ATLAS large-area micromegas muon chamber R&D

… some emphasis on resistive coating

Status report

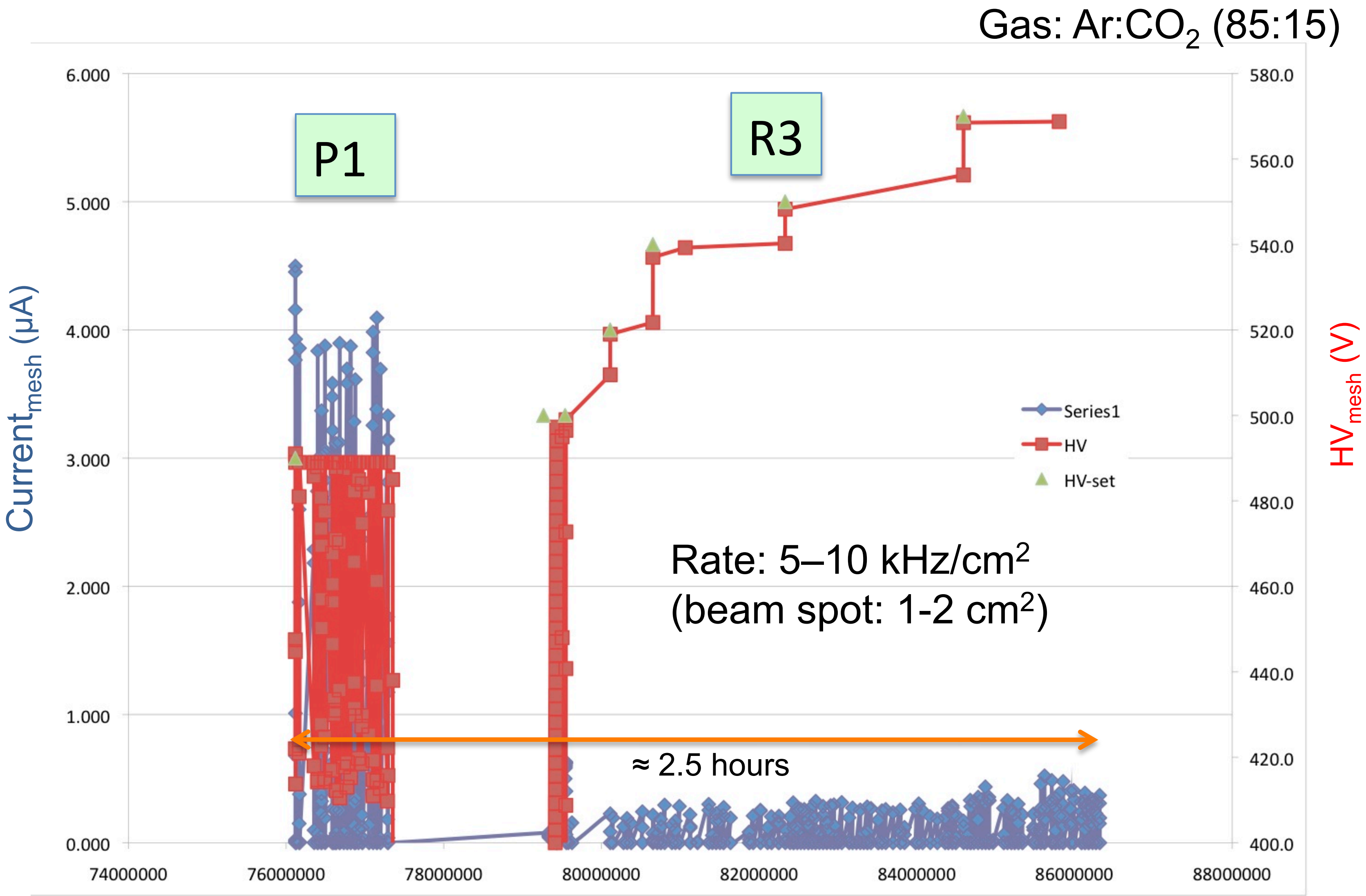
MAMMA activities

- Systematic studies with small µMs with a view to optimize chamber performance parameters and to define requirements for r/o electronics
- Study of different schemes to reduce impact of sparks on chamber performance
  - Resistive coating
  - Double-stage amplification
- Design and construction of full-size prototype chamber (1.2 x 1.2 m^2)

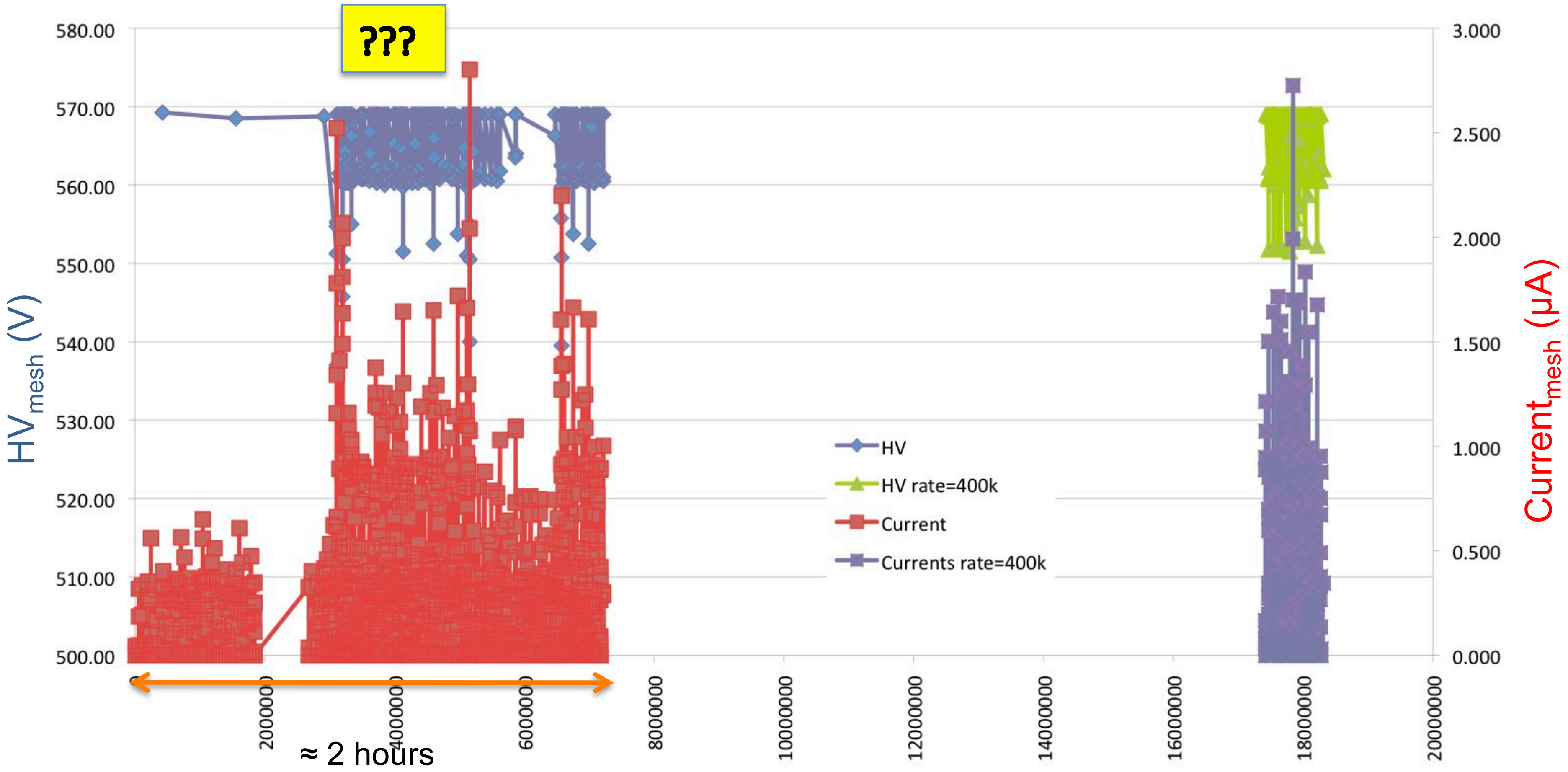
Experience with resistive coating

- R1 & R2 (resistive pads on r/o strips)
  - Resistive pads by means of resistive paste (10 MΩ, 10 GΩ)
  - Chambers started to draw currents after short time of exposure to beam (H6: 120 GeV/c pions)
  - Inspection showed local damage of the resistive layer at a few spots; small fragments of resistive material found between mesh and readout electrode
- R3 (resistive pads + metal caps on r/o strips)
  - Tested in H4 and H6 beams in Nov. 2009 (120 GeV/c pions)
  - Study of mesh currents and HV stability when sparking

Test of R3 (resistive pads) in H4 and H6

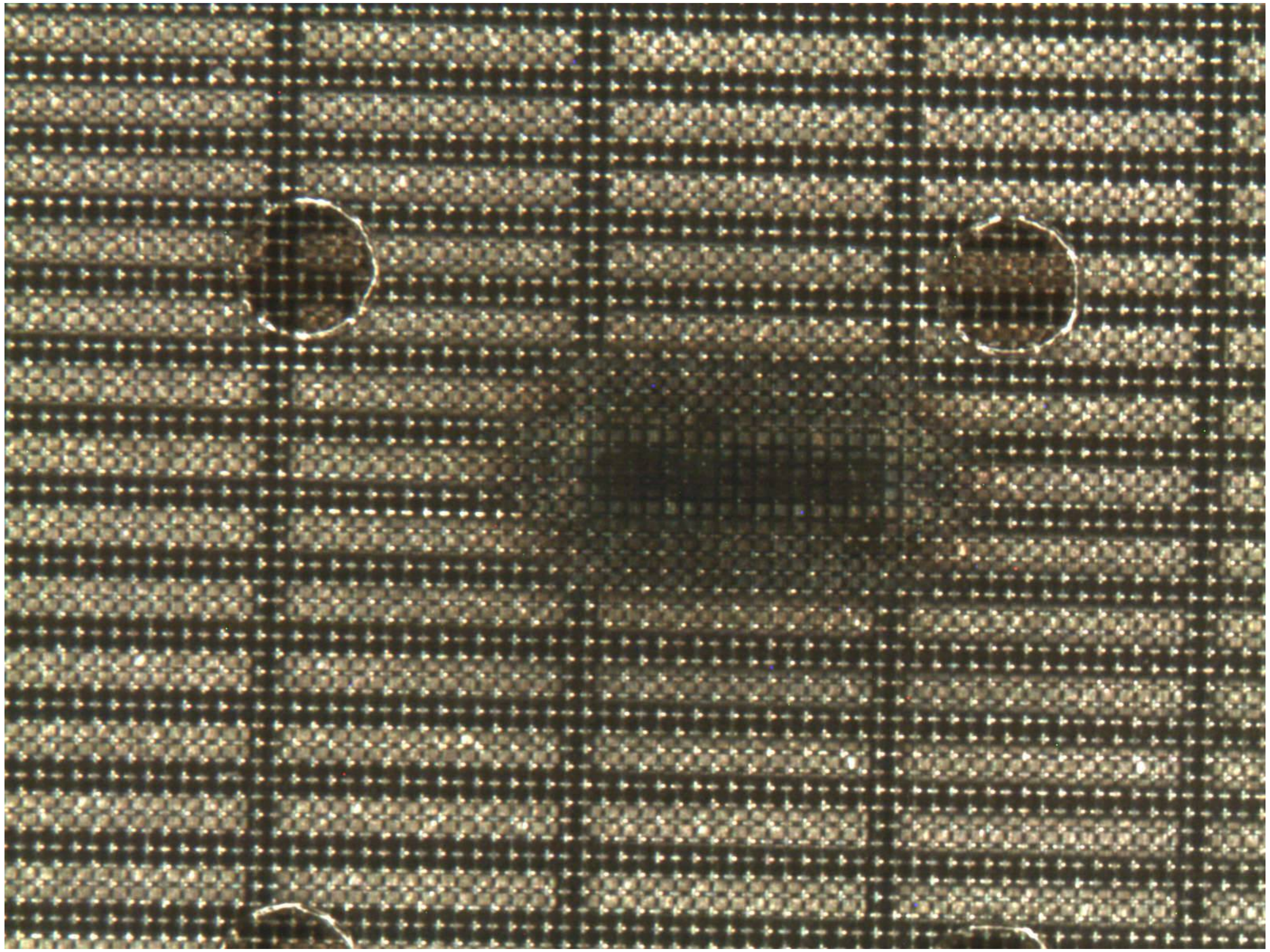


HV/Current R3 – 20 Nov



Rate: ≈15 kHz/cm² ≈20 kHz/cm² Rate: ≈ 25 kHz/cm²

R3 ‘short’

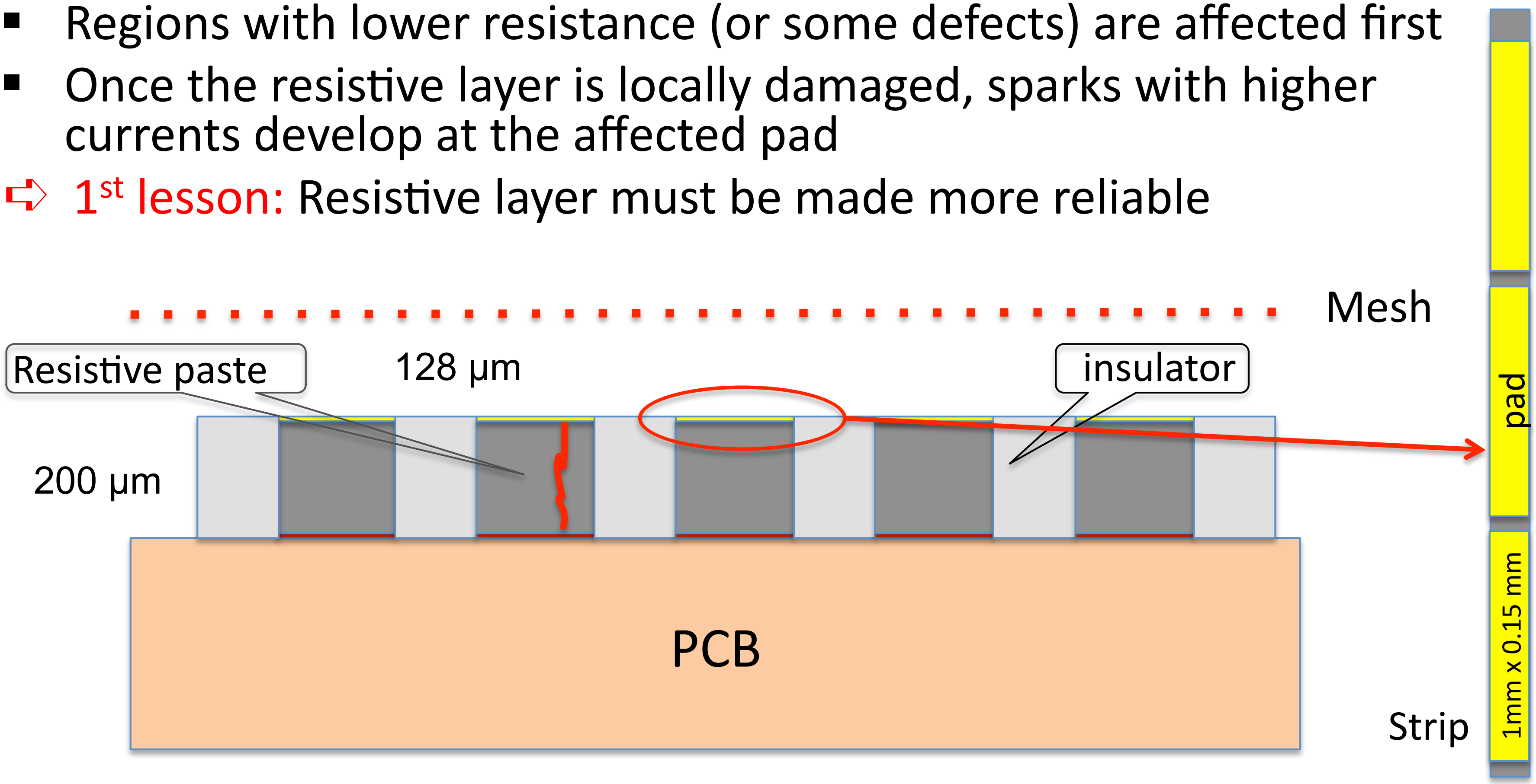


- Signs of discharges at a few (2–3), isolated spots over full detector area of 100 x 100 mm^2
- single pads affected per spot

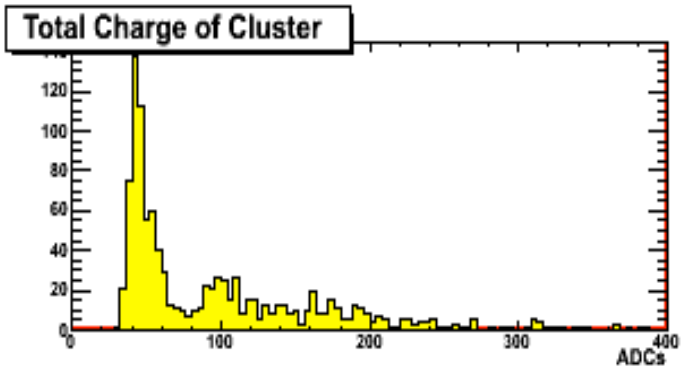
Local damage of resistive layer

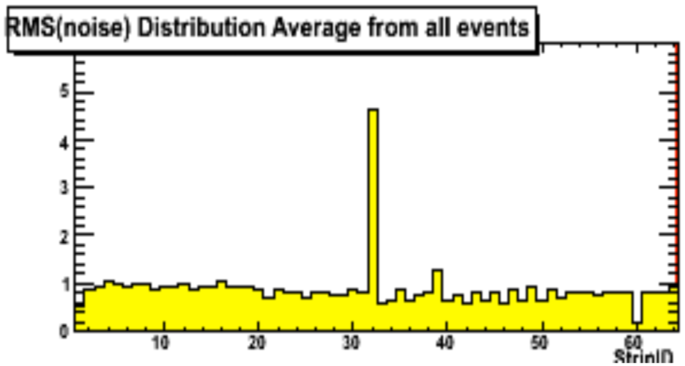
- Resistive layer is locally damaged, induced by some large charge (Resistive paste not very homogeneous, manually applied)
- Regions with lower resistance (or some defects) are affected first
- Once the resistive layer is locally damaged, sparks with higher currents develop at the affected pad

➪ 1st lesson: Resistive layer must be made more reliable



R3 performance





We observe

- Nice signals
- Noise is OK, not much different from std MM

But

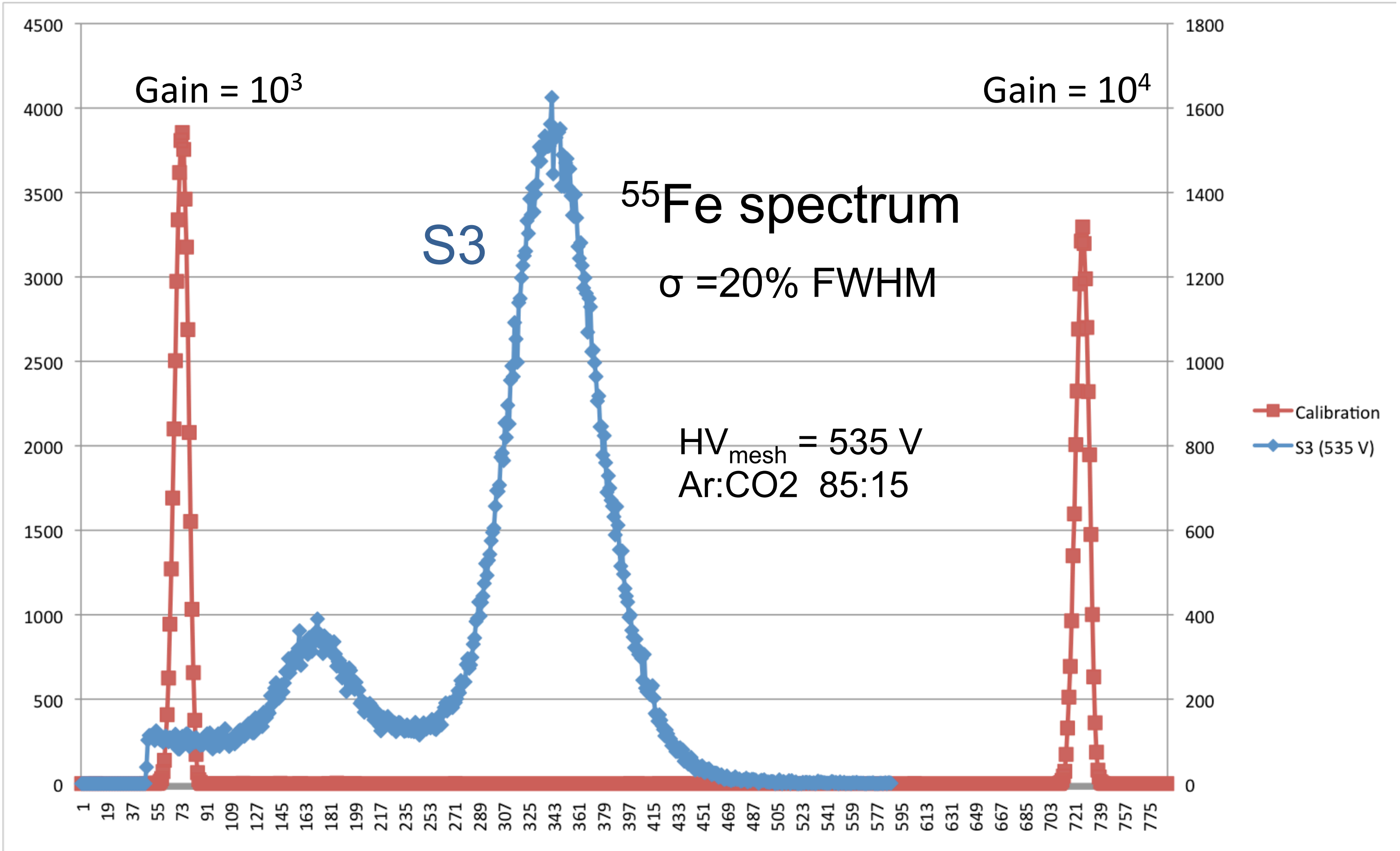
- Many events with no or very small signals
- Low efficiency
- ???

Test of R3 in lab with ^{55}Fe source

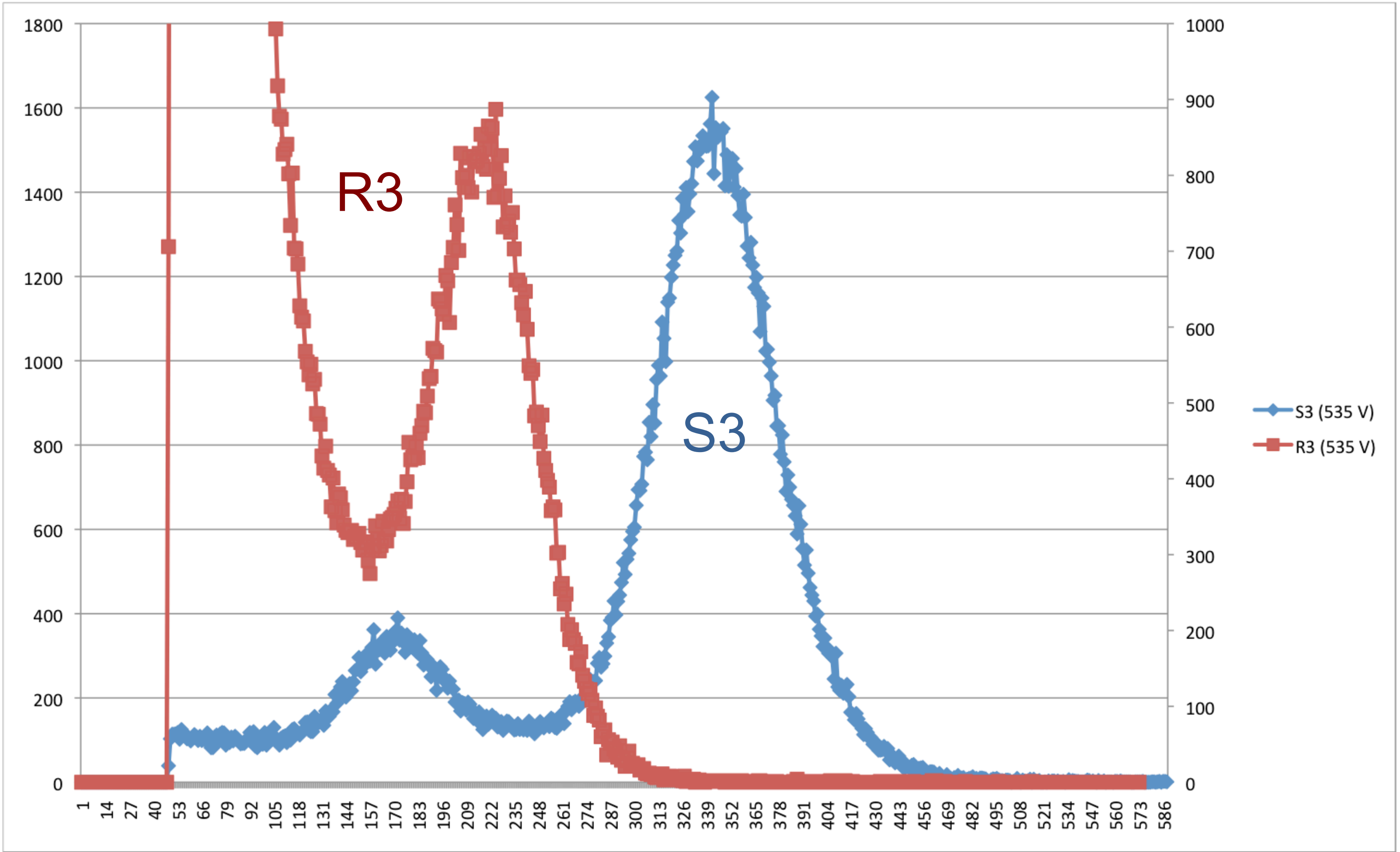
Same gas mixture $Ar:CO_2$ (85:15) as in H6

- Try to understand the behaviour of R3
- Measured pulse spectra
- 72 strips connected together -> single preamplifier + Ortec amplifier
- Coupling capacitor: C_{PA} = 1.8 pF
- ..... some surprises
- Started with S3 (no resistive coating)

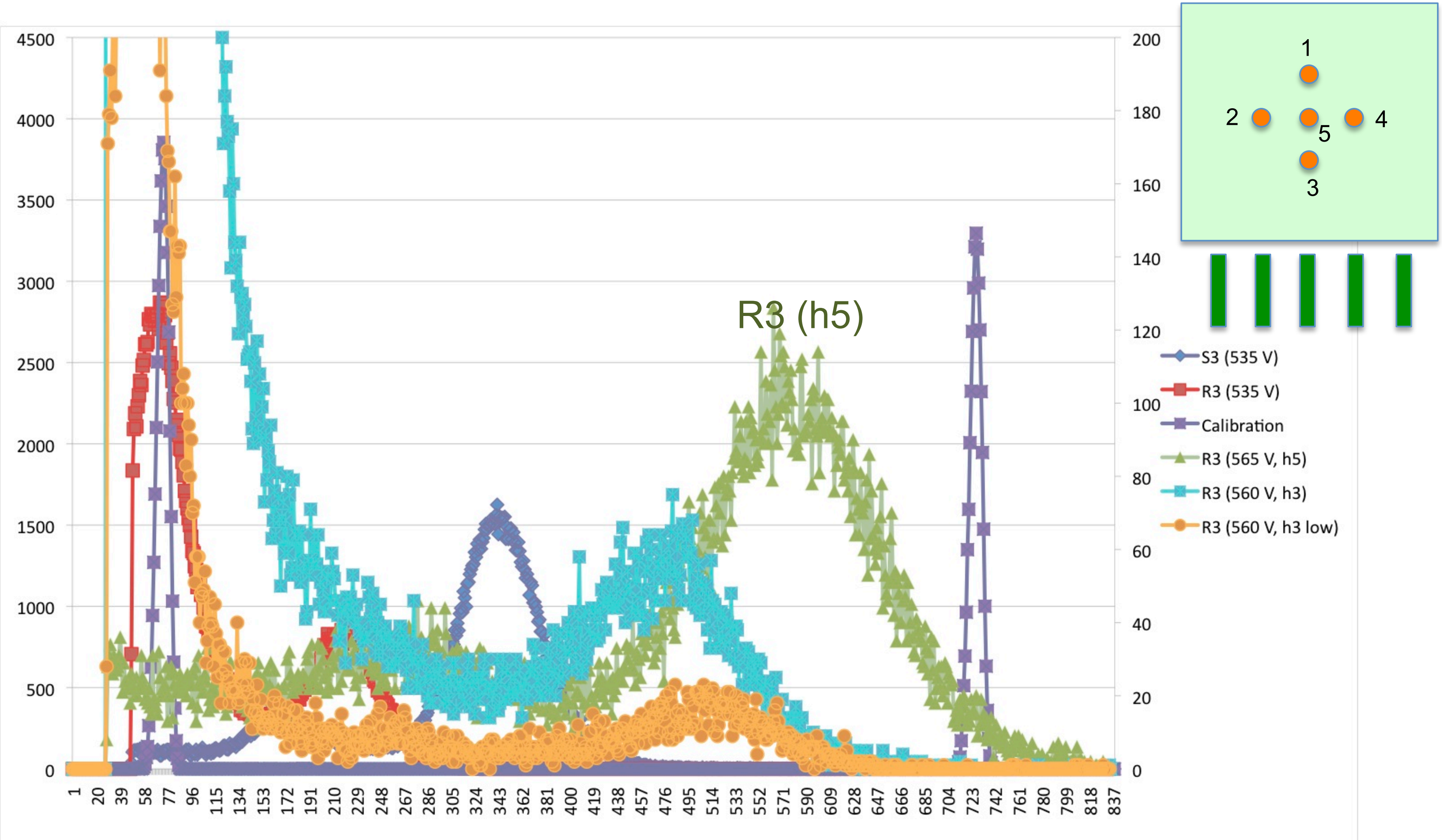
S3 (standard MM w/o resistive layer)



S3 + R3 (^{55}Fe source data)



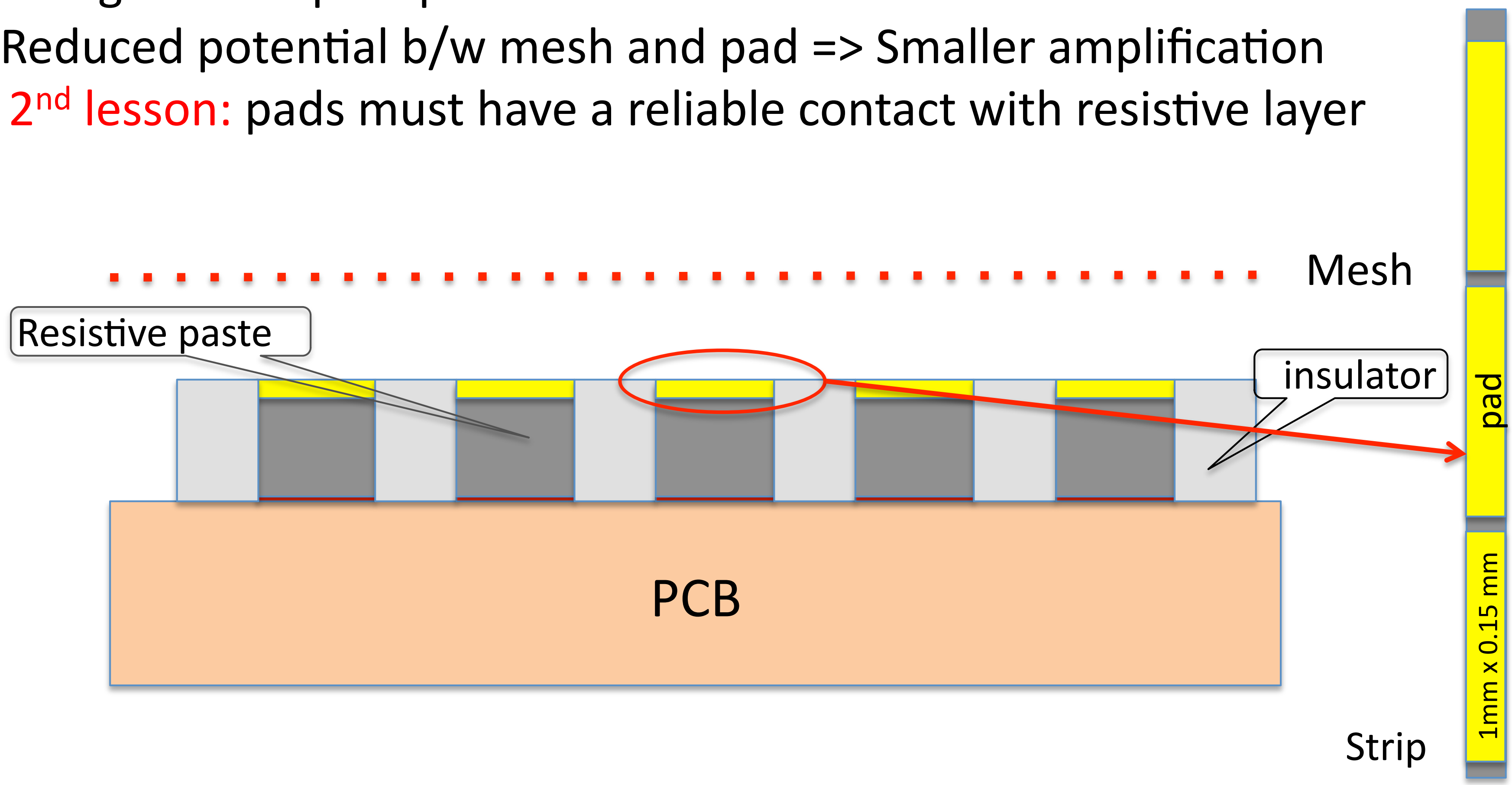
Rate effect and local variations



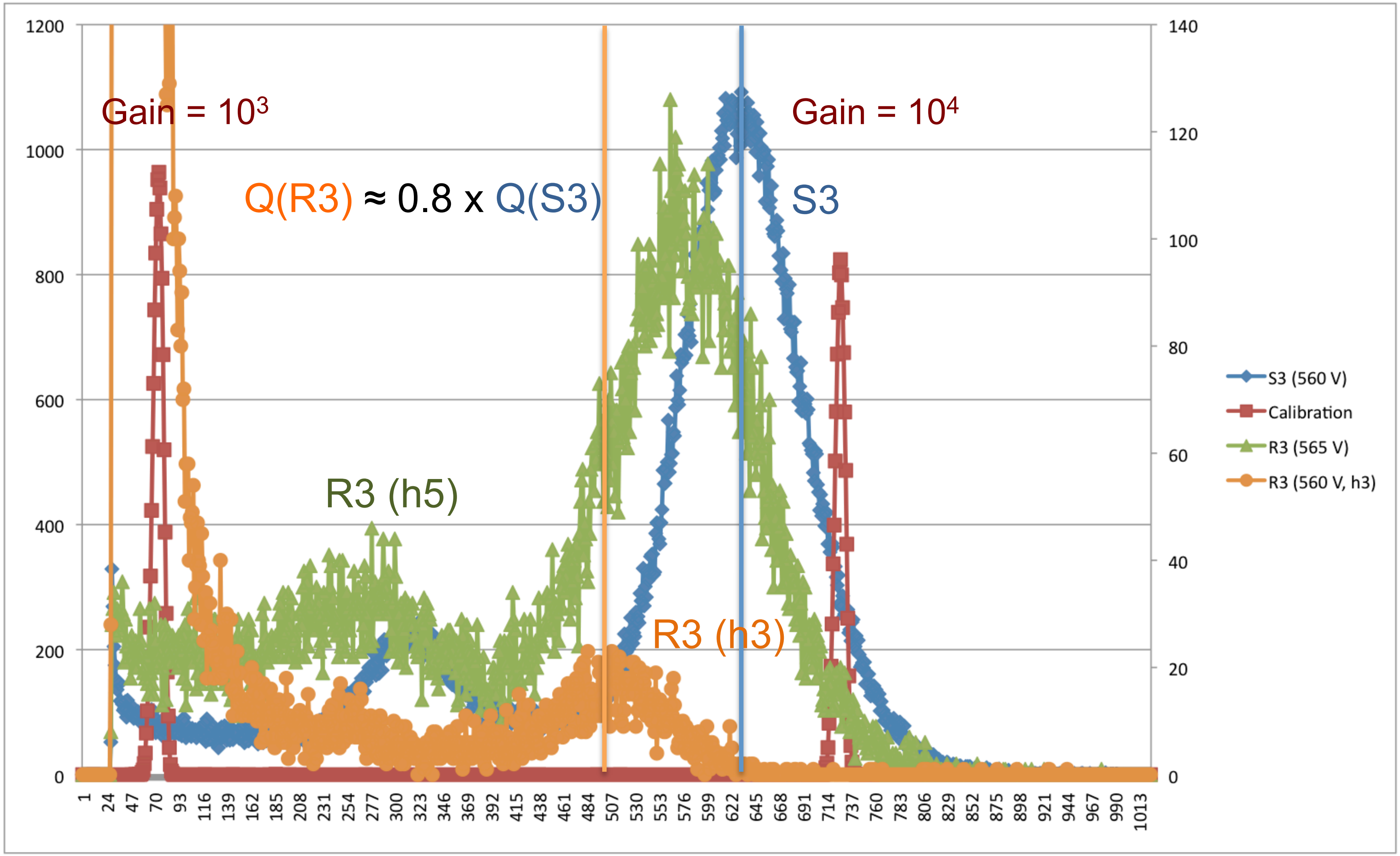
Likely explanation

- Bad contact b/w small pads and resistive paste => large resistance
- Charge build-up on pad
- Reduced potential b/w mesh and pad => Smaller amplification

➪ 2nd lesson: pads must have a reliable contact with resistive layer



The response of R3 vs S3

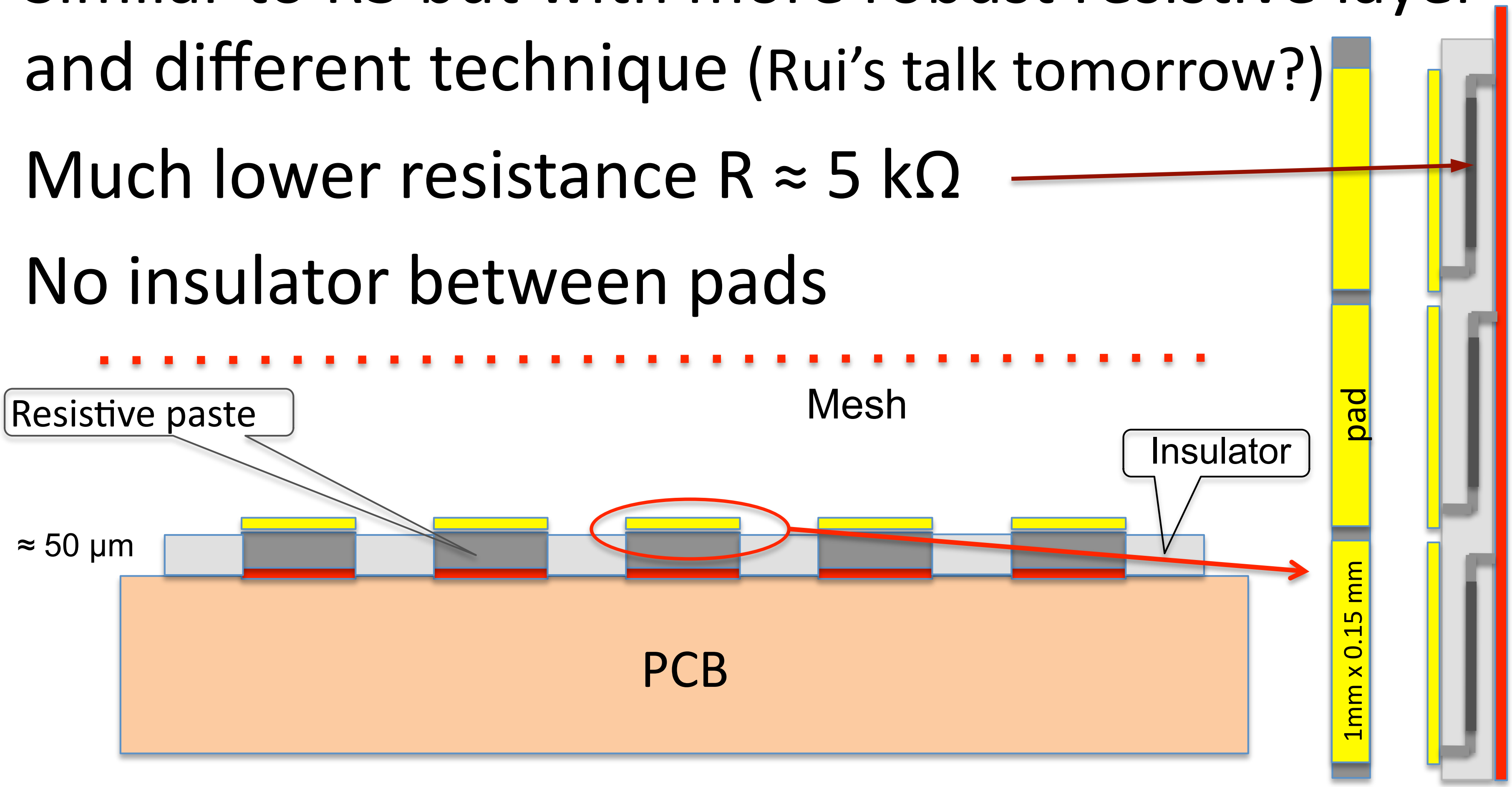


Conclusions on R3

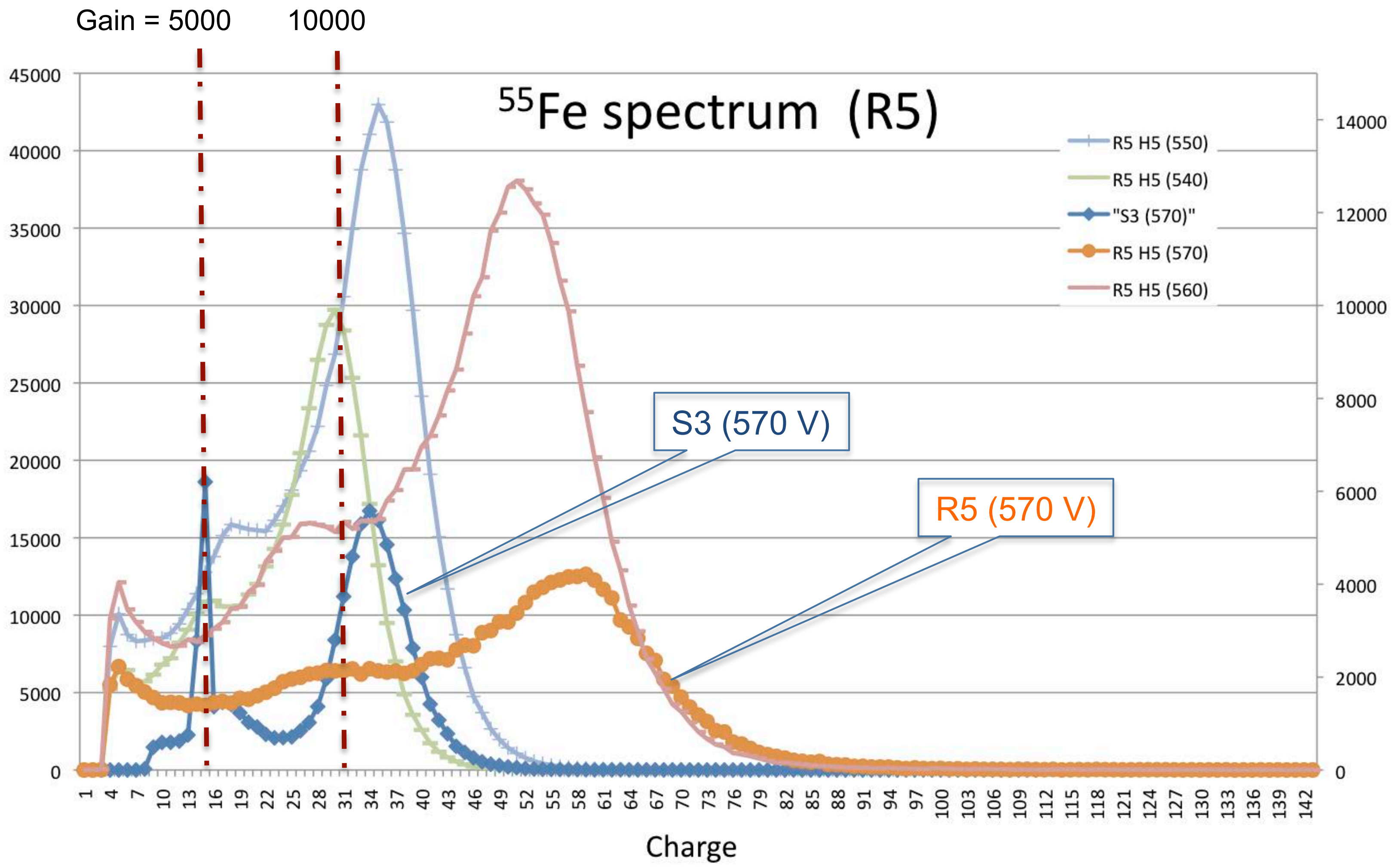
- R3 seemed to almost do what we want … for 'good' pads, and as long as it did not break
  - Signal almost as large as with non-resistive S3
  - But: low efficiency & high break-down rate
- Technical problems
  - Bad electrical pad contacts
  - Inhomogeneous resistive paste => burned pads

R5

- Similar to R3 but with more robust resistive layer and different technique (Rui's talk tomorrow?)
- Much lower resistance R ≈ 5 kΩ
- No insulator between pads

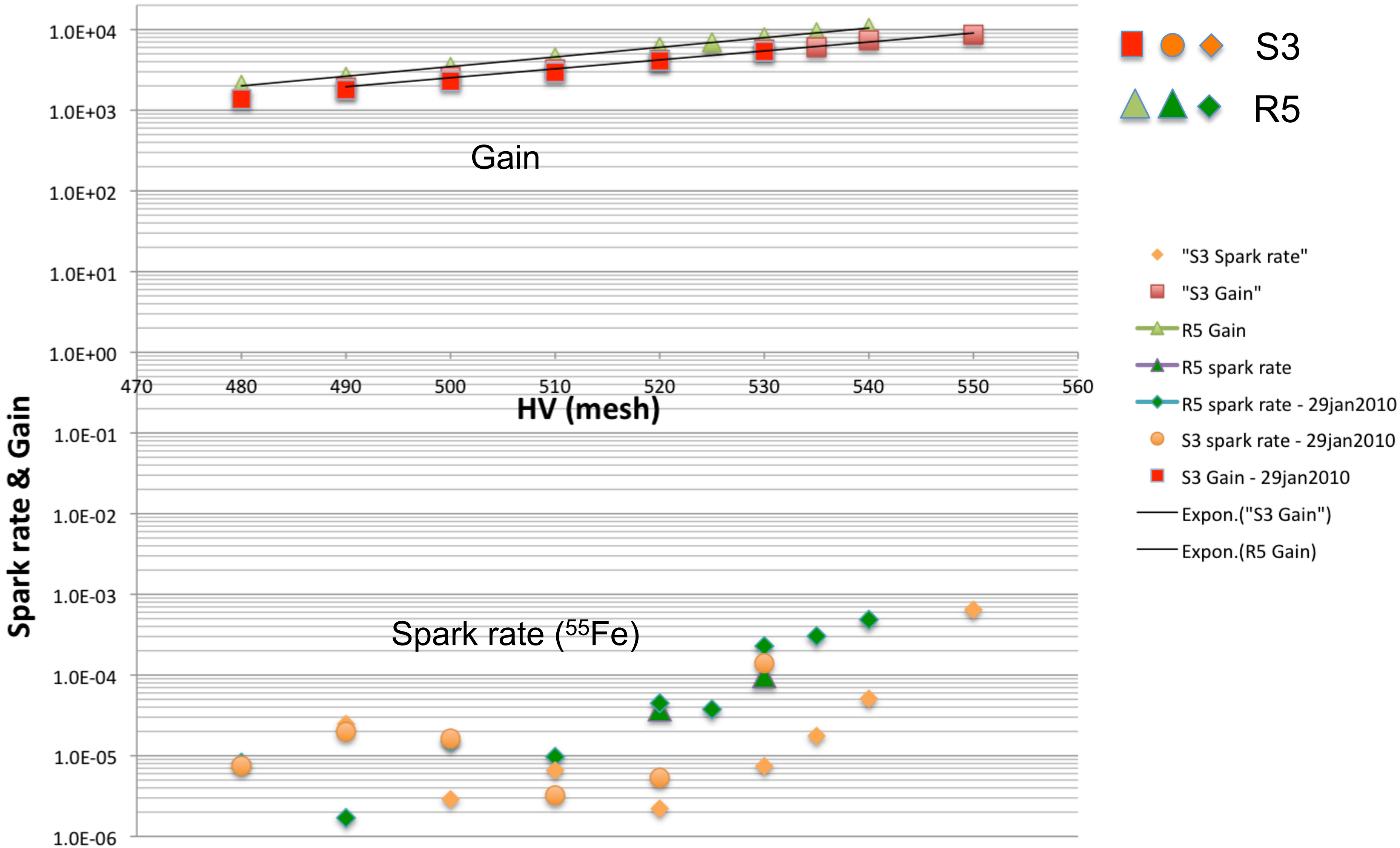


R5 spectra



Gain = 5000
10000
^{55}Fe spectrum (R5)
R5 H5 (550)
R5 H5 (540)
"S3 (570)"
R5 H5 (570)
R5 H5 (560)
S3 (570 V)
R5 (570 V)
Charge
45000
40000
35000
30000
25000
20000
15000
10000
5000
0
14000
12000
10000
8000
6000
4000
2000
0

Comparison S3 (non-resistive) & R5 (resistive, 5 kΩ)



R5: preliminary conclusions

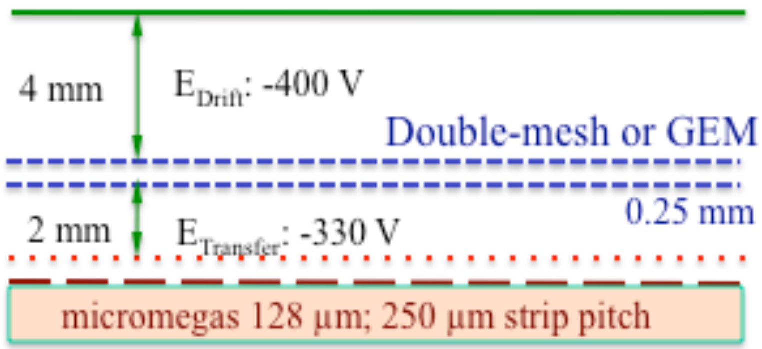
Measurements with ^{55}Fe source (and 8 KeV Cu x-rays)

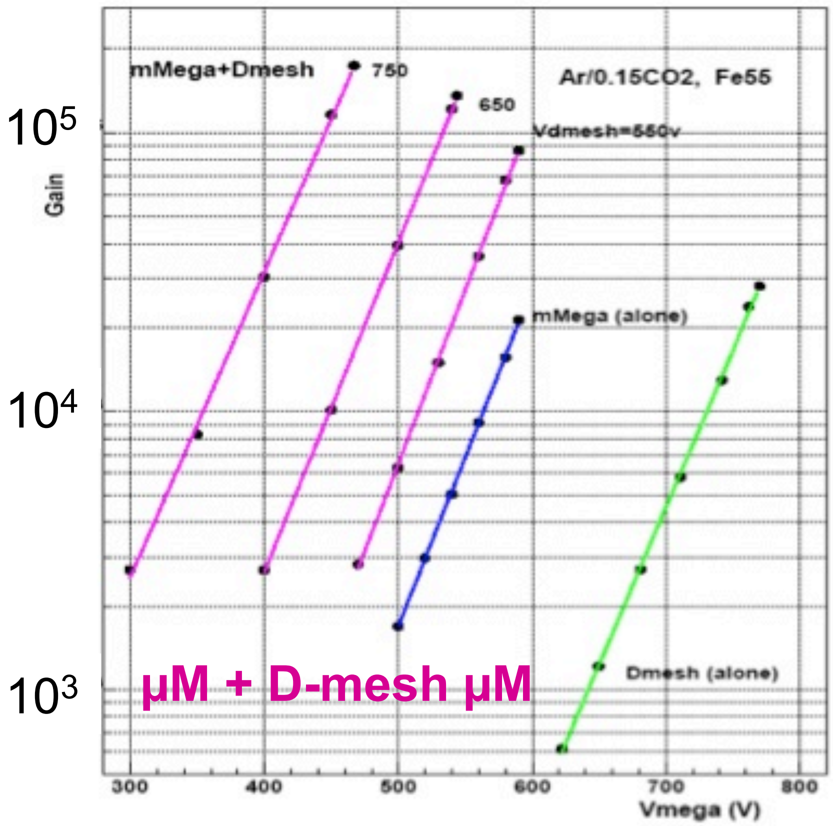
- Robust, no breakdown observed so far (despite lots of sparks)
- Performance:
  - R5 signal 50–100% larger than S3 signal (for comparison: R3 ≈ 0.8 x S3 !)
  - Charge resolution somewhat worse than for S3 (and R3) – may be an artefact of chamber construction (rows with many pillars at 1mm dist.)
- Sparking:
  - Sparking rates comparable to those of chamber w/o resistive coating (S3) for same 'gain'
  - Large currents (several µA) and HV drops (100–200 V), similar to S3

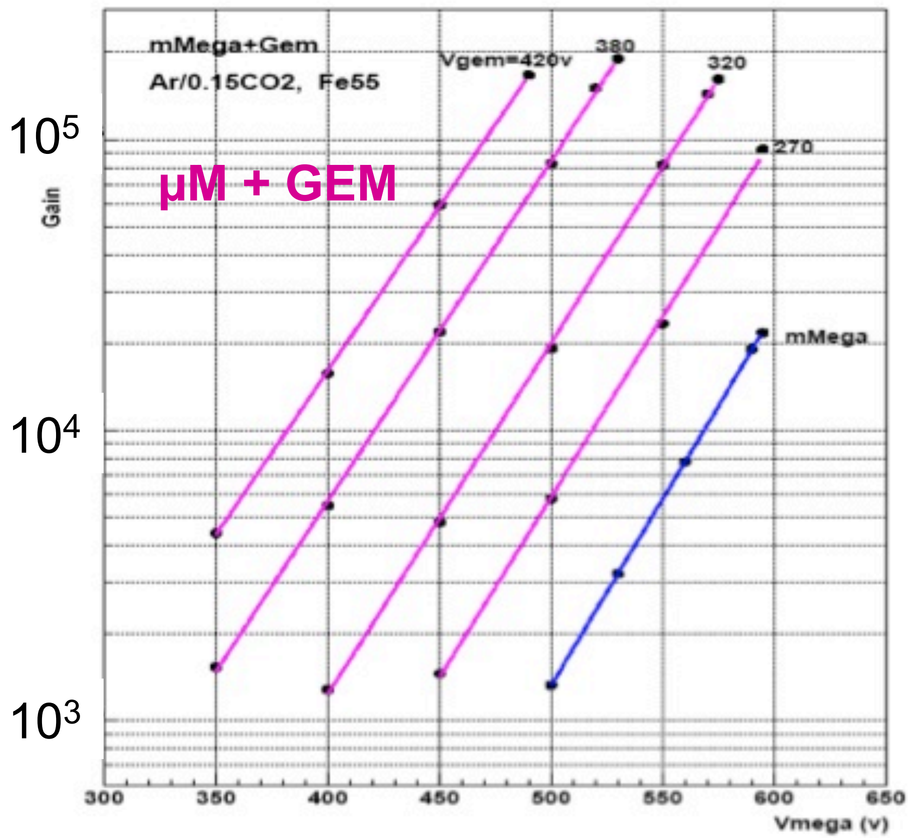
R5 does not fulfil our requirements

Two-stage amplification with µM + GEM/µM

- Measurements with ^{55}Fe source (V. Tcherniatine, similar results by M. Villa)
- Can reach factors of 10–100 in gain





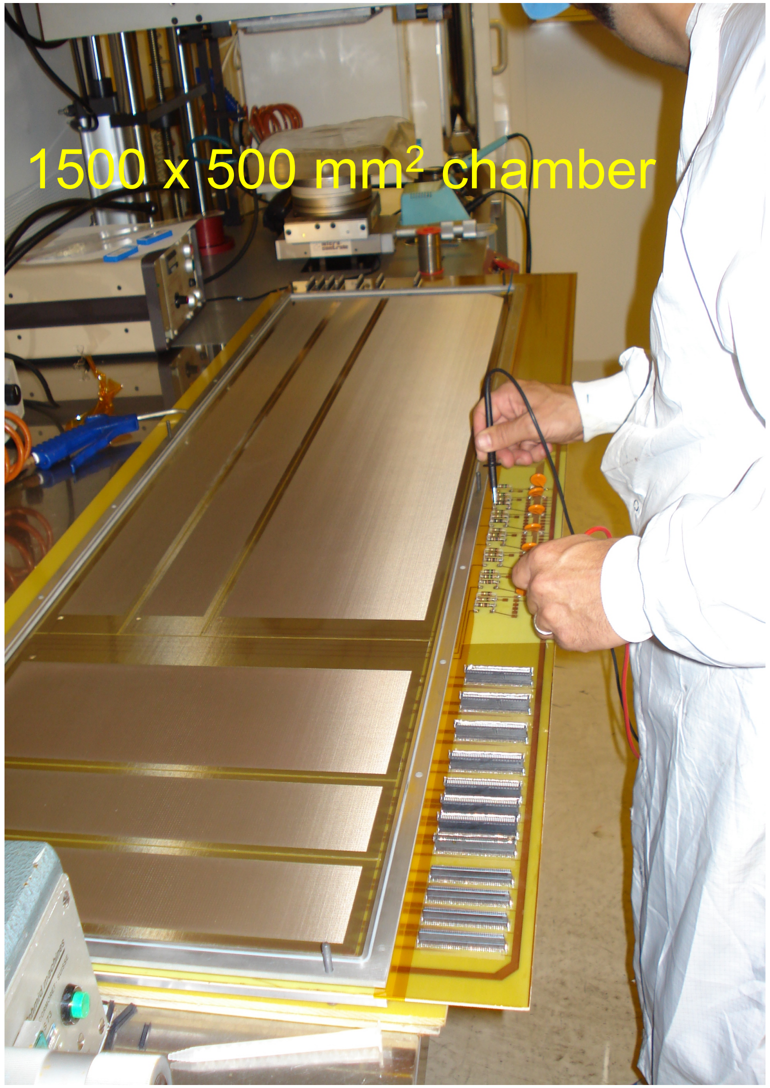


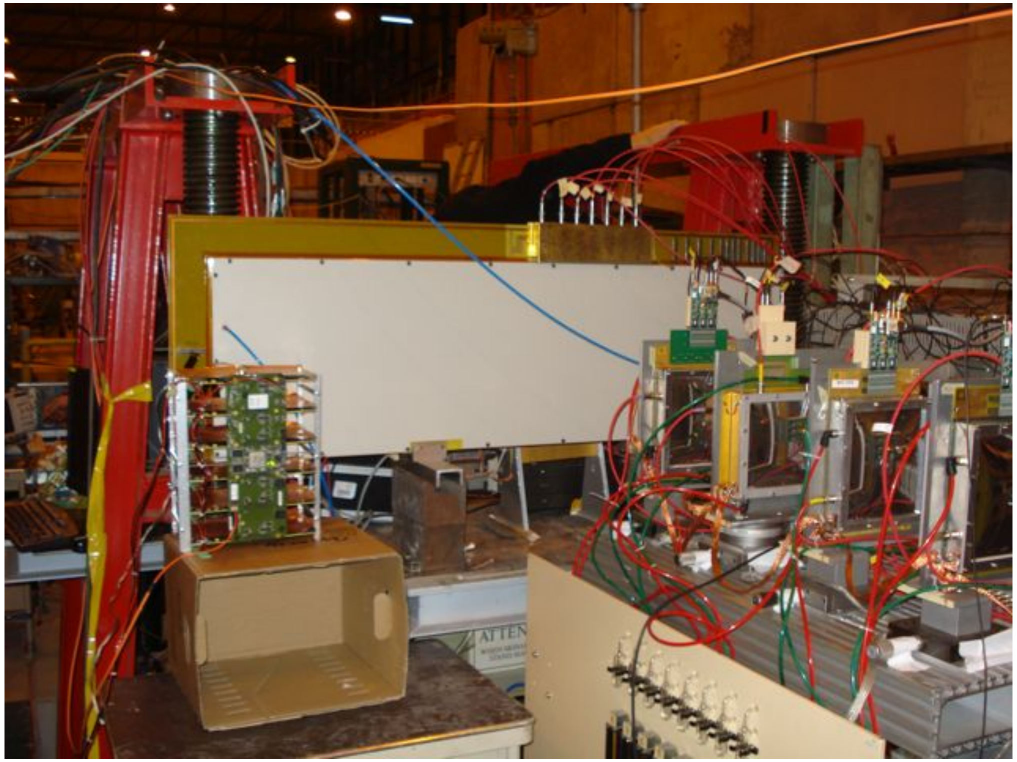
Conclusions on pre-amplification

- Pre-amplification with GEM foil or/and µM can give a factor 10–100 in gain
- Possibility to operate µM at lower HV leading to lower discharge rates
- Discharge rates still in 10^{-6} to 10^{-5} range; probably not sufficient for stable operation at sLHC
- Does not solve problem of large currents and HV drop when sparks occur; needs additional current limitation
- Also: double stage chambers more complicated to construct

Still, pre-amplification is an option to be pursued

Towards a full-size micromegas



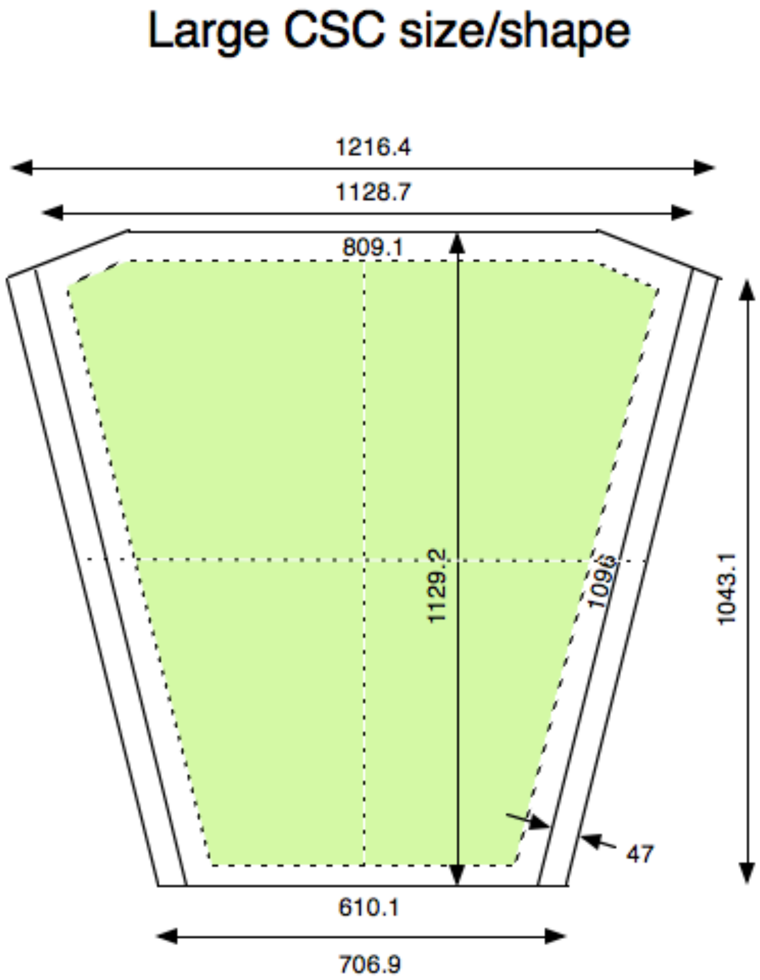


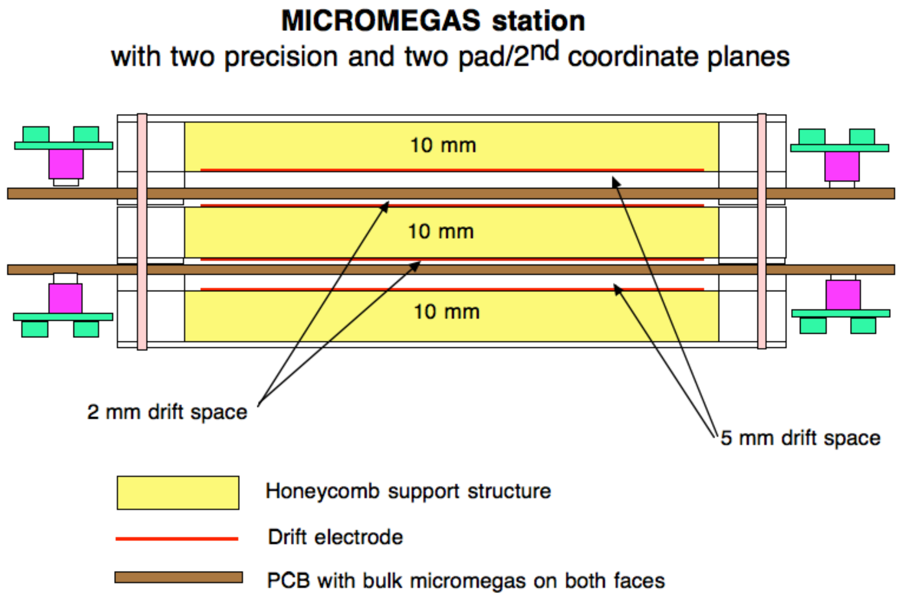
H6 Test beam Nov 2009

P3:

- strips 400 and 1000 mm long
- strip pitches 250 and 500 μm
- six mesh sections

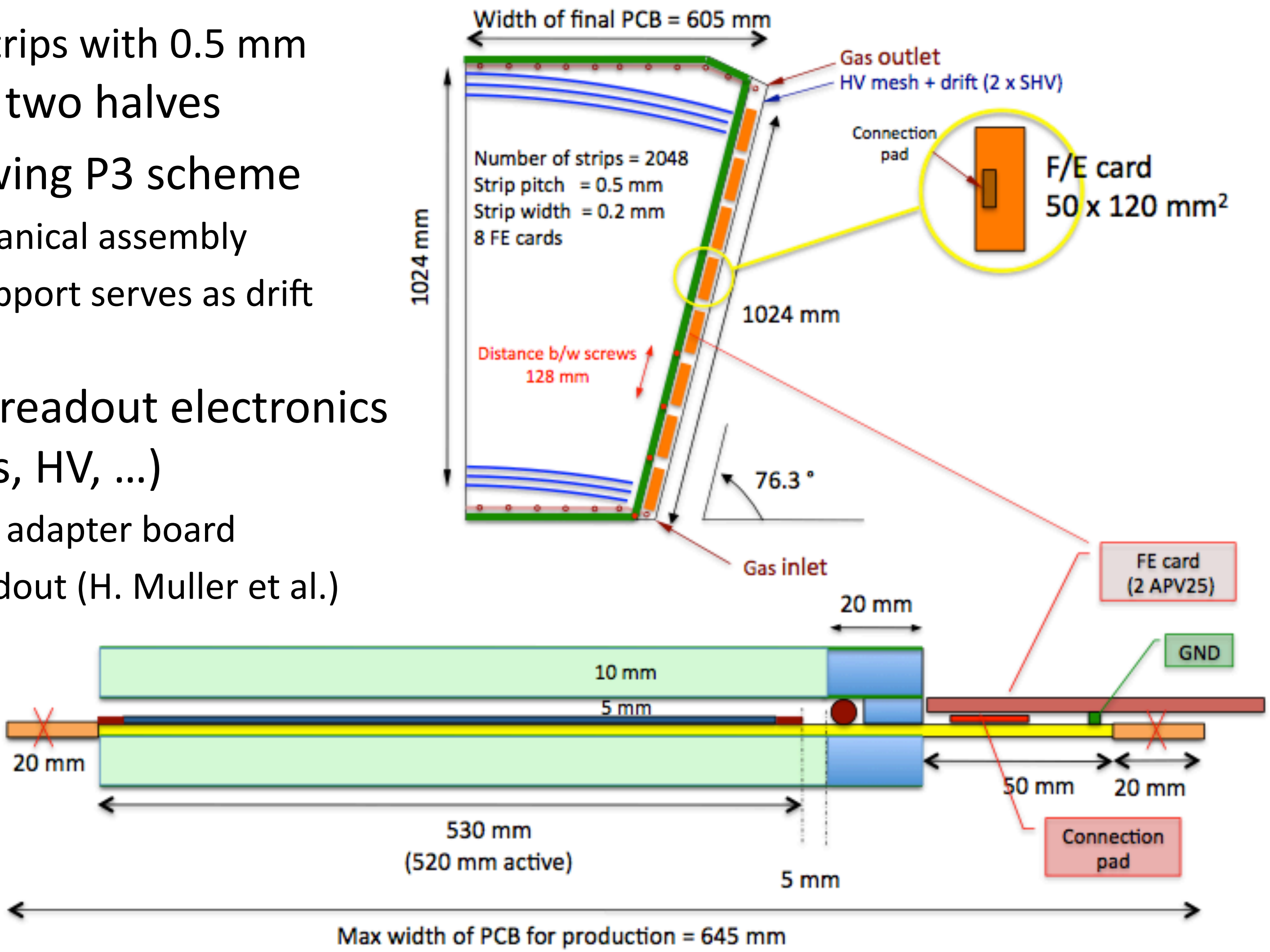
ATLAS-size µM muon chambers for Phase I





Under construction: CSC-size micromegas

- Full-size, single-plane
- µM (2 x 2048 strips with 0.5 mm pitch) made of two halves
- Housing following P3 scheme
  - simple mechanical assembly
  - structural support serves as drift electrode
- Integration of readout electronics & services (gas, HV, …)
  - F/E: APV25 + adapter board
  - Scalable Readout (H. Muller et al.)



In summary

- Main problem for micromegas (or GEMs) in LHC is sparks induced by heavily ionizing particles
- Some progress in resistive coating schemes, but: the ultimate spark neutralization scheme not yet there …More tests in the coming weeks …
- Double-stage amplification allows us to operate µMs at much lower HV and therefore lower spark rate, stays an option …
- First full-size prototype (1.2 x 1.2 m^2) is under construction; it will address issues of on-chamber services and electronics integration and industrial production.