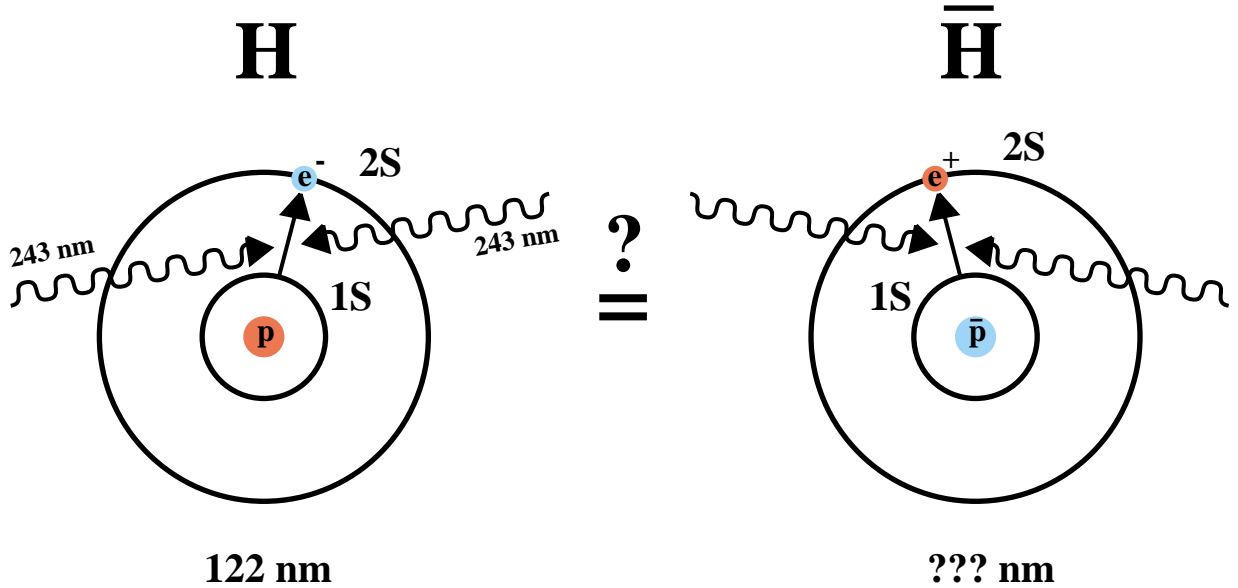




ATHENA (AnTi-HydrogEN Apparatus)

Production and study of
anti-hydrogen

D. Lindelof
Zürich University



Hydrogen Spectroscopy ...

- fundamental for development of QM and QED
- "astronomical" precision (two-photon laser spectroscopy)
 - measurement precision for energy difference 1S-2S : $\Delta\nu/\nu \sim 10^{-12}$
 - improvement to $\Delta\nu/\nu \sim 10^{-15}$ appears possible
 - split line 1:1000 $\rightarrow 10^{-18}$

Anti-Hydrogen Spectroscopy ...

- Comparison of 1S-2S energy difference between H and \bar{H} atom: $\Delta\nu/\nu \sim 10^{-15}$
(or better?)
- Precision of CPT test only rivalled by \bar{K}^0 - K^0 mass comparison
- Comparison of gravitational mass of matter and antimatter to 10^{-8}
(weak equivalence principle)



Any **local** quantum field theory, obeying **Lorentz invariance** and usual **spin-statistics** connection

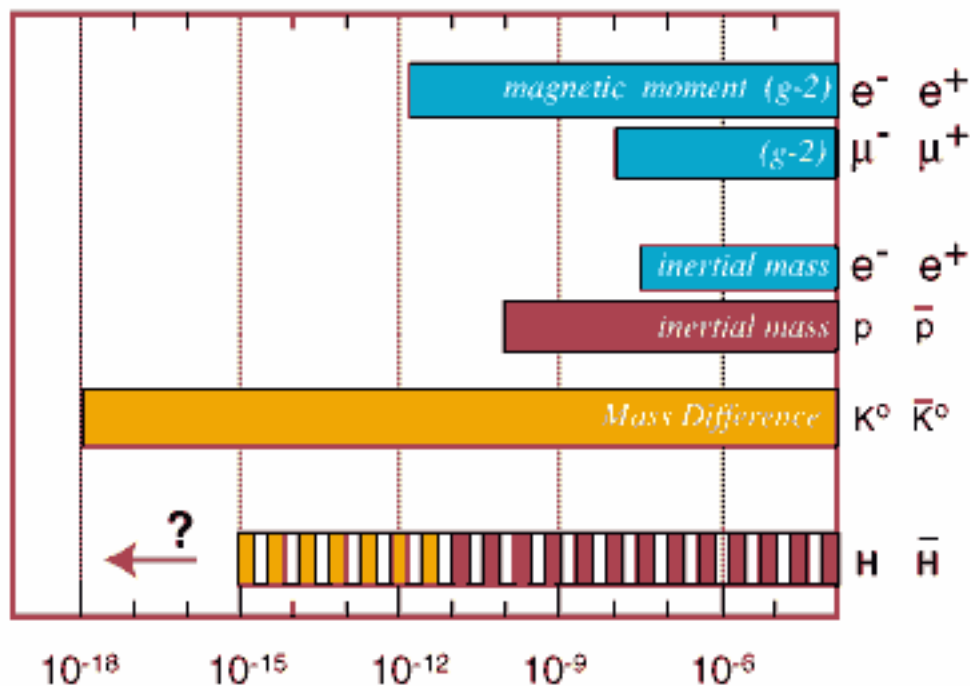


CPT Invariance

G. Lüders, Ann. Phys. 2, 1-15 (1957)
(also: W. Pauli, J. Schwinger)

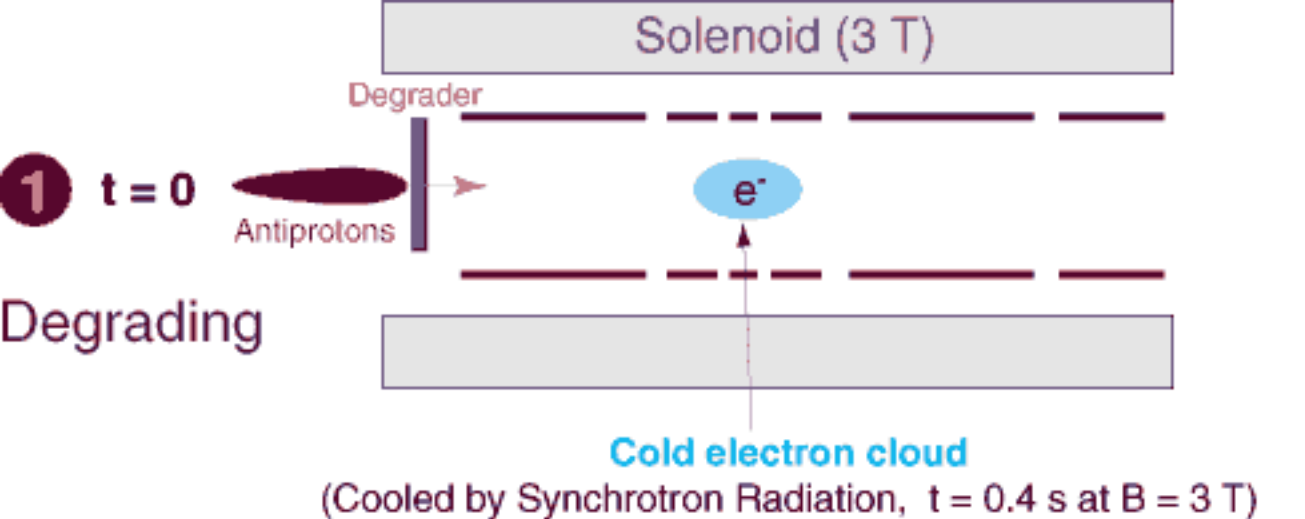
MATTER = ANTIMATTER at **any** level of precision

The most precise CPT Tests



(note the logarithmic scale)

1S-2S Spectroscopy



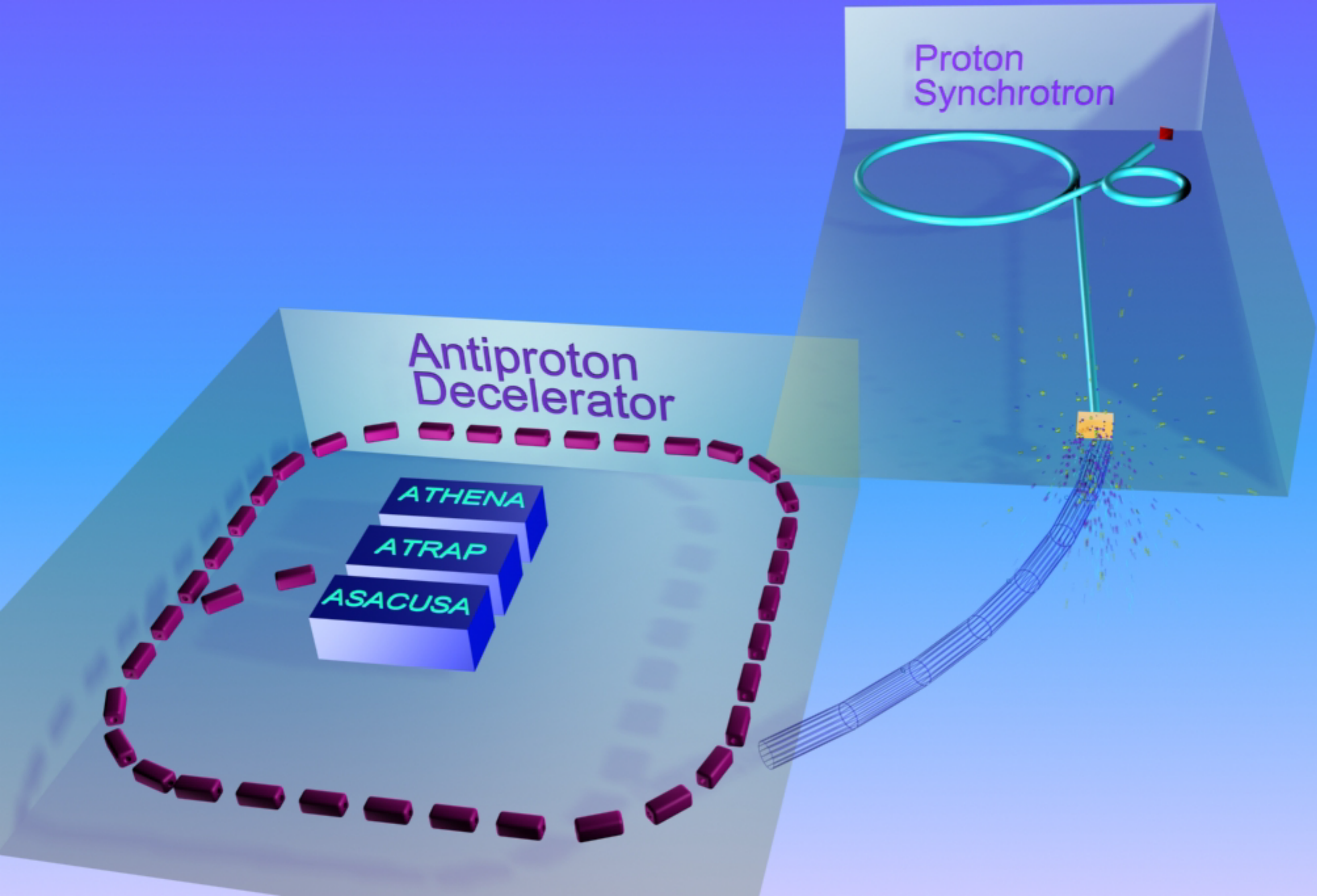
Proton
Synchrotron

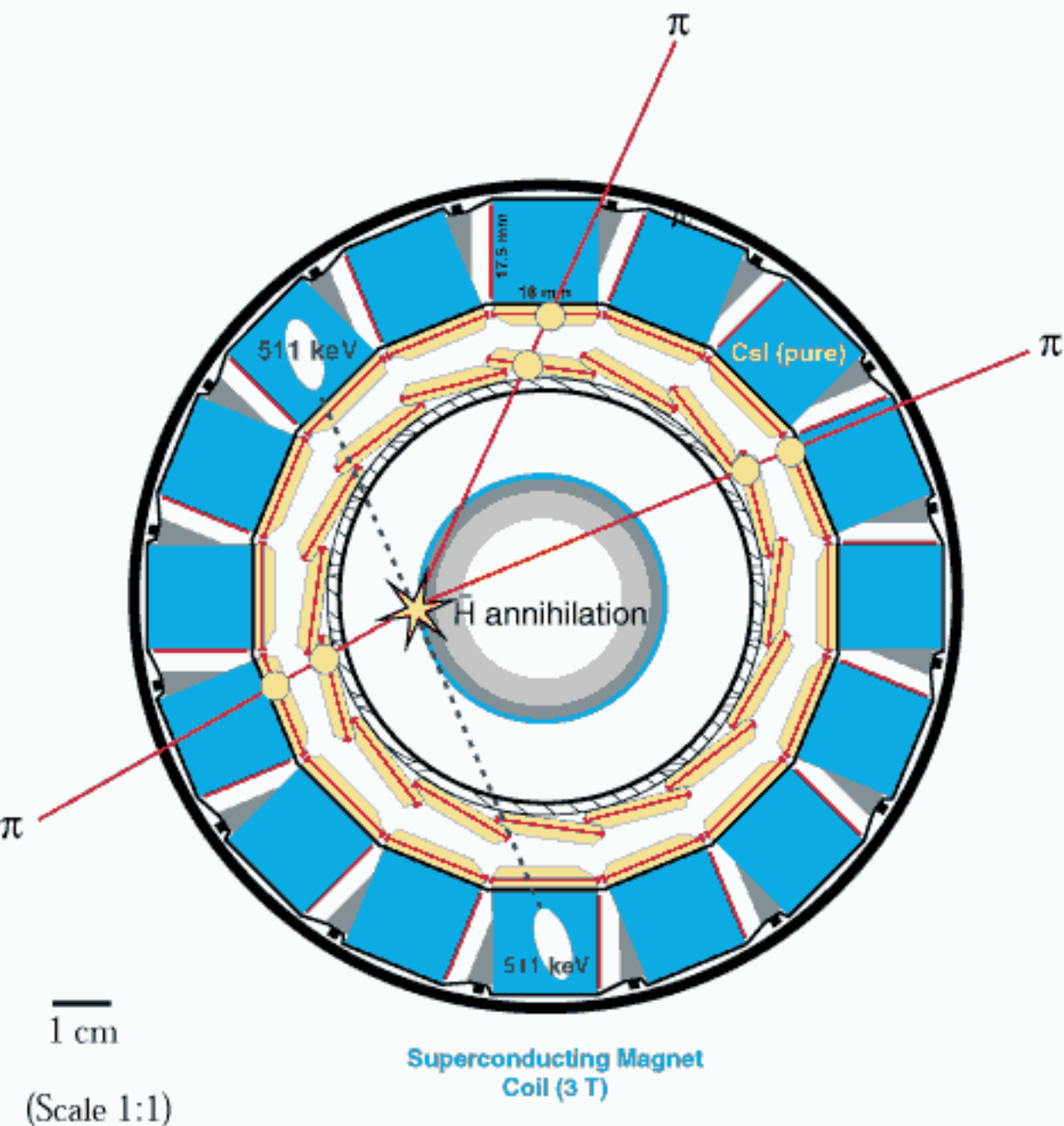
Antiproton
Decelerator

ATHENA

ATRAP

ASACUSA





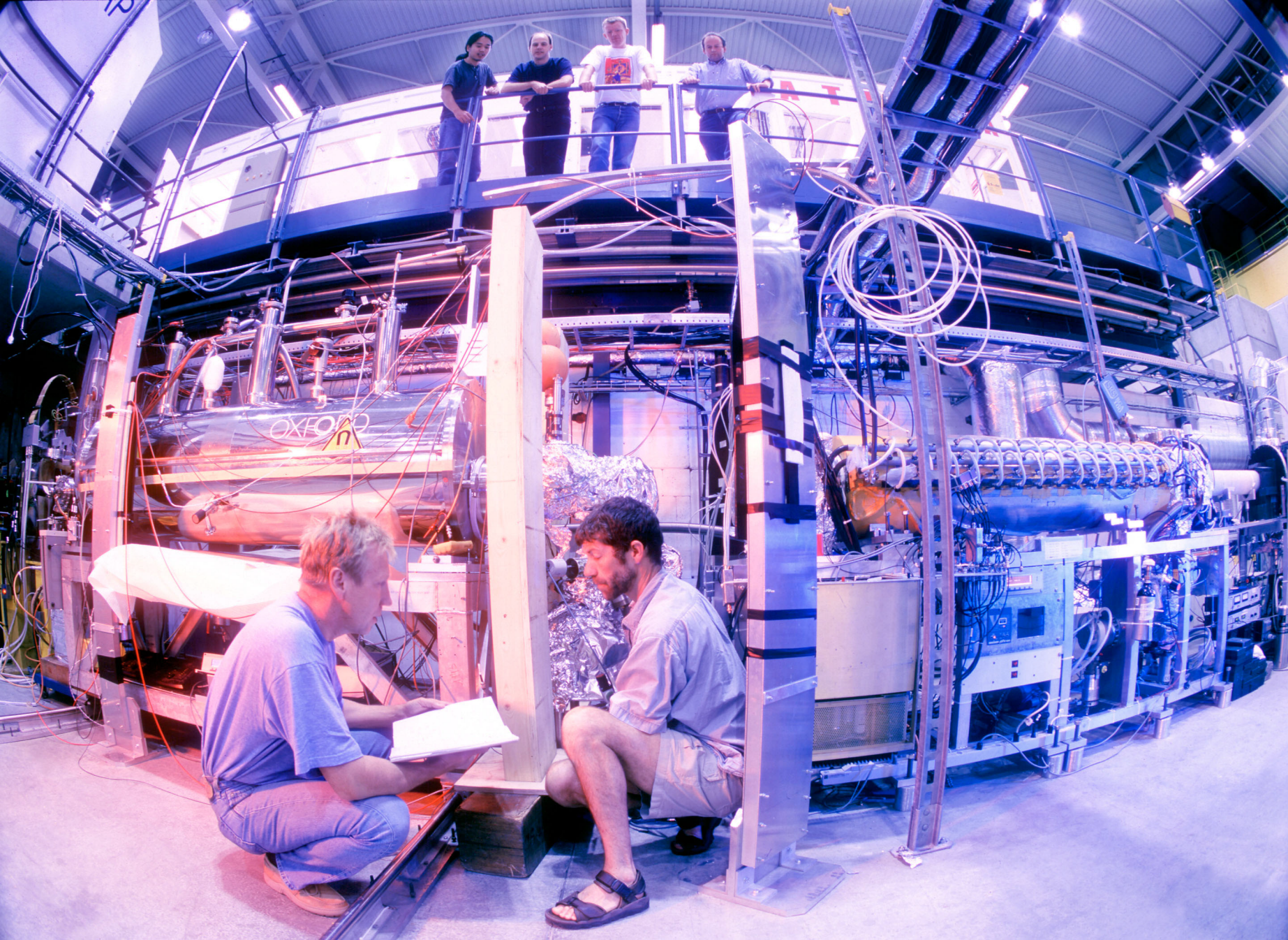
Discriminate Antihydrogen Annihilation from background of Antiproton annihilation and Positron annihilation

Good spatial resolution (< 1 cm) of vertex for

- Antiproton Annihilation (≥ 2 prongs)
- Positron Annihilation (2×511 keV γ)

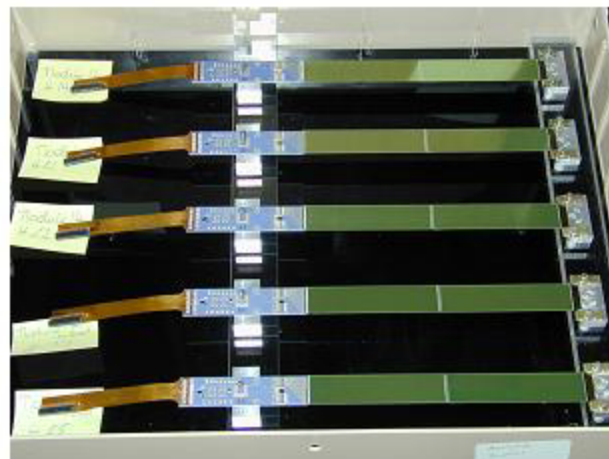
Time coincidence (~ 1 μ sec)

High rate capability

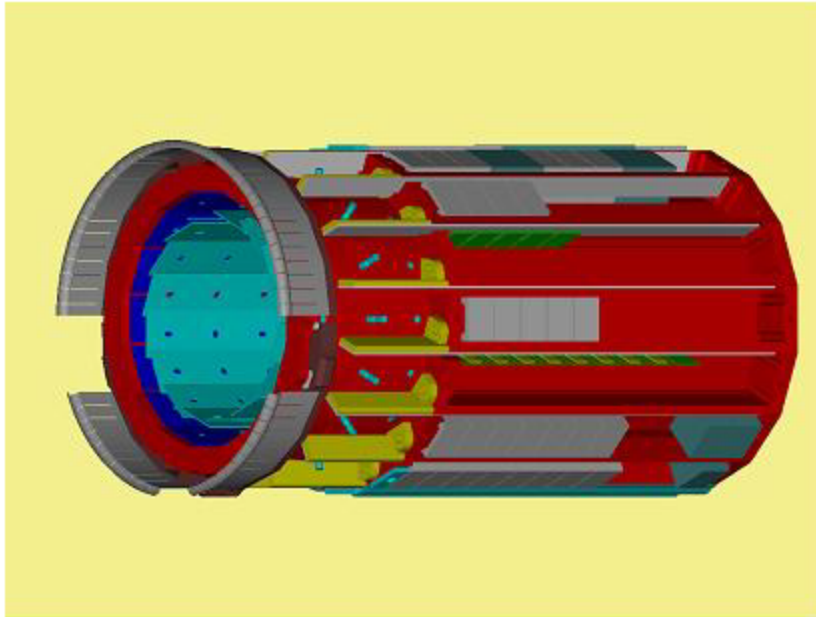


ATHENA detector status

- All silicone detectors completed and tested
- Crystals readout tested @ low temperature
- All mechanical pieces ready
- Fully-working partial assembly: now?

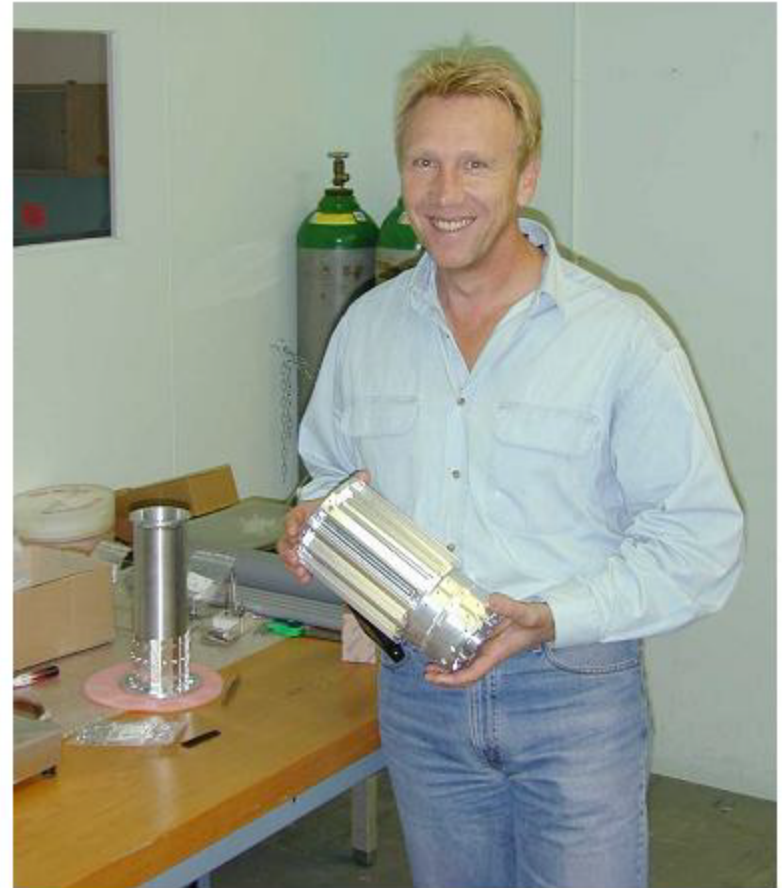


ATHENA detector design



**Low temperature
operation**

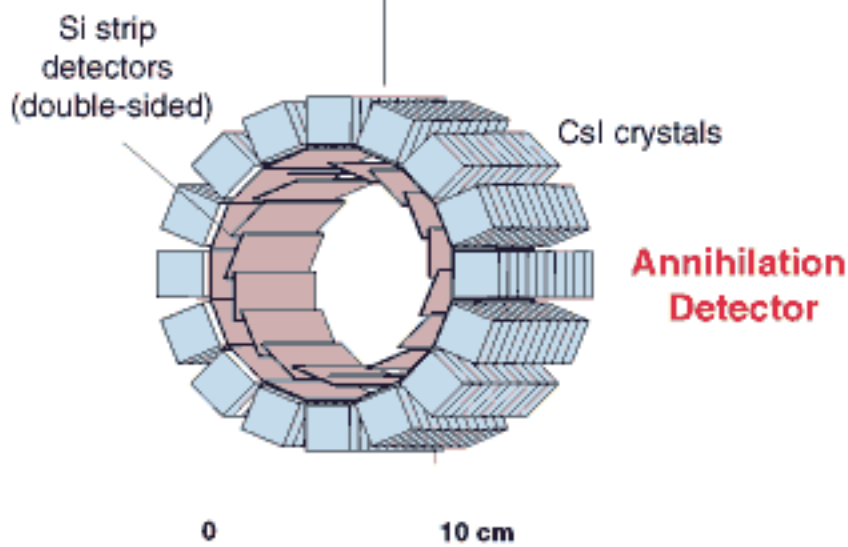
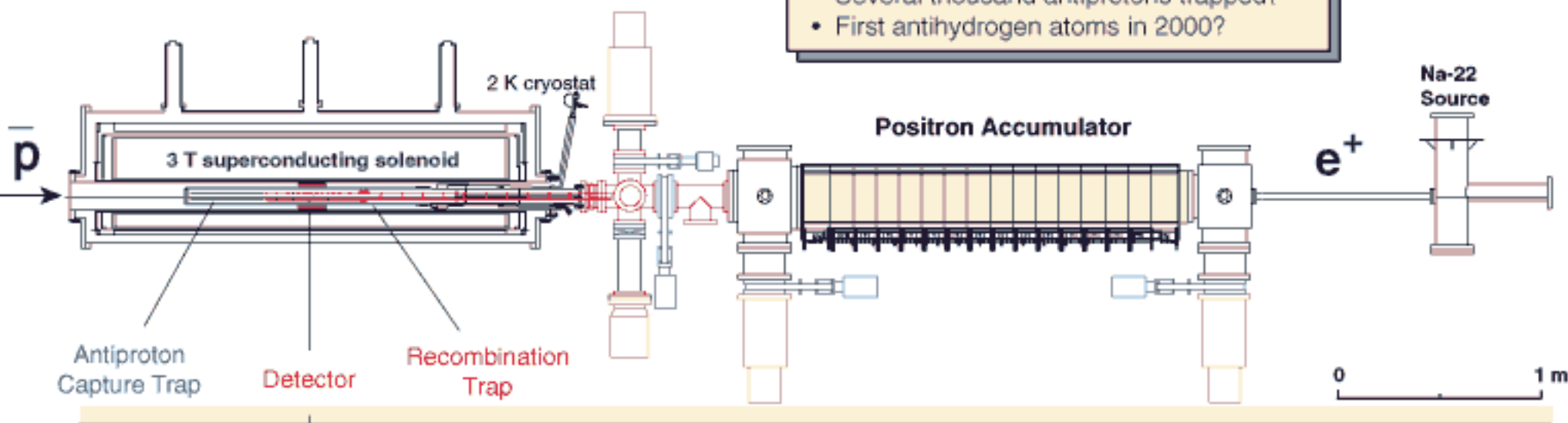
□ " **mechanical challenge**



ATHENA / AD-1 : Antihydrogen Production and Spectroscopy

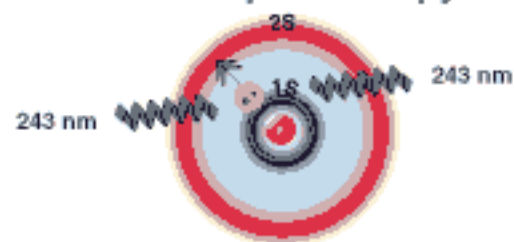
**Antiproton Accumulation +
Recombination with positrons**

- Installation of traps completed
- Several thousand antiprotons trapped
- First antihydrogen atoms in 2000?



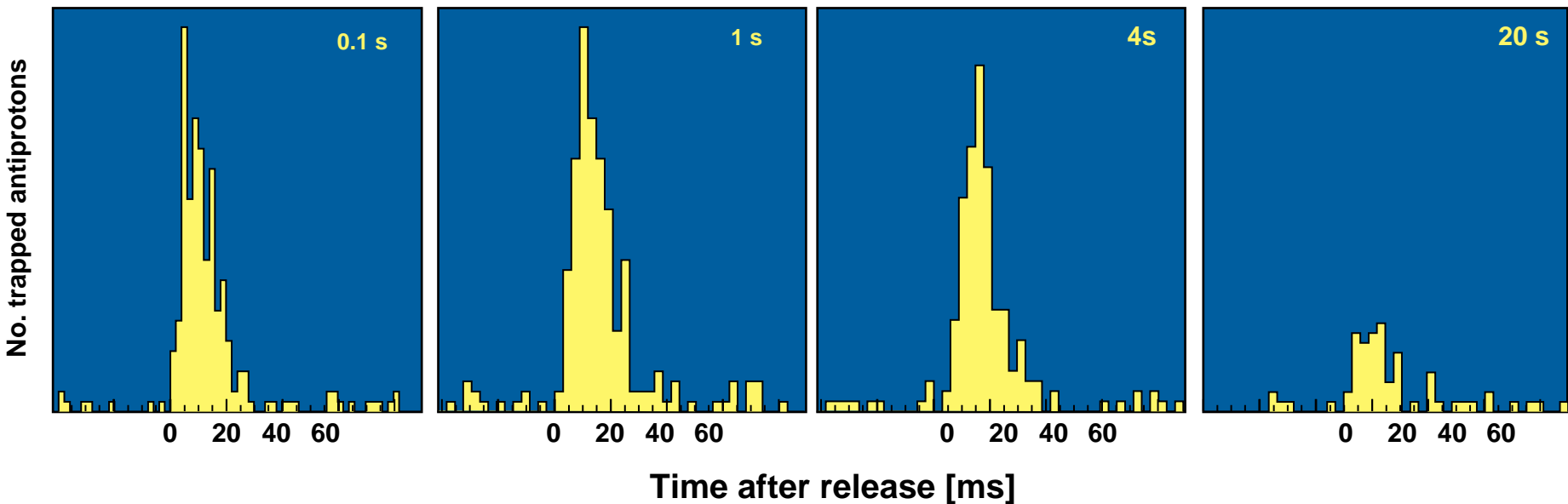
LONG TERM GOAL:

2-Photon Laser Spectroscopy: ΔE (1S-2S)



Comparison \bar{H} : H with precision 10^{-12} ... 10^{-15}

Lifetime of captured antiprotons as a function of pressure
(Example : $p = 10^{-8}$ mbar, $\tau_{1/2} \sim 10$ sec)



ATHENA
(preliminary)

ISAAC NEWTON AND THE ANTI APPLE

