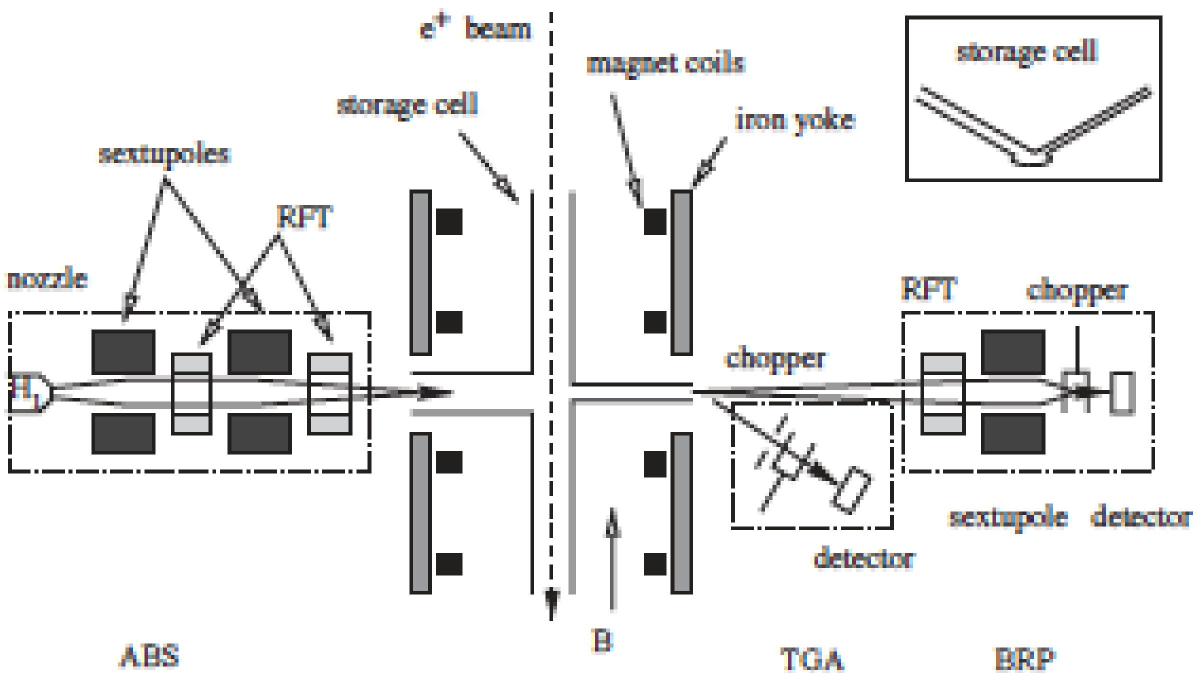
Polarized internal gas targets

P. Lenisa – University of Ferrara and INFN

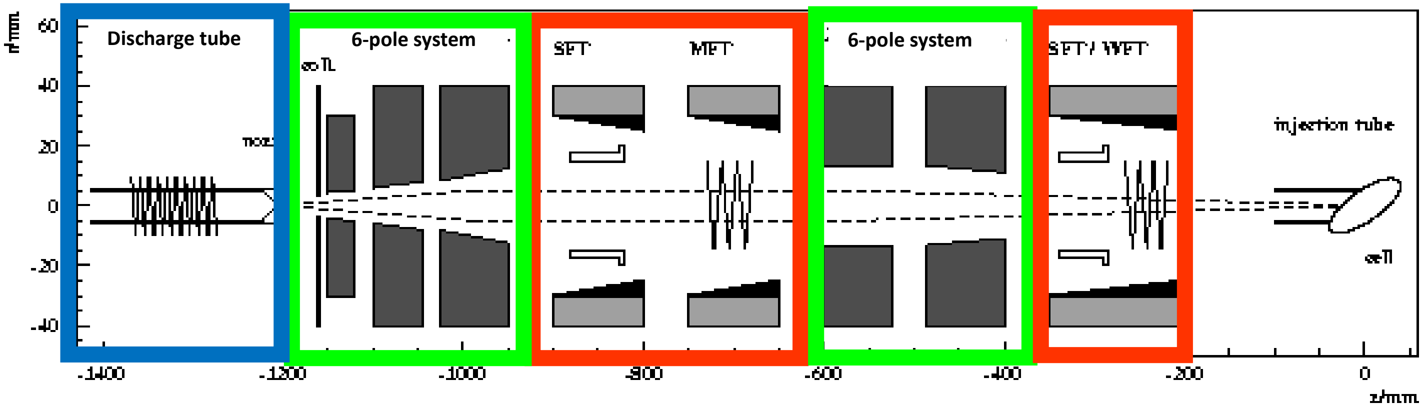
CERN - 06.04.22

Polarized atomic target and polarimeter



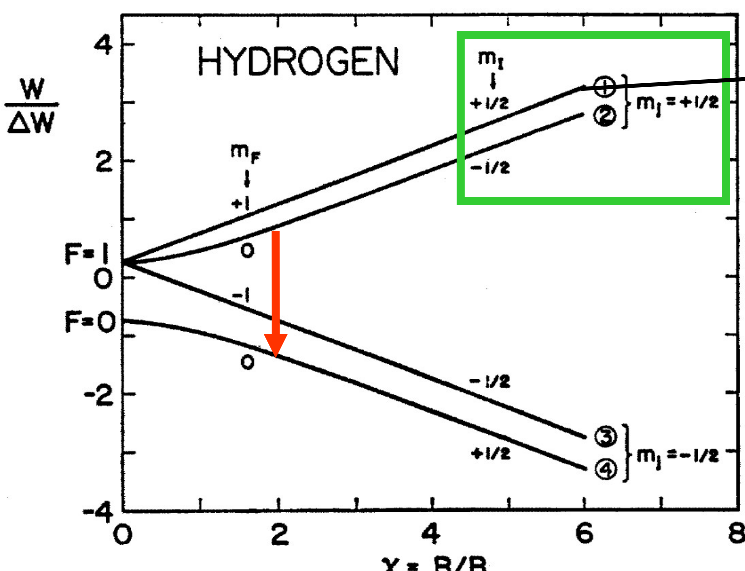
Polarized source Cell Polarimeter

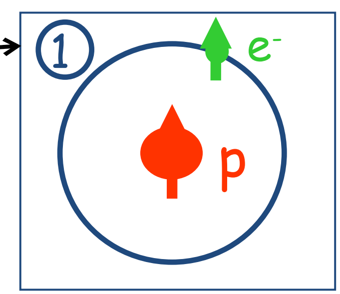
Polarized atomic beam source
Components and working principle



Main components:

- Dissociator
- 6-poles
- RF-transitions
- Vacuum system



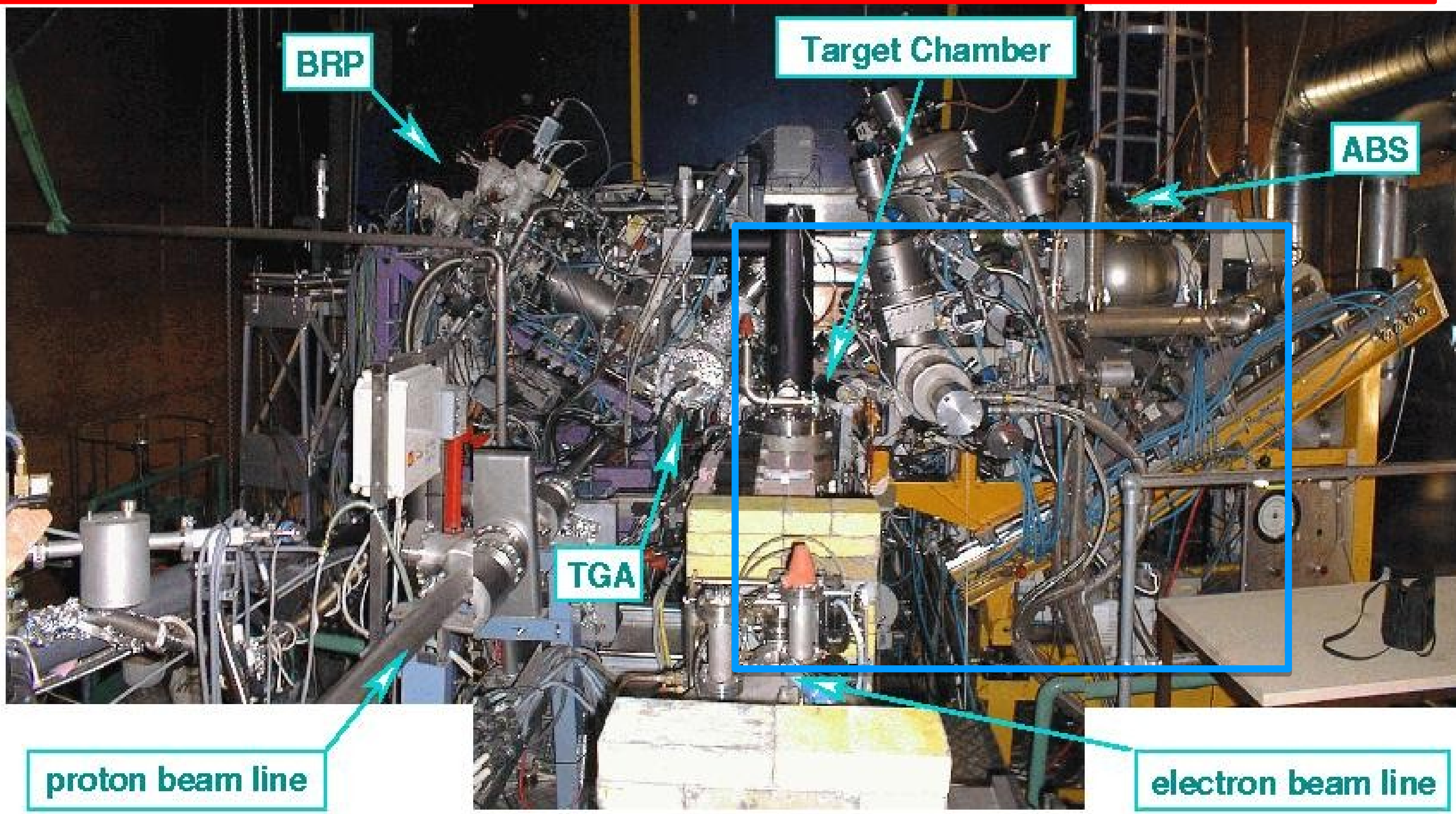


Atoms with m_j=+½ focused in sextupole magnets.

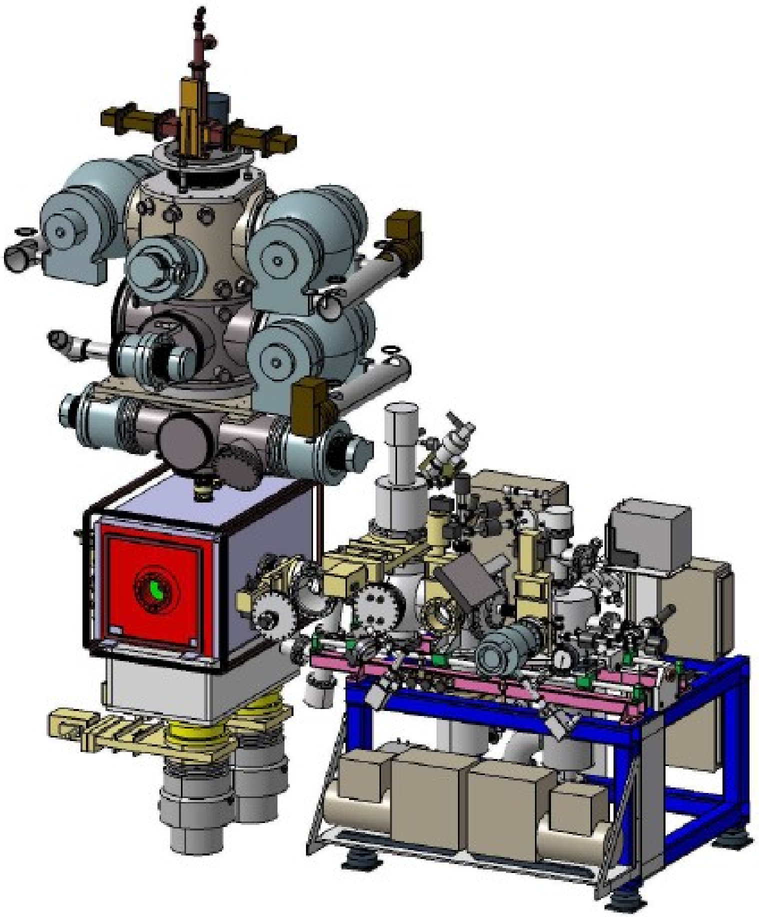
RF transitions select HFS.

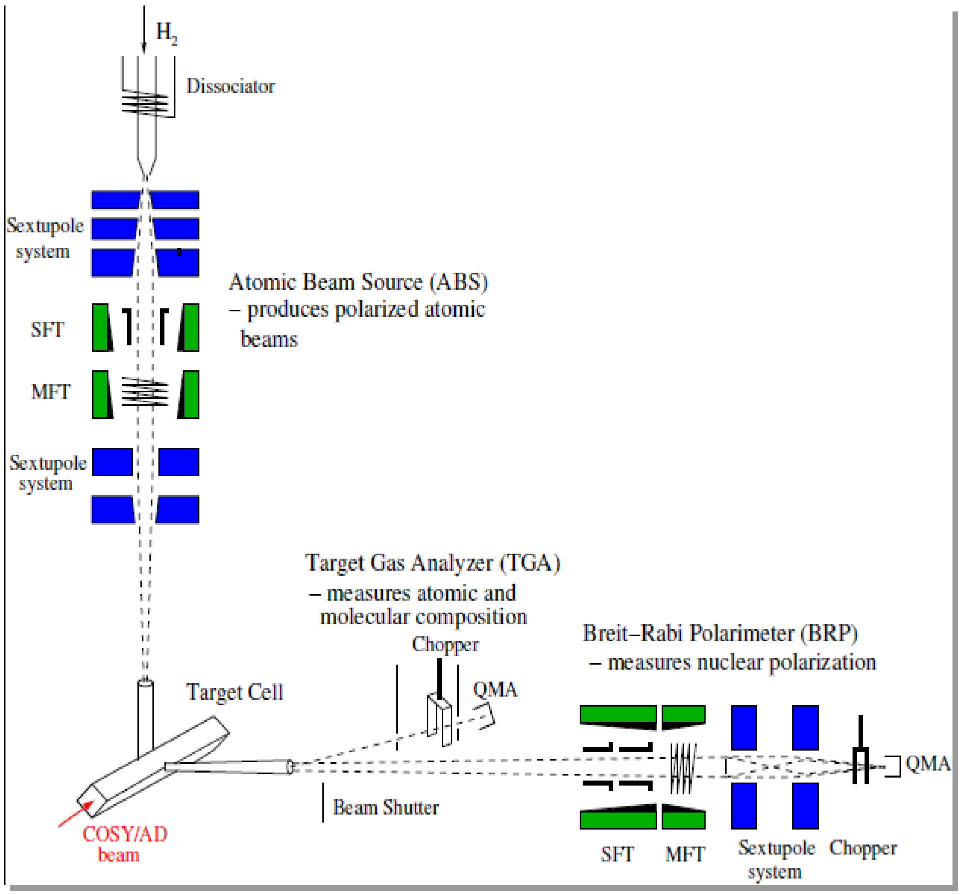
The HERMES target at HERA (DESY)

- No useful nuclear reactions to determine target polarization.
- Independent target polarimeter demanded.
- Determination of hyperfine state population by:
  - RF transitions
  - 6-pole magnet system

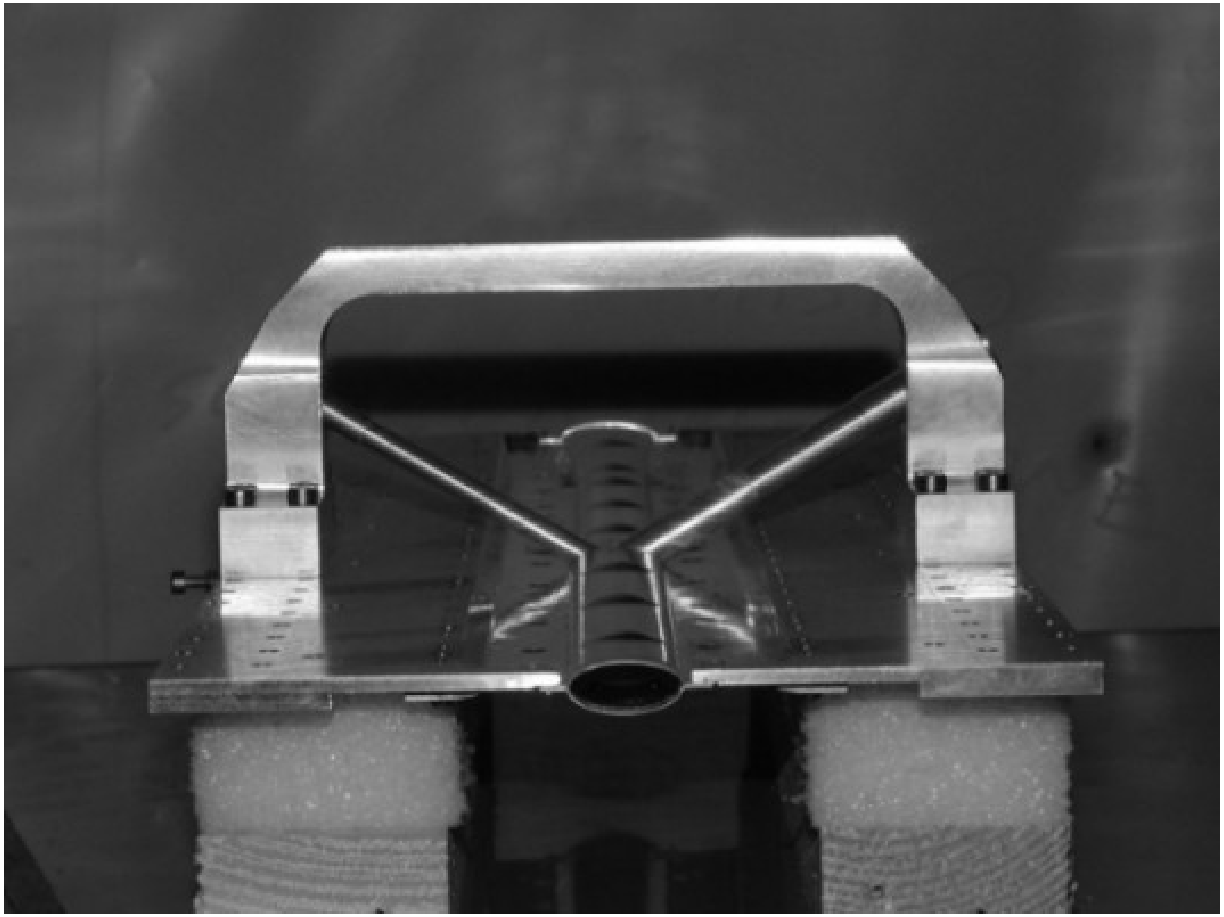


The PAX target at COSY (FZ-Juelich)





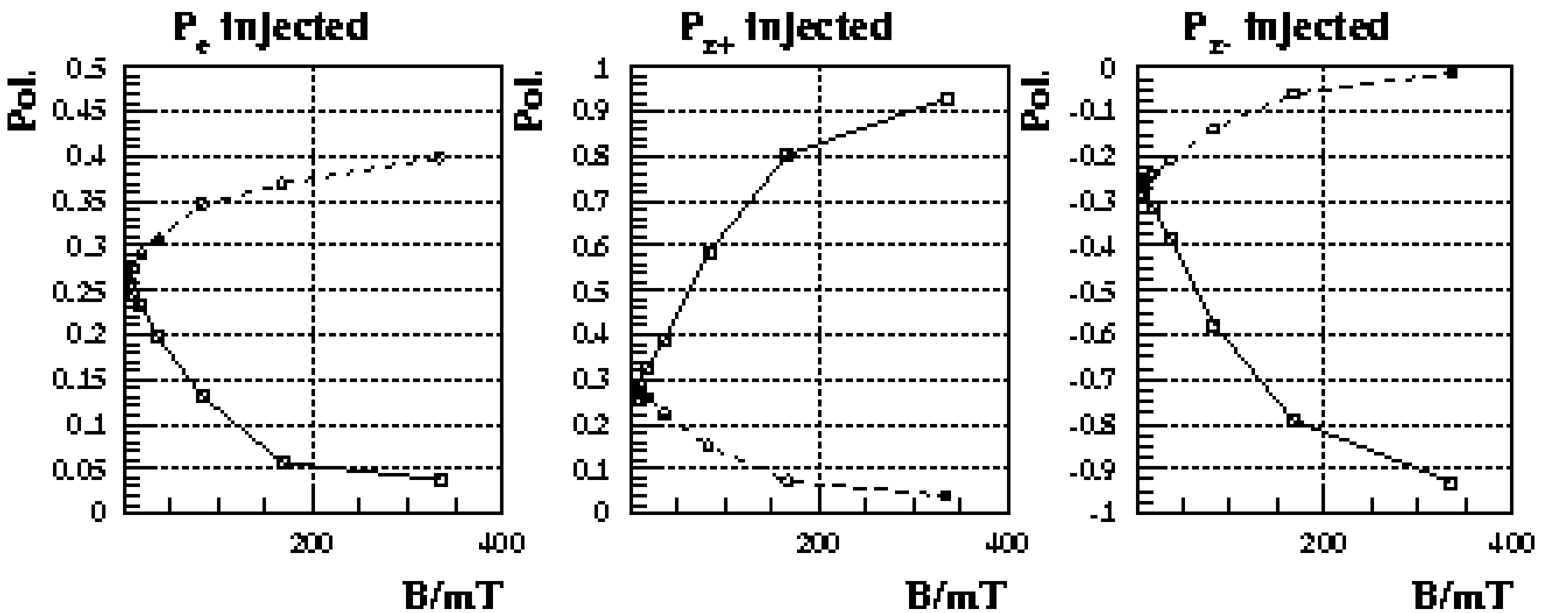
The HERMES storage cell



- Material: 75 μm Al with Drifilm coating (+ ice)
- Size: length: 400mm, elliptical cross section (21 mm x 8.9 mm)
- Working temperature: 100 K (variable 35 K - 300 K)

Magnetic holding field

- Polarization of mixed states is intensity dependent

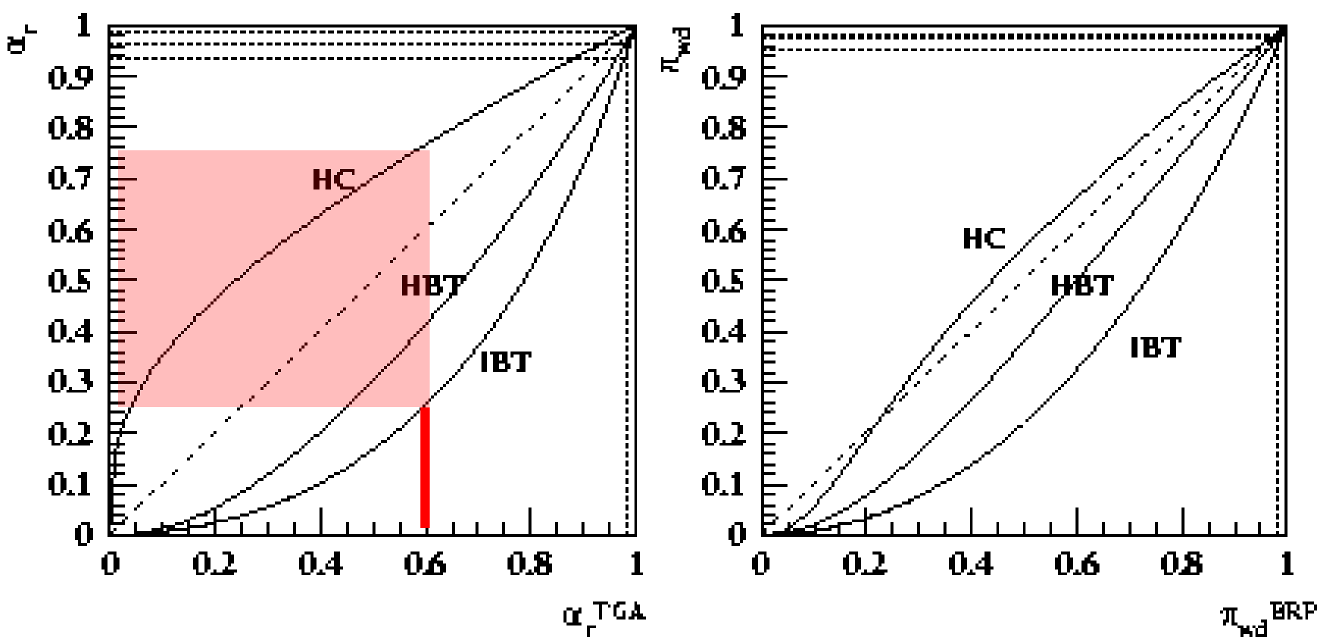


- Intensity inhibits spin relaxation due to wall collisions
- Homogeneity inhibits spin relaxation due to beam induced depolarization.

Target polarization
(internal target with storage cell)

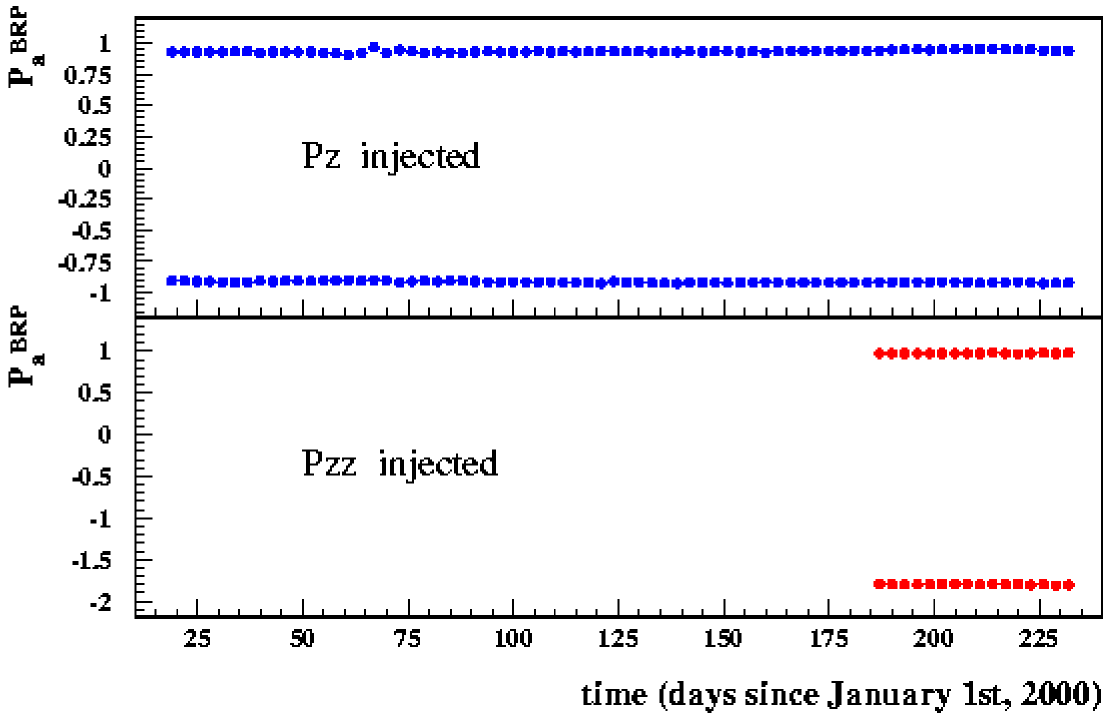
$$P_T = \alpha_0 \alpha_r P_a + \alpha_0 (1 - \alpha_r) P_m$$

- 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:
    - $\alpha_r = c_a \, \alpha_r^{TGA}$
    - $P_a = c_P \, P_a^{BRP}$



HERMES performance for D (1999/2000)

- Longitudinal Polarization (B=335 mT)



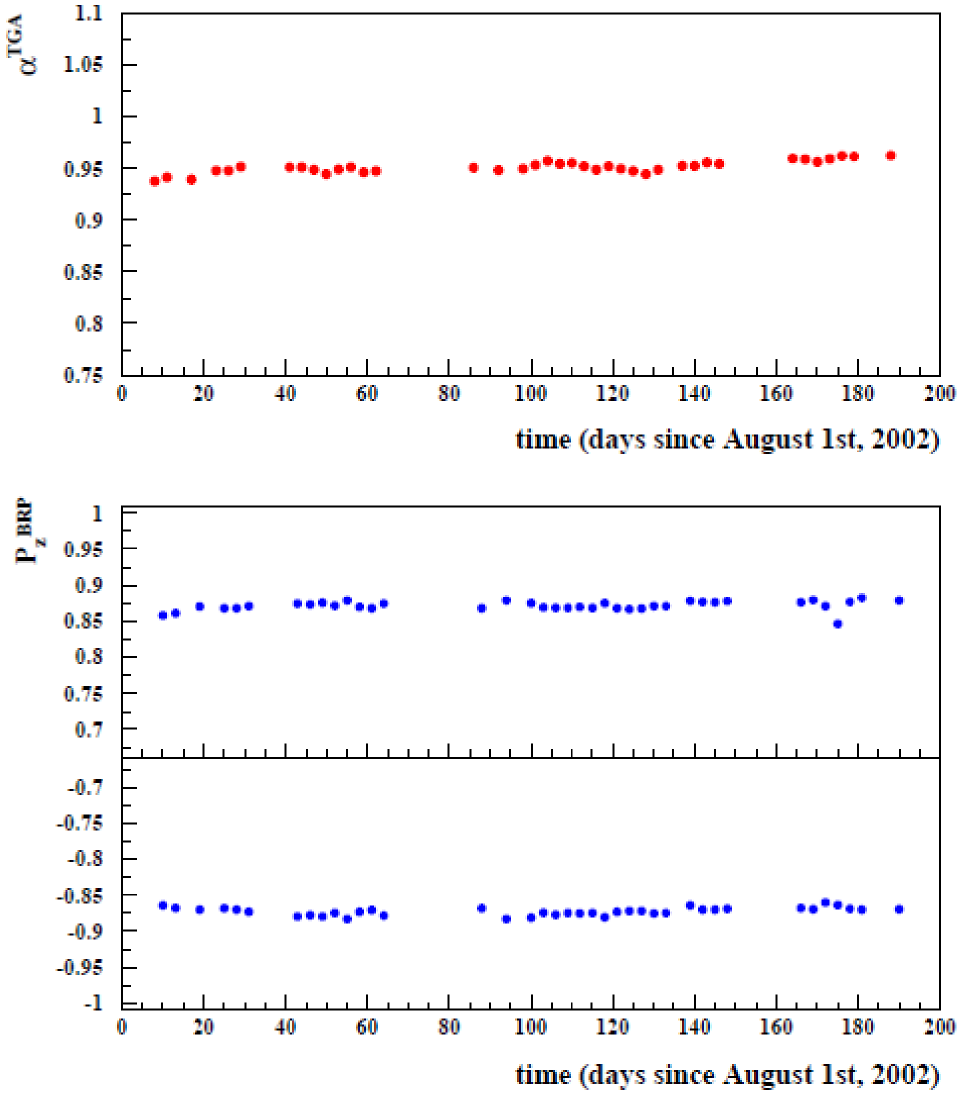
$P_t = 0.845 \pm 0.028$

HERMES performance for H (2002/03)

HERMES 2002/03 data taking with transverse proton polarization

Top: Degree of dissociation measured by the TGA (α = 1: no molecules);

Bottom: Vector polarization P_z measured by Breit-Rabi-Polarimeter.



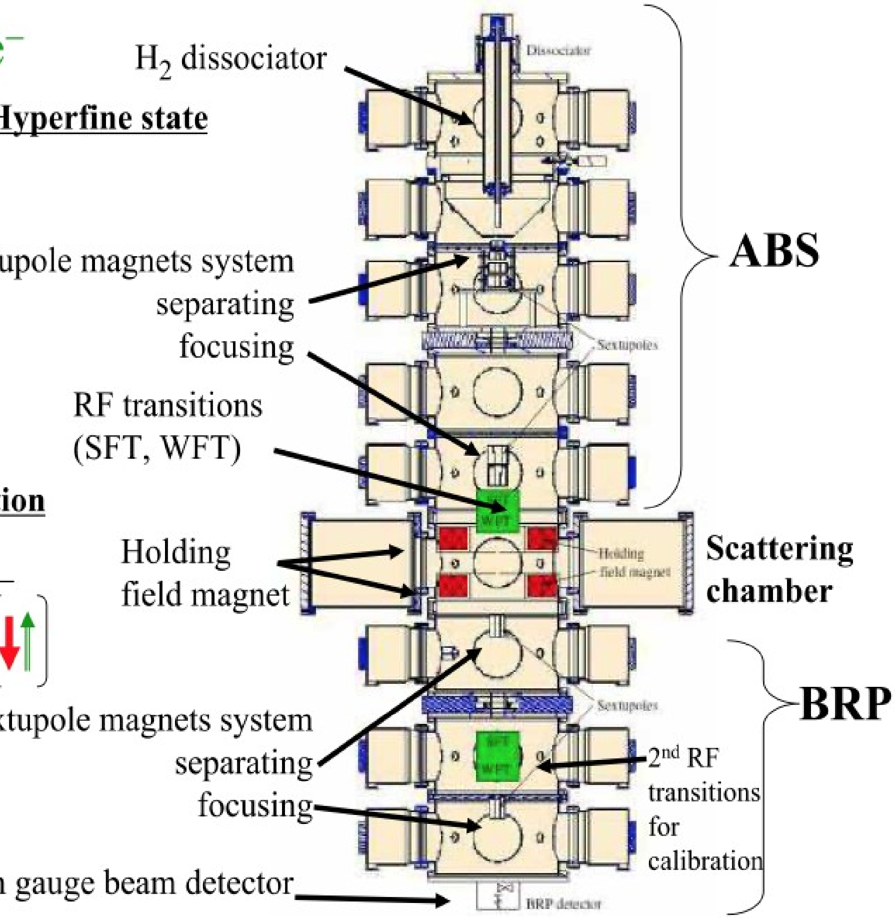
Summary of performance for longitudinal running

Target/year	$H_{\|\|}$(1997)	$D_{\|\|}$(2000)
P_t	0.851 ± 0.033	0.845 ± 0.028
$\Delta\alpha_r$	0.055	0.003 (absent)
ΔP_{SE}	0.035	≤0.001 (absent)
ΔP_{WD}	0.02	≤0.01 (absent)
ΔP_{BI}	-	-
t(10^{14} nucl/cm^2)	0.7	2.1
FOM (P^2t)	0.5	1.5

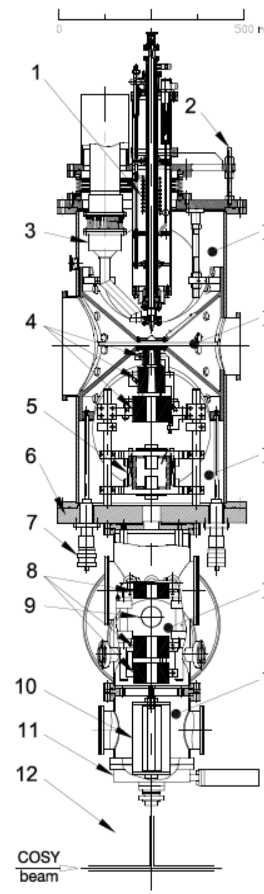
Summary of performance for transverse running

Period	10/2003-03/2004	04/2004-07/2004	01/2005-04/2005	04/2005 11/2005
cell	1	1 (warm-up)	2	3
P_t	0.786 ± 0.036	0.721 ±0.059	0.62 ±0.09	0.73 ±0.06
$\Delta\alpha_r$	absent	absent	0.24	0.035
ΔP_{SE}	0.055	0.055	0.055	0.055
ΔP_{WD}	0.055	0.12	0.17	0.12
ΔP_{BI}	≤0.01	≤0.01	≤0.01	≤0.01
$t(10^{14}nucl/cm^2)$	1.1	1.1	1.1	1.1
FOM (P^2t)	0.7	0.6	0.4	0.6

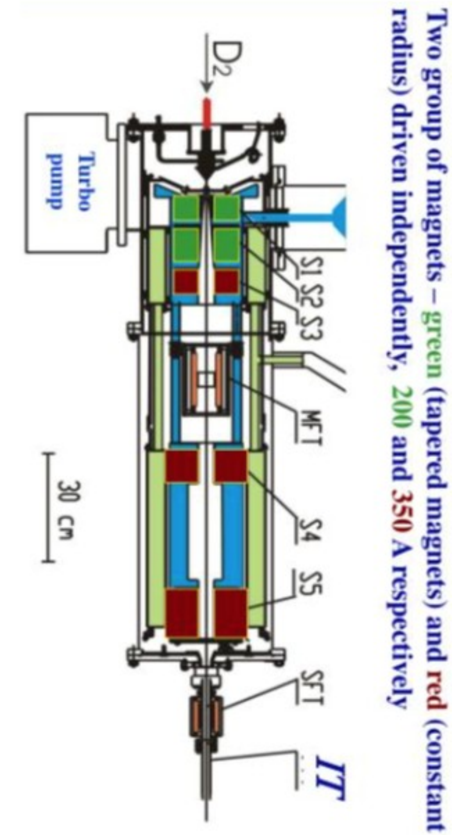
(Other) operational atomic beam sources



RHIC



ANKE



VEPP-3

RHIC source

- Designed to optimize intensity (long drift space 1st - 2nd 6-poles)
- Clever use of turbo pumps
- Simplified BRP ok for RF- tuning
- No measurement of atomic fraction

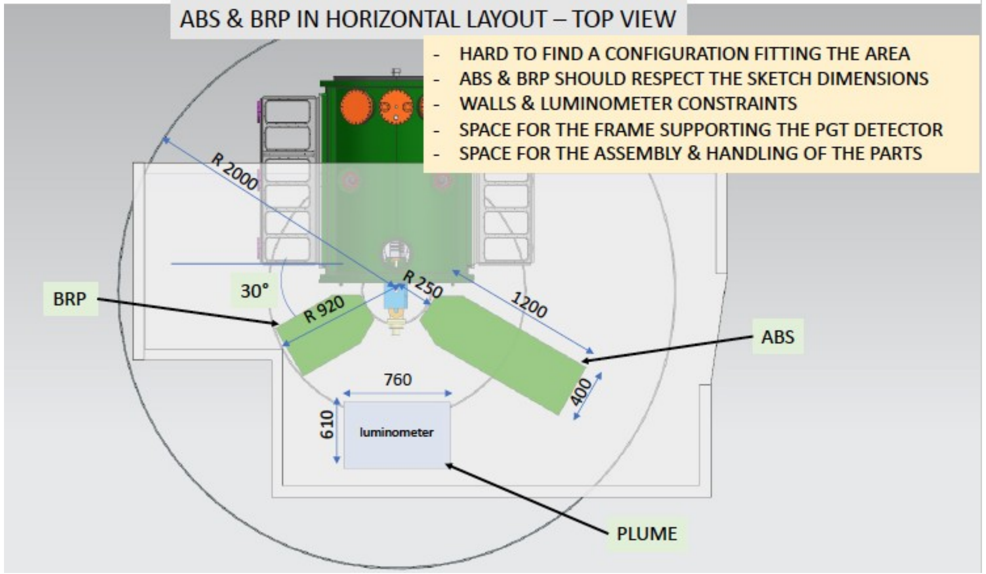
VEPP-3 cryogenic source

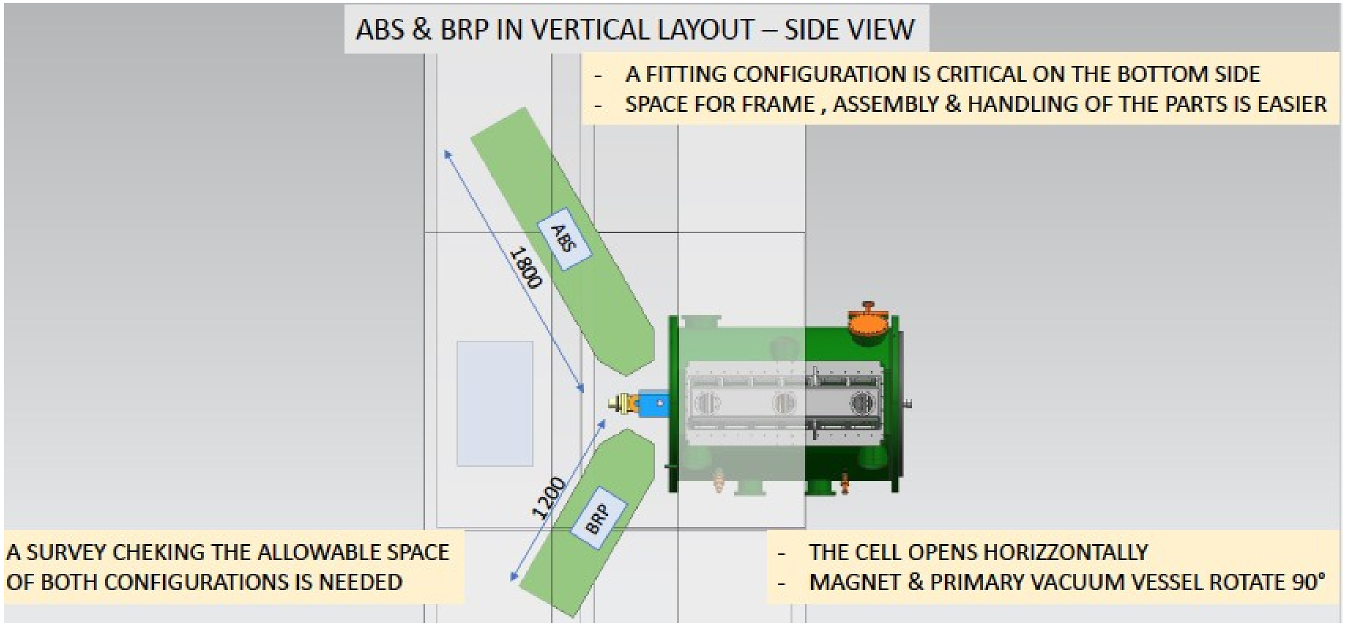
- SC-magnets increase mag poletip fields (B = 4.8 T, ϕ = 44 mm)
- Requires cryostat and regular surface regeneration
- Requires R&D
- Not suitable for remote operation

Spare slides

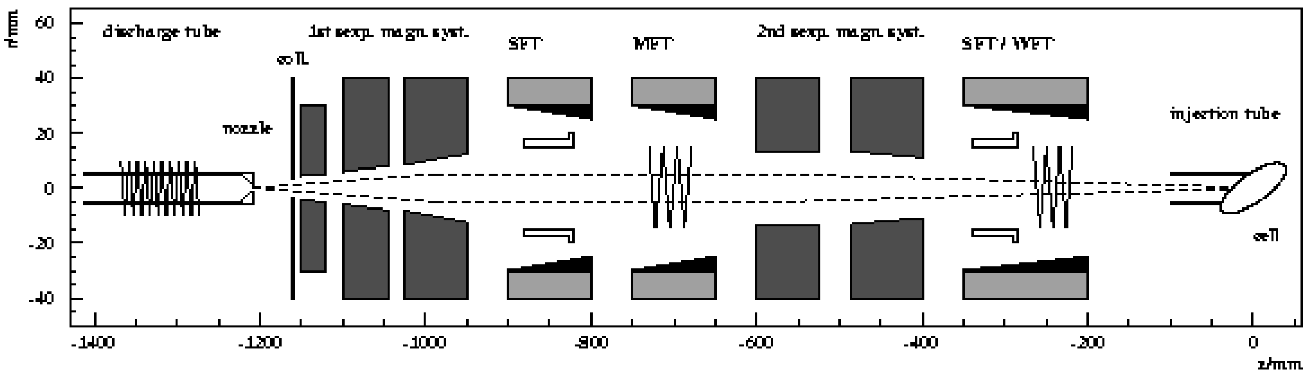
A few considerations for the LHC

Space constraints





Polarized Atomic Beam Source Design



(HERMES/PAX atomic beam source)

Requirements:

- MW dissociator
    - no water cooling;
    - reliable operation;
    - possible design of a shorter dissociator?
        - Test bench for velocity distribution characterization required
- Space constraints:
    - Z axis: possible gain compactness at the expense of intensity by removal of transitions after 2nd 6-pole (next slide)
        - Additional space for dissociator insertion and replacement
    - Beam simulations required
    - Radial
        - Services and pumps can be installed in the vertical plane gaining space in the horizontal
- Vacuum: no UHV (HV sufficient); no baking required
    - Turbo pumps
        - HERMES had cryopumps requiring maintenance and space
- Separation valve between ABS and LHC vacuum might be a critical issue
    - To be discussed with accelerator people

HF-transitions and injected polarization

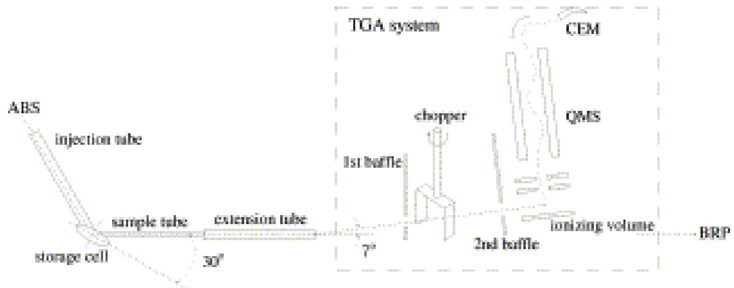
Table 2
Injection modes of the atomic beam source

Gas	HFT (betw. 6-poles)	HFT (after 6-poles)	Inj. states	P_z	P_z	P_{zz}	Use
H	—	—	|1⟩, |2⟩	+1	0	—	Cal
	—	WFT 1–3	|2⟩, |3⟩	0	−1	—	Data
	—	SFT 2–4	|1⟩, |4⟩	0	+1	—	Data
	SFT 2–4 / MFT 2–3	—	|1⟩	+1	+1	—	Cal
	WFT 1–3/MFT 1–3	—	|2⟩	+1	−1	—	Cal
	SFT 2–4 / MFT 2–3	WFT 1–3	|3⟩	−1	−1	—	Cal
	WFT 1–3 / MFT 1–3	SFT 2–4	|4⟩	−1	+1	—	Cal
	WFT 1–3, SFT 2–4	—	*no state*	—	—	—	Cal
D	—	—	|1⟩ |2⟩ |3⟩	+1	0	0	Cal
	SFT 2–5	WFT 1–4	|3⟩ |4⟩	0	−1	+1	Data
	SFT 3–5	SFT 2–6	|1⟩ |6⟩	0	+1	+1	Data
	MFT 1–4	SFT 3–5	|2⟩ |5⟩	0	0	−2	Data
	MFT 1–4	SFT 2–6	|3⟩ |6⟩	0	0	+1	Data
	MFT 3–4, SFT 2–6	—	|1⟩	+1	+1	+1	Cal
	WFT 1–4, SFT 2–6	—	|2⟩	+1	0	−2	Cal
	WFT 1–4, SFT 3–5	—	|3⟩	+1	−1	+1	Cal
	MFT 3–4, SFT 2–6	WFT 1–4	|4⟩	−1	−1	+1	Cal
	WFT 1–4, SFT 3–5	SFT 3–5	|5⟩	+1	0	−2	Cal
	WFT 1–4, SFT 2–6	SFT 2–6	|6⟩	−1	+1	+1	Cal

- HF transitions after 2nd 6-poles double ABS intensity at the expense of longitudinal length

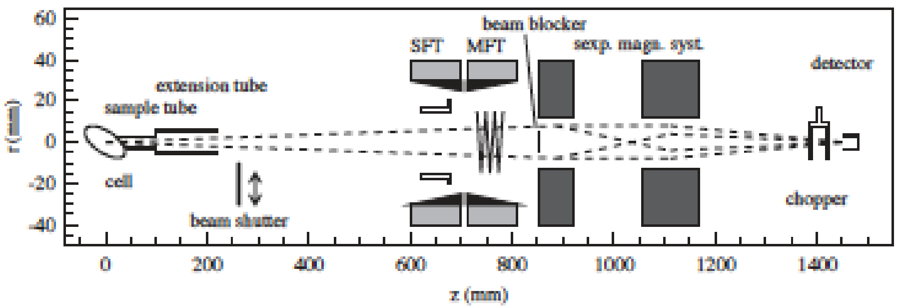
- SFT dual cavity (developed and installed in PAX ABS) can operate both for H and D without requiring hardware access
  - Complicate ”remote” tuning -> out of tunnel “engeneering model” ABS to reproduce and cure problems

Polarimeter



Target Gas Analyzer

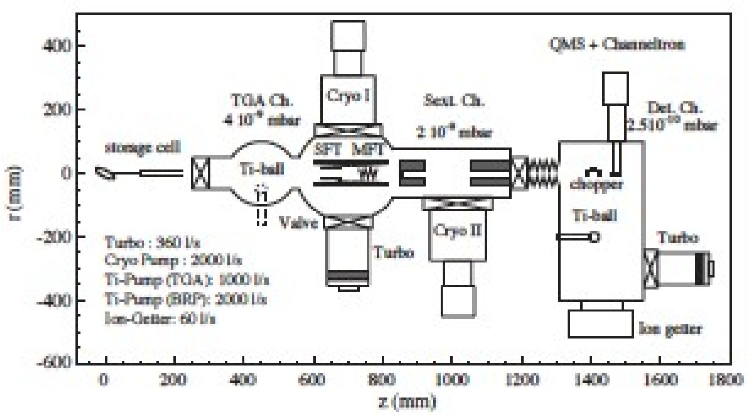
- Measures the atomic vs molecular fraction



Breit-Rabi polarimeter

- Measures the atomic polarization

Vacuum system



Requirements

- Space
  - More compactness in long. and radial plane?
    - Rearrangement of TGA?
    - Beam simulations required
- Vacuum
  - UHV necessary
  - Baking required
  - Turbo pumps + NEG
- Separation valve
  - As for ABS