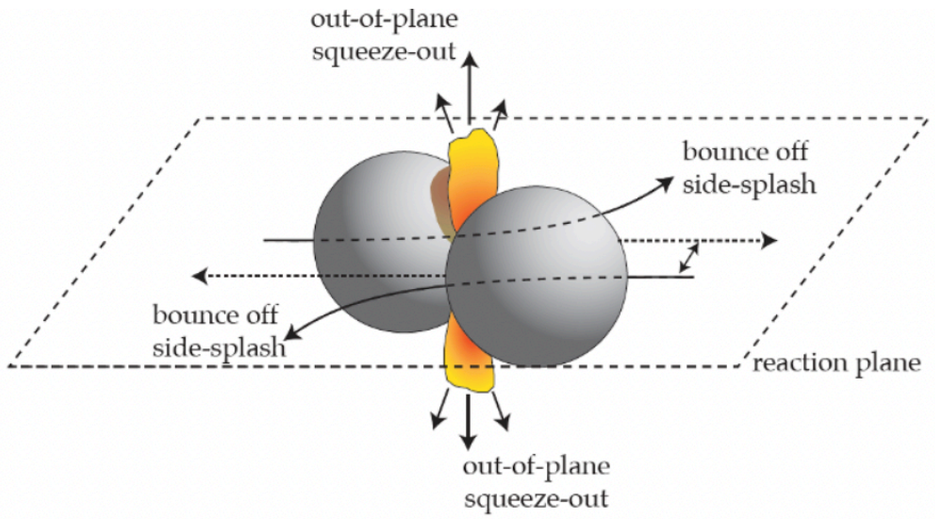
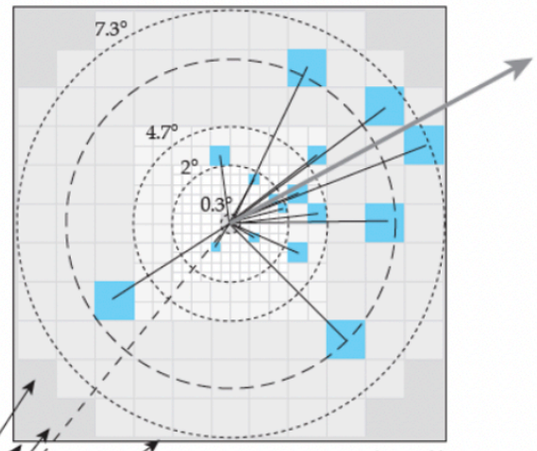
HADES - PWG Summary

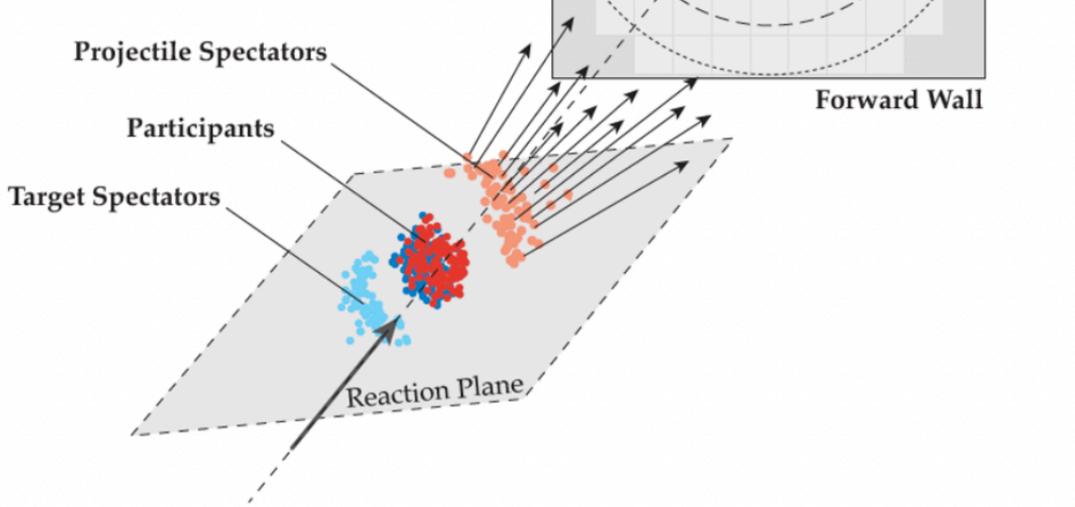
Correlations, Flow observables

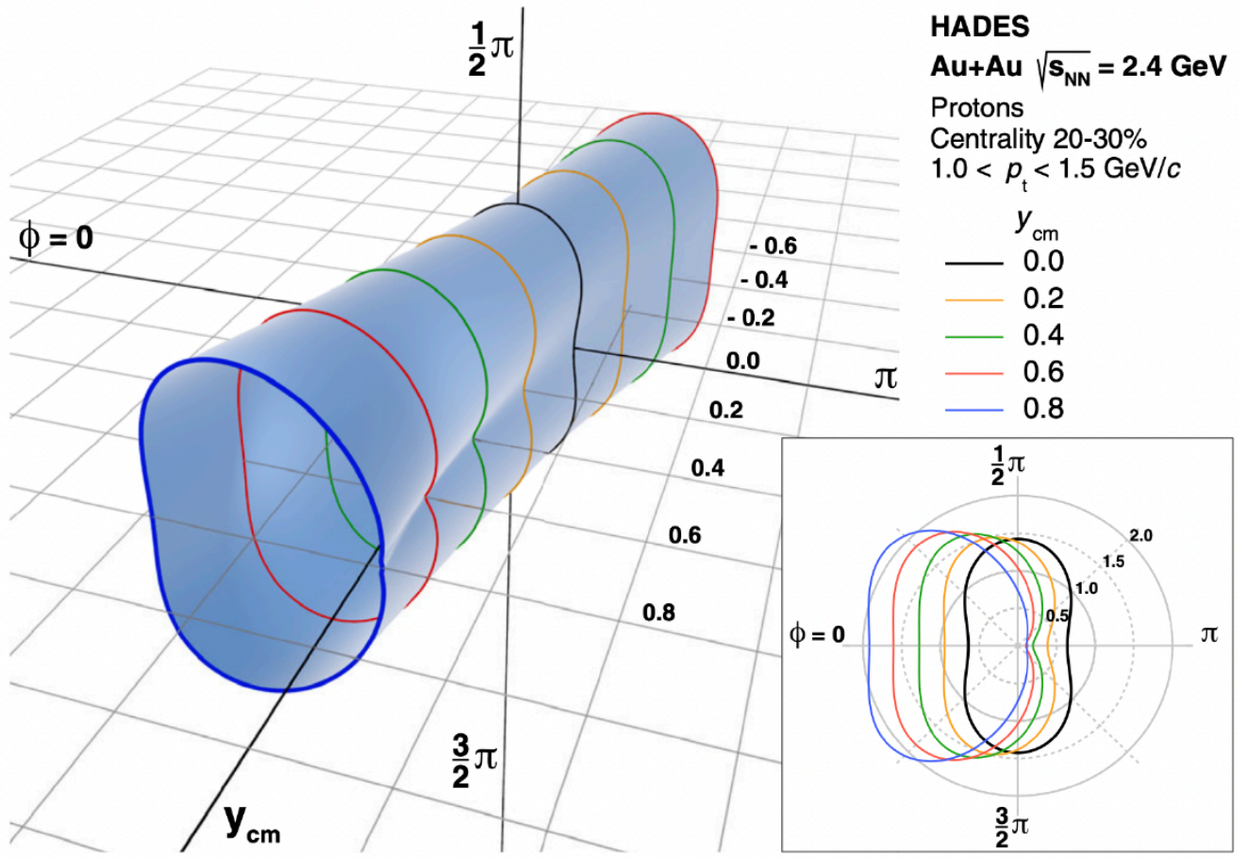
Christoph Blume
Hanna Zbroszczyk

HADES Analysis Meeting, Darmstadt, 22 - 24.07.2026







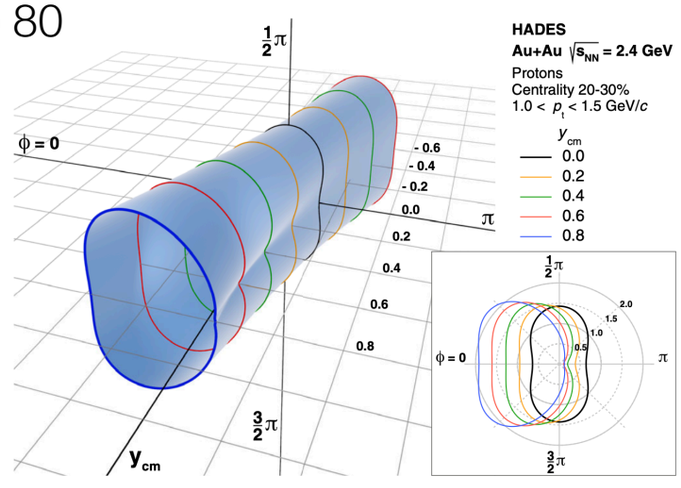


Flow Studies

… measure the anisotropies of particle emission. The flow coefficients are sensitive to basic matter properties, such as its equation-of-state, **viscosity**, etc. …

Overview on Topics

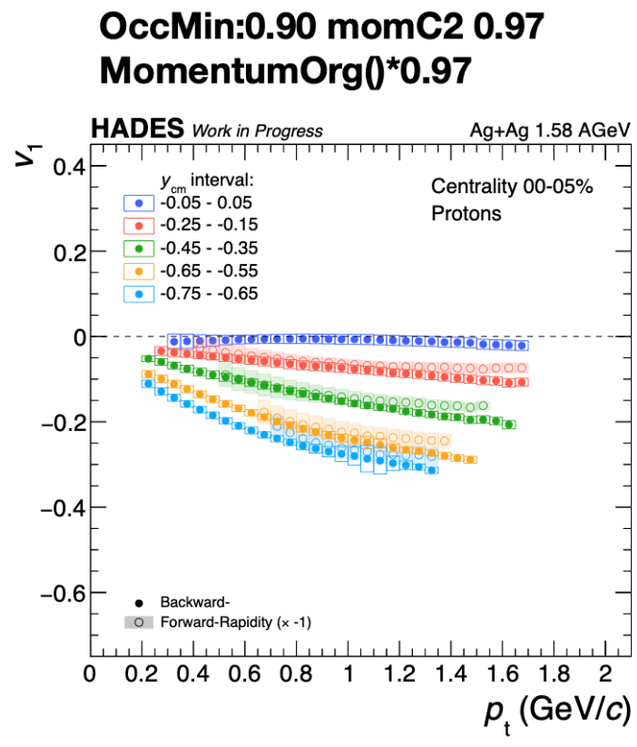
Phys. Rev. Lett. 125 (2020) 262301
Eur. Phys. J. A59 (2023) 80



- Flow of protons + light nuclei
  - **Behruz Kardan, Laura Lauf, Christopher Grimm, Patrick Schranz**
  - p, d and t flow in Au+Au at 1.23 AGeV
    Status: published
  - p, d, t and ^{3}He flow in Ag+Ag at 1.23+1.58 AGeV
    Status: paper in preparation
  - Flow fluctuations in Au+Au at 1.23 AGeV
    Status: first results
  - New analyses: hypernuclei flow and neutron flow
- Flow of strange particles
  - Jan Orliński
  - Λ flow in Ag+Ag at 1.58 AGeV
  - New: Φ and K^0_s, ...
  - Status: analysis advanced, move to publication?
- Global Λ polarization
  - Florian Alef
  - Status: methods verified and first results
- Strangeness fluctuations
  - Athira Sreejith
  - Status: analysis on-going

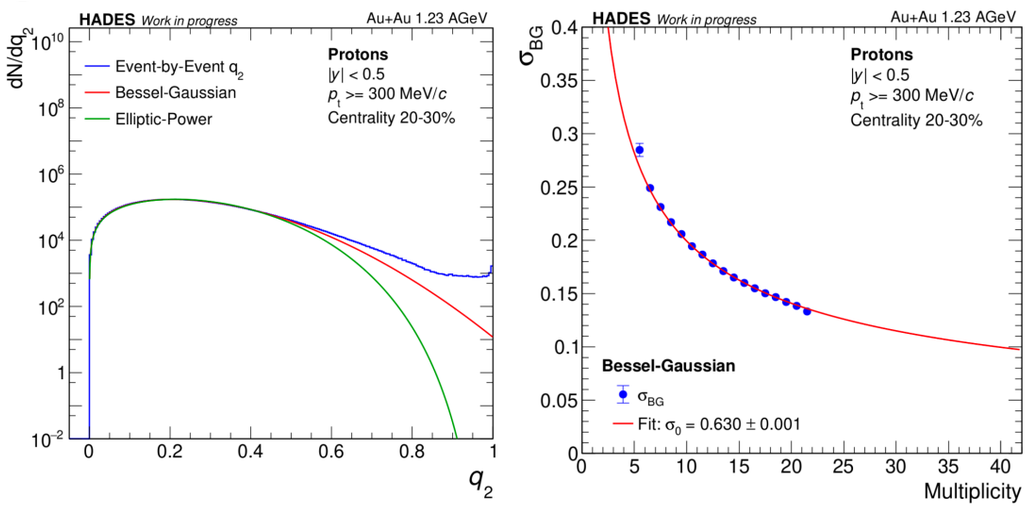
Flow of Protons + Light Nuclei

- p, d, t and ^{3}He flow in Ag+Ag at 1.23+1.58 AGeV
  - Analysis by **Behruz Kardan**
  - Paper draft has been started
  - Some issues showed up during paper preparation
  - Detailed discussion in PWG meeting: https://indico.gsi.de/event/25235/
- Done
  - Momentum determination at high p needs modification, reasonable solution available
  - AgCRemover (see talk by Niklas Schild on Tues.) now implemented
  - E-by-E correction of event plane resolution
  - Occupancy correction adjusted against momentum
- On-going
  - Purity of light nuclei ID: background assessment with real data
  - Finalize figures
  - See talk on Tues.



Flow of Protons + Light Nuclei

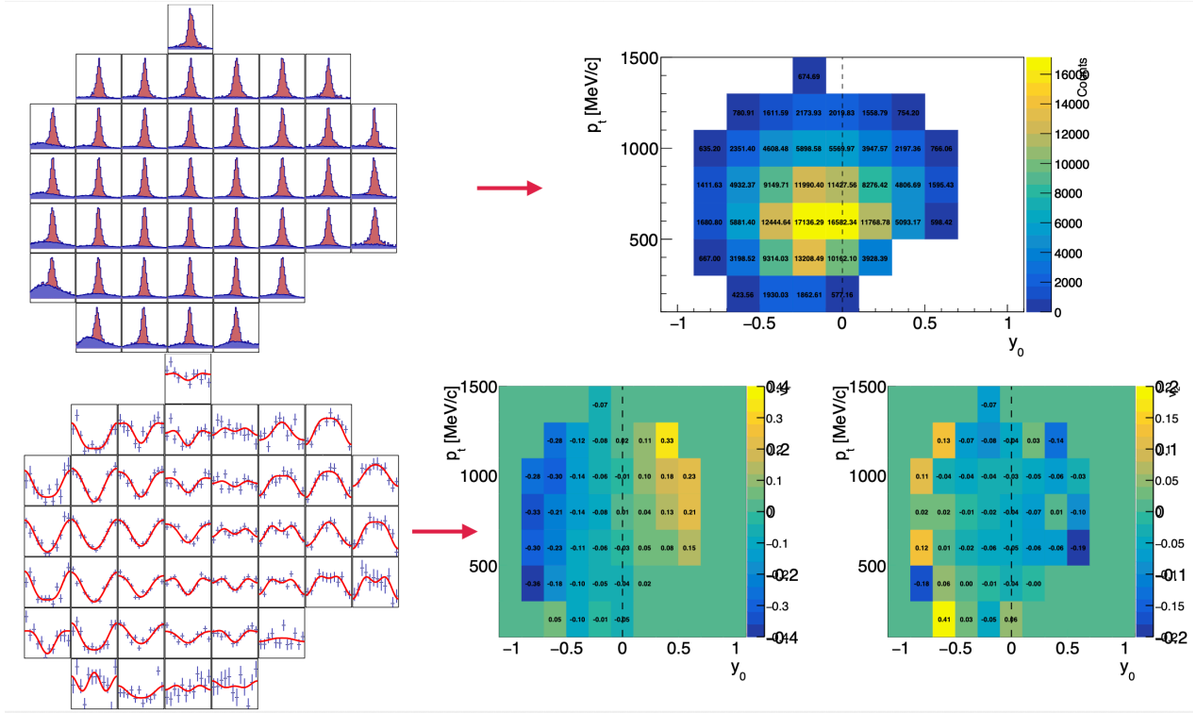
- Flow fluctuations in Au+Au at 1.23 AGeV
  - Analysis by **Laura Lauf** (MA-Thesis finished, left group)
  - E-by-E event plane resolution correction developed
  - Fluctuations of Q-Vector magnitude
  - Parameterization with Bessel-Gaussian or Elliptic-Power function possible
  - Allows extrapolations to infinite multiplicities
  - First results, should be explored further (systematic uncertainties, model comparisons, etc.)



- New analyses
  - Hypernuclei flow in Ag+Ag at 1.58 AGeV: Christopher Grimm (MA-Thesis)
  - Exploration of neutron flow in Ag+Ag at 1.58 AGeV: Patrick Schranz (BA-Thesis)

Flow of Strange Particles

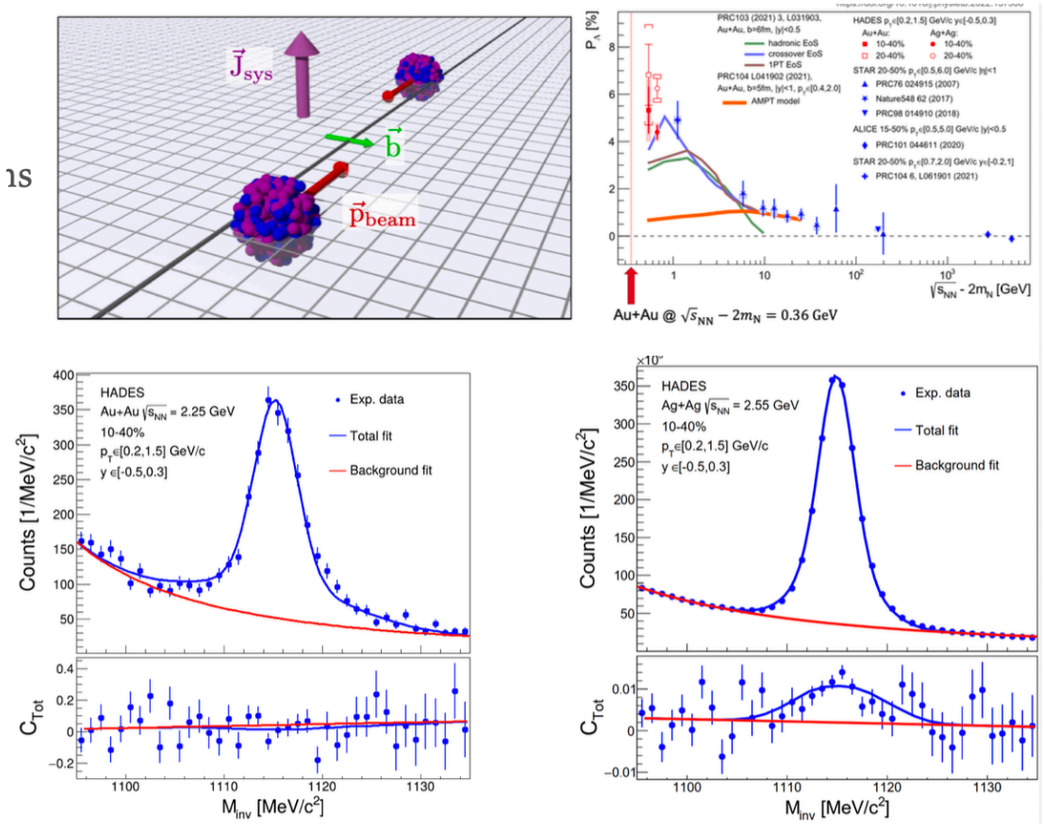
- Λ flow in Ag+Ag at 1.58 AGeV
  - Analysis by **Jan Orliński**
  - Study of medium interaction of strange particles (⟹ hyperon puzzle)
- Recent updates
  - Use of MVA for Λ identification
    ⟹ larger acceptance
  - Event mixing for background evaluation
  - Efficiency + acceptance available
- On-going
  - Occupancy correction
  - Systematic uncertainties
  - New particles: Φ and K^0_s (see talk on Tues.)
- Should start publication process soon (?)



Global Λ Polarization

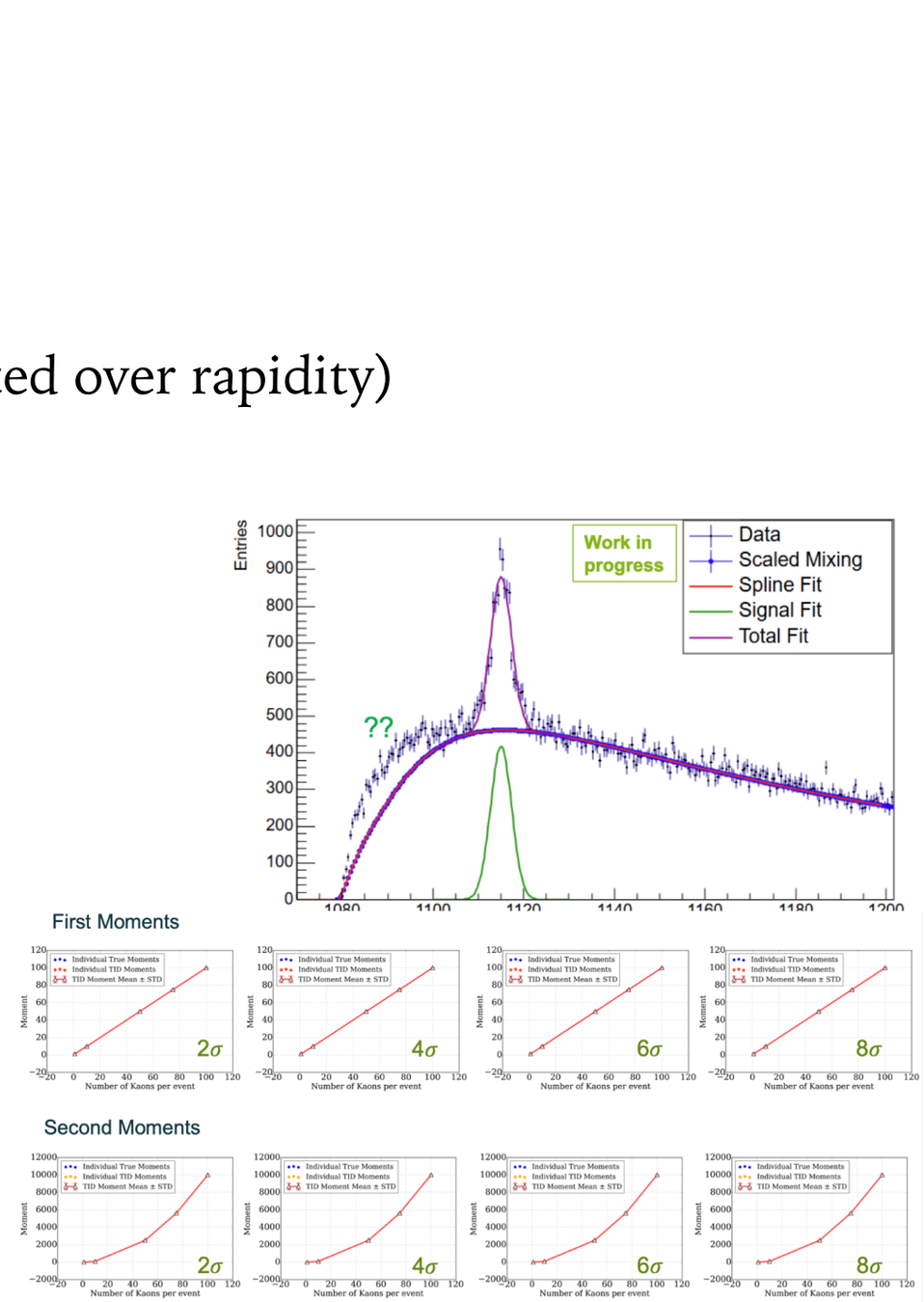
- Energy dependence of global Λ polarisation
  - Analysis by **Florian Alef**
  - Locate the onset of the polarization signal
- Recent updates
  - Reproduced old Au+Au analysis by Frederick Linz
  - First signal in Ag+Ag at 1.58 AGeV
    $P_\Lambda[\%] = 3.98 \pm 0.30$ (efficiency corrected)
- Outlook
  - Au+Au at 0.8 AGeV
  - Optimization of NN training
  - Challenge: sub-threshold Λ production

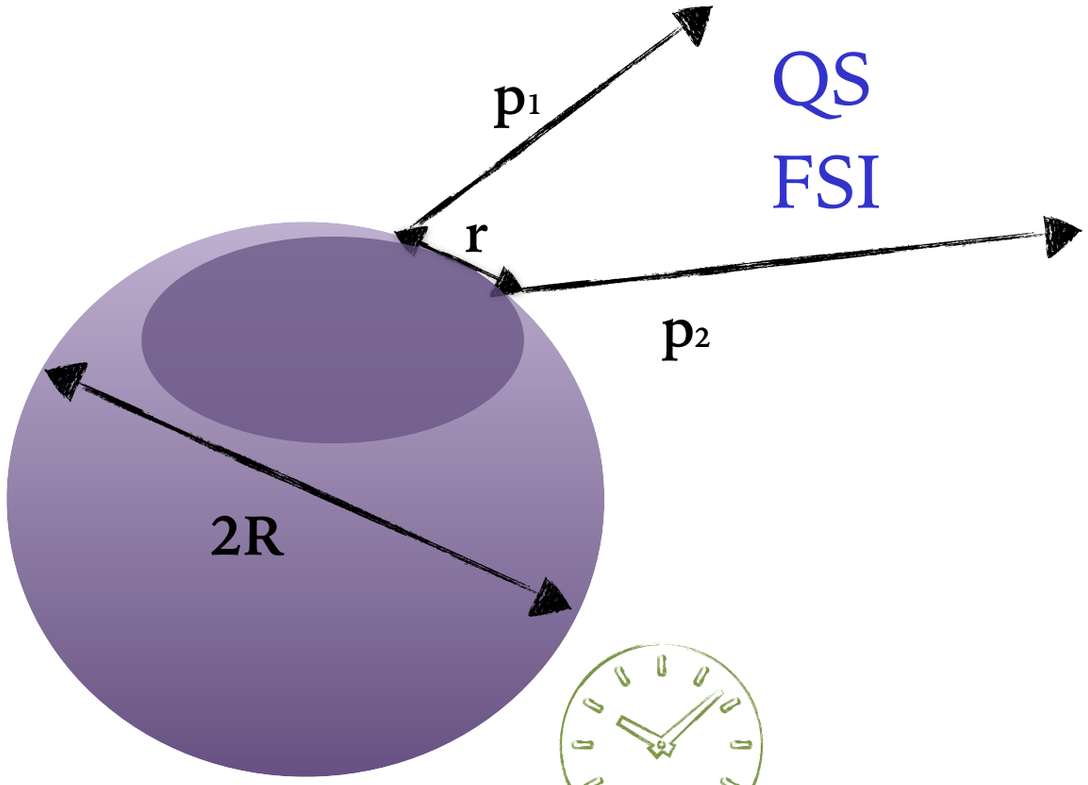
$\Longrightarrow$ low signal and higher background (Au+Au)

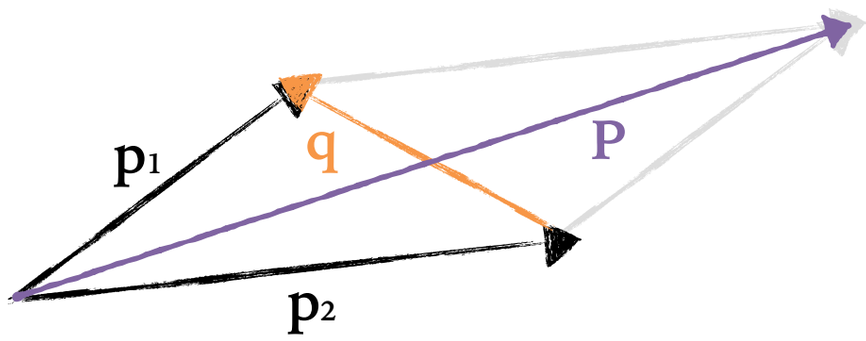


Strangeness Fluctuations

- Strangeness fluctuations in Ag+Ag at 1.58 AGeV
  - Analysis by **Athira Sreejith**
  - Fluctuations of conserved charges:
    sensitive to phase transition
- Recent updates
  - Agreement between calculated and expected value
    for moments of kaons (integrated over rapidity)
  - Larger rapidity windows required for Kaon fluctuations
- Outlook
  - Feasibility of Λ fluctuation analysis
  - See talk on Tues.

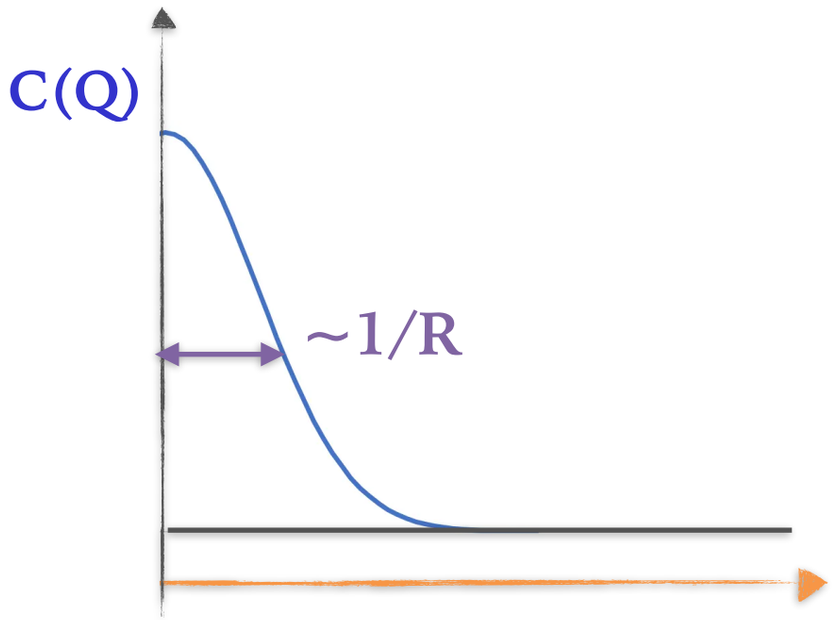






$10^{-23}\ s$

Femtometer $10^{-15}\ m$



Femtoscopy

… the method to probe **geometric** and **dynamic** properties of the source (emission region, range of correlations-interactions, phase-space cloud, …)
Femtoscopy does not measure the whole source, but homogeneity length.

$\gamma - \gamma$ correlations

Main Contributor: **Mateusz Grunwald**

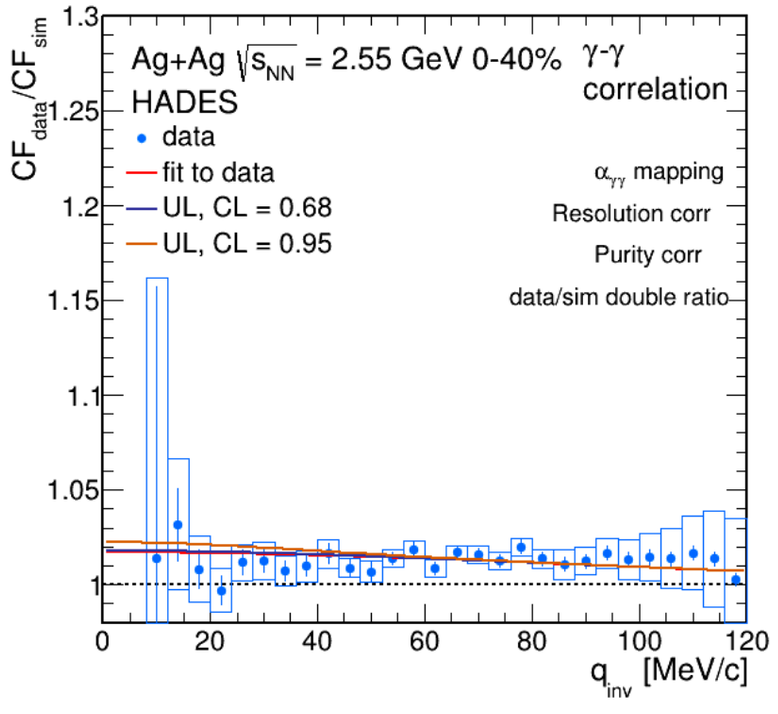
Physics Motivation:
To look for the signal from (direct) photons.

Status:
Analysis complete

Milestones achieved:
Estimated limits for direct phot

What's left:
Finalize paper

	Fit to data	1σ (CL=0.68) upper limit	2σ (CL=0.95) upper limit
χ^2 (fit)	33.13	34.47	43.60
NDF	19	21 (all par fixed)	21 (all par fixed)
χ^2/NDF	1.74	1.64	2.08
$\lambda_1 \cdot 10^{-2}$	0 +/- 0.06	0.08	0.53
$\Delta\chi^2$	-	1.34269	10.4759
$\Delta\chi^2_{crit}$	-	1.34494	10.4935



Eur. Phys. J. C manuscript No.
(will be inserted by the editor)

Study of two-photon femtoscopic correlations in Ag+Ag collisions at $\sqrt{s_{NN}}$ = 2.55 GeV with HADES

HADES collaboration

R. Abou Yassine[7,14], J. Adamczewski-Musch[6], C. Asal[9], M. Becker[12], A. Belounnas[14], A. Blanco[2], C. Blume[9,6,e], L. Chlad[15,g], P. Chudoba[8], I. Ciepał[4], J. Dreyer[8], W.A. Esmail[6], L. Fabbietti[11], H. Floersheimer[7], J. Förtsch[18], P. Fonte[2,a], J. Friese[11], I. Fröhlich[9], T. Galatyuk[7,6,c], R. Greifenhagen[8,d], M. Grunwald[17], M. Gumberidze[6], S. Harabasz[7,14], T. Heinz[6], C. Höhne[12,6], F. Hojeij[14], R. Holzmann[6], H. Huck[9], M. Idzik[3], B. Kämpfer[8,d], K-H. Kampert[18], B. Kardan[9,e], V. Kedych[7], S. Kim[18], I. Koenig[6], W. Koenig[6], M. Kohls[9,e], J. Kolas[17], G. Kornakov[17], R. Kotte[8], I. Kres[18], W. Krueger[7], A. Kugler[15], R. Lalik[5], S. Lebedev[6], S. Linev[6], F. Linz[6], L. Lopes[2], M. Lorenz[9,6], A. Malige[5], J. Markert[6], T. Matulewicz[16], S. Maurus[11], V. Metag[12], J. Michel[9], A. Molenda[3], C. Müntz[9], M. Nabroth[9], L. Naumann[8], K. Nowakowski[5], A. Opichal[15,13], J. Orliński[16], J.-H. Otto[12], M. Parschau[9], C. Pauly[18], D. Pawłowska-Szymanska[17], V. Pechenov[6], O. Pechenova[6], D. Pfeifer[18], K. Piasecki[16], J. Pietraszko[6], T. Povar[18], K. Prościński[5,b], A. Prozorov[15,f], W. Przygoda[5], K. Pysz[4], B. Ramstein[14], N. Rathod[17], J. Ritman[6,1], A. Rost[7,6], A. Rustamov[6], P. Salabura[5], J. Saraiva[2], K. Scharmann[12], N. Schild[7], E. Schwab[6], F. Scozzi[7,14], F. Seck[7], I. Selyuzhenkov[6], U. Singh[5], L. Skorpil[9], J. Smyrski[5], S. Spies[9], A. Sreejith[18], H. Ströbele[9], J. Stroth[9,6,e], K. Sumara[5], O. Svoboda[15], M. Szala[9], P. Tlusty[15], M. Traxler[6], S. Treliński[4], I. C. Udrea[7,6], F. Ulrich-Pur[6], C. Ungethum[7], V. Wagner[15], A.A. Weber[12], C. Wendisch[6], J. Wirth[11,10], A. Władyszewska[5,b], H.P. Zbroszczyk[17], E. Zherebtsova[h], M. Zieliński[5], P. Zumbruch[6]

[1]Ruhr-Universität Bochum, 44801 Bochum, Germany
[2]LIP-Laboratório de Instrumentação e Física Experimental de Partículas, 3004-516 Coimbra, Portugal
[3]AGH University of Krakow, Faculty of Physics and Applied Computer Science, 30-059 Krakow, Poland
[4]Institute of Nuclear Physics, Polish Academy of Sciences, 31342 Kraków, Poland
[5]Smoluchowski Institute of Physics, Jagiellonian University of Cracow, 30-059 Kraków, Poland
[6]GSI Helmholtzzentrum für Schwerionenforschung GmbH, 64291 Darmstadt, Germany
[7]Institut für Kernphysik, Technische Universität Darmstadt, 64289 Darmstadt, Germany
[8]Institut für Strahlenphysik, Helmholtz-Zentrum Dresden-Rossendorf, 01314 Dresden, Germany
[9]Institut für Kernphysik, Goethe-Universität, 60438 Frankfurt, Germany
[10]Excellence Cluster 'Origin and Structure of the Universe' , 85748 Garching, Germany
[11]Physik Department E62, Technische Universität München, 85748 Garching, Germany
[12]II.Physikalisches Institut, Justus Liebig Universität Giessen, 35392 Giessen, Germany
[13]Faculty of Science, Palacký University Olomouc, 779 00 Olomouc, Czech Republic
[14]Laboratoire de Physique des 2 infinis Irene Joliot-Curie, Universite Paris-Saclay, CNRS-IN2P3, F-91405 Orsay, France
[15]Nuclear Physics Institute, The Czech Academy of Sciences, 25068 Rez, Czech Republic
[16]Uniwersytet Warszawski, Instytut Fizyki Doświadczalnej, 02-093 Warszawa, Poland
[17]Warsaw University of Technology, Faculty of Physics, 00-662 Warsaw, Poland
[18]Bergische Universität Wuppertal, 42119 Wuppertal, Germany

[a] also at Instituto Politecnico de Coimbra, Instituto Superior de Engenharia de Coimbra, 3030-199 Coimbra, Portugal
[b] also at Doctoral School of Exact and Natural Sciences, Jagiellonian University, Cracow, Poland
[c] also at Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Darmstadt, 64390 Darmstadt, Germany
[d] also at Technische Universität Dresden, 01062 Dresden, Germany
[e] also at Helmholtz Research Academy Hesse for FAIR (HFHF), Campus Frankfurt, 60438 Frankfurt am Main, Germany
[f] also at Charles University, Faculty of Mathematics and Physics, 12116 Prague, Czech Republic
[g] also at Czech Technical University in Prague, 16000 Prague, Czech Republic
[h] also at University of Wrocław, 50-204 Wrocław, Poland
e-mail: hades-info@gsi.de (J. Stroth)

Received: date / Accepted: date

$\pi - \pi$ correlations in pp

Main Contributor: **Michał Prędota**

Physics Motivation:

To look for $\pi - \pi$ correlations in pp to study production mechanisms and to validate the description of femtoscopic correlations

Status:

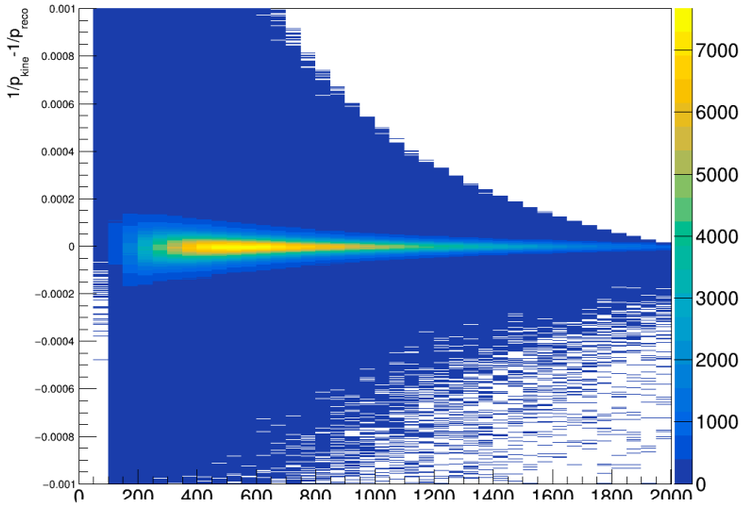
Work in progress results shown internally at HADES only

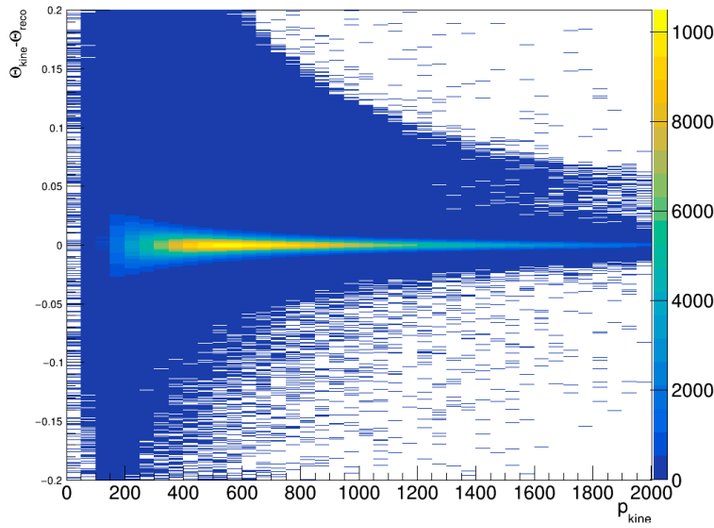
Milestones achieved:

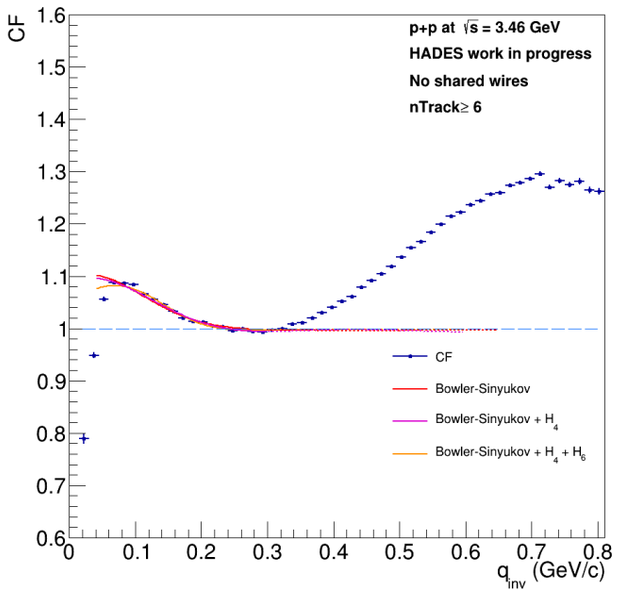
Correlation functions for negative pion pairs for various event multiplicities, **momentum resolution**

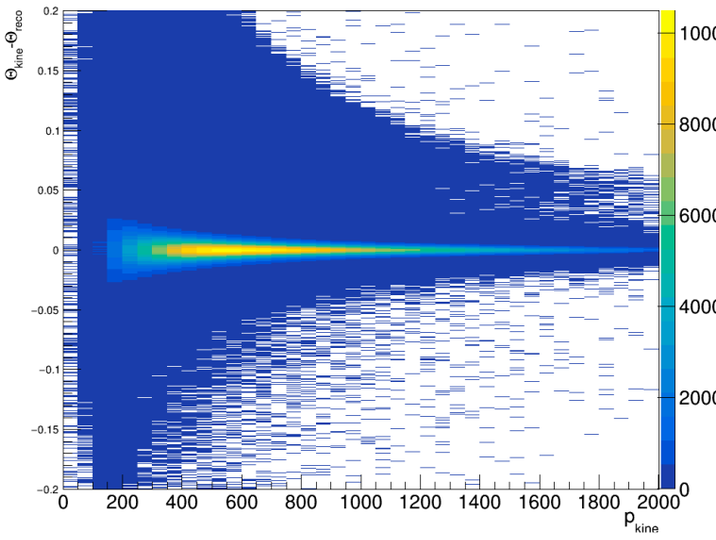
What's left:

Proper parametrization









	λ	R (fm)
Bowler-Sinyukov	0.1322 ± 0.0027	1.411 ± 0.028
Bowler-Sinyukov + H_4	0.089 ± 0.018	0.843 ± 0.060
Bowler-Sinyukov + H_4+H_6	0.1170 ± 0.0042	1.530 ± 0.056

$\pi - \pi$ correlations in Ag+Ag

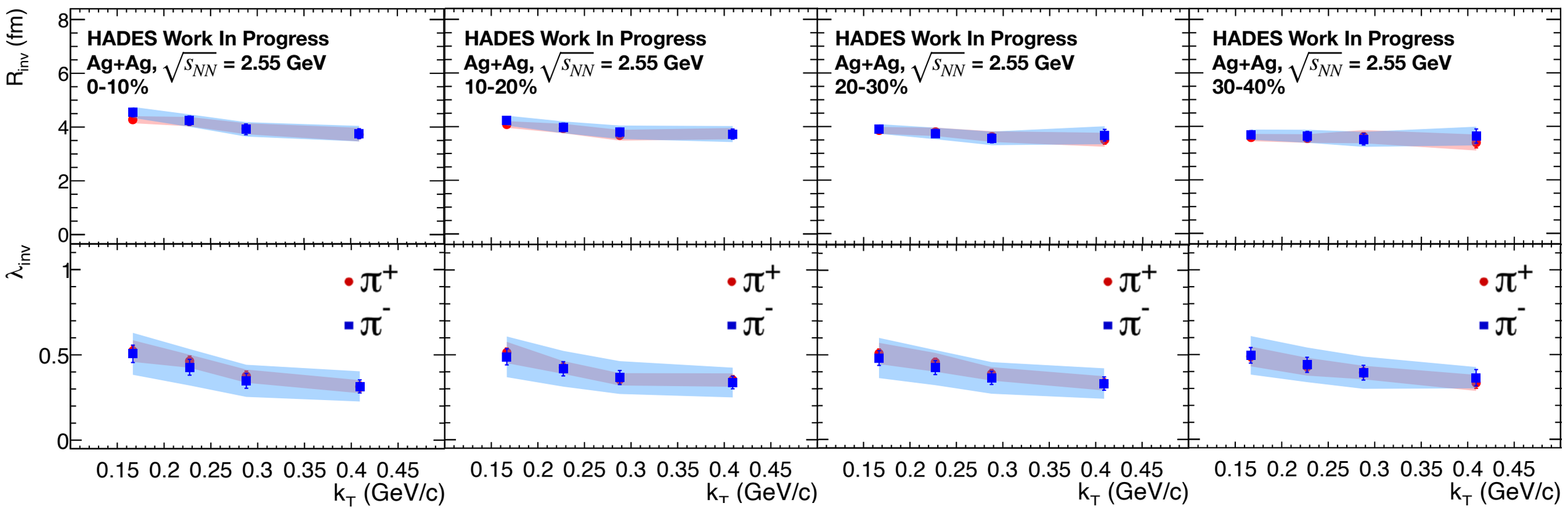
Main Contributor: **Anna Kodym**

Physics Motivation:
To look for $\pi - \pi$ correlations in Ag+Ag collisions to study HBT parameters

Status:
Work in progress results shown internally at HADES only

Milestones achieved:
Full finished analysis for 1D
Ongoing (advanced) systematic analysis for 3D

What's left:
Finish full 3D systematic analysis (very advanced at this moment)

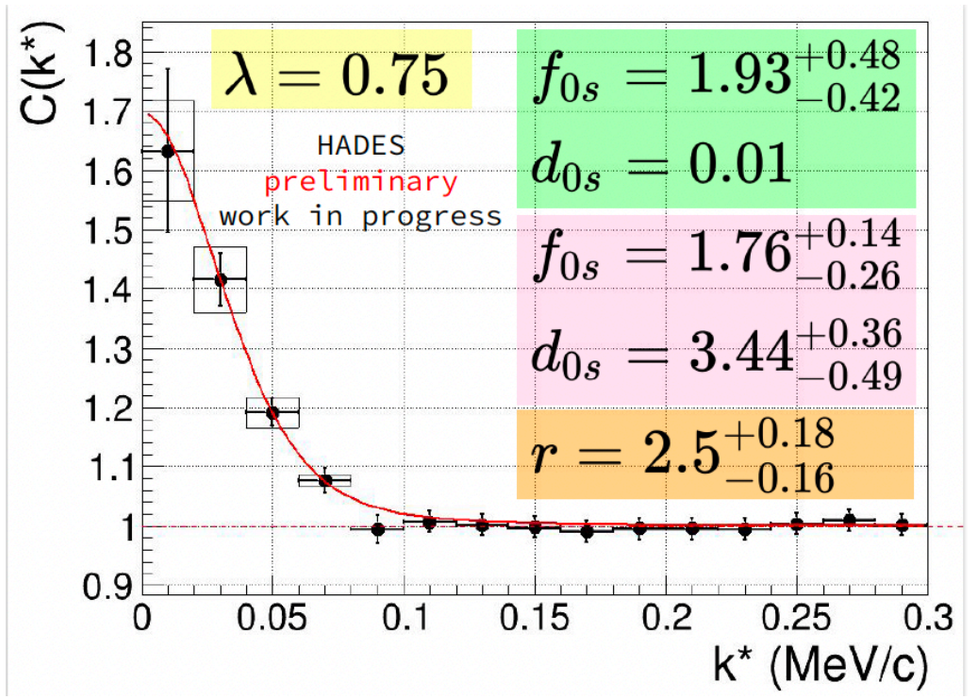


$p - \Lambda$ correlations

Main Contributor: **Narendra (Kinga Urban)**

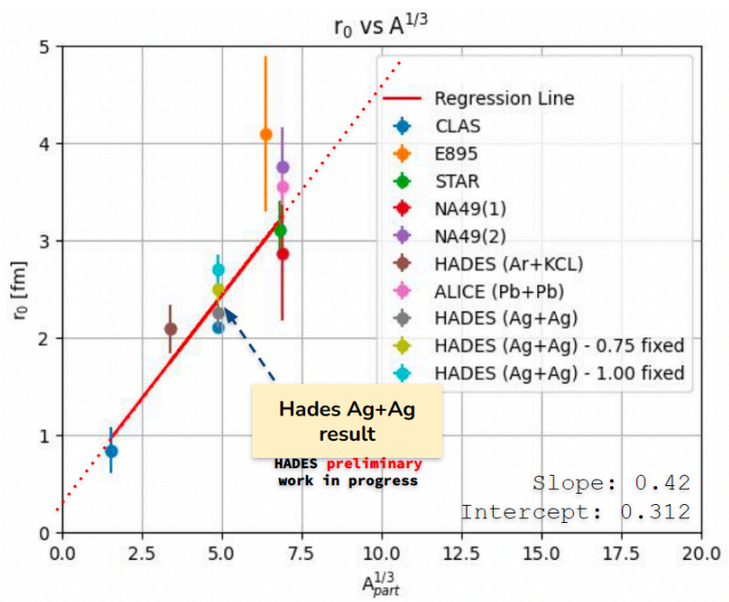
Physics Motivation:
To look for FSI parameters (to separate spin states)

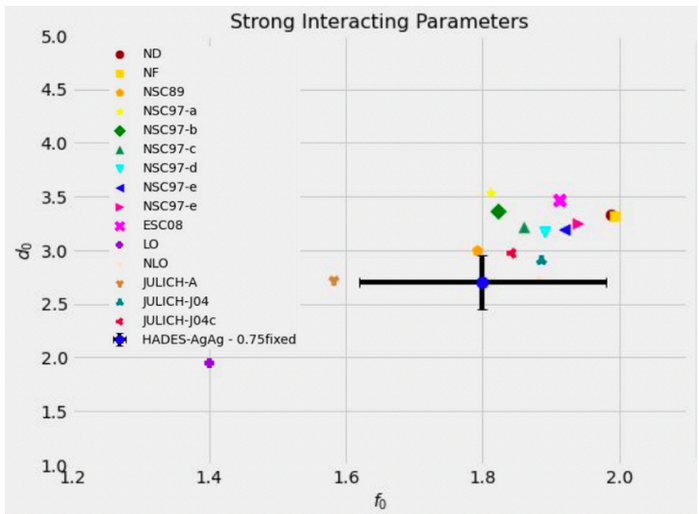
Status:
Paper proposal discussed last CM



Milestones achieved:
Singlet and triplet states separated
FSI parameters extracted (3 centrality classes, 3 k_T intervals)

What's left:
To write the draft of publication



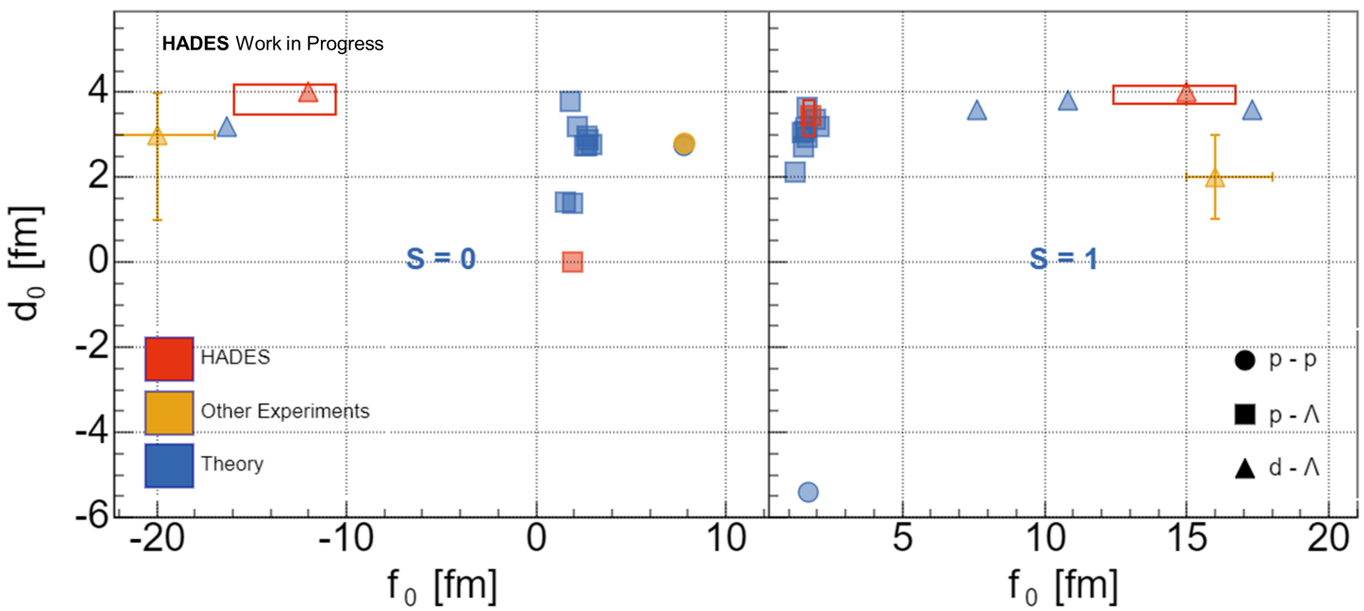


$d - \Lambda$ correlations

Main Contributor: **Diana, Arkadip Mukherjee**

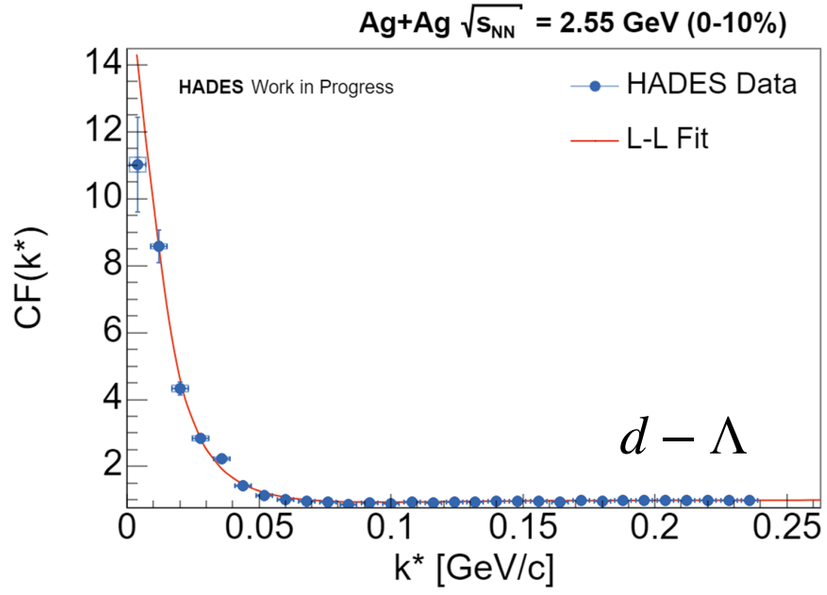
Physics Motivation:
To look for FSI parameters (to separate spin states)

Status:
Work in progress results shown outside of HADES



Milestones achieved:
Doublet and quartet states separated
FSI parameters extracted (2 centrality classes)

What's left:
Systematic uncertainties evaluation

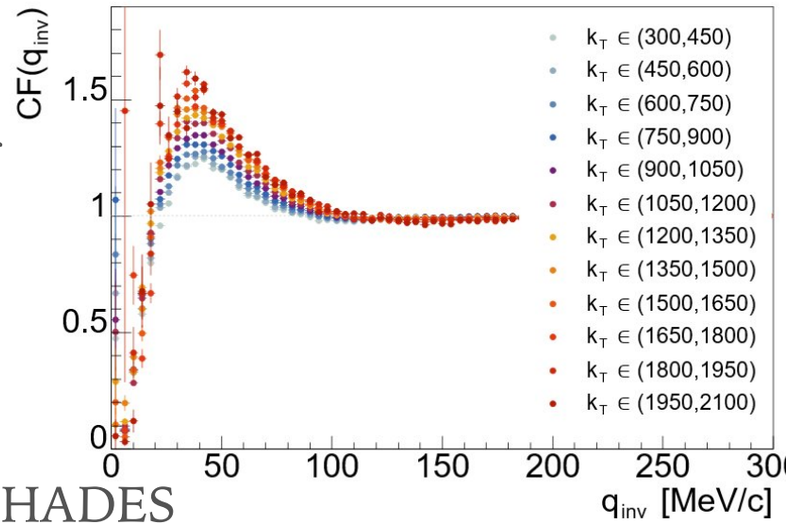


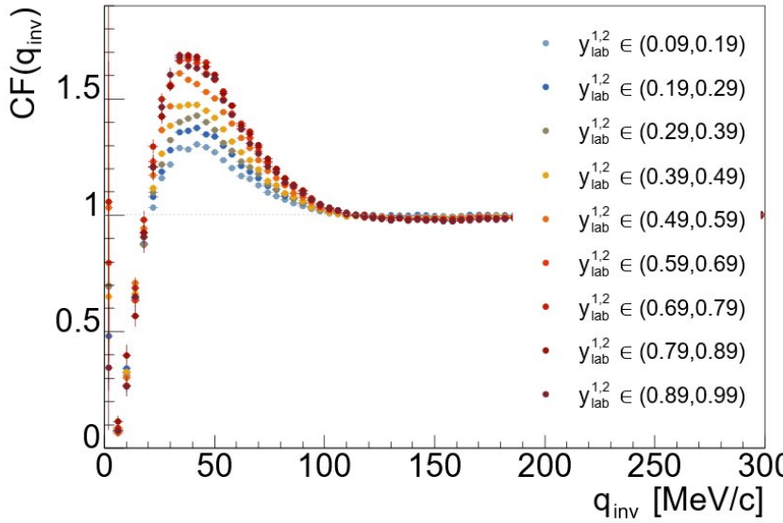
$p - p$ correlations

Main Contributor: **Jędrzej, Jan Bogdański**

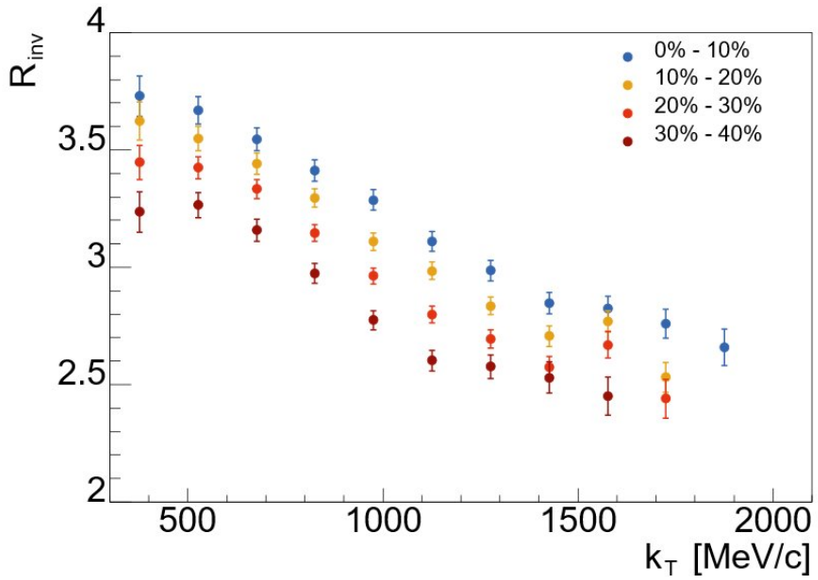
Physics Motivation:
To look for p-p correlations as a probe of correlations sensitivities to various EoS

Status:
Work in progress results shown outside of HADES





Milestones achieved:
1-dim correlation functions fully corrected (w/o systematics) (4 centrality classes,
12 k_T intervals, 9 rapidity bins)



What's left:
Systematic uncertainties evaluation of 1-dim c.f
3-dim studies

Thank you!