IR Working Group update

Alexander Kiselev

EICUG IB meeting March,14 2019

The charge and the conveners

- Charge:

"The EICUG IR working group's mission is to provide an interface between the machine design / IR design and the physics needs to ensure that the EIC program outlined in the White-paper is properly implemented with a broad range of physics measurements in particular those requiring forward / backward instrumentation. This should include challenging questions related to the measurement of nuclear fragments for a variety of processes and associated measured energy / momentum range and spacial acceptance. The requirements for the IR design should be determined from detailed simulations for proposed processes. In addition to specific aspects of the IR design, the working group should also address the scheme for luminosity measurement and its impact on the machine element layout. It is strongly suggested that the new EICUG IR working group interface directly with existing efforts at BNL and JLab. The working group will be open to all members of the EICUG. It will communicate via a new mailing list and organize regular online and in-person meetings that enable broad and active participation from within the EICUG as a whole"

- Conveners:
  - Charles Hyde (ODU)
  - Alexander Kiselev (BNL)
  - Christoph Montag (BNL)
  - Vasiliy Morozov (JLAB)

Luminosity measurement @ an EIC

Videoconference 02/15/2019

https://indico.bnl.gov/event/5743/

10:00 AM → 10:15 AM **Brief overview of the purpose of this meeting**

Speaker: Charles Hyde (Old Dominion University)

CHyde-IRWG-Lumin... CHyde-IRWG-Lumin...

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...

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)

Morozov_JLEIC_IR_...

11:15 AM → 11:45 AM **Experience with Van der Meer scans to measure absolute luminosity at RHIC**

Speaker: Angelica Drees (Collider-Accelerator)

VernierScans2019.p...

11:45 AM → 12:15 PM **Review of the ZEUS luminosity measurement**

Speaker: William Schmidke (BNL)

zeus_lumi.pdf

12:15 PM → 1:00 PM **Discussion**

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

Requirements from EIC Physics

- EIC a high luminosity machine 10^{33-34} cm^{-2} s^{-1}
  - to capitalize on this luminosity one needs to have as low as possible systematics
  - luminosity measurement as precise as possible $\delta L_{int} \lesssim 1\%$
    - → critical for cross section measurements
  - most of the measurements we will be systematically limited
    - → Dominant systematics for double spin asymmetries
    - → Luminosity Measurement → Relative Luminosity

$$A_{LL} = \frac{1}{P_e P_p}\left(\frac{N^{++/--} - RN^{+-/-+}}{N^{++/--} + RN^{+-/-+}}\right); \text{ with } R = \frac{L^{++/--}}{L^{+-/-+}} \qquad \delta A_{LL} \sim \frac{1}{P_e P_p \sqrt{L_{int}}}$$

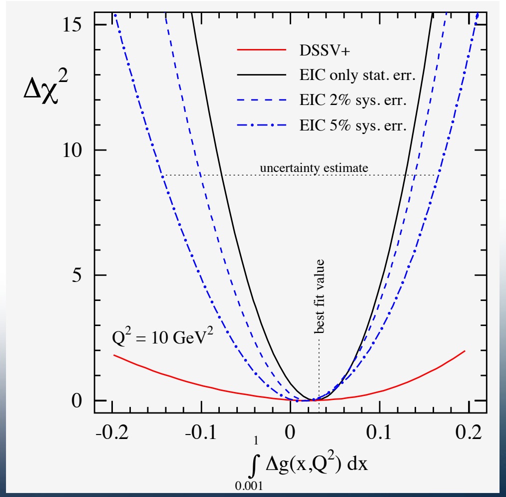
relative luminosity

- R needs to be controlled better then A_{LL}~10^{-4} at low x → RHIC: R ~ 2.-4.x10^{-4} @ 500 GeV
- high precision polarization measurement with small systematics ~1%
- flexible spin orientation bunch to bunch

  Spin patterns combinations, i.e.

  1: +-+--+-++-+- 2: -+-++-+--+-+ 3: ++--++--++-- 4: --++--++--++

  strongly minimizes systematics due to instabilities with time



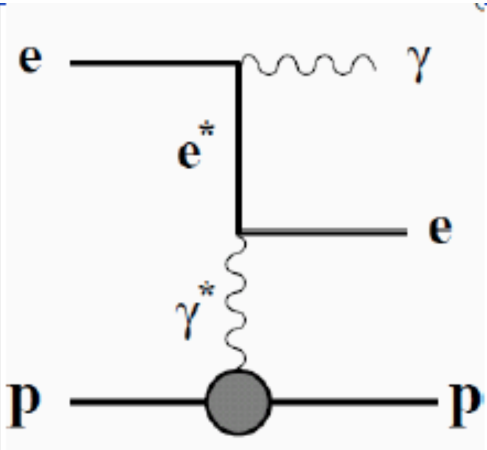
- EIC first collider with polarized lepton and hadron beams
  - luminosity measurement depends on beam polarization

$$\sigma_{Brems.} = \sigma_o(1 + aP_eP_p)$$

  - How big is "a"? Need a theorist to calculate

- Need overall systematics ≤ 2% (arXiv:1206.6014)

Luminosity Measurement: physics processes

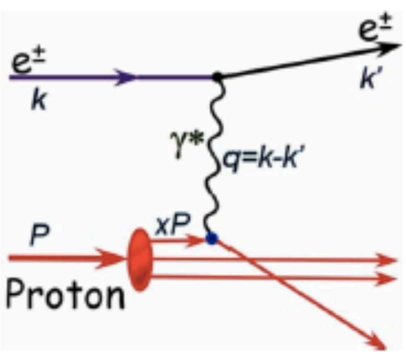


Bremsstrahlung ep→ eγp

Bethe-Heitler (collinear emission):
- very high rate of 'zero angle' photons and electrons, but
- sensitive to the details of beam optics at IP
- requires precise knowledge of geometrical acceptance
- suffers from synchrotron radiation
- aperture limitation
- pile-up

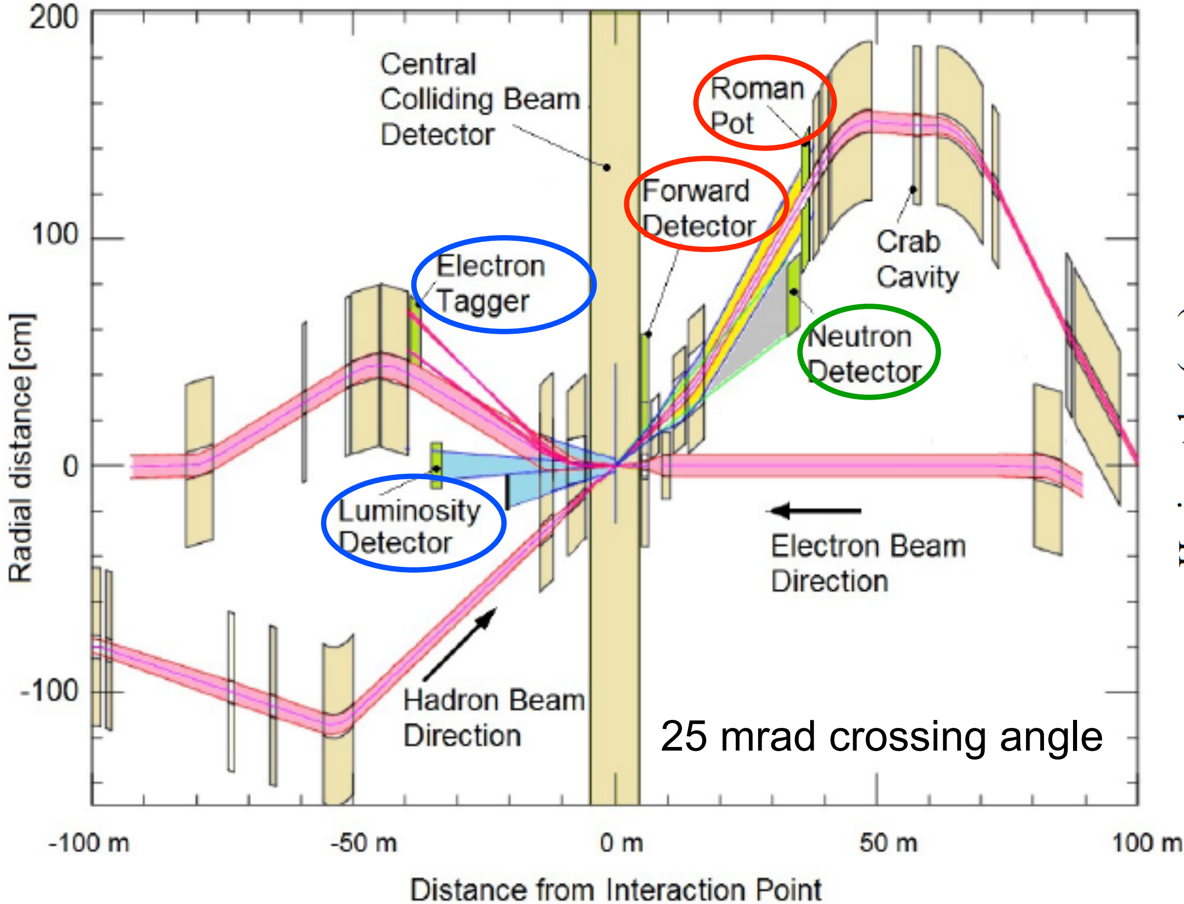
QED Compton (wide angle bremsstrahlung):
- lower rate, but
- stable and well known acceptance of central detector

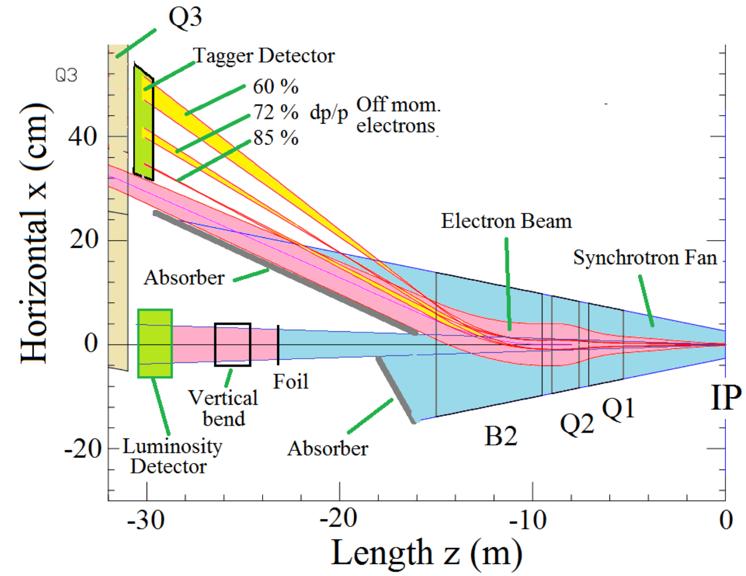
→ **Methods are complementary, different systematics**



NC DIS in (x,Q^2) range where F_2 is known to O(1%)
for relative normalisation and mid-term yield control

eRHIC: IR Design





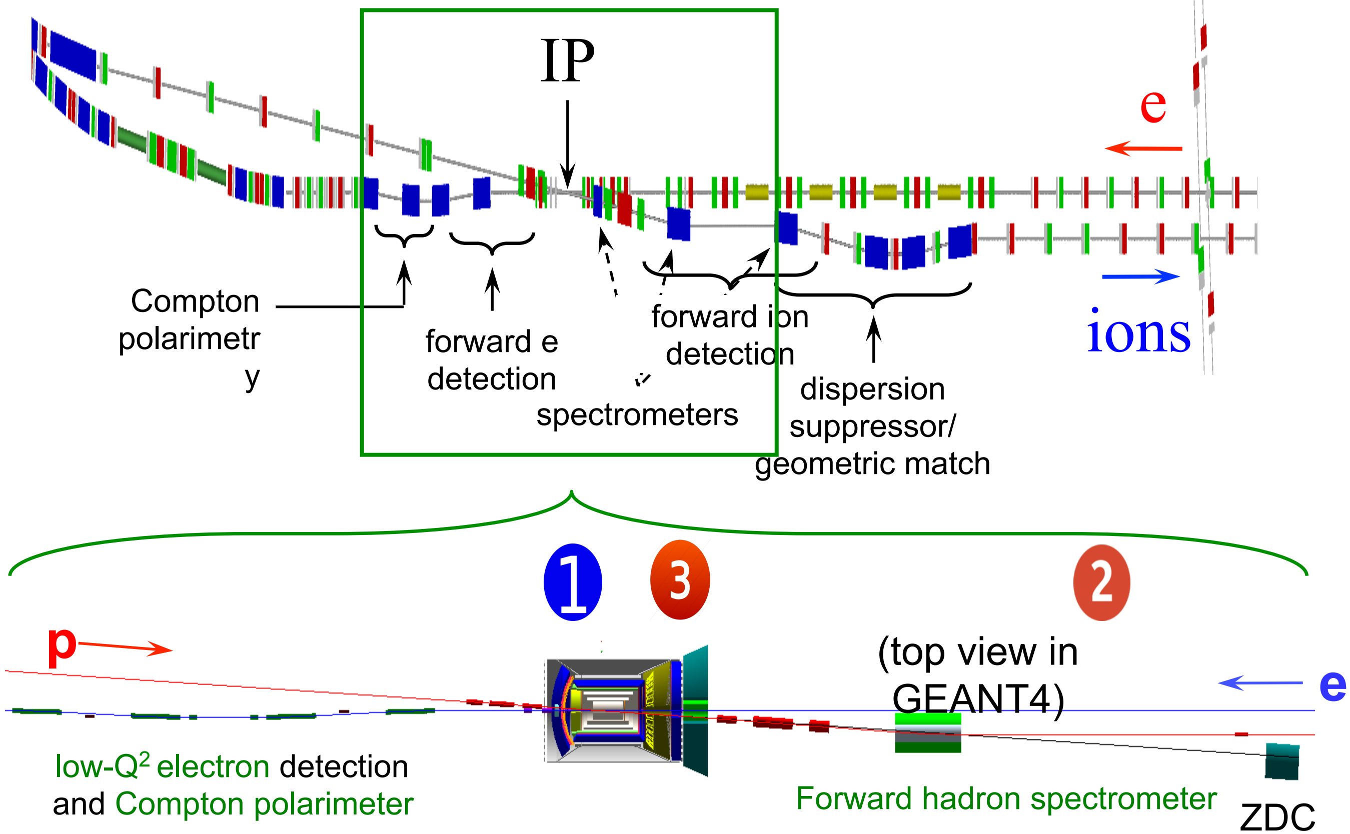
- main emphasis on integrating requirements for hadron beam direction
  - B0Fp: Forward Spectrometer (6 - 20 mrad)
  - Roman pots (Sensitive 1 to 5 mrad)
  - Neutron Detector (0 to 4 mrad)
- B1Re and B2Re: separate BH photons from beam, separate low Q^2 electrons from beam and lepton beam from SR-fan

→ electron and hadron polarimetry at IP-12

Vasiliy Morozov

JLEIC Interaction Region Layout

- Most recent changes occurred in the ion IR due to redesign for 200 GeV/c ion momentum
- Streamlined updates of GEMC and GEANT4 detector region models
- Continued development of an engineering design of the detector region

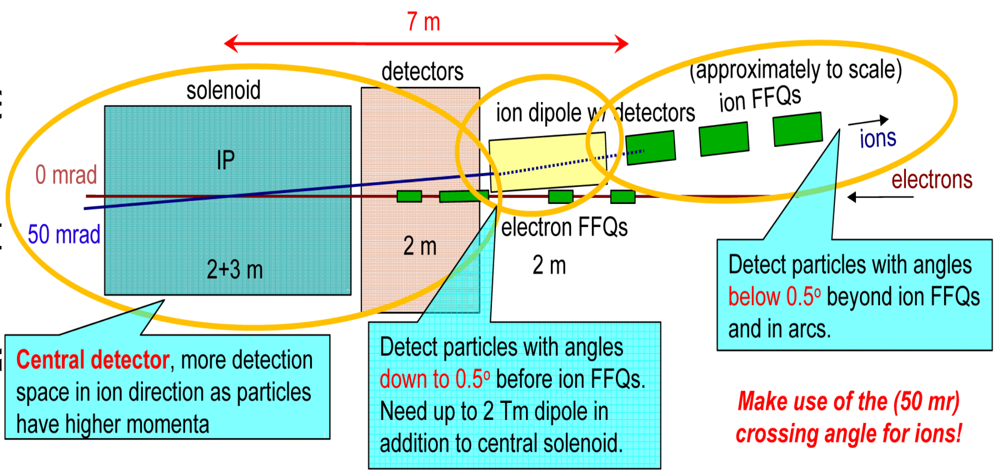


Jefferson Lab

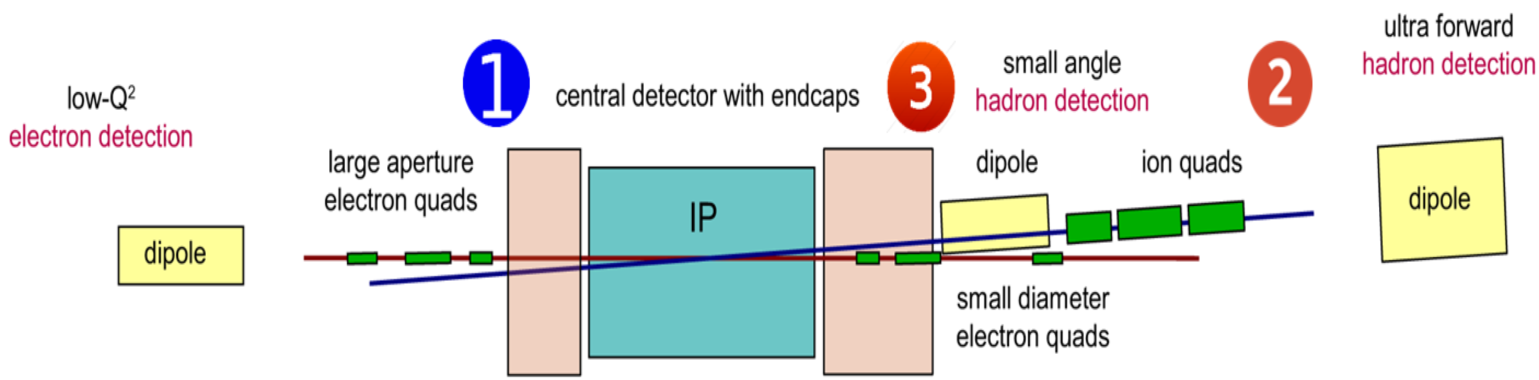
Schematic of Full-Acceptance Detector

Vasiliy Morozov

- 50 mrad crossing angle
- Forward hadron detection in thre
  - Endcap
  - Small dipole covering angles up
  - Far forward, up to ~10 mrad, fo passing through accelerator qua



- Low-Q2 tagger
  - Small-angle electron detection



Angelica Drees

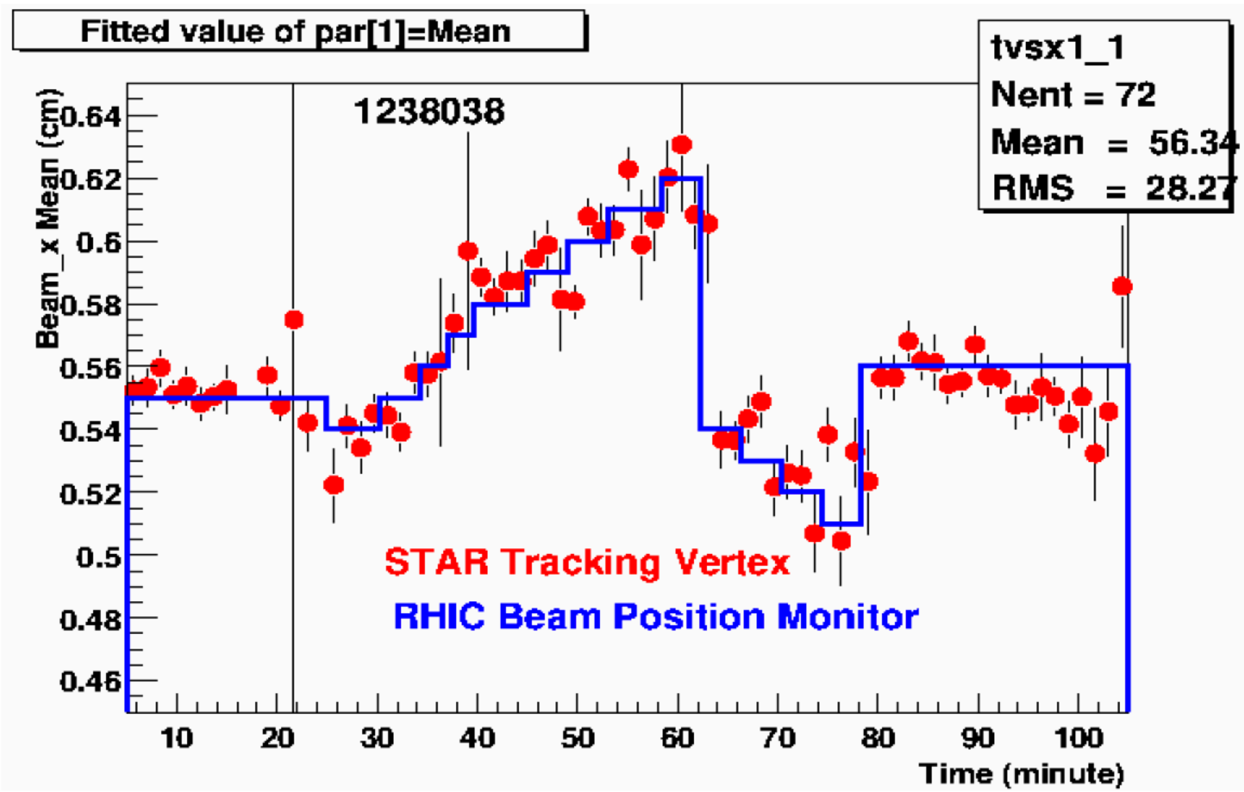
What are Vernier Scans?

Van-der-Meer Scans or Vernier Scans are done by stepwise sweeping one beam across the other while measuring collision rates as a function of beam displacement. This is done in both planes.

Needed basic instrumentation: the ZDCs or other collision monitors (BBC ...) at the various IRs, corrector magnet control to apply 4-bumps at IR, DX Beam Position Monitors (BPM) and beam current measurements from Wall Current Monitor (WCM) or DCCTs.

A Gauss function is fitted to the result yielding the maximum rates (R_x^{max}, R_y^{max}) the location of the maximums (x_{max}, y_{max}) and the effective beam overlap widths (σ_x, σ_y) in both planes.

The Method



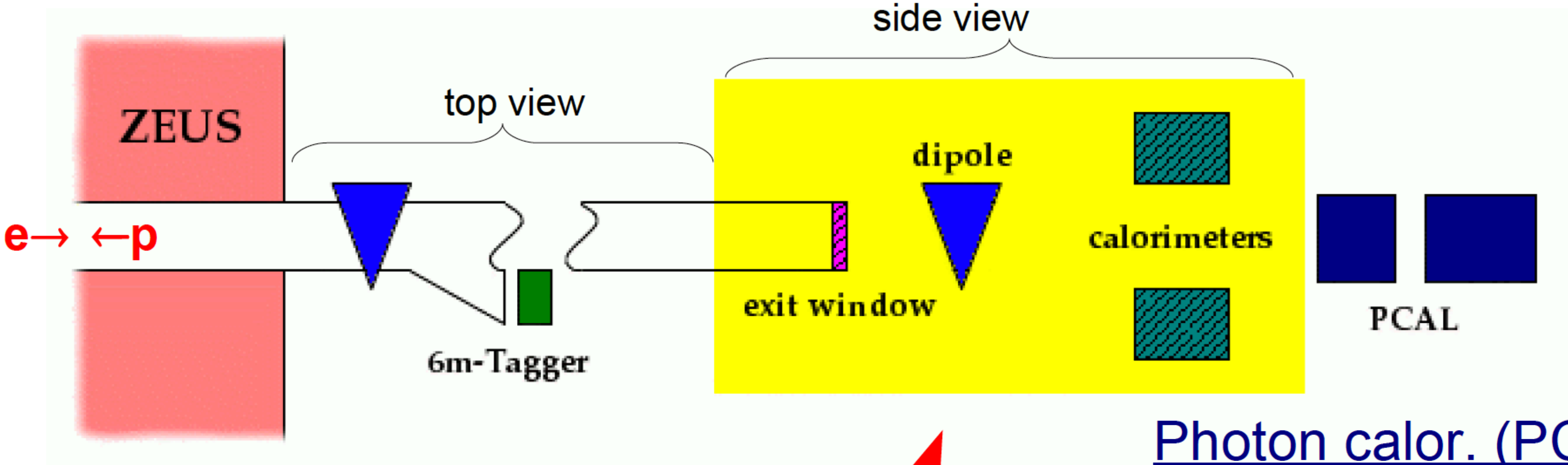
- Sweeping blue or yellow beam
- Stepsize: 100-500 µm
- approx. 2 min./point
- good agreement with STAR data

STAR reconstructed vertex during a horizontal scan in 2000 (arbitrary offset added to adjust both data sets).

Bill Schmidke

ZEUS LUMI system: 2 γ detectors

~100 m from I.P.



<u>Photon calor. (PCAL)</u>

- Direct measure γ

<u>*e* tagger @ 6m from I.P.</u>

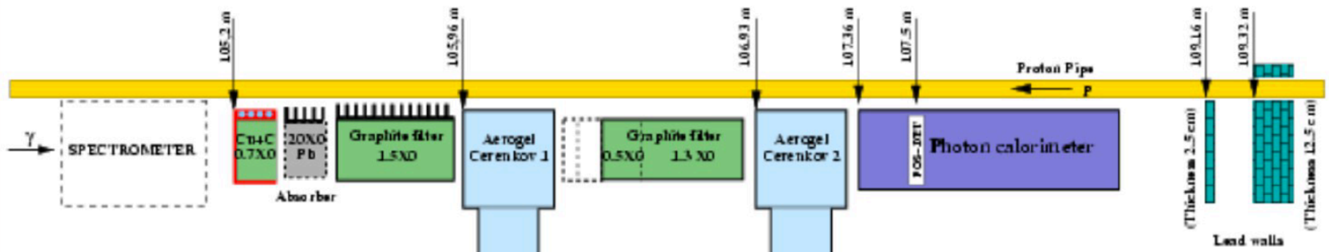
- Measure scattered *e*
- W-scint. spaghetti calor.
- Check photon accept. (work in progress...)
- Also for physics: tag high W photoprod.
- Not discussed more here...

<u>Pair spectrometer</u>

- Measure pairs from $\gamma \rightarrow e^+e^-$ in exit window

Bill Schmidke

PCAL: direct γ measurement



<u>C filters</u>

- $\sim$3-4 X_0
- w/ Aerogel Ckv. det. (not used for LUMI, used for physics)

<u>PCAL</u>

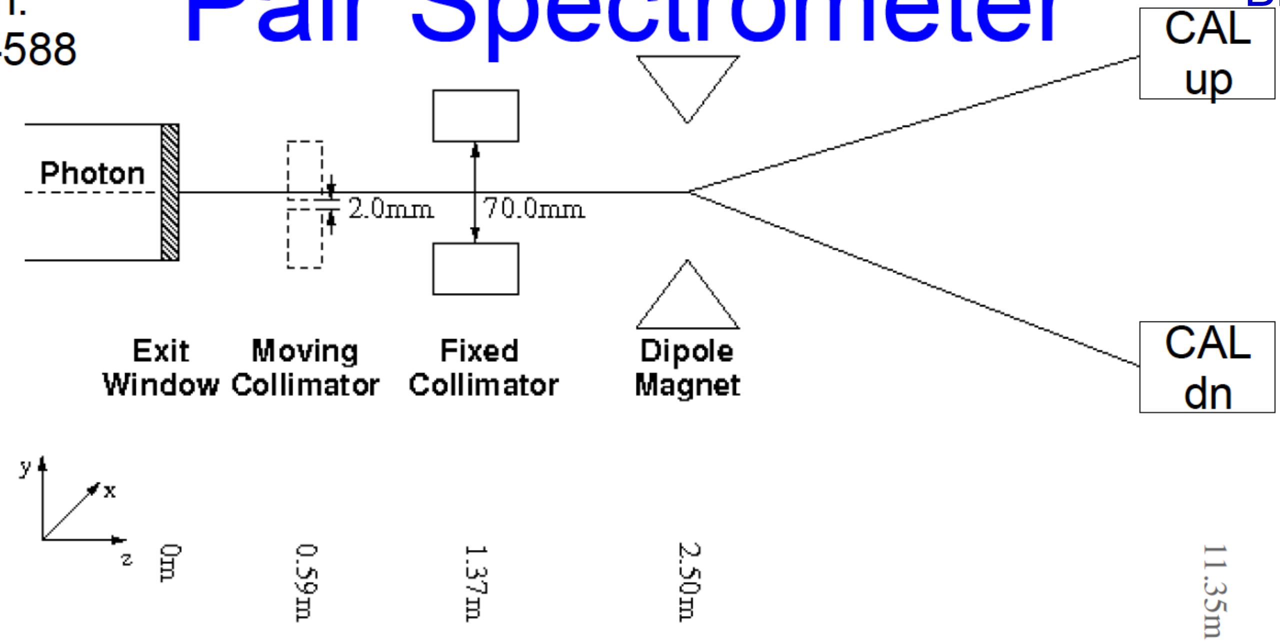
- Pb-scint. sandwich
- Scint. hodoscope for position recon.

- PCAL sits in direct γ beam, also primary syc. rad. fan
- PCAL *must* be shielded: C/graphite filters
- Serious resolution degradation; must be MC modeled
- Does provide soft cutoff E_γ<few hundred MeV, protect against IR divergence in B-H spectrum

Nucl.Instrum.Meth.
A565 (2006) 572-588

Pair Spectrometer

Bill Schmidke



- In exit window ~9% $\gamma \rightarrow e^+e^-$ conversions $\Rightarrow$ **>10 rate reduction**
- Pair separated vertically by dipole $\int Bdl \approx 0.3$ T-m ≈ 0.1 GeV p_T
- e^+, e^- detected in W-scint. sandwich calorimeters horiz., vert. segmented for position recon. $\Rightarrow$ **out of primary sync. rad. fan**

Calibration:

- Insert 'moving collimator', defines narrow vert. pair position
- Now a 'true spectrometer':
  - From $\int Bdl$ & distance to calorimeters, vertical position in calorimeter determines energies e^+, e^-

Future activities

- Figure out what is the manpower to do the actual studies
- Organize a follow-up videoconference
  - backgrounds
  - auxiliary IR detectors
  - forward acceptance
  - ...
- Look for theory support to do the Lumi calculations