Università Degli Studi di Ferrara

Dottorato di ricerca in
Fisica
ciclo XXI

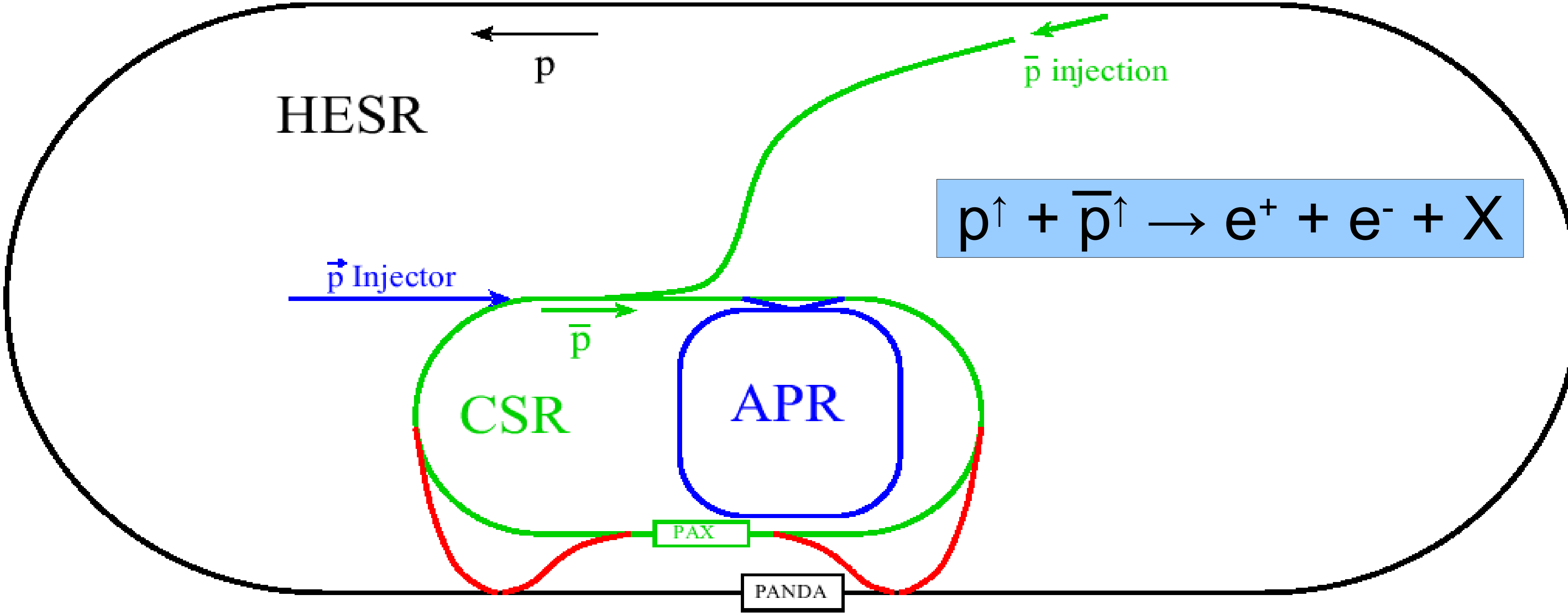
Internal polarized gas targets: systematic studies on intensity and correlated effects

Settore scientifico disciplinare FIS/01

24/03/2009 Luca Barion

FAIR in 2015(?)

PAX experiment



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

FAIR @ GSI, Darmstadt

Drell-Yan to measure
transversity of nucleons

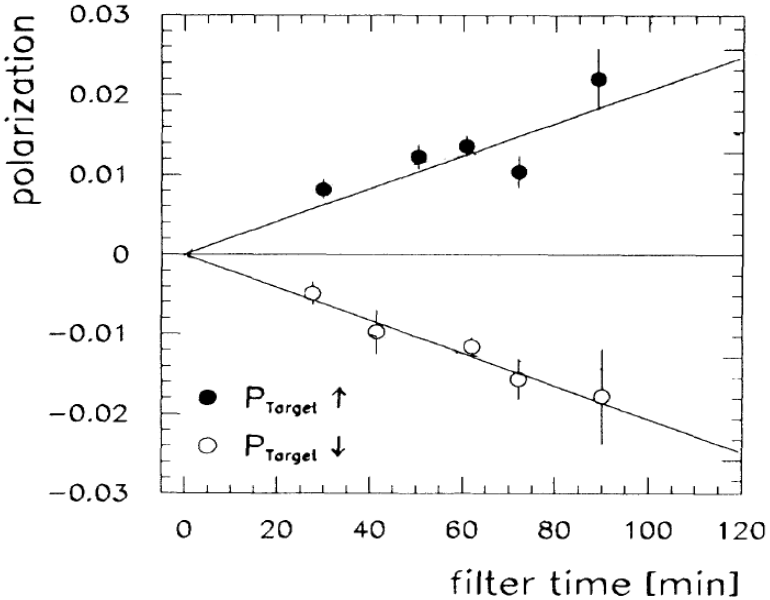
Requrements:
- stored intense p polarized beam in HESR (15 Gev/c)
- stored intense $\bar{p}$ polarized beam in CSR (3.5 GeV/c)

Antiproton polarization

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

Spin filtering

Tested in FILTEX in 1992 (p)



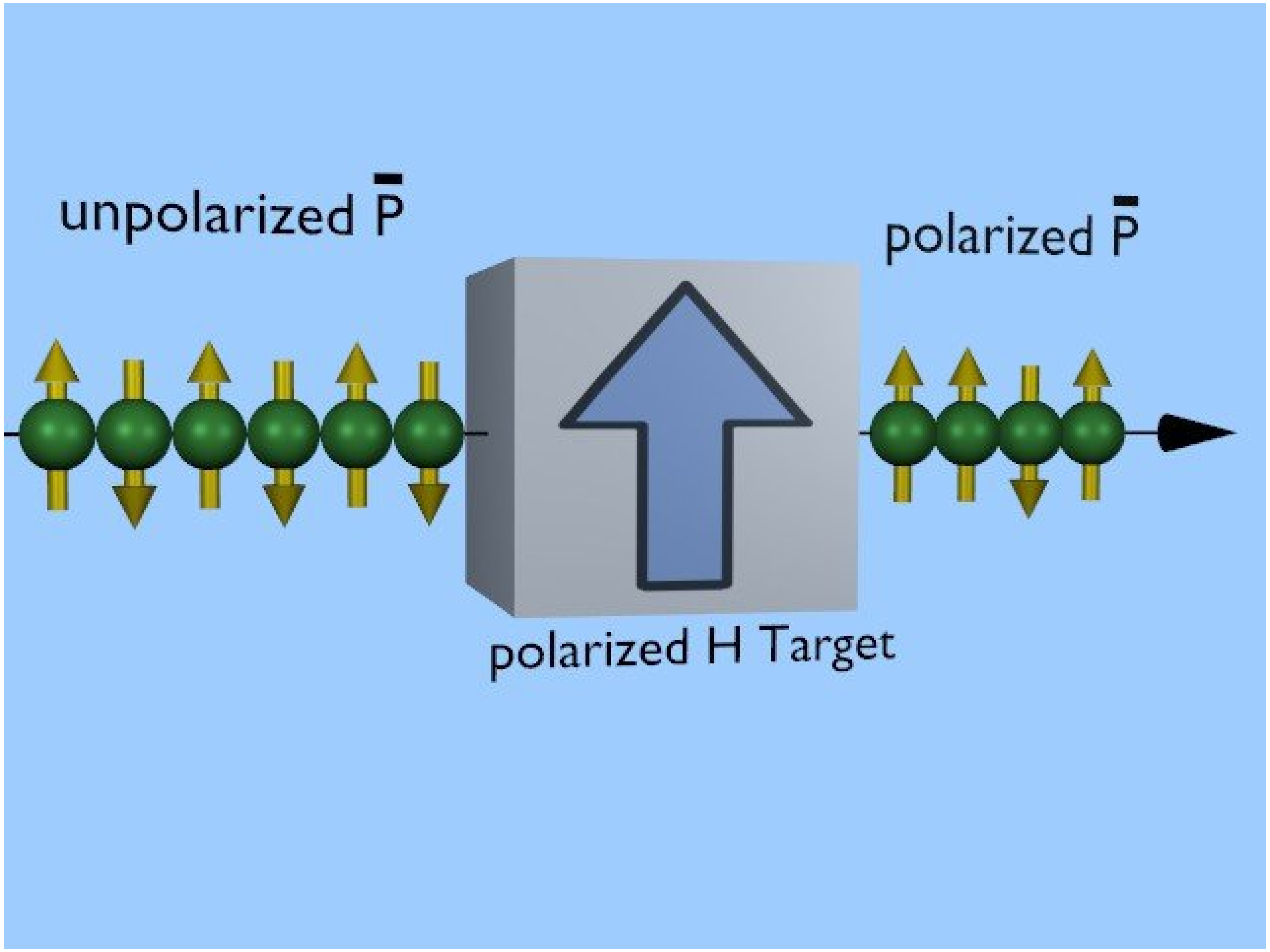
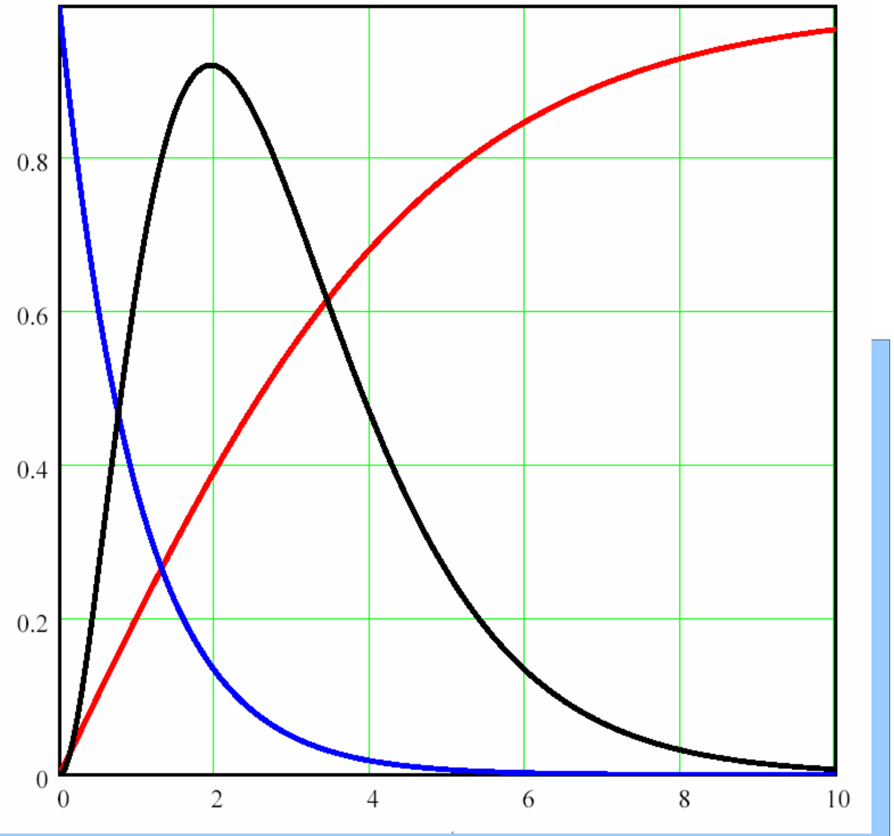


Figure Of Merit
(for polarization)



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

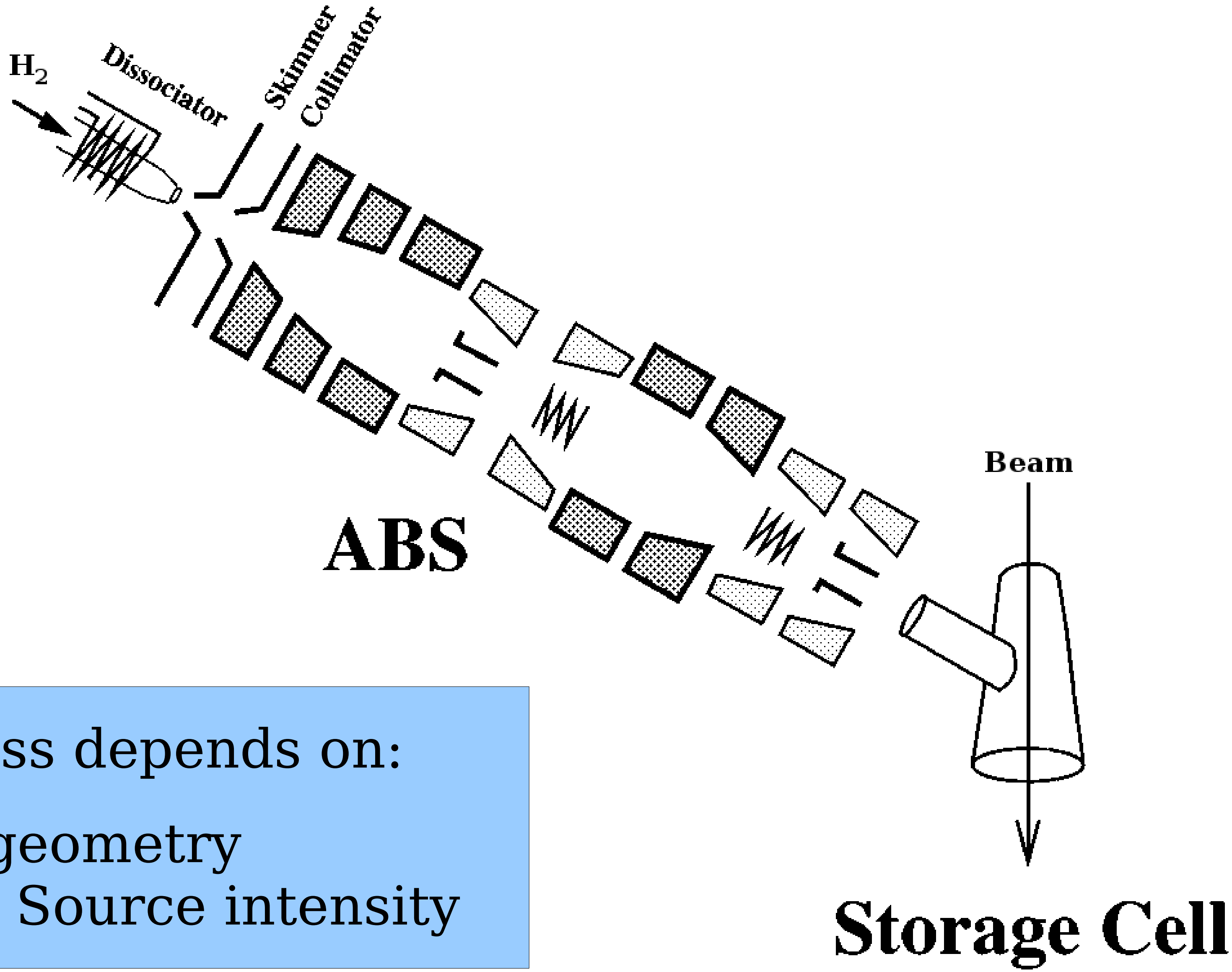
P antiproton beam polarization
I antiproton beam intensity
T time

Optimum filtering time:
$T_0 = 2\,\tau_B$ (τ_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)

$T_{.} \propto \frac{1}{t}$ → Increase in target density is desirable
(to decrease filtering time)

Polarized gas target



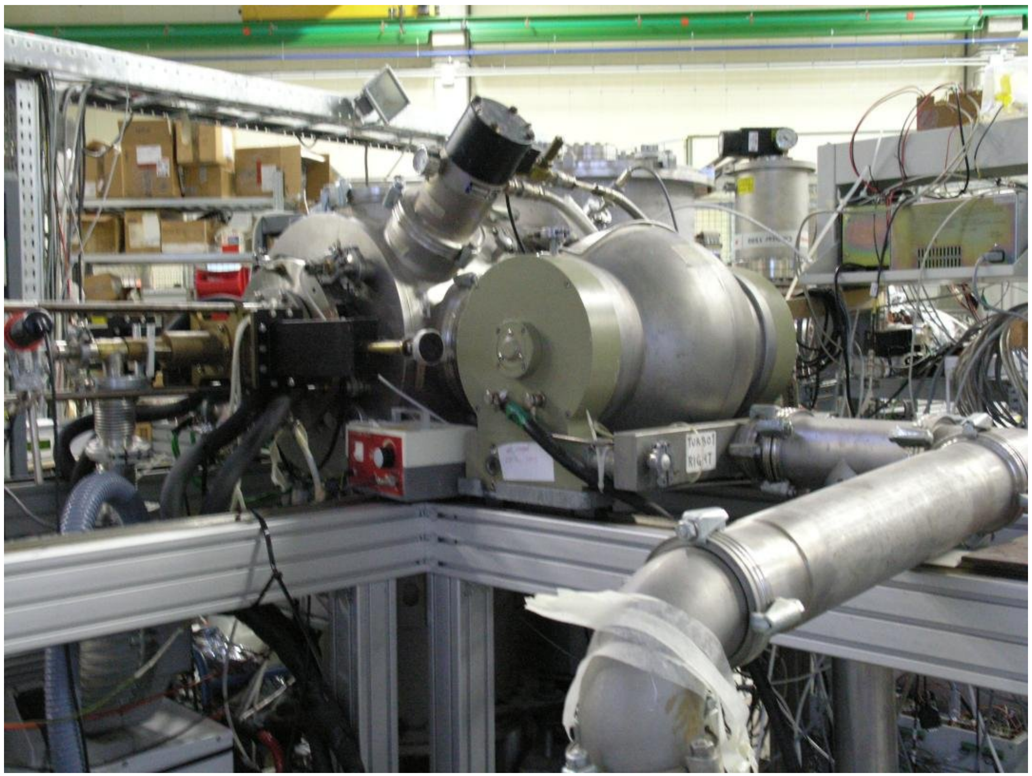
Target thickness depends on:

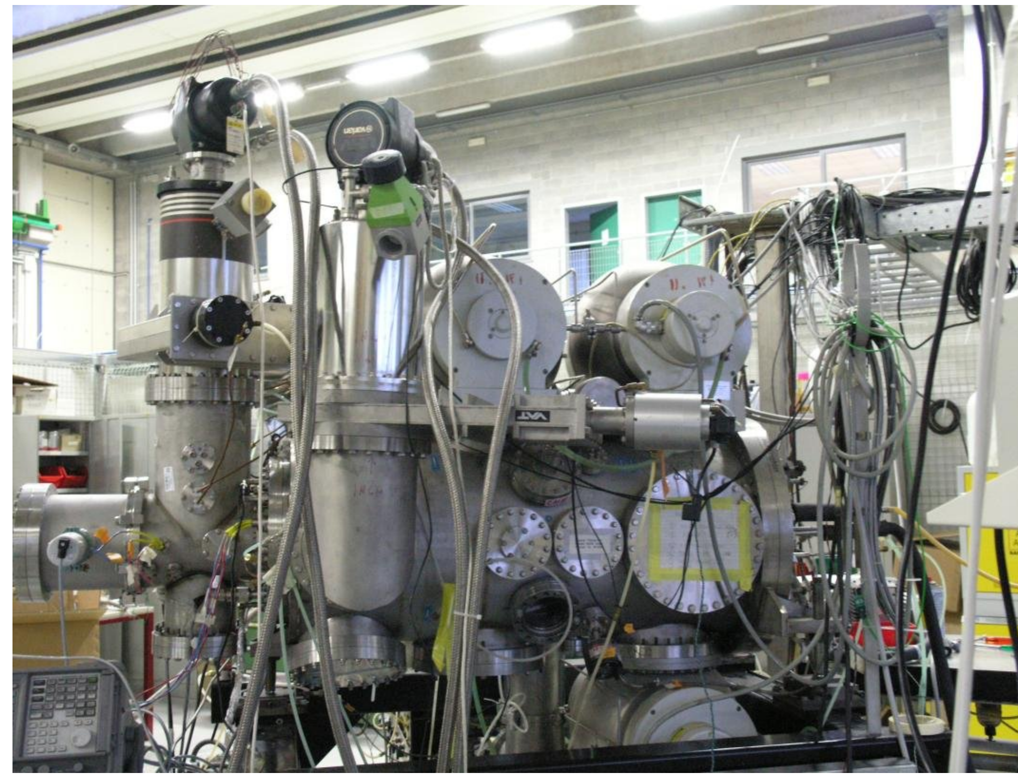
- Storage cell geometry
- Atomic Beam Source intensity

Spin Lab

ABS1
(CERN)

ABS2
(Wisconsin)

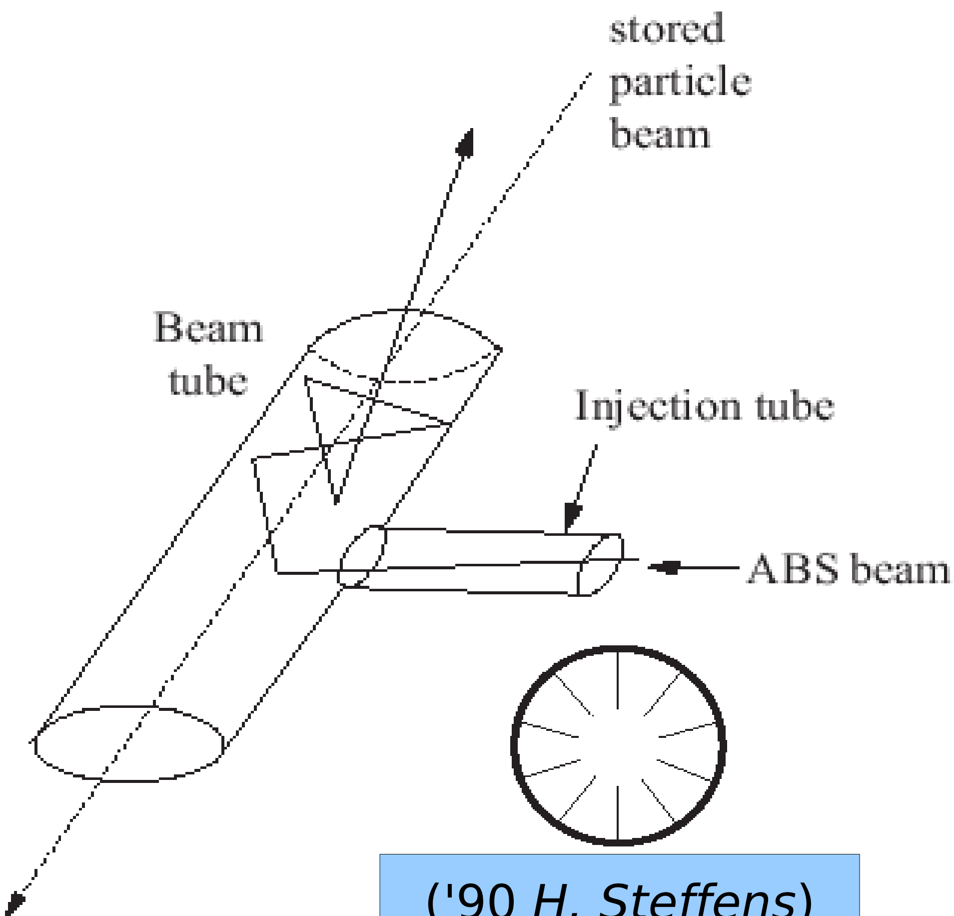




ABS intensity

Modification to storage cell

Effects of modified storage cell



('90 *H. Steffens*)

Thickness of gaseous target:

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

$$C_{tot} = \text{٢}\ C_{beam} + \boldsymbol{C}_{\boldsymbol{inj}} \quad \left[cm^{\text{٣}} / s \right]$$

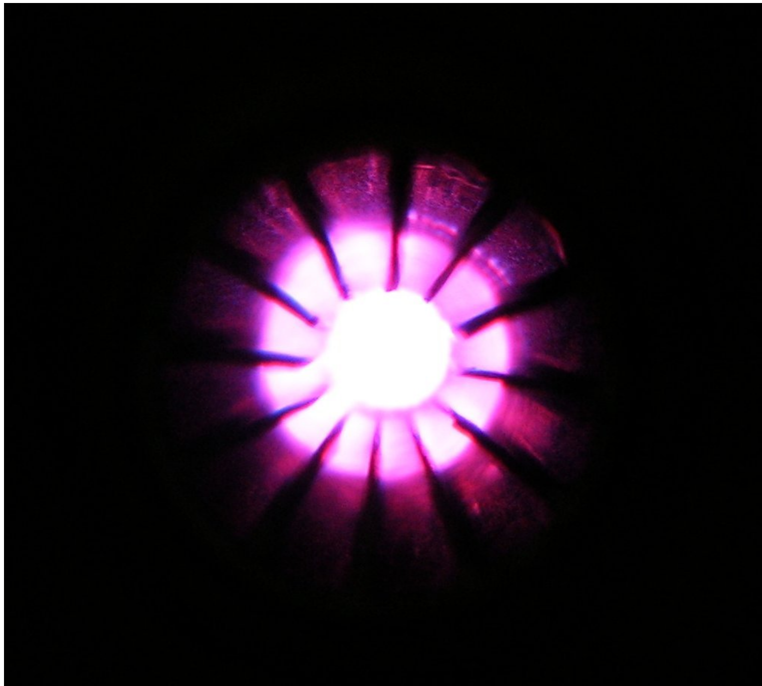
I intensity of beam to the cell [at/s]
L beam tube half length
M molec/at gas mass

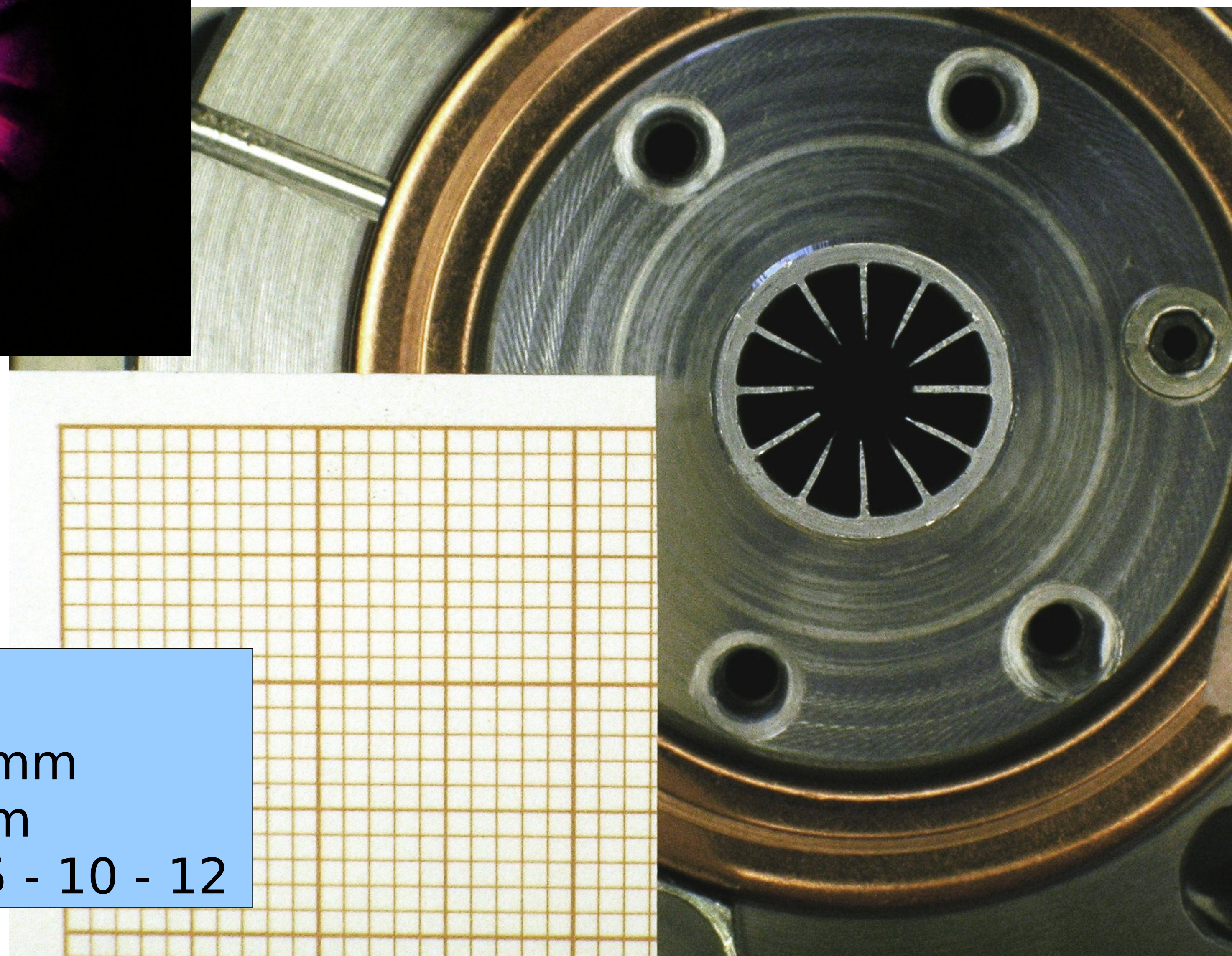
W. Haeberli, E. Steffens, Rep. Prog. Phys. 66 p 1887 (2003)

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

Vacuum Technology - Roth A (1990)

Finned injection tube
(mounted on test stand)

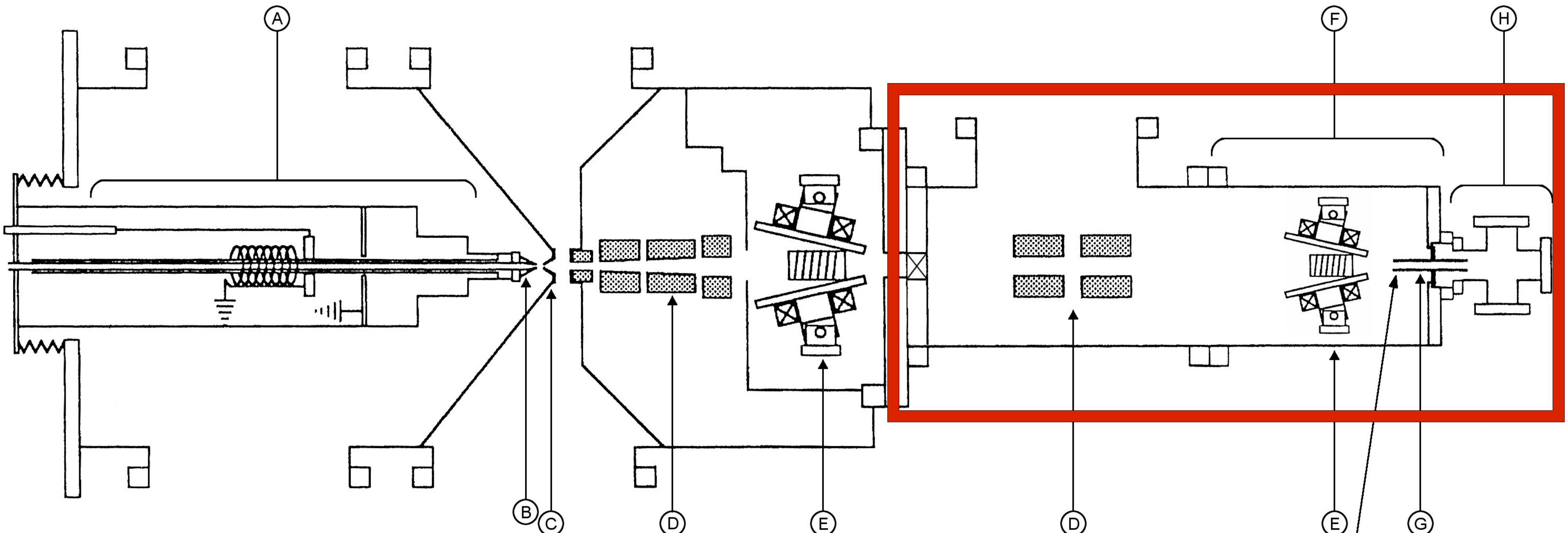


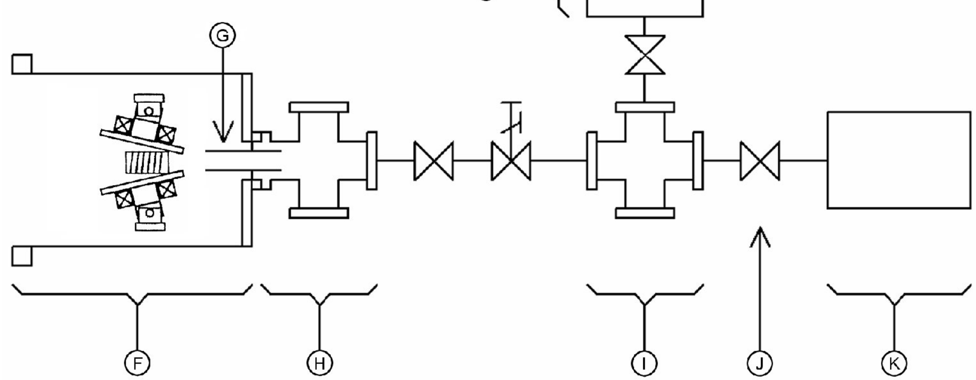


Fins

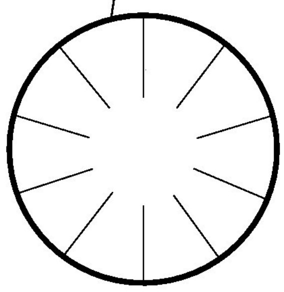
Thickness:	0.2 mm
Length:	3 mm
Number:	0 – 5 - 10 - 12

Test stand (ABS2)





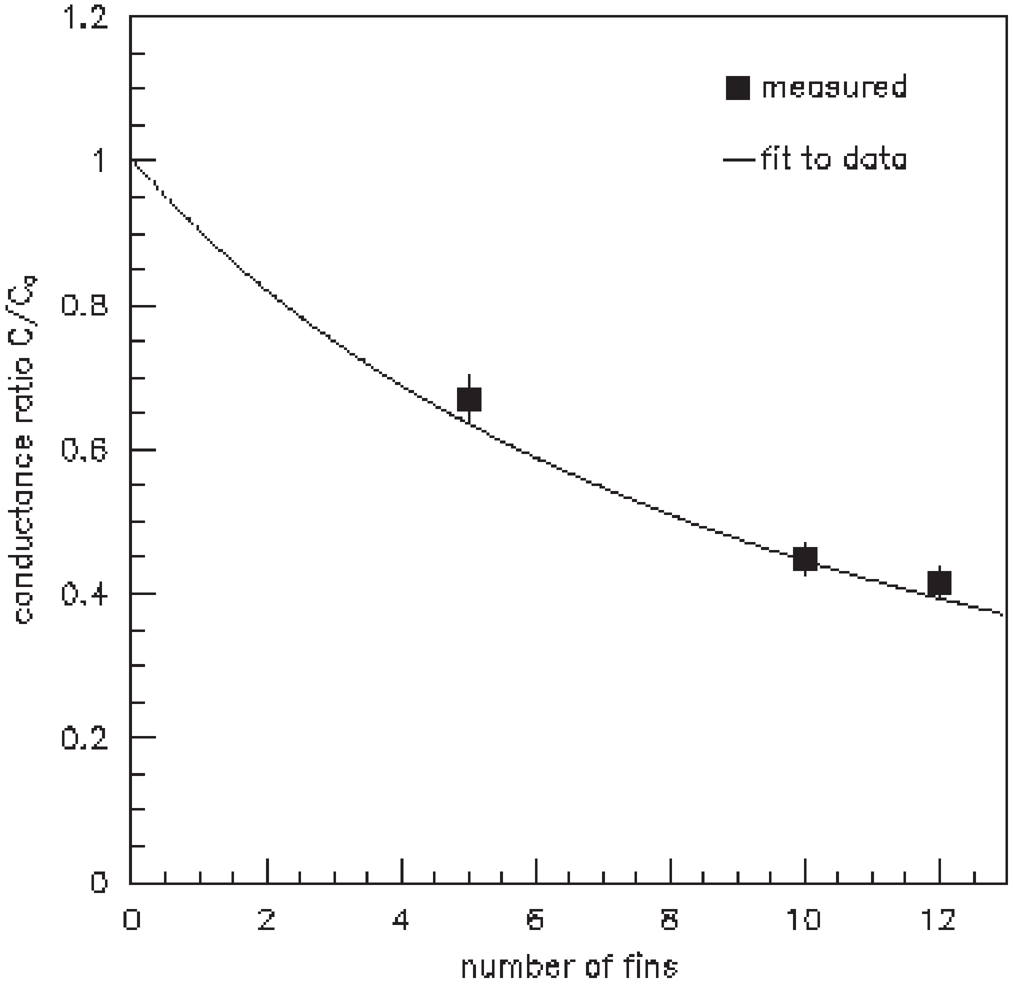
B) Nozzle
C) Skimmer
G) Compression Tube
H) Compression Volume
I) Vcal



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

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

Relative conductance
(meas + fit)



$$C=Q/P_{cv}$$

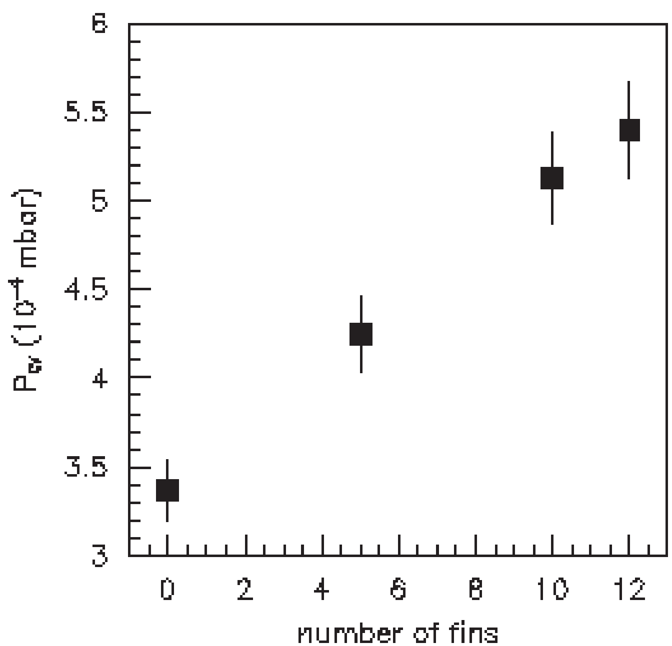
$$C=\frac{8}{3\sqrt{\pi}}\left(2k_B\frac{T}{M}\right)^{1/2}\left(\frac{A^2}{\mathbf{s}\ L}\right)$$

CV intensity

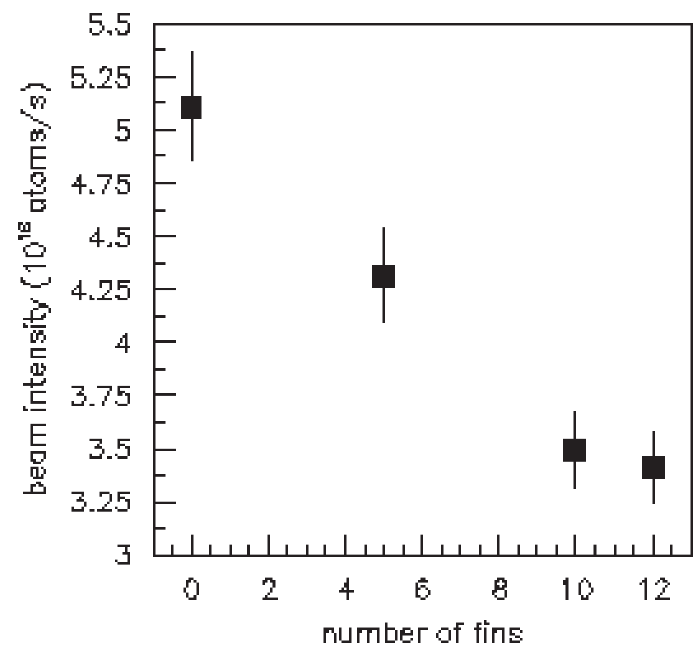
$$t = \frac{I\,L}{C_{tot}}$$

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

Pressure (meas)



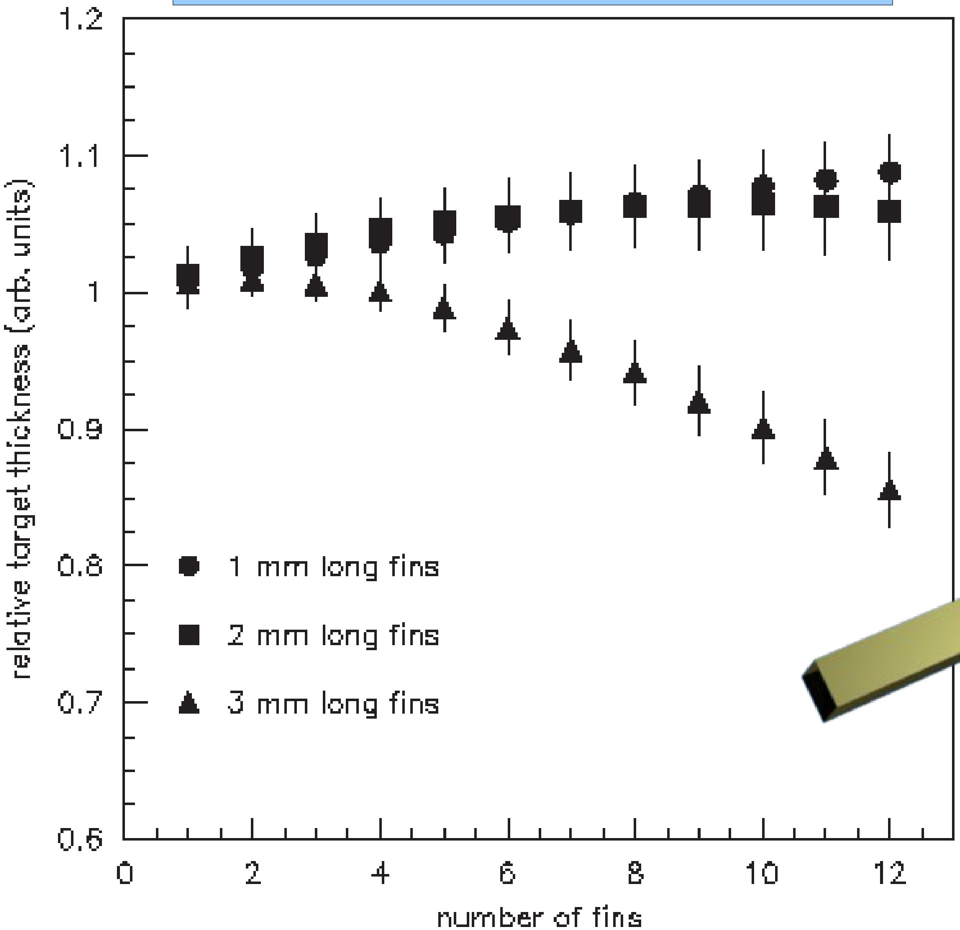
Intensity (calculated)

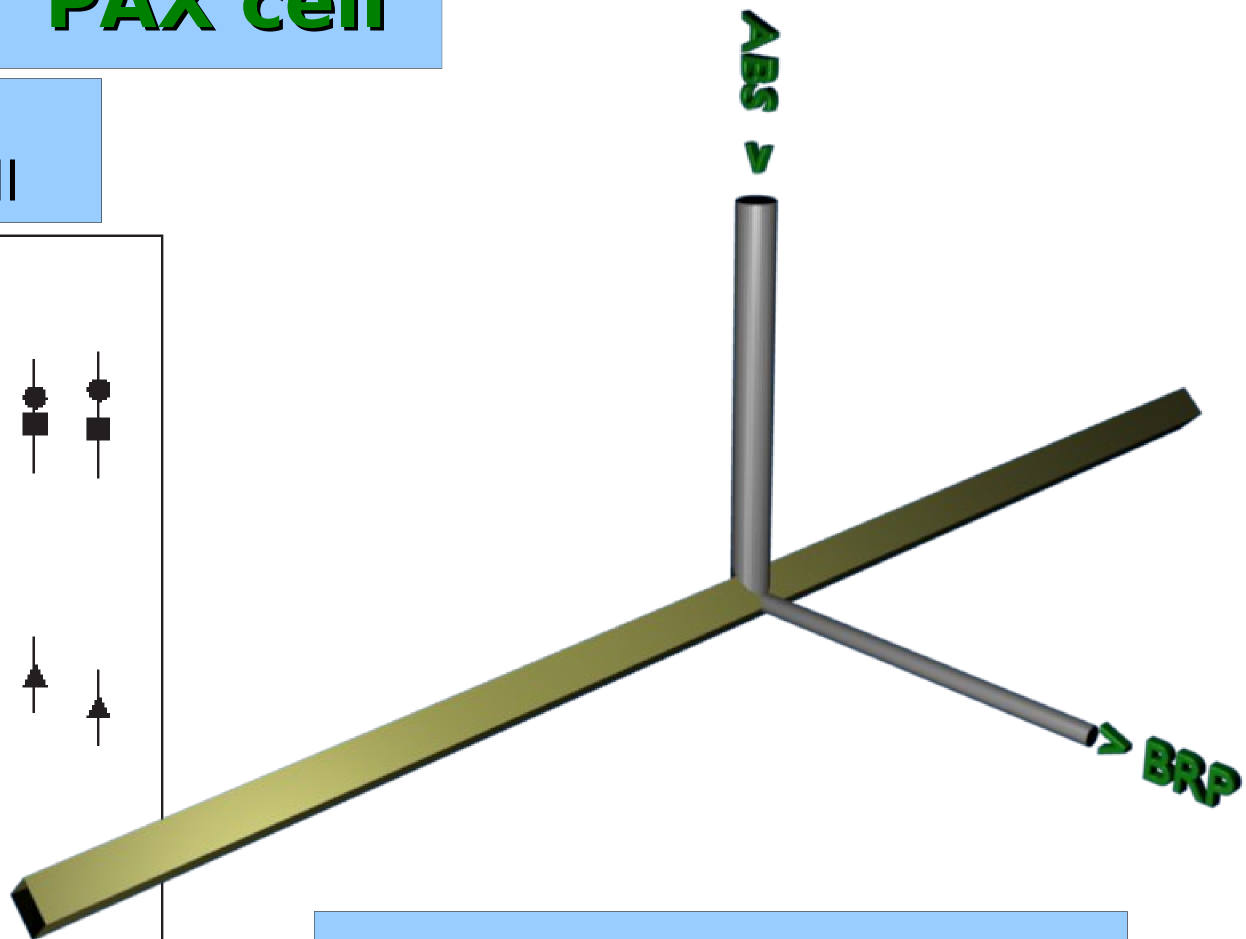


Intensity decrease larger than expected

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!)

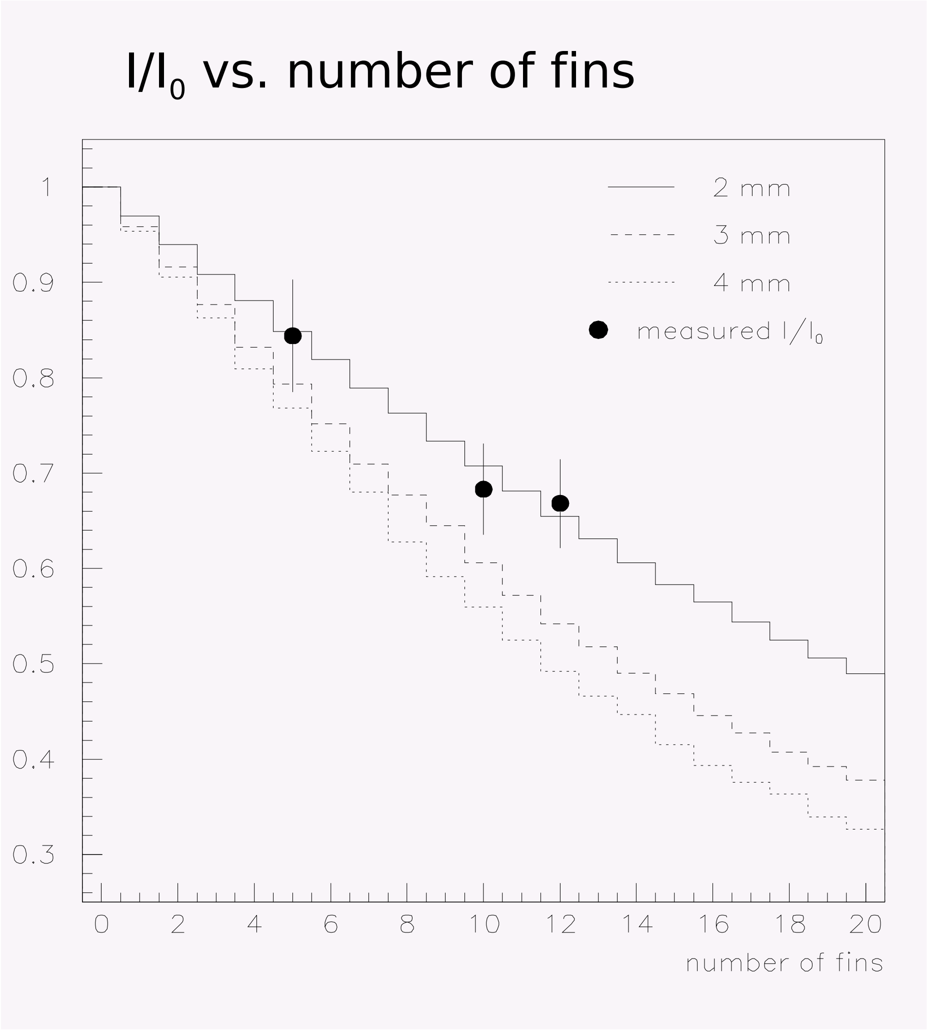
Calculations with surfaces of area 2 - 3 - 4 mm used as "**starting generator surface**"

▼

Match with 2mm (like nozzle)

z_{SGS} independent for 0-30 mm

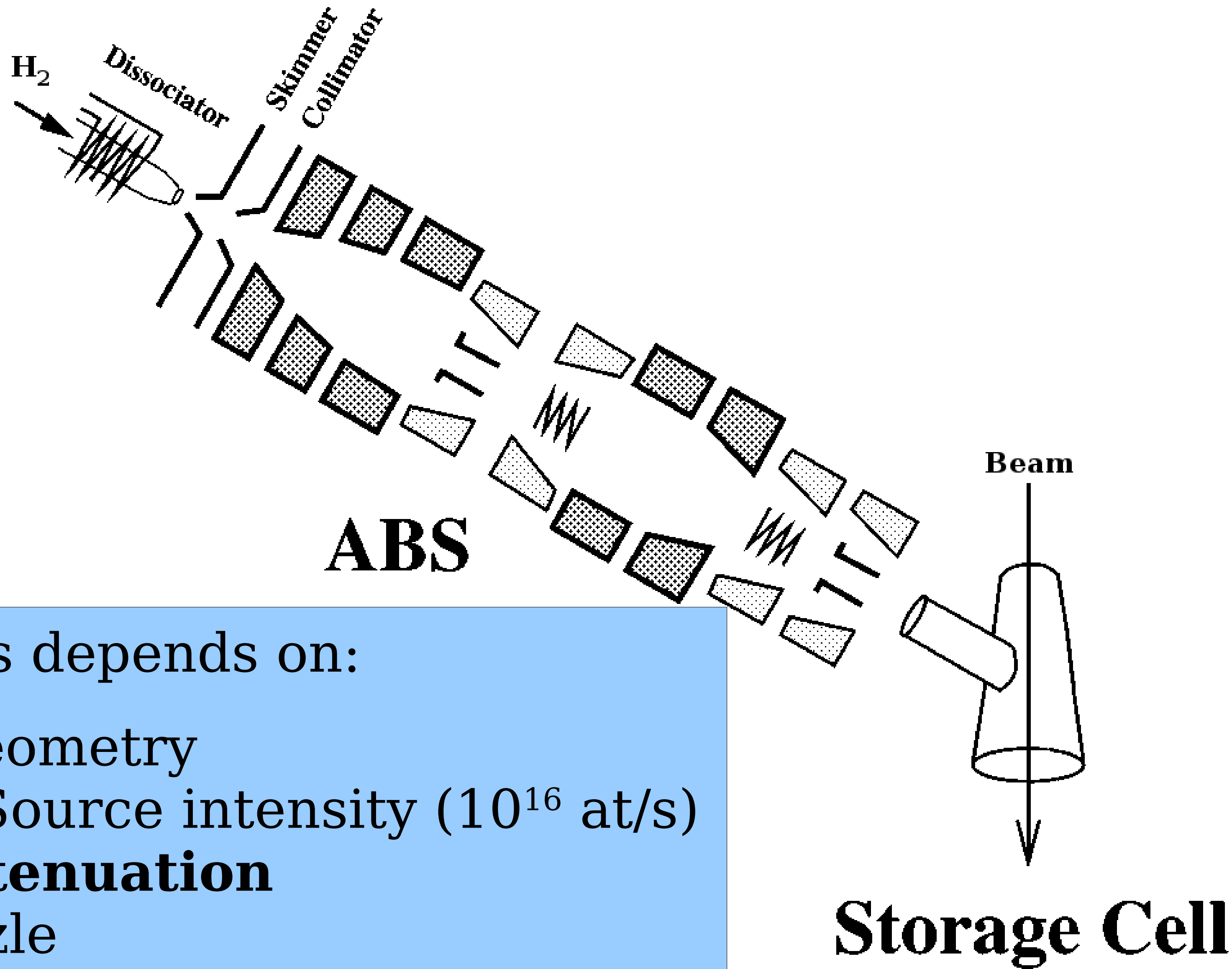
Nuclear Instruments and Methods in Physics Research A 594 (2008) 126-131



SCAN (sextupole tracking software)

#

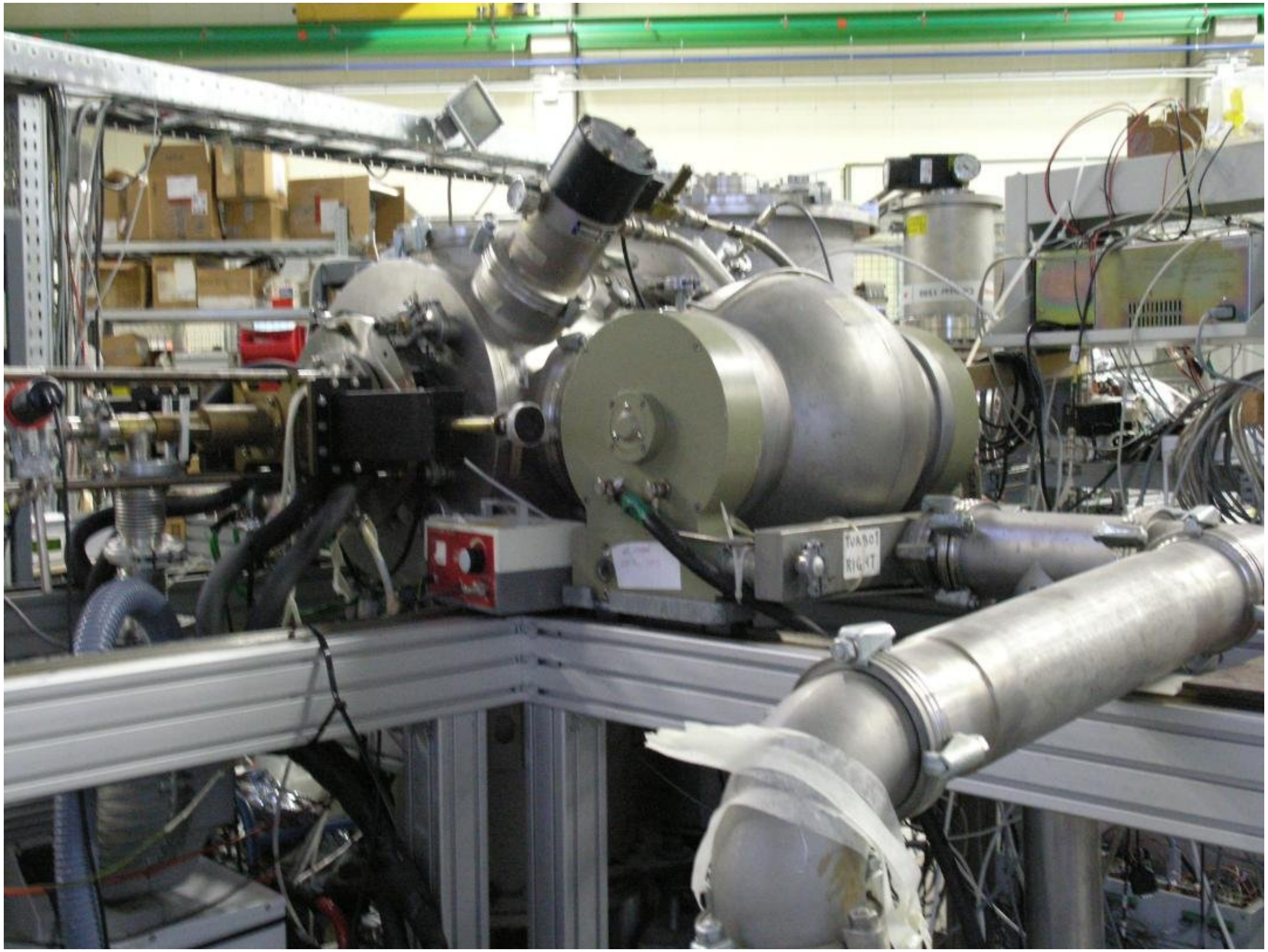
Polarized gas target



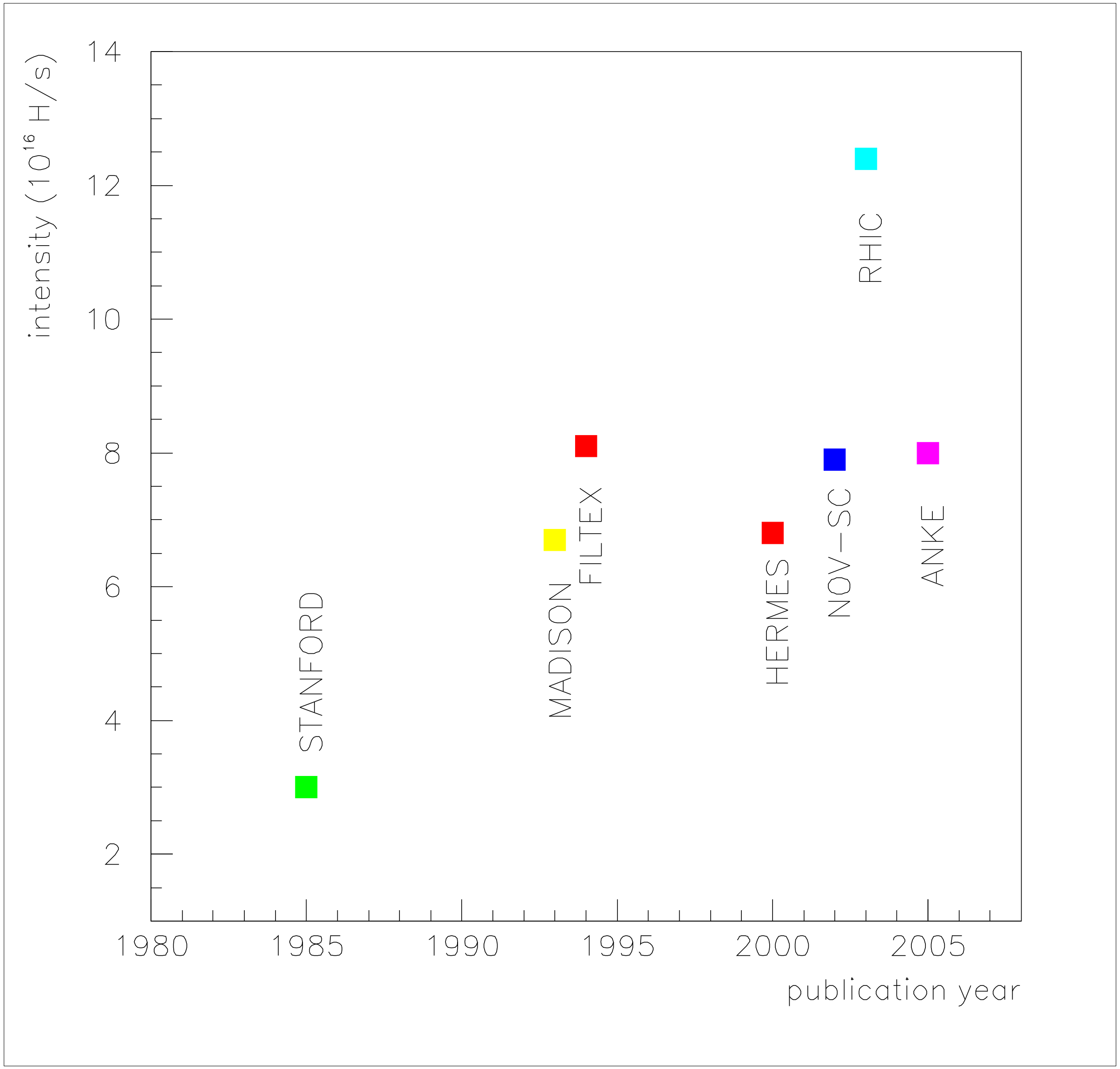
Target thickness depends on:

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

Rest Gas Attenuation measurements on H/D beams



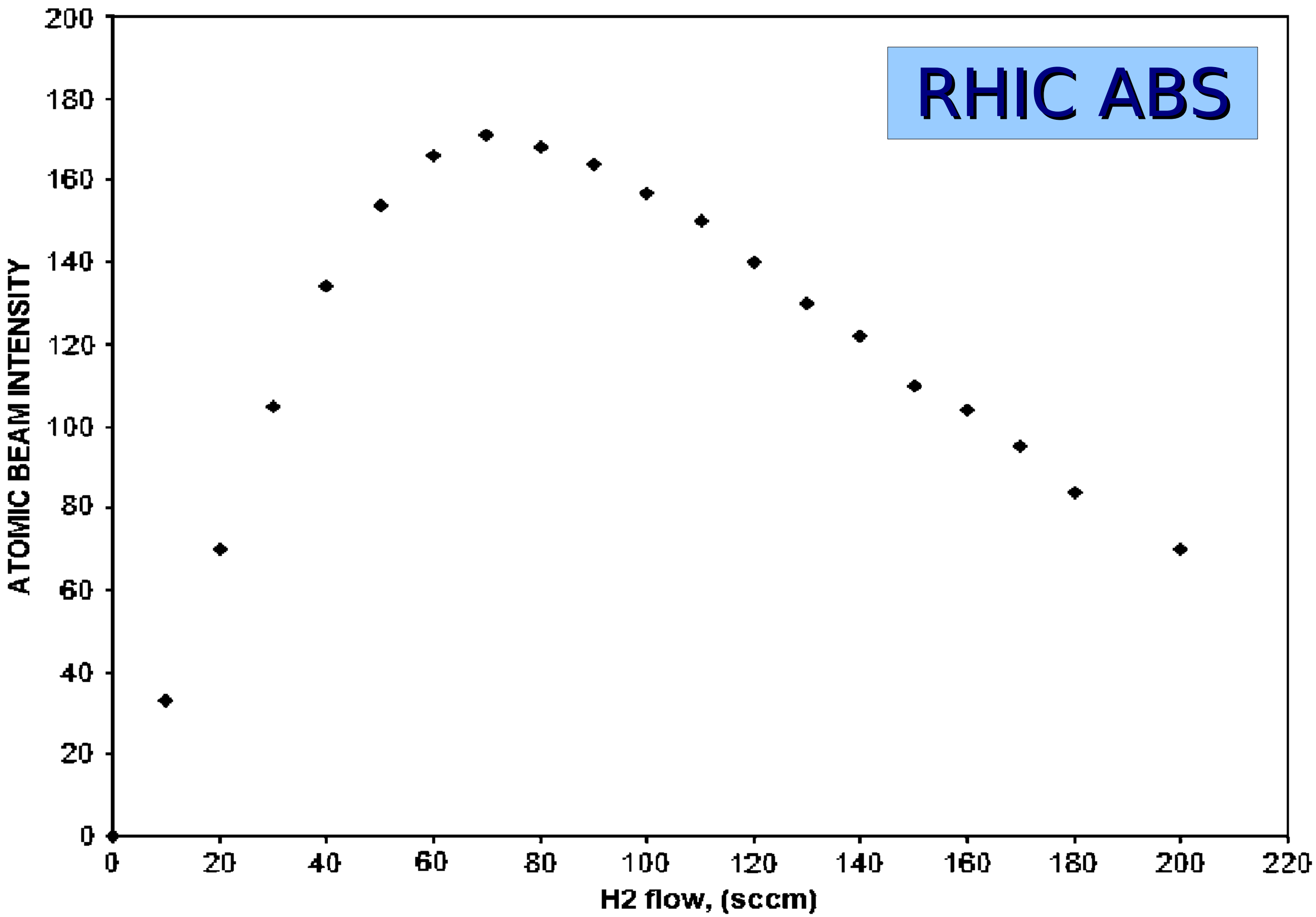
Intensity of world ABS



- Intra Beam Scattering
- Rest Gas Attenuation

RHIC still unexplained

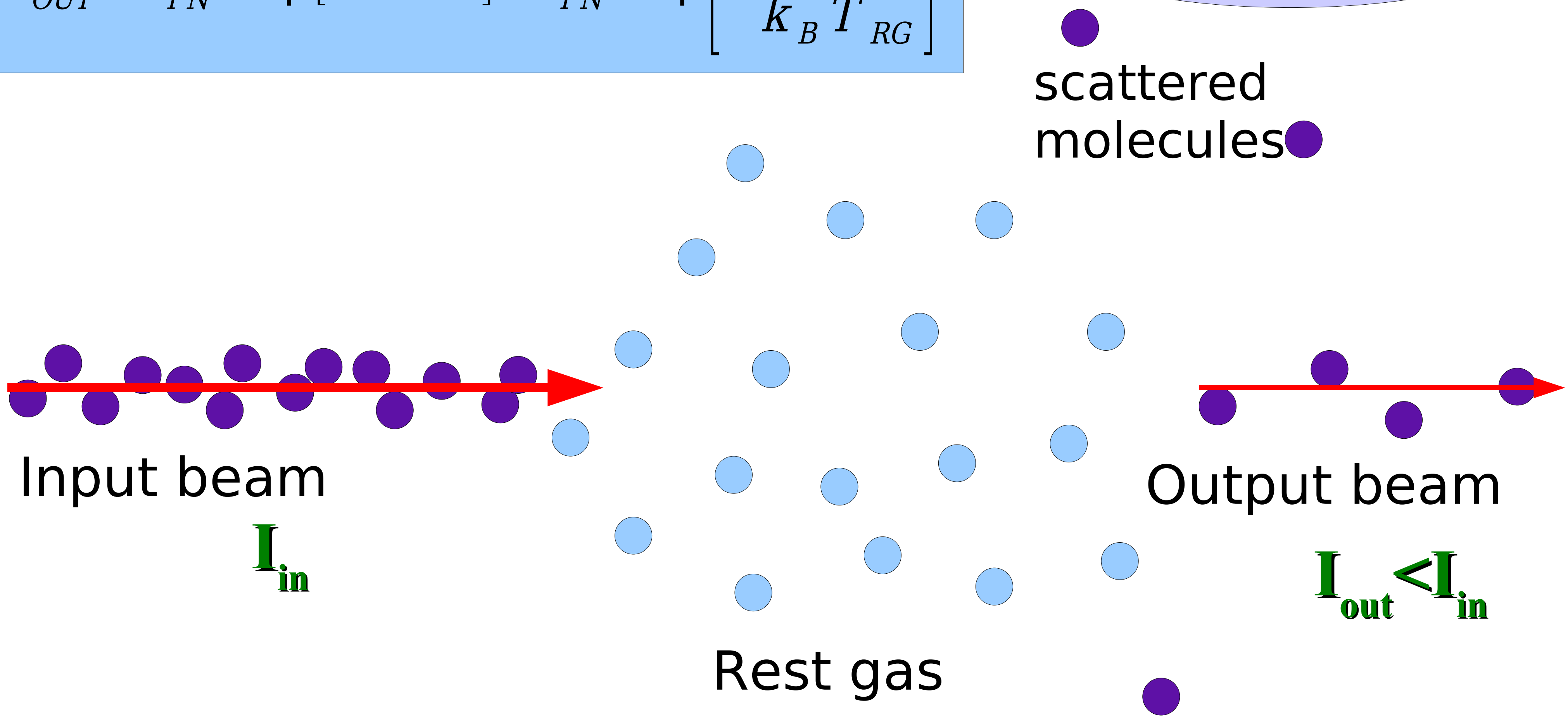
ABS beam intensity
(how to increase it)



Interaction beam - rest gas

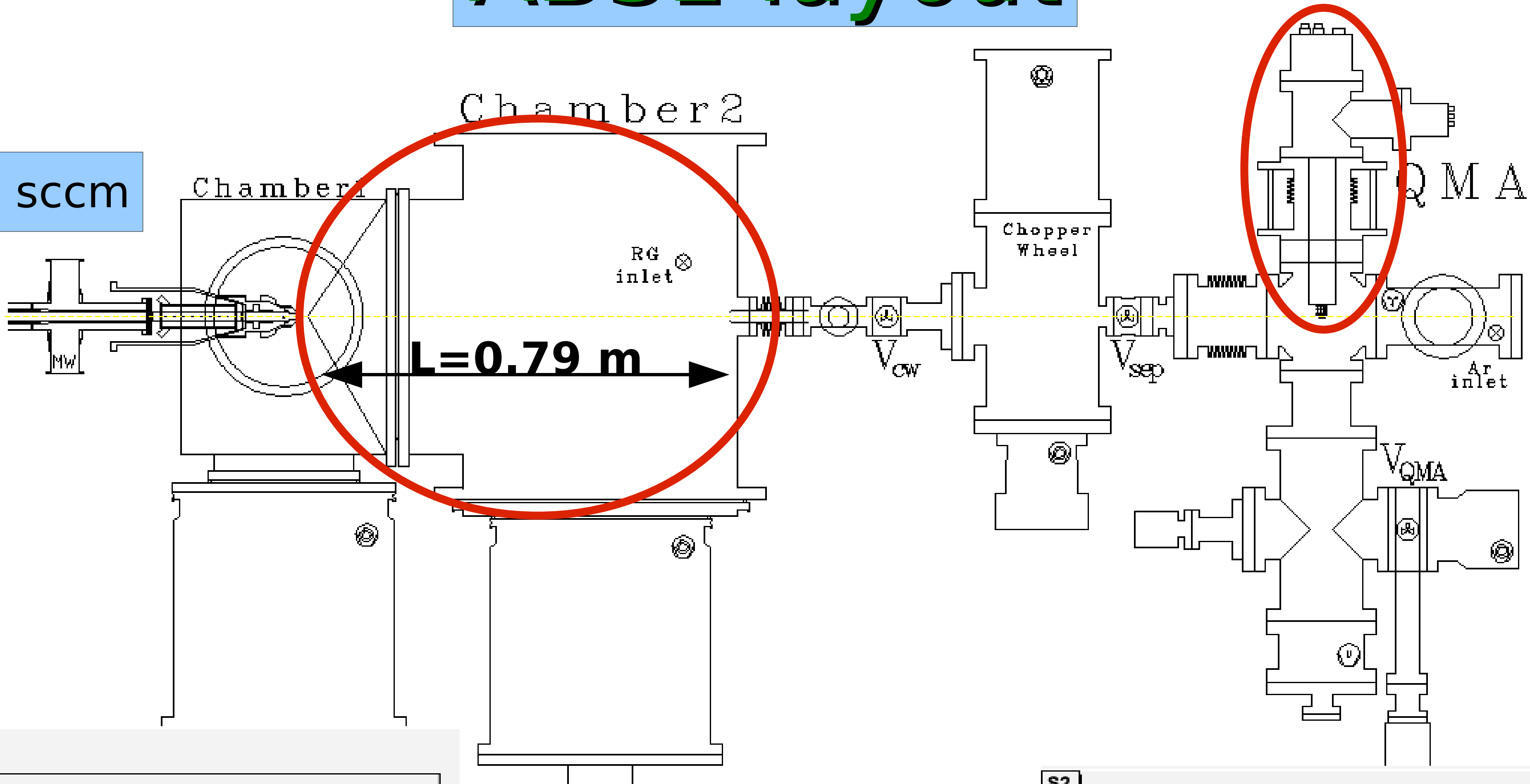
$$I_{OUT} = I_{IN} \cdot \exp[-\boldsymbol{A}\, n\, L] = I_{IN} \cdot \exp\left[-\frac{\boldsymbol{A}\, P\, L}{k_B\, T_{RG}}\right]$$

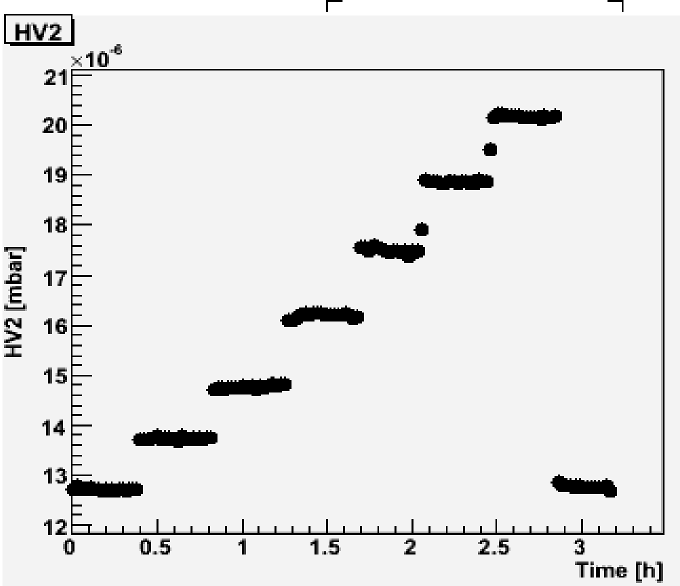
A
attenuation coefficient

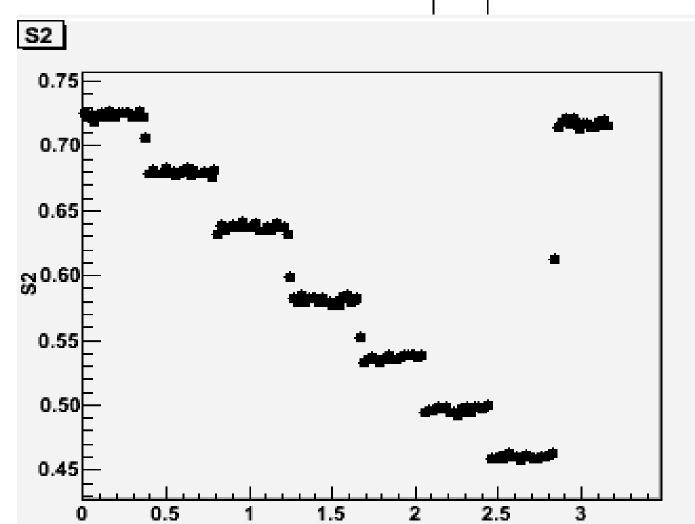


ABS1 layout

125 sccm

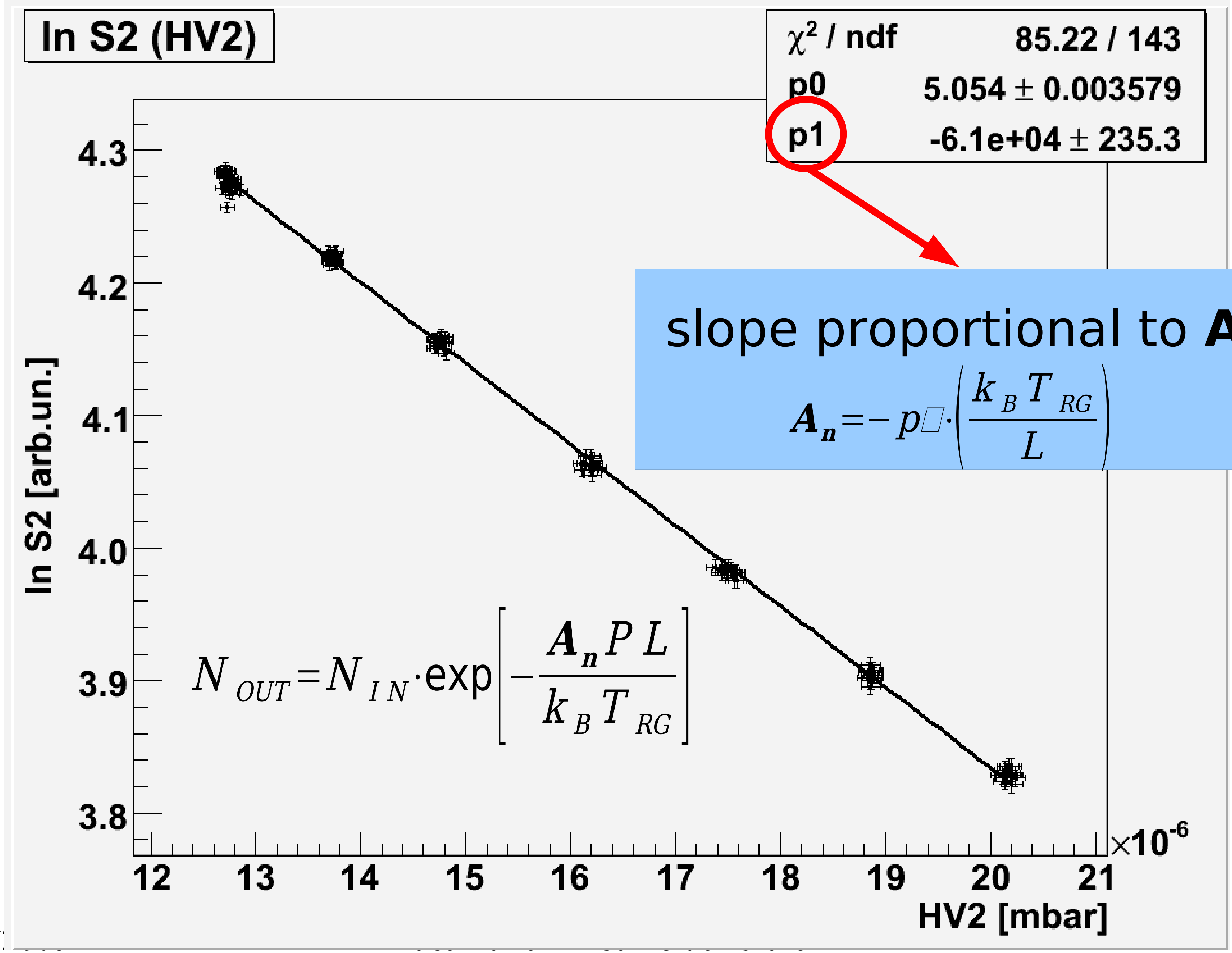






Measurements

Set 1 (mol)
T_{noz} 55 K

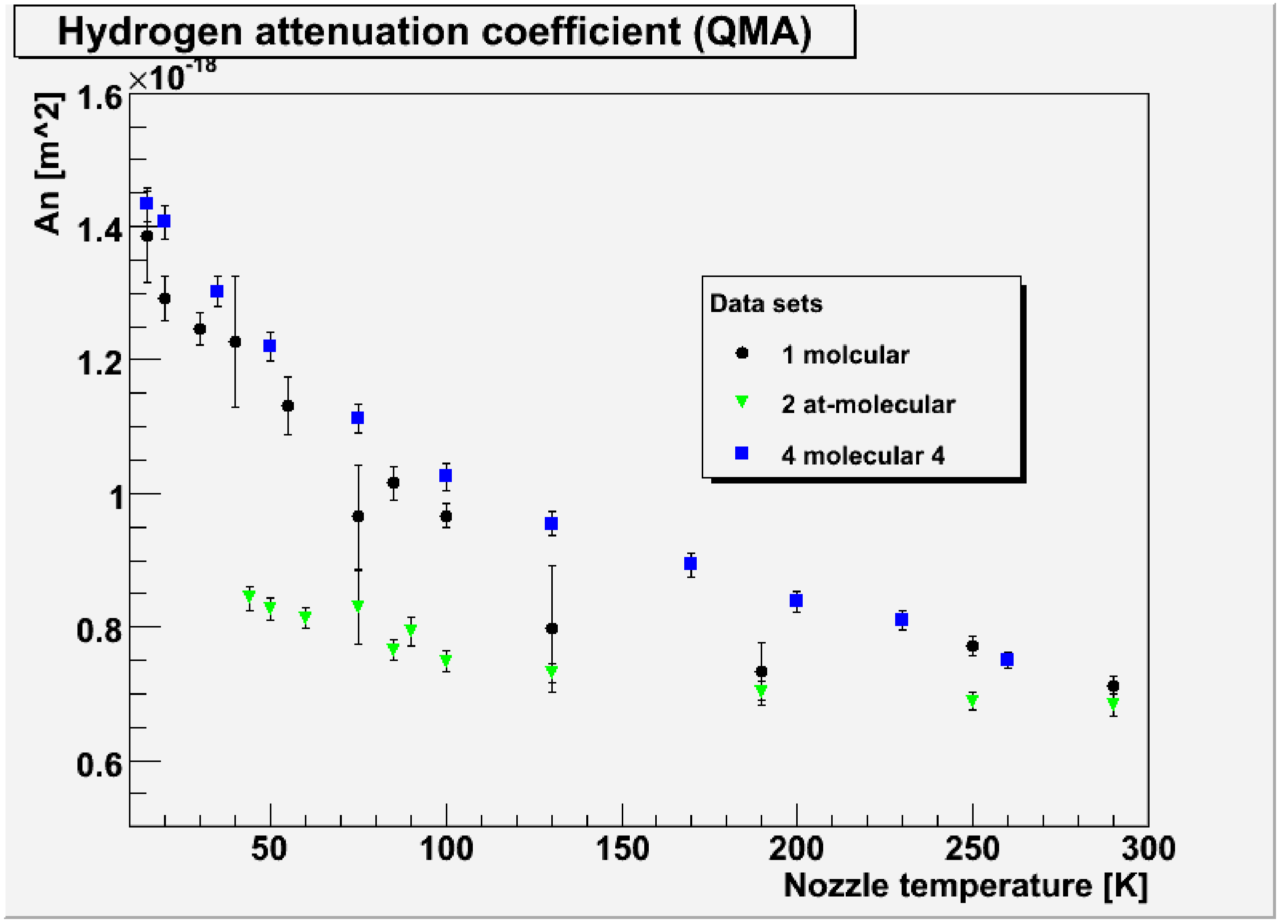


slope proportional to $\mathbf{A_n}$

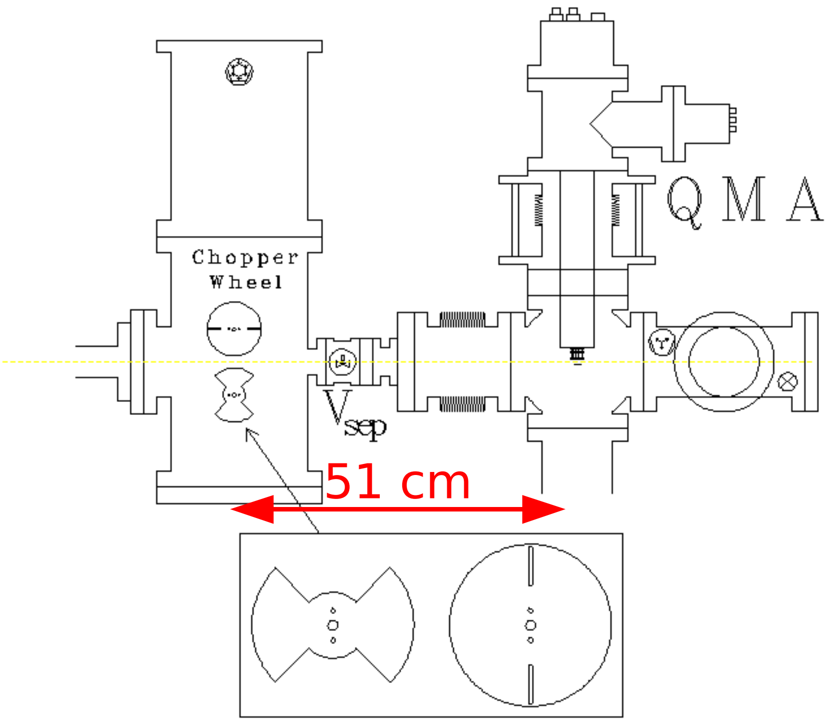
$$A_n = -p\square \cdot \left(\frac{k_B T_{RG}}{L}\right)$$

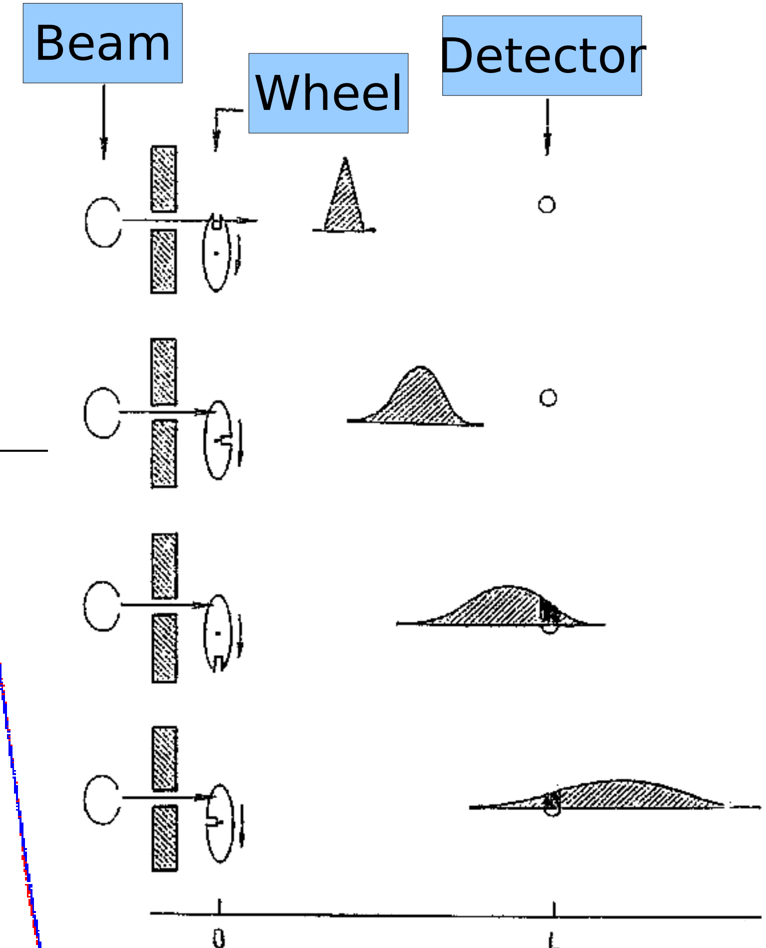
$$N_{OUT} = N_{IN} \cdot \exp\left[-\frac{A_n P L}{k_B T_{RG}}\right]$$

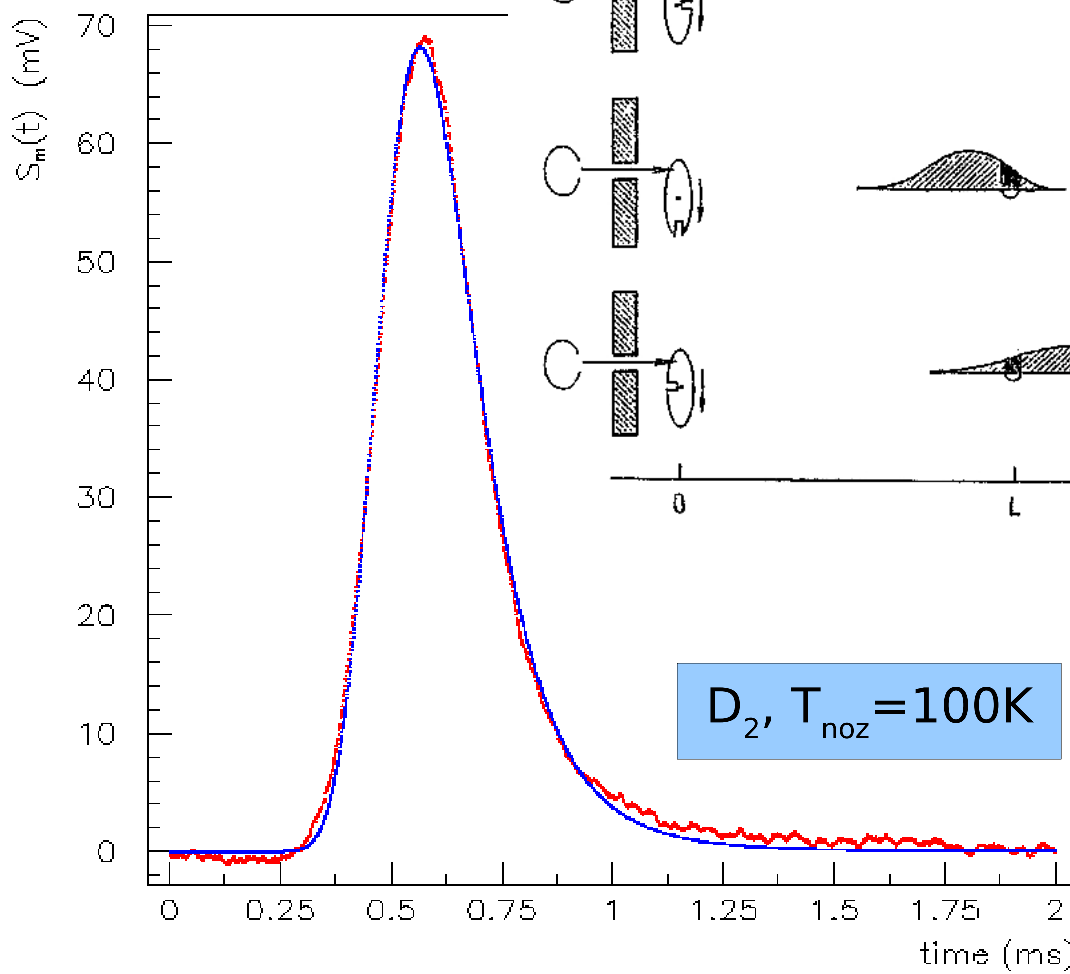
Attenuation coefficient as function of T_{nozzle} (standard in literature)



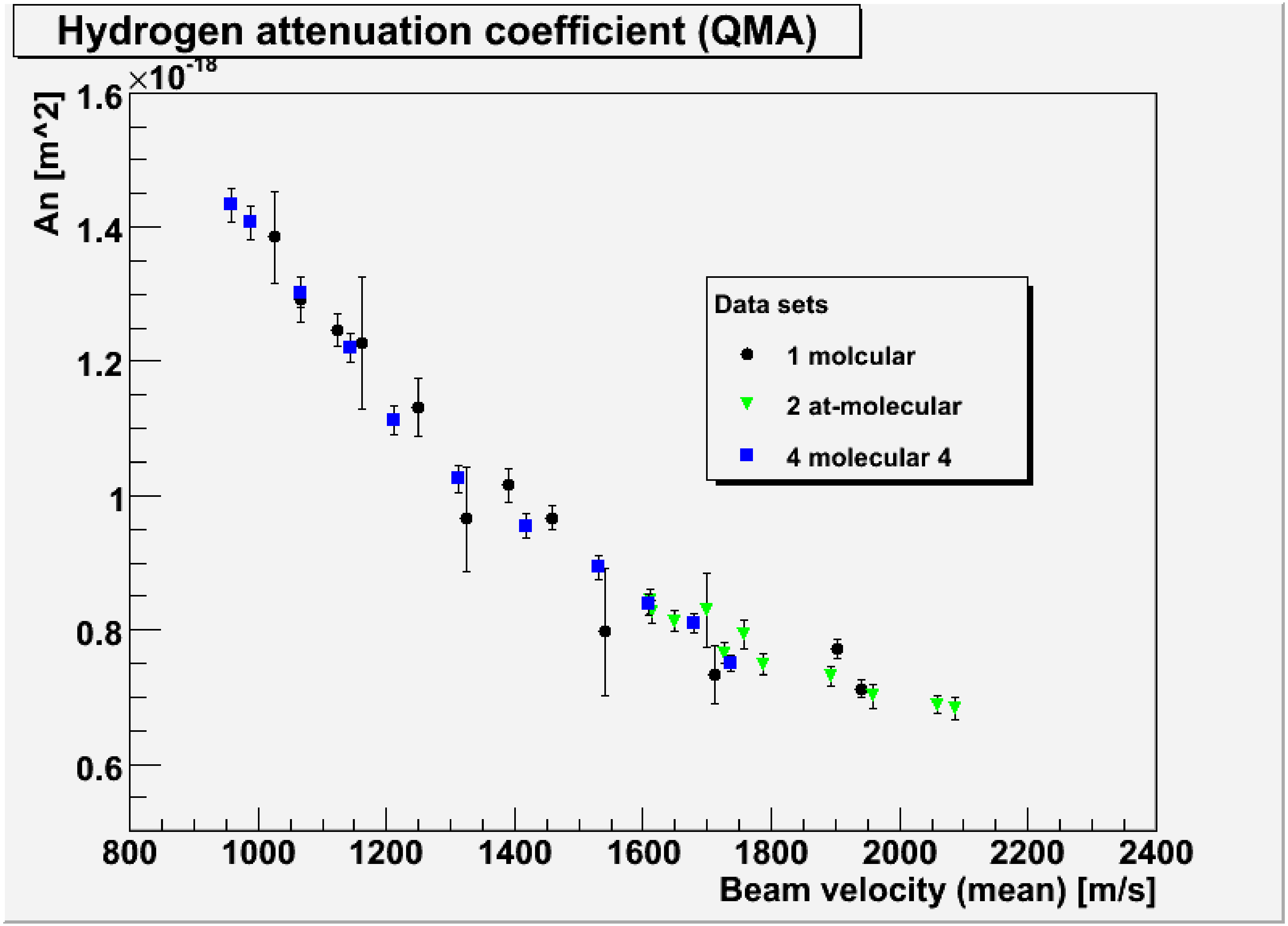
Time Of Flight (TOF)
(working principle)



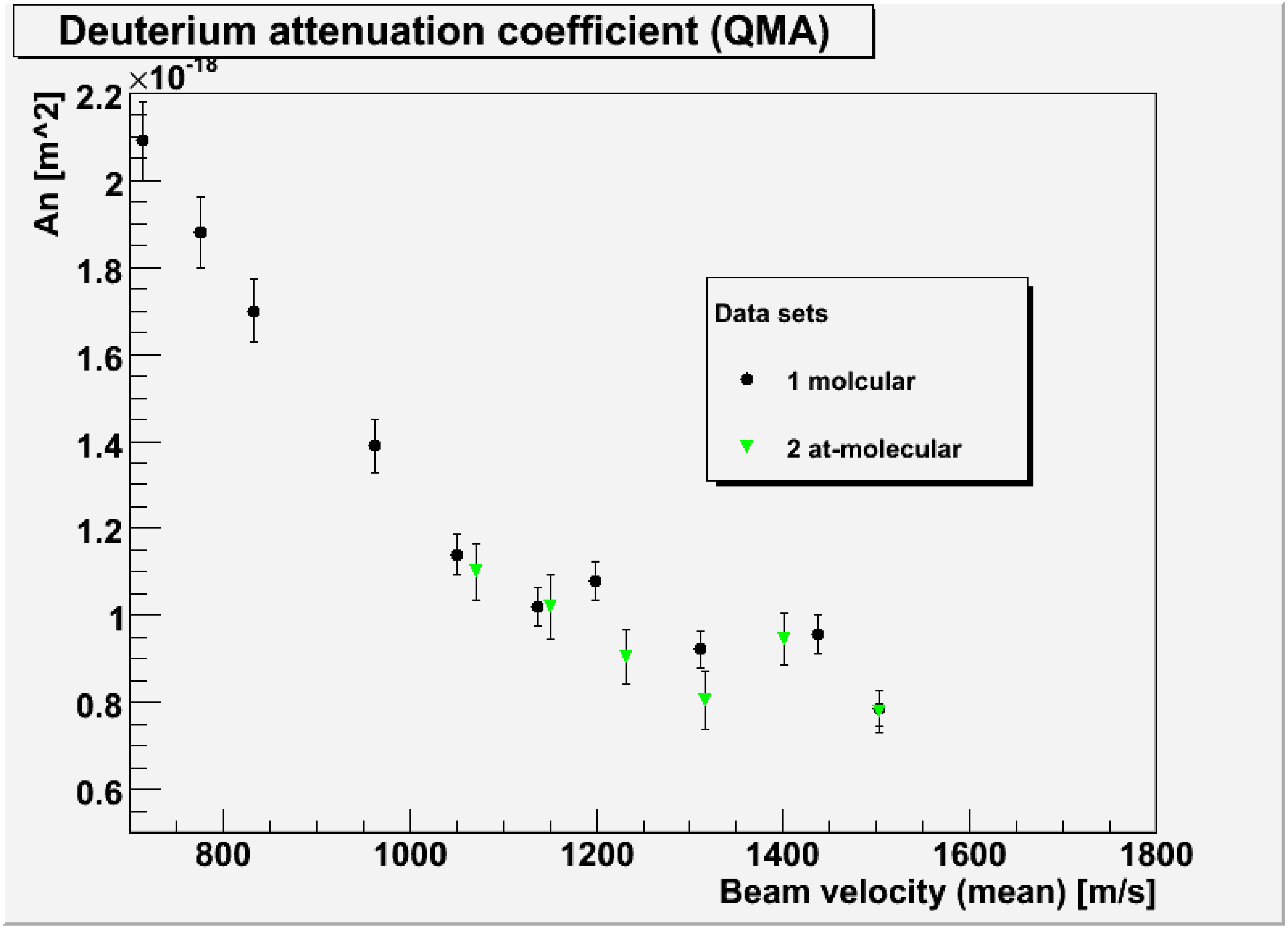




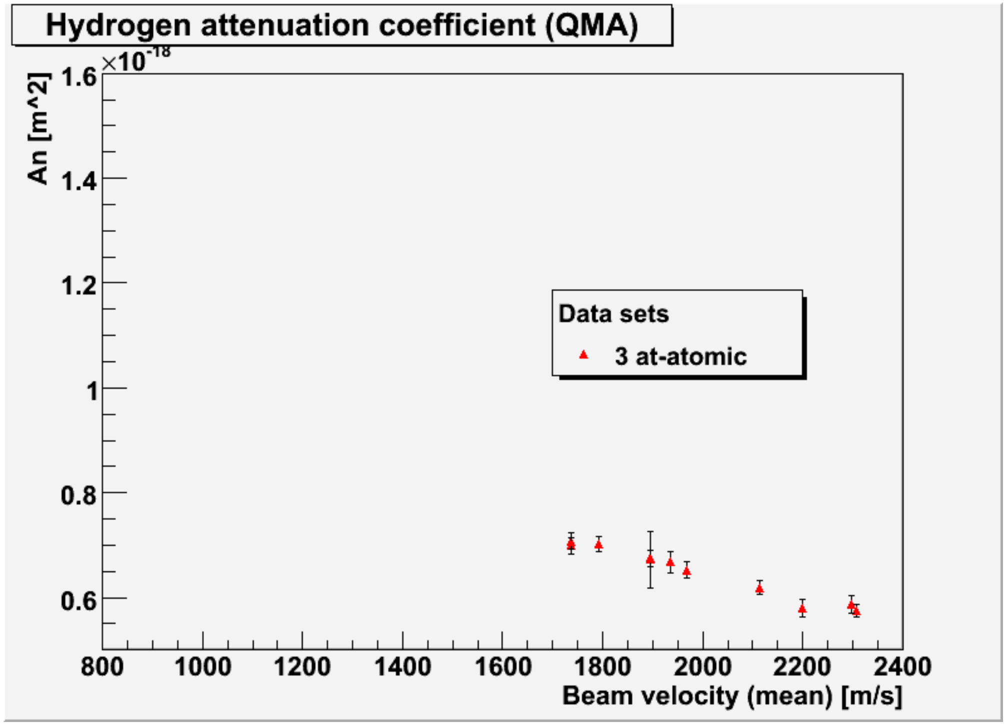
Attenuation coefficient as function of Beam velocity (NEW!) (Molecular Hydrogen beam)

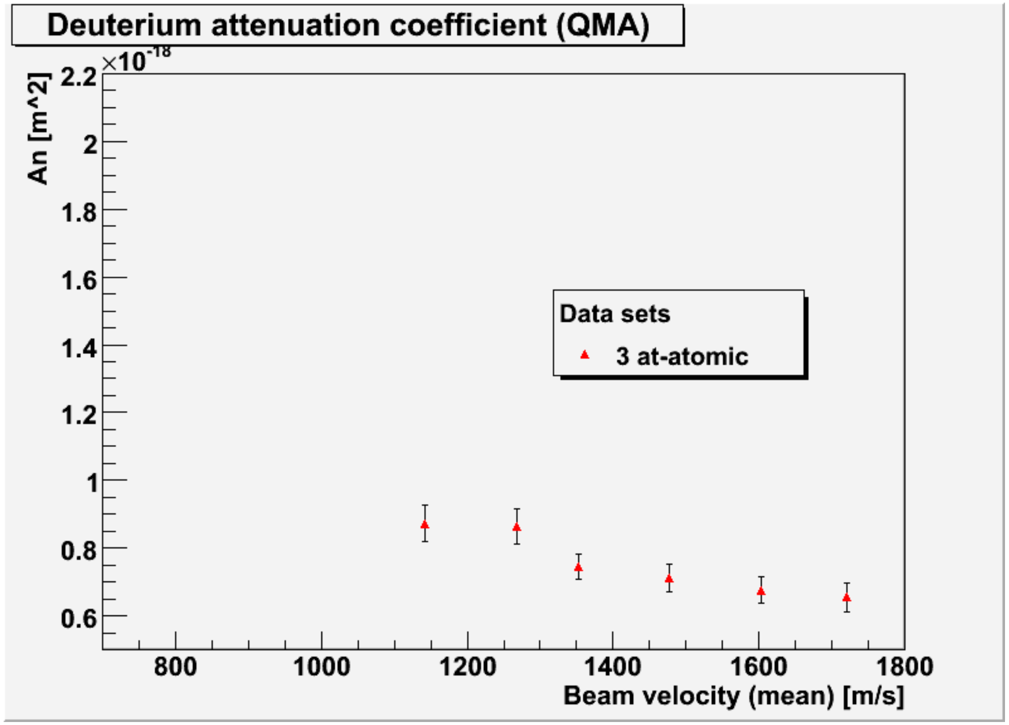


Attenuation coefficient as function of Beam velocity (Molecular Deuterium beam)



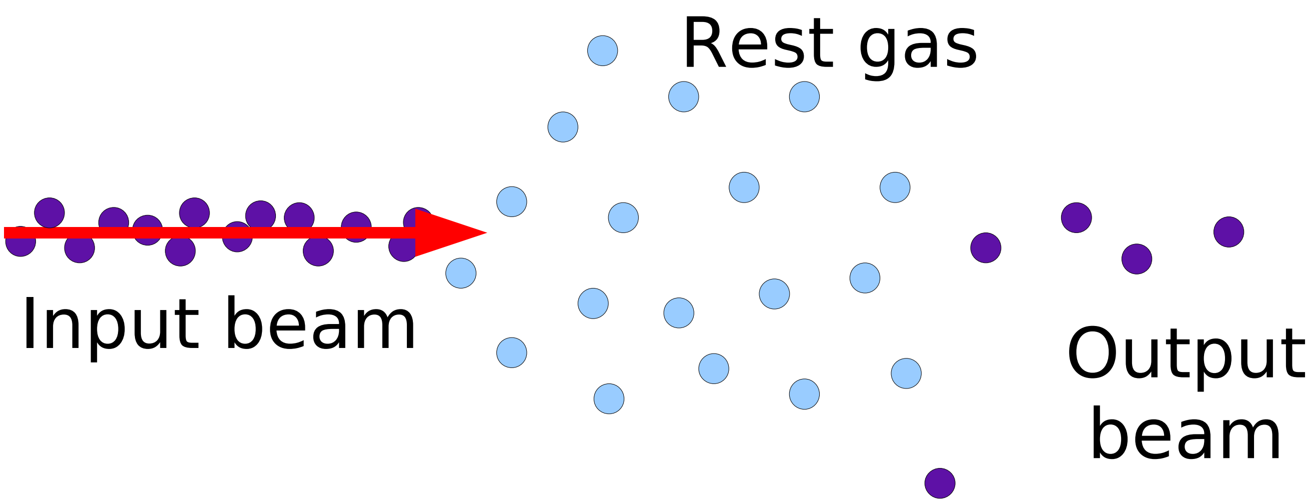
Attenuation coefficient as function of Beam velocity (Atomic Hydrogen and Deuterium)





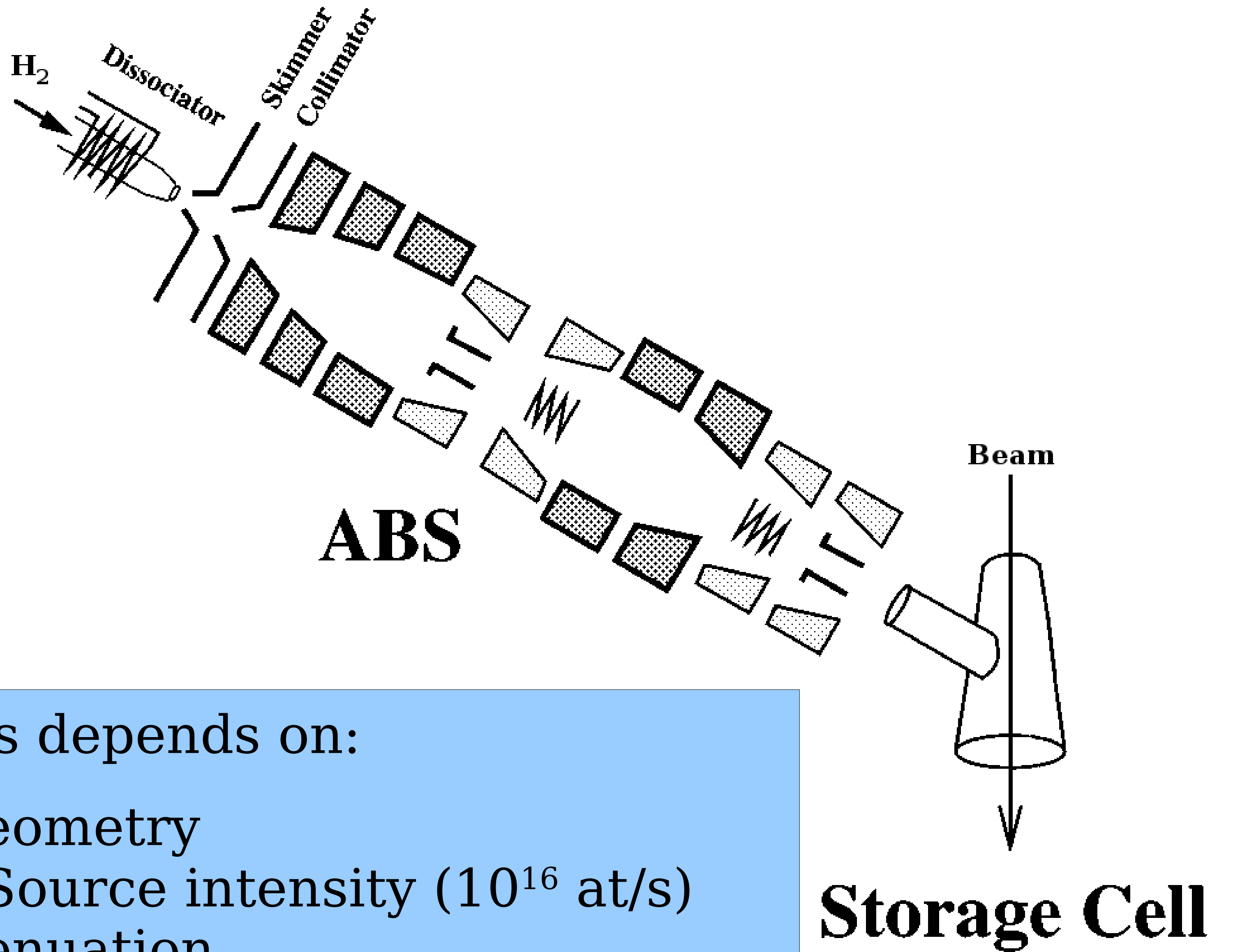
(Publication in preparation)

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

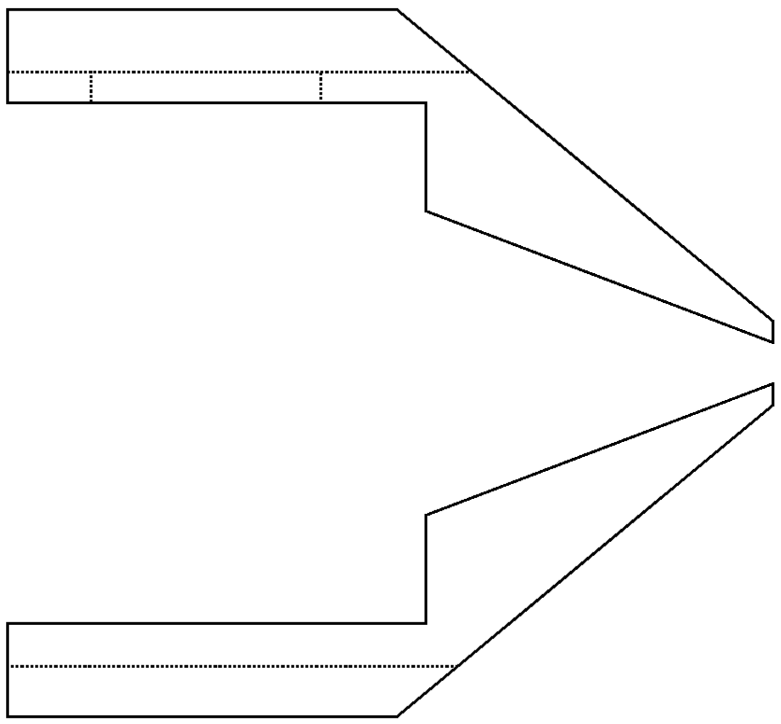


Target thickness depends on:

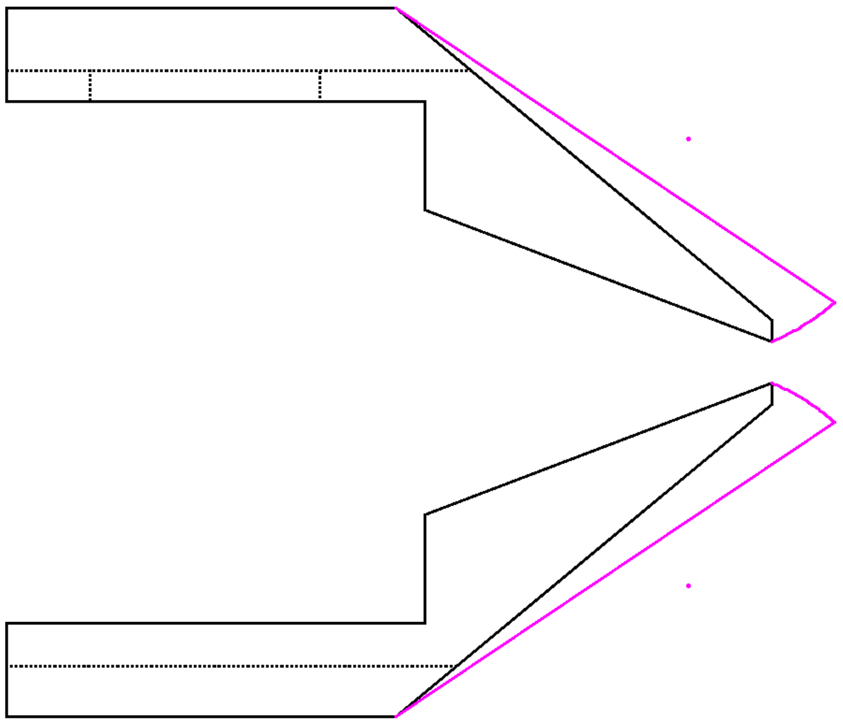
- Storage cell geometry
- Atomic Beam Source intensity (10^{16} at/s)
  - Rest Gas Attenuation
  - **Trumpet nozzle**

Trumpet nozzle

Possible way to increase beam intensity



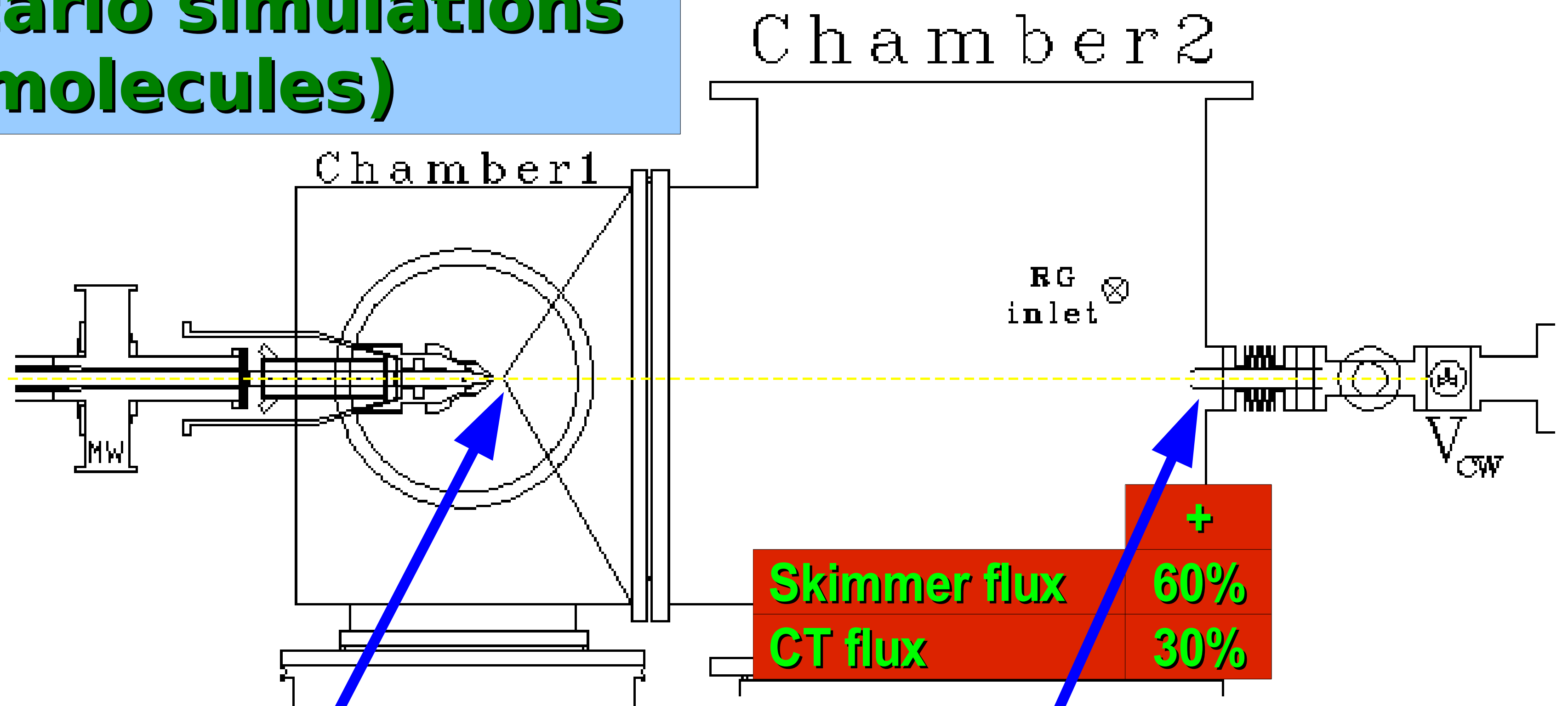
Nozzle #3 (sonic)



Nozzle #4 (trumpet)

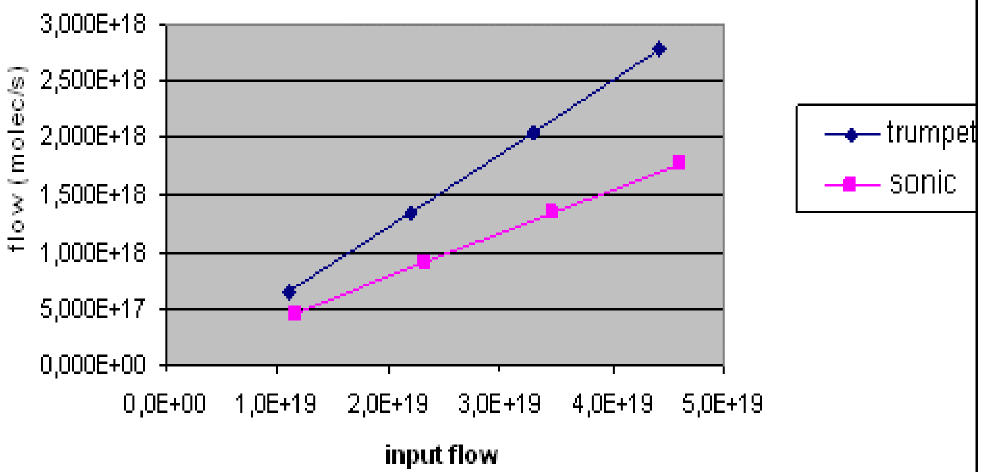
Monte Carlo simulation (ds2g by Bird) => improvement of beam intensity

Montecarlo simulations (molecules)

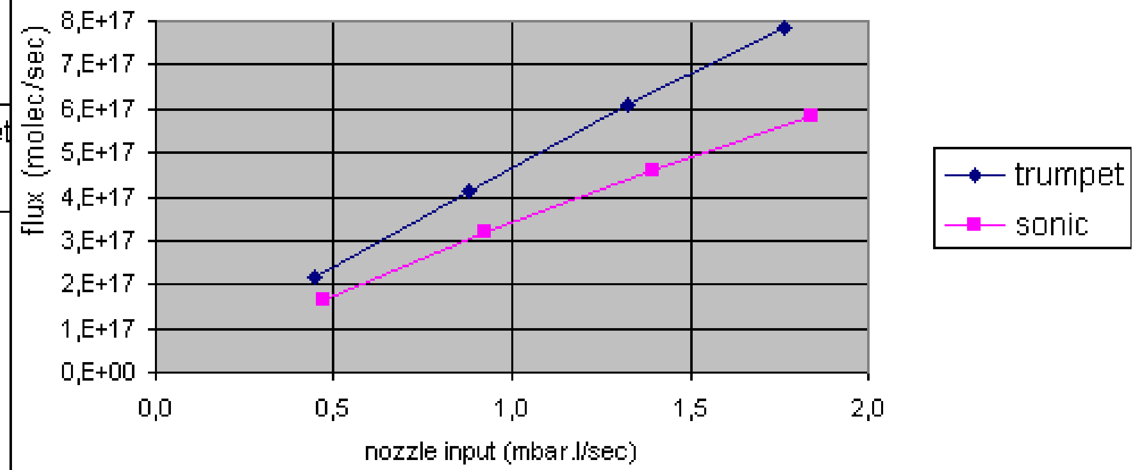


	+
Skimmer flux	60%
CT flux	30%

Skimmer flux



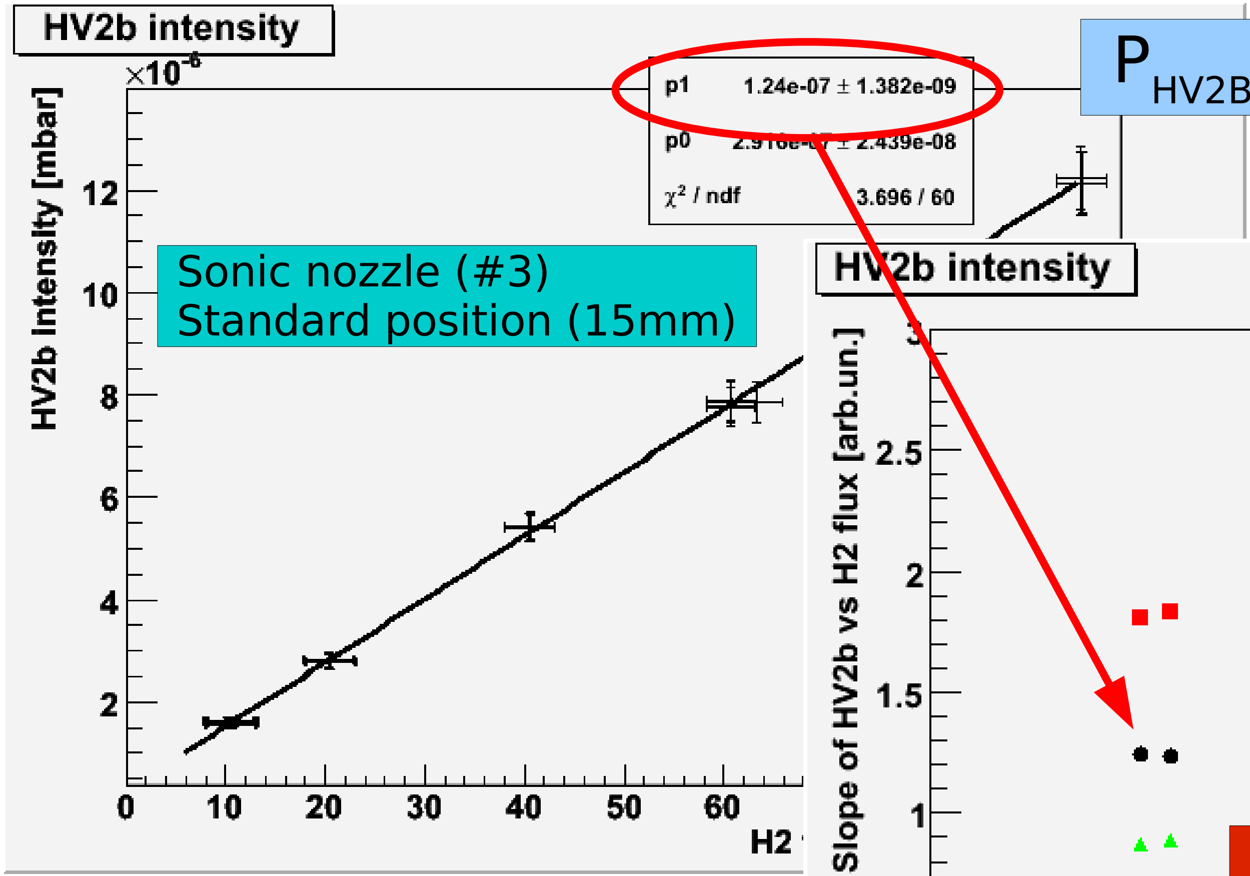
CT flux

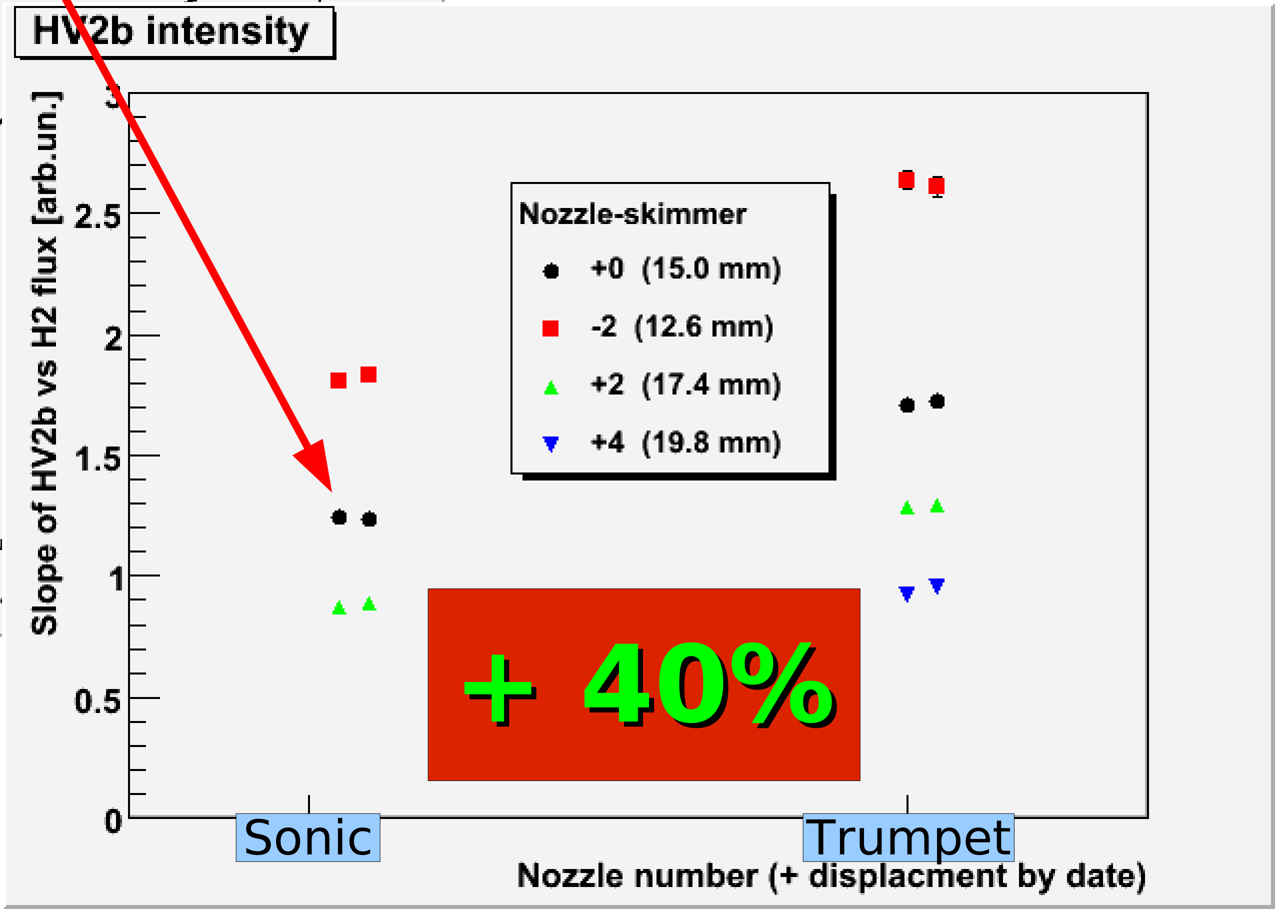


Measured beam intensity through skimmer
(Chamber 2 used as Compression Volume)

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

T_{noz} = 100K (always)



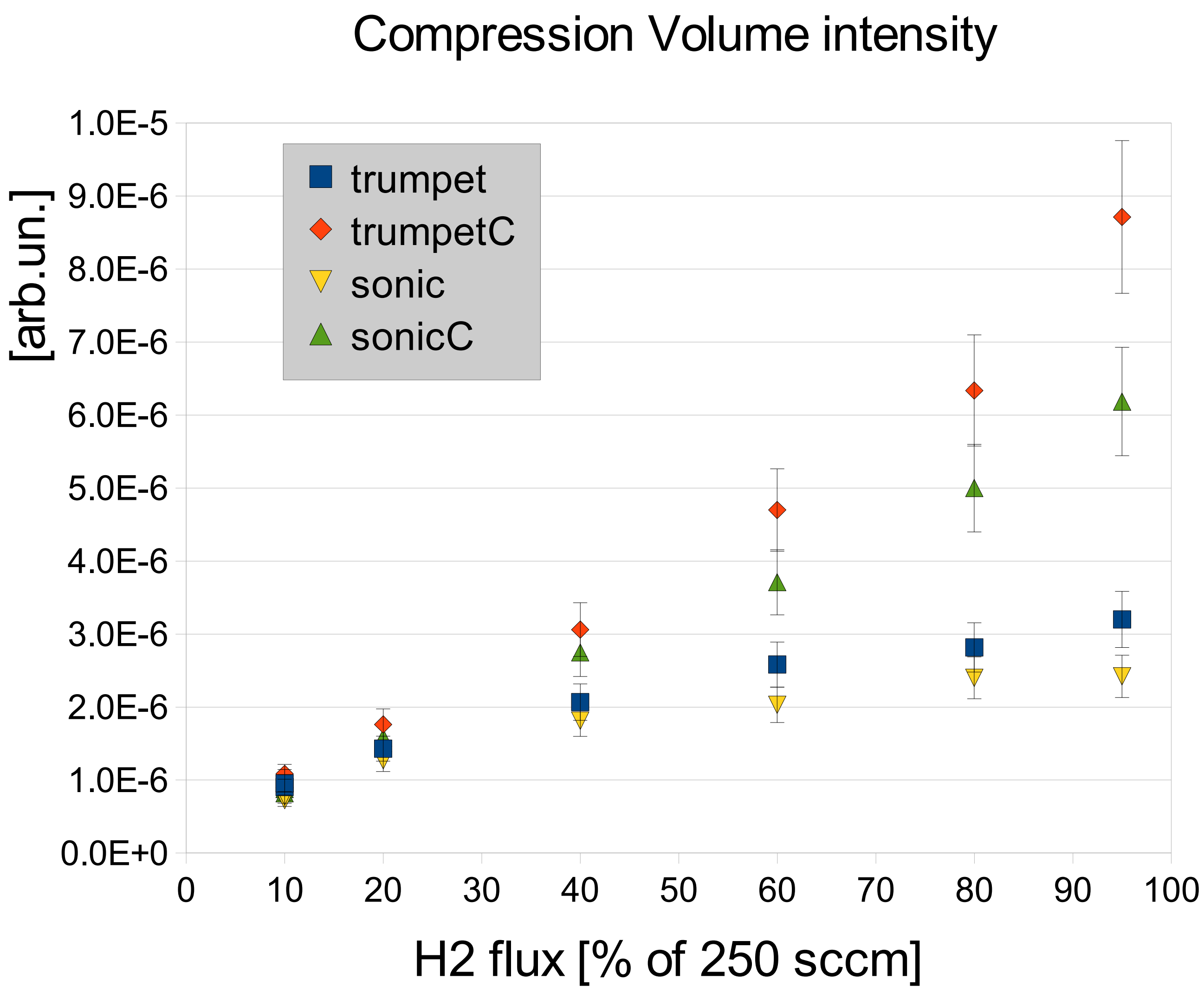


Measured beam intensit in the Compression Volume

Beer's law:

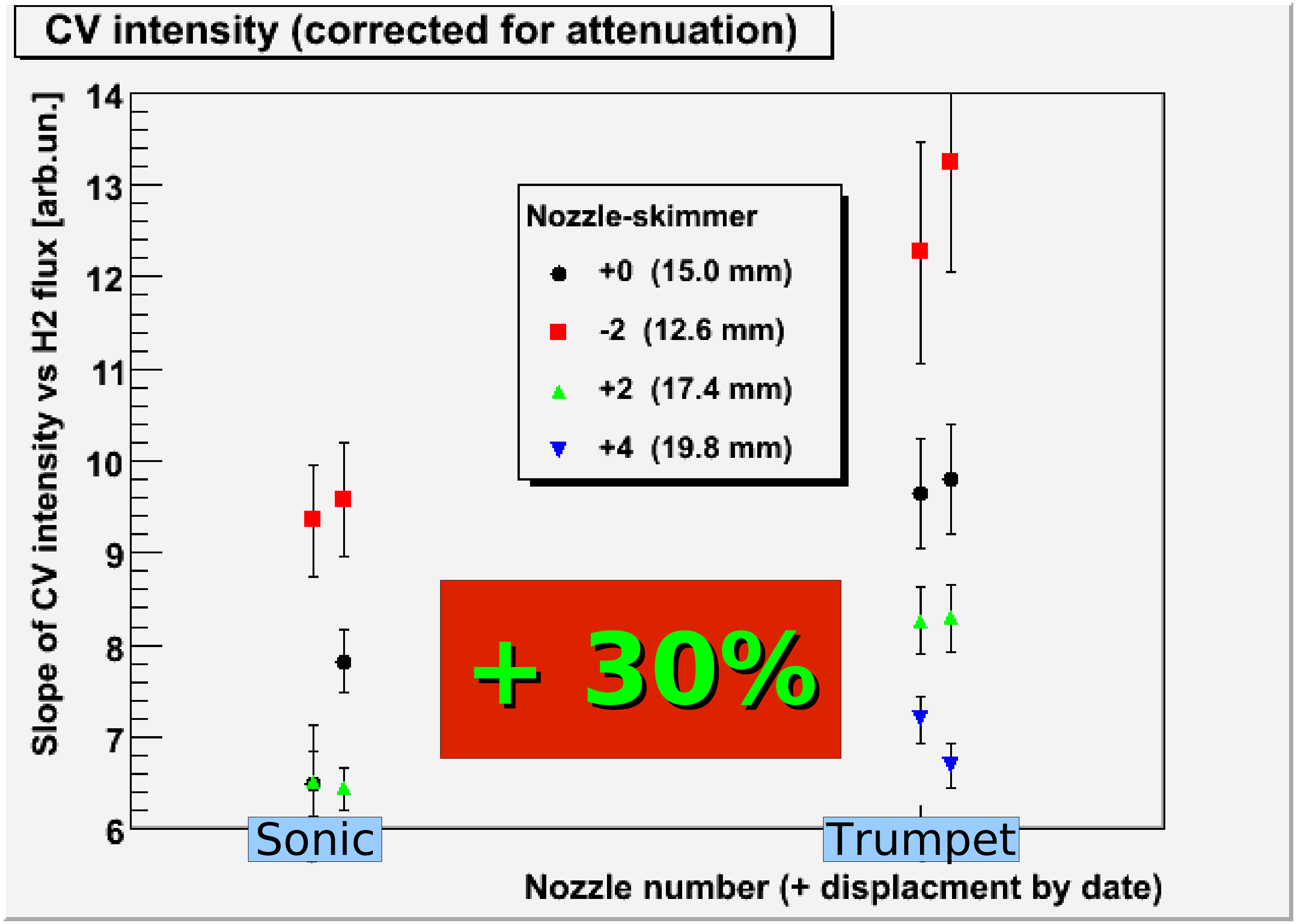
$$I = I_0 \cdot \exp\left(-\boldsymbol{A_i}\, n\, L\right)$$

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



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