Abort Gap Monitoring Status

Randy Thurman-Keup

4 / 28 / 2004

Beam Phys / Inst. Meeting

Abort Gap Monitor

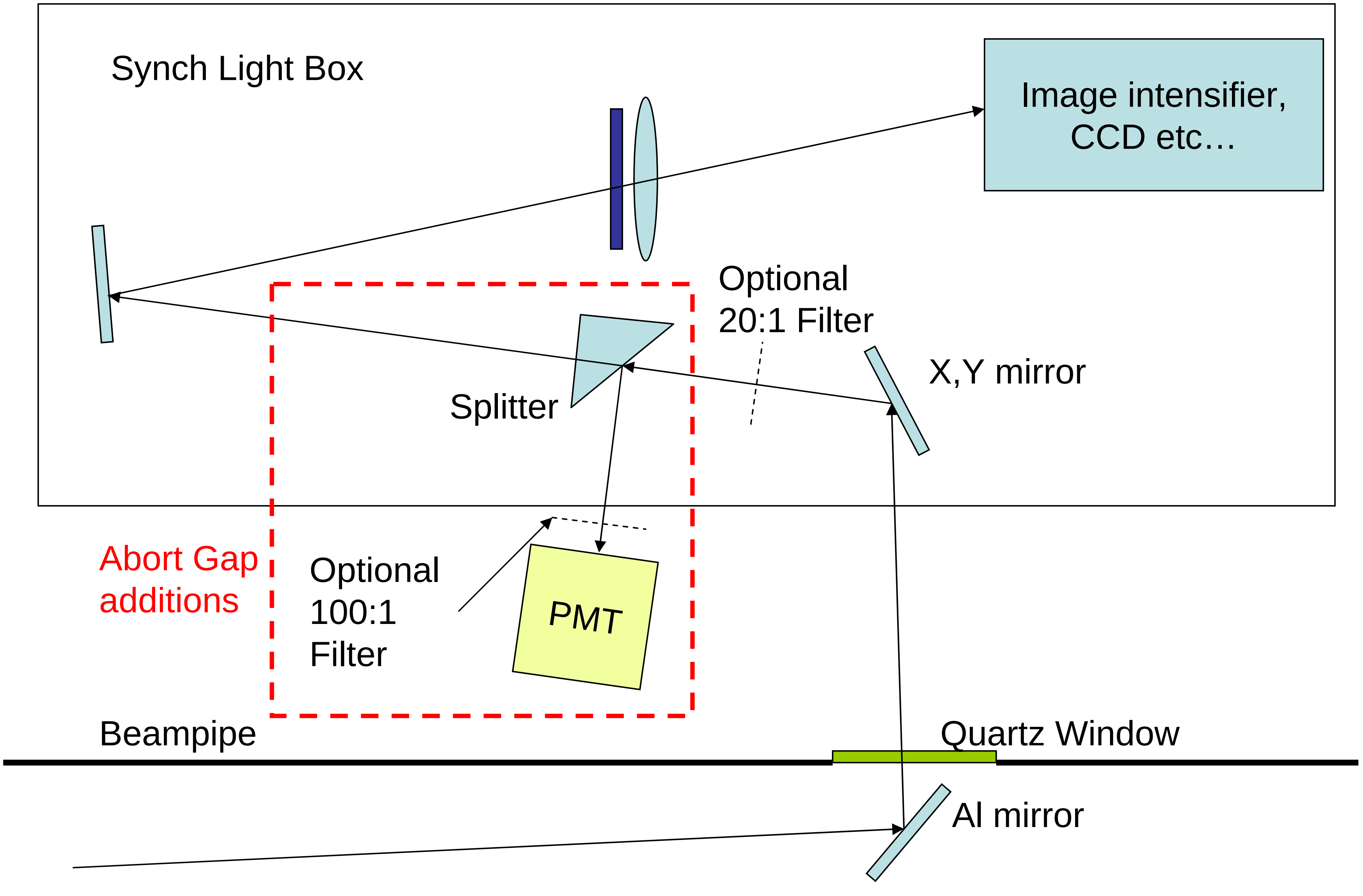
Measure the turn-by-turn synchrotron light intensity during the abort gap using a gated photomultiplier connected to a fast integrator / ADC

The ADC output is accumulated and summed by front end software for 1000 turns

The cycle is repeated once per second

The gated PMT will share the synch light facilities via a beam splitter

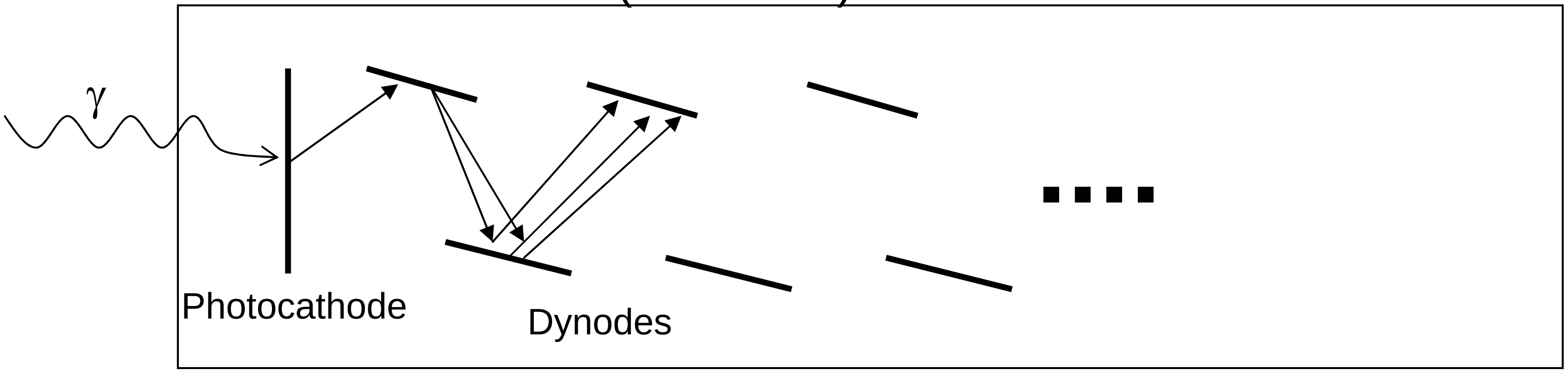
Abort Gap Monitor Status



Abort Gap Monitor Status – Gated PMT

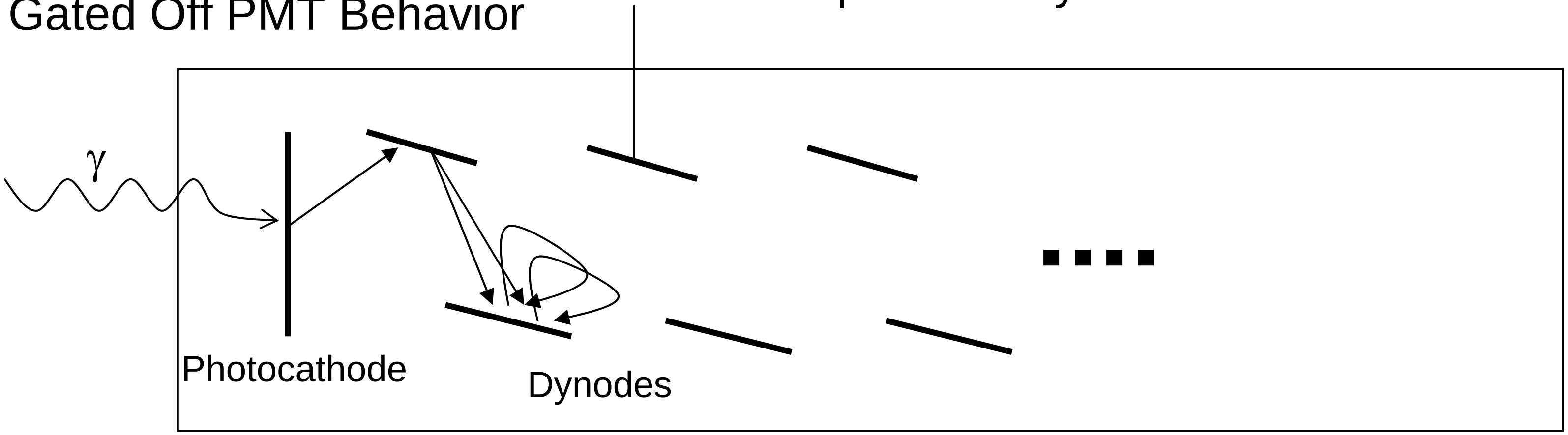
The PMT has 2 dynodes connected to a pulsing circuit which holds the dynode potentials below the previous dynode to effectively block the electron flow. When the gate is applied, the dynodes are pushed up to their nominal voltages.

Nominal PMT Behavior (Gated On)



Gated Off PMT Behavior

HV below previous dynode



AG Monitoring Status – Expected Signal

Want to measure DC beam at a level of 10^{-4} of total beam

protons in DC beam, N_{DC}, ~10^{9} (total beam ~10^{13})

N_{DC} ~ 3.6 x 10^{-3} N_{bunch}

abort gap protons, N_{AG}, ~ 4.5 x 10^{-4} N_{bunch} ~ 1.3 x 10^{8}

From A. Hahn **Beams-doc-418**:

photons / 25nm / 6 x 10^{10} protons ~ 3 x 10^{4}

Wavelength acceptance ~ 100nm

Optical losses ~ 40% efficiency *(50% from beam splitter)*

Gating duty cycle ~ 1.5μs / (2.5 μs abort gap) = 60%

$N_{photons}$ ~ (3 x 10^{4}) * (1.3 x 10^{8} / 6 x 10^{10}) * 4 {100 nm acc.} * 0.4 * 0.6

$N_{photons}$ ~ 62

PMT Quantum Efficiency ~ 15%

photoelectrons ~ 9

AG Monitoring Status – Expected Signal

PMT Signal will be fed into an integrator with a voltage out proportional to integrated charge

$V_{out} = Q * (5 \times 10^{9})$

Gain ~ 10^{6}

$Q = N_{pe} * \text{Gain} * (1.6 \times 10^{-19}) \sim 1.4$ pC

$V_{out} \sim (1.4 \times 10^{-12}) * (5 \times 10^{9})$

$V_{out} \sim$ 7 mV

ADC is 14 bit 0-1V, so roughly 100 counts

AG Monitoring Status – Test Setup

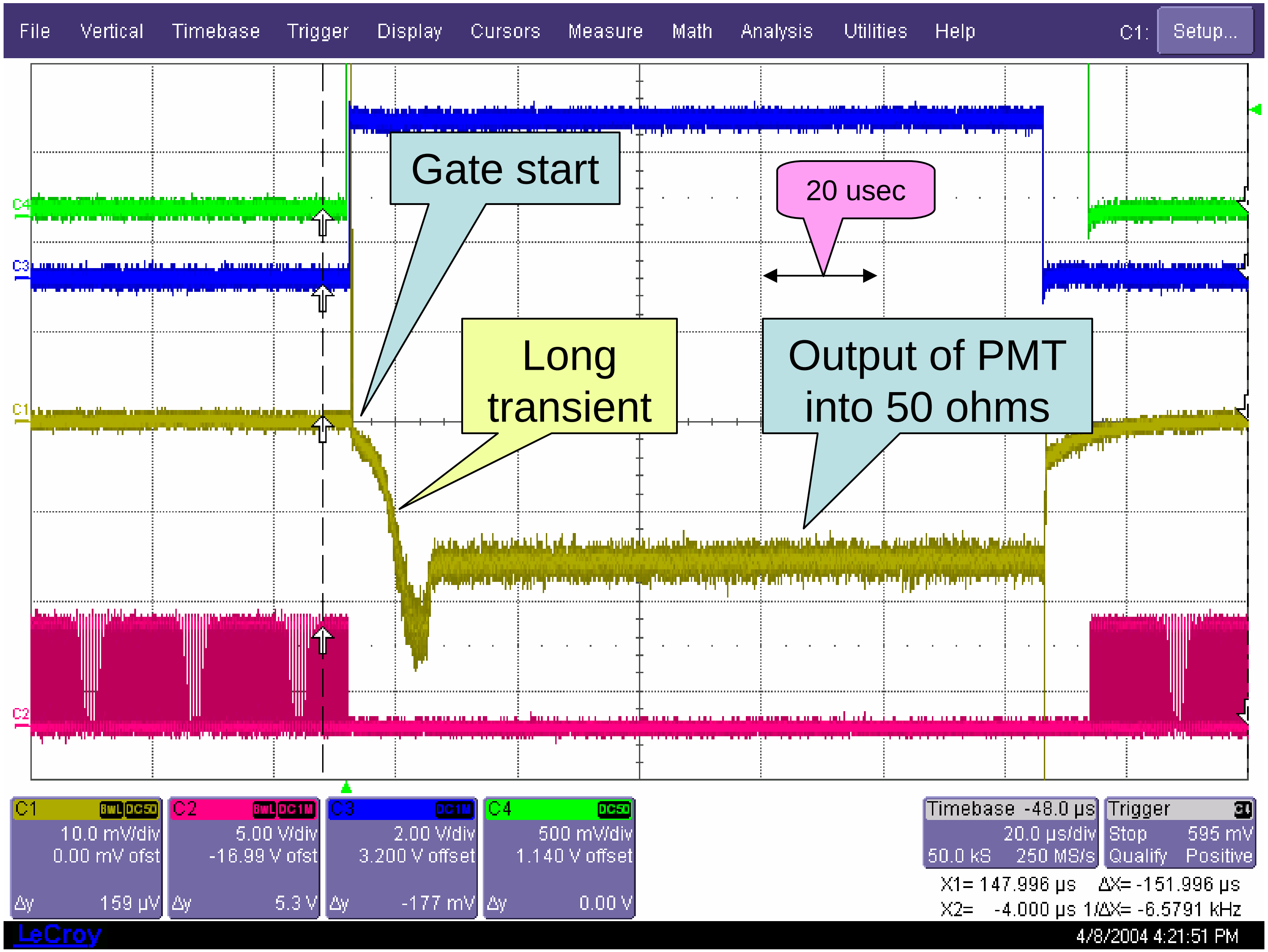
Setup uses pulsed blue LED to simulate bunch light and yellow LED to simulate DC beam

Focused on trying to eliminate sensitivity of measurement to bunch light levels just prior to gating PMT, and on removing turn-on transients

- Dynode 2 alone – Very Sensitive to pre-AG light
- Dynode 2 and Dynode 4 – Still quite sensitive to pre-AG light
- Dynode 1 and Dynode 4 – Small sensitivity to pre-AG light, but significant turn on transient (20% w/ 20μs time constant)

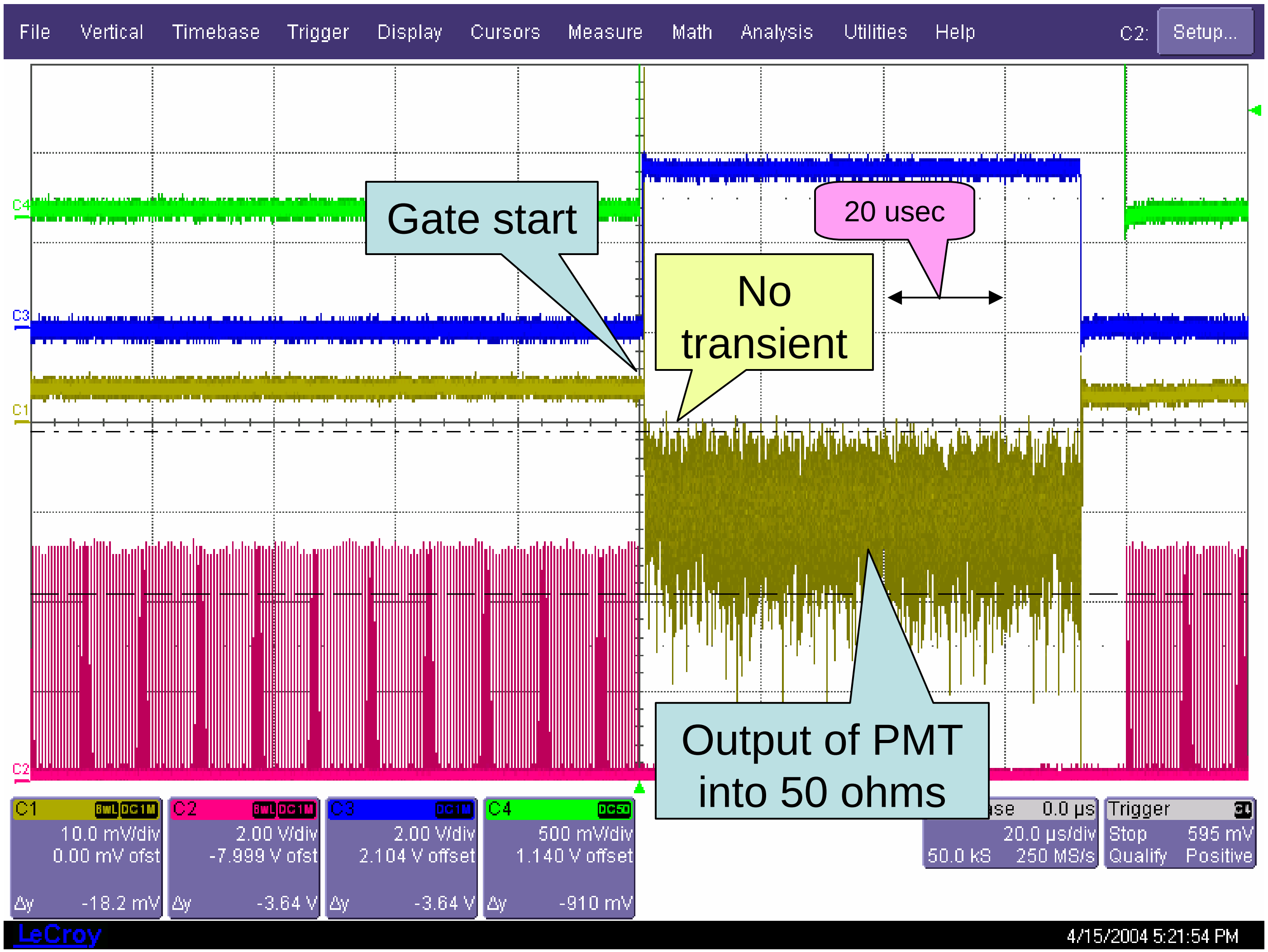
AG Monitoring Status – Slow Dyn. Resp.

PMT base has ~300K between dynodes; dynamic response is not good



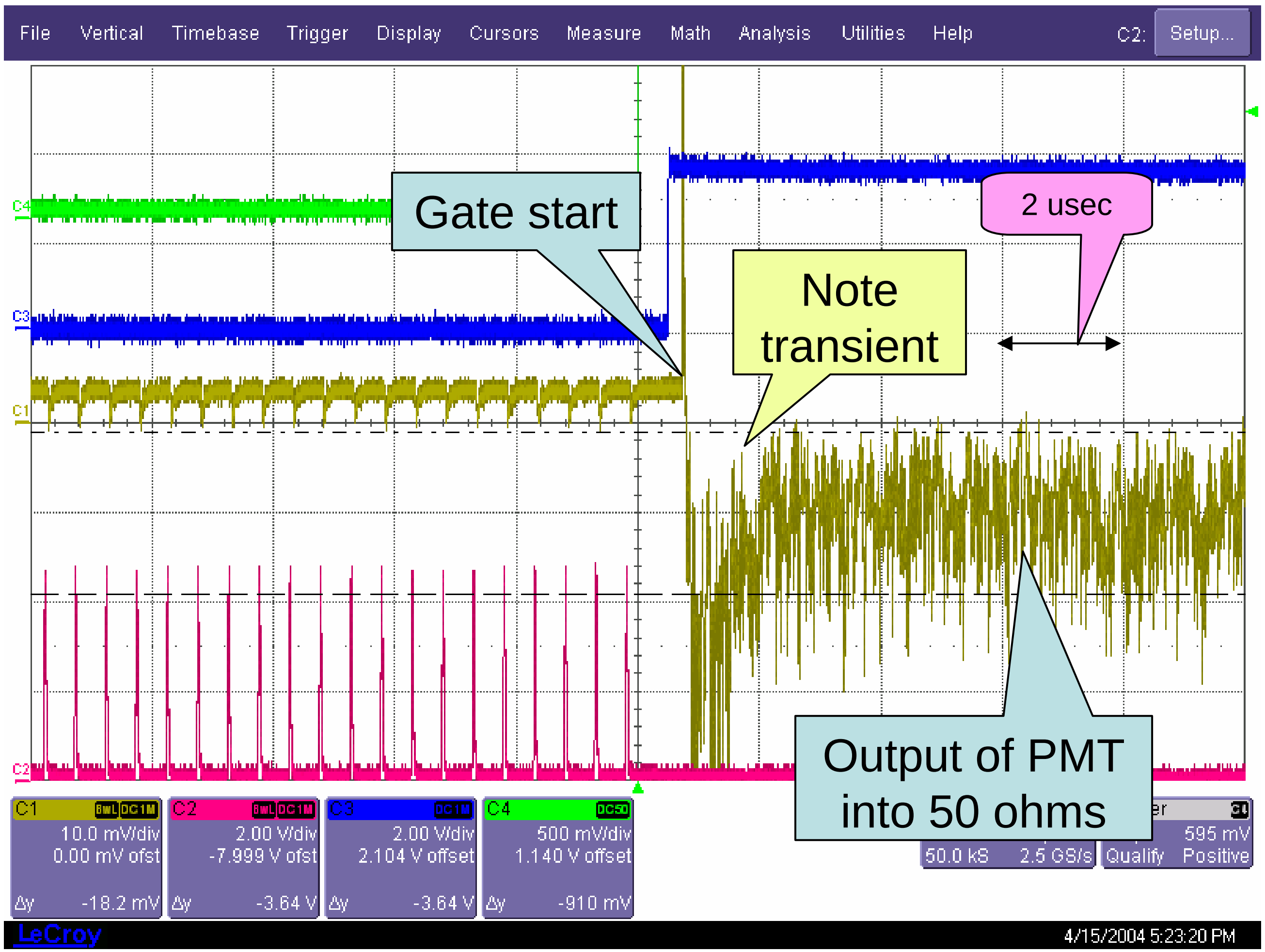
AG Monitoring Status – Fast Dyn. Resp.

PMT has capacitors between dynodes to improve dynamic response



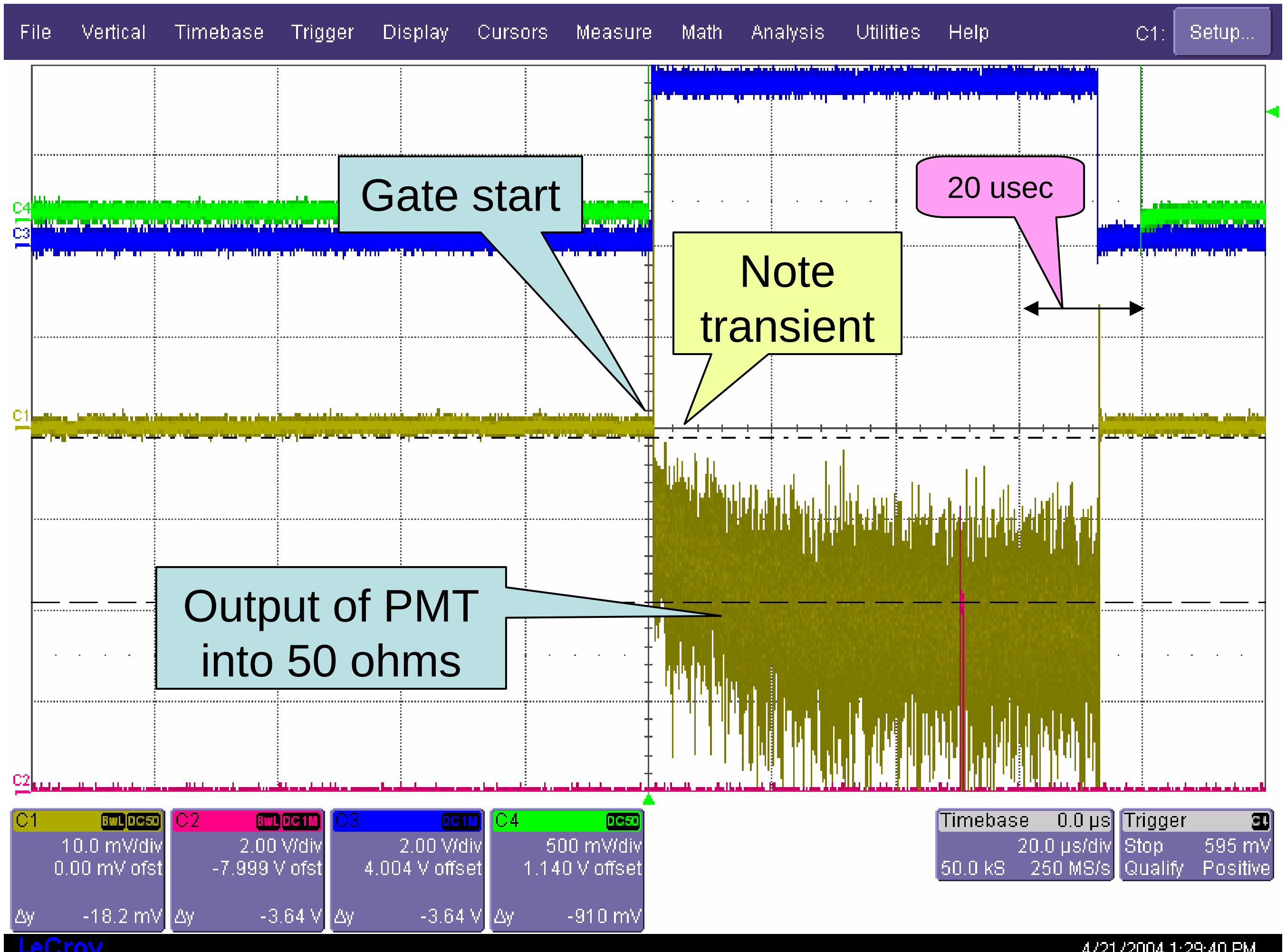
AG Monitoring Status – Dynode 2

Gating dynodes 2 and 4. Beam light transient is clearly present. Switching to dynode 1 significantly reduced the sensitivity to beam light.



AG Monitoring Status – Dynode 1

Gating dynodes 1 and 4. Even without beam light, a clear 10-20usec gating transient is present that was not present in dynode 2 version. Possibly due to photocathode resistance? In any case, can probably calibrate it away since it is reproducible.



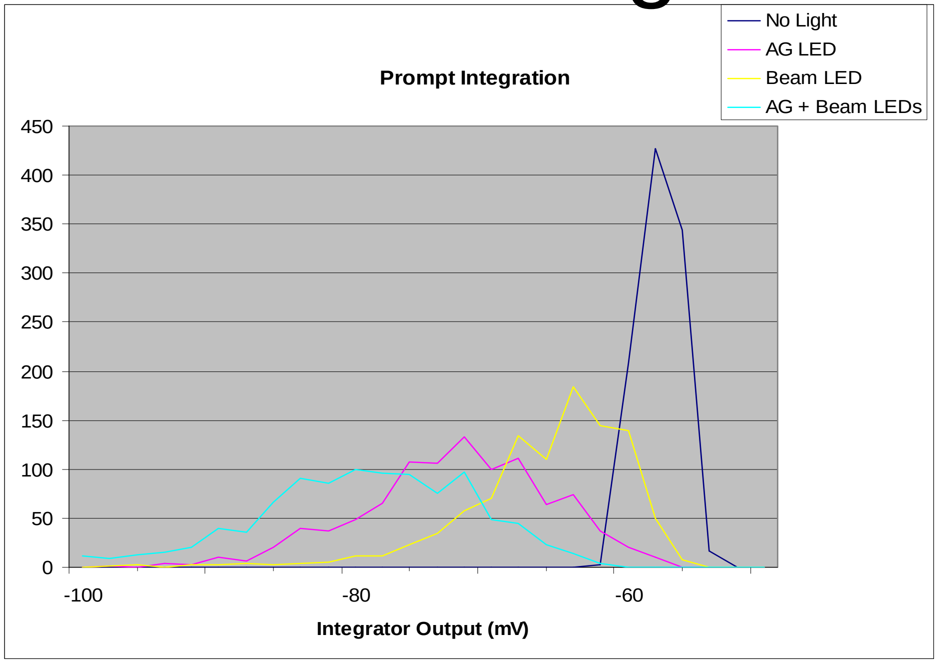
AG Monitoring Status – Dynode 1

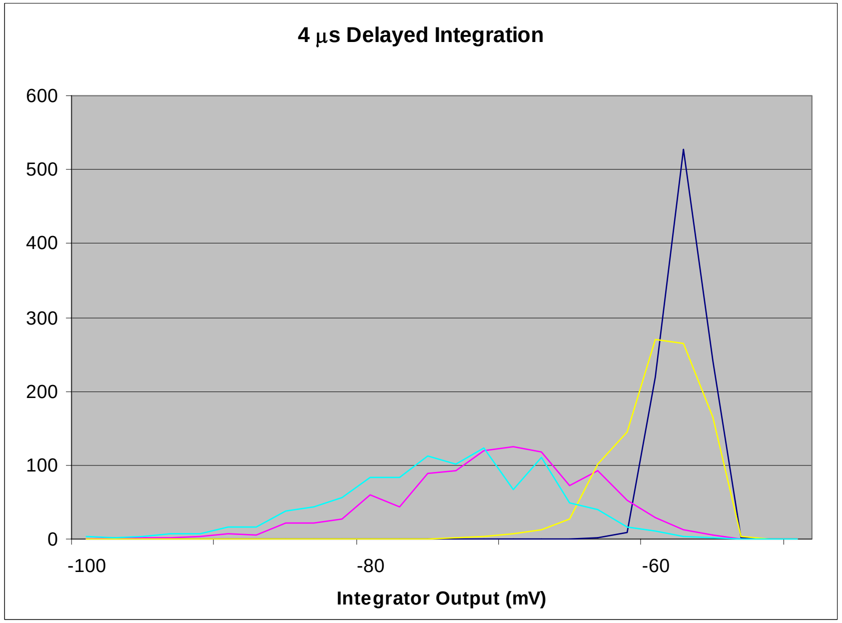
Use dynodes 1 and 4 and look at sensitivity of signal to beam light.

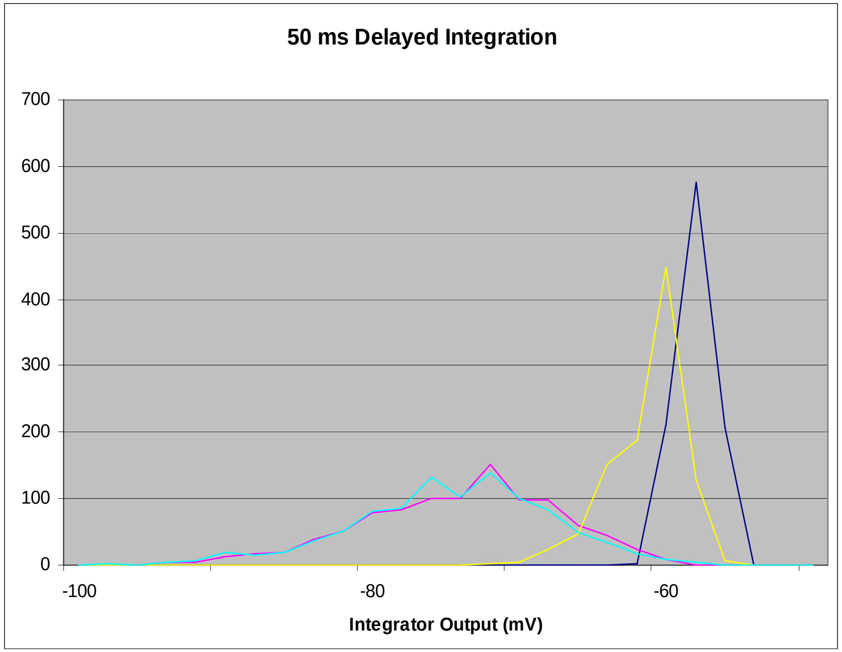
Beam light is simulated using a pulsed LED and abort gap light is simulated using an always-on LED

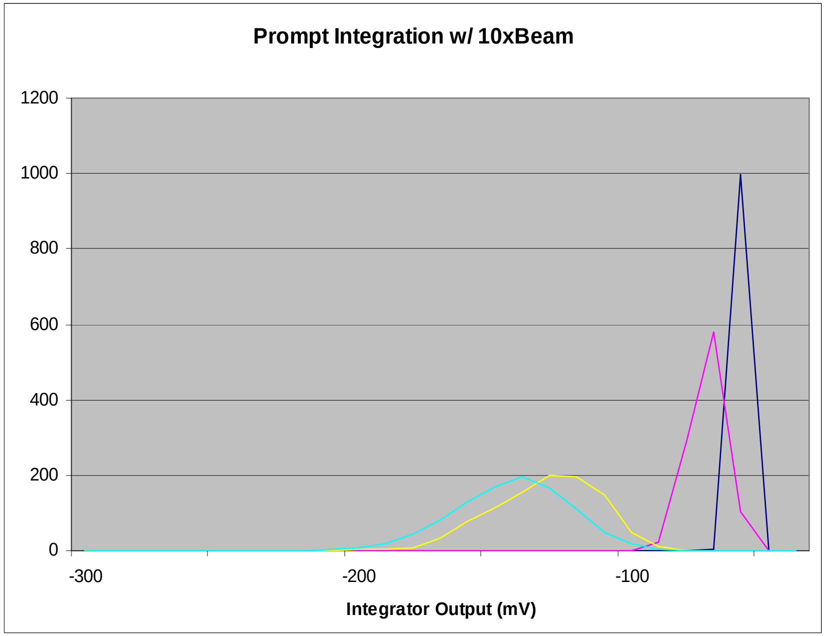
Slide the integration window and see how long the beam light impact takes to go away

AG Monitoring Status – Int. output, DY1

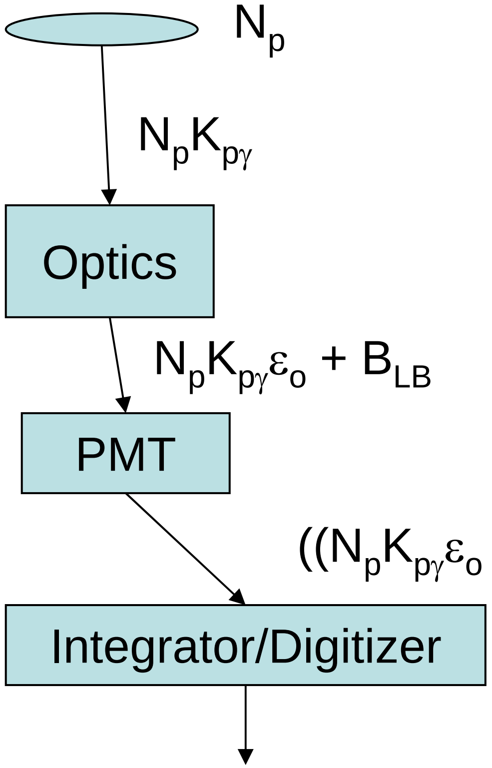








Abort Gap Detection



$$V = (((N_p K_{p\gamma} \varepsilon_o + B_{LB})\ \varepsilon_{QE} + B_{HL})\ (g + \mathcal{N}\{I_b, (N_p K_{p\gamma} \varepsilon_o + B_{LB})\ \varepsilon_{QE} + B_{HL}\}) + B_{DC})\ K_{QV} + B_P$$

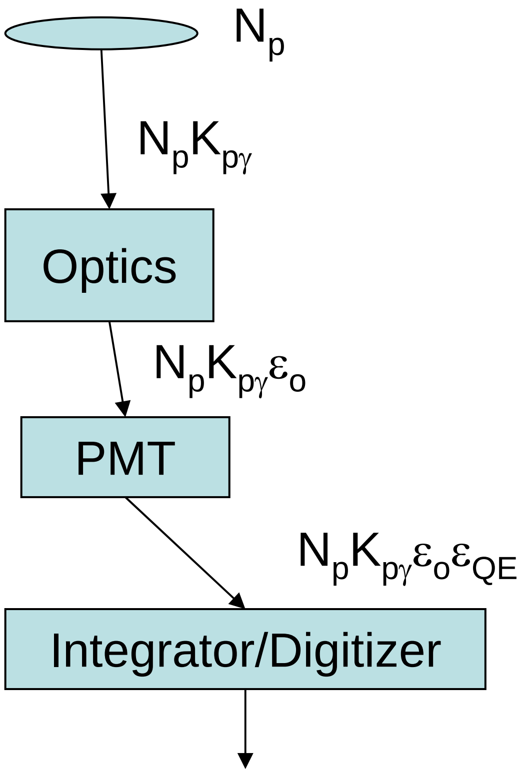
$$N_p = ((((V - B_P) / K_{QV} - B_{DC}) / (g + \mathcal{N}\{I_b, (N_p K_{p\gamma} \varepsilon_o + B_{LB})\ \varepsilon_{QE} + B_{HL}\}) - B_{HL}) / \varepsilon_{QE} - B_{LB}) / (K_{p\gamma} \varepsilon_o)$$

Abort Gap Detection – Version 2

Dark current is < 1% of expected signal

Beam halo/losses < 1% of expected signal

Engineer light box to suppress ambient light



$$V = N_p K_{p\gamma} \varepsilon_o \varepsilon_{QE} \, (g + \mathcal{N}\{I_b, N_p K_{p\gamma} \varepsilon_o \varepsilon_{QE}\}) \, K_{QV} + B_P$$

$$N_p = (V - B_P) \, / \, (K_{QV} \, (g + \mathcal{N}\{I_b, N_p K_{p\gamma} \varepsilon_o \varepsilon_{QE}\}) \, K_{p\gamma} \varepsilon_{QE} \varepsilon_o)$$

Background processes

- Halo and losses
  - Put filters in place
  - Measure abort gap signal
  - No light reaches PMT from light box
- Light box
  - Put first filter in place
  - Measure abort gap signal
- Need to verify that backgrounds are same in bunch and in abort gap. One possible difference due to beam halo and losses?

Calibration process

On benchtop, measure $\mathscr{N}$

In situ…

Put in filters

Measure bunch signal after abort gap (need to correct for later integration time)

Determine efficiencies and gain from width/peak of ADC distribution, correct for $\mathscr{N}$

Factors influencing Gain of tube

of photoelectrons

- Presumably the smallest effect

Pre-gate light intensity and distribution

- The closer the integration window is to the last bunch, the more pronounced the effect

Time from gate to integration

- Tube has a gate-on transient

AG Monitoring Status – Software

- DAQ software is fully working with Comet board; backgrounds, timing selection, etc…
- Work is progressing on Struck board

AG Monitoring Status

- Have a viable gated PMT
  - Needs to be calibrated for intensity of bunches prior to gate
  - Backgrounds should be negligible
- PMT base/gating circuit layout proceeding
- Ordered a Hamamatsu gated PMT
- May try side-on PMT to check photocathode resistance
- Need to have box designed and built
- DAQ is functioning with Comet board; working on Struck