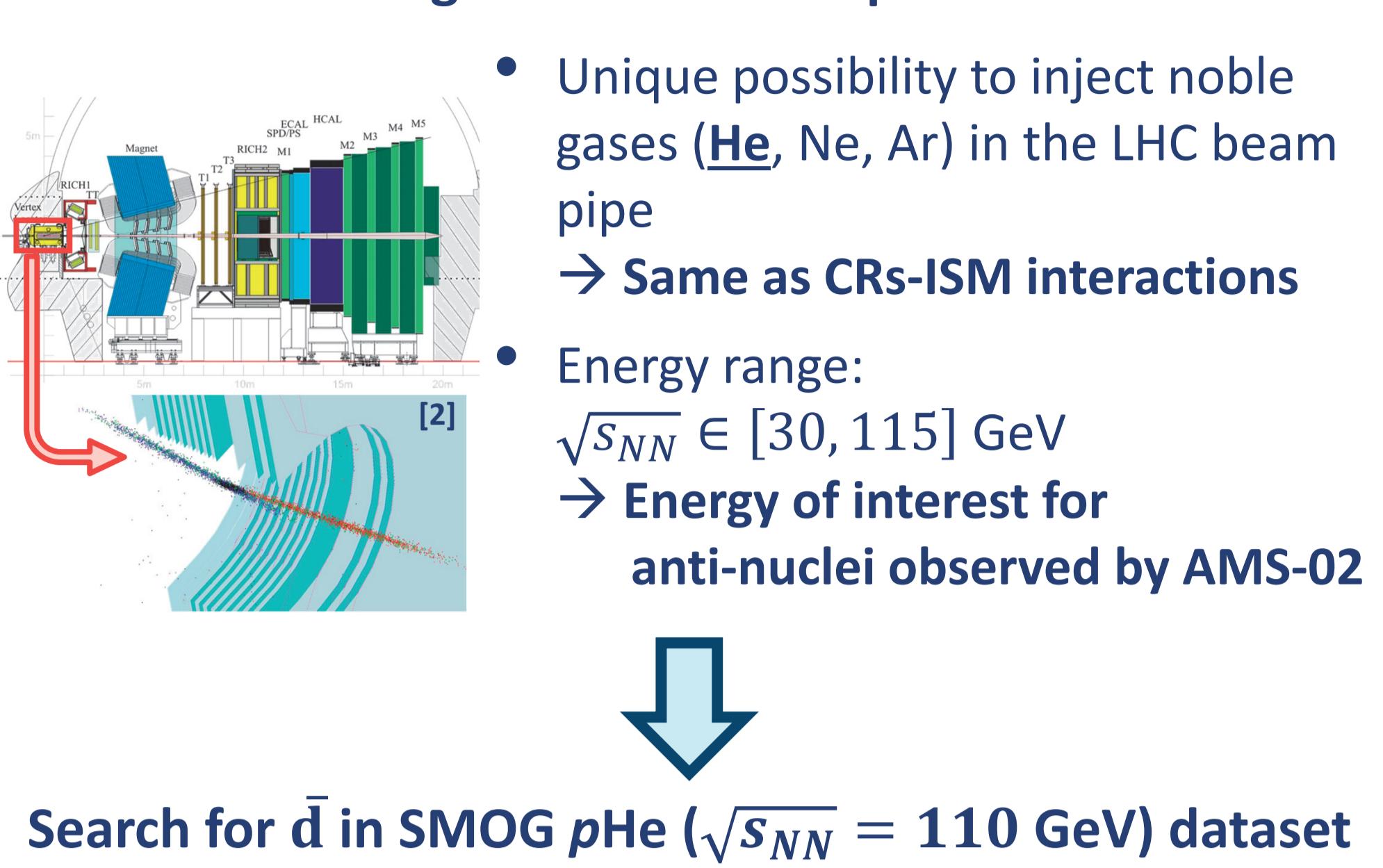


Anti-nuclei in Cosmic Rays^[1]

- Antimatter fraction in Cosmic Rays (CR) is a sensitive indirect probe for Dark Matter or exotic sources:
- Anti-nuclei production cross-section in standard model processes scales with mass number
→ **Less background, ideal channels**
 - Lack of production measurements in relevant systems for CR measurements by AMS-02: $p\bar{p}$ and $p\text{He}$ with $\sqrt{s_{NN}} \in [10, 100] \text{ GeV}$
→ **Limited knowledge of production mechanism**
- More direct measurements are needed

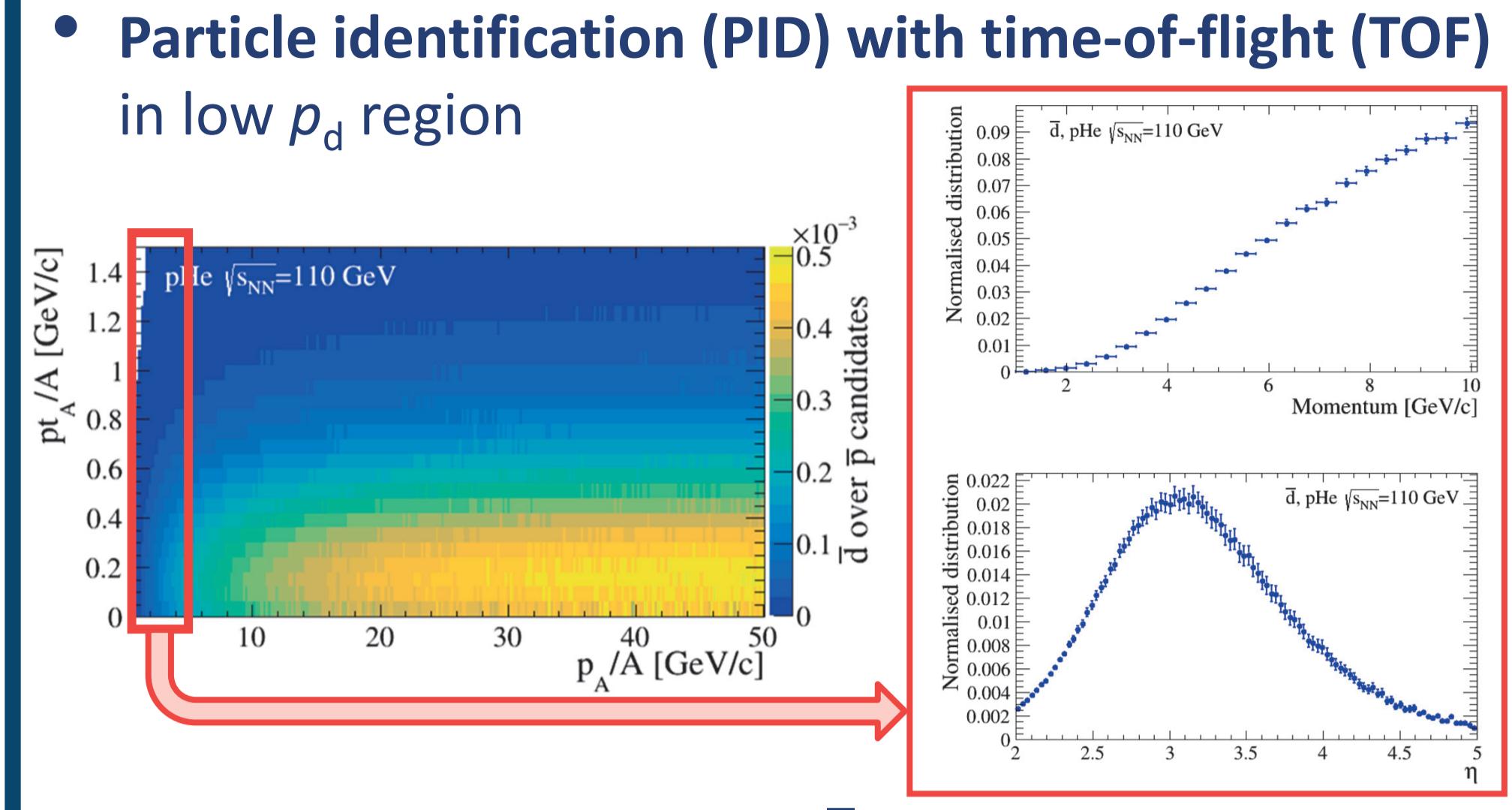
LHCb fixed target system: SMOG^[1]

LHCb: single-arm forward spectrometer



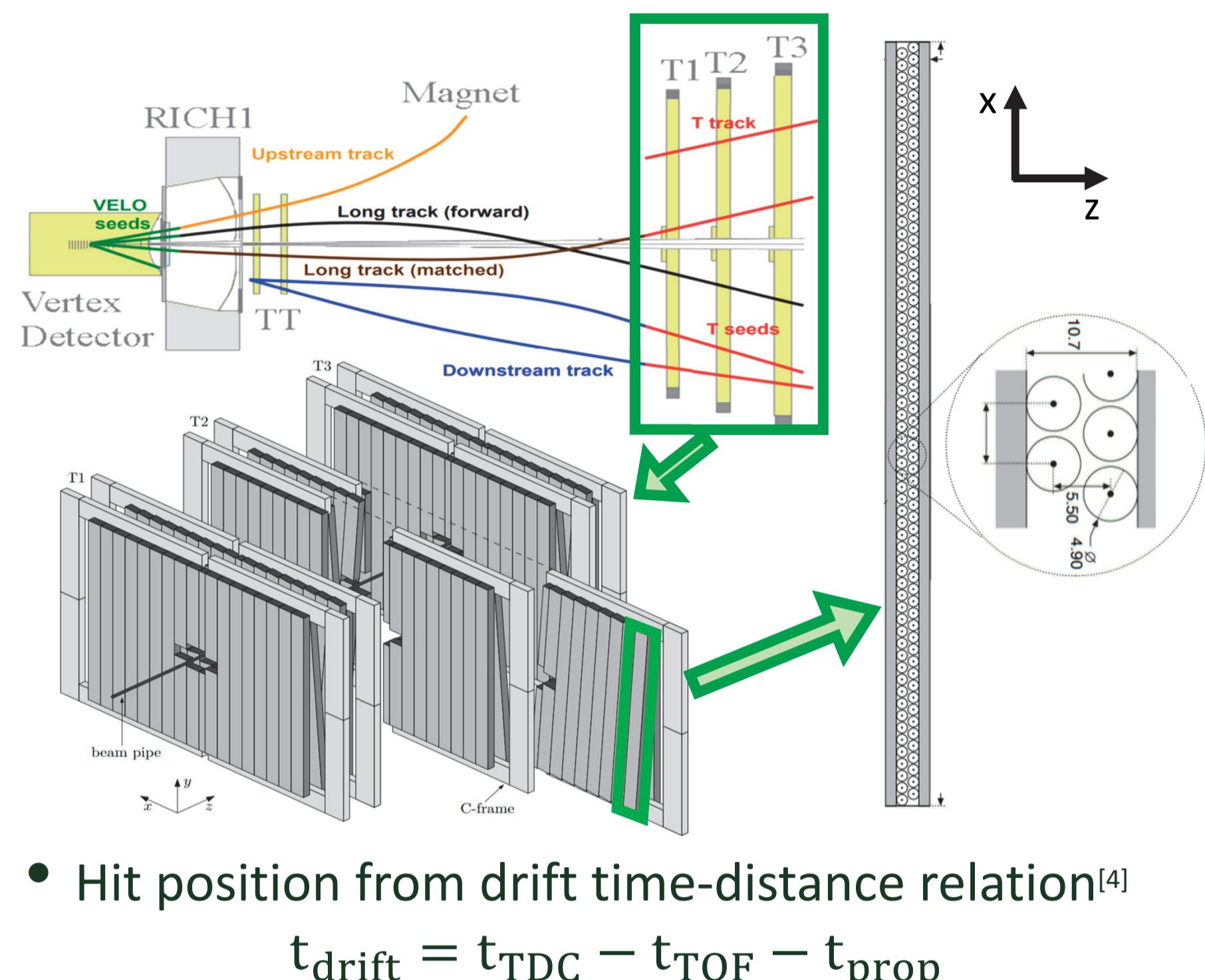
Search for \bar{d} in SMOG $p\text{He}$ ($\sqrt{s_{NN}} = 110 \text{ GeV}$) dataset

Expected \bar{d} in SMOG $p\text{He}$

- EPOS-LHC for $p\text{He} + \text{coalescence afterburner}$
 - Particle identification (PID) with time-of-flight (TOF) in low p_d region**
- 
- For $p_d < 10 \text{ GeV}/c$, \bar{d}/\bar{p} is 0.3×10^{-3}
→ 300 candidates

LHCb standard reconstruction algorithm

Outer Tracker OT: straw-tube drift chambers^[3]

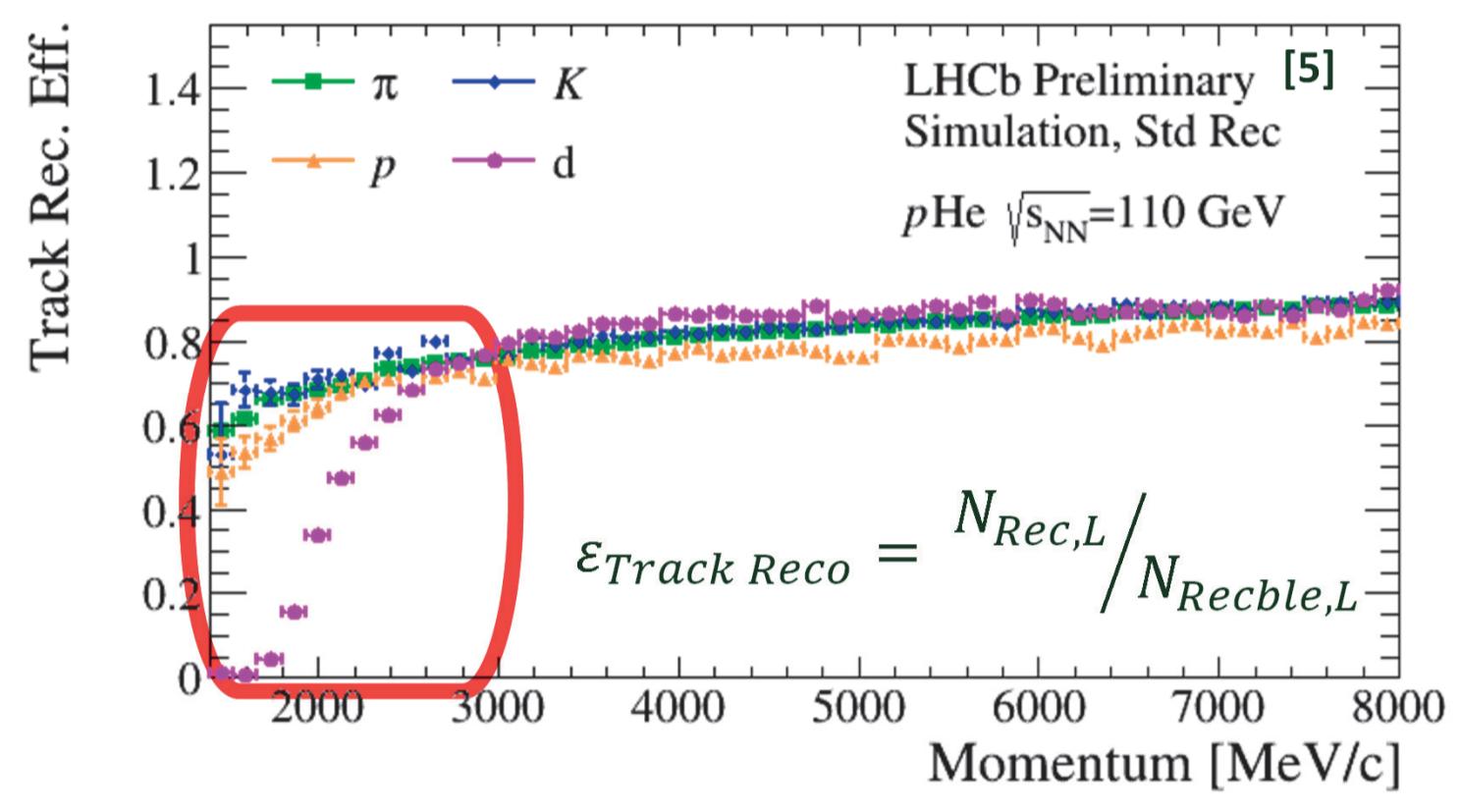


- t_{TOF} calculated in the $\beta=1$ hypothesis
- Residual between t_{TOF} and $t(r)$, expected arrival time for fitted track, is proportional to β_{real}
→ Some capabilities for proton ID with TOF^[4]

For $\beta < 1$: $t_{\text{TOF,rec}} < t_{\text{TOF,real}} \Rightarrow t_{\text{drift,rec}} > t_{\text{drift,real}}$
⇒ error introduced in r determination

- For d at $p=2 \text{ GeV}/c$, r shifted up to 1 mm
- Hits discarded or fit χ^2 too large because of error on r

Low d reconstruction efficiency at low p



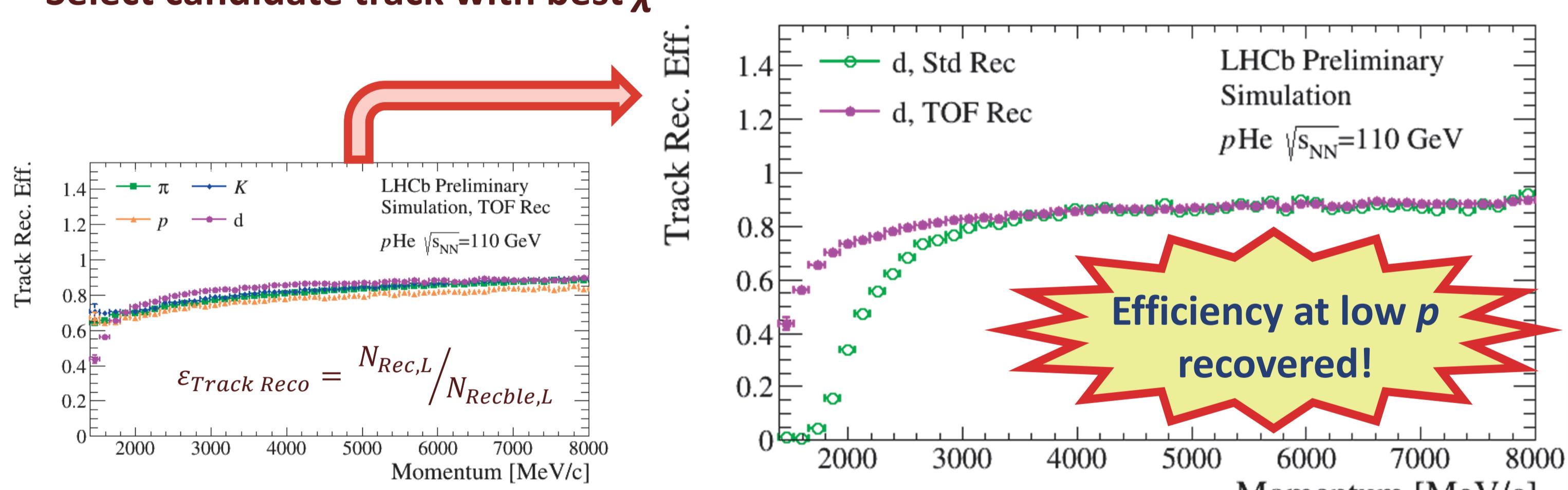
Need new reconstruction algorithm and PID strategy

TOF Rec: a modified pattern recognition algorithm^[5]

Target: Correct hits position to recover the reconstruction efficiency

Loop on $\beta \in [1/\sqrt{1 + M_{\text{max}}^2/p^2}, 1]$ and save track with best fit χ^2

- PreLoop with no OT drift time:** hit position at center of the straw, $\sigma_{\text{hit}} = 2.5 \text{ mm}$
 - If no track candidate, stop algorithm
 - If no OT hit, run regular reconstruction
 - If track with OT hit, use track momentum to set β range for loop
- Loop on β :** for each step, correct hits position for β value and perform fit
- Select candidate track with best χ^2**

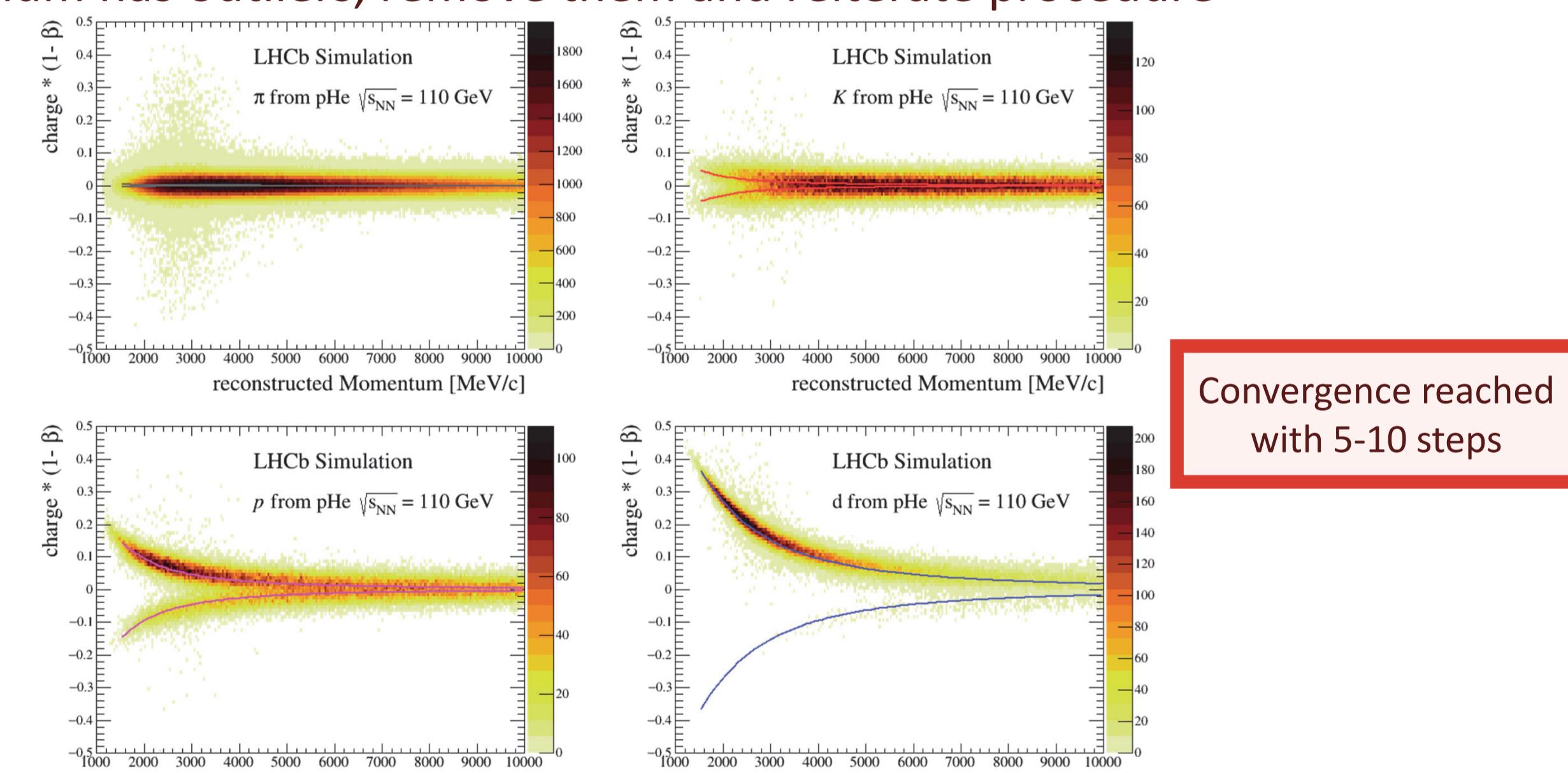


TrackBetaTool: a time-of-flight PID tool^[5]

Target: Refit reconstructed tracks to determine β

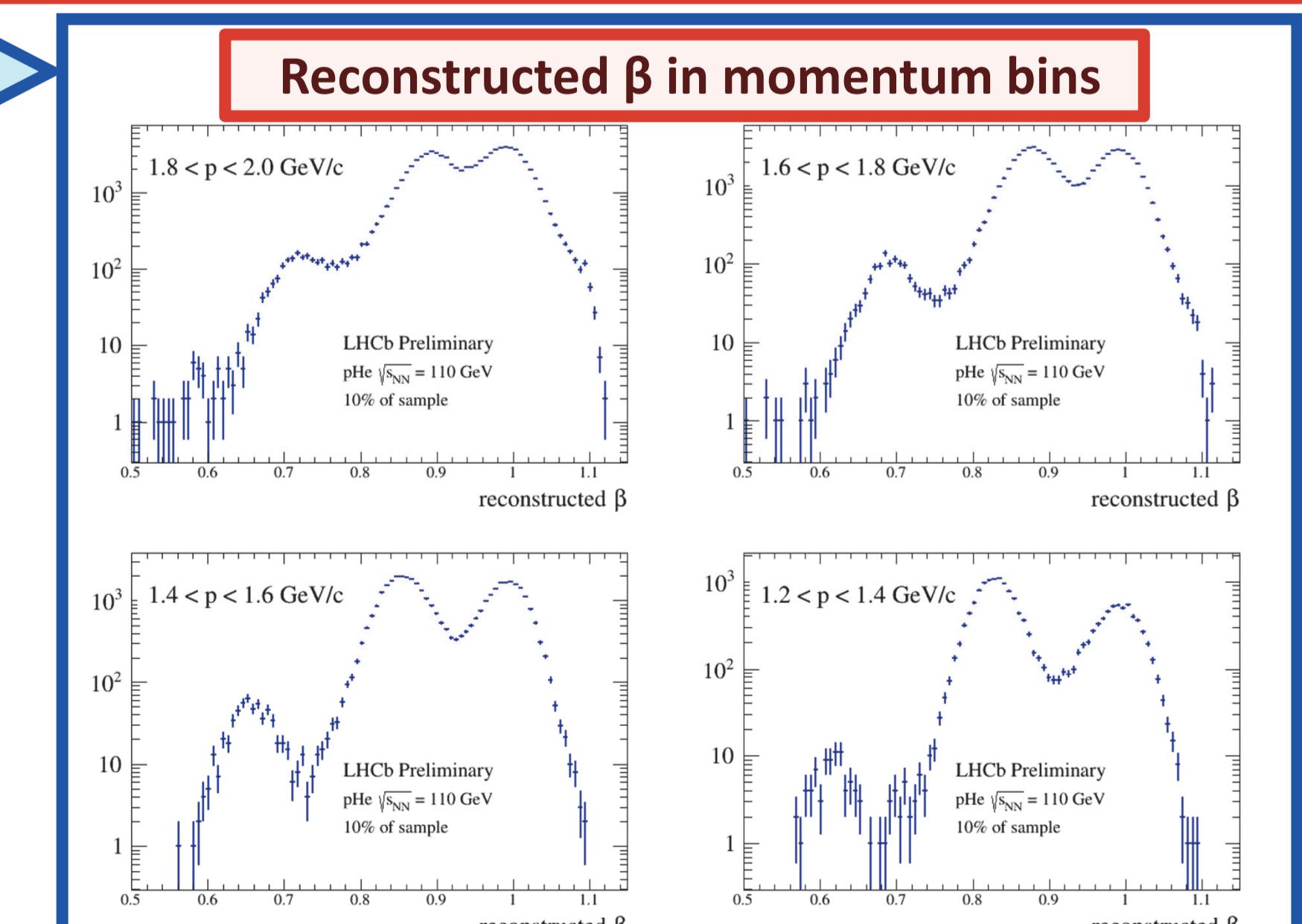
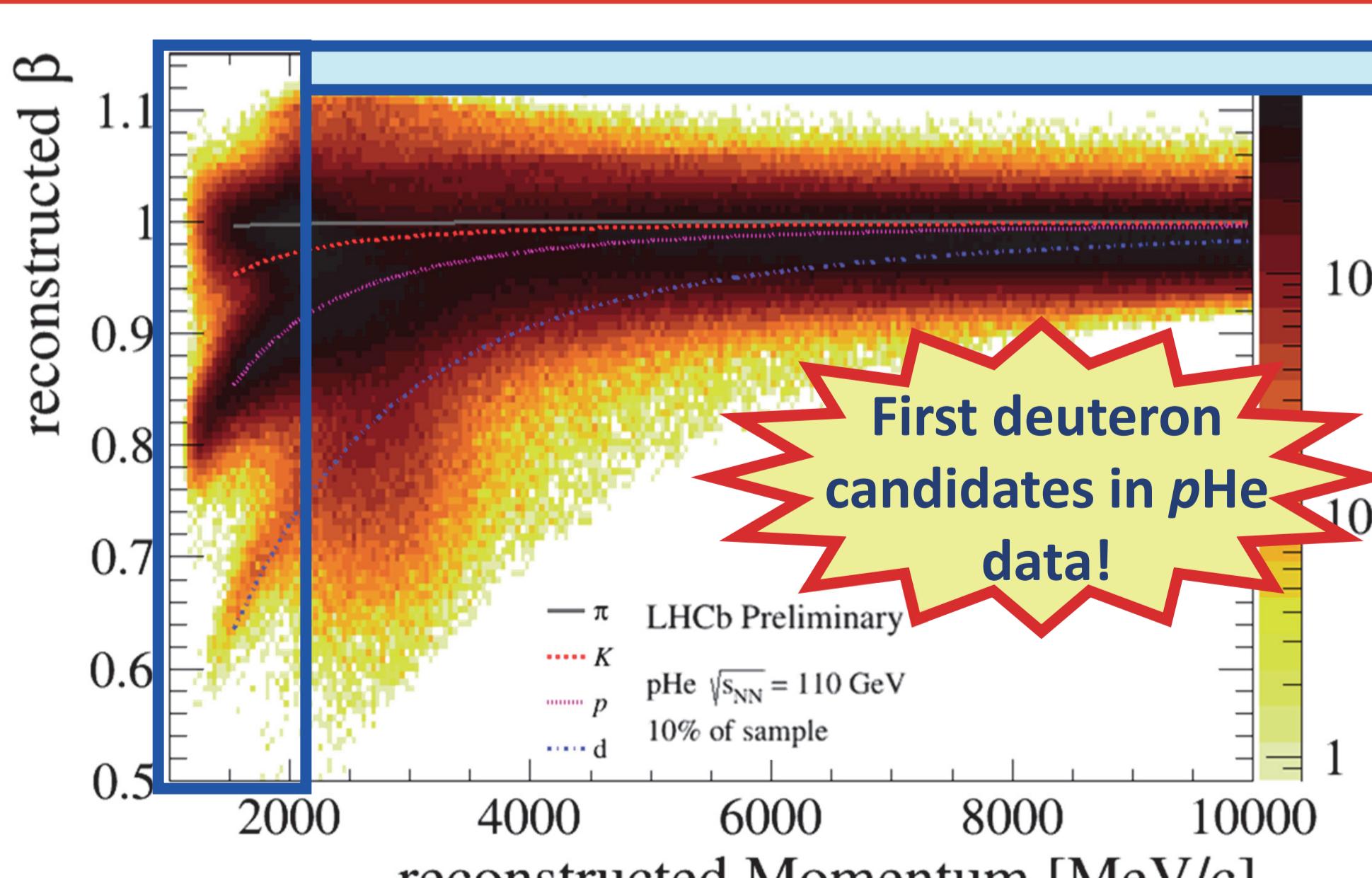
Iterative procedure rerunning Kalman fit with different β hypotheses

- At least 15 OT hits required on each track
- Change β following the fit χ^2 decrease (gradient descent) without outliers removal
- Fit around minimum to estimate β_{fit} and its uncertainty
- If fit at minimum has outliers, remove them and reiterate procedure



Results on data^[5]

- SMOG $p\text{He}$ ($\sqrt{s_{NN}} = 110 \text{ GeV}$) dataset:
→ **10% of data** reconstructed with TOF Rec and analyzed with TrackBetaTool
- Background suppressed with cuts on quality-related variables:
 - $\sigma(\beta) < 0.02$
 - $\chi^2_{\text{OT hits}}/\text{ndf} < 2$



Conclusions and prospects

Optimized TOF reconstruction algorithm to efficiently reconstruct light nuclei and developed PID tool based on β_{track} measurement

First deuteron candidates observed in $p\text{He}$ in SMOG data!

Promising start! Work ongoing towards \bar{d} measurement:

- Reprocess the complete dataset
- Develop MVA-based filter for efficient background suppression
- Systematics studies, e.g. DATA/MC discrepancies in OT response

References

- [1] LHCb-PUB-2018-015
- [2] JINST 9 (2014) P12005
- [3] LHCb-2003-035
- [4] JINST 12 (2017) P11016
- [5] LHCb-FIGURE-2023-017