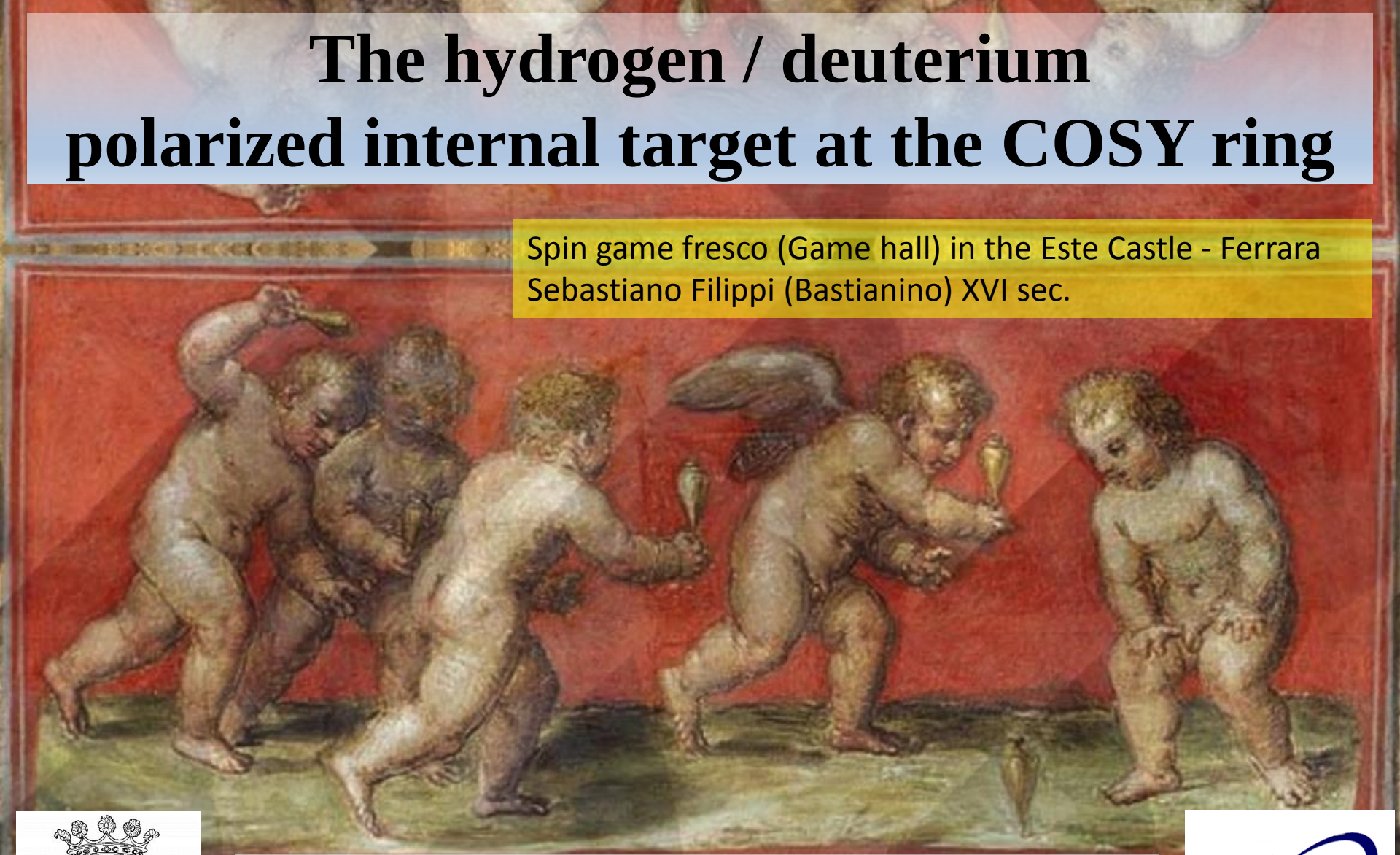
The hydrogen / deuterium polarized internal target at the COSY ring



Spin game fresco (Game hall) in the Este Castle - Ferrara
Sebastiano Filippi (Bastianino) XVI sec.

SPIN 2016 – Champaign september 27th 2016

COoler SYnchrotron

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Germany

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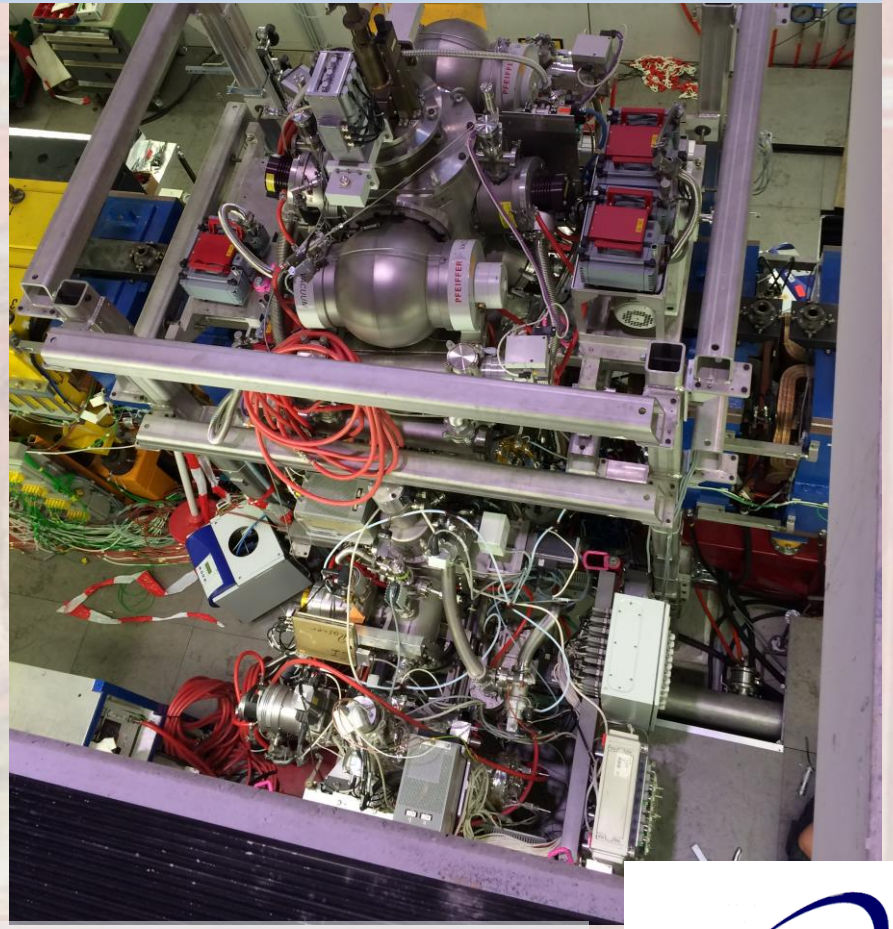
G. Ciullo

The hydrogen / deuterium polarized internal target at the COSY ring

Ciullo G.*,
M. Statera, A. Nass,
G. Tagliente, A. Pesce
and P. Lenisa

* Ferrara University and INFN
44122 – Ferrara - ITALY



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From DESY to COSY

- **@ DESY as Fixed Target for HERMES**

  1996-2005

  - For HERMES as FIXED polarized TARGET H or D

    (months required for commissioning)

- **@ COSY: easily transportable target from 2006**
  - PAX experiment… polarization filter for antiproton
    - ✓ Openable cell, H / D (one/few weeks required for moving and commissioning)
  - TRIC experiment … time reversal invariance at COSY
    - ✓ Openable cell, D (one/few weeks required for moving and commissioning)

COSY projects with internal target:

presentation of B. Lorenz 26/09/16

A ductile tool available for future Physics

(@ LHC presentation by P. Lenisa)

Physics motivations for the PAX project (Proton Antiproton eXperiment)

Polarized antiprotons: a new tool for the investigation of the spin structure of the nucleon

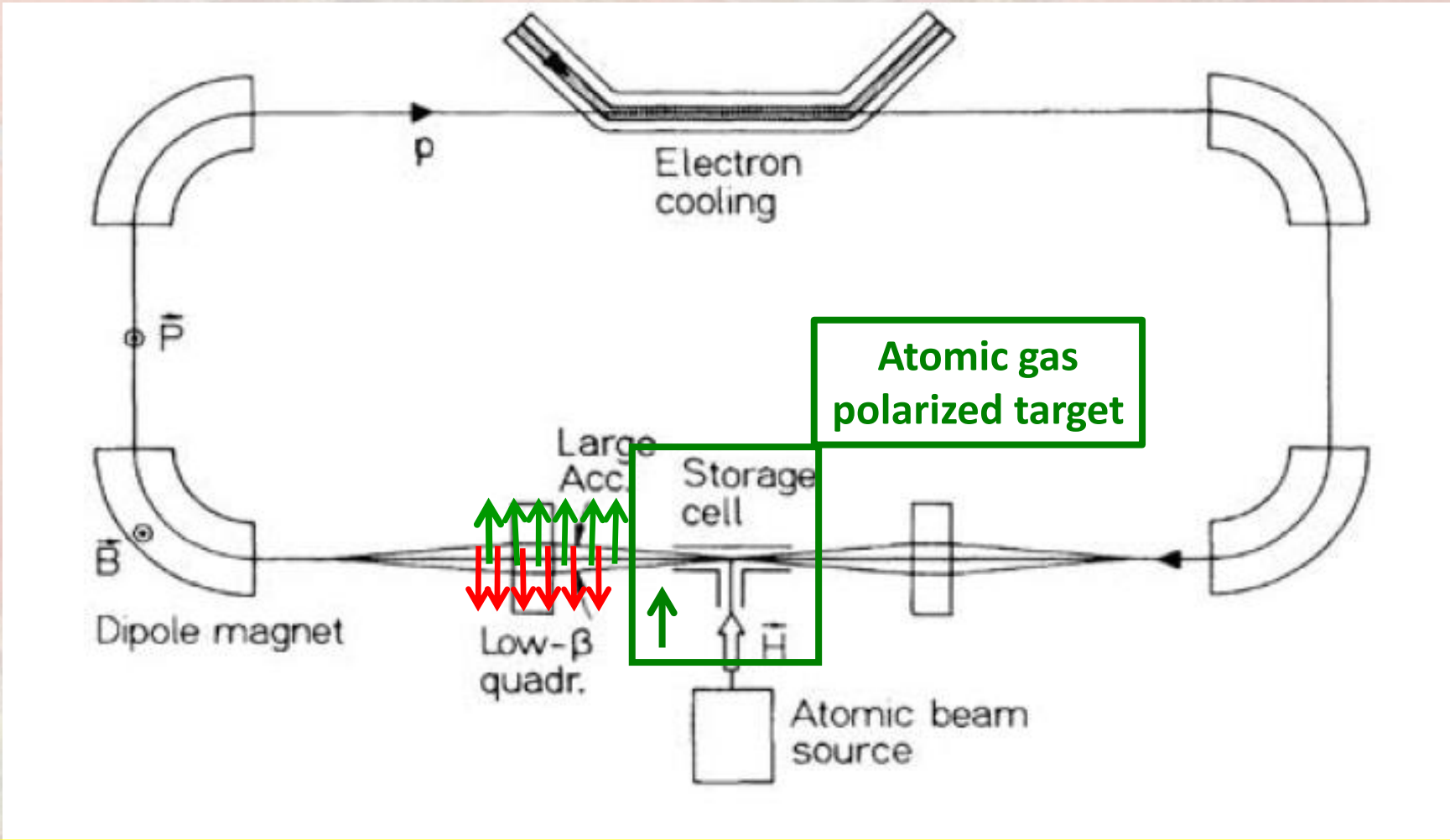
Direct access to the **transversity:** distribution of the valence quarks in the proton,

measurement of the **moduli** and the **relative phase** of

the time-like electric and magnetic form factors $G_{E,M}$ of the proton.

PAX collaboration: http://collaborations.fz-juelich.de/ikp/pax/

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.

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

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

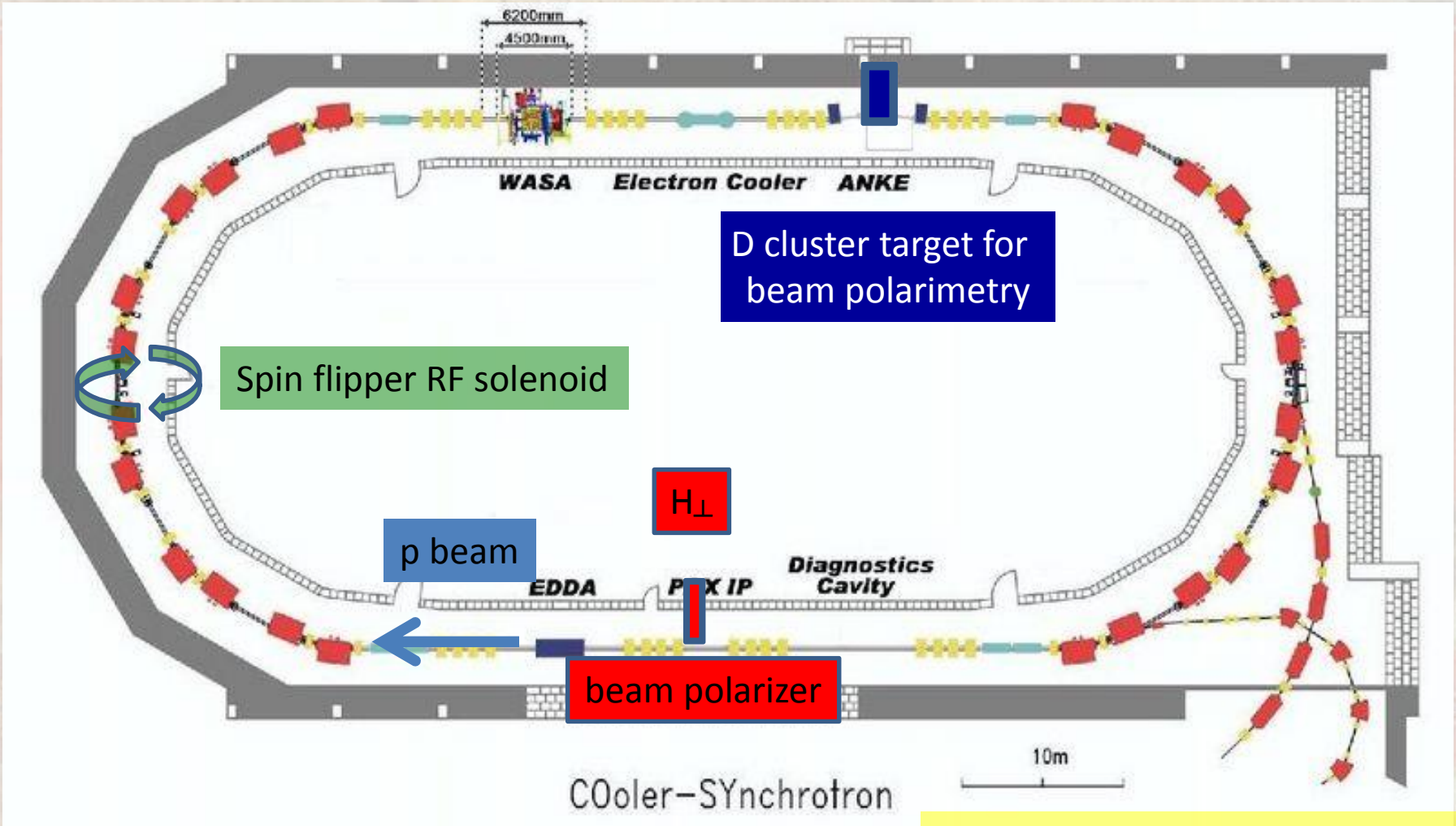
Longitudinal case

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

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

Intensity of spin-up and spin-down decreases with different time constant.

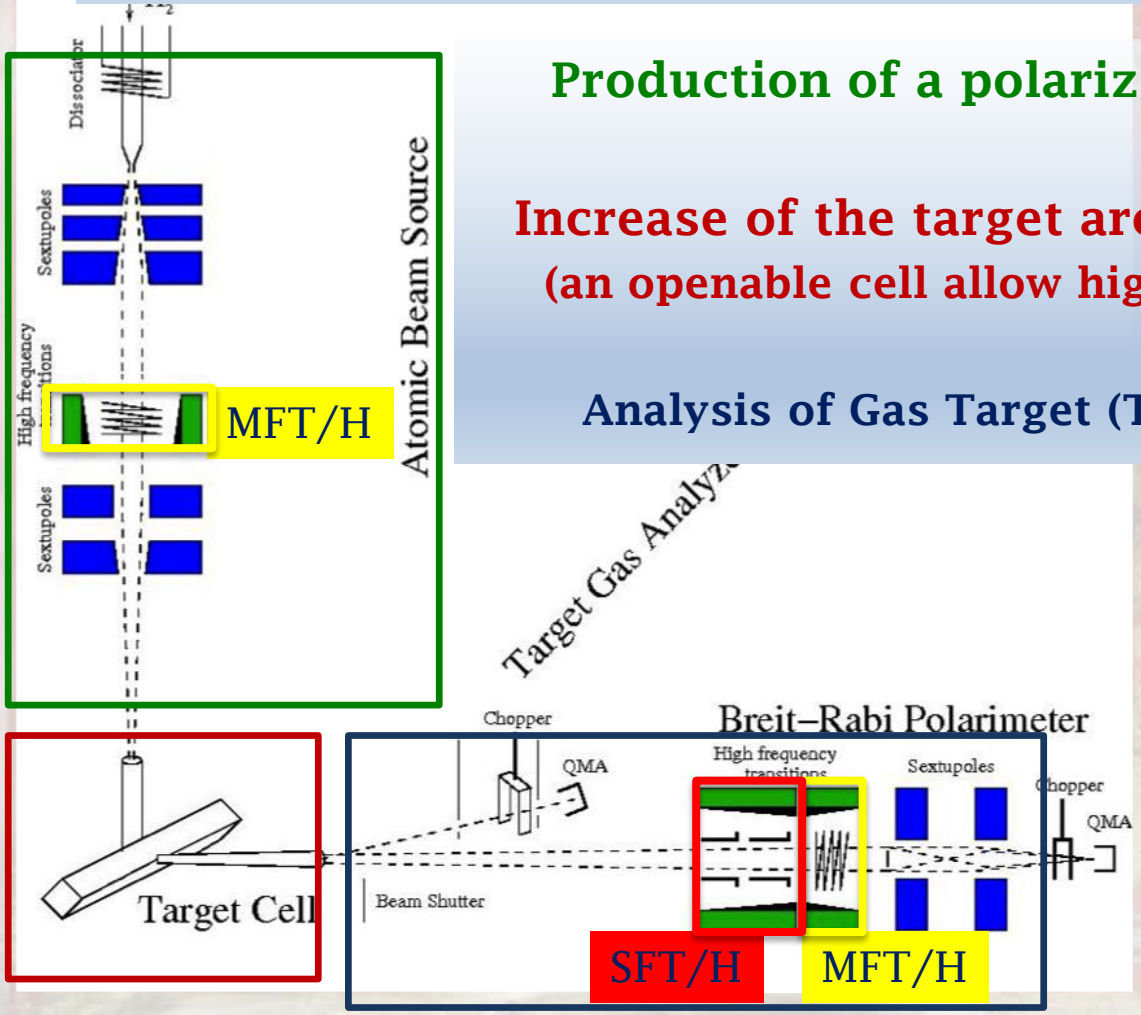
COSY set up for σ_1 transverse case



See also B. Lorentz talk on 26/09

The H polarized for PAX transverse case

The polarized target: 1 state injection - low holding field

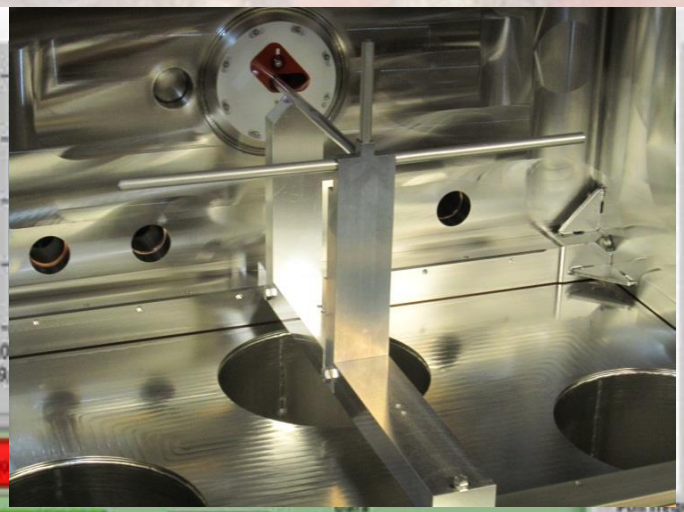


Production of a polarized atomic beam by an ABS

Increase of the target areal density by a storage cell
(an openable cell allow higher intensity at the injection)

Analysis of Gas Target (TGA) and Polarization (BRP)

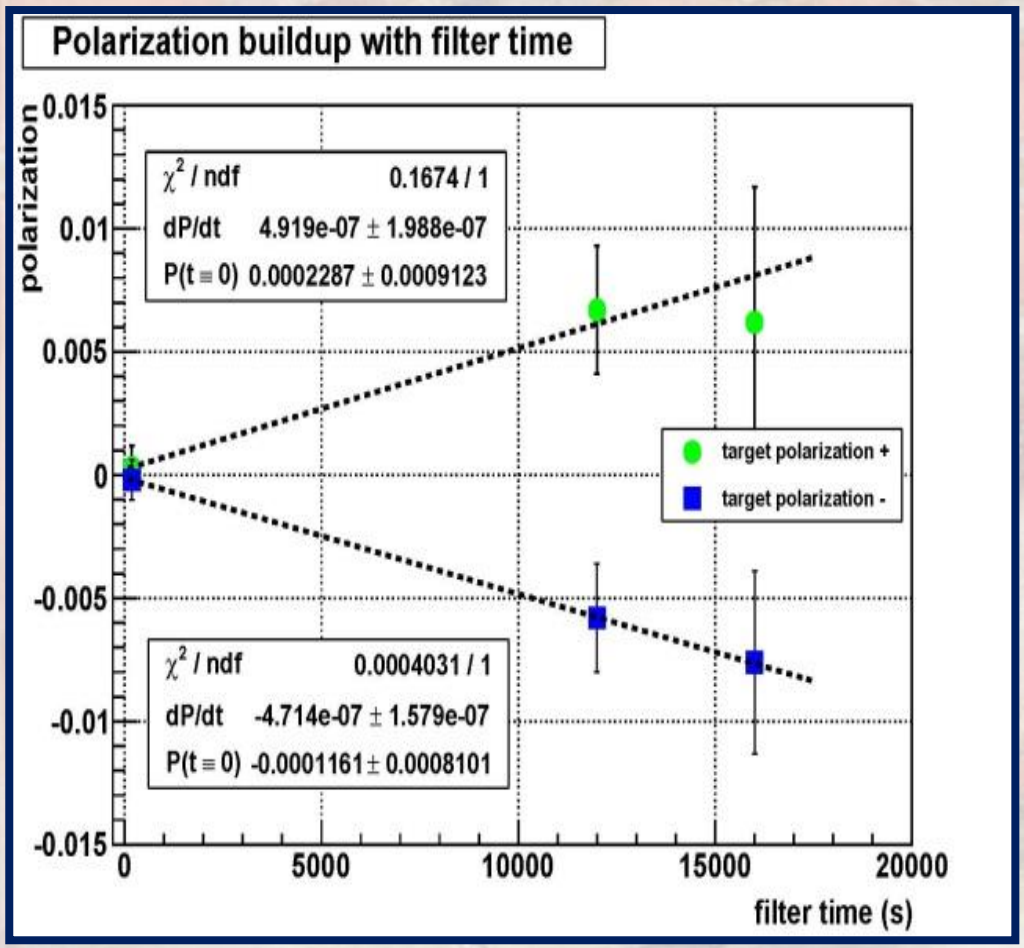
Performance of the Target



$\alpha = 0.85$

$P = 0.79$

From polarization build-up we get σ_1



Beam polarization obtained from spin-filtering cycles of different time length

The HF+ (Holding Field in up direction) induces e positive polarization build-up in the stored beam and viceversa (due to the negative value of effective spin dipendent cross section.

The linear fit of the build up allow to estimate the time

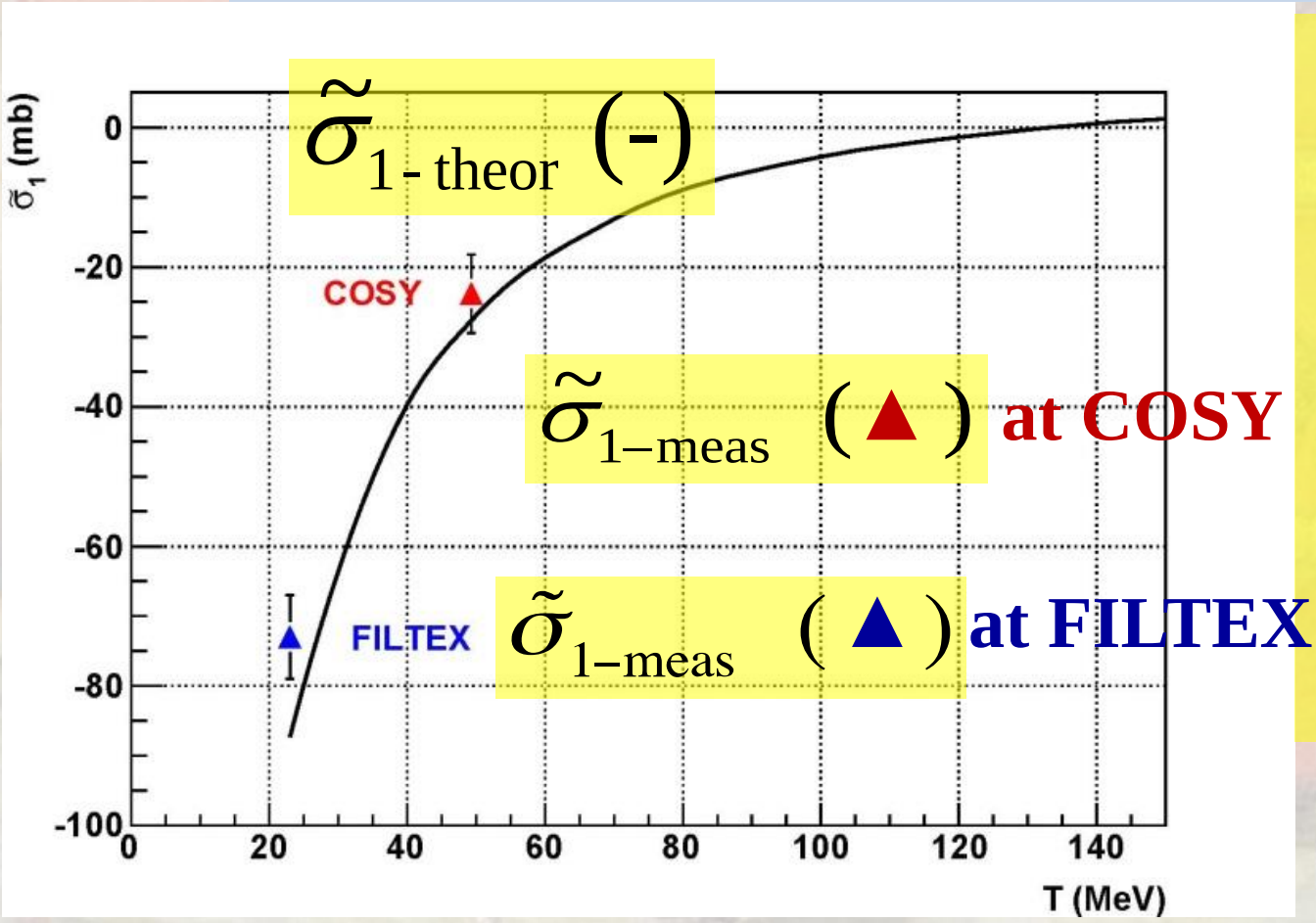
$$\frac{dP}{dt} \approx \frac{1}{\tau_\perp}$$

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

... then the cross section

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

A second point added to the plot



COSY, polarized target, and other equipements confirmed their **usefulness** for **spin dependent precise** measurements

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

Polarization build-up: || case

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

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

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

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

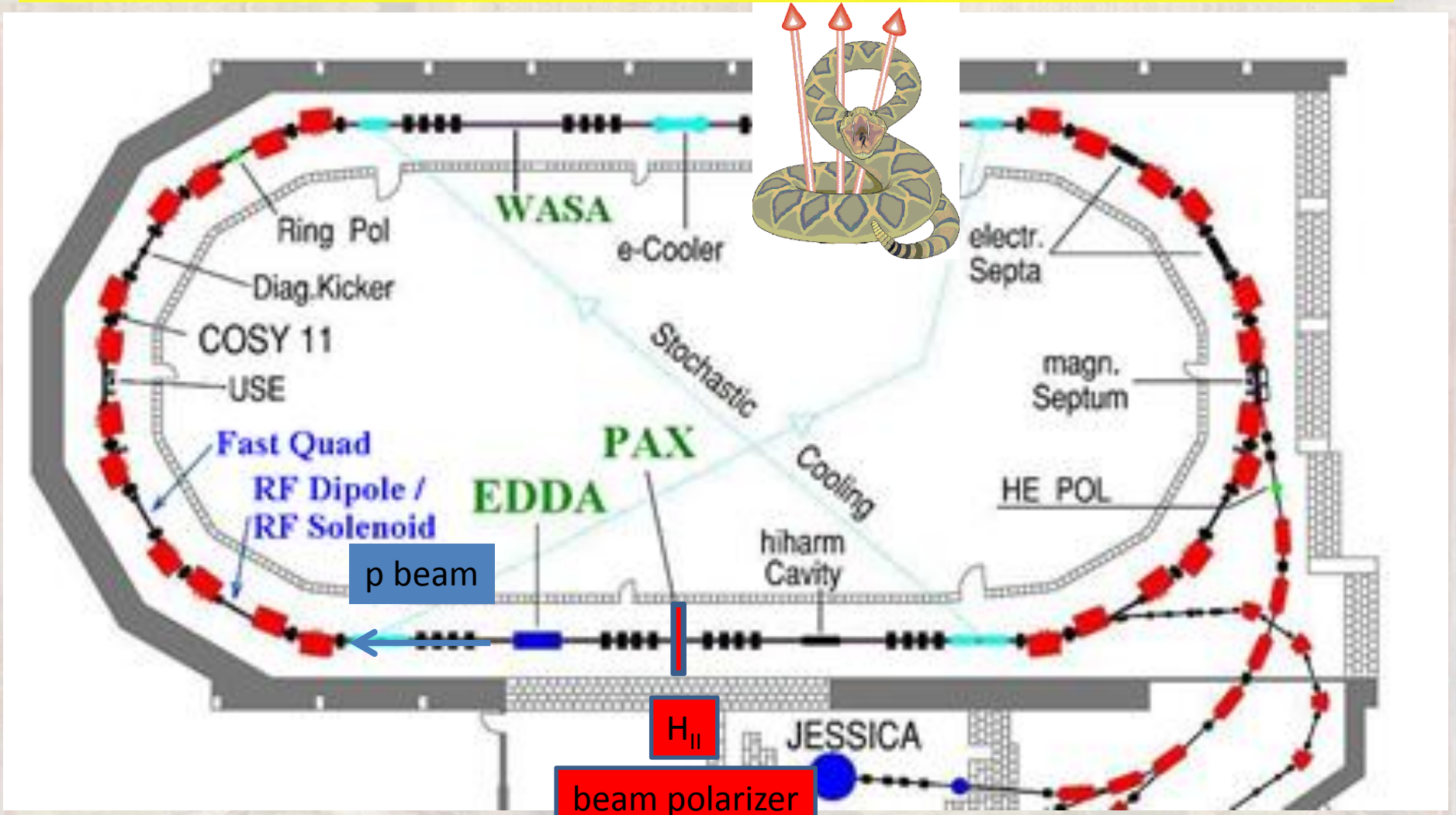
where:

$P_{\parallel}$ prevision in the order of 5 -10 % at 135 MeV

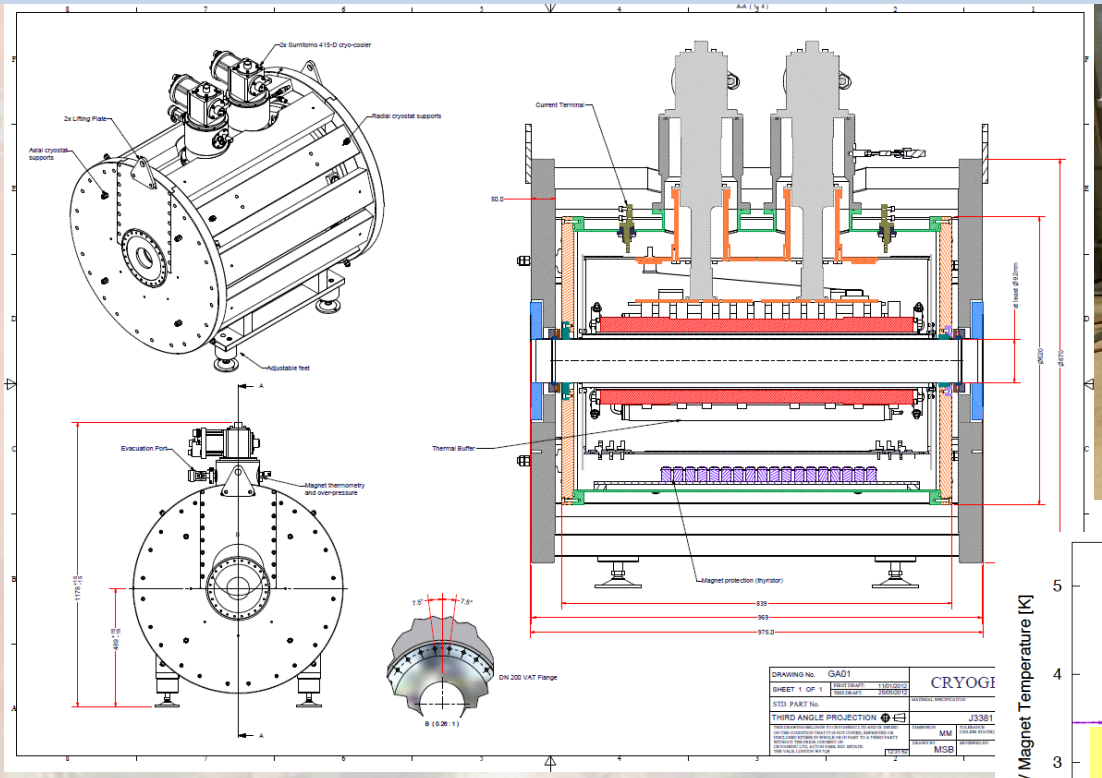
The longitudinal measurement will complete the understanding of the spin dependence p – p cross-section, and will give the answer for the possibility to polarize antiproton via the spin – filtering process.

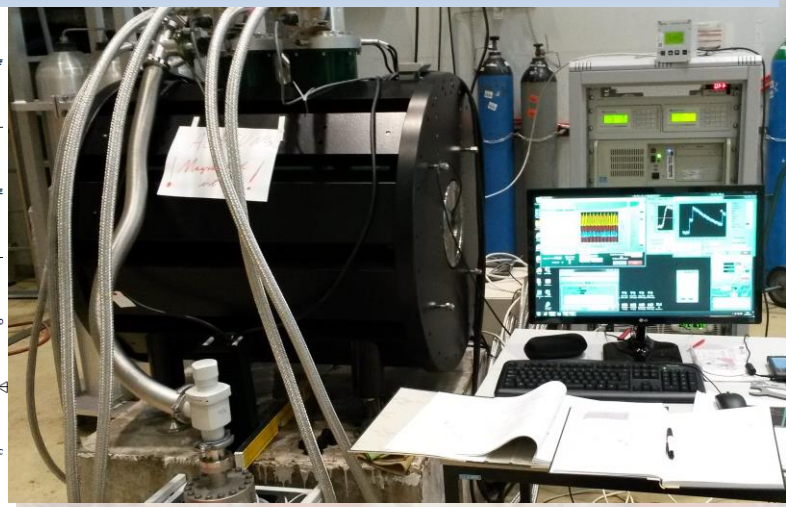
COSY upgrading for the longitudinal case

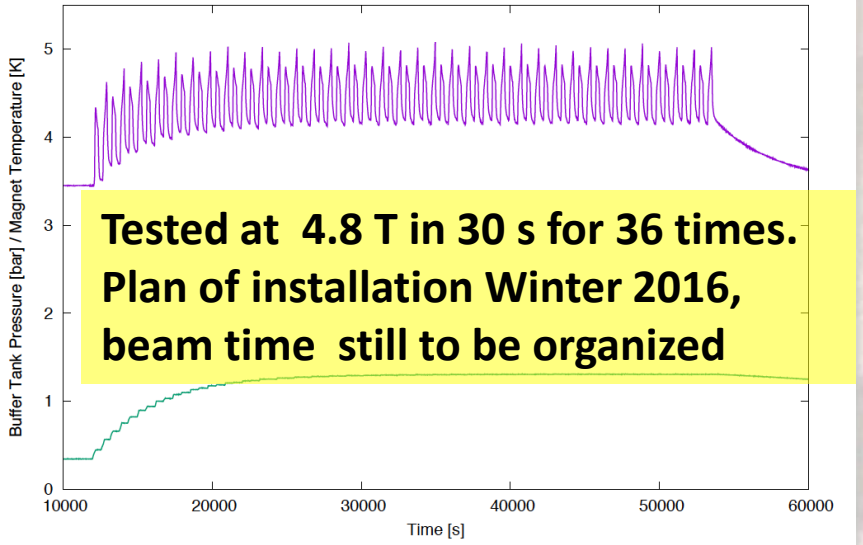
Main change on COSY: a dedicated solenoid for the operation of the longitudinal polarization



Syberian Snake for longitudinal beam polarization in COSY







Superconducting 4.7 Tm solenoid is ordered.
Overall length: 1 m
Ramping time 30 s

Tested at 4.8 T in 30 s for 36 times.
Plan of installation Winter 2016, beam time still to be organized

Spin dynamics and longitudinal polarized beams for experiments.

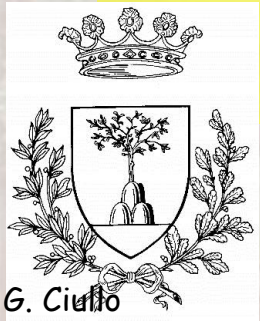
Future Plans

The possibility to complete the measurement for the filtering process is under the COSY physics program, which now it is moving

from hadron physics to fundamental physics

In this direction we'are updating the target for a Time Rerversal Invariance Test at COSY

(TRIC experiment)



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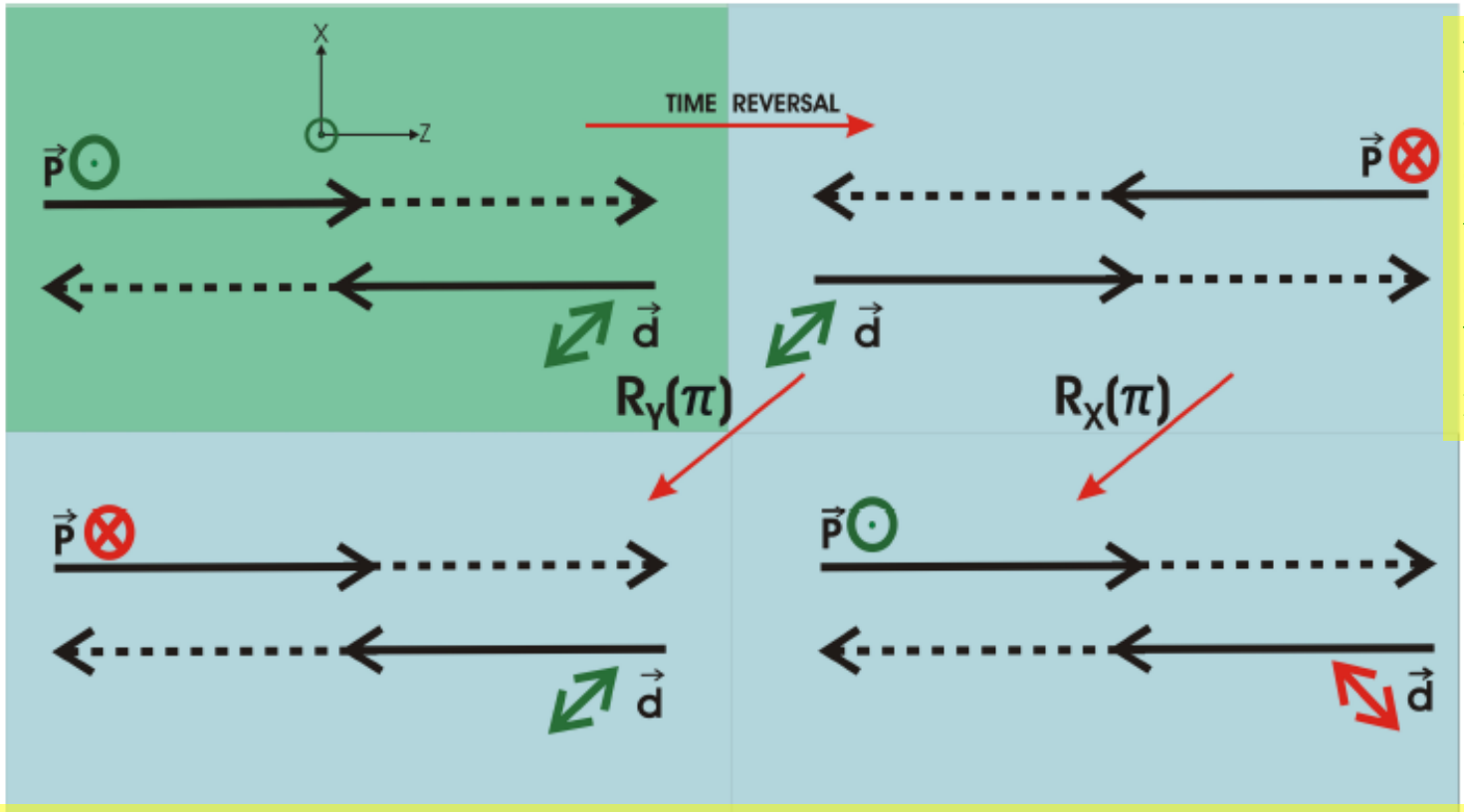
TRIC requirements



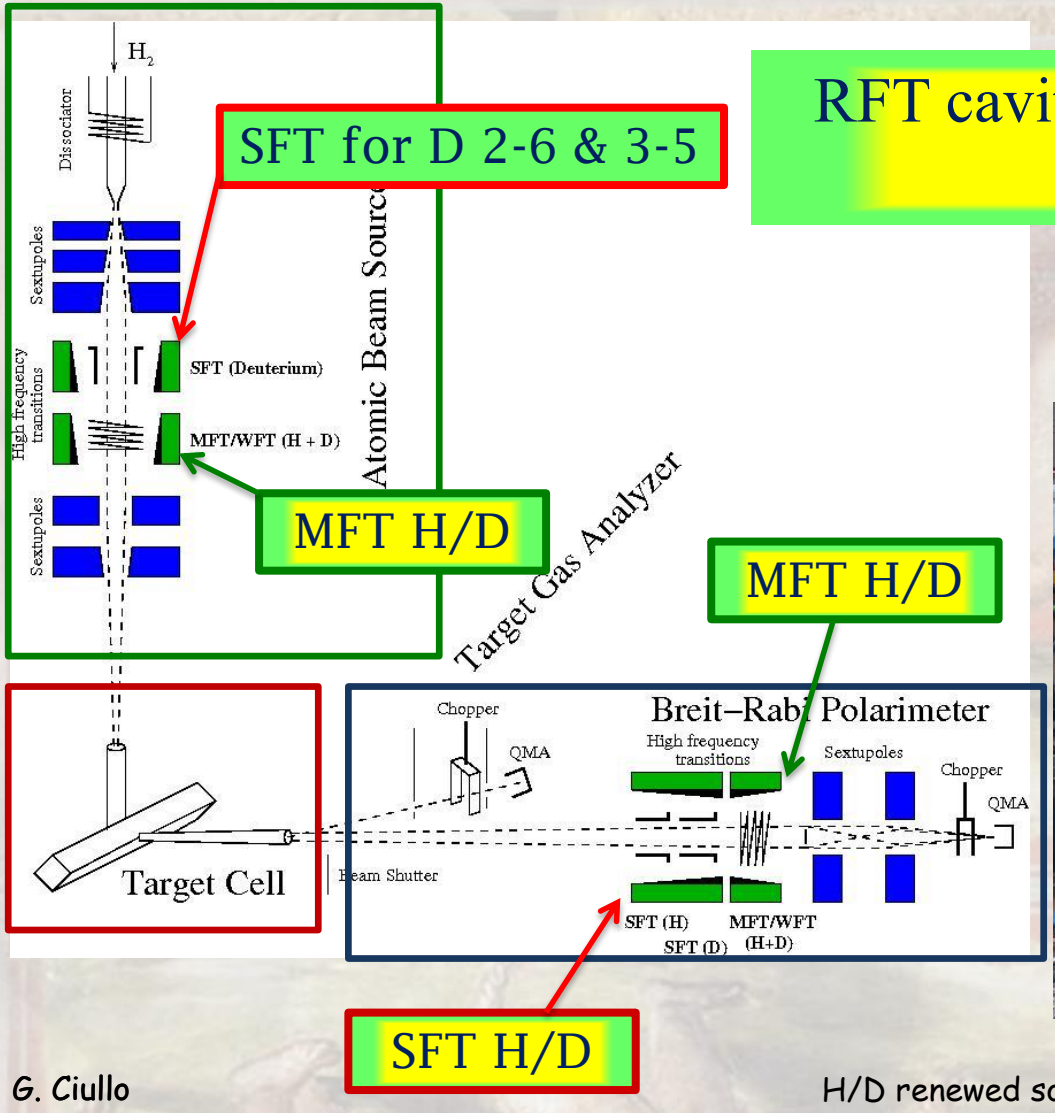
D tensor polarized at 45° in a plane ortogonal to the polarization of the stored proton beam in the COSY ring

Details on TRIC Y. Valdau presentation today 12:45 (B. Lorentz)

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.

H/D following the plans

- The polarized target has to work *in situ* with H or D



SFT for D 2-6 & 3-5

MFT H/D

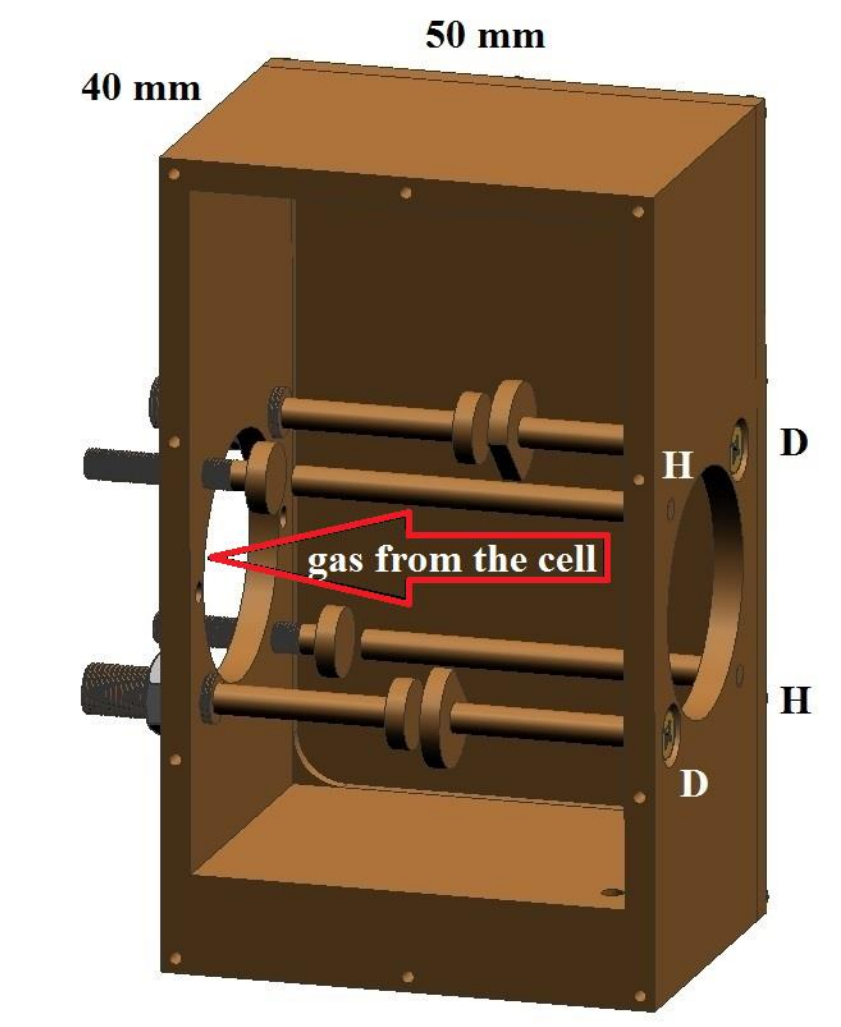
MFT H/D

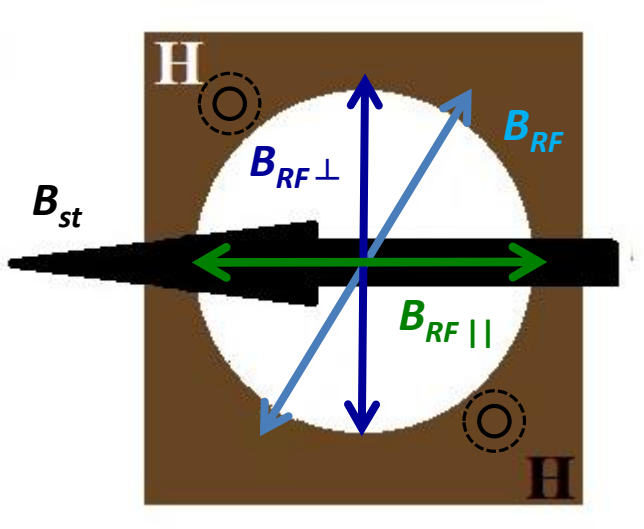
SFT H/D

RFT cavity which can operate *in situ* for H or D

RF cavity for D

The *in situ* SFT dual cavity for H or D





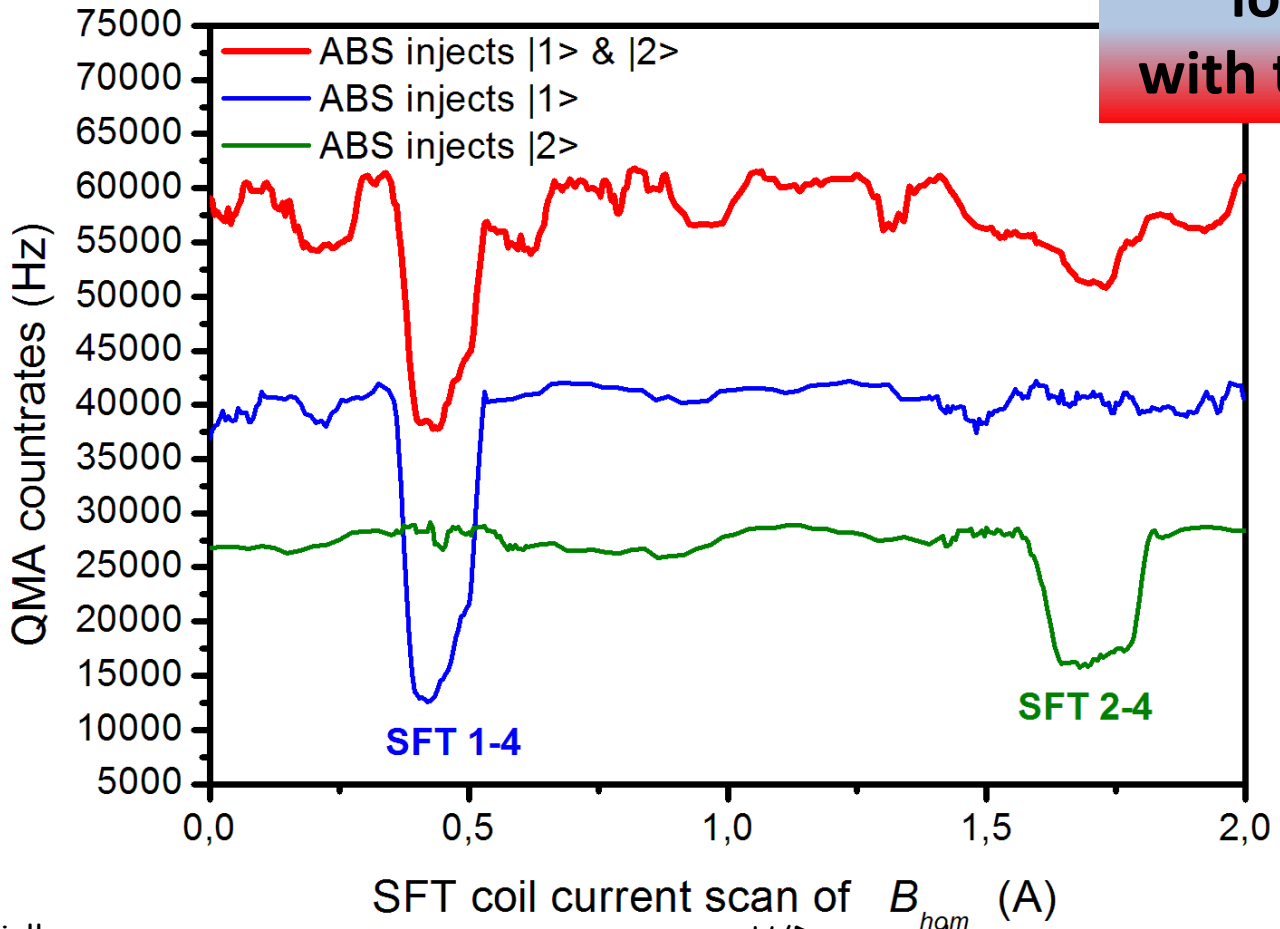
H: transition SFT1-4 and 2-4

D: transition SFT1-6, 2-6, SFT 3-6/2-5 and SFT3-5

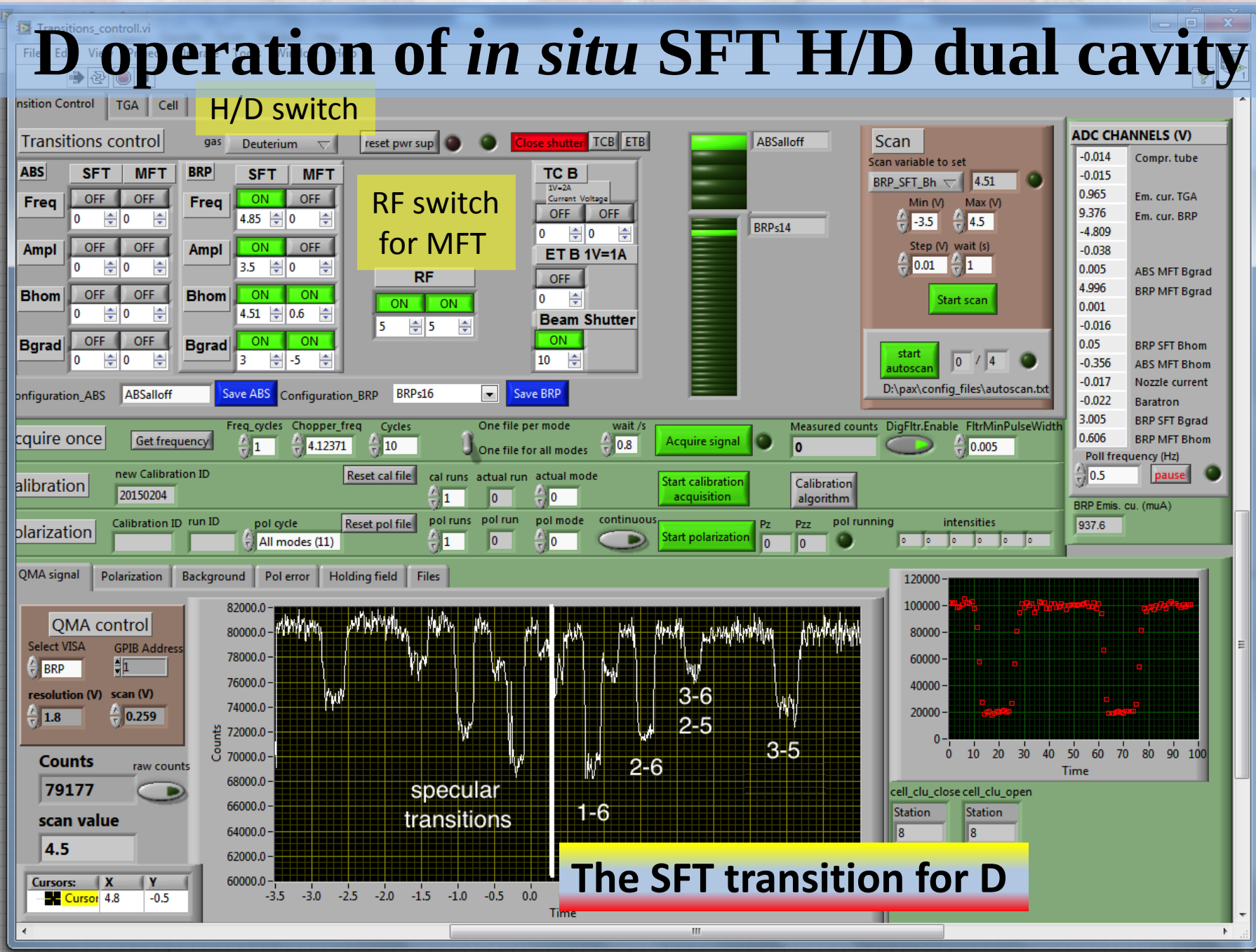
G. Ciullo *et al.*, Intern. J. Mod. Phys: Conf. Ser. **40** (2016) art. n. 1660149

The *in situ* SFT H/D dual cavity: H operation

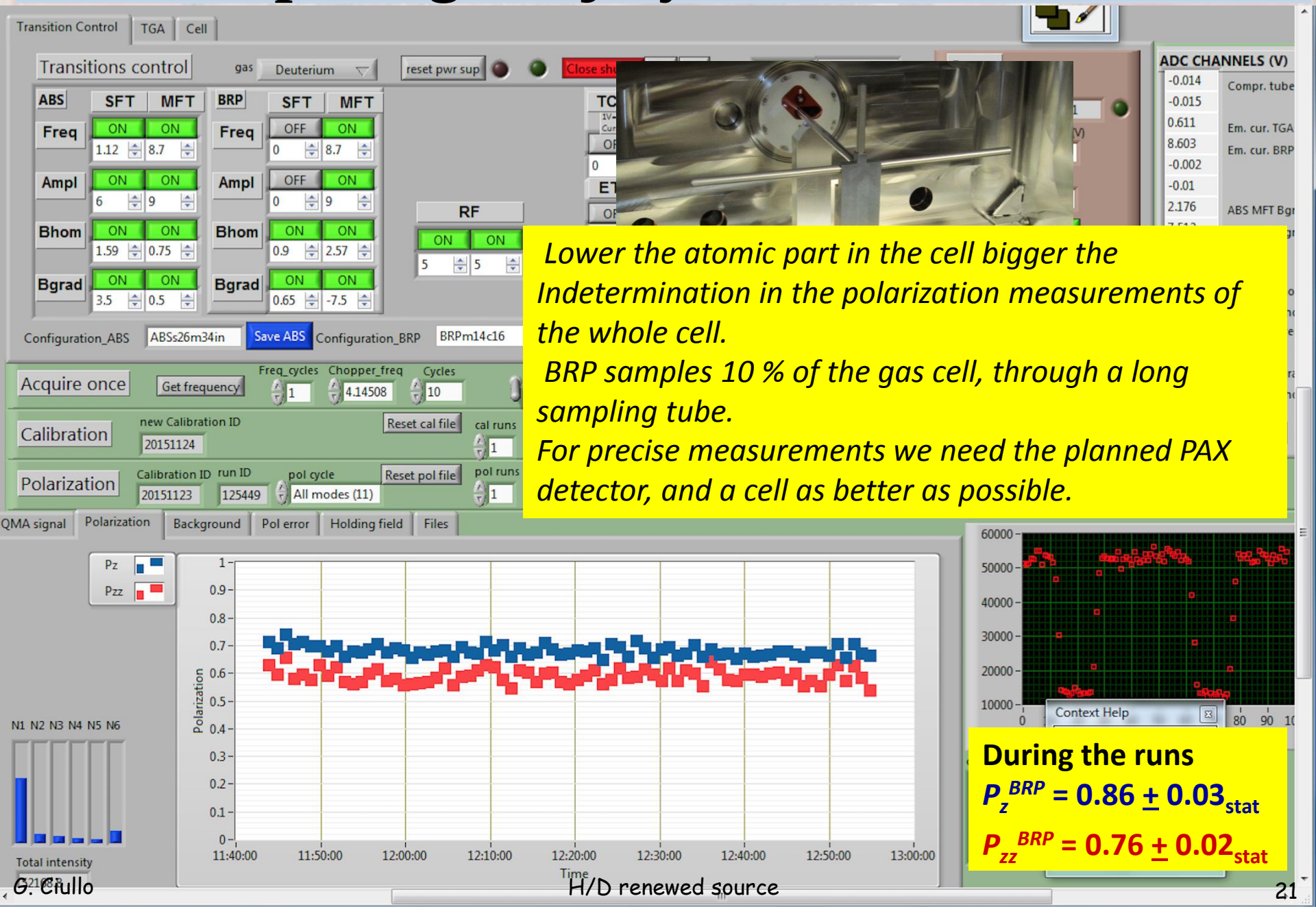
TARGET ready
for
longitudinal runs,
with the new dual cavity



D operation of *in situ* SFT H/D dual cavity



Preparing the july 2016 beam time



Lower the atomic part in the cell bigger the Indetermination in the polarization measurements of the whole cell.

BRP samples 10 % of the gas cell, through a long sampling tube.

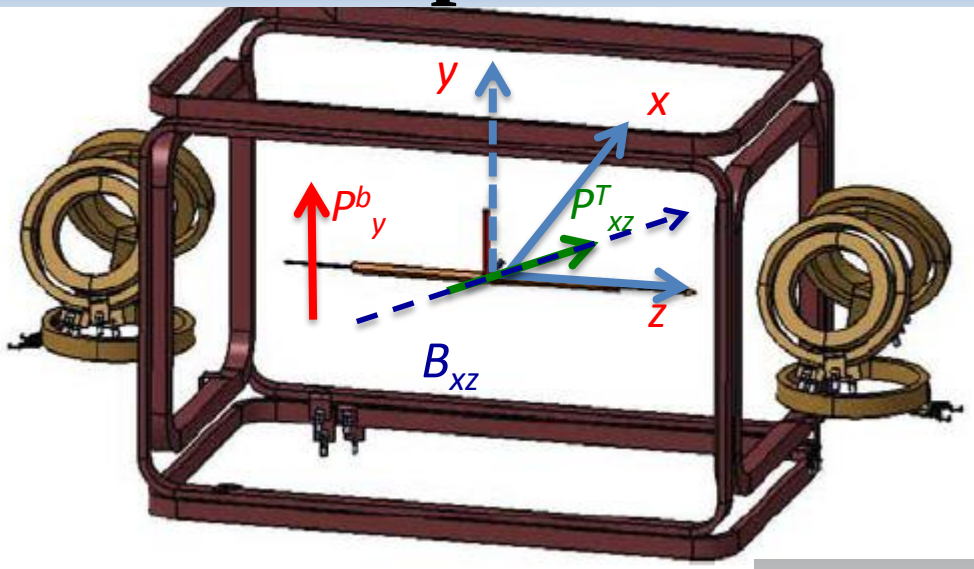
For precise measurements we need the planned PAX detector, and a cell as better as possible.

During the runs

$P_z^{BRP} = 0.86 \pm 0.03_{stat}$

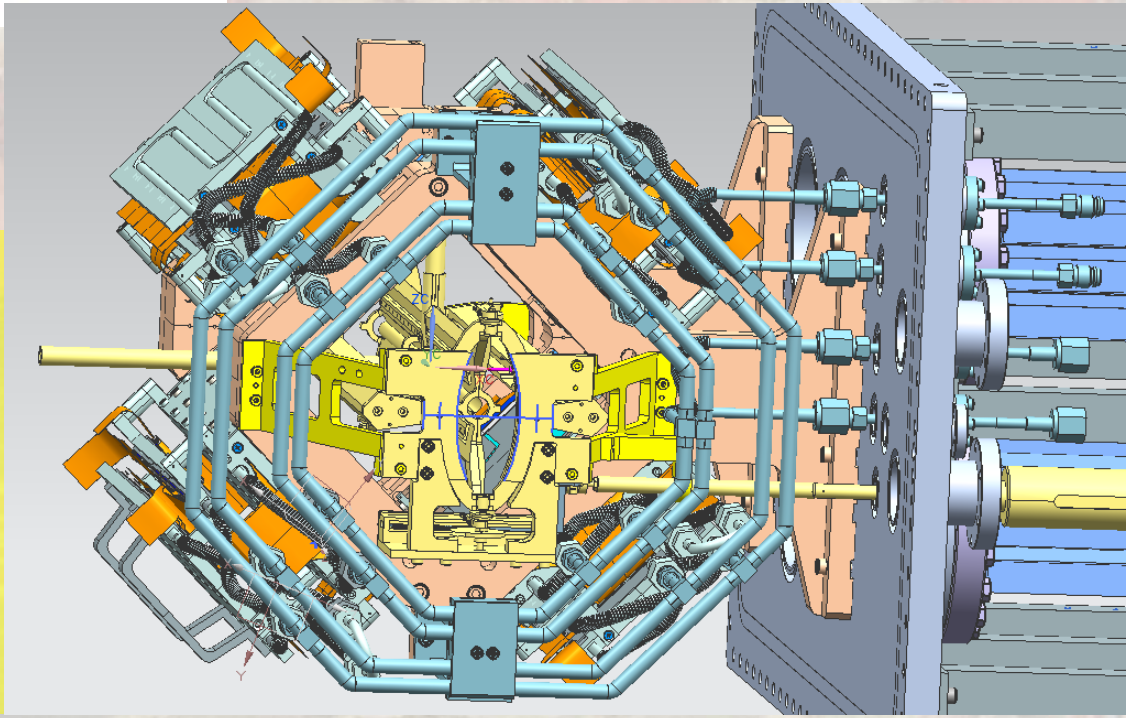
$P_{zz}^{BRP} = 0.76 \pm 0.02_{stat}$

The completeness of the PAX (TRIC) - IP



The target is equipped with three set of rectangular **Helmholtz** coils, plugged on the outside of the vacuum chamber, which allow to define a holding field of 10 gauss in any direction. Here is drawn B_{xz} at 45 ° in the *xz* – plane in z and x positive quadrant.

the PAX detector surrounding an openable cell is under construction.
The detector will allow to calibrate the BRP via p-d scattering. The openable cell allows to inject and then store more particles in the ring.



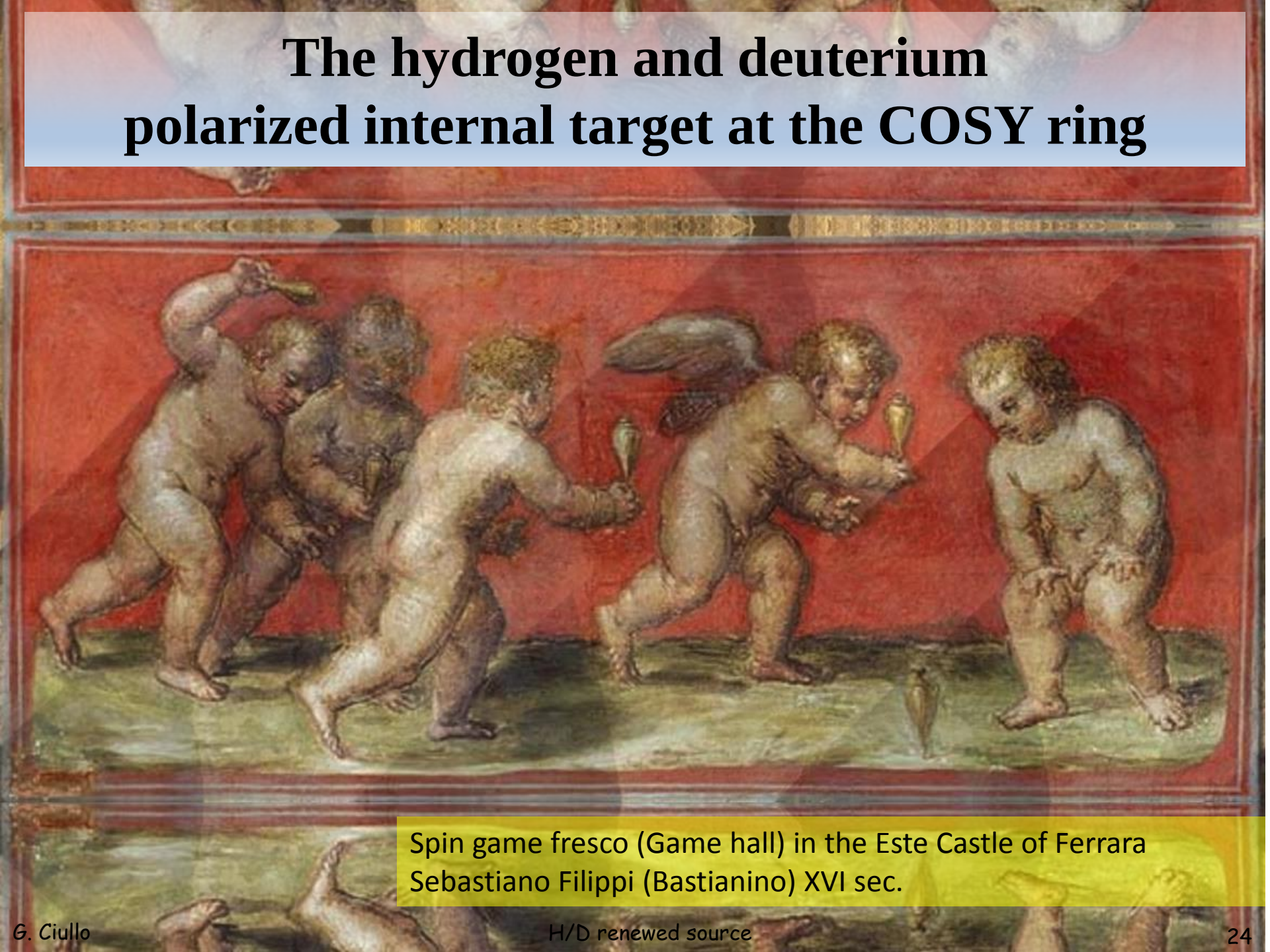
Conclusion

The PAX target at COSY is upgraded in line with the requirements of the measurements and the Physics programs of the ring.

It was successfully used for the transverse case of PAX experiments, and upgraded for both in situ H or D operation.

We are on the way to fulfill the working conditions, for TRIC experiments - D tensor polarized, or for PAX longitudinal measurements- H polarized, following the physics program of the COSY ring.

The hydrogen and deuterium polarized internal target at the COSY ring



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Sebastiano Filippi (Bastianino) XVI sec.