladder structure