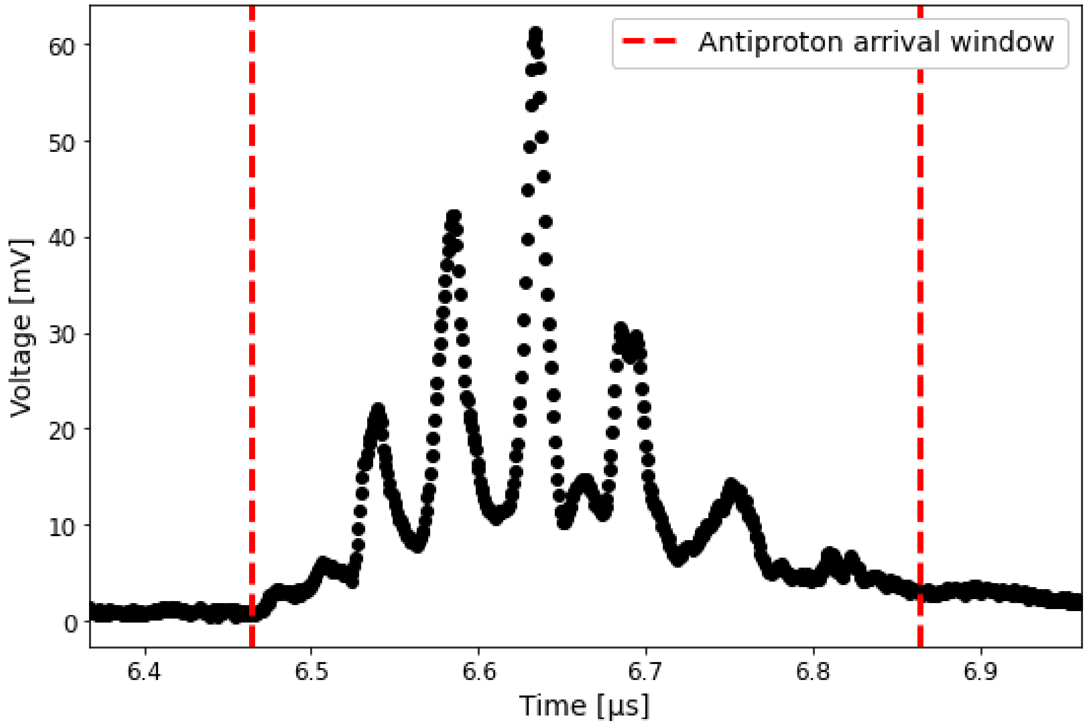
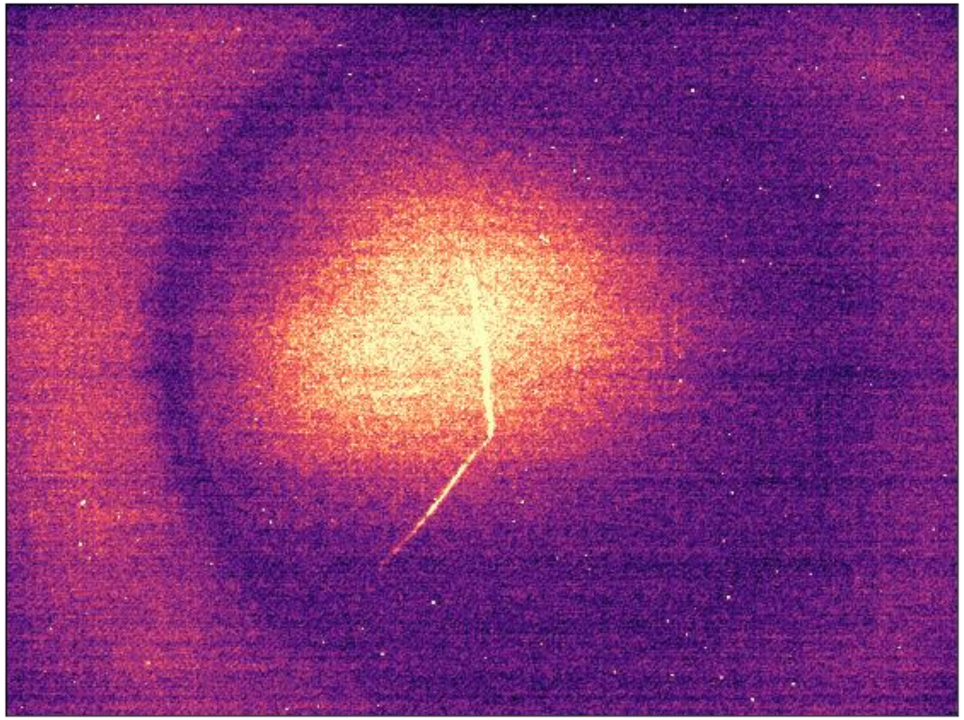
$\overline{\mathrm{H}}$ production in 2024 and comparison to 2022

Laurin Koller
9. October 2024

$\overline{\mathrm{H}}$ arrival time at MCP5





- Antiprotons on MCP5 in runs 610, 618
  - 11 cycles in total
- MCP5 voltage averaged over the 11 cycles
- Arrival window chosen to start at $6.46\ \mu s$ and last for $0.4\ \mu s$

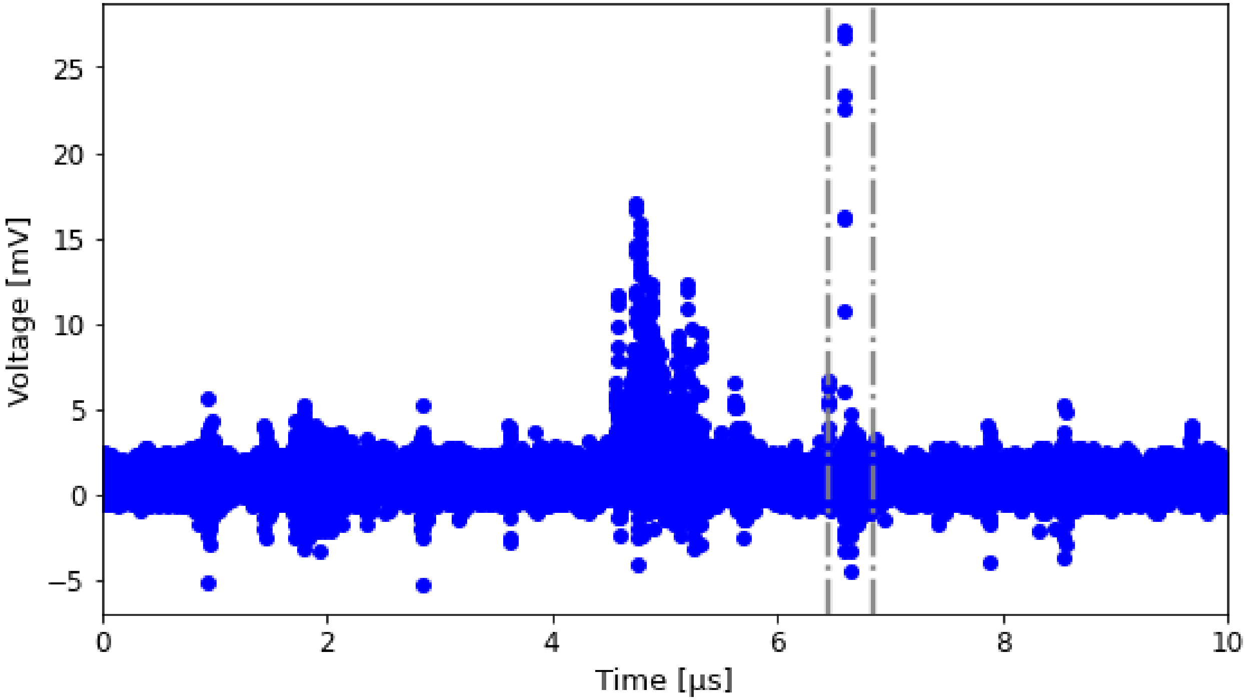
- Image of $\overline{p}$ beam of the MCP5 phosphor screen for one cycle

Data taken in 2024

- Mixing runs: 609, 614, 616, 619, 621, 622
  - Total of 561 cycles
- Background runs: 611, 617, 620, 623
  - Total of 777 cycles
- Only takes cycles with particle intensity above $7 \cdot 10^6$ from ELENA and check for positrons in mixing runs
  - Left with 468 mixing (MIX) and 771 background (BGD) cycles to analyse
- In 2022: 6897 mixing cycles and 8468 background cycles were analysed
  - Analysed in "*Adrich, P., Blumer, P., Caratsch, G. et al. Production of antihydrogen atoms by 6 keV antiprotons through a positronium cloud. Eur. Phys. J. C **83**, 1004 (2023). https://doi.org/10.1140/epjc/s10052-023-12137-y*"

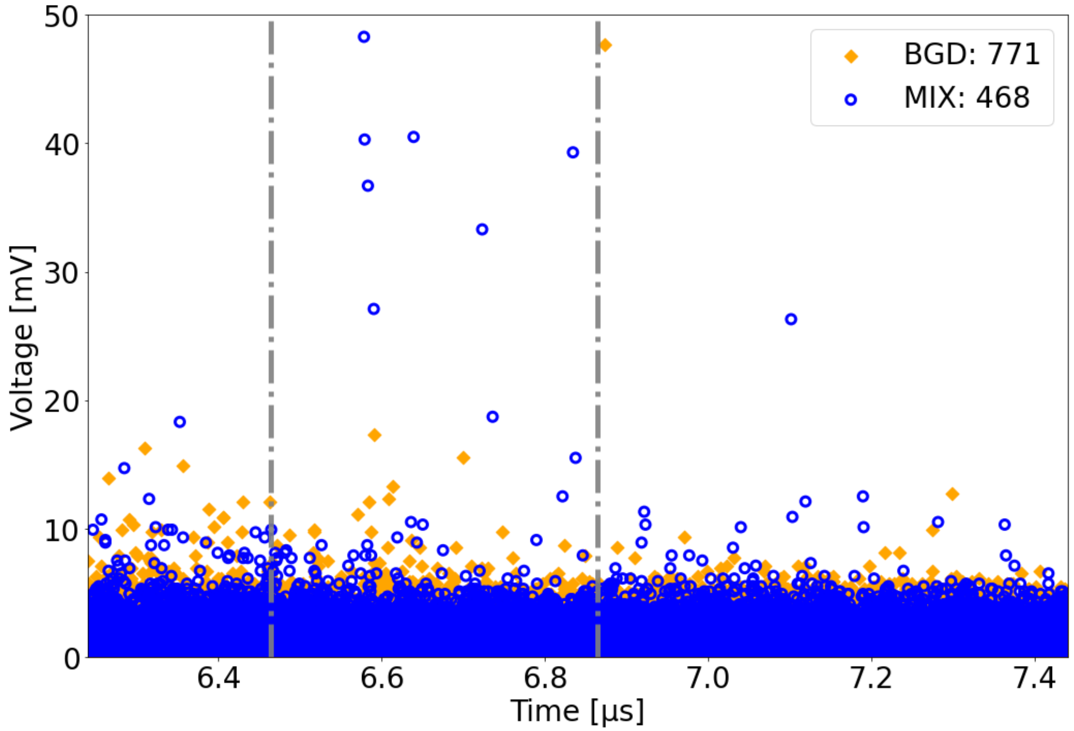
$\Longrightarrow$ Around 15 times more data available in 2022

Determine $\overline{\mathrm{H}}$ production using MCP5 voltage

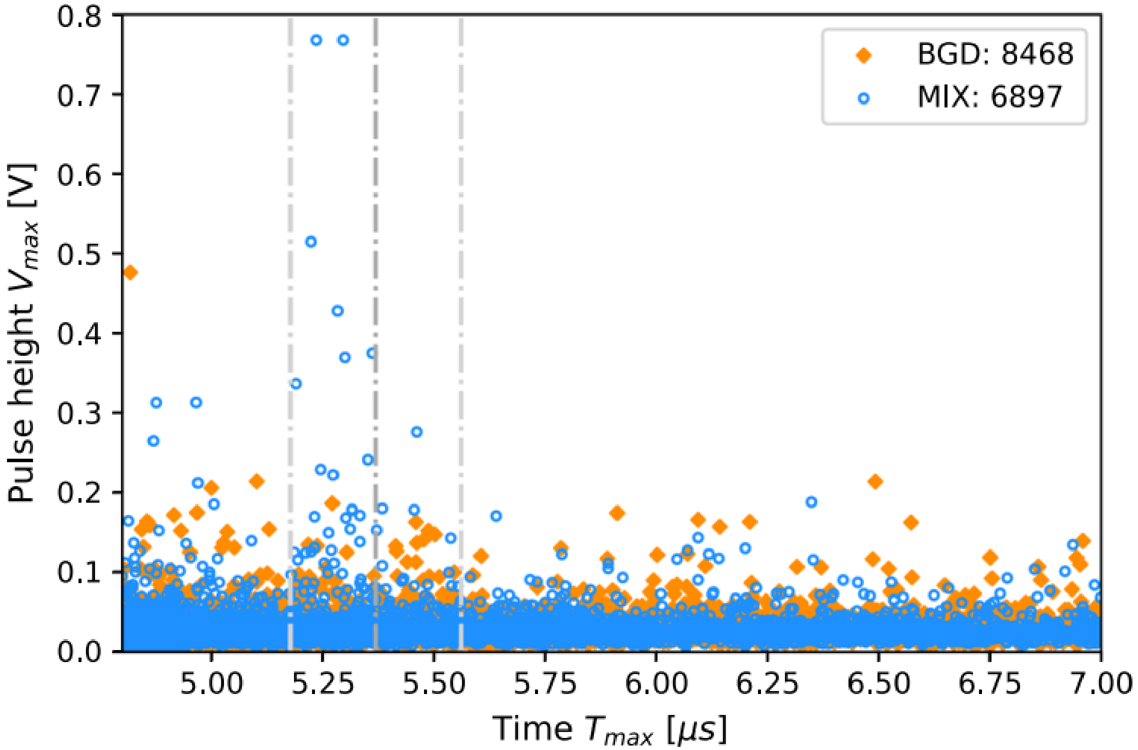


- MCP5 voltage for one mixing cycle
- To find $\overline{\mathrm{H}}$, search for all signals in MCP5 voltage in all mixing and background cycles
- Most positrons from $\overline{\mathrm{p}}$ annihilation arrive at around $5\ \mu\mathrm{s}$
- Grey lines show the time window in which $\overline{\mathrm{H}}$ are expected to reach MCP5
- $\overline{\mathrm{H}}$ create large signals in the voltage of MCP5, one example of a $\overline{\mathrm{H}}$ candidate can be seen in the image

Signals in the MCP5 voltage found in 2024 and 2022



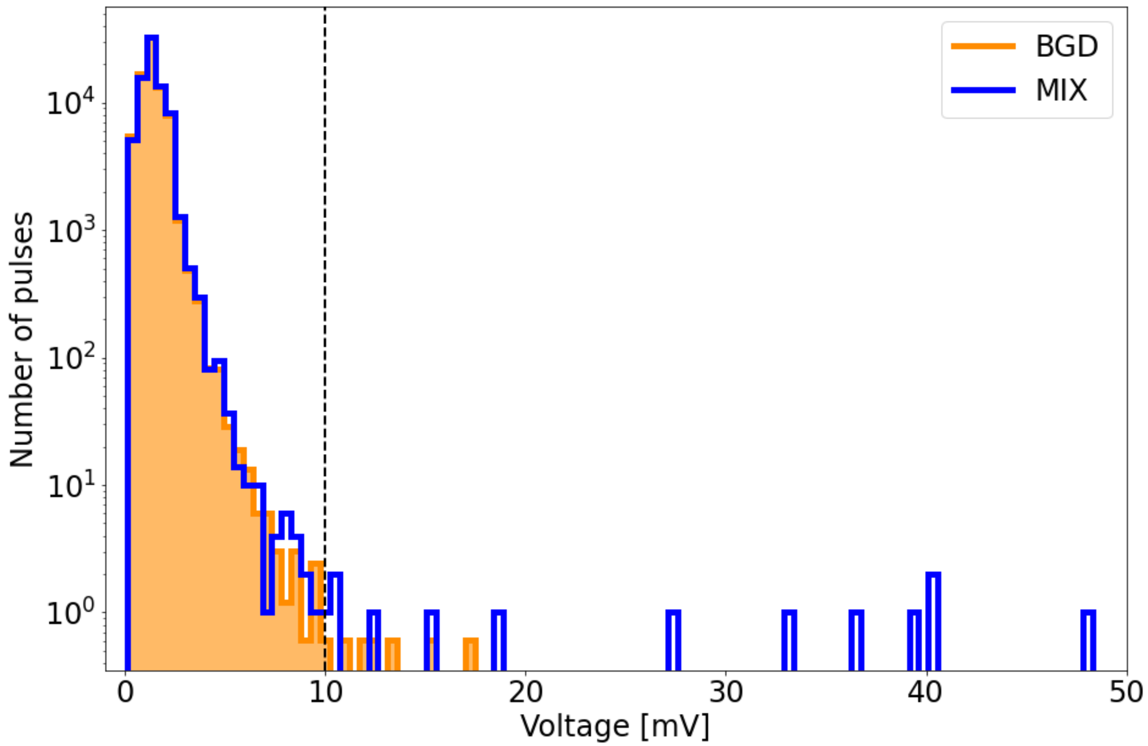
Taken from https://doi.org/10.1140/epjc/s10052-023-12137-y



- Maximum height and timing of all signals found in the voltage of MCP5 for MIX (orange) and BGD (blue)
  - On the left for 2024, on the right for 2022

ETH zürich

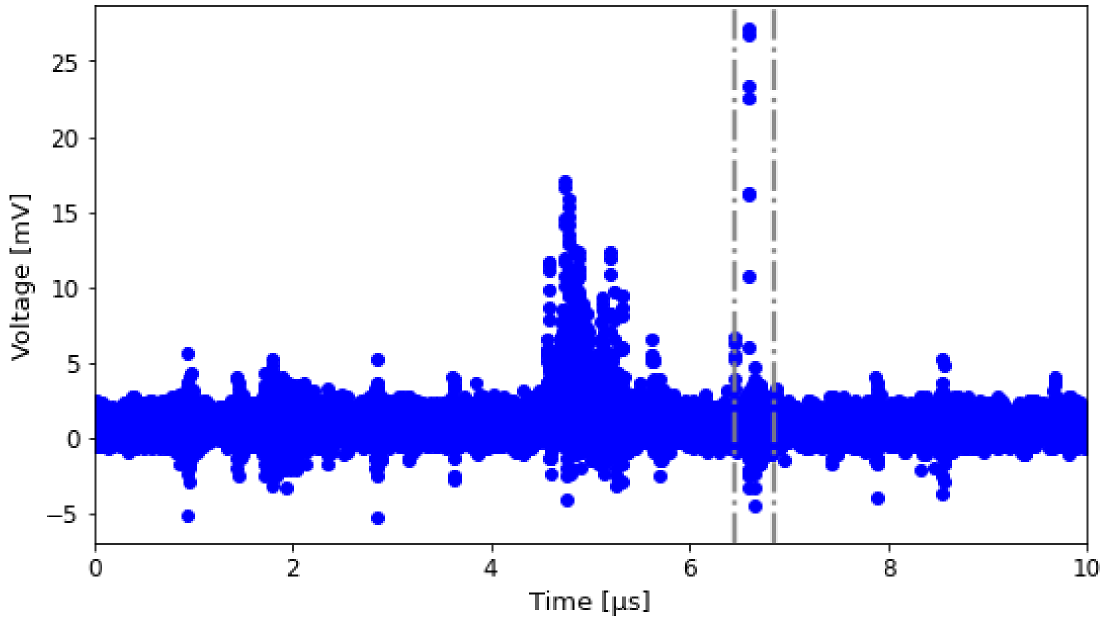
$\overline{\mathrm{H}}$ production rate with the voltage signals

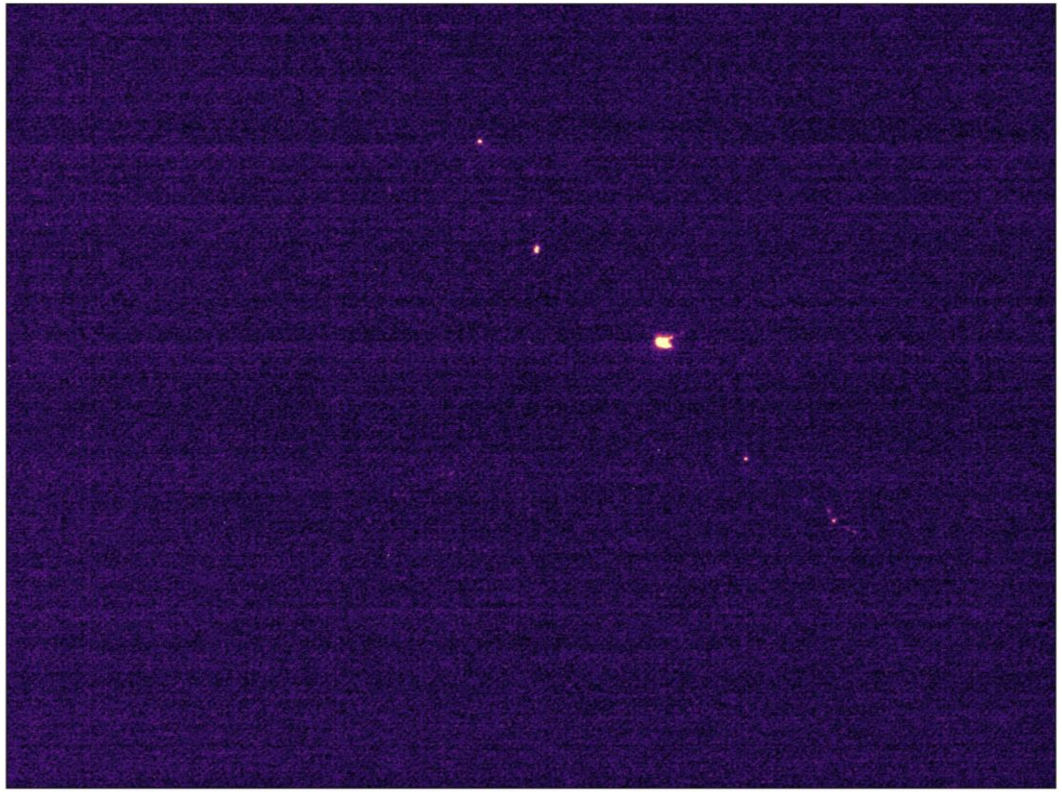


- Distribution of the signal heights from BGD (orange) and MIX (blue)
  - BGD normalized to MIX using the number of cycles
- Subtract normalized number of signals in BGD above threshold from number of signals in MIX above threshold to get the number of detected $\overline{\mathrm{H}}$
- Using a threshold of $10\ \mathrm{mV}$:
  - 12.0 ± 3.5 signals in MIX
  - 6.0 ± 2.4 signals in BGD → 3.64 ± 1.50 with normalization
  - Excess of $n_{2024} = 8.4 \pm 3.8$ signals above the threshold in MIX corresponding to the number of $\overline{\mathrm{H}}$ detected

$\Longrightarrow 0.018 \pm 0.008\ \overline{\mathrm{H}}$ detected per mixing cycle

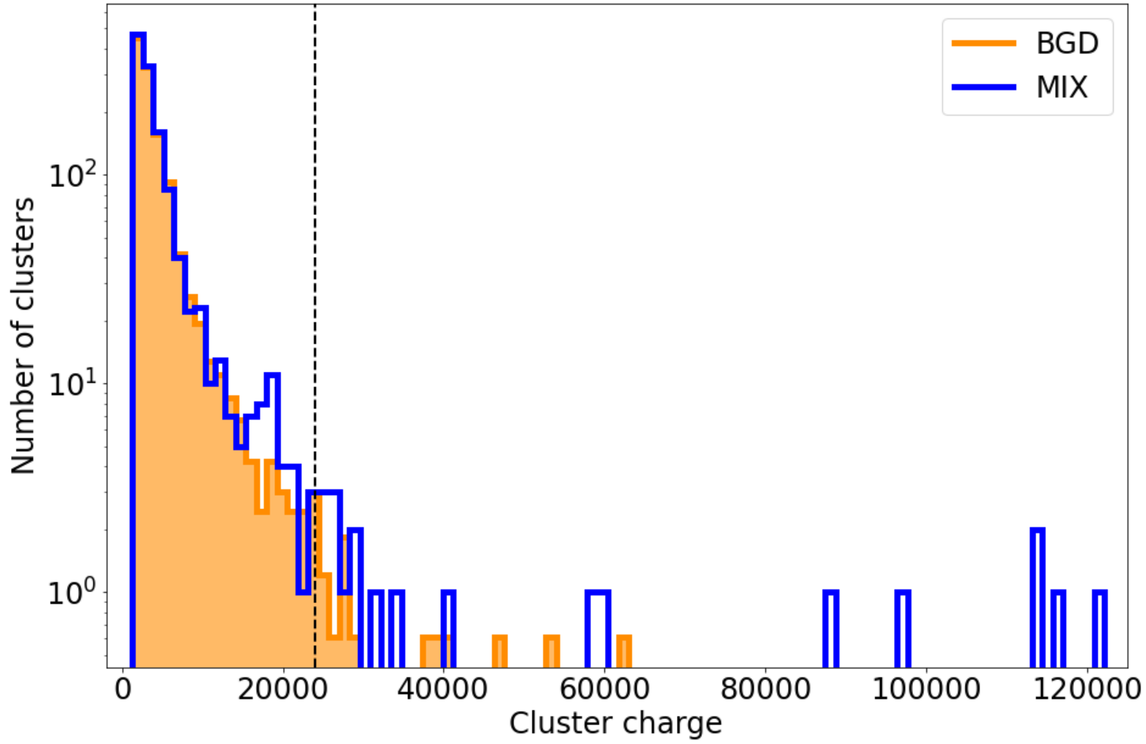
$\overline{\mathrm{H}}$ production rate with MCP5 images





- Voltage of MCP5 for $\overline{\mathrm{H}}$ candidate event on the left and on the right the corresponding image of MCP5
- Determine $\overline{\mathrm{H}}$ production by looking for clusters in the MCP5 images
  - Define cluster charge as the sum of the pixels contained by each cluster

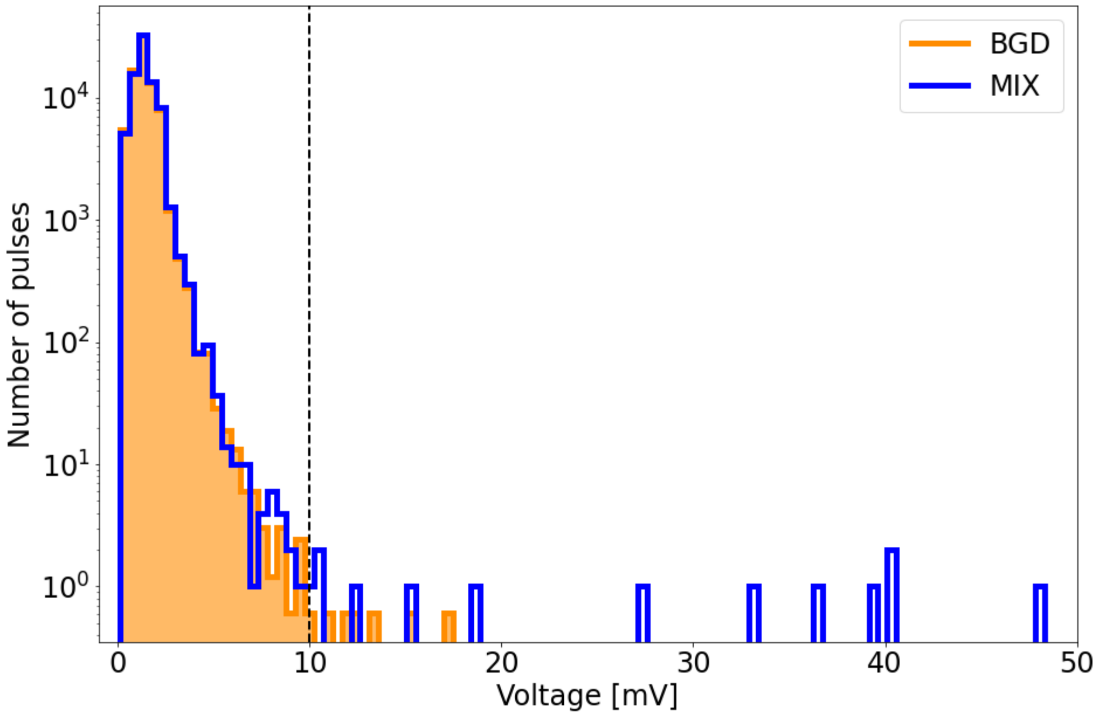
$\overline{\mathrm{H}}$ production rate with MCP5 images



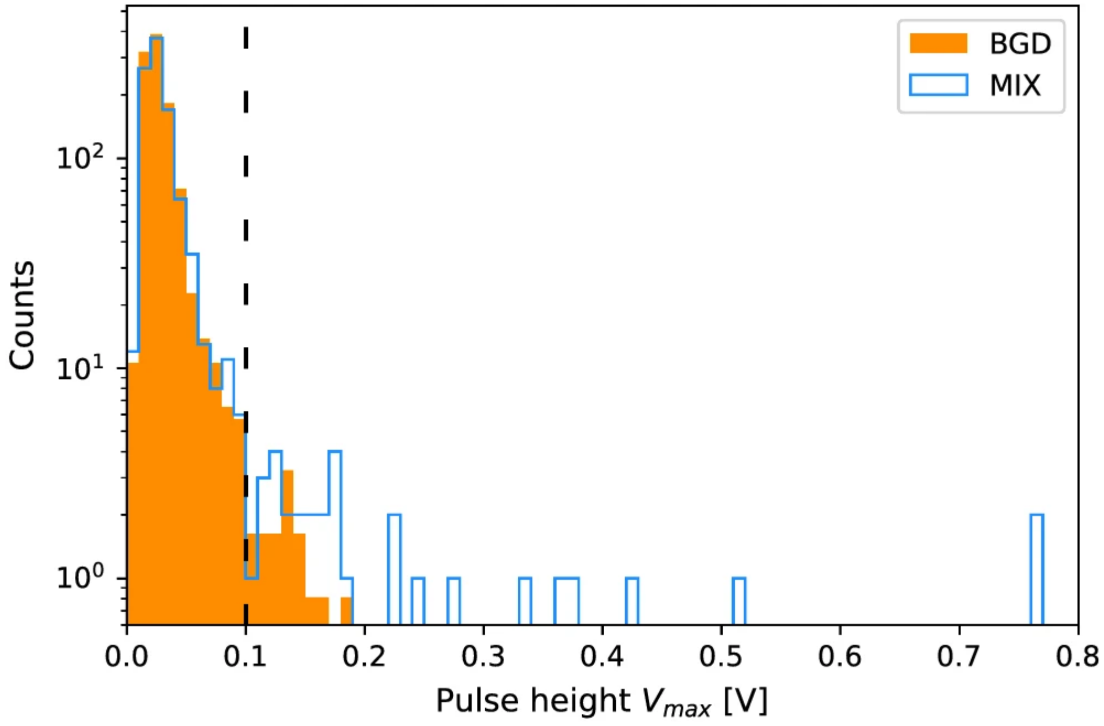
- Distribution for the cluster charges from BGD (orange) and MIX (blue)
  - BGD normalized to MIX using the number of cycles
- Set threshold and determine the number of detected $\overline{\mathrm{H}}$ similarly to before
- Using a threshold of 28000:
  - 15 ± 4 signals for MIX above the threshold
  - 8.0 ± 2.8 signald for BDG above the threshold, normalizing to 4.9 ± 1.7

$\Longrightarrow 0.022 \pm 0.010\ \overline{\mathrm{H}}$ detected per mixing cycle

Distribution of the signal heights found in 2024 and 2022



Taken from https://doi.org/10.1140/epjc/s10052-023-12137-y



- Distributions of the signal height for BGD (orange) and MIX (blue) for 2024 on the left, for 2022 on the right
- In 2022 with a threshold of $100\ \mathrm{mV}$: $n_{2022} = 19.8 \pm 6.4\ \overline{\mathrm{H}}$ detected

  $\Longrightarrow 0.0029 \pm 0.0009\ \overline{\mathrm{H}}$ Detected per mixing cycle
  - Comparing this to 0.018 in 2024 gives around a sixfold increase

ETH zürich

Conclusion

- Around 40 hours of beam taking until now
  - Improvement of a factor around 4 visible in the antihydrogen production
- Possible to increase statistics by a factor of 20 in 2024 possible
  - Around 2 months of beamtime
  - This would lead to reduce the statistical uncertainty by a factor of around $\sqrt{20 \times n_{2024}/n_{2022}} = \sqrt{20 \times 8.4/19.8} \approx 3$