# HIGH LUMINOSITY CONSIDERATIONS*

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There appears to be some controversy over how high a luminosity one can use before a variety of detector limitations impose a practical limit. It seems appropriate in this paper to discuss factors leading to flux limitations for a variety of detector types and practical considerations to extending those limits. Attached to this detector group report is a paper giving examples of several detectors that operate in the $10^{32}$ to $10^{33}$ luminosity range. This paper also shows a method of reducing the effects of pileup inherent in calorimeter use at $L = 10^{33}/\mathrm{cm}^2/\mathrm{sec}$.

## Tracking Detectors

In this section we list a number of factors that contribute to limitations on rate capability of several types of tracking detectors.

1. Electronics requirements
   a. Deadtimeless - no loss of analog or time information due to baseline shifts or data acquisition deadtime. MPS II electronics resolves clusters 50 ns apart (in principle it could resolve 8 ns).
   b. Short shaping time constants such that > 20 MHz/channel can be resolved. MPS II has 2-3% pulse overlap at 1 MHz/channel.
   c. DC coupling or DC restoration for charge quantification is mandatory.

2. Efficiency vs. rate
   a. PWC and drift chambers - > $3 \times 10^4$ tracks/mm of anode for an observed reduction of gain (at gain = $10^5$ with 5μa threshold).
   b. Silicon strip - electronics limited to 100-200 MHz/strip. This detector has no gain, so ion space charge buildup occurs at $\gtrsim$ 100 higher flux per strip than in PWC's and drift chambers.
   c. Fibre optic hodoscope - electronics limited to $\gtrsim$ 200 MHz/fibre.

3. Lifetime
   a. PWC - Drift Chambers
      $10^{16}$ avalanches electronics/$\mathrm{cm}^2$ (R807)
      $10^{18}$ avalanches electronics/$\mathrm{cm}^2$ (split field magnet).
   b. Silicon strip
      > $10^{14}$ relativistic particles/$\mathrm{cm}^2$
   c. Fibre Hodoscope
      > $10^{14}$ relativistic particles/$\mathrm{cm}^2$

A practical tracking detector for operation at $L = 10^{33}/\mathrm{cm}^2$ would consist of 2 or more regions. Inside a radius of 20 cm silicon strips of 20μ widths and 200μ charge division intervals would provide < 5 ns timing and sufficient granularity to function with good efficiency at this luminosity. A fibre optic hodoscope would work just as well with a somewhat different resolving time (2 ns) to spatial resolution tradeoff (500 μ).

Outside a radius of 20 cm, a drift chamber using MPS II electronics and drift chamber configuration would have high efficiency and allow rapid isolation of out-of-time (10 ns) track segments. This configuration allows rapid sorting out of the typically 2.5 overlapping events without factorial combinatorial calculations. The bit rate per wire at a radius of 20 cm is $<10^6$/sec., a level at which MPS II operates with > 95% efficiency.

## Calorimeters

Table I is a list of relavent parameters effecting high rate behavior of several types of calorimeters.

TABLE I

|  | Resolving Time | Overlap Time | Cell Size ($\mathrm{cm}^2$) | Radiation* Damage Level |
|---|---|---|---|---|
| Liquid A radiator | < 5 ns | 200ns | 1 | ∞ |
| Scintillator radiator | < 5 ns | < 100ns | > 20 | $\sim 10^{12}$ |
| Pb glass | < 2 ns | < 30ns | > 10 | $\sim 10^{12}$ |
| BGO | ∿ 5 ns | 350ns | > 10 | > $10^{14}$ |
| High pressure gas - radiator | see Liquid A |  | 1 | ? |

*hadrons/$\mathrm{cm}^2$

Calorimeters having $10^3$ cells per unit of rapidity and 2π azimuthal coverage will have $\gtrsim$ 70 cells registering any charge in a 200 ns sample period at $L = 10^{33}/\mathrm{cm}^2$. In a liquid A detector only 4 cells/1000 would detect hit timing to be within 10 ns of the true event time. If in addition a charge deposition threshold of 1 GeV per cell is imposed only 1 in 3-200 ns intervals would any of the $10^3$ cells exceed this threshold. A Monte Carlo simulation of this overlap situation at $L = 10^{33}/\mathrm{cm}^2$ shows the largest $\Delta Y$, $\Delta\phi = \pi/2$ interval in a $\Delta Y = 4$ and $\Delta\phi = 2\pi$ calorimeter with the 1 GeV/cell cutoff is 4.5 ± 2.6 GeV. Thus the overlap causes an apparent increase in energy resolution of a size comparable to the inherent calorimeter resolution at 15 GeV. Tacit to this conclusion is the use of DC coupled or DC restored circuitry.

## Particle Identification

Table II is a list of some parameters important to particle identification at high rates in several types of detectors.

TABLE II

|  | Resolving Time | Overlap Time | Cell Size |
|---|---|---|---|
| Cerenkov |  |  |  |
| -threshold | 1 ns | < 5 ns | several $\mathrm{cm}^2$ |
| - imaging | 10 ns | .1-several μs | ∿ .5 $\mathrm{cm}^2$ |
| dE/dx in gases |  |  |  |
| - transverse drift | 10 ns | .3 μs | 10-100 $\mathrm{cm}^2$ |
| - longitudinal drift/fine sampling | 10 ns | 1-2 μs | 1-10 $\mathrm{cm}^2$ |

TABLE II (continued)

| | Resolving Time | Overlap Time | Cell Size |
|---|---|---|---|
| Transition Radiation | | | |
| - conventional | 20 ns | 400 ns | 10-100 $cm^2$ |
| - cluster counting | 10 ns | 600 ns | 1-10 $cm^2$ |

It should be noted that both dE/dx with fine sampling and transition radiation with cluster counting can be matched with calorimeter towers so that hit resolving time rather than overlap time can be used to filter the out-of-time tracks. The fine granularity possible with such detectors (> $10^4$ cells) reduces the cell hit probability to a few percent. Even with 2 $\mu$s overlaps, the rate of unresolvable tracks will be small.

## Triggering

It is generally accepted that primary triggering in hadron colliders will usually involve calorimetry. At first glance this appears to be a formidable task at L = $10^{33}/cm^2$, except for Pb glass, hit overlap times are 100 to 500 ns. However a Monte Carlo simulation of a highly segmented calorimeter with 200 ns overlap time demonstrates that a low energy cutoff on each cell can greatly reduce the effect of pileup.[1] In fact, the minimum bias pileup after such a cut has the effect of widening the energy resolution by a few GeV. A $P_t$ trigger threshold of 25 GeV is broadened by less than the natural resolution of a typical calorimeter.

Secondary level triggering could involve lepton detection, vertex finding (look for short lifetime decays) and particle identification. Lepton detection would involve either a $\mu$ signature in an externally shielded detector with good time resolution, i.e. scintillators or electron detection with shower calorimetry spatially matched to TRD detectors. In order to provide additional rejection of competing events, both types of trigger would require tracking to the primary vertex. Methods are being developed to reconstruct enough of the event to make such spatial correlations in a few ms.

Work on high resolution vertex detectors is in progress for short lifetime meson decays such as $D^o$, $D^+$.[2] Although such detectors would have 30% resolving time overlaps of events at L = $10^{33}/cm^2$, the spatial separation along the colliding beam axis should allow reconstructed tracks from different events to be distinguished. In this case verticies spread along the beam axis by a few resolution elements already reduces the overlap to acceptable levels.

## Conclusion

Reasons have been given that by combining the good time resolution (< 5 ns) although there is relatively long overlap width in most commonly used detectors with small cell size it is possible to distinguish most individual events at L = $10^{33}/cm^2$. The good time resolution combined with good spatial resolution allows separation of verticies and tracks from different events. The high segmentation of particle identifiers and calorimeters insures low probability of multi-hits per cell even with longish overlap times. The conclusion is that most experiments that are carefully designed should be operable up to L = $10^{33}/cm^2$.

## References

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2. L.L. Chau, T. Ludlam, F.E. Paige, E.D. Platner, S.D. Protopopescu, P. Rehak, W.E. Cleland, J.A. Thompson. "Heavy Quark Jets". Contribution to "Beyond the Standard Model" Section of these proceedings.