Status of p-d femtoscopy

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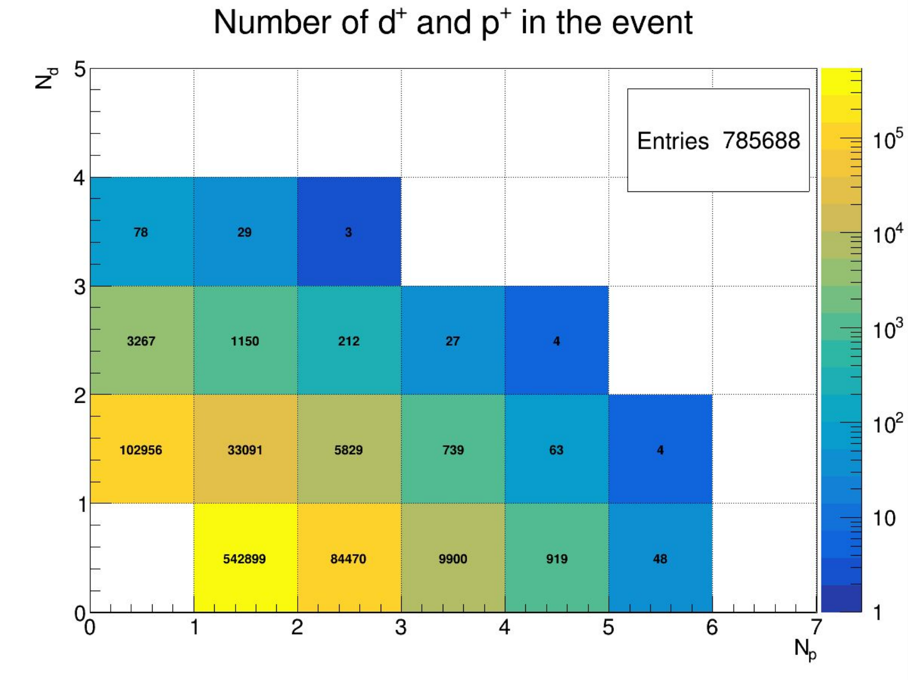
for BM@N collaboration

BM@N period 7, 3.2 AGeV Ar-beam, identified on TOF-700 data

2 725 618 entries

Target		p^+	d^+	p^+d^+
C	Carbon	30 668	5 682	1 586
Al	Aluminum	165 536	31 218	9 839
Cu	Copper	214 483	40 742	13 265
Sn	Tin	250 947	48 464	17 571
Pb	Lead	132 765	26 226	8 424
Total		794 399	152 332	50 685



BM@N Analysis Note: Production of p, d, t in 3.2 A GeV argon-nucleus interactions

Analysis team: M.Kapishin, L.Kovachev, V.Plotnikov, Yu.Petukhov, 6 I.Rufanov, A.Zinchenko

Motivation

Correlation function:

$$C(k^*) = \frac{A(k^*)}{B(k^*)}$$

$$k^* = \frac{1}{2} \cdot |\vec{p_1^*} - \vec{p_2^*}|$$

- Femtoscopy method allows one to obtain an information on the space-time parameters of the production process
- Models of the hadronization predict decreasing the size of baryon formation area with transverse momentum in general and for strange baryons in particular
- It is important to compare the femtoscopic sizes obtained with different baryons

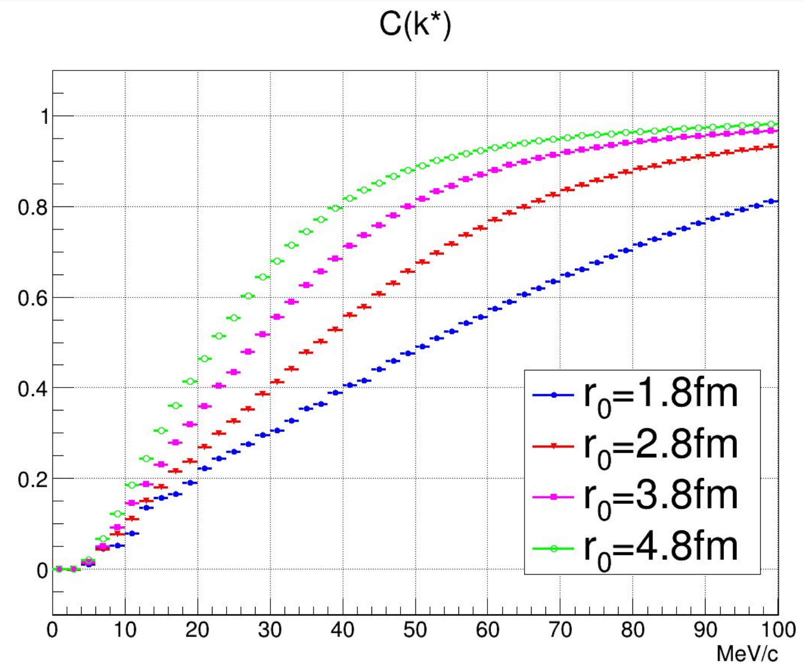
Status of baryon femtoscopy at BM@N
L.Kovachev, A.Stavinskiy for BM@N collaboration
10th Collaboration Meeting of the BM@N Experiment at NICA Facility, 14-19 May 2023

- BM@N experiment has already collected data with momentum resolution that is enough for femtoscopy analysis
- The easiest way to begin our planned baryon femtoscopy programme (pd, pp, pLambda, pn...) is to use particles with different masses or charges, e.g. the proton-deuteron femtoscopy
- Measured correlation function yields information on the "averaged" radius r_0 of the nucleon and deuteron sources, providing a known proton-deuteron FSI

Aims of the work

- Workout of method of correlation function calculation on BM@N experimental data
- Development of algorithm of the correlation function analysis taking into account FSI
- Obtaining the physical result: the effective radius of proton and deuteron sources

Calculated FSI correlation function:

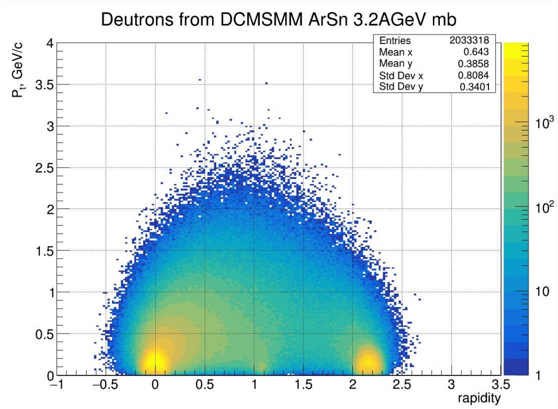


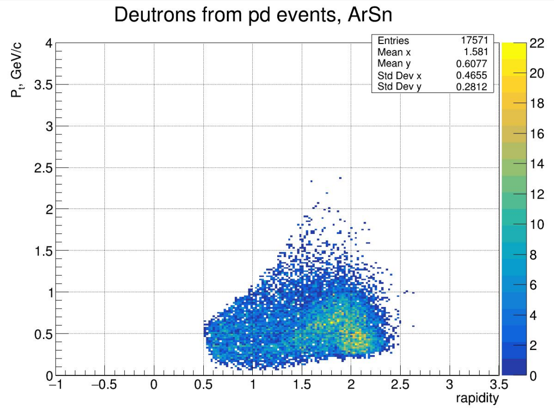
The FSI calculation assumes:

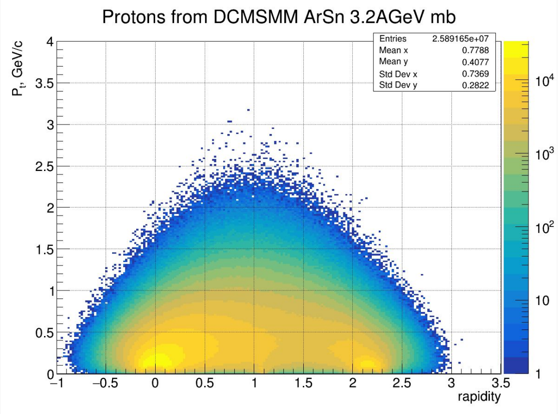
- a Gaussian r-distribution $\sim exp(-\frac{r^2}{4r_0^2})$

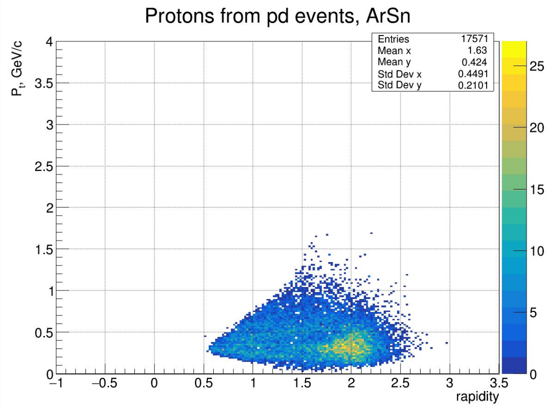
  where $r^2 = (\overrightarrow{r})^2, \overrightarrow{r} = \overrightarrow{r_1} - \overrightarrow{r_2}$
- short-range FSI dominated by s-wave
- approximate account of the inner region of the short-range FSI potential (valid if r_0 is larger than the effective potential radius)

P_t vs rapidity. ArSn 3.2 AGeV DCMSMM and exp. data

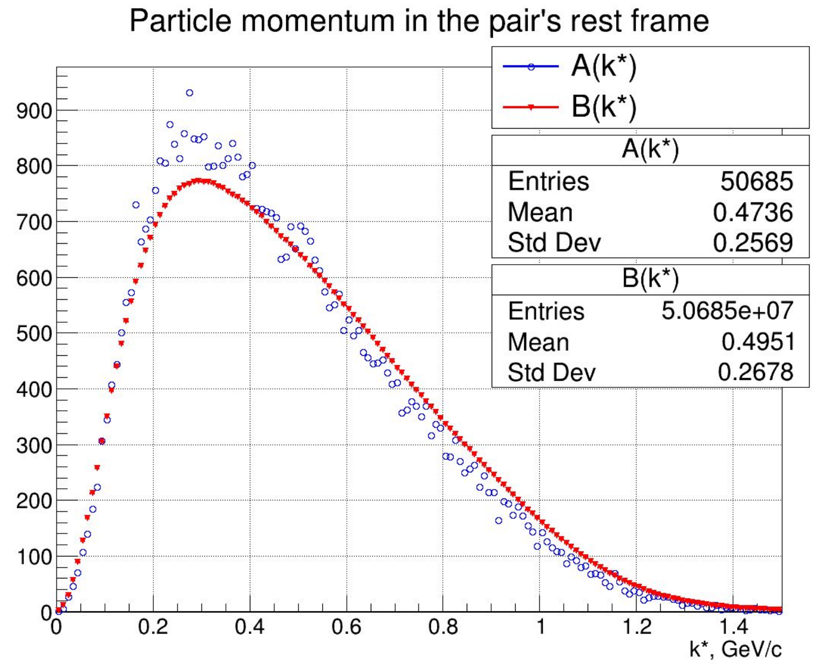


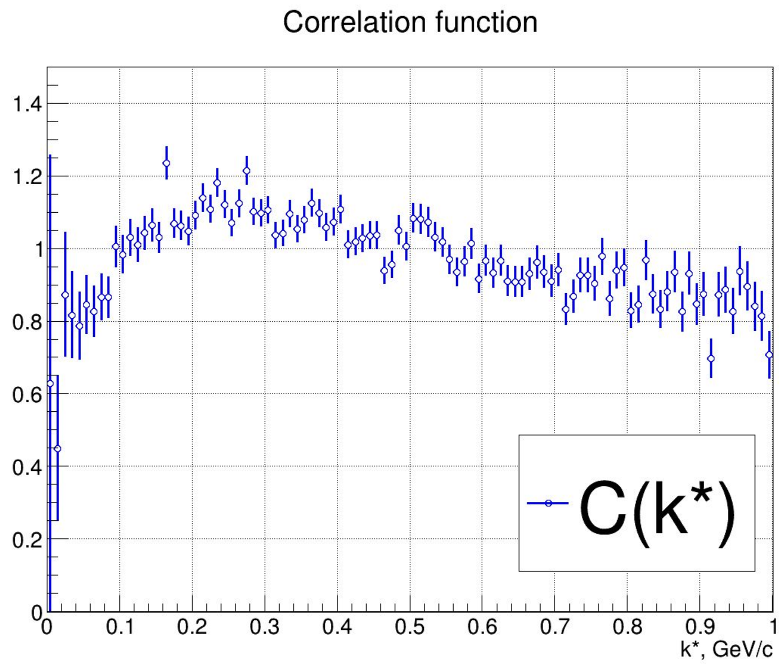




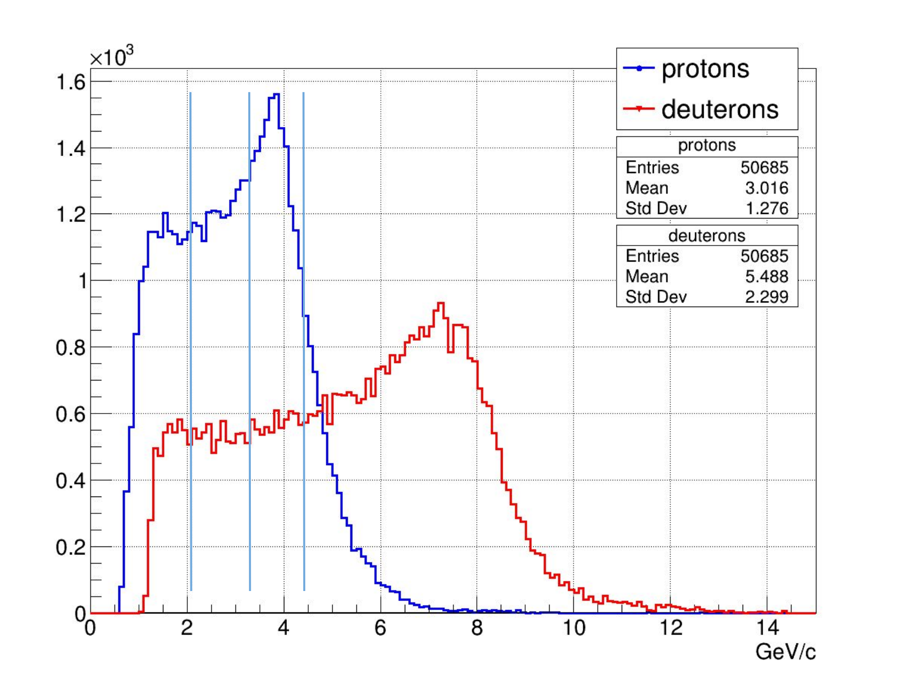


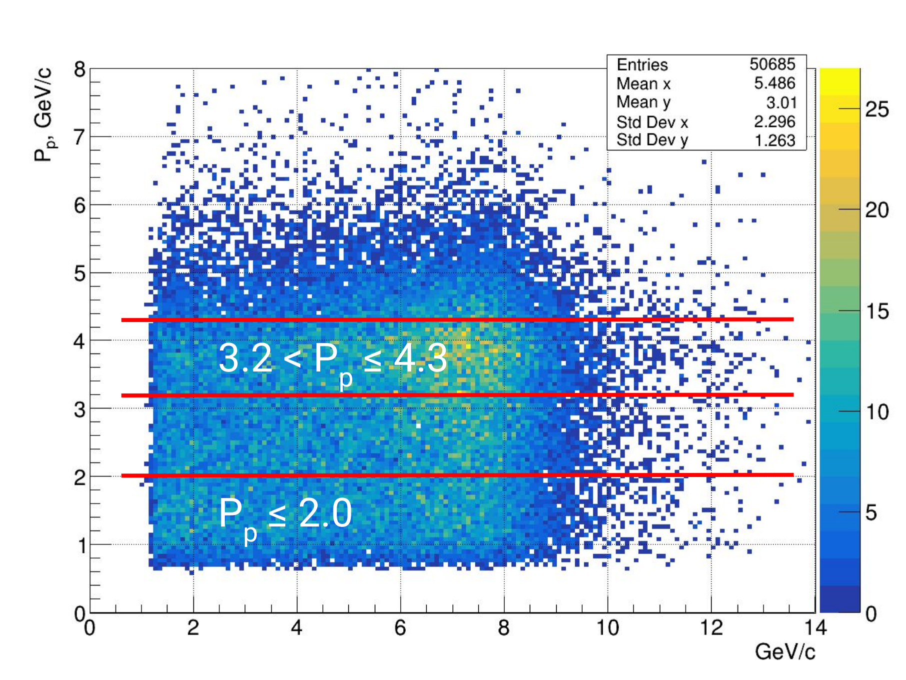
Correlation function from experimental data



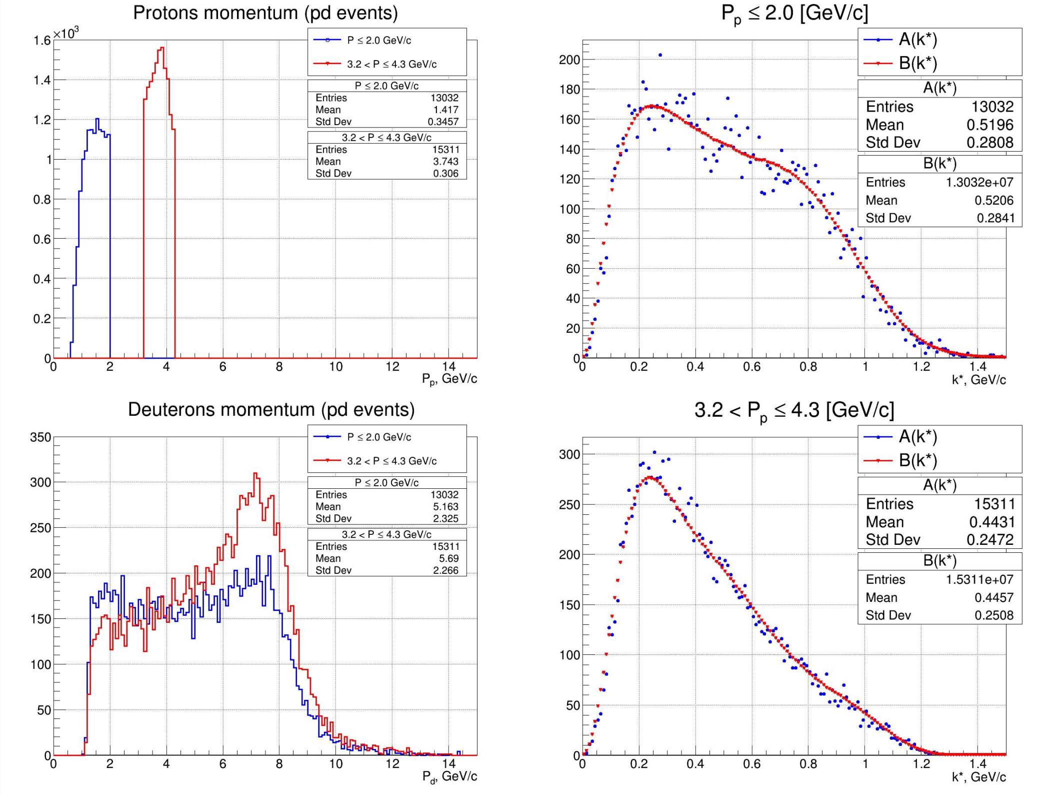


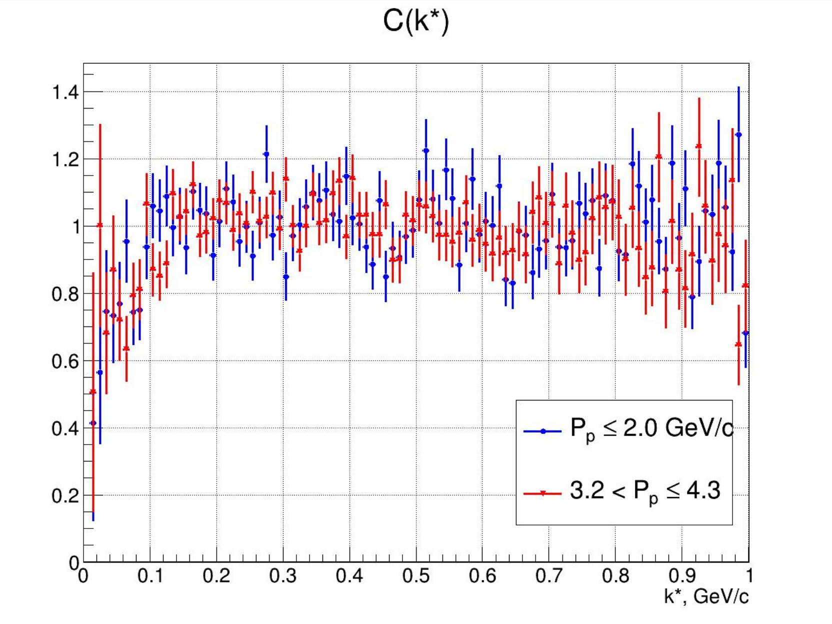
Momentum distribution of involved particles (experimental data)



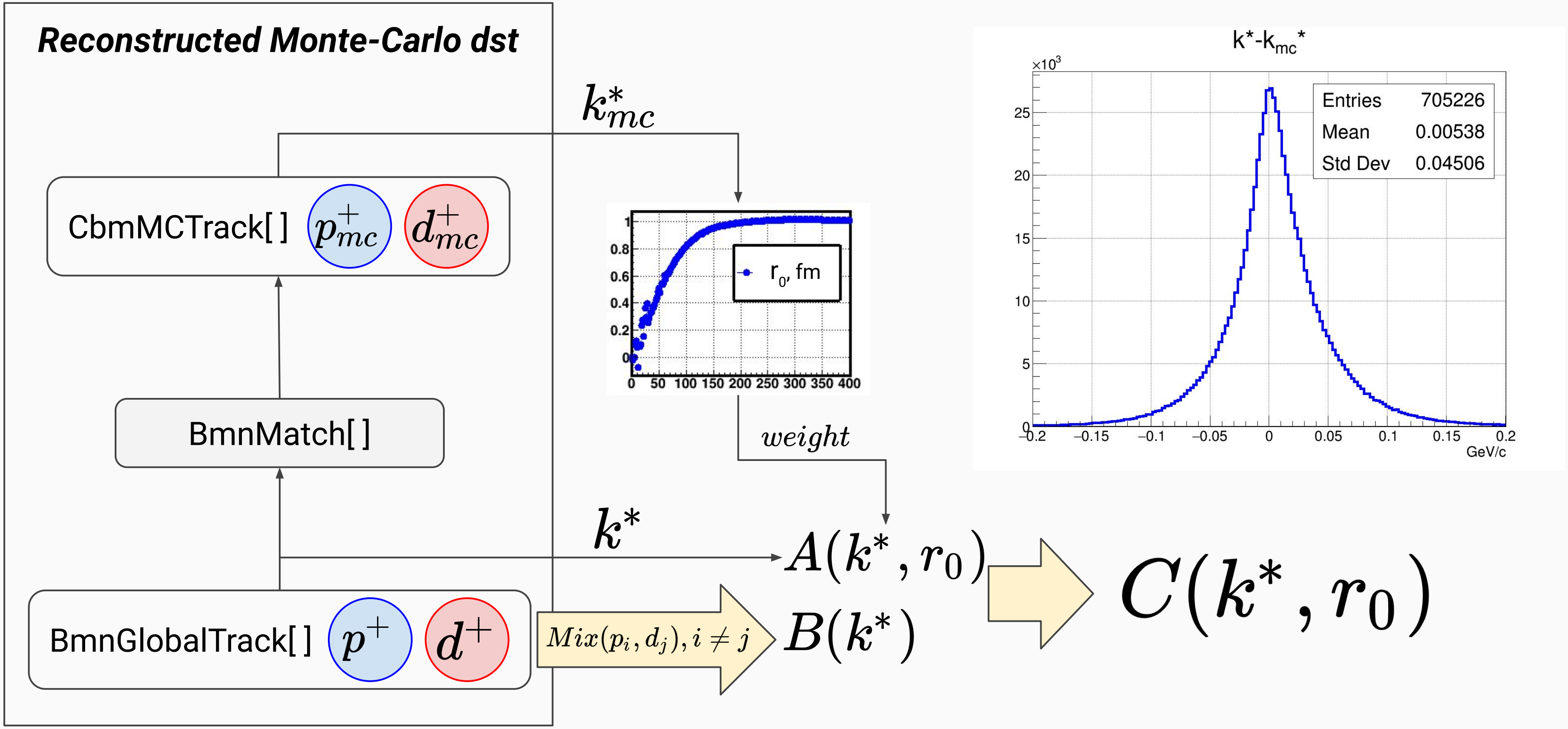


Correlation function for different proton momentum ranges (experimental data)

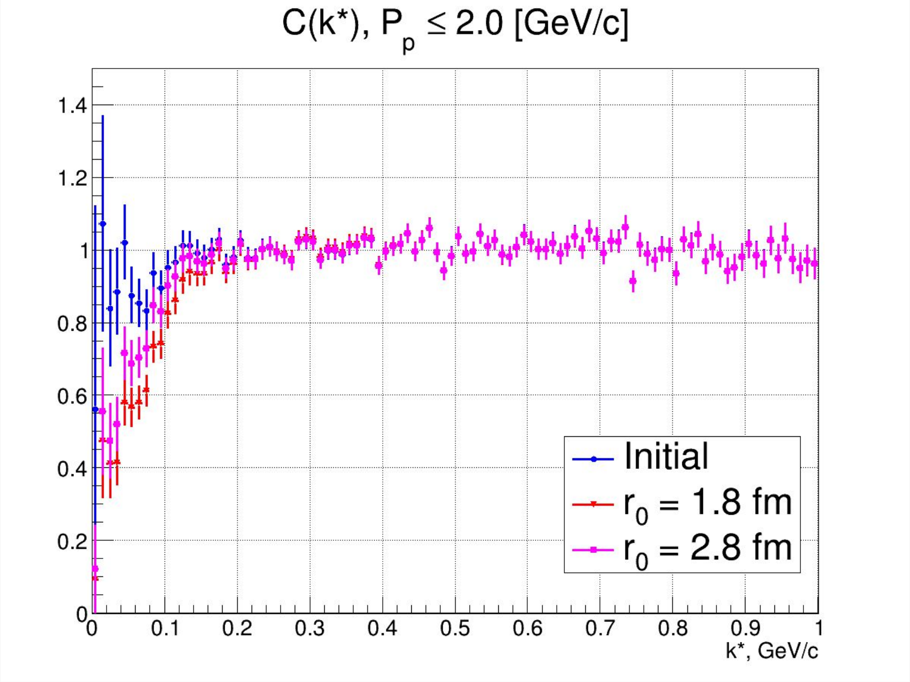


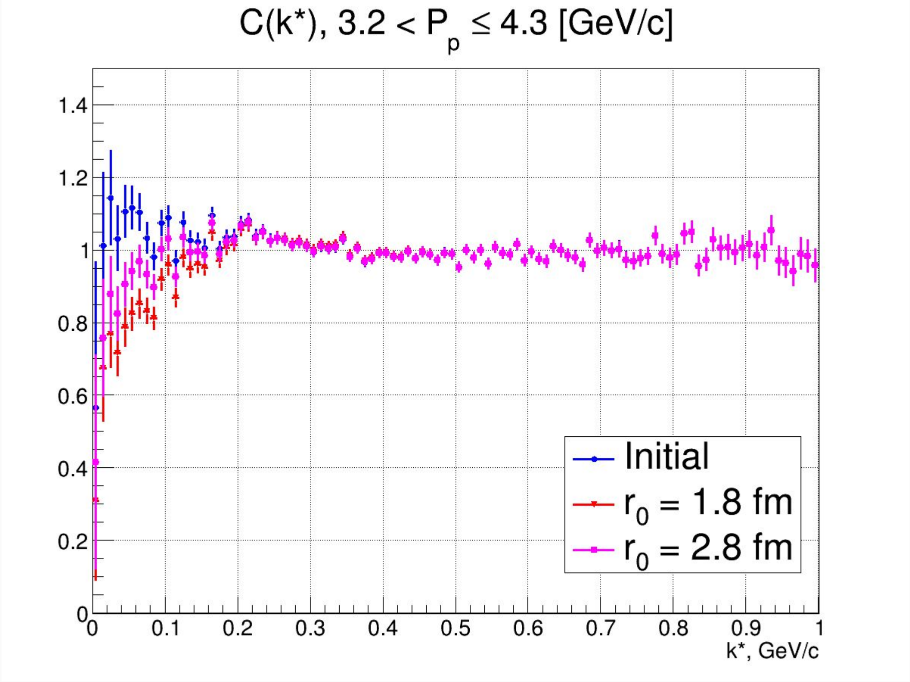


Applying detector resolution to the model (Monte-Carlo reconstruction)



Reweighting correlation function (Monte-Carlo reconstruction)

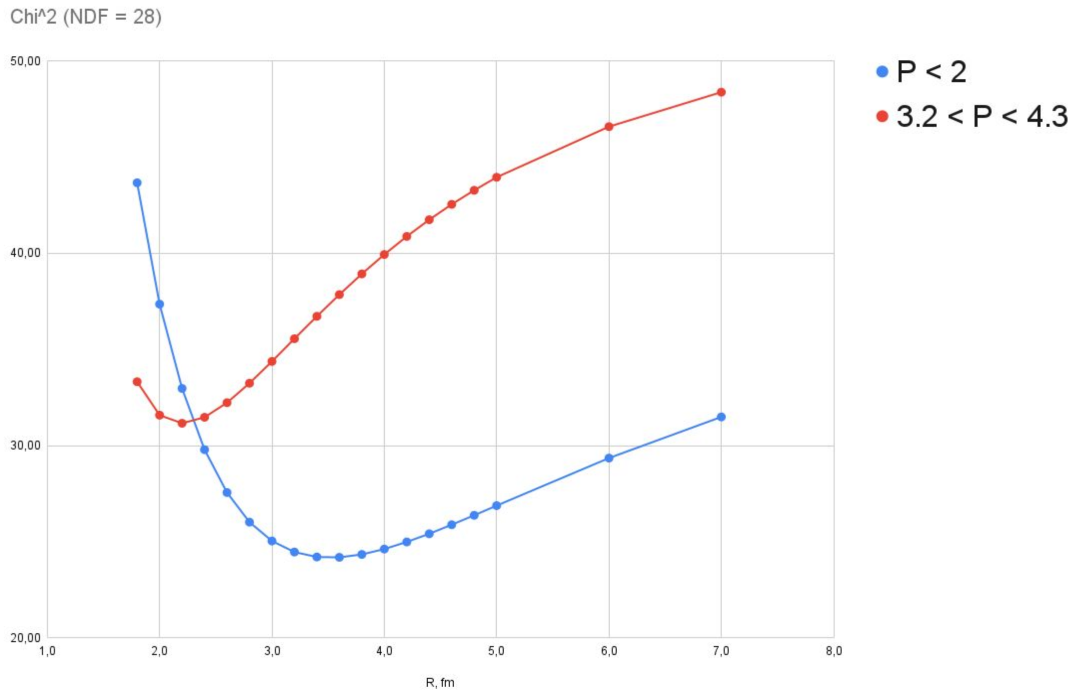




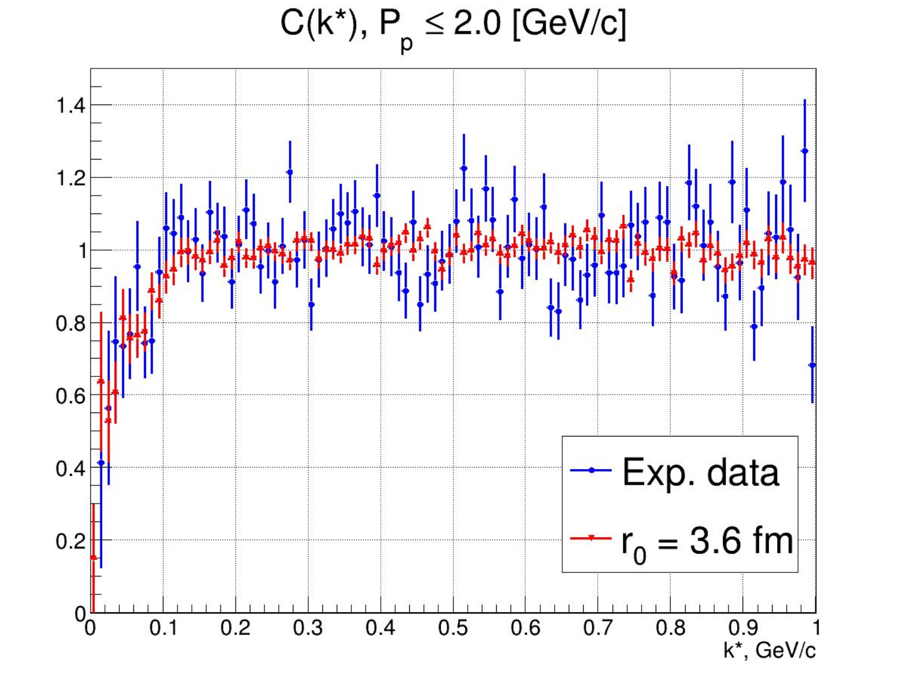
DCMSMM XeCsI 3.9AGeV

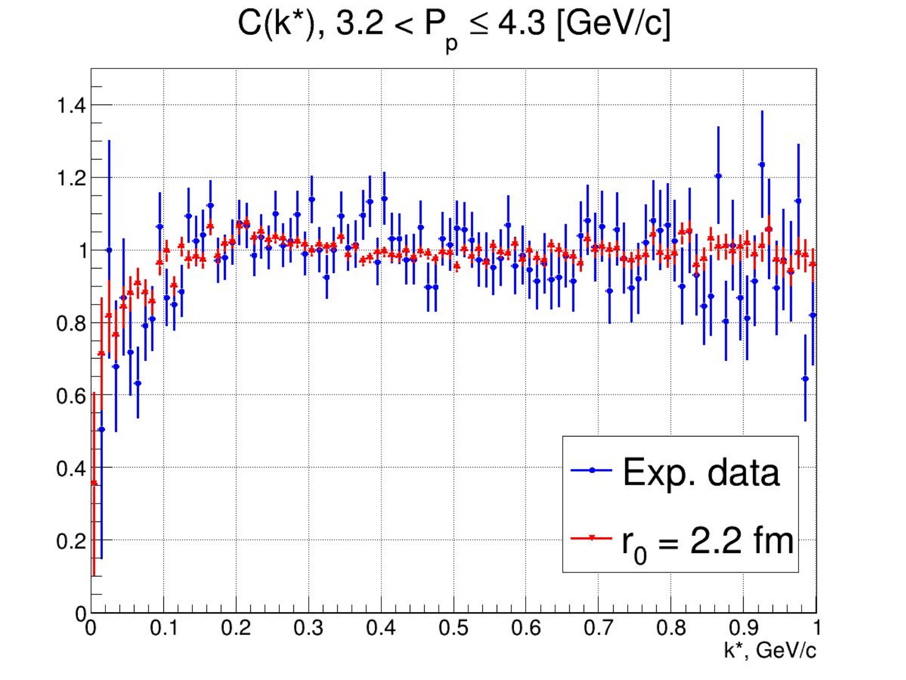
χ^2−test

r_0, fm	NDF	P < 2	3.2 < P < 4.3
1,8	28	43,67	33,32
2,0	28	37,36	31,58
2,2	28	32,97	**31,16**
2,4	28	29,79	31,47
2,6	28	27,56	32,23
2,8	28	26,02	33,25
3,0	28	25,04	34,38
3,2	28	24,46	35,56
3,4	28	24,21	36,73
3,6	28	**24,19**	37,86
3,8	28	24,34	38,93
4,0	28	24,62	39,94
4,2	28	24,99	40,88
4,4	28	25,41	41,75
4,6	28	25,88	42,55
4,8	28	26,37	43,28
5,0	28	26,88	43,96
6,0	28	29,35	46,59
7,0	28	31,49	48,39
No FSI	28	43,31	55,18



The best matching r_0





Conclusion and further steps

- Results for correlation function calculation on BM@N experimental data provided
- Method of correlation function analysis developed and tested on BM@N experimental and simulated data
- Preliminary results for source radii of p-d pairs FSI for different particle momentum ranges are obtained

Next steps:

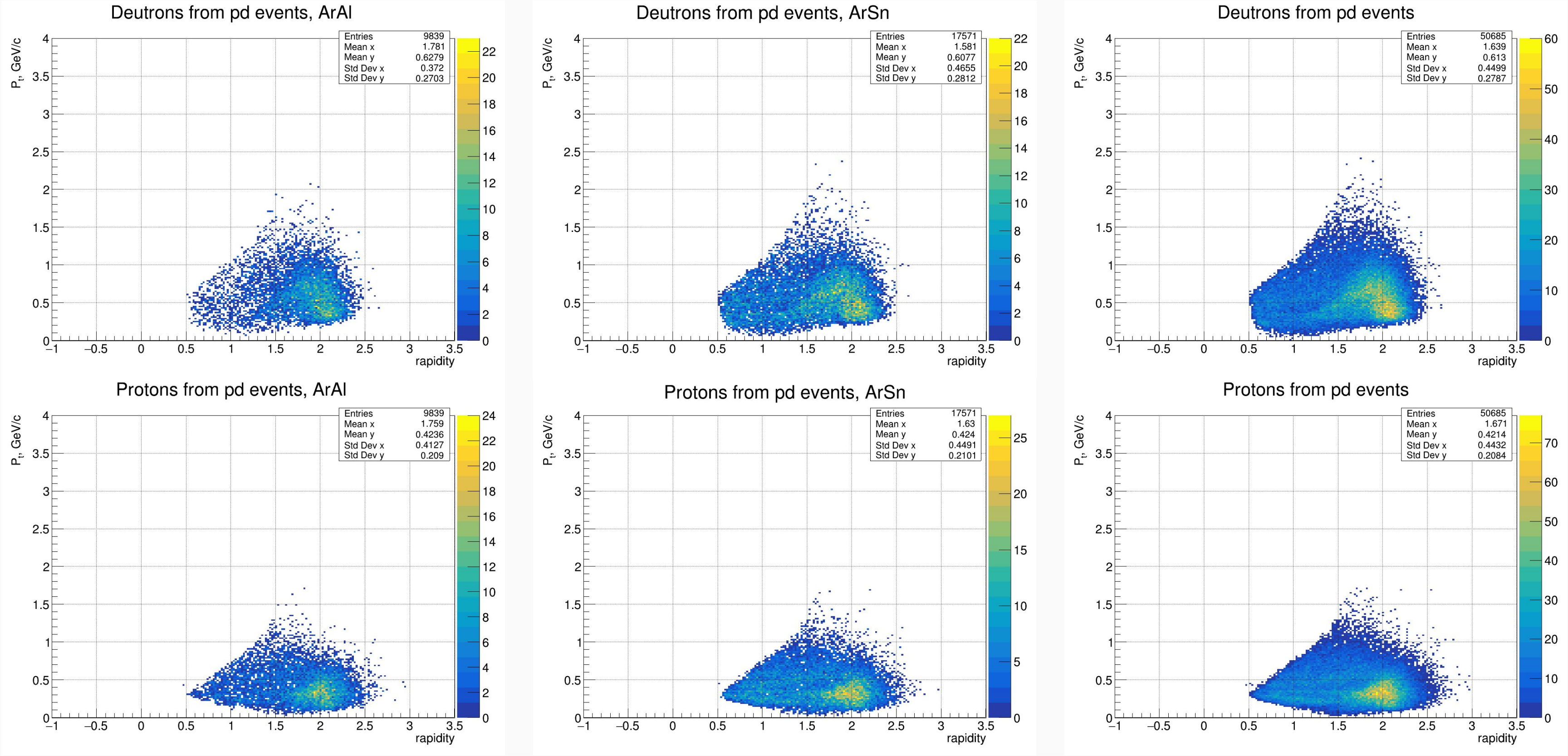
- Model:
  - Account of the p- and d-waves
  - Considering the deuteron as bound state*
- Analysis:
  - Finishing p-d on BM@N run 7 using full set of experimental data and appropriate Monte-Carlo statistic
  - Continue p-d on BM@N run 8 data
  - Go to p-p and other particles species

* S. Mrowczynski, arXiv:2004.07029: $4r_0^2 \to 3r_0^2$ in r-distribution
M. Viviani et al., arXiv:2306.02478: the above substitution is valid at large k only
full 3-body calculation is needed

Thank you for attention!

Backup

P_t vs rapidity. ArSn, ArAl, all targets



pd correlation function

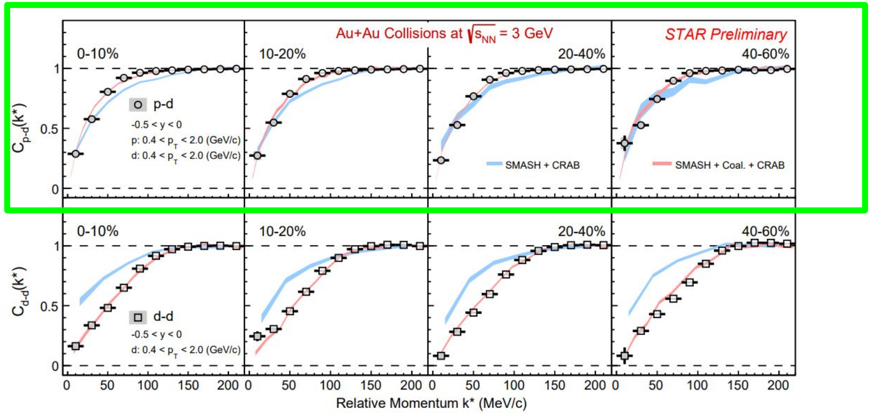
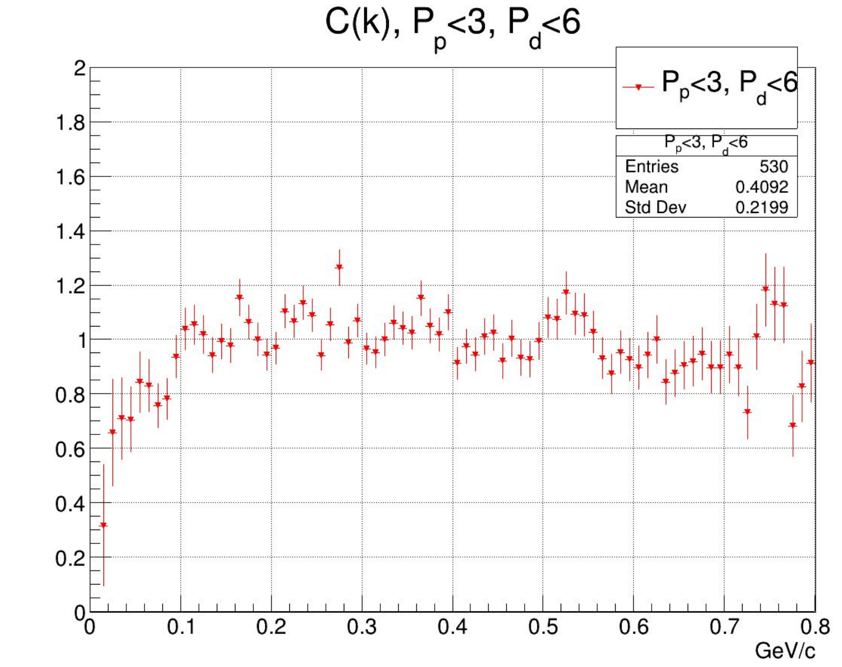
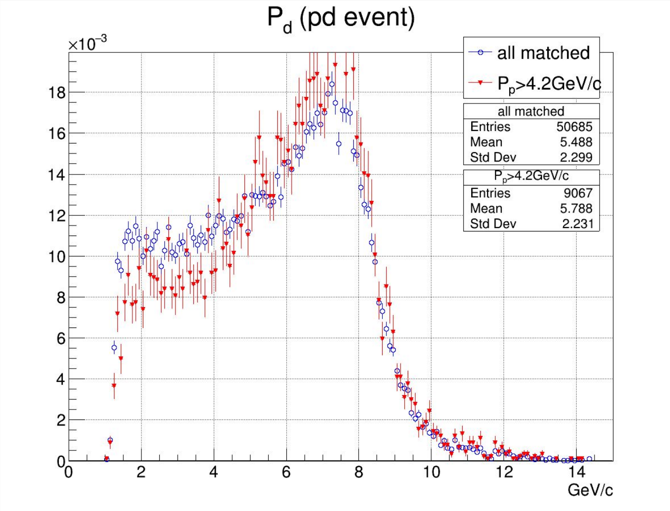


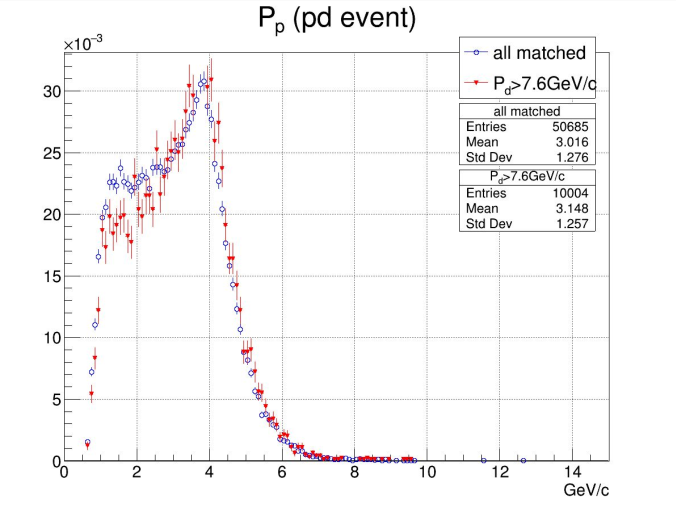
Fig. 4. The $p-d$ and $d-d$ correlation functions in different collision centralities in Au+Au collisions at $\sqrt{s_{NN}} = 3$ GeV. The statistical and systematic errors are shown as vertical lines and grey bands, respectively. The colored bands represent the $p-d$ and $d-d$ correlations obtained with the deuteron from nucleon coalescence (red) in SMASH and directly produced from SMASH via hadronic scattering (blue), respectively.

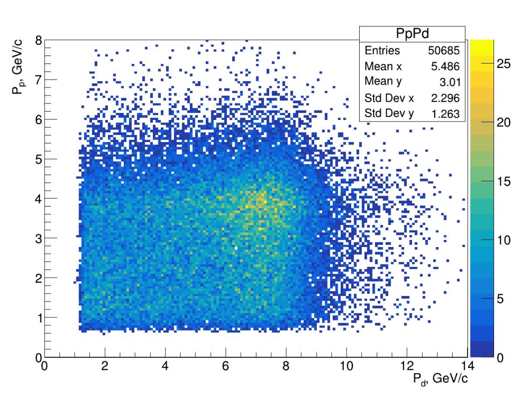
[STAR-(BES) ArXiv:2208.05722[nucl-ex],QM2022]



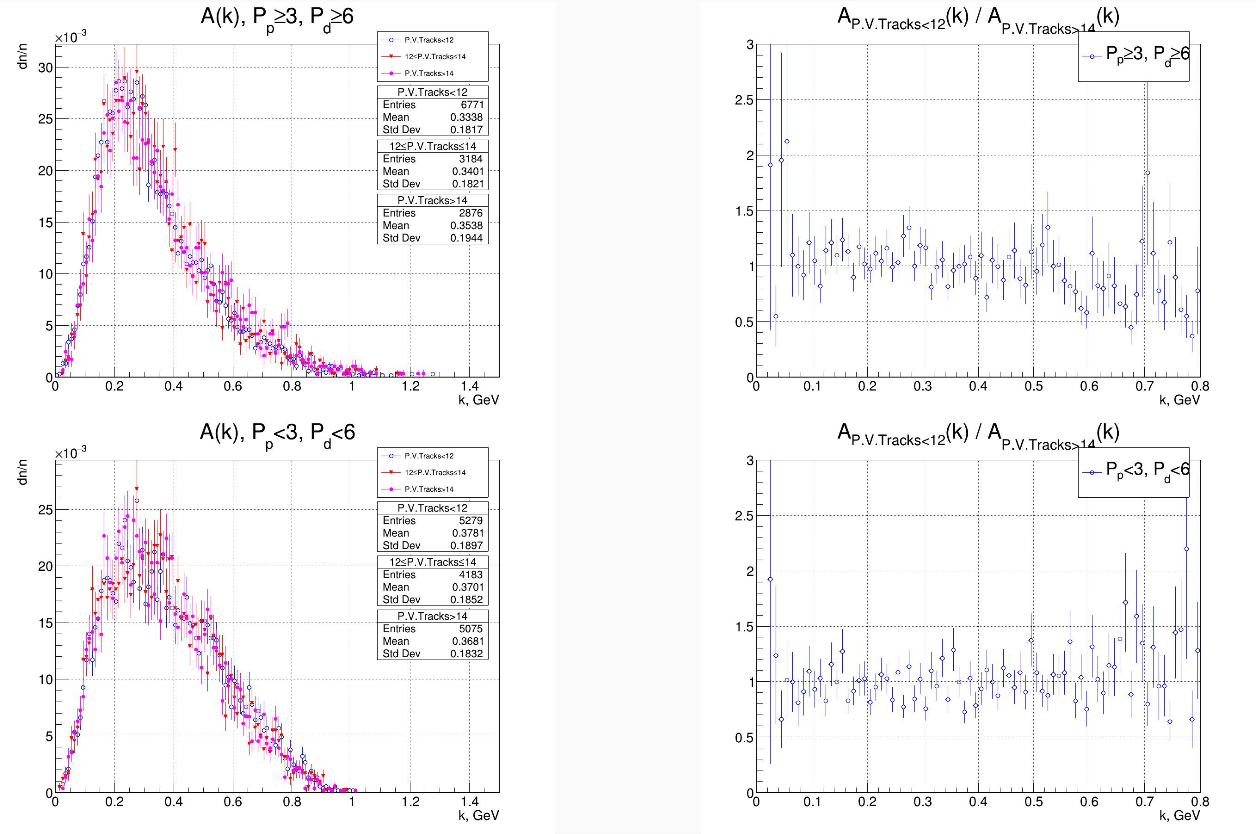
Correlation of proton and deutron momentum



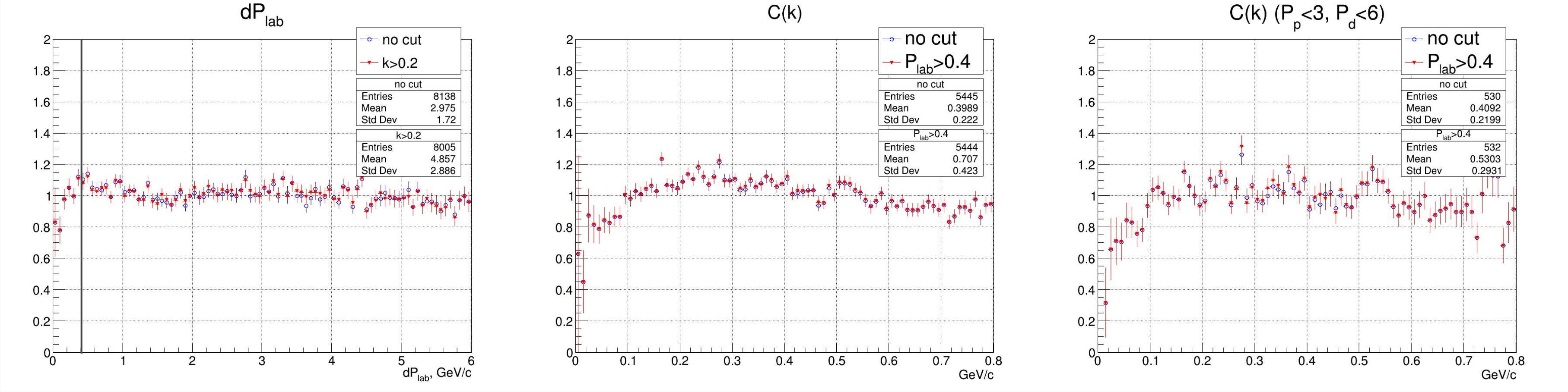




Estimation of multiplicity dependency



Efficiency of closest tracks



Registered p-d pairs dP_{lab} relative to the mixing

Excluding low-efficiency area by dP_{lab} has no significant effect on the range of interest (k < 200 MeV/c)