How nuclear physics can help us to unveil the origin of Antimatter?
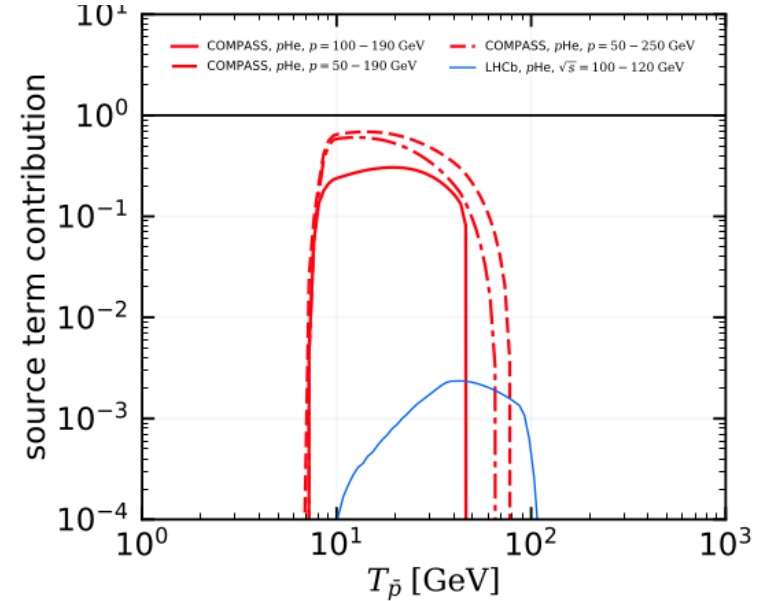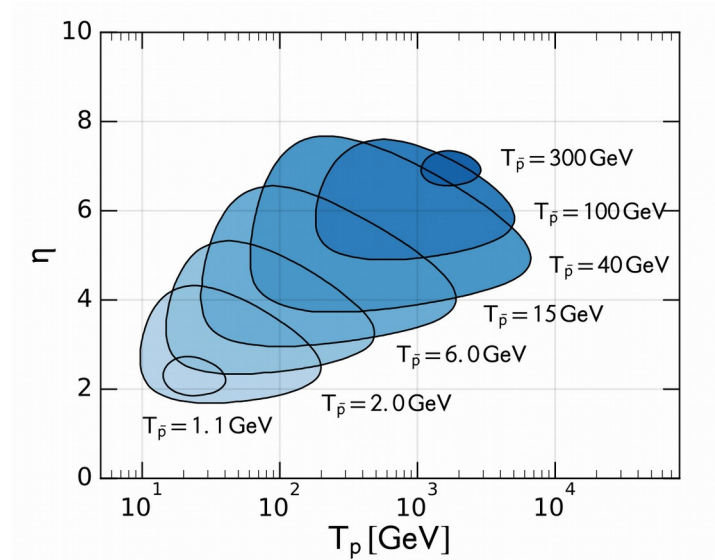
Round table discussion
[Panellists: David Maurin / Natasha Sharma]

1) Antiproton-related cross sections
2) Antimatter-related cross sections
3) Other cross sections?
4) Time for a roadmap?

1) Anti-protons: parameter space to be covered

→ *See Donato, Kachelrieß, Korsmeier, Oliva, Vittino, and Zuccon*

- Can nuclear experiments reach these regions of interest?
- Is there a higher priority region for CR physics, higher priority projectiles/targets?
- Is there a higher priority region where data can maximally constrain parametrisations?
- Should we rely on Monte Carlo generators tuned with 'all' accelerator physics data?

1) Anti-protons (cont'd): anti-hyperon and anti-neutron production

Slide borrowed from M. Boudaud

$$\sigma_{\text{inv}}^{\text{tot}} = \sigma_{\text{inv}}(2 + \Delta_{\text{IS}} + 2\Delta_{\Lambda})$$

Could mis-modelling create a structure in pbar spectrum?

Can we improve theoretical calculations? Do we need dedicated measurements?

Production XS: antihyperons and antineutrons

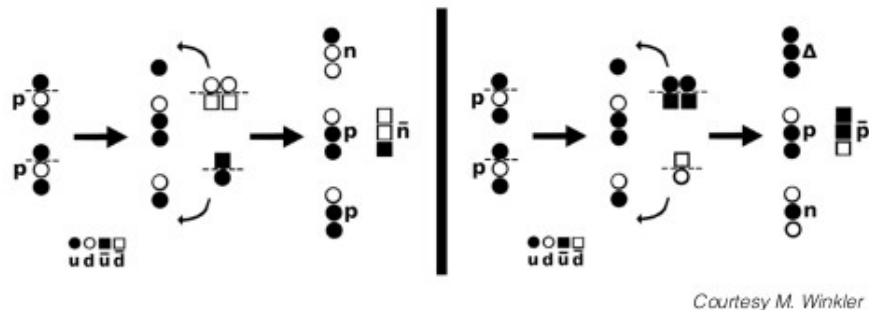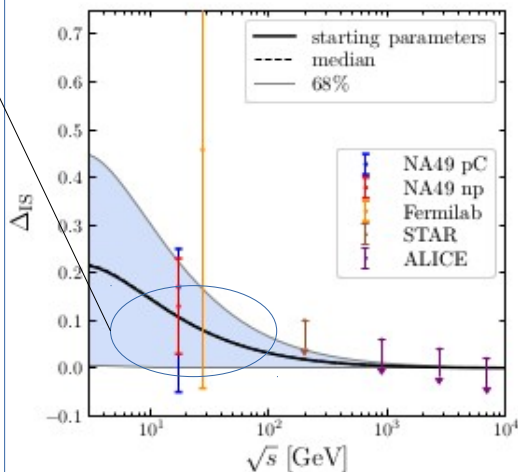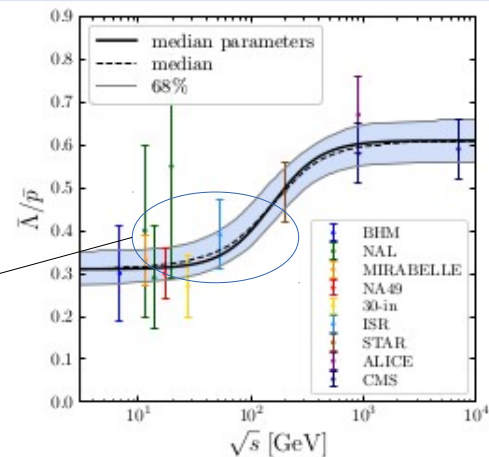- **Antihyperons decay:** $p + p \longrightarrow \{\bar{\Lambda}, \bar{\Sigma} \longrightarrow \bar{p}\} + X$

  Parametrisation from *Winkler(2016)*

  $$\Delta_{\Lambda}(\sqrt{s}) = (0.81 \pm 0.04)(\bar{\Lambda}/\bar{p})$$

- **Antineutrons decay:** $p + p \longrightarrow \{\bar{n} \longrightarrow \bar{p}\} + X$

  Isospin asymmetry: $\sigma_{pn \to \bar{p}} > \sigma_{pp \to \bar{p}} \implies \sigma_{pp \to \bar{n}} > \sigma_{pp \to \bar{p}}$
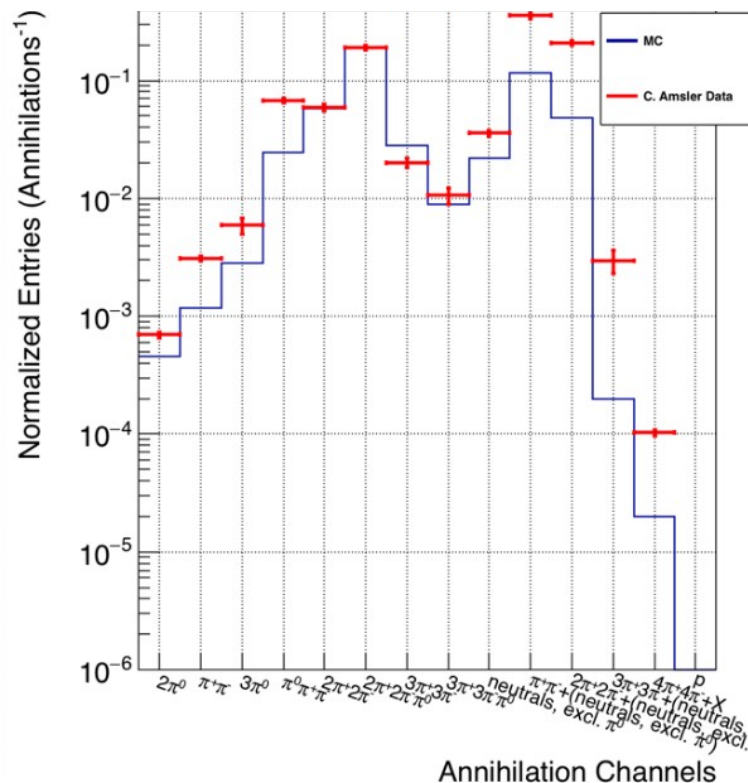
  (NA49) Anticic+(2010), Winkler(2016)

Courtesy M. Winkler

$$\Delta_{\text{IS}} = \frac{\sigma_{pp \to \bar{n}}}{\sigma_{pp \to \bar{p}}} - 1$$

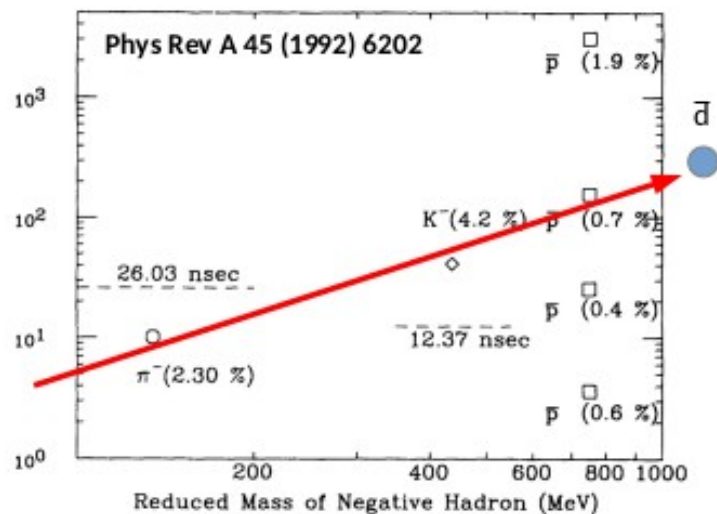$$\Delta_{\text{IS}}(\sqrt{s}) = c_0(x + c_2)^{c_3} \exp(-x/c_1), \quad x = \log(\sqrt{s})$$

1) Anti-protons (cont'd): dedicated measurements for GAPS/HDHD?
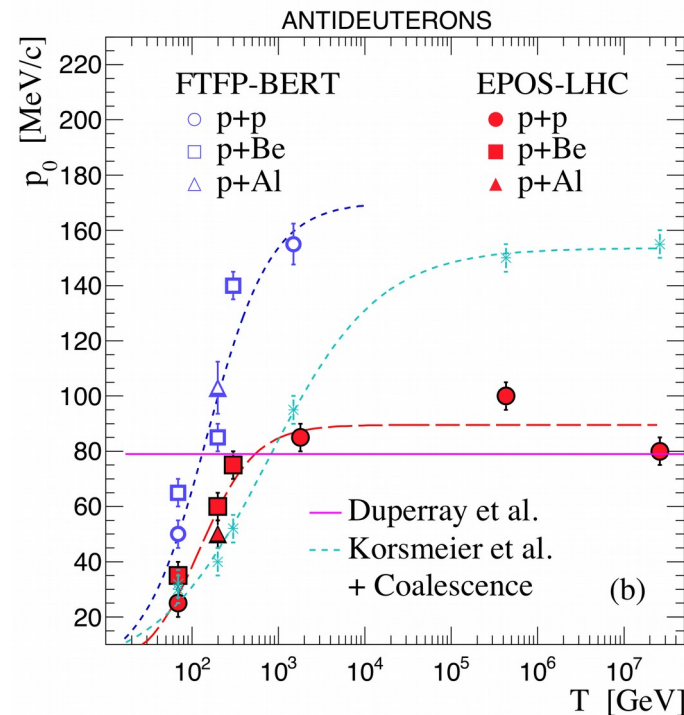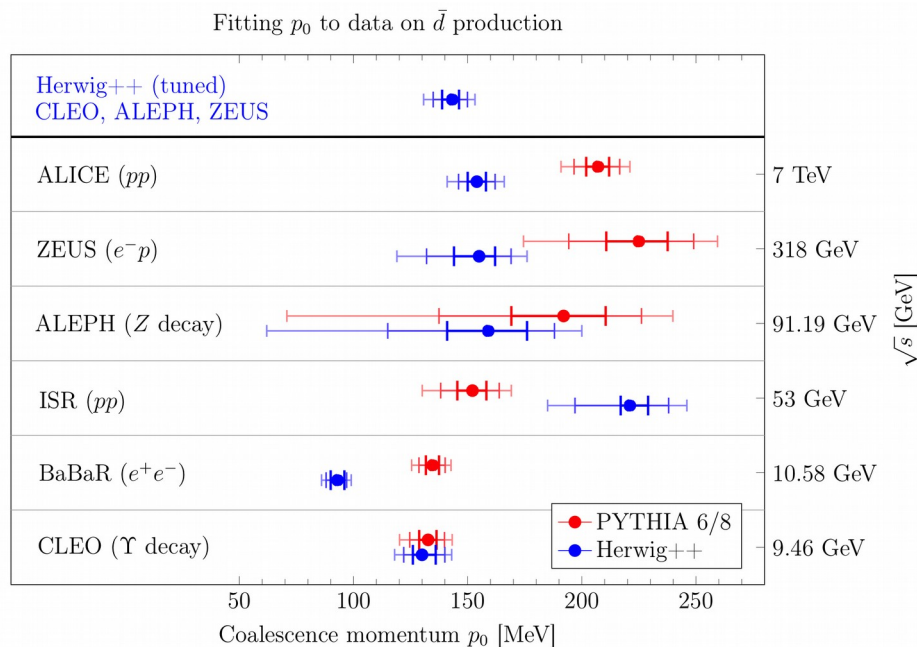
P. Von Doetinchem

F. Nozzoli

Isotope effect:
expected lifetime increase as squared of the
reduced mass => **expected for antideuterium**

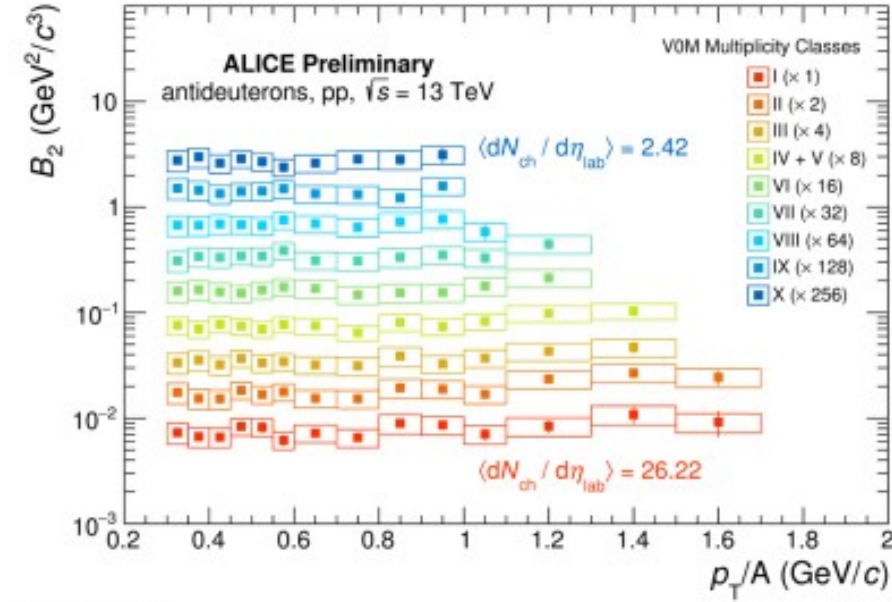Are there key measurements to perform?

2) Anti-deuterons and anti-nuclei

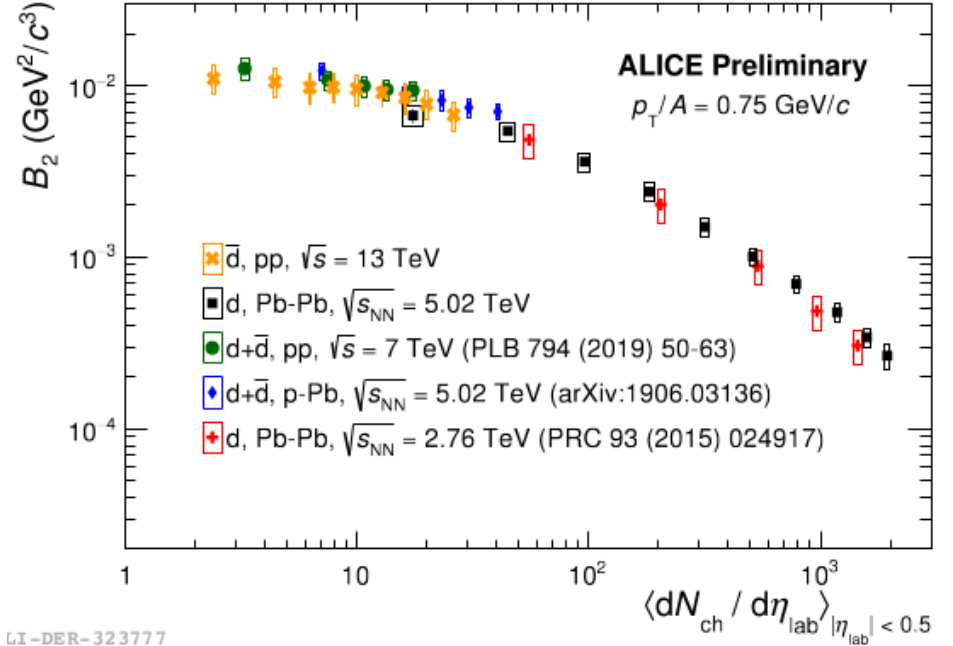*→ See Salati, Kachelrieß, Sharma, Oliva, and Von Doetinchem*

Fitting p_0 to data on $\bar{d}$ production

- More data needed to constrain p_0 parameter?

- More data for anti-^{3}He and anti-^{4}He to test coalescence model?

- Shall we abandon coalescence model for event-by-event generators?

2) <u>Anti-deuterons</u>

→ See Sharma
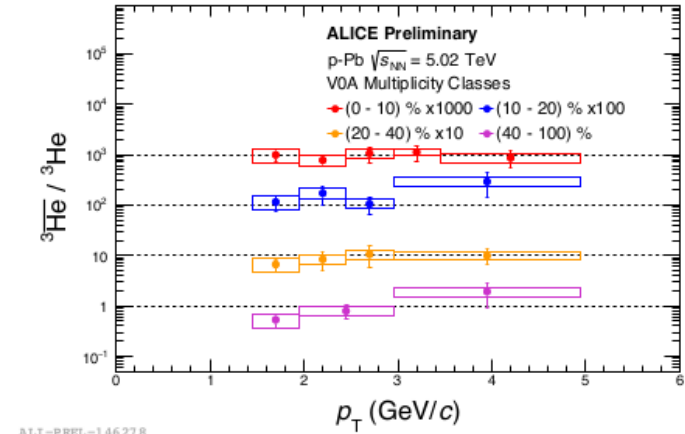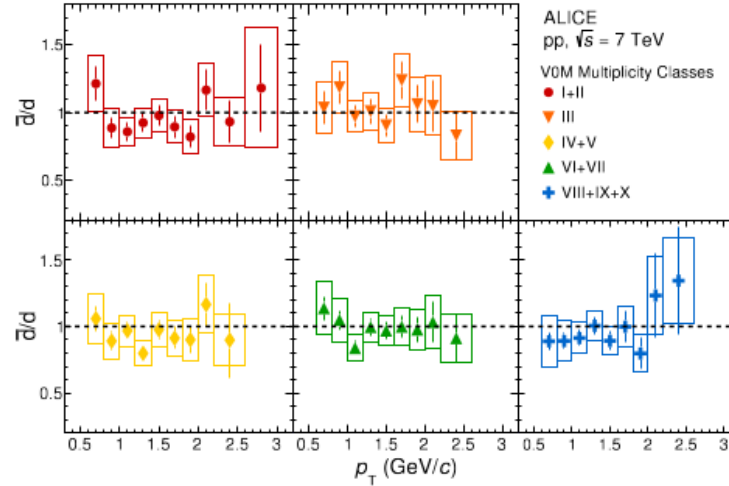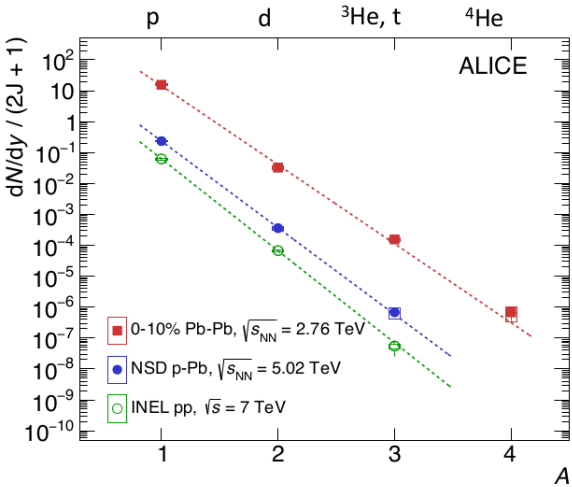

Shall we not abandon coalescence models?

2) <u>Anti-nuclei</u>

→ *See Sharma*

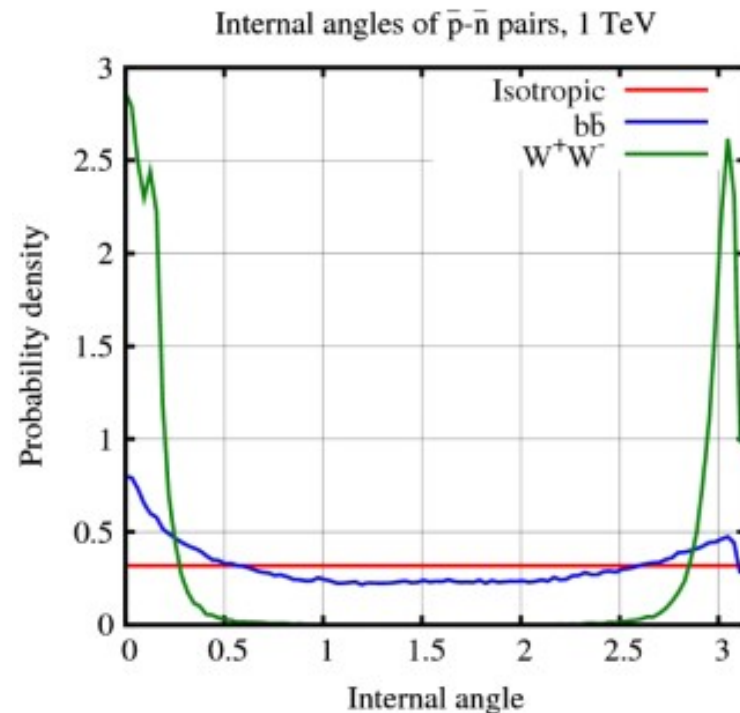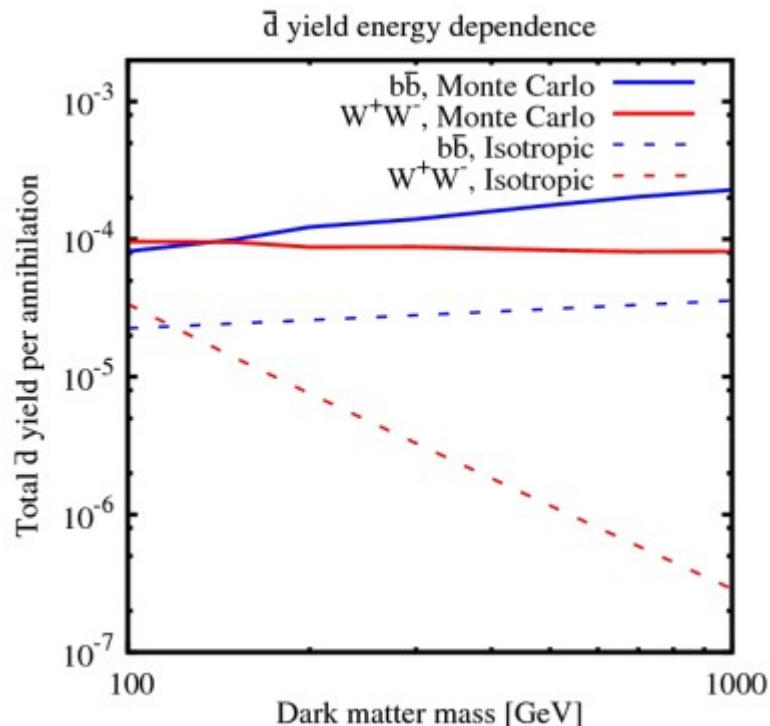*N.B.: all cross sections behave as expected: the heavier the rarer...*

Colliders cross sections help demotivate us believing in anti-^{3}He and anti-^{4}He event?
→ More data needed to be further demotivated?

2) Anti-deuterons and anti-nuclei (cont'd)

→ See Kachelrieß

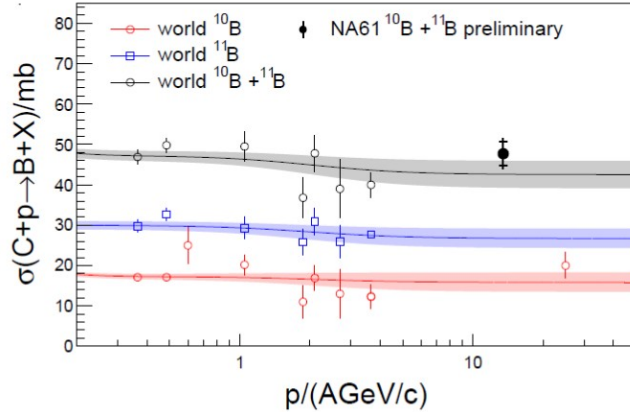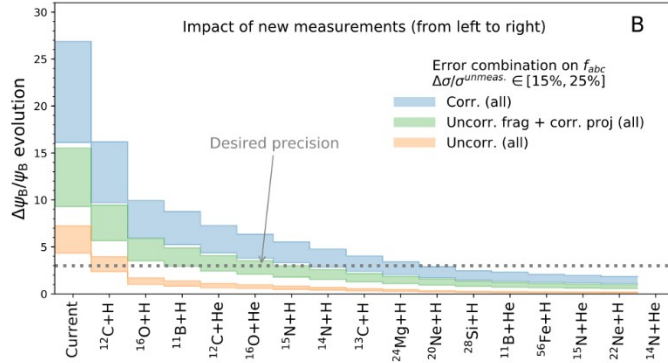d̄ yield energy dependence

Internal angles of p̄-n̄ pairs, 1 TeV

- Shall we abandon coalescence model for dark matter-induced WW antideuterons?
- Is it really pressing to put efforts in this direction given "good" DM candidates are "light"?
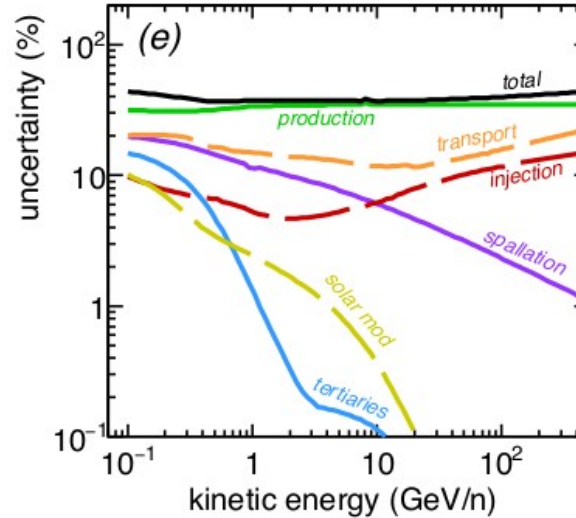- Could simple "effective" parametrisations provided for the community?
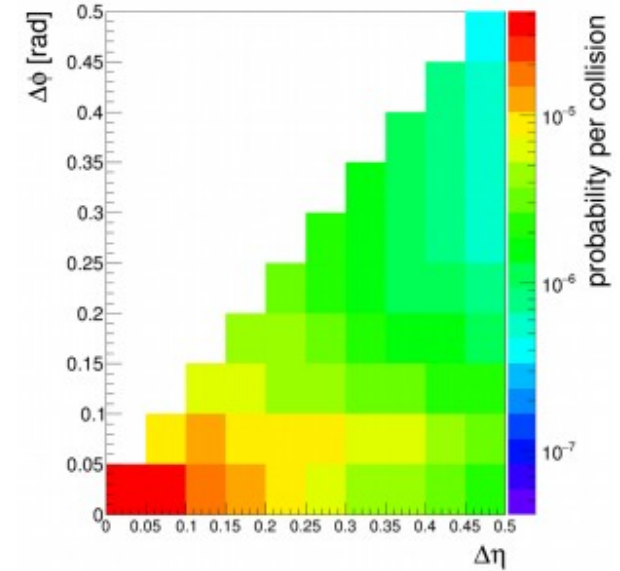
3) Other cross sections

→ *See Maurin, Oliva, and Von Doetinchem*

Nuclear measurements to decrease propagation uncertainties on anti-beasts?

Do we need better non-annihilating cross section measurements?

Angular correlation of p-p pairs within a radius of Δp=100MeV/c

Other reactions that could shed light on antinucleus-related cross sections?

4) <u>Time for a roadmap?</u>

We have experts from

- CR propagation
- CR solar modulation
- Anti-nuclei production cross sections (theory and experiments)
- GAPS, AMS-02, etc. experiments
- "New physics" candidates (WIMP, PBH, anti-stars)

$\rightarrow$ Would it be interesting to coordinate our efforts to produce a roadmap to pave the way forward do deal with all these uncertainties?

$\rightarrow$ Status of present calculations and uncertainties
$\rightarrow$ Foreseen improvements, needs on some given timescales