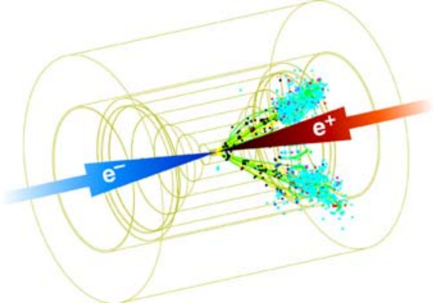
World-Wide Studies of ILC Physics and Detectors



ILC-World

DAQ Issues and Machine-Detector Interface

Mike Woods, *SLAC*

Backgrounds

data rates:

- T. Markiewicz at Victoria ALCPG, 2004
- P. Le Dû at LCWS2004

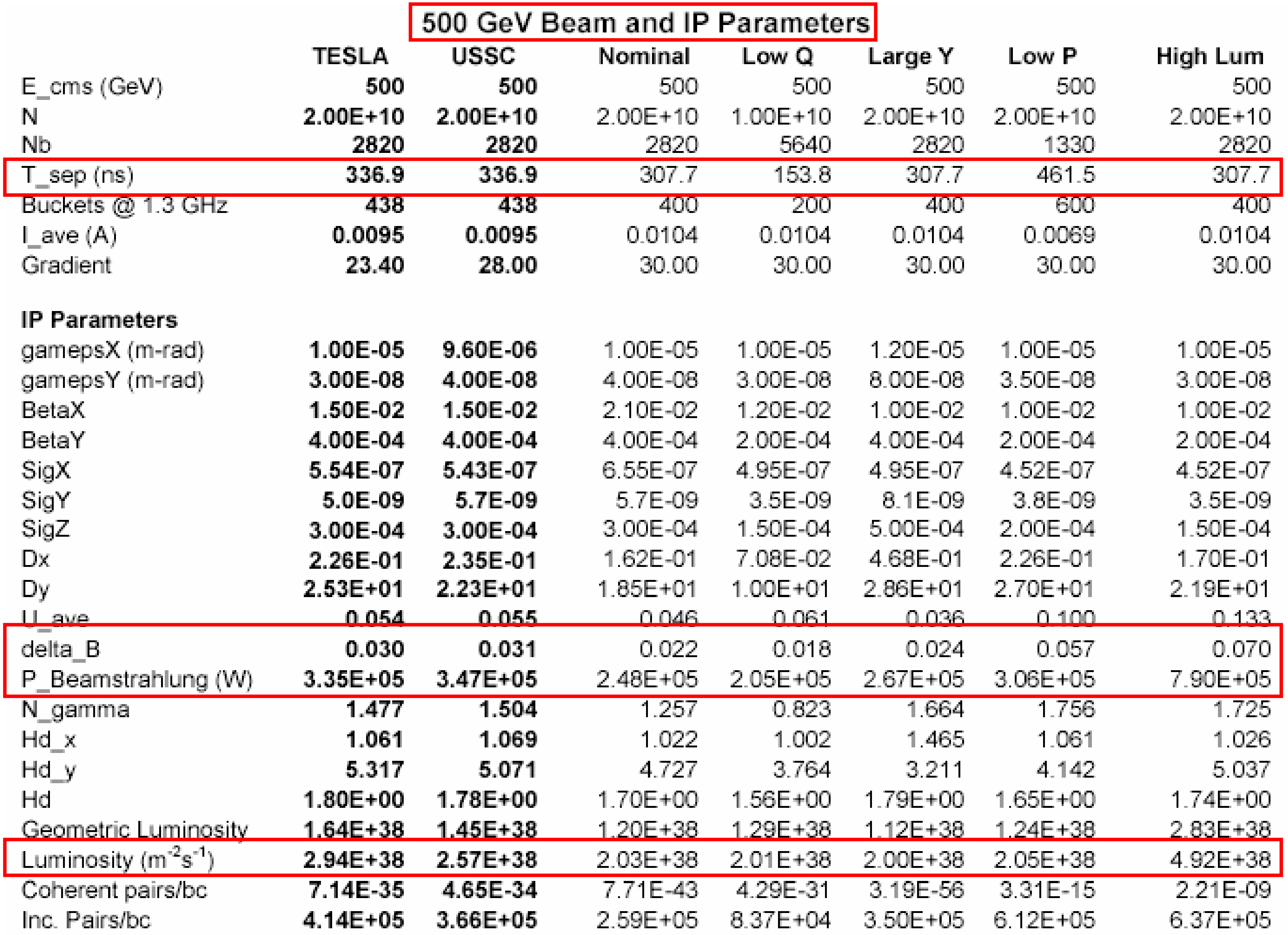
➢ how well do we know the backgrounds? What safety margin to build in?

Exchange of Data between Machine and Detector

- E. Torrence at Victoria ALCPG, 2004

Electromagnetic Interference from Beam RF (EMI)

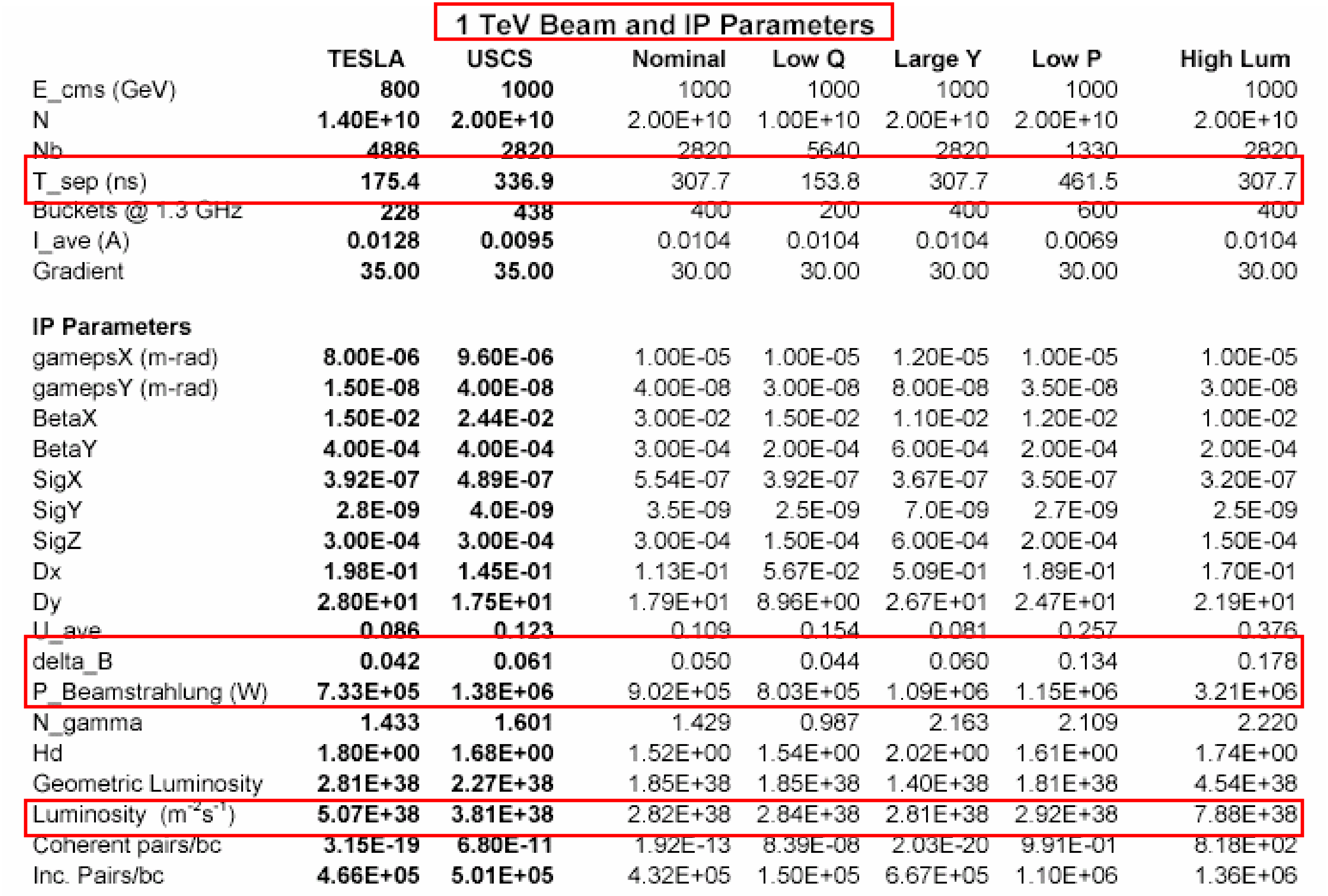
Large range of Collision parameters being evaluated!



500 GeV Beam and IP Parameters

	TESLA	USSC	Nominal	Low Q	Large Y	Low P	High Lum
E_cms (GeV)	**500**	**500**	500	500	500	500	500
N	**2.00E+10**	**2.00E+10**	2.00E+10	1.00E+10	2.00E+10	2.00E+10	2.00E+10
Nb	**2820**	**2820**	2820	5640	2820	1330	2820
T_sep (ns)	**336.9**	**336.9**	307.7	153.8	307.7	461.5	307.7
Buckets @ 1.3 GHz	**438**	**438**	400	200	400	600	400
I_ave (A)	**0.0095**	**0.0095**	0.0104	0.0104	0.0104	0.0069	0.0104
Gradient	**23.40**	**28.00**	30.00	30.00	30.00	30.00	30.00
IP Parameters							
gamepsX (m-rad)	**1.00E-05**	**9.60E-06**	1.00E-05	1.00E-05	1.20E-05	1.00E-05	1.00E-05
gamepsY (m-rad)	**3.00E-08**	**4.00E-08**	4.00E-08	3.00E-08	8.00E-08	3.50E-08	3.00E-08
BetaX	**1.50E-02**	**1.50E-02**	2.10E-02	1.20E-02	1.00E-02	1.00E-02	1.00E-02
BetaY	**4.00E-04**	**4.00E-04**	4.00E-04	2.00E-04	4.00E-04	2.00E-04	2.00E-04
SigX	**5.54E-07**	**5.43E-07**	6.55E-07	4.95E-07	4.95E-07	4.52E-07	4.52E-07
SigY	**5.0E-09**	**5.7E-09**	5.7E-09	3.5E-09	8.1E-09	3.8E-09	3.5E-09
SigZ	**3.00E-04**	**3.00E-04**	3.00E-04	1.50E-04	5.00E-04	2.00E-04	1.50E-04
Dx	**2.26E-01**	**2.35E-01**	1.62E-01	7.08E-02	4.68E-01	2.26E-01	1.70E-01
Dy	**2.53E+01**	**2.23E+01**	1.85E+01	1.00E+01	2.86E+01	2.70E+01	2.19E+01
U_ave	**0.054**	**0.055**	0.046	0.061	0.036	0.100	0.133
delta_B	**0.030**	**0.031**	0.022	0.018	0.024	0.057	0.070
P_Beamstrahlung (W)	**3.35E+05**	**3.47E+05**	2.48E+05	2.05E+05	2.67E+05	3.06E+05	7.90E+05
N_gamma	**1.477**	**1.504**	1.257	0.823	1.664	1.756	1.725
Hd_x	**1.061**	**1.069**	1.022	1.002	1.465	1.061	1.026
Hd_y	**5.317**	**5.071**	4.727	3.764	3.211	4.142	5.037
Hd	**1.80E+00**	**1.78E+00**	1.70E+00	1.56E+00	1.79E+00	1.65E+00	1.74E+00
Geometric Luminosity	**1.64E+38**	**1.45E+38**	1.20E+38	1.29E+38	1.12E+38	1.24E+38	2.83E+38
Luminosity ($m^{-2}s^{-1}$)	**2.94E+38**	**2.57E+38**	2.03E+38	2.01E+38	2.00E+38	2.05E+38	4.92E+38
Coherent pairs/bc	**7.14E-35**	**4.65E-34**	7.71E-43	4.29E-31	3.19E-56	3.31E-15	2.21E-09
Inc. Pairs/bc	**4.14E+05**	**3.66E+05**	2.59E+05	8.37E+04	3.50E+05	6.12E+05	6.37E+05

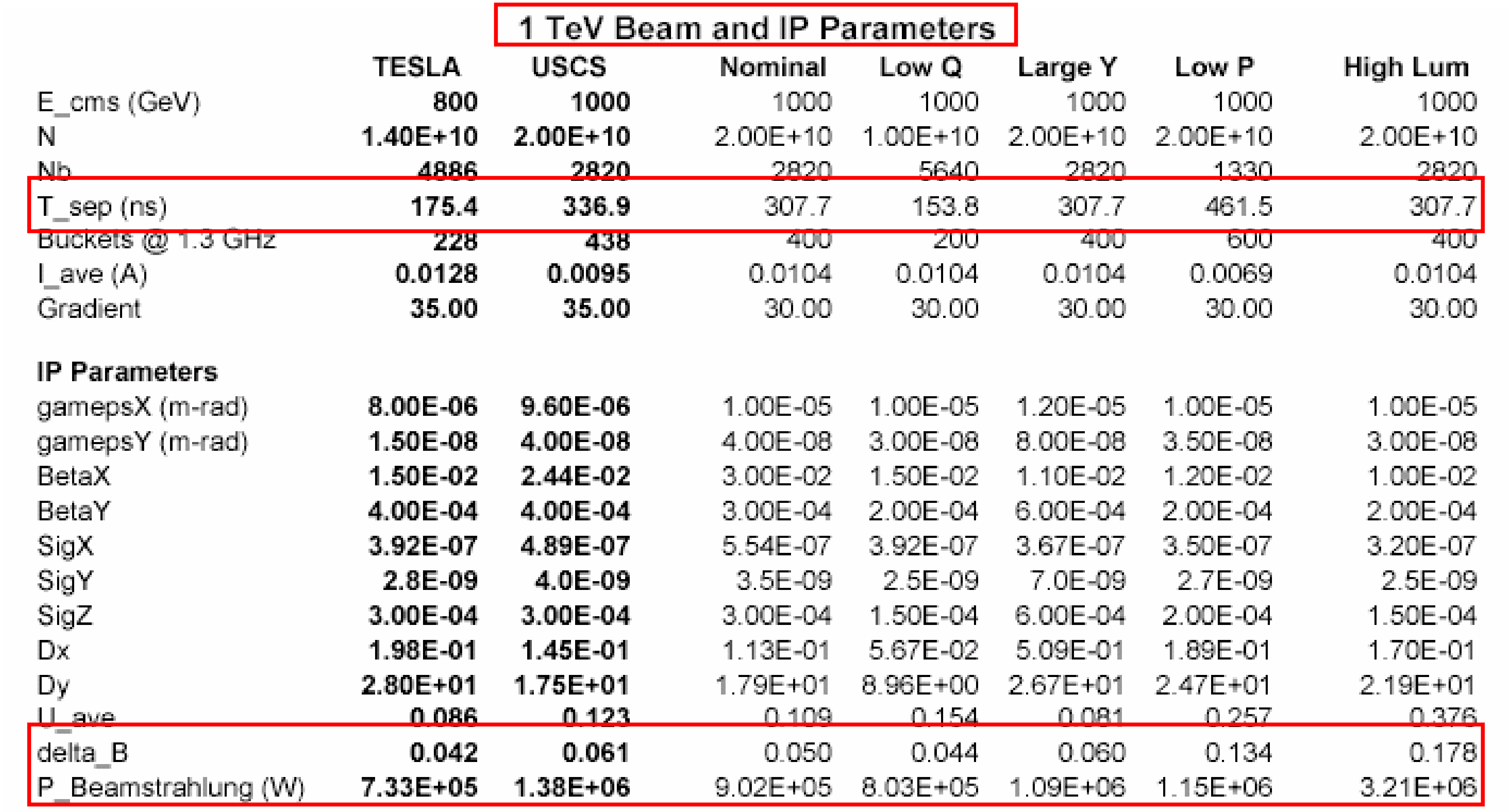
Large range of Collision parameters being evaluated (cont.)



1 TeV Beam and IP Parameters

	TESLA	USCS	Nominal	Low Q	Large Y	Low P	High Lum
E_cms (GeV)	**800**	**1000**	1000	1000	1000	1000	1000
N	**1.40E+10**	**2.00E+10**	2.00E+10	1.00E+10	2.00E+10	2.00E+10	2.00E+10
Nb	**4886**	**2820**	2820	5640	2820	1330	2820
T_sep (ns)	**175.4**	**336.9**	307.7	153.8	307.7	461.5	307.7
Buckets @ 1.3 GHz	**228**	**438**	400	200	400	600	400
I_ave (A)	**0.0128**	**0.0095**	0.0104	0.0104	0.0104	0.0069	0.0104
Gradient	**35.00**	**35.00**	30.00	30.00	30.00	30.00	30.00
IP Parameters							
gamepsX (m-rad)	**8.00E-06**	**9.60E-06**	1.00E-05	1.00E-05	1.20E-05	1.00E-05	1.00E-05
gamepsY (m-rad)	**1.50E-08**	**4.00E-08**	4.00E-08	3.00E-08	8.00E-08	3.50E-08	3.00E-08
BetaX	**1.50E-02**	**2.44E-02**	3.00E-02	1.50E-02	1.10E-02	1.20E-02	1.00E-02
BetaY	**4.00E-04**	**4.00E-04**	3.00E-04	2.00E-04	6.00E-04	2.00E-04	2.00E-04
SigX	**3.92E-07**	**4.89E-07**	5.54E-07	3.92E-07	3.67E-07	3.50E-07	3.20E-07
SigY	**2.8E-09**	**4.0E-09**	3.5E-09	2.5E-09	7.0E-09	2.7E-09	2.5E-09
SigZ	**3.00E-04**	**3.00E-04**	3.00E-04	1.50E-04	6.00E-04	2.00E-04	1.50E-04
Dx	**1.98E-01**	**1.45E-01**	1.13E-01	5.67E-02	5.09E-01	1.89E-01	1.70E-01
Dy	**2.80E+01**	**1.75E+01**	1.79E+01	8.96E+00	2.67E+01	2.47E+01	2.19E+01
U_ave	**0.086**	**0.123**	0.109	0.154	0.081	0.257	0.376
delta_B	**0.042**	**0.061**	0.050	0.044	0.060	0.134	0.178
P_Beamstrahlung (W)	**7.33E+05**	**1.38E+06**	9.02E+05	8.03E+05	1.09E+06	1.15E+06	3.21E+06
N_gamma	**1.433**	**1.601**	1.429	0.987	2.163	2.109	2.220
Hd	**1.80E+00**	**1.68E+00**	1.52E+00	1.54E+00	2.02E+00	1.61E+00	1.74E+00
Geometric Luminosity	**2.81E+38**	**2.27E+38**	1.85E+38	1.85E+38	1.40E+38	1.81E+38	4.54E+38
Luminosity ($m^{-2}s^{-1}$)	**5.07E+38**	**3.81E+38**	2.82E+38	2.84E+38	2.81E+38	2.92E+38	7.88E+38
Coherent pairs/bc	**3.15E-19**	**6.80E-11**	1.92E-13	8.39E-08	2.03E-20	9.91E-01	8.18E+02
Inc. Pairs/bc	**4.66E+05**	**5.01E+05**	4.32E+05	1.50E+05	6.67E+05	1.10E+06	1.36E+06

Large range of Collision parameters being evaluated (cont.)



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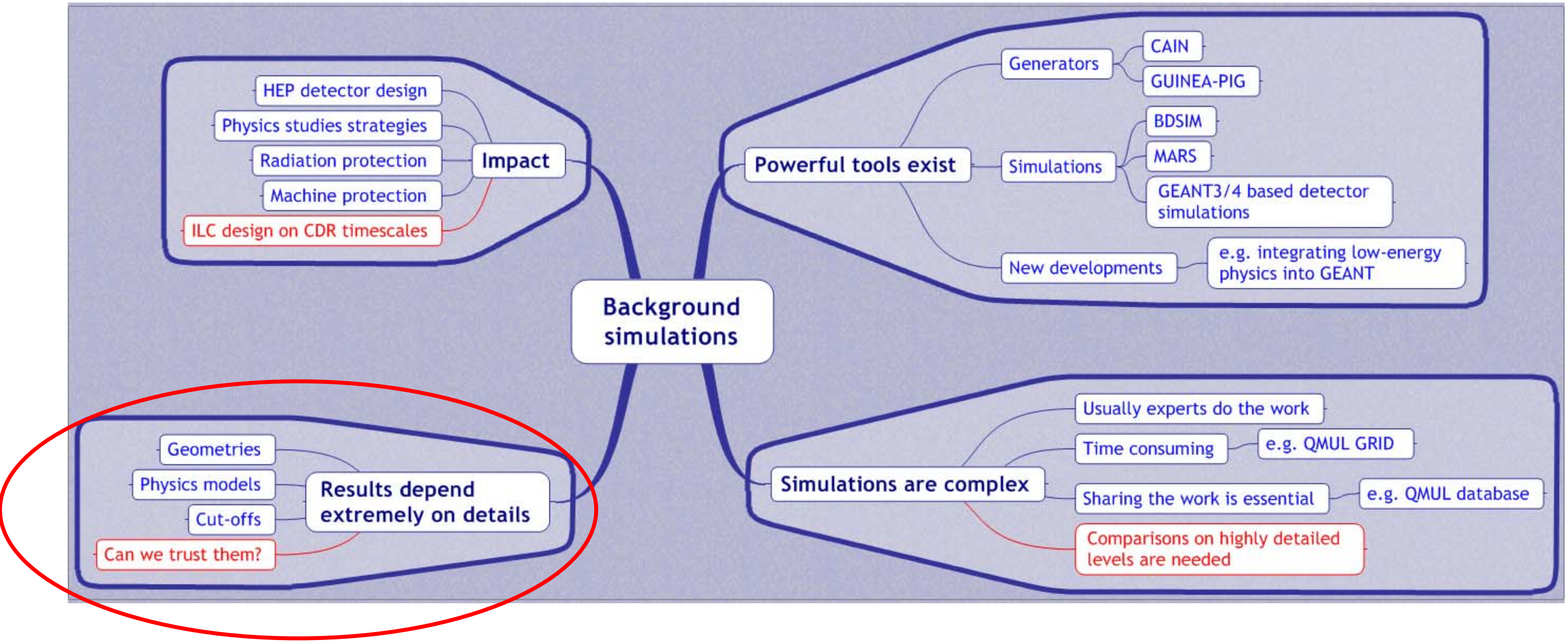
Gradient	35.00	35.00	30.00	30.00	30.00	30.00	30.00
IP Parameters							
gamepsX (m-rad)	8.00E-06	9.60E-06	1.00E-05	1.00E-05	1.20E-05	1.00E-05	1.00E-05
gamepsY (m-rad)	1.50E-08	4.00E-08	4.00E-08	3.00E-08	8.00E-08	3.50E-08	3.00E-08
BetaX	1.50E-02	2.44E-02	3.00E-02	1.50E-02	1.10E-02	1.20E-02	1.00E-02
BetaY	4.00E-04	4.00E-04	3.00E-04	2.00E-04	6.00E-04	2.00E-04	2.00E-04
SigX	3.92E-07	4.89E-07	5.54E-07	3.92E-07	3.67E-07	3.50E-07	3.20E-07
SigY	2.8E-09	4.0E-09	3.5E-09	2.5E-09	7.0E-09	2.7E-09	2.5E-09
SigZ	3.00E-04	3.00E-04	3.00E-04	1.50E-04	6.00E-04	2.00E-04	1.50E-04
Dx	1.98E-01	1.45E-01	1.13E-01	5.67E-02	5.09E-01	1.89E-01	1.70E-01
Dy	2.80E+01	1.75E+01	1.79E+01	8.96E+00	2.67E+01	2.47E+01	2.19E+01
U_ave	0.086	0.123	0.109	0.154	0.081	0.257	0.376
delta_B	0.042	0.061	0.050	0.044	0.060	0.134	0.178
P_Beamstrahlung (W)	7.33E+05	1.38E+06	9.02E+05	8.03E+05	1.09E+06	1.15E+06	3.21E+06

Signal Processing and DAQ impact:

- Beamstrahlung power ~ determines DAQ rates
- Should accommodate background rates at least x2 above expectations for "design luminosity"

Backgrounds Summary Slide from 2005 MDI Workshop

(K. Buesser and T. Maruyama, convenors)



Background simulations

- Impact
  - HEP detector design
  - Physics studies strategies
  - Radiation protection
  - Machine protection
  - ILC design on CDR timescales
- Powerful tools exist
  - Generators
    - CAIN
    - GUINEA-PIG
  - Simulations
    - BDSIM
    - MARS
    - GEANT3/4 based detector simulations
  - New developments
    - e.g. integrating low-energy physics into GEANT
- Results depend extremely on details
  - Geometries
  - Physics models
  - Cut-offs
  - Can we trust them?
- Simulations are complex
  - Usually experts do the work
  - Time consuming
    - e.g. QMUL GRID
  - Sharing the work is essential
    - e.g. QMUL database
  - Comparisons on highly detailed levels are needed

Biggest problem: the parameter space is infinite!

- Beam parameters
- Detector concepts
- Geometries
- etc.

Beam RF effects at Colliders

SLC

Problem with EMI for SLD's VXD3 Vertex Detector:
- Loss of lock between front end boards and DAQ boards
- Solved with 10 μsec blanking around beamtime – front end boards ignore commands during this period

(talk by M. Breidenbach at 2005 MDI Workshop)

PEP-II

Beampipe heating near IR due to High-order Modes (HOMs)
- S. Ecklund et al., *High Order Mode Heating Observations in the PEP-II IR*, SLAC-PUB-9372 (2002).
- A. Novokhatski and S. Weathersby, *RF Modes in the PEP-II Shielded Vertex Bellows,* SLAC-PUB-9952 (2003).

(talk by M. Sullivan at 2005 MDI Workshop)

HERA

Beampipe heating and beam-gas backgrounds

HOM-heating related to short positron bunch length

(see references listed on MDI forum at forum.linearcollider.org)

UA1

Initial beam pipe at IP too thin – not enough skin depths for higher beam rf harmonics

Beam RF effects at ILC IR?

	SLC	PEP-II e^+	ILC
Electrons/Bunch, Q	4.0×10^{10}	5.0×10^{10}	2.0×10^{10}
Bunch Length, σ_Z	1 mm	12 mm	0.3 mm
Bunch Spacing	8 ms	4.2 ns	337 ns
Average Current	7 nA	1.7 A	50 μA
$(Q/\sigma_Z)^2$ relative	92	1	256

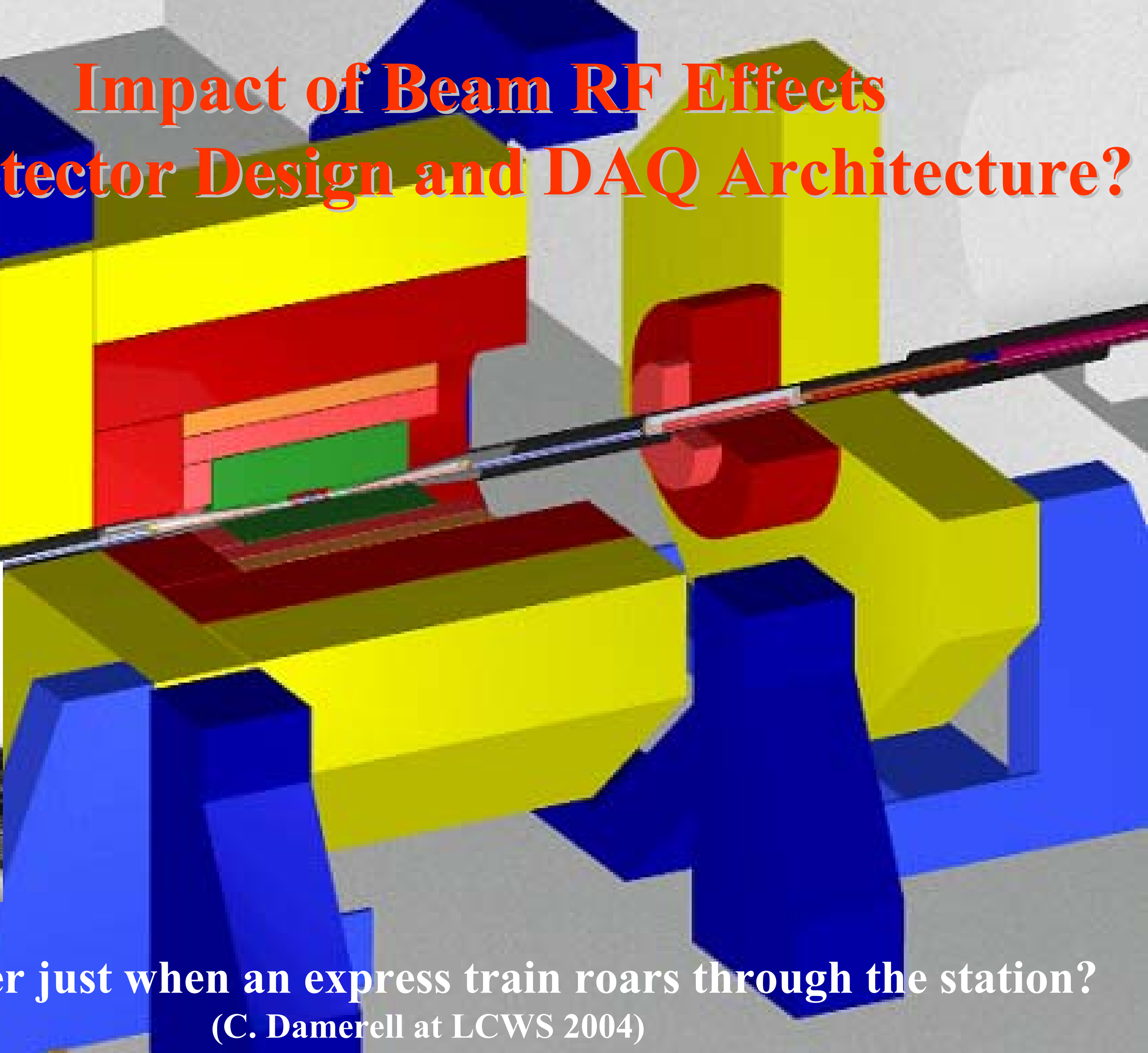
PEP-II experience

- HOM heating scales as $(Q/\sigma_Z)^2$
  - same scaling for EMI affecting detector electronics?
  - does scaling extend to mm and sub-mm bunch lengths?
  - need a cavity of suitable dimensions to excite
- IR geometry (aperture transitions, BPMs) has similar complexity as for ILC
- VXD and other readout systems ok for EMI in signal processing

ILC Considerations

- HOM heating probably ok because of small average beam current
- EMI affecting Signal Processing and DAQ? Impact on Detector Design and Signal Processing Architecture?

Impact of Beam RF Effects on Detector Design and DAQ Architecture?



Why whisper just when an express train roars through the station?

(C. Damerell at LCWS 2004)

Impact of Beam RF Effects on Detector Design and DAQ Architecture?

Do EMI worries necessitate storing signals locally for readout to DAQ during (quiet) inter-train period?

VXD

- CCD small signals; 20-micron pixels need readout 20X per train to have acceptable occupancy/pixel
- ISIS proposal: CCD Image Sensor with In-Situ Storage?
  -800M pixel detector → 800M x20 pixels!
  (see talk by C. Damerell at LCWS 2004)
- FPCCD proposal: 5-micron CCD pixels!
  (see talk by Y. Sugimoto at ACFA Nov. 2004 Workshop)

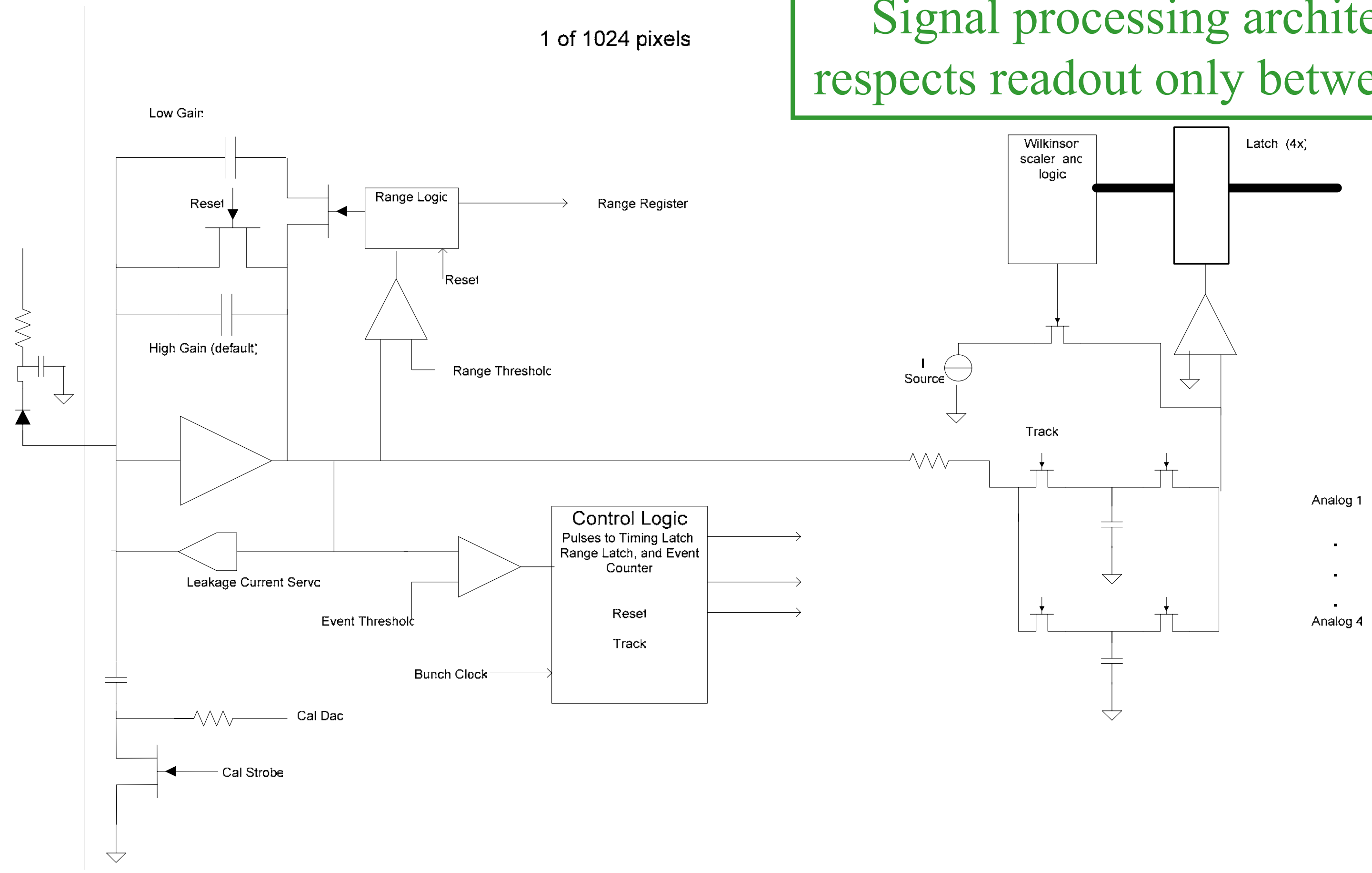
Other Systems sensitivity?

- in particular for forward region detectors with large occupancy
- SiD electronics design (see Breidenbach's talk at Jan. 2005 MDI Workshop) does local storage of signals for inter-train readout

Si-W Pixel Analog Section

1 of 1024 pixels

Signal processing architecture respects readout only between trains



Simplified Timing:

There are ~ 3000 bunches separated by ~300 ns in a train, and trains are separated by ~200 ms.

Say a signal above event threshold happens at bunch n and time T0
The Event discriminator triggers in ~100 ns and removes resets and strobes the Timing Latch (12 bit), range latch (1 bit) and Event Counter (5 bits).
The Range discriminator triggers in ~100 ns if the signal exceeds the Range Threshold.
When the glitch from the Range switch has had time to settle, Track connects the sample capacitor to the amplifier output. (~150 ns)
The Track signal opens the switch isolating the sample capacitor at T0 + 1 micro s. At this time, the amplitude of the signal at T0 is held on the Sample Capacitor
Reset is asserted (synched to the bunch clock) . Note that the second capacitor is reset at startup and following an event, while the high gain (small) capacitor is reset each bunch crossing (except while processing an event)
The system is ready for another signal in ~1.2 microsec.
After the bunch train, the capacitor charge is measured by a Wilkinson converter.

Beam RF Effects Summary From MDI Workshop, Jan. 2005

Significant impact on:

- RF shielding for beamline and detector components
- Detector design
- Signal Processing and DAQ architecture

Beam rf effects have had a significant effect at previous colliders:
ex. SLC, PEP-II, HERA, UA1
beampipe heating and EMI from HOMs

Detector physicists MUST study this seriously together with the accelerator experts

Beam Test at SLAC ESA to further investigate this is proceeding:

- with SLD's VXD3 and with simpler beampipe
- strong desire for this from international vertex community
- can provide important information for VXD design and for signal processing/DAQ for all LC Detector systems

Working group participants: M. Woods, C. Hast, N. Sinev, R. Arnold, S. Worm,
D. Cussans, Y. Sugimoto, T. Nelson, S. Parker, …