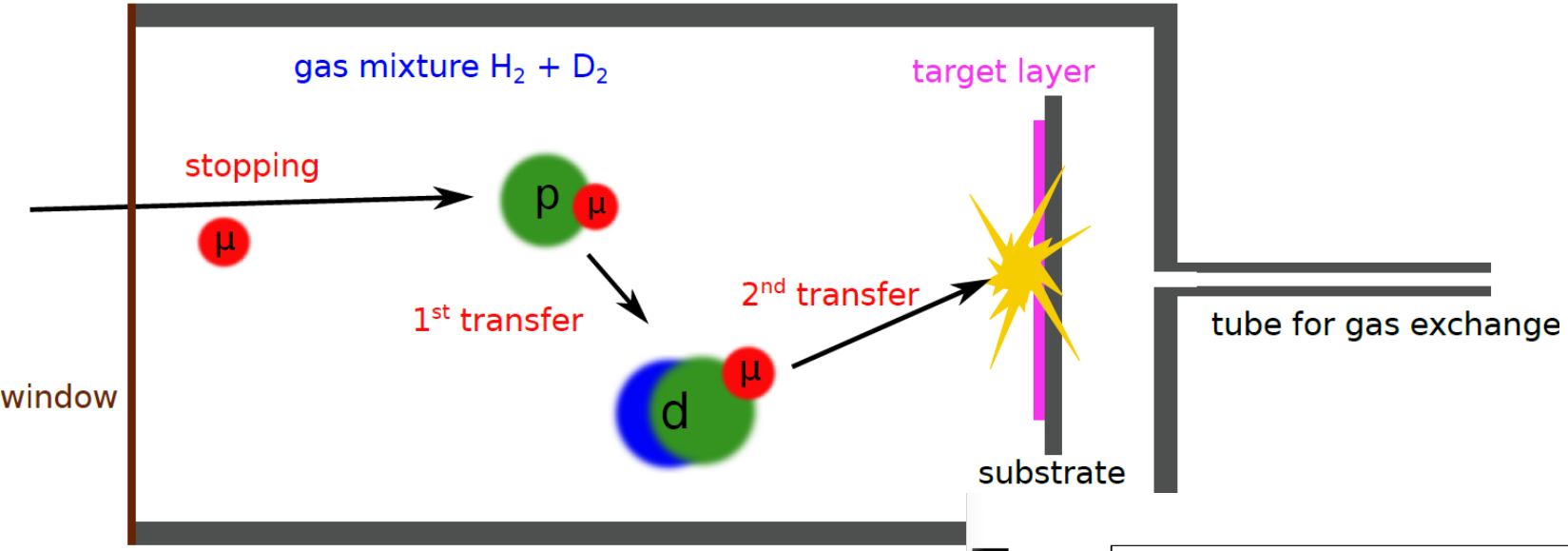
Status of Transfer Simulations

muX Collaboration Meeting 2018

Talk by Jonas Nuber

Reminder: The muX transfer mechanism

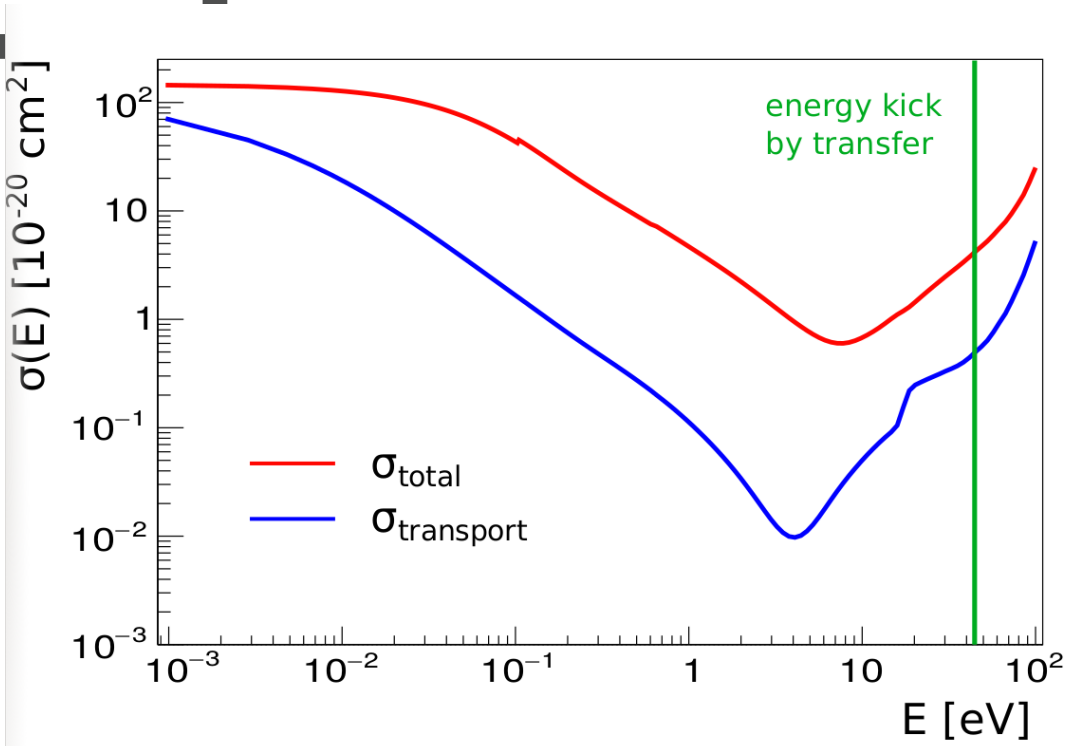


- Isotopic muon exchange:

  ~ 43 eV kinetic energy kick

- Ramsauer-Townsend minimum

  at ~ 4 eV



Outline

Implementation of Diffusion Simulations

Comparison to experimental data

Potential improvements of the geometry

Implementation of the diffusion process in Geant4

- Molecular scattering processes: $\mu a(\mathrm{F}) + \mathrm{BC} \longrightarrow \mu a(\mathrm{F'}) + \mathrm{BC}$
- Isotopic exchange: $\mu a + \mathrm{BC} \longrightarrow \mu b + \mathrm{AC}$

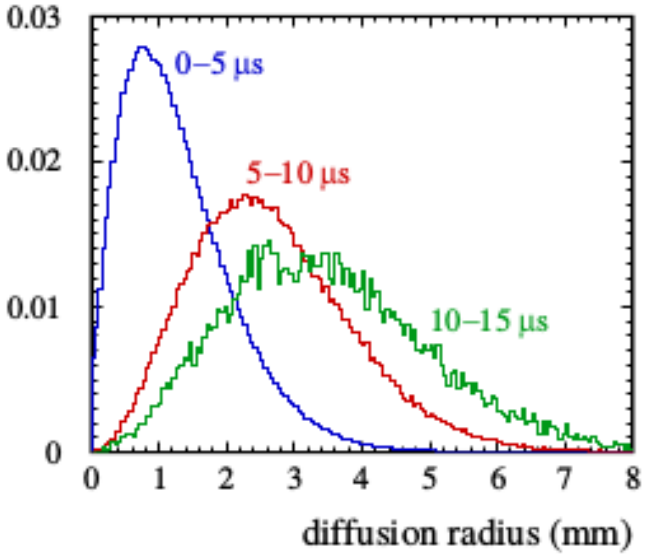
- Differential cross sections calculated by A. Adamczak (adiabatic framework)

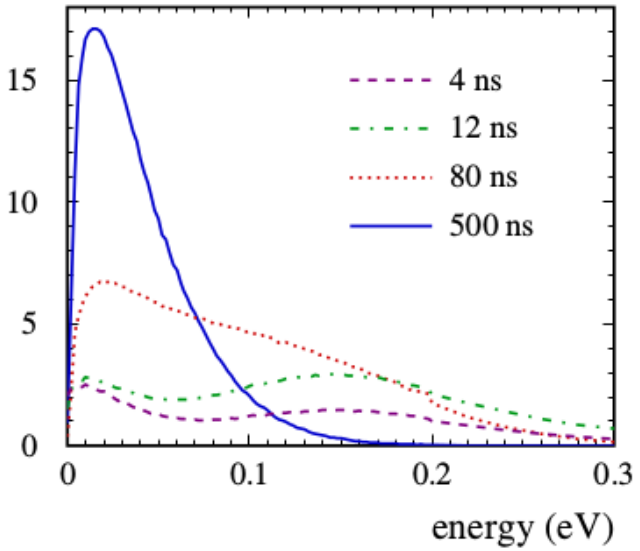
- Implementation in Geant4
  - Tracking / Stepping already included
  - New particles and physical processes easily added to simulation

- Testing of correct functionality of algorithms 

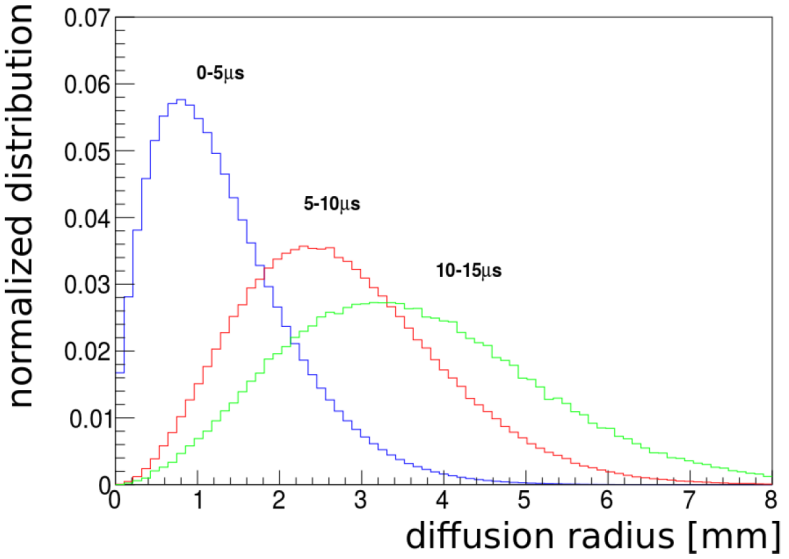
Cross check with simulations from A. Adamczak

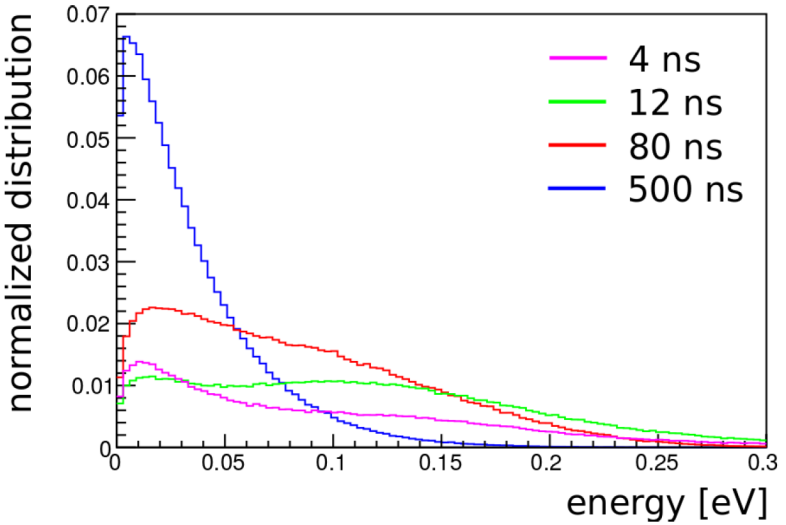
A. Adamczak



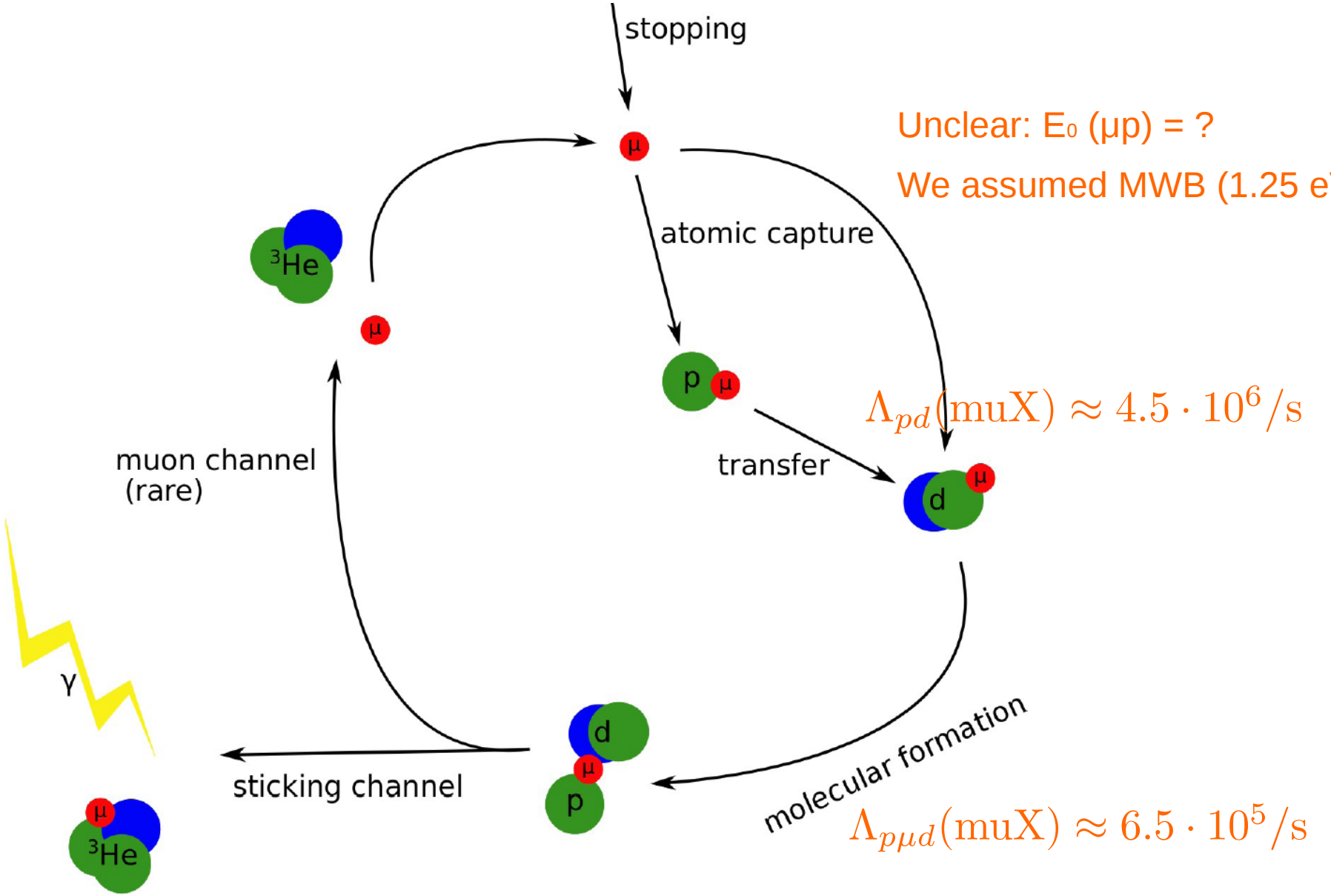


our results





The fusion cycle in H_2/D_2



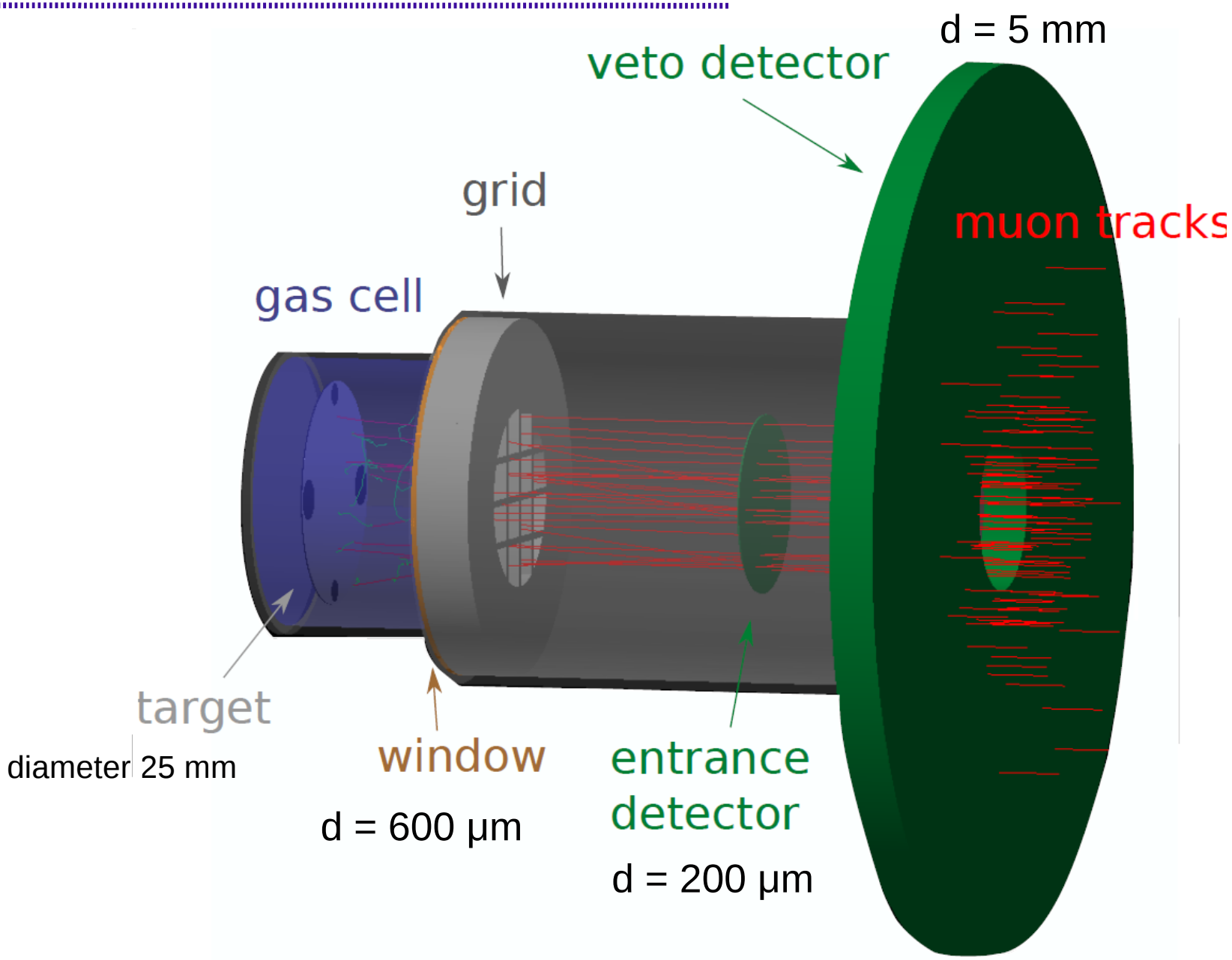
Unclear: E_0 (μp) = ?

We assumed MWB (1.25 eV)

$$\Lambda_{pd}(\mathrm{muX}) \approx 4.5 \cdot 10^6/\mathrm{s}$$

$$\Lambda_{p\mu d}(\mathrm{muX}) \approx 6.5 \cdot 10^5/\mathrm{s}$$

muX target model



Momentum distribution of muon beam

Experiment:

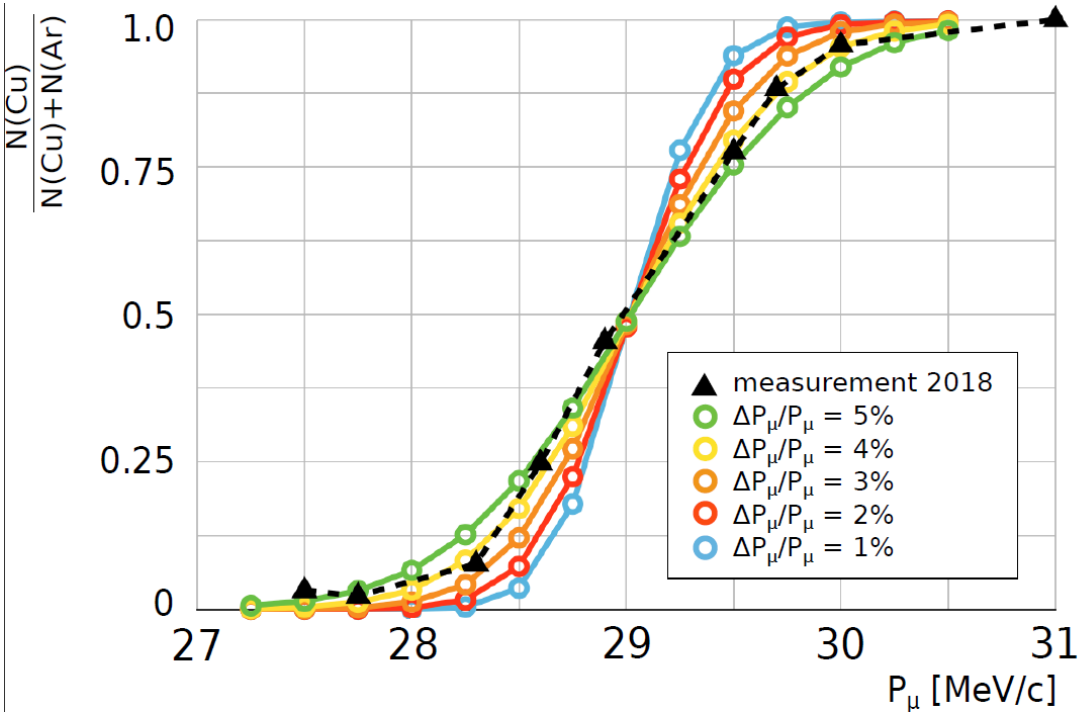
- Target: gold on Cu
- Gas mixture: H_2 + Ar
- Compare number of x-rays in 2p-1s of Cu and Ar

Stopping simulations [N. Ritjoho]:

- Gaussian momentum distribution
- Vary momentum bite $\Delta P_\mu / P_\mu$

Initial conditions for target simulations:

- gaussian momentum
- $\Delta P_\mu / P_\mu = 4\%$

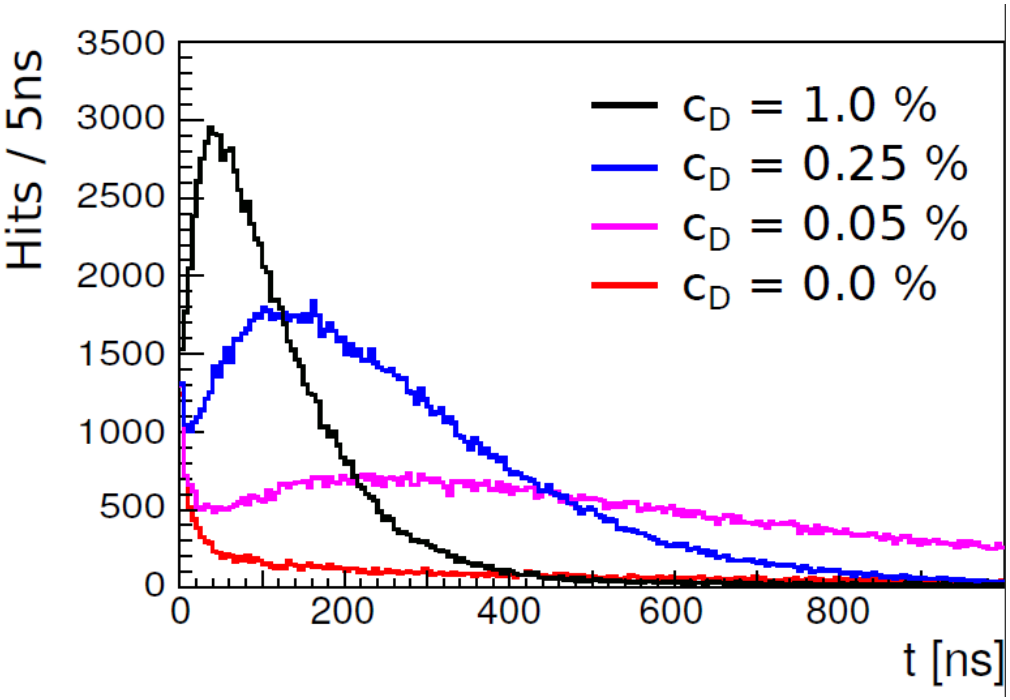


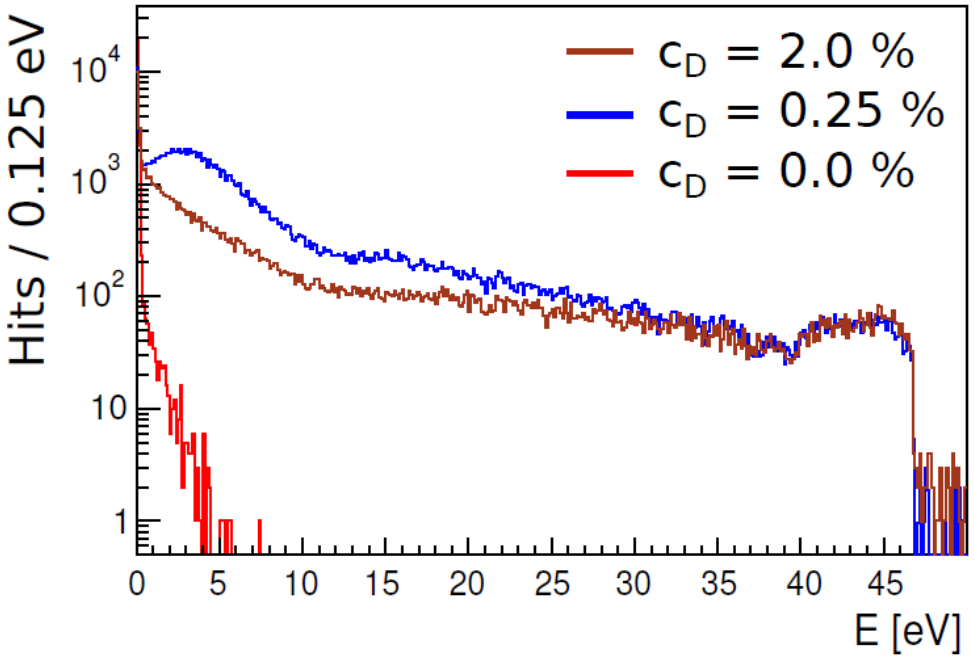
[courtesy N. Ritjoho]

Energy and time distributions of target hits

- Time distributions:
  - The higher cD,

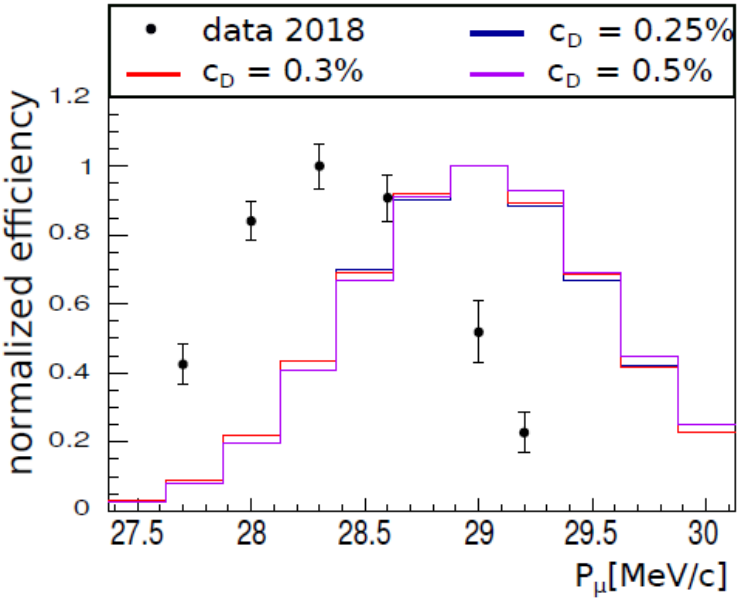
    the faster the transfer
  - Experiment: on average faster transfer





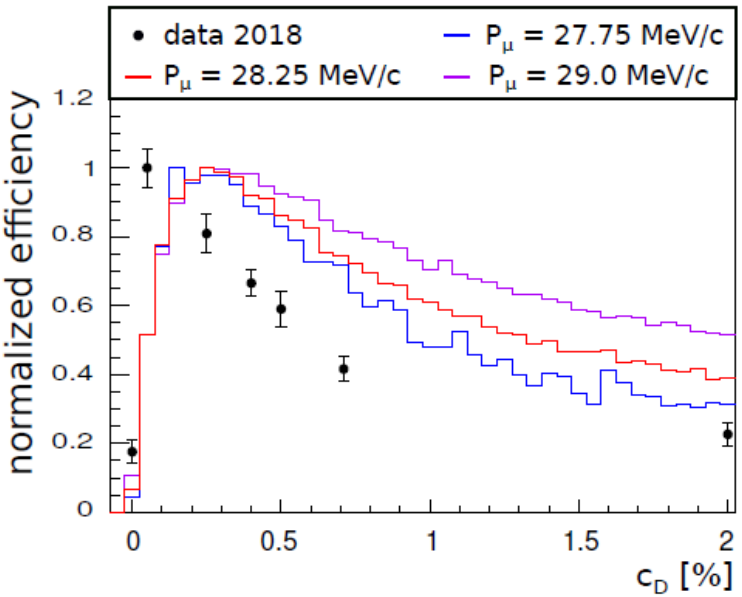
- Energy distributions:
  - Exchange peak (43eV) washed out due to initial energy
  - Ramsauer-Townsend peak at 4 eV for cD=0.25%

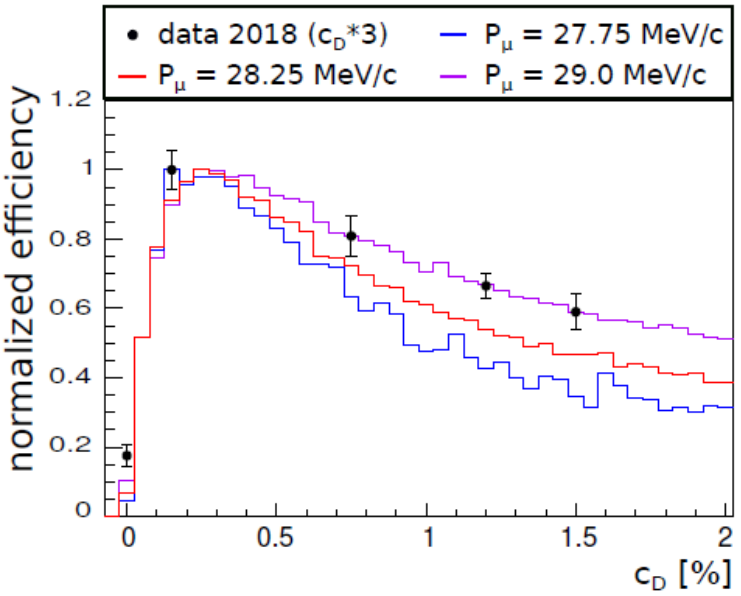
Matching of experimental data and simulation results



- Shift in distribution of momentum scan (left)

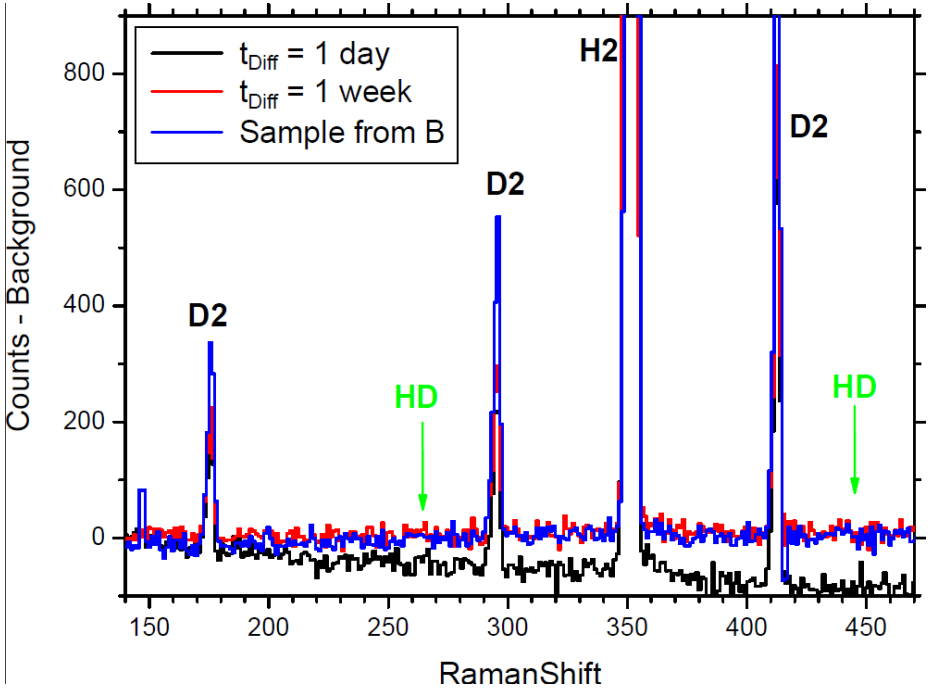
- Discrepancy in measured c_D values (below) compared to simulation

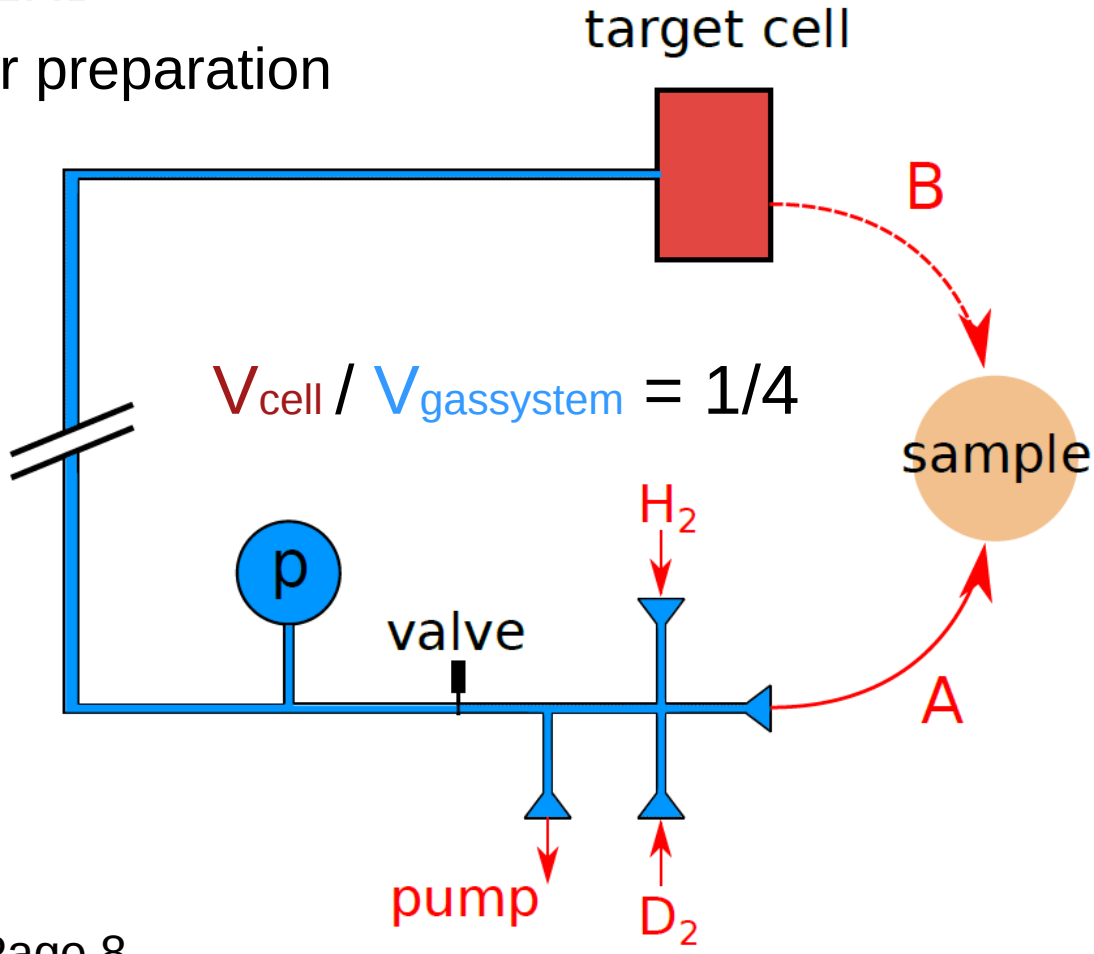




Investigation of mixing behavior

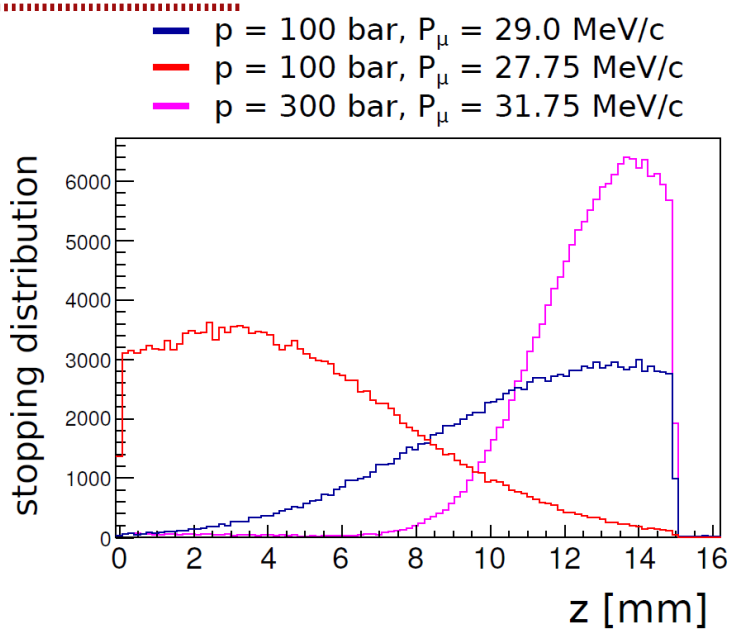
- Prepare gas mixture and wait for various times t_{Diff}
- Measure D_2 concentration with Raman spectrometer
- Results:
  - No catalysis of $H_2 + D_2 \rightarrow 2HD$
  - Higher c_D in target cell after preparation



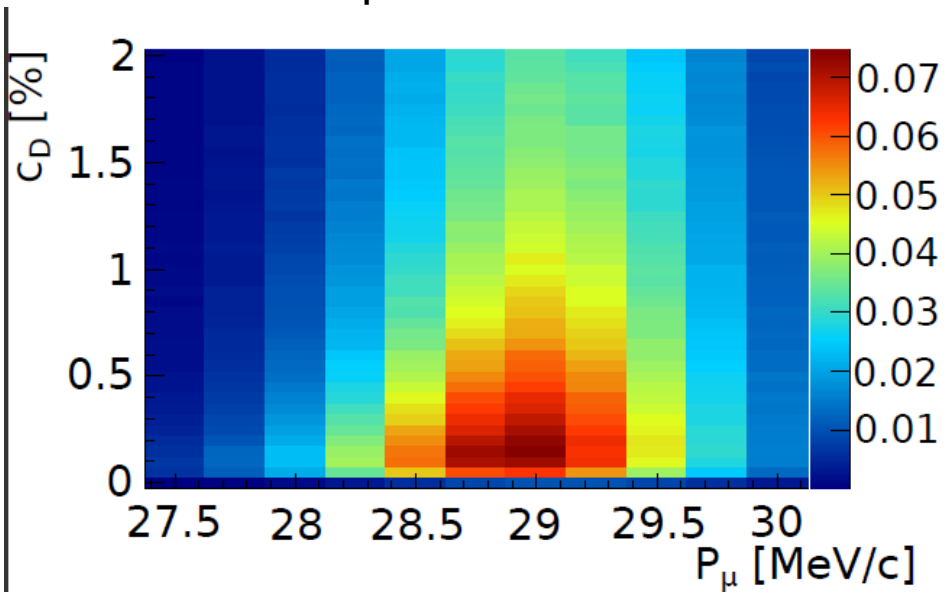


Effect of a variation in pressure on transfer efficiency

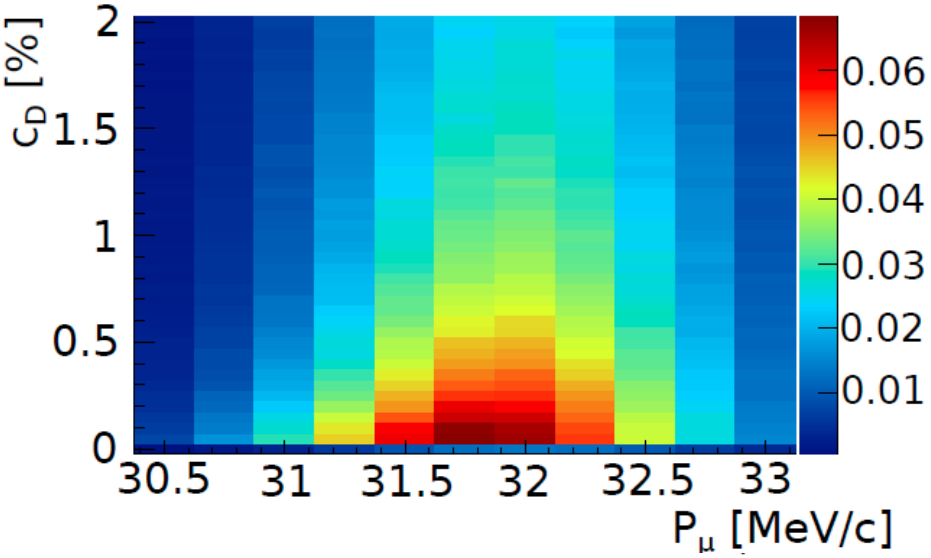
- High Pressure → narrow stopping distribution
- But: balanced by stronger scattering
- Sensitivity of total transfer efficiency to variation of pressure is small



p = 100 bar



p = 300 bar

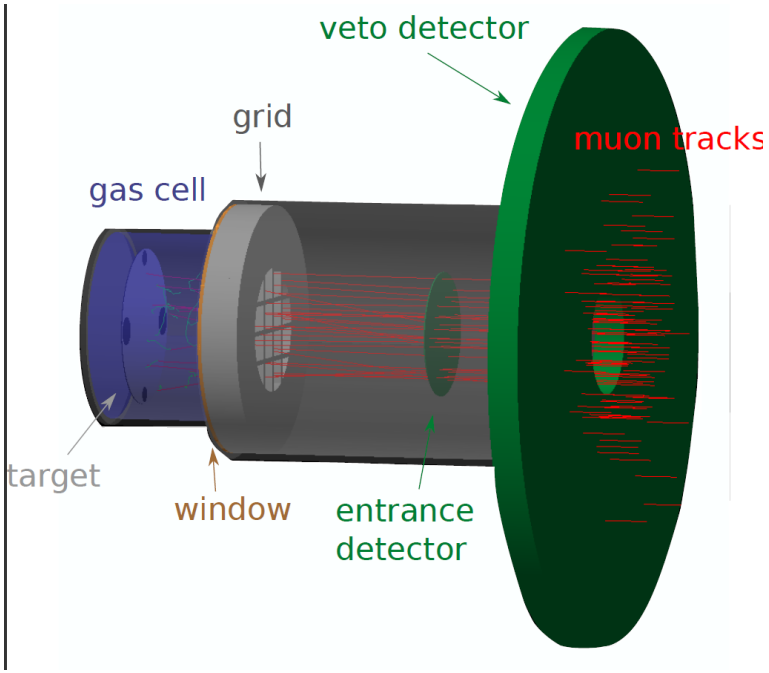


Variation of entrance detector and window

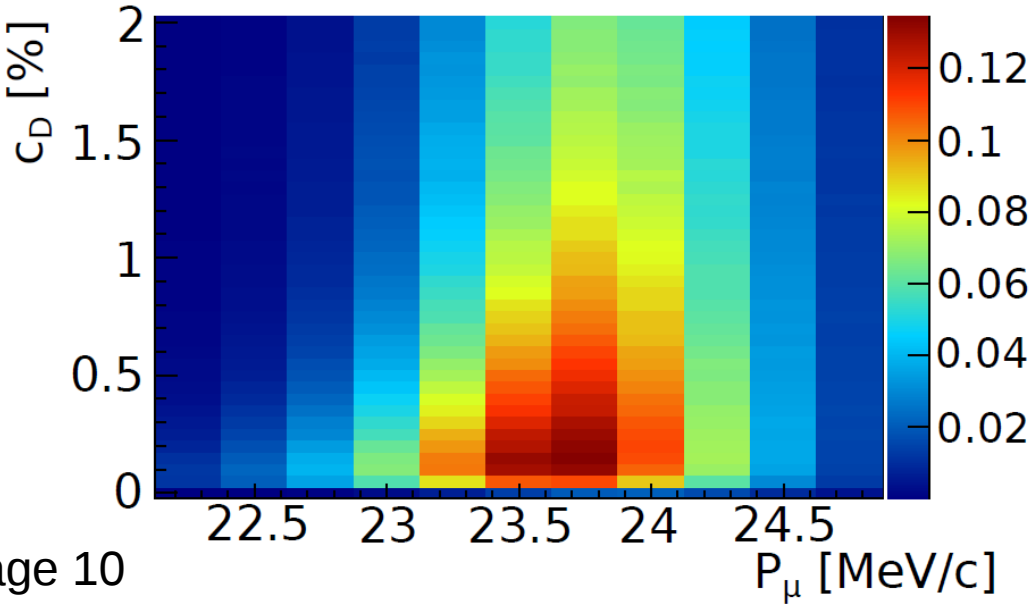
- Reduction of thickness narrows down stopping distribution
- Increasing transfer efficiency with decreasing thickness
- But: muon rate in beam

$$\hat{r}_\mu \sim P_\mu^3$$

- Only small win possible, but lower Background

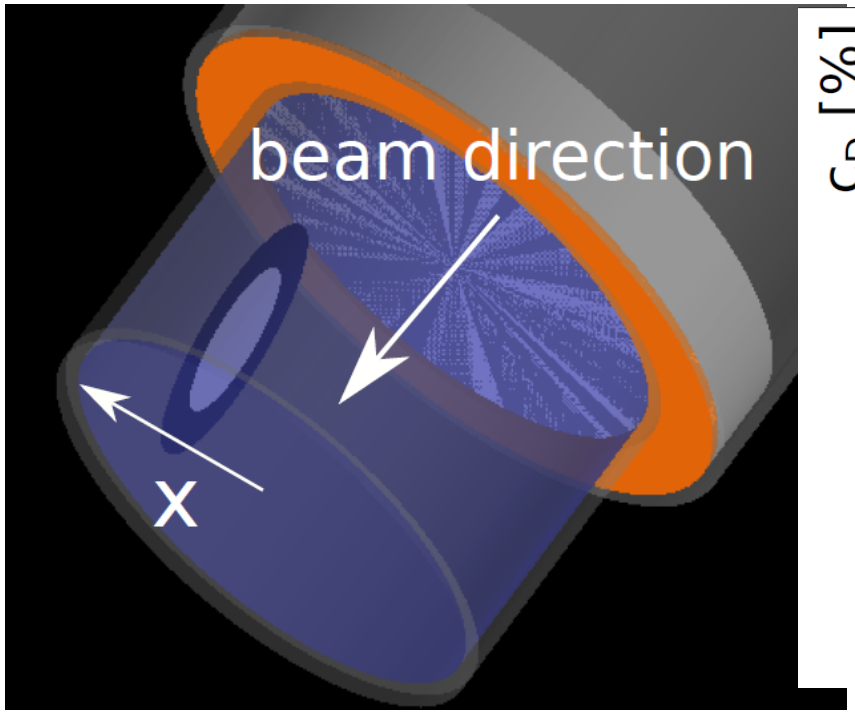


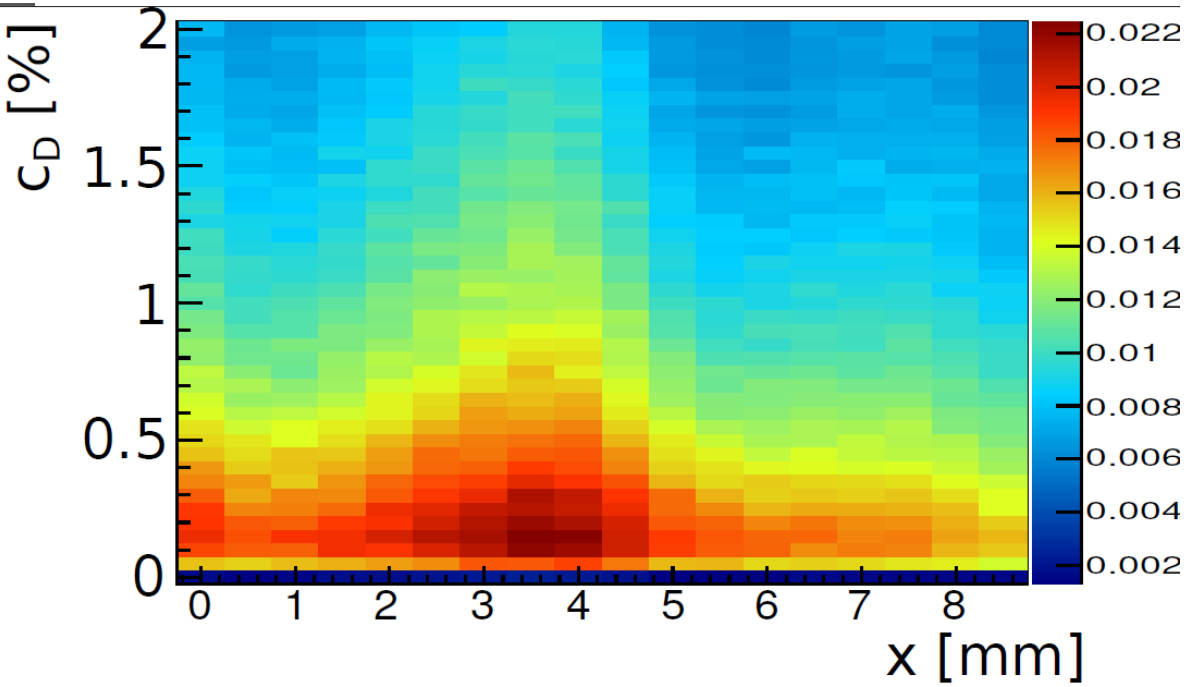
d(entrance) = 100 µm, d(window) = 200 µm



Turned target

- Simulations for target turned by 90°
- Beam momentum fixed: stopping maximum in center of target
- Smaller target:
  - diameter 10mm
  - original target position: transfer efficiency 2.5%





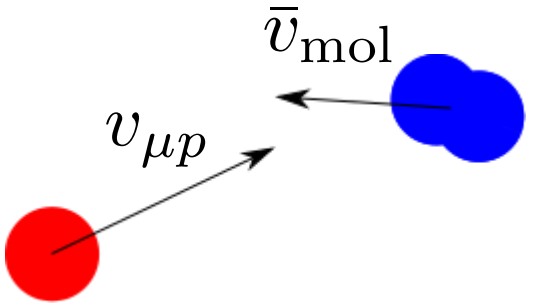
Summary

- Geant4 implementation of diffusion process
  - Atomic formation
  - Molecular scattering + isotopic exchange (A. Adamczak)
  - Molecular formation + muon-catalyzed fusion
- Matching between experimental data and simulations reveals inconsistencies regarding the deuterium concentration
- Measurement with Raman spectrometer: D_2 gets pressed into gas cell
- Sensitivity to variations is low, maybe try reducing thickness of entrance detector and window
- Future: Validation with data 2019?

If Time left

Mean free path correction for lab cross sections

- $v_{\mu p} \gg \bar{v}_{\mathrm{mol}} : \hat{r}_1 = \rho_n \cdot \sigma_{\mathrm{LAB}} \cdot v_{\mu p}$
- $v_{\mu p} \ll \bar{v}_{\mathrm{mol}} : \hat{r}_2 = \rho_n \cdot \sigma_{\mathrm{LAB}} \cdot \bar{v}_{\mathrm{mol}}$

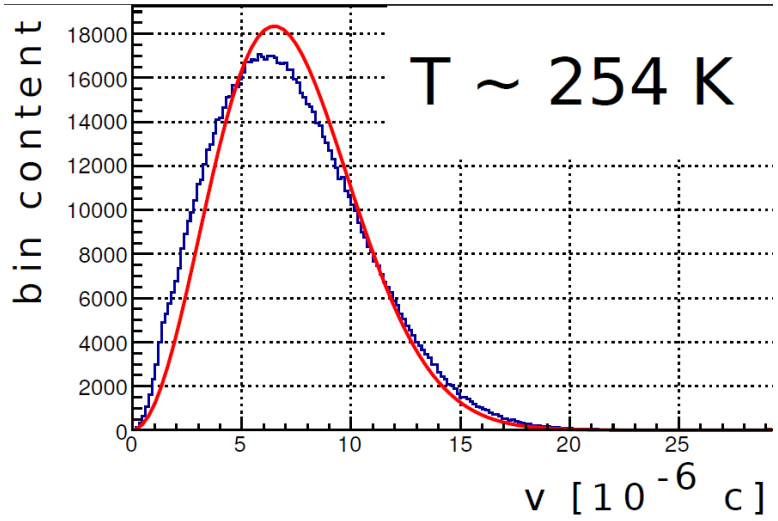


- include correction in mean free path:

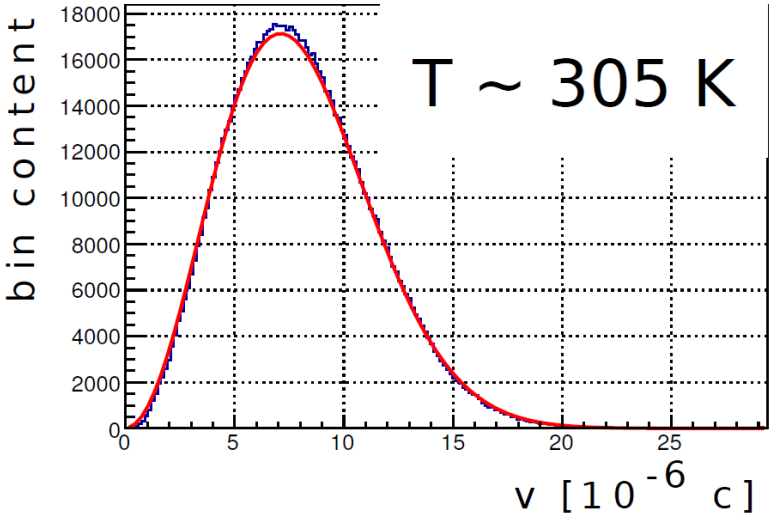
$$\lambda = \left(1 - e^{-\frac{v_{\mu p}}{\bar{v}_{\mathrm{mol}}}}\right) \cdot \frac{1}{\rho_n \cdot \sigma_{\mathrm{LAB}}}$$

Thermalized velocity distribution (μp)

without correction



with correction



Implementation of the diffusion process in Geant4

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- Isotopic exchange: $\mu a + \mathrm{BC} \longrightarrow \mu b + \mathrm{AC}$

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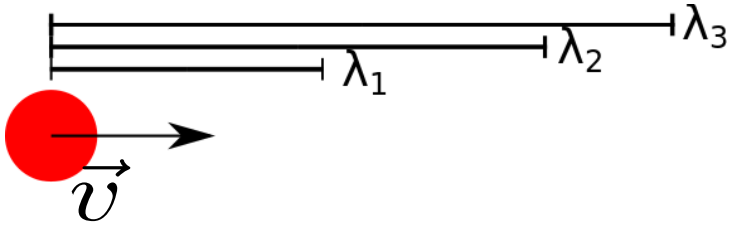

- Testing of correct functionality of algorithms