Luminosity monitors for PETRA, SPS and LEP
…….a walk back in history

Rüdiger Schmidt, lumimon meeting 26 April 1999

- Some Requirements
- PETRA
- SPS
- LEP

Requirements

- Measure the relative luminosity integrated over all bunch collisions with an error of less than, say, 1% in one second
  - for optimising luminosity similar to the LEP luminosity scanning
- Acceptance and sensitivity of the monitors must be independent of the beam positions and beam angles at the IP over the whole range of possible displacements (citation UA1 Note 59, P.Gutierrez, A.Kernan)
- The acceptance and sensitivity of the monitors must be independent of the beam sizes and beam divergence at the IP
- A drastic change in the background should not change the counting rate in the monitors
- Measure the relative luminosity of individual bunch pairs with an error of less than, say, 1% in 50 seconds (matches error of above)
  - the measurement of individual bunch luminosity would allow simple interpretation of results (see beam-beam workshop)
  - such a measurement would be useful, also if it is much slower
  - would it be sufficient to integrate over 10 bunches?

PETRA

- Problem for e+e- colliders: event rate very low, for optimisation a high rate is required
  - Bhabha scattering in the order of some 10 Hz (at small angle, some mrad)
  - wide angle events in the order of 1 Hz
- Single Bremsstrahlung rate of some 100 kHz: lets use it
  - in 1/gamma cone with respect to beam axis
  - was measured using the Polarisation monitor
  - Problem A: very sensitive to beam parameters at IP (angle, divergence, and position)
  - Problem B: very sensitive to background from long straight section, changes in vacuum pressure, scraping of tails, ...

  - …turned out to be useless for any luminosity optimisation

SPS proton antiproton collider

- Both beams were separated along most of the circumference with electrostatic separators, therefore the luminosity had to be optimised
  - without optimising, the beams would not meet
- Luminosity monitors built by E.Rossa and G.von Holtey, later taken over by UA1 and UA2 (see slides)
  - fast, efficient and simple, outside vacuum chamber, between 23 mrad and 40 mrad (about)
- To measure luminosity at IP without detector, a “quick and dirty” detector was build and used to optimise the beam crossing in collision point without experiment (see slides)
- Such type of monitors, positioned correctly, are likely to fulfil the requirements for LHC luminosity monitoring
  - not too high rate in order not to damage them
  - high enough rate to get fast measurement (100 kHz - 1 MHz)
  - fast photomultipliers, or other light detectors

LEP small angle Bhabha detectors

- In order to have a sufficient rate for luminosity optimisation, a silicon strip calorimeter was developed and inserted inside collimators, and were positioned close to the beam (30 mm)
- The rate of Bhabha scattered particles was in the order of 40-80 Hz
- The background rate was in the order of up to some kHz after other collimators were driven close to the beam to minimise background
- Coincidences between 2 Monitors, right and left from the IP, were measured
- By subtracting the accidental coincidences the luminosity could be measured
- The detector was not 100% available, but the monitors of the LEP experiments could always used as back-up
- The spatial resolution of the detector was not used (until 1996)
  - the detector and the electronics could have been therefore much simpler
  - to keep the detector operating required at least one person full time

- This was the only way to get a high counting rate

Conclusion

- Comparing those three - my preferred monitor was the SPS luminosity monitor
  - fast luminosity detector at SPS was much simpler to build
  - worked very reliably, very little follow up from machine people
  - conceptually simple
  - matched requirements formulated previously
- Luminosity measurement at PETRA and LEP much more difficult
  - LEP: mainly due to complicated device and high background
  - PETRA: very sensitive to beam manipulations, for operation SPS like counters were used (H.C.Dehne)
- LHC: acceptance of monitors does not to be very high - counting rate of 100 kHz -1 MHz for maximum luminosity sufficient (less problems with radiation dose)
- Calibration between IP's possible since beam overlap can be measured in both planes (monitor constant can be established)
- Measurement of absolute luminosity is a task for the LHC experiments

Very fast luminosity monitor? .....why yes

- Main task of any luminosity monitor is to measure the integrated luminosity, in order to allow for an optimisation of the beam overlap - possibly the luminosity monitor response should be independent of beam parameters over the whole range of possible values
- Most arguments from yesterday and this morning (beam-beam workshop)
- The question is: do we need / prefer to measure the luminosity...
  - for each bunch
  - for sets of, say, 10 bunches (fast luminosity measurement, possibly any number in between)
- Into luminosity equation enter: N_{p1}, N_{p2}, σ_{xp1} , σ_{xp2} , σ_{yp1} , σ_{yp1} , δ_x , δ_y , $\alpha_{crossing}$
- Every bunch in the LHC is different - and bunches can be rather different from their direct neighbours (see J.Jowetts slide on bunch classes)
  - δ_x , δ_y in the order of 0.1-0.2 σ
  - in particular, δ_x and δ_y can be different for adjacent bunches, to calculate offsets is not trivial, but being developed (beam beam simulations) - does it matter? Not clear..
  - should be measured for individual bunches, in order to understand LHC accelerator physics. Such offsets could excite resonances, but it is likely that other effects will dominate.
  - measurement of offsets nontrivial (should be done with a resolution of 1-2 μm). To achieve such precision with BPMs some distance left and right, and then interpolate - not easy

.....why yes

- Van der Meer type of scan in x and y direction gives:
  - relative luminosity
  - δ_x
  - δ_y
  - overlap integral in x direction (can be calculated sigma for both bunches known)
  - overlap integral in y direction (can be calculated sigma for both bunches known)
- If bunch positions, currents, sizes are measured, the relative luminosity can be used a an independent consistency check (remember of the time spend at LEP for cross-calibrations of emittance measurement devices)
- My opinion: such “very fast” luminosity measurement is very desirable
  - We do not need to perform such very fast luminosity measurement in a short time (1 min or longer is sufficient)
- **The very fast luminosity monitor should not replace the capability of other instruments to measure bunch-by-bunch**
- It will take some time that all other instruments will be commissioned in order to give all information required (comment by J.Gareyte, 11:56 today)
- Finally: interest in measuring beam losses at collimators for individual bunches (a very few fast beam loss monitors)