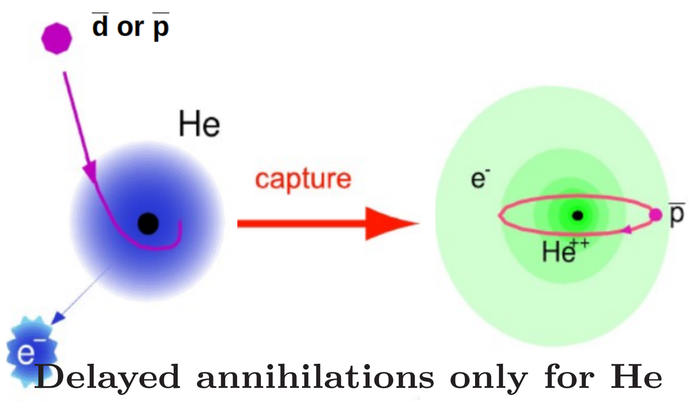
An Helium calorimeter for Anti-Deuteron identification in cosmic rays

F. Nozzoli[1,2], F. Dimiccoli[1,2], R. Iuppa[1,2], E. Ricci[1,2], P. Zuccon[1,2]

[1] INFN-TIFPA Trento Institute for Fundamental Physics and Applications. [2] Universitá degli Studi di Trento, Trento, Italy.

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



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)

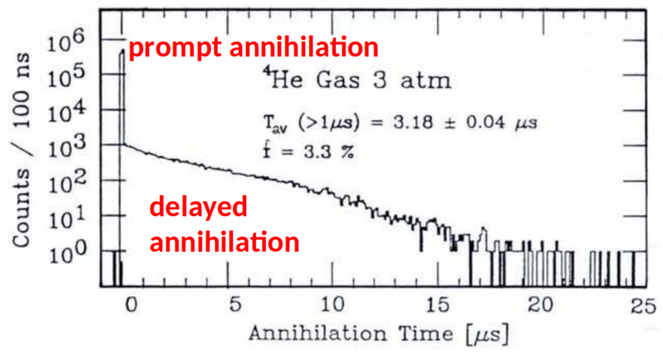
Phys.Lett.9(1964)65 - PRL23(1969)63

Typ. annihilation time for $\bar{p}$ $\sim$ ps

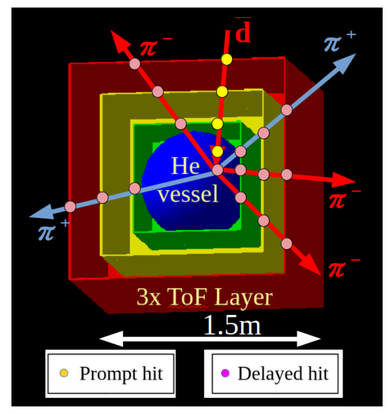
Delayed annihilation $\sim \mu$s in He

$\bar{p}$ (π^-,k^-,$\bar{d}$) captured to n$\sim$38 level (same binding energy of the replaced e^-)

Radiative transitions from n$\sim$38 to 1s



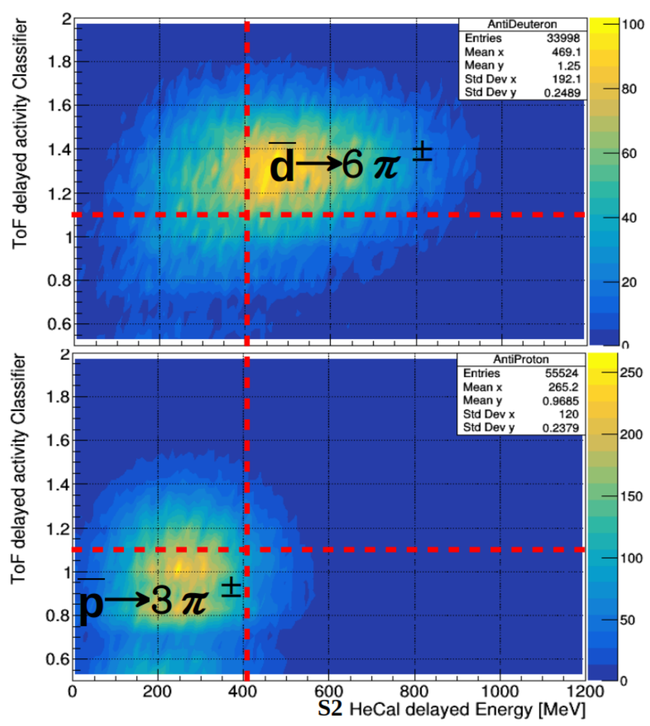
ADHD detector scheme



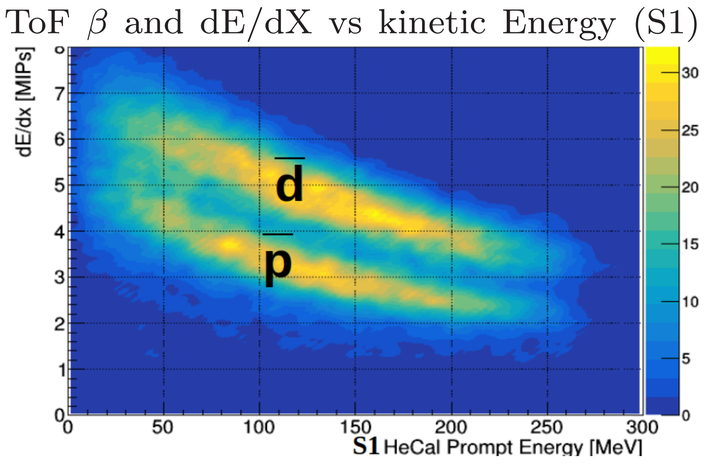
ToF 110 kg
4mm x 27m^2
3 scint. layers
σ_β5% σ_E10%
HeCal 20 kg
300L r=45cm
400 bar He
scint. $\sigma_t \sim ns$
Vessel 100kg
3cm plastic

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

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



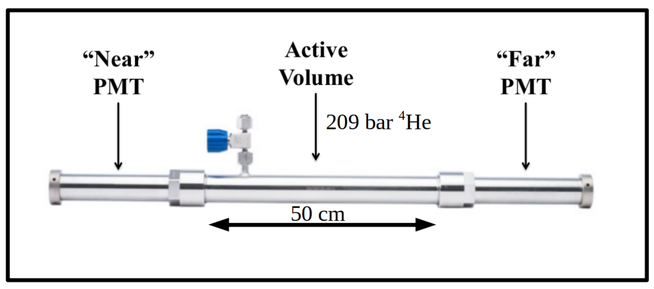
ToF β and dE/dX vs kinetic Energy (S1)

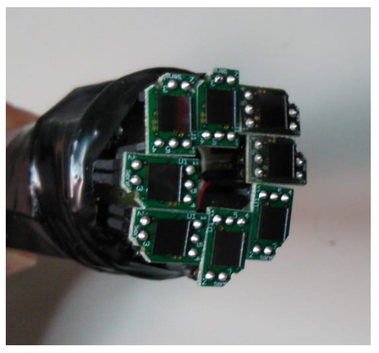


$\bar{p}$ rejection factor 1500 @ 65% $\bar{d}$ efficiency (capability to identify 1 $\bar{d}$ over 1000 $\bar{p}$)

"$\bar{p}$-bkg-free" to $\sim 10^{-6}$ (m^{2}sr GeV/n)$^{-1}$

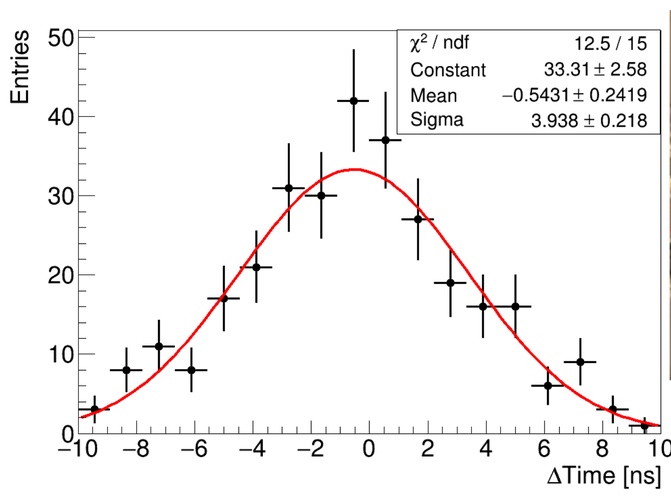
Test of HeCal prototype

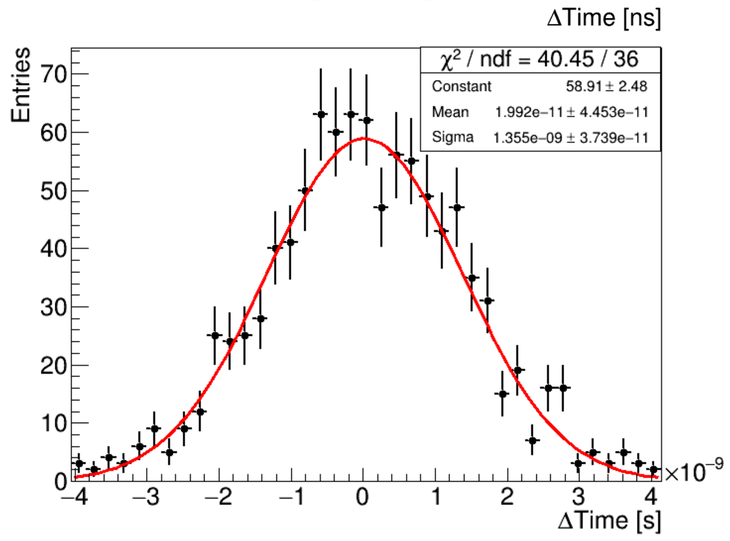


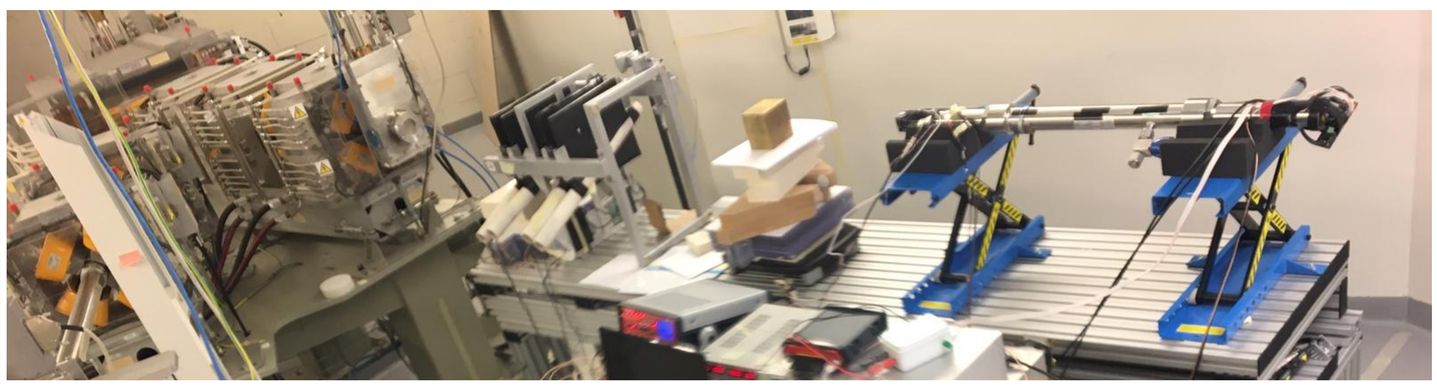


Prototype:
Arktis B-470
^{4}He scintillatr
(for fast n)
PMT replaced
8xSiPM array
allow test with
proton beam

Preliminary time resolution mesurement with μ and Proton test beam







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

Prototype time resulution preliminary test with cosmic μ:
300 keV => 3.9 ns (μ crossing the diameter)
3 MeV => 1.36 ns (μ 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/