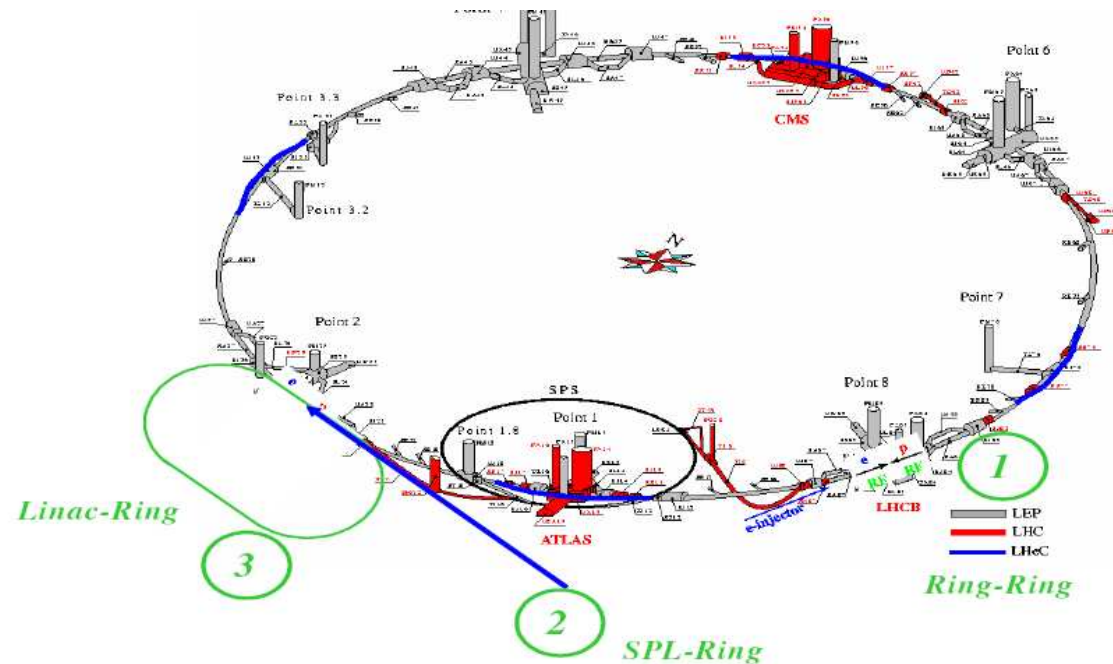




# Luminosity Measurement and $e$ -tagging at the LHeC

S. Levonian, DESY

- Brief preview
- Mission
- Challenges
- Possible options
- Conclusions



- This presentation is based upon my report on DIS-2010 with few updates:
  - ▷ some changes in optics at IP (crossing angle, etc.);  $E_e$  : 70  $\Rightarrow$  60 GeV
  - ▷ additional option of VLQ/BPC at  $z = 6\text{m}$  is considered ("QEDC tagger")
- Active SR absorber at 22m
  - ▷ good geometrical acceptance, up to 90% (for latest RR optics update)
  - ▷ increased dipole field at IP  $\Rightarrow$  bigger  $E_{critical} \Rightarrow$  bgr from SR tail to B-H photons ?
- Electron tagger(s)
  - ▷ detector's dipole field so far ignored; this will change acceptance somewhat (not critical)
  - ▷ ET at 62m looks most promising
  - ▷ application for  $\gamma p$  physics: triggering might be an issue (good  $\gamma_{BH}$  veto efficiency required)
- Realistic precision estimate:
  - ▷ fast monitoring:  $\delta\mathcal{L} \simeq 3 - 5\%$  seems to be within reach
  - ▷ absolute lumi for physics:  $\delta\mathcal{L} \simeq 2\%$ , could be achieved by utilizing QEDC
  - ▷ no proven solution for  $\delta\mathcal{L} = 1\%$  so far

- optimization and tuning of  $ep$ -collisions

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

- mid-term variations of instantaneous  $L$

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

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

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

$$L_{\text{LHeC}}(ep) = 10^{31} - 10^{33} \text{ cm}^{-2}\text{s}^{-1}$$



$$\sigma_{\text{vis}}^{\text{lumi}}$$

- optimization and tuning of  $ep$ -collisions

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

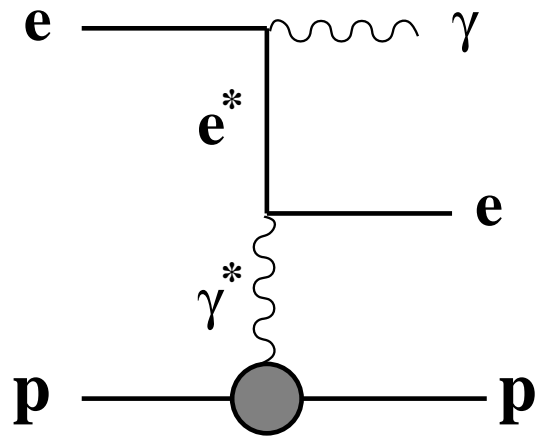
- mid-term variations of instantaneous  $L$

$$dL_{\text{stat}} = 1\% \text{ per run (10 min - few hours)} \Rightarrow 20 \text{ Hz} > (0.02 - 2) \mu\text{b}$$

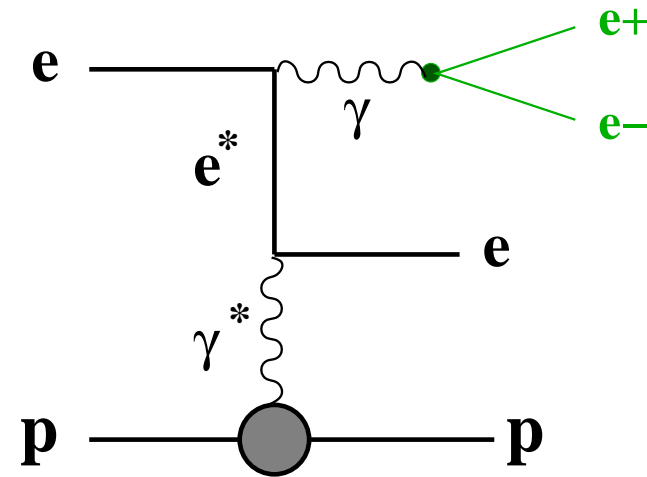
- absolute integrated  $\mathcal{L}$  for physics normalization

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

All cross sections in this talk are estimated for the case  
 $60 \times 7000 \text{ GeV}$



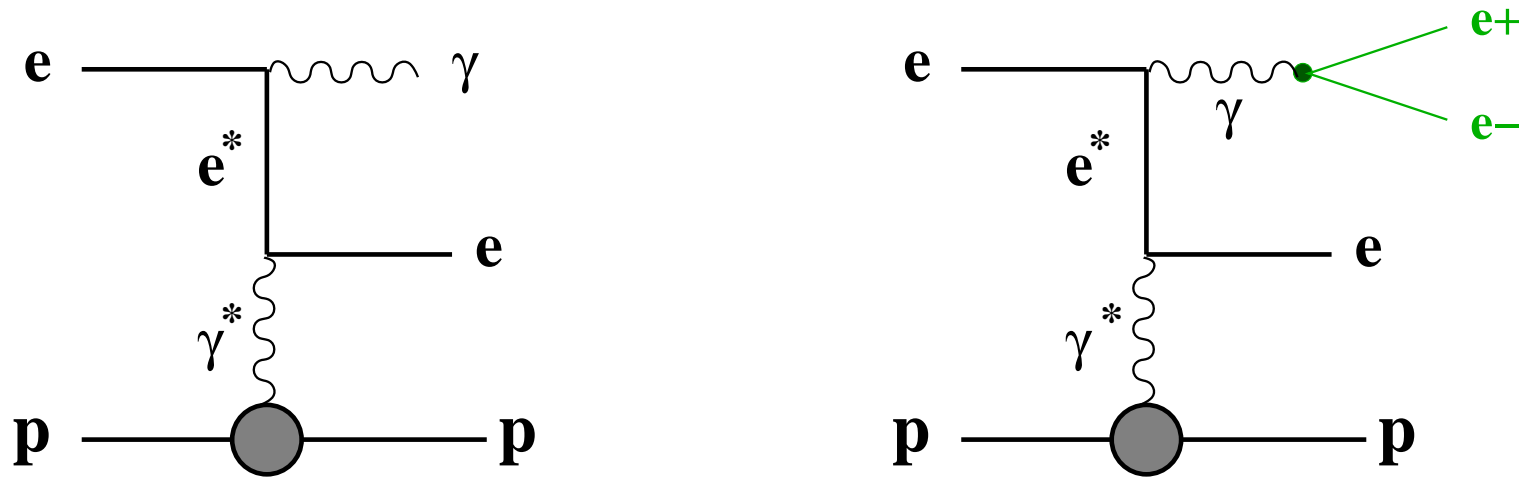
B-H process:  $\sigma(E > 8) = 102\text{mb}$   
 (poles in both  $e^*$  and  $\gamma^*$  propagators)



B-H with "internal conversion"  
 $\sigma \simeq 1/200\sigma_{BH}$

QED Compton:  $\sigma_{\text{el}}(\theta < 179^\circ) = 5\text{nb}$   
 (poles in  $\gamma^*$  propagator, but large  $e^*$  mass)

F2 (NC DIS):  $\sigma(Q^2 > 10) = 300\text{nb}$   
 $\sigma(Q^2 > 100) = 25\text{nb}$



Dedicated (tunnel) detectors ( $\theta_{\gamma,e} < 0.5\text{mrad}$ )

B-H process:  $\sigma(E > 8) = 102\text{mb}$   
(poles in both  $e^*$  and  $\gamma^*$  propagators)

B-H with "internal conversion"  
 $\sigma \simeq 1/200\sigma_{BH}$

Main detector

QED Compton:  $\sigma_{\text{el}}(\theta < 179^\circ) = 5\text{nb}$   
(poles in  $\gamma^*$  propagator, but large  $e^*$  mass)

F2 (NC DIS):  $\sigma(Q^2 > 10) = 300\text{nb}$   
 $\sigma(Q^2 > 100) = 25\text{nb}$

# Detector options

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

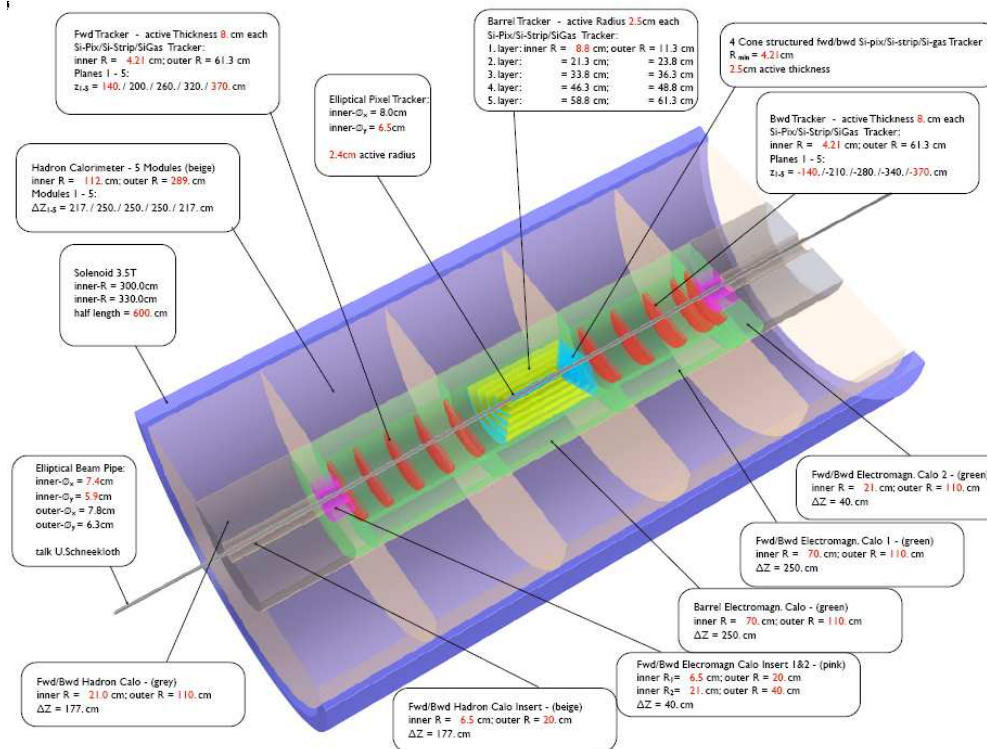
$1^\circ - 179^\circ$  acceptance (9 units in  $\eta$ )

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

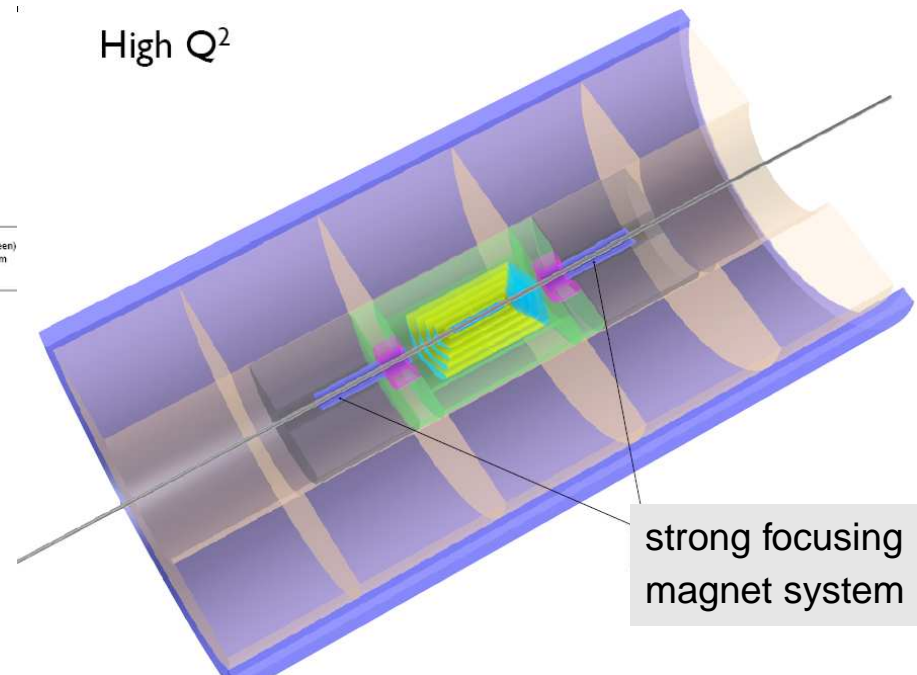
$10^\circ - 170^\circ$  acceptance (5 units in  $\eta$ )

at  $L = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

(courtesy P. Kostka)



High  $Q^2$



# Detector options

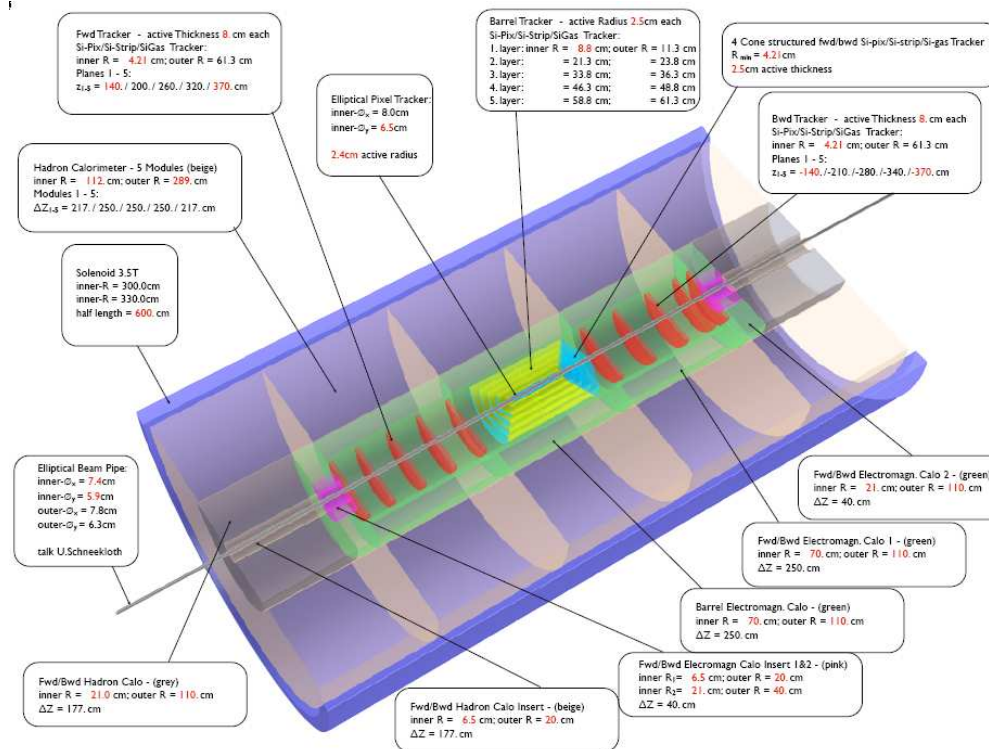
## Two setups for Main Detector (low $Q^2$ vs high $Q^2$ )

$1^\circ - 179^\circ$  acceptance (9 units in  $\eta$ )

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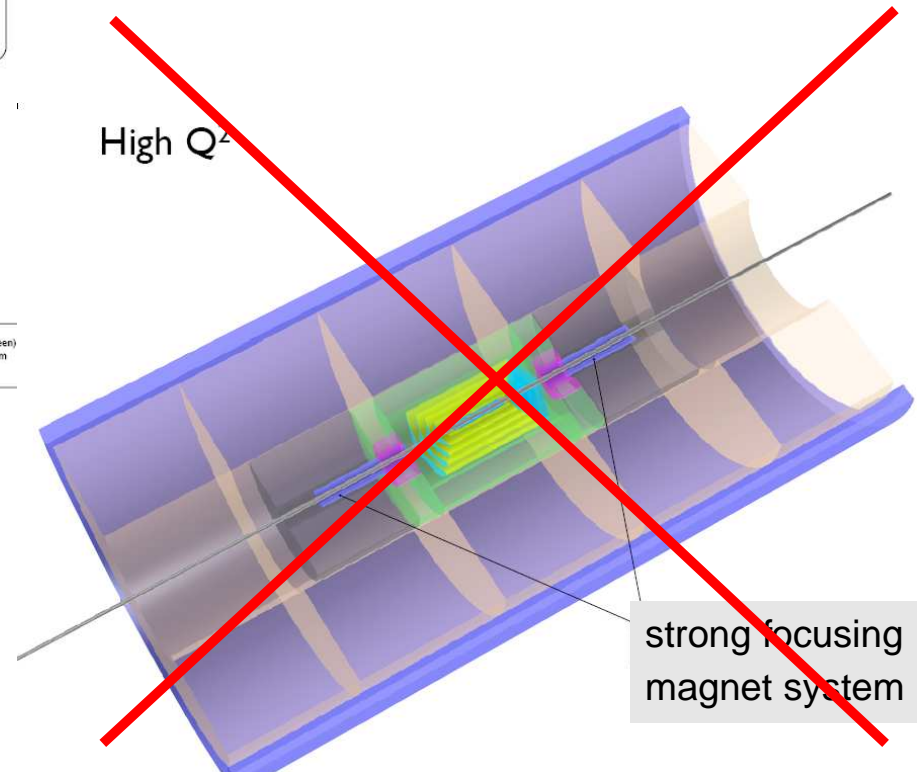
$10^\circ - 170^\circ$  acceptance (5 units in  $\eta$ )

at  $L = 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$

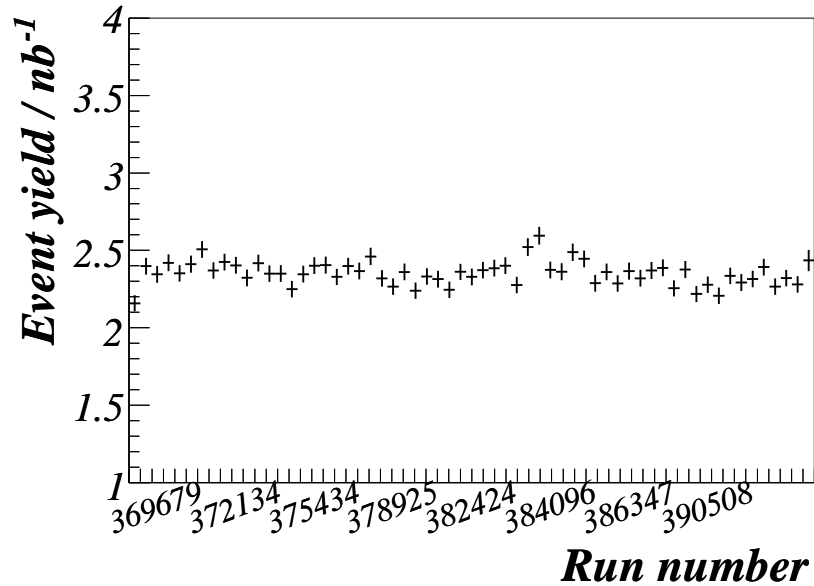


(courtesy P. Kostka)

High  $Q^2$





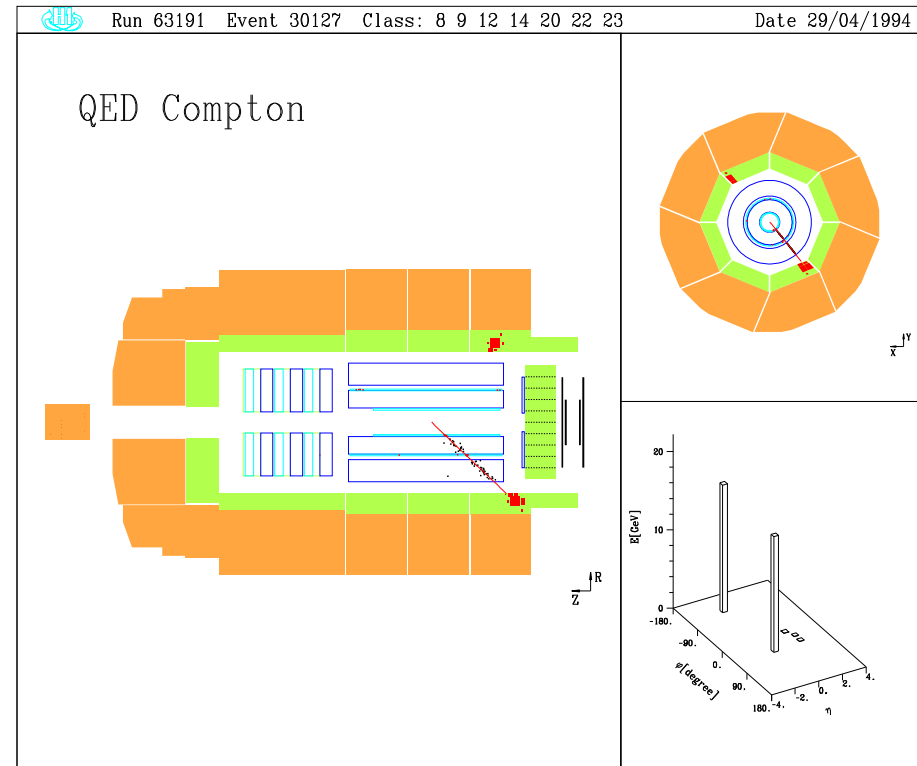


High  $Q^2$  NC DIS

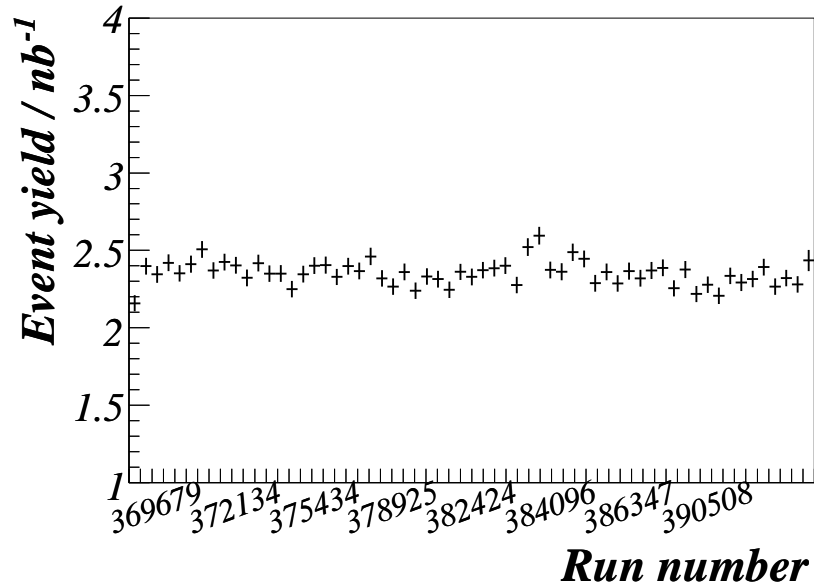
Precision: 1 – 2% ( $F_2$ ), 2% (QEDC)

LHeC MC study: (using H1 analysis strategy)

Generator: DJANGO ( $0.05 < y < 0.6$ )  
 high  $Q^2$  setup:  $\sigma_{vis} \simeq 10$  nb  
 low  $Q^2$  setup:  $\sigma_{vis} \simeq 150$  nb  
 Rate (stat.err): 1.5 – 10 Hz ( $\delta\mathcal{L} \simeq 1\%/hour$ )



COMPTON MC (elastic part)  
 $\sigma_{vis} \simeq 0.025$  nb  
 $\sigma_{vis} \simeq 3$  nb  
 0.025 – 0.03 Hz ( $\delta\mathcal{L} \simeq 0.5\%/month$ )

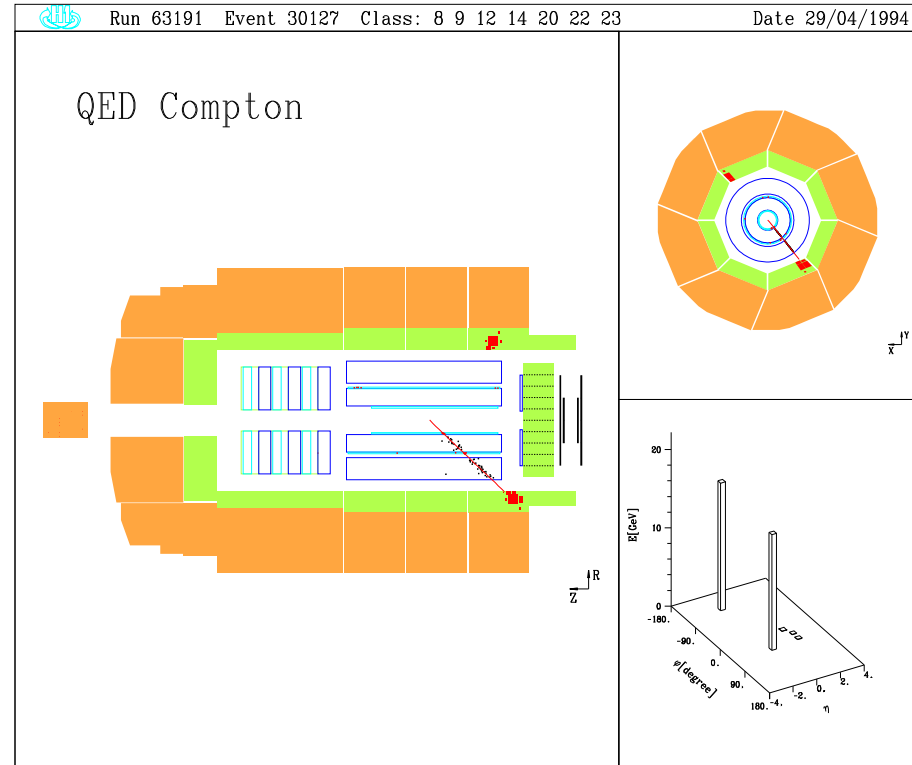


High  $Q^2$  NC DIS

Precision: 1 – 2% ( $F_2$ ), 2% (QEDC)

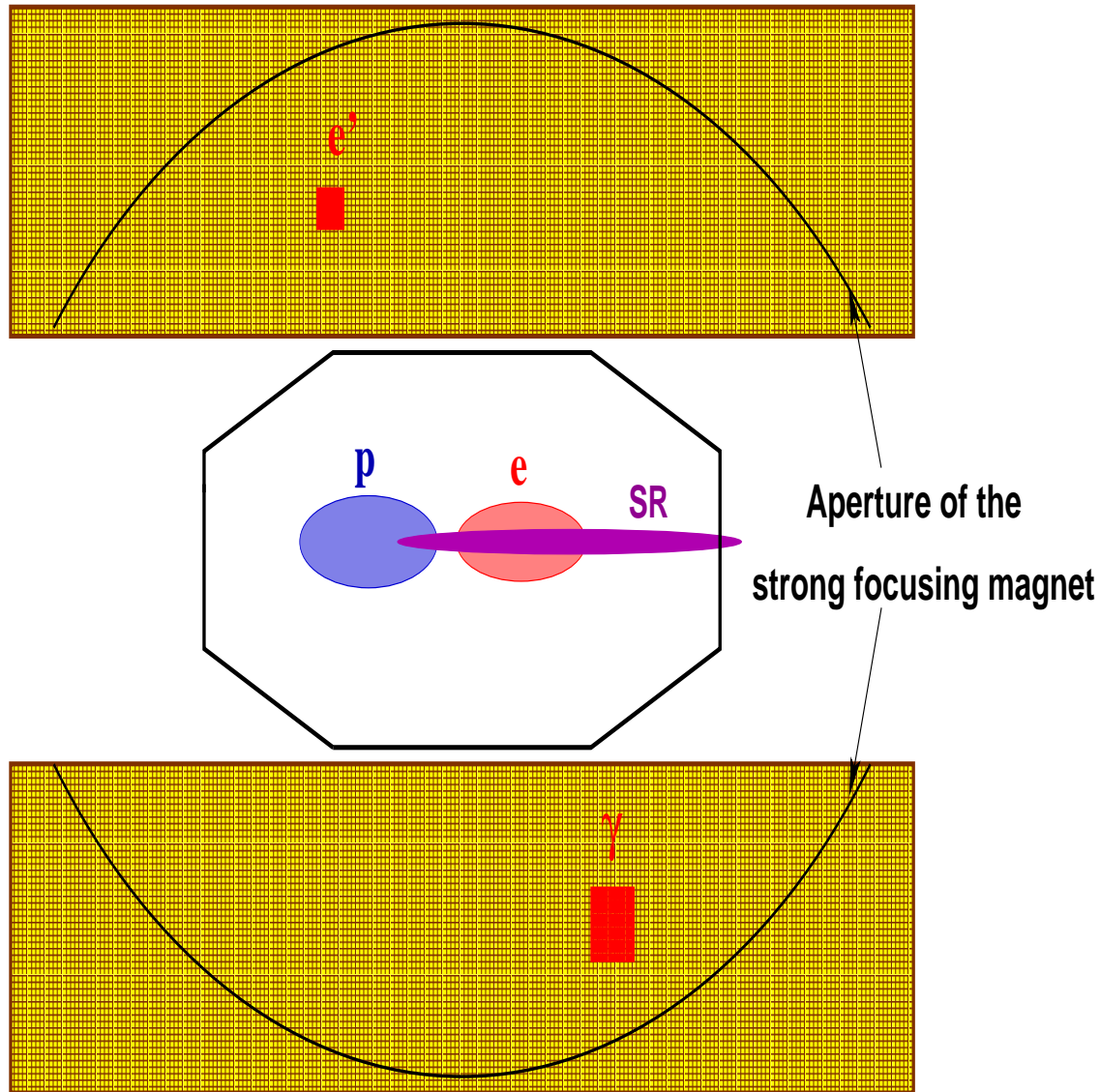
LHeC MC study: (using H1 analysis strategy)

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 Rate (stat.err): 1.5 – 10 Hz ( $\delta\mathcal{L} \simeq 1\%/hour$ )



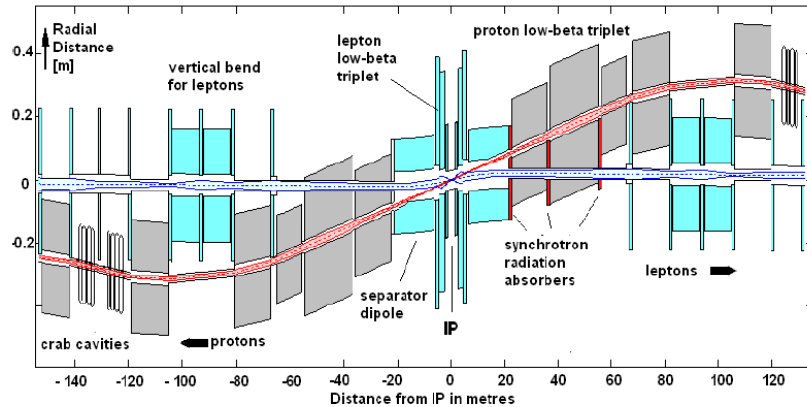
COMPTON MC (elastic part)  
 $\sigma_{vis} \simeq 0.025$  nb  
 $\sigma_{vis} \simeq 3$  nb + VLQ (6m)?  
 0.025 – 0.03 Hz ( $\delta\mathcal{L} \simeq 0.5\%/month$ )

# An option of VLQ/BPC at 6m ?



- $\sigma_{\text{vis}}^{QEDC} = 4.3 \pm 0.2 \text{ nb}$   
 $\Rightarrow 4 \text{ Hz @ } 10^{33} \text{ cm}^{-2} \text{ s}^{-1}$
- Elastic QEDC:  
 no vertex ( $\theta' = 0.5^\circ - 1^\circ$ )  
 precision of  $\theta \Rightarrow \delta\sigma_{\text{vis}}?$
- Inelastic events:  
 precise vertex from HFS  
 $\Rightarrow$  extended capability  
 for low  $Q^2/\gamma p$  physics

## IR Layout

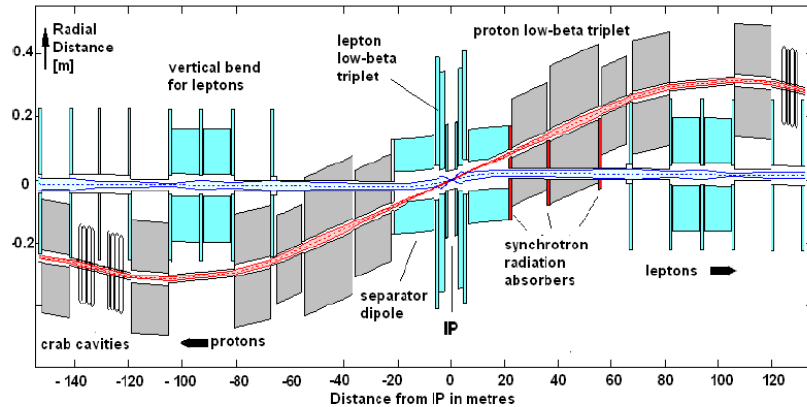


- crossing angle at IP
- large SR flux

⇒ Challenge: difficult  
to catch zero-angle  $\gamma$ 's

**RR scheme**

## IR Layout



- crossing angle at IP
- large SR flux

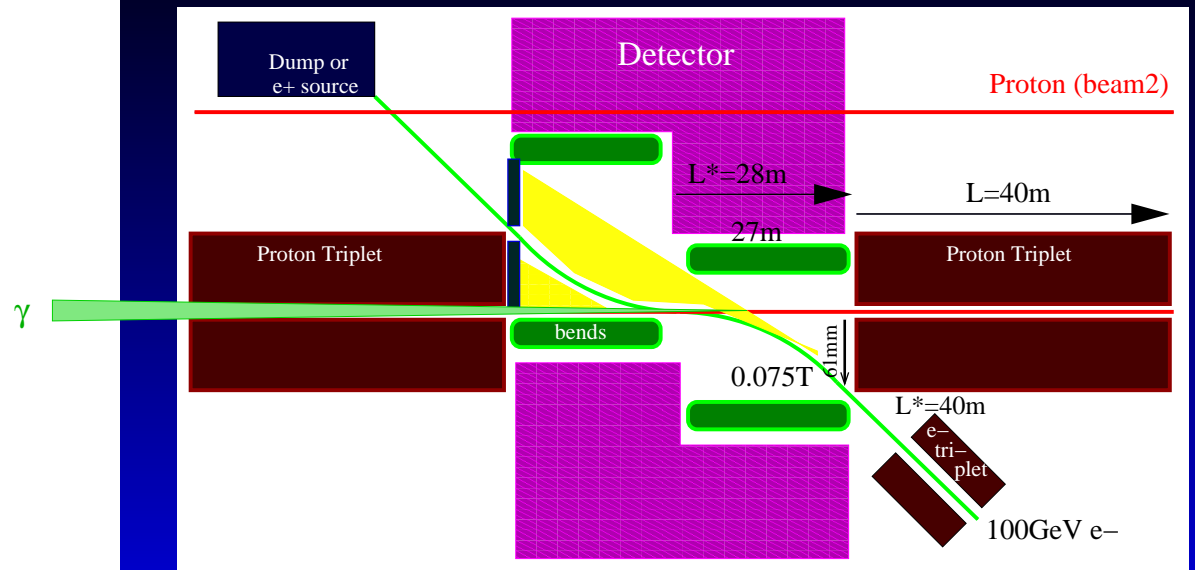
⇒ Challenge: difficult to catch zero-angle  $\gamma$ 's

RR scheme

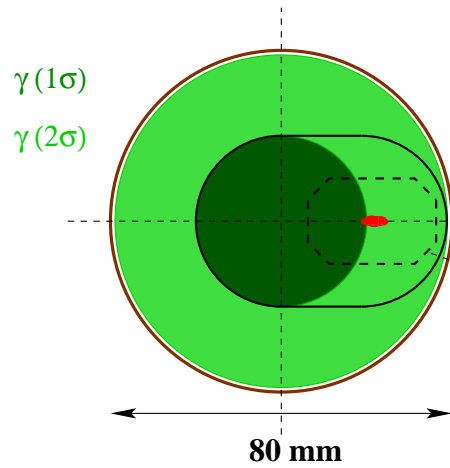
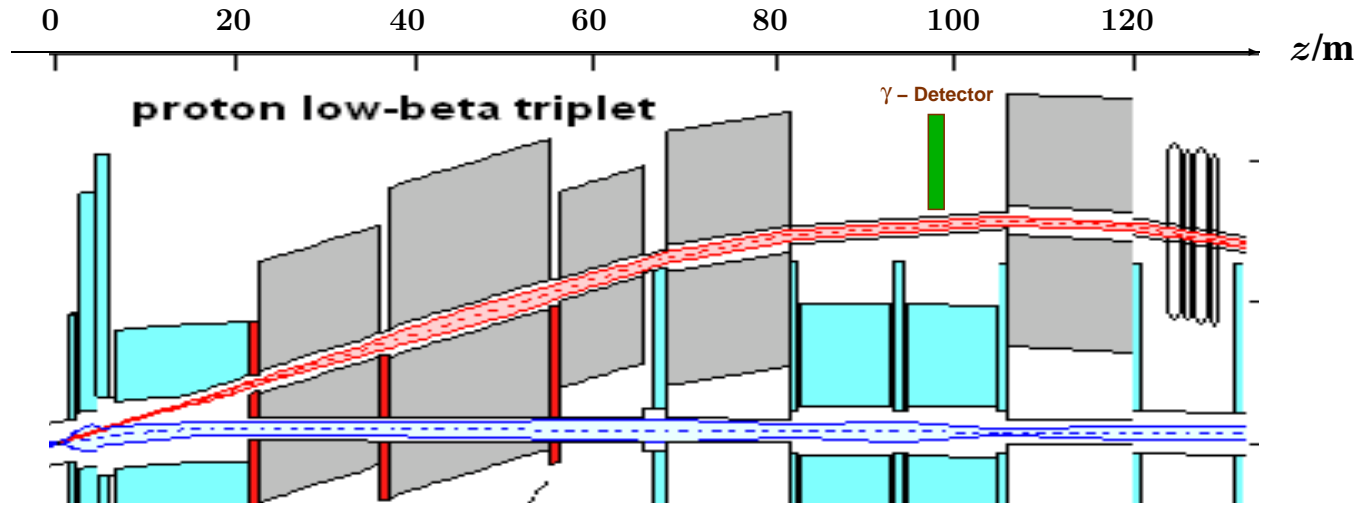
- Head-on collisions. Similar to HERA,  $\gamma$ 's travel along the **p-beam**
  - Lumi monitor located after proton dipole at  $z = 100\text{m}$
- ⇒ Challenge: large aperture required for proton magnets at  $z = 60 - 80\text{m}$

## IR sketch for 100GeV $e^-$

F. Zimmermann et al.



LR scheme

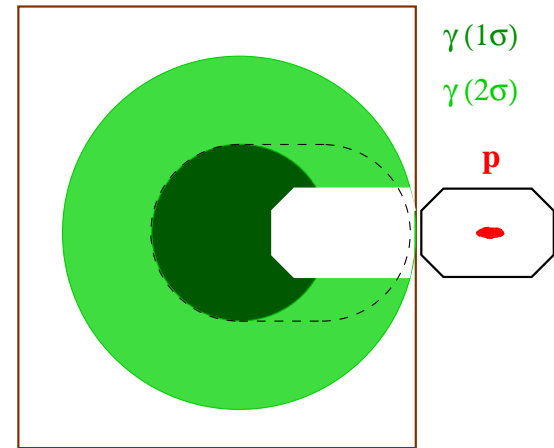


Beampipe at  $z=80m$

Medium BP -  $A_\gamma = 35 - 45\%$

Large BP -  $A_\gamma = 70 - 80\%$

$\delta L = 2.5 - 6.0\%$



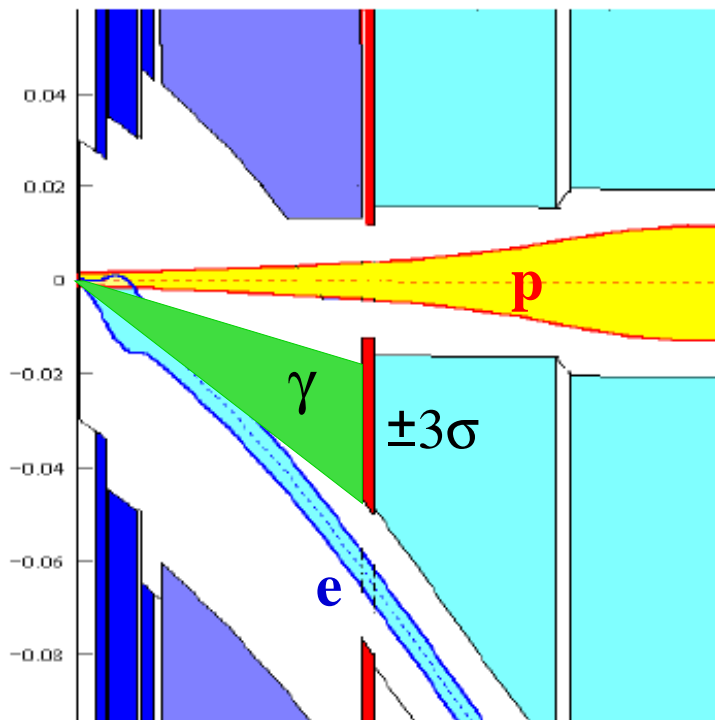
Photon Detector at  $z=100m$

Crossing angle = 2 mr

- A** Magnetic separation = 2 mr  
 $\Rightarrow$  60 mm beam separation at 22m

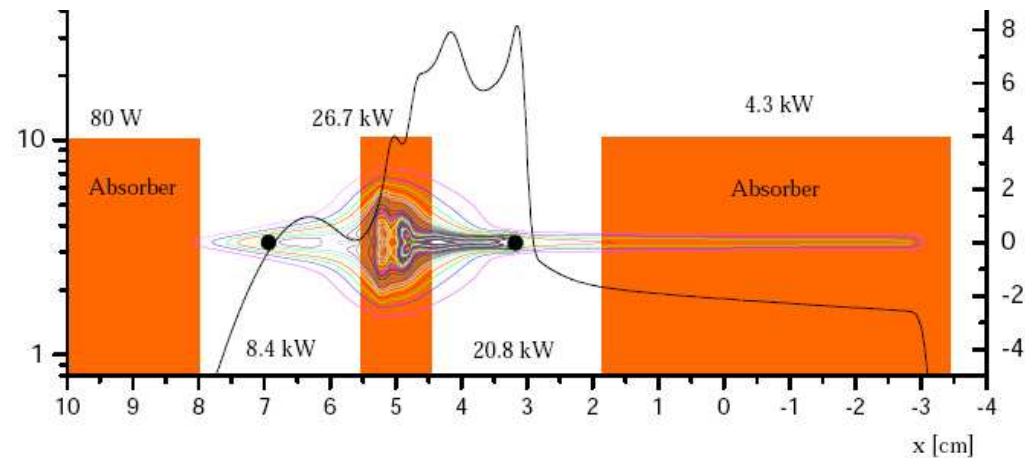
Crossing angle = 1.5 mr

- B** Magnetic separation = 0.75 mr  
 $\Rightarrow$  40 mm beam separation at 22m



F. Willeke, May 2008

### SR power profile at 22m



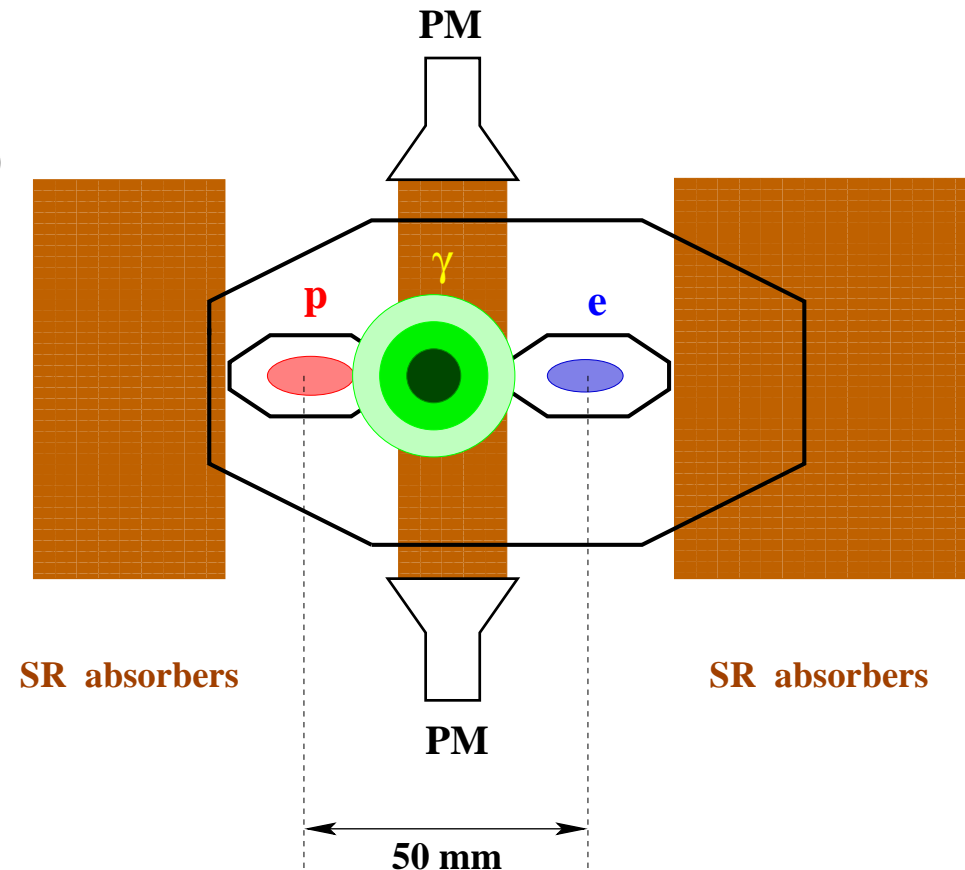
B. Holzer / B. Nagorny, Sept 2008

BH spot at the hottest place!

## BH-photon detector integrated into SR absorber

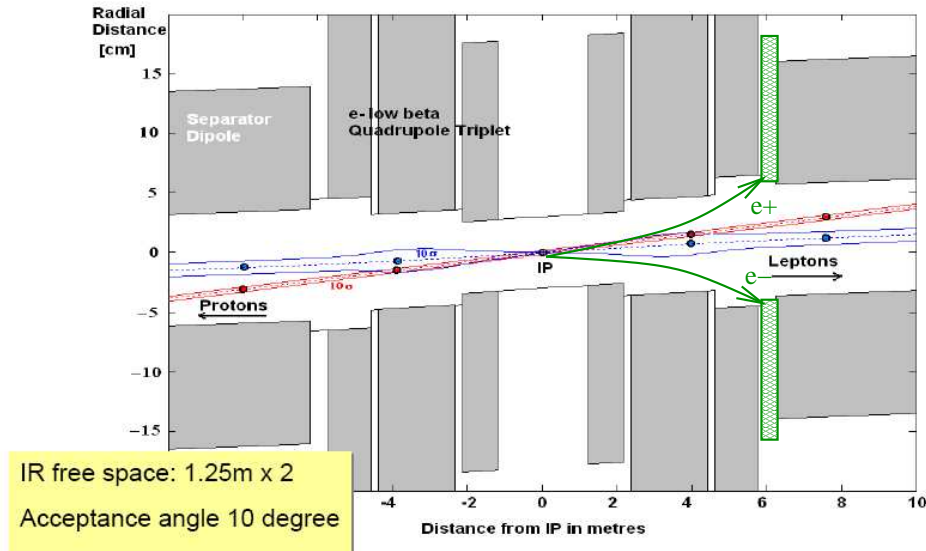
- Cooling system with 10 – 20 cm long water bath acting as Čerenkov radiator for BH  $\gamma$ 's
- Radiation hard, (almost) insensitive to SR  
(but: high  $E_{crit} \Rightarrow$  effect of the tail?)
- For latest optics (1 mrad crossing angle)  
acceptance is up to 90%
- Exact BH counter design and R/O  
still to be worked out
- Accurate acceptance control  
requires precise beam tilt  
monitoring (10-15% of the x-angle)

$\delta L = 3\%$  within reach



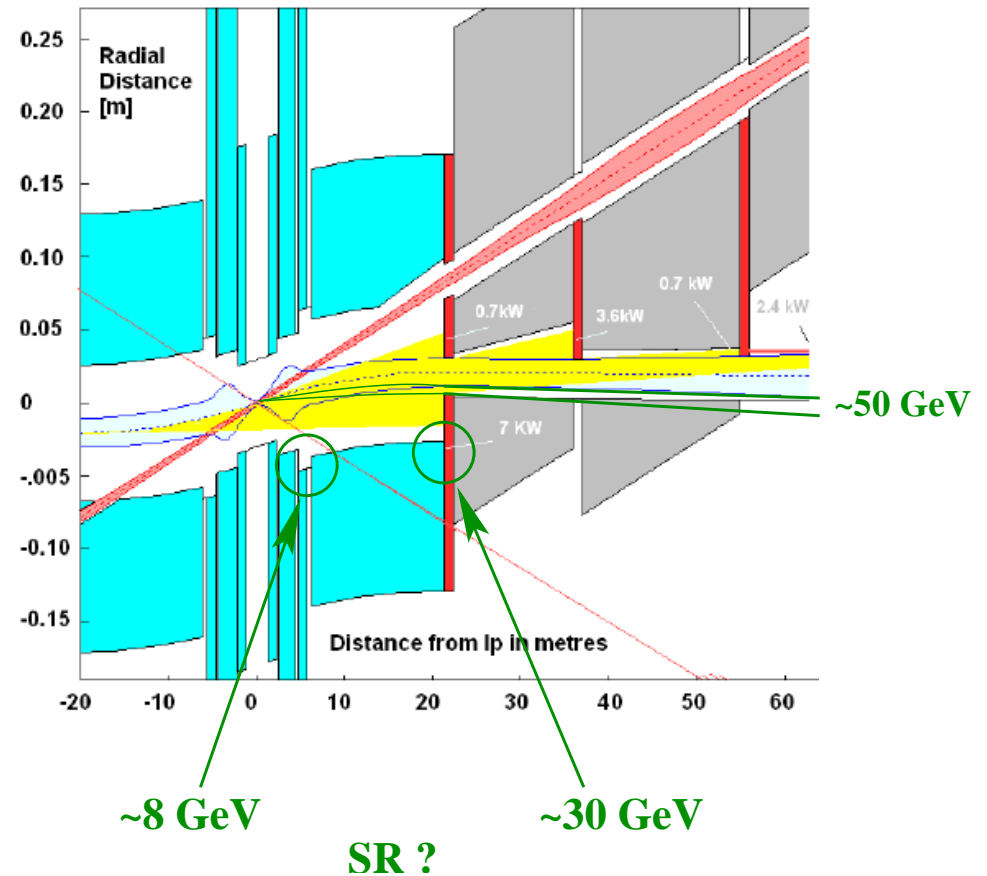


## IR Layout

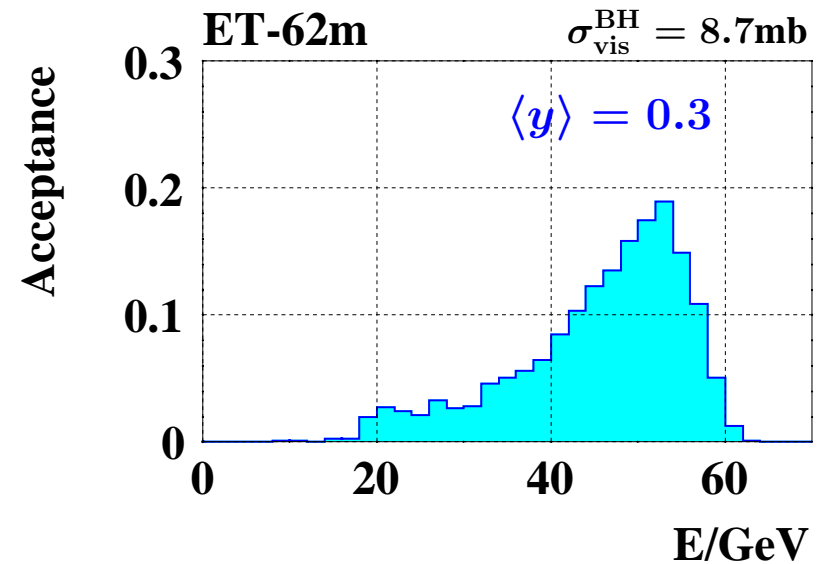
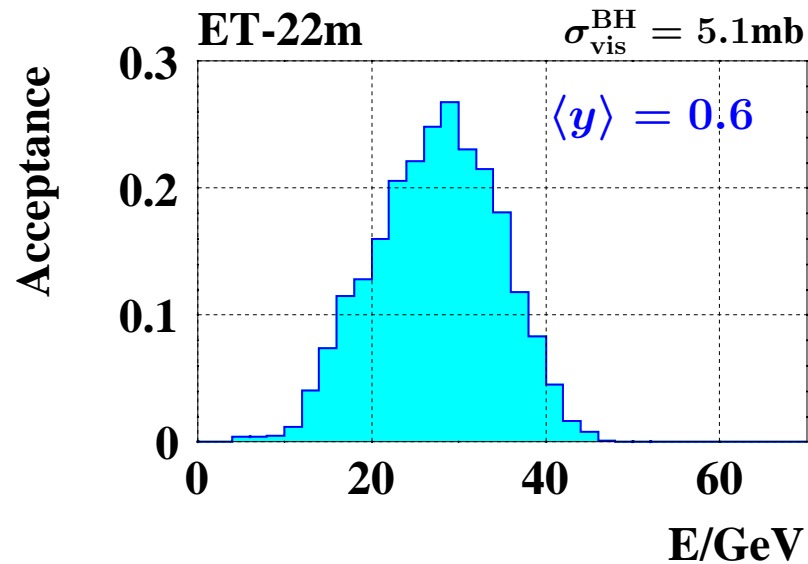
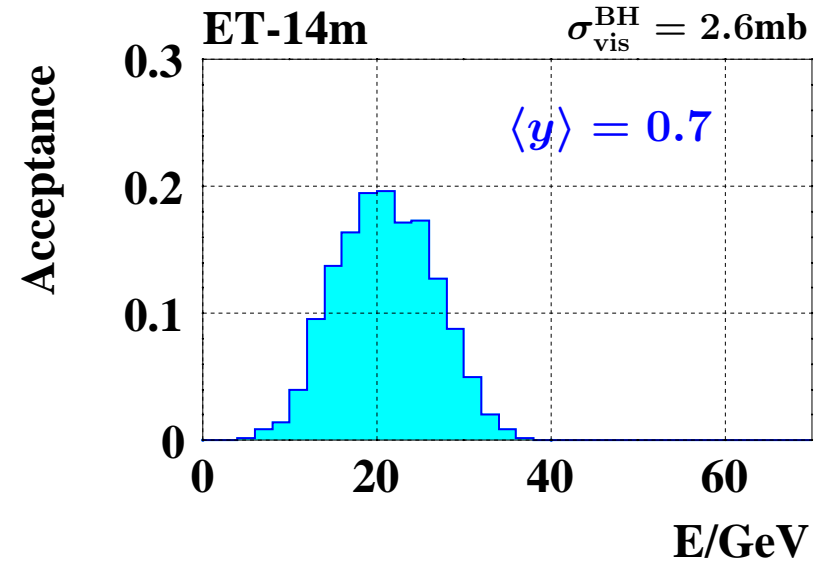
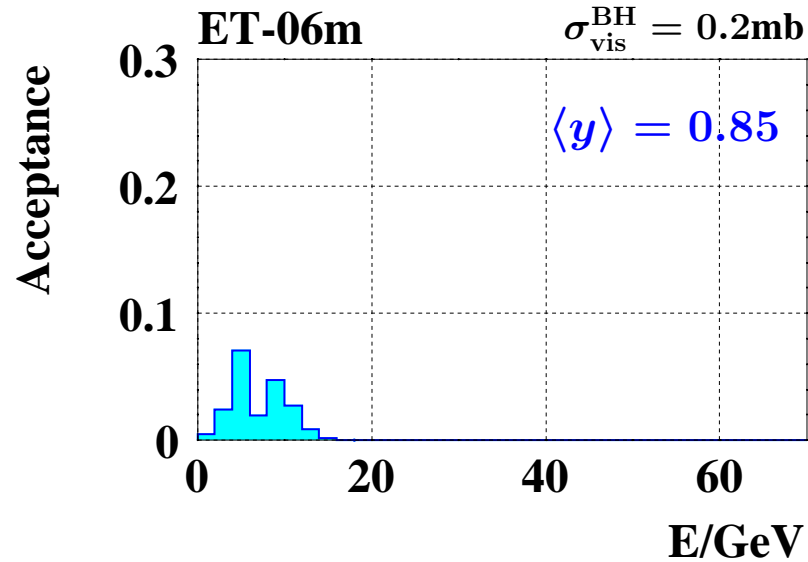


- ET-6m requires some dipole field  $\Rightarrow$  not possible for low luminosity setup
- This place perhaps better suited for vertical VLQ stations ("QEDC tagger")

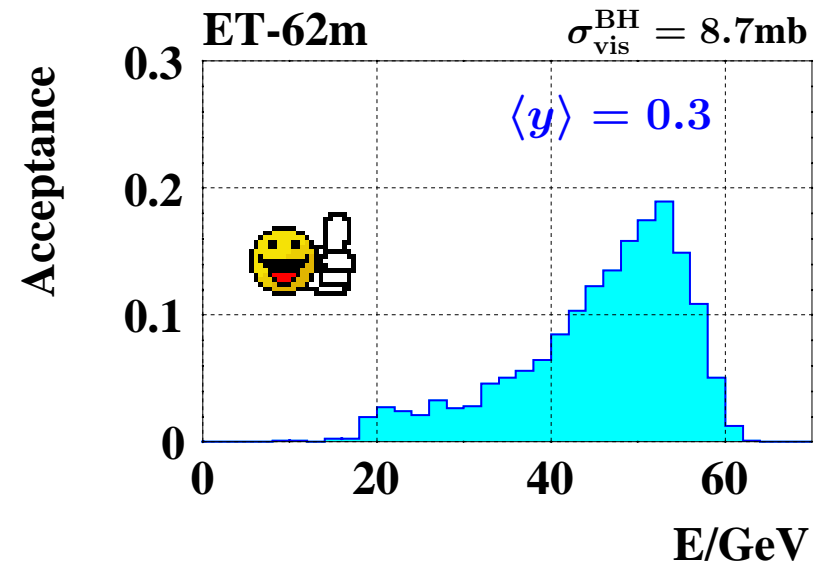
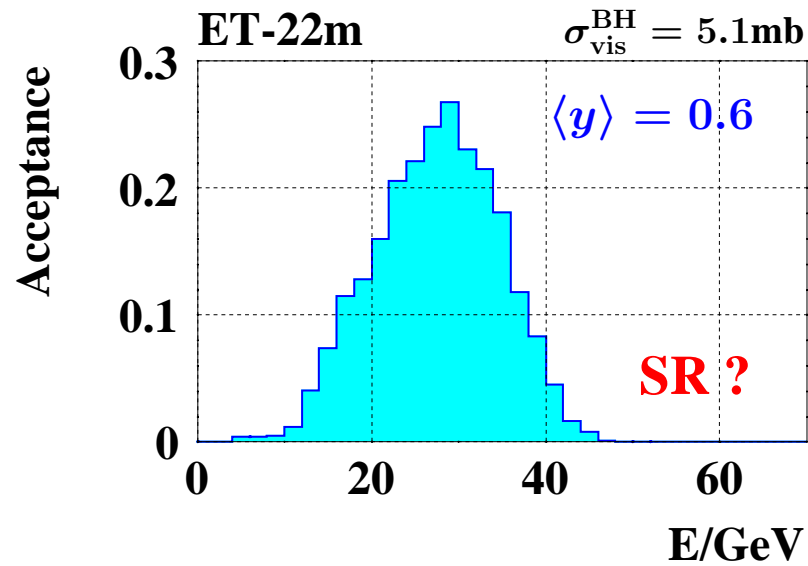
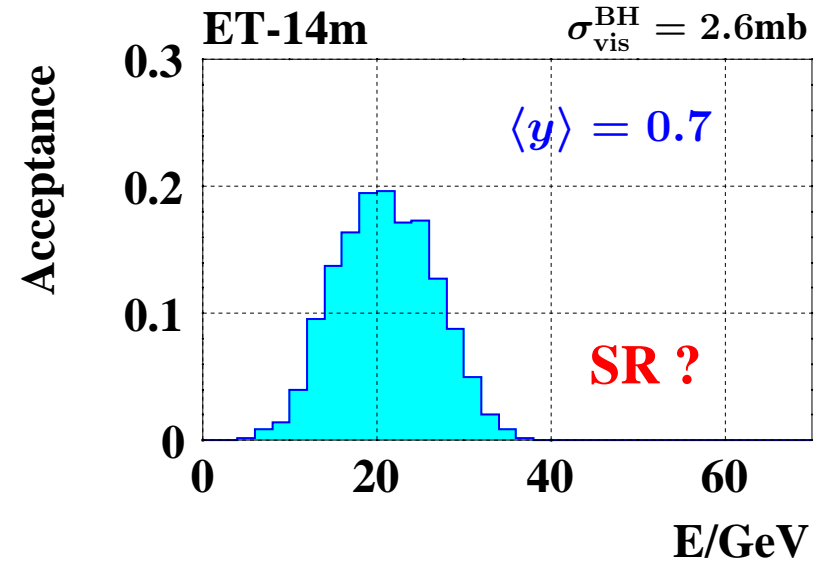
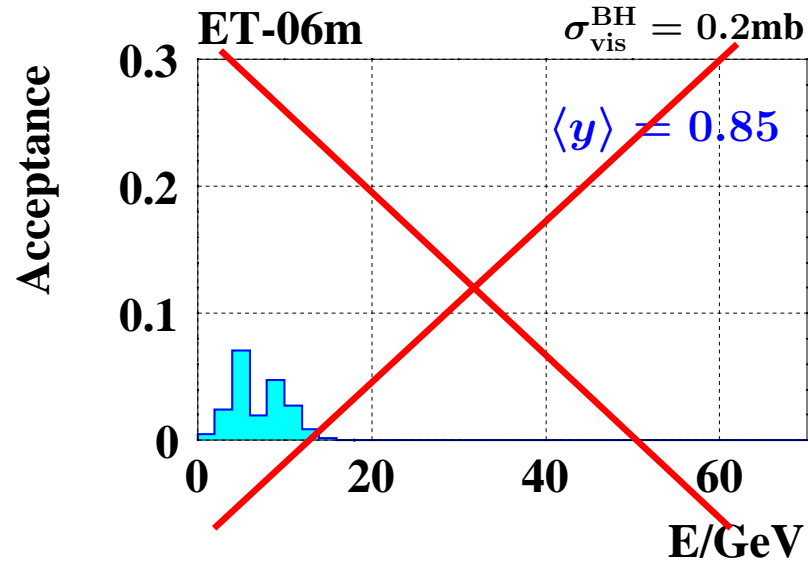
- An option: split separator dipole and position ET at  $z = 13 - 14\text{m}$  ?

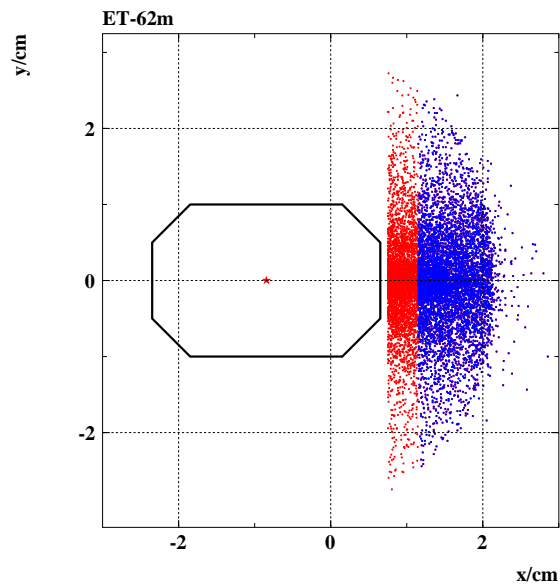
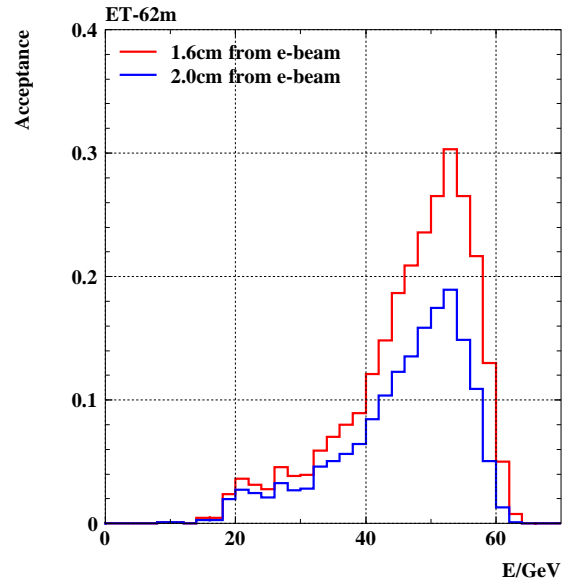


## e-Tagger Acceptances (70 GeV case)



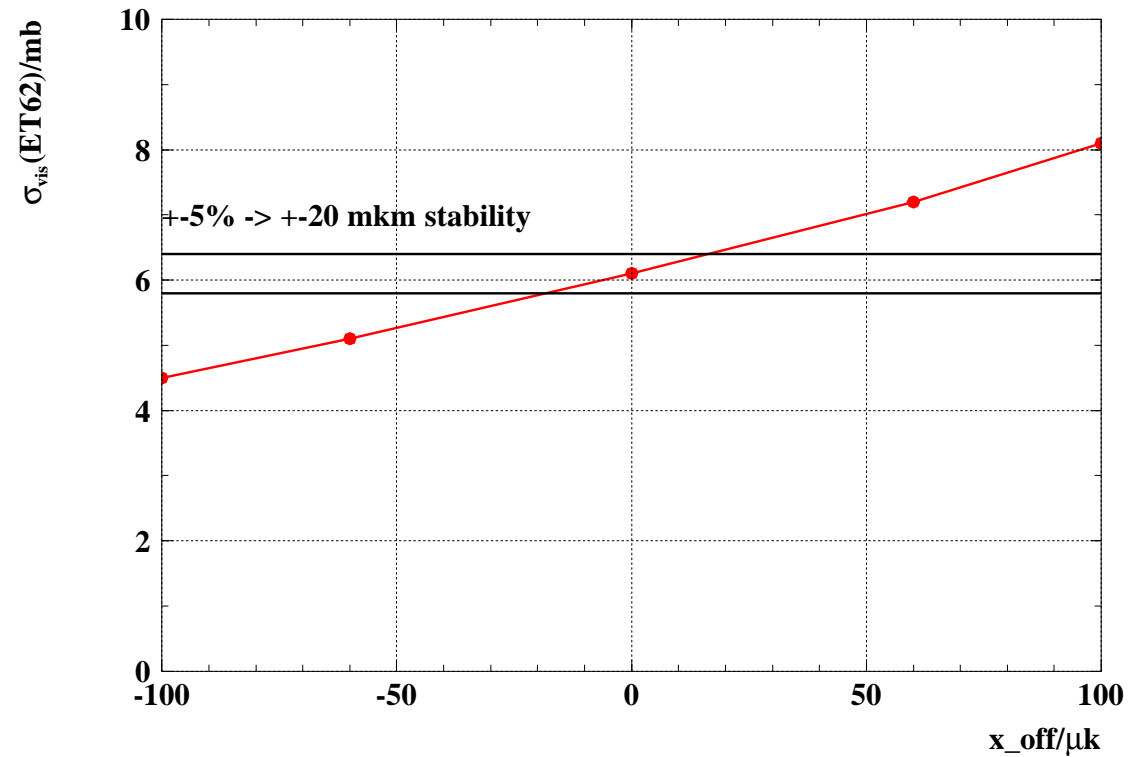
## e-Tagger Acceptances (70 GeV case)





## Acceptance control requirements

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

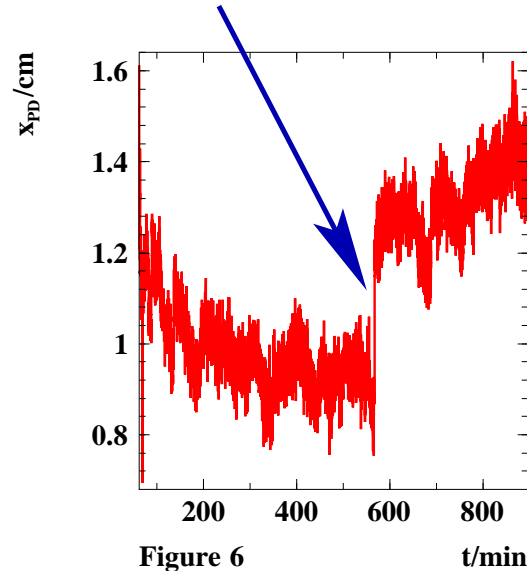


- $e$ -taggers are also useful to enhance physics programme (tagged  $\gamma p$ ). Note however, that triggering might be problematic due to inefficient  $\gamma$ -veto
- Can be used to control  $\gamma p$  background in DIS samples
- ET-62m is most promising (good acceptance, no/small SR, available 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)

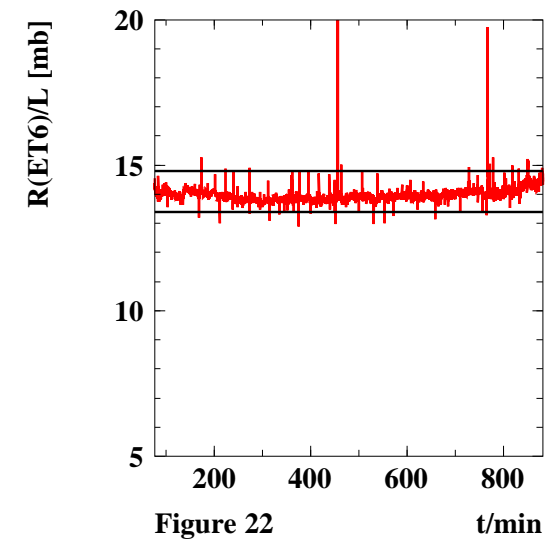
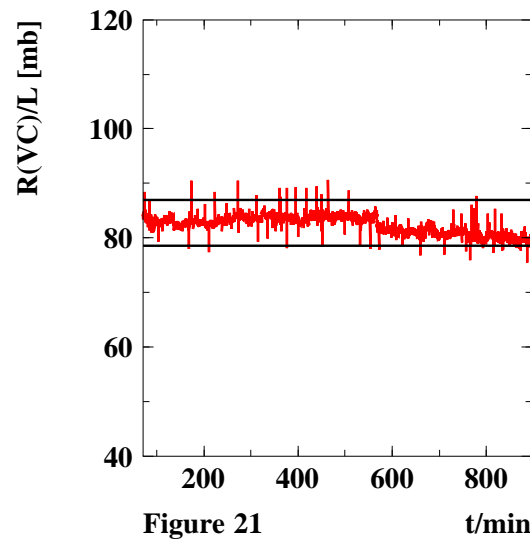
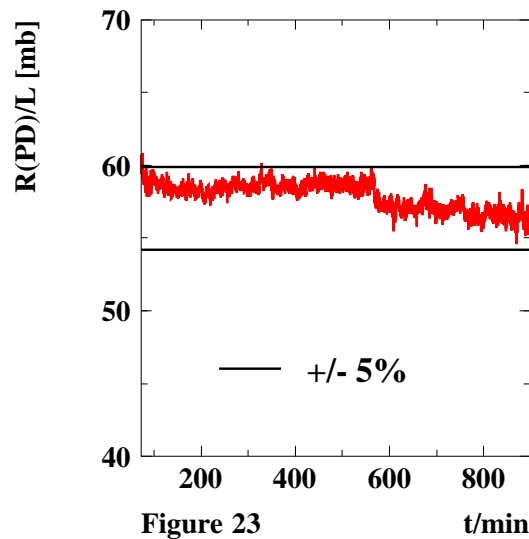
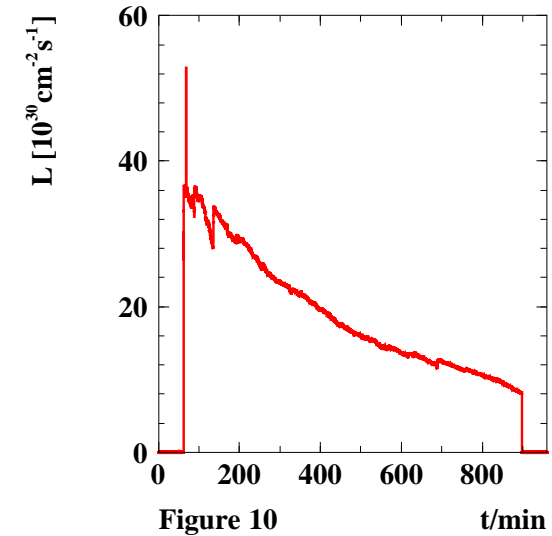
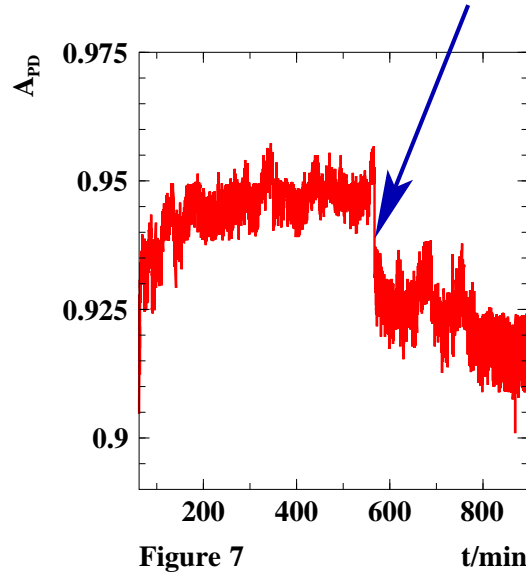
**Can one rely on Water Counter and  $e$ -taggers for online lumi measurement?**

**$\Rightarrow$  Look at HERA experience**

jump in the beam tilt



jump in the acceptance



## Dominant systematics

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

- 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
  - ▷ Photon Detector for LR option requires large p-beampipe at  $z = 80\text{m}$
  - ▷ In case of RR option B-H photons can be detected using water Čerenkov counter integrated with SR absorber at 22m
  - ▷ Electron tagger at 62 m is very promising 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 3 – 5% level



- Update ET-62m acceptance with full and final IP optics
- Clarify p-beamline aperture for head-on LR option
- Study the effect of high  $E$  tail of SR on B-H photon detection: fraction of SR flux above Čerenkov threshold ?
- Detailed design of active SR absorber: shape, water flow/supply, light collection, readout
- Triggering for  $\gamma p$  physics:  
 $\gamma$  veto efficiency for the condition  $e(ET) \ll \epsilon \ll \epsilon_{\gamma}(PD/ASRF)$
- Continue to look for bright ideas capable of  $\delta\mathcal{L} \leq 1\%$