Antihydrogen production and cross section measurement for GBAR experiment

PHENIICS Fest, 07/03/2025

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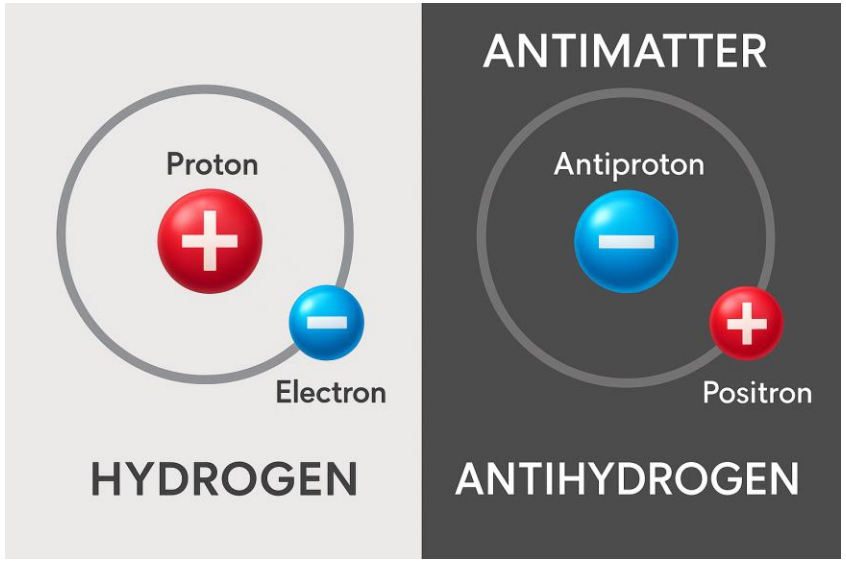
Antimatter?

Antimatter: mirror images of normal particles but with opposite electric charge



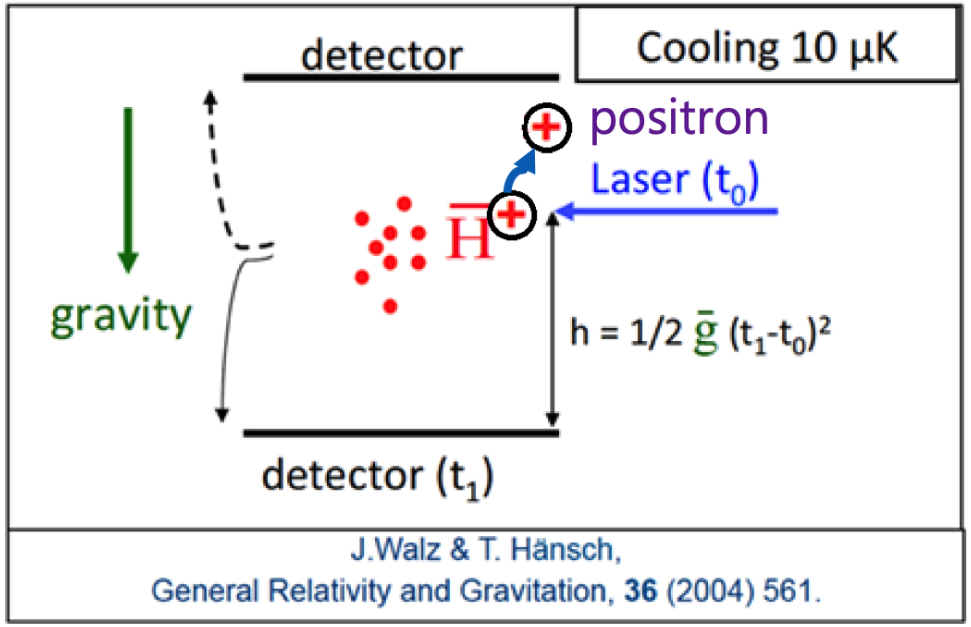
The **Weak Equivalence Principle** states that all objects fall at the same rate in a gravitational field, regardless of their mass or composition

What is the effect of gravity on antimatter?

The GBAR experiment

Gravitational Behaviour of Anti-hydrogen at Rest

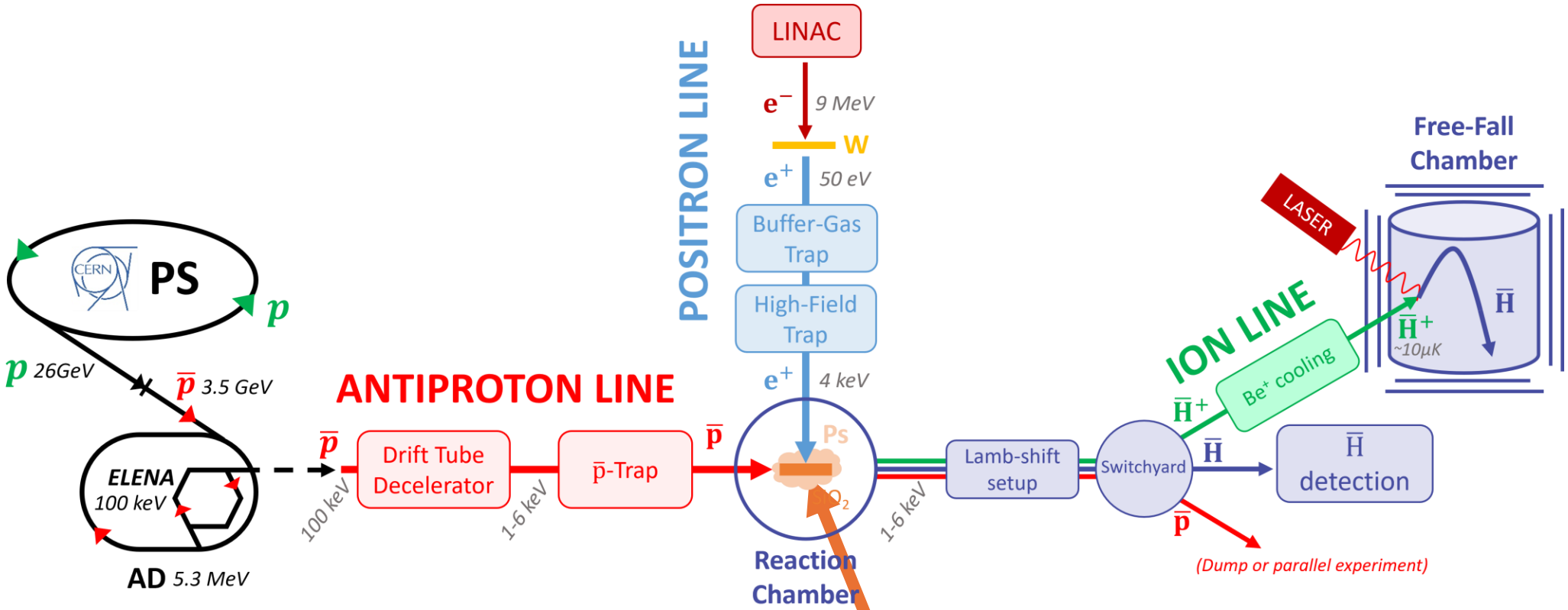
- Study of a free-fall of antihydrogen atom.



- To achieve this, double charge exchange reaction needed :

$$\bar{p} + Ps \rightarrow \bar{H} + e^-$$
$$\bar{H} + Ps \rightarrow \bar{H}^+ + e^-$$

The GBAR experiment



$$\bar{p} + Ps \rightarrow \bar{H} + e^-$$
$$\bar{H} + Ps \rightarrow \bar{H}^+ + e^-$$

First reaction cross-section

2022-2024

$$\bar{p} + Ps \rightarrow \bar{H} + e^-$$

$$\bar{H} + Ps \rightarrow \bar{H}^+ + e^-$$

What is the cross section of this reaction?

The reaction cross section is a measure of the probability that a specific nuclear or particle reaction will occur when two particles interact.
Knowing the cross-section of a reaction tells us how much $\bar{p}$ *and* Ps we need to send in to get a certain amount of $\bar{H}$ from this reaction.

Crucial for the $\bar{H}^+$ production

First reaction cross-section

What is the cross section of this reaction?

$$\sigma(oPs, \bar{p}) = \frac{N_{\bar{H}}}{f_{(oPs)}^{(t,z,y,x)}}$$

With $N_{\bar{H}}$ the number of antihydrogen produced per pulse and $f_{(oPs)}^{(t,z,y,x)}$ the function describing the $oPs - \bar{p}$ interaction.

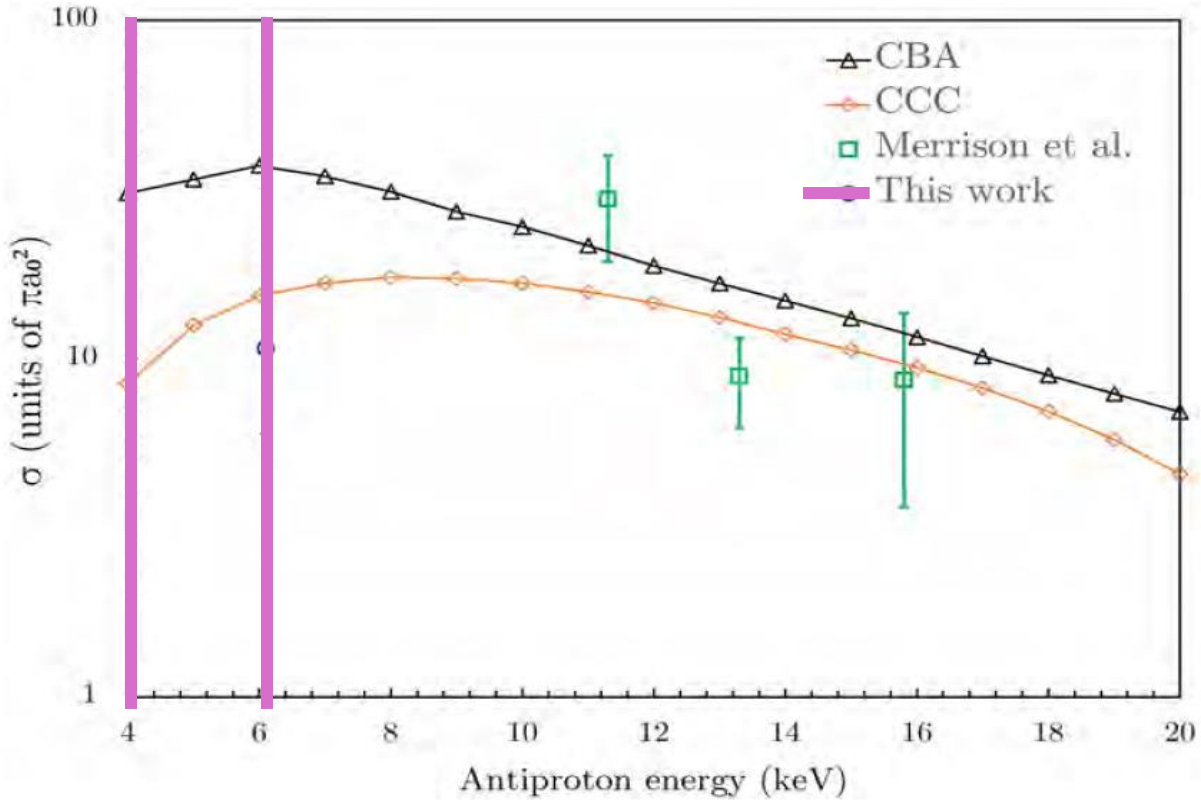
$f_{(oPs)}^{(t,z,y,x)}$ is a function of :

- The interaction region between both ingredients
- The density of positronium
- The antiproton distribution and velocity

It should be the **same as the matter equivalent reaction**!

First reaction cross-section

It should be the **same as the matter equivalent reaction**!

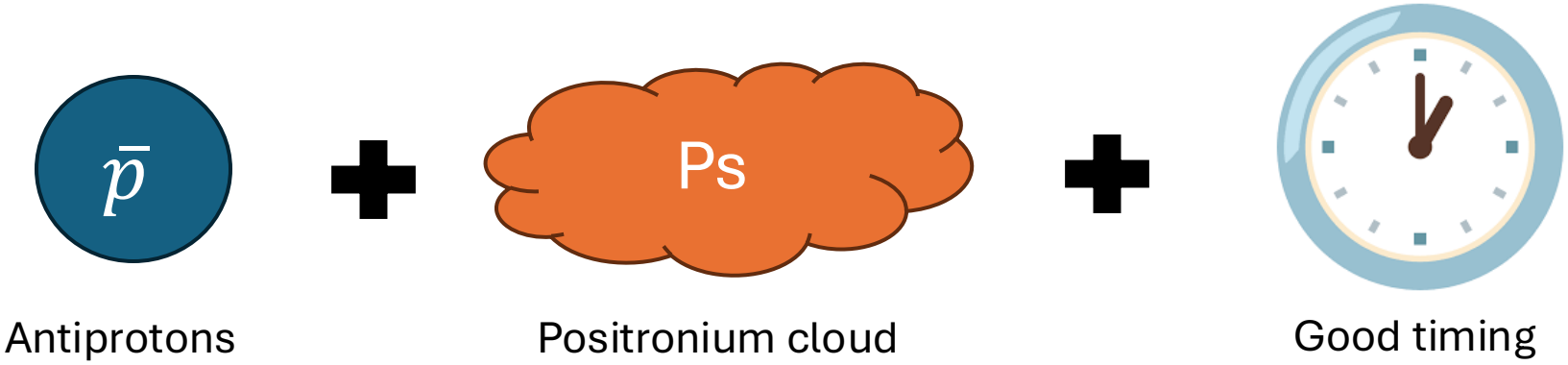


C Roumegou, CERN-THESIS-2023-274; 2023UPASP093

(Some) of the data needed for cross-section measurement

$$\sigma(oPs,\bar{p}) = \frac{N_{\bar{H}}}{f_{(oPs)}^{(t,z,y,x)}} \text{ and } N_{\bar{H}} = \frac{Number\ of\ \bar{H}\ detected}{Number\ of\ events\ in\ correct\ conditions}$$

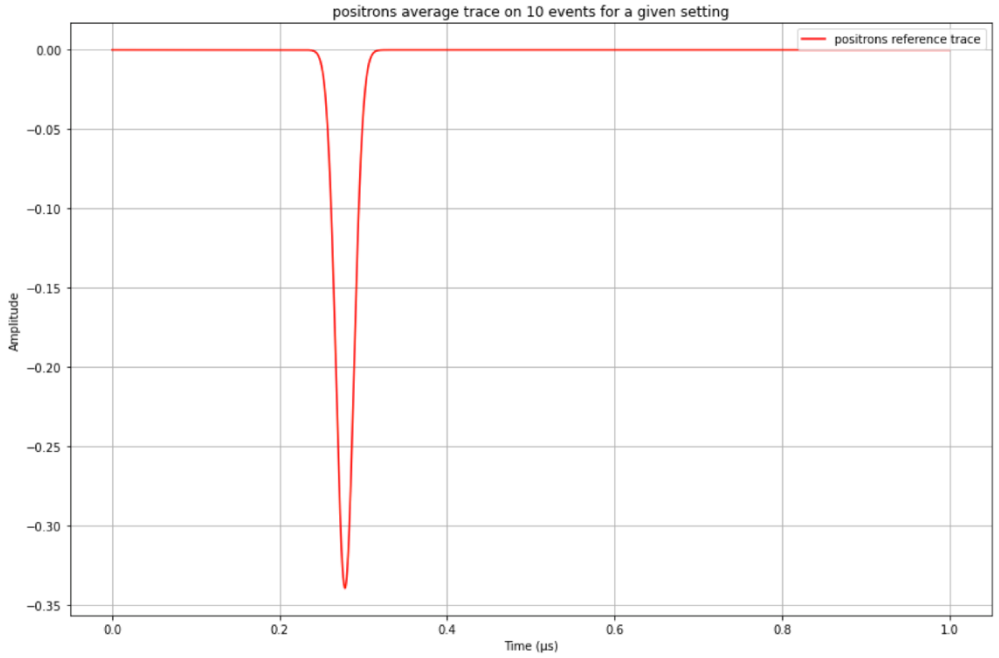
Correct conditions?



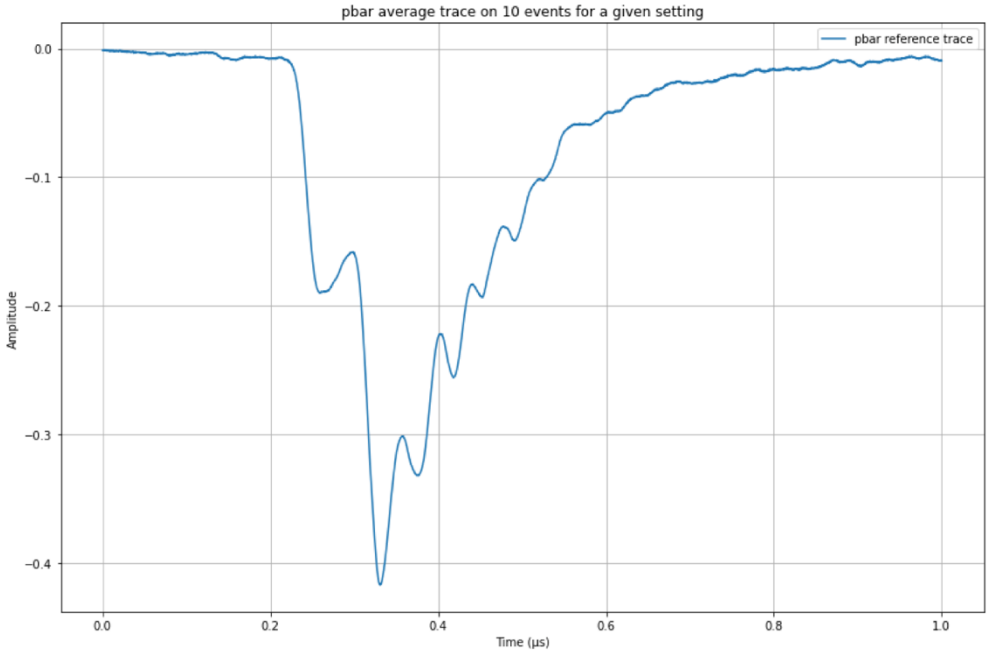
Antiprotons | Positronium cloud | Good timing

(Some) of the data needed for cross-section measurement

Correct conditions? Check with PbWO4 scintillating detector



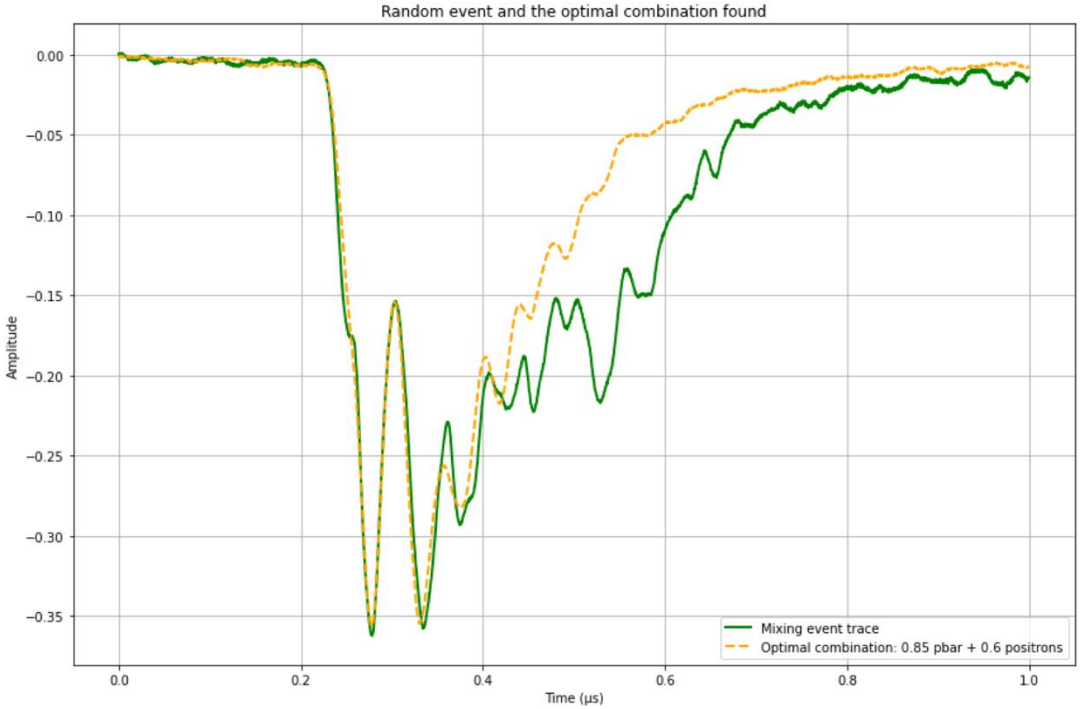
Positrons sent to create positronium



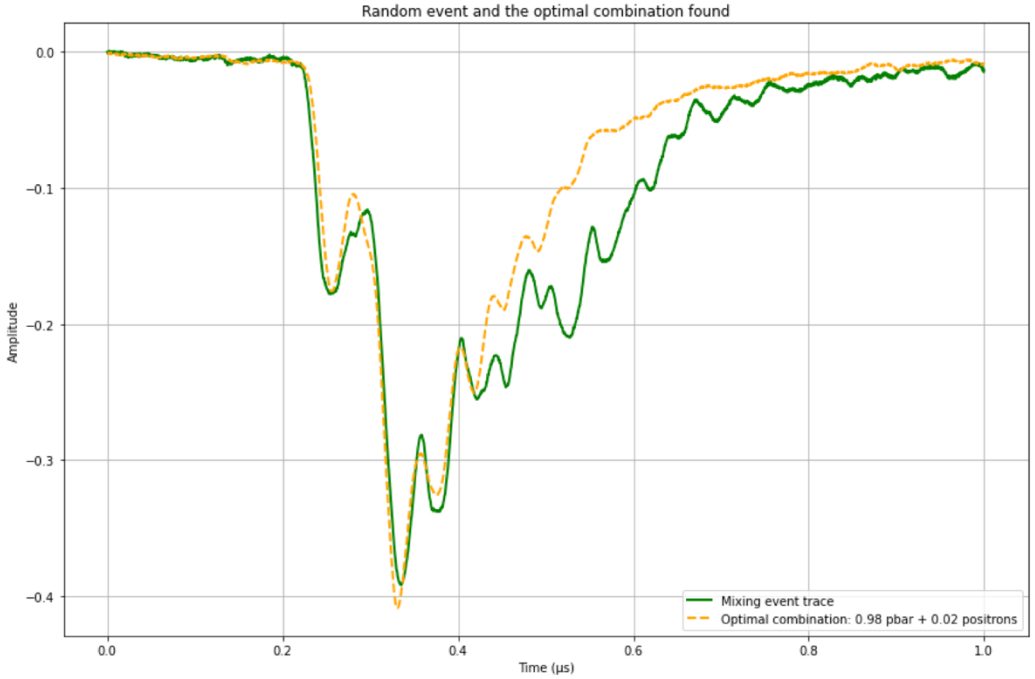
Antiprotons sent in the reaction chamber

(Some) of the data needed for cross-section measurement

Correct conditions? Check with $PbWO_4$ scintillating detector



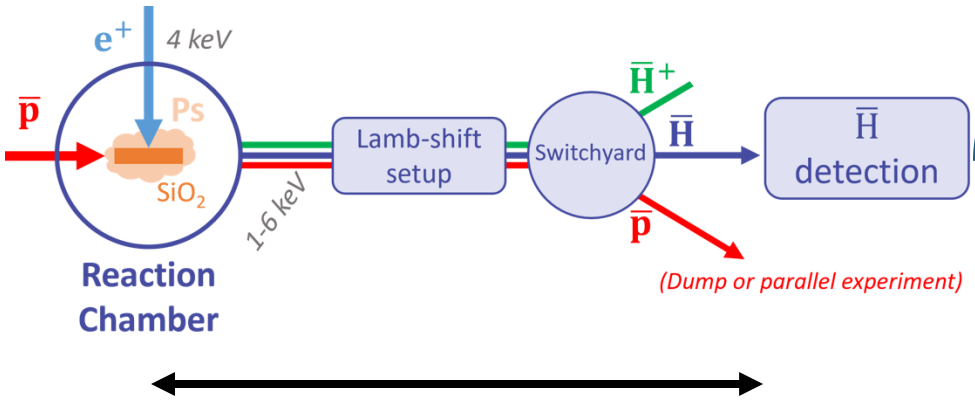
Event in correct conditions



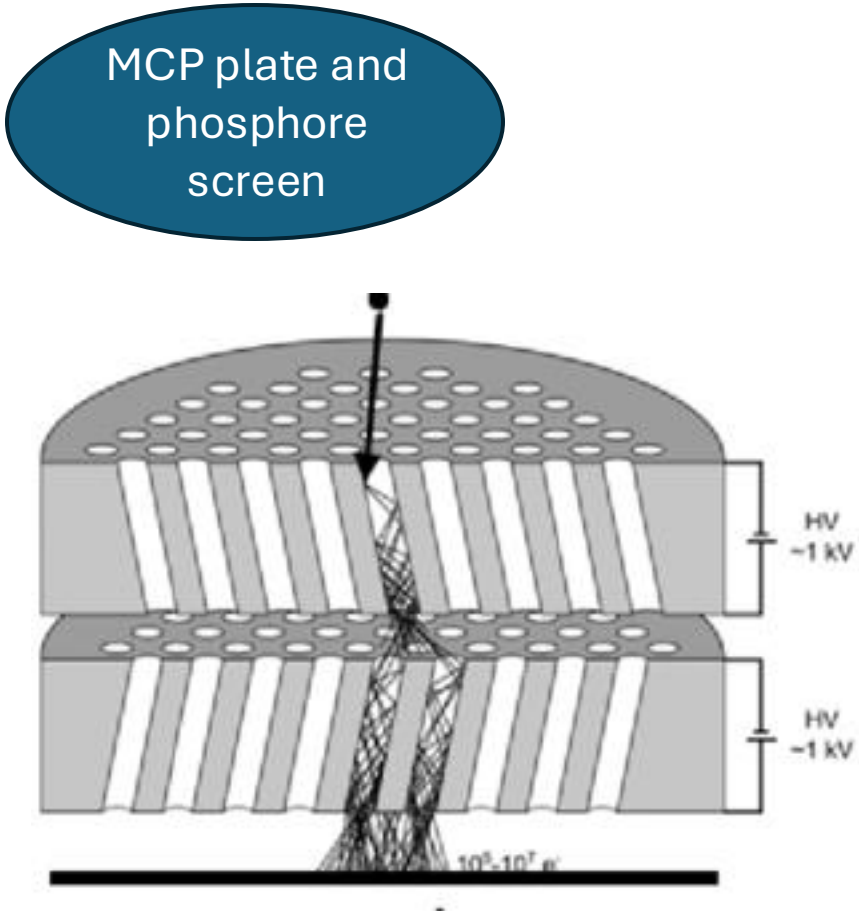
No positrons here

(Some) of the data needed for cross-section measurement

How do we know we produce an antihydrogen atom?



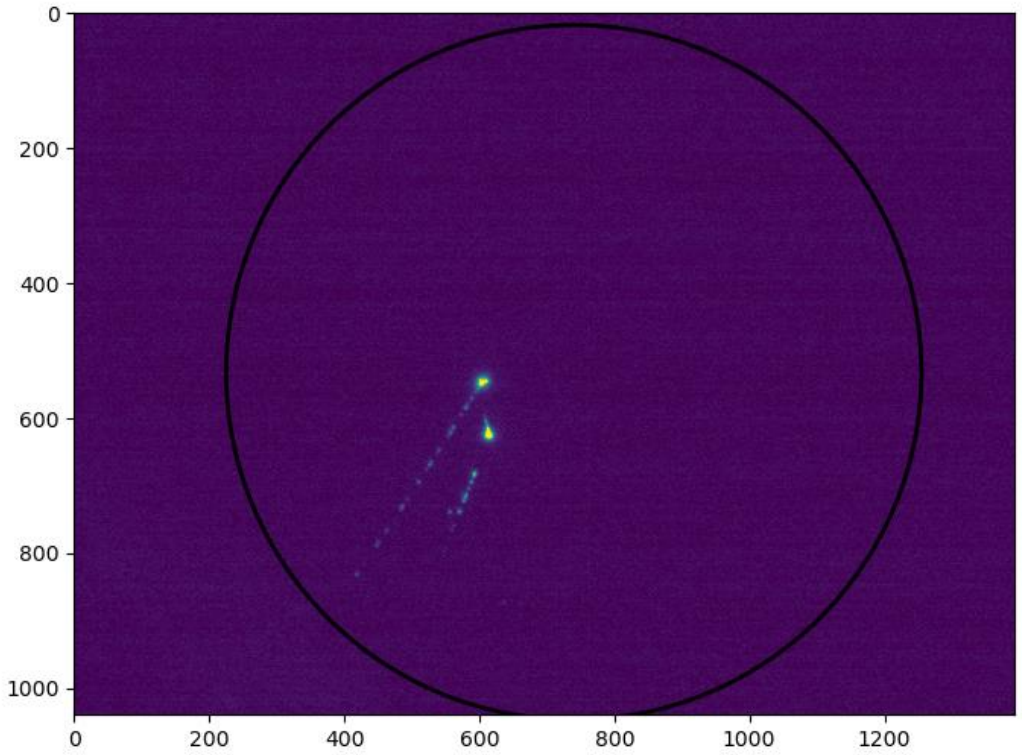
1.7 m
6 keV antihydrogen
$t \approx 1.6\ \mu s$



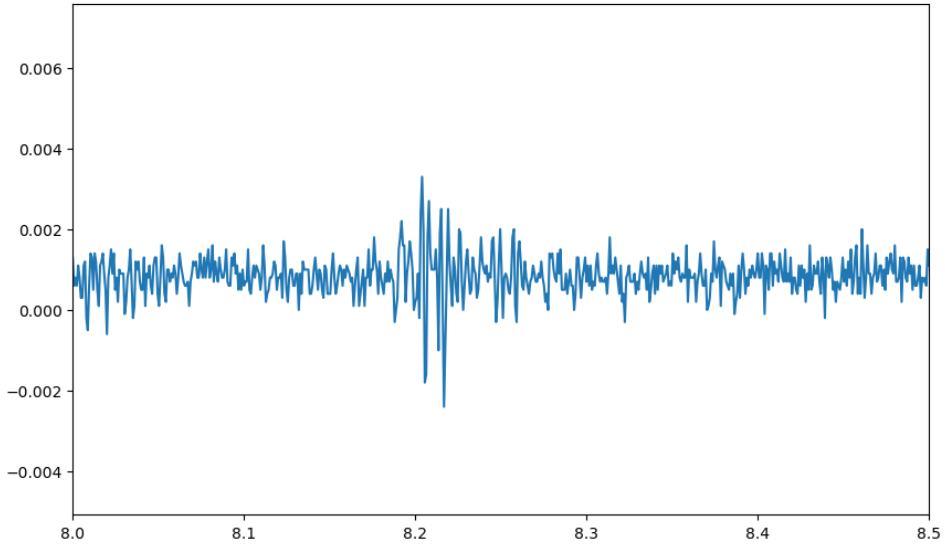
Cremer, Till & Adams (2019). 21. 10.1117/12.2530037.

(Some) of the data needed for cross-section measurement

We look at the MCP image and for an electric peak in the right time window



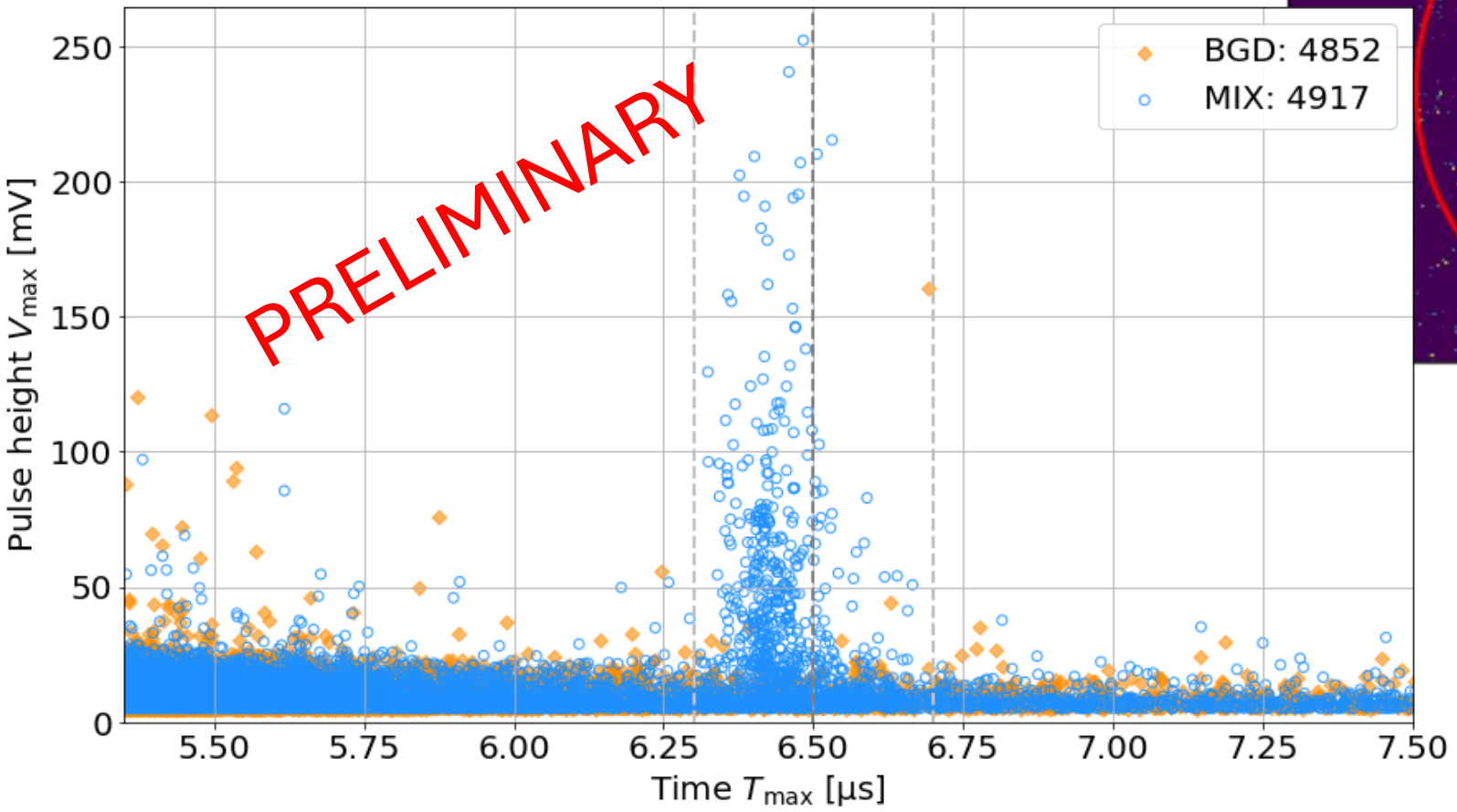
MCP image – $\overline{H}$ candidate

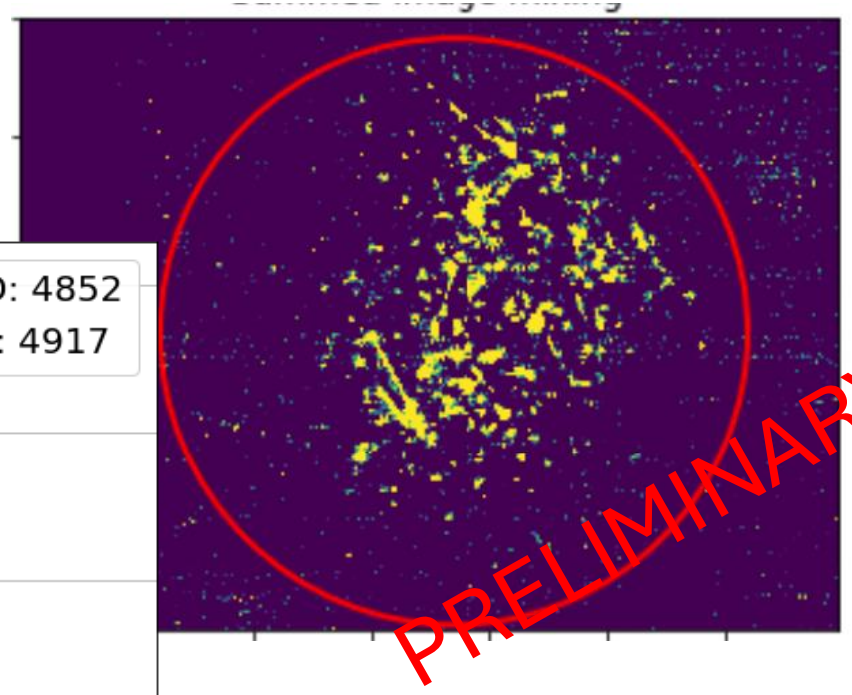


Electric signal for the same event

First results for the cross-section measurement

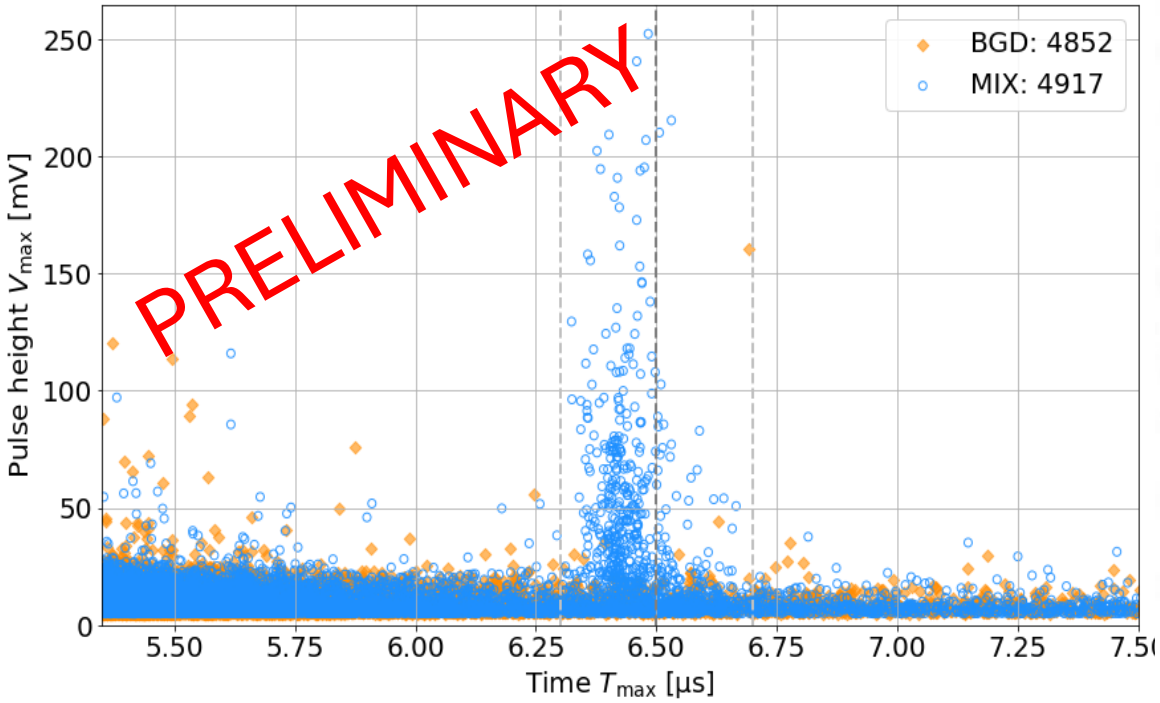
Almost 5000 events later…



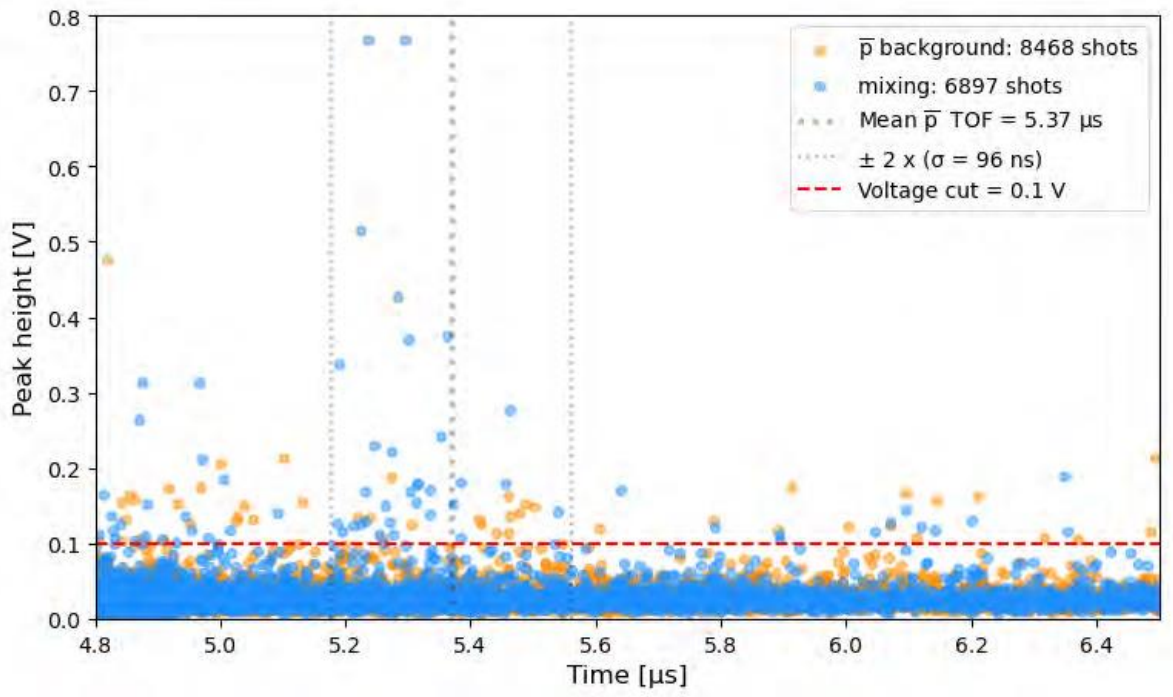


Around 0.08 $\bar{H}$ per shot

Improvement of $\bar{H}$ production



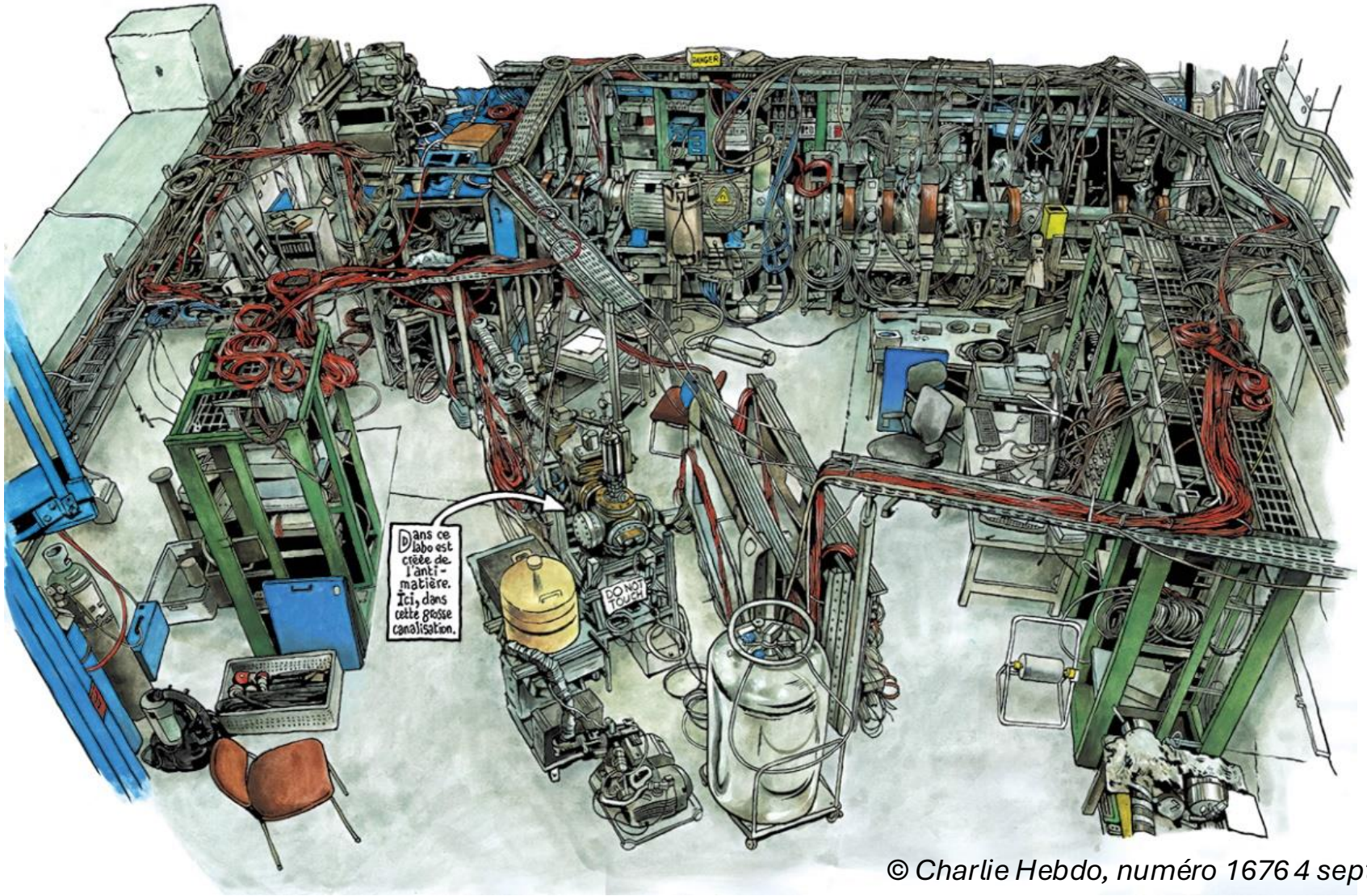
2024: 5000 events



2022: 7000 events

And now? $\sigma(oPs, \bar{p}) = \dfrac{N_{\bar{H}}}{f_{(oPs)}^{(t,z,y,x)}}$ **coming very soon…**

THANK YOU



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