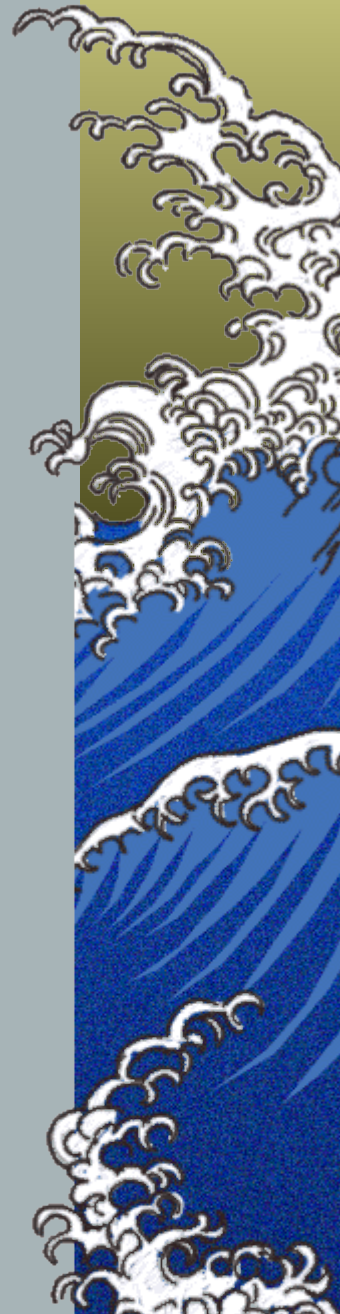


VERITAS L1 trigger Constant Fraction Discriminator

Vladimir Vassiliev

Jeremy Smith

David Kieda



Content

Night Sky Background Noise

Traditional Threshold Discriminator

Constant Fraction Discriminator

CFD: NSB and DC offset effects

CFD: discriminator rate feedback

CFD: schematic

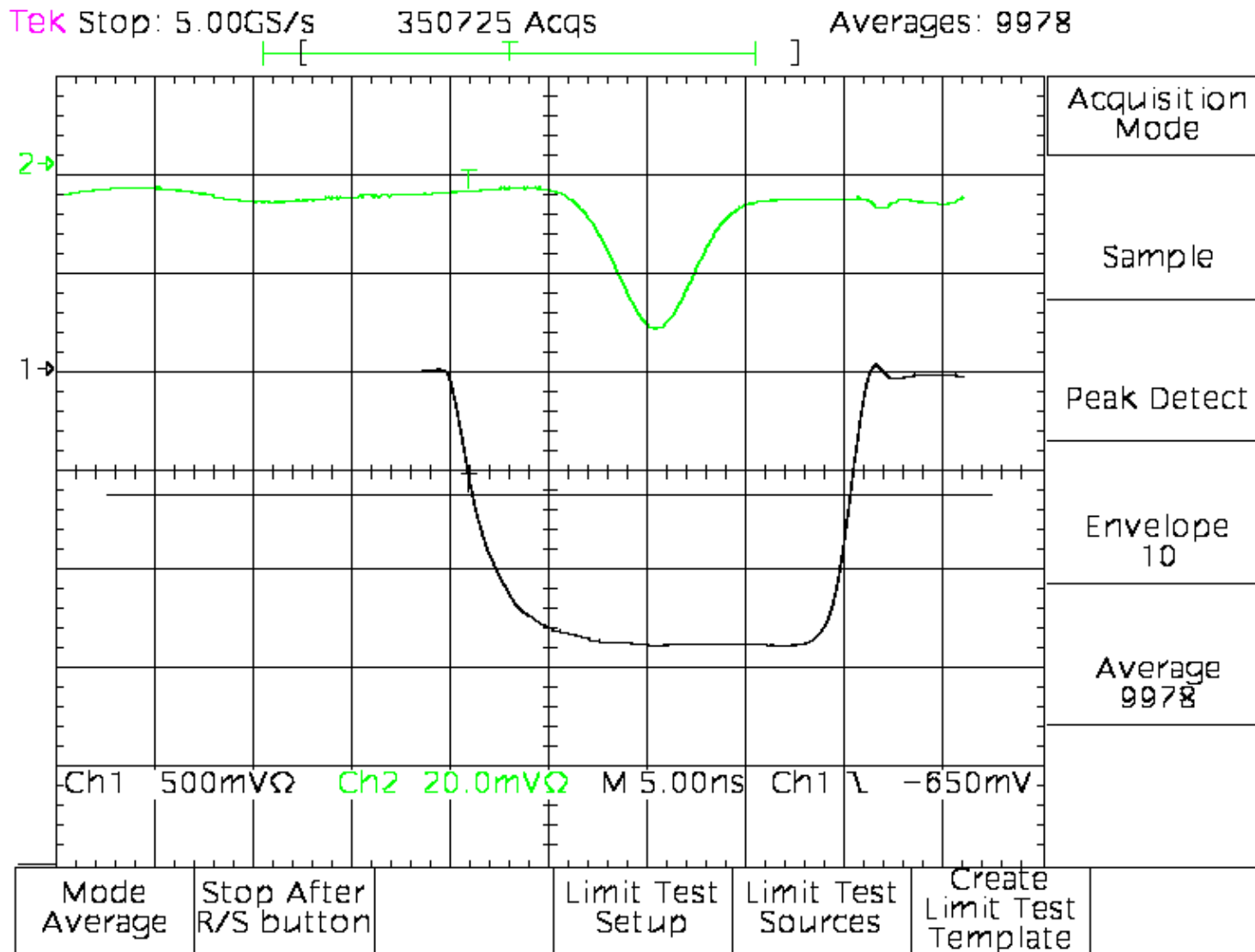
CFD: simulated performance

Pricing

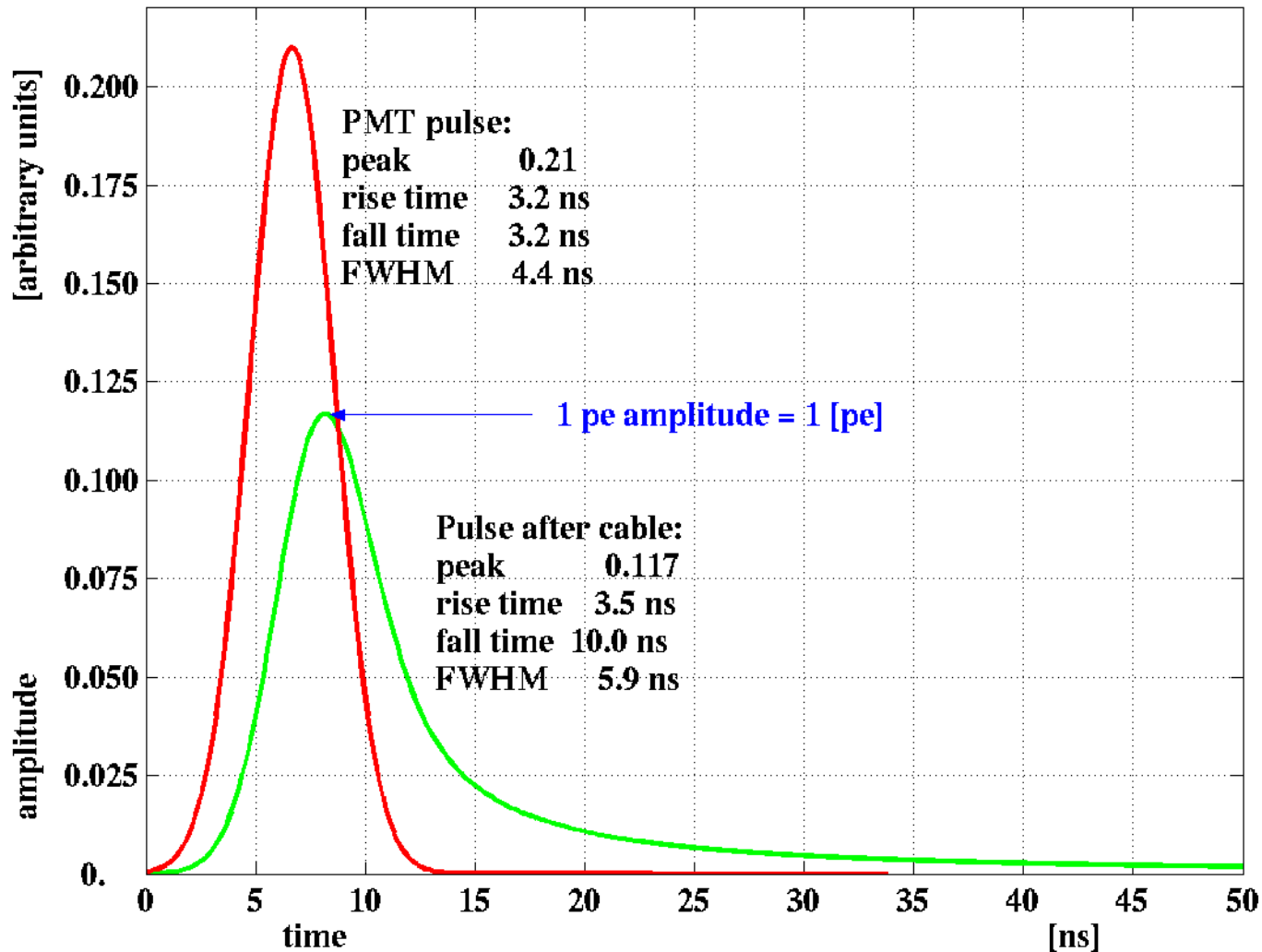
Budget



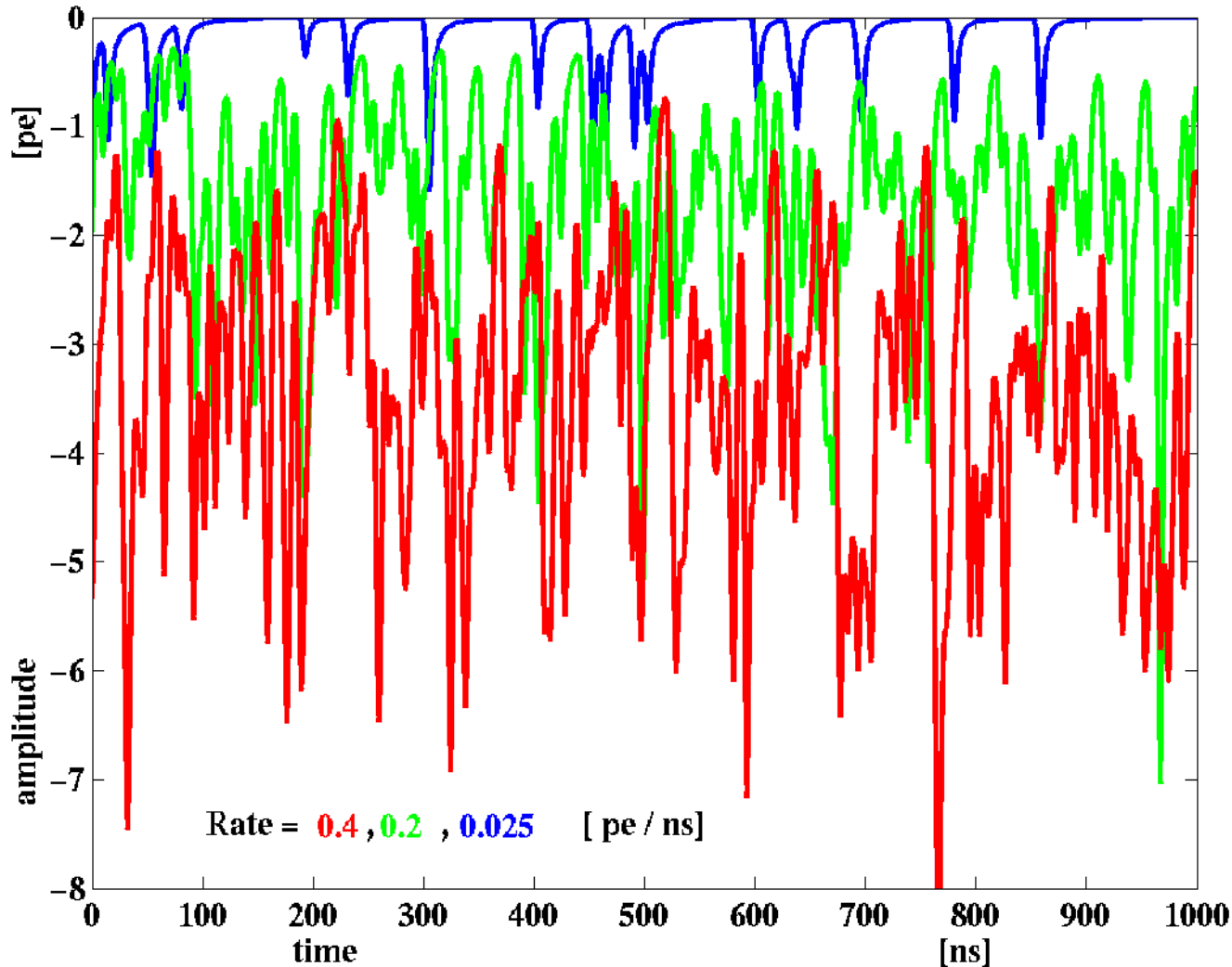
1 pe pulse: measurements



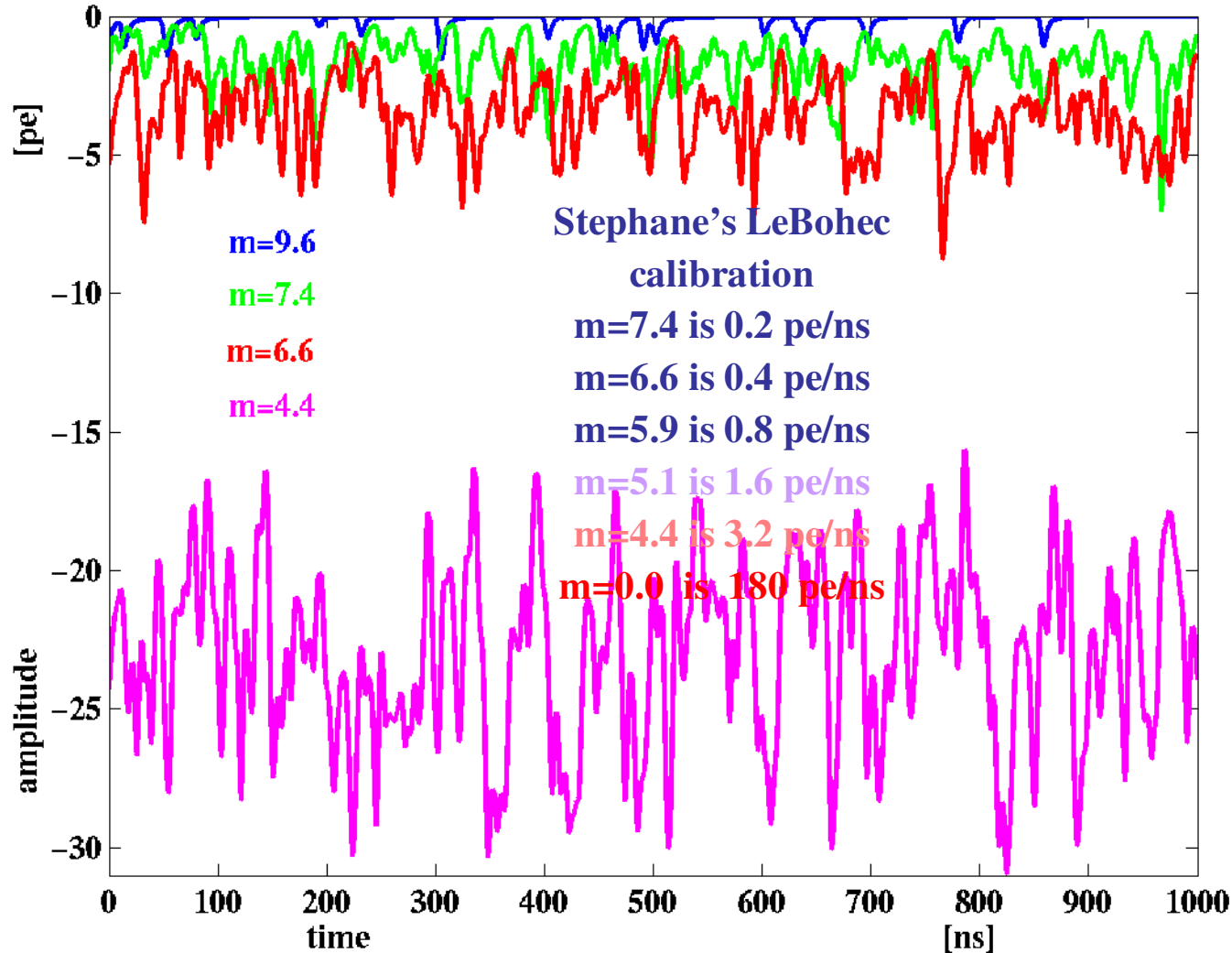
1 pe pulse: simulations



Night Sky Background (1)



Night Sky Background (2)



Statistical characteristics of NSB amplitude, $A(t)$.

1st momentum

$$\langle A(t) \rangle_{Av t} = \text{Rate} / 1 \text{ pe peak} \quad 1 \text{ pe peak} = 0.117 \text{ [ns}^{-1} \text{ pe}^{-1}]$$

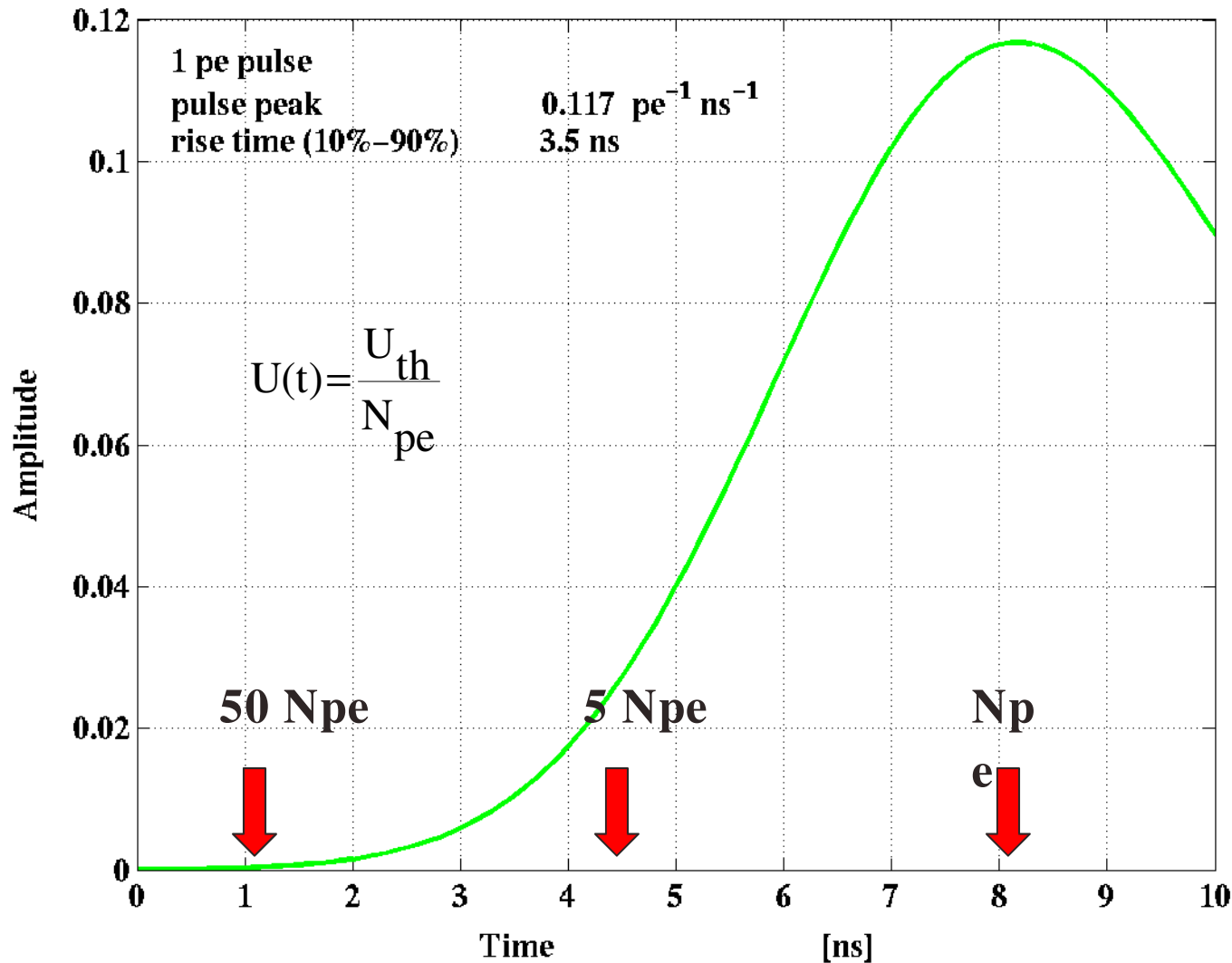
2nd momentum

$$\langle (A(t) - \langle A(t) \rangle_{Av t})^2 \rangle_{Av t} = a_2 \langle A(t) \rangle_{Av t} \quad a_2 = 0.62 \text{ [pe]}$$

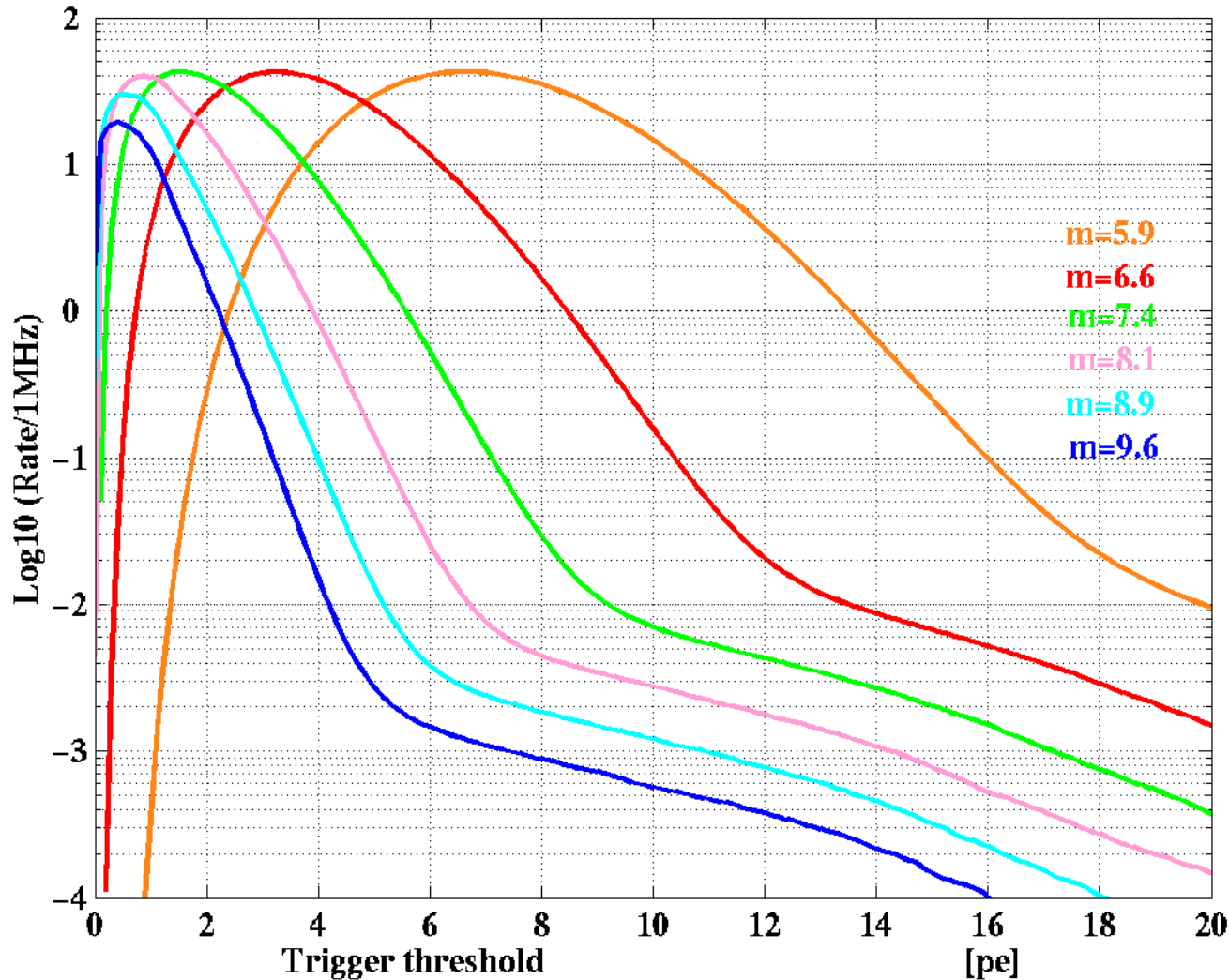
3rd momentum

$$\langle (A(t) - \langle A(t) \rangle_{Av t})^3 \rangle_{Av t} = a_3^2 \langle A(t) \rangle_{Av t} \quad a_3 = 0.81 \text{ [pe]}$$

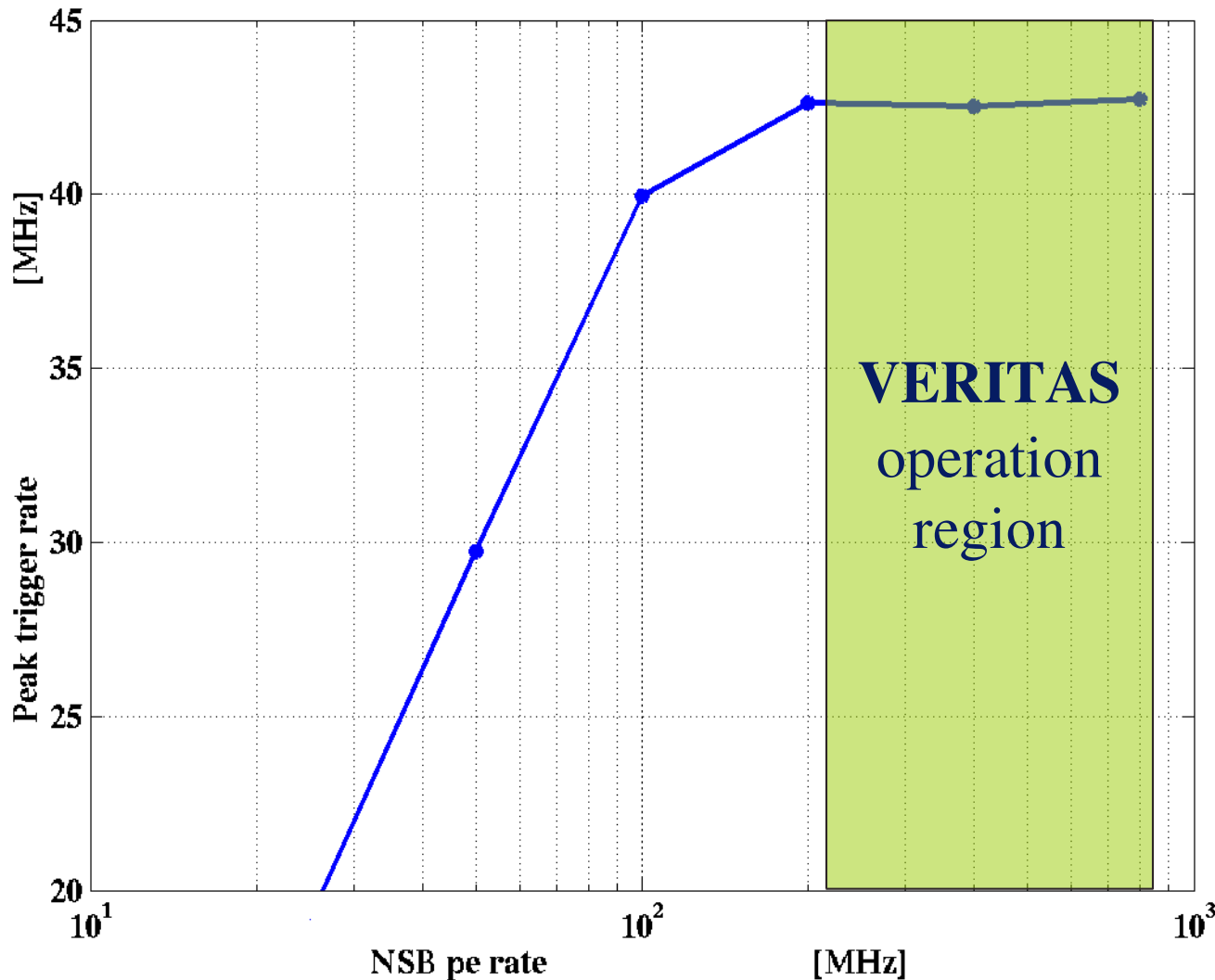
Threshold discriminator



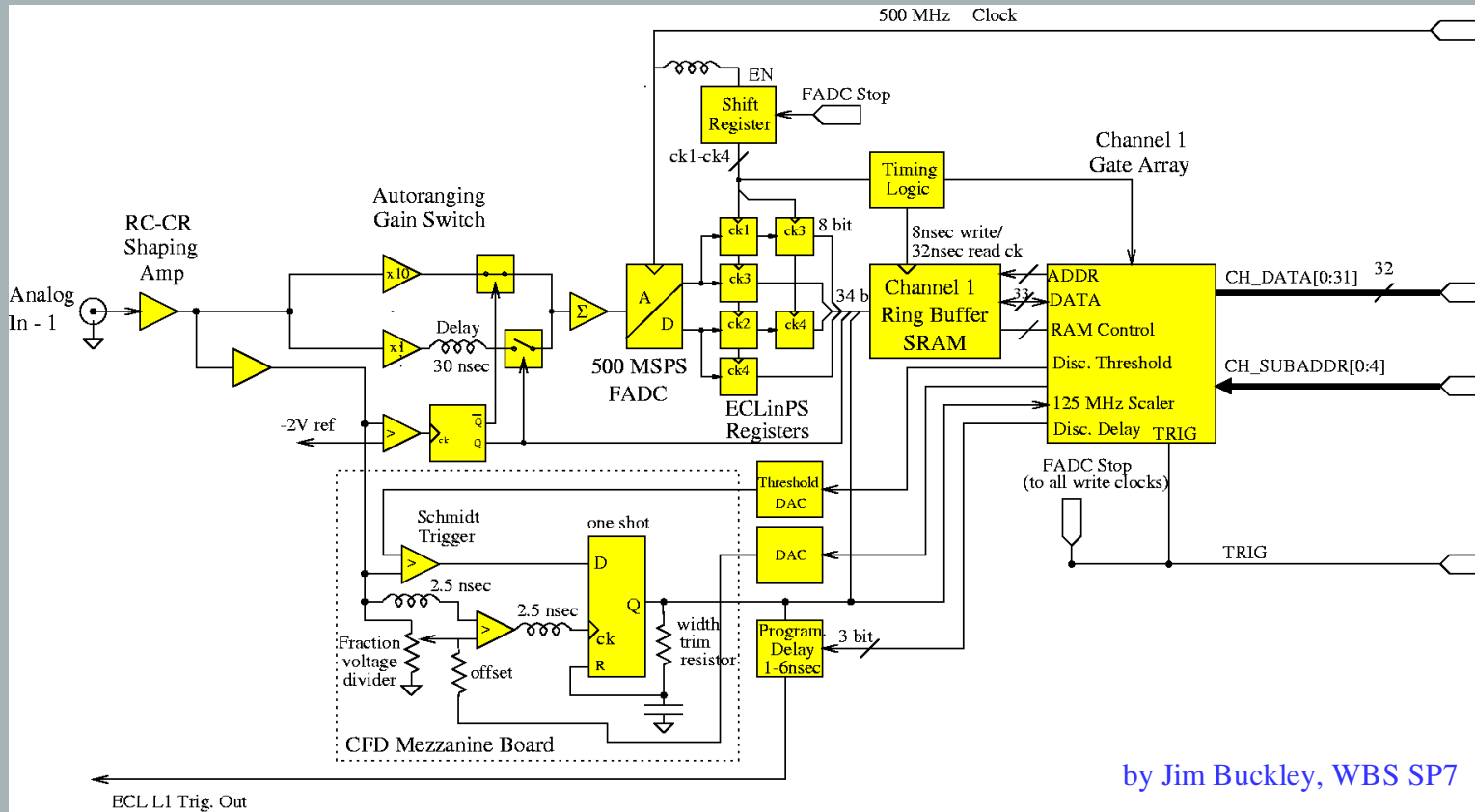
Threshold discriminator rate (positive edge)



Peak trigger rate (threshold discriminator)



CFD in fADC channel



by Jim Buckley, WBS SP7

Theory

$$-(1 + \frac{2}{3}) \cdot N_{pe} \cdot U(t - \tau) + \frac{2}{3} \cdot N_{pe} \cdot U(t) = 0$$

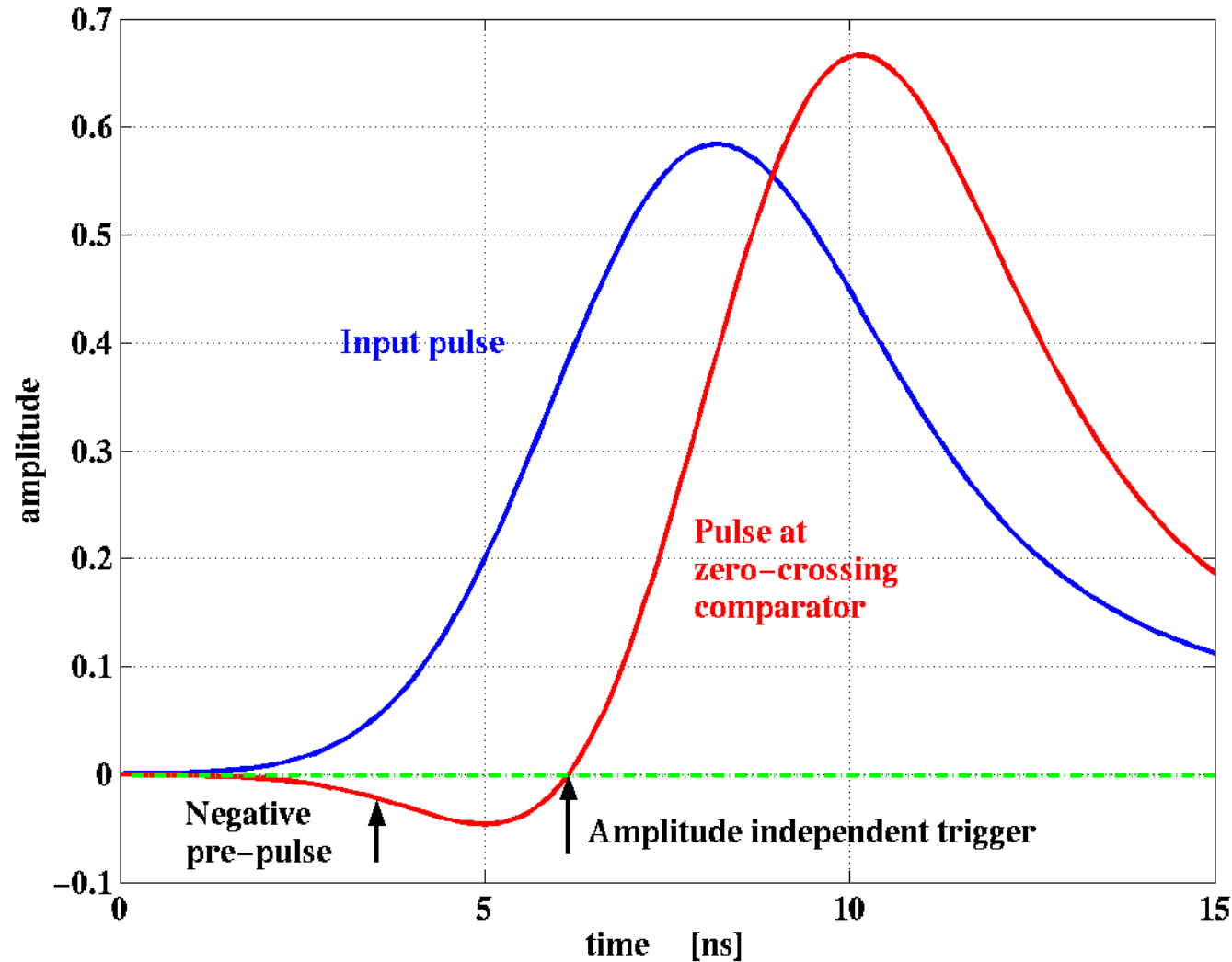
$$-(1 + \frac{2}{3}) \cdot U(t - \tau) + \frac{2}{3} \cdot U(t) = 0$$

Practice

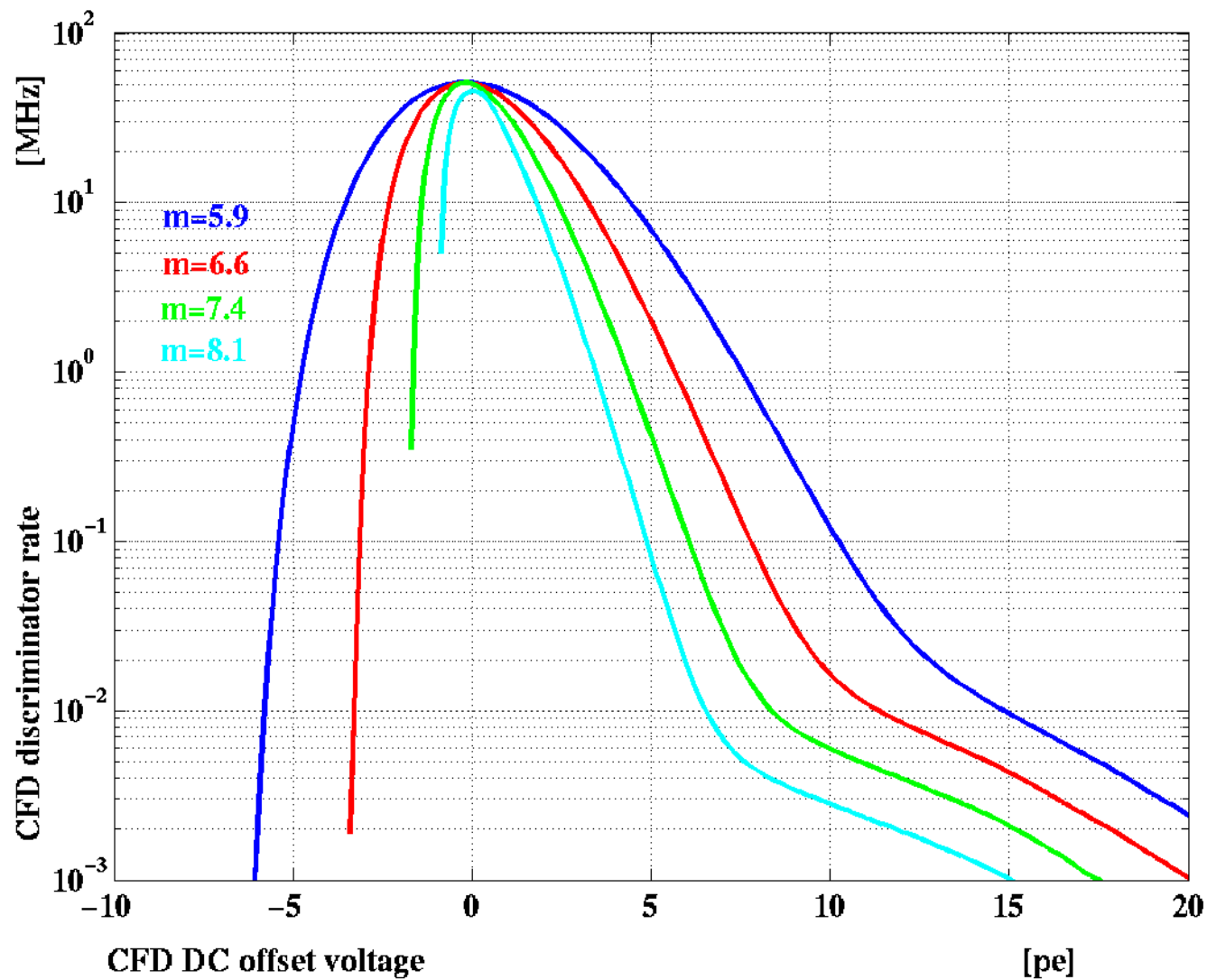
$$-(1 + \frac{2}{3}) \cdot N_{pe} \cdot U(t - \tau) + \frac{2}{3} \cdot N_{pe} \cdot U(t) = U_{dc} + noise^{(t)} + \sqrt{N_{pe}} \cdot U(t)$$

$$-(1 + \frac{2}{3}) \cdot U(t - \tau) + \frac{2}{3} \cdot U(t) = \frac{U_{dc}}{N_{pe}} + \frac{noise^{(t)}}{N_{pe}} + \sqrt{\frac{1}{N_{pe}}} \cdot U(t)$$

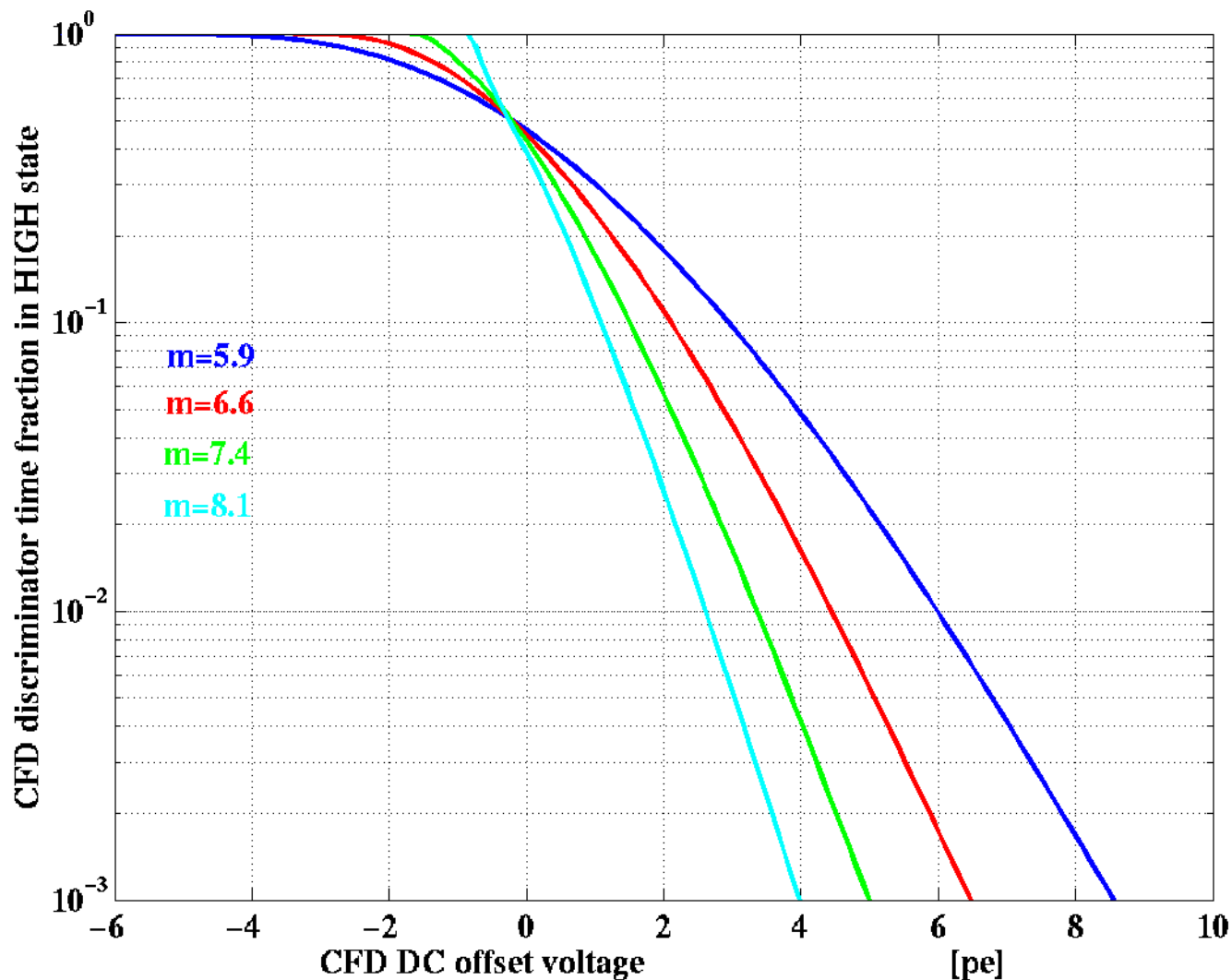
CFD principle



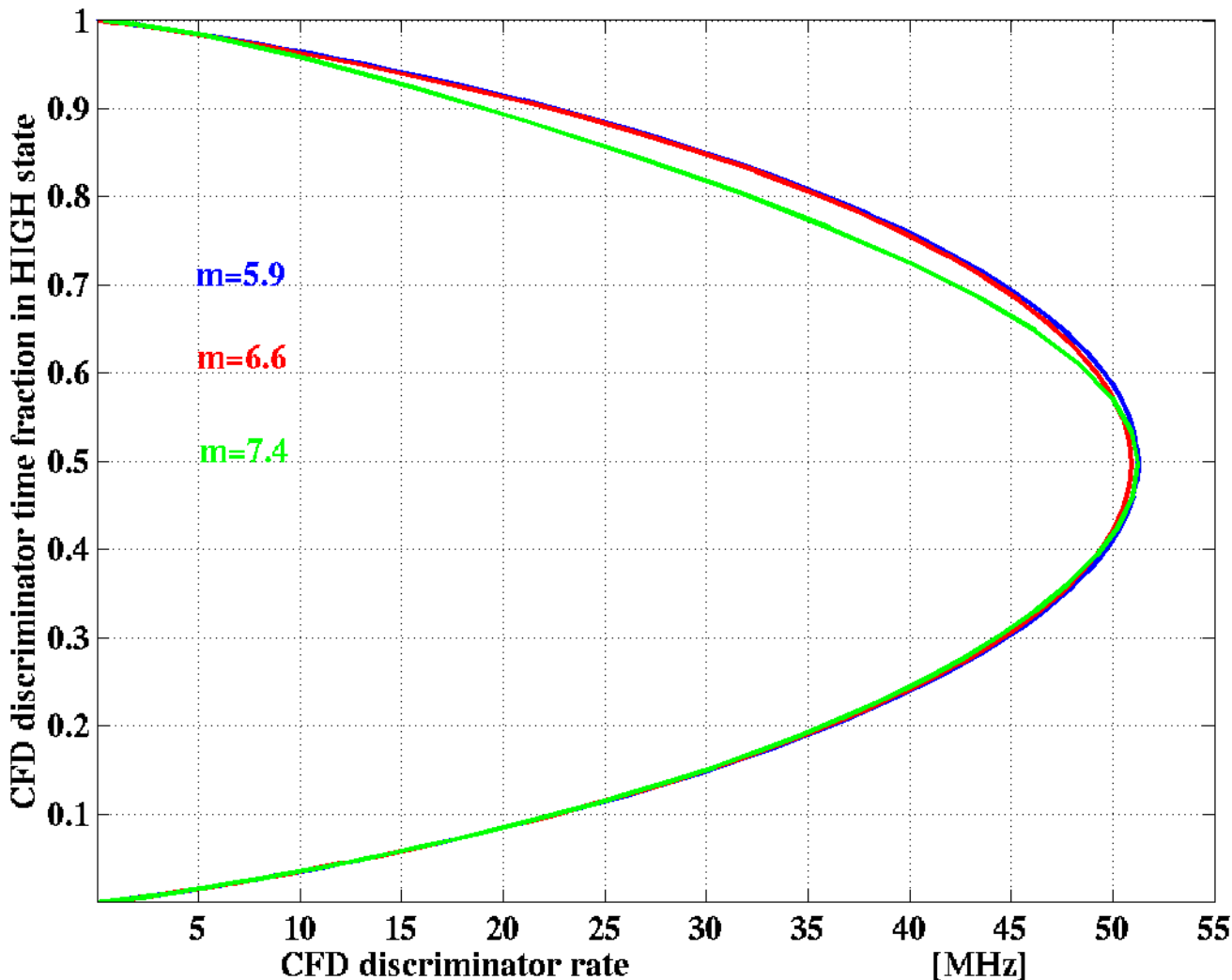
CF discriminator: rate vs. offset



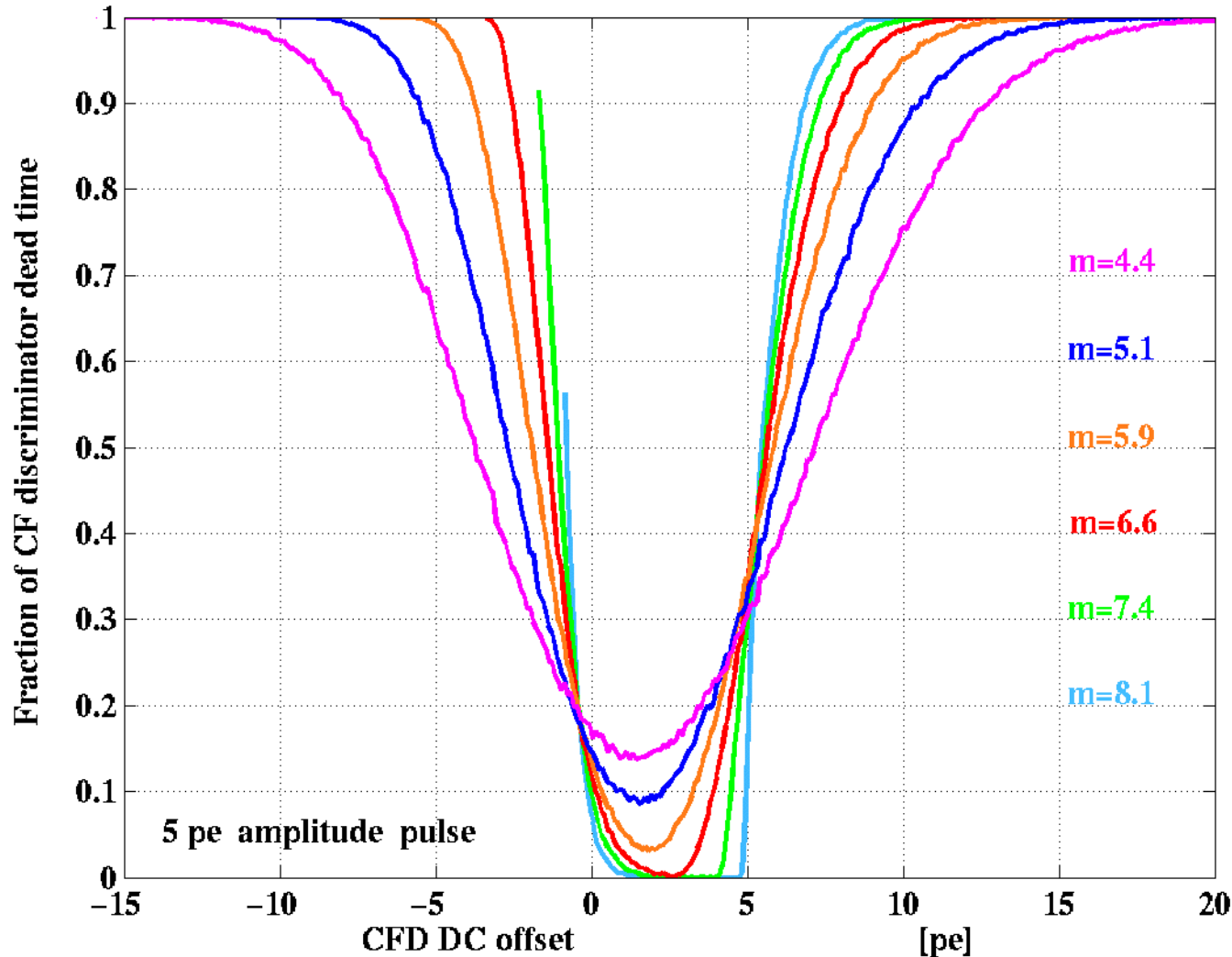
CF discriminator: HIGH state time fraction vs. offset



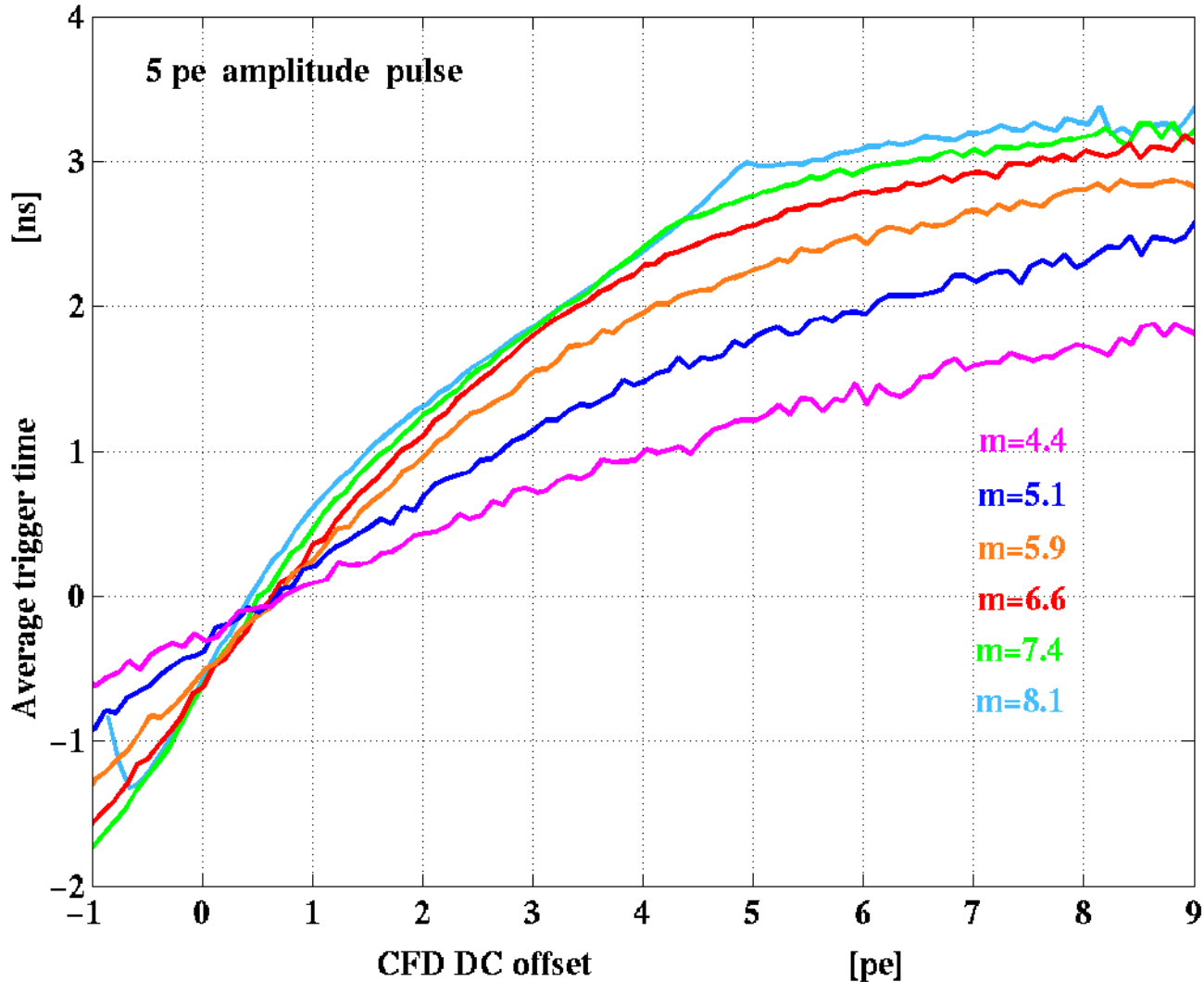
CFD: HIGH state time fraction vs. rate



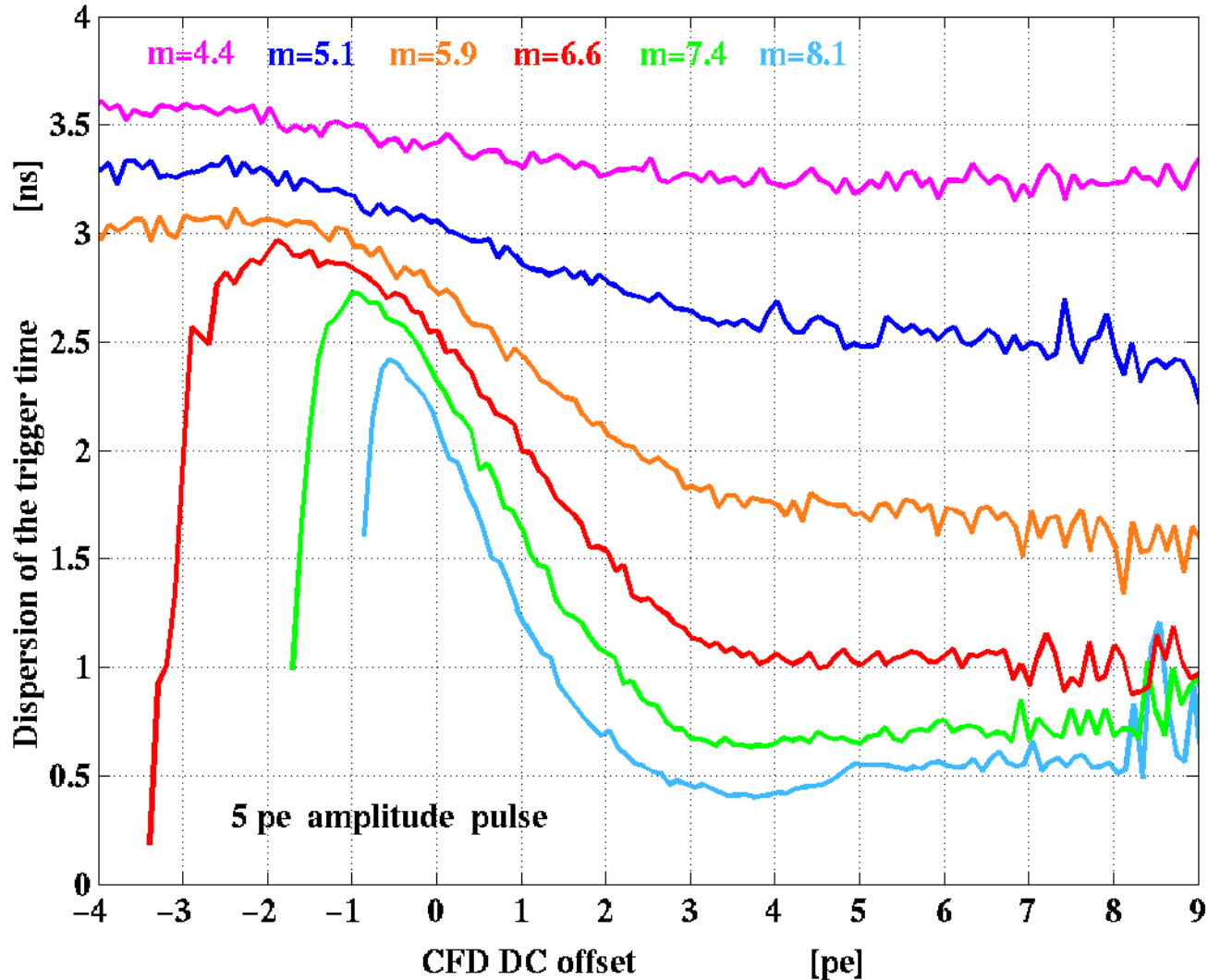
CF discriminator dead time



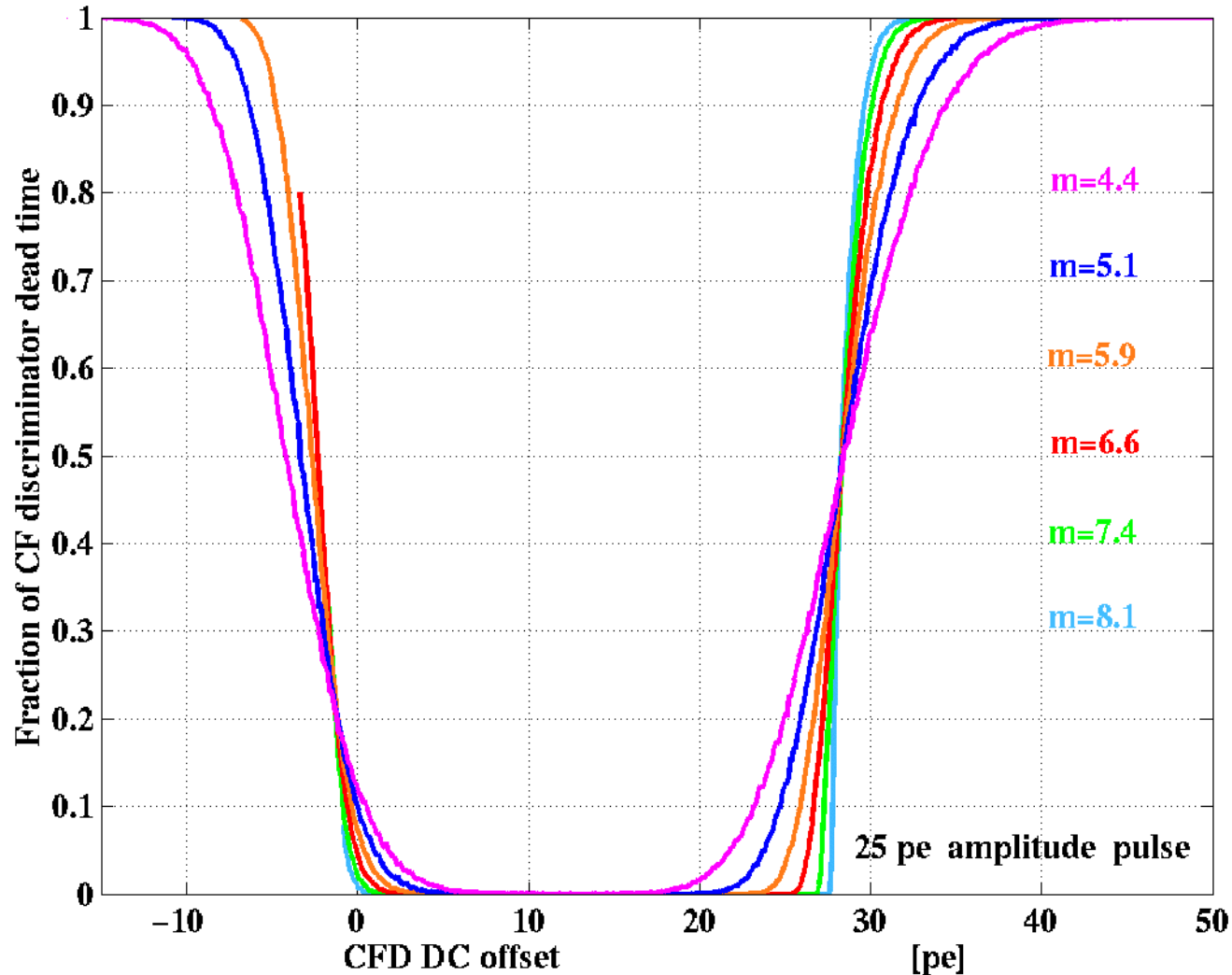
CF discriminator time walk



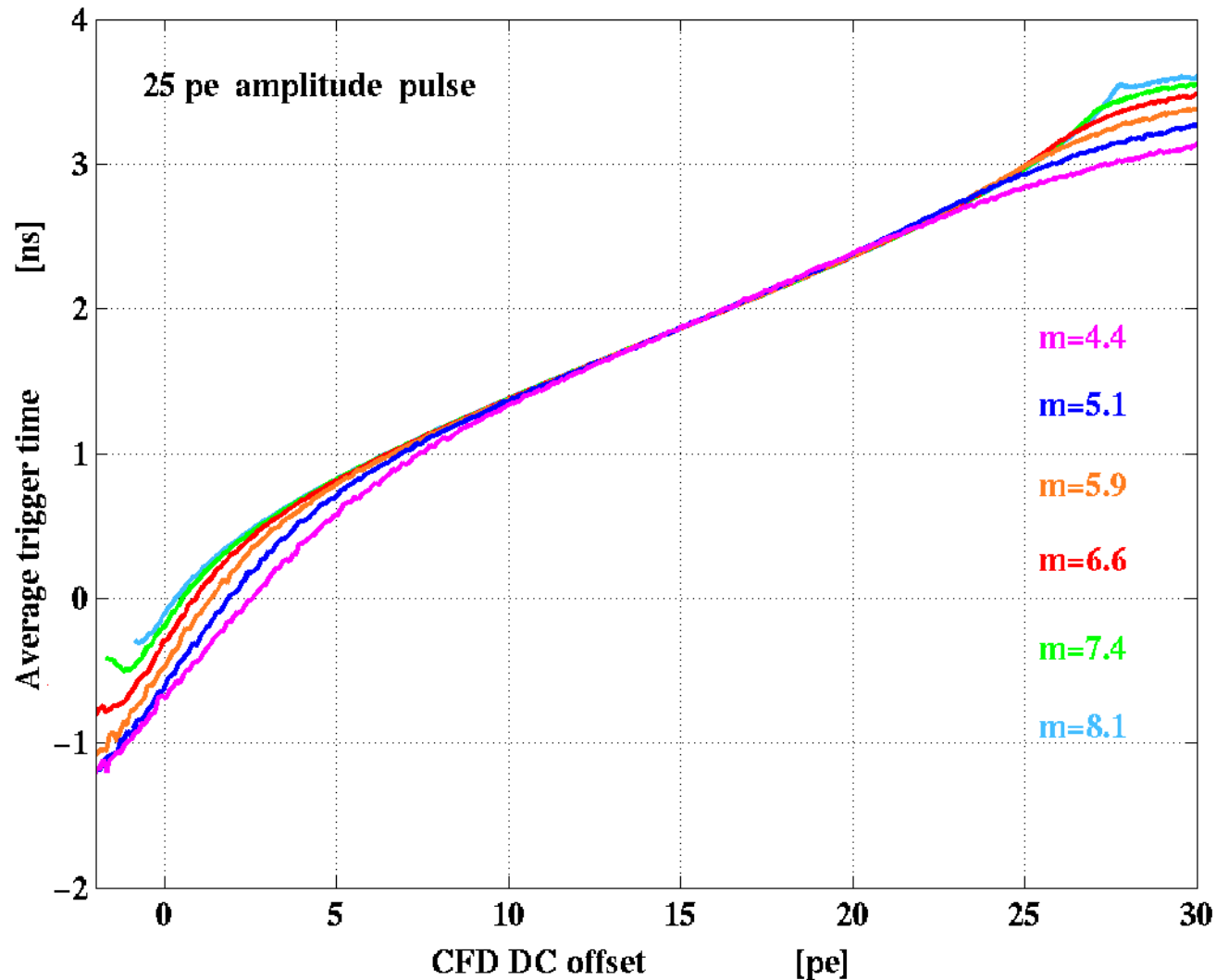
CFD discriminator time dispersion



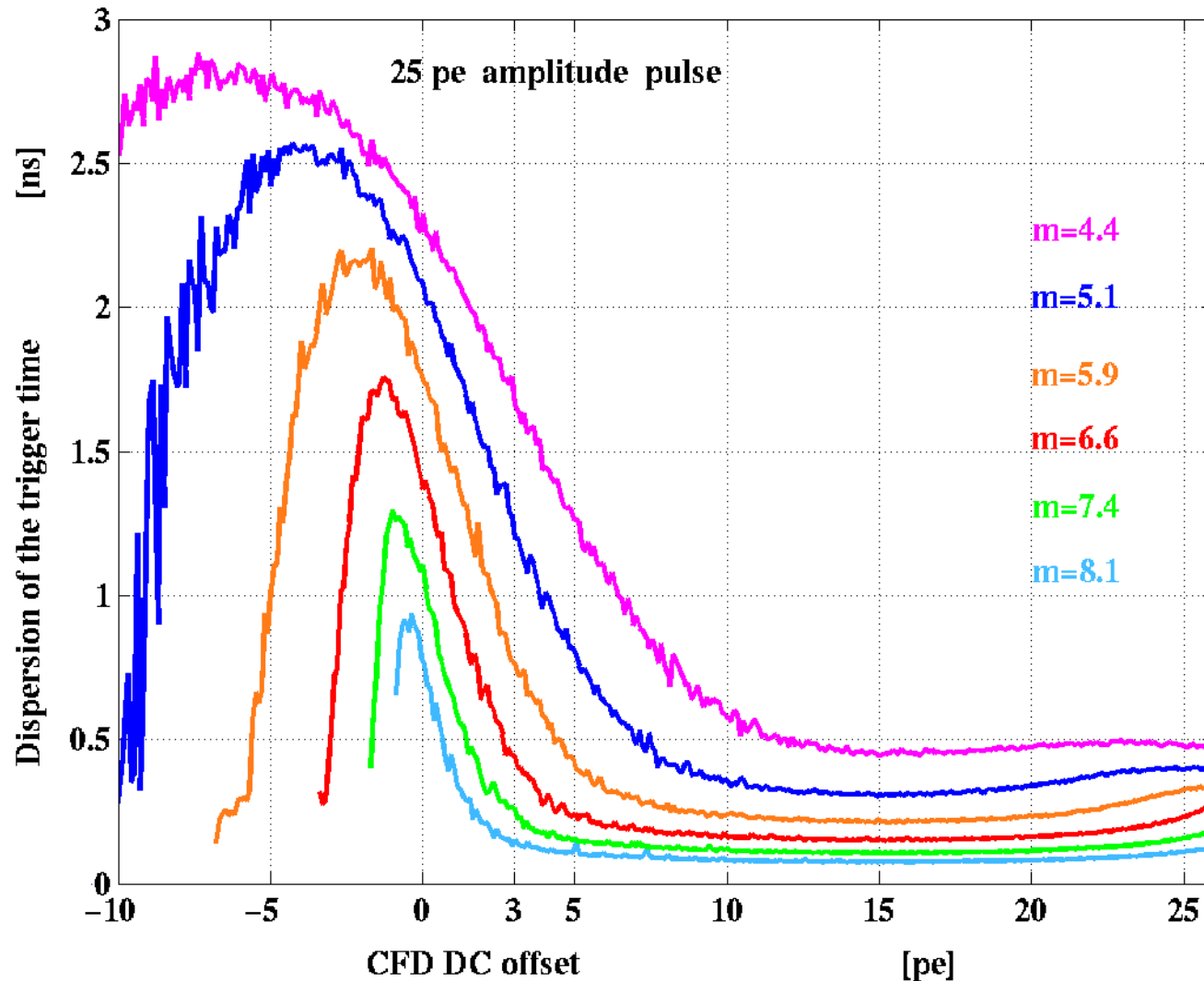
CF discriminator dead time



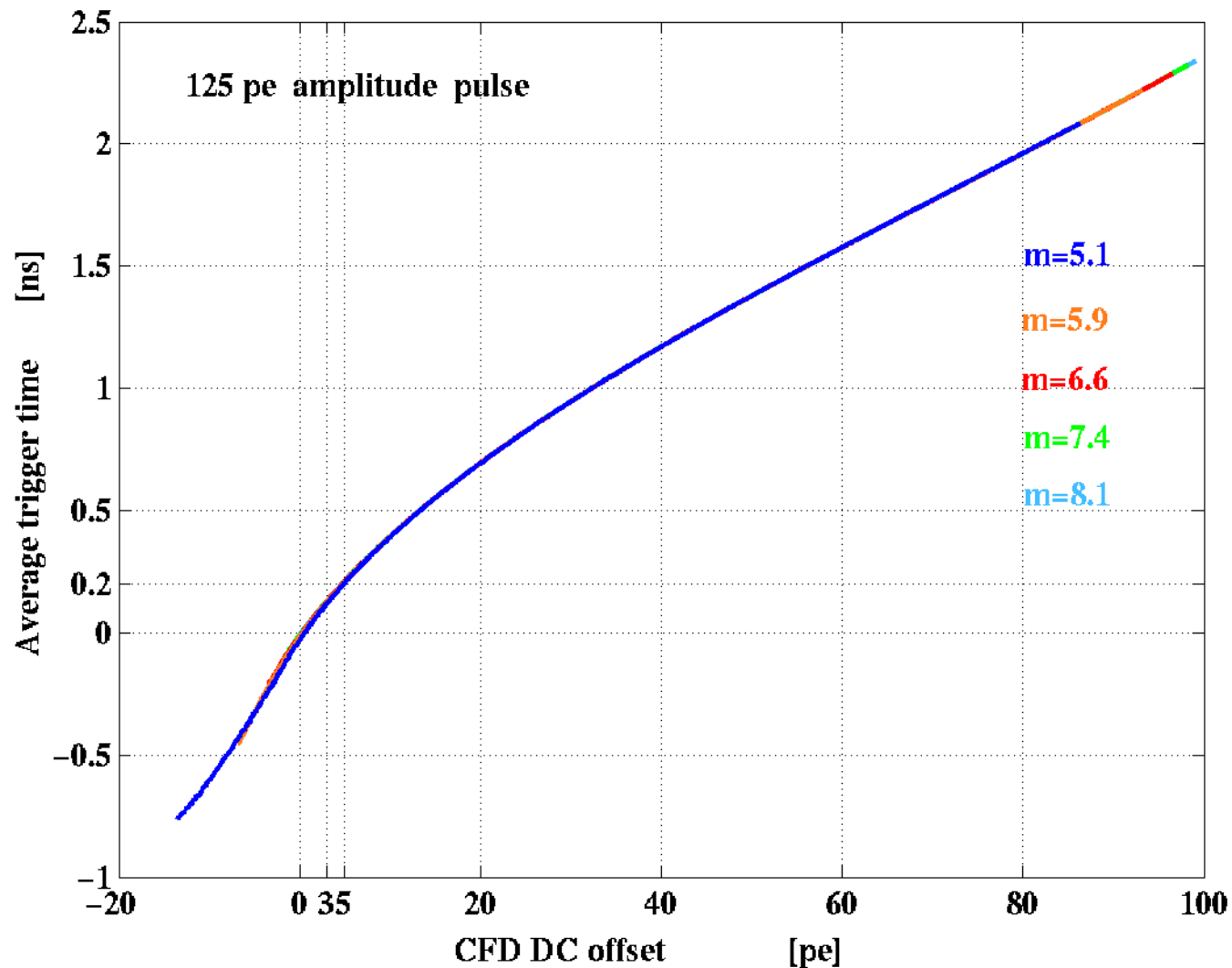
CF discriminator time walk



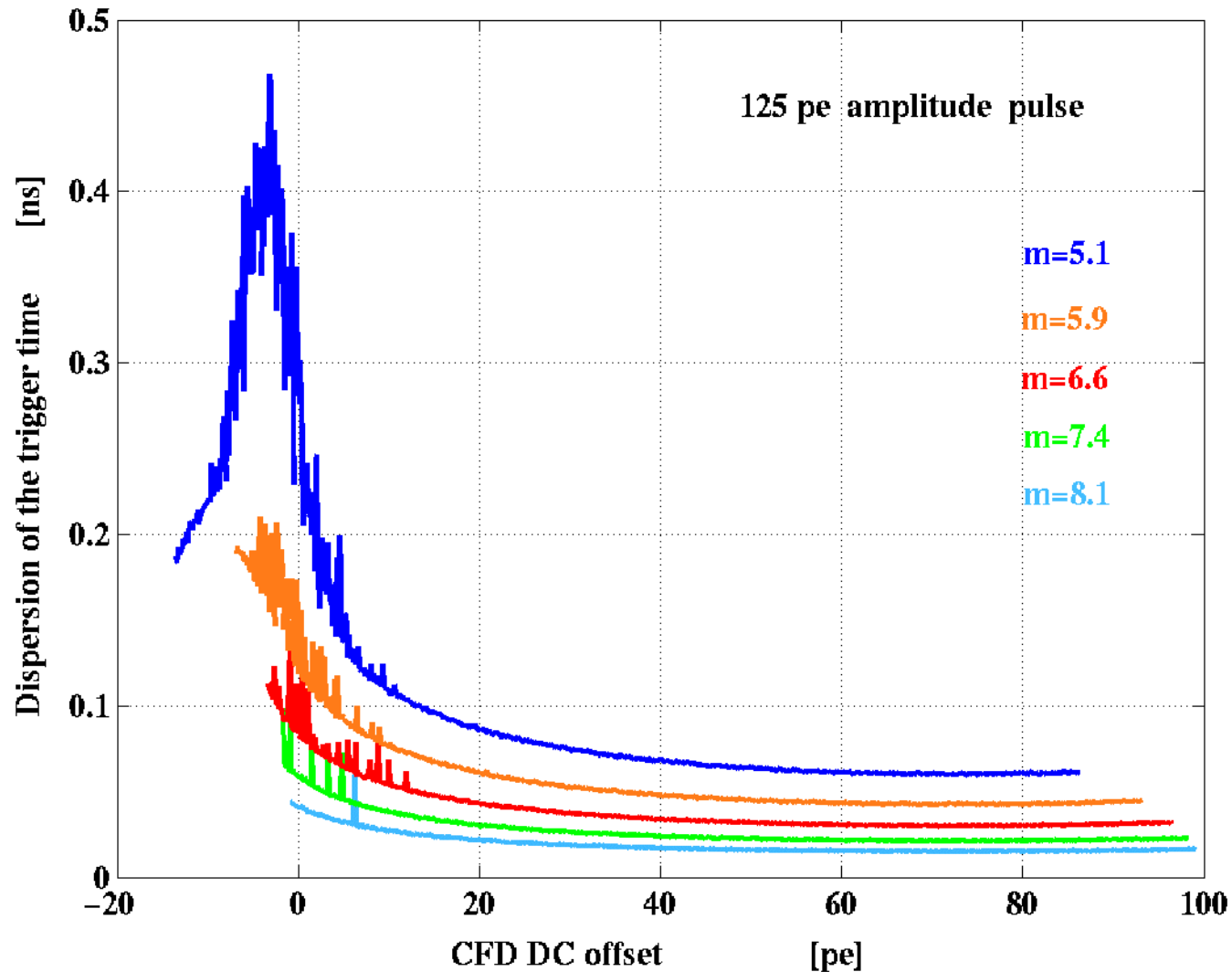
CF discriminator time dispersion



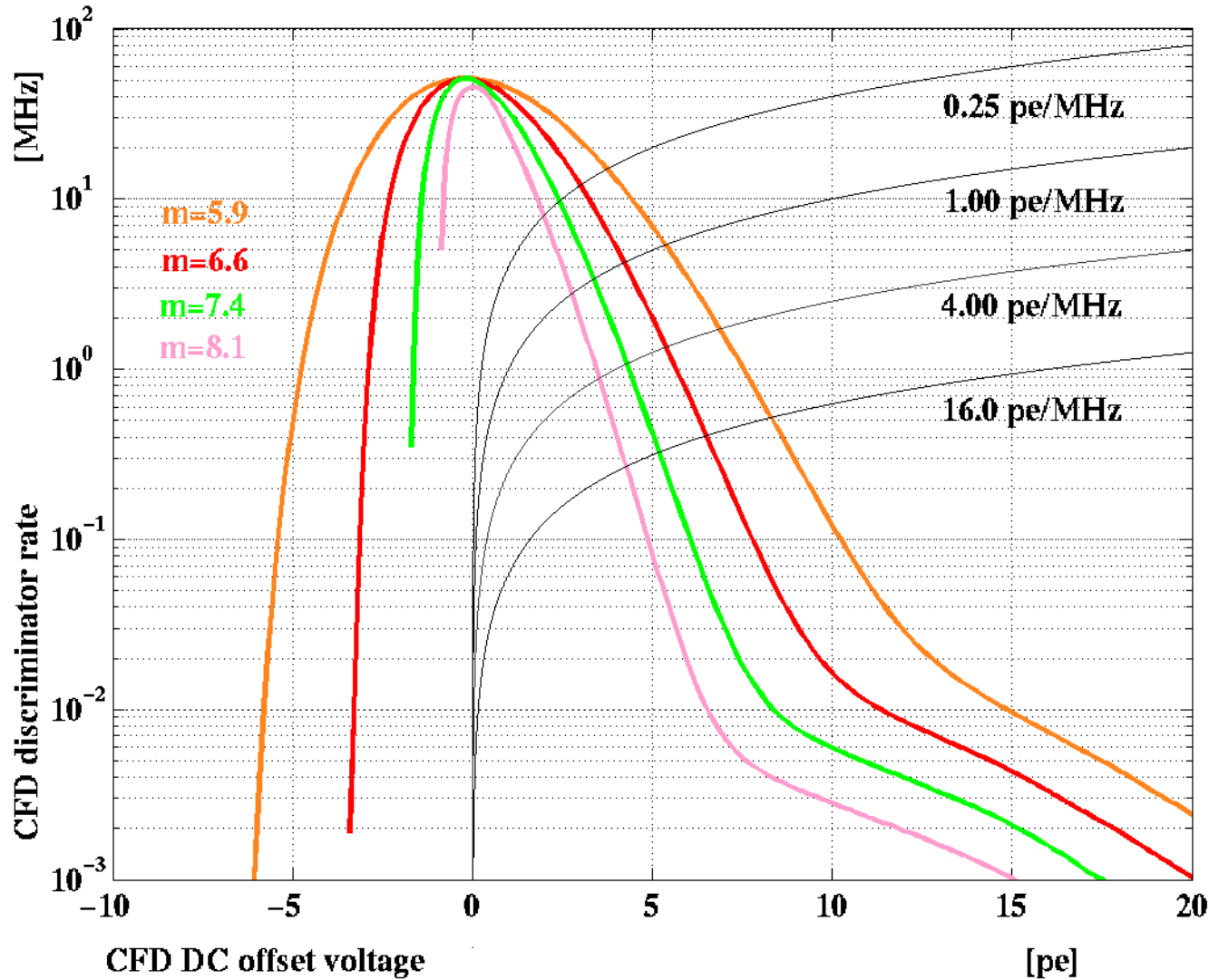
CF discriminator time walk



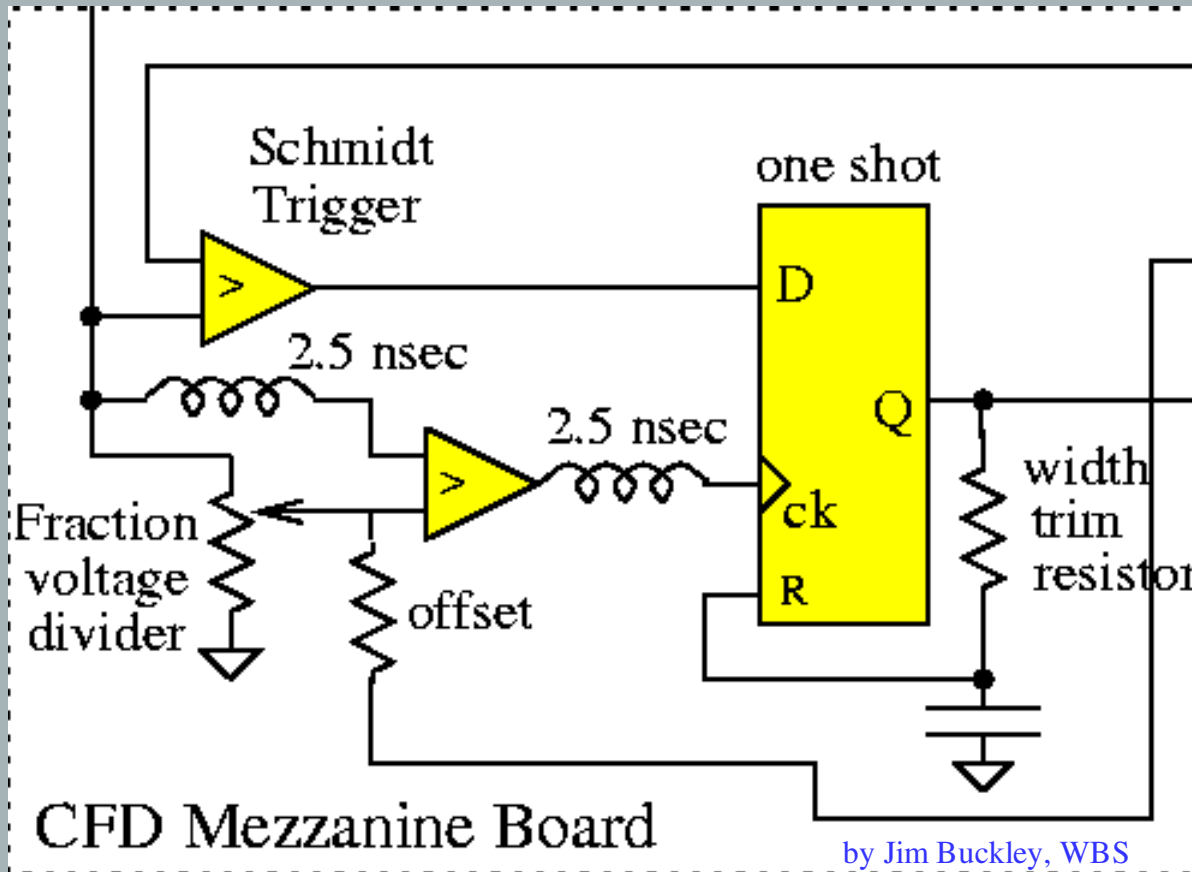
CFD discriminator time dispersion



Frequency to voltage feedback



Original CFD board design



Board Fabrication: \$18.70

Board Stuffing: \$27.50

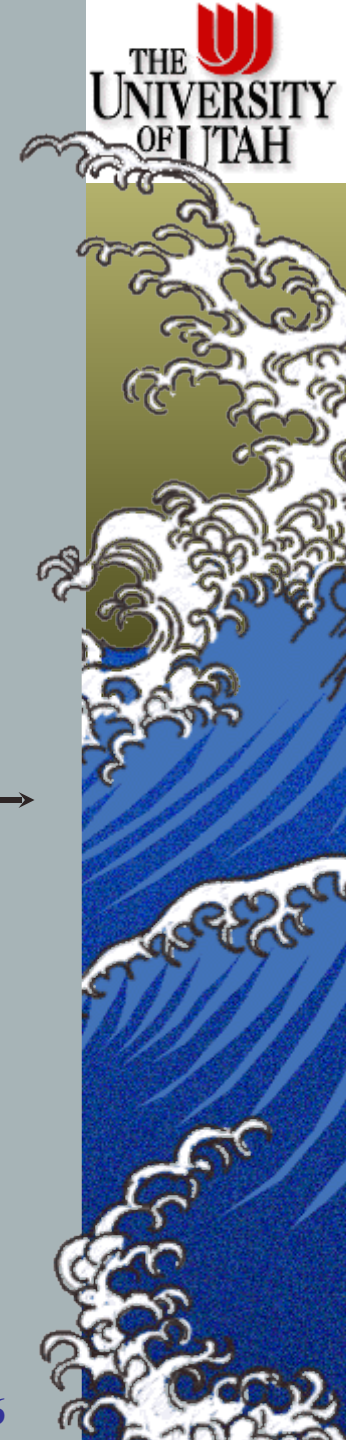
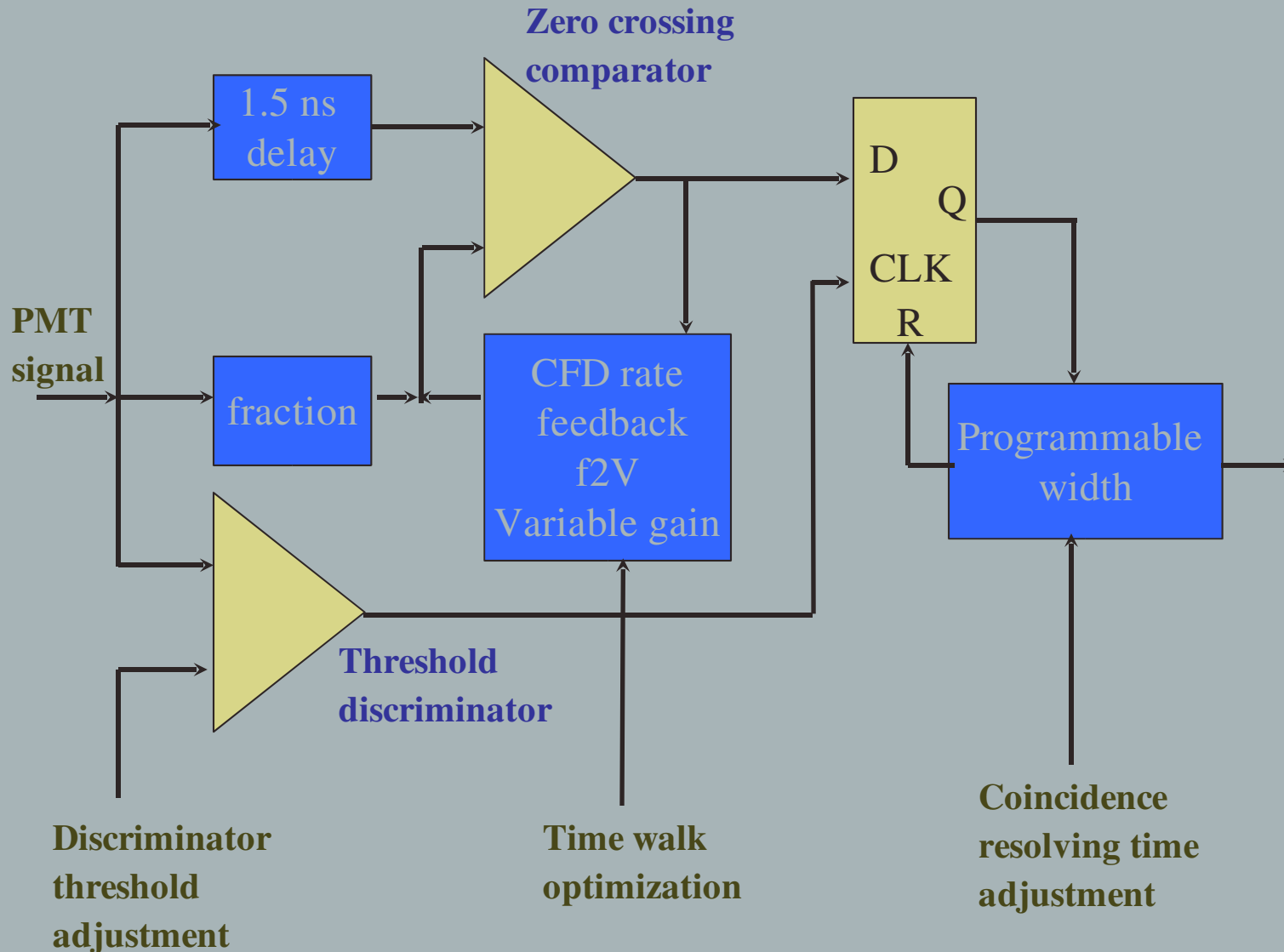
Board Components: \$22.80

WBS budget per board: \$69.00

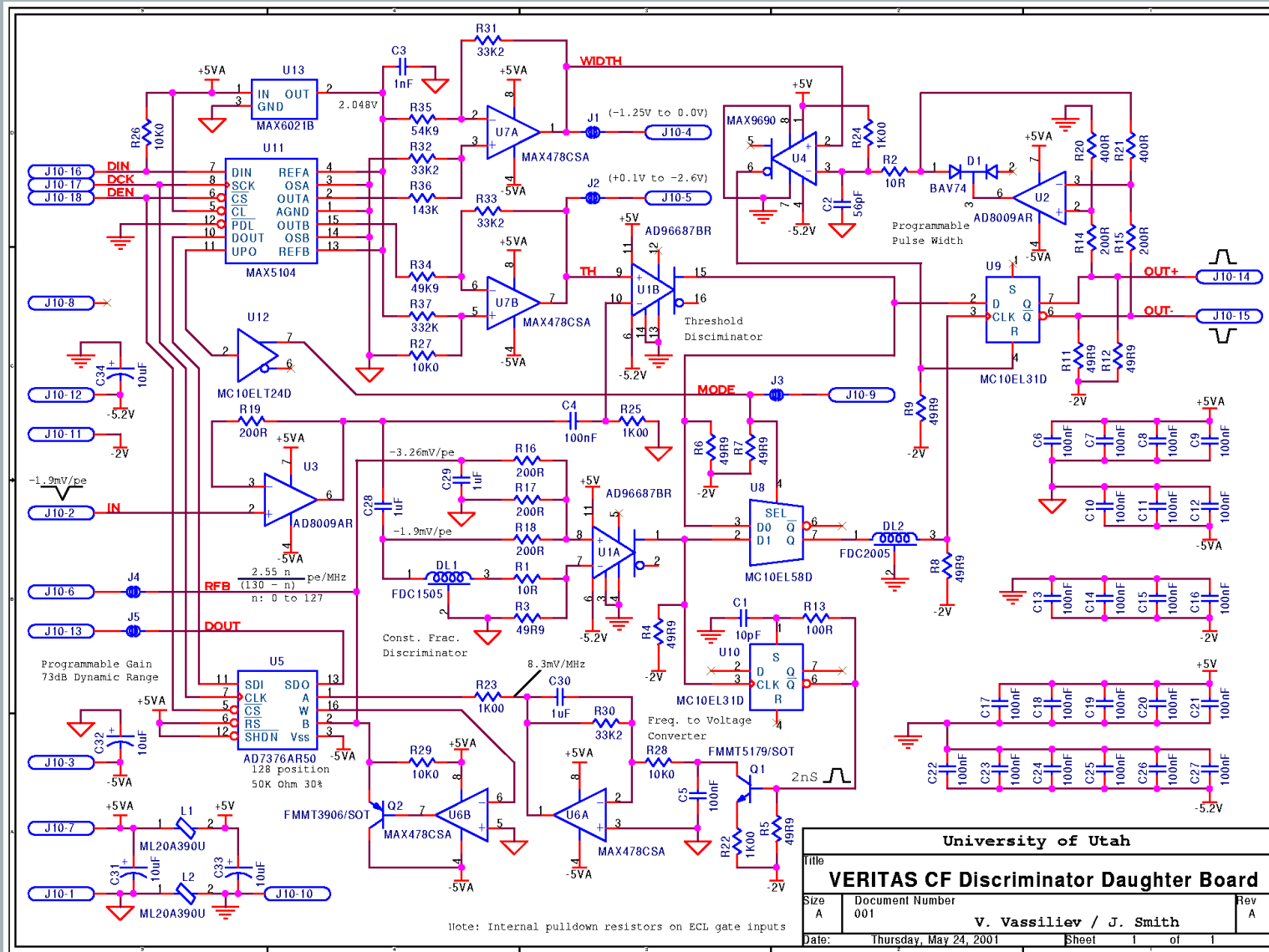
Total for 3,500 boards: \$241.5K

Total for CFDs in WBS: \$308.2K

CFD Functional Schematic

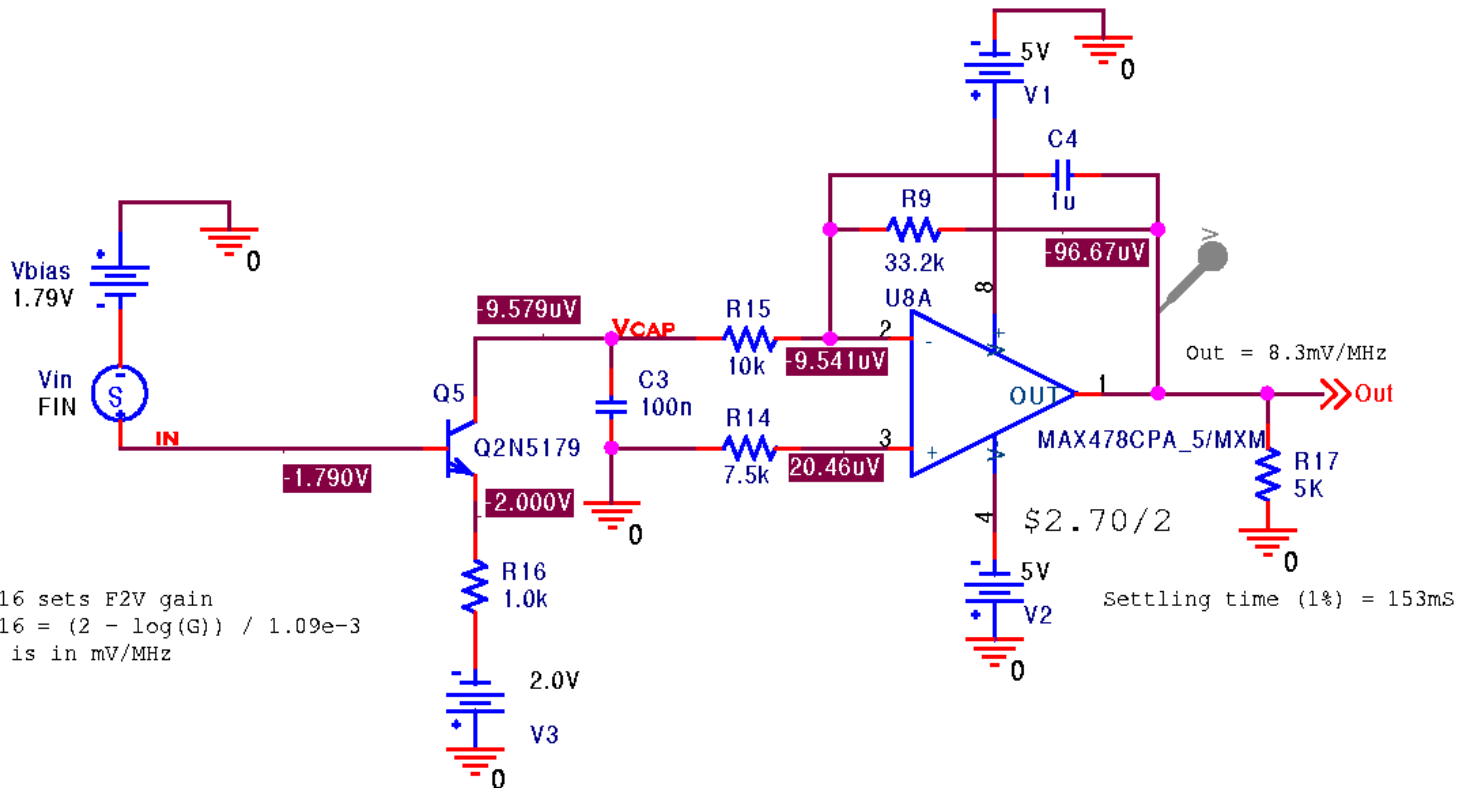


CFD board schematic

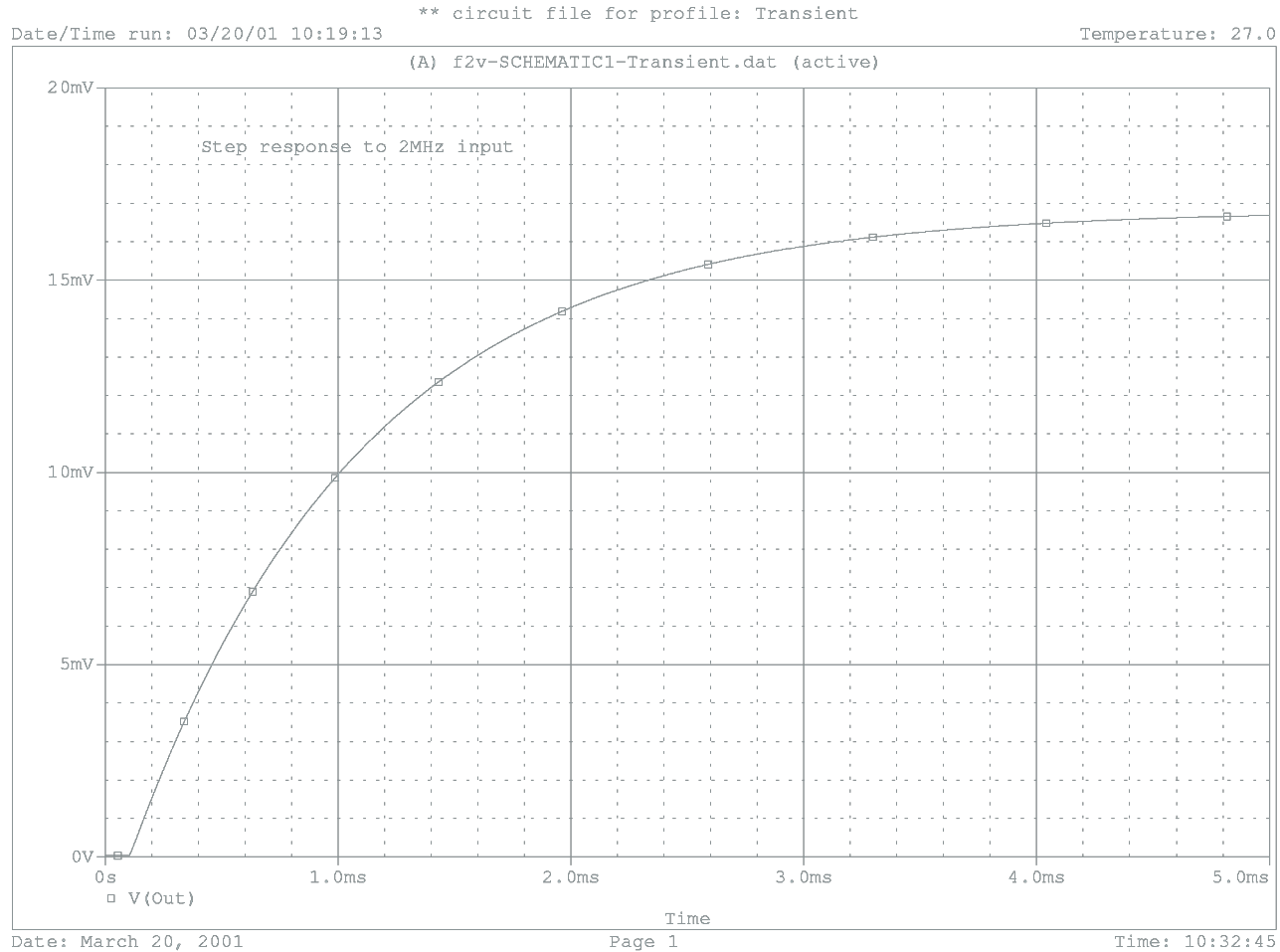


f2V SPICE simulations

Frequency to Voltage Converter

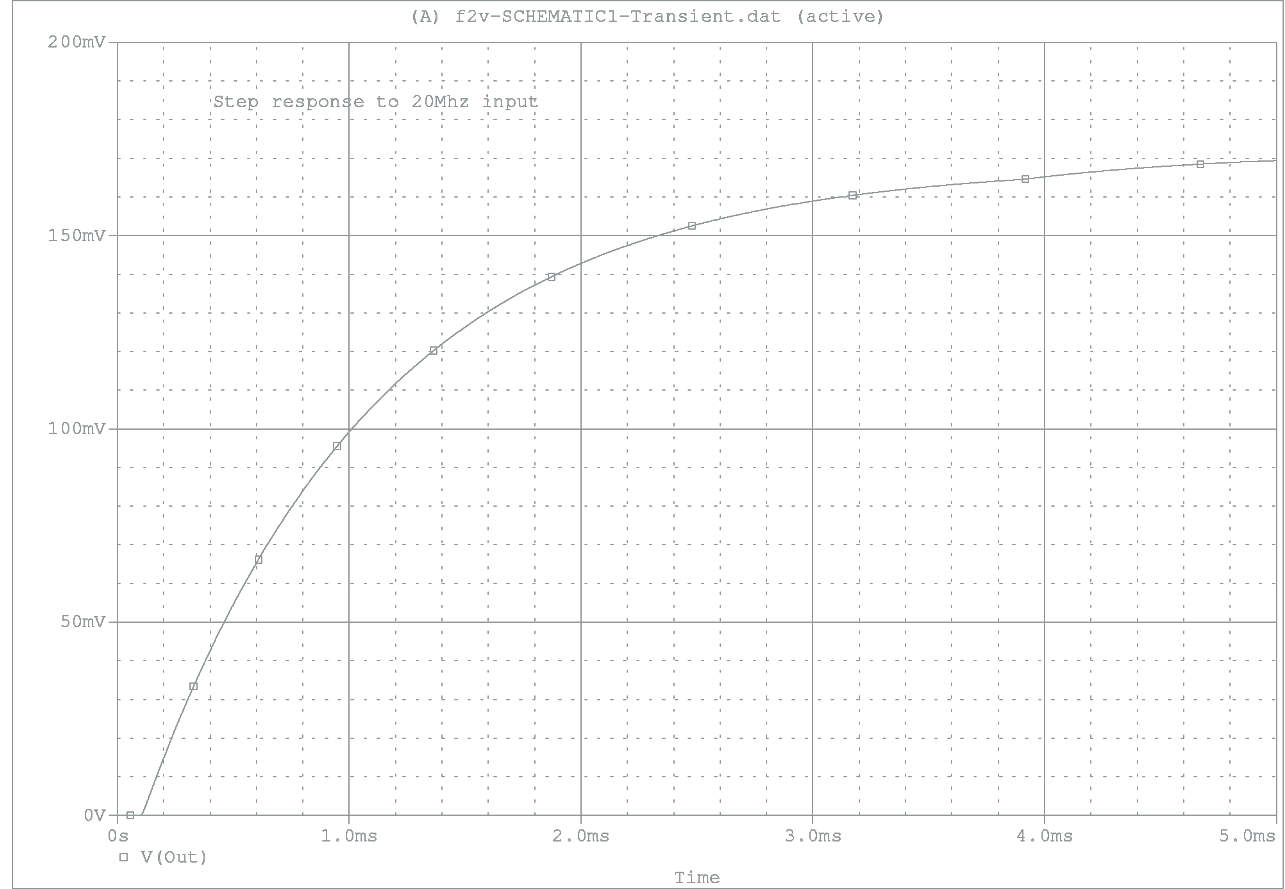


f2V 2MHz input



f2V 20MHz input

Date/Time run: 03/20/01 10:34:30 ** circuit file for profile: Transient Temperature: 27.0



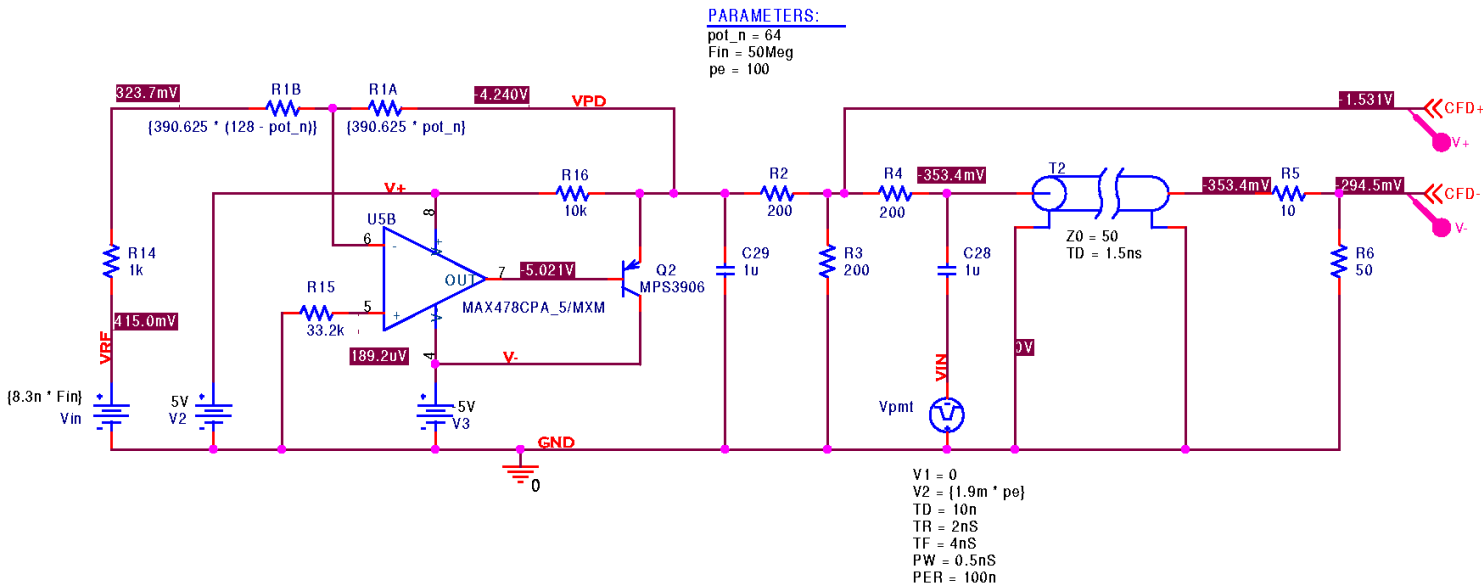
Date: March 20, 2001

Page 1

Time: 13:14:42



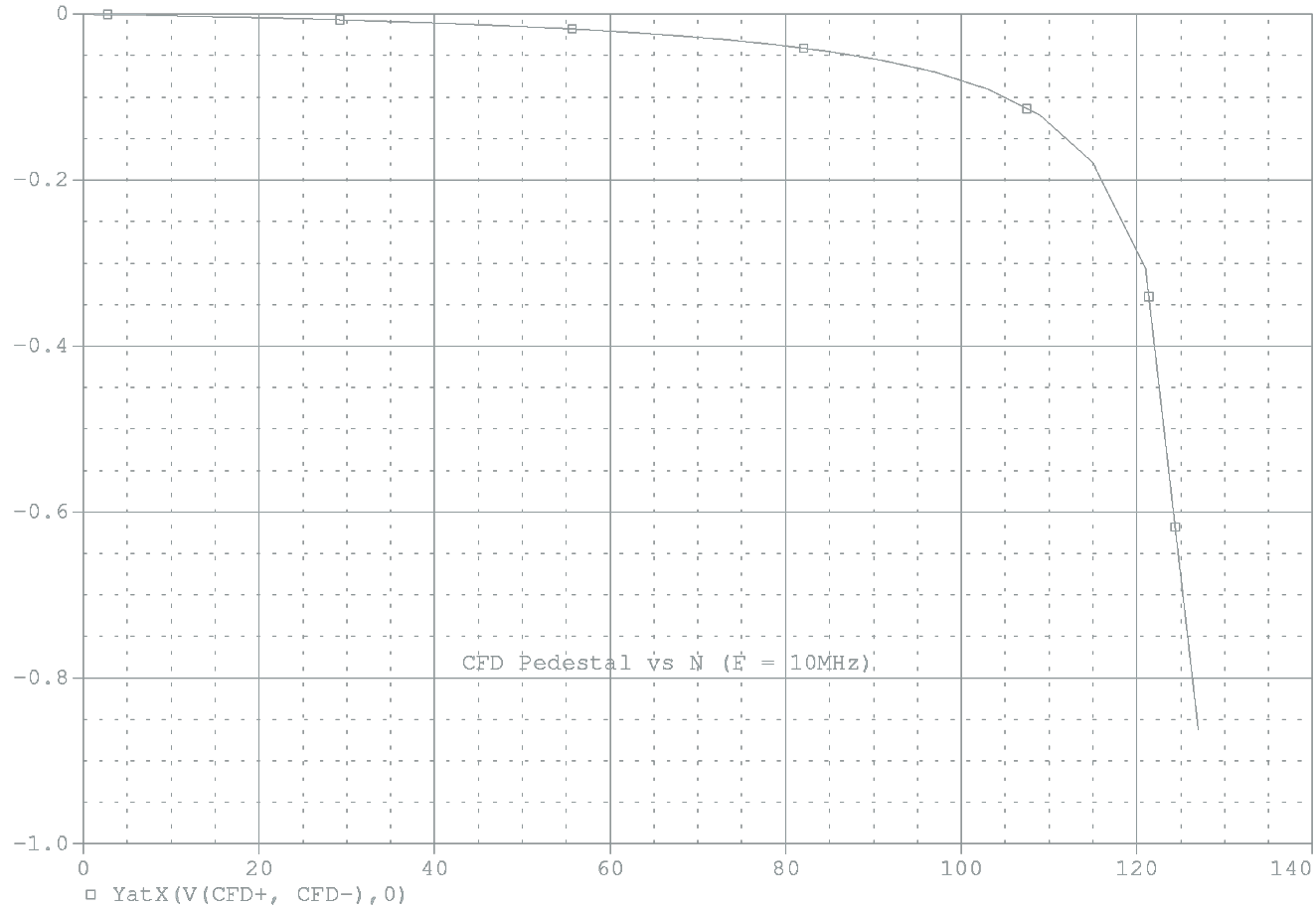
Variable Gain Circuit



Variable Gain (10 MHz)

** circuit file for profile: f2v_sweep
Date/Time run: 04/26/01 16:33:51 Temperature: 27.0

(B) progattn-SCHEMATIC1-f2v_sweep.dat (active)



Date: April 26, 2001

pot_n
Page 1

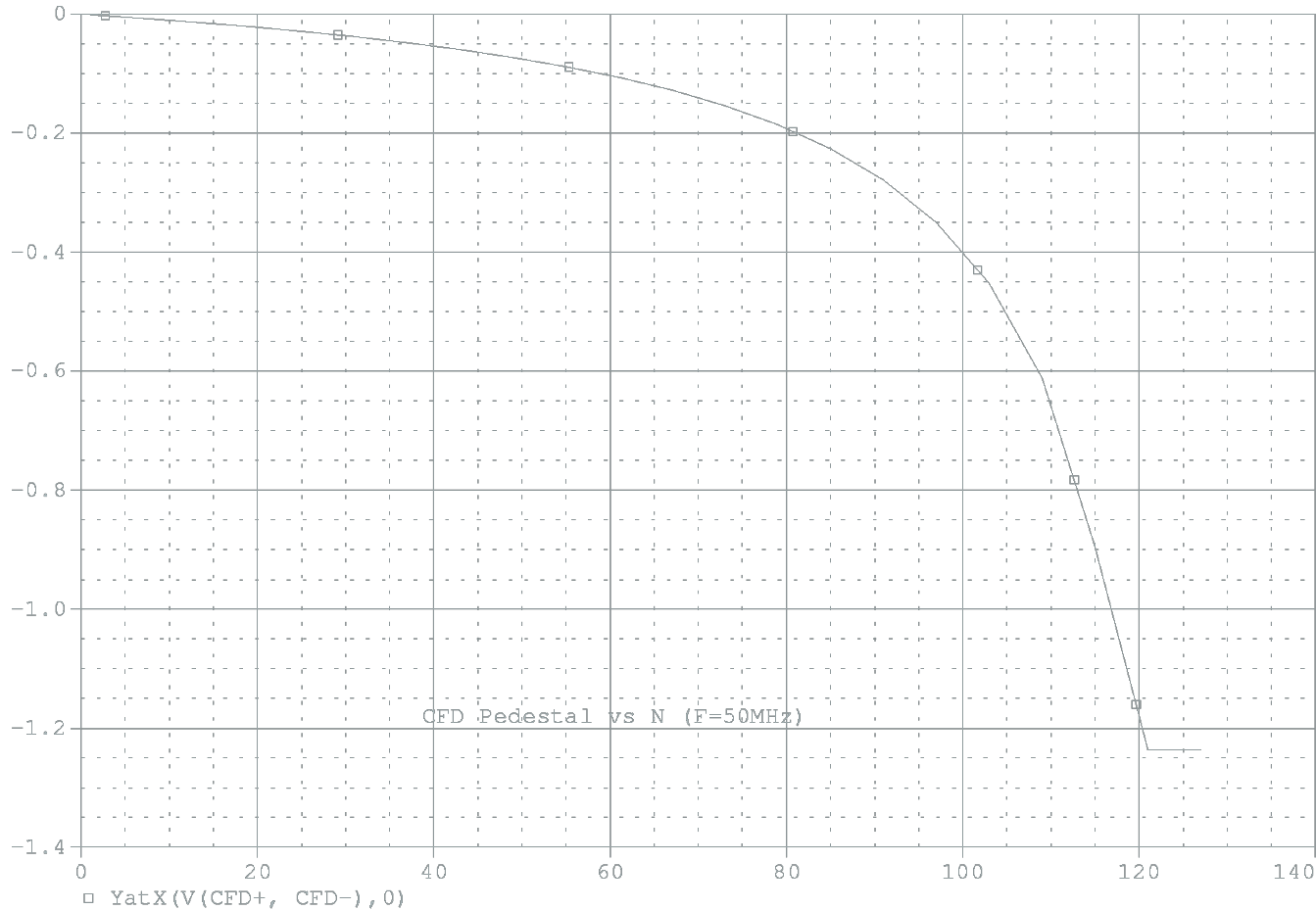
Time: 16:38:59



Variable Gain (50 MHz)

** circuit file for profile: f2v_sweep
Date/Time run: 04/26/01 16:00:59 Temperature: 27.0

(B) progattn-SCHEMATIC1-f2v_sweep.dat (active)



CFD Pedestal vs N (F=50MHz)

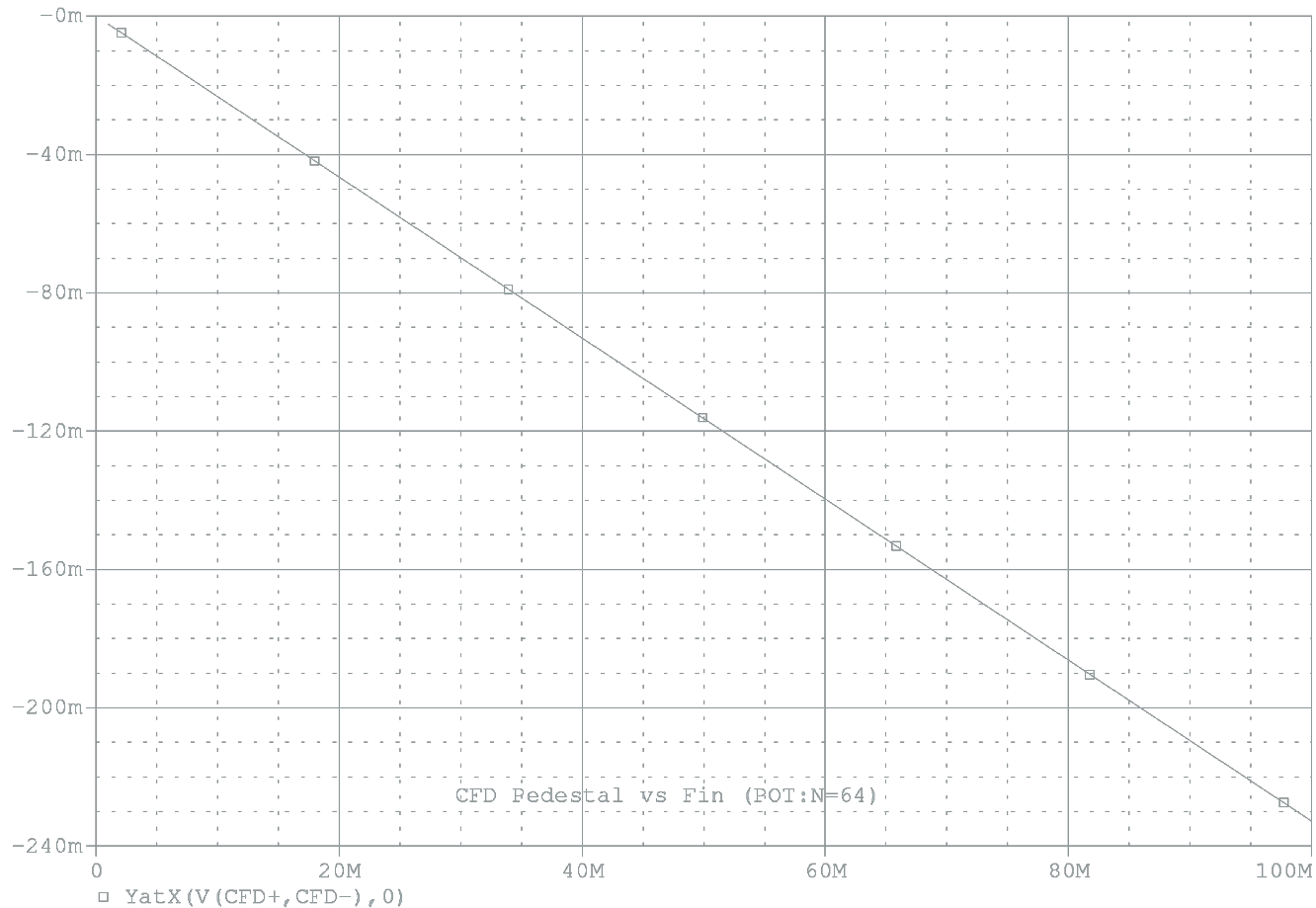
Date: April 26, 2001

pot_n
Page 1

Time: 16:33:29

Variable Gain (n=64)

** circuit file for profile: f2v_sweep
Date/Time run: 04/26/01 16:42:51 Temperature: 27.0
(B) progattn-SCHMATIC1-f2v_sweep.dat (active)



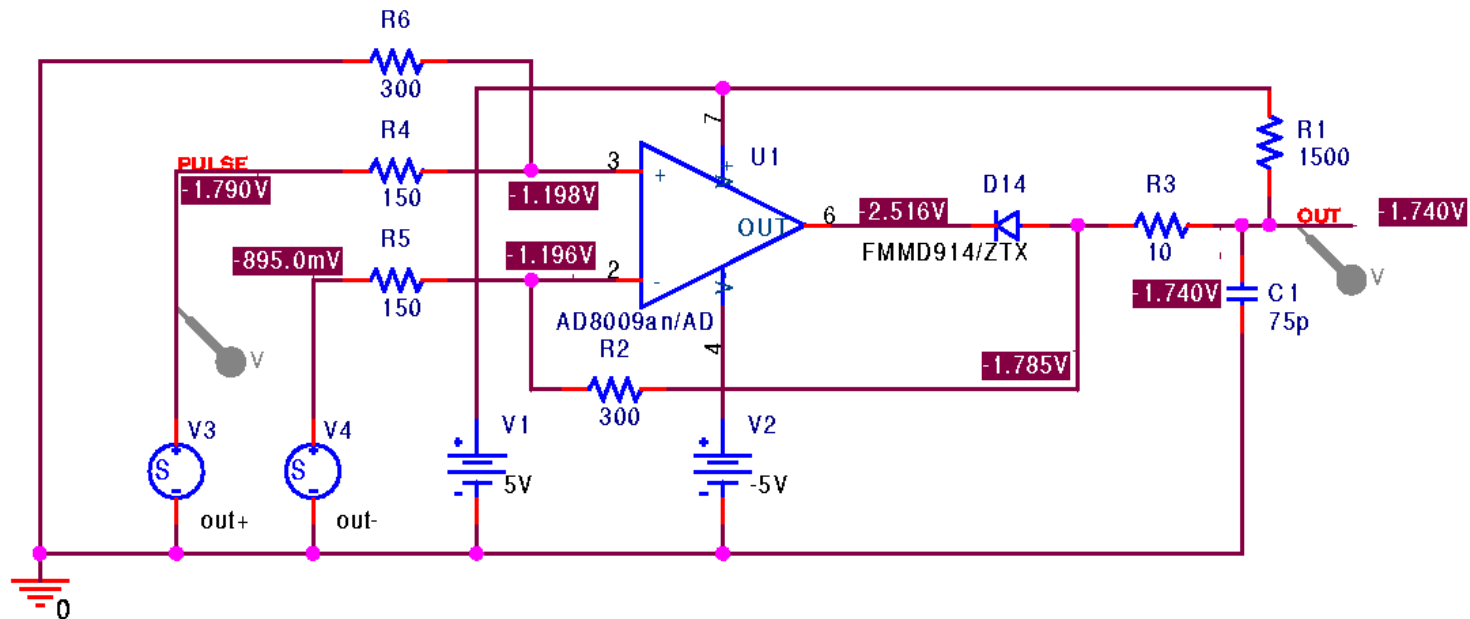
Date: April 26, 2001

Page 1

Time: 16:47:25

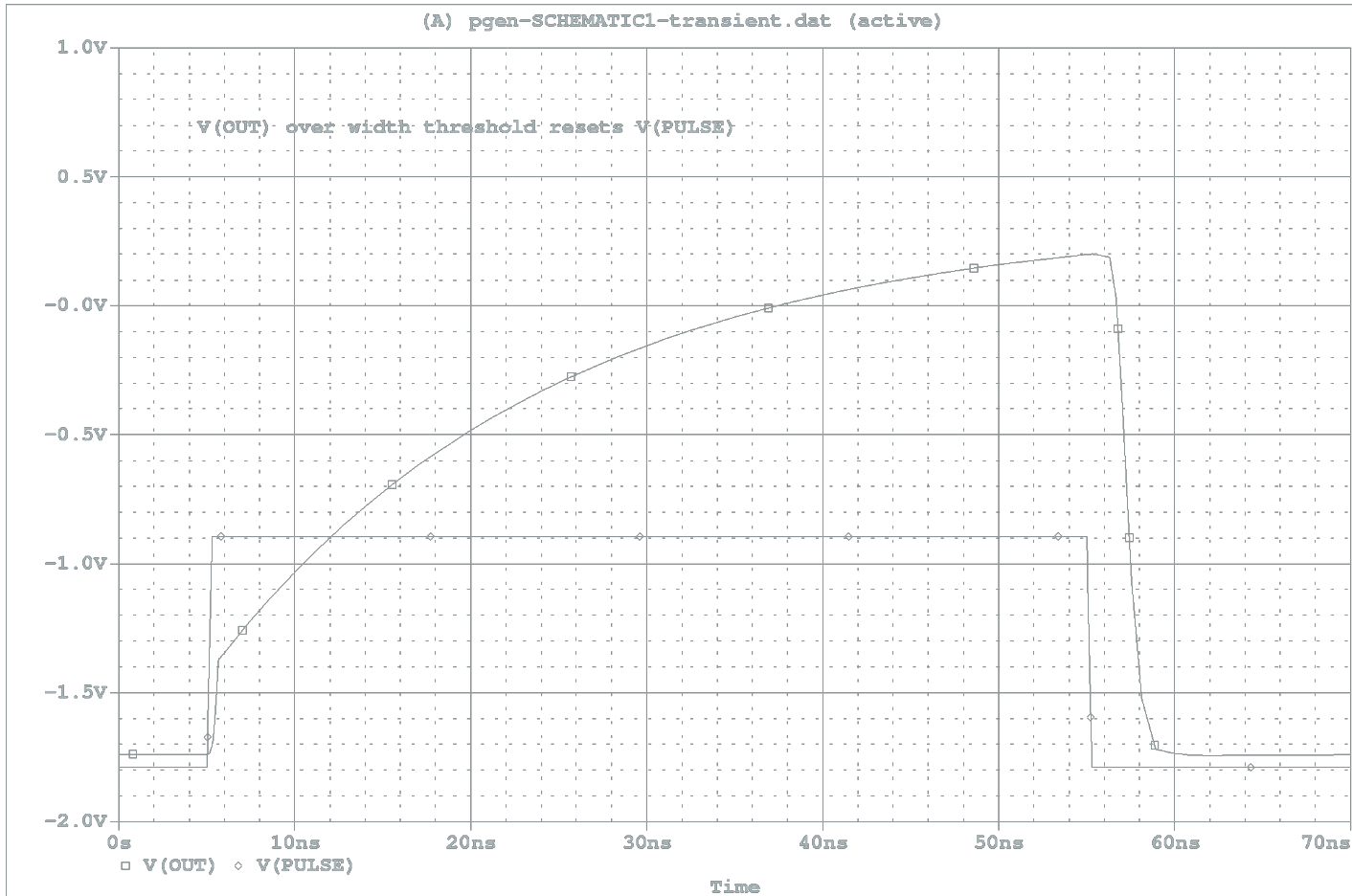


L1 Width circuit



Width simulations

Date/Time run: 04/17/01 14:00:41 ** circuit file for profile: transient Temperature: 27.0



Date: April 17, 2001

Page 1

Time: 14:04:39

CFD board pin-outs

Pin	Name/Function	Description	Specification
J10-1	AGND	Analog Ground	
J10-2	IN	PMT Signal Input	-1.9mV/pe
J10-3	-5VA	Analog Power	-5 V
J10-4	WIDTH	L1 Width Control	+0.0V to -1.25V
J10-5	TH	Discriminator Threshold Control	+0.1V to -2.6V
J10-6	RFB	Rate FeedBack Control	-3.26 mV/pe
J10-7	+5VA	Analog Power	+5 V
J10-8		Not in use	
J10-9	MODE	Trigger Mode Control	ECL
J10-10	GND	Digital Ground	
J10-11	-2V	Digital ECL termination	-2 V
J10-12	-5.2V	Digital Power	-5.2 V
J10-13	DOUT	Serial Data Output	TTL/CMOS
J10-14	OUT+	Positive Trigger Output	ECL
J10-15	OUT-	Negative Trigger Output	ECL
J10-16	DIN	Serial Data Input	TTL/CMOS
J10-17	DCK	Serial Data Clock (Rising Edge)	TTL/CMOS
J10-18	DEN	Serial Data Strobe (Clock data while LOW , Latch data on rising edge)	TTL/CMOS



CFD board components

#	Part	Description	Ref Des	Manufacture	Vendor	Qnty	Cost(500)	Total(500)	Cost(3000)	Total(3000)	Package
1	AD9687CS	Dual, Ultra-Fast ECL-Output Compar	U1	Maxim	Maxim	1	\$ 6.000	\$ 6.000	\$ 5.120	\$ 5.120	SO-16
2	AD8009AR	Low Distortion Amplifier, 1GHz, 550C	U2	Analog Devic	Future	2	\$ 3.770	\$ 7.540	\$ 2.397	\$ 4.795	SO-8
3	MAX9690	Ultra-Fast ECL-Output Comparator	U3	Maxim	Maxim	1	\$ 6.000	\$ 6.000	\$ 3.290	\$ 3.290	SO-8
4	AD7376ARU50	Digital Potentiometer, +/-15V Oper	U4	Analog Devic	Future	1	\$ 2.950	\$ 2.950	\$ 2.950	\$ 2.950	TSSOP-14
5	MAX478CSA	Dual Precision Op Amp	U5,10	Maxim	Maxim	2	\$ 2.580	\$ 5.160	\$ 2.580	\$ 5.160	SO-8
6	MC10EL58D	ECL 2:1 Multiplexer	U6	ON Semicor	Future	1	\$ 4.650	\$ 4.650	\$ 4.650	\$ 4.650	SO-8
7	MC10EL31D	ECL D Flip-Flop with Set and Reset	U7,8	ON Semicor	Future	2	\$ 4.542	\$ 9.084	\$ 4.542	\$ 9.084	SO-8
8	MAX5104CEE	Dual 12-Bit DAC, Voltage Out, Serial	U9	Maxim	Maxim	1	\$ 3.750	\$ 3.750	\$ 3.750	\$ 3.750	QSOP-16
9	MAX6021B	Voltage Reference, 2.048V	U12	Maxim	Maxim	1	\$ 1.170	\$ 1.170	\$ 1.170	\$ 1.170	SOT-23
10	MC10ELT24D	5V TTL to Differential ECL Translator	U11	ON Semicor	Future	1	\$ 3.392	\$ 3.392	\$ 3.392	\$ 3.392	SO-8
11	CDA1505	Delay Line, 1.5nS, 50 ohm, Fixed, HDL1		ELMEC	Elmic	1	\$ 6.360	\$ 6.360	\$ 6.350	\$ 6.350	SOL-8
12	CDA2005	Delay Line, 2.0nS, 50 ohm, Fixed, HDL2		ELMEC	Elmic	1	\$ 8.350	\$ 8.350	\$ 8.350	\$ 8.350	SOL-8
13	EXC-ML20A390U	Surface Mount Bead Core	L1	Panasonic	Digikey	2	\$ 0.270	\$ 0.540	\$ 0.130	\$ 0.260	805
14	BAV74ZX	Dual Diode w/ common cathode	D1	ZETEX	Digikey	1	\$ 0.195	\$ 0.195	\$ 0.117	\$ 0.117	SOT-23
15	FMMT5179CT	RF Transistor	Q1	ZETEX	Digikey	1	\$ 0.405	\$ 0.405	\$ 0.162	\$ 0.162	SOT-23
16	ERJ-6ENF10.0KV	Resistor, 10.0K ohm 1% 0805 1/10W	R1,11,16	Panasonic	Digikey	3	\$ 0.007	\$ 0.021	\$ 0.007	\$ 0.021	805
17	ERJ-6ENF200V	Resistor, 200 ohm 1% 0805 1/10W	R2-4	Panasonic	Digikey	3	\$ 0.007	\$ 0.021	\$ 0.007	\$ 0.021	805
18	ERJ-6ENF10.0V	Resistor, 10.0 ohm 1% 0805 1/10W	R5,27	Panasonic	Digikey	2	\$ 0.007	\$ 0.014	\$ 0.007	\$ 0.014	805
19	ERJ-6ENF49.9V	Resistor, 49.9 ohm 1% 0805 1/10W	R6,7,9,11	Panasonic	Digikey	10	\$ 0.005	\$ 0.045	\$ 0.005	\$ 0.045	805
20	ERJ-6ENF100V	Resistor, 100 ohm 1% 0805 1/10W	R8	Panasonic	Digikey	1	\$ 0.007	\$ 0.007	\$ 0.007	\$ 0.007	805
21	ERJ-6ENF1.00KV	Resistor, 1.00K ohm 1% 0805 1/10W	R10,14	Panasonic	Digikey	2	\$ 0.007	\$ 0.014	\$ 0.007	\$ 0.014	805
22	ERJ-6ENF7.50KV	Resistor, 7.50K ohm 1% 0805 1/10W	R12	Panasonic	Digikey	1	\$ 0.007	\$ 0.007	\$ 0.007	\$ 0.007	805
23	ERJ-6ENF33.2KV	Resistor, 33.2K ohm 1% 0805 1/10W	R13,15,1	Panasonic	Digikey	5	\$ 0.007	\$ 0.035	\$ 0.007	\$ 0.035	805
24	ERJ-6ENF150V	Resistor, 150 ohm 1% 0805 1/10W	R23,24	Panasonic	Digikey	2	\$ 0.007	\$ 0.014	\$ 0.007	\$ 0.014	805
25	ERJ-6ENF300V	Resistor, 300 ohm 1% 0805 1/10W	R25,26	Panasonic	Digikey	2	\$ 0.007	\$ 0.014	\$ 0.007	\$ 0.014	805
26	ERJ-6ENF1.50KV	Resistor, 1.50K ohm 1% 0805 1/10W	R28	Panasonic	Digikey	1	\$ 0.007	\$ 0.007	\$ 0.007	\$ 0.007	805
27	ERJ-6ENF110KV	Resistor, 110K ohm 1% 0805 1/10W	R33	Panasonic	Digikey	1	\$ 0.007	\$ 0.007	\$ 0.007	\$ 0.007	805
28	ERJ-6ENF25.5KV	Resistor, 25.5K ohm 1% 0805 1/10W	R34	Panasonic	Digikey	1	\$ 0.007	\$ 0.007	\$ 0.007	\$ 0.007	805
29	ERJ-6ENF49.9KV	Resistor, 49.9K ohm 1% 0805 1/10W	R36	Panasonic	Digikey	1	\$ 0.007	\$ 0.007	\$ 0.007	\$ 0.007	805
30	ERJ-6ENF681KV	Resistor, 681K ohm 1% 0805 1/10W	R37	Panasonic	Digikey	1	\$ 0.007	\$ 0.007	\$ 0.007	\$ 0.007	805
31	ERJ-6ENF20.5KV	Resistor, 20.5K ohm 1% 0805 1/10W	R38	Panasonic	Digikey	1	\$ 0.007	\$ 0.007	\$ 0.007	\$ 0.007	805
32	ECJ-2VC2A100D	Capacitor, 10pF +/-0.5pF 0805 100V	C1	Panasonic	Digikey	1	\$ 0.066	\$ 0.066	\$ 0.066	\$ 0.066	805
33	ECU-V1H750JCG	Capacitor, 75pF 5% 0805 50V	C2	Panasonic	Digikey	1	\$ 0.020	\$ 0.020	\$ 0.020	\$ 0.020	805
34	ECU-V1H102JCX	Capacitor, 1000pF 5% 0805 50V	C3	Panasonic	Digikey	1	\$ 0.043	\$ 0.043	\$ 0.043	\$ 0.043	805
35	ECU-V1H562KBG	Capacitor, 5600pF 10% 0805 50V	C4	Panasonic	Digikey	1	\$ 0.021	\$ 0.021	\$ 0.021	\$ 0.021	805
36	ECJ-2YB1H104K	Capacitor, 0.1uF 10% 0805 25V	C5-27	Panasonic	Digikey	23	\$ 0.061	\$ 1.403	\$ 0.061	\$ 1.403	805
37	ECJ-2YB1A105K	Capacitor, 1uF 10% 0805 10V	C28-30	Panasonic	Digikey	3	\$ 0.188	\$ 0.564	\$ 0.188	\$ 0.564	805
38	ECS-1YCX106R	Capacitor, 10uF 16V Tantalum Chip	C31-34	Panasonic	Digikey	4	\$ 0.238	\$ 0.952	\$ 0.142	\$ 0.568	EIA-B
39	334-10-118-00-050	Interconnect, Single Row, 0.331 High	J10	Mill-Max	Mill-Max	1	\$ 1.500	\$ 1.500	\$ 1.500	\$ 1.500	
40	PCB	4 layer, 1.2" x 2.0" nre: \$100/layer		Viktron-Lika		1	\$ 2.000	\$ 2.000	\$ 0.770	\$ 0.770	
		additional 2 layers				1	\$ 0.500	\$ 0.500	\$ 0.280	\$ 0.280	
41	Board Stuffing	Budgetary Quote		CirTran		1	\$ 11.080	\$ 11.080	\$ 6.550	\$ 6.550	
	Complete Board:						Total:	\$ 83.93	Total:	\$ 70.62	



CFD Budget

	Total(500) per board	500	Total(3000) per board	3000
Components	\$ 70.35	\$ 35,173.20	\$ 63.02	\$ 189,048.60
Fabrication	\$ 2.50	\$ 1,250.00	\$ 1.05	\$ 3,150.00
Stuffing	\$ 11.08	\$ 5,540.00	\$ 6.55	\$ 19,650.00
Total:	\$ 83.93	\$ 41,963.20	\$ 70.62	\$ 211,848.60

Total for 3500: **\$ 253,811.80**

Total budgeted in
WBS for 3500: **\$ 241,500.00**

Total in WBS: **\$308,200.00**

Available for
engineering,
R&D, test board
manufacturing,
and testing: **\$54,388.20**

