Electron Cloud Effects Session L

R. Macek, H. Fukuma, co-convenors

	Time	Title	Presenter
1	8:35-9:05	Electron cloud effects (ECE) at e+/e- machines and electron cloud diagnostics	K. Harkay (ANL)
2	9:05-9:35	Observation of ECE at the KEKB	Hitoshi Fukuma (KEK)
3	9:35-10:05	Observation of ECE at the PSR	R. Macek et al. (LANL)
4	10:05 -10:35	Theory and simulation of ECE	Kazuhito Ohmi (KEK)
	10:35 -11:00	Break	
5	11:00-11:30	Simulations of electron cloud generation in the PSR and SNS	Mauro Pivi (LBL)
6	11:30-12:00	Nonlinear delta-f simulation studies of e-p two-stream instabilities	H. Qin (PPPL)
7	12:00-12:30	ECE in the KEK PS and the JHF project	T. Toyama et al. (KEK)

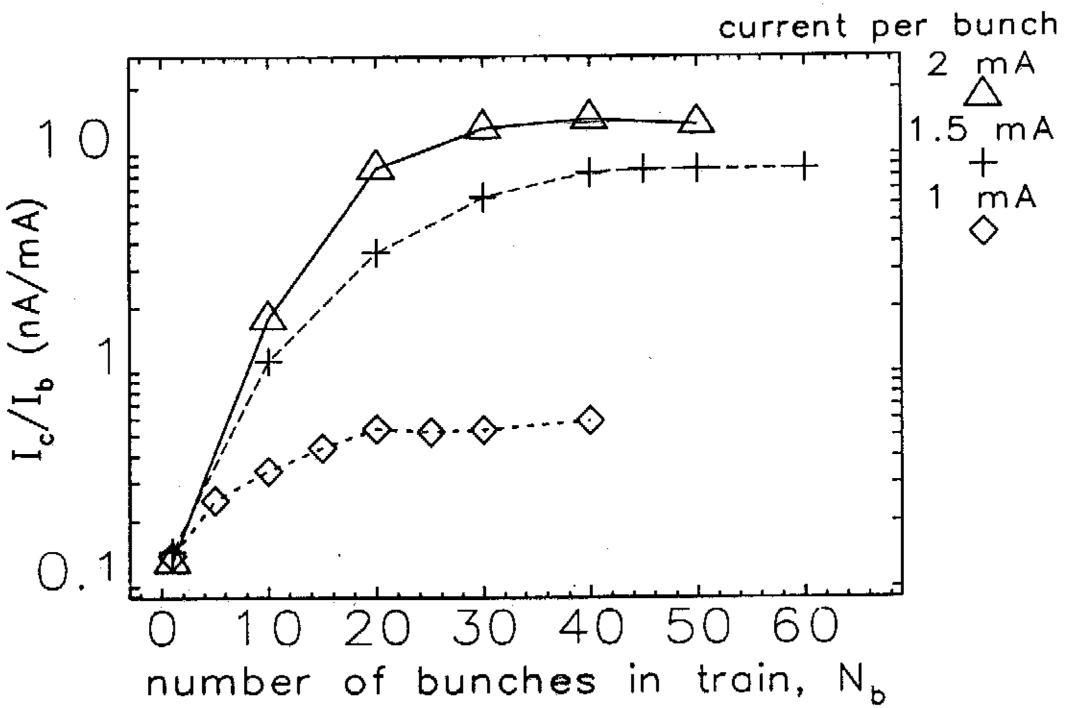
Electron Cloud Effects

- Vacuum degradation (e-stimulated gas desorption)
- Beam induced multipacting
  - Resonant (APS, KEKB, PS, SPS, LHC?)
  - Trailing-edge multipactor (PSR, SNS?, JHF?)
- Two-stream e-p instability [redacted] (ISR, PSR, AGSB, SNS?, JHF?)
- Transverse coupled bunch instability (APS, B factories, PS, SPS, LHC?)
- Single bunch (head-tail) instability; emittance blowup (APS, B factories, PS, SPS)
- Heat load on cryogenic wall (LHC)
- Cloud-induced noise or spurious signals in beam diagnostics (e.g., wirescanners, electrostatic pickups, IPM) (PSR, PS, SPS...)
- Electrons trapped in distributed ion pump leakage field (CESR)

K. Harkay: New electron cloud diagnostics

- Retarding field analyzer (RFA) developed at ANL
  - Measures e-flux, energy spectra and time structure of electrons striking the wall
  - Well characterized detector response
- Electron sweeper developed at LANL
  - Extends RFA concept using pulsed electrode to sweep low energy electrons from the pipe into RFA

Electron cloud build-up rate and saturation as function of bunch charge



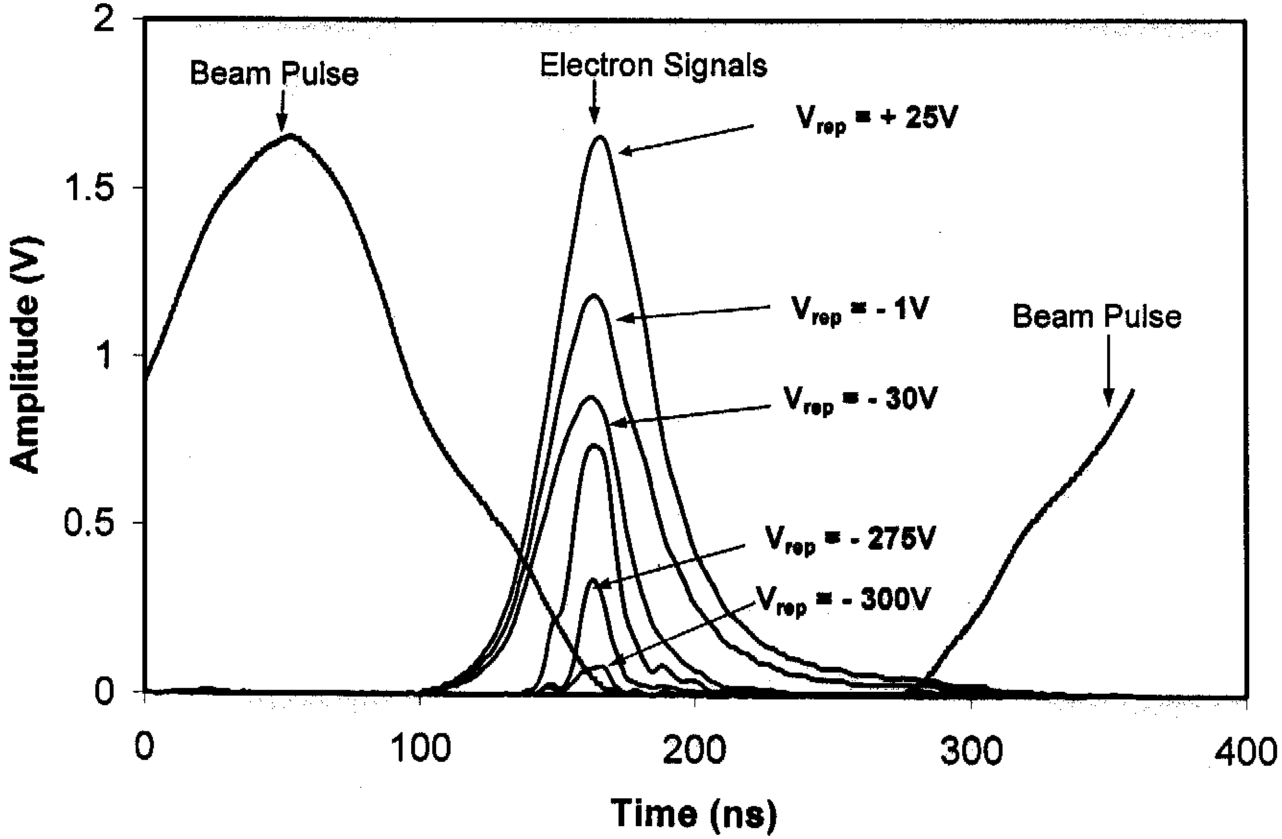
Estimate cloud density given flux at wall and avg. electron velocity; compare to avg. beam density (e.g. at 100 mA, 2 mA/bunch):

$$n_{EC} = (I_c/I_b) / \text{detArea} * I_b / \langle v_e \rangle = 1.5\text{x}10^{10}\ \text{cm}^{-3}$$

$$n_{beam} = N_b / \text{chambArea} / \text{bunch sep} = 3\text{x}10^{10}\ \text{cm}^{-3}$$

Saturated EC density varies locally by up to a factor of 3; nonlinear with total beam current;
horizontal EC-induced coupled-bunch instability observed for 2 mA/bunch, >90 mA

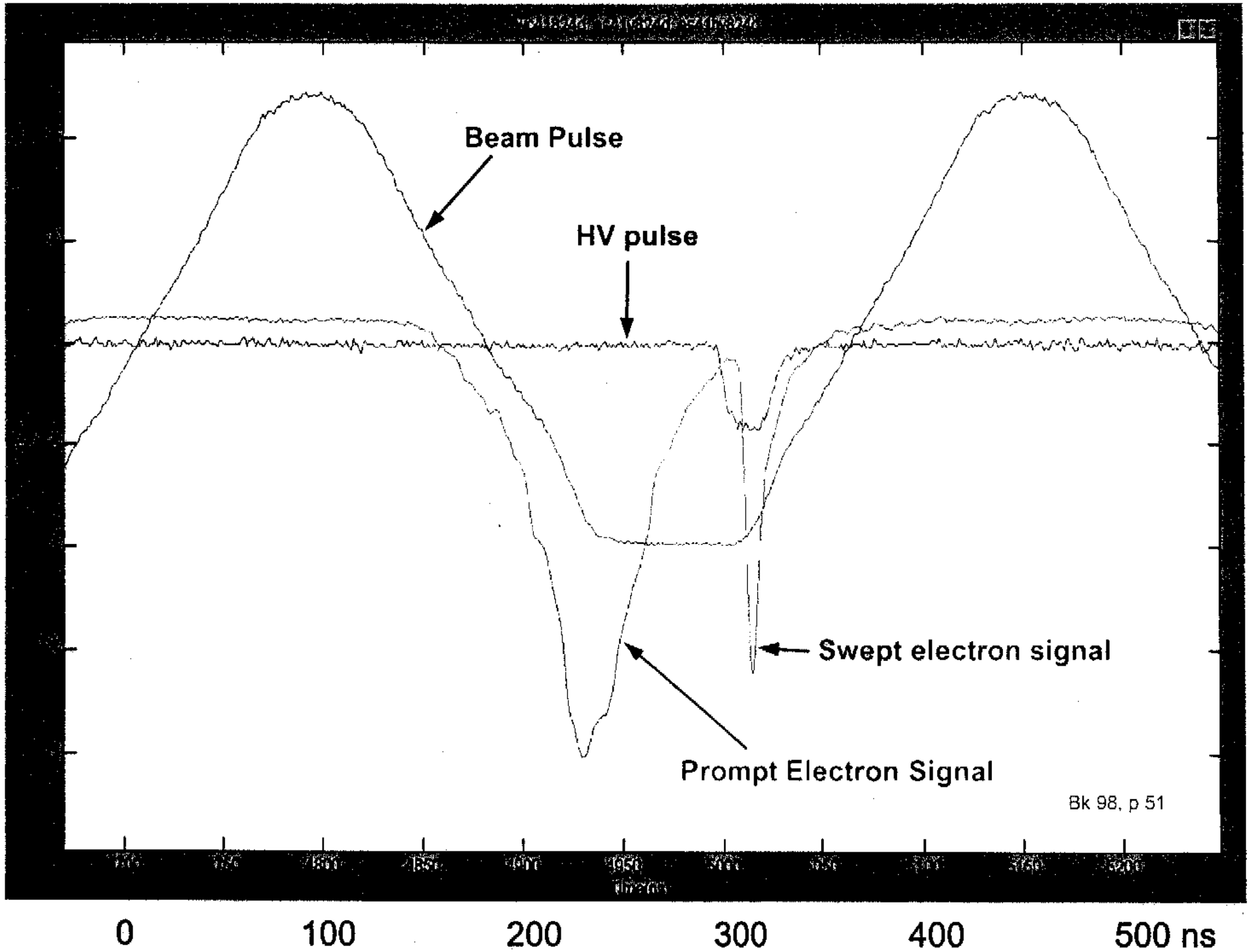
Electron signals from RFA in straight section 4



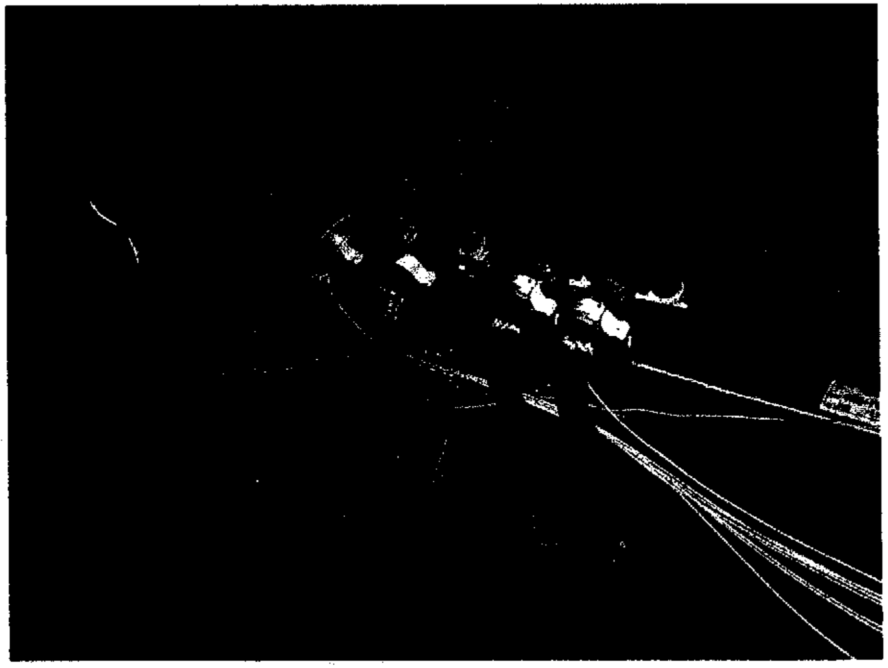
- **RFA signal has contributions from "trailing edge multipactor" and "captured electrons" released at end of beam pulse plus their secondaries**
- **Key issue is how many electrons survive the gap to be captured by the beam**

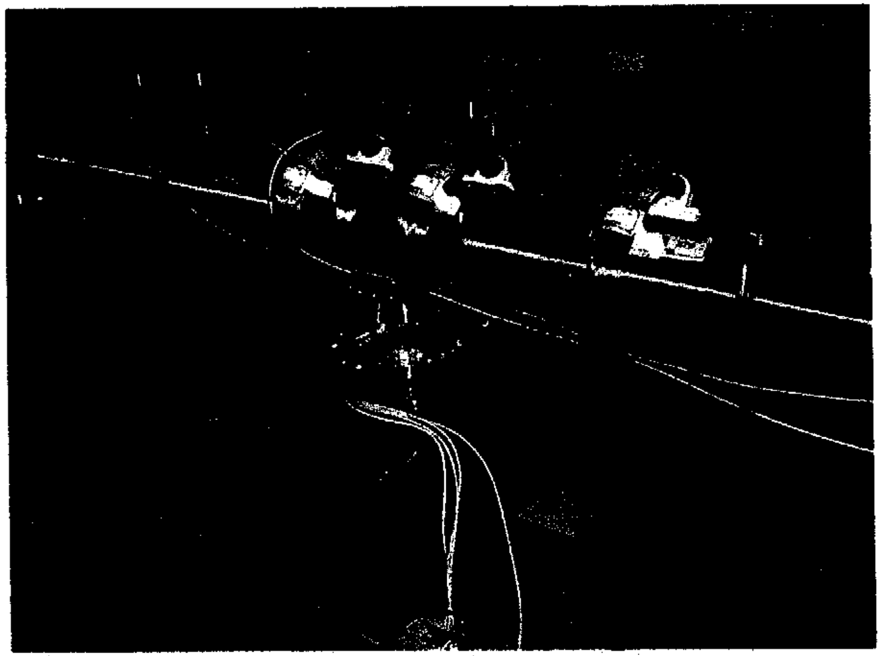
Signals averaged for 32 beam macropulses, ~ 8 μC/pulse beam intensity, device is labeled ED42Y,
Transimpedance = 3.5 kΩ, opening ~1 cm²

Sample electron data using electron sweeper at PSR



7.7 µC/pulse, bunch length = 280 ns, 30 ns injection notch,
signals averaged for 32 macropulses, repeller = - 25V, HV pulse = 500V

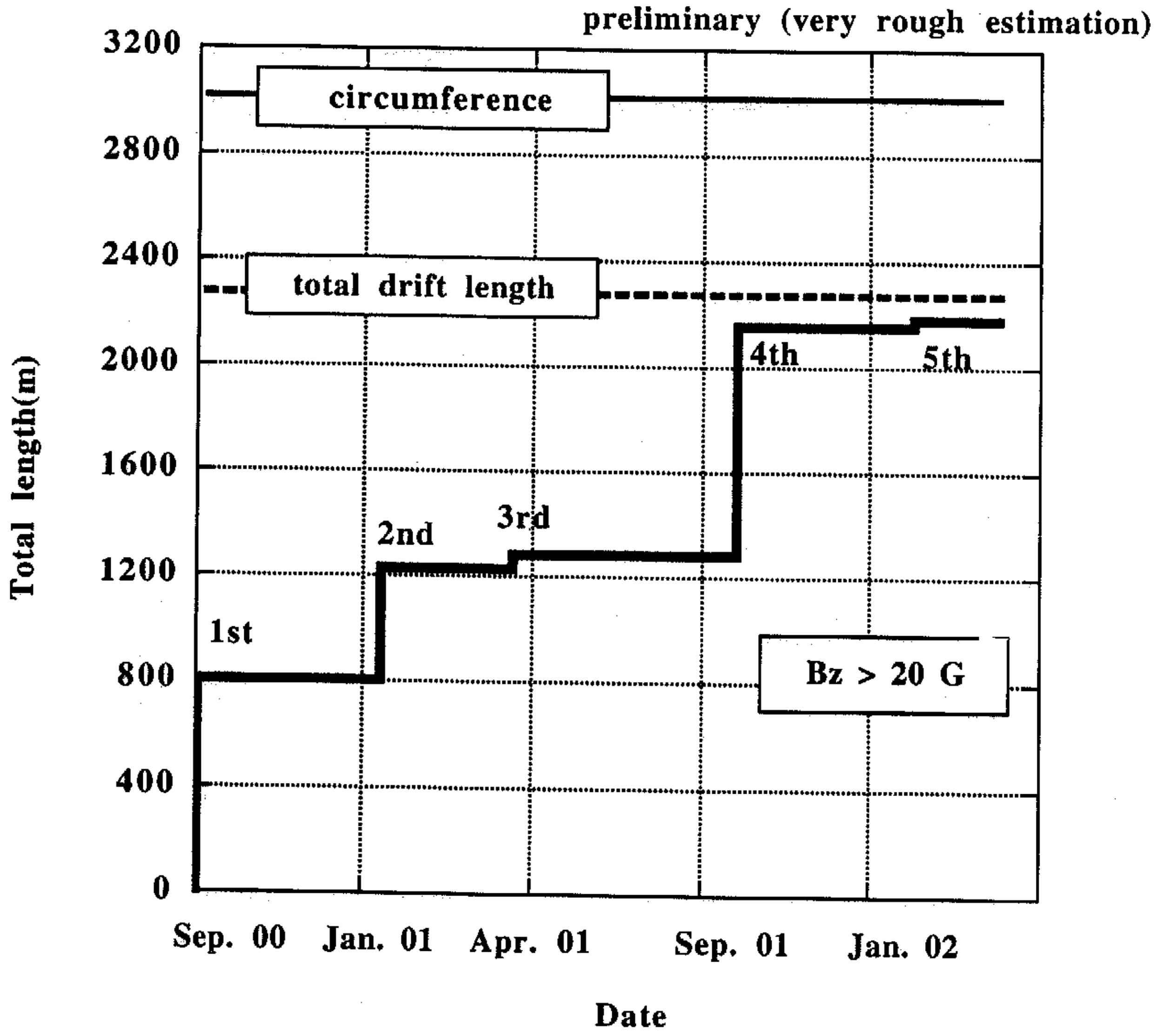


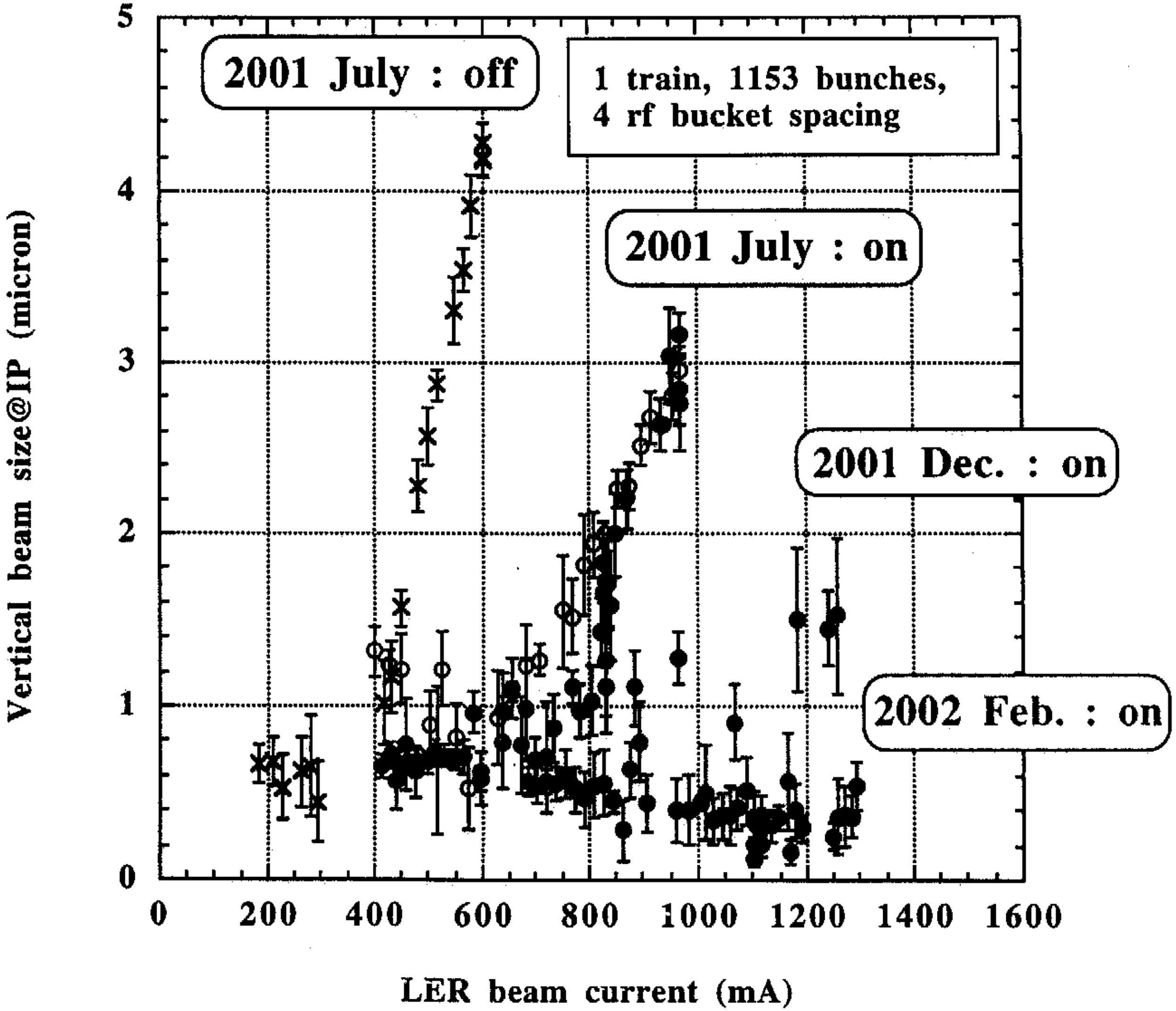


NEG pump and Bellows

Ion pump

Total length of solenoid



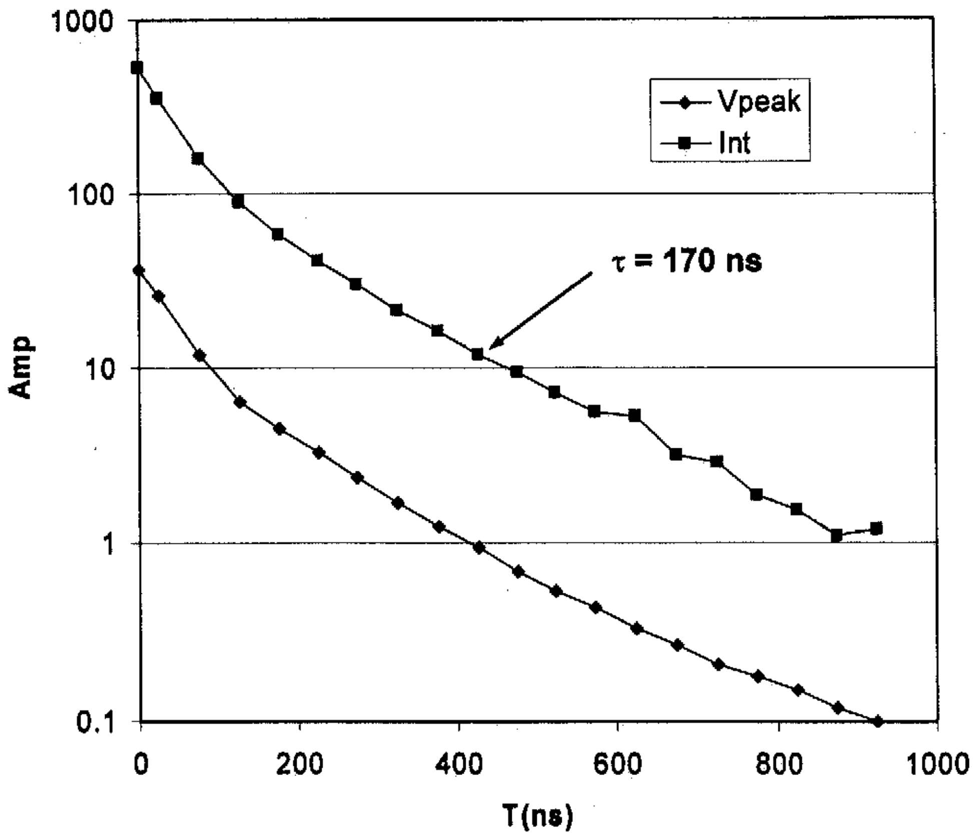

2001 July : off
1 train, 1153 bunches,
4 rf bucket spacing
2001 July : on
2001 Dec. : on
2002 Feb. : on
Vertical beam size@IP (micron)
LER beam current (mA)
0
1
2
3
4
5
0
200
400
600
800
1000
1200
1400
1600

Swept Electrons in pipe vs time after end of beam pulse

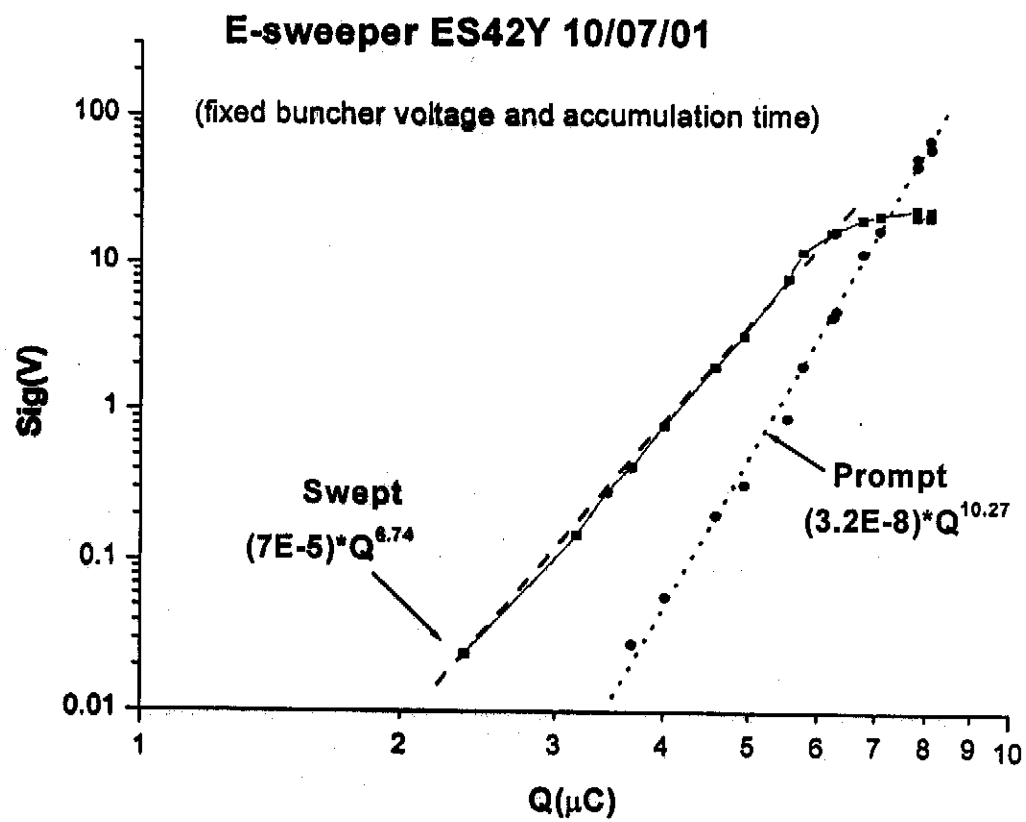
- Early results from electron sweeper for 5μC/pulse looking just after extraction
- Peak signal or integral have essentially the same shape curve
- Long exponential tail seen with ~170 ns decay time
- Still see electrons after 1 μs
- Implies a high secondary yield (reflectivity) for low energy electrons (2-5 eV)

$$\delta_{eff} = \exp\left[-\frac{d}{c\cdot\tau}\cdot\sqrt{\frac{m_e\cdot c^2}{2E}}\right] \approx 0.5$$

- Implies neutralization lower limit of ~1.5% based on swept electrons signal at the end of the ~100ns gap

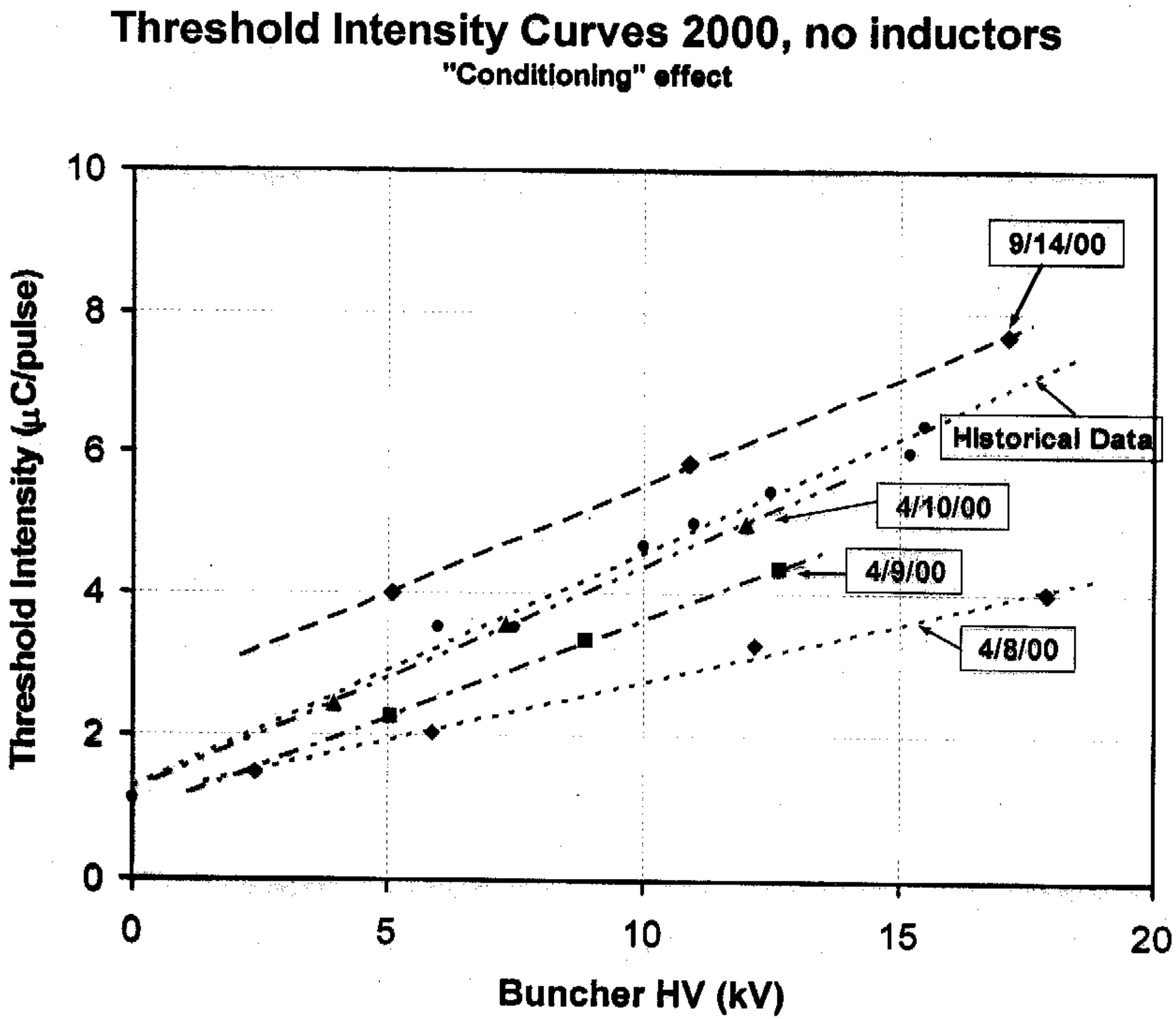


Prompt and Swept Electrons vs Beam Intensity



- The saturation of swept electrons above 5 μC/pulse is not restricted to variations of beam intensity but includes other variables that affect the prompt signal such as:
  - Variation in beam loss
  - Bursts
  - Changes in pulse shape
- Saturation explains several puzzles:
  - Why instability threshold is unchanged by increases in losses or vacuum pressure
  - Why the threshold intensity curves vs buncher voltage do not plateau at some intensity

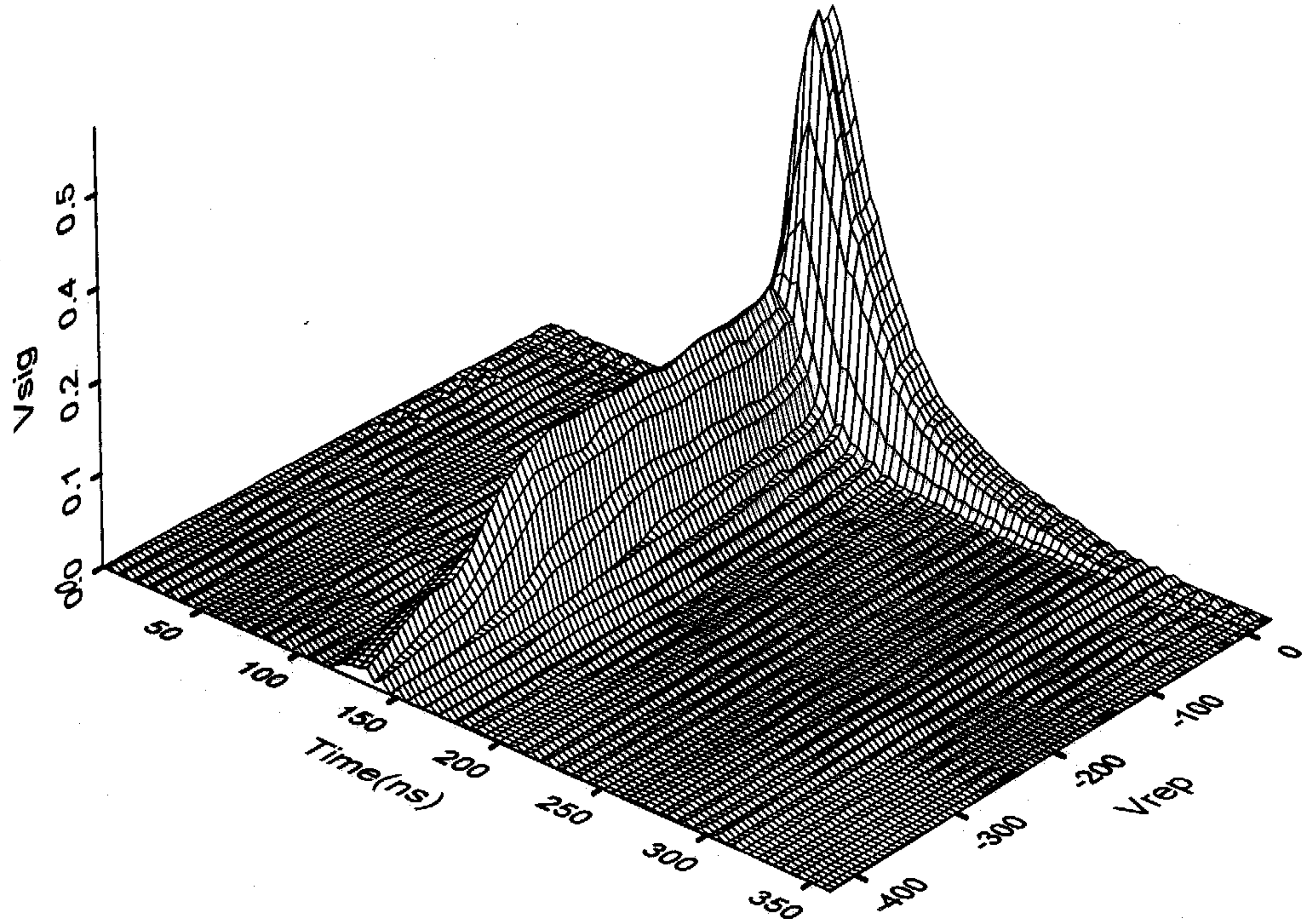
Conditioning effect



M. Pivi: Simulations of e-cloud generation in PSR & SNS

- Features of LBNL code POSINST
  - Rigid proton beam using measured or calculated beam profile
  - Primary electrons from losses ($4x10^{-6}$/prot/turn for PSR) and/or residual gas ionization
  - Electrons move in 3D subject to 2D forces from proton beam and e-cloud space charge
  - Detailed model of SEY at wall
- Reproduces general features of RFA signals from PSR
- Predicts large neutralization for SNS which is reduced significantly by conditioned TiN coatings
- Primary electron source(s) and SEY are key input parameters

Electron energy cumulative spectrum (3D profile)



H. Qin: Nonlinear Δf studies of e-p

- Key features:
  - A Vlasov-Maxwell approach which provides a self-consistent description of detailed mode structures, instability threshold and growth rate.
  - The delta-f particle in cell simulation reduces simulation noise
  - Theory and simulation of the e-p instability in bunched beams are being developed
- Main results:
  - Confirmation of main results of centroid model
  - Landau damping emerges naturally
  - Thresholds, mode structure and growth times for the linear phase agree reasonably well with experiment observations
  - Theory and simulation predicts a nonlinear saturation level below the experiment sensitivity

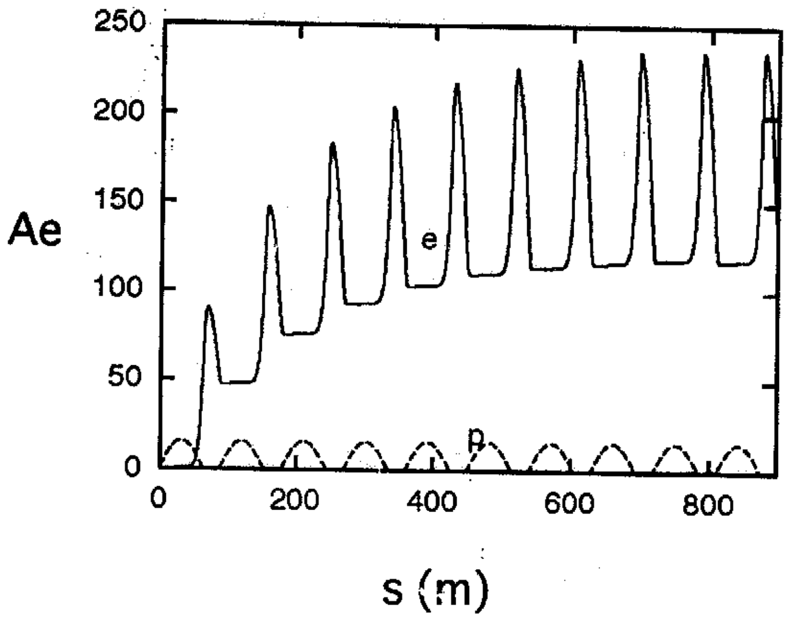
Ohmi: Theory and simulation of ECI

- Simulations of electron cloud buildup
  - using primary electrons (~0 eV) from losses at the wall or ionization at beam position and
  - electron motion in electron static field of beam
- Calculated wake field (and impedance) of proton moving through cloud
- Instability threshold from coasting beam model

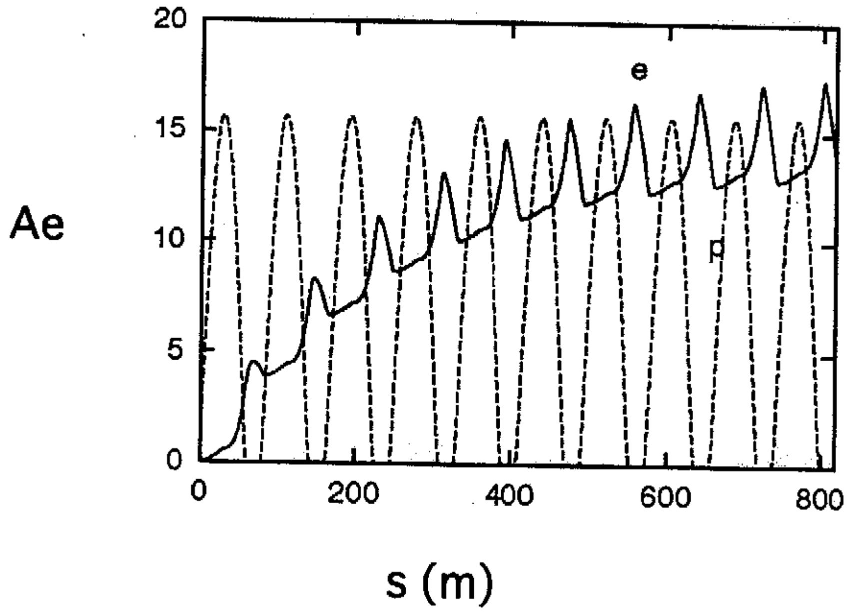
$$U \equiv \frac{\sqrt{3}\lambda_p r_0 \beta}{\eta \sigma_e \gamma} \frac{\omega_0}{\omega_e} \frac{|Z_\perp(\omega_e)|}{Z_0} = 1$$

Estimation of E-cloud

PSR



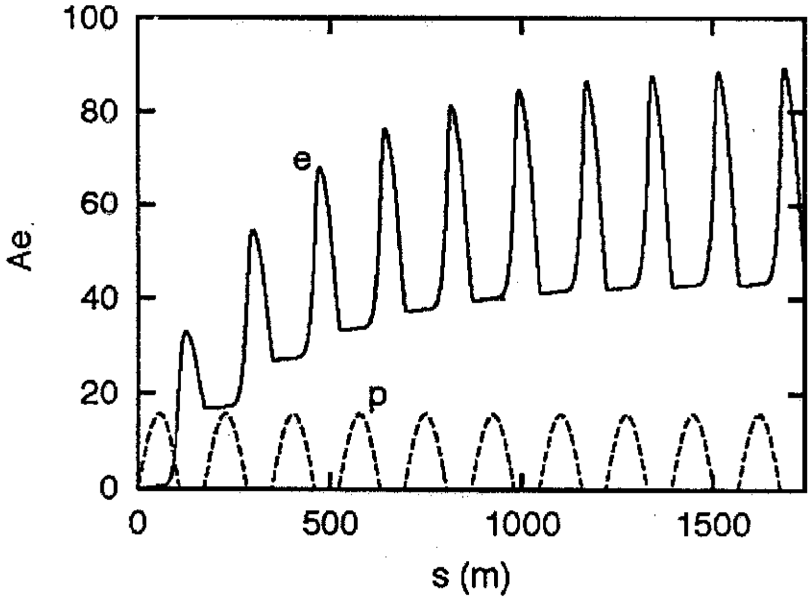
ISIS



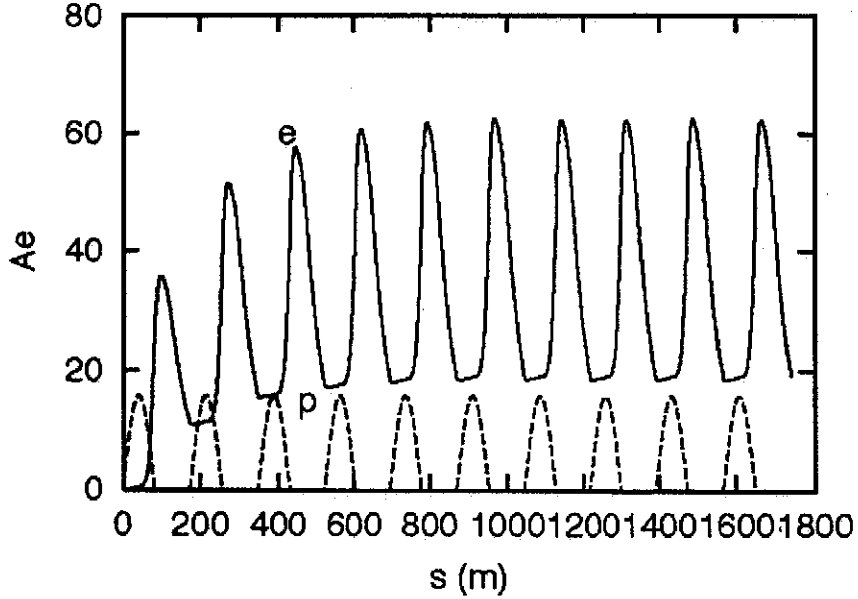
Estimation of E-cloud

JHF 3 GeV RCS

@injection



@extraction



Estimation of stability

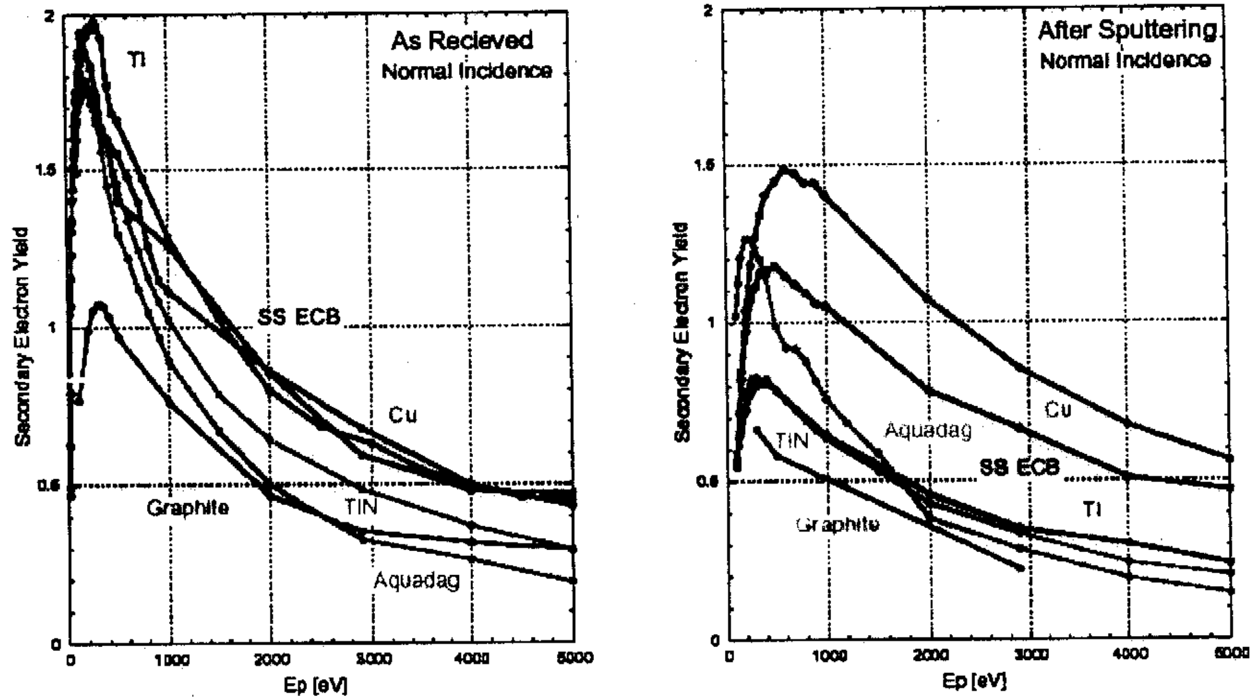
Wake field and stability for electron cloud instability

Variable		Joint project				PSR	ISIS
		3 GeV RCS		50 GeV MR			
		inj.	ext.	inj.	ext.		
$Z(\omega_e)_L/Q$	(MΩ/m)	0.11	0.088	0.21	0.006	0.17	0.002
$Z(\omega_e)_H/Q$	(MΩ/m)	0.22	0.30	3.0	0.30	0.34	0.003
$\omega_e \ell_p / c$		134	185	185	261	83	15
U_L		0.08	0.23	0.11	0.02	1.6	0.10
U_H		0.16	0.81	1.5	1.1	3.2	0.17

Slow beam extraction @50GeV MR: e-trapping due to residual gas ionization unstable if neutralization factor > 0.7%, electron build-up time ~ 4 ms

SEY measurements

- Chamber material
  - Secondary electron emission from metals and graphites / S. Kato and M. Nishiwaki



Dependence of secondary electron yields on a primary electron energy at the surfaces as-received and after sputtering.