Michigan Ultra-Cold Spin-Polarized Hydrogen Jet Target

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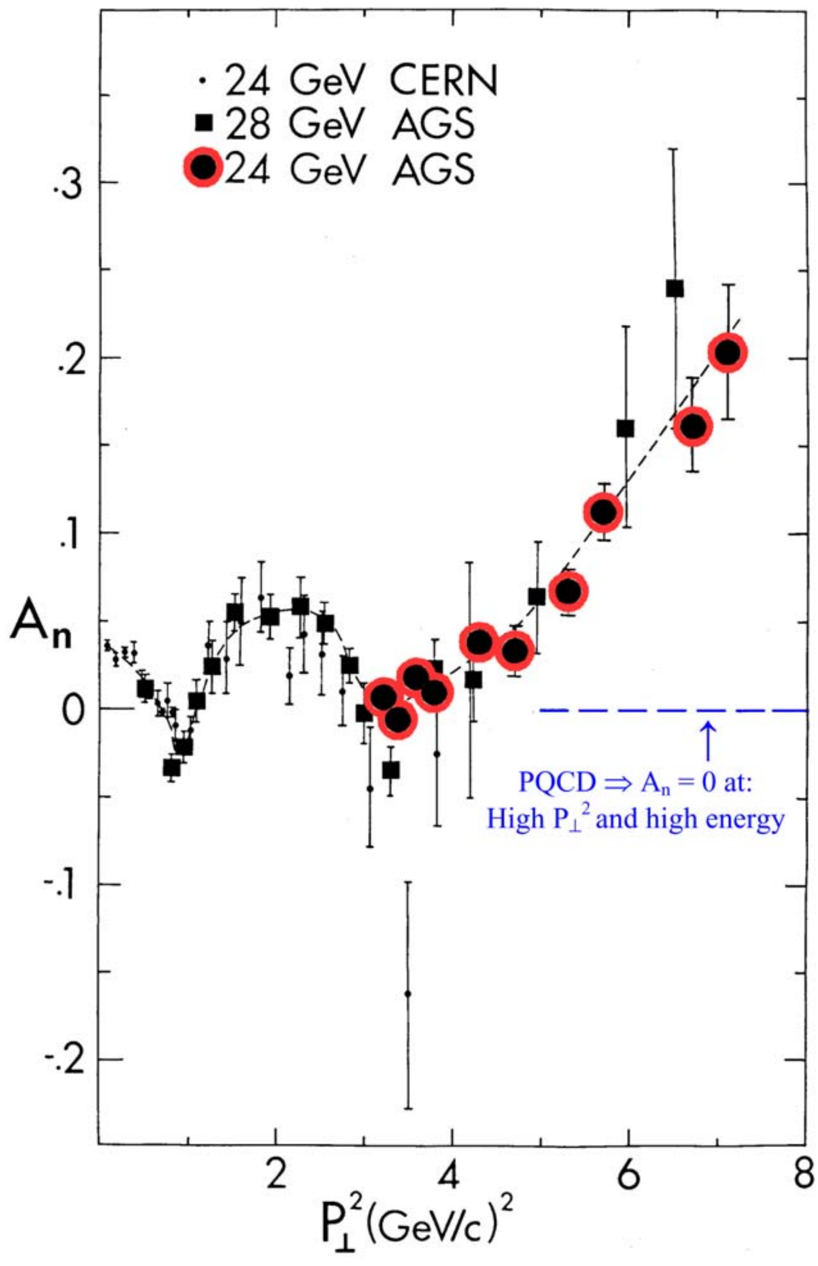
The Jet's Purpose

- High energy polarized *p-p* elastic scattering experiments
- Theoretical goal: understand spin behavior of constituents that make up the proton



(D.G. Crabb et al. PRL **65,** 3241 (1990))

Advantages of Ultra-Cold Polarized Atomic Hydrogen Gas Jet Target

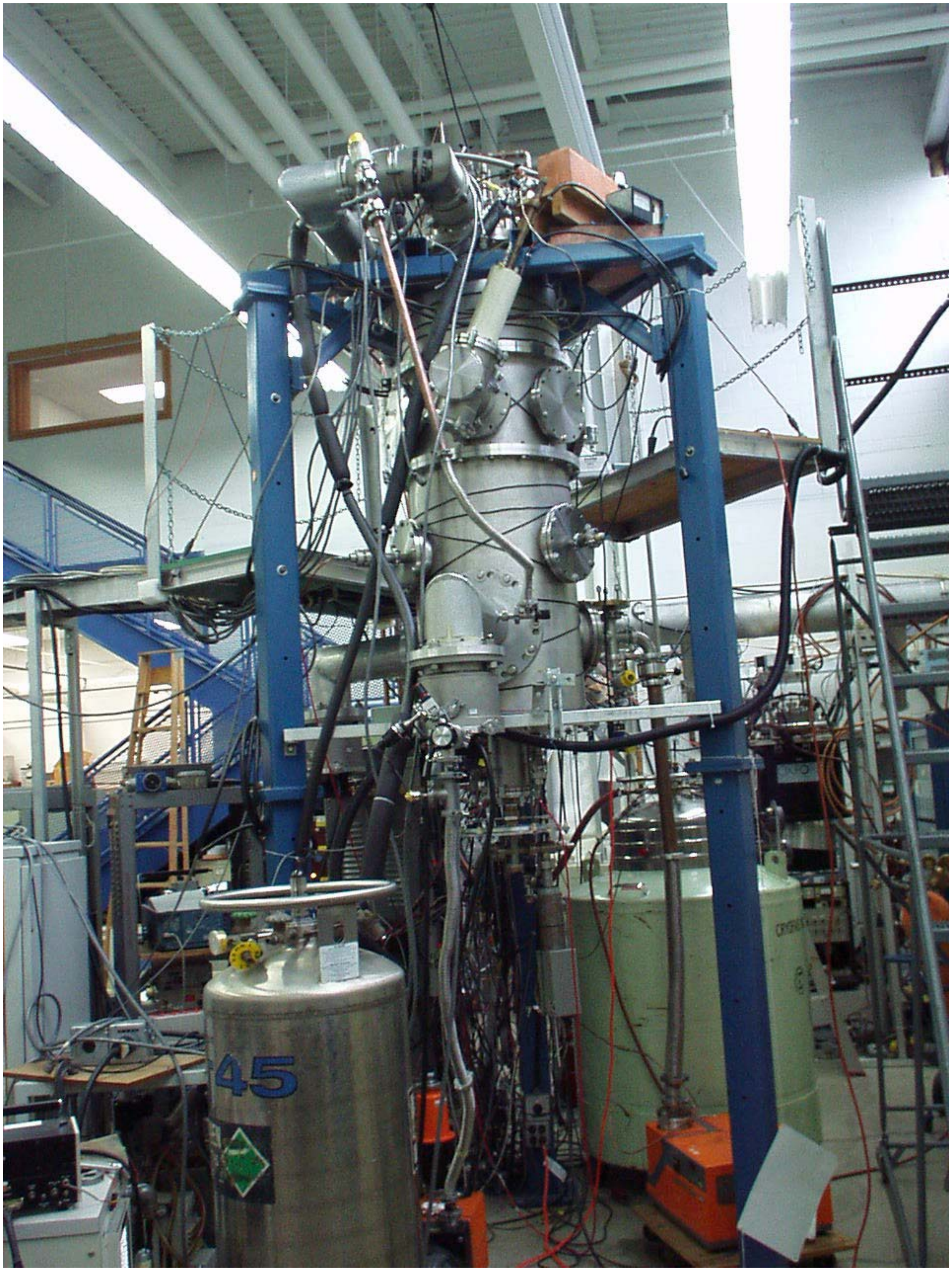
- Pure atomic hydrogen
  - No background from un-polarized nuclei in scattering experiments

- Very monochromatic beam

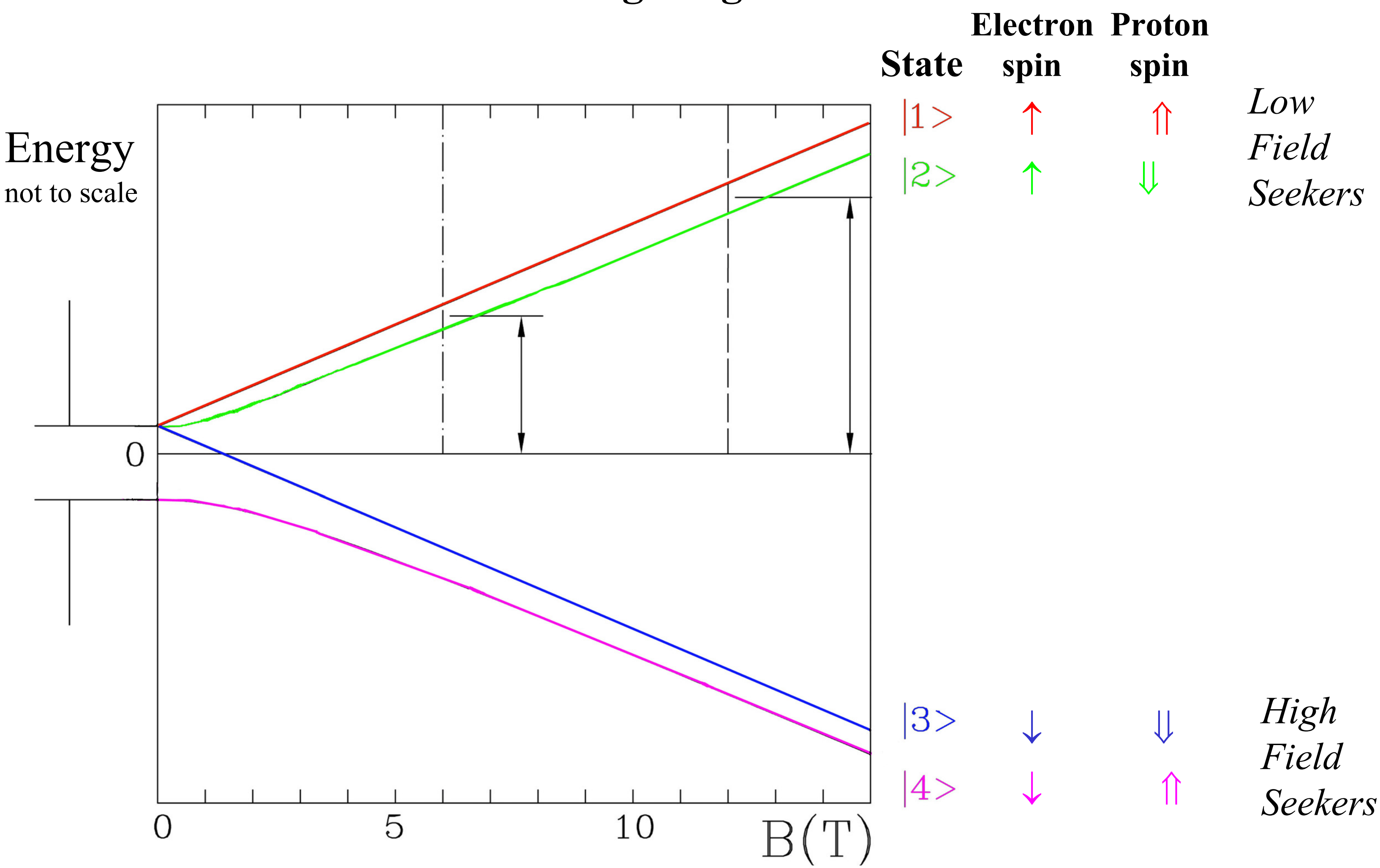
  (all H atoms have the same energy)

  - Very small spot size
  - High density compared to other gas jet targets

The Ultra-Cold Michigan Jet Target

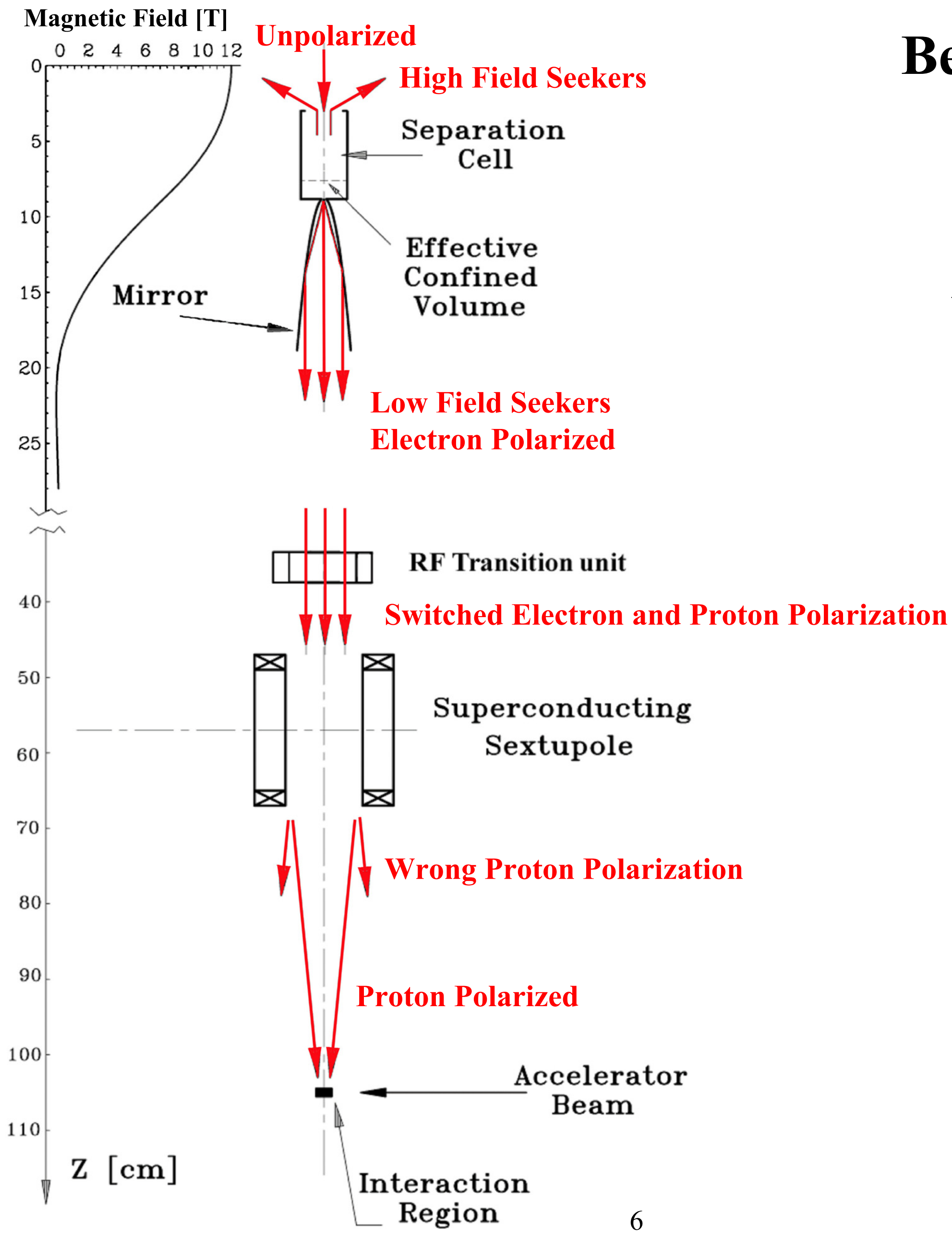


Energy diagram of atomic hydrogen in Strong Magnetic Fields



Schematic Breit-Rabi diagram for atomic hydrogen

Beam Formation



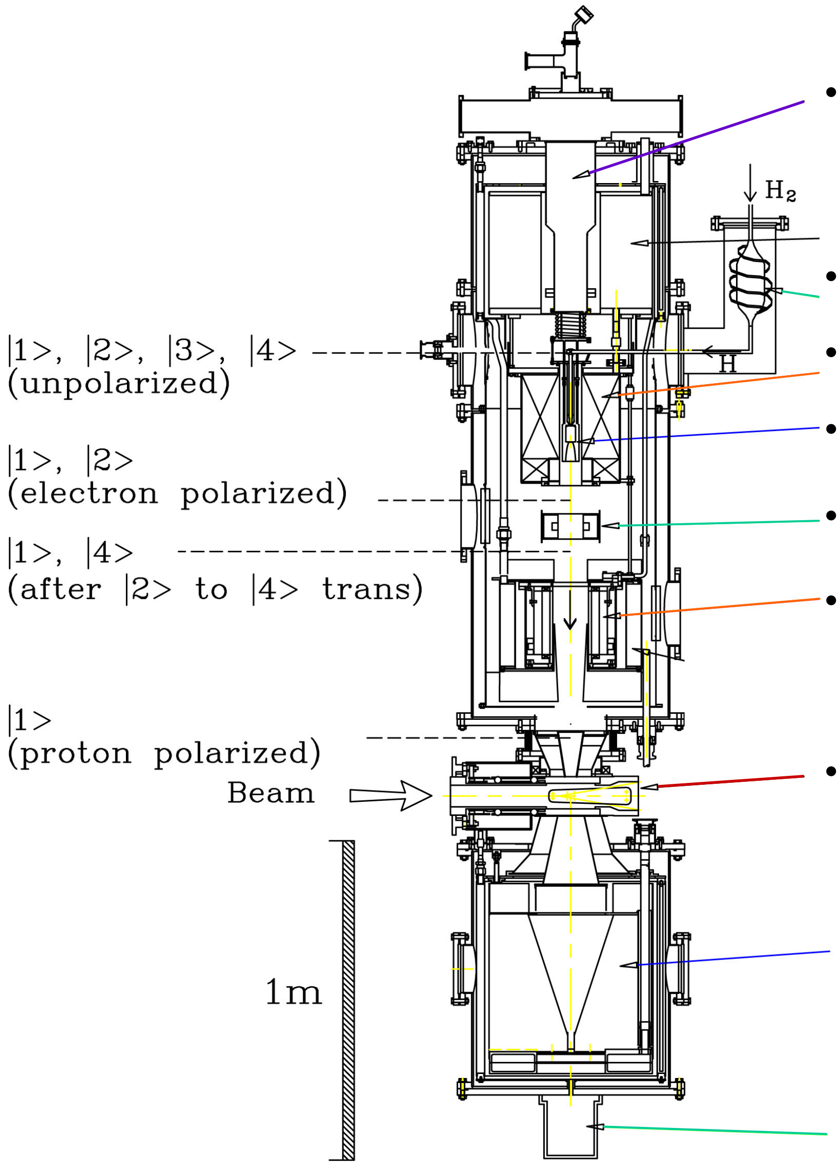
Acceleration by solenoid magnet

$F \sim -\mu_e \, \partial B_z / \partial z$

Focusing by sextupole magnet

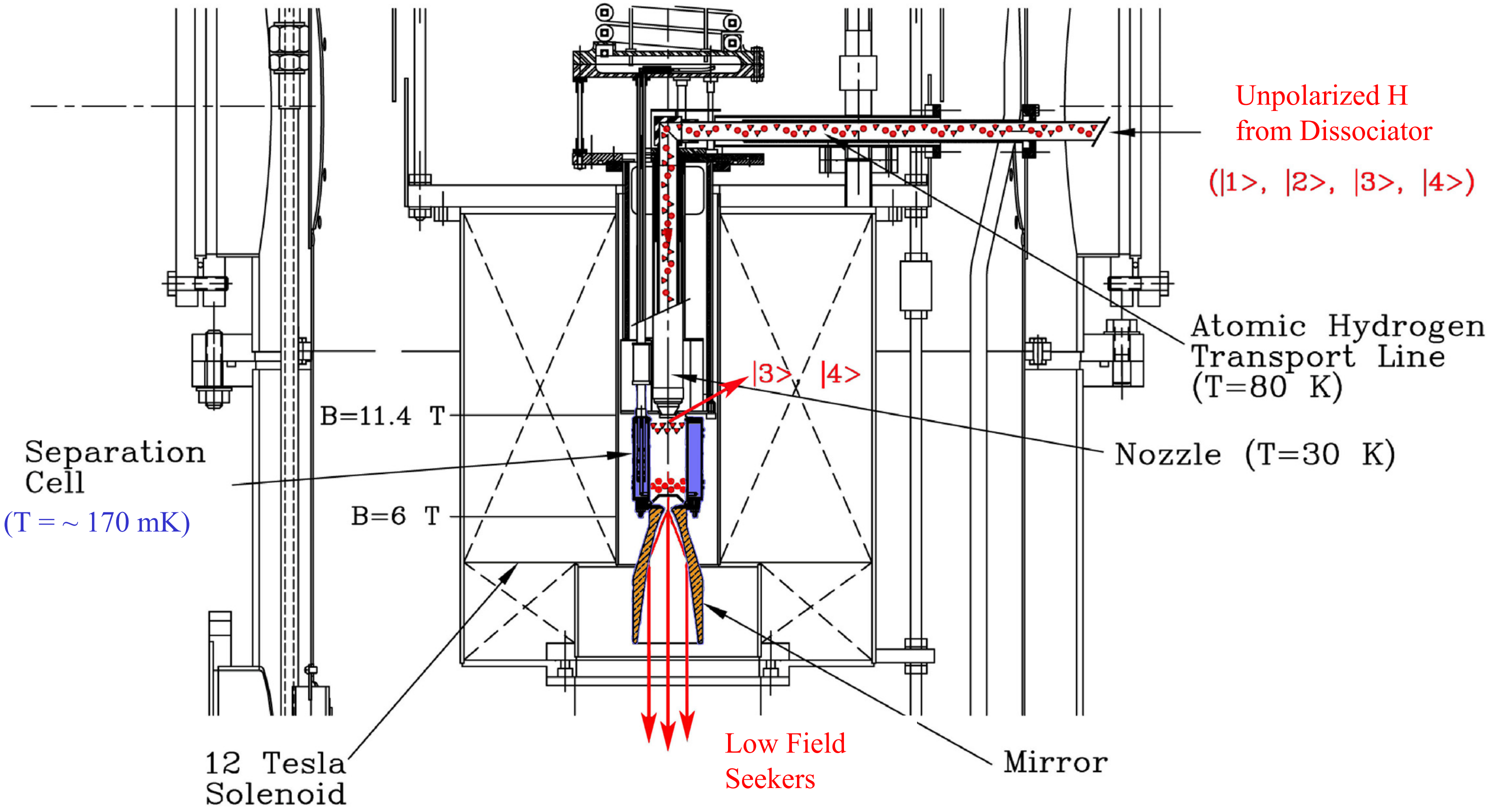
$F \sim -\mu_e \, \partial B / \partial r$

Michigan Ultra-Cold Jet



- **Refrigerator**
  - *75mW @ 300mK*
  - *22mW @170mK*
- **RF dissociator**
  - *Produces unpolarized atomic-hydrogen*
- **Superconducting 12T solenoid**
  - *Separates electron-polarized states*
- **Separation cell and Mirror**
  - *Cools down atoms & makes beam parallel*
- **RF transition unit**
  - *|2> to |4>transition*
- **Superconducting sextupole magnet**
  - *Focuses |1> and Defocuses |4>*
- **Interaction Region Vacuum Box**
- **Catcher**
  - *Cryocondensation pump 1.2 x 10^7 l/sec*
  - *Apparently the world's larget*
- **H Maser Polarimeter**

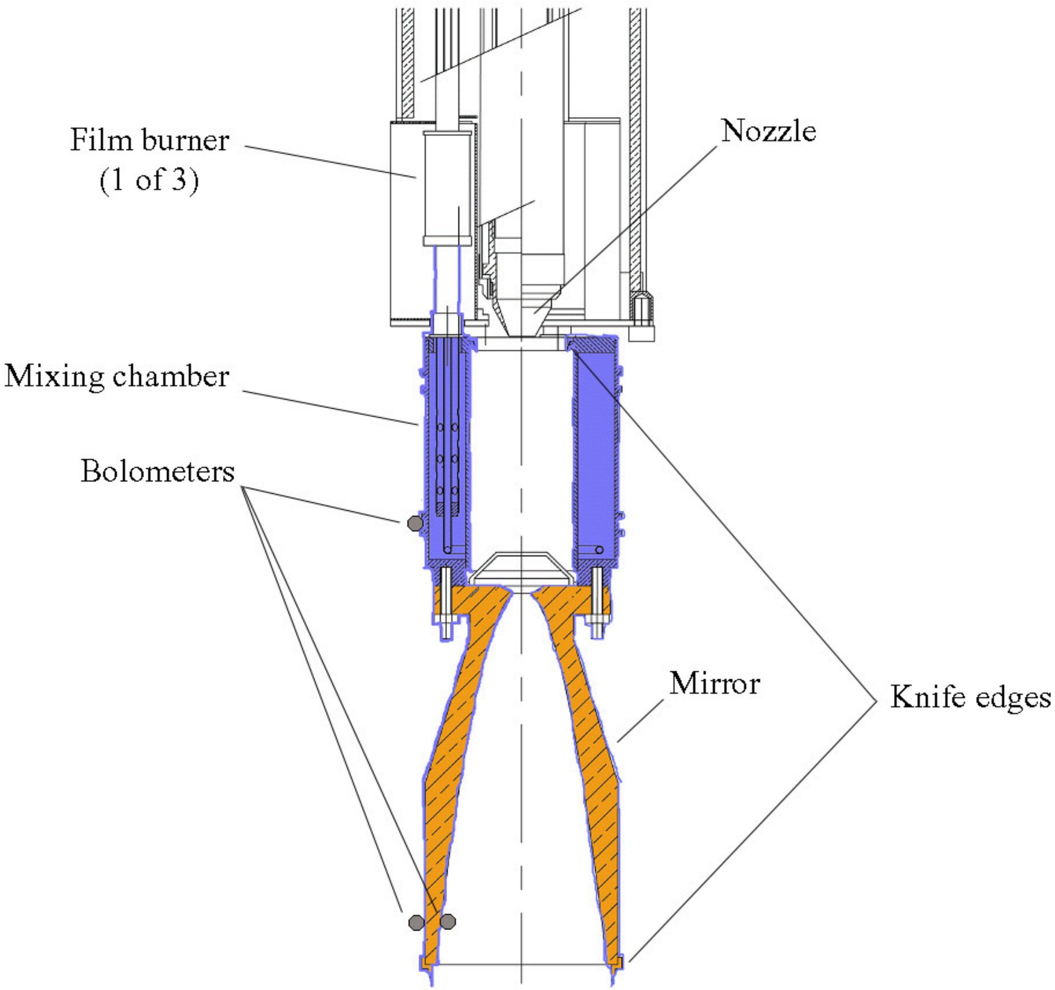
Separation region

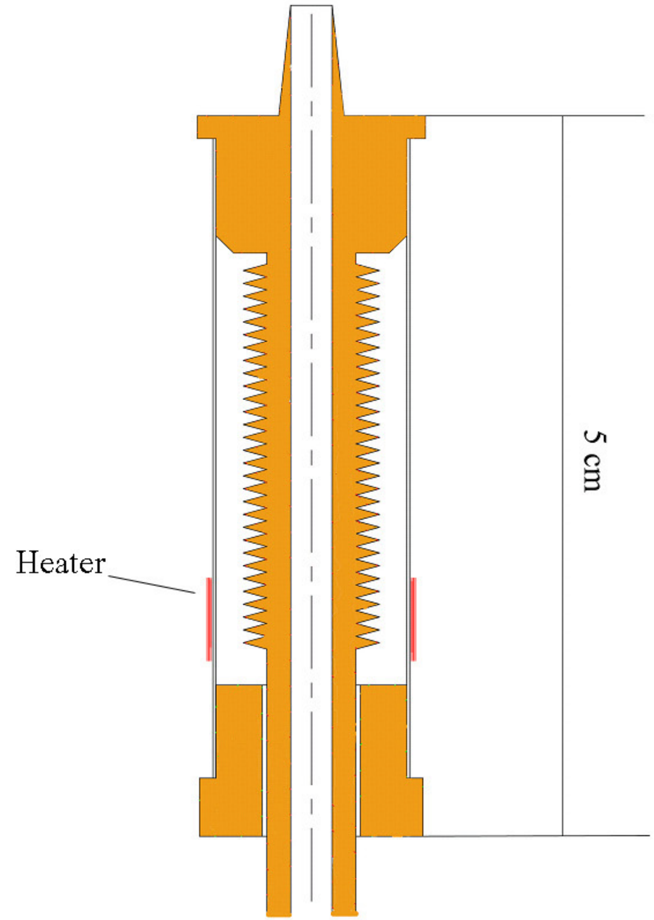


Parabolic mirror makes hydrogen beam parallel:

- ***Coated with superfluid ^{4}He film to suppress depolarization and recombination of hydrogen atoms***
- ***80 % mirror reflection of cold hydrogen from a helium-film-covered surface***

  *(J.J. Berkhout et al. PRL **63**, 1689 (1989))*
- ***Beam intensity increases by a factor of 3.***





Cross-sectional view of film burner

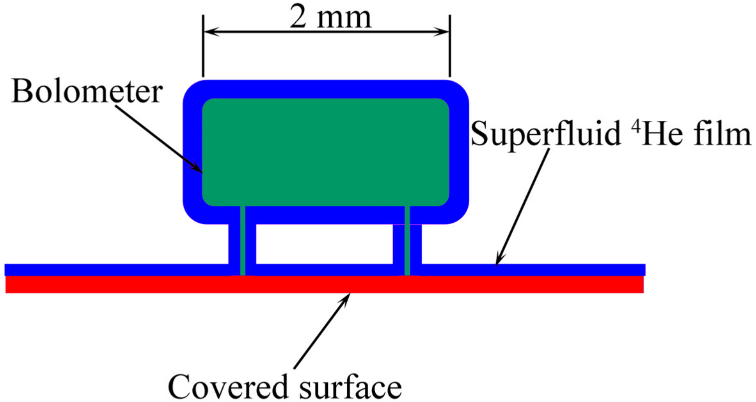
Building, Measuring, and Controlling, the Superfluid ^4He

- ^4He from the main reservoir at 30 torr
  - Reduced ^4He concentration

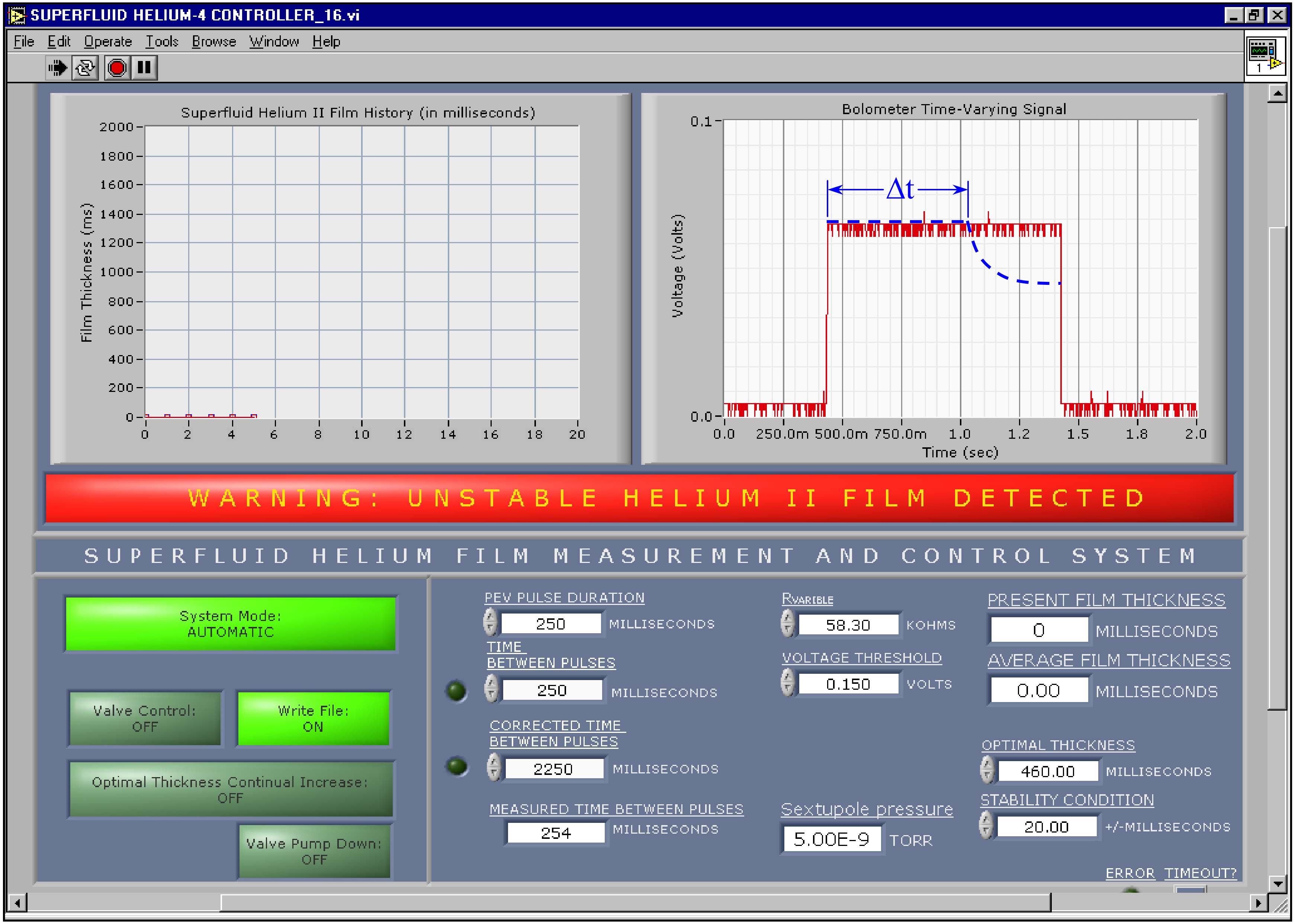
- Feed rate then controlled by a LabView program

- Film thickness measured by program (using a bolometer)

What is our bolometer?



- A small (2 mm) resistor
  - As temperature decreases, resistance (voltage) increases
- Supply power to the resistor for 1 second
  - Measure the voltage across the bolometer at the same time
- Measure the time it takes to evaporate the film
  - Film thickness is measured in msec


SUPERFLUID HELIUM-4 CONTROLLER_16.vi
File Edit Operate Tools Browse Window Help
Superfluid Helium II Film History (in milliseconds)
Film Thickness (ms)
2000
1800
1600
1400
1200
1000
800
600
400
200
0
0 2 4 6 8 10 12 14 16 18 20
Bolometer Time-Varying Signal
Voltage (Volts)
0.1
0.0
Δt
0.0 250.0m 500.0m 750.0m 1.0 1.2 1.5 1.8 2.0
Time (sec)
WARNING: UNSTABLE HELIUM II FILM DETECTED
SUPERFLUID HELIUM FILM MEASUREMENT AND CONTROL SYSTEM
System Mode: AUTOMATIC
Valve Control: OFF
Write File: ON
Optimal Thickness Continual Increase: OFF
Valve Pump Down: OFF
PEV PULSE DURATION
250 MILLISECONDS
TIME BETWEEN PULSES
250 MILLISECONDS
CORRECTED TIME BETWEEN PULSES
2250 MILLISECONDS
MEASURED TIME BETWEEN PULSES
254 MILLISECONDS
RVARIBLE
58.30 KOHMS
VOLTAGE THRESHOLD
0.150 VOLTS
Sextupole pressure
5.00E-9 TORR
PRESENT FILM THICKNESS
0 MILLISECONDS
AVERAGE FILM THICKNESS
0.00 MILLISECONDS
OPTIMAL THICKNESS
460.00 MILLISECONDS
STABILITY CONDITION
20.00 +/-MILLISECONDS
ERROR TIMEOUT?

Reducing the Film Thickness Outside of the Mixing Chamber

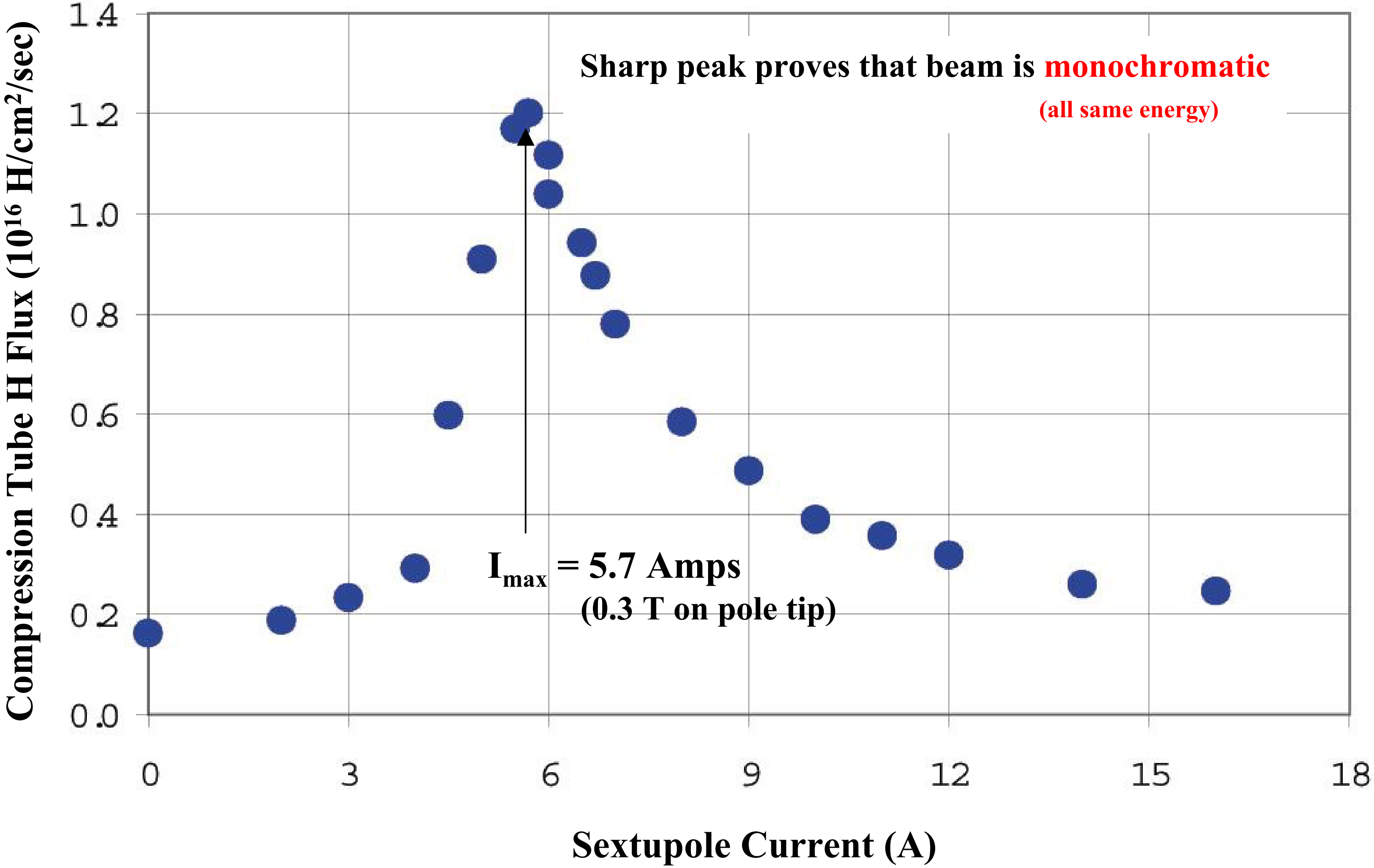
- Multiple knife edges placed at the bottom of the mirror
  - Restricts flow out of the inside of the mirror

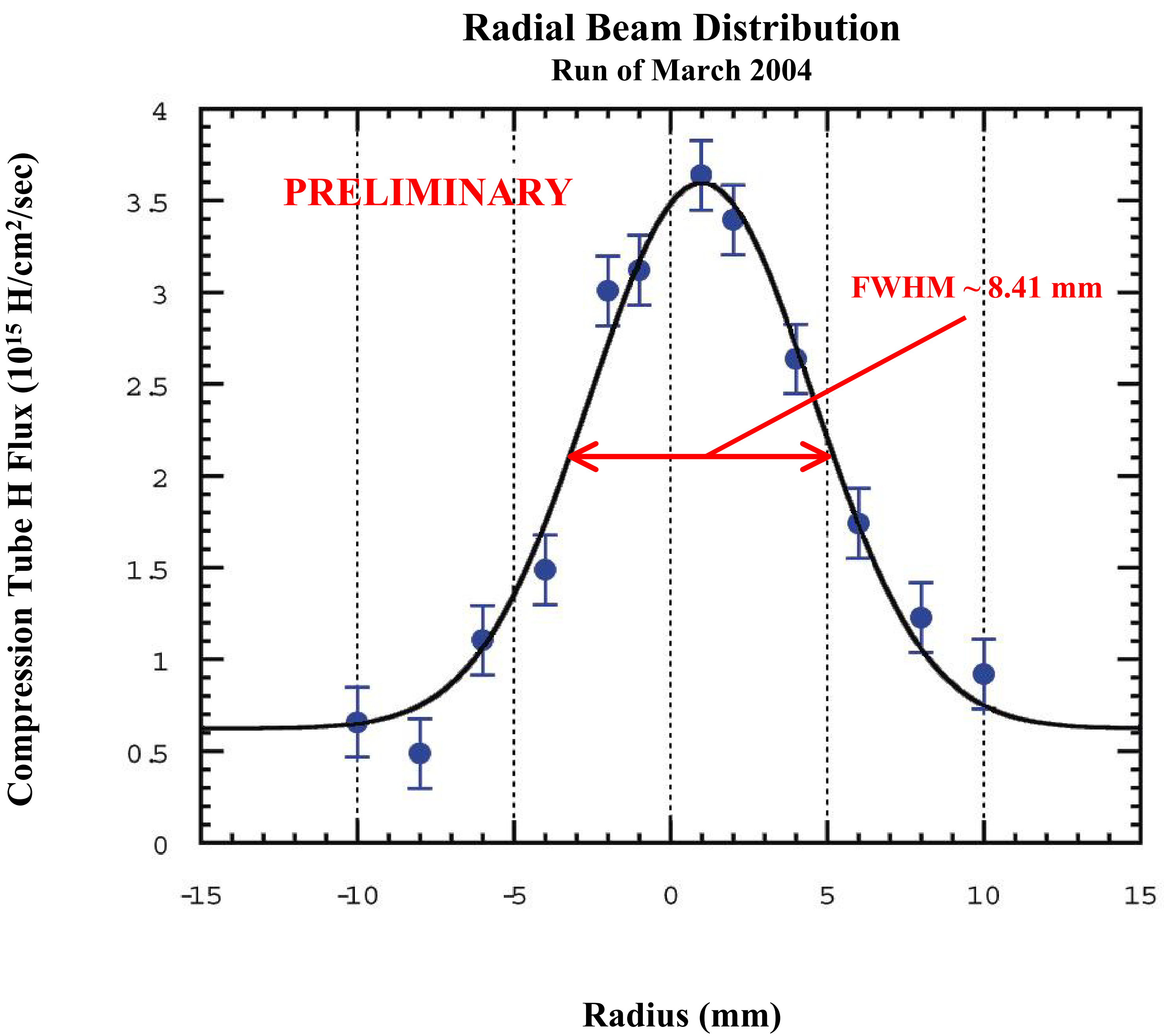
- Multiple knife edges placed at the top of the mixing chamber
  - Restricts flow out of the top of the mixing chamber

Active Cooling Changes for the August Run

- Run with only one active cooling line
  - Cuts usage by 2
- Increase a pumping impedance by a factor of approximately 2.3
  - Cuts usage by another factor of 2.3
- Reroute the lines and move the pumping impedance to a different position
- Add another pump in series to decrease pressure after the impedance

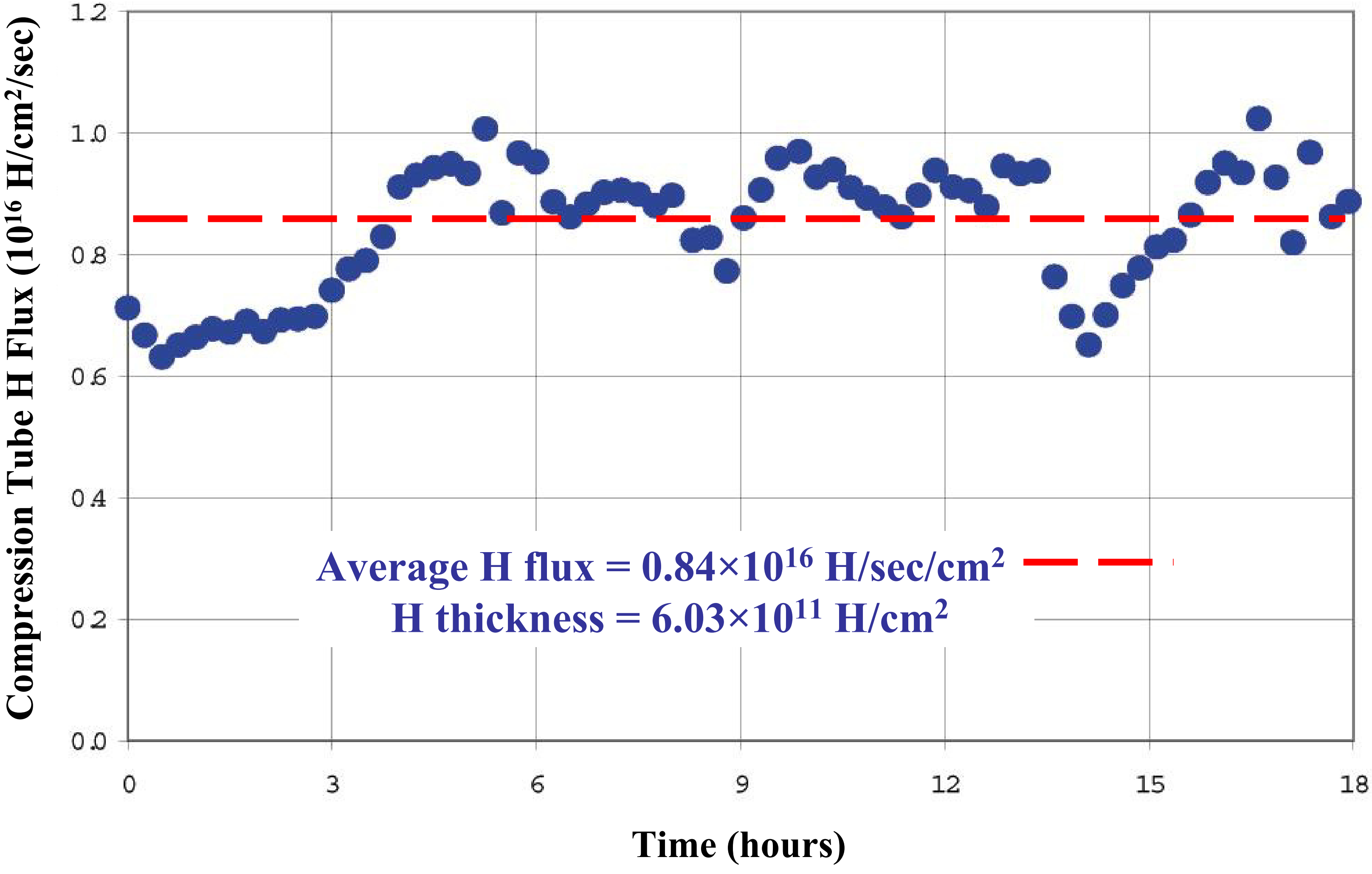
Hydrogen Flux Rate vs Sextupole Magnet Current





Radial Beam Distribution
Run of March 2004
PRELIMINARY
FWHM ~ 8.41 mm
Compression Tube H Flux (10^{15} H/cm^2/sec)
4
3.5
3
2.5
2
1.5
1
0.5
0
-15
-10
-5
0
5
10
15
Radius (mm)

Long Term Hydrogen Flux Stability



Present status of Michigan Jet

- Basic parameters
  - *Velocity of atomic hydrogen* **~ 280 m/sec**
  - *Electron polarization* **~ 100 % (in high field)**
  - *Proton polarization* **~ 50 % (in low field)**

- Summary of long term flow stability
  - *Average hydrogen flow* **1.3×10^{15} H/sec**
  - *Average hydrogen jet thickness* **8×10^{11} H/cm^2**
  - *Longest running time* **18 hours**

- World record hydrogen jet density **1.4×10^{12} H/cm^3**