

# Transversity Polarized $^3\text{He}$ Target Analysis Status

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December 15, 2009  
Hall A Collaboration Meeting



# $^3\text{He}$ Target people

- Dr. Jian-Ping Chen
- Dr. Yi Qiang
- Jin Huang
- Yi Zhang
- Joe Katich
- Chiranjib Dutta

Most of the target offline analysis done by Yi Zhang (Yi')

# Outline

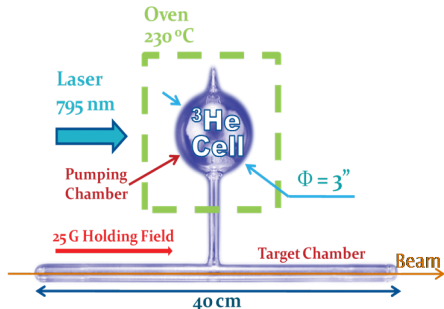
- E06010 : Target system
- Hall A polarized  $^3\text{He}$  target
- E06010 :  $^3\text{He}$  target set up
- E06010 : Target performance (online)
- Analysis progress (offline)
- Conclusion/Status

# Overview of E06010 target system components

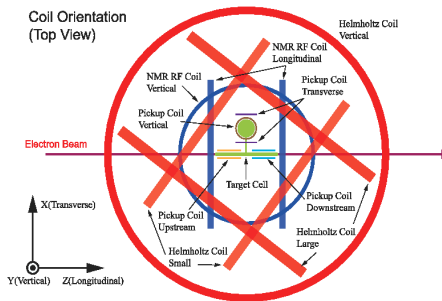
- A lot of modifications done to the existing system
- Three pairs of Helmholtz coils to ensure the generation of holding fields in all three orthogonal directions
- Two pairs of RF coils (vertical and longitudinal)
- Five pairs of pick-up coils (Three on pumping chamber/two on target chamber for NMR)
- One EPR RF coil inside the oven and a new EPR D2 light collection assembly
- Three new narrow bandwidth COMET lasers ( $\sim 25$  W each)
- Three lines of polarization optics assembly to ensure pumping in all three orthogonal directions
- Three 5-to-1 fiber combiners
- New control softwares for NMR,EPR and SPIN FLIP

## Quick overview of the Hybrid cell

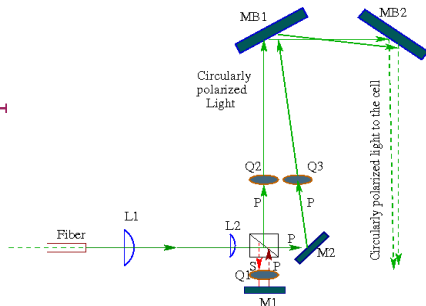
- Three cells used : Astralweek(UVa), Maureen(WM) and Brady(UVa)
  - 40 cm long target chamber, 3 inch in diameter ( pumping chamber)
  - contains Rb and K for spin exchange and  $\text{N}_2$  for quenching of unpolarized light in addition to  $^3\text{He}$
- 
- $^3\text{He}$  pressure  $\sim 10$  atm
  - $^3\text{He}$  density  $\sim 2 \times 10^{20} \text{cm}^{-3}$
  - Density of Rb  $\sim 4 \times 10^{14} \text{cm}^{-3}$
  - Density of K  $\sim 20 \times 10^{14} \text{cm}^{-3}$
  - Density of  $\text{N}_2$   $\sim 1.8 \times 10^{18} \text{cm}^{-3}$



# Schematic of the target set up and optics

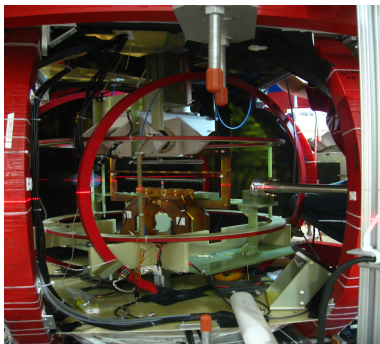


**Figure:** Helmholtz coils set up in the Hall capable of producing magnetic field in all three orthogonal directions

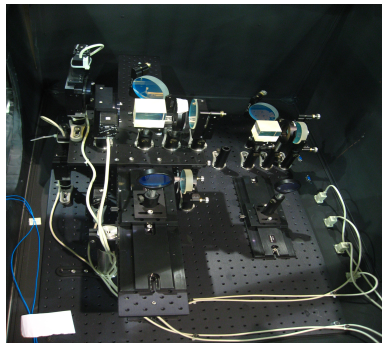


**Figure:** Polarization optics

# The target and optics set up in the Hall



**Figure:** Helmholtz coils set up in the Hall capable of producing magnetic field in all three orthogonal directions



**Figure:** Polarization optics (Top view)

# Target performance (online)

- Transversity required the flipping of  $^3\text{He}$  spins in every 20 mins.
- Frequency sweep NMR used to flip the spins in the pumping chamber
- EPR used to calibrate the NMR (spin flip) in the pumping chamber

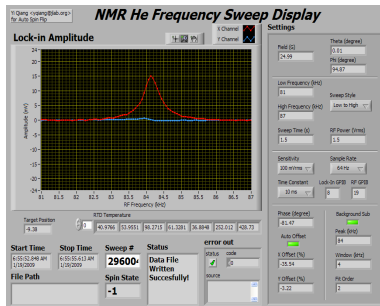


Figure: NMR

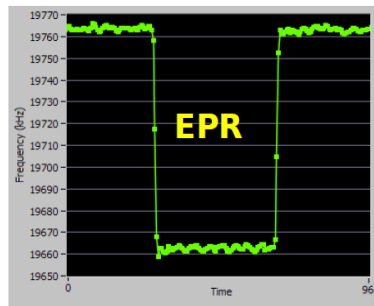
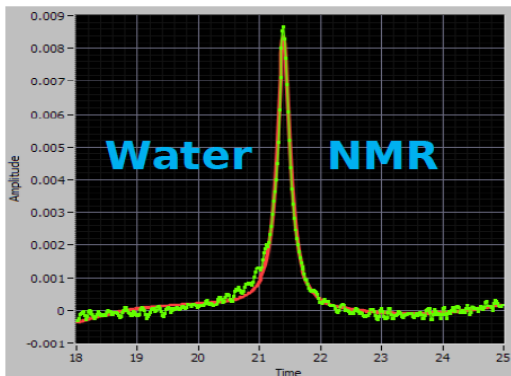


Figure: EPR



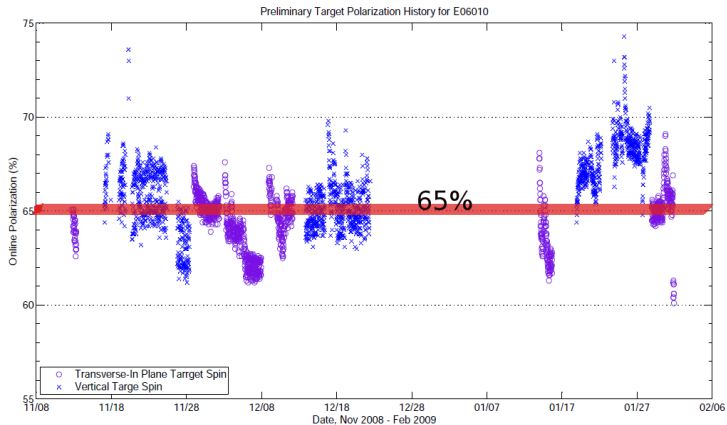
# Target performance (online)

- Water NMR performed in the target chamber
- An absolute measurement of polarization in the target chamber
- Two water NMR measurements : (Dec. 2008 and Mar. 2009)



# Polarization History (online)

- 3 cells used : Astralweek, Maureen and Brady
- Polarization remained very stable during the entire run period



# Overview

- Density measurements and wall thickness measurements for all the 3 cells done
- Water NMR analysis completed
- Internal Temperature analysis done
- EPR analysis completed
- Calibrations applied to each spin flip and a preliminary run-by-run polarization table available now

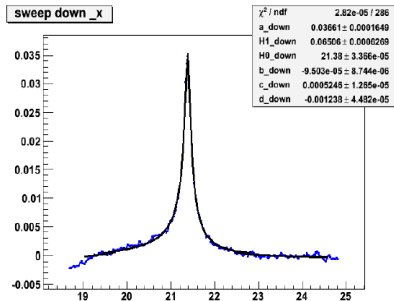
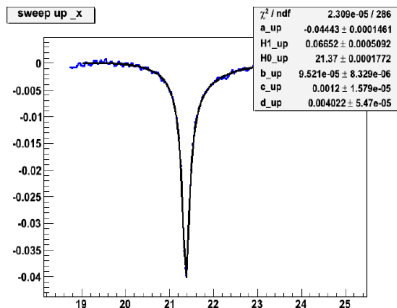
## Density/Wall thickness measurements

- The wall thickness measurements for Astralweek, Maureen and Brady completed
- The densities of Astralweek, Maureen and Brady measured to cross check with the results from UVA and WM
- Very important for the EPR analysis to calculate  $^3\text{He}$  polarization
- The density results :

| Cell       | UVA (amg)       | WM (amg) | JLab (amg)      |
|------------|-----------------|----------|-----------------|
| Astralweek | $8.18 \pm 0.03$ | –        | $8.12 \pm 0.04$ |
| Maureen    | –               | 7.71     | $7.80 \pm 0.03$ |
| Brady      | $7.87 \pm 0.01$ | –        | $7.95 \pm 0.03$ |

# Water NMR

- Two sets of data : one with  $> 2000$  sweeps and one with  $> 6000$  sweeps
- Both sets analyzed (flux calculation included)
- Statistical uncertainty  $< 1\%$



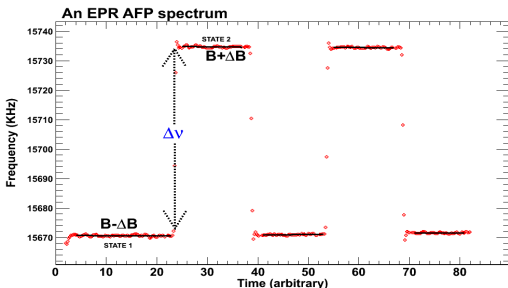
## Internal Temperature Analysis Results

- Pumping chamber temperature measured by two RTDs attached to it from outside
- Internal temperature tests performed to get the real temperature inside the chamber
- Internal temperature measured better than 5°C

| Cell       | Pumping Direction | RTD(°C) | Test result(°C) |
|------------|-------------------|---------|-----------------|
| Astralweek | Vertical          | 247.49  | 264.78          |
| Astralweek | Transverse        | 253.53  | 270.80          |
| Maureen    | Vertical          | 242.24  | 255.07          |
| Maureen    | Transverse        | 251.04  | 260.17          |
| Brady      | Vertical          | 253.95  | 268.32          |
| Brady      | Transverse        | 255.15  | 268.78          |

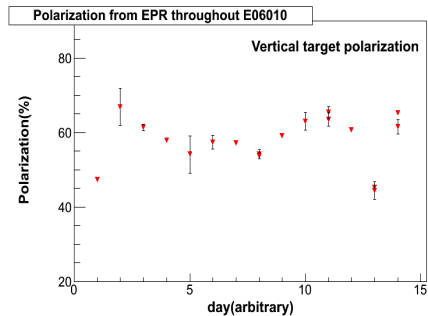
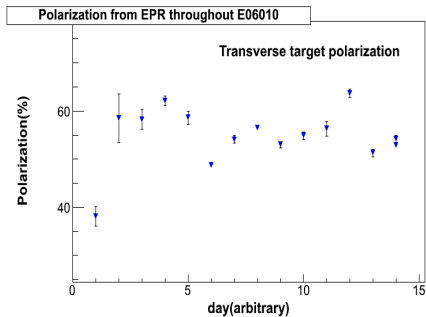
# EPR analysis

- Several EPR measurements performed in the pumping chamber during the experiment
- Each of the EPR AFP signal fitted and an absolute polarization number calculated
- Measured density numbers and internal temperature corrections applied in the analysis
- $\Delta\nu \propto P_{3\text{He}}$



# EPR analysis

- EPR results in both transverse and vertical target configurations
- THIS IS JUST THE EPR POLARIZATION NUMBER not to be confused with PRODUCTION POLARIZATION

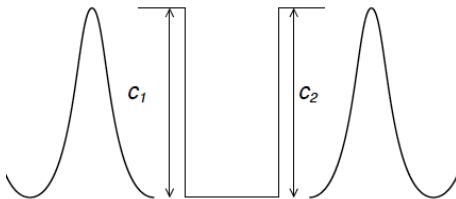




# EPR analysis

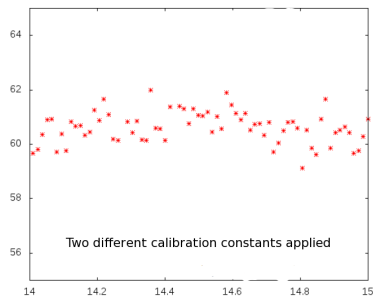
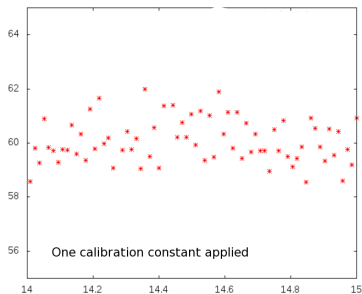
- Each flip in EPR corresponds to a frequency sweep NMR
- A calibration constant can be calculated by comparing the absolute polarization and the NMR
- e.g.  $P_{^3\text{He}}$  is the polarization and  $S$  is the NMR amplitude

$$\text{Calibration constant } C = P_{^3\text{He}}/S$$



# Spin flip calibration

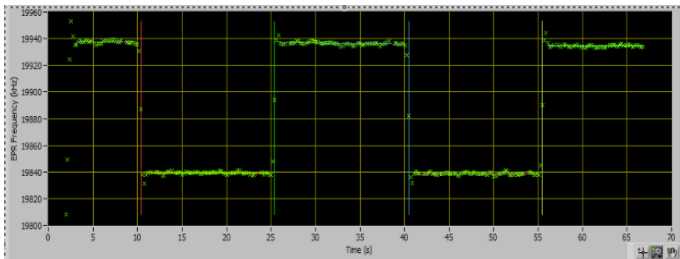
- More than 1000 spin flips during production
- Divided into different stages depending on different cells, different pumping directions etc.
- Calibration constants from EPR applied to each spin flip
- Spin-up flip and spin-down flip calibrated separately
- Sample plots for the polarization during a day for each flip :



# Status of the analysis

- Polarization analysis ( EPR/spin flip calibration) mostly done
- Final polarization number ( $\sim 60\%$  to  $62\%$ ) < Online polarization number ( $\sim 65\%$ )  
mostly coming from the different density measurements
- Water NMR analysis completed
- Polarization diffusion study to be done
- Pressure curve/ $N_2$  analysis ongoing
- Final polarization table (run-by-run) coming soon

Thanks to Dr. Yi Qiang, Yi Zhang and Jin Huang for few plots and figures



**NMR VS Time (EPR-Matched Data Only)**

