INTERNATIONAL MAX PLANCK RESEARCH SCHOOL PTFS FOR PRECISION TESTS OF FUNDAMENTAL SYMMETRIES

BASE

Baryon Antibaryon Symmetry Experiment

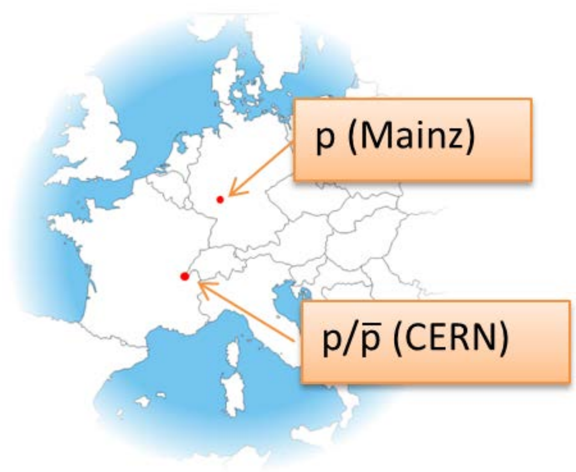
Kurt Franke

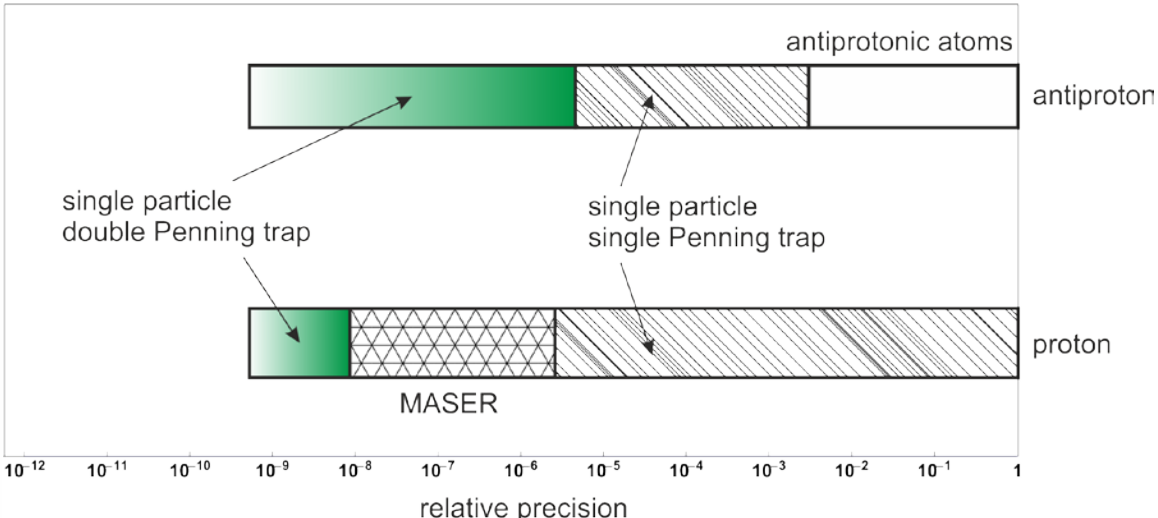
IMPRS-PTFS Evaluation

Motivation

High-precision test of CPT invariance in Baryons by comparing the proton and antiproton magnetic moments:

$$\vec{\mu}_{p/\bar{p}} = g_{p/\bar{p}} \frac{q_{p/\bar{p}}}{2m_{p/\bar{p}}} \vec{S}$$





$$g_{\bar{p}} = 5.585690(24)$$

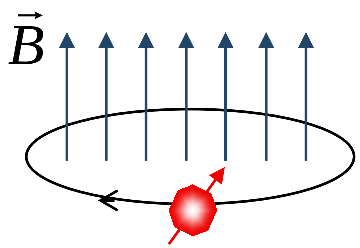
$$g_p = 5.585694713(46)$$

P. F. Winkler *et al.*, Phys. Rev. A **5**, p. 83 (1972).
J. DiSciacca *et al.*, Phys. Rev. Lett. **110**, 130801 (2013).

Experimental principle

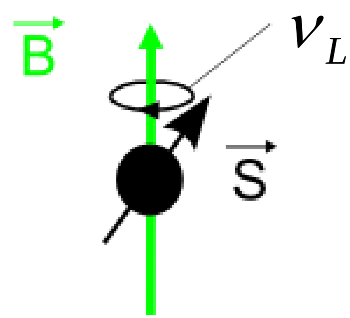
- Charged particle in magnetic field:

Cyclotron Motion



$$\nu_c = \frac{1}{2\pi}\frac{q \cdot B}{m}$$

Spin precession

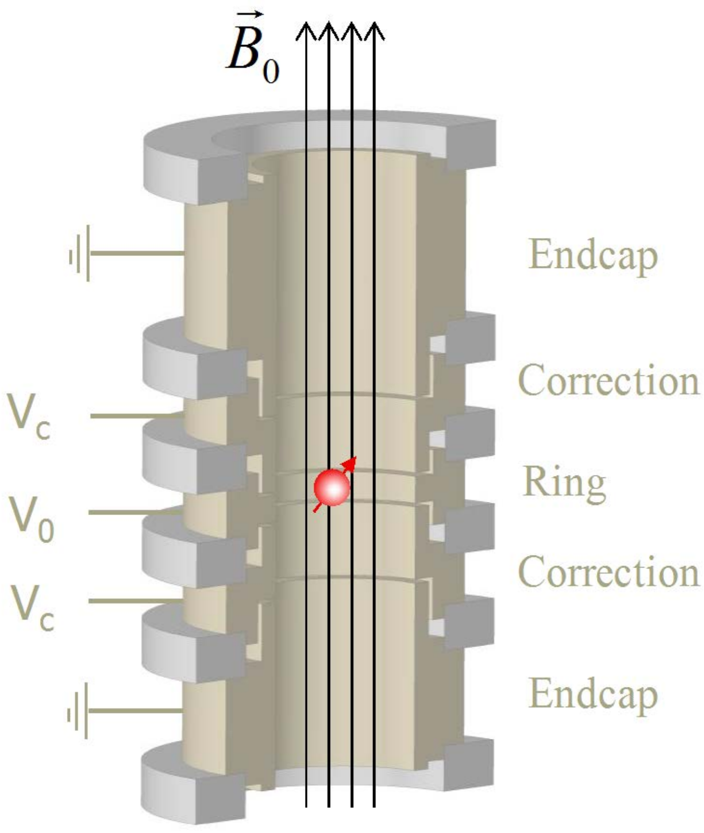


$$\nu_L = \frac{1}{2\pi}\frac{g}{2}\frac{q \cdot B}{m}$$

$$g = \frac{2\,\nu_L}{\nu_c}$$

- g found as ratio of two frequencies
- $\rightarrow$ Stable homogeneous magnetic field
- $\rightarrow$ Long observation time

The Penning trap

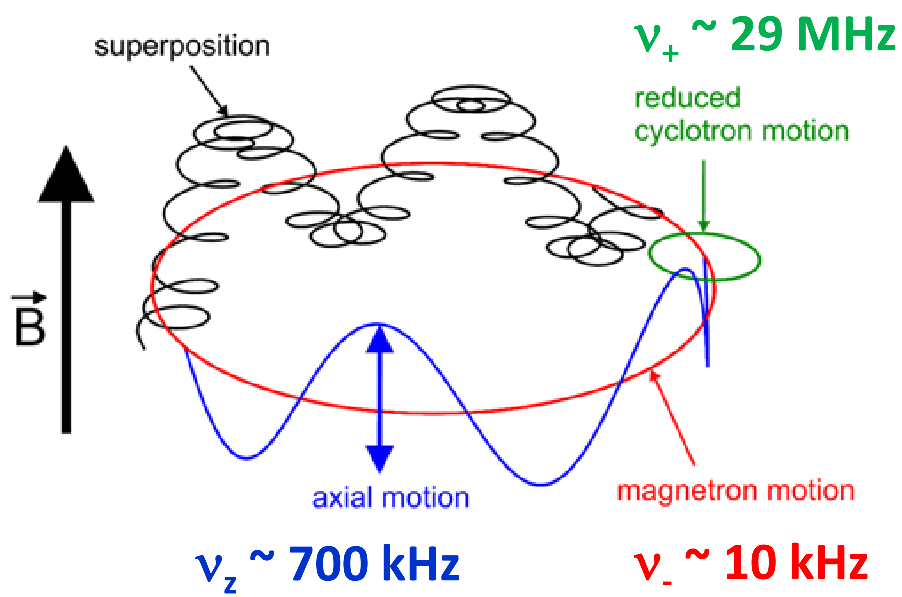


Ideal Penning Trap

$\vec{B} = B_0 \vec{e}_z$ → Radial confinement

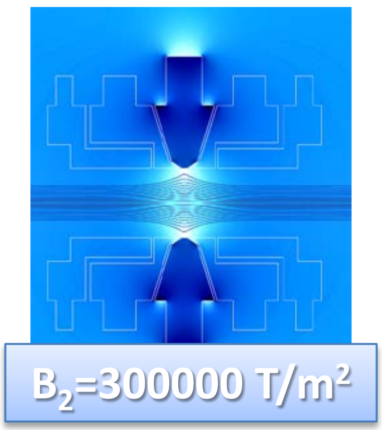
$\Phi = V_0 C_2 (z^2 - \rho^2/2)$ → Axial confinement

Motion in a Penning Trap



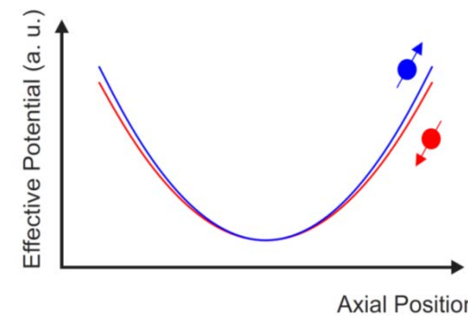
Continuous Stern-Gerlach Effect

- Measure ν_{SF} frequency to flip S_z
- “Magnetic bottle” to affect motion



$$\Phi_M = -\vec{\mu}_{p/\bar{p}} \cdot \vec{B}$$

$$B_z = B_0 + B_2\left(z^2 - \rho^2/2\right)$$



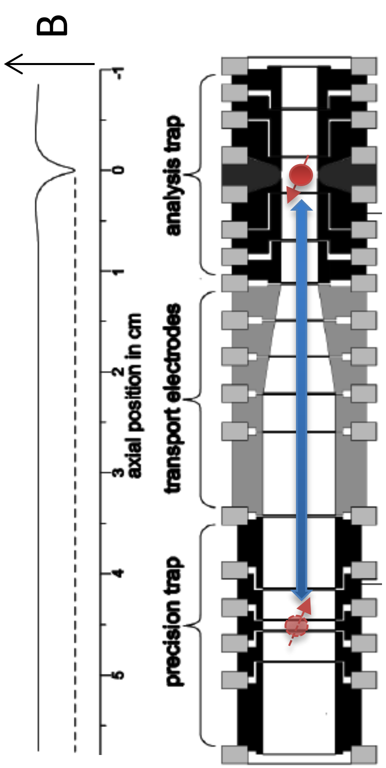
$$\frac{\Delta\nu_z}{\nu_z} \approx \frac{B_2}{4\pi^2 m\nu_z^2}\left(\pm\mu + \frac{E_+ + |E_-|}{B_0}\right)$$

$\Delta\nu_{SF} = \cdots$

Electron:	228 kHz
Electron in $^{28}Si^{13+}$:	4.4 Hz
Proton/antiproton:	0.17 Hz

Double Trap Technique

- Detection of spin requires large B_2
- High precision requires small B_2 → Split up the work



AT

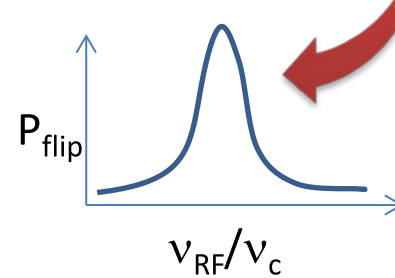
PT

1 Drive until unambiguous spin transition

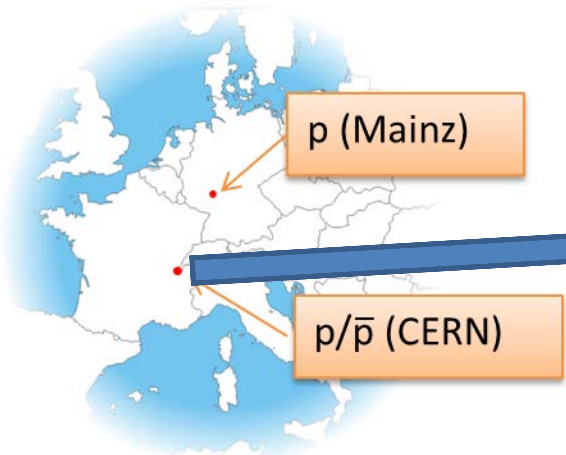
2 Measure ν_c
Drive spin at ν_{RF}

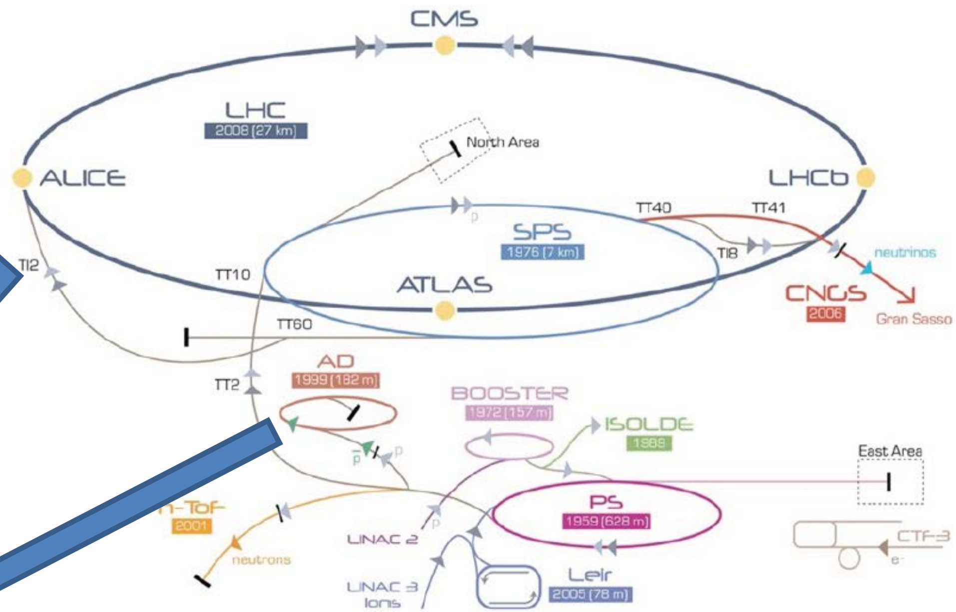
3 Determine spin state (spin flipped?)

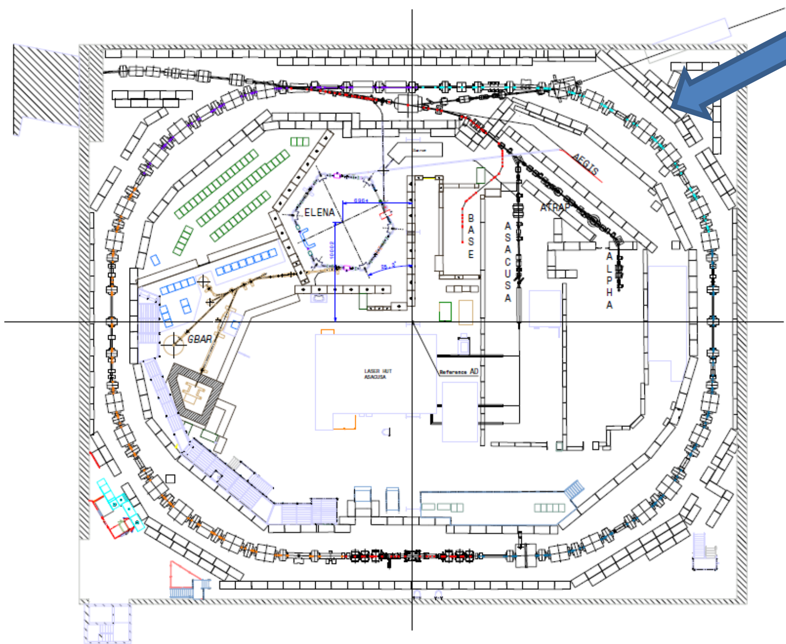
(Many cycles)



Implementation of BASE in the AD



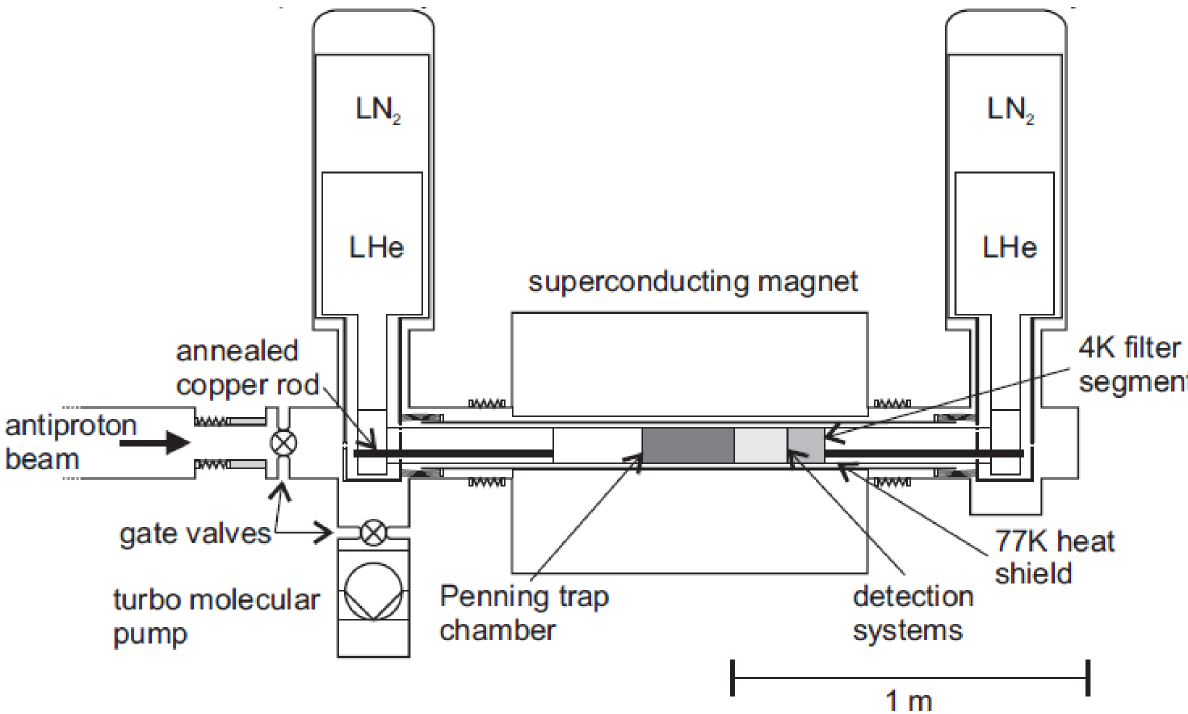


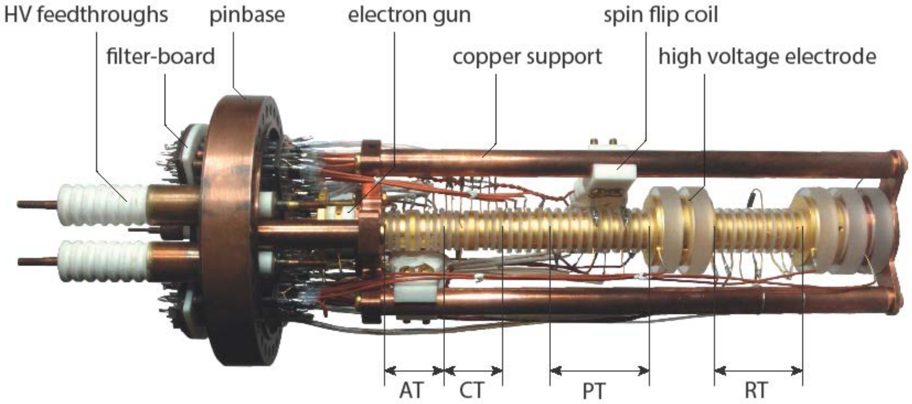


BASE approved by the CERN research board

Installation of BASE in the AD during LS1

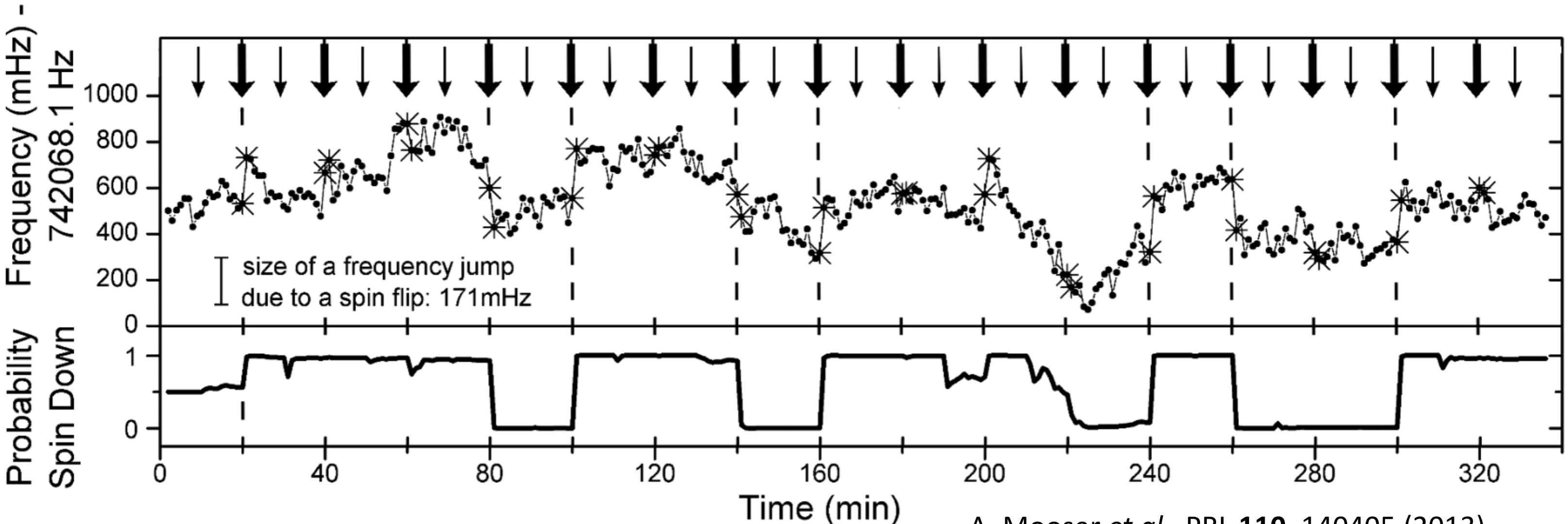
BASE Apparatus





Detecting Spin State

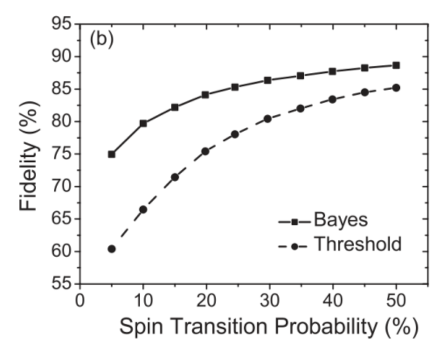
AT as spin state detector:



A. Mooser *et al.*, PRL **110**, 140405 (2013).

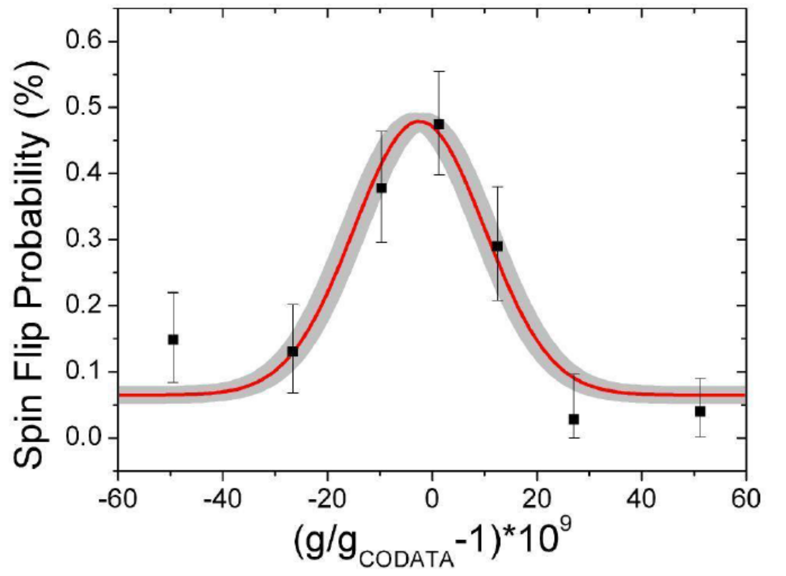
State estimator using Bayesian recursive formula:

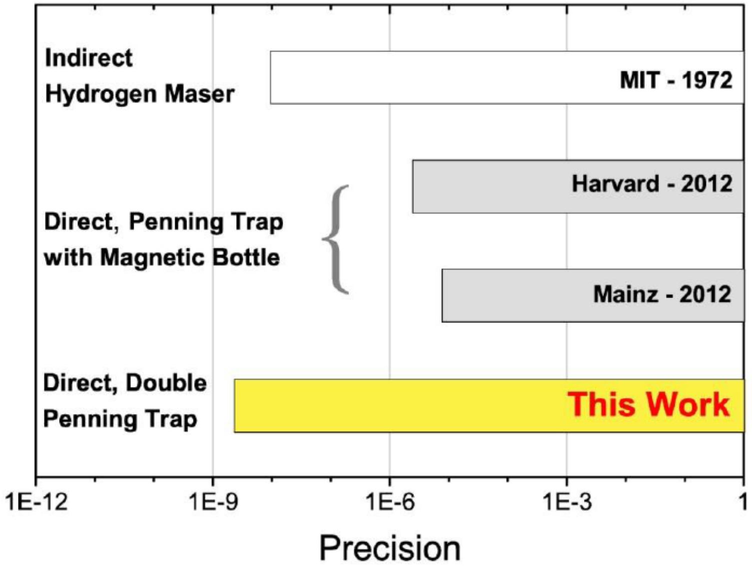
$$P(s_i, W_i \,|\, f_i, f_{i-1} \ldots) = \frac{P(f_i \,|\, s_i, W_i, f_{i-1} \ldots)\, P(s_i, W_i \,|\, f_{i-1} \ldots)}{P(f_i \,|\, f_{i-1} \ldots)}$$



Fitting the Resonance

- Bayesian parameter-based model selection
  - $P(\mu, \sigma, n_0, n_1, \ldots | \nu_c, spin\ flip\ data)$
  - Numerically integrate out everything except μ
  - Uncertainty reduced by 30%!
- First improvement in g_p in over 40 years!





A. Mooser *et al, Nature (accepted)*

People/Funding

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東京大学 THE UNIVERSITY OF TOKYO

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GSI

INTERNATIONAL MAX PLANCK RESEARCH SCHOOL

PTFS FOR PRECISION TESTS OF FUNDAMENTAL SYMMETRIES

Thank you for your attention!

BASE