AD: Quest for dbars

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07/02/2025 – IPP MD Days 2025

Why dbars?

- **Next simplest anti-nucleus we can produce:** one n-bar + one p-bar
- **Not much physics quantities well measured compared to “normal” deuteron:**

Property	Deuteron	Antideuteron
Mass	8 ppt [15]	4.3 % [17]
Magnetic dipole moment	0.5 ppb [16]	Undetermined
Electric quadrupole moment	700 ppm [16]	Undetermined
Binding energy	1 ppm [16]	Undetermined
Electric dipole moment	Proposed [18]	Undetermined

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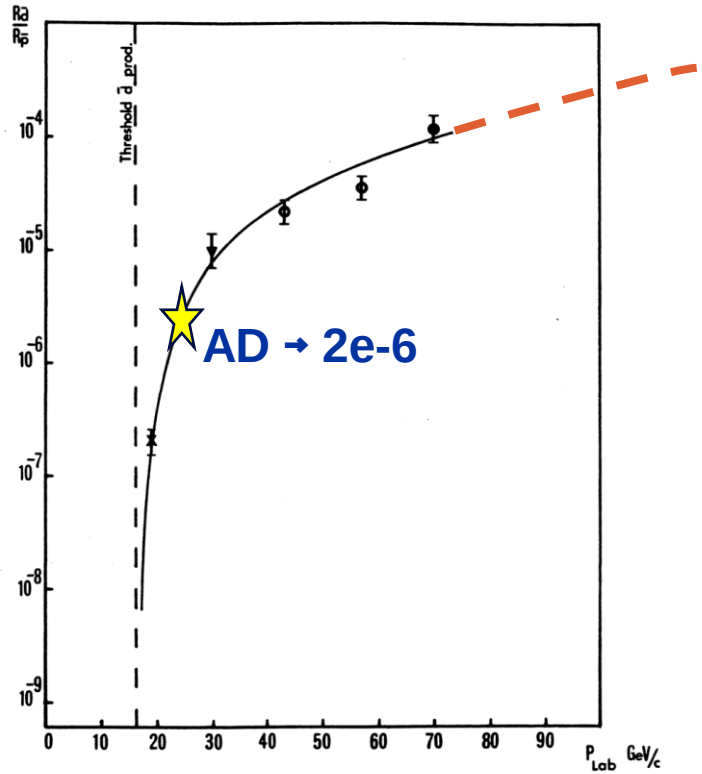
EXA-LEAP2024

Table 1: Intrinsic properties of the deuteron and antideuteron.

- **Growing interest in AD/ELENA user community**
  - It is a ”convenient” (charged particle) way to get **access to the anti-neutron**
- **Interest from high-energy physics community**
  - They are used to produce dbars with p or ions at high energy in LHC, which they model well, but there is much **uncertainty on production cross-section at low energy**

How many dbar/pbar to be expected? In literature:

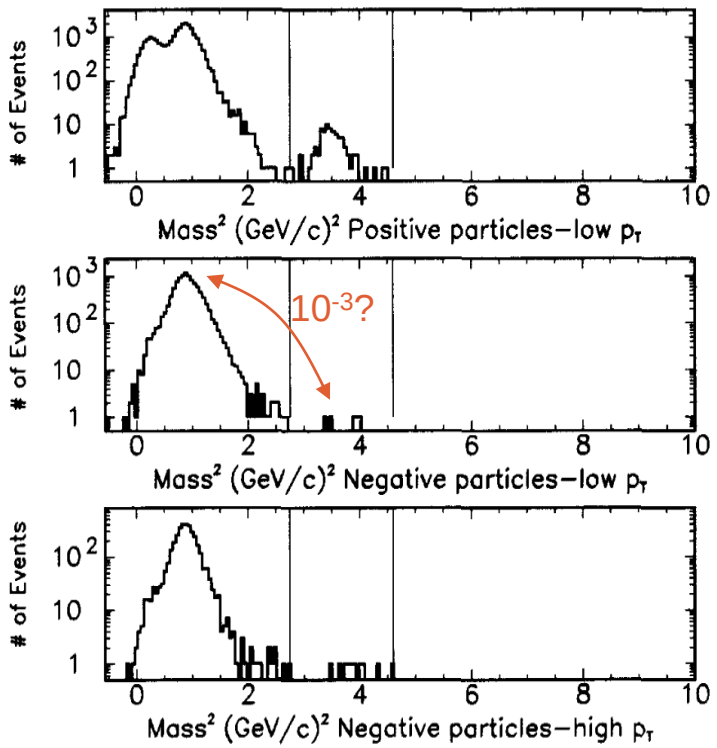


Source		p_{inc} (GeV/c)	p_{sec} (GeV/c)	p_T (GeV/c)	Lab. angle
● Antipov et Al. [10]	p-Al	70	13.3	0.6	
○ Binon et Al. [11]	p-Al	52	18.7		0°
○ Binon et Al.	p-Al	43	15.5		0°
▼ Dorfan et Al. [2]	p-Be	30	5	0.4	
✕ Massam et Al. [3]	p-Be	19.2	2.5		6°

Fig. 1 - Experimental antideuteron/antiproton production ratios, Rd/Rp, where Rd = d̄/π⁻ and Rp = p̄/π⁻.

C.D. Johnson et al. – CERN-PS-88-05-AR

p_{lab} 450 GeV/c @ NA44



J. Simon-Gillo et al. – Nucl.Phys.A 590(1995)

Beam energy dependence of (anti-)deuteron production in Au + Au collisions at the BNL Relativistic Heavy Ion Collider

J. Adam[12], L. Adamczyk[2], J. R. Adams[35], J. K. Adkins[26], G. Agakishiev[24], M. M. Aggarwal[37], Z. Ahammed[57], I. Alekseev[3,31], and D. M. Anderson[51] *et al.* (STAR Collaboration)

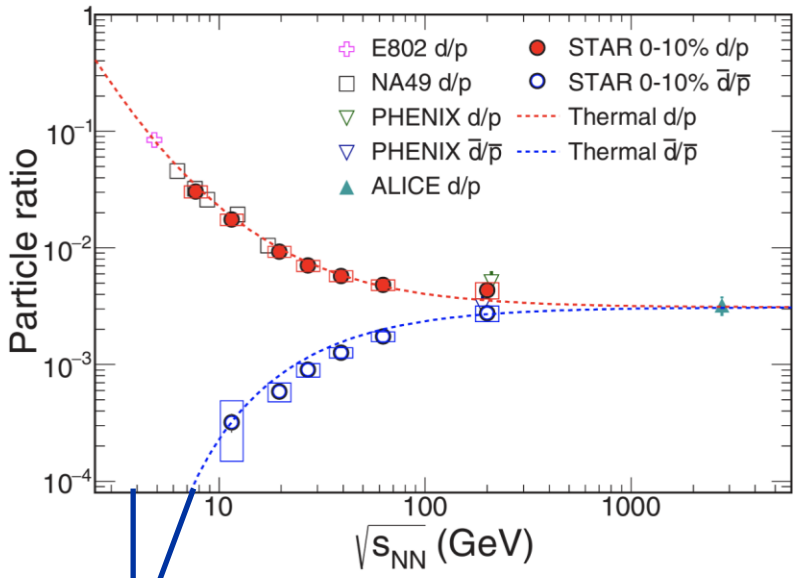
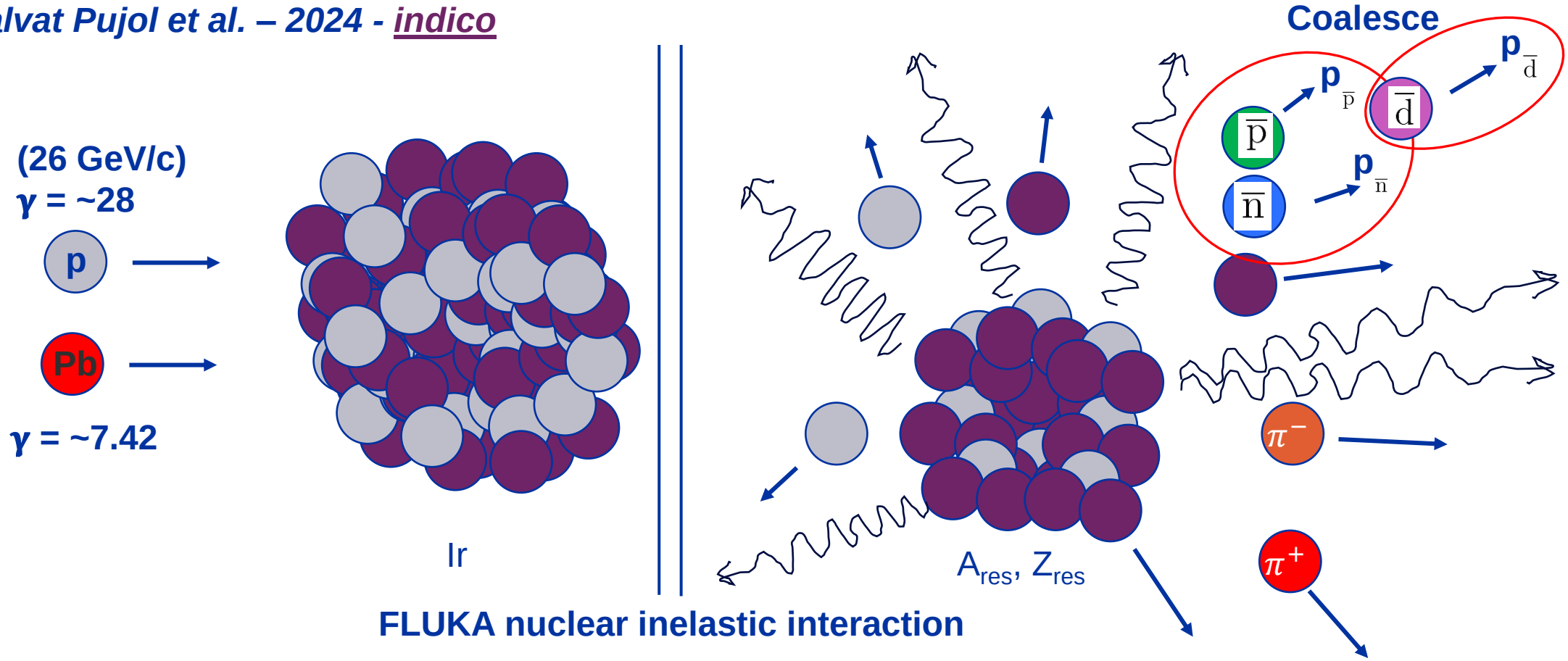


FIG. 10. Energy dependence of d/p and $\bar{d}/\bar{p}$ yield ratios. The curves represent the thermal model results as described in the text. The symbols represent measured data [16,32,36,39].

https://doi.org/10.1103/PhysRevC.99.064905

a FLUKA simplified model [PRELIMINARY!!!]

By F. Salvat Pujol et al. – 2024 - indico



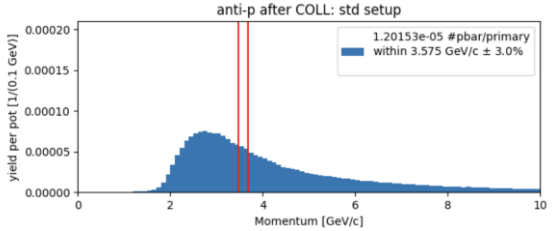
FLUKA nuclear inelastic interaction

⇒ **Confirming 1988 expectations: ~2e-6 dbar/pbar => only about 50-100 dbars in AD (?)**

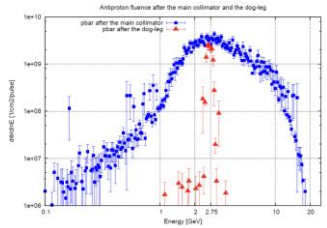
⇒ **What if we were using Pb as primary? ~1e-4 dbar/pbar (but Pb/p ~5e-5 …)**

Tests we started doing in AD

1. **Check if we see something already now on Schottky at frev=1.45509226 MHz (instead of 1.589328 MHz of pbars)**
   - **[done] – nothing seen**
2. **Try to re-bunch at anti-deuteron frequency, start deceleration (to kill the pbars), then scrape the leftovers: do we "kill" something else, i.e. anti-deuteron??**
   - **[partially done] - no signal visible.**
3. **Try to configure s-cooling notch filter to cool (longitudinally) anti-deuteron**
   - Maybe possible with old 2 GeV/c notch filter
4. **Inject in AD at different (lower) momentum**
   - Kind of check for expected pbar distribution



L. S. Esposito – SY-STI – FLUKA simulations April 2024

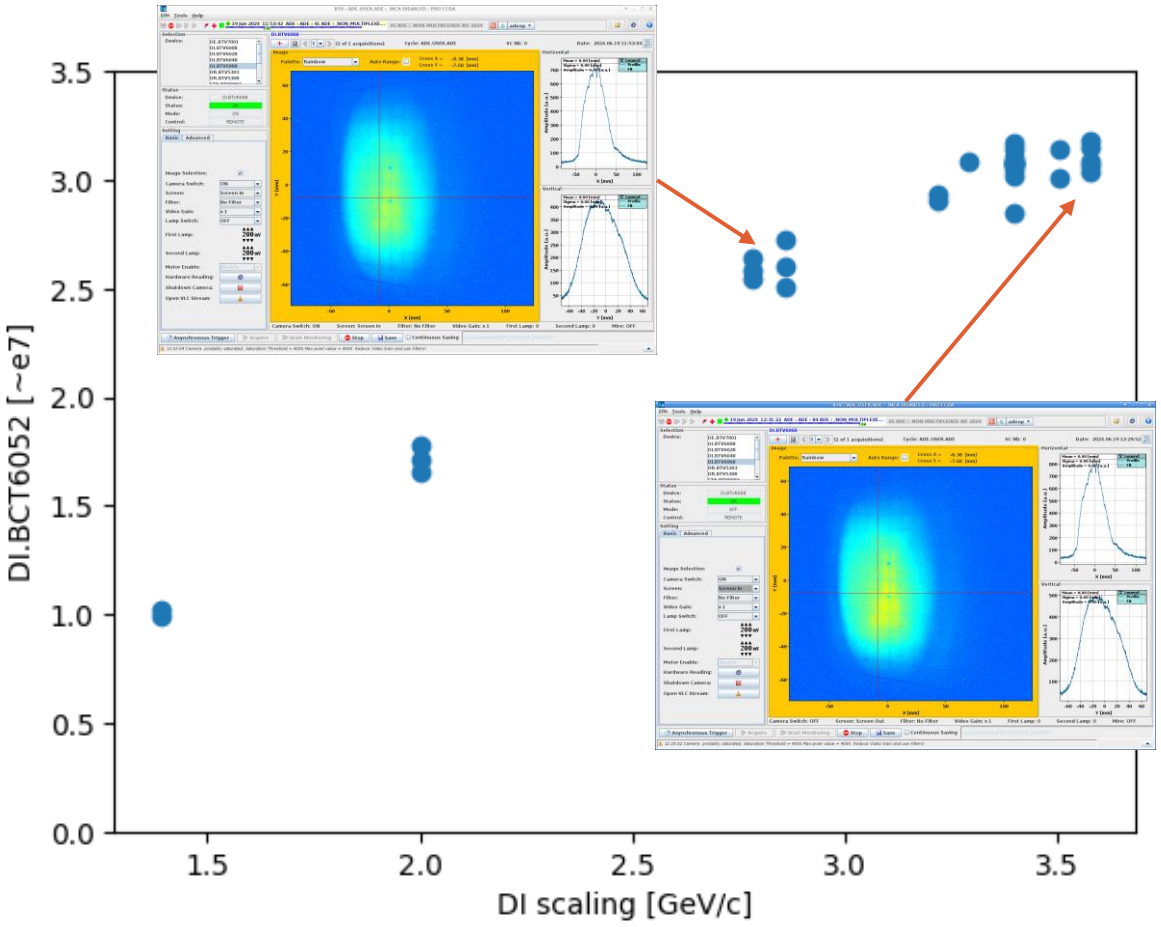


From ATS_Note_2012_069_TECH

5. **Try to inject at p=2.781 GeV/c**
   - This corresponds to C10 h=7 for anti-deuteron: maybe possible to see a coherent signal at injection?
6. **… Develop/install resonant Schottky monitor like the one used in GSI for single particle measurements?**
   1. Started to think about it in AFMD-6

Some 2024 tests: pbars(?) momentum distribution measurement

Scaling of DI line (from horn to AD injection septum and kickers) to see if we could potentially inject lower momentum pbars (and other particles) – see logbook



First attempt shows that enough negatively charged particles would reach the ring…

Note 1: most points obtained with -150A offset removed to the settings on DI.BHZ24/25, starting from p=2.7 GeV/c, then “linearly” lower offset for p values close to 3.57 GeV/c. This is a “known” effect of those two initial dipoles in the line.

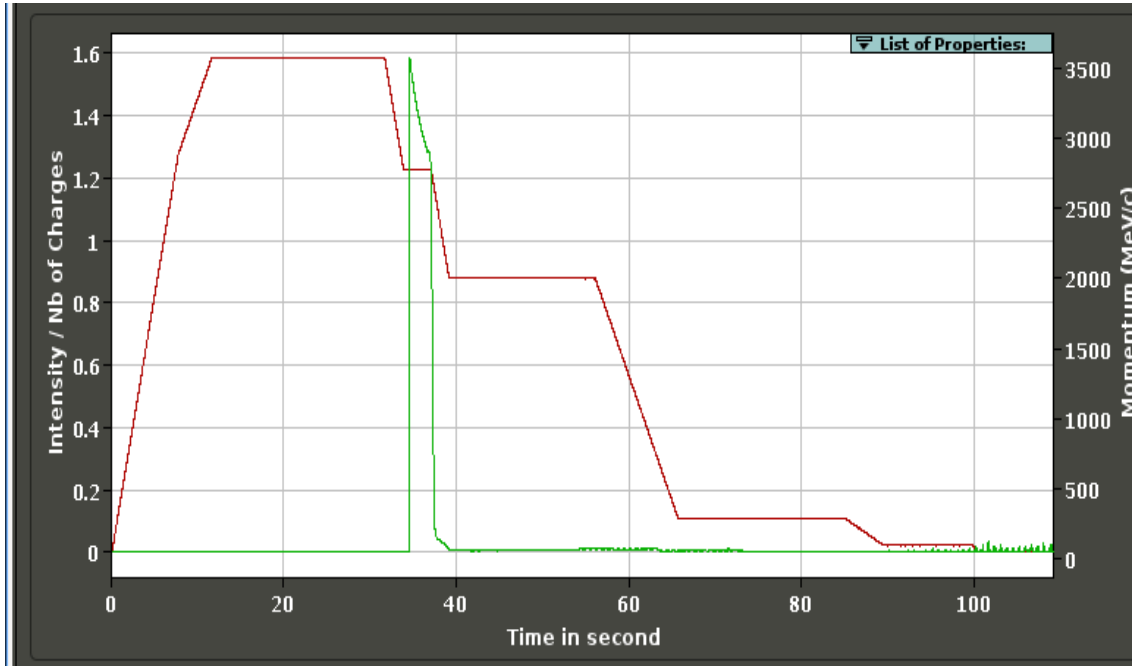
Note 2: spot on BTV6068 seems very similar: some hope for a reasonable matching with AD.

WARNING! At this location we measure all particles! We don’t know the pbar content here!

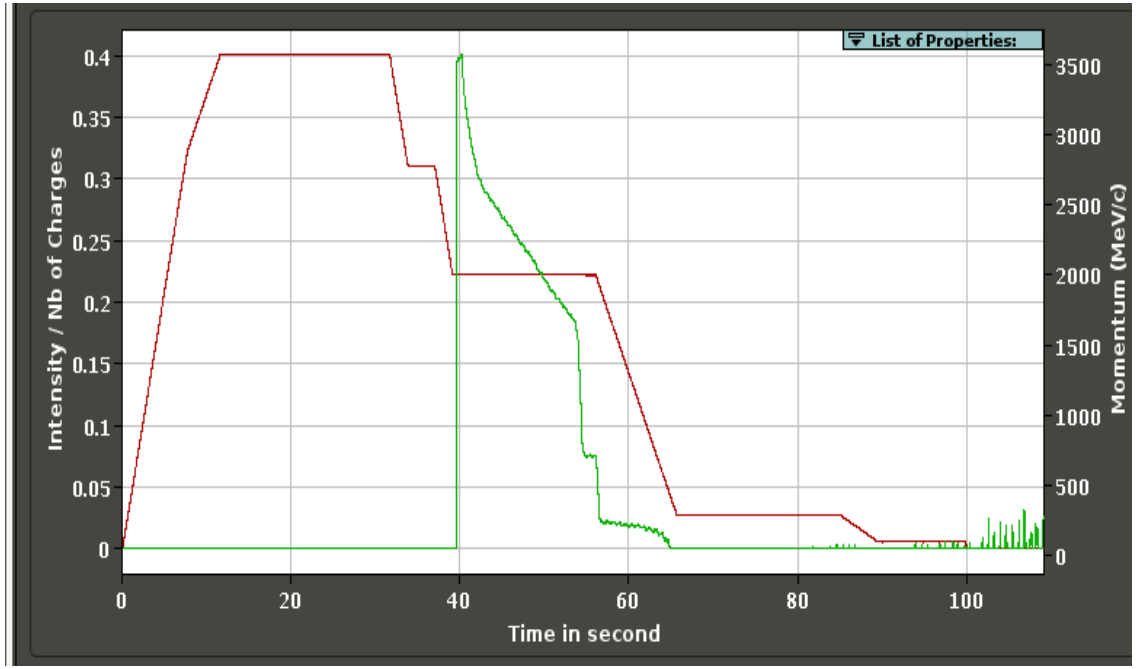
Some 2024 tests: injecting pbars at different momenta in AD

1. **Injecting pbars in the ring at different momenta**
    1. ~1/3 of intensity injected and circulating at 2.7 GeV/c
    2. ~1/10 of intensity injected and circulating at 2 GeV/c

Injecting in AD at ~2.7 GeV/c



Injecting in AD at 2 GeV/c



What to expect in 2025

1. **Exploring the feasibility of detecting dbars with (available) instrumentation**
   - Ongoing but **sparse discussions** among ABP, BI, OP, RF, etc.; **a dedicated meeting is needed** to identify promising solutions
   - **If experiments formalise a request (SPSC call ongoing)**, initiate discussions/studies on developing a dedicated monitor for post-LS3, including potential s-cooling (and bunch rotation?!) modifications

2. **Systematic data collection on pbar yield at different momenta**
   - Valuable opportunity to **further validate FLUKA models** and DI transport (see Y. Dutheil et. all)

3. **The actual request for you: could we think of having a Pb beam sent to AD?**
   - Primarily useful for validating **FLUKA's production cross-section predictions**
   - (I assume this would be a single bunch, of maximum intensity, no compression/rotation/… with same rigidity as p beam, … maybe keeping Pb54+?, maybe stripping to Pb82+ before the PS?, …)

More Ideas are Welcome!