Scattering and annihilation electromagnetic processes

Trento

18-22 february 2013

Polarized Antiproton

P.F.Dalpiaz,
Ferrara University and INFN

Introduction

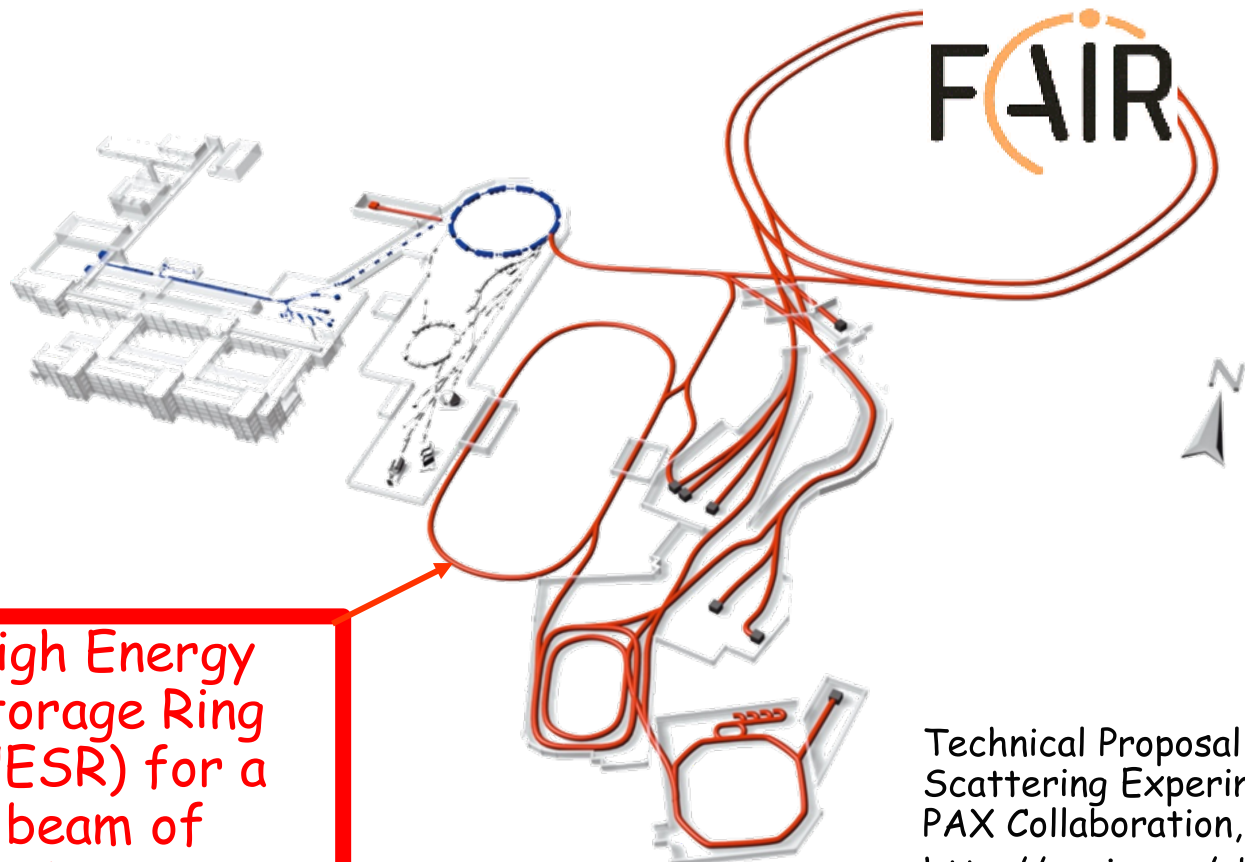
The idea to polarize the antiproton stored in HESR is born in Ferrara in the frame of the HERMES polarised gas target group

In 2005 with the polarized target experts of COSY, we have proposed a method to polarize the HESR antiprotons by „**spin-filtering**"

The PAX collaboration has developed out of this group

PAX Proposal to FAIR (2005)

178 Collaborators 36 institutions (15 EU, 21 NON-EU)



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

Technical Proposal for Antiproton-Proton Scattering Experiments with Polarization, PAX Collaboration, http://arxiv.org/abs/hep-ex/0505054 (2005).

Polarize antiproton is challenging

How polarize antiproton?

1985

Krisch,Bogadena Bay 1985 april 18-21, Workshop on Polarized Antiproton source

1. From Antihyperon Decay
2. Using a Spin Filter
3. Stochastic Tecniques
4. Dynamic Nuclear Polarization
5. From Spontaneus Syncrotron Radiation emission
6. From induced Syncrotron Radiation
7. Polarization of directly produced Antiproton
8. Repeated Stern-Gerlaqch effect
9. By Antihydrogen foormation
10. In a penning trap
11. ...

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)

30 years later

1. From Antihyperon Decay

   Fermilab, 1987

$$\text{Polarization} \approx 0.3,$$

$$\text{Intensity} \leq 1.5 \times 10^{5}\, s^{-1}$$

2. **Spin Filtering**

3. **Spin flip**

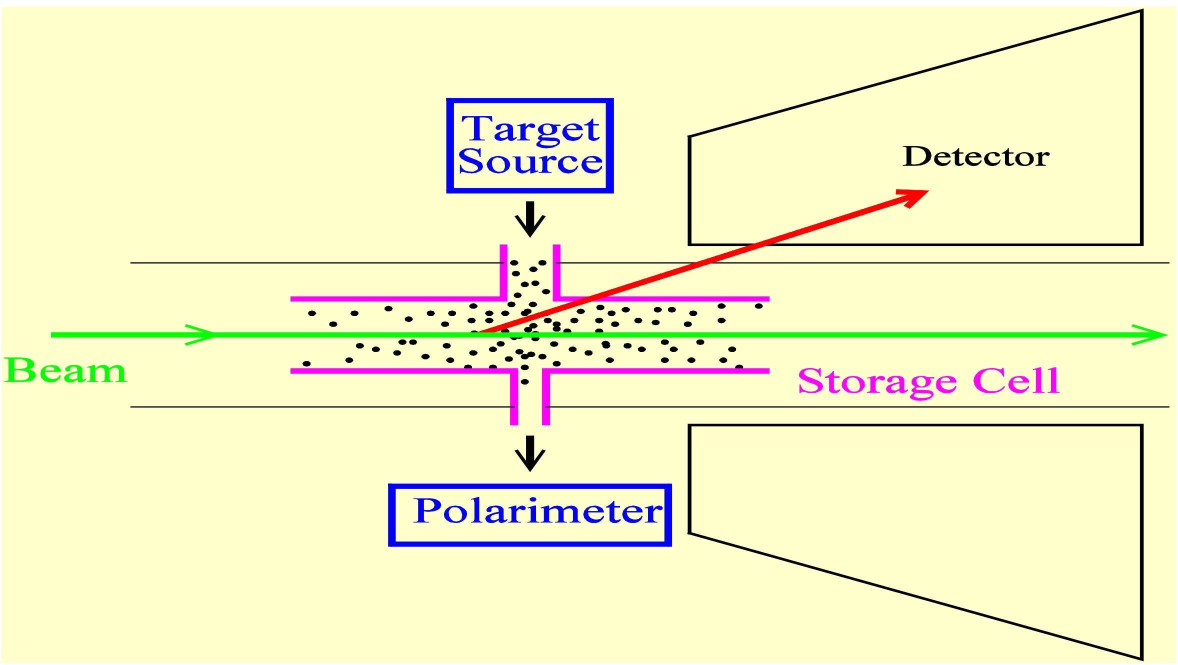
spin-filtering

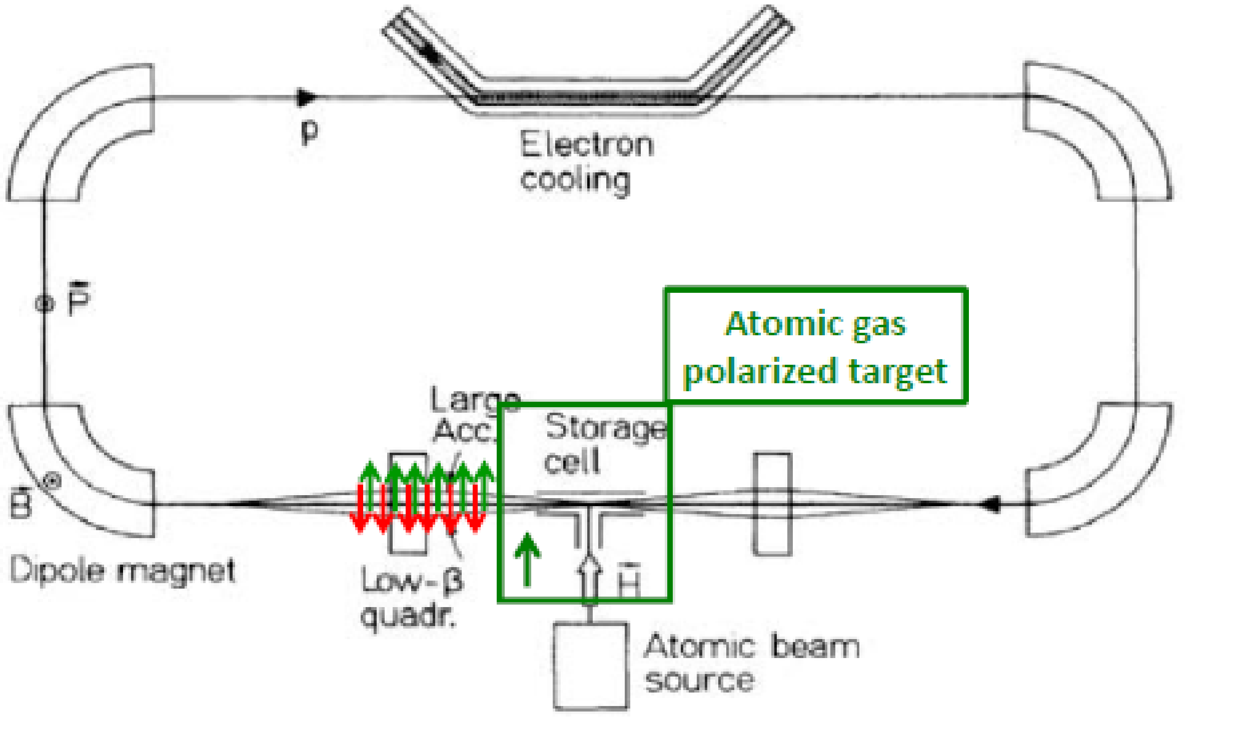
P.L.Csonska, 1968: NIM 63 (1968)247

"The strong interactions might be used to polarize protons (anti-protons) beams "

"…..polarization by transmission. We place a polarized proton target in a circulating beam………. When passing through the target, protons with one of the two possible polarization states are scattered out of beam more often then the other. … The result is that the transmitted beam becomes polarized "

Polarized internal target





An un-polarized beam by multiple passage through a polarized target, due to different crosssection for parallel (↑ ↑) **and antiparallel (↓↑) spin alignment, becomes polarized, while the** intensity decreases.

The filter method has been tested in 1992

FILTEX at the TSR-Heidelberg

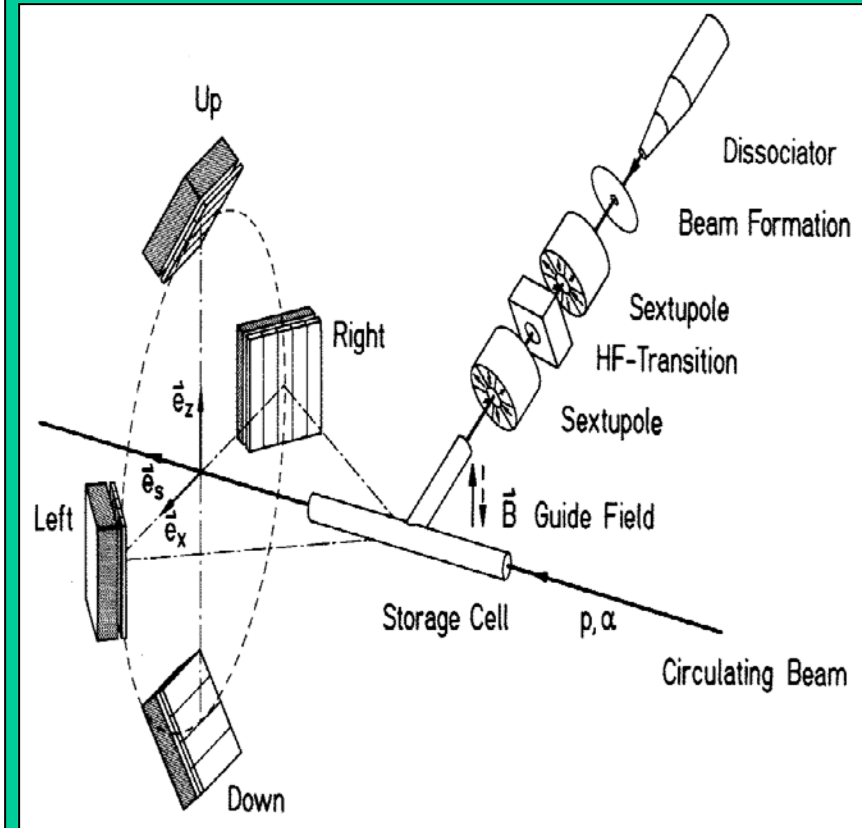
spin-filter experiment with 23MeV stored protons on a polarized hydrogen target in state 1.

In 90 minutes, the intensity of the beam was 5% of the initial one and the polarization degree amounted to 2.4%.

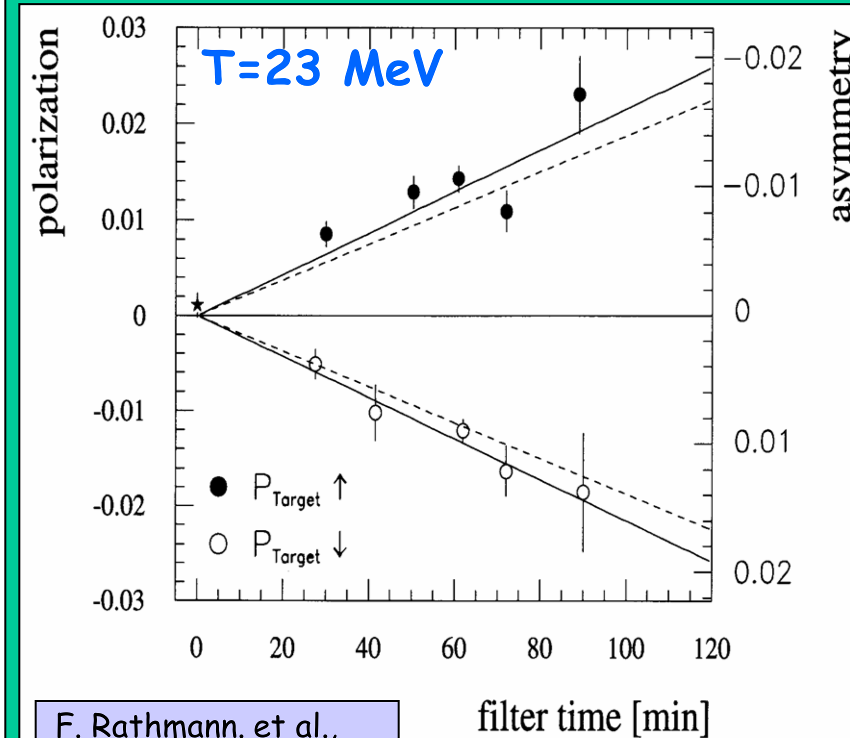
PRL 71(1993) 1379

1992 Filter Test at TSR with protons

Experimental Setup



Results



F. Rathmann. et al.,
PRL 71, 1379 (1993)

Low energy pp scattering

$\sigma_1 < 0 \Rightarrow \sigma_{tot+} < \sigma_{tot-}$

Expectation	
Target	Beam
↑	↑
↓	↓

Polarization build-up function, time constant and cross-section

$$\sigma_t = \sigma_0 + \tilde{\sigma}_1 Q$$

$$P(t) = \frac{N^{\uparrow}(t) - N^{\downarrow}(t)}{N^{\uparrow}(t) + N^{\downarrow}(t)} = \tanh(t/\tau_1)$$

$$\frac{dP}{dt} = \frac{1}{\tau_1} = \tilde{\sigma}_1 Q d_t f$$

Time constant gives the "**efficace cross section**" ,spin depedent, of the interaction (in the FILTEX esperiment, the trasverse p[olarization is adressed)

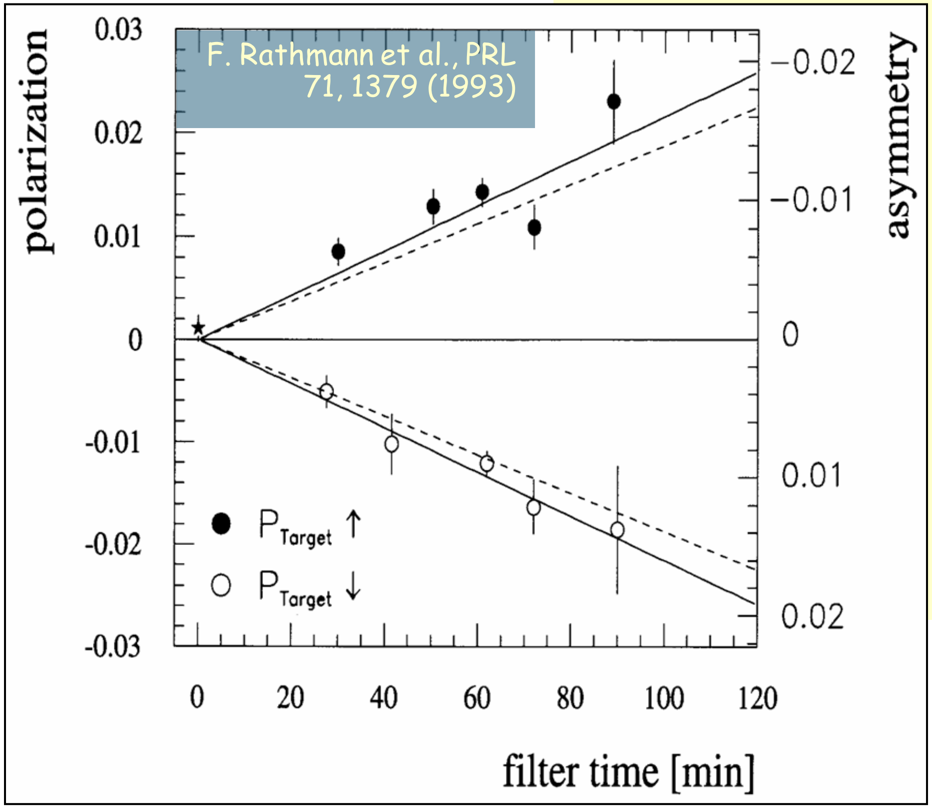
$\tilde{\sigma}$ efficace cross - section

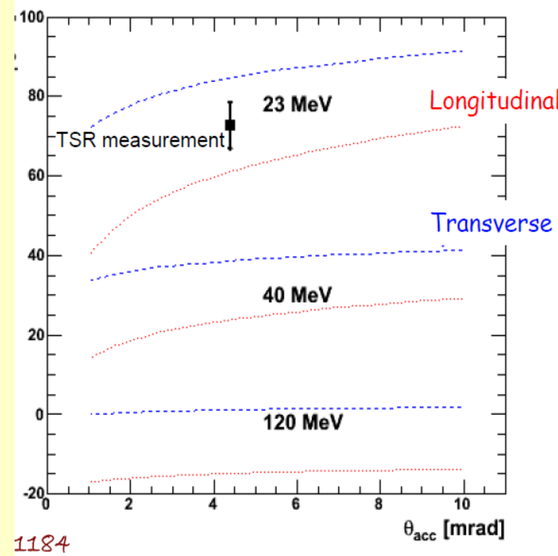
Q target polrization

d_t target density

f revolution frequency

Spin-filtering at TSR: „FILTEX" - proof-of-principle





Spin filtering works for protons

Puzzle from FILTEX Test

the rate of polarization buildup due to filtering mechanism was also estimated theoretically, taking into account only strong pp interaction. This estimation is noticeably different from the experimental result.

Expected build-up: $P(t)=\tanh(t/\tau_{pol})$, $dP/dt= 1/\tau_{pol}=\sigma_1 Q d_t f$**$=2.4\times10^{-2}\ h^{-1}$**

σ_1 = 122 mb (pp phase shifts)
Q = 0.83 ± 0.03
d_t = (5.6 ± 0.3) x 10^{13}cm^{-2}
f = 1.177 MHz

about factor 2 larger

?

Observed polarization build-up: $dP/dt = \pm$ (**1.24 ± 0.06**) x $10^{-2}\ h^{-1}$

In term of cross sections

Filtex observed cross section

Desumed from PRL 71(1993) 1379 σ=63 mbarn

Calculated cross section

only strong interaction σ=122 mbarn

1994 First Theorethical Interpretation of the FILTEX results (Meyer and Horowitz)

Among the strong interaction between projectle and target:

- The interference of the Coulomb amplitude. and the spin-dependent part of the hadronic amplitude:this effect diminishes the corresponding cross section more than by 40%
- the interaction of a projectile with the polarized electrons of the hydrogen gas target **(projectile stay in the beam)** **SPIN_FLIP**
- scattering of a projectile on polarized protons of the target at $\theta <$ θacc. **(projectile stay in the beam)**

1. Selective removal through scattering beyond θ_{acc}=4.4 mrad ($\sigma_{R\perp}$=83 mb)
2. Small angle scattering of target prot. into ring acceptance ($\sigma_{S\perp}$=52 mb)
3. Spin-flip from pol. el. of target atoms to stored prot. ($\sigma_{E\perp}$=-70 mb)

$$\sigma_1 = \sigma_{R\perp} + \sigma_{S\perp} + \sigma_{E\perp} = 65 \text{ mb}$$

Observed σ_1 = 72.5 ± 5.8 mb

In term of cross sections

Filtex observed cross section

Desumed from PRL 71(1993) 1379 σ=63 mb

Calculated cross section

only strong interaction σ=122 mb

1993

calculated cross section

by Meyer and Horowitz

$\sigma_1 = \sigma_{R\perp} + \sigma_{S\perp} + \sigma_{E\perp} =$ 65 mb

Filtex reanalized

(Rathmann Thesis) $\sigma_1 = 72.5 \pm 5.8$ mb

1995

The result accounting for all three contributions agrees very well with the experiment.

Basing on these results it was suggested to polarize an antiproton beam by **spin-flip**

- using the polarized electrons of a polarized hydrogen target (Phys. Rev. Lett. 94, 014801 (2005))
- with a dedicated positron beam (Eur. Phys. J. A 34(2007) 447.)

2005 Second Teorethical Interpretation of the FILTEX results (Milstein and Strakhovenko)

A. I. Milstein, V. M. Strakhovenko, Phys. Rev. E 72, 066503 (2005).

"In conclusion, it is demonstrated that, for $\theta < \theta acc$ (a proton remains in the beam), the polarization buildup is completely due to the spin-flip transitions. **The corresponding cross sections turn out to be negligibly small for both proton-proton and proton-electron scattering.** For a pure electron target, filtering mechanism also does not provide a noticeable polarization. Evidently, these statements are valid for the antiproton beam as well. Thus, the filtering method using a hydrogen gas target with the proton polarization seems to be the most promising way to polarize stored antiprotons."

Conclusions confirmed by Nicolajev and Pavlov

N. N. Nikolaev, F. F. Pavlov, Polarization Buildup of Stored Protons and Antiprotons: Filtex Result and Implications for Pax at Fair, arXiv:hep-ph/0601184 (2006).

Spin Filtering: Status in 2006

Spin Filtering works, but:

1. Controversial interpretations of FILTEX experiment
    - Further experimental tests necessary
        - Which role do electrons play?
        - How does spin filtering work?

    → Tests with protons at COSY

2. No data to predict polarization from filtering with antiprotons

    → Measurements with antiprotons at AD/CERN

- In these last years the PAX collaboration has systematically studied a viable mechanism, the "**spin-filtering**", to produce polarized antiprotons

- The PAX collaboration has verified by **dedicated experiments at the COSY proton ring** the TSR results as well as the theoretical interpretation of this polarization mechanism that is, after these experiments, completely clarified

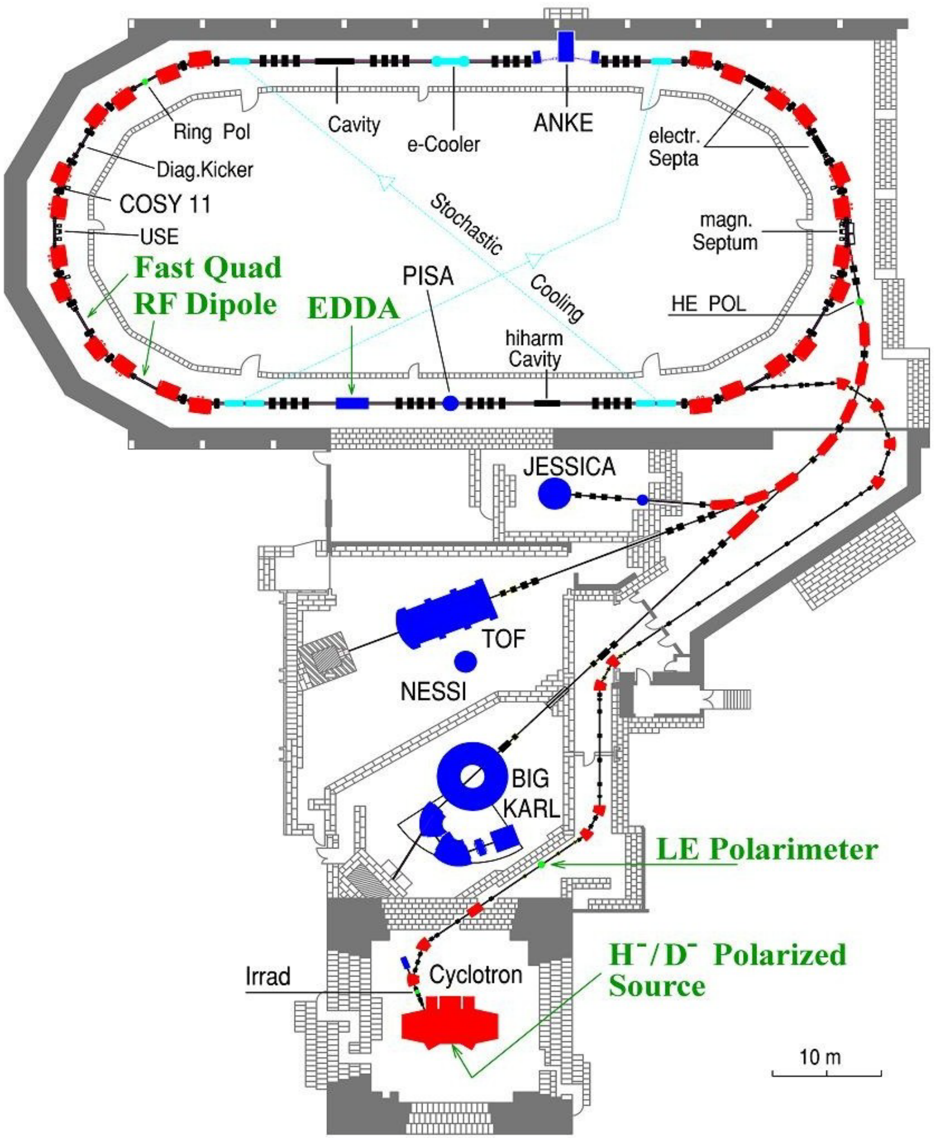
- Meanwhile the PAX collaboration has demonstrated with a dedicated experiment using the COSY electron cooling, that the "**spin-flip**" method as recently suggested by T. Walcher at al. **does not work.**

- **The spin-filtering method has been demonstrated to be the only possible method to polarize in situ stored nucleons**

Sistematic studies at COSY

The COSY ring has been upgraded to a precise machine, improoving vacuum, beam-lifetime etc

Cooler Synchrotron COSY

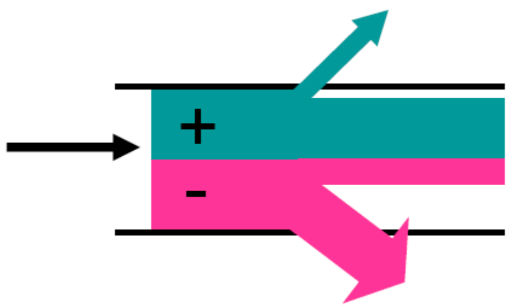


- Storage Ring with synchrotron acceleration and cooling
- Momentum range 0.3 - 3.7GeV/c
- Storage of polarized p and d beams
- Electron cooling at ≈ injection
- Stochastic cooling at high momenta
- Several internal target experiments:
  - EDDA (pol. H jet)
  - COSY-11 (H cluster target)
  - ANKE (pol. H, D cell)

planned: - WASA (H pellet target)

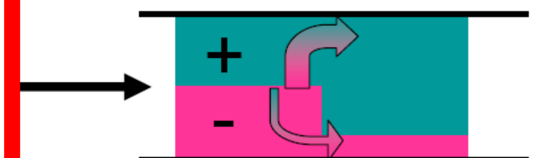
spin filtering versus spin flip

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)

A surprising method for polarising antiprotons.

Th. Walcher[1,2], 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: date / Revised version: date

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 sections. Two possibilities for providing a positron source with sufficient flux density are presented. A polarised positron beam with a polarisation of 0.70 and a flux density of approximately $1.5 \cdot 10^{10}/(\mathrm{mm}^2\ \mathrm{s})$ appears to be feasible by means of a radioactive ^{11}C dc-source. A more involved proposal is the production of polarised positrons by pair production with circularly polarised photons. It yields a polarisation of 0.76 and requires the injection into a small storage ring. Such polariser sources can be used at low (100 MeV) as well as at high (1 GeV) energy storage rings providing a time of about one hour for polarisation build-up of about 10^{10} antiprotons to a polarisation of about 0.18. A comparison with other proposals show a gain in the figure-of-merit by a factor of about ten.

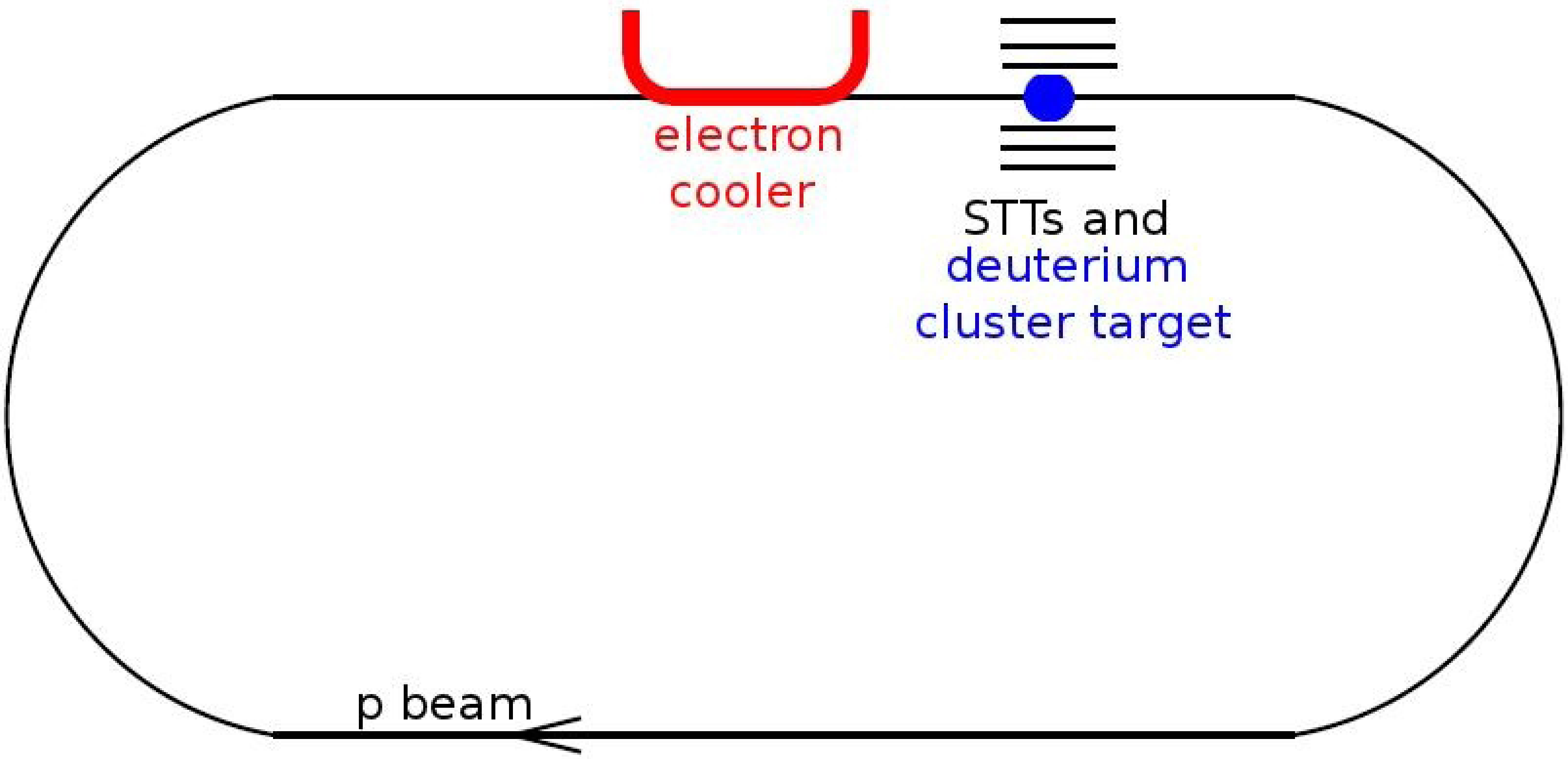
PACS. 13.88.+e Polarisation in interactions and scattering – 29.20.Dh Storage rings – 29.25.Bx Electron sources – 29.27.Hj Polarised beams

Eur. Phys. J. A 34, 447 (2007)

-> need for experimental test of this idea

If a polarized electron (positron) beam polarize an unpolarized proton (antiproton) beam, then an unpolarized electron (positron) beam will depolarize a polarized proton (antiproton) beam

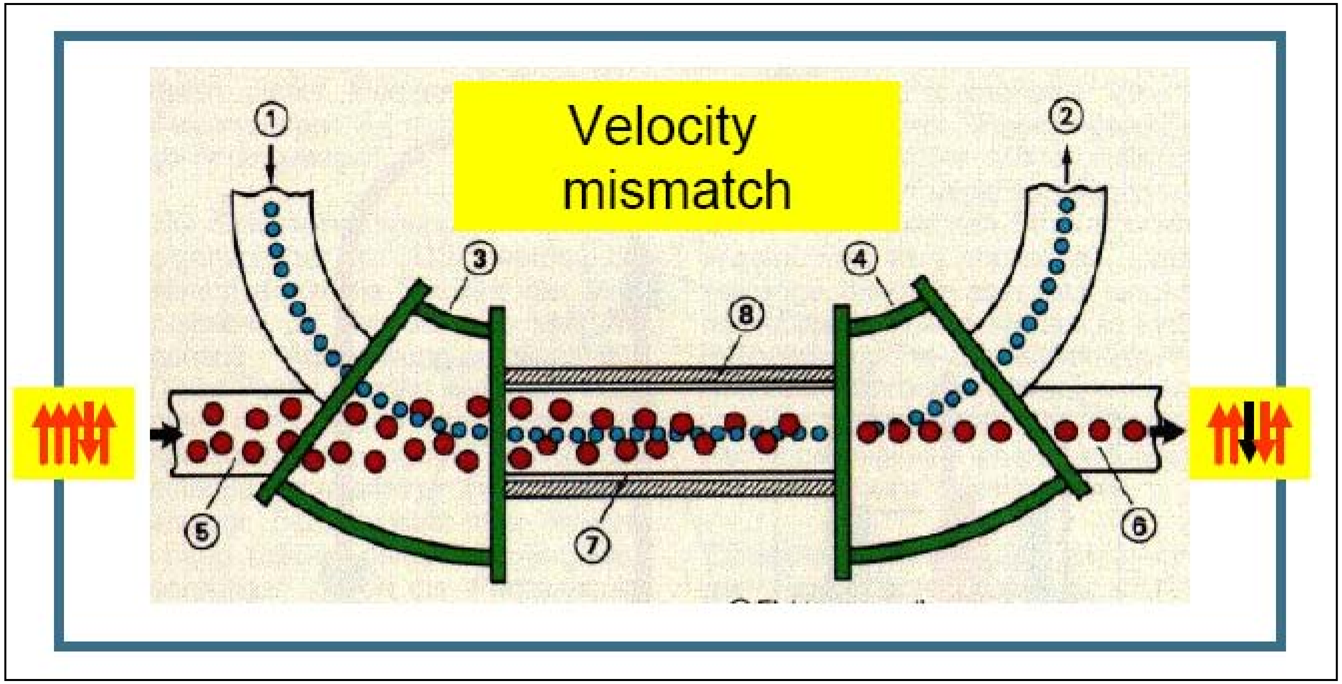
At COSY polarized proton circulate in the ring across the unpolarized electron cooling beam


electron
cooler
STTs and
deuterium
cluster target
p beam

Depolarization studies at COSY: idea

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

  i.e. depolarization of a polarized proton beam



The COSY electron cooler serves two functions:

1. it provides the phase-space cooling of the stored proton beam,
2. it plays the role of an electron target for the actual measurement of the low energy spin-flip cross section in e-p scattering.

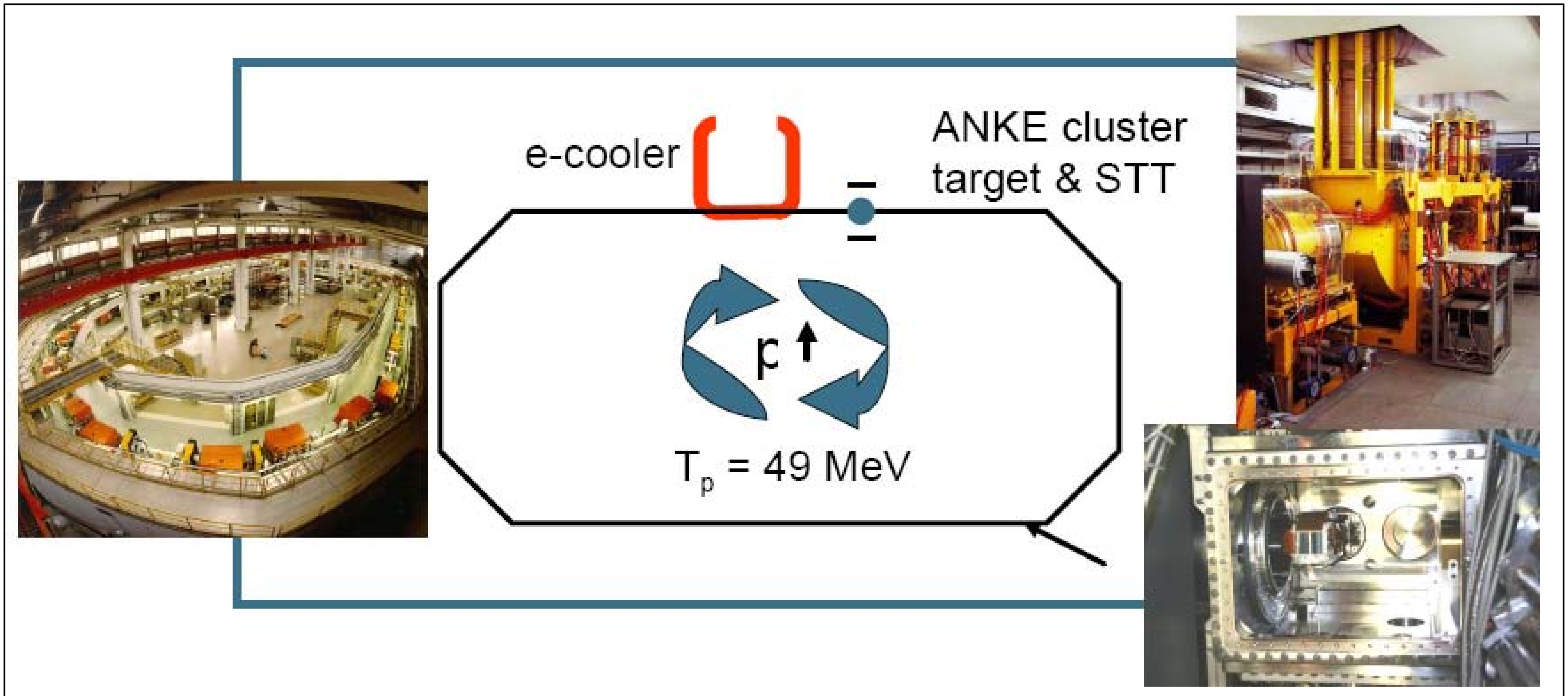
In the cooling mode, the electron velocity is adjusted to the velocity of the stored protons. This is the case if the accelerating potential equals U

$$U = \frac{m_e}{m_p} T_p$$

When the cooler is used as a target, a relative motion between the proton and the electron beam is achieved by 'detuning' the accelerating voltage by ΔU, changing the electron velocity and inducing an average relative 'detune' velocity.

Depolarization studies at COSY: principle

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

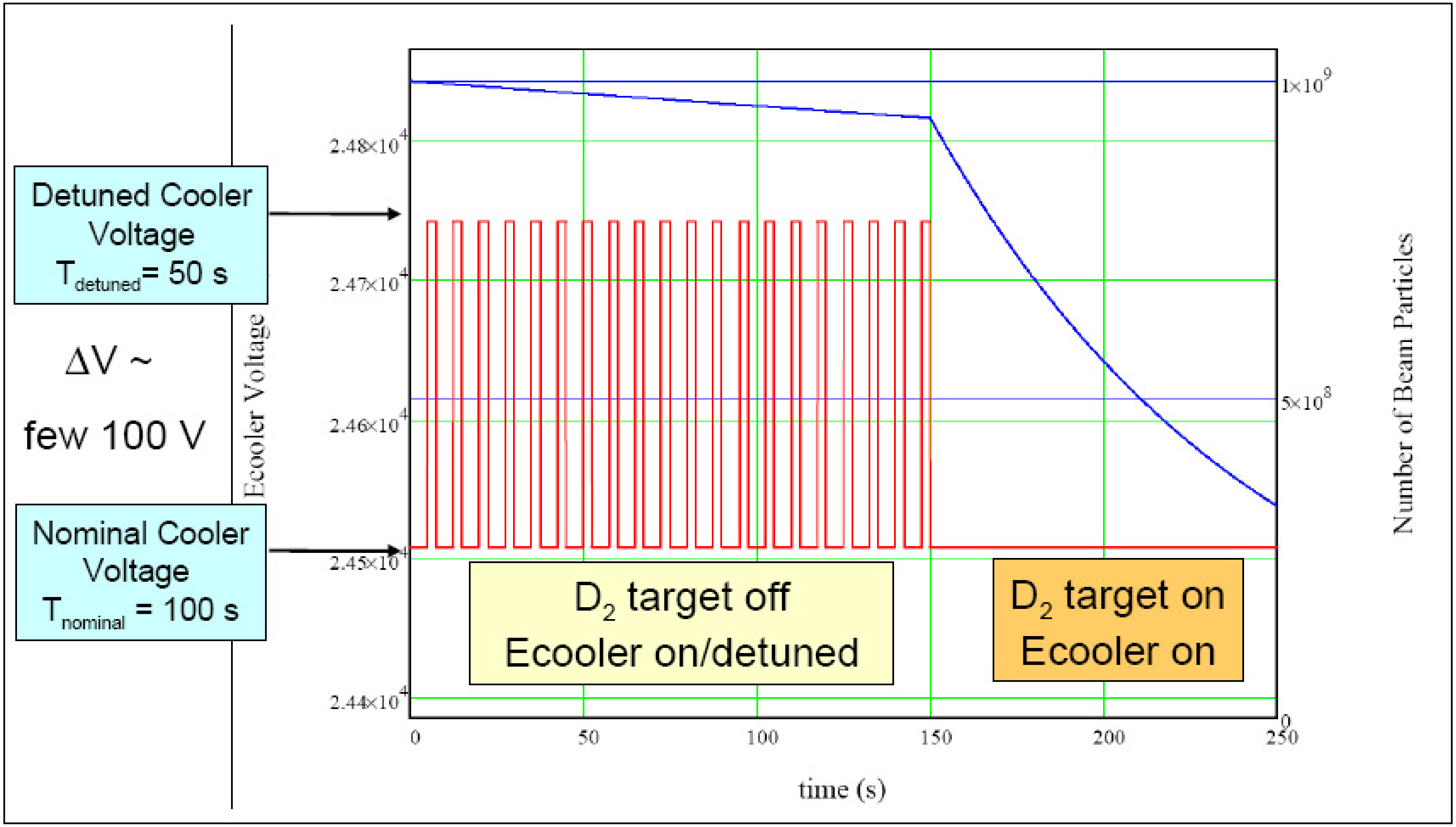


Fill Cycles

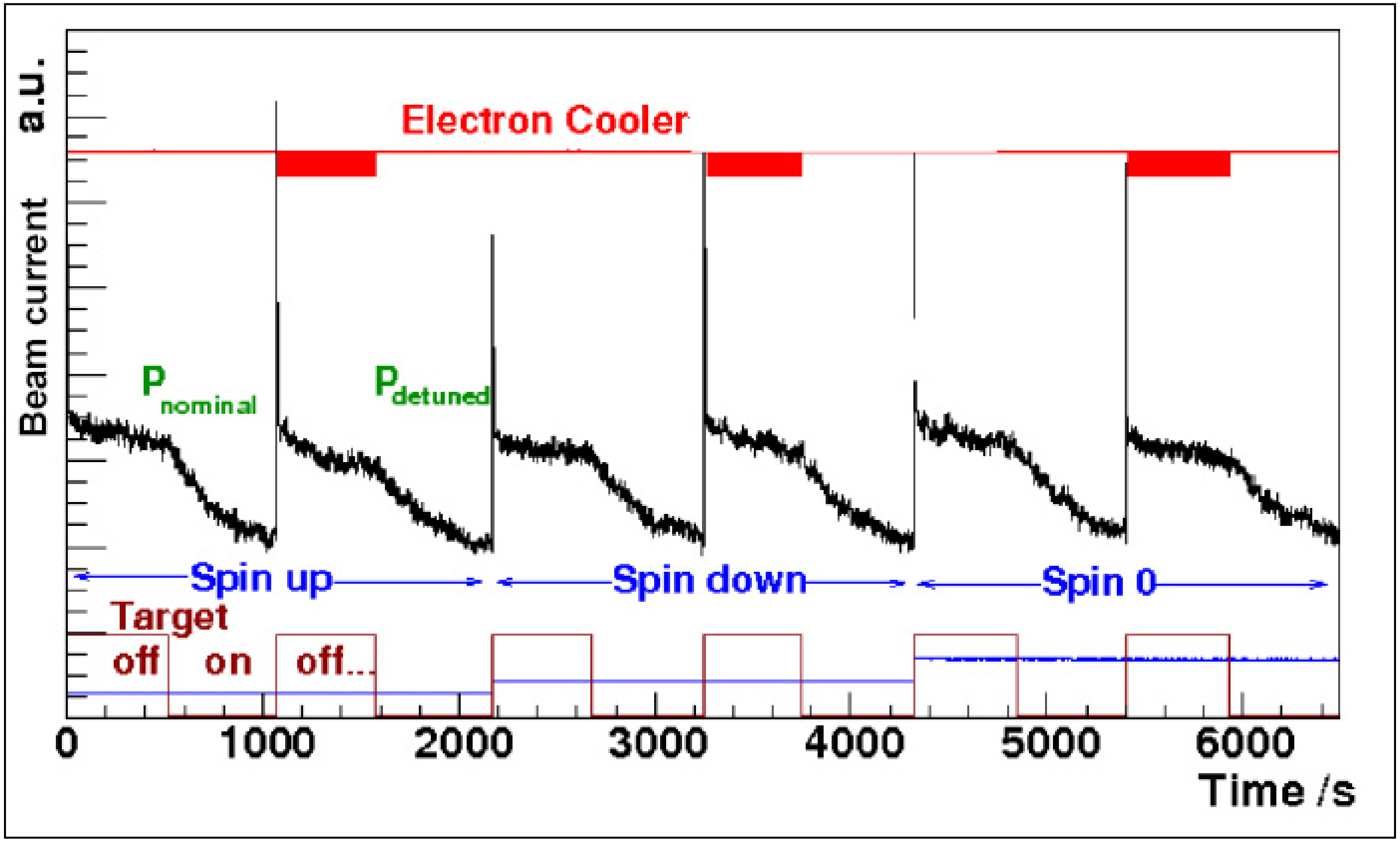
At the beginning of the cycle, the ring is filled with vertically polarized protons (beam polarization is P_B ~0.5). During the first half of the cycle, the proton beam is interacting with the electrons in the cooler. During the second half, while cooling the beam, the internal deuteron target is turned on to measure the beam polarization.

The first half of the cycle contains 49 sub-cycles of 10 s length. During such a subcycle the electron velocity is first tuned to the beam velocity to cool the beam for 5 s, then the electron beam velocity is detuned for another 5 s. **This is the time when the polarized beam is depolarized. with a total 'interaction' time in the detuned mode of 245 s per cycle.**

Depolarization studies at COSY: cycle



Depolarization studies at COSY: cycle



The beam polarization is measured using p+d elastic scattering. Precise analyzing power data are available at

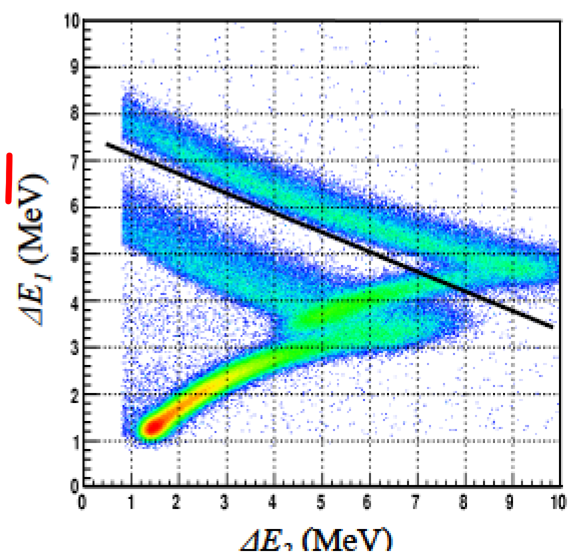
Tp = 49.3 MeV

and cross sections have been measured at a nearby energy (*Tp = 46.3 MeV)* :The beam energy for this experiment was chosen partly because of this.

The target consists of a deuterium cluster jet with about

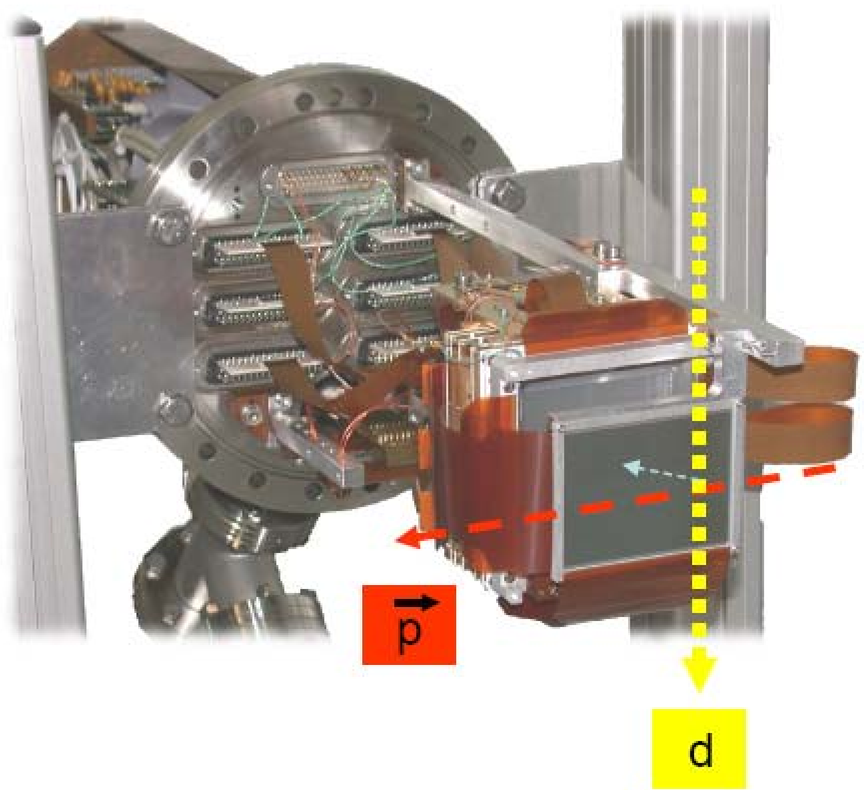
5 · 1014 deuterons per cm2

The detector system consists of two sil telescopes placed symmetrically to the the beam.

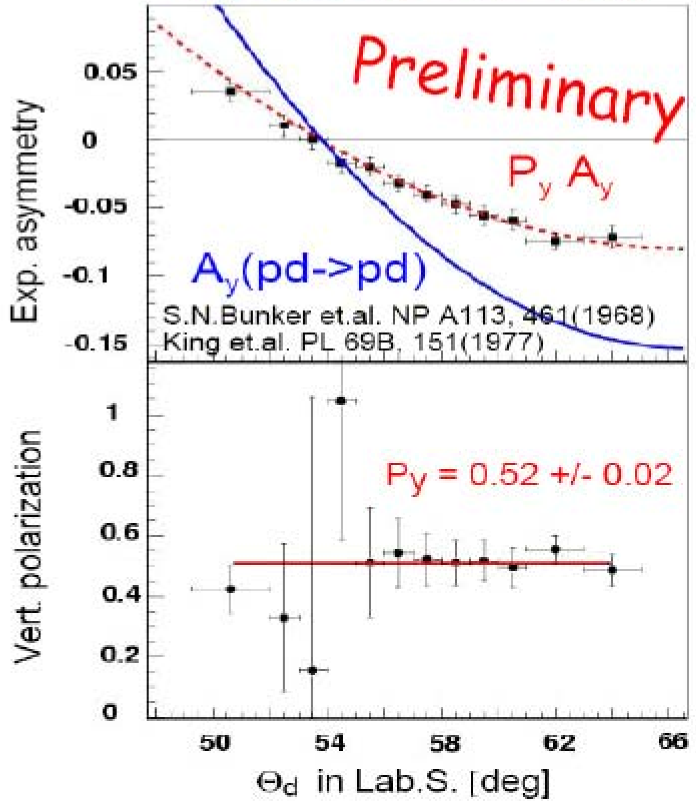


Depolarization studies at COSY: Polarimetry

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



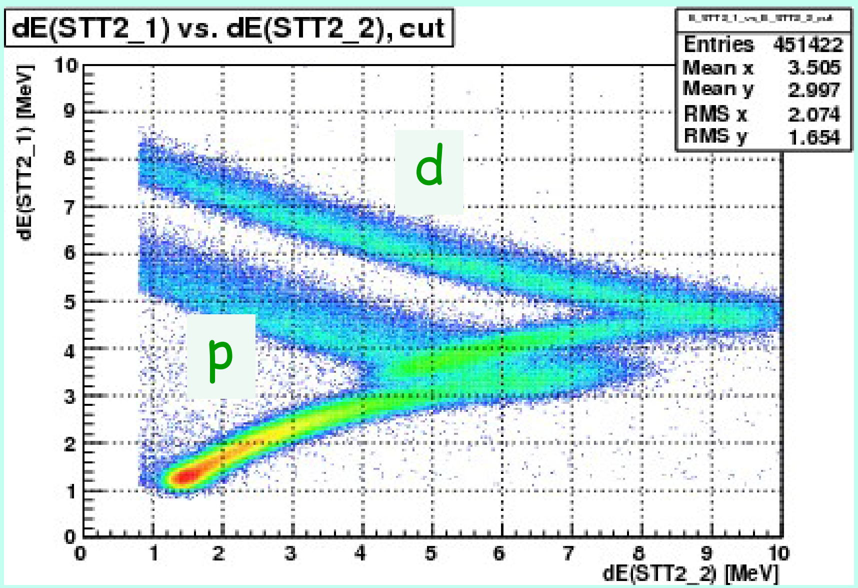
Beam polarization (deuterons selected)

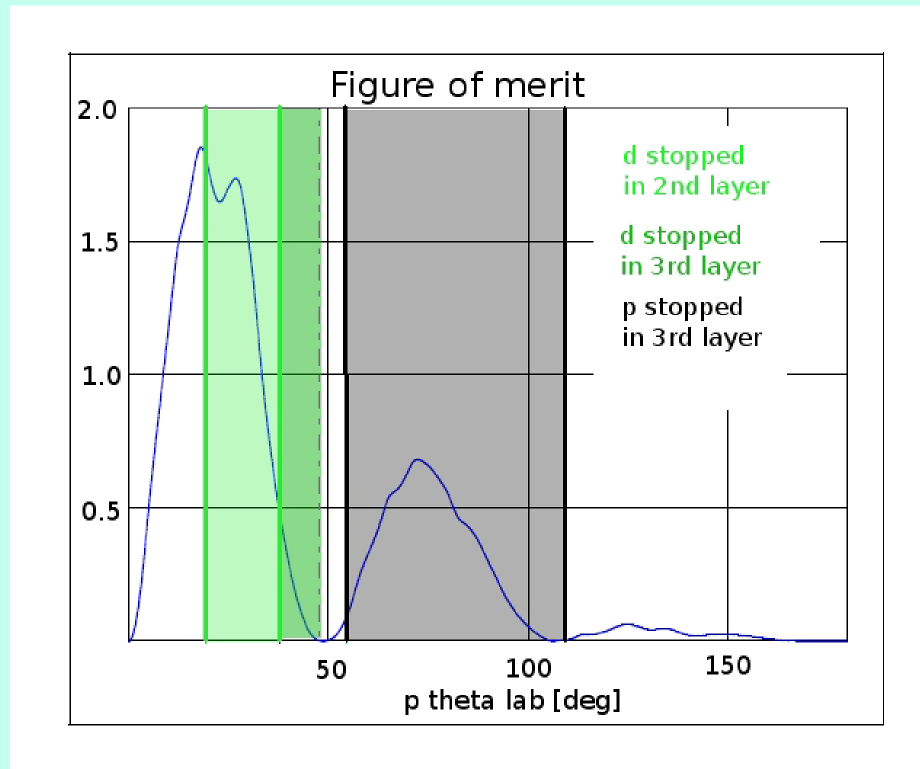


Commissioning of the experimental setup (2010)
Beam Polarimeter

pd elastic scattering:
detection in two (L-R) symmetric Silicon Tracking Telescopes

Deuteron identification

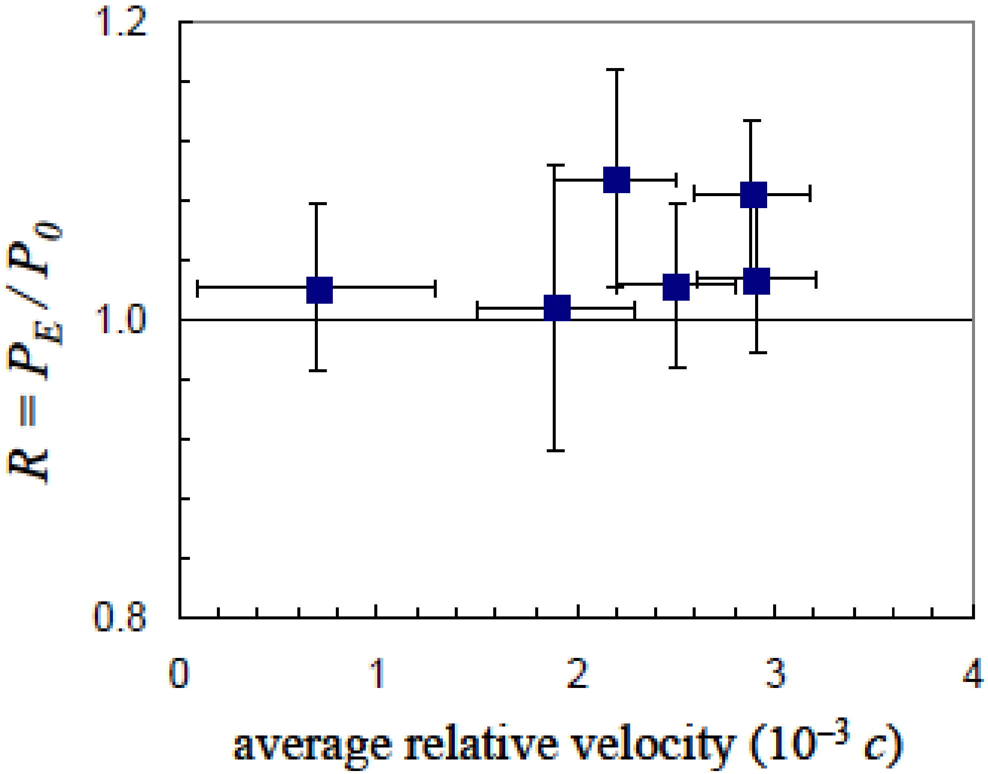




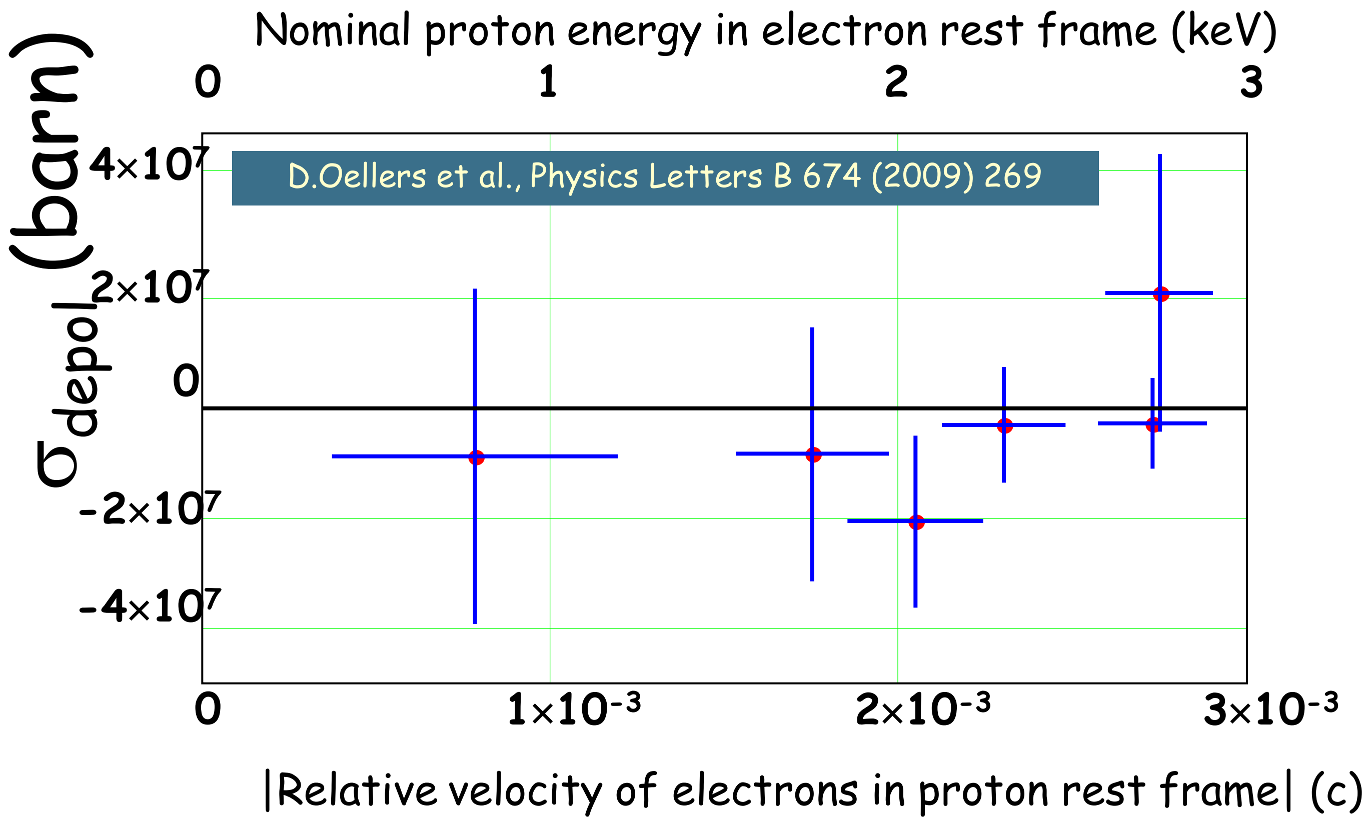
The result

No effect is observed!

the measured ratio R, of the polarization with and without electron target



$\vec{e}p$ spin-flip cross section at COSY



No effect observed: measured cross sections at least 6 orders-of-magnitude smaller than predicted 10^{13} b.

Meanwhile, Mainz group discovered numerical problems in the calculation → two errata.

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

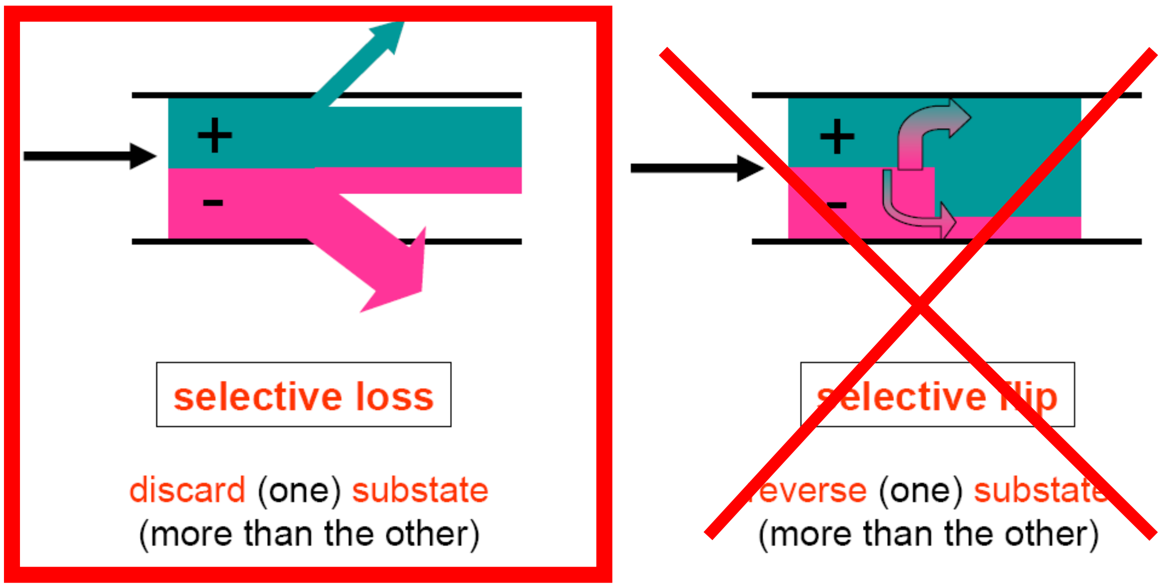
The cross section which addresses the spin-flip transitions of a proton (antiproton) interacting with a polarized non-relativistic electron or positron is calculated analytically. In the case of attraction, this cross section is greatly enhanced for sufficiently small relative velocities as compared 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!

spin filtering versus spin flip

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



The Spin Filter Method

2012

Two interpretations of FILTEX result (2006)

Observed polarization build-up: $dP/dt = \pm (1.24 \pm 0.06) \times 10^{-2}\ h^{-1}$

$P(t)=\tanh(t/\tau_1)$, $1/\tau_1=\sigma_1 Q d_t f$

$\sigma_1 = 63 \pm 3$ mb (PRL 71(1993) 1379)

$\sigma_1 = 72.5 \pm 5.8$ mb (Rathmann Phd Thesis(1994)

1994 Meyer and Horowitz: three distinct effects

1. Selective removal through scattering beyond θ_{acc}=4.4 mrad ($\sigma_{R\perp}$=83 mb)
2. Small angle scattering of target prot. into ring acceptance ($\sigma_{S\perp}$=52 mb)
3. Spin-transfer from pol. el. of target atoms to stored prot. ($\sigma_{E\perp}$=-70 mb)

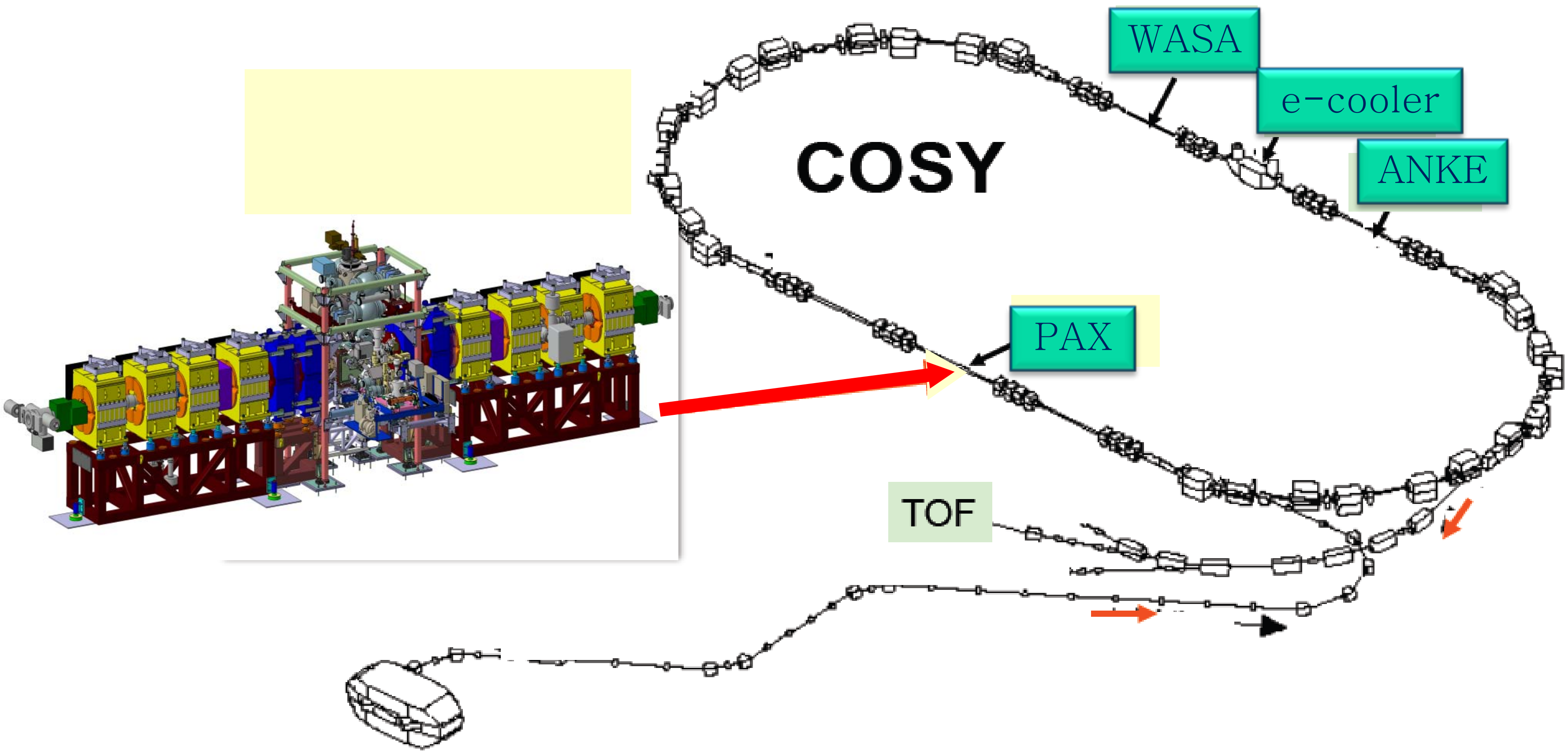
$\sigma_1 = \sigma_{R\perp} + \sigma_{S\perp} + \sigma_{E\perp} = 65$ mb

2005 Milstein & Strakhovenko + Nikolaev & Pavlov: only one effect

Only pp elastic scattering contributes

No contribution from other two effects $\sigma_1 = 85.6$ mb

Spin-filtering experiment at COSY (2009-2012)

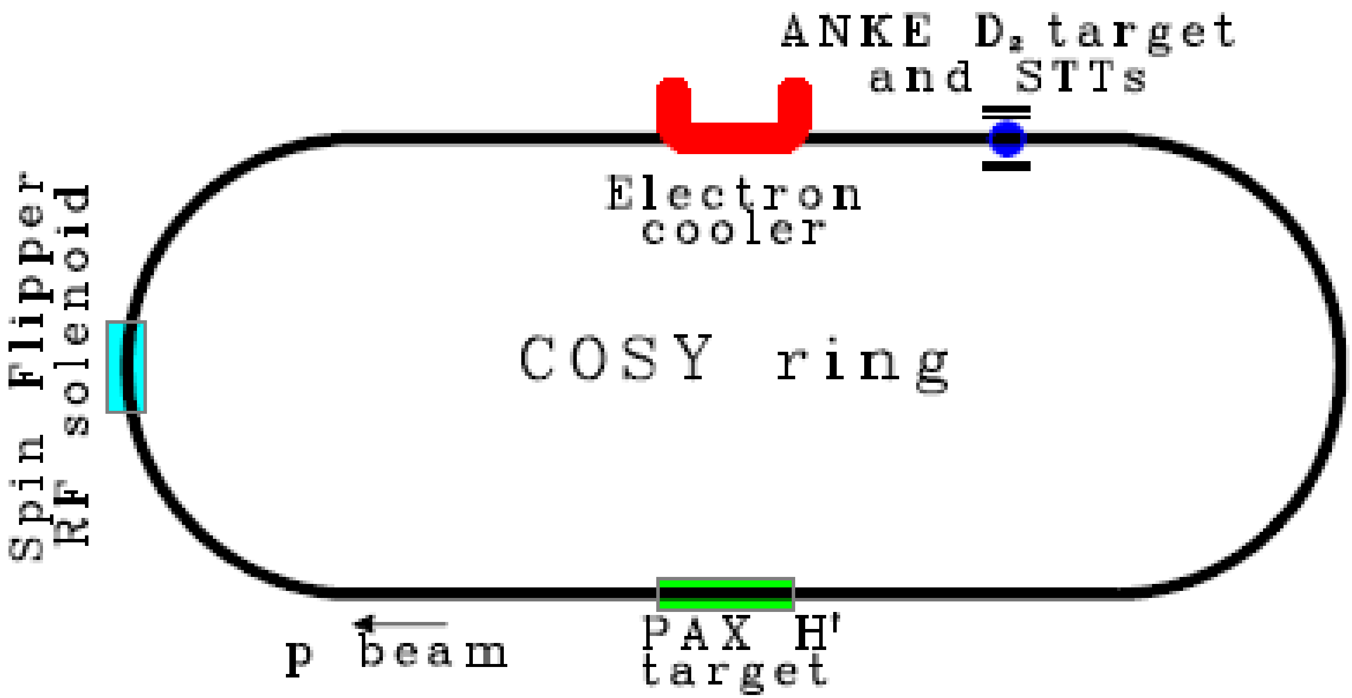


Spin-filtering experiment at COSY (2009-2012)

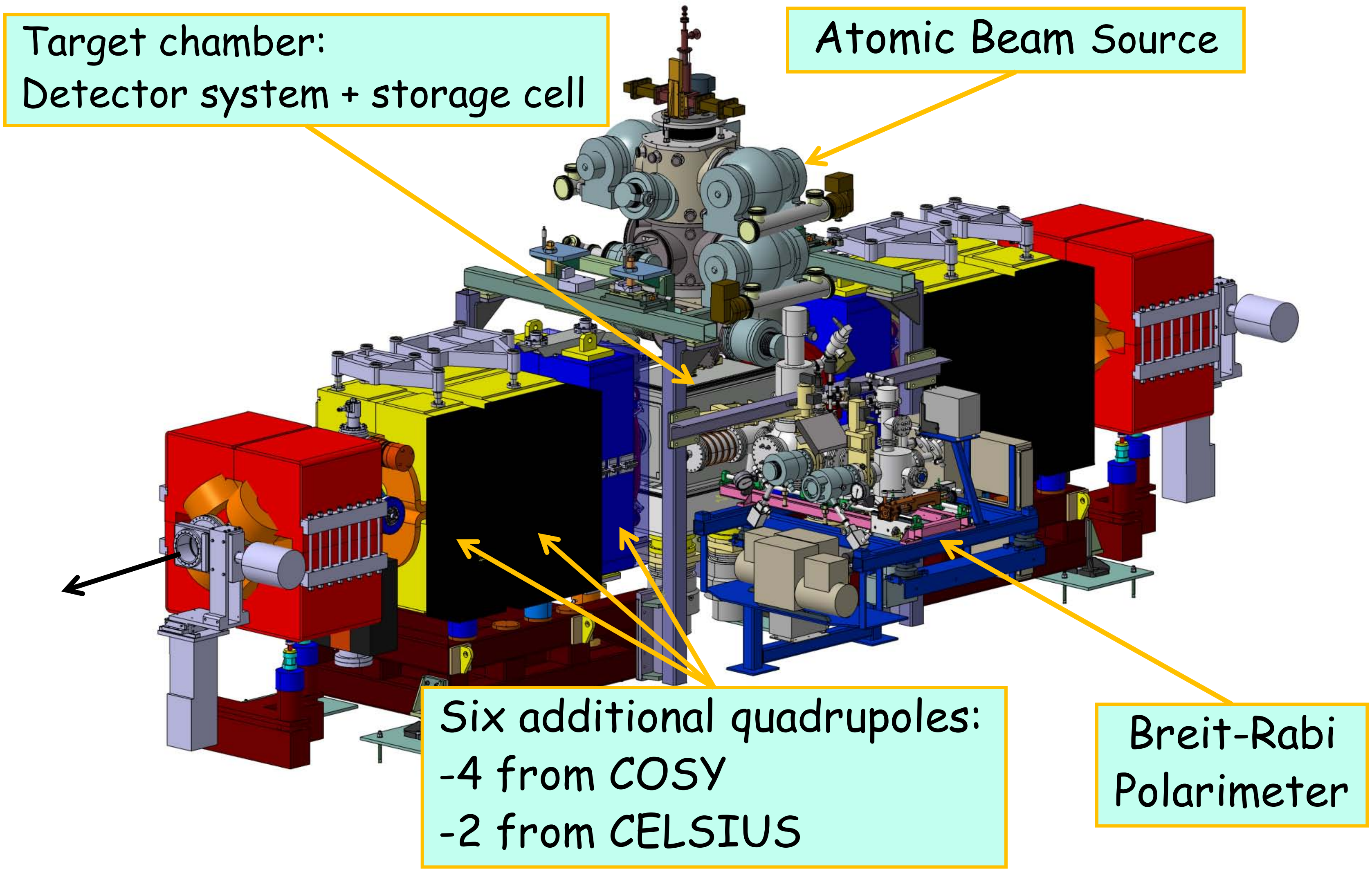
- to provide an additional measurement to the existing one, confirming the validity of the filtering-method to polarize a stored beam,
- to test the present theoretical understanding of the mechanism under different experimental conditions.

- To test the low-β section that could be installed at AD,CERN

- ~ 5.10^9 unpolarized proton are injected in the COSY ring at a beam energy of 45 MeV. The beam is cooled and subsequently accelerated to 49.3 MeV.
- the spin-filtering starts: polarized hydrogen is injected into the storage cell at the PAX interaction point.
- the spin-filtering stop. the PAX polarized target is switched off, the ANKE deuterium-cluster target is switched on and the data acquisition of the beam polarimeter starts.

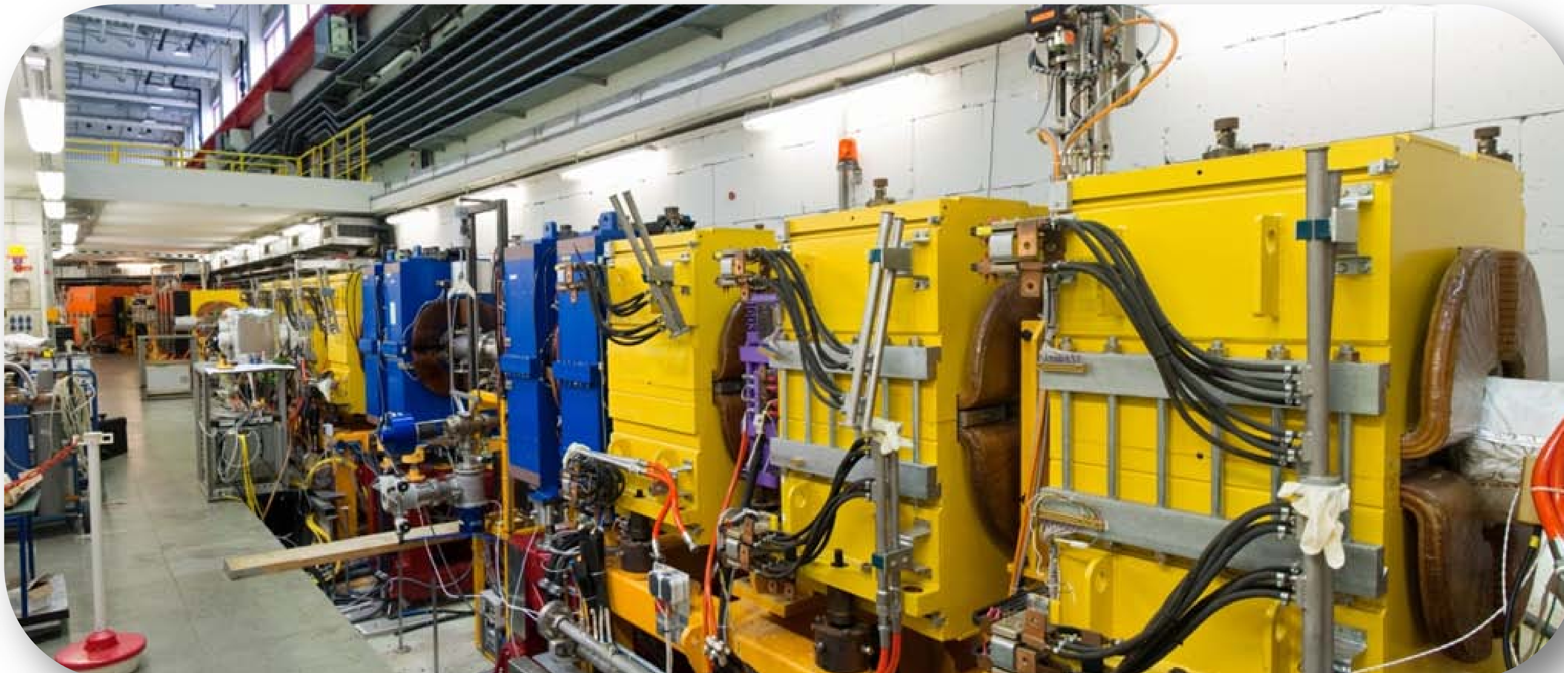


Experimental Setup



Installation of low-β section (2009)

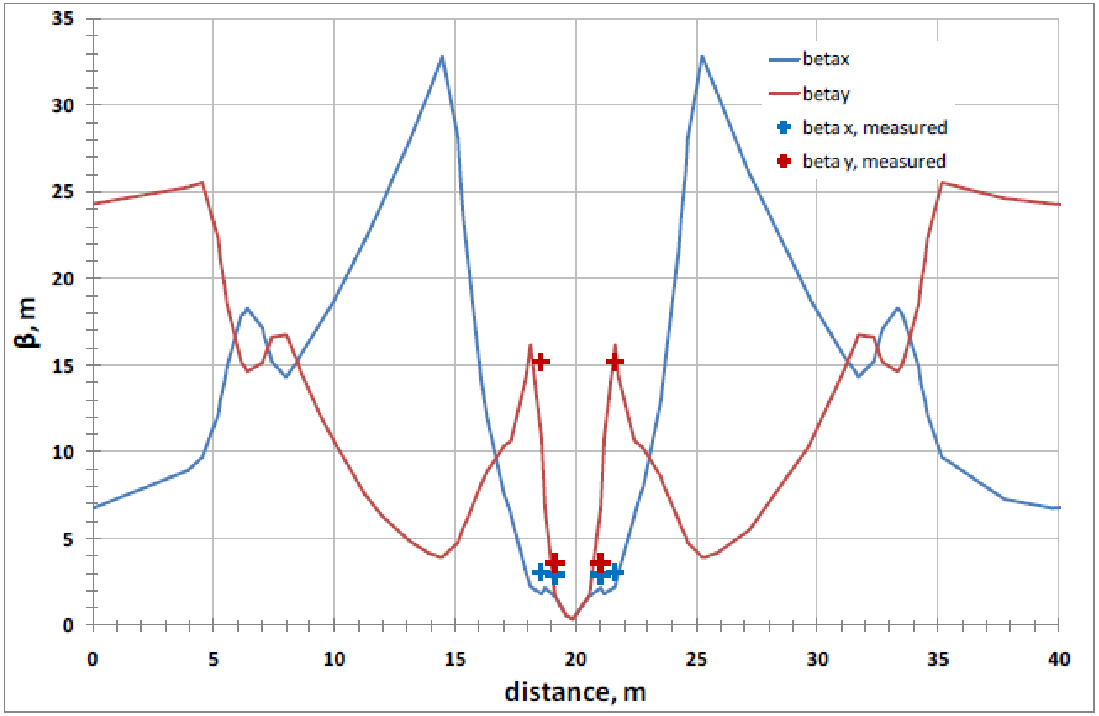
- Beam has to fit through storage cell target (d_t=5x10^{13} atoms/cm^2)
- Increase acceptance angle at target position



Commissioning of the experimental setup (2010-11)
Low-β section implementation and machine studies

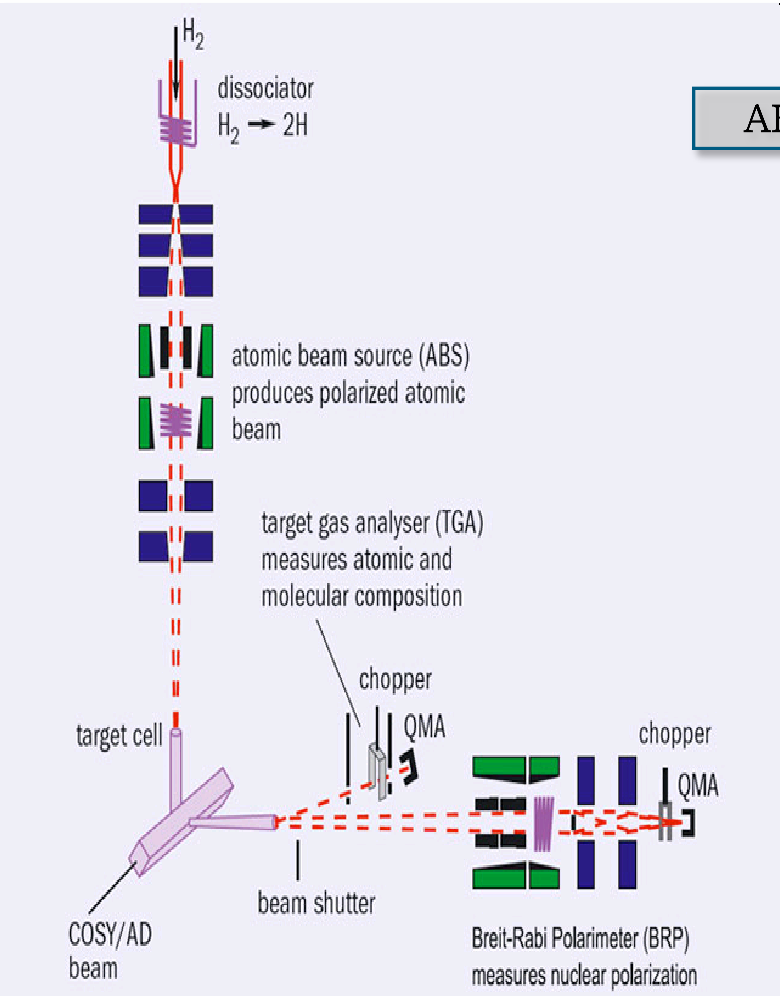
- Model in good agreement with measurement: β ~ 0.3m

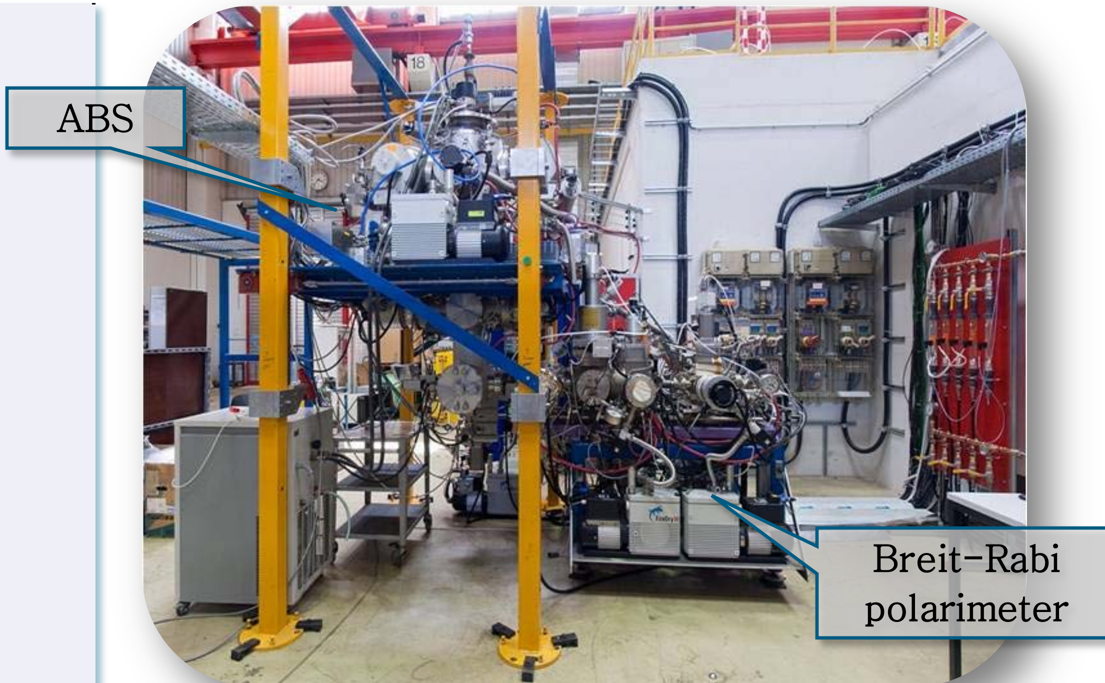
-> **beam fits through the cell!**



- Beam-lifetime: 500s ↦ 8000 s

Commissioning of the experimental setup (2010)
Polarized target

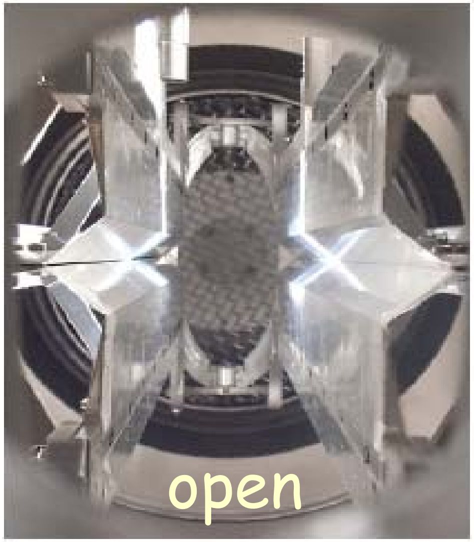


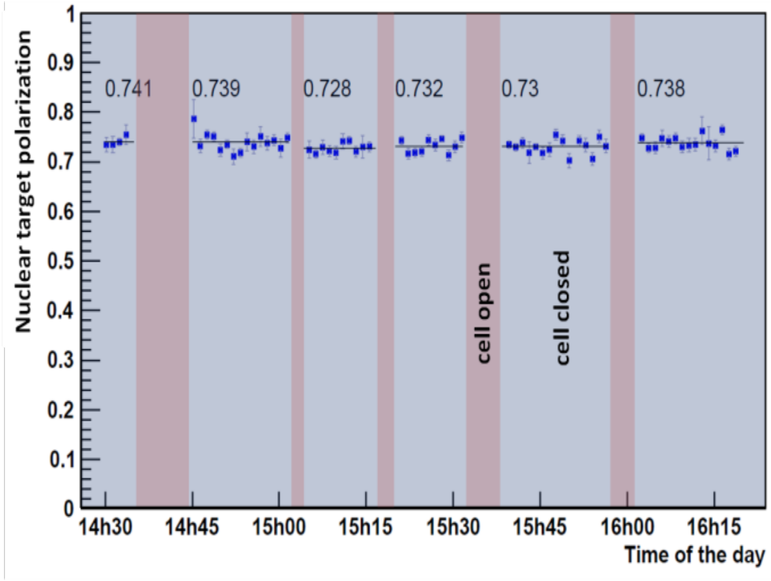


- Spin filtering requires >10^{13} atoms/cm^2 → ABS + openable storage cell
- Analysis of target polarization by Breit-Rabi polarimeter (BRP) and a target gas analyzer (TGA)

Openable storage cell

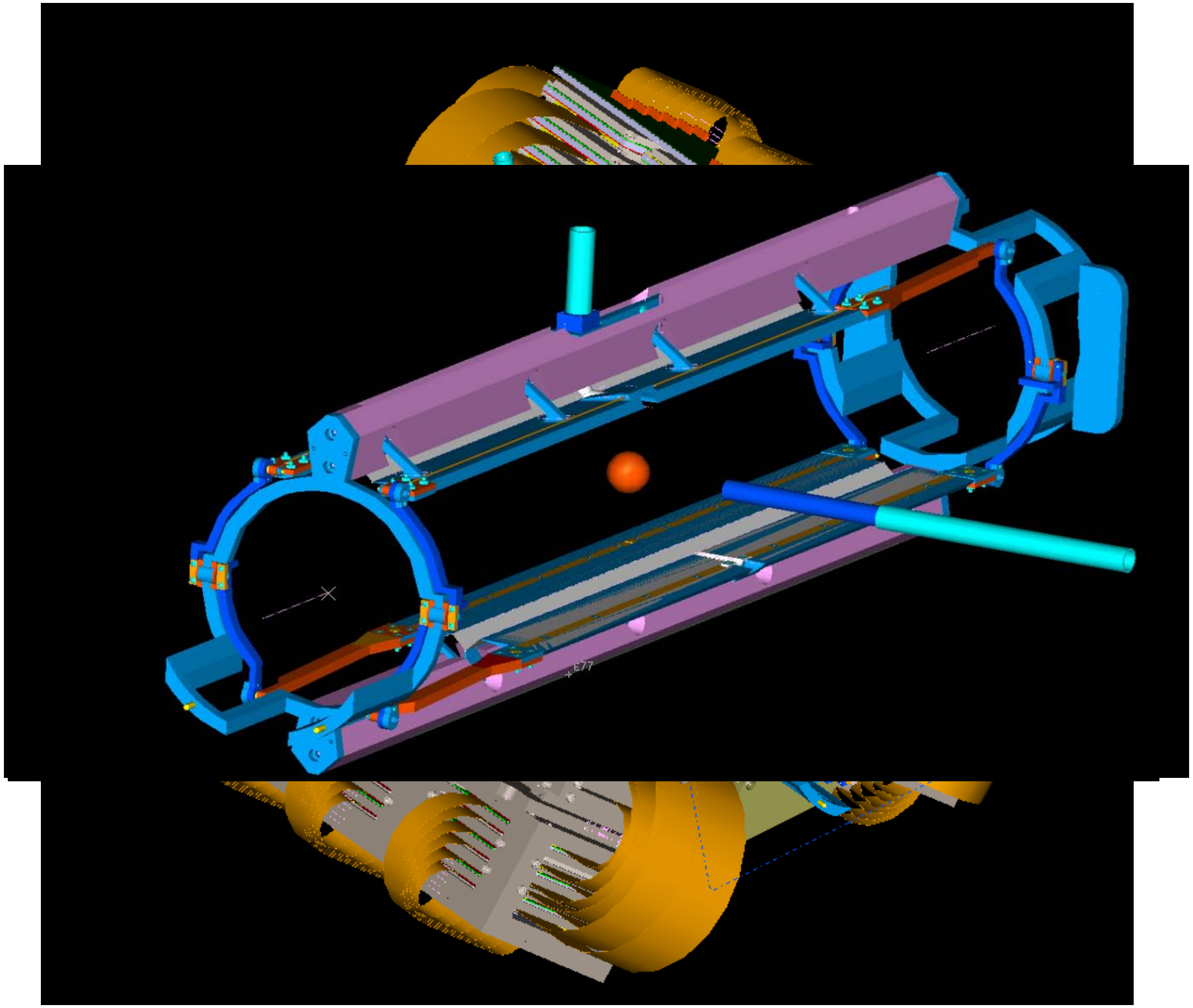
•Atomic beam source provides polarized hydrogen target



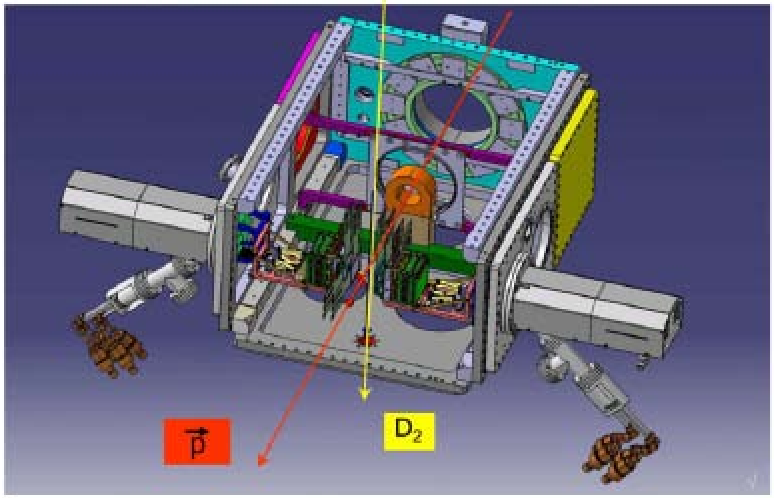


Nuclear polarization of the hydrogen target determined with the Breit-Rabi polarimeter after opening and closing of the storage cell a few times

mechanical design of high acceptance Si detectors



- -openable cell
- - mechan. support
- - 3 layers of Si det.
- - front-end electr.
- - cooling

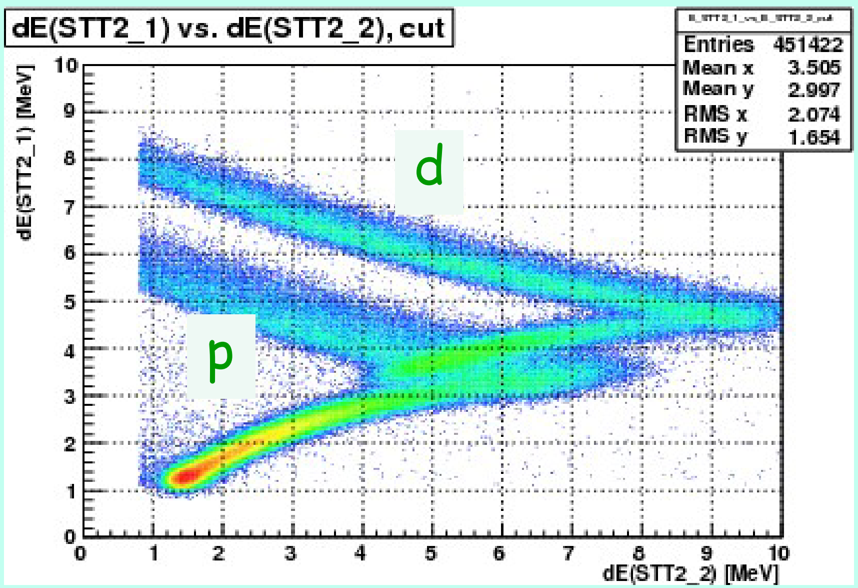


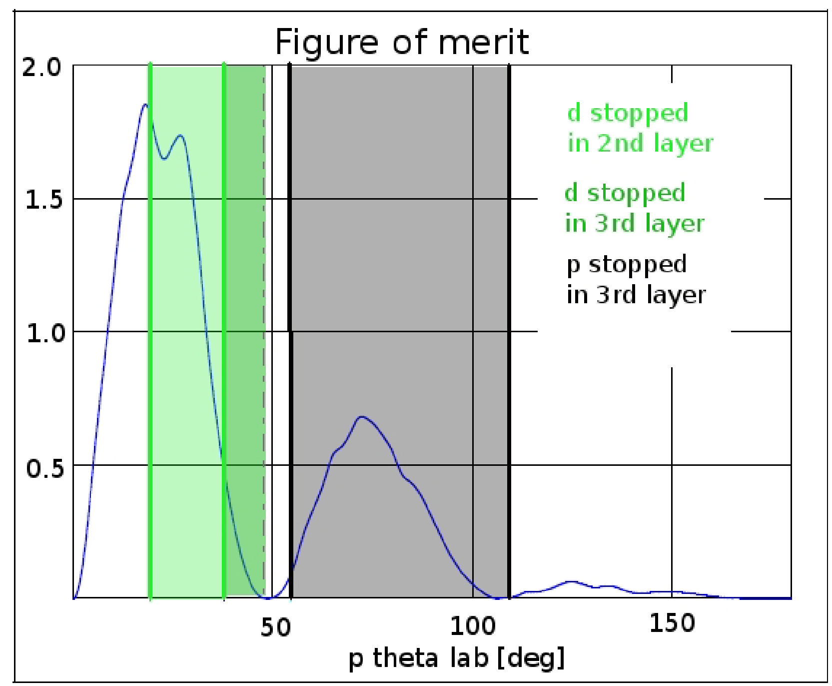
The polarimeter

Commissioning of the experimental setup (2010)
Beam Polarimeter

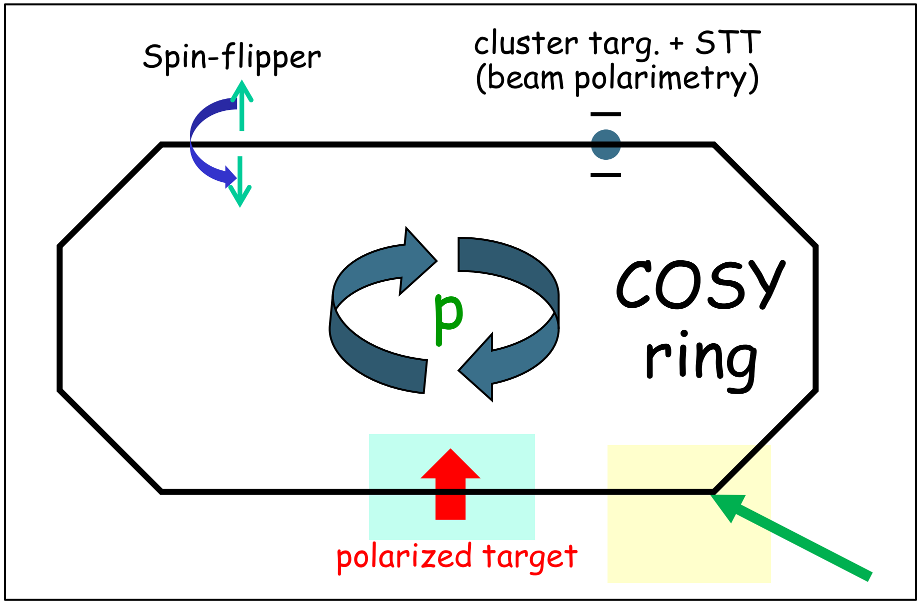
pd elastic scattering:
detection in two (L-R) symmetric Silicon Tracking Telescopes

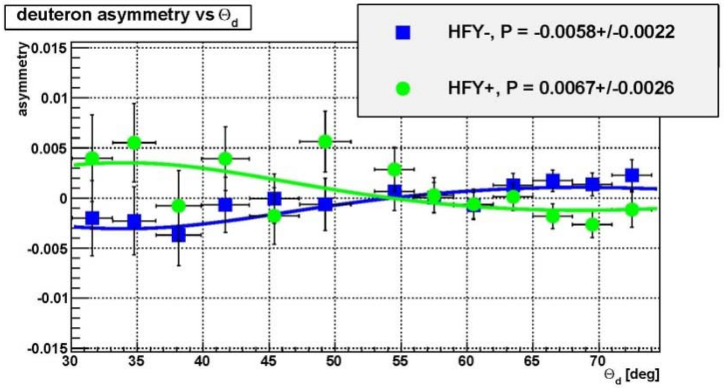
Deuteron identification

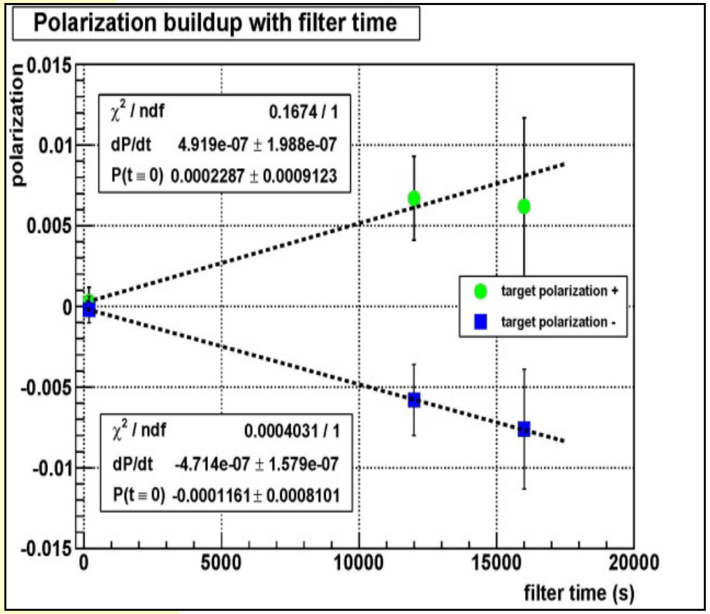




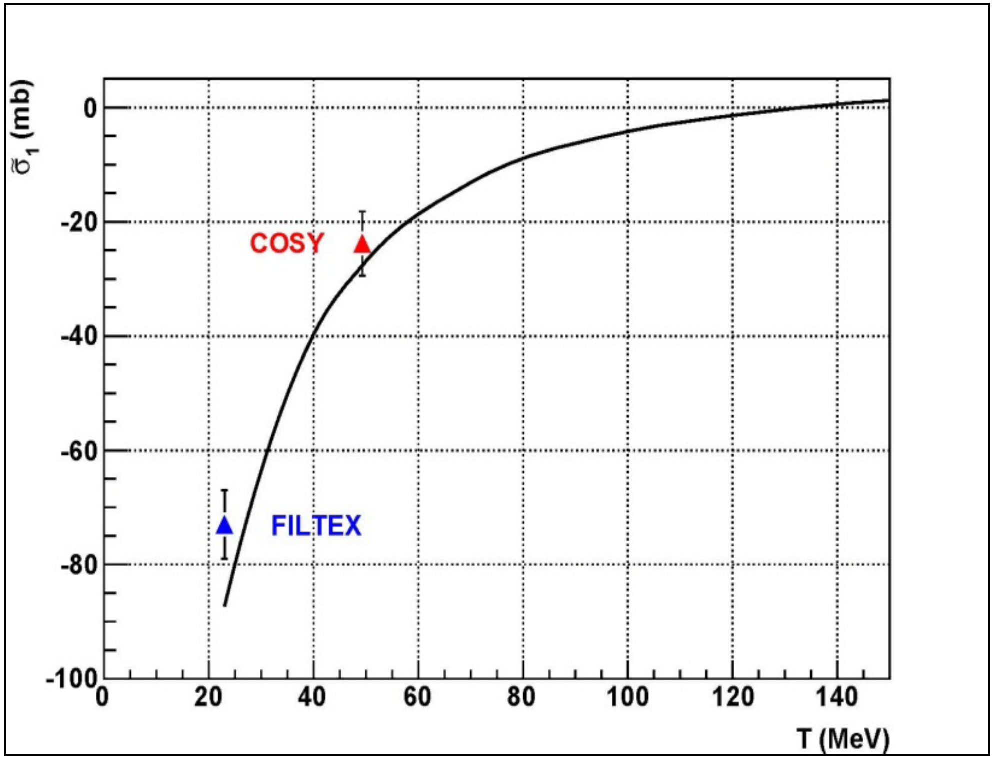
2011: Spin-filtering measurement







Result



- Milestone for the field!
  - Confirms understanding of spin-filtering as a viable method to polarize a stored beam.
  - Confirms complete control of the systematics of the experiment
  - Does not cover for the lack of knowledge of the pbar-p interaction.

Spin-filtering: status in 2012

- No contribution from EM interaction to polarization buildup.
- Only viable solution for "in-situ" polarization is spin-filtering
- Complete understanding of the physics spin-filtering mechanism
- Spin-dependence of proton antiproton interaction still unkown
  - New prediction existing

What about the antiprotons?

Antiprotons

At present, the AD of CERN is the only place world wide, where the proposed measurements can be performed.

Submitted to SPS Comm, CERN in 2009

Measurement of the Spin-Dependence of the pbar p Interaction at the AD-Ring (April 2009) arXiv 09042325[nucl-ex]

$$\sigma_{tot} = \sigma_0 + \sigma_1 \left(\vec{P} \cdot \vec{Q}\right) + \sigma_2 \left(\vec{P} \cdot \hat{k}\right)\left(\vec{Q} \cdot \hat{k}\right)$$

σ_{tot} total hadronic cross section

σ_0 total spin-indipendent hadronic cross section

σ_1, σ_2 total spin dependent cross sections for transverse or longitudinal orientaion of beam $\vec{P}$ and target $\vec{Q}$ polarization.

$\hat{k}$ unit vector along the collision axis

Submitted to SPS Comm, CERN

Measurement of the Spin-Dependence of the pbar p Interaction at the AD-Ring (April 2009) arXiv 09042325[nucl-ex]

$$P(t) = \tanh(t/\tau)$$

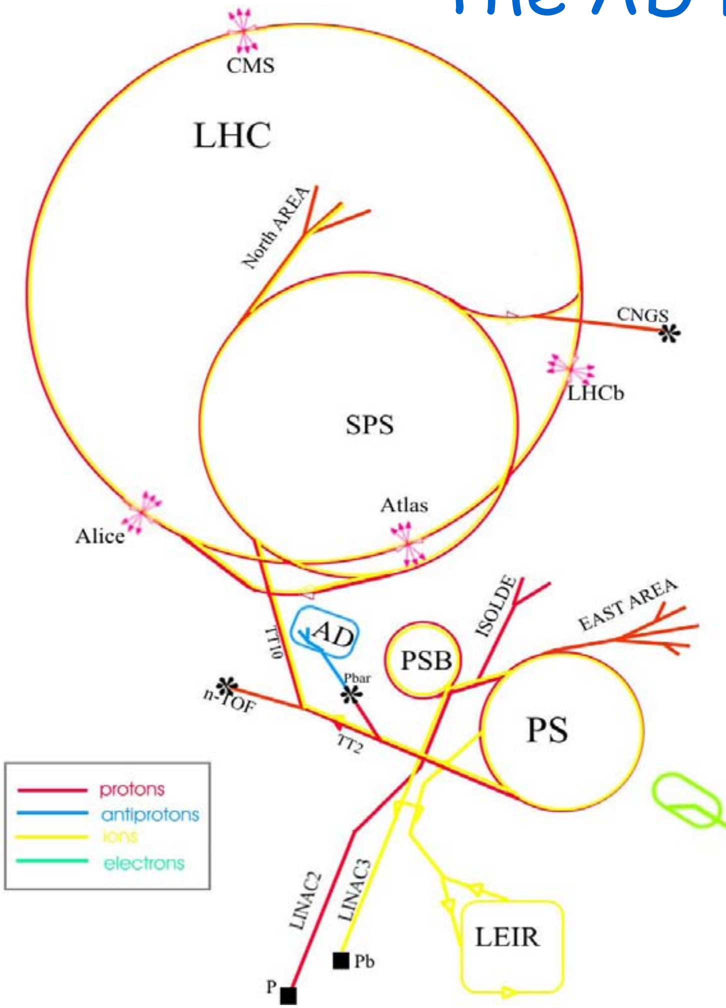
$$\frac{dP}{dt} = \frac{1}{\tau}$$

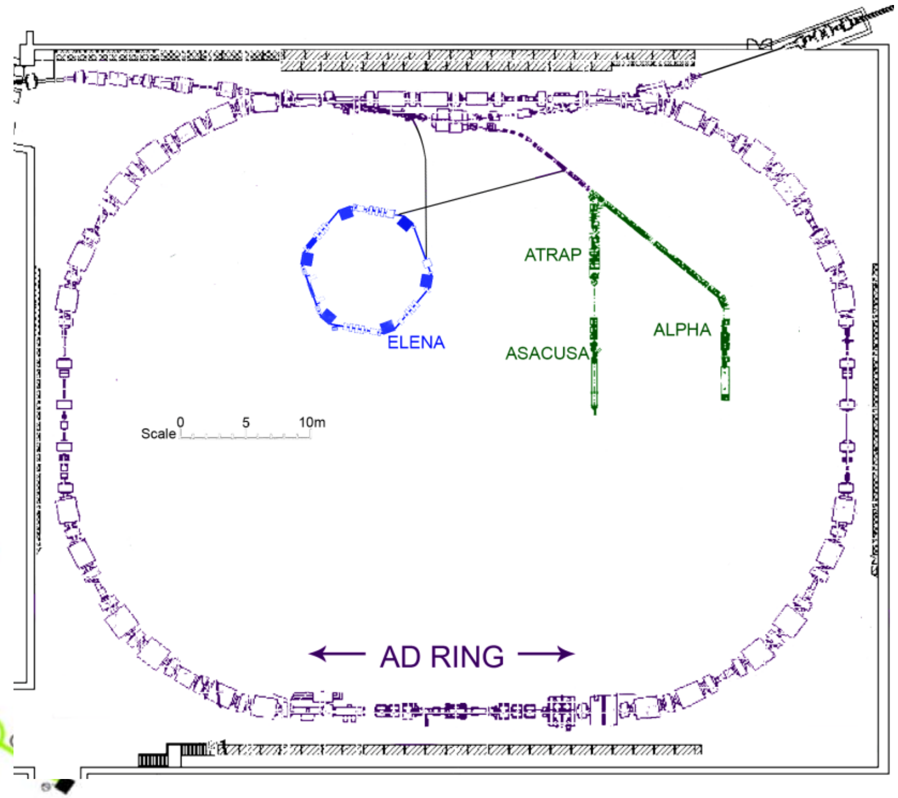
Polarization build-up function

Time constants

$$\boxed{\begin{aligned} \tau_1^{\perp} &= \frac{1}{\tilde{\sigma}_1 Q d_t f}; \\ \tau_1^{\mathrm{II}} &= \frac{1}{(\tilde{\sigma}_1 + \tilde{\sigma}_2) Q d_t f} \end{aligned}}$$

The AD ring at CERN





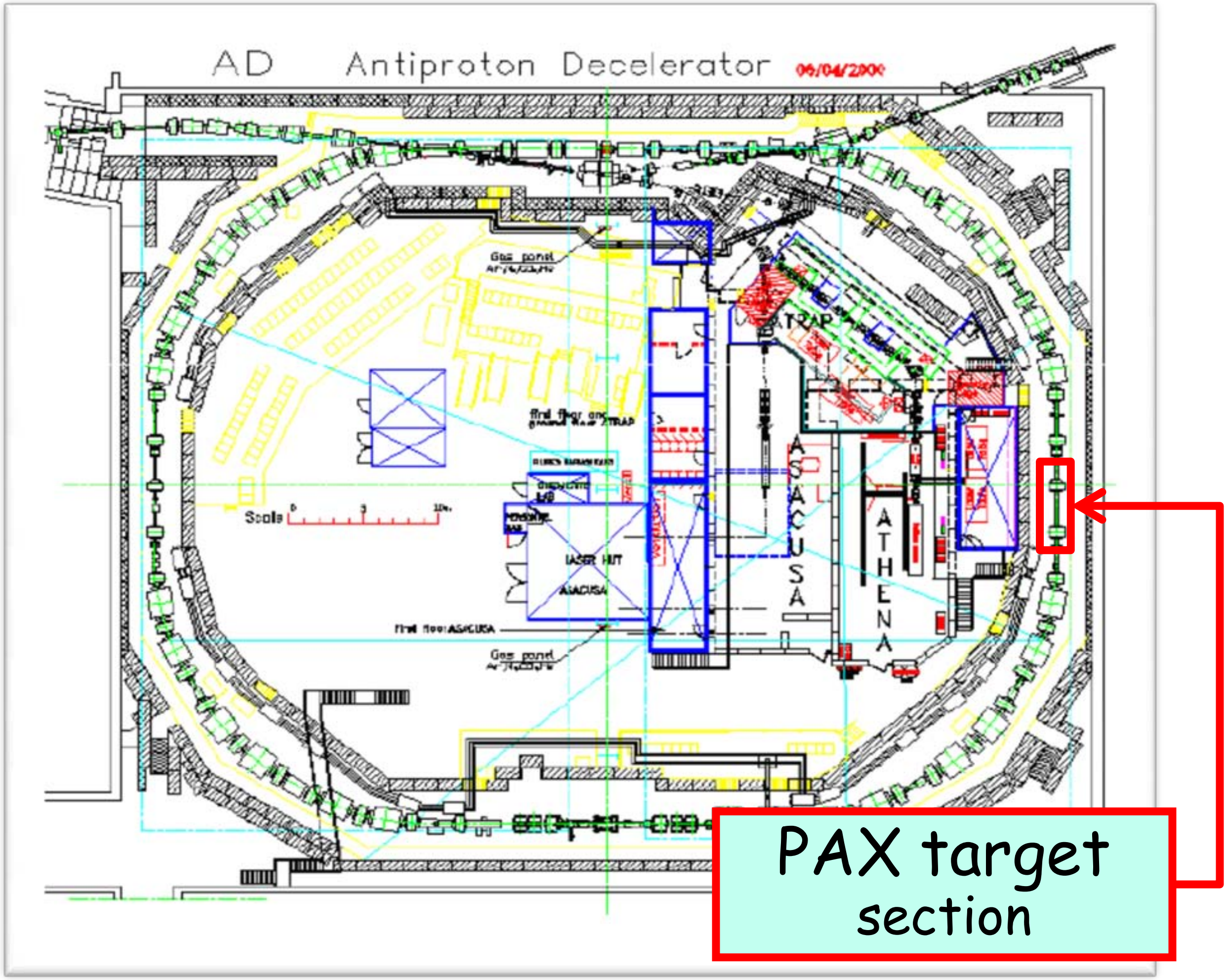
3 $\times 10^7$ pbars

3.57 GeV/c to 50 MeV/c

The AD ring at CERN

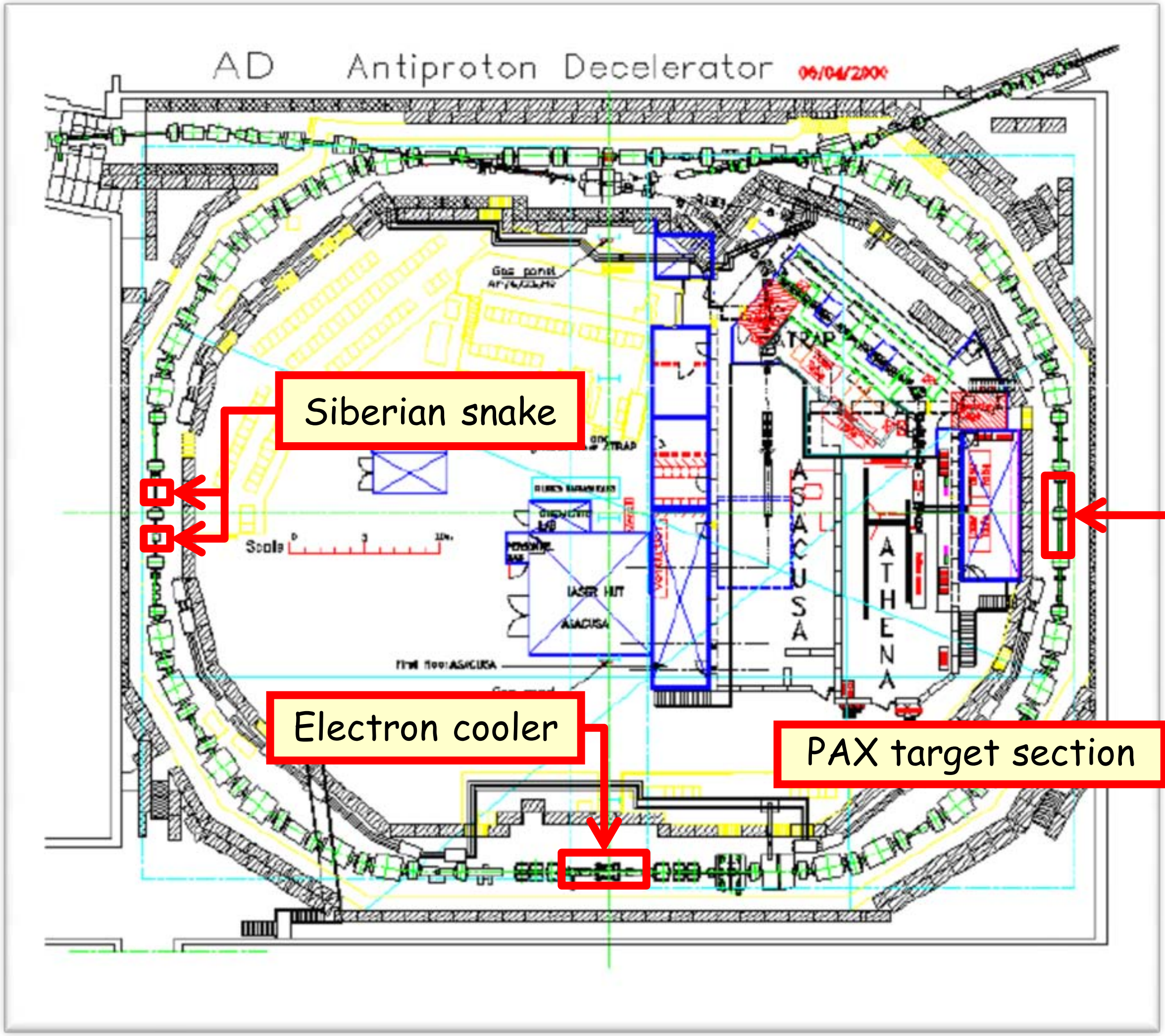
1st measurement of the spin-dependence of the pbar-p cross section

- Method: measurement of polarization build-up by spin-filtering



PAX at the AD: implementations

the foreseen locations of the polarized internal target,
the upgraded electron cooler and the Siberian snake

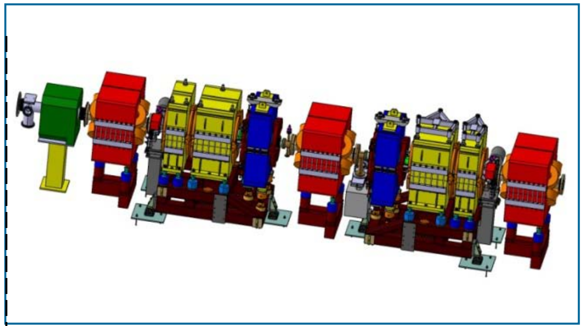


PAX at the AD: implementations

- At injection at 3.57 GeV/c the beam is not yet cooled, the apertures in the target region shall not be restricted by the storage cell
- . For the measurements proposed here, the beam is ramped down to the energies of interest (50-450 MeV).
- The operation of the polarized target requires transporting the stored beam through the narrow storage cell.
- The storage cell must be opened at injection until the beam is ramped down to experiment energy and the 'squeezed' optics is set up.
- **low-β section**: strong focusing with additional quadrupole magnets
- After this is accomplished, the storage cell is closed.
- In the straight section opposite the PIT, **a solenoidal Siberian snake** must be implemented to measure the longitudinal polarization. In this case the beam spin direction has to be longitudinal at the position of the PIT
- A hope: **increasing the number of antiprotons stored in theAD**. After spin filtering for a few beam lifetimes a substantial remaining beam intensity is needed in order to measure the beam polarization

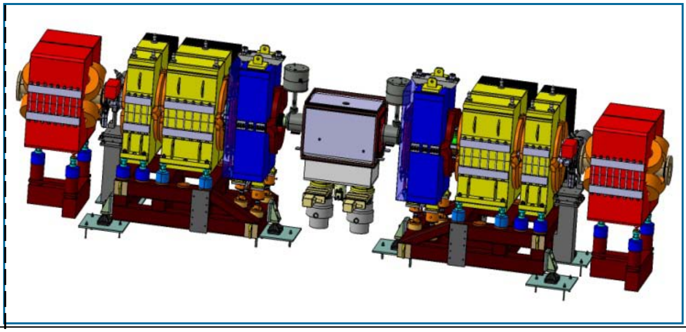
PAX work and Stages of installation at AD

Phase 1



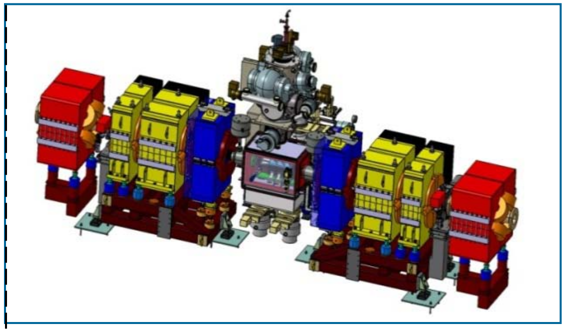
Installation of six magnets for the low-β insertion

Phase 2



Installation of the target chamber: Machine acceptance studies. Stacking studies

Phase 3



Spin-filtering measurements up to 70 MeV with transverse beam polarization

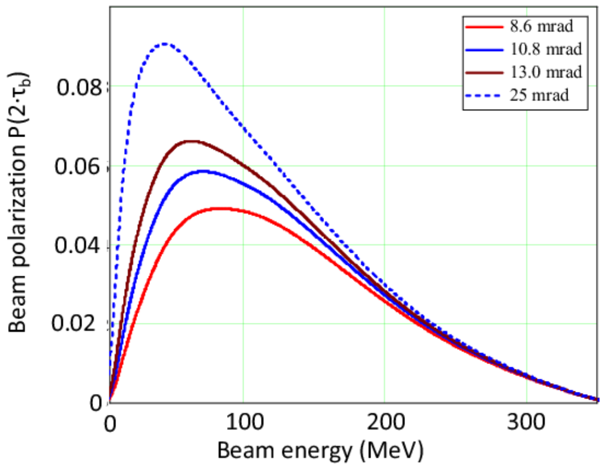
Models and previsions for pbar-p interaction

Expected polarizations after filtering for two lifetimes

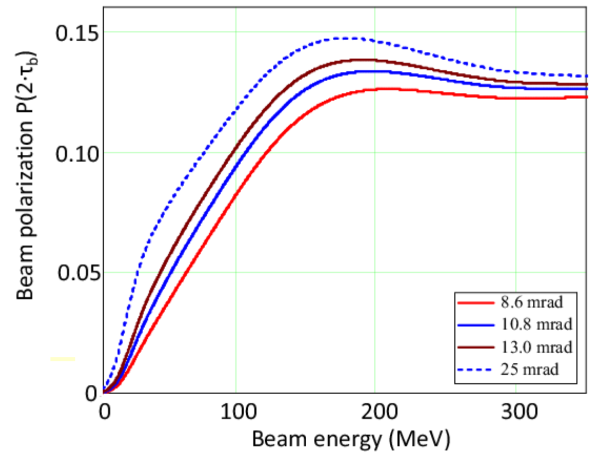
- Measurement of the polarization buildup allows determination of σ_1 and σ_2
- Once pbar polarization available, spin-correlation coefficients accessible

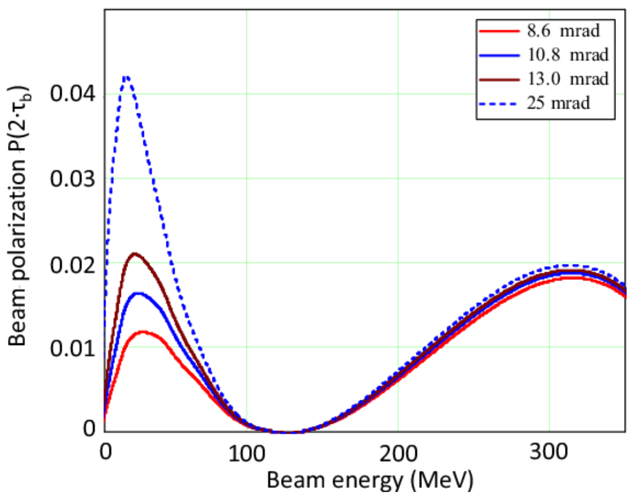
transverse

longitudinal

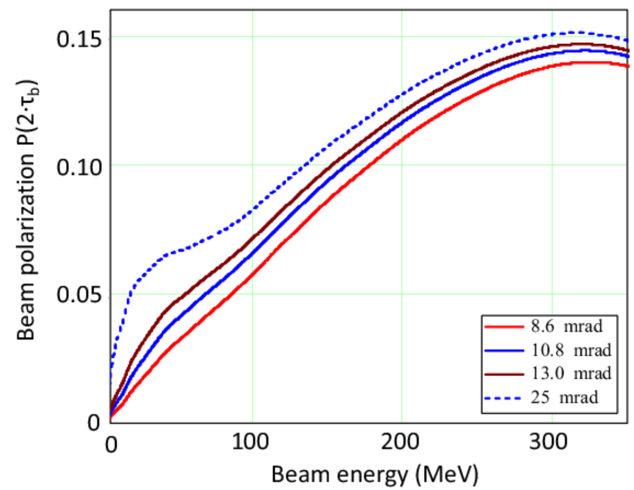


A





D



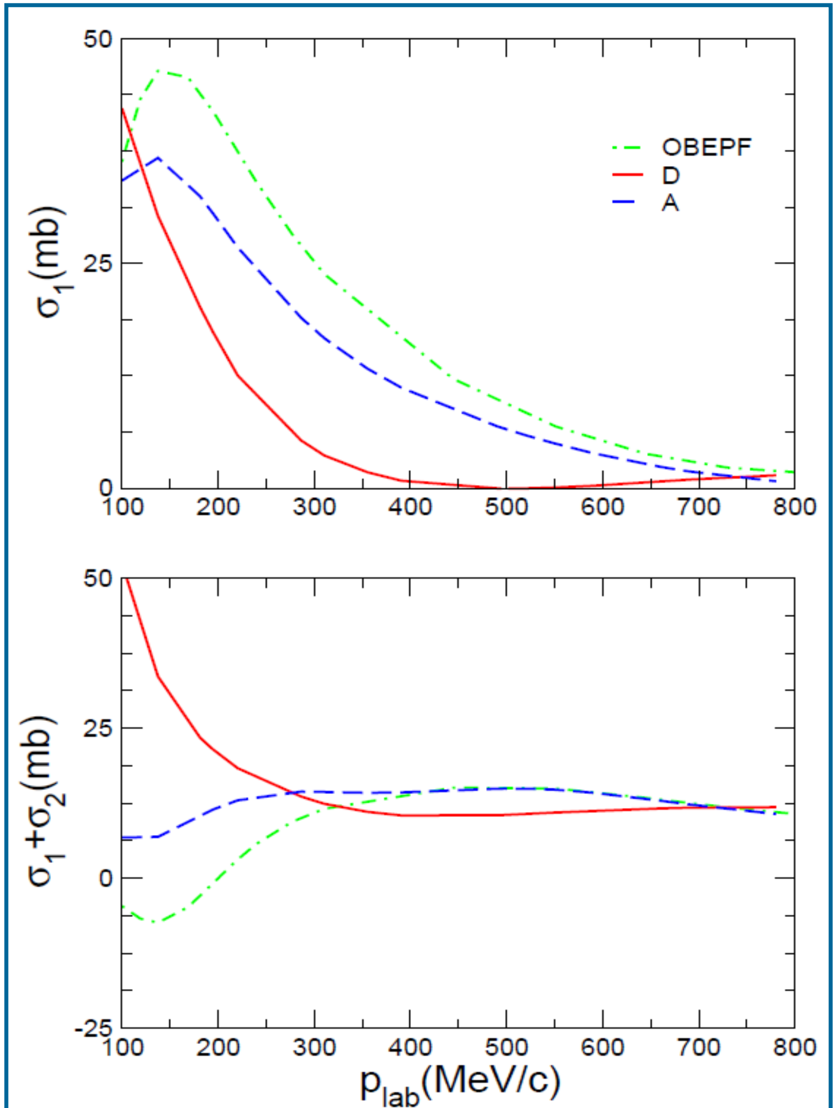
Spin-dependence of the pbar-p interaction

- Measurement of the polarization buildup equivalent to the determination of σ_1 and σ_2
- Once a polarized antiproton beam is available, spin-correlation data can be measured at AD (50-500 MeV)

Model A: T. Hippchen et al., Phys. Rev. C 44, 1323 (1991).

Model OBEPF: J. Haidenbauer, K. Holinde, A.W. Thomas, Phys. Rev. C 45, 952 (1992).

Model D: V. Mull, K. Holinde, Phys. Rev. C 51, 2360 (1995).

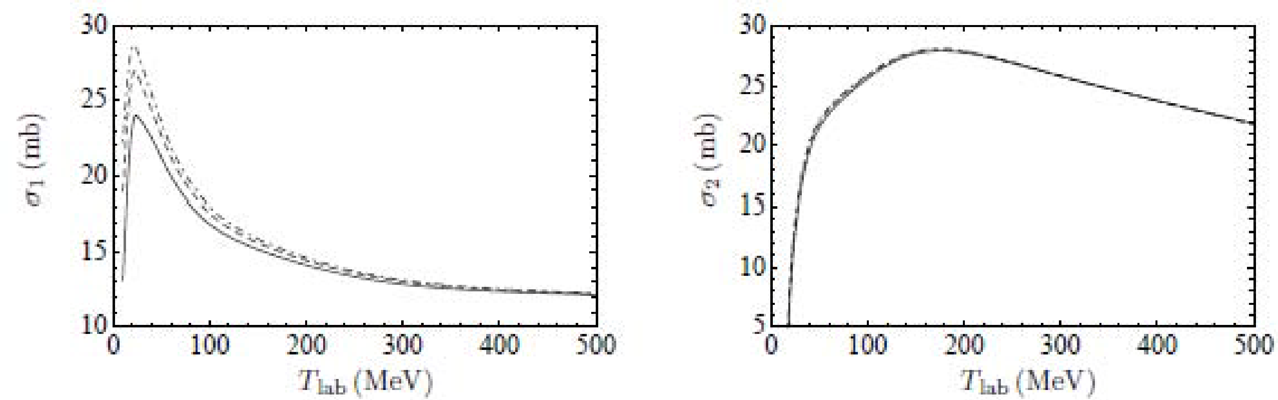


Additional calculations…

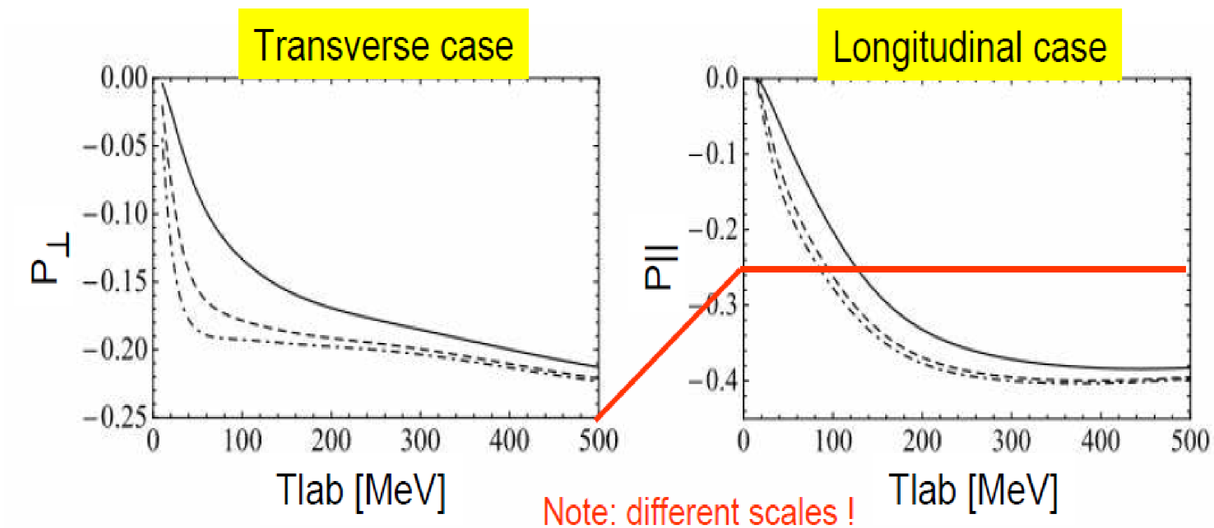
Spin-dependent part of $p\bar{p}$ interaction cross section and Nijmegen potential

V.F. Dmitriev [a,b], A.I. Milstein [a,b], S.G. Salnikov [a,b,*]

PLB 690 (2010)

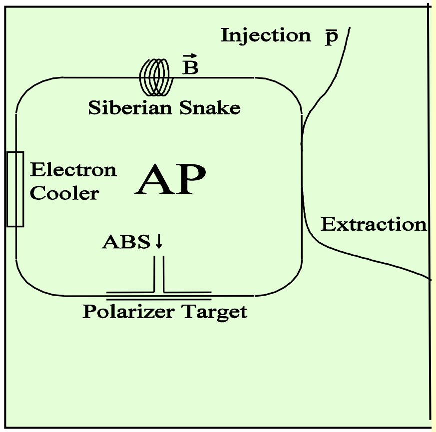


Cross sections



Projected polarizations

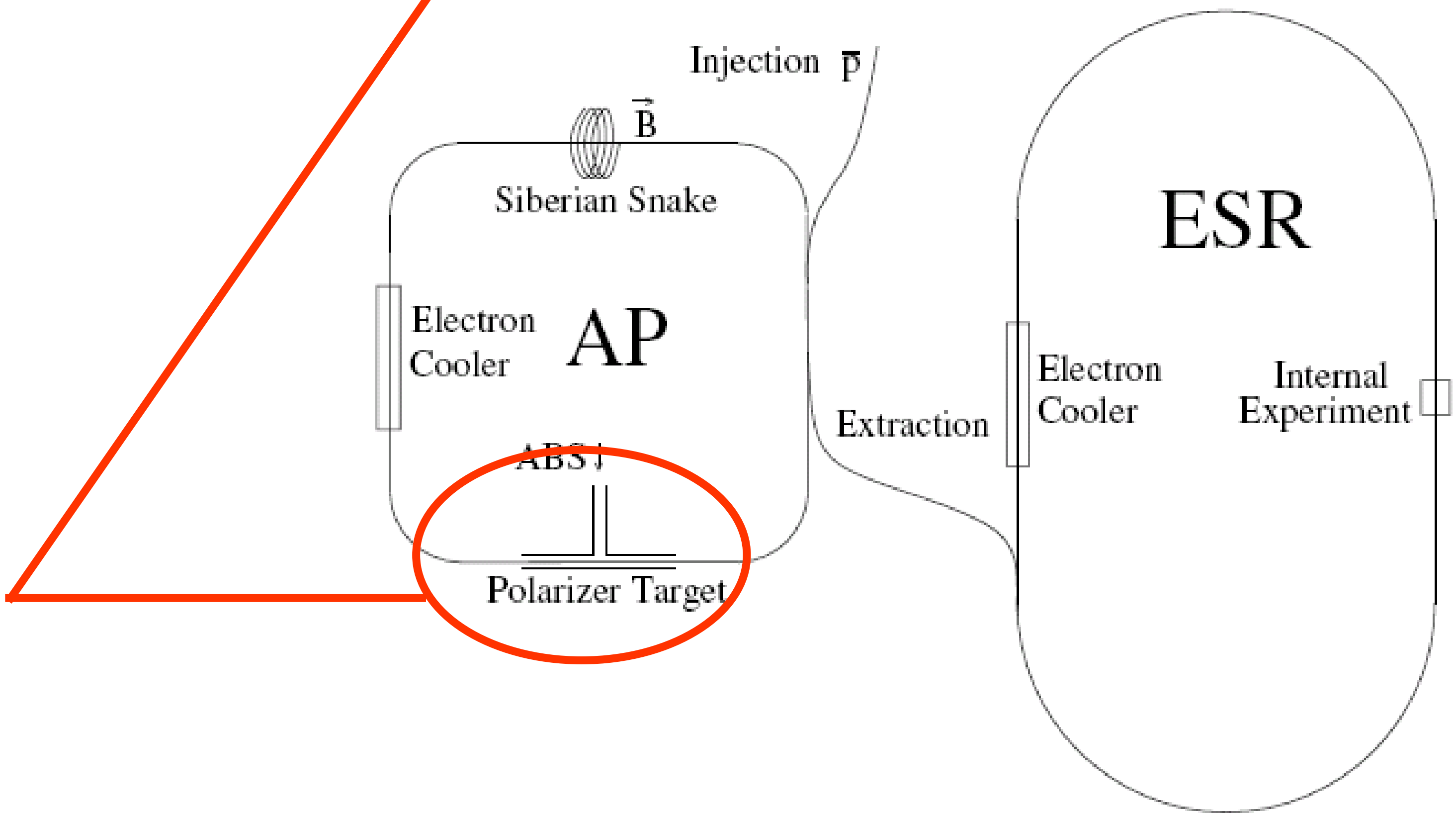
What have we learned



An Antiproton Polarizer Ring (APR) seems a necessary item. It will be optimized after the tests on the building-up of the polarization

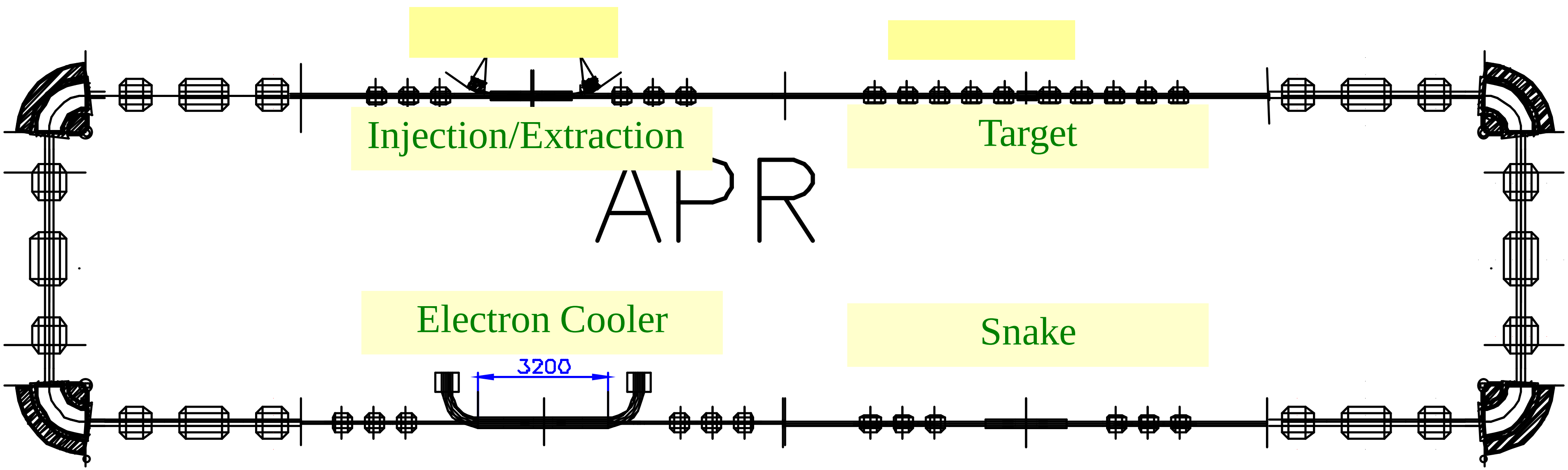
PAX Accelerator Setup

Spin filtering



Antiproton Polarizer Ring (APR)

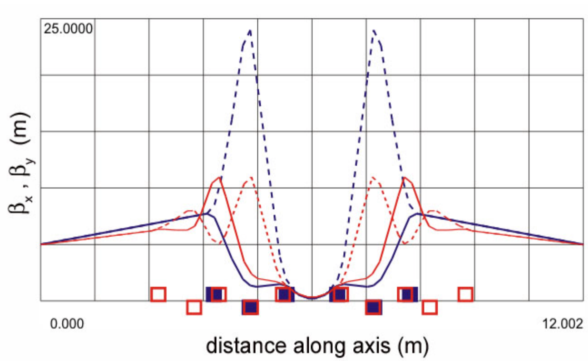
Final configuration after spin-filtering studies



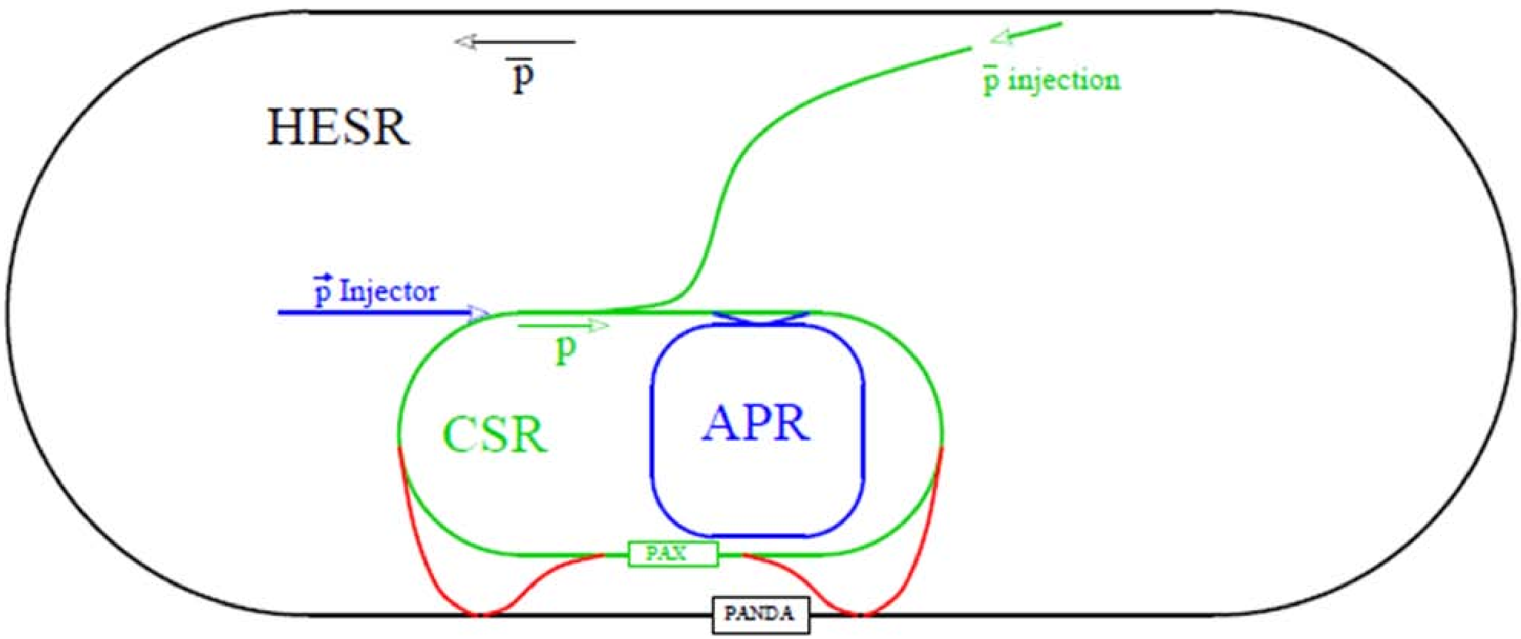
Atomic Beam Source (ABS) parameter	
ABS flow in feeding tube	$1{,}5\cdot10^{17}$ /s
Storage cell length	40 cm
Feeding tube diameter length	1 cm 15 cm
Long. holding field	300 mT
Electron polarization	0.9
Cell temperature	100 K

Ring Parameter	
Beam energy	250 MeV
Number of antip.	10^{12}
Ring acceptance	250 mm mrad
Betatron ampl. at IP	< 0.3m
Ring circumference	86,5 m
Snake strength	2.4 Tm

Ion-optics at IP



The PAX collaboration proposes an asymmetric proton-antiproton collider, in which polarized protons with momenta of about 3.5 GeV/c, circulating in CSR, collide with polarized antiprotons with momenta up to 15 GeV/c. circulating in HESR . APR is the antiproton polarizer ring.



CSR

APR, beam transfer lines and polarized proton injector

Transfer lines: an asymmetric collider is set up.

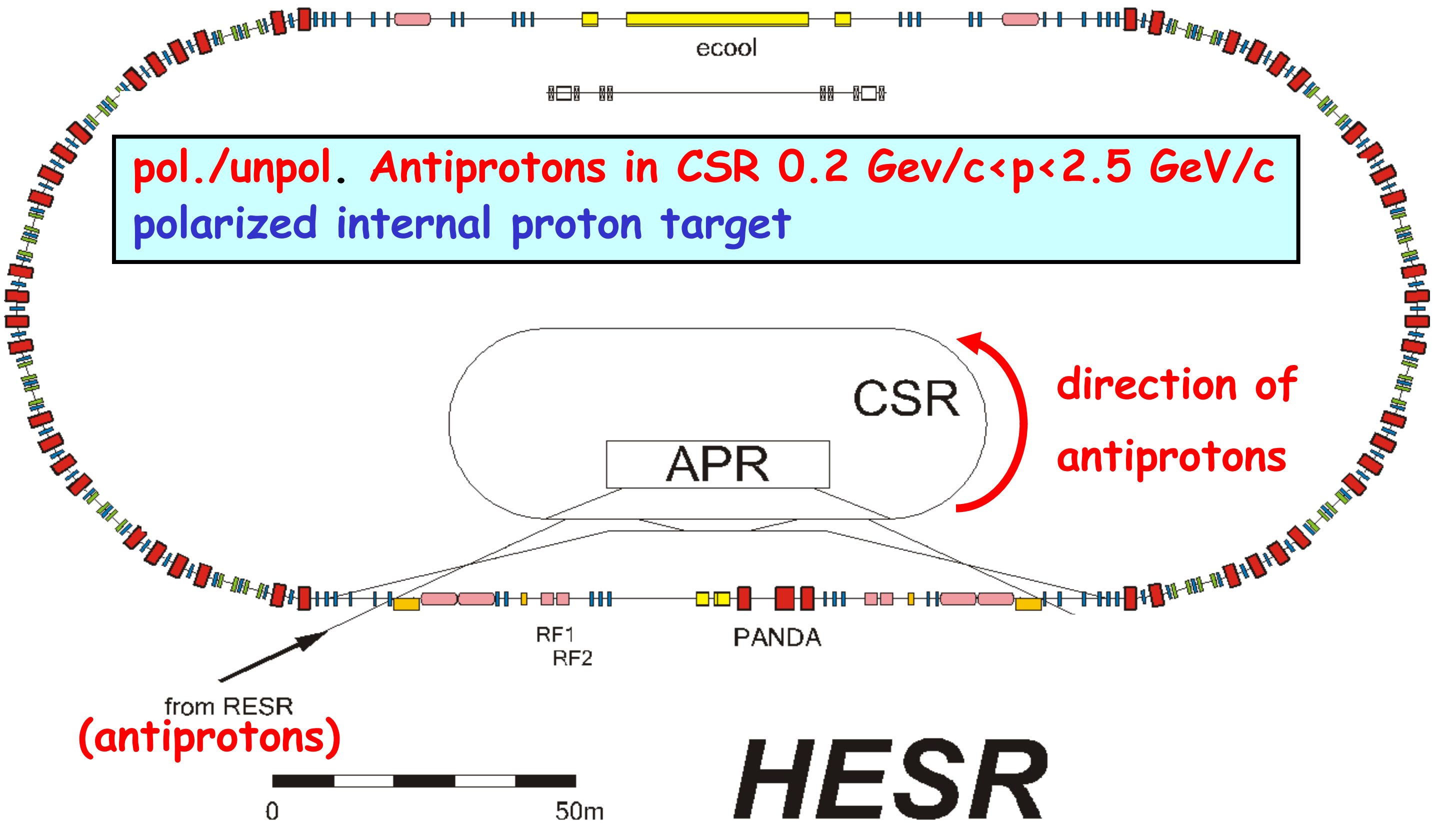
1. An Antiproton Polarizer Ring (APR) built inside the HESR area to polarize antiprotons at kinetic energies around ≈ 50 MeV to be accelerated and injected into the other rings.

2. A second Cooler Synchrotron Ring (CSR, COSY-like) in which protons or antiprotons can be stored with a momentum up to 3.5 GeV/c. This ring shall have a straight section, where a PAX detector could be installed, running parallel to the experimental straight section of HESR.

3. By deflection of the HESR beam into the straight section of the CSR, both the collider or the fixed-target mode become feasible.

Phase I: Fixed target experiments in CSR

Physics: **EMFF**
pbar-p elastic



pol./unpol. Antiprotons in CSR 0.2 Gev/c<p<2.5 GeV/c
polarized internal proton target

direction of antiprotons

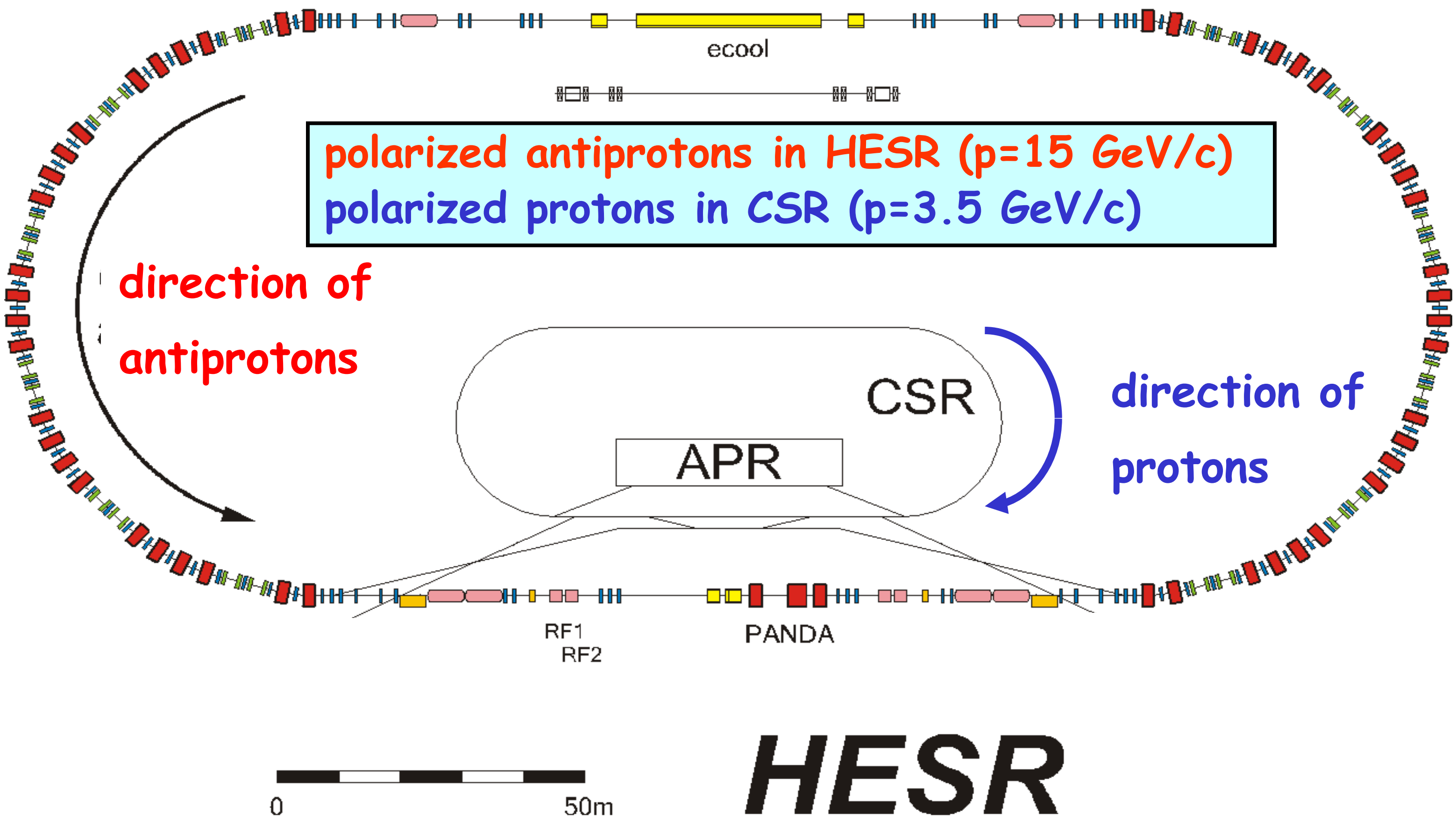
(antiprotons)

Independent from HESR running

Phase II: Asymmetric Proton-Antiproton Collider

Physics: Transversity
EMFF
pbar-p elastic

polarized antiprotons in HESR (p=15 GeV/c)
polarized protons in CSR (p=3.5 GeV/c)



Physics with
Polarized Antiprotons
At HESR

Among meny items, the possibility to investigate **the annichilation proton-antiproton in double spin, near threshold** is in my opinion of the utmost importance

Luminosity Considerations for Collider Mode

	"old"		"new"	
	CSR	HESR	CSR	HESR
Particle species	protons	antiproton	antiprotons	proton
Momentum / GeV/c	3.65	15	3.65	15
Number of bunches	10	30	-	-
Total number of particles	10^{12}	$3\cdot10^{11}$	0.02	0.006
Beam lifetime / h	~ 45	~ 800	~ 1500	~ 300
Peak luminosity / $cm^{-2}\ s^{-1}$	$1.6\cdot10^{30}$		$1.2\cdot10^{31}$	

$\boxed{L>10^{31}s^{-1}cm^{-2}}$

Antiprotons in HESR -> protons

Bunched beams -> coasting

The end ?