Università Degli Studi di Ferrara

Dottorato di ricerca in
Fisica
ciclo XXI

# Internal polarized gas targets: systematic studies on intensity and correlated effects

Settore scientifico disciplinare FIS/01

24/03/2009

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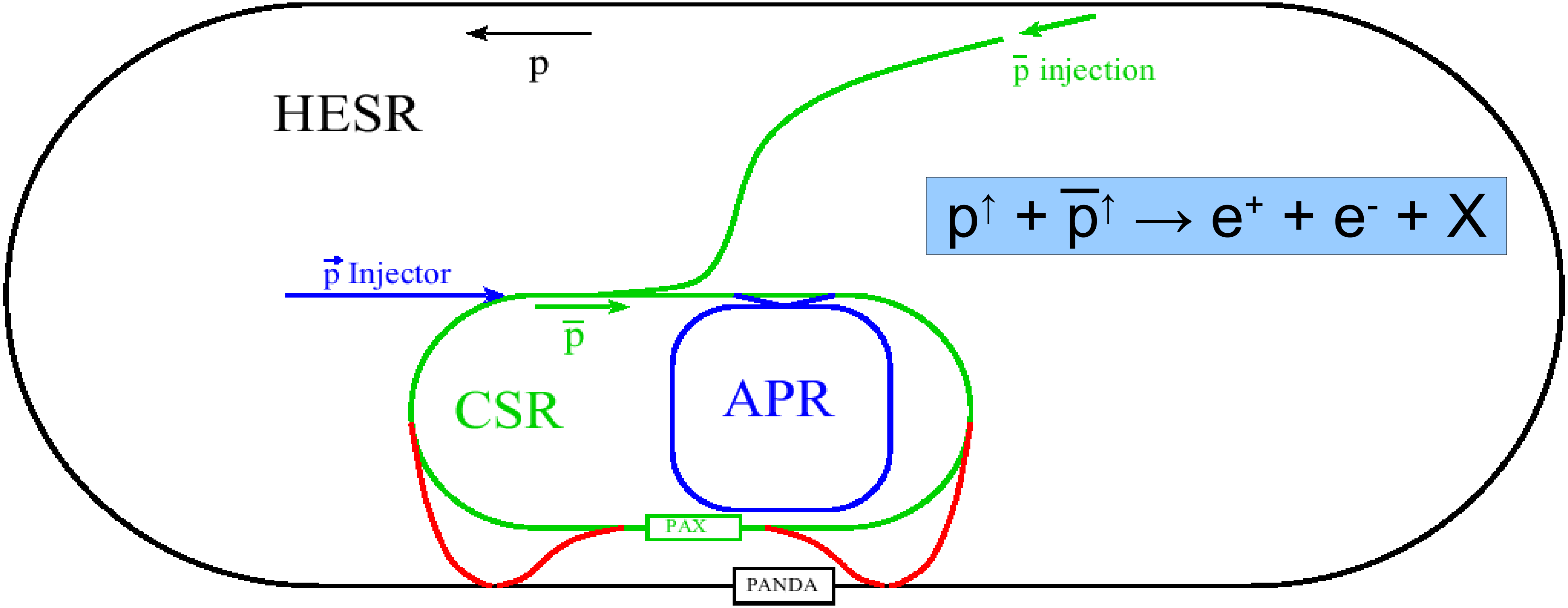
# FAIR in 2015(?)

# PAX experiment




$p^{\uparrow} + \bar{p}^{\uparrow} \rightarrow e^{+} + e^{-} + X$

FAIR @ GSI, Darmstadt

**Drell-Yan** to measure
transversity of nucleons

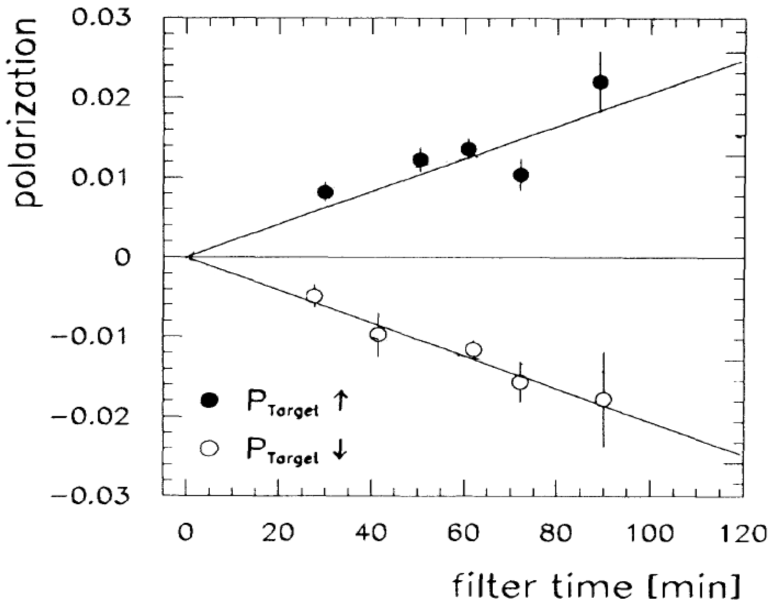
Requrements:
- stored intense p polarized beam in HESR ( 15 Gev/c )
- stored intense $\bar{p}$ polarized beam in CSR ( 3.5 GeV/c )

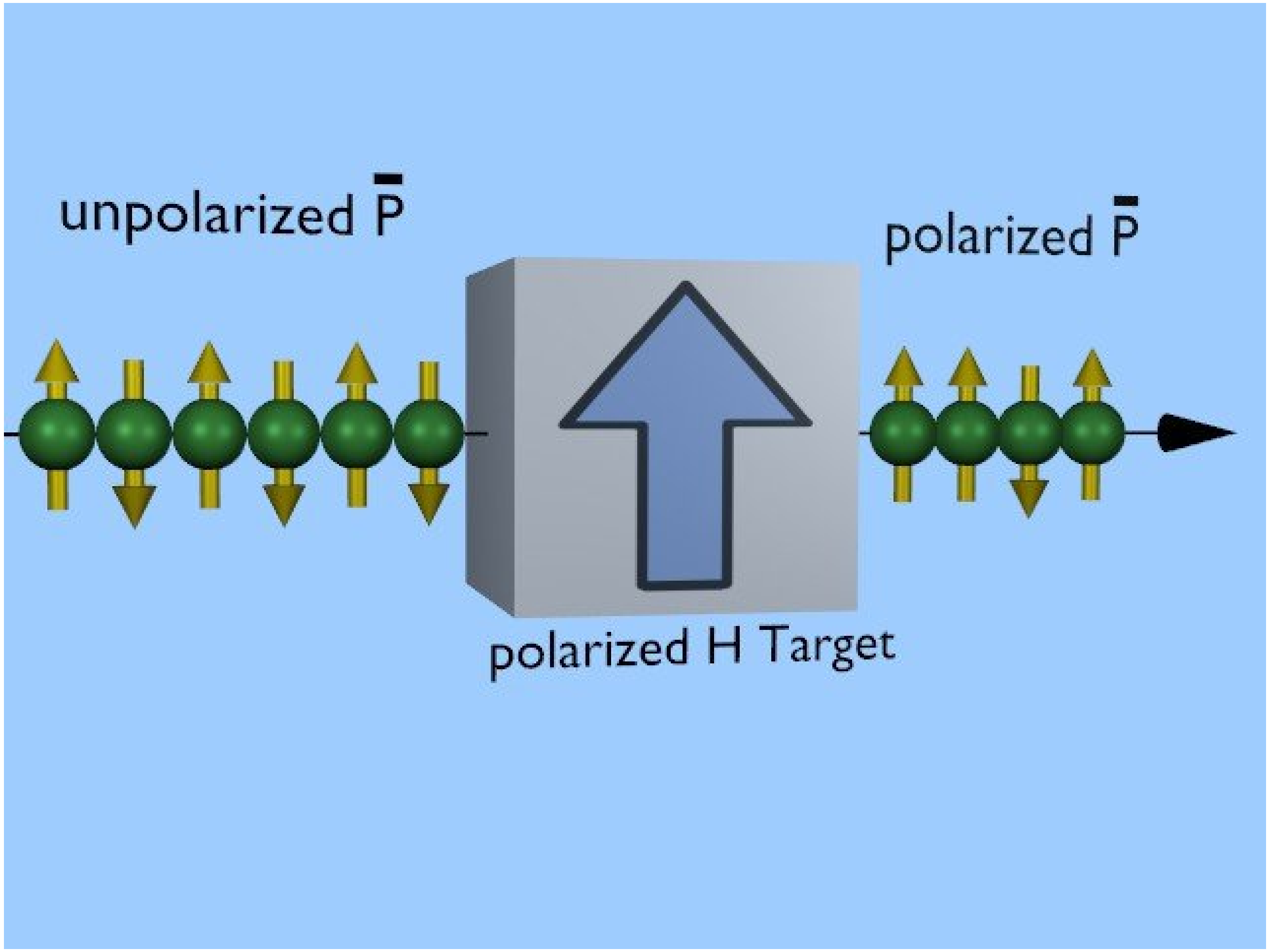
# Antiproton polarization

- ABS -> not possible
- Stern-Gerlach -> never tried
- Channeling -> never tested

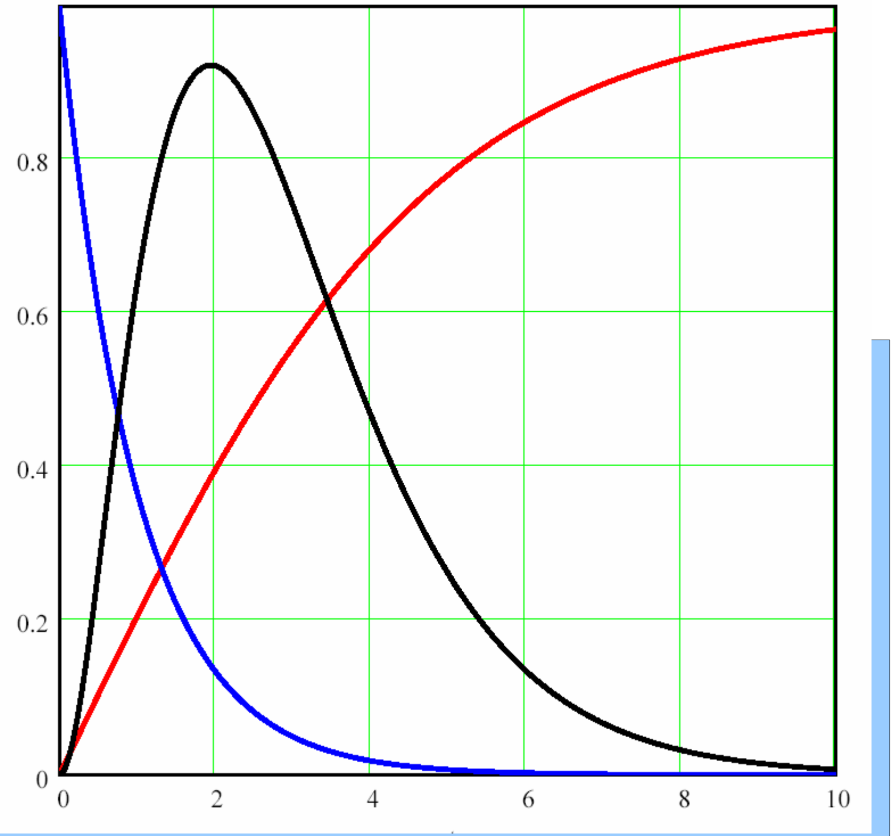
## Spin filtering

**Tested in FILTEX in 1992 (p)**



# Figure Of Merit
## (for polarization)




$FOM(t) = P(T)^2 \cdot I(T)$

P antiproton beam polarization
I antiproton beam intensity
T time

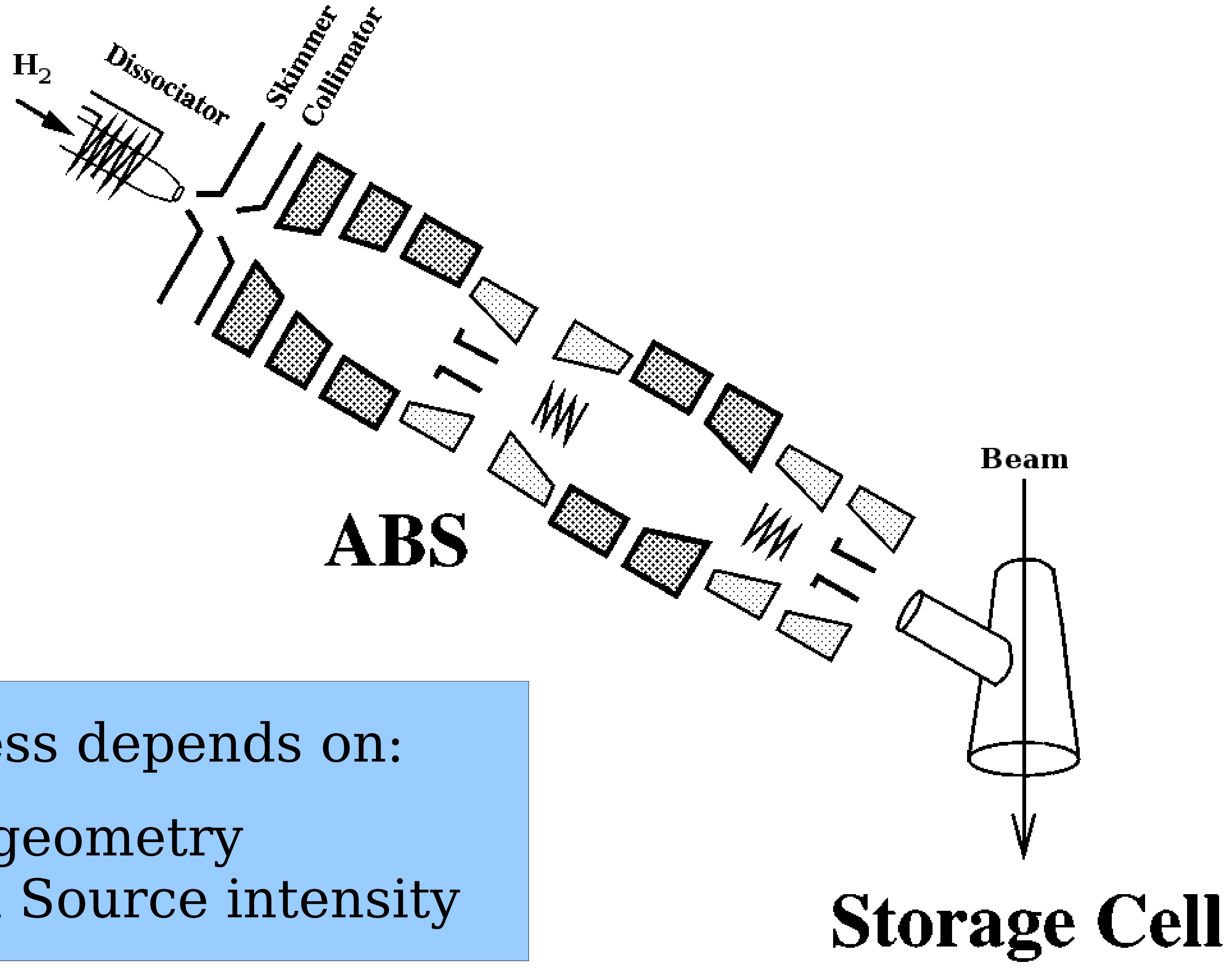
Optimum filtering time:
$T_0 = 2\ \tau_B$ ($\tau_B$ beam lifetime, time to reduce beam intensity to $I_0/e$)

Beam lifetime depends on target thickness
(present target thickness $t=10^{14}$ at/cm$^2$)

$$T_0 \propto \frac{1}{t}$$

→ Increase in target density is desirable
(to decrease filtering time)

# Polarized gas target



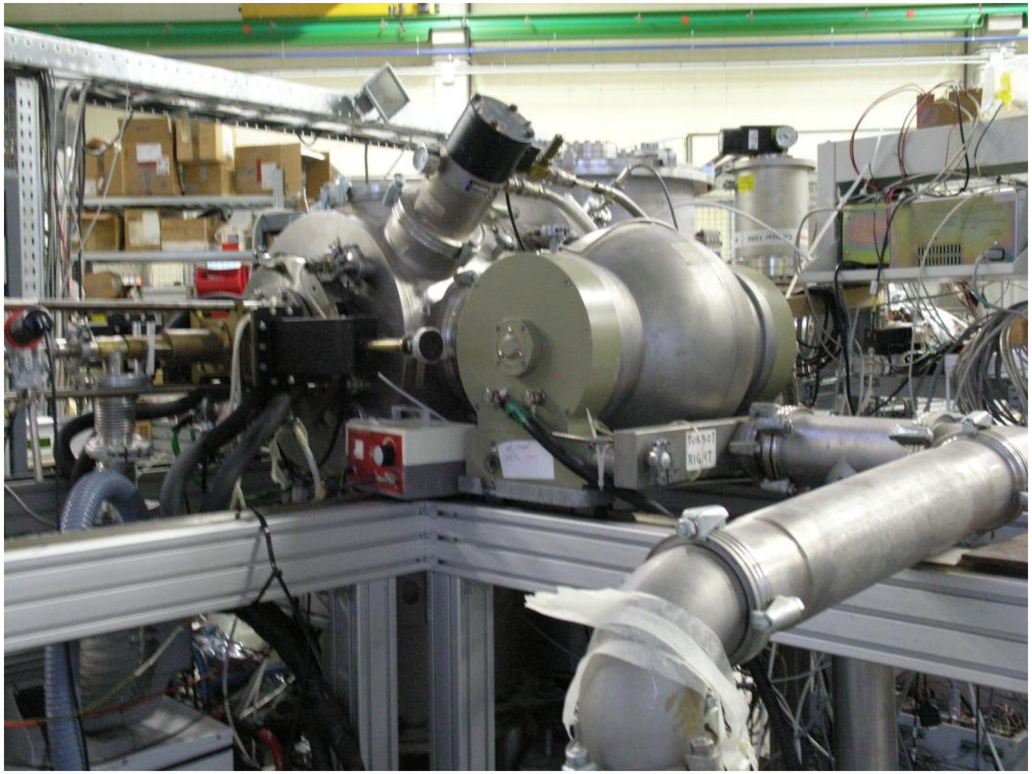

Target thickness depends on:

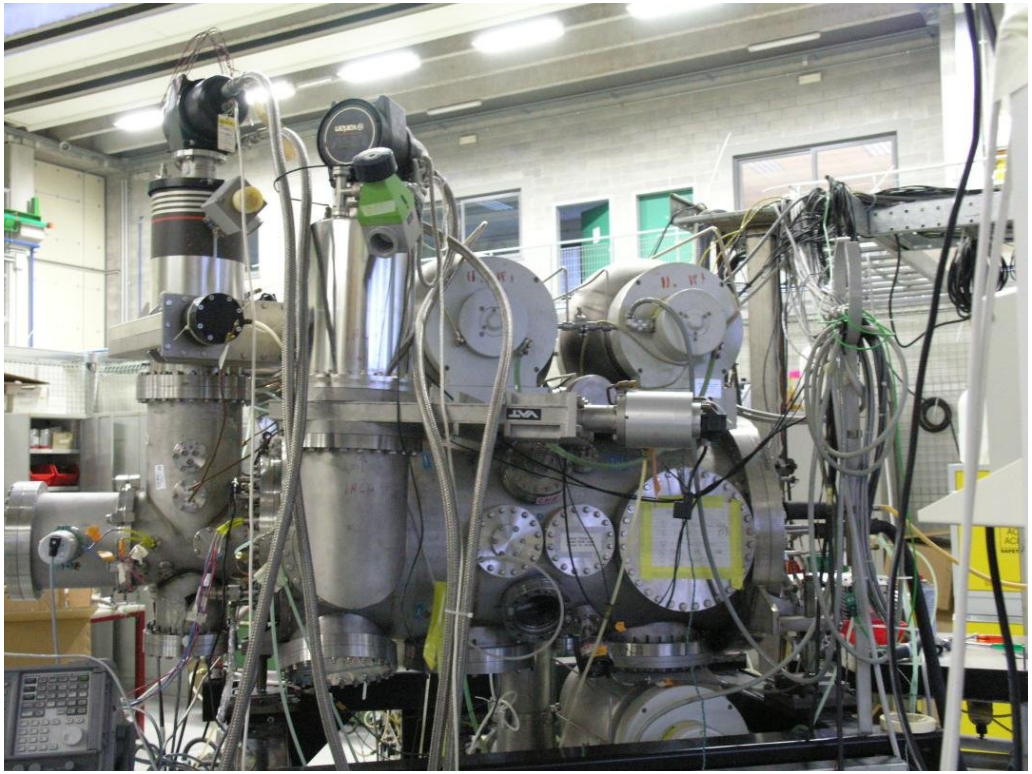
- Storage cell geometry
- Atomic Beam Source intensity

# Spin Lab

**ABS1**
(CERN)

**ABS2**
(Wisconsin)

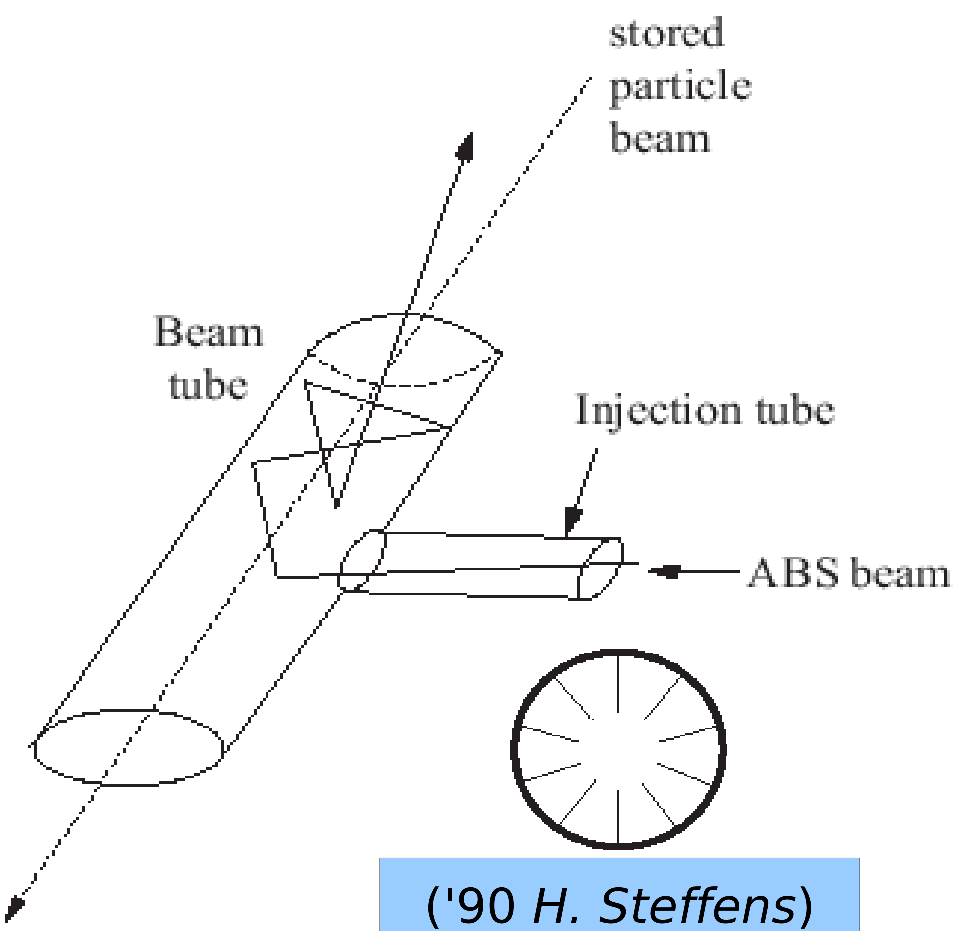




ABS intensity

**Modification to storage cell**

# Effects of modified storage cell




('90 *H. Steffens*)

Thickness of gaseous target:

$$t = \frac{I\,L}{C_{tot}} \quad \left[\frac{at}{cm^2}\right]$$

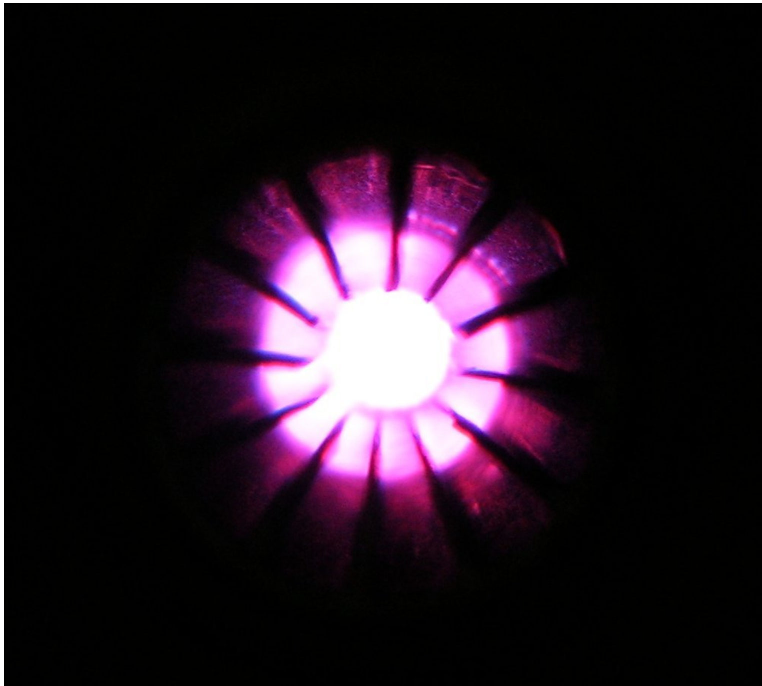
$$C_{tot} = 2\,C_{beam} + \boldsymbol{C_{inj}} \quad [cm^3/s]$$

I intensity of beam to the cell [at/s]
L beam tube half length
M molec/at gas mass

W. Haeberli, E. Steffens, Rep. Prog. Phys. 66 p 1887 (2003)

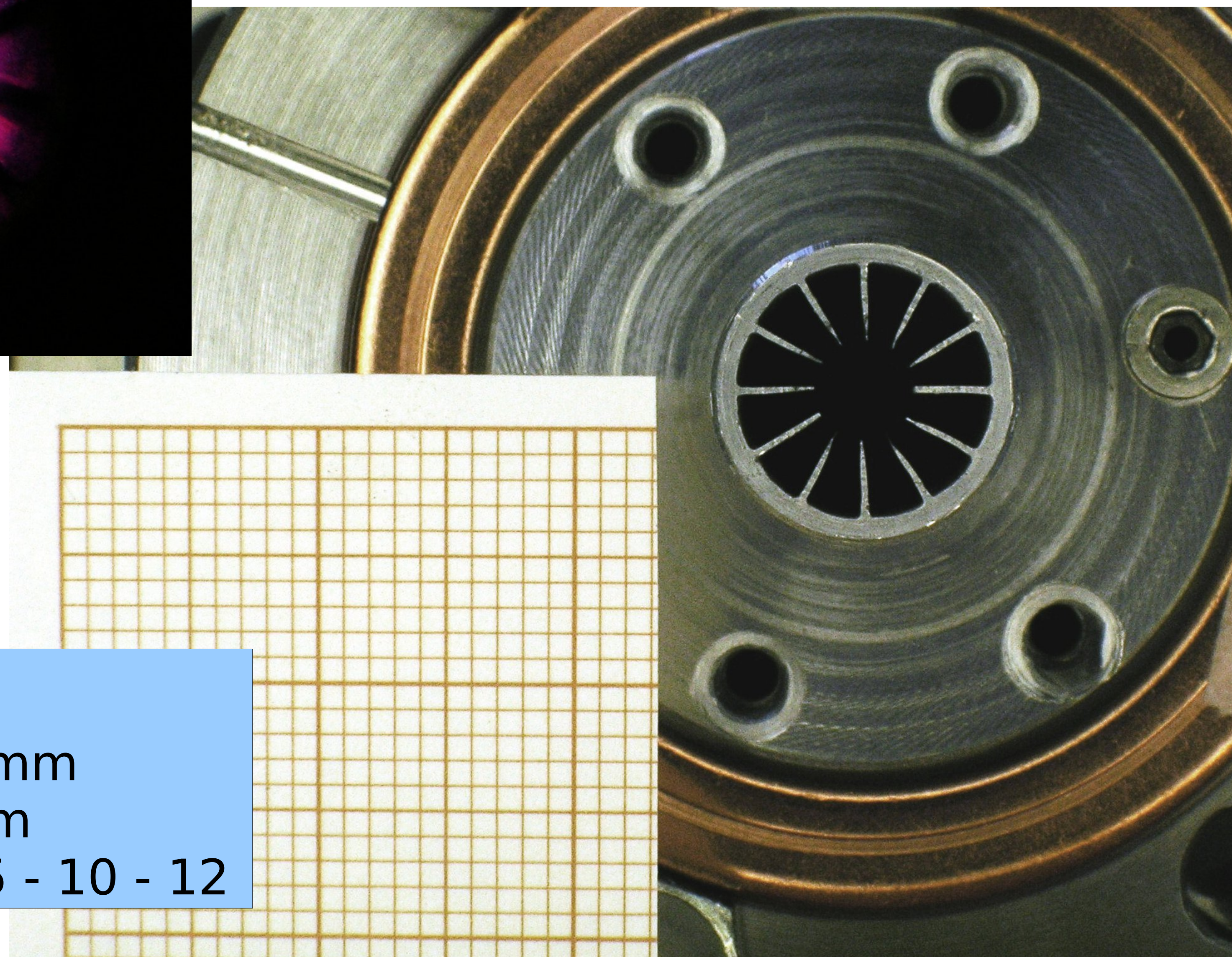
$$C = \frac{8}{3\sqrt{\pi}}\left(2\,k_B\,\frac{T}{M}\right)^{1/2}\left(\frac{A^2}{\boldsymbol{s}\,L}\right)$$

Vacuum Technology - Roth A (1990)



# Finned injection tube

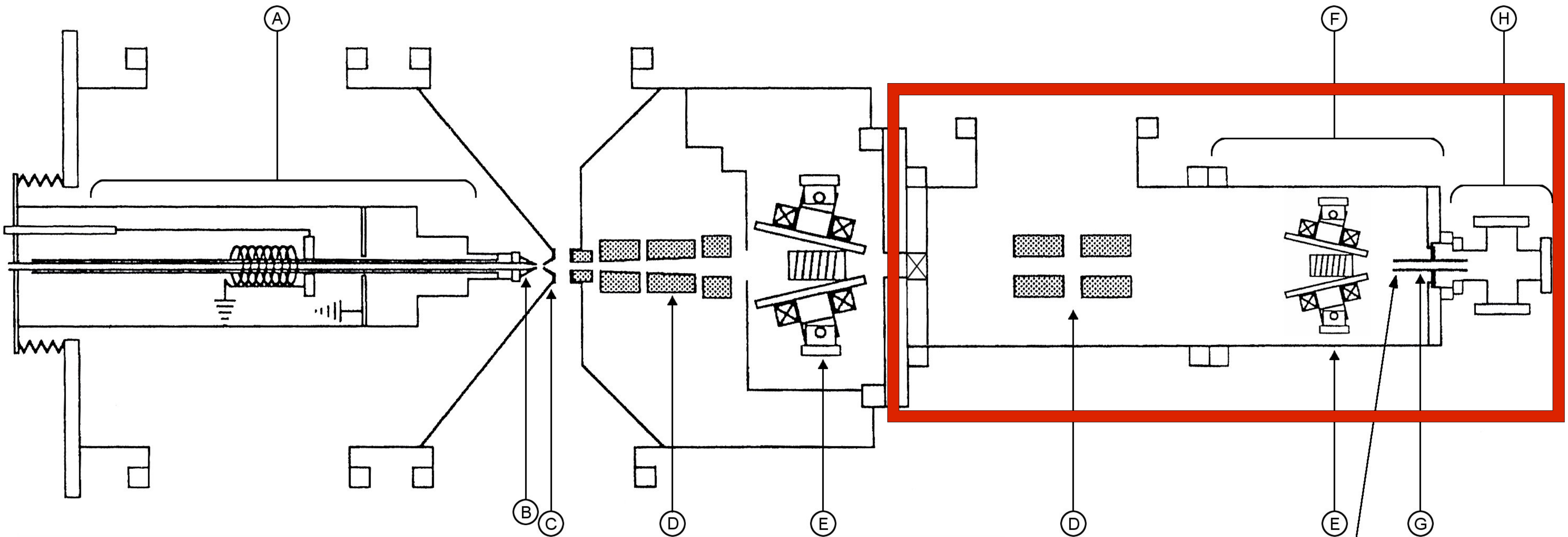
**(mounted on test stand)**

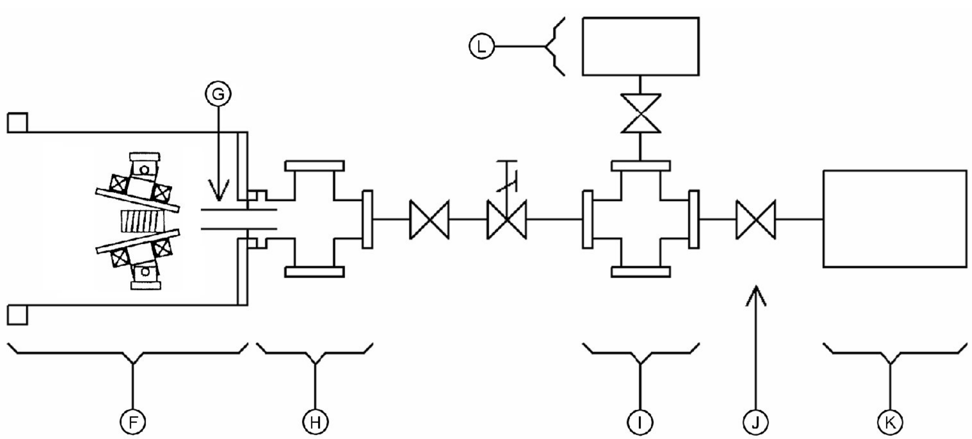


**Fins**

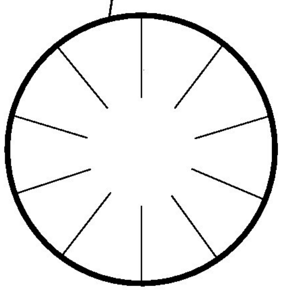
| | |
|---|---|
| Thickness: | 0.2 mm |
| Length: | 3 mm |
| Number: | 0 – 5 - 10 - 12 |

# Test stand (ABS2)



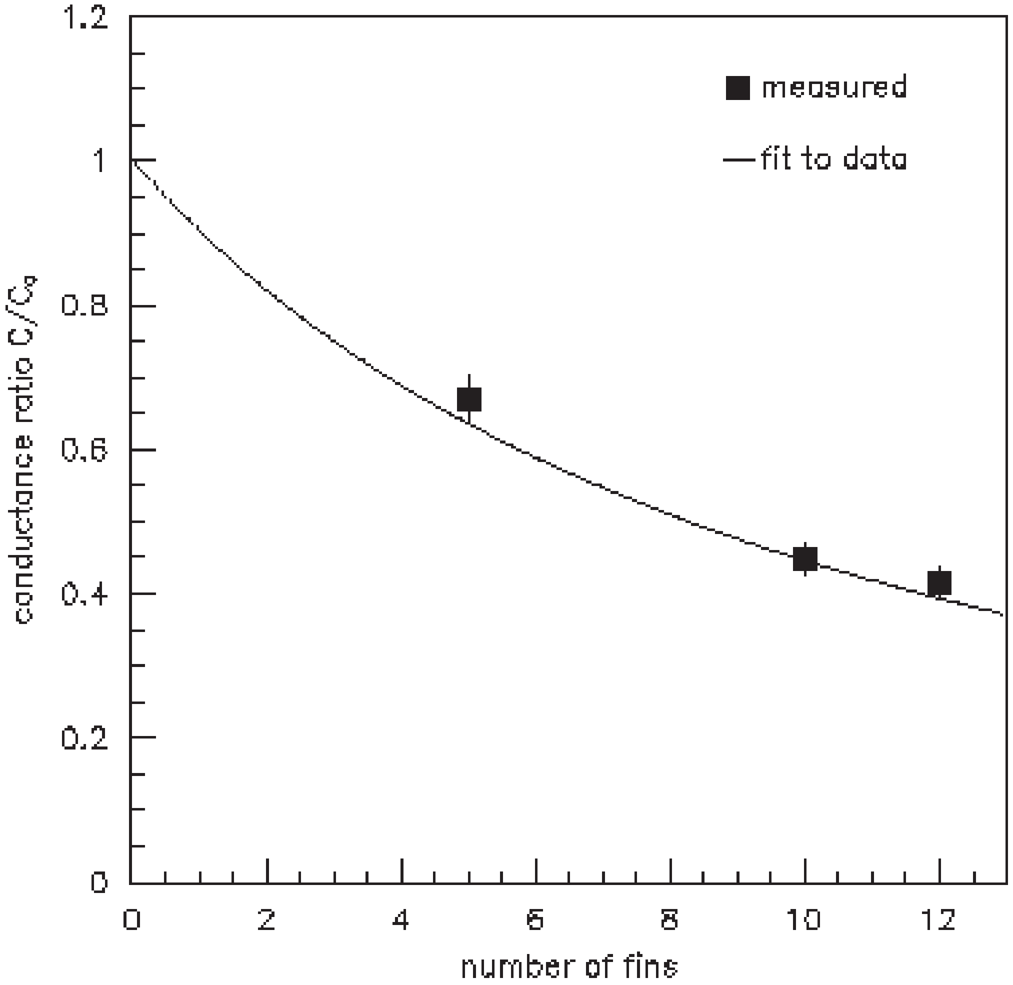

B) Nozzle
C) Skimmer
G) Compression Tube
H) Compression Volume
I) Vcal



$$I = \frac{2}{K_B T} \cdot P_{CV} C_{inj}$$

[at/s] [Pa m$^3$/s]

# Relative conductance
## (meas + fit)




$C = Q/P_{cv}$

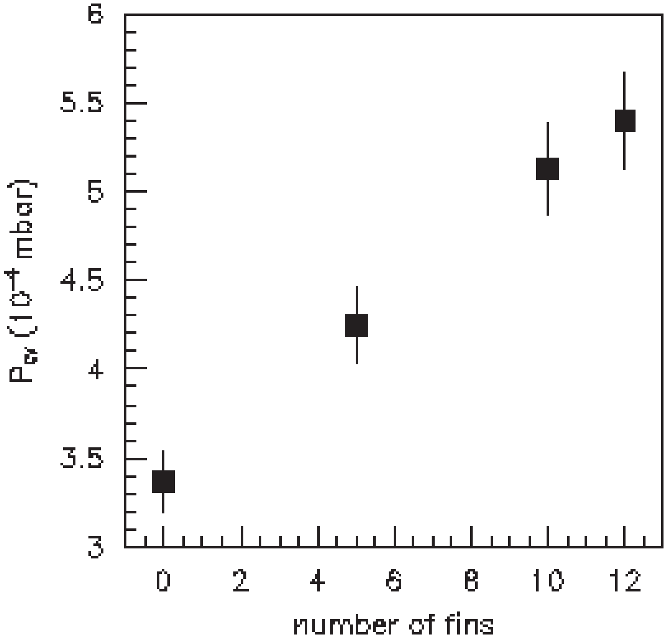
$$C = \frac{8}{3\sqrt{\pi}}\left(2\,k_B\frac{T}{M}\right)^{1/2}\left(\frac{A^2}{\mathbf{s}\ L}\right)$$

# CV intensity

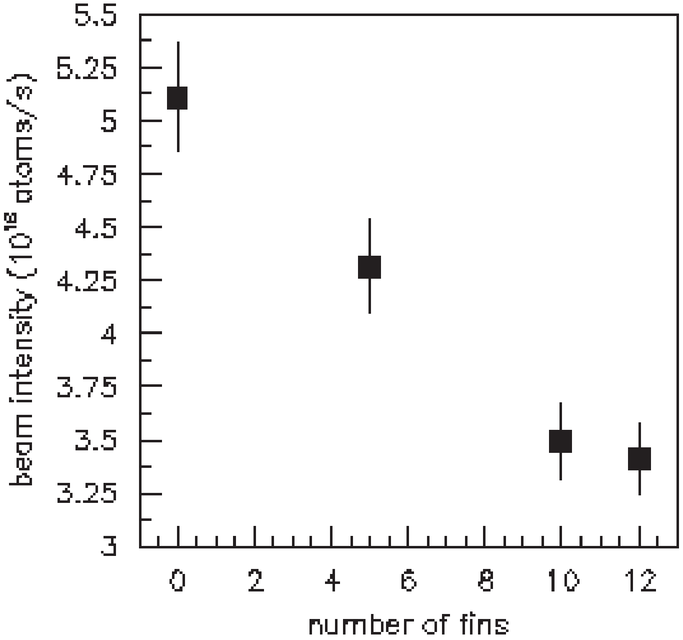
$$t = \frac{I\,L}{C_{tot}}$$

$$I = \frac{2}{K_B T} \cdot P_{CV}\, C_{inj}$$

Pressure (meas)



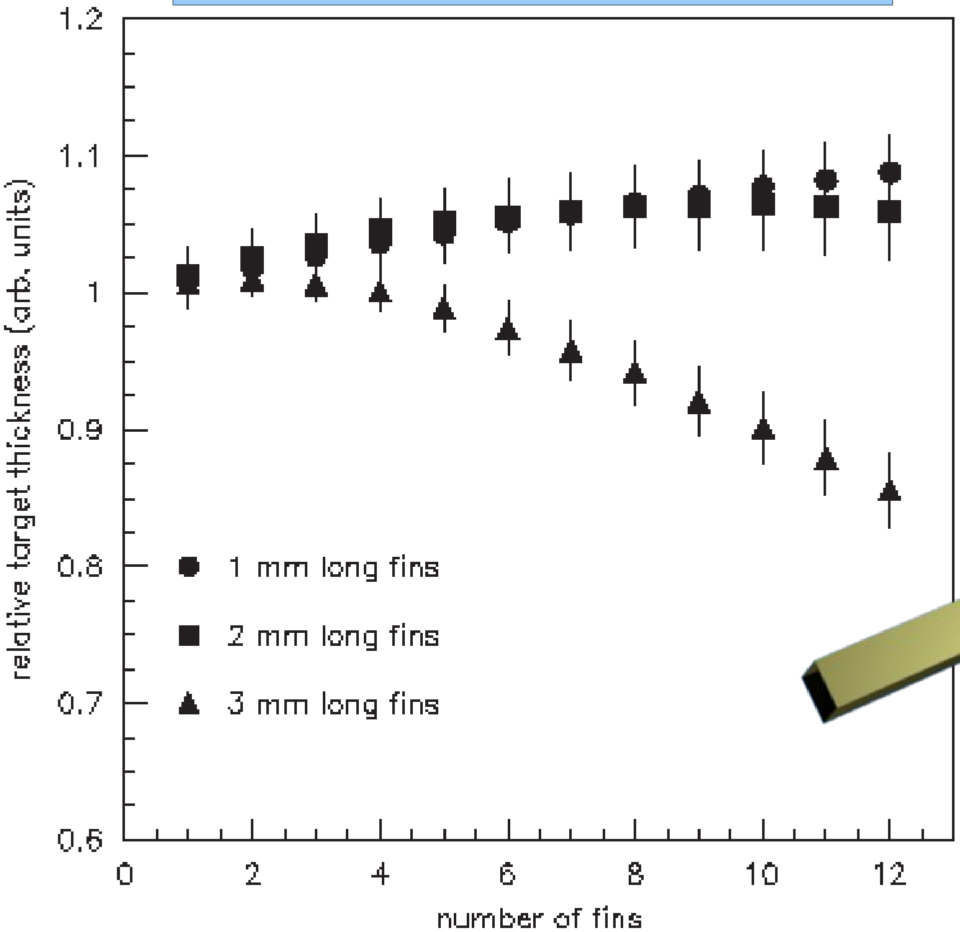

Intensity (calculated)

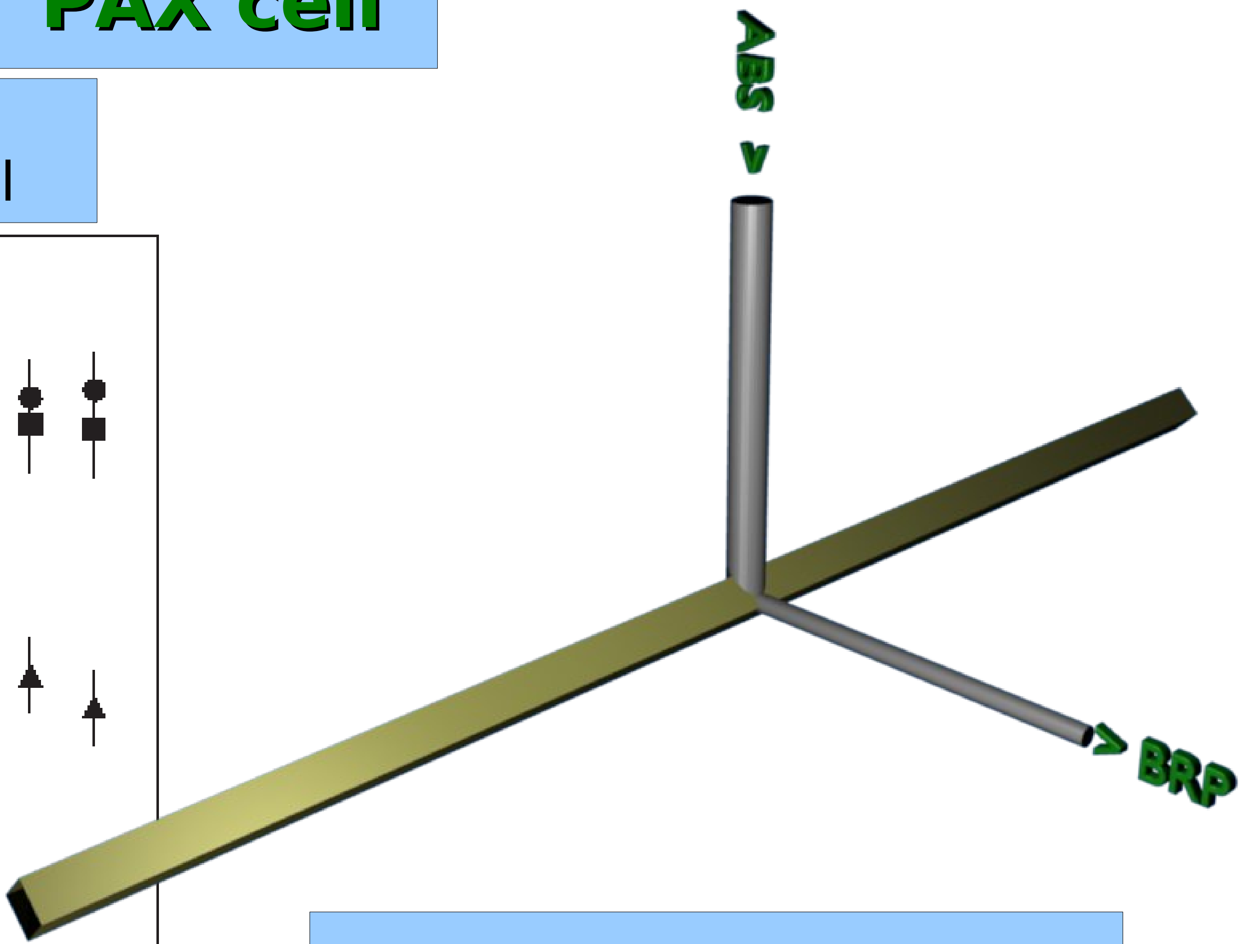



Intensity decrease larger than expected

# PAX cell

Relative target thickness for PAX cell




For PAX cell ($C_{INJ}$ 39%) geometry no useful results

(lower conductance but also lower beam intensity)

# First evidence of azimuthal velocity component of the atomic beam

Intensity drop ($I/I_0$) is bigger than expected: necessary to consider **azimuthal component** of atoms velocity (new!)

Calculations with surfaces of area 2 - 3 - 4 mm used as "**starting generator surface**"

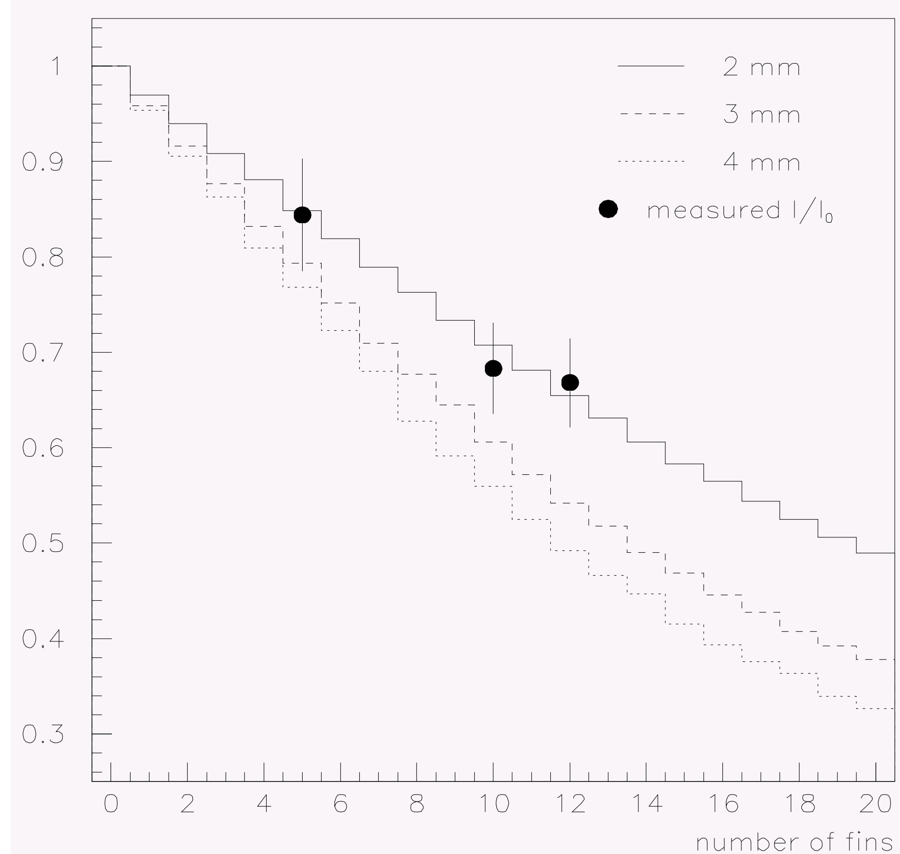
▼

Match with 2mm (like nozzle)

$z_{SGS}$ independent for 0-30 mm

*Nuclear Instruments and Methods in Physics Research A 594 (2008) 126-131*

$I/I_0$ vs. number of fins

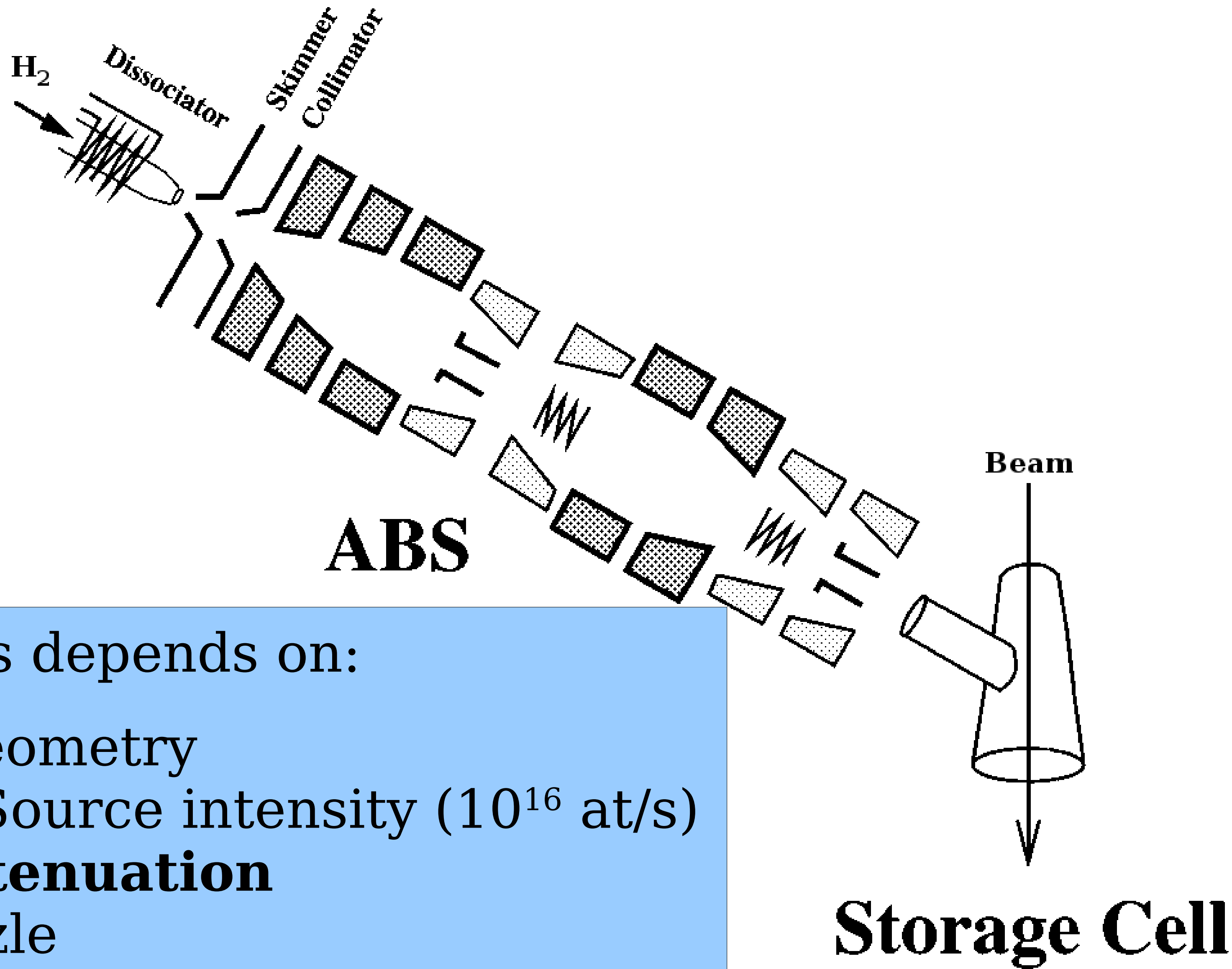



SCAN (sextupole tracking software)



#

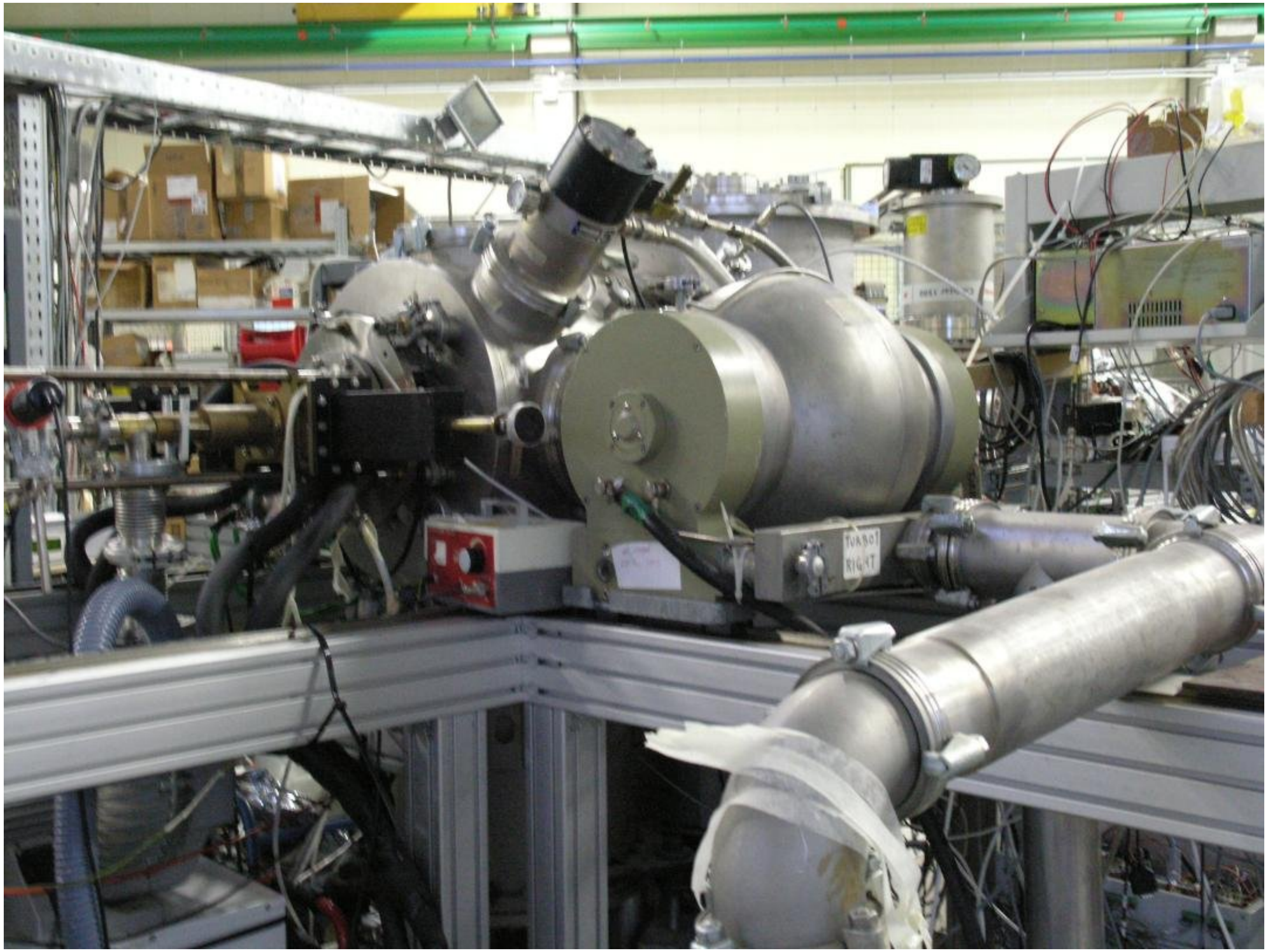
# Polarized gas target



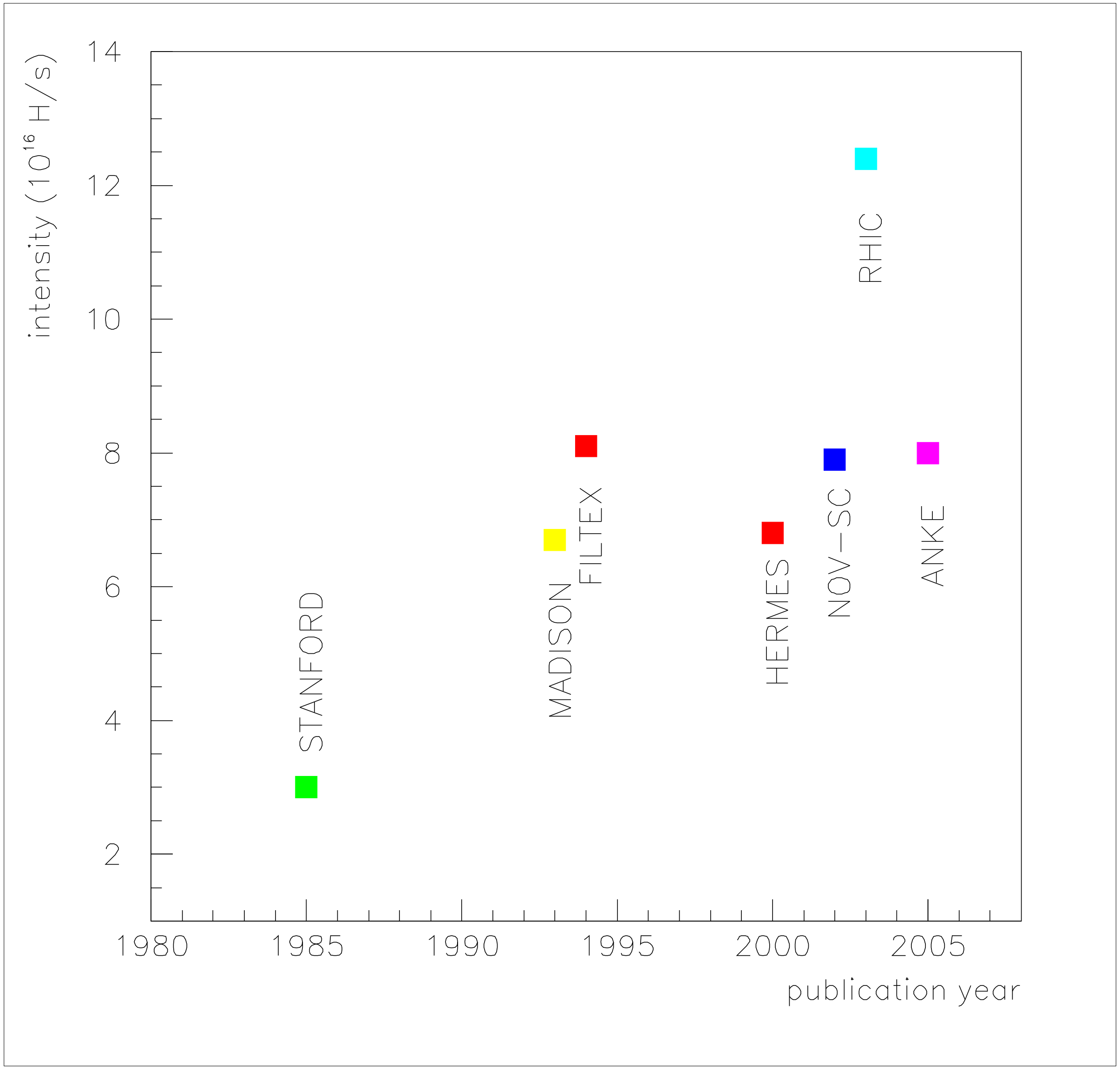

Target thickness depends on:

- Storage cell geometry
- Atomic Beam Source intensity ($10^{16}$ at/s)
  - **Rest Gas Attenuation**
  - Trumpet nozzle

# Rest Gas Attenuation measurements on H/D beams



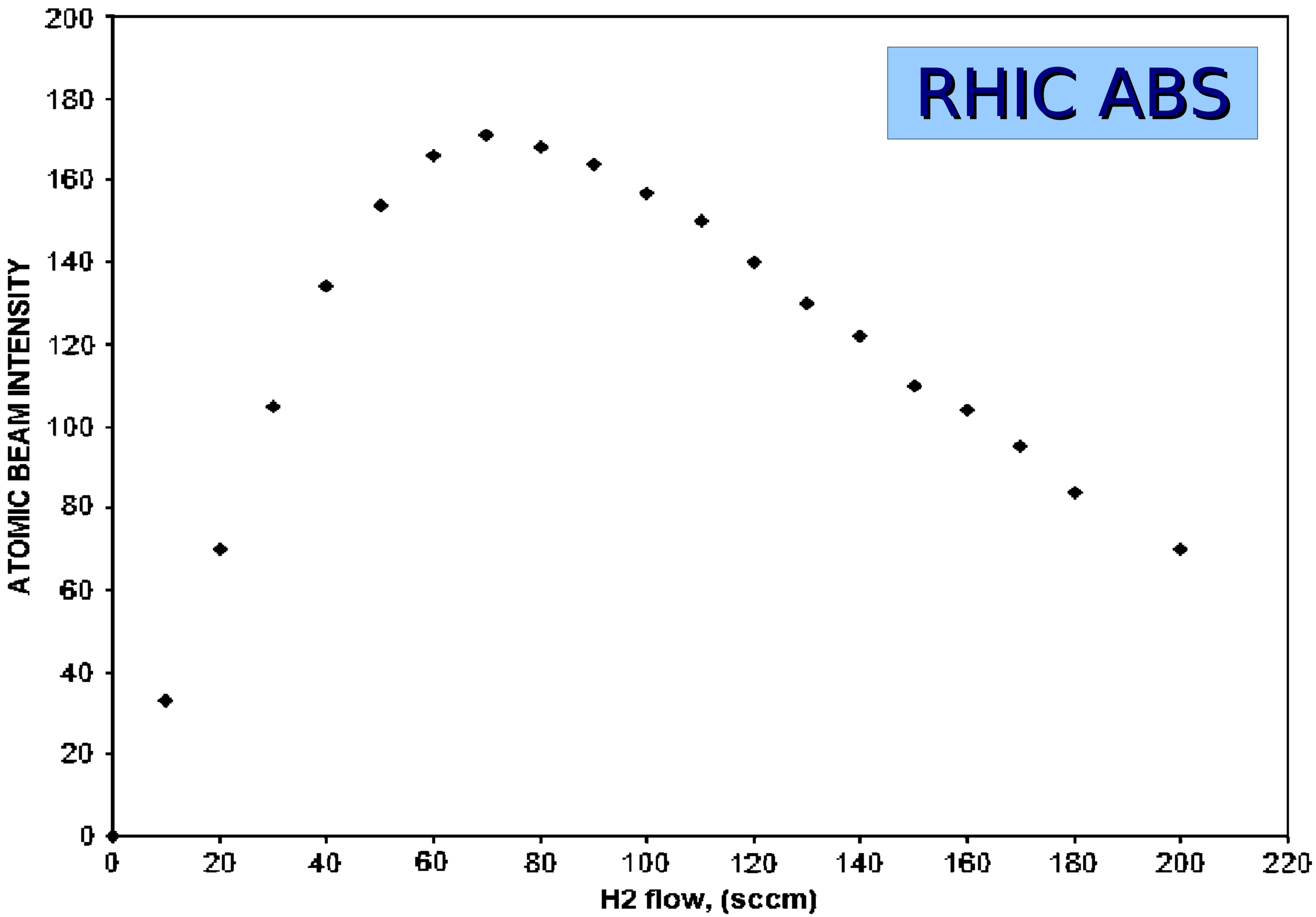
# Intensity of world ABS




- Intra Beam Scattering
- Rest Gas Attenuation

RHIC still unexplained

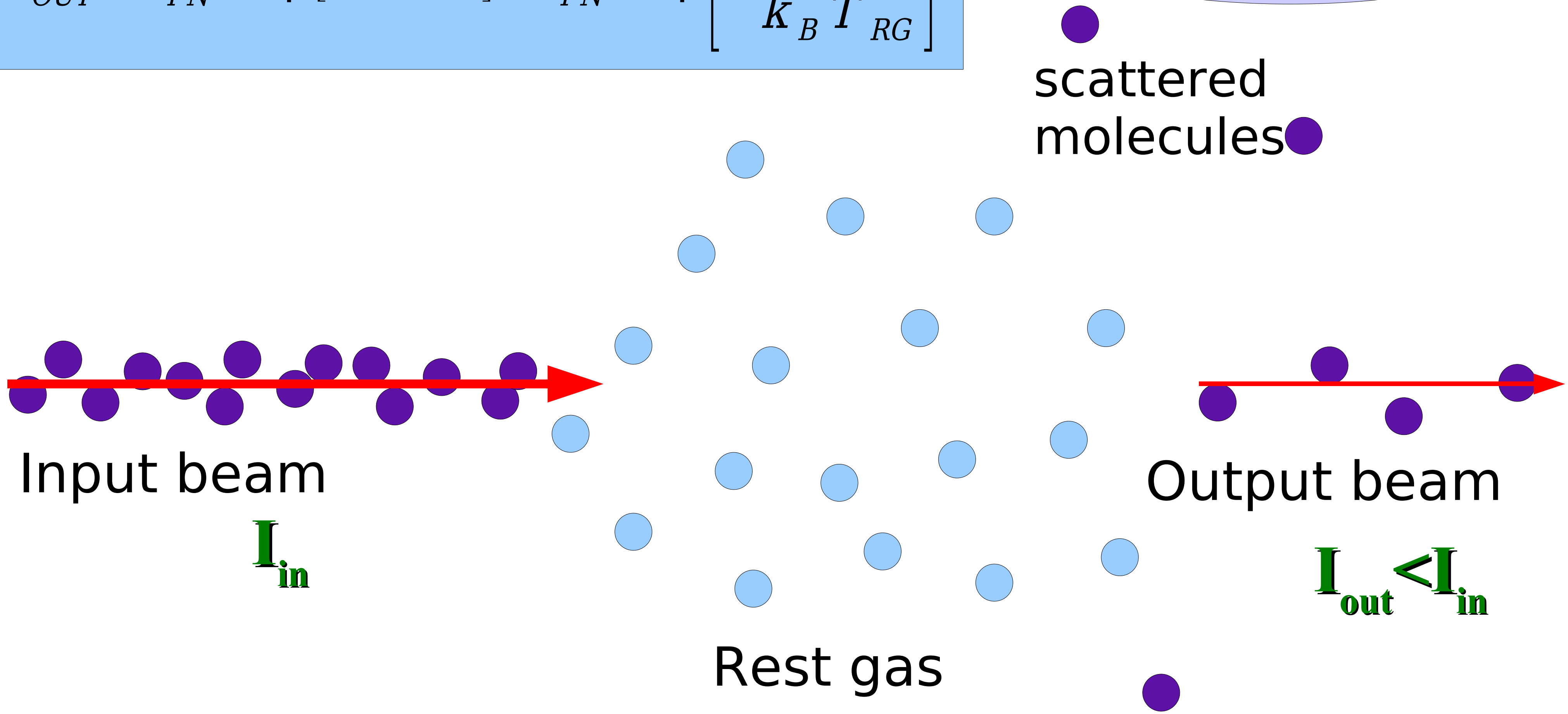
# ABS beam intensity
## (how to increase it)



# Interaction beam - rest gas

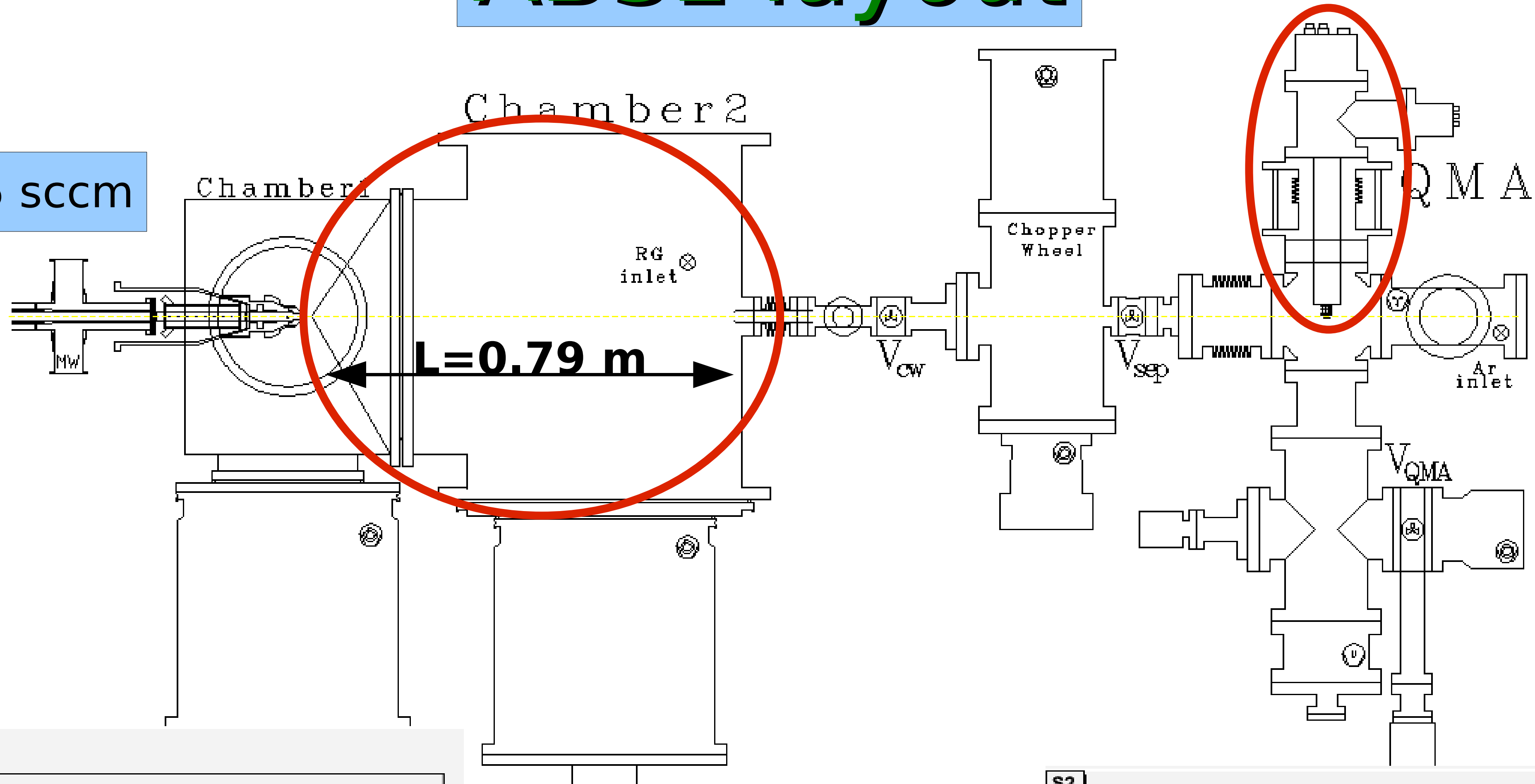
$$I_{OUT} = I_{IN} \cdot \exp[-\boldsymbol{A}\, n\, L] = I_{IN} \cdot \exp\left[-\frac{\boldsymbol{A}\, P\, L}{k_B\, T_{RG}}\right]$$

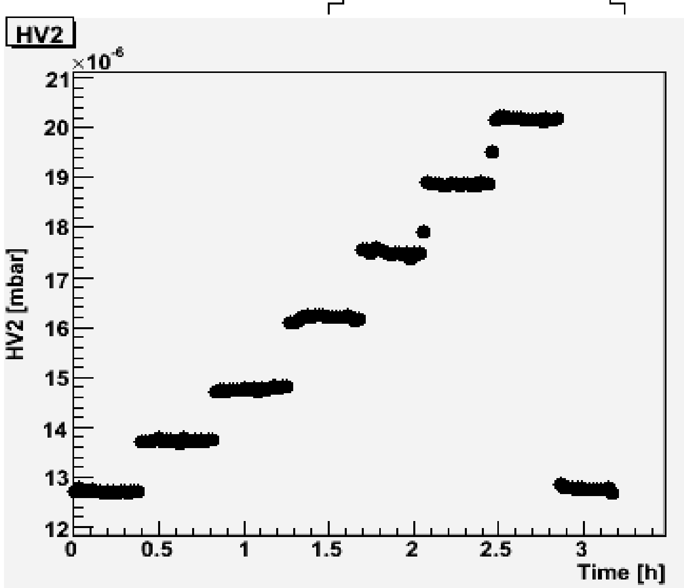
**A**
attenuation coefficient

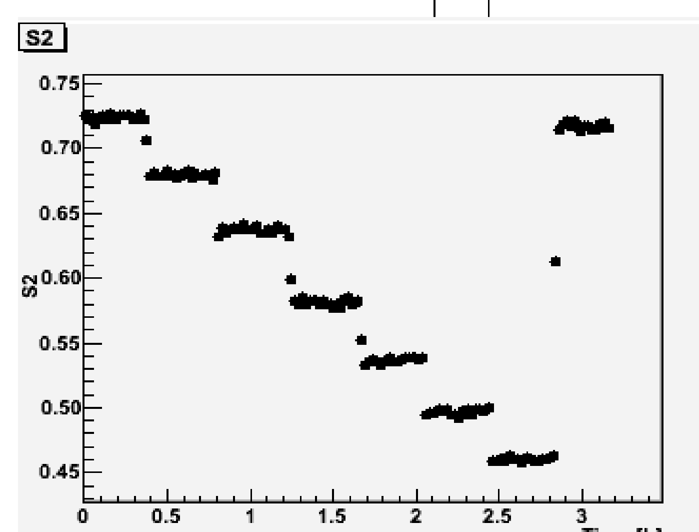


# ABS1 layout

125 sccm

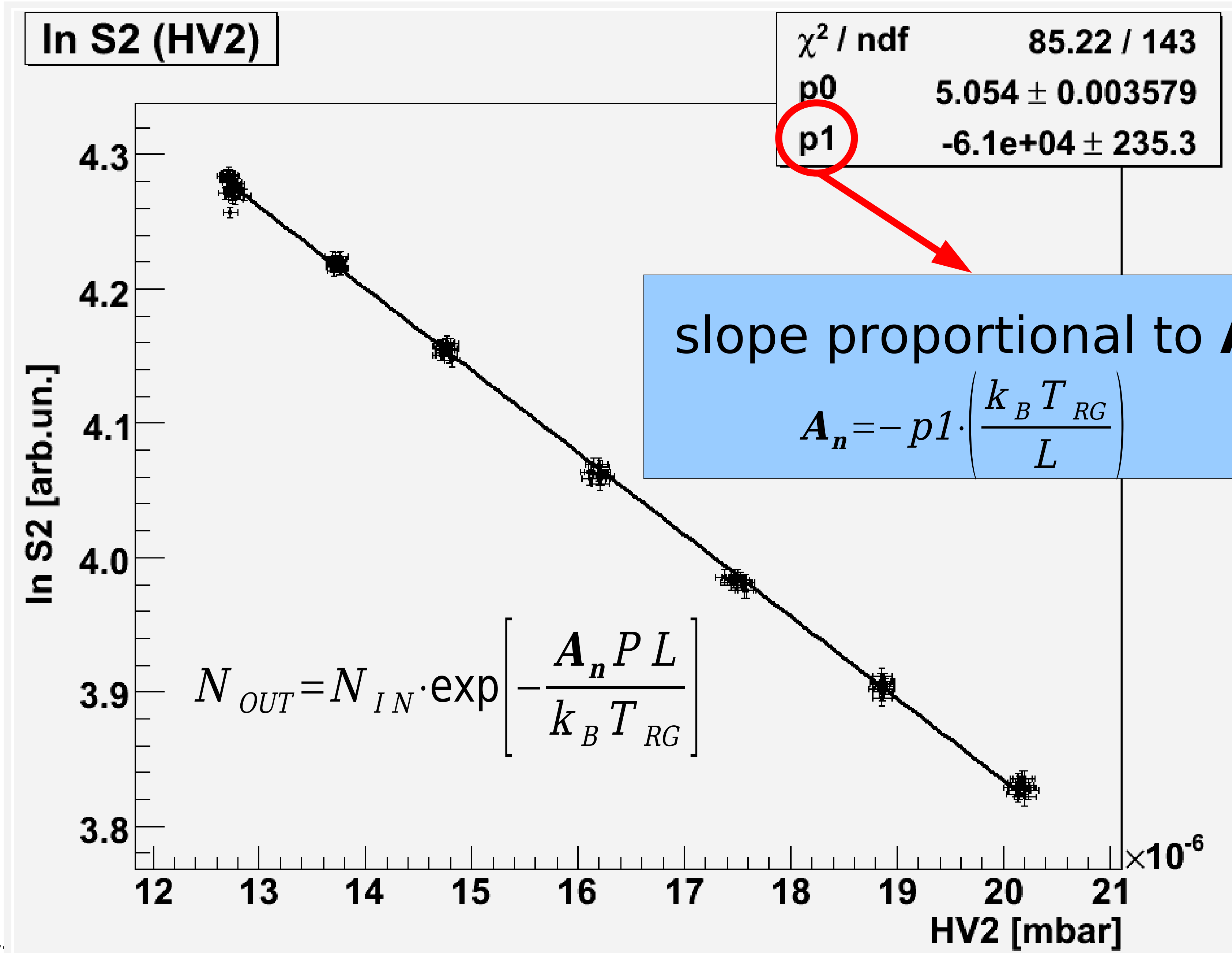


# Measurements

Set 1 (mol)
$T_{noz}$ 55 K

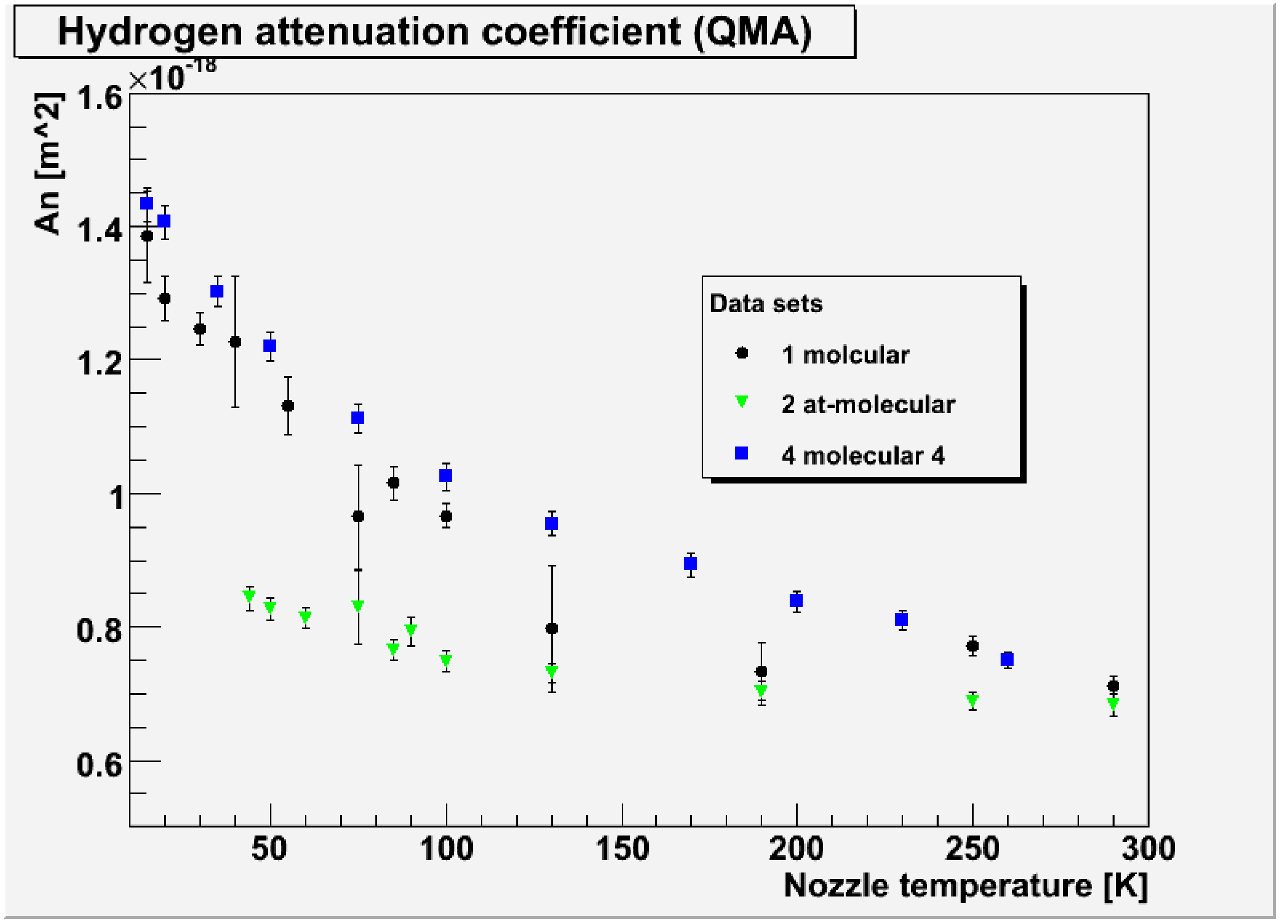



slope proportional to $\mathbf{A_n}$

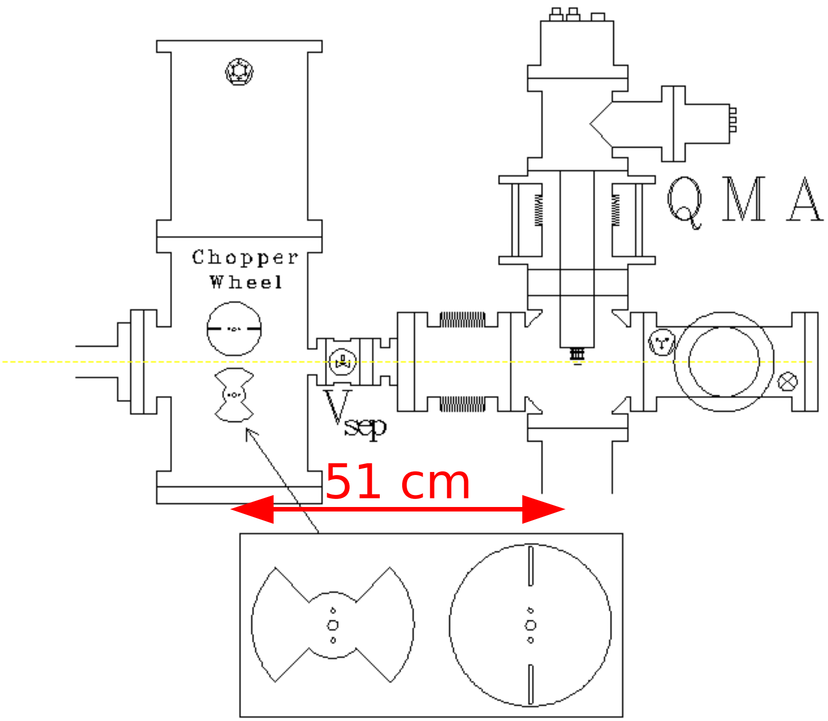
$$\boldsymbol{A_n} = -p1 \cdot \left( \frac{k_B T_{RG}}{L} \right)$$

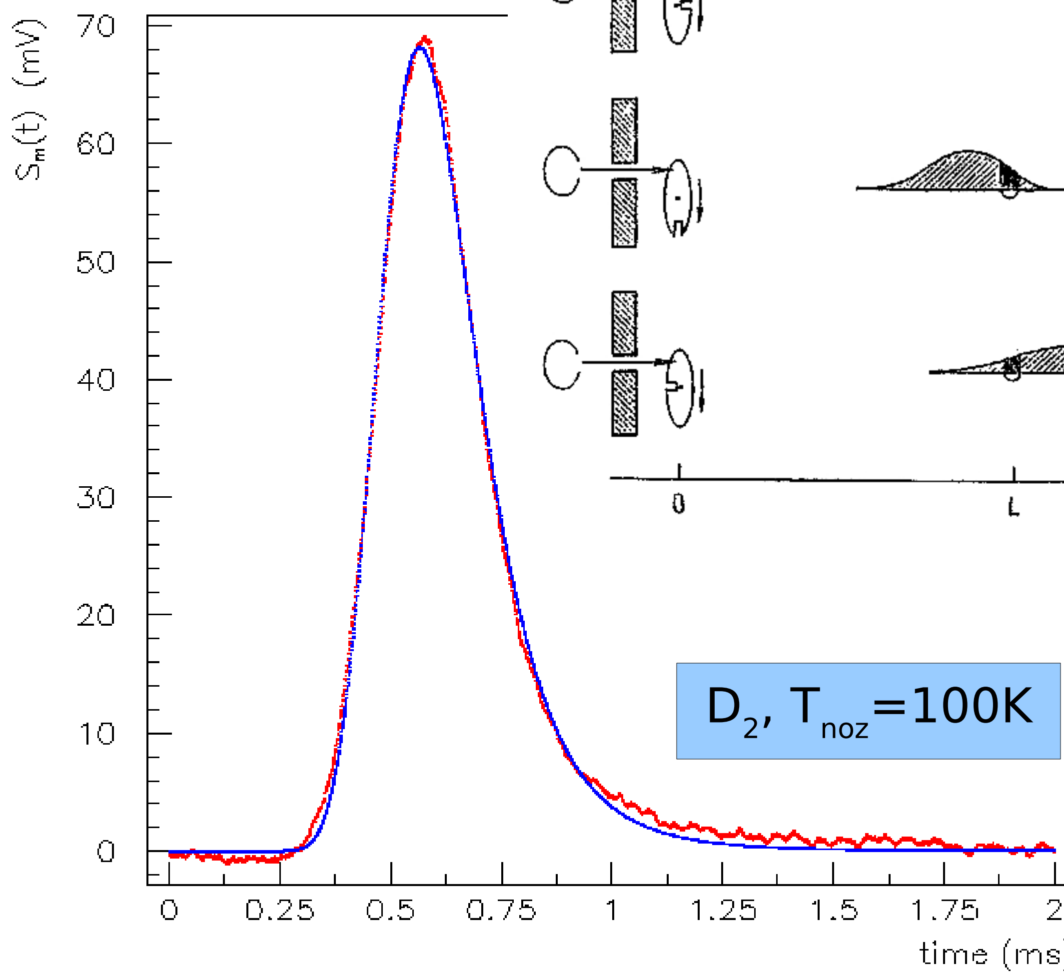
$$N_{OUT} = N_{IN} \cdot \exp\left[ -\frac{\boldsymbol{A_n} P L}{k_B T_{RG}} \right]$$

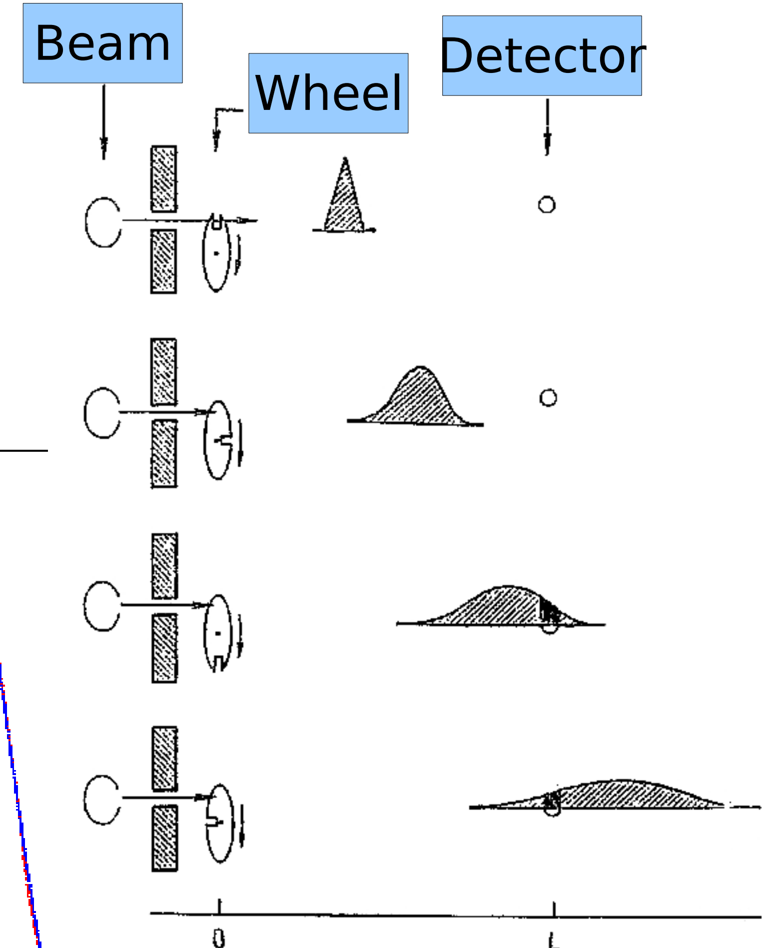
# Attenuation coefficient as function of $T_{nozzle}$ (standard in literature)



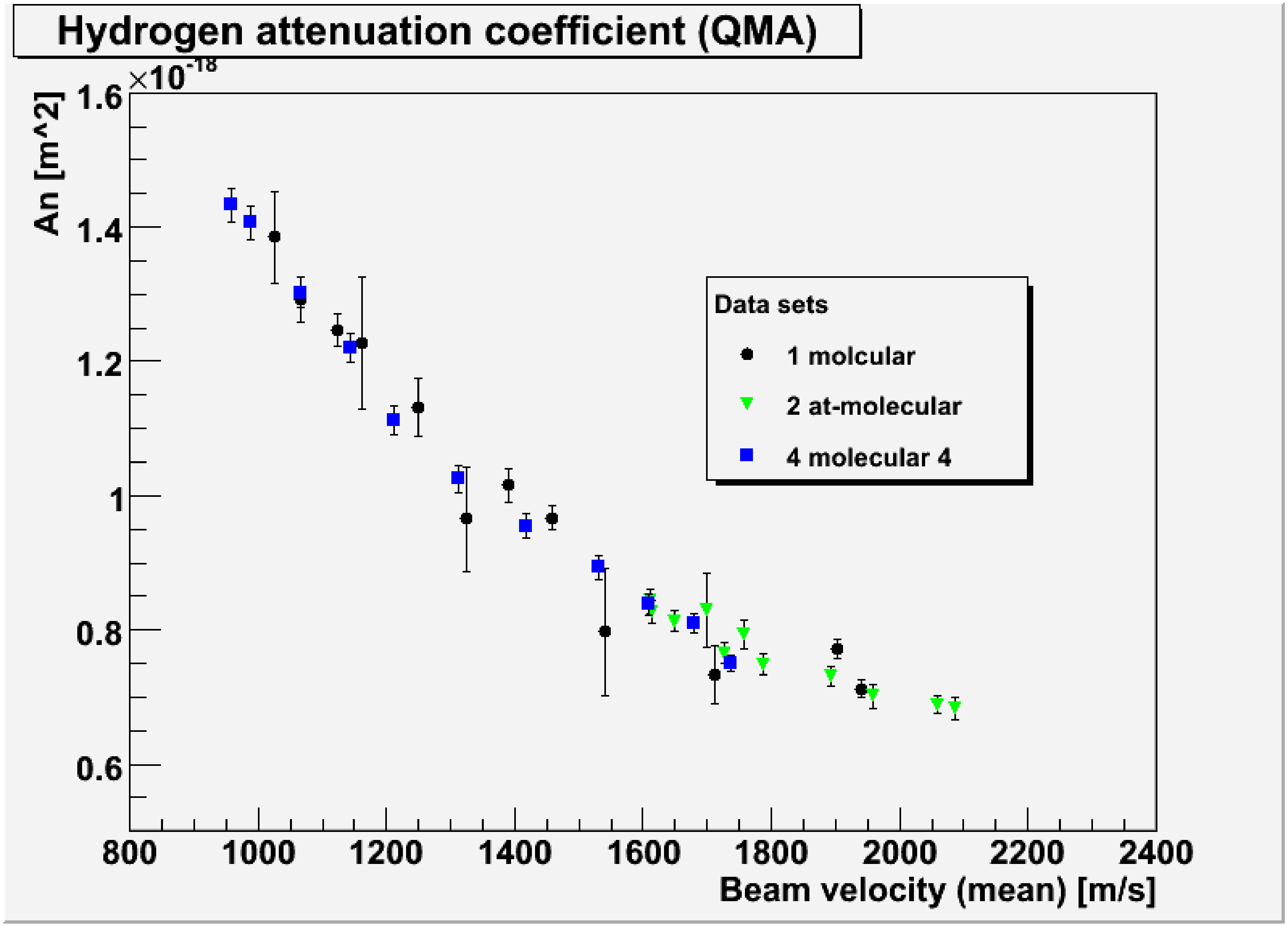
# Time Of Flight (TOF)
## (working principle)



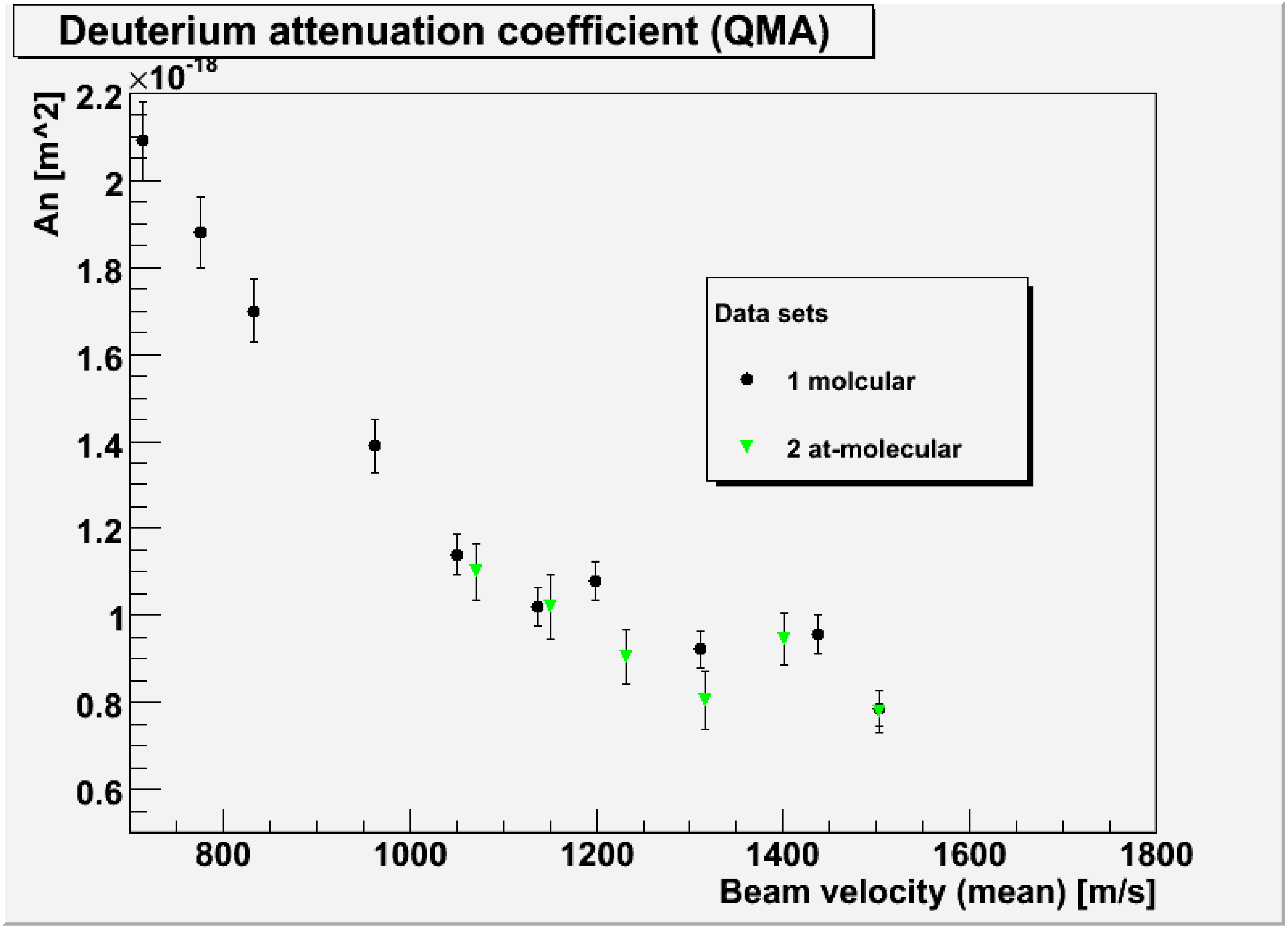



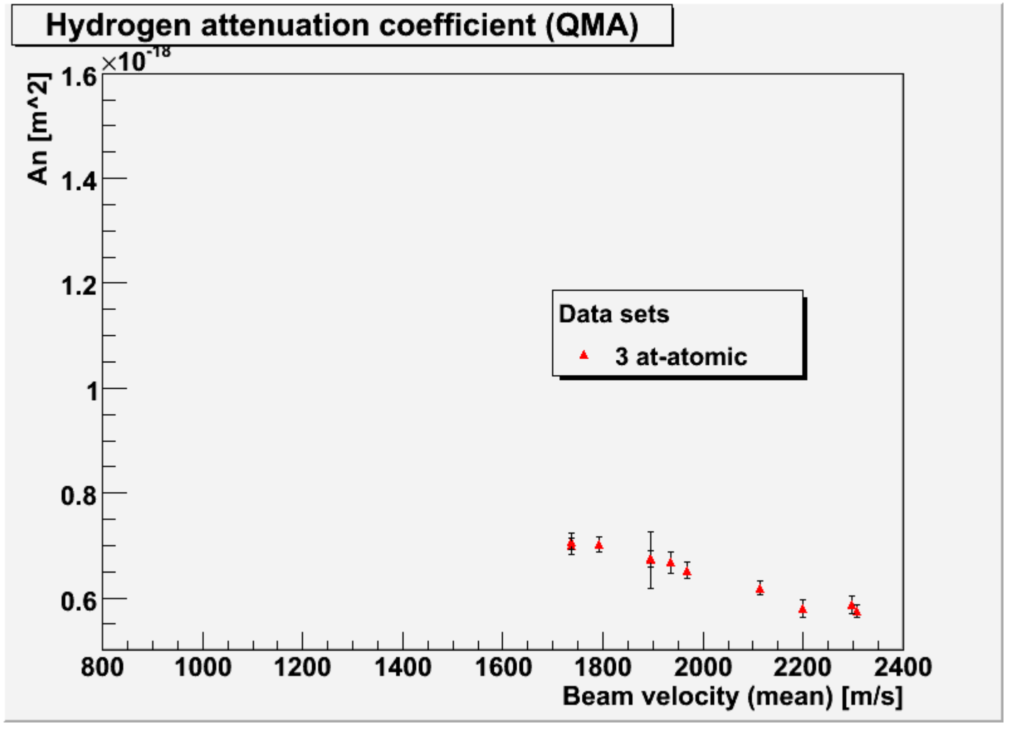
# Attenuation coefficient as function of Beam velocity (NEW!) (Molecular Hydrogen beam)

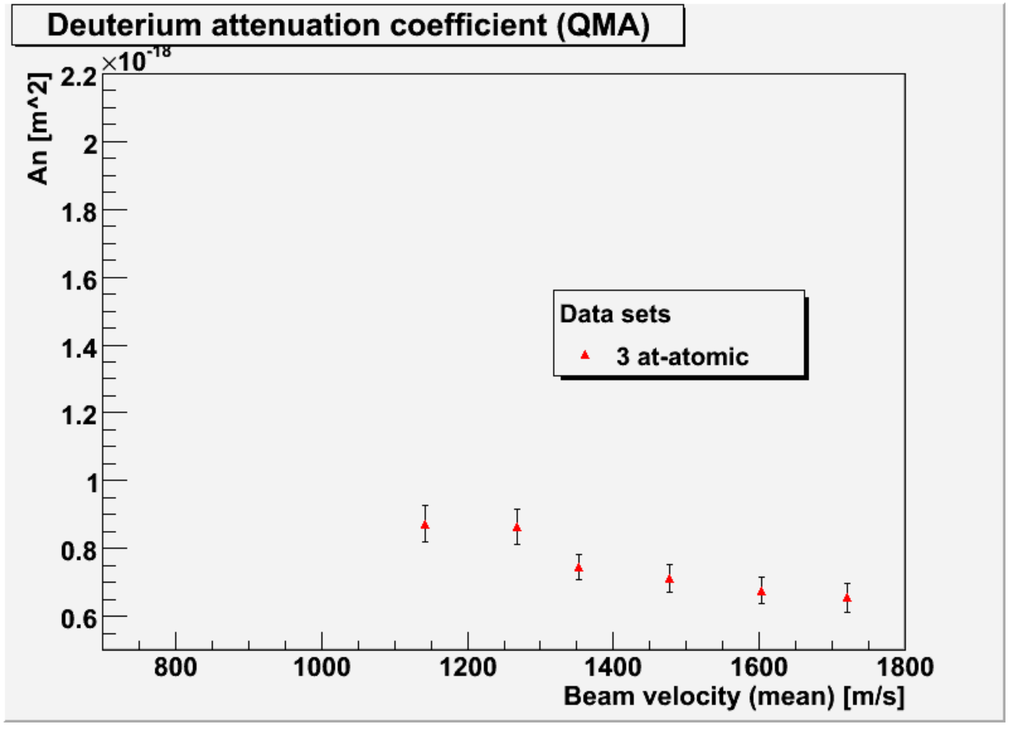


# Attenuation coefficient as function of Beam velocity (Molecular Deuterium beam)



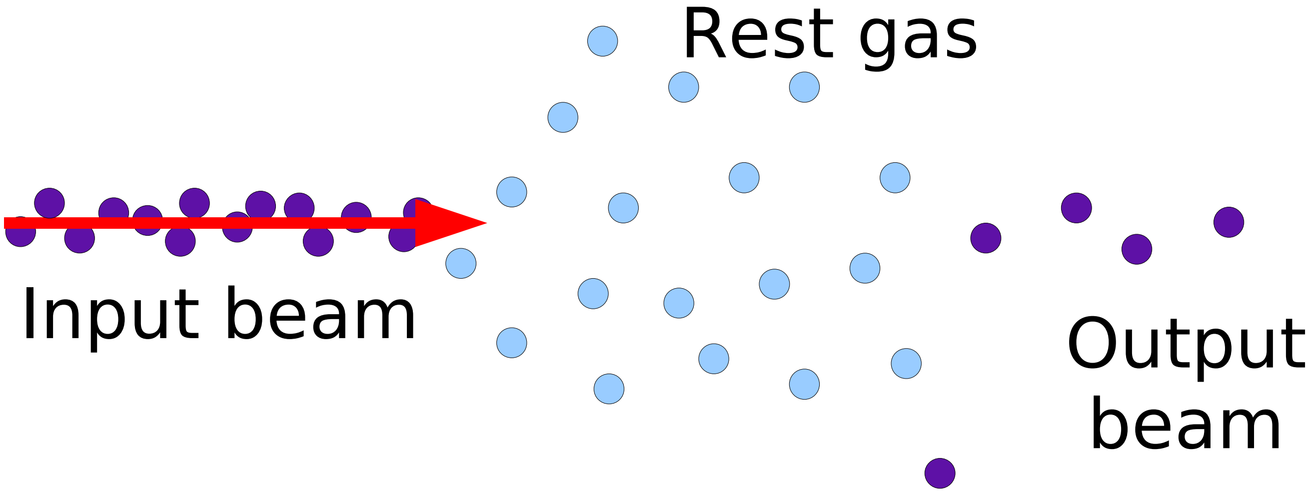
# Attenuation coefficient as function of Beam velocity (Atomic Hydrogen and Deuterium)



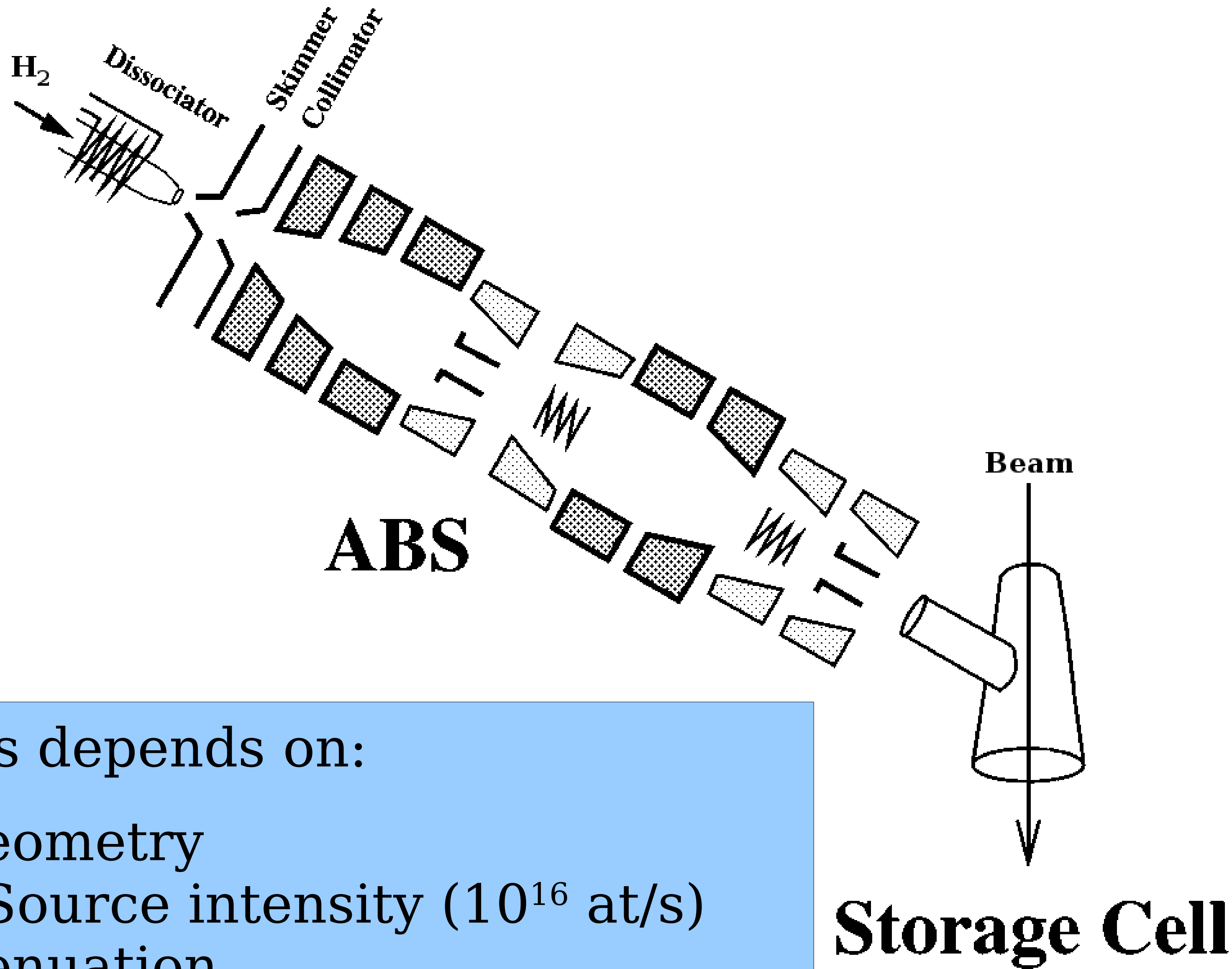

(Publication in preparation)

# Atomic beam attenuation in ABS1




In ABS1 at standard operating conditions **> 45%** of atomic beam is lost due to rest gas attenuation in Chamber 2

# Polarized gas target

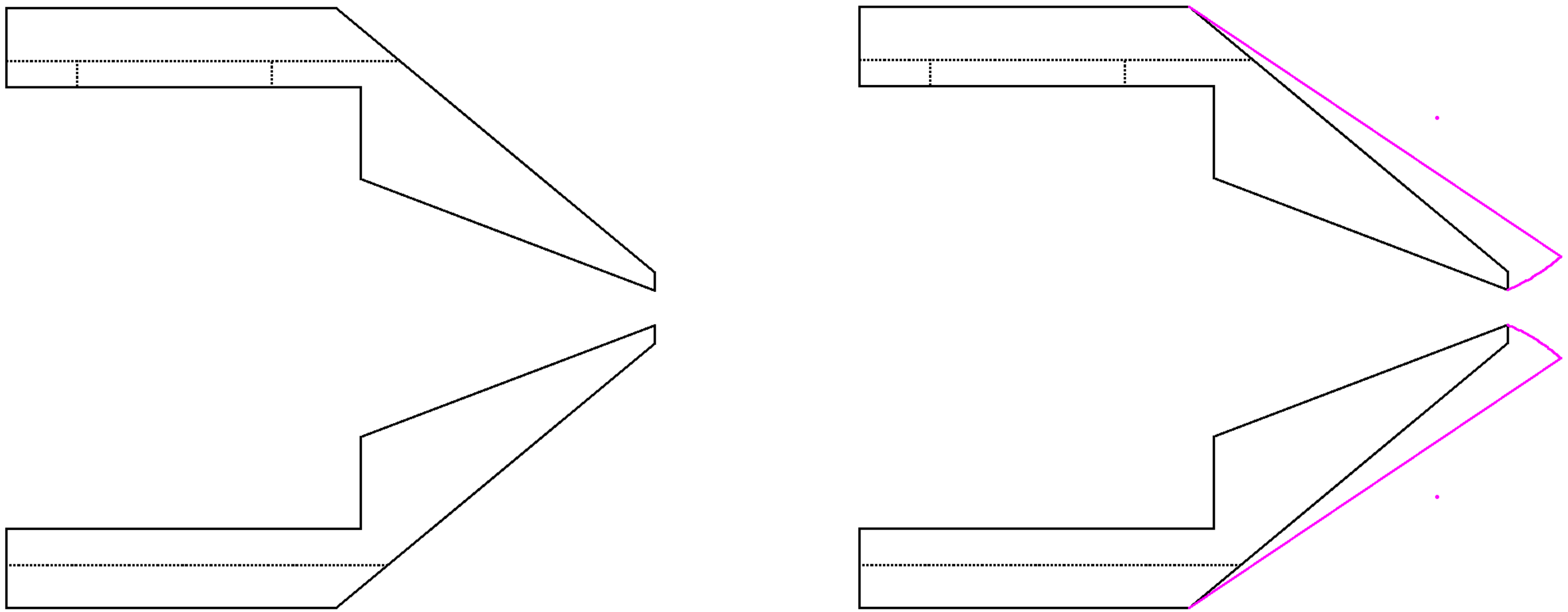



Target thickness depends on:

- Storage cell geometry
- Atomic Beam Source intensity ($10^{16}$ at/s)
  - Rest Gas Attenuation
  - **Trumpet nozzle**

# Trumpet nozzle

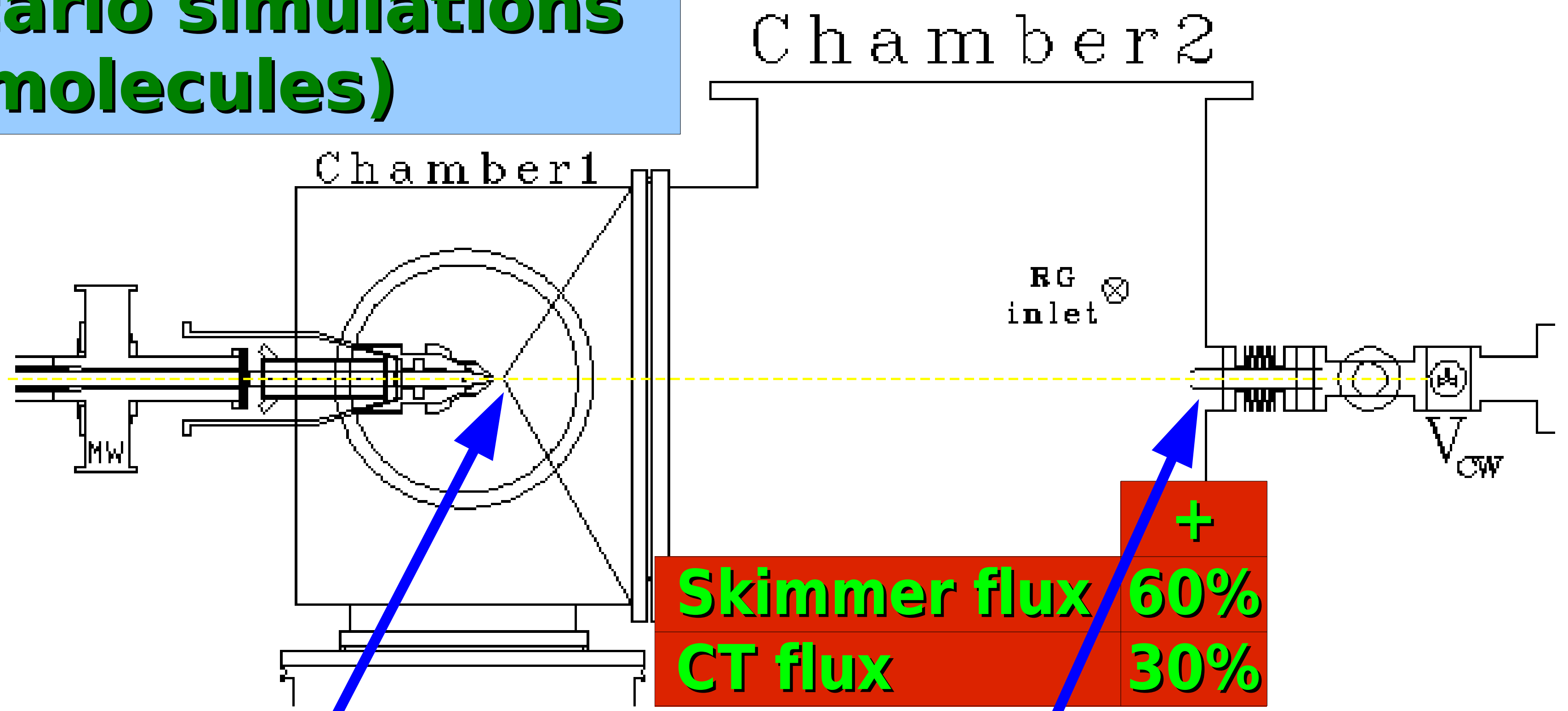
## Possible way to increase beam intensity



Nozzle #3 (sonic) Nozzle #4 (trumpet)

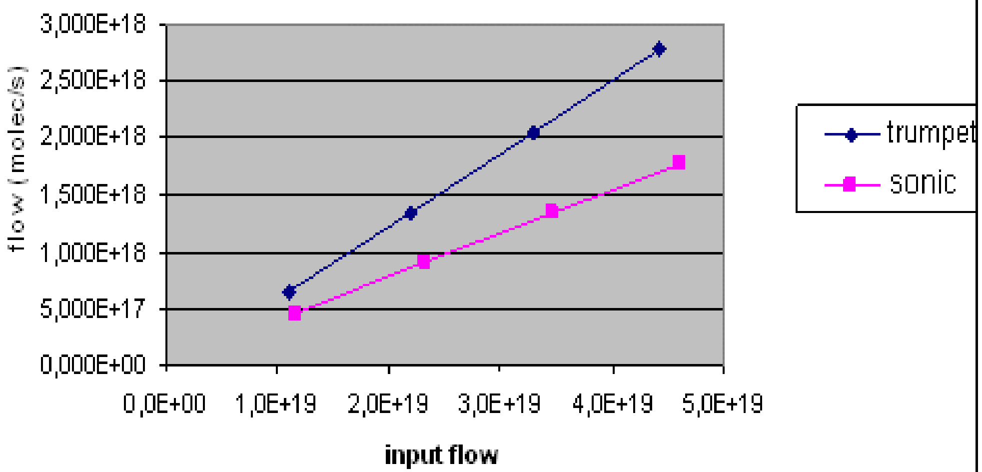
Monte Carlo simulation (ds2g by Bird) => improvement of beam intensity

# Montecarlo simulations (molecules)

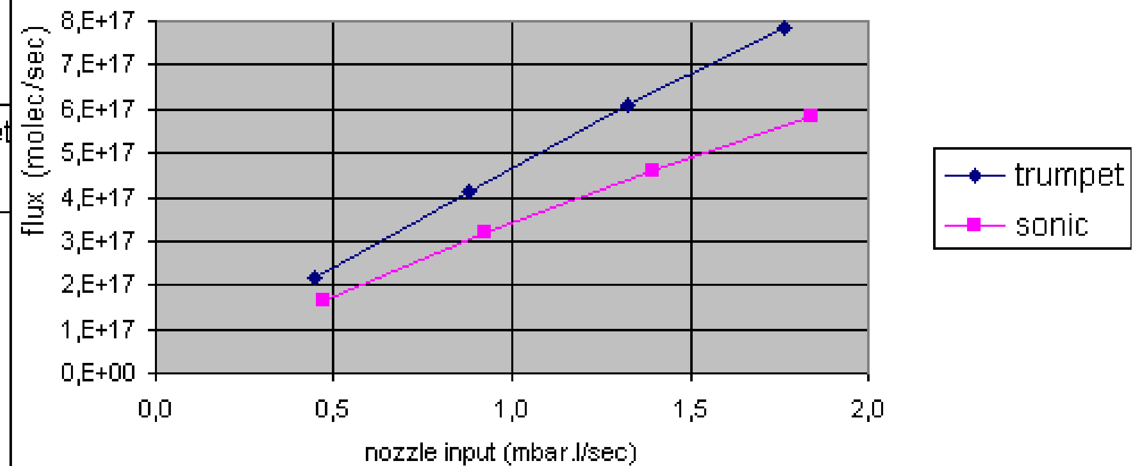



| + | |
|---|---|
| Skimmer flux | 60% |
| CT flux | 30% |

Skimmer flux



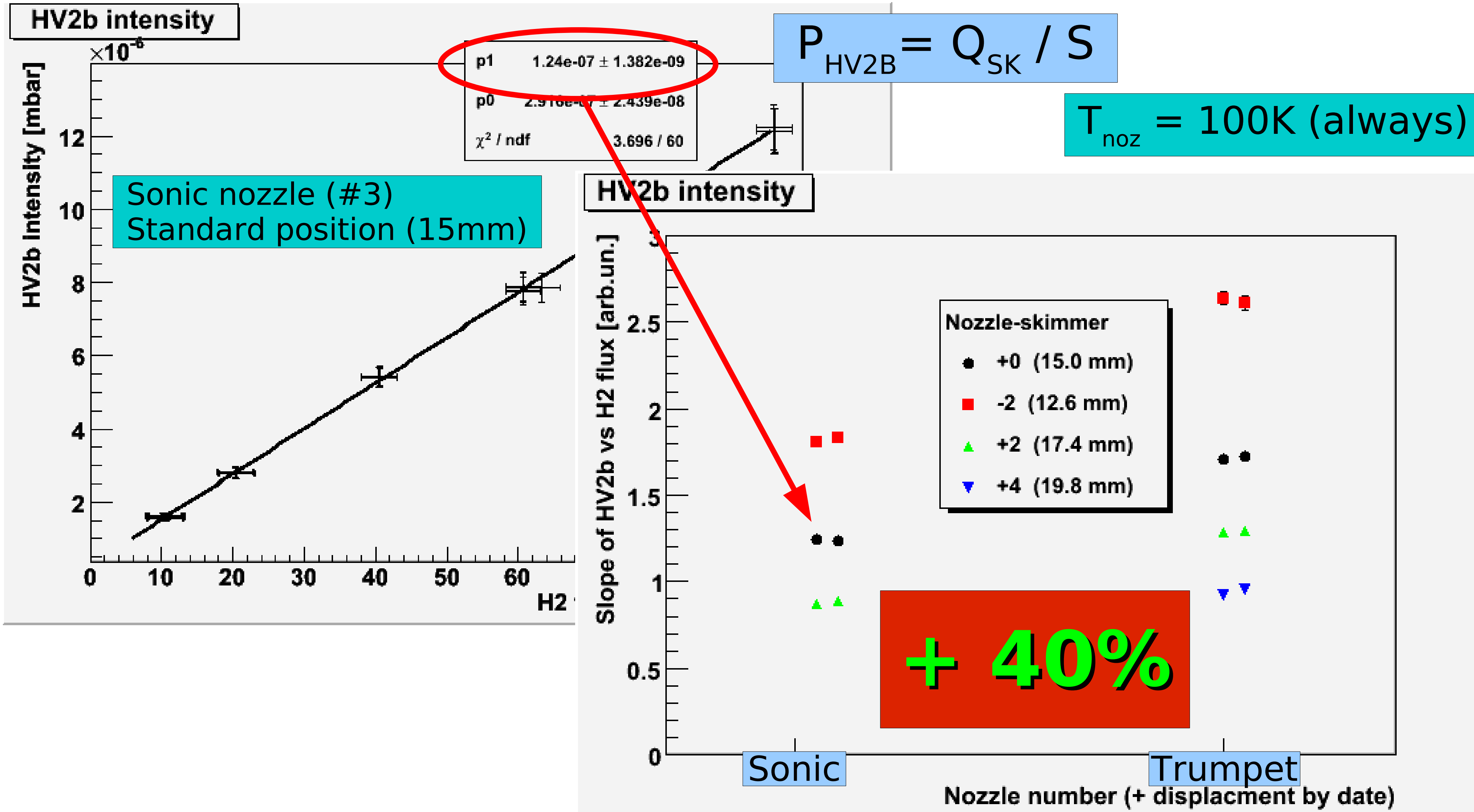

CT flux



# Measured beam intensity through skimmer
## (Chamber 2 used as Compression Volume)

$P_{HV2B} = Q_{SK} / S$

$T_{noz}$ = 100K (always)

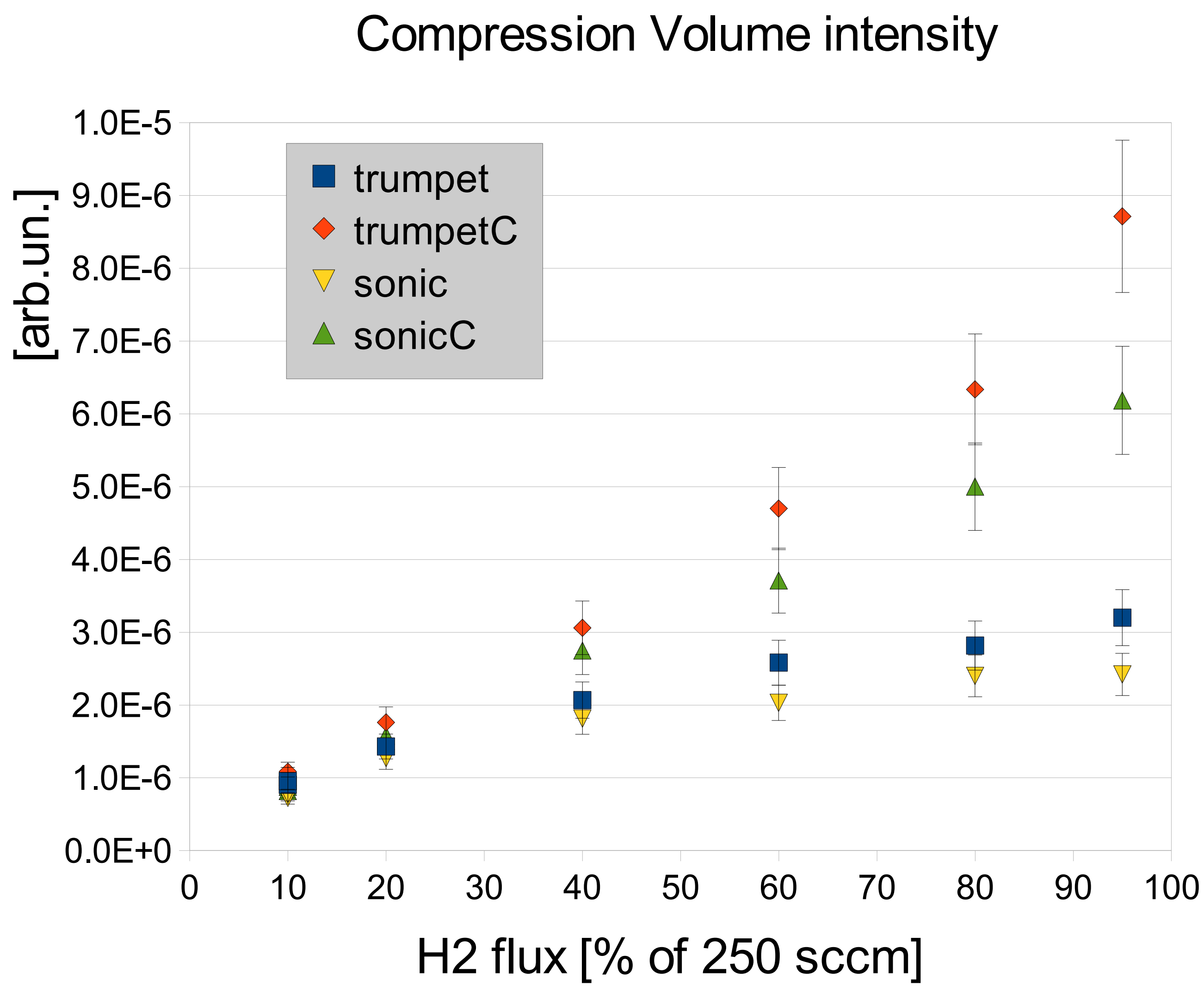


# Measured beam intensit
# in the Compression Volume

Beer's law:

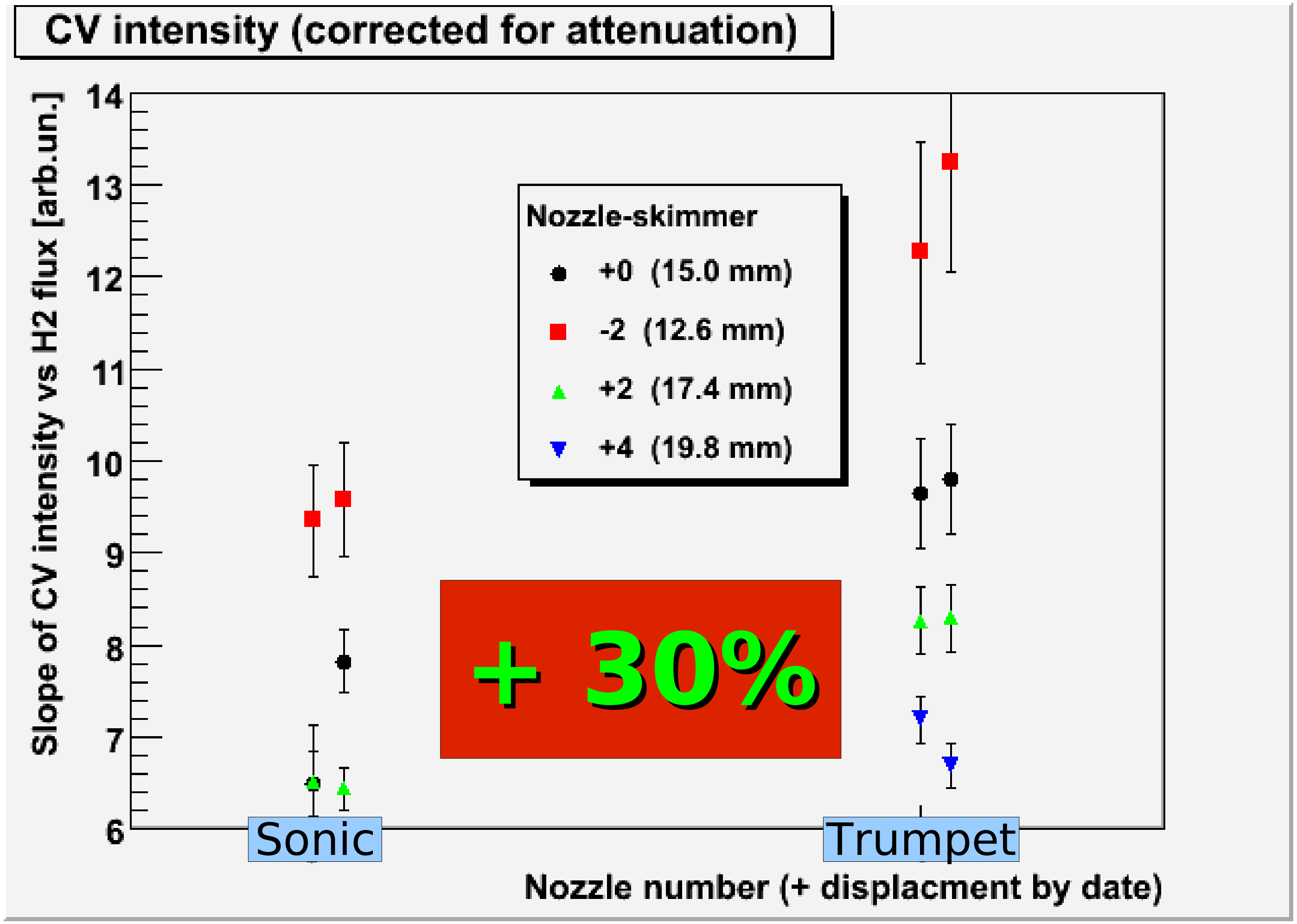
$$I = I_0 \cdot \exp\left(-\boldsymbol{A_i} n L\right)$$

$$I_0 = I \cdot \exp\left[\frac{A_i p L}{k_B T}\right]$$



# Measured beam intensity in the Compression Volume

$$I = \frac{1}{k_B T} \cdot P_{CV} C_{CT}$$






#

# Summary

- **Finned injection tube** (published)
  - Not useful for PAX but maybe useful for other geometries
  - Azimuthal velocity component
  - Appropriate Starting surface for our apparatus

- **Rest Gas Attenuation** (publication in preparation)
  - Attenuation coefficients useful for calculations (independent from experimental setup)

- **Trumpet nozzle** (publication in preparation)
  - Simulations and measurements foresee beam intensity increase