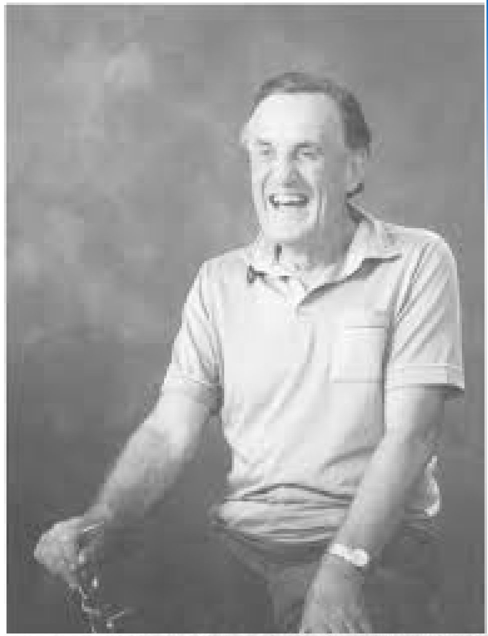
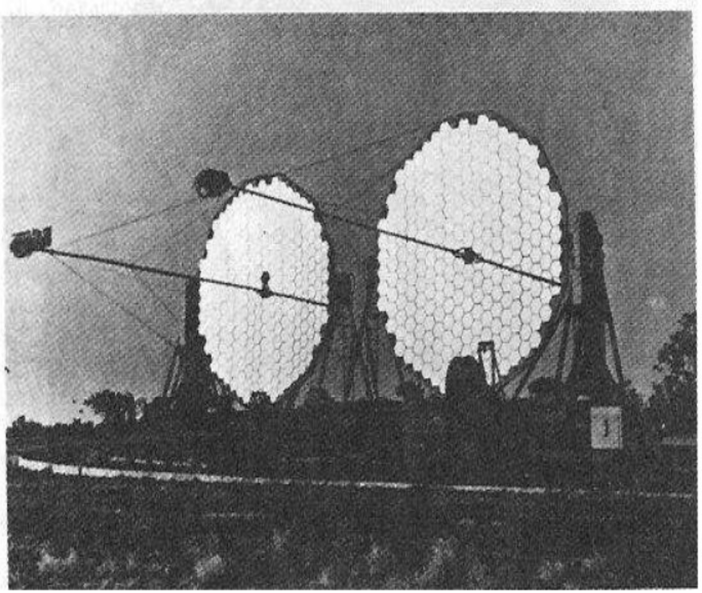
Bose-Einstein correlations in deep-inelastic scattering from nuclei

Gevorg Karyan

(for the HERMES Collaboration)

Hanbury-Brown and Twiss effect





LXXIV. *A New Type of Interferometer for Use in Radio Astronomy*

By R. Hanbury Brown
Jodrell Bank Experimental Station, Cheshire
and
R. Q. Twiss
Services Electronics Research Laboratory, Baldock, Herts.*

[Received March 20, 1954]

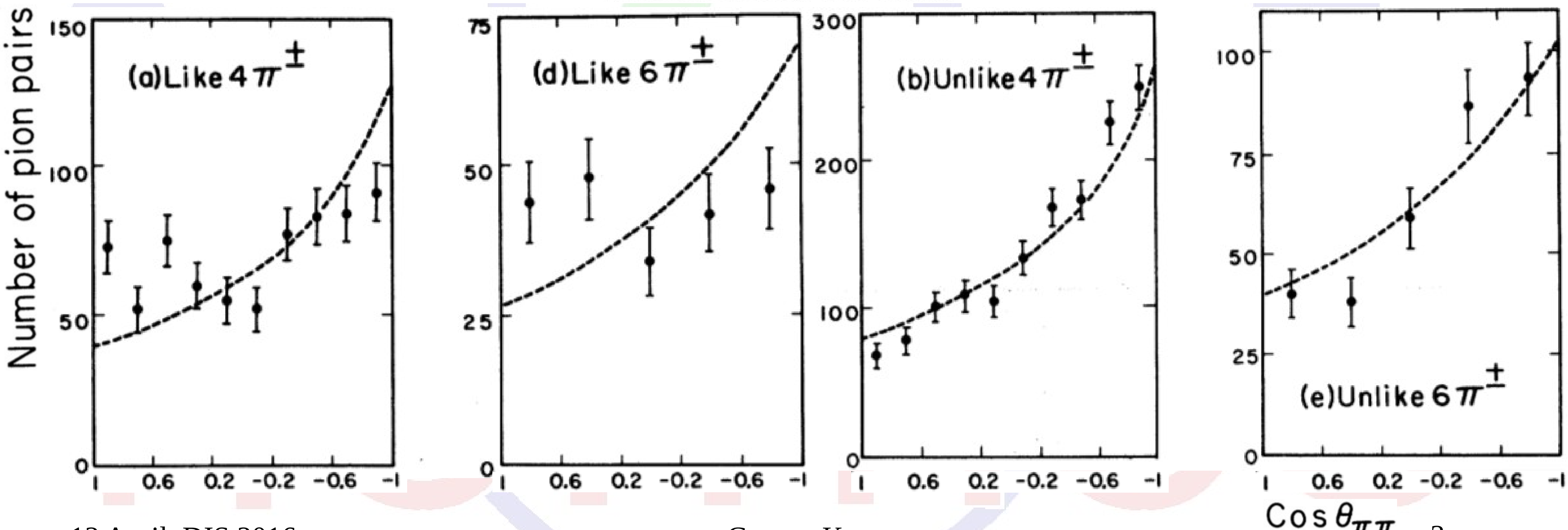
Summary

A new type of interferometer for measuring the diameter of discrete radio sources is described and its mathematical theory is given. The principle of the instrument is based upon the correlation between the rectified outputs of two independent receivers at each end of a baseline, and it is shown that the cross-correlation coefficient between these outputs is proportional to the square of the amplitude of the Fourier transform of the intensity distribution across the source. The analysis shows that it should be possible to operate the new instrument with extremely long baselines and that it should be almost unaffected by ionospheric irregularities.

HBT effect in accelerator physics

PION-PION CORRELATIONS IN ANTIPROTON ANNIHILATION EVENTS*

Gerson Goldhaber, William B. Fowler, Sulamith Goldhaber, T. F. Hoang,
Theodore E. Kalogeropoulos, and Wilson M. Powell
Lawrence Radiation Laboratory and Department of Physics, University of California, Berkeley, California
(Received July 17, 1959)



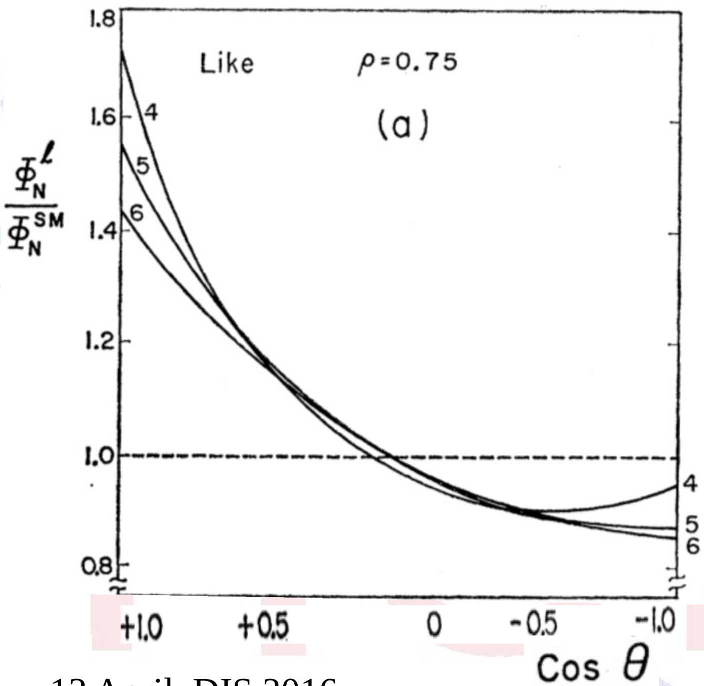
Bose-Einstein correlation (GGLP effect)

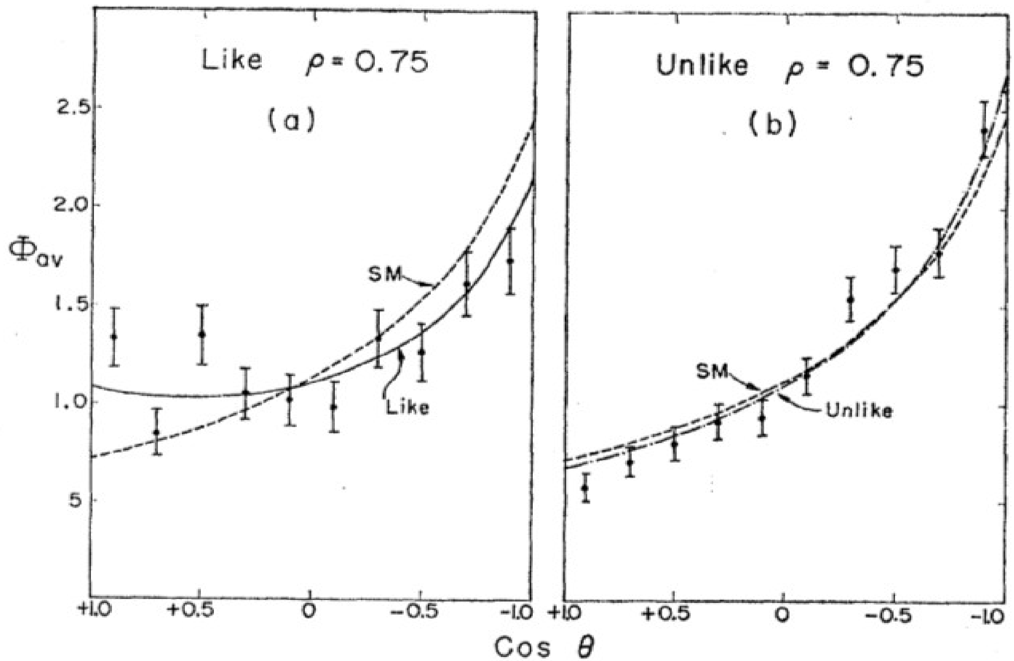
PHYSICAL REVIEW VOLUME 120, NUMBER 1 OCTOBER 1, 1960

Influence of Bose-Einstein Statistics on the Antiproton-Proton Annihilation Process*

Gerson Goldhaber, Sulamith Goldhaber, Wonyong Lee, and Abraham Pais†
Lawrence Radiation Laboratory and Department of Physics, University of California, Berkeley, California

(Received May 16, 1960)





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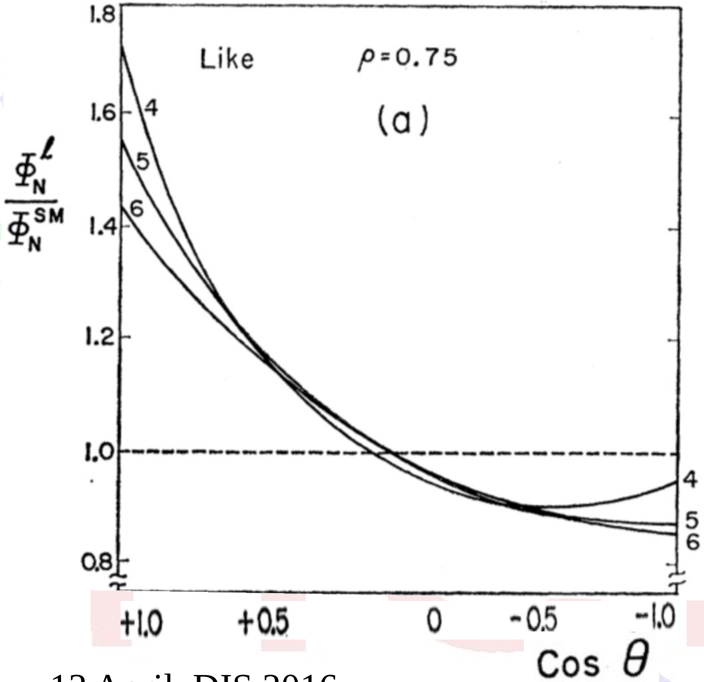
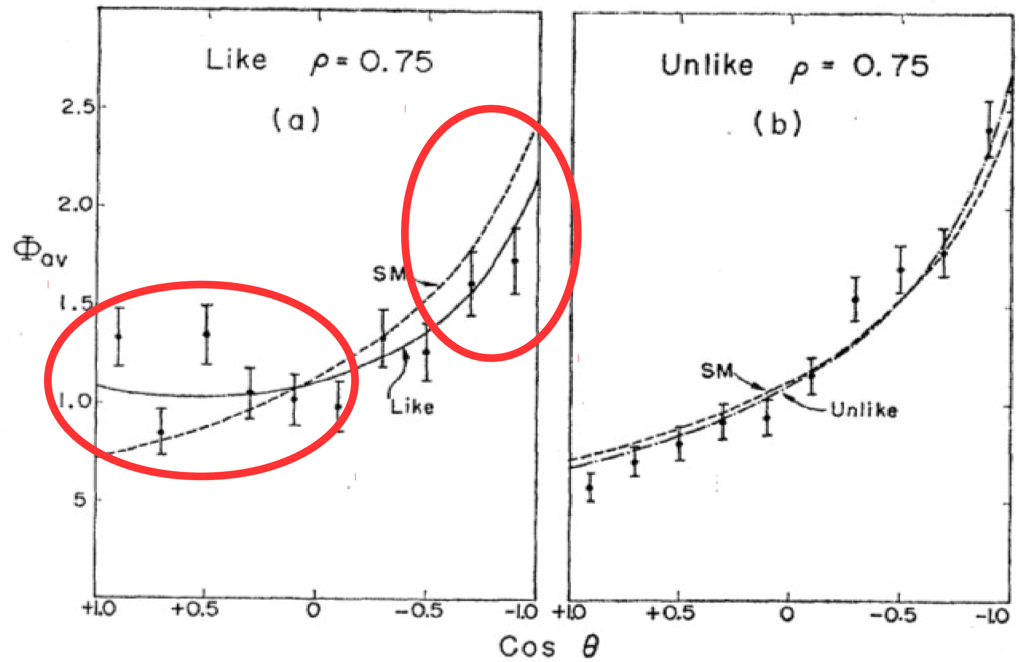
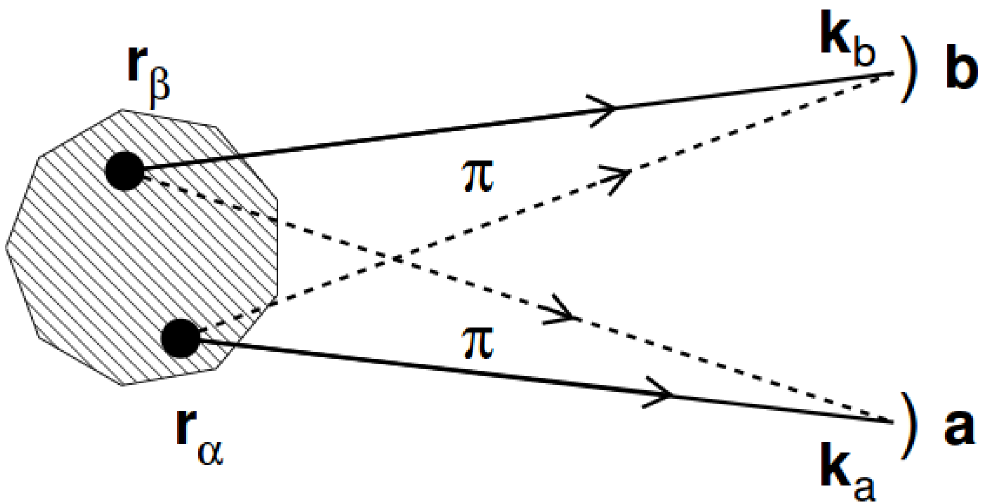




The underlying physics



$$\Psi_{2\pi} = \frac{\Psi_{a\alpha}\Psi_{b\beta} + \Psi_{b\alpha}\Psi_{a\beta}}{\sqrt{2}}$$

$$\Psi_{a\alpha} \approx e^{ik_a r_\alpha}, \Psi_{a\beta} \approx e^{ik_a r_\beta}, \ldots$$

$$|\Psi_{2\pi}|^2 = 1 + \cos(\delta k \delta r), \; \delta k = k_a - k_b, \delta r = r_\alpha - r_\beta$$

$$R(k_a, k_b) \approx 1 + \cos(\delta k \delta r)$$

Measuring the BEC

$$R(k_a, k_b) \approx 1 + \cos(\delta k \, \delta r)$$

(two point source)

$$R(p_1, p_2) = \frac{D(p_1, p_2)}{D(p_1)D(p_2)}$$

(continuous space-time distribution)

$D(p_1, p_2)$ - two particle probability density

$D(p_1), D(p_2)$ - one particle probability density

Measuring the BEC

$$R(p_1,p_2) = \frac{D(p_1,p_2)}{D(p_1)D(p_2)}$$ ↔ experimental observable

↕

Goldhaber parametrization

↕

$R(p_1,p_2) \longrightarrow R(T),\ T^2 = -(p_1 - p_2)^2$

$$R(T) = 1 + \lambda e^{-T^2 r_G^2}$$

λ - chaoticity parameter

r_G - source distribution size

Measuring the BEC

Goldhaber parametrization

$$R(T) = 1 + \lambda e^{-T^2 r_G^2}$$

$$R(T) = \gamma\left(1 + \lambda e^{-T^2 r_G^2}\right)P(T)$$

$$P(T) = 1 + \delta T^2$$

γ - normalization parameter

P_T - long range correlation

$r_G, \lambda, \gamma, \delta$ - free parameters

Measuring the BEC

$$R(p_1,p_2) = \frac{D(p_1,p_2)}{D_r(p_1,p_2)}$$ ↔ experimental observable

$$D_r(p_1,p_2) \equiv D(p_1)D(p_2)$$

$D_r(p_1,p_2)$ - two particle probability density reference distribution

experimental two particle distributions without BECs

Measuring the BEC

$$R(p_1,p_2) \equiv \frac{D(p_1,p_2)}{D_r(p_1,p_2)} \longleftrightarrow \text{experimental observable}$$

$$D_r(p_1,p_2) \equiv D(p_1)D(p_2)$$

$D_r(p_1,p_2)$ - two particle probability density reference distribution

1. Method of Event Mixing (MEM)
2. Method of Unlike-Sign pairs (MUS)

Measuring the BEC

1. Method of Event Mixing (MEM)

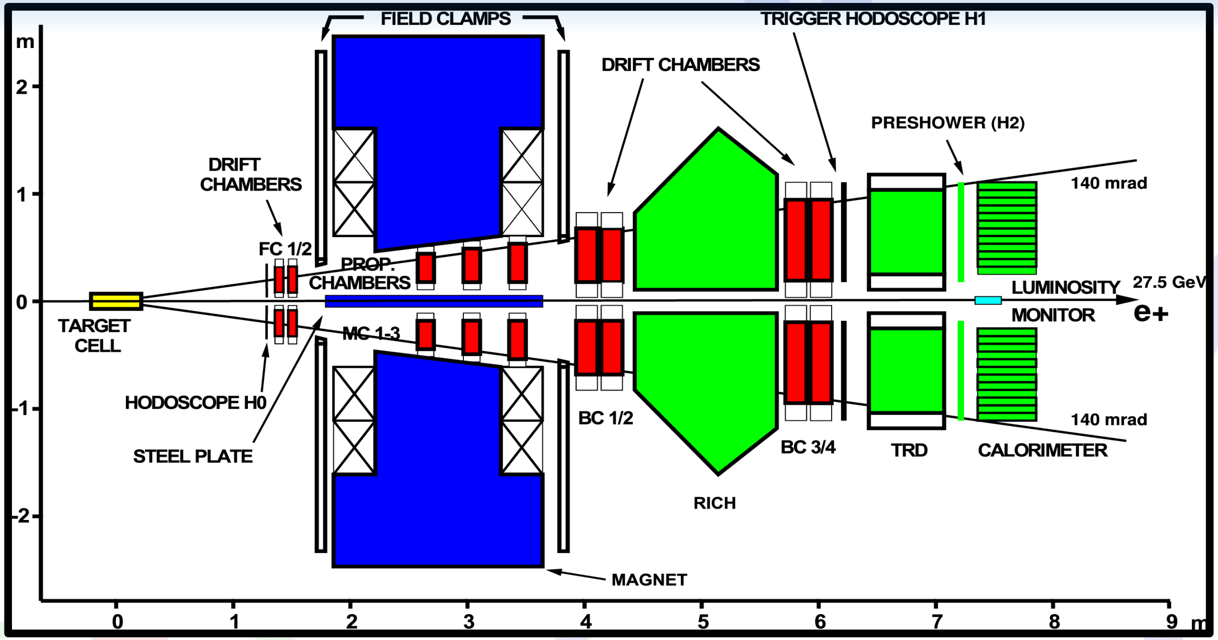
violation of energy and momentum conservation

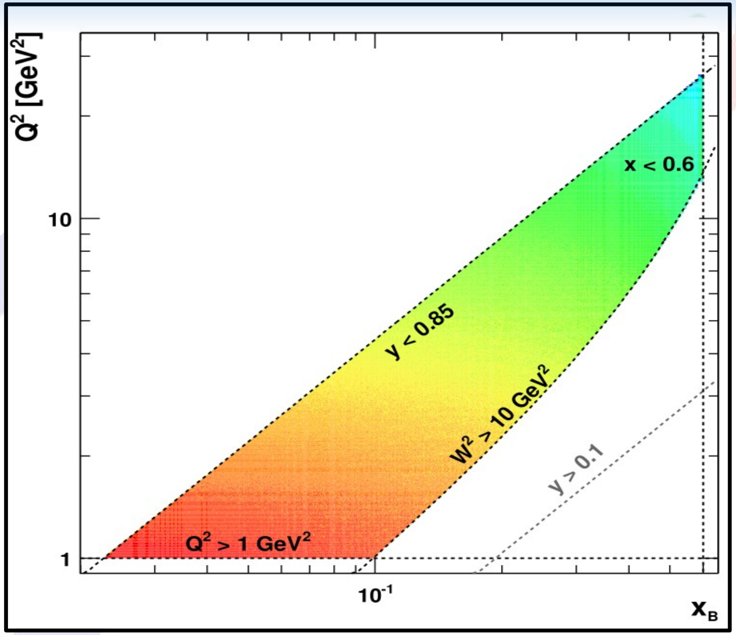
2. Method of Unlike-Sign pairs (MUS)

contribution from resonances excluded in the case of MEM

PYTHIA-based MC tuned to provide an accurate description

Experiment





Beam : e^-/e^+ 27.6 GeV

Target : H, D, ^{3}He, ^{4}He, N, Ne, Kr, Xe pure gaseous

Good momentum resolution : $\frac{\delta p}{p} < 2\ \%$

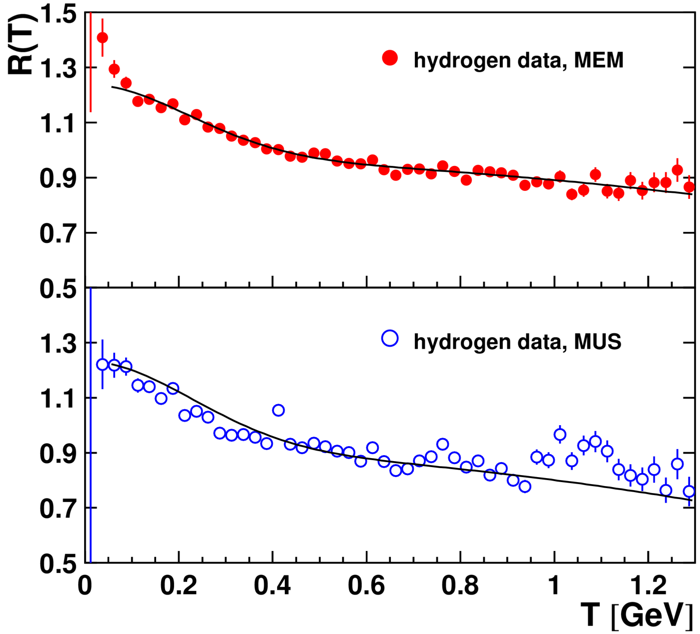
Excellent particle identification

Data selection

- $Q^2 > 1$ GeV ^{2}
- $W^2 > 10$ GeV ^{2}
- at least two charged hadrons
- 2 GeV < p < 15 GeV

Nucleus	N_{ev}	N^{like}	N^{unlike}
^{1}H	1145046	478946	958185
^{2}H	1297356	680143	1178797
^{3}He	34391	15295	29165
^{4}He	79776	30539	59244
N	92968	41112	78402
Ne	175594	75898	146145
Kr	211456	91391	172946
Xe	106274	46130	87125

Black curve – result of fit using the Goldhaber parametrization.



Results

A. Airapetian et. al, Eur. Phys. J. C 75 (2015) 361

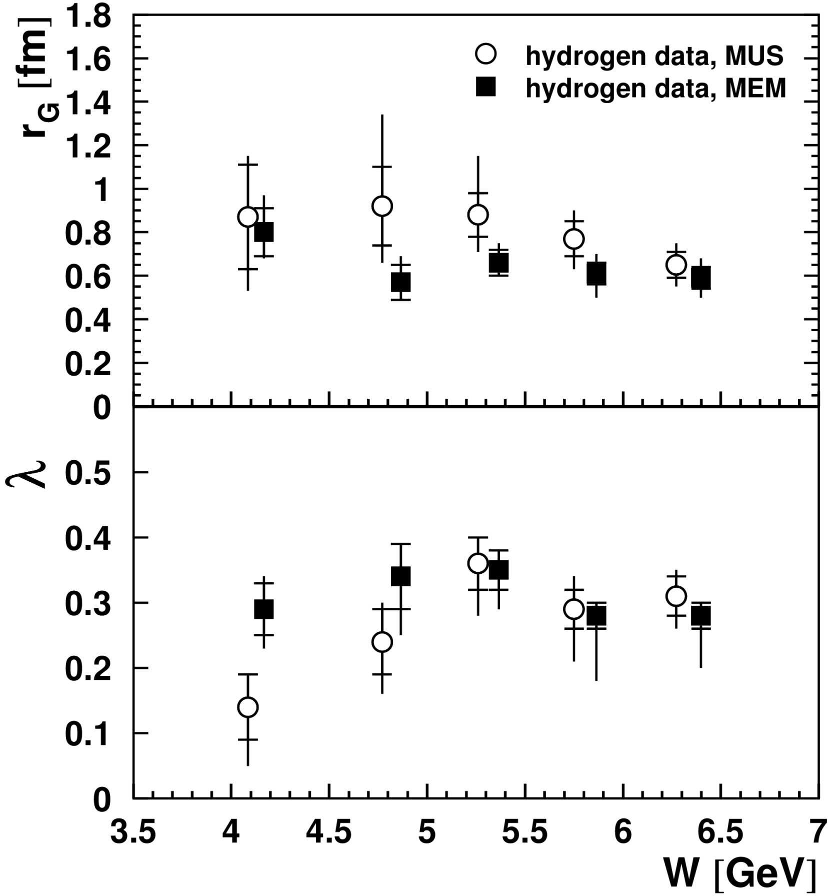
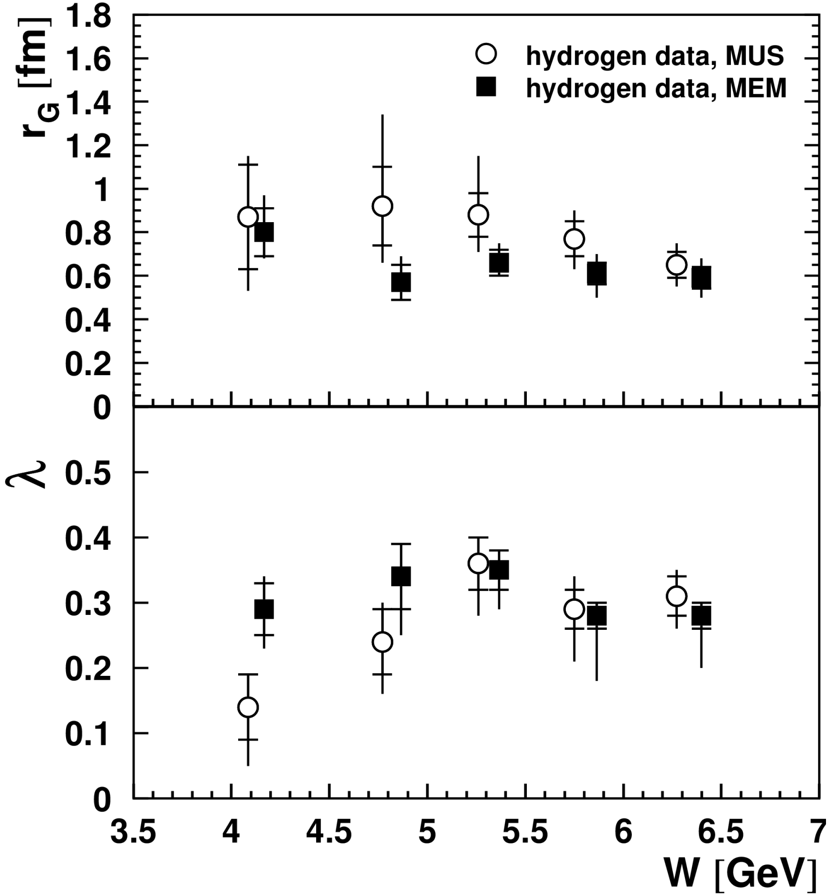


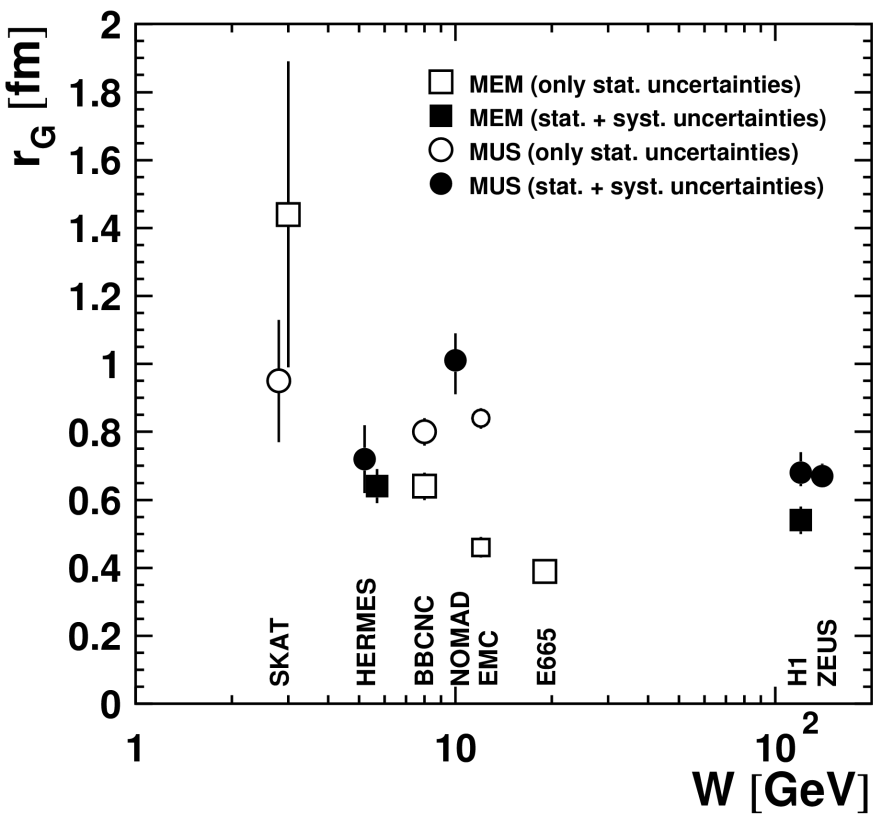
Table 2. Results for the Goldhaber parametrization fitted to the HERMES hydrogen data, both for the mixed-event method (MEM) and the method of unlike-sign pairs (MUS).

Method	Goldhaber parameters
MEM	$r_G = 0.64 \pm 0.03(\text{stat})^{+0.04}_{-0.04}(\text{sys})$ fm $\lambda = 0.28 \pm 0.01(\text{stat})^{+0.00}_{-0.05}(\text{sys})$
MUS	$r_G = 0.72 \pm 0.04(\text{stat})^{+0.09}_{-0.09}(\text{sys})$ fm $\lambda = 0.28 \pm 0.02(\text{stat})^{+0.02}_{-0.04}(\text{sys})$

Results

A. Airapetian et. al, Eur. Phys. J. C 75 (2015) 361





Results

A. Airapetian et. al, Eur. Phys. J. C 75 (2015) 361

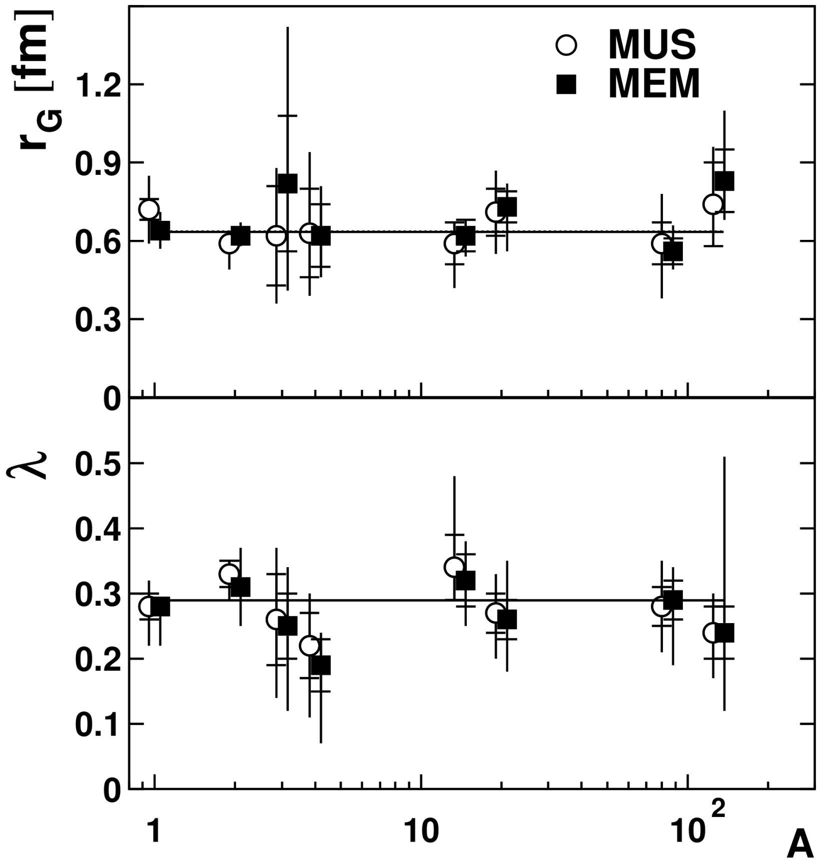


Table 3. Fit of a constant to the Goldhaber parameters as a function of the target atomic mass A. Results are given for both the mixed-event method (MEM) and the method of unlike-sign pairs (MUS).

Method	Value	χ^2/NDF
MEM	$r_G = 0.634 \pm 0.017$ fm $\lambda = 0.289 \pm 0.006$	1.5 2.1
MUS	$r_G = 0.636 \pm 0.021$ fm $\lambda = 0.289 \pm 0.011$	1.2 1.4

Summary

- Bose-Einstein correlation between two like-sign hadrons produced in semi-inclusive deep inelastic electron/positron scattering off nuclear targets ranging from hydrogen to xenon has been measured.

- The results obtained using the two reference sample methods (i.e MUS and MEM) are in a good agreement.

- Within the total experimental uncertainties, no dependence of the parameters r_G and λ on the target atomic mass is observed.

Backup

Data/MC comparison