JÜLICH
FORSCHUNGSZENTRUM

How to produce polarized antiprotons - and what to use them for?

# Towards Polarized Antiprotons

June 7, 2008 | Hans Ströher

MESON 2008 (Cracow, Poland)

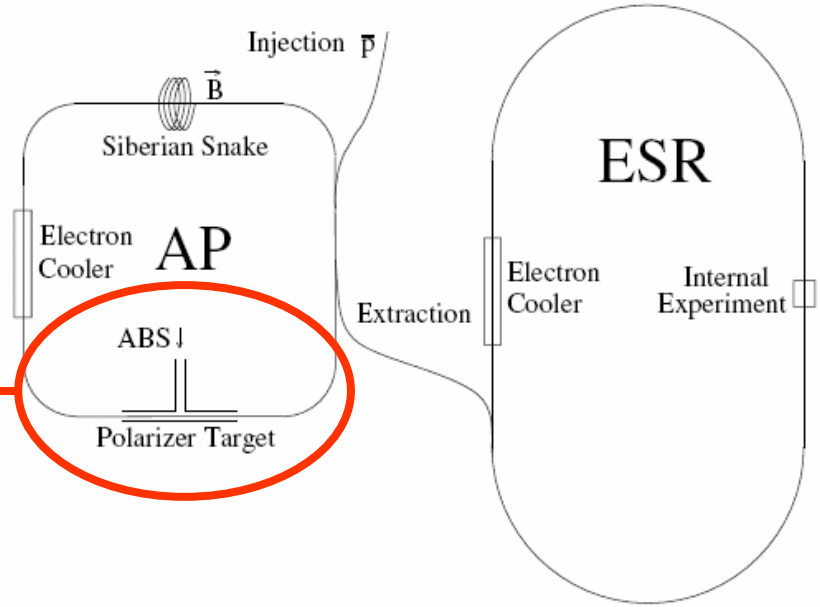
# Introduction

PRL 94, 014801 (2005) PHYSICAL REVIEW LETTERS week ending 14 JANUARY 2005

**A Method to Polarize Stored Antiprotons to a High Degree**

F. Rathmann,[1,*] P. Lenisa,[2] E. Steffens,[3] M. Contalbrigo,[2] P. F. Dalpiaz,[2] A. Kacharava,[3] A. Lehrach,[1] B. Lorentz,[1] R. Maier,[1] D. Prasuhn,[1] and H. Ströher[1]

~ 3 years ago, we proposed a method to polarize antiprotons by „spin-filtering“



# Introduction

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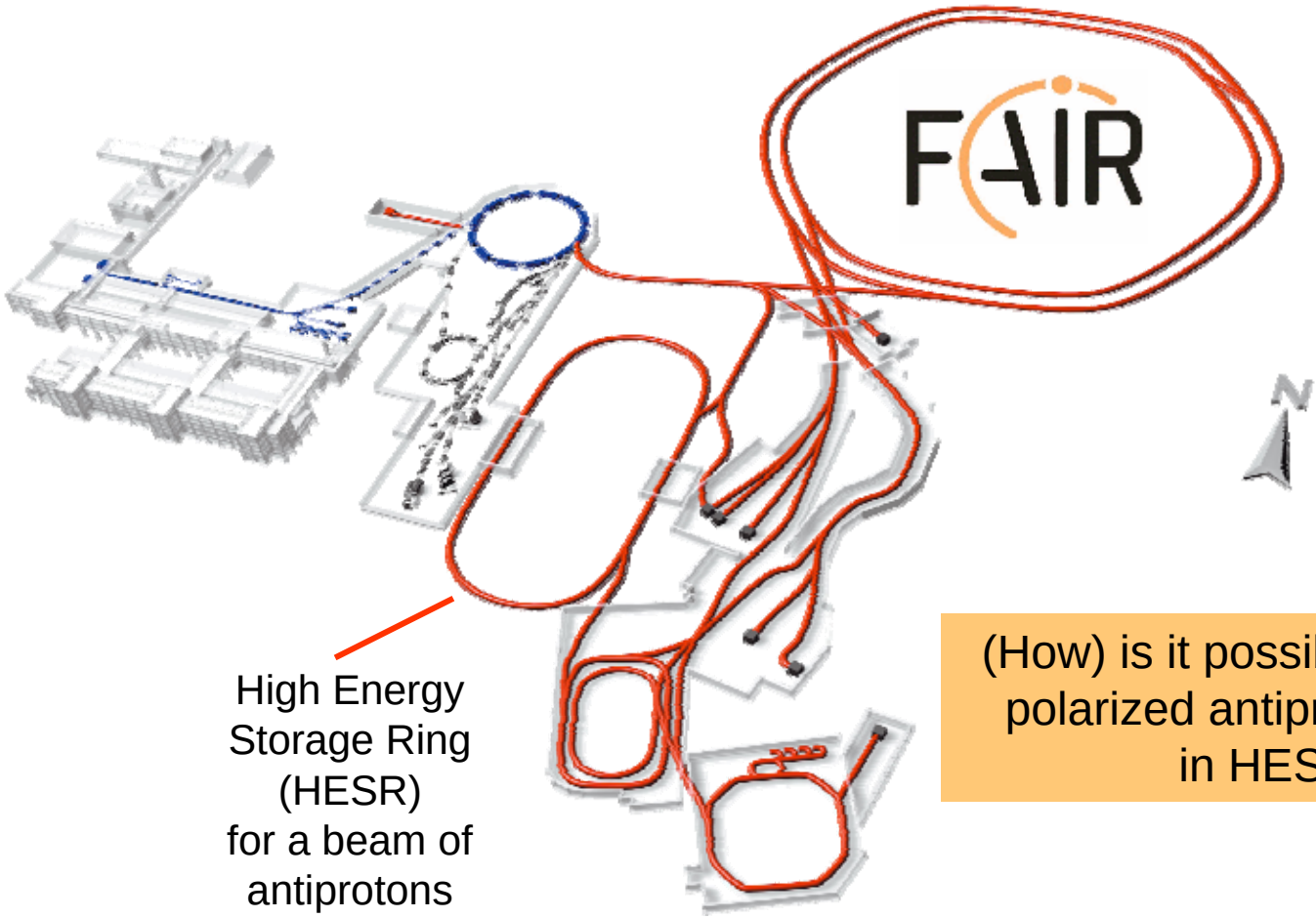



High Energy Storage Ring (HESR) for a beam of antiprotons

(How) is it possible to provide polarized antiproton beams in HESR ?

# Plan of talk

- The (long) road to polarized antiprotons:
  - Proposals, ideas, calculations, …
  - Experiments

    Depolarization studies at COSY

    FILTEX (TSR)

    Spin-filtering at COSY

    Spin-filtering at AD/CERN
  - Summary, Conclusion

… taken on by the PAX-collaboration (Spokespersons: F. Rathmann (Jülich), P. Lenisa (Ferrara))

# Proposed methods (1): Some history …

460 Nuclear Instruments and Methods in Physics Research A255 (1987) 460–476
North-Holland, Amsterdam

## SELF-POLARIZATION OF PROTONS IN STORAGE RINGS

T.O. NIINIKOSKI and R. ROSSMANITH *
*CERN, Geneva, Switzerland*

Received 23 April 1985 and in revised form 21 October 1986

It has been proposed that stored proton or heavy ion beams can be polarized by spatially separating particles with opposite spin directions, using the Stern–Gerlach effect in alternating quadrupole fields. The growth rate of the vertical betatron amplitude is

## POLARIZED ANTIPROTONS WITH THE SPIN SPLITTER

H. Kreiser (Univ. Hamburg), Y. Onel (Iowa State Univ.), A. Penzo (CERN), and R. Rossmanith (CEBAF)
representing the Spin Splitter Collaboration[1]
CEBAF, 12000 Jefferson Avenue, Newport News, VA 23606 EPAC 1988

→ Stern-Gerlach splitting never tried (huge effort)

# Proposed methods (2): Recent paper

Eur. Phys. J. A **34**, 447–461 (2007)
DOI 10.1140/epja/i2007-10462-x

THE EUROPEAN PHYSICAL JOURNAL A

Special Article – Tools for Experiment and Theory

## A surprising method for polarising antiprotons

Th. Walcher[1,2,a], H. Arenhövel[1], K. Aulenbacher[1], R. Barday[1], and A. Jankowiak[1]

[1] Institut für Kernphysik, Johannes Gutenberg-Universität Mainz, D-55099 Mainz, Germany
[2] Laboratori Nazionali di Frascati, Istituto Nazionale di Fisica Nucleare, I-00044 Frascati (Rome), Italy

Received: 26 June 2007 / Revised: 11 January 2008
Published online: 6 February 2008 – © Società Italiana di Fisica / Springer-Verlag 2008
Communicated by E. De Sanctis

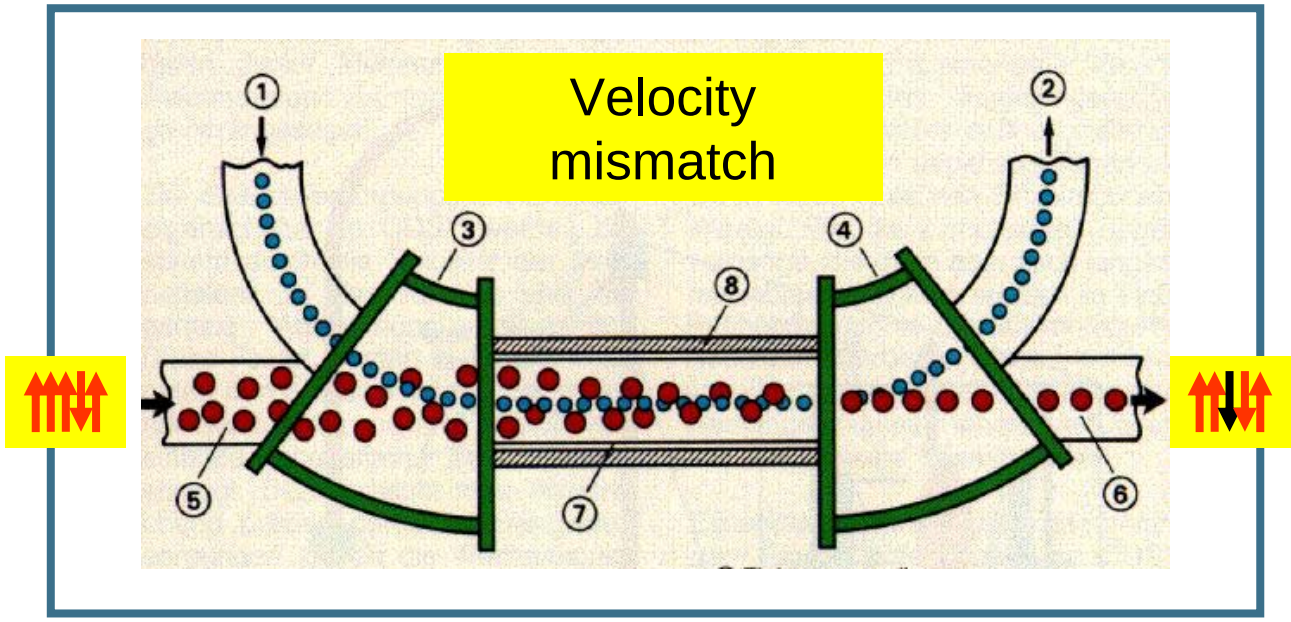
**Abstract.** We propose a method for polarising antiprotons in a storage ring by means of a polarised positron beam moving parallel to the antiprotons. If the relative velocity is adjusted to $v/c \approx 0.002$ the cross-section for spin-flip is as large as about $2 \cdot 10^{13}$ barn as shown by new QED calculations of the triple spin cross-

→ Need for an experimental test of this idea !

# Depolarization Studies at COSY: Idea

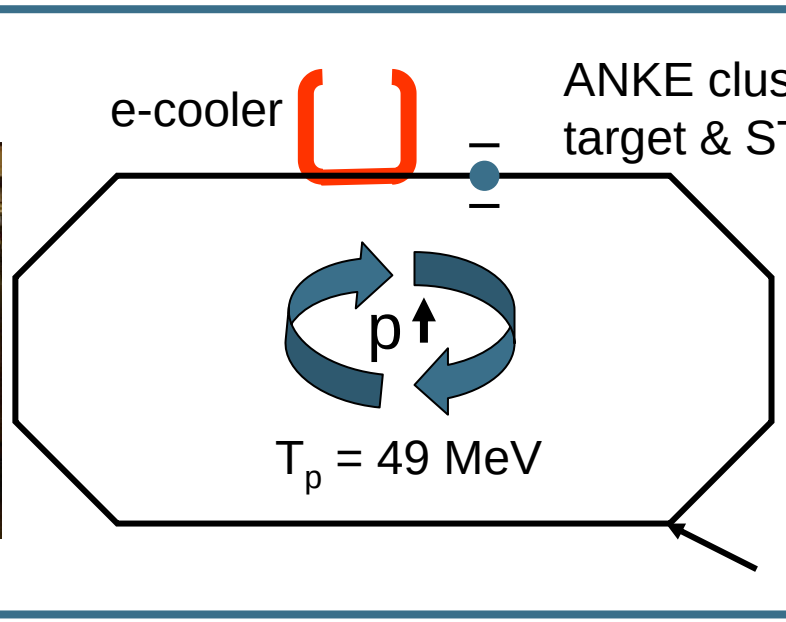
- Use proton beam and co-moving electrons
- Turn experiment around: p $\vec{e}$ → $\vec{p}$ into $\vec{p}$ e → p

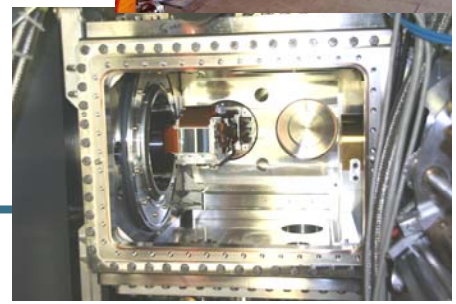
  i.e. depolarization of a polarized proton beam



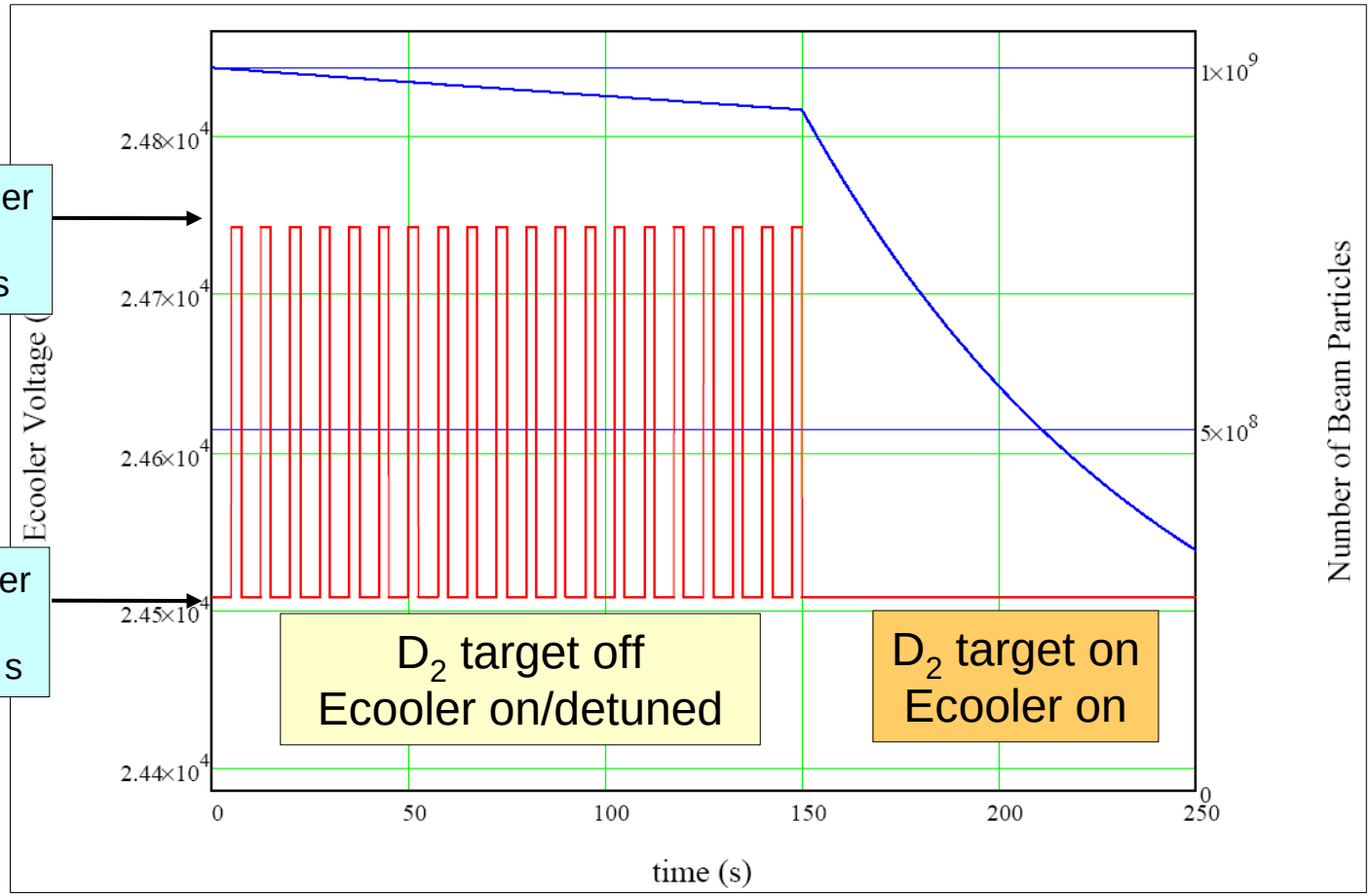
# Depolarization Studies at COSY: Principle

- Use (transversely) polarized proton beam circulating in COSY
- Switch on (detuned) electron cooler to depolarize proton beam
- Analyze proton polarization with internal $D_2$-cluster target of ANKE

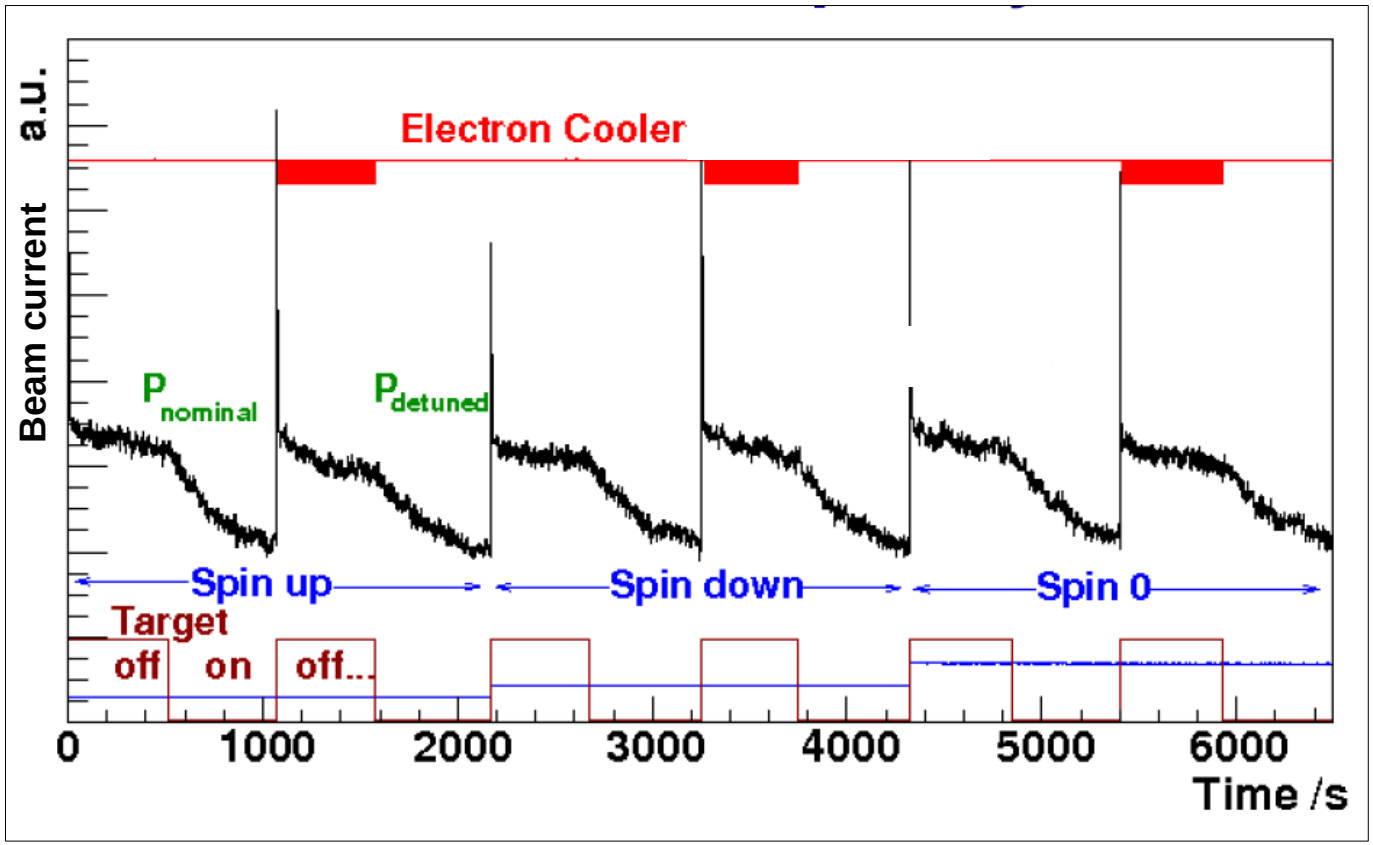


# Depolarization Studies at COSY: Details

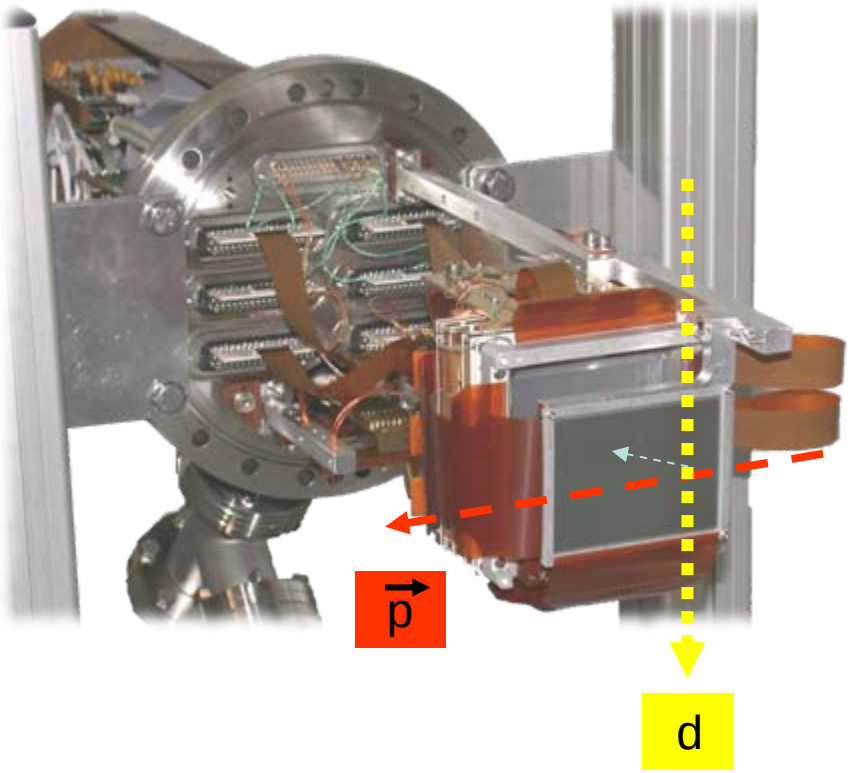


# Depolarization Studies at COSY: Measurements

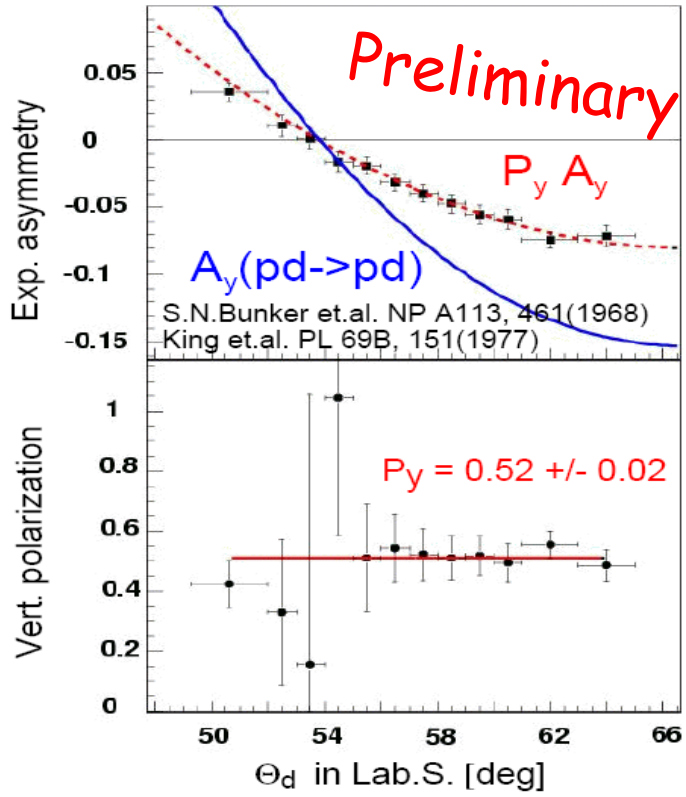


# Depolarization Studies at COSY: Polarimetry

pd elastic scattering; detection in silicon tracking telescopes (STT)

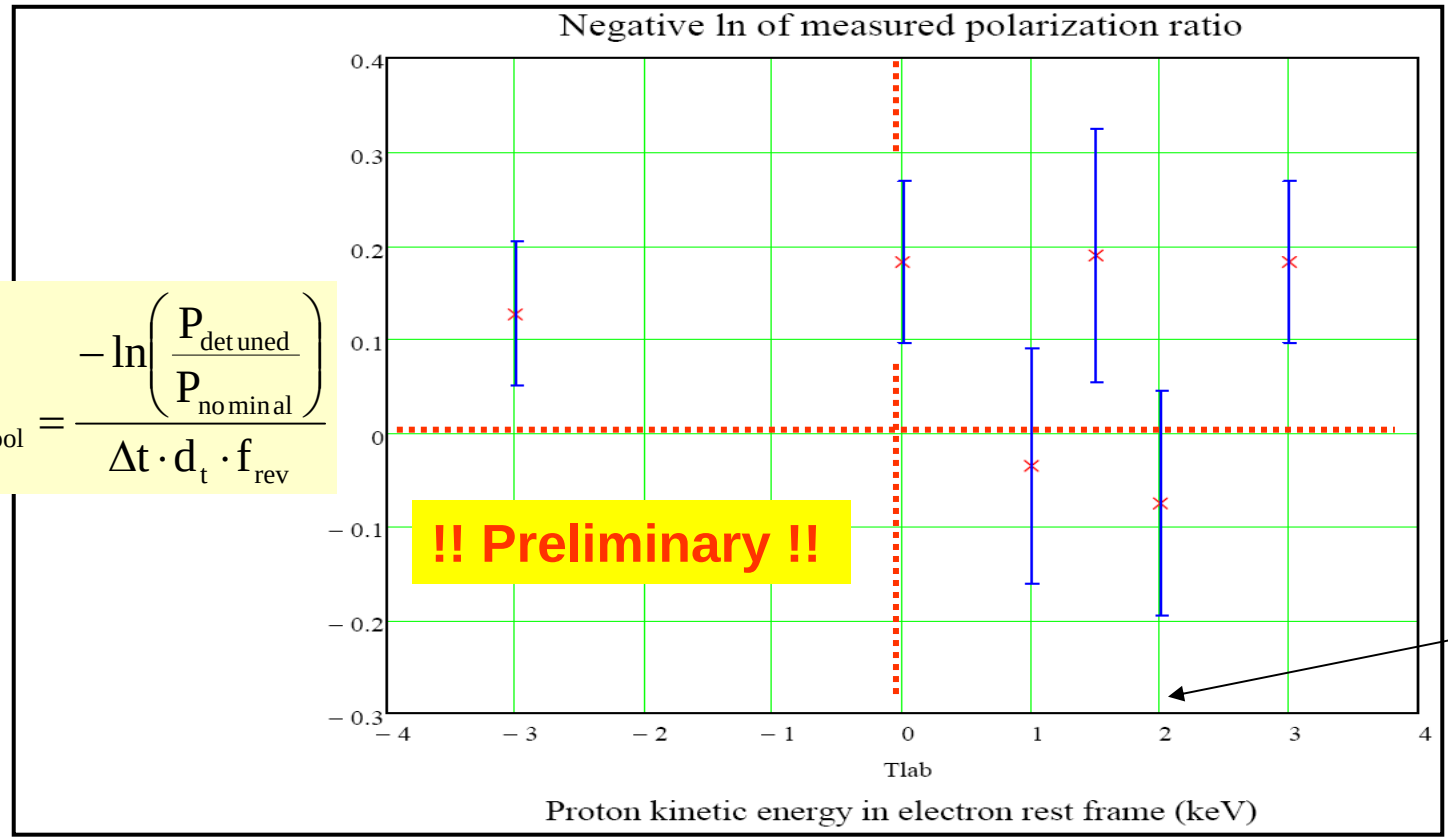



Beam polarization (deuterons selected)



# Depolarization Studies at COSY: Results

$$\sigma_{depol} = \frac{-\ln\left(\frac{P_{detuned}}{P_{nominal}}\right)}{\Delta t \cdot d_t \cdot f_{rev}}$$




→ No effect observed, i.e. cross section must be many orders-of-magnitude smaller than $10^{13}$b !

# Depolarization Studies at COSY: New calc´s

ACCEPTED MANUSCRIPT (NIM B)
10.1016/JNIMB.2008.04.010

## Polarization effects in non-relativistic *ep* scattering

A.I. Milstein, S.G. Salnikov, and V.M.Strakhovenko

*Budker Institute of Nuclear Physics, 630090 Novosibirsk, Russia*

(Dated: April 21, 2008)

Abstract

The cross section which addresses the spin-flip transitions of a proton (antiproton) interacting with a polarized non-relativistic electron or positron is calculated analytically. In the case of attraction, this cross section is greatly enhanced for sufficiently small relative velocities as compared to the result obtained in the Born approximation. However, it is still very small, so that the beam polarization time turns out to be enormously large for the parameters of $e^{\pm}$ beams available now. This practically rules out a use of such beams to polarize stored antiprotons or protons.

~ 1 mb

→ No effect expected !

# Depolarization Studies at COSY:

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THE EUROPEAN PHYSICAL JOURNAL A

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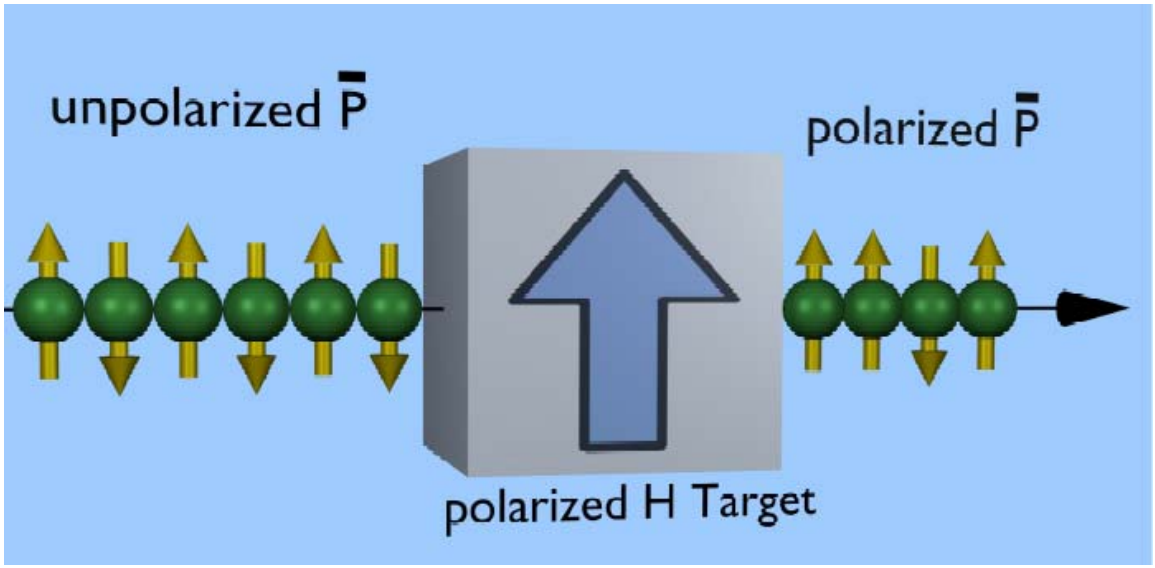
→ No effect expected, too ?
(since high cross section is for longitudinal polarization)
Note: disagreement w/ MSS calculation by $10^{16}$ !!

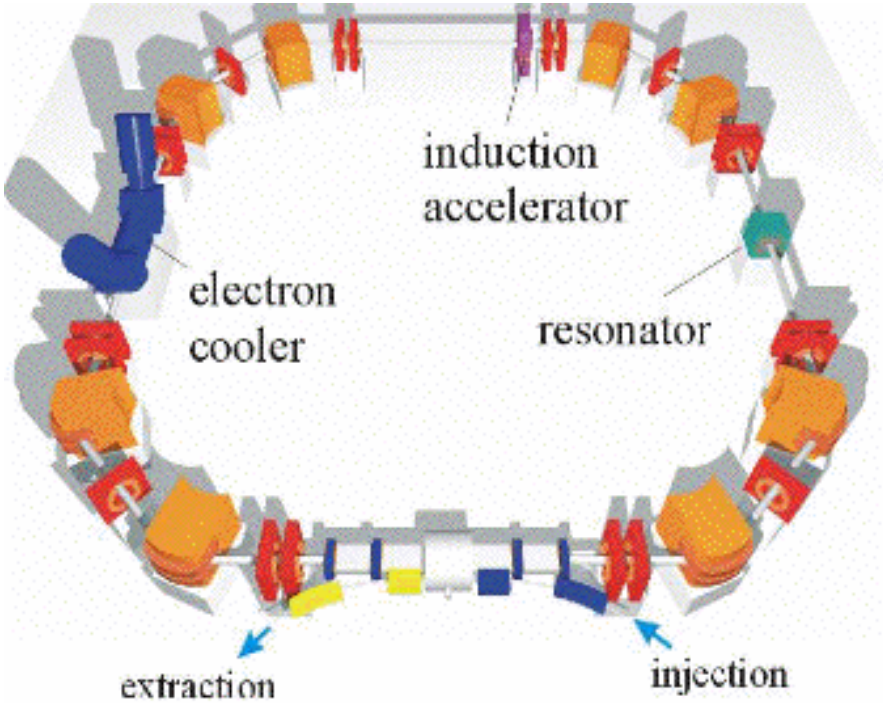
# Spin-filtering:

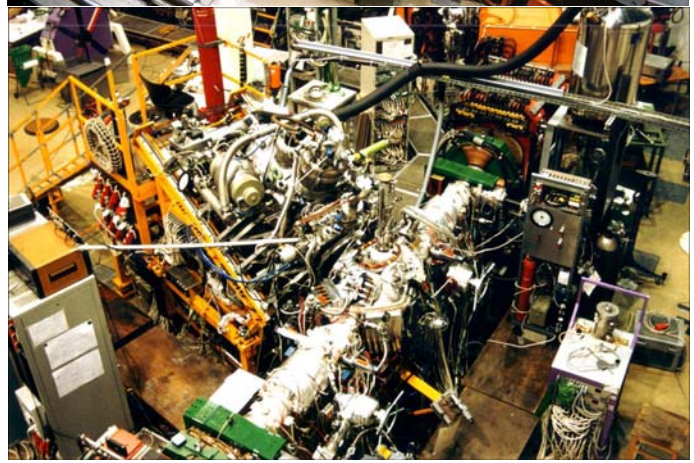
Polarization build-up of an originally unpolarized particle beam by repeated interaction with polarized hydrogen target, e.g. in a storage ring:




Spin-filtering is known to work („FILTEX“); not clear, how (see above)

# Spin-filtering at TSR: „FILTEX“

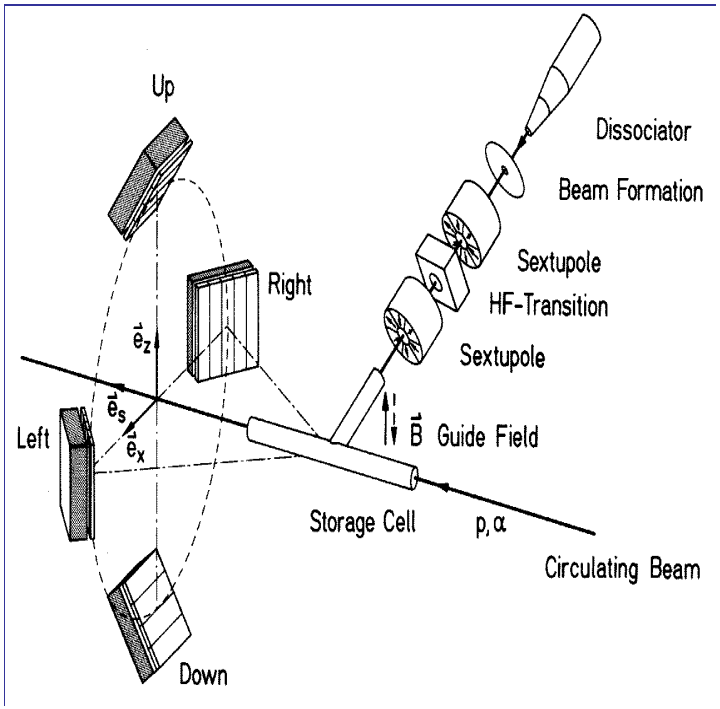


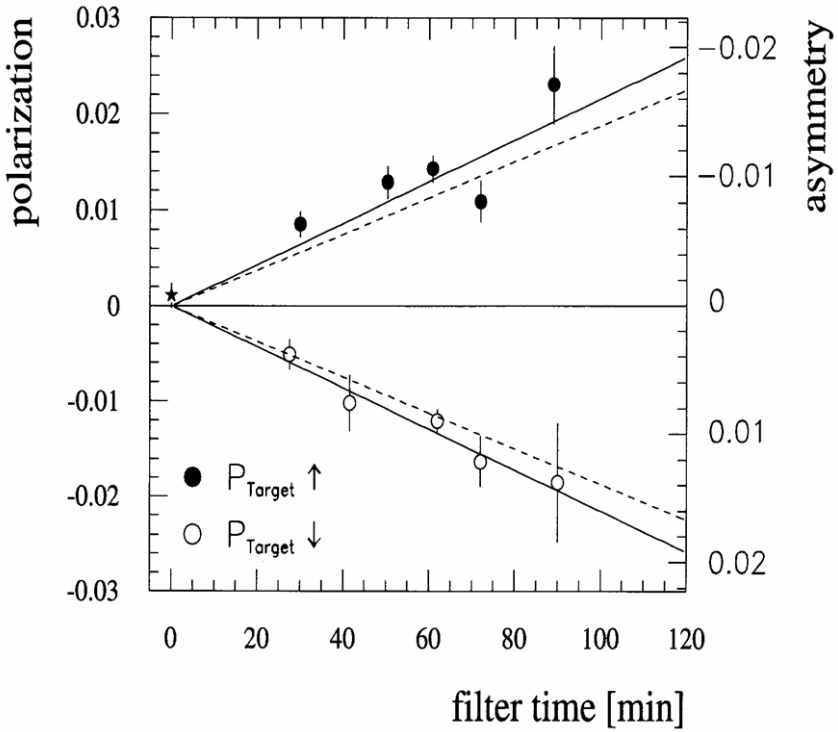
TSR … Test Storage Ring at MPI Heidelberg

FILTEX … Filter Experiment (1992)

# Spin-filtering at TSR: „FILTEX“ – proof-of-principle

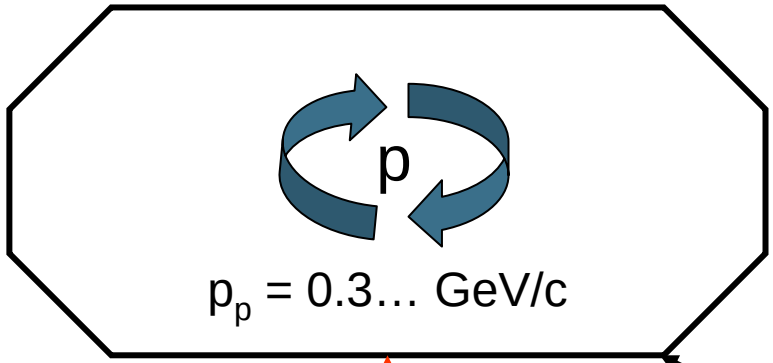



PhD of F. Rathmann

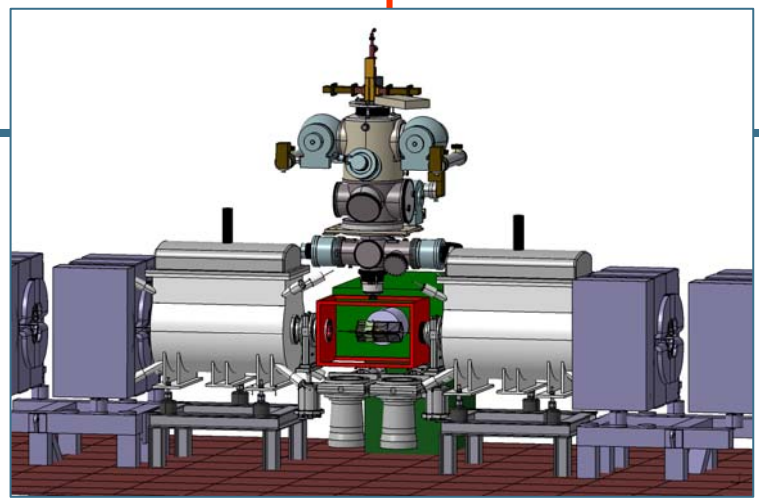



→ Spin filtering works for protons

# Spin-filtering at COSY: Optimize, understand FILTEX



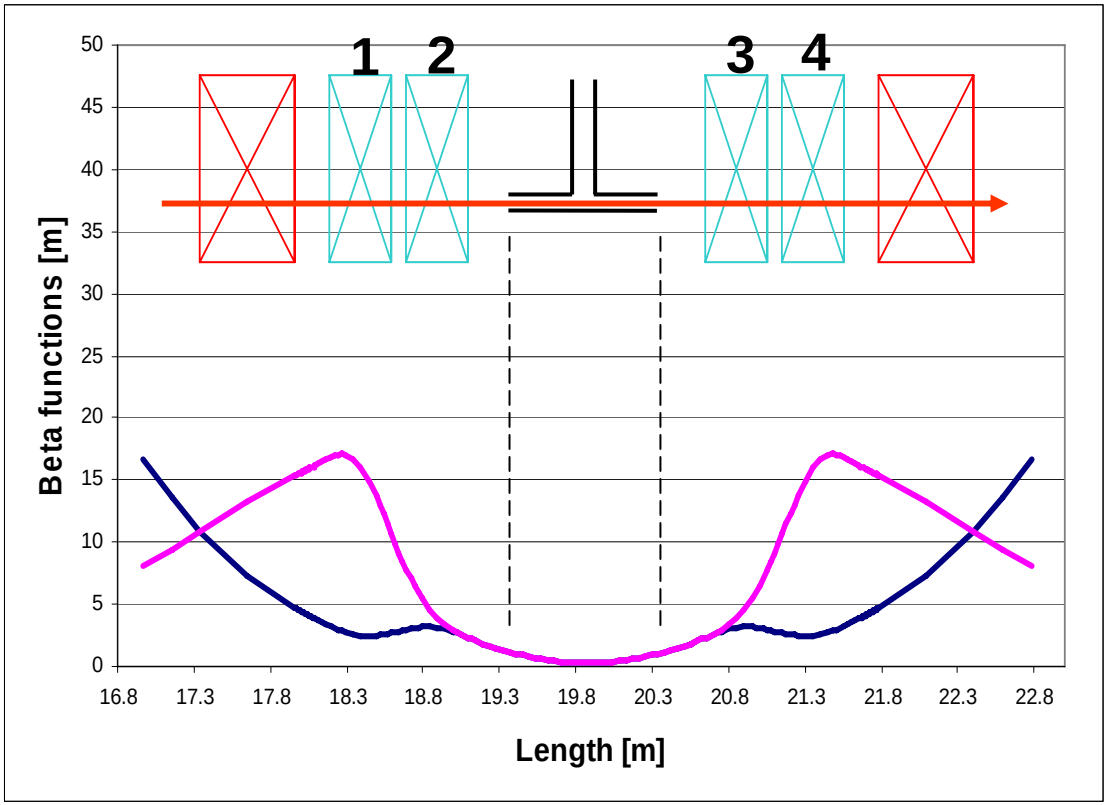

Need a „low-ß section“ in COSY



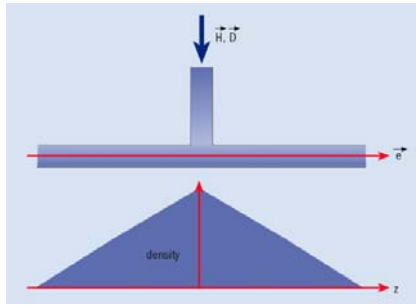
Superconducting quadrupole (new)

ABS + storage cell, Si-tracking det´s (HERMES)

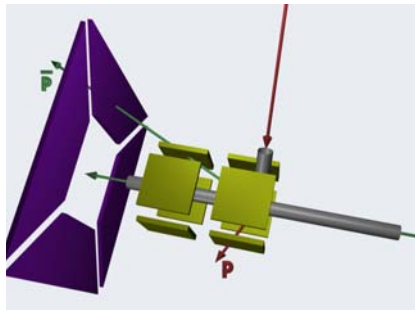
# Spin-filtering at COSY: Low-ß Section




Target: Storage cell

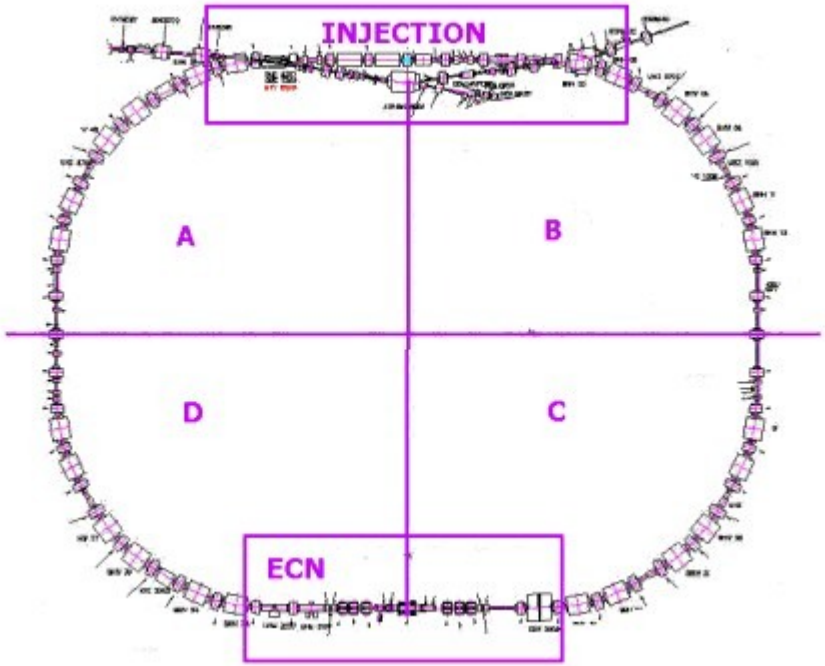



Polarimeter



→ Need superconducting quadrupoles

# Spin-filtering at CERN/AD: $\bar{p}p$ and $\bar{p}d$ scattering




- Target (equipment used, tested at COSY)
- Electron cooler (upgrade of existing AD-cooler)
- Snake (also longitudinal; new)

→ Measurement of effective $\bar{p}$ polarization build-up cross section

→ First measurement of spin-correlations in above reactions

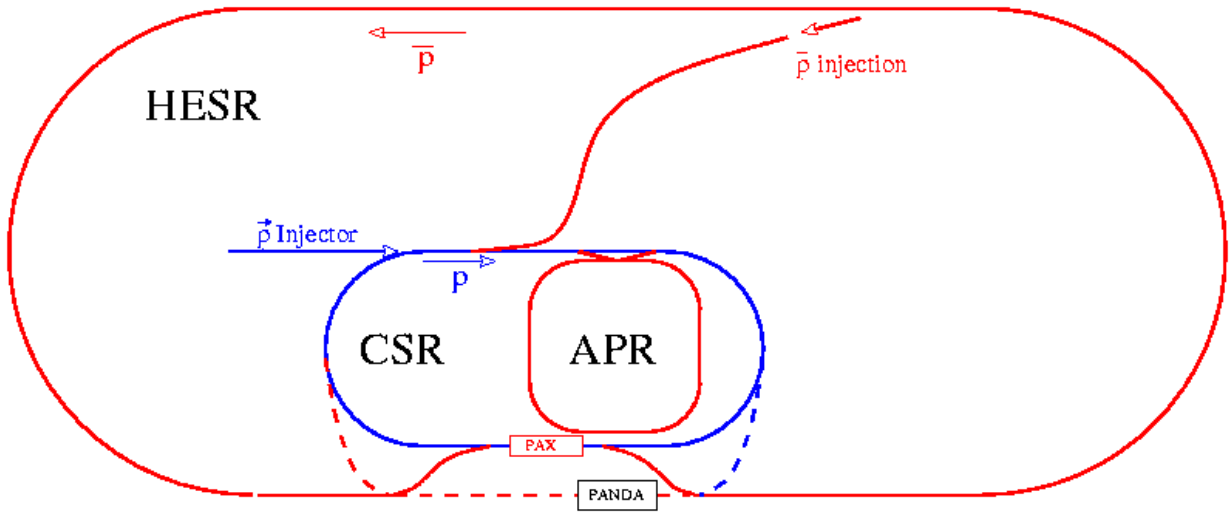
# Spin-filtering at COSY: Milestones, timeline

- COSY: determine / optimize beam lifetime - needed for large filtering time (beamtime in II/2008)
- SC quadrupoles – design almost ready; companies have been contacted (order in 2008)
- COSY: set up HERMES-ABS and recoil detectors (2009)
- COSY: implement set-up in ring (early 2010), perform sf - measurements
- CERN/AD: LoI → full proposal; move equipment and repeat with anti-protons (~ 2011)

→ By 2012/13 we will know how to do spin-filtering!!

- Design the APR (antiproton polarizer ring)

# Hadron Physics „Dream Machine“ for FAIR:



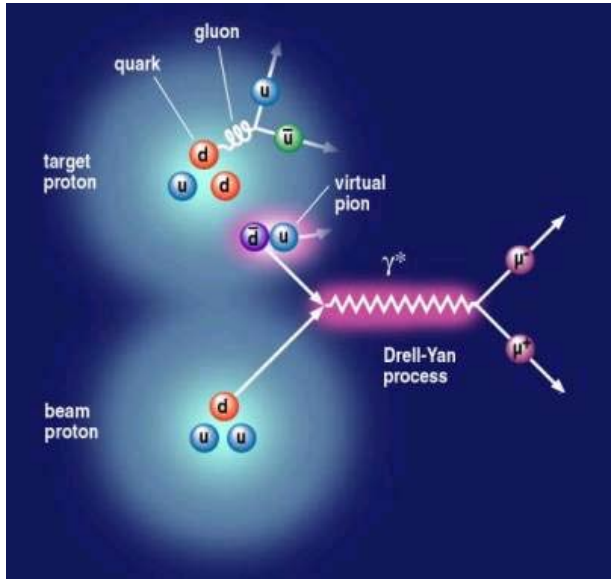

… an asymmetric (double-polarized)
proton (15 GeV/c) – antiproton (3.5 GeV/c) collider

using HESR,
CSR and APR

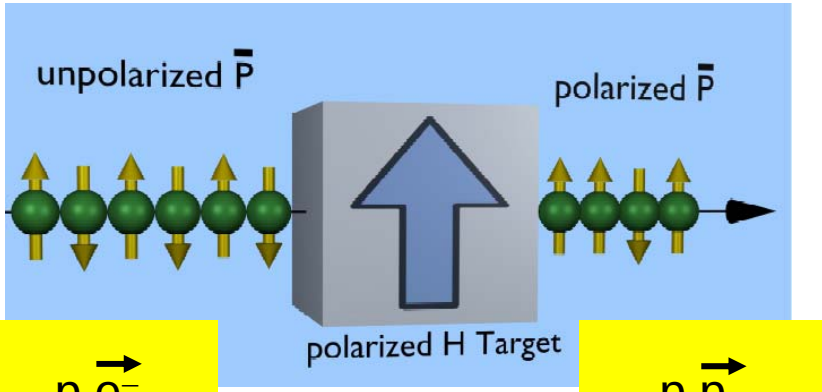
# Quark Transversity Distribution in Drell-Yan:

Double transverse spin asymmetry:

$$A_{TT} \equiv \frac{d\sigma^{\uparrow\uparrow} - d\sigma^{\uparrow\downarrow}}{d\sigma^{\uparrow\uparrow} + d\sigma^{\uparrow\downarrow}} = \hat{a}_{TT} \frac{\sum_q e_q^2 h_1^q(x_1, M^2) h_1^{\overline{q}}(x_2, M^2)}{\sum_q e_q^2 q(x_1, M^2) \overline{q}(x_2, M^2)}$$



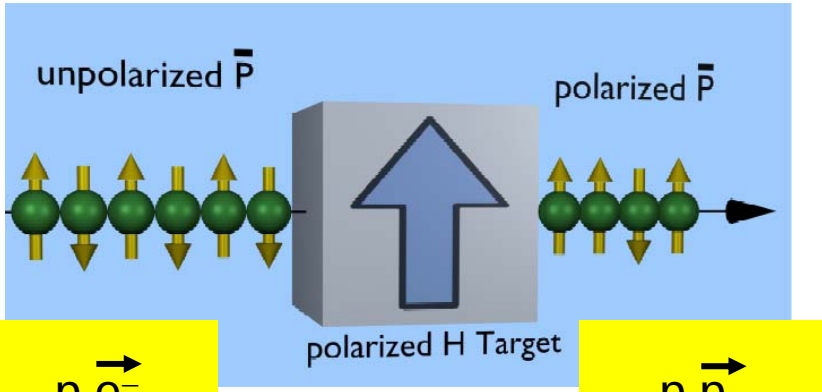
# Summary:




| | long. | trans. |
|---|---|---|
| WAKBJ: | gigantic | ??? |
| MSS: | small | small |

$10^{16}$

# Summary:

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No depolarization of polarized protons

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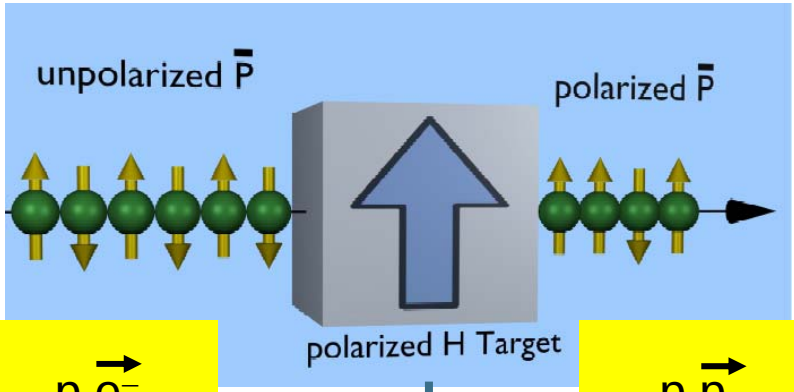


$p\ e^-$

$\bar{p}\ e^+$

$p\ p$

$\bar{p}\ p$

Spin-filtering works:

p (FILTEX) → COSY

$\bar{p}$ → CERN/AD

| | long. | trans. |
|---|---|---|
| WAKBJ: | gigantic | ??? |
| MSS: | small | small |

No depolarization of polarized protons

# Conclusion:

- The road towards polarized antiprotons is long …
- But: - clear roadmap
  - commitment by PAX-collaboration
  - first measurements/achievements
- We appreciate any help!
- Note:

Now and here (expertise)

or „never“ (not in a very long time)!