# Summary

## Conditional Review of E12-13-011 and E12-15-005 Experiments

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# E12-13-011

**Issues:**
In order to obtain conclusive data with sufficient precision it is crucial to achieve a tensor polarization significantly higher than the value of 20% assumed in the proposal. While methods such as RF- “hole burning” are known to increase the tensor polarization above the thermal equilibrium value, these techniques including the polarization measurement have to be developed further to allow for a reliable operation under experimental conditions.

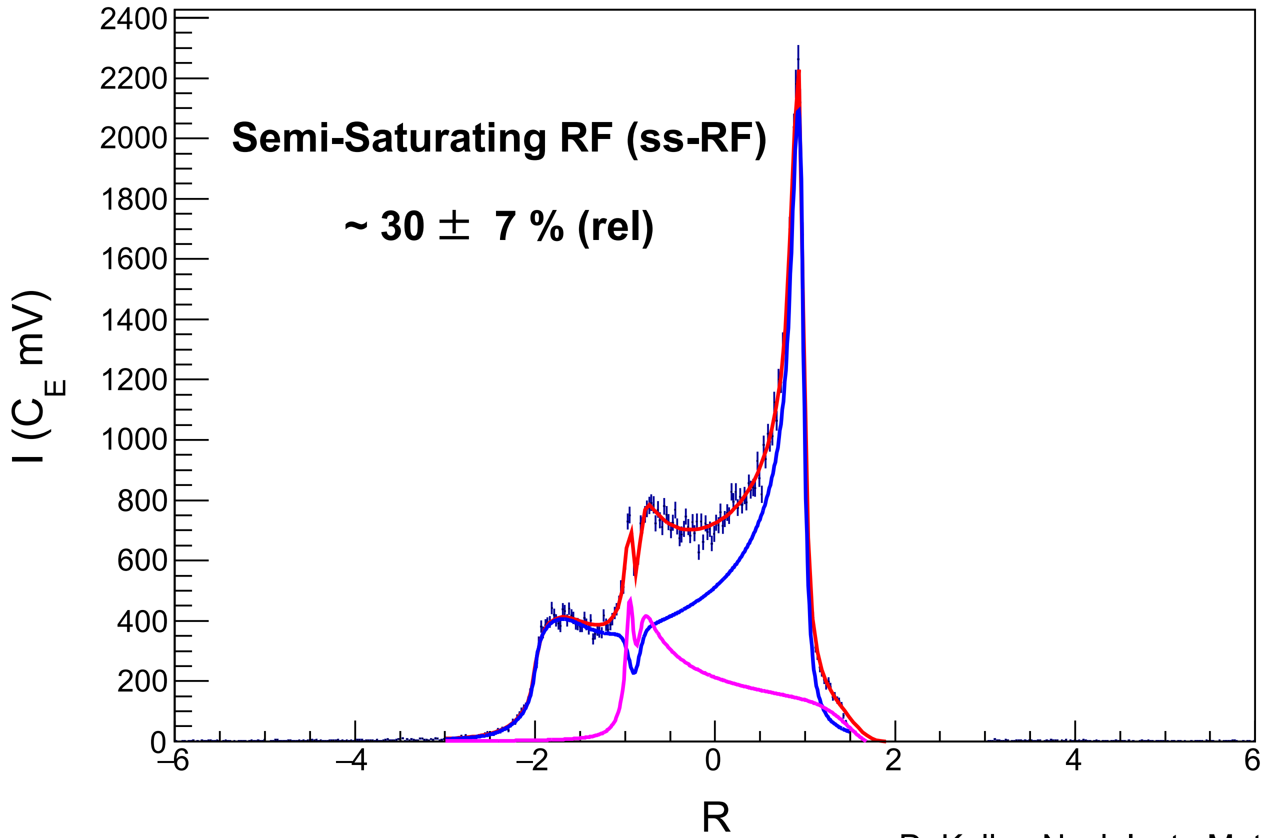
**Conditions:**
The experiment is conditionally approved with the condition that a tensor polarization of at least 30% be achieved and reliably demonstrated under experimental conditions.

# E12-15-005

**Issues**: It is important to achieve the tensor polarization of 30% assumed in the proposal. While methods such as RF- “hole burning” are known to increase the tensor polarization above the thermal equilibrium value, these techniques including the polarization measurement have to be developed further to allow for a reliable operation under experimental conditions.

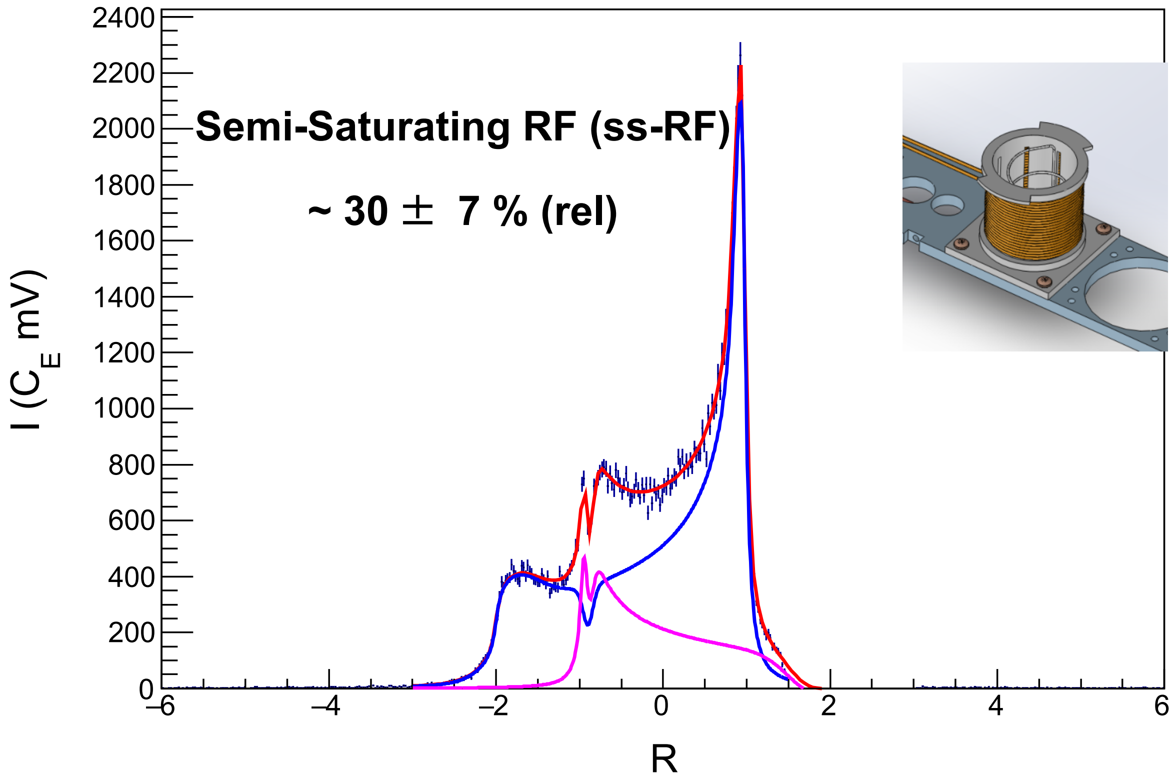
**Summary:**
The experiment is conditionally approved with the condition that a tensor polarization of close to 30% be achieved and reliably demonstrated under experimental conditions.

**UVa solid polarized target group**
**has achieved polarizations ≥ 30 %**




D. Keller. Nucl. Instr. Meth.A 981 (2020)

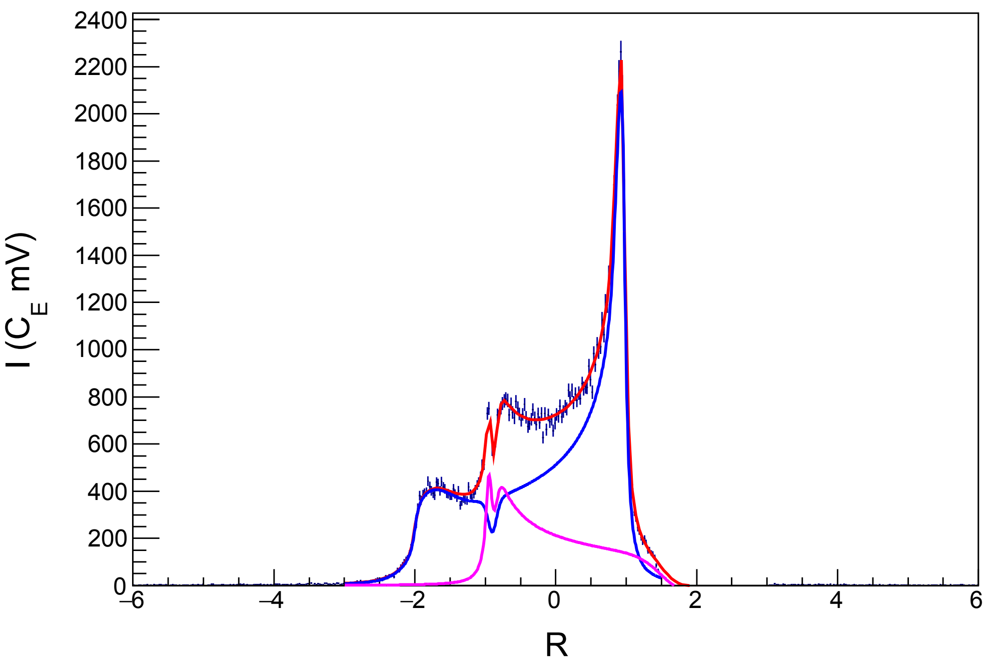
**Charge 1: What technique(s) will be used to produce "a tensor polarization of 30% under standard experimental conditions".**




**ssRF + AFP: ~32 ± 8.5 % (rel)**
**rssRF: ~ 36 ± 9.5 % (rel)**

D. Keller. Nucl. Instr. Meth.A 981 (2020)

**Charge 2: How will the tensor polarization be measured and with what uncertainty?** What crosschecks or auxiliary measurements can be made to validate the results? Will this uncertainty be sufficient to achieve meaningful physics results?




## Measurement:

1. **Differential binning**
2. **Spin temperature consistency**

$$P = C(I_+ + I_-)$$
$$Q = C(I_+ - I_-)$$

3. **Rate response**

$$A_{gained} = \frac{1}{2} A_{lost}$$

J. Clement, D. Keller, Submitted to Nucl. Instr. Meth. A (2022)

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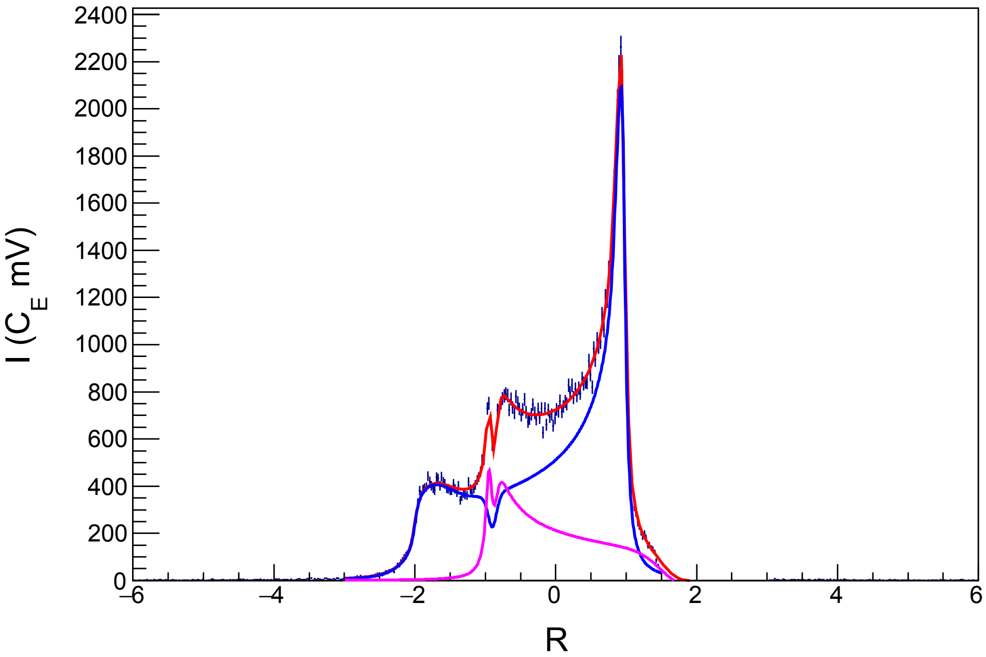


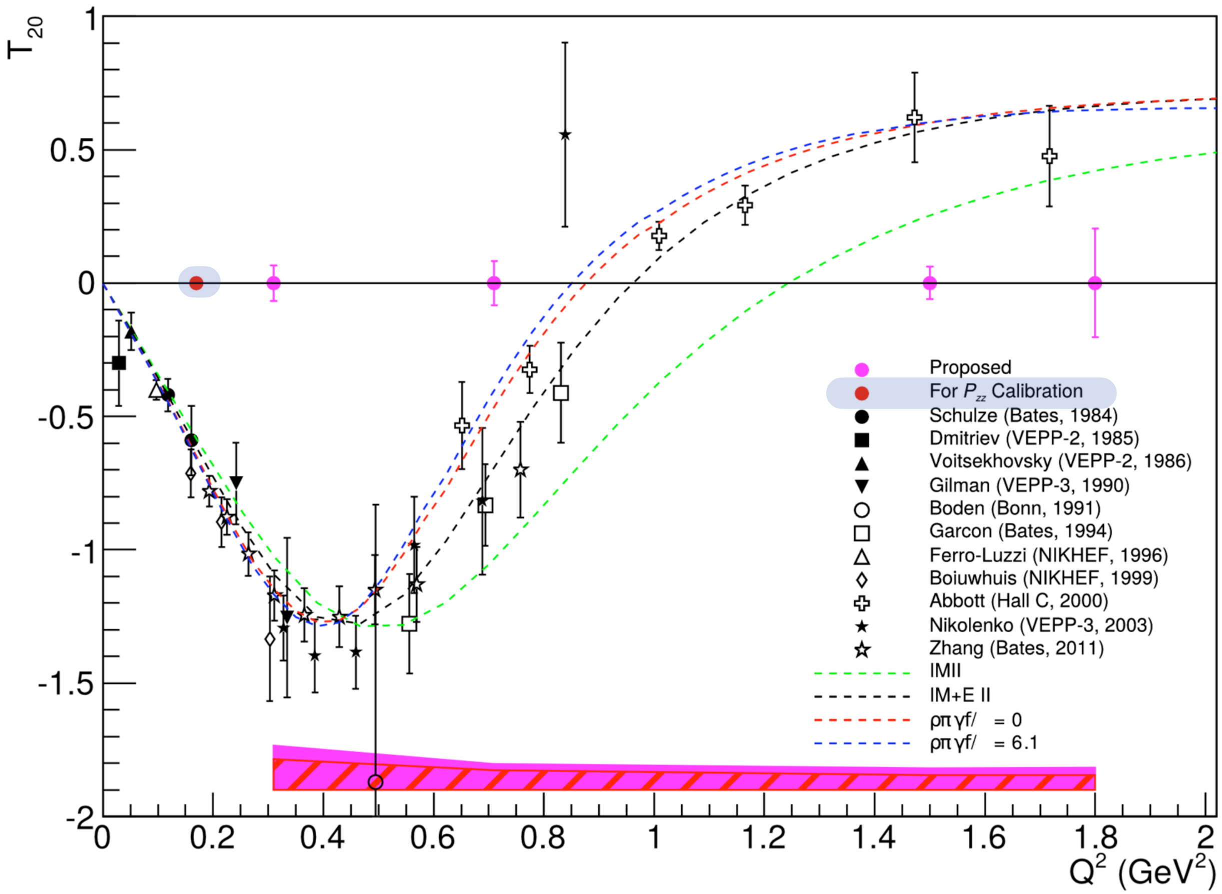

D. Keller. Nucl. Instr. Meth.A 981 (2020)

**Sources of Uncertainty:**

1. TE (area, temperature stability, among others)
2. Systematic variation in enhanced signal
3. NMR measurement limitations with respects to relaxation rate
4. Line-shape analysis

- **ss-RF (~7 % relative uncertainty )**
- **ss-RF + AFP ( ~8.5 % uncertainty measured)**
- **rss-SF (~9.5% relative uncertainty)**

**Charge 2:** How will the tensor polarization be measured and with what uncertainty? **What crosschecks or auxiliary measurements can be made to validate the results?** Will this uncertainty be sufficient to achieve meaningful physics results?




## Crosschecks:

**$T_{20}$ Measurement**

$$P_{zz} \sim \frac{1}{T_{20}}$$

The low $Q^2$ elastic measurement will validate the proposed enhancement and measurement techniques.

E. Long, et al. E12-15-005 proposal (2016).

**$P_{zz}$ Expected Uncertainty:**
**8.63% from $T_{20}$ parametrization**

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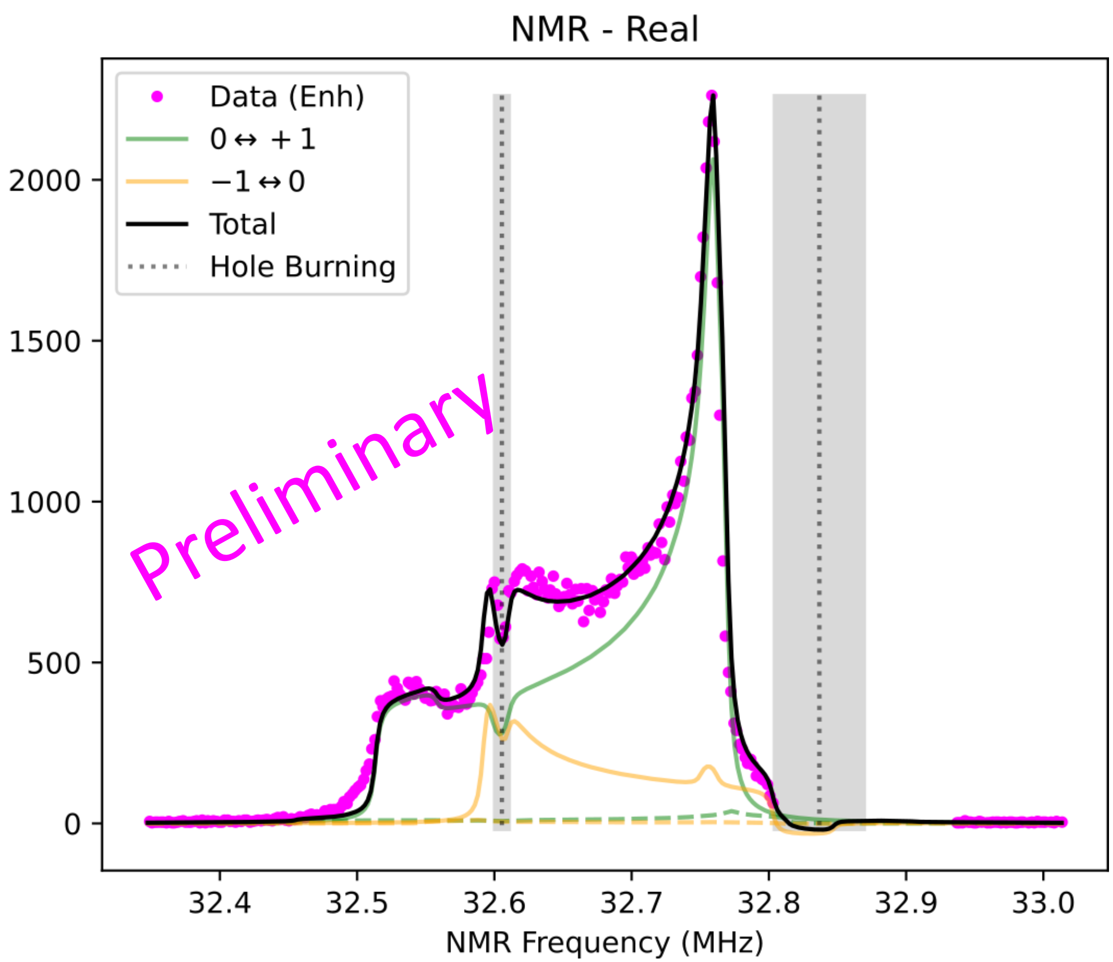


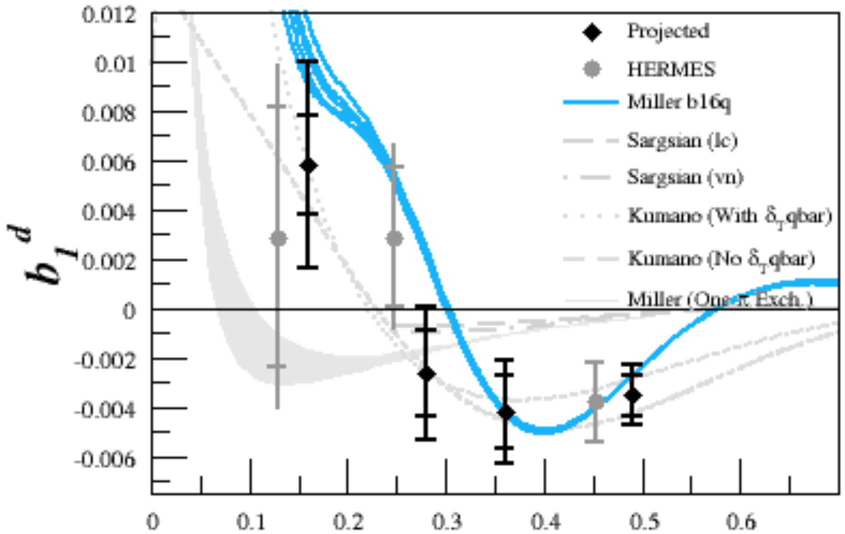

Simulation package in development at UNH

Courtesy of E. Long.

**Charge 2:** How will the tensor polarization be measured and with what uncertainty? What crosschecks or auxiliary measurements can be made to validate the results? **Will this uncertainty be sufficient to achieve meaningful physics results?**

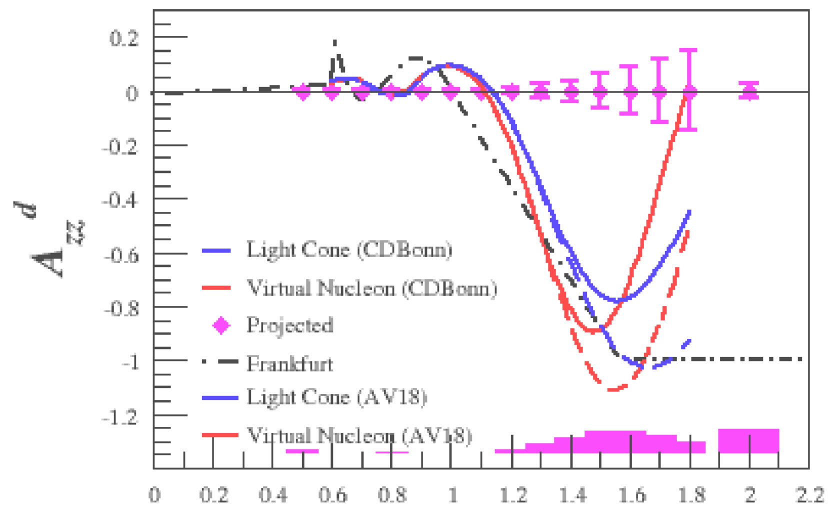
**Proposal**

**$P_{zz}$ = 30 ± 8 % (rel)**



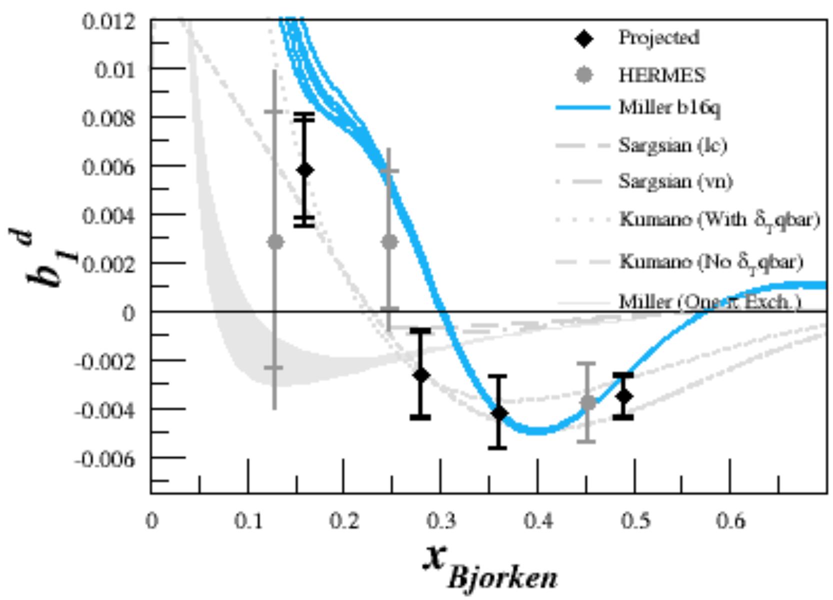

**Proposal**

**$P_{zz}$ = 30 ± 6 % (rel)**



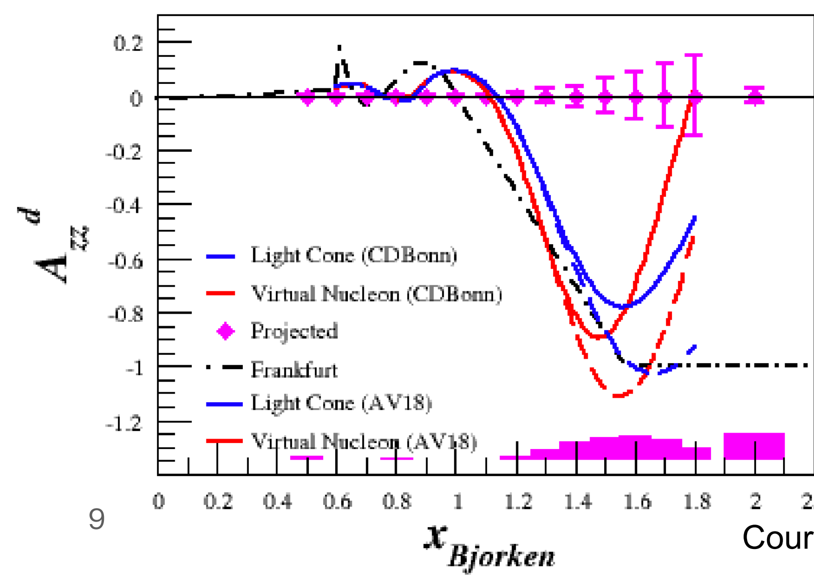

**Update**

**$P_{zz}$ = 30 ± 7 % (rel)**



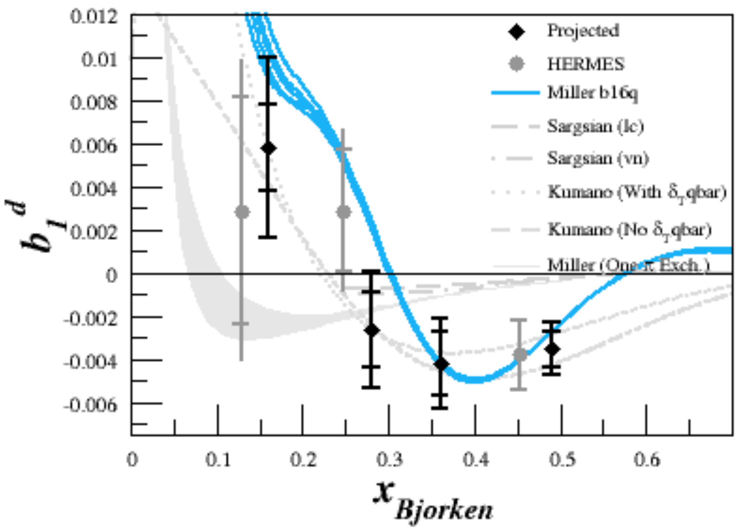

**Update**

**$P_{zz}$ = 30 ± 7 % (rel)**




Courtesy of E. Long

**Charge 2:** How will the tensor polarization be measured and with what uncertainty? What crosschecks or auxiliary measurements can be made to validate the results? **Will this uncertainty be sufficient to achieve meaningful physics results?**




**Proposal:**

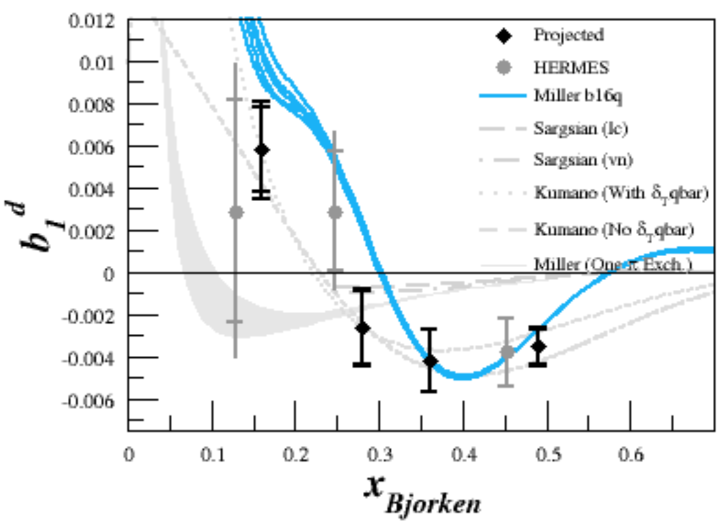
I = 115 nA (Current)

$P_{zz}$ = 0.3 (Tensor polarization)

**N = 30** (Helicity changes)

**$\epsilon$ = 0.81** (Efficiency )

$IP_{zz}^2\sqrt{N} \sim$ **57**




**Update:**

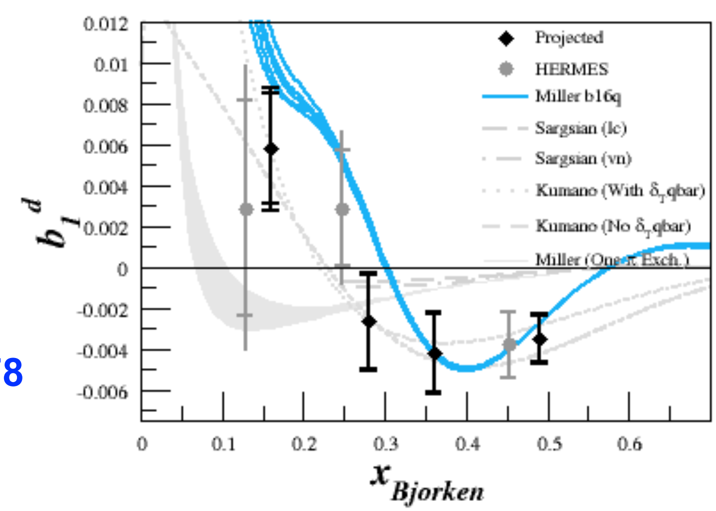
I = 115 nA

$P_{zz}$ = 0.30

**N = 720**

**$\epsilon$ = 0.72**

$IP_{zz}^2\sqrt{N} \sim$**278**




**Conservative Update:**

I = 85 nA

$P_{zz}$ = 0.26

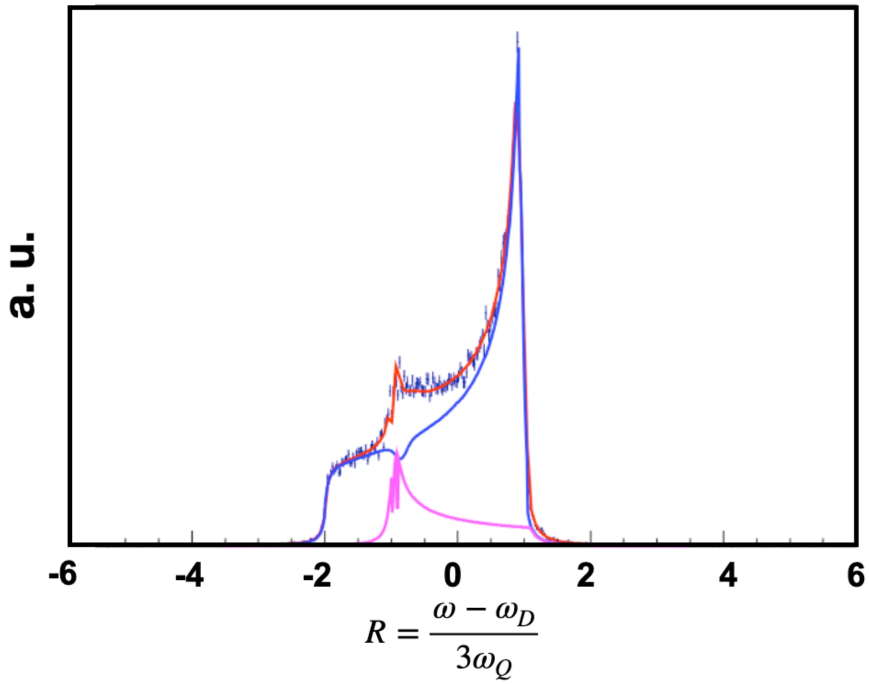
**N = 720**

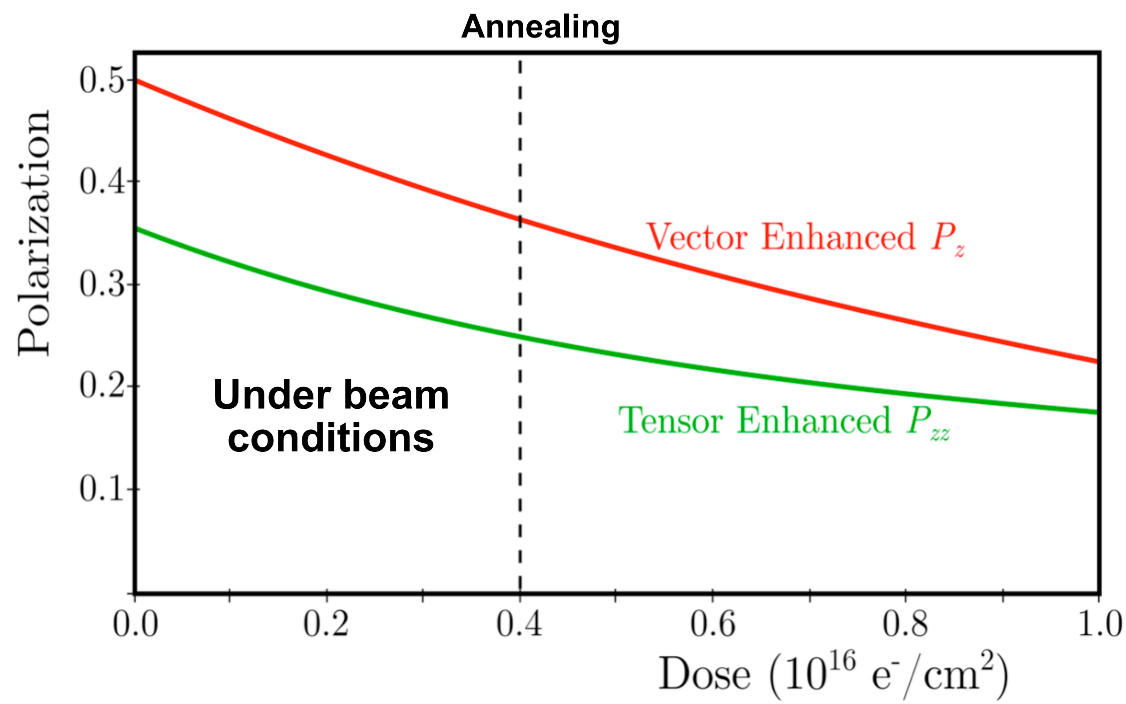
**$\epsilon$ = 0.72**

$IP_{zz}^2\sqrt{N} \sim$ **154**

**Helicity states changes will be done in the order of minutes with RF**

**Charge 3: What assumptions are made regarding the vector polarization of the target?**
**How is the tensor polarization expected to respond as the vector polarization decays in beam?**




Courtesy of D. Keller.

- **2 target cups**
- **One cup change per PAC day**
- **1 anneal per PAC day**
- **Total of 6 material changes (After $2.1 \times 10^{16} e^-/cm^2$ accumulated dose per cup)**

**Charge 4: What is the current experimental situation? What is the maximum tensor polarization that has been achieved under the anticipated polarizing conditions of 5 T and 1 K?**

## Experimental setup:

**DNP**
5 T magnet
1 K with an evaporation refrigerator(1 W cooling power)
0.3 W microwave on material

**Material**
Irradiated Butanol ($C_4D_9OH$)
Note: Tensor enhancement can be treated similarly for materials with the same lineshape ($ND_3$).

D. Keller. Nucl. Instr. Meth.A 981 (2020)

**ssRF: ~30 $\pm$ 7 % (rel)**
**ssRF + AFP: ~32 $\pm$ 8.5 % (rel)**
**rssRF: ~ 36 $\pm$ 9.5 % (rel)**

**Also shown**: Rapid spin state transitions (polarization flips *several per hour*)

# Thank You

**Special thanks to**

**E12-13-011 and E12-15-005 collaborations**