PROPERTIES OF THE ELECTRON CLOUD AT A HIGH-ENERGY ELECTRON RING

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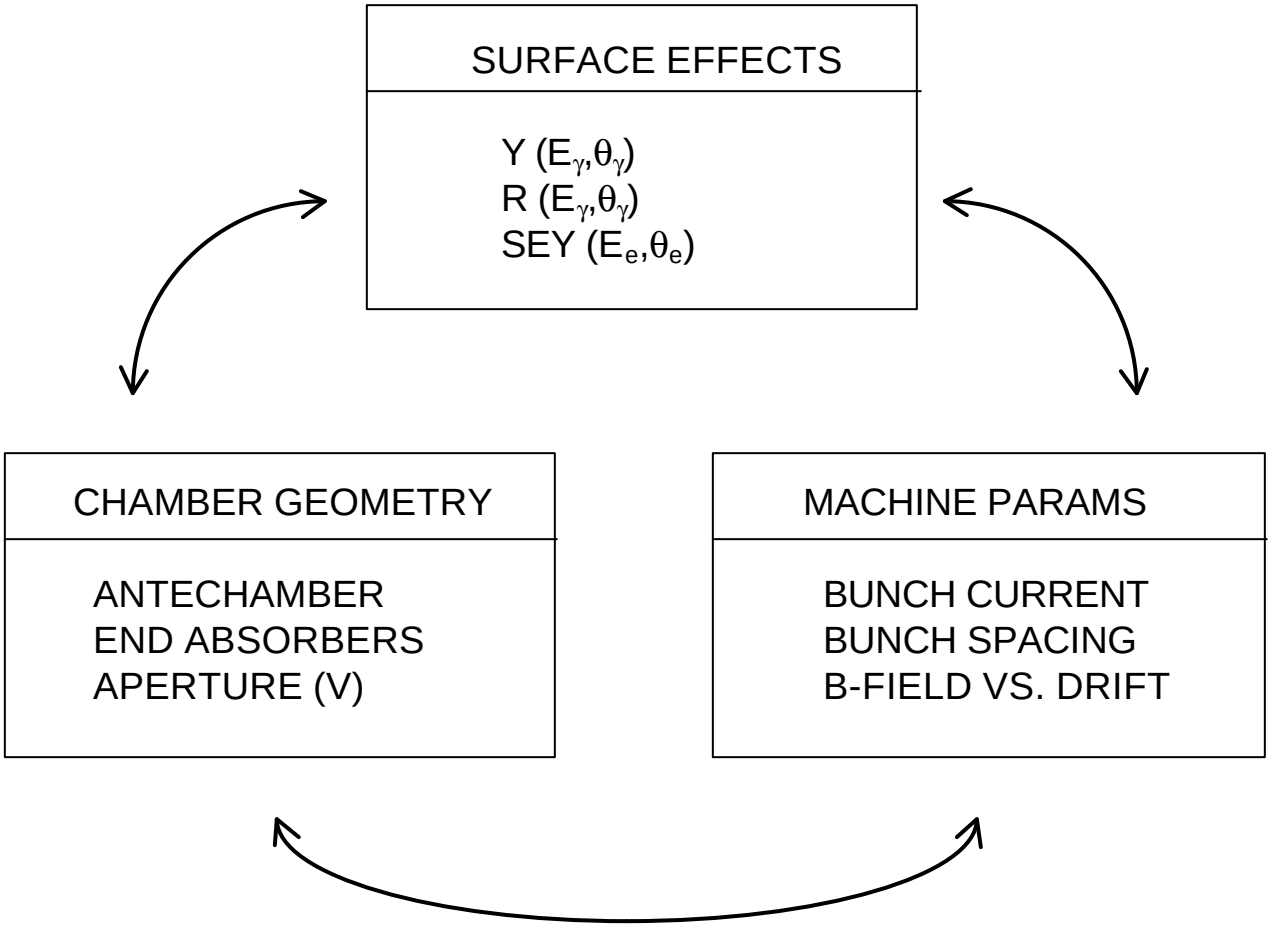
THANKS ALSO TO: MIGUEL FURMAN, LBNL/CBP, FOR MODEL

WORKSHOP ON SYNCHROTRON RADIATION EFFECTS AT THE VLHC
BNL, Upton, NY, 2000 Sep 18-20

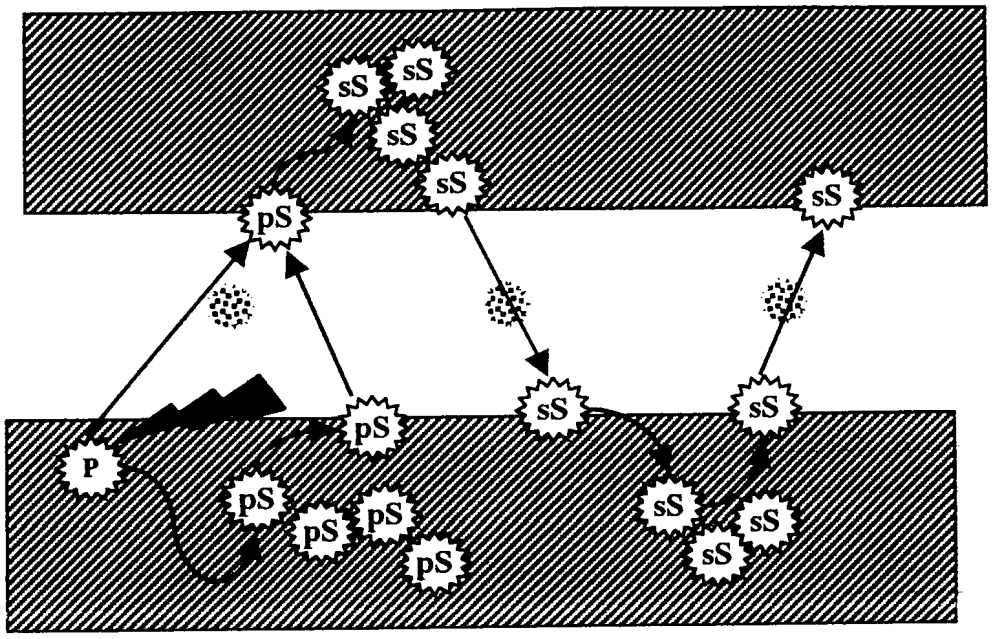
CRITICAL PARAMETERS FOR ELECTRON CLOUD



- **Not obvious that simple scaling rules can be found**

MECHANISMS FOR

BEAM-INDUCED ELECTRON CLOUD



R. Rosenberg

beam bunch

synchrotron photons

P photoelectron

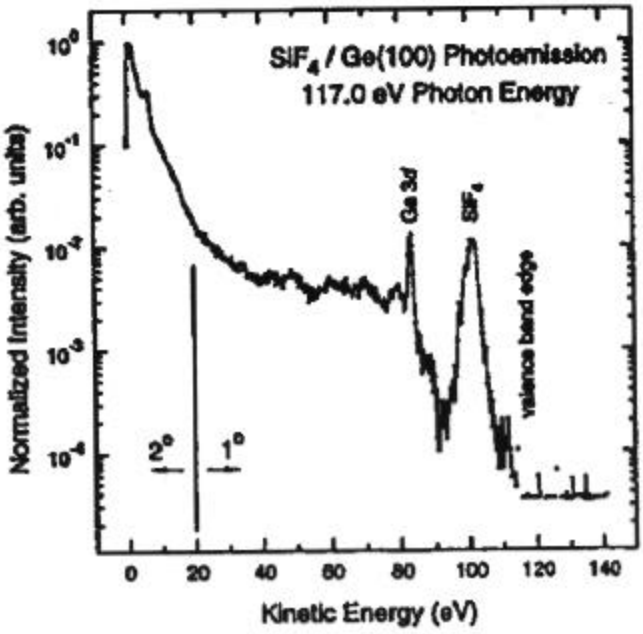
pS primary secondary electrons

} PE: primary component

sS secondary secondary electrons

} SE: secondary component

Photoemission spectrum showing primary (1°) and secondary (2°) processes*



*R.A. Rosenberg and S.P. Frigo in "Chemical Applications of Synchrotron Radiation" (World Scientific, to be published).

Schematic photoemission spectra as a function of photon energy*

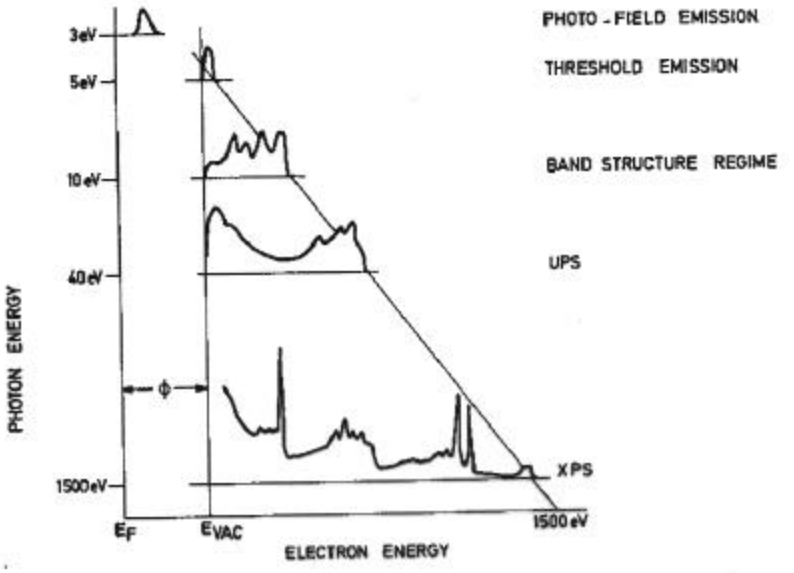
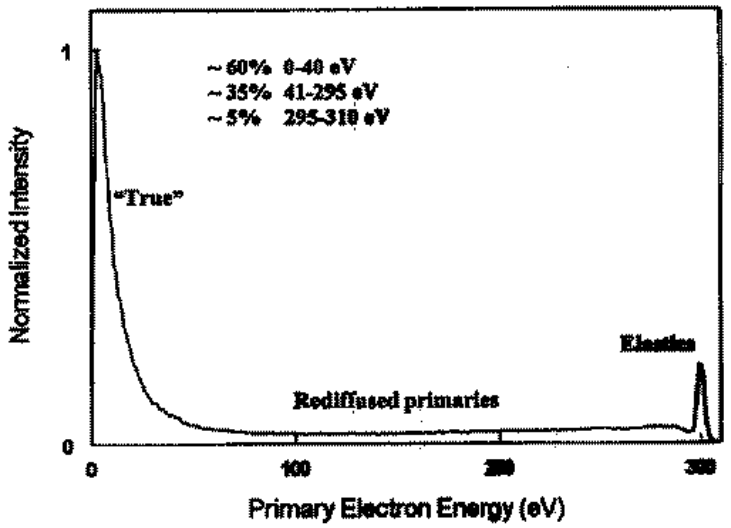


Fig. 5.3 Energy ranges and specialized spectroscopies in photoemission. XPS, excited by soft X-rays, shows spectra of considerable complexity including core level spikes, Auger peaks, valence-band emission and inelastic electrons. UPS has an intrinsically higher resolution and cross section for the valence band. The bandstructure regime, $\hbar\omega \approx 10$ eV, shows sharp structure arising from bulk selection rules. Threshold emission is generally observed without energy analysis. Subthreshold spectroscopy requires additional means to emit photoexcited electrons over the work function barrier ϕ, such as, e.g., a high electric field

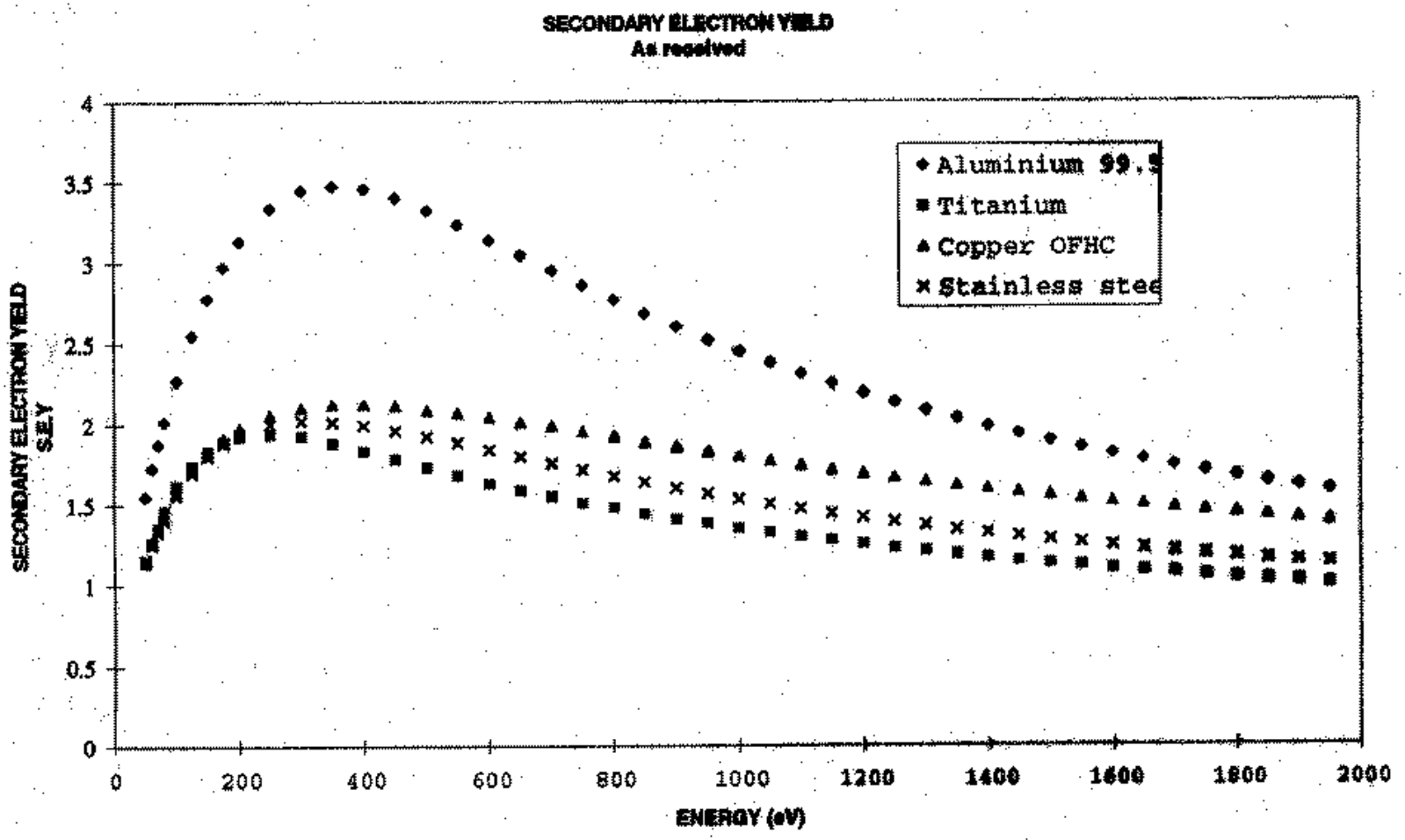
*B. Fuerbacher and B. Fitton in "Electron Spectroscopy for Surface Abnalysis", p. 155 (Springer-Verlag, Berlin, 1977).

Energy Distribution Of Secondaries



TiN/Al

Robert E. Kirby - SLAC



NH - SI.FE 00
EBEC

N. Hilleret, CERN

APPROX. REGIMES FOR VARIOUS EFFECTS

ECI
(KEK PF, BEPC, KEK-B)

$$t_{WAKE} \geq t_b \geq \frac{2r}{\Delta v}$$

beam-induced multipacting
(ISR, PEP-II, LHC, APS, etc)

where

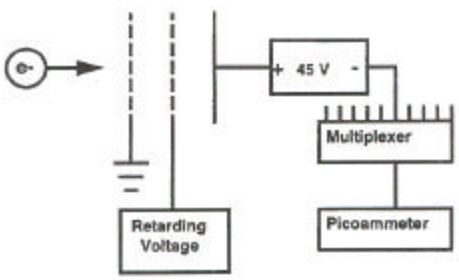
t_{WAKE} is the range of the effective EC wakefield,
t_b is the bunch spacing,
r is chamber half-height and
Δv is velocity change of electron due to kick by beam bunch

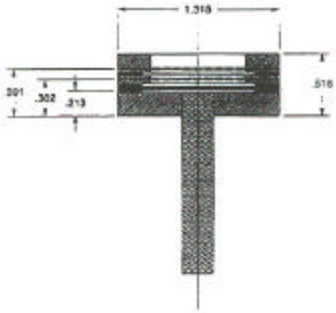
PRIMARY ELECTRON DOMINATED:

SEY unimportant
Very large or very small t_b
$t_{WAKE} \longrightarrow$ $\langle E_{e^-} \rangle$

SECONDARY ELECTRON DOMINATED: BEAM-INDUCED MULTIPACTING

Electron-cloud energy analyzer





Schematic showing mounting of two detectors (left) or a bpm opposite a detector (right) on vacuum chamber

Energy gain of electrons at wall accel. by beam

$$\left(\frac{\nu}{c}\right)_{max} = \frac{2N_b r_e}{a}$$

$$K = \frac{mv^2}{2} = 10\,eV$$

time to traverse $2a$ (vert) $= 21\,ns$

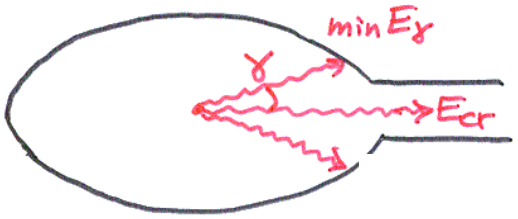
Advanced Photon Source

Richard Rosenberg

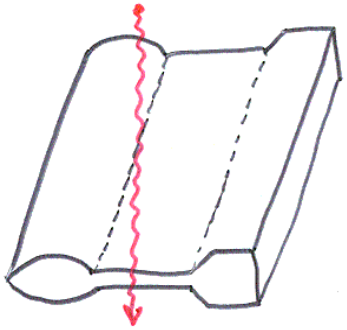
to be published soon: R. Rosenberg and K. Harkay, NIM-A (2000)

VACUUM CHAMBER GEOMETRY

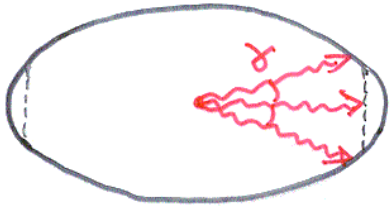
typical antechamber



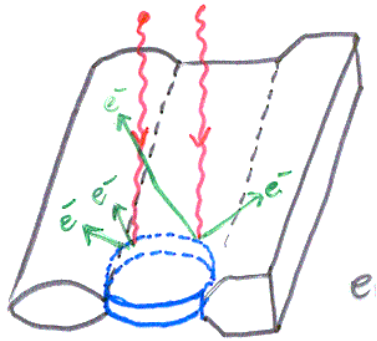
photons emitted from upstream bend



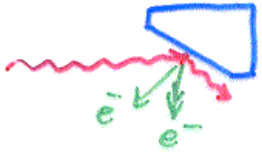
no antechamber



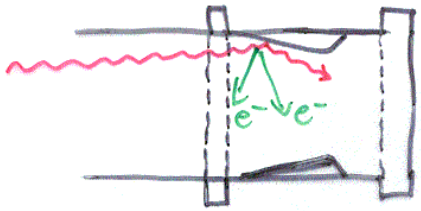
radiation end absorber (EA)



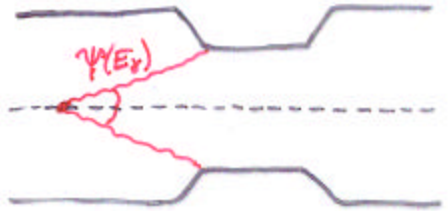
side view, EA

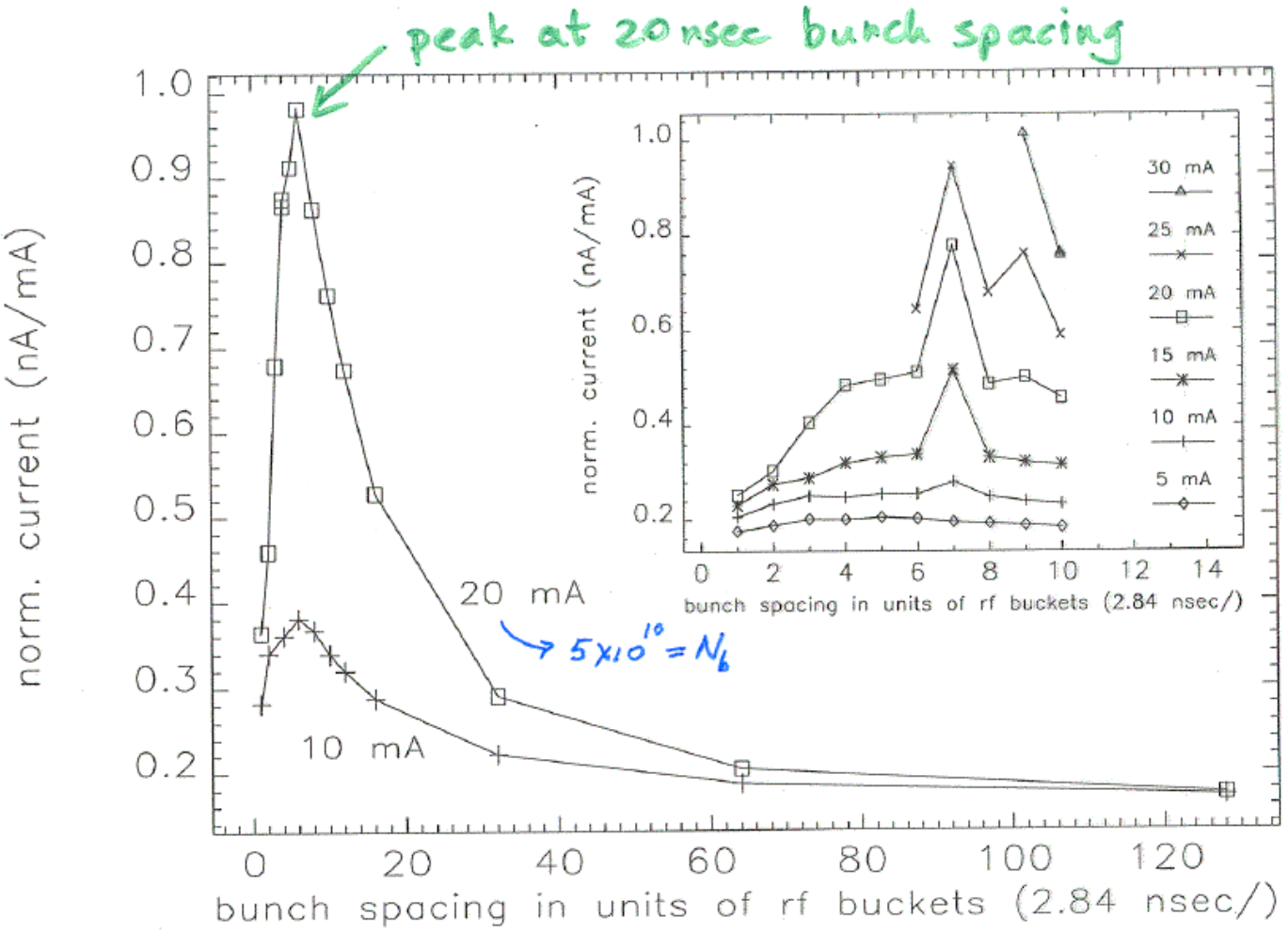


radiation mask

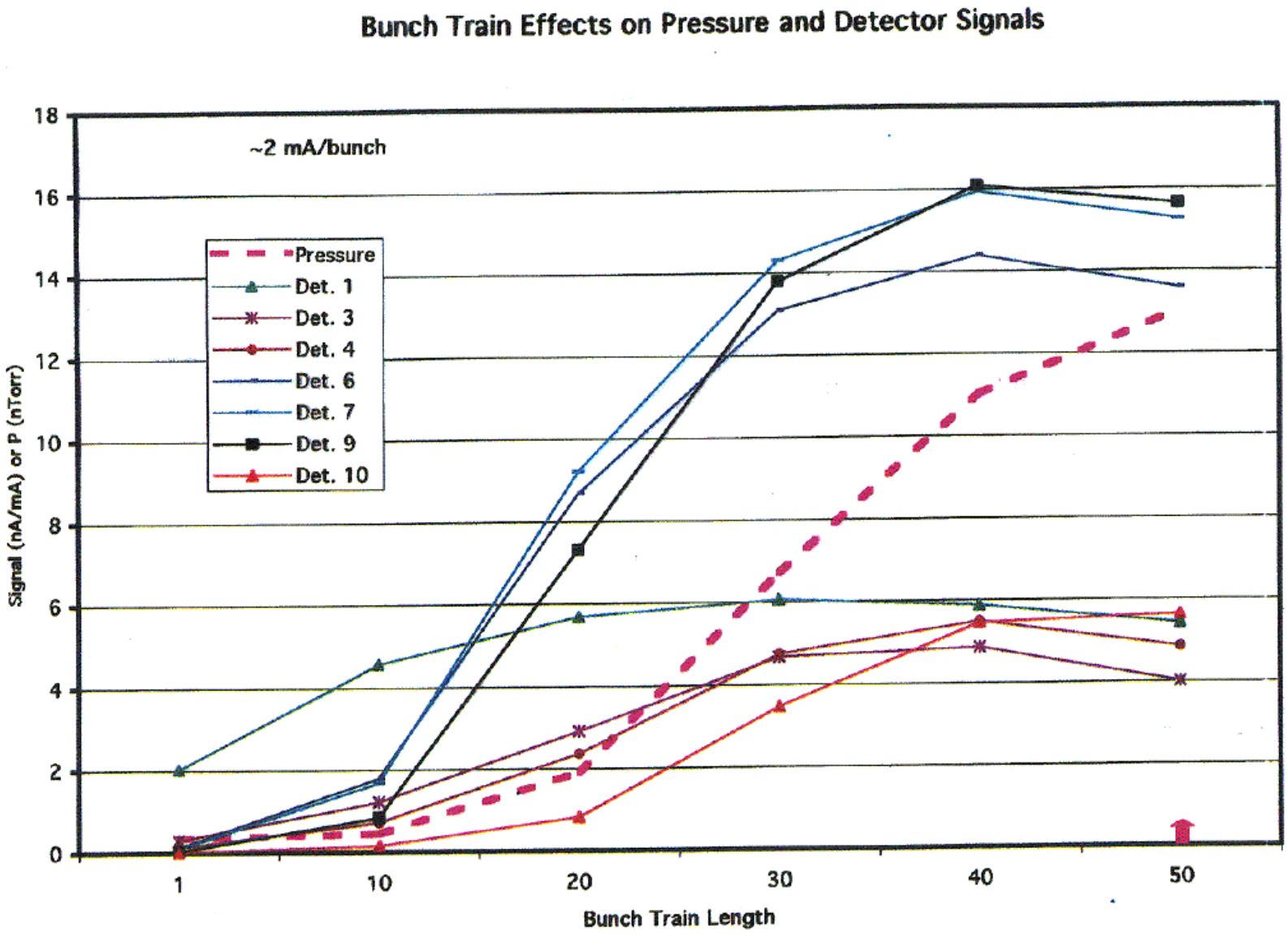


vertical restriction (e.g. small-gap chamber)

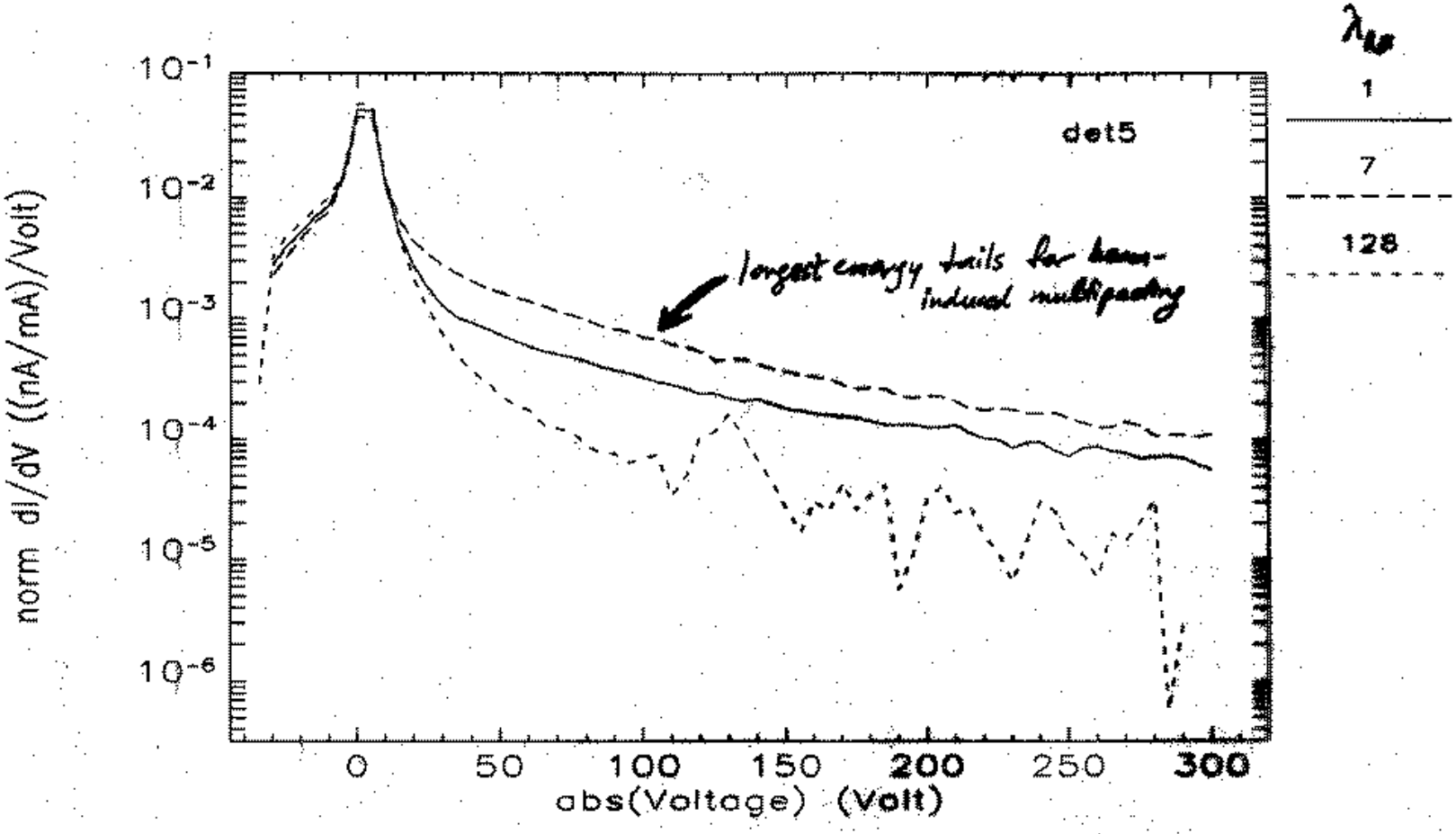




Comparison of normalized current as a function of bunch spacing and current (10 bunches total)

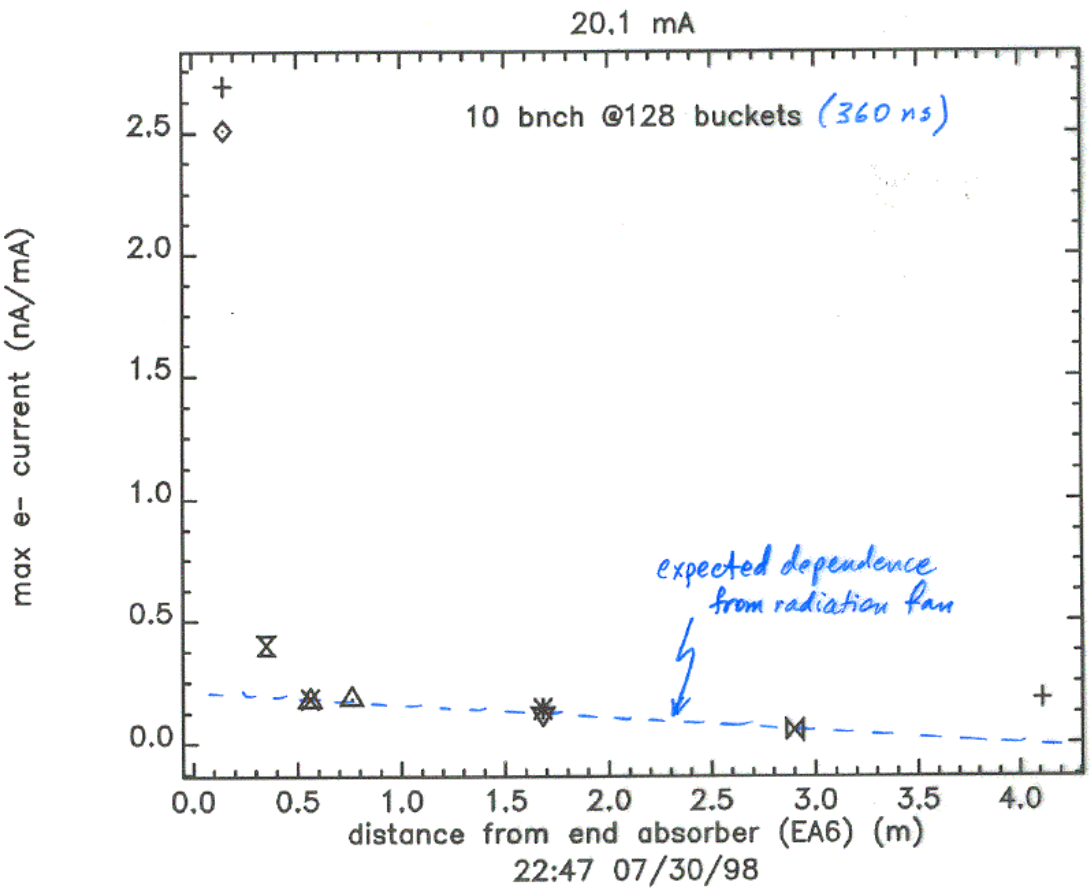


BIM threshold <~ 2 mA/bunch; little effect on vacuum pressure with 1 mA/bunch

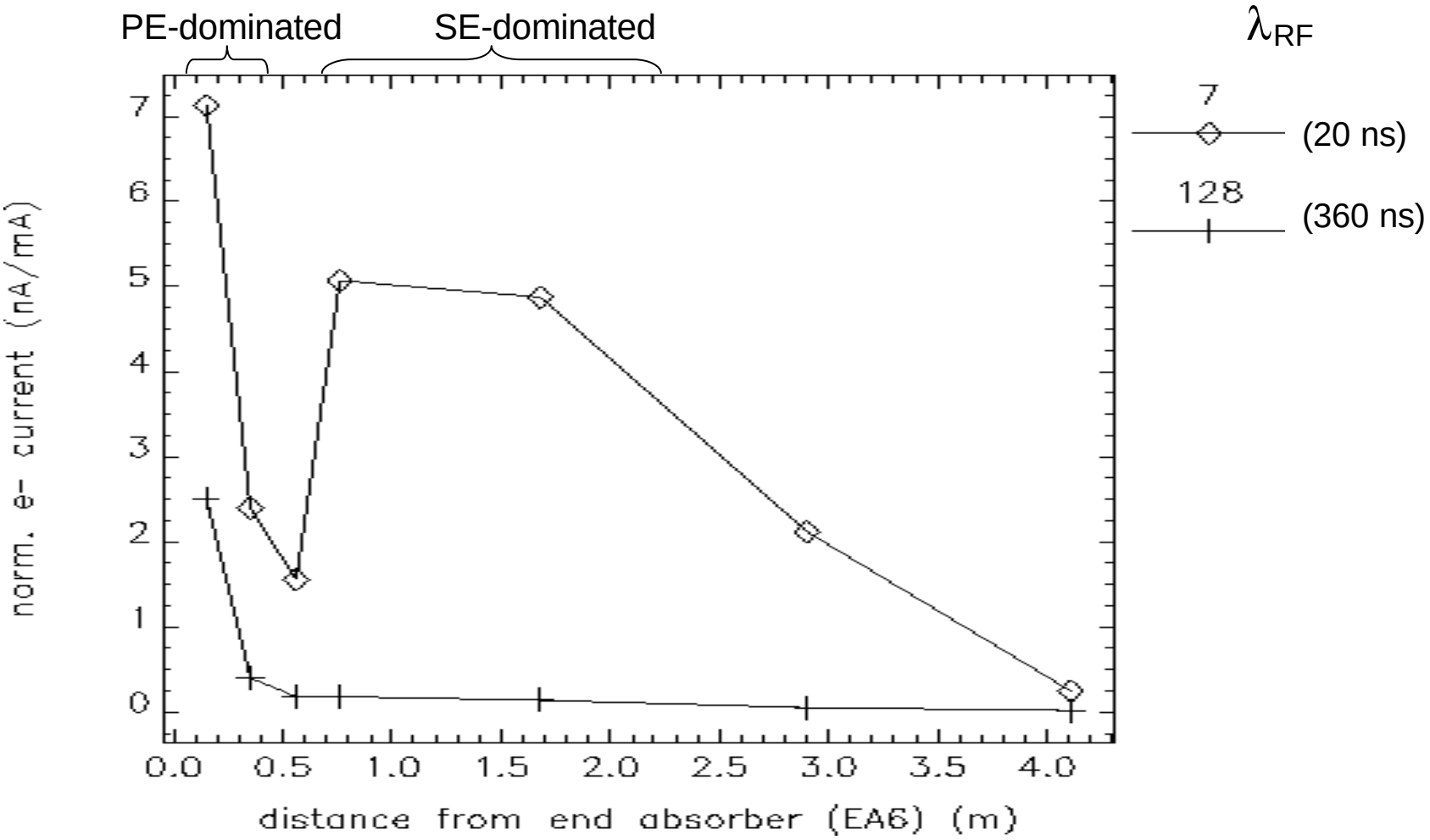


Measured Electron energy distribution vs. bunch spacing.

End absorber (EA6) a source of electrons, dominating detectors 1 - 3



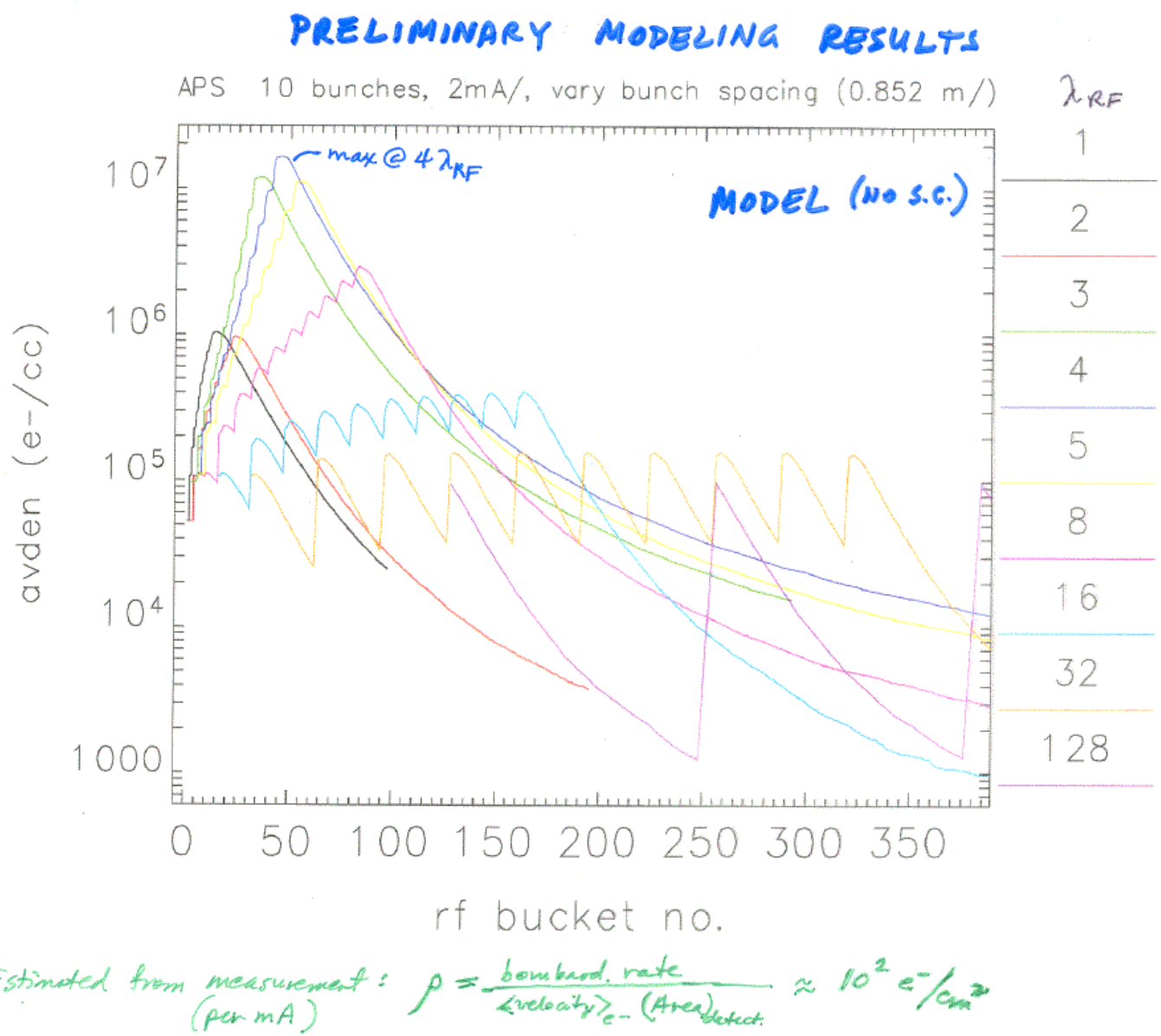
Detector current as a function of distance from EA6, bunches widely spaced (few secondary elecrtons)

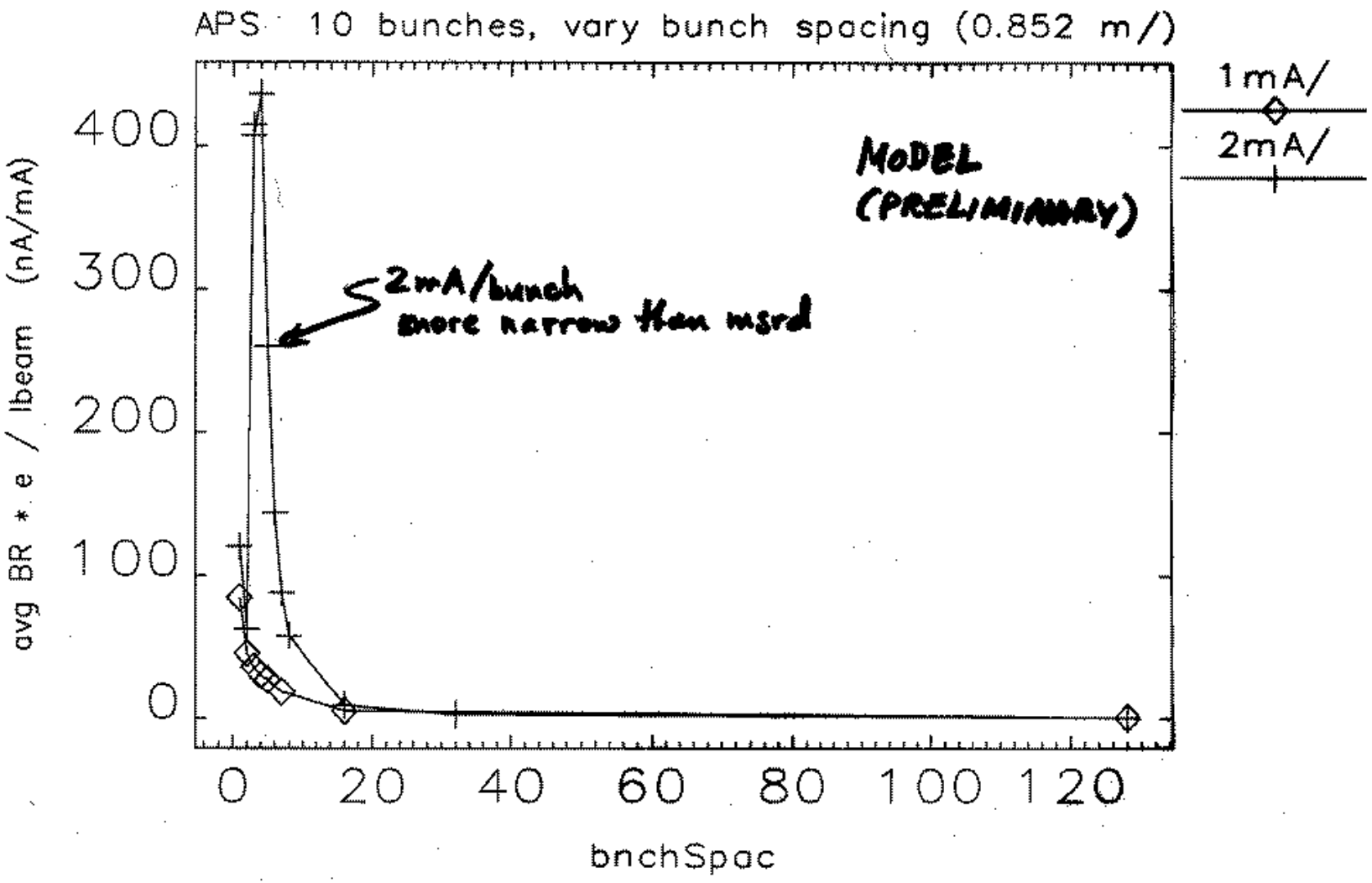


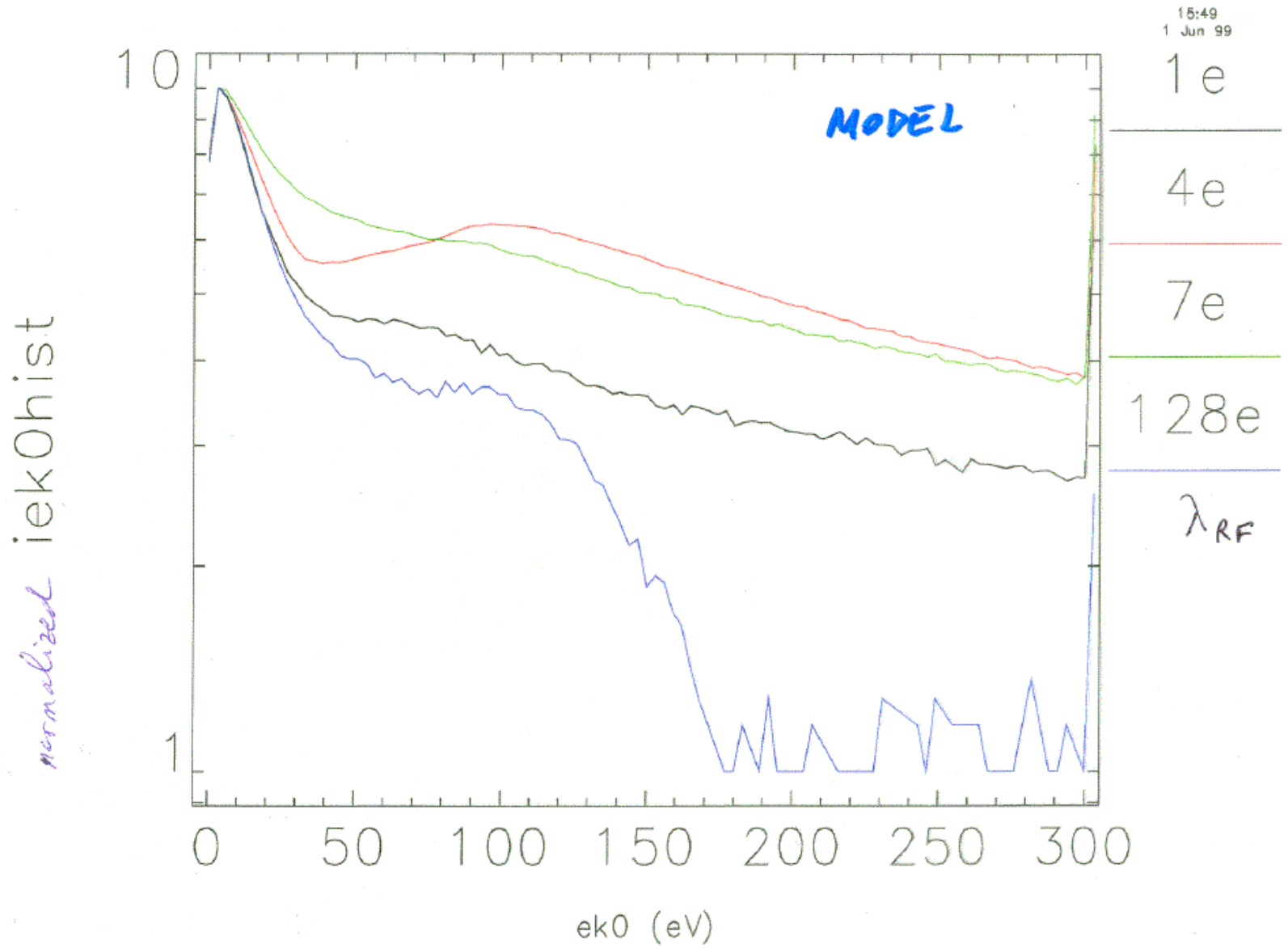
Total, normalized electron current per detector vs. distance from EA6 as a function of bunch spacing (10 bunches, 20 mA). Strong amplification for a bunch spacing, t_b, of 20 ns; by comparison:

PEP-II: chamber HH (SS) 45 mm; t_b = 13 ns

LHC: chamber HH (Cu) 22 mm; t_b = 25 ns


PRELIMINARY MODELING RESULTS
APS 10 bunches, 2mA/, vary bunch spacing (0.852 m/)
max @ 4 λRF
MODEL (NO S.C.)
avden (e-/cc)
10^7
10^6
10^5
10^4
1000
0 50 100 150 200 250 300 350
rf bucket no.
λRF
1
2
3
4
5
8
16
32
128
Estimated from measurement (per mA): ρ = bombard. rate / ⟨velocity⟩e- (Area)detect. ≈ 10^2 e-/cm^2


APS 10 bunches, vary bunch spacing (0.852 m/)
1mA/
2mA/
MODEL
(PRELIMINARY)
2mA/bunch
more narrow than msrd
avg BR * e / Ibeam (nA/mA)
400
300
200
100
0
0
20
40
60
80
100
120
bnchSpac


15:49
1 Jun 99
MODEL
1e
4e
7e
128e
λRF
normalized iek0hist
10
1
0
50
100
150
200
250
300
ek0 (eV)

SUMMARY

- Electrons are ubiquitous in accelerators/storage rings
- Independent experimental results at APS, PEP-II, CERN SPS on beam-induced multipacting are beginning to converge (-> universal scaling rules???)
- Challenges remain in predicting electron cloud distribution (results of APS modeling are PRELIMINARY)
  - Surface effects/conditioning
  - Model input parameters
  - Influence of external magnetic field