Developments for pulsed antihydrogen production towards direct gravitational measurement on antimatter

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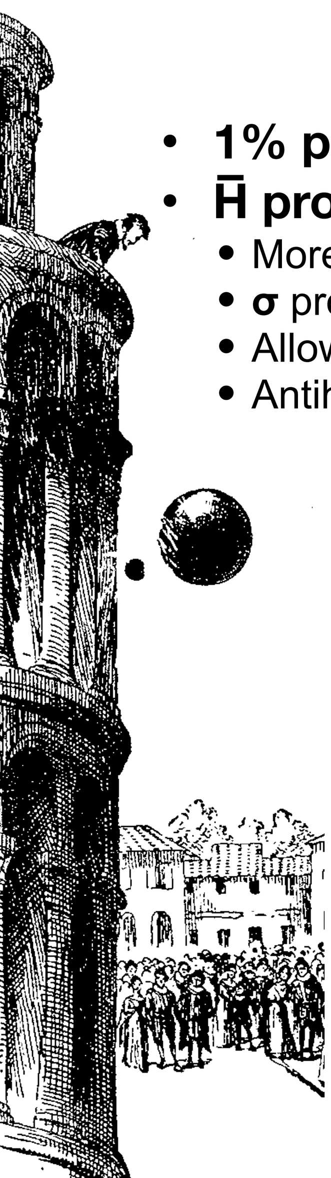
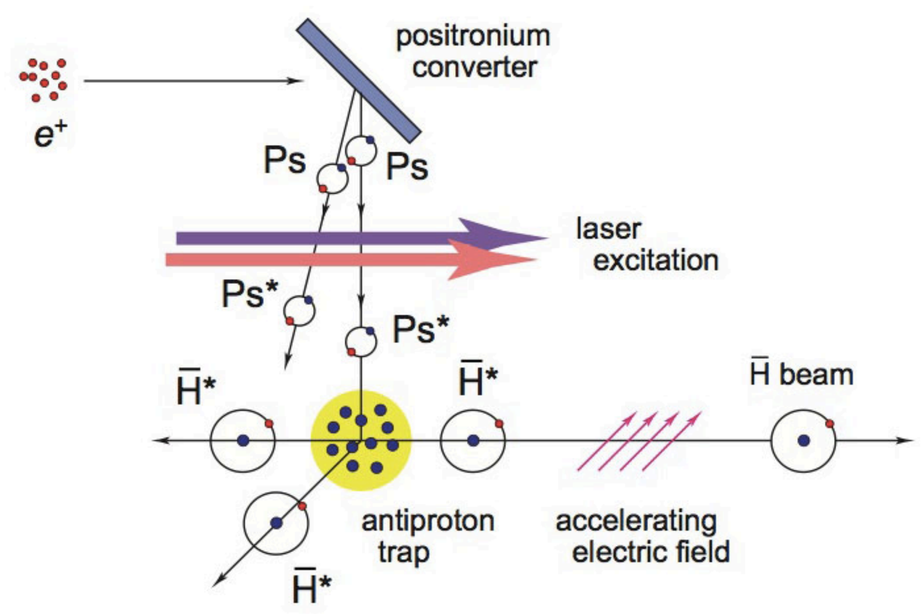
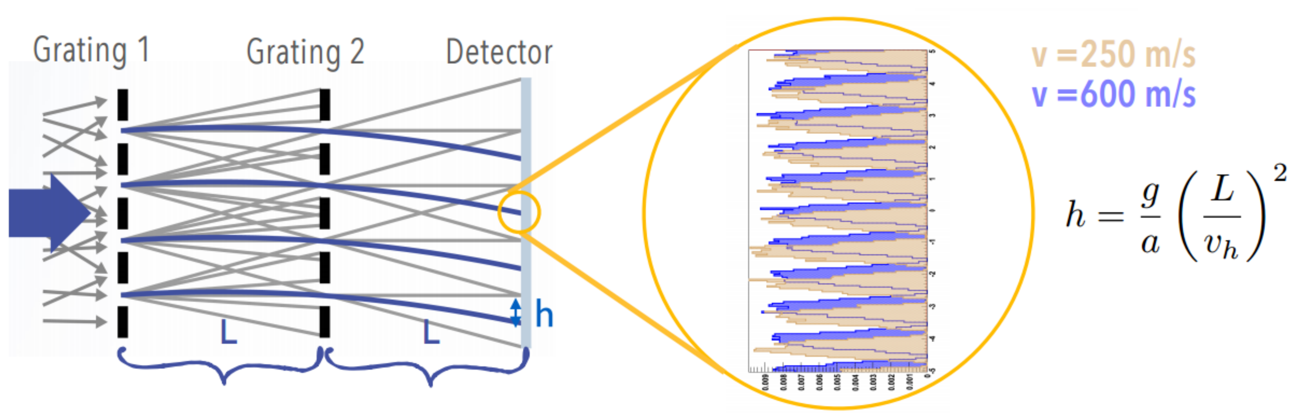


The AEḡIS Experiment

- 1% precision g($\bar{H}$) measurement
- $\bar{H}$ production: Charge exchange reaction
  - More narrow and well defined quantum state
  - σ proportional to the 4th power of the Ps Rydberg level
  - Allows antihydrogen pulsed production
  - Antihydrogen temperature is antiproton temperature





The AEḡIS monitor detection and diagnostic system

Internal charge collection
- Faraday cups cryo UHV

Laser diagnostic
- Scintillating fiber, etc..

Temperature measurement
- External scintillators

Outer particle detection system
- External plastic scintillators + PMTs (either in counting or analog mode)

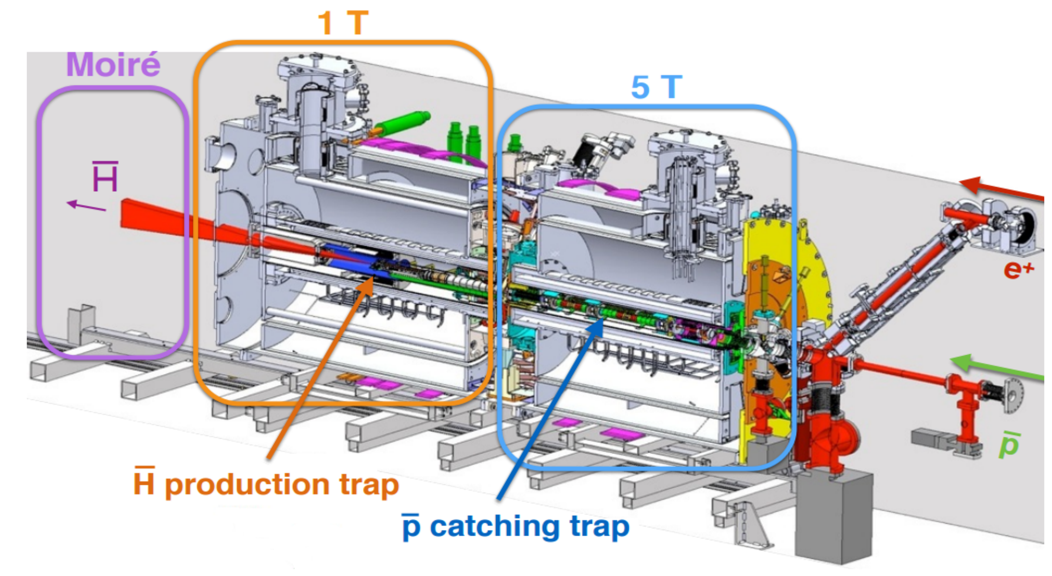
Antiproton monitoring
- HPD + plastic scintillator
- Real time plasma manipulation online monitor (mult. detectors)

Plasma imaging system
- MCP phosphor
- CMOS camera

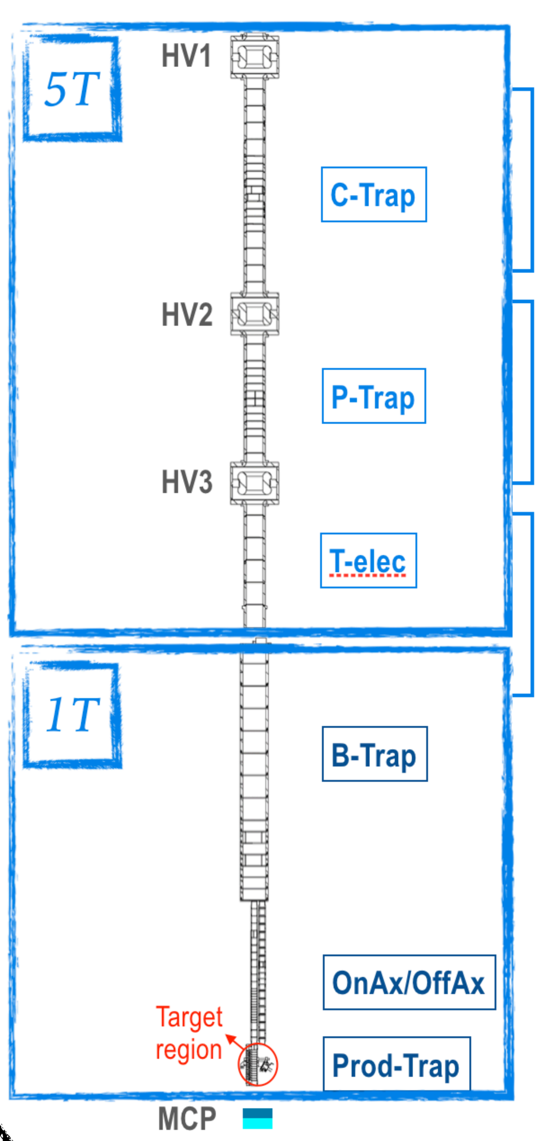
Positron diagnostic and monitoring
- Dedicated CsI scintillator system
- Induced charge during the passage in proper pick-up electrode
- Transfer line scintillators

Antihydrogen detection
- Detection via outer scintillators NEW!
- The FACT detector

Positronium diagnostic
- Ext. plastic scintillator with fast 12 bit r/o
- Photo-e+ detection NEW!
- Outer fast detector NEW!



Antiproton capture and compression



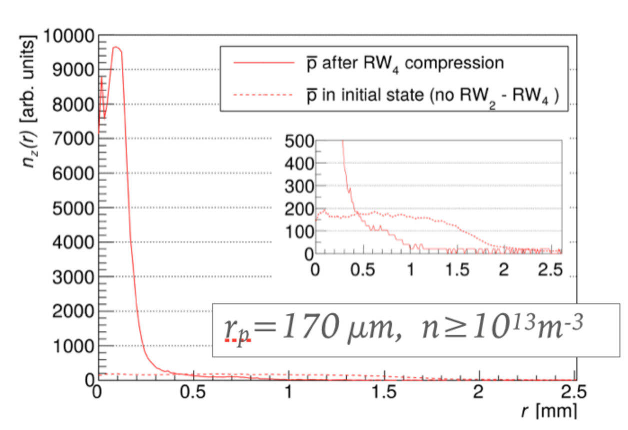
Preload electrons
Capture antiprotons at 9 kV
Cooling by radiation + collision
Remove the hottest fraction

Move potentials
Cool down
Apply compression

Lower one edge of the well
Transfer
In-flight recenter (segm. electr.)

Plasma cloud moves along the field line towards the MCP at end of the apparatus

- Remove significant part of the electrons
- Apply RW technique on multispecies plasma
- Use additional electron reduction
- Repeat in compression stages to reach lower radii



- Destructive measurement
  Detection= MCP + Phosphor + CCD
- The MCP measures radial distribution integrated along the trap axis
- Image intensity will be proportional to the number of particles

Lowest antiproton cloud radius + highest density ever!

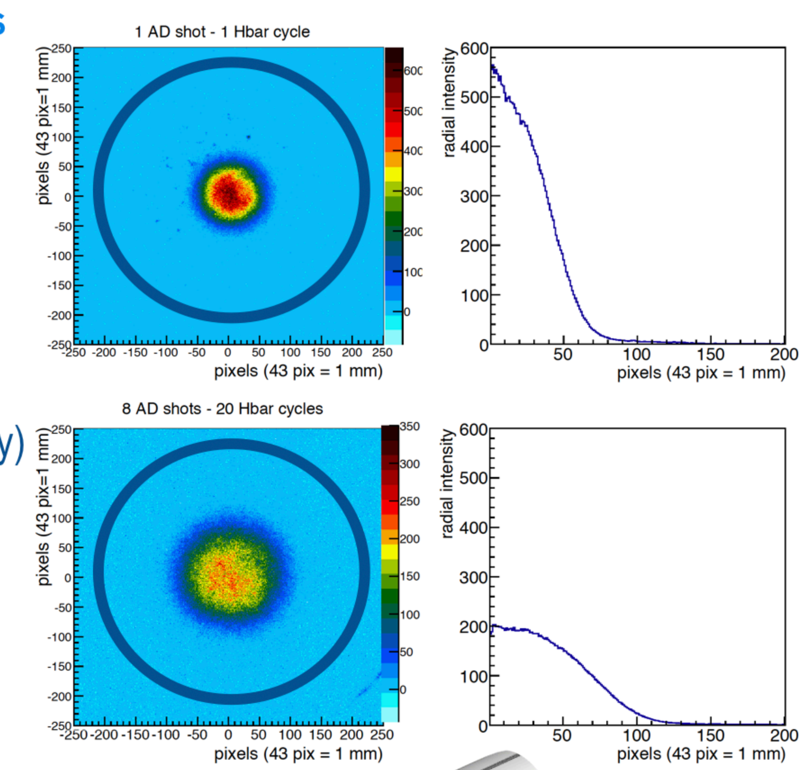
Storing antiproton for antihydrogen production

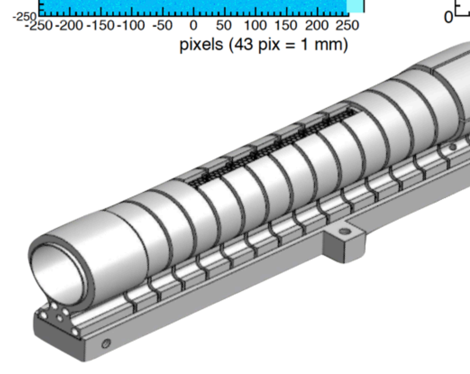
Accumulation and compression of several AD shots
- Trade-off between stability and performances.
- Linear growth of the number of antiprotons cooled and compressed with number of AD bunches
- Best: 8 AD antiproton bunches

Transport towards the production region
- Ballistic transfer: 1.5 m, radially compressed cloud
- In-flight dynamical centring and recapture (90% efficiency)
- Electrons loaded after antiprotons! (progressively removed to avoid centrifugal separation)

Multiple antihydrogen production cycles
- Up to 10^6 antiprotons available for each production cycle
- Up to 60 production cycles per stored antiproton cloud

Antiproton plasma lifetime mainly affected by
- Radial expansion rate (plasma angular moment is not conserved)
- Losses in the residual gas
- Control of the losses (typically ~30% in 20 cycles)





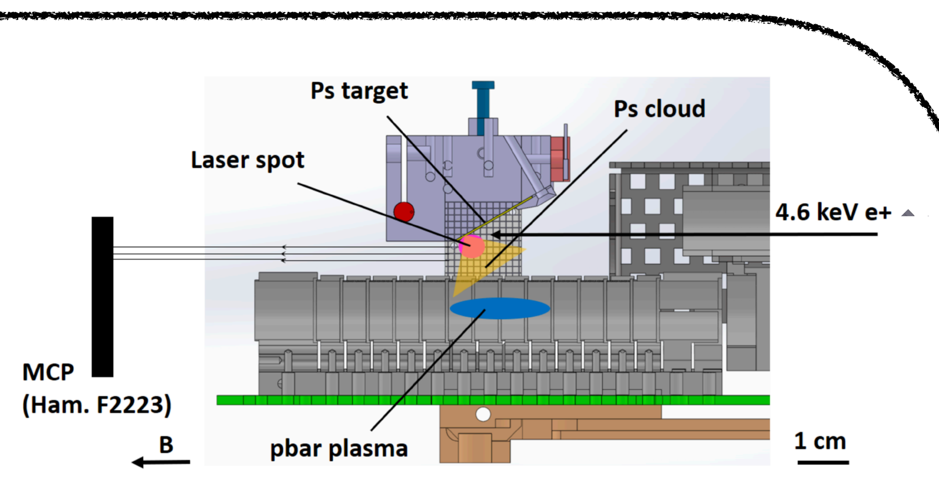
Non-standard trap design
Radial transport

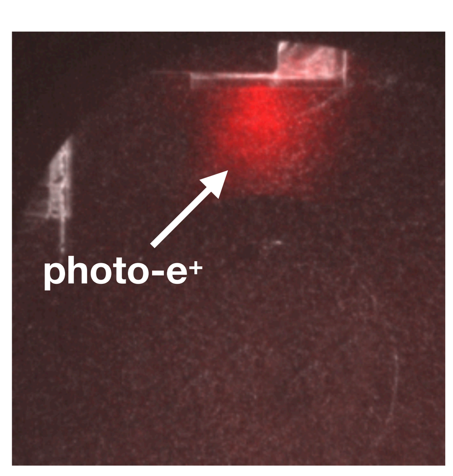
Positronium in 1T

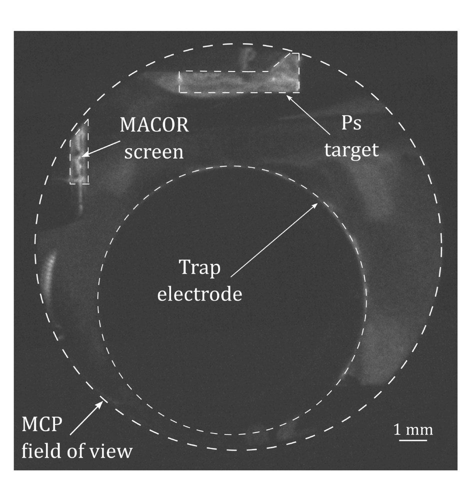
Improved visibility in the target region
- Target region modified to allow for significantly improved diagnostics
- Mount the target as close as possible to the production trap

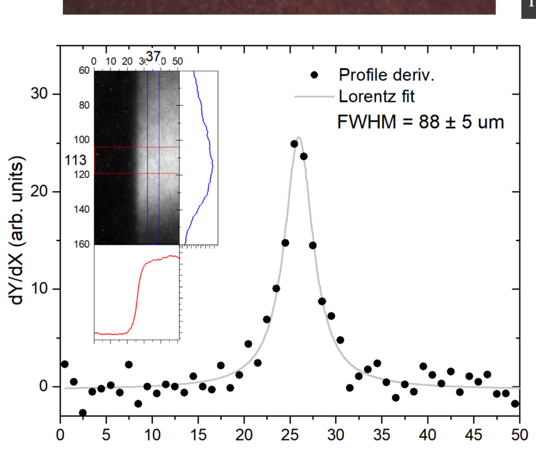
Rework of the laser diagnostics
- New CMOS camera from outside vacuum for imaging of laser excitation position relative to positron implantation point
- Optical fibres for positioning coupled to a PMT for timing information + Phosphor, Macor with meshgrid

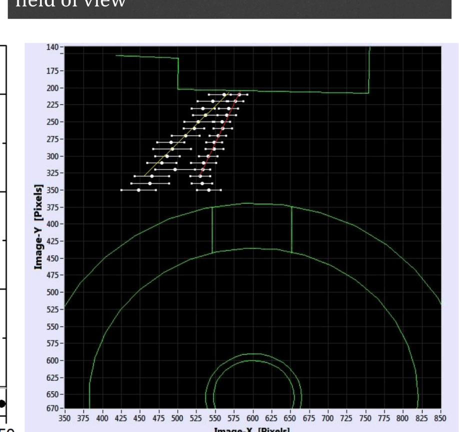
MCP added to the Ps diagnostics
- Move the MCP to add Ps cloud path to its view for imaging of released positrons and electrons



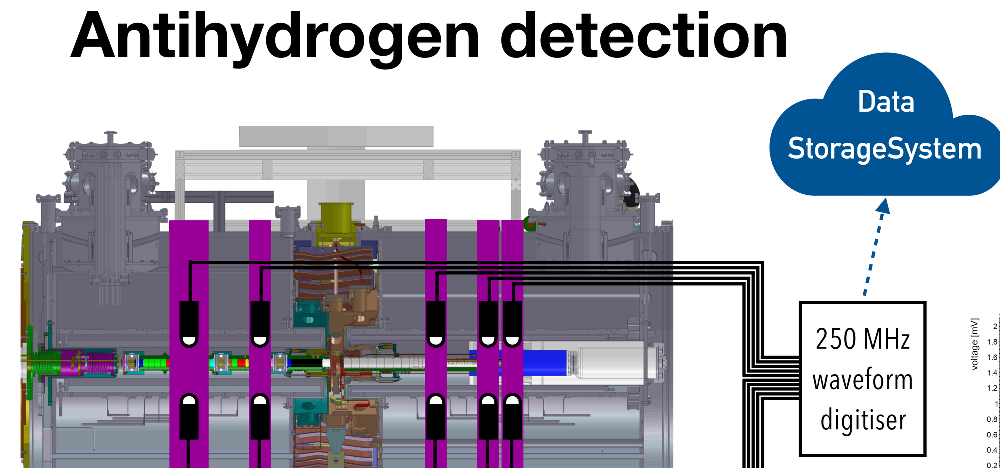


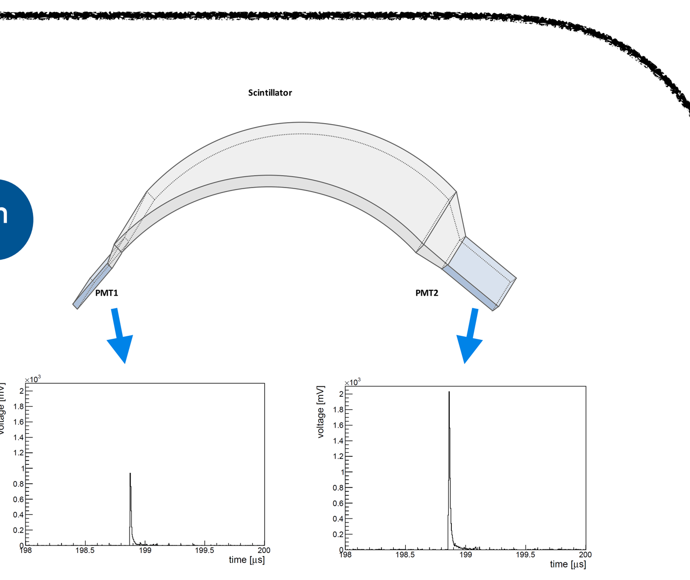


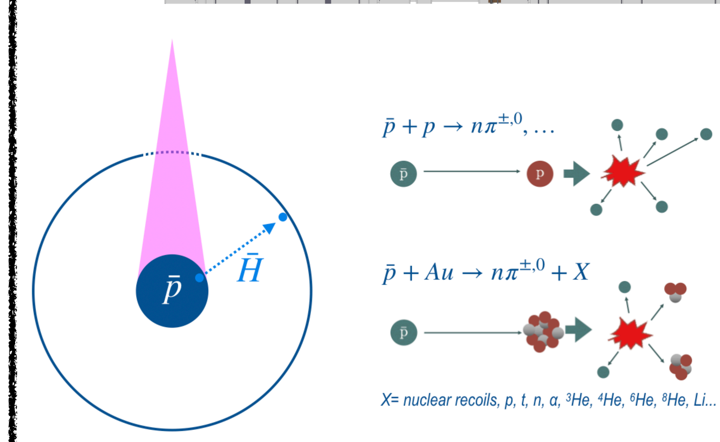




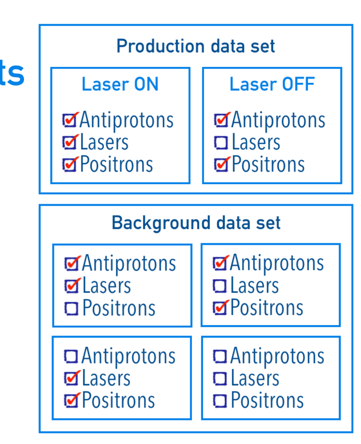
Antihydrogen detection

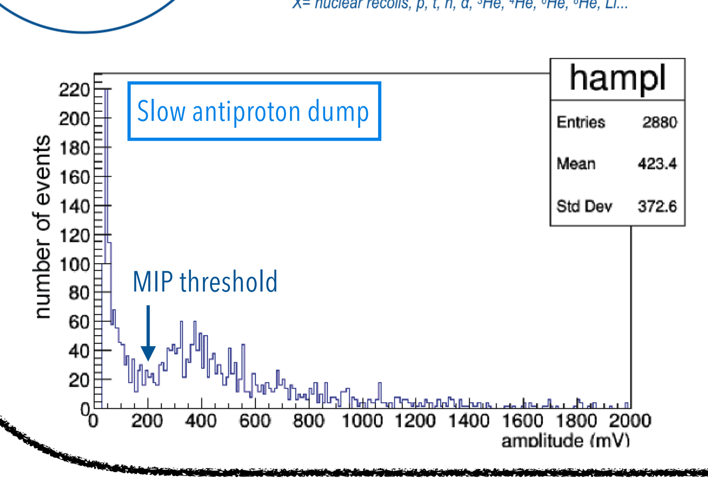


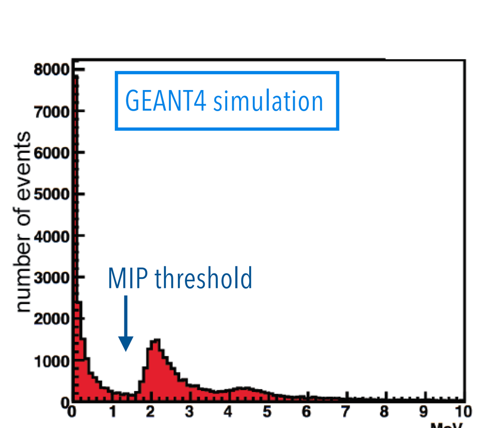


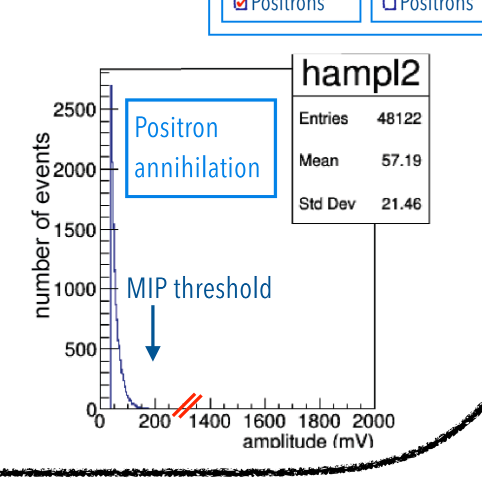


Background sources and undesirable effects
- **Cosmic rays**
- **Procedure-induced** (e.g. antiproton losses, positron burst, …)
- **All other possible systematics** (e.g. laser induced)









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