Spin Filtering Studies at COSY and AD (Target Issues)

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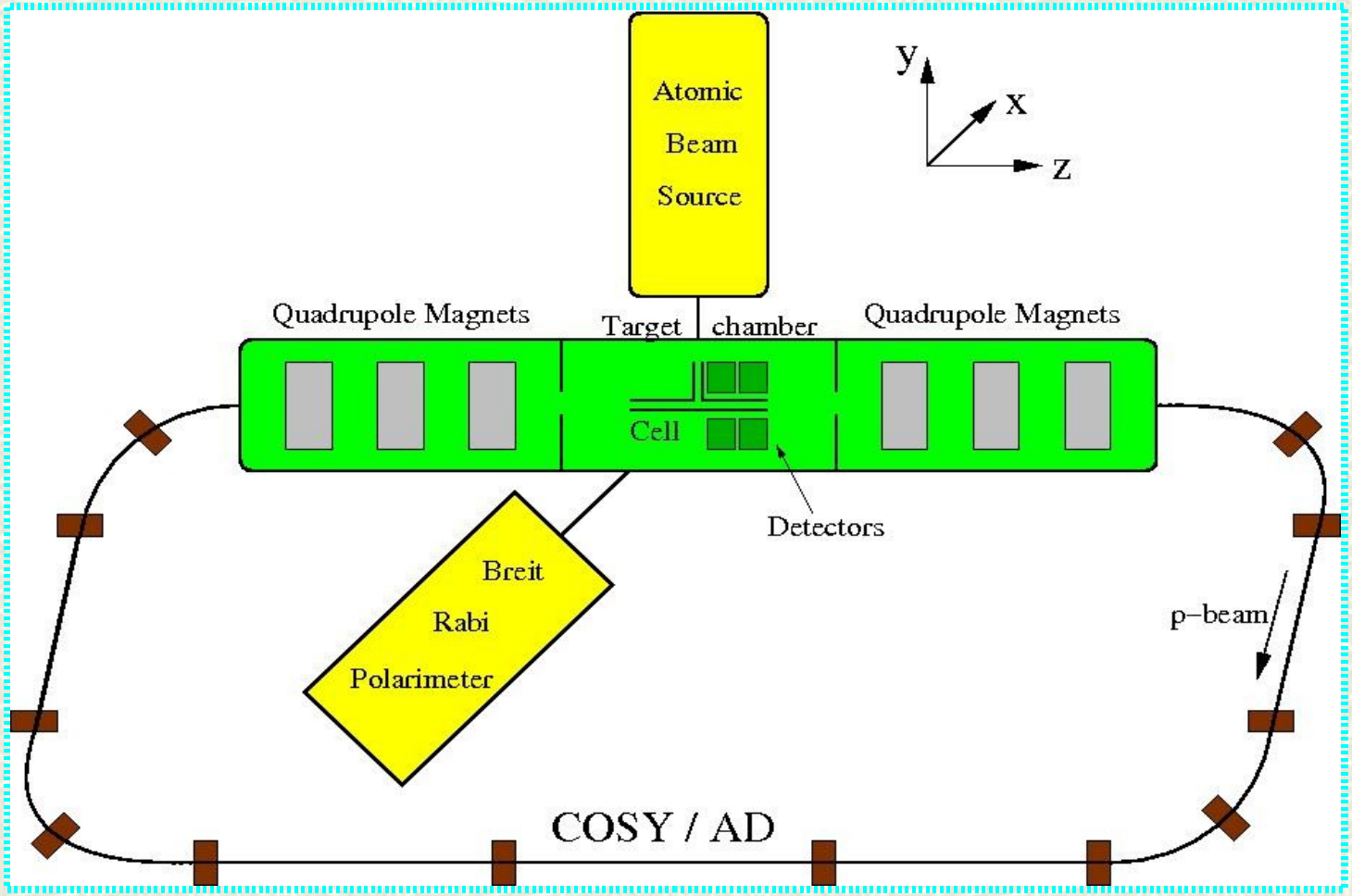
Introduction

- Proposal of PAX for polarized $\bar{p}p$ experiments
- Polarization of protons by spin filtering demonstrated by FILTEX (1993)
- Theoretical understanding unclear, two competing interpretations with or without an electron contribution
- Clarification needed in this point: measurements with pure electron and pure nuclear polarization at COSY (Jülich) to disentangle the effects
- Polarization of antiprotons: filtering measurements with at AD (CERN)

See also talks by F.Rathmann and N.Nikolaev

Overview


Atomic
Beam
Source
y
x
z
Quadrupole Magnets
Target chamber
Quadrupole Magnets
Cell
Detectors
Breit
Rabi
Polarimeter
p–beam
COSY / AD

Requirements for Spin Filtering

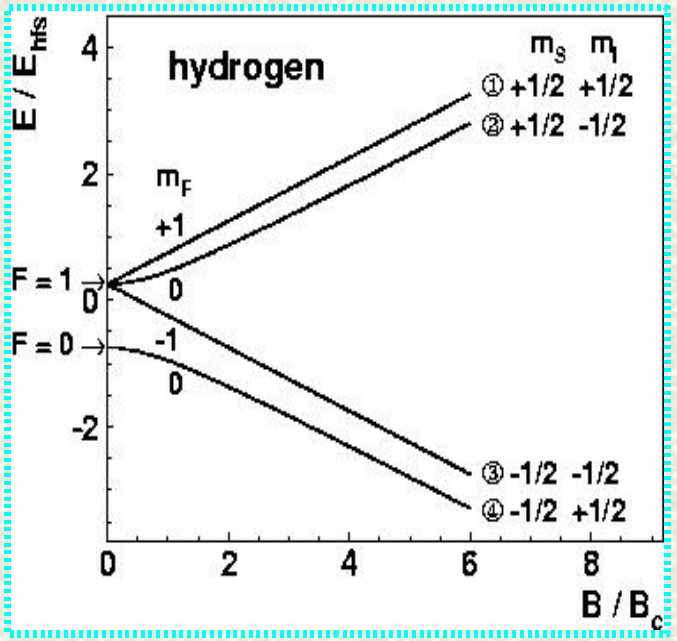
- High polarization of the target
- Density up to 10^{15} atoms/cm^2
- Variability of the direction of the spin axis
- Implementation into storage rings
- Ability to produce electron and nuclear polarization separately
- Polarization measurement independent of the beam
- Ability to produce polarized H and D in short sequence with the same setup for filtering with D and measuring with H (no A_y for $\bar{p}$d known)

Polarization of the Target Gas

- Hydrogen states are defined as ($|a\rangle = |m_S, m_I\rangle$):

$|1\rangle = |\,½, ½\rangle$
$|2\rangle = \cos\boldsymbol{\theta}\,|\,½, -½\rangle + \sin\boldsymbol{\theta}\,|\,-½, ½\rangle$
$|3\rangle = |\,-½, -½\rangle$
$|4\rangle = -\sin\boldsymbol{\theta}\,|\,½, -½\rangle + \cos\boldsymbol{\theta}\,|\,-½, ½\rangle$

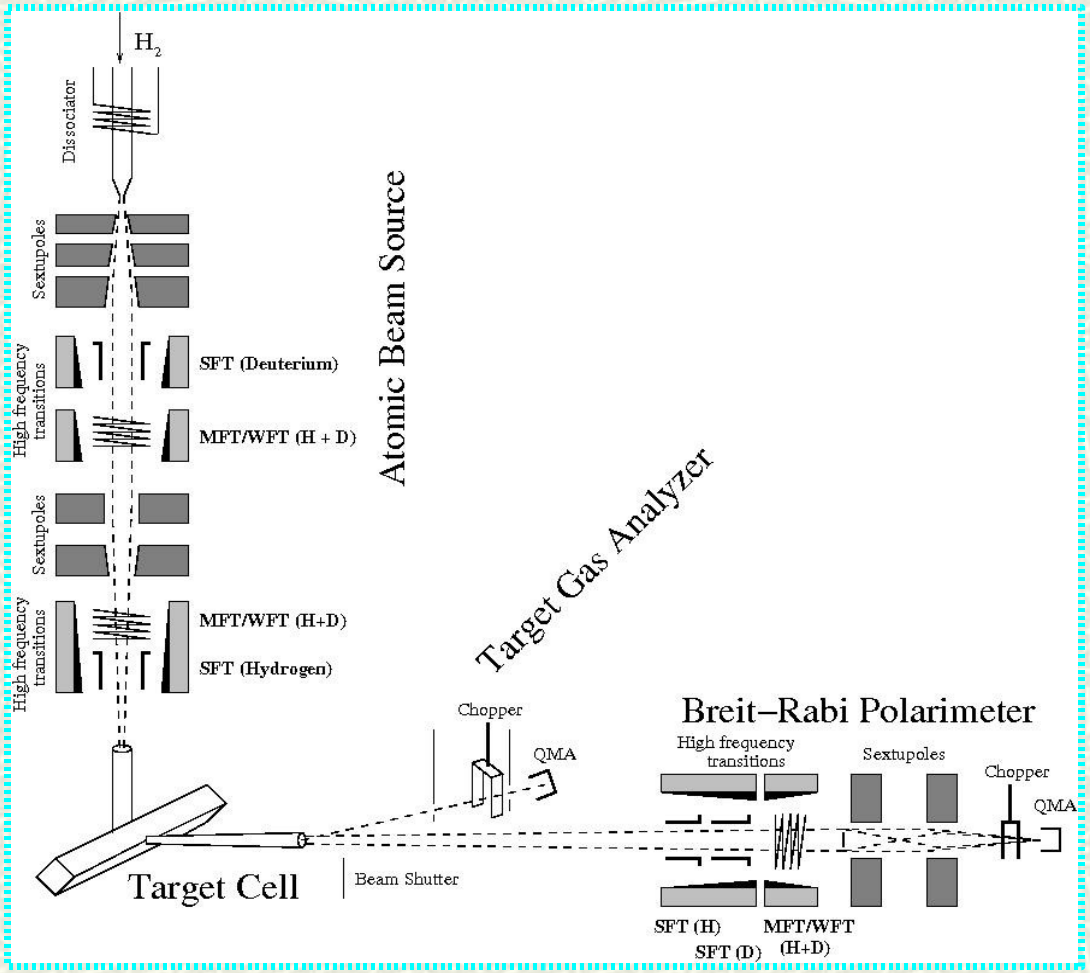
with $\boldsymbol{\theta} = ½ \arctan(B_C/B)$



- Polarization:

$P_e = n_1 - n_3 + (n_2 - n_4)\cos 2\boldsymbol{\theta}$
$P_z = n_1 - n_3 - (n_2 - n_4)\cos 2\boldsymbol{\theta}$

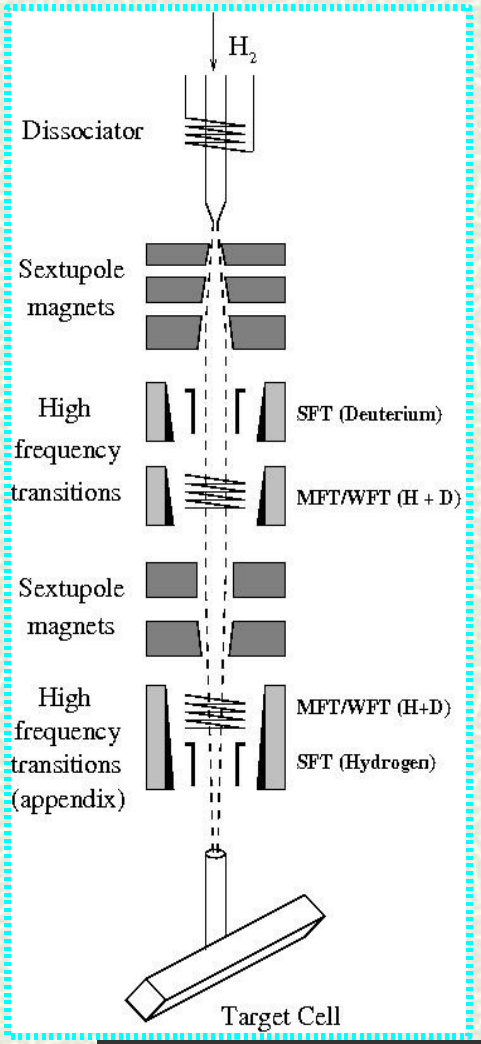
Setup of the Polarized Target



- Production of a polarized atomic beam by an atomic beam source (ABS)
- Increase of the target density by means of a storage cell
- Analysis of target polarization by a so-called Breit-Rabi polarimeter (BRP) and a target gas analyzer (TGA)

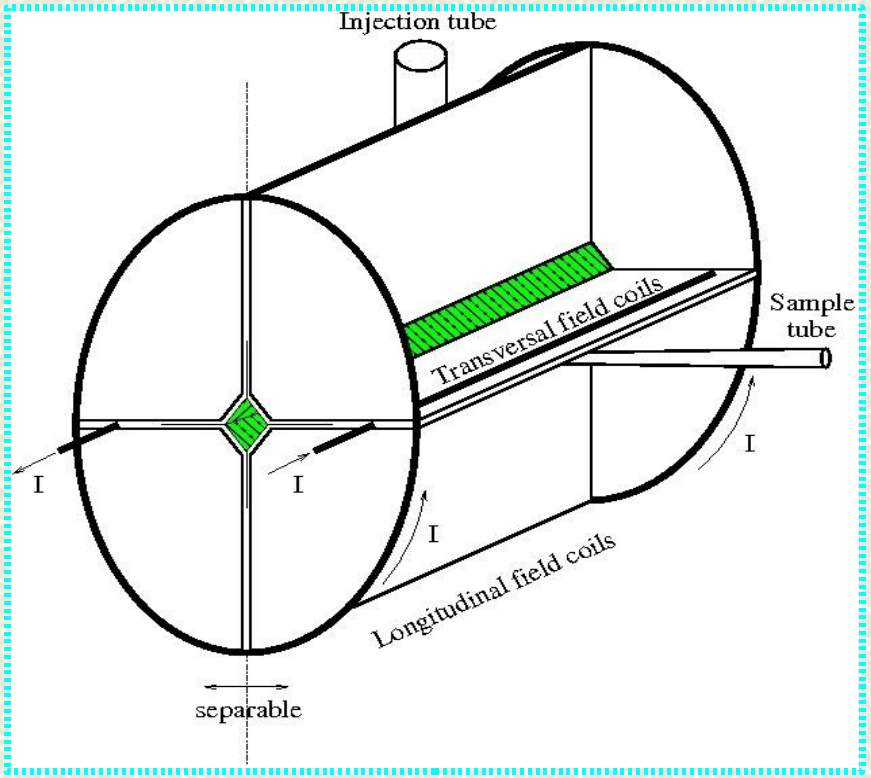
The Atomic Beam Source

- ABS vacuum consists of 7 turbo molecular pumps with total pumping speed of ~10000 l/s
- Atomic beam is produced when the dissociated gas expands through a cooled nozzle into the vacuum
- Sextupole magnets produce electron polarization by focussing atoms in hyperfine states |1> and |2> and defocussing |3> and |4>
- High frequency transitions (HFT's) exchange populations of hyperfine states and are used to produce nuclear polarization
- HFT's will be tuned for H and D for filtering with D and beam polarization measurement with H



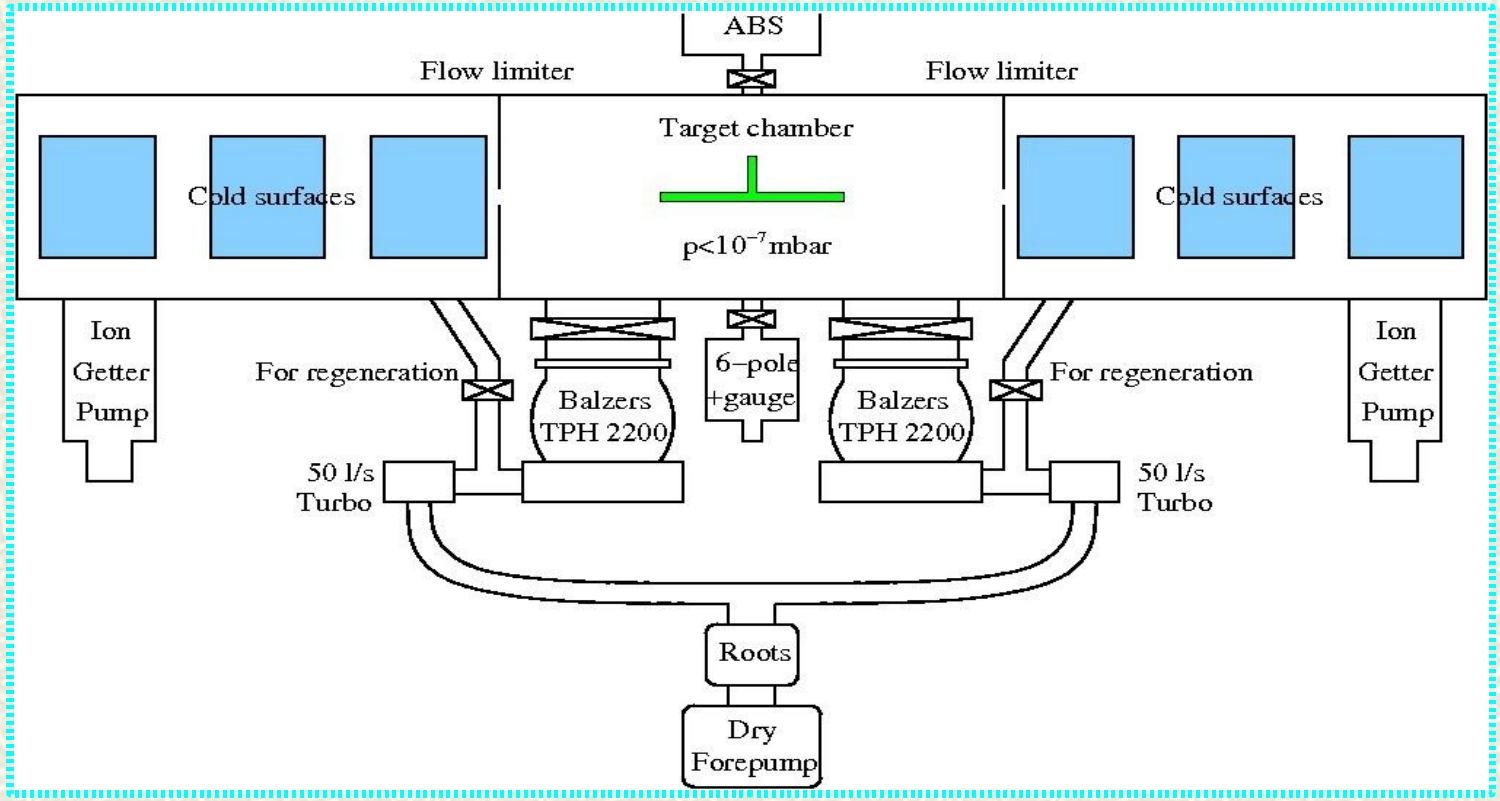
Storage Cell and Holding field

- Filtering requires 10^{15} atoms/cm^2 therefore use of storage cell
- Use of Teflon foil to detect recoils and suppress depolarization and recombination
- Openable cell to allow injected uncooled AD beam to pass
- Weak holding field coils included in cell design to define spin axis



- Pair of superconducting Helmholtz coils to provide a strong longitudinal holding field for separate determination of nuclear and electron effects during spin-filtering

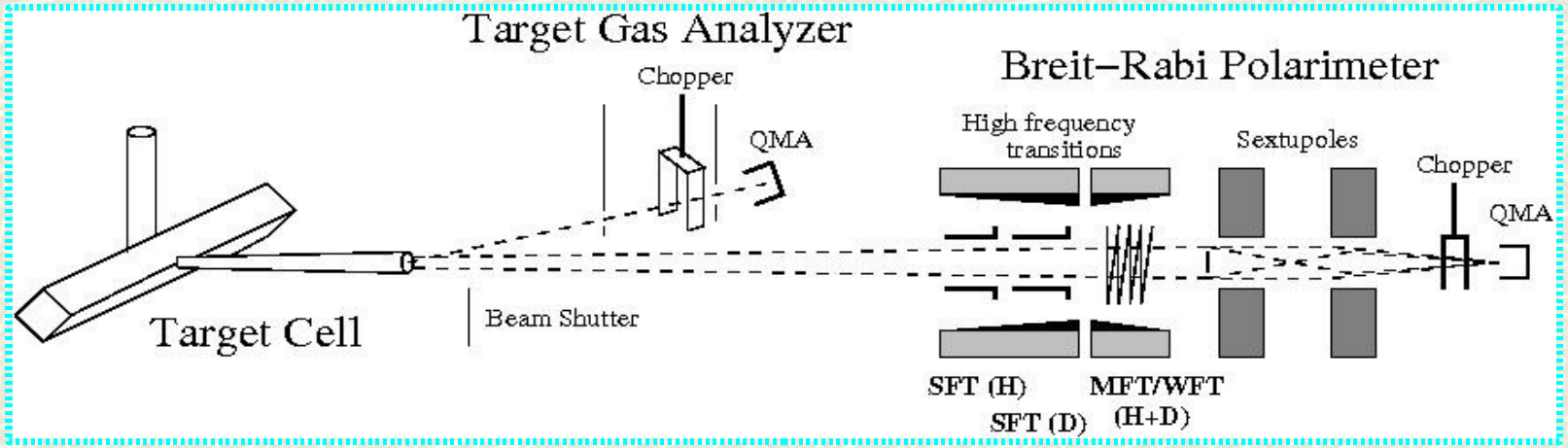
Beam line vacuum at the target



- Flow limiters to reduce gas flow into the adjacent sections
- Pump with cold surfaces of the superconducting quadrupoles

Polarization analysis

- TGA is used to determine atomic fraction of the target gas
- BRP measures the polarization of the target gas atoms using combinations of high frequency transitions in ABS and BRP
- Calibration for H and D to measure both in a short time interval
- Cross check of the BRP measurement using pp ($\bar{p}p$) scattering with unpolarized COSY (AD) beam



Planned measurements

- Filtering measurements with pure electron polarized hydrogen target (states |1> and |2>) and pure nuclear polarized hydrogen (states |1> and |4>) in a strong magnetic holding field at COSY using a proton beam to determine the effect of electrons and nuclei separately
- Filtering tests at COSY with nuclear polarized hydrogen and deuterium target (state |1>) in a weak magnetic holding field to redo the FILTEX measurements with protons and test the setup for AD
- Filtering measurements at AD with nuclear polarized hydrogen and deuterium target (state |1>) in a weak magnetic holding field and an antiproton beam to show the ability of the method to produce polarized antiprotons

Summary

- Polarized gas target meets the requirements for the filtering tests
- Ability to provide highly polarized H and D in short sequence
- Storage cell will increase density to the values needed but thin teflon wall will allow to detect recoils
- Change of spin direction can be achieved by switching the weak target holding field from vertical to longitudinal
- BRP will be able to measure the target polarization with required accuracy (calibration using pp ($\bar{p}p$) scattering)
- Target setup will be completed end of 2007, measurements starting in summer 2008 at COSY and 2009/10 at AD

The Polarized Target to use

Former HERMES-target at HERA