Perspectives for polarized antiprotons

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Università di Ferrara and INFN - Italy

MENU 2013 – Rome, September 3rd 2013

Motivation

- The PAX collaboration proposed to investigate Drell Yan processes in scattering of polarized proton - antiproton beams at the HESR (FAIR).

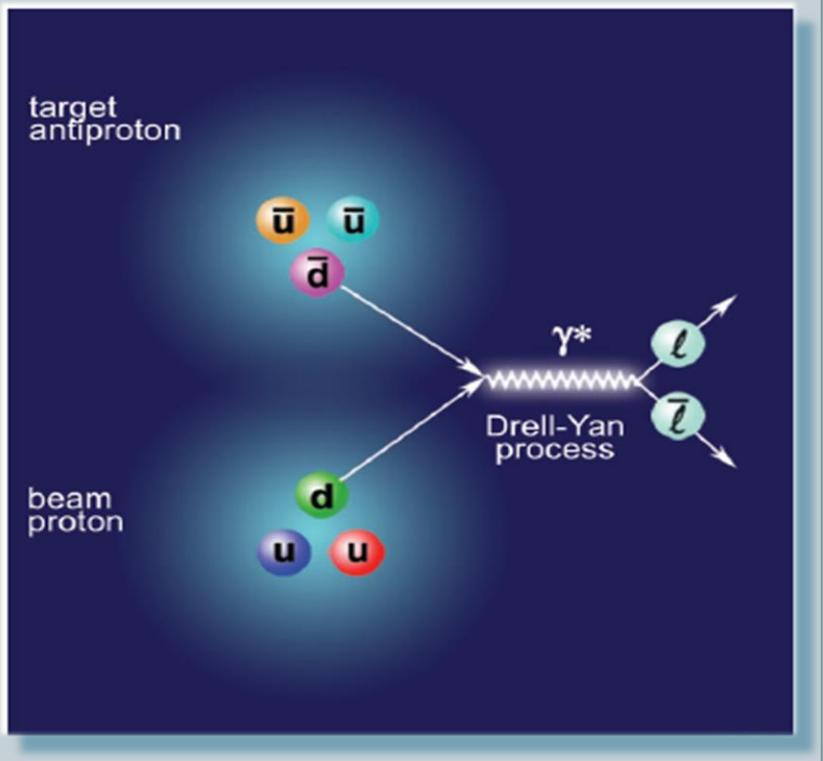
- Annihilation of valence quark with an antivalence quark allows direct access to: transversity, ….

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

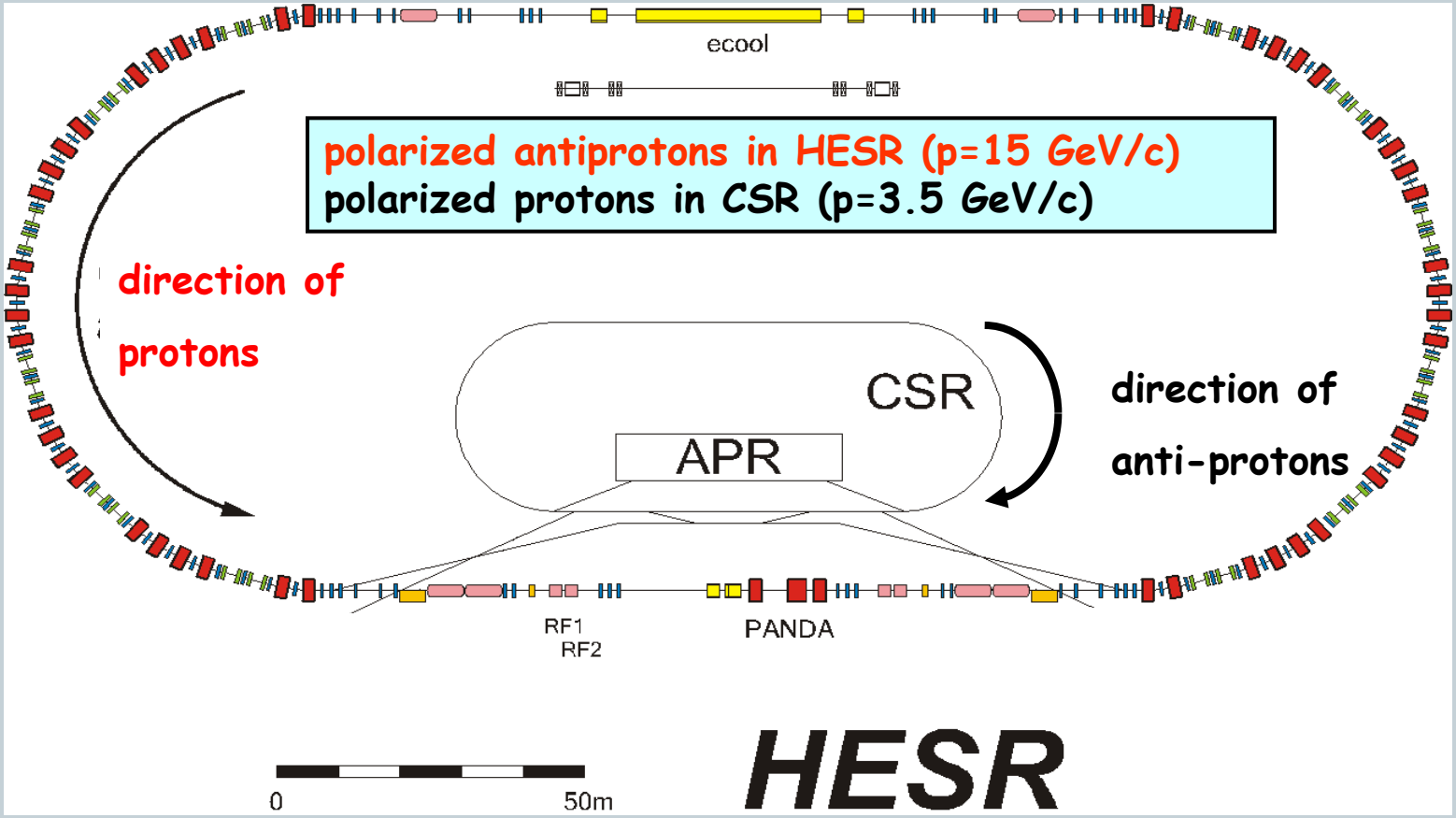
- **Requirements:**

  Polarized proton beam ✓

  Polarized antiproton beam ✗



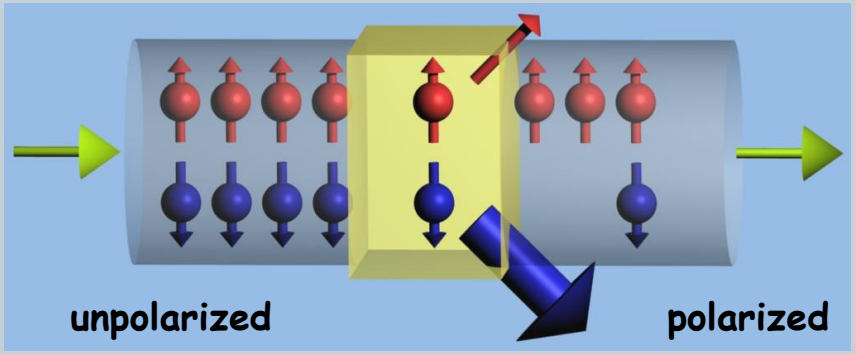
A polarized Proton-Antiproton Collider at FAIR



How to Polarize Antiprotons?

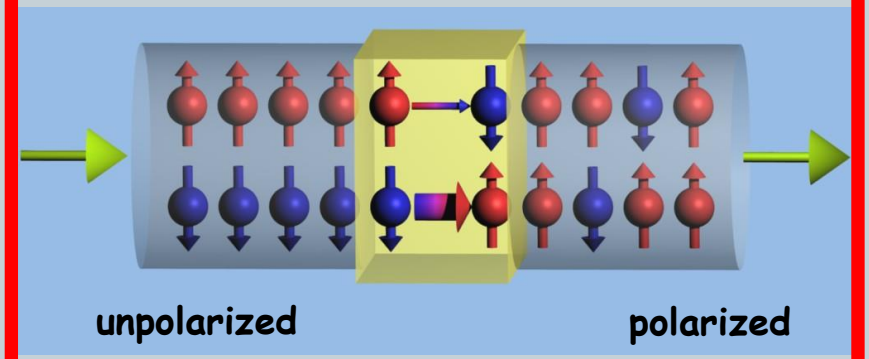
- Spin-1/2 particles ⟶ 2 states

selective removal



- Reduces beam intensity

selective flip



- Does not affect intensity

Selective-flip: a proposal

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.

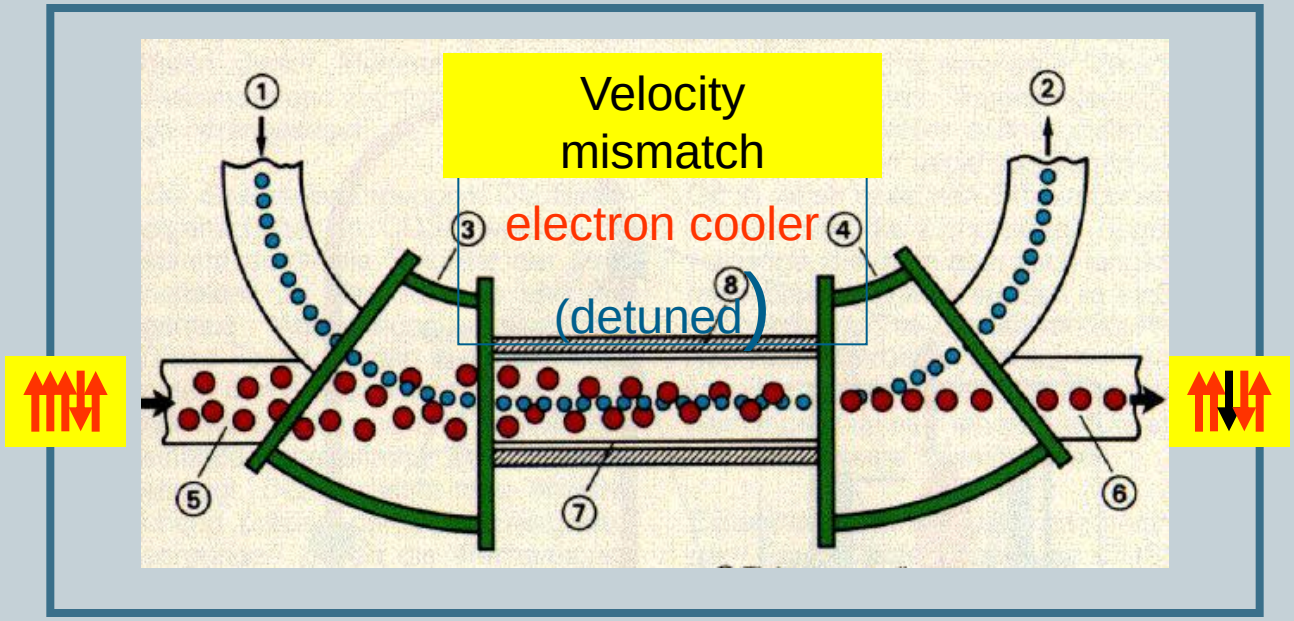
PACS. 13.88.+e Polarisation in interactions and scattering – 29.20.Dh Storage rings – 29.25.Bx Electron sources – 29.27.Hj Polarised beams

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

Spin-flip studies at COSY

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

  i.e. observe **depolarization** of a polarized proton beam

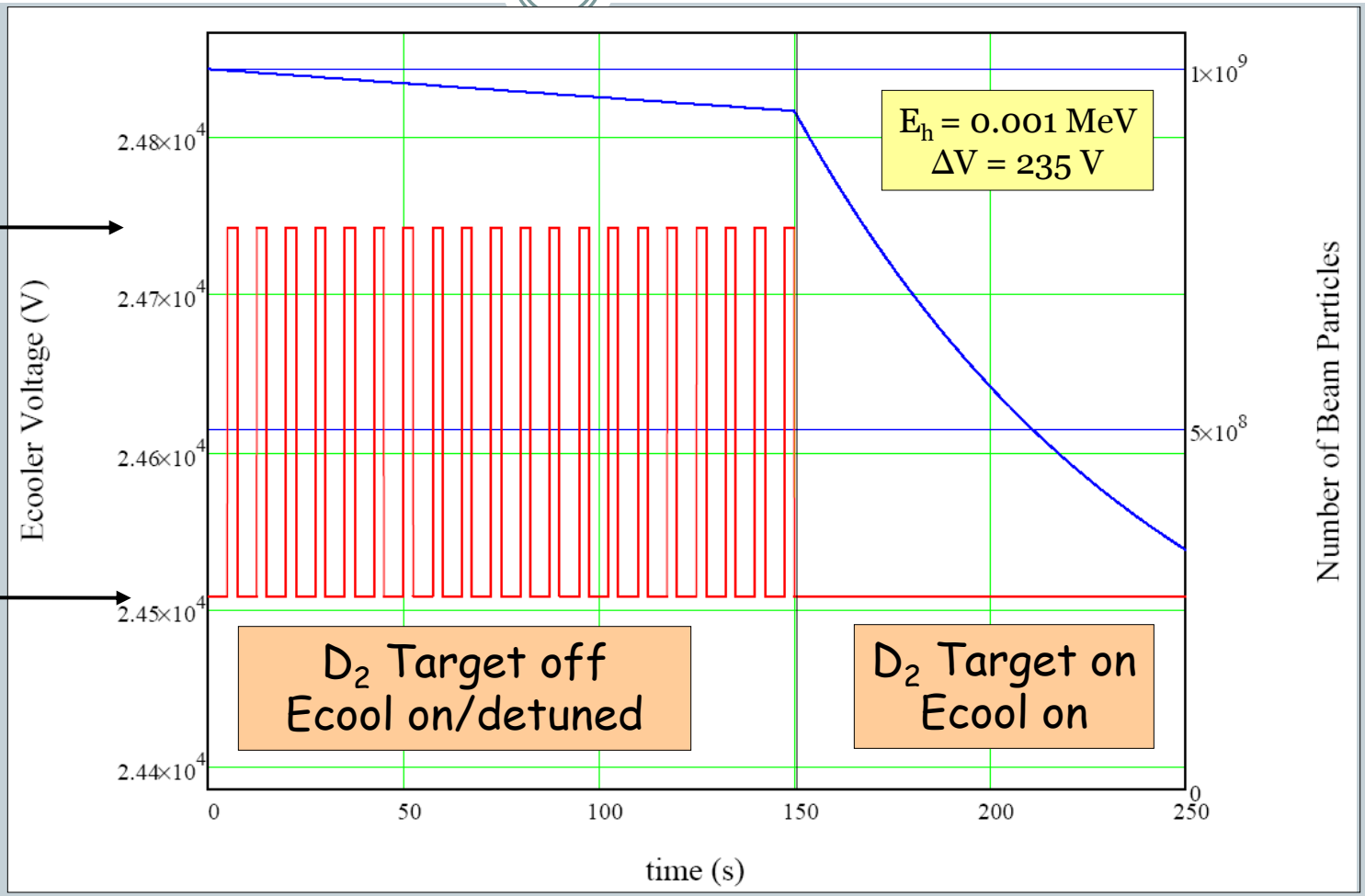


Measurement cycle

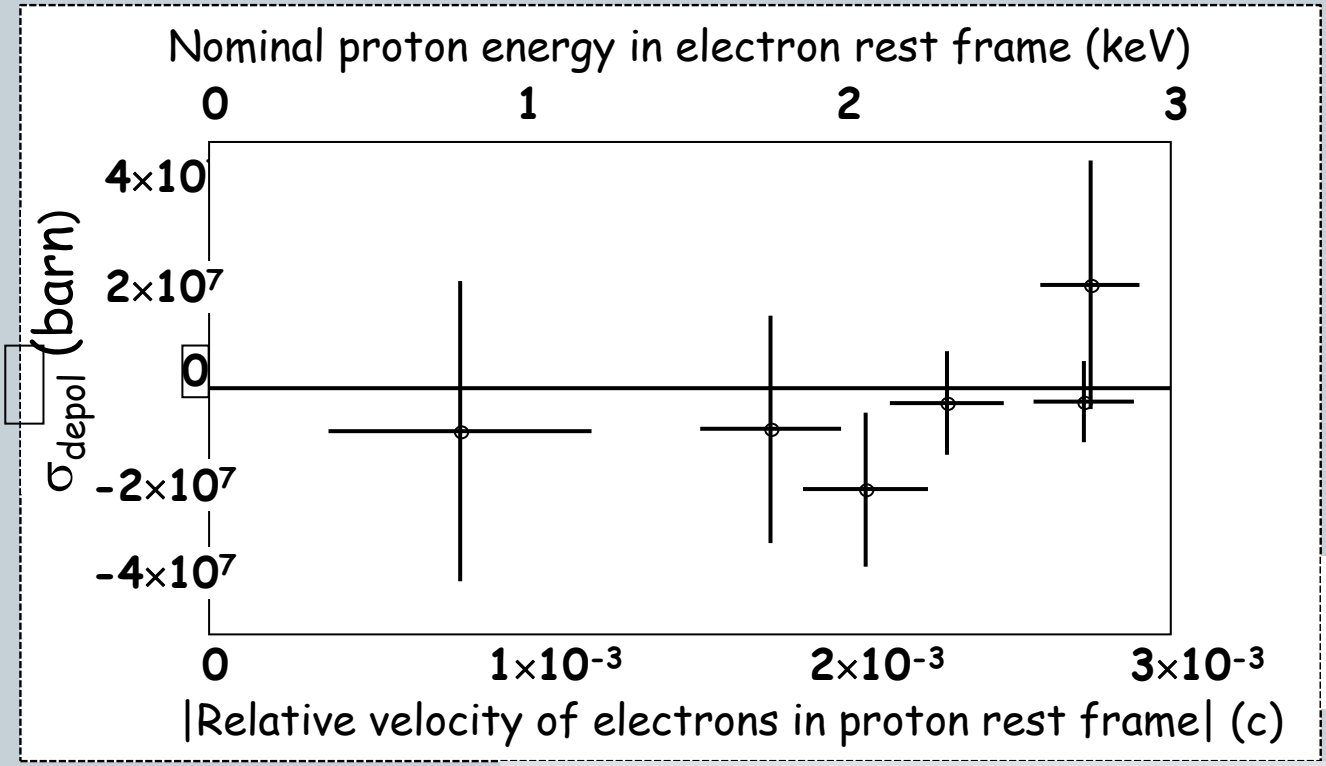
Detuned Cooler Voltage
$T_{detuned}$= 50 s

Nominal Cooler Voltage
$T_{nominal}$ = 100 s

$$\frac{T_{nominal}}{T_{detuned}} = 2$$



Spin-flip: results



$\sigma_{\parallel} < 3.2 \times 10^{7}$ b

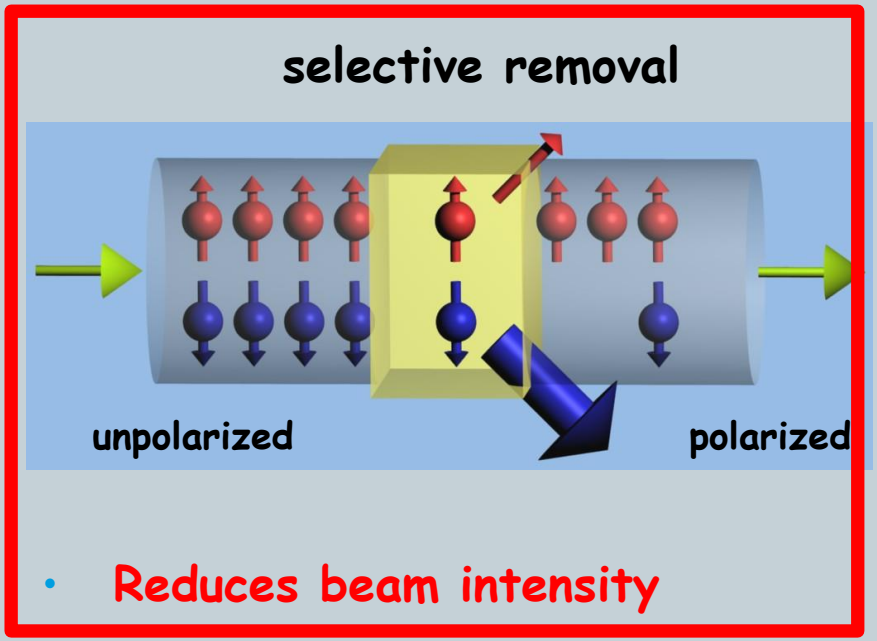
$\sigma_{\perp} < 1.7 \times 10^{7}$ b

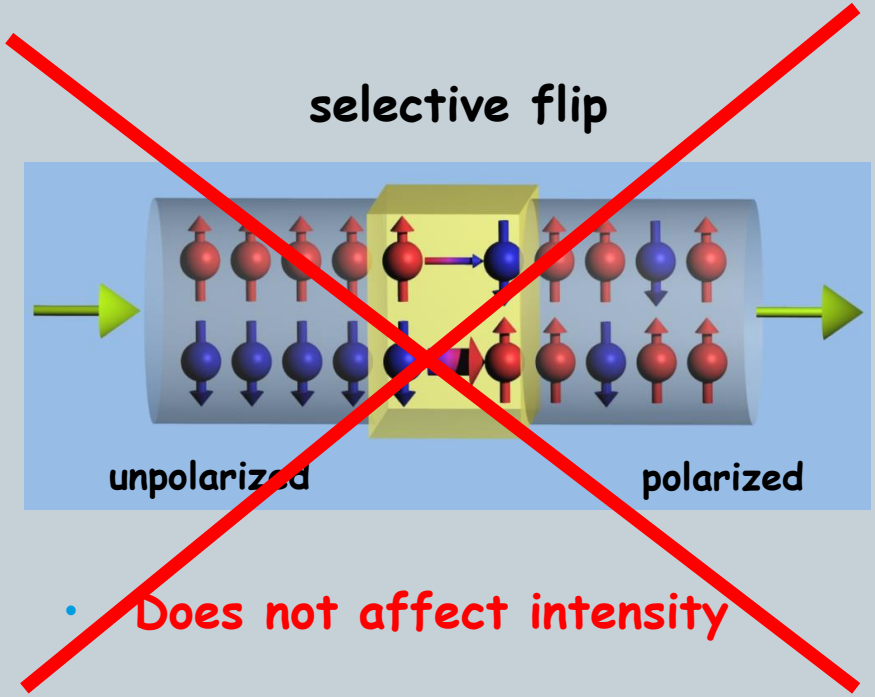
D.Oellers et al., Physics Letters B 674 (2009) 269

RESULT: Selective flip: e^{+} pbar spin-flip cross-section is too low

How to Polarize Antiprotons?

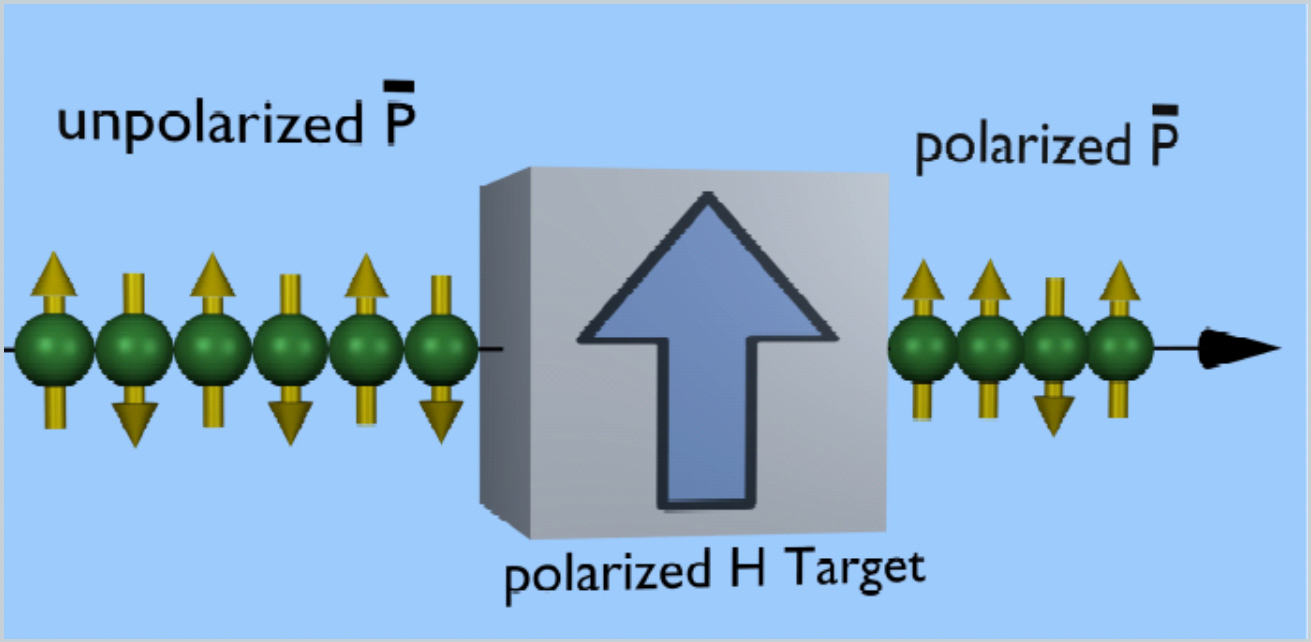
- Spin-1/2 particles ⟶ 2 states





Spin-filtering

Polarization build-up of a circulating particle beam by interaction with a polarized gas target

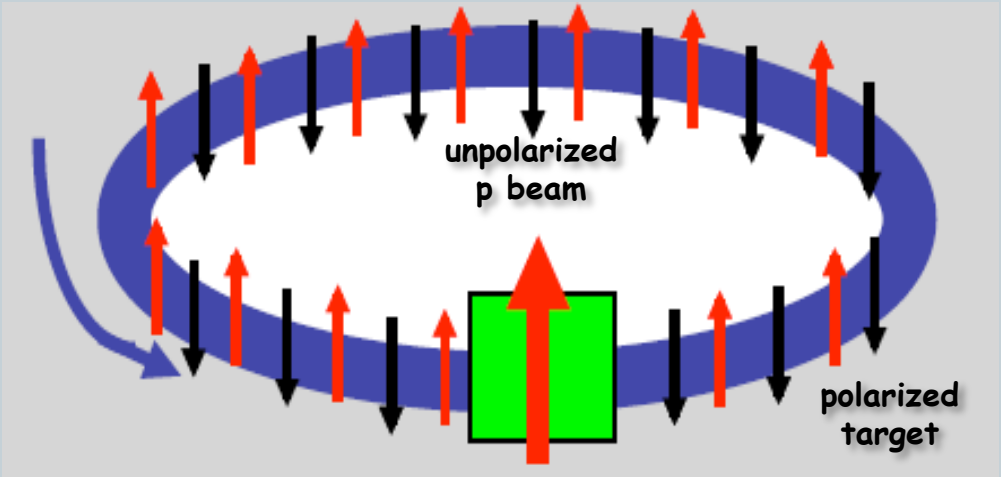


Spin-filtering

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

P…beam particle spin orientation
Q…target particle spin orientation
k // beam direction

$$P(t) = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow} = \tanh\left(\frac{t}{\tau_1}\right) \approx t\cdot\tilde{\sigma}_1\cdot Q\cdot d_t\cdot f$$



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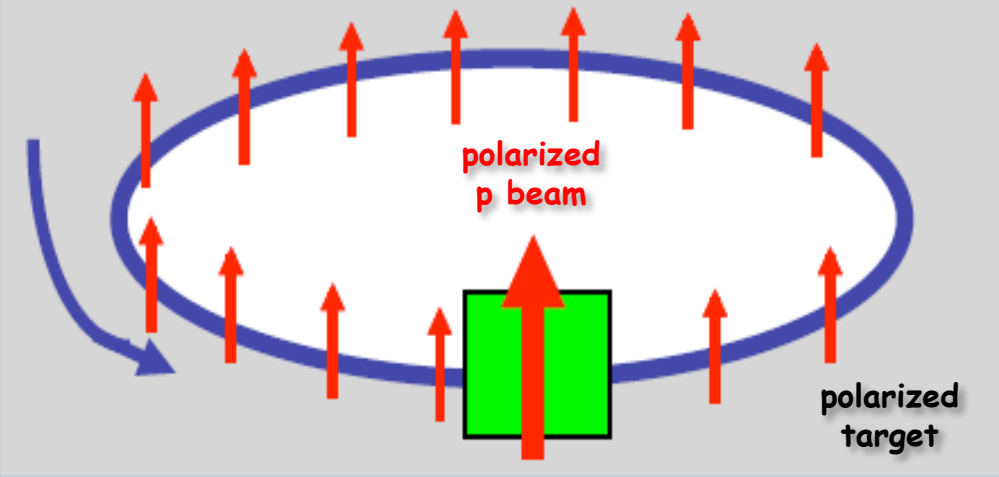
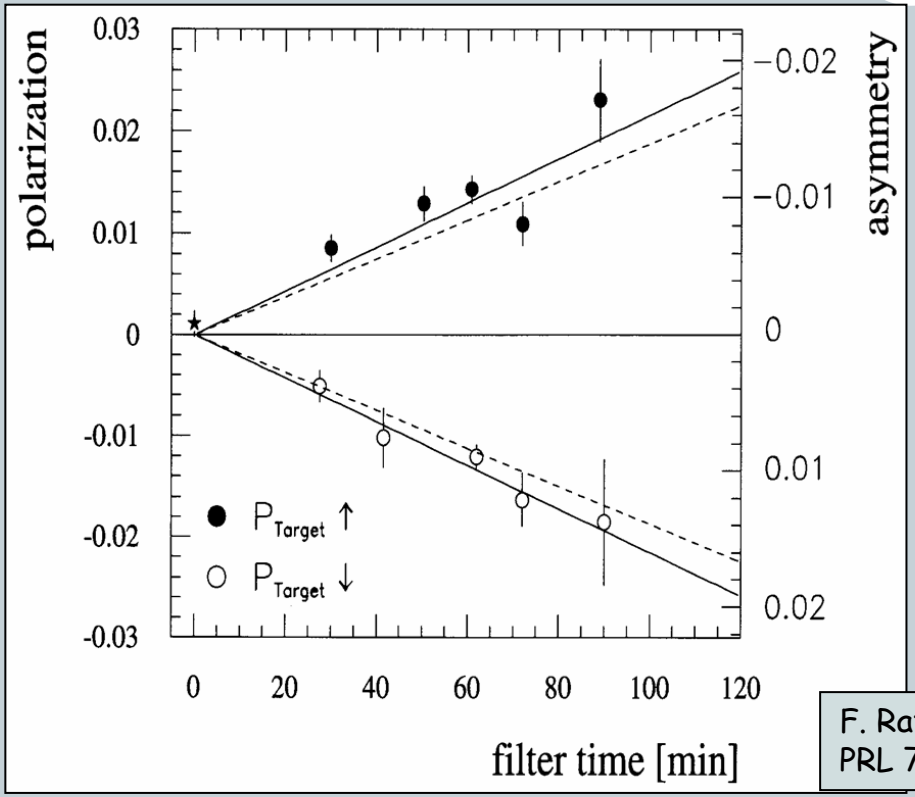


1992: Filter Test at TSR with protons



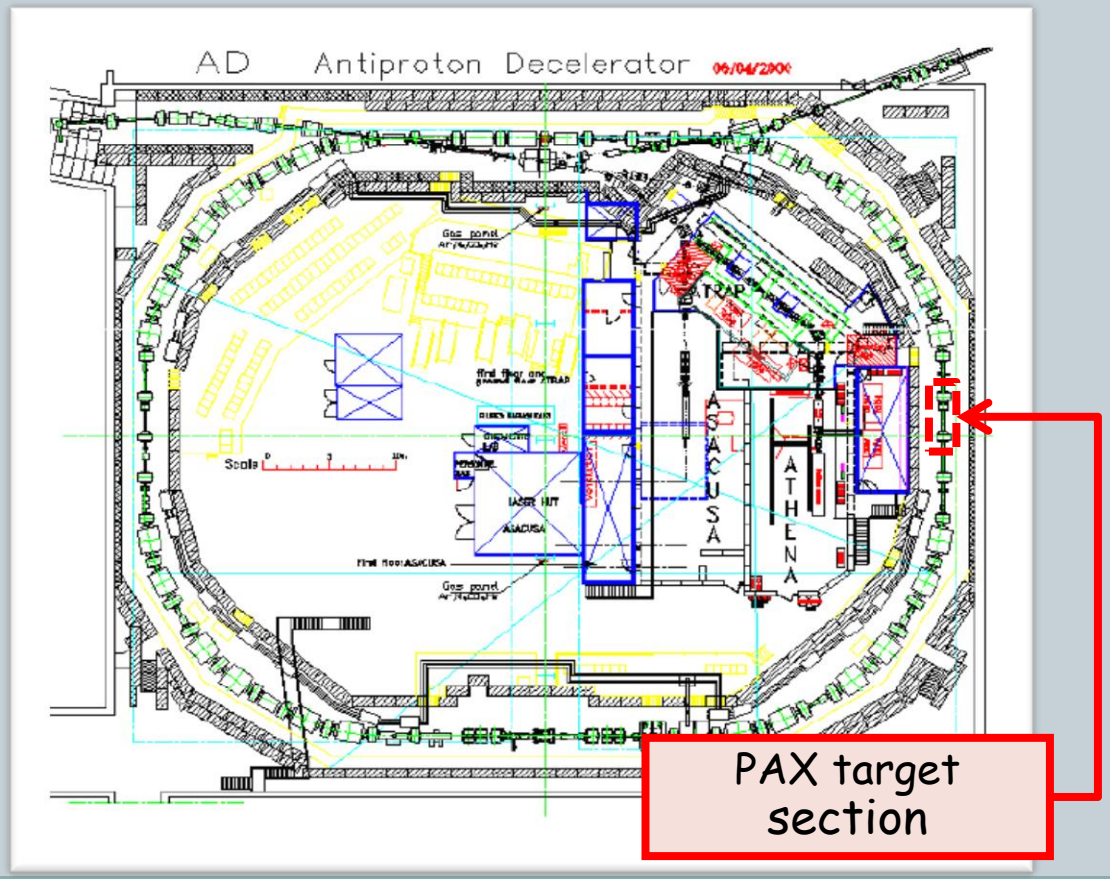
F. Rathmann. et al.,
PRL 71, 1379 (1993)

Spin filtering works
for protons

PAX submitted new proposal to find out how well does spin filtering work for antiprotons
Measurement of the Spin-Dependence of the pp Interaction at the AD Ring
(CERN-SPSC-2009-012 / SPSC-P-337)

Measurements at AD (CERN)

- Aim: 1st measurement of the spin-dependence of the pbar-p cross section
- Method: measurement of polarization build-up by spin-filtering

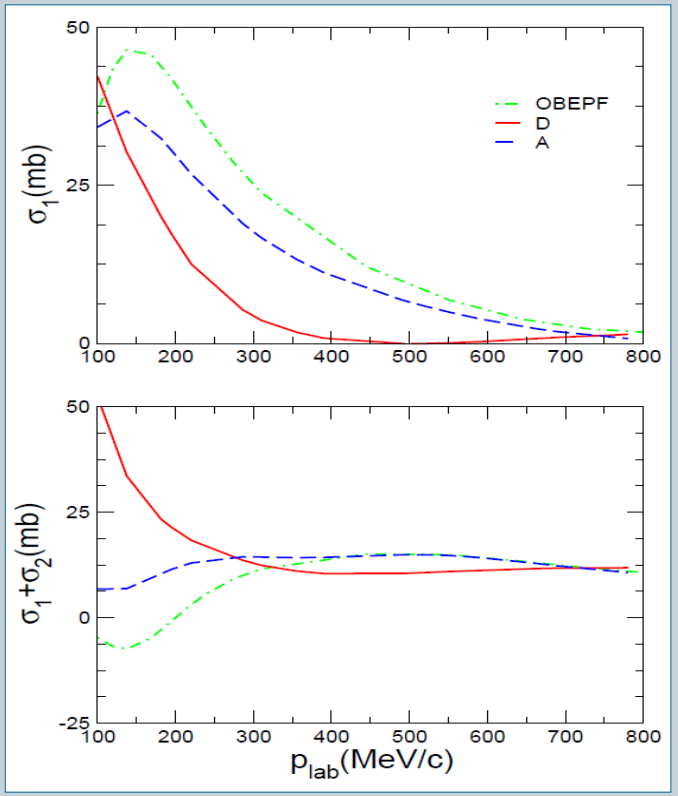


Spin-dependence of the pbar-p interaction

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).



Oct. 2009 SPS Committee:

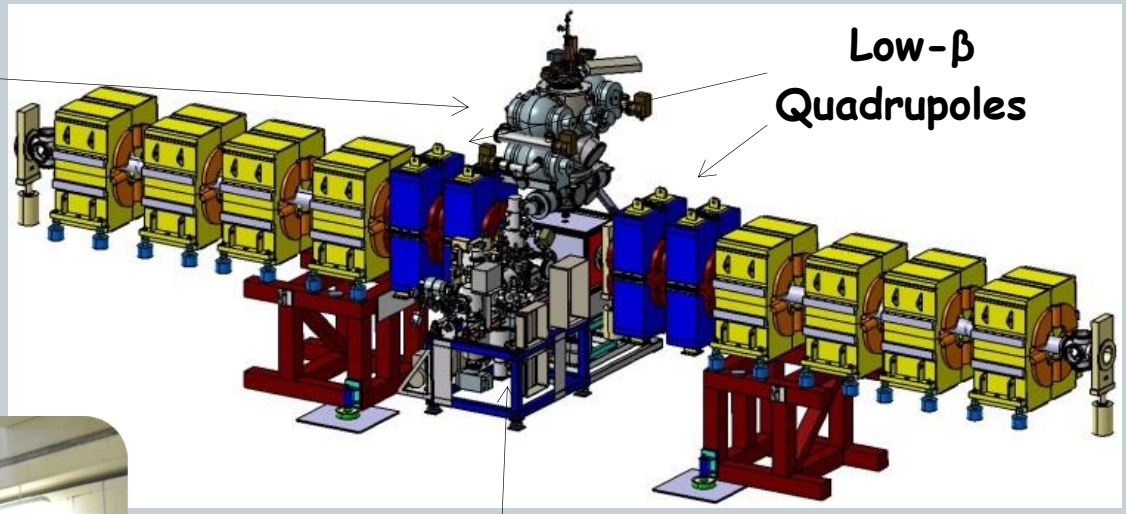
… Taking into account the timeline and constraints of the various projects concerned, the SPSC **encourages the PAX Collaboration to first perform their spin filtering measurements at COSY…**

Spin Filtering at COSY

Spin filtering with protons for better understanding of the underlying processes and commissioning of the experimental setup

- Length: 183.4 m
- Injection energy: 45 MeV
- Electron cooling for long lifetimes up to 600 MeV/c (p)

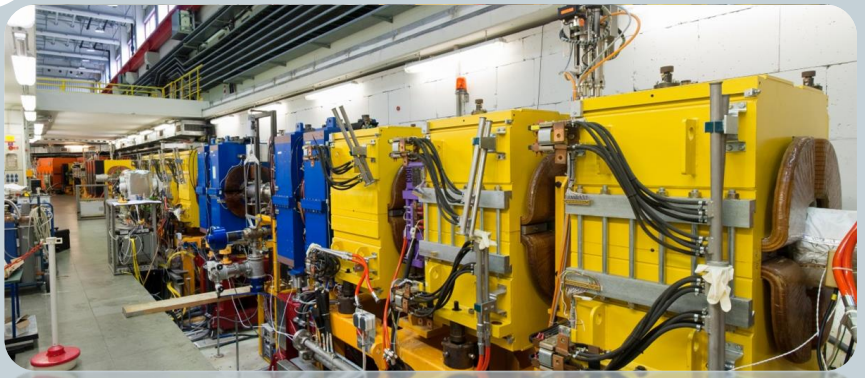
Experimental setup at PAX-IT



Low-β section

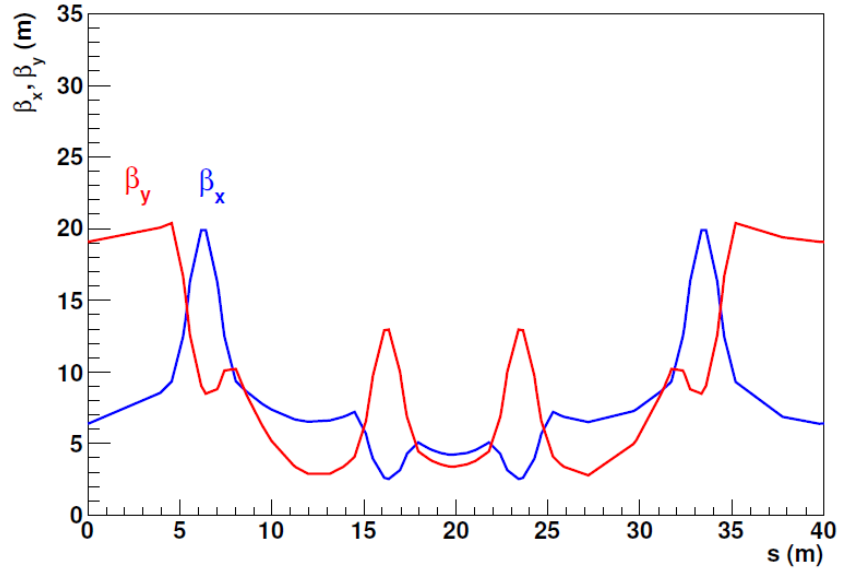
Beam lifetime τ:

$$\tau \propto \frac{1}{d_t \cdot \beta}$$



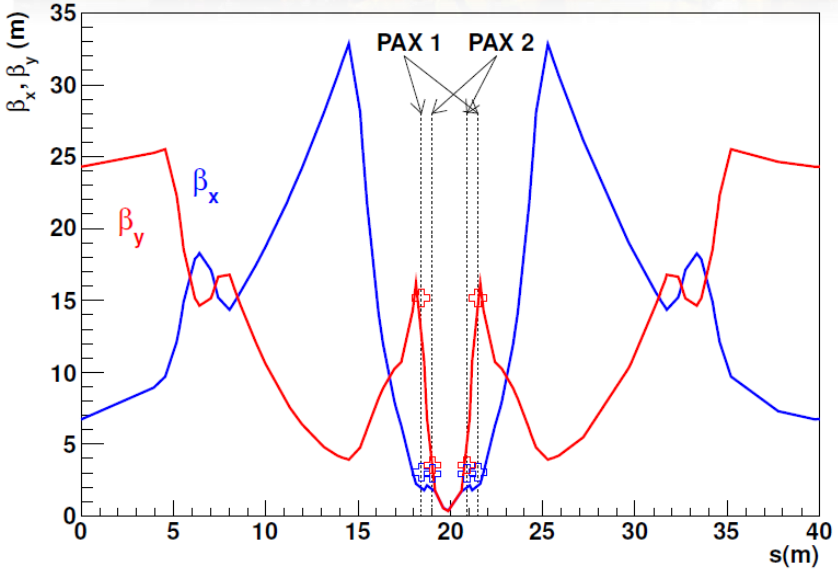
Low-β section off

PAX OFF

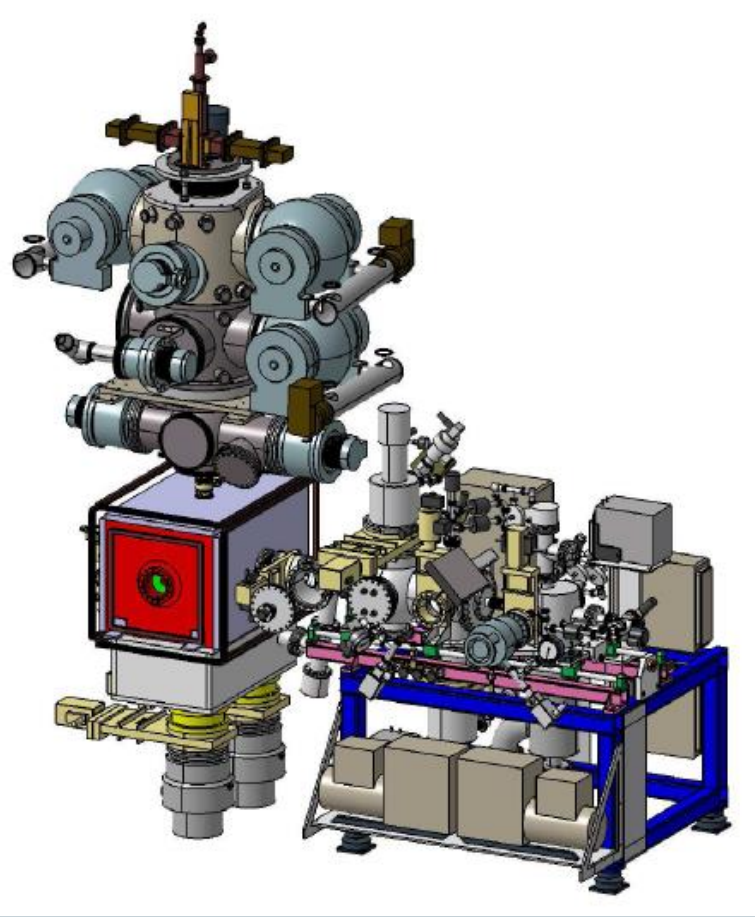


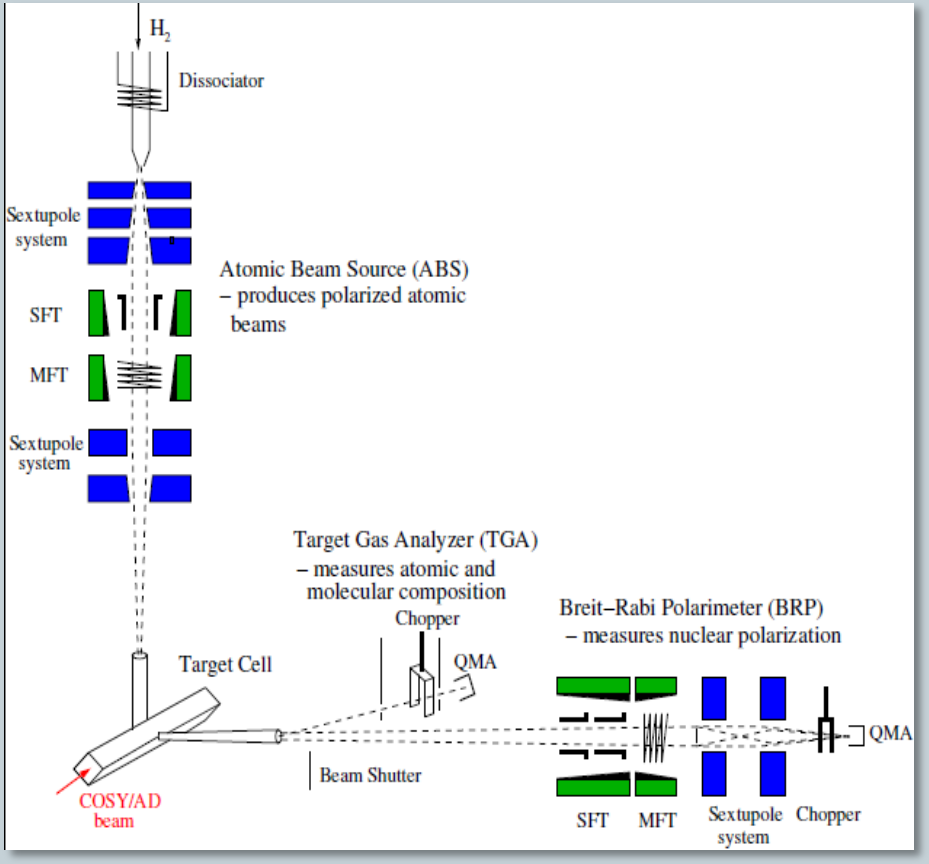
Low-β section on

PAX ON

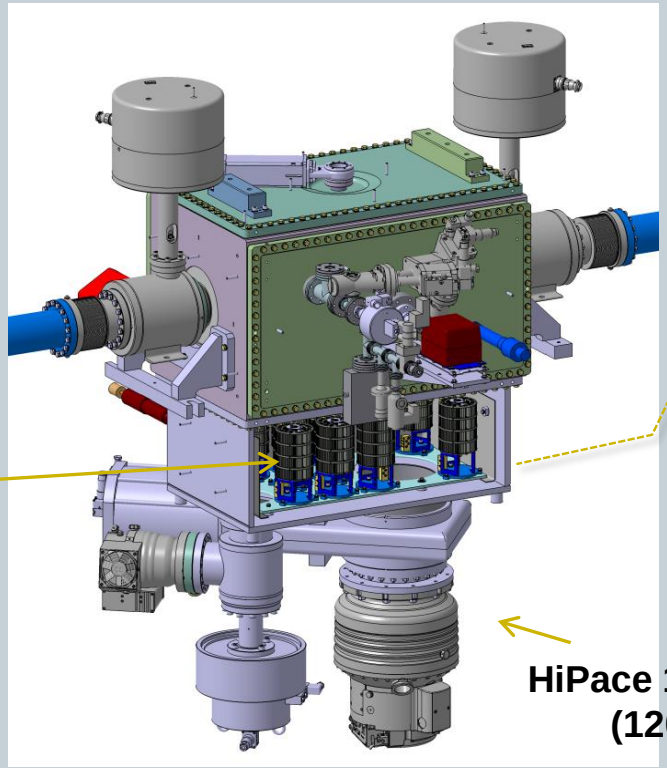


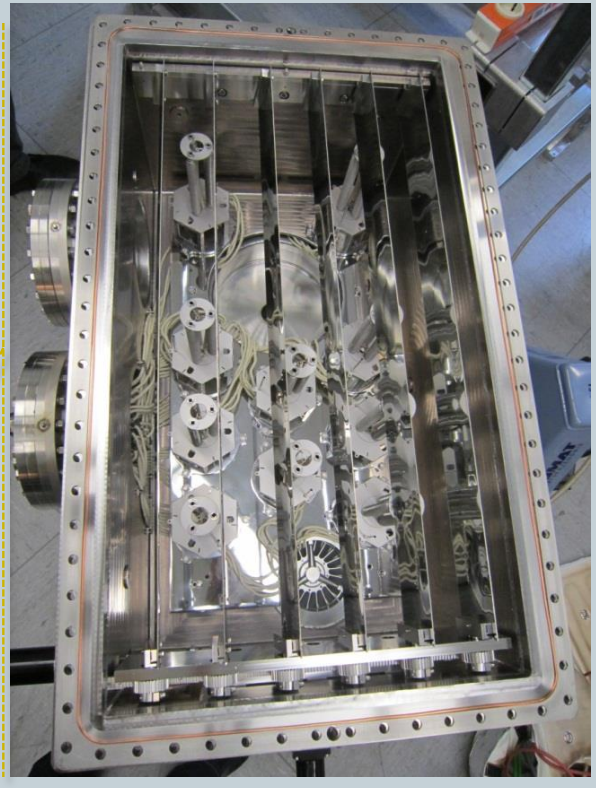
Atomic Beam Source



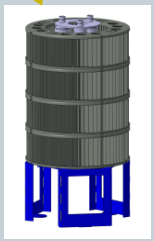


Target chamber





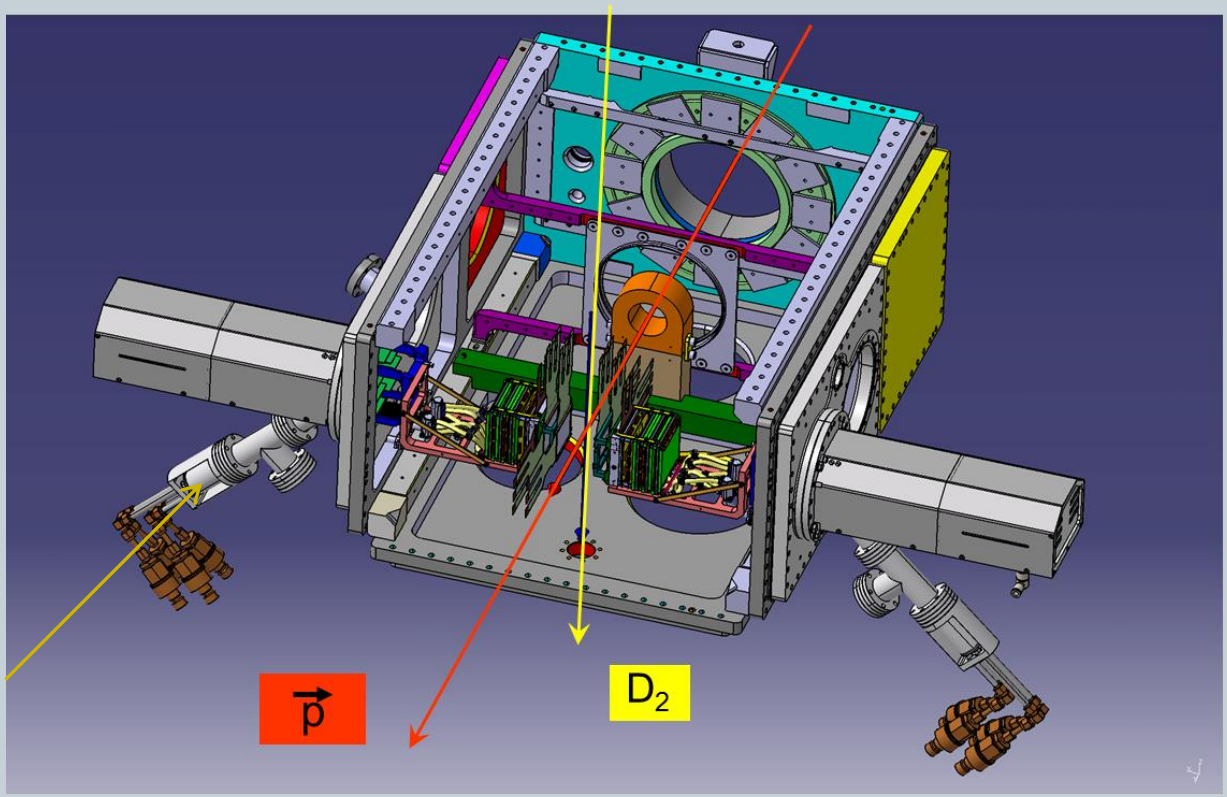
SAES getter pump
(each 1900 l/s)



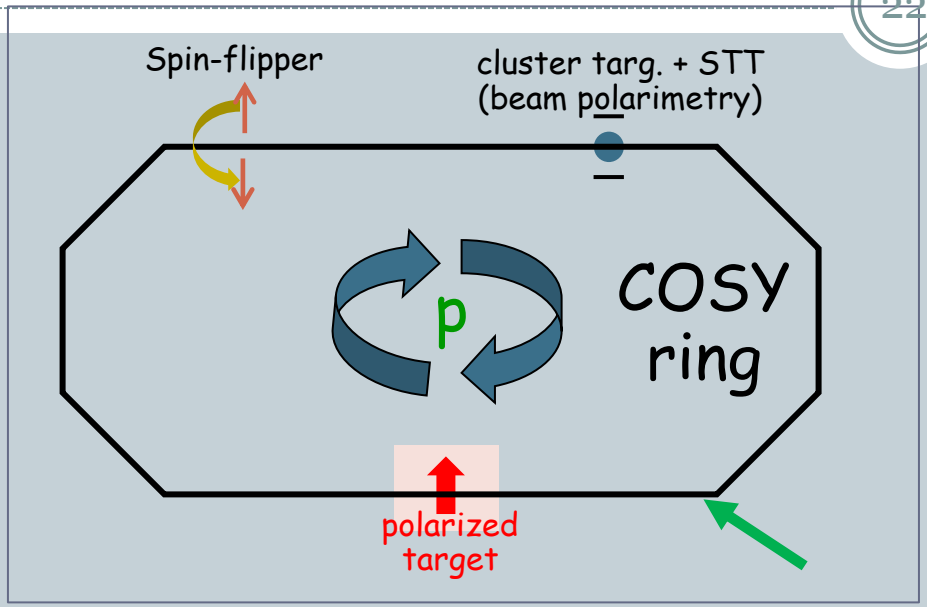
HiPace 1800 turbo
(1200 l/s)

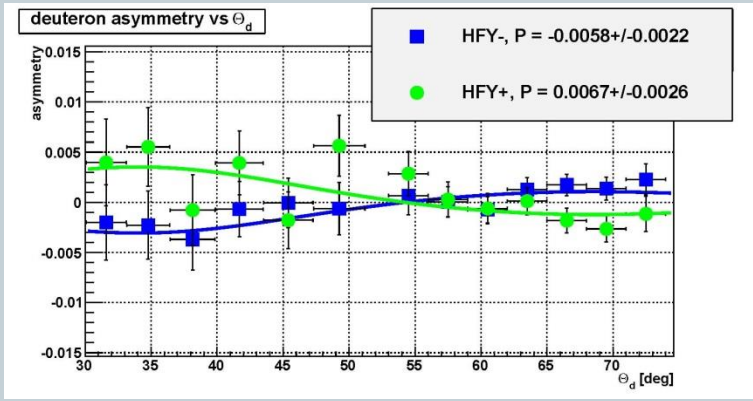
Beam polarimeter

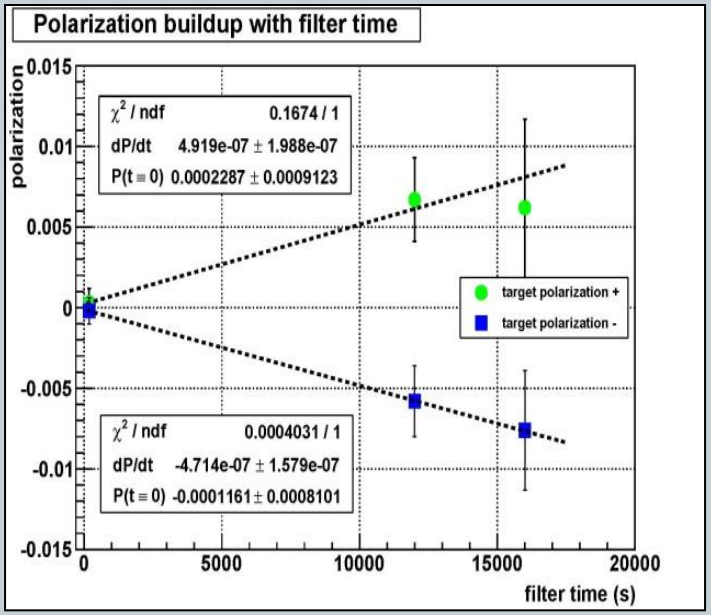
- Measurement of asymmetry in pd-elastic scattering
- 2 Silicon Tracking Telescops left and right of the COSY beam
- Deuterium Cluster Target ($d_t = 10^{14}\ atoms/cm^2$)



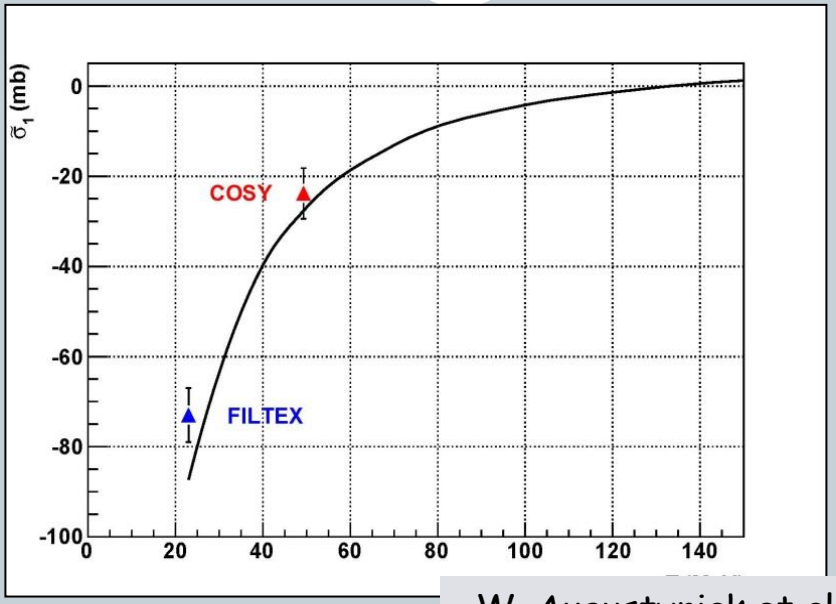
Spin-filtering cycle







Spin-filtering: result



W. Augustyniak et al., Physi. Lett. B 712 (2012) 64

- 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.

Mar. 2012 SPS Committee:

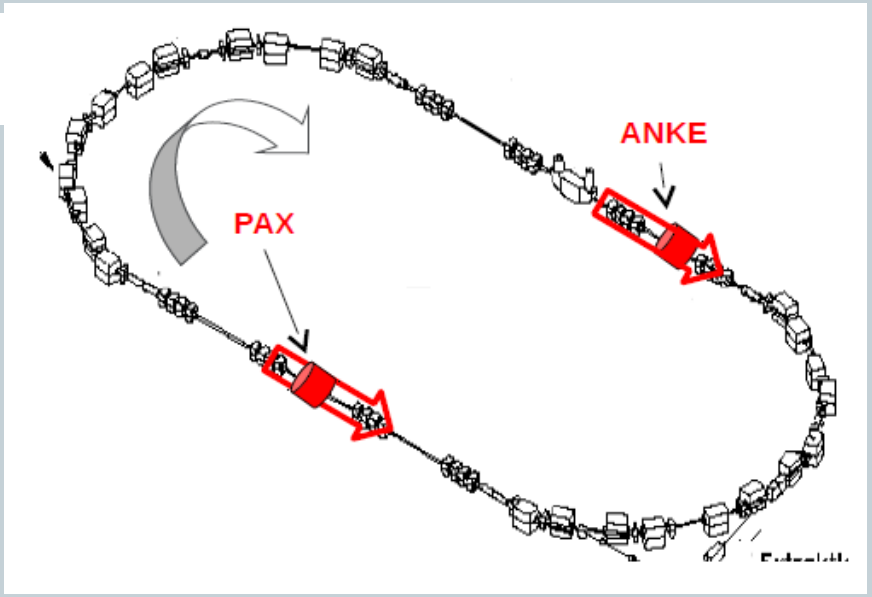
… many positive developments have occurred at the AD, leading to an updated program for the coming years ….We consider that PAX is **now** incompatible with this program.

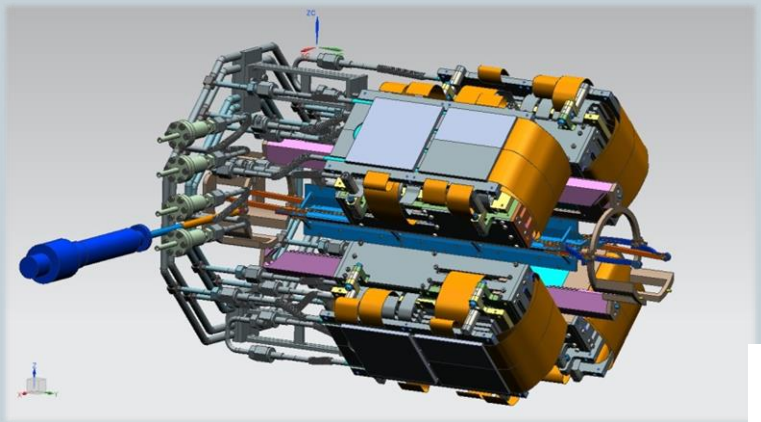
Future plans

Waiting for approval at CERN (or construction of FAIR facility)

Longitudinal spin-filtering test at COSY

Superconducting 4.7 Tm solenoid ordered





Longitudinal beam polarimeter in preparation

Summary

Status:

- Successfull spin filtering measruement at COSY on transverse polarized target.
- Excellent agreement with theoretical predictions for protons
- Successfull commissioning of experimental setup for experiments with antiproton

Future plans at COSY

- Spin filtering with protons and a longitudinally polarized gas target at COSY at $T_p = 130$ MeV ($\vec{p}\vec{p}$ scattering)

Still pending:

- Spin-filtering experiments at AD exploring the systems p(bar)p, p(bar)d, (p(bar)^{3}He) (transverse and longitudinal polarization)

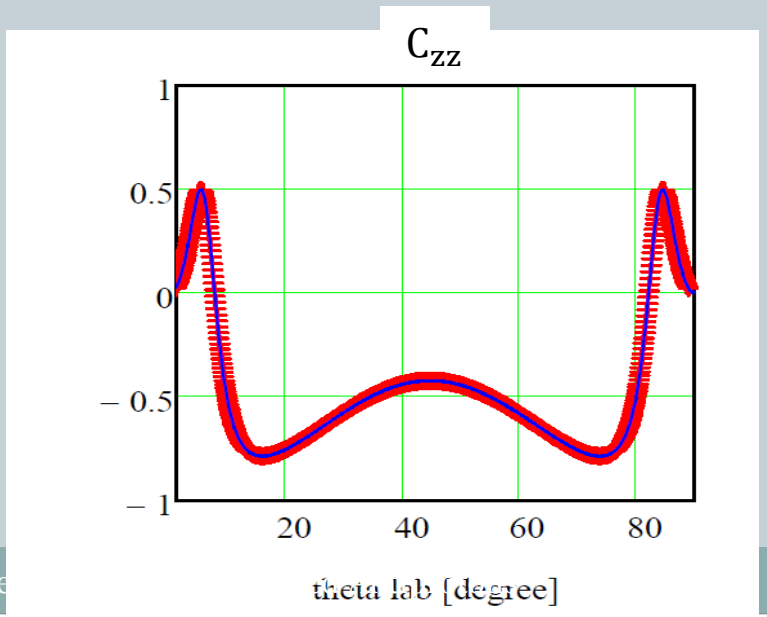
Thank you!

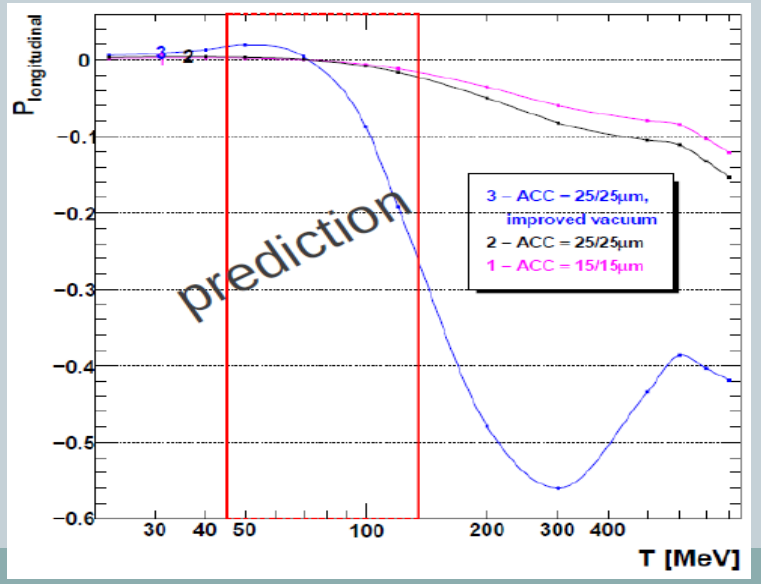
Additional Slides

Spin Filtering with Longitudinal Polarization

- Buildup of longitudinal beam polarization due to repeated interaction with a longitudinally polarized hydrogen target
- $T_p \approx 45$ - 130 MeV kinetic proton energy
- Detector: Measurement of longitudinal beam polarization using $\vec{p}\vec{p}$ elastic scattering
  - Measurement during filtering with hydrogen target possible
  - Spin correlation coefficient (~ 0.5)
  - No background

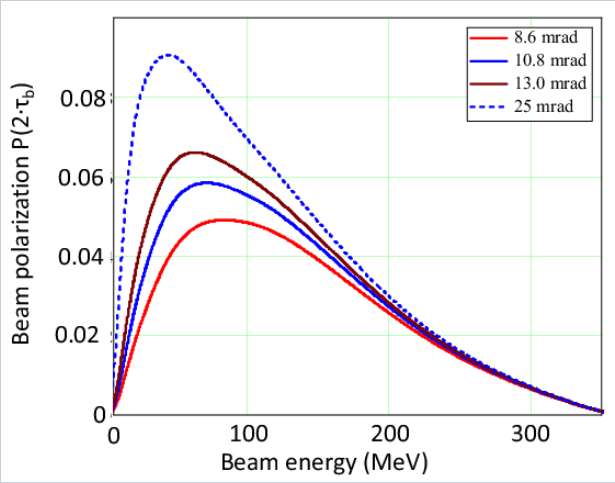
$$\frac{d\sigma}{d\Omega} = \frac{d\sigma_0}{d\Omega}(1 + C_{zz} \cdot P_z Q_z)$$





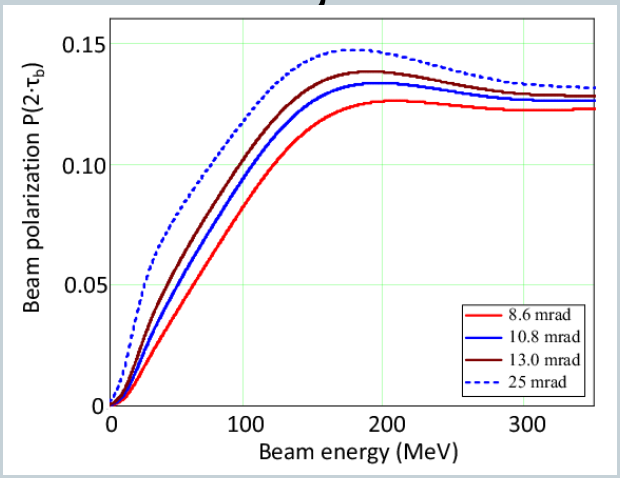
Expected polarizations after filtering for two lifetimes

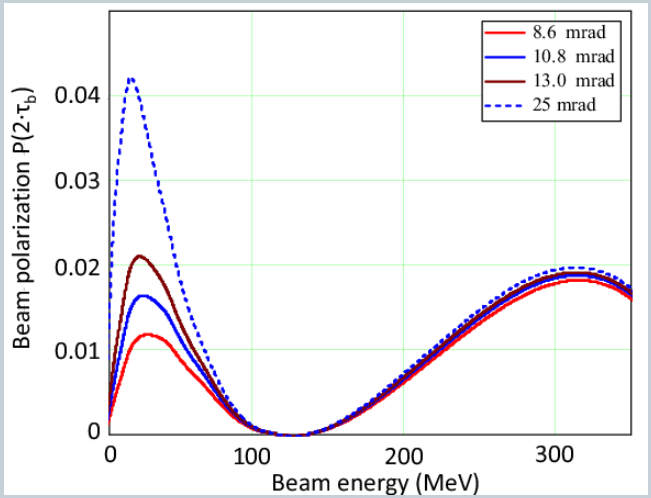
transverse



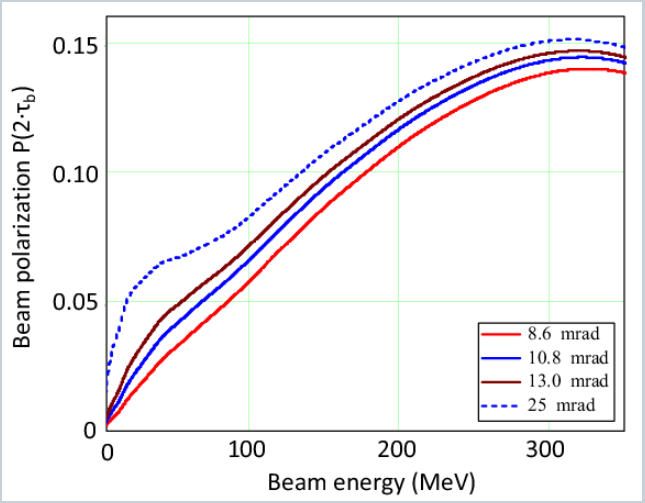
A

longitudinal





D

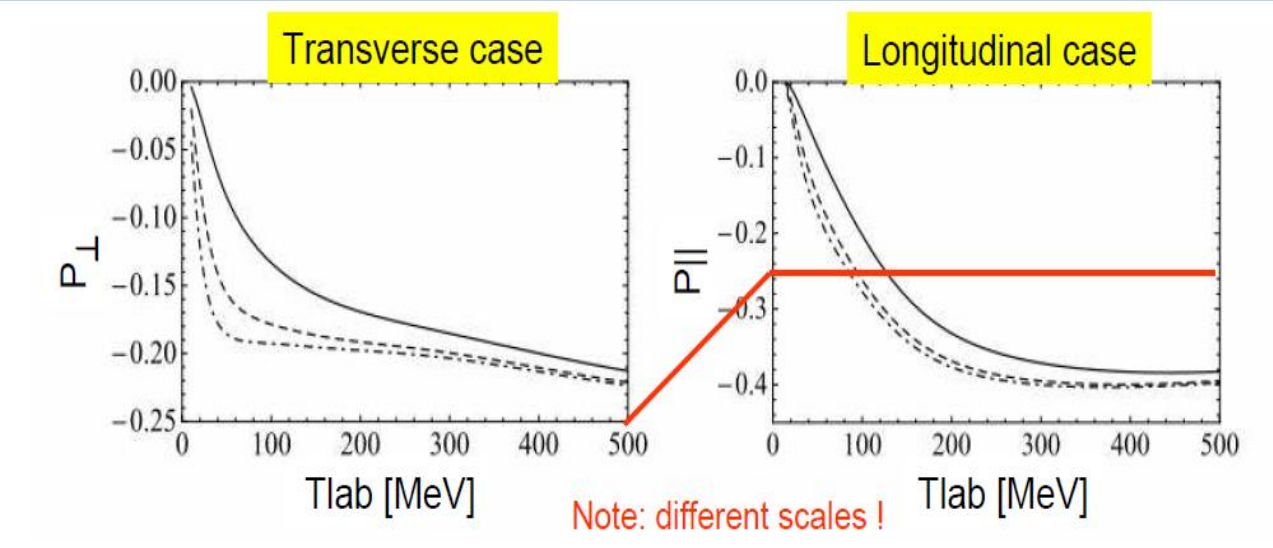


Additional calculations…

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,*]

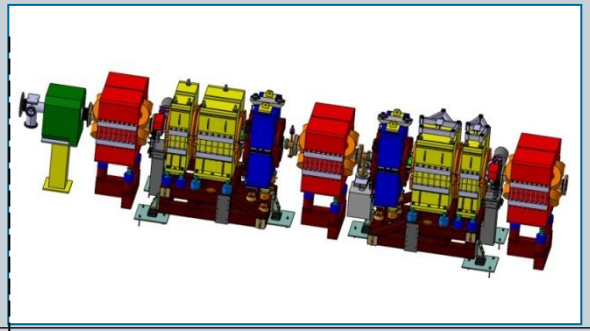
PLB 690 (2010)



Projected polarizations

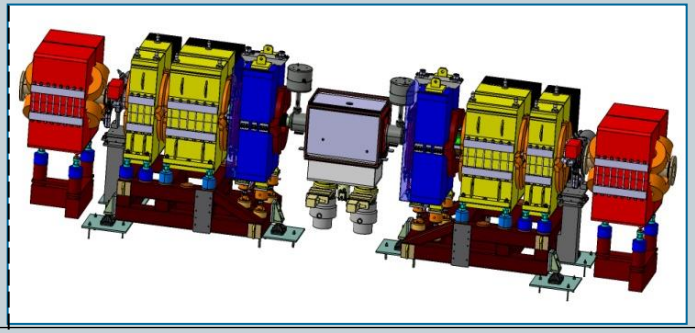
Stages of installation at AD

Phase 1



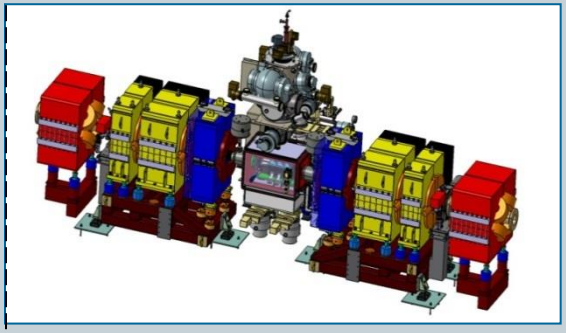
Installation of six magnets for the low-β insertion

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