Spin Filtering Studies at COSY and AD

- Status
- Work to be done, etc.

Frank Rathmann

Ferrara, May 30, 2007

Polarization Buildup by Spin Filtering (removal only)

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

P beam polarization
Q target polarization
k || beam direction

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

transverse case:

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

longitudinal case:

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

$$\tau_{beam} = \frac{1}{(\sigma_0 + \Delta\sigma_c) \cdot d_t \cdot f_{rev}}$$

$$\tau_{pol} = \frac{1}{\sigma_{pol} \cdot Q \cdot d_t \cdot f_{rev}}$$

$$I_+(t) = \frac{I_0}{2} \cdot e^{-\frac{t}{\tau_{beam}}} \cdot e^{-\frac{t}{\tau_{pol}}}$$

$$I_-(t) = \frac{I_0}{2} \cdot e^{-\frac{t}{\tau_{beam}}} \cdot e^{+\frac{t}{\tau_{pol}}}$$

Time dependence of P, I, and FOM

$$P(t) = \frac{I_+ - I_-}{I_+ + I_-} = -\tanh\left(\frac{t}{\tau_{pol}}\right)$$

$$I(t) = I_+ + I_- = I_0 \cdot e^{-\frac{t}{\tau_{beam}}} \cdot \cosh\left(\frac{t}{\tau_{pol}}\right)$$

$$FOM(t) = P(t)^2 \cdot I(t)$$

Polarization Buildup II

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

P beam polarization
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k || beam direction

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

transverse case:

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

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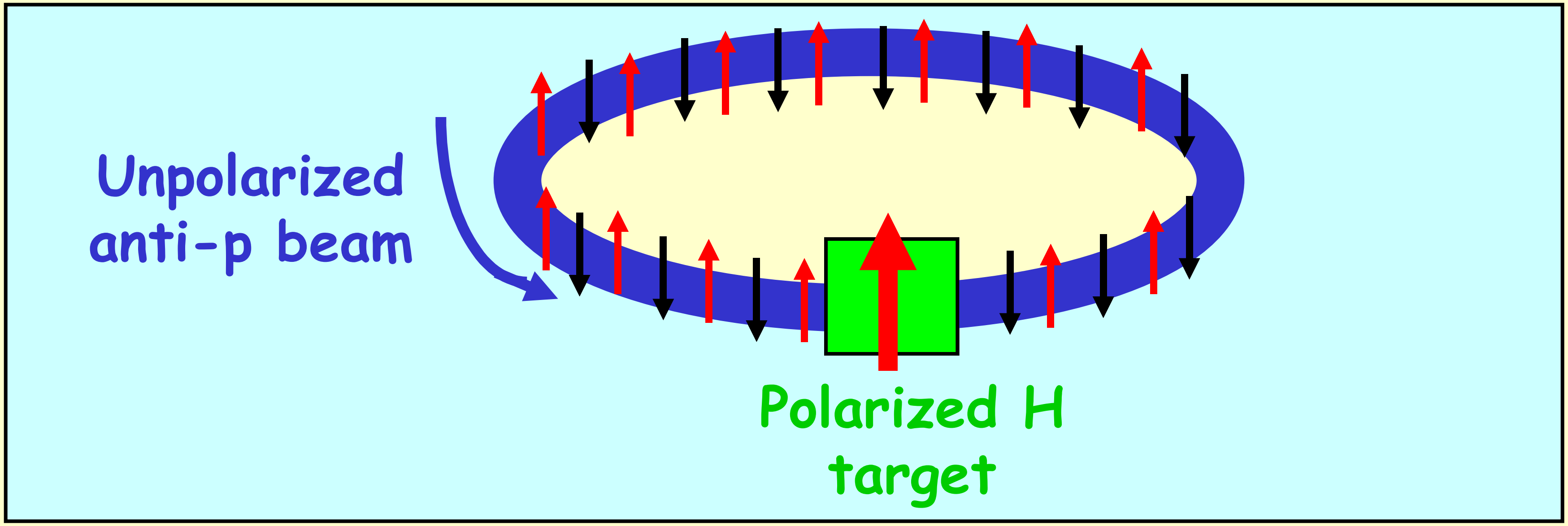

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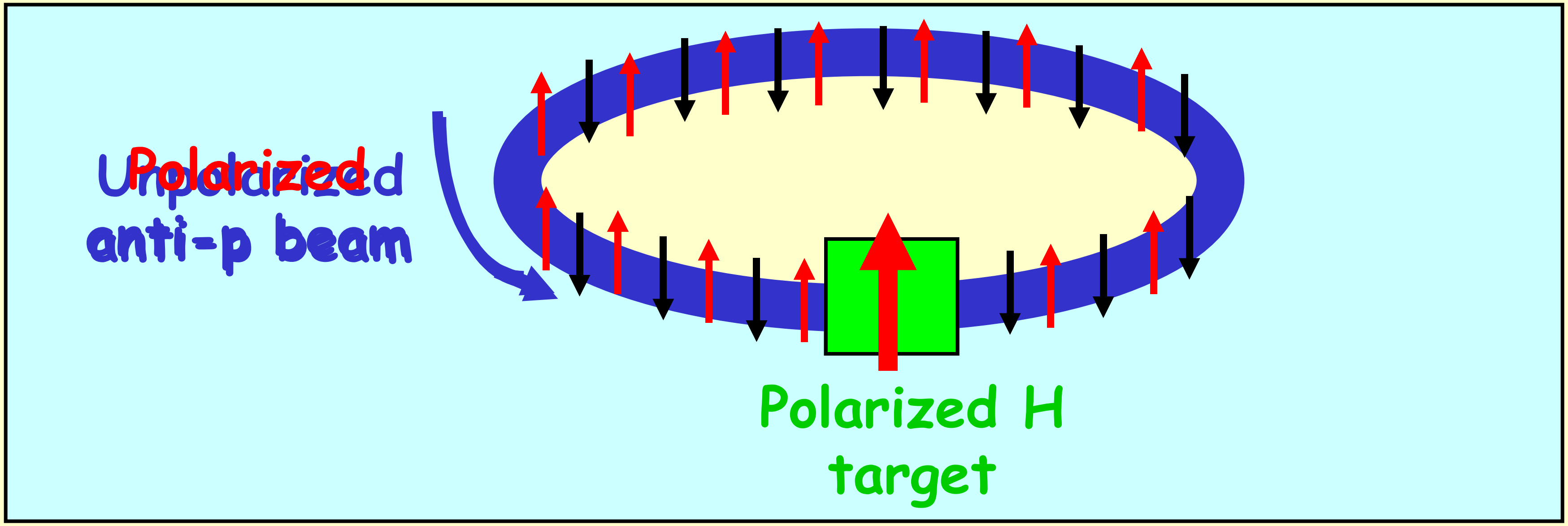
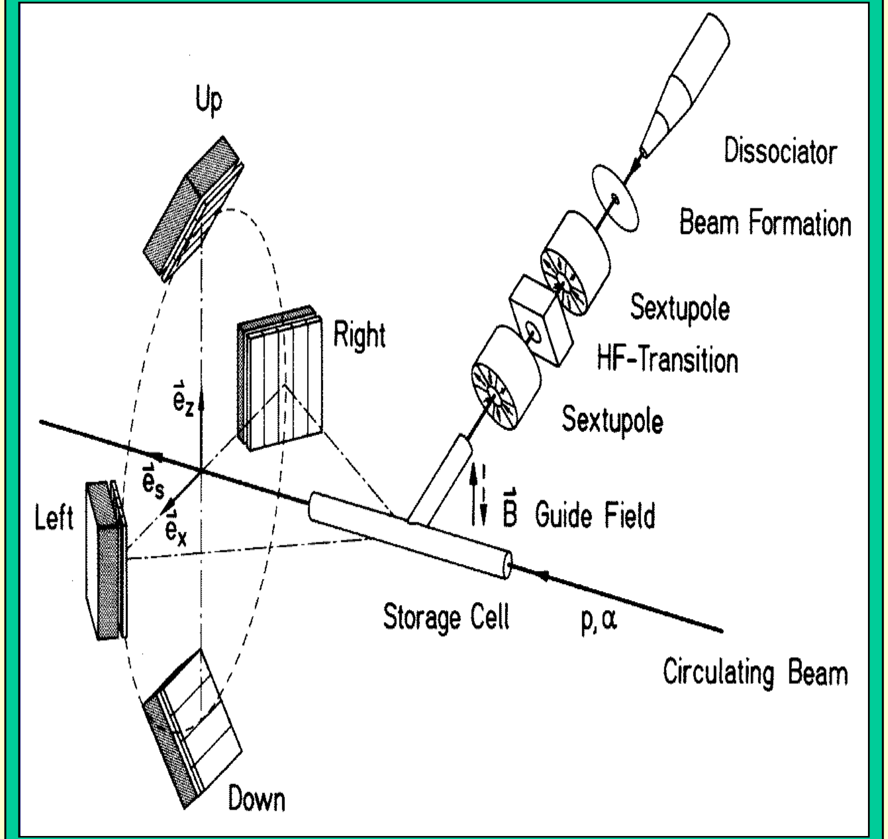
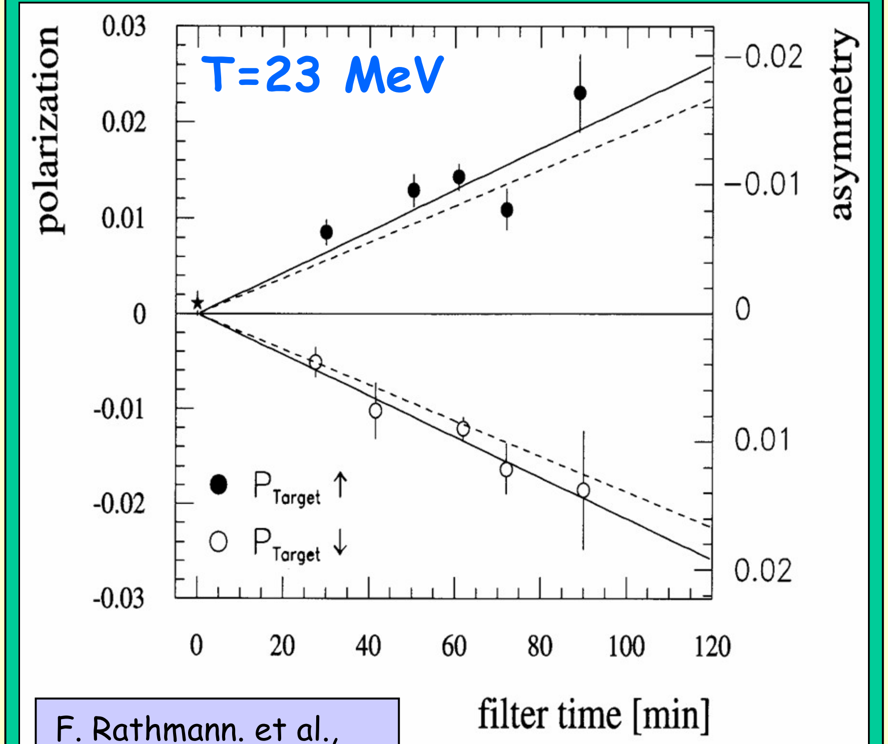


1992 Filter Test at TSR with protons

Experimental Setup



Results



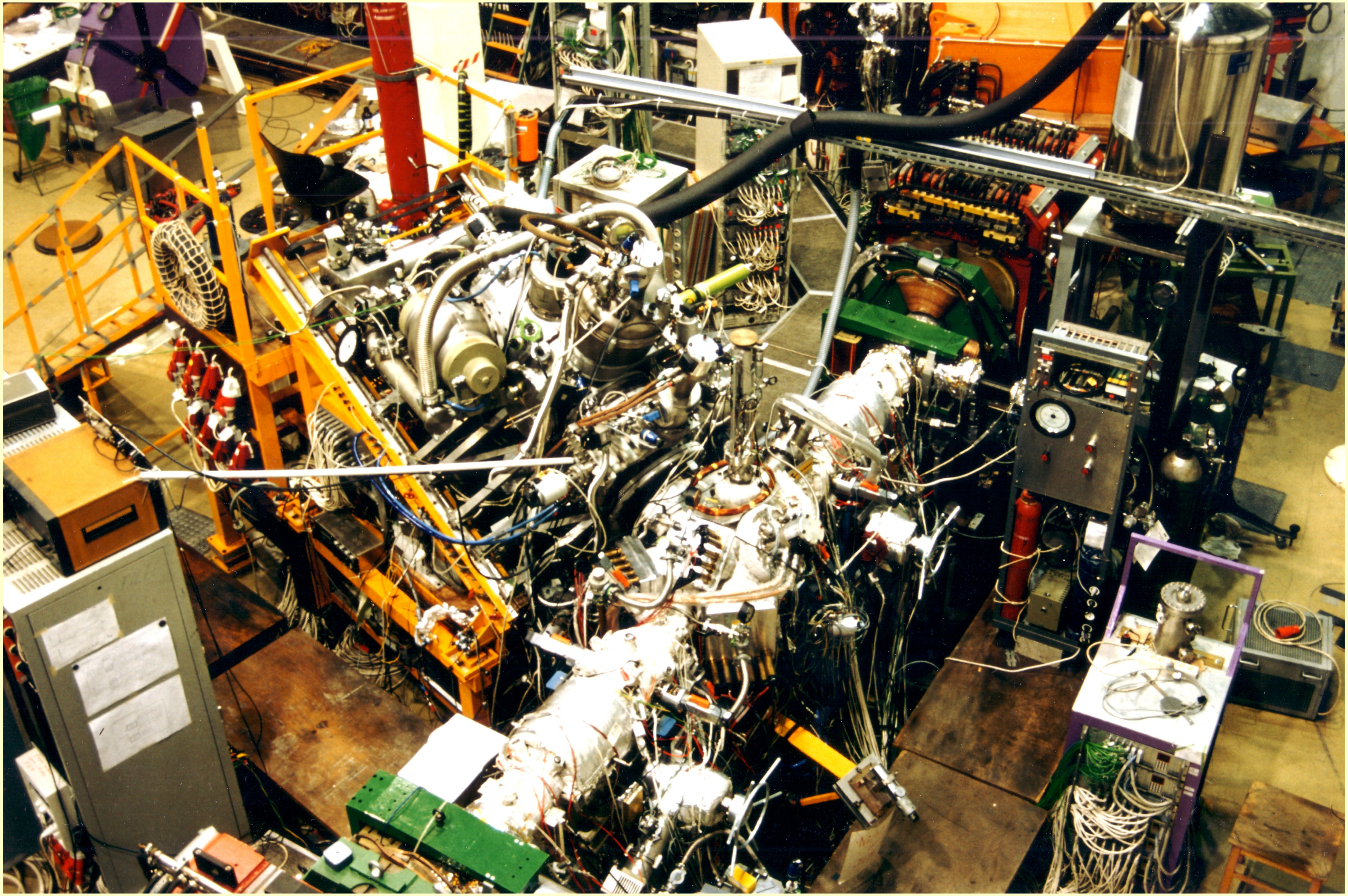
F. Rathmann. et al.,
PRL 71, 1379 (1993)

Low energy pp scattering

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

Expectation	
Target	Beam
↑	↑
↓	↓

Experimental Setup at TSR (1992)



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

Only pp elastic scattering contributes

No contribution from other two effects σ_1 = 85.6 mb

Present Status

Spin filtering works, but:

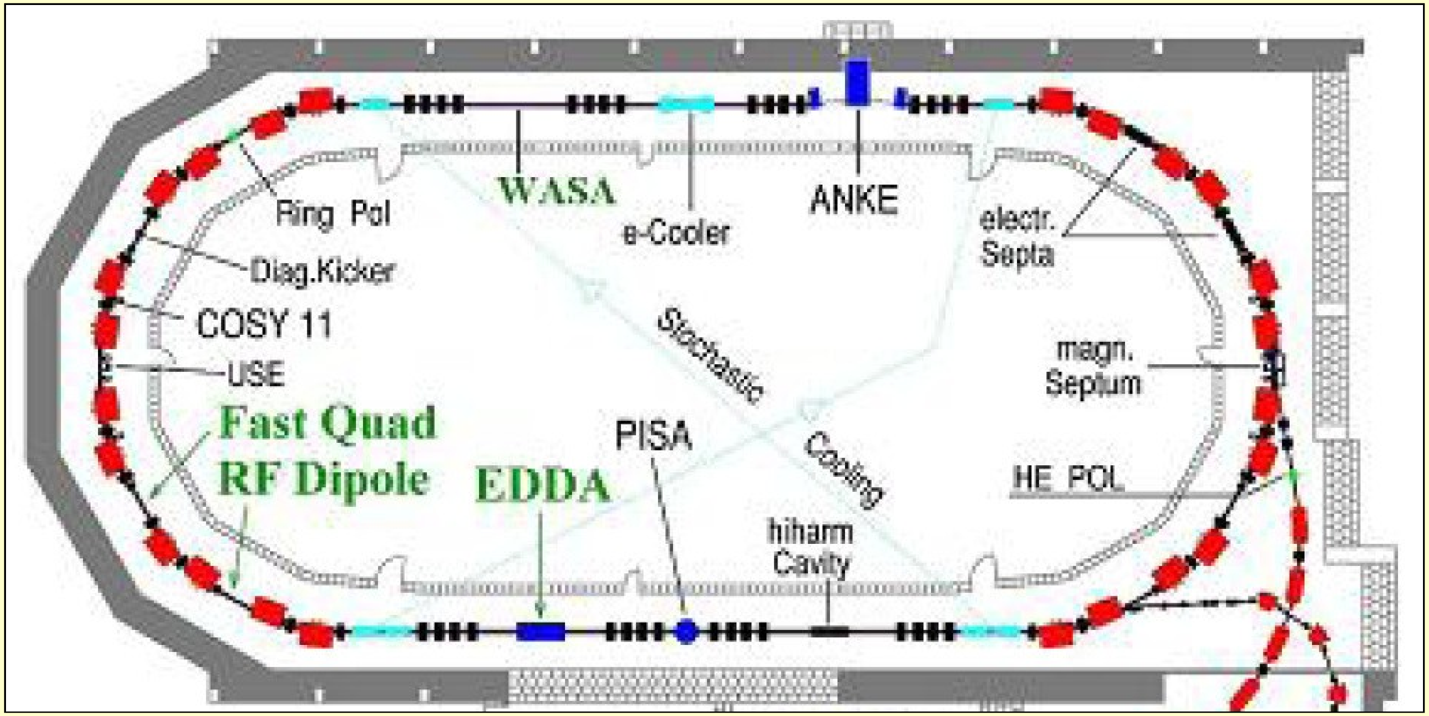
3. Controversial interpretation of FILTEX experiment
    - Further experimental tests necessary
        - How does spin filtering work?
        - Which role do electrons play?

    → Tests with protons at COSY

2. No data to predict polarization from filtering with antiprotons

    → Measurements with antiprotons at AD/CERN

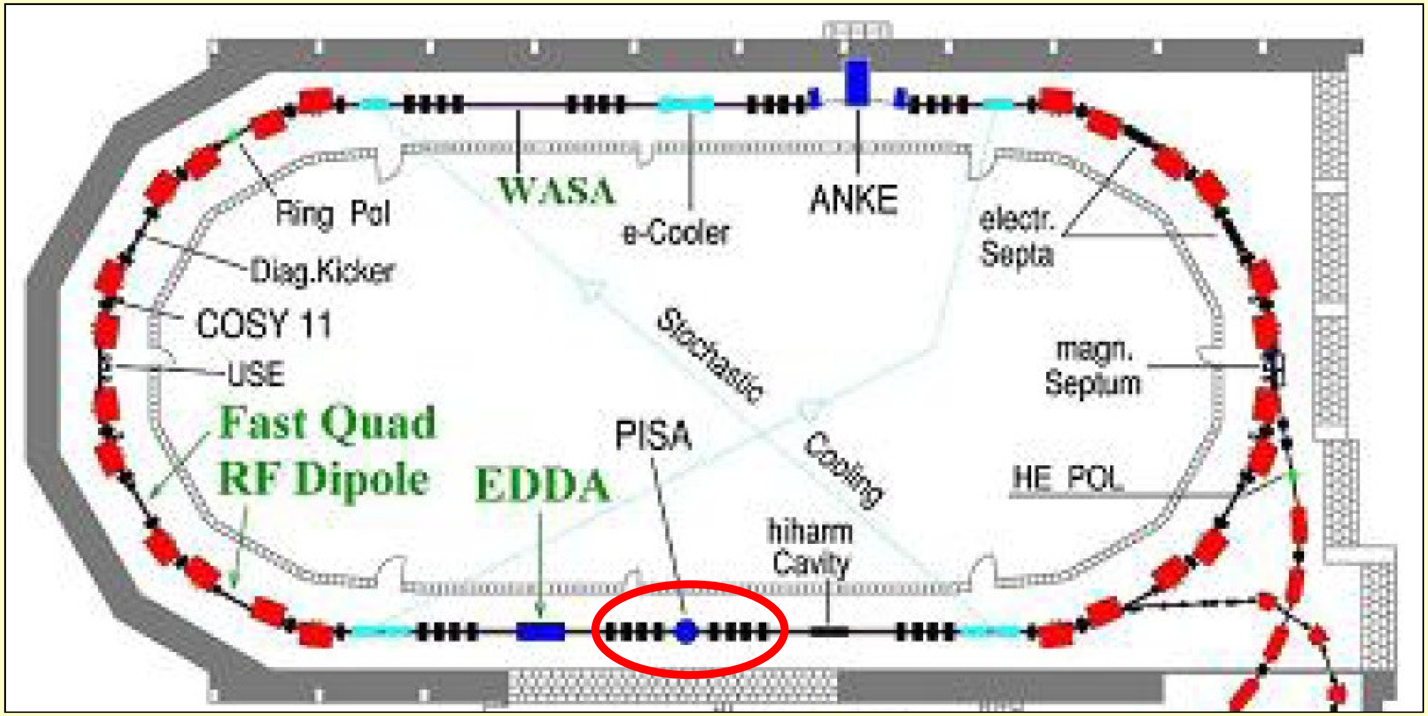
Spin Filtering studies at COSY



Goal:

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

Spin Filtering studies at COSY

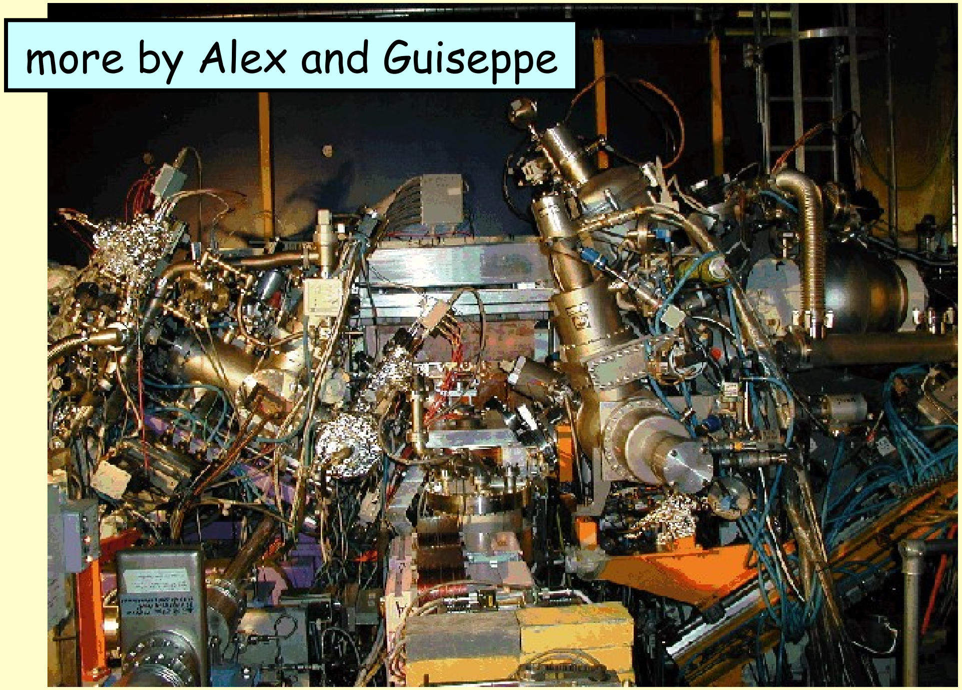


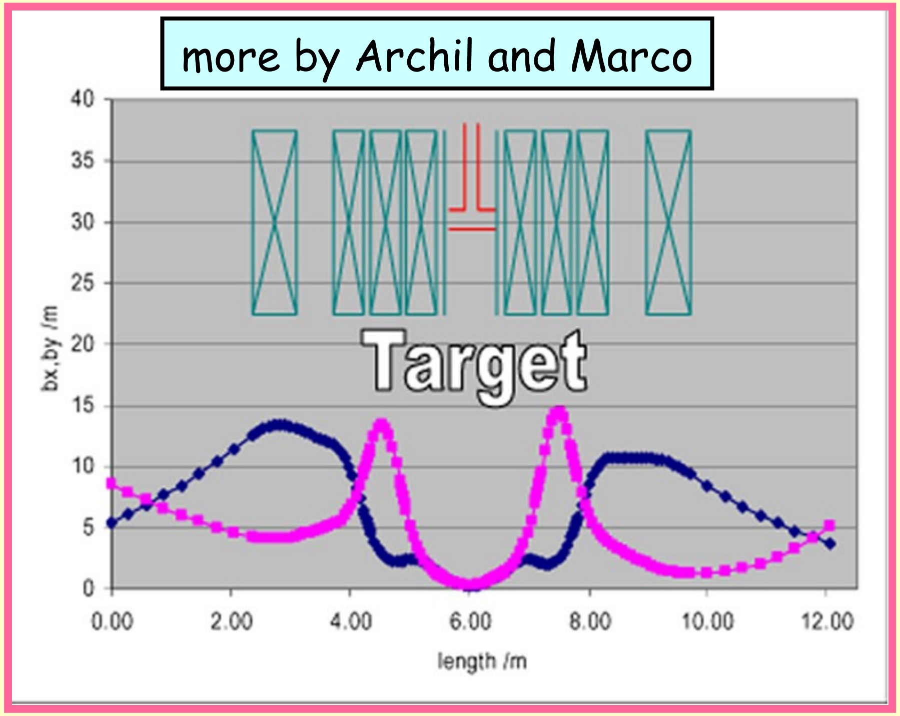
- Low-beta section
- Polarized target (former HERMES target)
- Detector
- Snake at COSY by combination of (ecooler + WASA) solenoid
- Commissioning of AD setup

Low beta section

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

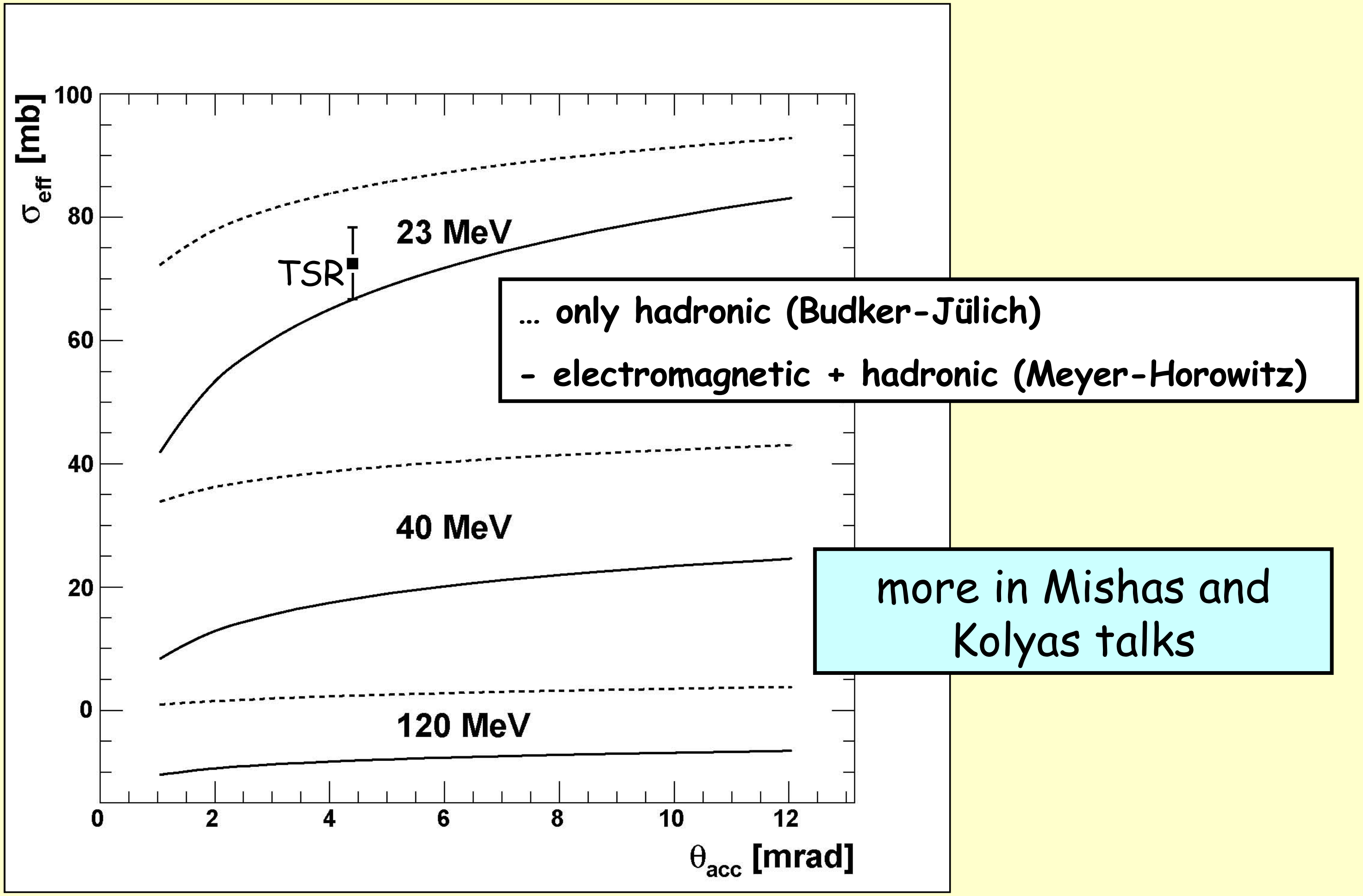
- Shorter buildup time, higher rates
- Larger polarization buildup rate due to larger acceptance
- Use of former HERMES target





Superconducting quadrupoles necessary

Polarizing cross sections from the two models



more in Mishas and Kolyas talks

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} ?

Method 1: 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

Target polarimetry requires BRP for pure electron and nuclear polarization

HOMs suggestion

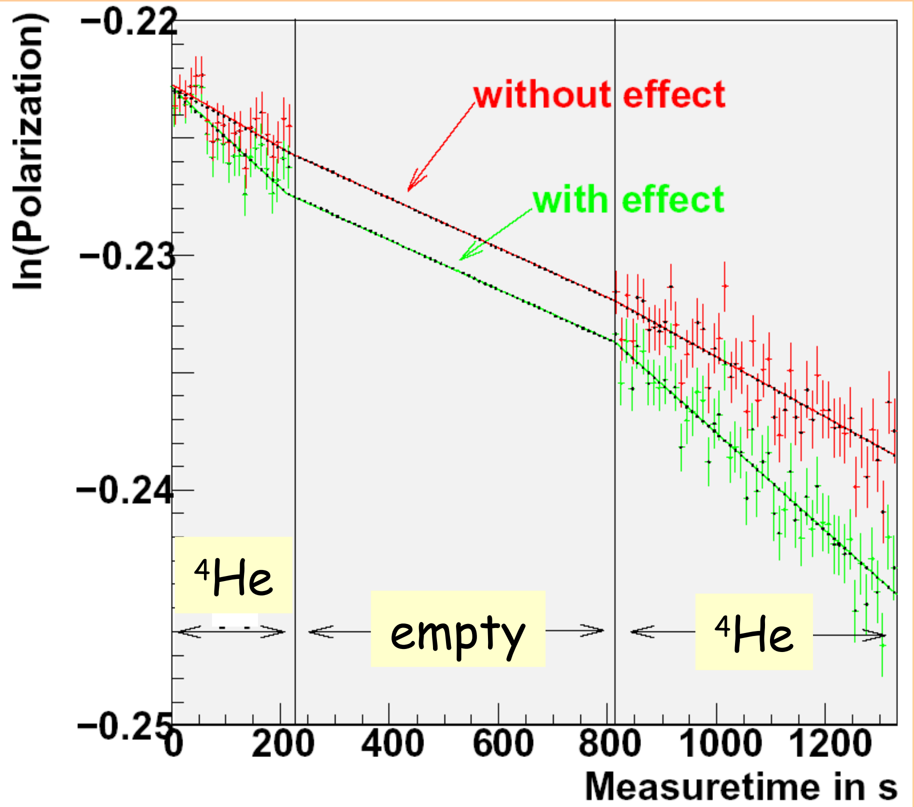
"If polarized electrons polarize an initially unpolarized beam, then, unpolarized electrons should depolarize an initially polarized beam!"

Method 2: Depolarization experiments

Electrons in ^{4}He storage cell or D cluster-jet target:
- Large analyzing power
- Large counting rates

- Distinguish electron effect from normal depolarization in COSY
- Prerequisites:
  - Large beam lifetime
  - Large polarization lifetime

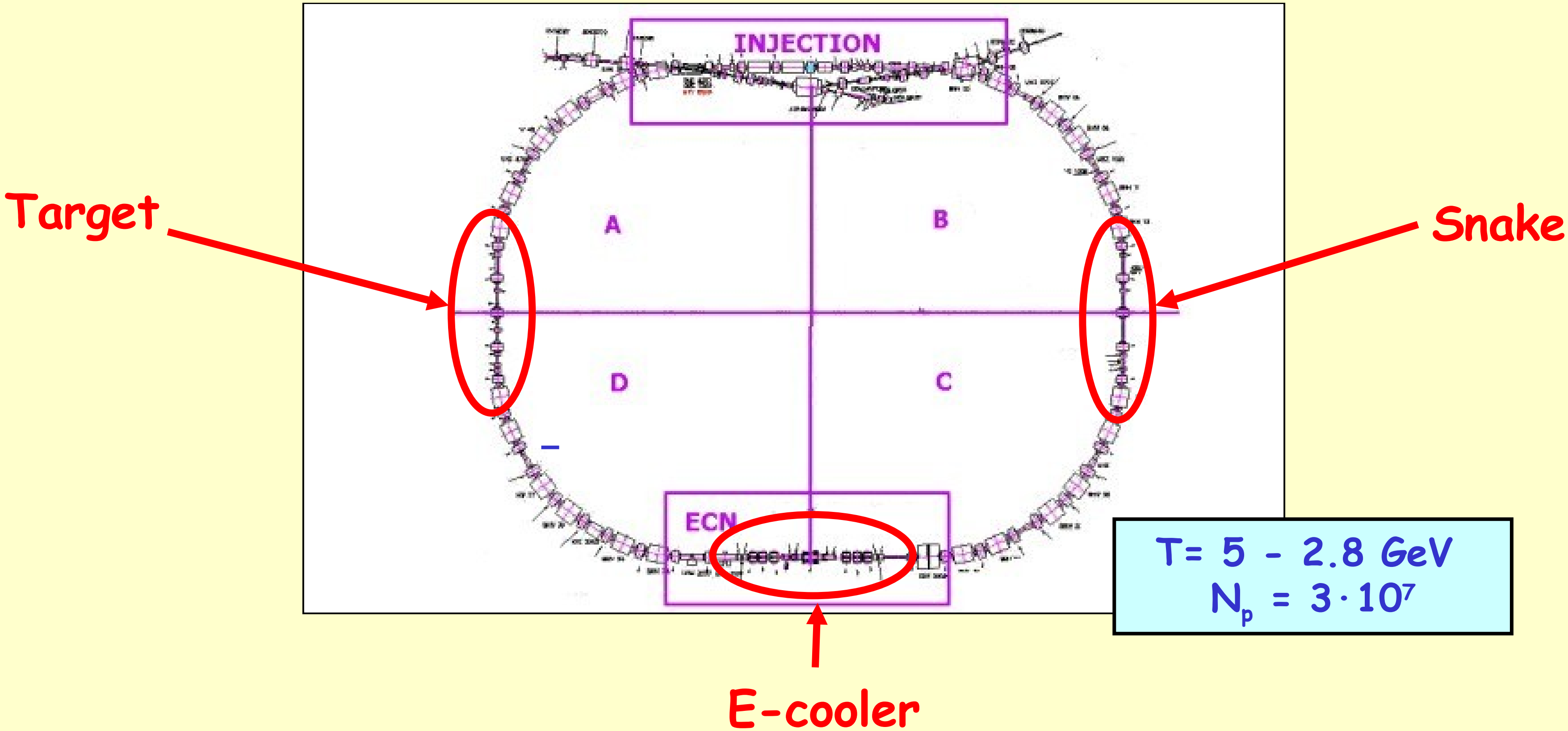
Prediction for ANKE/COSY (4 weeks)



more in Dieters talk

AD ring at CERN

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



T= 5 - 2.8 GeV

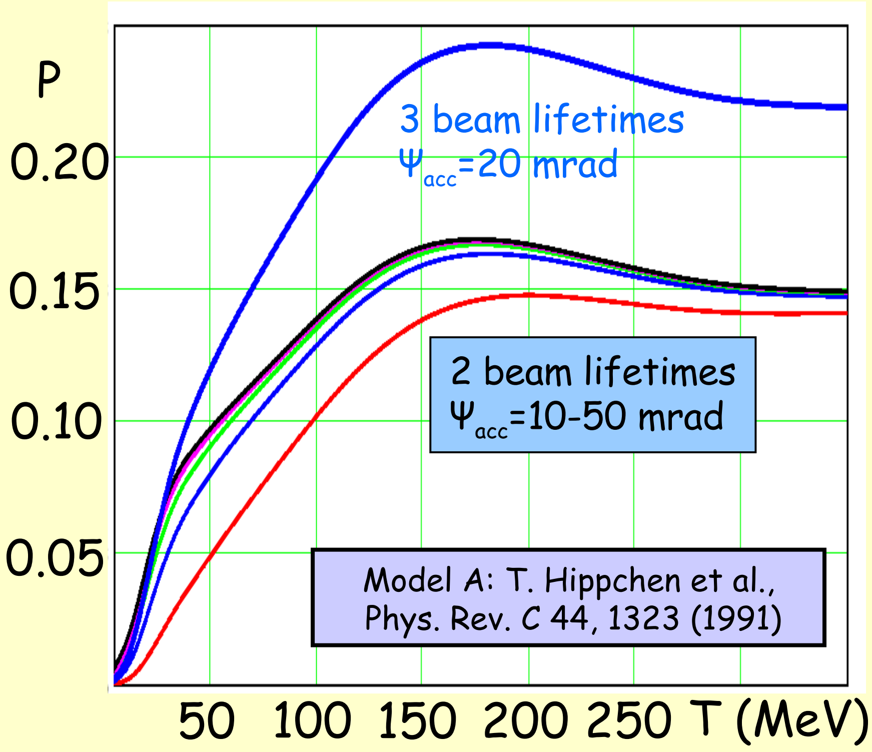
$N_p = 3 \cdot 10^7$

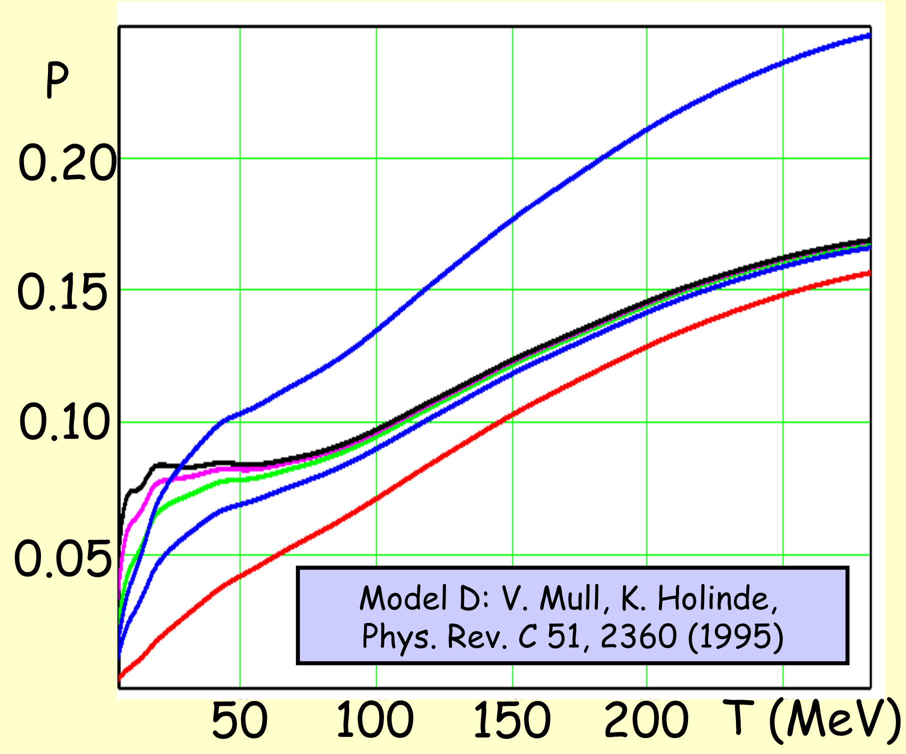
Measurement of effective polarization buildup cross-section

- Both transverse and longitudinal
- Variable acceptance at target
- Test also polarized D target

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

Theoretical estimate of Antiproton Beam Polarization (Hadronic Interaction: Longitudinal Spin Filtering)





Timeline, Proposals, Applications

Fall 2006	Proposal to COSY: Beam depolarization studies
Spring 2007	Beam Request: Beam & polarization lifetime studies
	- Submission of FP 7 application
	- Application to FZJ Ausbaumaßnahmen
	- Application to FZJ Innovationsfond
	- Heraeus Seminar: June 23-25, 2008 in Bad Honnef
Fall 2007	JRA Physics with polarized Hadronic Probes (FZJ)
	JRA Polarized Targets for Storage Ring Experiments (Ferrara)
	JRA Silicon Detectors for Internal Targets (FZJ)
	Technical proposal to COSY-PAC for spin filtering
	Technical proposal to SPSC for spin filtering at AD
	conditional: Beam Request for 4 week depolarization run
2006-2007	Design and construction phase
2008-2009	Spin-filtering studies at COSY
	Commissioning of AD experiment
2010	Installation at AD
2010-2011	Spin-filtering studies at AD

Work to be done until Fall 2007

1. General stuff
   - Paper about „Theory of Spin Filtering“ (Nikolaev, Nekipelov):
     - Transparent description of MH and Budker-Jülich + Predictions for proton and antiproton polarization buildup
2. Depolarization Study
   - Run plans for June and November Machine development
   - Theoretical estimates of effects that could fake an electron effect
   - Second STT
   - Online Software to determine beam polarization and τ_p
3. Spin Filtering at COSY and AD
   - Bottom line on detector
     - COSY studies can be carried out with HERMES recoil detector and new Jülich Electronics (2 layers, modules ~10x10 cm^2, 20 cm coverage)
     - Strong longitudinal guide field has to be implemented
     - AD studies need more detector coverage, but no strong field
     - Detector Simulations in good shape
   - Lattice Studies for Spin filtering studies
     - COSY lattice at T=45 MeV seems feasible with 4 SC quads
     - AD lattice based on Pavel Belochitskys idea (switch on low beta)
   - No solution yet for AD Snake
   - Quadrupole Magnet design
4. Mechanical Engineering (Heidi + 2nd Klehr-like full time ZAT)