First measurement of spin-exchange collision cross section in the low temperature region

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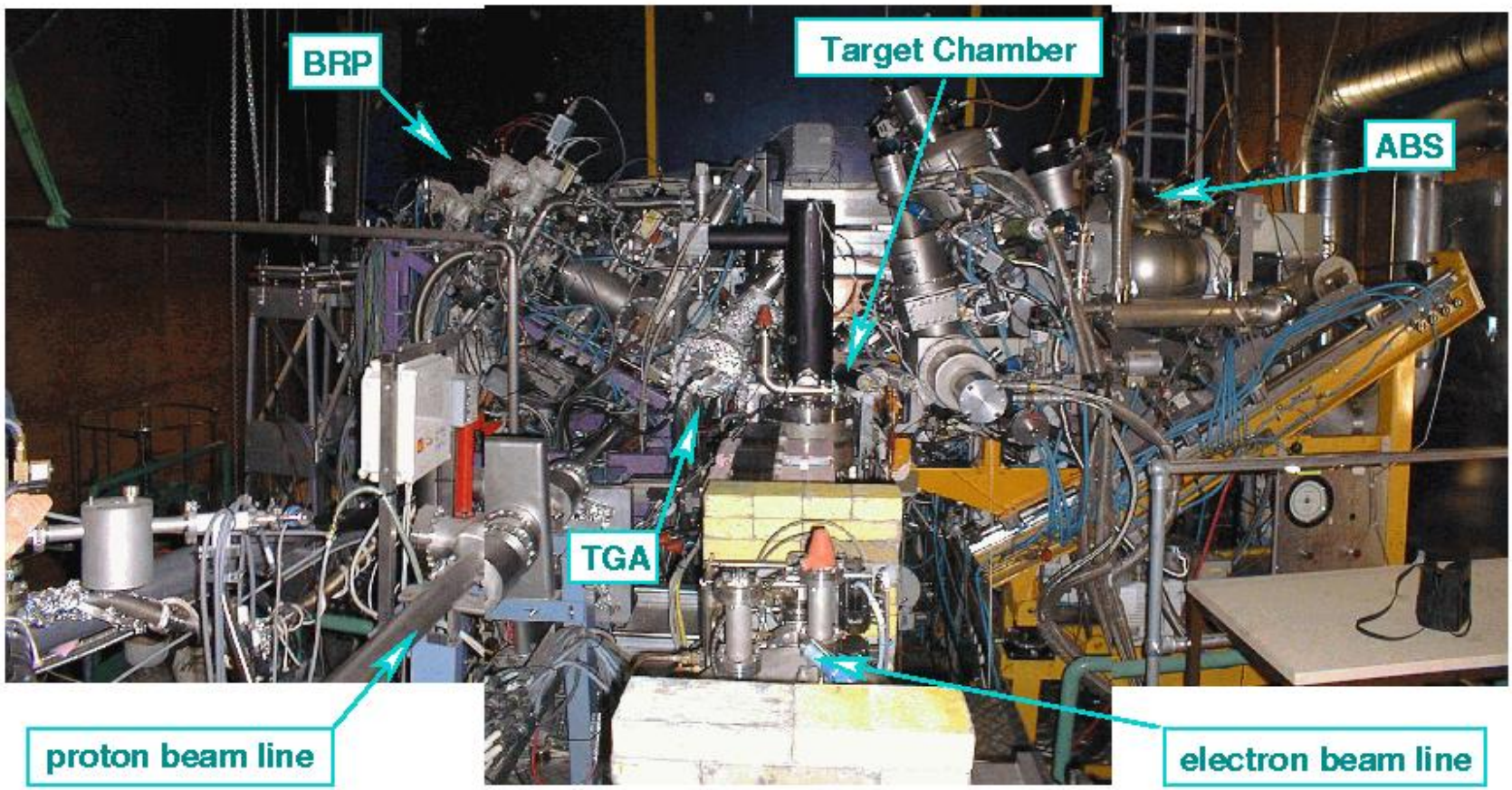
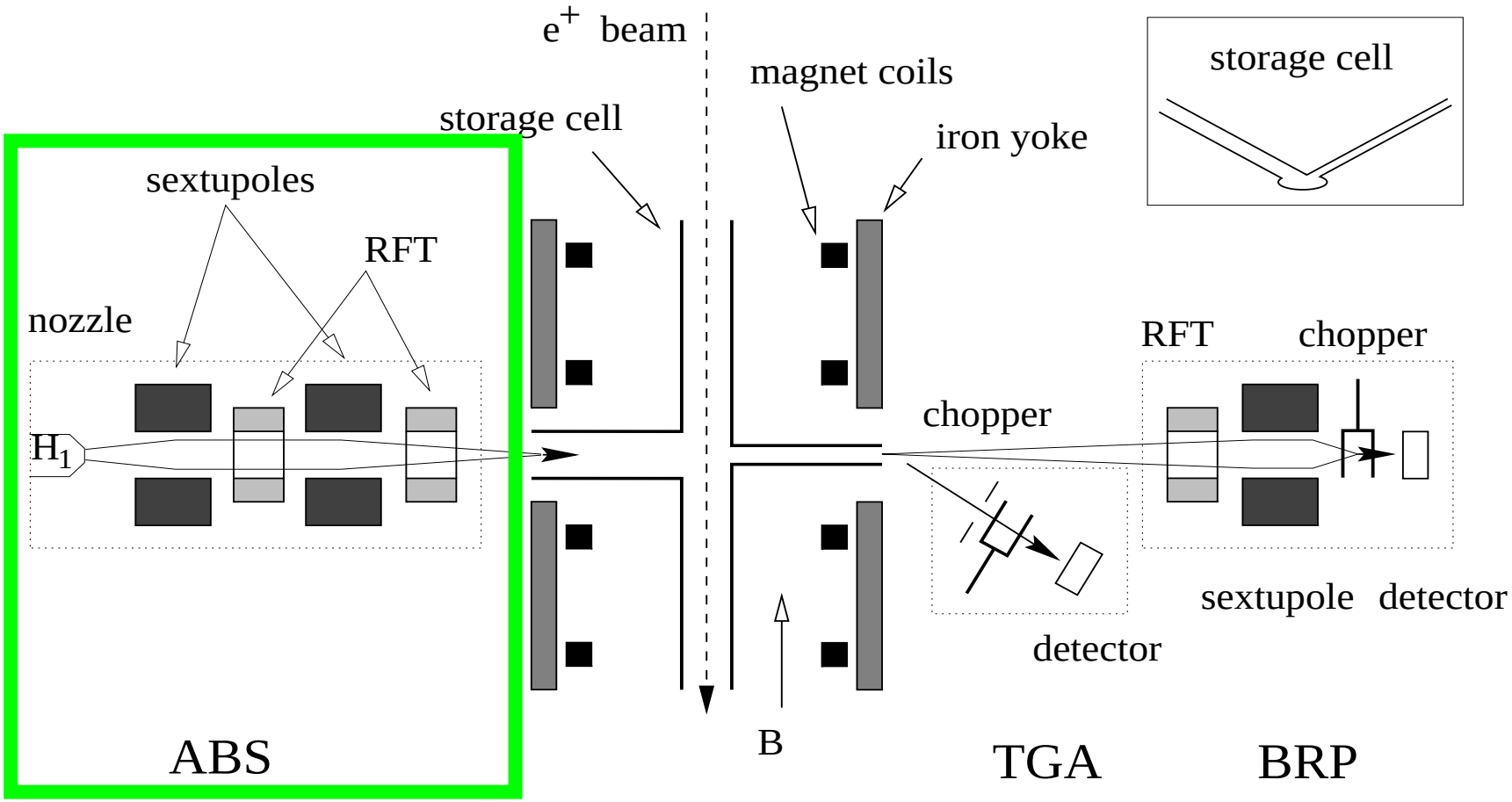
Outline

- HERMES target
- Spin exchange collision measurement
- Conclusion

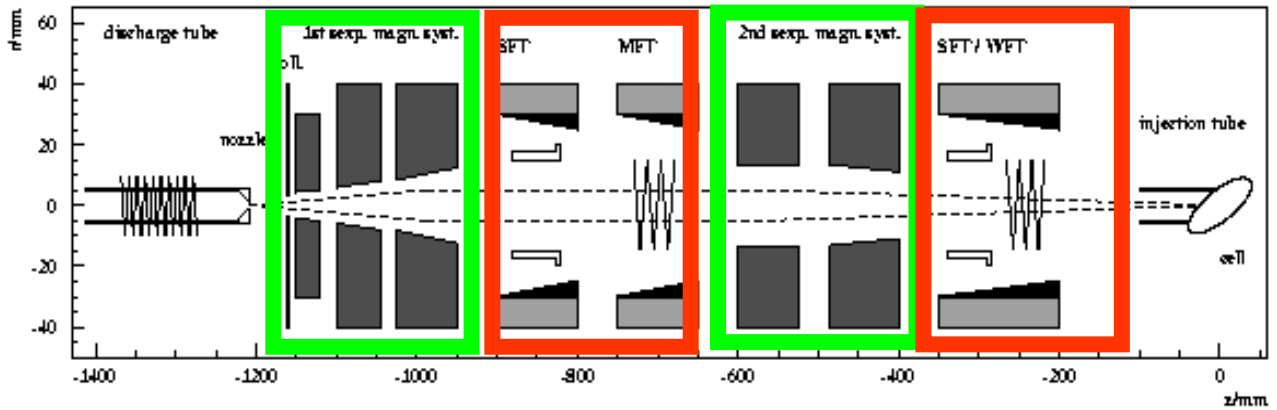
- $e^{\pm}$ storage ring (27 GeV)
- $e^{\pm}$ self polarized by Sokolov-Ternov (P ~ 40 %)
- HERMES fixed target experiment

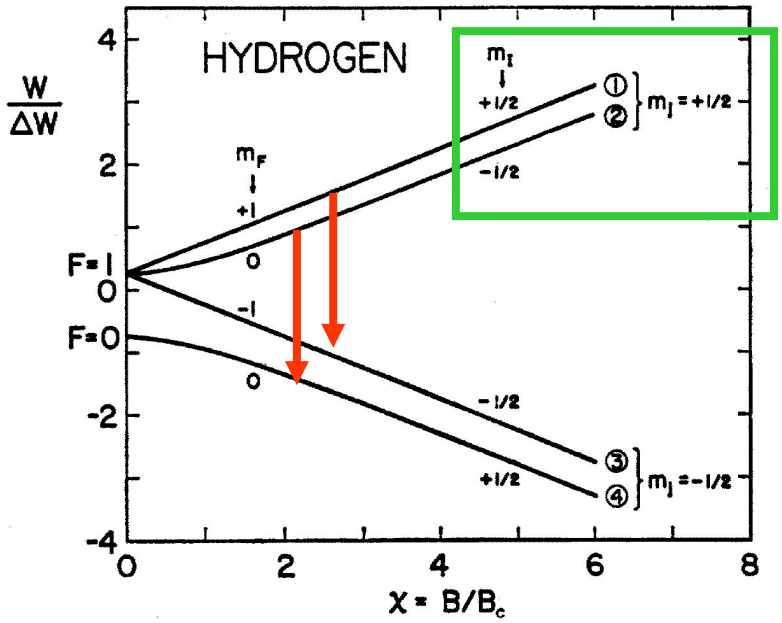
Polarized Gas Target




e+ beam
magnet coils
storage cell
iron yoke
storage cell
sextupoles
RFT
nozzle
RFT
chopper
H1
chopper
sextupole
detector
detector
B
ABS
TGA
BRP

Atomic beam source





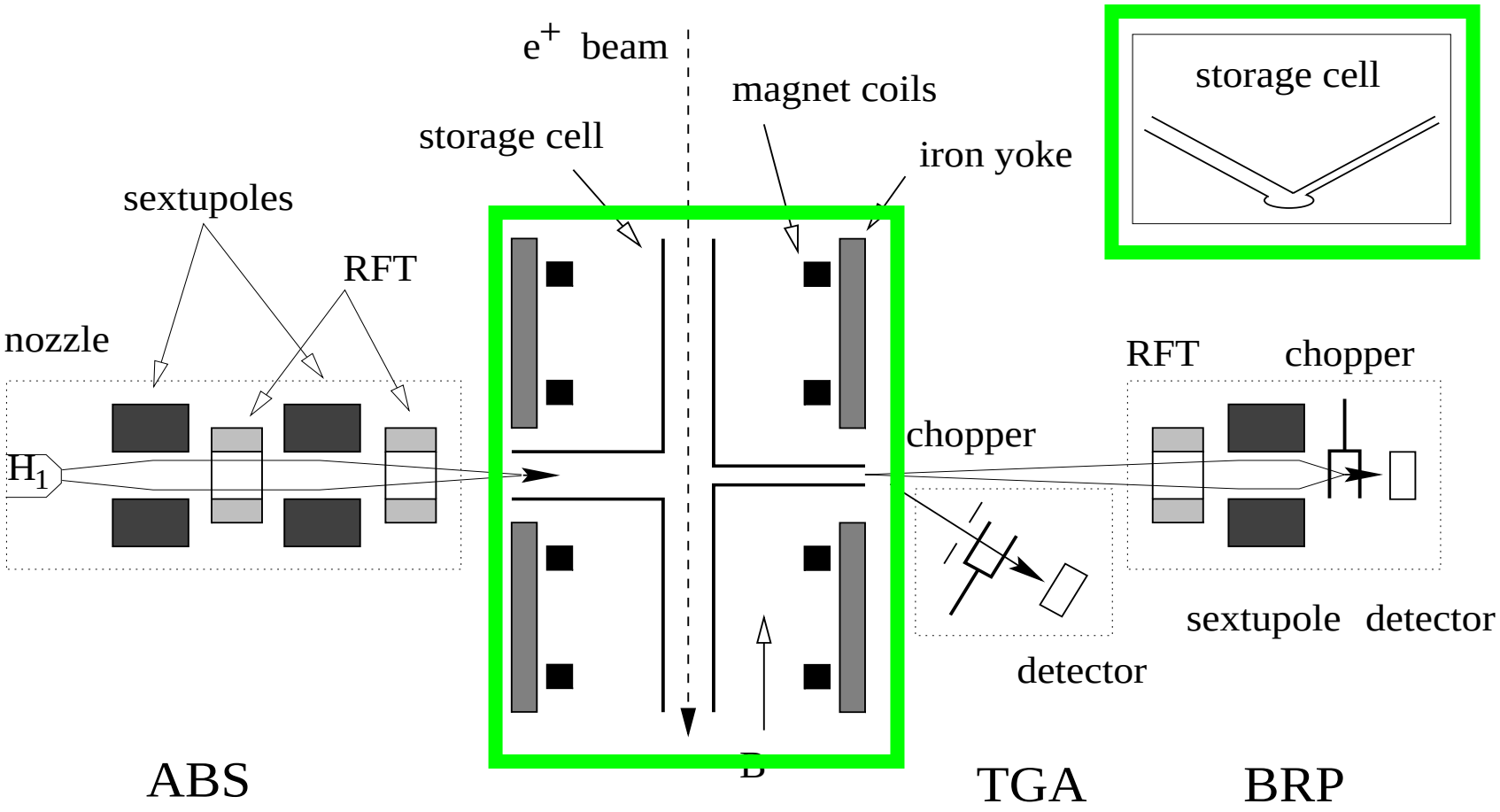
Atoms with m_j=+½ focused in sextupole magnets.

RF transitions select HFS.

Injection for data taking:

P_z^+ $|1\rangle$ $|4\rangle$

P_z^- $|2\rangle$ $|3\rangle$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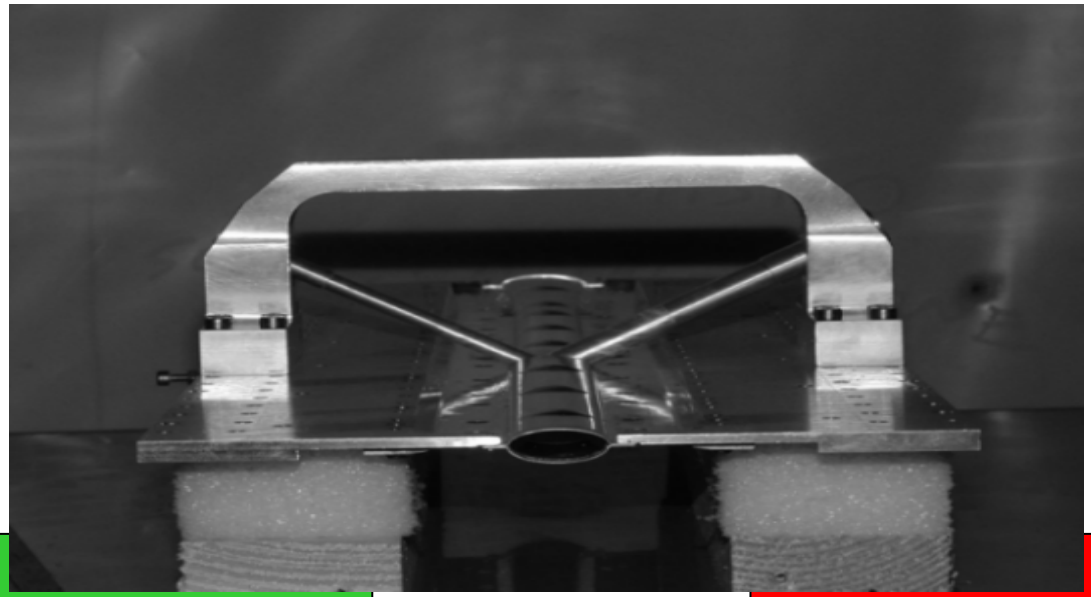
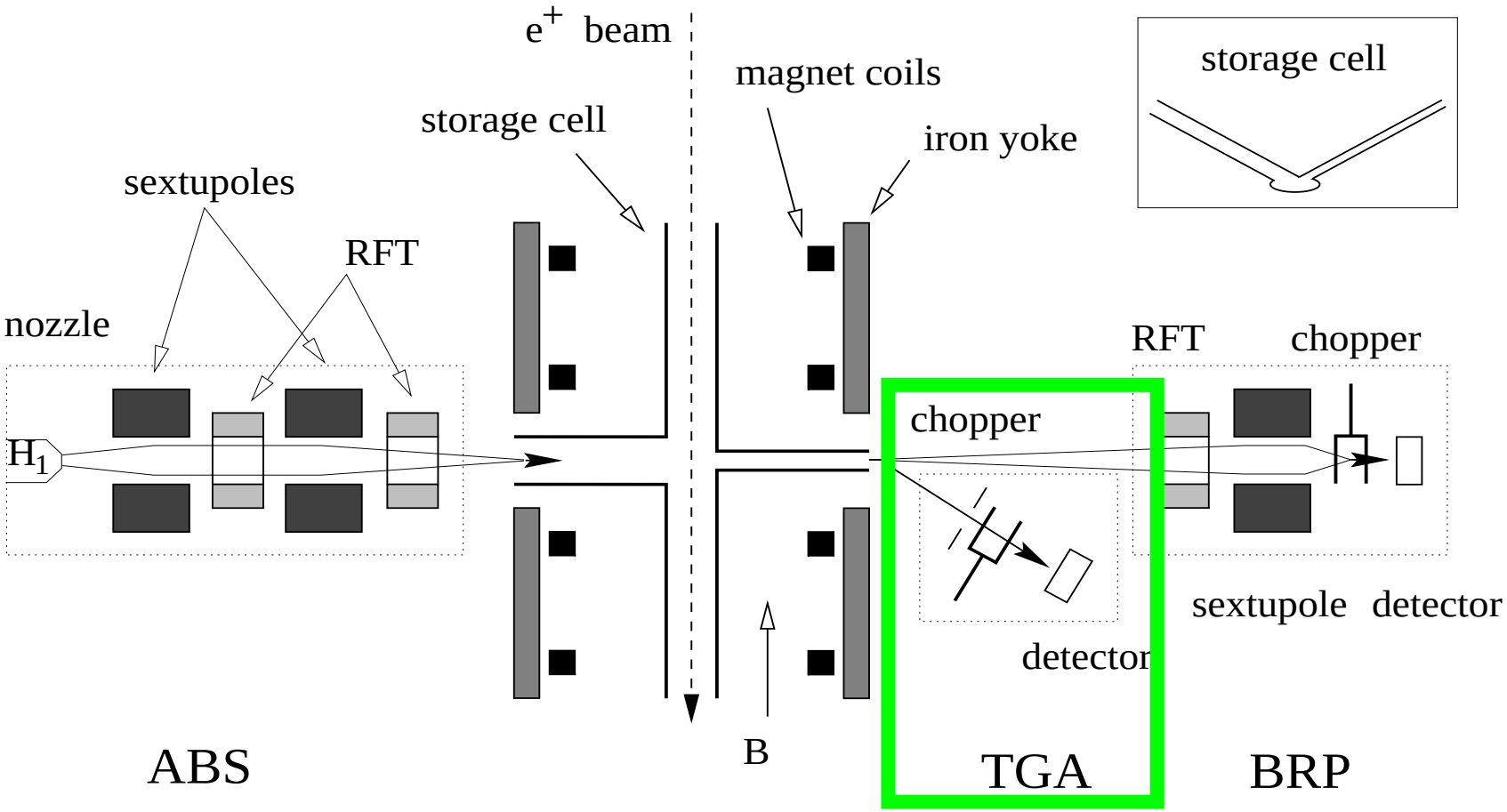
The storage cell



- **DENSITY increase**
- **No dilution factor**

- **Recombination**
- **Depolarization**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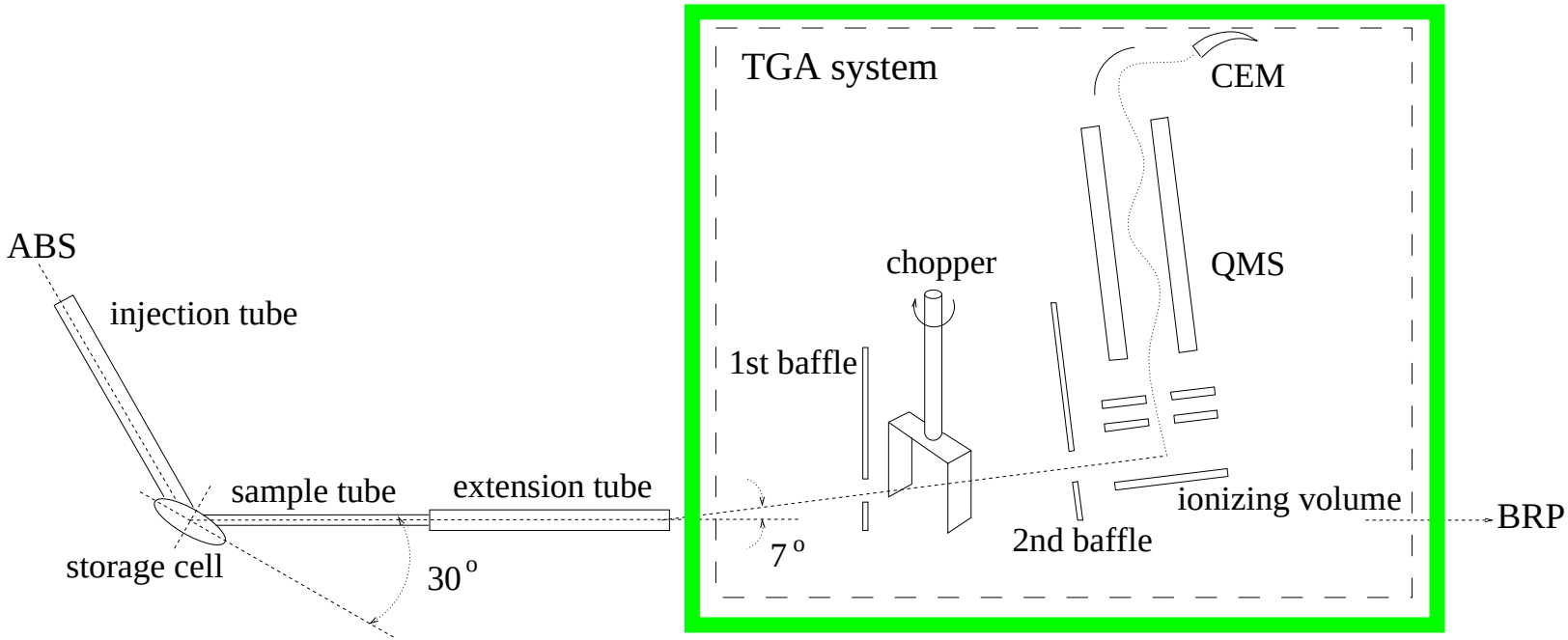
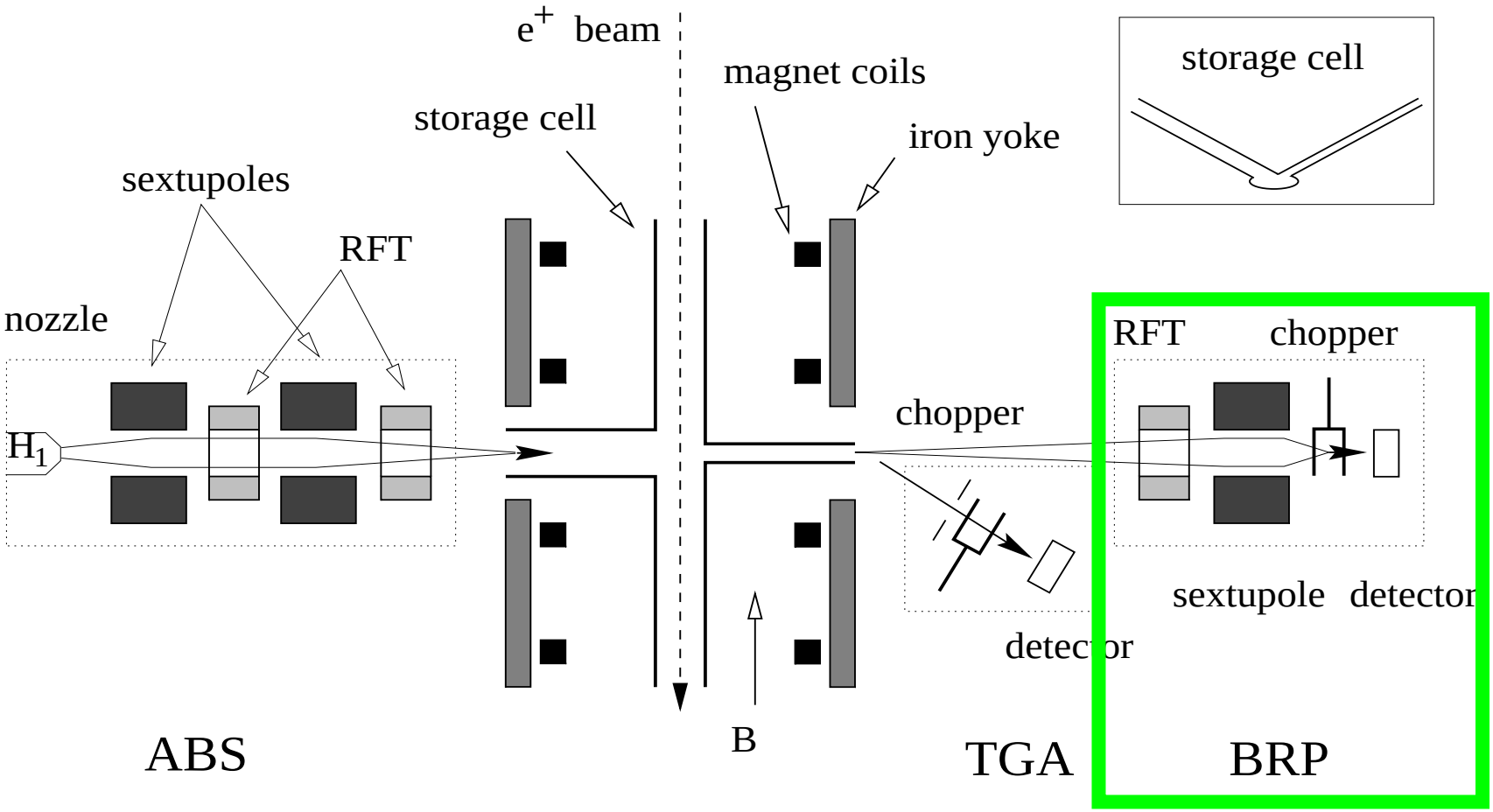
Target Gas Analyzer



Atomic fraction $(\alpha^{TGA}) \sim \dfrac{\phi_a}{\phi_a + \phi_m}$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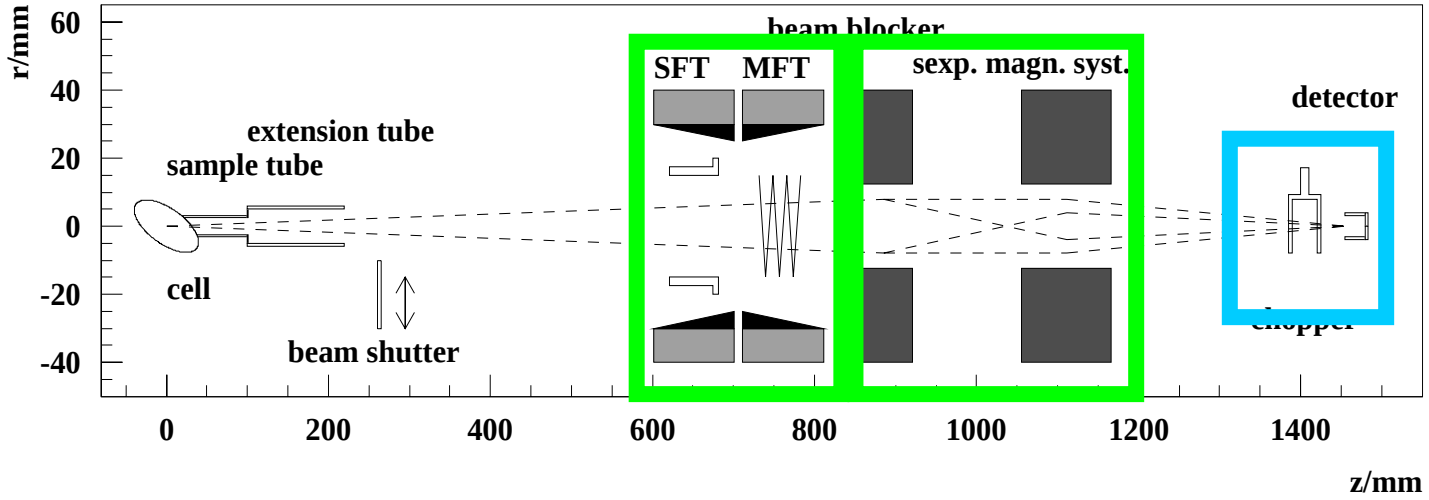
Brait – Rabi Polarimeter



Hyperfine states selection

Atoms detection

$\Rightarrow$ n_1 n_2 n_3 n_4 $\Rightarrow$ $P_a^{BRP} = \underbrace{n_1 + n_4}_{P_z^+} - \underbrace{(n_2 + n_3)}_{P_z^-}$

Target polarization

$$P_T = \alpha_0 \left[\alpha_r P_a + (1 - \alpha_r) P_m \right]$$

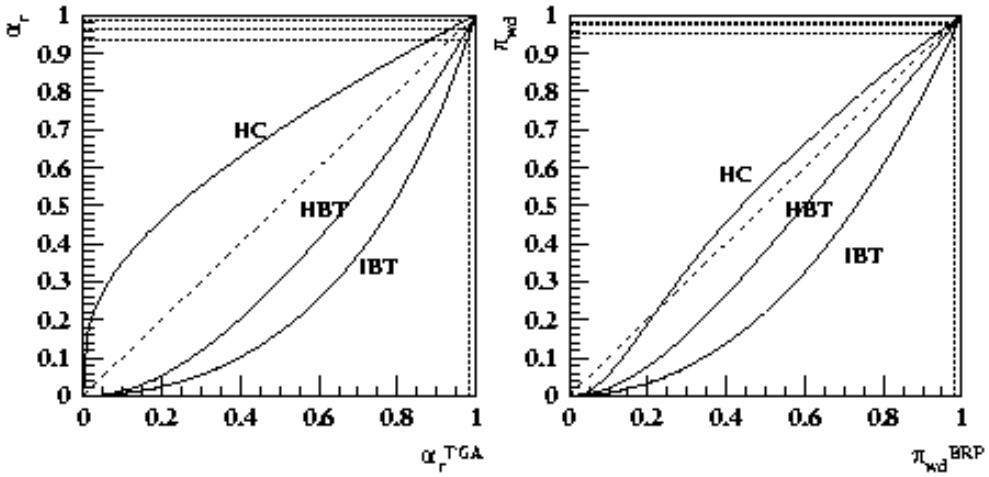
- P_T = **total target polarization**
- α_0 = atomic fraction in absence of recombination
- α_r = atomic fraction surviving recombination
- P_a = polarization of atoms
- P_m = polarization of recombined molecules

Relation to **measured quantities**:

- Sampling corrections

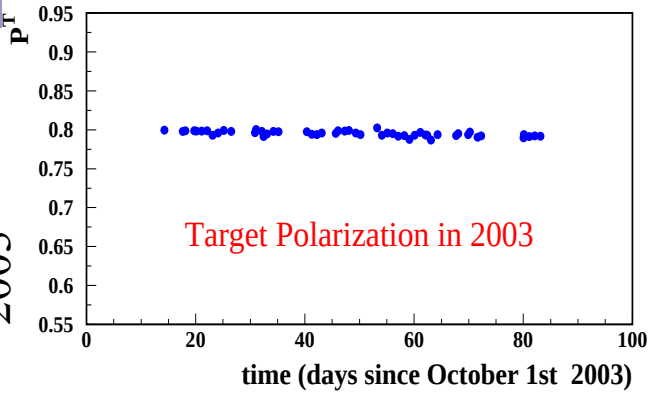
$\alpha_r = c_a \, \alpha_r^{TGA}$

$P_a = c_P \, P_a^{BRP}$



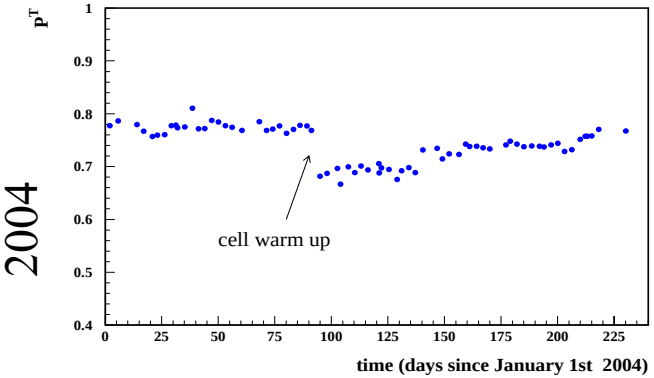
2003 – 2005 target running

2003



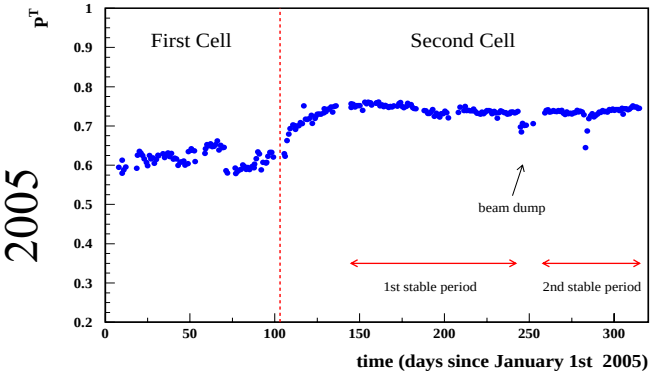
Smooth performance
$P_T = 0.795 \pm 0.033$

2004



Cell damaged by a warming up of the line

2005



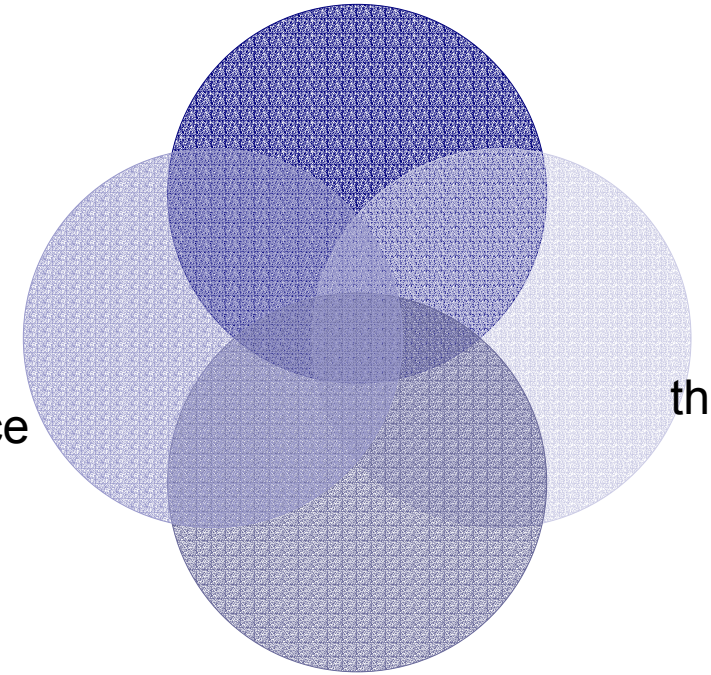
First cell damaged by a beam dump

Spin Exchange Measurement

- Introduction
- Measurement with the HERMES target
- Results
- Conclusion

Introduction

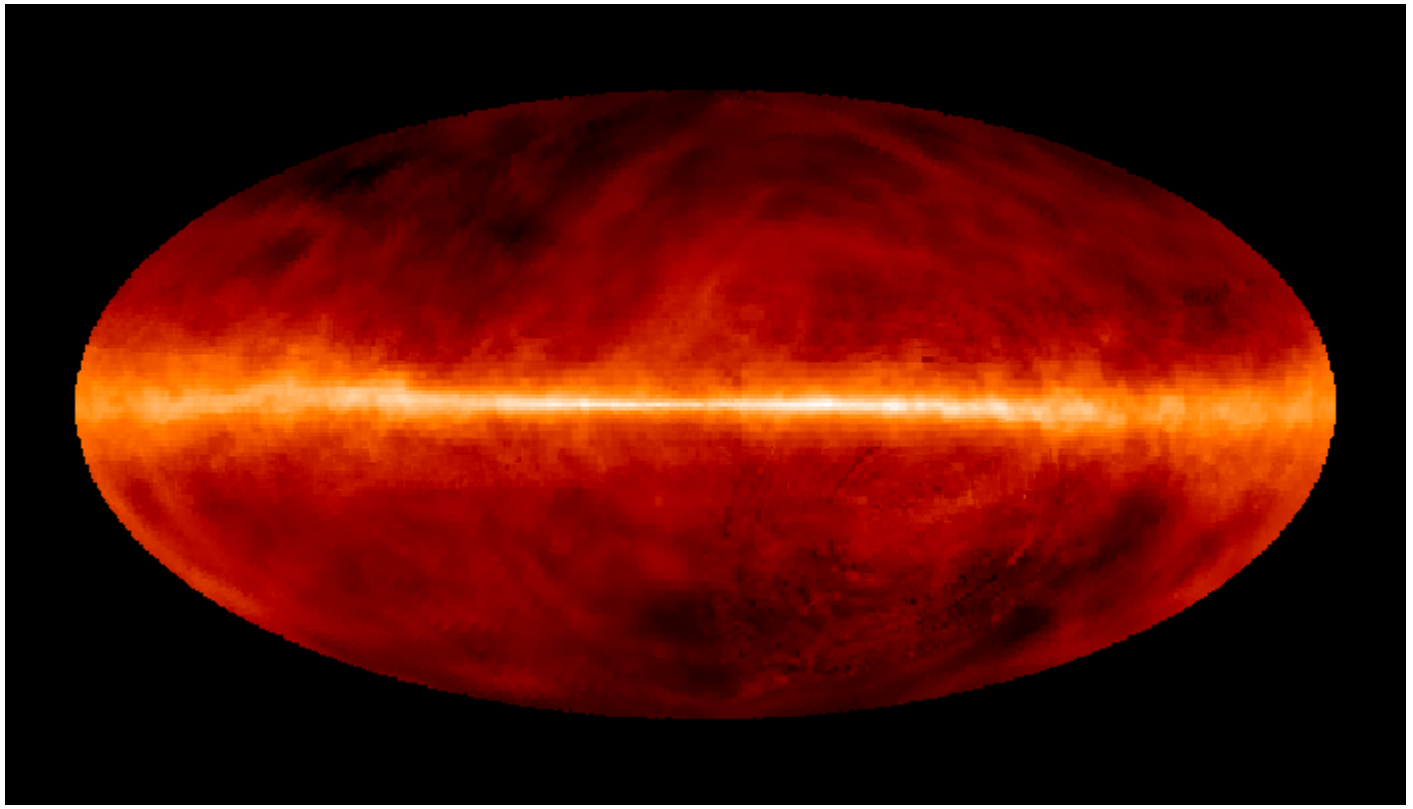
Universe fill
by hydrogen
atoms



Determination
of the
distribution of
Hydrogen in the space

In case of
collision
switch from
the triplet to the singlet
configuration

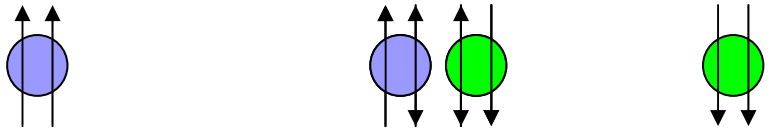
Emission of radio
Waves (1.42 GHz)



http://antwrp.gsfc.nasa.gov/apod/ap961218.html

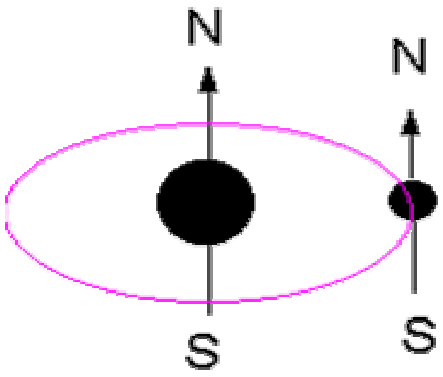
The process

$\Sigma_i m_F$ = constant

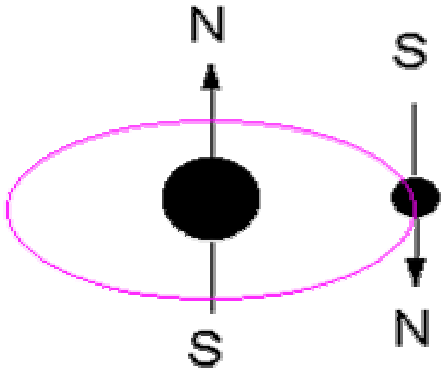


Theory

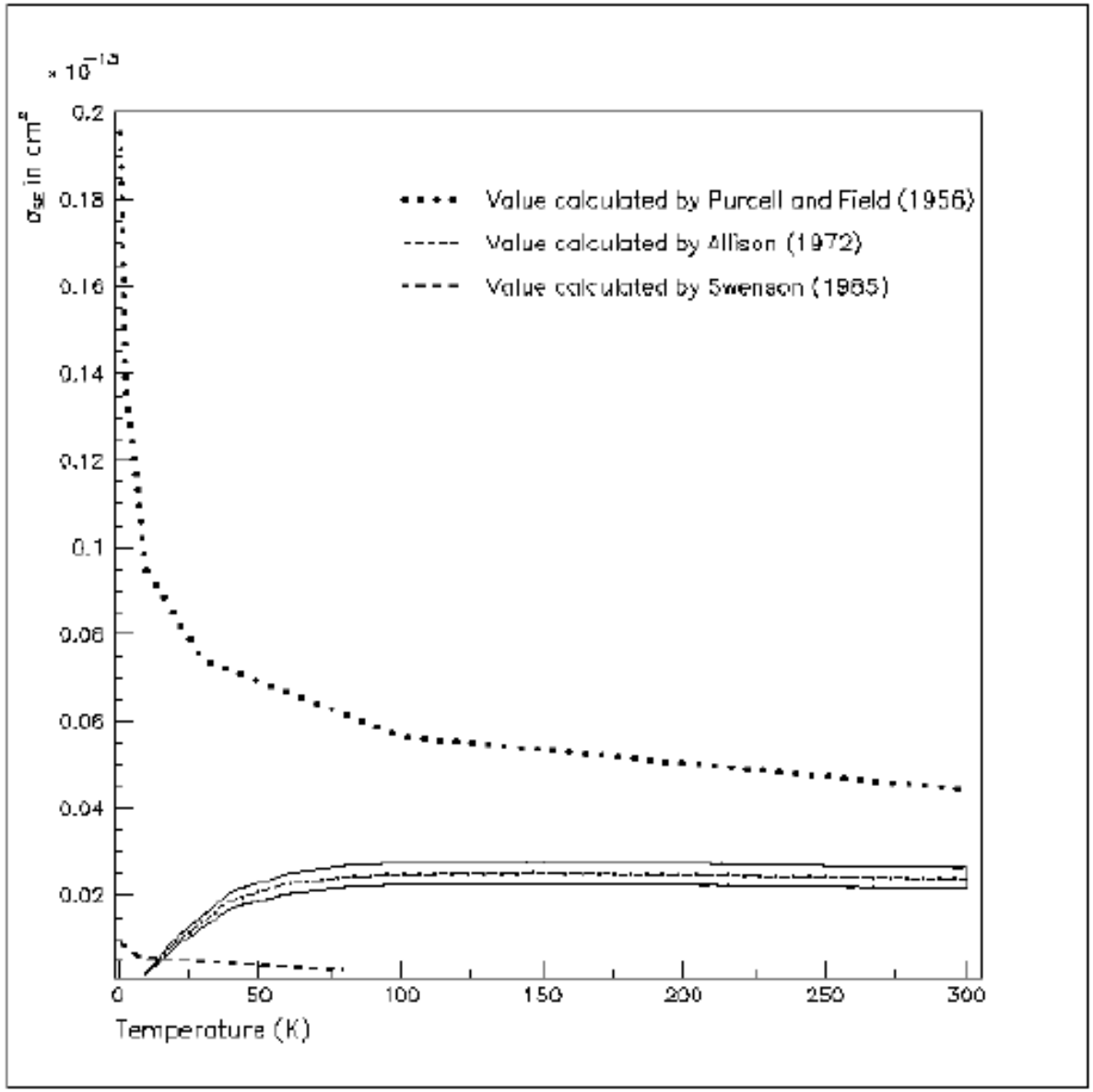
Poles Aligned
(higher energy state)



Poles Opposite
(lower energy state)



A 21-cm photon is emitted when poles go from being aligned to opposite (a spin flip).


× 10⁻¹⁵
σ_SE in cm²
0.2
0.18
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
50
100
150
200
250
300
Temperature (K)
Value calculated by Purcell and Field (1956)
Value calculated by Allison (1972)
Value calculated by Swenson (1965)

Measurement with HERMES target

- P_z^+ injected (|1>, |4>)

spin-exchange collision

$|4\rangle \rightarrow |2\rangle$ (ΔP_z)

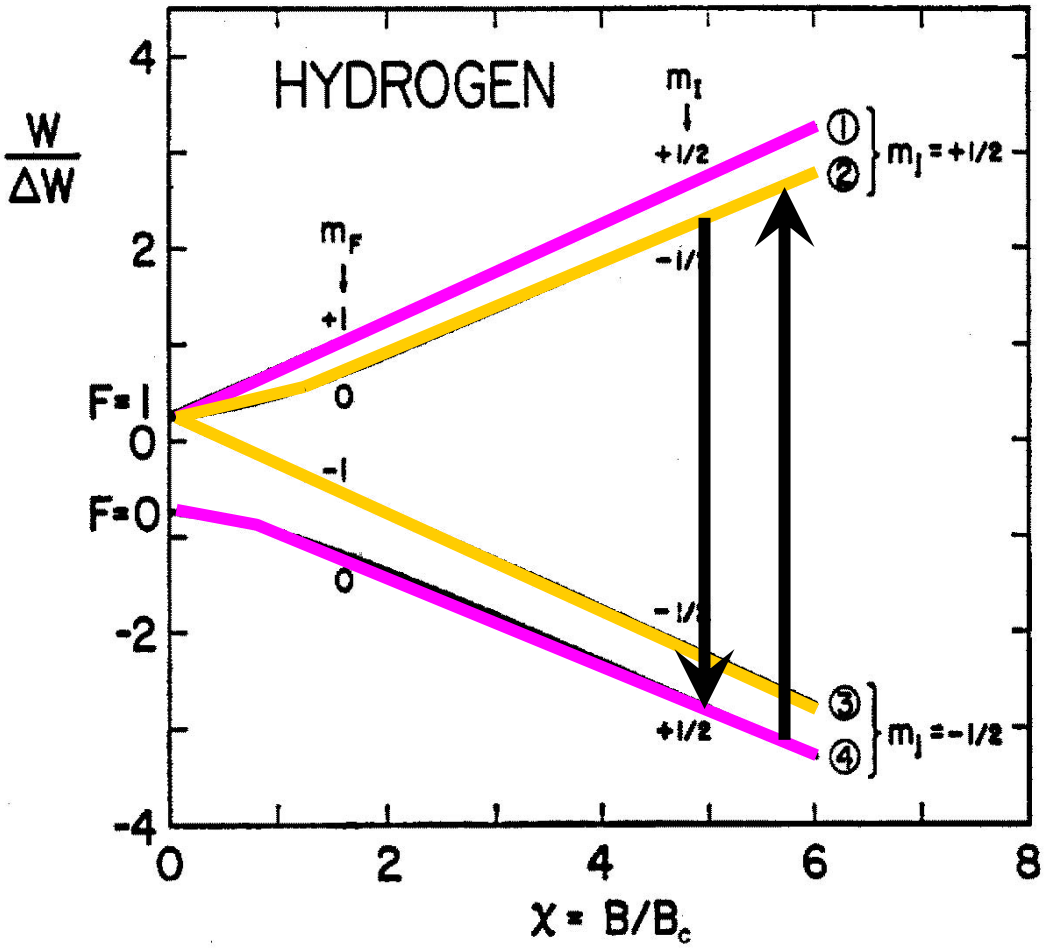
- P_z^- injected (|2>, |3>)

spin-exchange collisions

$|2\rangle \rightarrow |4\rangle$ (ΔP_z)

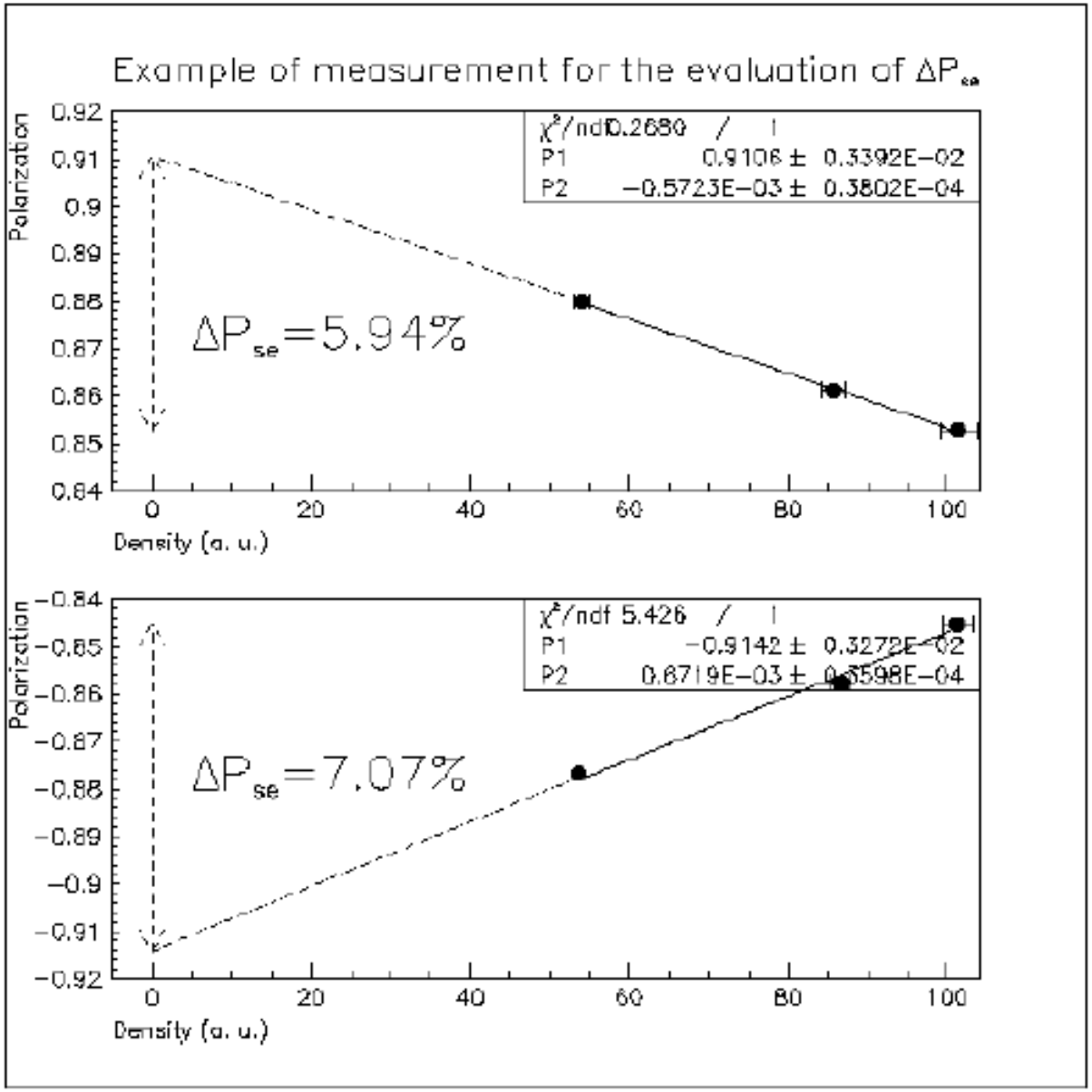
↓

spin exchange collisions cause depolarization of the sample



The sp
sectio

- L_d d
- n averag
- ΔP_{se} depo
- $x = B/B_c^H$



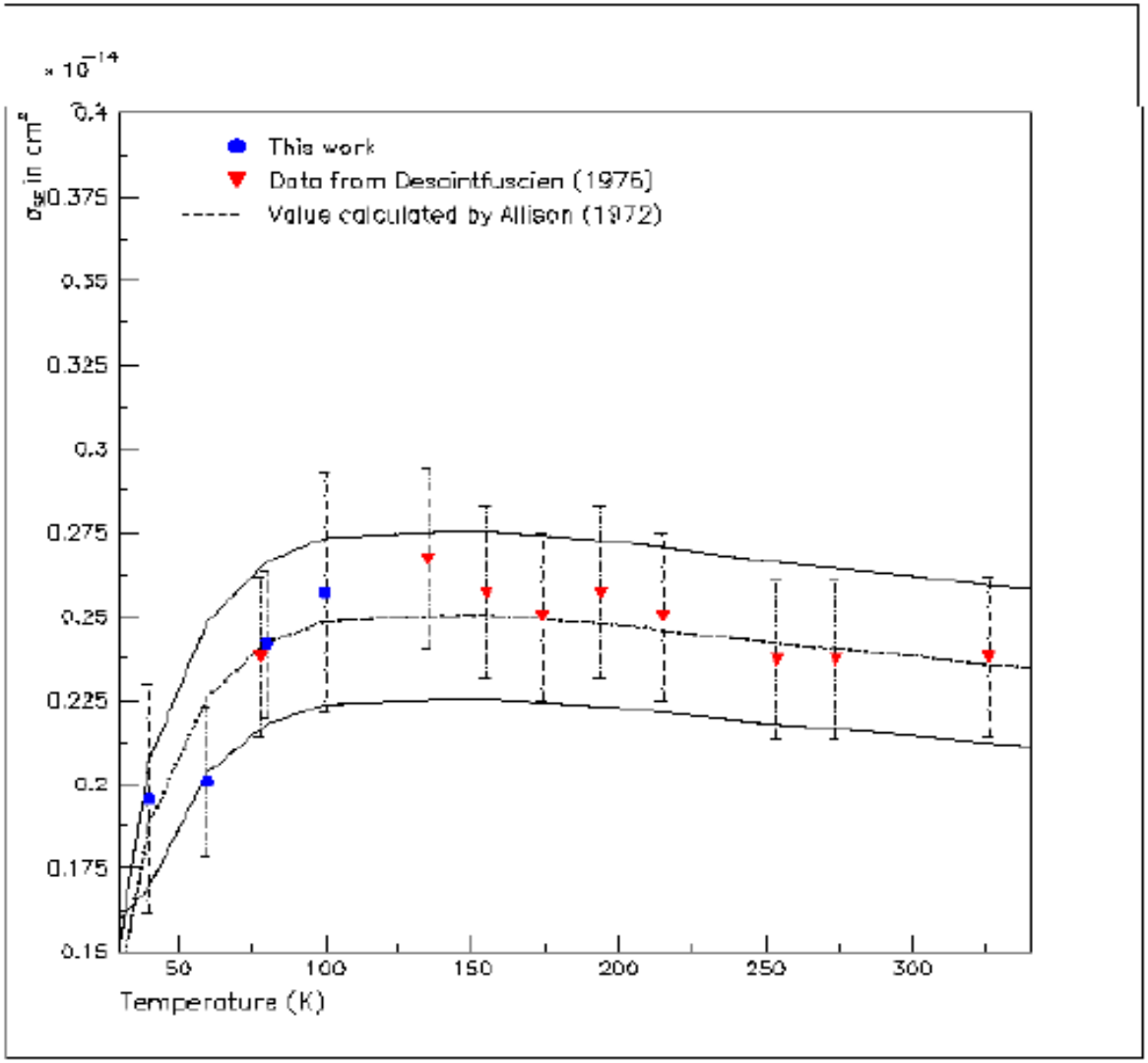
Monte Car

m

02 - 2005)

Total cross section (10^{-16} cm^2)

	40 K	60 K	80 K	100 K
First set	21.8±2.3	20.1±1.0	24.5±1.4	22.5±2.3
Second set	19.0±0.9	19.9±1.4	24.0±1.2	26.9±1.9
Third set	20.4±2.3	√	√	√


× 10⁻¹⁴
σ_tot in cm²
0.4
0.375
0.35
0.325
0.3
0.275
0.25
0.225
0.2
0.175
0.15
This work
Data from Descintfuscien (1976)
Value calculated by Allison (1972)
50
100
150
200
250
300
Temperature (K)

Conclusions

- first measurement in the low temperature region;
- novel method to measure the spin – exchange collision cross section presented;
- good agreement with the only other existing experimental data;
- experimental data in agreement with Allison's calculation;