A dual H and D Polarized Target for measurements at COSY (Cooler SYnchrotron)

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program in the mainframe of

Polarized Antiproton EXperiments

collaboration

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SPIN 2014

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Outline

- **The H polarized target of PAX experiment at COSY.**
- **Performances and present status.**
- **What comes next (upgrading in program)**
  p H longitudinal !
  p D ? and … H/D target

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Physics motivations (p_{bar} polarized)

Starting point

New key to get clearest insight in structure of the nucleon

- Direct measurement of the **transversity** distribution of the valence quarks in the proton,
- **test** of the predicted **opposite sign** of the Sivers-function, related to the quark distribution inside a transversely polarized nucleon in Drell–Yan as compared to semi-inclusive deep-inelastic scattering,
- measurement of the **moduli** and the **relative phase** of the time-like electric and magnetic form factors $G_{E,M}$ of the proton

Information on proposal and results of PAX collaboration:
http://collaborations.fz-juelich.de/ikp/pax/

Next future

A tool to study p-p spin dependent observables,

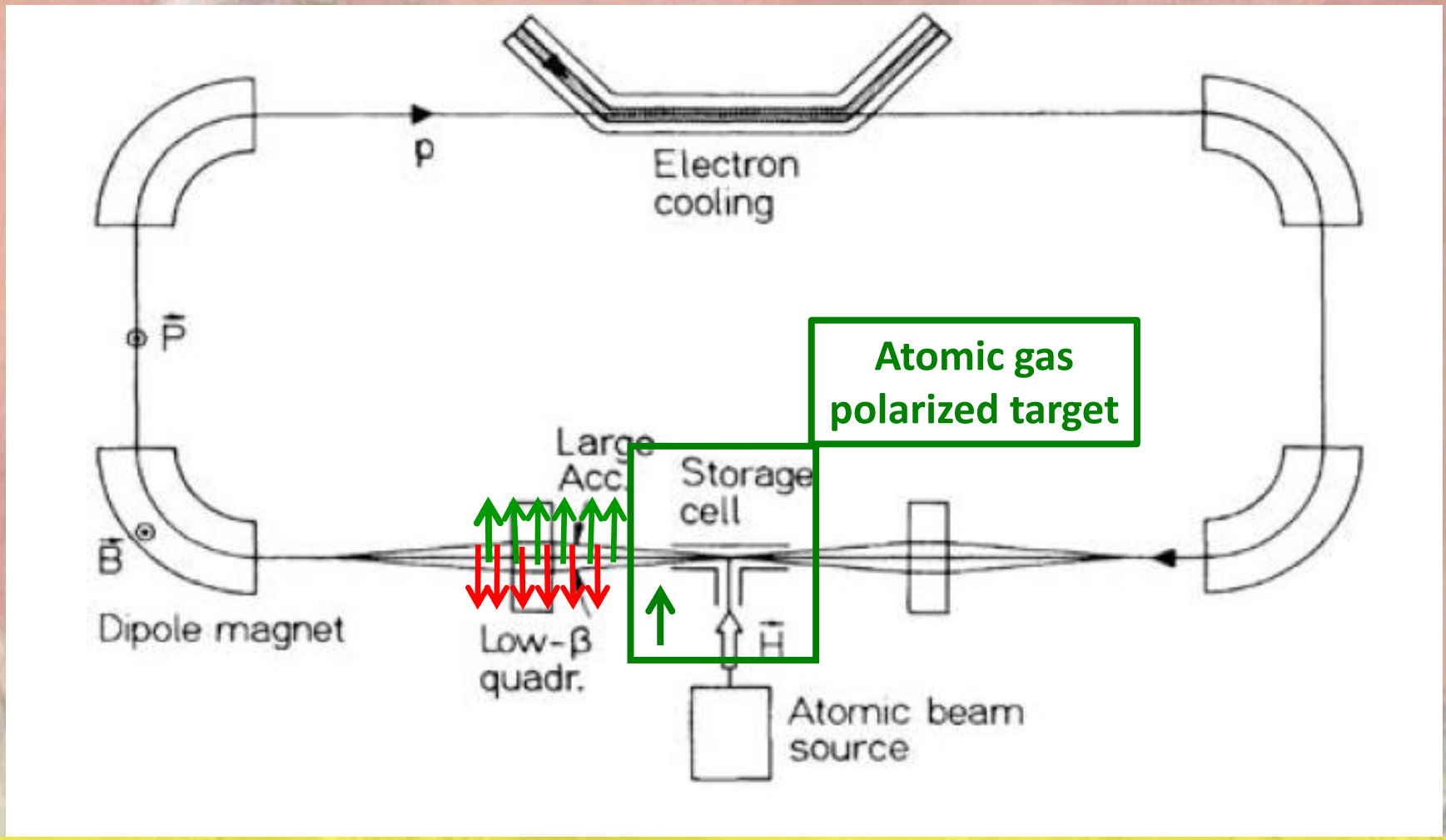
and p-d spin dependent observables (the 3 body system)

A new window p_{bar} p and p_{bar} d polarized cross sections

future?

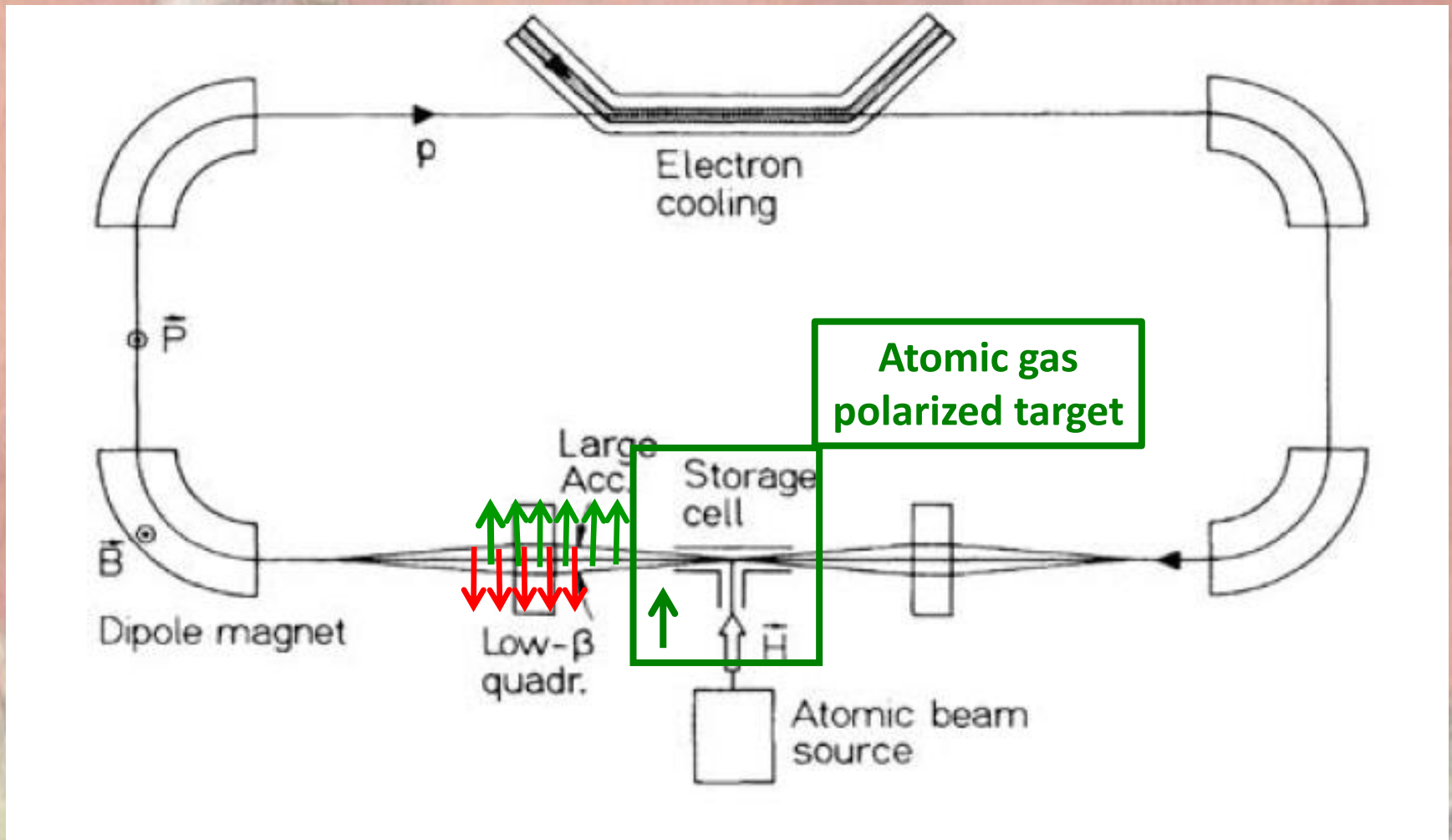
P. Lenisa talk on 21st October

Spin Filtering test on p: pictorial view



An un-polarized beam by multiple passage through a polarized target, due to different cross-section for parallel (↑ ↑) and antiparallel (↓ ↑) spin alignment, becomes polarized, while the intensity decreases.

Spin Filtering test on p: pictorial view



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Polarized beams by spin-filtering

Interaction between a polarized beam (***P***) spin ½ and a polarized target (***Q***) spin ½

$$\sigma_{tot} = \sigma_0 + \sigma_1(\boldsymbol{P}\bullet\boldsymbol{Q}) + \sigma_2(\boldsymbol{P}\bullet\boldsymbol{k})(\boldsymbol{Q}\bullet\boldsymbol{k})$$

k is the beam direction.

For initially equally populated spin states : $m_s = \frac{1}{2}$ and $m_s = -\frac{1}{2}$

Transverse case

$$\sigma_{tot\pm} = \sigma_0 \pm \sigma_1 Q$$

Longitudinal case

$$\sigma_{tot\pm} = \sigma_0 \pm (\sigma_1 + \sigma_2) Q$$

\+ for (↑ ↑) beam and target spins parallel
\- for (↑ ↓) beam and target spins anti-parallel

Intensity of spin-up and spin-down decreases with different time constants

Polarization build-up

The polarization $P = \frac{N_\uparrow - N_\downarrow}{N_\uparrow + N_\downarrow}$ along the quantization axis $\frac{Q}{Q}$

$$P(t) = \tanh\left(\frac{t}{\tau}\right)$$

$$\frac{dP}{dt} \approx \frac{1}{\tau}$$

build-up of beam polarization

Transverse case (respect to ***k***)

$$\tau_\perp = \frac{1}{\tilde{\sigma}_1 \cdot Q \cdot d_t \cdot f}$$

Longitudinal case (respect to ***k***)

$$\tau_\parallel = \frac{1}{(\tilde{\sigma}_1 + \tilde{\sigma}_2) \cdot Q \cdot d_t \cdot f}$$

where:

d_t is the areal density of the target atoms cm^{-2}

f is the revolution frequency of the beam Hz

$\tilde{\sigma}$ are effective cross sections : $\tilde{\sigma} \equiv \sigma$

if scattering angle is less than acceptance angle (Θ_{acc}) in the IP.

Polarization studies at COSY (⊥ case)

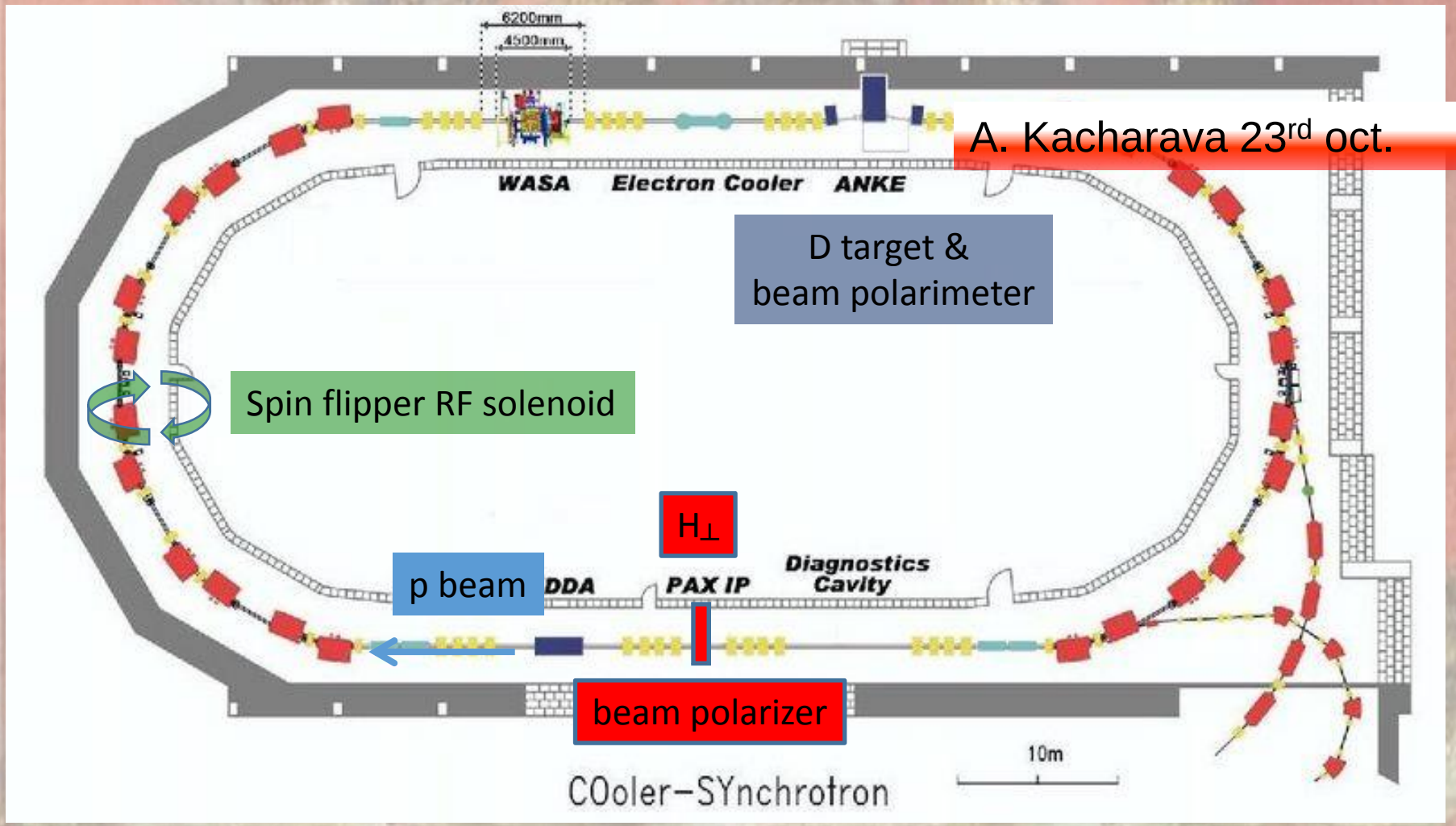
$$\frac{dP}{dt} \approx \frac{1}{\tau_\perp}$$

- Measuring polarization build up we measure $\tau_\perp$.

$$\tau_\perp = \frac{1}{\tilde{\sigma}_1 \cdot Q \cdot d_t \cdot f}$$

- Measuring the target polarization (Q), its target areal density (d_t) and the beam revolution frequency (f), we measure the effective polarizing cross section ($\tilde{\sigma}_1$).

COSY set up for σ_1



Ingredients for spin-filtering at COSY

- COSY ring requirements
  - High beam lifetime of the beam
  - long *P* lifetime of the beam
  - precise measurement of acceptance in the IP
  - stable condition of the beam and monitoring.
- PAX IP
  - FOM of the Target = $Q^2\, d_t$, stable condition,
  - Law holding field, unperturbed stored beam optics.
  - pump down feeded gas from the cell and the near ring pipes
- Spin Flippers
  - In order to reduce systematic errors in measurements.
- Beam Polarimeter
  - Measurements of beam polarization (*P*).

All requirements fulfilled: P. Lenisa talk on 21st October

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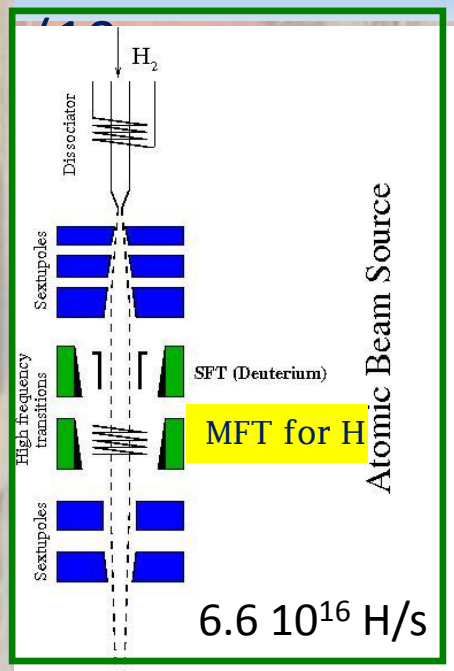
PAX H polarized target

The polarized target: 1 state injection - low holding field (10 G)

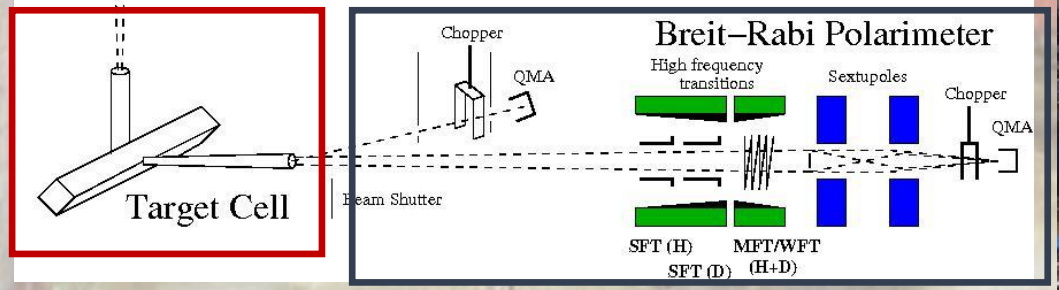


Production of a polarized atomic beam by an ABS

Increase of the target areal density by a storage cell

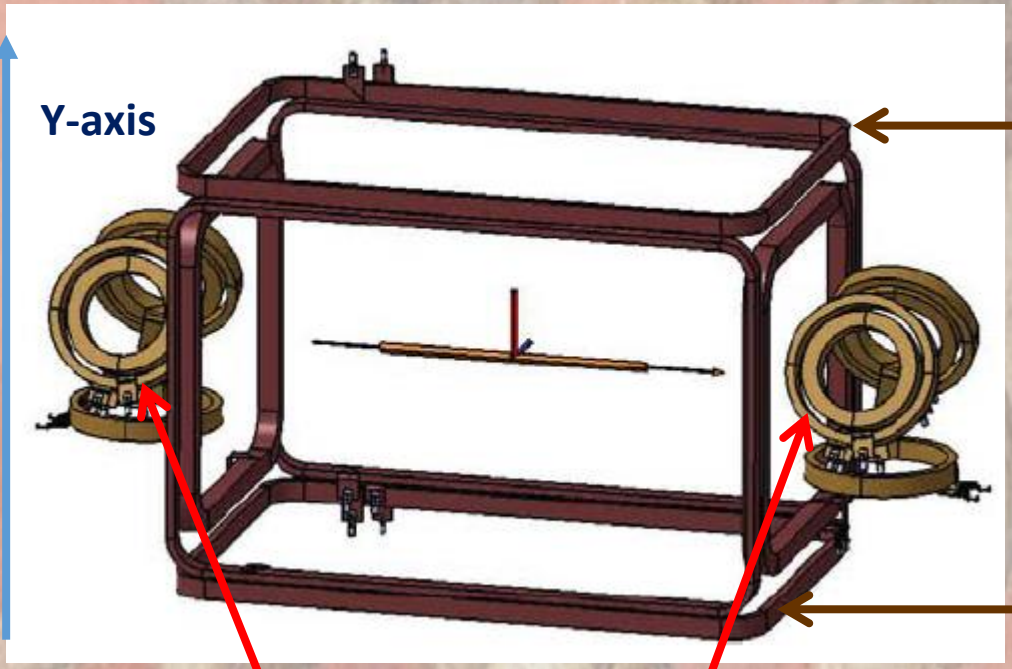
Analysis of G… Pola…

Target Gas Analyzer



SFT for H MFT for H

PAX IT Holding fields (10 G)



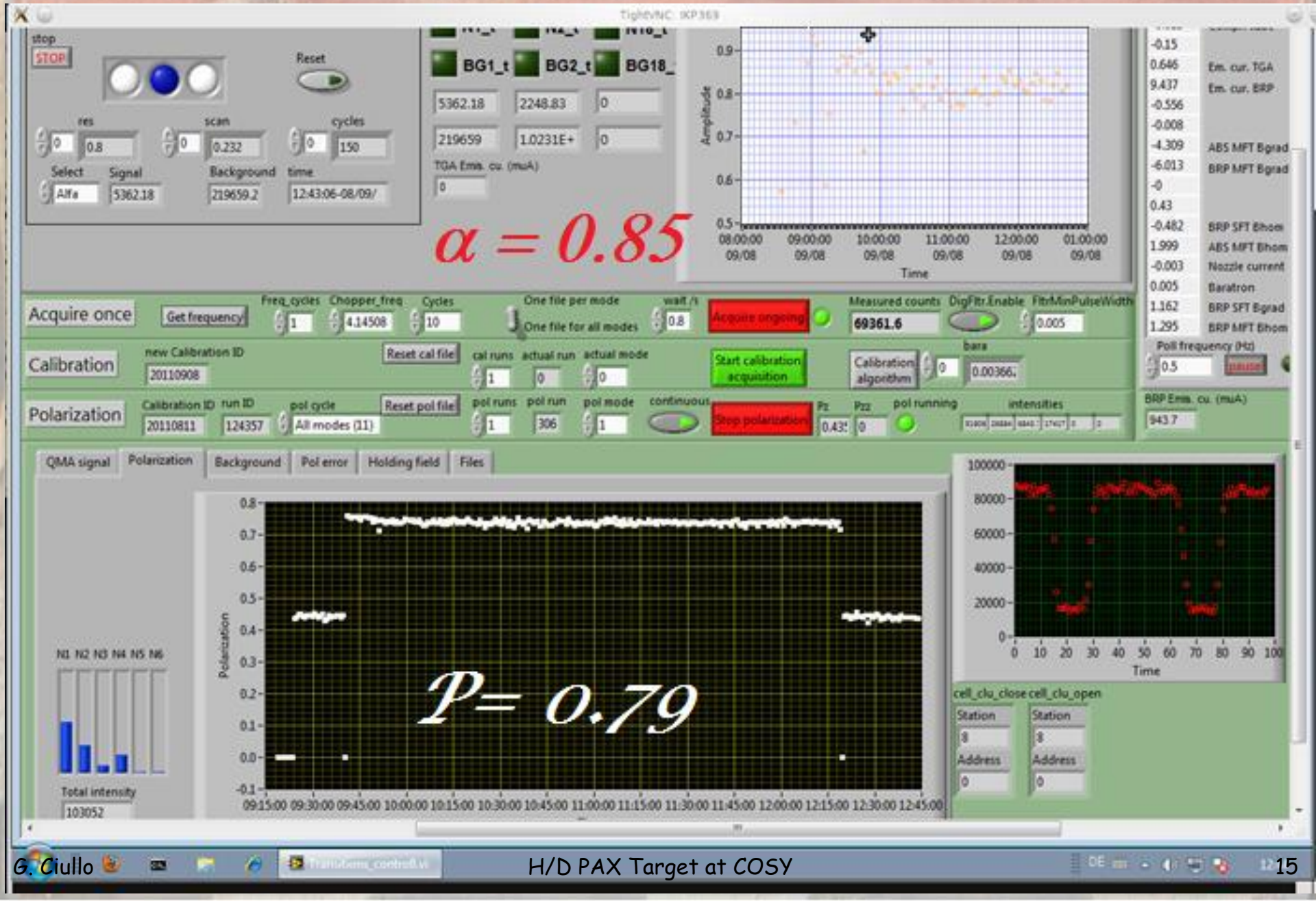
Spin filtering
in transverse case,
quantization axis, defined
by the **top** and **bottom**
Holding field coils.

HF + (Holding Field pos *y*)
and
HF – (Holding Field neg *y*).

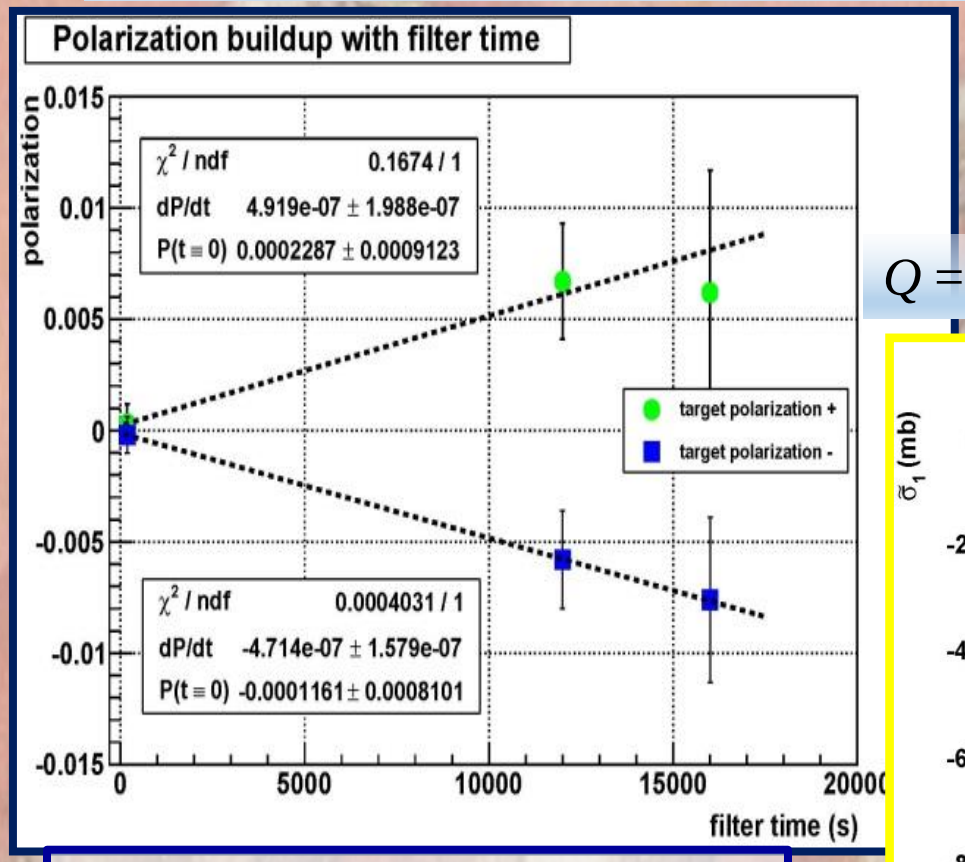
The intensity of the field is 10 G.

Almost perfect **compensation coils** during the powering of the holding field coils:
no transverse displacement of the beam position could be detected by BPM.

Performance of the Target (during runs)



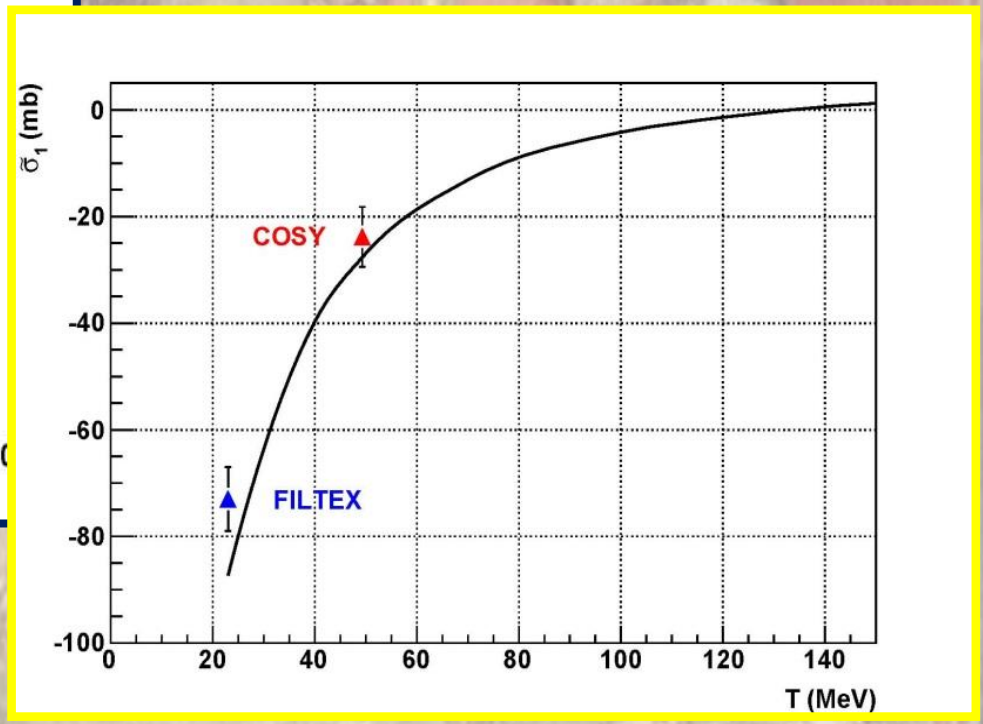
From polarization build-up: σ_1



$$\frac{dP}{dt} \approx \frac{1}{\tau_\perp} \qquad \tau_\perp = \frac{1}{\tilde{\sigma}_1 \cdot Q \cdot d_t \cdot f}$$

$Q = 0.73 \pm 0.5$ $d_t = 5.5 \pm 0.2\ 10^{13}$ H/cm^{-2}

$$\frac{dP}{dt} = (4.8 \pm 0.8) \cdot 10^{-7}\ \text{s}^{-1}$$



Good agreement confirms that spin-filtering is well described, contribution from p-p scattering from SAID database.

Summary: performance and status

- PAX successfully completed the spin dependent σ_1 measurements at COSY on p useful for a **deep understanding of the spin filtering process**.
- Results on p-p interaction are in good agreement with the theory.
- OVER ALL the result demonstrates that **procedure** and **apparatus** involved are **under control**.
- This result still doesn't alleviate the lack on spin-dependent cross section on **p-p_{bar}** interactions.

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Longitudinal case (respect to ***k***)

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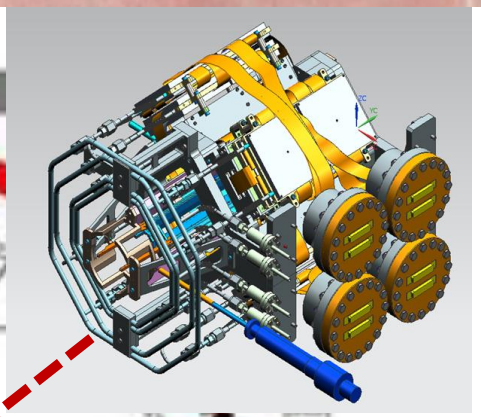
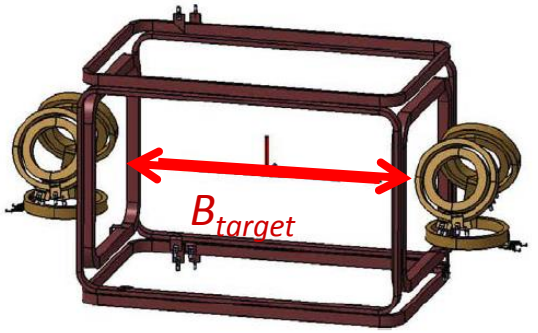
conclusive test for spin filtering

COSY set up for longitudinal spin filtering

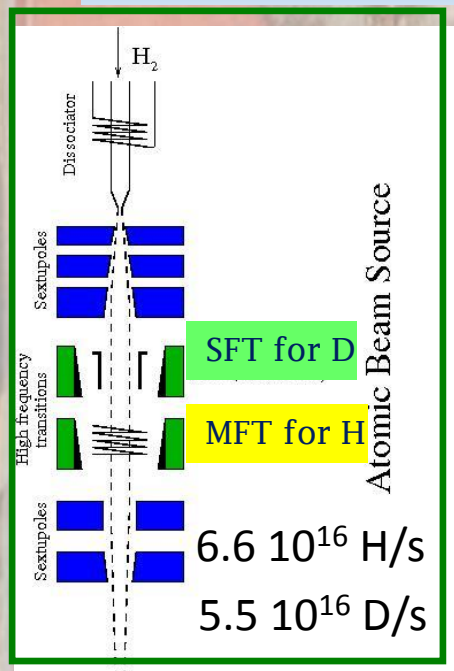




Details in P. Lenisa talk on 21st October

H/D following PAX plans

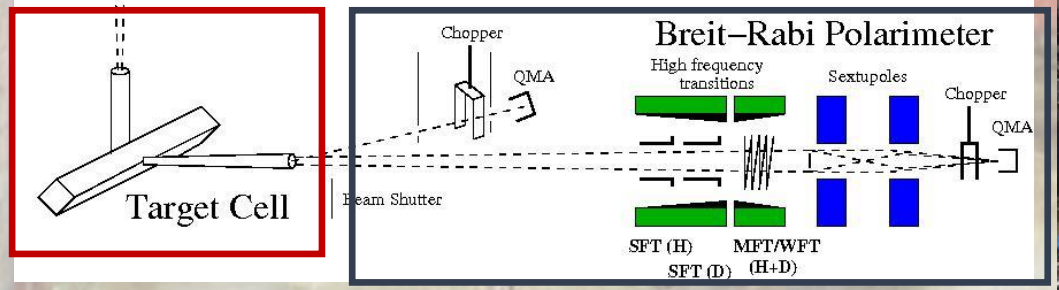
- The polarized target as to work with H and ..(D):



RF transition for H HFT manipulation already used

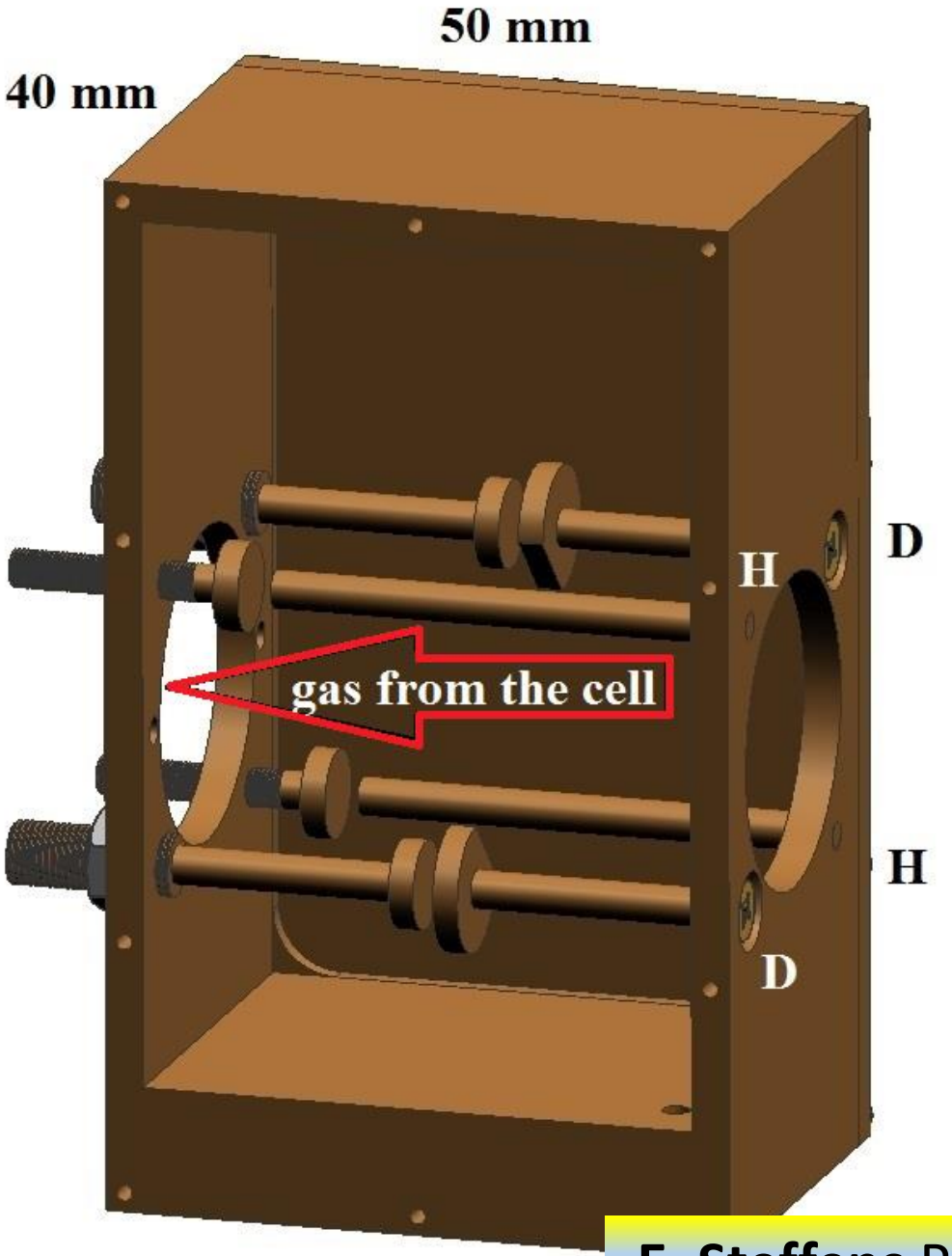
Required RF transition for D HFT manipulation

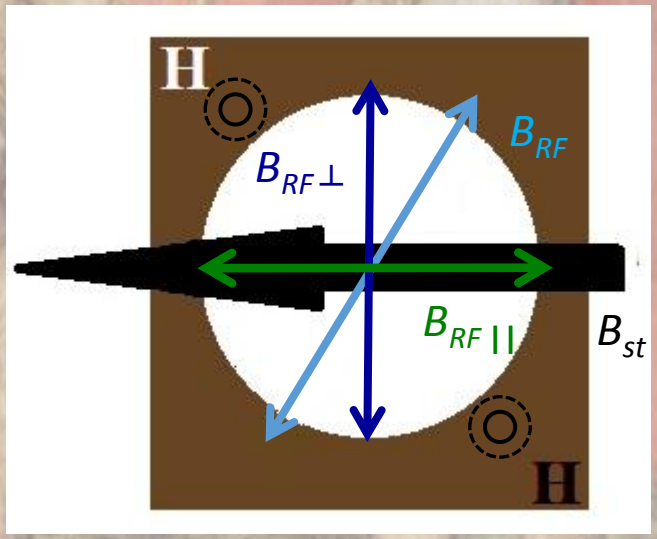
Target Gas Analyzer



SFT for H/DMFT for H

BRP new hardware in vacuum H/D dual Cavity



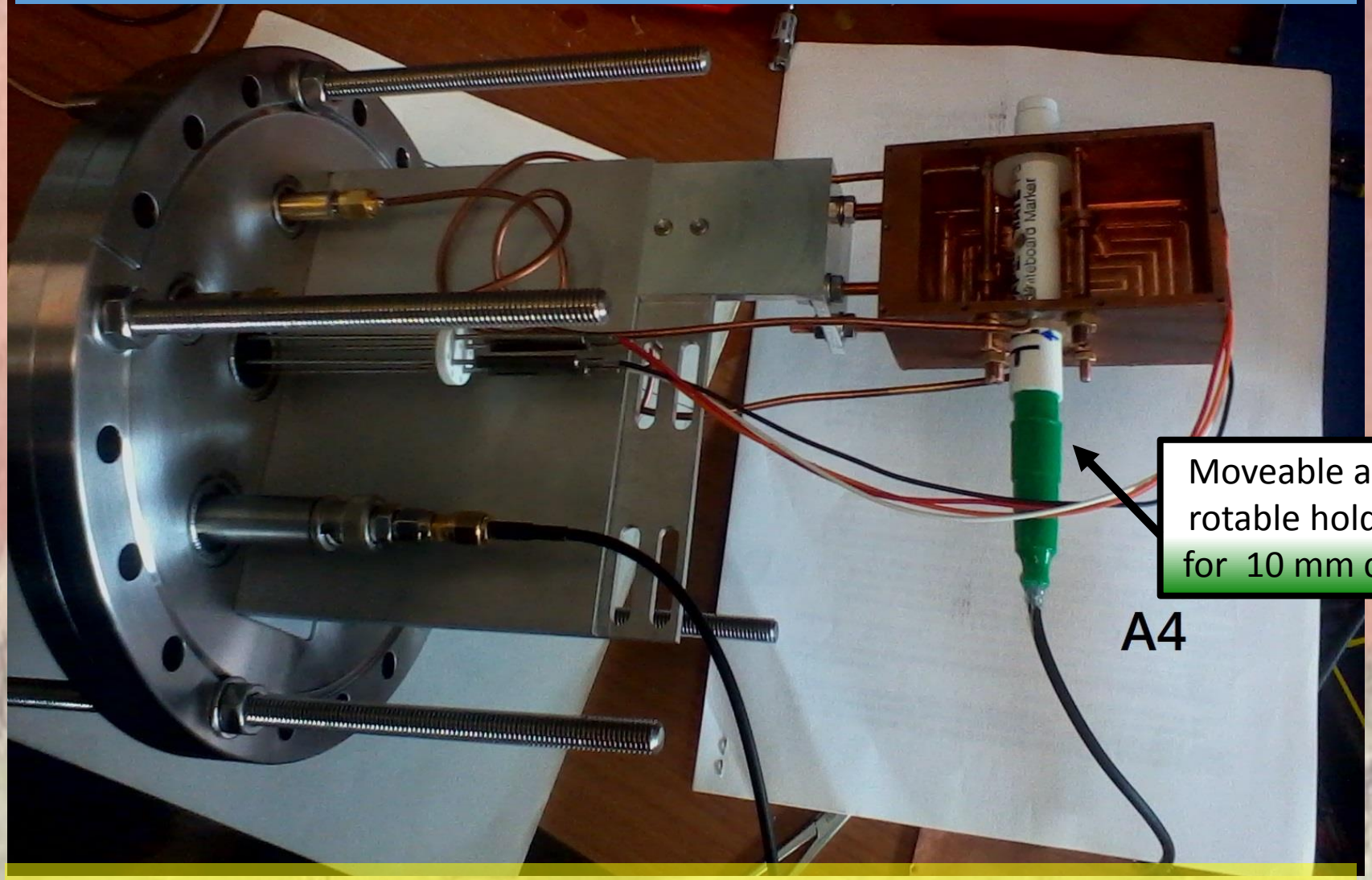


σ transition Δm_F= 0: SFT2-4

π transition Δm_F= $\pm$1: SFT1-4

E. Steffens Proposal and prototype @ FE

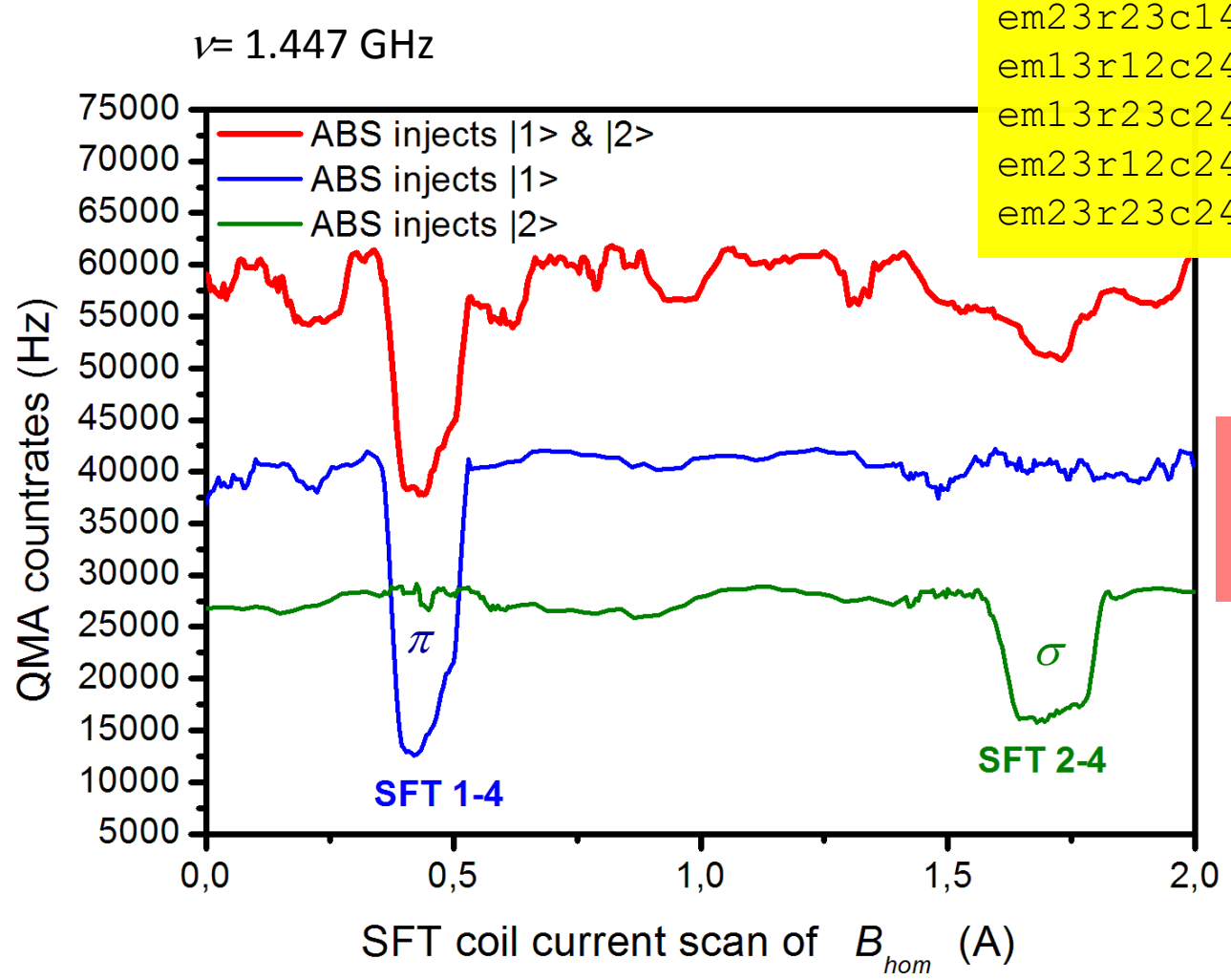
Ex situ tuning and characterization



Check on 45° B_{rf} and adiabatic transition conditions.

Dual SFT cavity *in situ* commissioning of H

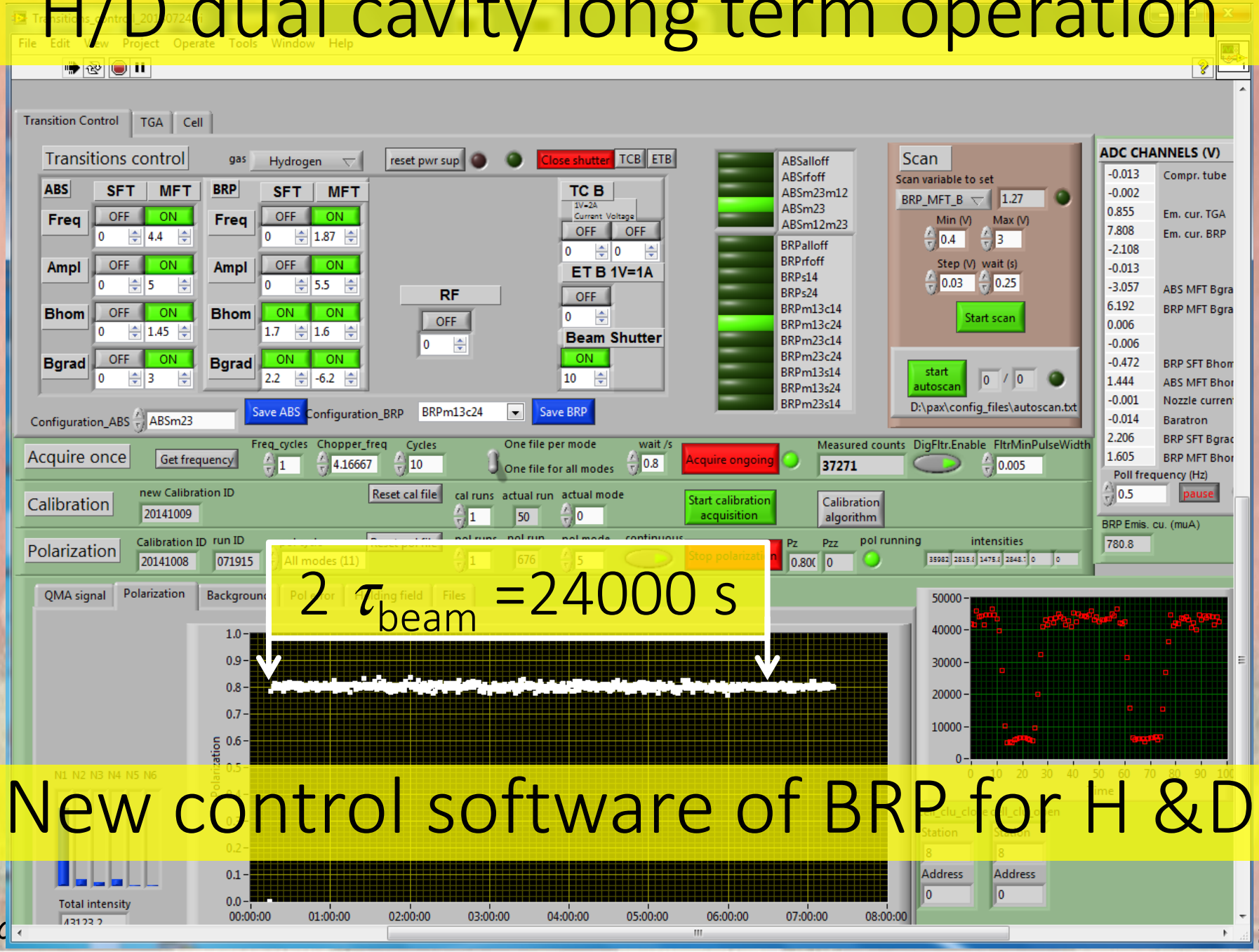
```
20141009_BRP_Calibration
      es14 = 0.832 ± 0.005
      es24 = 0.981 ± 0.012
em13r12c14 = 0.935 ± 0.009
em13r23c14 = 0.974 ± 0.010
em23r12c14 = 0.010 ± 0.007
em23r23c14 = 0.547 ± 0.007
em13r12c24 = 0.954 ± 0.010
em13r23c24 = 0.990 ± 0.011
em23r12c24 = 0.013 ± 0.006
em23r23c24 = 0.699 ± 0.009
```



One single scan

TARGET is back for H longitudinal runs.

H/D dual cavity long term operation



Conclusion - close plans (2015-2016)

The H target performed very nicely

during the σ_1 measurements (transverse case).

In the PAX program was require an easy switchable H/D target.

Following the program,

We will continue for the D commissioning.

The H/D target is interesting

on other programs under study at COSY →

A. Kacharava 23rd oct.

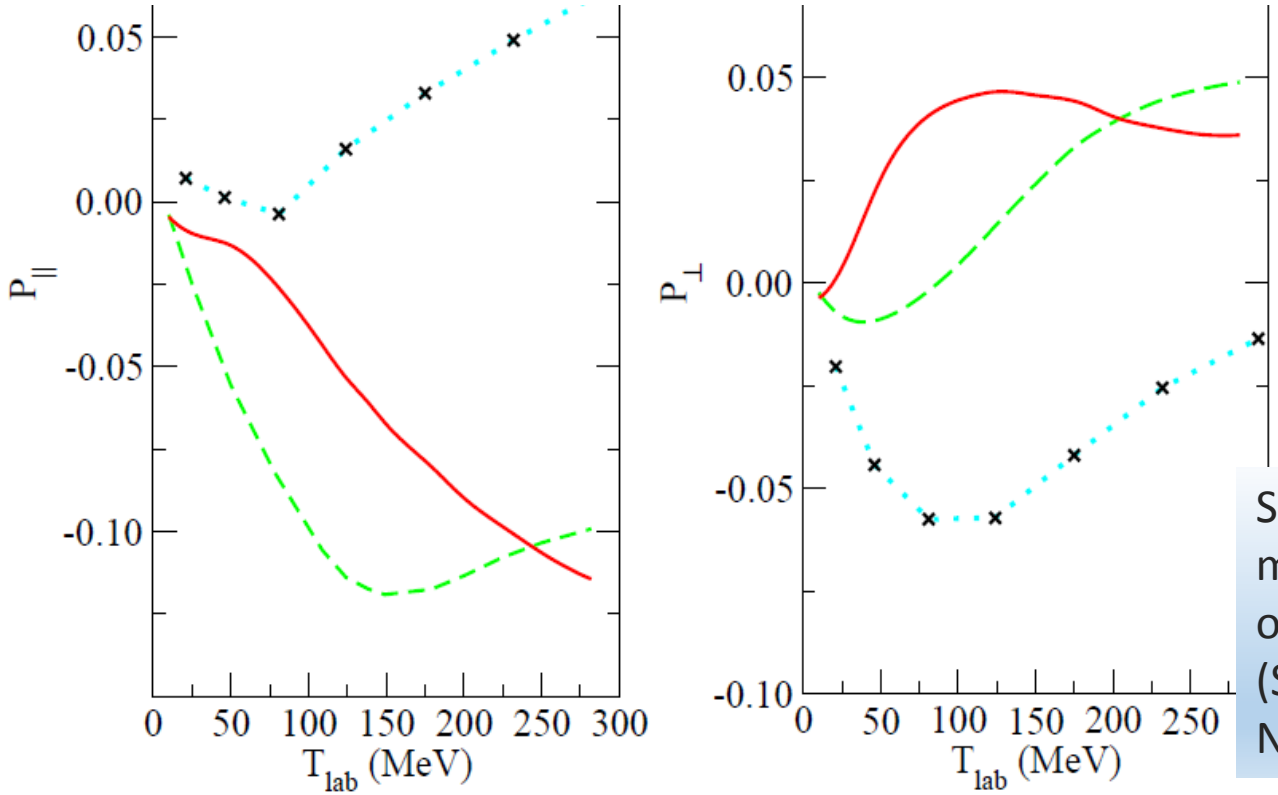
Extension on $p_{(bar)}$ - $D_{\uparrow}$ spin filtering

Spin-dependence in p-p_{bar} elastic and annihilation cross sections unknow.

arXiv:1307.3415 [nucl-th] July 2013

Elastic $\bar{p}d$ scattering and total $\bar{p}d$ cross sections revisited

Yu.N. Uzikov[1,2] and J. Haidenbauer[3]



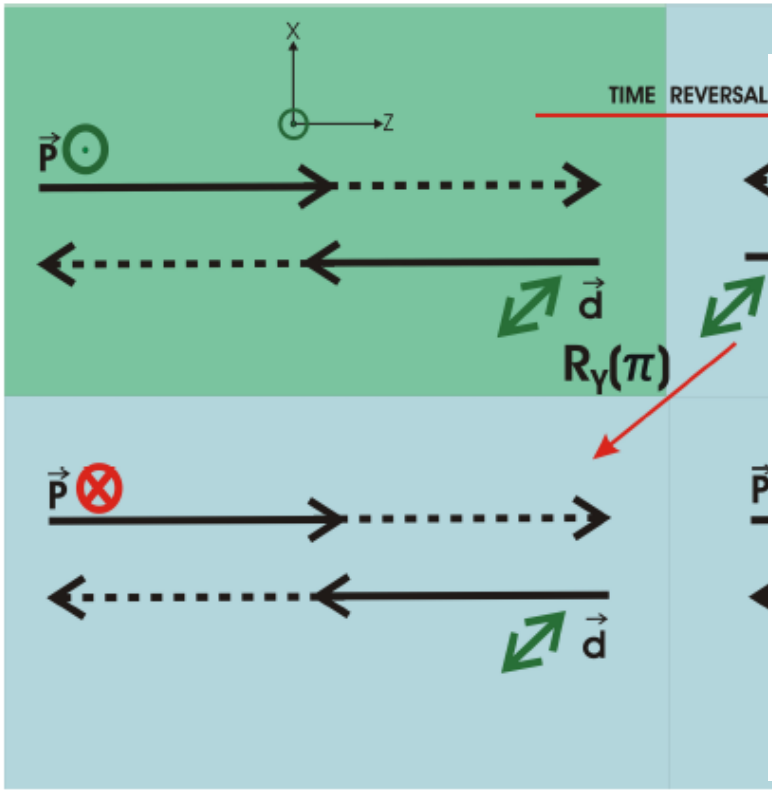
$\bar{N}N$ model A Jülich

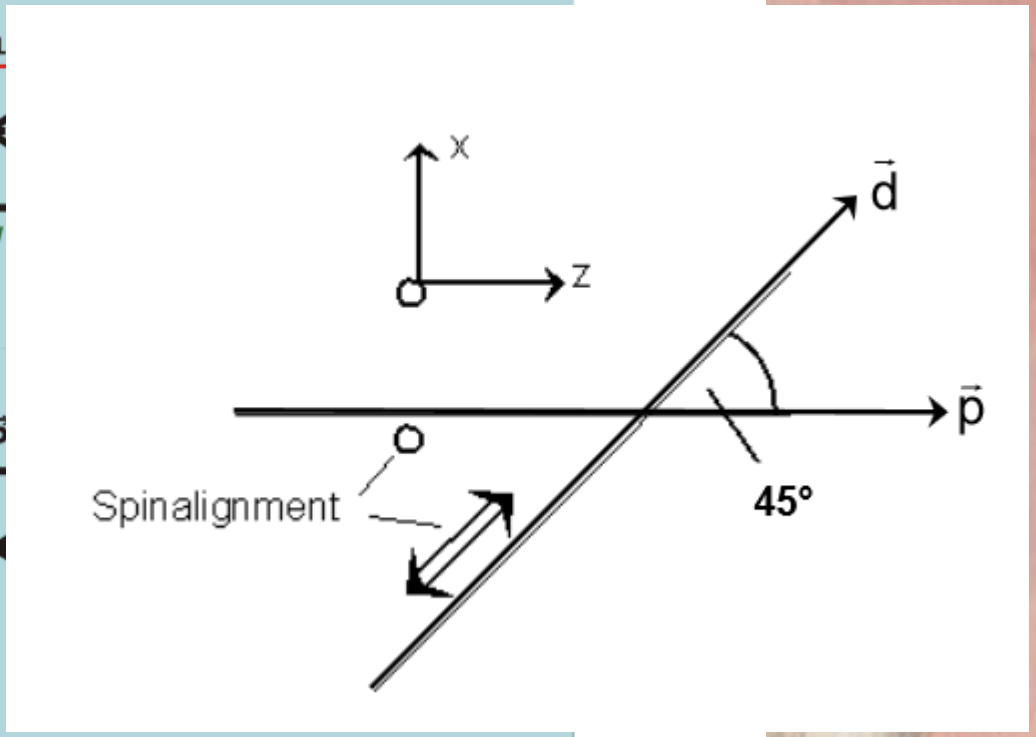
$\bar{N}N$ model D Jülich

$\bar{N}N$ ZT model

Sizeable difference between models , Larger (30 %) with old Nijmegen NN PWA (S.G. Salnikov Nucl.Phys.A 874 (2012)98

Open chance: pol D ↑ also for TRIC





Time reversal corresponds to flipping of the spin of the proton beam or deuteron target alignment. The block with the green background represents the reaction in the "time-forward" world and the others represent the same reaction in the "time-reversed" world.

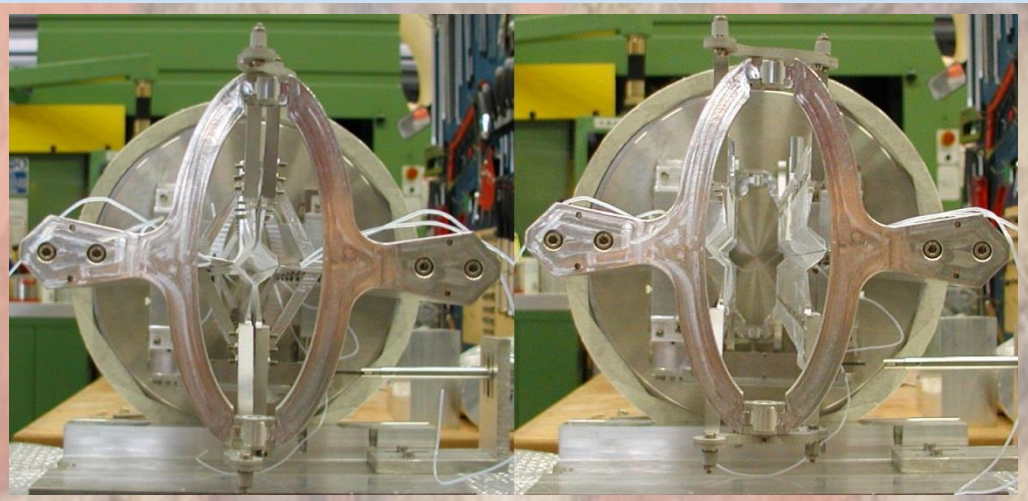
http://apps.fz-juelich.de/pax/paxwiki/index.php/Test_of_Time-Reversal_Invariance_at_COSY_(TRIC)

D. Eversheim talk on 20 oct.

Y.ry Uzikov 20 oct.

Accumulation Cell

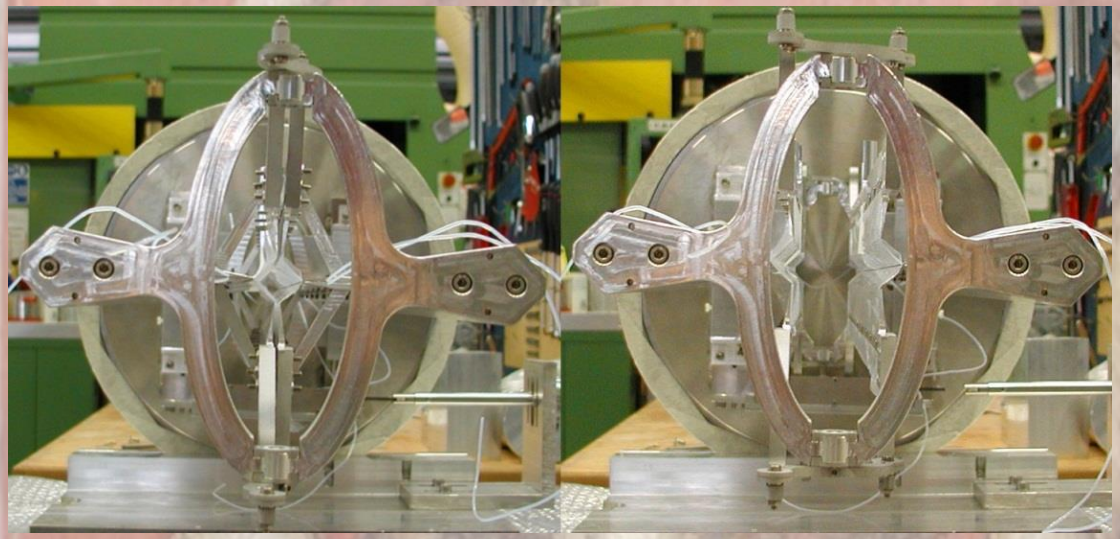
- The (openable) storage cell



- Storage cell increases target areal density up to 10^{14} atoms/cm^2
- Storage cell walls should suppress recombination and depolarization

- Openable storage cell to allow the uncooled AD beam to pass and (*) for higher intensity at COSY
- Teflon foil walls to detect low energy recoils and suppress recombination and depolarization
- Fixed cell used in the COSY experiments due to problems with the density in the openable cell

Openable Cell? … less loss of stored beam



First prototype worked nicely for the Target commissioning, but on COSY the target -… stressed.

Construction and test in air by He sniffer : leaks < 1%.