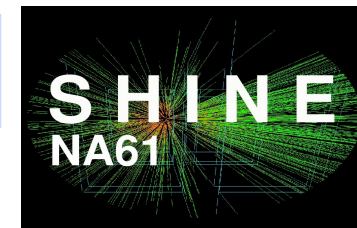


Ultra-relativistic Heavy-Ion Collision Experiments

Adam Kisiel
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Institutions in Poland:

- Jagiellonian University, University of Silesia, Jan Kochanowski University, University of Warsaw, Warsaw University of Technology, National Center for Nuclear Studies, University of Wrocław

Participants:

- 24 staff, 9 PhD students, 3 support

Main contribution:

- Construction of Quartz and Gas Cherenkov Z-detectors (20 kCHF)
- Significant contribution to construction of PSD detector
- Building of new beam position detectors (BPD) + electronics (25 kCHF)
- New Detector Control System (DCS), LabVIEW → EPICS (under development) (8k CHF + 160k CHF planned)

Main responsibilities:

- During data taking: maintenance, supervision (and development) of: DCS, web-based utilities, gas system of TPCs, BPDs, experimental databasis
- Significant contribution to data calibration and reconstruction
- Analysis of data for neutrino physics: measurement of cross-section and hadron spectra in p+C interaction at 31 GeV
- Analysis of data for ion program: spectra and yields ($K^{+/-}$, $\pi^{+/-}$, (anti-)protons, (anti-)lambdas, K^* resonance, etc.), fluctuations and correlations (multiplicity, p_T , azimuthal angle, chemical composition). Supervision of all analyses within NA61 ion program

Financing:

- N N202 3956 33 (MNiSW) 439 950 zł, 667/N-CERN/2010/0 (MNiSW) 2 720 000 zł, N N202 180638 (MNiSW), application 5 181 704 zł (NCN)



The most interesting region of the phase diagram is covered by SPS!

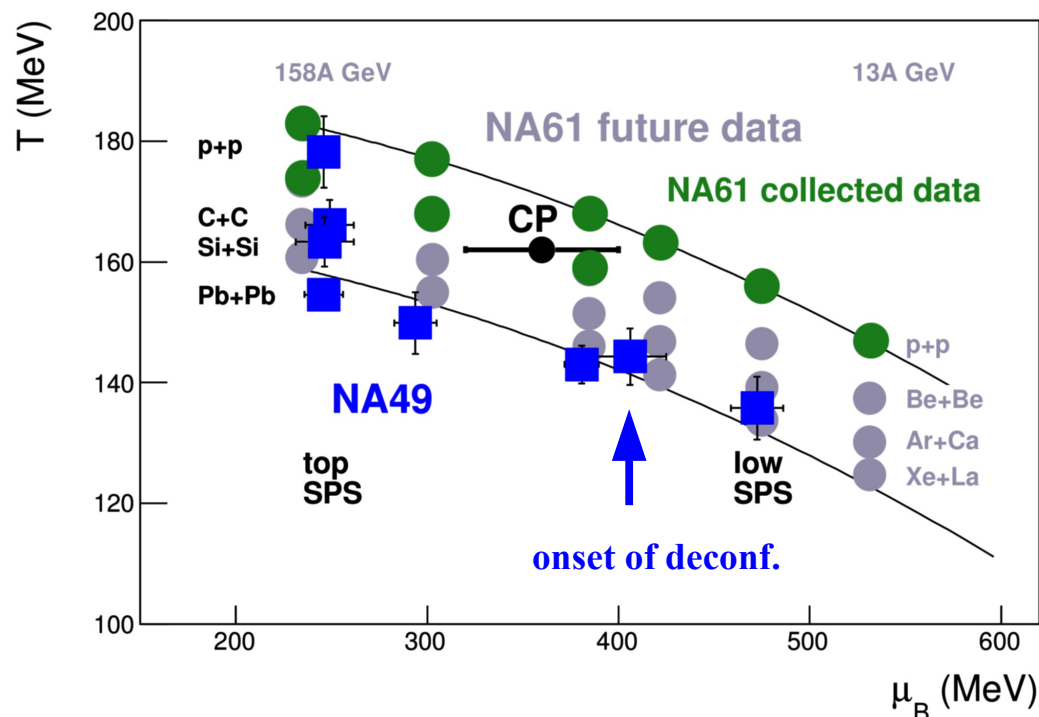
- Onset of deconfinement at ≈ 30 AGeV

Alt et al. (NA49), PR C77, 024903 (2008)

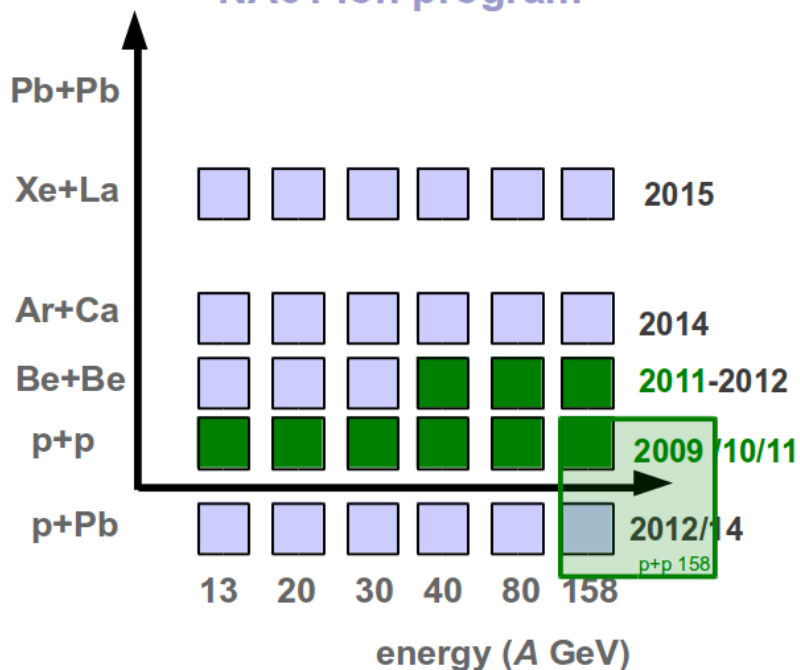
- Critical point?

$$(T^{\text{CP}}, \mu_B^{\text{CP}}) = (162 \pm 2, 360 \pm 40) \text{ MeV}$$

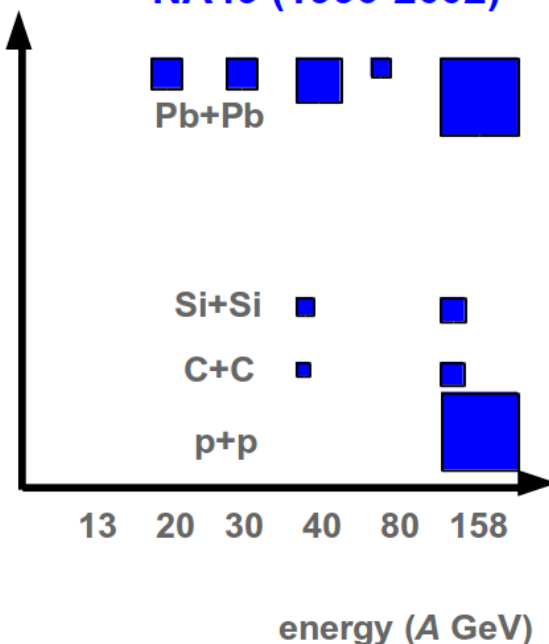
Fodor and Katz, JHEP 0404, 050 (2004)



NA61 ion program



NA49 (1996-2002)

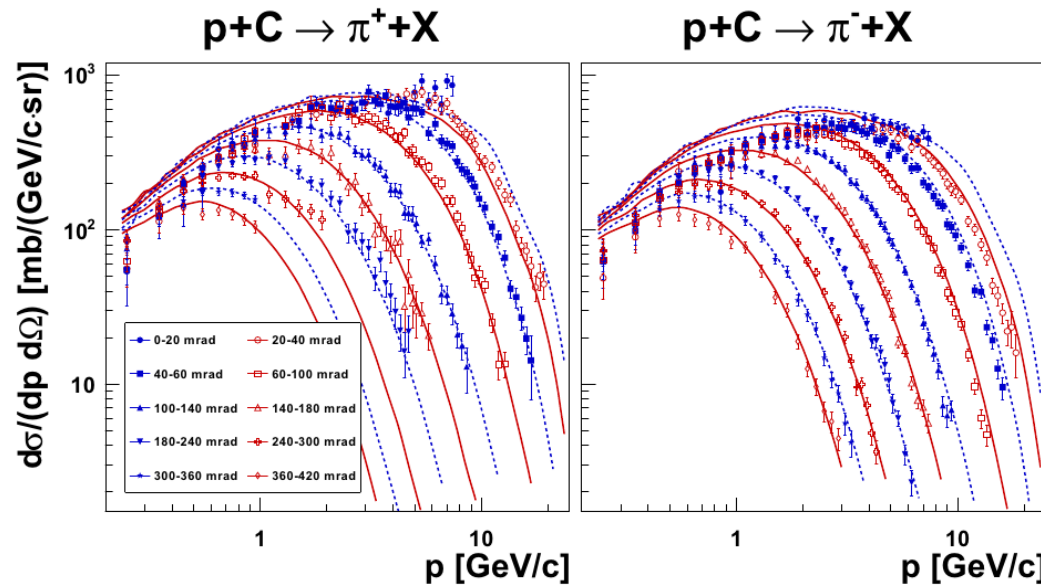


NA61/SHINE ion program:
comprehensive scan in the
whole SPS energy range
(13-158 AGeV) with **light
and intermediate mass
nuclei**

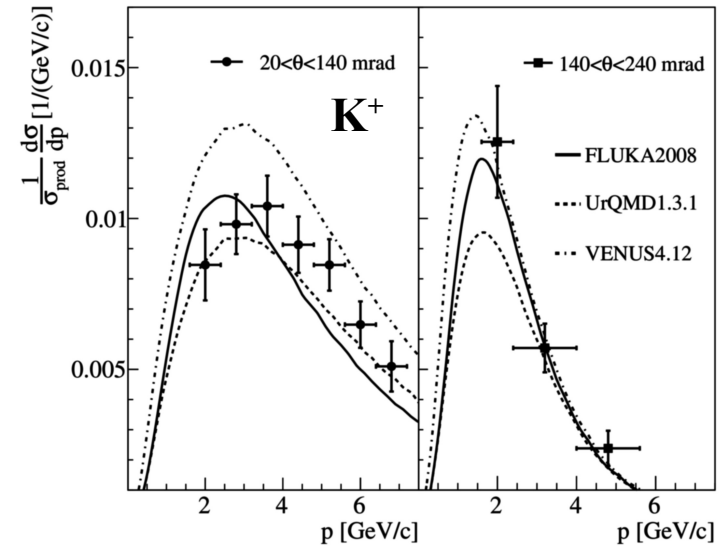
First time in history when
such a 2D scan (energy,
system size) will be
performed

Results from p+C at 31 GeV

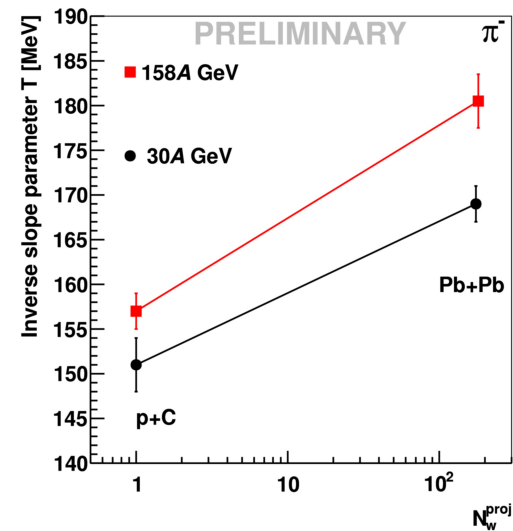
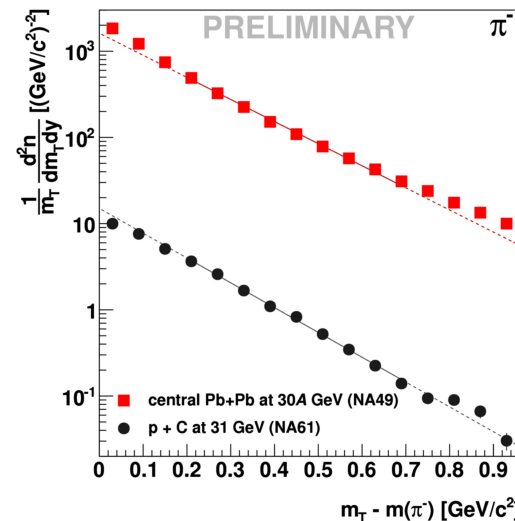
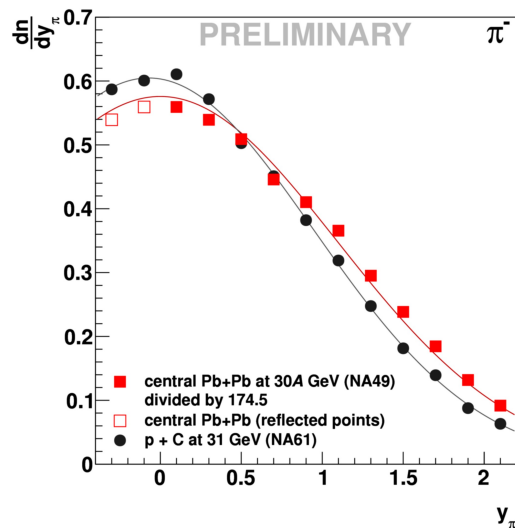
PR C84, 034604 (2011)



PR C85, 035210 (2012)



comparison to patched UrQMD1.3.1 (arXiv:1107.0374v1)



arXiv:1201.5879;

arXiv:1201.0742

Fitted in:
 $0.2 < m_T - m(\pi^-) < 0.7$ GeV/c²

Pilot results on hadron production (spectra and fluctuations) in p+p interactions at 20, 31, 40, 80 and 158 GeV are ready and they will be shown on summer conferences



Institutions in Poland:

- Warsaw University of Technology, The H. Niewodniczański Institute of Nuclear Physics Polish Academy of Sciences, AGH University of Science and Technology, Cracow University of Technology

Participants:

- 5 staff, 4 PhD students

Main contribution:

- Contribution to the STAR apparatus upgrade (power supplies for the Roman Pots) 110 k PLN
- Planned: Dedicated Computing facility for STAR reconstruction

Main responsibilities:

- Analysis of femtoscopic two-particle correlations (meson + baryon)
- Convenorship of the BulkCorr Physics Analysis Group
- Participation in the Energy Scan Programme
- Analysis of the J/Psi production and polarization
- Analysis of the elastic, diffractive and ultraperipheral data
- Significant contribution to the offline computing software, computer simulations and participation in the installation works of the Roman pots detectors.

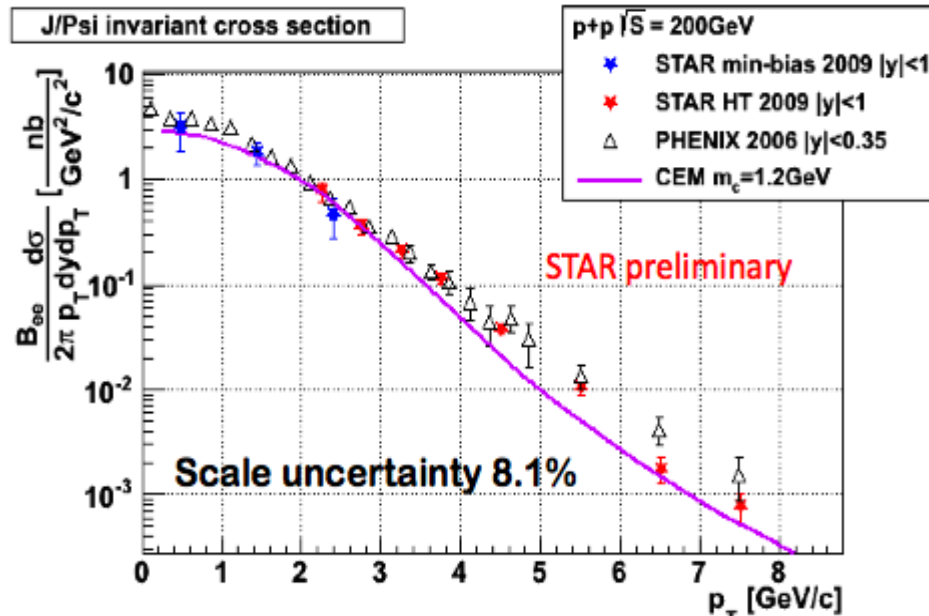
Financing:

- 2011/01/M/ST2/04126 (NCN) 1 418 602 PLN

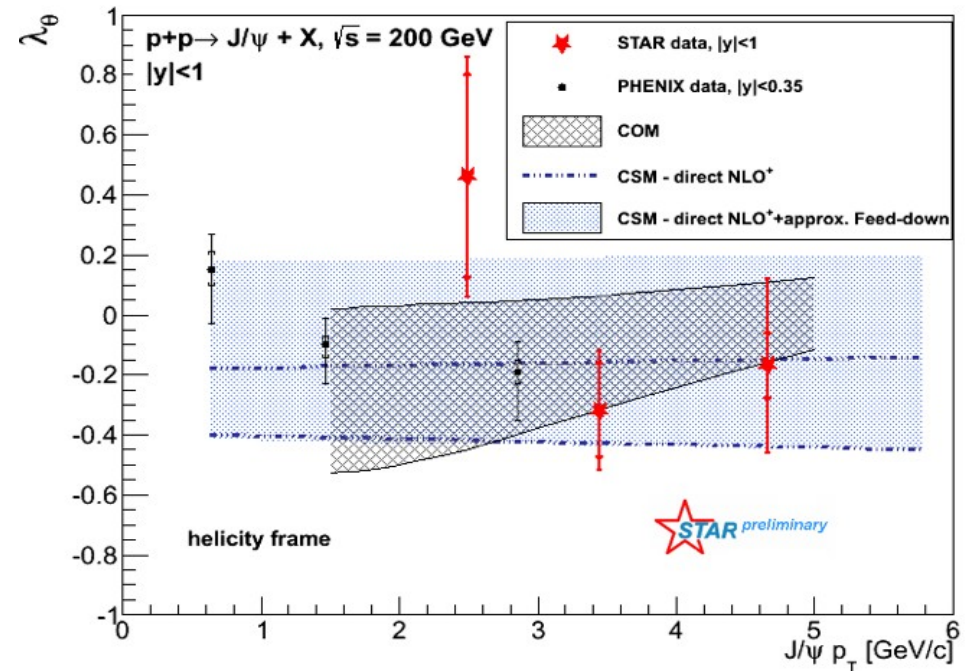


J/ψ production and polarization in p+p collisions at $\sqrt{s} = 200$ GeV in STAR

J/ψ p_T spectrum



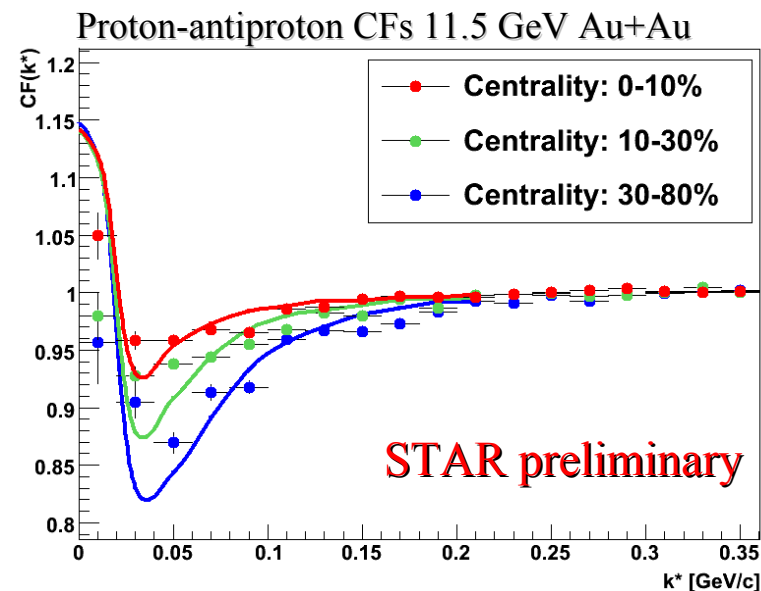
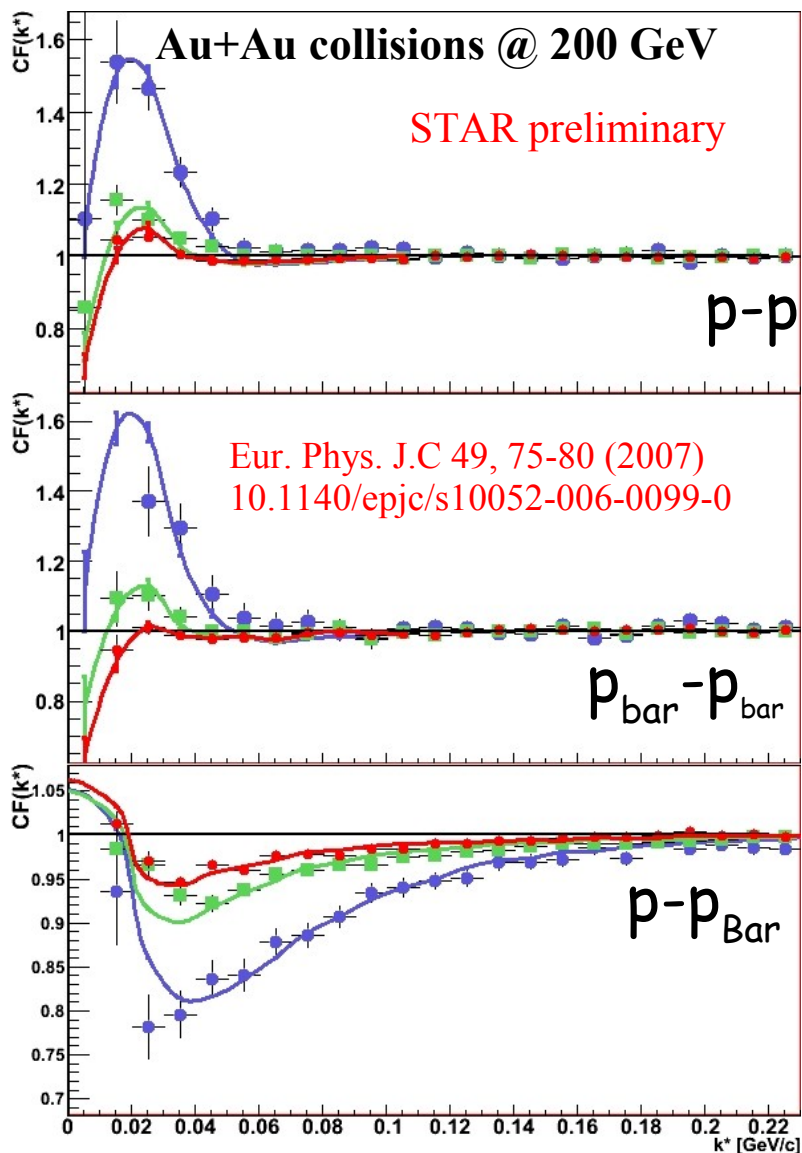
J/ψ spin alignment (polarization)



- ✓ J/ψ production measurement for min-bias data, in 0-3 GeV/c p_T range
- ✓ J/ψ production cross section: $40.6 \pm 6.0(\text{stat.}) [\text{nb}]$
- ✓ J/ψ polarization measured in 2-6 GeV/c p_T range, polarization parameter λ extracted in helicity frame in 3 $J/\psi p_T$ bins
- ✓ Obtained p_T dependent polarization parameter consistent with NLO+ CSM, COM model predictions and with no polarization within current theoretical and experimental uncertainties

Baryon Femtoscopy

- ✓ Baryon femtoscopy an important cross-check for hydrodynamic evolution hypothesis
- ✓ Correlations with anti-baryons possible for the first time in accelerator experiments – due to low net baryon density
- ✓ Same analysis performed for the Beam Energy Scan programme at RHIC



Institutions in Poland:

- Warsaw University of Technology, National Centre for Nuclear Research, The H. Niewodniczański Institute of Nuclear Physics Polish Academy of Science

Participants:

- 18 staff, 6 PhD students, 3 other

Main contribution:

- M&O costs: $3 \times 50 \text{ kCHF} = 150 \text{ kCHF/yr.}$
- PHOS: 1000 crystals + electronics (500 kCHF)
- TPC – detector construction (500 kCHF)
- Planned: 500 kCHF for PHOS upgrade

Main responsibilities:

- TPC – software development, calibration
- PHOS – upgrade of detector electronics
- Convenorship of the Femtoscopy Physics Analysis Group
- Detector Construction DataBase (DCDB): maintenance&operation
- Data analysis – femtoscopic two-particle correlations (meson, baryon, pp vs. PbPb)
- Outreach&Offline – event display, visualization, MaterClass

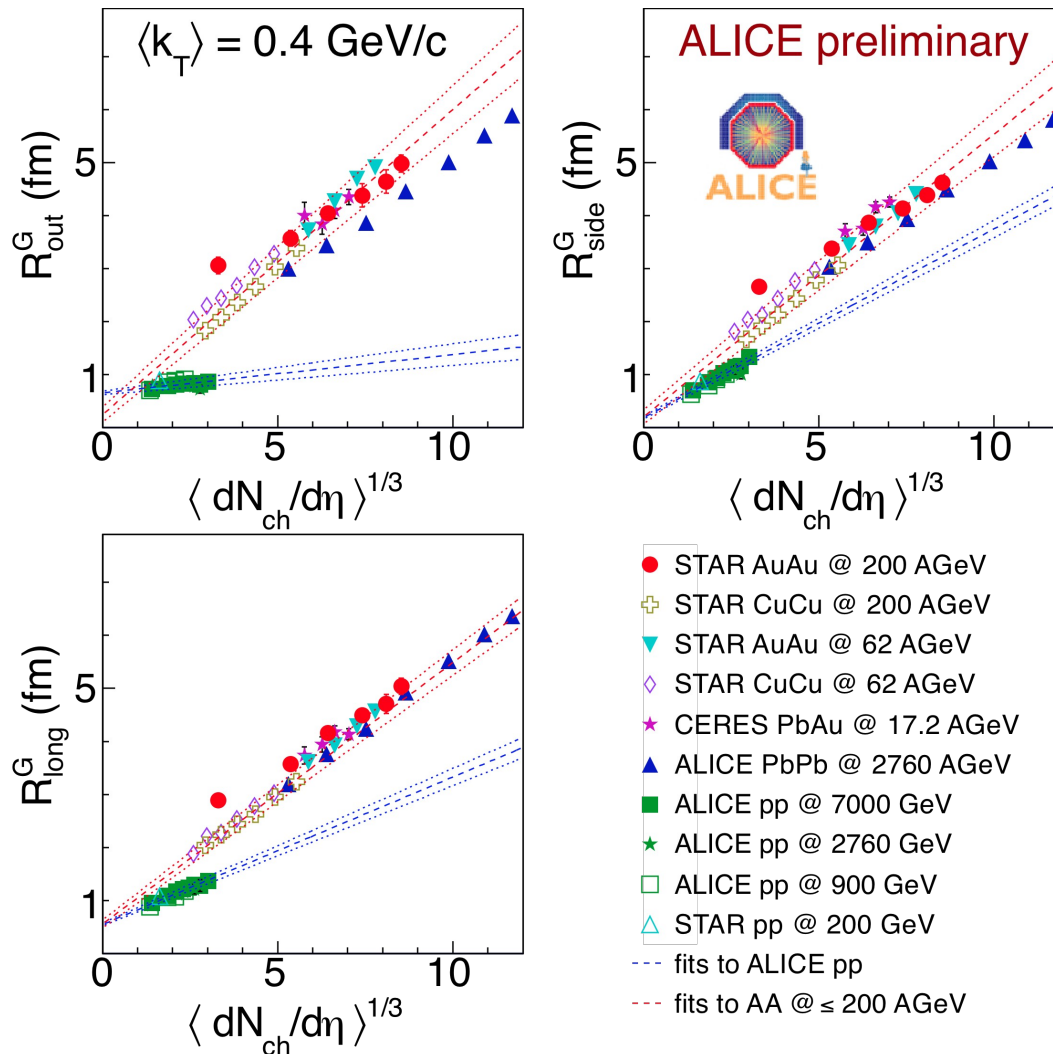
Financing:

- DPN/M2/3552/09/2010 (MNiSW) 3 883 000 PLN, 2011/01/B/ST2/03483 (NCN) 407 600 PLN



Pion Femtoscropy in ALICE

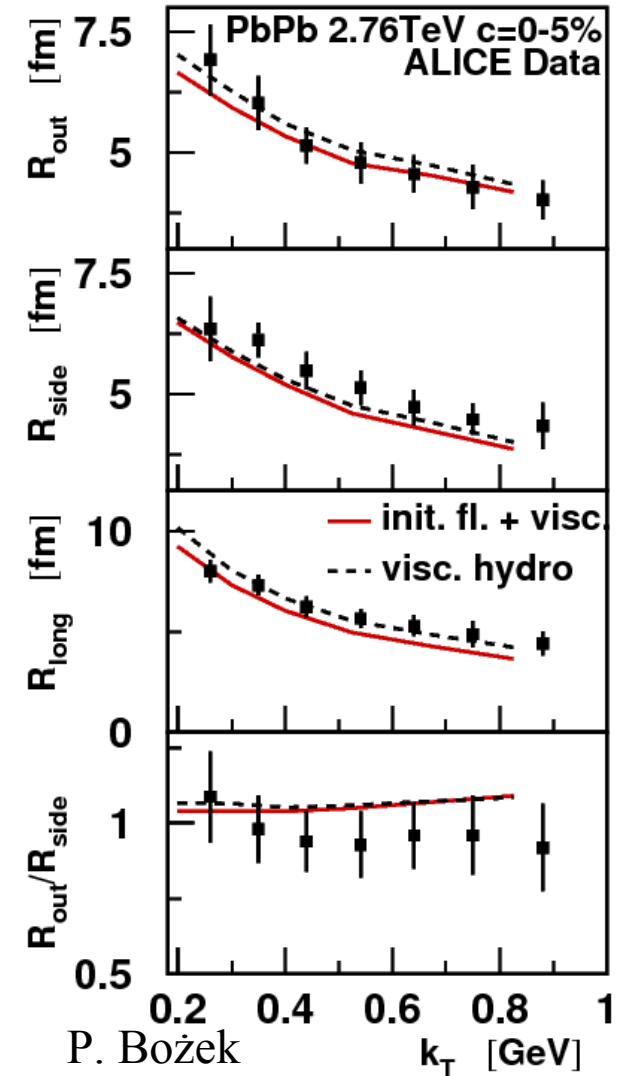
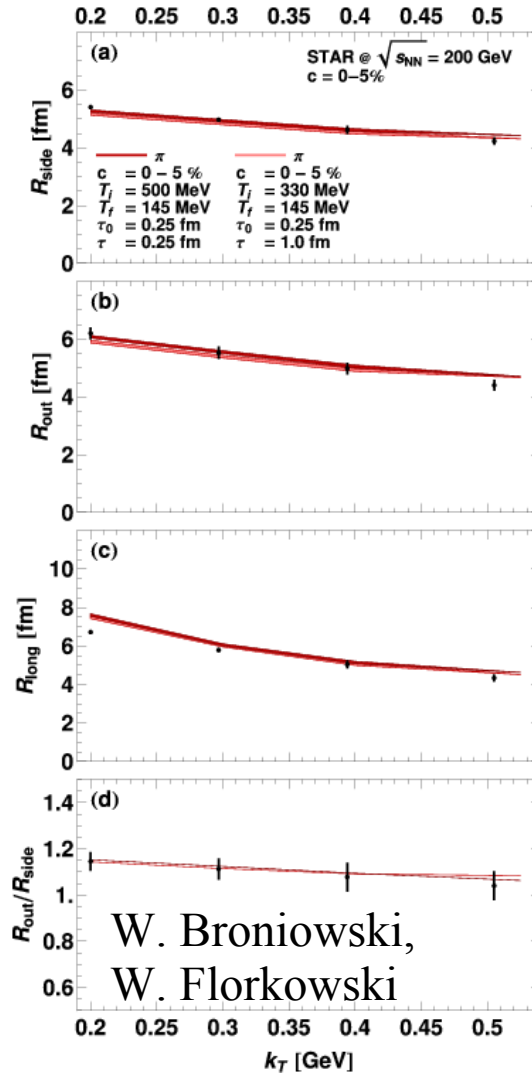
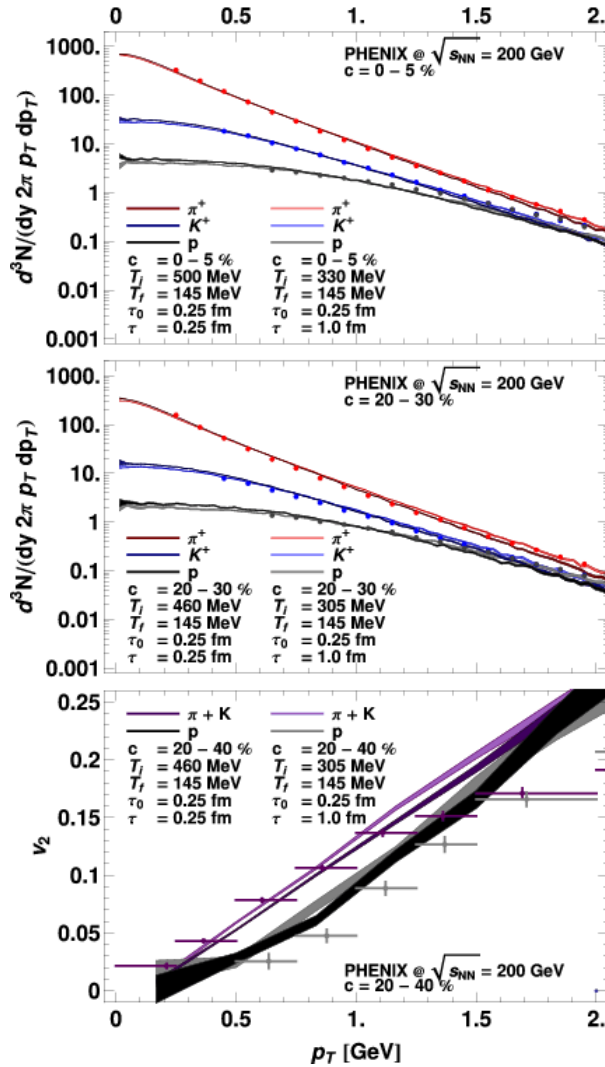
Pion femtoscopy in pp collisions at $\sqrt{s} = 0.9, 2.76, 7$ TeV and PbPb collisions at $\sqrt{s}_{NN} = 2.76$ TeV



- ✓ Pion femtoscopy with same apparatus for different collision types and vs. Collision energy
- ✓ For the first time multiplicity scaling seen in pp, but different from AA
- ✓ Linear scaling in AA seen (as expected), differences to RHIC trends observed, explained as consequences of hydrodynamic evolution of the system
- ✓ For the first time direct comparison of pp and AA possible at similar multiplicity – address the question of “initial” vs. “final” state driving the freeze-out shape and time

Connection to theory

- ✓ Hydrodynamics + statistical hadronization (THERMINATOR, THERMINATOR 2) successful at describing soft physics at RHIC (spectra, v_2 , femtoscopy)
- ✓ Versatile tool, being tailored to new tasks (LHC, 3+1 hydro, viscous hydro), adopted and used by other authors and experimental collaborations



Summary

- ✓ Several groups focused on ultra-relativistic heavy-ion physics present in a few scientific centers
- ✓ Basic funding secured for the participation in all experiments for the next few years
- ✓ Participation in experiments at all the main accelerator programs in the field (NA61 at SPS, STAR at RHIC, ALICE at LHC)
- ✓ Experimental data analysis focused on the selected topics, with where Polish groups can have significant contribution
- ✓ Successful collaboration with theory