Testbeam data analysis of a polarimeter Cherenkov detector

Parameter Scans

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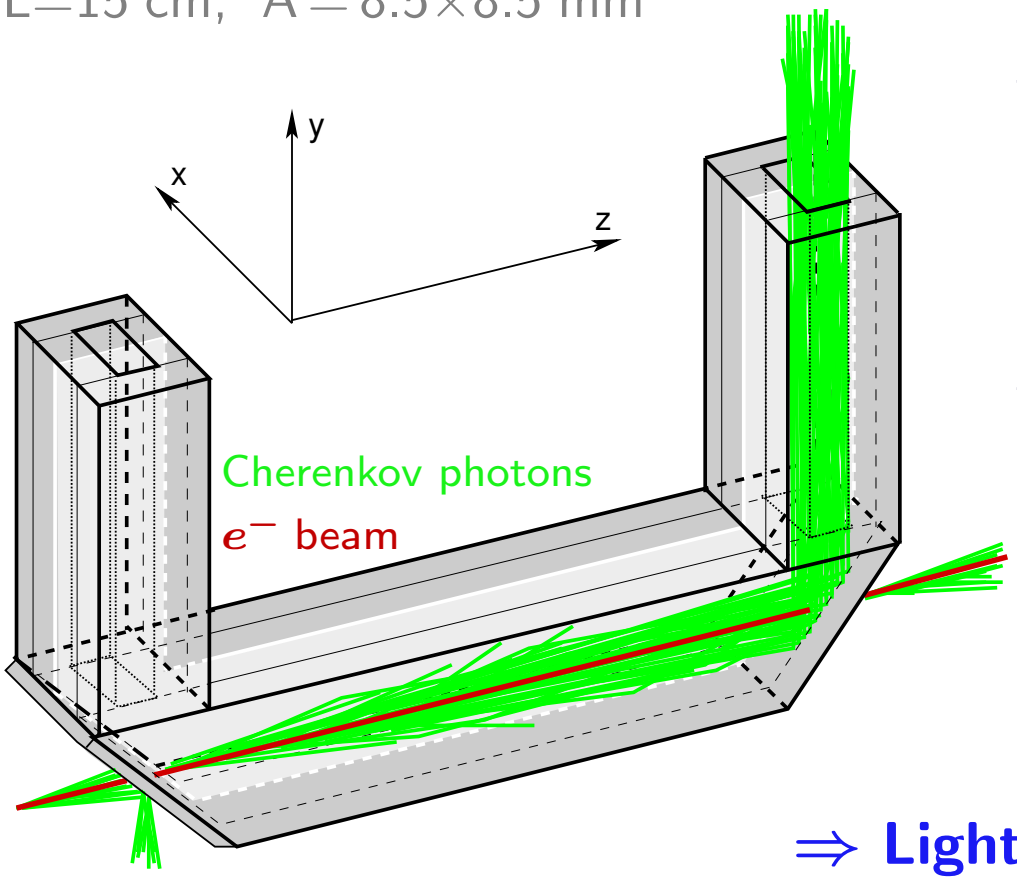
Optical Simulation (GEANT4)

Goal: find characteristics like photon-yield per electron, average number of reflections, asymmetry effects due to geometry a/o material

Two-channel prototype

L=15 cm, A = 8.5×8.5 mm^2



- gas: C_4F_{10}, threshold: 10 MeV
- wall reflectivities: λ-dependent!
  - ▷ diamant-milled: R ≈ 85%
  - ▷ foil (0.3 mm): R ≈ 40% ?
- all Cherenkov processes & all subsequent / secondary processes

  multiple scattering, scint., ionisation, as well as reflection, refraction & absorption at surface & boundary areas

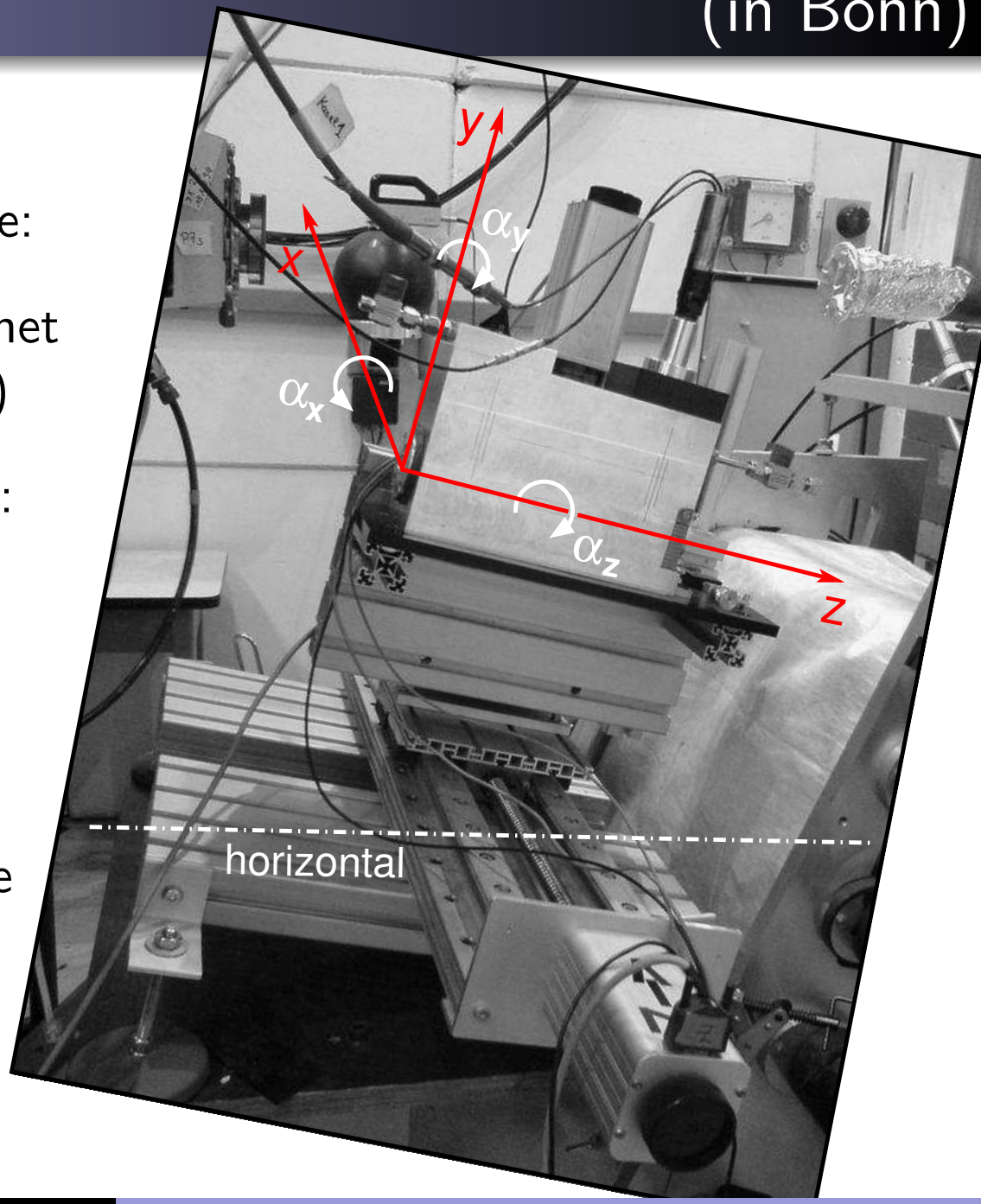
⇒ **Light distribution at photocathode!**

Prototype Setup @ ELSA (in Bonn)

Located in an external beam line:

- directly behind a dipole magnet (dumping the electron beam)
- fixated to a translation stage: movable in x and y

- tilt $\alpha_x \approx 7.5°...7.8°$
- tilt α_y adjustable via mount on turnable base plate
- tilt $\alpha_z \approx 0°$ via spirit level



A Load of Parameters

- Beam profile $\rightarrow$ round Gaussian beam spot:
  - point-like beam spot with $\sigma_x = \sigma_y = 0.001$ mm (as reference)
  - and $0.1 \ldots 1.0$ mm in steps of 0.1 mm

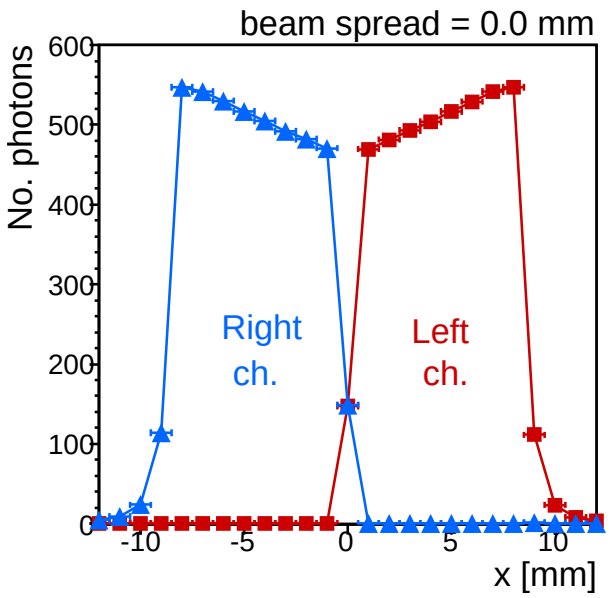
- Reflectivity of inter-channel wall w.r.t. reflectivity of other walls:
  from $50\% \ldots 100\%$ (50% is lower limit)

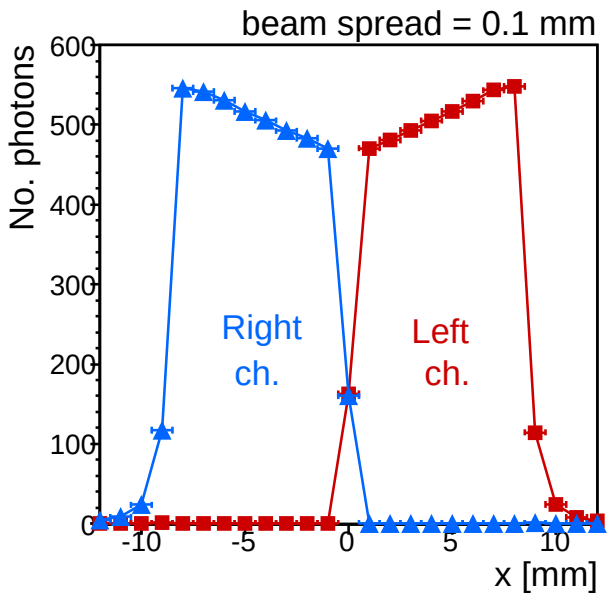
- Detector alignment w.r.t. beam axis: shifts & tilts $\rightarrow 6$ param's
- Photodetector alignment w.r.t. channel: coverage/shifts/tilts

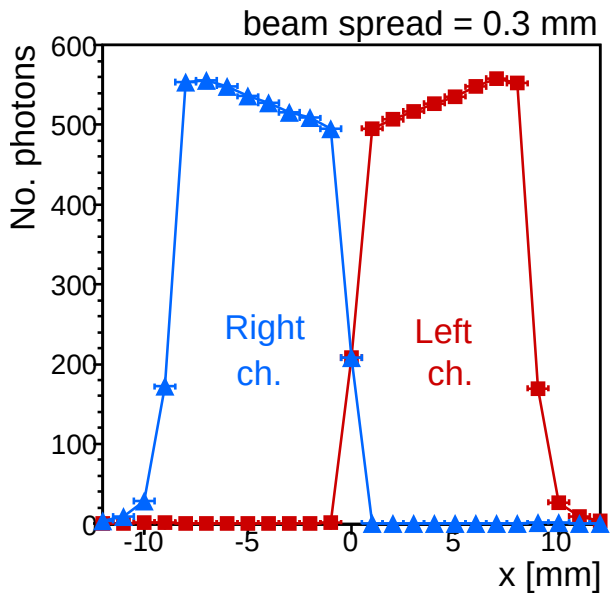
Get beam profile and relative reflectivities as accuratly as possible

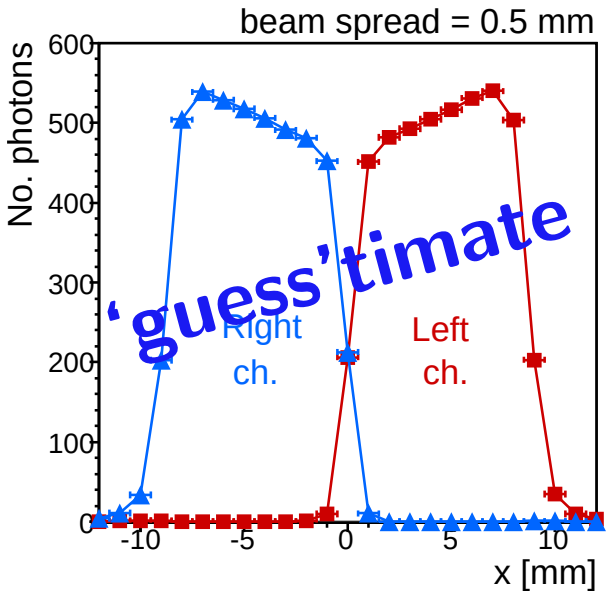
$\Rightarrow$ **Tune simulation to testbeam data** $\leftrightarrow$ iterative steps?!

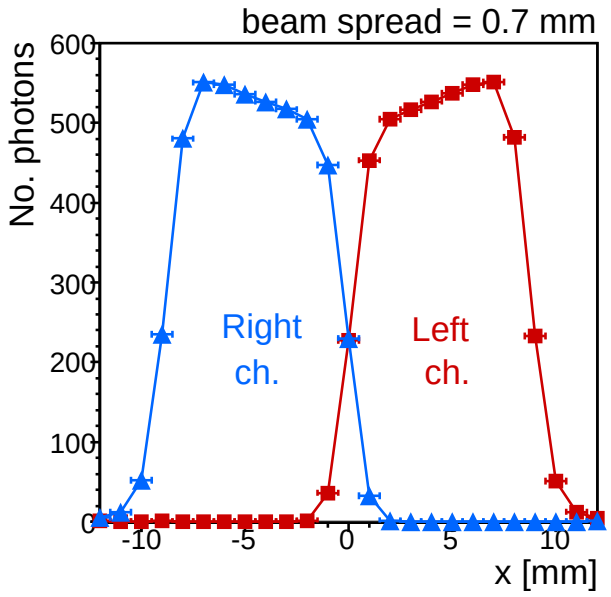
Beam Profile: $\sigma_x = \sigma_y$

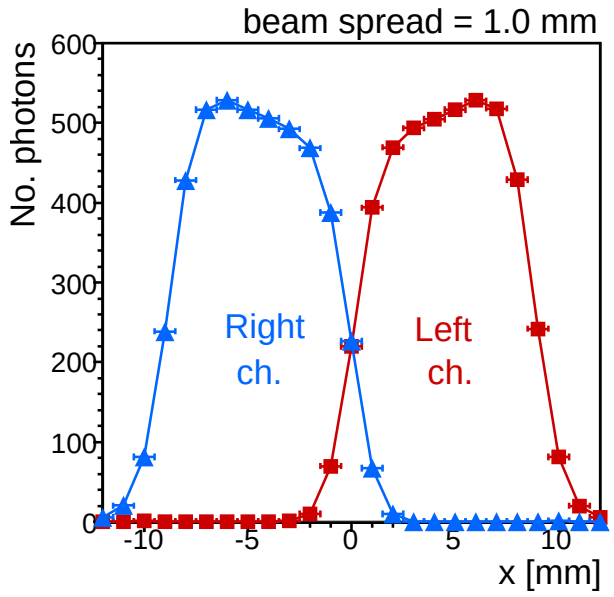




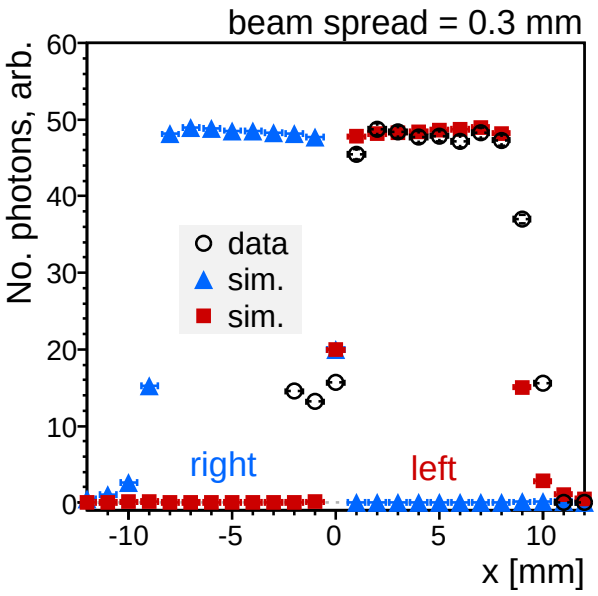


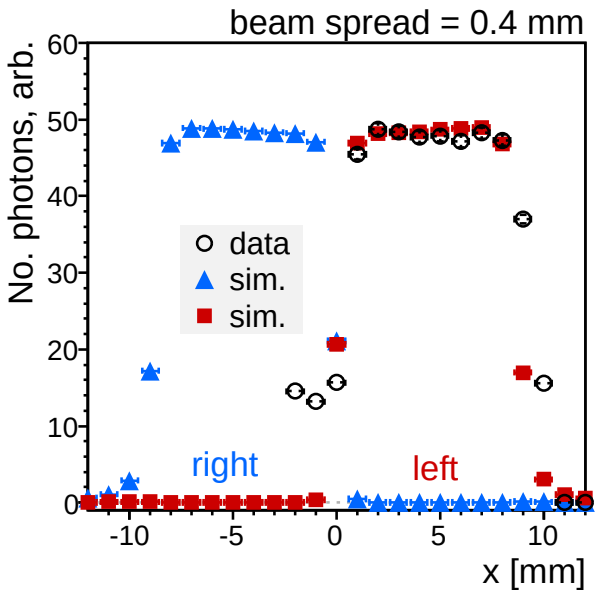


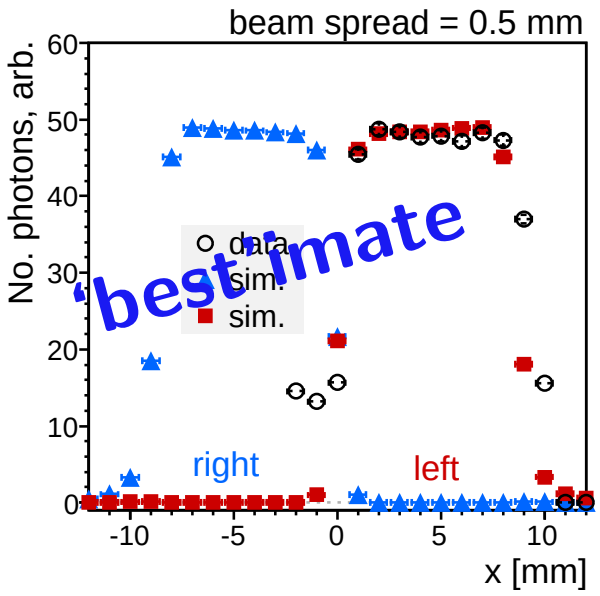


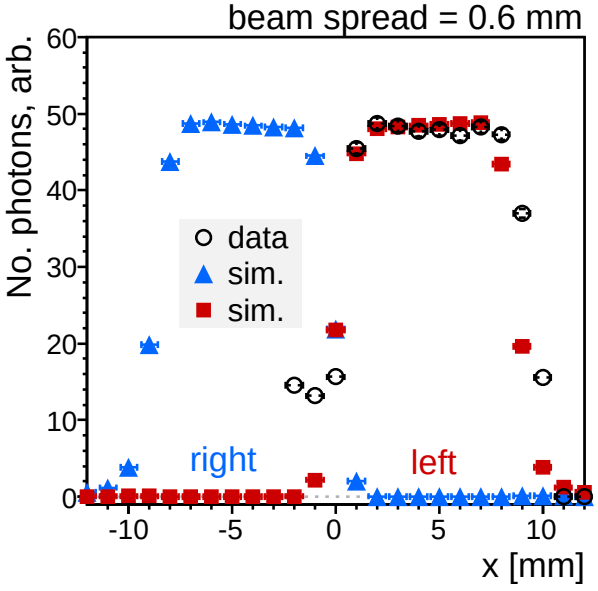


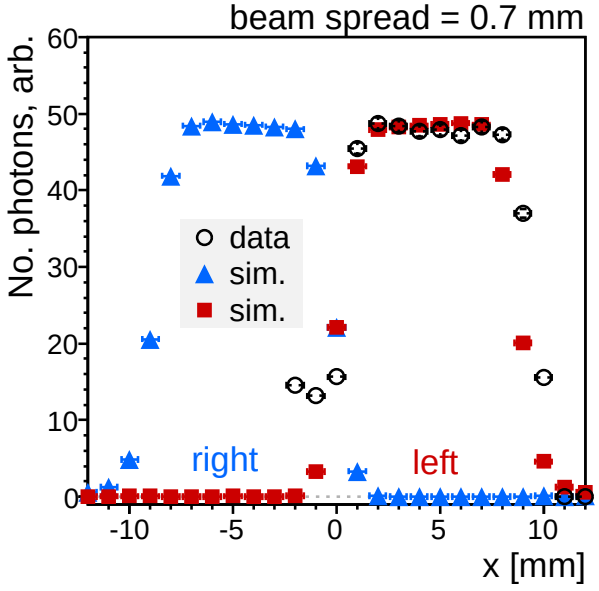
Beam Profile: $\sigma_x = \sigma_y$

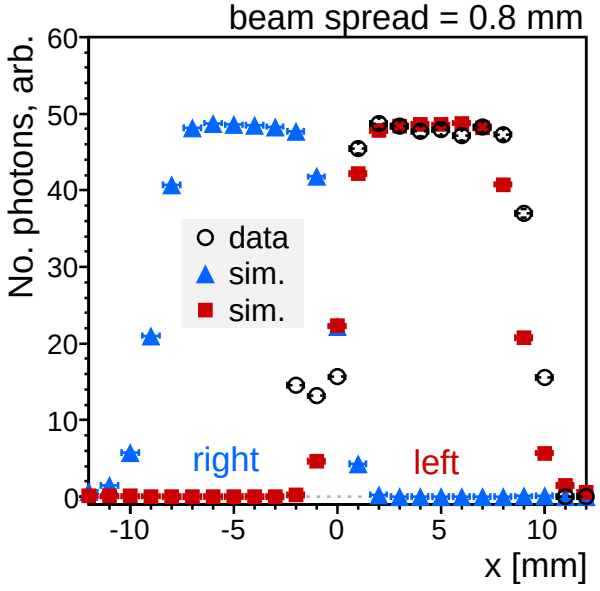




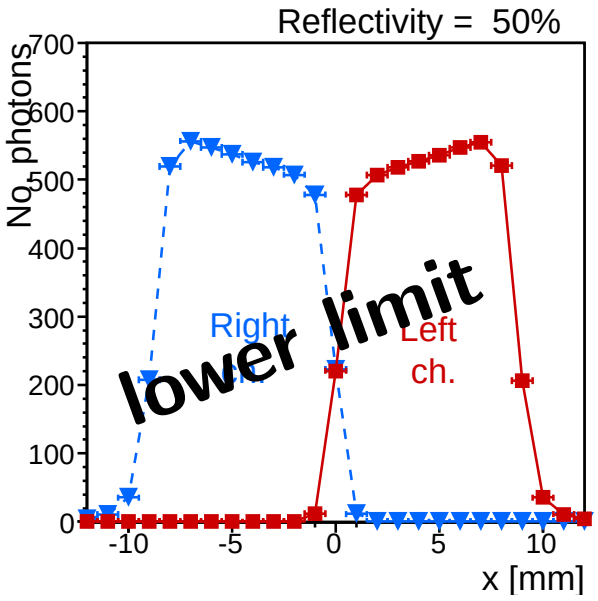


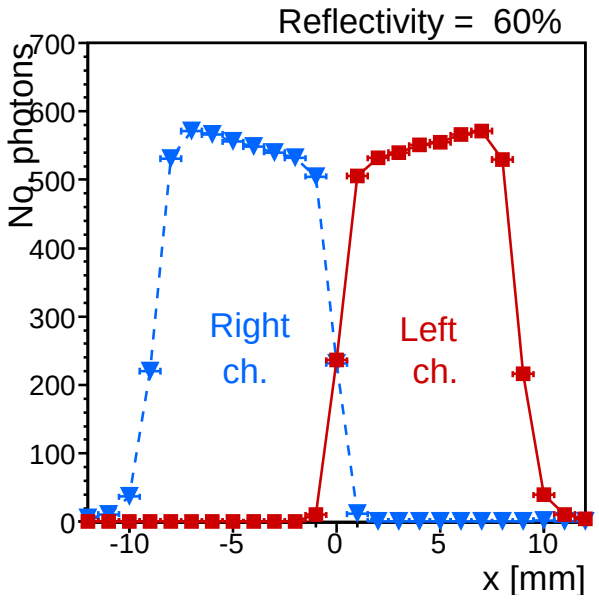


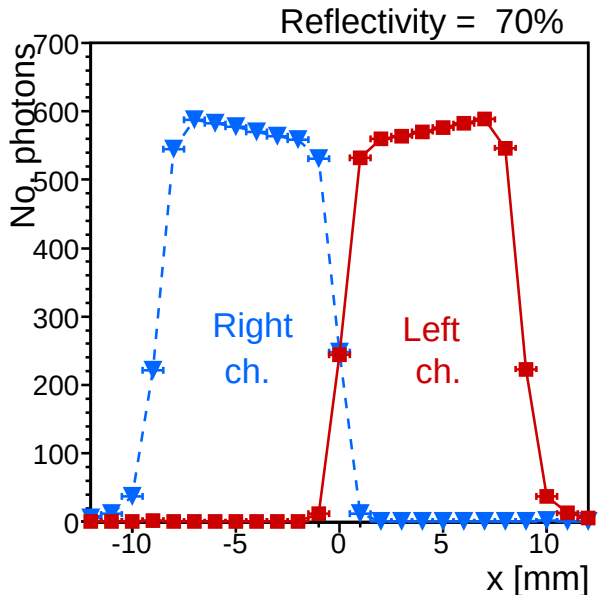


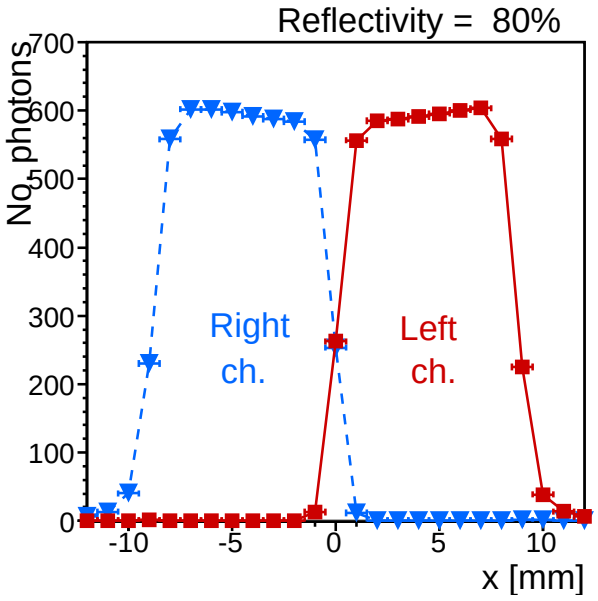


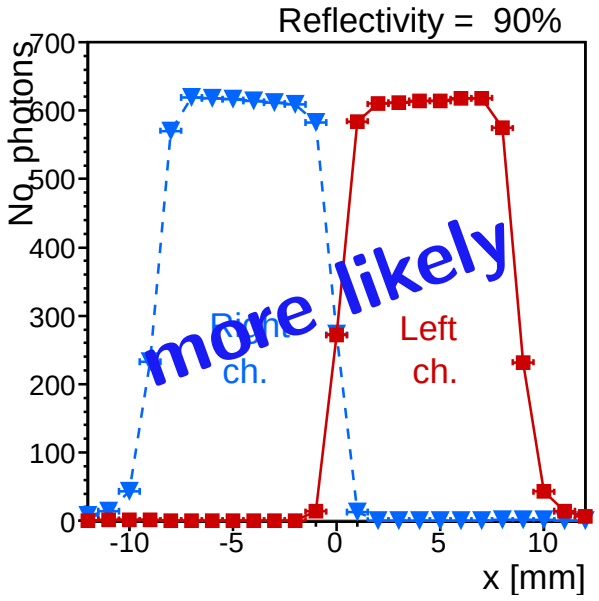
Reflectivity of the Inter-channel Wall

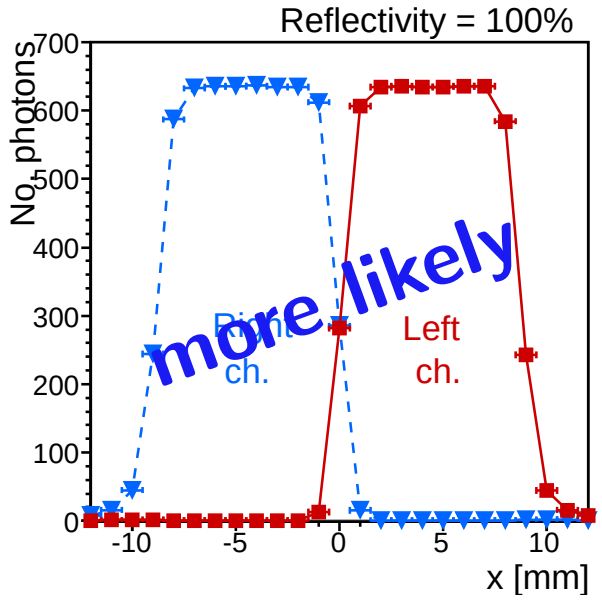












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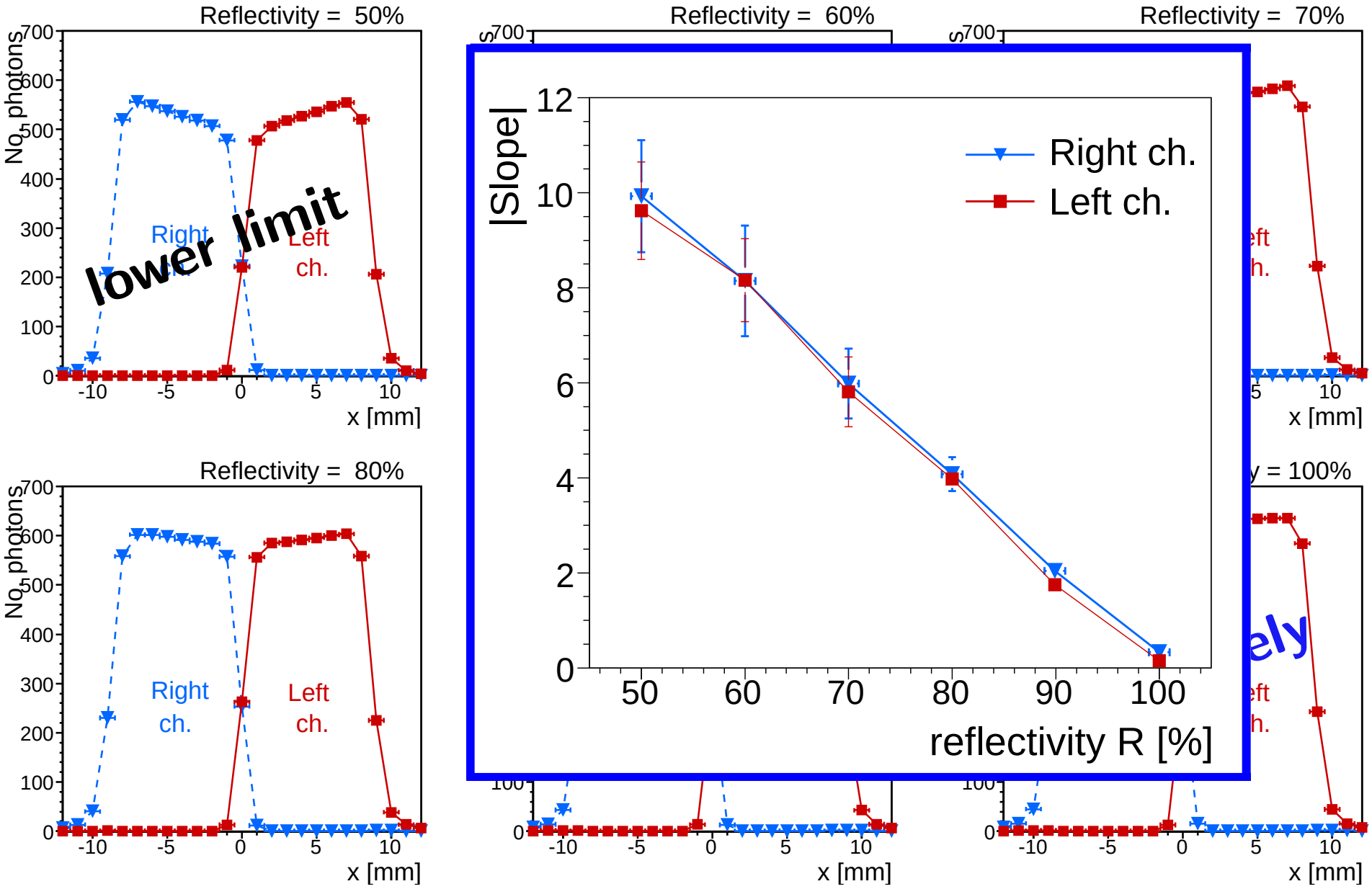
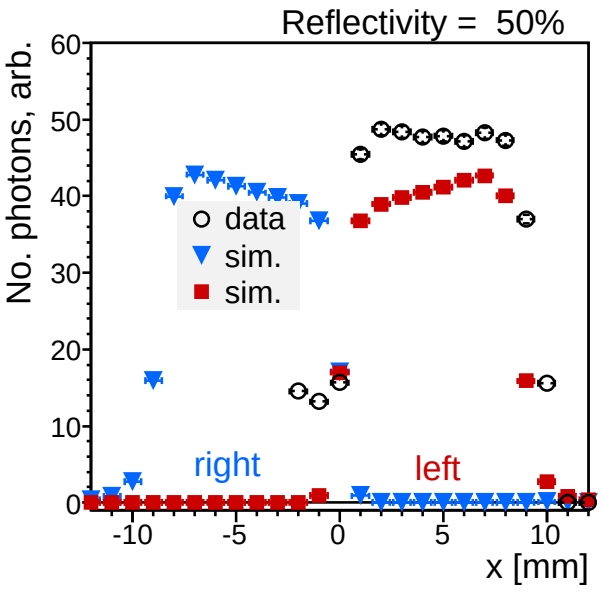
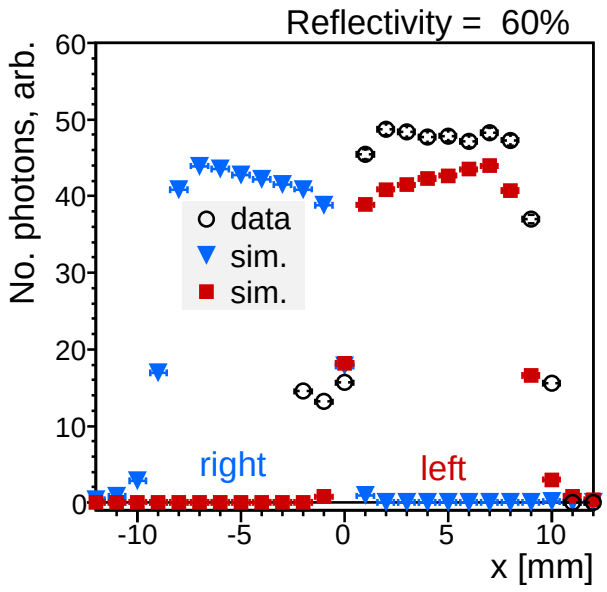
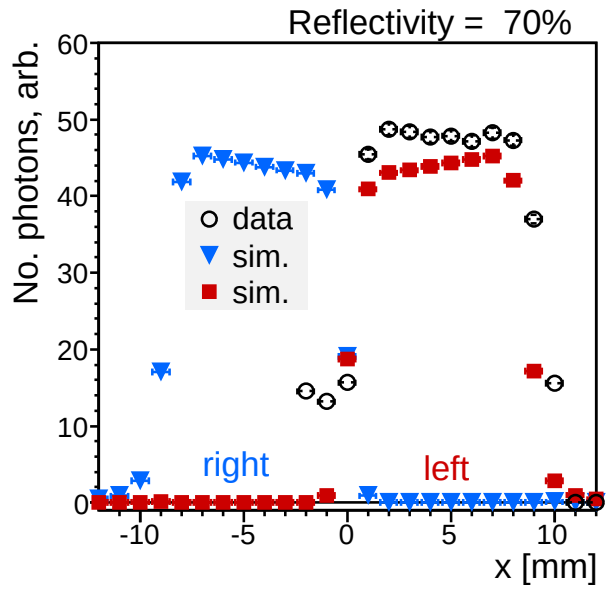
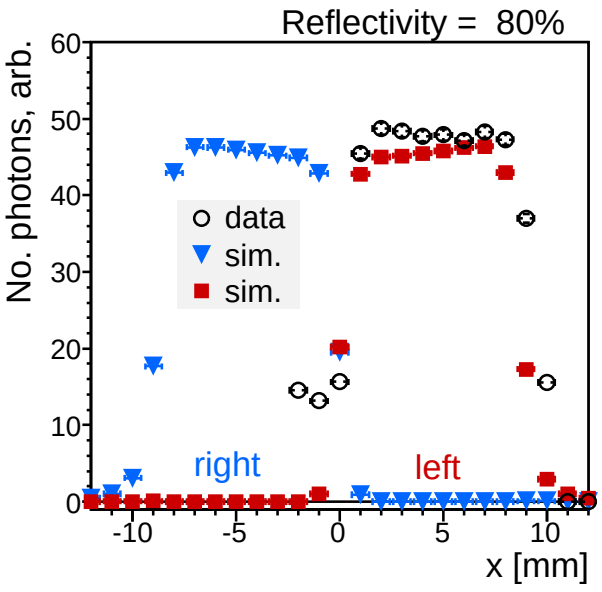


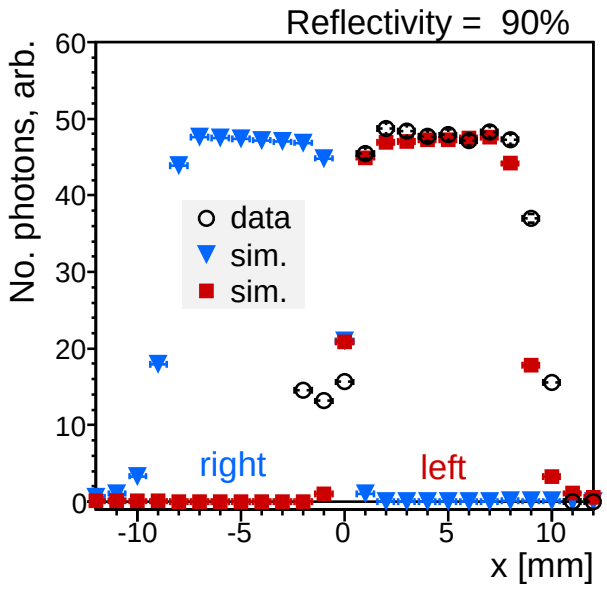
Reflectivity of the Inter-channel Wall

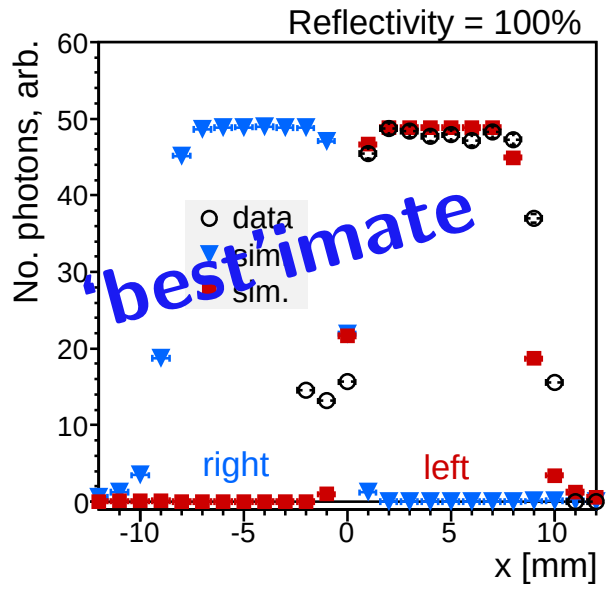












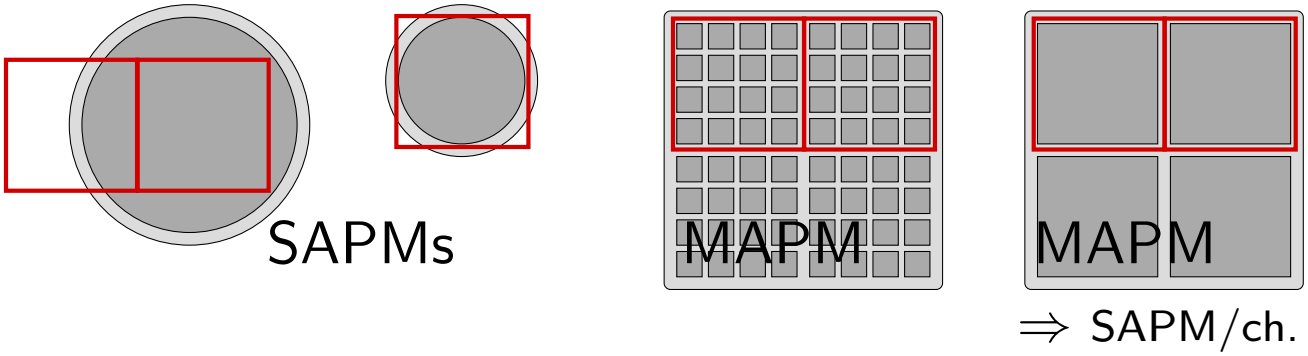
Parameters II

- Beam profile: assumed as round Gaussian with $\sigma_x = \sigma_y = 0.5$ mm
- Reflectivity of inter-channel: assumed as $R \approx 70\%$ or 80%

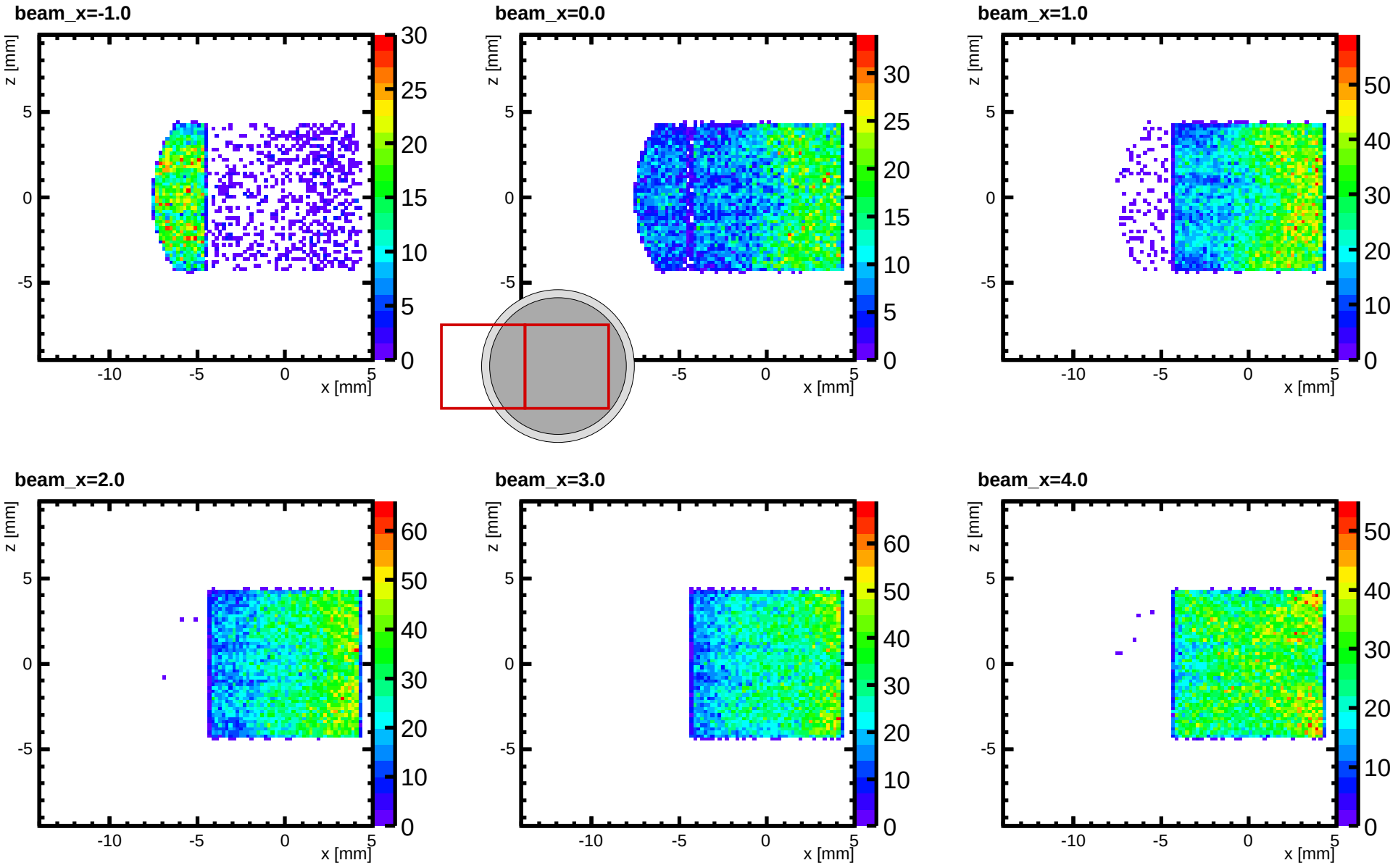
Now: start fine tuning detector alignment (& finally PD-alignment)
Anode vs. channel coverage: PD shifts or tilts w.r.t. channel

- Detector alignment w.r.t. beam axis
  - shifts: $(x, y) < 0.5$ mm
  - tilts: $(\alpha_x, \alpha_y, \alpha_z) < (1.0°, 0.5°, 2.0°)$

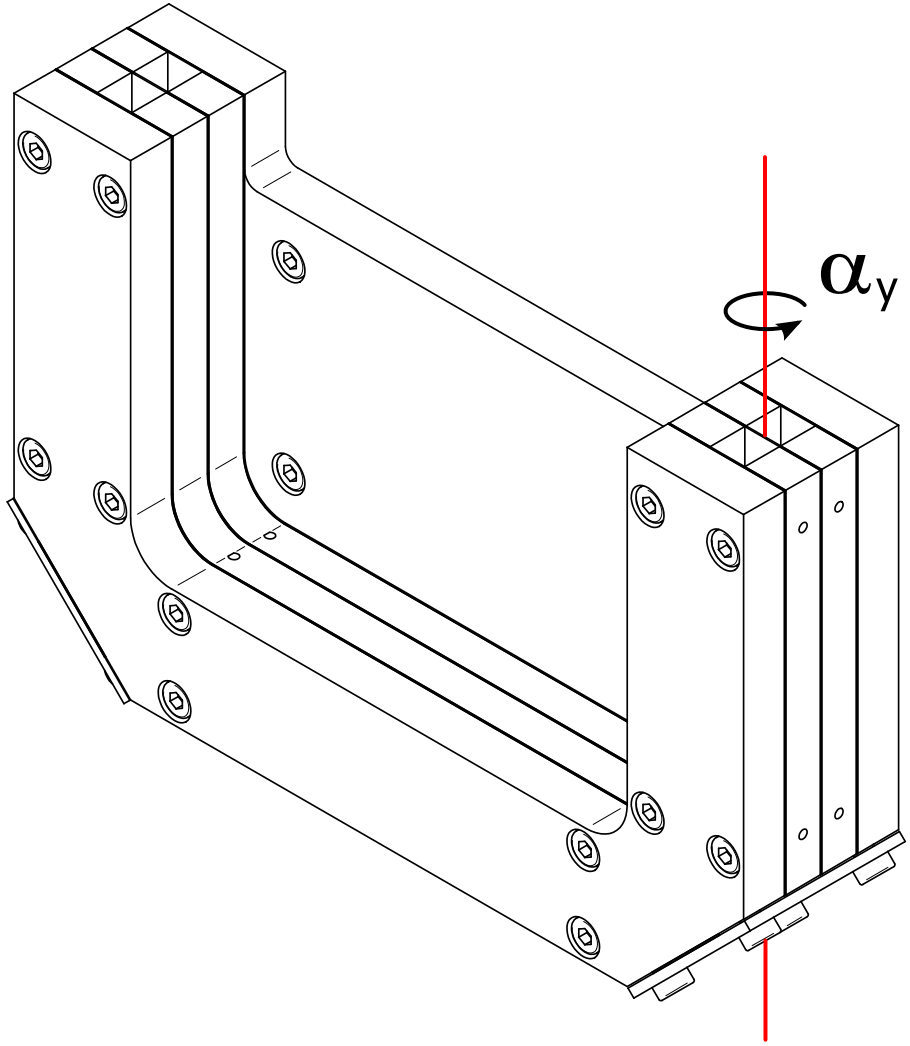
- Photodetector alignment w.r.t. channel: coverage, shifts, tilts



Channel Illumination for diff. Beam Positions



PD-anode vs. Channel Light Yield



Different tilt angles $\alpha_y \leq 0$:

$\longrightarrow$ beam path lengths through the detector U-base vary

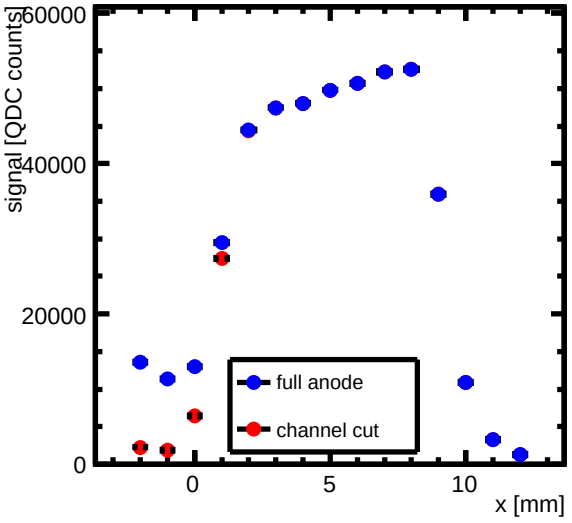
$\longrightarrow$ different light path lengths

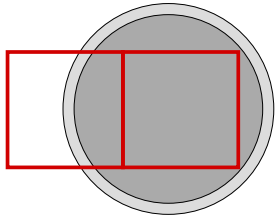
$\longrightarrow$ more/less reflections

$\longrightarrow$ no defined plateau forms as for $\alpha_y = 0$

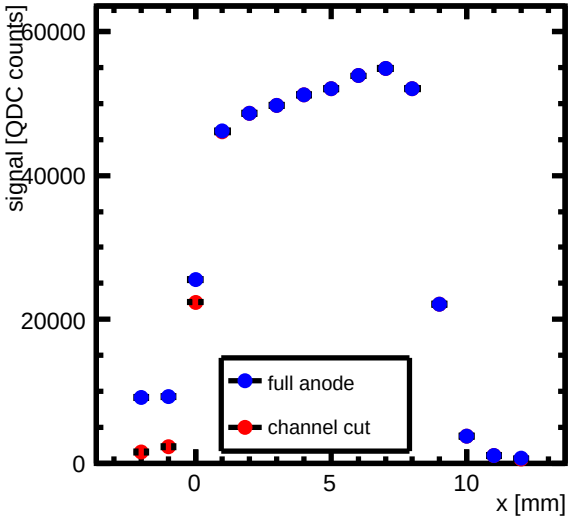
PD-anode vs. Channel Light Yield

SIM R4125, angle_y=-0.5

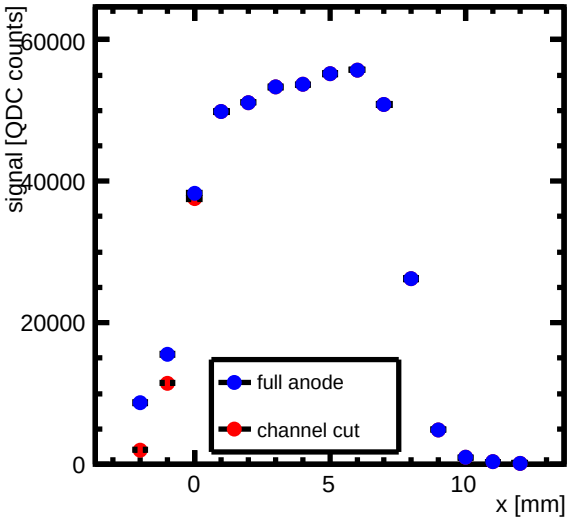




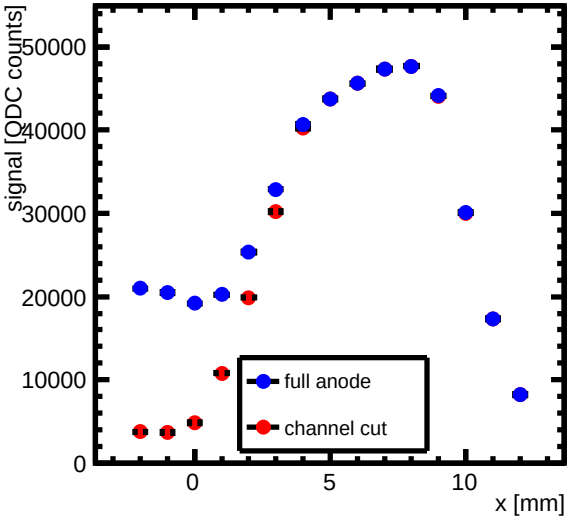
SIM R4125, angle_y=0.0



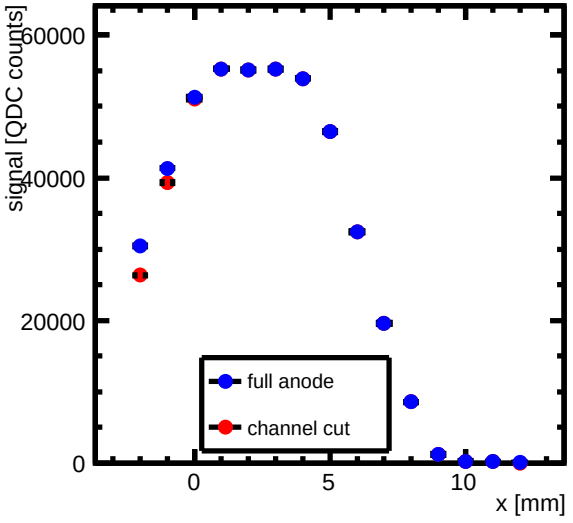
SIM R4125, angle_y=0.5



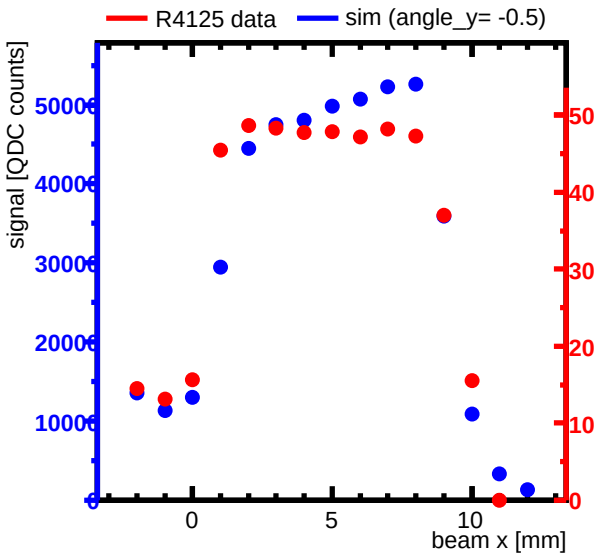
SIM R4125, angle_y=-1.5

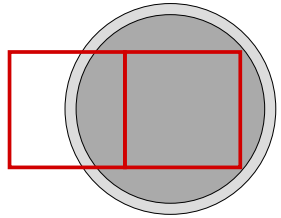


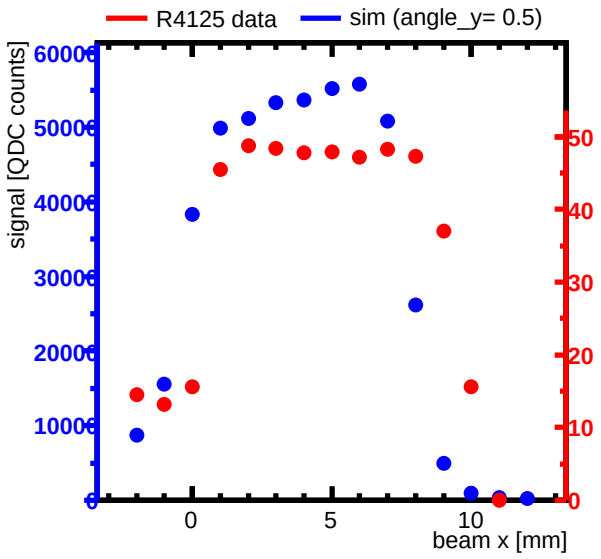
SIM R4125, angle_y=1.5

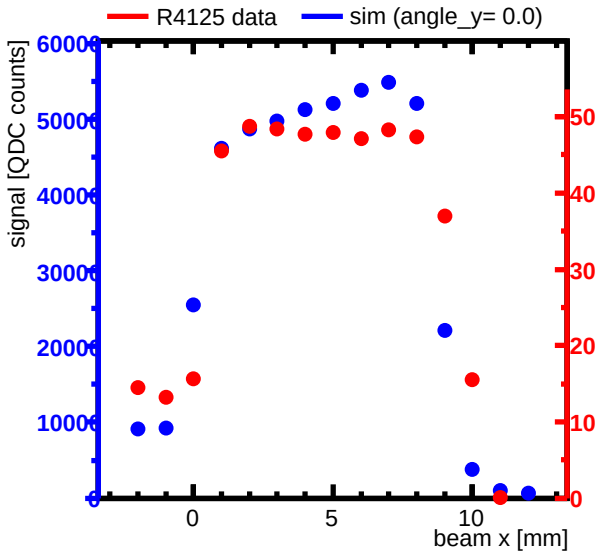


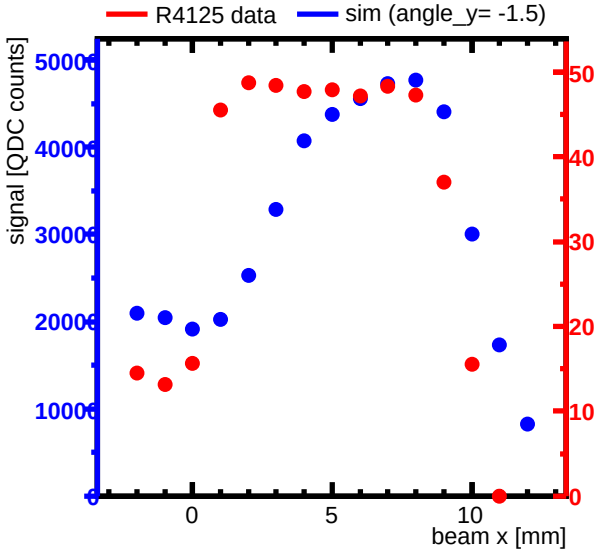
Simulation vs. Data (large SAPM)



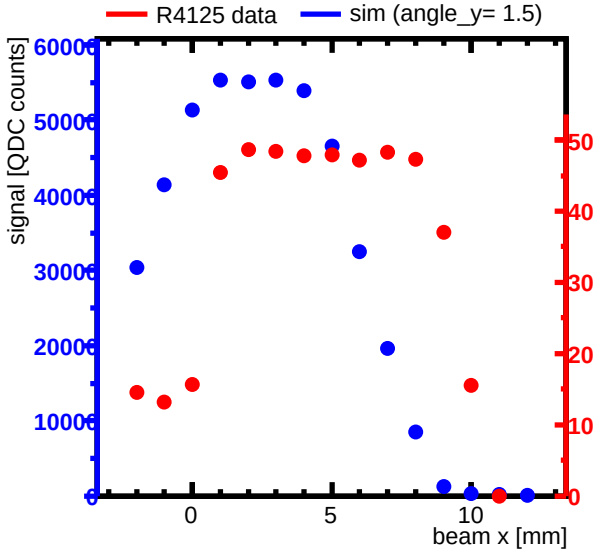






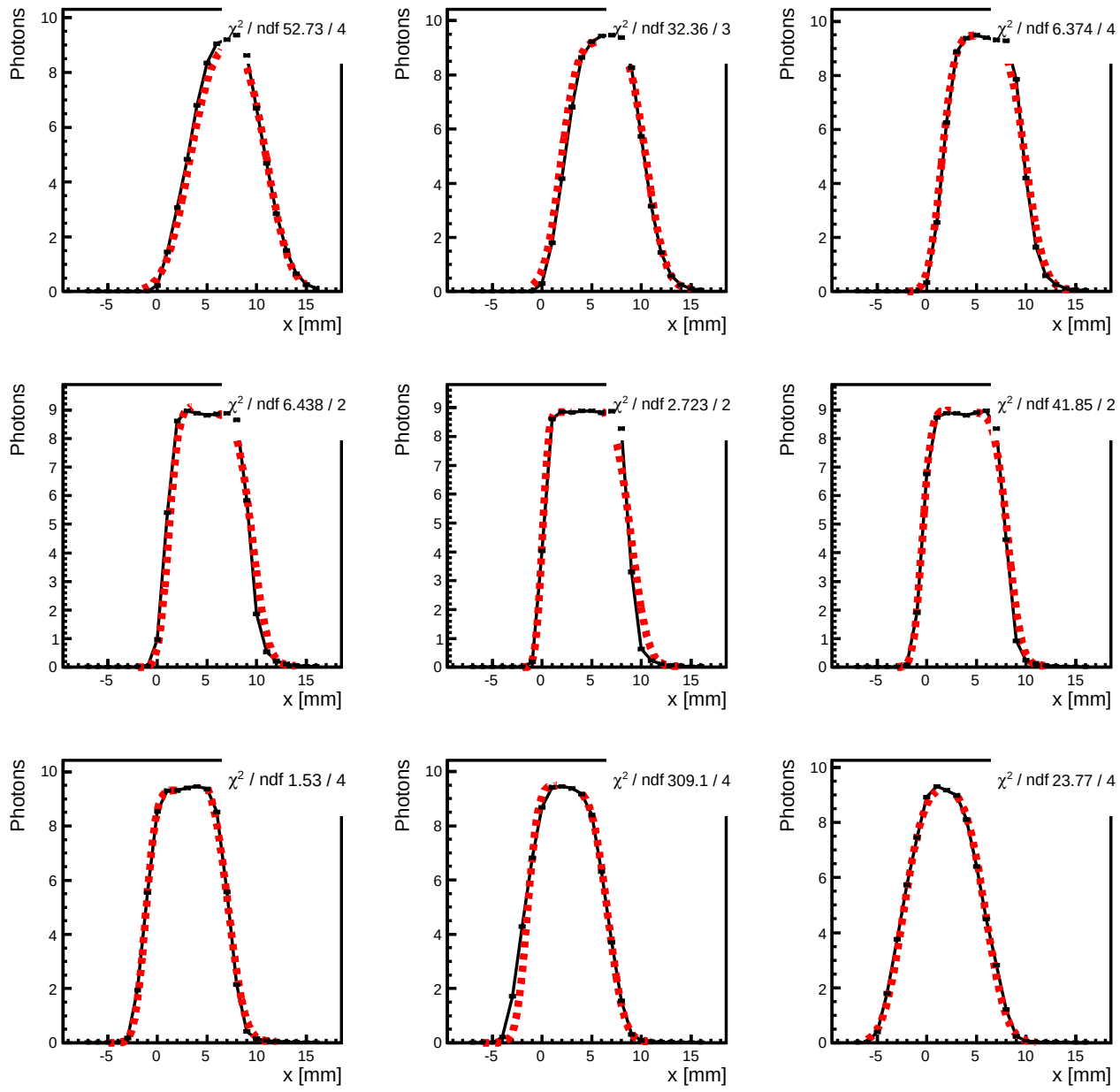


No influence from
PD coverage/shift/tilt



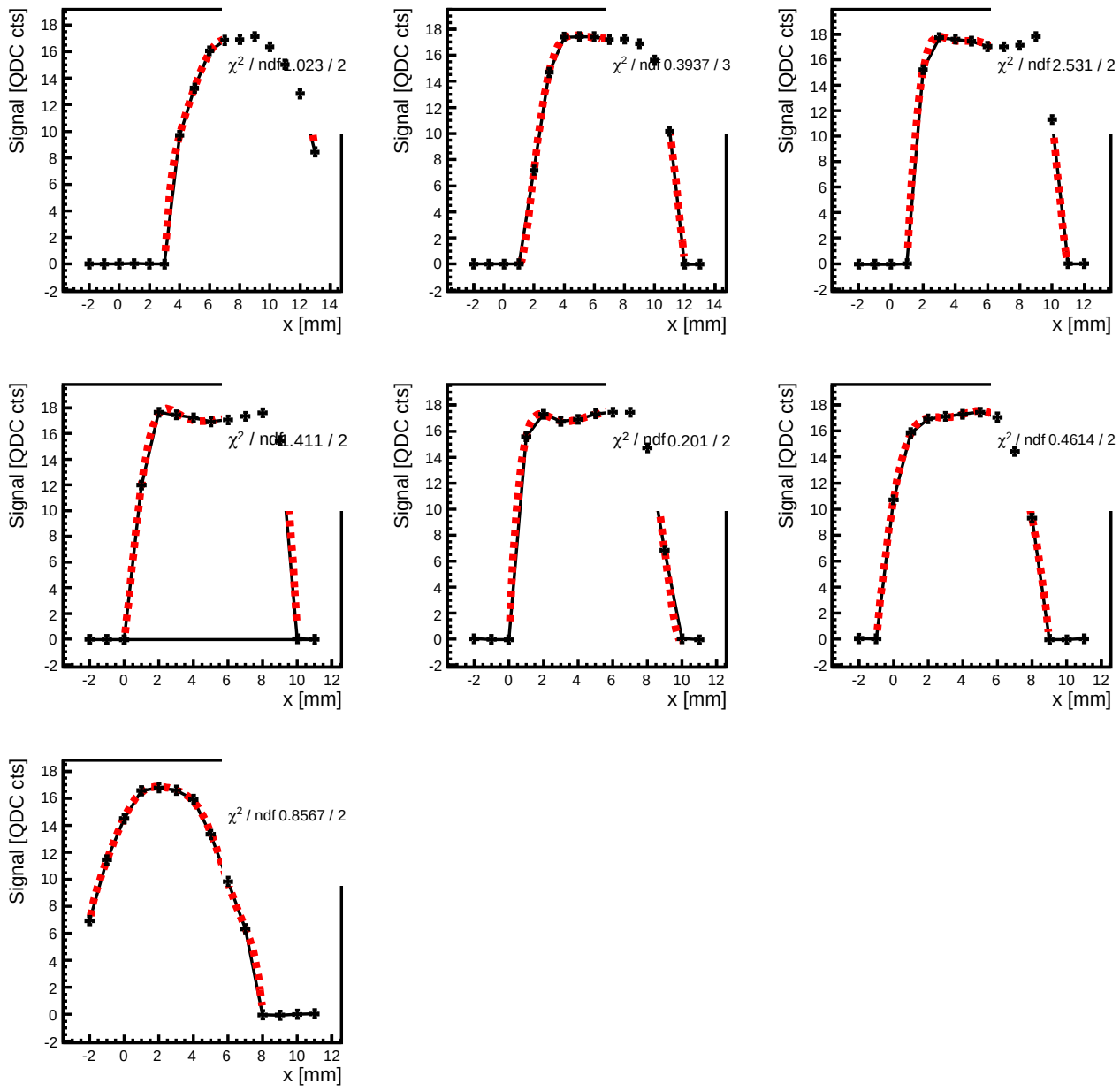
Simulation vs. Data (small SAPM)

zero pos.



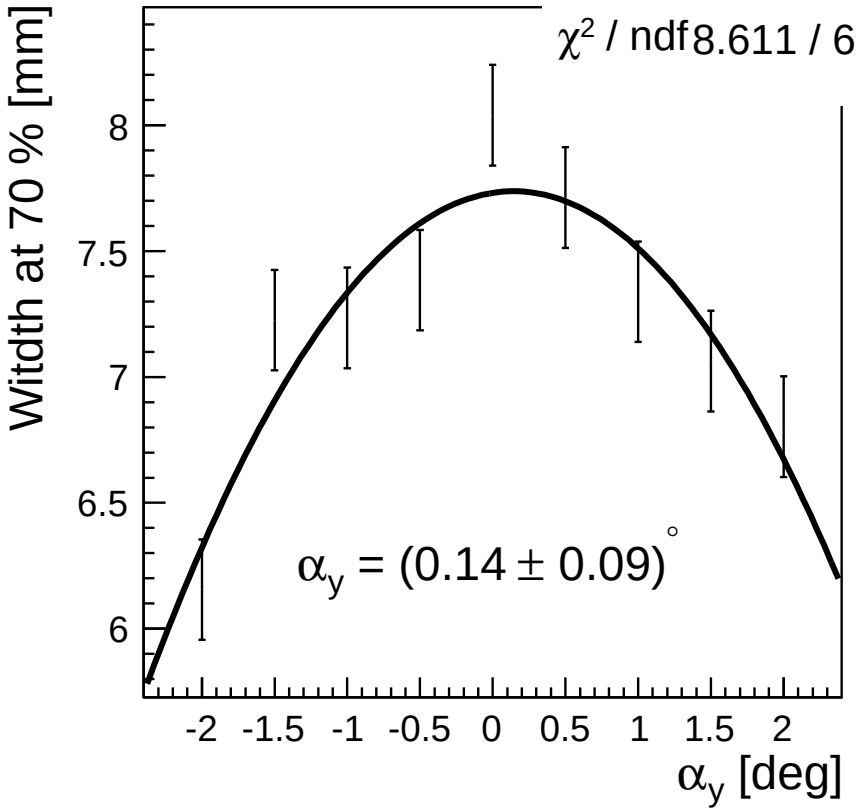
Simulation vs. Data (small SAPM)

zero pos.

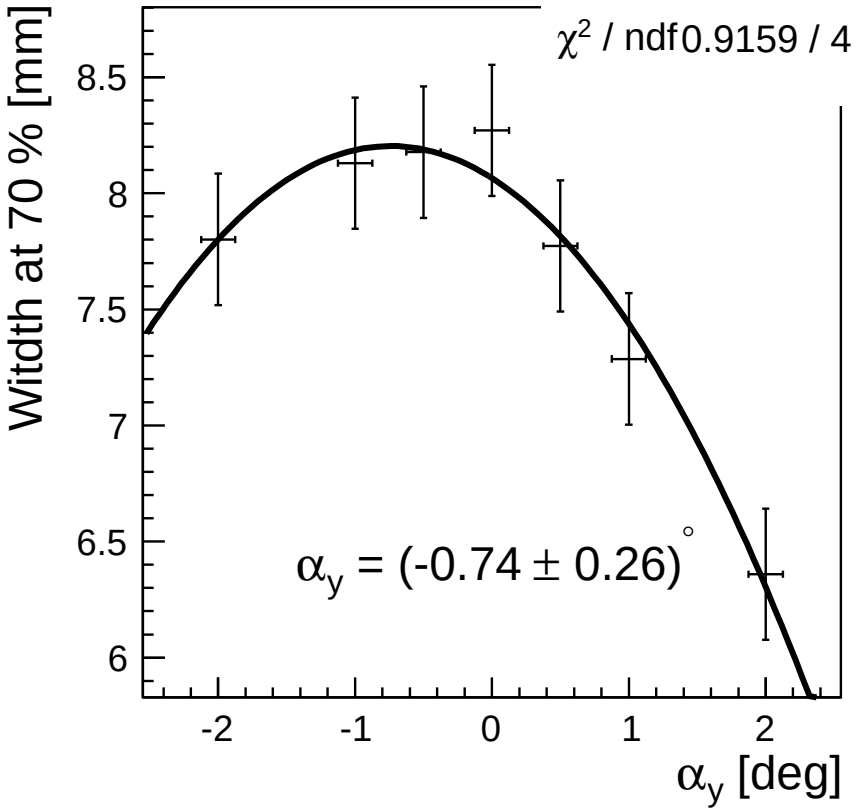


Channel width at 70%

Simulation



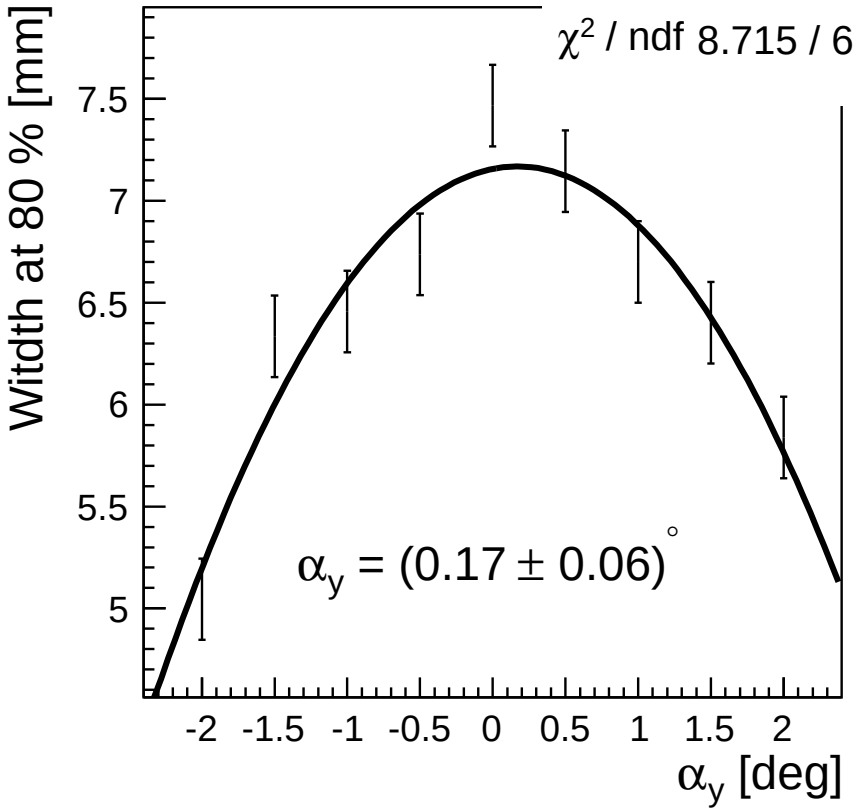
Data (small SAPM)



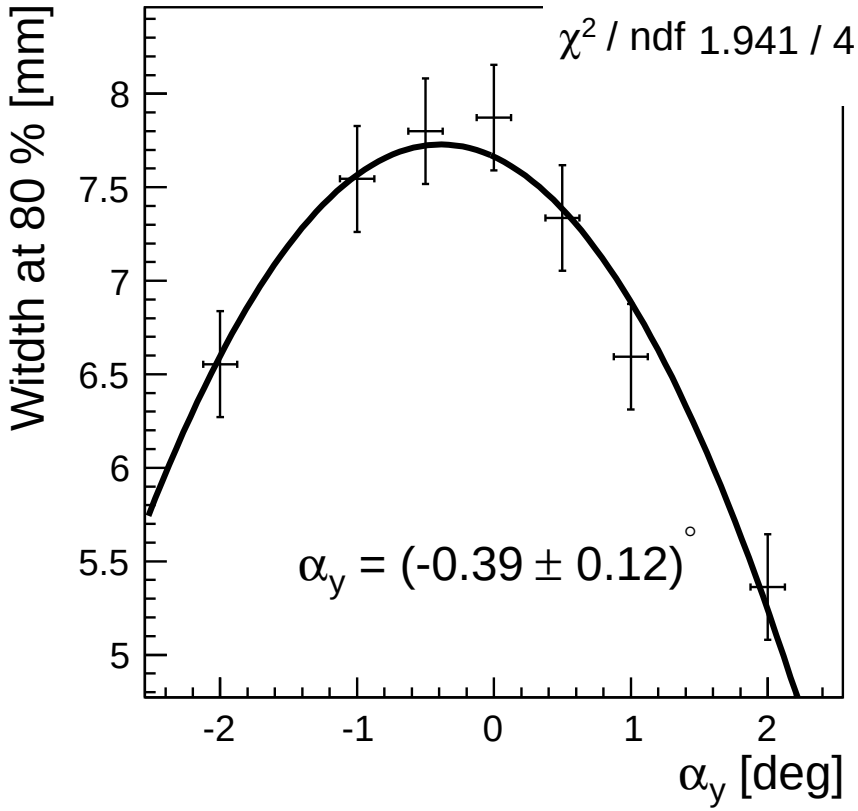
Sim.-Data ⟶ Channel Width

Channel width at 80%

Simulation

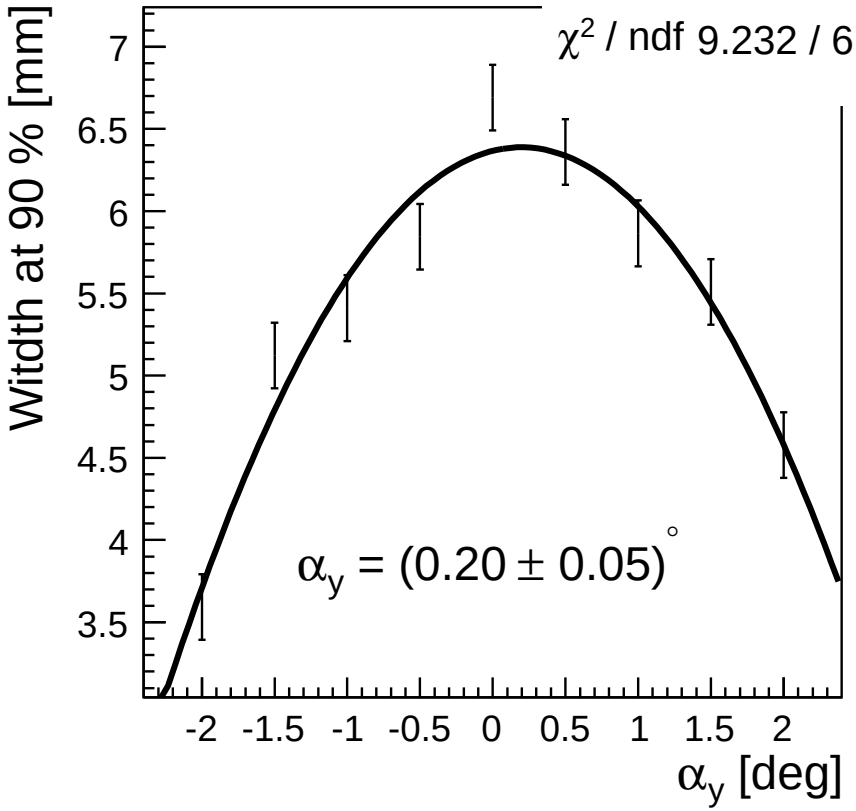


Data (small SAPM)

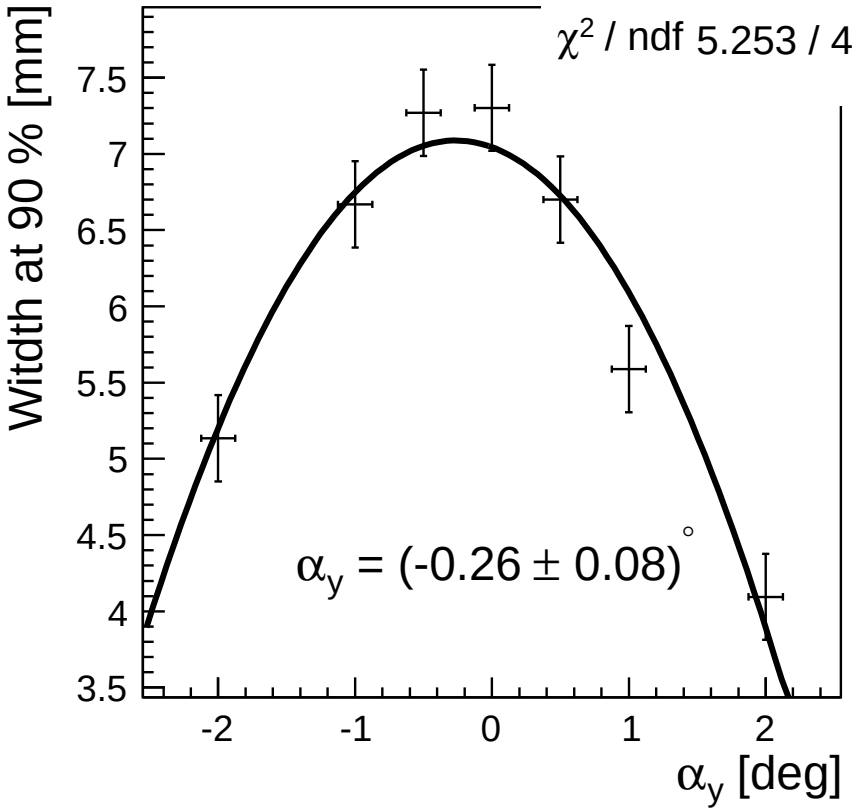


Channel width at 90%

Simulation



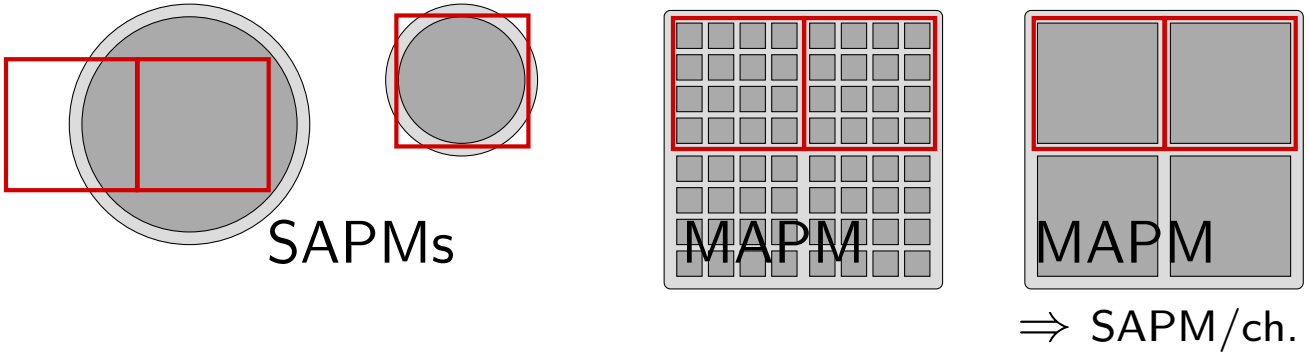
Data (small SAPM)



Parameters III

- Beam profile: assumed as round Gaussian with $\sigma_x = \sigma_y = 0.5$ mm
- Reflectivity of inter-channel: assumed as $R \approx 70\%$ or 80%
- Detector alignment w.r.t. beam axis: not fully done, but...

- Photodetector alignment w.r.t. channel: coverage, shifts, tilts
  - shifts: $(x, y) < 0.3$ mm
  - tilts: $(\alpha_x, \alpha_y) < (1.0°, 1.0°)$ any PD-tilts only important for M64

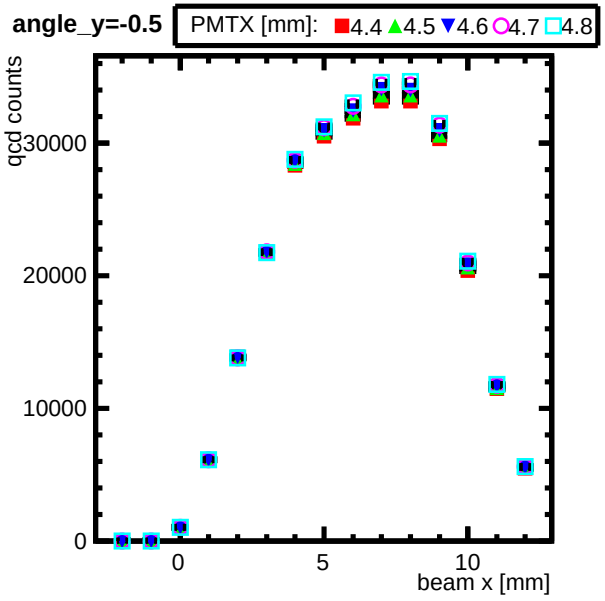


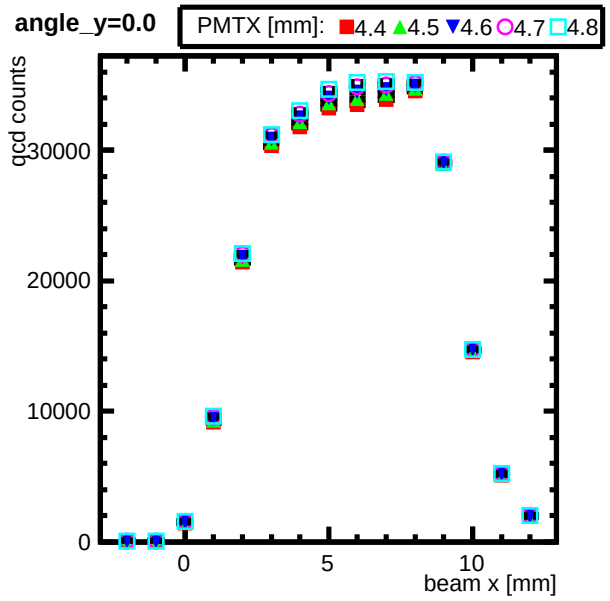
$\Rightarrow$ SAPM/ch.

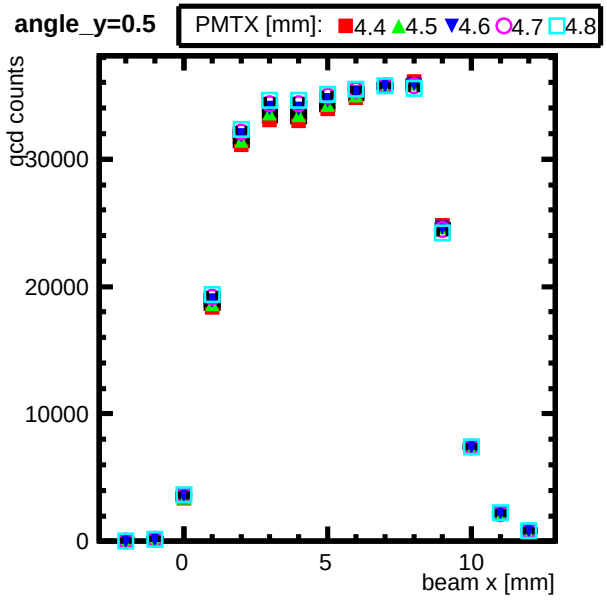
Photodetector Shift w.r.t. Channel

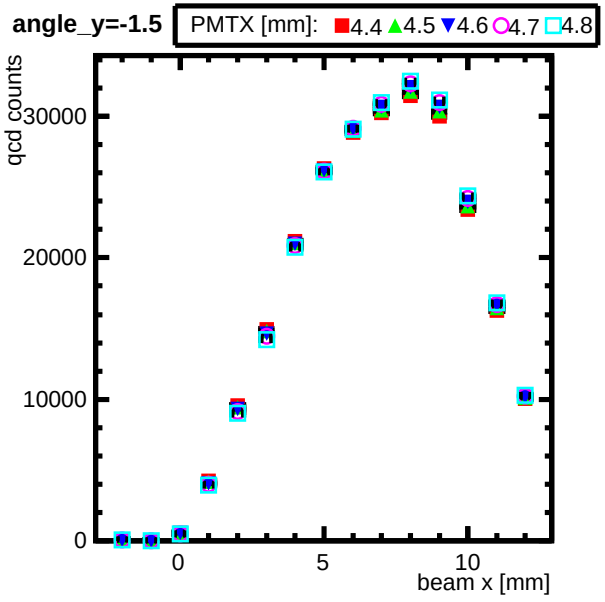
zero pos.

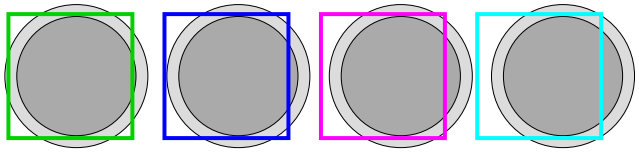
absolute positions

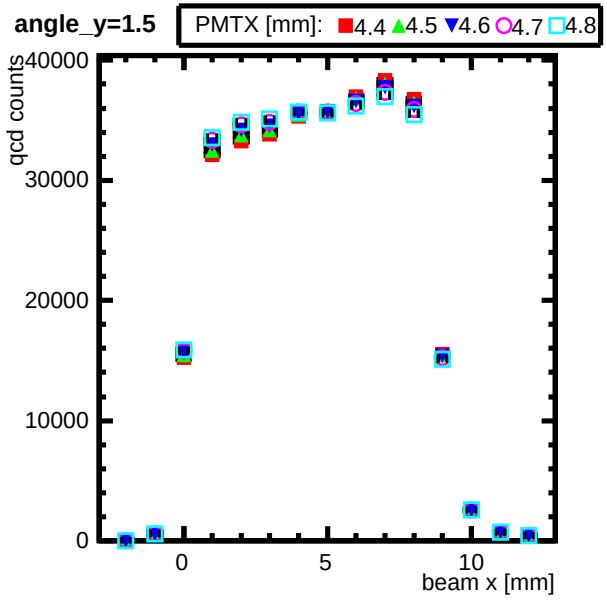






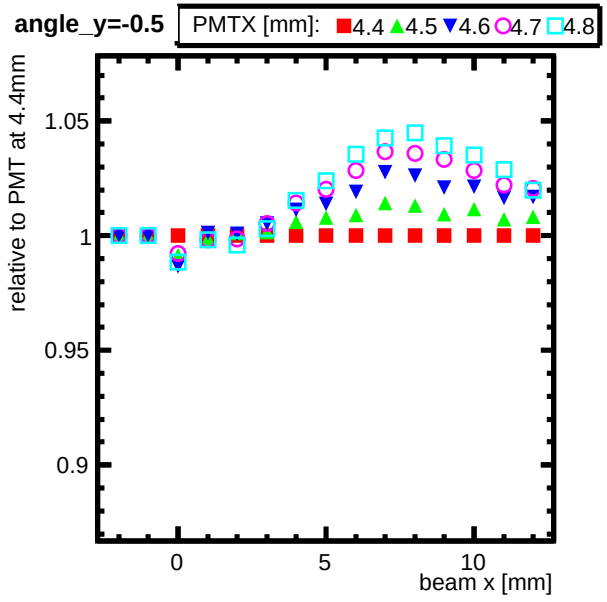




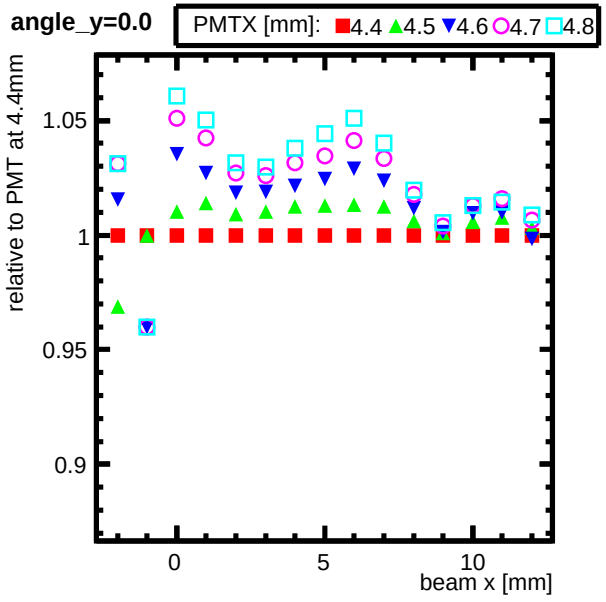


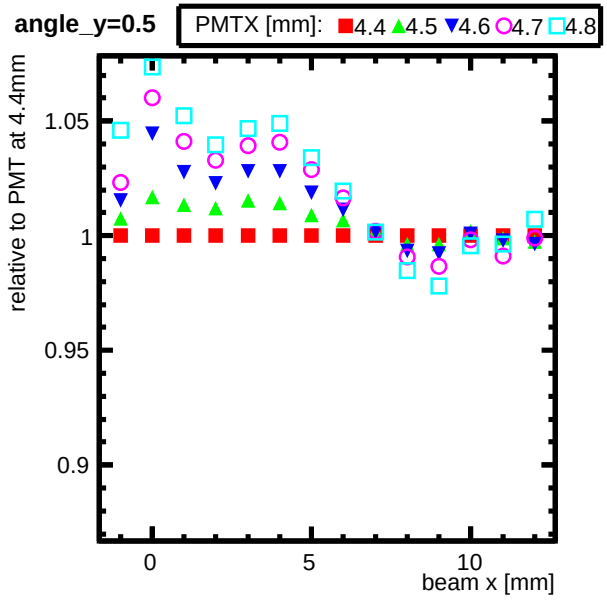
Photodetector Shift w.r.t. Channel

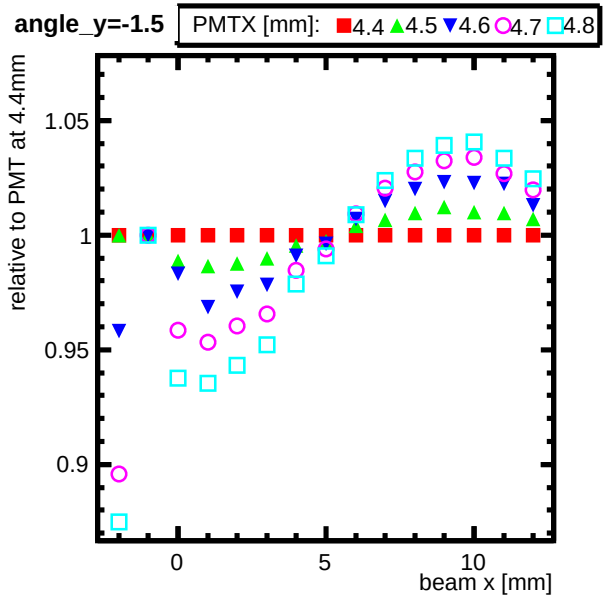
zero pos.

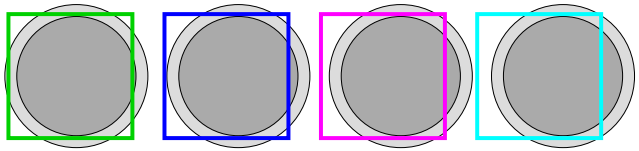


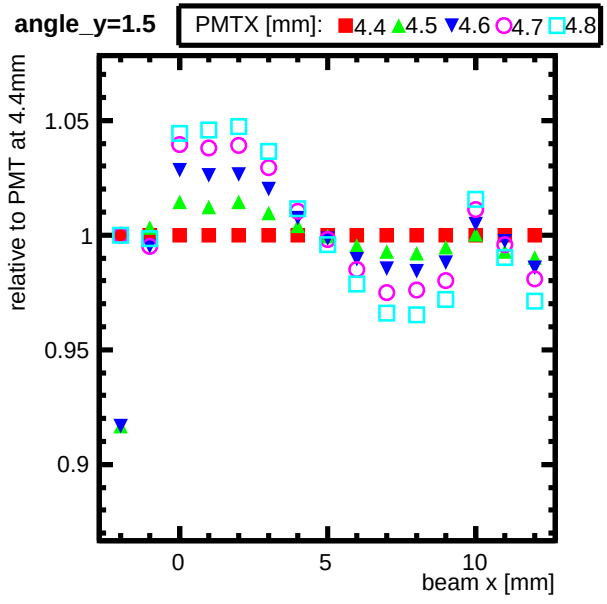
relative
positions





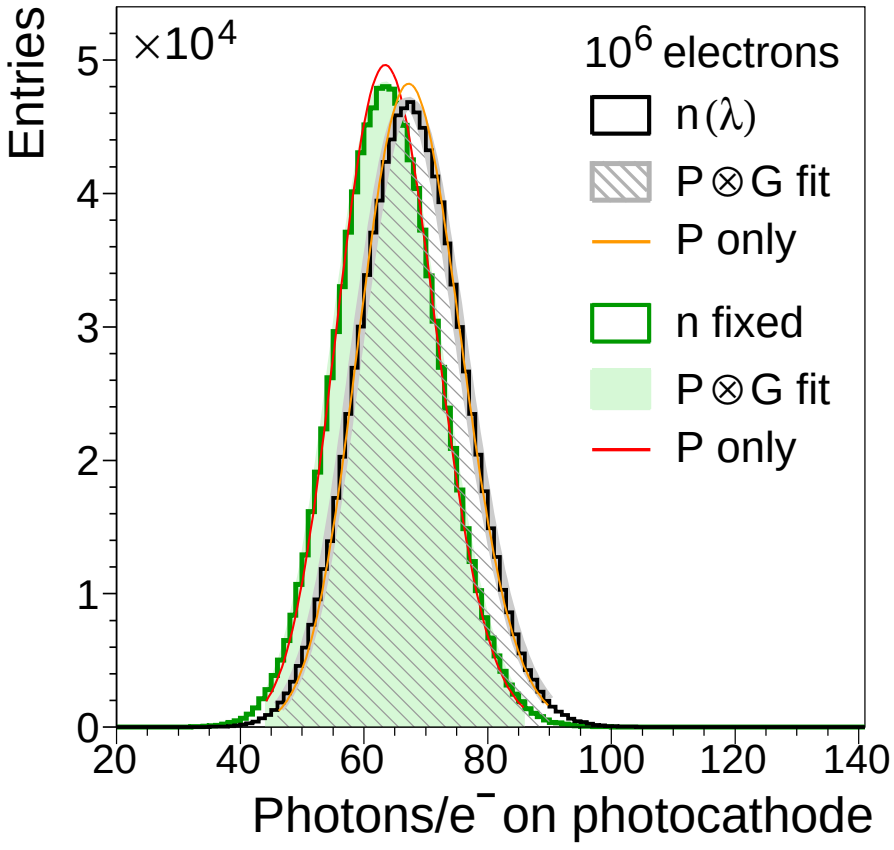






Light Yield per Electrons (on Photocathode)

$R = 100\%$



$n \longrightarrow n(\lambda)$:

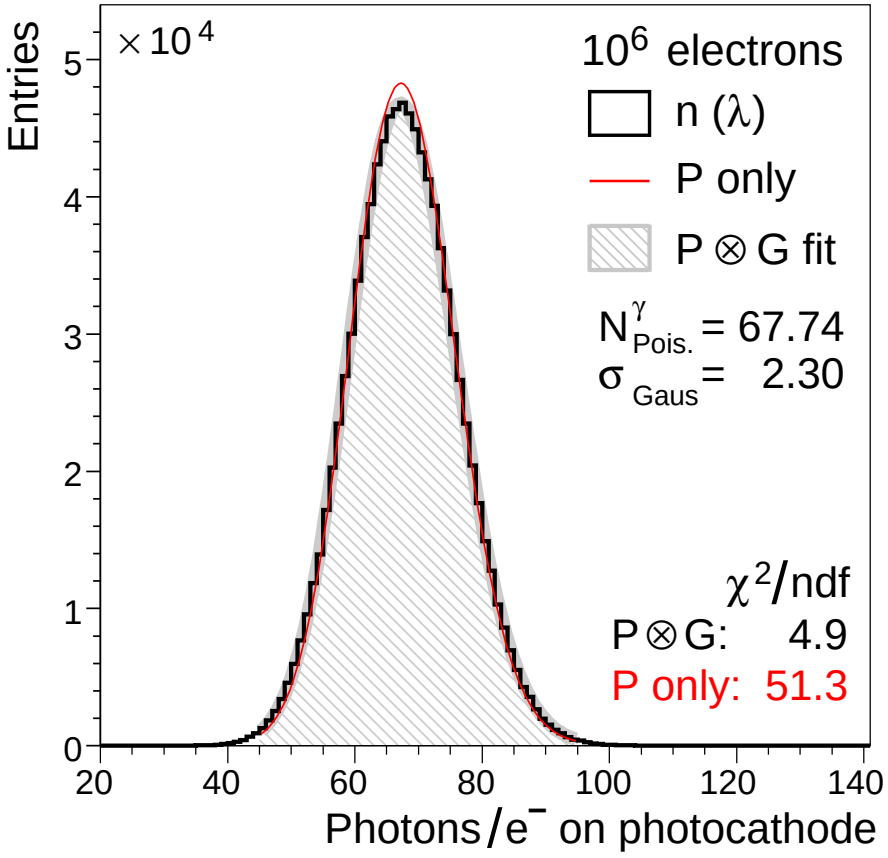
- slightly more photons

Fit with Poisson ⊗ Gauss:

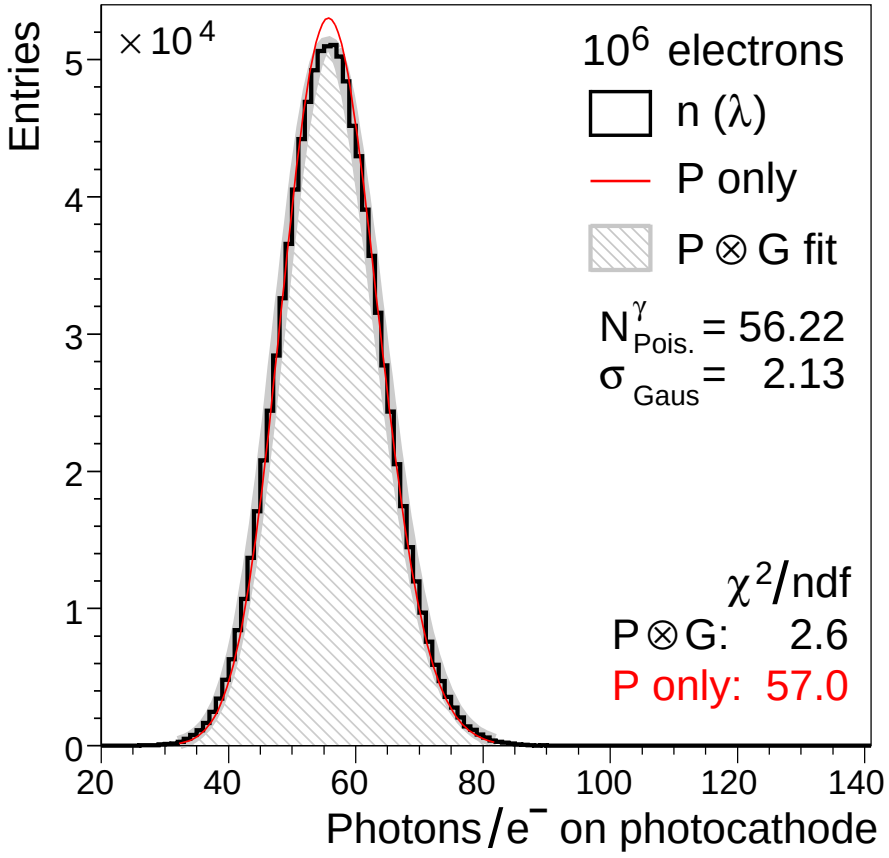
- pure Poisson fit not good
- add small Gaussian smearing
- improves χ^2 by factor ≈ 10

Light Yield per Electrons (on Photocathode)

R = 100%

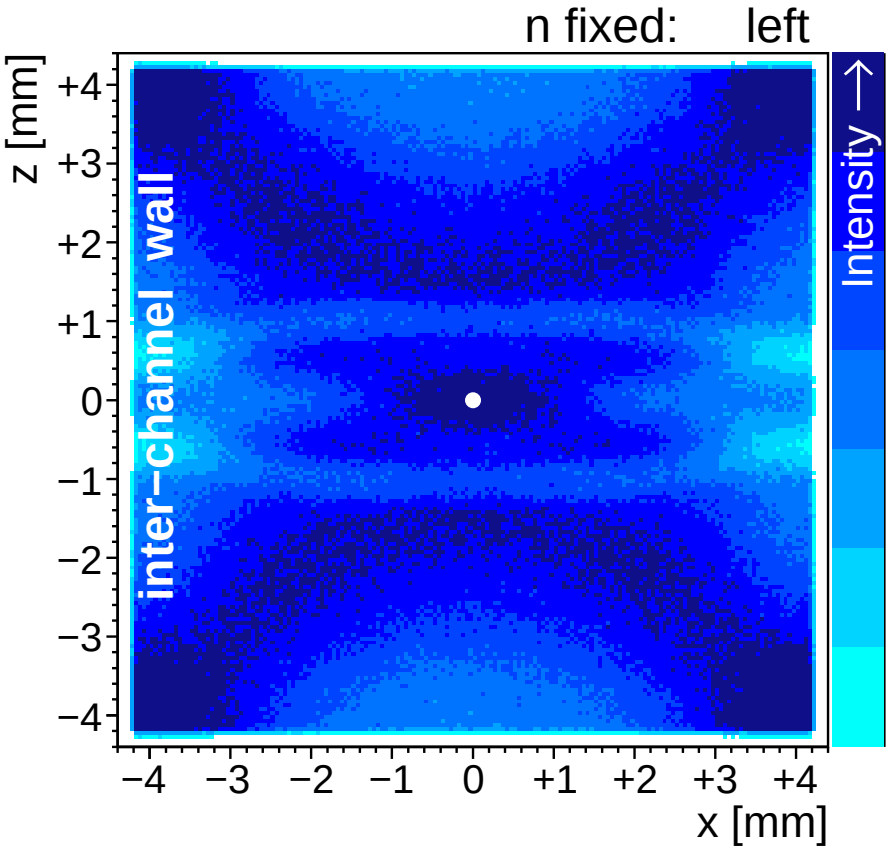


R = 50%

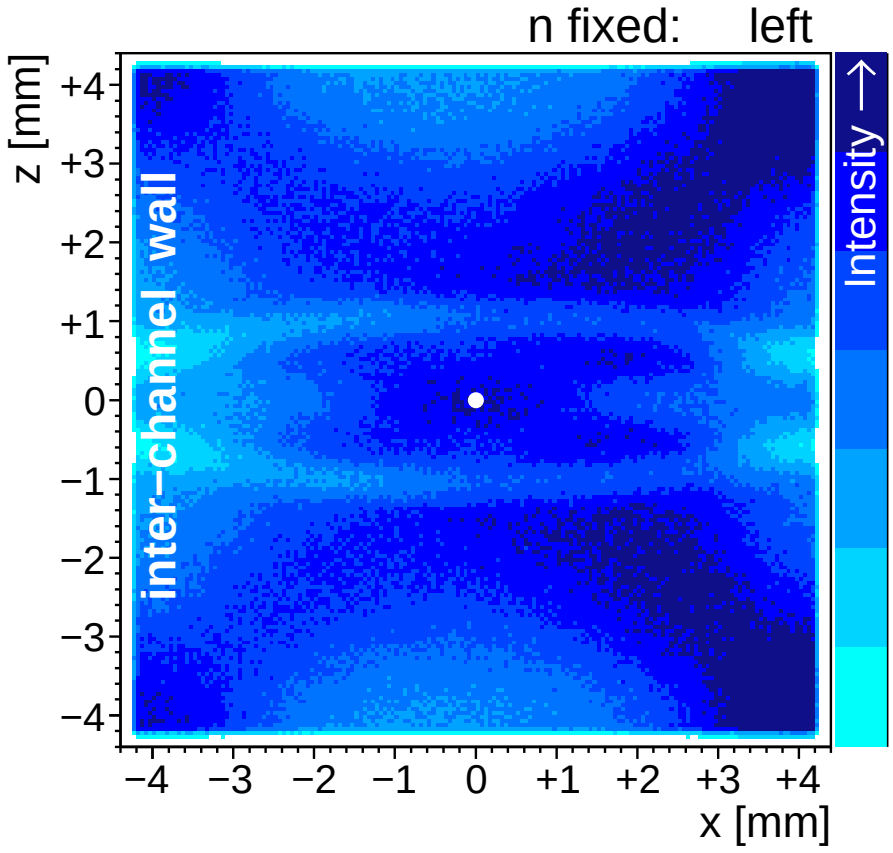


Light Distributions (on Photocathode)

R = 100%

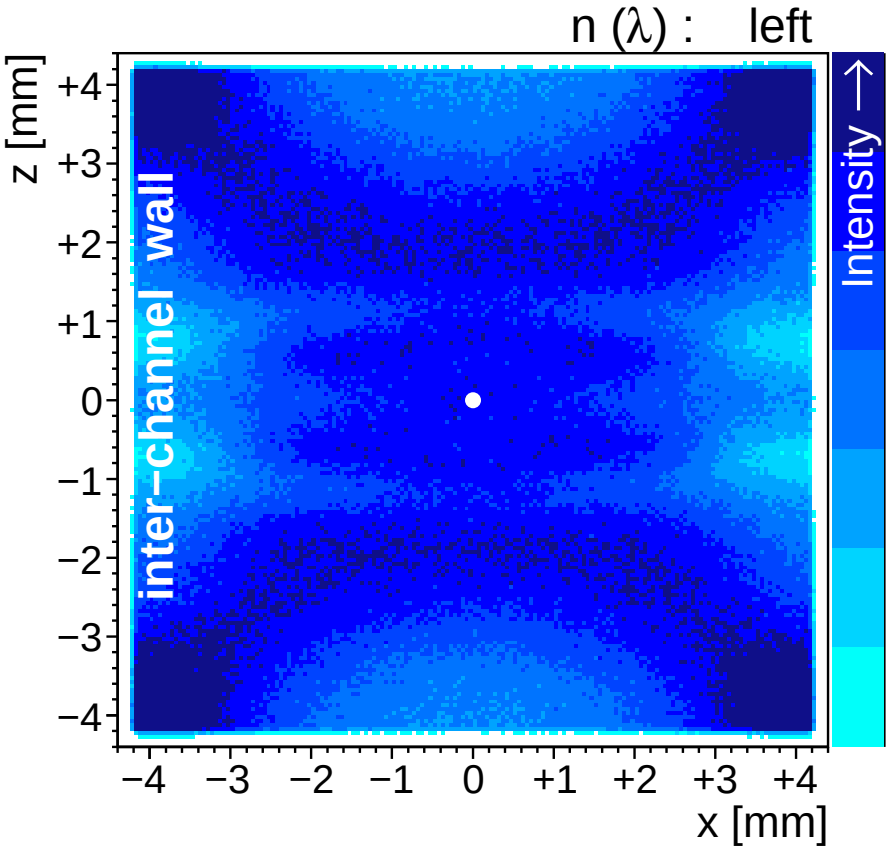


R = 50%

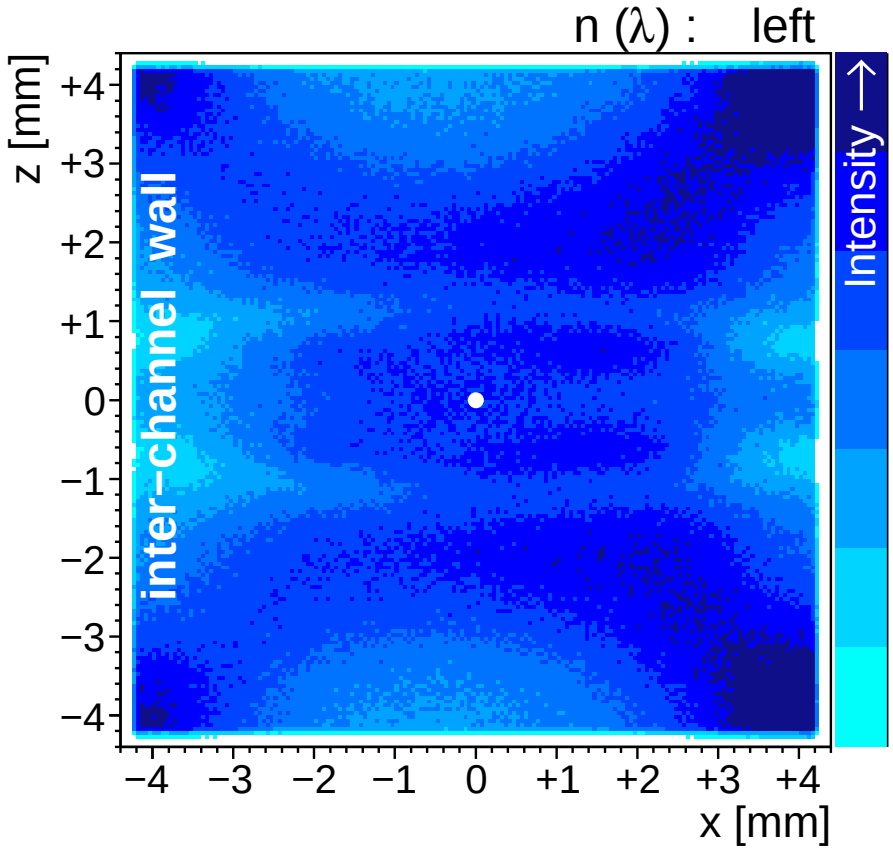


Light Distributions (on Photocathode)

R = 100%

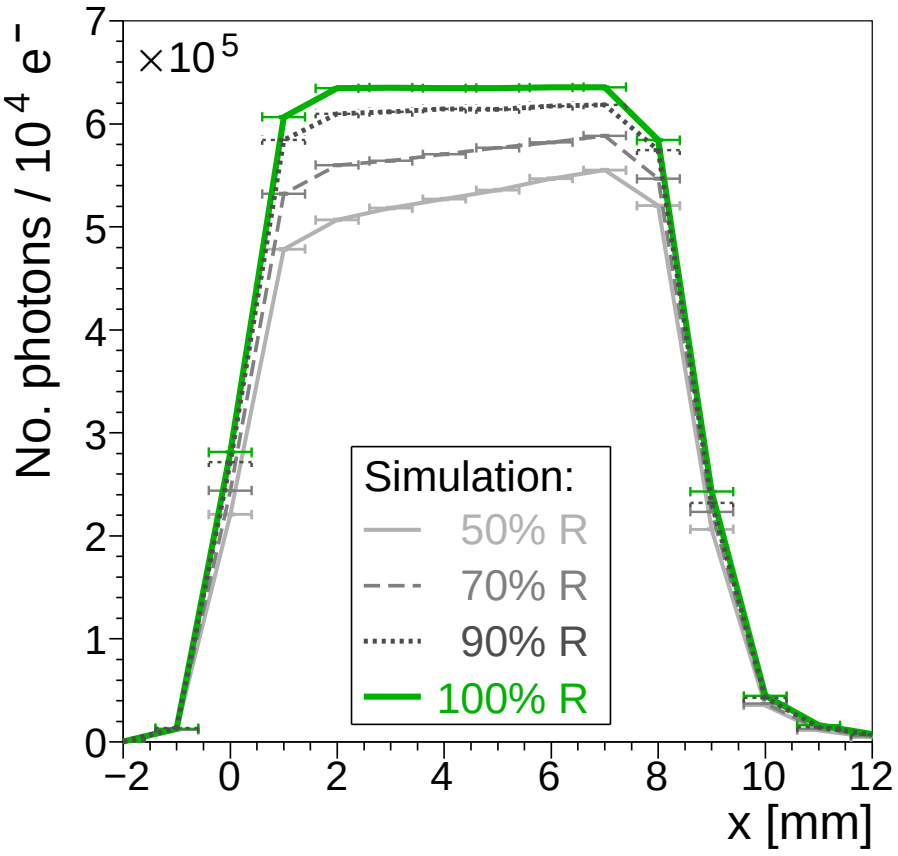


R = 50%



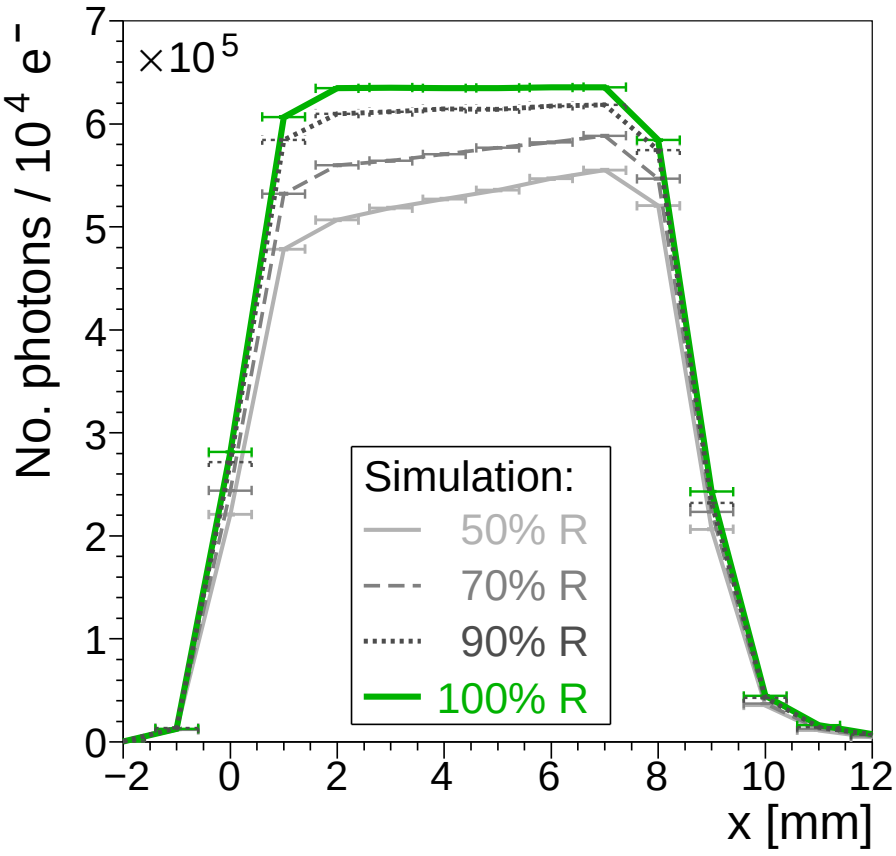
Data-Sim. Comparison w.r.t. Reflectivity

Simulation for:
diff. inter-ch. wall reflectivities



Data-Sim. Comparison w.r.t. Reflectivity

Simulation for:
diff. inter-ch. wall reflectivities



Comparison (data-sim.)
normalised to “plateau” region