Luminosity Measurement
Constraints on the Interaction Region

Uwe Schneekloth

DESY

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Outline

- Requirements for luminosity measurement
- Luminosity measurement (at HERA)
- Constraints on LHeC IR
- Conclusions

Requirements Lumi Measurement

Need measurement of instantaneous and integrated luminosity

Instantaneous luminosity

- Machine tuning and optimization
- Need fast measurement (few seconds update rate)

Integrated luminosity

- Needed for cross section measurements
- Need precise measurement (error few %, ~1 %?)
- Good understanding of acceptance and systematics
- No radiation damage of detector

Luminosity Measurement at HERA

Method: measure rate of bremsstrahlung process $ep \rightarrow e' p\gamma$

Originally, measure coincidence of e′ and γ. $E_e = E_{e'} + E_\gamma$

Detectors in HERA tunnel:

- Photon detector 105m from IP at 0^0 (p beam is bent upwards)
- Electron detector 35m from IP (HERA magnets act as spectrometer)

$$L = 1/\sigma_{BH}^{obs}\left[R_{tot} - (I_{tot}/I_0)R_0\right]$$

Bethe-Heitler cross section $\sigma_{BH}^{obs} = A_\gamma \sigma_{BH}^{corr}$

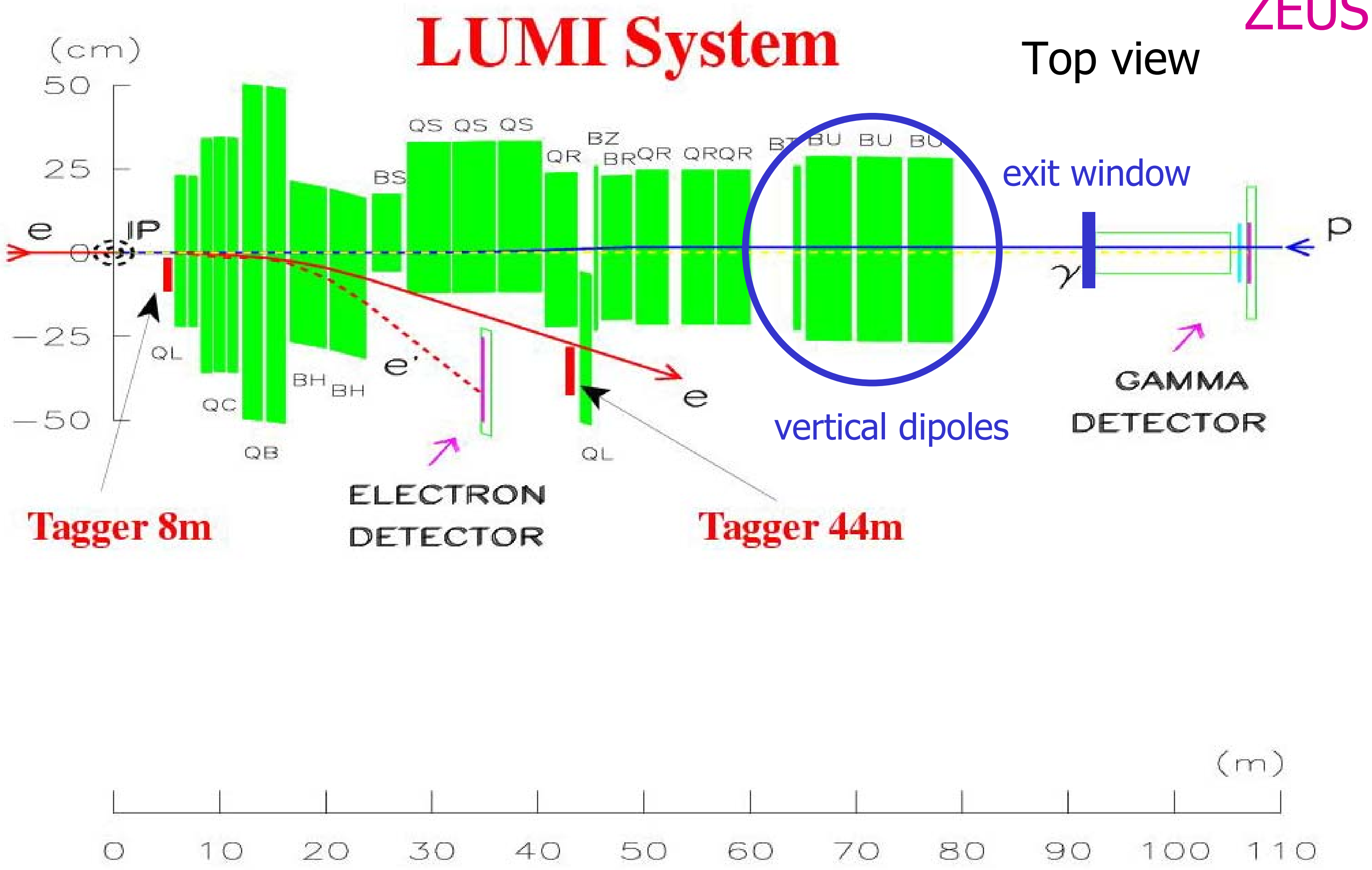
Main background beam gas scattering:

Subtracted using pilot bunches

- bunch structure: p 180, e 194, colliding 174 (HERA I)

Overview of Luminosity Monitor – HERA I

ZEUS



Luminosity Measurement - HERA I

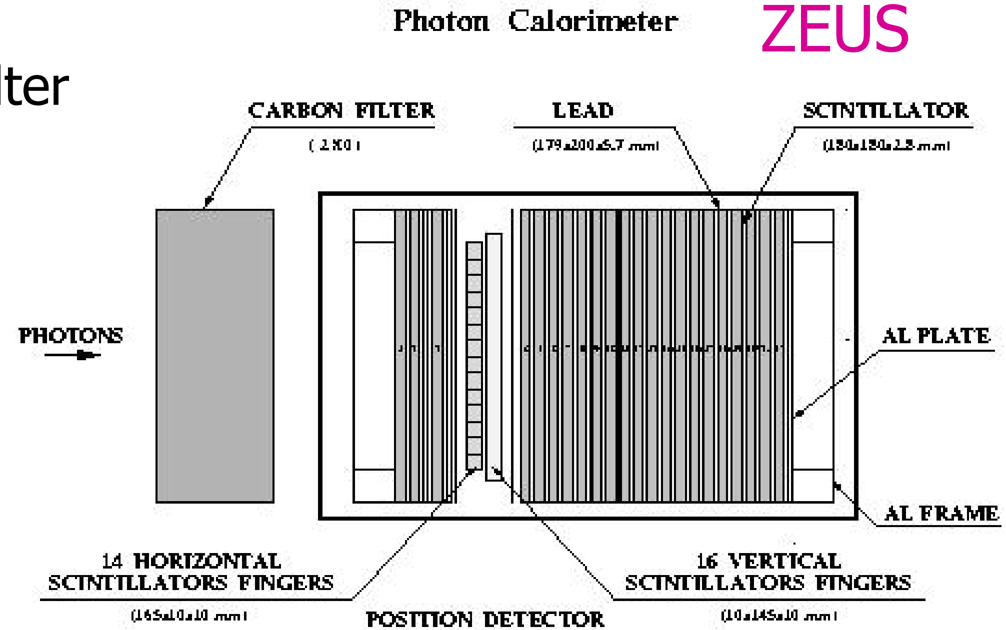
Synchrotron radiation requires filter in front of calorimeter

- Very good background conditions.
- Good photon acceptance.
- Electron acceptance more difficult
- Only using photon detector for luminosity measurement

Electron detector:

- systematic checks (calibration and acceptance)
- tag photoproduction events
- estimate background of photoproduction events in DIS

ZEUS



Typical systematic errors

Acceptance error	0.8%
Cross section calculation	0.5%
e gas background substr.	0.1%
Multiple event correction	0.03%
Energy scale error	0.5%
Total error	1.05%

Luminosity Monitor Upgrade-HERA II

Challenge

- Rate of bremsstrahlung photons increase by factor of 5
- Significant increase of synchrotron radiation hitting luminosity monitor
  - power in photon detector 400 → 1800 W
  - critical energy 35 → 150 keV
- Photon calorimeter would be damaged in a few months, expected dose O(Trad/year), need thicker filter in front.
- Somewhat lower acceptance due to larger beam divergence

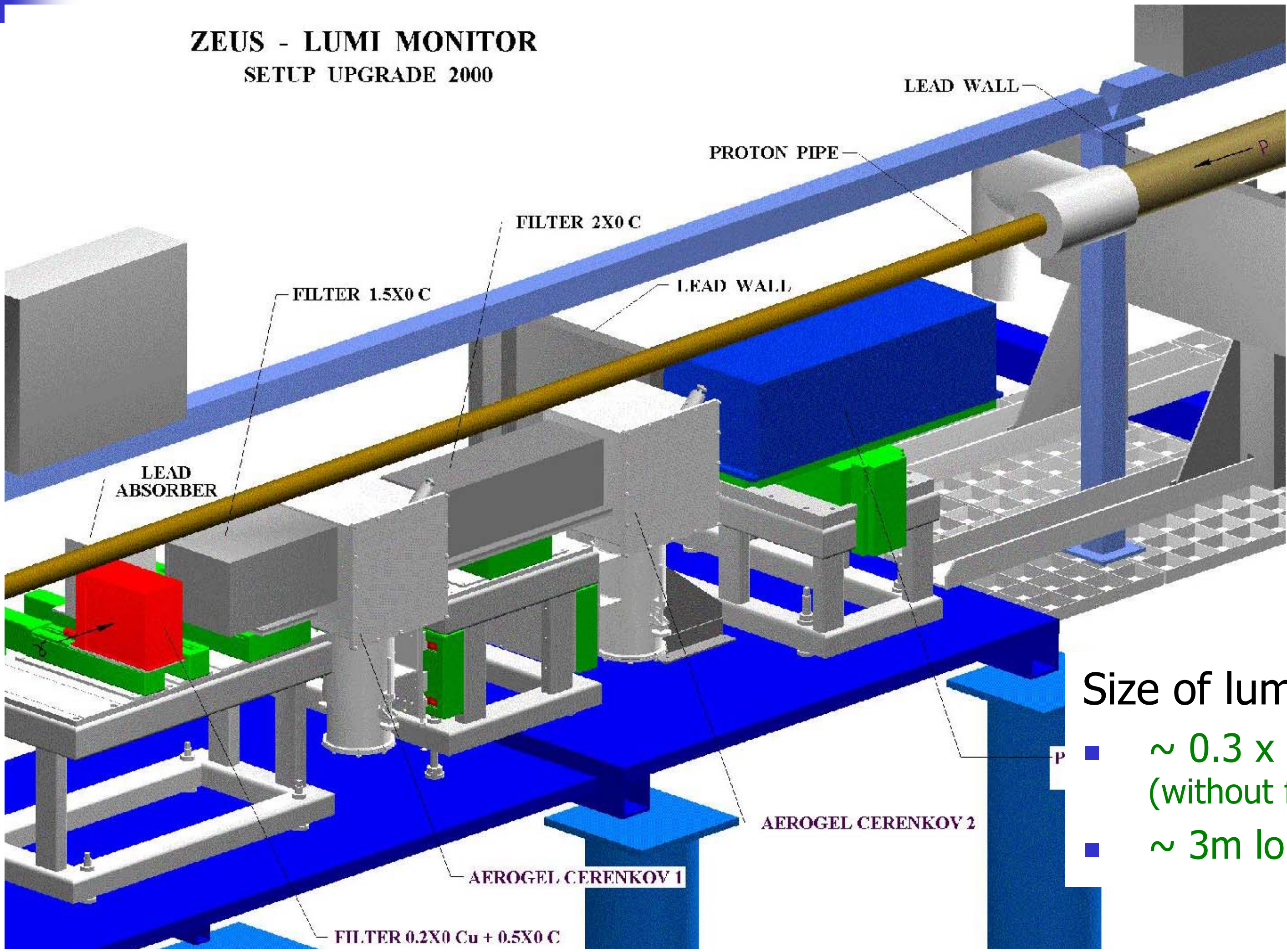
Upgrade (ZEUS)

- Build radiation hard calorimeter with increased filter thickness (4 X_0)
- Active filter (correct for energy loss in filter)
- Electron - positron pair spectrometer
- Goal 1% luminosity measurement

Upgrade (H1)

- Build radiation hard quarz fiber Cherenkov calorimeter (not sensitive to synchrotron radiation)

Luminosity Monitor Upgrade-HERA II



Size of lumi monitor

- ~ 0.3 x 0.3 x 1 m (without filter)
- ~ 3m long with filters

Luminosity Measurement HERA II

Experience

- Luminosity measurement quite challenging
- Acceptance determination more difficult than expected
- Reduced acceptance due to larger beam divergence
- Photon CAL:
  - Cherenkov detector not really used. Position dependence. Still synchrotron radiation in first detector
  - Uncertainties in energy scale (small non-linearities)
- Spectrometer
  - Did suffer from radiation damage (back-scattered S.R.)
  - Some hardware instabilities
- 6m tagger
  - Suffered from radiation damage

Systematic error presently 2.5%. Progress towards 2%

Two independent detectors/methods very useful.

Lumi Monitor Acceptance

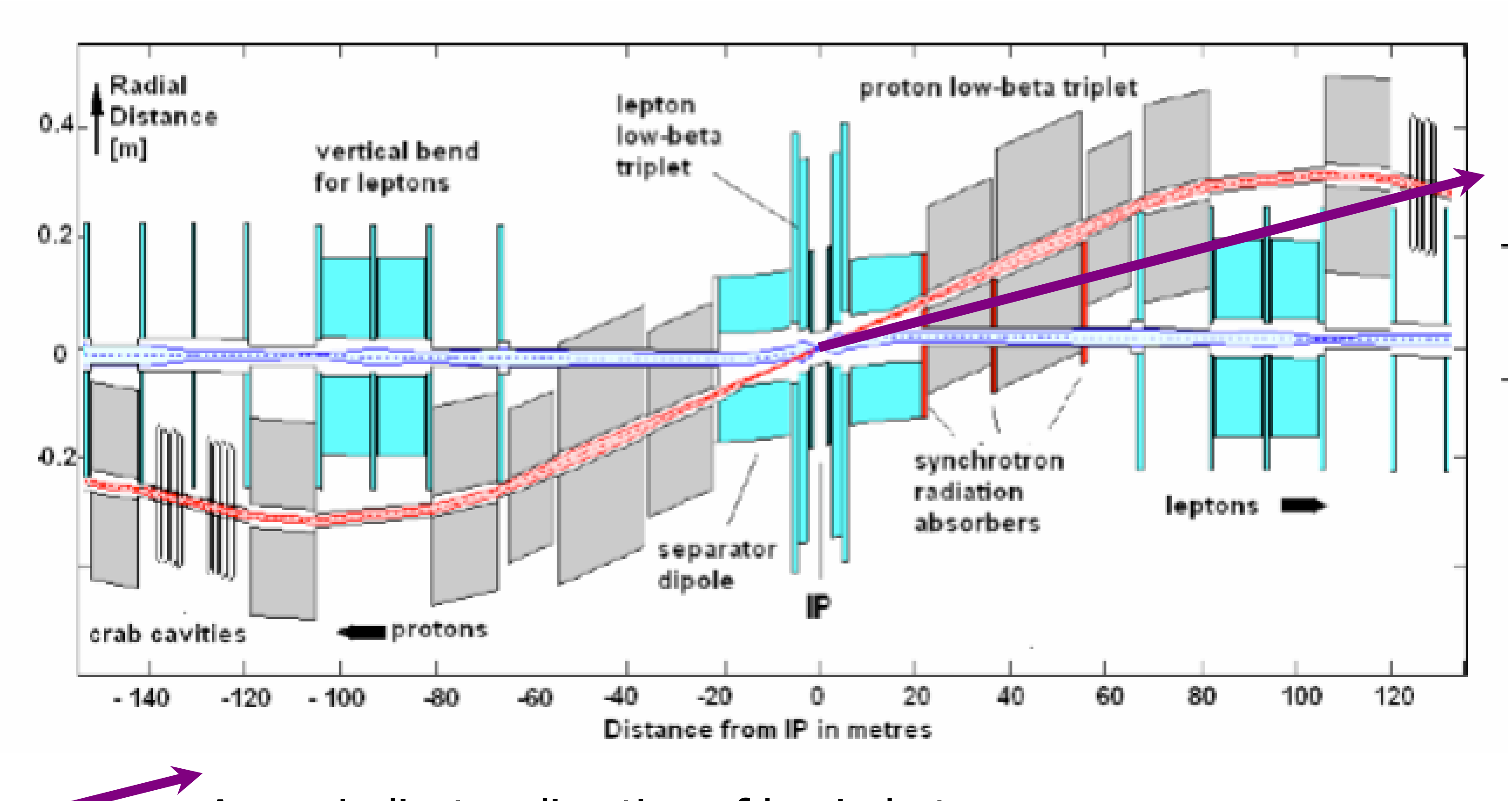
- Width of Bethe Heitler photons similar to electron beam divergence
- Acceptance at HERA II $\pm 3\sigma$.
  - At bit too tight. Should be larger.

	horizontal		vertical	
	LHeC	HERA II	LHeC	HERA II
beta (m)	0.127	0.63	0.071	0.26
emittance (nm)	7.6	22	3.8	3.96
beam size (mm)	0.031	0.118	0.016	0.032
divergence (mrad)	0.245	0.187	0.231	0.123
photon width (mm) at 92m	22.5	17.2	21.3	11.4
photon width (mm) at 85m	20.8		19.7	
+-3 sigma (mm) at 21.5m	32		30	
+-3 sigma (mm) at 85m	125		118	

LHeC Luminosity Measurement

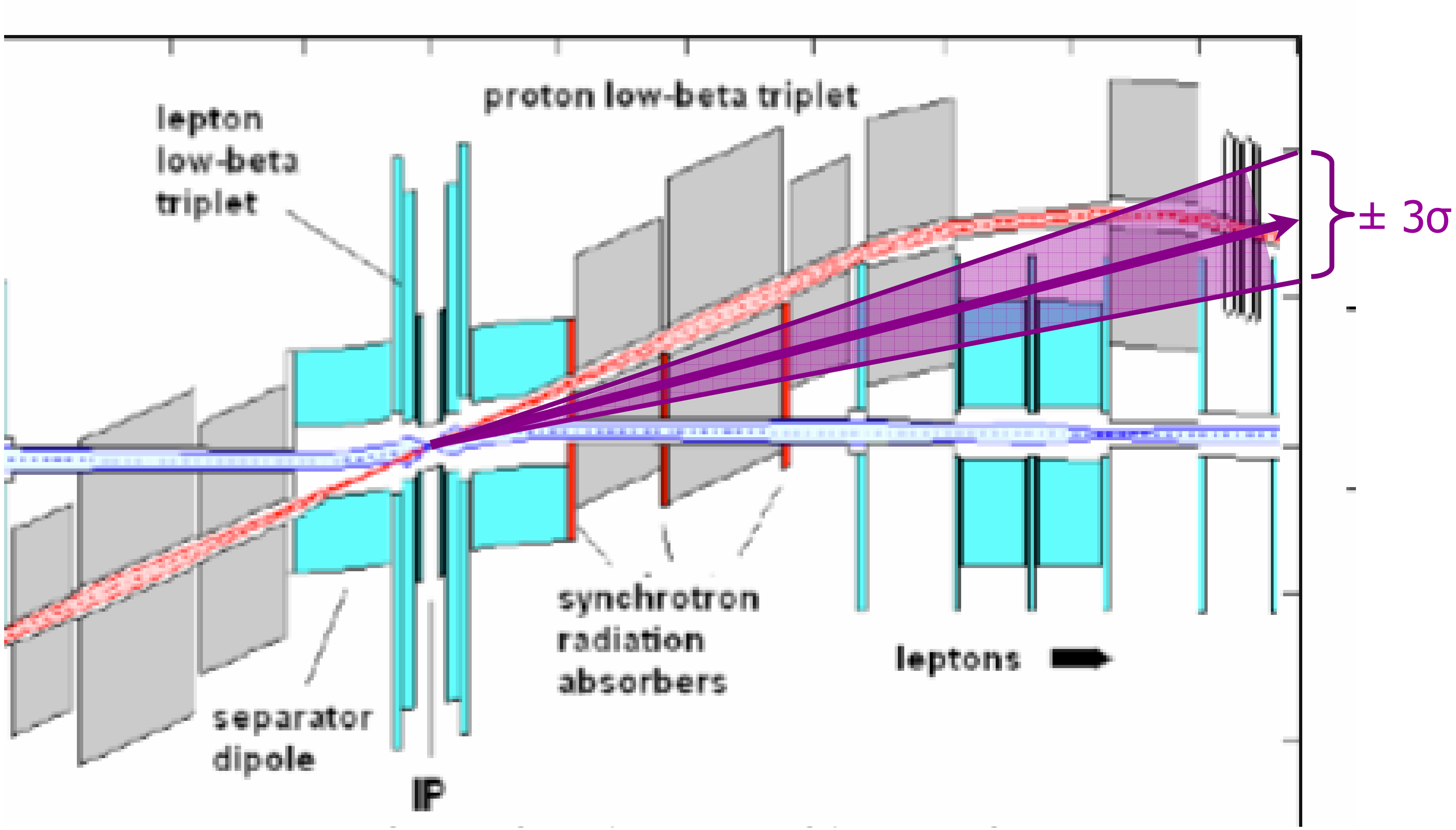
- Group at DESY started looking into luminosity measurement at LHeC using Bethe Heitler process, similar to HERA (V. Andreev, N. Gogitidze, S.Levonian Y. Soloview, U.S.)
- So far, luminosity monitor not implemented in IR design (RR option).
- Bethe Heitler photons would “go through” superconducting proton magnets. Disadvantage of crossing angle

Present LHeC RR IR Layout



Arrow indicates direction of lumi photons
Photons would "go through" superconducting proton magnet

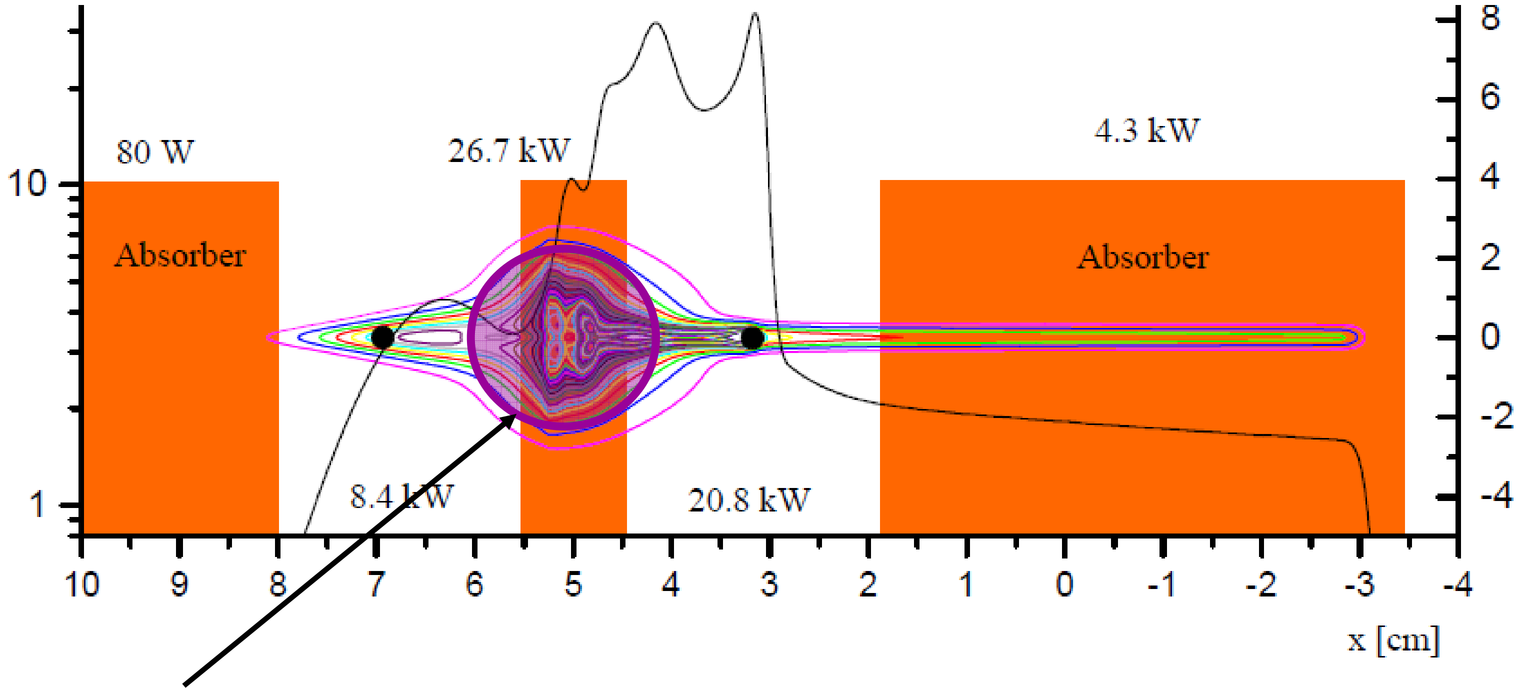
Present LHeC RR IR Layout



Acceptance – Synchrotron Radiation

2D distribution of synchrotron radiation (B.Nagorny)

power (kW/cm²)



± 3 σ contour of Bethe Heitler photons at absorber 21.2m from IP

Synchrotron radiation power about 30kW

Conclusions

- Present IR design not yet compatible with luminosity monitor
- Crossing design more difficult for integration of lumi monitor
- Large synchrotron radiation power
- Holes in magnets ????

- Luminosity measurement will be difficult due to large rate (pile-up) and potentially large synchrotron radiation power