Di-lepton production in Ar+KCl @ 1.756 AGeV measured with the HADES

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for the HADES collaboration

Overview

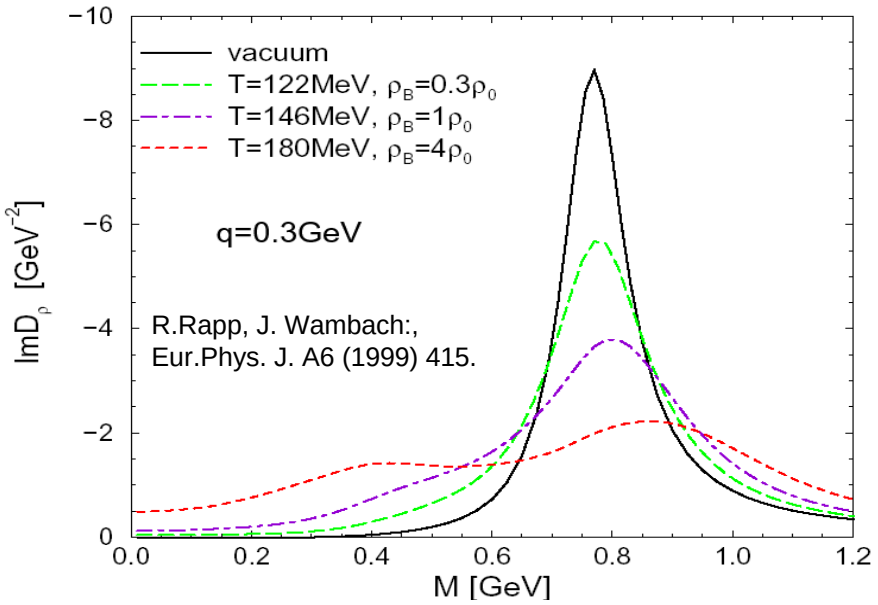
- Motivation
- HADES setup
- Analysis of the Ar+KCl run
- Comparison with naïve, MC based, event generator PLUTO
- Summary

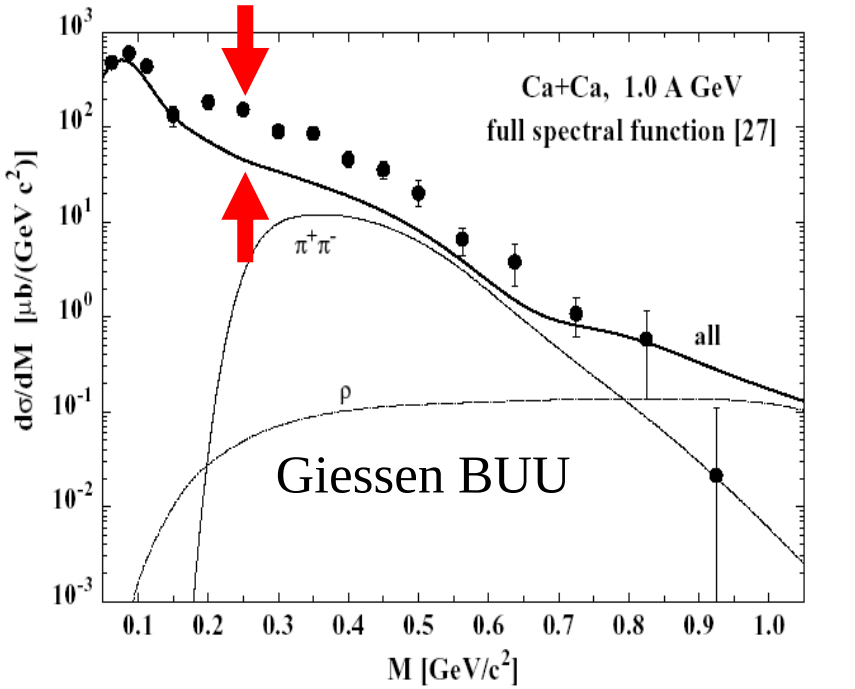
Motivation

- **Does the surrounding nuclear medium change properties of embedded hadrons?**

-di-lepton decays of vector mesons
-rare processes:
small cross sections,
tiny branching ratios ~10^{-4} - 10^{-5}

- **DLS puzzle** – in A+A collisions, DLS measured strong excess of a pair yield over several transport model predictions in the mass range 0.2 - 0.6 GeV/c^2.





Data: **R.J. Porter et al.:** PRL 79 (1997) 1229
BUU model: **E.L. Bratkovskaya et al.:** NP A634 (1998) 168
transport + in-medium spectral functions

HADES spectrometer

- Placed in the GSI Darmstadt
- SIS accelerator facility.
  (heavy ion beams 1-2 AGeV)

Geometry:

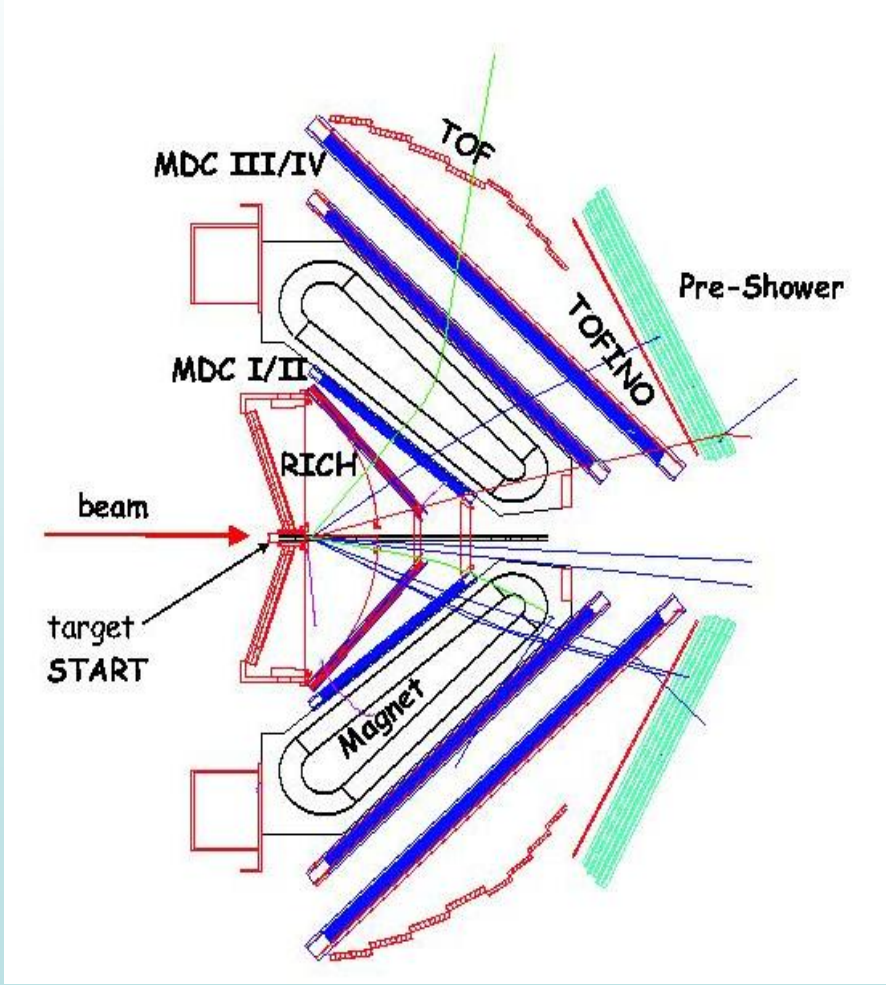
- full azimuth angle,
  polar angle 18 – 85 deg
- Pair acceptance ~ 35%

Particle identification:

- RICH hadron blind
  Cherenkov detector (γ_{thr} > 18.3).
- Time of flight TOF, TOFINO
- Pre-Shower

Momentum measurement:

- MDC I to IV are four layers
  of drift chambers measuring
  position before and behind
  magnetic field.
- Magnet (Bρ = 0.36 Tm)



Ar+KCl @ 1.756 AGeV

- carried out in September and October 2005
- heaviest system measured with the HADES (A_{Ar}~40, A_K~39, A_{Cl}~35)
- target made of natural KCl

- high resolution tracking (Runge-Kutta)

  expected mass resolution in the ω pole mass region: $\frac{\Delta M}{M} \sim 3\%$

Trigger

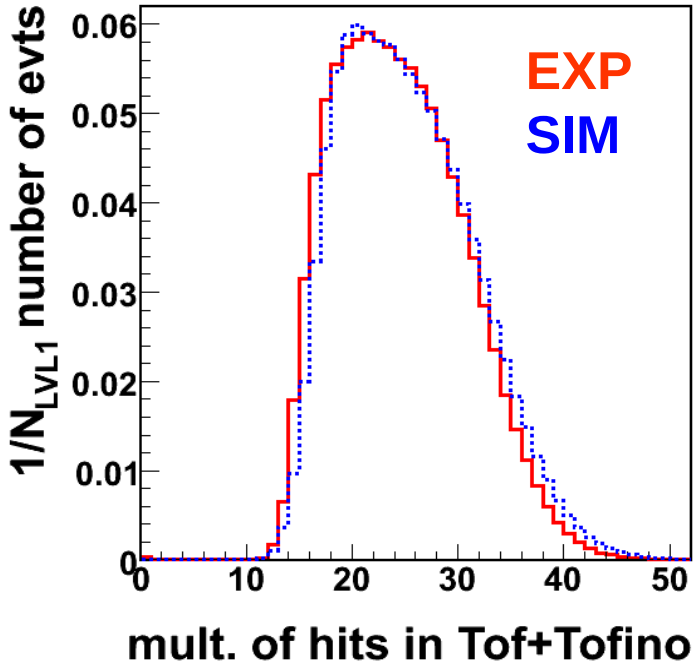
• HADES has two level on-line trigger
• **First level trigger** (LVL1) selects more central collisions.

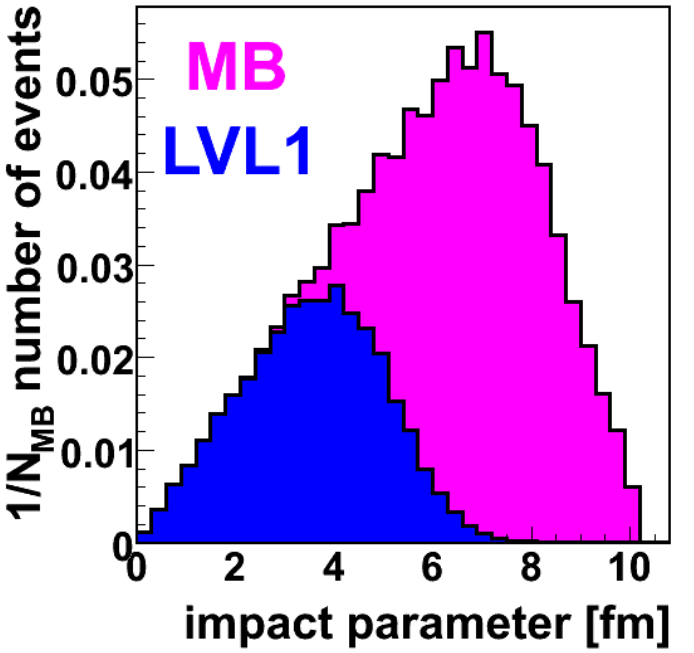
$Mult_{TOF}+Mult_{TOFino} >$ LVL1 threshold

• **Second level trigger** searches for lepton candidates in LVL1 events.

• In experiment we collected statistics corresponding to **2.1×10^9** LVL1 events.

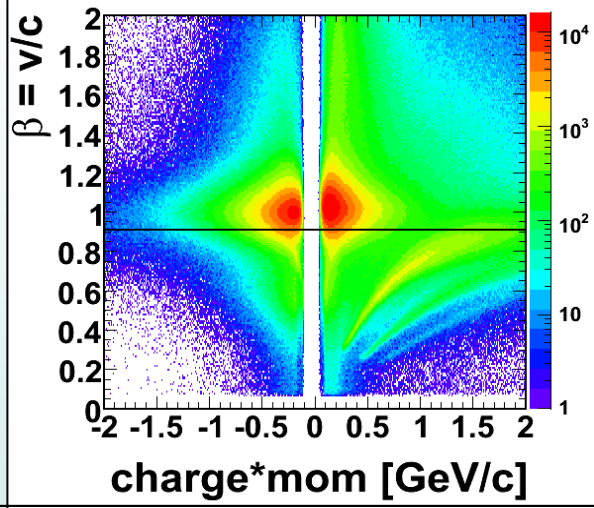
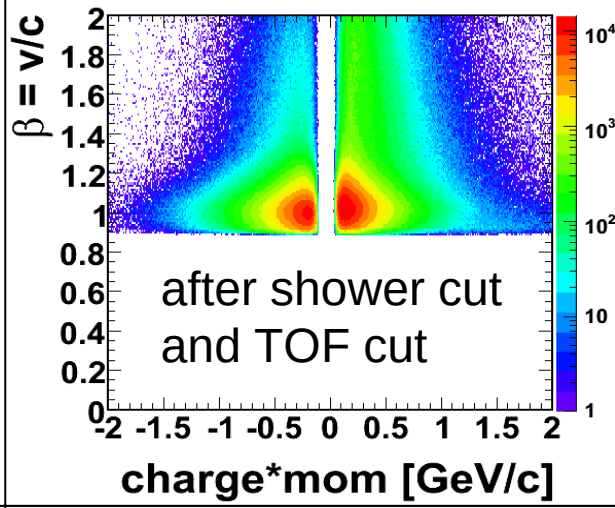
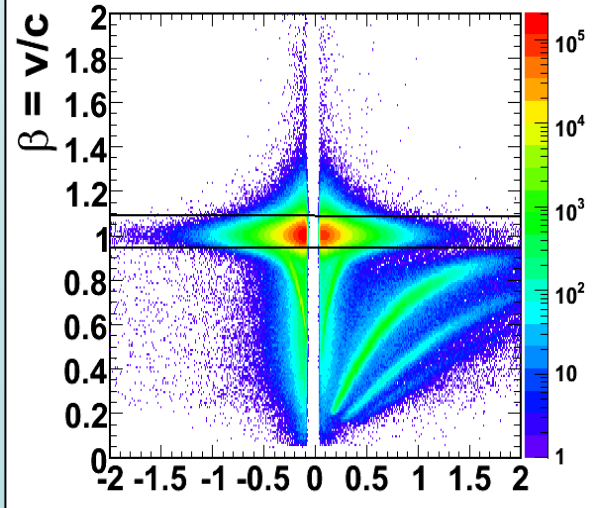
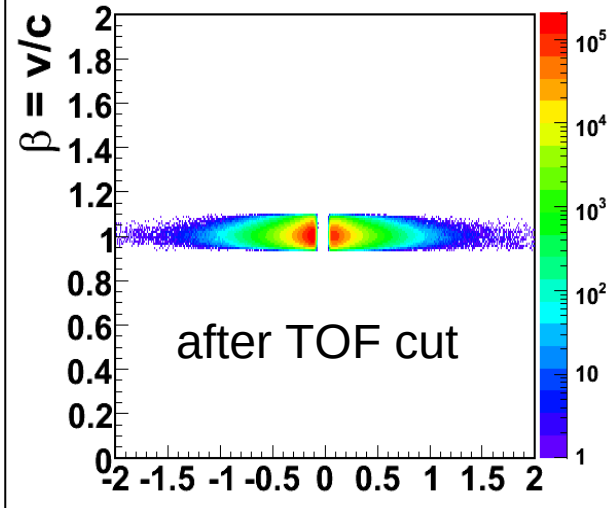
UrQMD simulation suggests:
- mean pion multiplicity of LVL1 events is 2 times larger with respect to minimum bias
- mean selected impact parameter is 3.5 fm
-LVL1 trigger selects about 34 % events out of minimum bias



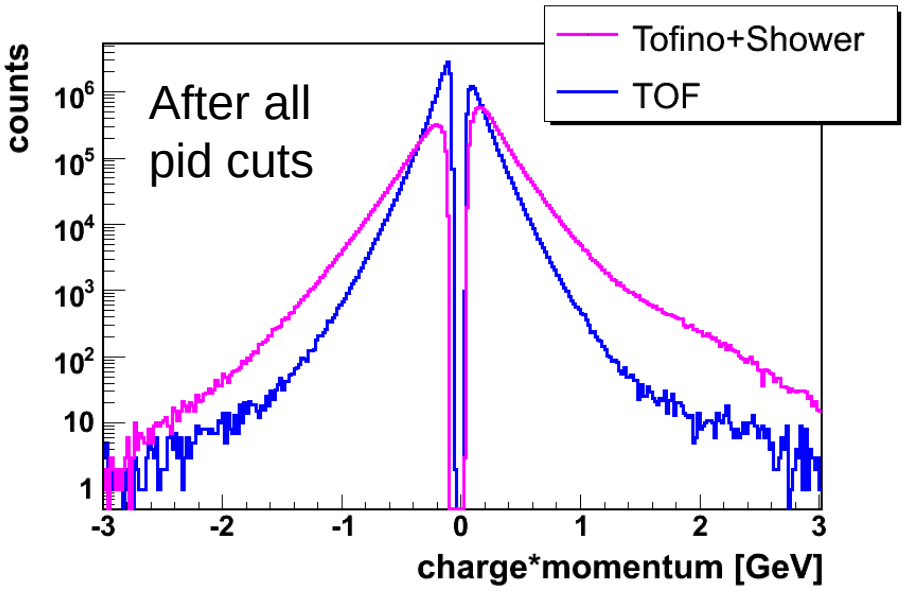


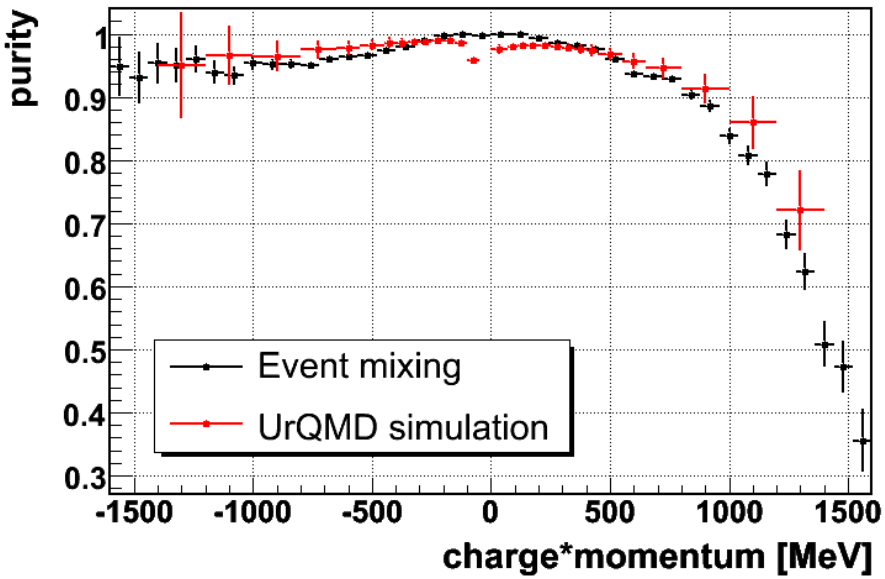
Lepton identification

Selection criteria for leptons:
1) track is associated with a RICH ring
2) ring quality
3) time of flight
4) shower condition

	Tracks assoc. with a ring	After all pid cuts
TOFino-Shower 18<θ<45 deg		
TOF 45<θ<85 deg		

Lepton identification





High momentum tails suffer from large hadron contamination
=>upper cut on momentum size in pair analysis: $p < 1.1$ GeV/c

$$\mathrm{Pur} = \frac{\text{true lep in sample}}{\text{all identified lep}}$$

Purity estimated by two independent approaches:
1) UrQMD simulation
2) event mixing of real data (mixing of rich rings and hadron tracks from two similar events)

Average purity of the sample of identified leptons is well above 90%.

Main sources of pairs

- only 9.8% of events with identified lepton contains a pair
- Main sources of pairs :

  Low invariant mass region (masses <150 MeV):

  - γ conversion (dominant source $\pi^0 \rightarrow \gamma\gamma$)
  - $\pi^0 \rightarrow e^+e^-\gamma$

  Sources producing also pairs with higher invariant masses:

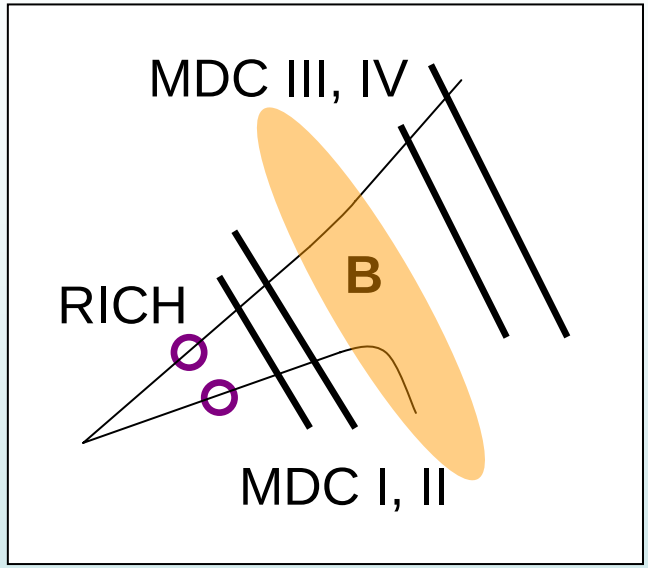
  - $\eta, \omega \rightarrow e^+e^-\gamma$
  - Δ, $N^* \rightarrow N\ e^+e^-$
  - $\omega, \rho^0, \Phi \rightarrow e^+e^-$
  - p-n Bremsstrahlung

In the spectrometer we see:

$$N_{e+e-} = S_{e+e-} + CB$$

Pair selection and CB suppression

- **Suppression of conversion**
  - pair opening angle α_{ee} > 9 deg
  - angle between lepton track and closest inner track segment pointing to a RICH ring > 9 deg.

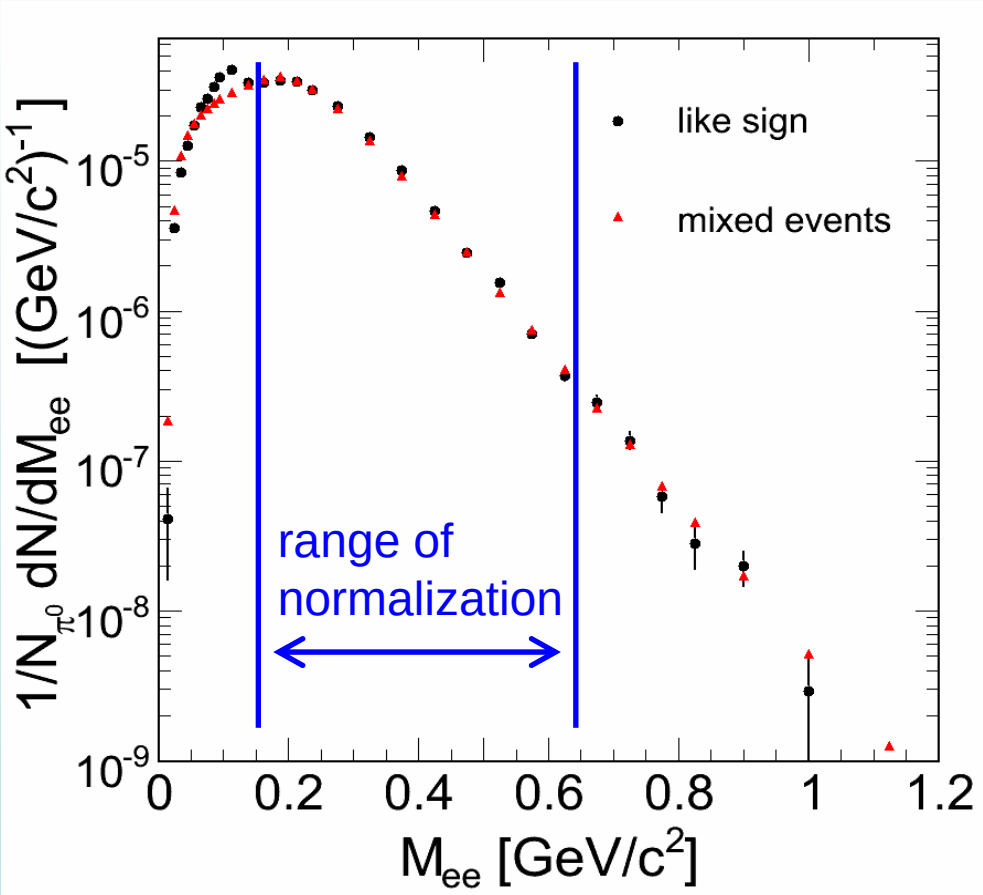


- **Suppression of fake pairs**

-removing tracks which share a common hit in any of the HADES sub-detectors.

-lepton momentum size 0.1 < p <1.1 GeV/c.

Combinatorial background



- **same-event like sing pairs**

$$CB = 2\sqrt{N_{e+e+} N_{e-e-}}$$

-**mixed event background**
mixing of leptons from two similar events => 8 reaction classes
(4 bins in target position, 2 bins in track multiplicity)

-mixed event background normalized on the same-event like sign background in the region 150 -- 650 MeV/c^2.

sum of CB from all reaction classes

Uncorrected spectrum

- **No efficiency correction**
- **No acceptance correction**
- **Normalized to the total number of π^0 in the corresponding number of LVL1 events**.

Mean number of π^0 in one LVL1 event was (3.6±0.4)

$$S_{e+e-} = N_{e+e-} - CB$$

- **Combinatorial background**

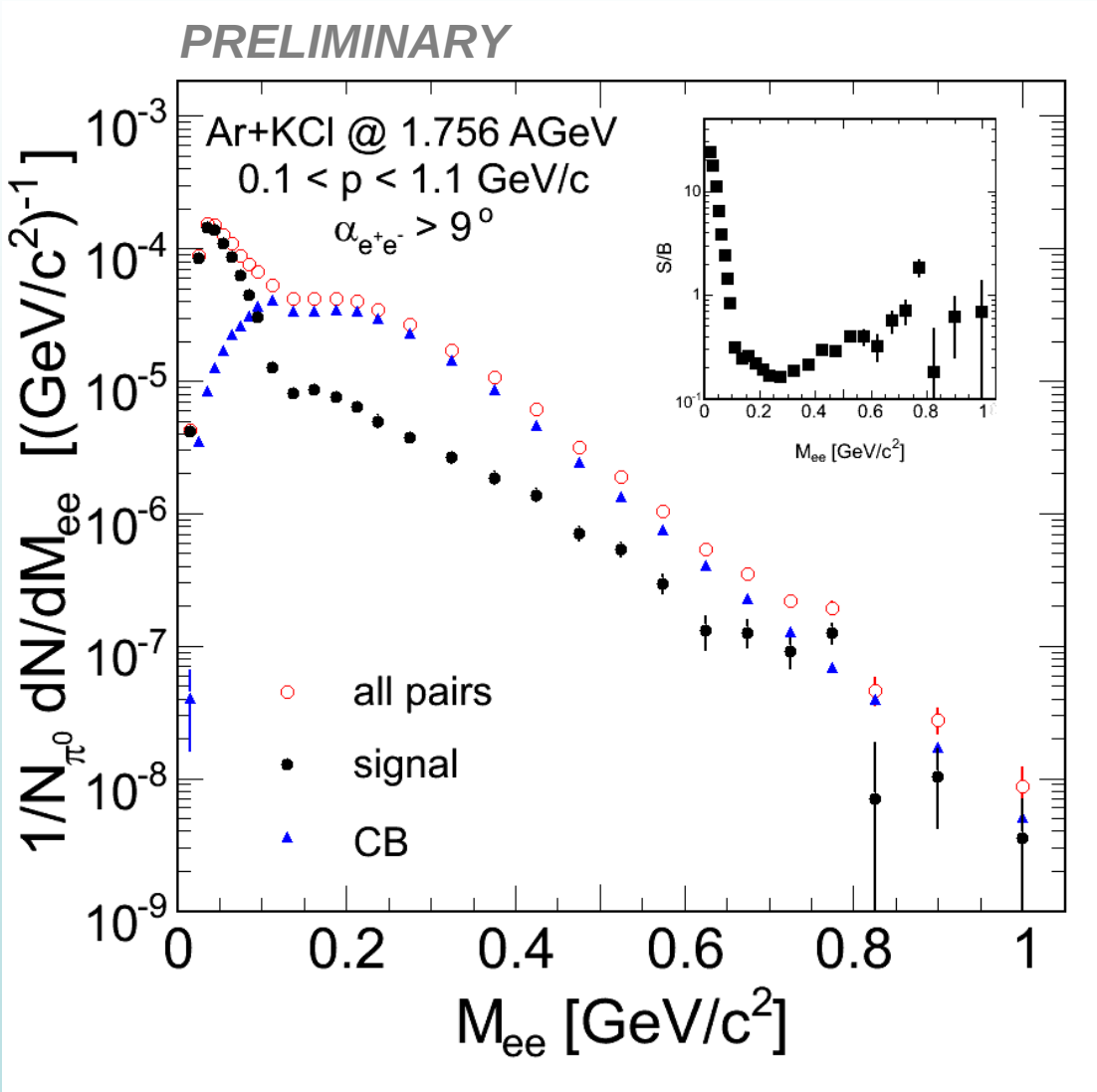
M_{ee} < 450 MeV/c^2 like-sign

M_{ee} > 450 MeV/c^2 mixed event

- **Net number of signal pairs**

M_{ee} < 150 MeV/c^2 ~52400

M_{ee} > 150 MeV/c^2 ~8800



Efficiency corrected spectrum

- **Pair eff. correction:** $\left(\varepsilon_1 \varepsilon_2\right)^{-1}$

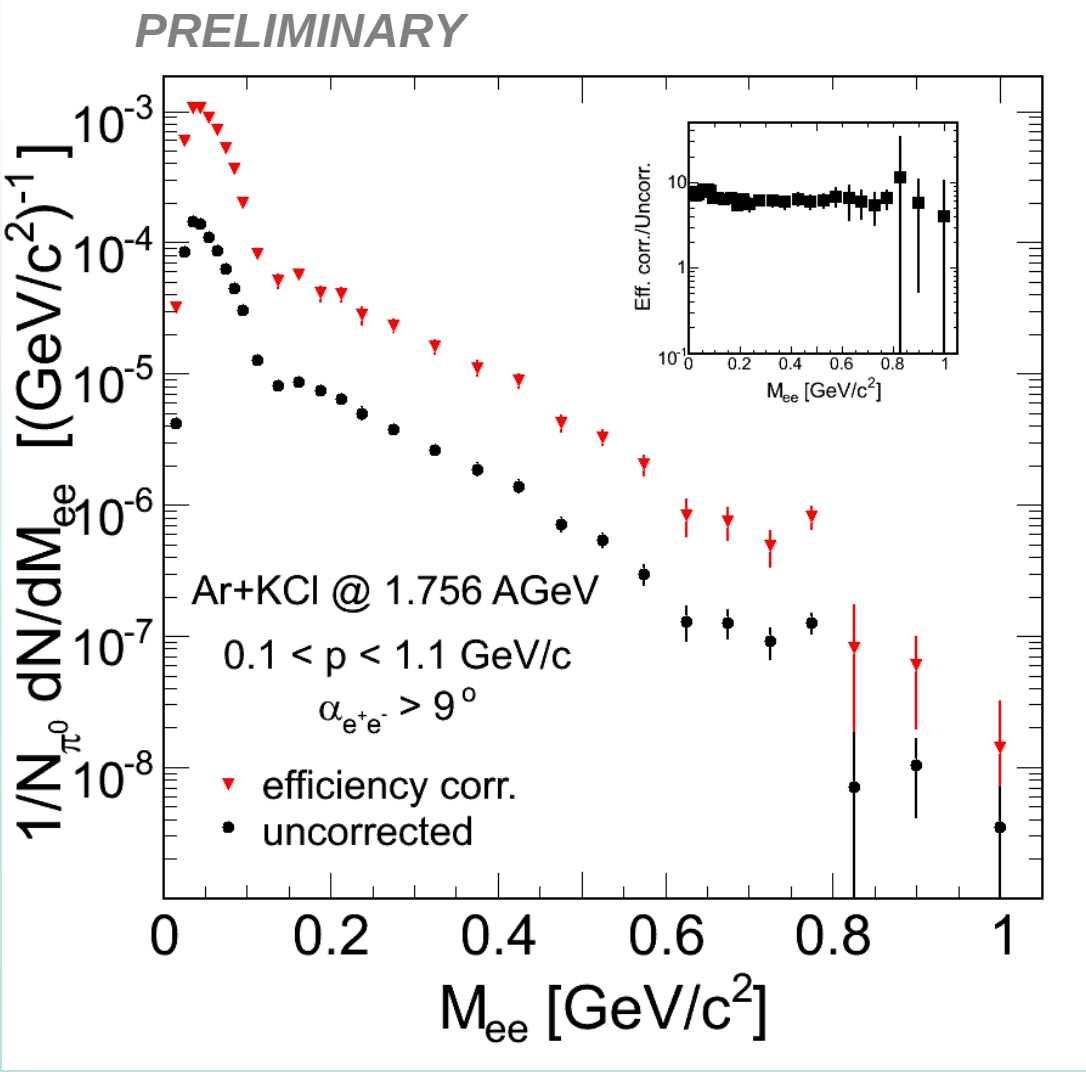
ε_i identification & reconstruction efficiency of a single e+ or e-.

Lower RICH eff. in exp w.r.t. sim $\Rightarrow$ eff. corr. spectrum scaled up 1.7× to reach Pluto in π^0 region

- **Figure shows only stat. errors**

- **Estimate of syst. errors:**
  efficiency correction ~20%
  CB subtraction ~20%
  normalization to π^0 ~11%

  The total systematic error is about 30 %.



Pluto generator

PLUTO – Monte Carlo based event generator

– incoherent sum of di-electron sources

– meson multiplicities, temperature slopes, branching ratios, anisotropy coefficients are taken or estimated from known experimental data.

π^0, η - fit to the TAPS data systematic measurements

R. Averbeck et al.: Z. Phys., A359, 65 (1997).
R. Averbeck et al. Phys. Rev., C67 (2003) 024903 .
S. Nagamiya et al. Phys. Rev., C24, 971 (1981).

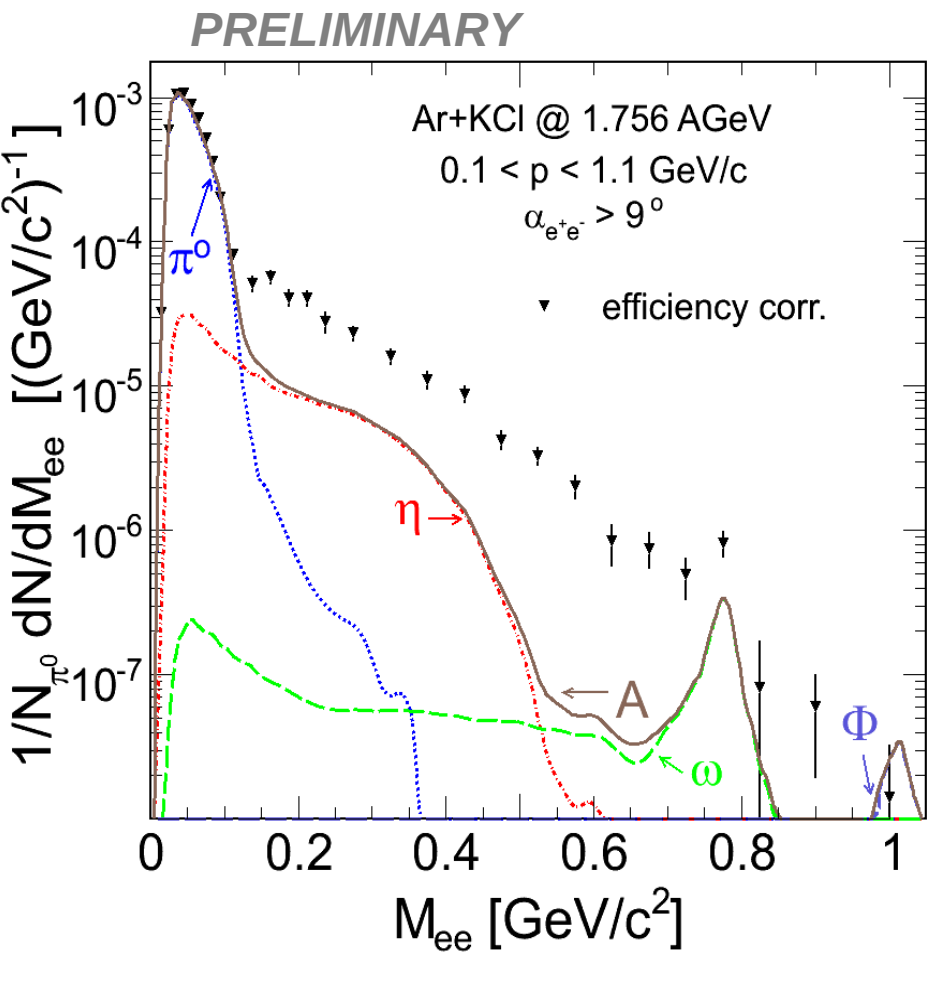
Δ - production proportional to π^0

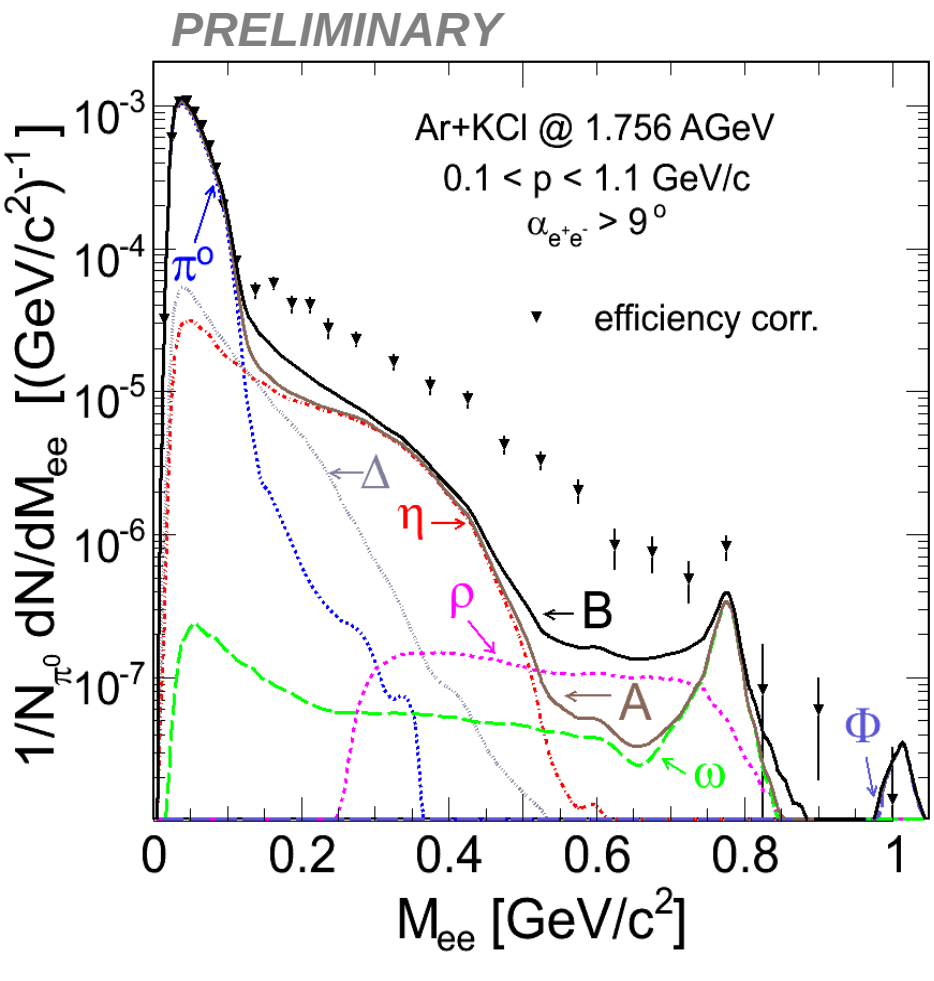
ω, ρ, Φ - mT scaling from η

Comparison to Pluto cocktail

cocktail A = π^0 + η+ ω + Φ

cocktail B = cocktail A + Δ + ρ



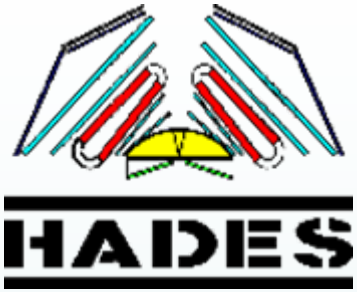


Summary

- preliminary HADES di-electron data from

  Ar+KCl @ 1.756 AGeV

- large excess over Pluto cocktail in the mass region 0.15-0.6 GeV/c^2
- good statistics of pairs above 0.5 GeV/c^2 => convenient data for in-medium studies
- for the first time, HADES has seen a hint of ω peak



collaboration

G. Agakishiev[8], C. Agodi[1], A. Balanda[3,e], G. Bellia[1,a], D. Belver[15], A. Belyaev[6], A. Blanco[2], M. Böhmer[11], J. L. Boyard[13], P. Braun-Munzinger[4], P. Cabanelas[15], E. Castro[15], S. Chernenko[6], T. Christ[11], M. Destefanis[8], J. Díaz[16], F. Dohrmann[5], A. Dybczak[3], T. Eberl[11], L. Fabbietti[11], O. Fateev[6], P. Finocchiaro[1], P. Fonte[2,b], J. Friese[11], I. Fröhlich[7], T. Galatyuk[4], J. A. Garzón[15], R. Gernhäuser[11], C. Gilardi[8], M. Golubeva[10], D. González-Díaz[4], E. Grosse[5,c], F. Guber[10], M. Heilmann[7], T. Hennino[13], R. Holzmann[4], A. Ierusalimov[6], I. Iori[9,d], A. Ivashkin[10], M. Jurkovic[11], B. Kämpfer[5], K. Kanaki[5], T. Karavicheva[10], D. Kirschner[8], I. Koenig[4], W. Koenig[4], B. W. Kolb[4], R. Kotte[5], A. Kozuch[3,e], F. Krizek[14], R. Krücken[11], W. Kühn[8], A. Kugler[14], A. Kurepin[10], J. Lamas-Valverde[15], S. Lang[4], J. S. Lange[8], L. Lopes[2], L. Maier[11], A. Mangiarotti[2], J. Marín[15], J. Markert[7], V. Metag[8], B. Michalska[3], D. Mishra[8], E. Morinière[13], J. Mousa[12], C. Müntz[7], L. Naumann[5], R. Novotny[8], J. Otwinowski[3], Y. C. Pachmayer[7], M. Palka[4], Y. Parpottas[12], V. Pechenov[8], O. Pechenova[8], T. Pérez Cavalcanti[8], J. Pietraszko[4], W. Przygoda[3,e], B. Ramstein[13], A. Reshetin[10], M. Roy-Stephan[13], A. Rustamov[4], A. Sadovsky[10], B. Sailer[11], P. Salabura[3], A. Schmah[4], R. Simon[4], S. Spataro[8], B. Spruck[8], H. Ströbele[7], J. Stroth[7,4], C. Sturm[7], M. Sudol[4], A. Tarantola[7], K. Teilab[7], P. Tlusty[14], M. Traxler[4], R. Trebacz[3], H. Tsertos[12], I. Veretenkin[10], V. Wagner[14], H. Wen[8], M. Wisniowski[3], T. Wojcik[3], J. Wüstenfeld[5], S. Yurevich[4], Y. Zanevsky[6], P. Zumbruch[4]

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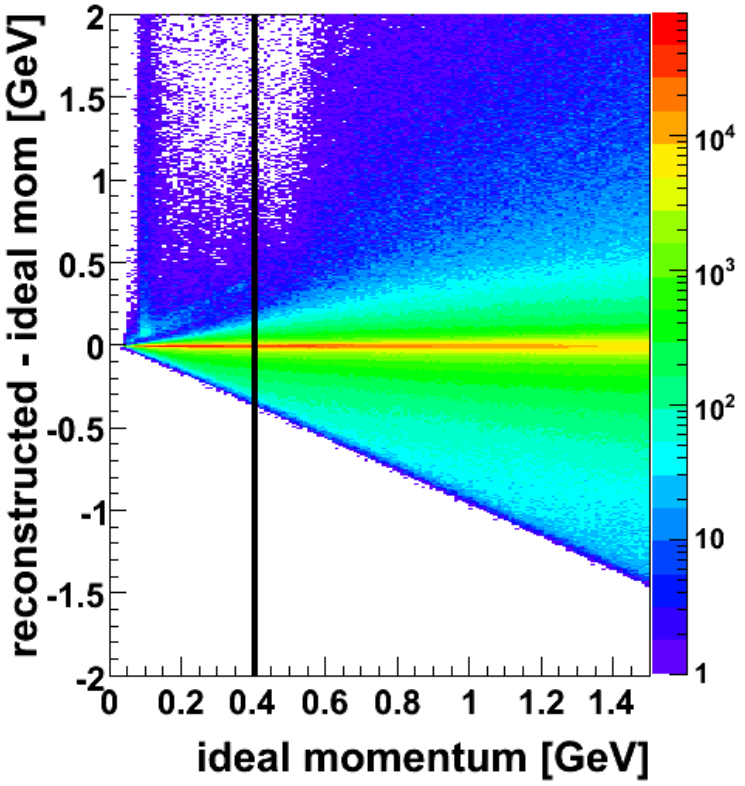
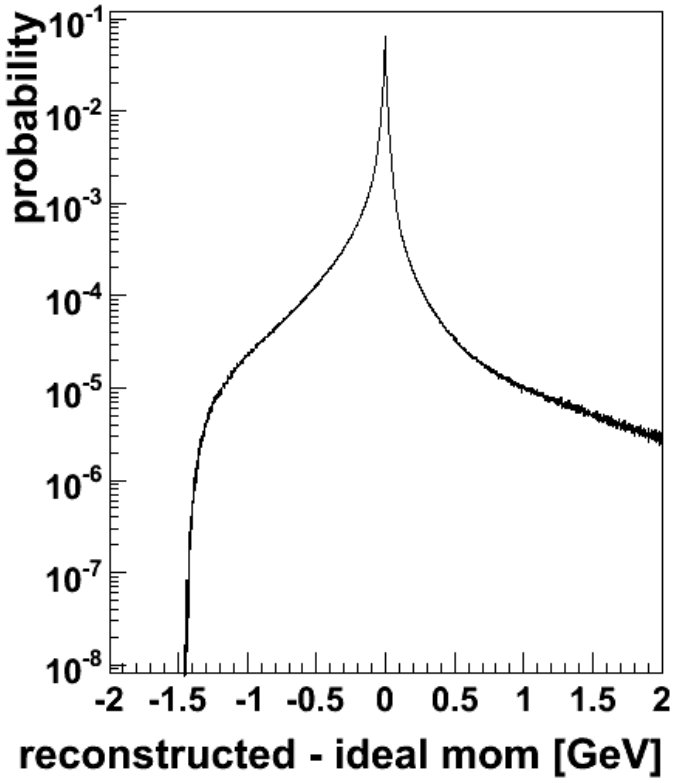
Back-up slides

Momentum smearing



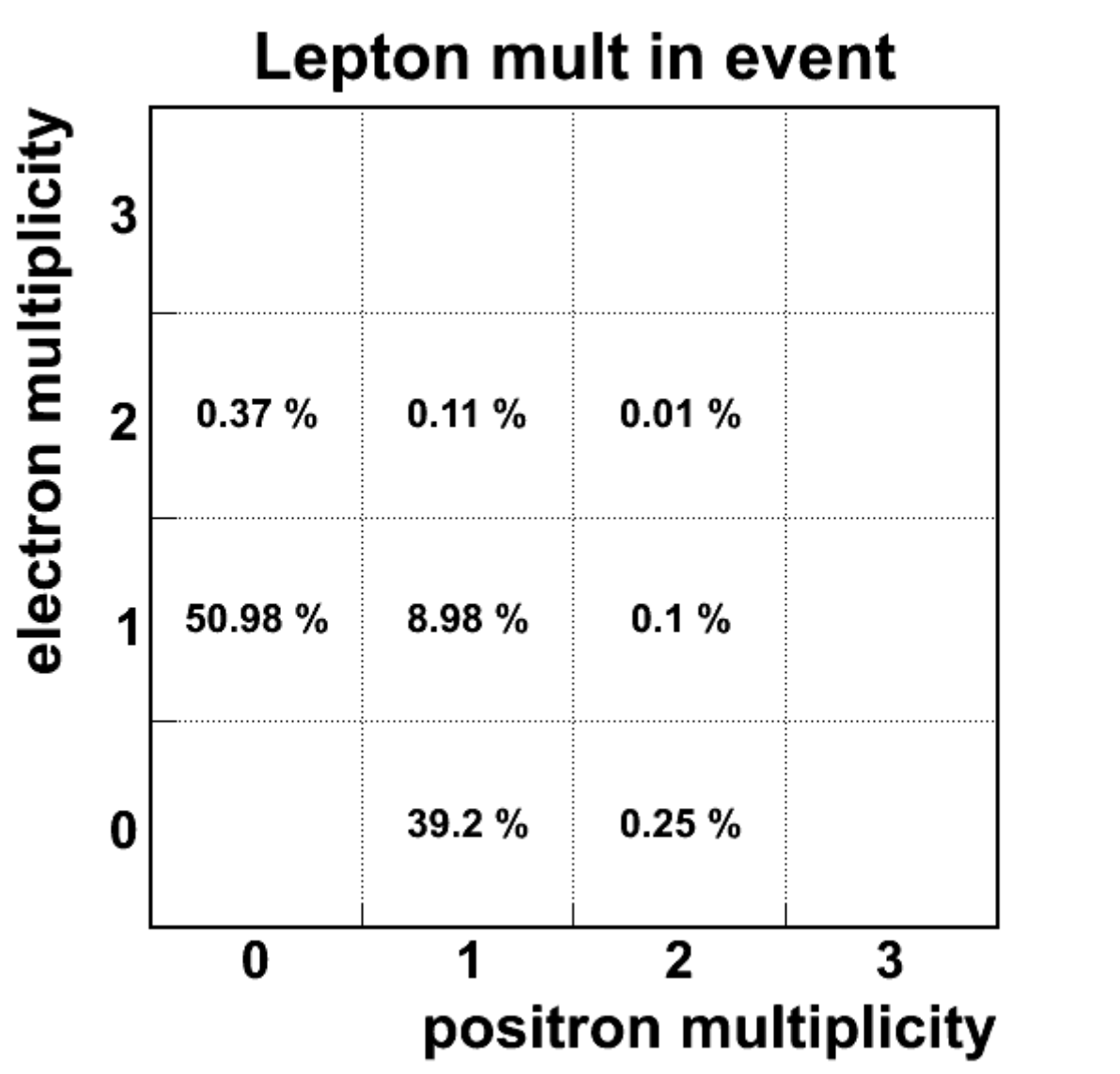


Approximate relations describing relative momentum smearing:

4 MDC σ_p/p [%] = 1.4 + 1.1*p [GeV]

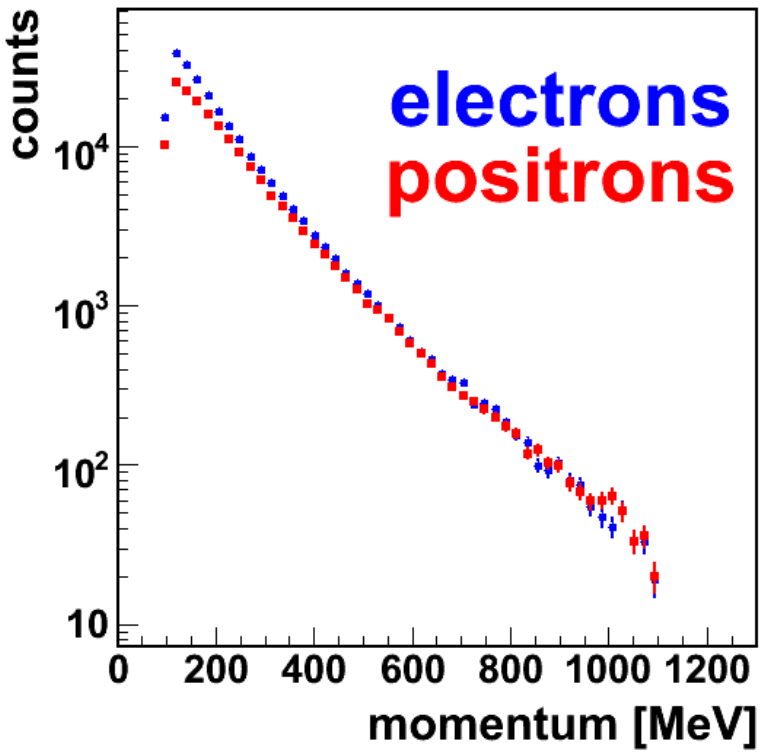
3MDC σ_p/p [%] = 1.0 + 4.5*p [GeV]

Lepton multiplicity in events

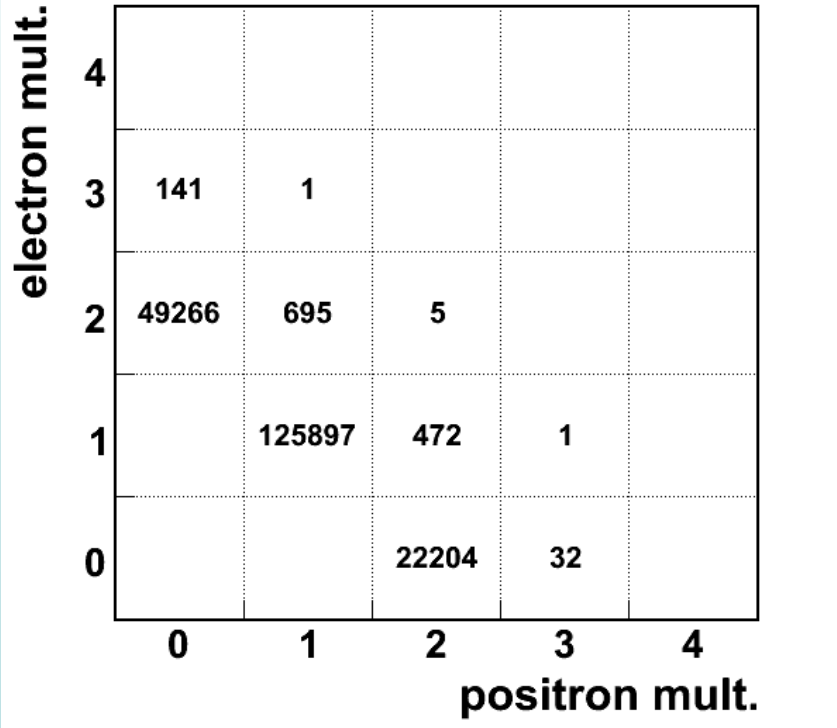


- 9,8 % of events contains a lepton pair.
- 0.8 % of events contains a like-sign lepton pair.

Momentum distribution of leptons in pairs after all pair cuts were done.



Multiplicity distribution of leptons in pairs after all pair cuts were done.



Event mixing reaction classes: