An Upgraded Polarized ^{3}He Atomic Beam Source for the Cryo. nEDM Exp. @ SNS in ORNL

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§0 Contents

1. Why ^{3}He ABS?

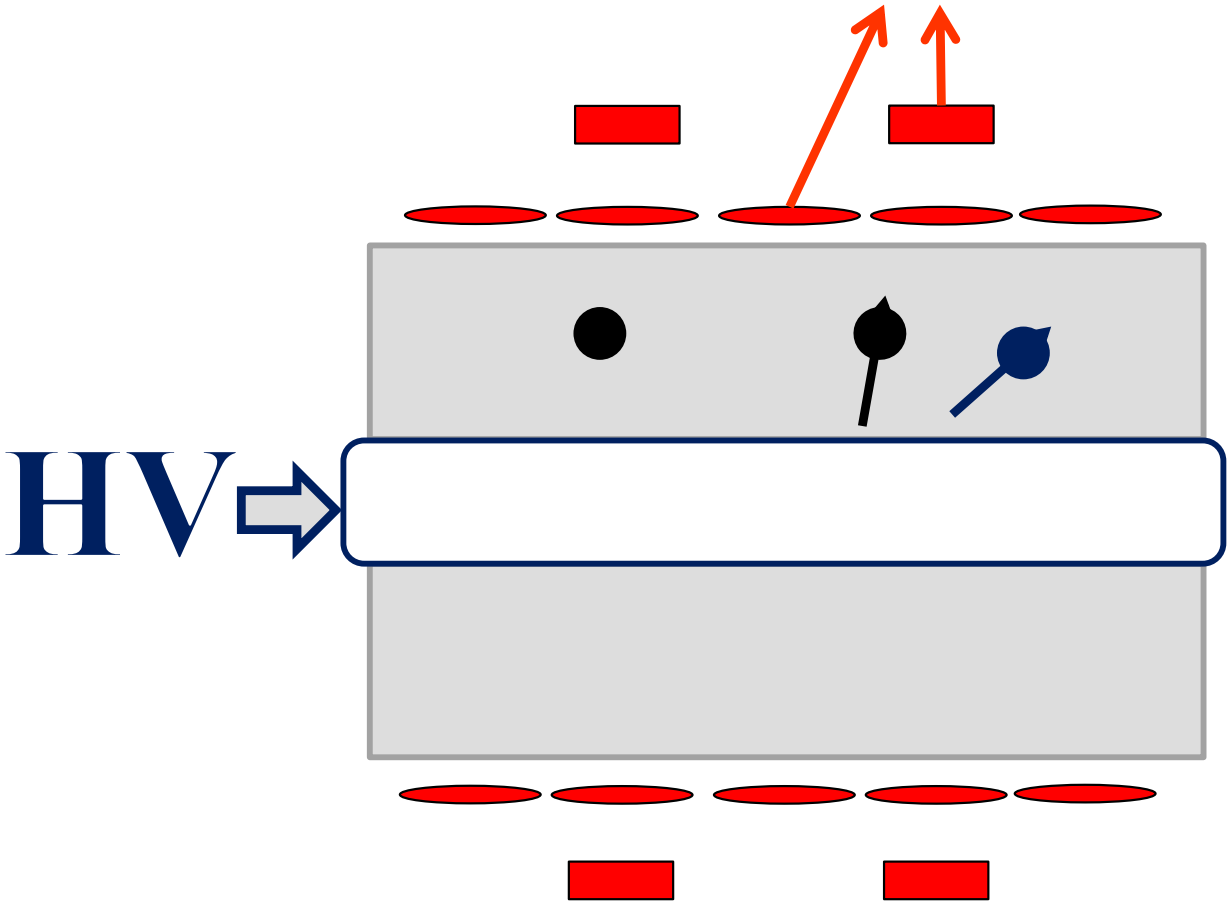
2. Basic Components:
   - Cryo-chamber
   - MCP & Actuation system
   - Quadrupole magnet

3. Major Upgrades (easier to discuss knowing the components):
   - Vertical orientation
   - MCP
   - Actuation system

4. Preliminary Findings (aided by simulations)

§1 Why polarized ^{3}He?

^{3}He is a good: co-magnetometer + neutron detector



SQUID loops

Measurement Cells

UCN: 500k

^{3}He: 10^{16}

^{3}He/ ^{4}He ~ 10^{-10}

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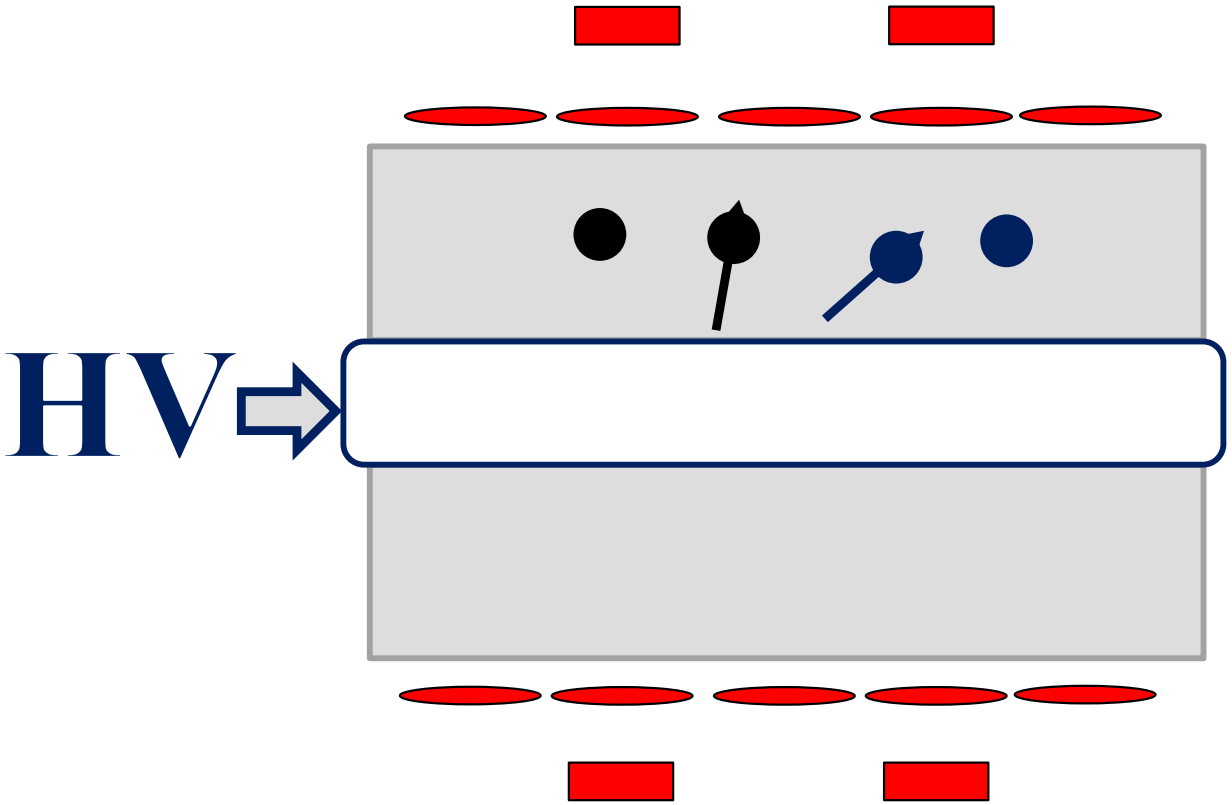

SQUID loops

Measurement Cells

UCN: 500k

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UCNs and ^{3}He are moving and precessing

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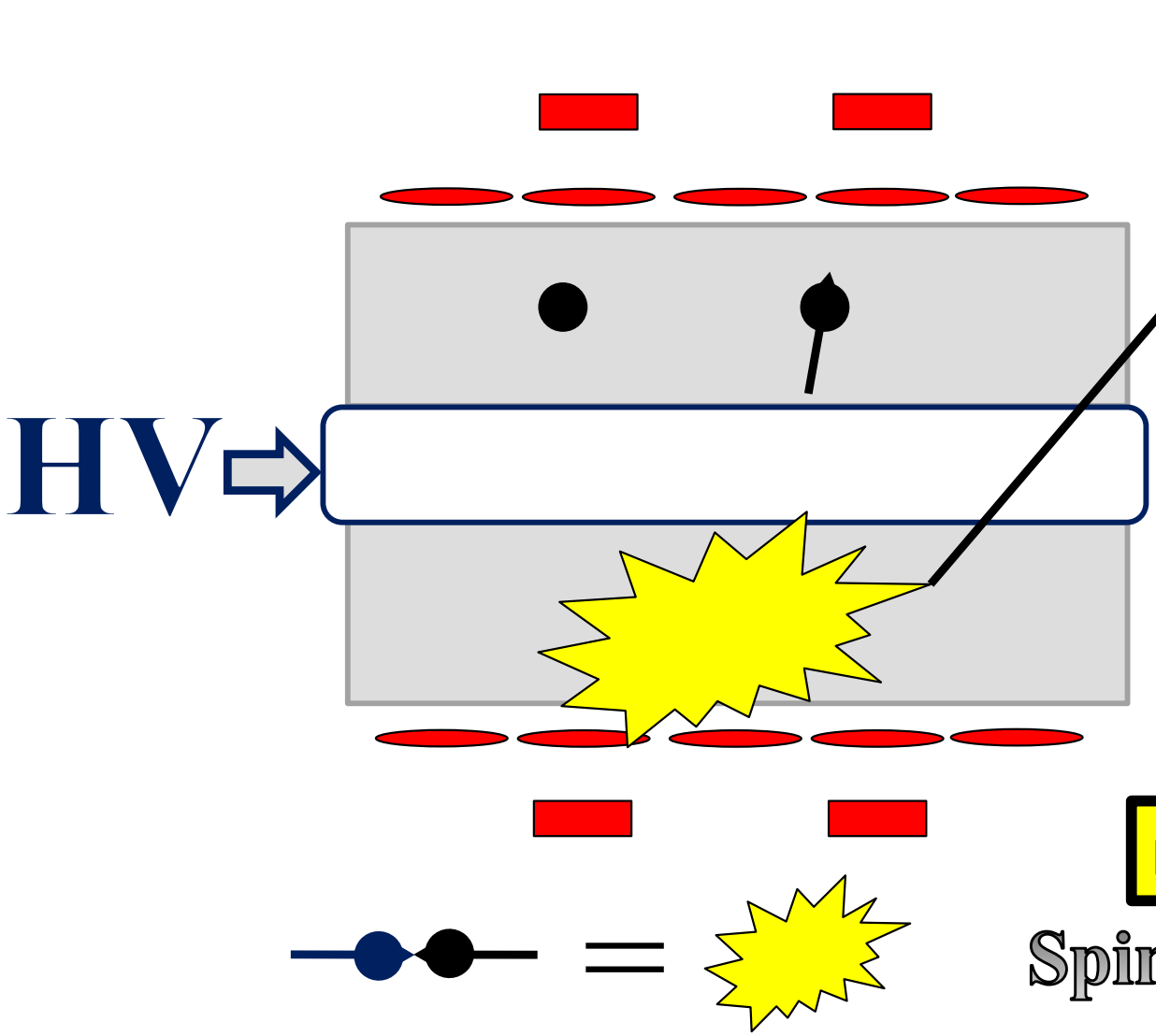

SQUID loops

Measurement Cells

UCN: 500k

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^{3}He/ ^{4}He ~ 10^{-10}

$n + {}^3He \rightarrow p + t$

Spin dependent capture

§ 1 Why polarized ^{3}He?

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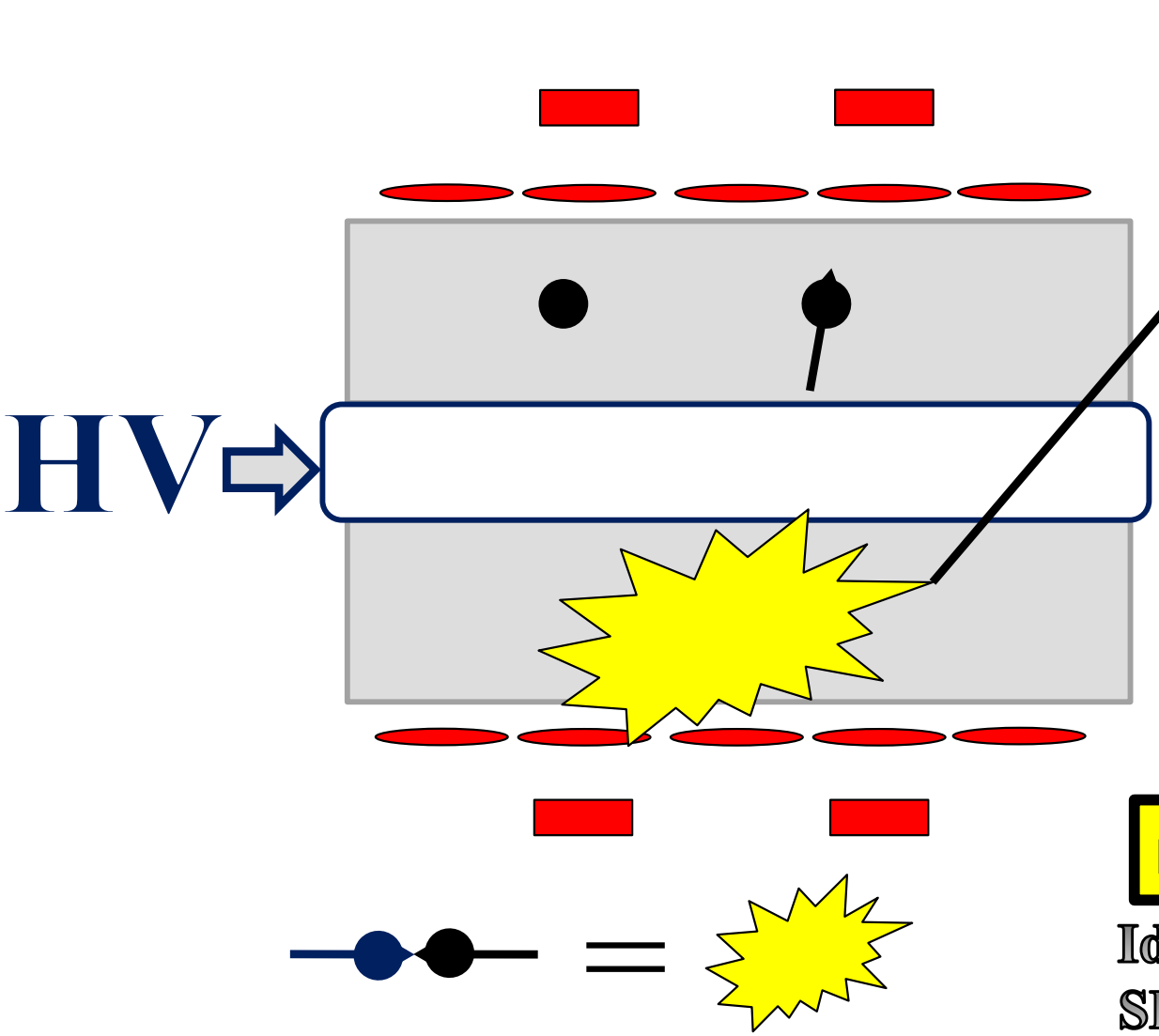


$n + {}^3He \rightarrow p + t$

Ideally ~100% polarized:
SEOP/MEOP won't work

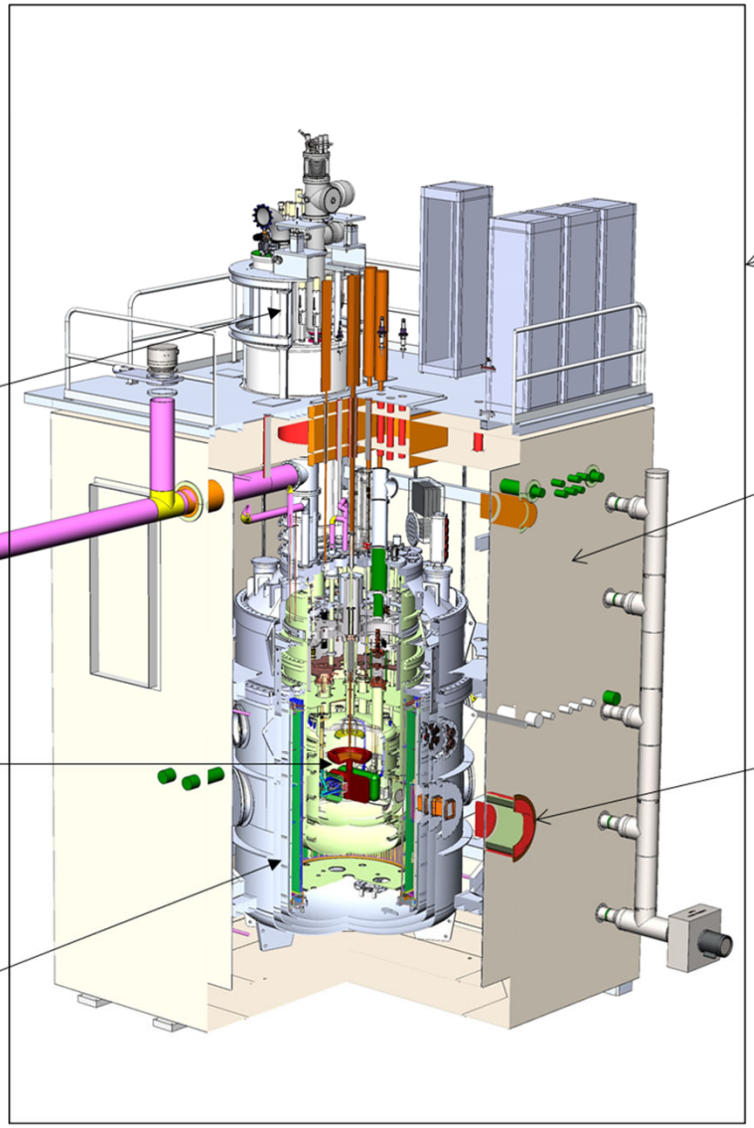
§1 nEDM @ SNS-ORNL

Experiment Design

Helium-3 Services
- Prepare polarized 3He
- Isotopically purify 4He each measurement cycle

Central Detector System
- Generate electric field
- Store 3He, neutrons
- Monitor 3He, neutron precession frequencies

Magnet Coil Package
- Inner magnetic shielding
- Generate uniform B-field



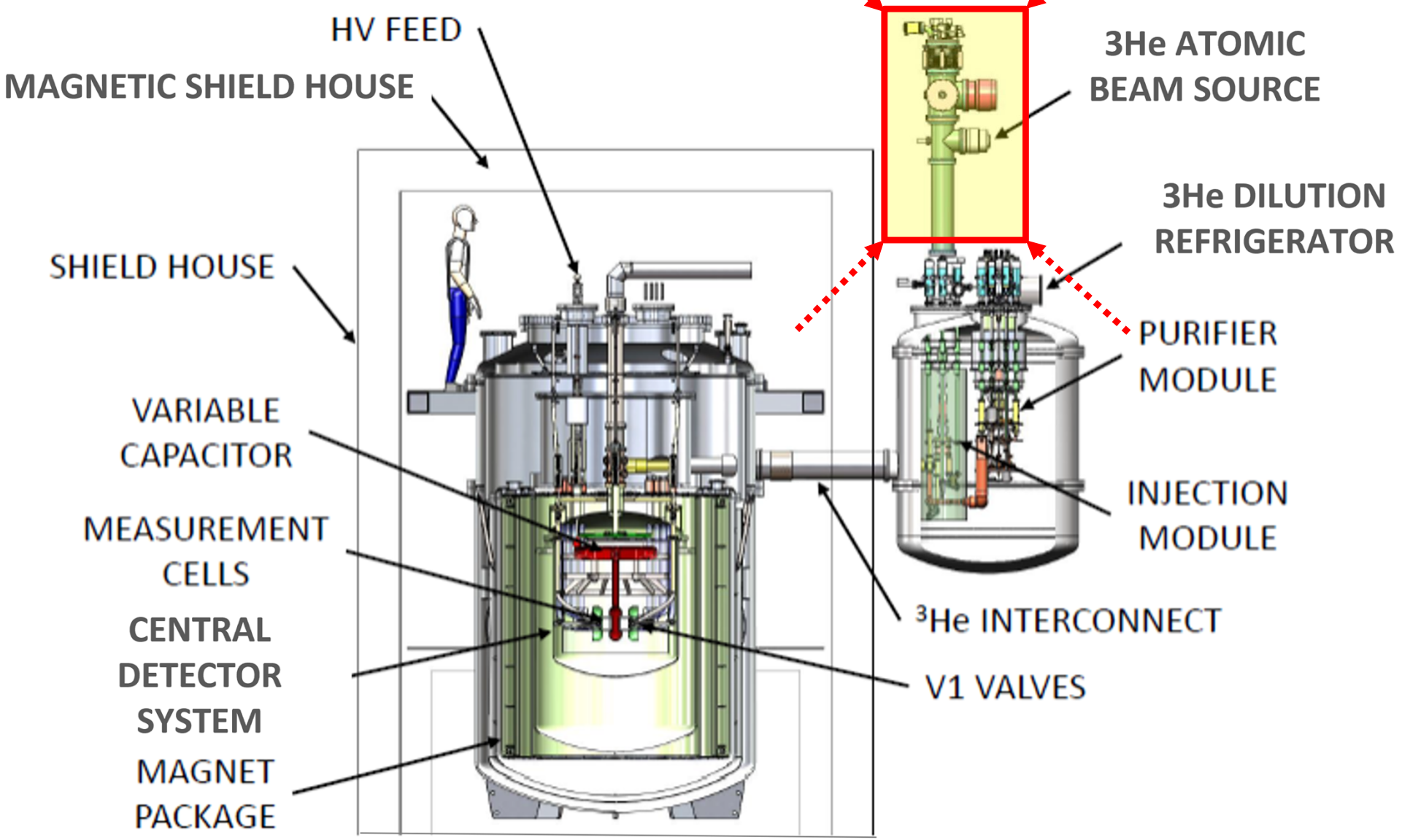
Outer magnetic shielding
Cancellation coils

Magnetically Shielded Enclosure

Cold Neutrons

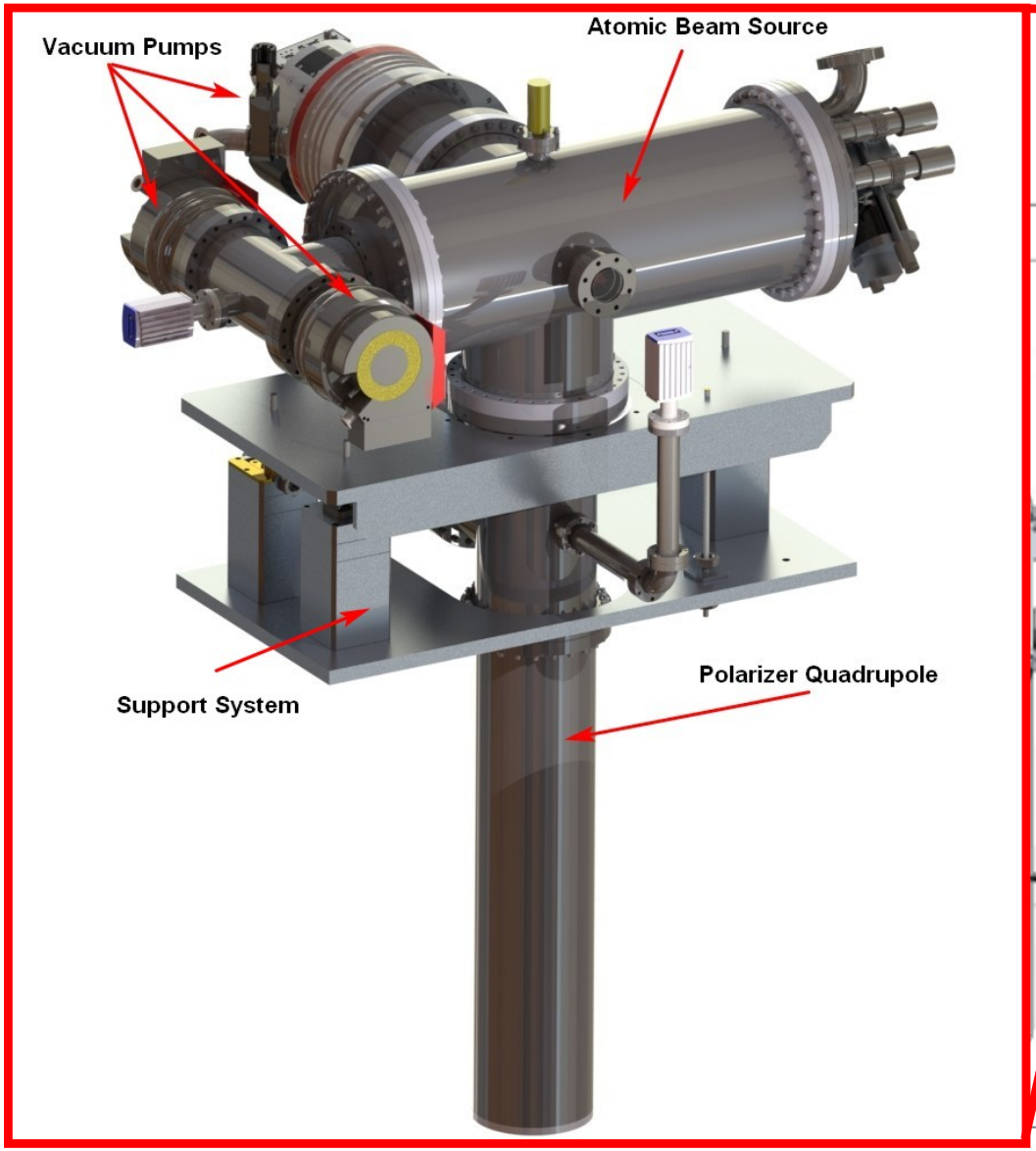
Guide 8.9Å into apparatus

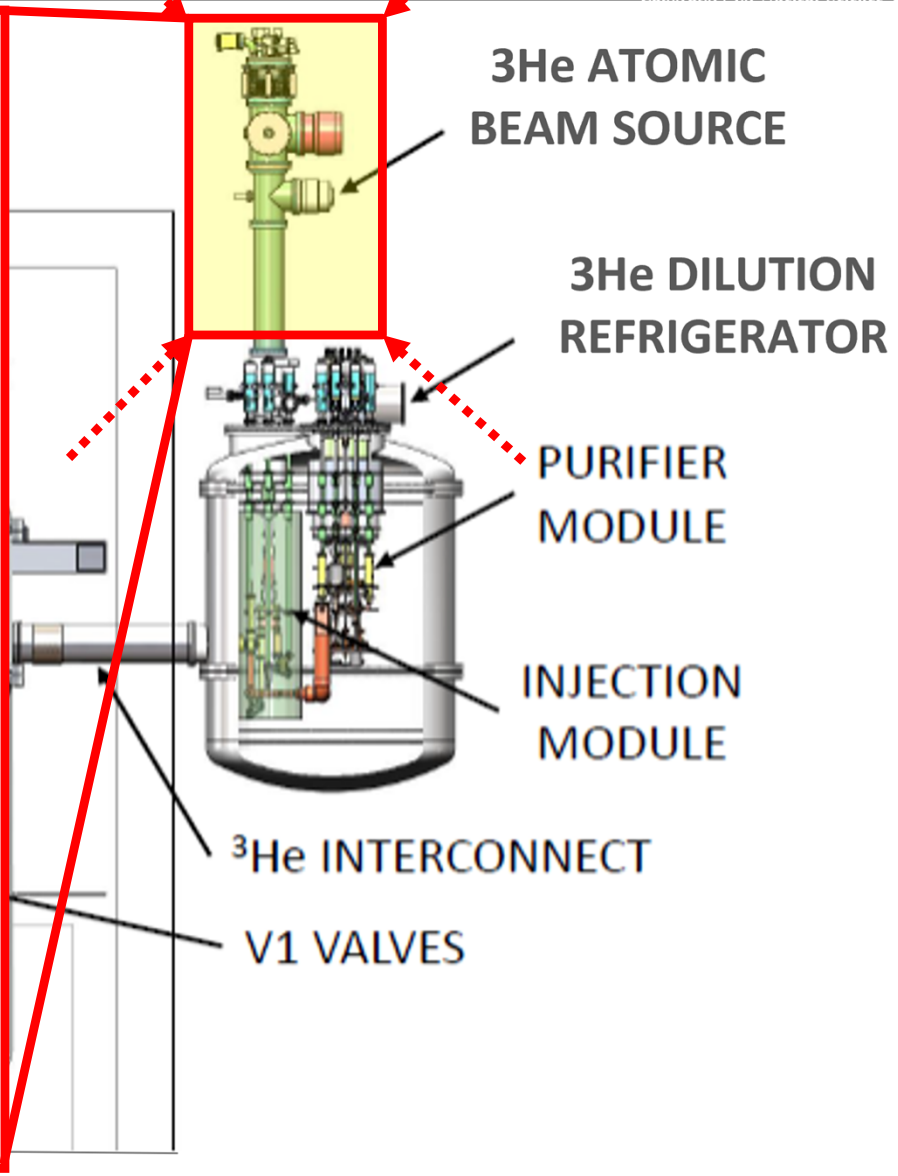
§2 ABS Components



^{3}He ABS part of ^{3}He services

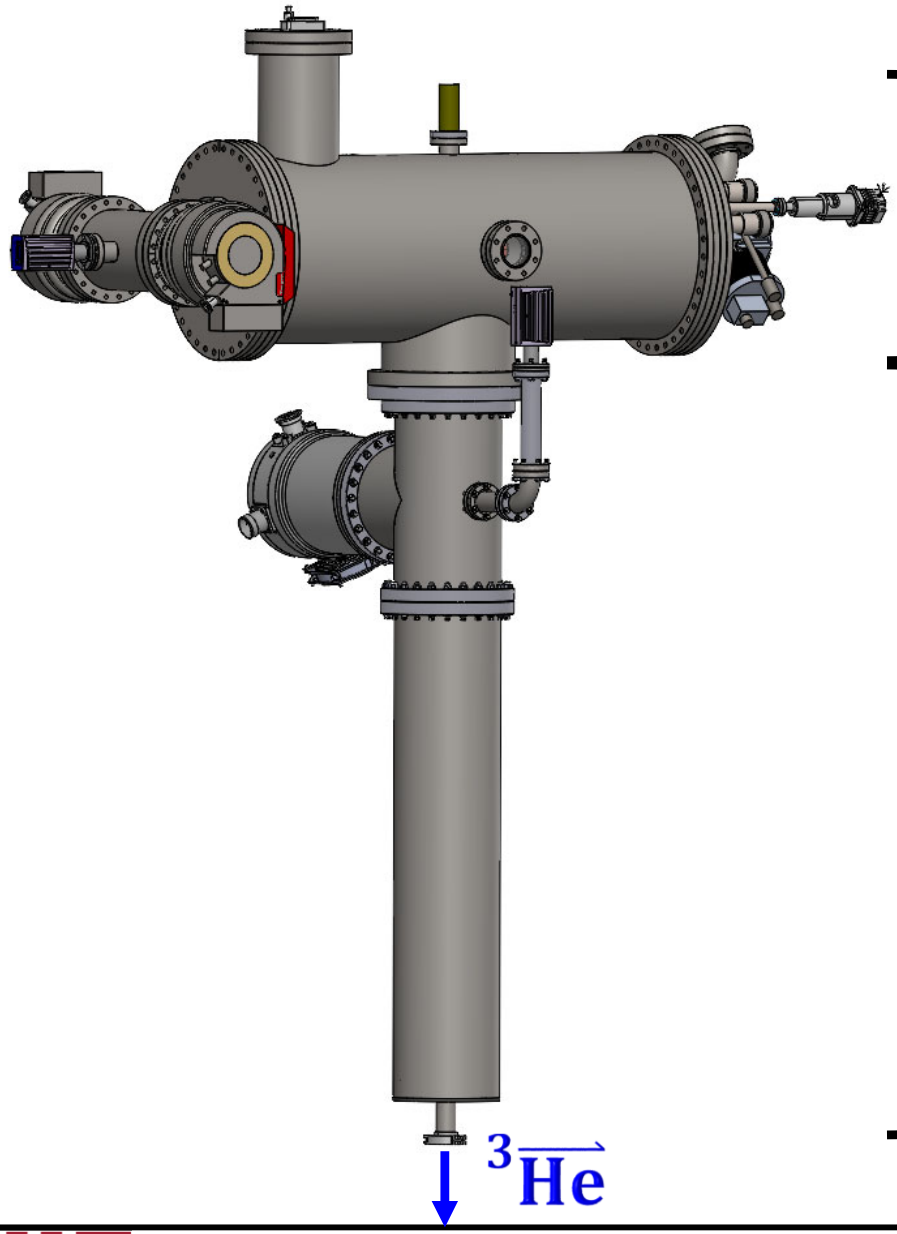
§2 ABS Components





^{3}He ABS part of ^{3}He services: minus dil. ref., purifier, injection

§2 ABS Components



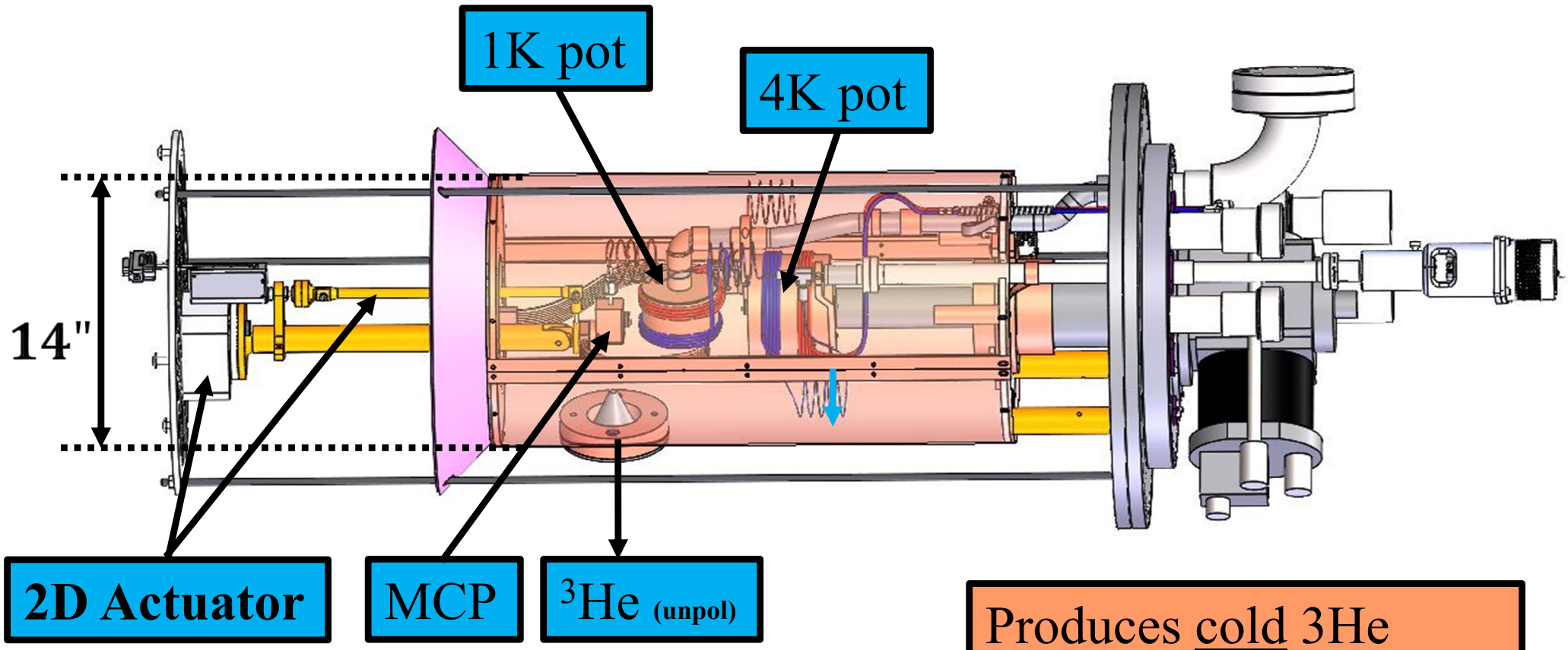
Cryo-vessel

Quadrupole magnet

Produces <u>cold</u> 3He <u>polarized</u> atoms

- ~ **1.3 K** (112 μeV)
- Flux $\gtrapprox$**10^{14} atoms/s**

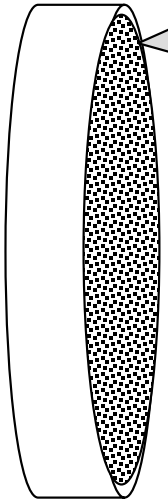
§2 ABS: Cryo-Vessel



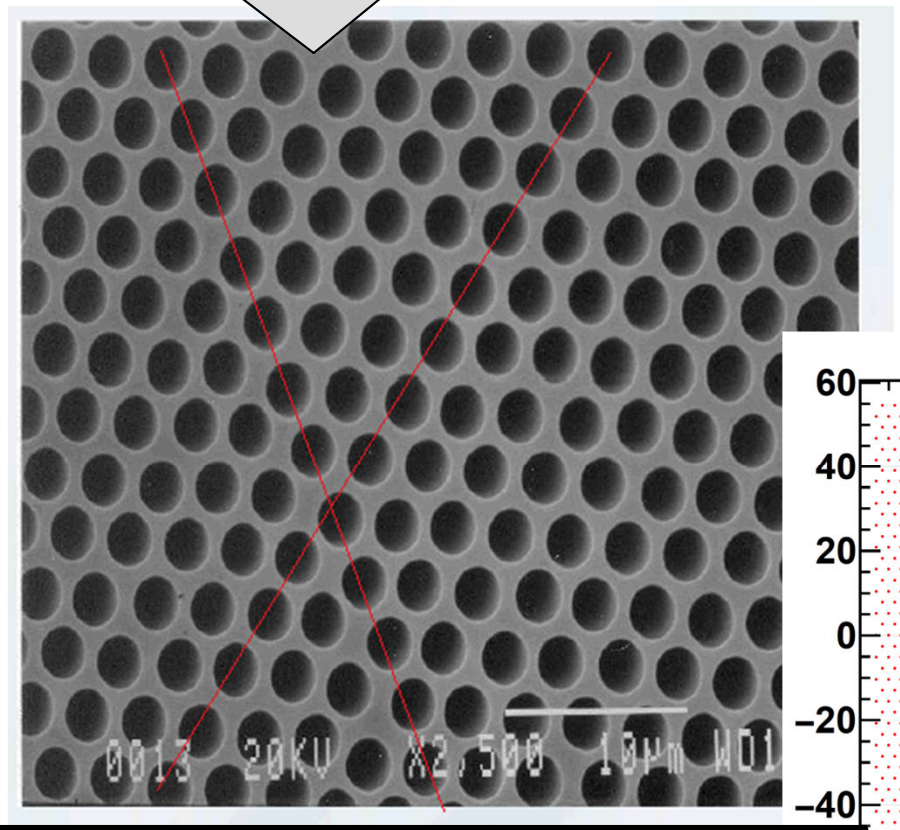
Uses both ^{4}He (for cooling) & ^{3}He
! Not a dilution refrigerator

Produces cold 3He polarized atoms
- ~ **1.3 K** (112 μeV)
- Flux ≳**10^{14} atoms/s**

§2 ABS: Multi Channel Plate

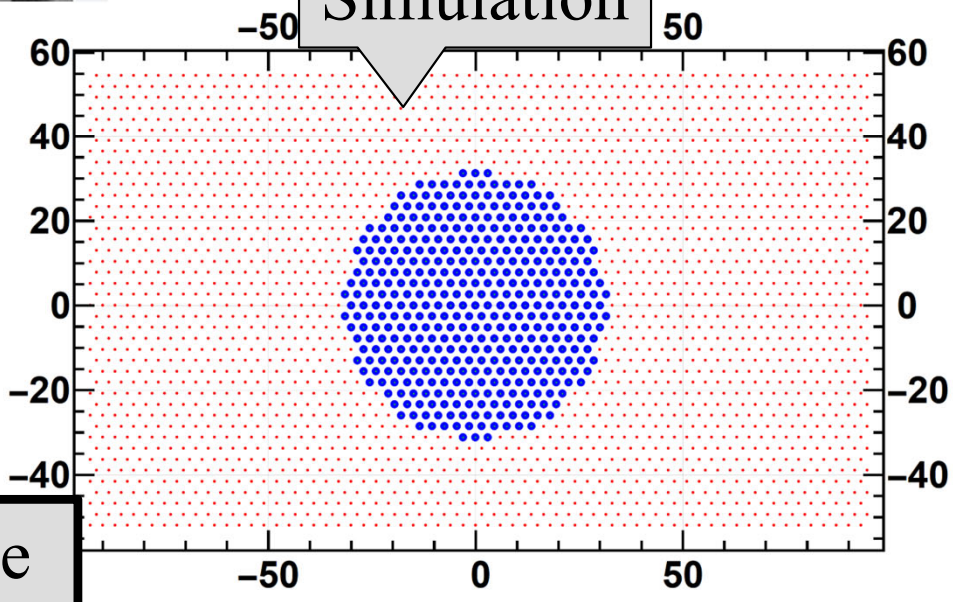


Microscope (2 μm)



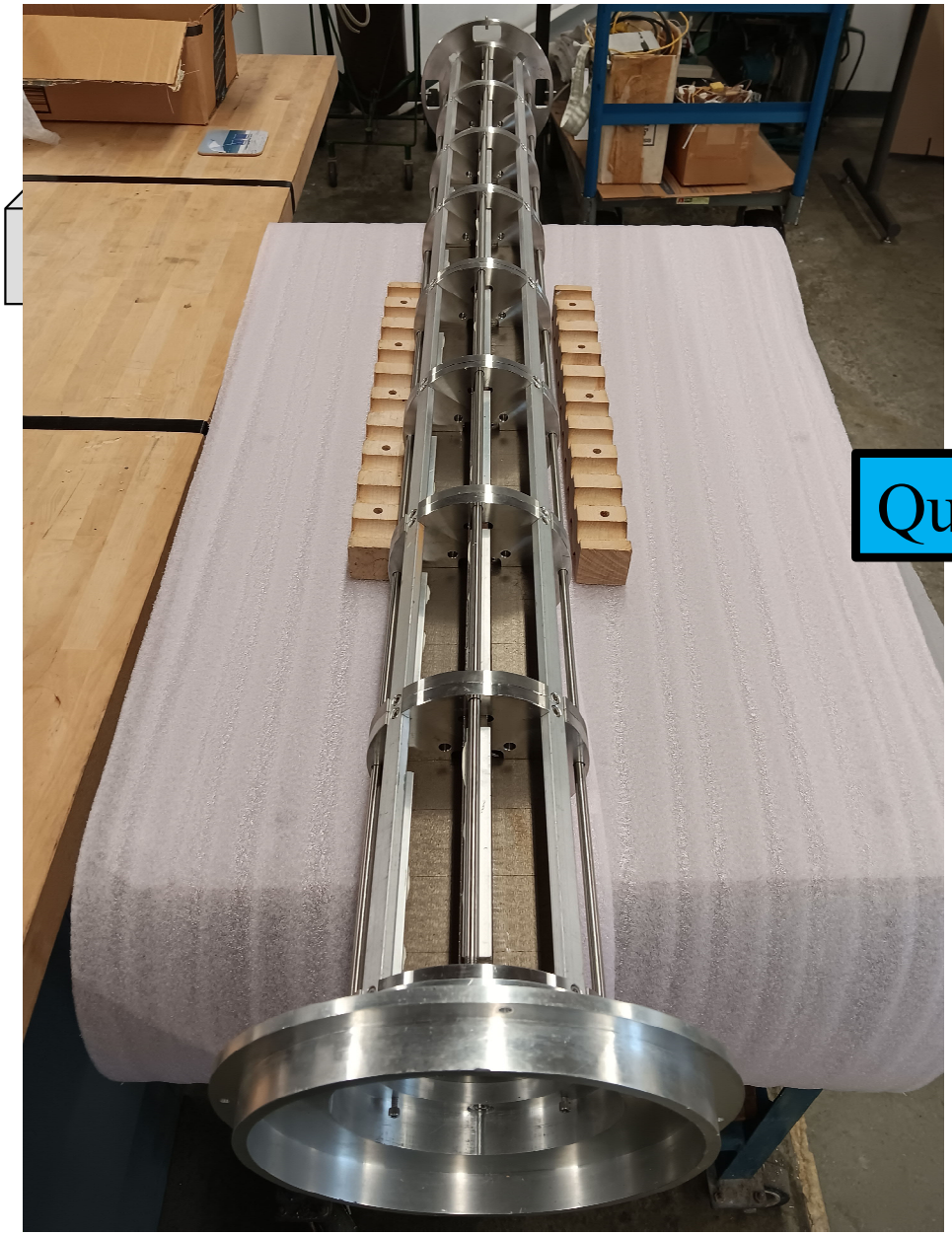
- Arranged in hexagon (side 25 μm)
- Pores at vertex and center of hexagon
- Pore diameter: 5 μm
- Pore length: 0.5mm

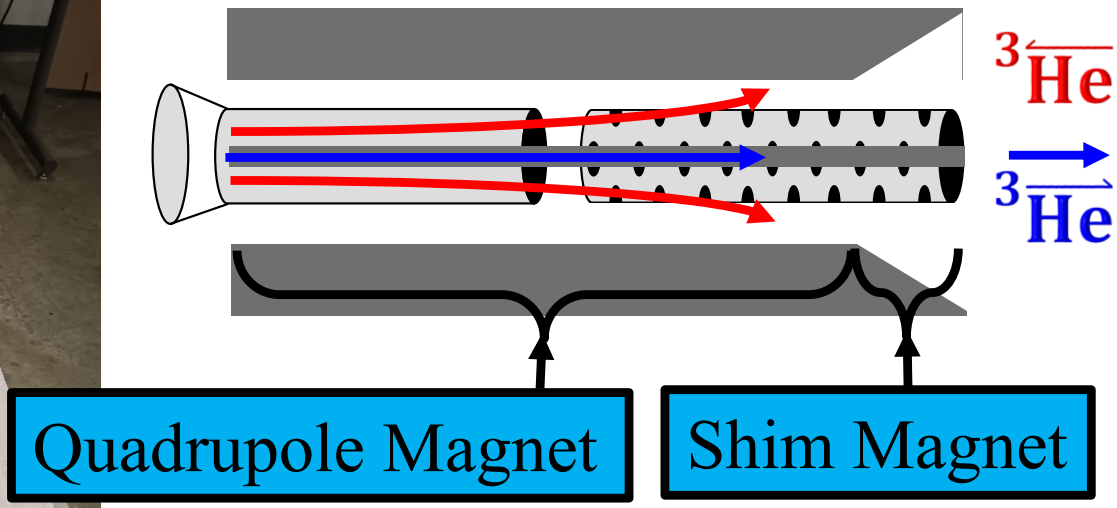
Simulation

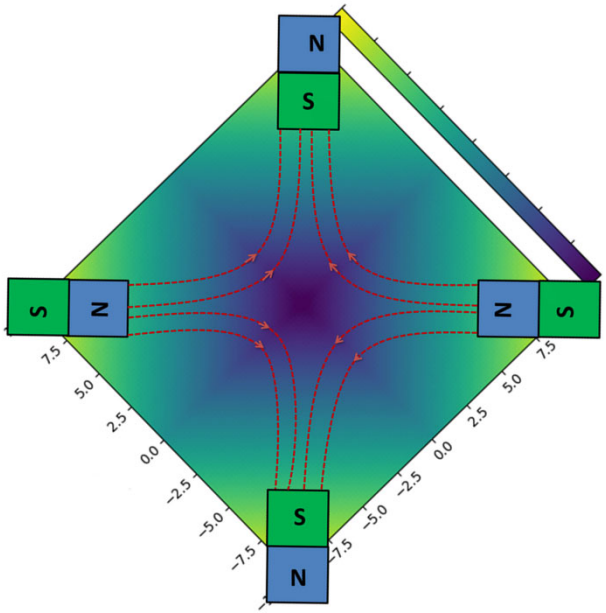


Quartz MCP: Unidirectional ^{3}He beam

§2 ABS: Quad. Magnet

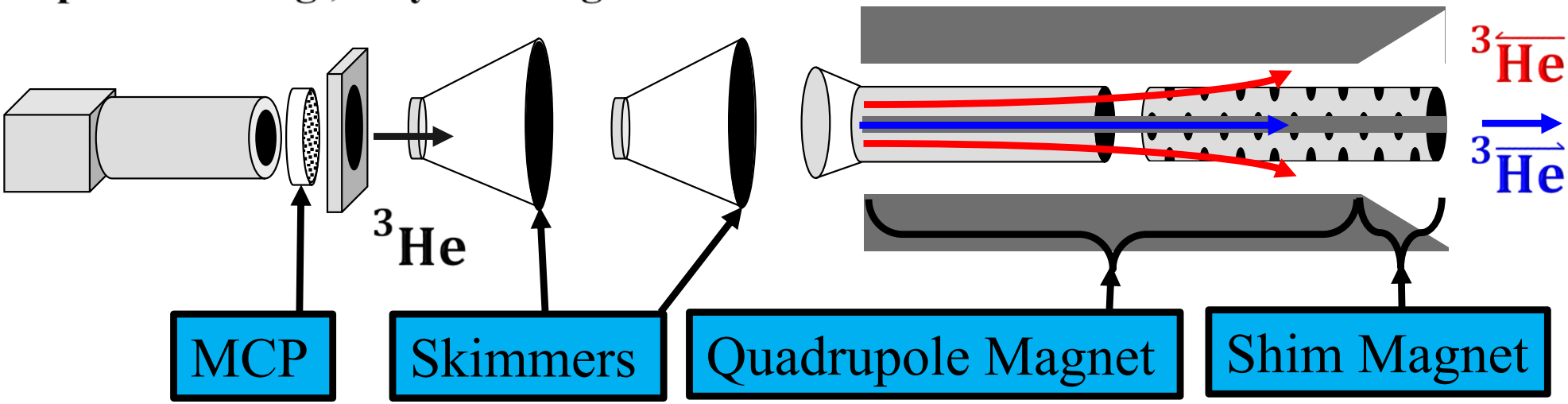






§2 ABS: Quad. Magnet

Spin-Tracking , Ray-Tracing Simulation

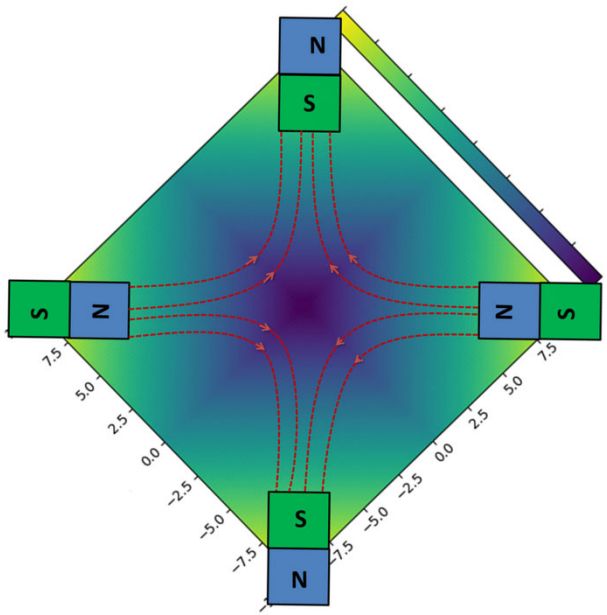


UCN: Can be completely reflected

- E < 300 neV
- $\Delta E = \mu_m \approx 60$ neV/T

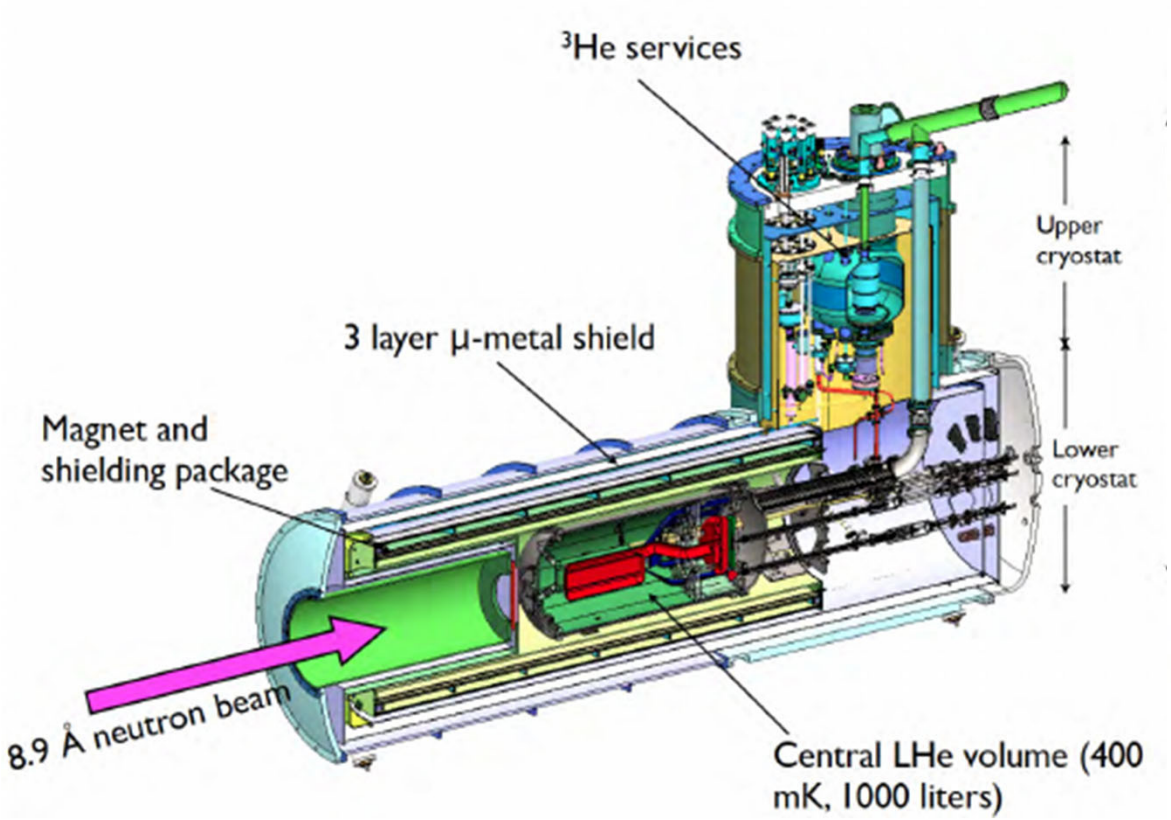
$^3\overrightarrow{\text{He}}$: Only >deflected<

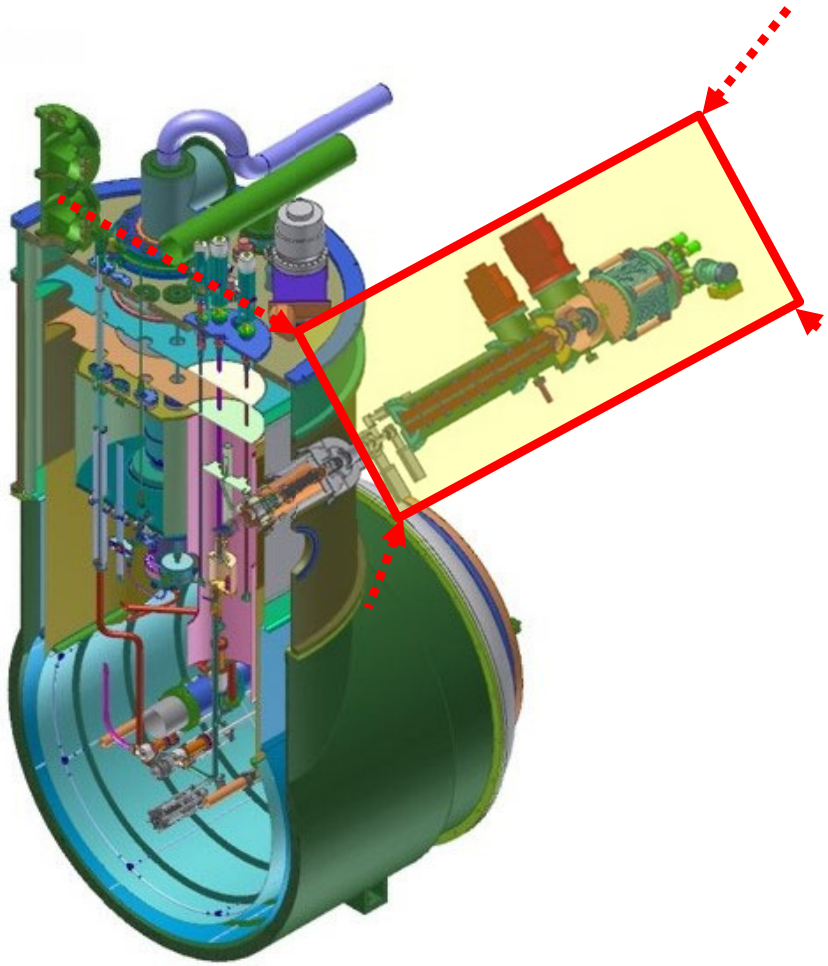
- 1.3 K ≈ 86 μeV
- $\Delta E = \mu_m \approx 67$ neV/T
- Making initial angle very important



§3 Upgrade: Vertical

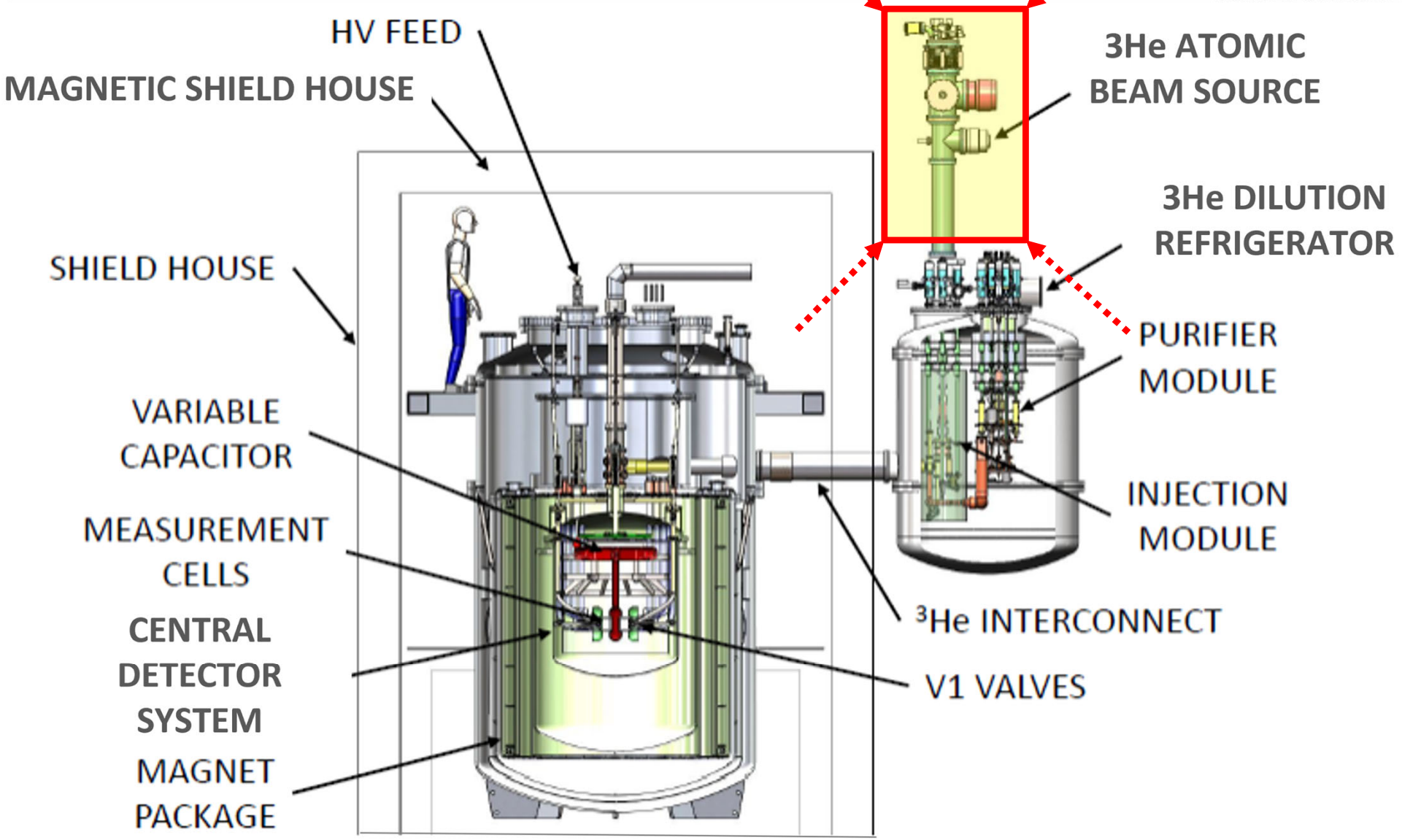
Pre HV-cavallo design "Thomas the Tank Engine"





^{3}He ABS came in from the side

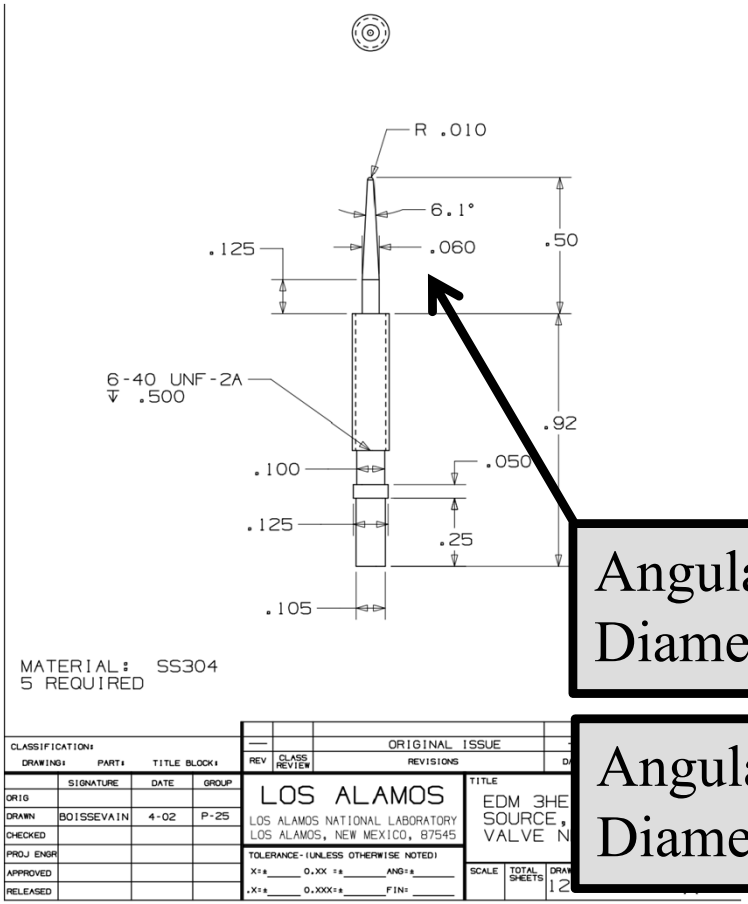
Upgrade: Vertical

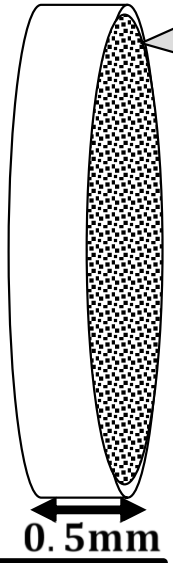


Now: ^{3}He ABS comes in vertically down → Major eng. design

§3 Upgrade: MCP

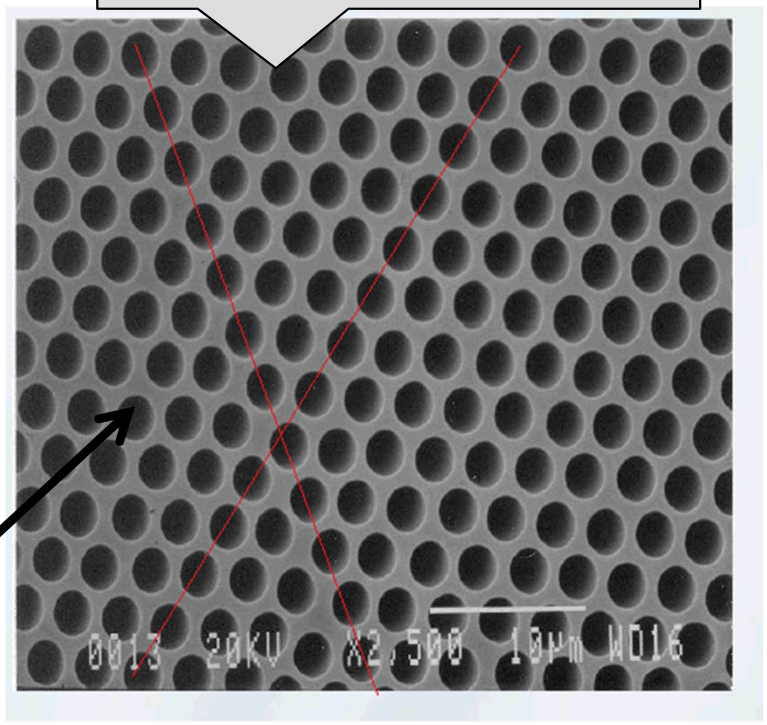
Before: ^{3}He ABS used a needle valve to effuse





Schematic

Microscope (2 μm)



Angular distribution set by:
Diameter/length = 0.01/0.5

Angular distribution set by:
Diameter/length = 0.005/0.5

Now: ^{3}He ABS uses a Quartz MCP

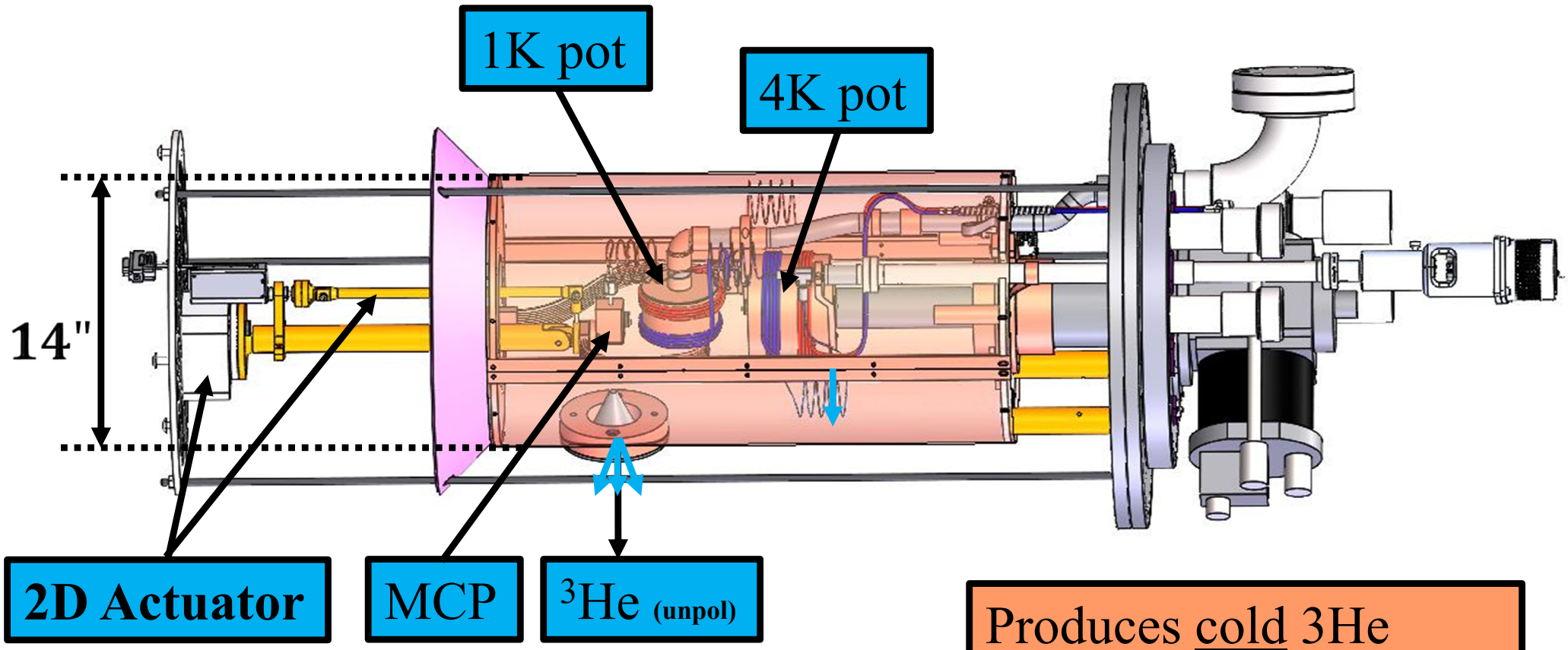
Constraints the angular distribution to (before: 1.5°) 0.5°

Upgrade: Actuation

Before: ^{3}He nozzle was fixed

Now: ^{3}He nozzle can be moved – pitch and yaw

§ 3 Upgrade: Actuation

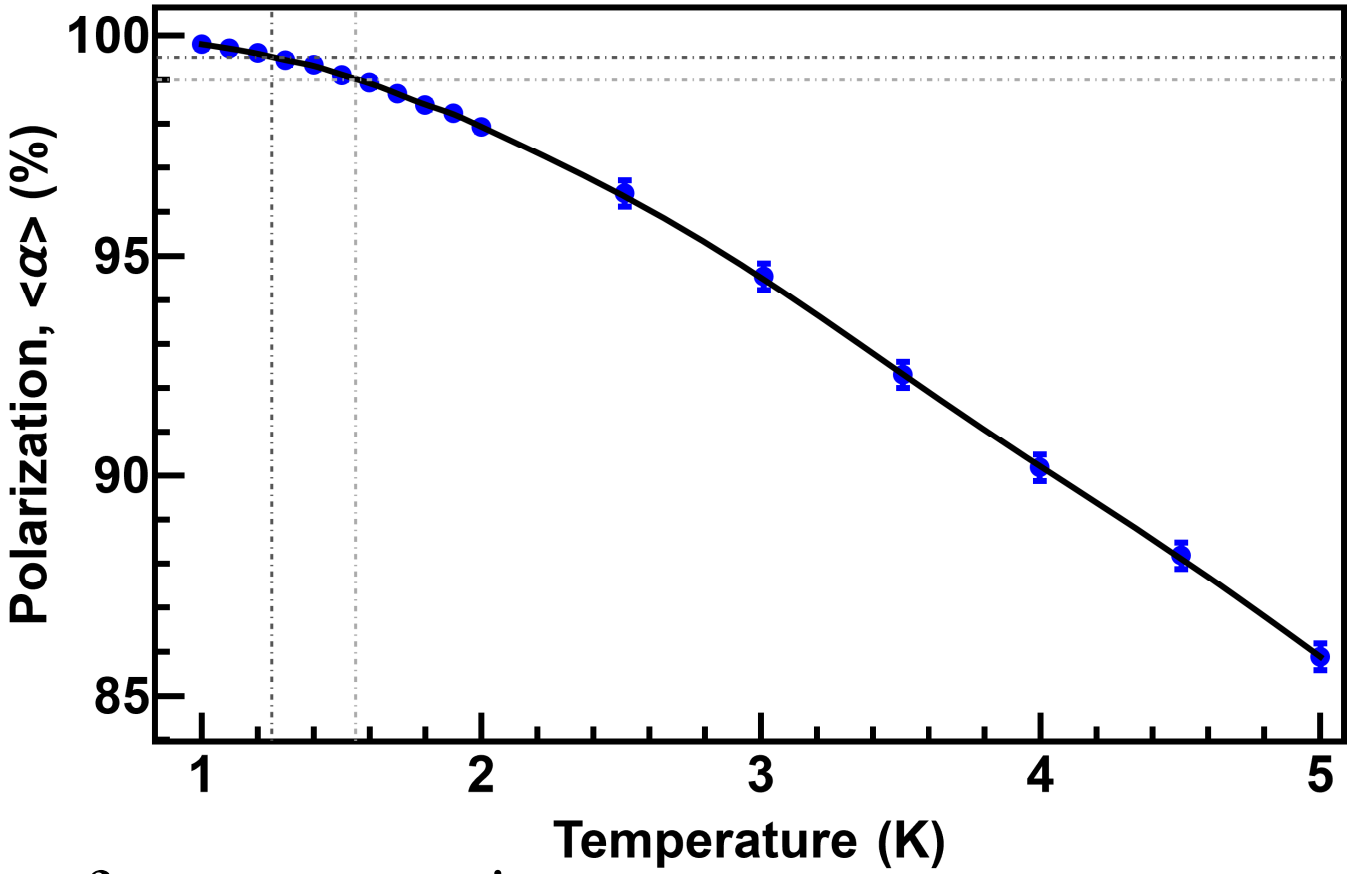


MCP: Unidirectional ^{3}He beam
Actuation: Gives direction control

Produces cold 3He polarized atoms
- ~ **1.3 K** (112 μeV)
- Flux ≳**10^{14} atoms/s**

§4 Preliminary Polarization

From Simulation



- Key performance requirement:
  - 99.5% @ 1.25K
  - 99% @ 1.55K

§3 Summary

1. Major upgrades:
   - Redesign of new larger cryo-vessel: vertical orientation
   - Use of MCPs
   - MCP actuation

2. New spin-tracking code:
   - Helps understand the final polarization
   - Addresses depolarization concerns
   - Quantifies material properties: η

3. New setup will be tested in 2024

=> Should Deliver Key Param.: flux (10^{14}.^{3}He/s) & Pol. (99.5%)

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