

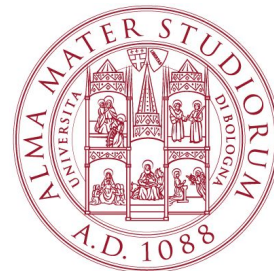
# Deuteron yield & p–p femtoscopy measurement in pp collisions at $\sqrt{s} = 900$ GeV in Run3 data

## Paper Overview

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**ALICE TOF and e-PIC meeting**  
**26 March 2024**

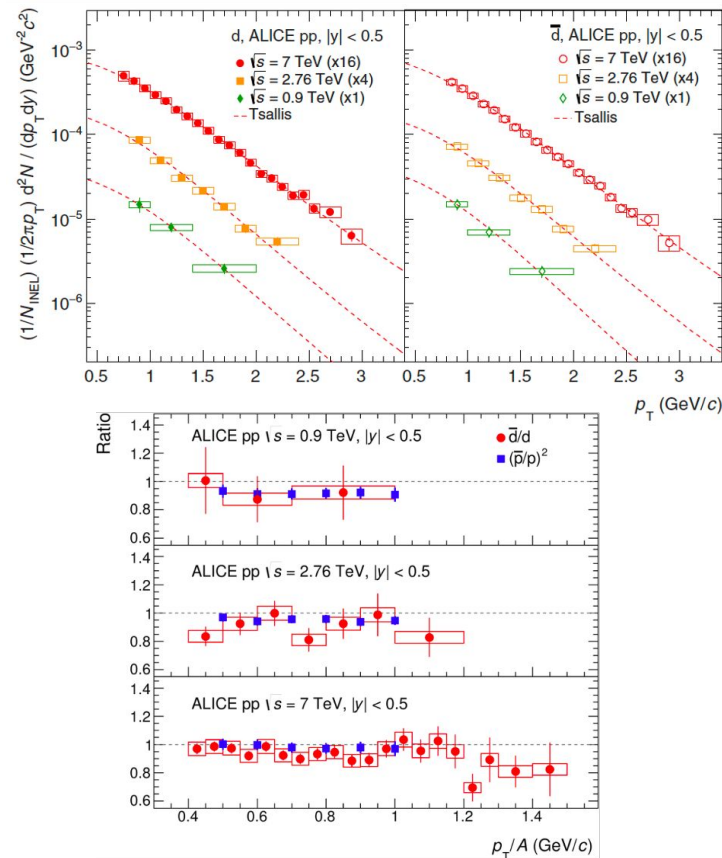


# Motivation #1: (anti)deuteron production

- d and dbar production in pp 900 GeV was measured in Run 1 with **limited precision and  $p_T$  coverage**
- **Lowest energy at the LHC**  
→ useful for validating the extrapolations at low energy in model tuning and astrophysical applications
- larger data sample wrt Run1 available + when we started the analysis, used to test performance of ALICE2

With the new measurement:

- **higher granularity in  $p_T$**
- extension to **lower  $p_T$**
- **increased precision** on yields and dbar/d ratio
- comparison with **models** (incl. PYTHIA production via inelastic processes and coalescence implementations)



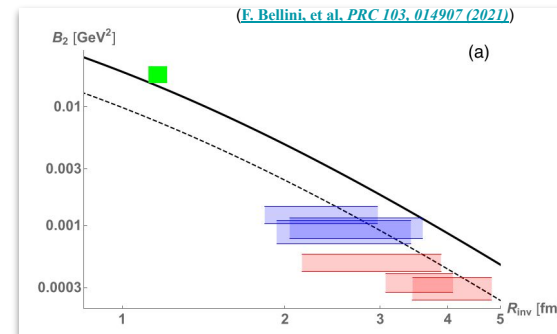
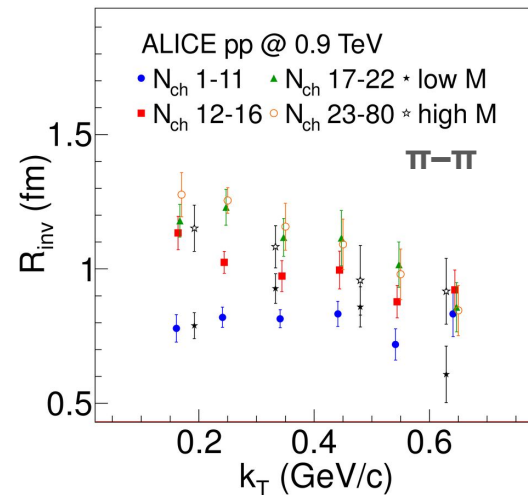
# Motivation #2: determination of proton source size

- The pion source is measured in Run1 for pp collisions at 900 GeV (right plot)  
[ALICE Coll: PRD 82, 052001 \(2010\)](#), [ALICE Coll: PRD 84, 112004](#)
- No proton source was measured at 900 GeV → first measurement
- Interesting to study  $\langle m_T \rangle$  scaling and multiplicity dependence
- Application: measure the proton source size and use it in a **coalescence model** to predict the production of antideuteron, then compare with the new deuteron measurement in [ALICE](#).  
(coal.: [M. Mahlein et al., Eur. Phys. J. C \(2023\) 83: 804](#))  
→ requires knowledge of **emission source size** and **anti-deuteron production for the same event classes**  
For example, the **coalescence parameter** for **deuteron formation** can be calculated as -

$$B_2(p) \approx \frac{2(2s_d + 1)}{m(2s_N + 1)^2} (2\pi)^3 \int d^3\mathbf{r} |\phi_d(\mathbf{r})|^2 S_2(\mathbf{r}).$$

Probability to form a (anti)d from nucleons

Source function → radius from femtoscopy



# The current status of the two analysis

## ANALYSIS SUMMARY AND STATUS

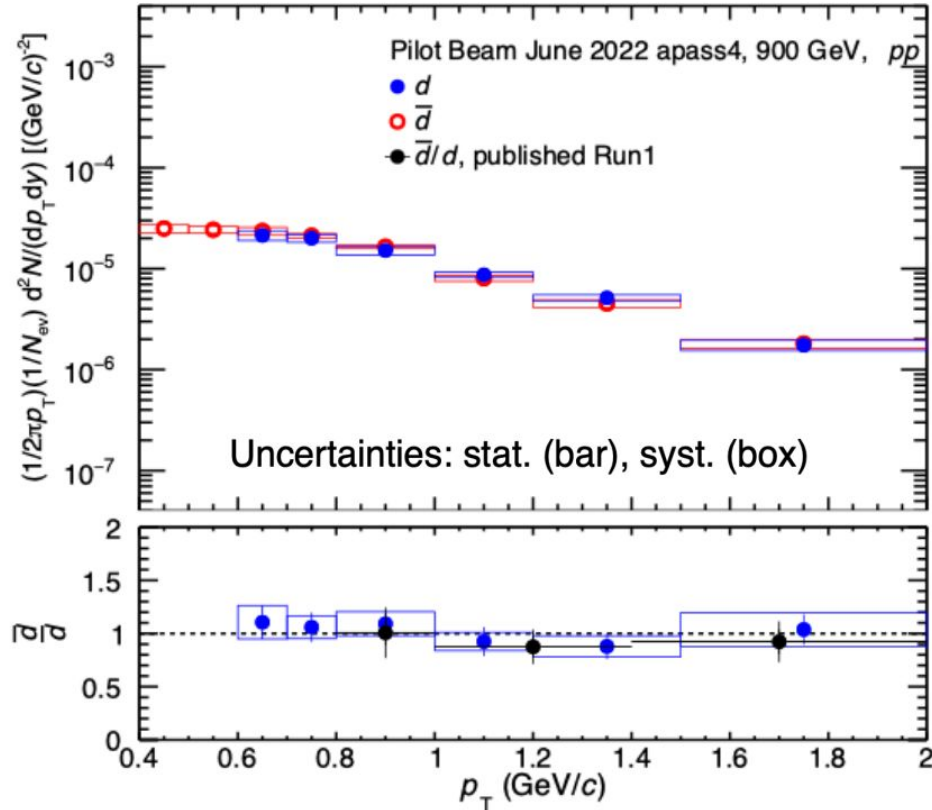
- **Analysis 1 - Proton source size** measurement is **completed**
  - paper proposal presented in February at Femto PAG meeting (<https://indico.cern.ch/event/1514582/> )
  - given analysis note with final results (<https://alice-notes.web.cern.ch/node/1517>)
  - got green light from ARC and PAG
- **Analysis 2 - Deuteron yield** analysis is **close to be completed**
  - will be presented to the PWG in April
  - analysis note is ready to upload for ARC and PWG comments and approval

**After approval by nuclei PWG, a combined paper proposal is planned to be presented in April to PWG-LF+CF and subsequently to the Physics Forum**

## Paper content/figures

- $p_T$ -spectrum of deuteron and anti-deuteron, comparison with Run 1
- (anti-)deuteron to (anti-)proton ratio as a function of  $p_T$
- Fully corrected correlation function, fitted with model
- Coalescence parameter (B2) as a function of  $p_T/A$

# deuteron corrected $p_T$ spectrum - candidate for the paper



The (anti)deuteron  $p_T$  spectra is calculated in the (0.4) 0.6 to 2 GeV/c  $p_T$  range

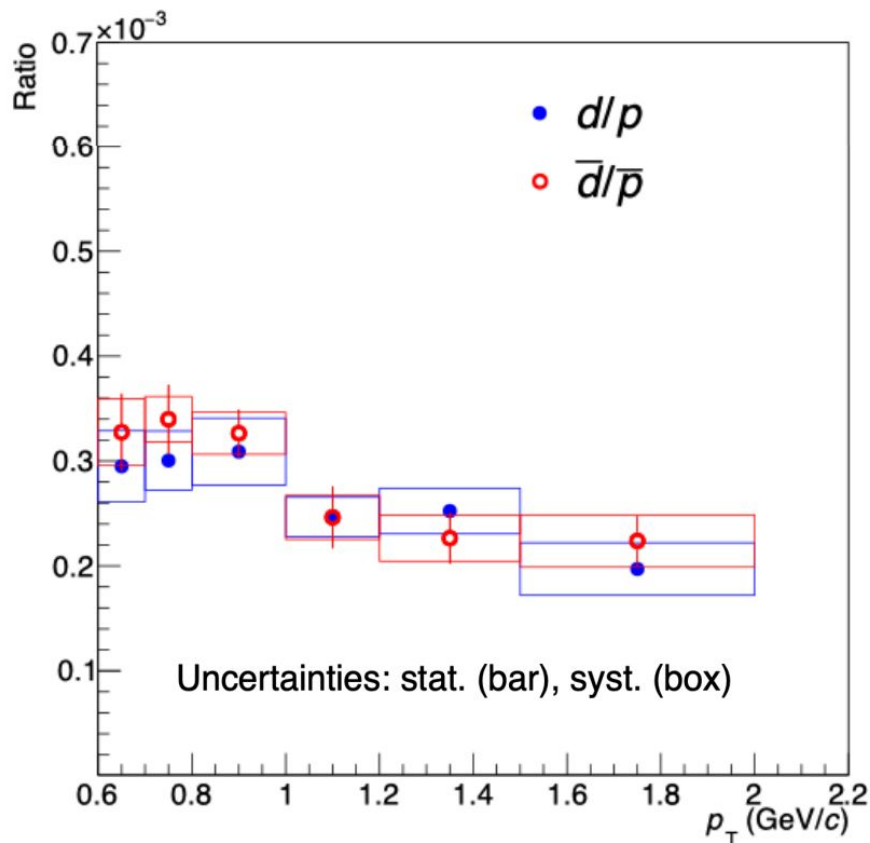
→ shows good agreement with each other

→ particle to antiparticle ratio is in agreement with the already published Run1 data

→ extended the  $p_T$  range and granularity as compared to Run1 data

→ increased statistical precision

# Deuteron/p ratio vs pt - candidate for the paper



The **(anti)deuteron to (anti)proton ratio** is calculated

→ higher  $d/p$  at low  $p_T$  suggests thermal production

→ lower  $d/p$  at high  $p_T$ , a hint of coalescence

## Ratio:

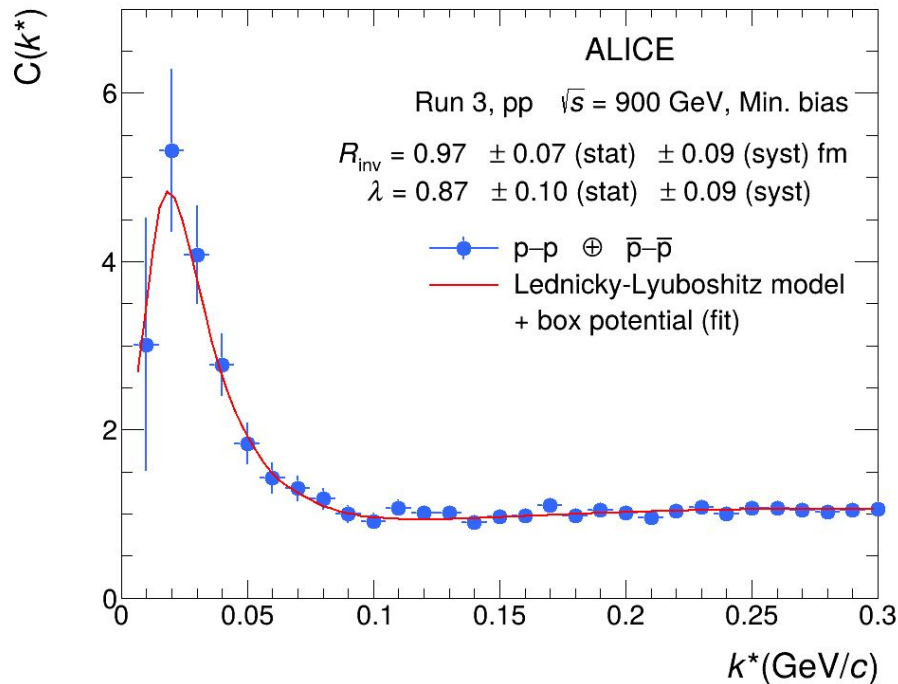
- ✓  $d/p : 0.00132 \pm 0.00007$  (stat)  $\pm 0.00015$  (sys)
  - ✓  $\text{anti-d/anti-p} : 0.00138 \pm 0.00004$  (stat)  $\pm 0.00011$  (sys)
- (quite in a good agreement with Run1)

## Run 1

0.00138  $\pm 0.00011$  stat  
 $\pm 0.00015$  sys

0.00139  $\pm 0.00014$  stat  
 $\pm 0.00015$  sys

# Measuring the proton source size - candidate for the paper



**Free  $\lambda$  from the fit = 0.87** and the  **$\lambda$  calculated by pair purity and primary fraction = 0.83** can be considered as an indirect **validation of the theoretical model** used for the fit

→ The **correlation function** is divided by the baseline, then fitted

→ Fit is done by using the Lednicky-Lyuboshitz model with a box potential approach

(LL model presentation link:

<https://indico.cern.ch/event/1270991/>)

→ The fit function is calculated as

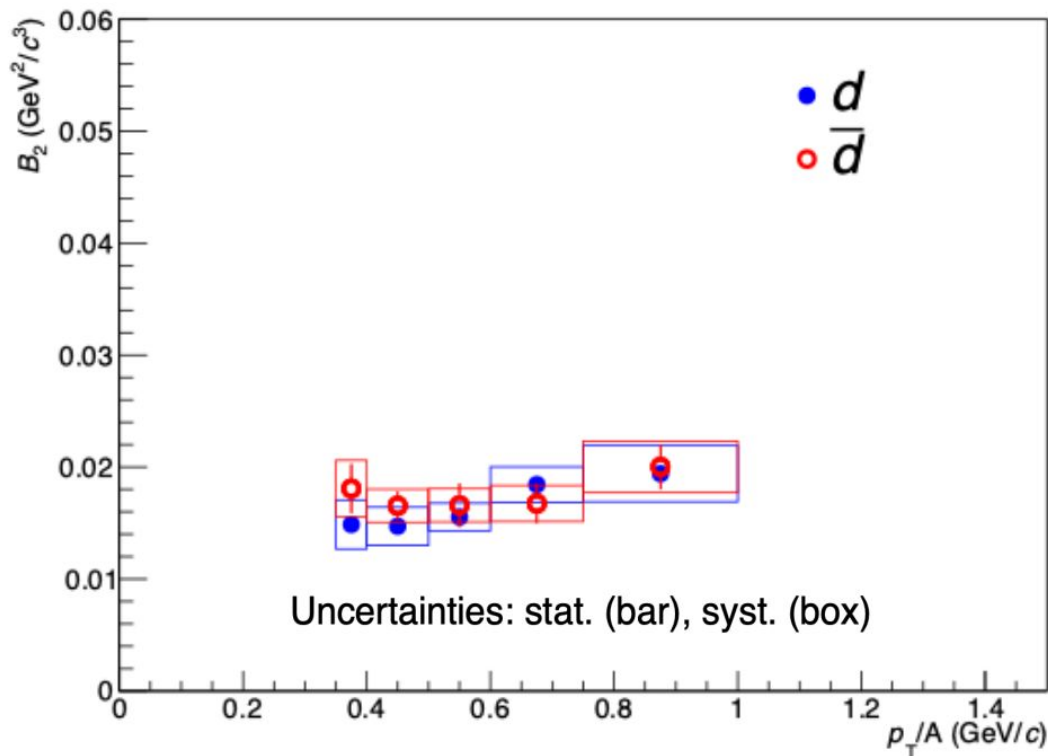
$$CF_{\text{fit}}(k_{\text{rec}}^*) = N (1 + \lambda (CF_{\text{smeared}}(k_{\text{rec}}^*) - 1))$$

→  $\lambda$  in fit is **free parameter**

From MC:  $\lambda^{\text{purity}} \times \lambda^{\text{primary}} \approx 0.83$

From Fit:  $\lambda = 0.87$

# Coalescence ( $B_2$ ) parameter - candidate for the paper



The **coalescence (B2) parameter** for deuteron and antideuteron is calculated

→ smoothly increases for deuteron as a function of  $p_T/A$

→ almost flat for antideuteron case

→ calculations from coalescence model is ongoing (generating pythia events for 900 GeV)

→ once the calculation from model is ready, it will be added to the plot



# Summary

## **The whole idea of the paper of combining the two measurement is presented**

- due to the complementary work from both analysis is well suited for a single publication
- also, making two publication can be challenging due to lack of enough material and mainly the physics aspects side too

## **The two analysis crew from CF and LF are merged together for the final paper proposal to make it a one presentation**

- the planned timeline is after the QM2025 conference in april
- PWG already liked the idea of combining two work together and would like to bring it to the Physics Forum too
- your valuable feedback/suggestions on the overall paper plan/content is important to us

**Thank you for your attention ..**