Simulation results for the upgraded RICH detector in the HADES experiment.

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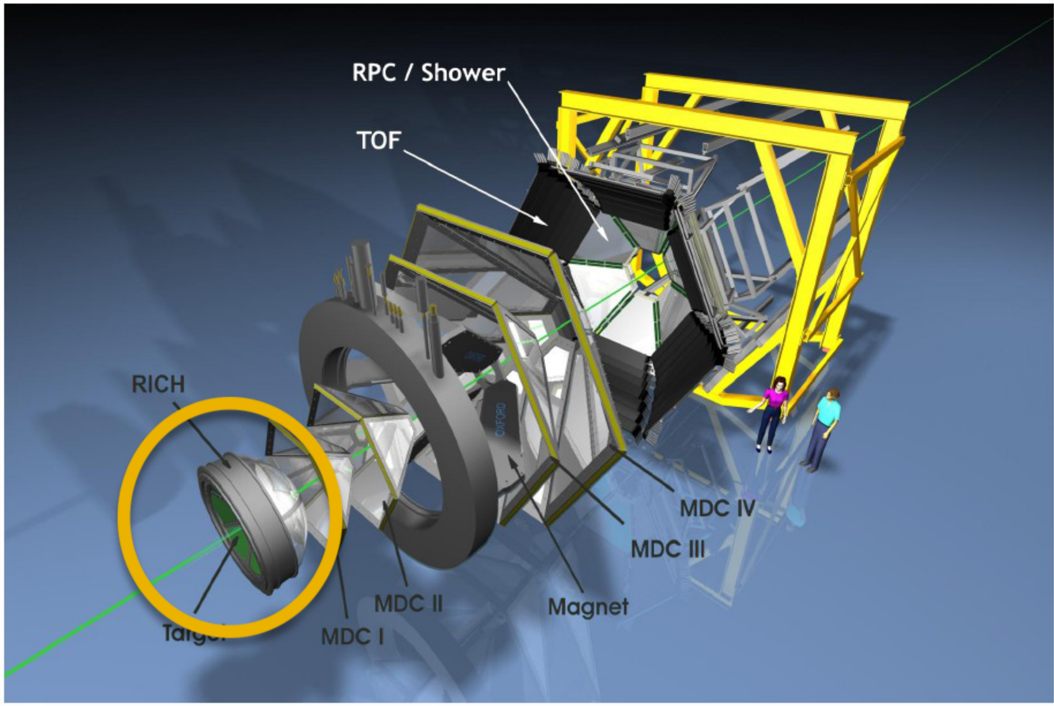
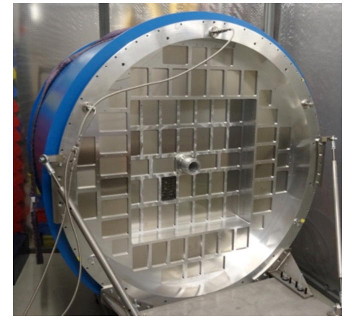
HADES experiment

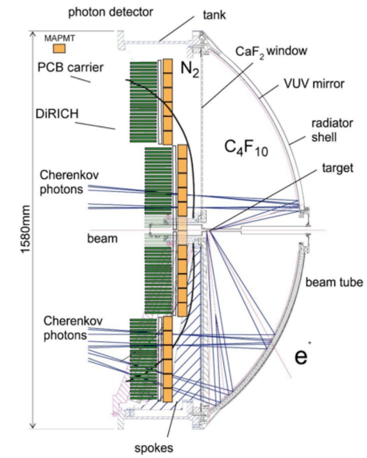
- The High Acceptance Di-Electron Spectrometer (HADES) experiment explores the properties of matter at moderate temperature and high baryon density.
- Fixed target experiment. Elementary (p, p → p, A) and heavy ion (A+A, 1-2 AGeV) collisions at SIS18 (GSI, Darmstadt).

- Search for very rare probes
- Large acceptance: full azimuth, polar angles θ [18°, 85°]
- Tracking system
  - Superconducting magnet and four sets of multiwire drift chambers
  - $\Delta M/M \sim 2\%$
- Good particle identification
  - TOF+RPC wall for hadron ID
  - RICH and Pre-Shower for electron ID



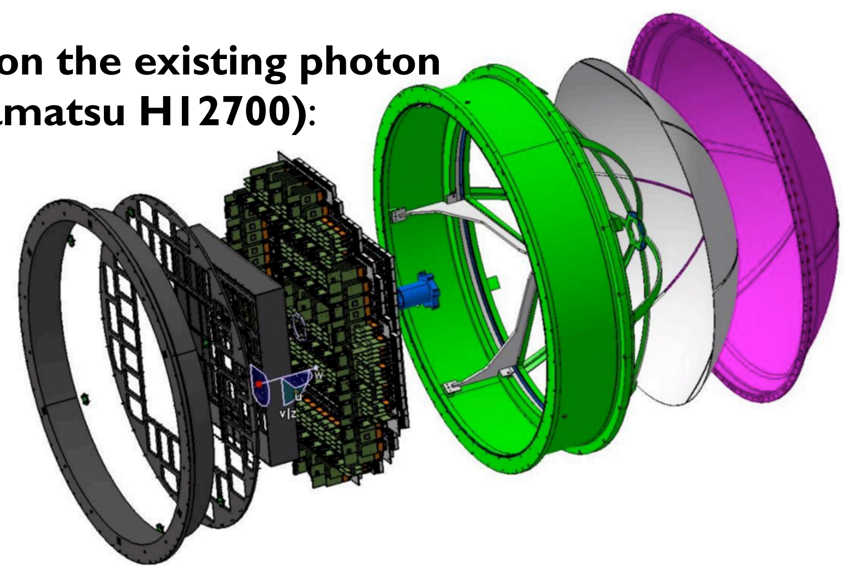
Old and new HADES RICH detector



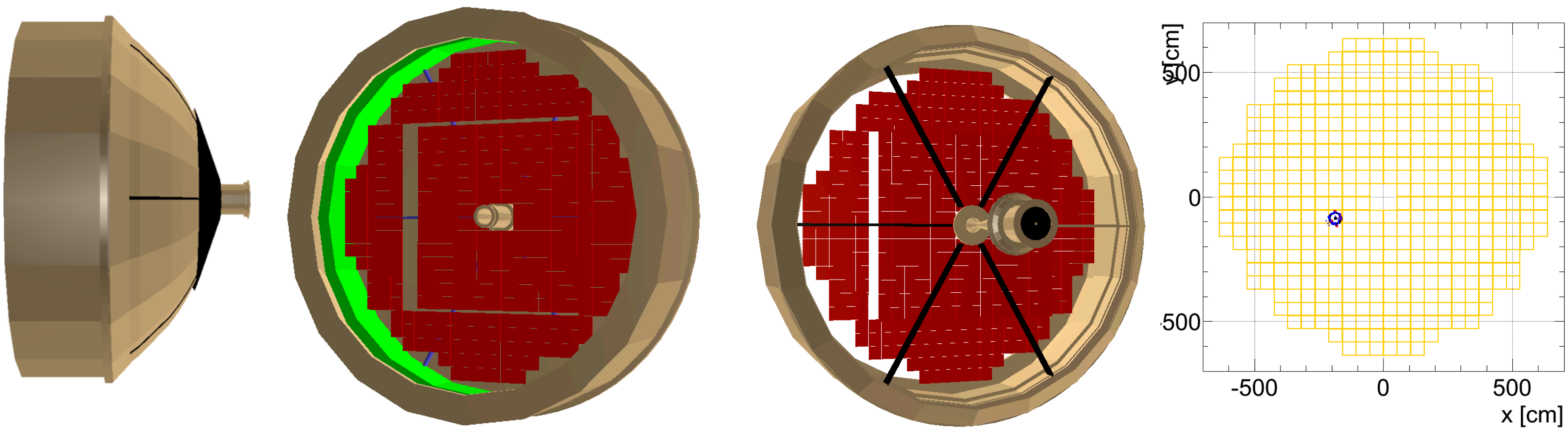


- HADES RICH is a hadron blind RICH detector
  - C_4F_{10} radiator
  - gaseous photon detector based on MWPCs with CsI cathode
  - electron identification $p < 1.5$ GeV/c
  - successfully operated since 1999
- Old photon detector shows signs of aging. Exchange to a new photon detector is needed for reliable future operation.

- **In cooperation with the CBM-RICH collaboration the existing photon detector will be replaced with MAPMTs (Hamamatsu H12700)**:
  - 428 MAPMTs, 64ch each.
  - Sensitive wavelength range from 200 – 600nm.
  - Photon detector area ~2 m^2
  - High efficiency (>30% q.e.).
- Significant gain in detector performance expected.
- Start of operation is planed for 2018.



New RICH geometry in the simulation



- The upgraded RICH geometry was implemented within the HYDRA2 framework of HADES.
- New detector simulation and reconstruction software was implemented.
- The geometry was optimized in simulations with constraints from mechanics.

Hit producer.
MAPMT response simulation.

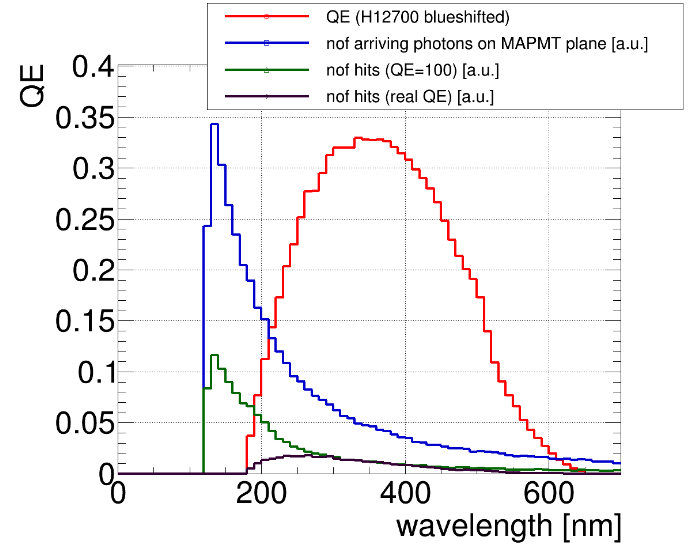
Photon on PMT plane (x, y, wavelength)

↓

Check QE measurements

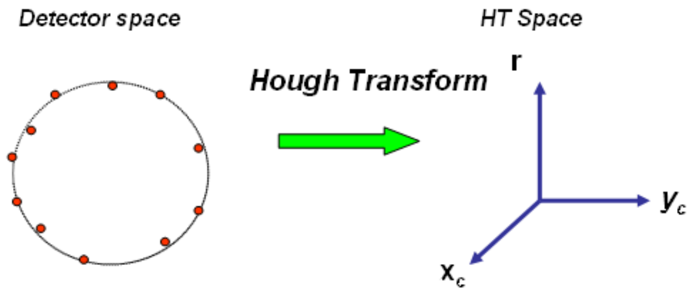
↓

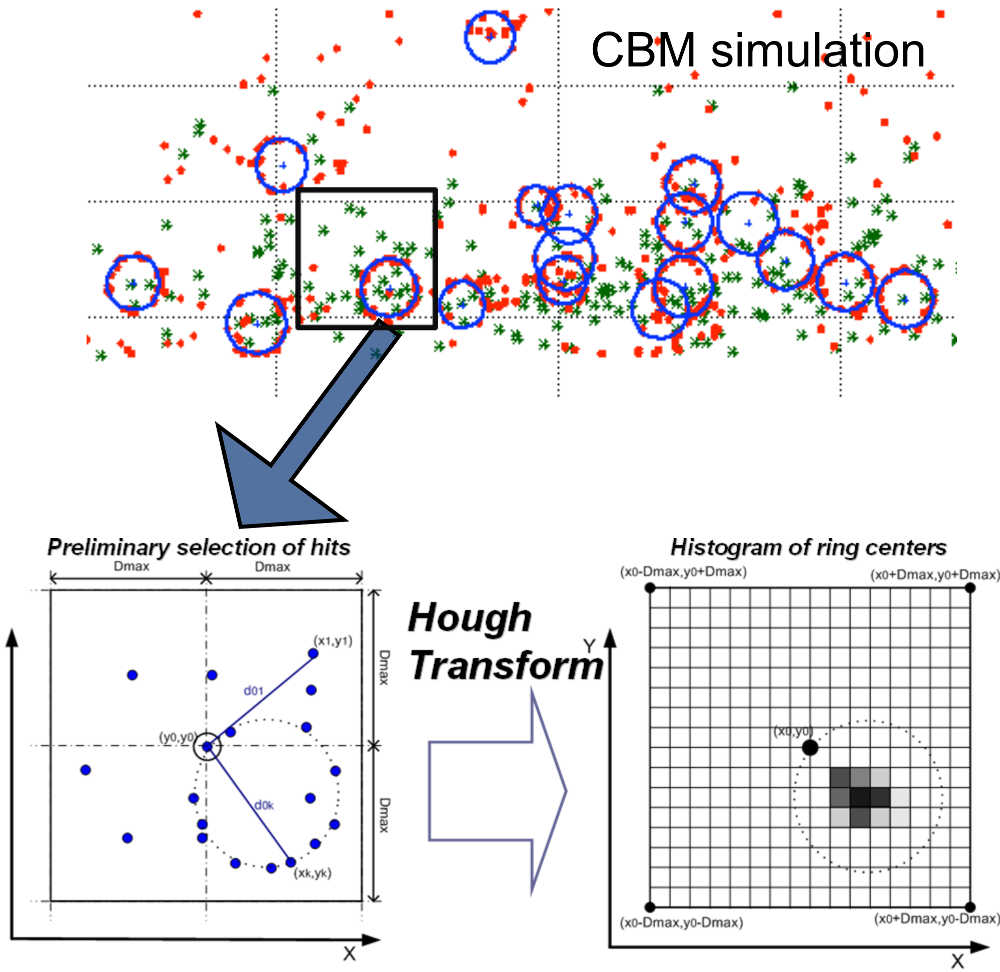
Check if pixel is fired.
Only one photon per pixel



- Simulate MAPMT response with real QE measurements (currently the H8500-03 CERN Oct 2011).
- A 70% collection efficiency is applied on top of the QE → simulated number of hits are calculated rather conservatively.
- Cross-talk and noise hits.
- Mirror and window reflectivity; window and gas transmission are included in simulations.

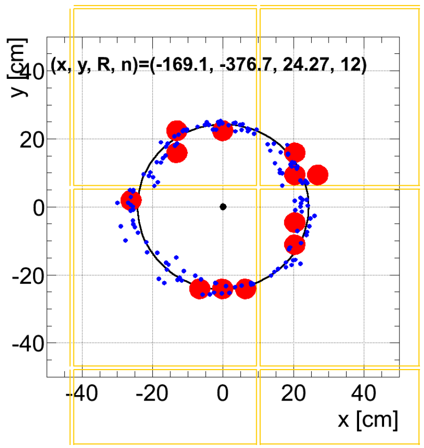
Hough Transform for the ring reconstruction

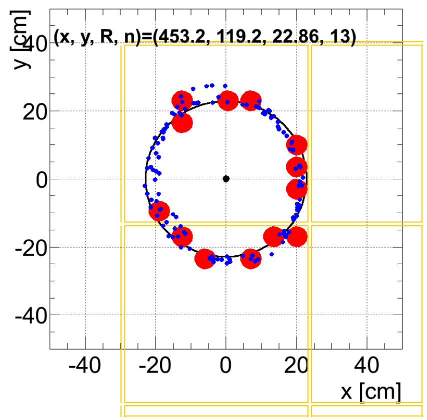


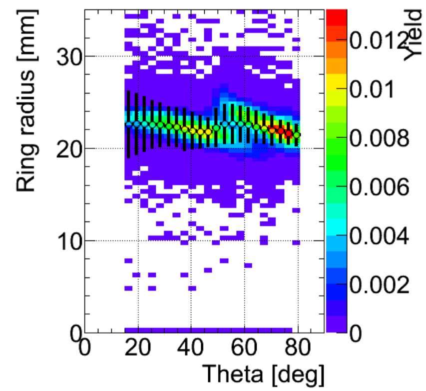


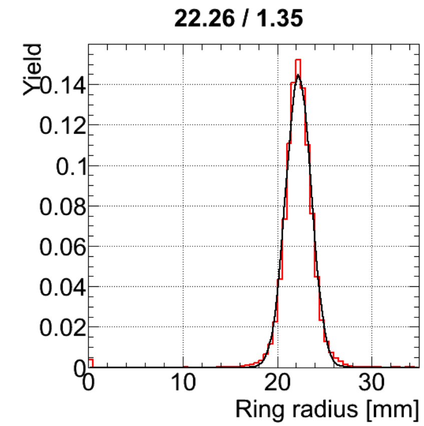
- Same reconstruction algorithms which were developed for the CBM RICH detector.
- Standalone algorithm based on Hough Transform. 3 steps:
  - Preliminary selection of the hits
  - Hough Transform
  - Fake rejection, ring quality: # hits, ring distortion etc. (needed for events with many overlapping rings)
- Ring parameters are derived by a circle fitting based on the COP method.

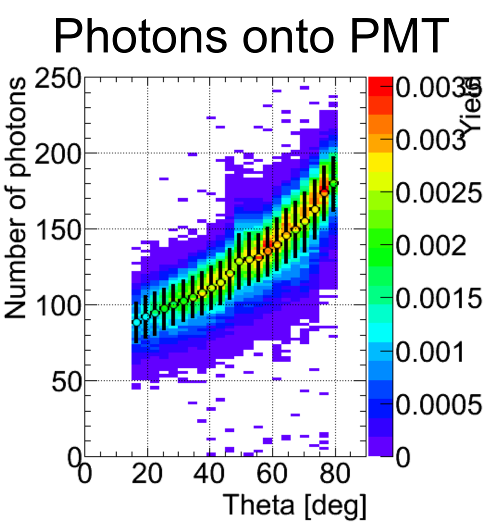
Simulation results
Number of hits

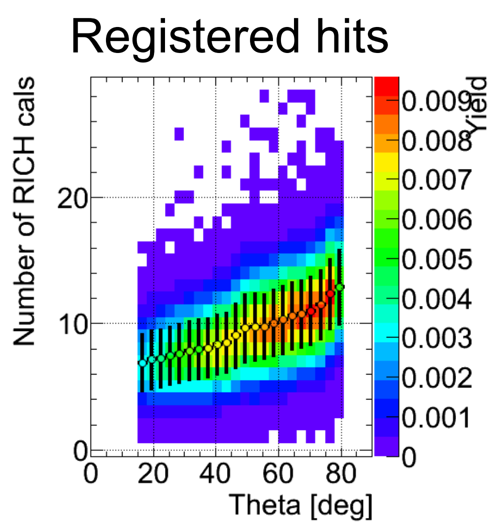






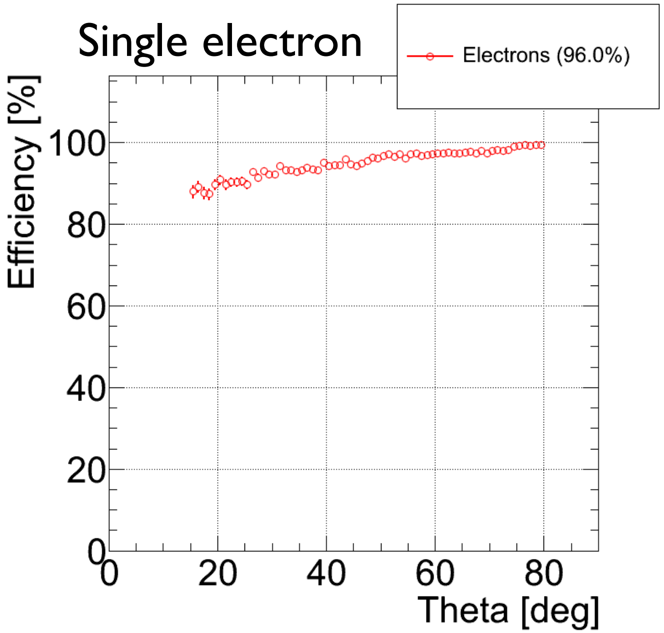


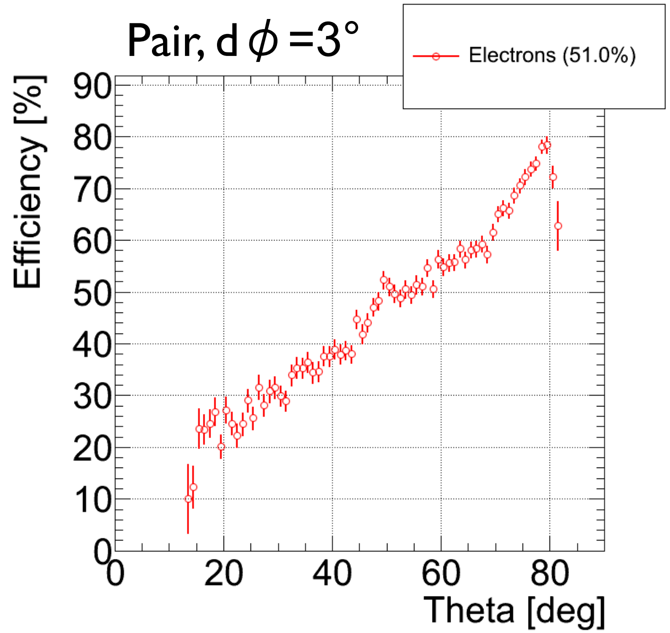


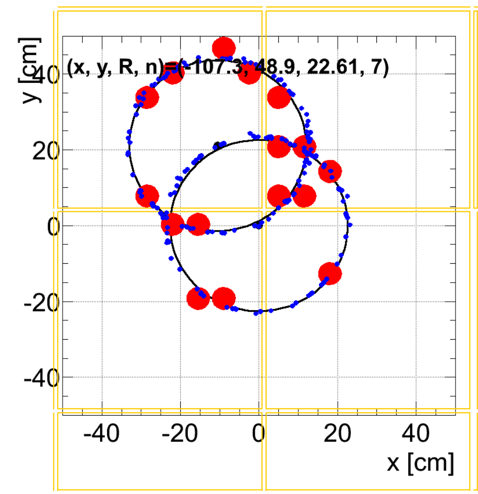


- **90-170** photons onto PMT plane → **7-13** registered hits per electron ring
  - without crosstalk,
  - 70% collection efficiency,
  - one converted photon per pixel,
  - MAPMT granularity (pixel size 6x6 mm^2)
  - the photon yield increases due to the longer optical path length in the radiator.
- Bump in ring radius due to the different positions of the inner and outer part of the PMT plane.

Ring reconstruction results





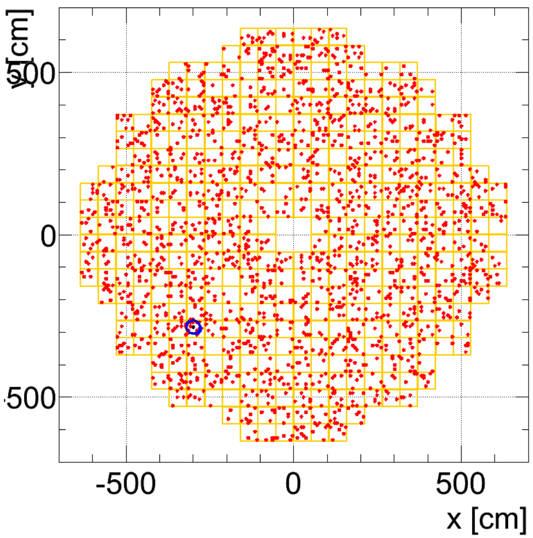


- **Single ring**: 96% reconstruction efficiency for rings with >=5 hits
- **Dielectron pairs**: θ [15-80]°, ϕ [0,360]°, P [100, 1500] MeV/c. Both rings must be correctly reconstructed!

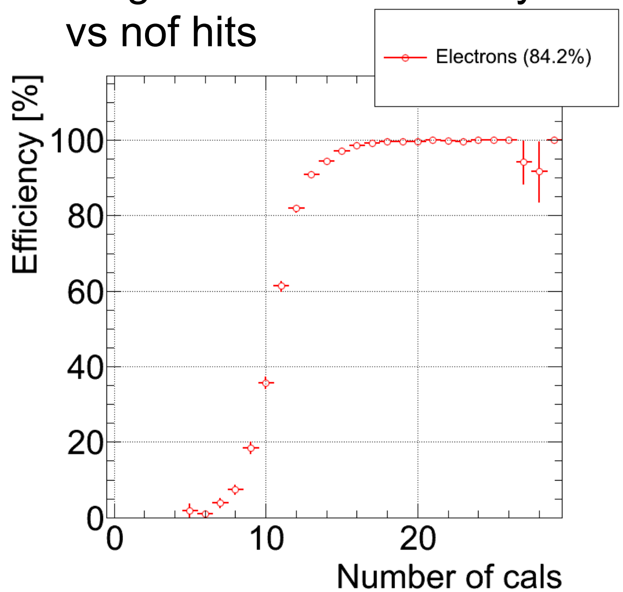
d ϕ	Rec. eff. [%]
3°	51.0
4°	58.3
5°	57.8

Noise hits
Extreme example (2000 noise hits)

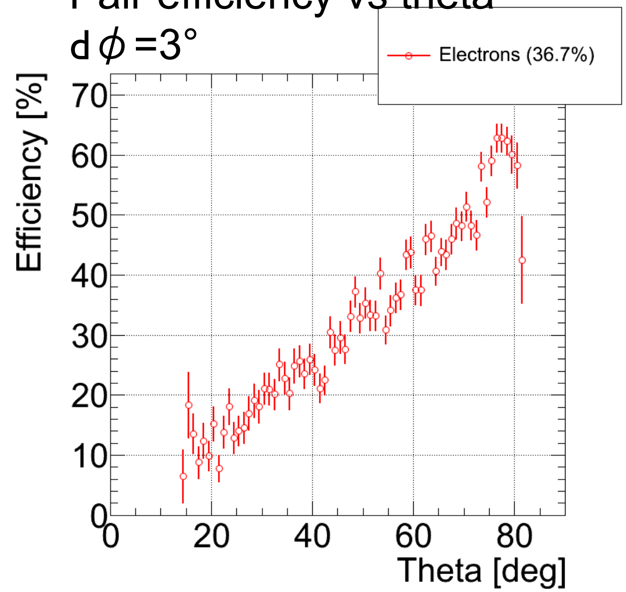
Examples with 2000 noise hits per event (~7,5% of pixels).



Single electron efficiency vs nof hits



Pair efficiency vs theta d ϕ =3°



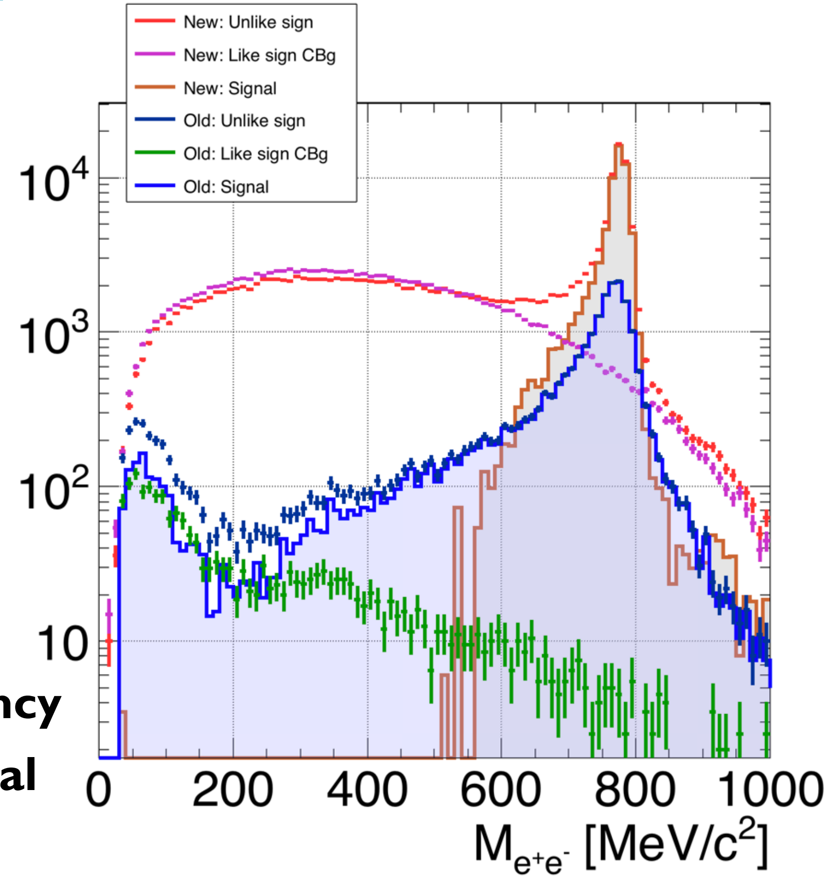
- Up to 1200 - 1400 scintillation photons per Au+Au event expected on top of the noise.
- Efficiency normalized to rings with >= 5 hits
- Keep # fake rings < 0.25 per event
- 100% collection efficiency

# noise	500	750	1000	1500	2000
Single [%]	98.5	96.8	94.6	90.1	84.2
Pair [%]	78.7	70.8	63.2	49.2	36.7

ω -> e^+e^- reconstruction Comparing Old and New RICH

Preliminary results

- Simulation:
  - Signal: 1 ω -> e^+e^- pair decay at 100% BR (PLUTO)
  - BG: p+Nb UrQMD at 3.5 GeV
  - 400k events
- Opening angle cut of 9°
- Different shape of the BG:
  - Old/new tracking;
  - Additional BG rejection cuts for Old RICH
- **Overall the high pair reconstruction efficiency of the new RICH significantly increases signal reconstruction efficiency.**



- BG is also increased. No additional BG rejection cuts applied yet. Further studies are ongoing.

Summary

- Simulation and reconstruction software for upgraded HADES RICH were developed within HYDRA2 framework.
- Simulations show that the reconstruction efficiency for dielectron pairs increases significantly in comparison to the current RICH, in particular for pairs with small opening angles.
- First preliminary results of the physics performance were shown.

- Backup

Cross-talk hits implementation

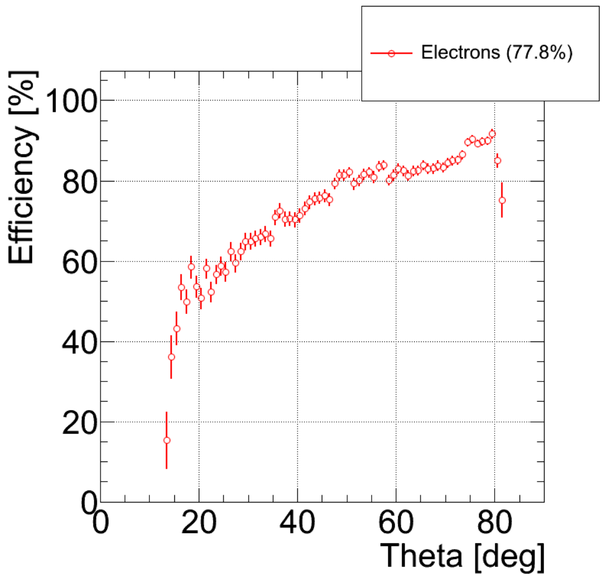
Probability to get cross-talk hit.

P/4	P	P/4
P		P
P/4	P	P/4

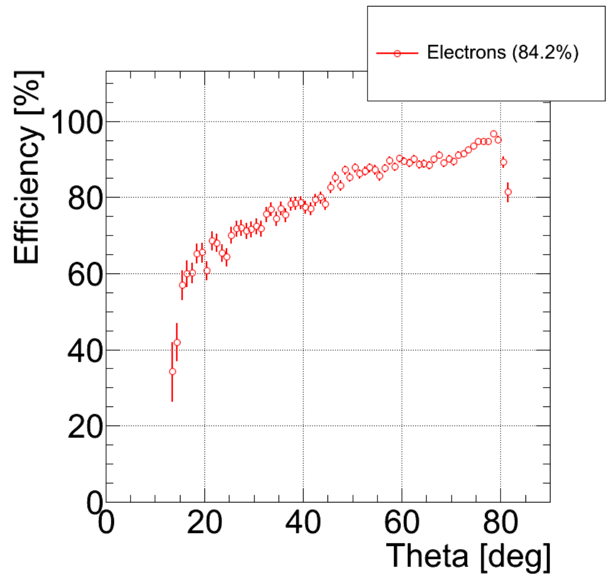
- Each hit can produce only one cross-talk hit.
- Cross-talk hit probability is set to 2% by default (P=2%).
- MCTrackId is taken from main hit.

Pair reconstruction
Collection efficiency 100%

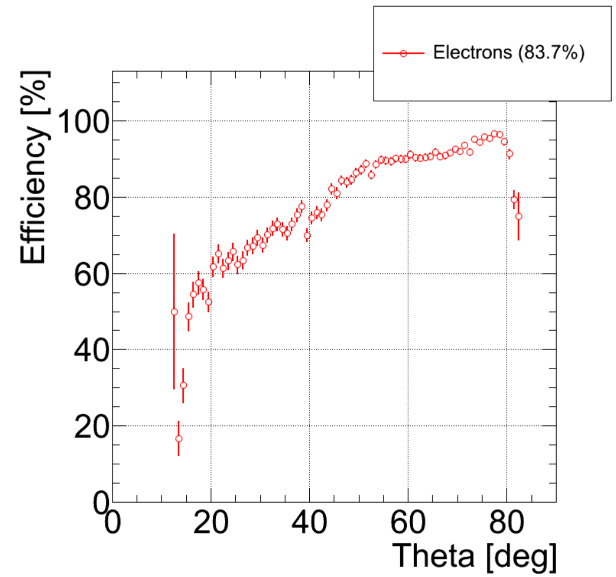
d ϕ =3°



d ϕ =4°



d ϕ =5°



- Collection efficiency is 100%. Number of hits 10-15 per ring.
- Dielectron pairs : were generated with Kine θ [15-80]°, ϕ [0,360]°, P [100, 1500] MeV/c
- Both rings must be correctly reconstructed