Laser Status After Proton Beam Commissioning

03 October 2016

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Secondary Beamline Meeting

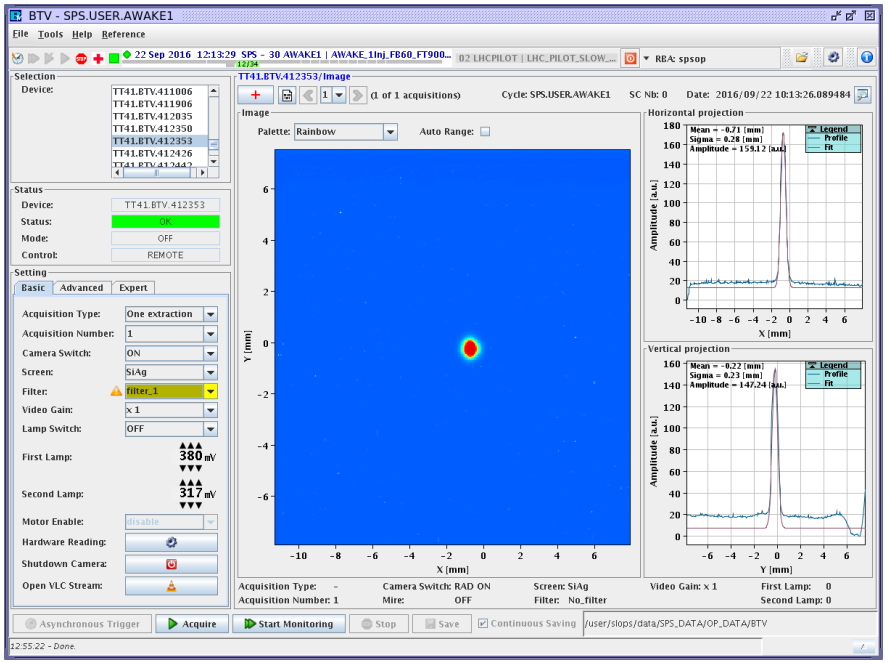
Review of Goals for Commissioning Period

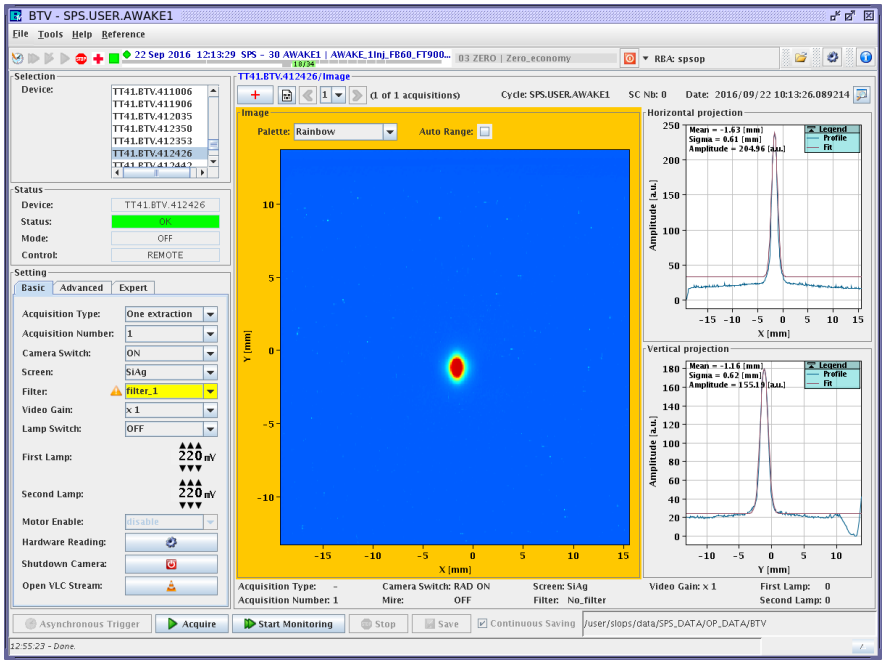
- Spatial overlap of the proton beam and laser on screens up and downstream of the vapor source
- Temporal overlap of the laser pulse with the proton beam

Spatial Overlap

- Proton beam on final trajectory
- Place central position of MP5 mirror with respect to proton beam in merging tank using translation stage
- Use MP4 and MP5 rotation to overlap laser with proton beam on BTVs upstream and downstream of vapor source

Proton Beam References

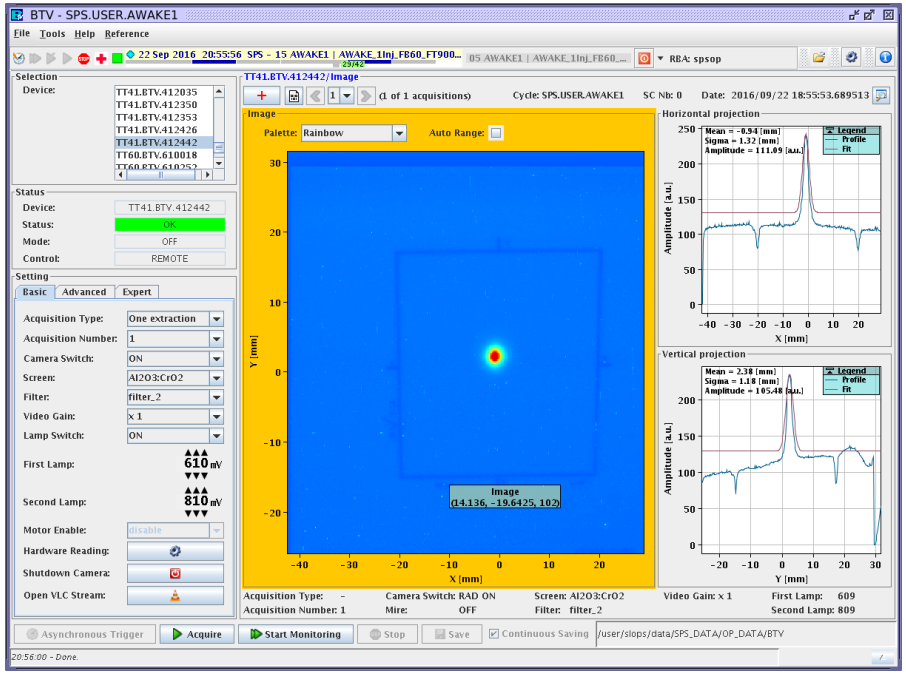




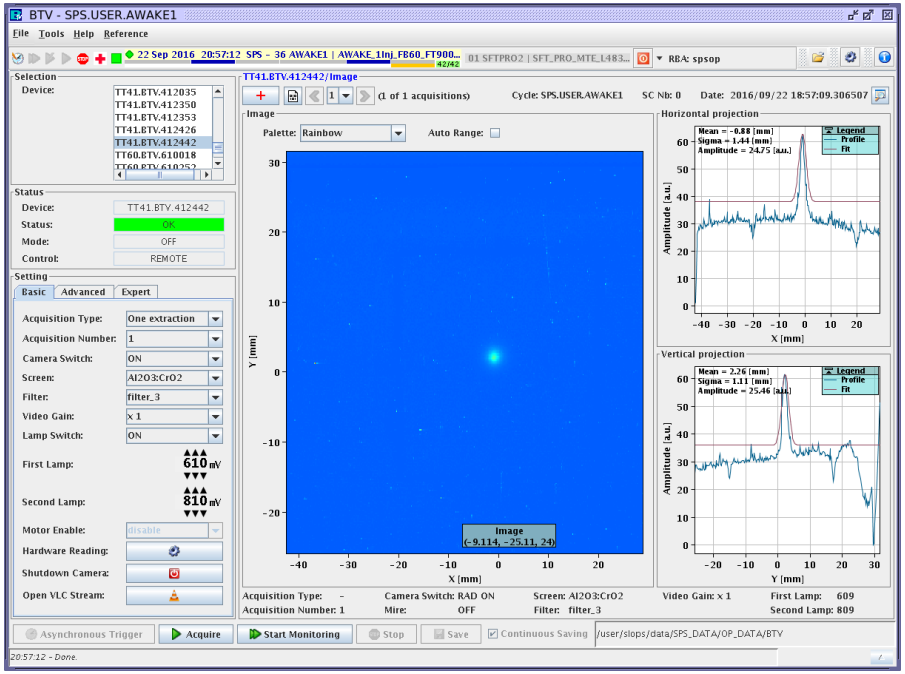
Images a bit saturated but decent for spatial alignment to within 100 microns

More about Protons

Saturated Image on last BTV (after diags)



Unsaturated Image on last BTV (after diags)



Proton is well centered on halo so that even a saturated image is a decent reference for alignment because no significant skewness, at least to the 200 micron scale, which was our limit for the spatial overlap due to some laser jitter

Laser Jitter

We saw laser jitter on the order of 200- 300 microns (single shot differences, not RMS) on the BTVs.

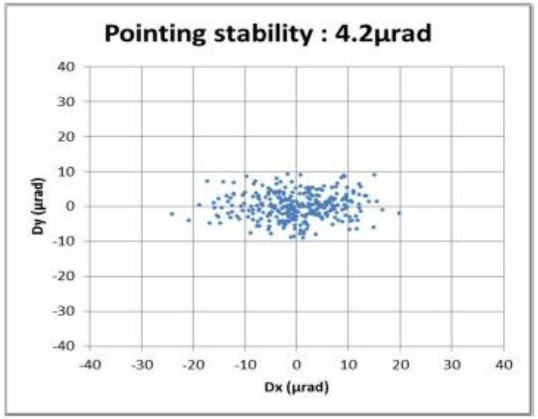
Keep in mind: this is a ~50meter throw from the nearest optic

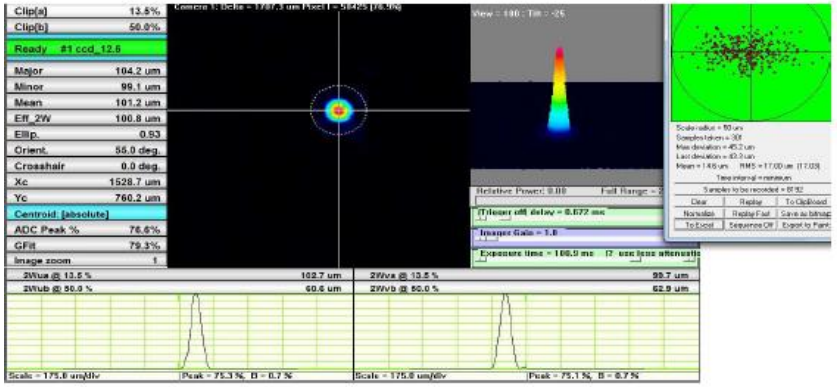
So 300 micron on a 50 meter throw is 6 urad pointing jitter

We will quantify the jitter with some decent statistics on the virtual line and cross correlate with measurements on BTVs (smaller sample size due to acquisition difficulties)

<u>Things we can do for improvement:</u>

- Changing the flashlamp in the CFR, stabilizing the regenerative amplifier
- Checking alignment of system, particularly through regen, preamp, amplifier
- Tubing/enclosing in-air transport up to the window to the compressor



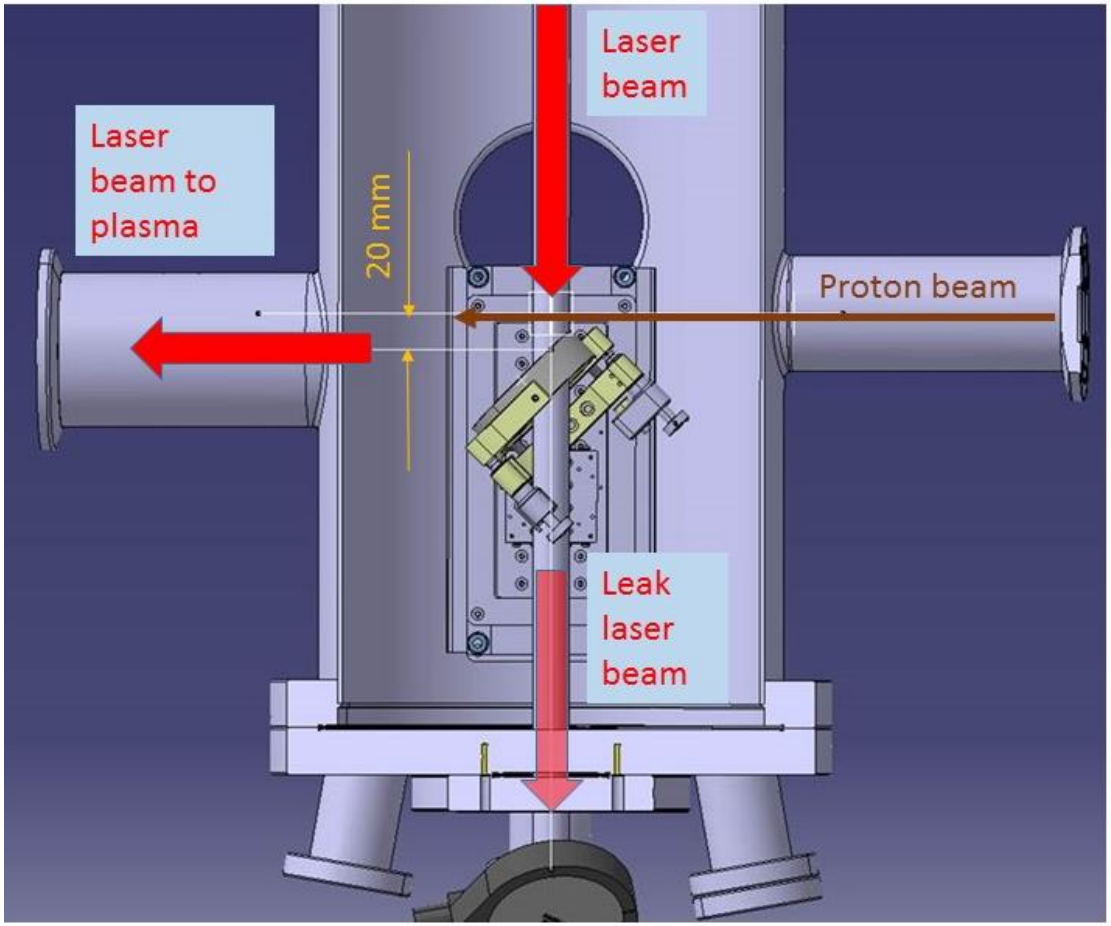


From OSAT

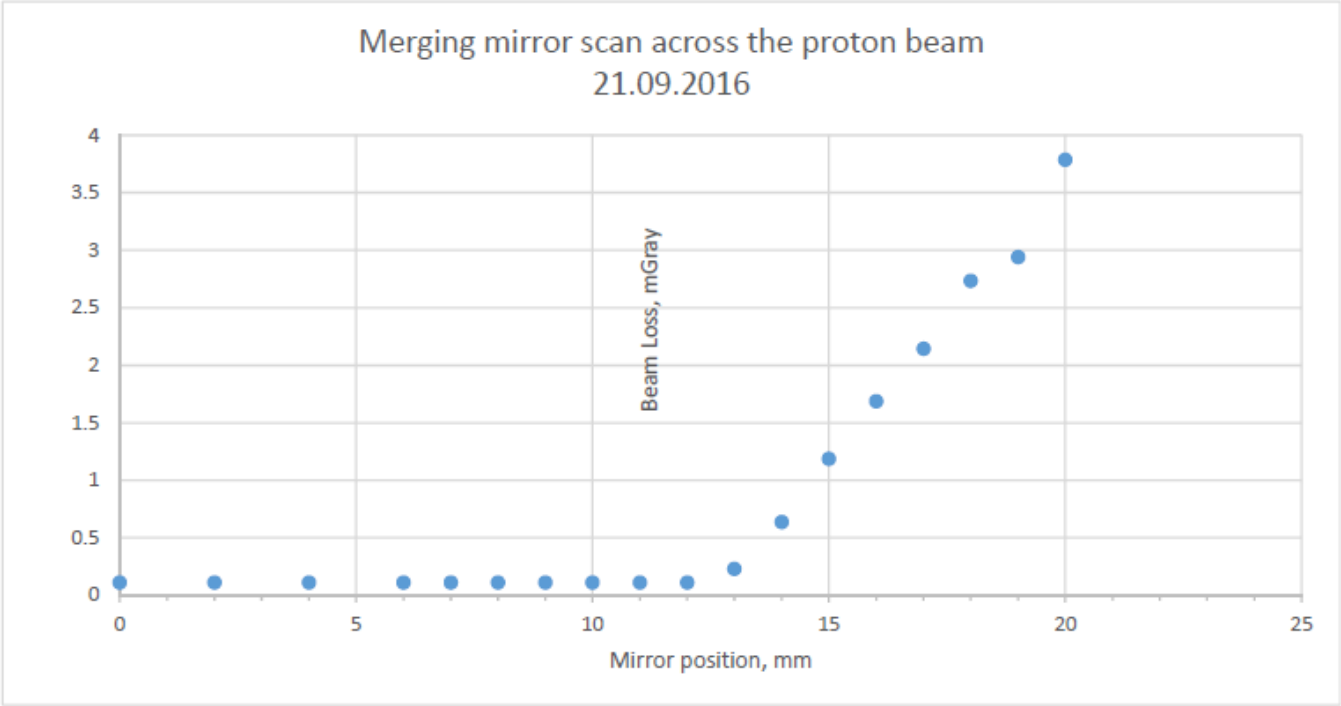
4.2 urad RMS pointing jitter

Laser Overlap / Alignment

1. Set translation stage
2. Use MP4 and MP5 to place laser on proton beam references on BTVs up and downstream of vapor source



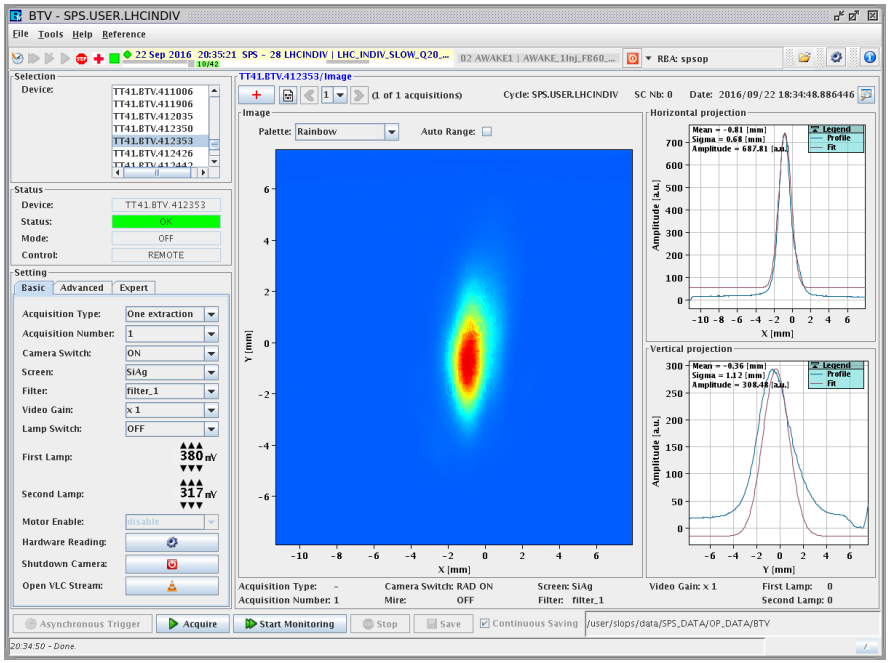
Positioning of Mirror on Translator

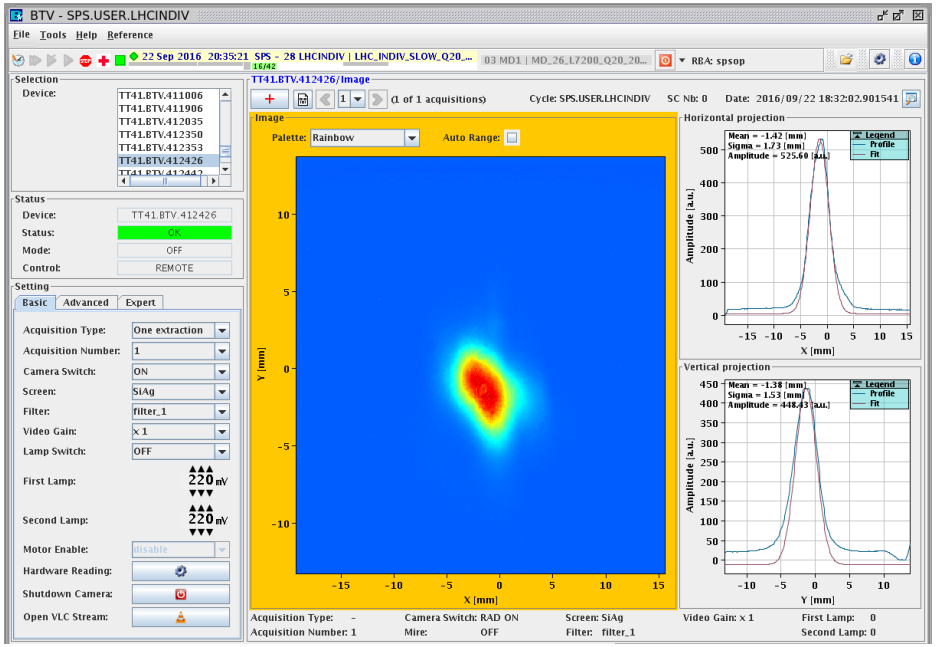


Operational Point: 11 mm

We even ran with full proton beam “intensity” of 3 *10^{11} and saw no losses from this position on the BLM.

Laser overlap





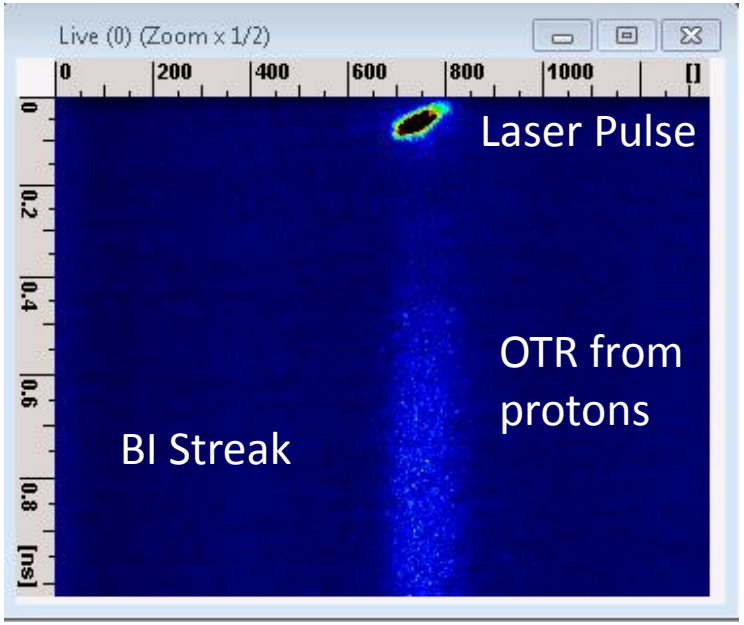
- Got laser positioned on proton beam references to within 300 microns
- Will try to make mode nicer, reduce jitter, and go in for final alignment.
- Can verify direct alignment on BTVs if we enter low power mode

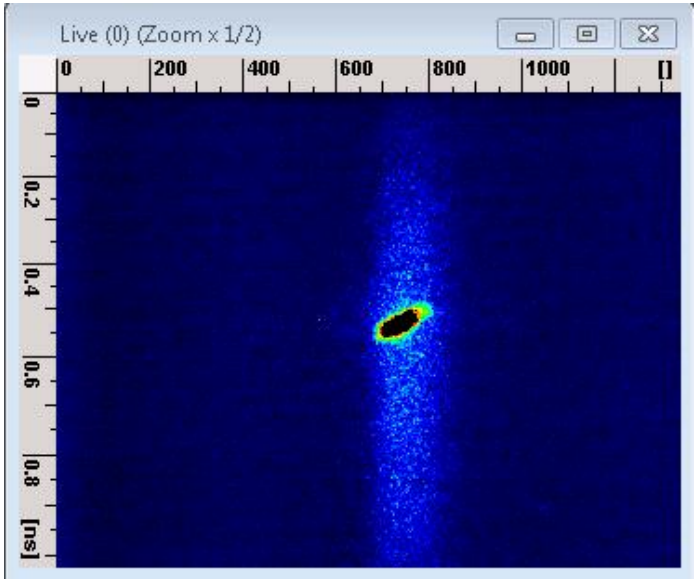
Temporal Overlap

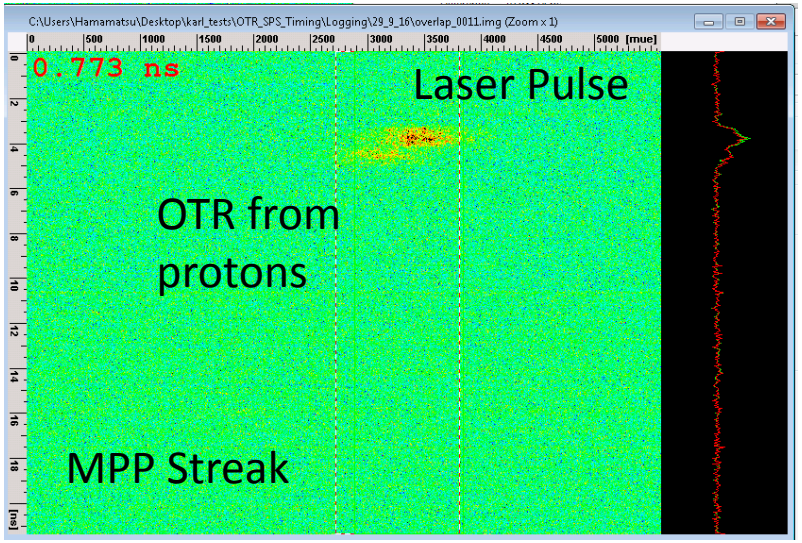
- Synchronization
  - Part I: Nearest 10Hz pulse overlap to ~10ps level
    - 6 GHz master clock
    - Heiko's divider sends singles to lock SPS, etc.
    - 88 MHz modelocked pulse train of laser is locked using piezo
    - "fc and frep" divided signals are sent to the SPS to change the time of arrival of the proton beam with respect to the 10Hz laser pulse train.
  - Part II: Extraction warning causes amplification of laser pulse by dynamic trigger delay shift.

Streak Camera

Achieved overlap of proton beam and nearest 10 Hz laser pulse





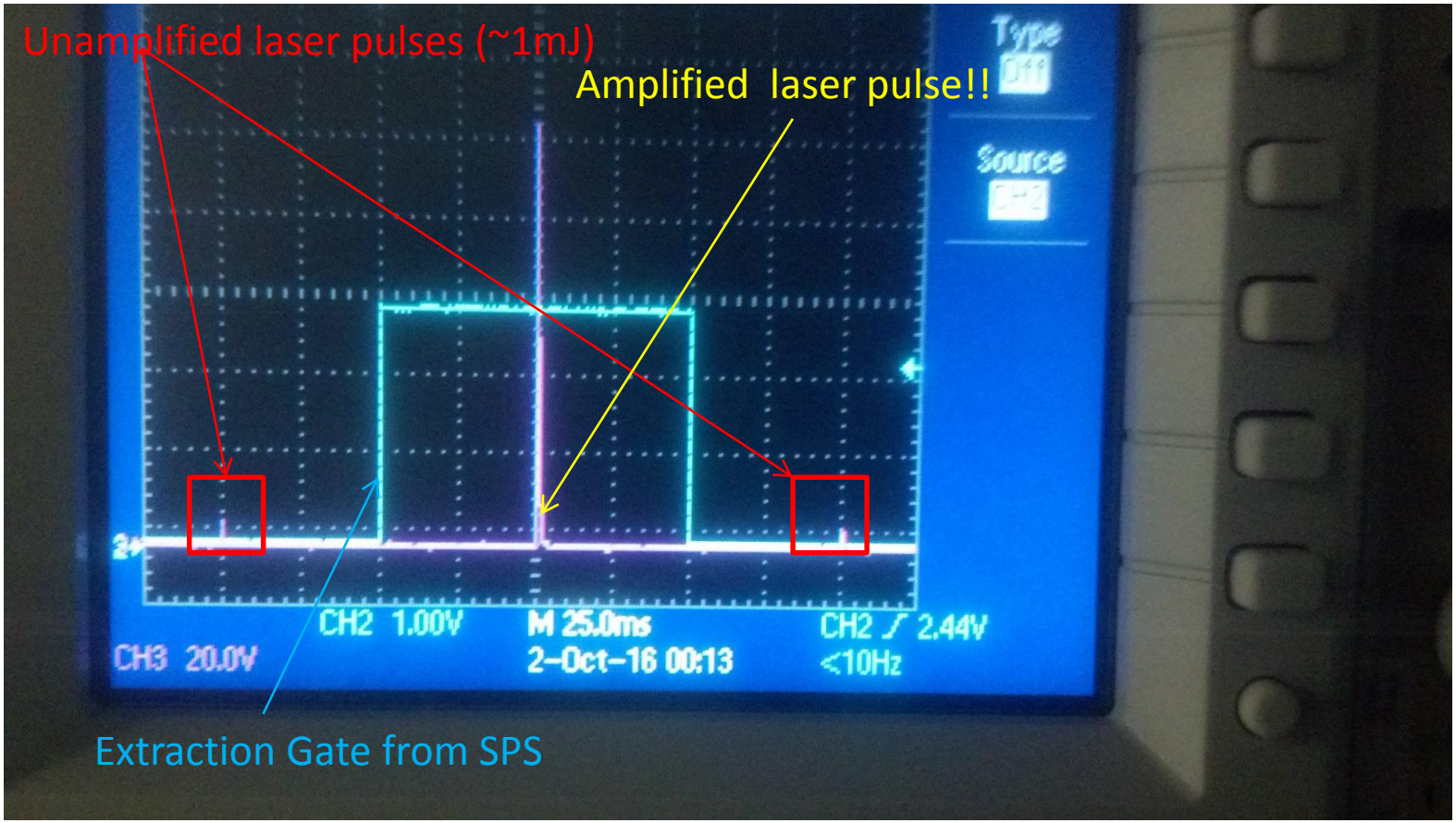


Gross Synchronization

- Synchronization with streak cameras was performed on nearest 10Hz laser pulse to proton beam
- Fast shutter could only let laser pulse ~300 ms after receiving trigger
- The fast shutter relies on a ‘burst trigger’ that is received asynchronously and forces synchronization by triggering off the second synchronous counted pulse
- However we run the experiment with the fast shutter open and only amplify the nearest laser pulse to the extraction of the protons using the dynamic delay function
  - This is to monitor and adjust the laser alignment for slow drifts before the proton beam shot at ~mJ energy then only amplify the needed shot to 100+ mJ
- The dynamic delay reduced the delay when another channel in the timing box is present. This other channel can be synchronously triggered by the extraction pulse
  - There is a software bug that has a -1 error in the setting of this channel so setting Channel 15 for the trigger actually triggers off of Channel 14.

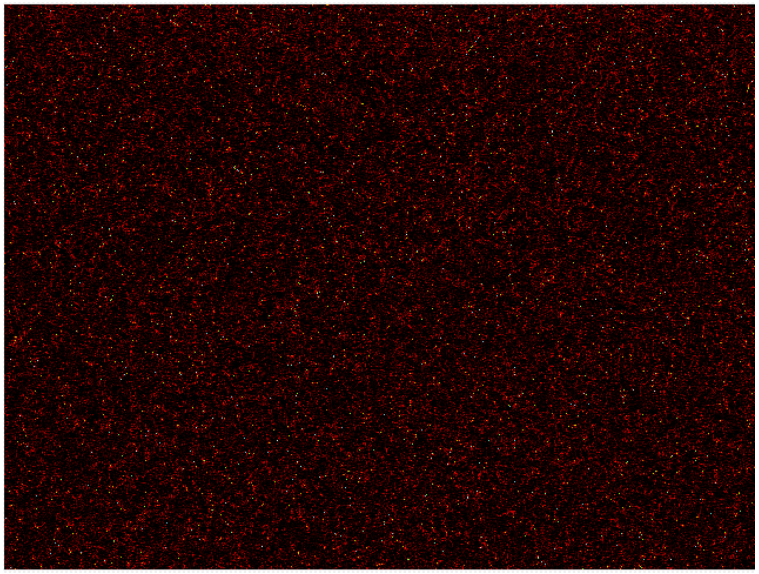
Dynamic Delay Result

Channel 2: Gate based off of extraction warning from SPS
Channel 3: Photodiode collecting diffuse light after main amplifier

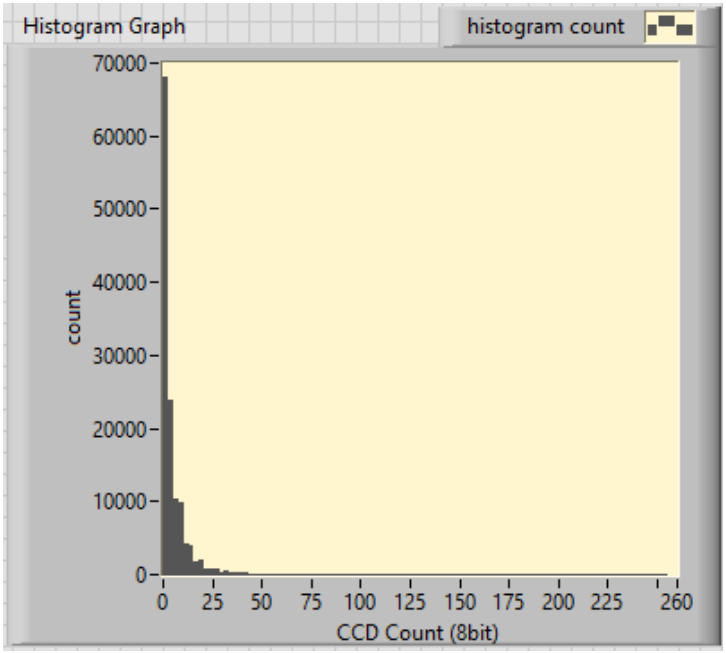


Miscellaneous

- Radiation Effecting virtual line cameras
- Captured acquisition of proton beam radiation with 3e11 protons (AWAKE nominal) on new CCD (not CMOS)
- CMOS had 60% apparently saturated pixels making it unusable but CCD appears to be more resistive to radiation and appears to be useable with a reasonable background



CCD Image of radiation noise



Histogram of CCD Image

Conclusions

- Spatial and Temporal Overlap has been done
  - 300 micron transversely
  - Both gross and fine synchronization down to ~10ps scale
- Things to do:
  - Before December Run
    - Finish low power mode implementation
    - Finish Dynamic Delay protection circuit
    - Finish diagnostics:
      - Replace CMOS cameras with CCDs
      - Place energy meter
      - Finish autocorrelator acquisition/file reader
    - Optimize telescope
    - Replace flashlamp in regen and check in-laser alignment to optimize laser stability, contrast ratios