Fermilab U.S. DEPARTMENT OF ENERGY Office of Science

High Yield Muon Catalyzed Fusion

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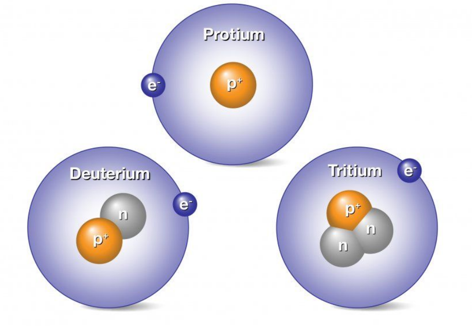
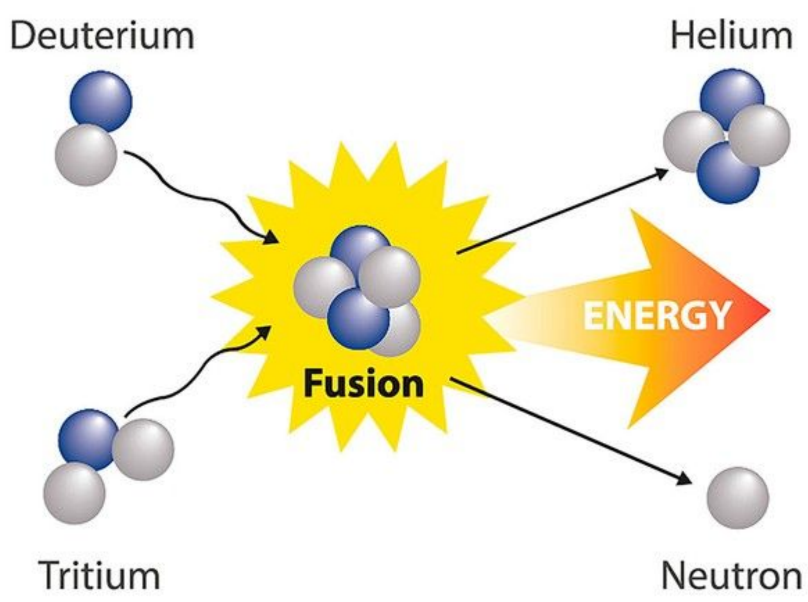
Thermonuclear Fusion

Need for PLASMA -> temperatures >50 million degrees (several times hotter than the center of the sun).



Isotopes of Hydrogen

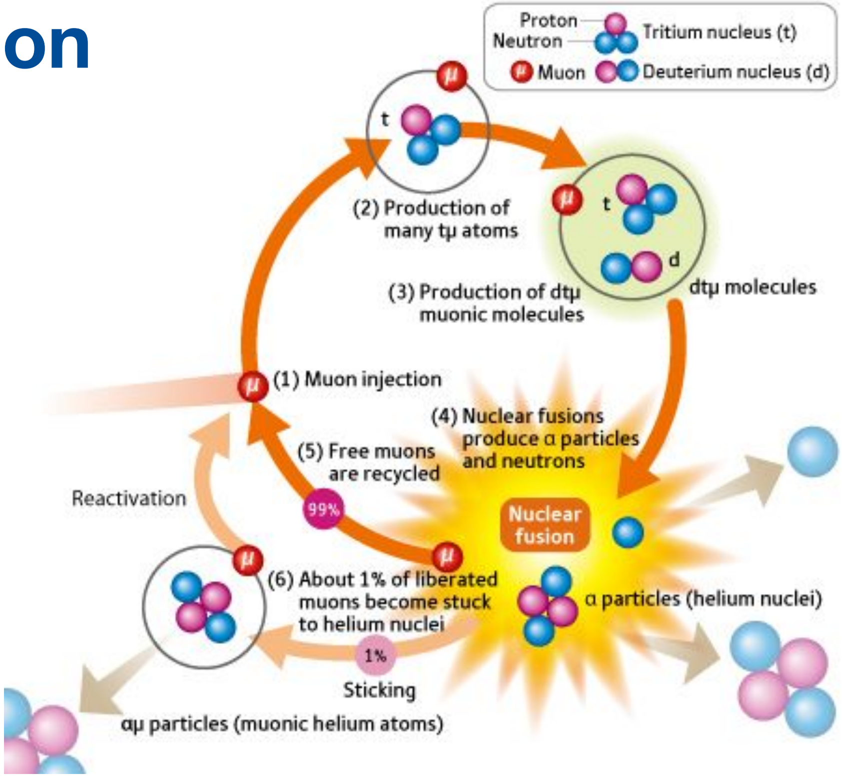
Our Sun



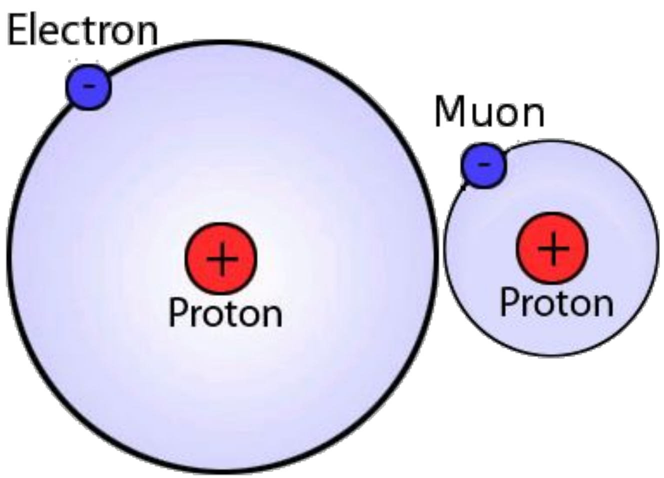
Fusion Outcome

Muon-Catalyzed Fusion

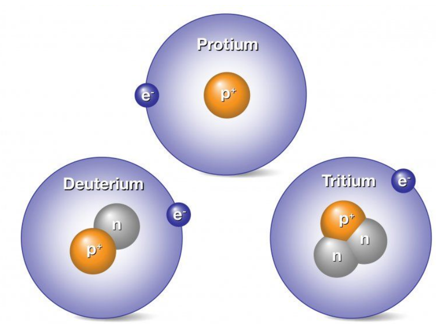
- Mixture of Deuterium-Tritium
- Muon replaces electron
- Overcome Coulomb barrier
- Fusion!
- Emission of α particle + neutron + μ



Muonic Hydrogen Fusion Process



Atomic size of Hydrogen vs. Muonic Hydrogen



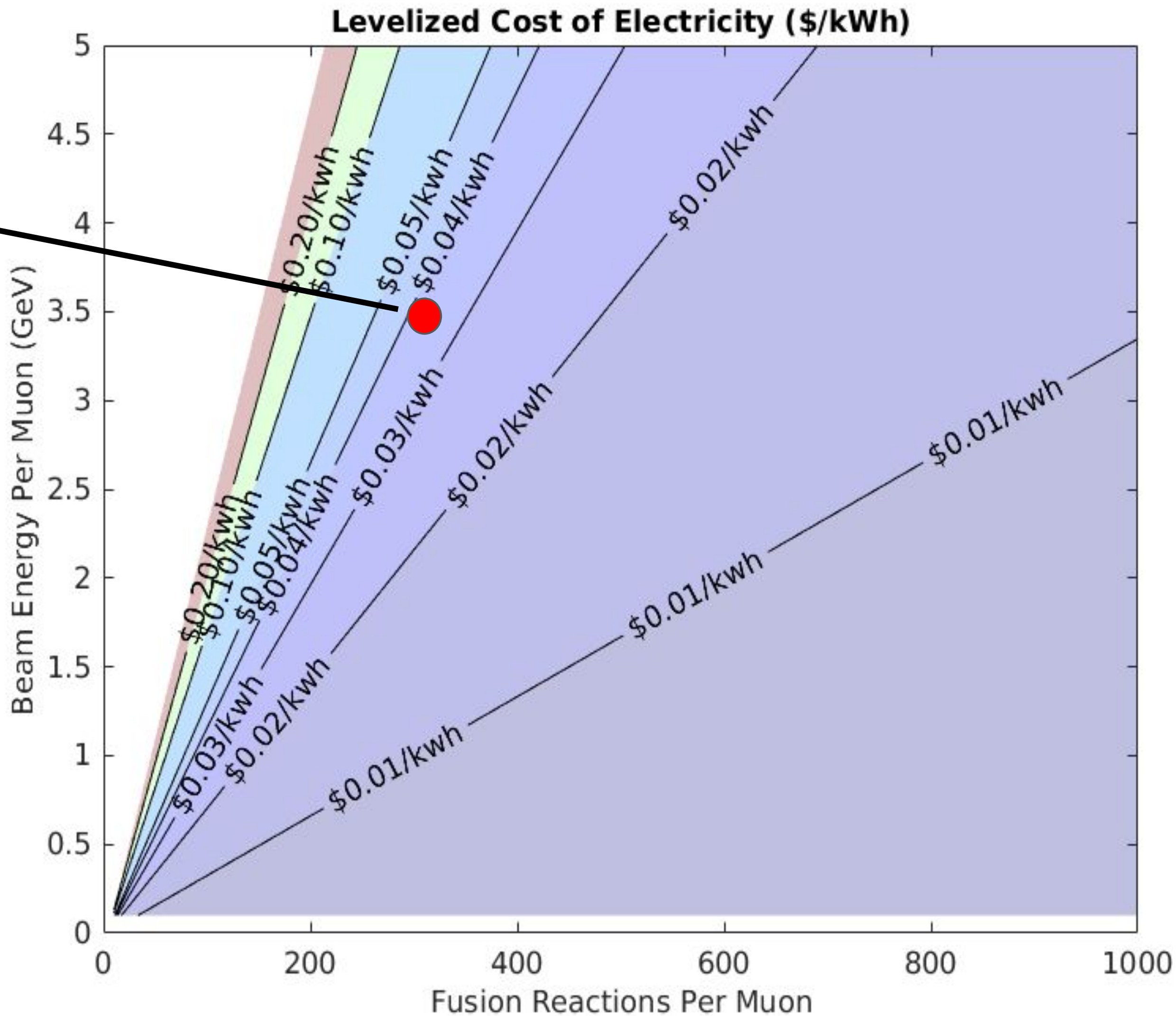
Isotopes of Hydrogen

Goal -> Increase **Fusion per Muon!**

Method -> Decrease **time between fusions** & **sticking factor.**

Commercially Viable Fusion

Target operating point for commercial fusion



(Assumes superconducting accelerator, Brayton cycle balance-of-plant, exothermic tritium breeding, and revenue from heat sales.)

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Temperature and Pressure Dependence

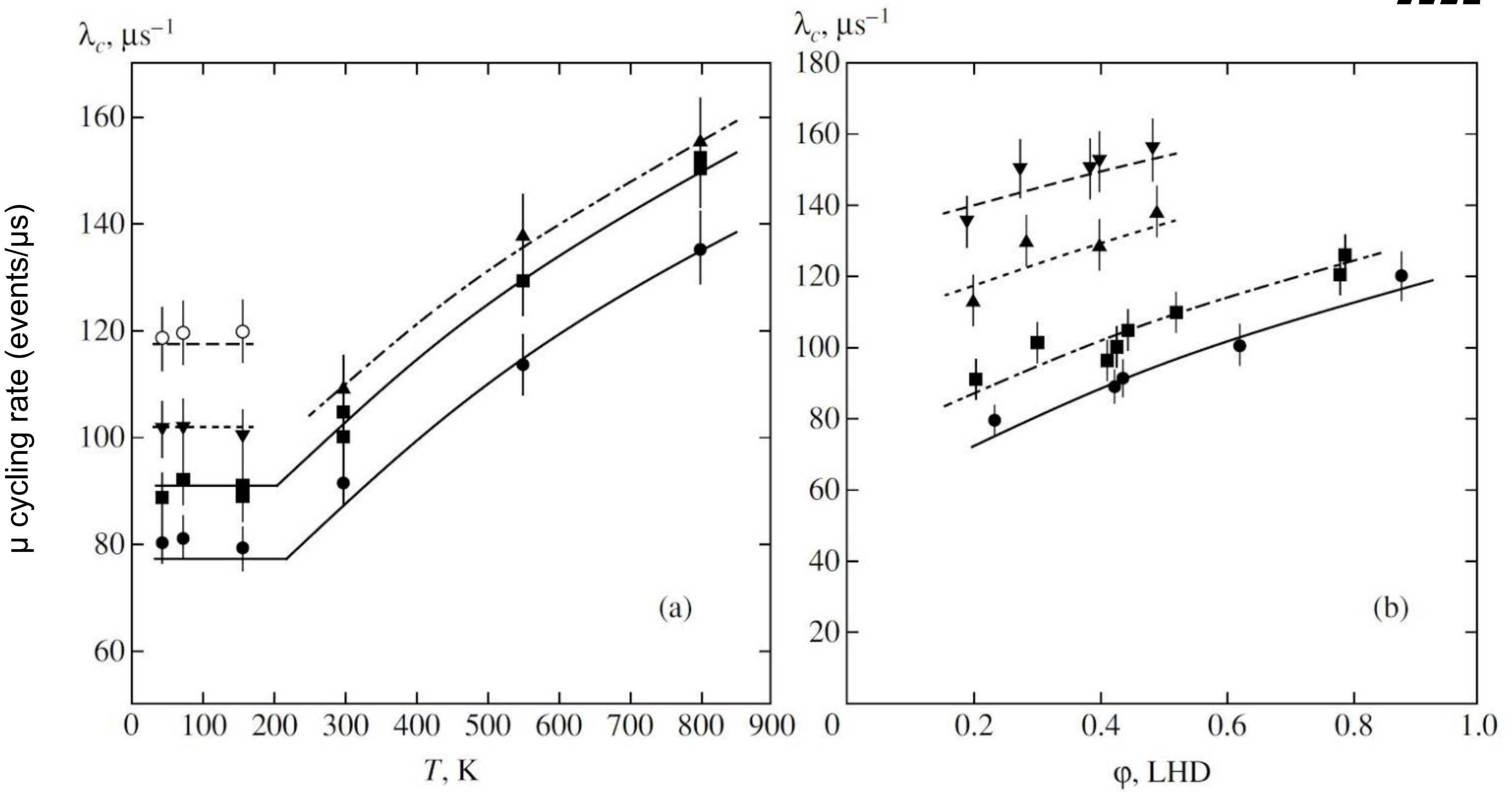
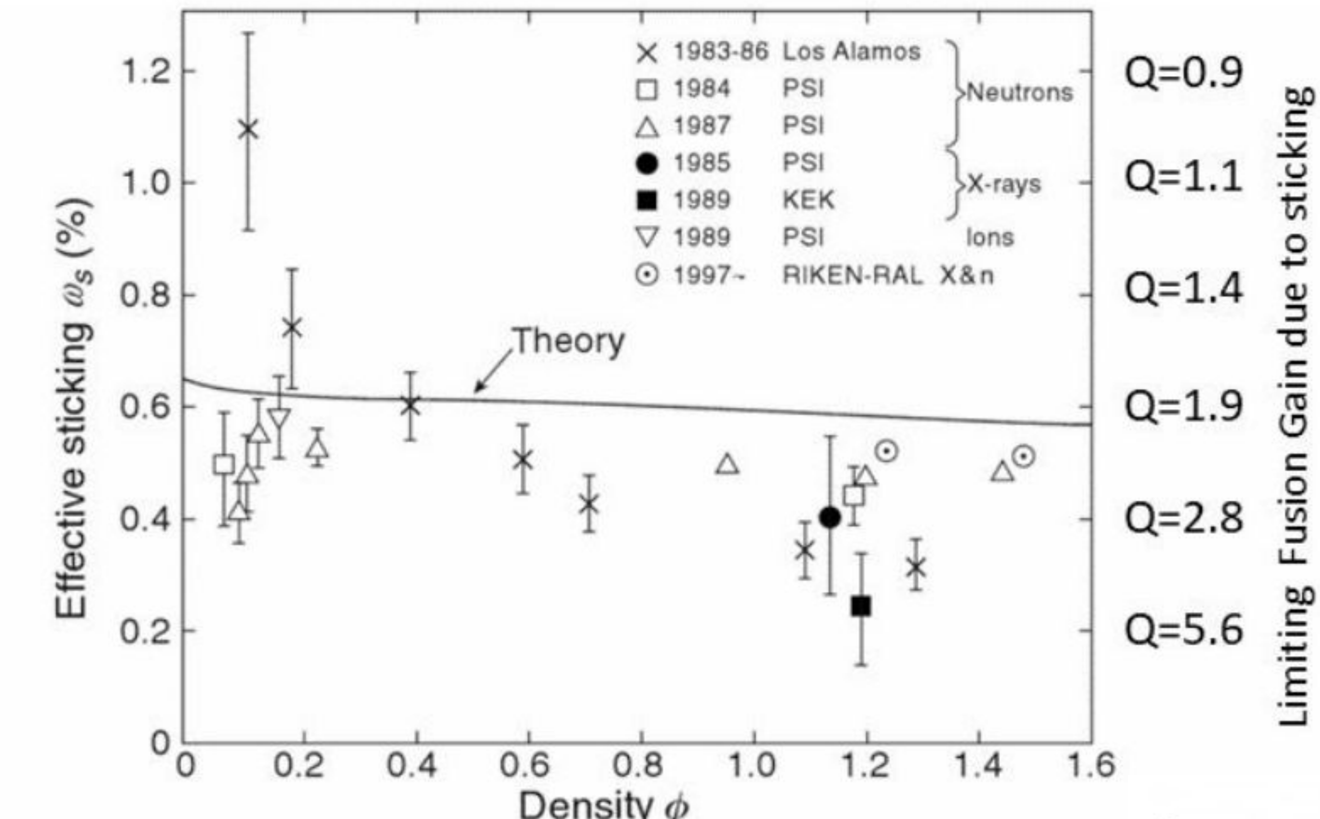


Fig. 12. (a) Normalized cycling rates as a function of temperature for the gaseous D/T mixture at $C_t \approx 33\%$ and different densities $\varphi = 0.88$–0.91 (○), 0.62–0.64 (▼), 0.49–0.52 (▲), 0.39–0.45 (■), 0.19–0.24 (●) LHD. (b) Normalized cycling rates as a function of density for the gaseous D/T mixture at $C_t \approx 33\%$ and different temperatures $T = 800$ K, $C_t = 0.34$–0.36 (▼); $T = 550$ K, $C_t = 0.33$–0.36 (▲); $T = 300$ K, $C_t = 0.31$–0.36 (■); $T = 158$ K, $C_t = 0.31$ (●). The curves are obtained with optimum parameters.

Theory and Experiment Disagree Quantitatively

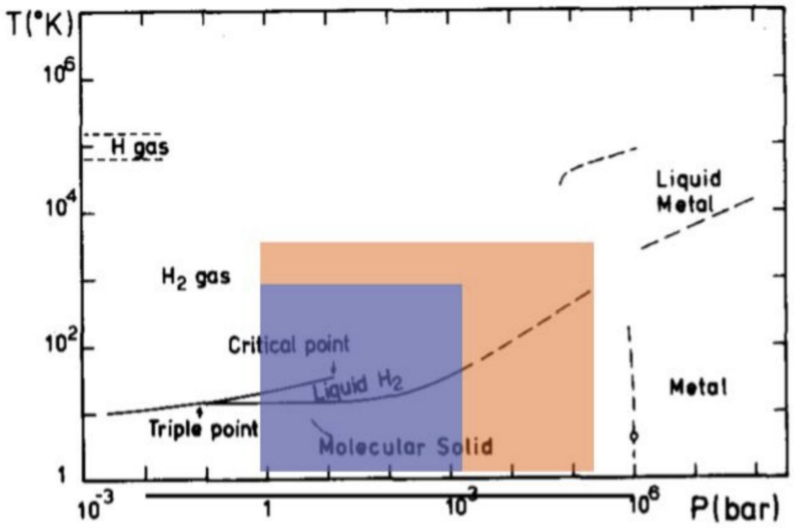


$$Q = 22.4\text{MeV} \times \frac{N_{fusions/\mu}}{E_\mu}$$

K. Nagamine, 2009.

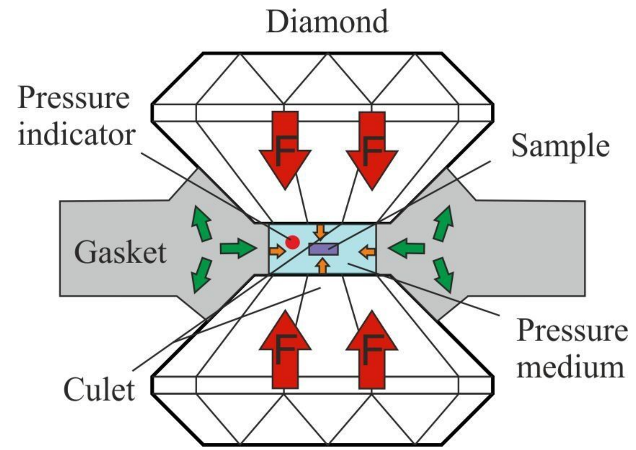
New Areas of Temperature and Pressure

Explore Temperatures from 7 to 1500 K



New Areas of Temperature & Pressure that will be Explored

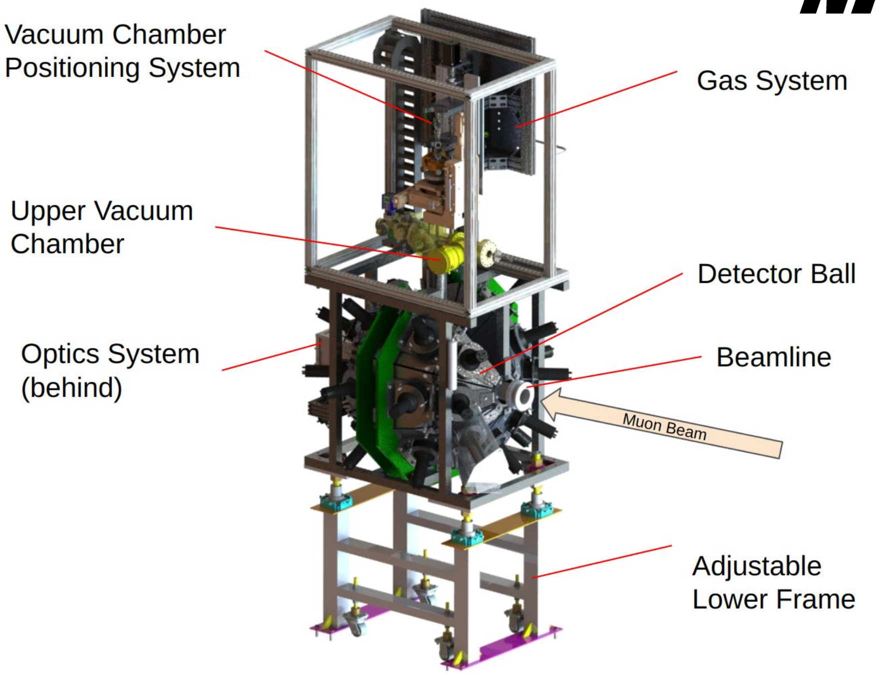
Explore density of up to 3 LHD

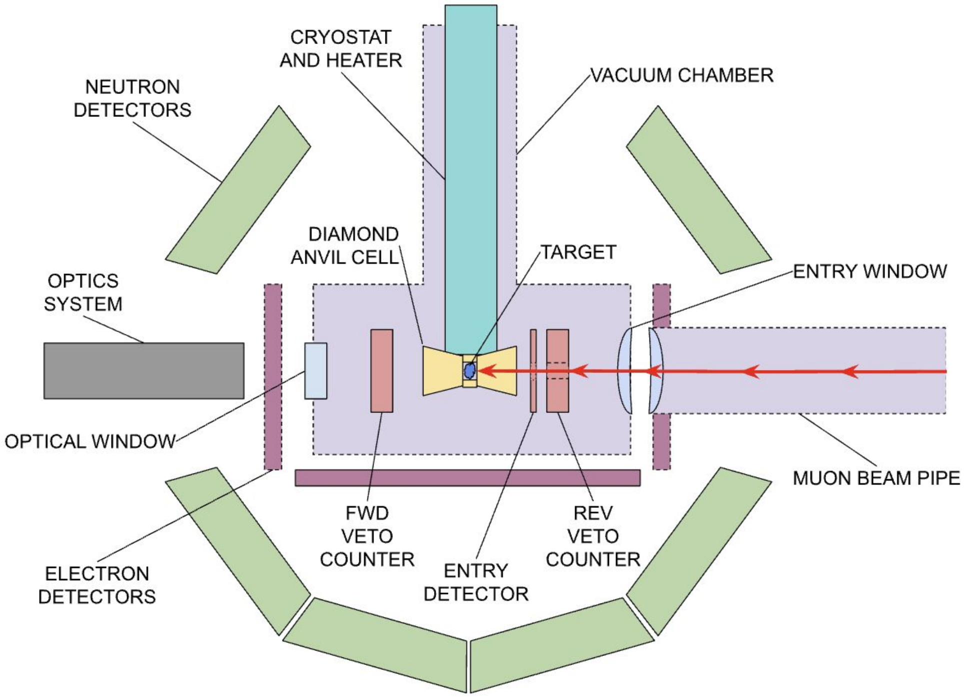


$$\text{Pressure} = \frac{\text{Force}}{\text{Area}}$$

Diamond Anvil Cell - Used to Achieve High Pressures

Experimental Setup

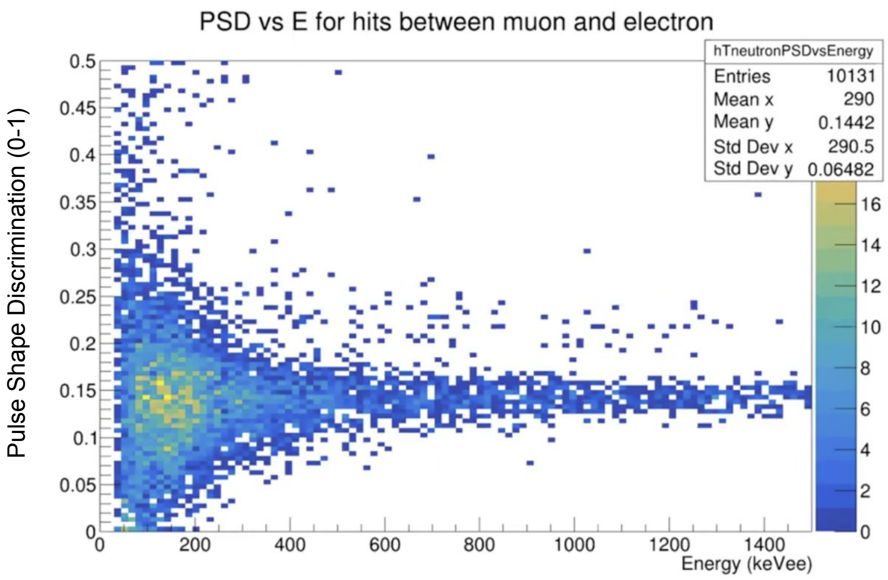




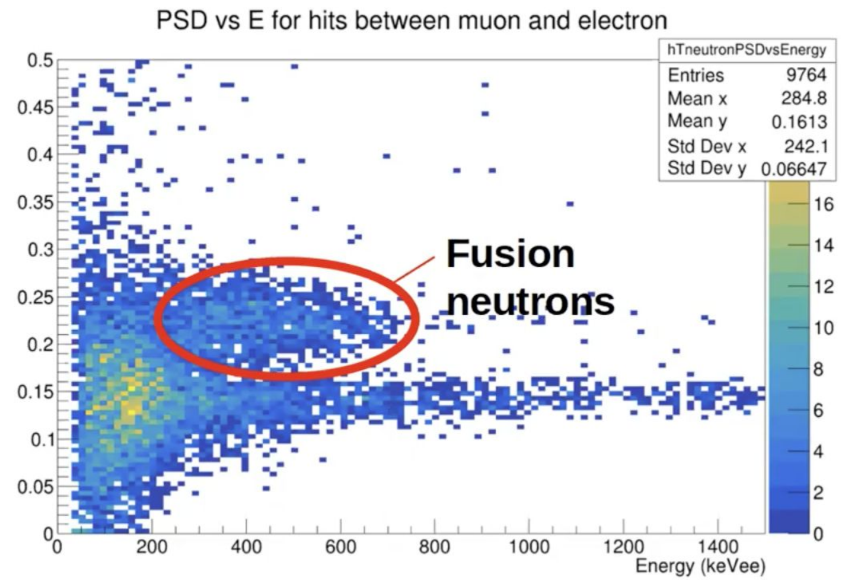
Experimental Setup at PSI in 2022

piE1 muon beamline - around 50,000 μ^-/s - Villigen, Switzerland

Results

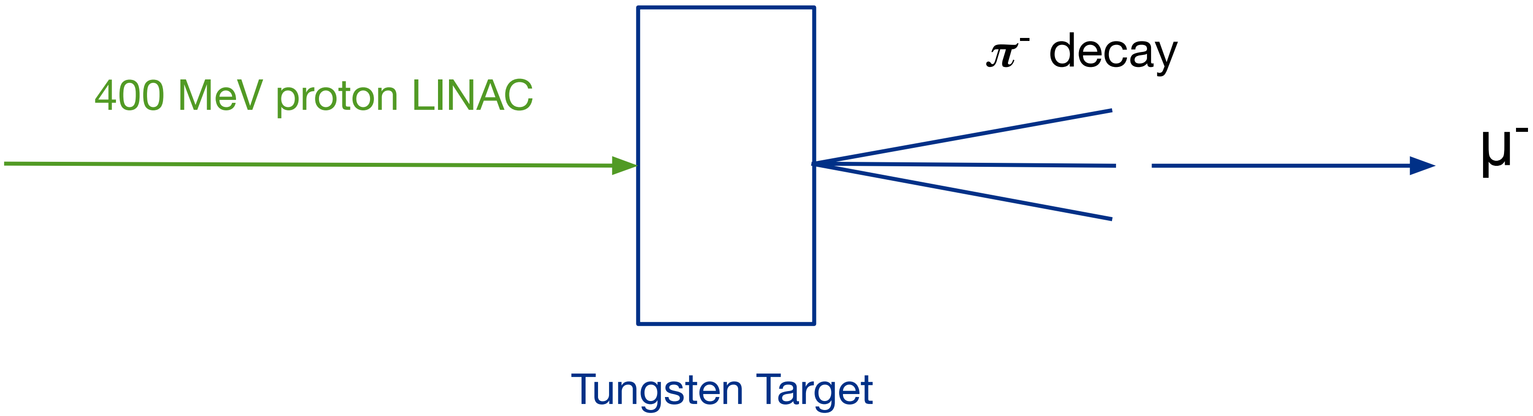


Hydrogen (18K, 1 LHD)



Deuterium (22K, 1 LHD)

Fermilab Muon Beam



Collaborators

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arpa·e CHANGING WHAT'S POSSIBLE

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