MTA Wigner FK, RMI, Femtoscopy Research Group

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(*): Listed at the Hadron Physics Research Group, retired during 2017

The Femtoscopy Research Group is actively participating both in **theoretical and experimental research**. The **PHENIX** experiment at the RHIC accelerator is in the data analysis phase at Brookhaven National Laboratory publishing in Nature Physics in 2018, while the **TOTEM** experiment at Large Hadron Collider (LHC) at CERN continued its data taking and data analysis as well. During 2018, we have achieved important breakthroughs in theory, as well as in PHENIX and also in TOTEM.

In our **theoretical femtoscopy related research**, related to proton-proton and heavy ion physics at RHIC and LHC,

- We have written a series of four manuscripts on a new family of exact solutions of 1+1 dimensional relativistic fireball hydrodynamics with acceleration and realistic equation of state.
- As applications, we have evaluated the pseudorapidity distributions, the longitudinal HBT radii and the initial energy density in proton-proton and heavy ion collisions at RHIC and LHC.

We have reached a **break-through** in our **theoretical femtoscopy** research related to imaging of the **internal structure of the protons** at LHC energies. With our model-independent Lévy imaging method,

- We have reconstructed the scattering amplitude of high-energy proton-proton elastic scattering processes and determined the excitation function of the shadow profile P(b) of elastic proton-proton $_{and}$ proton-antiproton collisions at the TeV scale.
- **We have identified** significant differences of the four-momentum transfer dependence of the elastic slope B(t) between proton-proton and proton-antiproton collisions, **a clear-cut Odderon effect, indicating the discovery of a new quasi-particle at LHC,** a vector glueball - a quarkless bound state of odd, predominantly 3, number of gluons.

In our **experimental femtoscopy research in the CERN LHC experiment TOTEM**, we have made significant contributions to the

- measurement of the differential cross-section of elastic proton-proton (pp) collisions at 13 TeV
- measurement of the differential cross-section of elastic pp collisions at 2.76 TeV, and to the
- publication of the first measurements of the pp total cross-section at 13 TeV.
- For these achievements, the **Hungarian TOTEM group** received the **2018 TOTEM Achievement Award** and F. Nemes the **2018 TOTEM Publication Award**.

In our **PHENIX related femtoscopy research**, we have made two important discoveries in 2018:

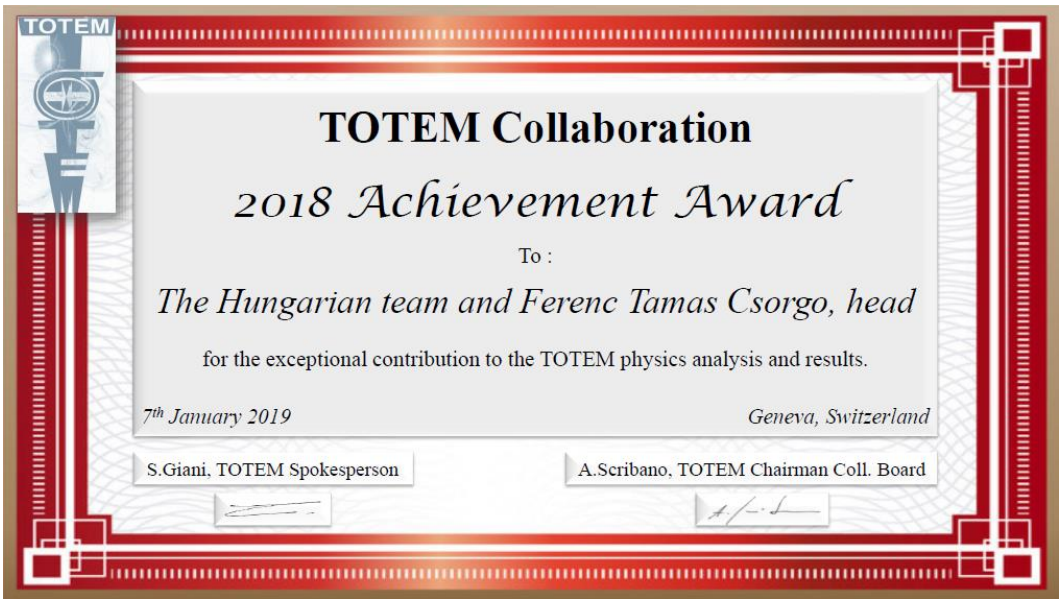
- In p+Au, d+Au and ^{3}He+Au collisions at $\sqrt{s_{NN}}$ = 200 GeV feature **droplets of a perfect fluid with three distinct geometries** on the femtometer scale, thus tiny droplets of strongly interacting quark gluon plasma can be engineered. This PHENIX result was published in **Nature Physics**.
- In 0-30% central Au+Au collision at 200 GeV, the shape of the Bose-Einstein correlation function is significantly different from the Gaussian shape, however, the Levy form describes these data precisely. The PHENIX paper on **Levy stable Bose-Einstein correlations** in $\sqrt{s_{NN}}$ = 200 GeV Au+Au collisions indicated results that are not inconsistent with a **significant mass drop of η' mesons**.

Grants:

- Hungarian - Ukrainian Academies of Sciences bilateral grant NKM-092/2017-18 (PI: T. Csörgő)
- Participation, NKTIH FK 123842 and FK 123959 grants (PI: M. Csanád, ELTE & A. László, Wigner)
- Participation in EFOP EFOP 3.6.1-16-2016-00001 grant (PI: Papp József, EKE)
- Participation in WG0839/2018 Circles of Knowledge Club – Wigner RCP sponsorship agreement

International cooperations:

- **PHENIX** Collaboration (**Brookhaven National Laboratory,** USA): Memorandum of Understanding between the **PHENIX** Experiment and KFKI representing the PHENIX-Hungary team (Hungarian Principal Investigator: M. Csanád (ELTE), participants in 2018: T. Csörgő, G. Kasza, D. Kincses, T. Novák, J. Sziklai.
- **TOTEM** Collaboration (CERN LHC, Svájc). Hungarian Principal Investigator: T. Csörgő, other participants in 2018: T. Csörgő, F. Nemes, I. Szanyi, J. Sziklai.
- **CERN,** Memorandum of Understanding for Collaboration in the Construction of the **TOTEM** detector and Memorandum of Understanding for the Maintenance and Operation of the TOTEM detector at LHC (Hungarian Principal Investigator T. Csörgő (Wigner RCP and EKE KRC). During 2017 this membership lead us to participation in the **CMS** Precision Proton Spectrometer, too.
- **Bogoliubov Institute for Theoretical Physics** (Kiev, Ukraine): bilateral grant NKM-092/2017-18 . Hungarian PI : T. Csörgő, Ukrainian PI: D. Anchiskin
- **Lund University** (Lund, Sweden) – Wigner RCP, Memorandum of Understanding on bilateral collaboration (T. Csörgő, A. Ster, with L. Lönnblad , G. Gustafson and R. Pasechnik from Lund).
- **State University of New York at Stony Brook** (Stony Brook, NY, USA) – Wigner RCP, Memorandum of Understanding on bilateral international collaboration (PIs T. Csörgő, R. Lacey (SUNY SB)). Participants in this collaboration: T. Csörgő, D. Kincses.
- **Radboud University** (Nijmegen, The Netherlands) Bilateral international collaboration. Participants during 2018: T. Csörgő, T. Novák as well as W. Metzer (Nijmegen).
- **Central China Normal University, Wuhan, China:** Bilateral international collaboration. Participants during 2018: T. Csörgő, G. Kasza as well as Z.-F. Jiang (Wuhan).



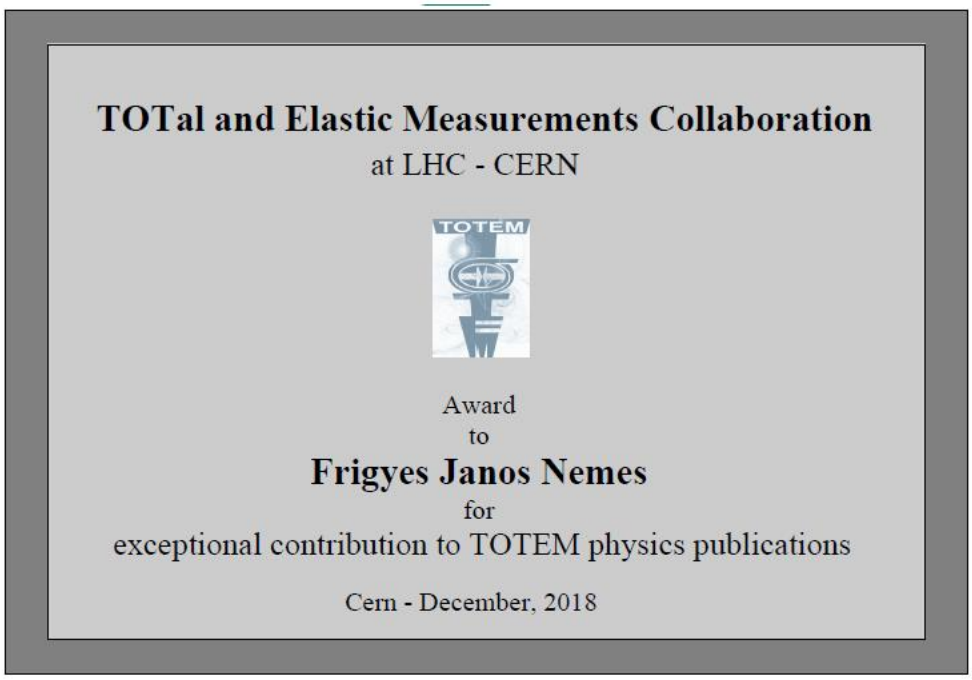


Figure 1. *Two of our awards received in 2018. Top:* ***TOTEM Collaboration 2018 Achievement Award*** *to the Hungarian team and the head of the group, given by Prof. S. Giani, Spokesperson of the TOTEM experiment at CERN LHC and Prof. Angelo Scribano, Chair of the TOTEM Collaboration Board. Bottom:* ***2018 TOTEM Physics Publication Award*** *to F. Nemes.*

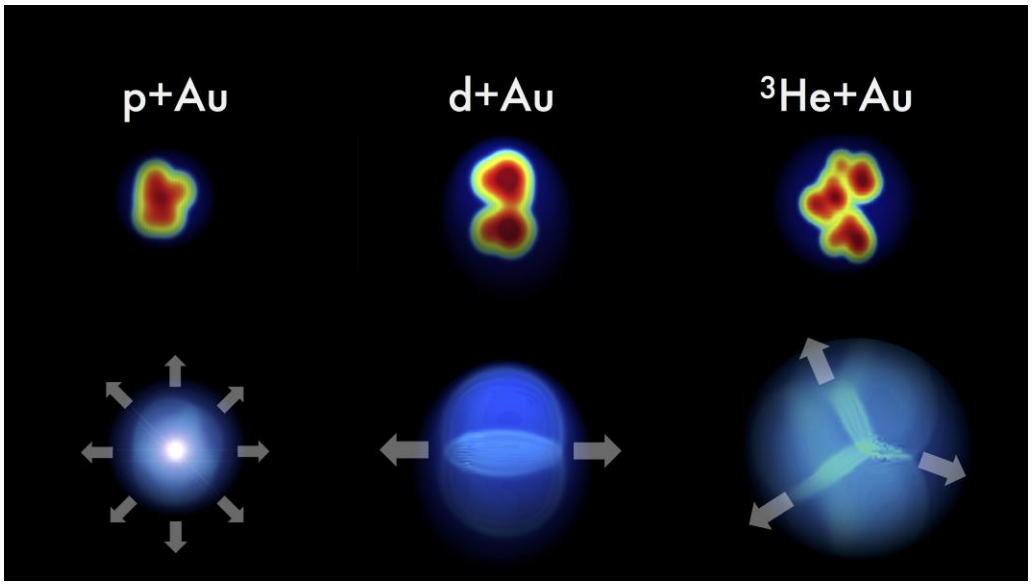


Figure 2: *In proton-gold (p+Au), deuteron-gold (d+Au) and helium-gold (3He+Au) collisions at RHIC, the observation of the elliptic and triangular shape of the final state momentum distribution indicates that circular, linear and triangular shapes of quark matter or strongly interacting quark-gluon plasma droplets are engineered at √sNN = 200 GeV colliding energy.* Source: *Creation of quark–gluon plasma droplets with three distinct geometries*, **Nature Physics** (12/10/2018), **DOI:** 10.1038/s41567-018-0360-0 by **PHENIX Collaboration:** Aidala C, Akiba Y, Csanád M, Csörgő T, T. Novák, J. Sziklai et al.