Matthew Jones/ Riei Ishiziki Purdue University

Electronics Simulation in the Photon Transport Monte Carlo

- Preamp model
- Receiver/discriminator circuit
- CAFÉ driver circuit model
- Examples
- Summary

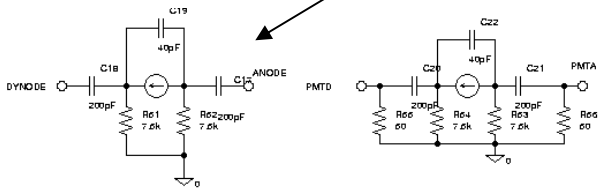
January 31, 2005 – last update: Jan 30

Preamp Model

- So far, the effect of the preamp has been ignored, although some degradation in rise-time was included. *This was just a wild guess.*
- Need a good preamp model to relate anode charge to output of ADC…
- Particularly important for large pulses.
- Best studied using SPICE simulation of preamp circuit.
- Useful check of schematics for the NIM paper.

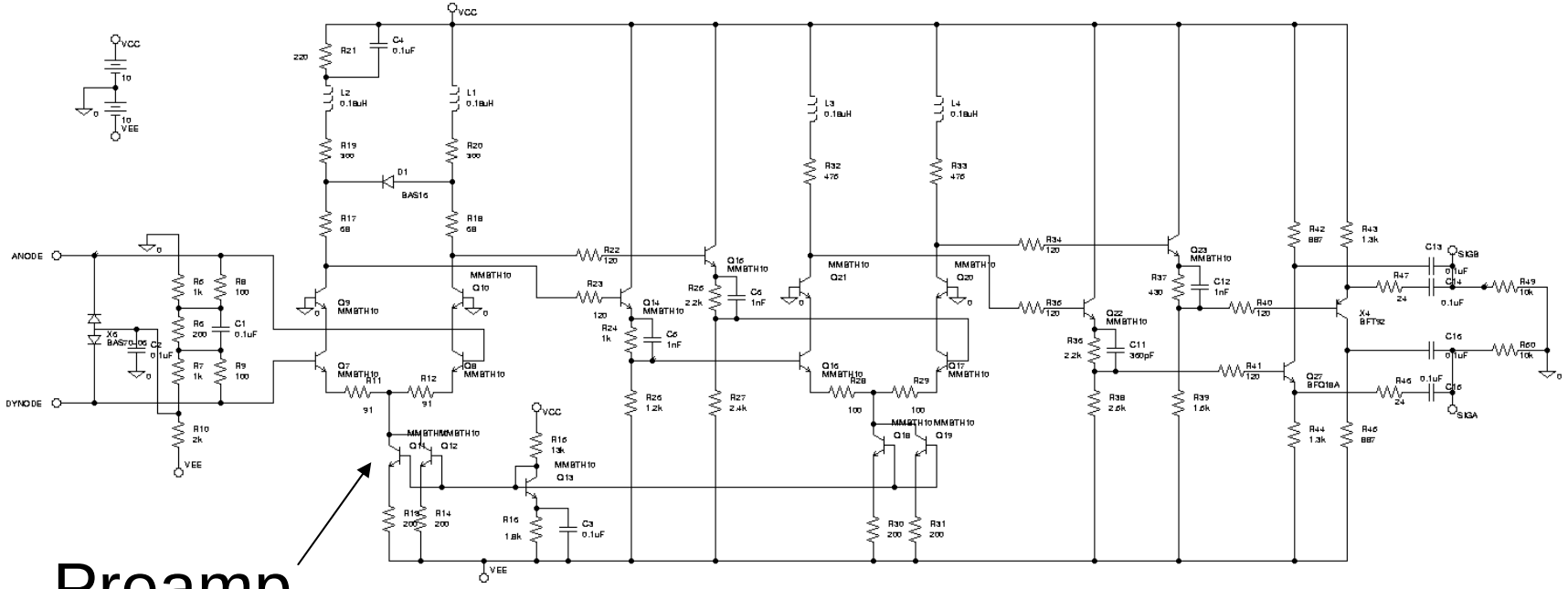
Preamp Model

Model for PMT driving preamp



(See CDF Note 5358)

Model for PMT driving 50 Ω load

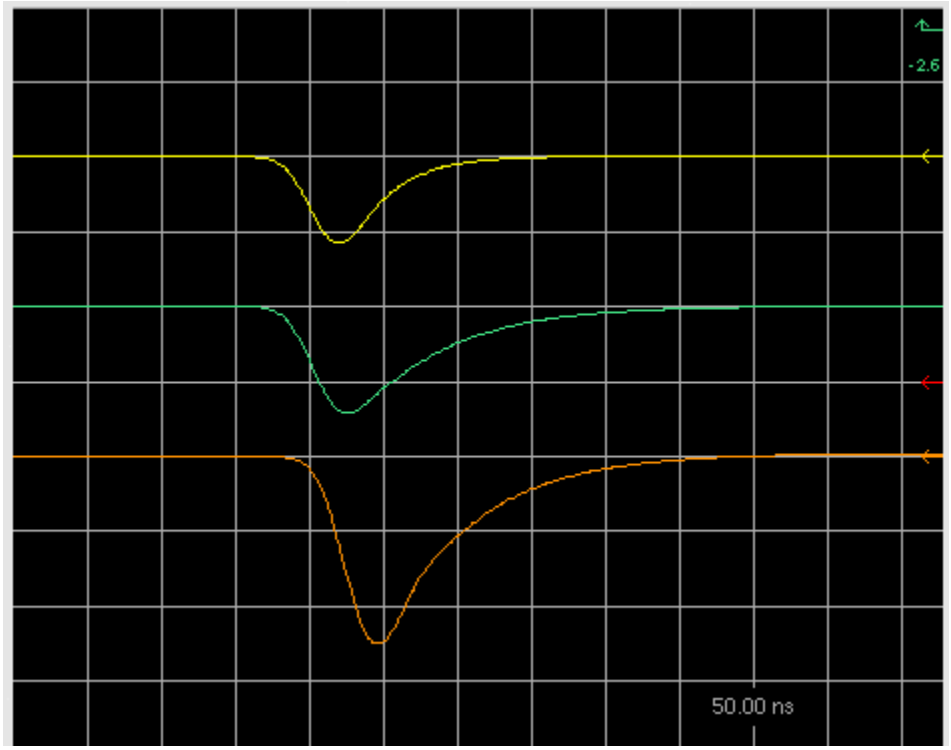


Preamp

Preamp Model

- Important to validate the simulation by comparing with real preamp.
- Input pulse:
  - Gaussian, 1.5ns width, typically 0.01 nC
  - 0.01 nC corresponds to 2080 p.e. when the PMT gain is $3x10^4$
- Allows comparison with preamp checkout measurements performed with charge injector.

Preamp Model



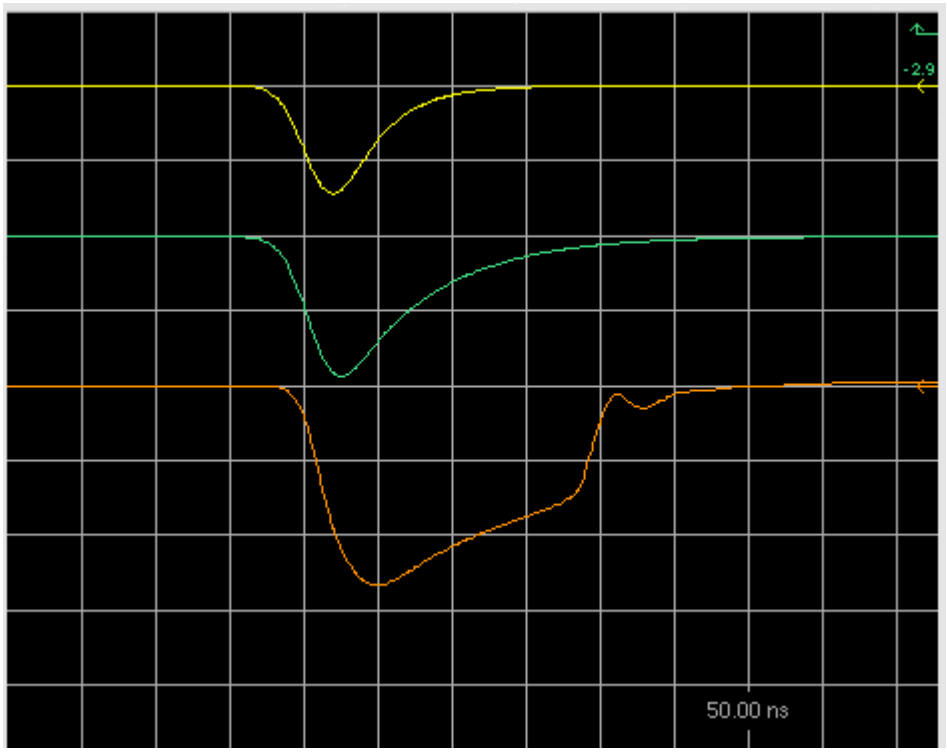
50Ω load, 50 mV/div

preamp, 50 mV/div

output, 500 mV/div

Response to 0.01 nC pulse

Preamp Model



50Ω load, 200 mV/div

preamp, 200 mV/div

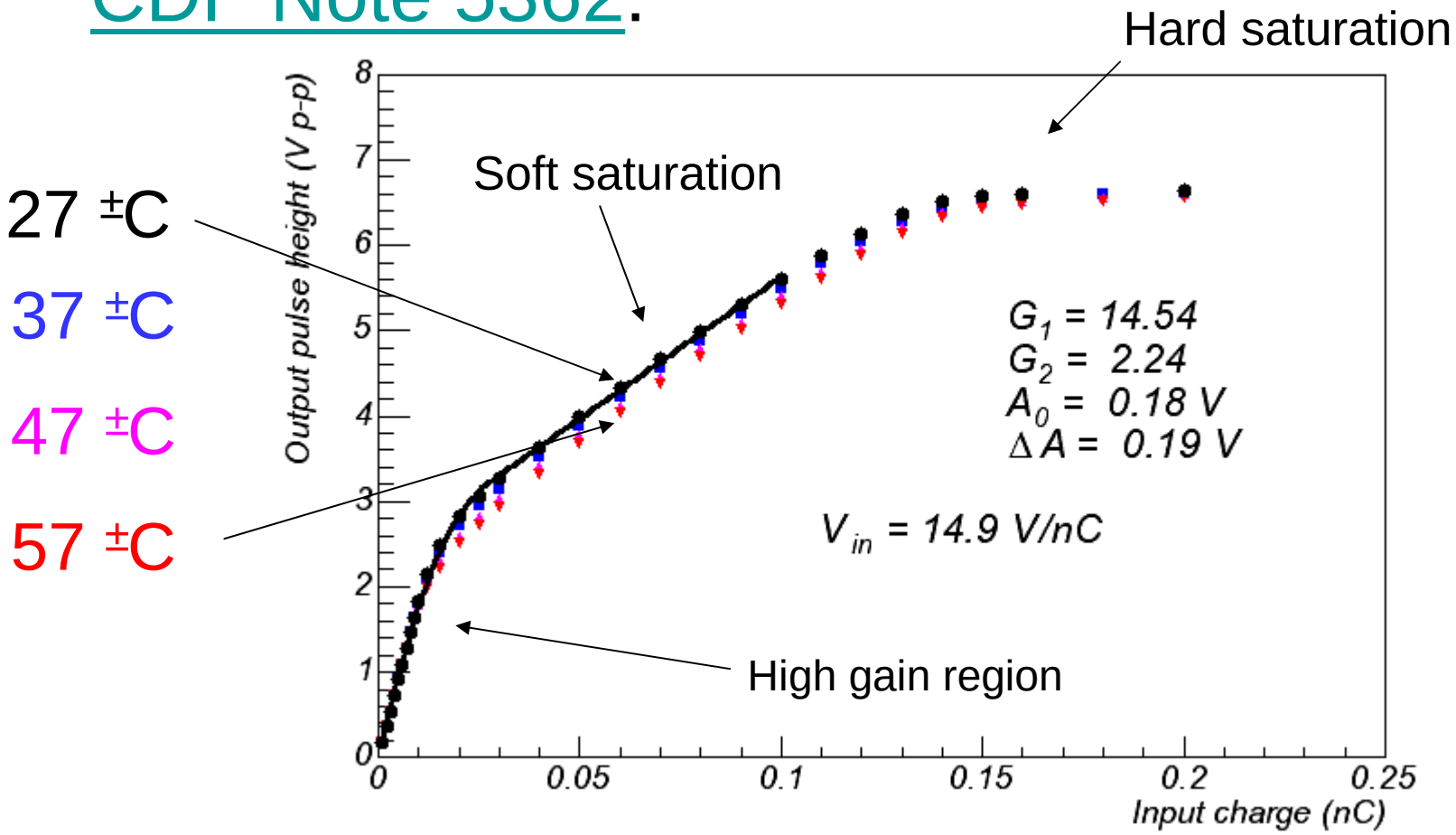
output, 1 V/div

Soft saturation properly modeled

Response to 0.05 nC pulse

Preamp Model

- Gain response parameterized as in CDF Note 5362:



Preamp Model

- Measured parameters:

Parameter description	Notation	Approximate range of values
Differential gain before switching	G_1	13 - 17
Differential gain after switching	G_2	1.5 - 3
Position of the switching region	A	0.25 - 0.4 V
Width of the switching region	ΔA	0.1 - 0.18 V

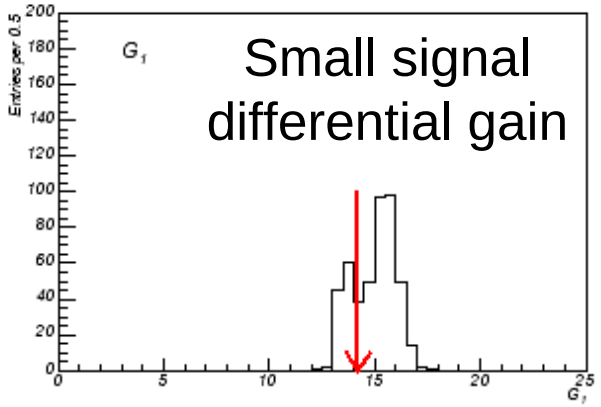
Table 5: Typical values of preamplifier fit parameters.

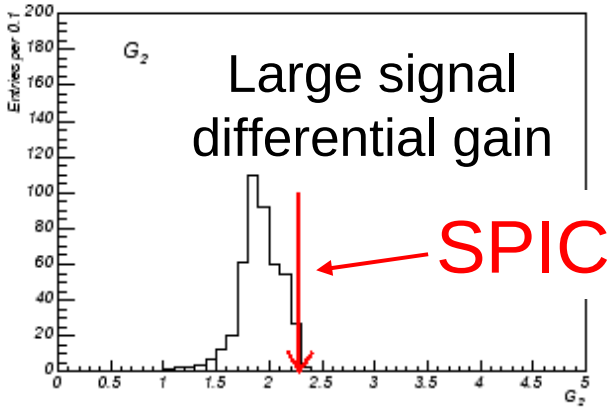
- Simulation:

$$G_1 = 14.5$$
$$G_2 = 2.2$$
$$A = 0.18V$$
$$\Delta A = 0.19V$$

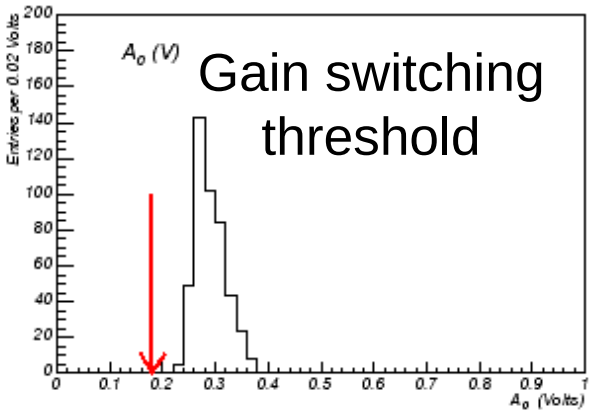
Preamp Model

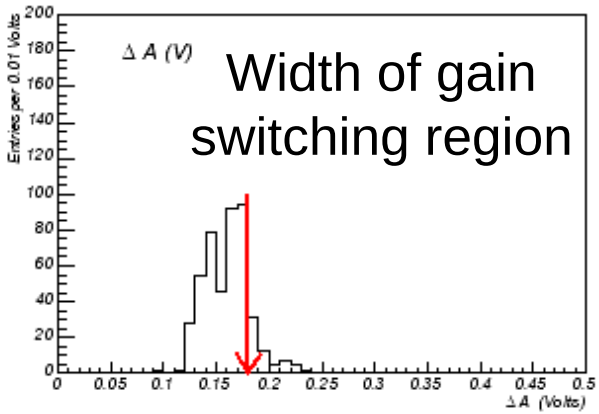
- Comparison of gain parameters with measured distributions:





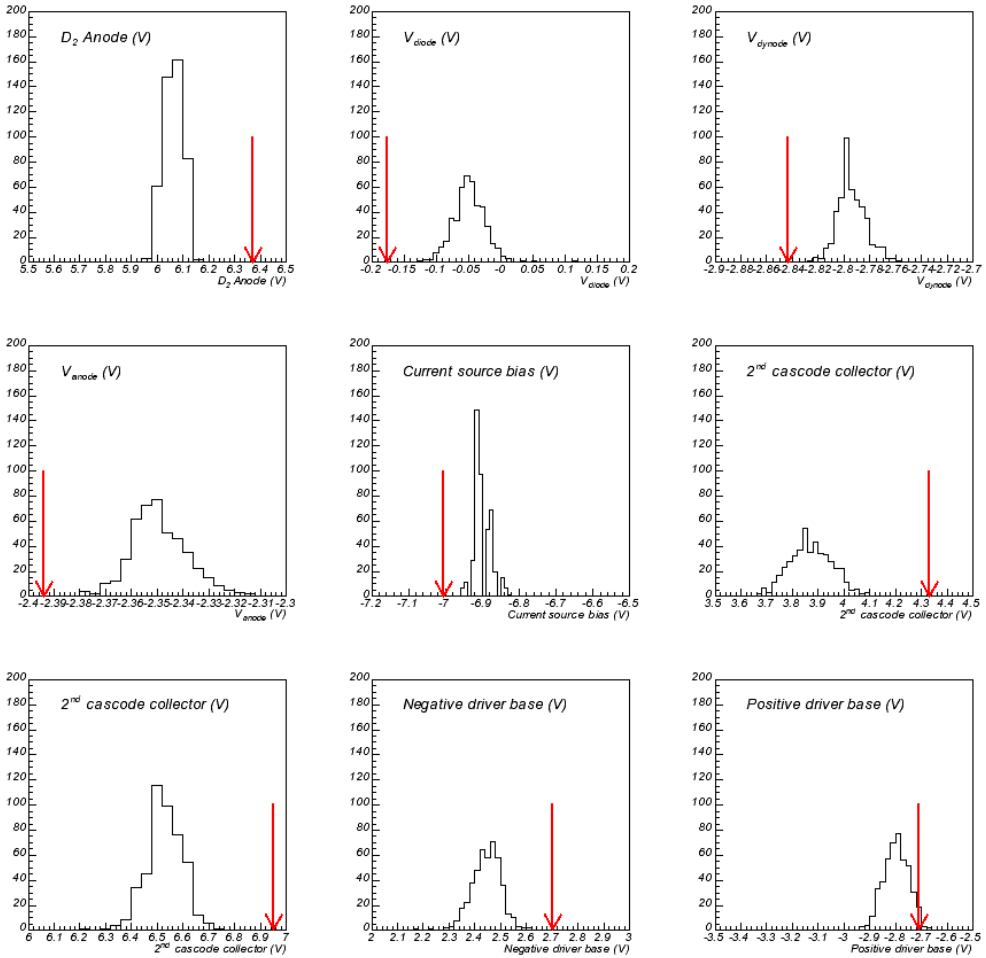
SPICE model





Preamp Model

- Comparison of node voltages:



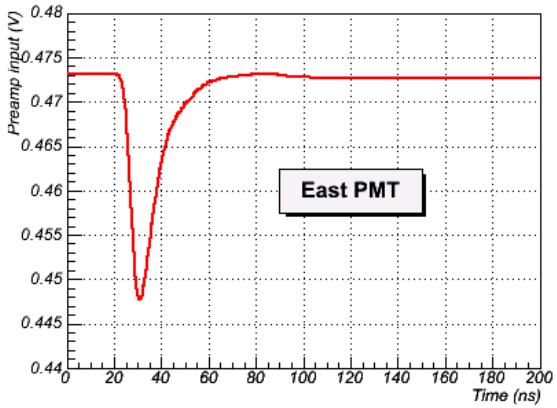
Small differences are not likely to affect small signal gain.

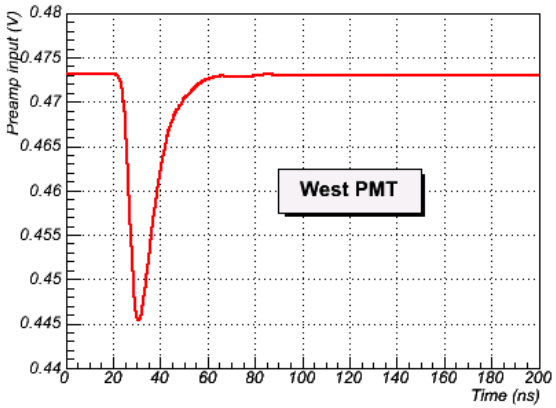
Preamp Model

- Probable unknowns:
  - Supply voltages in the detector
    - Measure them next time the plugs are open
  - Temperature in the detector
  - No simulation of parasitic capacitance
  - Parameters for gain switching diode model
- Qualitative behavior seems reasonable.
- *Small signal response agrees well with measurements and should be adequately described.*

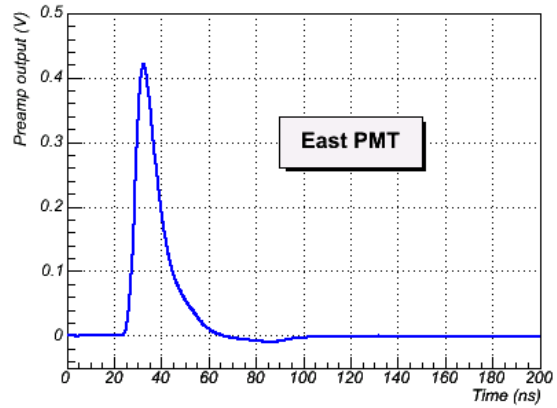
Preamp Model

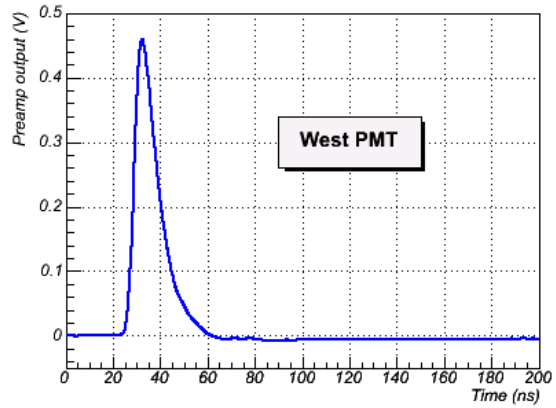
- SPICE3 simulation now interfaced with photon transport Monte Carlo:





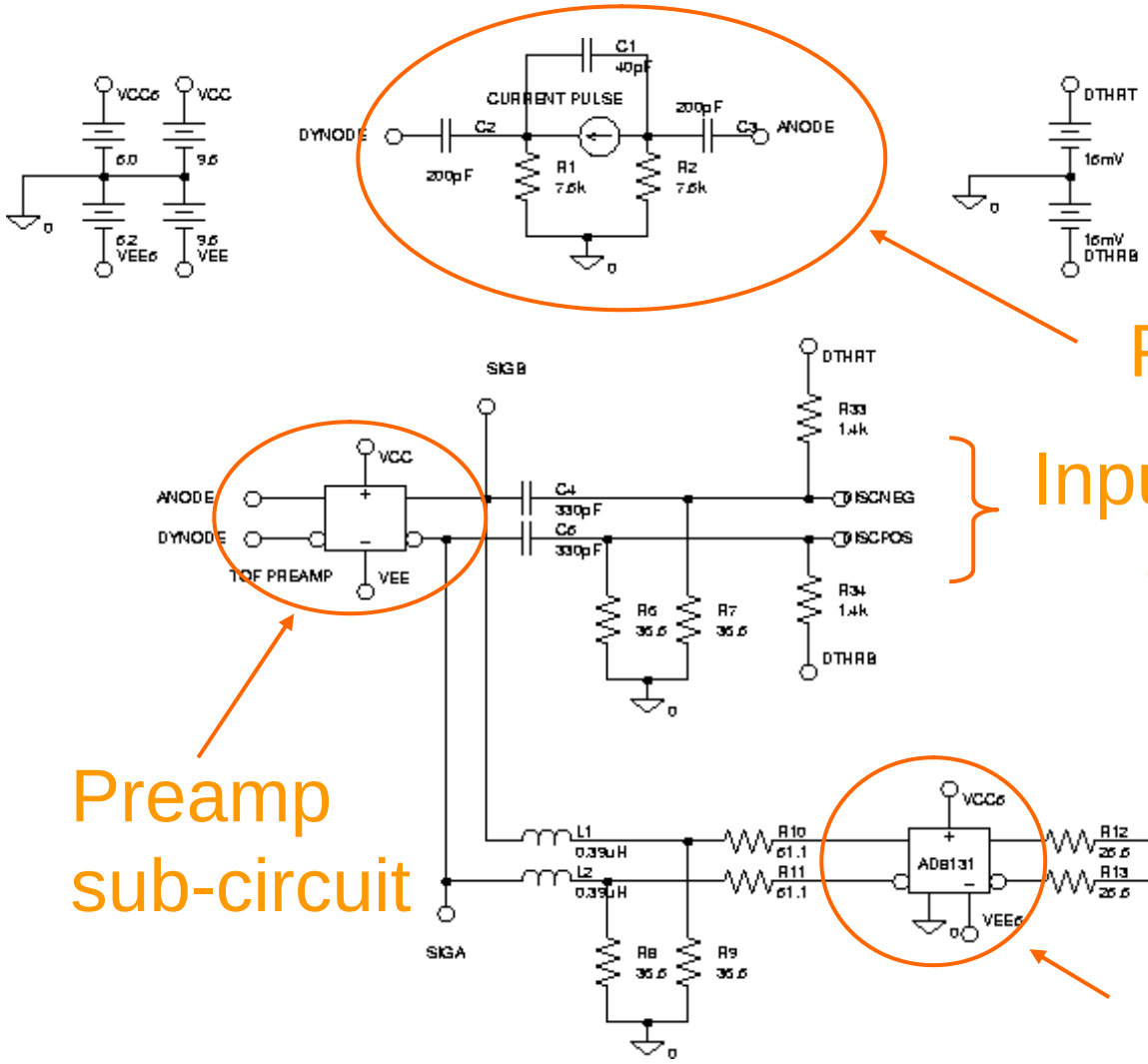
Response to 1 MIP through bar at z=0.



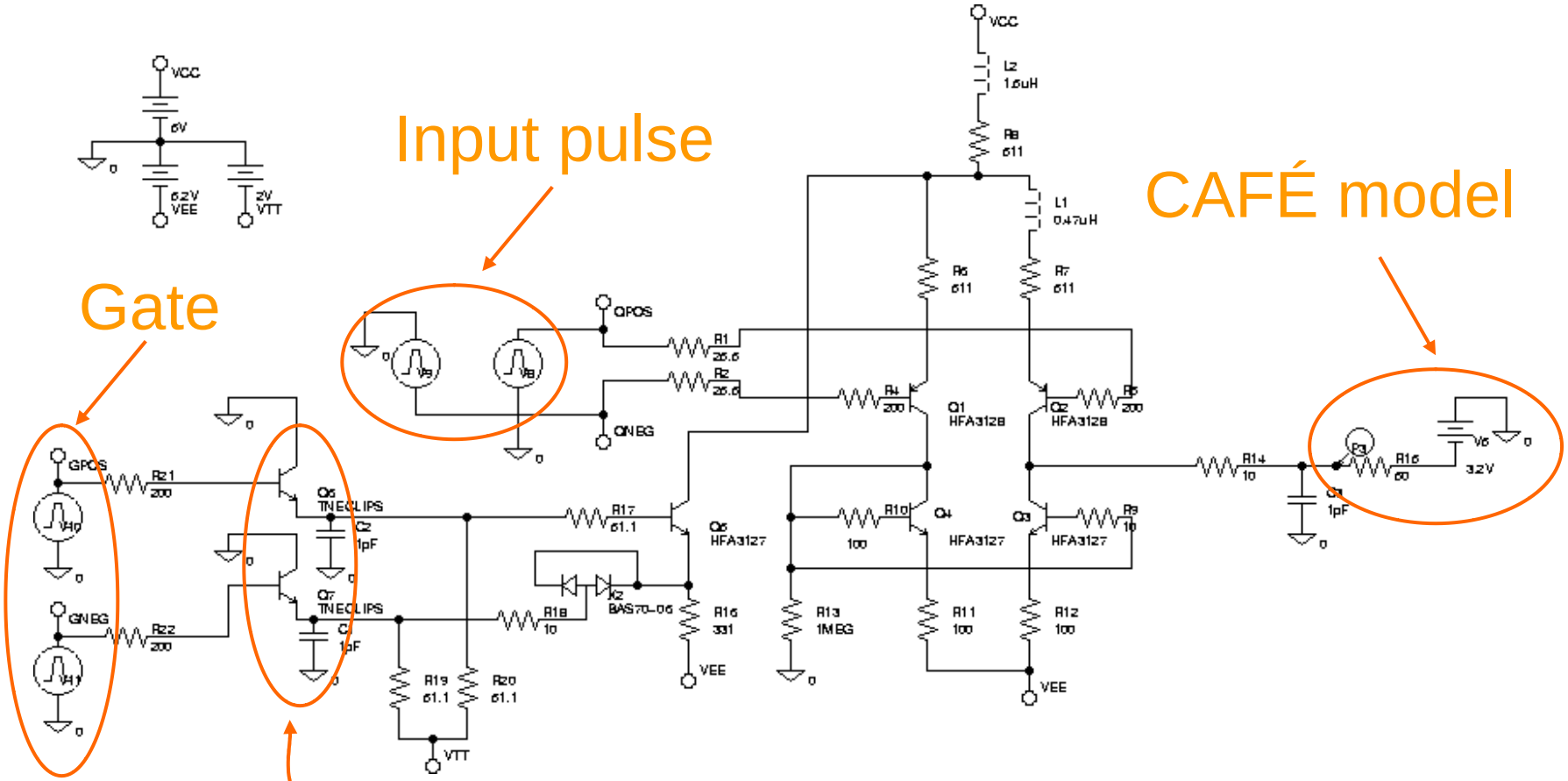


This is an important achievement!

Receiver/discriminator model



CAFÉ Driver Circuit Model



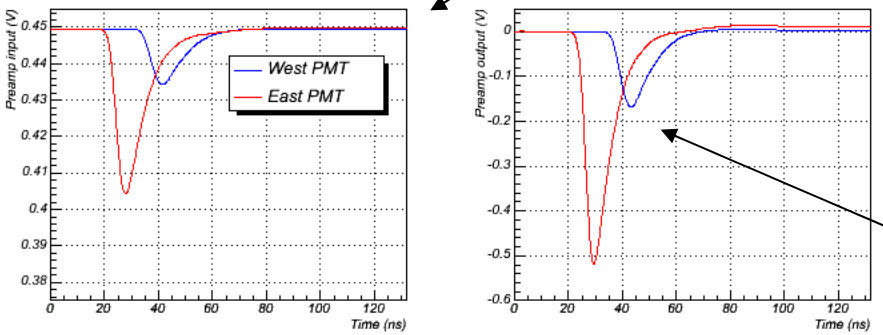
TOAD Electronics

- Still should perform more validation:
  - Compare with production TOAD board node voltages
  - Still not simulating signal cable (22 m attenuation length) and RF transformer
  - Need to determine phase of CAFÉ clock
  - Include parasitic capacitances on TOAD and connector inductances to CAFÉ card

Software Interface

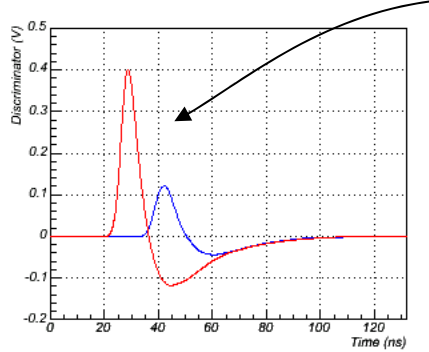
- Interfaced with photon transport MC:
  - PMT class constructs SPICE3 model for current pulse at the anode.
  - System call to invoke SPICE3 with circuit models
  - Output vectors read from binary file
  - Currently stored as non-persistent TGraph objects
- Simulation is fast (few seconds) compared with photon propagation

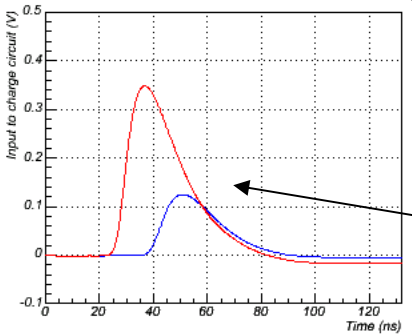
Example: 1 MIP at z=100 cm



Voltage pulse at preamp input

Voltage pulse at preamp output

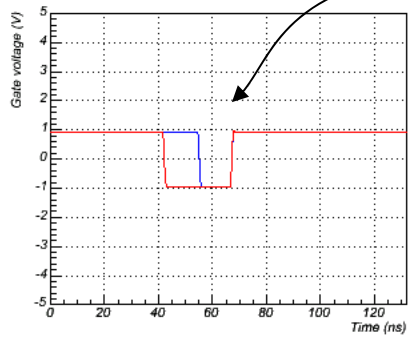


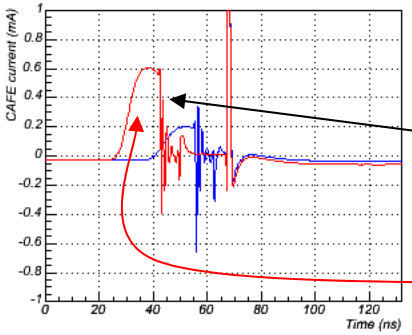


Discriminator input

CAFÉ driver input

CAFÉ driver gate



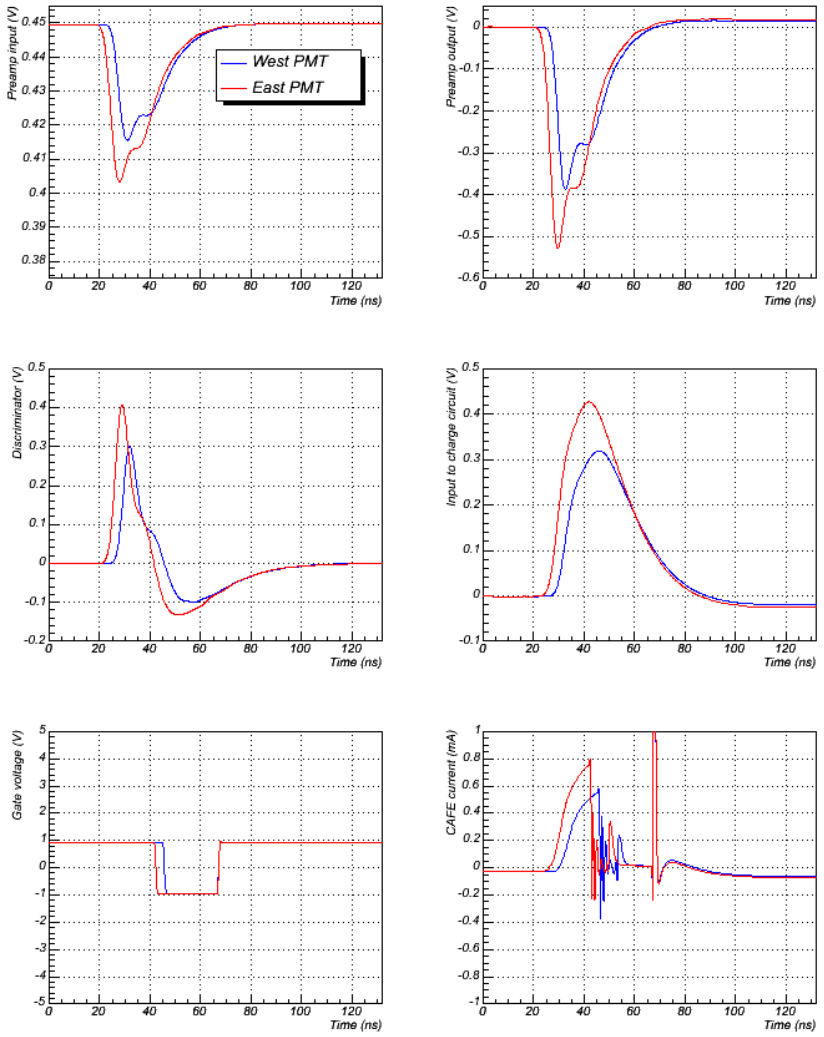


Current into CAFE

about 2000 ADC counts

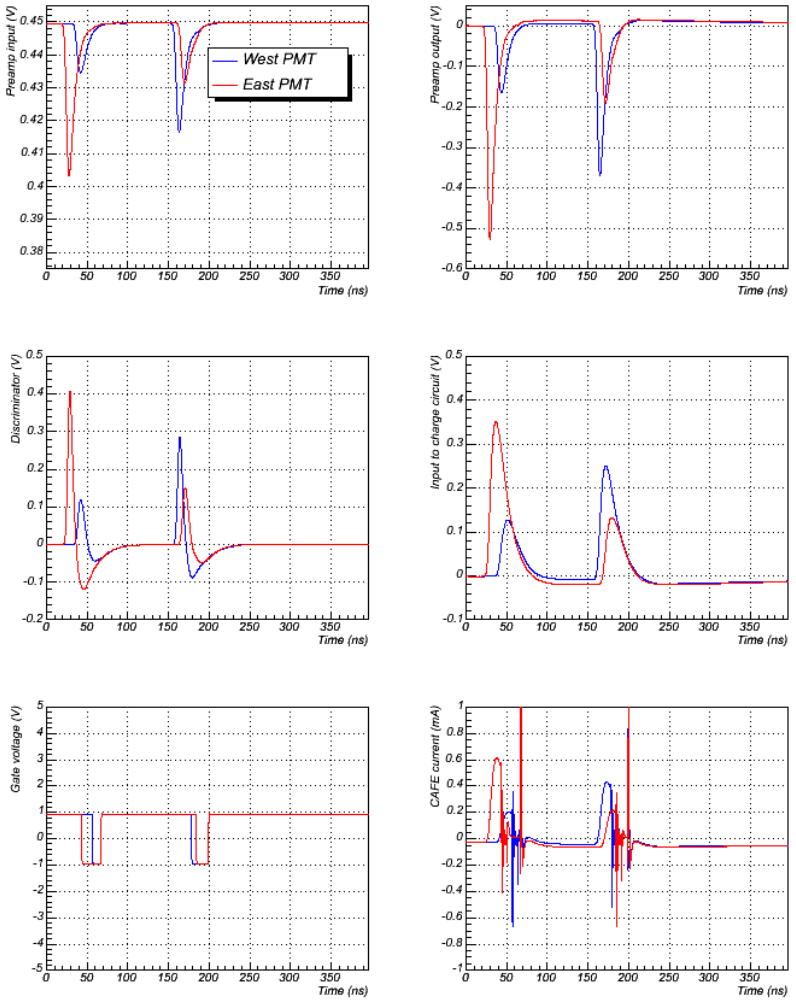
Another example:

- Two tracks hit simultaneously at z=100 cm and z=-50cm:



Yet another example:

- Two tracks in different 132 ns bunch crossings:



Electronics Simulation

- It is now possible to study:
  - Absolute scale of discriminator threshold
  - Functional form of time slewing correction
  - ADC bias due to multiple hits
  - Baseline shifts from hits in earlier bunch crossings (luminosity dependence of ADC)
  - ADC response to monopoles, MIP's, etc.
- Limiting factors will probably come from the PMT parameters (photocathode sensitivity, absolute gain) and scintillator.

Summary

- SPICE3 models:
  - Preamp: good shape now
  - Discriminator: should be okay
    - Use simulation instead of parameterized model?
    - Need to check threshold circuit in more detail.
  - CAFE driver: *Predicted ADC counts have the right order of magnitude!*
    - Still need to work out the phase of the CAFÉ integration gate
    - Now we will have to subtract pedestals in the simulation
- Real limitation probably comes from things we can’t measure (PMT and scintillator properties).