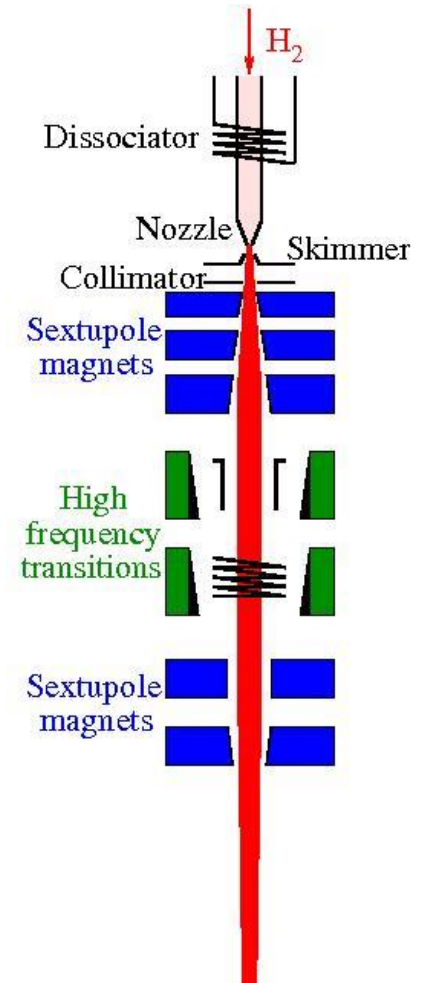


ATOMIC BEAM SOURCES AT STORAGE RINGS

LHCSPIN KICKOFF MEETING, DECEMBER 18, 2023 | ALEXANDER NASS

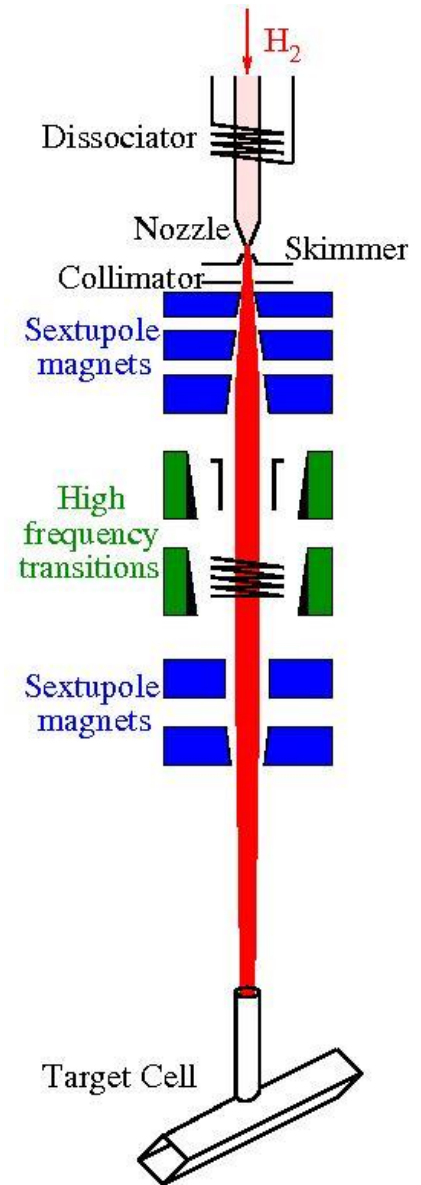
PRINCIPLE OF ABS

- Dissociation of hydrogen molecules
- Expansion of the atomic gas
→ supersonic beam
- Formation of atomic beam using skimmer and collimator
- Removal of atoms with electron spin $-1/2$ in sextupole system, prefocussing
- Exchange of hyperfine state populations
- Removal of atoms with electron spin $-1/2$ in sextupole system, focussing into the target cell



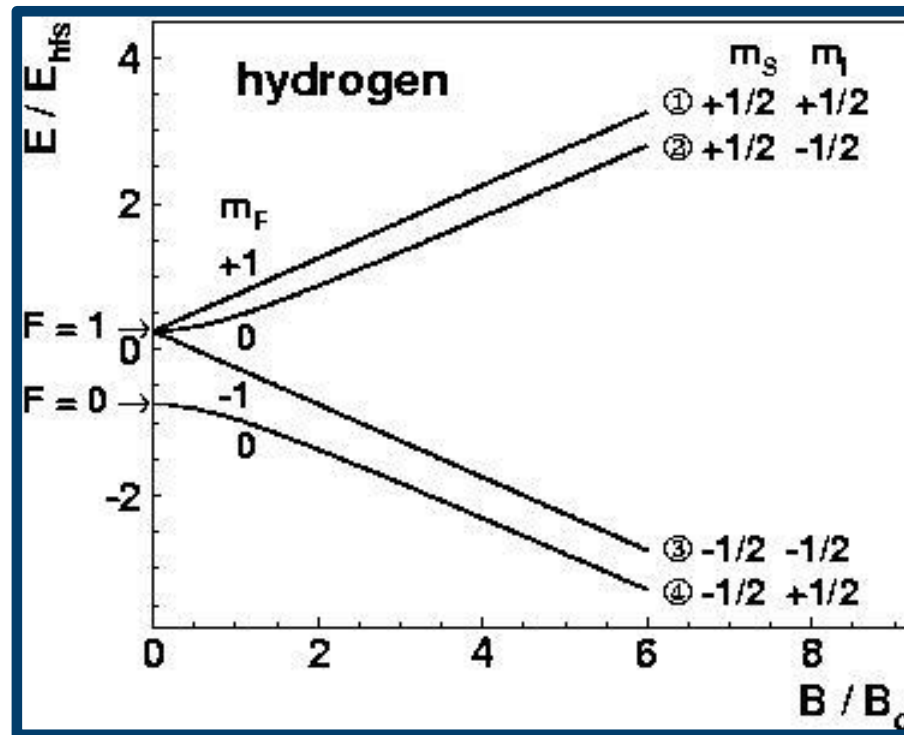
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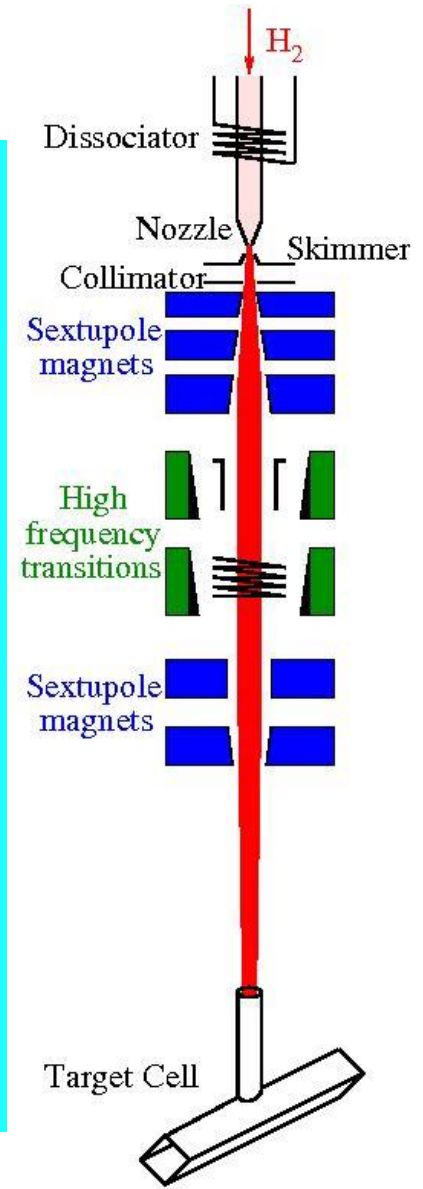
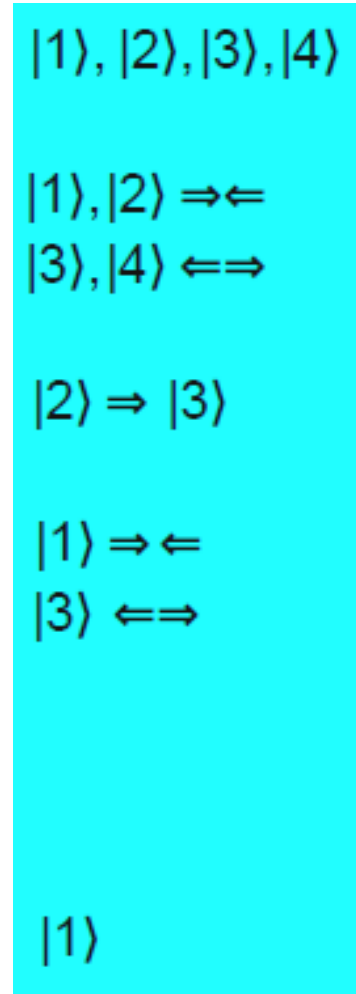
HYPERFINE STATES OF HYDROGEN

- Breit-Rabi diagram of the hyperfine states in hydrogen



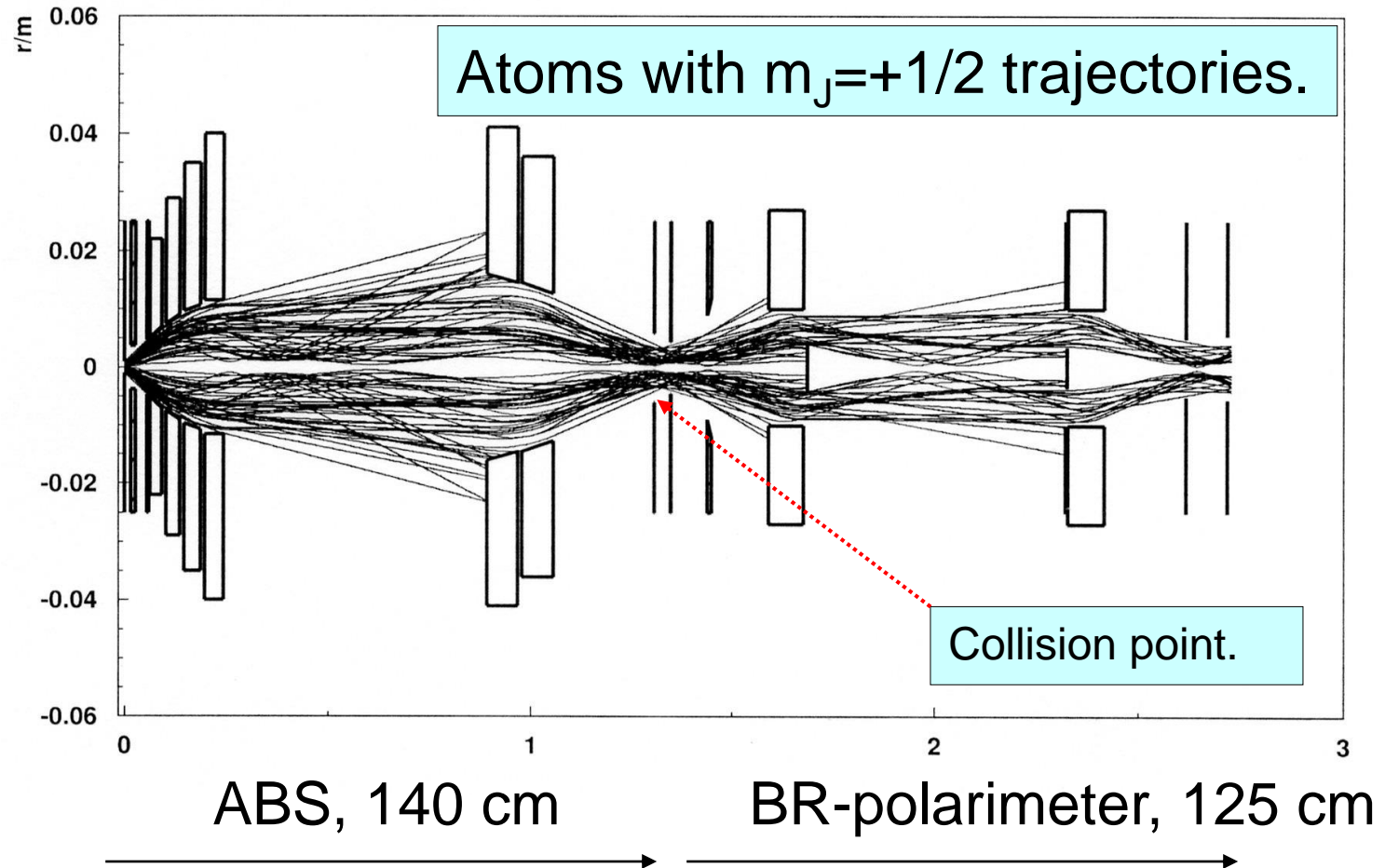
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- For two injected states additional HFT necessary



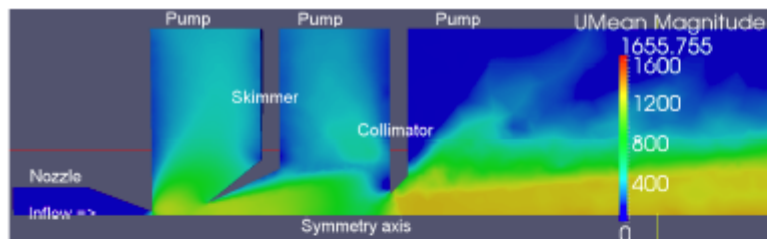
DESIGN OF ABS

- Tracking of atoms through the sextupoles (example H-Jet @ RHIC)

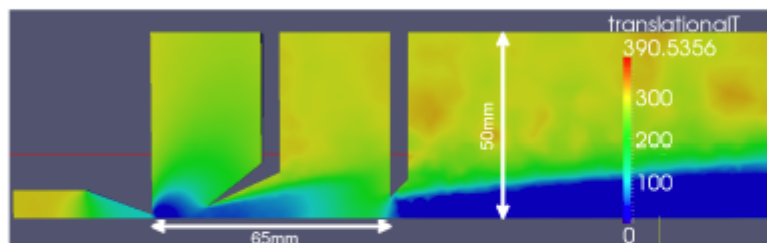


DESIGN OF ABS

- Tracking of atoms through the sextupoles using DSMC methods
- Optimization for maximal density (jet) or intensity (storage cell)



Magnitude of velocity distribution



Temperature distribution



Pressure distribution

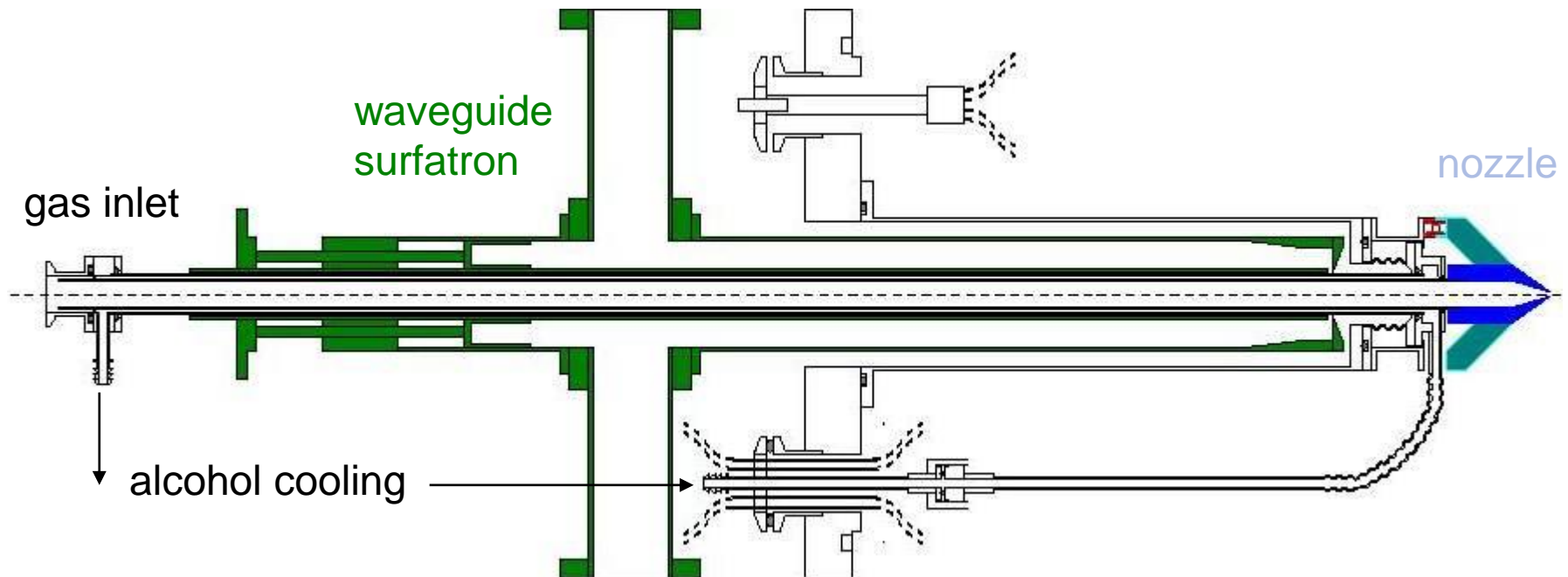
Parameters:

Species: H_2
 T_{inflow} : 300 K
 T_{nozzle} : 100 K
 Q : 1 mbar/s

	measured	simulated
v [m/s]	1274 ± 8.4	1290
T [K]	19.03 ± 1.11	16.5
p_1 [mbar]	$(2.1 \pm 0.2) \cdot 10^{-4}$	$3.4 \cdot 10^{-4}$
p_2 [mbar]	$(1.8 \pm 0.2) \cdot 10^{-5}$	$2.7 \cdot 10^{-5}$
p_3 [mbar]	$(7.0 \pm 0.7) \cdot 10^{-7}$	$8.0 \cdot 10^{-7}$
p_4 [mbar]	$(1.7 \pm 0.2) \cdot 10^{-7}$	$1.7 \cdot 10^{-7}$

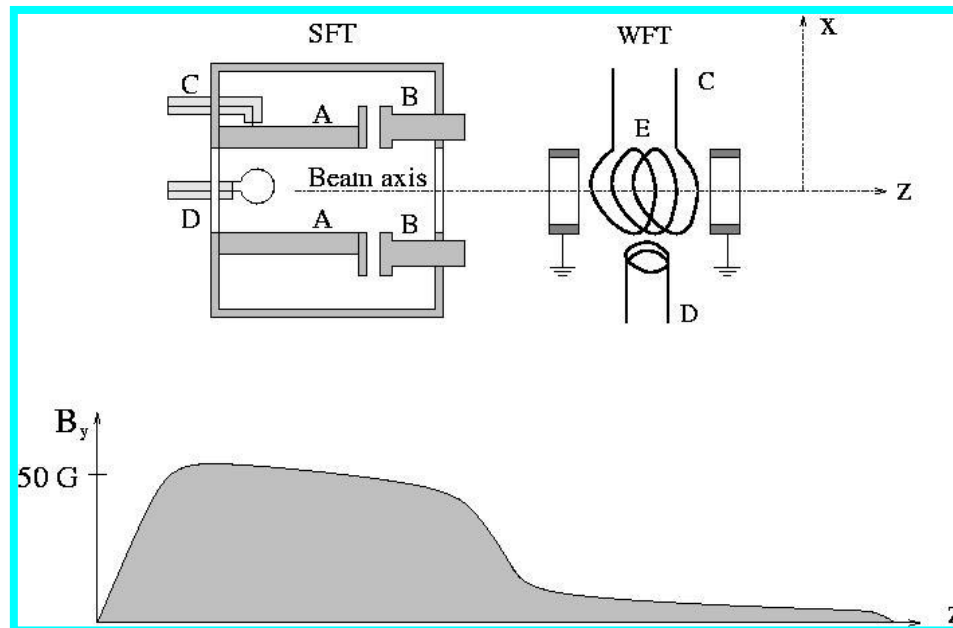
SETUP OF ABS - DISSOCIATOR

- Dissociator to produce a supersonic beam of hydrogen atoms
- Liquid cooled vs air cooled (air cooled needs more O₂ addition)
- RF vs microwave dissociators (MW needs more space)



SETUP OF ABS – SEXTUPOLES AND HFT'S

- Permanent Sextupoles focus / defocus hyperfine states
- High frequency transitions exchange populations of hyperfine states
 - Are a combination of RF fields and static magnetic fields
 - For WFT surrounding magnetic field needs to be low

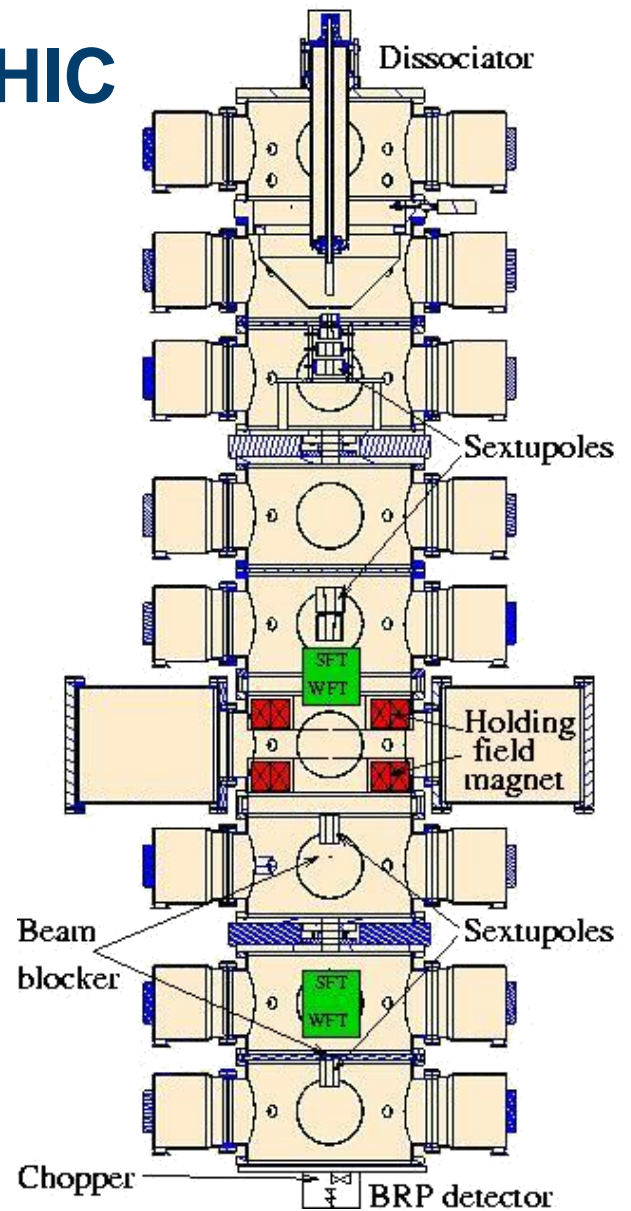


SAFETY ISSUES

- Interlock system of ABS ensures that in case of failure of components the system is isolated from the LHC vacuum
 - Fast shutters are used for the isolation
 - ABS is vented in case of glass tube breaking to avoid entering of cooling liquid
- Air cooled dissociator might be favorable **but** liquid cooled has better performance (shorter regeneration cycle)
- Vacuum system with 10000 l/s pumping speed using oil free pumps
 - Pressure in last chamber before LHC vacuum $\leq 10^{-7}$ mbar
 - Connection to LHC vacuum with CF-40 fast shutter

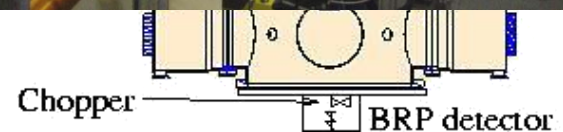
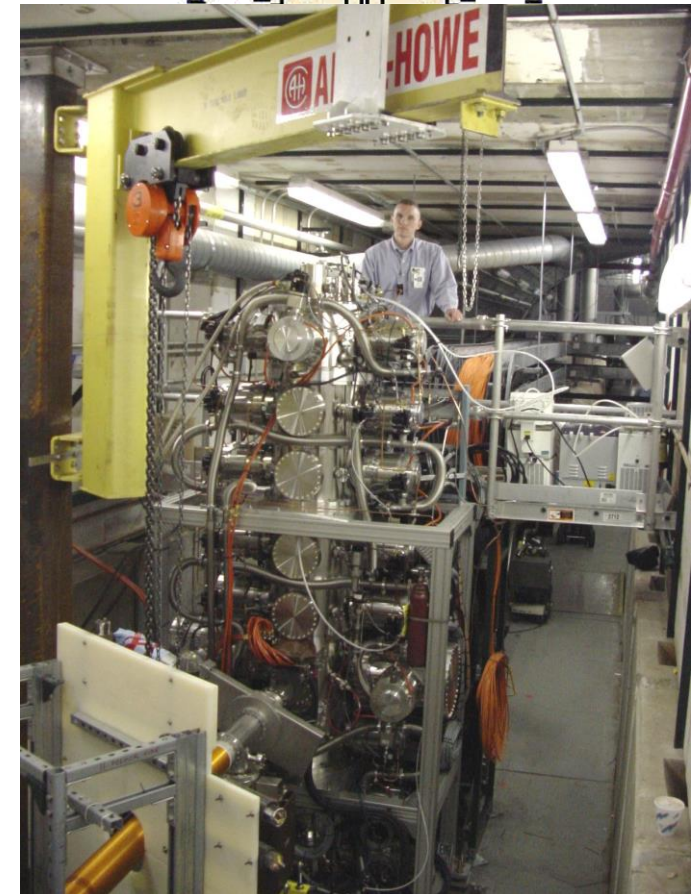
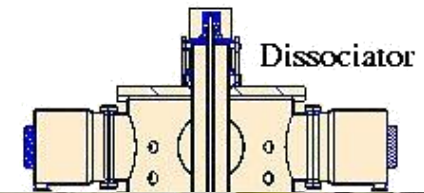
EXAMPLE: H-JET-TARGET @ RHIC

- H-Jet polarimeter at RHIC
- **Two** hyperfine states
- High (300 mT) vertical magnetic holding field produced by a pair of Helmholtz coils surrounded by another pair of Helmholtz coils to compensate the field for the beam and the detected recoil protons
- Jet density about 1.3×10^{12} atoms/cm²
- Polarisation of about 0.95
- Installed in 2004 and running since



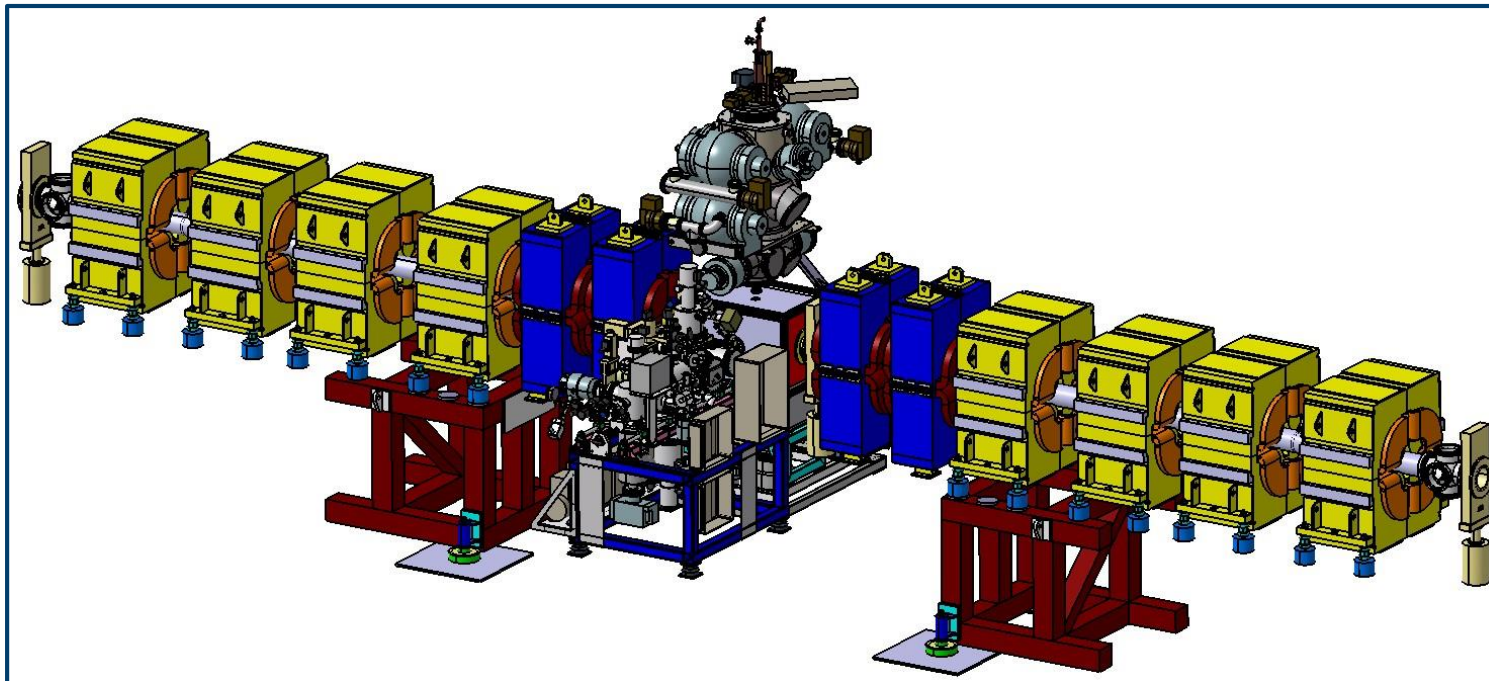
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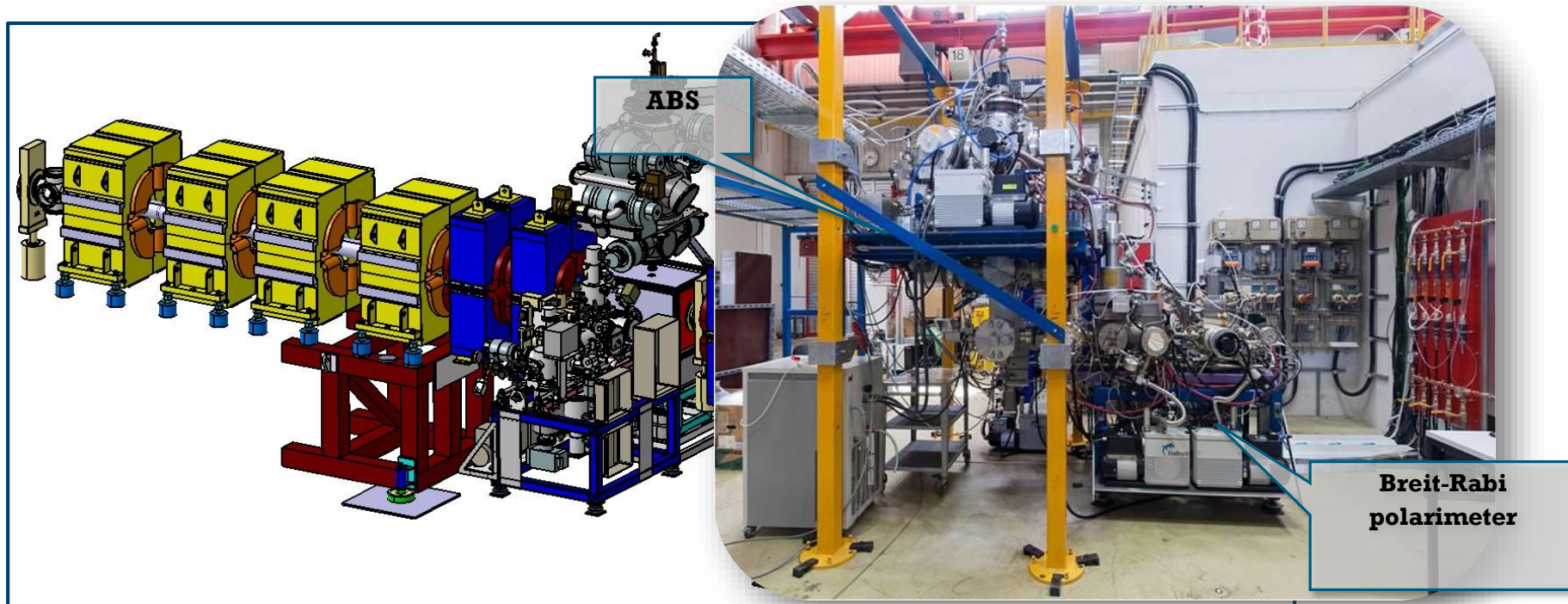
EXAMPLE: PAX STORAGE CELL TARGET

- PAX (former HERMES) polarized target
- **One** hyperfine state, Low (1 mT) xyz magnetic holding field
- Target thickness of about 5.5×10^{13} atoms/ cm²
- Polarisation of about 0.73
- Installed in COSY/Jülich in 2010-2014



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CONCLUSION

- Comparison of intensities of Atomic Beam Sources

