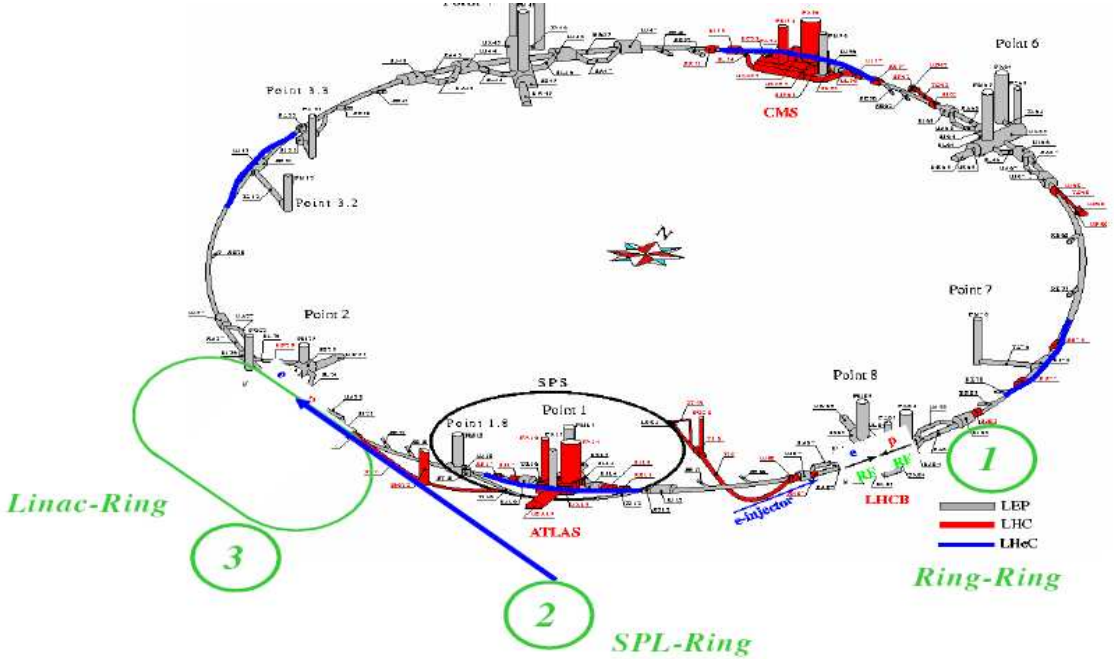
Luminosity Measurement at the LHeC

S. Levonian, DESY

- Mission
- Suitable processes
- Challenges
- Possible options
- Conclusions



Mission

- optimisation and tuning of ep-collisions

  $dL_{stat} = 1\%/sec$, overall scale $\sim 5\%$ is Ok $\Rightarrow$ 20 kHz

- mid-term variations of instantanious L

  $dL_{stat} = 1\%$ per run (10 min - few hours) $\Rightarrow$ 20 Hz

- absolute integrated $\mathcal{L}$ for physics normalization

  $dL_{tot} = 1 - 2\%$ per sample (week-month) $\Rightarrow$ 0.02 Hz

Mission

$$L_{\rm LHeC}(ep) = 10^{31} - 10^{33}\ {\rm cm^{-2}s^{-1}} \quad \Rightarrow \quad \sigma_{\rm vis}^{\rm lumi}$$

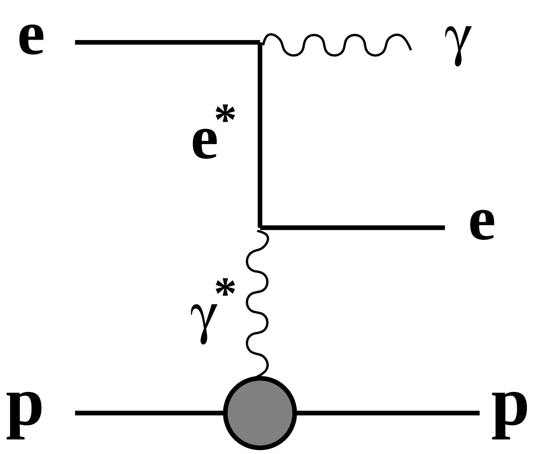
- optimisation and tuning of ep-collisions
  $dL_{stat} = 1\%/sec$, overall scale $\sim 5\%$ is Ok $\Rightarrow$ 20 kHz $> (0.02 - 2)$ mb

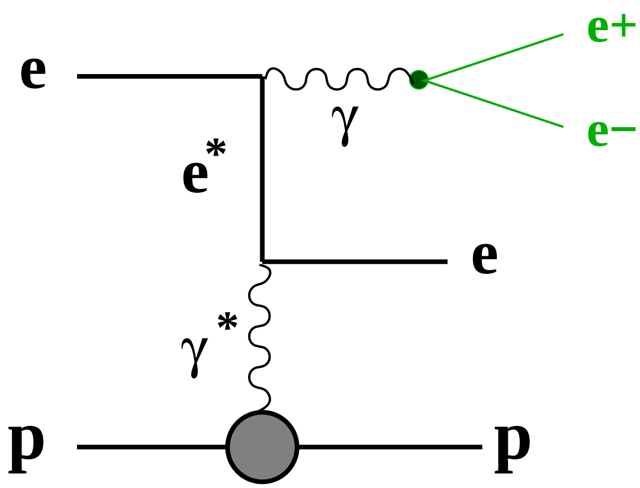
- mid-term variations of instantanious L
  $dL_{stat} = 1\%$ per run (10 min - few hours) $\Rightarrow$ 20 Hz $> (0.02 - 2)$ μb

- absolute integrated $\mathcal{L}$ for physics normalization
  $dL_{tot} = 1 - 2\%$ per sample (week-month) $\Rightarrow$ 0.02 Hz $> (0.02 - 2)$ nb

All cross sections in this talk are estimated for the case
70×7000 GeV

Processes





B-H process: $\sigma(E > 8) = 112$mb

(poles in both e^* and γ^* propagators)

B-H with "internal conversion"

$\sigma \simeq 1/200\sigma_{BH}$

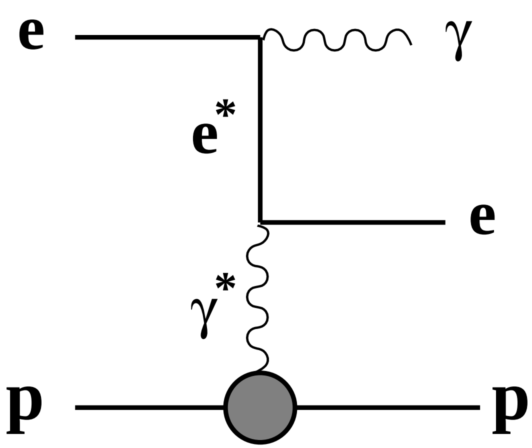
QED Compton: $\sigma_{\rm el}(\theta < 179^o) = 6$nb

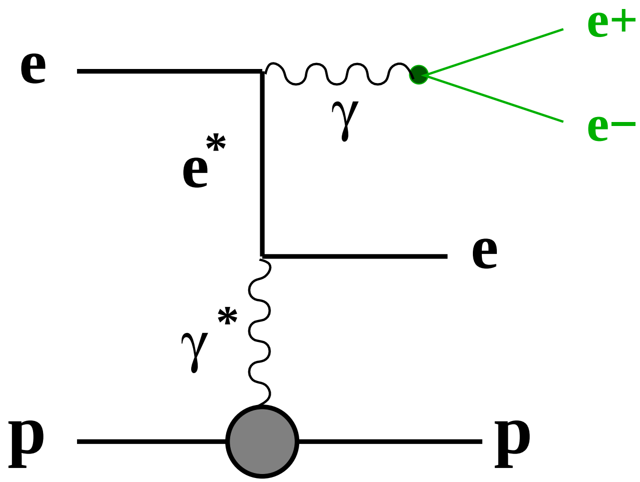
(poles in γ^* propagator, but large e^* mass)

F2 (NC DIS): $\sigma(Q^2 > 10) = 300$nb

$\sigma(Q^2 > 100) = 25$nb

Processess





Dedicated (tunnel) detectors

B-H process: $\sigma(E > 8) = 112$mb

(poles in both e^* and γ^* propagators)

B-H with "internal conversion"

$\sigma \simeq 1/200\sigma_{BH}$

Main detector

QED Compton: $\sigma_{\mathrm{el}}(\theta < 179^o) = 6$nb

(poles in γ^* propagator, but large e^* mass)

F2 (NC DIS): $\sigma(Q^2 > 10) = 300$nb

$\sigma(Q^2 > 100) = 25$nb

Detector options

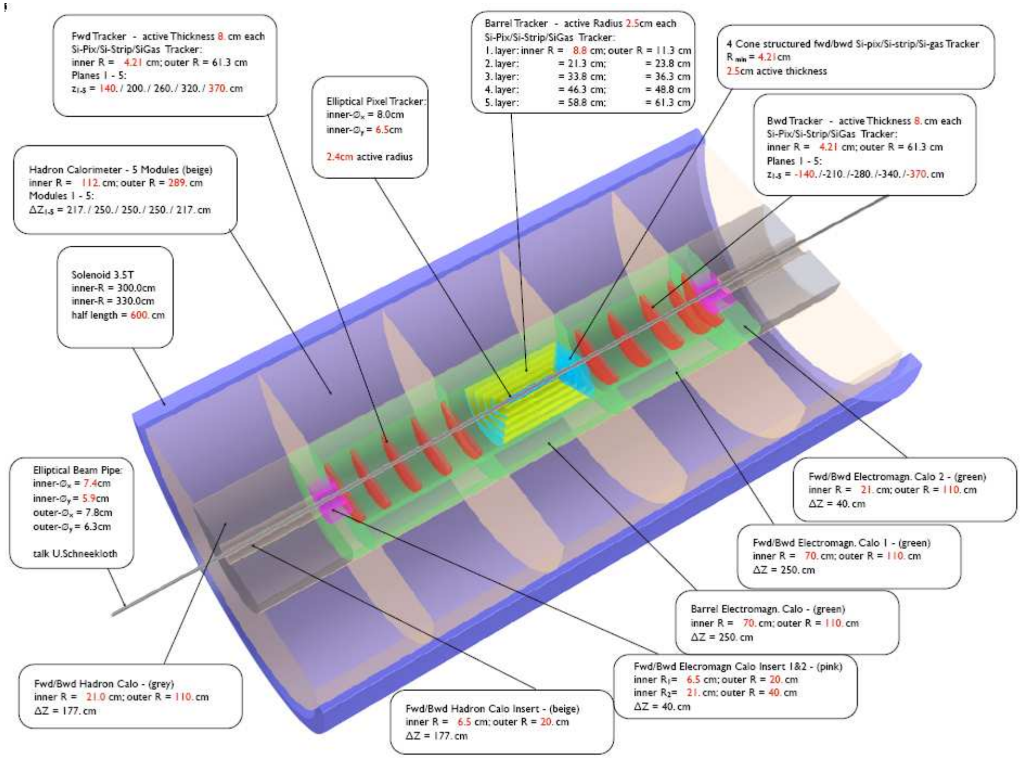
Two setups for Main Detector (low Q^2 vs high Q^2)

Detector options

Two setups for Main Detector (low Q^2 vs high Q^2)

$1^o - 179^o$ acceptance (9 units in η)

at $L = 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$



Low Q^2

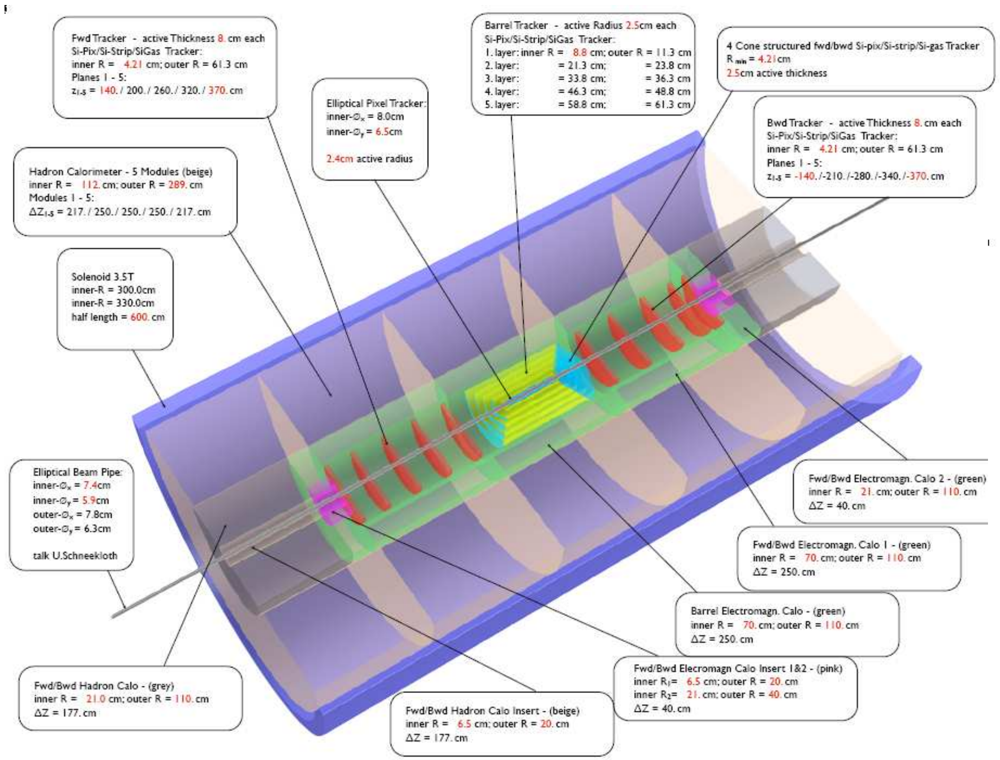
Detector options

Two setups for Main Detector (low Q^2 vs high Q^2)

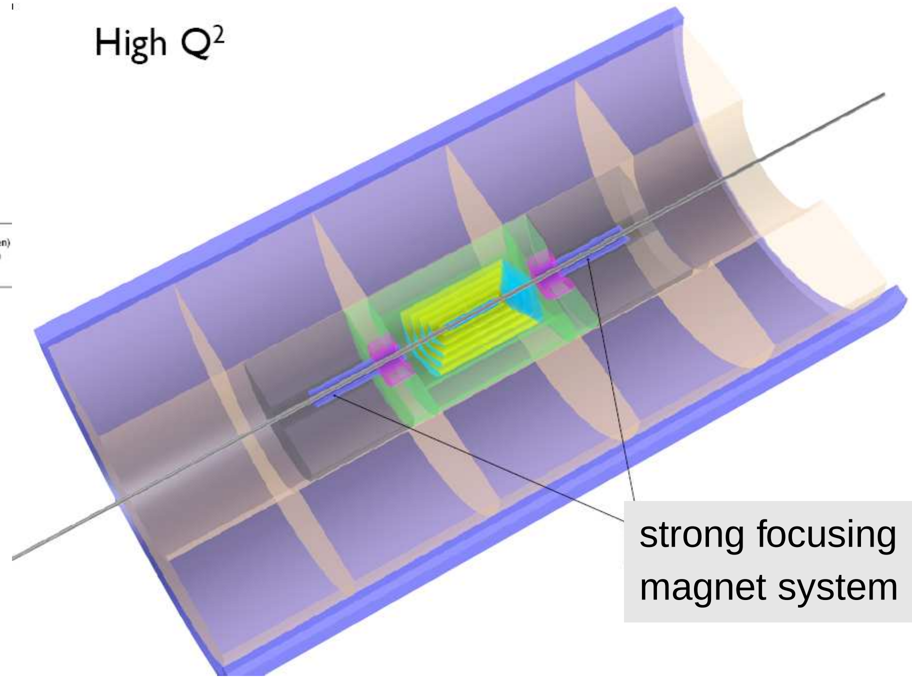
$1^o - 179^o$ acceptance (9 units in η) at $L = 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

$10^o - 170^o$ acceptance (5 units in η) at $L = 10^{33}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

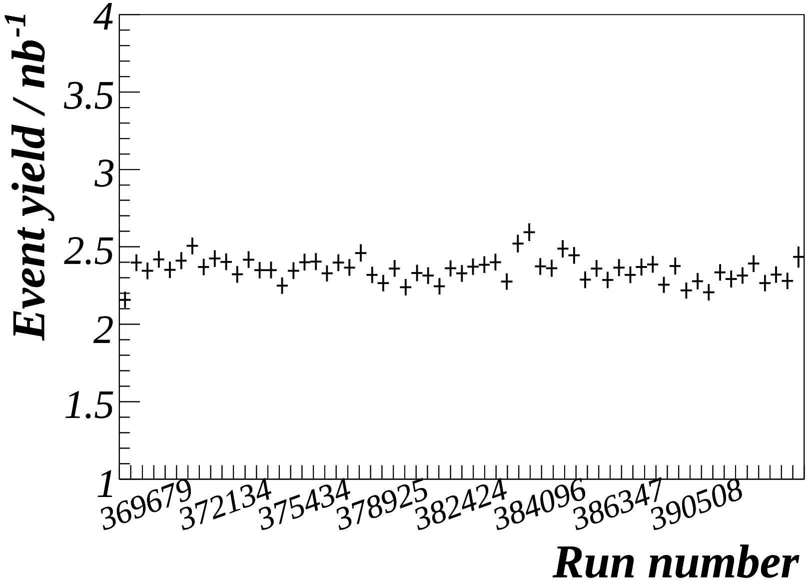
(courtesy P. Kostka)



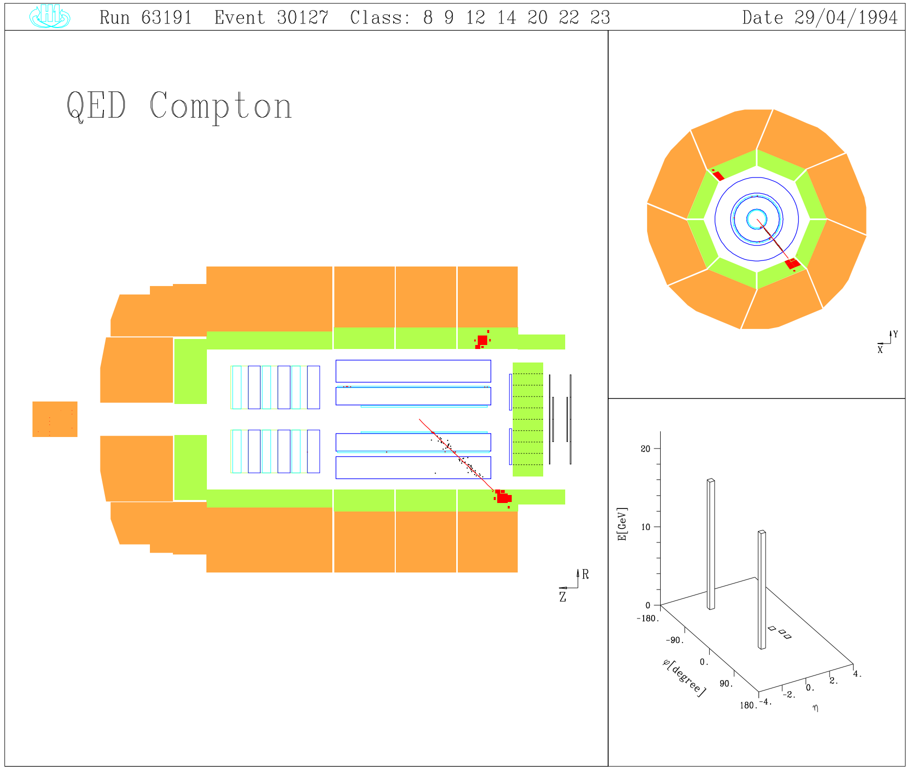
Low Q^2



Examles from HERA

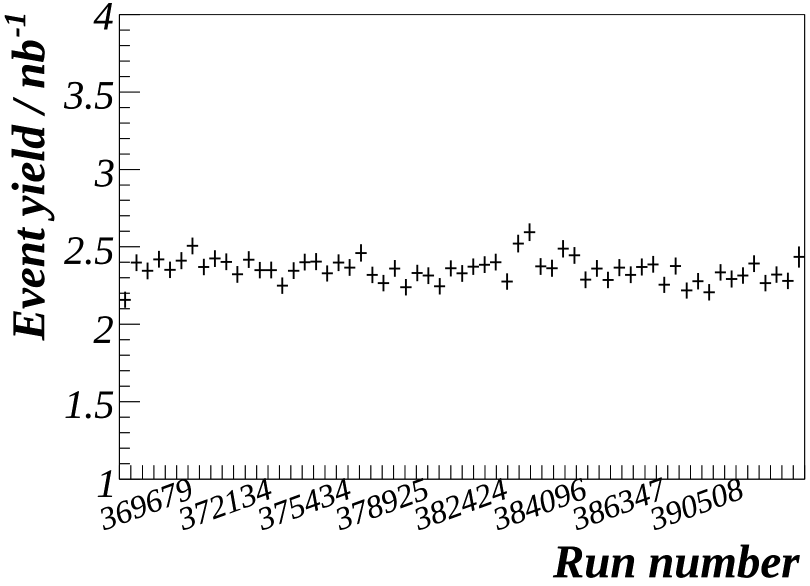


High Q^2 NC DIS

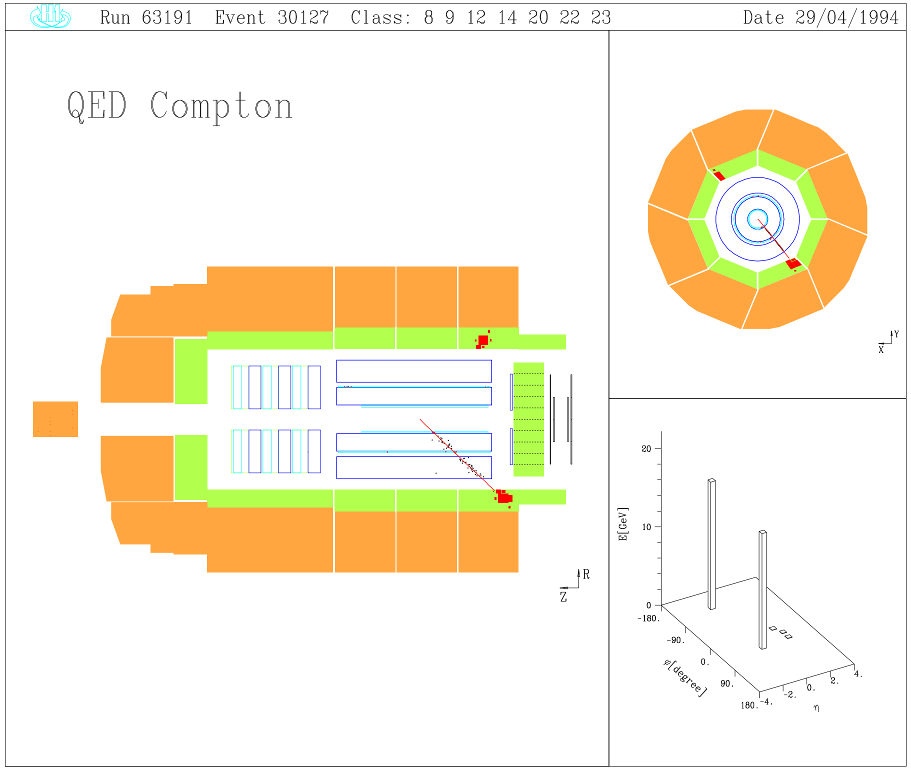


Precision: $1-2\%$ (F_2), 2% (QEDC)

Examles from HERA



High Q^2 NC DIS



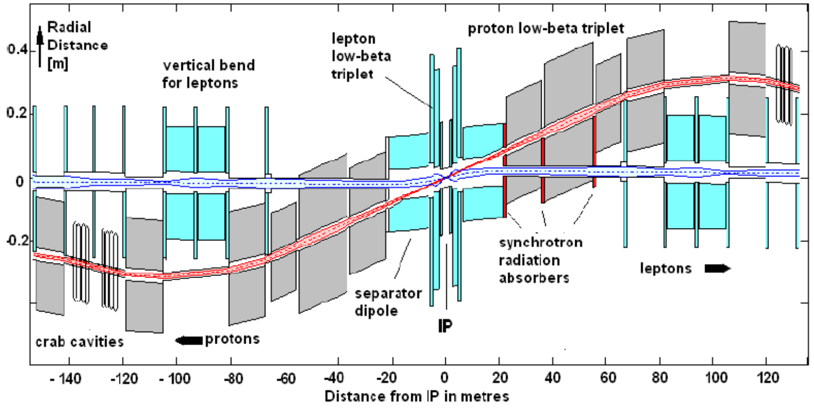
Precision: $1-2\%$ (F_2), 2% (QEDC)

LHeC MC study: (using H1 analysis strategy)

Generator:	DJANGOH ($0.05 < y < 0.6$)	COMPTON MC (elastic part)
high Q^2 setup:	$\sigma_{vis} \simeq$ 10 nb	$\sigma_{vis} \simeq 0.025$ nb
low Q^2 setup:	$\sigma_{vis} \simeq 150$ nb	$\sigma_{vis} \simeq 3$ nb
Rate (stat.err):	$1.5-10$ Hz ($\delta\mathcal{L} \simeq 1\%$/hour)	$0.025-0.03$ Hz ($\delta\mathcal{L} \simeq 0.5\%$/month)

Challenges in Linac-Ring and Ring-Ring options

IR Layout



- crossing angle at IP
- large SR flux

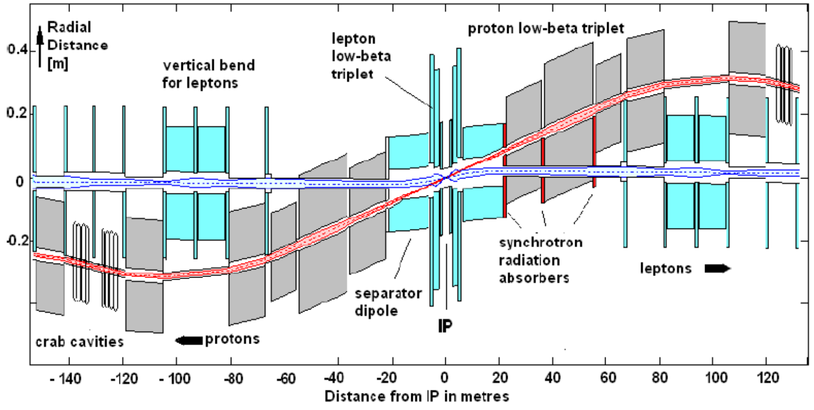
$\Rightarrow$ Challenge: difficult

to catch zero-angle γ's

RR scheme

Challenges in Linac-Ring and Ring-Ring options

IR Layout

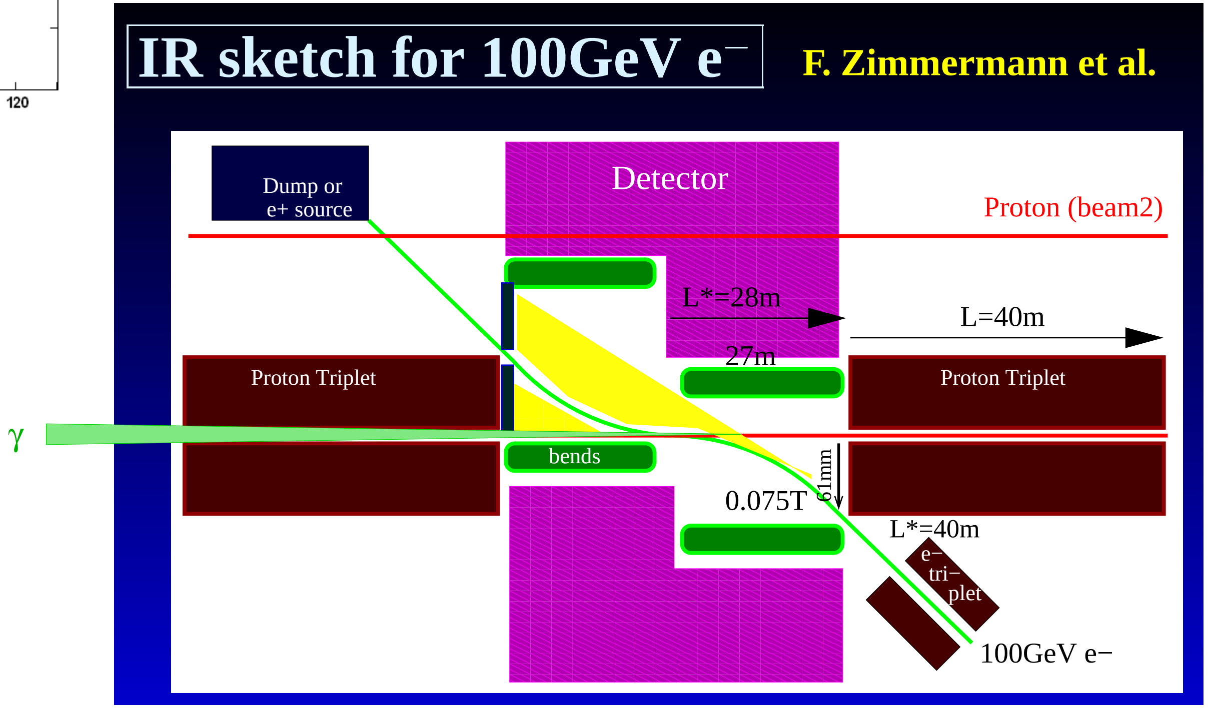


- crossing angle at IP
- large SR flux

⇒ Challenge: difficult to catch zero-angle γ's

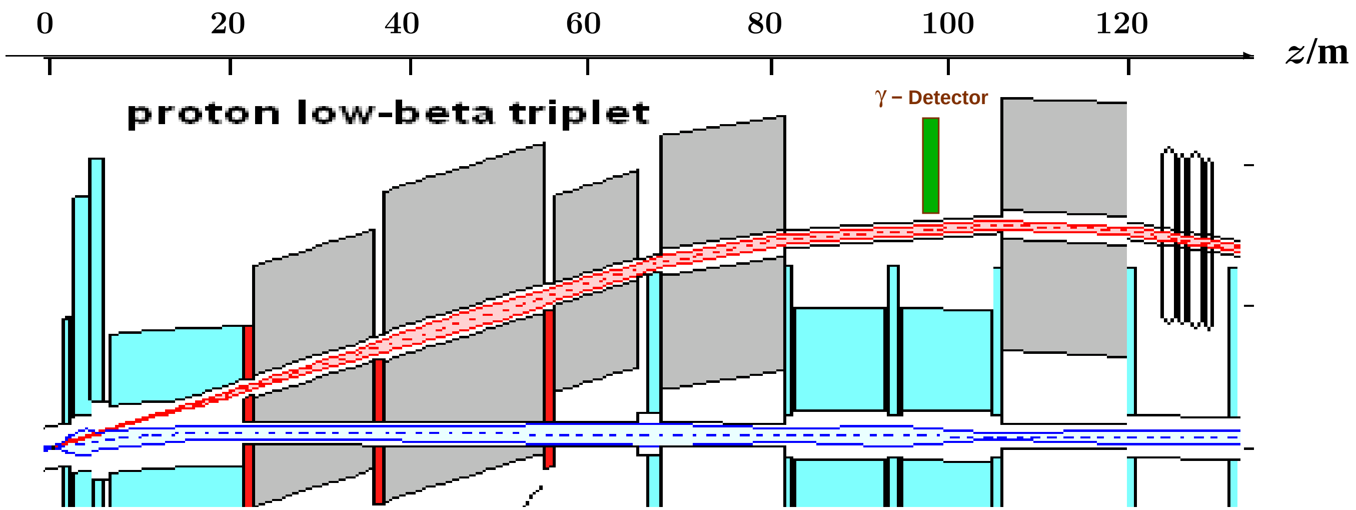
- Head-on collisions.
  Similar to HERA, γ's travel along the p-beam
- Lumi monitor located after proton dipole at $z = 100$m

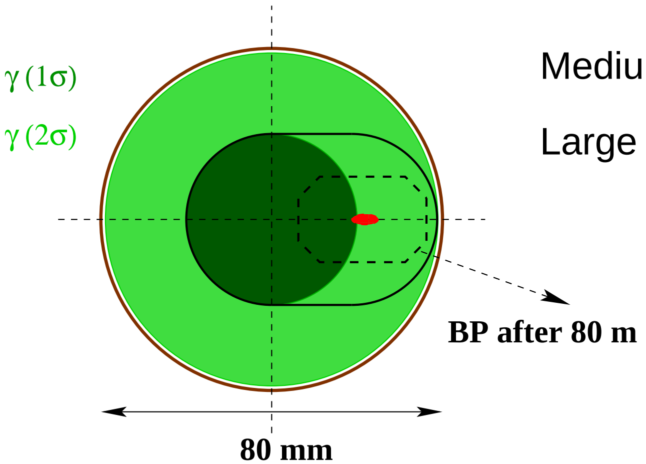
⇒ Challenge: large aperture required for proton magnets at $z = 60 - 80$m



RR scheme **LR scheme**

LR option



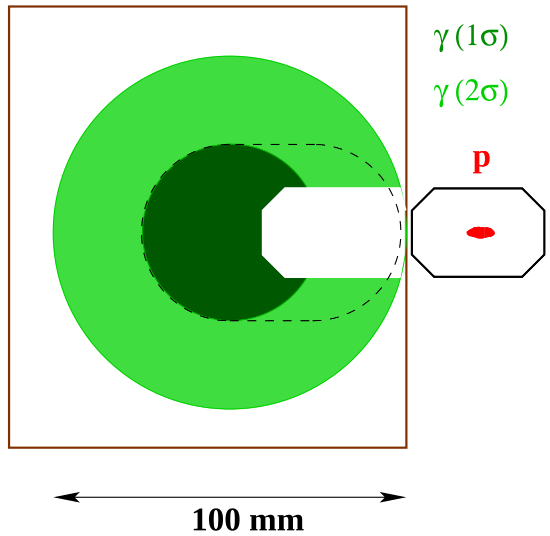


Beampipe at z=80m

Medium BP – $A_\gamma = 35 - 45\%$

Large BP – $A_\gamma = 70 - 80\%$

$$\delta L = 2.5 - 6.0\%$$



Photon Detector at z=100m

IP optics for RR option?

A

Crossing angle $= 2$ mr

Magnetic separation $= 2$ mr

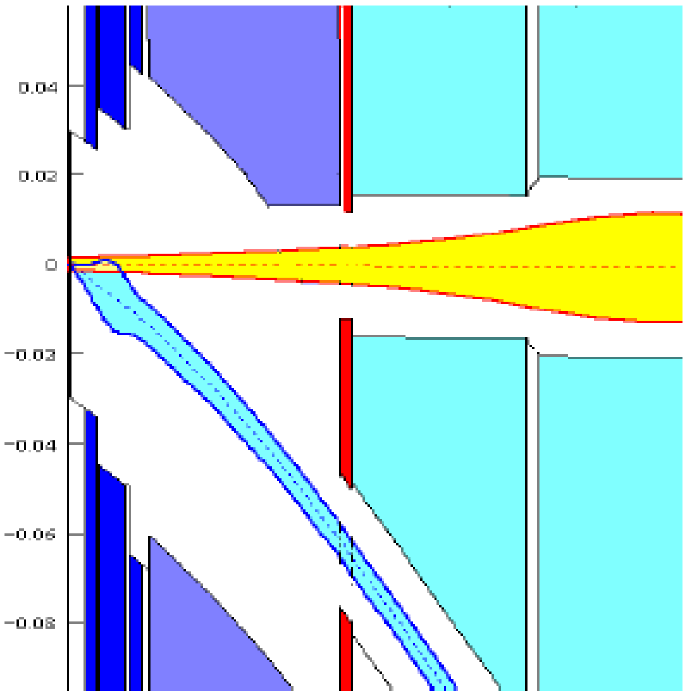
$\Rightarrow 60$ mm beam separation at 22m

B

Crossing angle $= 1.5$ mr

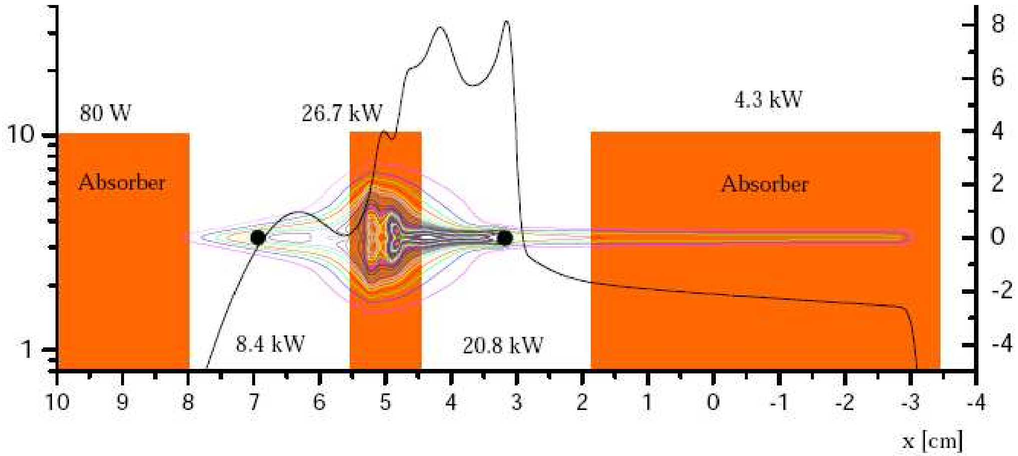
Magnetic separation $= 0.75$ mr

$\Rightarrow 40$ mm beam separation at 22m



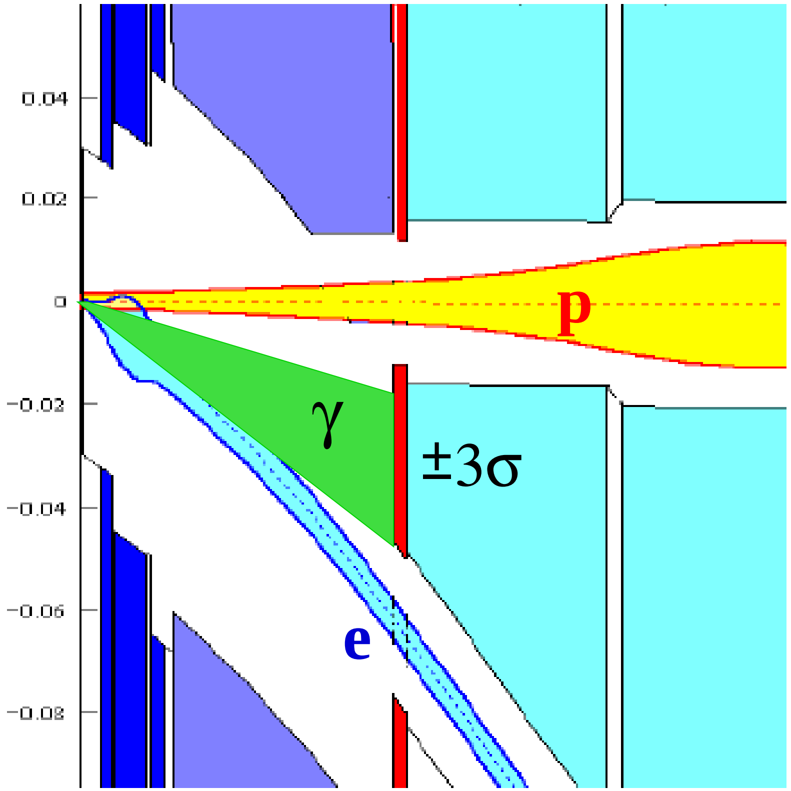
F. Willeke, May 2008

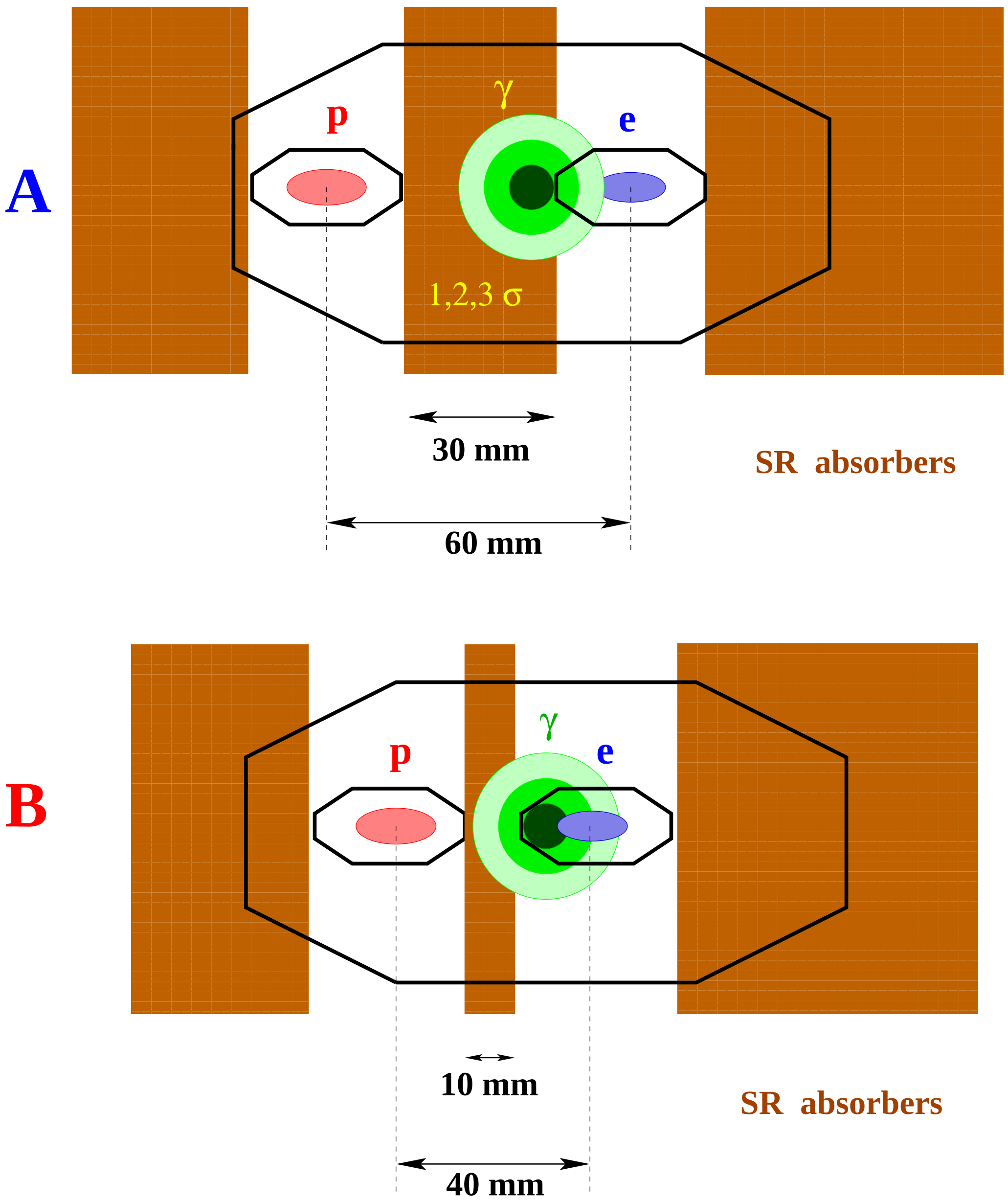
SR power profile at 22m



B. Holzer / B. Nagorny, Sept 2008

BH flux in SR absorber at 22m





- BH spot at the hottest place

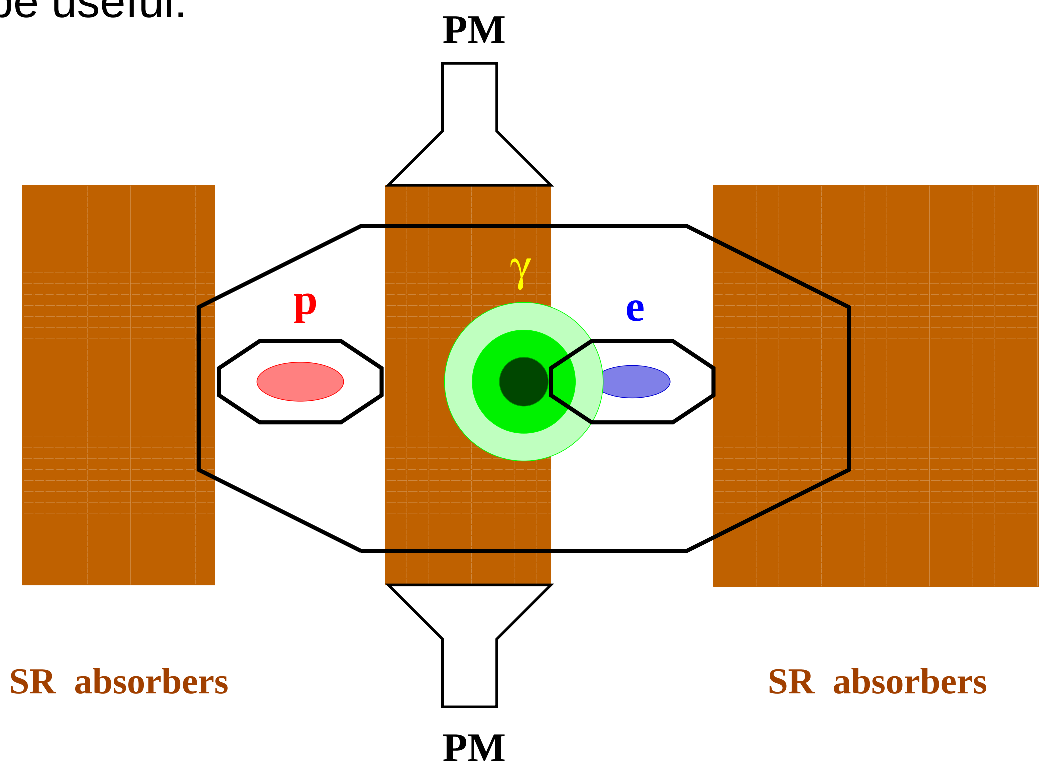
Active SR absorber?

BH-photon detector integrated into SR absorber

- Cooling system with $10-15$ cm long water bath acting as Čerenkov radiator for BH γ's
- Radiation hard, (almost) insensitive to SR
- Optimisation of crossing angle might be useful:

  Version **A:** acceptance $\simeq (84 \pm 2)\%$

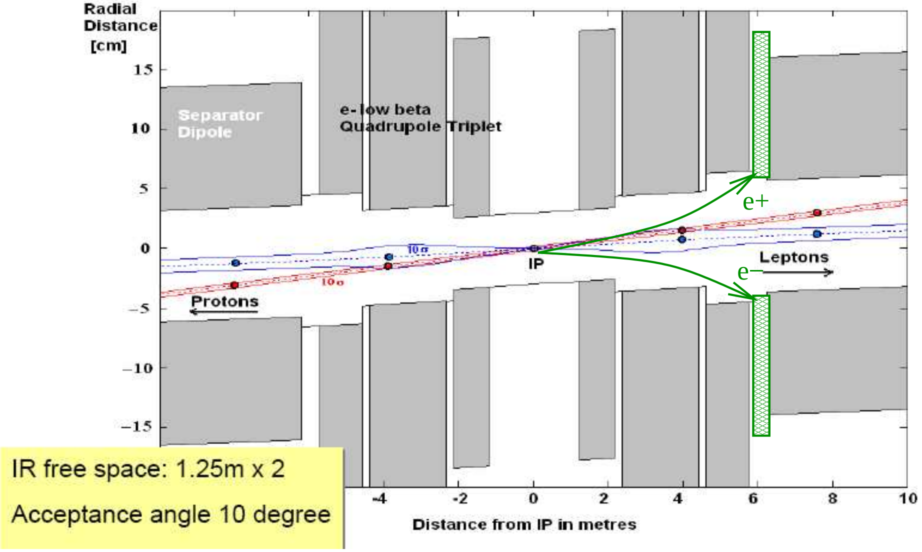
  Version **B:** acceptance $\simeq (10 \pm 1)\%$
- Exact BH counter design and R/O still to be worked out
- Accurate acceptance control requires precise beam tilt monitoring (10-15% of the x-angle)

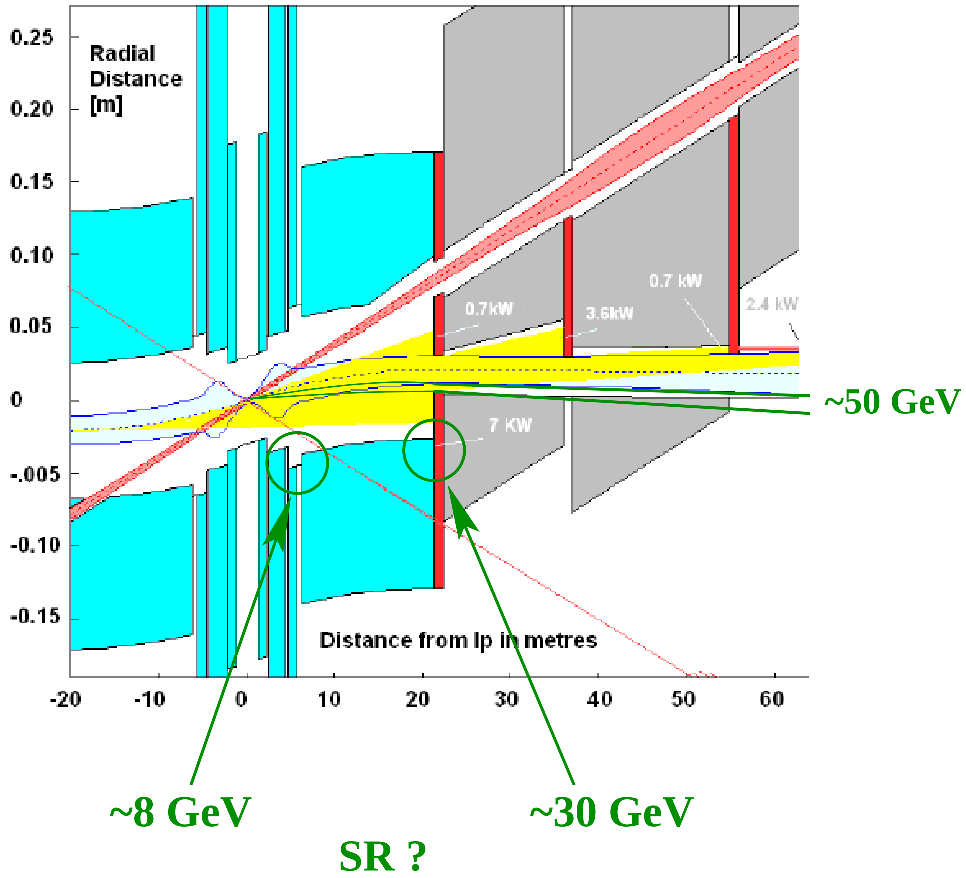


$$\delta L = 3 - 10\%$$

Options for Electron Taggers

IR Layout

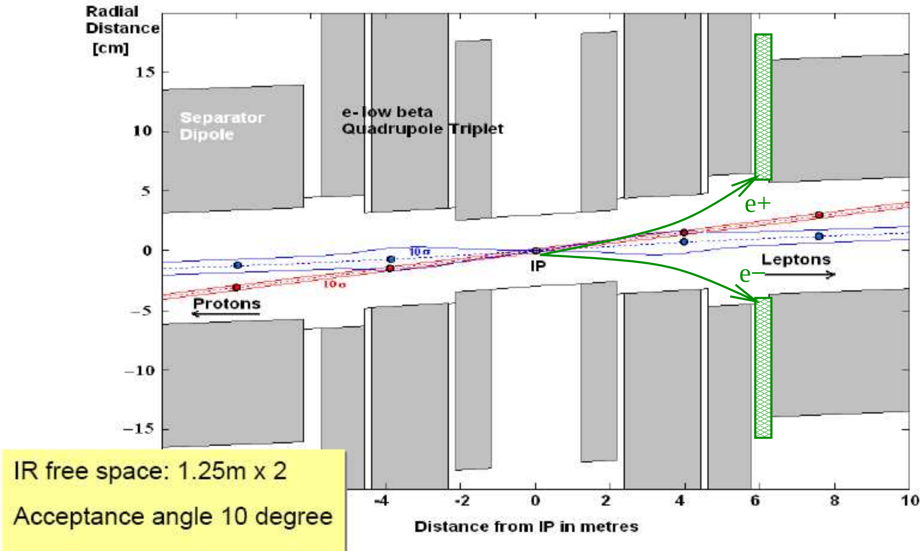




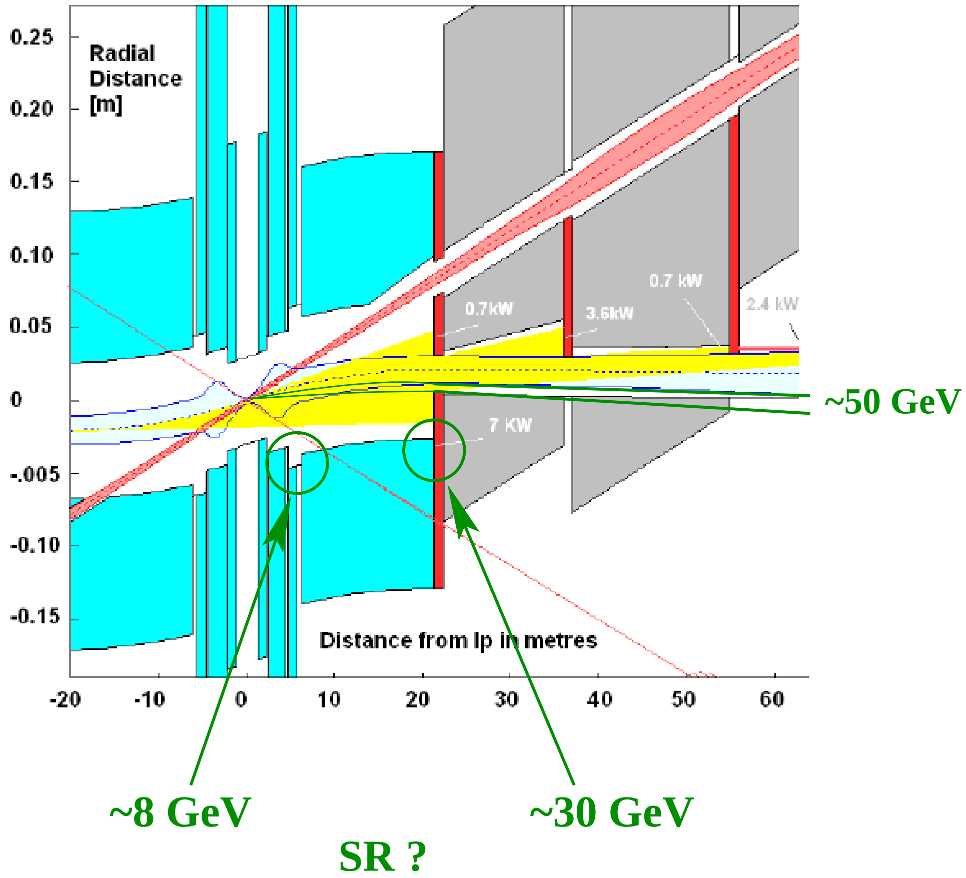
- ET-6m requires some dipole field ⇒ not possible for low luminosity setup
- An option: split separator dipole and position ET at $z = 13 - 14$m ?

Options for Electron Taggers

IR Layout

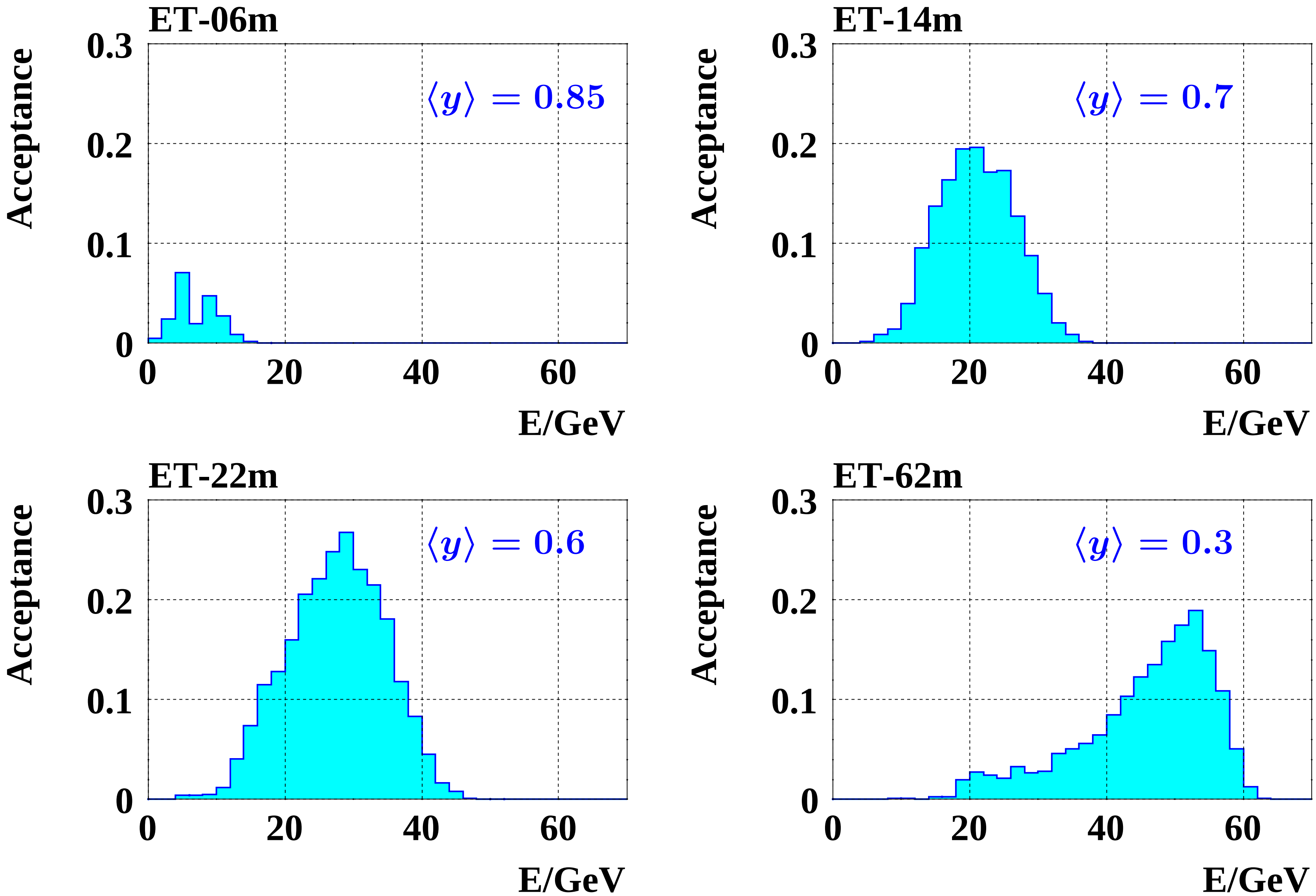


$\Rightarrow$ No acceptance for oppositely charged leptons (Internal Conversion process is not detectable) ☹

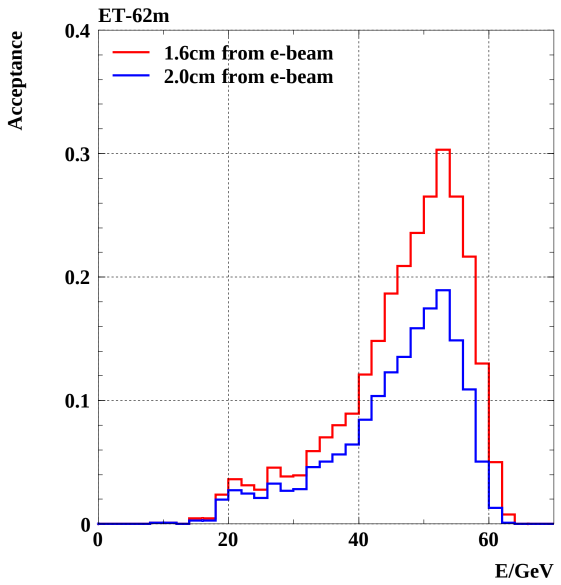


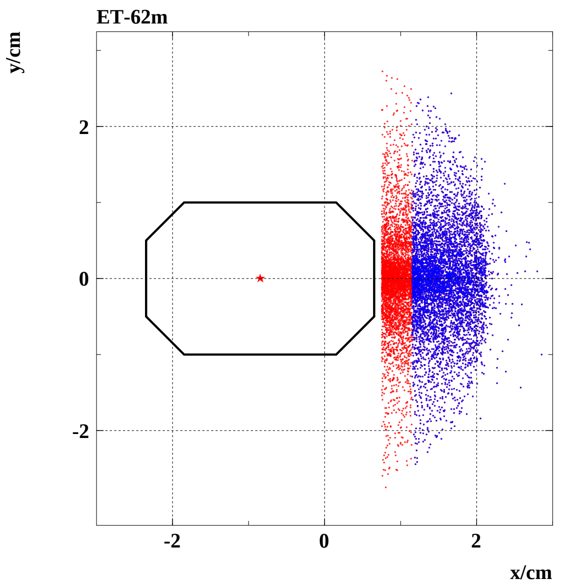
- ET-6m requires some dipole field $\Rightarrow$ not possible for low luminosity setup
- An option: split separator dipole and position ET at $z = 13 - 14$m ?

e-Tagger Acceptances at different positions



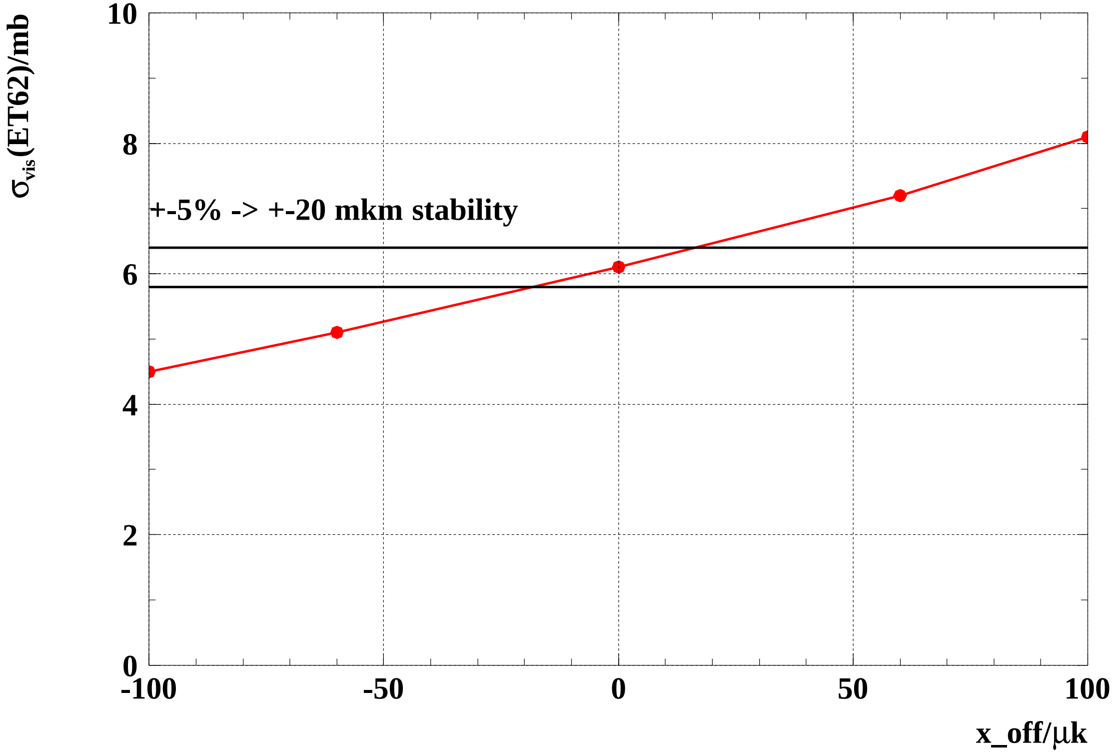
ET-62m Acceptance variations





Acceptance control requirements

- ET position wrt e-beam: $< \pm 0.5$mm
- e-orbit offset at IP $< \pm 20\ \mu$k



Further remarks about Electron Taggers

- $e-$taggers are also useful to enhance physics programme (tagged γp). Note however, that triggering might be problematic due to inefficient γ-veto

- ET-6m has small acceptance, but can access largest $W_{\gamma p}$
  ET-14m, ET-22m may suffer from SR,
  ET-62m is most promissing (good acceptanse, small SR, available space)

- Energy calibration might be a problem (leakage, abs.scale)

- Reliable geometrical acceptance determination (to $3-5\%$ precision) requires good knowledge/control of beam optics at IP (tilt, offset of e-trajectory)

Can one rely on Water Counter and e-taggers for online lumi measurement?
$\Rightarrow$ Look at HERA experience

Typical HERA Luminosity fill

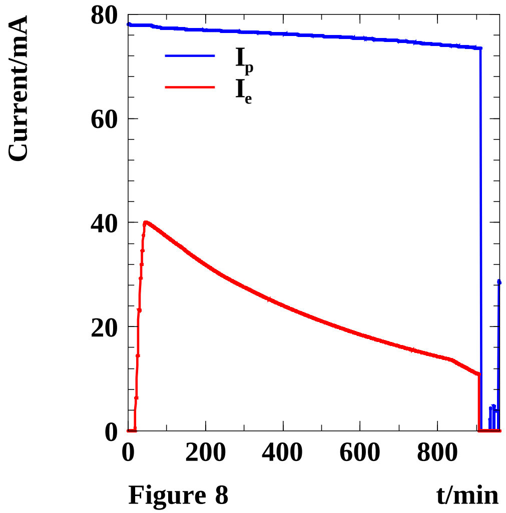


Figure 8

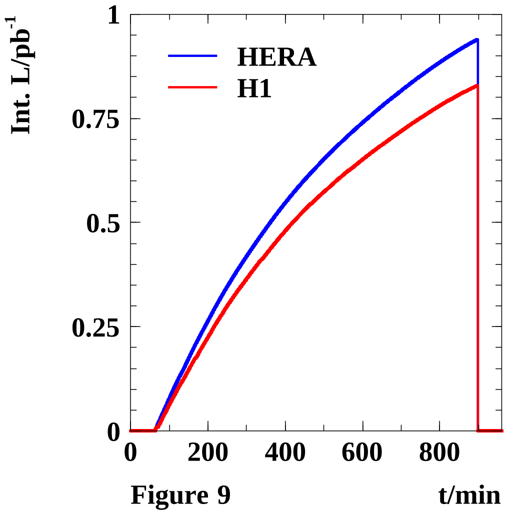


Figure 9

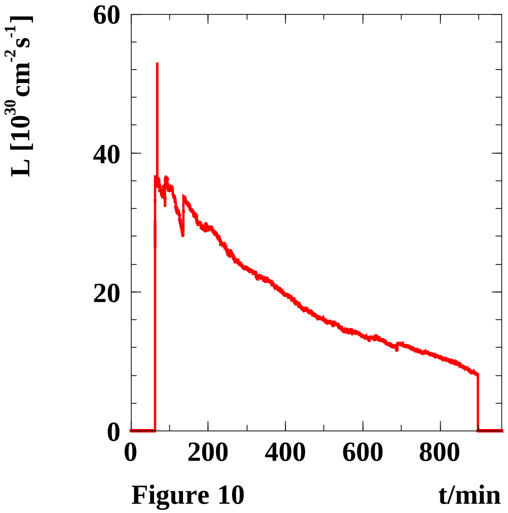
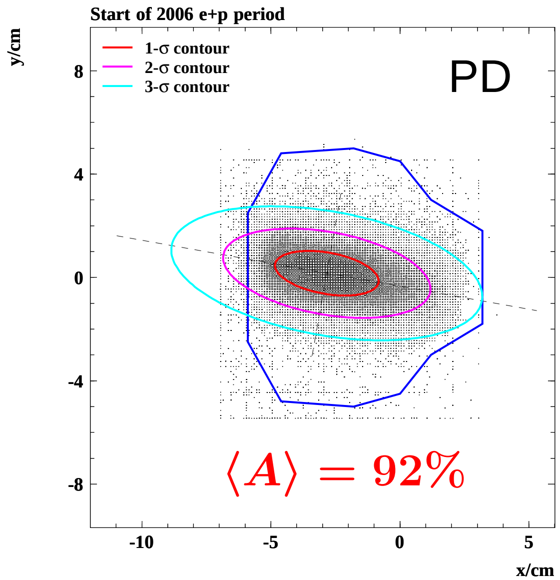
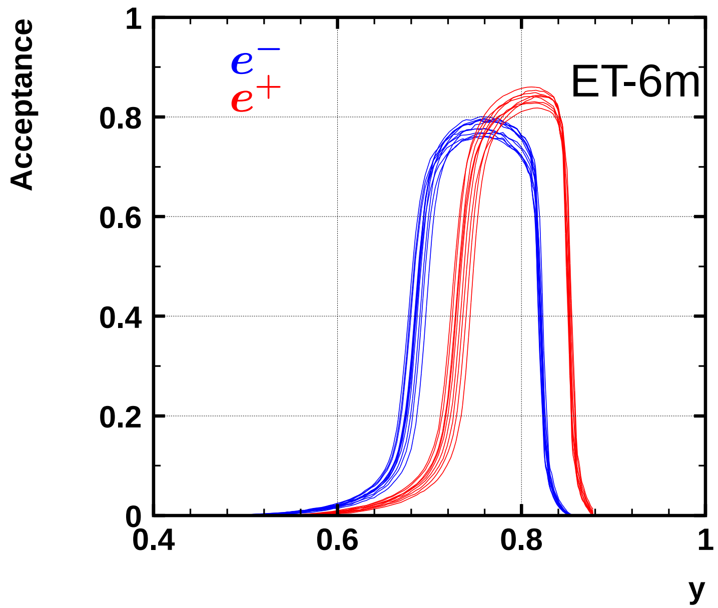


Figure 10





Rates at HERA (H1 Lumi system)

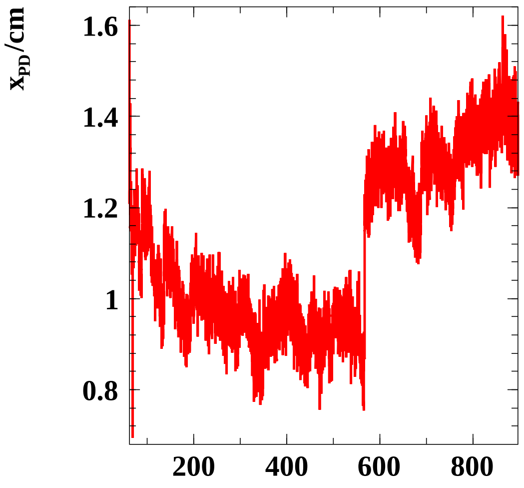


Figure 6

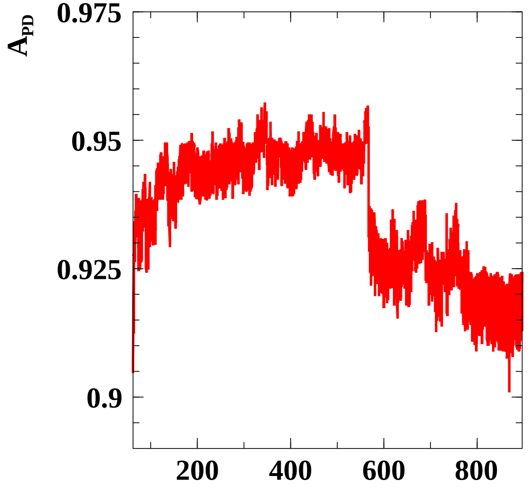


Figure 7

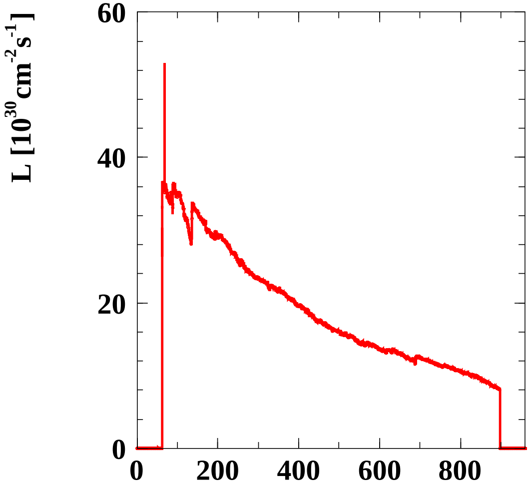


Figure 10

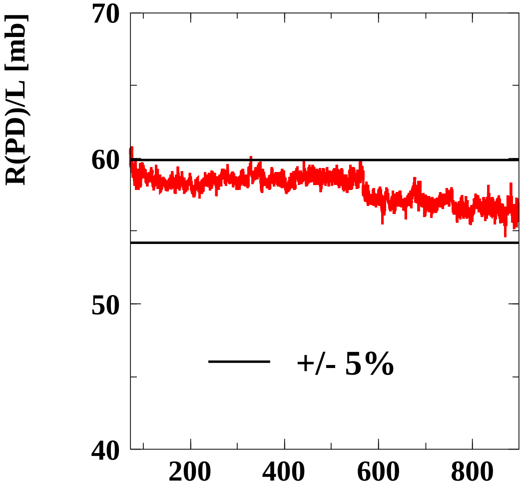


Figure 23

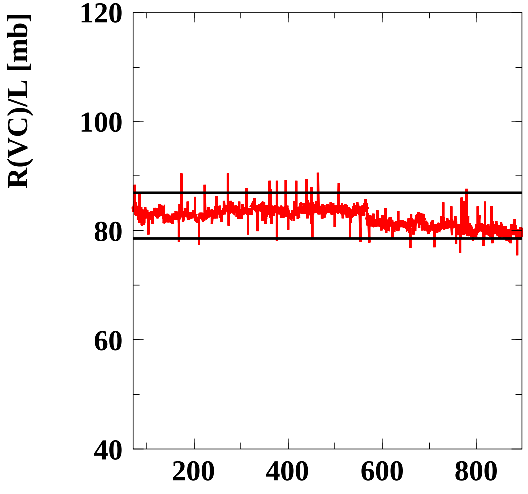


Figure 21

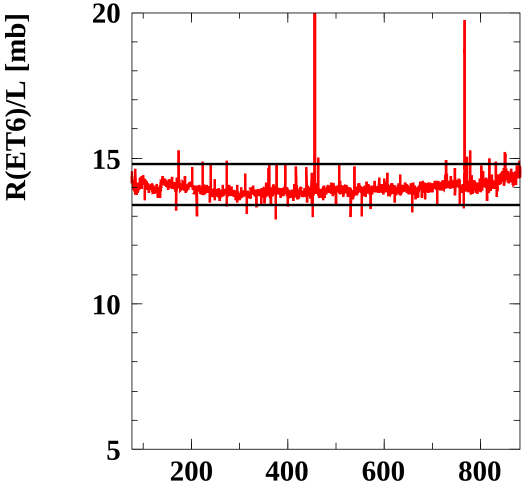


Figure 22

Dominant systematics

Method	Stat. error	Syst.error	Systematic error components			Application
BH (γ)	0.1%/sec	$3-10\%$	x-section	=	0.5%	Monitoring, tuning,
			acceptance, A	=	$10\%(1-A)$	Absolute L (?),
			E-scale, pileup	=	$0.5-3\%$	short term variations
BH (e)	$1-3\%$/sec	$5-6\%$	x-section	=	0.5%	Monitoring, tuning,
			acceptance, A	=	$4-5\%$	Relative L
			background	=	1%	
			E-scale	=	1%	
QEDC	$1-2\%$/week	$1.5-2\%$	x-section (el/inel)	=	1%	Absolute $\mathcal{L}$,
			acceptance	=	1%	Global normalisation
			event vertex eff.	=	1%	
			E-scale	=	0.3%	
F2	$0.5-1.5\%$/h	2.5%	x-section ($y<0.6$)	=	2%	Relative $\mathcal{L}$,
			acceptance	=	1%	mid. term variations
			event vertex eff.	=	1%	
			E-scale	=	0.3%	

Summary

- Luminosity measurement at the LHeC is a non-trivial task.
  HERA experience: surprises are possible $\Rightarrow$ prepare several scenarios

- Precise integrated $\mathcal{L}$ for physics is possible with main Detector (QEDC, F2)
  $\delta\mathcal{L} = 2\%$ is within reach

- Fast instantaneous L monitoring is challenging, but few options do exist
  - $\triangleright$ Photon Detector for LR option requires large p-beampipe at $z = 80$m
  - $\triangleright$ In case of RR option B-H photons can be detected using water Čerenkov counter integrated with SR absorber (this also requires relatively large crossing angle)
  - $\triangleright$ Electron tagger at 62 m is very promissing for both LR and RR schemes

- Good control of the e-beam optics at the IP is essential to monitor acceptances of the tunnel detectors at 5% level