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JÜLICH
FORSCHUNGSZENTRUM

Extra Physics with an Atomic Beam Source and a Lamb-Shift Polarimeter

22.06.2010

by Ralf Engels

JCHP / Institut für Kernphysik, FZ Jülich

Introduction

1.) PIT@ANKE

2.) Bound β decay

3.) Precision Spectroscopy of H and D

4.) Polarized Molecules

5.) PAX (Polarized Antiproton Experiment)

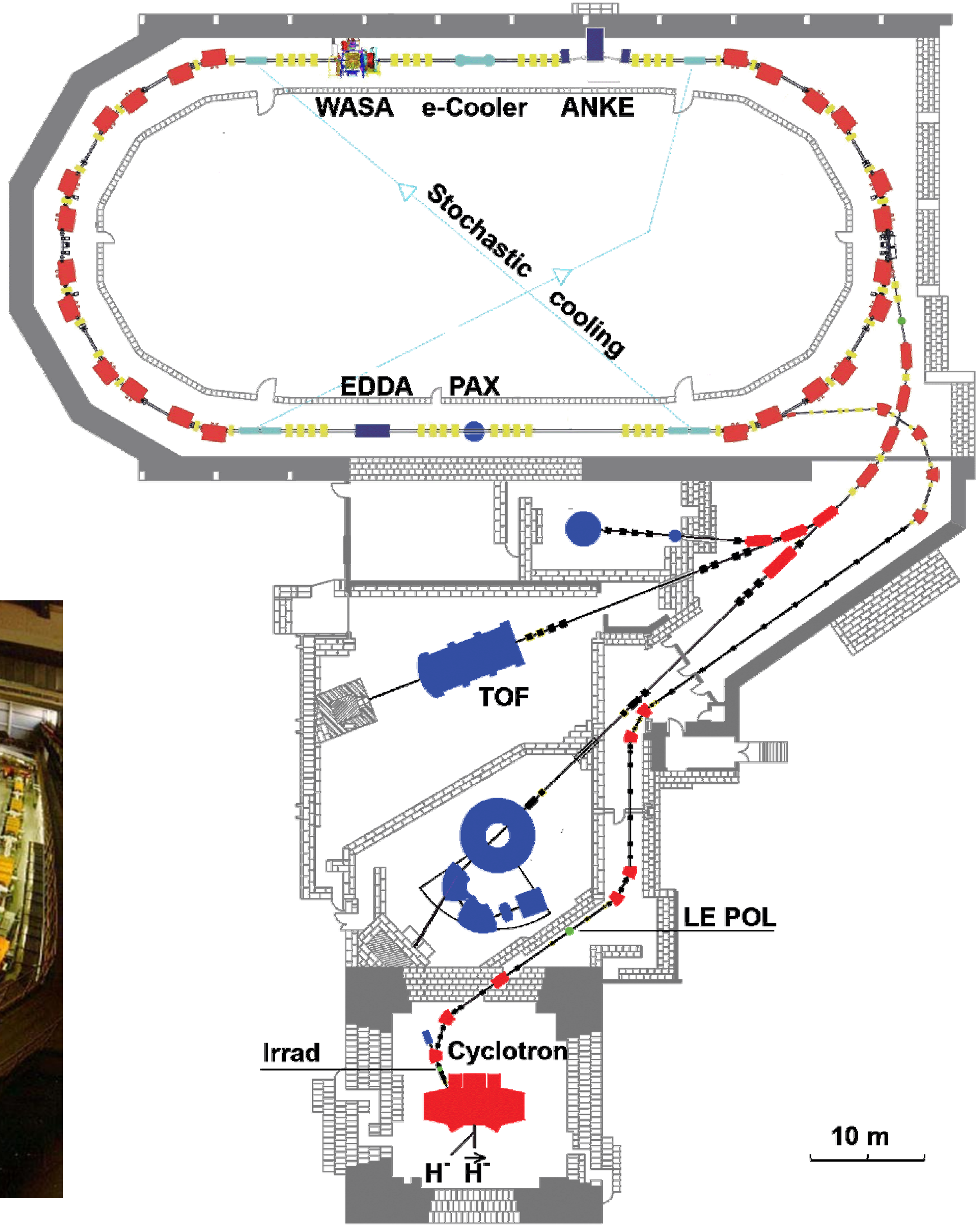
PIT@ANKE

$$p, \vec{p}, d, \vec{d}$$

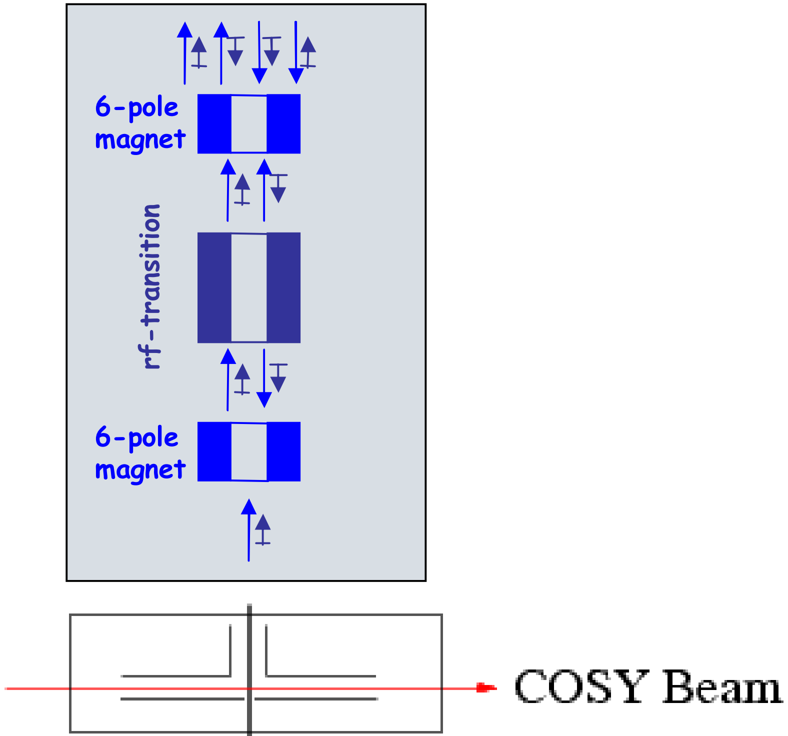
with momenta up to 3.7 GeV/c

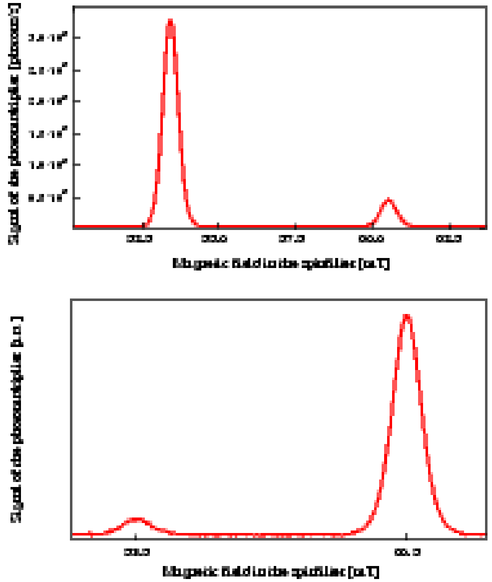
- **internal experiments** – with the circulating beam
- **external experiments** – with the extracted beam

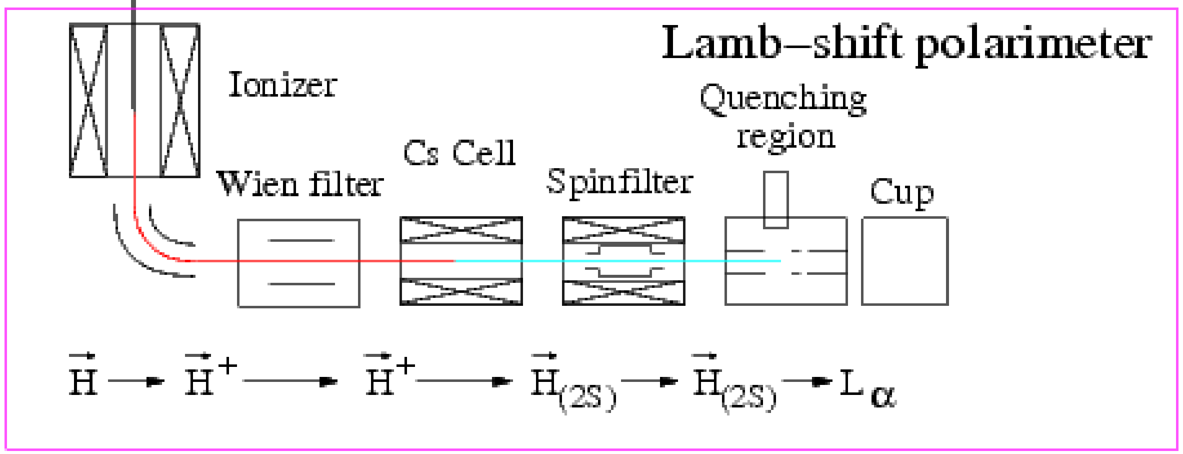
COSY



ABS and Lamb-shift polarimeter







PIT @ ANKE/COSY

Main parts of a PIT:

- Atomic Beam Source
  - Target gas

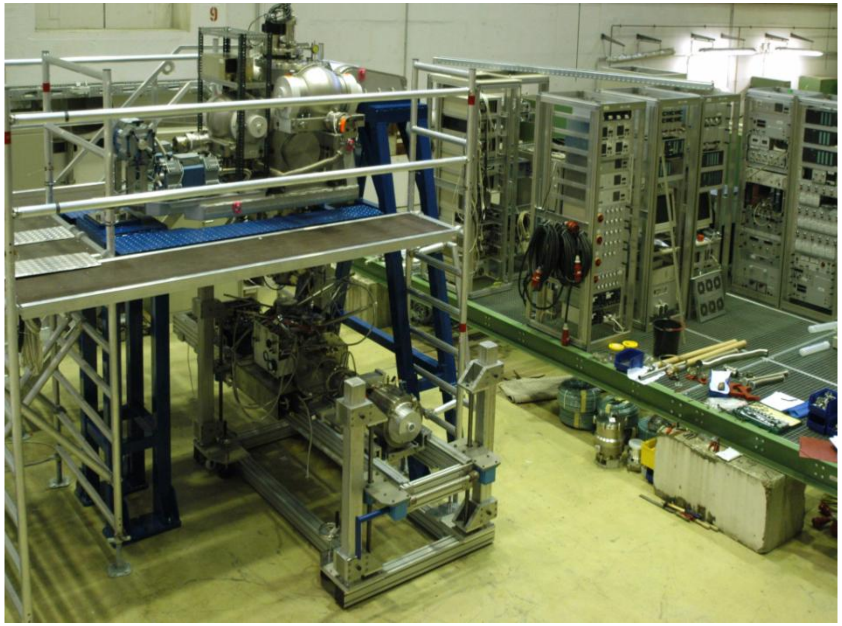
    hydrogen or **deuterium**
  - H beam intensity (2 hyperfine states)

    $8.2 \cdot 10^{16}$ atoms / s
  - Beam size at the interaction point

    $\sigma = 2.85 \pm 0.42$ mm
  - Polarization for hydrogen atoms

    $P_Z = +0.89 \pm 0.01$

    $P_Z = -0.96 \pm 0.01$



- Lamb-Shift Polarimeter
- Storage Cell

PIT @ ANKE/COSY

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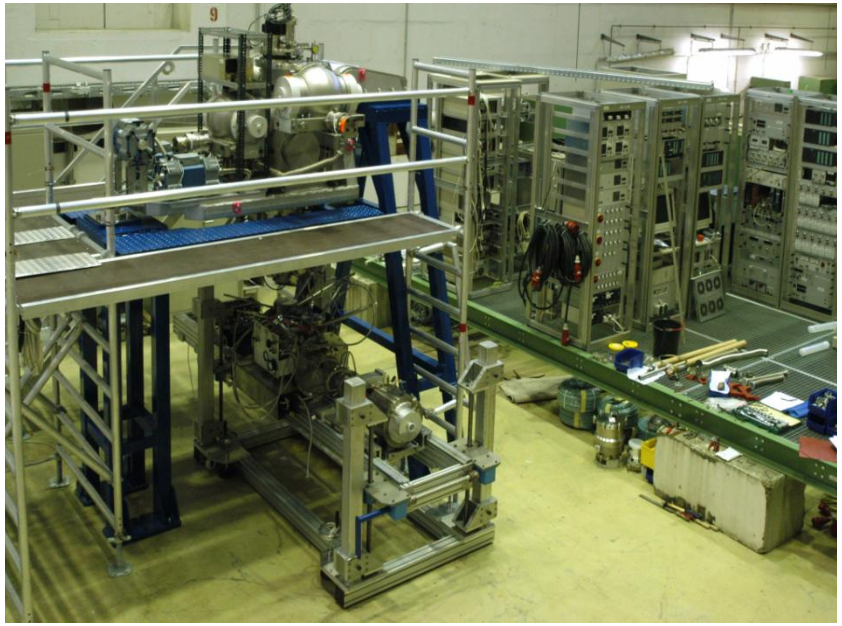
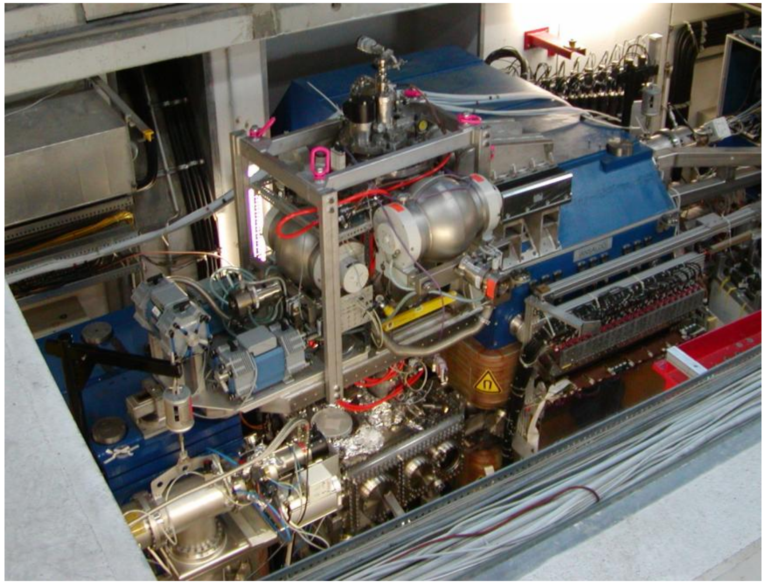
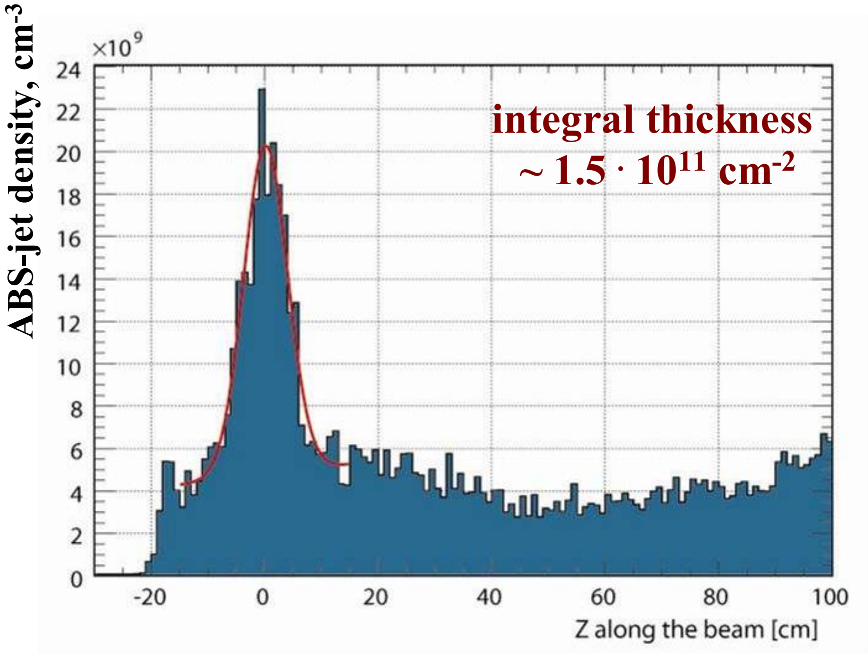


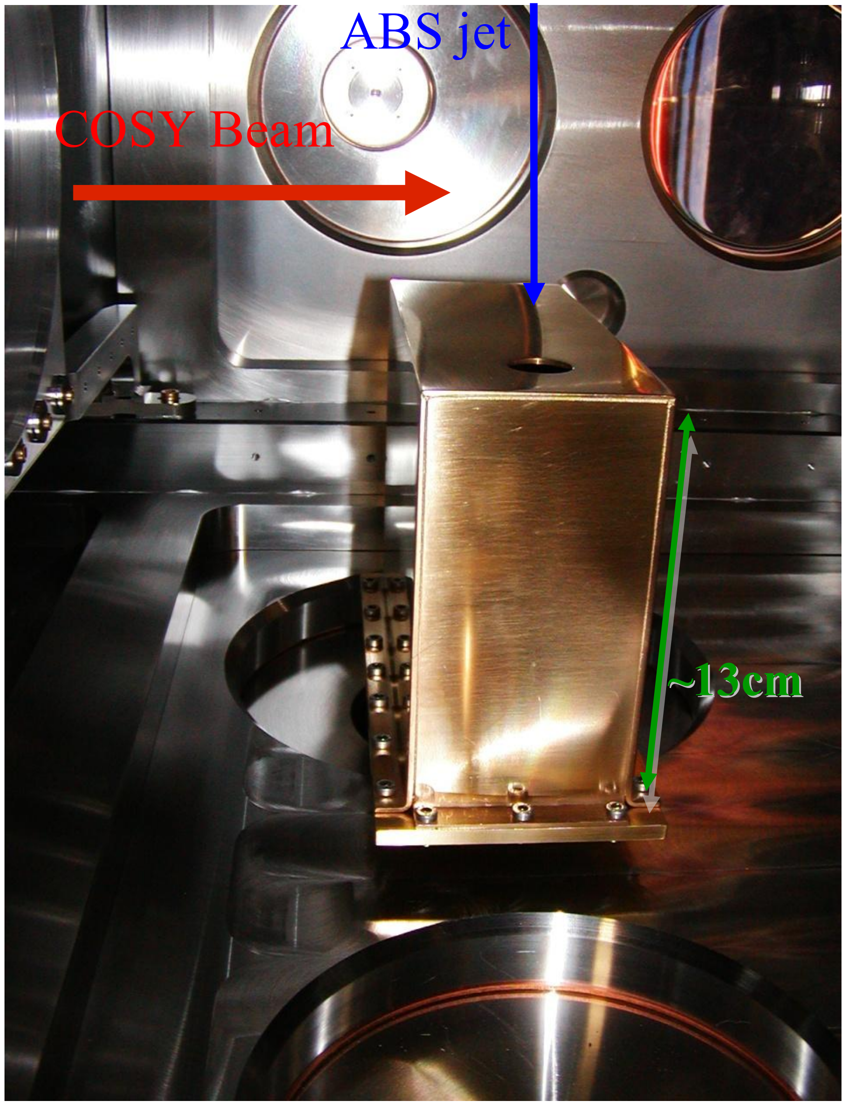


The ABS jet target

Measured pressures in the target chamber, mbar

	Without ABS jet	With ABS jet
Without catcher	**$4.0 \cdot 10^{-9}$**	**$3.0 \cdot 10^{-7}$**
With catcher	**$4.0 \cdot 10^{-9}$**	**$3.7 \cdot 10^{-8}$**



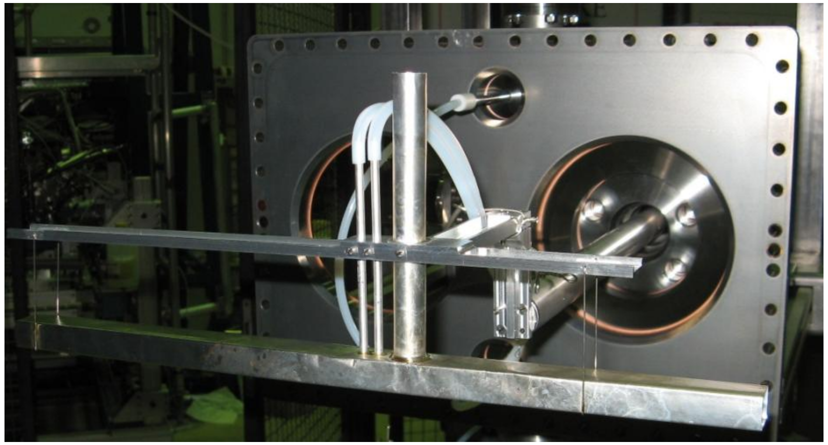


ABS beam catcher

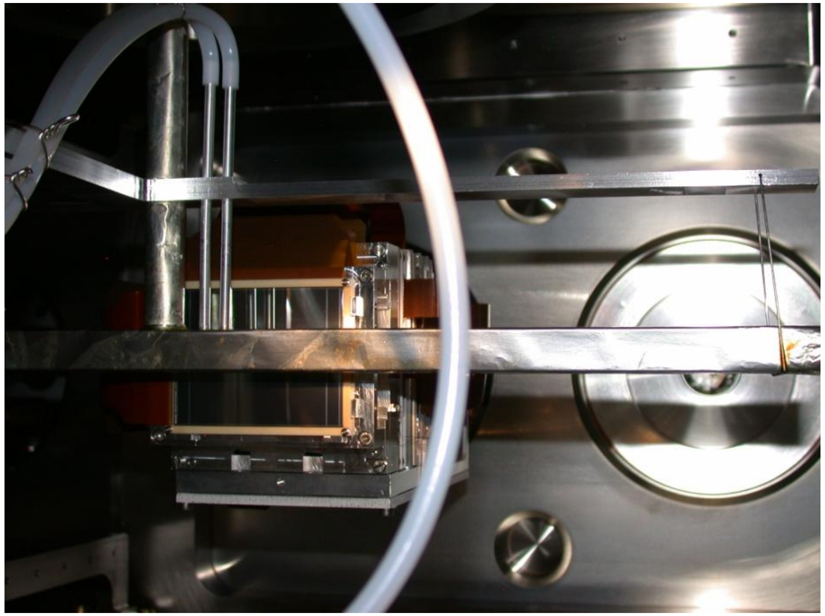
Storage cell: Final setup

Tools for the experiment

- New storage cell & support (20•20•390 mm)
  - > high target density
  - > unpolarized gas feeding system



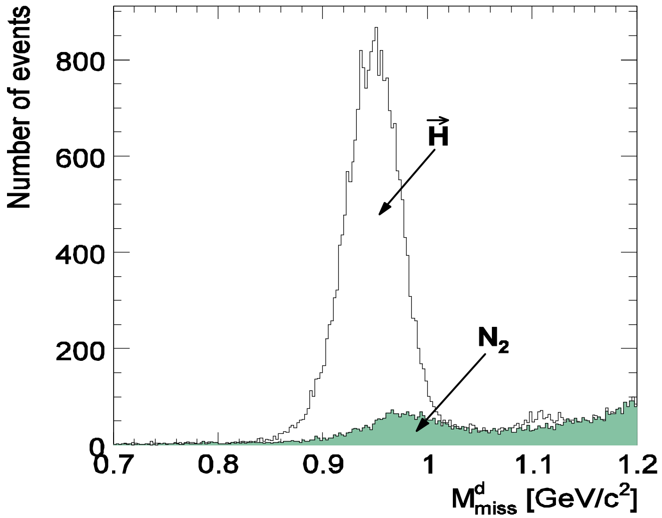
- LSP below the target chamber
  - > online measurement of the ABS beam polarization



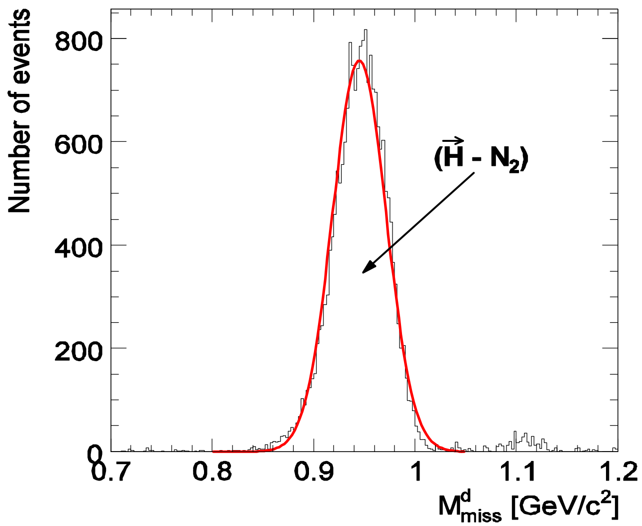
- Silicon Tracking Telescope (STT)
  - > measurement of spectator protons nearby the storage cell center

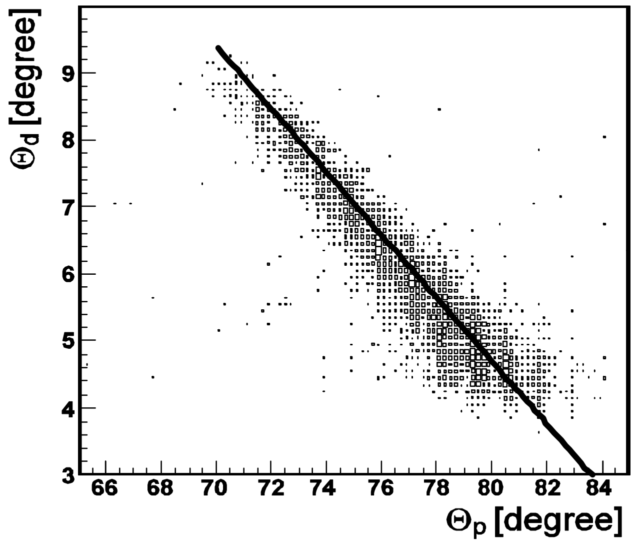
First Double Polarized Experiment: $\vec{d}\vec{p}$

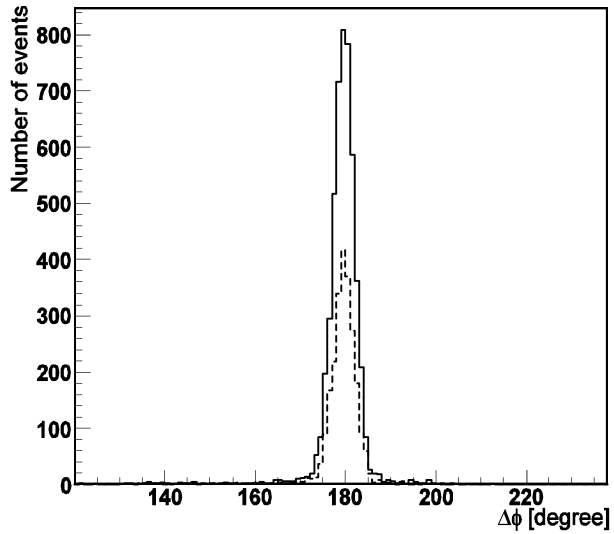
$\vec{d}\vec{p}$, T_d=1.2 GeV, target H (**N_2**) gas



dp→dp

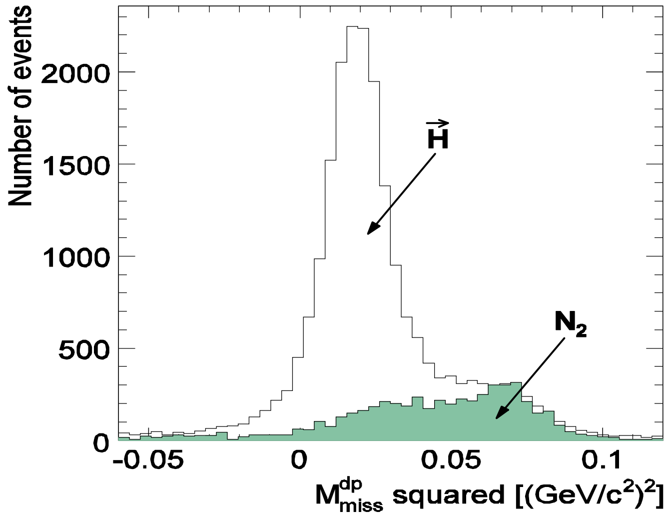






First Double Polarized Experiment: $\vec{d}\vec{p}$

$\vec{d}\vec{p}$, T_d=1.2 GeV, target H (N_2) gas

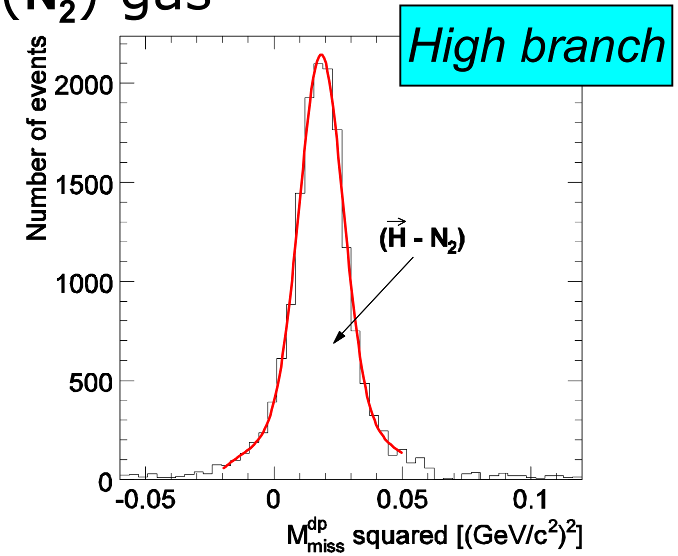


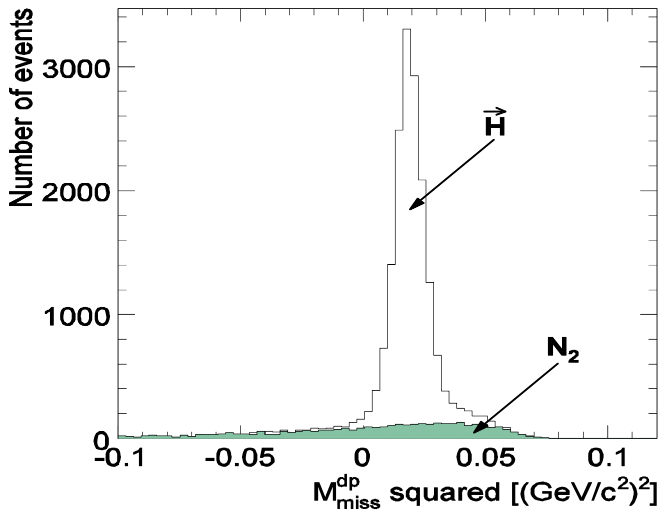
$dp \rightarrow (dp_{sp})\,\pi^o$

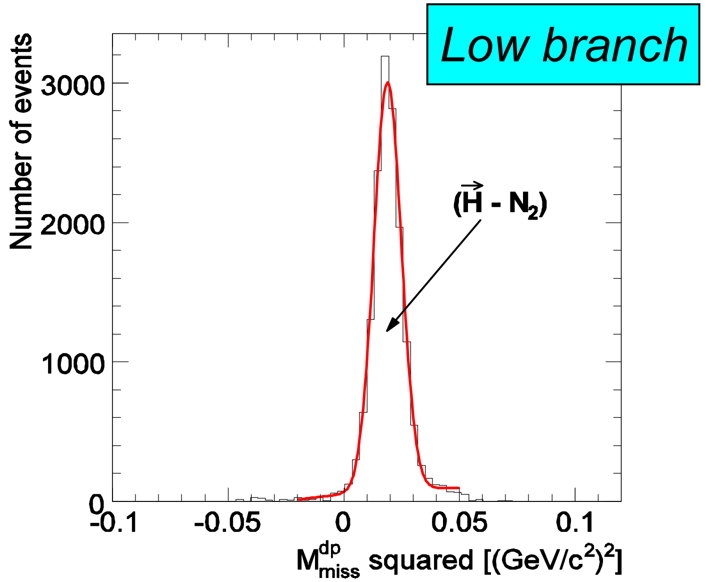
quasi-free

$np \rightarrow d\,\pi^o$

(High & Low branch)

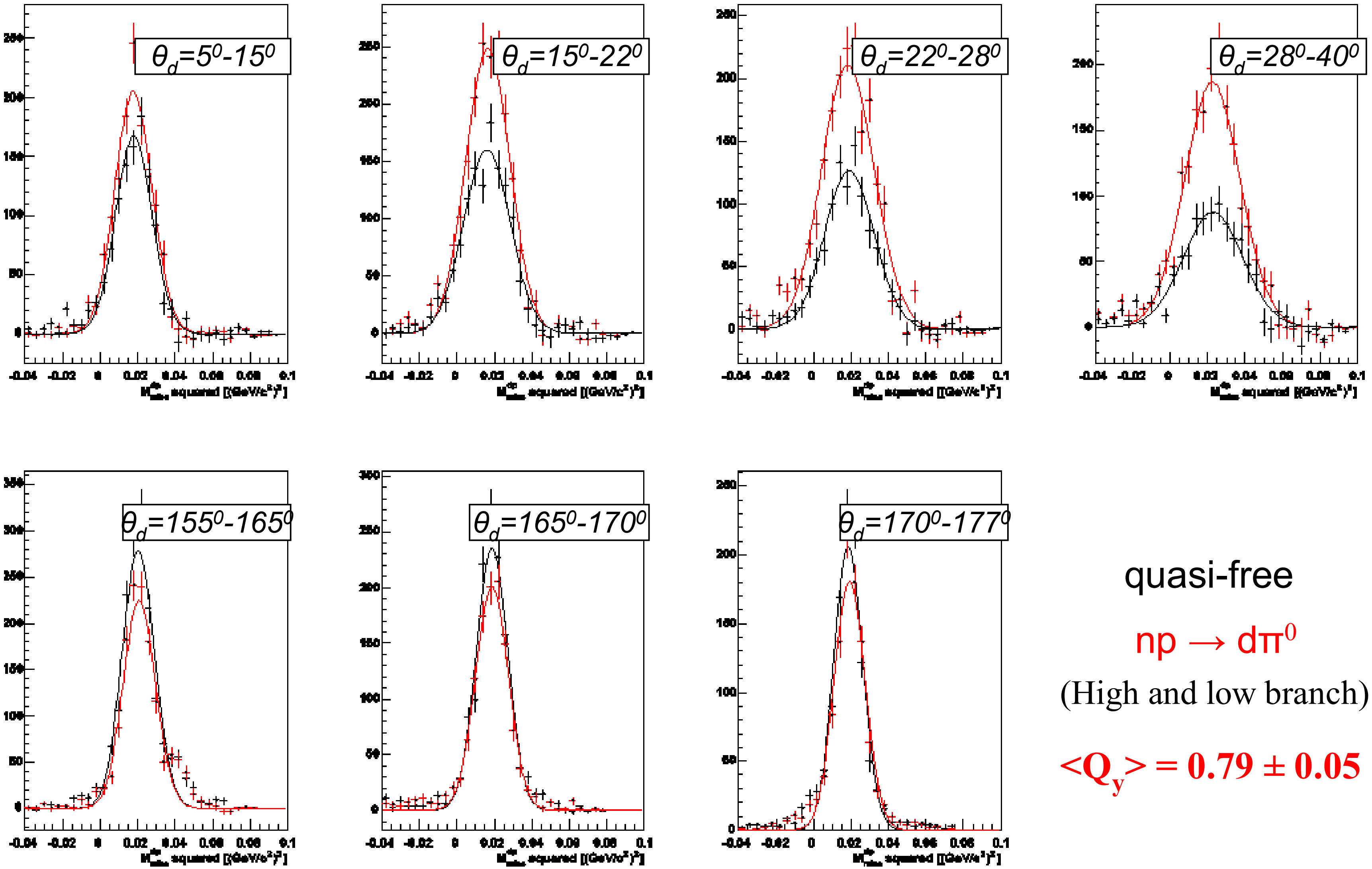






Polarization Measurement of the Target

$\vec{d}p$, T_d=1.2 GeV, polarized H gas



quasi-free

$np \rightarrow d\pi^0$

(High and low branch)

$\langle Q_y \rangle = 0.79 \pm 0.05$

More Experiments with ABS and LSP

2.) Bound β Decay

3.) Precision Spectroscopy of Hydrogen / Deuterium

4.) Polarized H_2 Molecules

5.) PAX (**P**olarized **A**ntiproton E**x**periment)

The Bound-β Decay (Tech. Uni. Munich)

JÜLICH FORSCHUNGSZENTRUM

$$n \longrightarrow p + e + \bar{\nu}_e$$

↓ Efficiency: $4 \cdot 10^{-6}$

$$n \longrightarrow H_{(1S)} + \bar{\nu}_e \qquad Q_H = 325.7 \text{ eV}$$

↓ Efficiency: $\sim 10^{-1}$

$$n \longrightarrow H_{(2S)} + \bar{\nu}_e \qquad Q_H = 325.7 \text{ eV}$$

L.L. Nemenov,
Sov. J. Nucl. Phys **31** (1980)

The Neutron Decay

Helicity of the Antineutrino: right-handedness

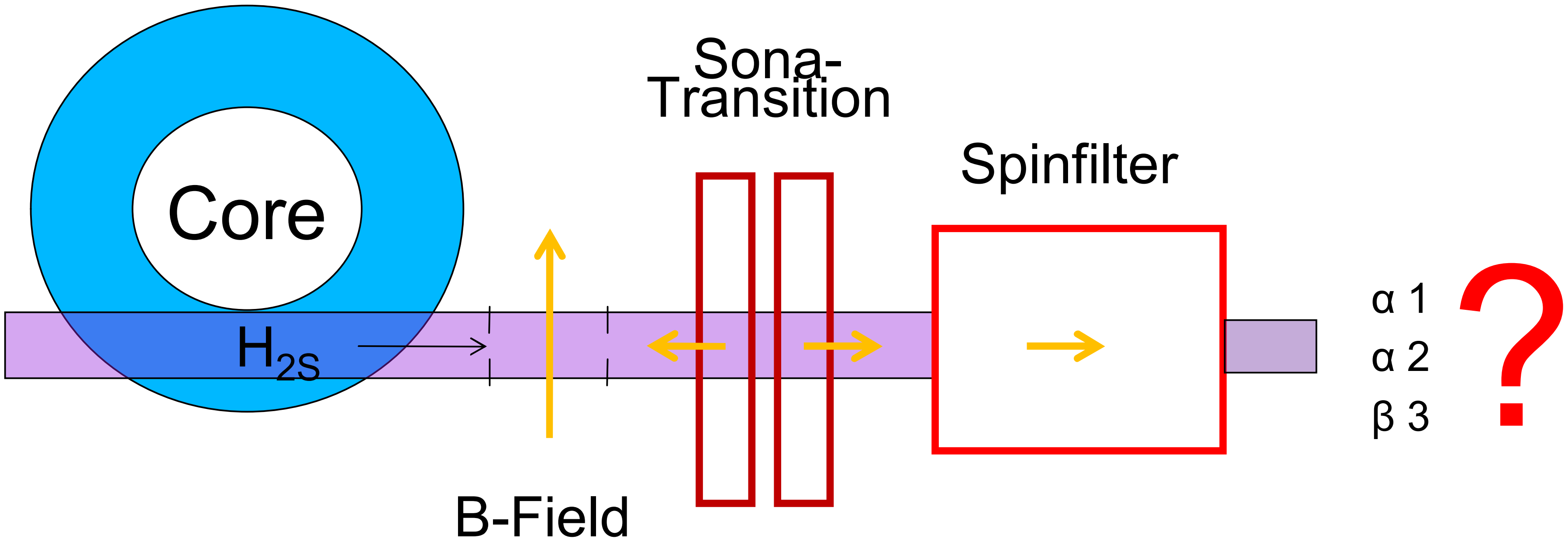
$\bar{\nu}$	n	p	e^-	W_i (%)	F	mF	HFS
←	←	←	→	44.14	0,1	0	α_2, β_4
←	←	→	←	55.24	0,1	0	β_4, α_2
←	→	→	→	0.62	1	1	α_1
→	←	←	←	0	1	-1	β_3
→	→	→	←	0	0,1	0	β_4,α_2
→	→	←	→	0	0,1	0	α_2,β_4

→ left handed admixtures ?

→ scalar or tensor contributions to the weak force ?

The Neutron Decay

Reactor: FRM II



Problem:

How to register single metastable hydrogen atoms?

(Count rates: H_{1S}: 3 s^{-1} / H_{2S}: 0.3 s^{-1} / $H_{2S(\alpha 2)}$: ≤ 0.1 s^{-1})

The Neutron Decay

1. Selective Ionization with 2 Laser (Hänsch et al.)

Advantage: - Efficiency ~50 % expected

Problems: - Not used before
- Very expensive and difficult (Resonator: 20 kW !!!)
- Background free ?

2. Lyman-α detection with PM

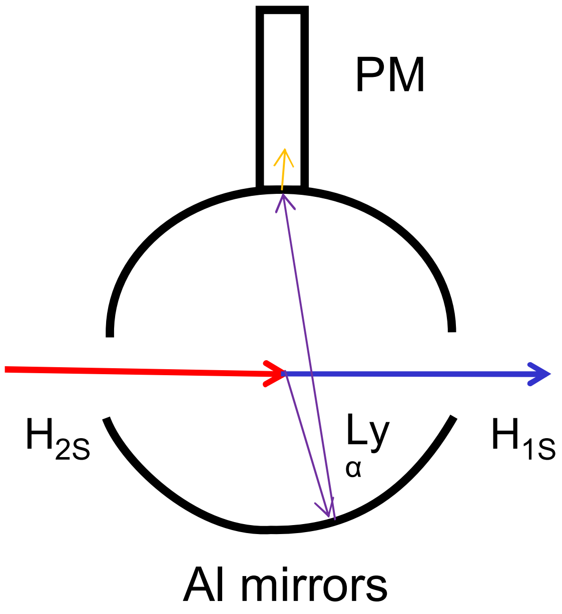
Advantage: - Used before (PM: sensitive to 110-135 nm)

Problems: - QE: ~10 % / LSP: Efficiency: 10^{-3}
- Ideas: a.) Mirrors for 121 nm → 5 % possible ?
b.) Photoeffect–Chamber → 80 % possible ?

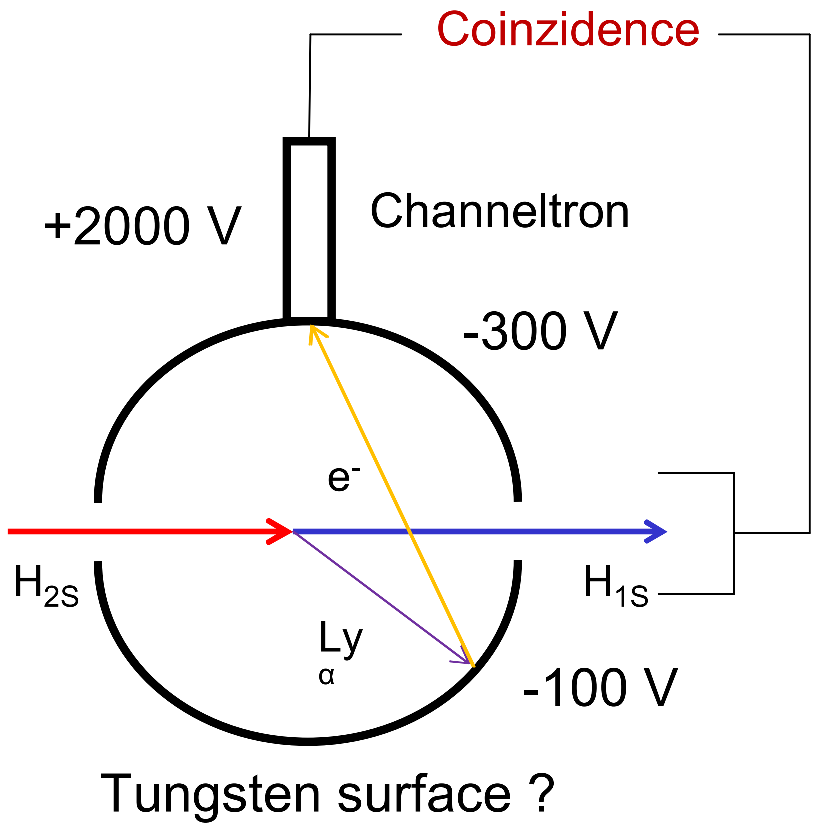
The Neutron Decay

2. Lyman-α detection with PM

Mirrors



Photoeffect



The Neutron Decay

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- Ideas: a.) Mirrors for 121 nm → 5 % possible ?

  b.) Photoeffect–Chamber → 80 % possible ?

3. Charge Exchange at Ar (K)

Advantage: - Used before (pol. Lamb-shift source)

Problems: - Efficiency: ~10 %, can not be increased much

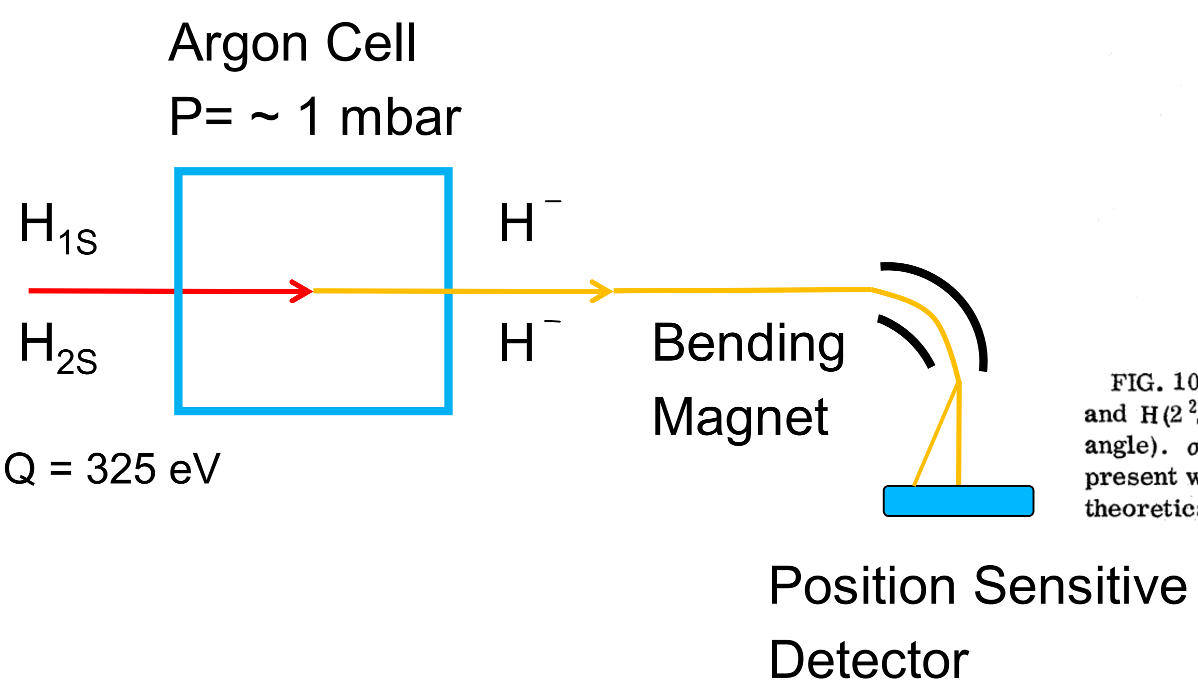
- Background free ? → Energy-separation necessary

The Neutron Decay

3. Charge Exchange at Ar (K)

$$H_{2S} + Ar \rightarrow H^{-} + Ar^{+}$$

$$(H_{1S} + Ar \rightarrow H^{-} + Ar^{+})$$



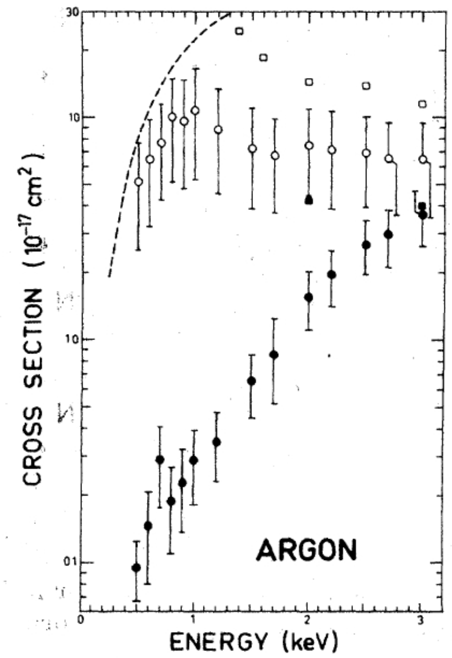


FIG. 10. Electron-capture cross sections for H (1 ^{2}S) and H (2 ^{2}S) in argon (55-mrad detector's acceptance angle). σ_{g^-}: ⧮, present work; ■, Williams.[5] σ_{m^-}: ⧲, present work; □, Dose and Gunz[7] recalibrated; ---, theoretical calculation by Olson.[14]

Paper is in preparation

Double Polarized Fusion

Can the total cross section of the fusion reactions be increased by using polarized particles ?

$^{3}\vec{He} + \vec{d} \longrightarrow {}^{4}He + p$ Factor: ~1.5 at 430 keV

$J = 3/2^{+}$ [Ch. Leemann et al. (1971)]

$\vec{t} + \vec{d} \longrightarrow {}^{4}He + n$ Factor: ~1.5 at 107 keV

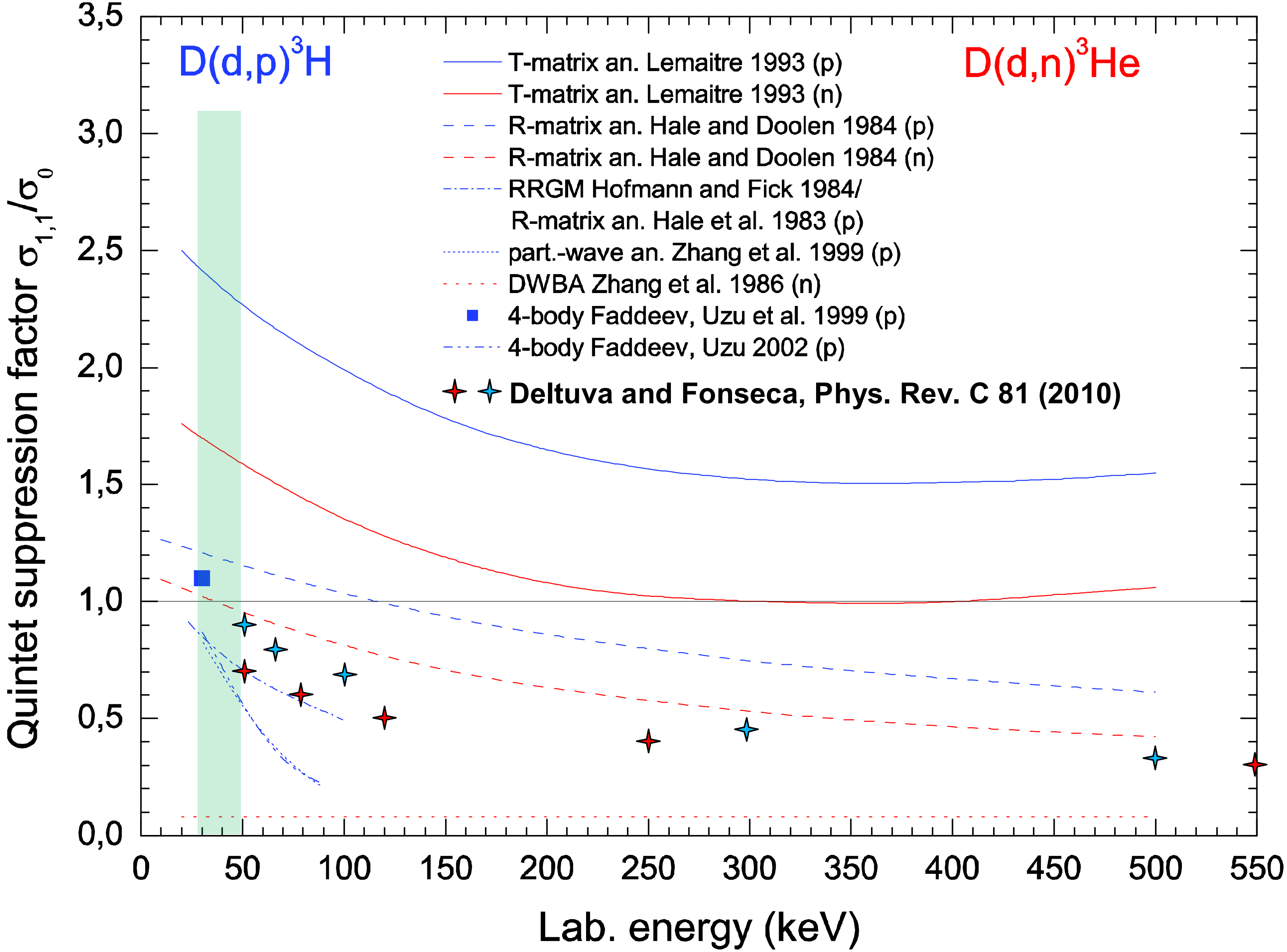
$\vec{d} + \vec{d} \rightarrow t + p$

$\vec{d} + \vec{d} \rightarrow {}^{3}He + n$

Can cross sections be increased ?
Can neutrons be suppressed ?
Can the trajectories of the neutrons be controlled?

H. Paetz gen. Schieck, Eur. Phys. J. A **44**, 321-354 (2010)

The Quintet Suppression Factor



The Formula

$$\sigma(\Theta,\Phi) = \sigma_0(\Theta)\{1 + \frac{3}{2}[A_y^{(b)}(\Theta)p_y + A_y^{(t)}q_y] + \frac{1}{2}[A_{zz}^{(b)}(\Theta)p_{zz} + A_{zz}^{(t)}(\Theta)q_{zz}]$$
$$+ \frac{1}{6}\left[A_{xx-yy}^{(b)}(\Theta)p_{xx-yy} + A_{xx-yy}^{(t)}(\Theta)q_{xx-yy}\right]$$
$$+ \frac{2}{3}[A_{xz}^{(b)}(\Theta)p_{xz} + A_{xz}^{(t)}(\Theta)q_{xz}]$$
$$+ \frac{9}{4}[C_{y,y}(\Theta)p_yq_y + C_{x,x}(\Theta)p_xq_x + C_{x,z}(\Theta)p_xq_z + C_{z,x}(\Theta)p_zq_x + C_{z,z}(\Theta)p_zq_z]$$
$$+ \frac{3}{4}[C_{y,zz}(\Theta)p_yq_{zz} + C_{zz,y}(\Theta)p_{zz}q_y]$$
$$+ C_{y,xz}(\Theta)p_yq_{xz} + C_{xz,y}(\Theta)p_{xz}q_y + C_{x,yz}(\Theta)p_xq_{yz}$$
$$+ C_{yz,x}(\Theta)p_{yz}q_x + C_{z,yz}(\Theta)p_zq_{yz} + C_{yz,z}(\Theta)p_{yz}q_z$$
$$+ \frac{1}{4}[C_{y,xx-yy}(\Theta)p_yq_{xx-yy} + C_{xx-yy,y}(\Theta)p_{xx-yy}q_y + C_{zz,zz}(\Theta)p_{zz}q_{zz}]$$
$$+ \frac{1}{3}[C_{zz,xz}(\Theta)p_{zz}q_{xz} + C_{xz,zz}(\Theta)p_{xz}q_{zz}]$$
$$+ \frac{1}{12}[C_{zz,xx-yy}(\Theta)p_{zz}q_{xx-yy} + C_{xx-yy,zz}(\Theta)p_{xx-yy}q_{zz}]$$
$$+ \frac{4}{9}[C_{xz,xz}(\Theta)p_{xz}q_{xz} + C_{yz,yz}(\Theta)p_{yz}q_{yz}]$$
$$+ \frac{8}{9}[C_{xy,yz}(\Theta)p_{xy}q_{yz} + C_{yz,xy}(\Theta)p_{yz}q_{xy}]$$
$$+ \frac{16}{9}C_{xy,xy}(\Theta)p_{xy}q_{xy}$$
$$+ \frac{1}{9}[C_{xz,xx-yy}(\Theta)p_{xz}q_{xx-yy} + C_{xx-yy,xz}(\Theta)p_{xx-yy}q_{xz}]$$
$$+ \frac{1}{36}C_{xx-yy,xx-yy}(\Theta)p_{xx-yy}q_{xx-yy}$$
$$+ \frac{1}{2}[C_{x,xy}(\Theta)p_xq_{xy} + C_{xy,x}(\Theta)p_{xy}q_x + C_{z,xy}(\Theta)p_zq_{xy} + C_{xy,z}(\Theta)p_{xy}q_z]\}$$

Spins of both deuterons are aligned:

Only $p_z(q_z)$ and $p_{zz}(q_{zz}) \neq 0$

$$\sigma(\Theta,\Phi) = \sigma_0(\Theta)\{1 + \frac{3}{2}[A_{zz}^{(b)}(\Theta)p_{zz} + A_{zz}^{(t)}(\Theta)q_{zz}] + \frac{9}{4}C_{z,z}(\Theta)p_zq_z + \frac{1}{4}C_{zz,zz}(\Theta)p_{zz}q_{zz}\}$$

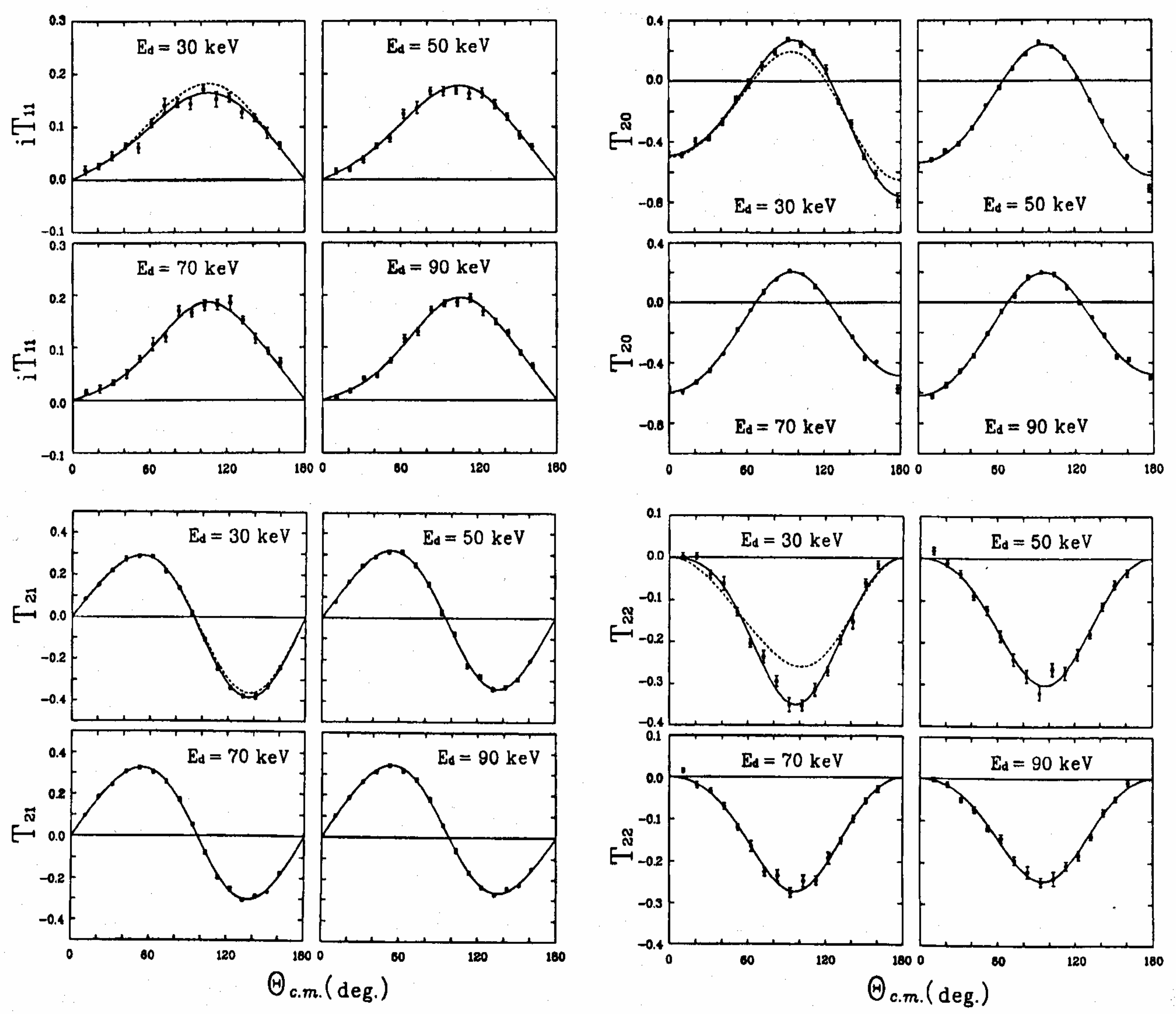
Only beam is polarized:

$(p_{i,j} \neq 0,\ q_{i,j} = 0)$

$$\sigma(\Theta,\Phi) = \sigma_0(\Theta) \cdot \{1 + 3/2\, A_y(\Theta)\, p_y + 1/2\, A_{xz}(\Theta)\, p_{xz} + 1/6\, A_{xx\text{-}yy}(\Theta)\, p_{xx\text{-}zz} + 2/3\, A_{zz}(\Theta)\, p_{zz}\}$$

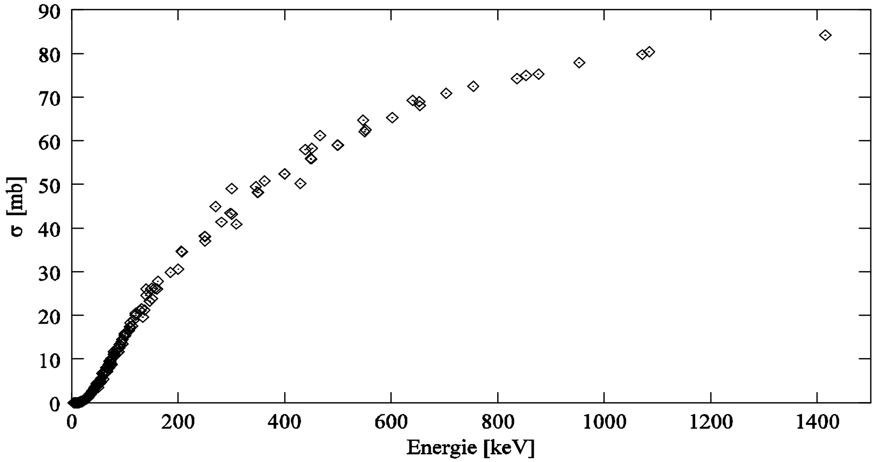
The Analysing Powers

Tagishi et al.; Phy. Rev. C **46** (1992) 1155-1158



The Experimental Setup

Total cross section



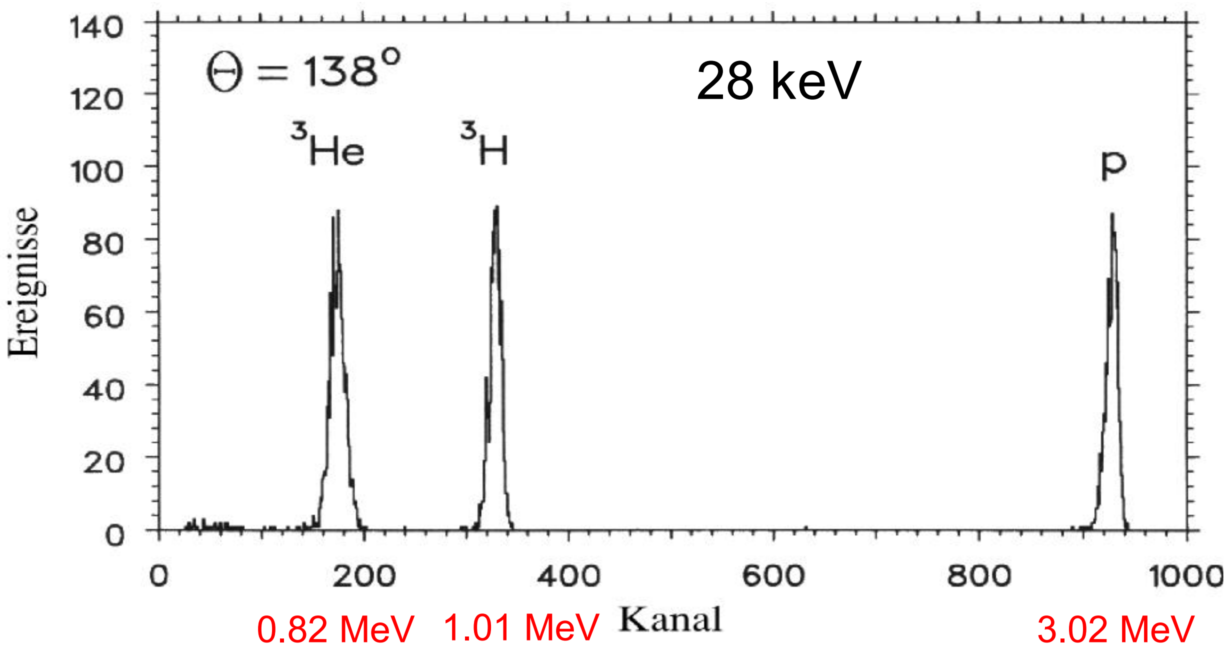
d + d ⟶ t + p Q: 4.033 MeV

d + d ⟶ ^{3}He + n Q: 3.268 MeV

Becker et al.
Few Body Sys. **13** (1992)
[Analysing Powers]

Tagishi et al.
Phys.Rev. C **46** (1992)
[Analysing Powers]

Imig et al.
Phys.Rev. C **73** (2006)
[Spin-Transfer Koeff.]



0.82 MeV 1.01 MeV 3.02 MeV

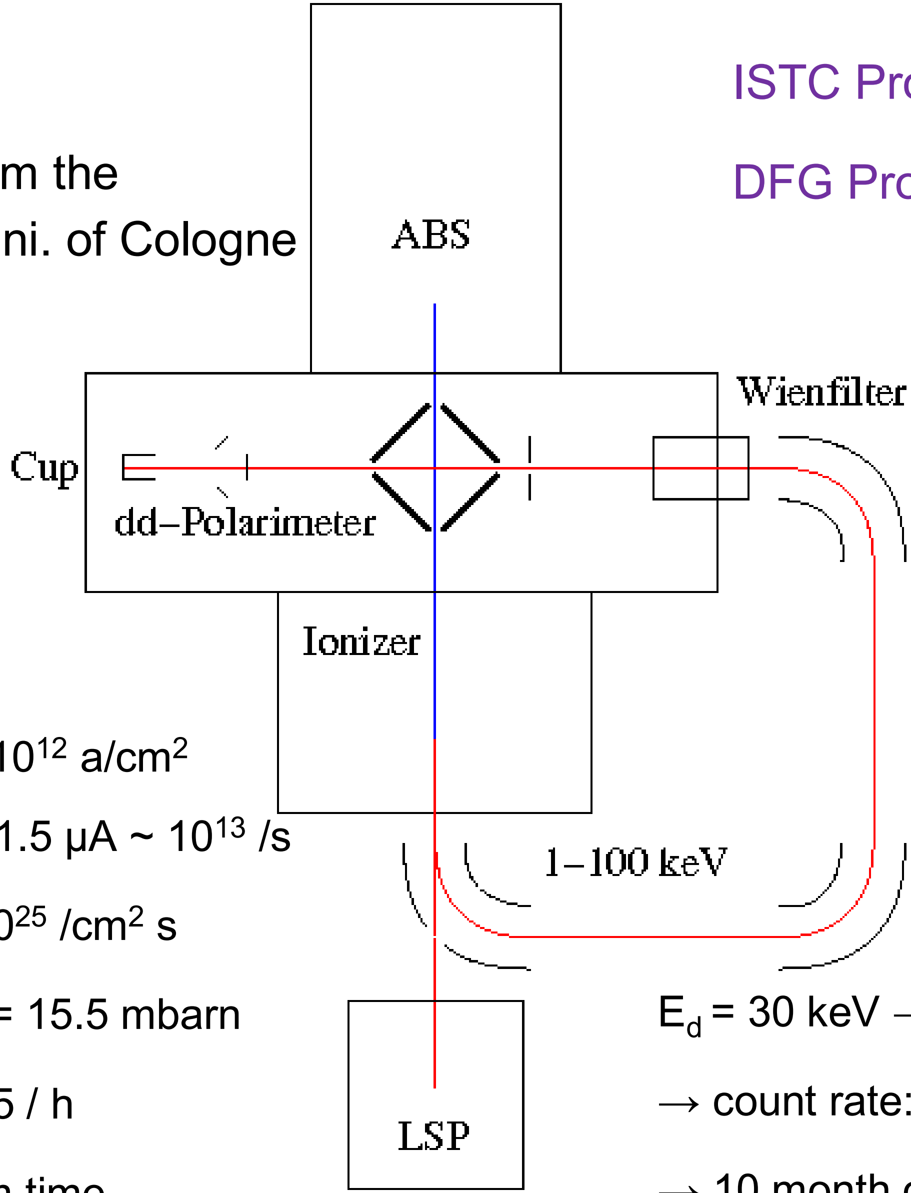
The Experimental Setup in St. Petersburg

1. Setup:

ISTC Project # 3881

DFG Project: EN 902/1-1

ABS and LSP from the
SAPIS Project, Uni. of Cologne



Target Density: < 10^{12} a/cm^2

Beam Intensity: > 1.5 μA ~ 10^{13} /s

→ Luminosity: ≤ 10^{25} /cm^2 s

E_d = 100 keV → σ = 15.5 mbarn

→ count rate: ~ 155 / h

→ 1 month of beam time

E_d = 30 keV → σ = 1.2 mbarn

→ count rate: ~ 12 / h

→ 10 month of beam time

The Experimental Setup in St. Petersburg

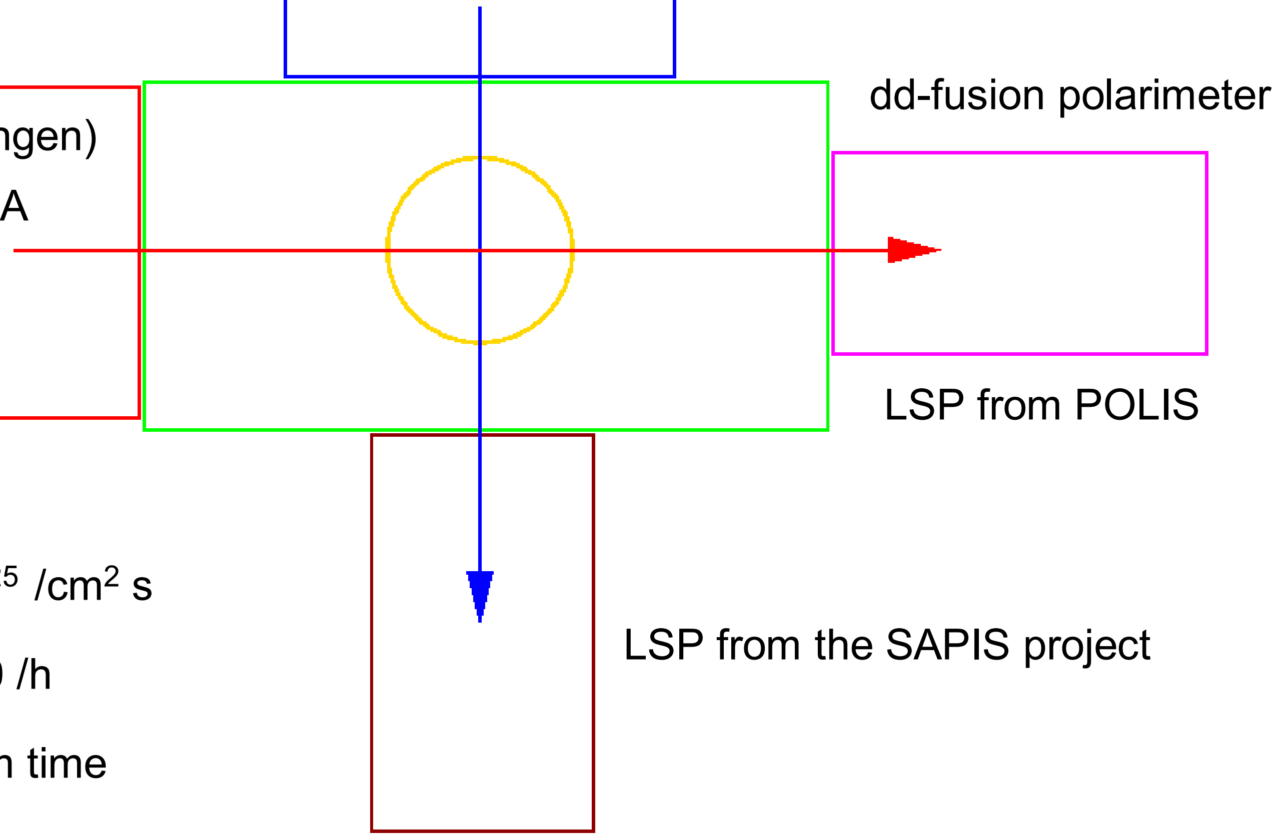
New Setup:

ABS from the
SAPIS project:
(after upgrade)
$\sim 4 \cdot 10^{16}$ a/s
$\rightarrow \sim 2 \cdot 10^{11}$ a/cm^2

Detector Setup:

4π covered by
- large pos. sens. Detectors
- (~300 single PIN diodes ?)

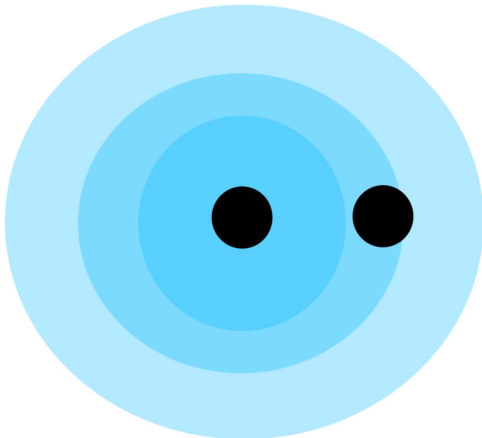
POLIS (KVI, Groningen)
Ion beam: I ≤ 20 μA
$\rightarrow 1.5 \cdot 10^{14}$ d/s
($E_{beam} \leq 32$ keV)



Luminosity: $3 \cdot 10^{25}$ /cm^2 s
→ count rate: ~ 40 /h
→ 2 month of beam time

The Electron Screening Effect

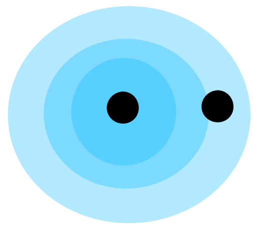
Projectile: Deuteron



Target: Deuterium Atom

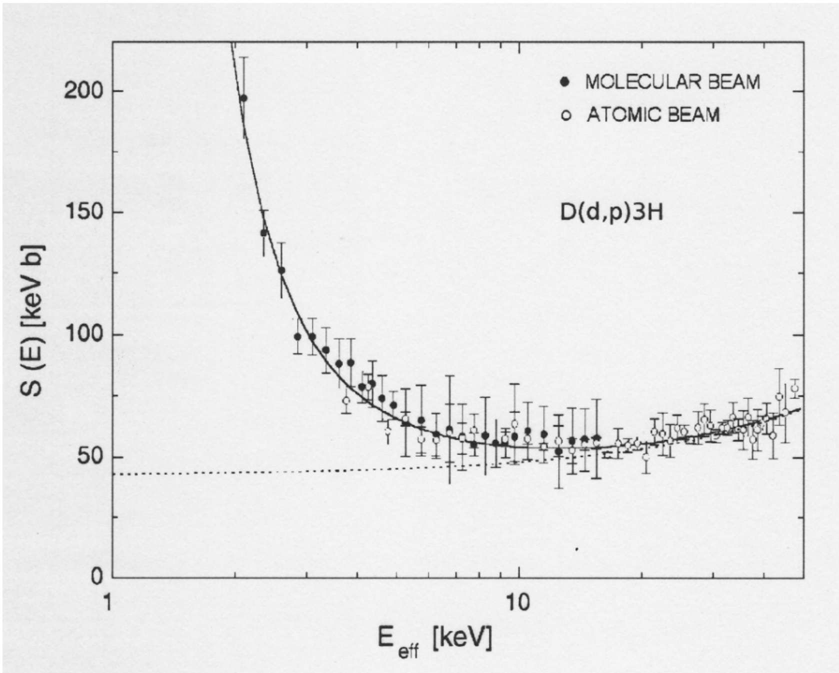
(Deuteron + Electron)

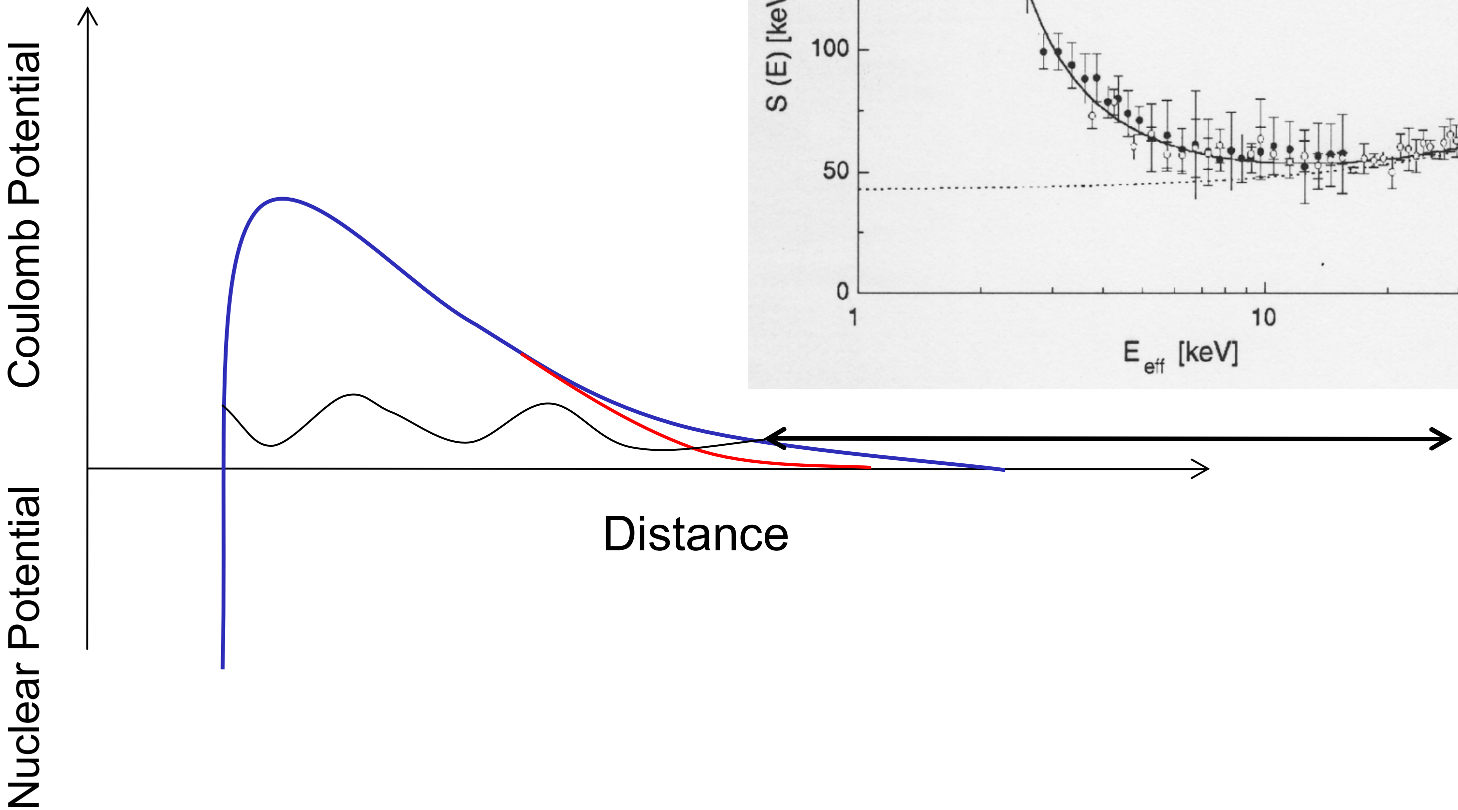
The Electron Screening Effect



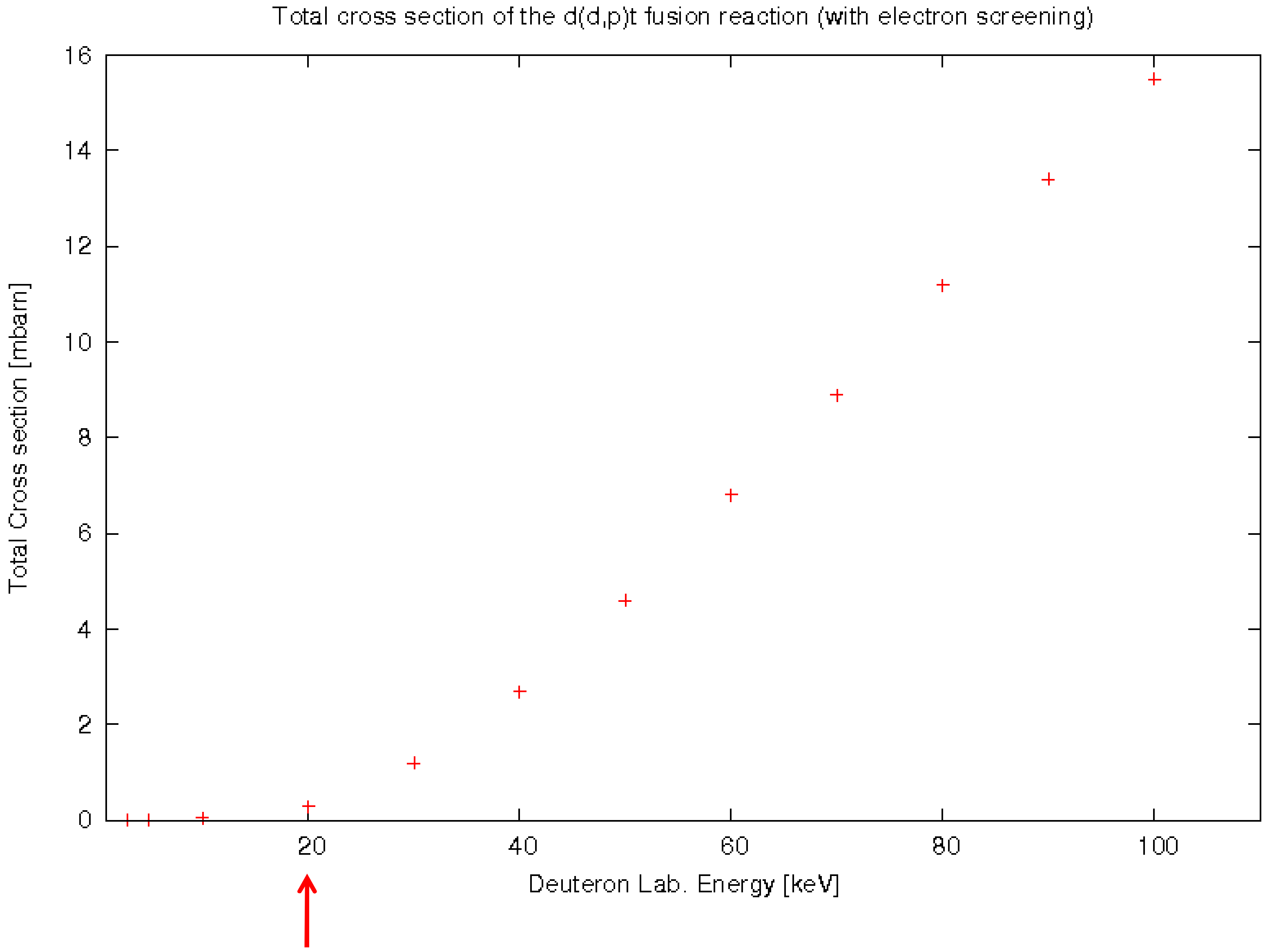
Astrophysical S-Factor:

F. Raiola et al.; Eur. Phys. J. **A 13**, 377 (2002)



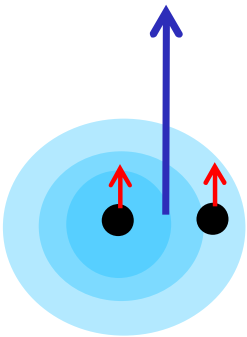


The Total Cross Section

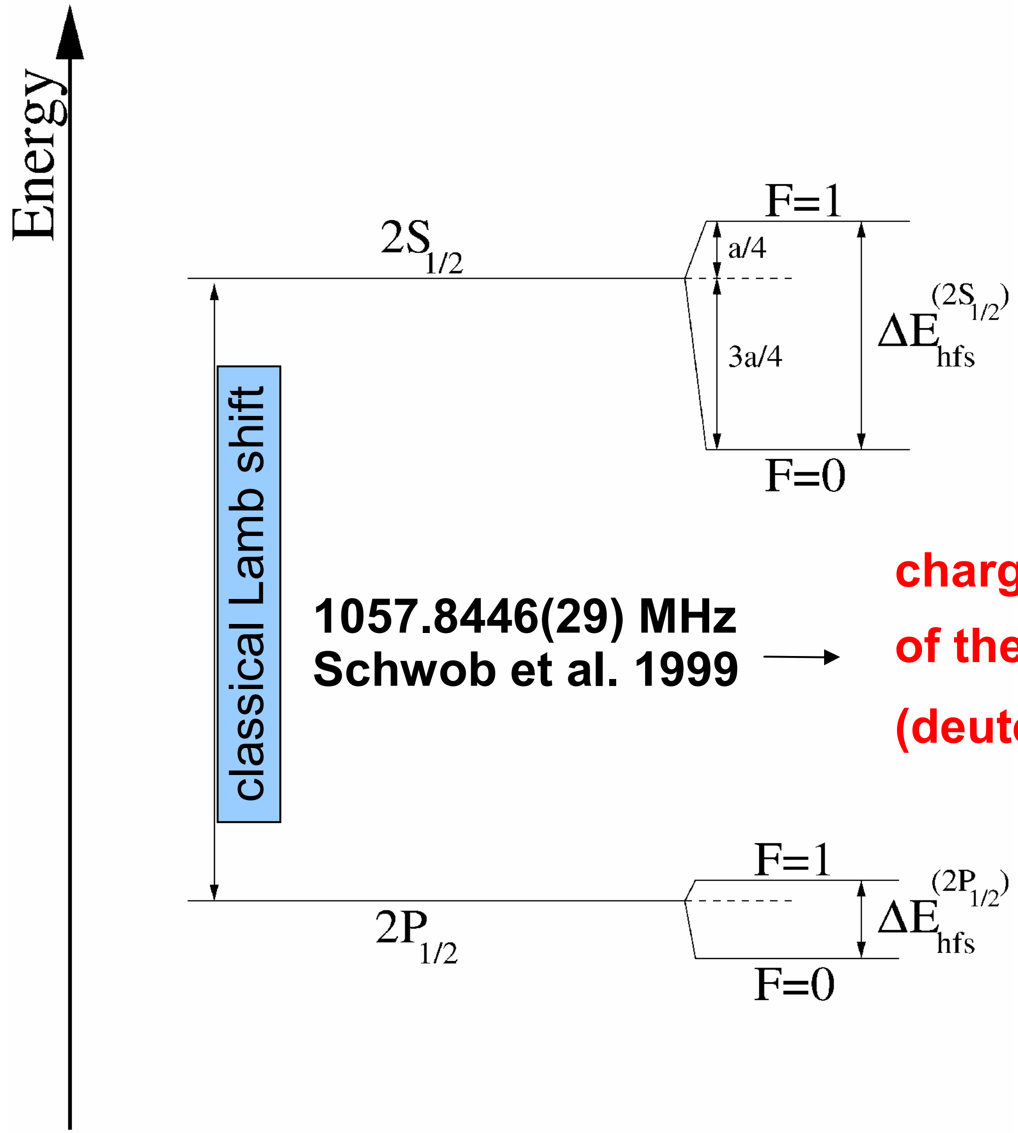


Electron Screening Effects starts

The Electron Screening Effect



Precision Spectroscopy of H and D for n=2: Actual Status



177556834.3 (6.7) Hz
Kolachevsky et al. 2009

177556785 (29) Hz
Rothery and Hessels 2000

1057.8446(29) MHz
Schwob et al. 1999 →

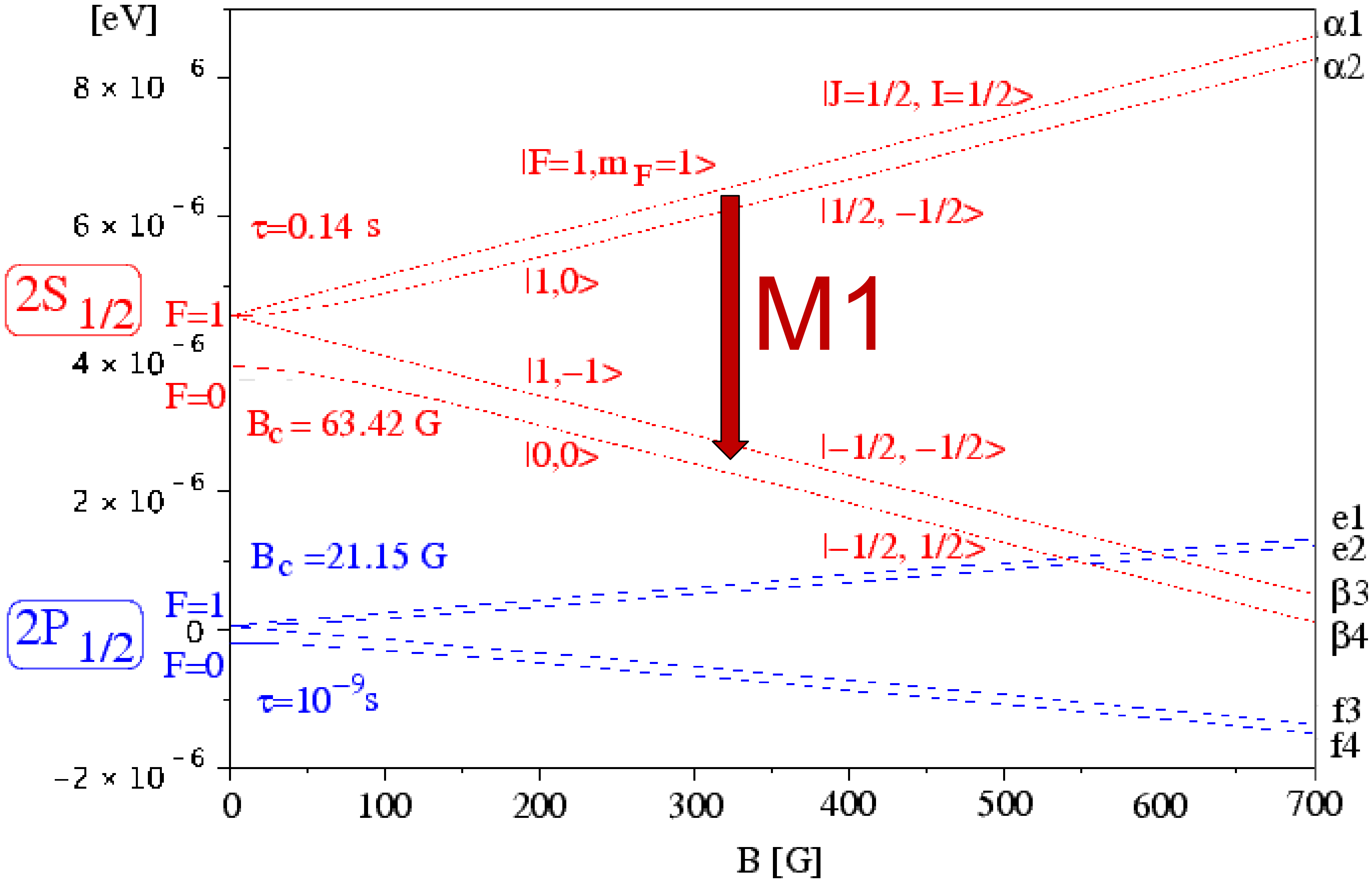
charge distribution of the proton (deuteron)

← **1057.842(4) MHz**
Pachucki 2001

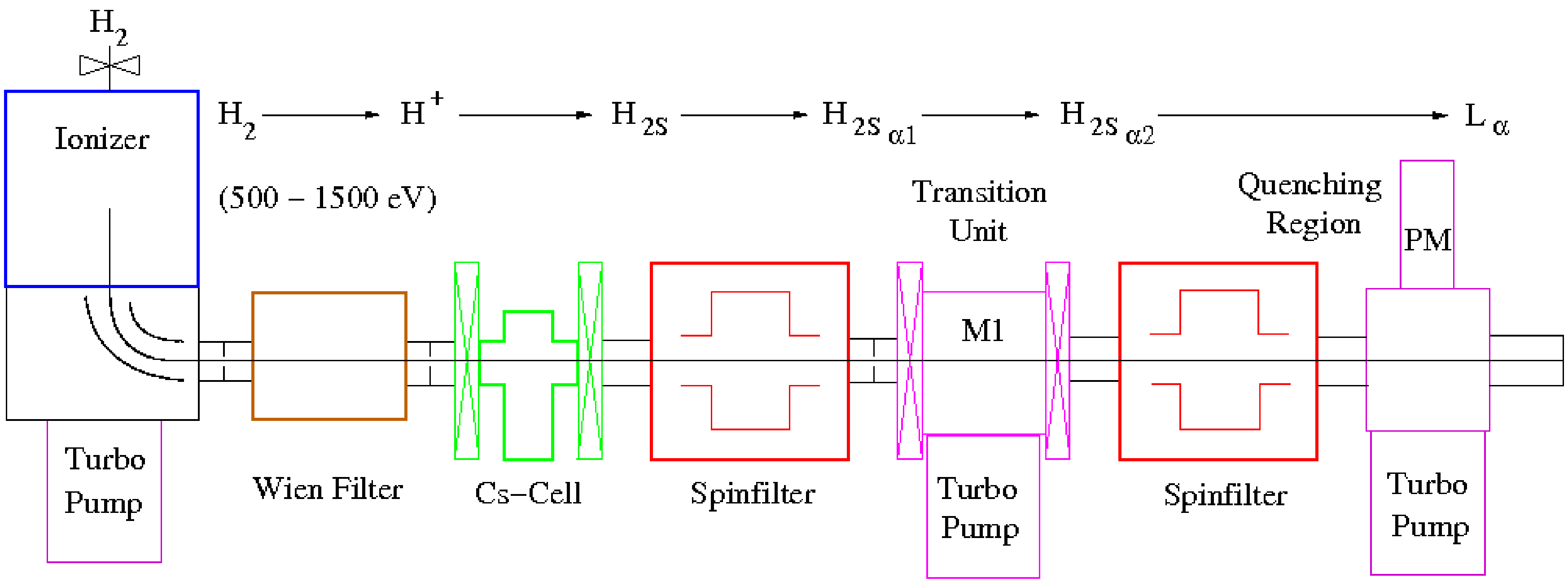
59.22(14) MHz
Lundeen et al. 1975

59.2212(?) MHz
Moskovkin et al. 2007

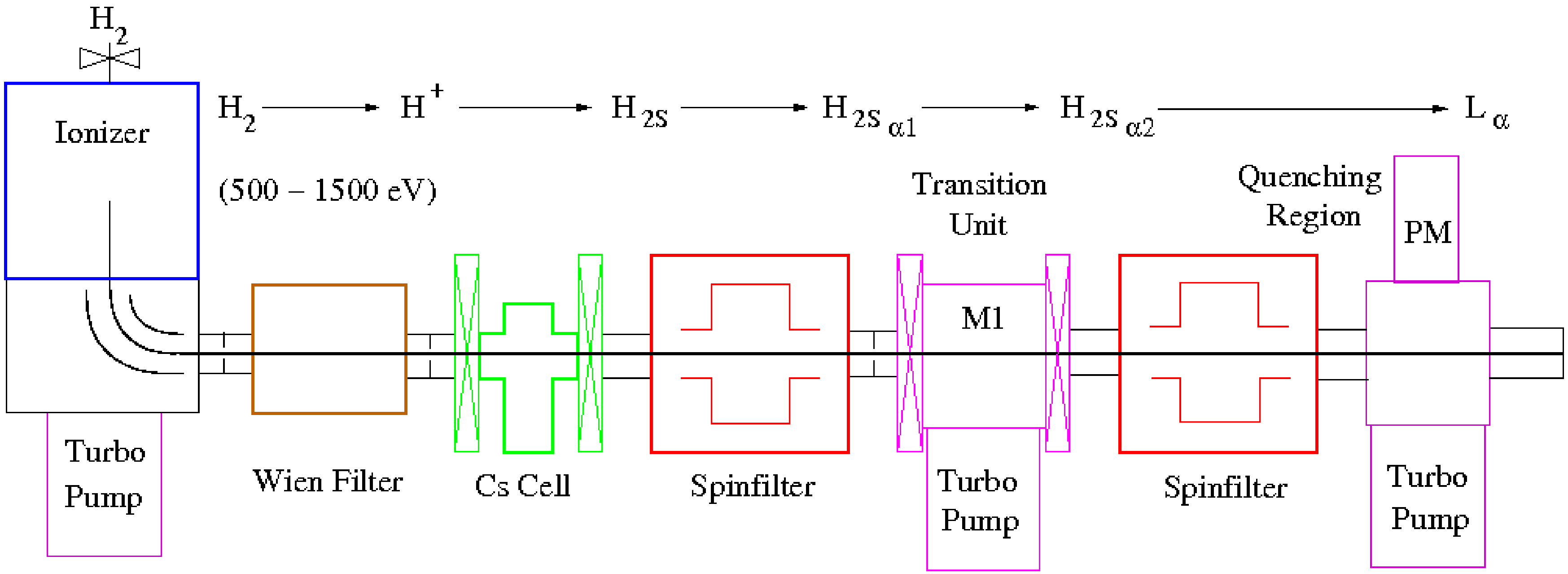
Breit-Rabi Diagram



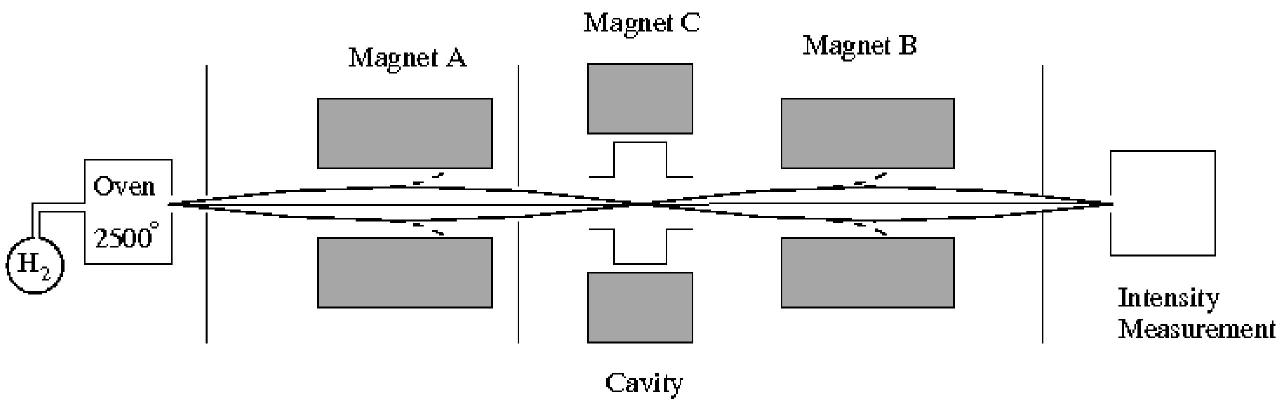
How to measure the HFS of the $2S_{1/2}$ state



How to measure the HFS of the $2S_{1/2}$ state

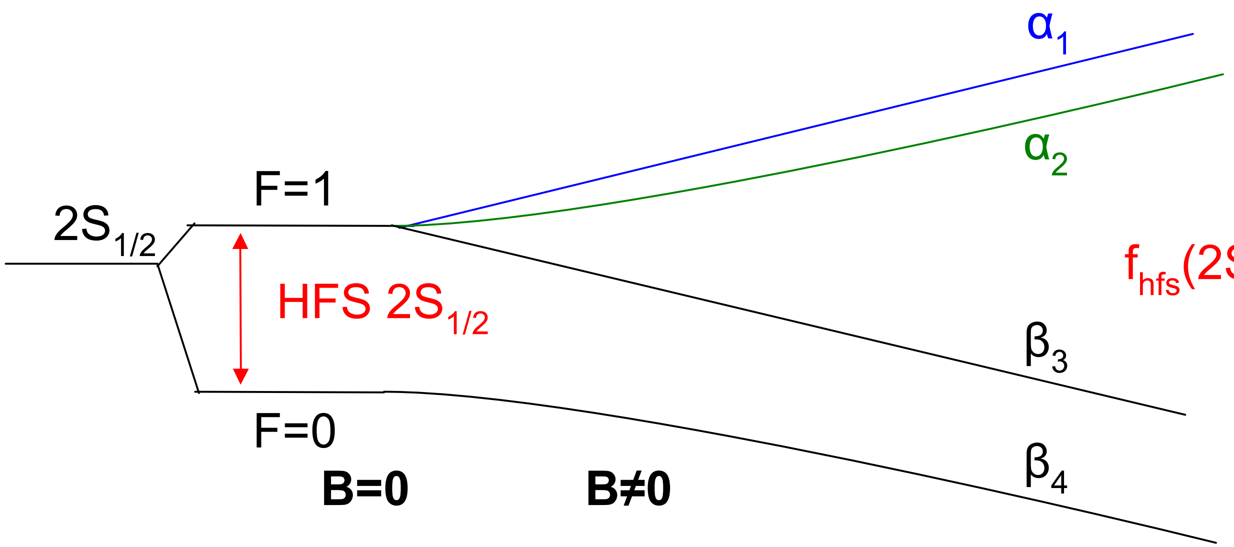


Rabi Apparatus



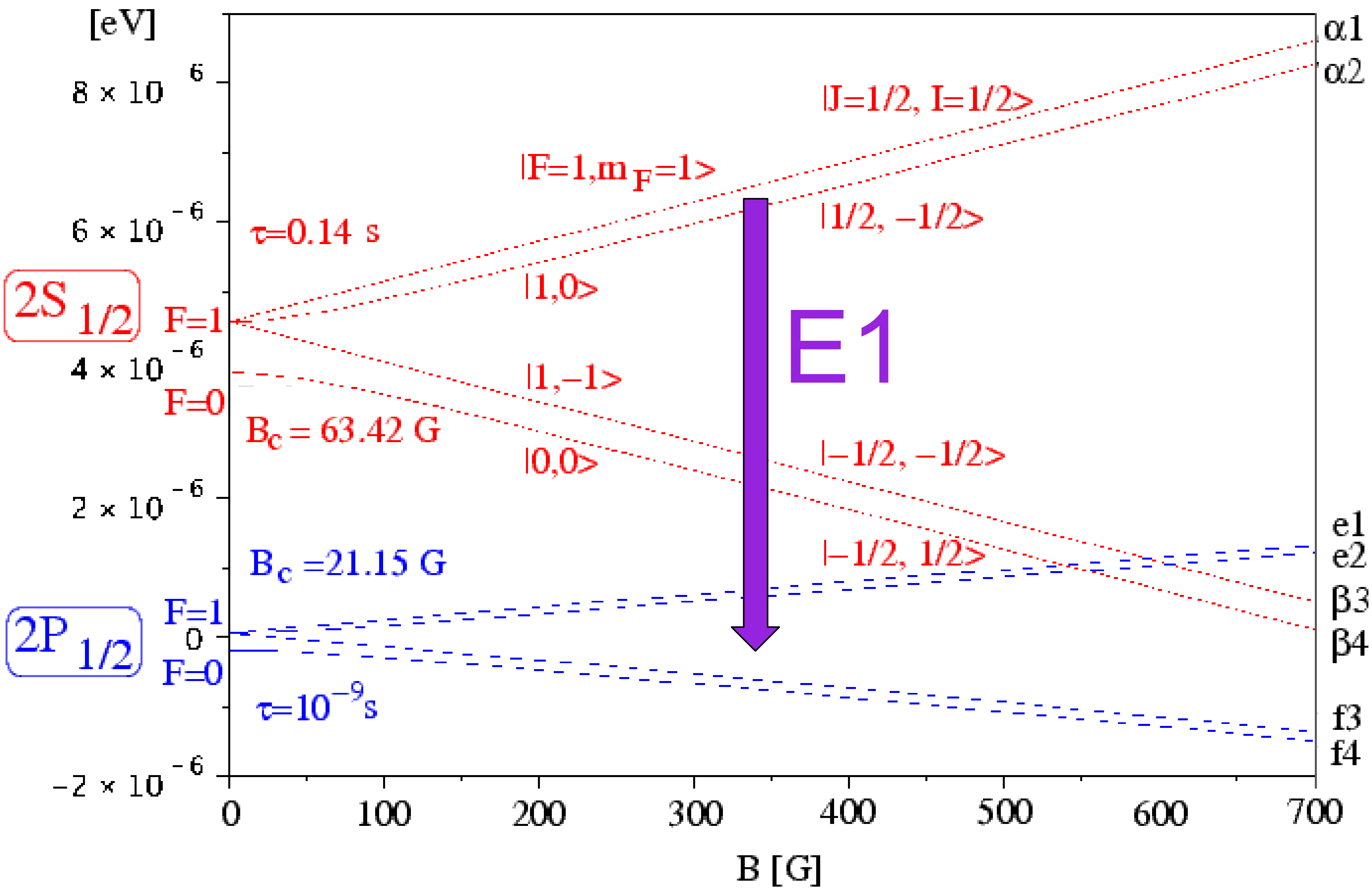
Advantages of this method

- natural linewidth: 1.1 Hz
- High Intensity: 1.5 μA protons → 10^{11} $H_{(\alpha 1)}$ /s → 10^5 photons/s
- direct measurement
- Doppler free (2^{nd} order can be measured)
- monochromatic beam energy can be changed: rel. /quadratic Doppler measurable
- HFS $2S_{1/2}$ can be measured without knowing the absolute strength of the magnetic field B in the interaction region
- relative magnetic field strength can be measured with the α1 ↔ α2 transition

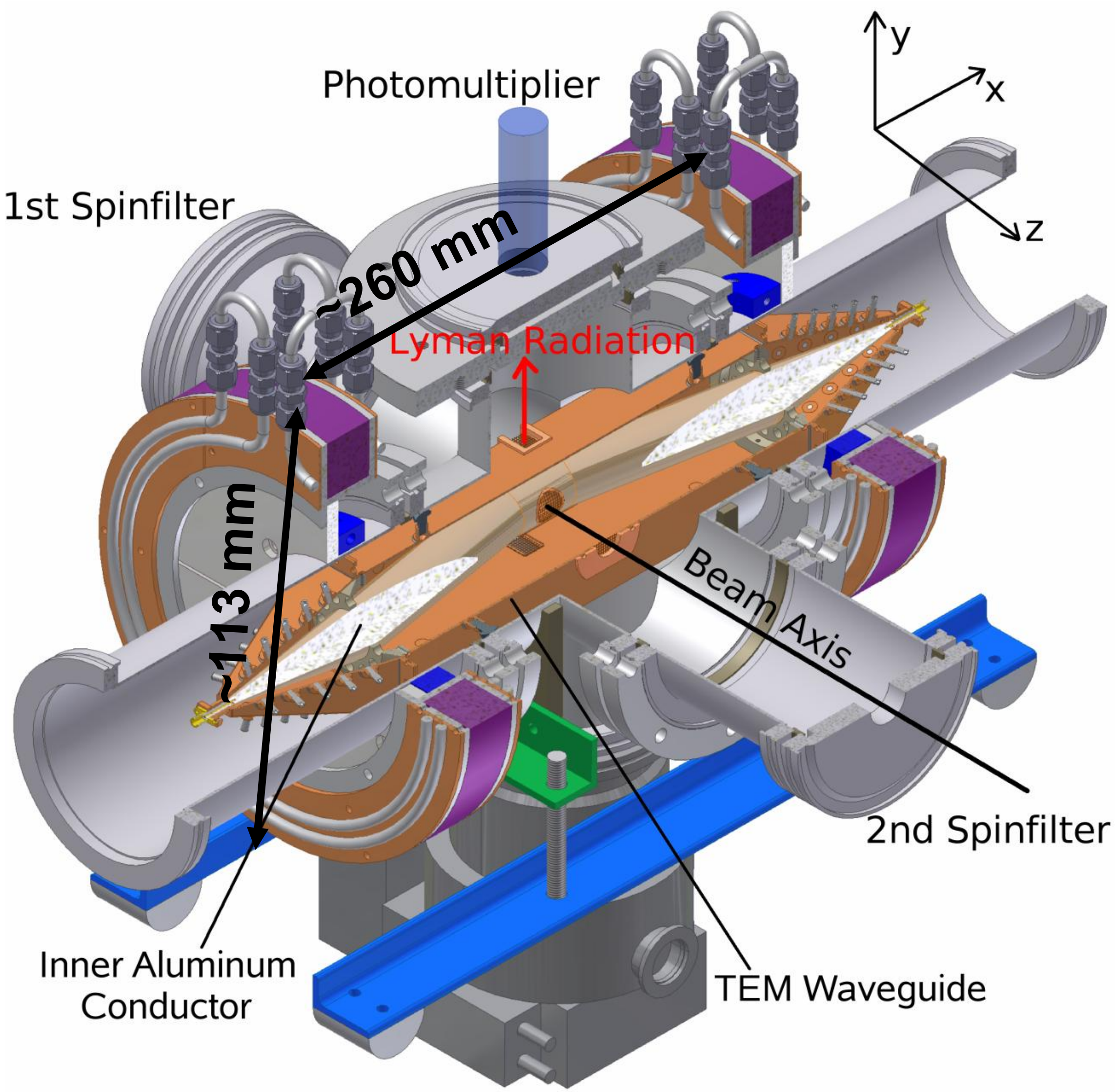


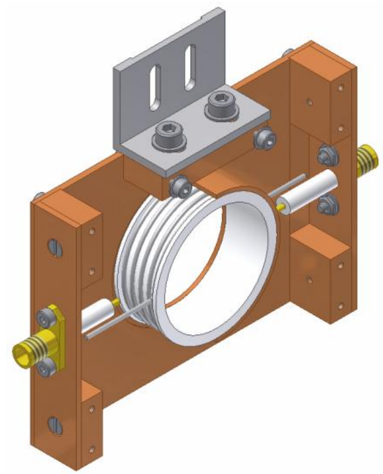
$$f_{hfs}(2S_{1/2}) = f_{(\alpha 1 - \beta 4)} - f_{(\alpha 2 - \beta 3)}$$
$$= f_{(\alpha 1 - \alpha 2)} + f_{(\beta 3 - \beta 4)}$$

Breit-Rabi Diagram



How to measure the classical Lamb shift and the HFS of the $2P_{1/2}$ state





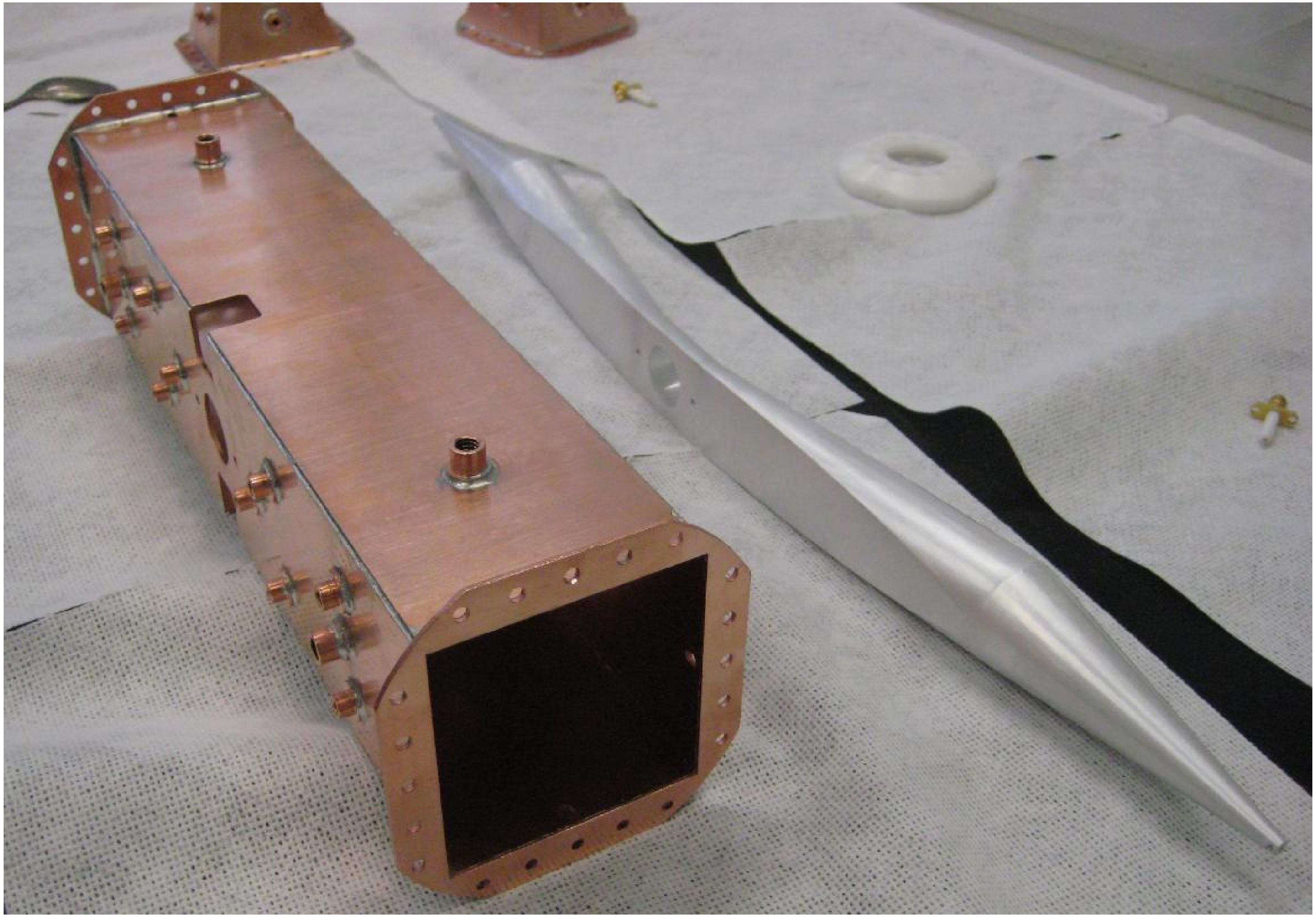
Possible Transitions:

B ⊥ v: $\alpha 1 \rightarrow f4$ ($\alpha 1 \rightarrow e2$)
: $\alpha 2 \rightarrow f3$ ($\alpha 2 \rightarrow e1$)

B ∥ v: $\alpha 1 \rightarrow e1$
: $\alpha 2 \rightarrow e2$ ($\alpha 2 \rightarrow f4$)

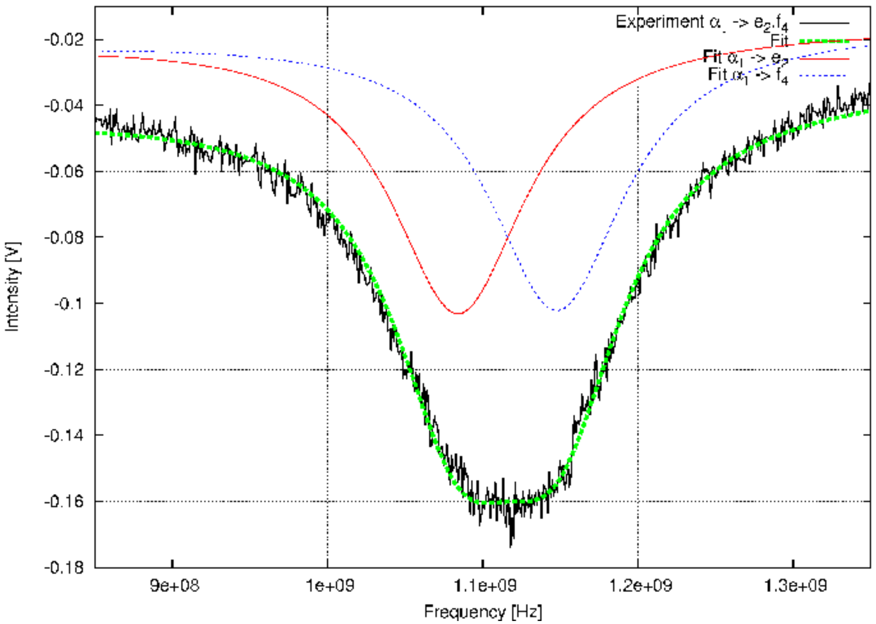
FWHM ~ 100MHz

The TEM waveguide



Preliminary Results (B~0 G)

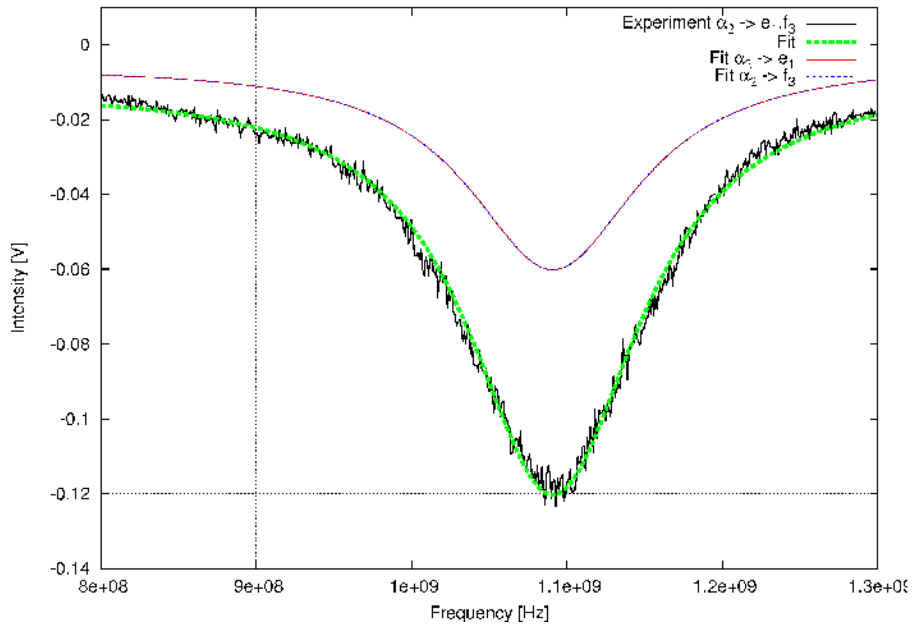
B ⊥ v: α1



$2P_{1/2}$ Hyperfine Splitting

Experiment	Theory
59.98(2.03) MHz **Westig (Cologne Uni.)**	59.2212 MHz **Moskovkin et al. 2007**
59.22(14) MHz **Lundeen et al. 1975**	

B ⊥ v: α2

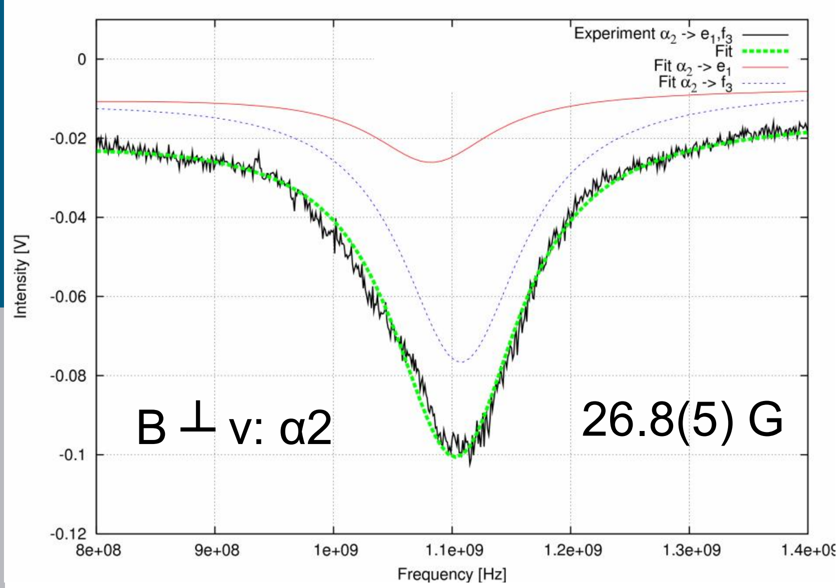


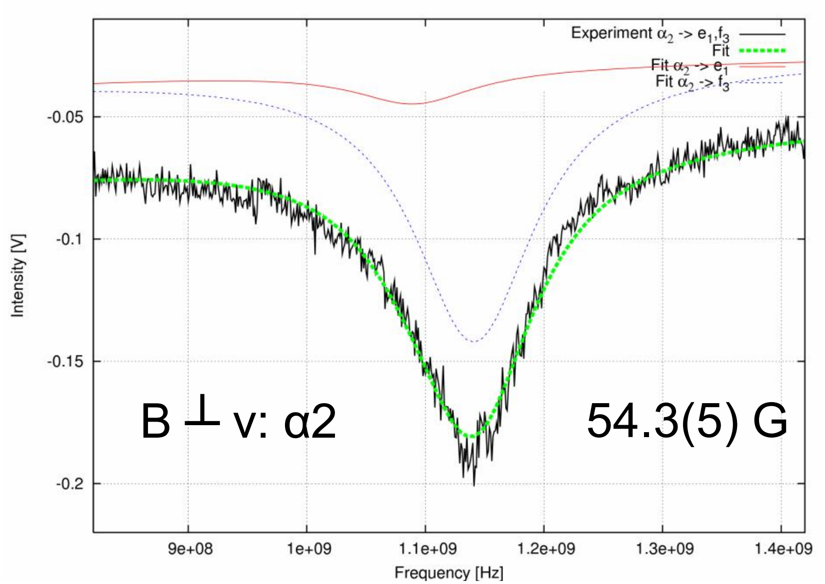
classical Lamb shift

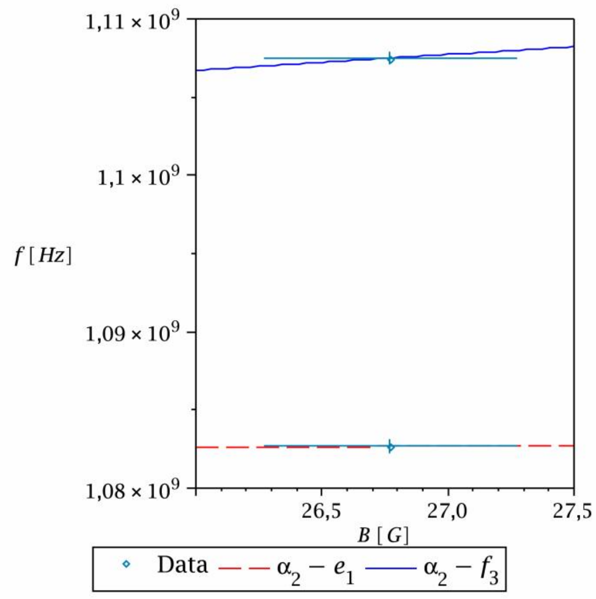
Experiment	Theory
1057.34(1.11) MHz **Westig (Cologne Uni.)**	1057.842(4) MHz **Pachucki 2001**
1057.8446(29) MHz **Schwob et al. 1999**	

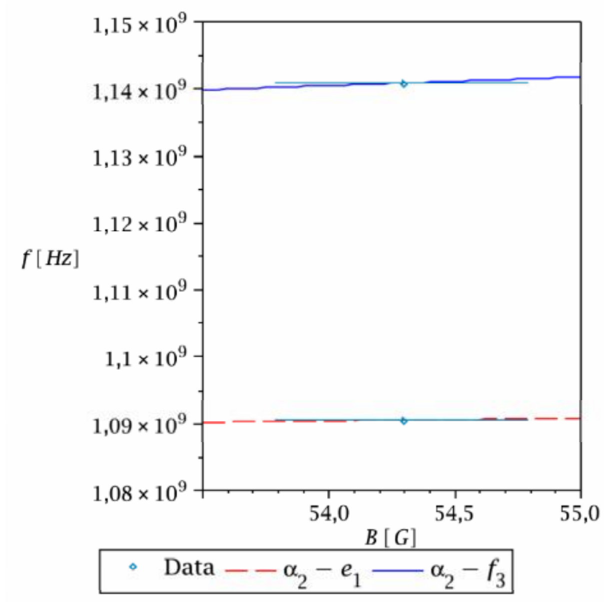
Westig et al.; Eur. Phy. J. D **57**, 27-32 (2010)

Preliminary Results (B= 26.8 and 54.3 G)





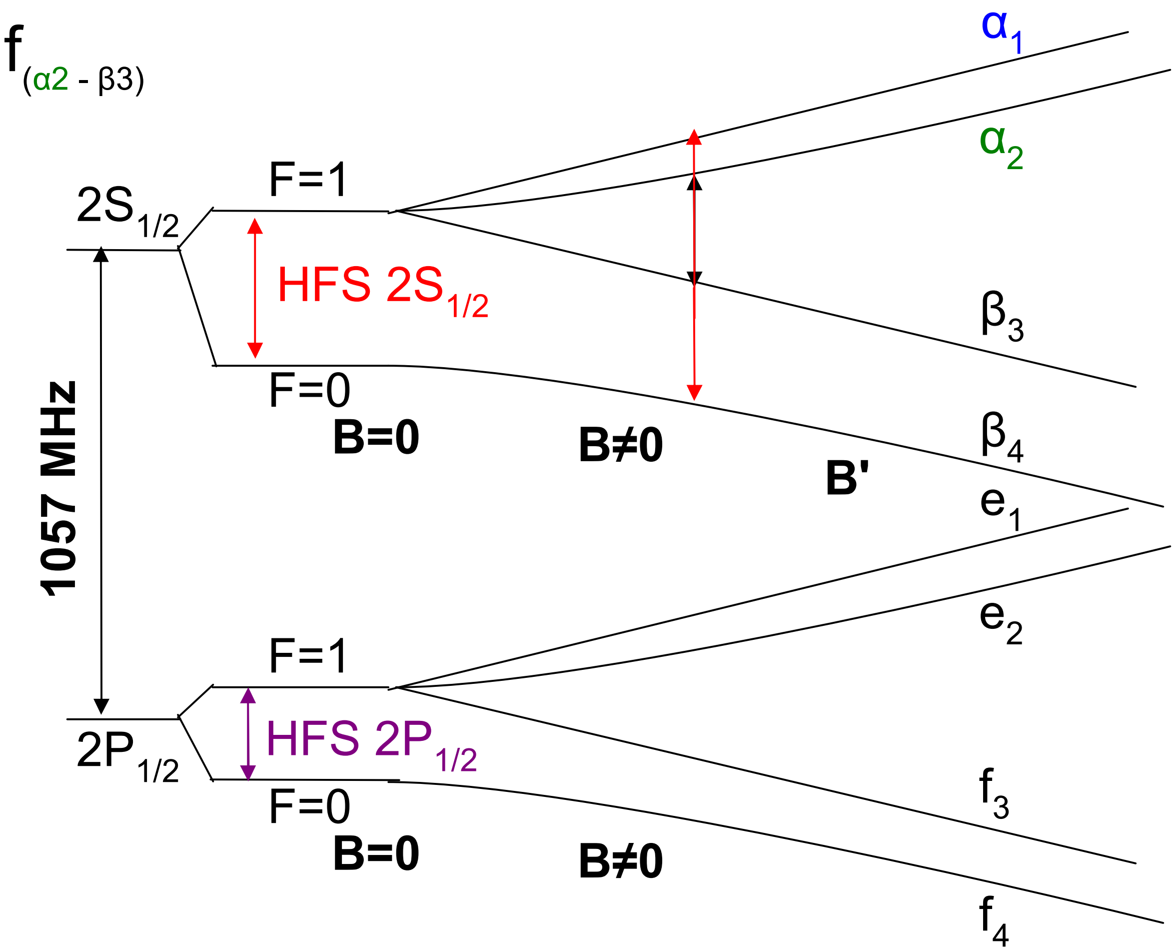




How to measure the HFS of the $2P_{1/2}$ state and the Lamb shift

HFS $2S_{1/2} = f_{(\alpha 1 - \beta 4)} - f_{(\alpha 2 - \beta 3)}$

Lamb shift



HFS $2P_{1/2} = [f_{(\alpha 1 - f4)} - f_{(\alpha 2 - f3)}] - [f_{(\alpha 1 - e1)} - f_{(\alpha 2 - e2)}]$

$B \perp v$ $\qquad$ $B \parallel v$

Uncertainty

- Statistics: E1 transitions: 10^7 photons/s → in 20 min: Δ ~ 1 kHz
  M1 transitions: 10^5 photons/s → in 20 min: Δ < 1 Hz

- Doppler effect: - longitudinal suppressed ($k \perp v$)
  - relativistic and transversal can be measured

- **Magnetic field:** - Homogeneity up to now: ± 0.5 G → Δ ~ 1 MHz !!!
  - Magnetic field direction not well fixed (B ~ 0 G) !!!

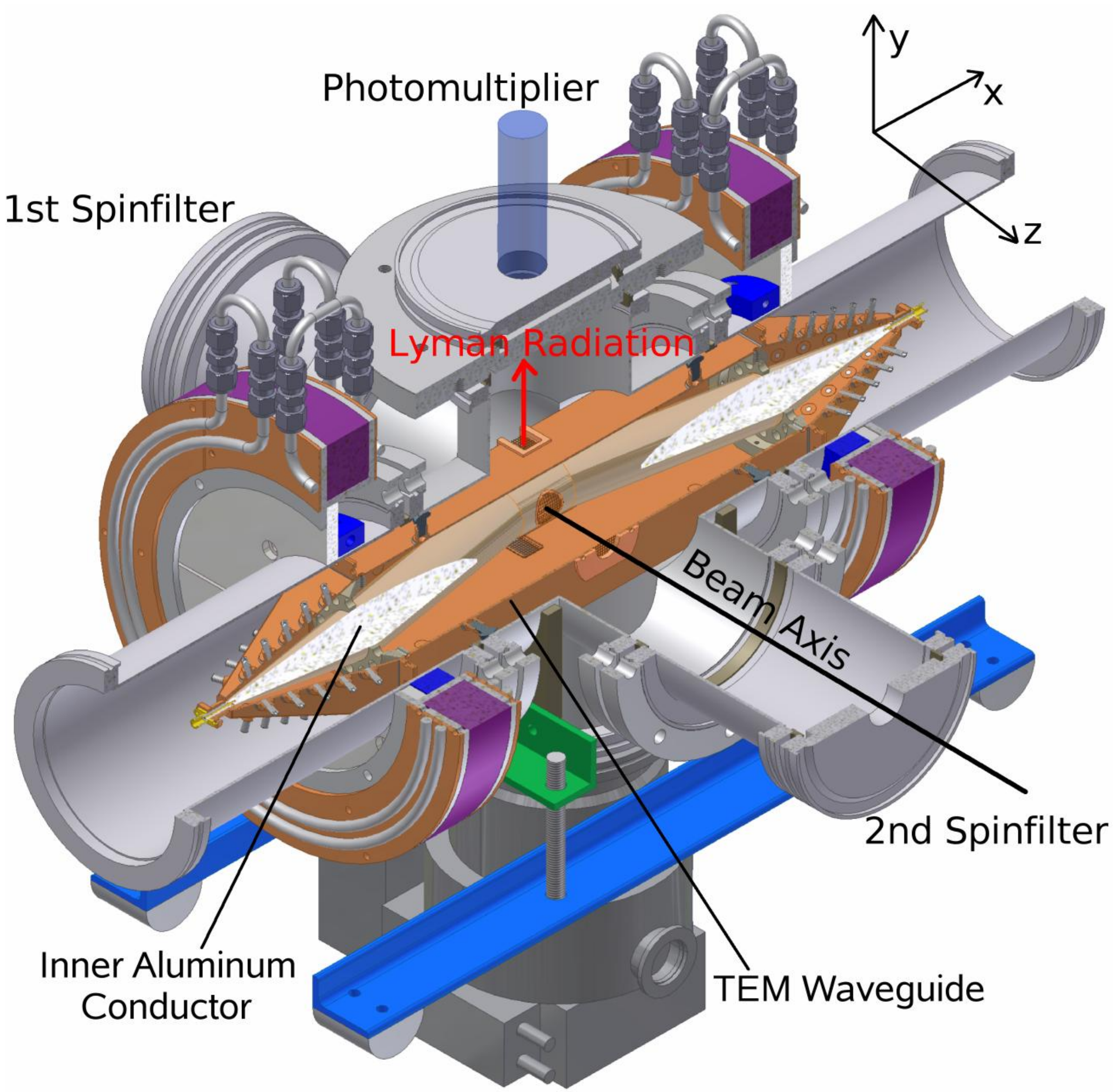
- Power measurement of the rf: - up to now: Δ P ~ 3% → Δ ~ 100 kHz (E1)
  (New device: Δ P ~ 0.002 % are possible !)

- Heisenberg: 1~ Δt * Δf → HWHH ~ 40 MHz (for 1 keV proton beam)

- Electric Fields, Motional Stark Effect, ...

- ?

Uncertainty



Uncertainty

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- Electric Fields, Motional Stark Effect, ...

- ?

Summary

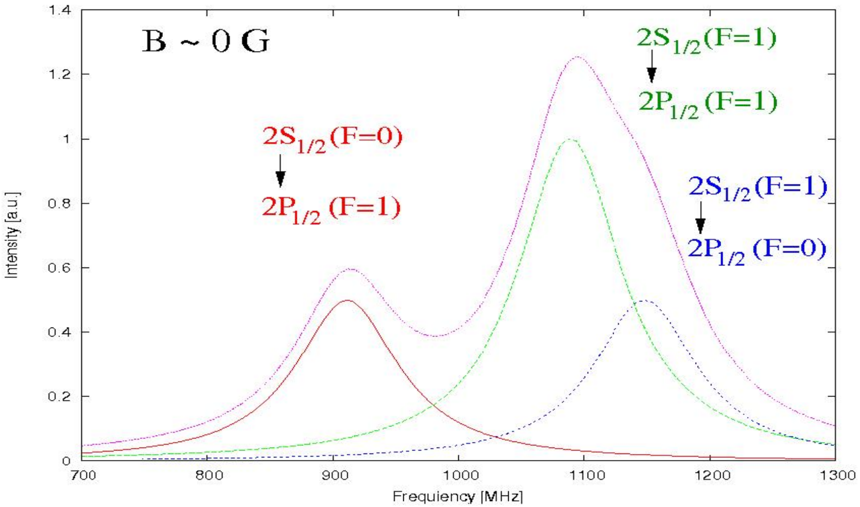
Measurement of the complete Breit-Rabi Diagram for n=2 for H and D

	1. Step (magnetic)	2. Step (SOF)	3. Step (ABS)
$2S_{1/2}$ state:	g-factor: 10^{-5} HFS: 1 kHz	g-factor: 10^{-6} HFS: 100 Hz	g-factor: 10^{-8} HFS: 10 – 1 Hz
$2P_{1/2}$ state:	g-factor: 10^{-4} HFS: 10 kHz	g-factor: 10^{-5} HFS: 1 kHz	g-factor: 10^{-6} HFS: 100 Hz
Lambshift:	10 kHz	?	100 Hz
$2P_{3/2}$ state	g-factor: 10^{-4} HFS: 10 kHz	g-factor: 10^{-5} HFS: 10-1 kHz	

An alternative method to measure g-factors, the Lamb shift and the hyperfine splittings for Anti-Hydrogen at FAIR ?

Ramsey: SOF-Method (1950)

Lundeen, Jessop and Pipkin, Phys. Rev. Lett. **34** (1975)



HFS $2P_{1/2}$ = 59.22 (14) MHz

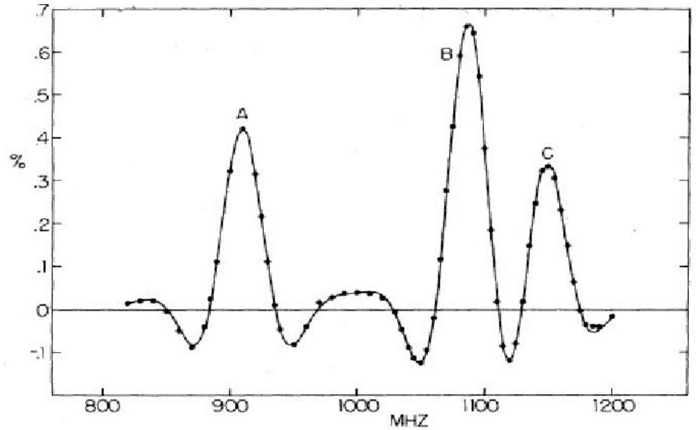


FIG. 2. The line profile observed for the $2\,^2S_{1/2}$ → $2\,^2P_{1/2}$ transition with separated oscillatory fields.

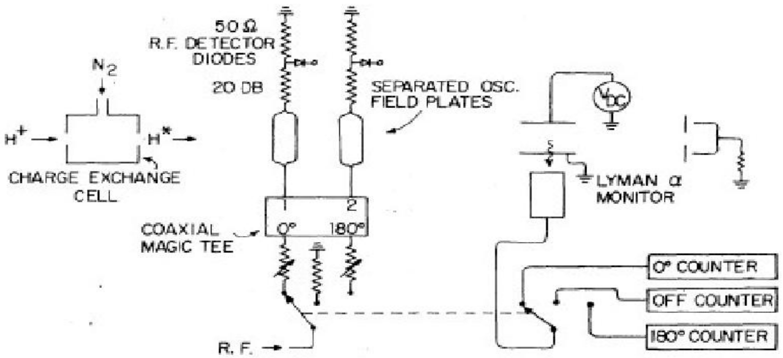


FIG. 3. A schematic diagram of the essential parts of the apparatus. The coaxial magic T divides the rf power equally between the two rf plates with a relative phase of 0° or 180° depending upon the input port used.

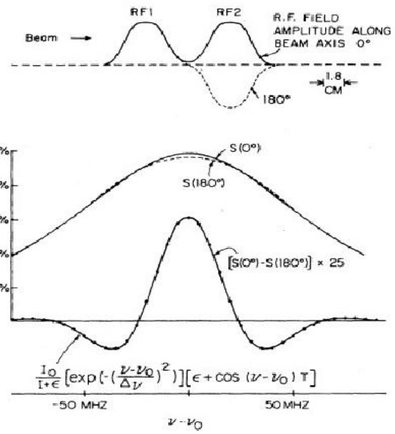


FIG. 4. A diagram showing the formation of the interference signal and the empirical fitting function.

Outlook

What else ?

- Deuterium (tritium) is possible (α1, α2 and α3) [D_{21} Theory]

- Other atoms are possible: ^{3}He, ...

- **Methode will work for Antihydrogen:**

  - During recombination of antiproton and positron up to 30% of the antihydrogen ends up as metastable atoms in the $2S_{1/2}$ state !!!

  - PM registrates single photons

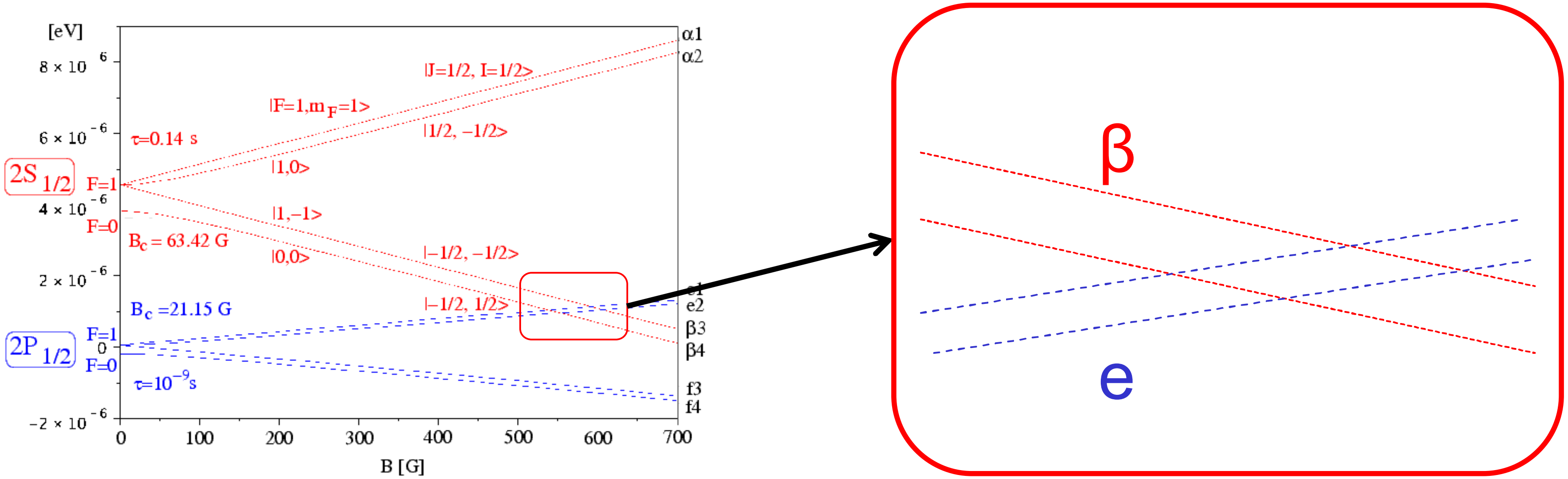
  - Huge range of beam energies is possible: 1/40 ↔ 2000 eV (smaller energy → smaller spinfilter → higher intensity)

  - Intensity: count rate 1 Photon/s ↔ $10^{3\text{-}4}$ $\bar{H}_{(2S)}$/s now !

$\bar{H}$ Hyperfine Splittings of the $2S_{1/2}$, $2P_{1/2}$ ($2P_{3/2}$) and

the classical Lamb shift can be measured with the spinfilter.

Outlook: Parity Violation



Direct transitions between β and e states are not allowed !!!

(**Parity conservation**)

Weak force is part of the binding energy of the S states !!!

Weak force parity violation → β-e transitions are possible

(R.W. Dunford and R.J. Holt; J. Phys. G **34** (2007) 2099-2118)

Polarized H_2 Molecules

- Beam intensities of conventional ABS barely reach $\sim 10^{17}$ at/s

$\Rightarrow$ target density $d_t \sim 10^{14}$ at/cm^2 (typical T-shaped storage cell)

- Depolarization at low T of storage cell don't allow further cooling

Performance of PIT using atomic beams saturates!

New storage cell materials

Polarized molecules?

Polarized H_2 Molecules

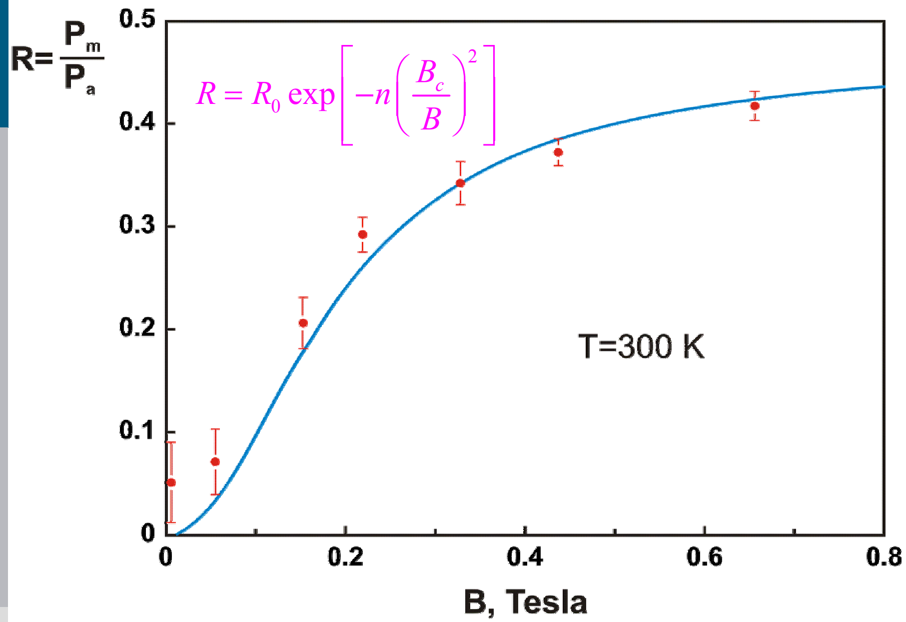
- **Sticking time** of molecules at the surface is much **smaller** compared to atoms
  $\Rightarrow$ cell can be cooled down to much **lower T**
  $\Rightarrow$ **higher** target density ($d_t \sim T^{-1/2}$)

- Polarized molecules is an interesting object for **atomic physics** which has never been deeply investigated (e.g. depolarization on the surface)

- Recombination of polarized atoms in different hyperfine states is interesting to **astrophysics** (e.g. formation of molecular hydrogen in cold clouds)

Polarized H_2 Molecules

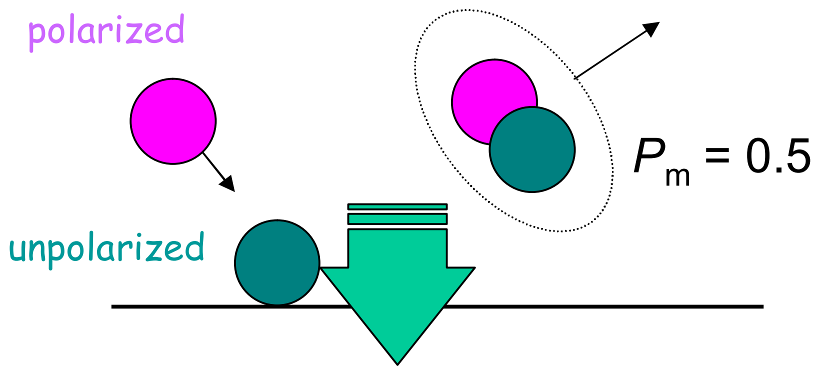
Measurements from NIKHEF, IUCF, HERMES show that recombined molecules retain fraction of initial nuclear polarization of atoms!



Nuclear Polarization of Hydrogen Molecules from Recombination of Polarized Atoms
T.Wise et al., Phys. Rev. Lett. 87, 042701 (2001).

$$\lim_{B\to\infty} R = 0.5$$

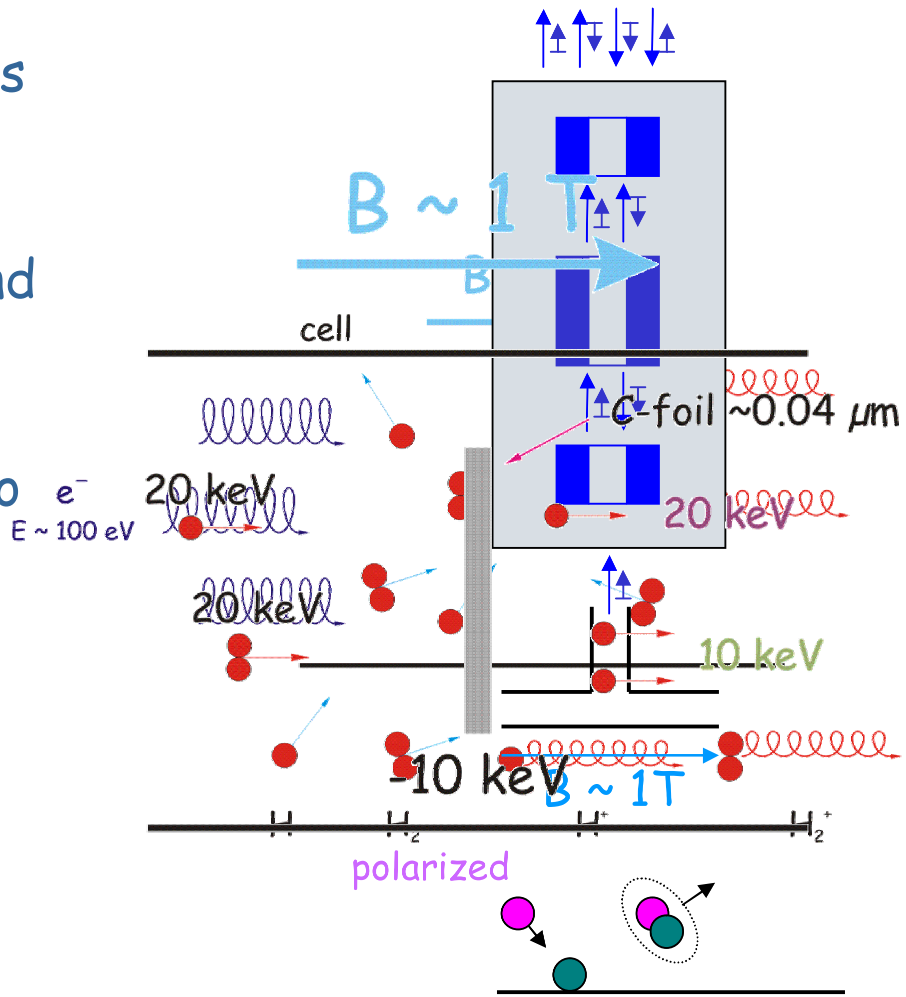
Naïve model



Is there a way to increase (surface material, T, B etc)?

Polarized H_2 Molecules

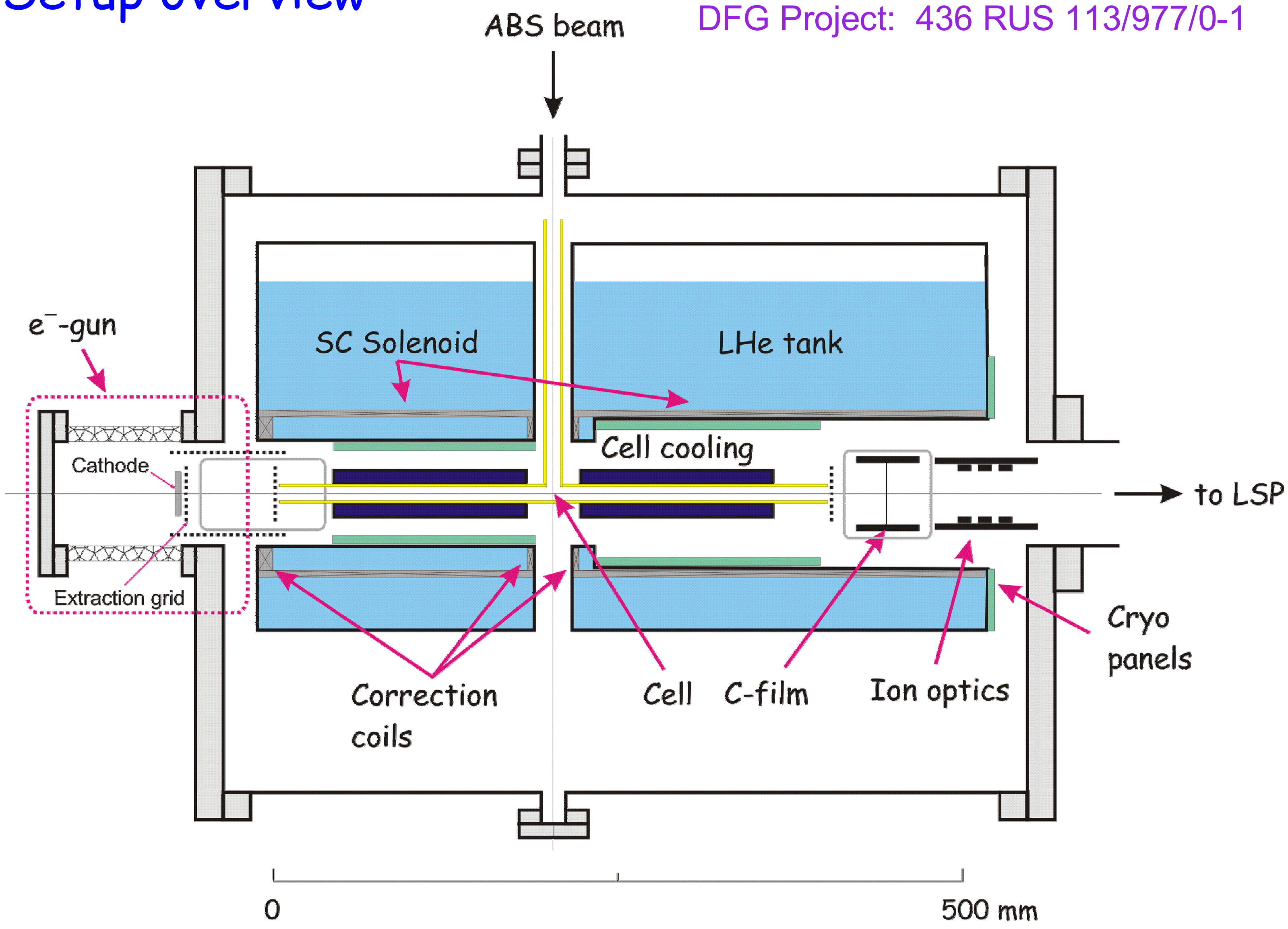
- Recombination of polarized atoms into molecules
- Conversion of polarized atoms and molecules into ions
- Conversion of H_2^+ and H^+ ions into protons with different energy (suggested by W.Haeberli)
- Separation of protons by energy
- Measurement of proton polarization in LSP



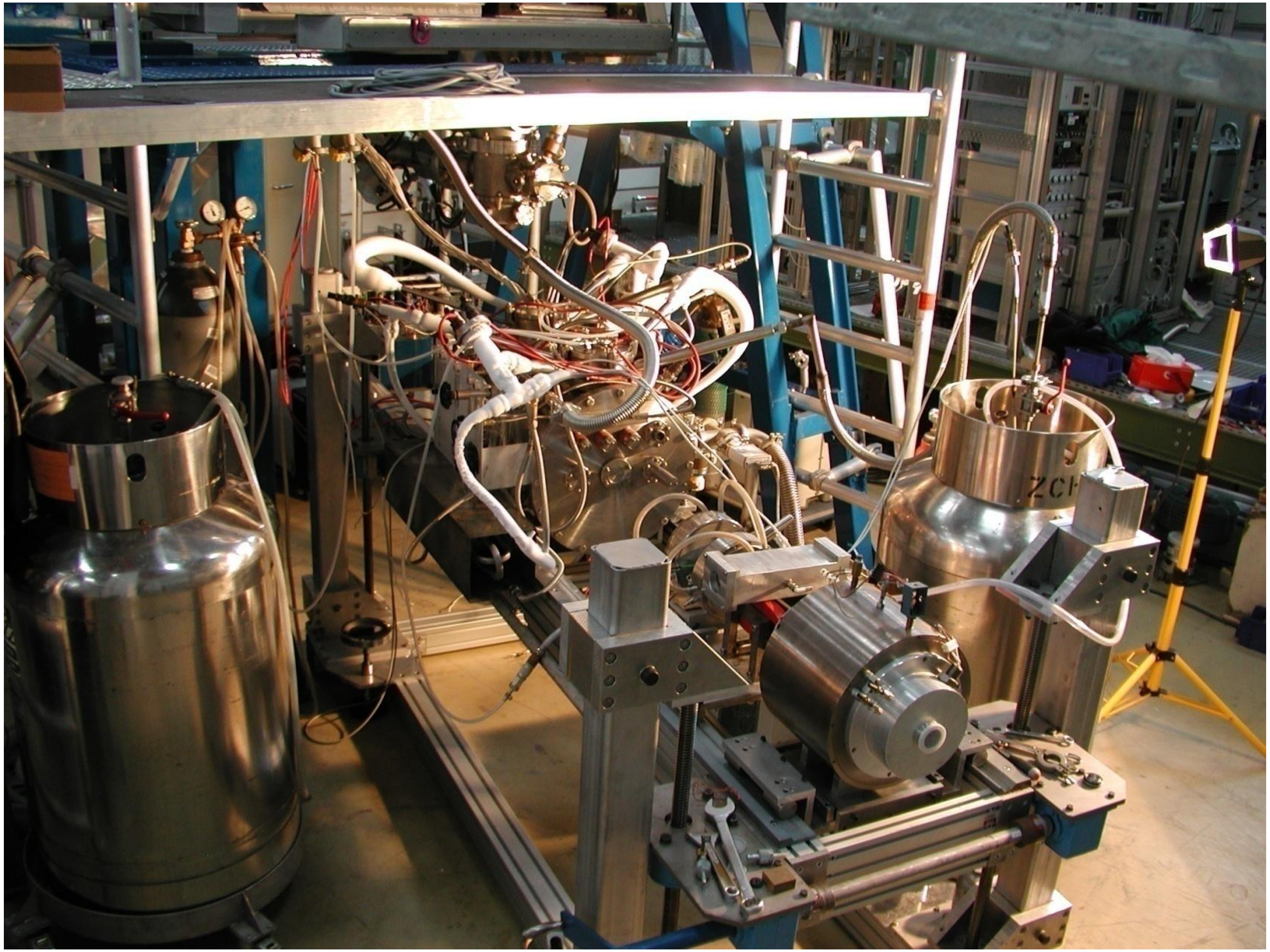
Polarized H_2 Molecules

Setup overview

ISTC Project # 1861 PNPI, FZJ, Uni. Cologne
DFG Project: 436 RUS 113/977/0-1

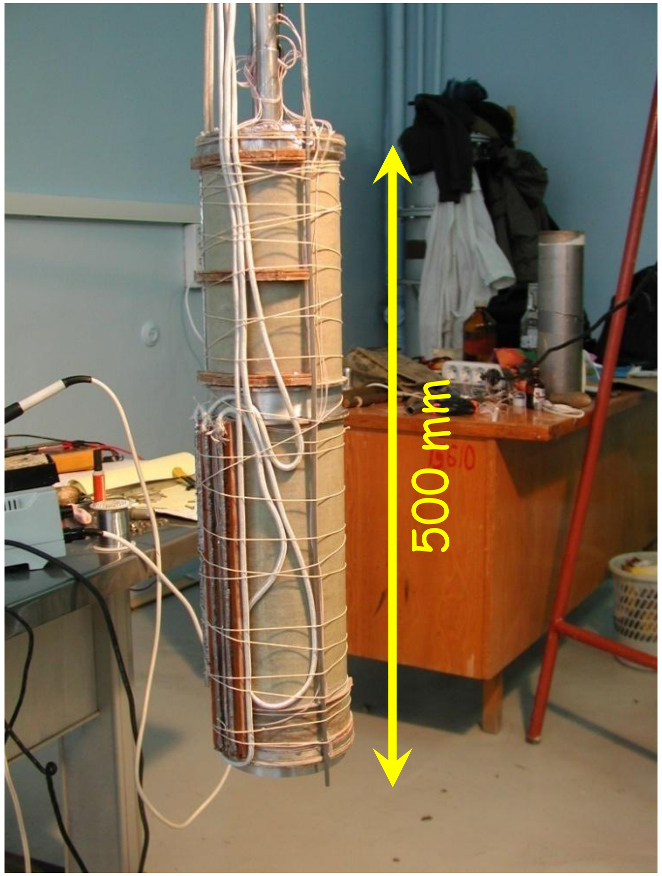


Polarized H_2 Molecules

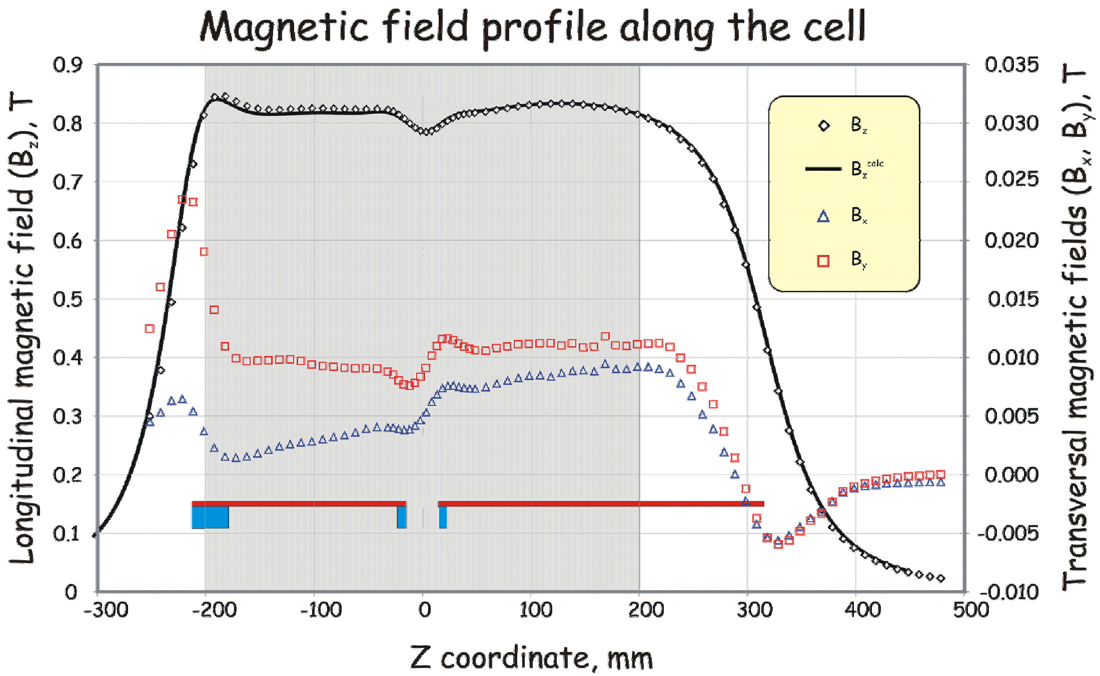


Polarized H_2 Molecules

Superconducting Solenoid

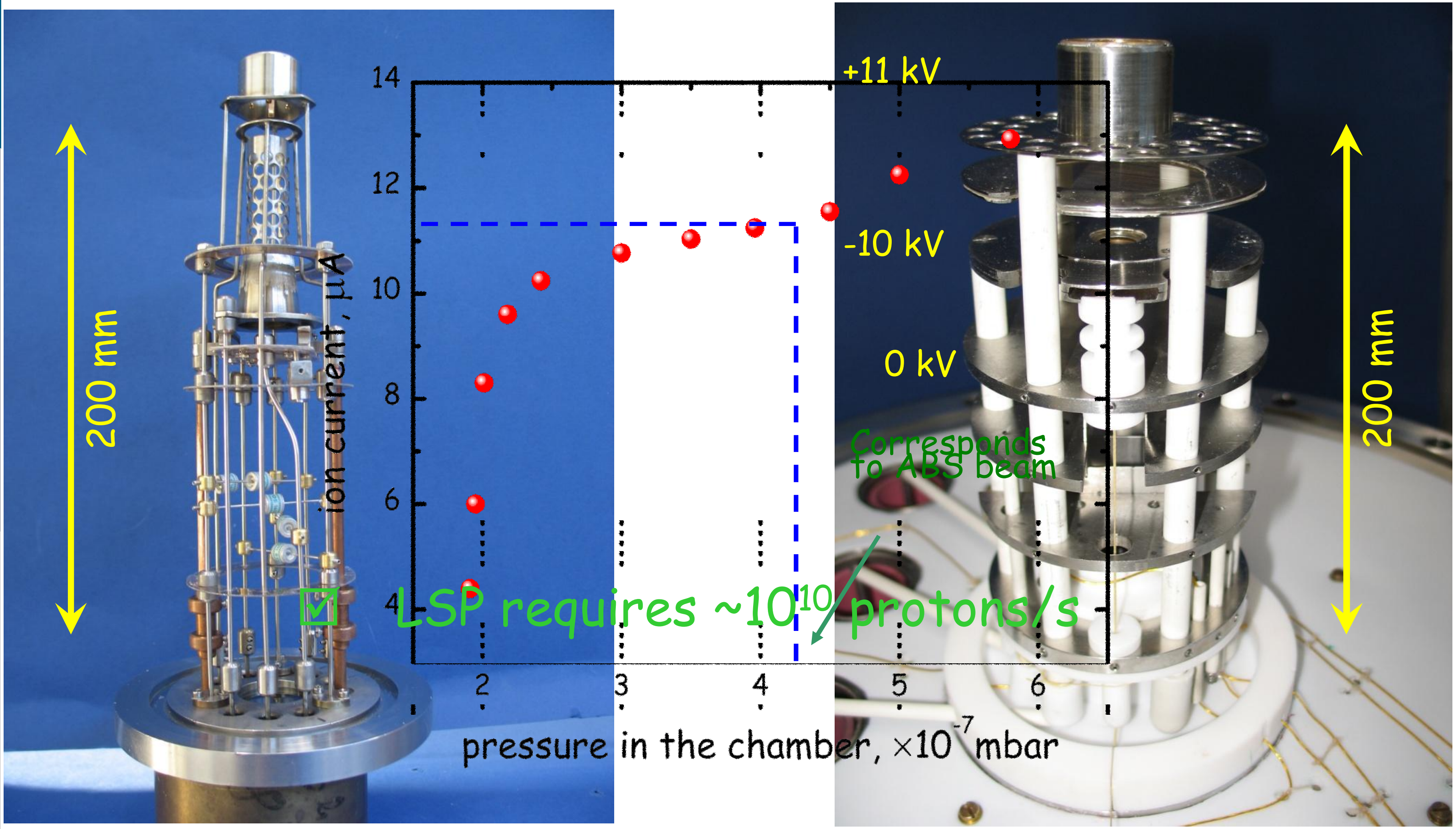


- SC wire NiTi+Cu (Ø 0.5 mm)
- Nominal current 50 A ⇒ B ~ 1 T
- Degradat ion of frozen field ≤ 0.1% per 5 hrs
- LHe consumption ~ 8 l/h



Polarized H_2 Molecules

e⁻-gun and ion optics



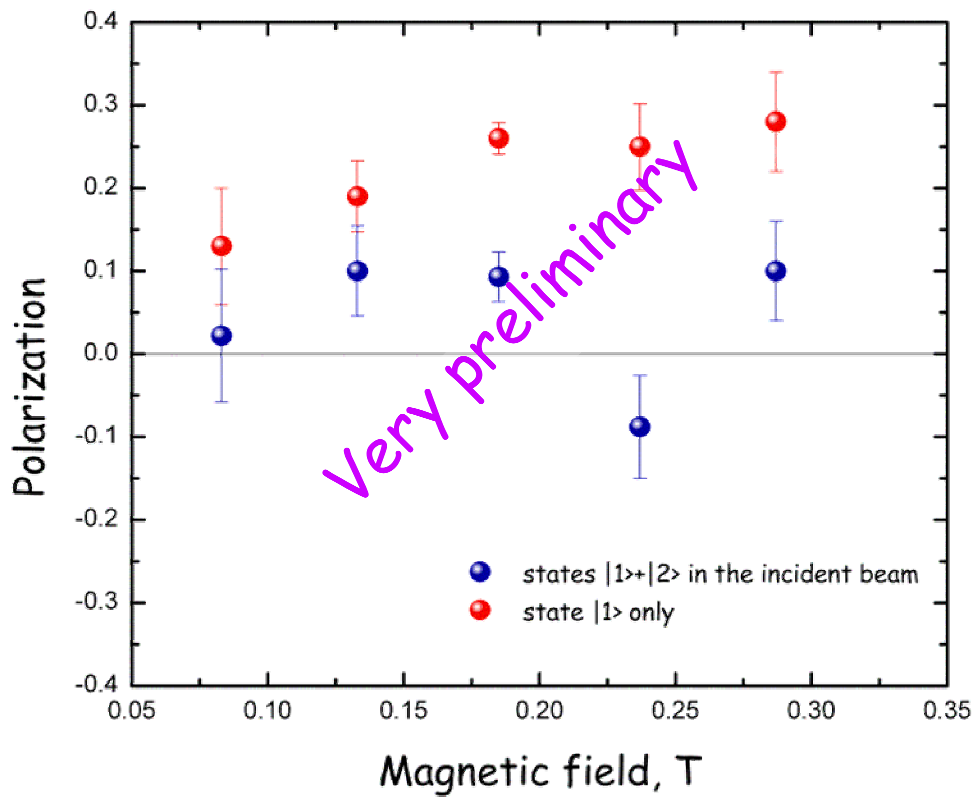
Polarized H_2 Molecules

Magnetic field dependence

- Cell coating: Au
- Cell temperature: 80K

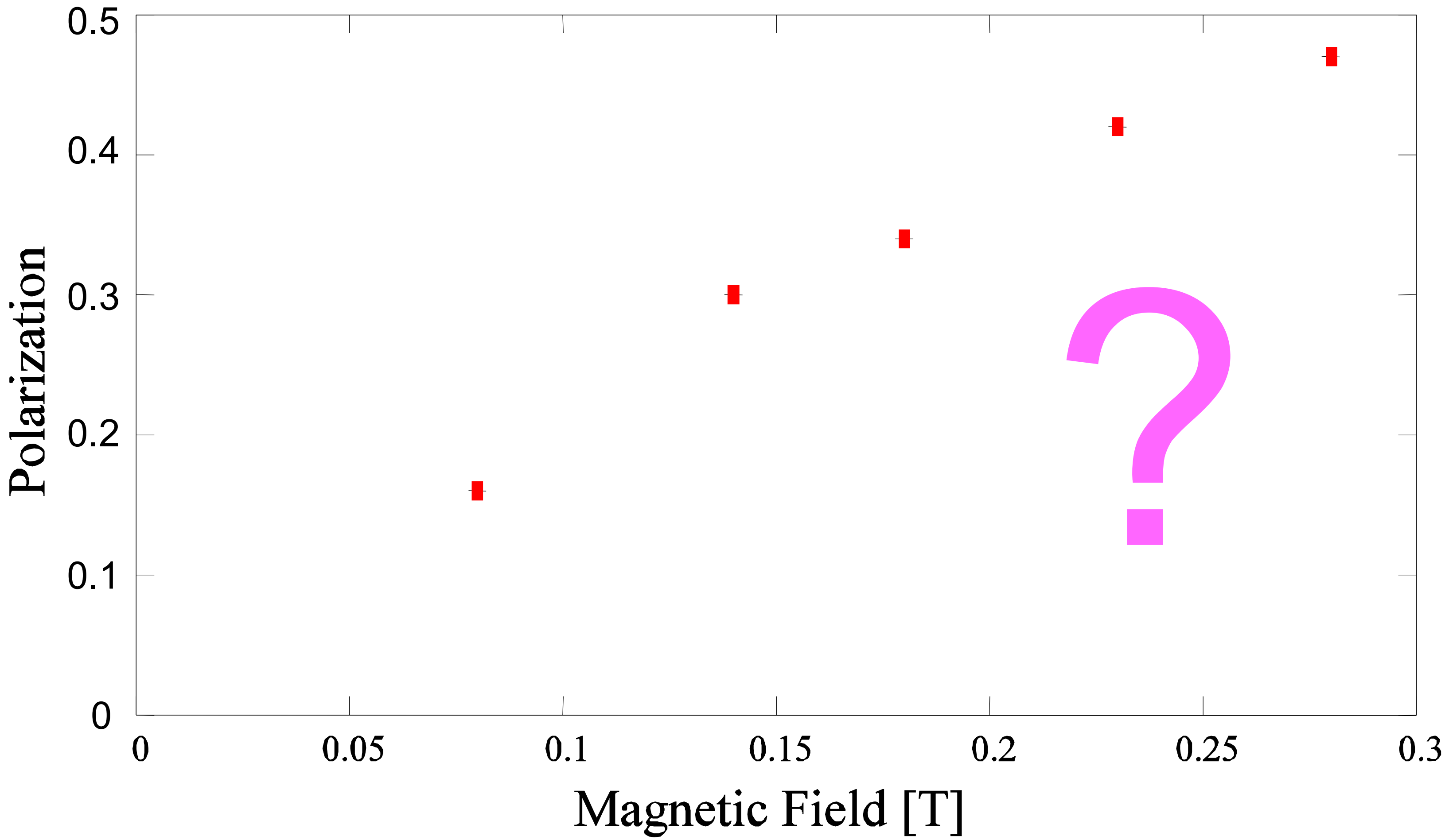
Low polarization???

- misalignment of quantization axis?
- T too low?
- Au is not an appropriate material?



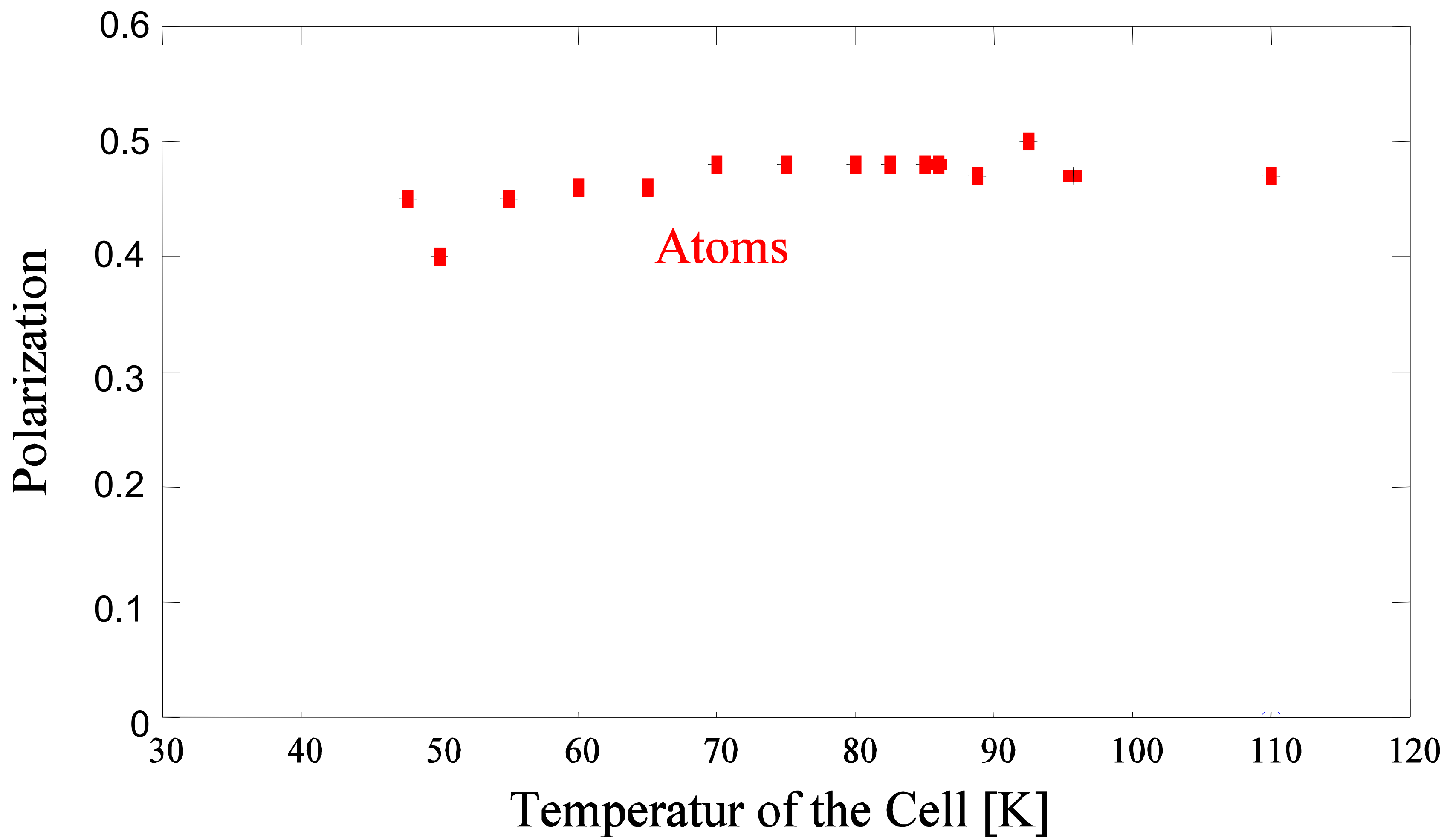
Polarized H_2 Molecules

Polarization of Hydrogen Atoms as Function of the Magnetic Field
(Surface: Gold, T = 47 K, HFS 1, Q = 3 keV)

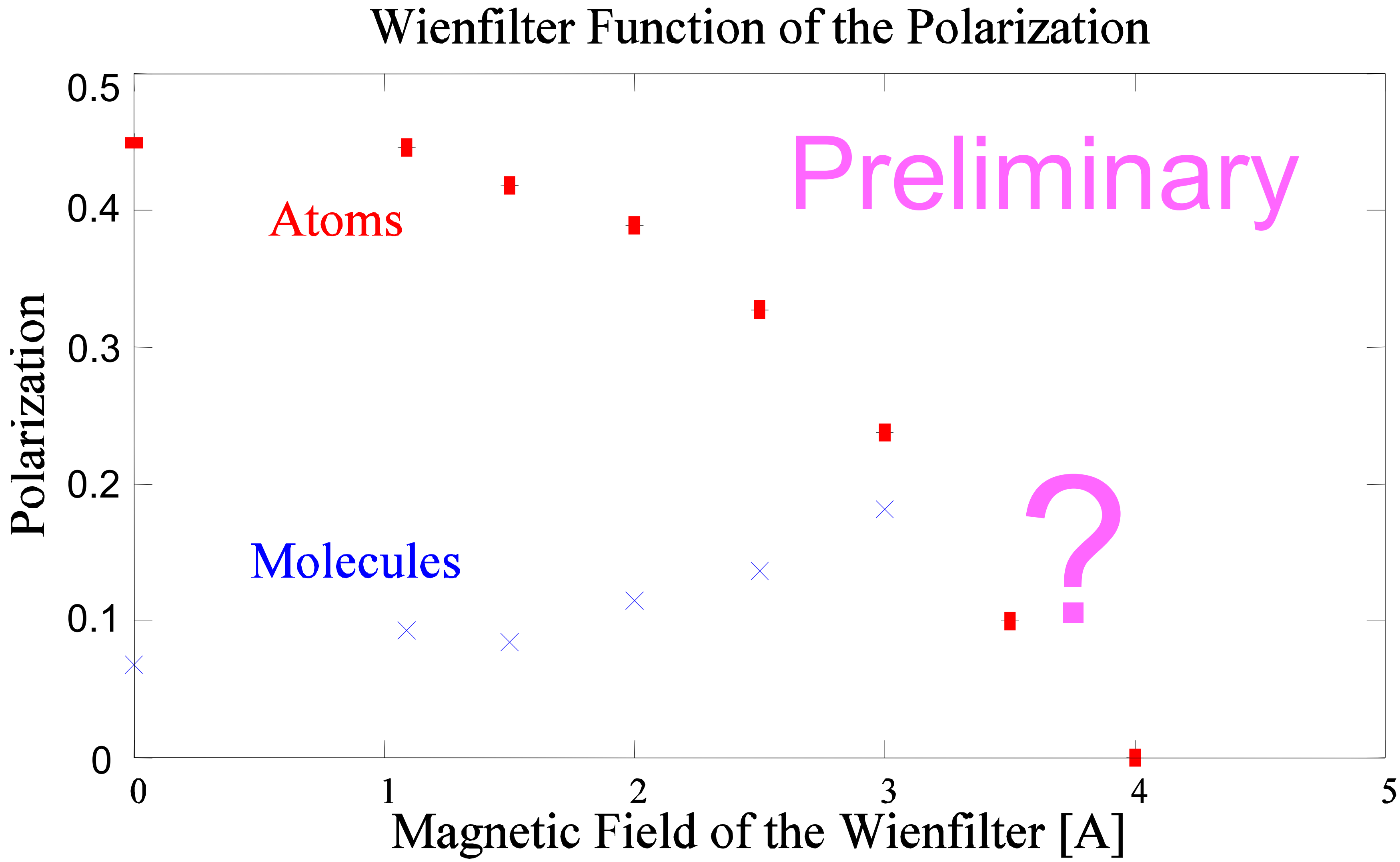


Polarized H_2 Molecules

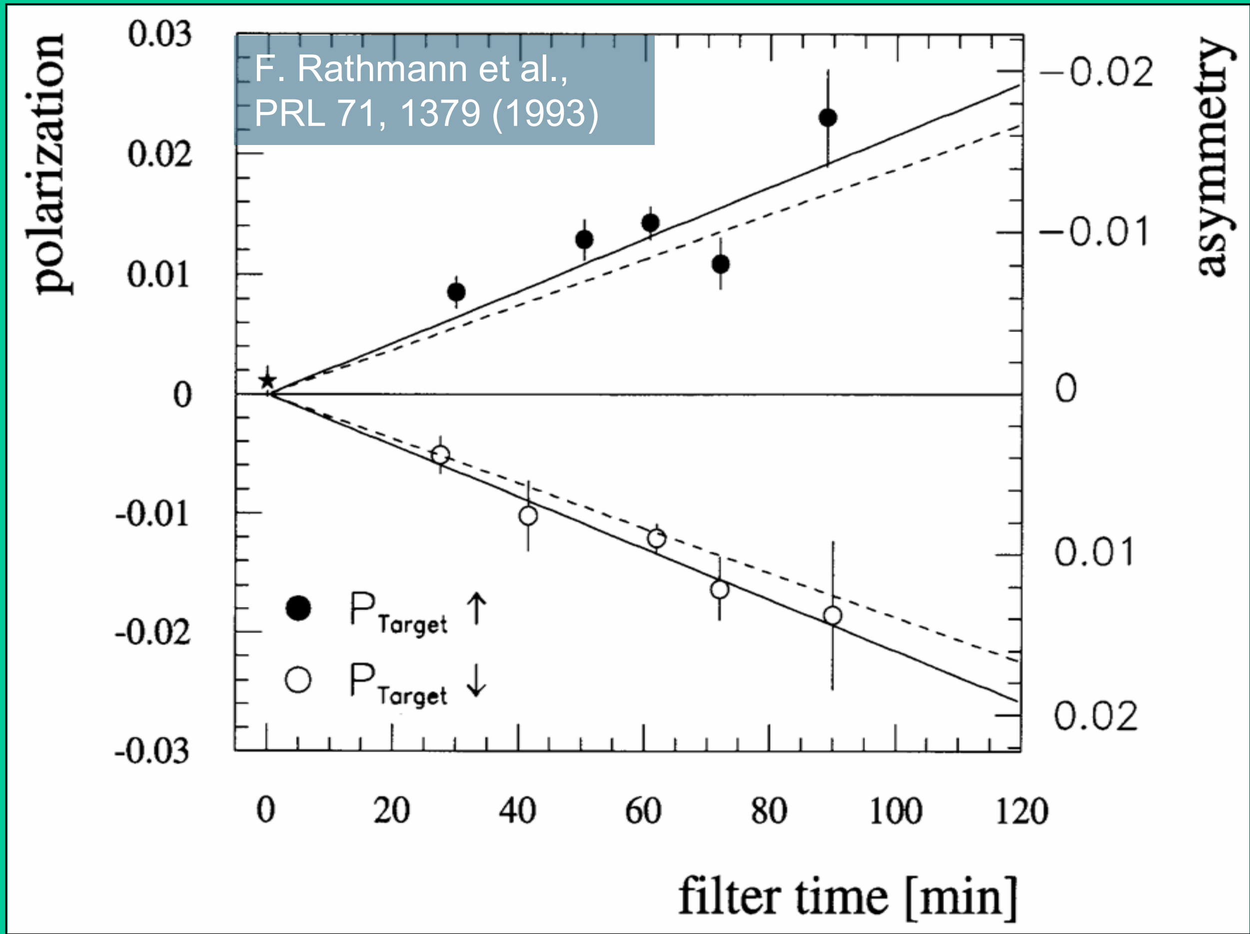
Polarization of Hydrogen Molecules and Atoms
(Surface: Gold, HFS 1, B = 0.28 T, Q = 4 keV)



Polarized H_2 Molecules



Spin-filtering at TSR: „FILTEX“ – proof-of-principle

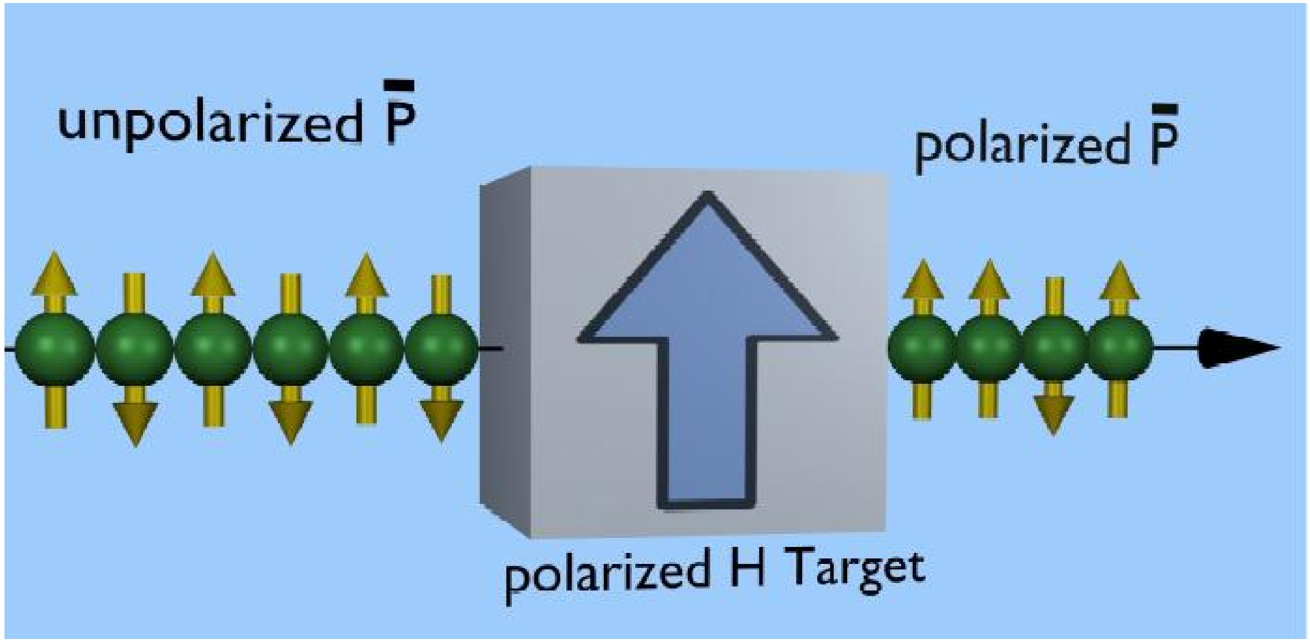


→ Spin filtering works for protons

PAX

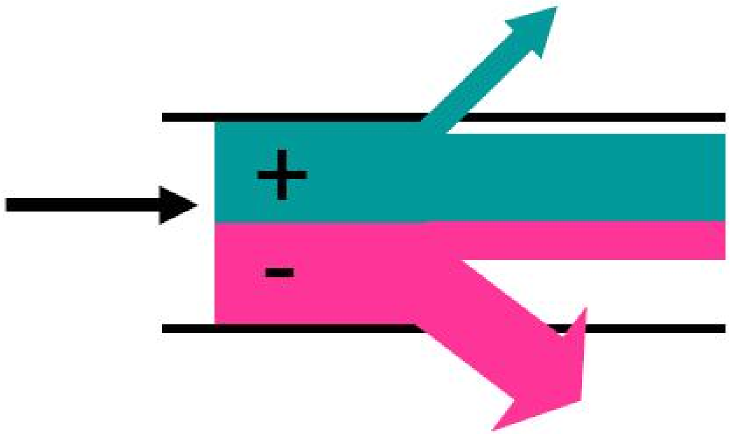
Spin-filtering

Polarization build-up of an initially unpolarized particle beam by repeated passage through a polarized hydrogen target in a storage ring:



PAX

Polarizing antiprotons: Two Methods: Loss



selective loss

discard (one) substate
(more than the other)

PAX

Eur. Phys. J. A 34, 447–461 (2007)
DOI 10.1140/epja/i2007-10462-x

THE EUROPEAN PHYSICAL JOURNAL A

Special Article – Tools for Experiment and Theory

A surprising method for polarising antiprotons

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Received: 26 June 2007 / Revised: 11 January 2008
Published online: 6 February 2008 –
Communicated by E. De Sanctis

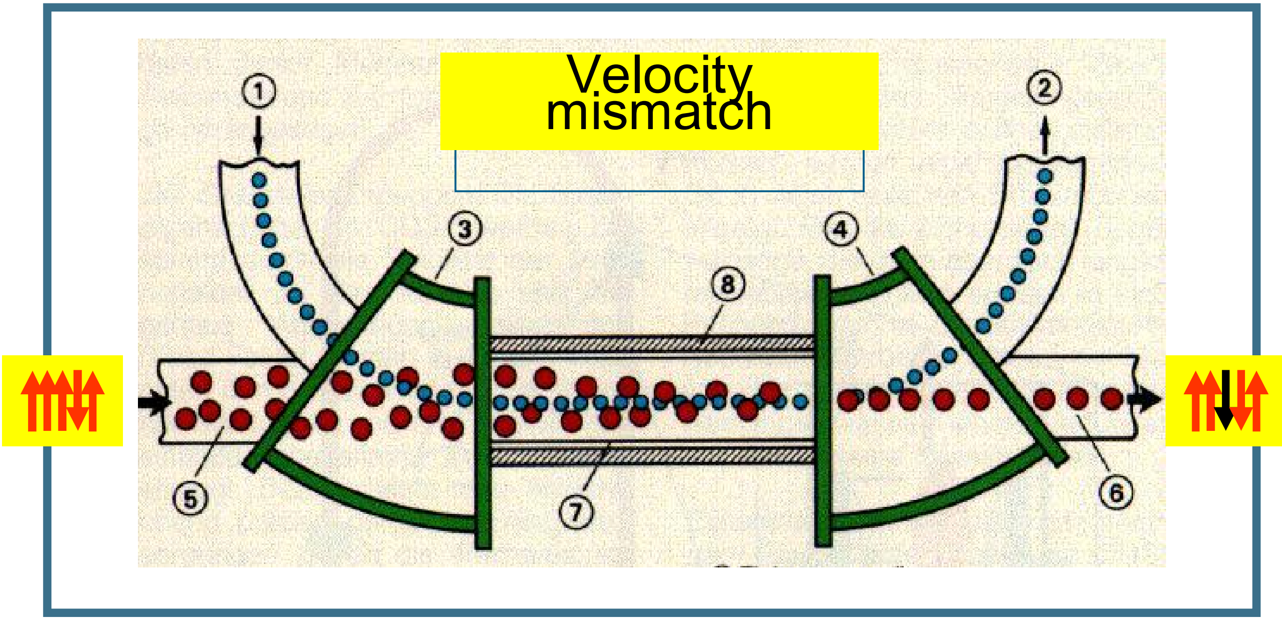
Abstract. We propose a method for polarising antiprotons in a storage ring by means of a polarised positron beam moving parallel to the antiprotons. If the relative velocity is adjusted to $v/c \approx 0.002$ the cross-section for spin-flip is as large as about $2 \cdot 10^{13}$ barn as shown by new QED calculations of the triple spin cross-

→ Need for an experimental test of this idea!

ep spin flip studies at COSY: Idea

- 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

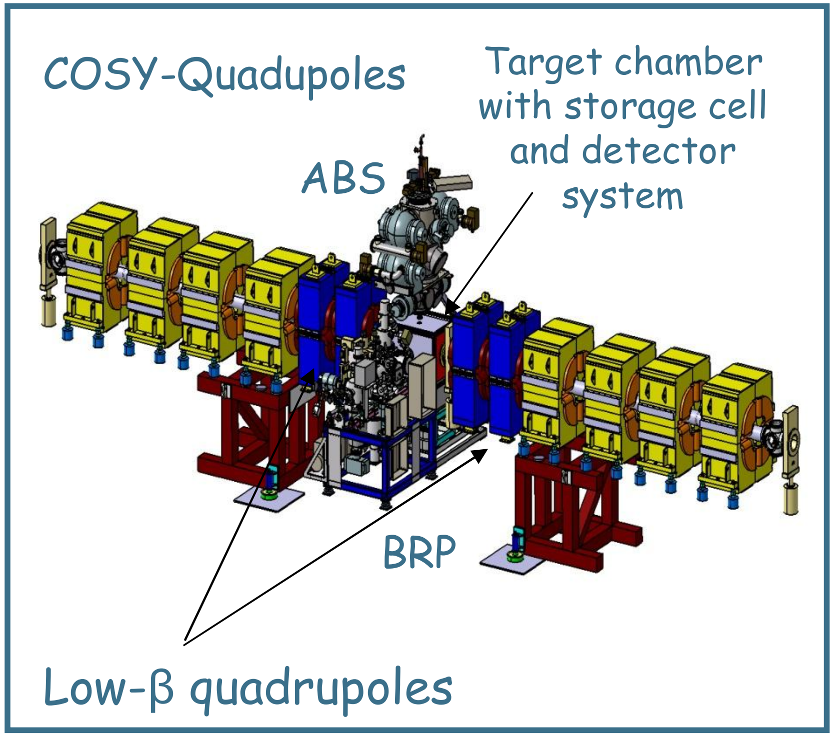


Spin-filtering studies at COSY

Main purpose:

1. Repeat spin-filtering with protons. No surprises expected
2. Commissioning of the experimental setup for AD

Proposal to COSY PAC will be submitted in July 2009



Low-β magnet installation at COSY