Energy Recovery Linac's (ERL) **Time Management System**

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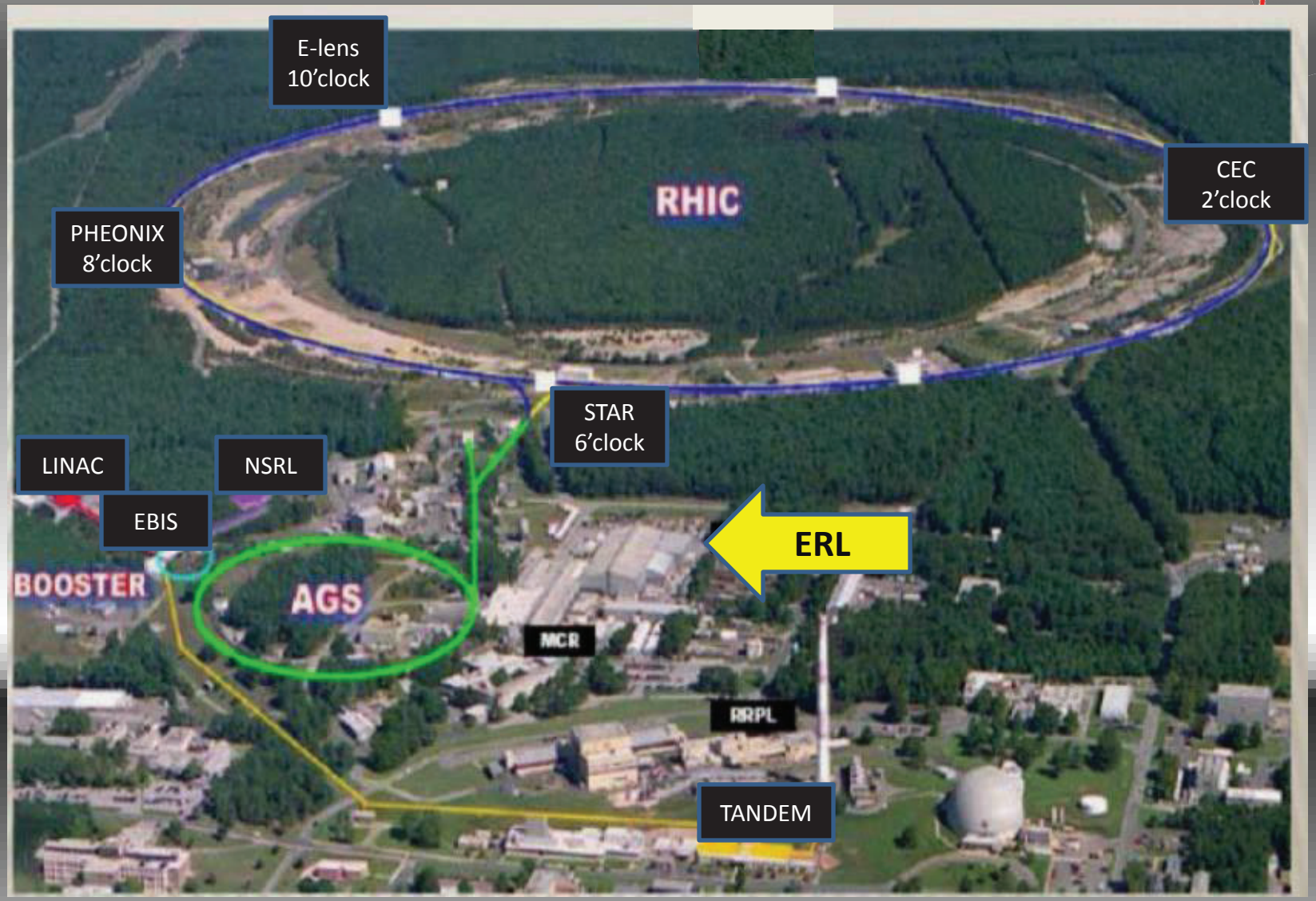

E-lens
10'clock
RHIC
CEC
2'clock
PHEONIX
8'clock
STAR
6'clock
LINAC
NSRL
EBIS
ERL
BOOSTER
AGS
MCR
RRPL
TANDEM

Tell'em what you are going to tell

- Introduction to ERL and its timing needs
- Hardware components of timing system
- Beam structure
- Software algorithm and its features
- Test scheme and Operational results
- Operator interface
- Status and plans

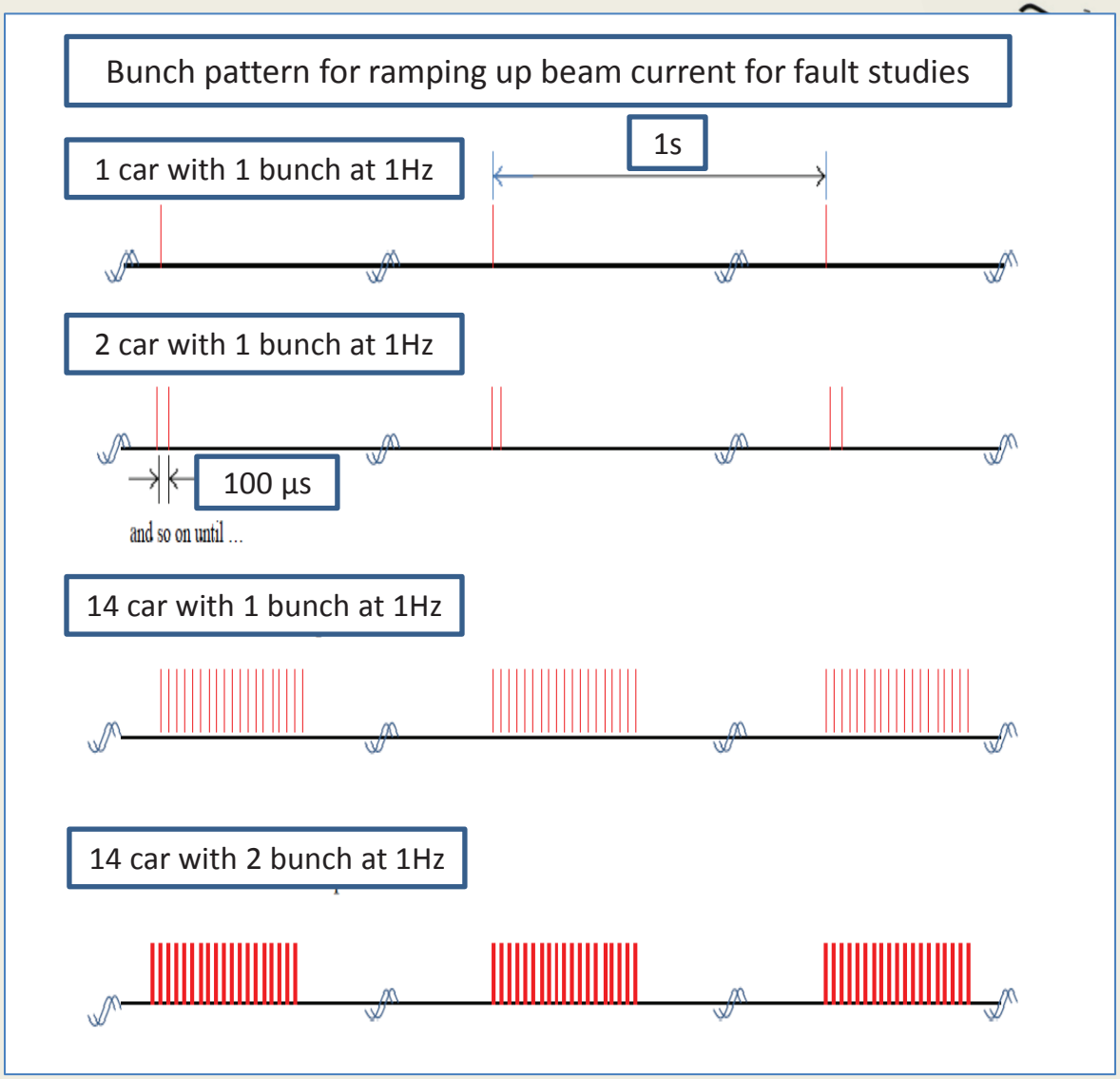
ERL LAYOUT

- For low energy electron cooling of RHIC (LeRec) and electron ion collider (eRHIC)
- These applications require up to 350 milli ampere CW current with low emittance

Required Bunch Structure

Group of **laser pulses** = **Bunch**
Groups of **Bunches** = **car**
Group of **Cars** = **Train**

Fig. 2 Bunch Train



Required Bunch Structure

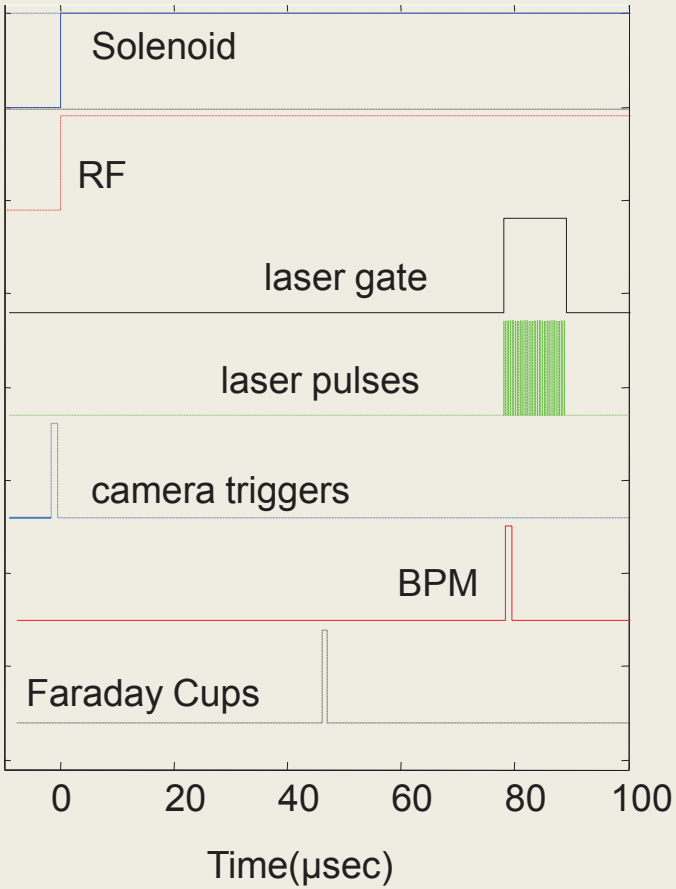
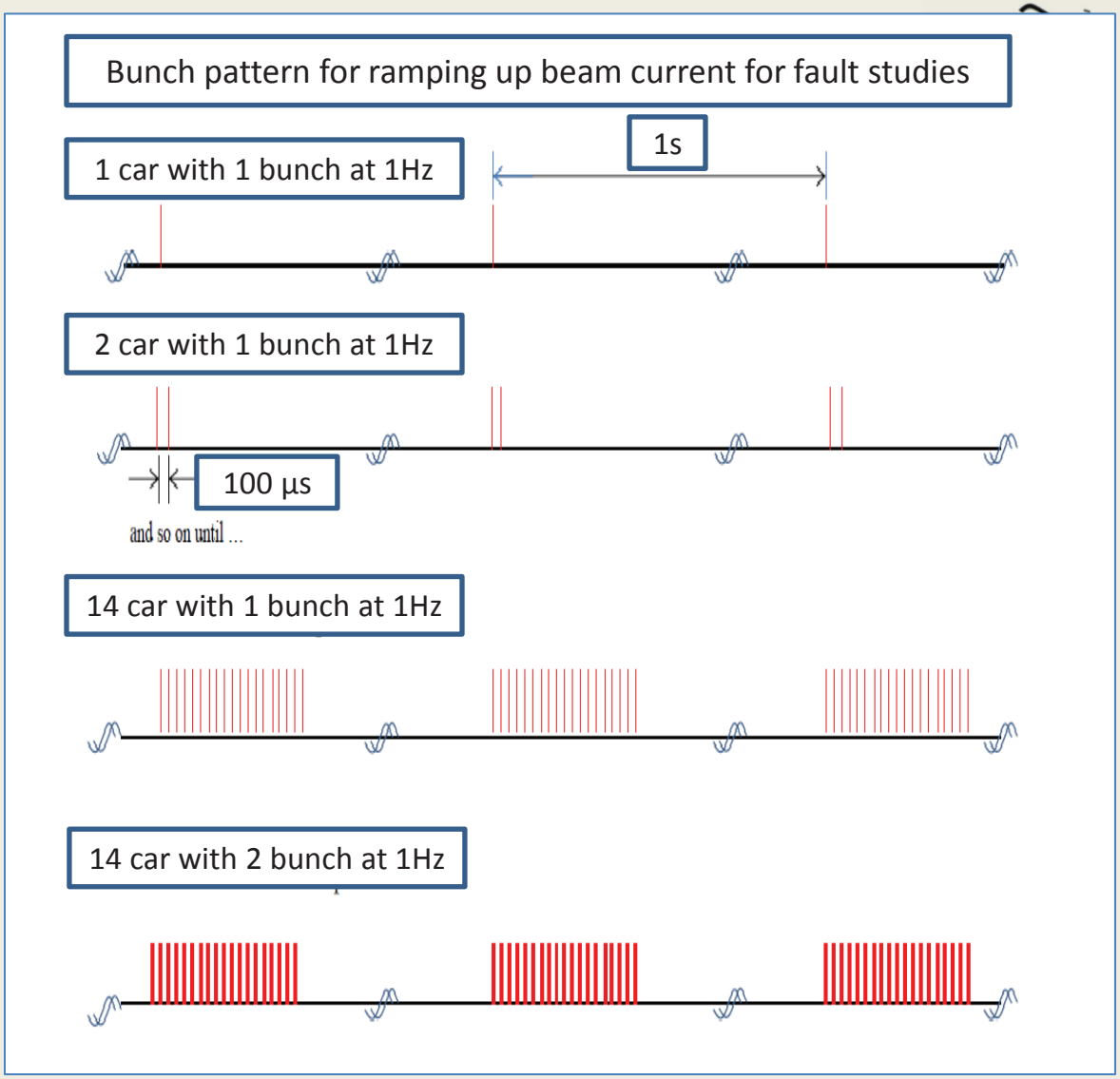


Fig. 1 Sequence of Triggers

Fig. 2 Bunch Train



Building Blocks of the Timing System

OPERATOR INTERFACE

Master Timing Accelerator Device Object (ADO)

RF Electronics operating at 703 Mhz. Phase locked with Laser

RHIC Event Link Generator embarks the start of Train at **1Hz**

INHIBIT LOGIC

V202#1

CLK

EXT

0 1 2 3 4 5 6 7

DG #1

EXT INH AB CD EF GH

DG #2

EXT INH AB CD EF GH

DG #3

EXT INH AB CD EF GH

DG #4

EXT INH AB CD EF GH

V202 #2

CLK

EXT

0 1 2 3 4 5 6 7

To Devices

- Red items are software entities configured by timing ADO.
- Blue Arrows are HW triggers/permits

V202: Delay modules programmed at BNL
DG: Stanford Research System **D**elay **G**enerator model 645.

Building Blocks of the Timing System

OPERATOR Interface

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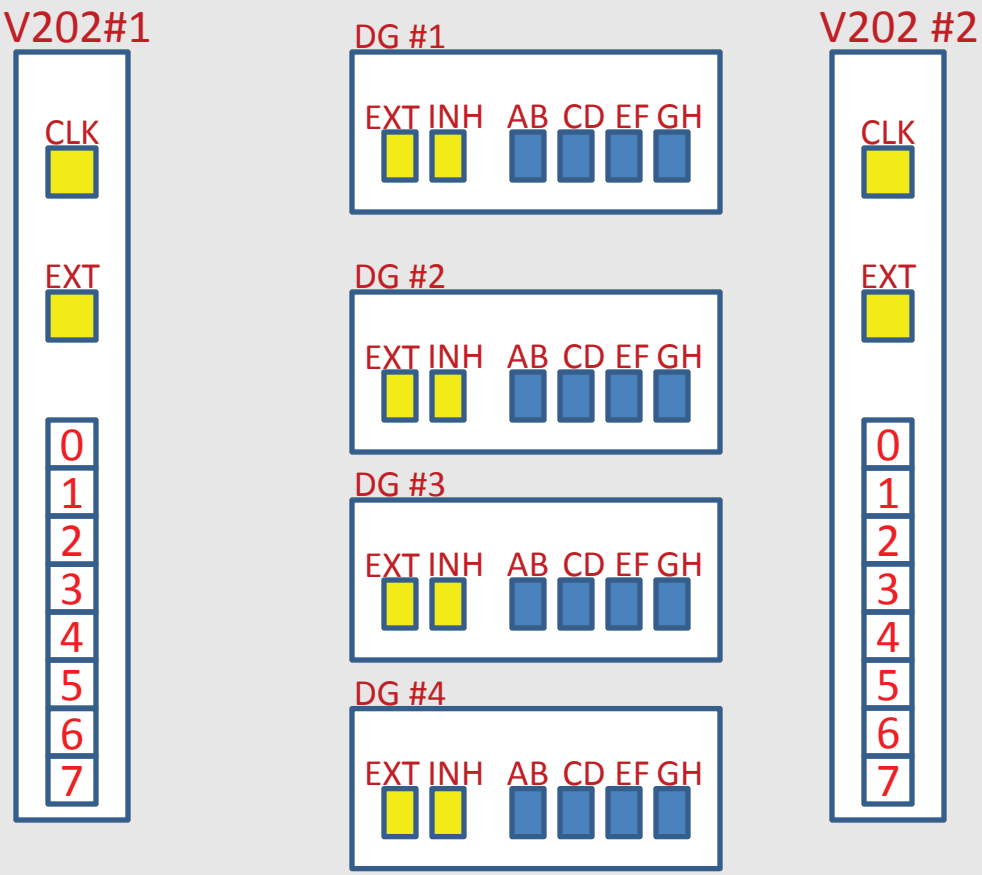

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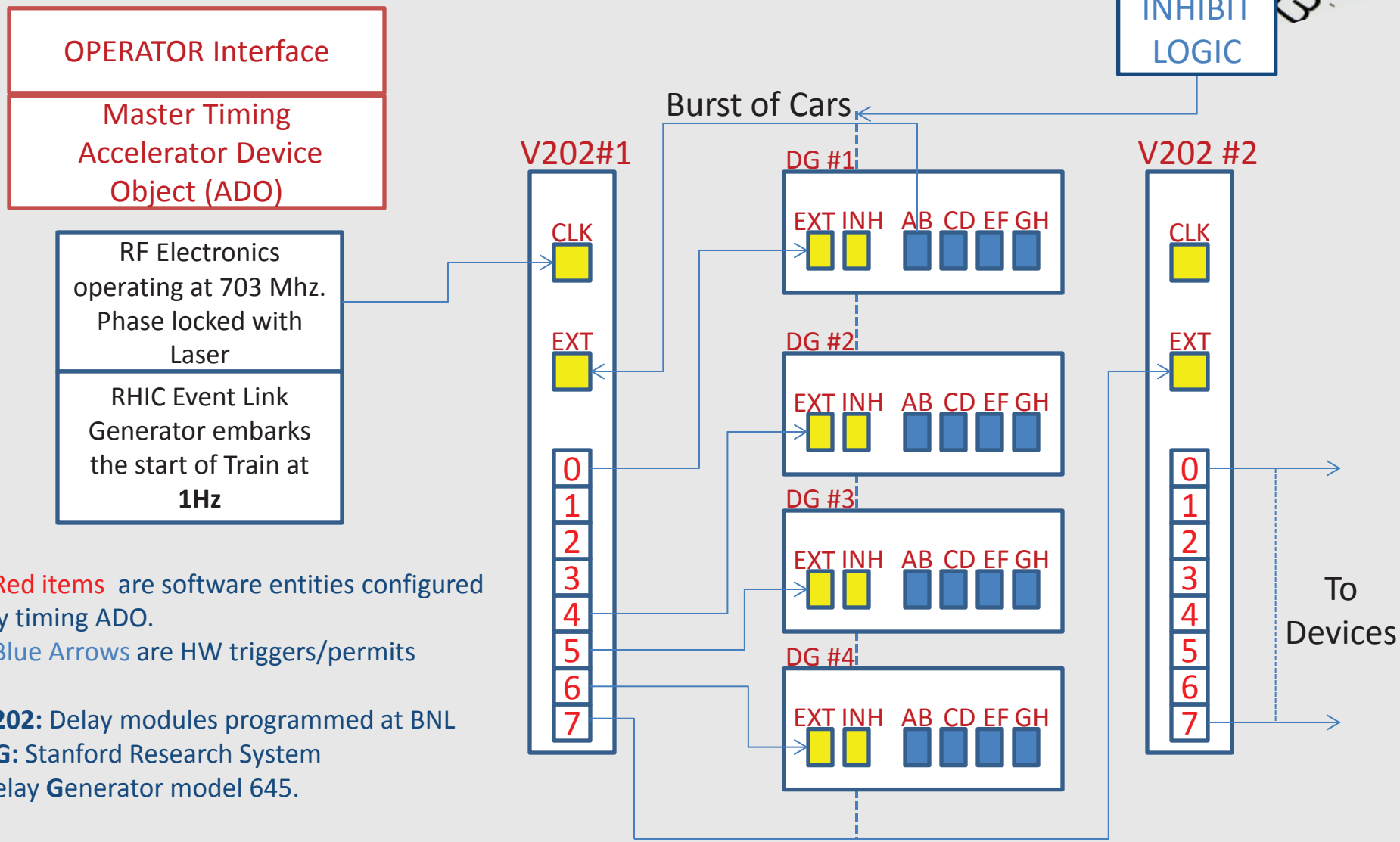

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DG: Stanford Research System
Delay **G**enerator model 645.

Algorithm

Goal: LASER is last device to be fired

- Set response time of all diagnostics, done by system experts manually. (δ_{dev})
- Find device with maximum response time (δ_{max})

  $\delta_{max} = MAX(\delta_{dev1} + \delta_{dev2} + \delta_{dev3} + \delta_{dev4} + \delta_{dev5} \ldots\ldots)$
- Calculate total insertion delay due to 4 DG645 boxes. ($InsertionDelay_{max}$)
- Set delay (T_{dev})of each channel to

  $$T_{dev} = \delta_{max} + InsertionDelay_{max} - \delta_{dev}$$

EASE OF USE

- Calculate and compensate insertion delays of each DG645 unit.
- Calculate delays in clock ticks of laser and internal clock when in test and operation mode.
- Change trigger properties based on change in train properties.
- Check for **Beam Power Limits**.
- Cater to electronics with special needs and supply reset triggers based on time constant of each.

User Interface

Page PPM Device Data Tools Buffer Help

MASTER CONTROLS						
erlTimingCtrl.MasterADO		Calculate Gates And Send				
DELAY GENERATOR #2	SET DELTA DEVICE(sec)	SET WIDTH(sec)	PULSE WIDTH(sec)	PULSE DELAY(sec)		
Communication Status	Active			Note: PULSE DELAY(ch) = INSERT_DEL + MAX_DELTA_DEV -DELTA_DEV(ch)		
Insertion Delay	0					
Laser	0	Laser Gate Set By Timing ADO ->	0.0003	8.00186e-05		
Laser Gate Duplicate			0.0003	8.00186e-05		
ERL IICT2.1 trigg	1.4e-05	1.5e-05	1.5e-05	6.60186e-05		
DELAY GENERATOR #3						
Communication Status	Active					
Insertion Delay	1.165e-08					
Faraday reset Mask	6.5e-05	5e-05	5e-05	0.0001450186		
DCCT Gate	7e-05	0.00023	0.00023	0.0001500186		
DELAY GENERATOR #4						
Communication Status	Active					
Insertion Delay	1.86e-08					
ERL ICT Interlock Reset	6.2e-05	1.2e-05	1.2e-05	1.8e-05		
ERL FC Interlock Reset	6.2e-05	1.2e-05	1.2e-05	1.8e-05		
ERL FC Interlock Start	1e-07	0.0003	0.0003	7.95e-05		
ERL ICT Interlock Start	1e-07	1e-05	1e-05	7.99e-05		
V202 VME1 CONTROLS	delayS	pulseLengthS	clockC	trigSourceC	pulsePolarity	pulseEnabl
delay.912erl-vme1.TestSignalTekScope	2	10	1MHz	Ext	Pos	On
delay.912erl-vme1.DCCTTrigger	0	2345	1MHz	Ext	Pos	On
delay.912erl-vme1.SignalLecScope	1	2345	1MHz	Ext	Pos	On
delay.912erl-vme1.GigECamera	34	2345	1MHz	Ext	Pos	On
delay.912erl-vme1.HlxBLMGate	2345	50	1MHz	Ext	Pos	On
delay.912erl-vme1.HlxBLMReset	4653000	50	1MHz	Ext	Pos	On
delay.912erl-vme1.E-PMT	0	2345	1MHz	Ext	Pos	On
delay.912erl-vme1.Kithely2001PMT	0	100	1MHz	Ext	Neg	On
V202 VME3 CONTROLS			The External clock freq = 4.69Mhz			
delay.912erl-vme3.StartTrainDG1	423000	50	1MHz	Event	Pos	On
delay.912erl-vme3.3123Ext	50	50	1MHz	PrevStart	Pos	On
delay.912erl-vme3.3122Ext	2345	100	1MHz	PrevStart	Pos	On
delay.912erl-vme3.LiberaBPM	423000	50	1MHz	Event	Pos	On
delay.912erl-vme3.ExtTrigDG2	1	50	1MHz	Ext	Pos	On
delay.912erl-vme3.ExtTrigDG3	1	50	1MHz	PrevStart	Pos	On
delay.912erl-vme3.ExtTrigDG4	1	50	1MHz	PrevStart	Pos	On
delay.912erl-vme3.V202Vme1	78	50	1MHz			

Set Test Mode

Set Laser Mode

Clock Source

INTERNAL

(14,2) erlTimingCtrl.MasterADO:erlFCMask

Thu Aug 13 17:29:28 2015: Get and Async requests complete.
Thu Aug 13 17:29:48 2015: Get and Async requests complete.

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MACROBUNCH CHARACTERISTICS					
Communication Status	Active				
	Bunch Frequency	Bunch Width	Beam Current	Laser Beam Power	Efficiency(Amps/W)
erlTimingCtrl.MasterADO	1960	1e-05	3.5e-06	1.8	0.0001
	Burst Count	Burst Delay	Burst Period	Burst Mode	
DG645.ERL.1	76	0	0.000510204081633	ENABLE	

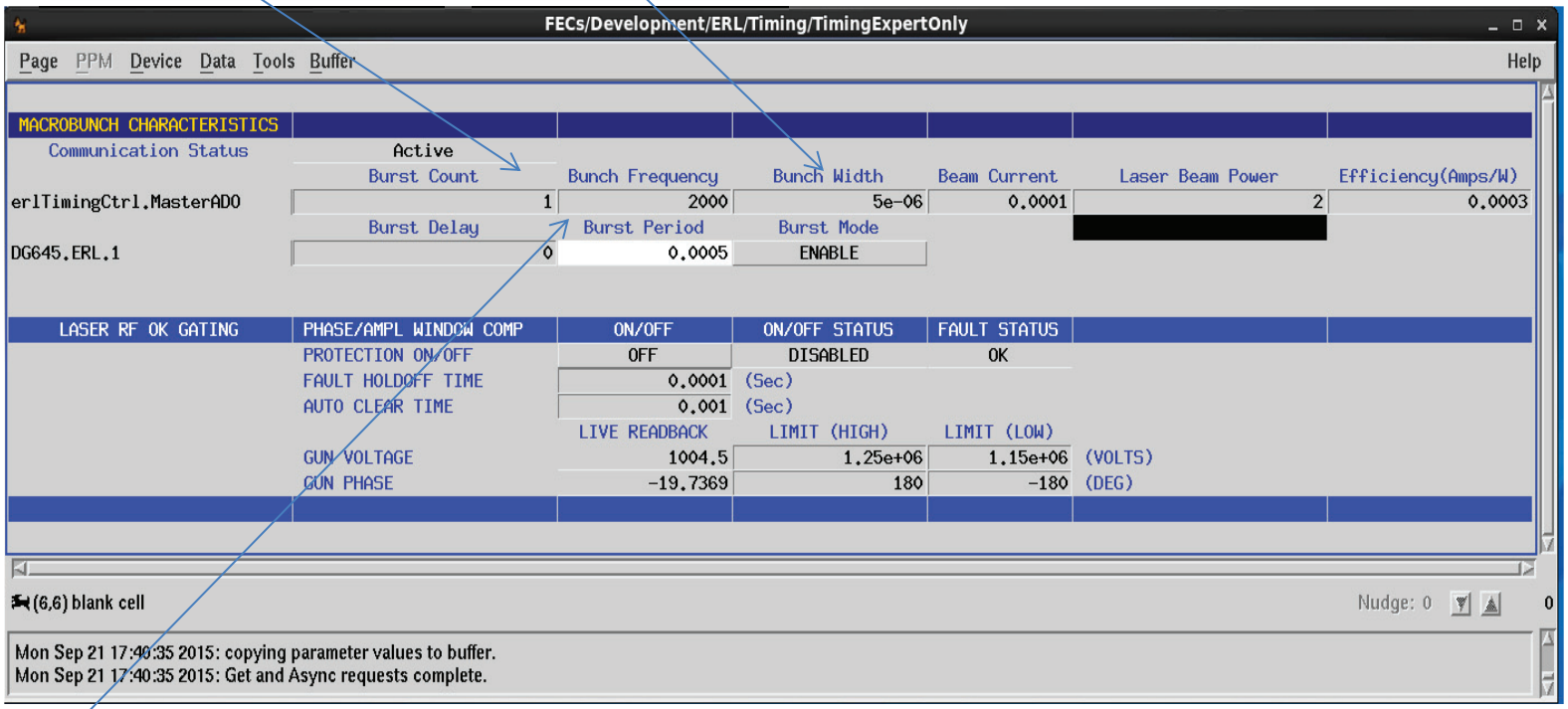
LASER RF DC GATING	PHASE/AMPL WINDOW COMP	ON/OFF	ON/OFF STATUS	FAULT STATUS
	PROTECTION ON/OFF	OFF	DISABLED	OK
	FAULT HOLDOFF TIME	0.0001	(Sec)	
	AUTO CLEAR TIME	0.001	(Sec)	
		LIVE READBACK	LIMIT (HIGH)	LIMIT (LOW)
	GUN VOLTAGE	2152.5	101000	100000 (VOLTS)
	GUN PHASE	-167.86	180	-180 (DEG)

(5,6) erlTimingCtrl.MasterADO:efficiencyS

Wed May 28 22:56:42 2014: PutGetAsyncErrorCB - adcCcPpc0.912erl-rf82.3:veavPhaseDegBArrayM[0] (16,3) - IO lib - Cannot extract array index from data
Wed May 28 23:02:33 2014: Get and Async requests complete.

Burst Count is Number of Cars to be generated

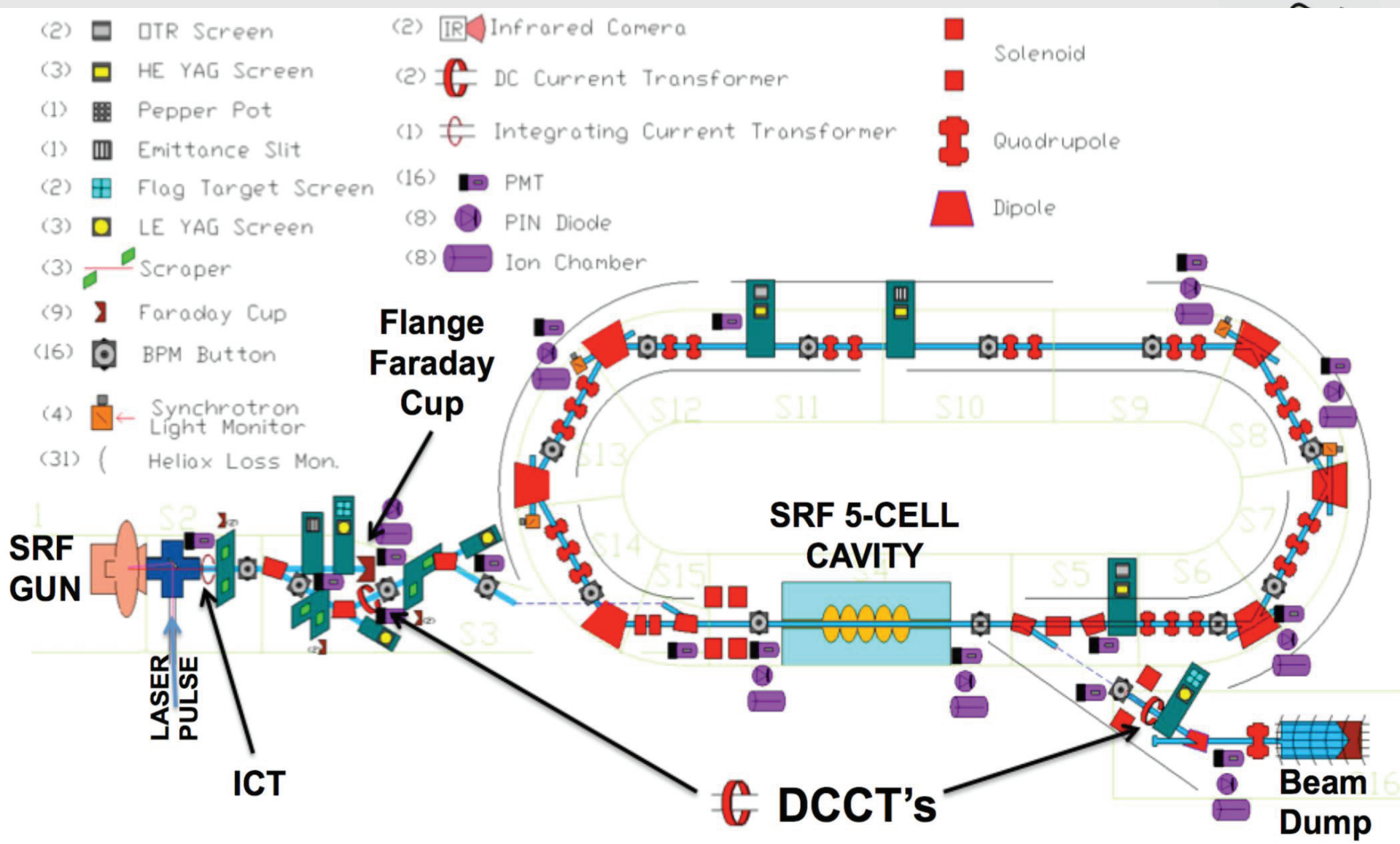
Bunch Width is the length of the car



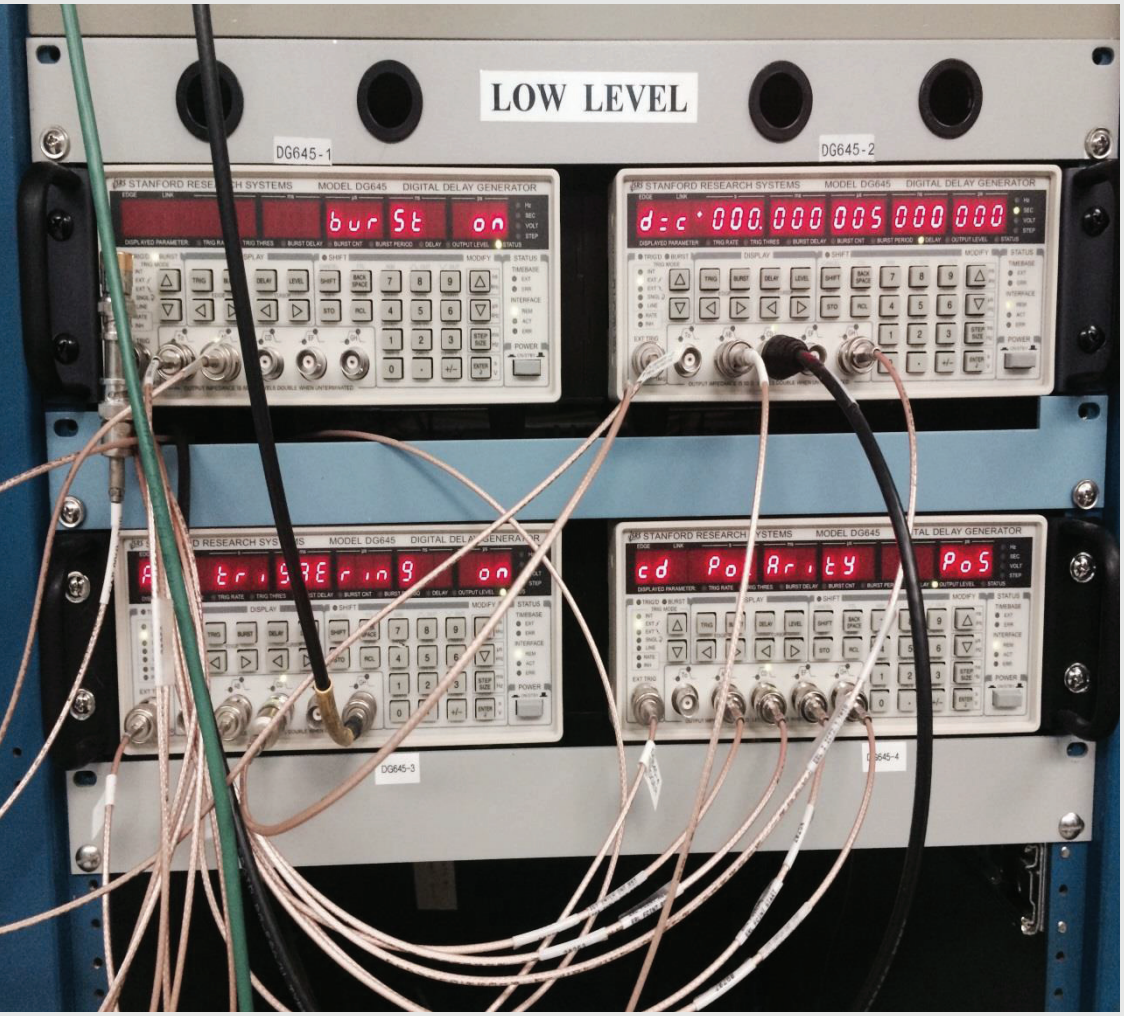
Bunch Frequency is the spacing of the cars

Number of laser pulses in a car = 9.38 MHz * Bunch Width

Beam Diagnostic Systems



Putting It All Together



Truth Be Told!

- 4 pulse outputs
- 8 delay outputs
- <25 ps rms jitter
- Trigger rates to 10 MHz

Limitations:

- Cannot disable individual output channel
- Rate error status limits the configurable delay value range
- Pre-scale trigger factor is not synchronized with external trigger.

SUMMARY

- Electron beam was generated. Yay!
- Fault studies are underway utilizing the synchronized beam instruments and diagnostics at ERL.
- Work continues to improve operator interface to minimize user intervention and include more systems.
- MRF Timing system or White Rabbit are potential options for future stand alone research project.

THANK YOU!