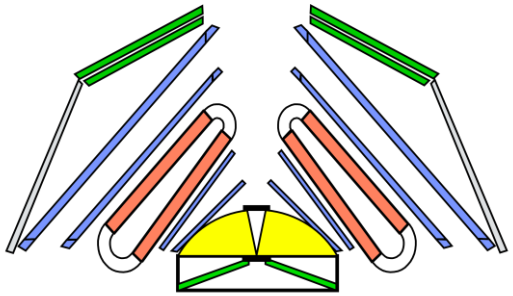
Non-decay photon HBT analysis in Ag+Ag@1.58 A GeV collisions at the HADES experiment

Mateusz Grunwald

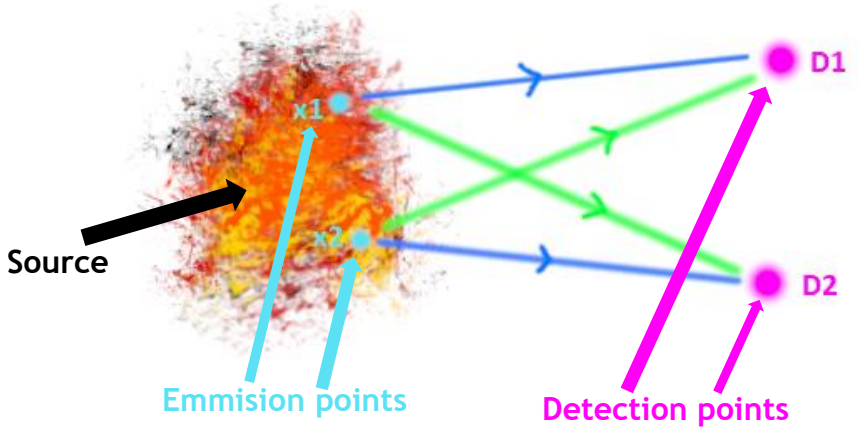


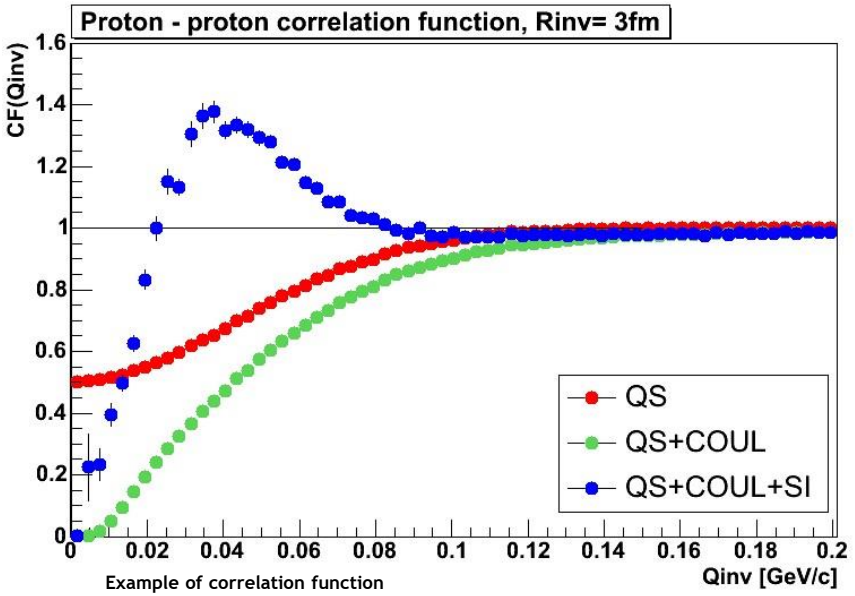
HADES

Wydział Fizyki

POLITECHNIKA WARSZAWSKA

(very) Basics of femtoscopy





Example of correlation function
Source: Hanna Paulina Zbroszczyk, „Eksperymentalne aspekty badania korelacji femtoskopowych w zderzeniach relatywistycznych ciężkich jonów".

Typical size: R ~ 10^{-15} m
Typical lifetime: τ ~ 10^{-23} s

No direct measurements available!

Femtoscopic (HBT) correlations

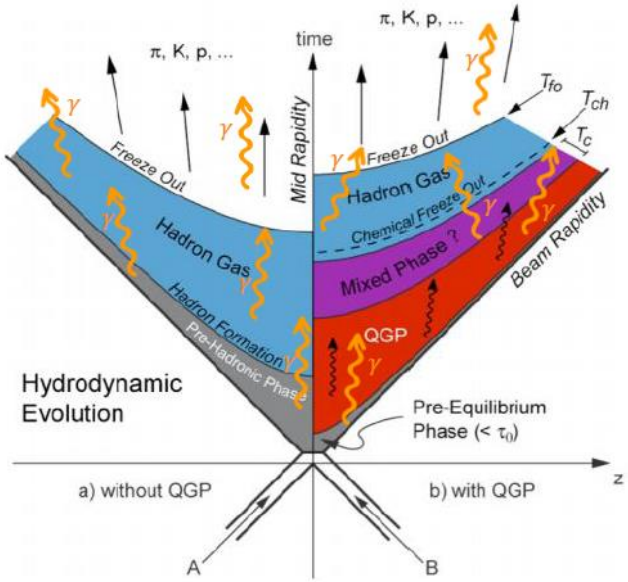
Experimental correlation function

$$CF(Q_{inv}) = \frac{Signal(Q_{inv})}{Background(Q_{inv})}$$

$$Q_{inv} = \sqrt{(\boldsymbol{p_1} - \boldsymbol{p_2})^2 - (E_1 - E_2)^2}$$

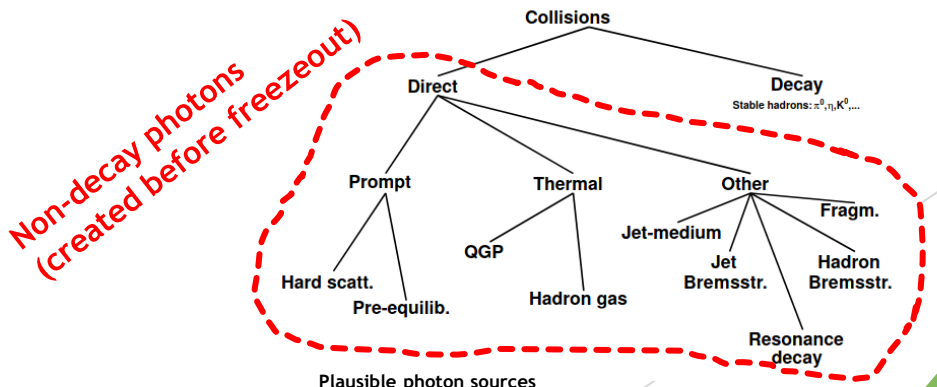
Non-decay photon correlations (pros)

Photons being cool
Source: https://pl.pinterest.com/pin/547539267174048711/



Photon emission during collisions
Source: J. Stachel. K. Reygers, QGP physics SS2015 6., „Space-time evolution of the QGP"

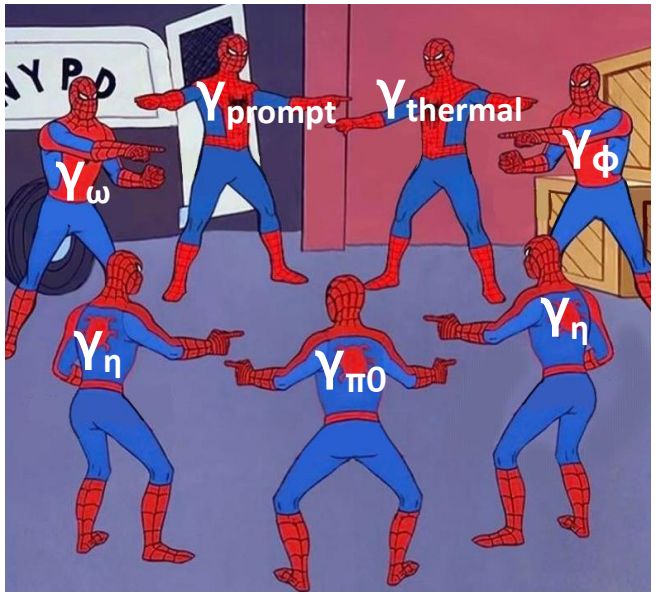
- **Clear** and **undistorted** information (due to lack of interaction).
- Access to **various stages** of collision.
- **Simple** correlation function **parametrization** (only QS).



Plausible photon sources
Source: http://dx.doi.org/10.1088/1361-6633/ab6f57

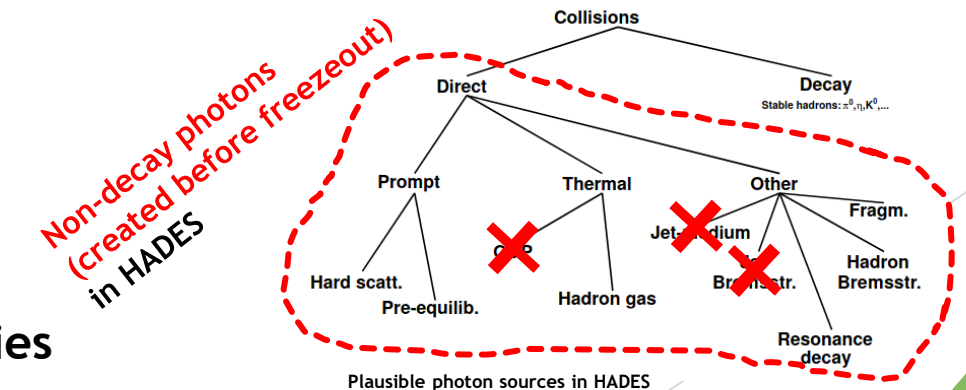
Non-decay photon correlations (cons)

Photons having issues
Source: https://pl.pinterest.com/pin/547539267174048711/



Photon distinguishment problem
Source: https://www.fortressofsolitude.co.za/top-10-hilarious-spider-man-memes/

- **Hard to detect** (due to lack of interaction).
- **Main source** of photons: **π^0 decay**
- **Hard to distinguish** (decay from non-decay)
- **Less** non-decay photons **at low energies**

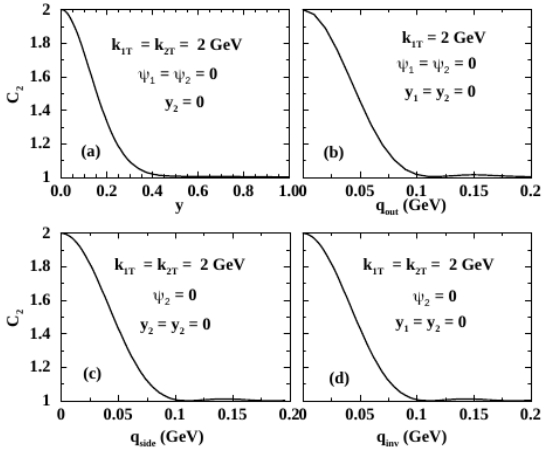


Plausible photon sources in HADES
Source: http://dx.doi.org/10.1088/1361-6633/ab6f57

Non-decay photon correlations previous attempts

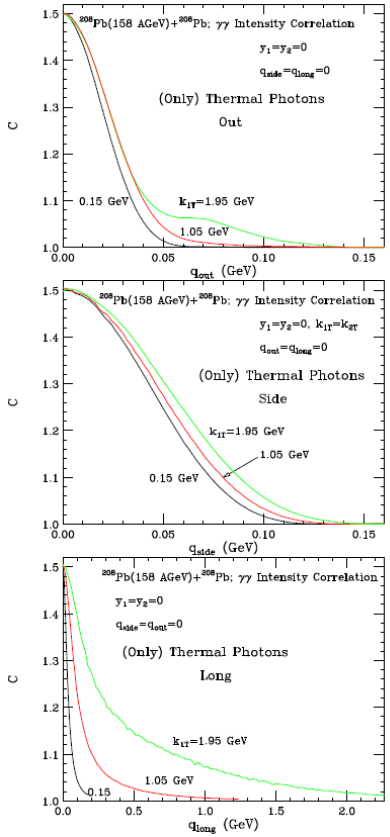
Simulations

SPS, Pb+Pb @ 158 GeV, model using the inputs reproducing the measured single photon spectra



Source: Evan Frodermann, Ulrich Heinz, „Photon HBT interferometry for non-central heavy-ion collisions”, arXiv: 0907.1292v2

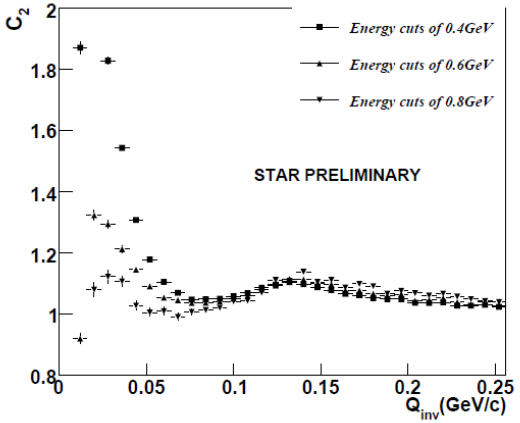
Pb+Pb @ 158 GeV, parton cansade model



Source:„Intensity interferometry of thermal photons from relativistic heavy ion collisions”. Dinesh Kumar Srivastava, https://arxiv.org/pdf/nucl-th/0411041.pdf

Real data

RHIC, Au+Au @ 62.4 GeV



Source:„Preliminary Results on Direct Photon-Photon HBT Measurements in $\sqrt{S_{NN}}$ = 62.4 GeV and 200 GeV Au+Au Collisions at RHIC”, Debasish Das et al., https://arxiv.org/pdf/nucl-ex/0511055.pdf

WA98, Pb+Pb @ 158 GeV

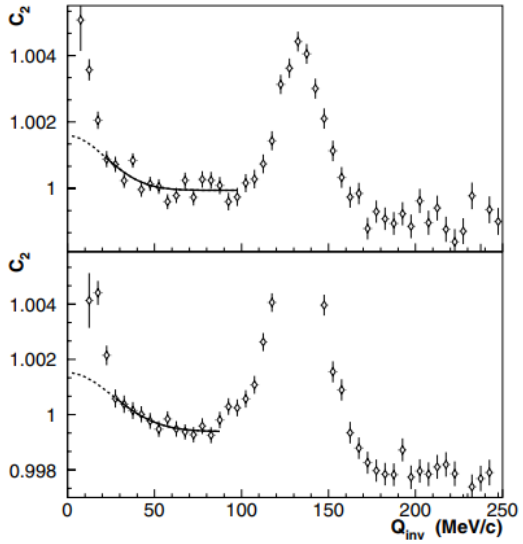
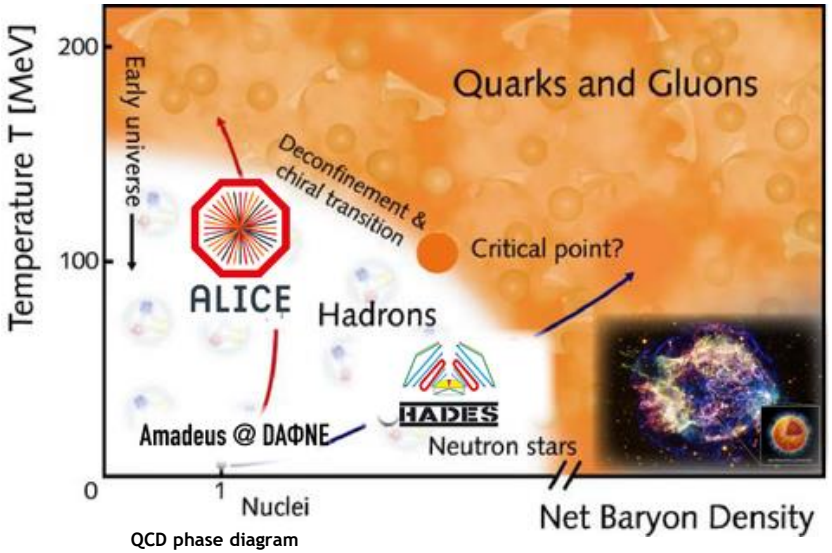


FIG. 1. The two-photon correlation function for narrow showers with $L_{min} > 20$ cm (diamonds) and average photon momenta $100 < K_T < 200$ MeV/c (top) and $200 < K_T < 300$ MeV/c (bottom) fitted with Eq. (1). The solid line shows the fit result in the fit region used (excluding the π^0 peak at $Q_{inv} \approx m_{\pi^0}$) and the dotted line shows the extrapolation into the low Q_{inv} region where backgrounds are large.

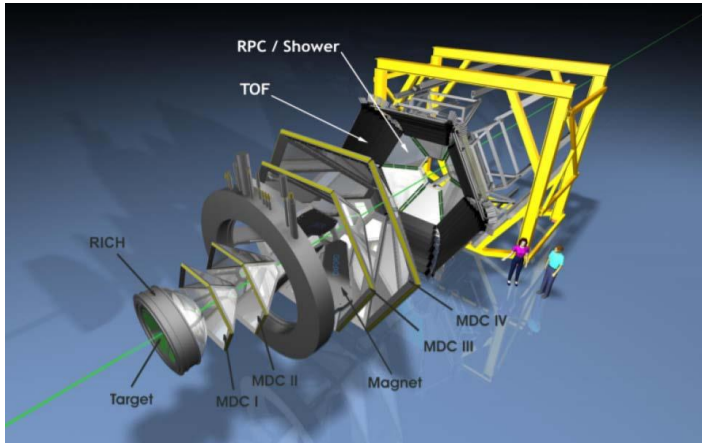
Source:M. M. Aggarwal et al. (WA98 Collaboration) Phys. Rev. Lett. 93, 022301 - Published 6 July 2004, https://doi.org/10.1103/PhysRevLett.93.022301

The HADES experiment

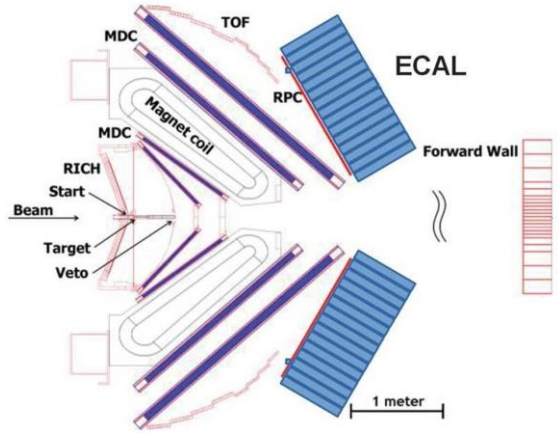


QCD phase diagram
Source: https://www.denseandstrange.ph.tum.de/en/research/

- **Fixed target** experiment,
  1-2 A GeV beam kinetic energy.
- Measurement of **light vector mesons**,
  decaying into dilepton pairs (ρ,ω,φ).
- **High angular acceptance** ($0<\varphi<2\pi$, $18^\circ<\theta<85^\circ$),
  split into 6 sectors.
- **High $e^{\pm}$ reconstruction efficiency** and $\pi^{\pm}/p^{+}$
  separation (RICH, TOF/RPC + MDC, ECAL[since 2019]).



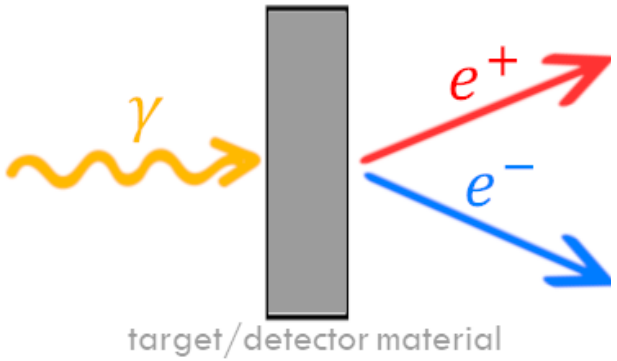
HADES subsystems visualization
Source: Mateusz Wasiluk, „Particle identification using machine learning at the HADES experiment"

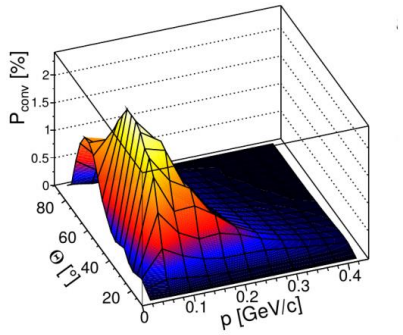


HADES cross-section
Source: https://www-hades.gsi.de

Photon detection in HADES

PCM (photon conversion method)



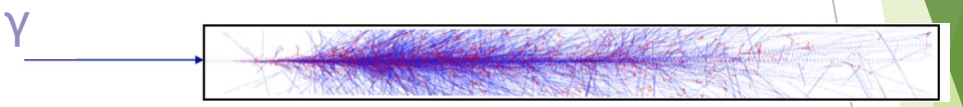


Photon conversion probability
Source: DOI: 10.1088/1742-6596/599/1/012029

+ High acceptance of $e^{\pm}$ in HADES
+ High momentum resolution

- Low statistics due to conversion probability
- $e^{\pm}$ close track effects (splitting/merging)

Ecal detection (direct)

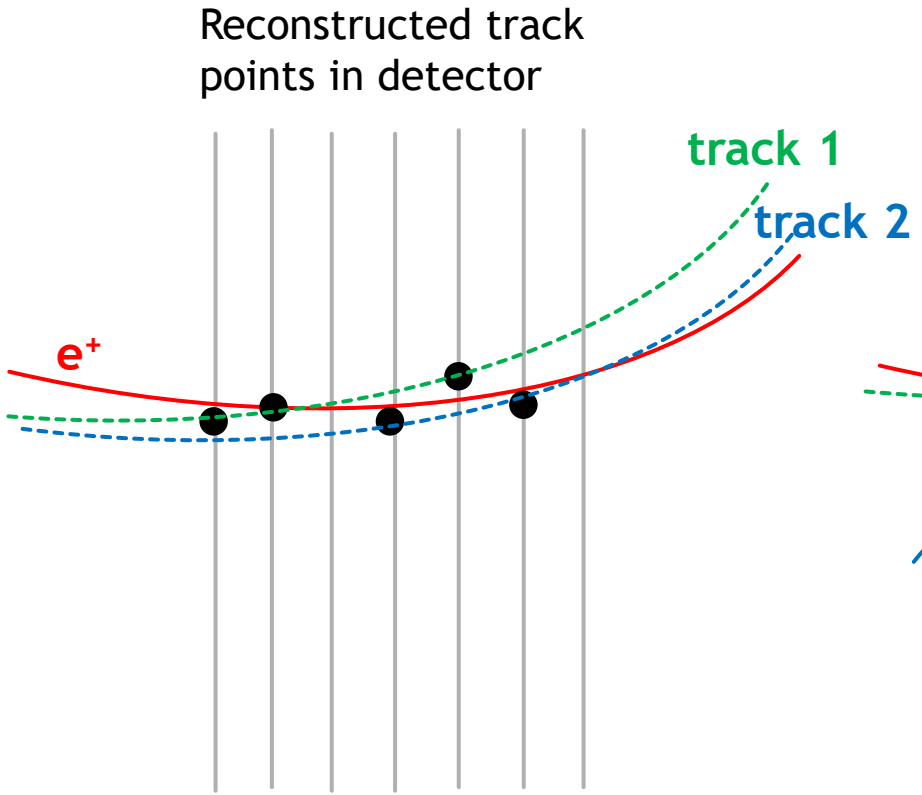


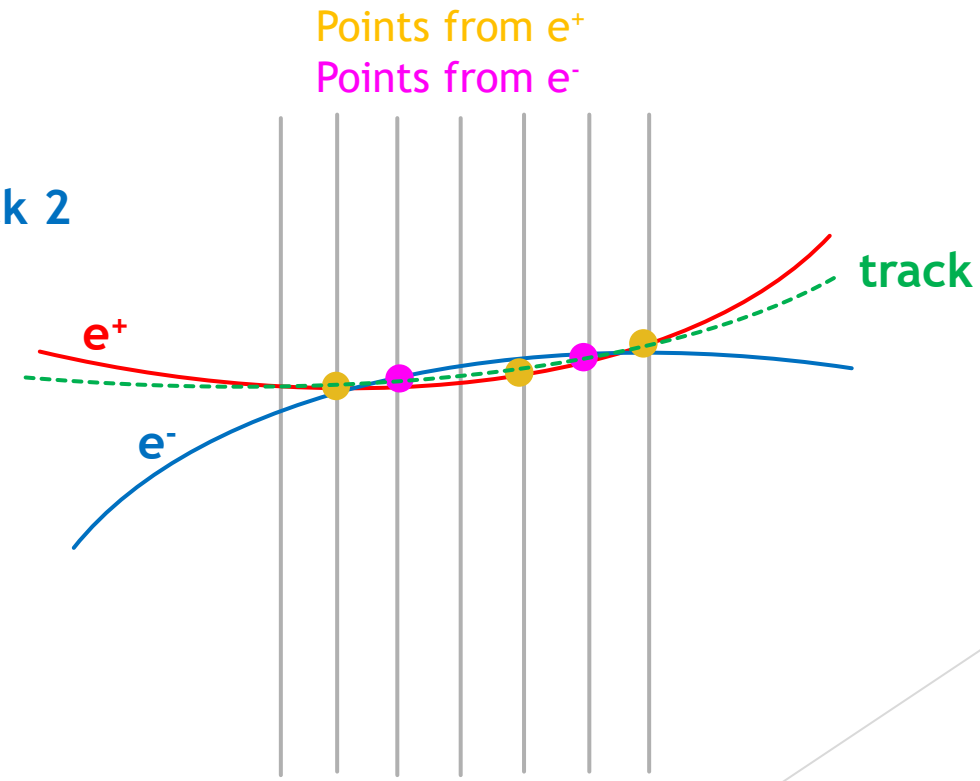
Electromagnetic callorimeter visualisation
Source: Electromagnetic and hadronic calorimeters, Silvia Masciocchi, GSI Darmstadt and University of Heidelberg

+ Easy detection of photons
+ High statistics

- Only half sectors working during beamtime
- Poor seperation of photons with opening angle $\alpha_{\gamma\gamma}<4^{\circ}$ (merging-like problem)

Splitting/Merging explanation

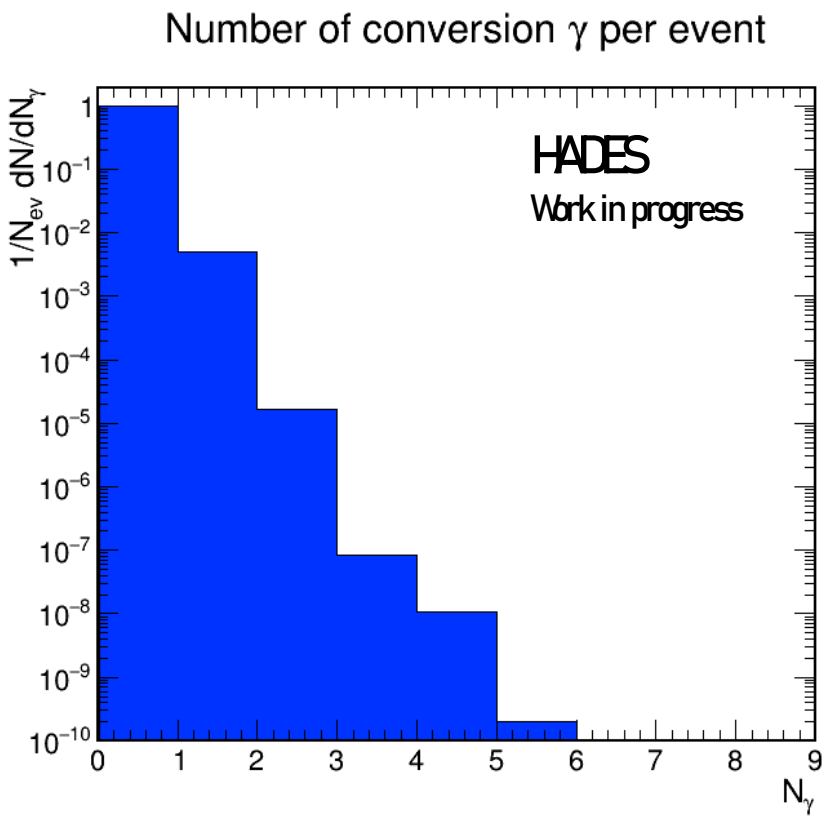


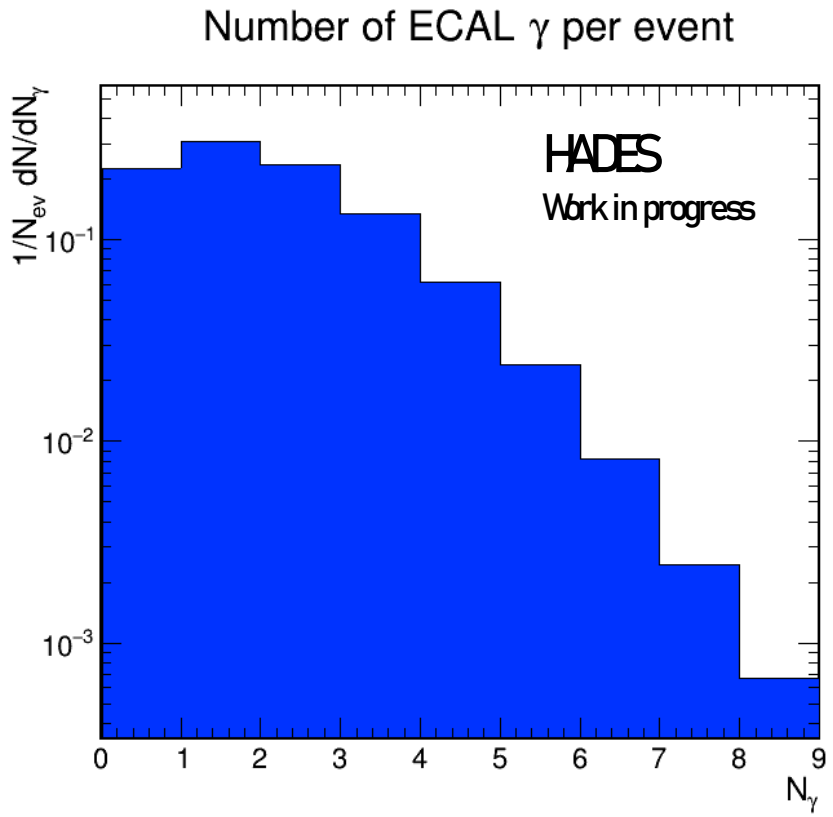


Splitting = 1 track recostructed as 2 with small momentum difference/opening angle

Merging = 2 tracks with small momentum difference/opening angle reconstructed as 1

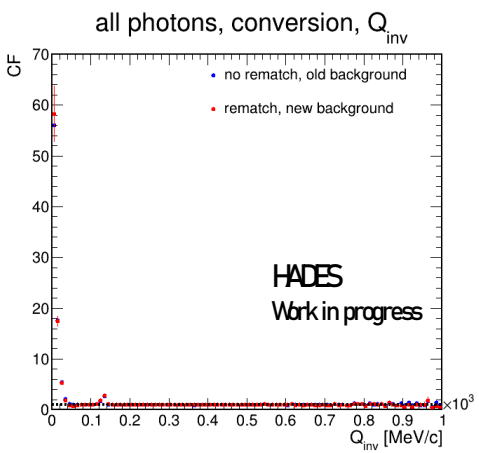
Reconstructed photons per event (real data)



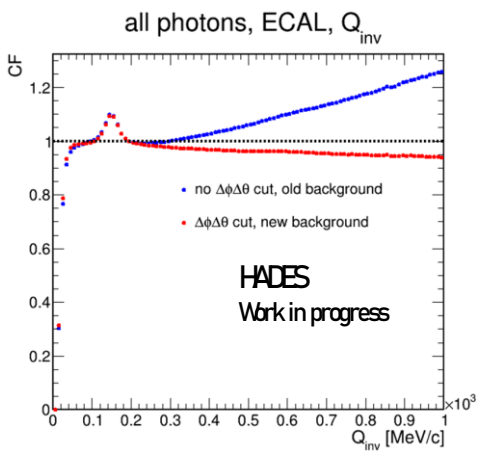


Correlation functions (real data)

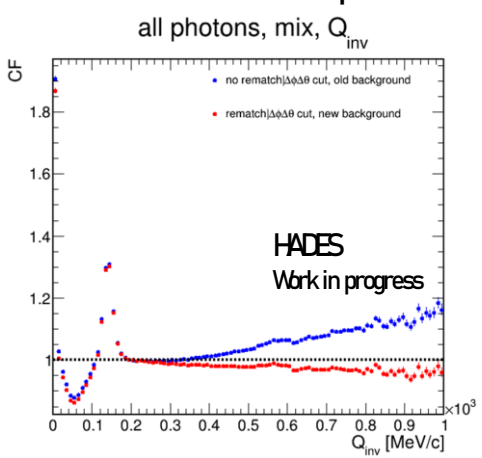
2 conversion photons

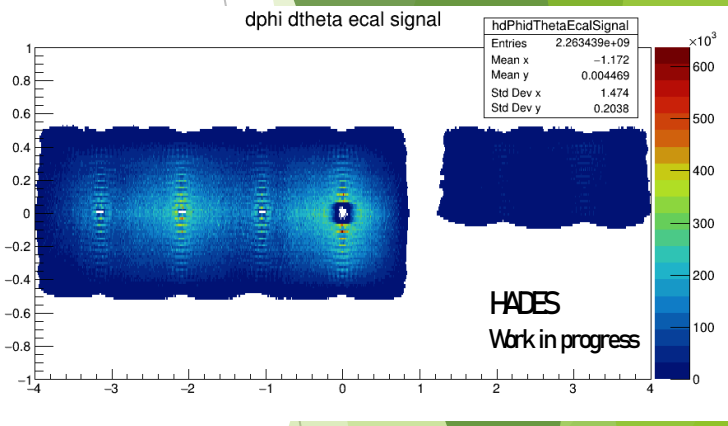


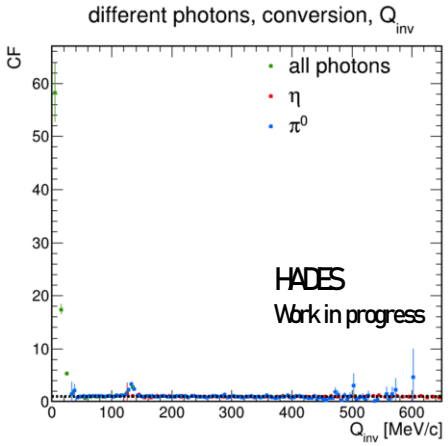
2 ECAL photons

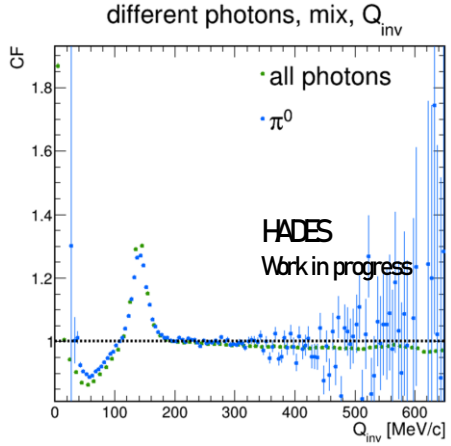


conversion + ECAL photon

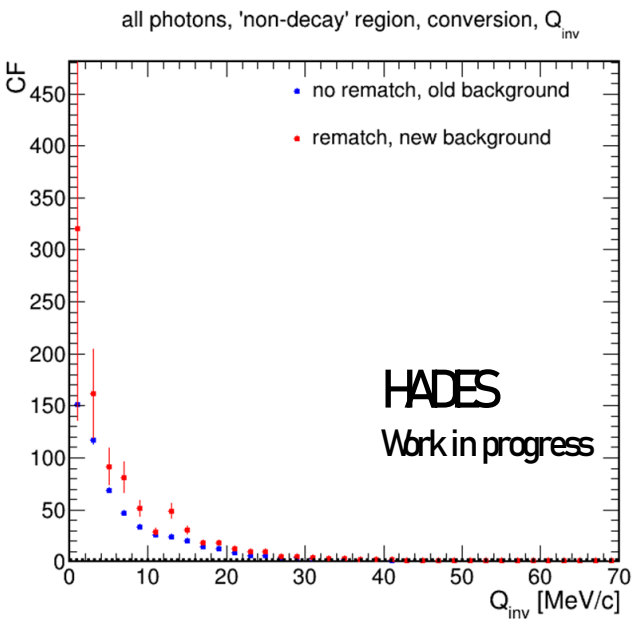


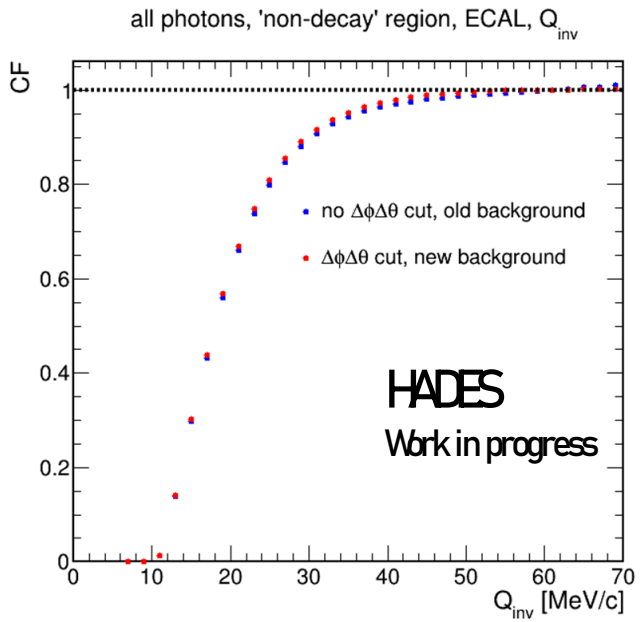


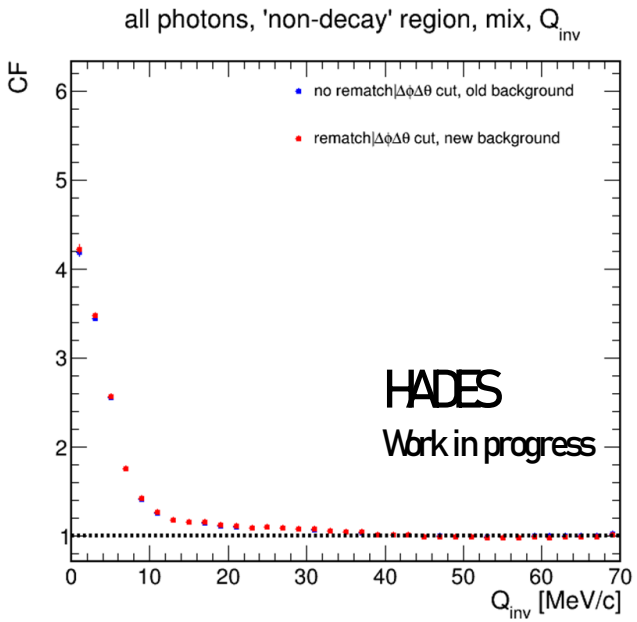




Correlation functions, non-decay region (real data)







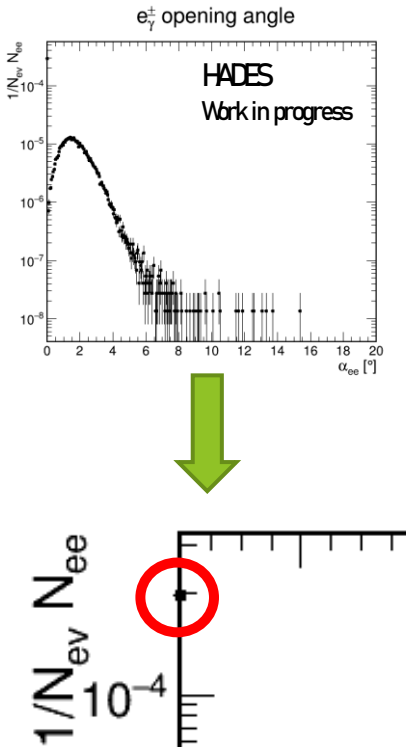
VERY high splitting
(happening on e± level)

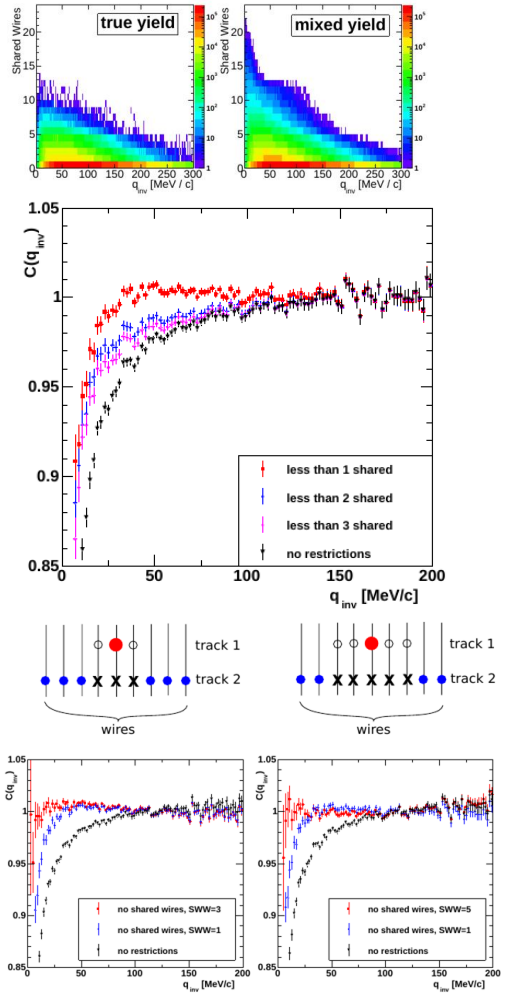
VERY high merging
($\alpha_{\gamma\gamma}$<4° → almost no signal function below 20 MeV/c)

Normalized to dip bottom (50 MeV/c), some splitting present

Plausible reasons of observed effects (simulated data)

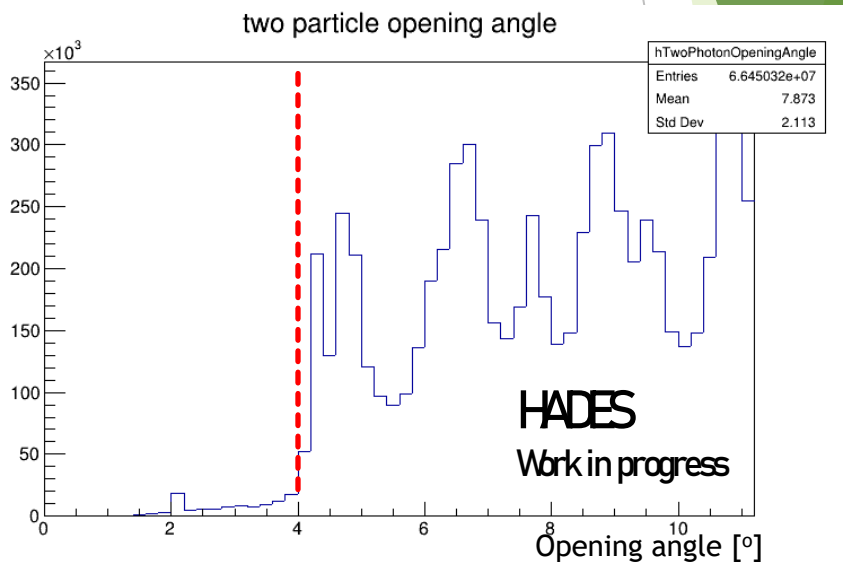
Conversion:





HADES merging correction
Source: Robert Greifenhagen, Two-Pion Interferometry in Collisions of Au+Au at $\sqrt{S_{NN}} = 2.41$ GeV measured with HADES, Dresden 2020

ECAL:



Ongoing improvements and ideas

- New $e^{\pm}$ and conversion γ selection, suppressing close track effects (in progress).
- $\eta \rightarrow \gamma\gamma$ selection for ECAL photons (and Mix).
- Correction of $\alpha_{\gamma\gamma} < 4^{\circ}$ ECAL merging (already done).
- If rich structures in CF would be after splitting/merging correction -> new CF parametrization (non-gaussian).