Technical challenge at ATHENA

Univ. of Tokyo
Ryo FUNAKOSHI
ATHENA collaboration

Out Line

- **Introduction;**

back ground (low energy facility at CERN), ATHENA collaboration

- **ATHENA experiment;**

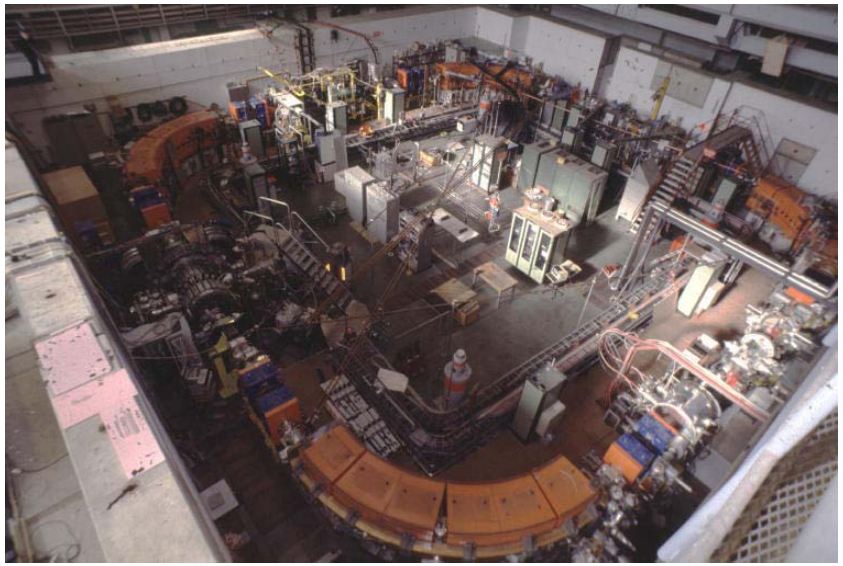
strategy, apparatus

- **ATHENA outputs;**

detector, positron source, plasma techniques, hbar production & study, etc. (after 2002)

and then…

Introduction: Pbar facility at CERN



LEAR
1986-1996

- 1992 Proposed by Munger *et al.*:
  pbar + Z → hbar
- 1996 9 events antihydrogen
  (*however* life time ~40 ns)

AD
1999-

Three experiments in AD hall:

Athena --- Antihydrogen

Asacusa --- Pbar He, etc.

Atrap --- Antihydrogen

Introduction: ATHENA collaboration


Univ. of Aarhus, Denmark


Univ. of Brescia, Italy

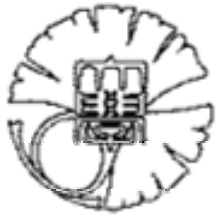

Univ. of Genova, Italy

CERN, Geneva, Suisse


Univ. of Pavia, Italy


Univ. of Rio, Brazil


Univ. of Swansee, Wales (UK)

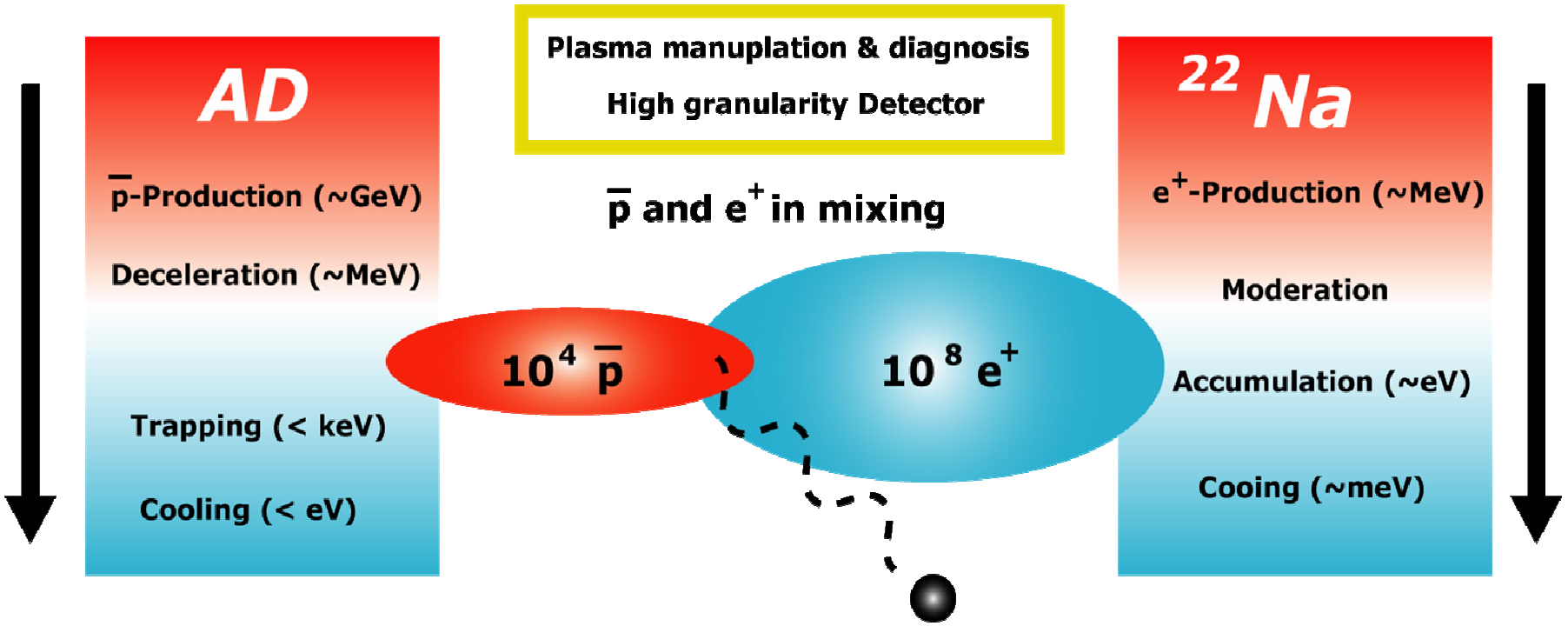

Univ. of Tokyo, Japan

Univ. of Zurich, Suisse

INFN, Italy

LANL, USA

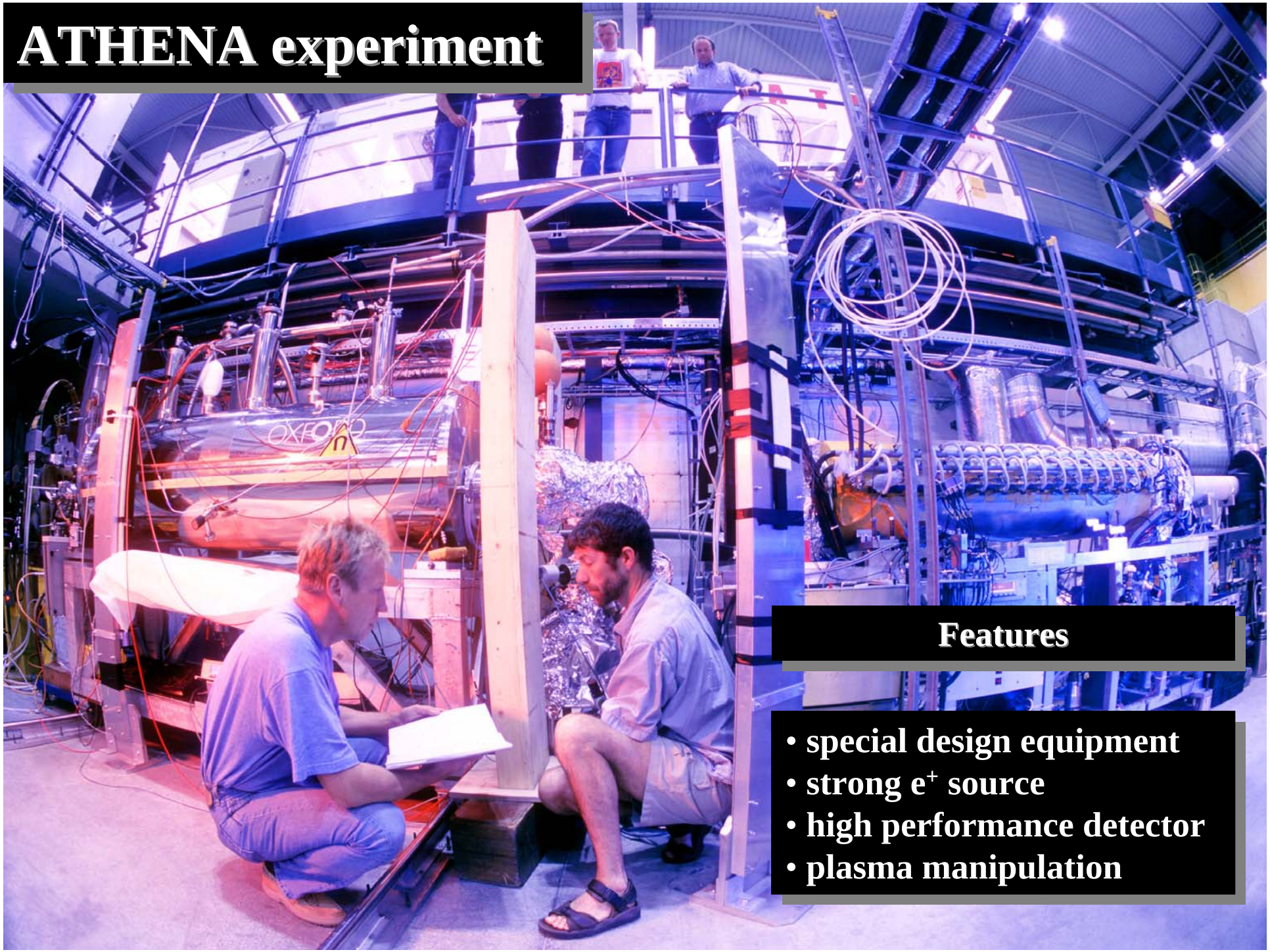
ATHENA experiment: Basic shame



Antihydrogen formation

THENA

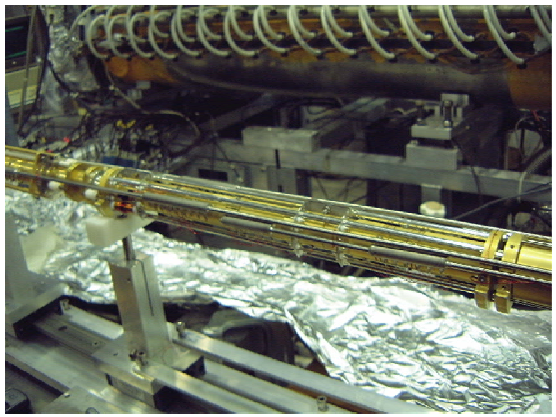
ATHENA experiment

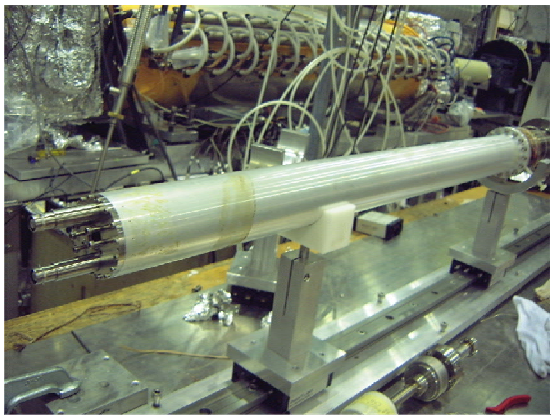


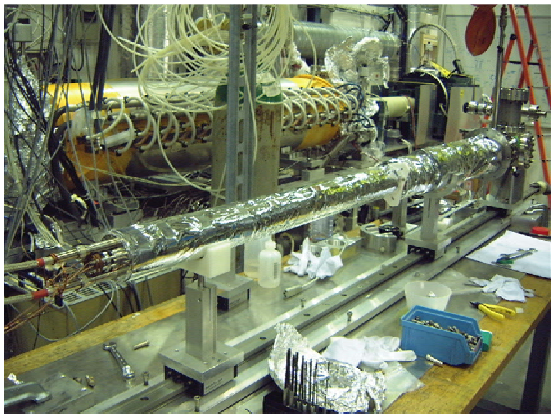
Features

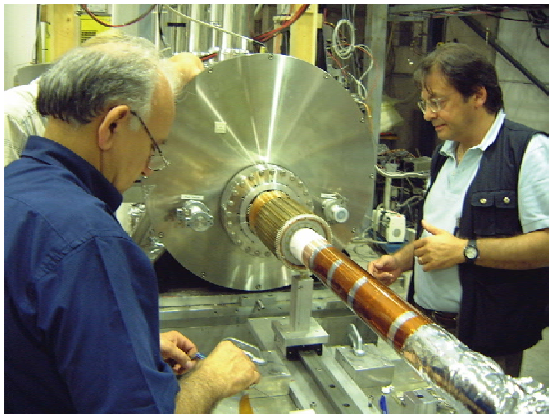
- special design equipment
- strong e^+ source
- high performance detector
- plasma manipulation

ATHENA experiment: Trap with detector









<Trap>
P<10^{-12}mbar, T~15K

Cold nose

<Detector>
P~10^{-9}mbar, T~130K

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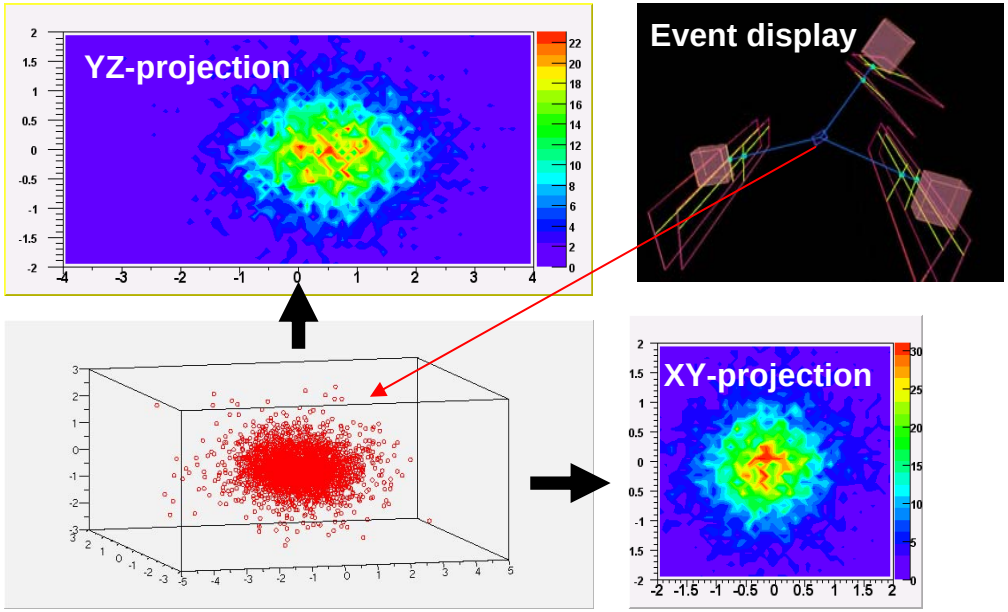
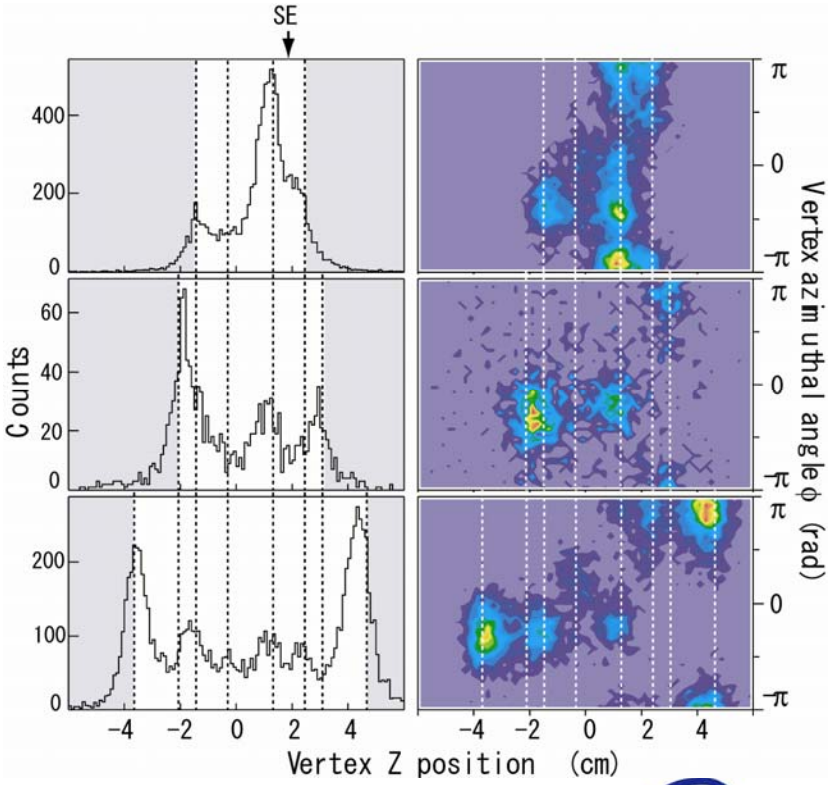
ATHENA Outputs: Antiprotons



10^4 pbar / AD 2 shots

M. C. Fujiwara *et al.*, Phys. Rev. Lett. **92**, 065005 (2004)



non-destructive 3D image of antiproton annihilations

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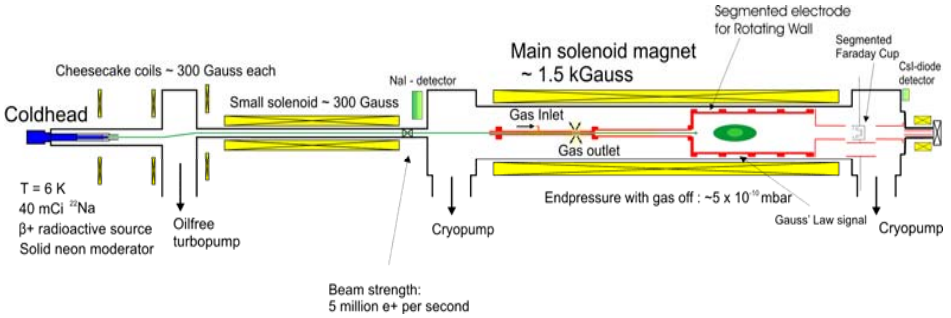
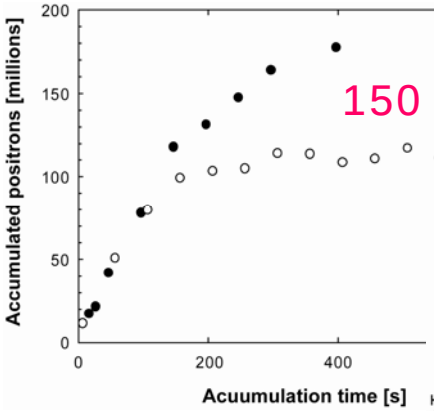
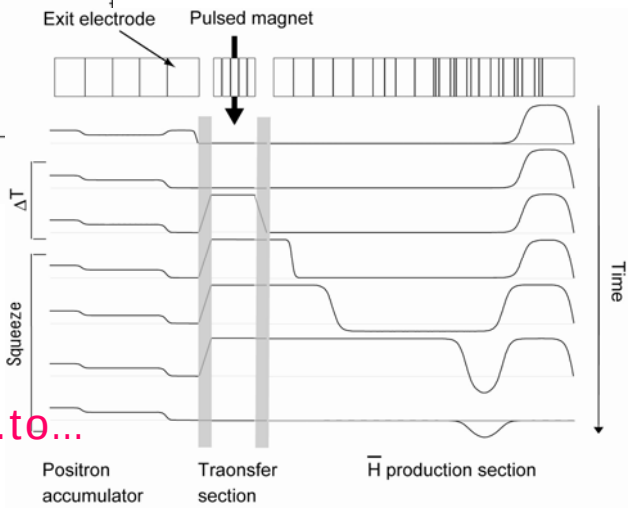
ATHENA Outputs: Positrons



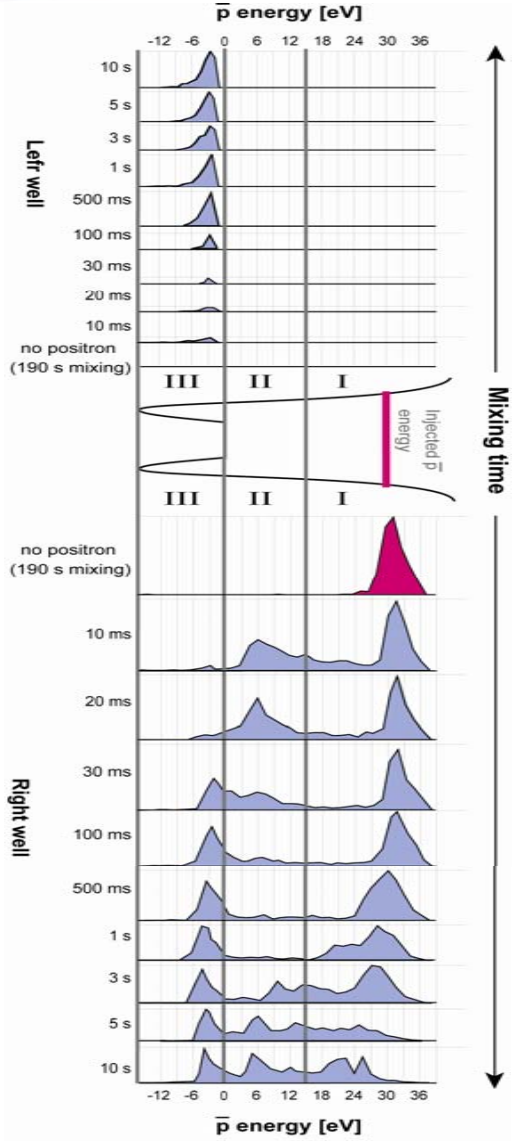


150 million e^+ / 200 s



Transfer from…to…

Submitted to PRL



75 million
e^+ cooling

M. Amoretti *et al.*, Phys. Lett. B **590,** 133-142 (2004)

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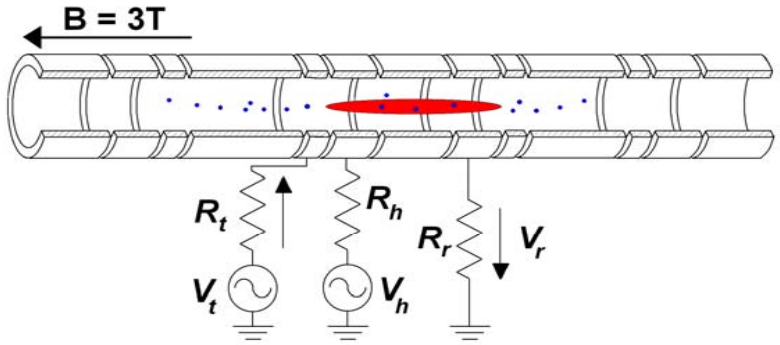
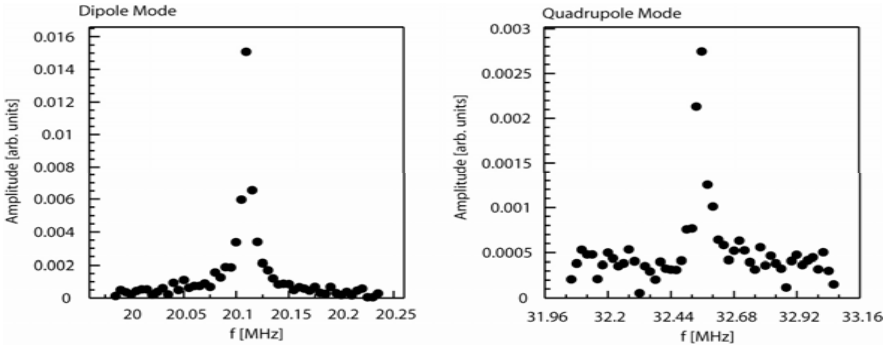
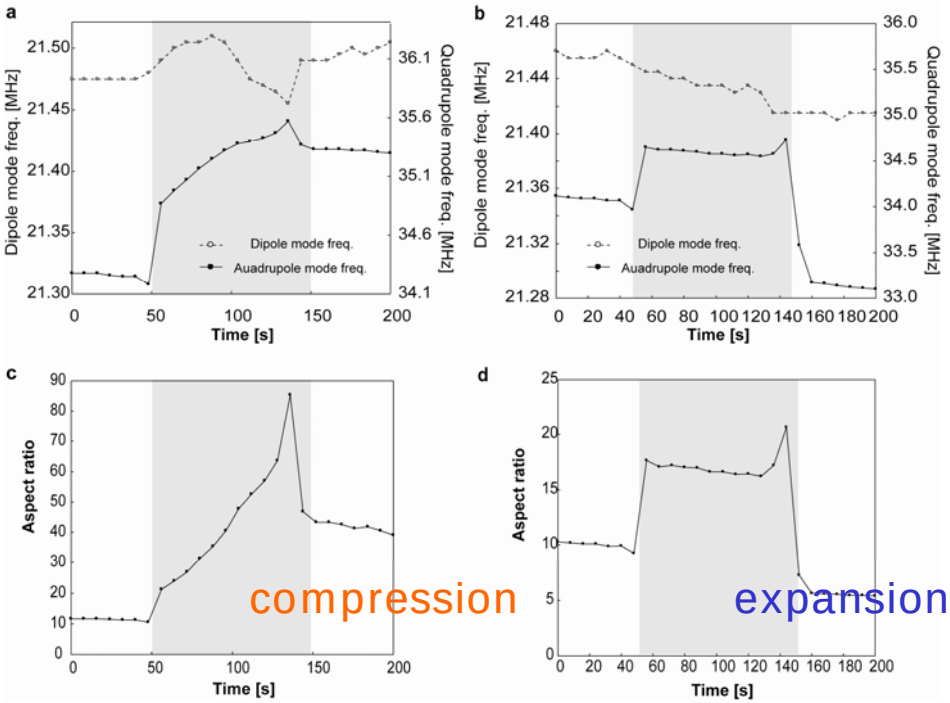
ATHENA Outputs: Plasma technique







M. Amoretti *et al.*, Phys. Rev. Lett. **91**, 055001 (2003)

non-destructive plasma monitoring;
shape (r, L), density, number

plasma manipulation:
- compression & expansion
- temperature control

R. Funakoshi, PhD thesis (2004)

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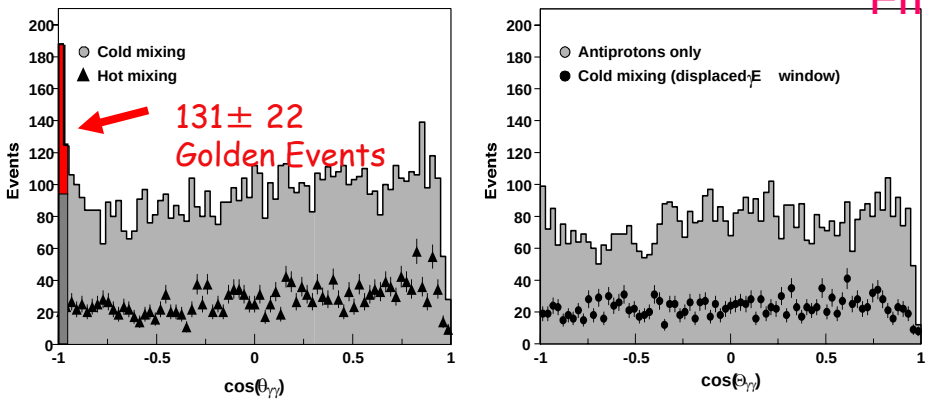
ATHENA Outputs: Hbar study I

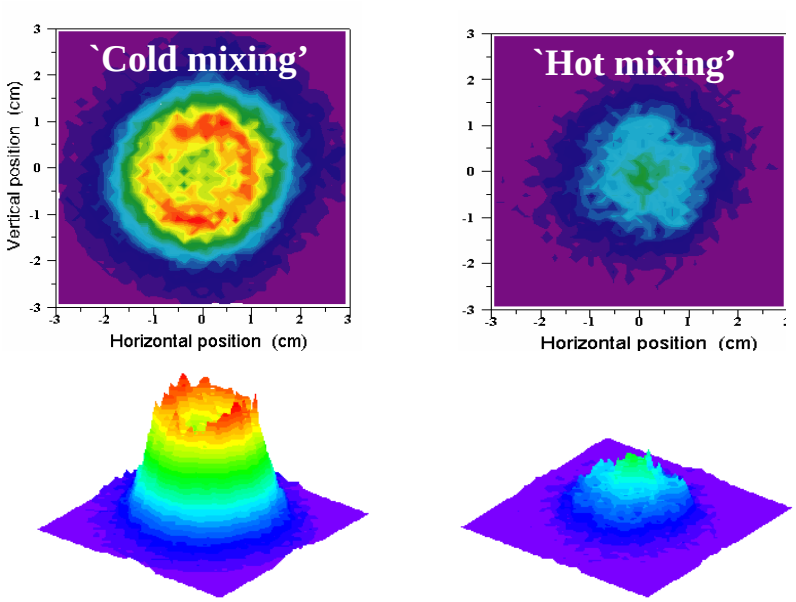
First antihydrogen

M. Amoretti *et al.*, *Nature* **419**, 456 (2002)

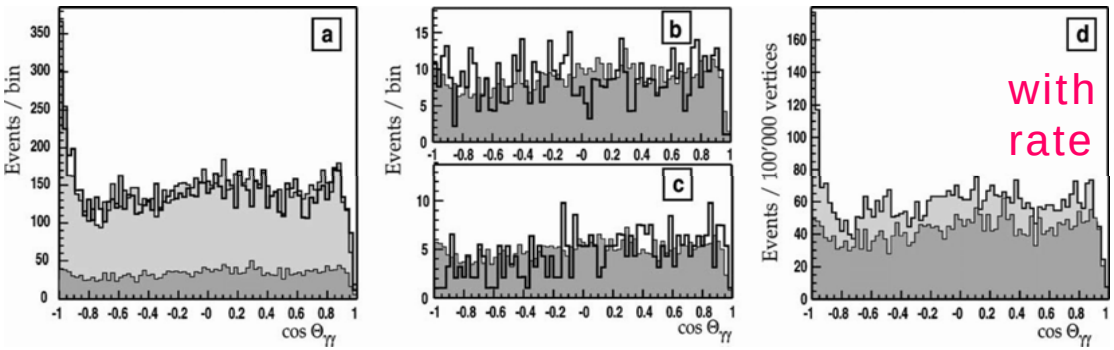


1. `Hot mixing'
→ suppress antihydrogen production

2. Antiprotons only
3. Displaced 511keV energy window

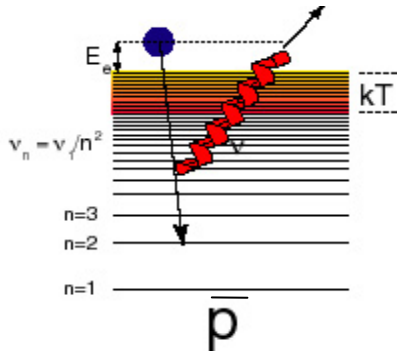


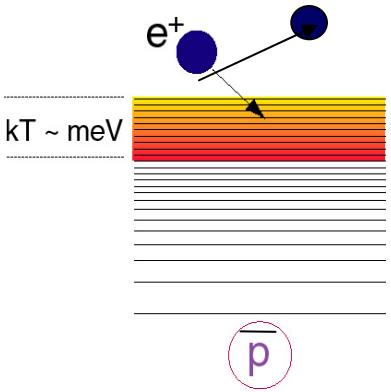
M. Amoretti *et al.*, Phys. Lett. B **578**, 23 (2004)

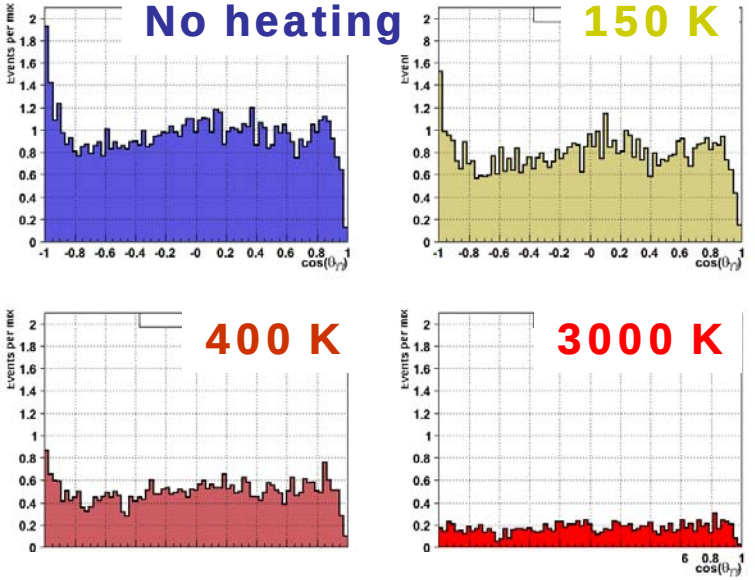


with high production rate > 100 Hz

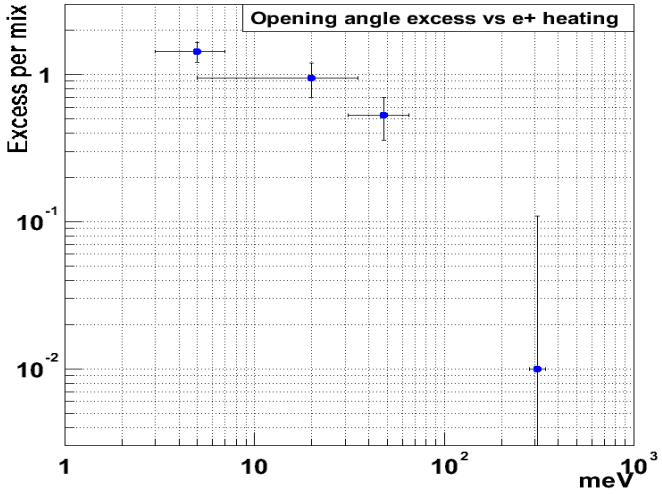
ATHENA Outputs: Hbar study II







	Radiative	Three-body
Temp. dependence	$T^{-1/2}$	$T^{-9/2}$
Final quantum state	n < 10	n >> 10
Stability (re-ionization)	high	low
Expected rates	~10s Hz	???



M. Amoretti *et al.*, Phys. Lett. B **583**, 59-67 (2004)

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ATHENA Outputs: Publications

-2002-

- *'Production and detection of cold antihydrogen atoms'*
  M. Amoretti *et al.*, *Nature* **419**, 456 (2002)

-2003-

- *'Complete Nondestructive Diagnostic of Nonneutral Plasmas Based on the Detection of Electrostatic Modes'*
  M. Amoretti *et al.*, Phys. Plasma **10**, 3056 (2003)
- *'Positron Plasma Diagnostic and Temperature Control for Antihydrogen Production'*
  M. Amoretti *et al.*, Phys. Rev. Lett. **91**, 055001 (2003)

-2004-

- *'The ATHENA antihydrogen apparatus'*
  M. Amoretti *et al.*, Nucl. Inst.Meth. Phys. Res. A **518,** 679-711 (2004)
- *'High rate production of antihydrogen'*
  M. Amoretti *et al.*, Phys. Lett. B **578**, 23-32 (2004)
- *'Antihydrogen production temperature dependence'*
  M. Amoretti *et al.*, Phys. Lett. B **583**, 59-67 (2004)
- *'Three-Dimensional Annihilation Imaging of Trapped Antiprotons'*
  M. C. Fujiwara *et al.*, Phys. Rev. Lett. **92**, 065005 (2004)
- *'Dynamics of Antiproton Cooling in a Positron Plasma During Antihydrogen Formation'*
  M. Amoretti *et al.*, Phys. Lett. B **590,** 133-142 (2004)

But no physics measurement, yet!!

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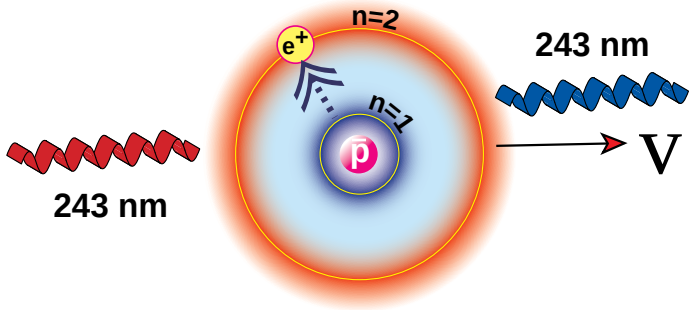
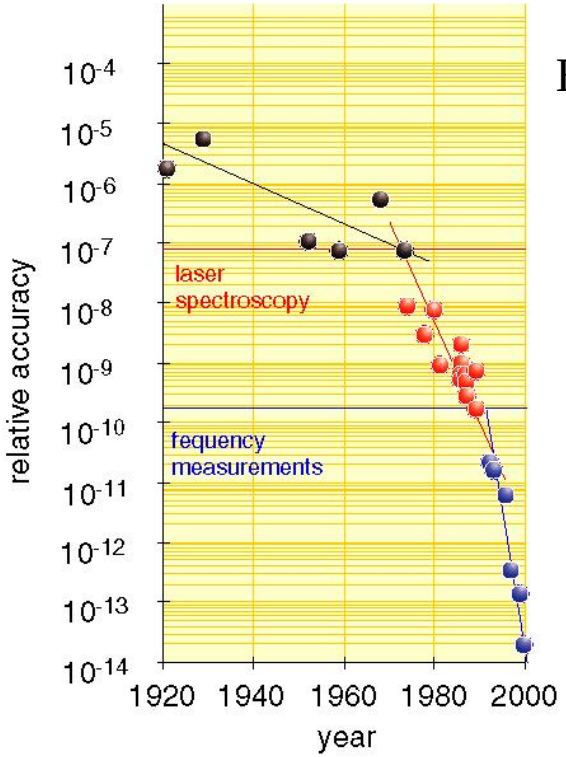
ATHENA outputs: and then...?

CPT theorem ⟶ (matter) ⟷ (antimatter)
same mass & life time, same & opposite charge

<laser spectroscopy with hydrogen atoms>





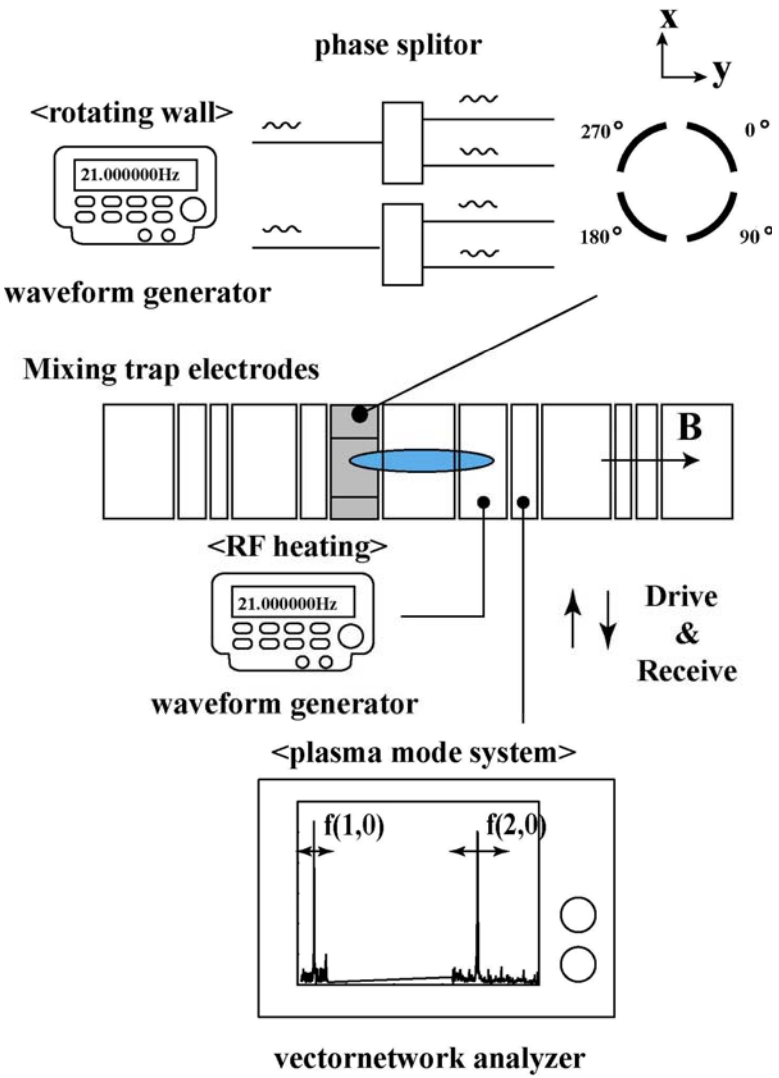
Energy deference between 1s-2s
precision of 10^{-14} (2004)

↓

antihydrogen atoms (???)

c.f. **(direct) CPT tests**
mass difference (e^- & e^{+}) ⟶ 10^{-9}
g-2 difference (e^- & e^+) ⟶ 10^{-12}

Further study: Rotating-wall



Optimum parameters;

I. Resonance frequency survey
II. Sweep condition
III. Amplitude optimization
IV. Cross check with destructive method

	n	α (r)
compress	> 1 x 10^{10} cm^{-3}	> 70 (0.3 mm)
standard	7 x 10^{9} cm^{-3}	20 (1 mm)
expand	1.5 x 10^{8} cm^{-3}	6.5 (2.5 mm)

R. Funakoshi, PhD thesis (2004)