BUNCH LENGTHENING

BUNCH FWHM ≤ 2 nsec AT BEGINING OF STORE.

NARROW BUNCHES HAVE SYNCHROTRON OSCILLATIONS AND FEED WIDE BUNCHES.

OVERSHOOT OBSERVED

2 ns → 6 ns

3.4 ns → 3.3 ns

SPREADING RELATED TO WAKE FIELDS OF PRECEEDING BUNCHES.

HIGH FREQ rf (OLD CEA CAVITY) WILL HOPEFULLY CONTROL THE LENGTHENING.

DOES NOT DIRECTLY AFFECT $\mathcal{L}$, BUT LONG INT. REGION IS A NUISANCE.

IF EACH BEAM HAS WIDTH σ_z THEN LUMINOUS REGION AS $\sigma_\ell = \sigma_z/\sqrt{2}$

$\sigma_\ell \approx \pm 40$ cm NOW

$\approx \pm 20$ cm IF NO LENGTHENING

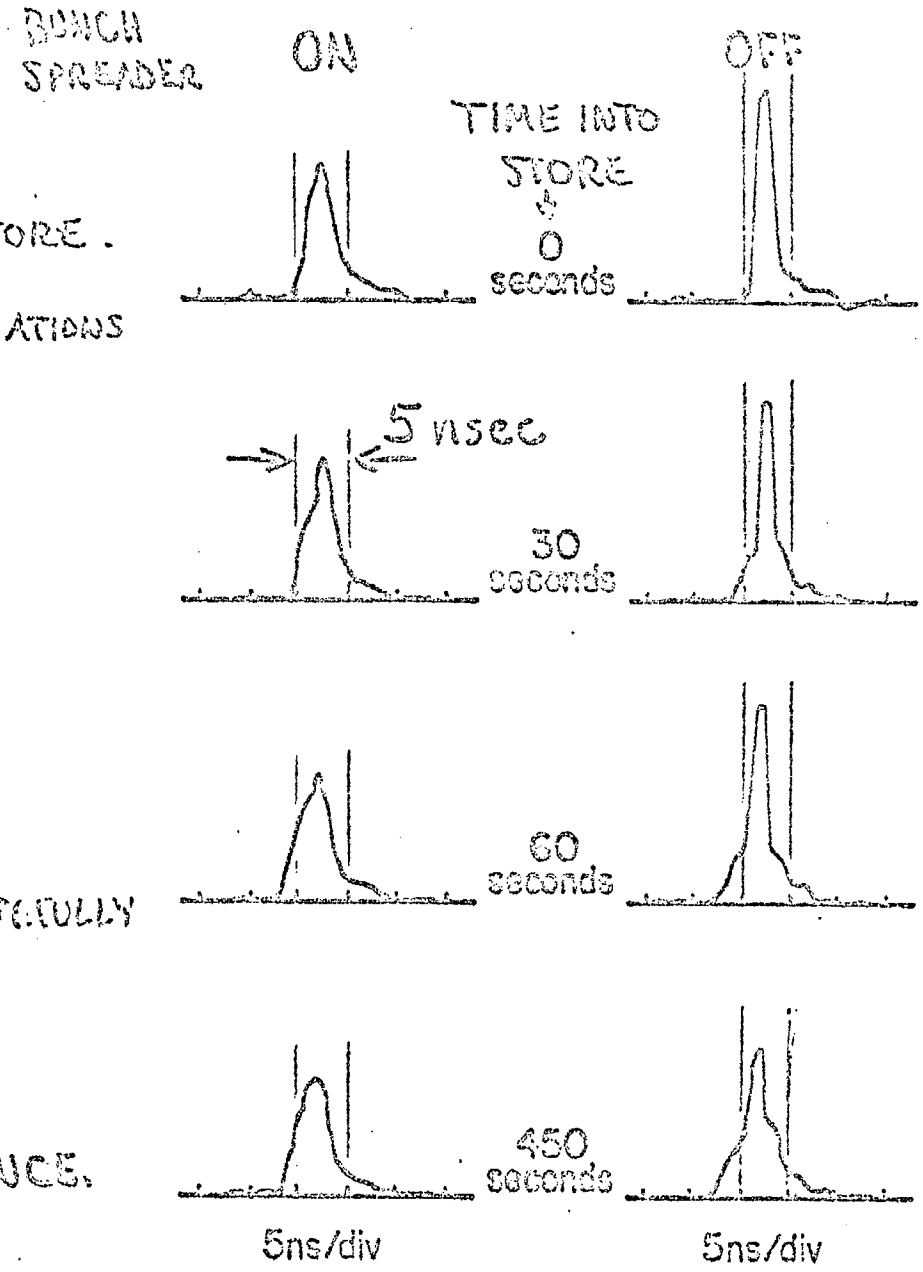


Fig. 4. Bunch shapes after 0, 30, 60, and 450 seconds of storage. Th scale is 5 nsec/div. The left column is a store with the bunch sprea on at 3.03 volts gain (Store 4 7/20/77). The right column is with the bunch spreader nearly off, at 0.07 volts gain (Store 6 7/20/77).

ECKLUND - SS-77

LUMINOSITY $\mathcal{L}(pp)$

ASSUME 2×10^{13} IN EACH RING AND 150×1000 GeV^2:

$$\mathcal{L} = \frac{0.3\times10^{30}}{\sigma_{MR}^2+\sigma_D^2}$$

σ = rms at int. region in mm

$$\sigma = 1.5\sqrt{\beta^*/p} \text{ mm}$$

for β^* in m and p in GeV

emittance = $13\pi/p$ mm mrad (1.5π from booster)

FOR $\beta^*_{MR} = 2.5$ m ($\beta_{max} = 1200$ m)

$\sigma_{MR} = 0.19$ mm AT 150 GeV/c

THEN

β^*_D (m)	β_D^{max} (m)	$\mathcal{L}$ (cm^{-2}sec^{-1})	beam-beam tune shift $\Delta\nu_{MR}$	$\Delta\nu_D$
70	124	1.5×10^{30}	0.2×10^{-3}	3.9×10^{-3}
17	150	4.0	0.9	0.9
10	250	5.0	1.5	0.6
2.5	1200	7.0	6.2	0.14

NOTE: THE β_{max} REGIONS ARE LOCALIZED AND IN ANY CASE THE BEAMS AT HIGH ENERGY AND $\beta = 1200$ m ARE SMALLER THAN AT INJECTION WITH NORMAL $\beta_{max} = 120$ m.

THE ABOVE CALCULATION IS CONSERVATIVE – IT DOES NOT ASSUME ANY

- 1) INCREASE IN INTENSITY ABOVE 2×10^{13} PER RING;
- 2) STACKING IN EITHER RING.
- 3) rf MANIPULATIONS TO INCREASE BUNCH DENSITY.

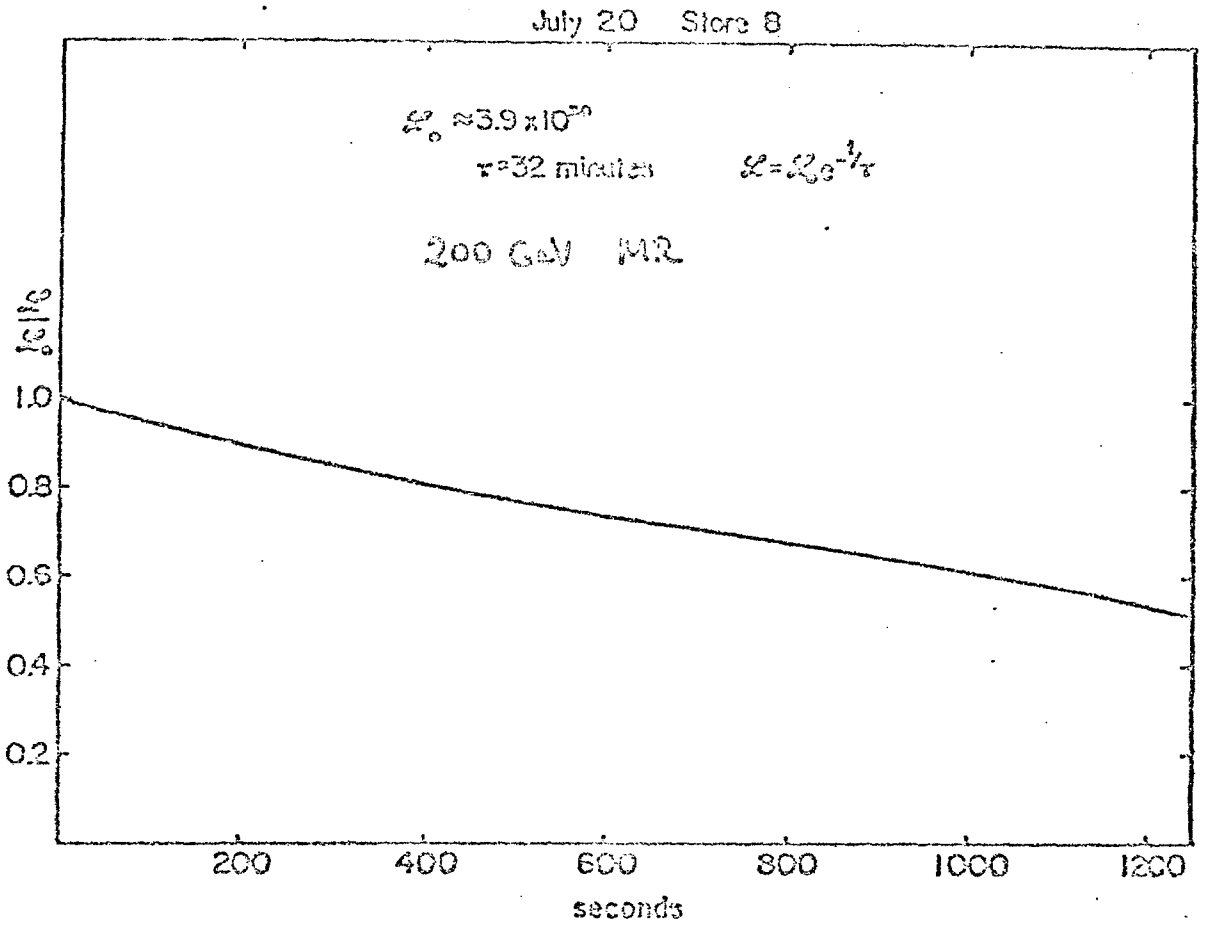


Fig. 14. Luminosity lifetime latest data.

LUMINOSITY LIFETIME DUE TO LOSSES AND BEAM BLOW-UP IN MR (ESD LOSSES NEGLECTED).

PROTON LIFETIMES OF SEVERAL HOURS OBSERVED.

MAIN LOSS OF $\mathcal{L}$ DUE TO TRANSVERSE BEAM GROWTH:

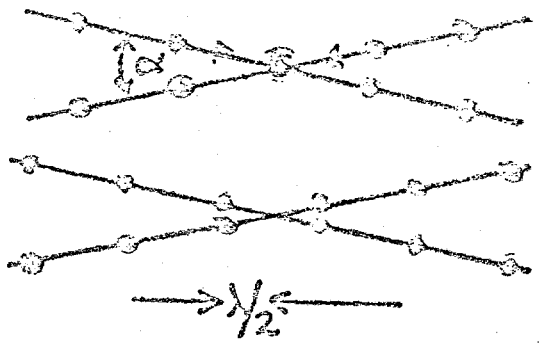
a) MULTIPLE SCAT ON RESIDUAL GAS,

b) RESONANT EFFECTS (SENSITIVE TO TUNE)

SUBSEQUENT VACUUM IMPROVEMENTS HAD LITTLE EFFECT ON $\tau_{\mathcal{L}}$

CROSSING ANGLE

COLLISIONS WOULD BE <u>NOT-QUITE HEAD ON</u> SO THAT BUNCHES WOULD COLLIDE ONLY AT ONE PLACE.



$\lambda/2 = 2.3$ m

FOR EXAMPLE, TAKE $\underline{\alpha = 1/2 \text{ mrad}}$

SEPARATION AT CLOSEST POINT

$$s = \alpha \lambda/2 = 1.4 \text{ mm}$$

$$s/\sigma = 1.4/(0.19 \times \sqrt{2}) = 5\sigma \text{ standard dev. separation for } \beta^* = 2.5 \text{ m}$$

THIS WILL LOSE A SMALL AMOUNT OF $\mathcal{L}$:

$$\frac{\mathcal{L}}{\mathcal{L}_0} = \frac{1}{\left[1 + \left(\frac{\alpha}{\alpha_0}\right)^2\right]^{1/2}}$$

$$\alpha_0 = 2\left[\frac{\sigma_{x1}^2 + \sigma_{x2}^2}{\sigma_{\ell 1}^2 + \sigma_{\ell 2}^2}\right]^{1/2}$$

σ_x = transverse rms
σ_ℓ = longitudinal rms

$$\left.\begin{aligned} &\approx 2 \times 0.19 \text{ mm}/0.4 \text{ m} \approx 1 \text{ mrad} \\ &\frac{\mathcal{L}}{\mathcal{L}_0} = \frac{1}{\sqrt{1.25}} = \underline{0.89} \end{aligned}\right\} \text{IF BUNCH LENGHENING NOT FIXED}$$

IF INSTABILITY IS CURED,

$$\alpha_0 \sim 2 \text{ mrad}, \quad \mathcal{L}/\mathcal{L}_0 \approx 0.97$$

INITIAL RUN

FOR PURPOSE OF DISCUSSION SUPPOSE

1) INITIAL TUNE UP OF COLLIDING BEAMS DONE IN SEVERAL SHORT RUNS OF A FEW DAYS EACH.

2) THEN A 3 MONTH DEDICATED RUN; FIRST HALF TUNING MACHINE AND DETECTOR, FOLLOWED BY A 6 WEEK RUN OF 100 HOURS/WEEK.

$$\int \mathcal{L}\, dt = (4\times10^{30}) \times (6\times100\times3600)$$

$$= \underline{8\times10^{36}\ \mathrm{cm}^{-2} \quad \text{IF NO LOSSES.}}$$

LOSS FACTORS

0.74	$\langle\mathcal{L}\rangle/\mathcal{L}_0$	CALC BY CROWIN IN A MODEL FOR $\mathcal{L}$ LIFETIME AND REFILL TIME
0.7	DEADTIMES	
0.5	DOWN TIMES, CALIBRATION RUNS, etc	
0.5	DETECTOR EFFICIENCY, CUTS, etc	

THUS WE MIGHT <u>EXPECT 1 USEFUL EVENT PER PICOBARN</u>

$$N = 10^{36}\sigma.$$

ISOCHRONISM

WITH BUNCHED BEAMS WE MUST HAVE EQUAL REVOLUTION TIMES EVEN THOUGH ENERGIES ARE UNEQUAL.

THEREFORE, THE CLOSED-ORBIT CIRCUMFERENCES (C) MUST BE SLIGHTLY DIFFERENT:

$$C_D - C_{MR} \approx C\Delta\beta \approx \frac{CM_p^2}{2}\left(\frac{1}{E_{MR}^2} - \frac{1}{E_D^2}\right)$$

$$\underline{\Delta C = 12 \text{ cm} \quad \text{FOR } 150 \times 1000}$$

$$\underline{\overline{\Delta R} = \Delta C/2\pi = 1.9 \text{ cm}}$$

CAN EITHER INSTALL ESD A FEW CM CLOSER TO TUNNEL WALL THAN MR, OR FOR SAME CENTRAL-ORBIT CIRCUMFERENCE CAN RETUNE rf IN ONE OR BOTH OF THE RINGS TO PULL THE BEAM(S) SLIGHTLY "OFF MOMENTUM"

$$\frac{\Delta p}{p} = \frac{E_{tr}^2}{2}\left(\frac{1}{E_{MR}^2} - \frac{1}{E_D^2}\right) \qquad \text{TRANSITION } E_{tr} \approx 18 \text{ GeV}$$

$$\approx \underline{0.67\%}$$

BACKGROUND RATES

(1-3)% OF THE rf BUCKETS WERE FOUND TO GIVE A SHOWER OF PARTICLES AT B_0 FOR VACUUM $\sim 10^{-7}$ TORR.

THIS RATE IS PROPORTIONAL TO

- a) LOCAL PRESSURE
- b) BEAM INTENSITY (RATHER THAN dI/dt)

ALREADY GOOD ENOUGH, THOUGH IMPROVEMENTS ARE CLEARLY WELCOME.

VERY GOOD LOCAL VACUUM, $10^{-(9 \text{ OR } 10)}$ WILL ALSO BE NEEDED TO REDUCE BEAM-GAS INTERACTIONS IN THE DETECTOR REGION.

LOVELESS - SS-77

WHY NOT 250 × 1000?

$\sqrt{s}$ = 1000 GeV

INSTEAD OF 775 GeV

× 1.6 IN S

BUT

- ~60 MW TO HOLD MR AT 250 GeV (DC)
  (INSTEAD OF ~22 MW AT 150).
- NEED LARGE-APERTURE SUPERCONDUCTING SEPTA.
- COLLINS' LOW β IN MR ONLY GOOD TO 150 GeV WITH PRESENT QUADS
- WILL GET $\sqrt{s}$ = 2000 GeV WITH $\bar{p}p$ ANYWAY.

STICK WITH 150 GeV IN MR (AT LEAST AT START) –

KEEP IT FAST AND INEXPENSIVE.