Dilepton measurements with HADES in $Ag + Ag$ and $p + p$ collisions at 1.58 GeV beam energy

Karina Scharmann for the HADES Collaboration
Justus-Liebig-Universität Gießen, Germany
Contact: karina.scharmann@physik.uni-giessen.de

Motivation

The **H**igh-**A**cceptance-**D**i**E**lectron-**S**pectrometer (HADES):

- Explore matter at high baryon densities and moderate temperatures
- Located at the SIS18 accelerator (1-2 GeV/nucleon) at GSI, Germany
- Fixed-target experiments in p, d, π and (heavy-) ion-induced reactions
- Large acceptance: 0° < ϕ < 360° and 18° < θ < 85° ($Ag + Ag$)

Particle identification:

- RICH - leptons
- RPC / TOF - hadrons
- FW - determination of collision centrality and event plane
- ECAL - photons, leptons
- MDC - tracking system

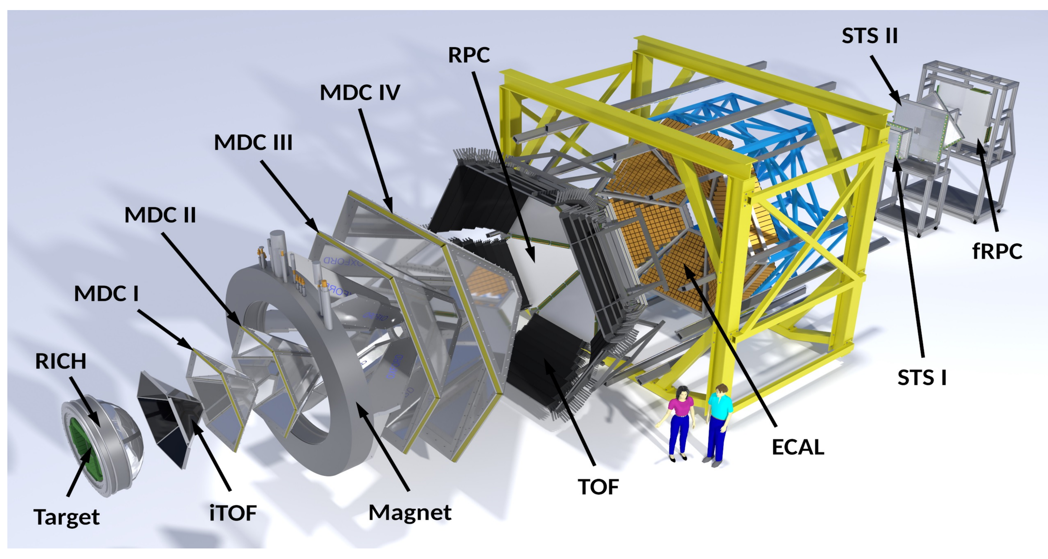

Fig. 1: Schematic view of HADES including all sub-detectors for the $p + p$ beamtime 2022.

Dilepton analysis within HADES:

- Electromagnetic probes offer direct access to all stages in heavy-ion collisions.
- The slope of the in-medium contribution allows for the extraction of the mean medium temperature in heavy-ion collisions.
- $p + p(n)$ collisions serve as baseline for the understanding of the $Ag + Ag$ data.

Electron analysis technique in HADES

Electron selection criteria:

- A velocity of $\beta > 0.9$ is required.
- 100 MeV/c < p < 1200 MeV/c ($Ag + Ag$)
- A RICH ring is demanded.
- PID based on the RICH and the rec. mass
- Conversion rejection based on the RICH
- Pairs with opening angles of $\alpha > 9°$

→ The upgraded RICH with a new photon detection camera enhances the electron efficiency and conversion rejection.

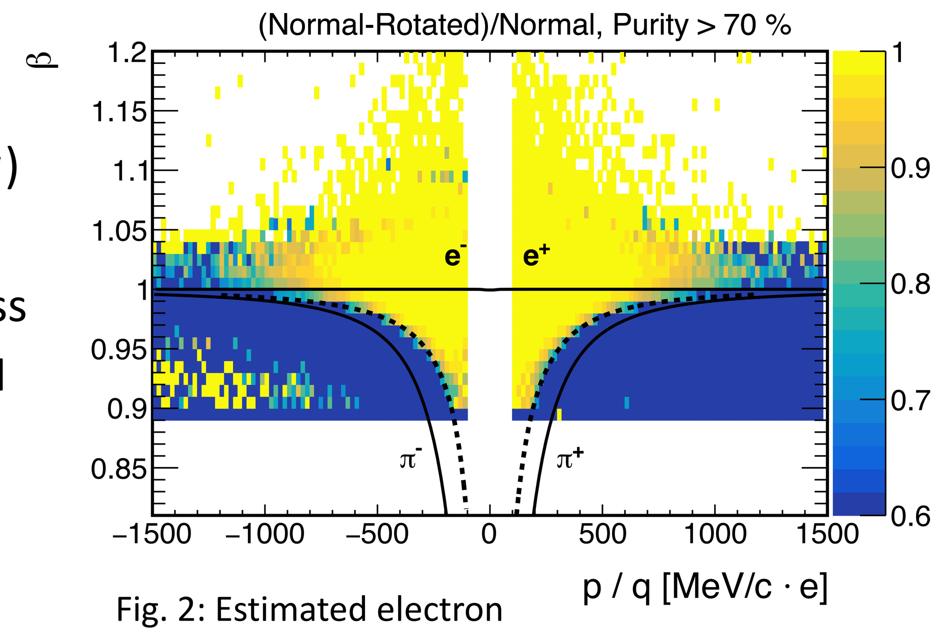

Fig. 2: Estimated electron purity in the RPC for the $Ag + Ag$ beamtime.[1]

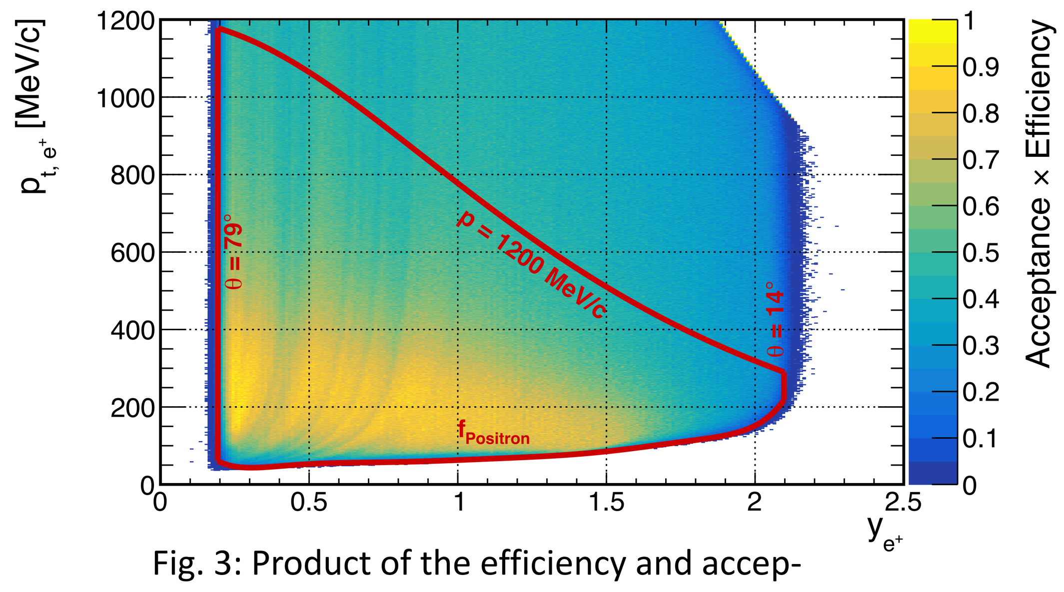

Fig. 3: Product of the efficiency and acceptance for the $p + p$ beamtime for positrons.

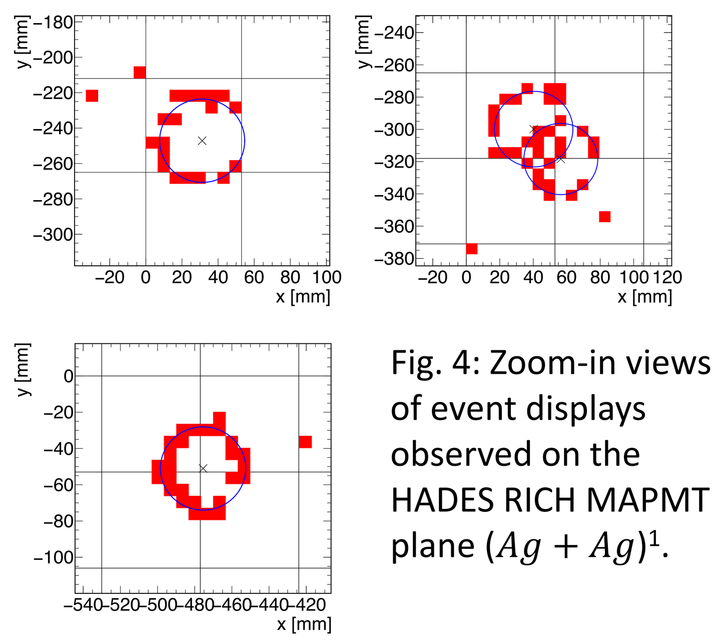

Fig. 4: Zoom-in views of event displays observed on the HADES RICH MAPMT plane ($Ag + Ag$)[1].

Efficiency and acceptance correction:

- Definition of acceptance: $a = \frac{N_{in,ee}|_{in\ Acc}}{N_{in,ee}|_{initial}}$ and efficiency: $\epsilon = \frac{N_{reco,ee}}{N_{in,ee}}\Big|_{in\ Acc}$
- Acceptance and efficiency are derived from electron / positron simulations.

Combinatorial background estimation $\langle BG_{+-}\rangle$:

- The geometric mean of like-sign electron pairs ($\langle FG\rangle$) is multiplied with the k-factor.
- The k-factor is derived from the event-mixing-technique ($\langle fg\rangle$). Resulting background:

$$\langle BG_{+-}\rangle = \frac{\langle fg_{+-}\rangle}{2\sqrt{\langle fg_{++}\rangle\langle fg_{--}\rangle}} 2\sqrt{\langle FG_{++}\rangle\langle FG_{--}\rangle} = k2\sqrt{\langle FG_{++}\rangle\langle FG_{--}\rangle}$$

$Ag + Ag$ at 1.58 AGeV beam energy[1]

5 billion $Ag + Ag$ collisions at 1.58 AGeV are available after all quality selections. The measurements were taken in March 2019.

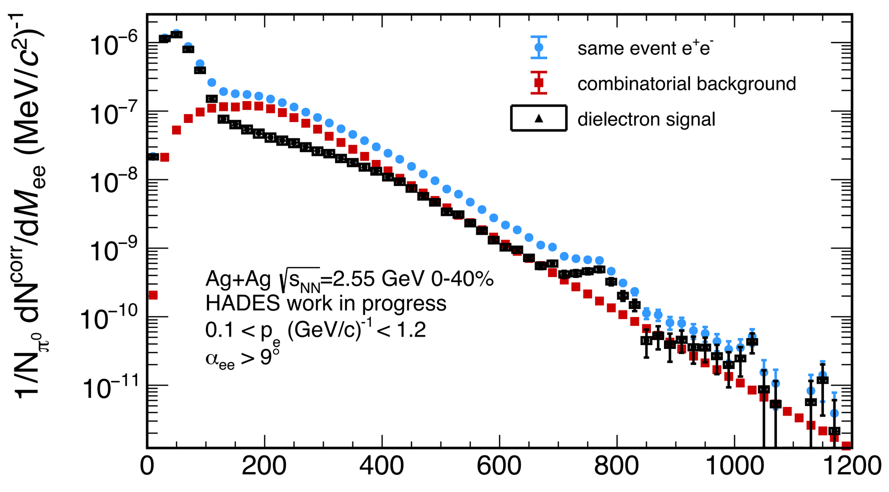

Fig. 5: Centrality integrated, efficiency corrected dielectron spectrum.[1]

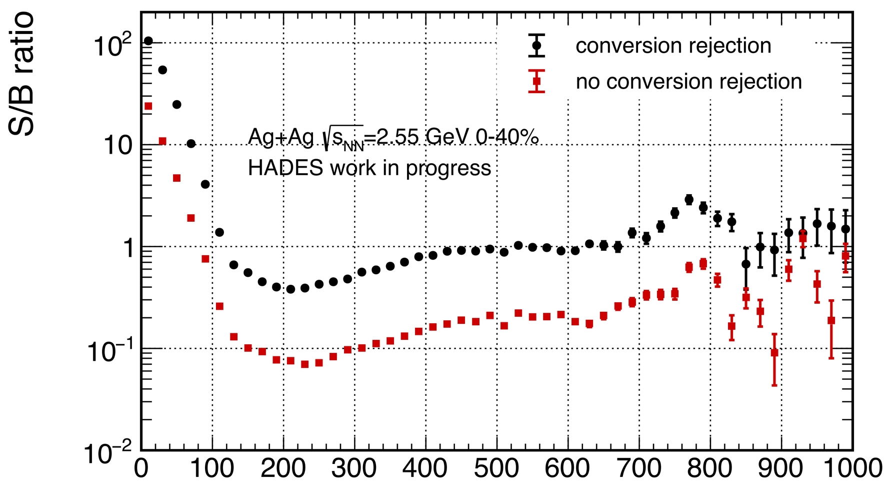

Fig. 6: Corresponding signal-to-background ratio for fig. 5.[1]

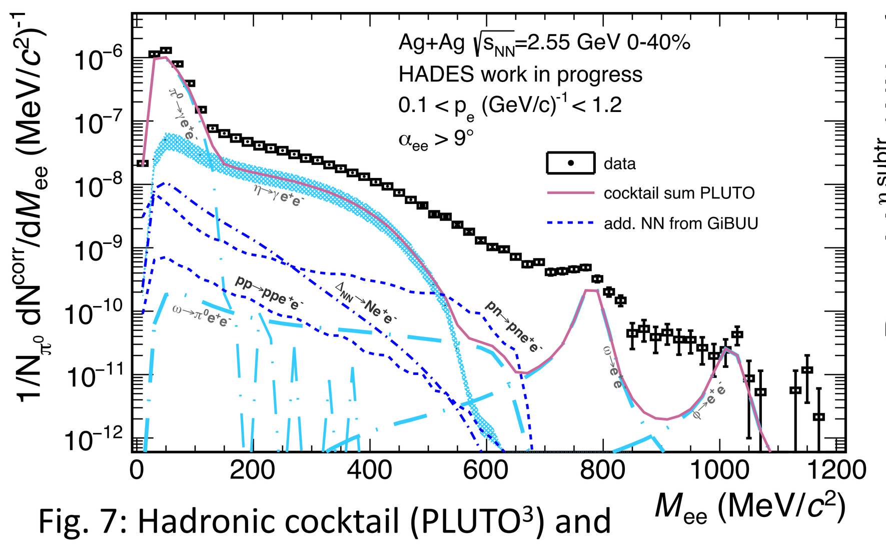

Fig. 7: Hadronic cocktail (PLUTO[3]) and relevant NN channels from GiBUU simulation.[1]

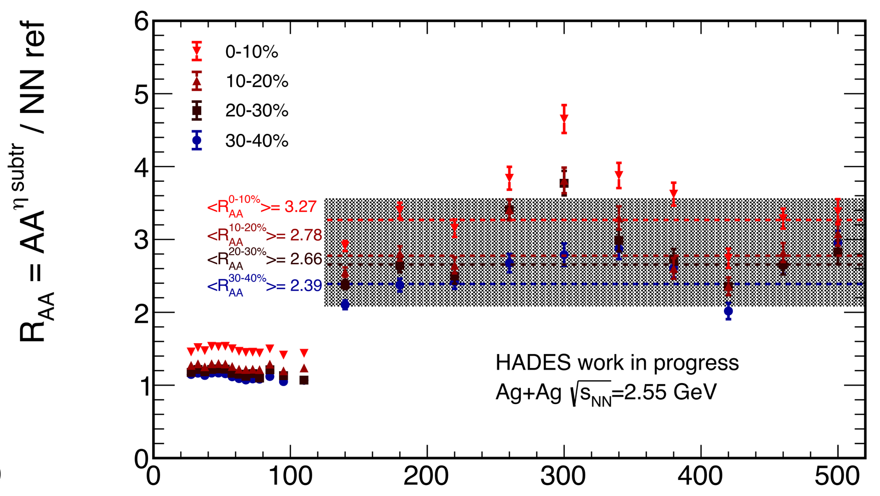

Fig. 8: Centrality dependence of the dielectron excess yield.[1]

- The dielectron spectrum shows a signal up to the ϕ meson mass region.
- Compared to simulated hadronic cocktail and nucleon-nucleon reference
- Strong contribution from the hot and dense phase is present
- The dielectron excess ratio has been calculated: $< R_{AA}^{AgAg} > = 3.05$ (main uncertainty from missing NN reference).
- The medium temperature $kT = 77.9^{+3.7}_{-2.9} MeV$ was extracted from a thermal fit.
- Estimated hadron multiplicities: $\pi^0_{mult}|_{0-40\%} = 7.37 \pm 0.43|_{sys} \pm 0.11|_{stat}$ and $\omega_{mult}|_{0-40\%} = (4.53 \pm 0.50|_{sys} \pm 0.63|_{stat}) \cdot 10^{-3}$

$p + p$ at 1.58 GeV beam energy

0.5 billion $p + p$ collisions at 1.58 GeV are available after all quality selections. The measurements were taken in February 2022.

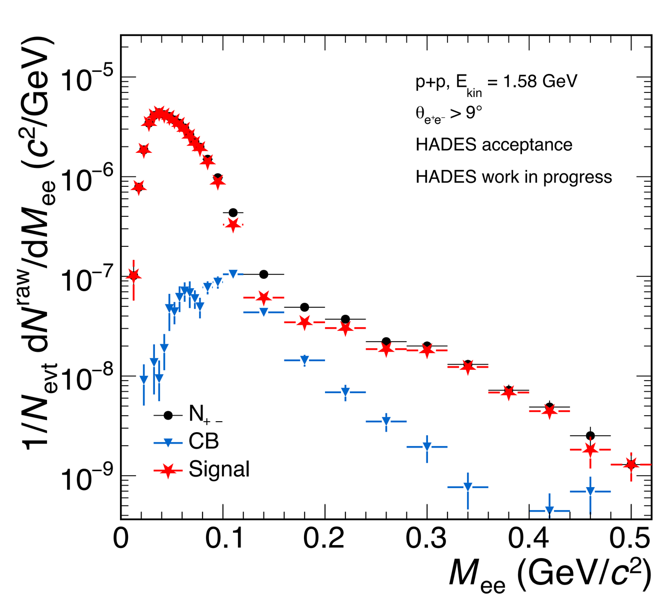

Fig. 9: Efficiency corrected dielectron spectra with HADES inel. pp trigger ("PT3").

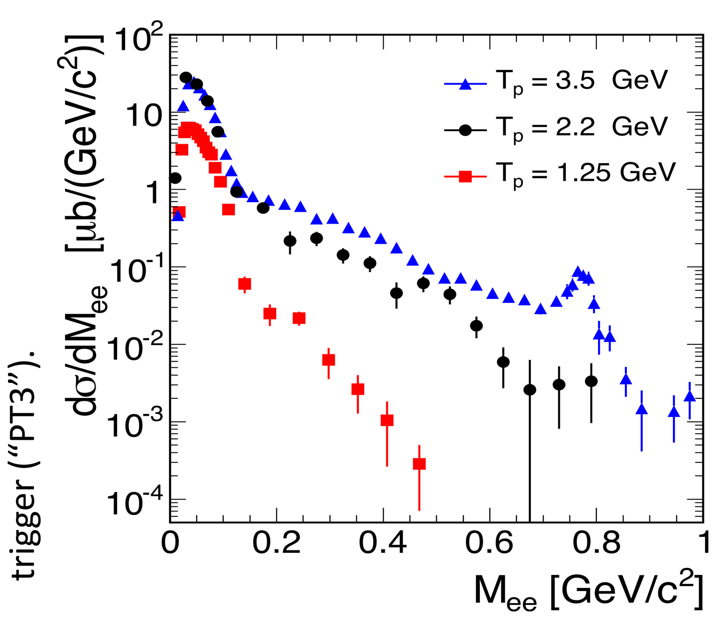

Fig. 10: Systematics of e⁺e⁻ differential production cross sections measured in $p + p$ reactions at T_p=1.25 GeV, 2.2 GeV, and 3.5 GeV, all obtained within the HADES acceptance[4], efficiency corrected, and CB subtracted.[2]

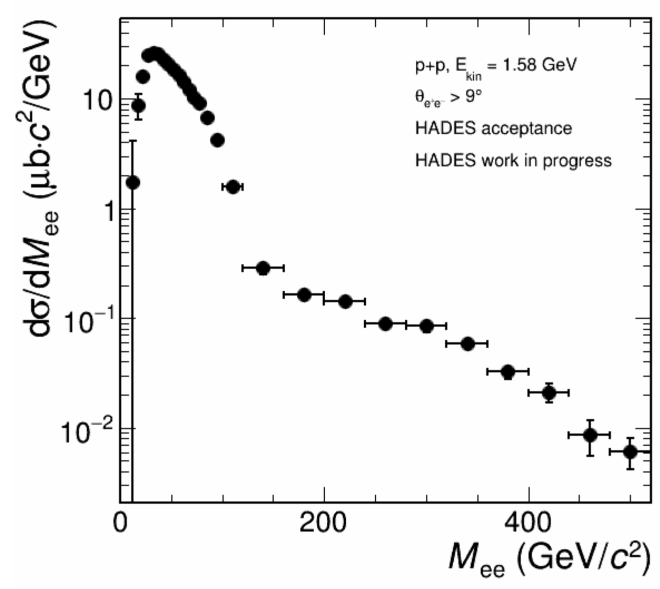

Fig. 11: Dilepton differential production cross section in HADES acceptance.

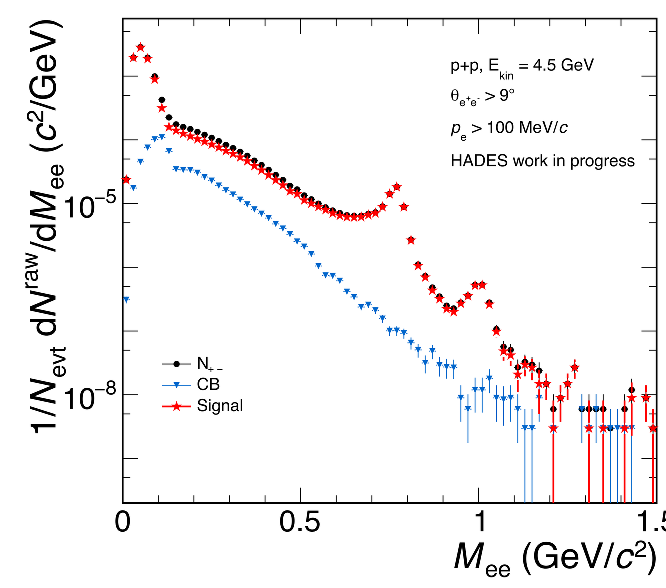

Fig. 12: Efficiency corrected dielectron spectra for $p + p$ at 4.5 GeV. The number of pairs allows multidifferential studies[5]: 0.15 < M_{e+e-} < 0.7 GeV/c²: $N_{e+e-} = 3.3 \cdot 10^5$, $N_\omega = 1.6 \cdot 10^4$, $N_\varphi = 350$, M_{e+e-} > 1.020 GeV/c²: $N_{e+e-} = 112$

- The dielectron spectrum shows a signal up to 0.5 GeV/c^2.
- It is scaled towards cross sections using the integrated luminosity $L_{int} = 400\frac{1}{nb}$ for elastic $p + p$ collisions in HADES (PT2 triggered events) and the calculated invariant mass dependent trigger bias factor.
- Complete systematics of e^+e^- production in $p + p$ collisions

[4] 1.25 GeV acceptance more restrictive than others
[5] R. Abou-Yassine, PhD TU Darmstadt (ongoing)

Summary

- In-medium effects clearly seen in $Ag + Ag$ dielectron analysis: excess radiation, in-medium temperature
- $p + p$ data at 1.58 GeV needed to provide NN reference for precise $Ag + Ag$ results and comparison to other HADES energies
- Ongoing work: final corrections, estimate dielectron yield in $p + n$

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[1] Otto, Jan-Hendrik (2022). *Dilepton reconstruction in Ag+Ag collisions at $\sqrt{s_{NN}} = 2.55$ GeV with HADES.* Justus Liebig University Giessen. DOI: 10.22029/JLUPUB-7207.
[2] Agakishiev, G. et al. (2012). *Inclusive dielectron production in proton-proton collisions at 2.2 GeV beam energy.* Physical Review C 85.5. DOI: 10.1103/physrevc.85.054005.
[3] Fröhlich et al. (2007). *Pluto: A Monte Carlo Simulation Tool for Hadronic Physics.* PoS ACAT p. 076. DOI: 10.22323/1.050.0076. arXiv: 0708.2382 [nucl-ex].