Spin-filtering experiments

Polarized Antiproton EXperiments

http://www.fz-juelich.de/ikp/pax

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PAX Collaboration

180 physicists

35 institutions (15 EU, 20 NON-EU)

TIMELINE

Jan. 04	Letter of Intent for FAIR
May 04	QCD-PAC meeting at GSI
Aug. 04	Workshop on polarized antiprotons at GSI
Jan. 05	Technical Report for FAIR
Mar. 05	QCD-PAC meeting at GSI
Nov. 05	LoI to CERN-SPSC to perform spin-filtering experiments with antiprotons at the AD ring
Apr. 06	LoI to COSY-PAC for spin filtering experiments with protons at COSY

Evaluation by QCD-PAC (March 2005)

… the PAC would like to stress again the uniqueness of the program with polarized anti-protons and polarized protons that could become available at GSI.

Recommendation of the STI of FAIR (Sept. 2005)

The STI requests R&D work to be continued on the proposed asymmetric collider experiment with both polarized anti-protons and protons:

-to demonstrate that the required luminosity for decisive measurements can be reached (-> Y. Shatunov & A. Smirnov talks)

- to demonstrate that a high degree of anti-proton polarisation can be reached

The STI believes that PAX should become part of the FAIR core research program based on its strong scientific merit once the open problems are convincingly solved.

Polarized antiprotons

Intense beam of polarized pbar never produced:

- Conventional methods (ABS) not appliable

- Polarized pbar from antilambda decay
  - $I < 1.5 \cdot 10^5\ s^{-1}$ ($P \approx 0.35$)

- Pbar scattering off liquid H_2 target
  - $I < 2 \cdot 10^3\ s^{-1}$ ($P \approx 0.2$)

- Stern-Gerlach separation of a stored beam (never tested)

- 05.2006 (Th. Walcher et al) polarized electron beam

Spin-filtering is the only succesfully tested technique

Principle of spin-filtering

$$\sigma_{tot} = \sigma_0 + \sigma_\perp \cdot \vec{P} \cdot \vec{Q} + \sigma_{||} \cdot (\vec{P} \cdot \vec{k})(\vec{Q} \cdot \vec{k})$$

P beam polarization
Q target polarization
k || beam direction

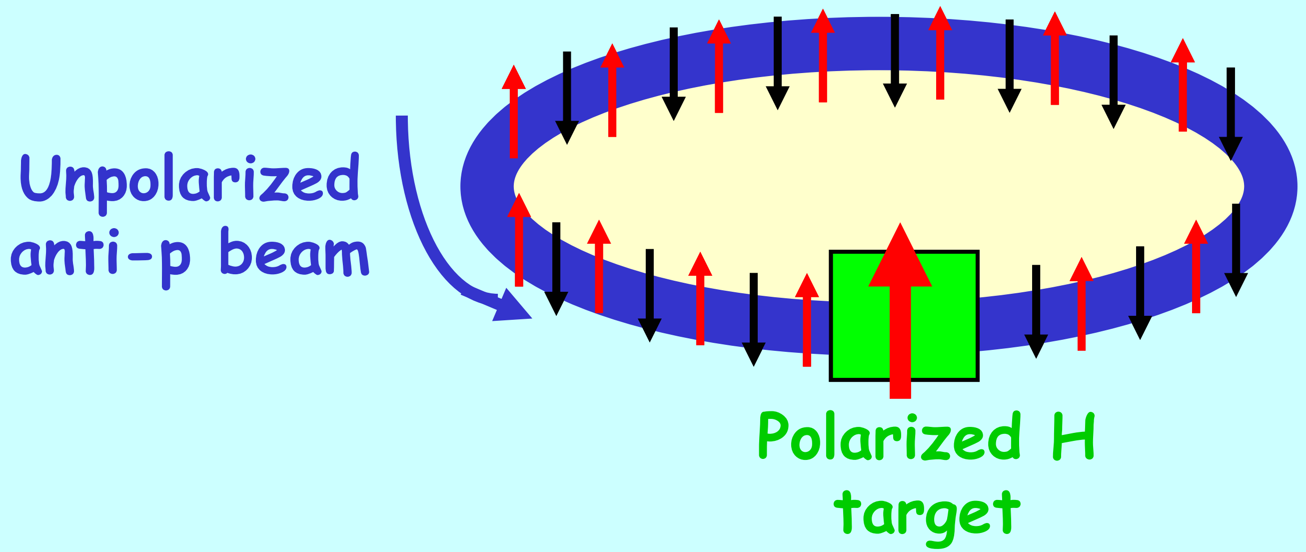
For initially equally populated spin states: ↑ ($m=+\frac{1}{2}$) and ↓ ($m=-\frac{1}{2}$)

transverse case:

$$\sigma_{tot\pm} = \sigma_0 \pm \sigma_\perp \cdot Q$$

longitudinal case:

$$\sigma_{tot\pm} = \sigma_0 \pm (\sigma_\perp + \sigma_{||}) \cdot Q$$



Principle of spin-filtering

$$\sigma_{tot} = \sigma_0 + \sigma_\perp \cdot \vec{P} \cdot \vec{Q} + \sigma_{||} \cdot (\vec{P} \cdot \vec{k})(\vec{Q} \cdot \vec{k})$$

P beam polarization
Q target polarization
k || beam direction

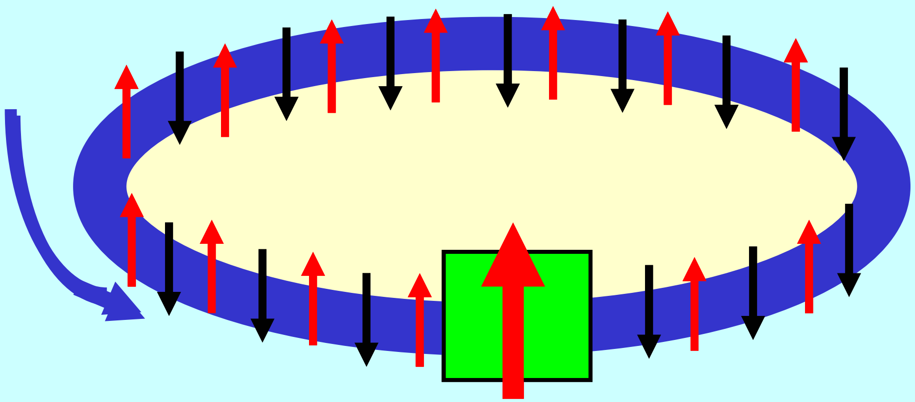
For initially equally populated spin states: ↑ (m=+½) and ↓ (m=-½)

transverse case:

$$\boxed{\sigma_{tot\pm} = \sigma_0 \pm \sigma_\perp \cdot Q}$$

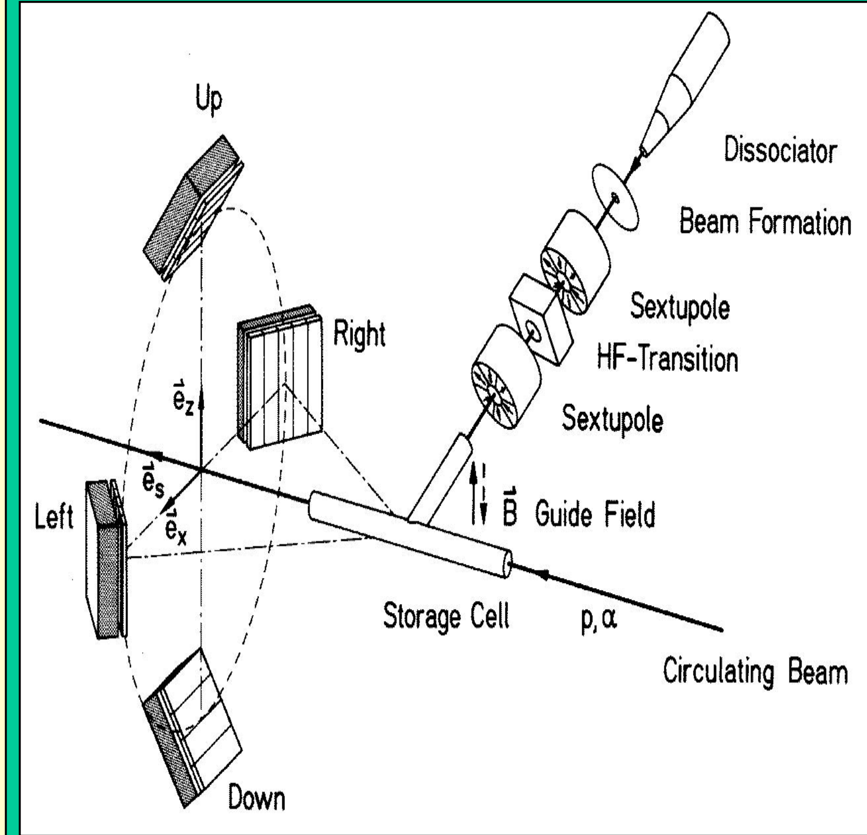
longitudinal case:

$$\boxed{\sigma_{tot\pm} = \sigma_0 \pm (\sigma_\perp + \sigma_{||}) \cdot Q}$$

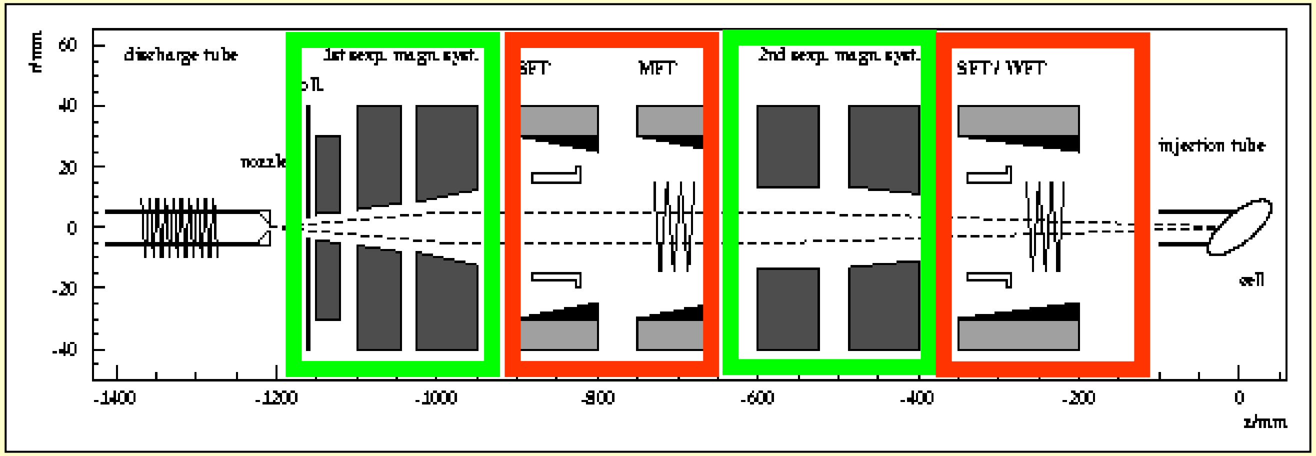


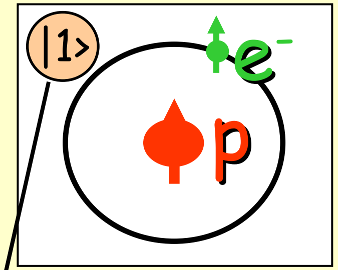
1992 Filter Test at TSR with protons

Experimental Setup

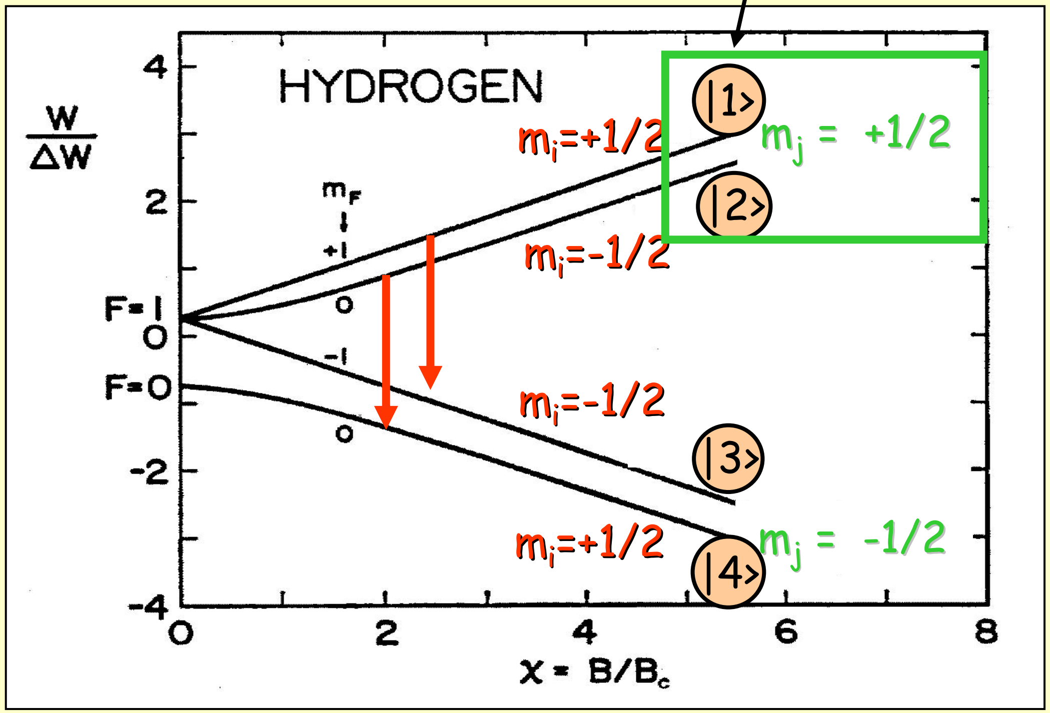


Polarized atomic beam source





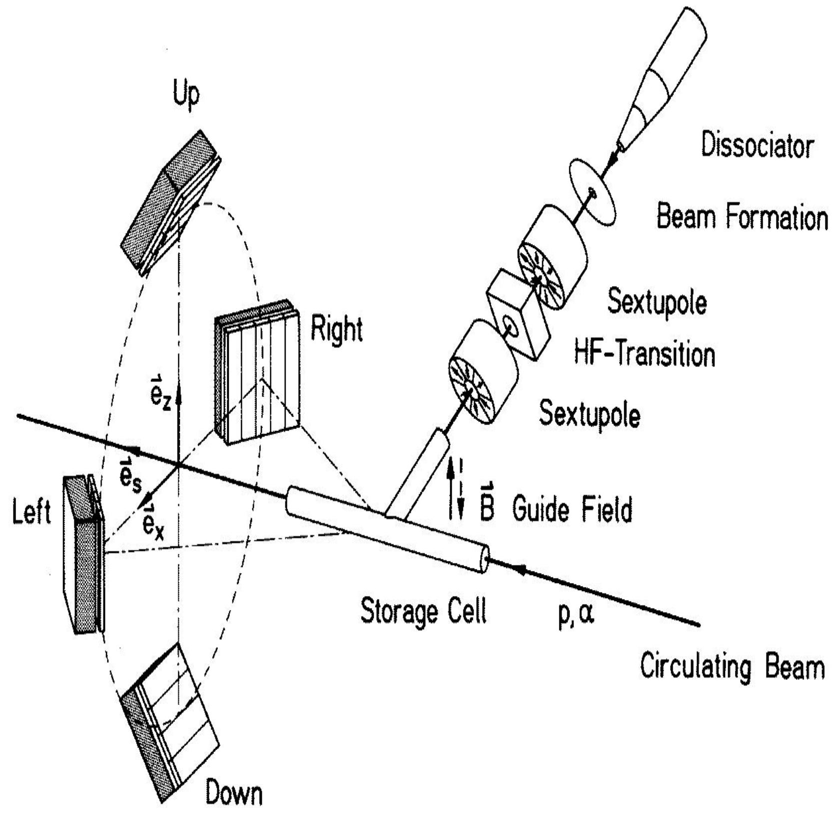
Atoms with $m_j=+\frac{1}{2}$ focused in sextupole magnets.



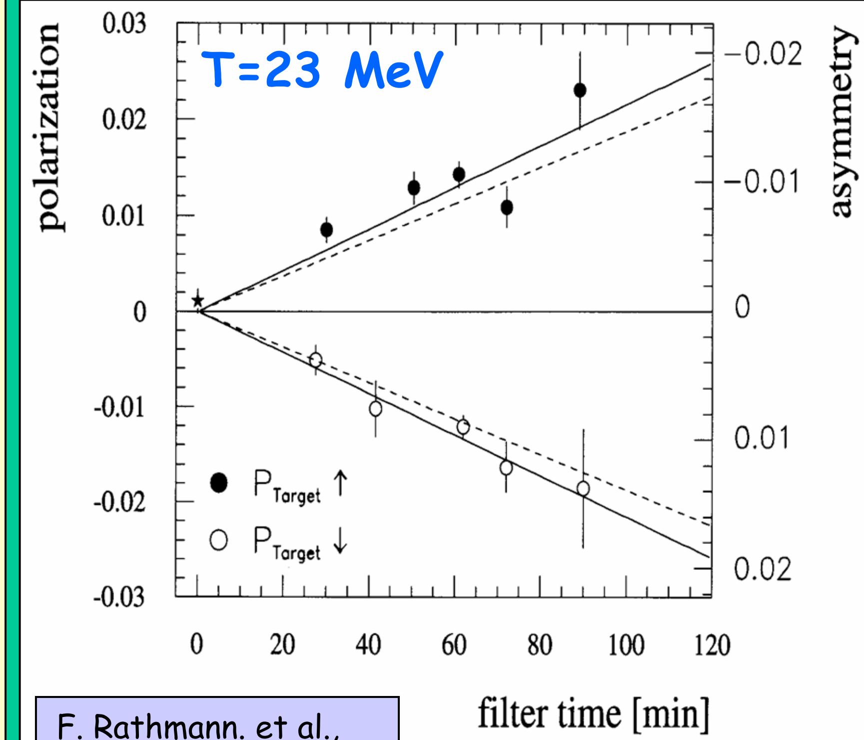
RF transitions select HFS.

1992 Filter Test at TSR with protons

Experimental Setup



Results



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

Two interpretations of FILTEX result

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

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

$\sigma_1 = 72.5 \pm 5.8$ mb

Spin-filtering works! But how?

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

1. Selective removal through scattering beyond θ_{acc}=4.4 mrad ($\sigma_{R\perp}$=85.6 mb)

No contribution from other two effects

(cancellation between scattering and transmission)

$\sigma_1 = 85.6$ mb

(-> more in Frank's presentation)

Spin-filtering: Present situation

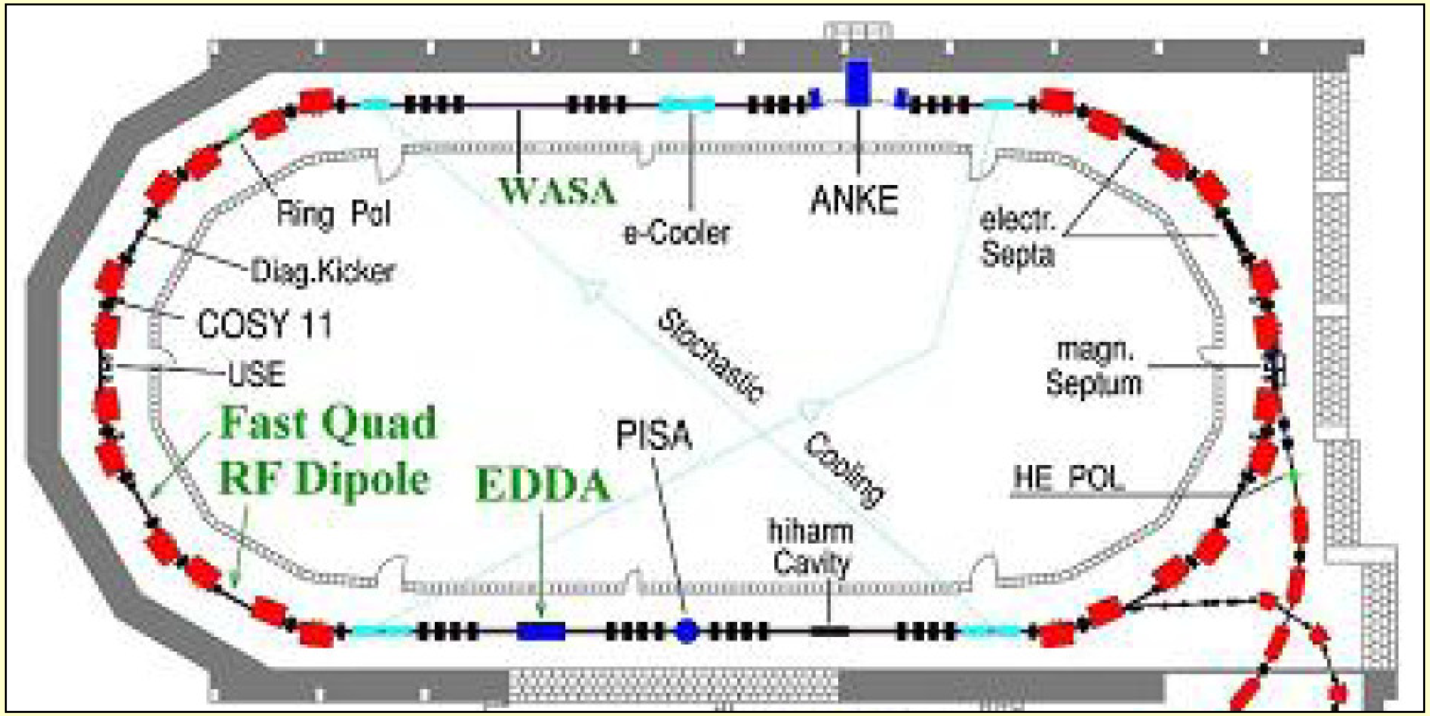
Spin filtering works, but:

1. Controversial interpretations of only experiment with protons
2. No experimental basis for antiprotons

Experimental tests needed with:

1. Protons at COSY
2. Antiprotons at AD

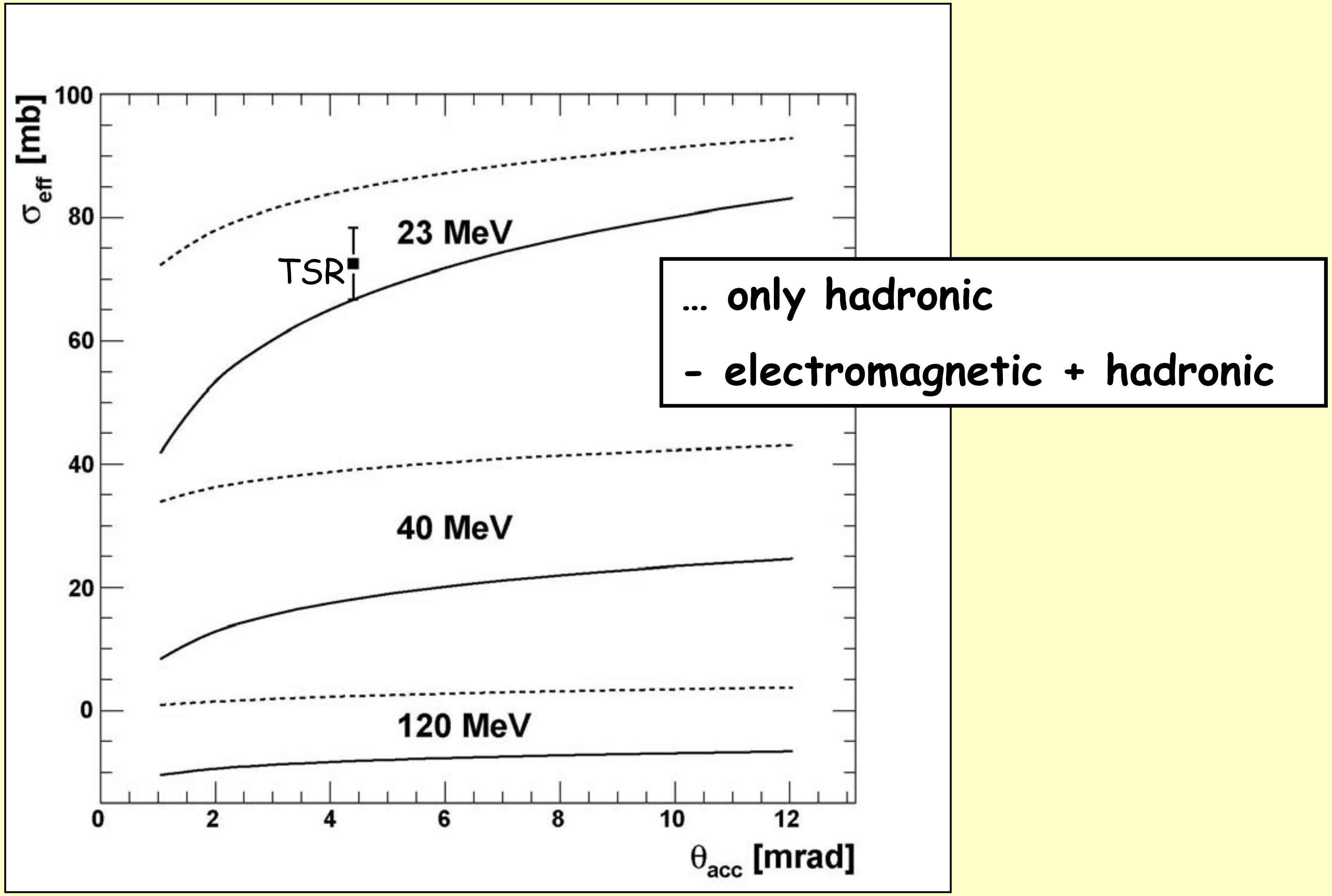
Spin-filtering studies at COSY



Objective:

- Understanding of spin-filtering mechanism:
- Disentangle electromagnetic and hadronic contributions to the polarizing cross section

Polarizing cross sections from the two models



A measurement of σ_{eff} to 10% precision requires polarization measurement with $\Delta P/P$ = 10%.

How to disentangle hadronic and electromagnetic contributions to σ_{eff} ?

(Polarization build-up experiments)

Injection of different combinations of hyperfine states

- Different electron and nuclear polarizations
- Null experiments possible:
  - Pure electron polarized target (P_z = 0), and
  - Pure nuclear polarized target (P_e=0)

Inj. states	P_e	P_z	Interaction	Holding field	
|1>	+1	+1	Elm. + had.	transv. + longit.	weak (20 G)
|1> + |4>	0	+1	only had.	longitudinal	strong (3kG)
|1> + |2>	+1	0	only elm.		

Strong fields can be applied only longitudinally (minimal beam interference)

- Snake necessary

AD Experiments require both transverse and longitudinal (weak)fields.

AD Experiments will be performed also with D target.

Target polarimetry requires BRP for pure electron and D polarization.

Preliminary test: do unpolarized electrons affect the polarization of a proton beam?

(Polarization "build-down" experiment)

Meyer: "If polarized electrons polarize an initially unpolarized beam, then, unpolarized electrons should depolarize an initially polarized beam!"

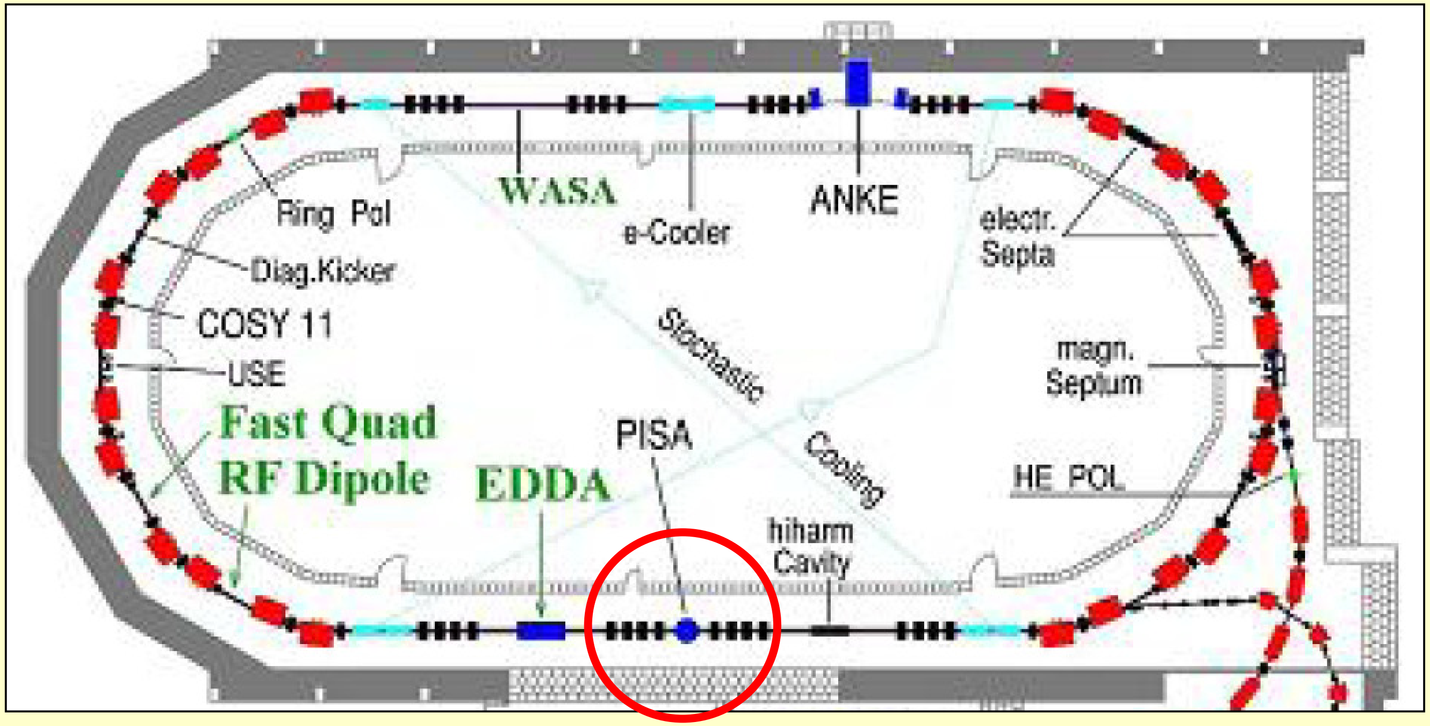
Test with unpolarized ^4He target (no hadronic effects):

Measure of depolarization of a polarized proton beam.

Will allow to test the electromagnetic contribution (and Walcher's proposal)

(-> D. Oeller in PAX meeting)

Experimental setup

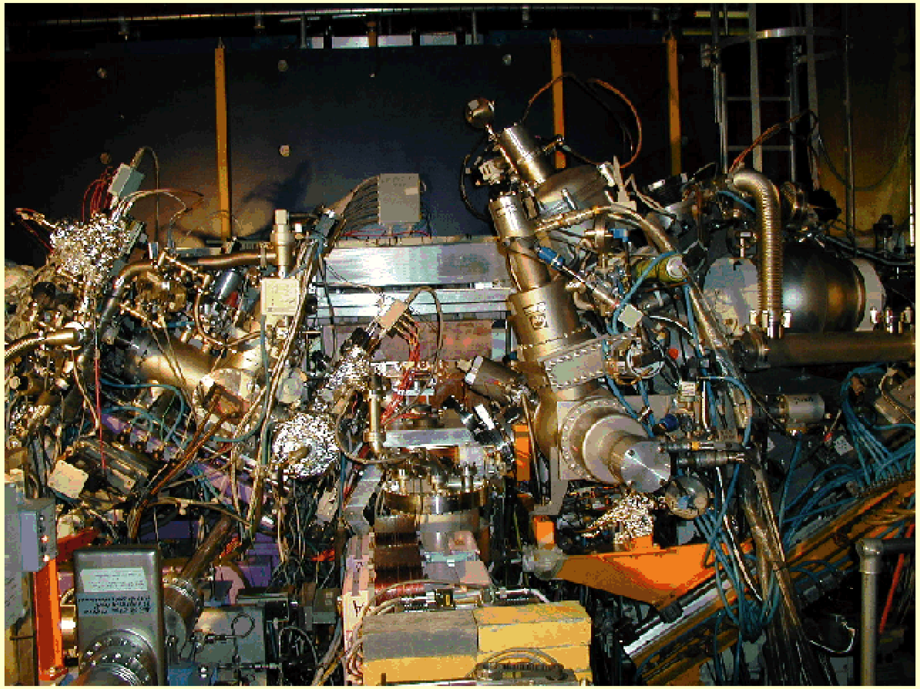


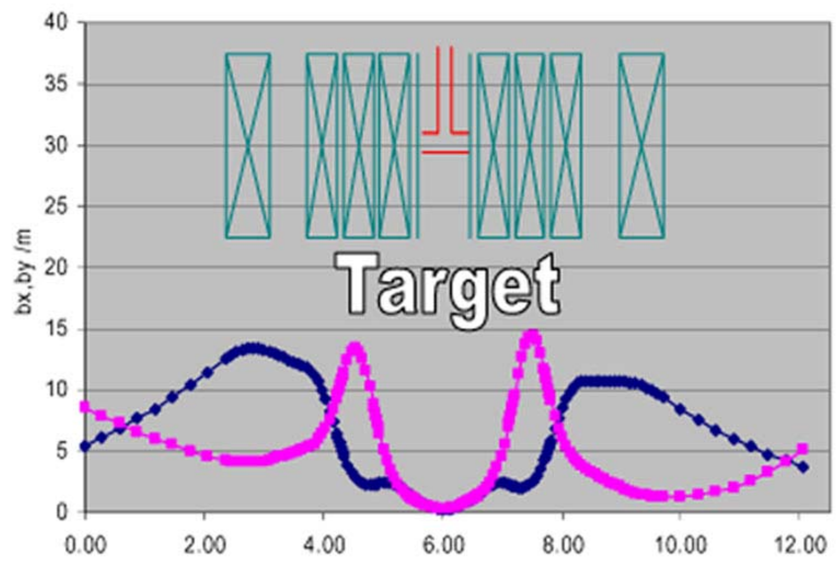
- Low-beta section
- Polarized target (former HERMES target)
- Detector
- Snake
- Commissioning of AD setup

Low beta section

$\beta_{x,y}^{new}$ = 0.3 m -> increase in density with respect to ANKE: factor 30

- Lower buildup time, higher rates
- Larger polarization buildup rate due to higher acceptance
- Use of former HERMES target (-> A. Nass' talk)



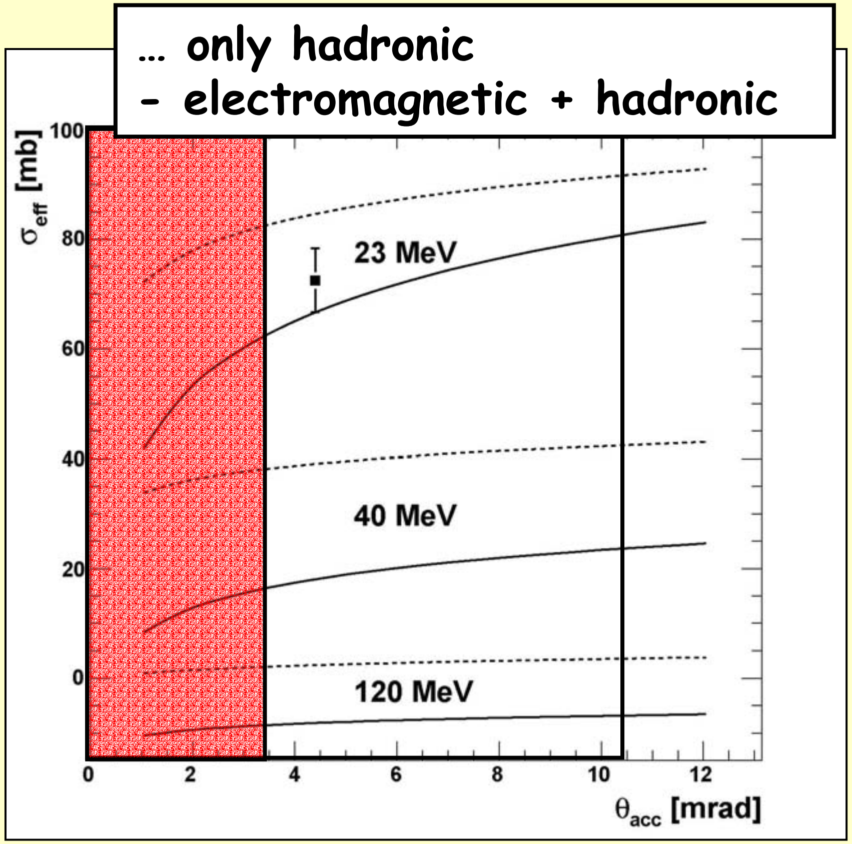


(-> A. Garishvili's talk)

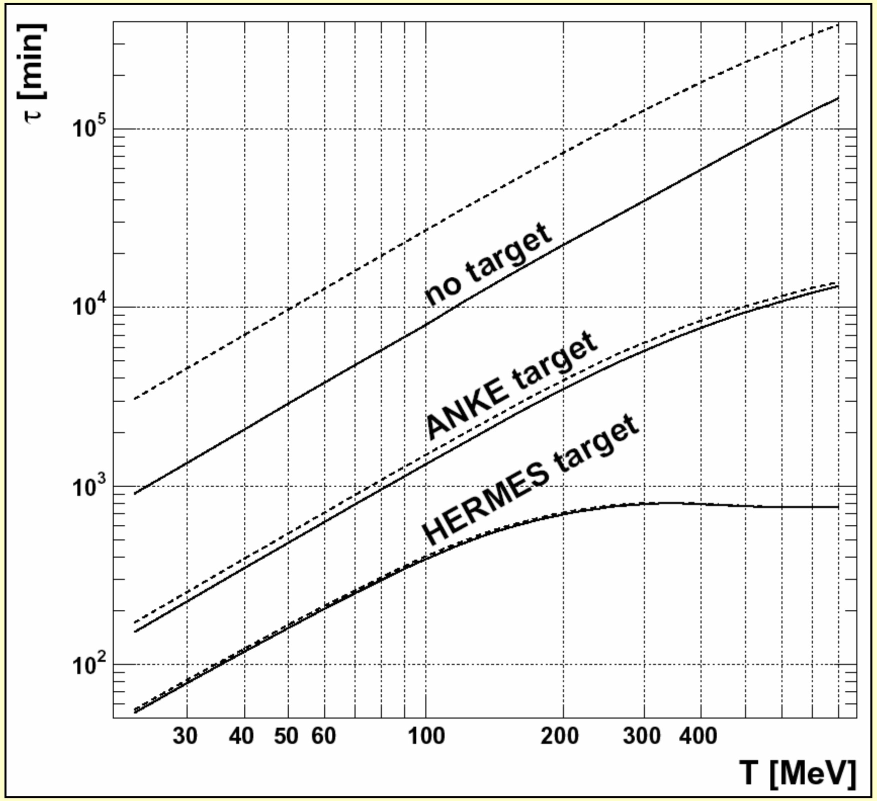
S.C. quadrupole development applicable to AD experiment

ANKE vs new IP: Acceptance and Lifetime

Cross sections



Lifetimes



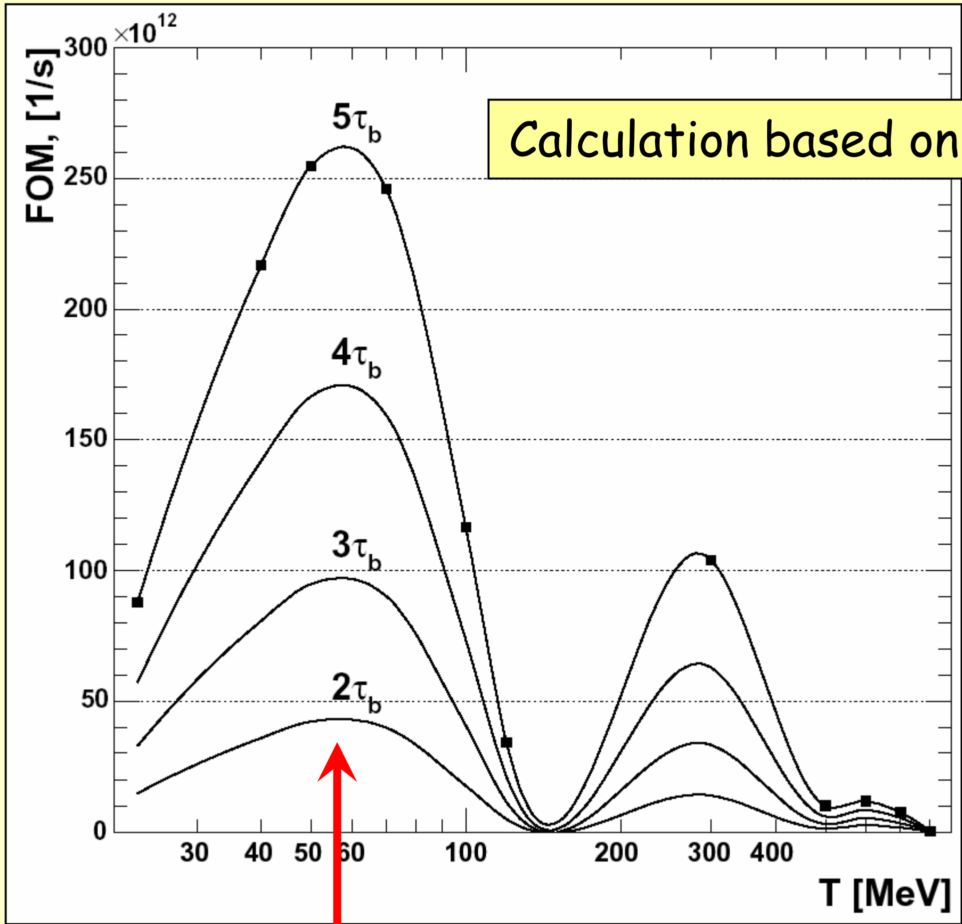
Acceptance @ ANKE

Acceptance @ new-IP

—— COSY average ψ_{acc} = 1 mrad

….. ψ_{acc} = 2 mrad

Figure of Merit at new IP



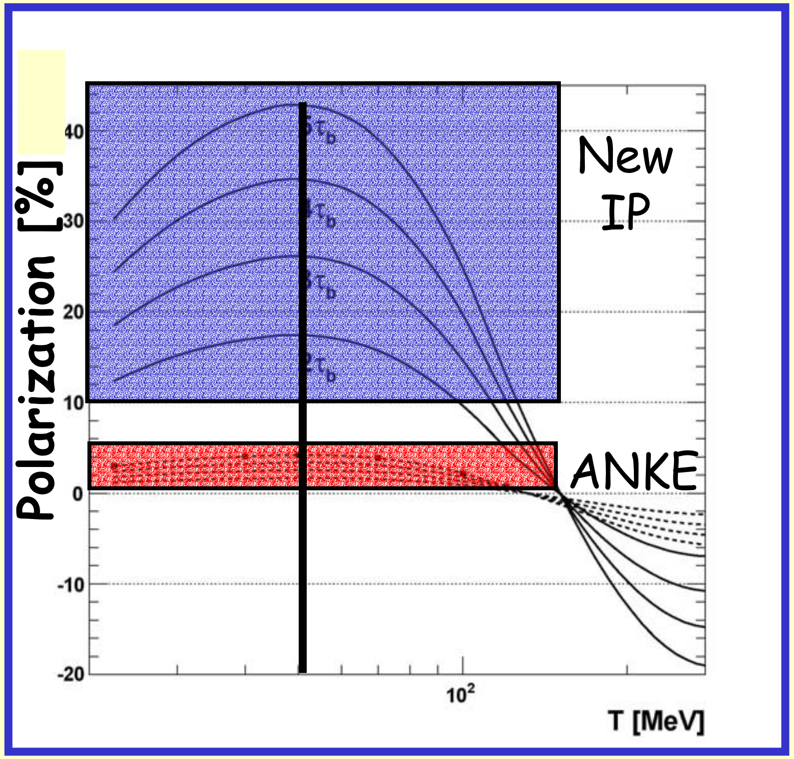
Calculation based on Budker-Jülich

$T^{opt} \sim 55$ MeV

ANKE vs new IP: Polarization

Expectations based on Budker-Jülich for:

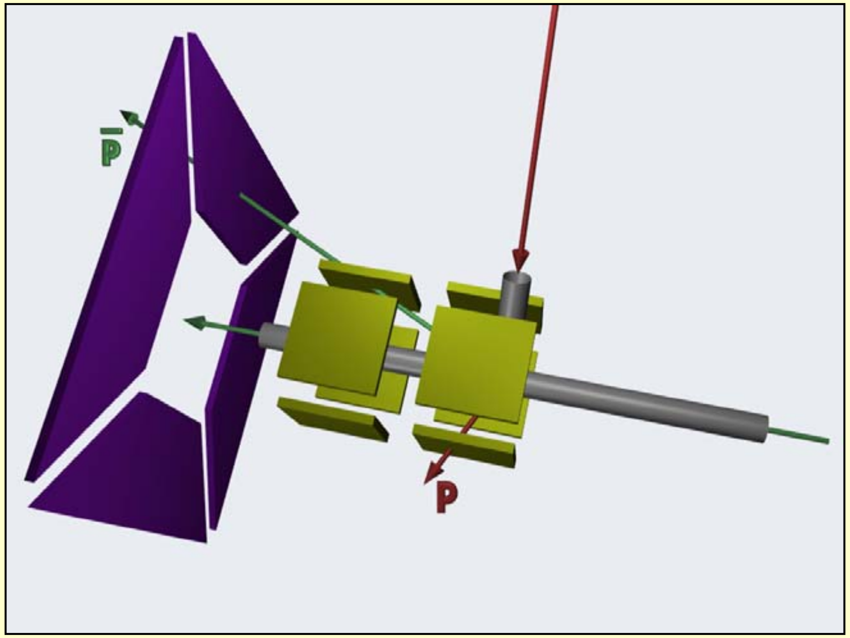
- T = 40 MeV
- N_{inj}=1.5x10^{10} protons

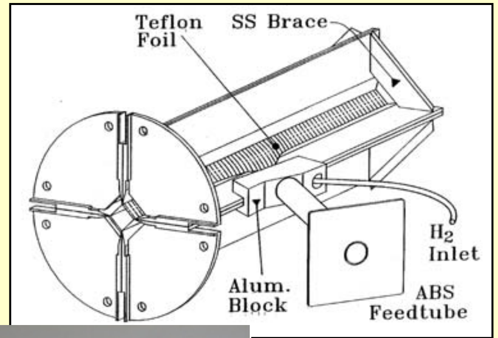


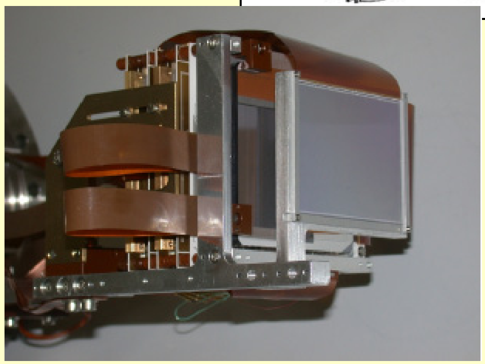
PIT	Filter. time	Polar.	Total rate	Meas. Time (ΔP/P=10%)
ANKE	2τ = 16 h	1.2 %	7.5x10^2 s^{-1}	44 min
	5τ = 42 h	3.5 %	5x10 s^{-1}	26 min
New IP	2τ = 5 h	16 %	2.2x10^4 s^{-1}	1 s
	5τ = 13 h	42 %	1.5x10^3 s^{-1}	< 1 s

Detector concept

- Will measure beam polarization by using the analysing power of:
    - p-p elastic (COSY)
    - pbar-p elastic (AD) (->M. Tabidze's talk)
- Good azimuthal resolution (up/down asymmetries)
- Low energy recoil (<8 MeV)
    - Silicon telescopes (-> D. Oellers' talk)
    - Thin 5μm Teflon cell needed
- Angular resolution for the forward particle for p-pbar at AD
- AD experiment will require an openable cell

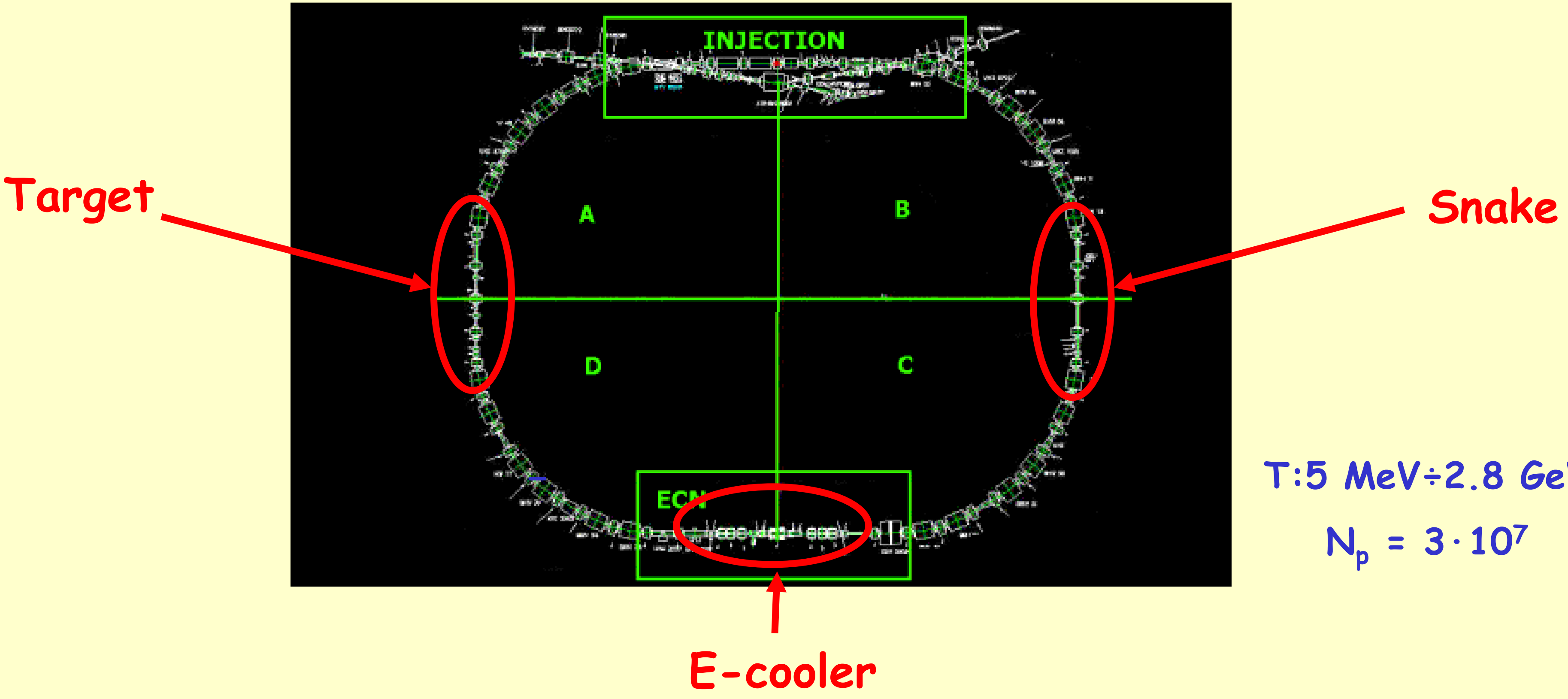






AD ring at CERN

Study of spin-filtering in pbar-p (pbar-D) scattering



T:5 MeV÷2.8 GeV

$N_p = 3 \cdot 10^7$

Measurement of effective polarization cross-section.

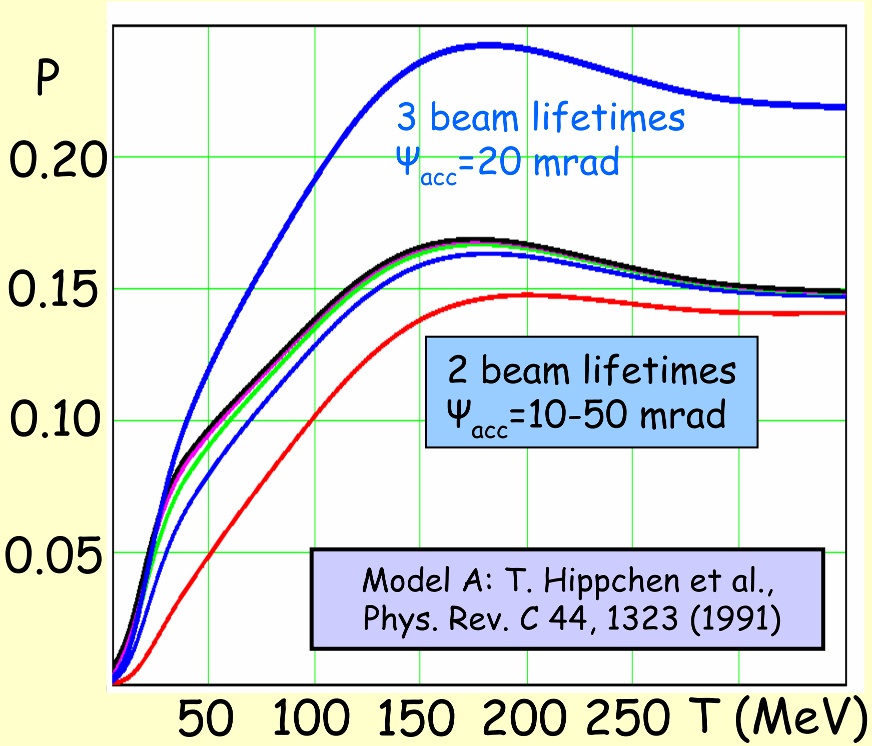
Both transverse and longitudinal.

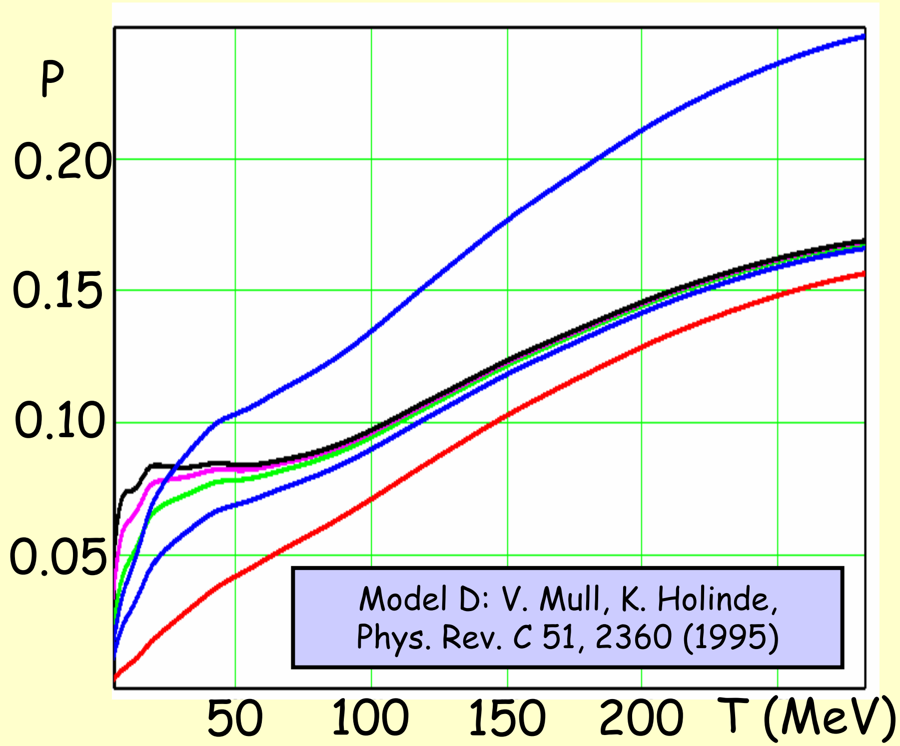
Variable acceptance at target

Polarized D target

First measurement at all for spin correlations in pbar-p (and pbar-D)

Antiproton Beam Polarization
(Hadronic Interaction: Longitudinal Case)





Timeline

Fall 2006	Submission of proposal to COSY-PAC
	Beam depolarization studies
	(Beam lifetime studies)
Spring 2007	Submission of FP 7 application (-> PAX meeting)
Fall 2007	Technical proposal to COSY-PAC for spin filtering
	Technical proposal to SPSC for spin filtering at AD
2006-2007	Design and construction phase
2008-2009	Spin-filtering studies at COSY
	Commissioning of AD experiment
2009	Installation at AD
2009-2010	Spin-filtering studies at AD

A hard challenge is in front of us:

Young (and less young) polarization enthusiasts are welcome!