Large-area Micromegas with embedded resistors, a uniformity study

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on behalf of the SCREAM Common Project consortium*

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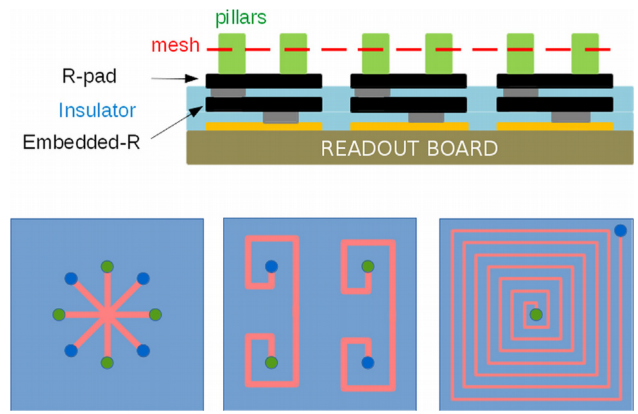
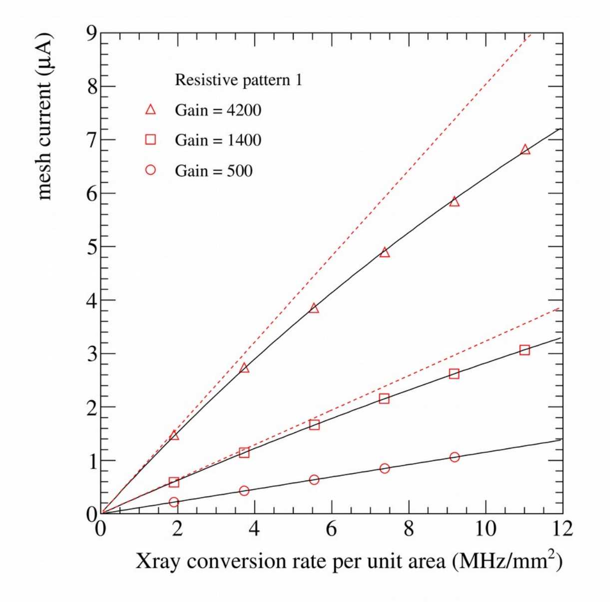
Overview

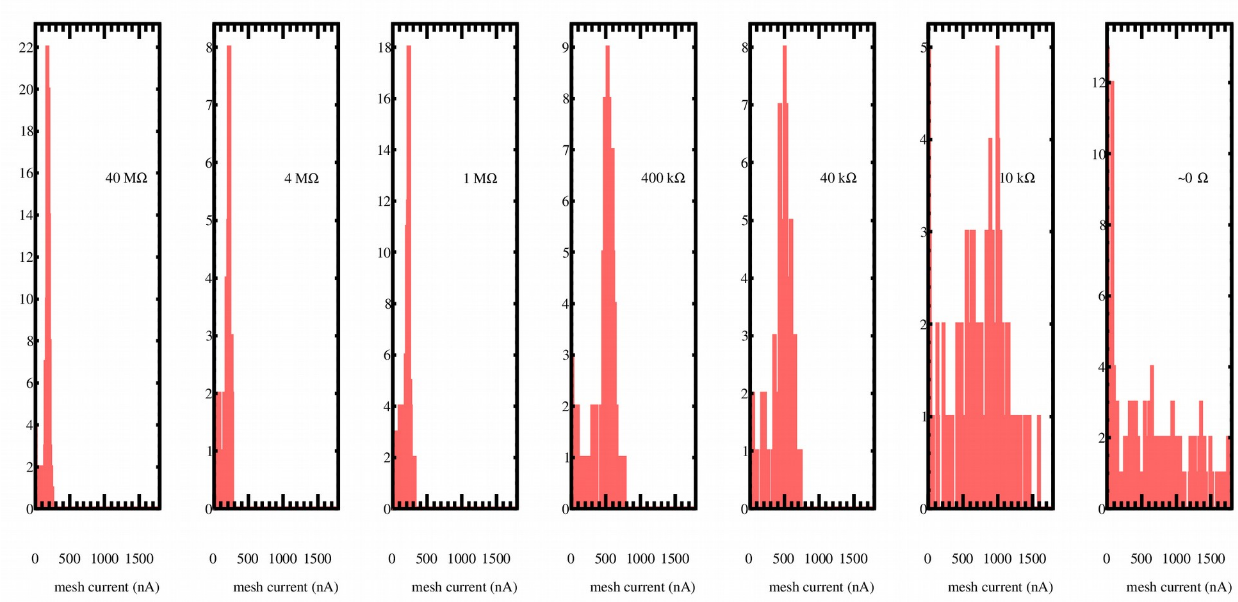
- Introduction
  - Embedded resistors & past results
- Experimental setup
  - New prototypes
  - Testbeam, August 2018
- Position scan
  - Data sample
  - Data analysis
- Results
  - Efficiency maps
  - Correlation with thresholds
- Outlook

Embedded resistors

- Principle: resistive pads → resistor → readout pad
  - Spark suppression & high-rate capability (NIMA 824 (2016) 510)
- R&D scope: LC PF-calorimetry or HL-LHC tracking
- First prototypes: 10x10 cm² with Gassiplex RO
  - Response VS rate (Ohm's law, left plot)
  - Sparking VS resistance (threshold effect, right plot)
- Now: scale size up & build a small calorimeter



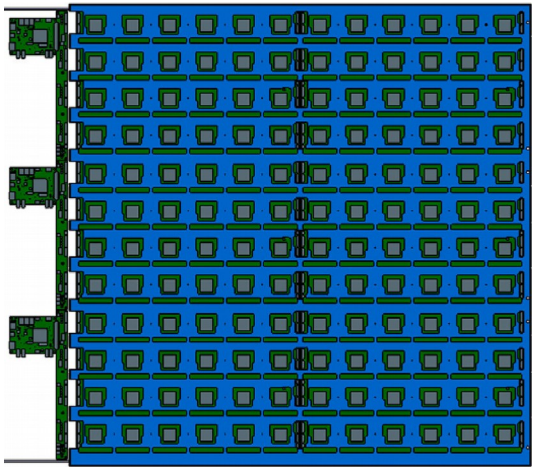




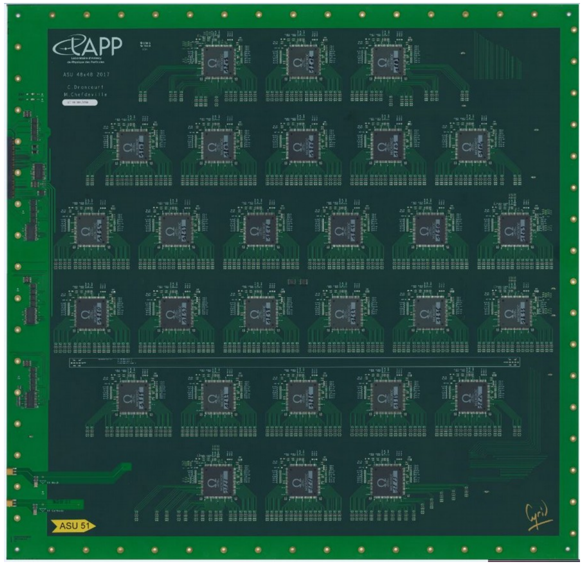
New prototypes

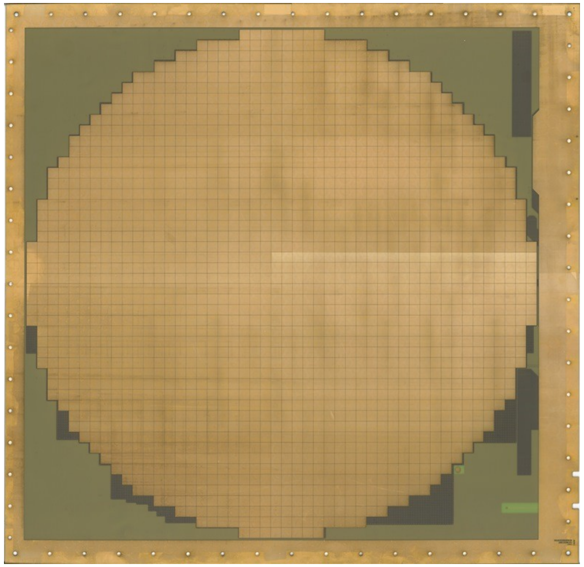
- Modif. of previous design used for 1x1 m^2 prototypes (Active Sensor Unit, ASU). Integrate inter-DIF board & remove flex connectors:
  - 28 MICROROC (x64 channels with 3 thr) → 1792 pads of 1x1 cm^2 (with or w/o diodes)
  - 60 pins connector to DIF readout board, 2 HV connectors
- Productions shared between Micromegas and RPWELL:
  - in 2017: 5 ASU (3 with diodes + 2 without)
  - in 2018: 7 ASU (6 with + 1 without)

Shower axial symmetry
→ circular matrix of pad
r = 24 cm → S = 0.18 m^2



1x1 m^2 prototype
NIMA 729 (2013) 90





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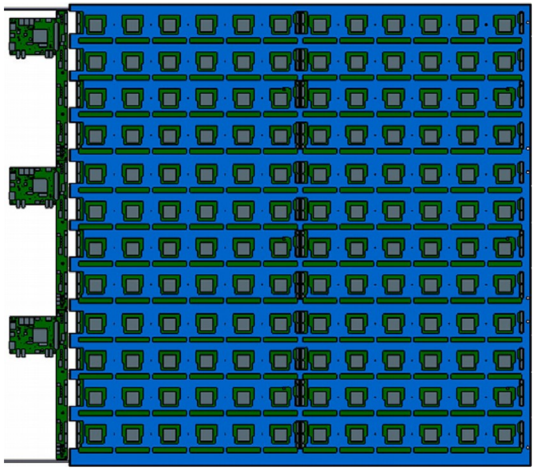

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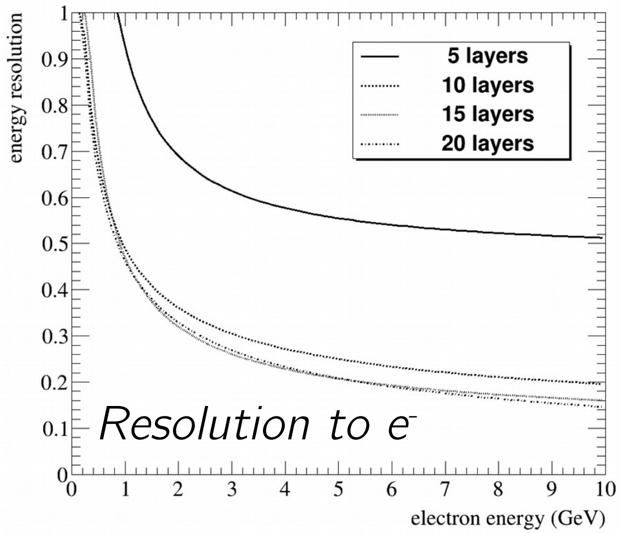
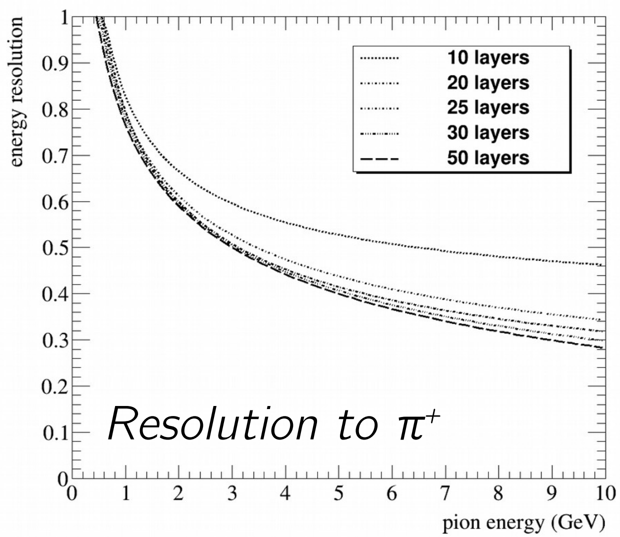
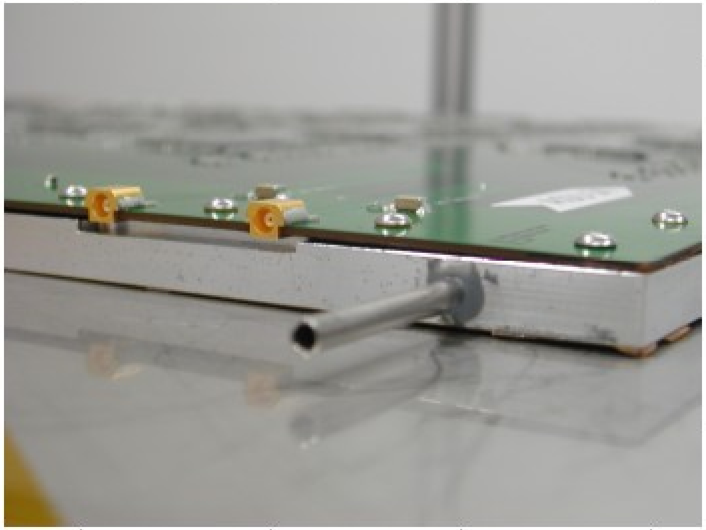
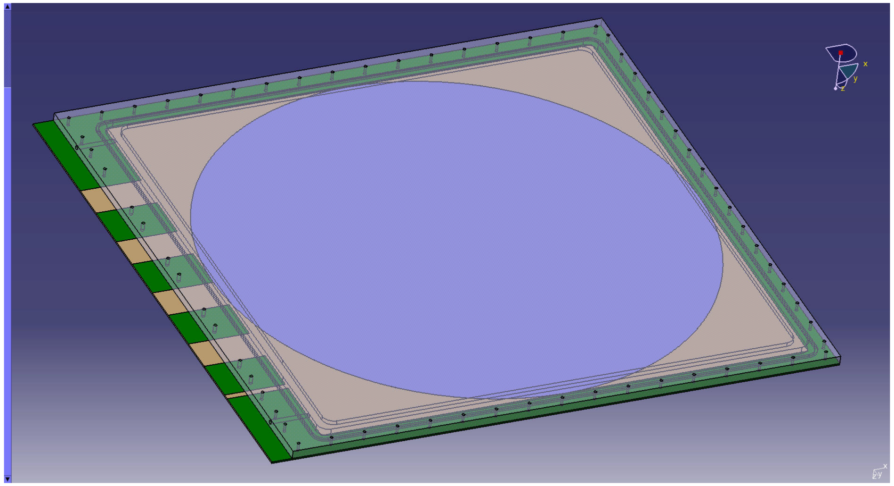


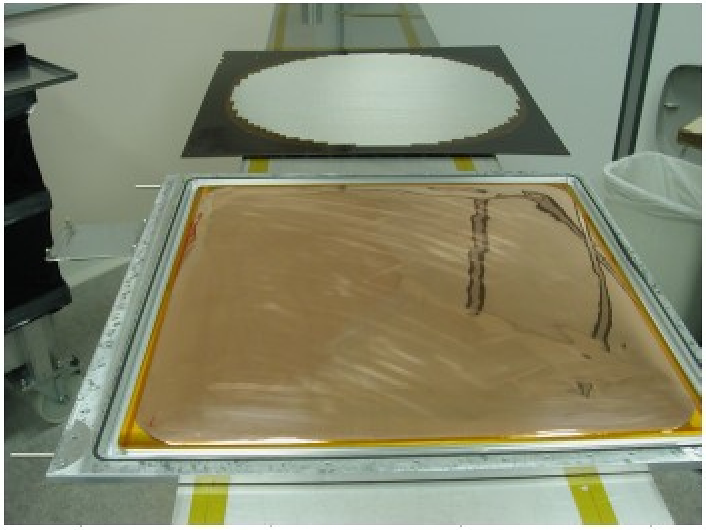


Mechanical design

- Possibility to open the chamber (for now)
  - No glue but screws + o-ring for gas tightness
- Aluminum cover on top of the Bulk
  - 3 mm drift gap, 0.75 L volume
  - cathode = kapton + Cu-kapton foils
  - add steel support for the DIF board
  - add grounding steel plate on the backside

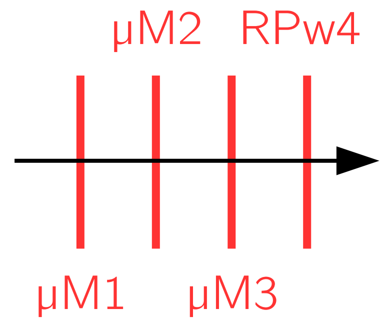






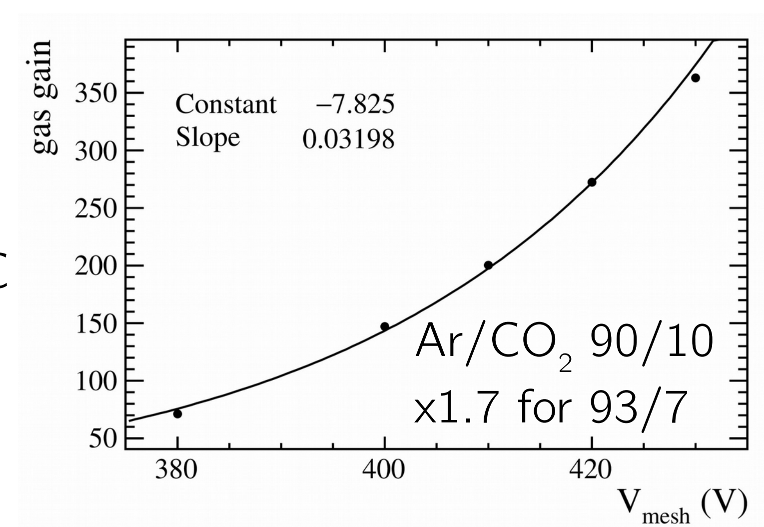
Testbeam, August 2018

- H4 RD51 beam line, 2 weeks, downstream of all setups
  - Structure with 3 Micromegas + 1 RPWELL on XY-table
  - 2 triggers: 3 PMT or RD51 telescope placed right upstream
  - Gas mixture: Ar/CO_2 93/7 distributed in parallel
- Many thanks to RD51 for:
  gas & CAEN mainframe & slow control
- First week lost due to HV cathode contacts, smooth running then



- Main measurements
  - Mesh voltage scans (150 GeV/c μ & π)
  - Threshold & position scans (μ)
  - Rate scans (π with & w/o absorbers)
- ASIC operating thresholds : 1 fC, 3 fC & 13 fC
- Operating voltages = 400-540 V

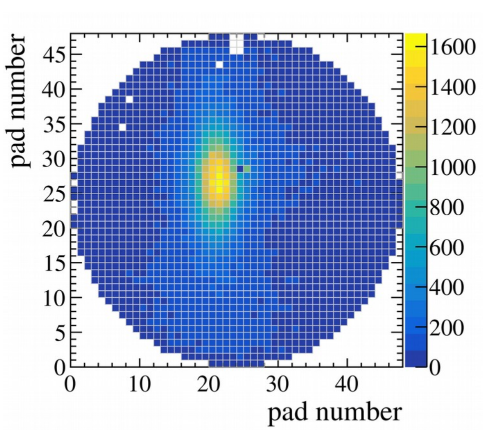
  → G = $2\text{x}10^2$ - $2\text{x}10^4$



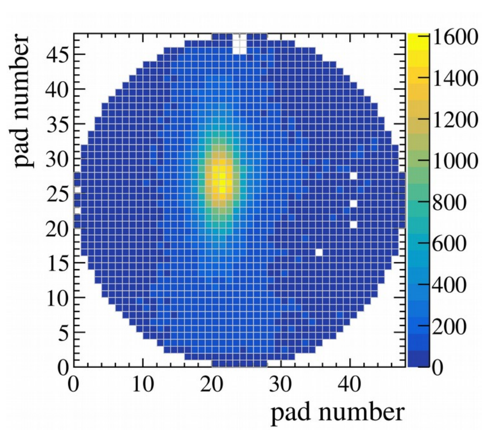
Hit selection, basics

- MICROROC: 5 MHz clock, hits stored in memory with BCID
- 2 operating modes of similar efficiency:
  - TB-like (ext. trigger): RO when trigger (resets when full)
    $\rightarrow$ useful with few layers, events accumulate @ fixed $\Delta t = t_{RO} - t_{HIT}$
  - ILC-like (int. trigger): RO when memory full
    $\rightarrow$ with several layers, events id'ed as peaks in time

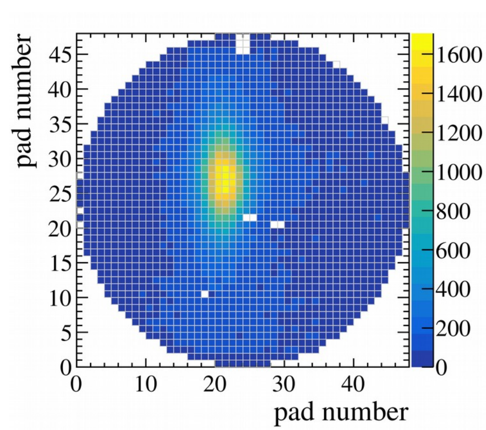
µM #1, 500 V
All hits



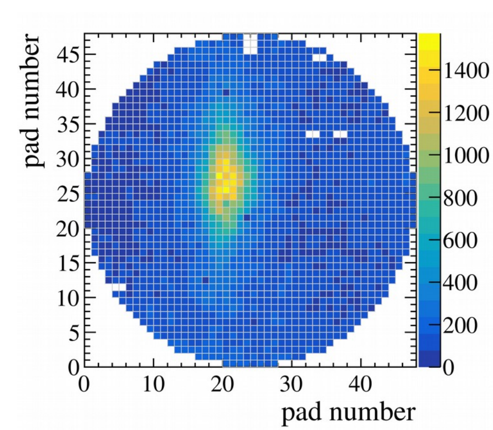
µM #2, 500 V
All hits



µM #3, 500 V
All hits



RPWELL, 1575 V
All hits



PS: @ 500 V, expect G = 6000, to be calibrated with threshold scan data

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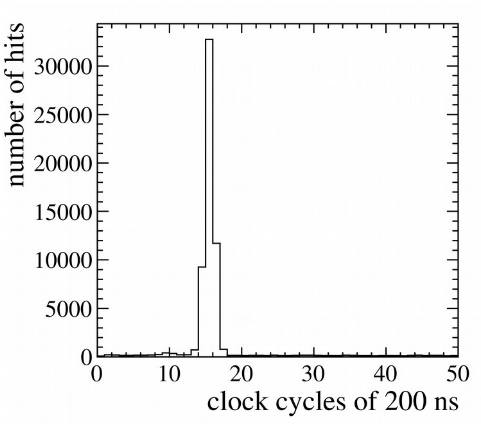
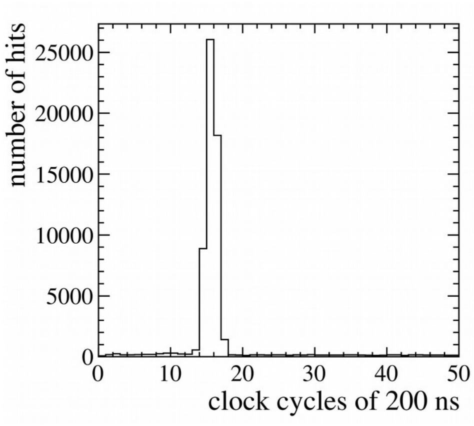
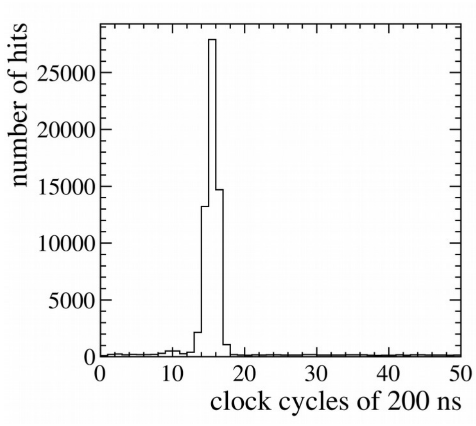
µM #1, 500 V
Δt distribution



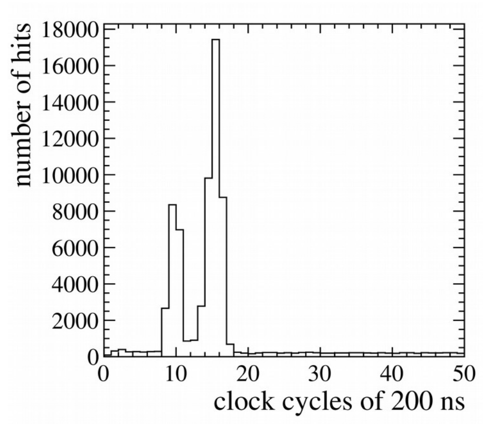
µM #2, 500 V
Δt distribution



µM #3, 500 V
Δt distribution



RPWELL, 1575 V
Δt distribution



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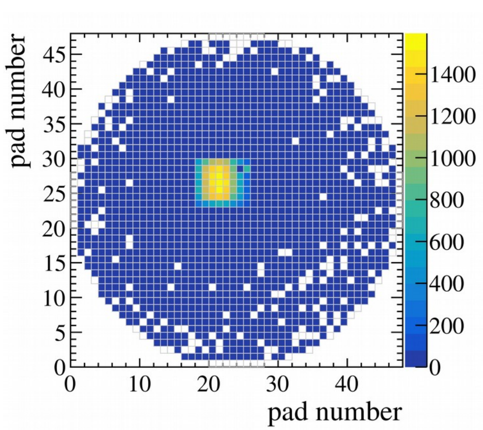
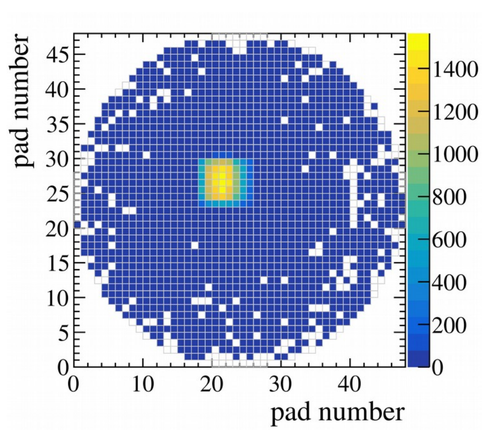
µM #1, 500 V
Δt hits



µM #2, 500 V
Δt hits



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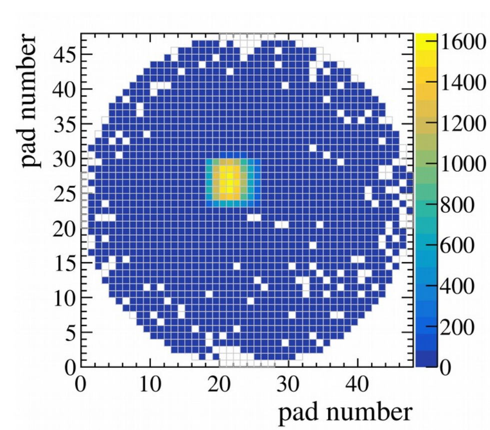

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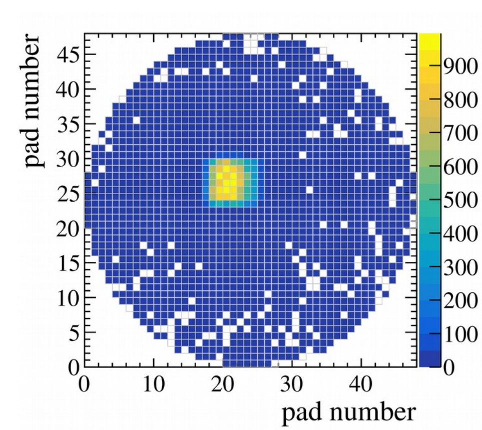
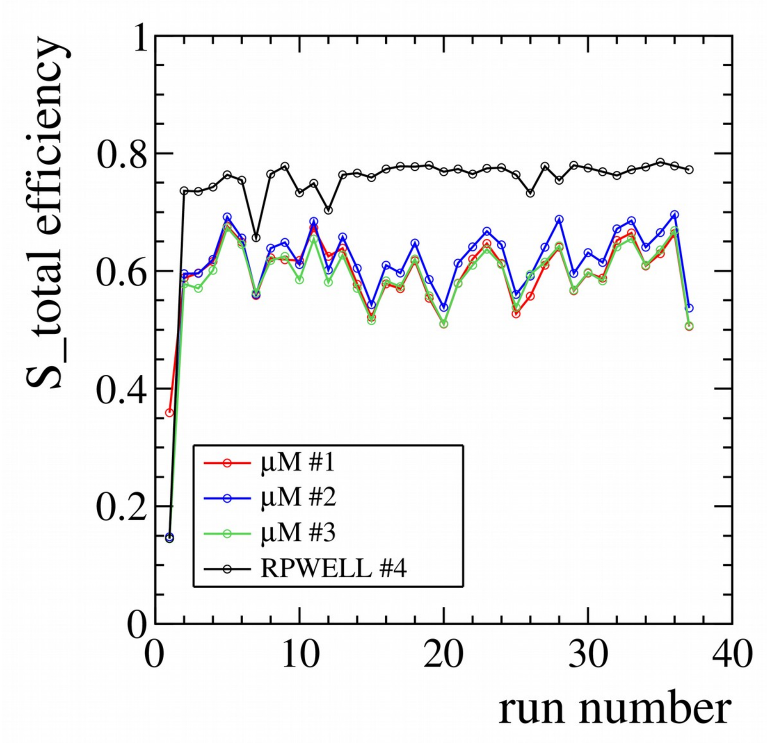
Δt hits



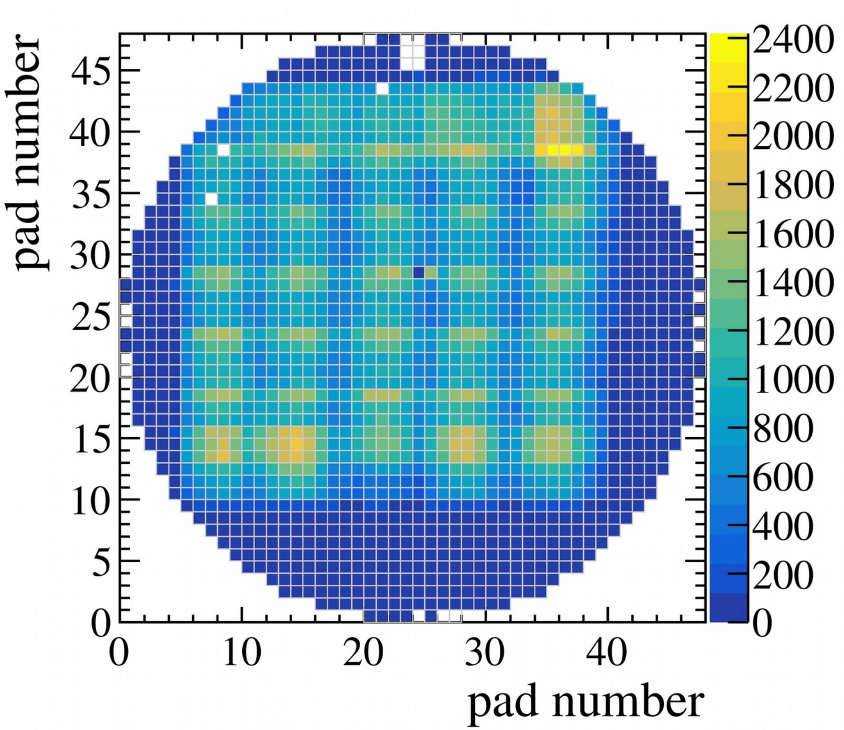
Position scan, sample & analysis

- Data sample: 5x7 positions, >25k triggers each, 28x28 cm² (table range of motion)
- Data analysis: find track in 3 chambers, test 4th one locally
- Total selection efficiency: ε(clean) x ε(telescope) x ε(MIP) x ε(ROI) x ε(track)

Sel_all: ε ~ 60%



All Δt hits, µM #1



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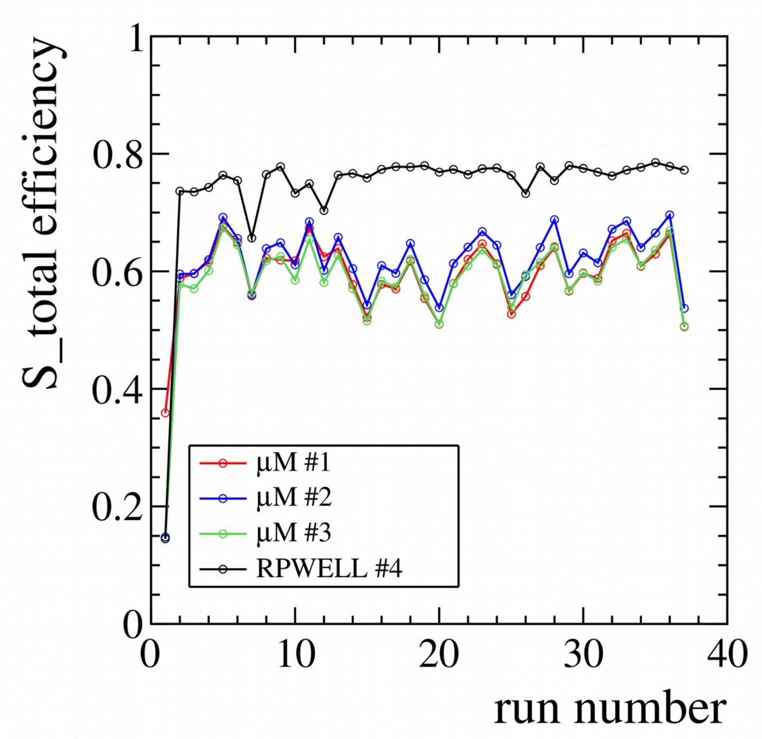
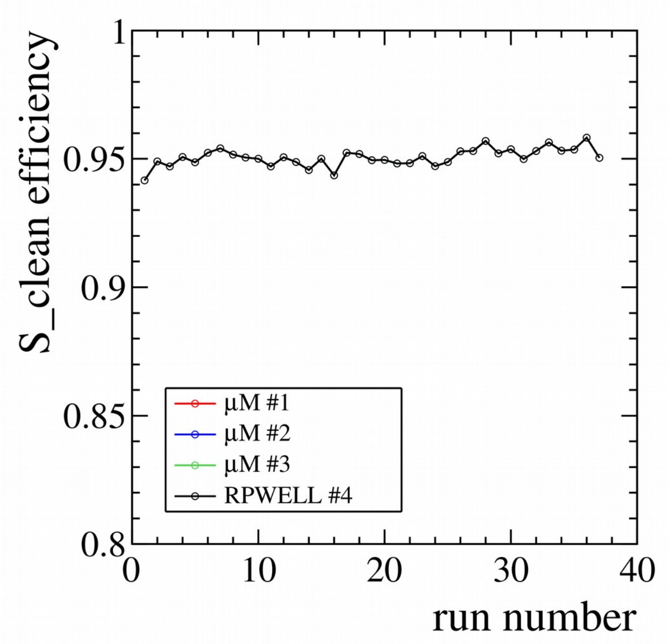


Sel_clean: [N_{hit} < 100]
ε ~ 95%



Dominated by RPWELL which is subject to HV instability leading to all pads firing.

Looks independent of where the beam crosses.

Position scan, sample & analysis

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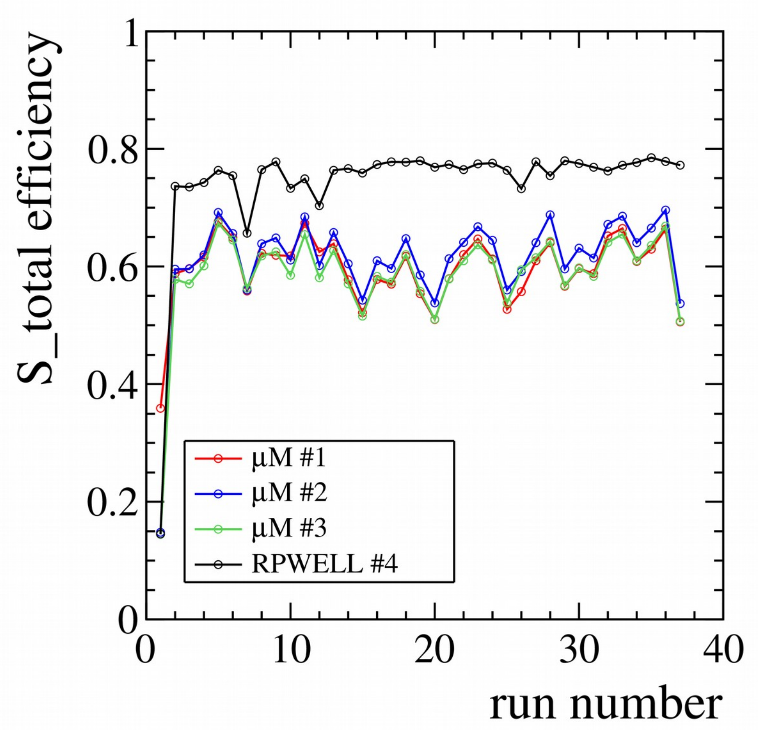
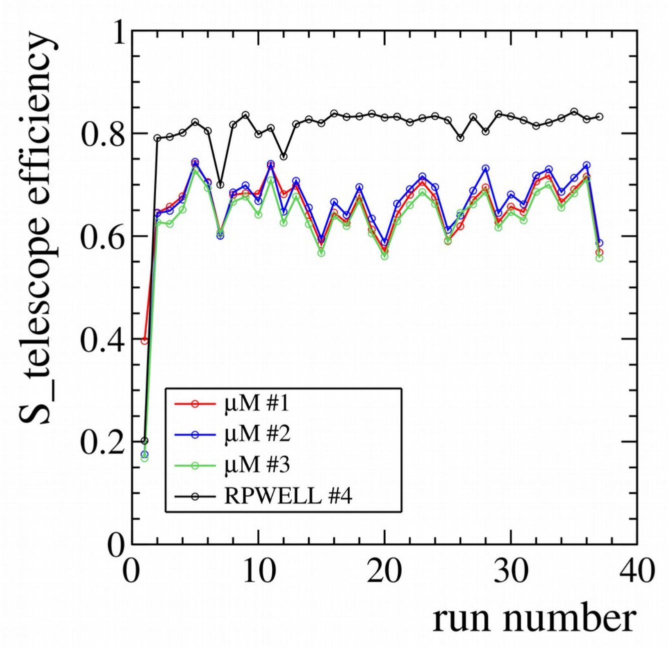


Sel_telescope: [$N_{hit-\Delta t} \neq 0$] in 3 chb
ε ~ 80% or 65%

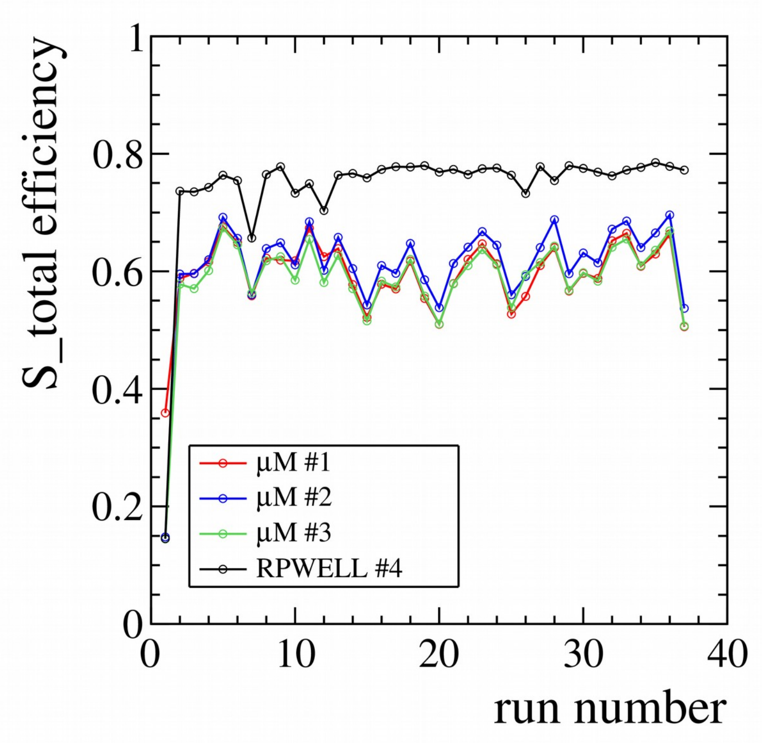


At the chosen voltages, the RPWELL efficiency is smaller than the µM efficiency, resulting in higher telescope efficiency for µM only.

Edge effects more pronounced when involving last chb.

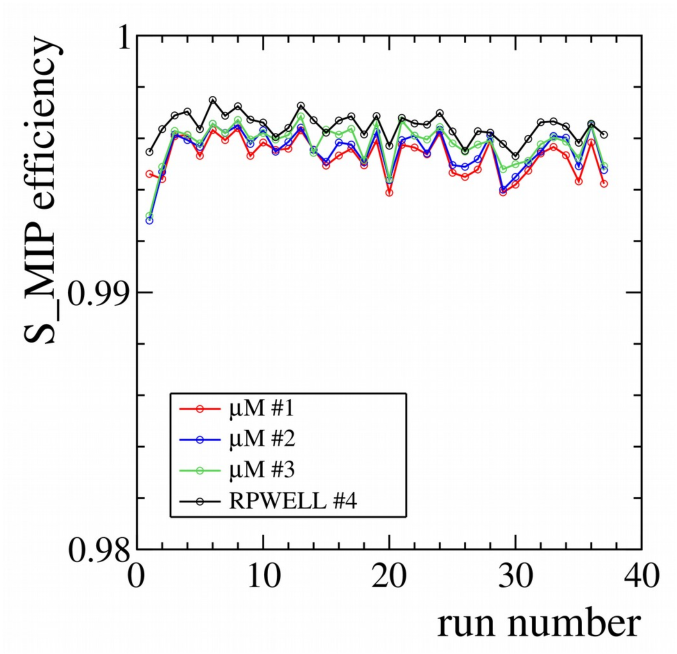
Position scan, sample & analysis

- Data sample: 5x7 positions, >25k triggers each, 28x28 cm^2 (table range of motion)
- Data analysis: find track in 3 chambers, test 4^{th} one locally
- Total selection efficiency: ε(clean) x ε(telescope) x **ε(MIP)** x ε(ROI) x ε(track)



Sel_MIP: [$N_{hit-\Delta t}$ < 10] in 3 chb

ε ~ 0.995



In case of π^+ contamination… which is probaly negligible.

Small increase of multiplicity from first to last chamber (in beam direction).

Position scan, sample & analysis

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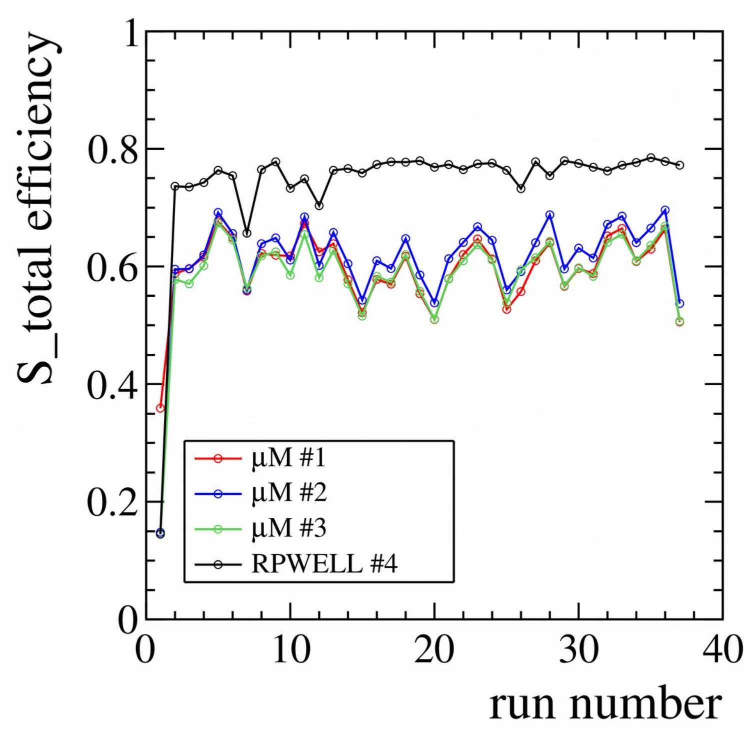
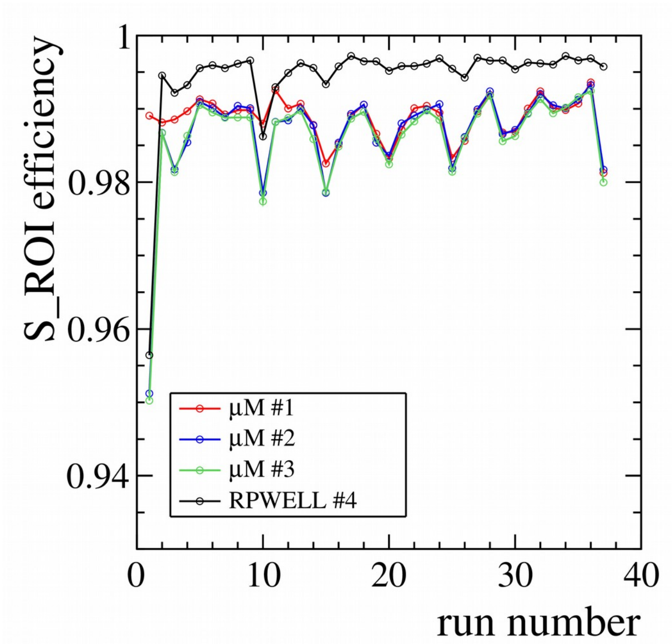


`Sel_ROI: [(x,y)`$_{hit\text{-}\Delta t}$ `⊂ ROI] in 3 chb`

`ε ~ 99.5% or 98.5%`



Remove noise hits

Region Of Interest taken as the area of the scintillator overlap (8x8 cm^2).

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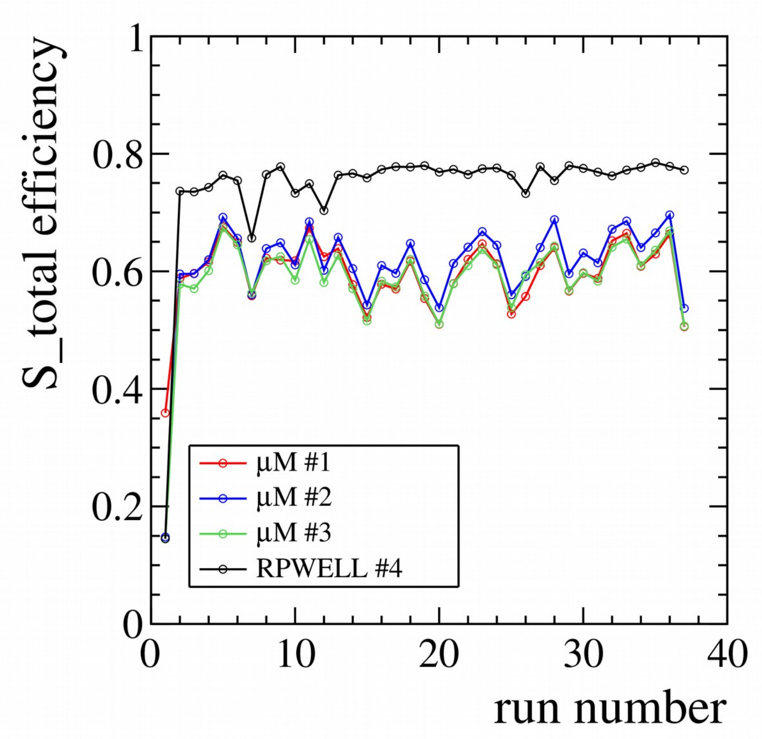
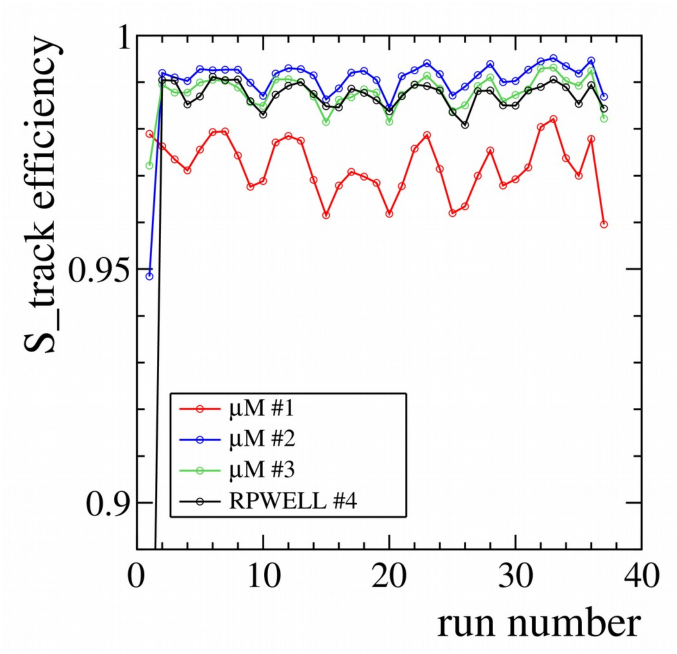


Sel_track: $[|a_{zx}, a_{zy}| < 2]$
ε ~ 99% or 97%



Fit 1D track param. in (xz) and (yz) planes. Cut = 2 pads for 2 adjacent chambers.

Is a fit quality cut: removes fits which would yield poor track extrapolation.

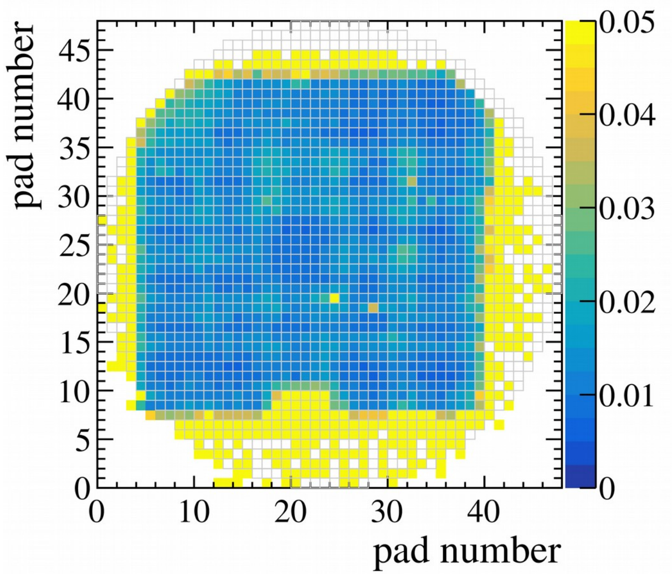
Edge effects: only straight tracks pass.

Efficiency maps - errors

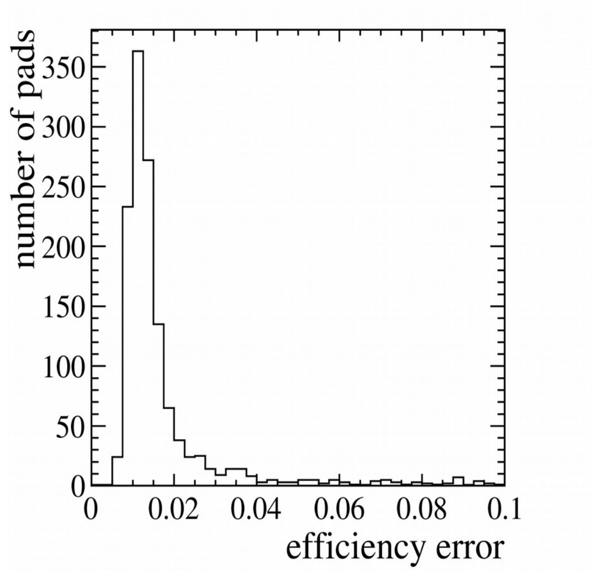
- For each track, the position in the test chamber is extra- or interpolated:
  - Efficiency & multiplicity are measured in a region of 5x5 cm²
- Plot only when $\sigma_\varepsilon < 5\%$ with $\sigma_\varepsilon = \sqrt{[\, \varepsilon.(1-\varepsilon) / N \,]}$

μM #1

σ_ε (thr0)



1D projection



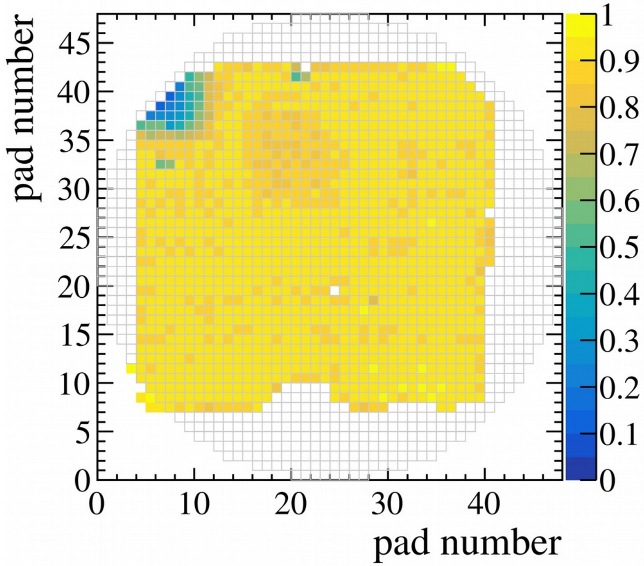
Most of the pads have a <2% error @ low threshold.

This increases slightly for higher thresholds: 3% for thr1 and 4% for thr2.

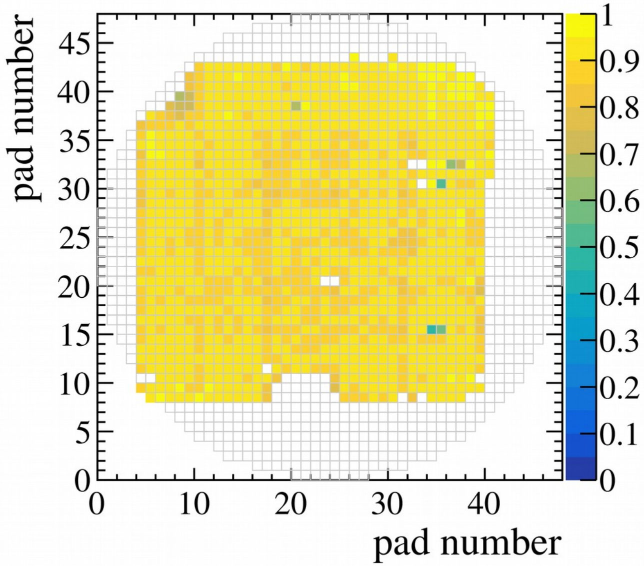
Efficiency maps - values

- For each track, the position in the test chamber is extra- or interpolated:
  - Efficiency & multiplicity are measured in a region of 5x5 cm^2
- Plot only when $\sigma_\varepsilon < 5\%$ with $\sigma_\varepsilon = \sqrt{[\,\varepsilon.(1-\varepsilon) / N\,]}$

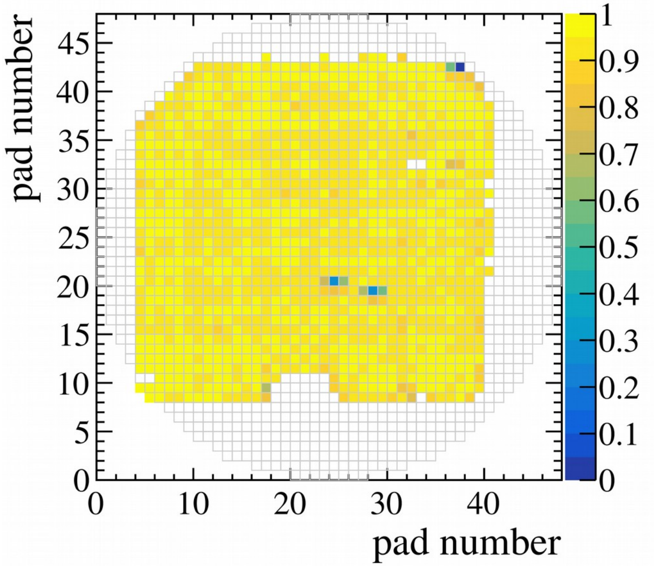
µM #1
ε(thr0)



µM #2
ε(thr0)



µM #3
ε(thr0)



Efficiency maps - values

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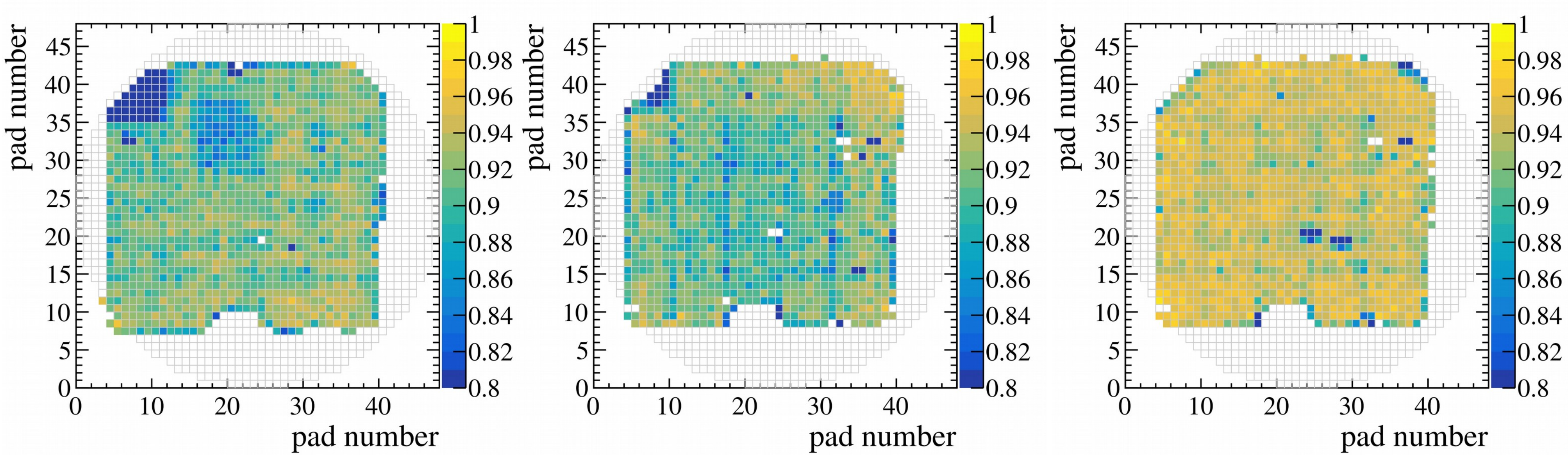
μM #1
ε(thr0)

μM #2
ε(thr0)

μM #3
ε(thr0)



- 1 zone with lower gain
- 1 ASIC with higher thr.

- vertical line pattern

- 4 noisy channels in the middle → embedded R?

Efficiency maps - values

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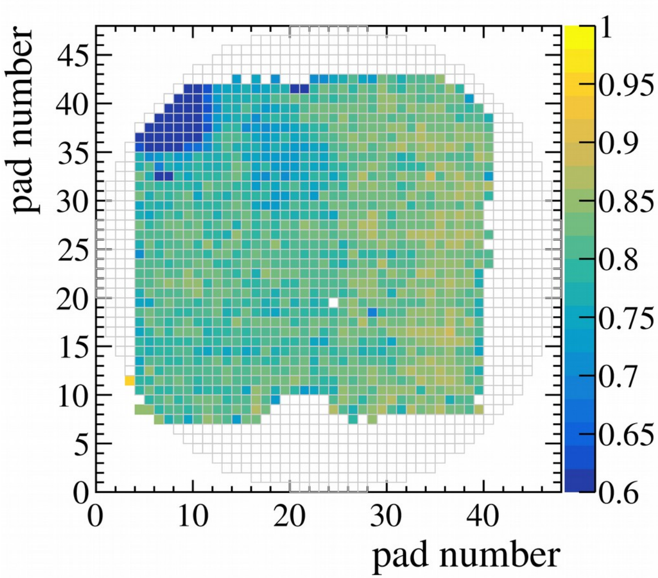
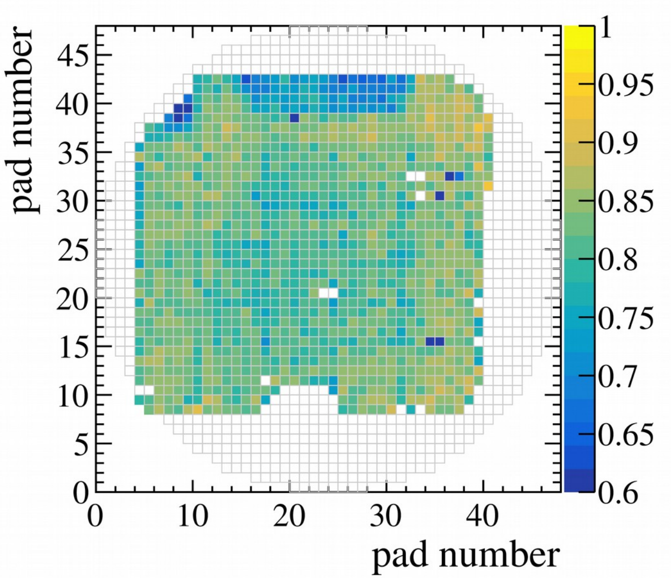
µM #1
ε(thr1)



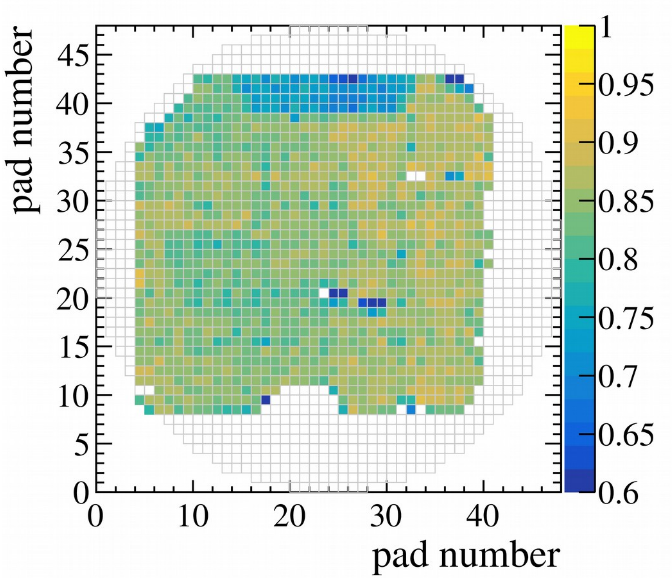
- 1 zone with lower gain
- 1 ASIC with higher thr.

µM #2
ε(thr1)



2 ASIC with higher thr

µM #3
ε(thr1)



2 ASIC with higher thr

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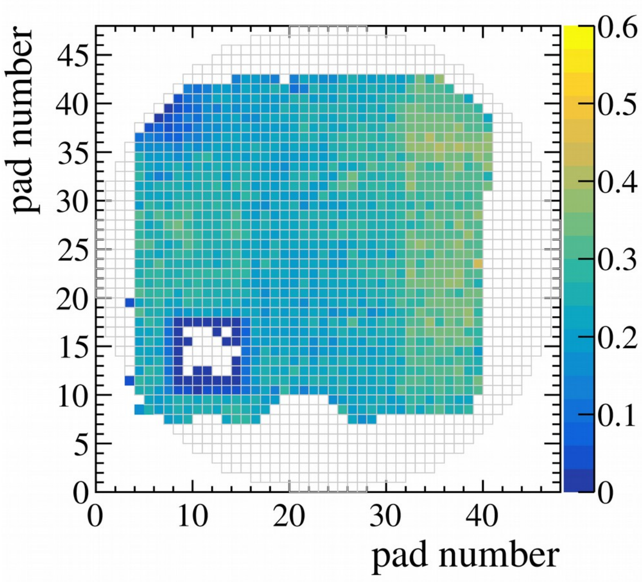
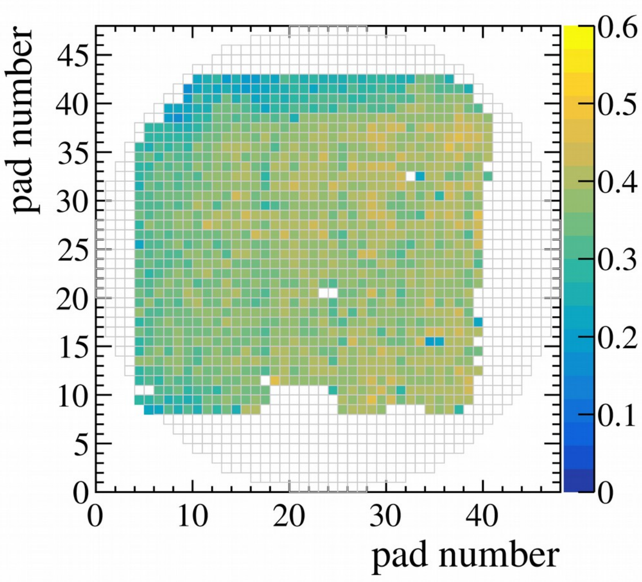
μM #1
ε(thr2)



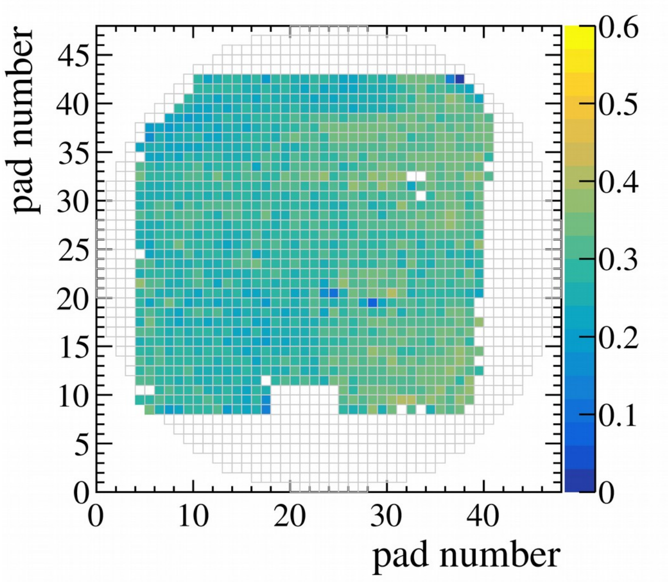
1 ASIC with wrong thr

μM #2
ε(thr2)



2 ASIC with higher thr

μM #3
ε(thr2)

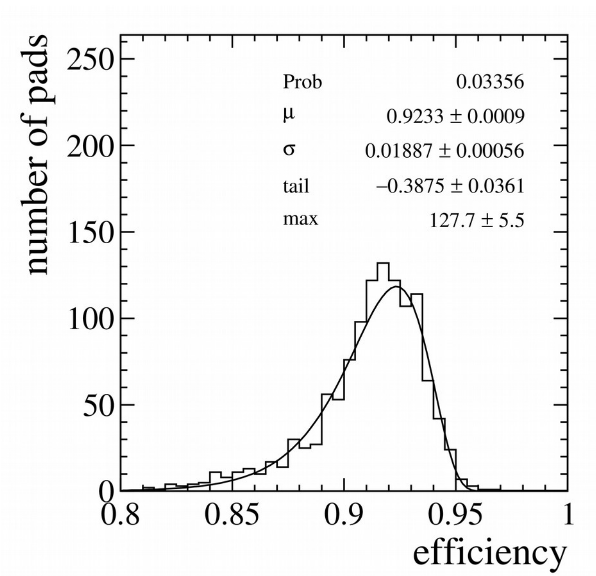


Fine

Efficiency maps - uniformity

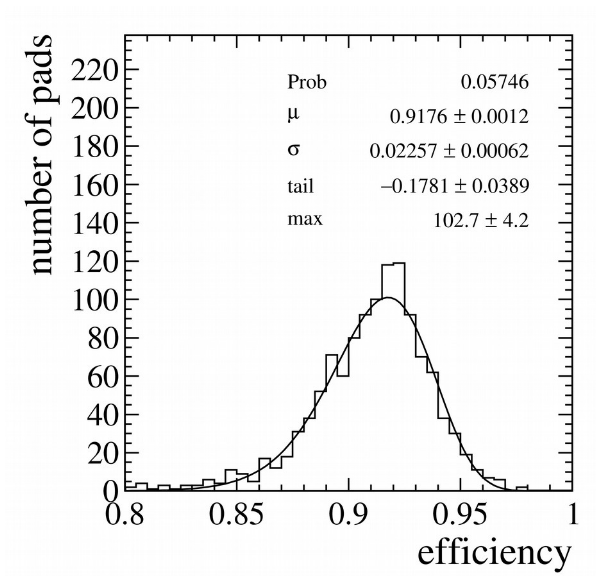
- For each track, the position in the test chamber is extra- or interpolated:
  - Efficiency & multiplicity are measured in a region of 5x5 cm^2
- Plot only when $\sigma_\varepsilon < 5\%$ with $\sigma_\varepsilon = \sqrt{[\varepsilon.(1-\varepsilon) / N]}$

μM #1
ε(thr0)



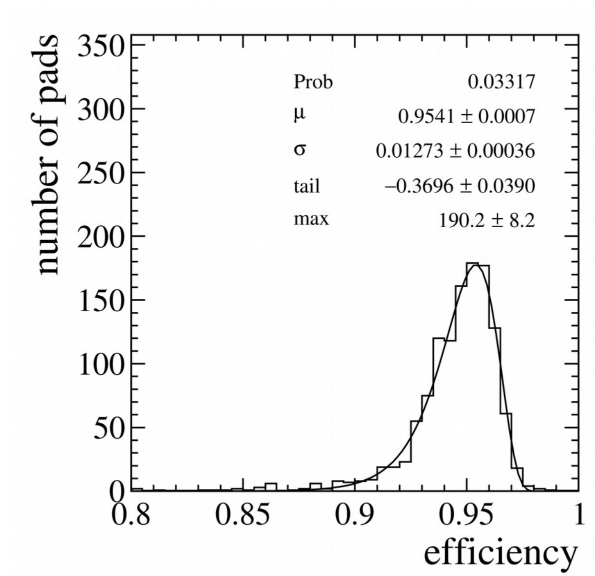
92.3% with 1.9% var.

μM #2
ε(thr0)



91.8% with 2.3% var.

μM #3
ε(thr0)

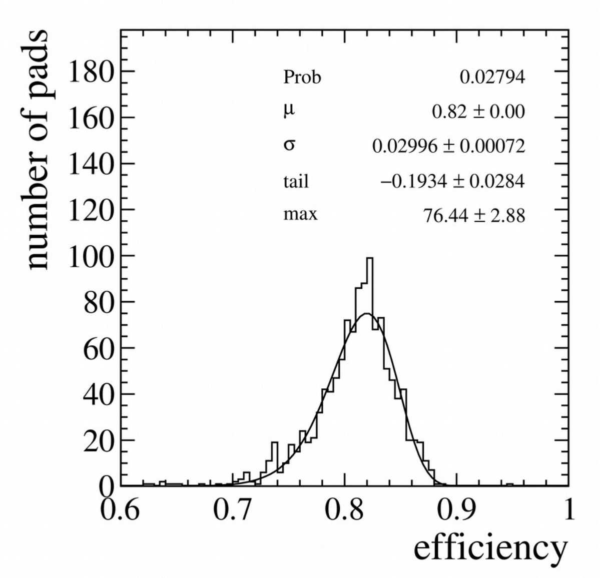


95.4% with 1.3% var.

Efficiency maps - uniformity

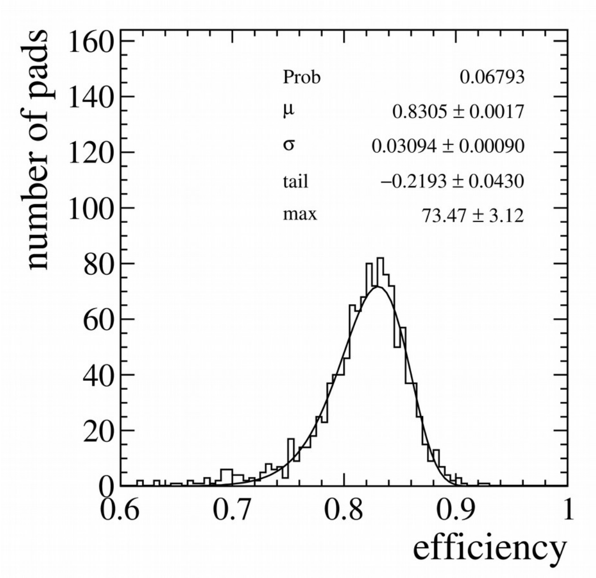
- For each track, the position in the test chamber is extra- or interpolated:
  - Efficiency & multiplicity are measured in a region of 7x7 cm^2
- Plot only when $\sigma_\varepsilon < 5\%$ with $\sigma_\varepsilon = \sqrt{[\varepsilon.(1-\varepsilon) / N]}$

μM #1
ε(thr1)



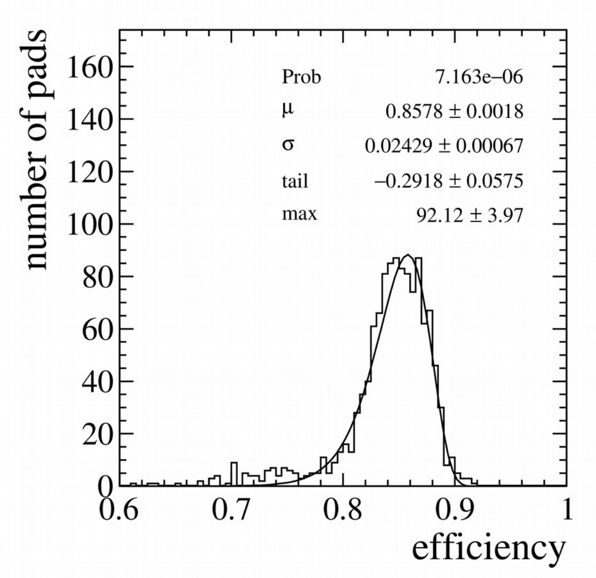
82.0% with 3.0% var.

μM #2
ε(thr1)



83.0% with 3.1% var.

μM #3
ε(thr1)

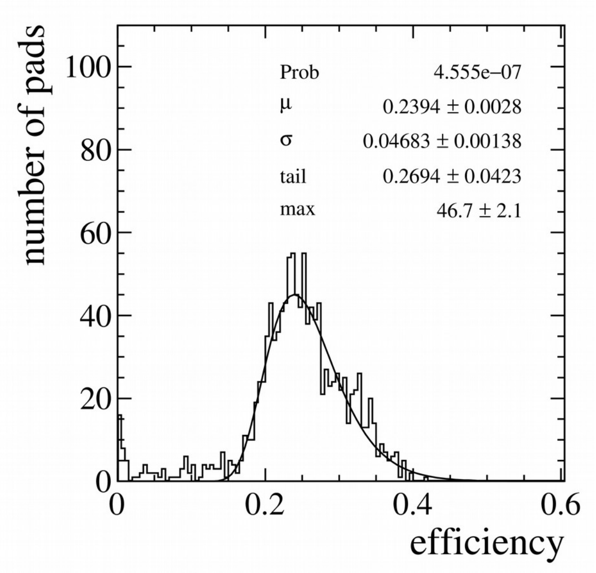


85.7% with 2.5% var.

Efficiency maps - uniformity

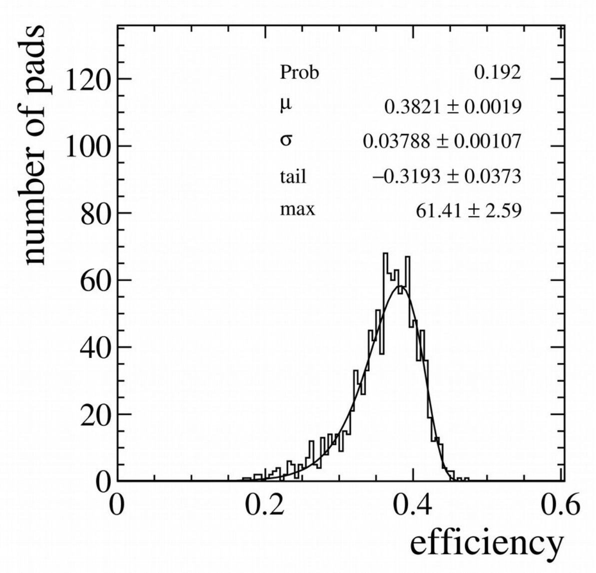
- For each track, the position in the test chamber is extra- or interpolated:
  - Efficiency & multiplicity are measured in a region of 7x7 cm^2
- Plot only when $\sigma_\varepsilon < 5\%$ with $\sigma_\varepsilon = \sqrt{[\varepsilon.(1-\varepsilon) / N]}$

μM #1
ε(thr2)



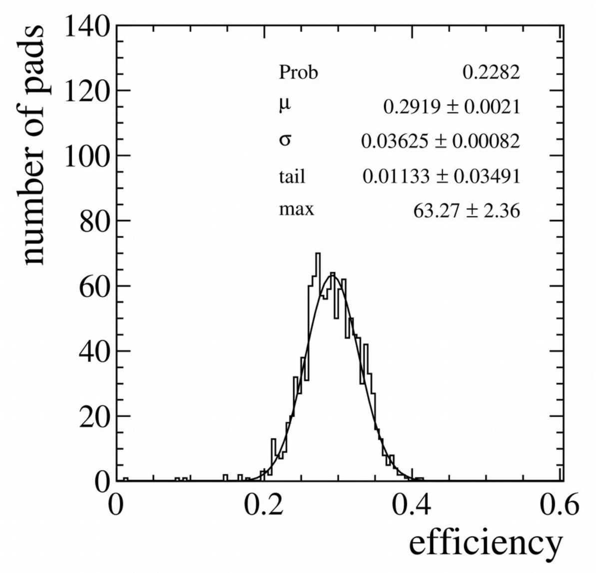
23.9% with 4.7% var.

μM #2
ε(thr2)



38.2% with 3.8% var.

μM #3
ε(thr2)

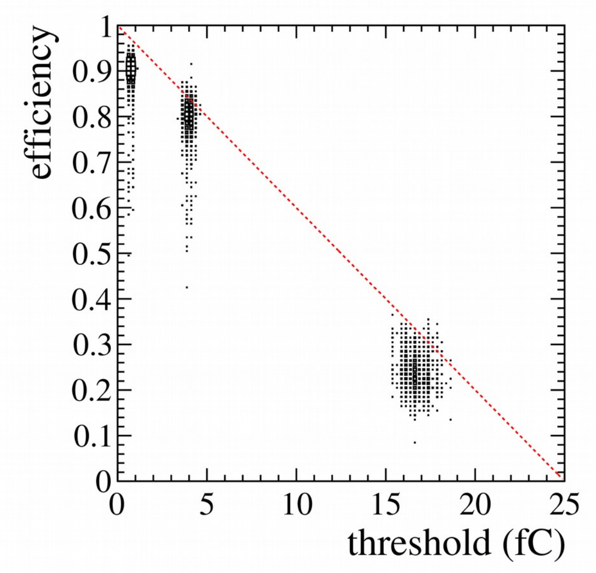


36.2% with 3.7% var.

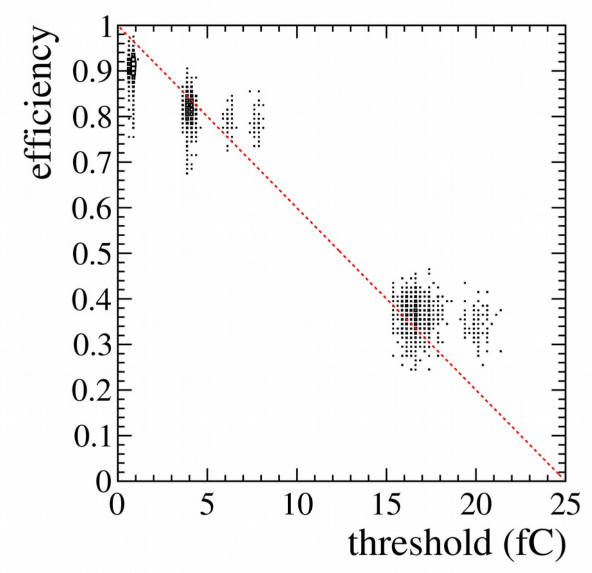
Correlations with threshold

- Similar correlation in 3 chambers
- For chamber #2 and #3: mistake in setting some ASIC thresholds

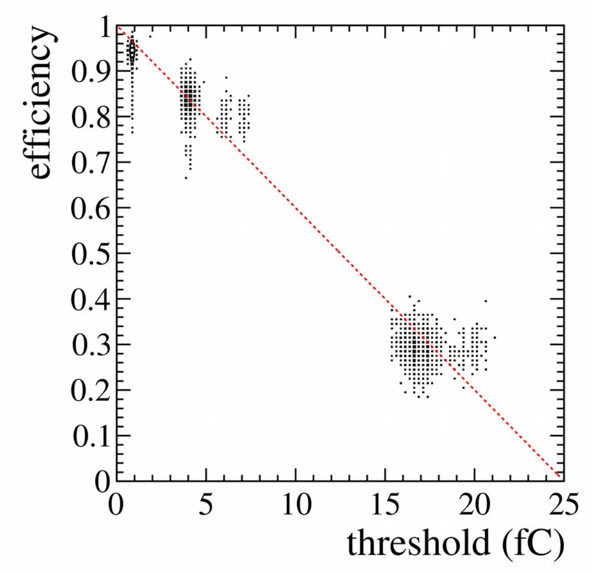
μM #1
ε(thr)



μM #2
ε(thr)



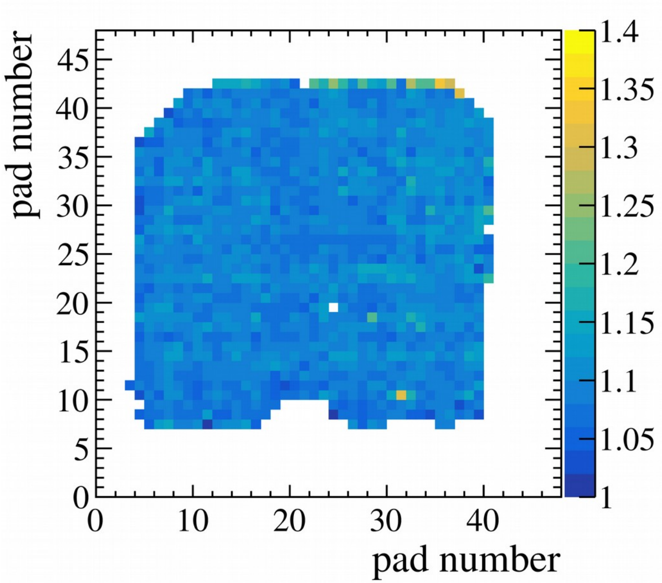
μM #3
ε(thr)



Hit multiplicity maps - values

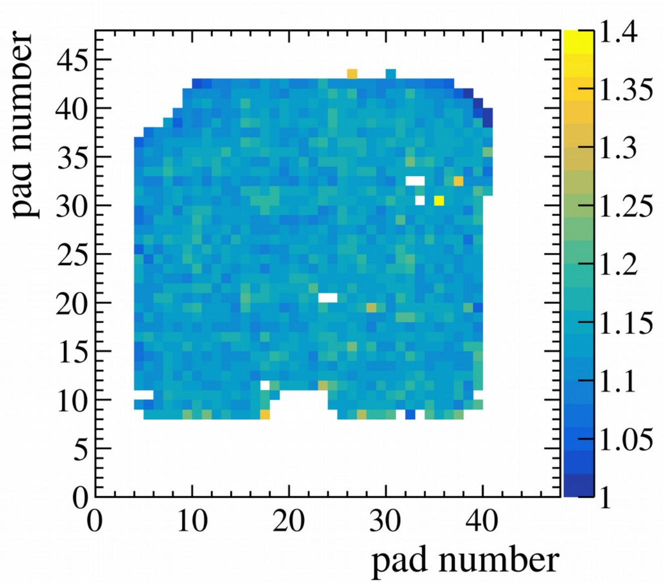
- For each track, the position in the test chamber is extra- or interpolated:
  - Efficiency & multiplicity are measured in a region of 5x5 cm^2
- Plot only when $\sigma_\varepsilon < 5\%$ with $\sigma_\varepsilon = \sqrt{[\varepsilon.(1-\varepsilon) / N]}$

µM #1
m(thr0)



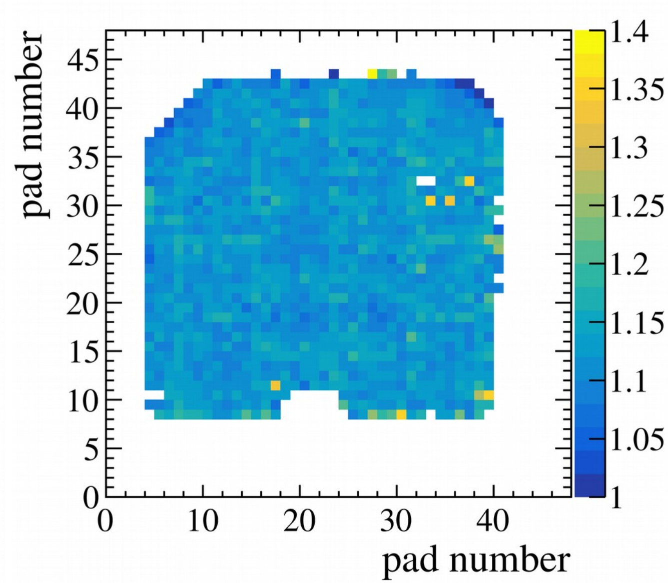
Smooth

µM #2
m(thr0)



Smooth

µM #3
m(thr0)

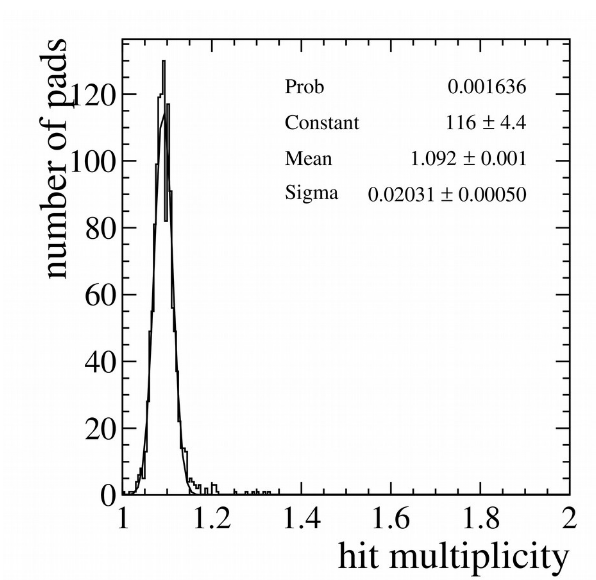


Smooth

Hit multiplicity maps - uniformity

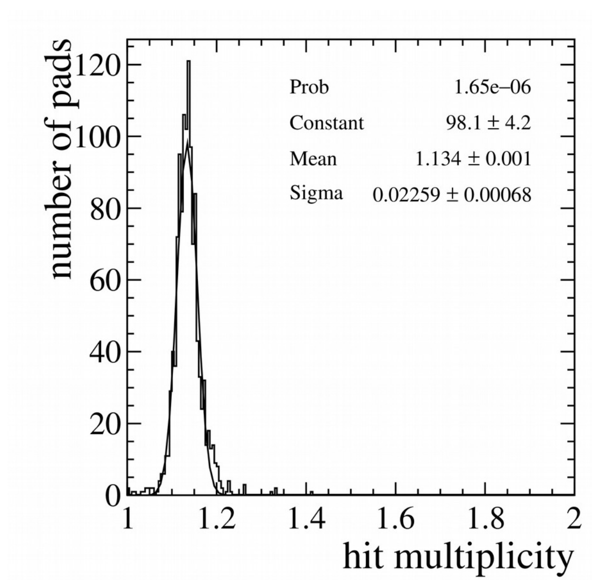
- For each track, the position in the test chamber is extra- or interpolated:
  - Efficiency & multiplicity are measured in a region of 5x5 cm^2
- Plot only when $\sigma_\varepsilon < 5\%$ with $\sigma_\varepsilon = \sqrt{[\varepsilon.(1-\varepsilon) / N]}$

µM #1
m(thr0)



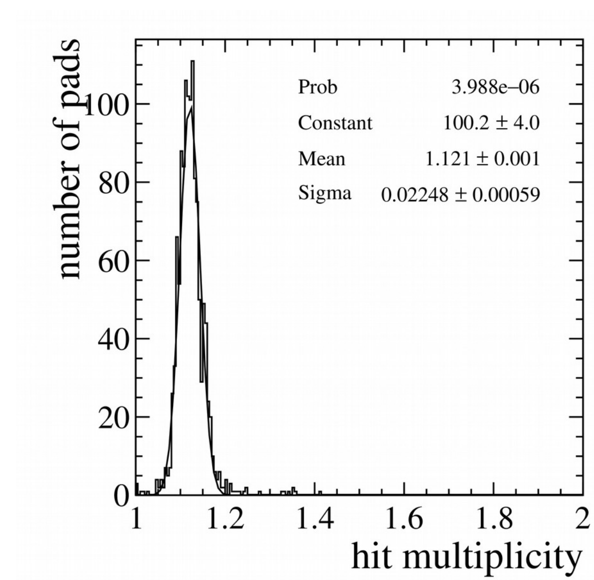
1.09 with 0.02 var.

µM #2
m(thr0)



1.13 with 0.02 var.

µM #3
m(thr0)



1.12 with 0.02 var.

Summary and outlook

- Three pad-readout Micromegas of 0.2 m^2 with embedded resistors and front-end electronics were constructed
  - Operational characteristics in line with earlier smaller prototypes (e.g. sparking)
  - Besides low gas gain area on one proto. & a few wrong chip settings:

    the performance are good (>90% efficiency) and well uniform (1-2% RMS var. @ low thr.)

    $\rightarrow$ The manufacturing process was succesfully applied on larger size.

- Now close to the conclusion of our work on embedded resistors
  - Analysis improvable: use off-trigger hits and thus full beam size
    $\rightarrow$ wider area can be tested, especially by the edges
  - Looks at systematics (e.g. target region size)
  - Results will be integrated into our current draft paper for circulation before Xmas.

- These detectors, combined with large RPWELL and smaller Micromegas, formed a small calorimeter which was tested to low-energy hadrons in October at the PS
  - See report from Dan Shaked Renous in WG7 on Thursday morning