Performance of the new hadron blind HADES RICH in heavy ion collisions

2022-09-12 | Jörg Förtsch (University of Wuppertal)
for the HADES RICH working group

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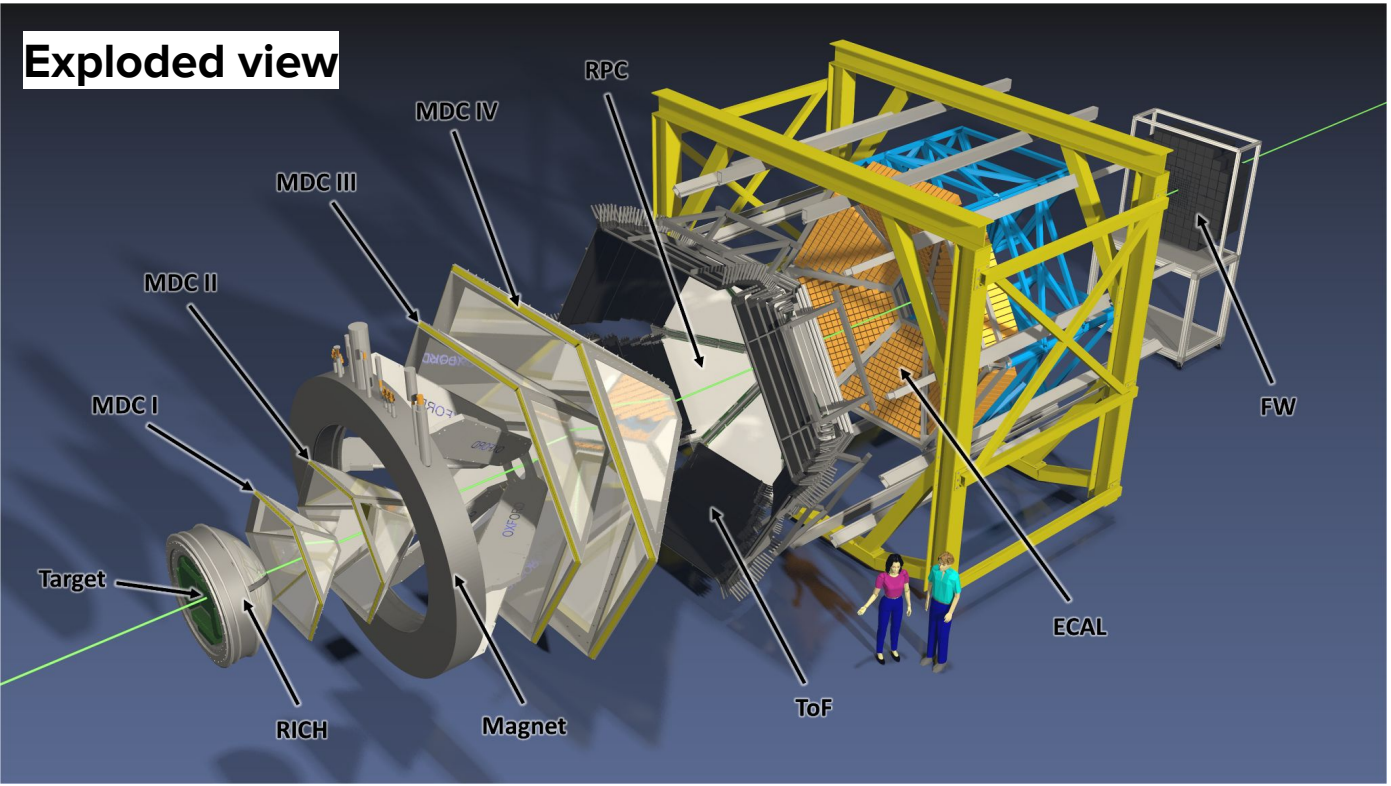
HADES
FAIR Phase 0 Research Program
TRB
GSI
Bundesministerium für Bildung und Forschung

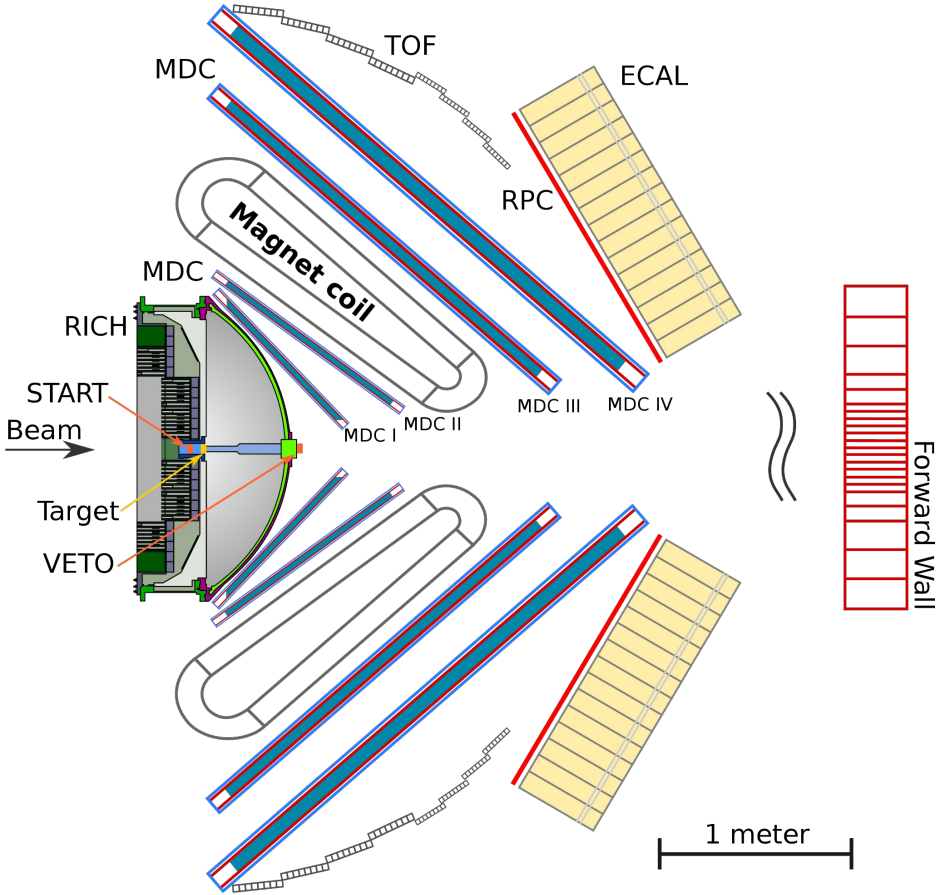
The HADES detector

High-**A**cceptance **DiE**lectron **S**pectrometer



- Installed at GSI Darmstadt SIS 18
- In operation since 2001
- Fixed target experiment
- Large acceptance
  - 85% azimuth
  - 18°–85° polar
- Part of FAIR – phase 0 program
- **Ag+Ag 1.58 GeV/u beamtime March 2019**

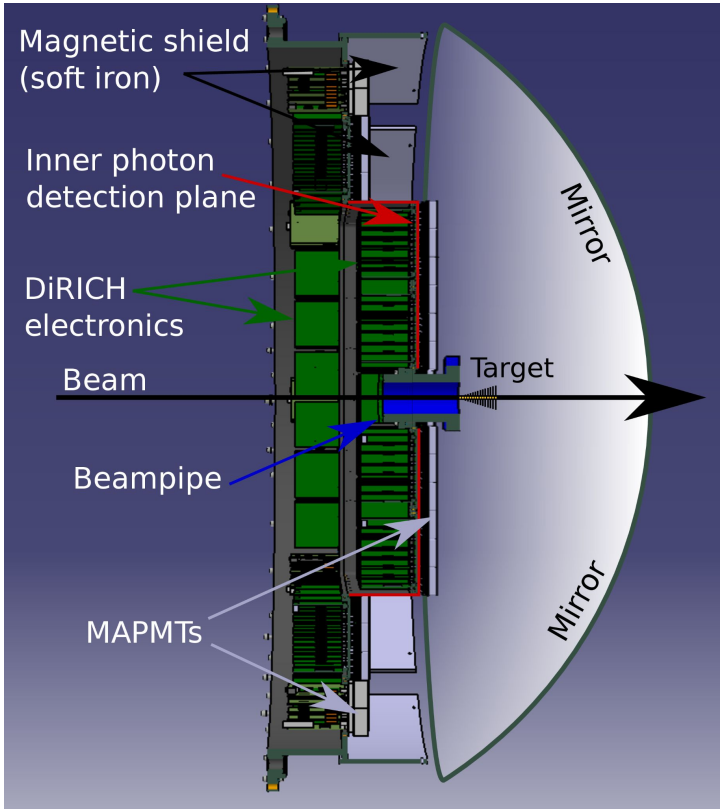
The HADES detector

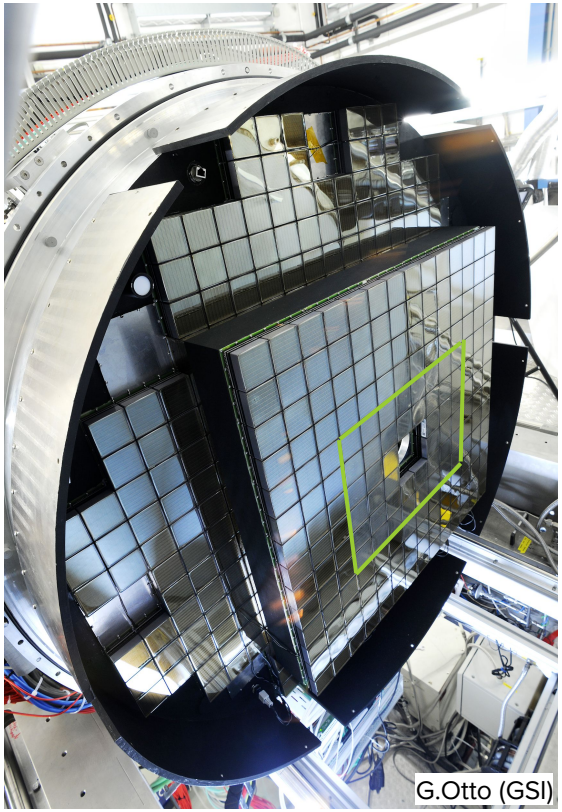


- Momentum determination through drift chambers and toroidal magnetic field
- RPC and scintillator based TOF detectors for velocity (β) determination
- ECAL for photon detection
- Event plane reconstruction using scintillators in a forward wall set-up
- **Gaseous RICH detector with CsI cathode until 2017**

  J. Adamczewski-Musch et al. (C. Pauly corr. author),Status of the CBM and HADES RICH projects at FAIR, Nucl. Instr. Meth. A 952 (2020) 161867, RICH 2018 conference, https://doi.org/10.1016/j.nima.2019.03.025
- **Situated at the very beginning of the detector**

The RICH detector



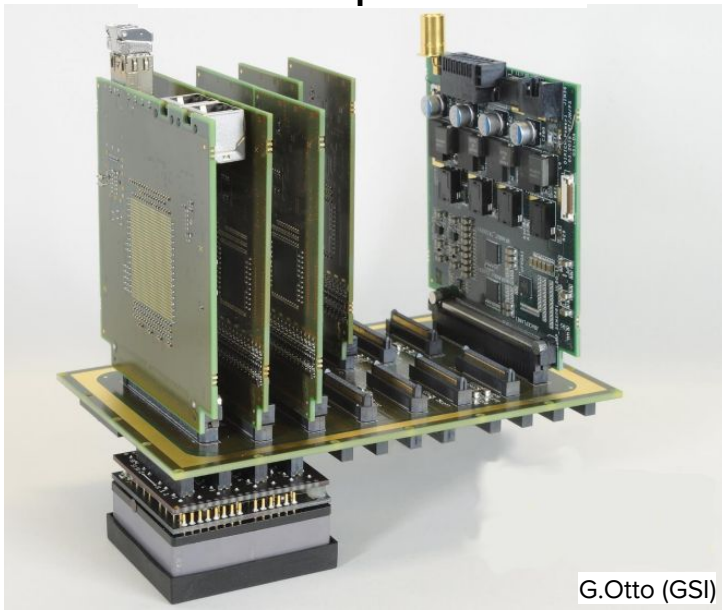


- Low material budget
  - Carbon mirror
- Electron ID
  15 MeV/c < p_e < 2.5 GeV/c
- C_4H_{10} (isobutane) radiator
- Staggered photodetection plane
- MAPMTs in center part coated with wavelength shifter (WLS p-terphenyl*)
- **Upgraded photon detector and read-out chain**

* J. Adamczewski-Musch et al. [CBM-RICH collaboration], Influence of wavelength-shifting films on multianode MAPMTs with UV-extended windows, Nucl. Instr. Meth. A, 783 (2015) 43, https://doi.org/10.1016/j.nima.2015.02.014

The upgraded Photon Detector and Readout

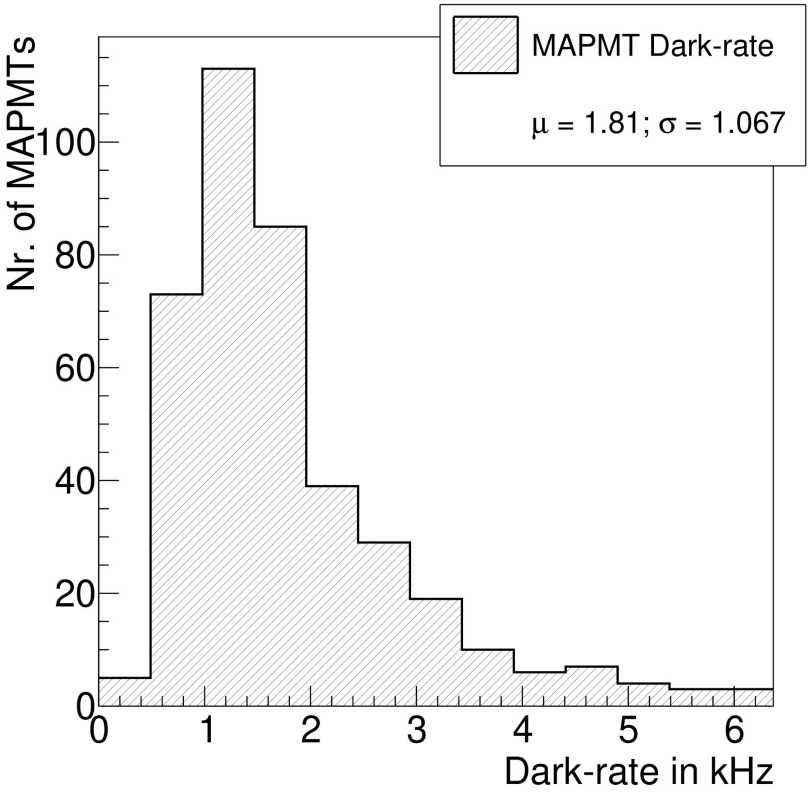
DiRICH Backplane-Module

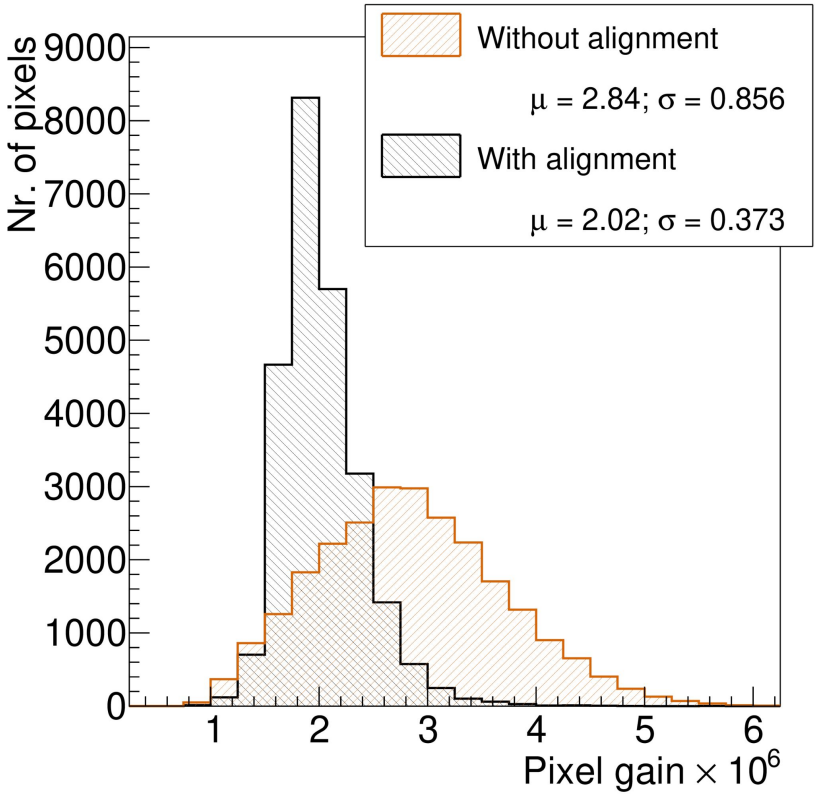


- Motivation:
  - Ensure stable RICH operation for future FAIR program - 2025 and beyond
  - Improve close-pair di-electron reconstruction

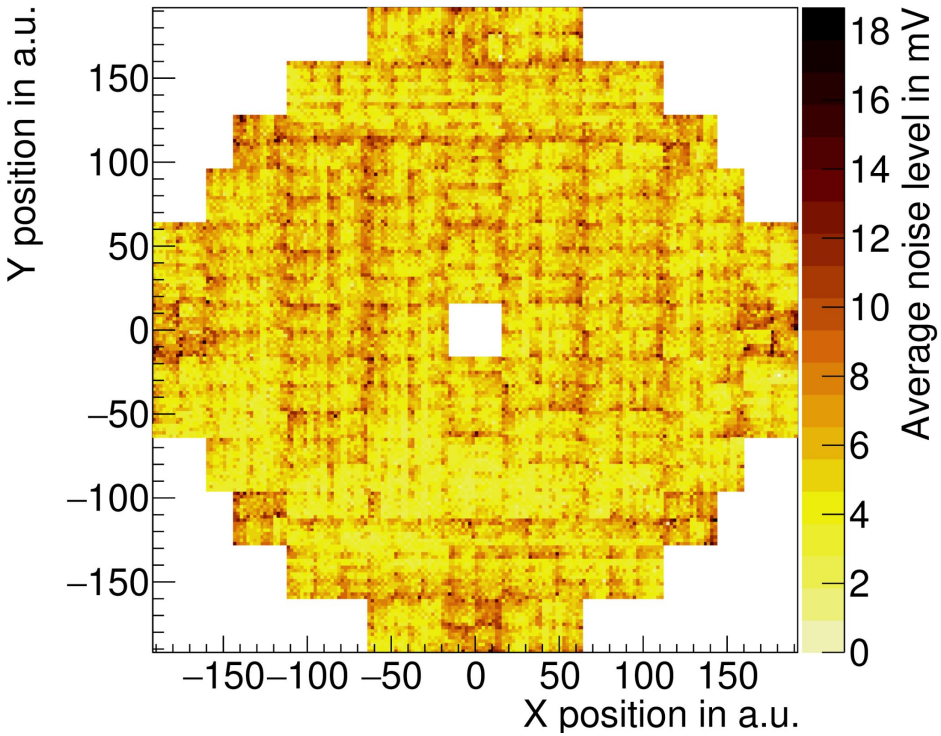
- Concept:
  - Share MAPMTs and readout chain development with CBM RICH (See talk C. Höhne Wednesday, 09:25)
  - Photodetection plane equipped with **428 64ch H12700 MAPMTs**
  - DiRICH-FEB measures (arrival) time **(LE)** and Time over Threshold **(ToT)** **for each channel** (See poster P.Subramani)
  - Modular backplanes serve as gas- and light tight seal grouping six MAPMTs (same HV)

Photon sensor selection





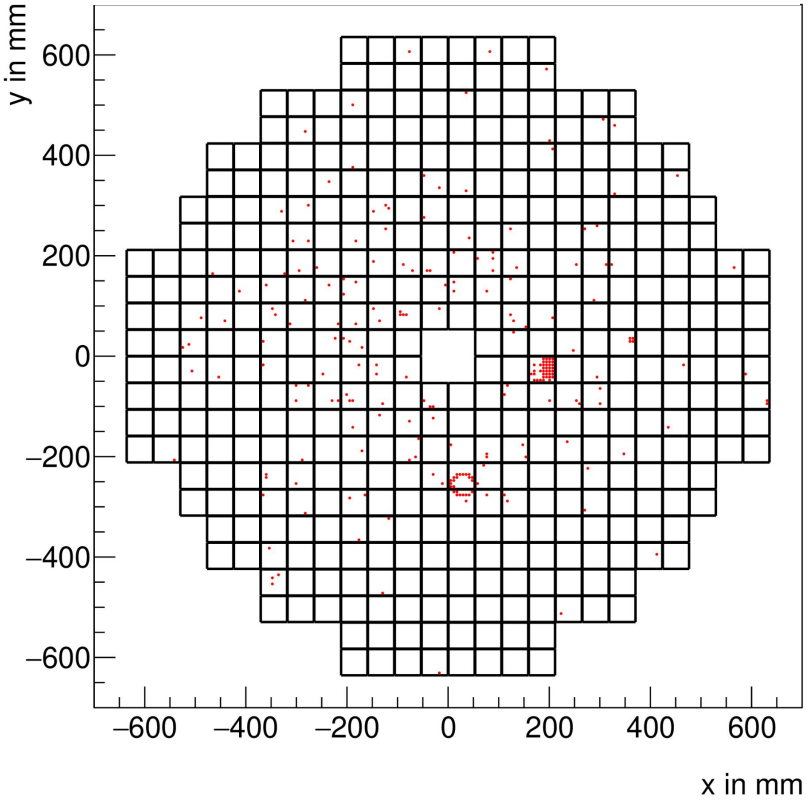
Readout hardware performance



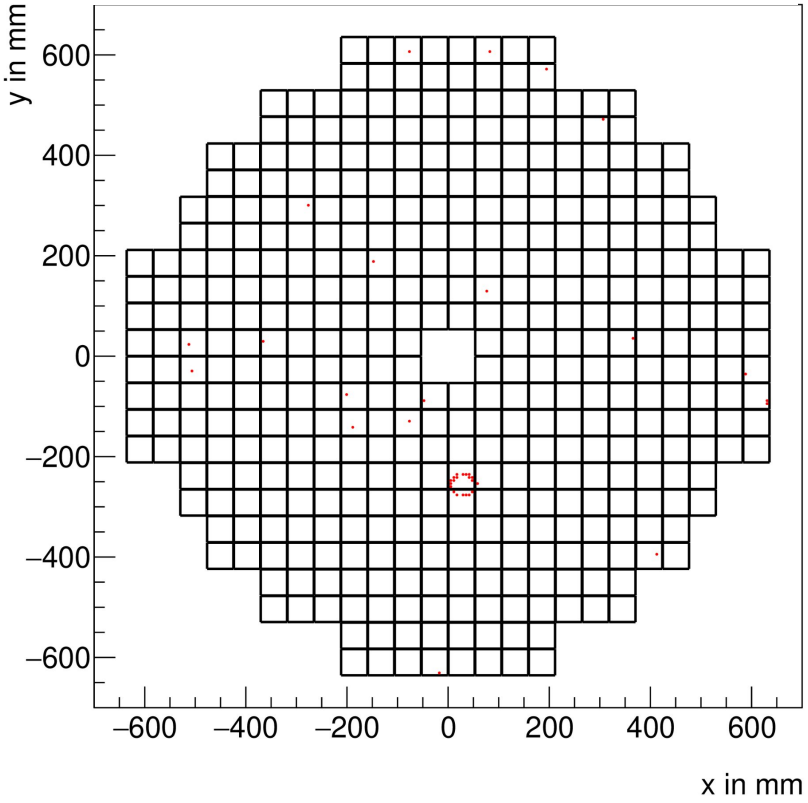
- **Average noise level of readout electronics after pre amplifier**
  - Average amplification ∼25×
- Typical thresholds of 50 mV – 70 mV
- **Average single photon amplitude at a gain of 2×10^6 after amplification: 150 mV – 250 mV**
- Rather homogeneous distribution

Single Event Display of first Rings

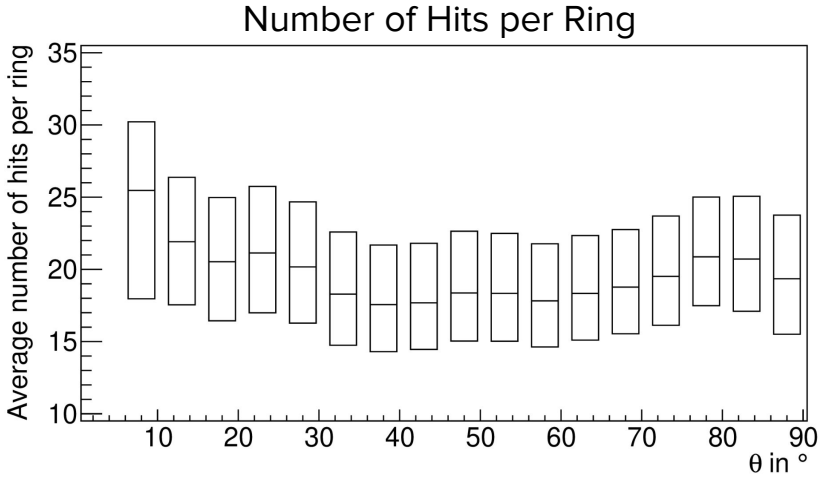
No cut on LE time (1.2 µs window)

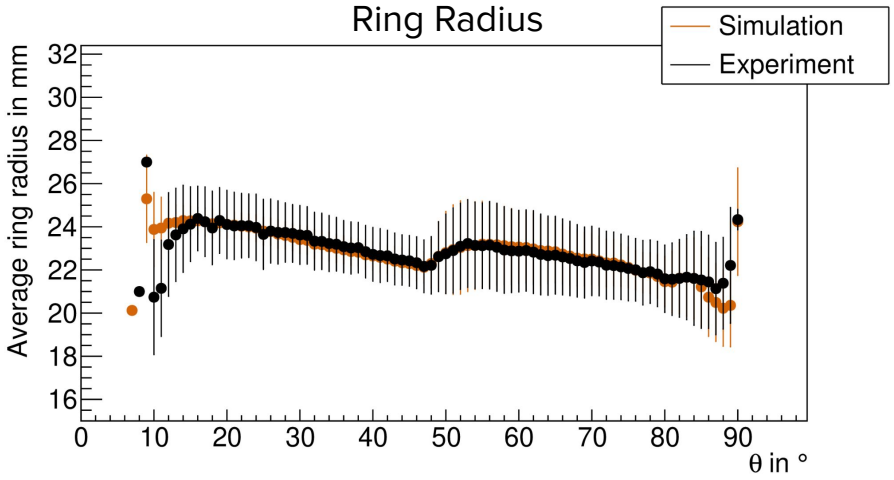


With LE time cut (∼2 ns window)



Ring properties



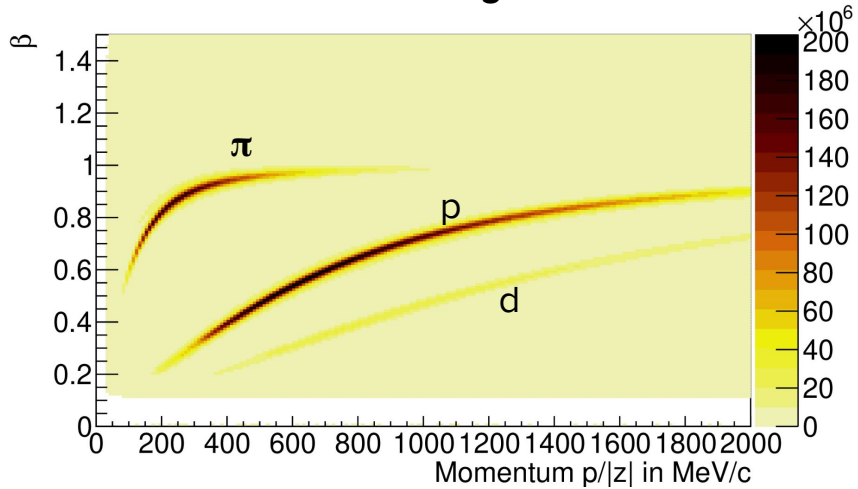


- More than 15 hits per ring on average over full detector
- Ring dR < 3 mm
  - Std. Dev. of hits w.r.t. fitted ring

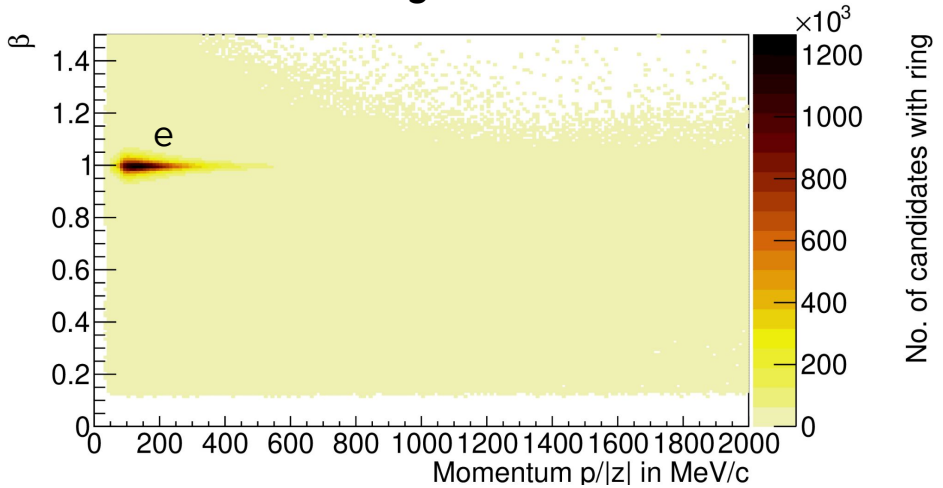
- Simulation and experiment agree very well
- Using a time cut of ~2 ns
  - 0.8 reconstructed rings per event
  - ~30 reconstructed hits per event

PID Performance of the RICH

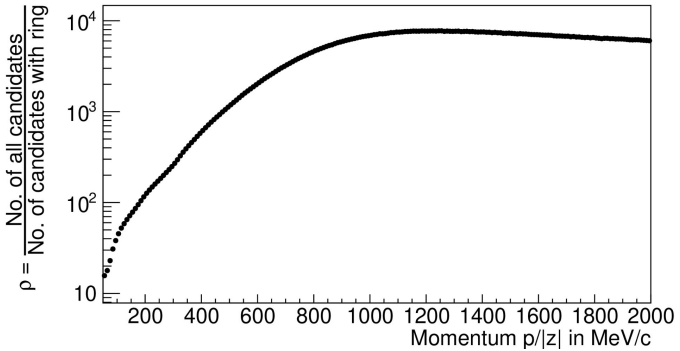
Without using RICH



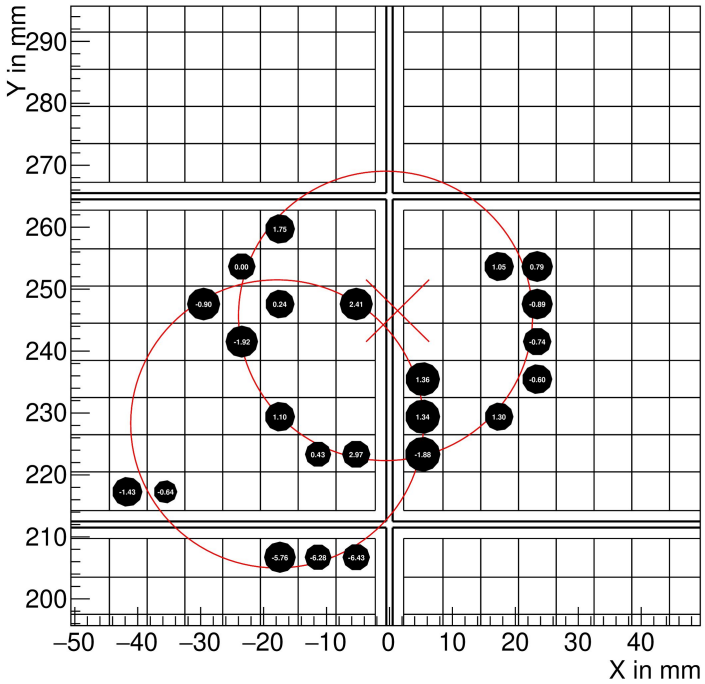
Using RICH

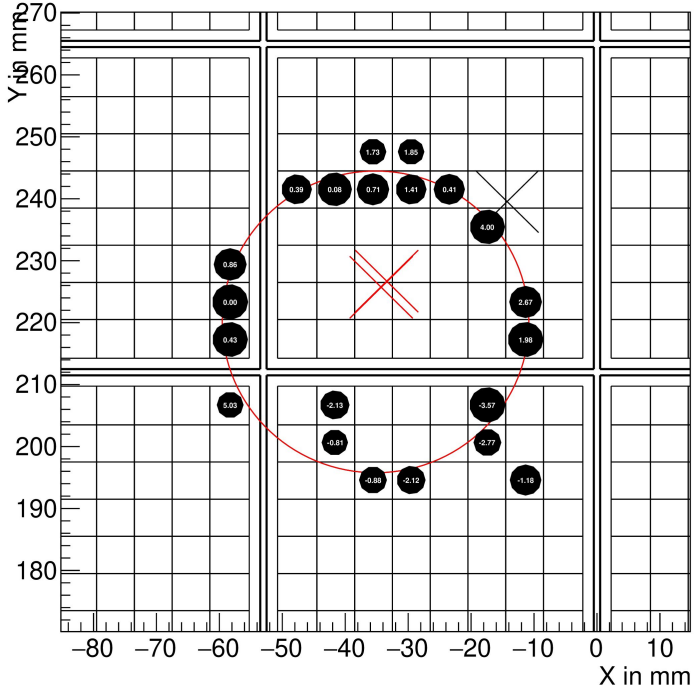


- Nearly all hadrons are suppressed
- Maximum suppression of $\sim 10^4$ reached for larger momenta

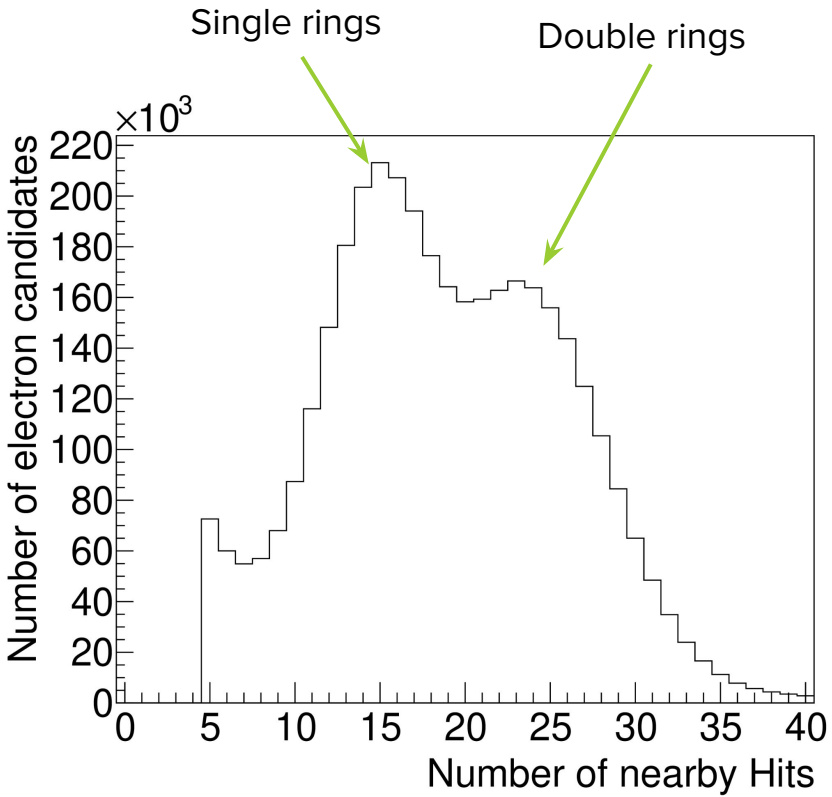


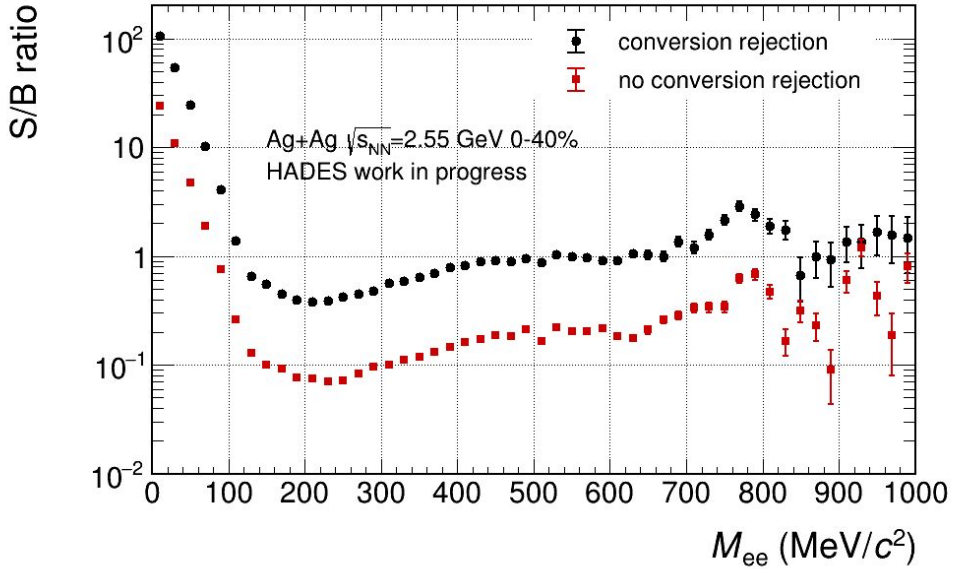
Single Event Plots of double rings



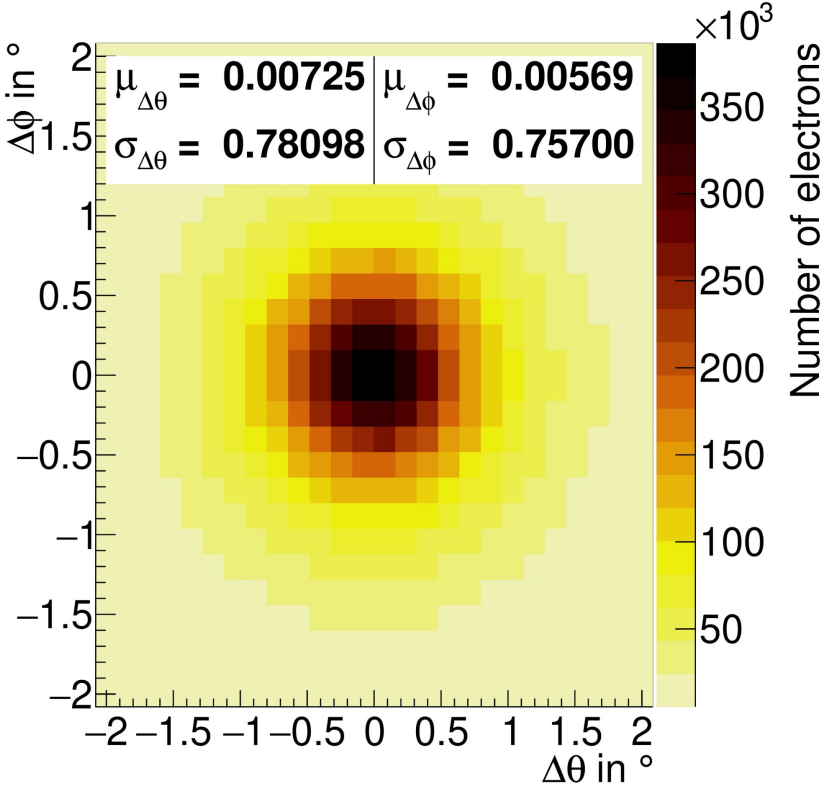


Close double ring suppression

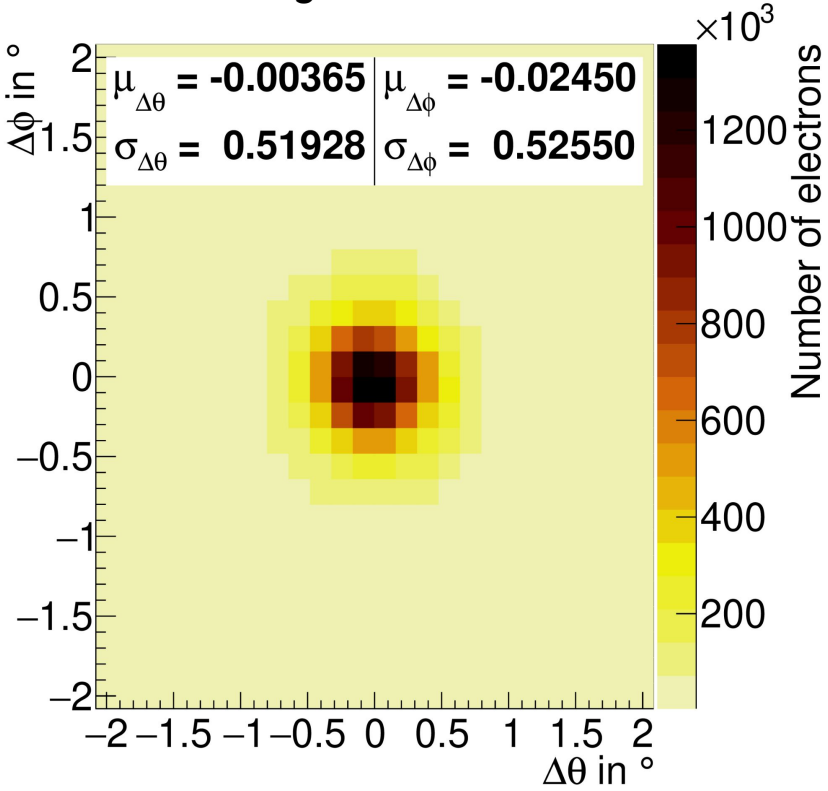




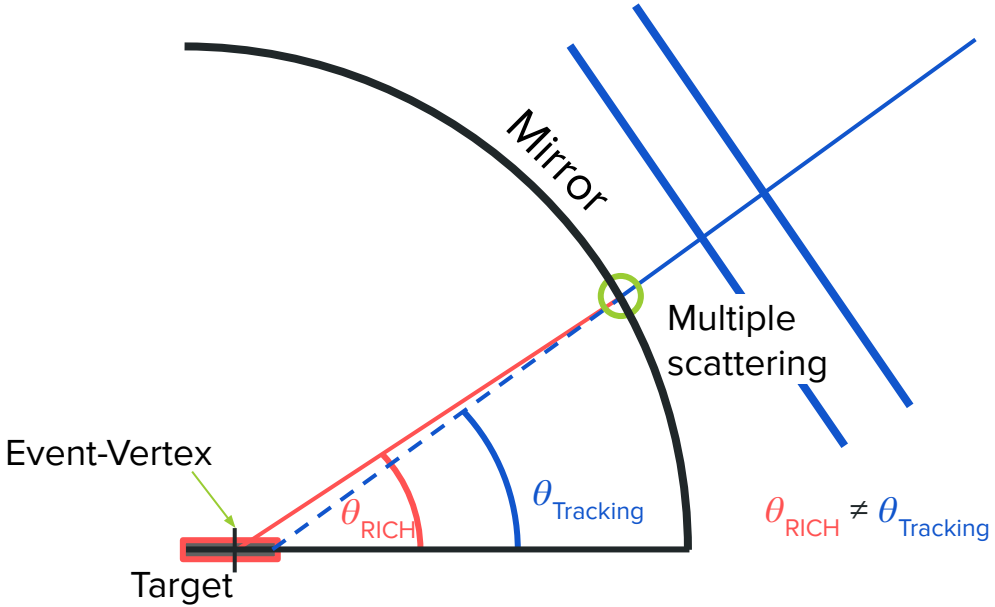
Angular matching precision

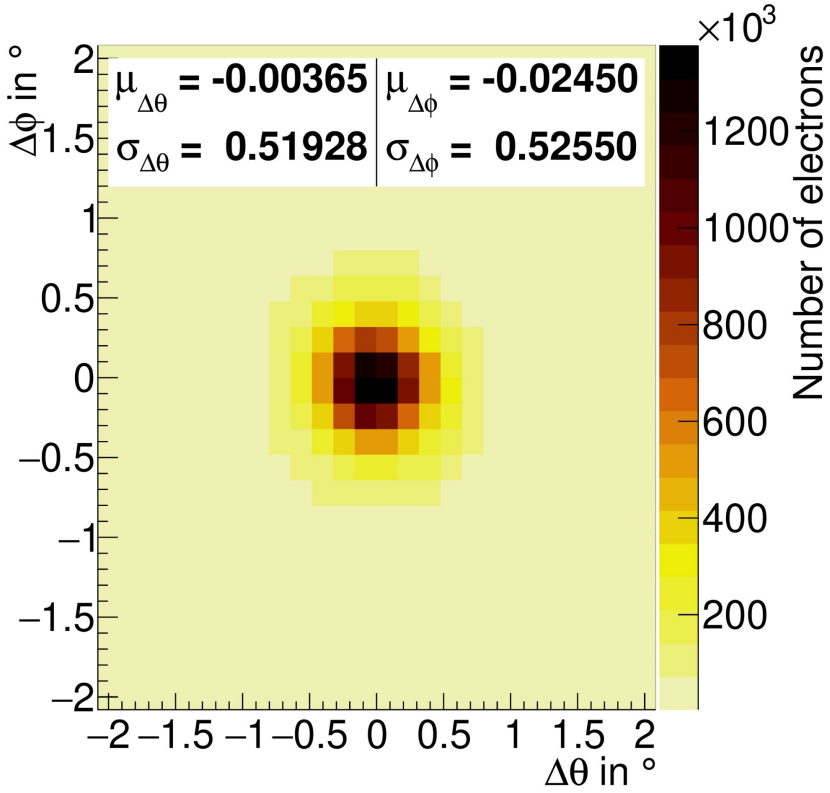


Correcting for Electron multiple scattering behind the RICH



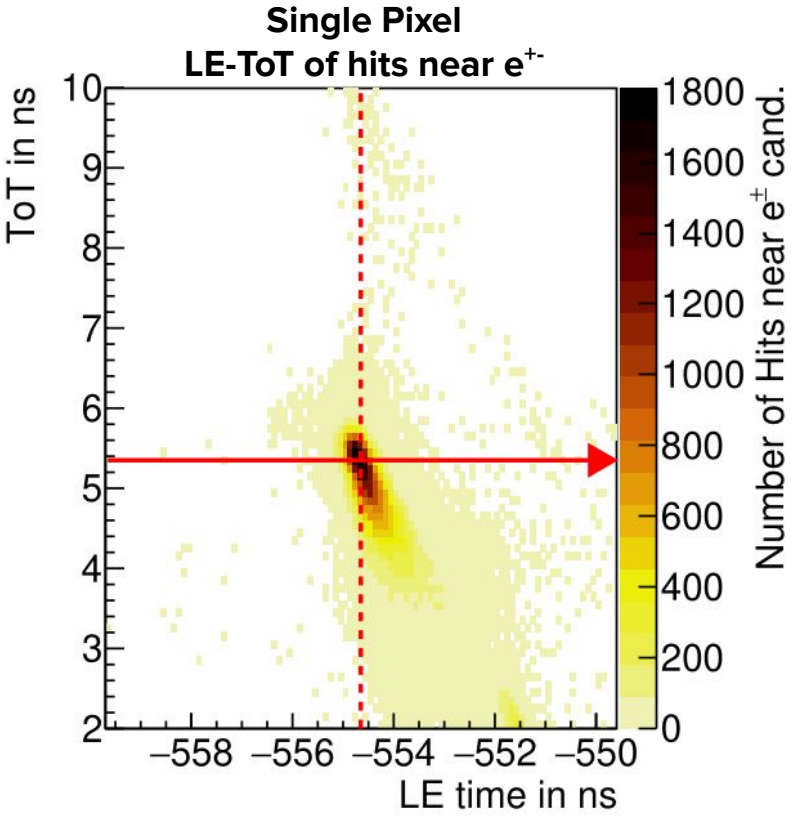
Multiple scattering correction method

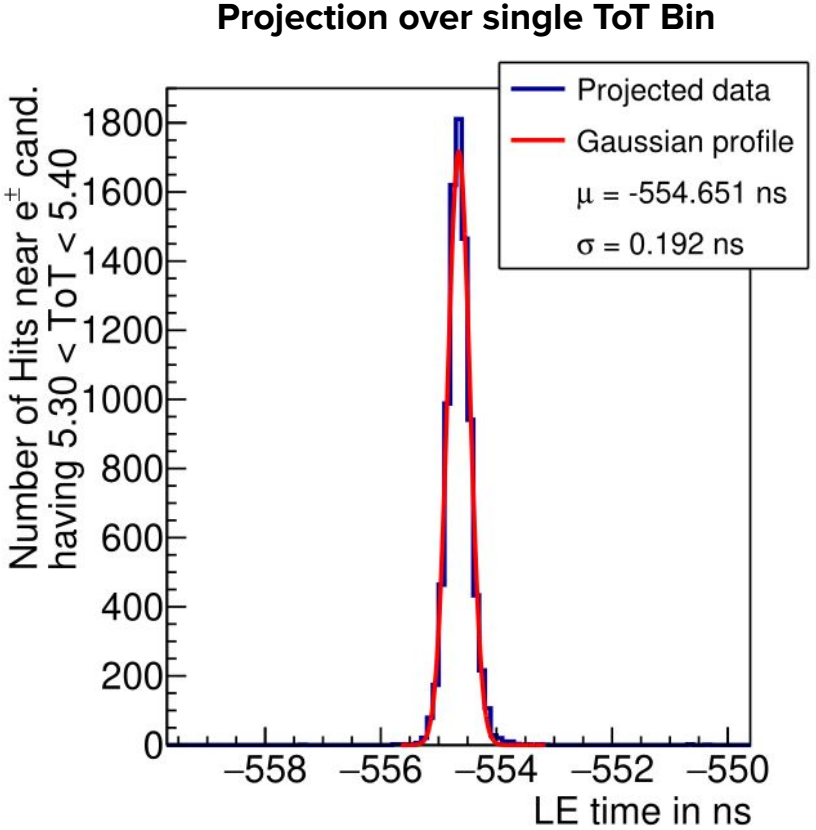




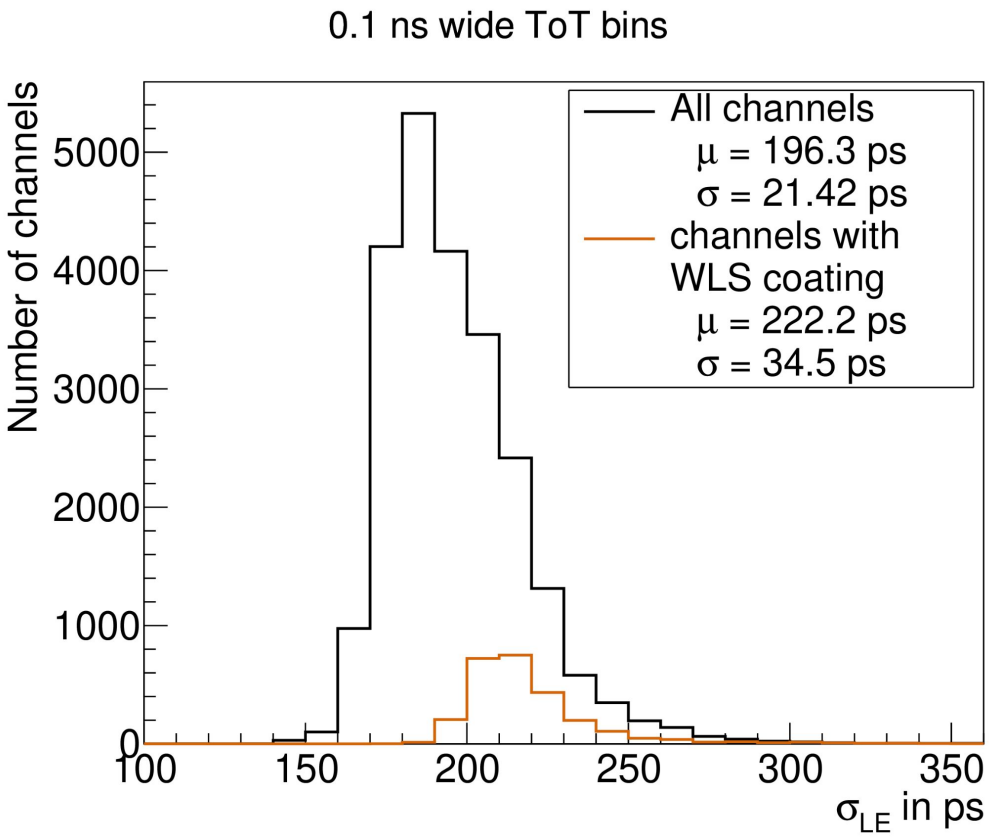
- Calculate track-intersection point with mirror
- Match ring to vector from intersection point to event vertex

Determination of the LE timing precision



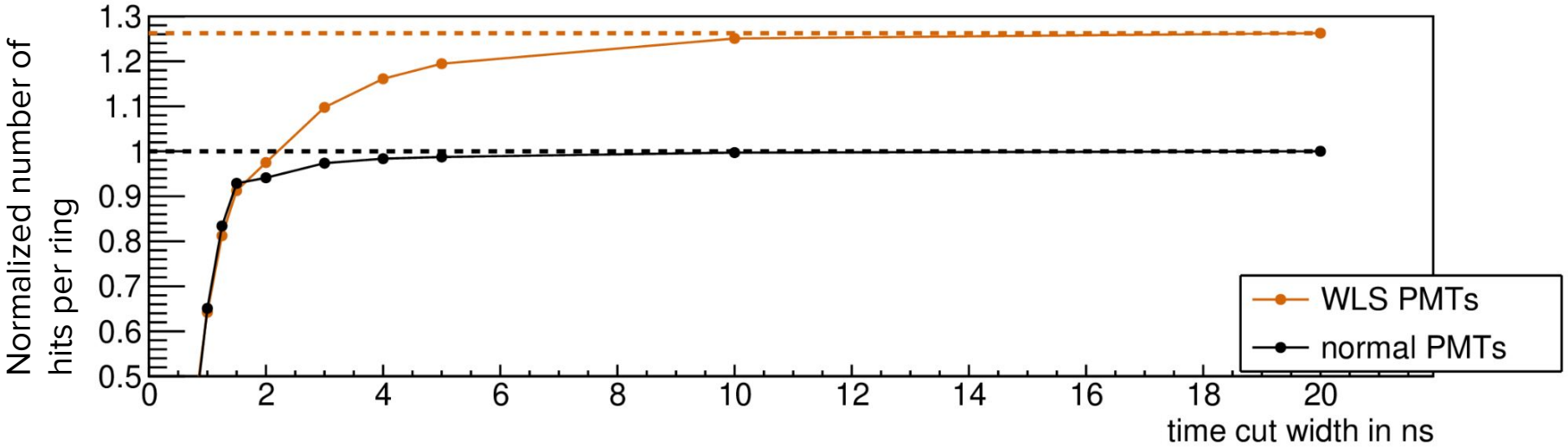


Timing precision



- Measured relative to HADES T_0 detector (Std. Dev. ∼50 ps timing precision)
- Typical time spread (TTS) of MAPMT: σ = 150 ps
- Timing precision of the readout electronics: RMS = 20 ps
- Disregarding walk effects a timing precision of below 200 ps can be reached
  Upgrade of the HADES RICH photon detector and first performance analyses
  Jörg Förtsch (September 2021)
- WLS coating slightly worsens the timing precision

Impact of WLS coating

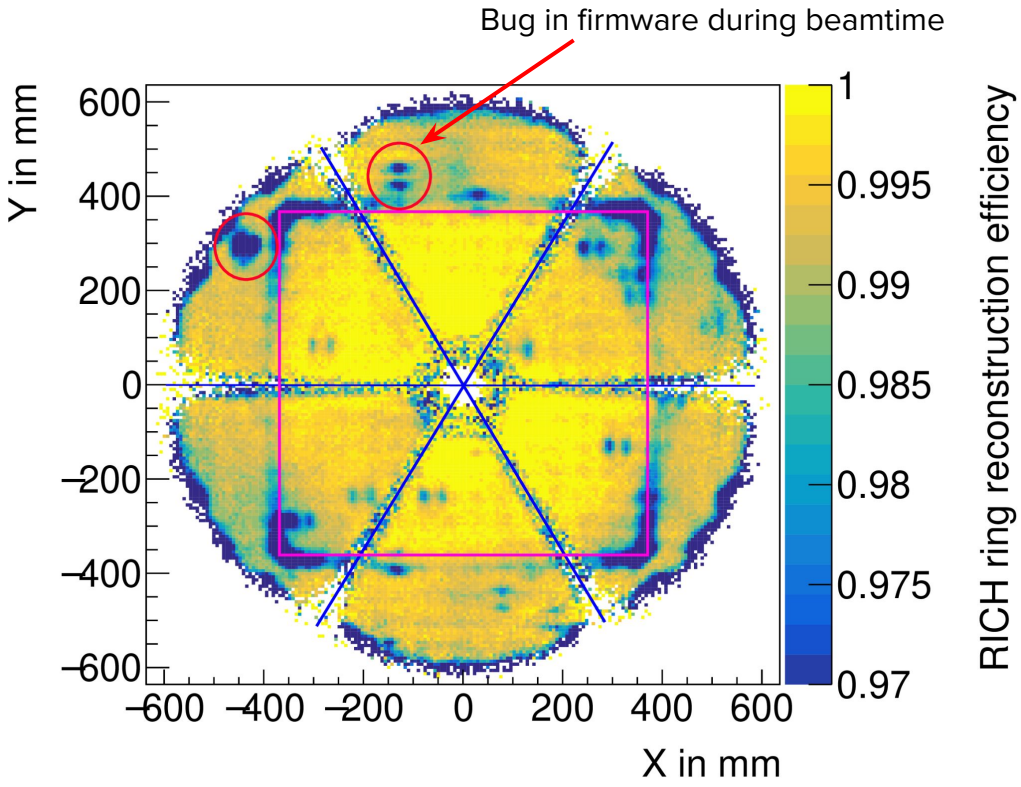


- Comparing MAPMTs at similar positions in the detector
- Maximum enhancement of∼25% reachable using WLS coating
- Significant improvement over uncoated MAPMTs only after∼1.5 ns

J. Adamczewski-Musch et al. (A. Weber corr. author), Efficiency and temporal response of p-terphenyl based wavelength shifting films on H12700 multi anode photomultipliers, Nucl. Instr. Meth. A 952 (2020) 161867, RICH 2018 conference, https://doi.org/10.1016/j.nima.2019.01.093

Ring reconstruction efficiency

- For **any electron candidate**
  - Defined by means of β (TOF) and momentum (tracking) **not using the RICH**
- Check if **no ring was found** for this candidate
- Check if **more than 10 hits** were found in the RICH **in the candidate's vicinity**
- **More systematic studies show an integrated ring reconstruction efficiency of 99%**



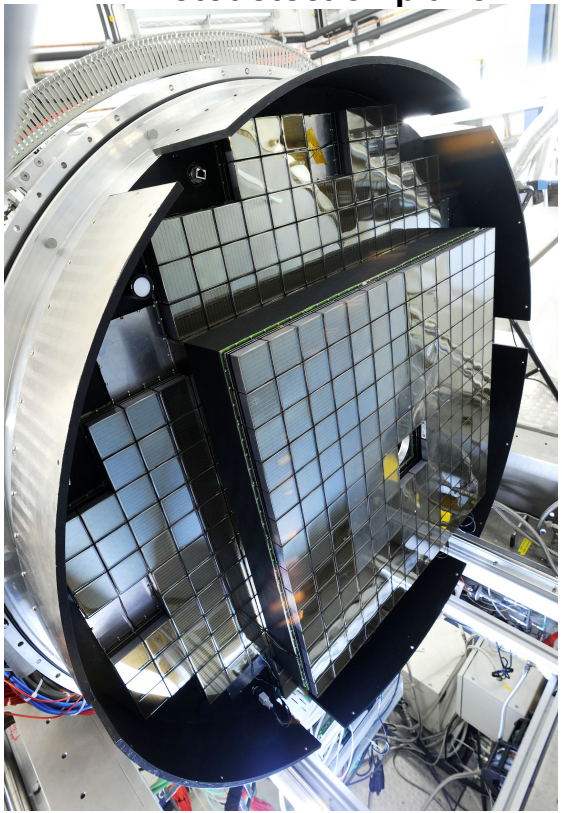
Summary

- HADES RICH upgrade with new MAPMT readout and DiRICH readout chain
- In time for very successful four week production beamtime March 2019
- Low noise and high single photon detection efficiency
- Angular ring-track matching < 0.55° possible when correcting for multiple scattering
- Ring finding efficiency reaches 99% integrated over full detector
- Double rings can be suppressed by counting hits in track-vicinity
- Timing precision of < 200 ps possible when disregarding effects of walk
- WLS coating increases photon yield significantly on the cost of timing precision

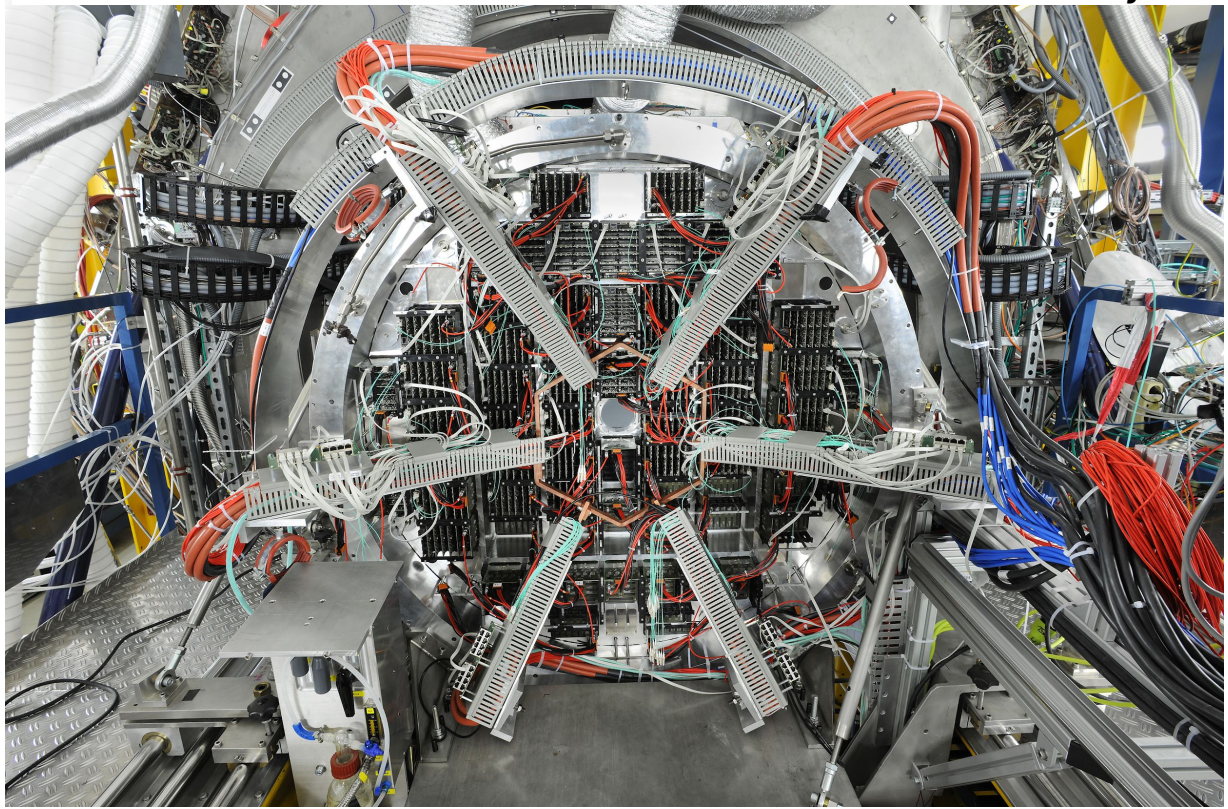
Backup

The upgraded RICH - The real thing

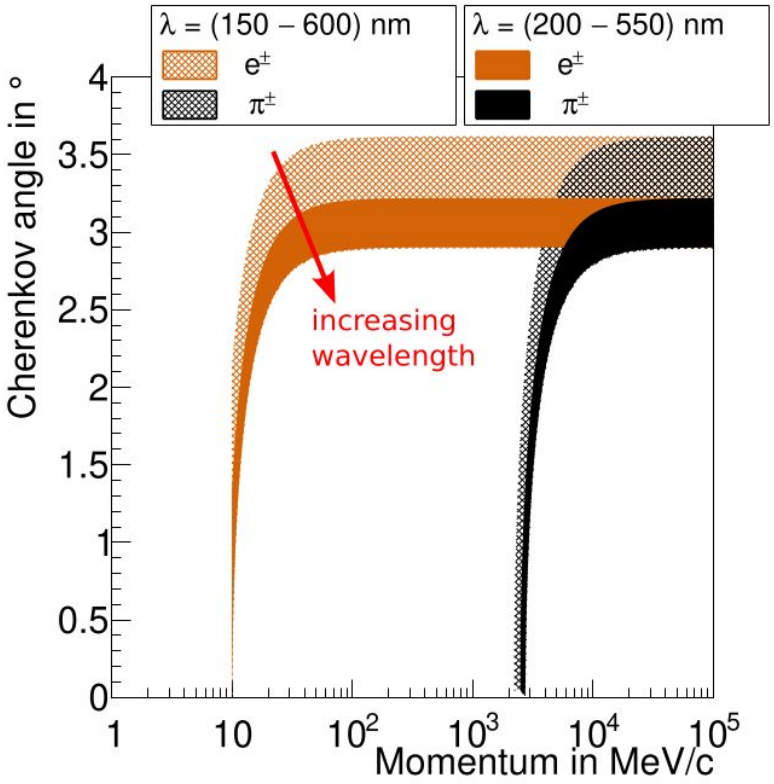
Photodetection plane

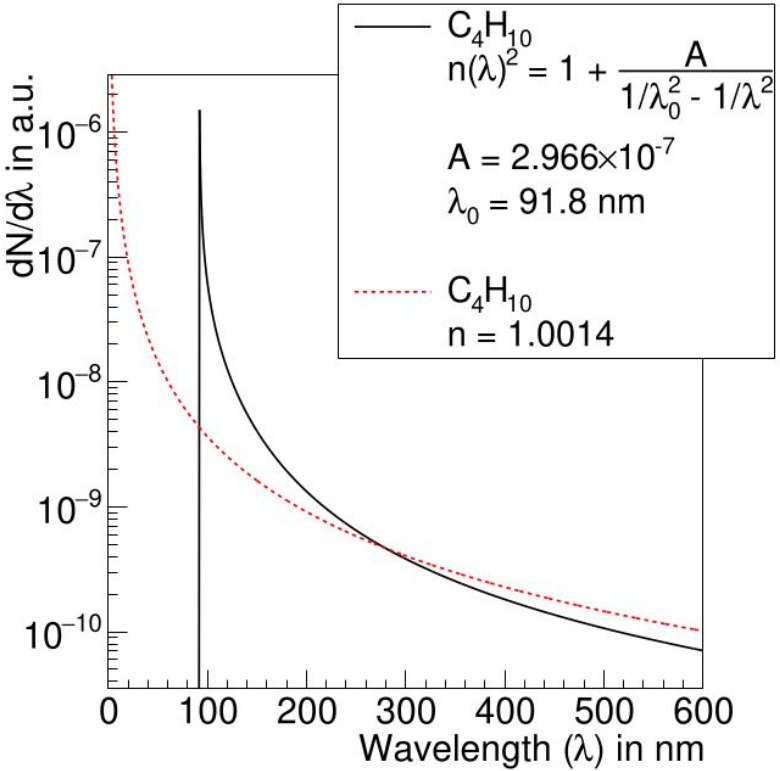


Backside of the HADES RICH with view onto the DiRICH readout system

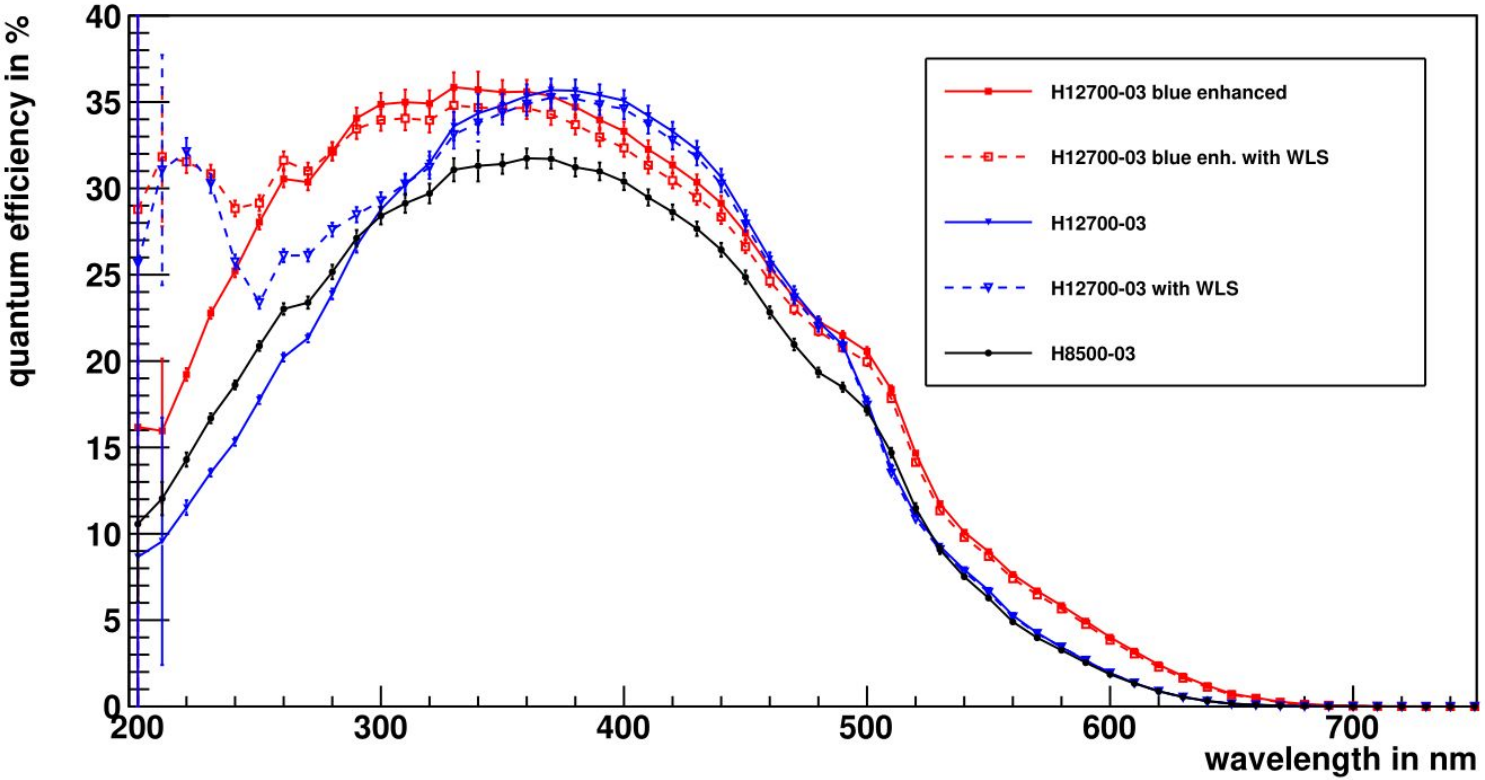


Cherenkov angle for C_4H_{10}



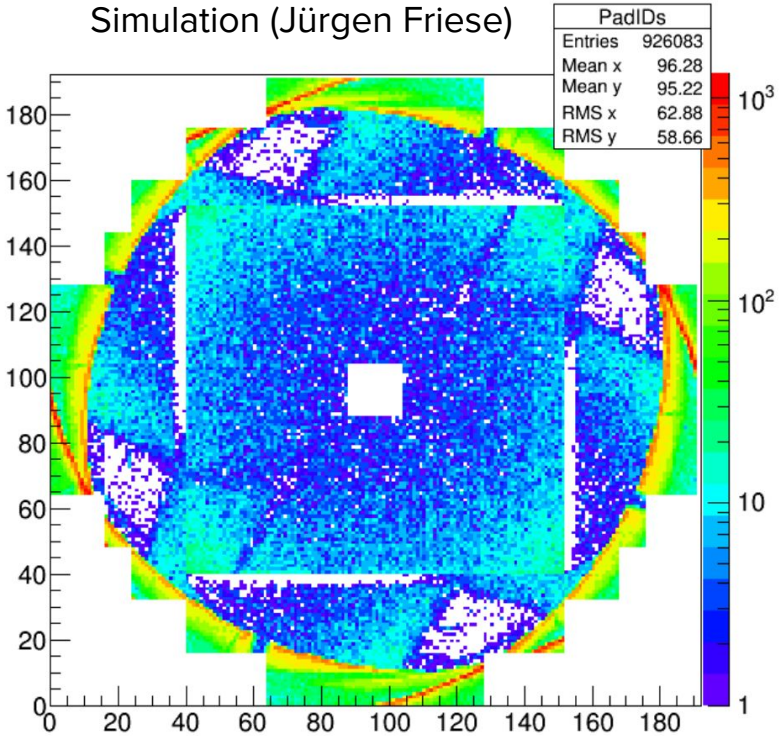


MAPMT QE

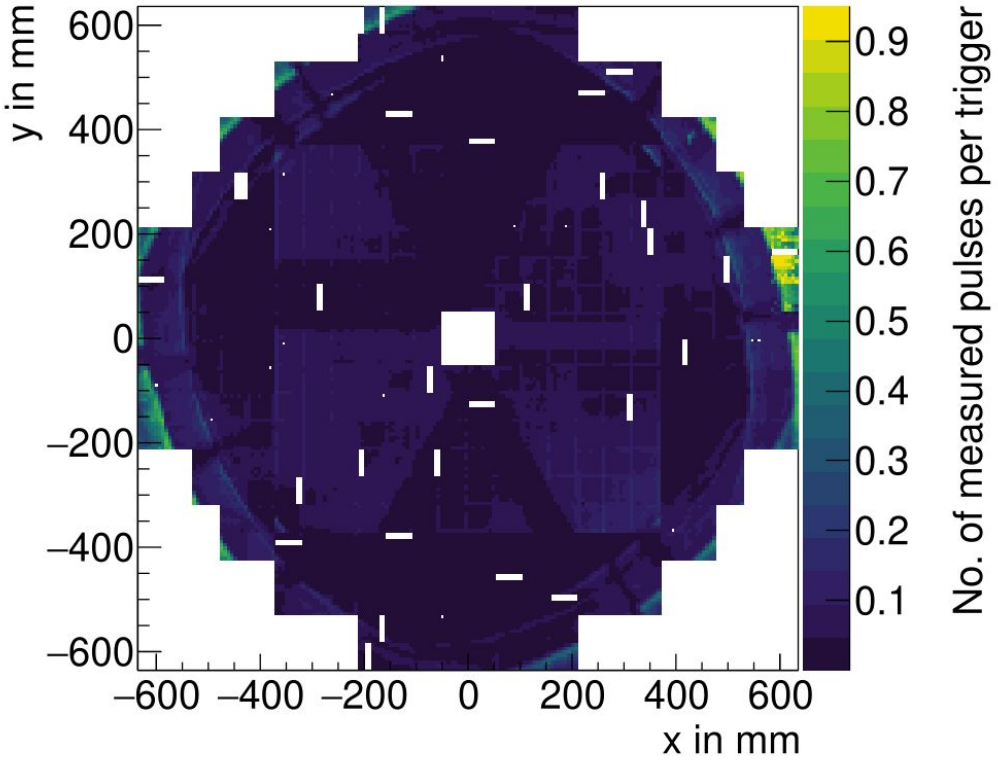

quantum efficiency in %
wavelength in nm
H12700-03 blue enhanced
H12700-03 blue enh. with WLS
H12700-03
H12700-03 with WLS
H8500-03

Laser system

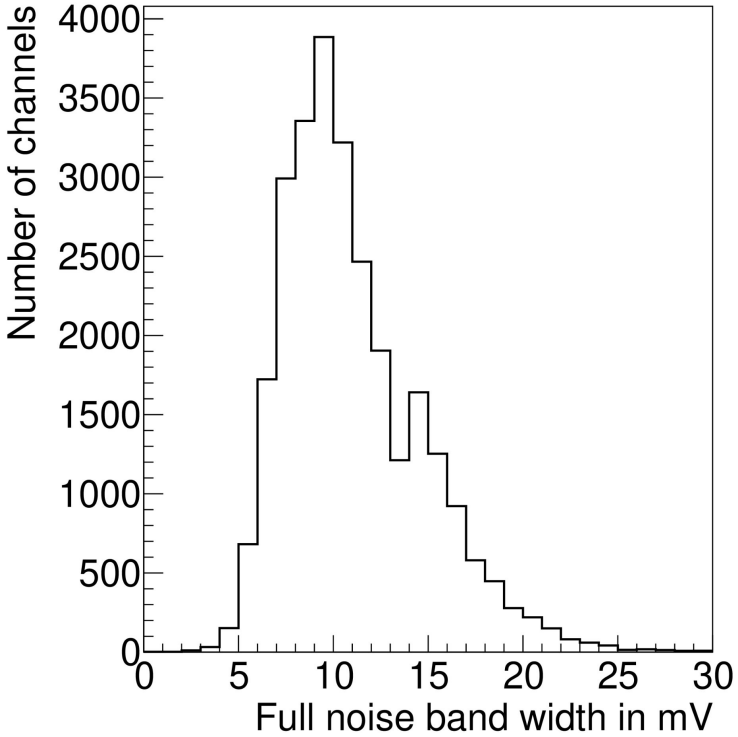
Simulation (Jürgen Friese)

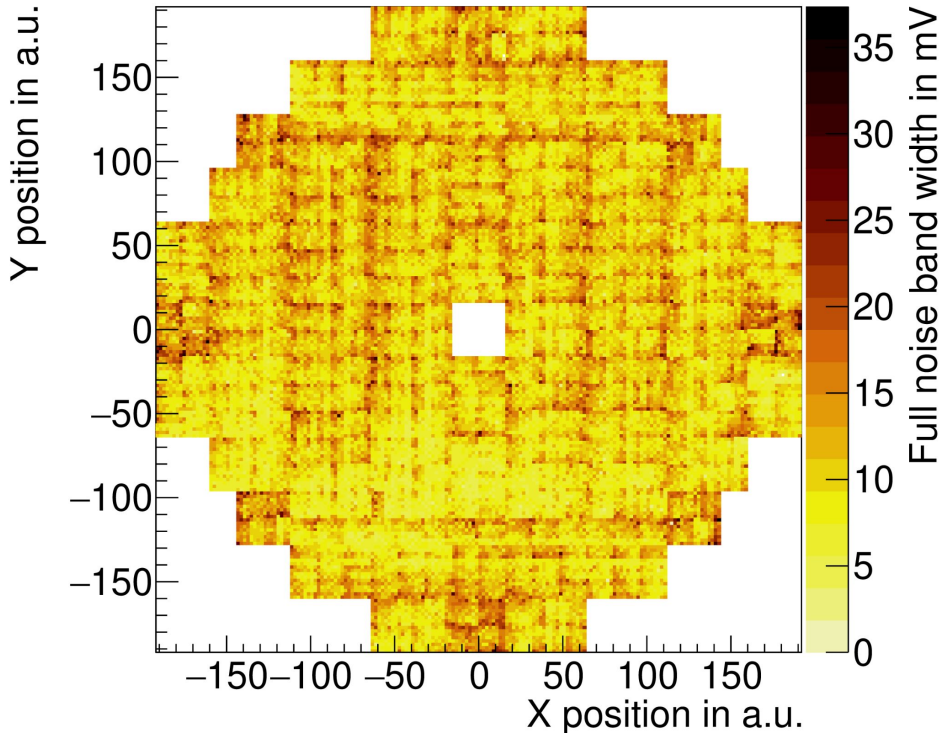


Experiment

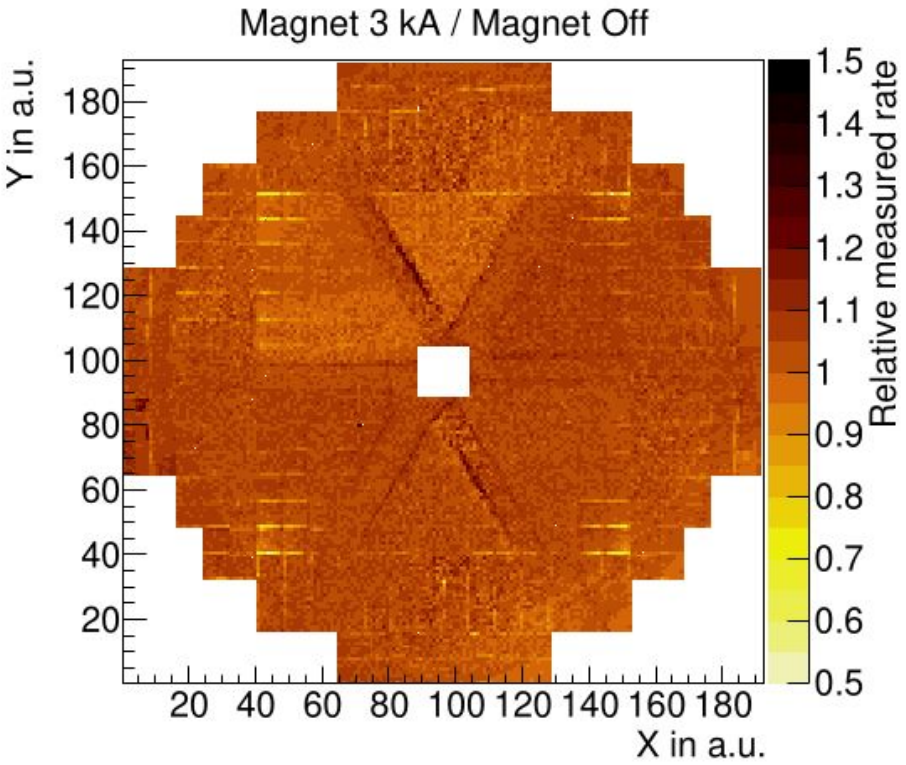


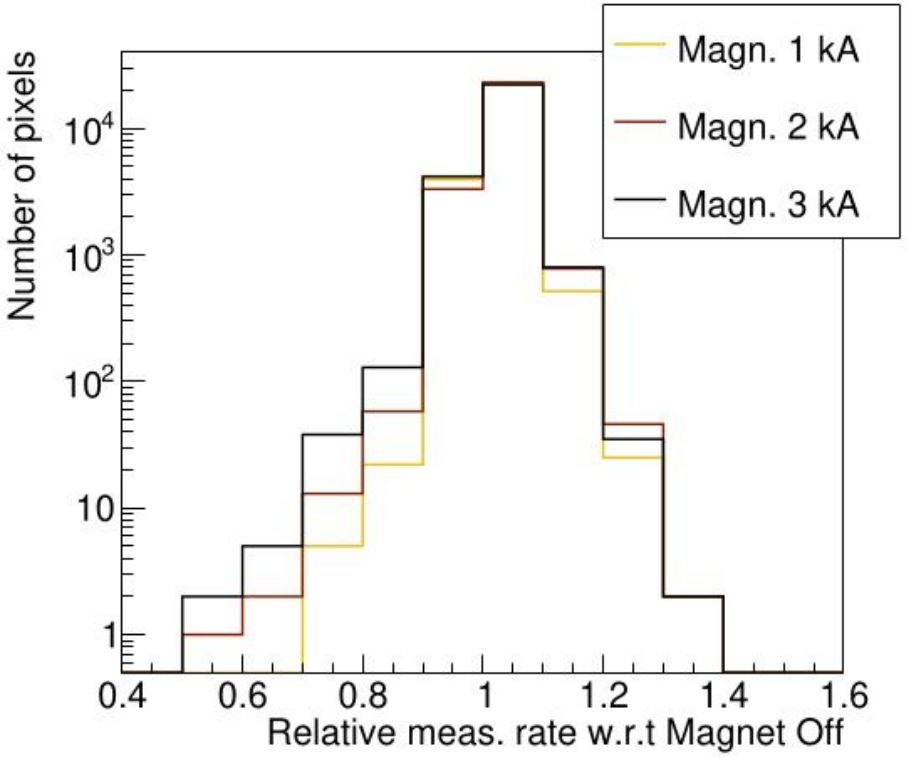
Readout hardware performance



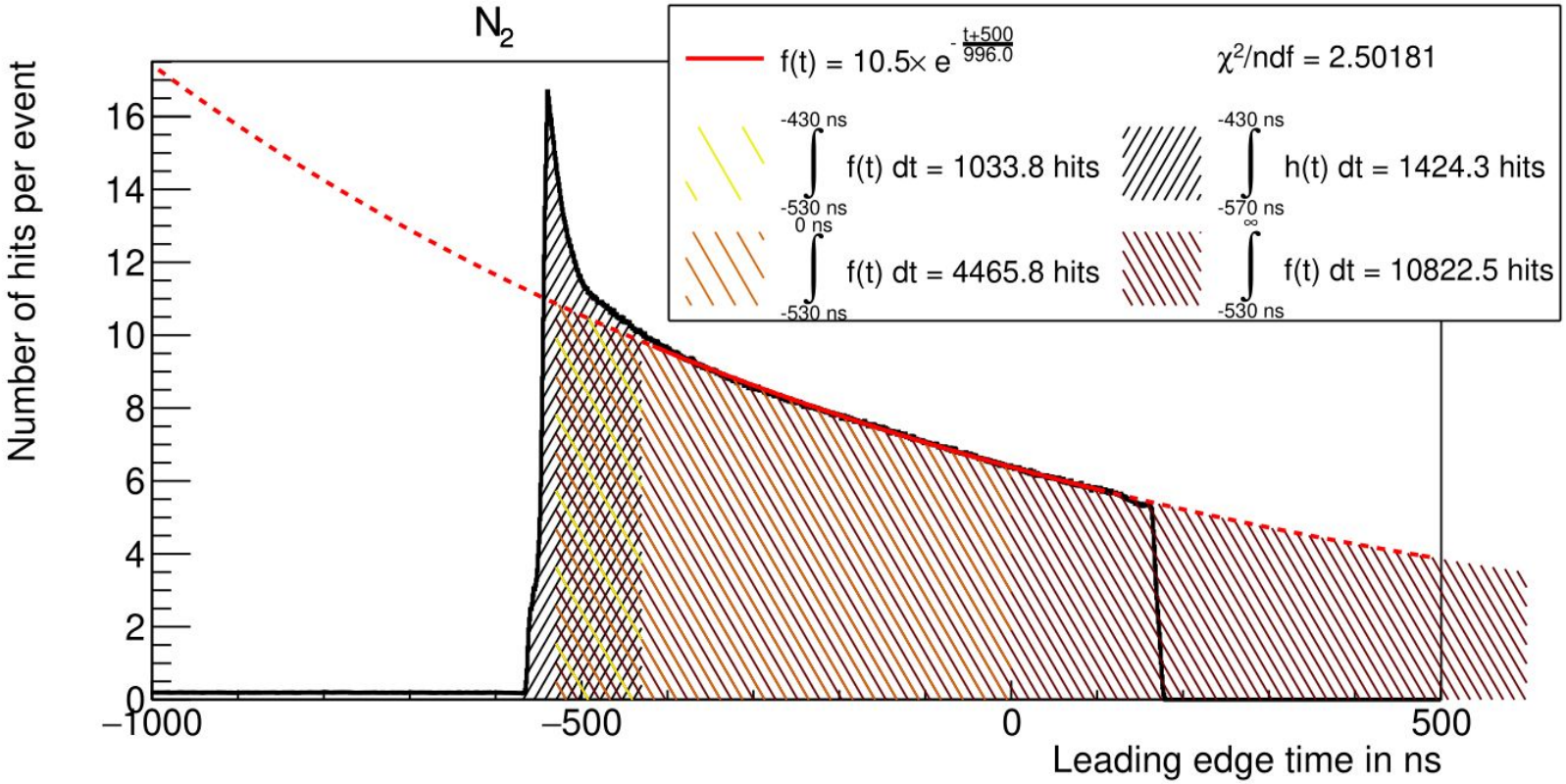


Impact of magnetic field

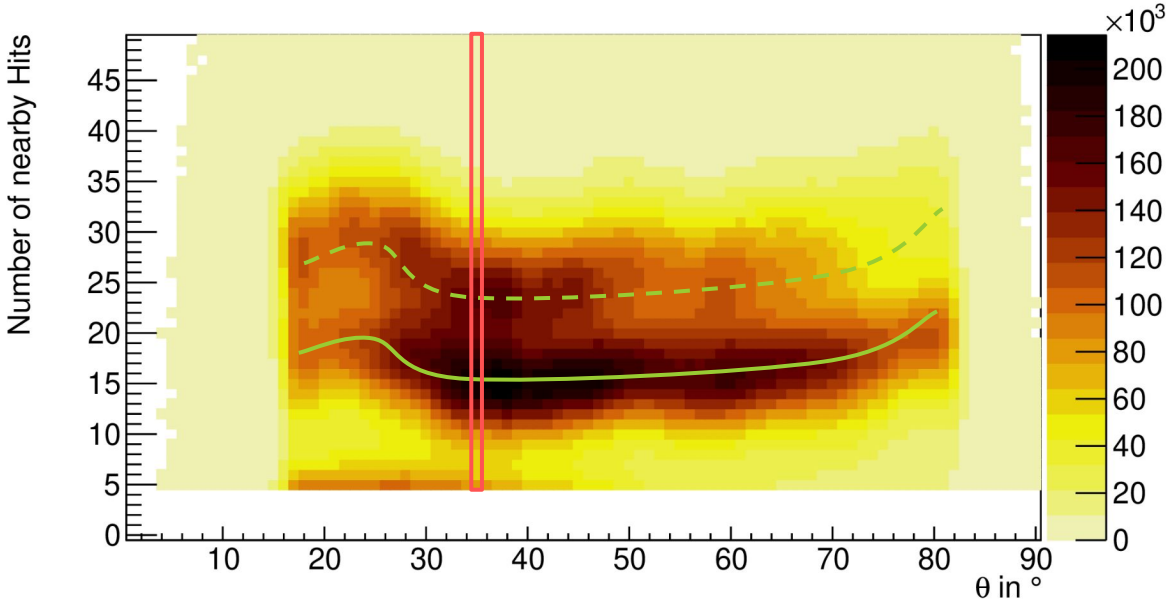


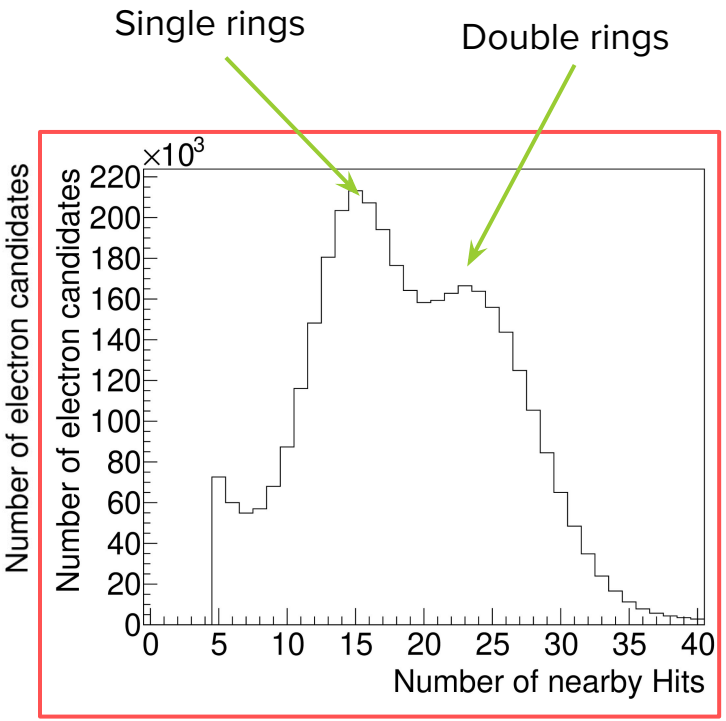


Impact of window CaF_2 window



Close double ring suppression





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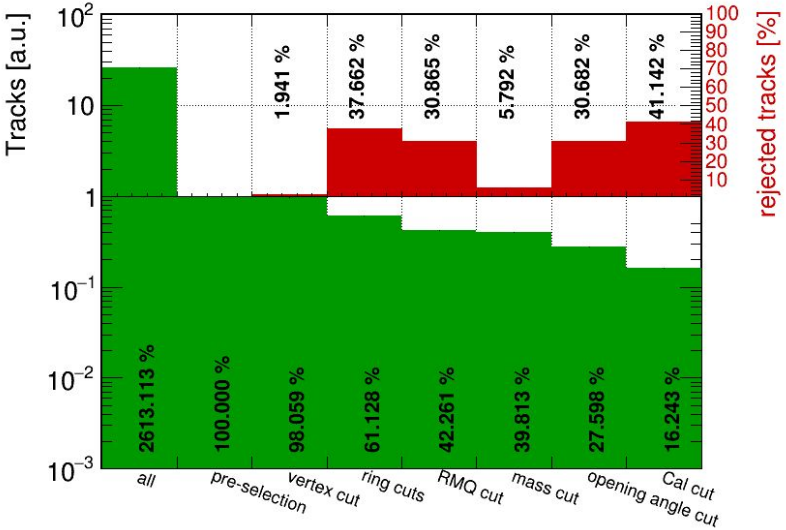
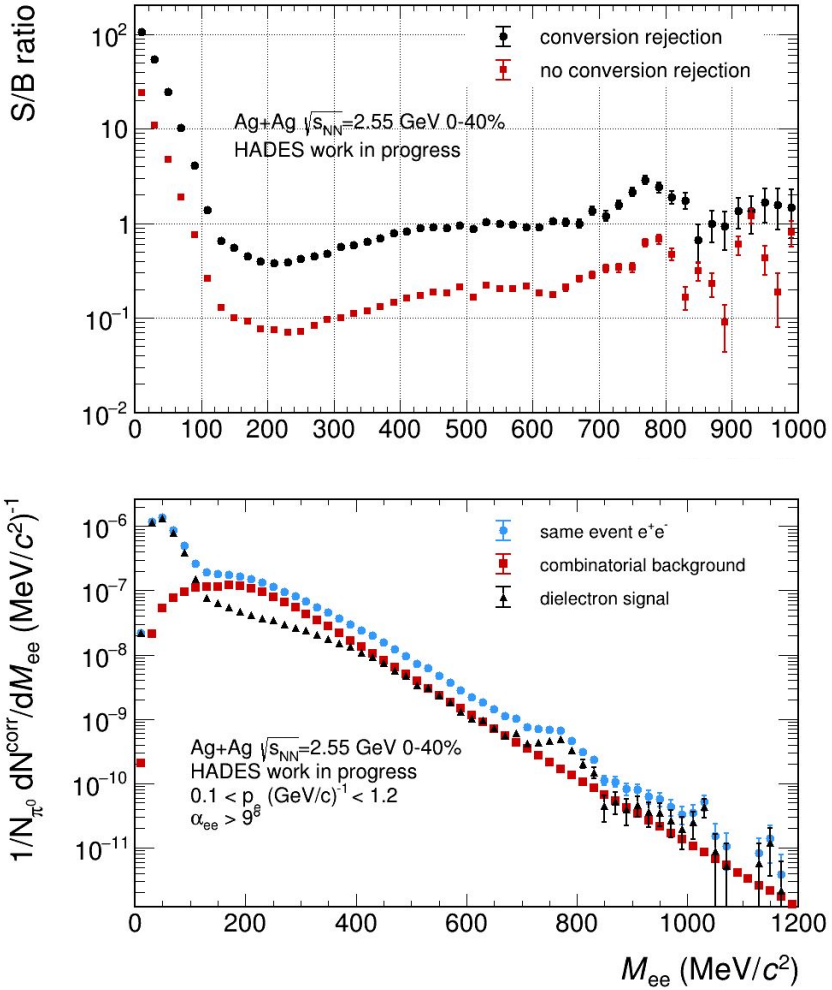
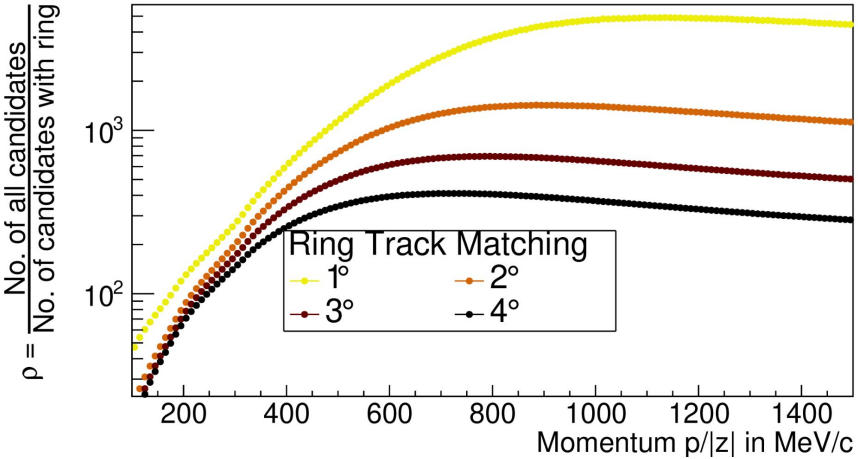
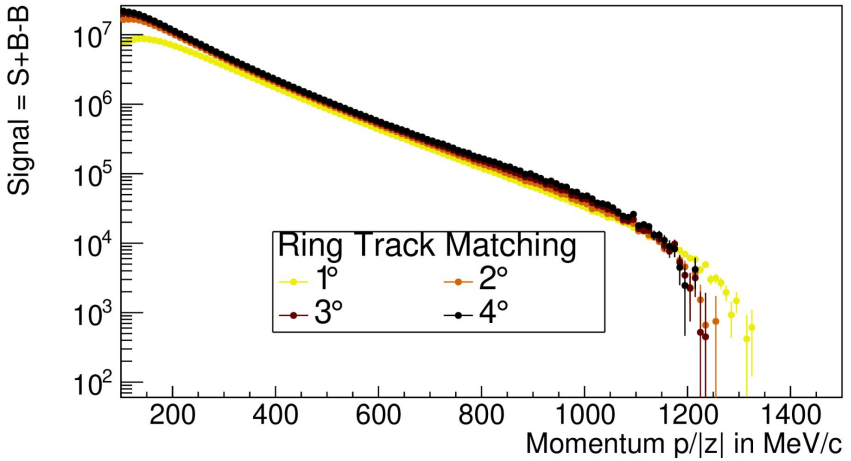


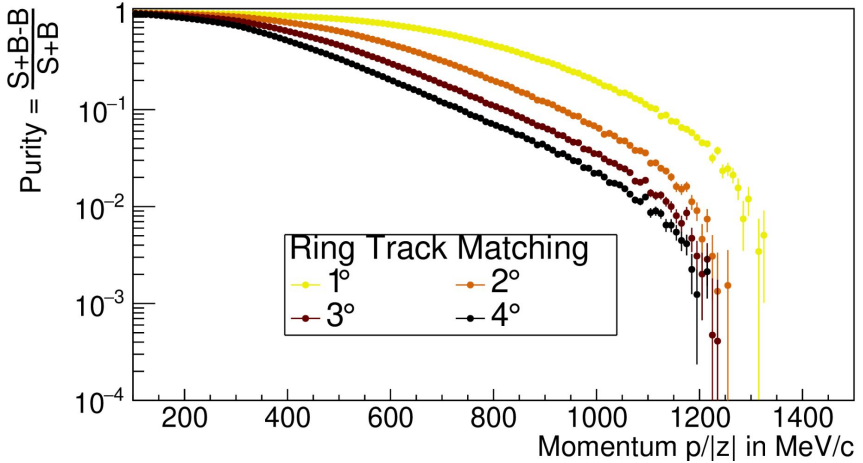


Performance of the RICH

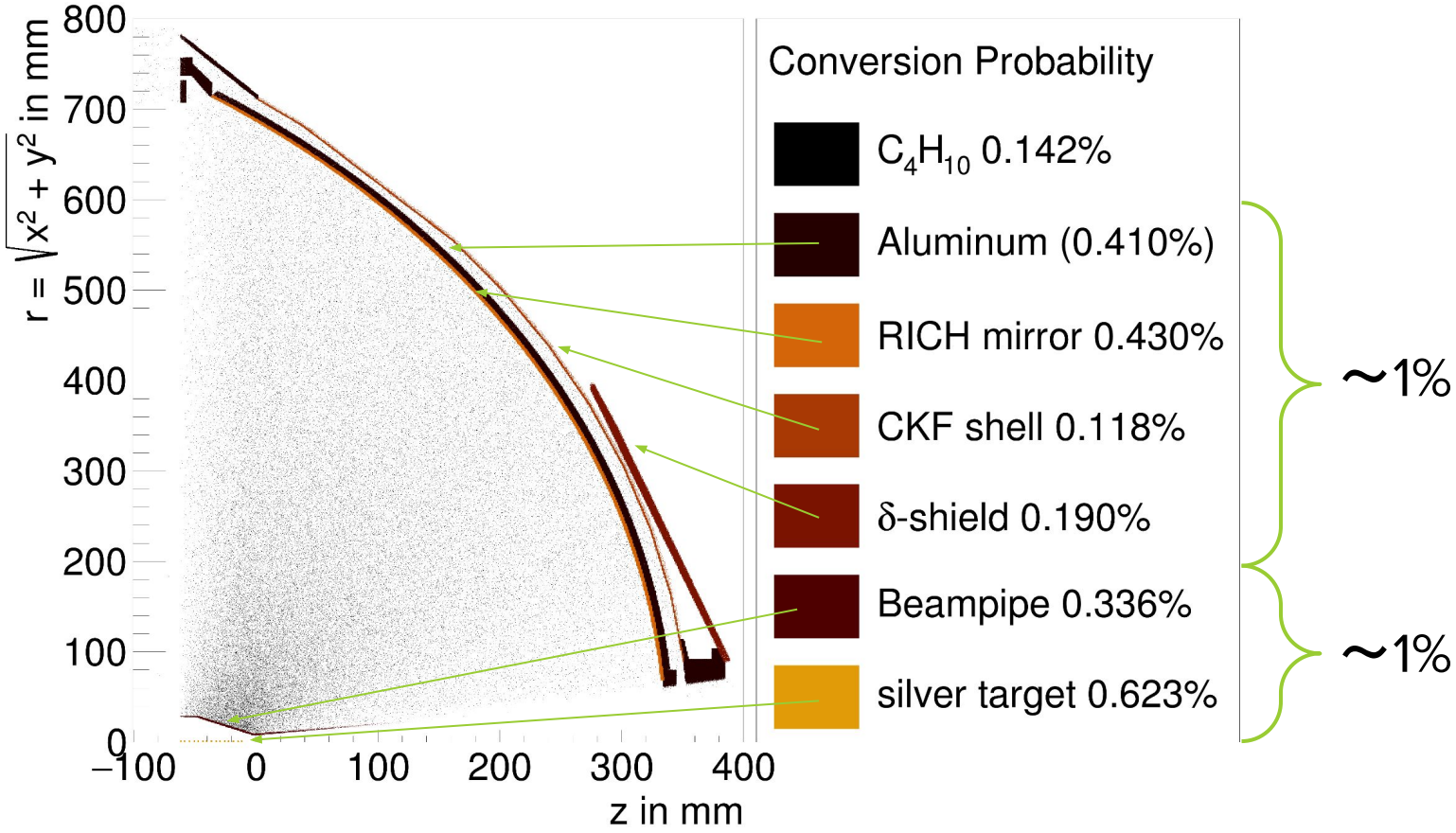


- Estimation on uncorrelated Background via RICH rotating technique
- Rotate azimuthal position of all RICH rings by $\phi = 180°$

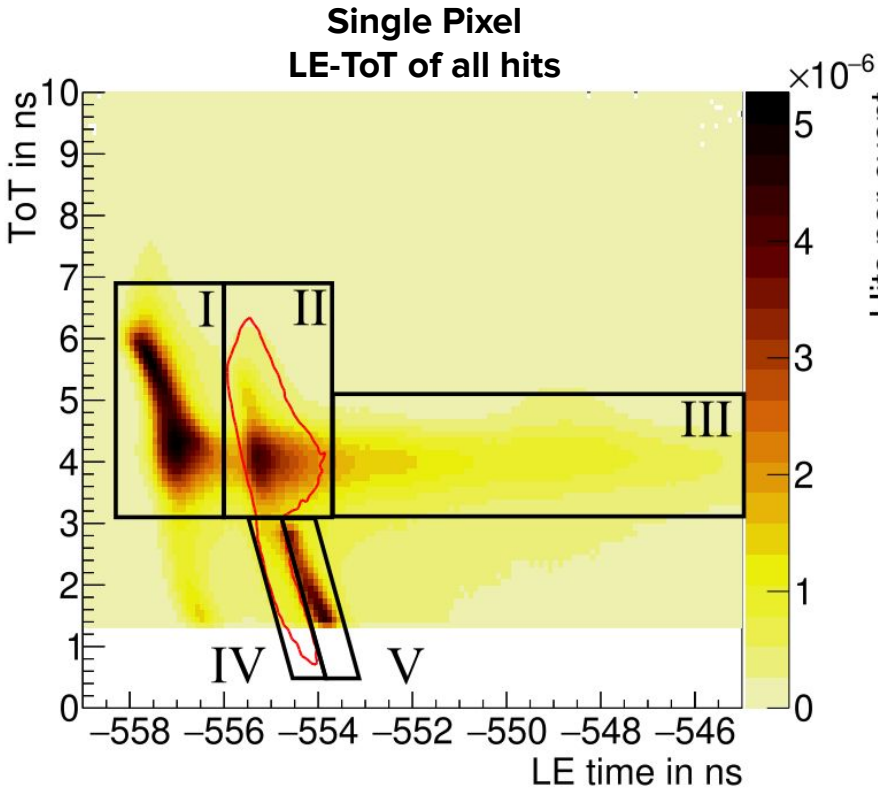


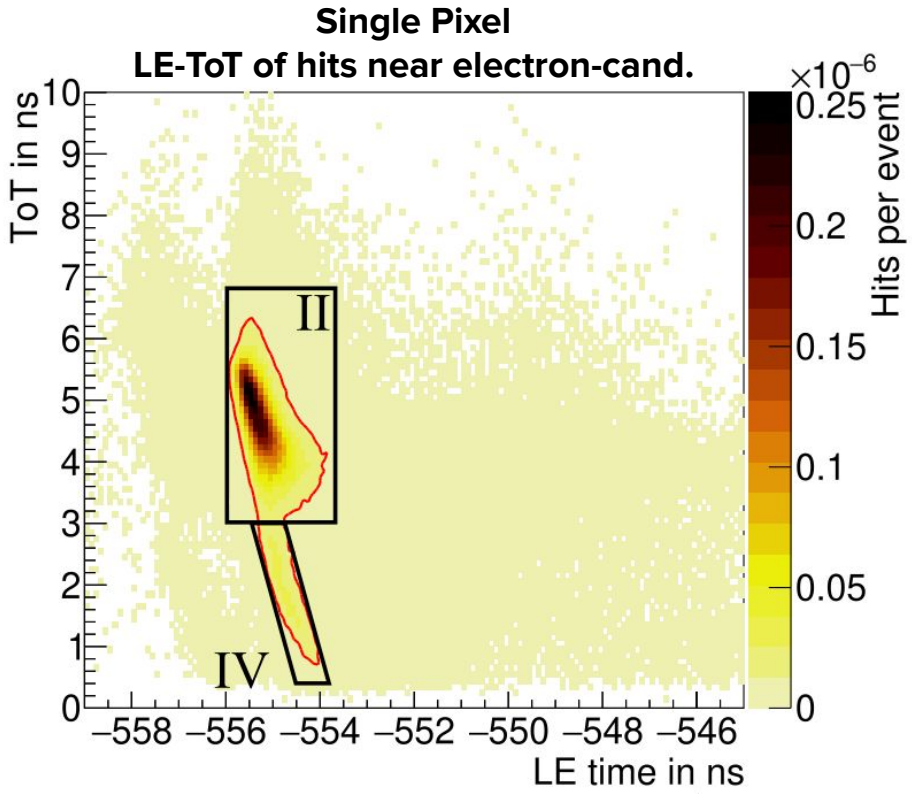


The problem - The material budget of the RICH

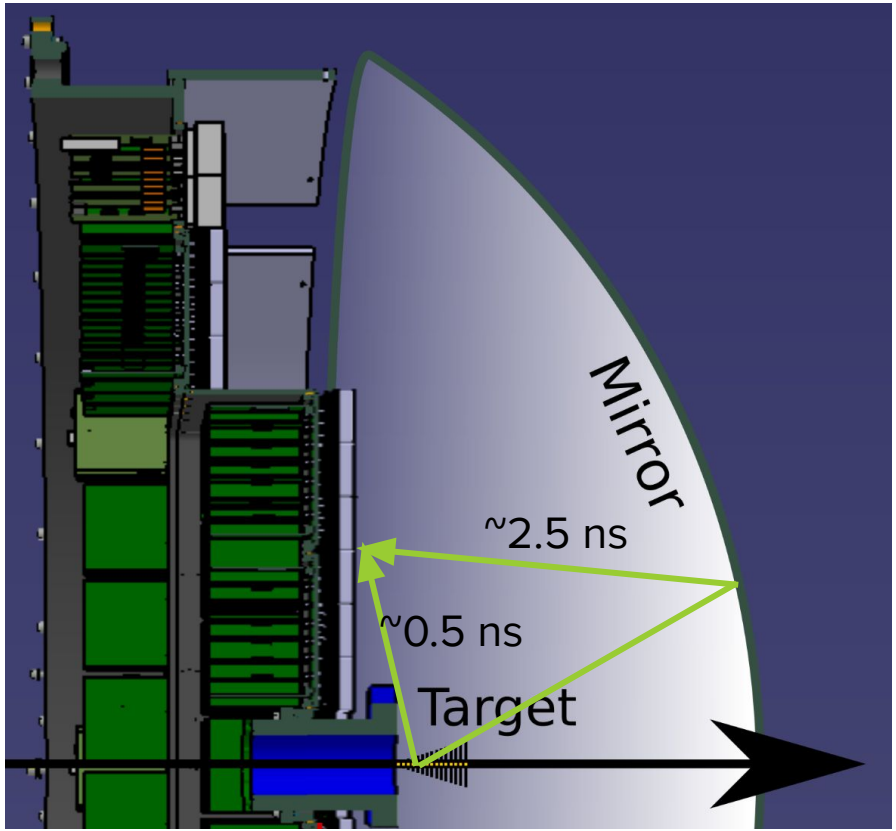


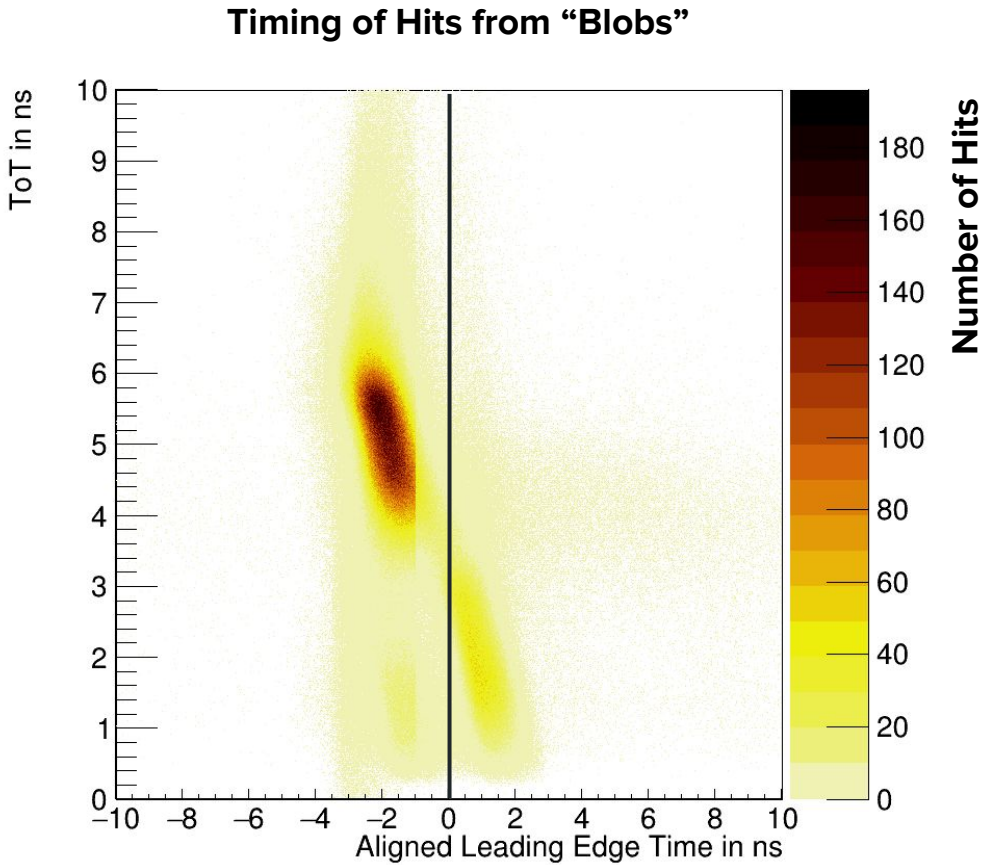
Discussion of the LE time spectrum





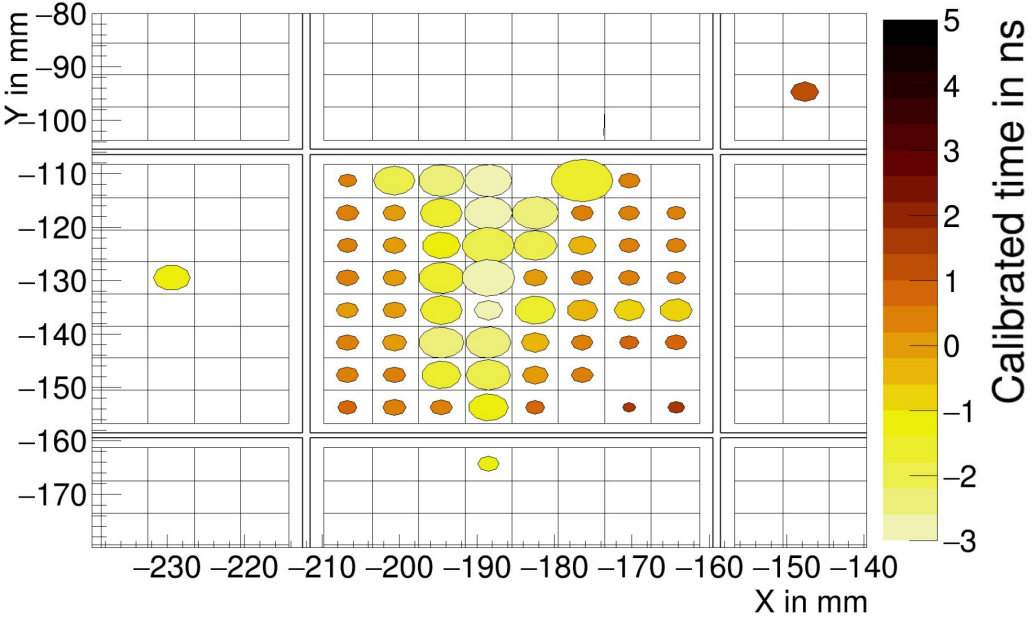
Discussion of the LE time spectrum - Regions I and V



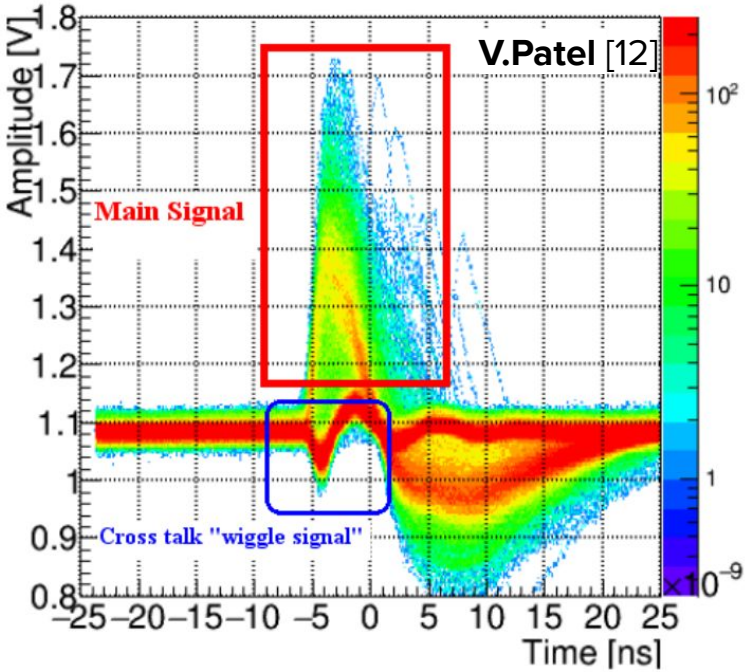


Discussion of the LE time spectrum - Regions I and V

Single Event Display
“Blob” event

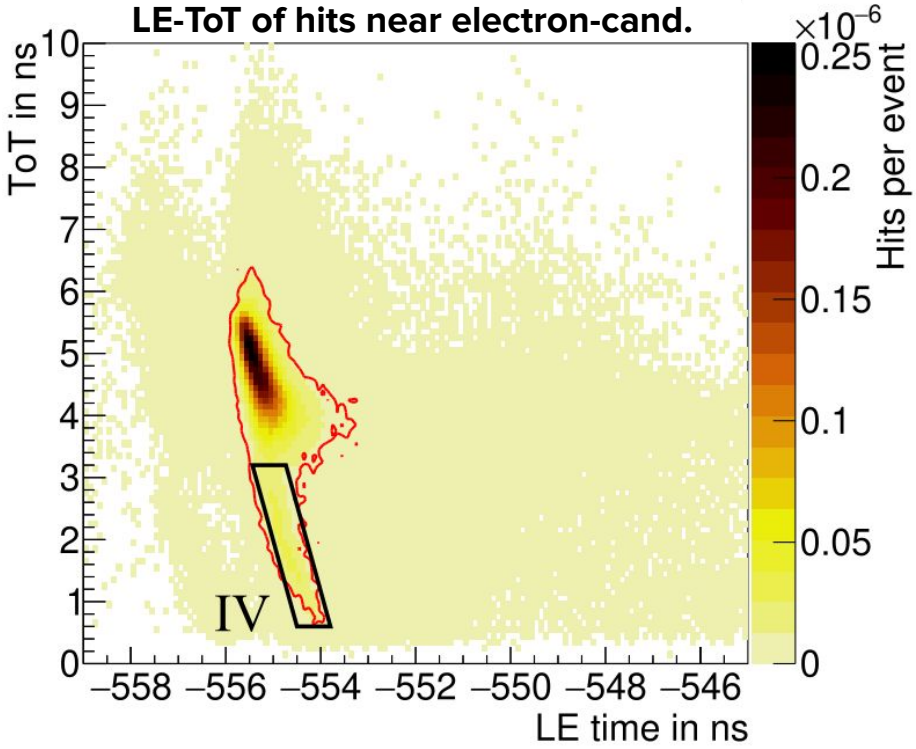


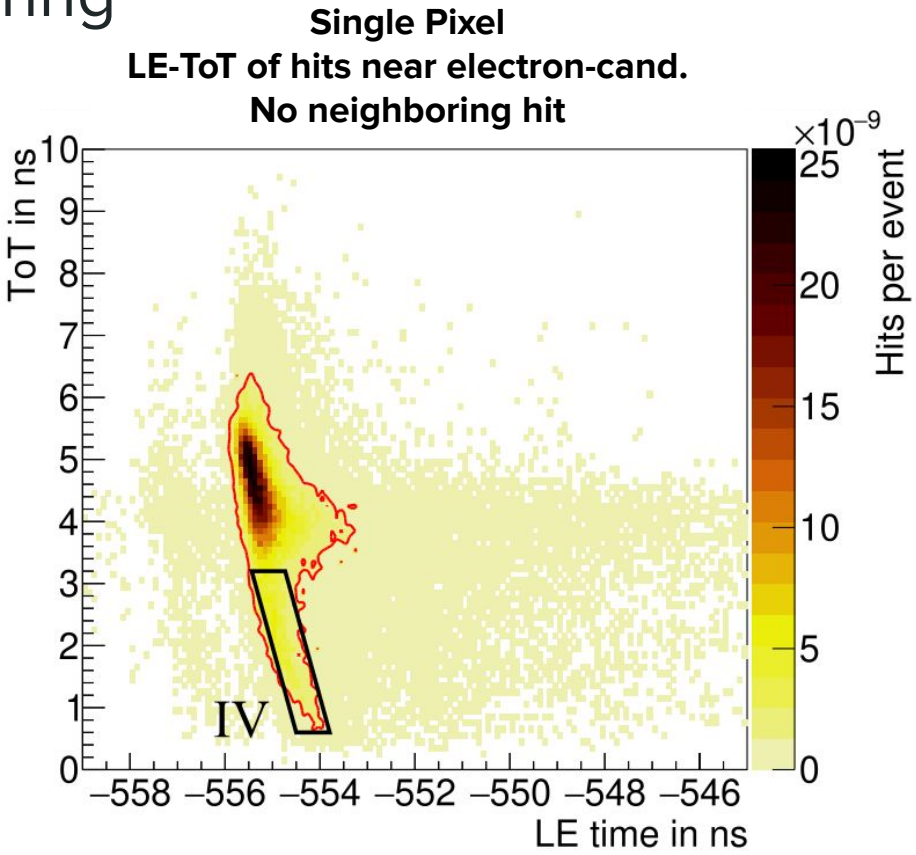
Oscilloscope measurement
MAPMT signal in the DiRICH input stage



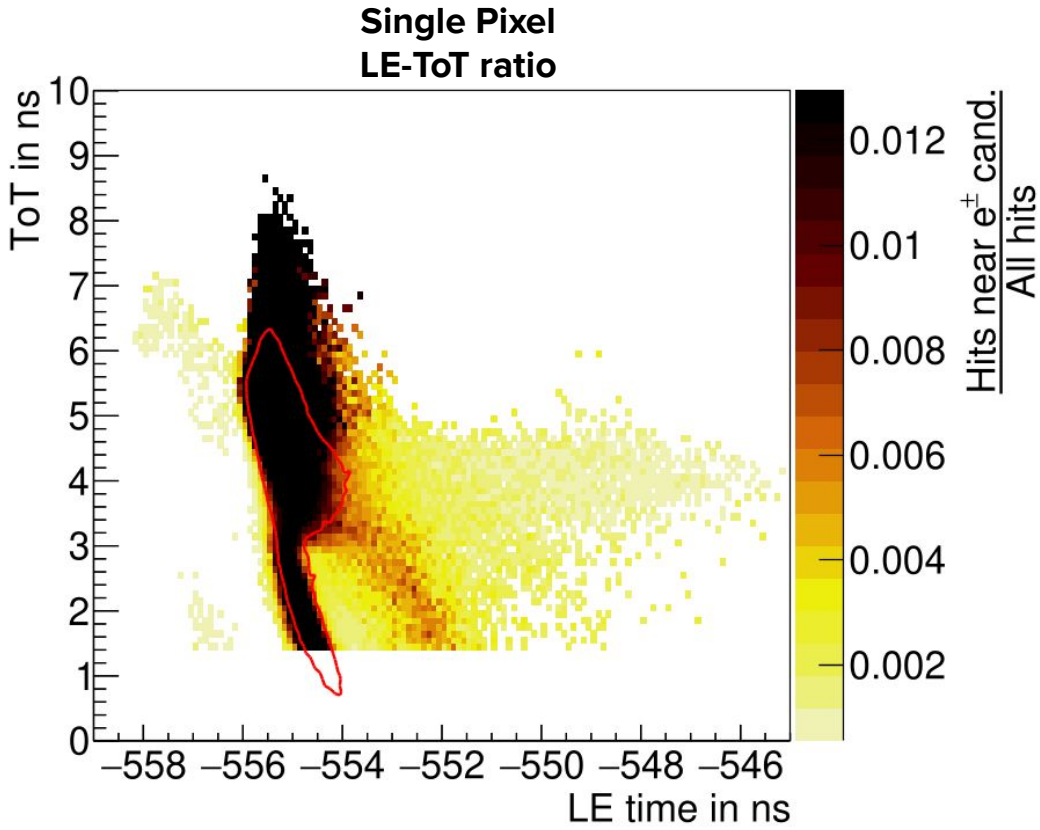
Discussion of the LE time spectrum

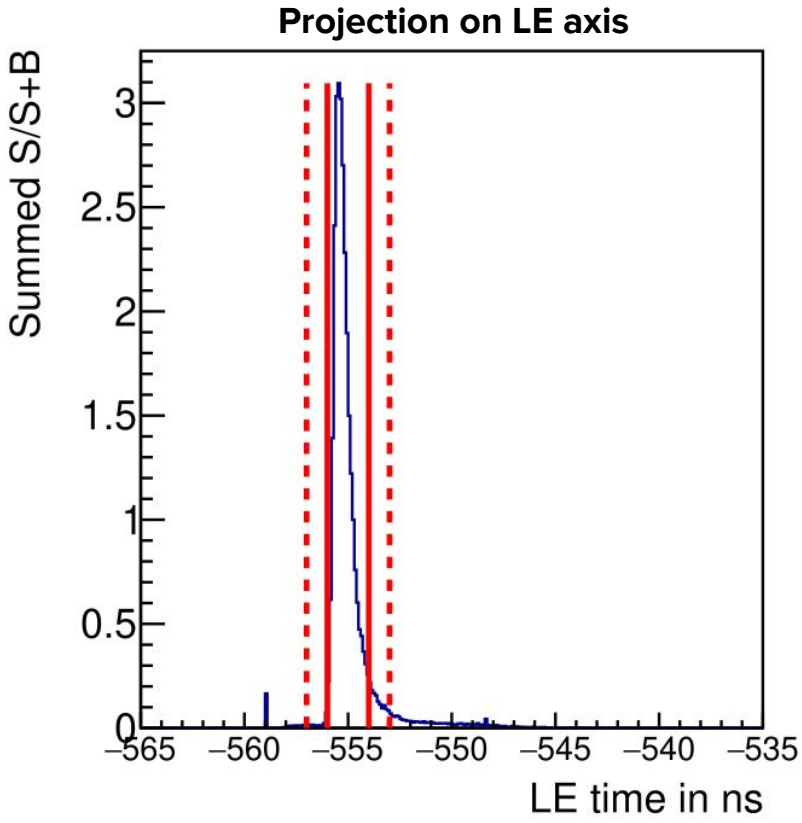
- Crosstalk and Charge sharing





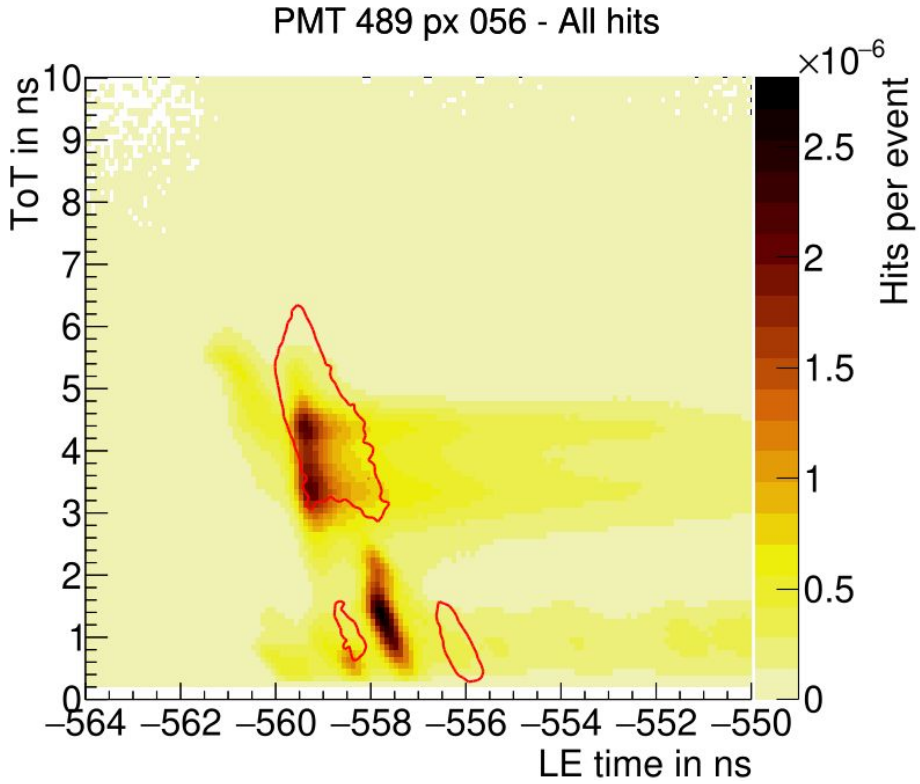
Derivation of sharp LE time cut

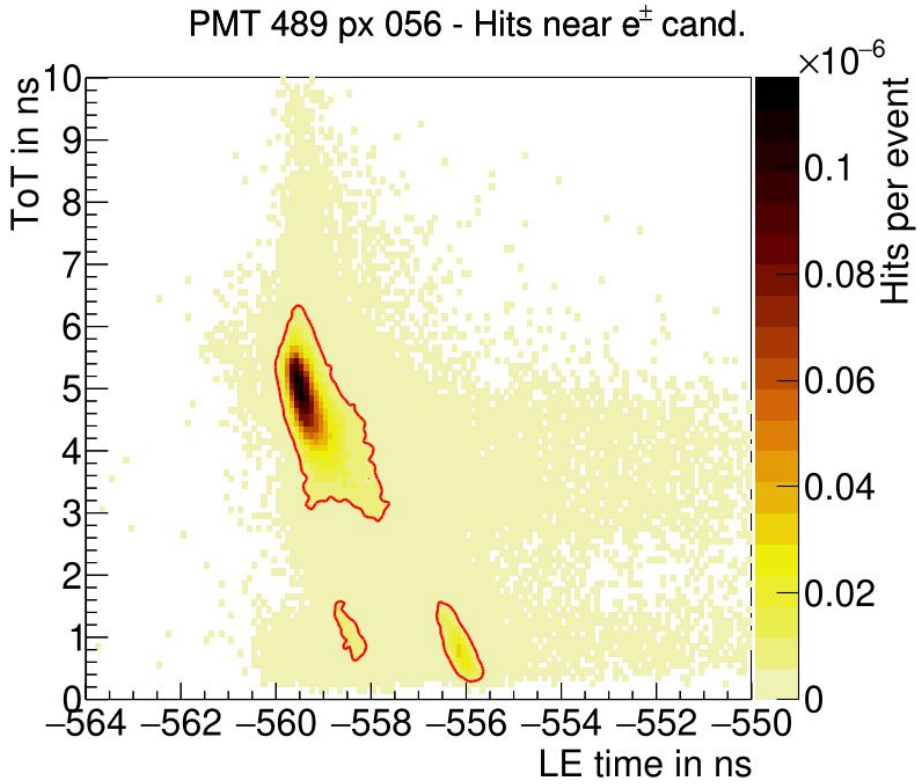




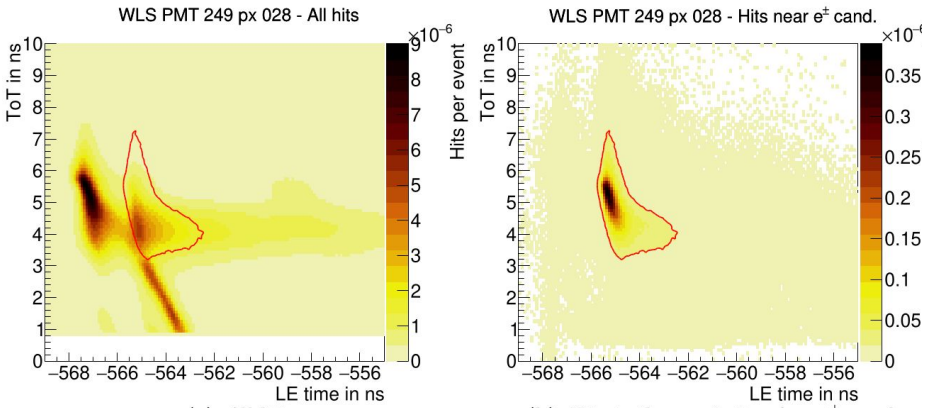
Discussion of the LE time spectrum

- Crosstalk and Charge sharing

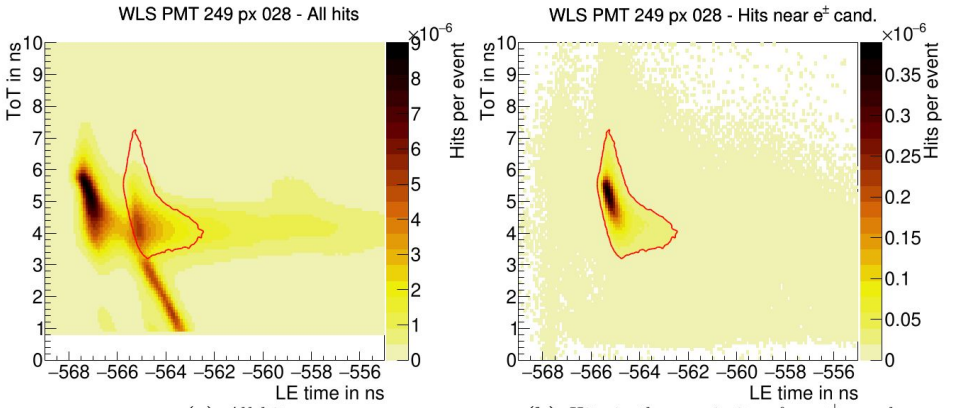




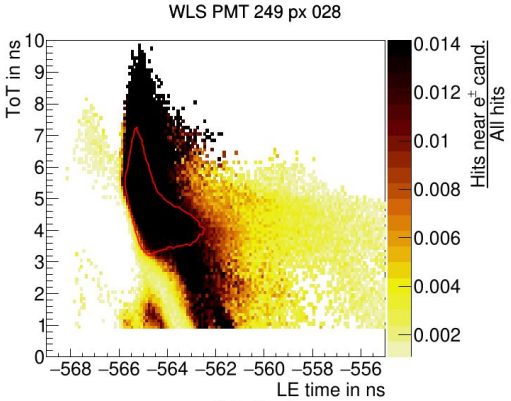
Discussion of the LE time spectrum



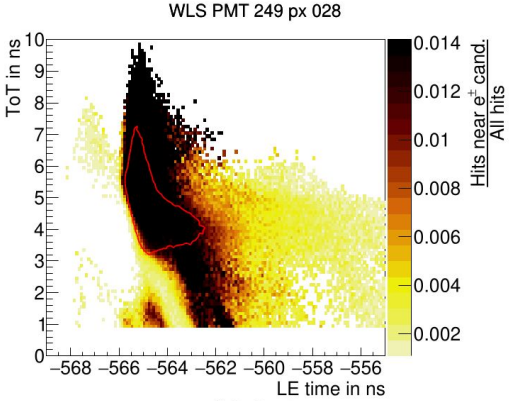
(a) *All hits* (b) *Hits in the proximity of an $e^{\pm}$ cand.*



(a) *All hits* (b) *Hits in the proximity of an $e^{\pm}$ cand.*

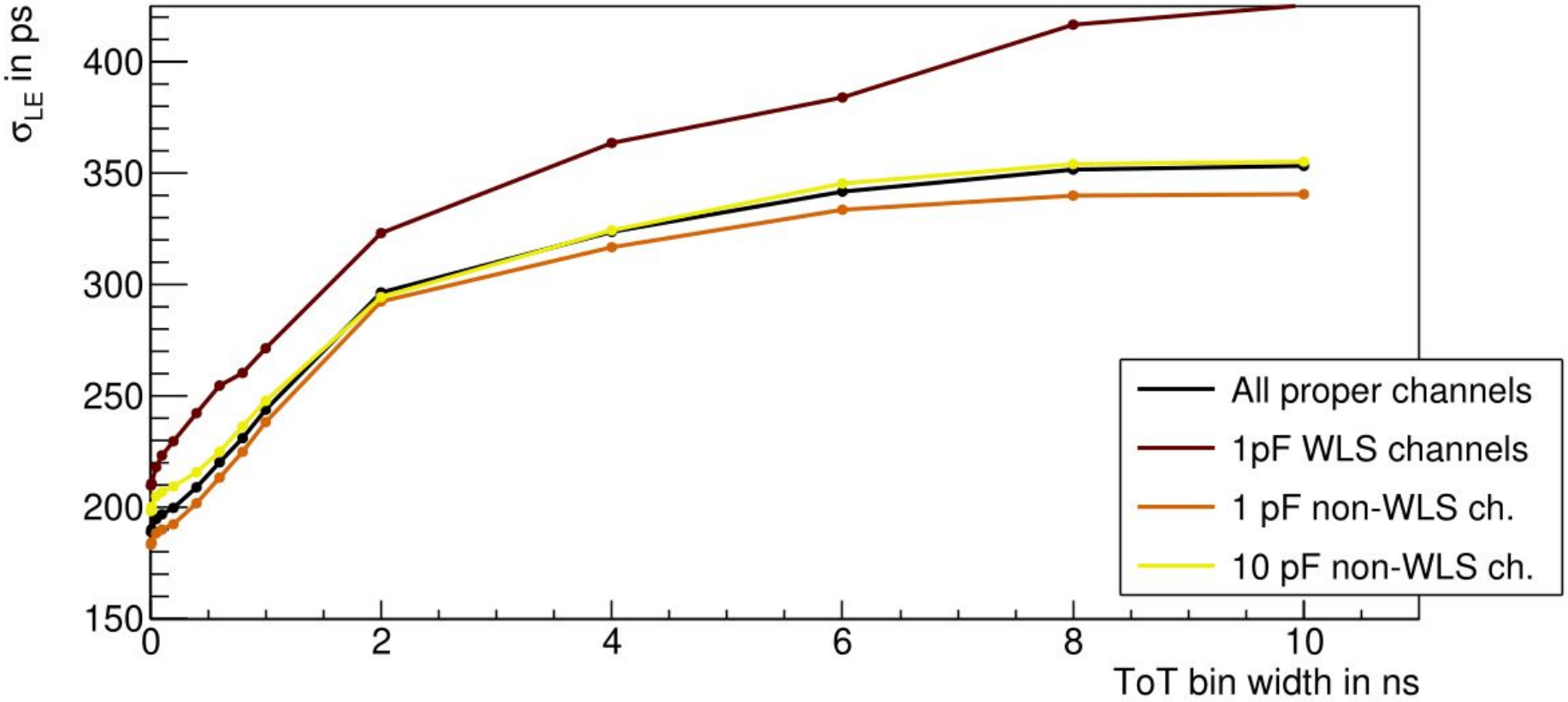


(c) *Ratio*

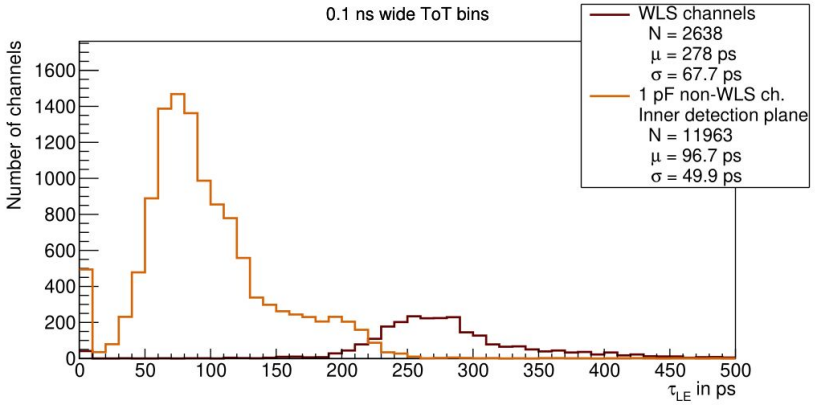


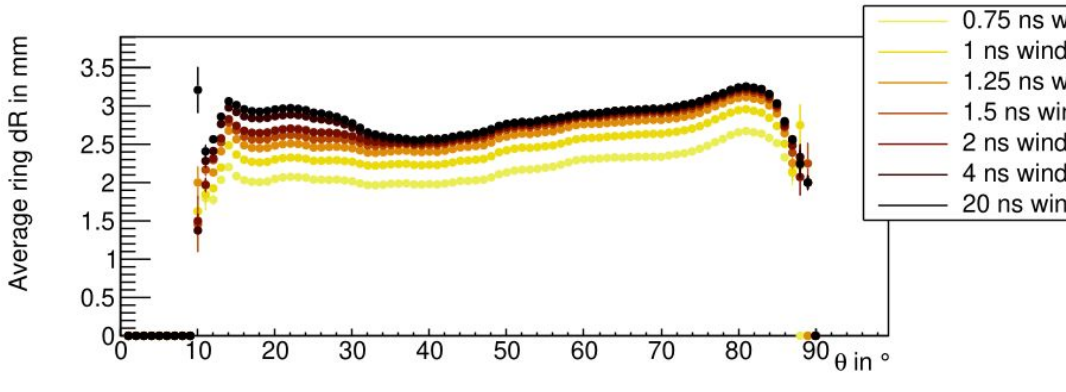
(c) *Ratio*

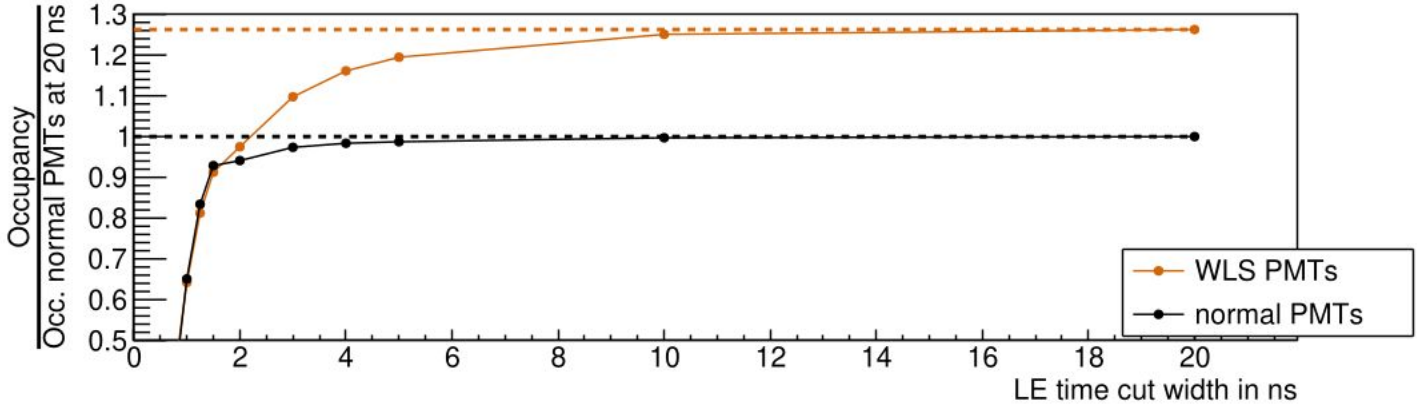
Determination of the LE timing precision



Determination of the LE timing precision for WLS

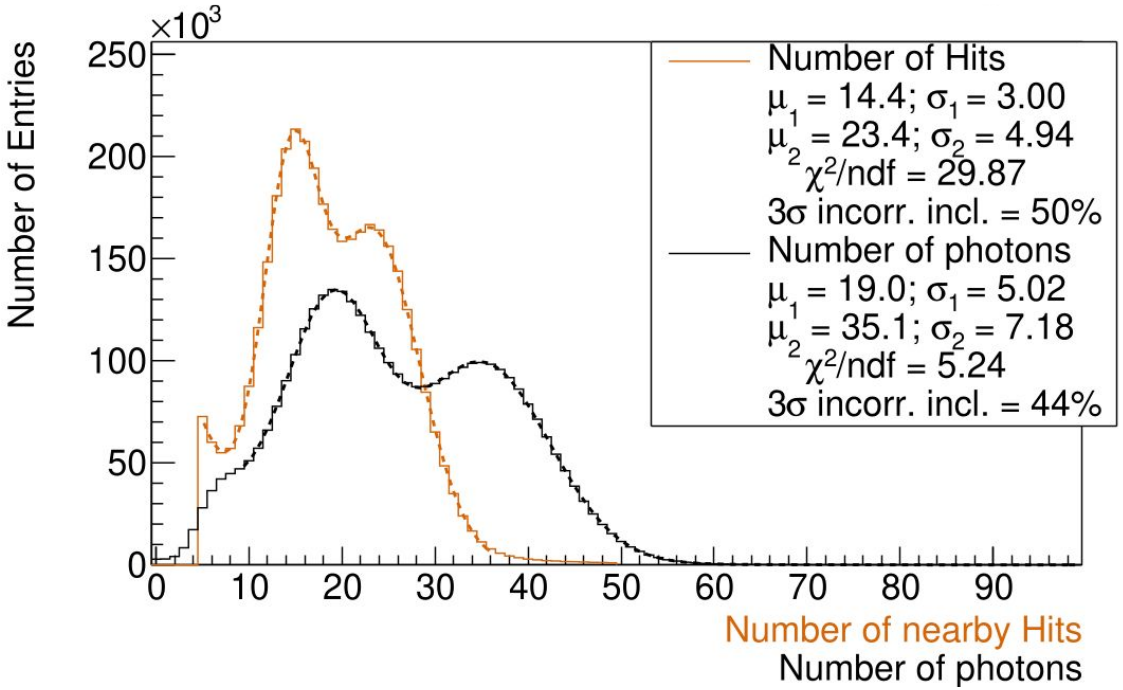




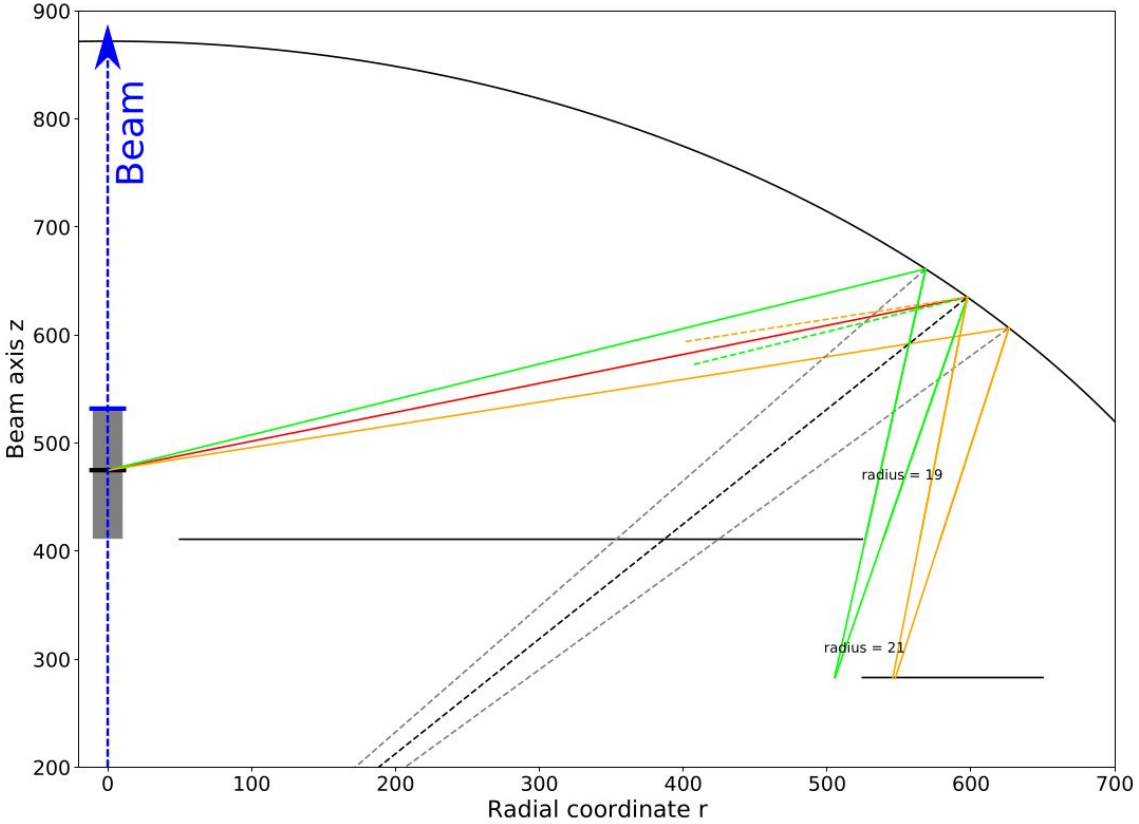


Calibration procedure and result

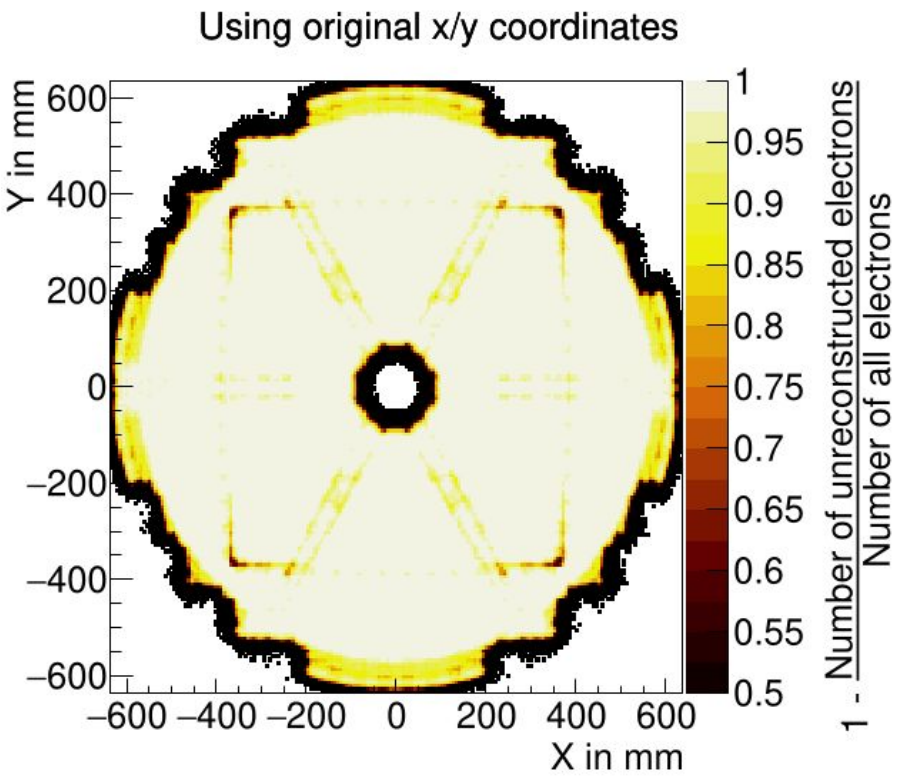
- Smooth spectra
- Fit “darknoise”/single photon spectra to extract single photoelectron peak position
- “Double” photoelectron response extracted from beam data
- Extrapolate linearly in-between to retrieve “Number of Photons”
- Improved shape
- Slightly improved distinction
- Nearly correct number of photons for two rings

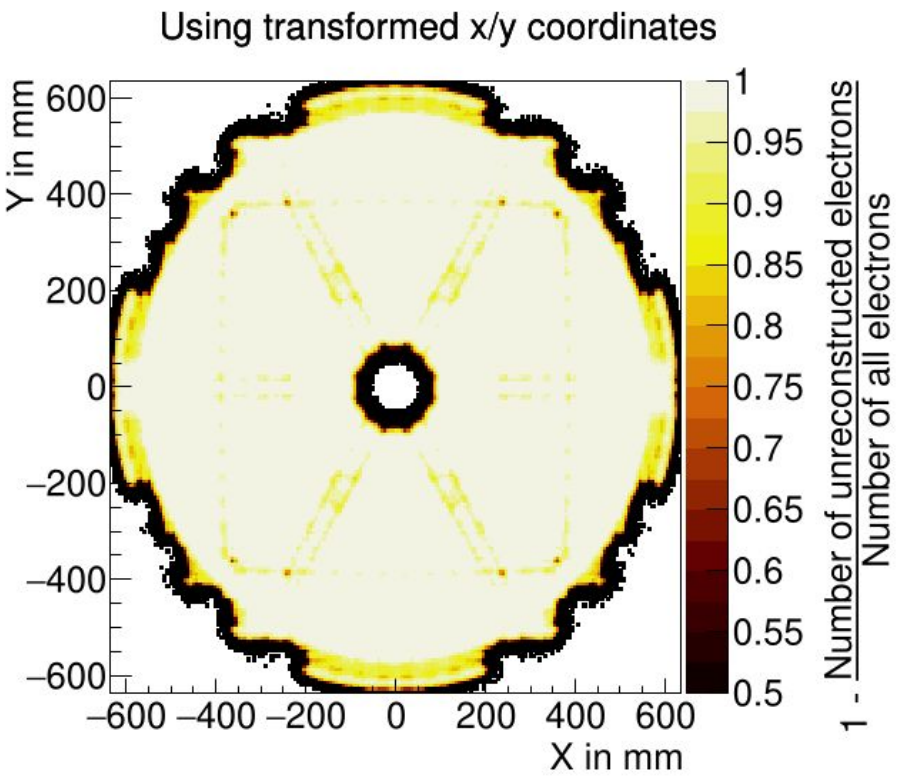


Problem - Ring hitting gap

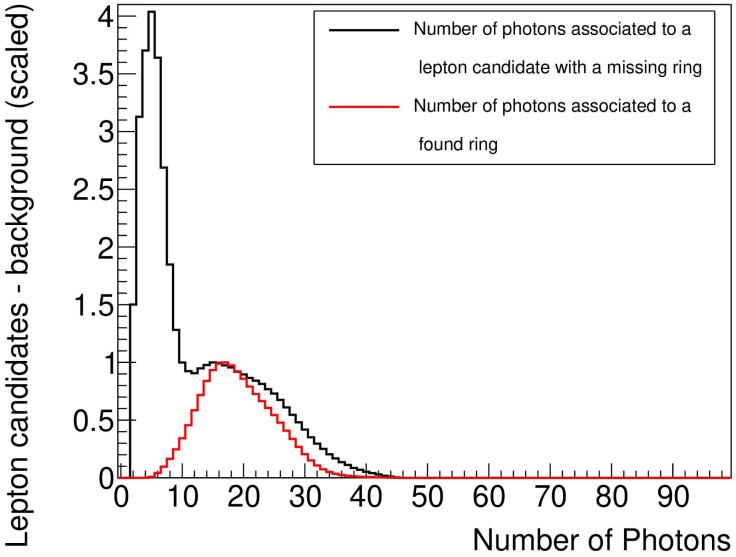


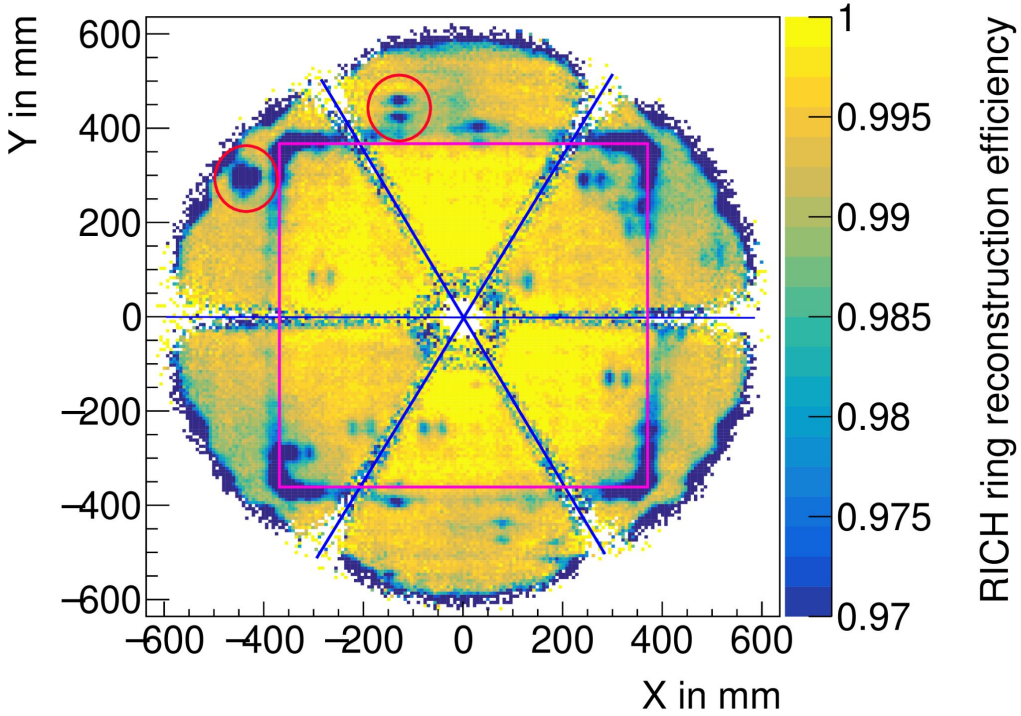
Results (Based on simulation)



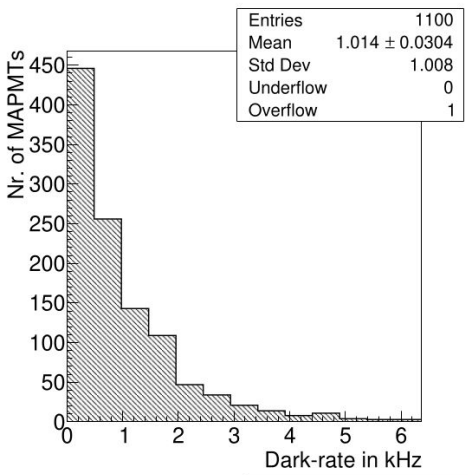


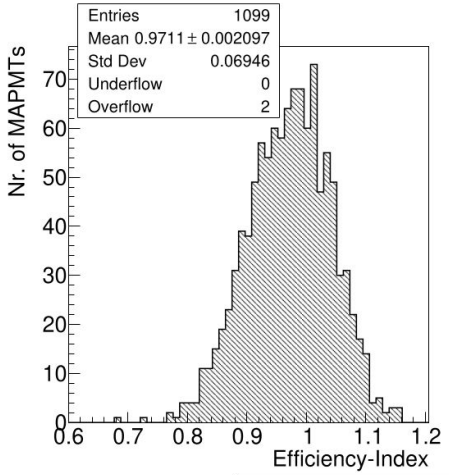
Ring reconstruction efficiency

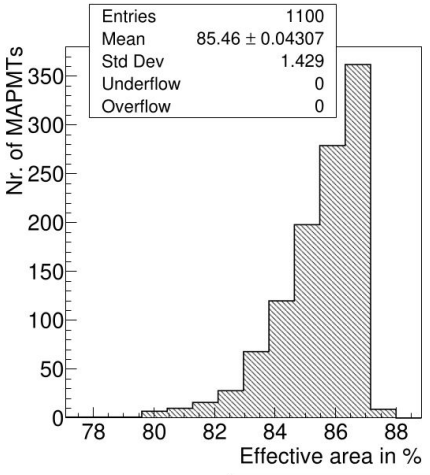


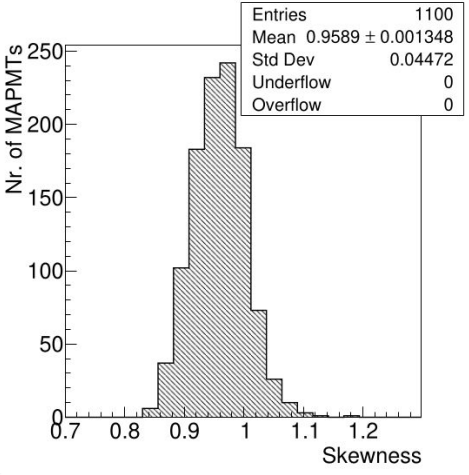


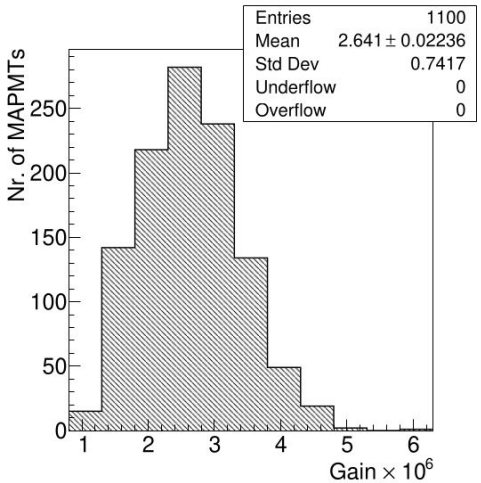
Key parameters histogramized

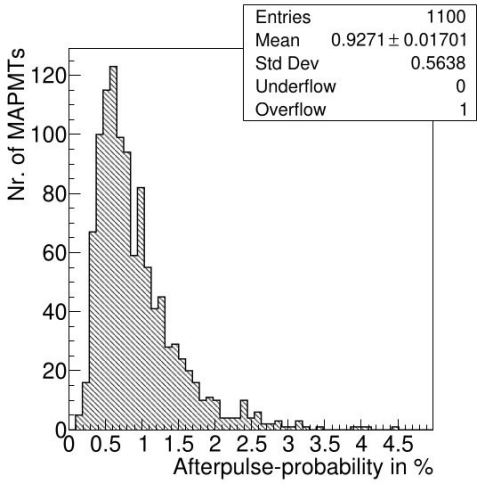


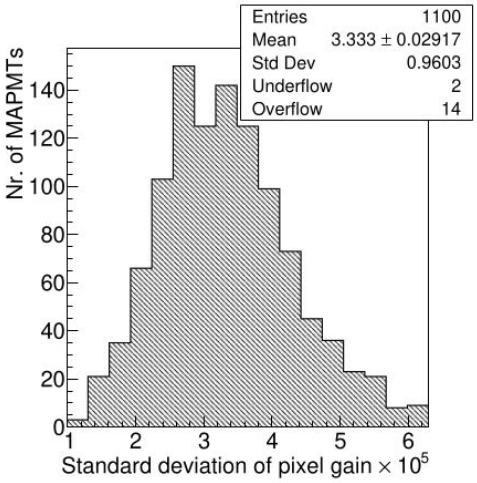




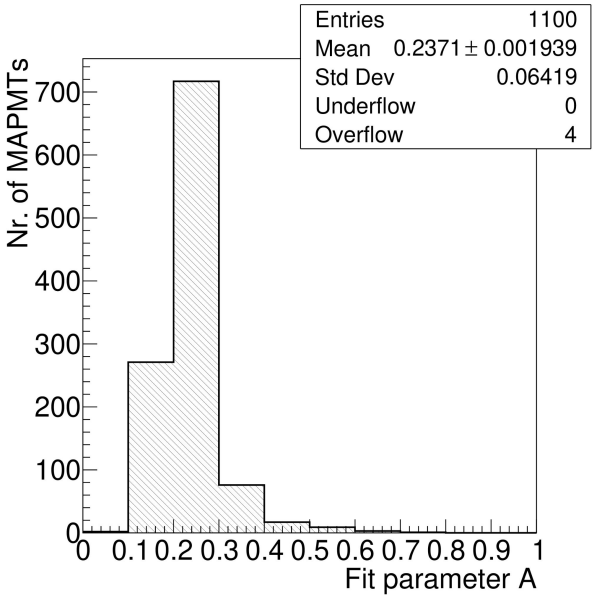


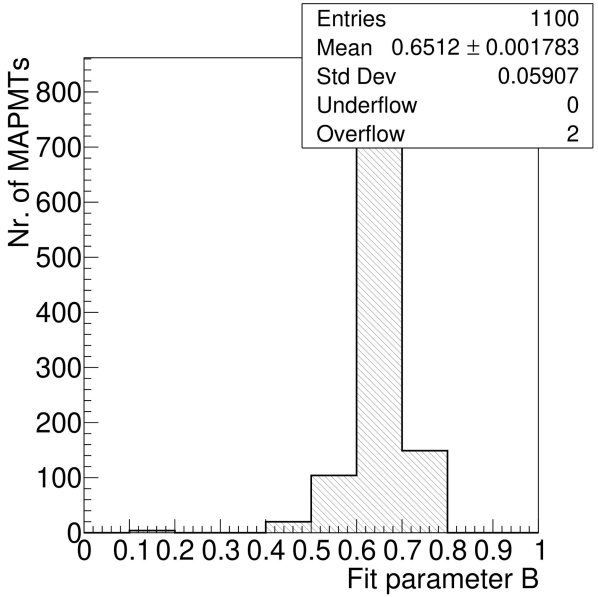






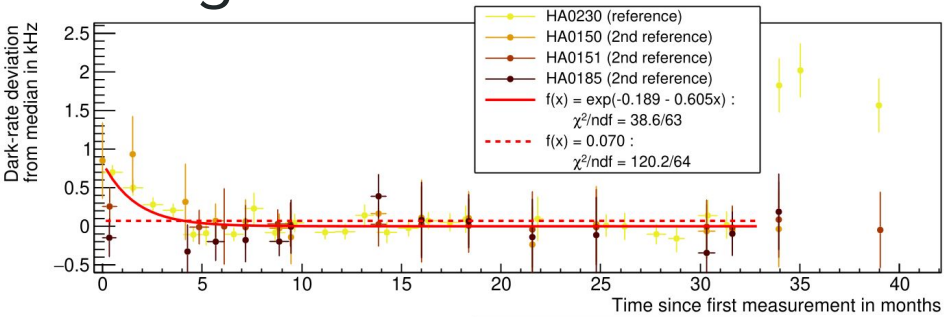
HV parameters histogramized

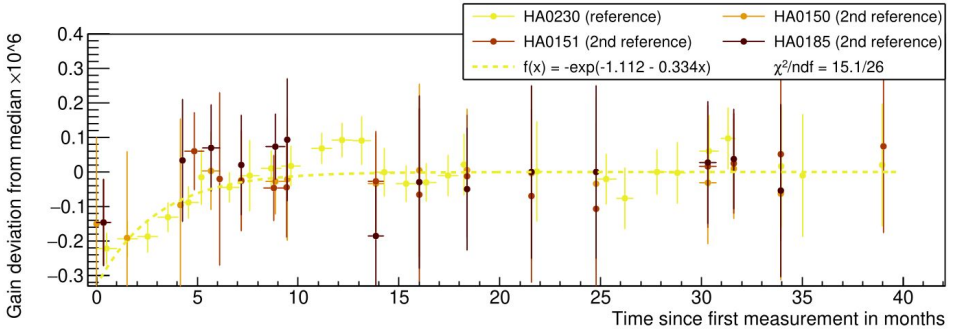


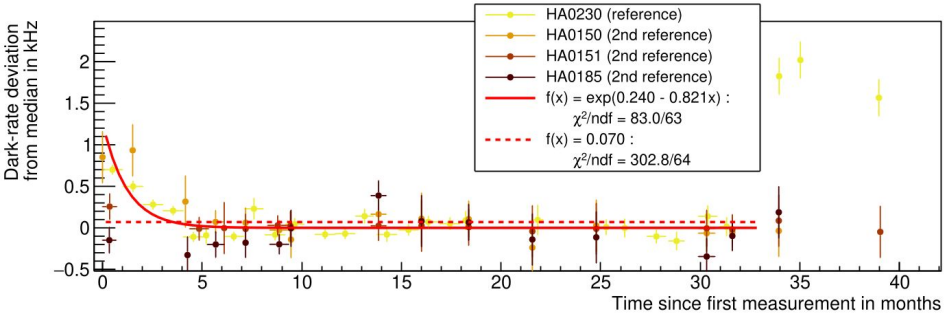


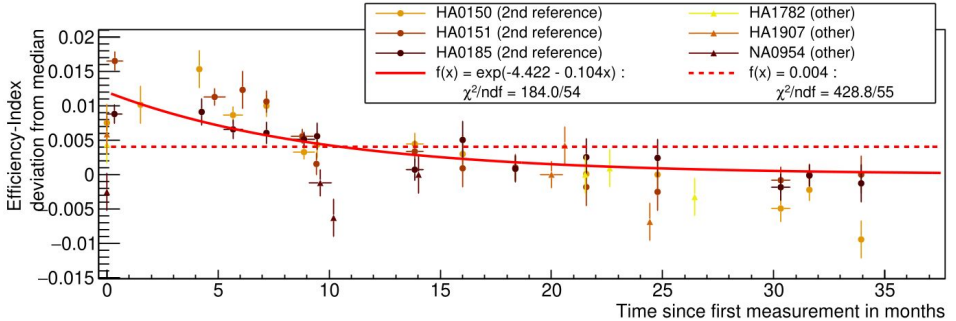
HV = wanted_gain^(1./(B*10)) * 11./A^(1./B);

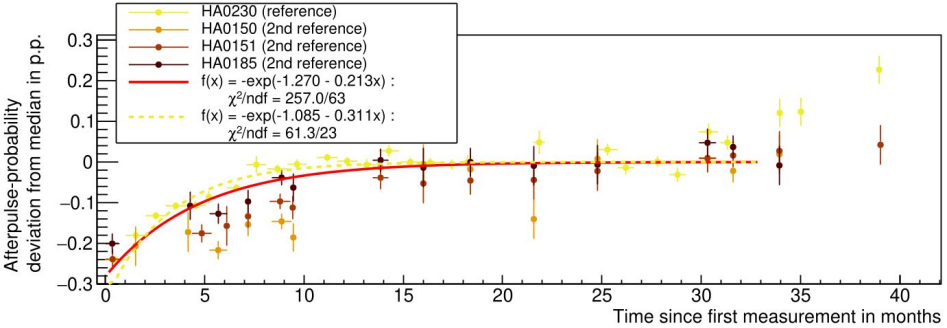
Long term variations

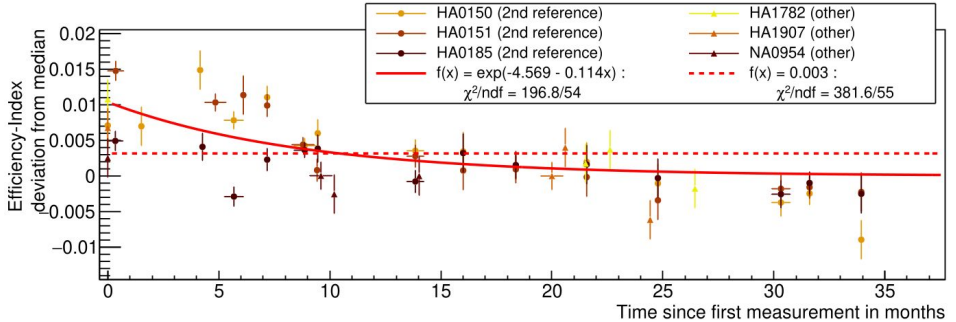












Variations over production period