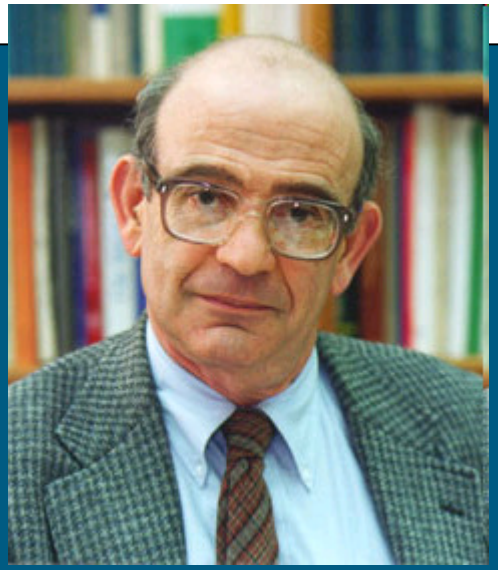
JÜLICH
FORSCHUNGSZENTRUM

Alan D. Krisch

Spin@COSY



November 2009 | Hans Ströher, Forschungszentrum Jülich

Spin@COSY: How it all began

JÜLICH FORSCHUNGSZENTRUM

COSY Proposal / Letter of Intent / Beam Request

For Lab. use	
Exp. No.: **113**	Session No. **25**

Title of Experiment: **SPIN@COSY: Spin-Flipping Polarized Deuterons and Protons**

Collaborators: Institute:

A.W. Chao, E.D. Courant, Ya.S. Derbenev, University of Michigan
A.D. Krisch, M.A. Leonova, A.M.T. Lin,
W. Lorenzon, V.S. Morozov, C.C. Peters,
R.S. Raymond, D.W. Sivers, V.K. Wong,
K. Yonehara;
A. Lehrach, B. Lorentz, R. Maier, COSY
D. Prasuhn, H. Stockhorst, U. Bechstedt,
R. Gebel, A. Schnase;
D. Eversheim, F. Hinterberger, H. Rohdjess; Universitaet Bonn
W. Scobel. Universitaet Hamburg

Spokesperson for collaboration: Name: **A.D. Krisch**
Address:
Spin Physics Center
University of Michigan
Ann Arbor, MI 48109-1120
USA

Is support from the LSF program of the EC requested?
NO

Date: **27 October 2002**

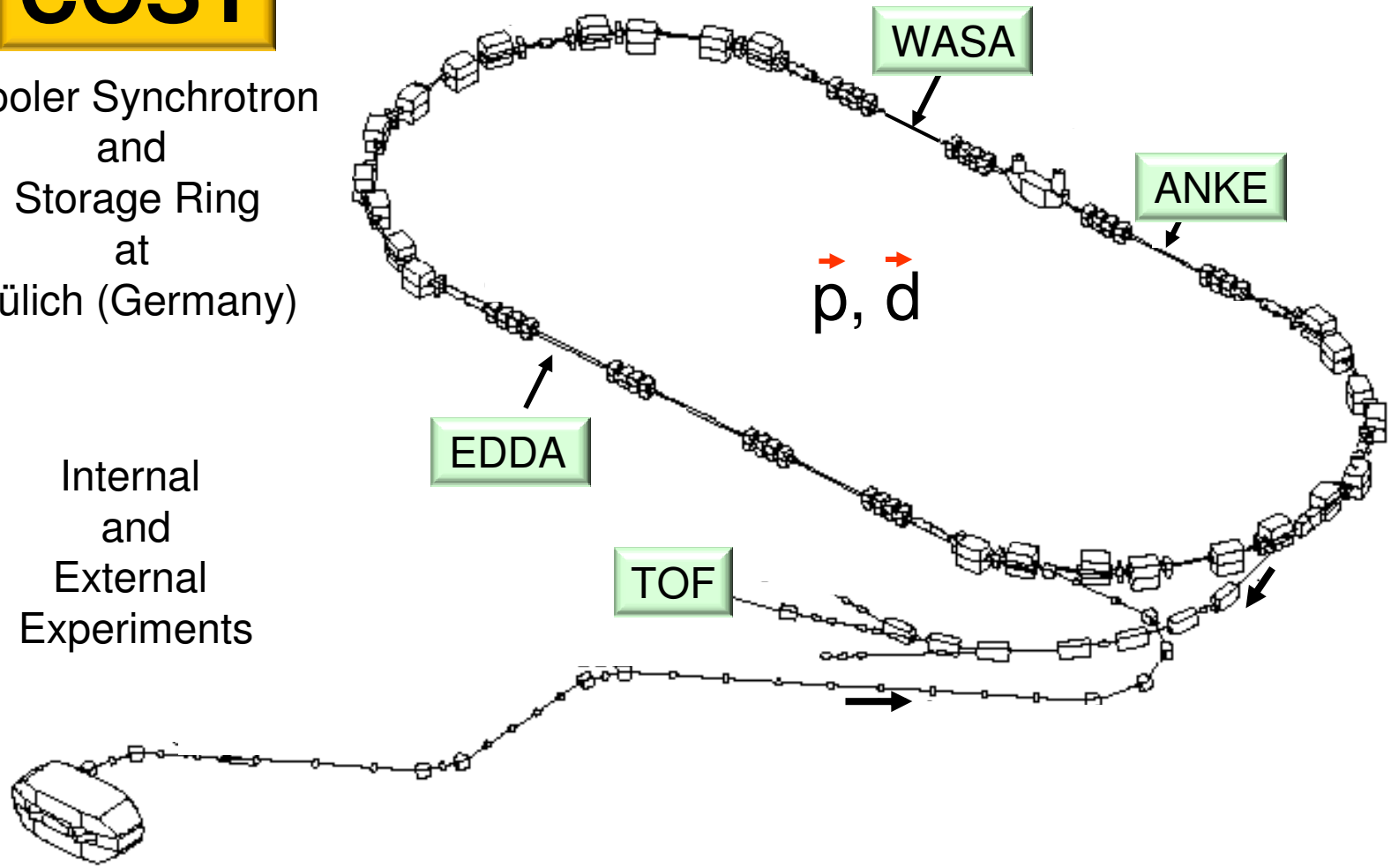
Spin@COSY: Alan at Work

(Picture not taken at a meeting in Jülich, but it is very representative of Alan)

COSY

Cooler Synchrotron
and
Storage Ring
at
Jülich (Germany)

Internal
and
External
Experiments



Spin@COSY: How it all began

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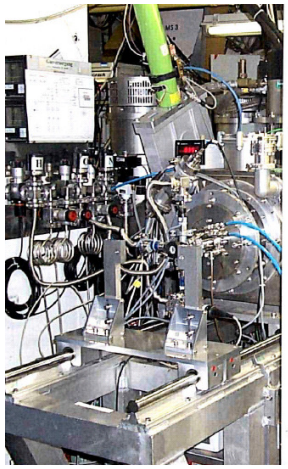
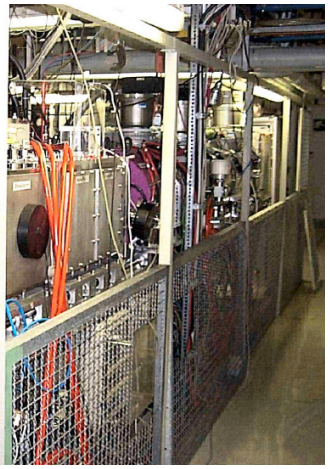
News

Spin-flipping crosses the Atlantic

After the venerable Cooler Ring at the Indiana University Cyclotron Facility (IUCF) passed on to accelerator heaven in autumn 2002, the polarized beam team, led by Alan Krisch, crossed the Atlantic to continue their spin-manipulation work at COSY, the cooler synchrotron at the Forschungszentrum in Jülich (figure 1). As part of the SPIN@COSY collaboration, they have been improving the polarization capabilities of the 3.5 GeV/c proton and deuteron storage ring. Recently, the collaboration - from Michigan and Brookhaven in America, COSY, Bonn and Hamburg in Germany, and KEK and J-PARC in Japan - has used a new ferrite RF-dipole magnet to flip the spins of stored 2.1 GeV/c protons with almost no polarization loss.

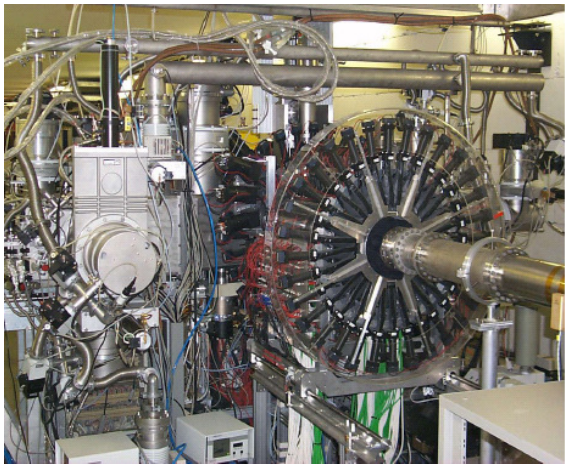
Spin@COSY: Hardware

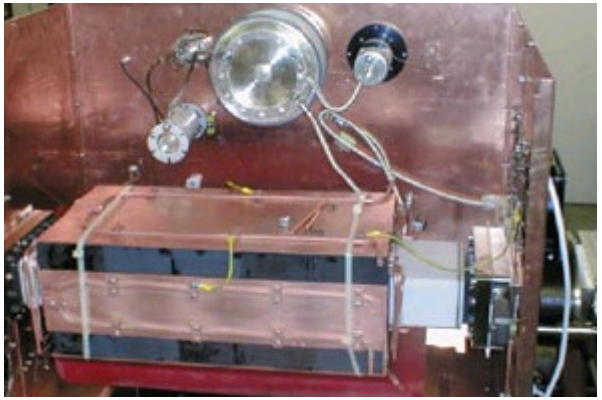




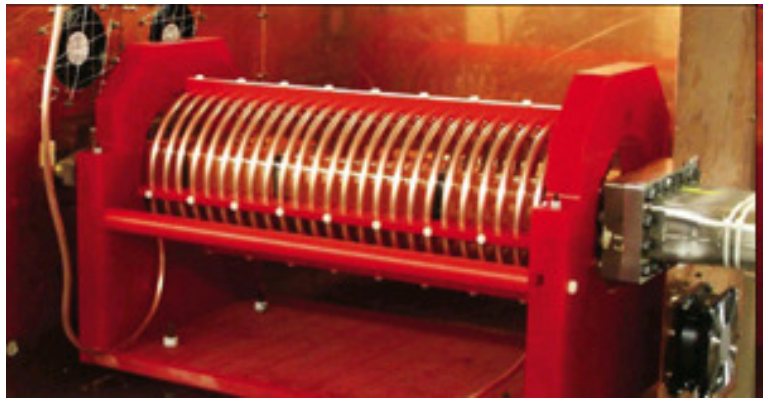
Polarized Ion Source

EDDA Detector





The ferrite-core water-cooled RF-dipole with a transverse RF magnetic-field integral of 1.5 Tmm peak-to-peak.



The water-cooled RF-solenoid with a longitudinal RF magnetic-field integral of 1.95 Tmm peak to peak.

Spin@COSY: Results / Paper

PRL 93, 224801 (2004) PHYSICAL REVIEW LETTERS week ending 26 NOVEMBER 2004

Achieving 99.9% Proton Spin-Flip Efficiency At Higher Energy With A Small rf Dipole

M. A. Leonova, A. D. Krisch, V. S. Morozov, R. S. Raymond, and V. K. Wong
Spin Physics Center, University of Michigan, Ann Arbor, Michigan 48109-1120, USA

R. Gebel, A. Lehrach, B. Lorentz, R. Maier, D. Prasuhn, A. Schnase, and H. Stockhorst
Forschungszentrum Jülich, Institut für Kernphysik, Postfach 1913, D-52425 Jülich, Germany

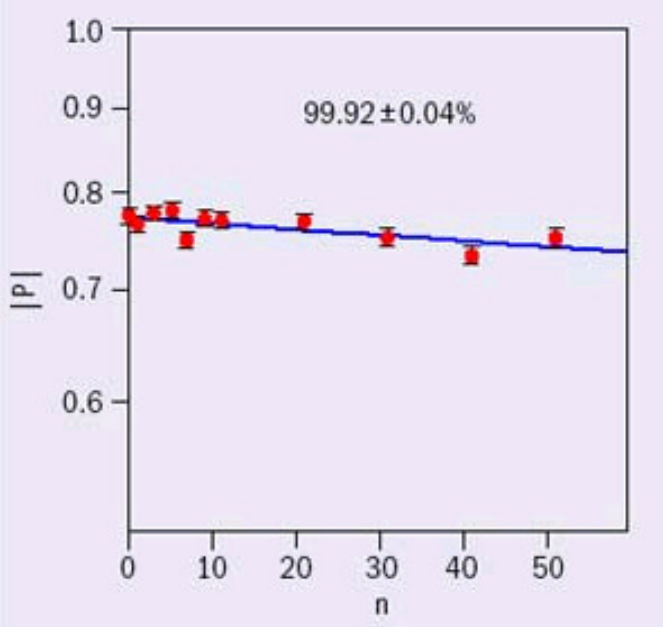
D. Eversheim, F. Hinterberger, and K. Ulbrich
Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, D-53115 Bonn, Germany
(Received 21 July 2004; published 22 November 2004)

We recently used a new ferrite rf dipole to study spin flipping of a 2.1 GeV/c vertically polarized proton beam stored in the COSY Cooler Synchrotron in Jülich, Germany. We swept the rf dipole's frequency through an rf-induced spin resonance to flip the beam's polarization direction. After determining the resonance's frequency, we varied the frequency range, frequency ramp time, and number of flips. At the rf dipole's maximum strength and optimum frequency range and ramp time, we measured a spin-flip efficiency of $99.92 \pm 0.04\%$. This result, along with a similar 0.49 GeV/c IUCF result, indicates that, due to the Lorentz invariance of an rf dipole's transverse $\int Bdl$ and the weak energy dependence of its spin-resonance strength, an only 35% stronger rf dipole should allow efficient spin flipping in the 100 GeV BNL RHIC Collider or even the 7 TeV CERN Large Hadron Collider.

Spin@COSY: Results / Paper

PRL 93, 224801 (2004) PHYSICAL REVIEW LETTERS week ending 26 NOVEMBER 2004

Achieving 99.9% Proton Spin-Flip Efficiency At Higher Energy With A Small rf Dipole



Spin@COSY: Results / Paper

PRL 100, 054801 (2008) PHYSICAL REVIEW LETTERS week ending 8 FEBRUARY 2008

Experimental Verification of Predicted Beam-Polarization Oscillations near a Spin Resonance

V. S. Morozov, A. W. Chao,* A. D. Krisch, M. A. Leonova, R. S. Raymond, D. W. Sivers, and V. K. Wong
Spin Physics Center, University of Michigan, Ann Arbor, Michigan 48109-1040, USA

A. Garishvili, R. Gebel, A. Lehrach, B. Lorentz, R. Maier, D. Prasuhn, H. Stockhorst, and D. Welsch
Forschungszentrum Jülich, Institut für Kernphysik, Postfach 1913, D-52425 Jülich, Germany

F. Hinterberger and K. Ulbrich
Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, D-53115 Bonn, Germany

A. Schnase
JAEA/J-PARC, Ring RF Group, Shirakata-Shirane 2-4, Tokai-Mura, Ibaraki 319-1195, Japan

E. J. Stephenson
IUCF, Indiana University, Bloomington, Indiana 47408-0768 USA

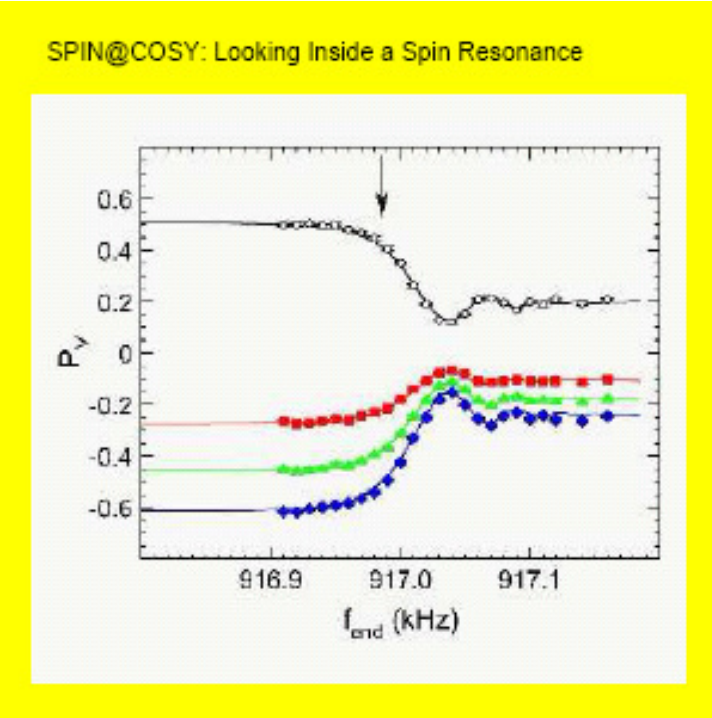
N. P. M. Brantjes, C. J. G. Onderwater, and M. da Silva
University of Groningen, Groningen, The Netherlands
(Received 22 September 2007; published 5 February 2008)

The Chao matrix formalism allows analytic calculations of a beam's polarization behavior inside a spin resonance. We recently tested its prediction of polarization oscillations occurring in a stored beam of polarized particles near a spin resonance. Using a 1.85 GeV/c polarized deuteron beam stored in the COoler SYnchrotron, we swept a new rf solenoid's frequency rather rapidly through 400 Hz during 100 ms, while varying the distance between the sweep's end frequency and the central frequency of an rf-induced spin resonance. Our measurements of the deuteron's polarization near and inside the resonance agree with the Chao formalism's predicted oscillations.

Spin@COSY: Results / Paper

PRL 100, 054801 (2008) PHYSICAL REVIEW LETTERS week ending 8 FEBRUARY 2008

Experimental Verification of Predicted Beam-Polarization Oscillations near a Spin Resonance



Frontpage IPK Annual Report 2007

Spin@COSY: Results / Paper

PRL 102, 244801 (2009) PHYSICAL REVIEW LETTERS week ending 19 JUNE 2009

Experimental Test of a New Technique to Overcome Spin-Depolarizing Resonances

V. S. Morozov,[1] A. W. Chao,[1,*] A. D. Krisch,[1] M. A. Leonova,[1] R. S. Raymond,[1] D. W. Sivers,[1] V. K. Wong,[1] A. Garishvili,[2,†] R. Gebel,[2] A. Lehrach,[2] B. Lorentz,[2] R. Maier,[2] D. Prasuhn,[2] H. Stockhorst,[2] D. Welsch,[2] F. Hinterberger,[3] and A. M. Kondratenko[4]

[1]*Spin Physics Center, University of Michigan, Ann Arbor, Michigan 48109-1040, USA*
[2]*Forschungszentrum Jülich, Institut für Kernphysik, Postfach 1913, D-52425 Jülich, Germany*
[3]*Helmholtz-Institut für Strahlen- und Kernphysik, Universität Bonn, D-53115 Bonn, Germany*
[4]*GOO Zaryad, Russkaya St. 41, Novosibirsk, 630058 Russia*

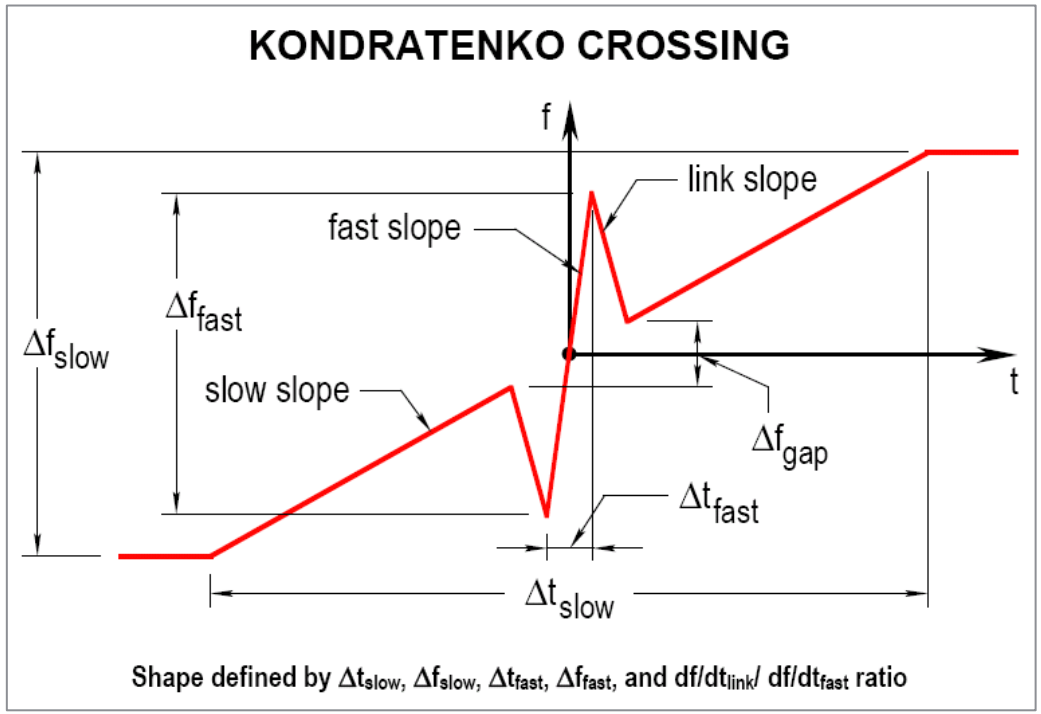
(Received 13 November 2008; published 16 June 2009)

We recently tested a new spin resonance crossing technique, Kondratenko Crossing (KC), by sweeping an rf-solenoid's frequency through an rf-induced spin resonance with both the KC and traditional fast crossing (FC) patterns. Using both rf bunched and unbunched 1.85 GeV/c polarized deuterons stored in COSY, we varied the parameters of both crossing patterns. Compared to FC with the same crossing speed, KC reduced the depolarization by measured factors of 4.7 ± 0.3 and 19^{+12}_{-5} for unbunched and bunched beams, respectively. This clearly showed the large potential benefit of Kondratenko Crossing over fast crossing.

Spin@COSY: Results / Paper

PRL 102, 244801 (2009) PHYSICAL REVIEW LETTERS week ending 19 JUNE 2009

Experimental Test of a New Technique to Overcome Spin-Depolarizing Resonances



Spin@COSY: Results / Paper

JÜLICH FORSCHUNGSZENTRUM

PRL 103, 144801 (2009) PHYSICAL REVIEW LETTERS week ending 2 OCTOBER 2009

Narrow Spin Resonance Width and Spin Flip with an rf-Bunched Deuteron Beam

V. S. Morozov,[1] A. W. Chao,[1,*] A. D. Krisch,[1] M. A. Leonova,[1] R. S. Raymond,[1] D. W. Sivers,[1] V. K. Wong,[1] and A. M. Kondratenko[2]

[1]*Spin Physics Center, University of Michigan, Ann Arbor, Michigan 48109-1040, USA*
[2]*GOO Zaryad, Russkaya St. 41, Novosibirsk, 630058 Russia*

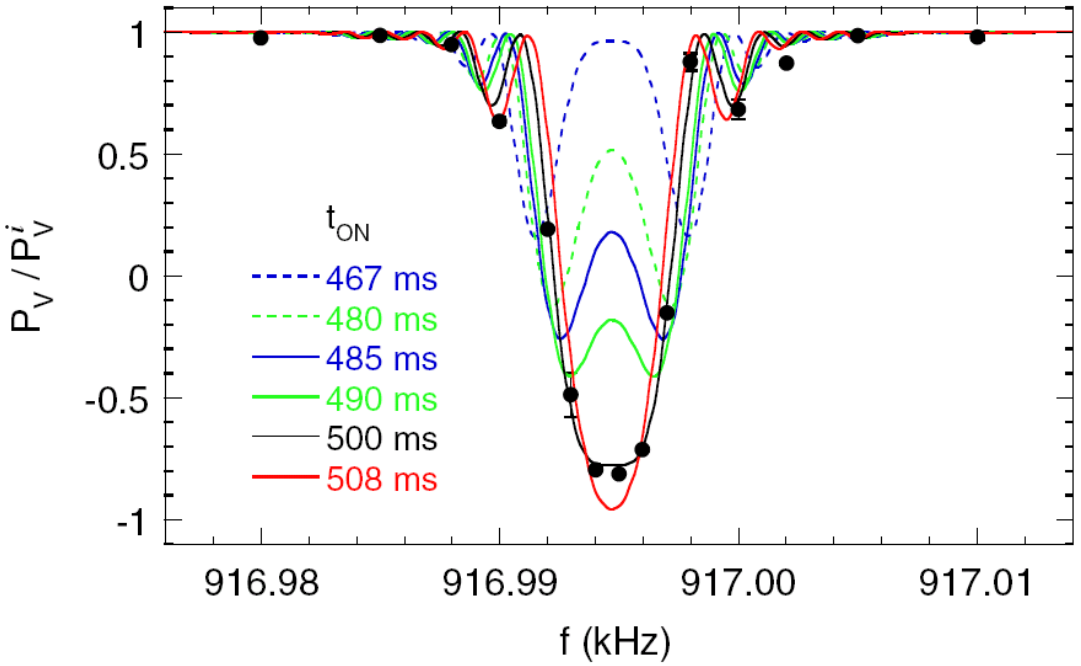
(Received 23 July 2009; published 28 September 2009)

We used an rf solenoid to study the widths of rf spin resonances with both ***bunched*** and ***unbunched*** beams of 1.85 GeV/c polarized deuterons stored in the COSY synchrotron. With the ***unbunched*** beam at different fixed rf-solenoid frequencies, we observed only partial depolarization near the resonance. However, the ***bunched*** beam's polarization was almost fully flipped; moreover, its resonance was much narrower. We then used Chao's recent equations to explain this behavior and to calculate the polarization's dependence on various rf-solenoid and beam parameters. Our data and calculations indicate that a ***bunched*** deuteron beam's polarization can behave as if the beam has zero momentum spread.

Spin@COSY: Results / Paper

PRL 103, 144801 (2009) PHYSICAL REVIEW LETTERS week ending 2 OCTOBER 2009

Narrow Spin Resonance Width and Spin Flip with an rf-Bunched Deuteron Beam



Spin@COSY: Results / Paper

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **10**, 041001 (2007)

Experimental test of the new analytic matrix formalism for spin dynamics

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **10**, 071001 (2007)

Unexpected reduction of rf spin resonance strength for stored deuteron beams

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **9**, 051001 (2006)

Unexpected enhancements and reductions of rf spin resonance strengths

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS **8**, 061001 (2005)

Spin manipulating stored 1.85 GeV/c vector and tensor polarized spin-1 bosons

PHYSICAL REVIEW SPECIAL TOPICS - ACCELERATORS AND BEAMS, VOLUME **7**, 024002 (2004)

Spin manipulation of 1.94 GeV/c polarized protons stored in the COSY cooler synchrotron

… and more to come … !

Spin@COSY: Talks

… e.g.:

trieste_italia
october 10_16 2004

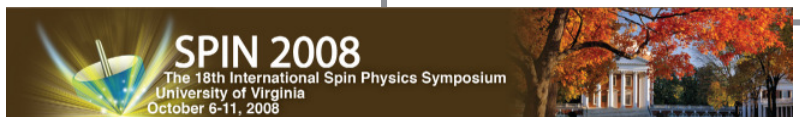
spin 2004
16th international spin physics symposium

11 October 2004
SPIN 2004

SPIN MANIPULATING 2 GeV/c POLARIZED PROTONS AND DEUTERONS STORED IN COSY*

A.D. Krisch, V.S. Morozov, M.A. Leonova, C.C. Peters, R.S. Raymond, D.W. Sivers, V.K. Wong
Spin Physics Center, University of Michigan, Ann Arbor, Michigan 48109-1120, USA

(…)



Charlottesville VA
SPIN 2008
10/10/2008

SPIN@COSY: Spin-Manipulating Polarized Deuterons and Protons *

M.A. Leonova[1], A.W. Chao[1,†], E.D. Courant[1], A.D. Krisch[1], V.S. Morozov[1], R.S. Raymond[1], D.W. Sivers[1], V.K. Wong[1]; A. Garishvili[2,‡], R. Gebel[2], A. Lehrach[2], B. Lorentz[2], R. Maier[2], D. Prasuhn[2], H. Stockhorst[2], D. Welsch[2]; F. Hinterberger[3], K. Ulbrich[3]; Ya.S. Derbenev[4], A.M. Kondratenko[5], Y.F. Orlov[6], E.J. Stephenson[7].

… and many more !

Spin@COSY: But … it ended

From: krisch@umich.edu
Date: Thu, 16 Jul 2009
To: h.stroeher@fz-juelich.de

Dear Hans
…
Thus, it appears that we can no longer work at COSY.

… proposal … will not be submitted …

We had 10-12 very successful runs at COSY
…

Best regards,
Alan

Spin@COSY: Impact on other Work

η-mass Measurement

High precision beam momentum determination in a synchrotron using a spin resonance method

P. Goslawski,[1,*] A. Khoukaz,[1] H. Ströher,[2] C. Wilkin,[3] and COSY-Crew[2]

[1] *Institut für Kernphysik, Universität Münster, D-48149 Münster, Germany*
[2] *Institut für Kernphysik, Forschungszentrum Jülich, D-52428 Jülich, Germany*
[3] *Physics and Astronomy Department, UCL, London WC1E 6BT, United Kingdom*

(Dated: July 20, 2009)

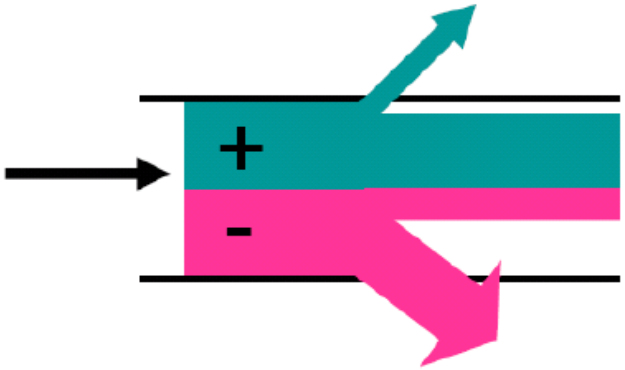
In order to measure the mass of the η meson with high accuracy using the $dp \rightarrow {}^3\mathrm{He}\,\eta$ reaction, the momentum of the circulating deuteron beam in the Cooler Synchrotron COSY of the Forschungszentrum Jülich has to be determined with unprecedented precision. This has been achieved by studying the spin dynamics of the polarized deuteron beam. By depolarizing the beam through the use of an artificially induced spin resonance, it was possible to evaluate the beam momentum p with a precision of $\Delta p/p < 10^{-4}$ for a momentum of roughly 3 GeV/c. Different possible sources of error in the application of the spin resonance method are discussed in detail and its possible use during a standard experiment is considered.

experiment. The spin-depolarizing studies for deuterons and protons were initiated at COSY by the group led by Professor Alan Krisch and we have benefited much from their experience. This work was supported in part by the

Spin@COSY: Impact on other Work

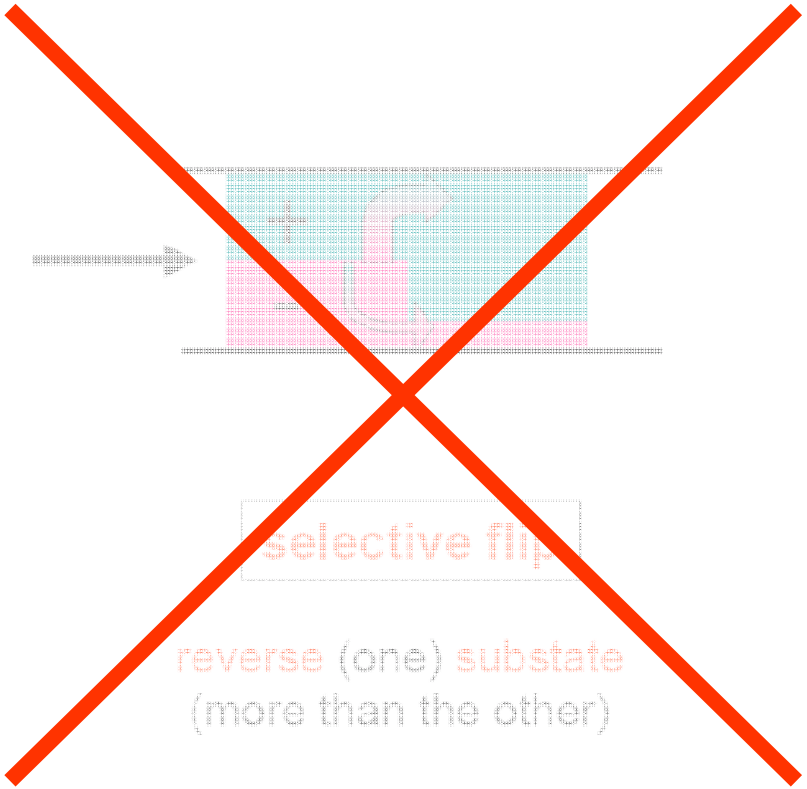
How to polarize anti-protons ?

For an ensemble of spin ½ particles with projections + (↑) and – (↓)



selective loss

discard (one) substate
(more than the other)



selective flip

reverse (one) substate
(more than the other)

Spin@COSY: And finally

Dear Alan,
congratulations on your scientific achievements; my (and IKP´s) best wishes – we hope to see you back in Jülich, latest for

The 19th Spin Physics International Symposium
SPIN 2010
Forschungszentrum Jülich (Germany)
September 27 - October 2, 2010

Jülich, November 2009