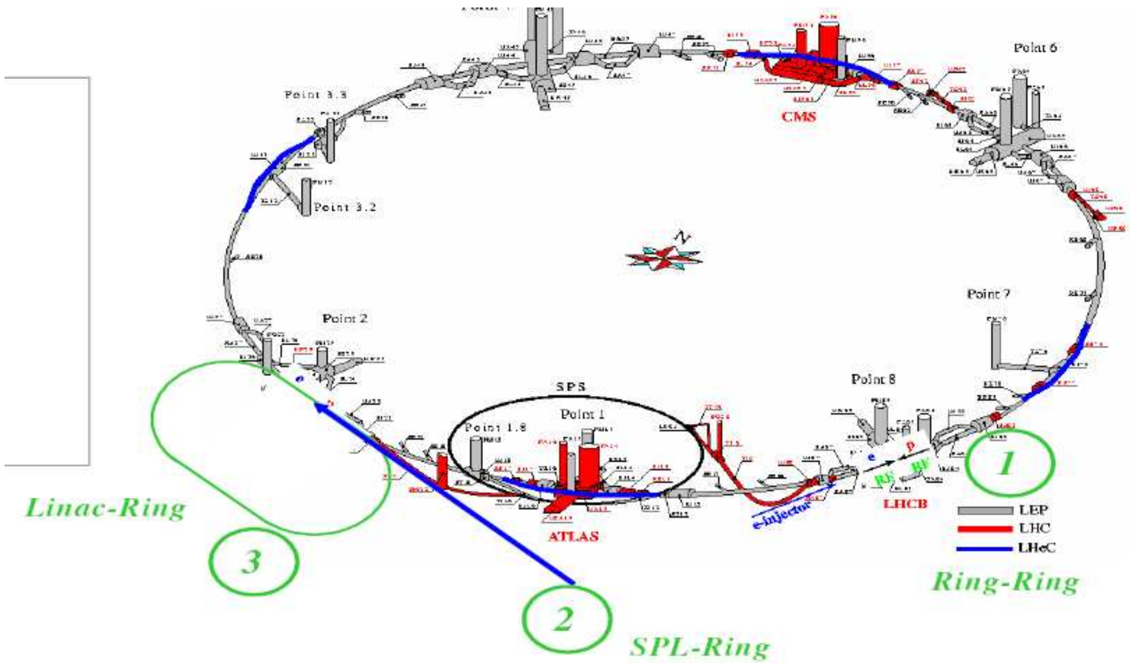
S. Levonian, December 14, 2009

Luminosity Measurements at LHeC

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



(Only RR option is discussed here)

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

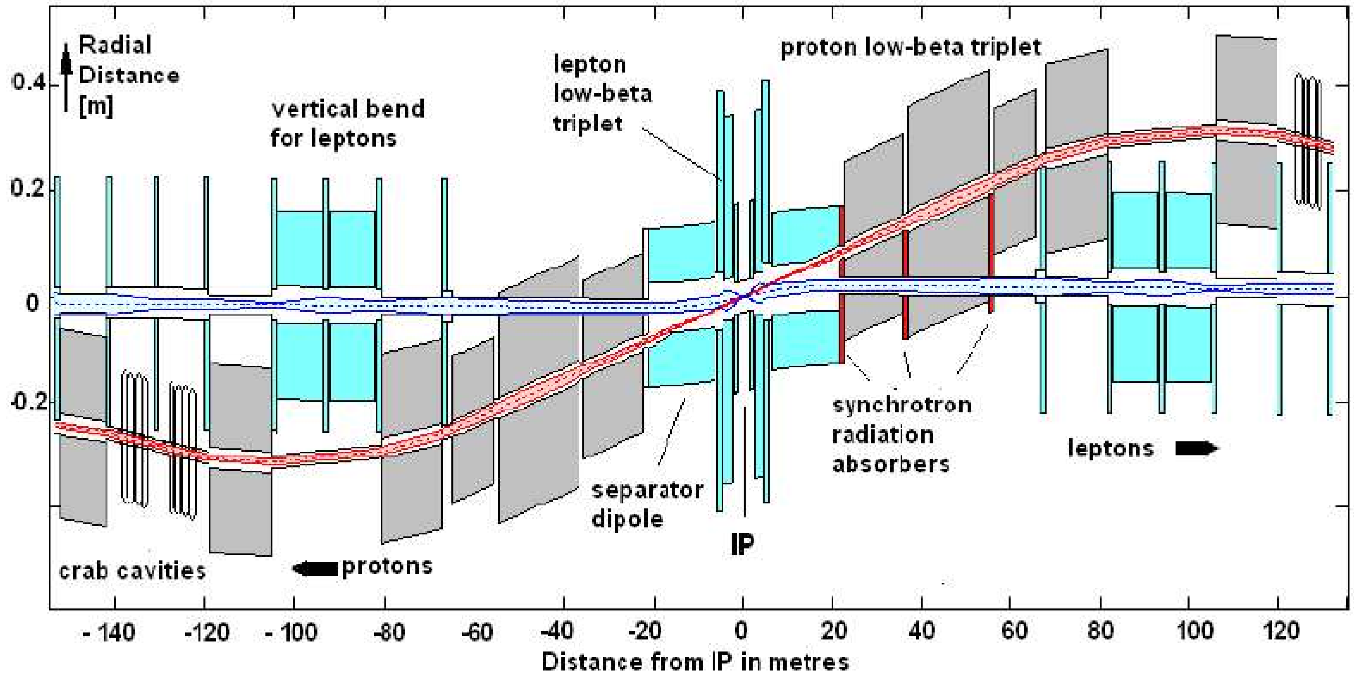
  $dL_{tot} = 1 - 2\%$ per sample (week-month) $\Rightarrow$ **0.02** Hz

In the following RR-option with 70×7000 GeV^2 is assumed

Challenges for RR option

- crossing angle at IP
- large SR flux

IR Layout

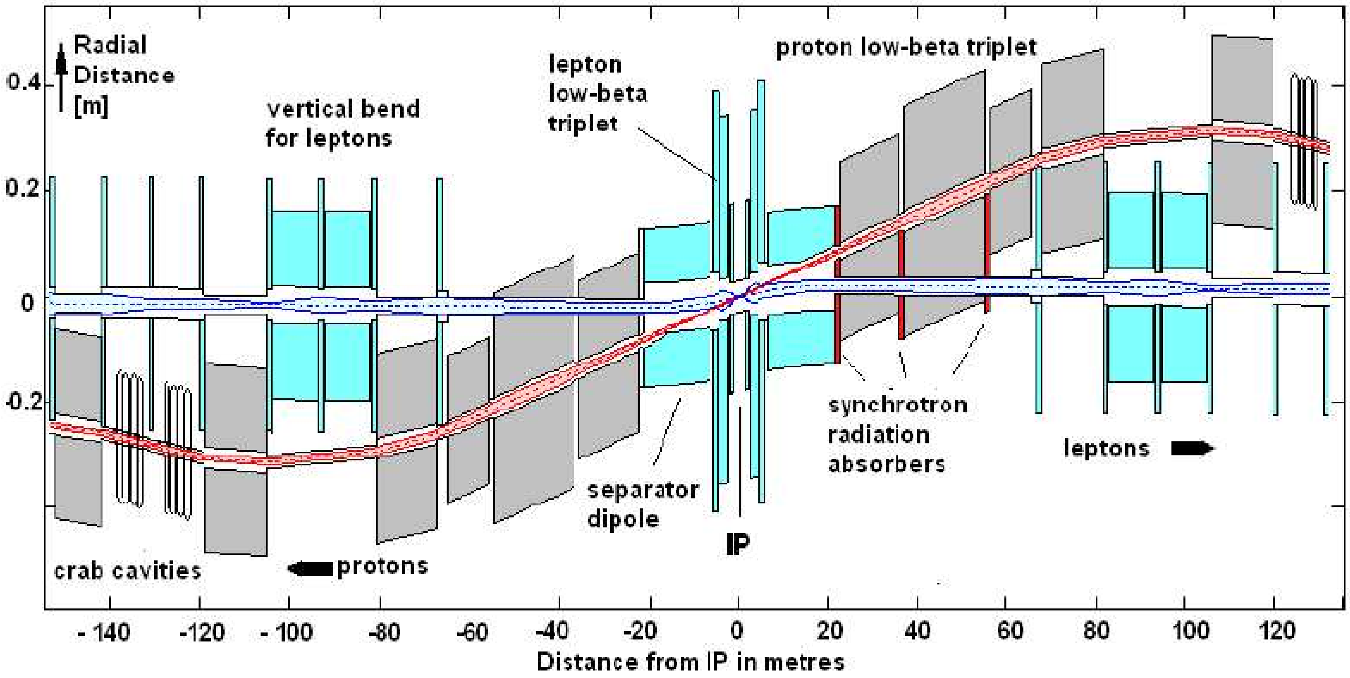


Challenges for RR option

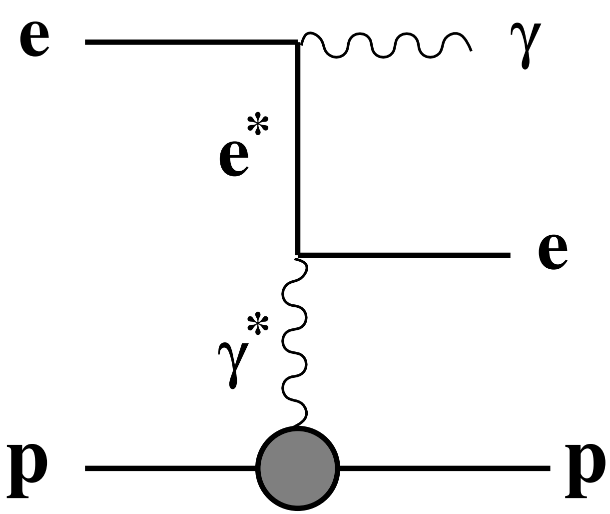
- crossing angle at IP
- large SR flux

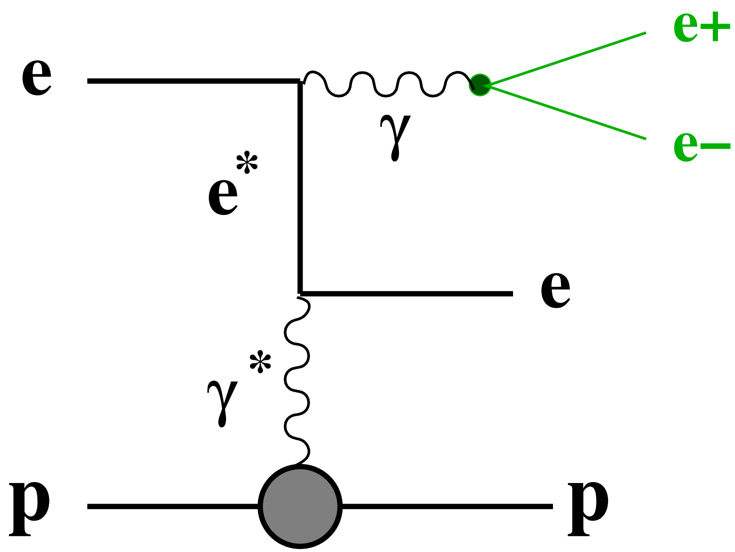
(LR option with head-on collisions is more similar to HERA, except of horizontal vs vertical $\gamma_{BH} - p$ separation)

IR Layout



Processess





B-H process: $\sigma(E > 10) = 95$mb

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

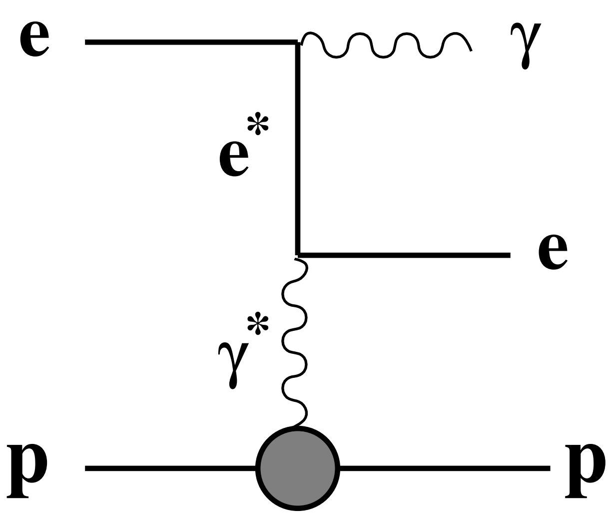
B-H with ”internal conversion”

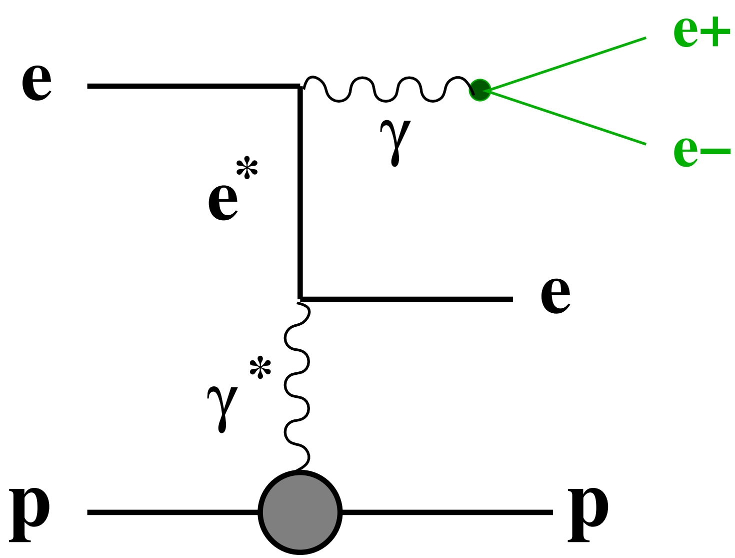
$\sigma \simeq 1/200\sigma_{BH}$

QED Compton: $\sigma(\theta < 179^o) = 6$nb

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

Processess





B-H process: $\sigma(E > 10) = 95$mb

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

B-H with "internal conversion"

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

QED Compton: $\sigma(\theta < 179^o) = 6$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
  - ▷ 10^o Detector at $L = 10^{33}\text{cm}^{-2}\text{s}^{-1}$ (using typical H1 strategy
  - ▷ 1^o Detector at $L = 10^{31}\text{cm}^{-2}\text{s}^{-1}$ for F2 and QEDC analyses)

- ”Crasy” options for the tunnel detectors
  - ▷ Hole in magnets for B-H photons (not discussed here)
  - ▷ **SR absorber with integrated BH photon counter**
  - ▷ **Electron taggers at 6m, 20m and 60m**

- Typical rates and stat.precision
  - ▷ BH photons: $R = 1 - 100$ MHz $\Rightarrow 0.1\%$ / sec
  - ▷ BH electrons: $R = 0.02 - 2$ MHz $\Rightarrow < 1\%$ / sec
  - ▷ positrons from BH(e^+e^-): $R = 1 - 50$ kHz $\Rightarrow 3\%$ / sec

  - ▷ F2: $R = 1.5 - 10$ Hz $\Rightarrow 1\%$ / hour
  - ▷ QEDC: $R = 0.015 - 0.020$ Hz $\Rightarrow 1 - 2\%$ / week

Dominant systematics

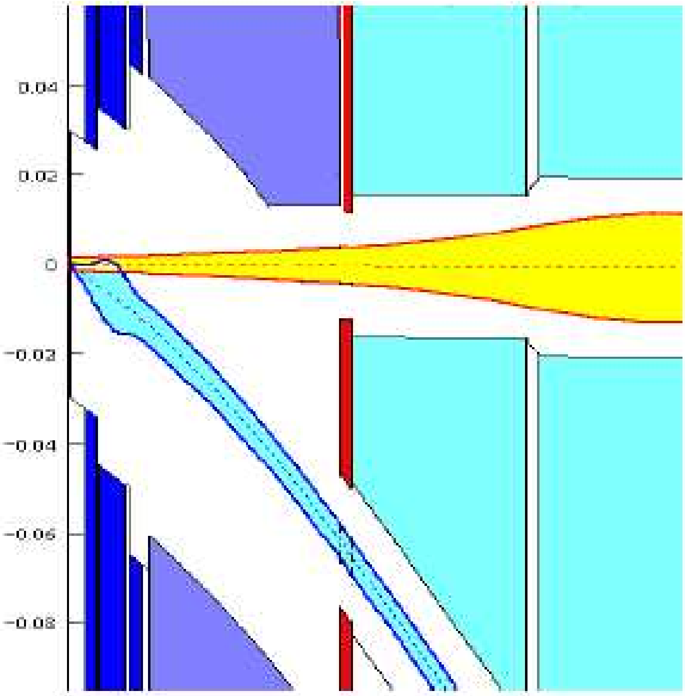
Method	Stat. error	Syst.error	Syst.error components			Application
BH (γ)	0.1%/sec	$1.5-2.0\%$	x-section	=	0.5%	Monitoring, tuning,
			acceptance, A	=	$10\%(1-A)$	Absolute L,
			E-scale, pileup	=	0.5%	short term variations
BH (e)	$1-3\%$/sec	$5-6\%$	x-section	=	0.5%	Monitoring, tuning,
			acceptance, A	=	$3-5\%$	Relative L
			background	=	1%	
			E-scale	=	1%	
QEDC	$1-2\%$/week	2%	x-section (el/inel)	=	1.2%	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%	Absolute $\mathcal{L}$,
			acceptance	=	1%	mid. term variations
			event vertex eff.	=	1%	
			E-scale	=	0.3%	

IP optics for RR option?

Crossing angle 2mr

Magnetic separation 2mr

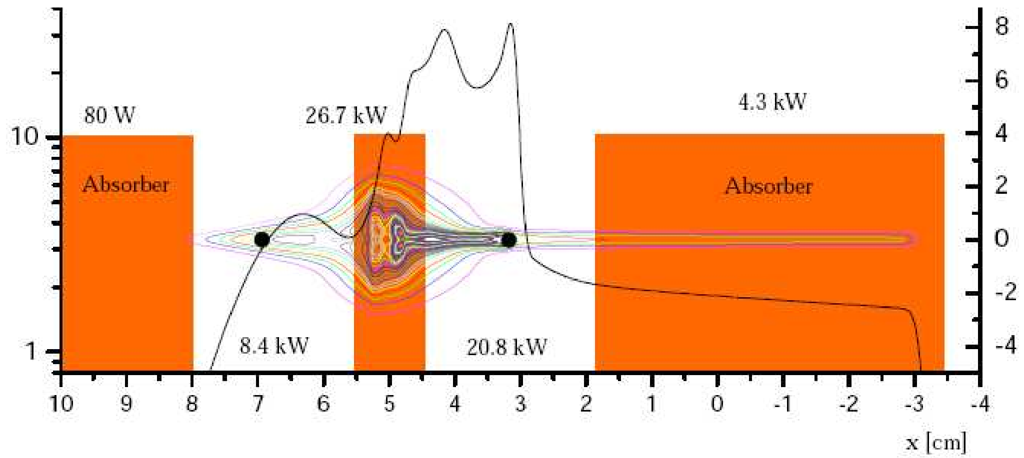
➔ 60 mm separation @20m



F.Willeke, May 2008

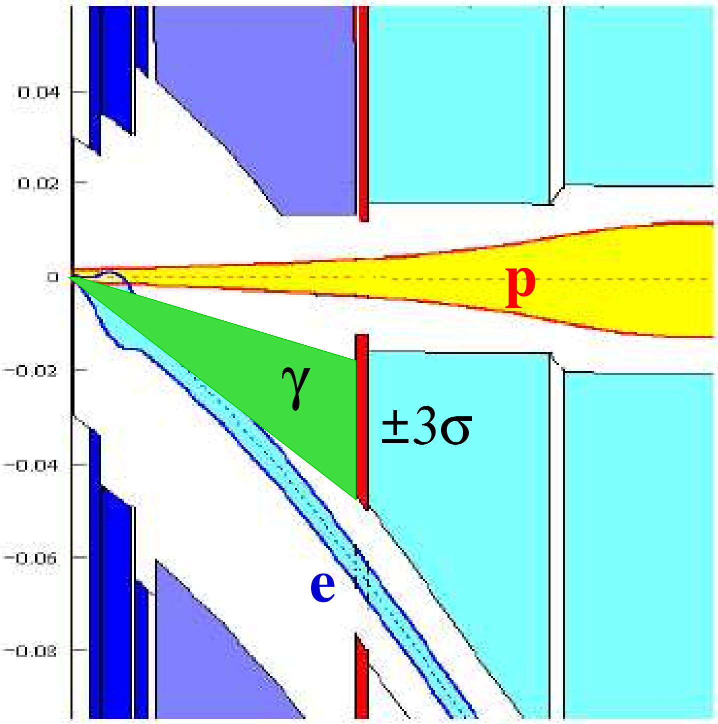
Crossing angle 1.5mr ?

40 mm beam separation at 20m?



B. Nagorny / B.Holzer, Sept 2008

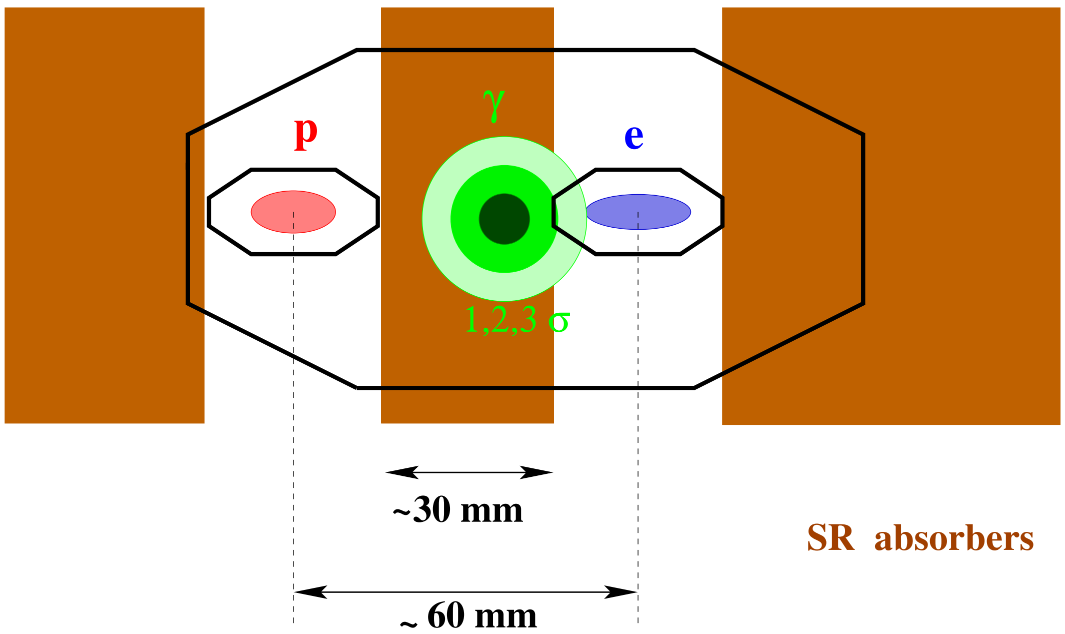
BH flux in SR absorber at 22m



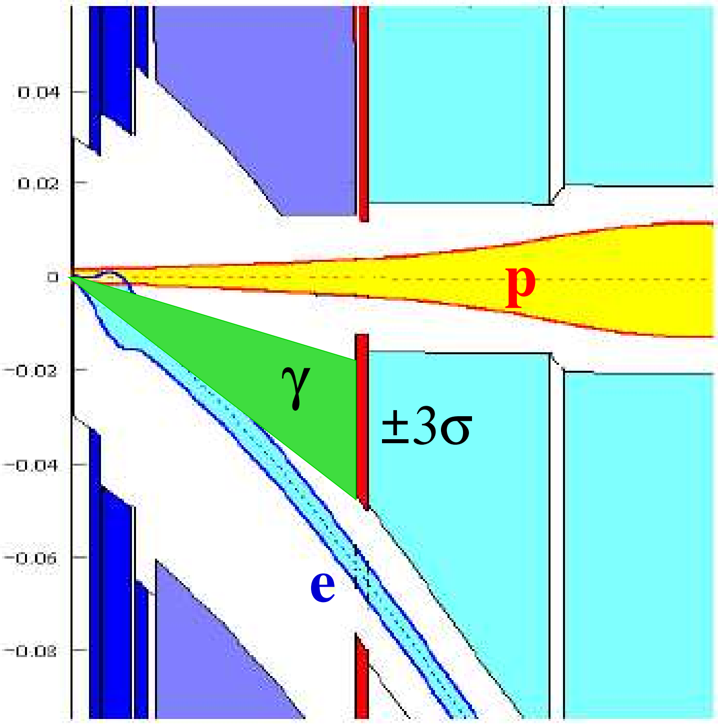
Active SR absorber?

- cooling system with $10 - 15$cm water bath acting as Čerenkov radiator for BH γ's
- radiation hard, (almost) insensitive to SR

- BH spot at the hottest place

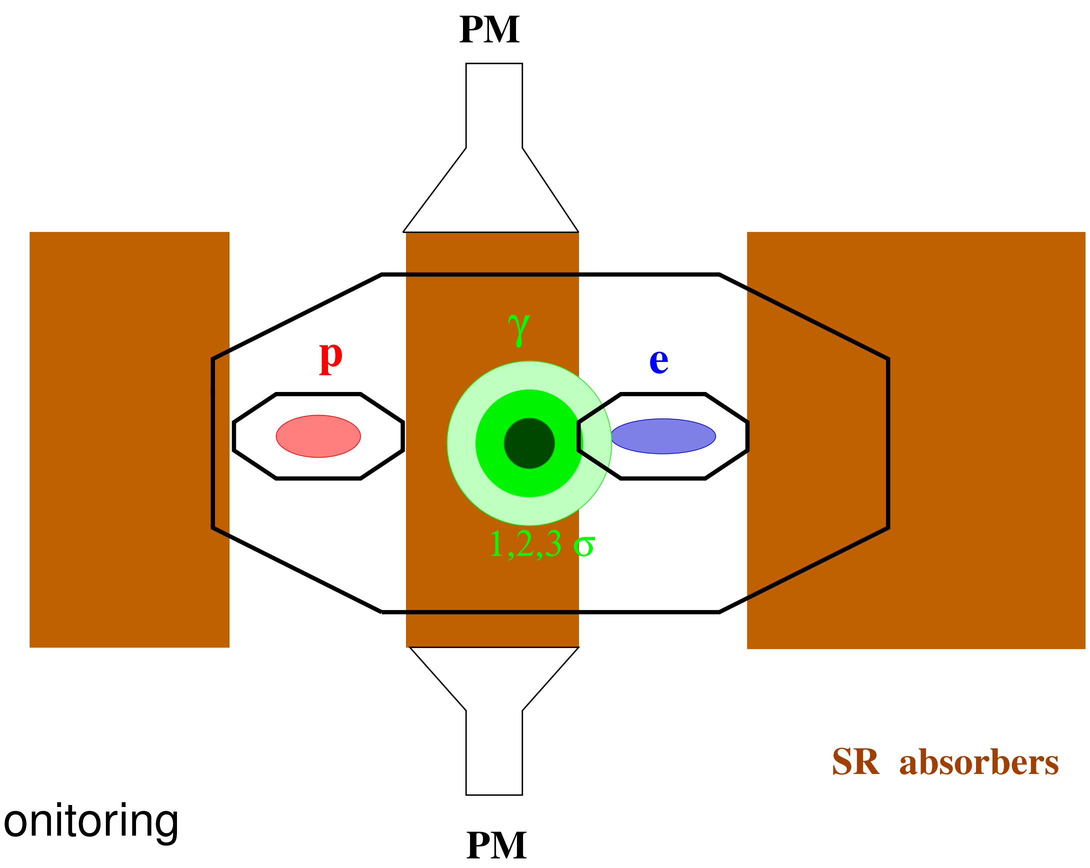


BH flux in SR absorber at 22m



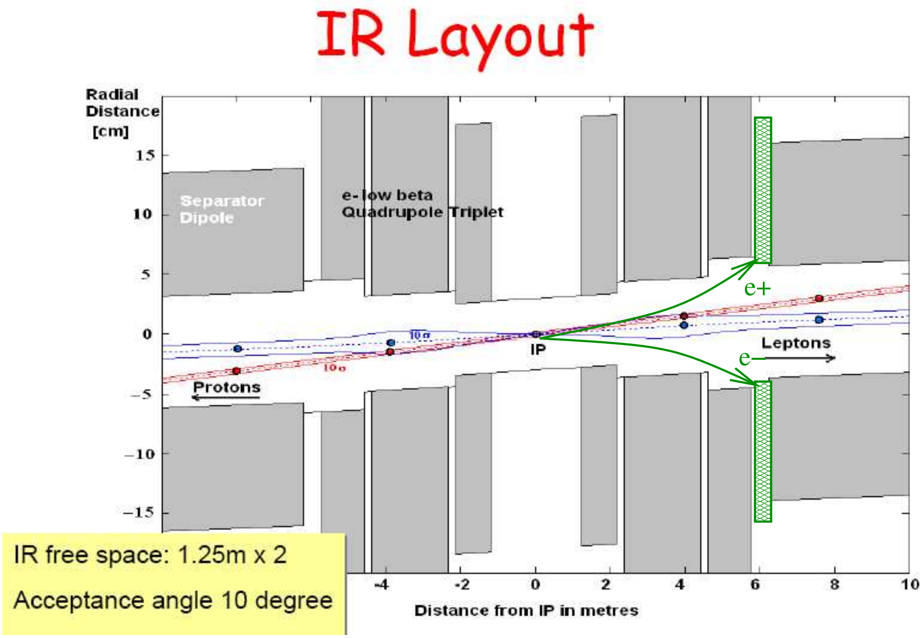
Exact BH counter design and R/O needed

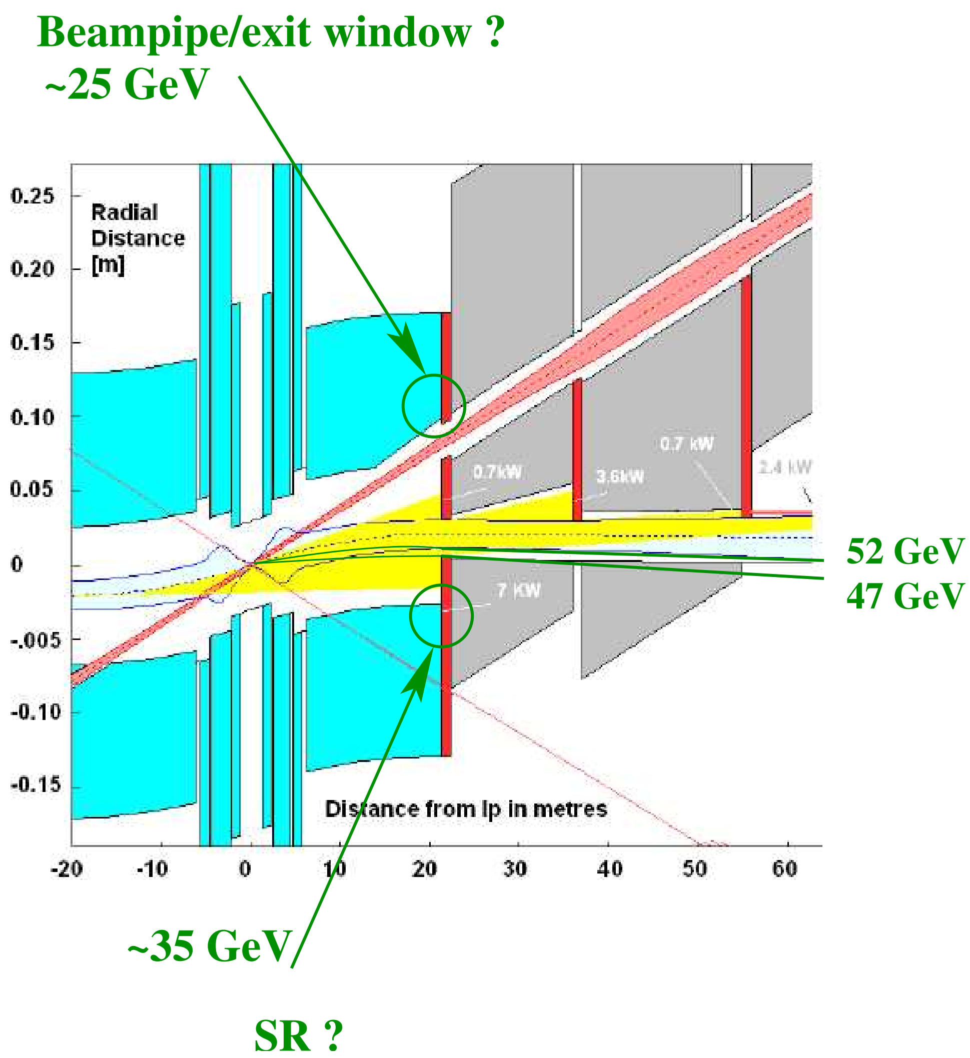
Optimisation of crossing angle might be useful



Acceptance control requires beam tilt monitoring

Options for Electron Taggers





- ET-6m requires some dipole field ⇒ not possible for low luminosity setup
- An option: split separator dipole and position ET at $z = 12 - 15$m ?

Further remarks about Electron Taggers

- $e-$taggers are also useful to enhance physics programme (tagged photoproduction)
- ET-6m is similar to H1/ZEUS taggers at HERA-2, or BP calorimeter of ZEUS at HERA-1
- Taggers for electrons/positrons with charge opposite to one of $e-$beam are in better positions for lumi monitoring as compared to "same-charge" taggers (lower off-momentum e-bgr, better SR environment)
- Energy calibration might be a problem (leakage, abs.scale – no $e - \gamma$ coinsidence)
- 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 Čerenkov Counter and e-taggers for online lumi measurement?
$\Rightarrow$ Look at HERA experience

Typical HERA2 Luminosity fill

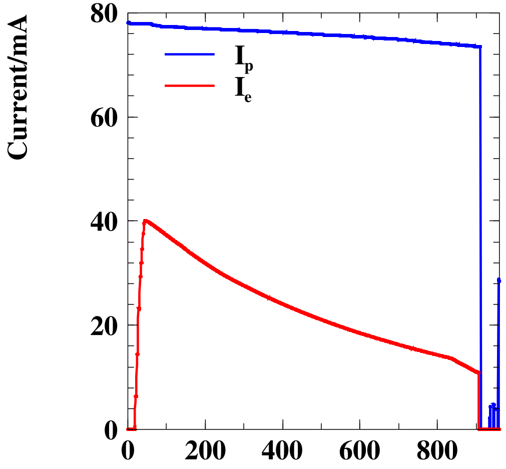


Figure 8

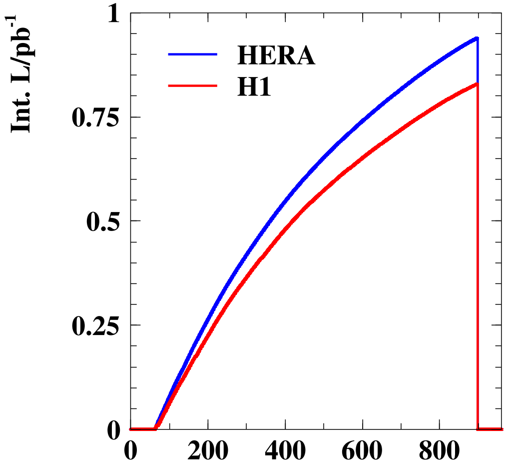


Figure 9

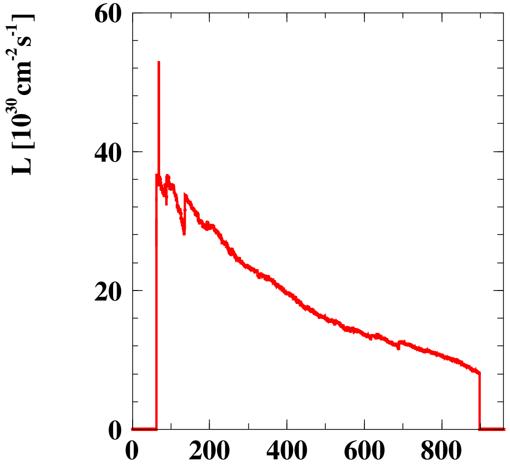
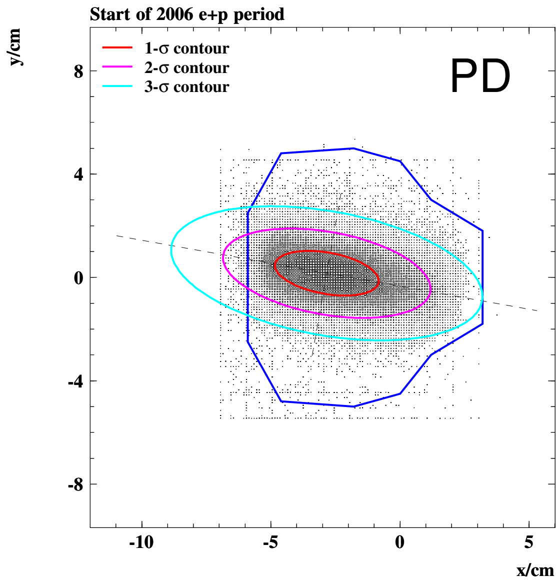
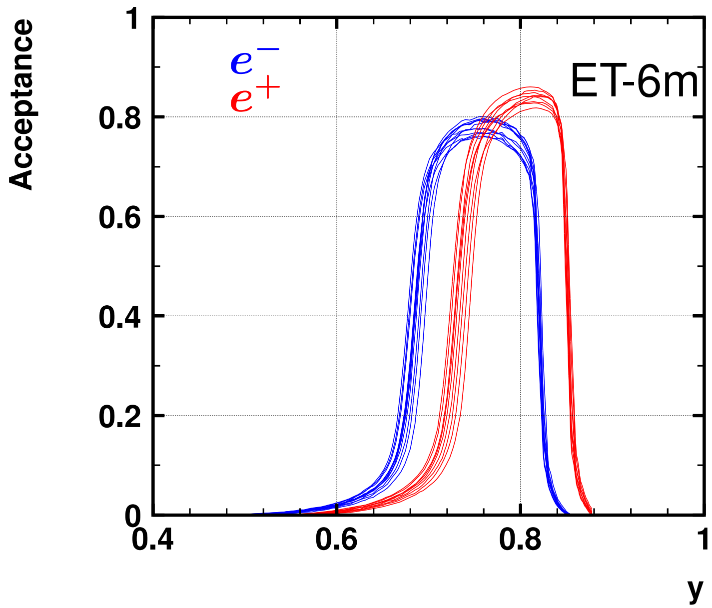


Figure 10





Rates at HERA2 (H1 Lumi system)

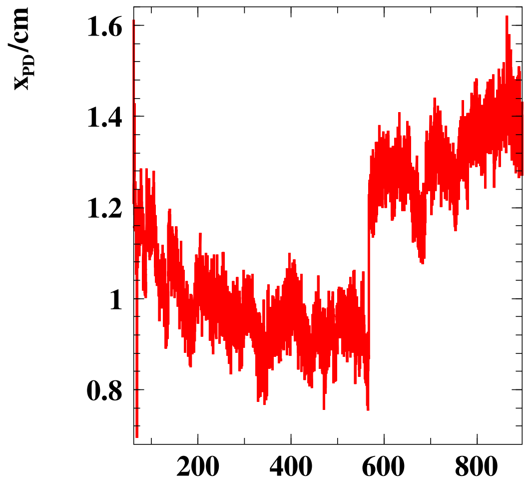


Figure 6

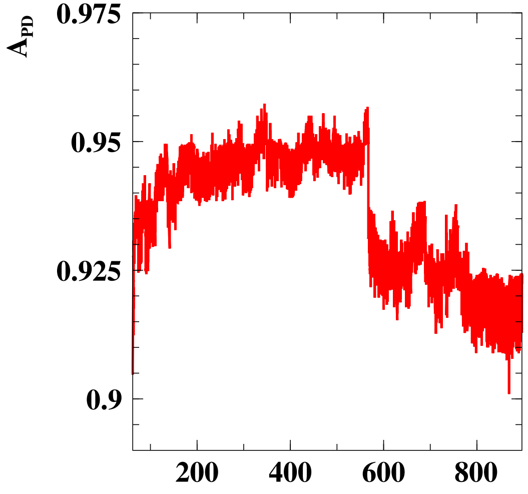


Figure 7

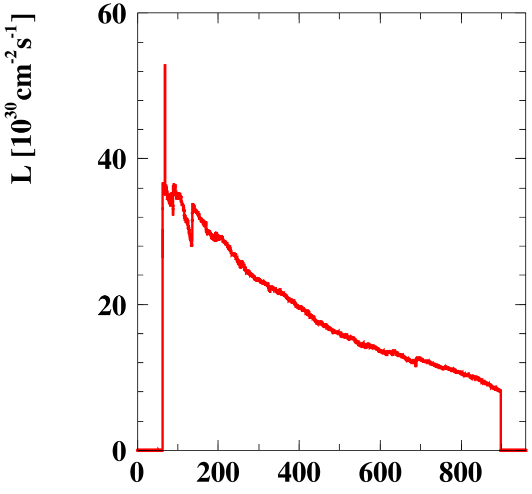


Figure 10

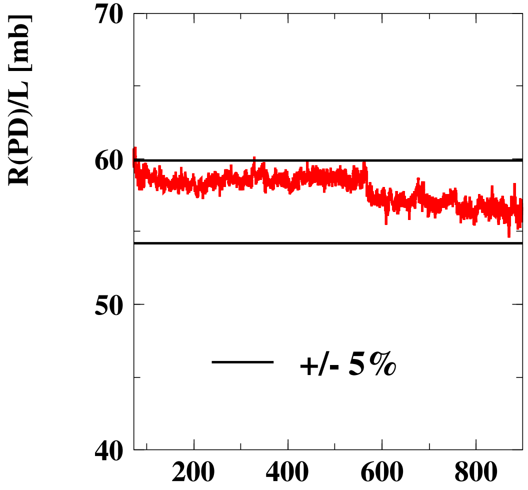


Figure 23

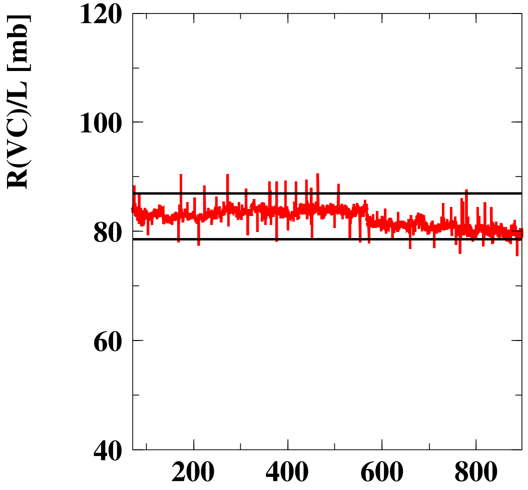


Figure 21

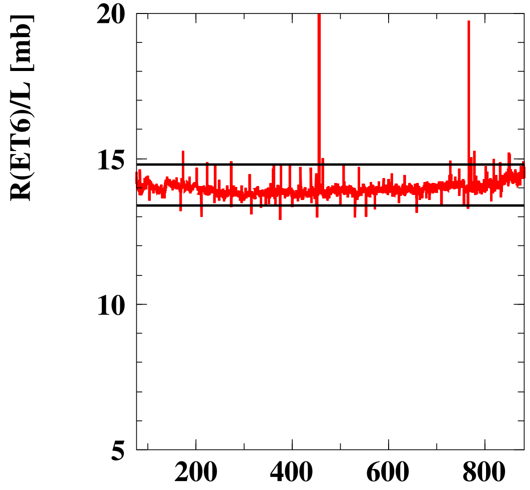


Figure 22

Summary

- Precise integrated $\mathcal{L}$ for physics is possible with main Detector (QEDC, F2)

- Fast instantaneous L monitoring is challenging, but few ”crasy” options exist

- Further investigations:
  - ▷ detailed optics at IP (is crossing angle and mag.separation fixed by now?)
  - ▷ more precise SR environment estimate at 6m, 21m and 60m
  - ▷ design of ”active absorber”, including light transmission and readout
  - ▷ acceptances of ET at 6m, 20m, 60m (optics and apertures)

- Prepare writeup
  - ▷ mention here also eA case ($L \propto 1/A$, $\sigma_{BH} \propto Z^2 \Rightarrow$ pileup $\propto Z/2$)