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Efficiency and timing measurements with pixel-modules

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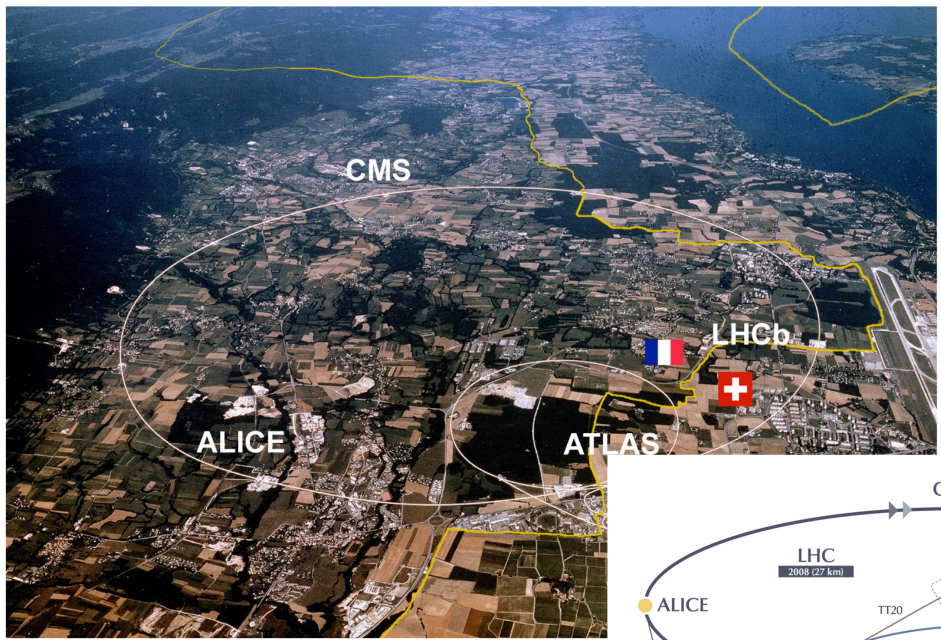
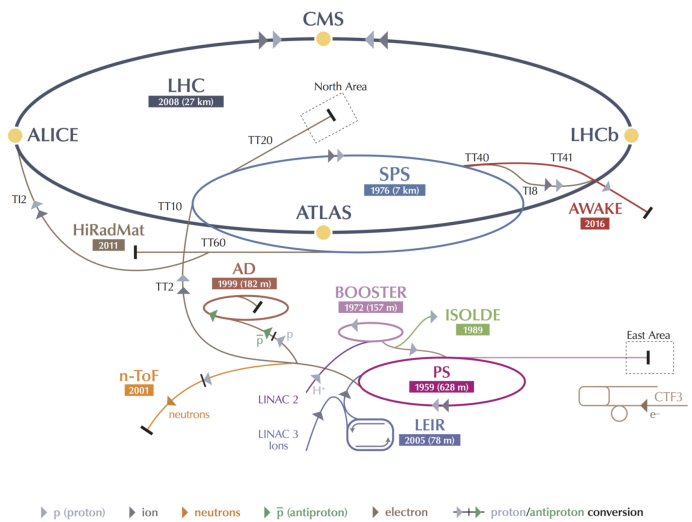
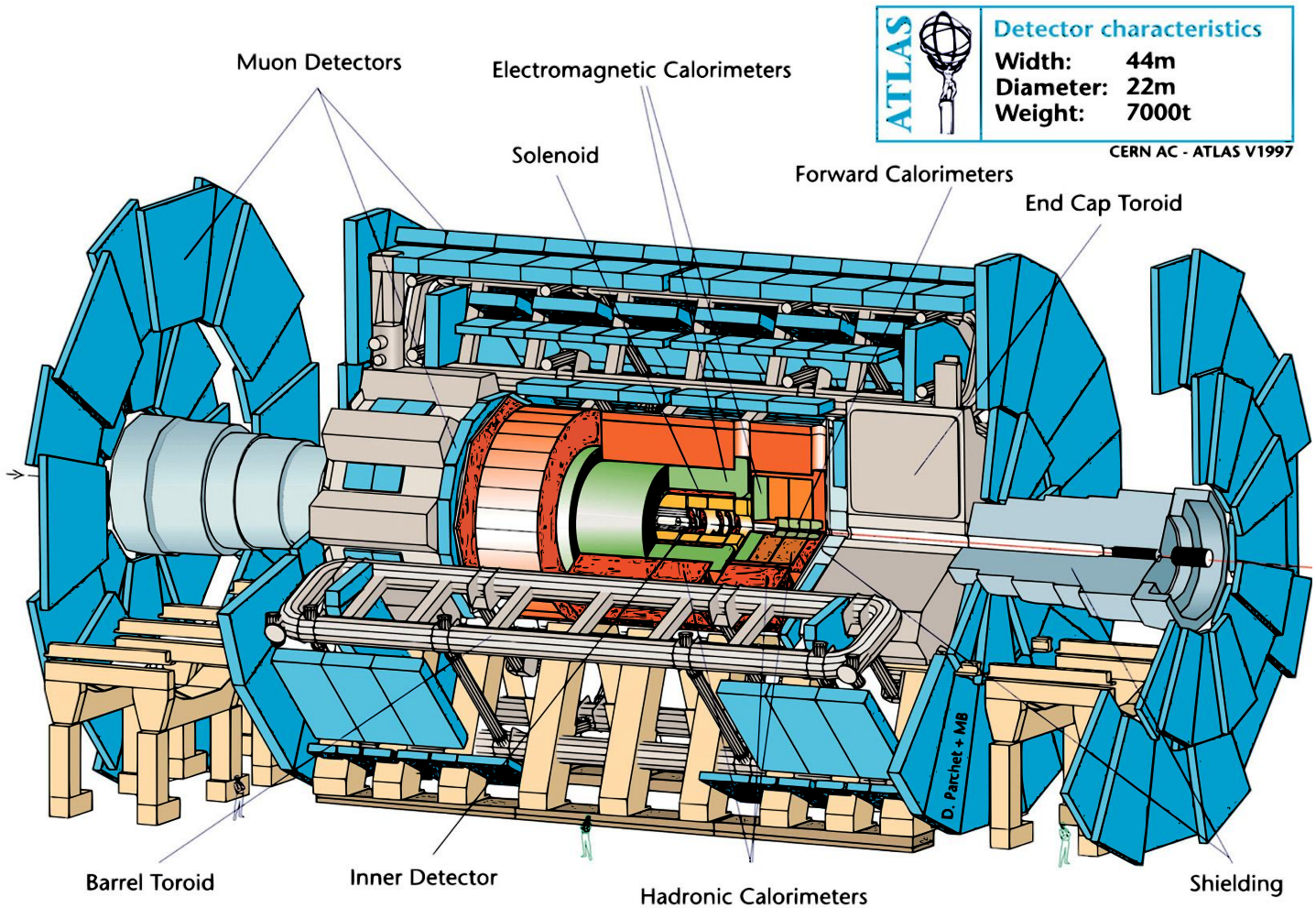
26.10.2015

Introduction
Large Hadron Collider





Introduction
A Toroidal LHC ApparatuS



HL-LHC

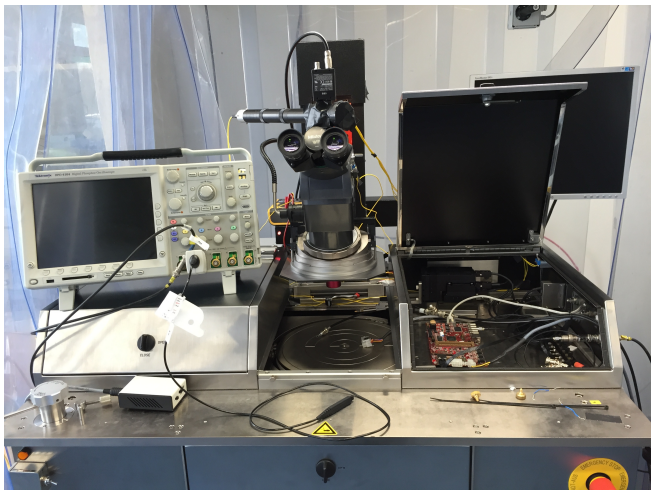
- higher luminosity → higher particle count
- detector needs to cope with higher demands

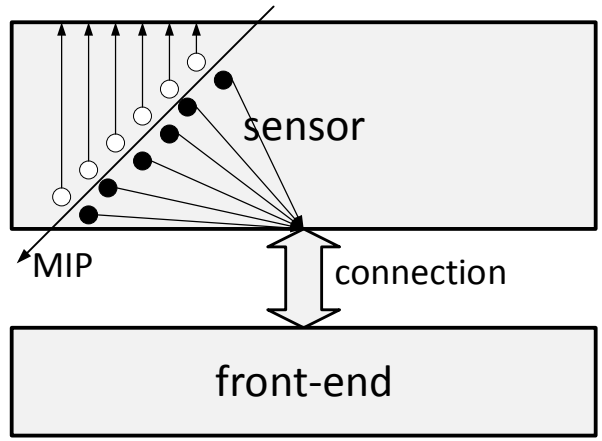
Motivation ITk

- resist harsher conditions
- cope with particle count
  → all silicon tracker
- end of lifetime of Inner Detector

Need for...

- new generation of pixel detector
- reproducible and unbiased tests during development
- benchmarks for final comparison





→ use laser to inject charge with high precission

Probestation

- probestation for positioning and housing of modules
  - accuracy of positioning: 0.25 µm (x/y) / 0.1 µm (z)
- laser system: 671 nm pulsed laser, external triggering, spot size: $\approx 1-2$ µm

Efficiency measurements

Spatially resolved

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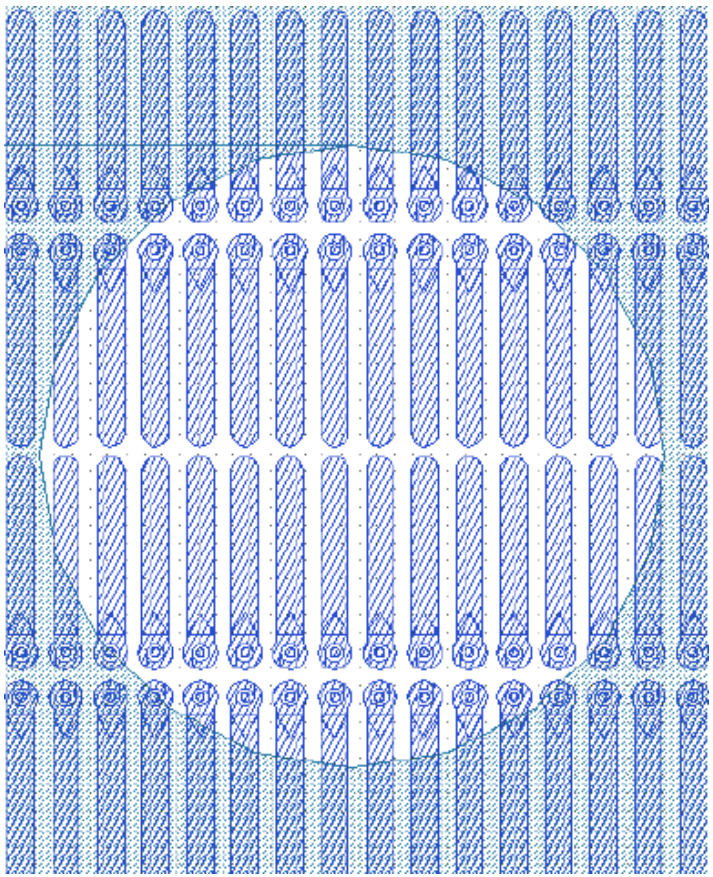
Aim

- spatially resolved hit efficiency
- time resolved hit efficiency

Measurement

- use well-known module (FE-I4A + planar n-in-p) for approval
- hole in metallization enables laser injections
- measurement region: $250 \times 250\,\mu m^2$ @ $2\,\mu m$
- 1000 injections per point
- amount of injected charge can be varied



Efficiency measurements

Spatially resolved

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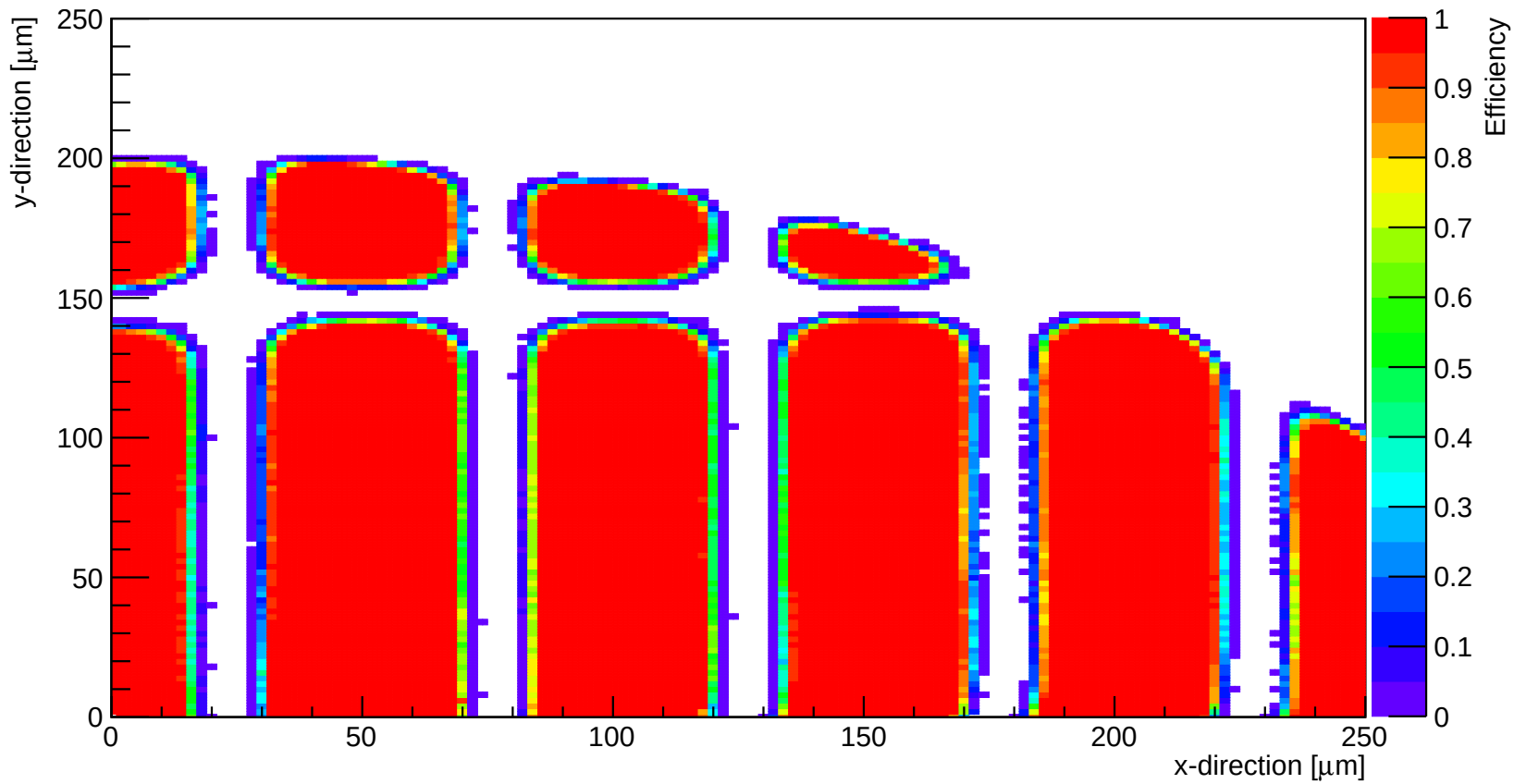
- threshold of discriminator: 3000 e
- injected charge: ≈6000 e



Efficiency measurements

Spatially resolved

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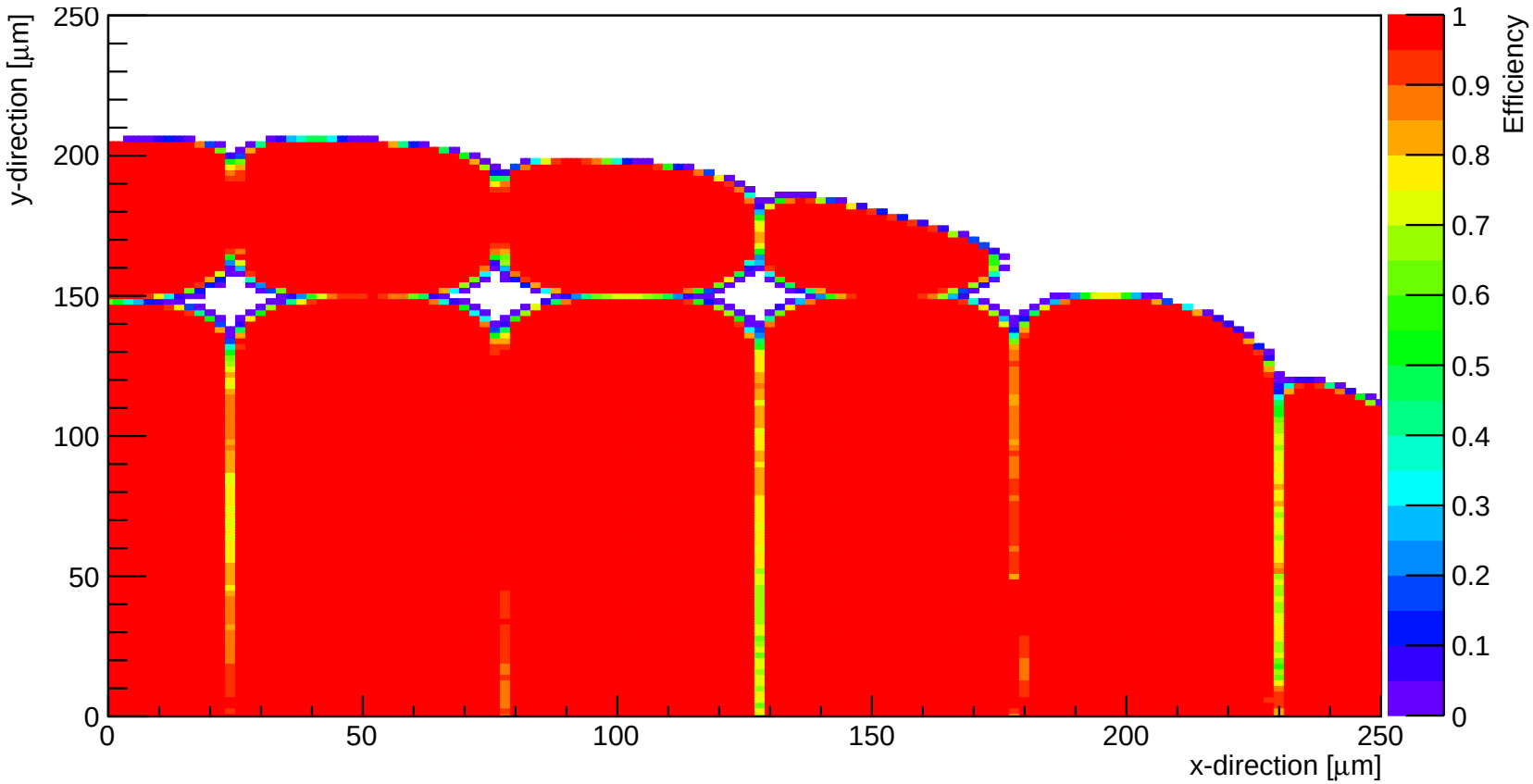
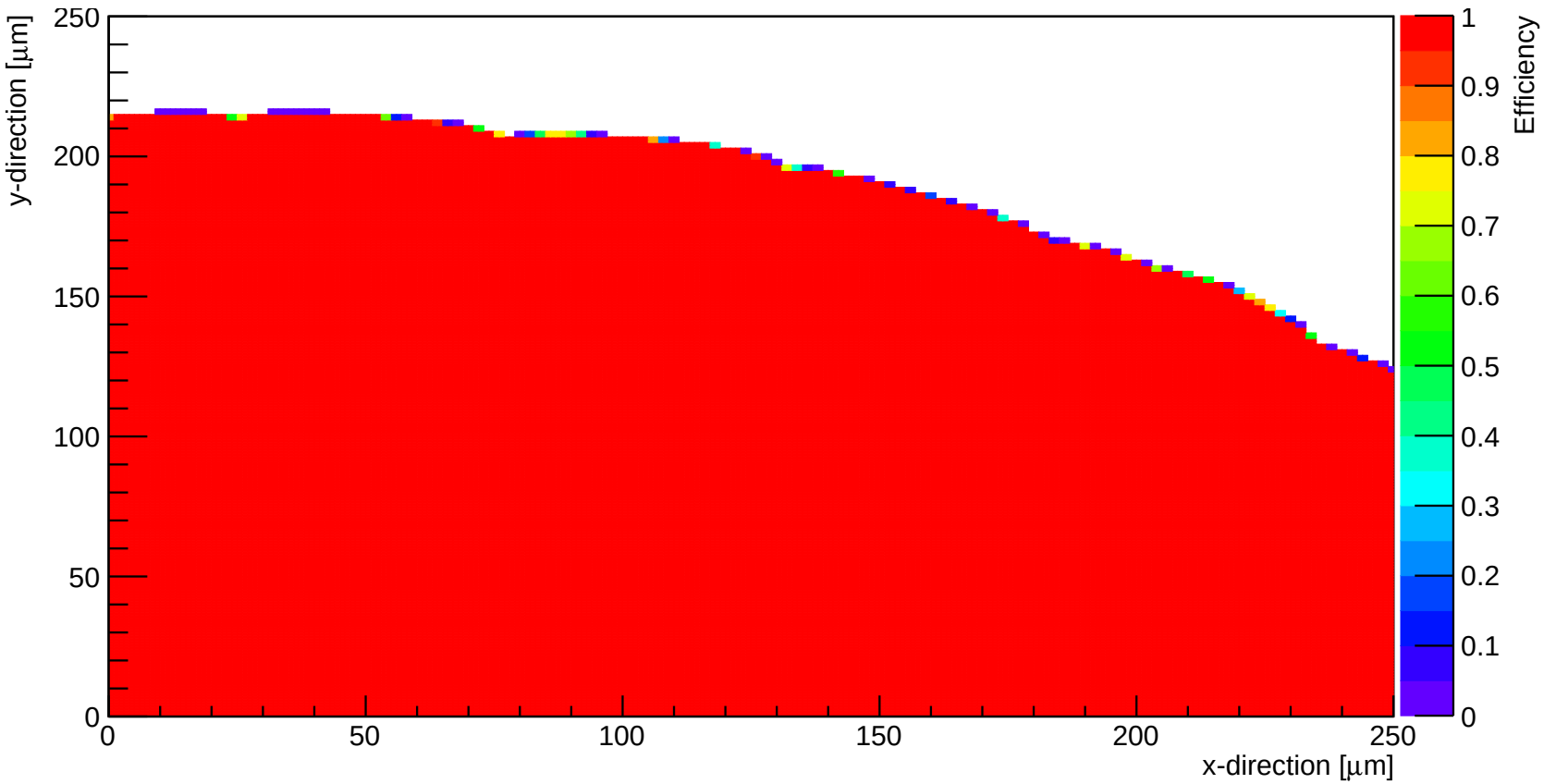
- injected charge: ≈9000 e



Efficiency measurements

Spatially resolved

- injected charge: ≈20 000 e



Efficiency measurements

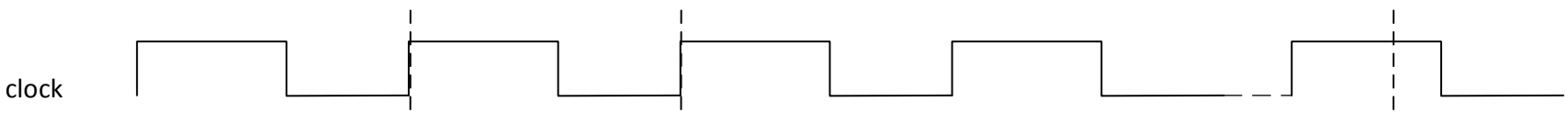
Time resolved

Timing

- important: assign hits in detector to correct bunch crossing
- module composition essential for timing behaviour
  $\rightarrow$ figure of merit
- determine in-time efficiency...
- ...in dependence of amount of charge $\rightarrow$ timewalk

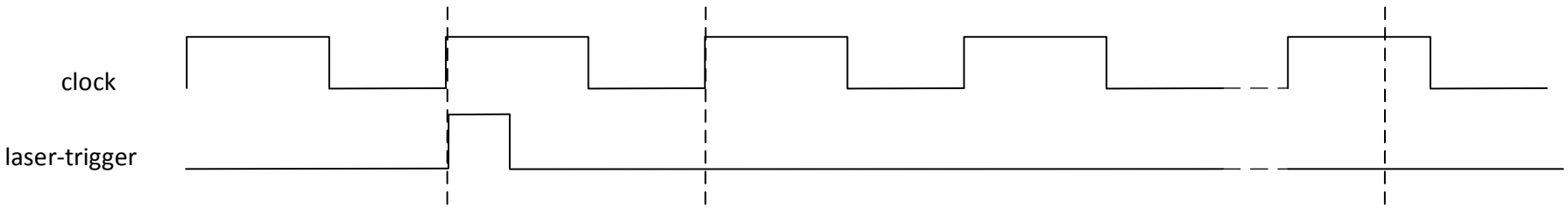
Timing measurements

in-time efficiency



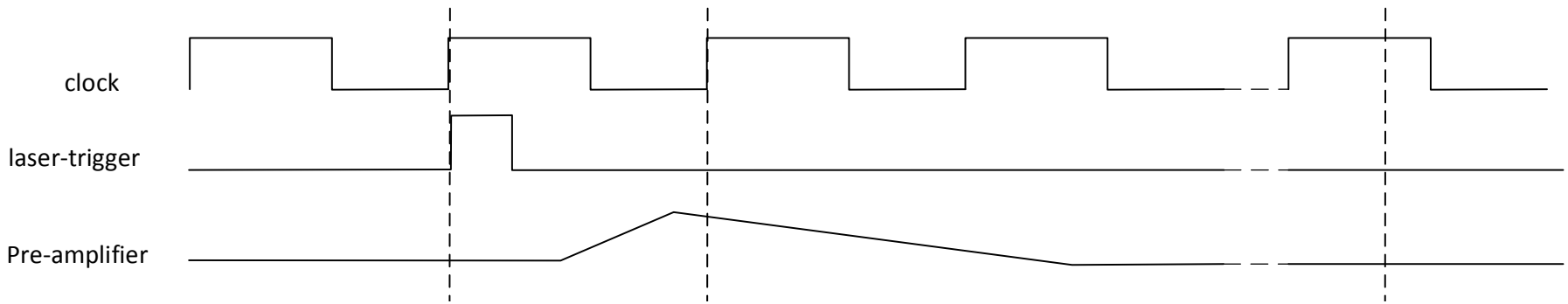
Timing measurements

in-time efficiency



Timing measurements

in-time efficiency



Timing measurements

in-time efficiency

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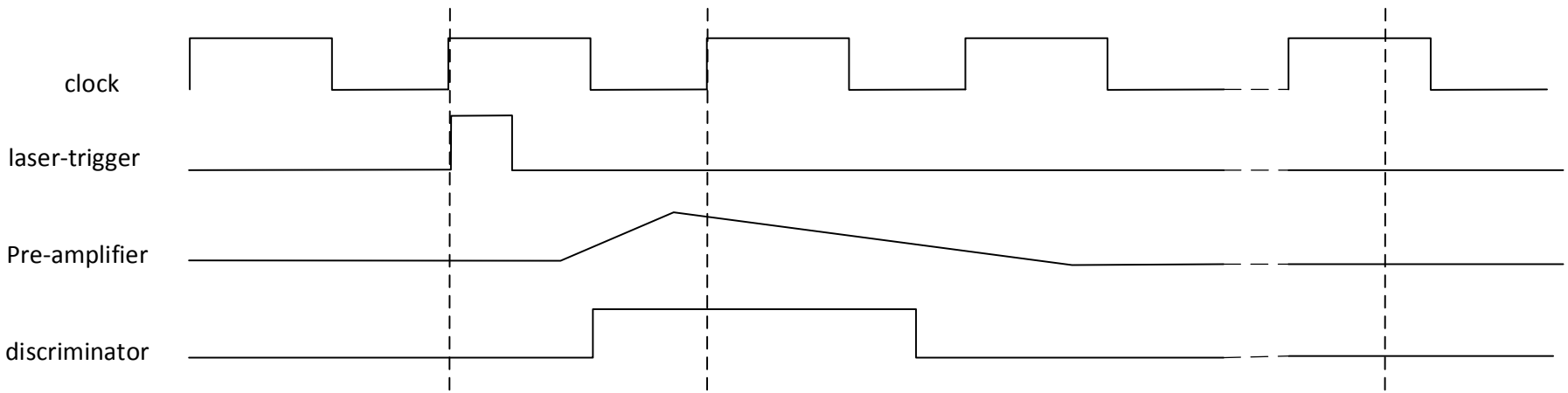
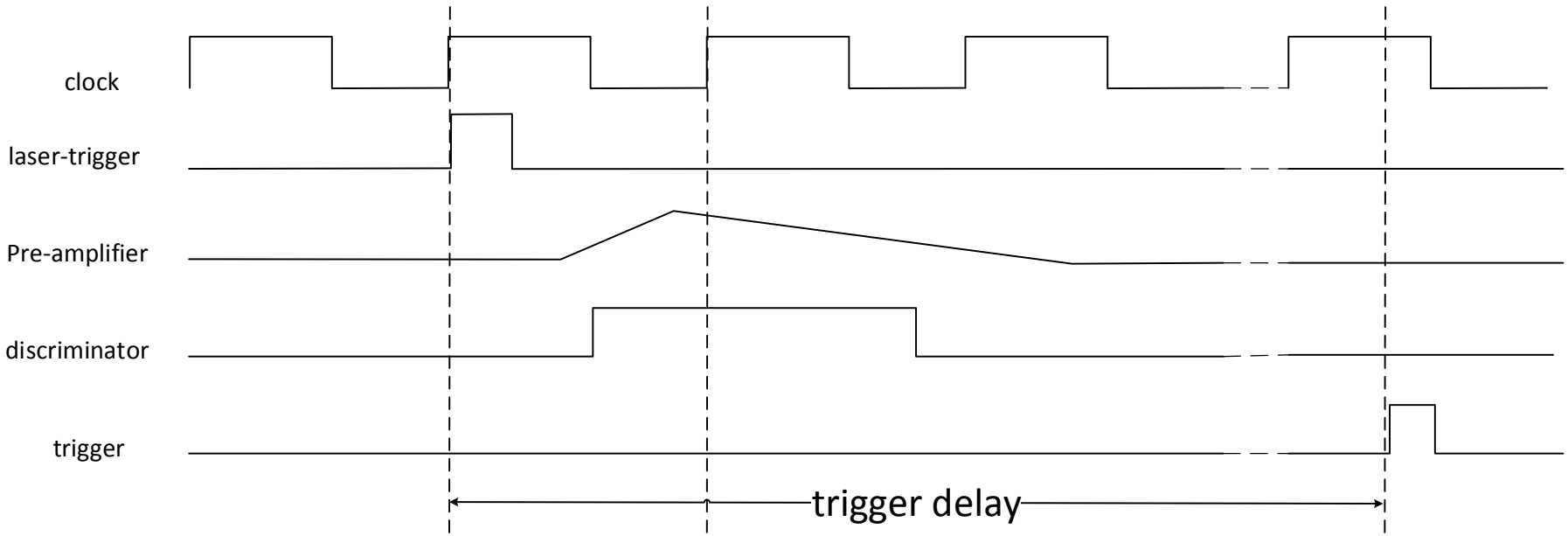


Timing measurements

in-time efficiency



Timing measurements

in-time efficiency

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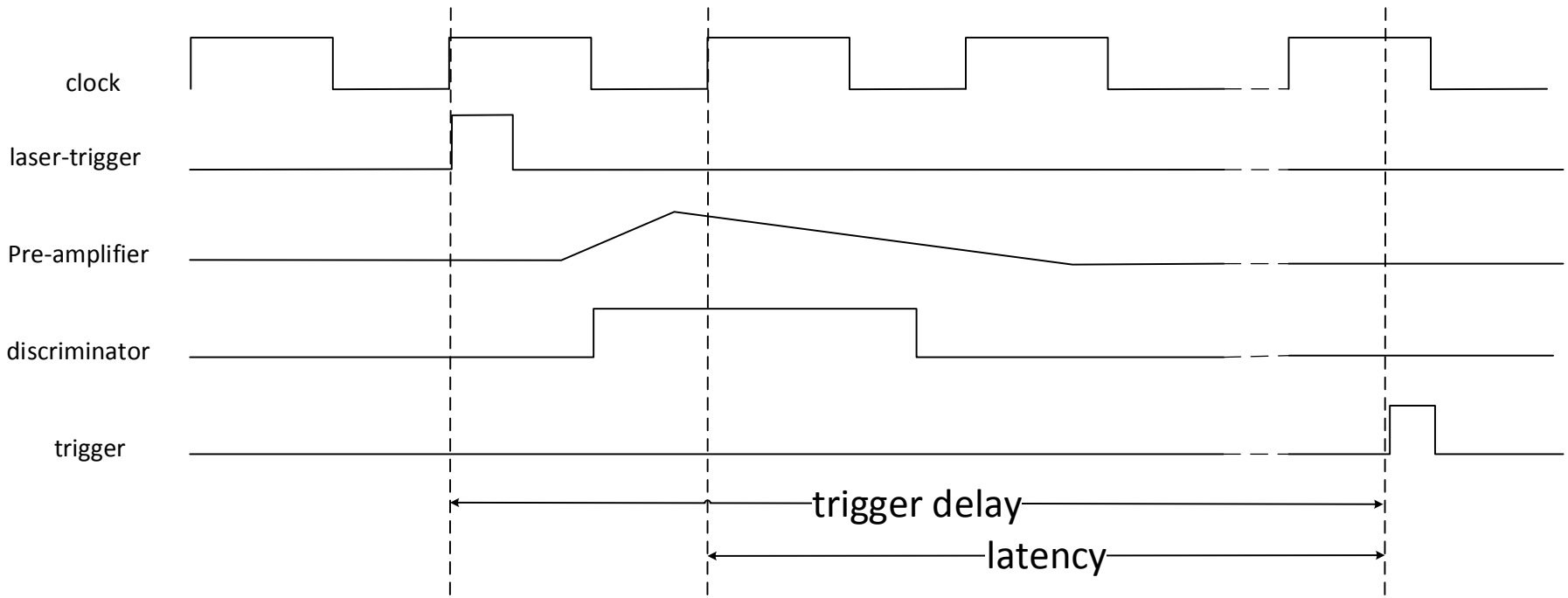
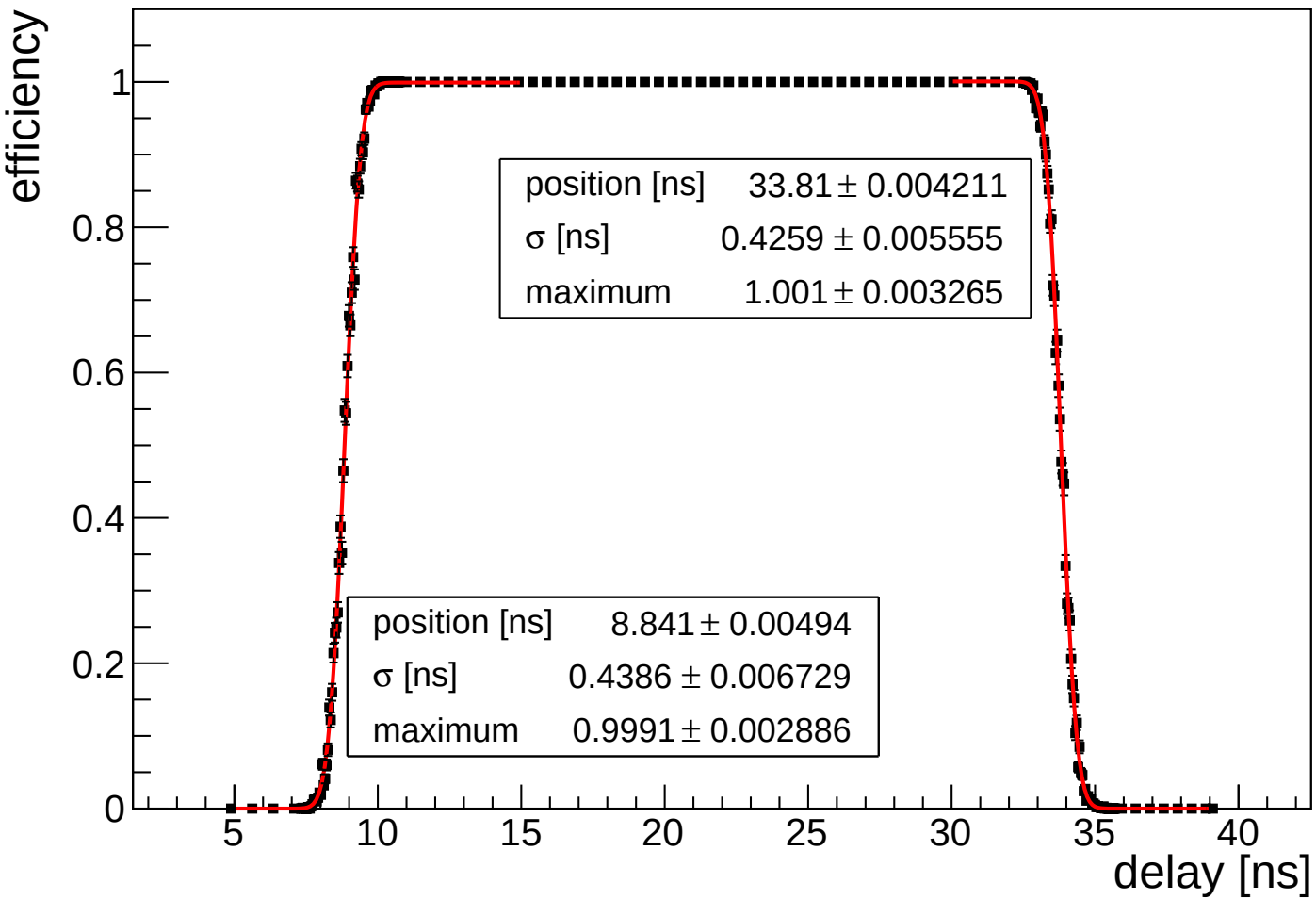
- measurement: vary laser-trigger → sample acceptance window



Timing measurements

in-time efficiency

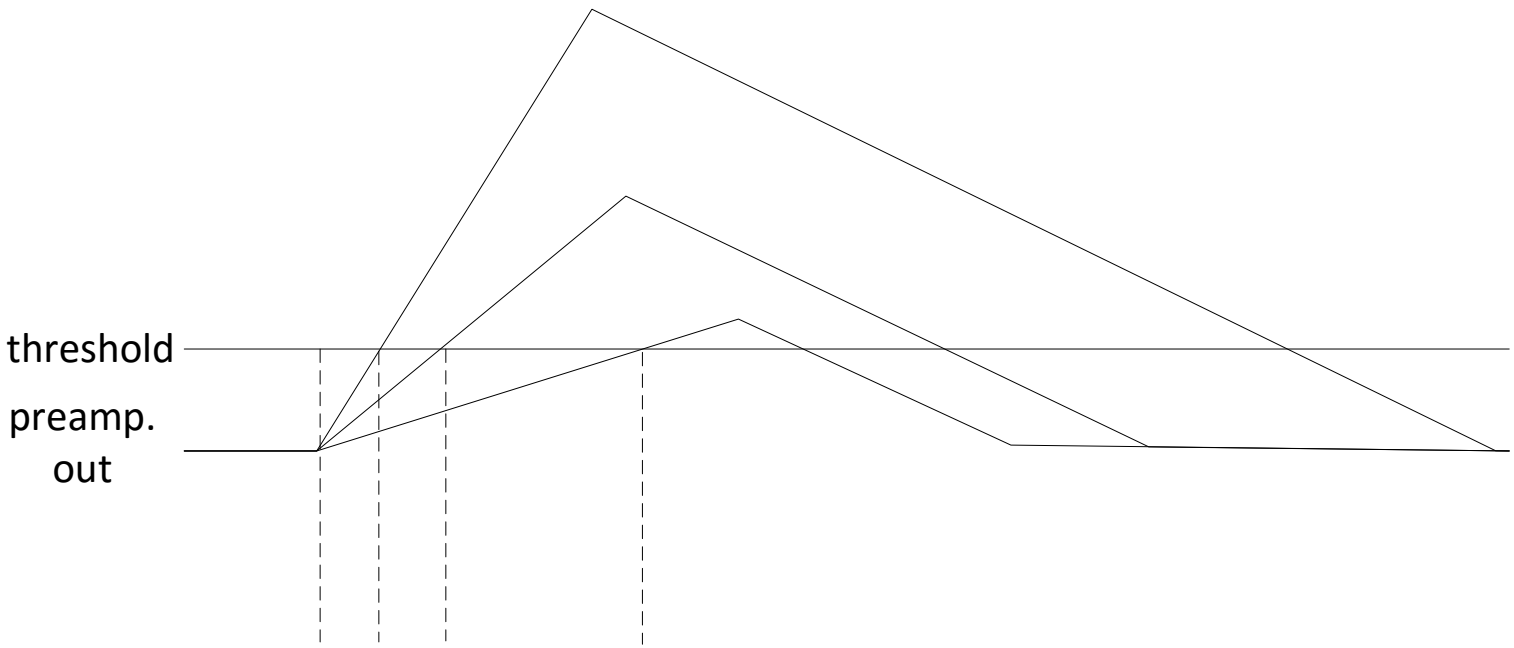
- FWHM: 24.97 ns



Timing measurements

Timewalk

- timewalk results from charge-dependent slope of preamplifier
- Δt(big charge$\leftrightarrow$small charge) = 20-50 ns
  $\rightarrow$ important for hit allocation



Timing measurements

Timewalk

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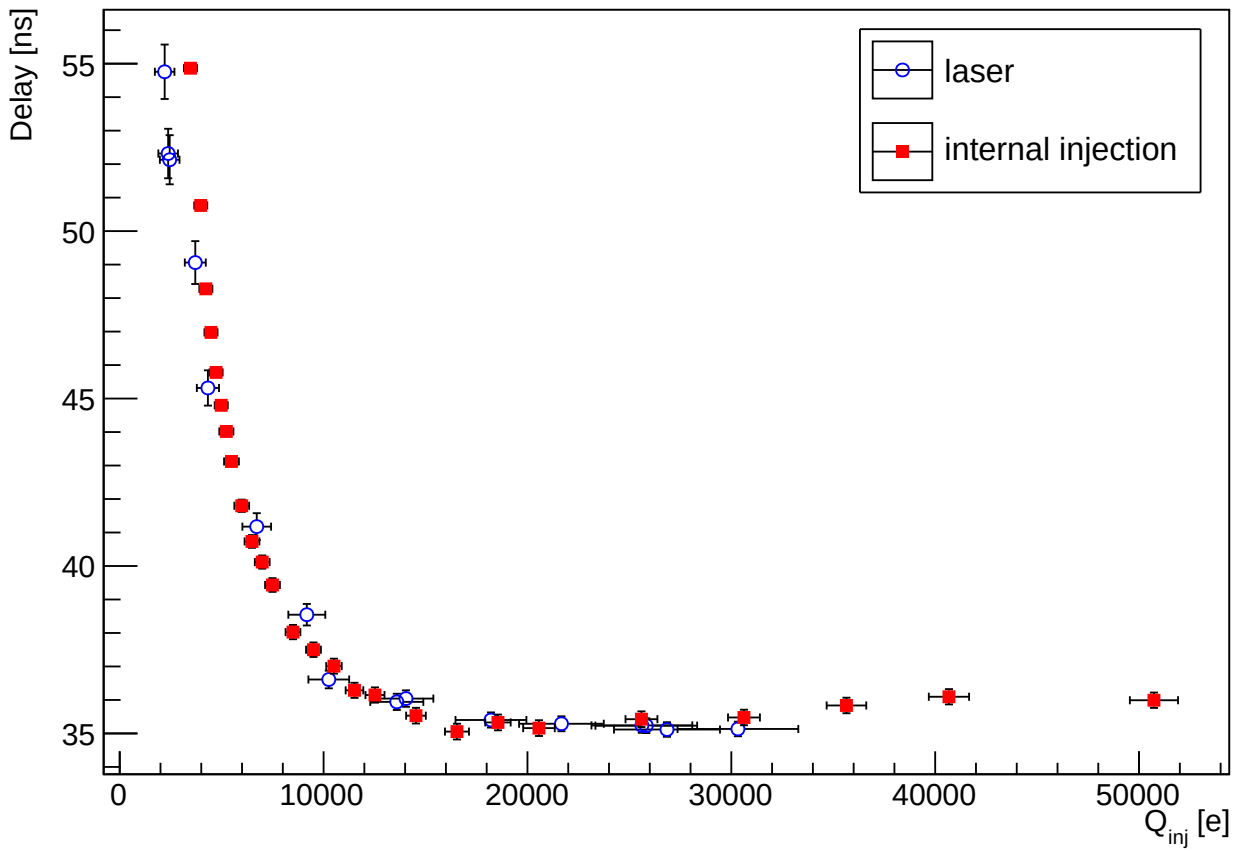
- plateau for large charges ($> 15000\,\mathrm{e}$)
- large slope for smaller charges



Conclusion

Spatially resolved efficiency measurements

- measurement principle and analysis tools established
- easy way to obtain basic and fundamental information

Time resolved efficiency measurements

- timing is important for hit allocation
- timing can be measured very precisely

The End

Thank you for your attention

Backup

Spatially resolved hit efficiency

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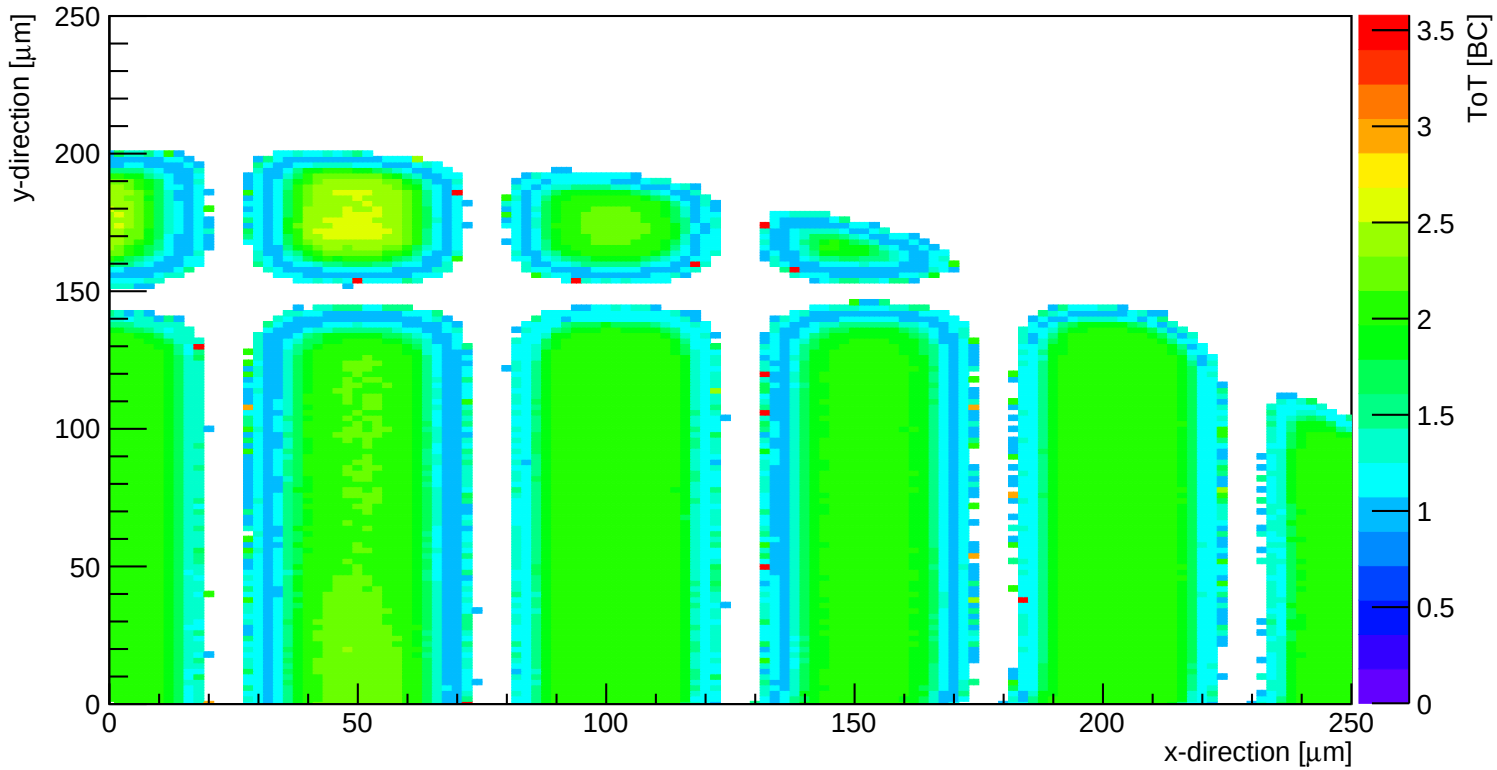
- threshold of discriminator: 3000 e
- injected charge: ≈6000 e



Spatially resolved hit efficiency

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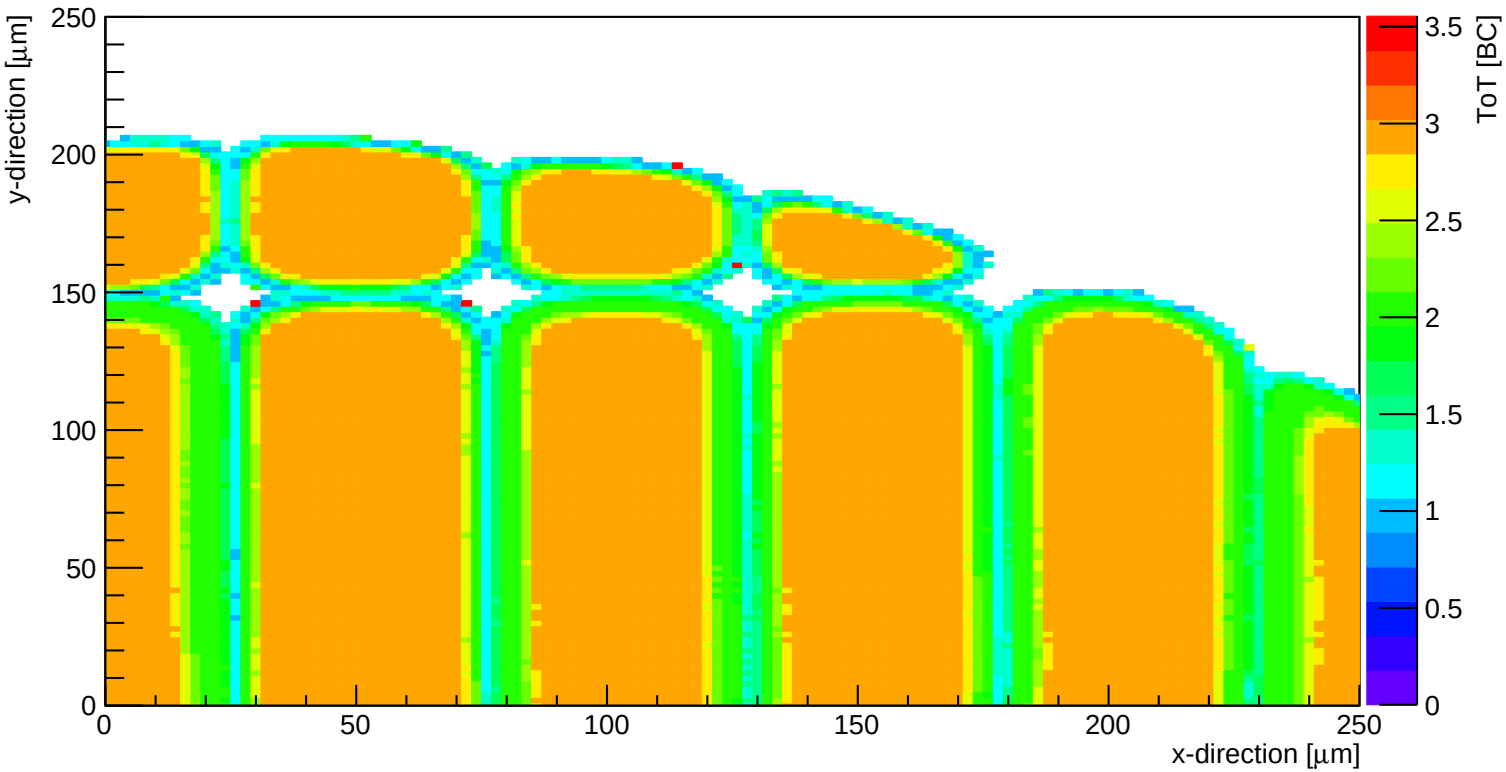
- injected charge: ≈9000 e



Spatially resolved hit efficiency

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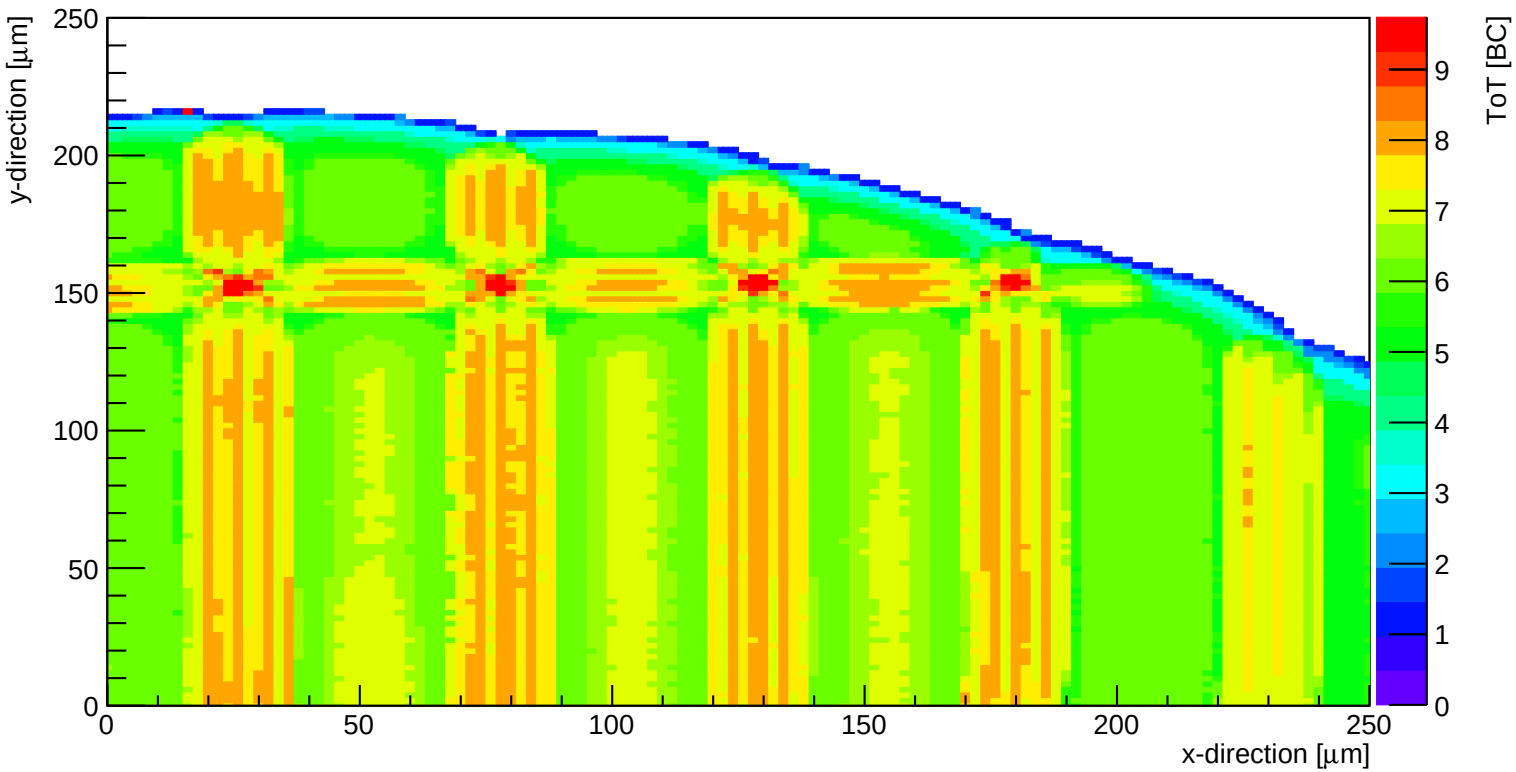
- injected charge: ≈20 000 e



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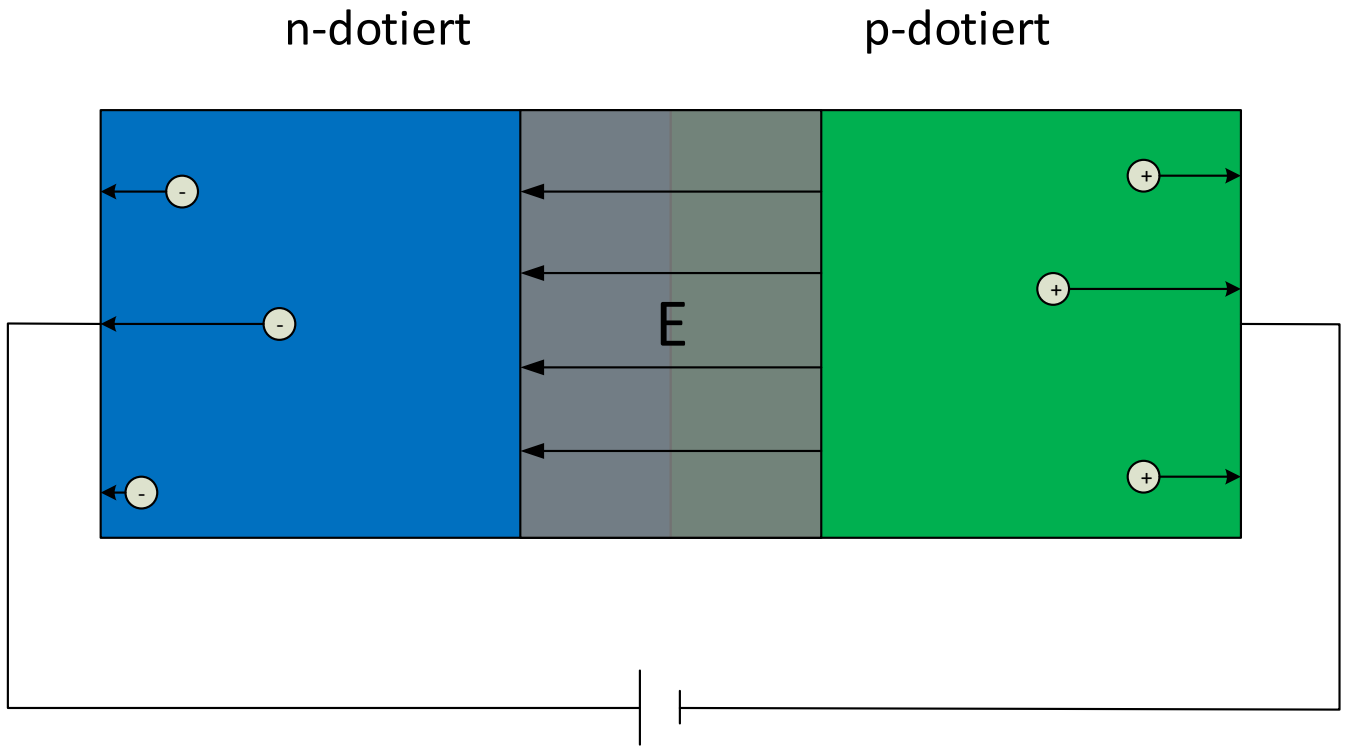

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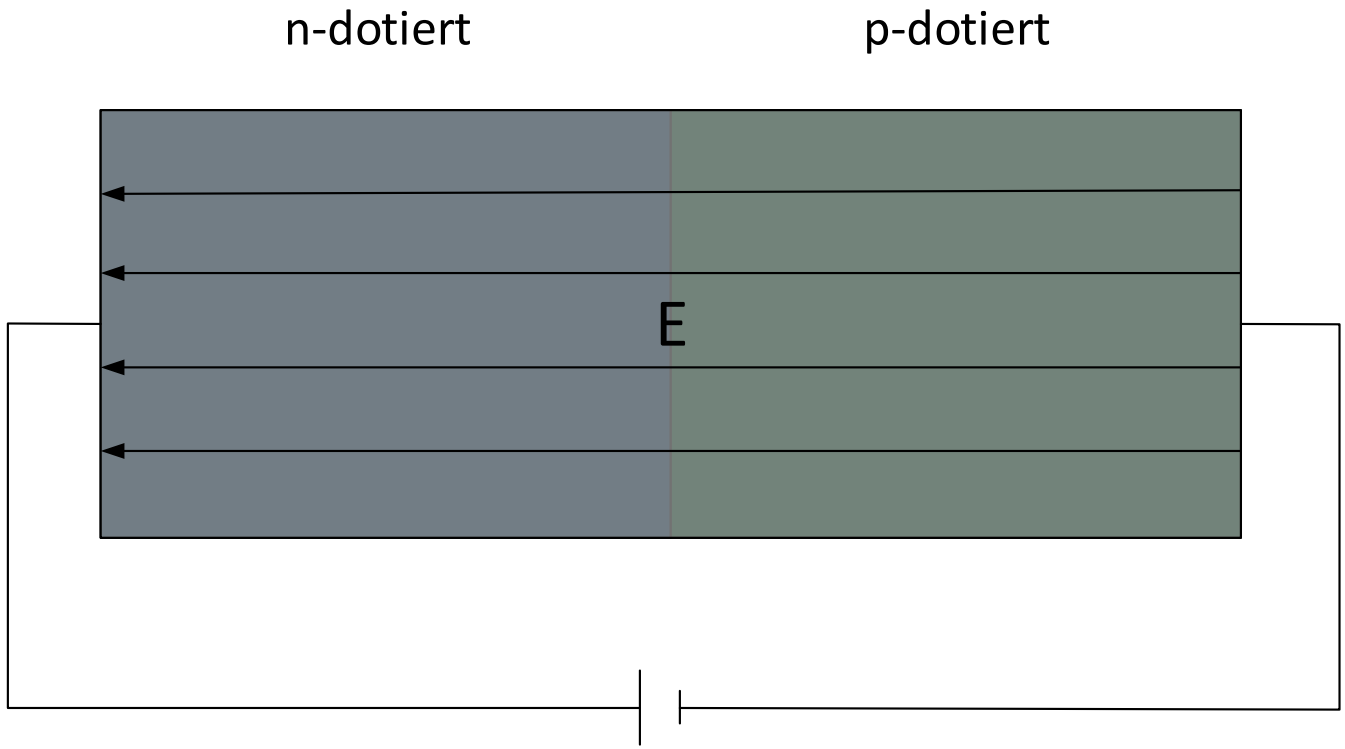

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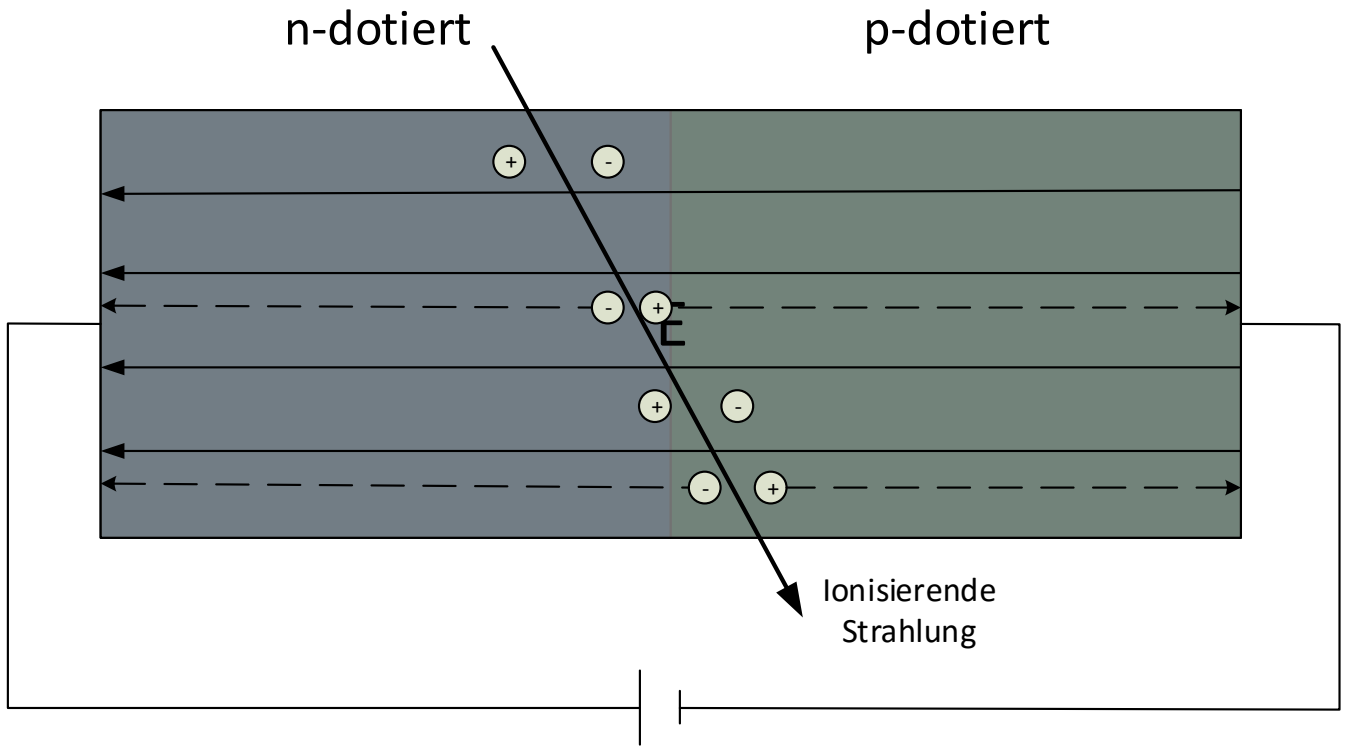

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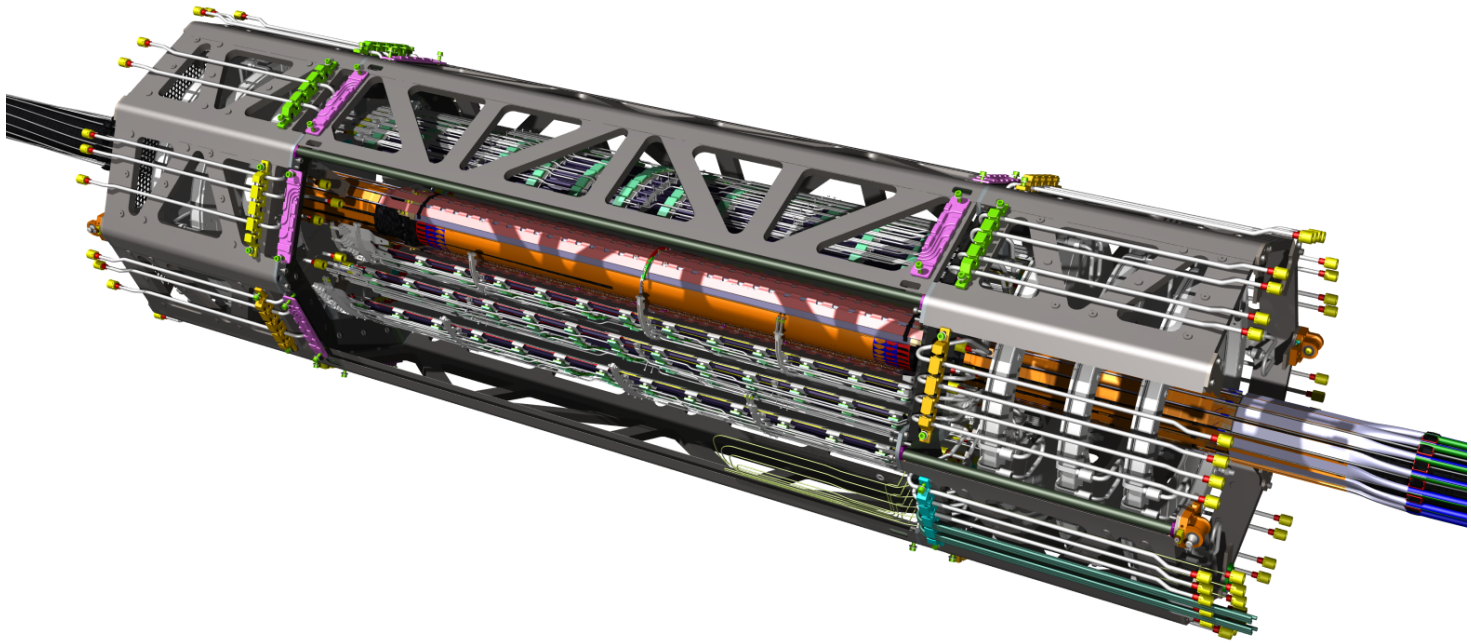

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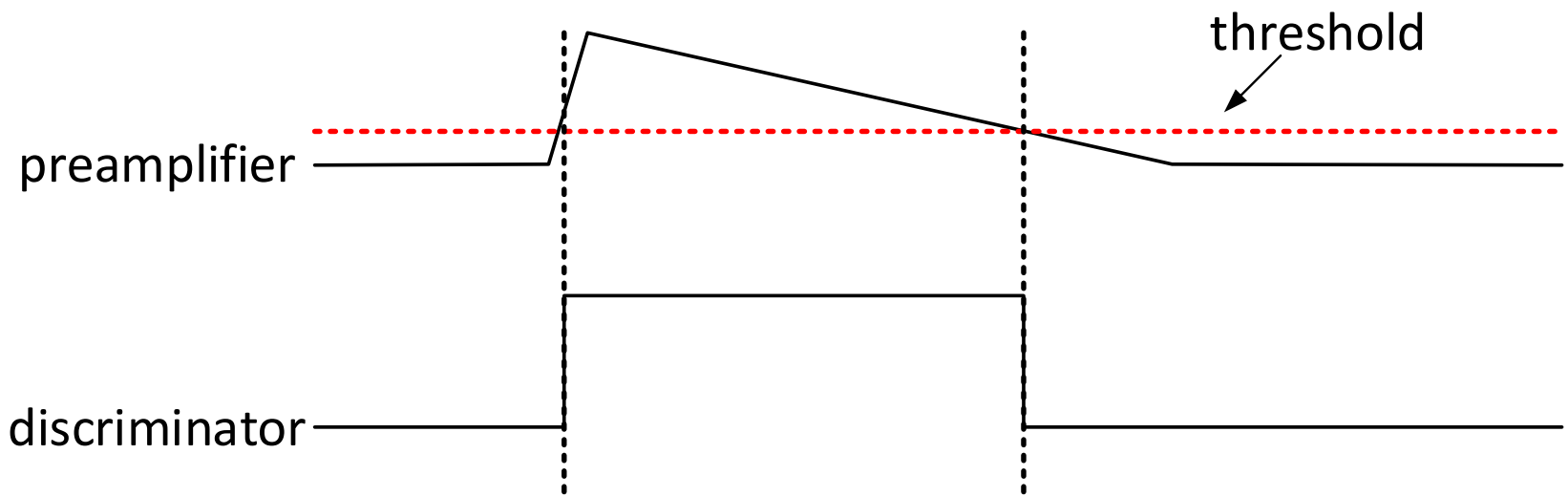
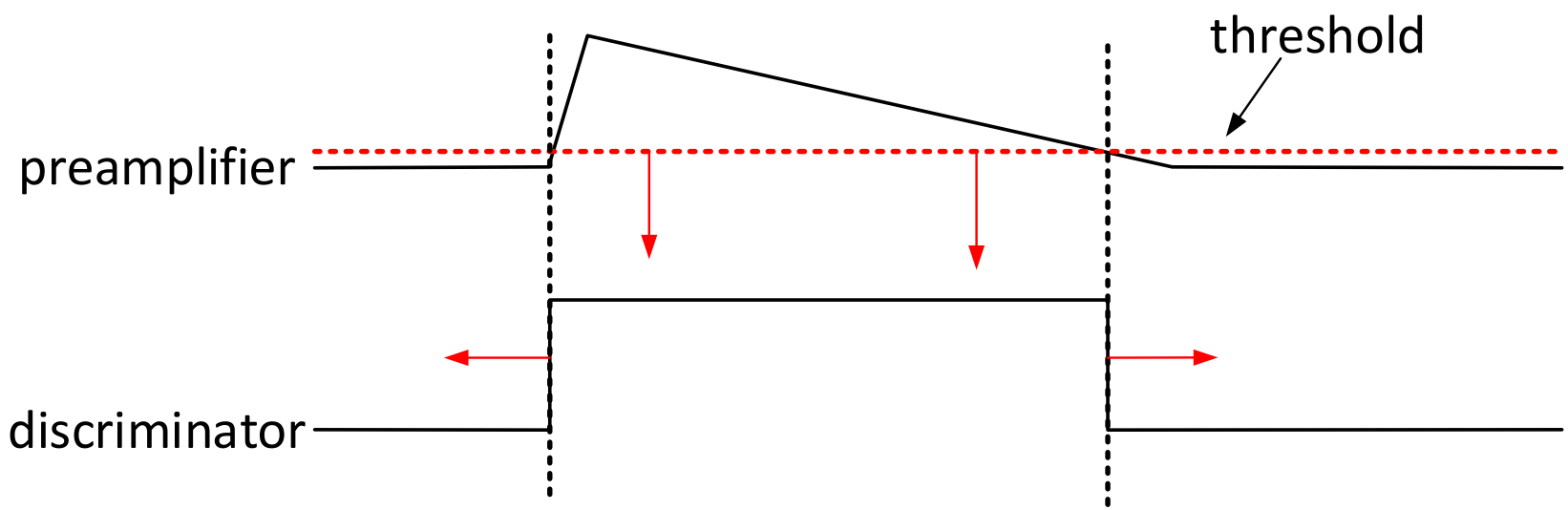
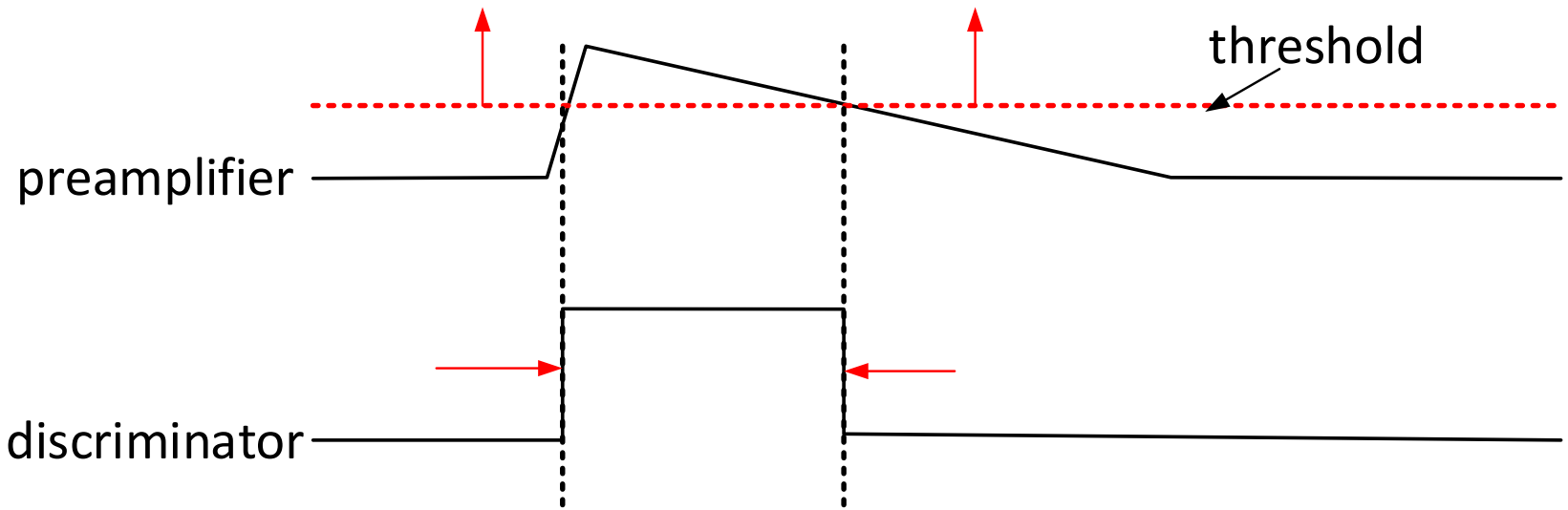
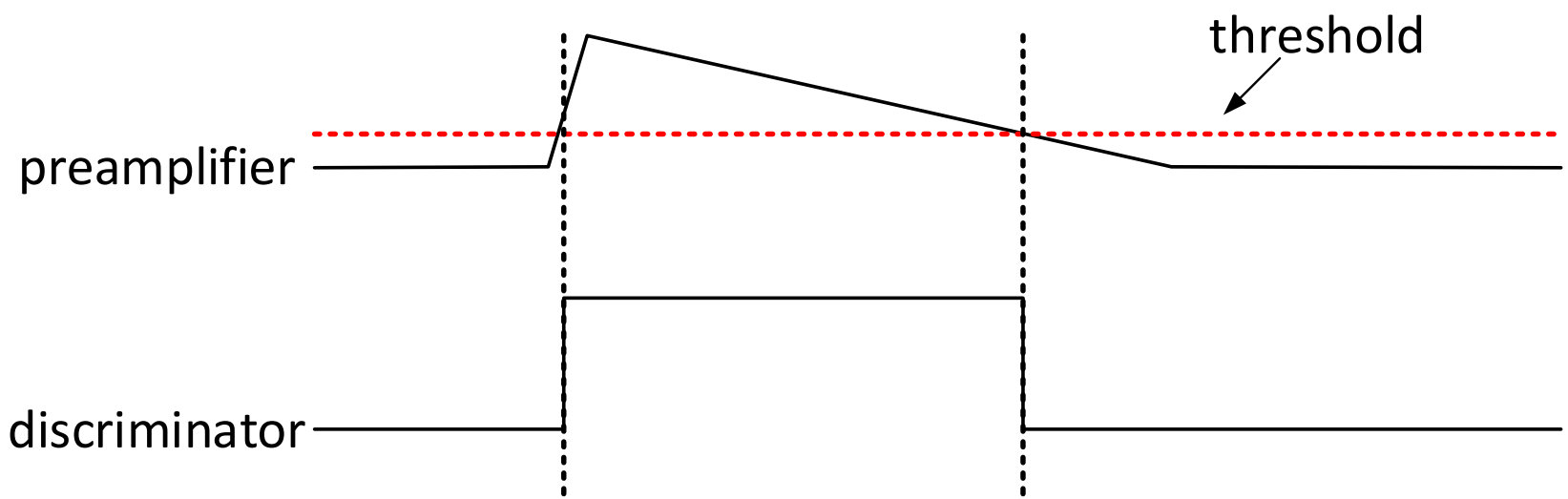
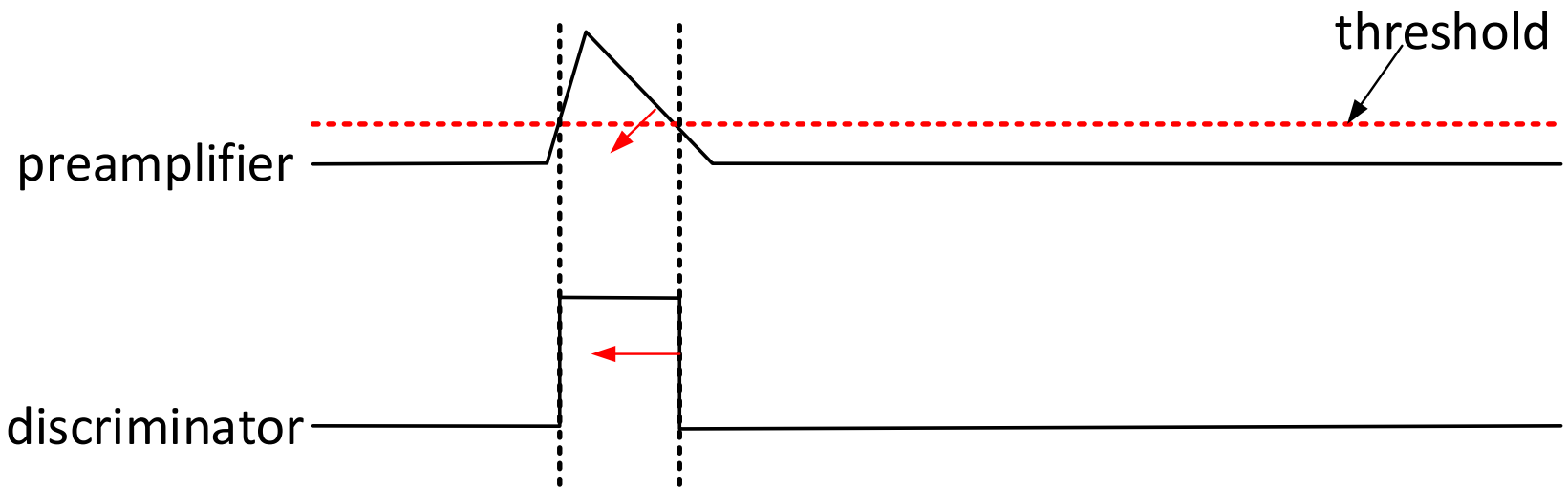



threshold
preamplifier
discriminator

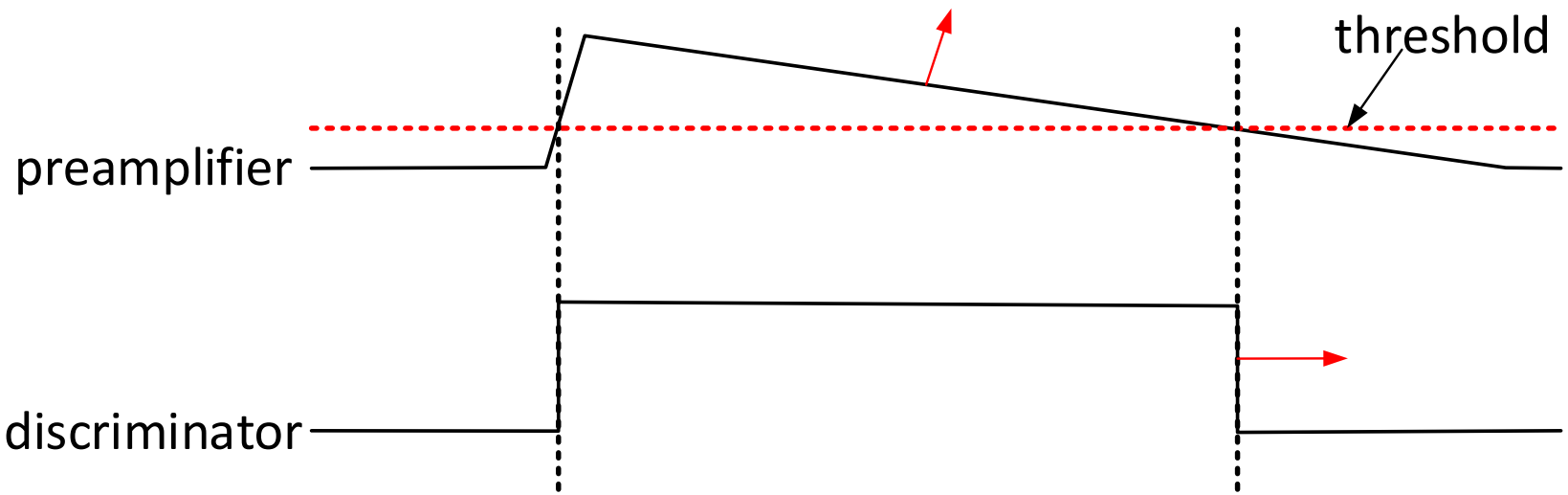

threshold
preamplifier
discriminator


threshold
preamplifier
discriminator


threshold
preamplifier
discriminator

Backup

FDAC/IF - discharge current



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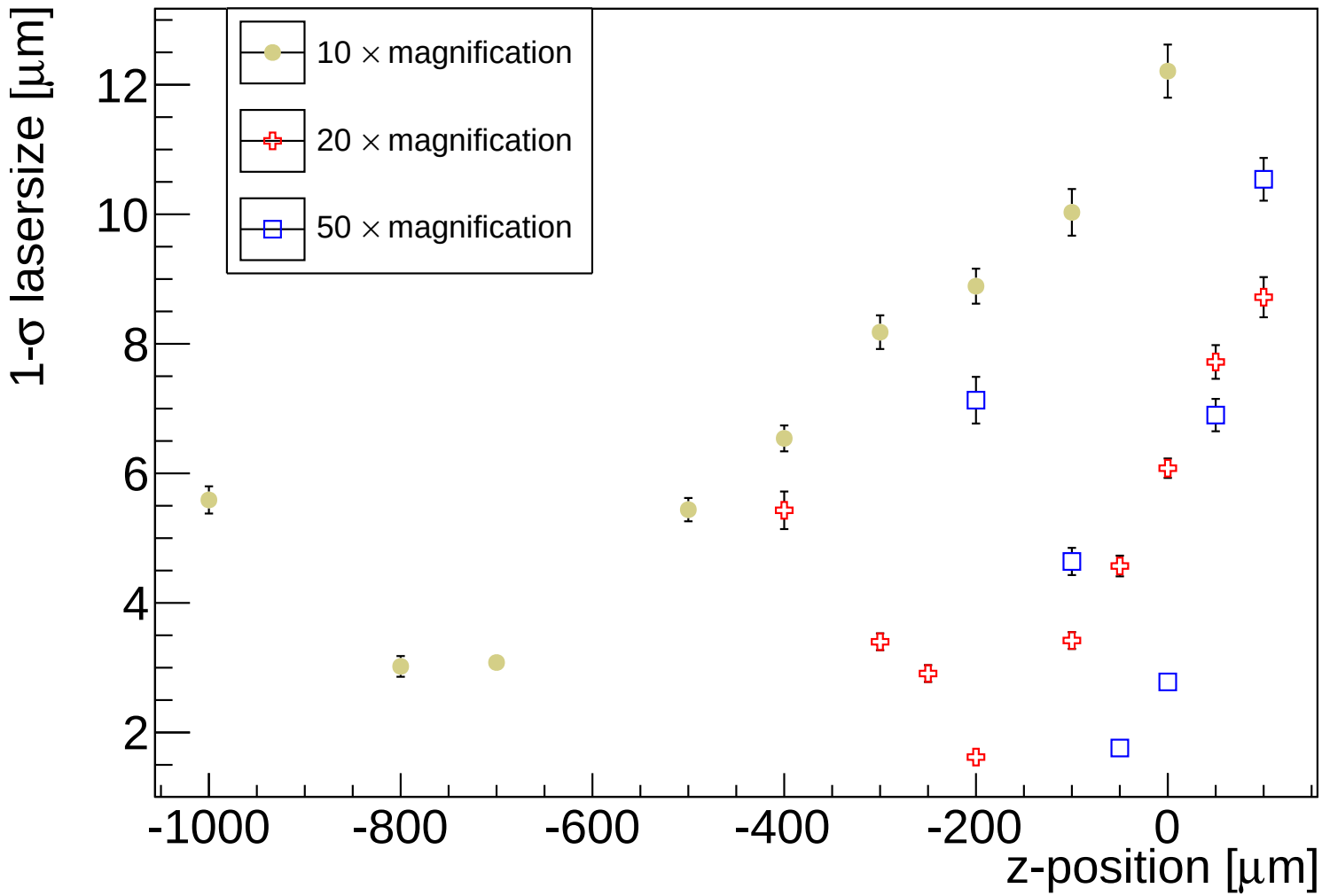
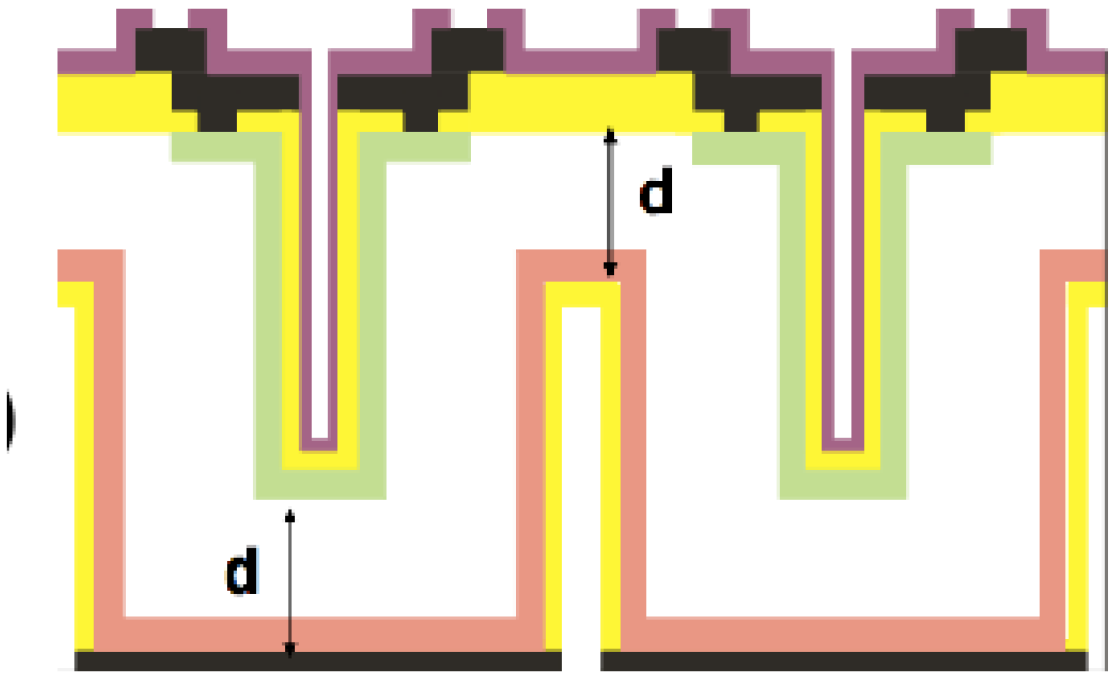
Beam-spot size



n+ etched and filled from top



p+ etched and filled

Backup

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