

An Upgraded Polarized ^3He Atomic Beam Source for Polarimetry at EIC

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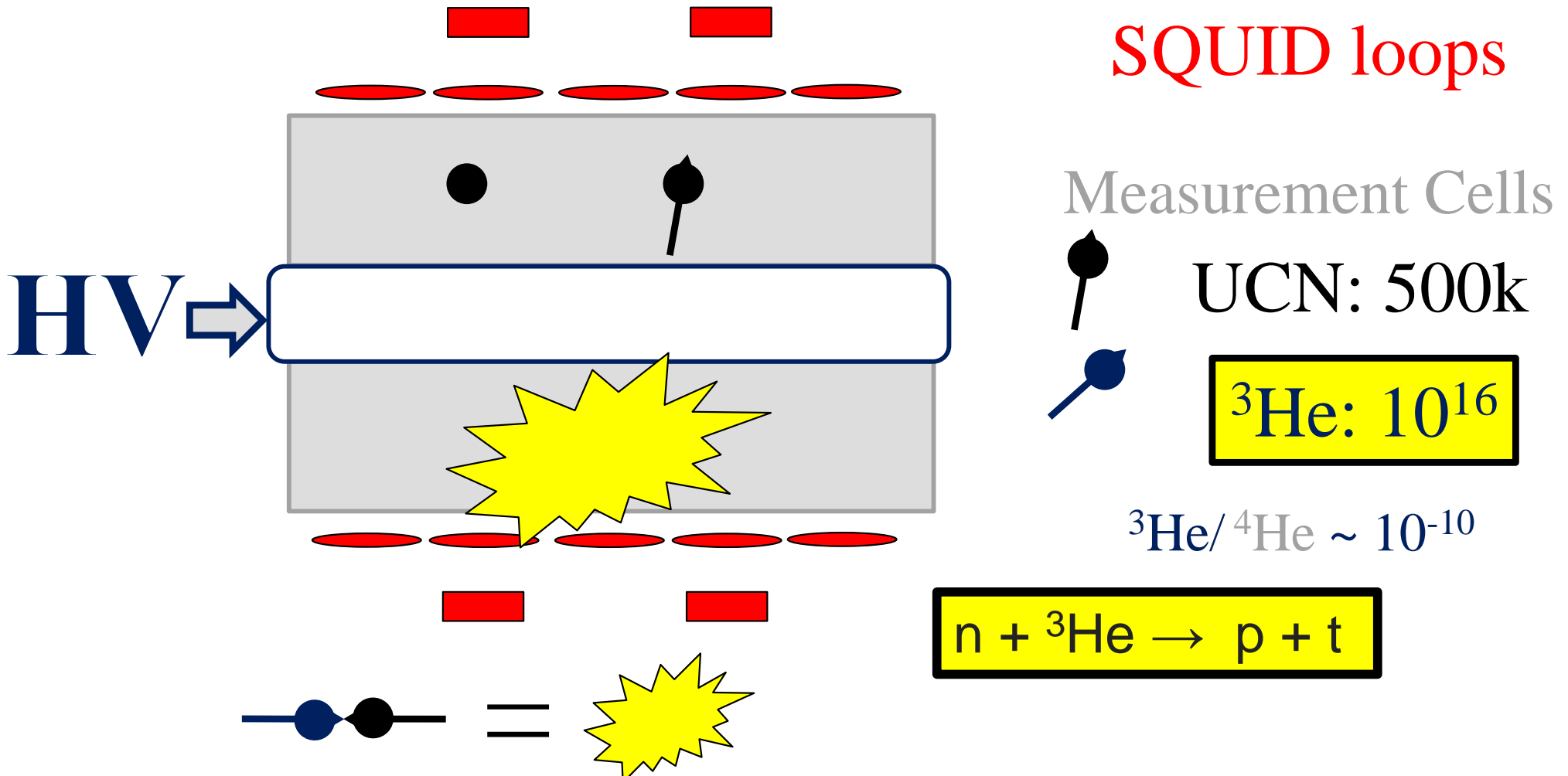
& P. Binns, B. O'Rourke

1. Why ^3He ABS?
2. Basic Components:
 - Cryo-chamber
 - MCP & Actuation system
 - Quadrupole magnet
3. Major Upgrades (easier to discuss knowing the components):
 - New cryo-chamber (Vertical orientation)
 - MCP
 - Actuation system
4. Polarimetry @ EIC

§1 Why polarized ^3He ?

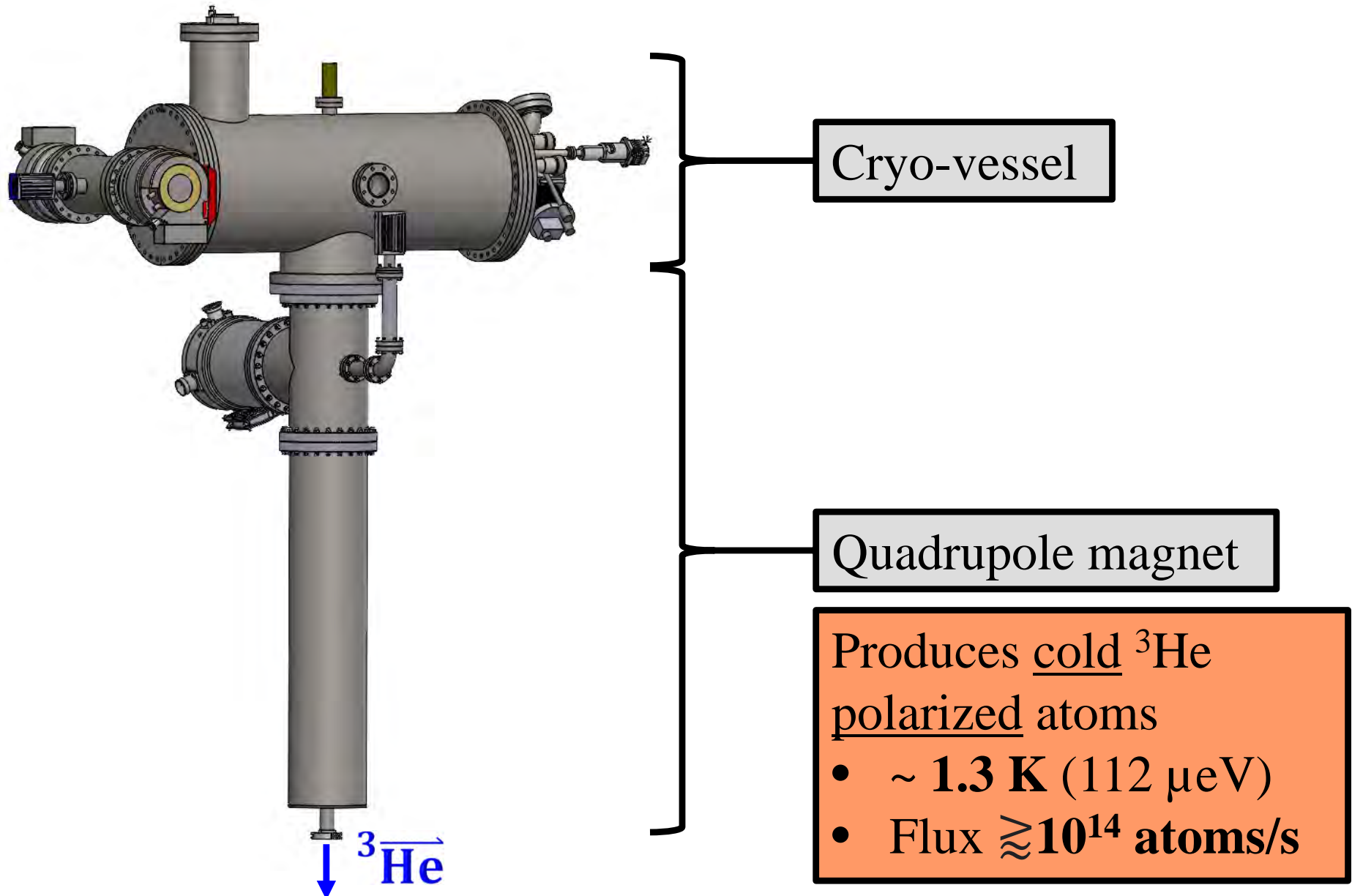
^3He is a good: **co-magnetometer** + neutron detector

Ideally $\sim 99\%$ polarized: SEOP/MEOP won't work



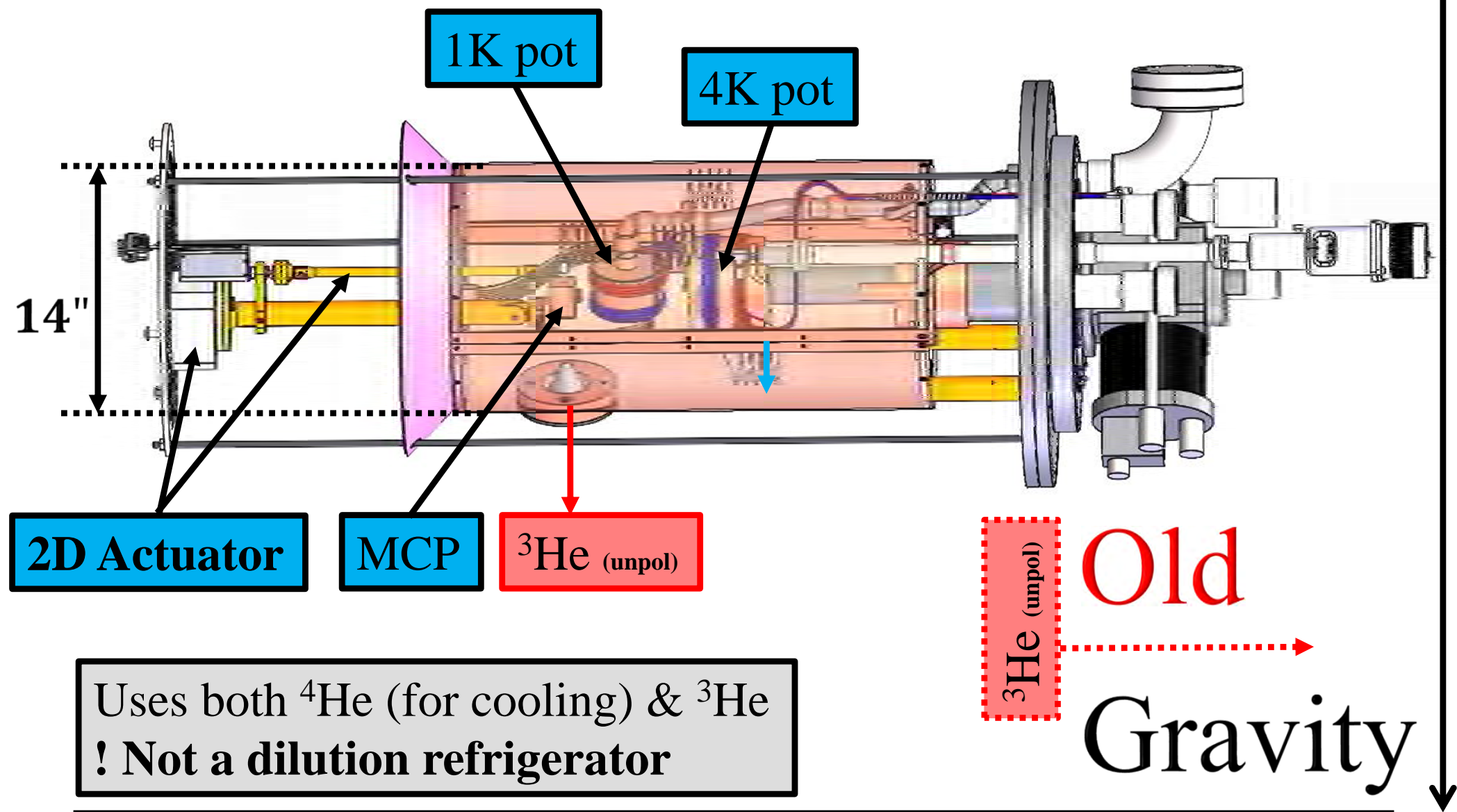
§2

ABS Components



§2

Upgrade: ABS Cryo-Vessel

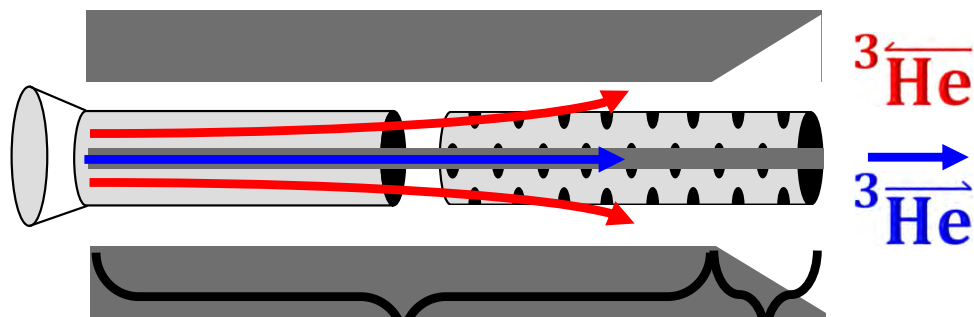
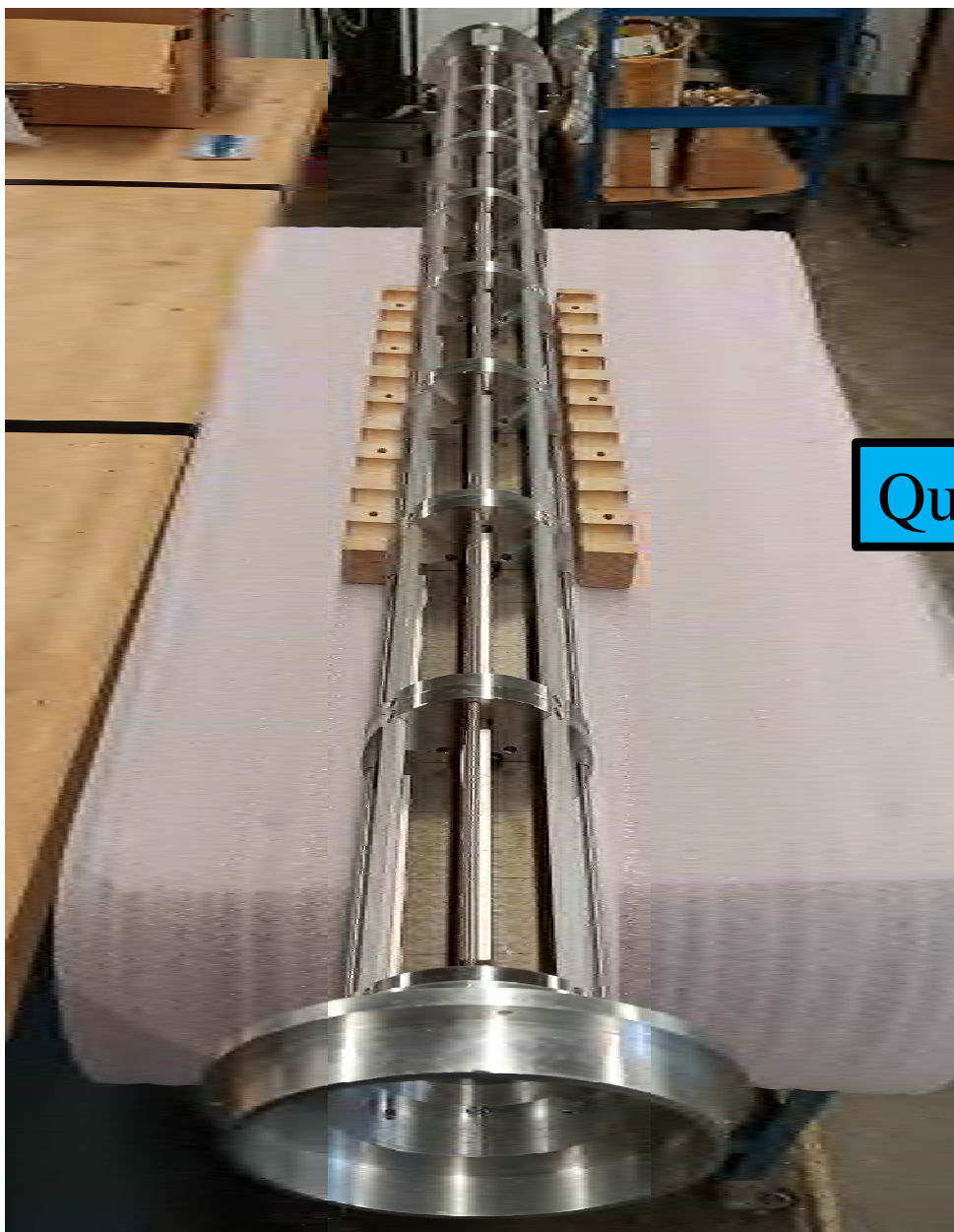


Uses both ^4He (for cooling) & ^3He
! Not a dilution refrigerator



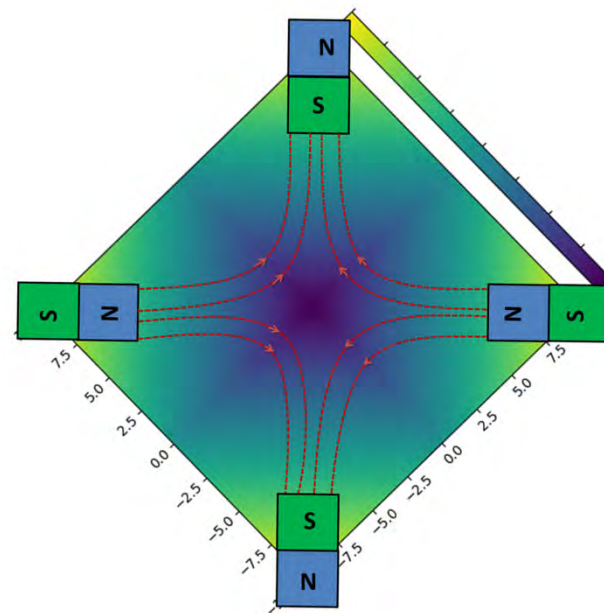
§2

ABS: Quad. Magnet



Quadrupole Magnet

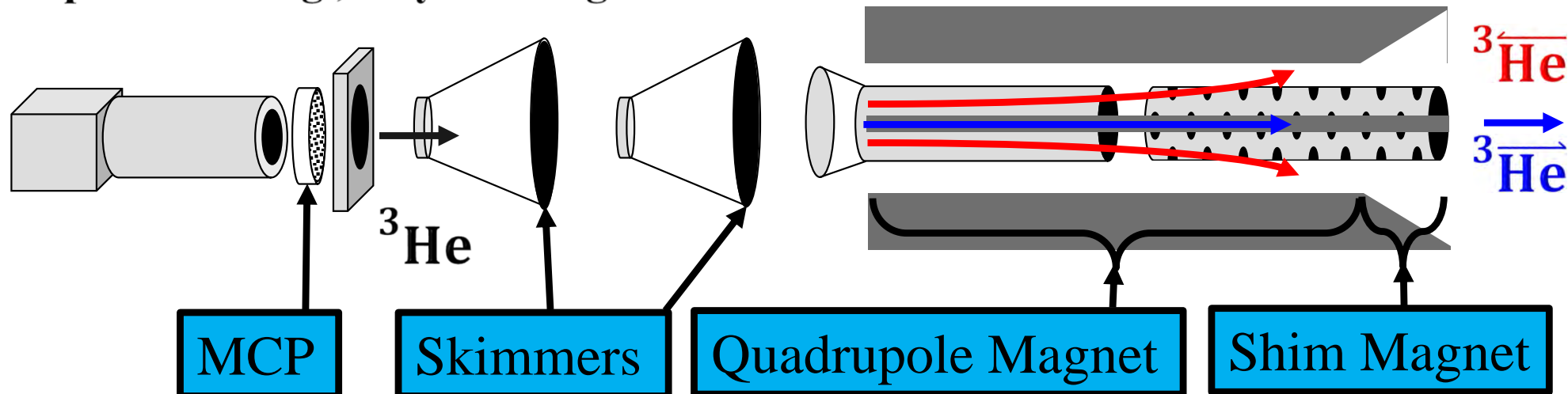
Shim Magnet



§2

ABS: Quad. Magnet

Spin-Tracking , Ray-Tracing Simulation

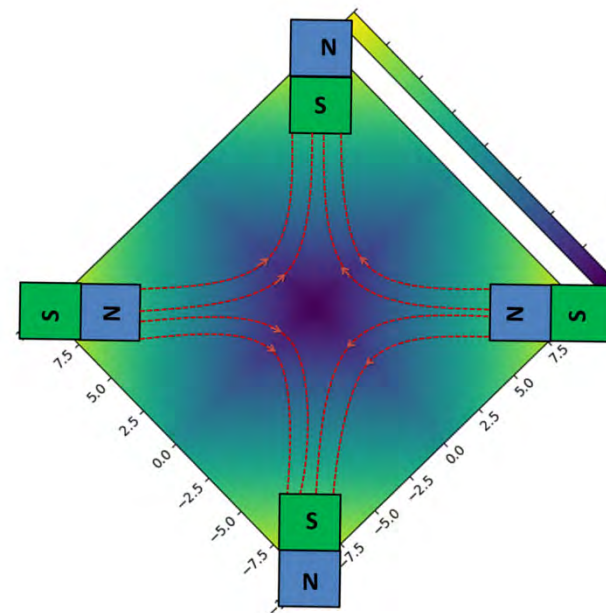


UCN: Can be completely reflected

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

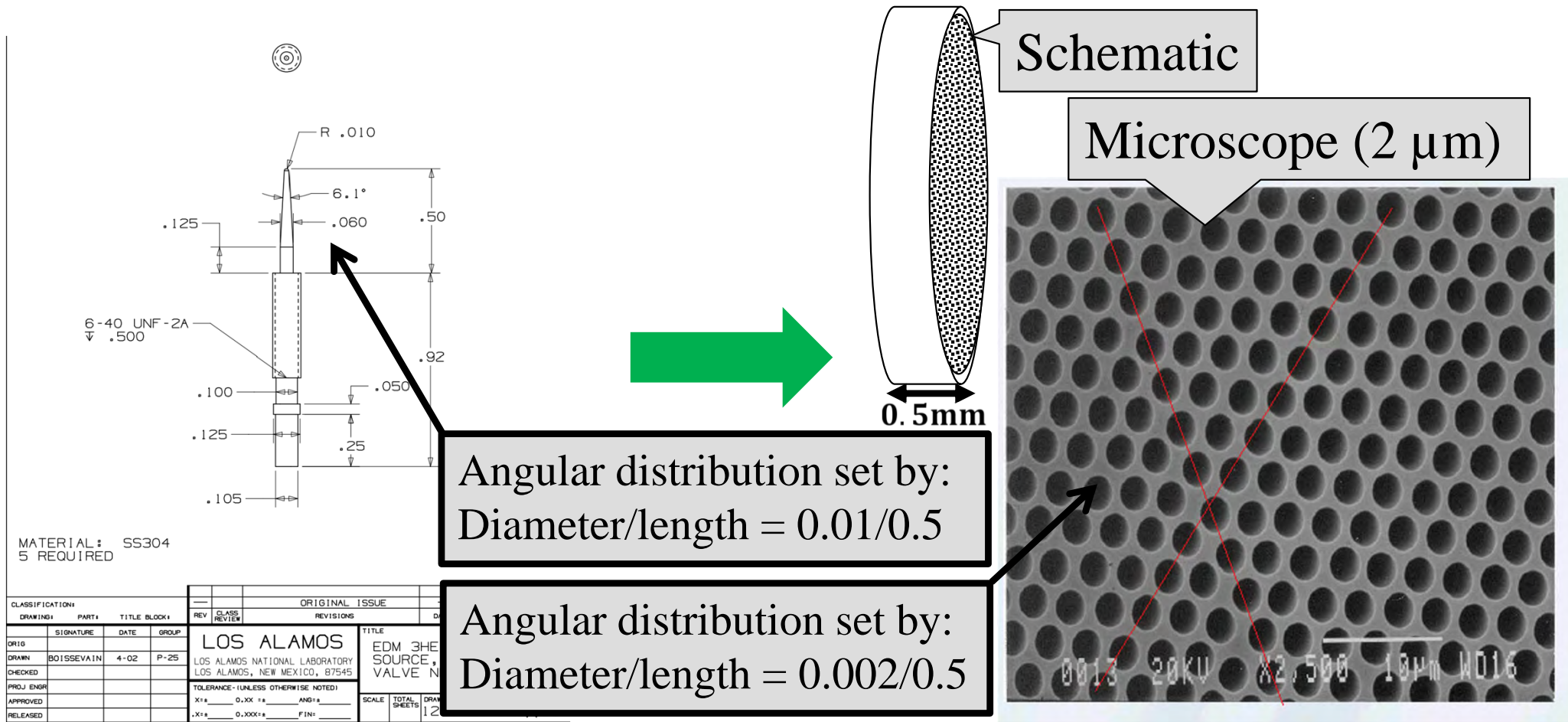
^3He : Only $>\text{deflected}<$

- $1.3 \text{ K} \approx 86 \mu\text{eV}$
- $\Delta E = \mu_m \approx 67 \text{ neV/T}$
- Making initial angle very important



§3 Upgrade: MCP

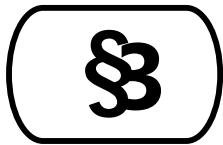
Before: ^3He ABS used a needle valve to effuse



Now: ^3He ABS uses a Quartz MCP

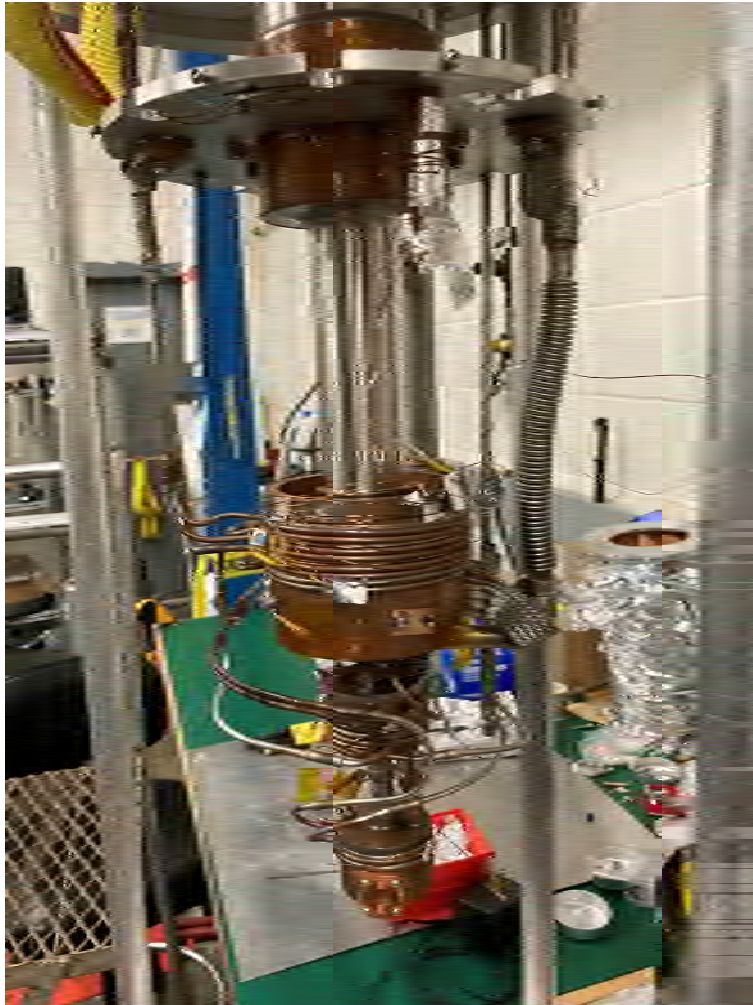
Constraints the angular distribution to (before: 1.5°) 0.3° [0.5°]





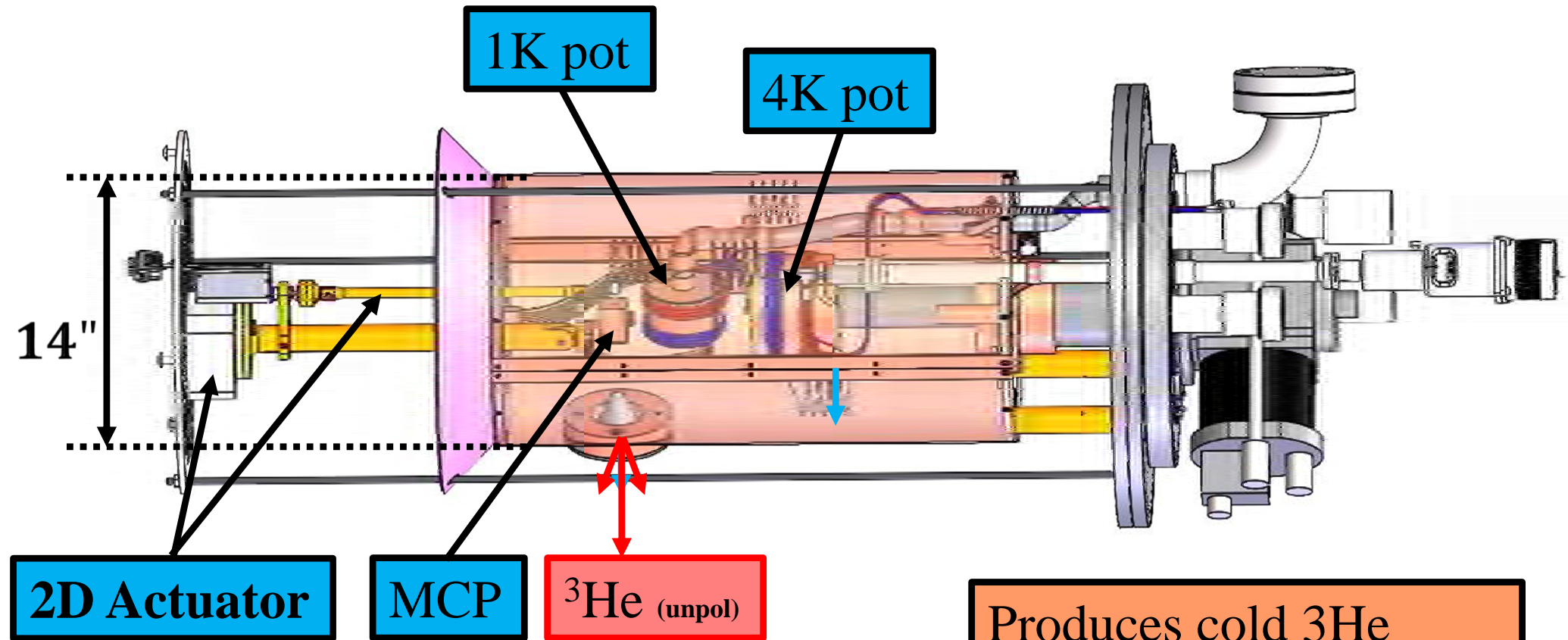
Upgrade: Actuation

Before: ^3He nozzle was fixed



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

§ 3 Upgrade: Actuation



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

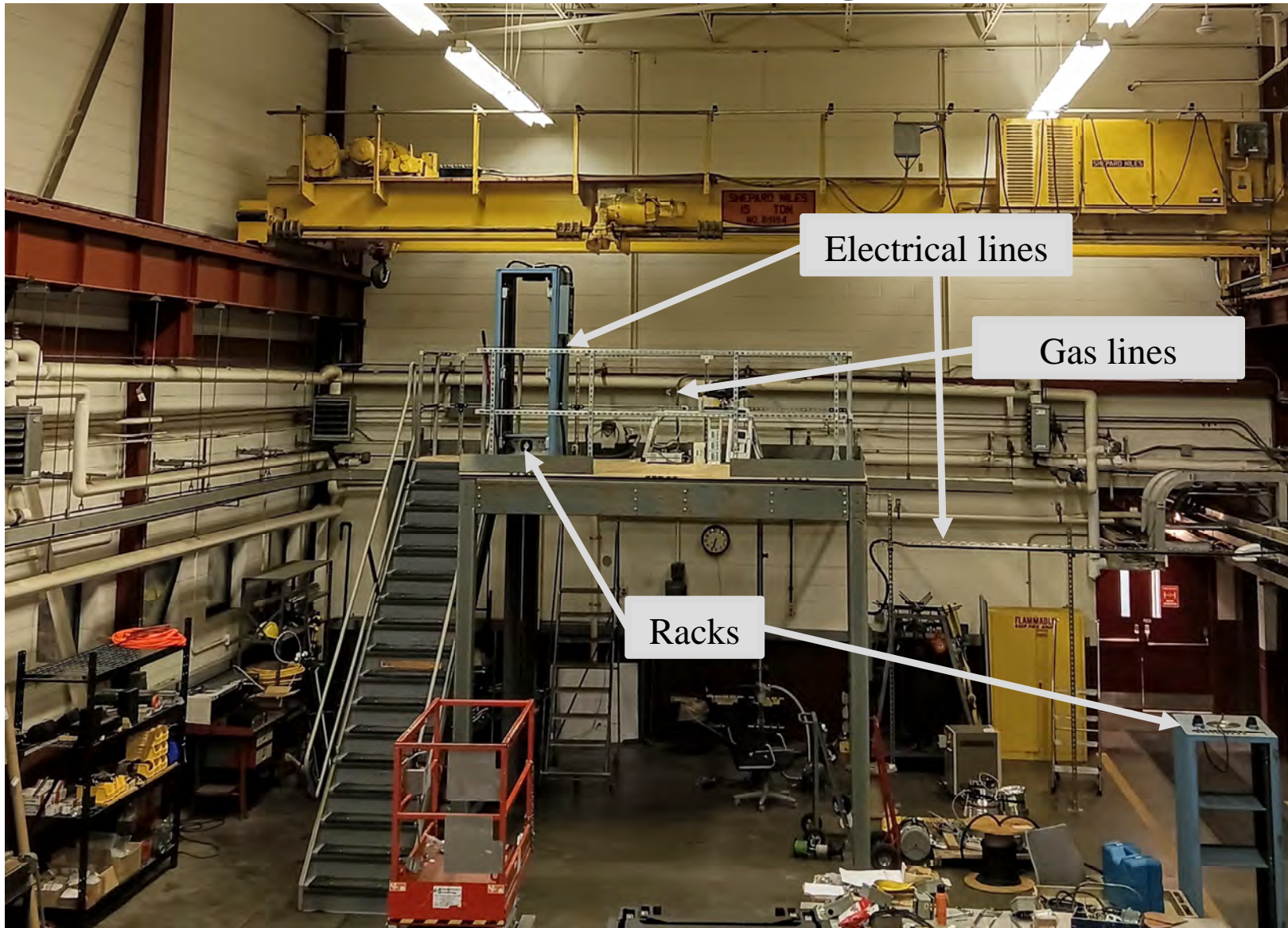
Produces cold ^3He polarized atoms

- $\sim 1.3 \text{ K}$ ($112 \mu\text{eV}$)
- Flux $\gtrsim 10^{14}$ atoms/s



§ x Mezzanine: Now...

Apr 2023: Mezzanine ++ Electrical outlets, gas lines, electronics rack





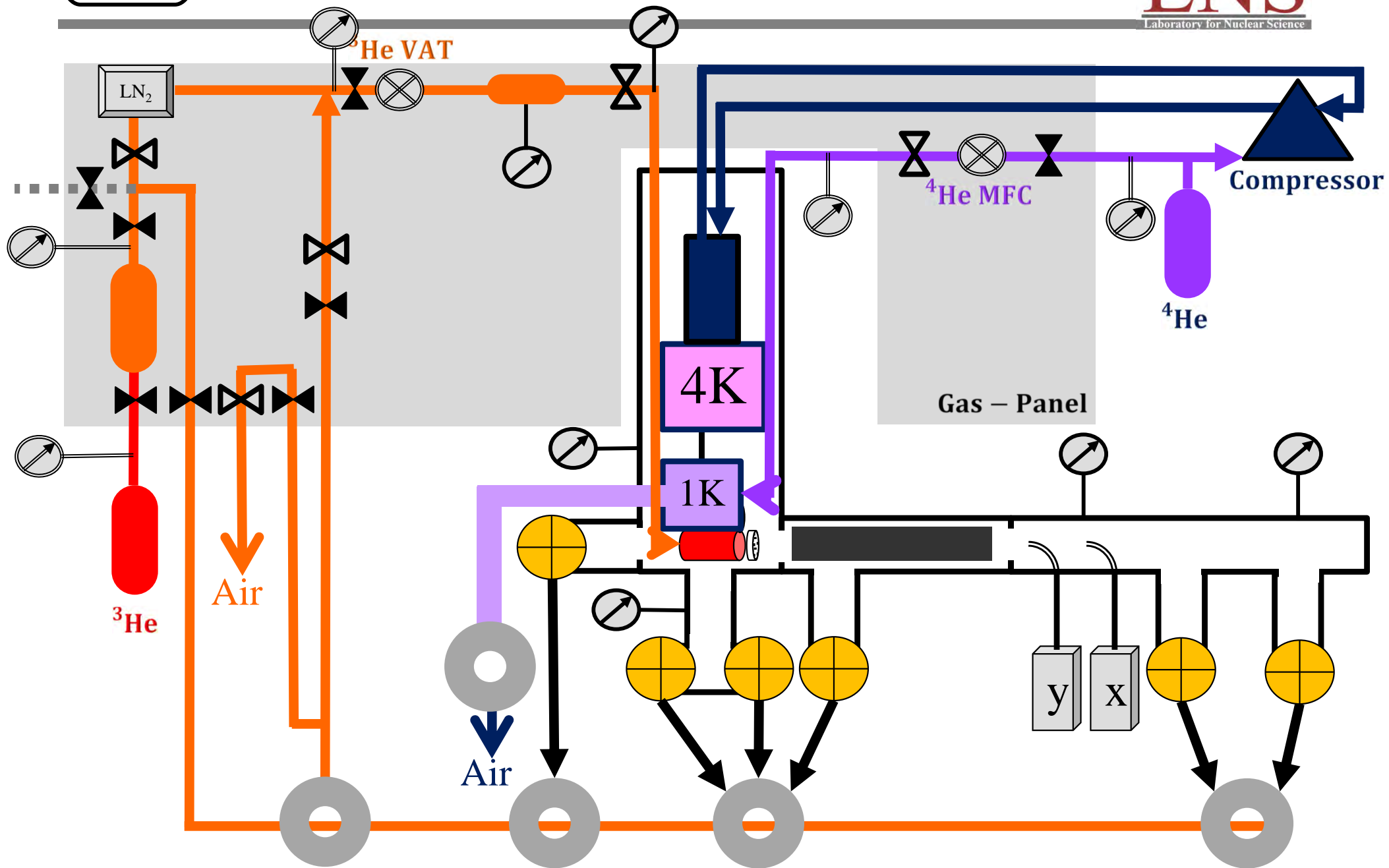
Mezzanine: Now...

Apr 2023: Mezzanine ++ Electrical outlets, gas lines, electronics rack



§ X

Vacuum Schematic + Gas Panel



§x Gas Panel





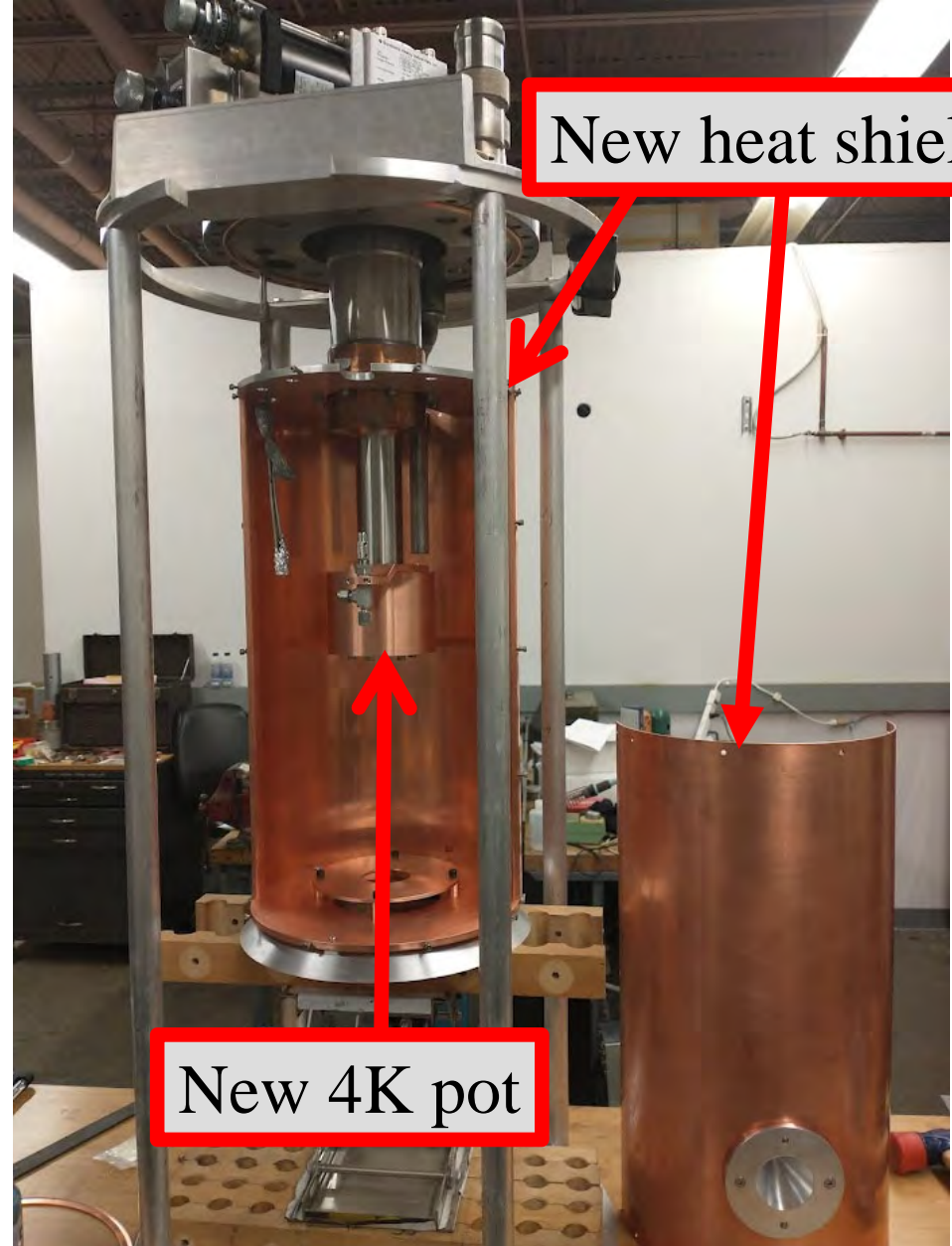
Magnetic Fields

Solenoid: 24 V

- 2-9 μT @ surface [measured]
- 0.067-0.225 nT @ 1m - MSR [calculated]
(Earth's magnetic field $\sim 5 \mu\text{T}$)

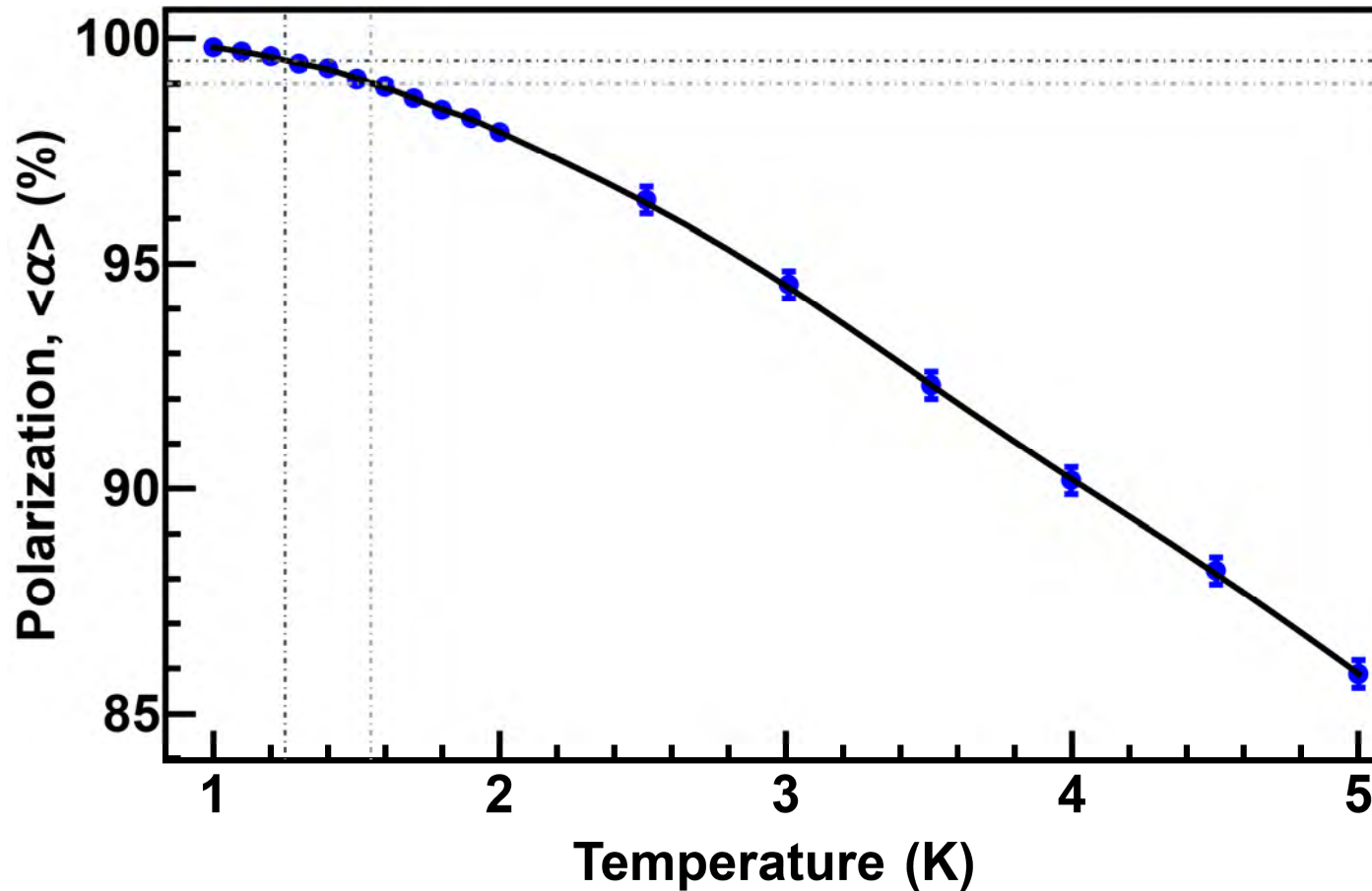
§x

Assembly: Cryo Insert





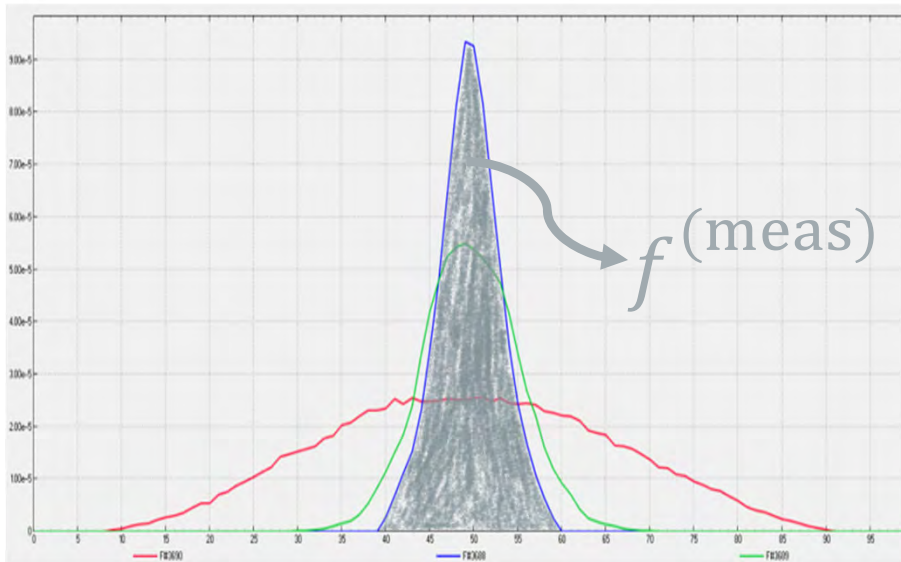
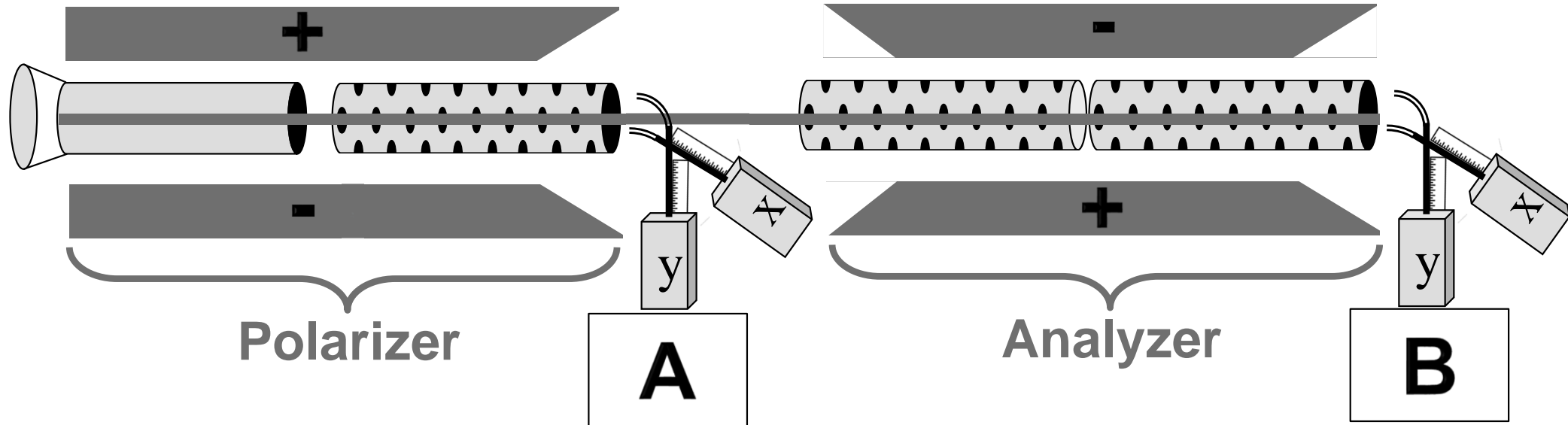
From Simulation



- Key performance requirement:
 - 99.5% @ 1.25K
 - 99% @ 1.55K
- 2 different simulations:
 - Spin-tracking: C++ based
 - Background gas: Mol-flow



§4 ^3He ABS Pol. Measurement



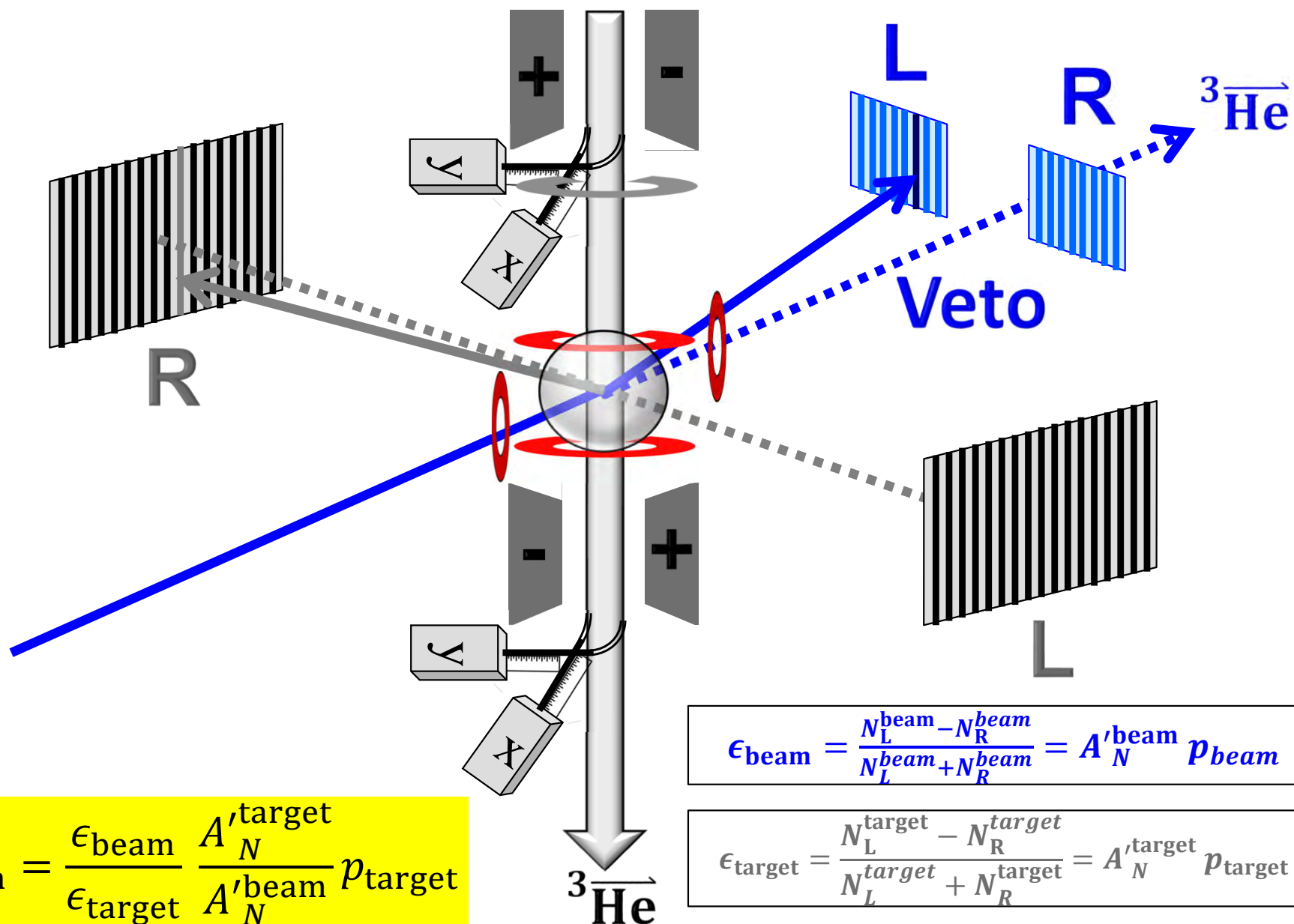
$$p = 1 - \frac{F_B}{F_A} = 1 - \frac{(f_B^{(\text{meas})} - f_B^{(\text{sim})}) \theta_A}{(f_A^{(\text{meas})} - f_A^{(\text{sim})}) \theta_B}$$

- $f^{(\text{sim})}$: Background/residual gas from simulation
- $f^{(\text{meas})}$: Raw measured profile
- θ : Angular diffusion

$$f^{(\text{sim})} / f^{(\text{meas})} \sim 1/20 \text{ [pre-upgrade]}$$

§4

^3He — ^3He Polarimeter



$$\epsilon_{\text{beam}} = \frac{N_L^{\text{beam}} - N_R^{\text{beam}}}{N_L^{\text{beam}} + N_R^{\text{beam}}} = A_N^{\text{beam}} p_{\text{beam}}$$

$$\epsilon_{\text{target}} = \frac{N_L^{\text{target}} - N_R^{\text{target}}}{N_L^{\text{target}} + N_R^{\text{target}}} = A_N^{\text{target}} p_{\text{target}}$$

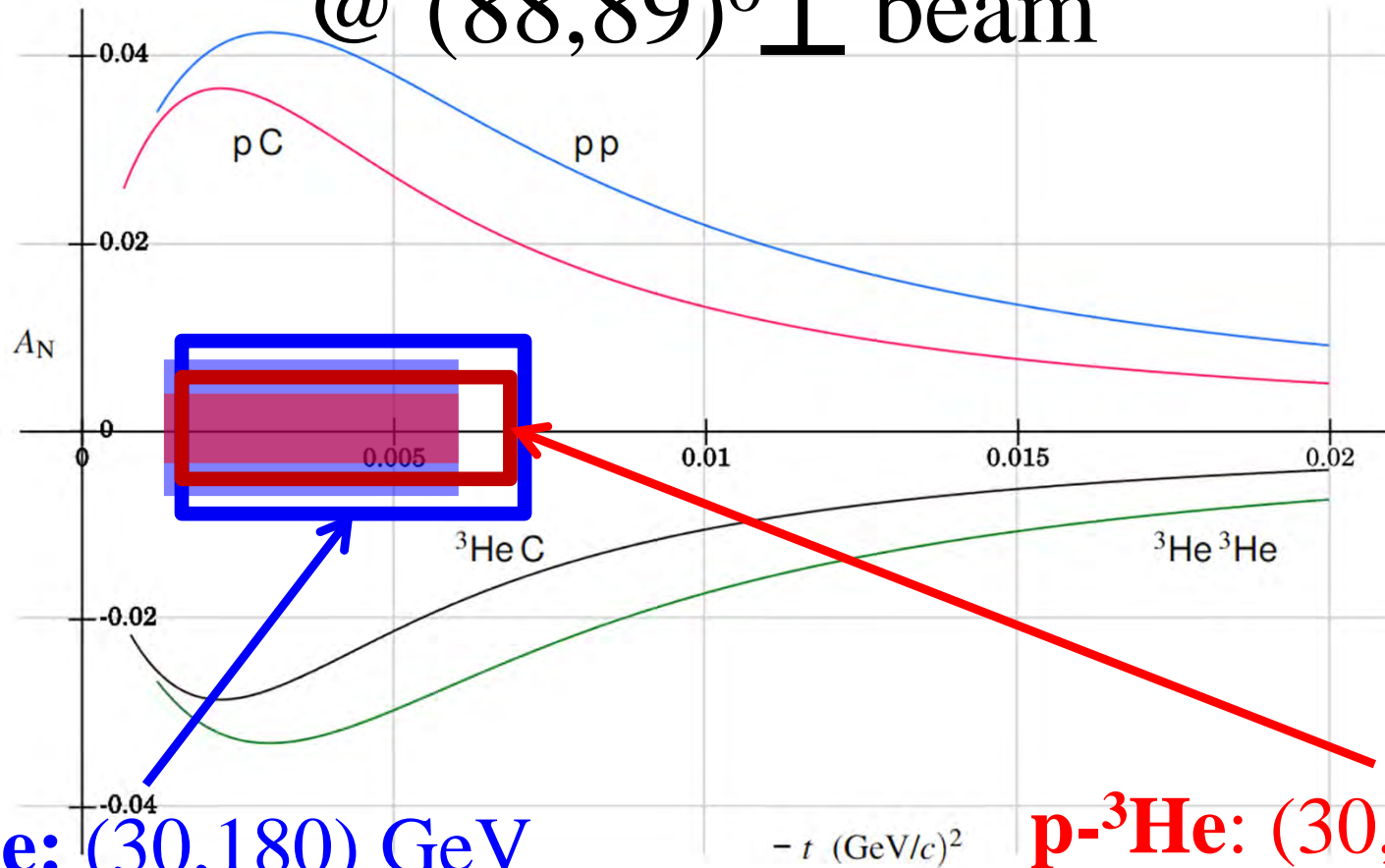
$$p_{\text{beam}} = \frac{\epsilon_{\text{beam}}}{\epsilon_{\text{target}}} \frac{A_N^{\text{target}}}{A_N^{\text{beam}}} p_{\text{target}}$$



§4

Polarimetry Analyzing Power

Calculated, but needs to be measured
 @ (88,89)° ⊥ beam



${}^3\text{He}-{}^3\text{He}$: (30,180) GeV

$p-{}^3\text{He}$: (30,140) GeV

$$p_{\text{beam}} = \frac{\epsilon_{\text{beam}}}{\epsilon_{\text{target}}} \frac{A_N^{\text{target}}}{A_N^{\text{beam}}} p_{\text{target}}$$

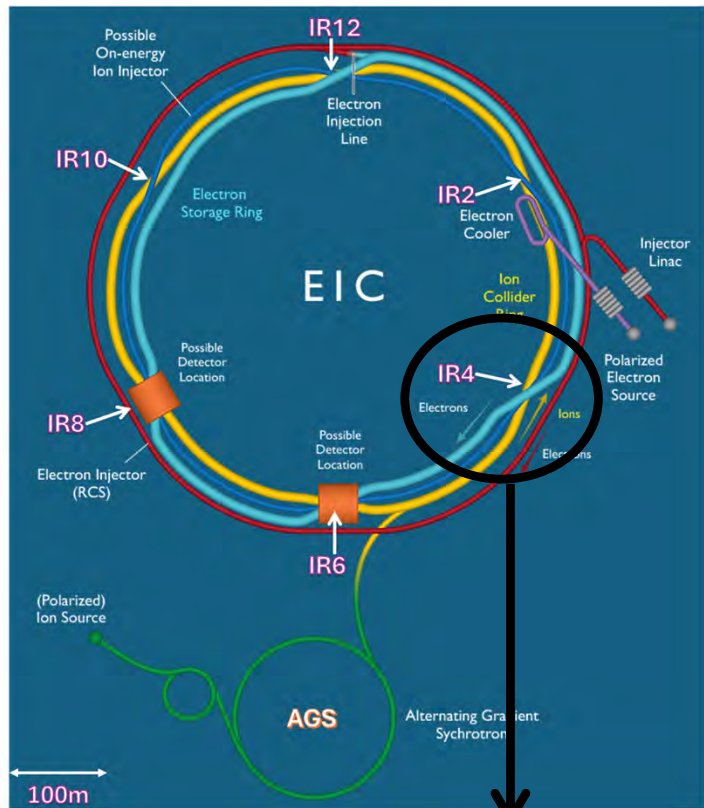
$$\epsilon = A_N p \gg 10^{-3}$$

$$\epsilon = \frac{N_L - N_R}{N_L + N_R}$$



§4

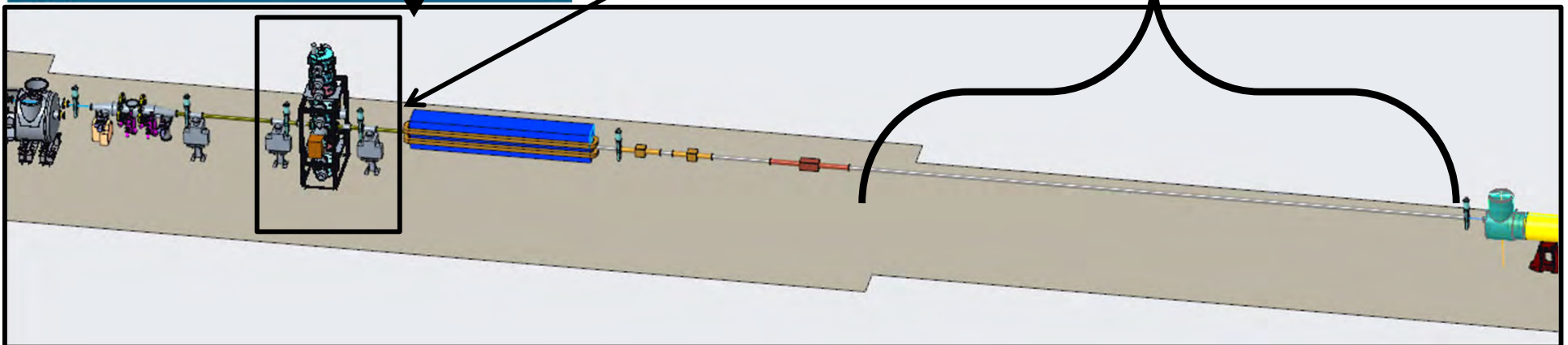
Location in RHIC



- Location: Right next to polarized H-Jet [also an ABS based absolute p-Polarimeter].
- 20m: Need to veto nuclear fragments.
- Characterization: Explicitly measure the analyzing power of both {p-³He, ³He-³He}
- Cross check with HJet {p-³He}.

H-Jet

20 m stretch



§5

Summary

1. Major upgrades under implementation:
 - Redesign of new larger cryo-vessel (vertical orientation)
 - Use of MCPs
 - Actuation
2. Program to develop and implement absolute ${}^3\text{He}$ - ${}^3\text{He}$ Pol.
 - Upgrade cold head to pulse tube
 - Design and construct scattered particle detectors
3. Ask me about: side-physics quest (Testing charge neutrality)!
4. **New setup → Should Deliver Key Param.:**
flux ($10^{14} \cdot {}^3\text{He}/\text{s}$) & Pol. (99.5%)



DOE:
DE-SC0018229,
~~DE-SC0019768~~

NSF:
~~PHY-1822502~~



BACKUP!