# An Helium calorimeter for Anti-Deuteron identification in cosmic rays
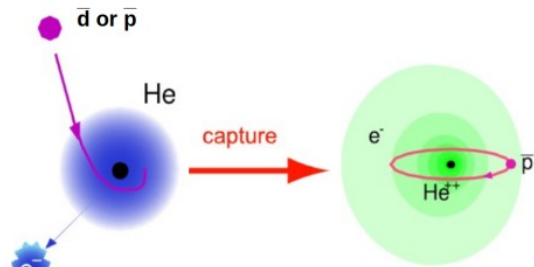
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The observation of GeV and sub-GeV anti-deuteron ($\bar{d}$) in the cosmic ray flux could be a very strong signature for dark matter annihilation in our Galaxy. Expected $\bar{d}$ background is negligible. Goal of the Anti Deuteron Helium Detector (ADHD) project is to study the signatures offered by an He calorimeter for the identification of $\bar{d}$ in cosmic rays thanks to $\bar{d}$-He metastable states.

## Meta-stability of exotic atoms $\bar{p}$-He and $\bar{d}$-He



Typ. annihilation time for $\bar{p} \sim$ ps
**Delayed annihilation** $\sim \mu$s in He
$\bar{p}$ ($\pi^-$,k$^-$,$\bar{d}$) captured to n$\sim$38 level
(same binding energy of the replaced e$^-$)
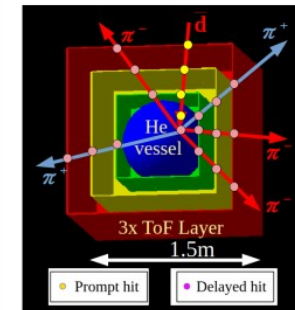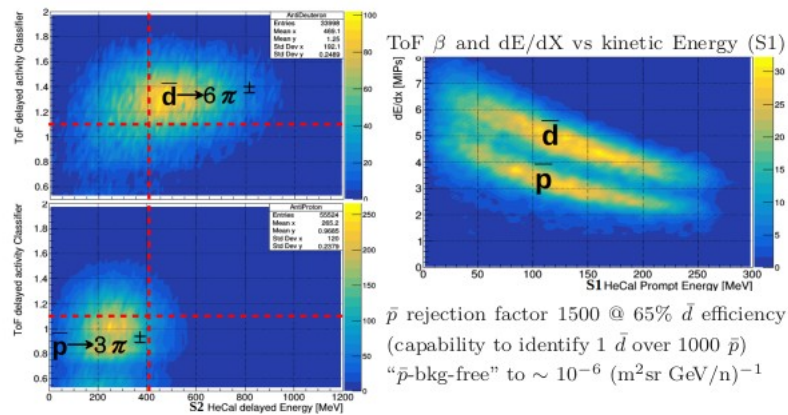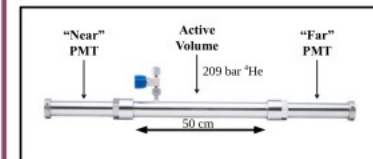Radiative transitions from n$\sim$38 to 1s



**Delayed annihilations only for He**

No Auger effect (only one remaining e$^-$)
No collisional Stark de-excitation (main channel for the electronless $\bar{p}$-H)
Phys.Lett.9(1964)65 - PRL23(1969)63
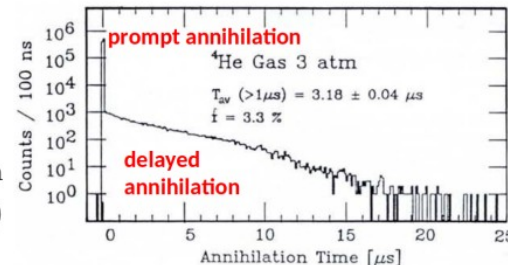
## ADHD detector scheme



**ToF 110 kg**
4mm x 27m$^2$
3 scint. layers
$\sigma_\beta$5% $\sigma_E$10%
**HeCal 20 kg**
300L r=45cm
400 bar He
scint. $\sigma_t \sim ns$
**Vessel 100kg**
3cm plastic

Trigger: prompt & $\mu$s delayed energy
prompt E S1 = kinetic energy in HeCAL
delayed E S2 = number of charged pions
Acceptance: $\sim 0.2$m$^2$ sr 50-150MeV/n

## $\bar{d}$ identification and $\bar{p}$ rejection (ToF + delayed Event)



ToF $\beta$ and dE/dX vs kinetic Energy (S1)

$\bar{d} \to 6\,\pi^{\pm}$

$\bar{p} \to 3\,\pi^{\pm}$

$\bar{p}$ rejection factor 1500 @ 65% $\bar{d}$ efficiency
(capability to identify 1 $\bar{d}$ over 1000 $\bar{p}$)
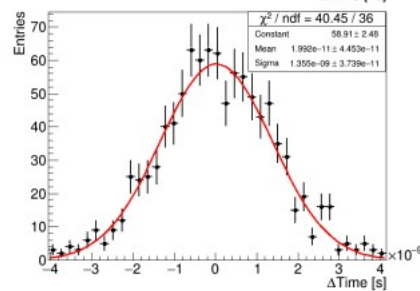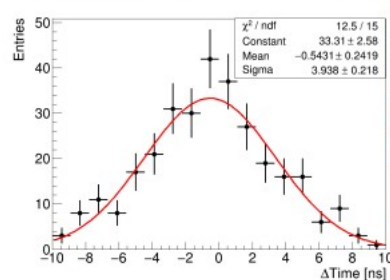"$\bar{p}$-bkg-free" to $\sim 10^{-6}$ $(\mathrm{m^2 sr\ GeV/n})^{-1}$

## Test of HeCal prototype



Prototype:
Arktis B-470
$^4$He scintillatr
(for fast n)
PMT replaced
8xSiPM array
allow test with
proton beam

## Preliminary time resolution mesurement with $\mu$ and Proton test beam



January 2021: Test Beam @ Trento Protontherapy facility 70-240 MeV

Prototype time resolution preliminary test with cosmic $\mu$:
300 keV => 3.9 ns ($\mu$ crossing the diameter)
3 MeV => 1.36 ns ($\mu$ crossing the whole detector)
Analysis of Proton Test Beam Data is ongoing

- Sensitivity similar to GAPS & AMS-02 expectations
- Complementarity in the explorable energy region
- Low energy $\bar{p}$ flux measurement with 5-10% error
- Lightweight & simple technology (<500 kg scintillators)

contacts: http://www.tifpa.infn.it/projects/adhd/