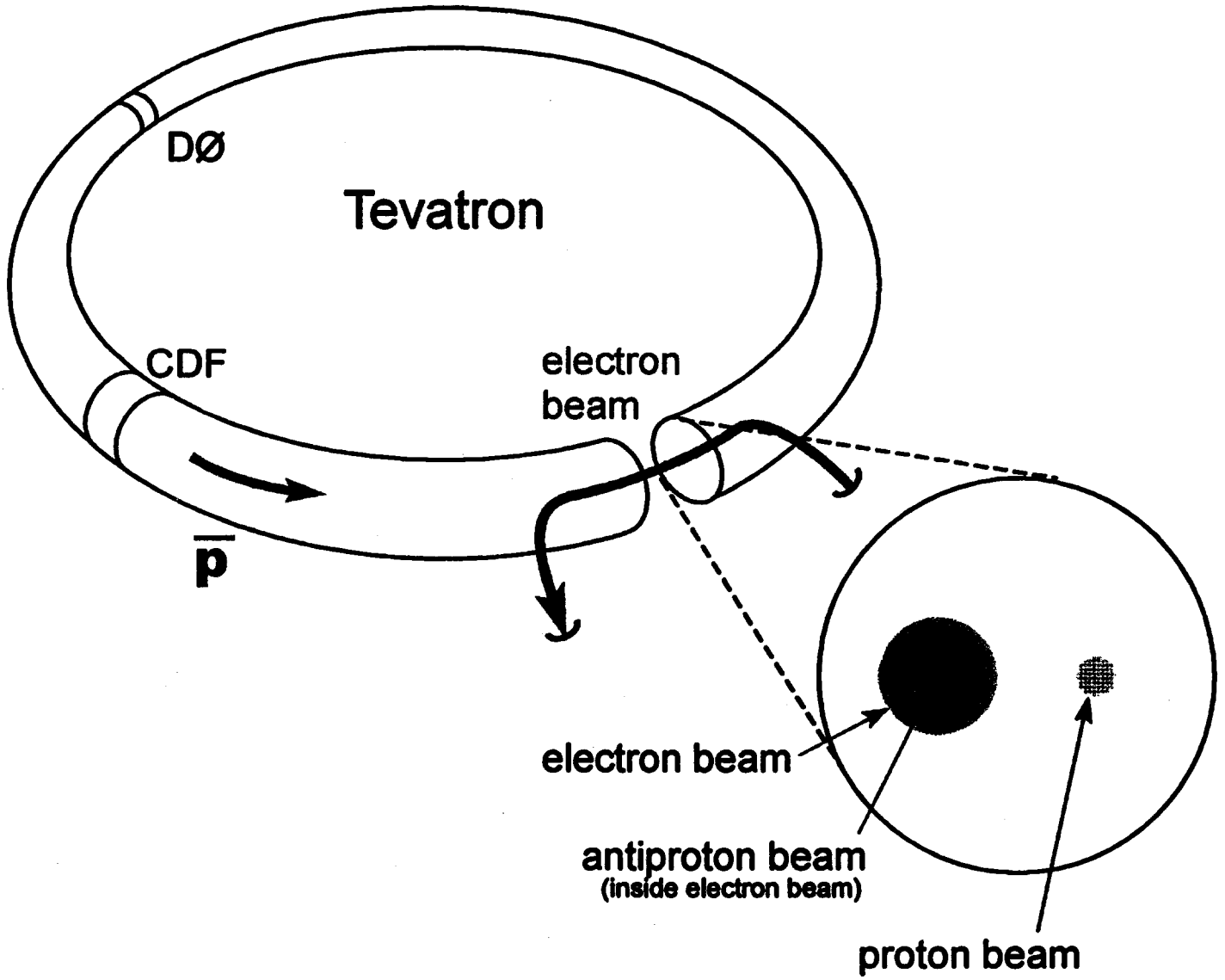
Vladimir Shiltsev

Beam-Beam Compensation with Tevatron Electron Lens: Status and Plans

1. what is TEL?
2. the first results
3. short term / long term plans

What does all this look like in the Tevatron?

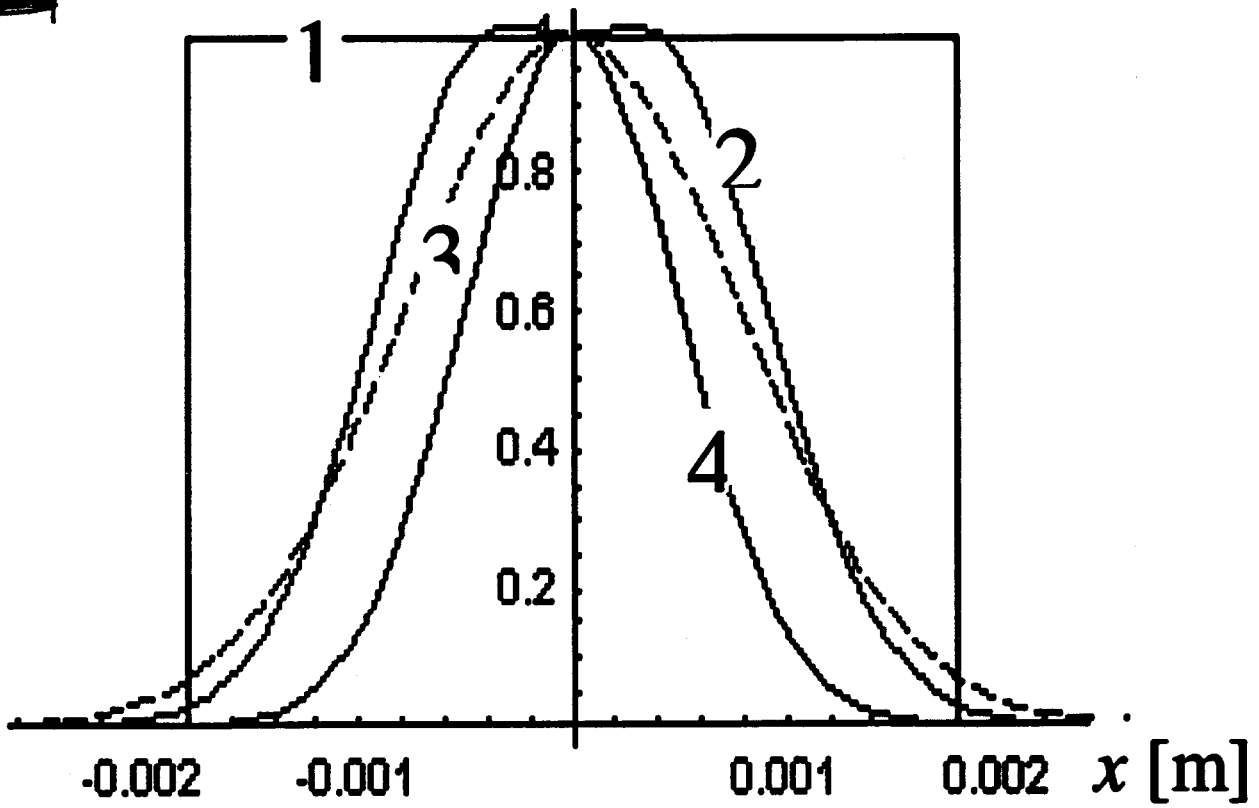


Features of the Tevatron Electron Lens:

1) Bunch-to-bunch tune shift "linear"

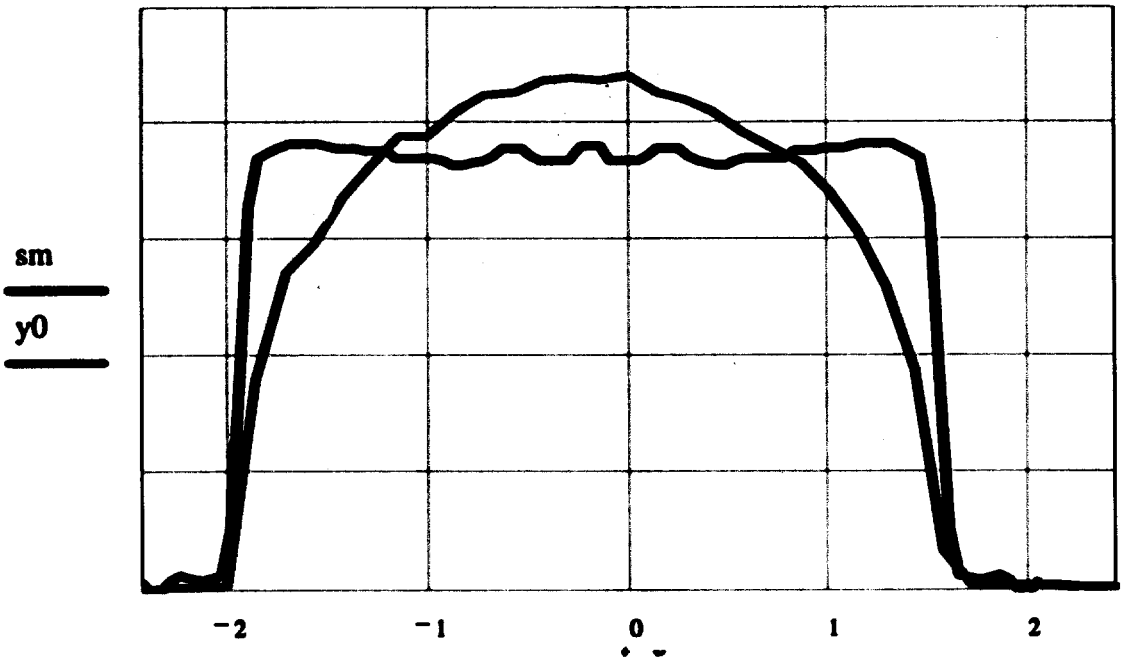
2) Proton beam profile matching "non-linear"

THEORY

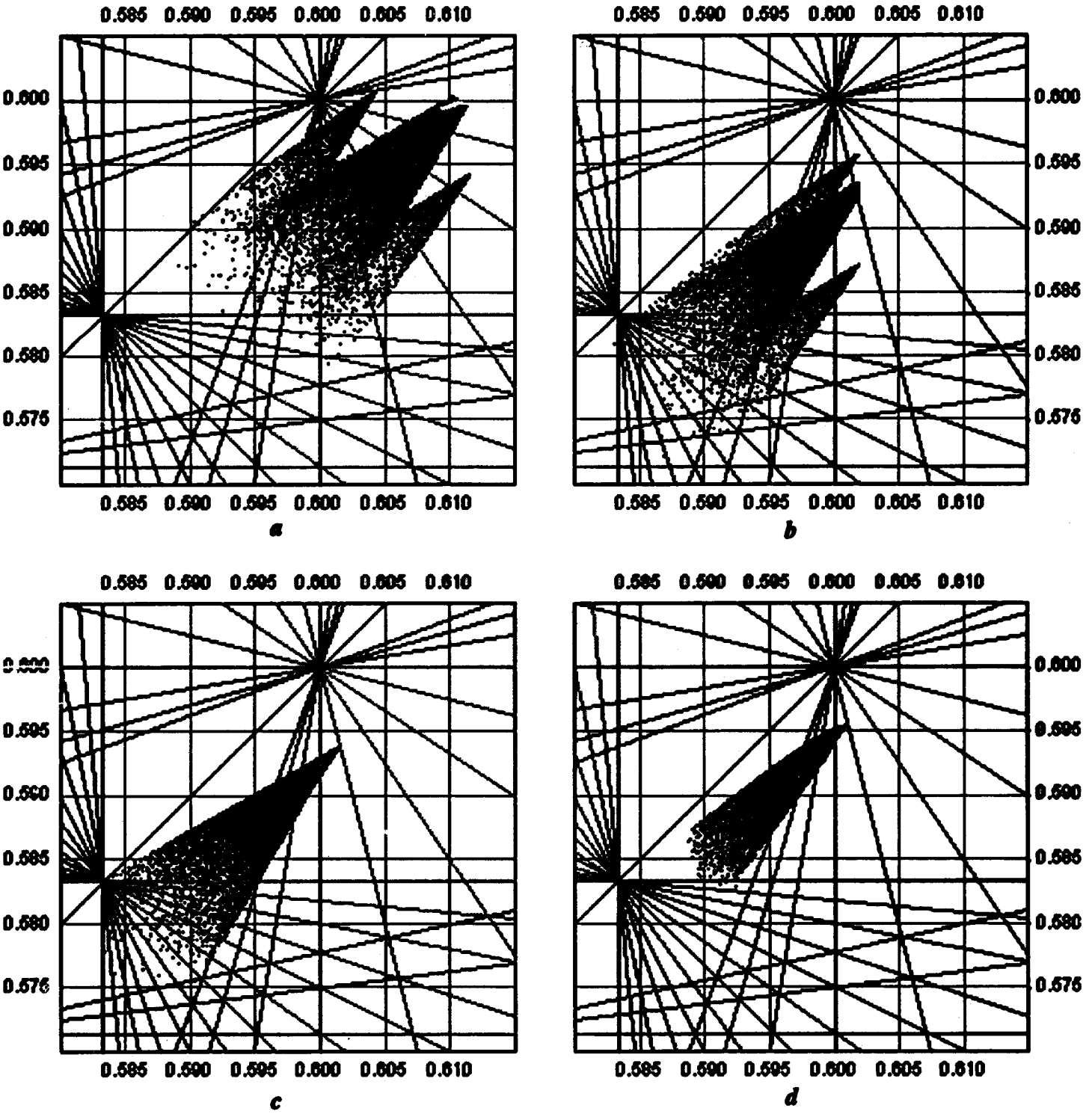


Space charge distributions: **1 – for linear TEL,**
2 , 3 – for non-linear TEL, **4 – pbar, Gaussian**

Measured electron beam profile in the TEL



Distribution of Tevatron pbar tunes



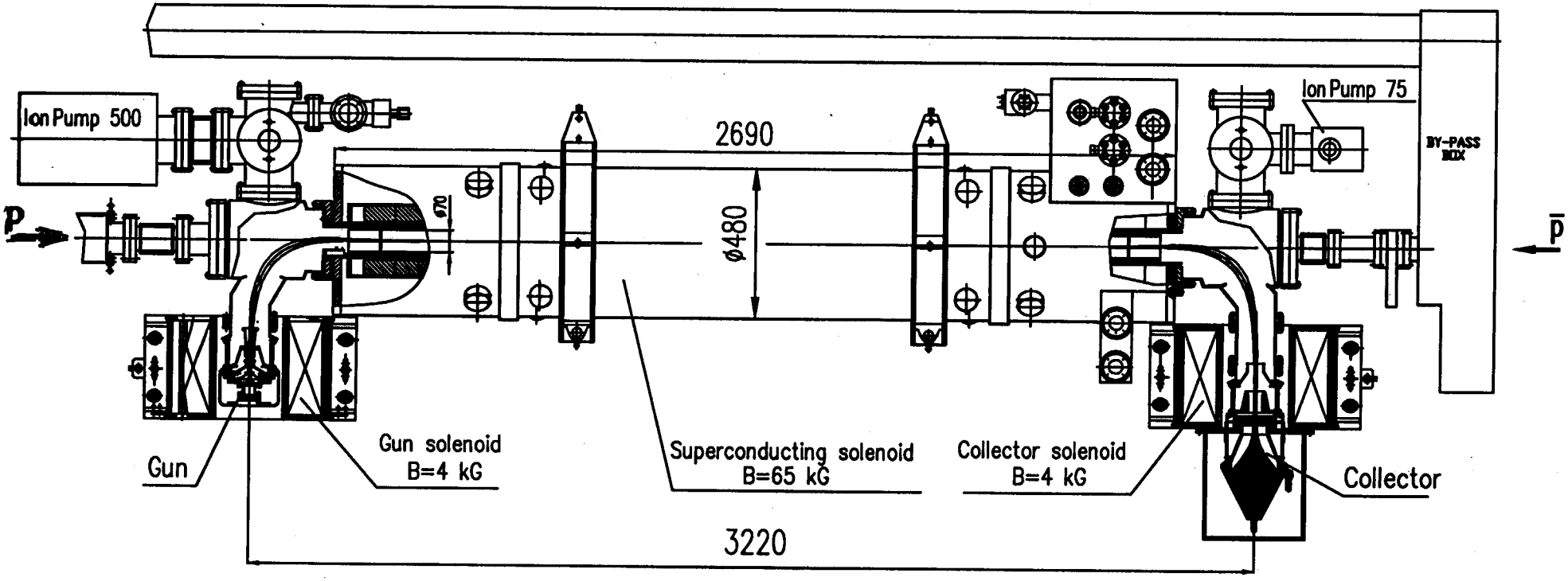
A – original 36x36

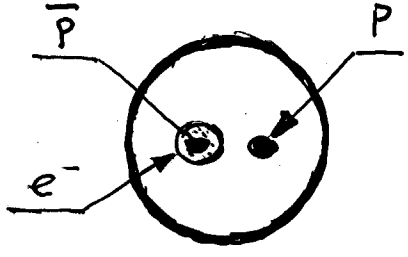
B – with one TEL

C – with two TELs

D – nonlinear BBC

Tevatron Electron Lens





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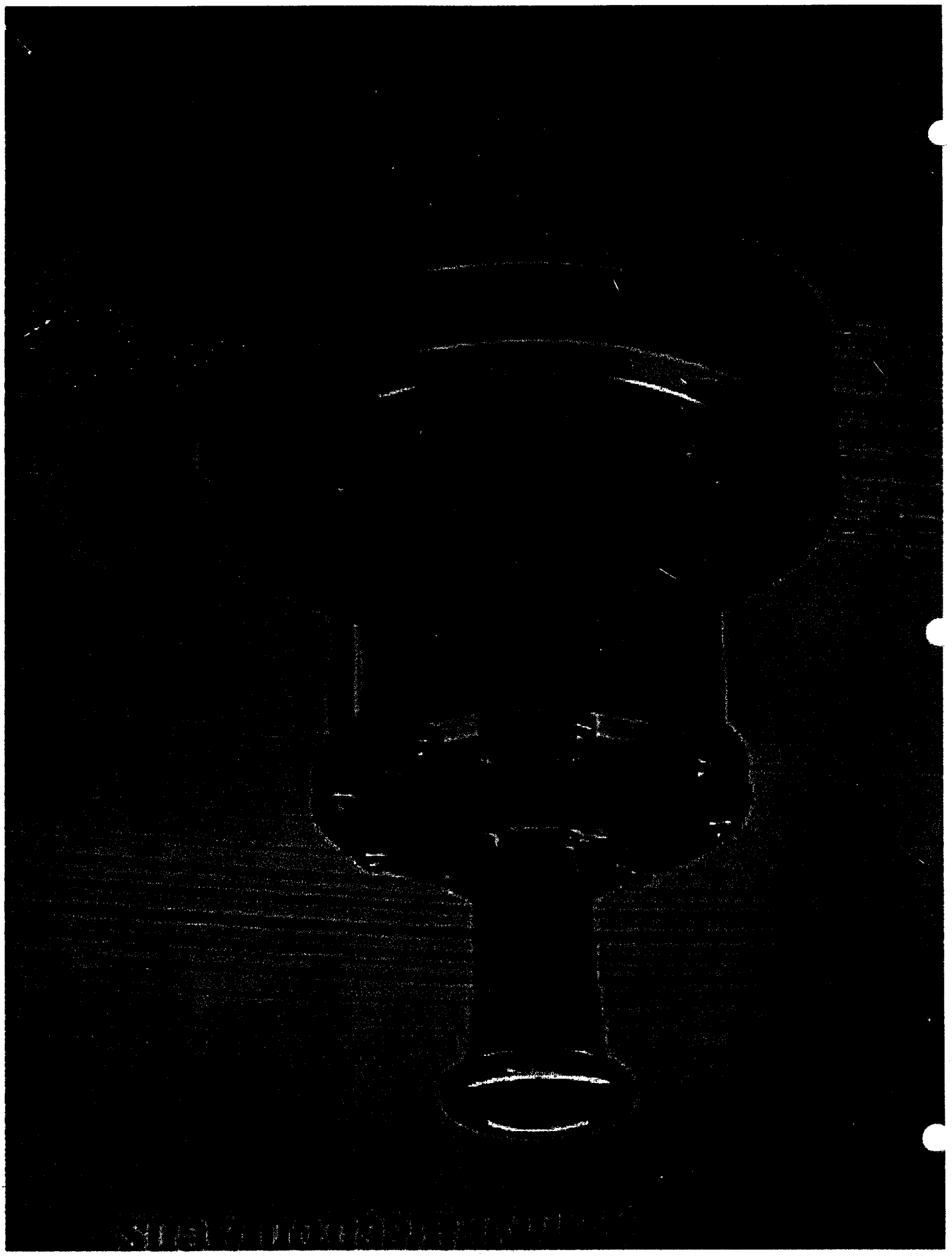
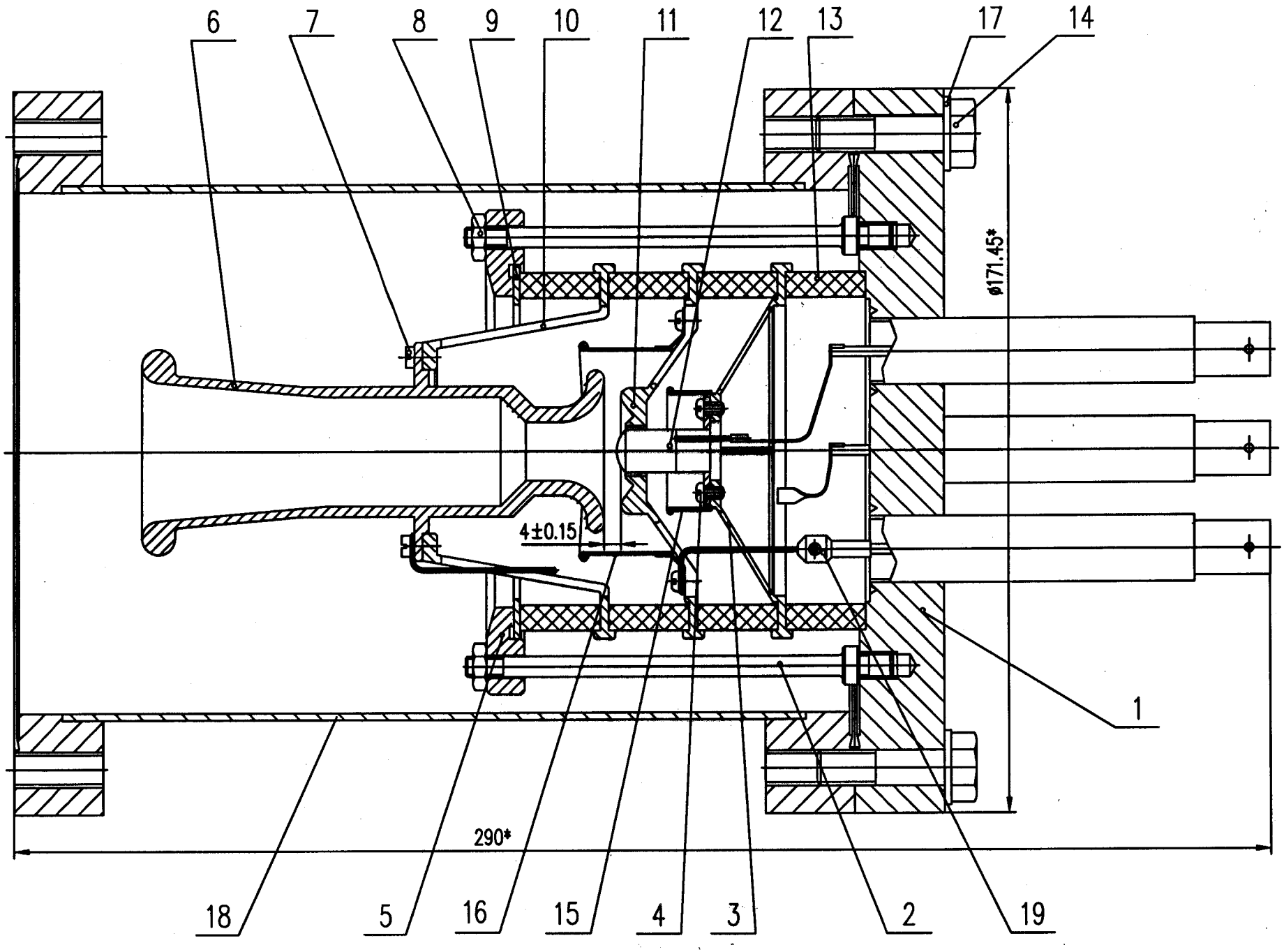
TEL parameters: Now and for RunIIa and b operations:

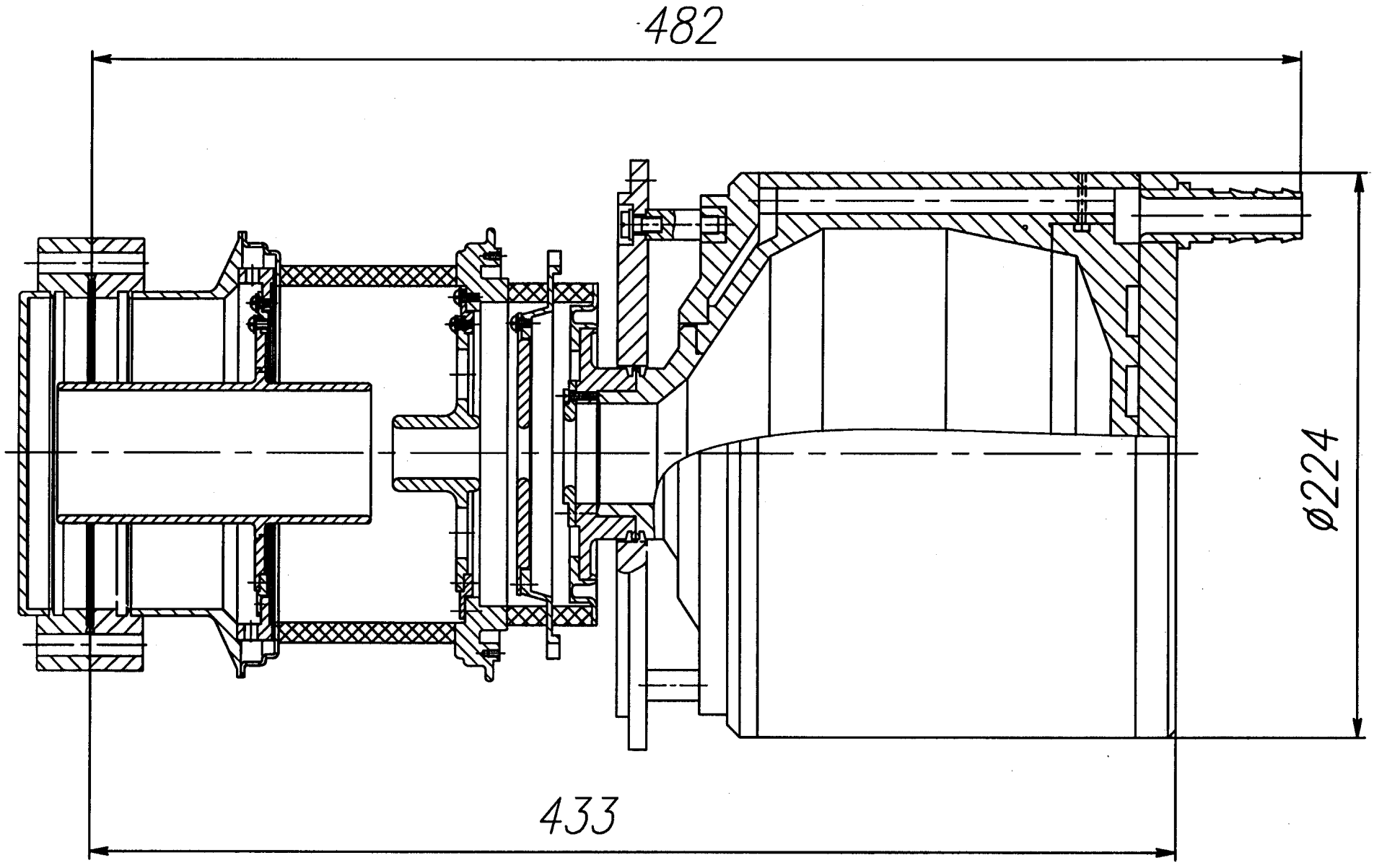
Parameter	TeV e-Lens	Upgrade
Effective length	2.0-2.5 m	same
Total length	3.65 m	~same
Configuration	U-shape	same
Electron energy	12 kV	25kV
Max electron current	3.5 A	8A
Current stability	~0.1 %	< 0.1 %
Electron beam radius	1-2.5 mm	same
B-field (gun/main)	4 kG/65 kG	modif'd bends
Size compression	2-5	same
Current modulation	800→100 ns	260 ns
Pulses/turn	1 (48 kHz)	36→ 121
Beam deviousness, rms	0.05 mm	same
Beam shape control	no(yes)	yes
Vacuum	10^{-8} Torr	same



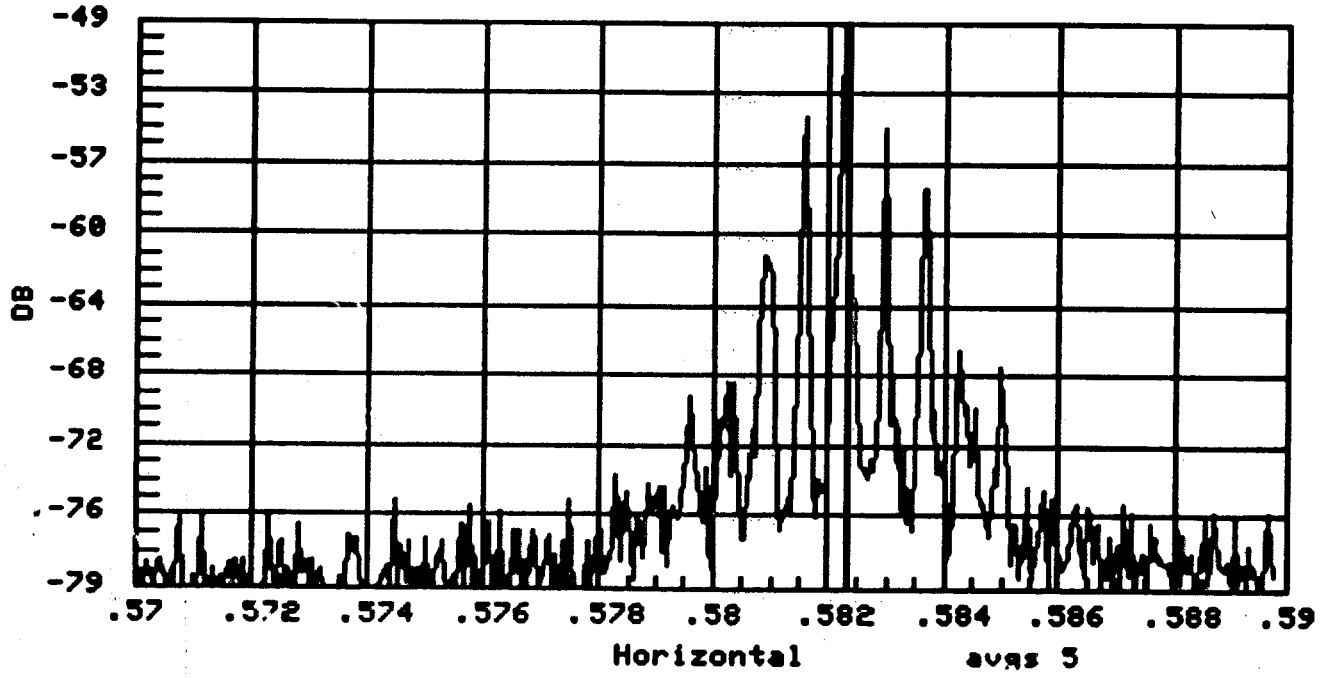
Gun

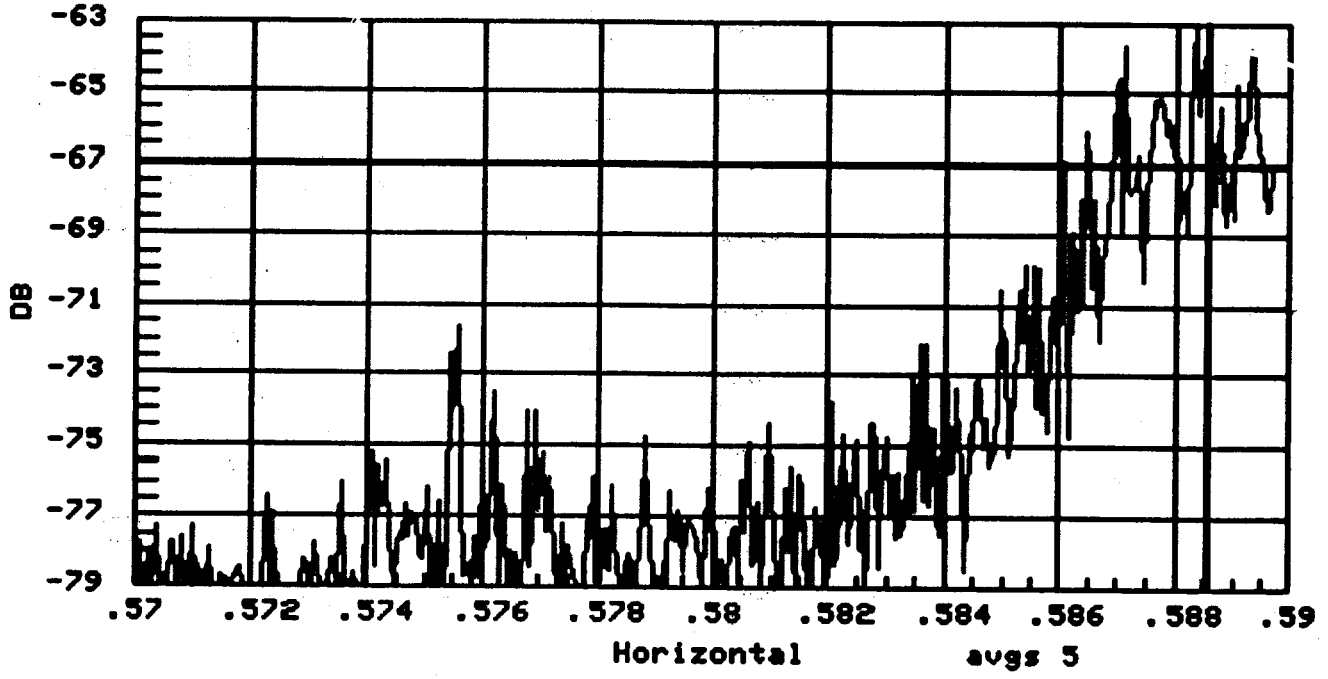


Collector

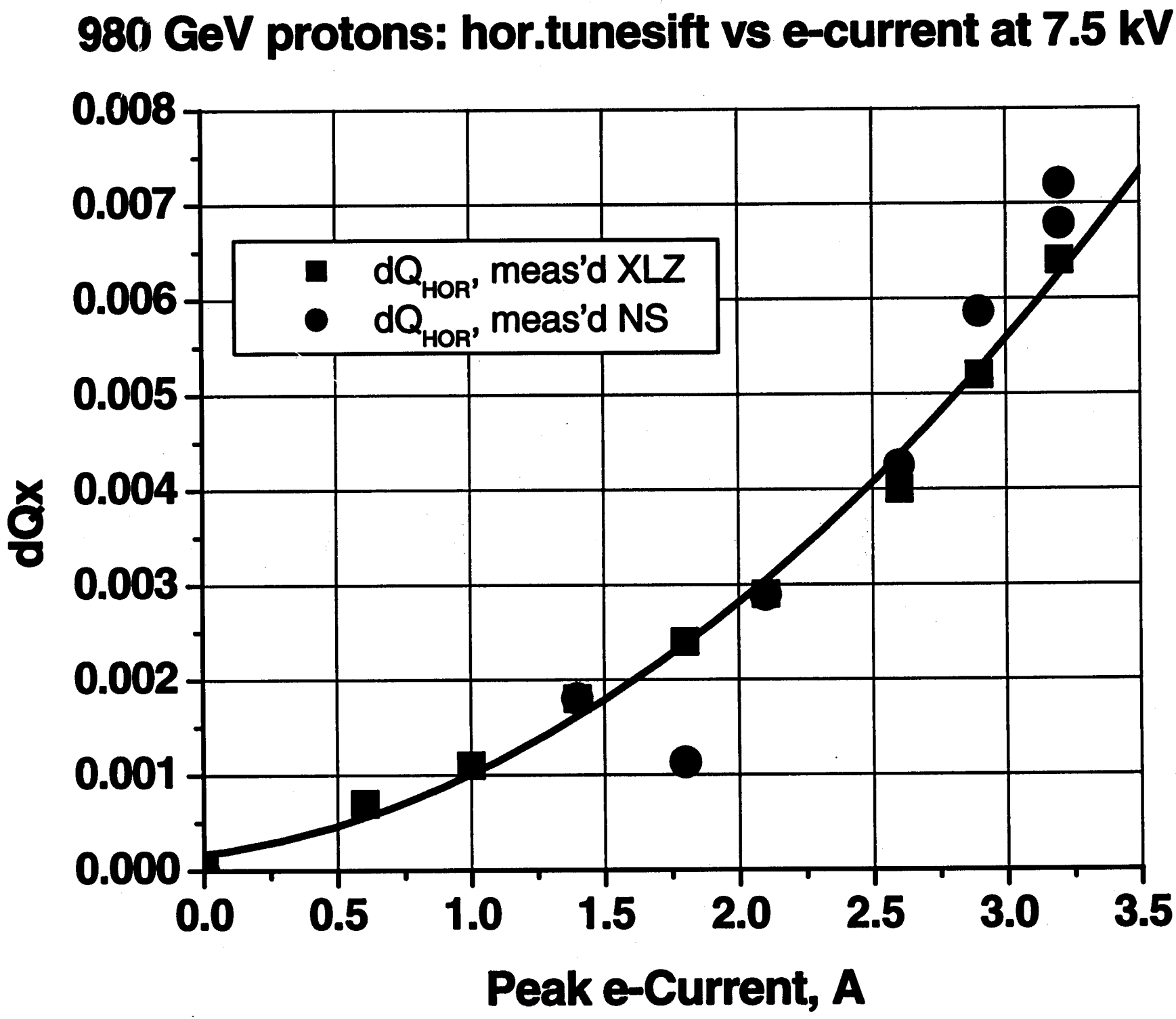


Horizontal Schottky spectra of 980 GeV protons without electron current (top) and with 3A of electron current (bottom)





dQ_{x+}=+0.0065 protons, equivalent to dQ_x=-0.01 for pbars


980 GeV protons: hor.tunesift vs e-current at 7.5 kV
dQx
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0.000
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
Peak e-Current, A
dQHOR, meas'd XLZ
dQHOR, meas'd NS

Protons instead of pbars: what's the difference for TEL?

Tuneshift formula:

$$dQ_{x,y} = \mp \frac{\beta_{x,y}}{2\pi} \cdot \frac{1 \pm \beta_e}{\beta_e} \cdot \frac{J_e L_e r_p}{e \cdot c \cdot a_e^2 \cdot \gamma_p}$$

Consider 10 kV e-beam → $\beta_e = 0.2$

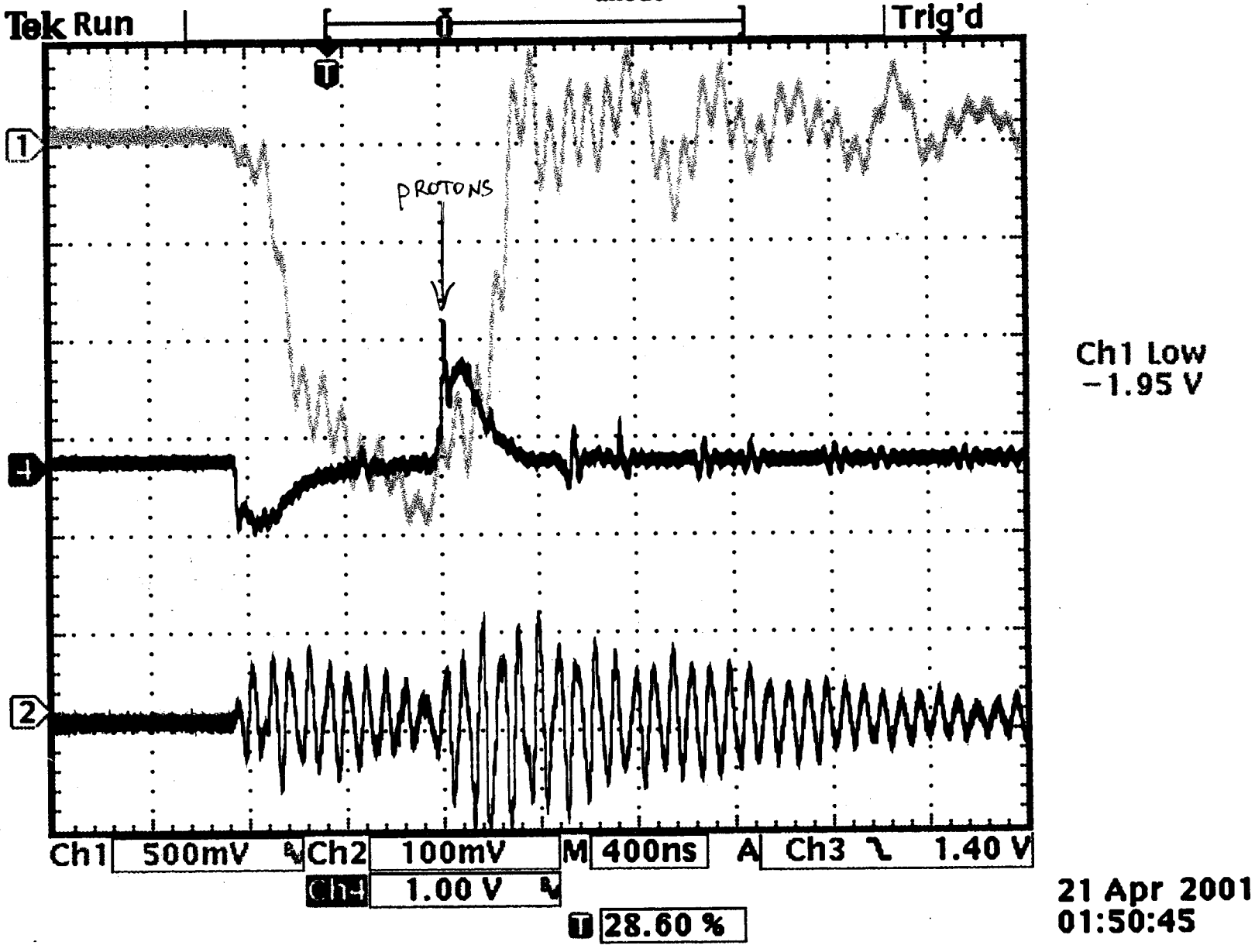
For protons (co-moving) $1 - \beta_e = 0.8$; for pbars (collide) $1 + \beta_e = 1.2$

Therefore, we expect that for pbars the tuneshift will be
1.2/0.8=1.5 times the protons dQ, e.g.,

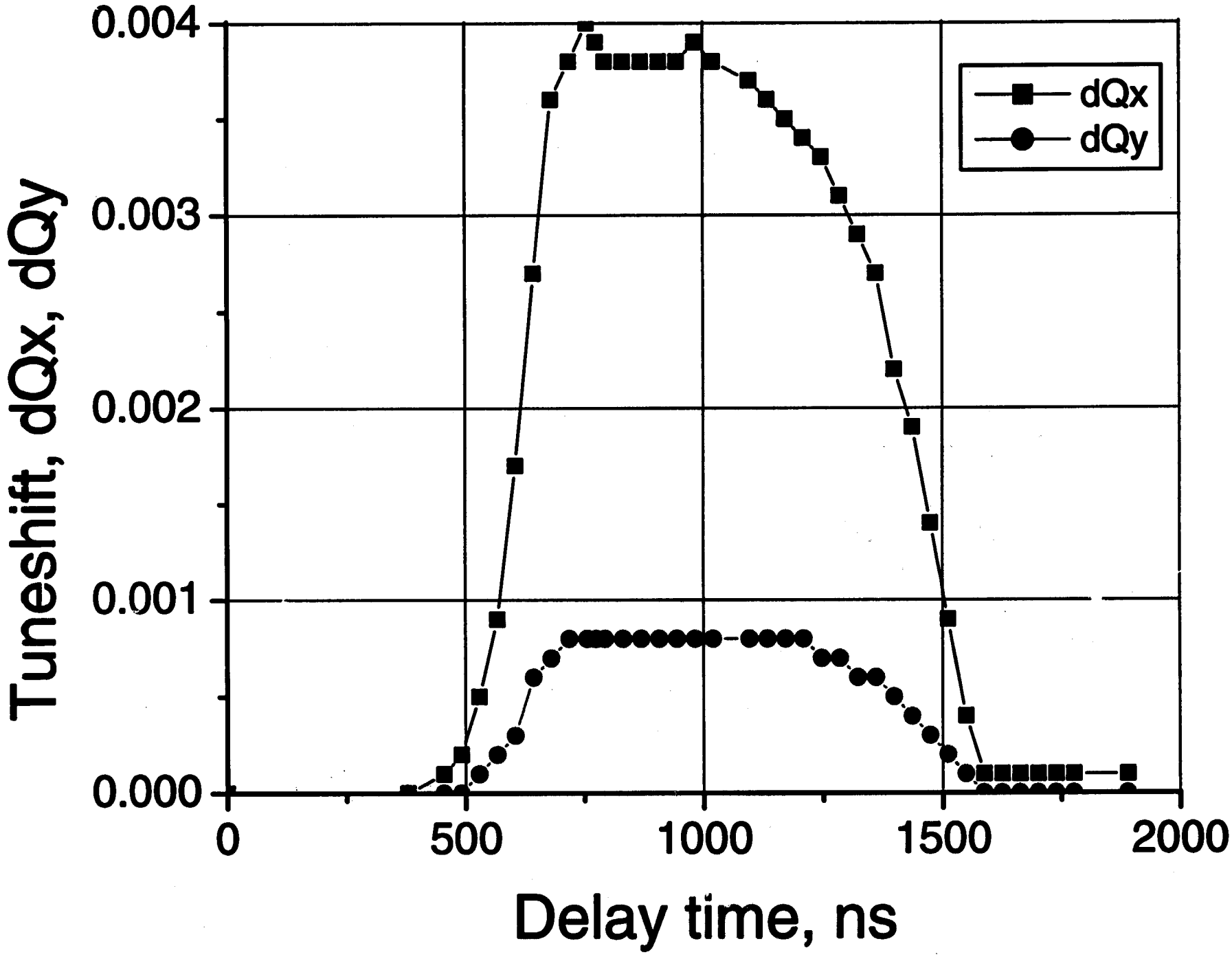
<u>+0.067 for protons equivalent to -0.01 for antiprotons</u>

2A e-pulse (yellow) and e,p-bunches seen byBPM:

RF Tube based HV modulator dU_{anode}=6kV, 800ns, J_e=1.95 A, U_e=6kV

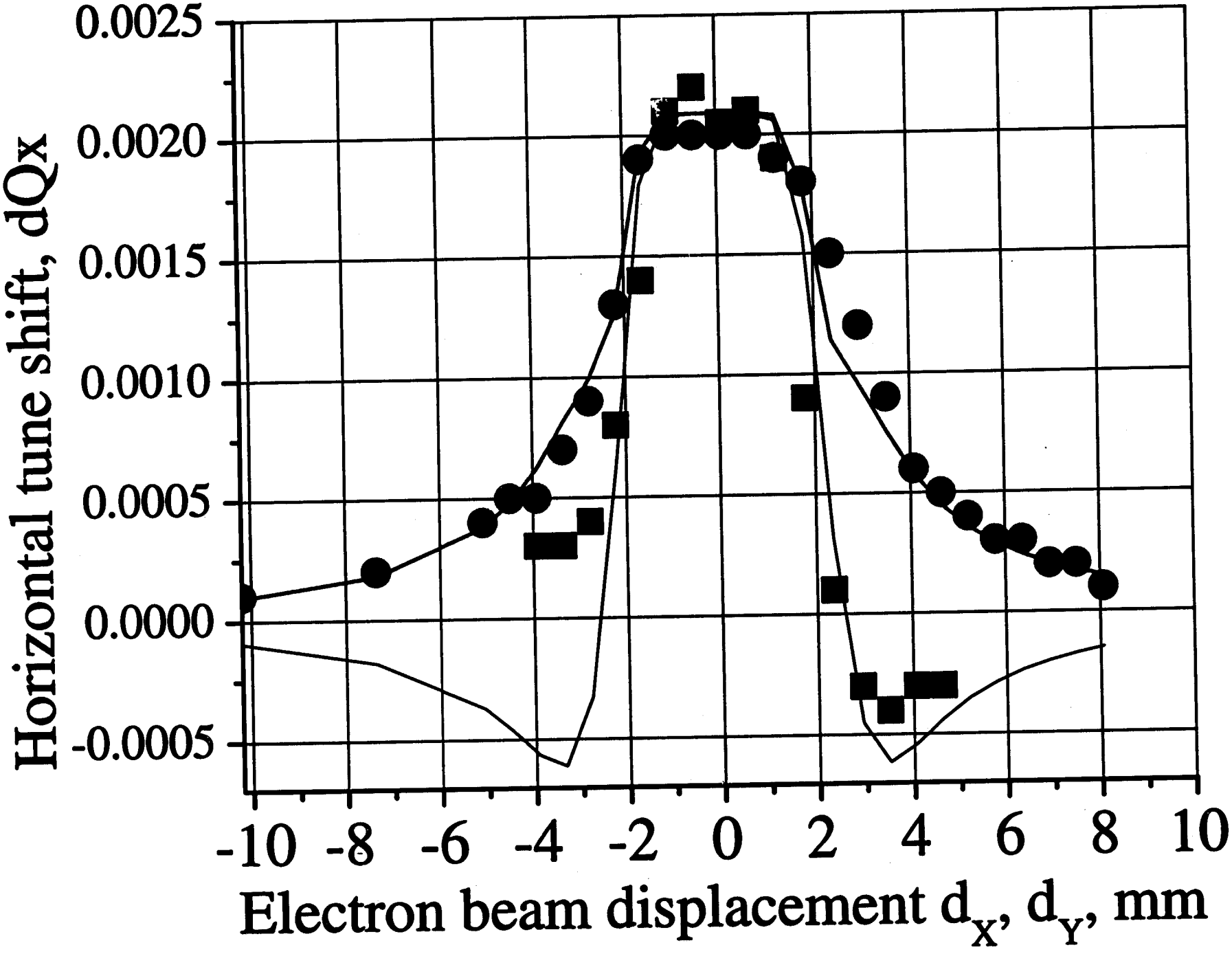


980 GeV p's: tuneshift vs e-beam delay

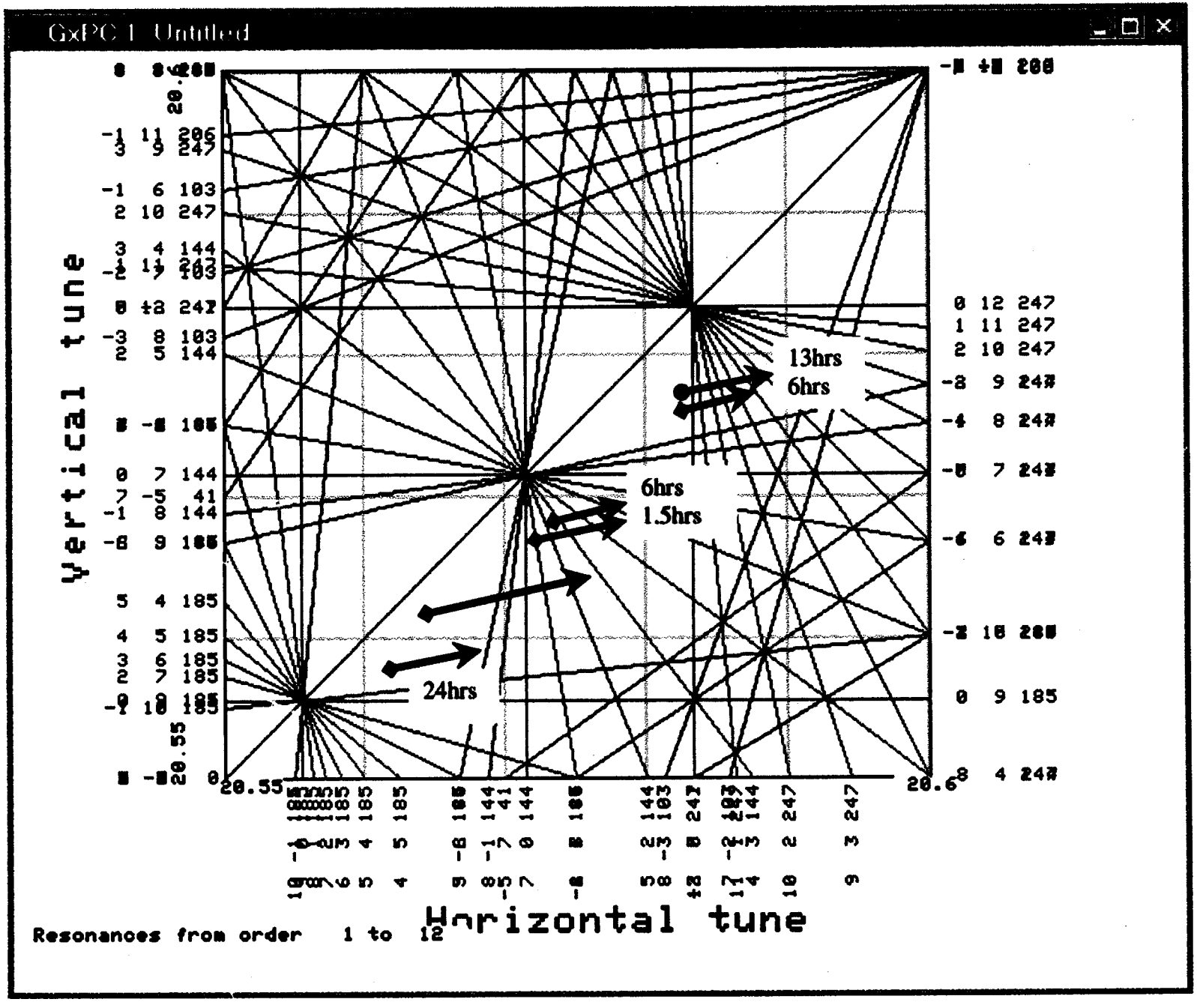


Hor tuneshift vs position of 1 A electron beam

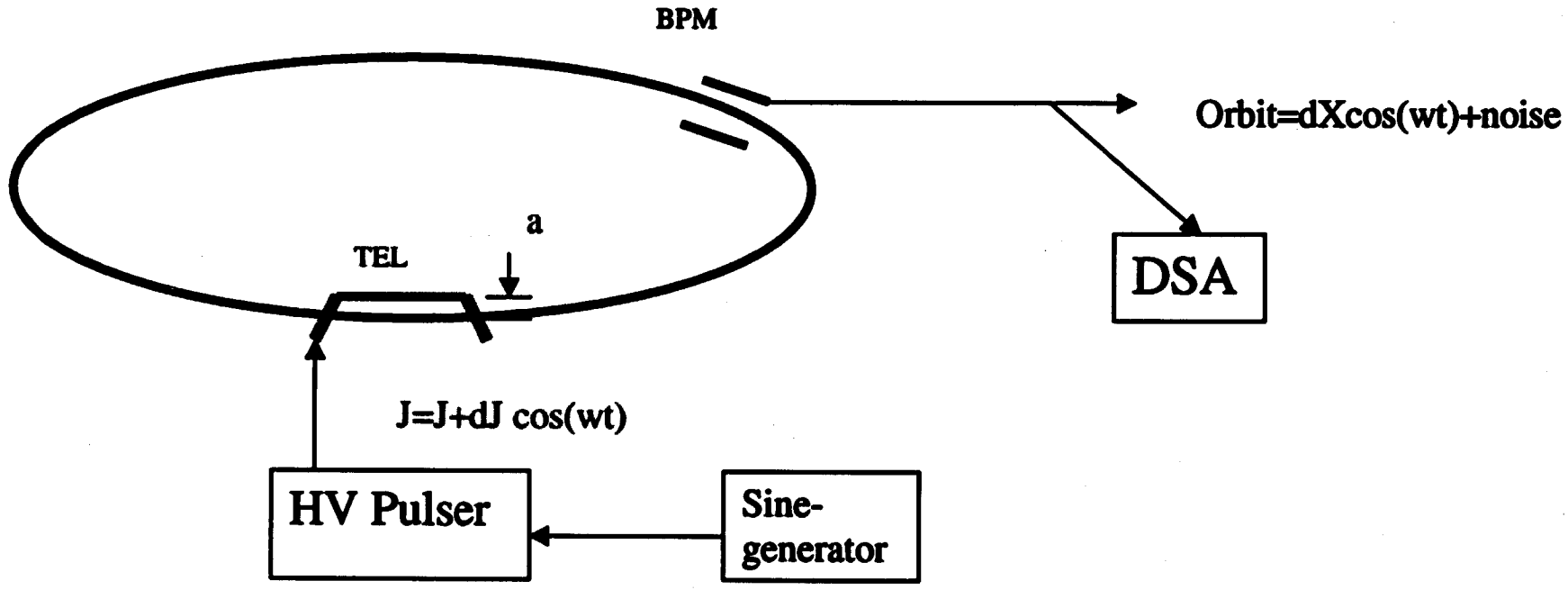
6 kV



p-tune shifts by TEL: ⟷ 150GeV, ⇄ 980 GeV

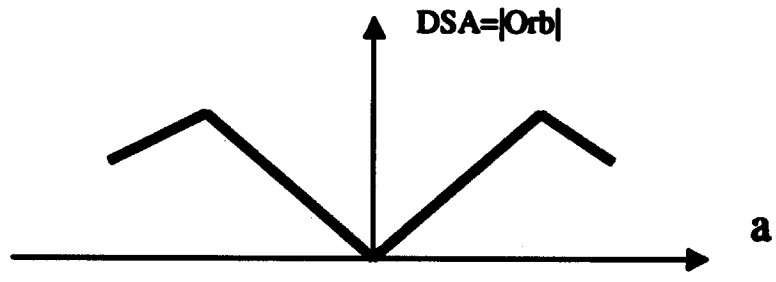


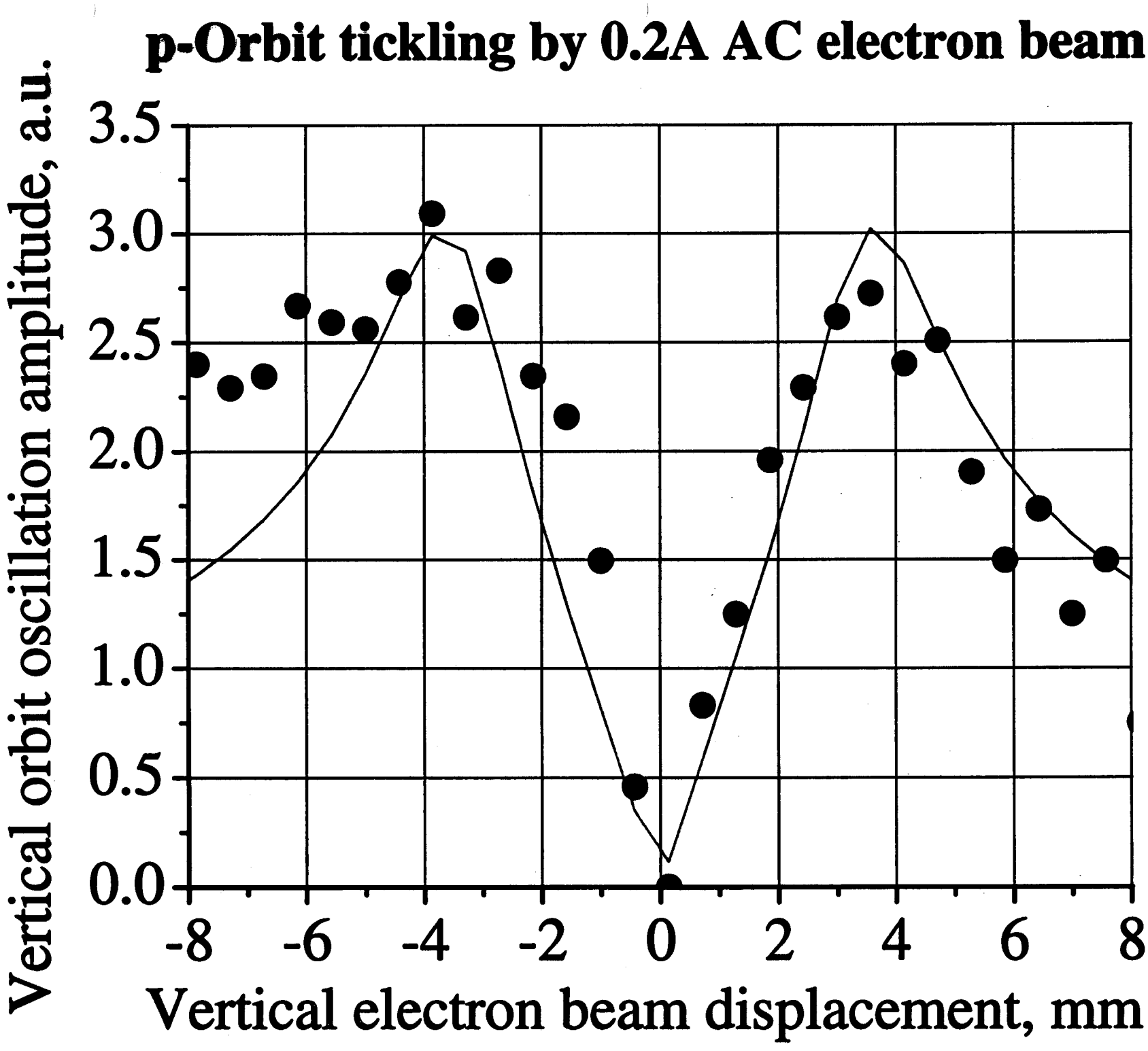
p-orbit tickling by TEL:



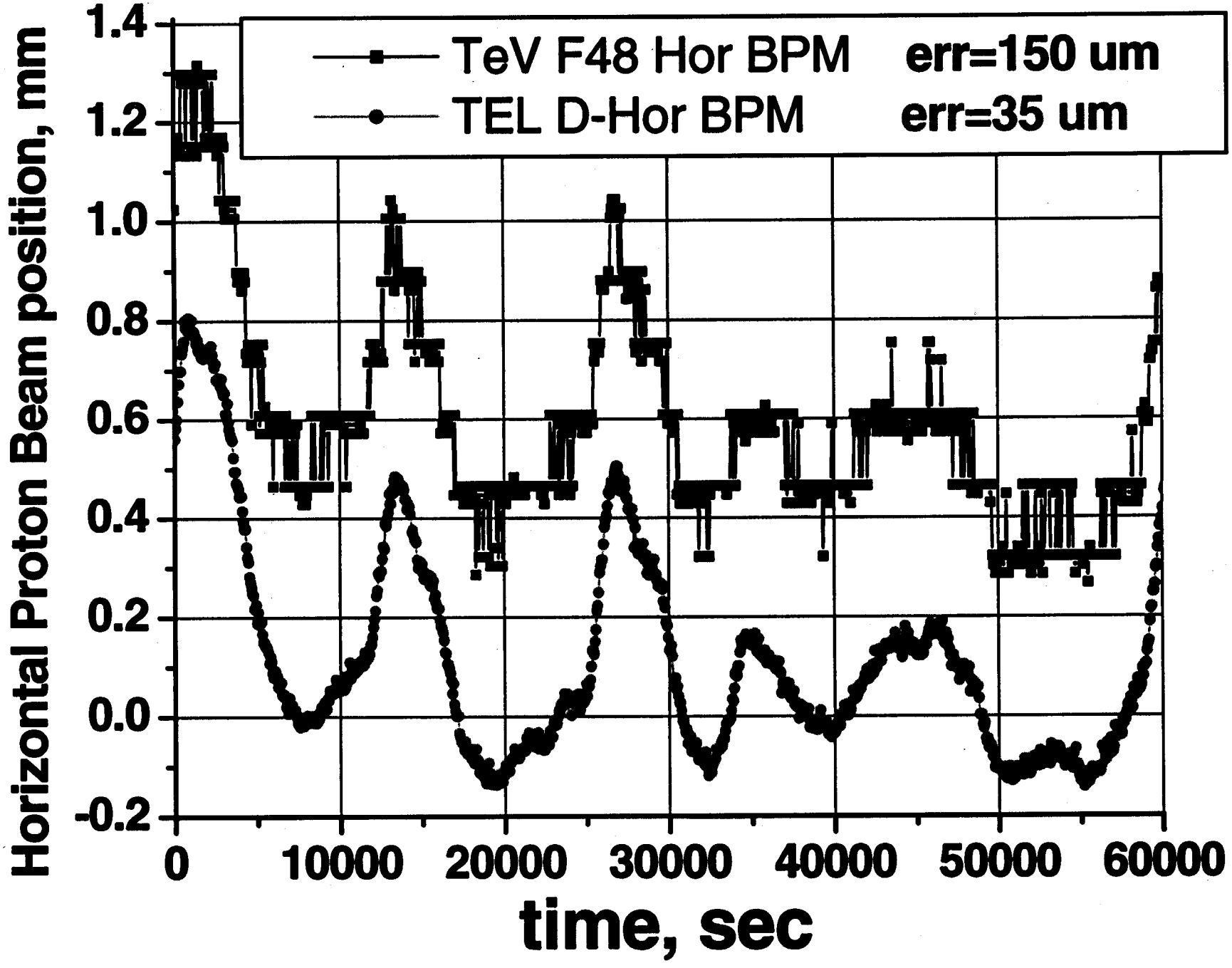
Kick $\sim 4\pi dQ\ a/\beta_1 \rightarrow$ Orbit change $\sim(\beta_1\beta_2)^2/2\sin(\pi Q)\cos(\psi)\times$Kick

Estimated dOrbit ~ 1μm



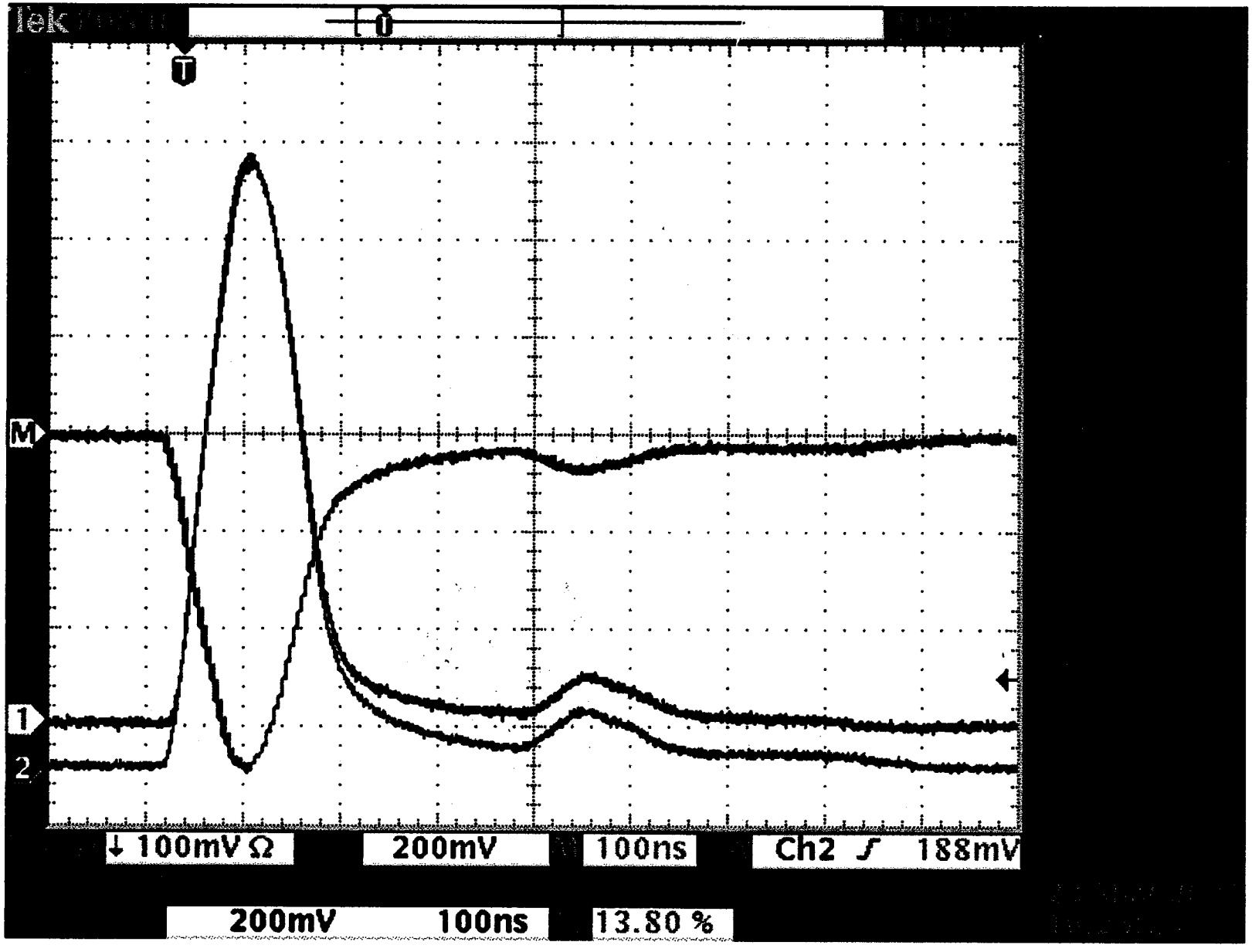

p-Orbit tickling by 0.2A AC electron beam
Vertical orbit oscillation amplitude, a.u.
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
-8
-6
-4
-2
0
2
4
6
8
Vertical electron beam displacement, mm

16 hrs hor p-orbit record: TeV vs TEL BPM



100 ns e-pulse seen by new BPM (A, B, A-B):

FID pulser dU_{anode}=12kV, 100ns, $J_e \approx 3$ A, U_e=10kV



BBC Project Path:

Demonstrate dQ ~0.005-0.01 without L lifetime drop by Jan (?) 2002

Build and install the second Tevatron Electron Lens by Dec 2002. → Make the system of 2 TELs for linear beam-beam compensation operational by fall 2003

Attack non-linear beam-beam compensation to ~double the maximum allowed beam-beam tuneshift in the Tevatron in 2004

Build electron beam hardware for crossing angle elimination (2005 ?)

Beam-Beam Compensation in the T[illegible]ron: Implementation Plan (draft)

	Current configuration		Linear BBC (2 TELs)		Nonlinear BBC		Nonlinear→ ZeroX-angle	
Magnets	exist	0	the 2nd set of magnets, minor changes in design, magnetic measu-rements radiation protection - 10mos	330 k$	Use existing	0	Use existing (TBD – larger e-current and smaller diameter may require new magnets)	0
Power Supplies	exist, minor im-provement	0	2nd set of PSs	70k$	Use existing	0	Use existing	0
Quench protection	exist	0	2nd set of QPS	60k$	Use existing	0	Use existing	0
Electron gun	Exist, design and R&D under way to increase current to 5-7A and voltage to 30kV	40 k$	2 more copies of the improved design gun	70k$	Optimized shape electrodes	25 k$	3 optimized shape electrode guns with 3-5 time larger current and twice larger cathode	100 k$
Electron collector	exist	0	two the same type	60k$	Use existing	0	3 100kW collectors	150$
HV PSs for e-system	exist	0	one more set of PSs	40k$	Use existing	0	Higher current higher voltage	120 k$
HV pulse generator and its PSs	exist	0	build two some-what modified tetrode 12kV 2MHz pulsers	300 k$	Use existing	0	Two 18kV and 6MHz pulsers to be built, existing 20kV PSs	100 k$
Vacuum/diagnostics	exist	0	Build the 2nd set	60k$	Use existing	0	Use existing	0
Cables/LCW/construction	exist	0	Work at sector A10	150 k$	Use existing	0	Additional cable work	60k$
Cryo	exist	0	He/N2 connections, bypass modification	70k$	Use existing	0	Use existing	0
Studies	20 TeV shifts till Jan'02	0	Magn.meas.+tests in E4R (3mos), 30 Tevatron shifts	40k$	30 Tevatron shifts, DC wires	95 k$	e-Studies in E4R with SC magnets needed (6 mos)	300 k$
Theory/calculations[2]	none		1ES+1RA		1ES+1RA		1ES+1RA	
Cost[3], M&S	total in FY'01	40 k$	50%-50% in FY'02-03	1500 k$	All in FY'04	150 k$	2/3 in FY'05 1/3 in FY'06	1000 k$
Time scale[4]	now-Jan'02		2yrs till Oct'03		1yr - Oct'04		1½ yr till Mar'06	
Additional man-power[5]	none		2x(P,EE),1x(S,PE,ME,CS,D)		2P, 1S		2x(P,EE),1(S,ME)	
Potential $\mathcal{L}$-increase[6]	0%		30% /20% -integr		100% /67%		100% /45%	

C ... Current configuration , Linear BBC and Non-linea BC refer to Run IIa conditions (e.g., 36x36); Nonlinear BBC→ Zero Crossing Angle" refers to Run IIb with 132 ns bunch spacing

[2] in terms of people working on the project: ES – "experienced scientist", RA – postdoc

[3] 20% contingency added for after FY'01

[4] estimated date when the corresponding option of the Beam-Beam Compensation provides mentioned "Potential Luminosity Increase"

[5] compared to Summer'01 work-force of 2 Physicists (P), 1 Student(S) and 1ProjectEngineer(PE); abbreviations: EE-Electrical Engineer, ME-mechanical engineer; CS – computer specialist; D- drafter; assumed that the people requested work over the time period listed in each column

[6] "Potential luminosity increase" is in % compared to Run II Handbook projections without Beam-Beam Compensation; calculated under assumption that maximum luminosity is proportional to the pbar beam-beam tuneshift $\mathcal{L}\sim\xi$ on base of current theoretical models; "potential" reflects that for columns 1,2,3 it may not be realized if not enough protons delivered in the same emittance.

Manpower request for FY02:

The BBC project group (Bishofberger, Kuznetsov, Zhang, Shiltsev) itself has man-power barely enough only for the beam studies with the 1st TEL and electron gun modification and vacuum/diagnostics designs

1 Electrical Engineer and 1 Tech to fabricate/test QPS (Hively+Pfeffer +??)

1 Electrical Engineer and ½ Tech to develop HV modulator (Wildman + ??)

1 Electrical Engineer and ½ Tech to develop other HV PSs (G.Saewert + ??)

1 Electrical Engineer to build beam diagnostics (M.Olson)

1 Mech.Engineer – project engineer (J.Fuerst)

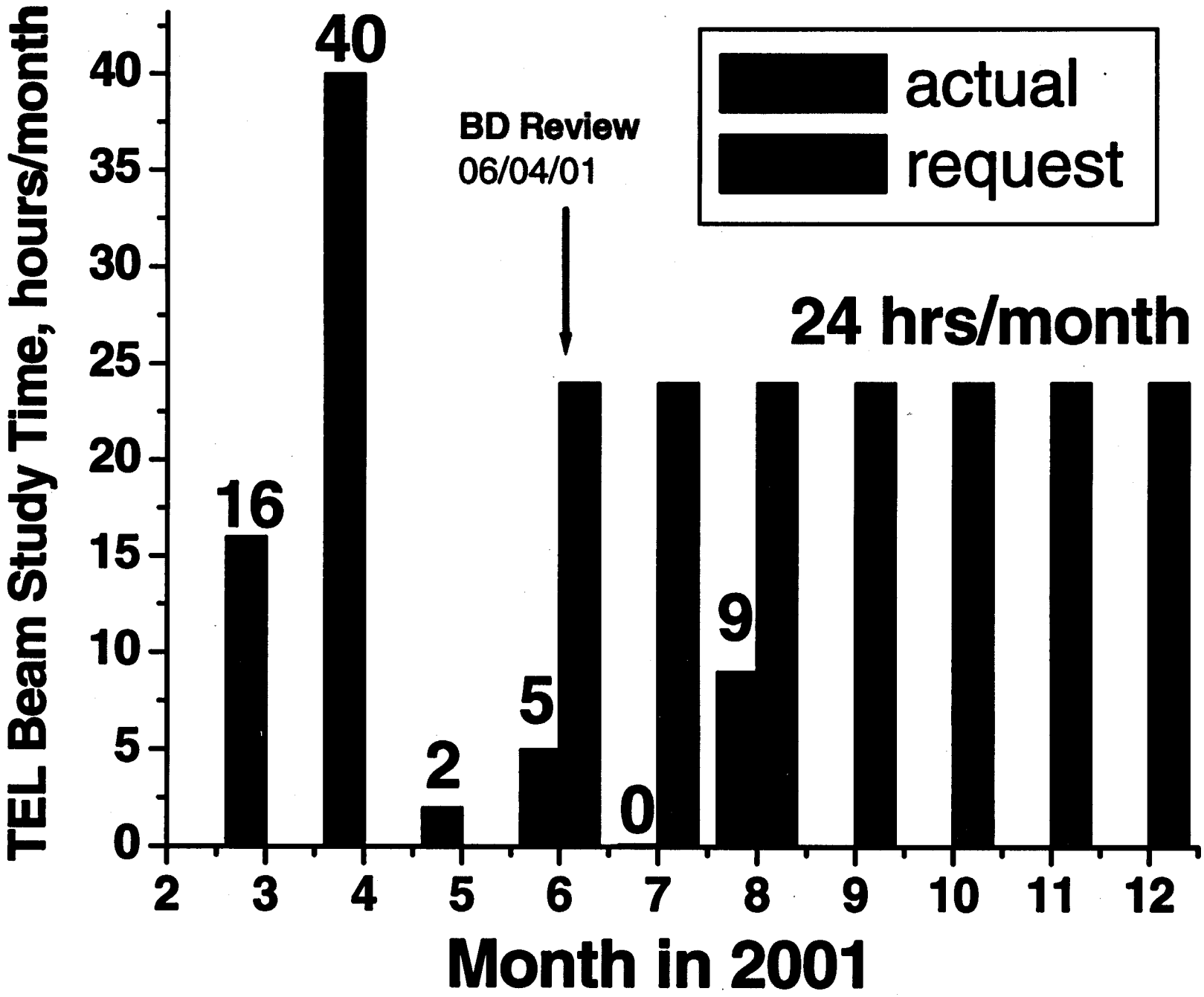
1 Drafter

½ CryoEngineer (A.Martinez)

½ Computer Specialist (??)

1 Scientist (Assoc.Sci. or higher) to carry out electron gun/collector diagnostic development/fabrication/test (??)

1(or 2) Scientist(s) (grad student/RA) to take part in beam studies

2 Scientists (Ass.Scientist/Sci.I-II-III (e.g. Alexahin) and RA) to carry out analytical and numerical studies of nonlinear BBC

Beam-Beam Compensation Studies in 2001