EICUG Working Group on the Interaction Region

Video Conference on High Precision Luminosity Measurements
15 February 2019

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EICUG IR working group co-convener

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,* ^{3}He, Li
- Bunch-by-Bunch measurements (time-averaged)
  - Emittance growth & polarization can be bunch specific

Program

10:00 AM → 10:15 AM	**Brief overview of the purpose of this meeting**	**Speaker:** Charles Hyde (Old Dominion University)	15m
10:15 AM → 10:45 AM	**Luminosity measurement requirements for an EIC detector and constraints imposed by the current eRHIC accelerator and Interaction Region design**	**Speaker:** Dr E. C. Aschenauer (BNL) eRHIC.Luminosity.e...	30m
10:45 AM → 11:15 AM	**JLEIC IR summary: Forward e– acceptance and Geometrical constraints on detector space in 0° photon line**	**Speaker:** Vasiliy Morozov (Thomas Jefferson National Accelerator Facility)	30m
11:15 AM → 11:45 AM	**Experience with Van der Meer scans to measure absolute luminosity at RHIC**	**Speaker:** Angelica Drees (Collider-Accelerator)	30m
11:45 AM → 12:15 PM	**Review of the ZEUS luminosity measurement**	**Speaker:** William Schmidke (BNL)	30m
12:15 PM → 1:00 PM	**Discussion**		45m

- 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.
- Interupts 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:
    - M. Ferro-Luzzi, Determination of the luminosity at the LHC experiments, in: Proceedings of ICHEP'10, Paris, July 2010, published in PoS (ICHEP 2010) 010:
    - S.M. White, et al., First luminosity scans in the LHC, in: Proceedings of IPAC'10, Kyoto, Japan, May 2010.

Bremsstrahlung

- At $\mathcal{L} = 10^{33}\ /cm^2/sec$:
  - Bremsstrahlung power ~ 0.04 Watt
  - Angular distribution dominated by *rms* angular spread of e^- beam: Photon *rms* ≈ 4 mm @ 20 m
  - Total Absorption ECal dose (10^7 sec exposure per year)
    - 0.4 MGray/year
    - Each photon absorbed in ~ 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
        - R. Anderson, NIM **65** (1968) 195–198
      - 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
- E. Aaron (H1 collaboration) Eur. Phys. J. C (2012) **72**:2163
  - 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:
  - A. Courau, P. Kessler, Phys Rev D 46 (1992) p. 117
  - K. Gaemers, M. van der Horst, Nuclear Physics B **316** (1989) 269-288: (Small angle theory, simulation)
- Compton22 Generator:
  - V. Lendermann*, et al.,* Eur. Phys. J. C **31**, 343 (2003). hep-ph/0307116

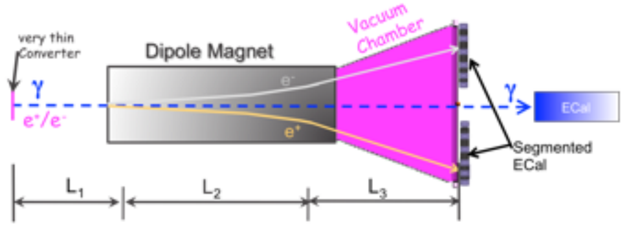
Luminosity Monitor: HERA Summary

Luminosity Detector

Concept:
Use Bremsstrahlung ep → epγ 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 → ~10^{-4} - 10^{-5}

EIC challenges:
- with 10^{33} 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 cone < 0.03 mrad
  → acceptance completely dominated by lepton beam size

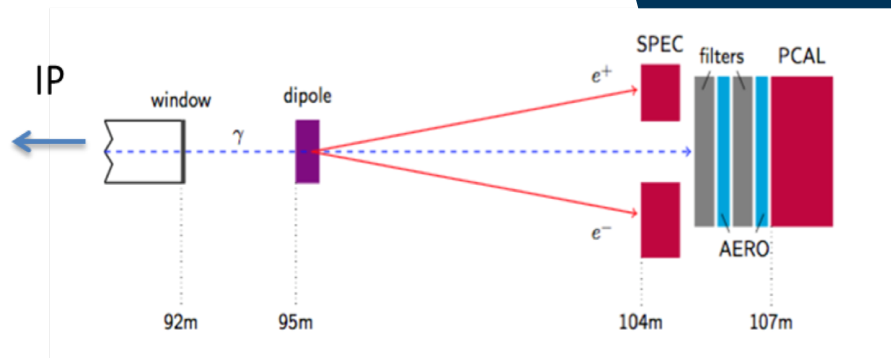


pair spectrometer
low rate
- High precision measurement for physics analysis
- The calorimeters are outside of the primary synchrotron radiation fan

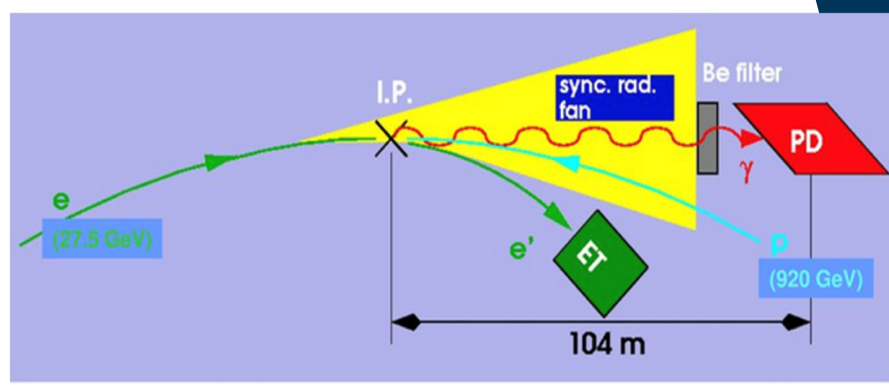
zero degree photon calorimeter
high rate
- Fast feedback for machine tuning
- measured energy proportional to # photons
- subject to synchrotron radiation

E.C. Aschenauer

Set up at ZEUS



At H1



R. Yoshida