EICUG Working Group on the Interaction Region
Video Conference on High Precision Luminosity Measurements
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Purpose of Meeting

• Review previous techniques / achievements / limitations for precision luminosity measurements.
• Review luminosity precision requirements for EIC physics program
• Stimulate necessary R&D efforts for EIC program
Techniques

• Van der Meer Scans
• Total Absorption Bremsstrahlung Calorimeter at 0°
• Small angle (2-10 mrad) “QED Compton”
  • $^A_Z(e,e' \gamma)^A_Z$
• Forward Pair spectrometer (thin convertor):
  $\gamma \rightarrow e^+e^-$
Challenges

• Absolution Precision < 2%
• Relative Precision < 1%
• Polarization dependence
• 100x → 1000x greater luminosity than HERA
• Valid for ep to eU
  • Polarized p, d, ³He, Li
• Bunch-by-Bunch measurements (time-averaged)
  • Emittance growth & polarization can be bunch specific
Program

- Following (backup) slides review some previous methods, and give references
Van der Meer Scans

• Absolute determination of Luminosity
  • Monitor a physics rate as the colliding beams are scanned across each other in 2D
  • Requires precision measurement of beam currents and collision centroid stability (3-D)
  • Does not require a priori knowledge of cross section.

• Interrupts experimental data taking
  • Not a continuous monitor

• V. Balagura, NIM A 654 (2011) 634–638
  • RHIC: (IPAC’10, Kyoto Japan, May 2010 proceedings)
    • K.A. Drees, S.M. White, Vernier scan results from the first RHIC proton run at 250 GeV,
  • LHC:
Bremsstrahlung

• At $\mathcal{A} = 10^{33}$/cm$^2$/sec:
  - Bremsstrahlung power $\sim 0.04$ Watt
  - Angular distribution dominated by $rms$ angular spread of $e^-$ beam: Photon $rms \approx 4$ mm @ 20 m
  - Total Absorption ECal dose ($10^7$ sec exposure per year)
    - 0.4 MGray/year
    - Each photon absorbed in $\sim 1$ kg of high-Z material
  - Calorimeter options
    - Liquid Argon
    - Quantameter (SLAC 1960s): Alternating HV plates in vacuo
      - D. Yount, NIM 52 (1967) 1–14
      - Calibrate with electron beam?
  - Pair Spectrometer (ZEUS method)
    - Rate is tunable (detector out of synchrotron and brem beam)
QED Compton: HERA experience

• Challenges:
  • acceptance, alignment, absolute precision

  • DOI 10.1140/epjc/s10052-012-2163-2
  • Erratum DOI 10.1140/epjc/s10052-014-2733-6
  • Electron gamma detection at 10° to 25° from e⁻-beam

• Theory:
  • K. Gaemers, M. van der Horst, Nuclear Physics B 316 (1989) 269-288: (Small angle theory, simulation)

• Compton22 Generator:
**Luminosity Monitor: HERA Summary**

**Luminosity Detector**

**Concept:**
- Use Bremsstrahlung $ep \rightarrow ep\gamma$ as reference cross section
- different methods:
  - Bethe-Heitler, QED Compton, Pair Production
  - Hera: reached 1-2% systematic uncertainty

**Goals for Luminosity Measurement:**
- Integrated luminosity with precision $\Delta L/L < 1\%$
- Measurement of relative luminosity:
  - physics-asymmetry/10 $\rightarrow 10^{-4}$ - $10^{-5}$

**EIC challenges:**
- with $10^{32}$ cm$^{-2}$s$^{-1}$ one gets on average 23 bremsstrahlungs photons/bunch for proton beam
  - A-beam $Z^2$-dependence
- Need more sophisticated solution
- BH photon core $< 0.03$ mrad
  - acceptance completely dominated by lepton beam size

**Set up at ZEUS**

**At H1**

- pair spectrometer low rate
  - High precision measurement for physics analysis
  - The calorimeters are outside of the primary synchrotron radiation fan

- zero degree photon calorimeter high rate
  - Fast feedback for machine tuning
  - measured energy proportional to # photons
  - subject to synchrotron radiation