3rd CERN-ECFA-NuPECC Workshop on the LHeC

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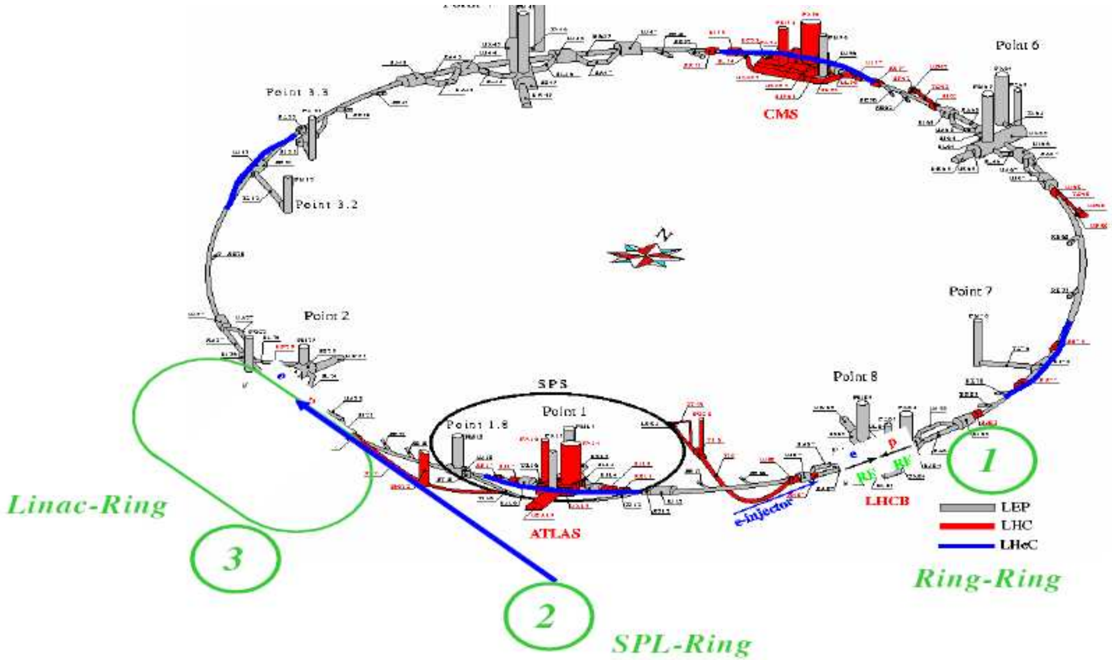
Europe/Zurich timezone

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

S. Levonian, DESY

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



# Preview

- 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 $z = 6$m is considered ("QEDC tagger")

- Active SR absorber at $22$m
  - ▷ 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 $62$m 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

# Mission

- optimization and tuning of $ep$-collisions
  $dL_{stat} = 1\%/sec$, overall scale $\sim 5\%$ is Ok $\Rightarrow$ $20$ kHz

- mid-term variations of instantaneous $L$
  $dL_{stat} = 1\%$ 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

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

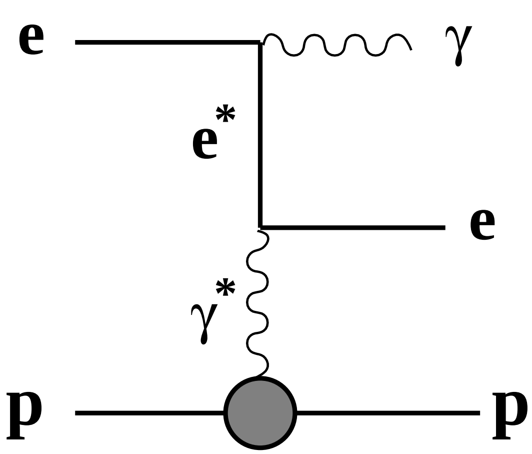
- optimization and tuning of $ep$-collisions
  $dL_{stat} = 1\%/sec$, overall scale $\sim 5\%$ is Ok ⇒ 20 kHz $> (0.02-2)$ mb

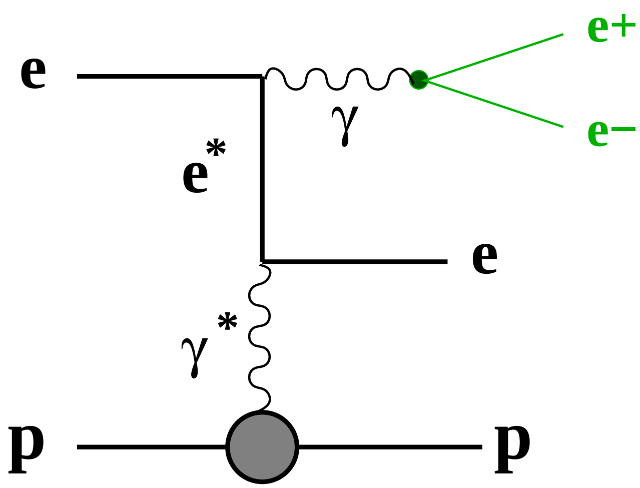
- mid-term variations of instantaneous $L$
  $dL_{stat} = 1\%$ per run (10 min - few hours) ⇒ 20 Hz $> (0.02-2)$ $\mu$b

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

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

# Processes




B-H process: $\sigma(E > 8) = 102$mb

(poles in both $e^*$ and $\gamma^*$ propagators)

B-H with "internal conversion"

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

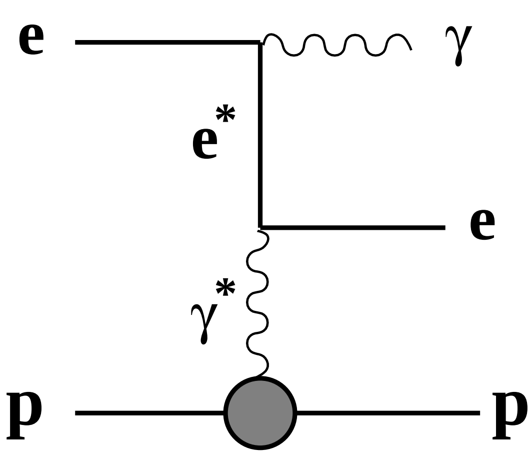
QED Compton: $\sigma_{\rm el}(\theta < 179^o) = 5$nb

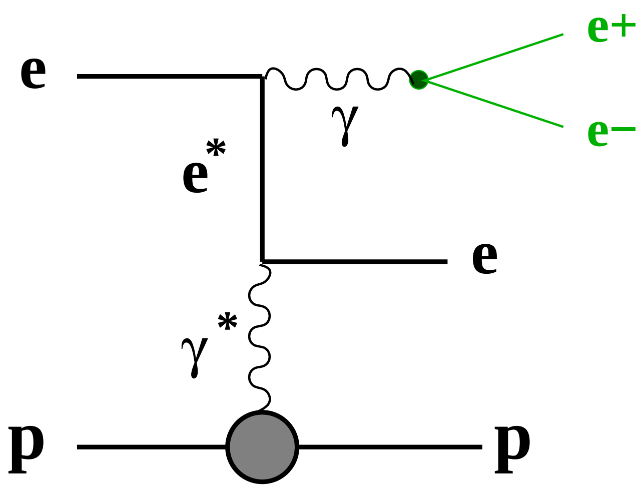
(poles in $\gamma^*$ propagator, but large $e^*$ mass)

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

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

# Processes




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

B-H process: $\sigma(E > 8) = 102$mb

(poles in both $e^*$ and $\gamma^*$ propagators)

B-H with "internal conversion"

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

## Main detector

QED Compton: $\sigma_{\rm el}(\theta < 179^o) = 5$nb

(poles in $\gamma^*$ propagator, but large $e^*$ mass)

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

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

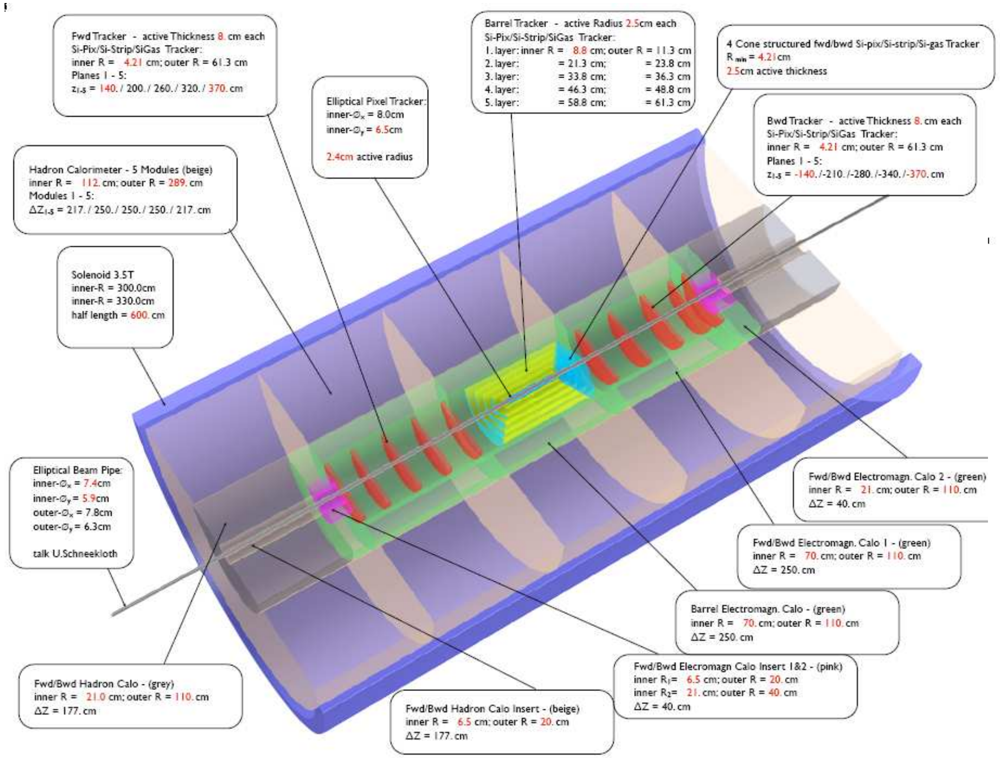
# Detector options

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

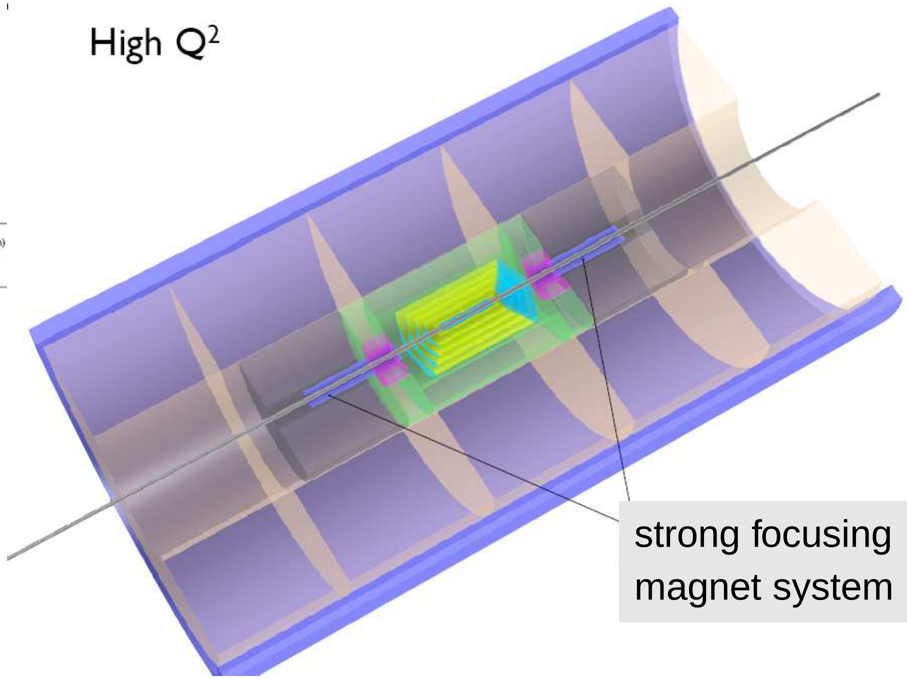
$1^o - 179^o$ acceptance ($9$ units in $\eta$)
at $L = 10^{31}\mathrm{cm}^{-2}\mathrm{s}^{-1}$

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

(courtesy P. Kostka)




Low $Q^2$



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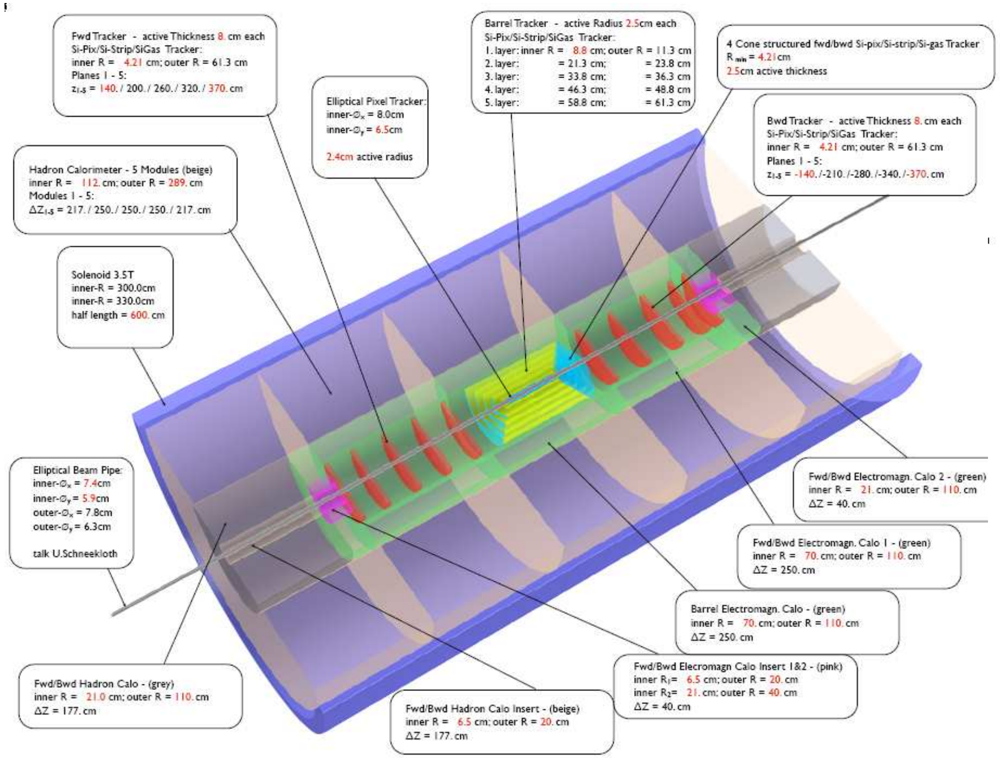
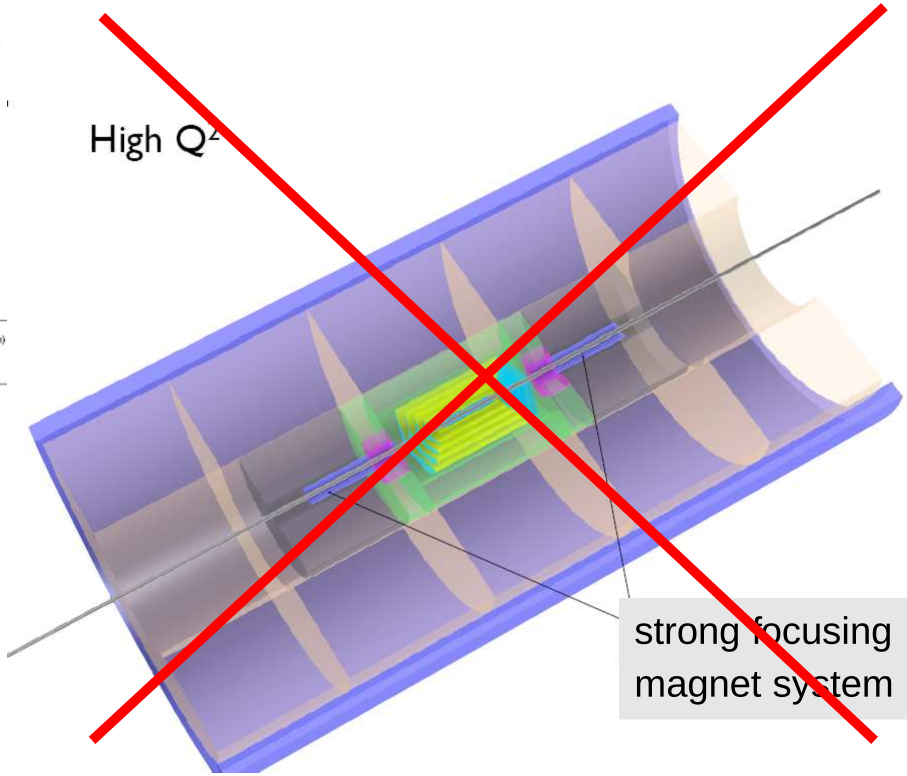


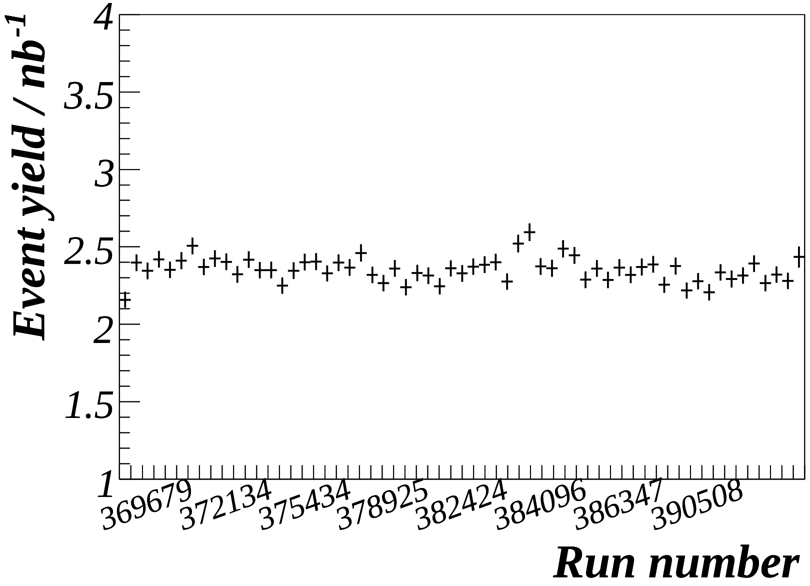

Low $Q^2$

(courtesy P. Kostka)

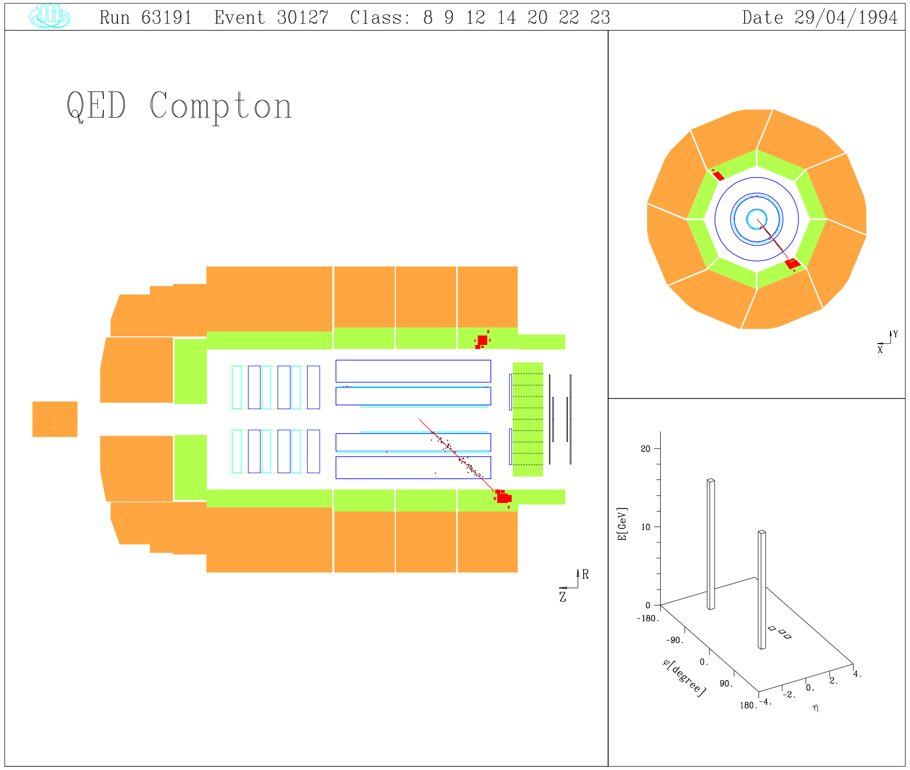


strong focusing magnet system

# Examples 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) |

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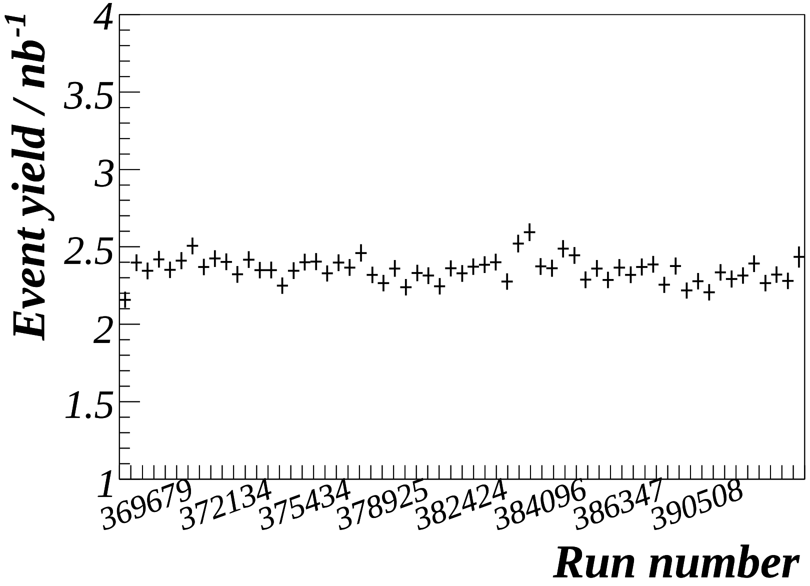


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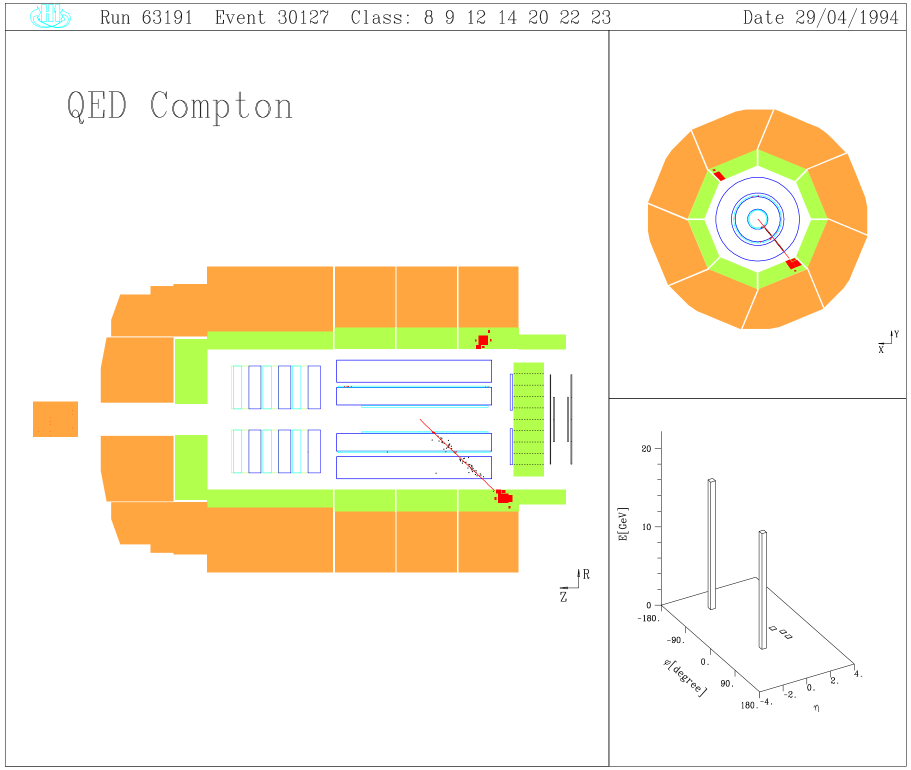


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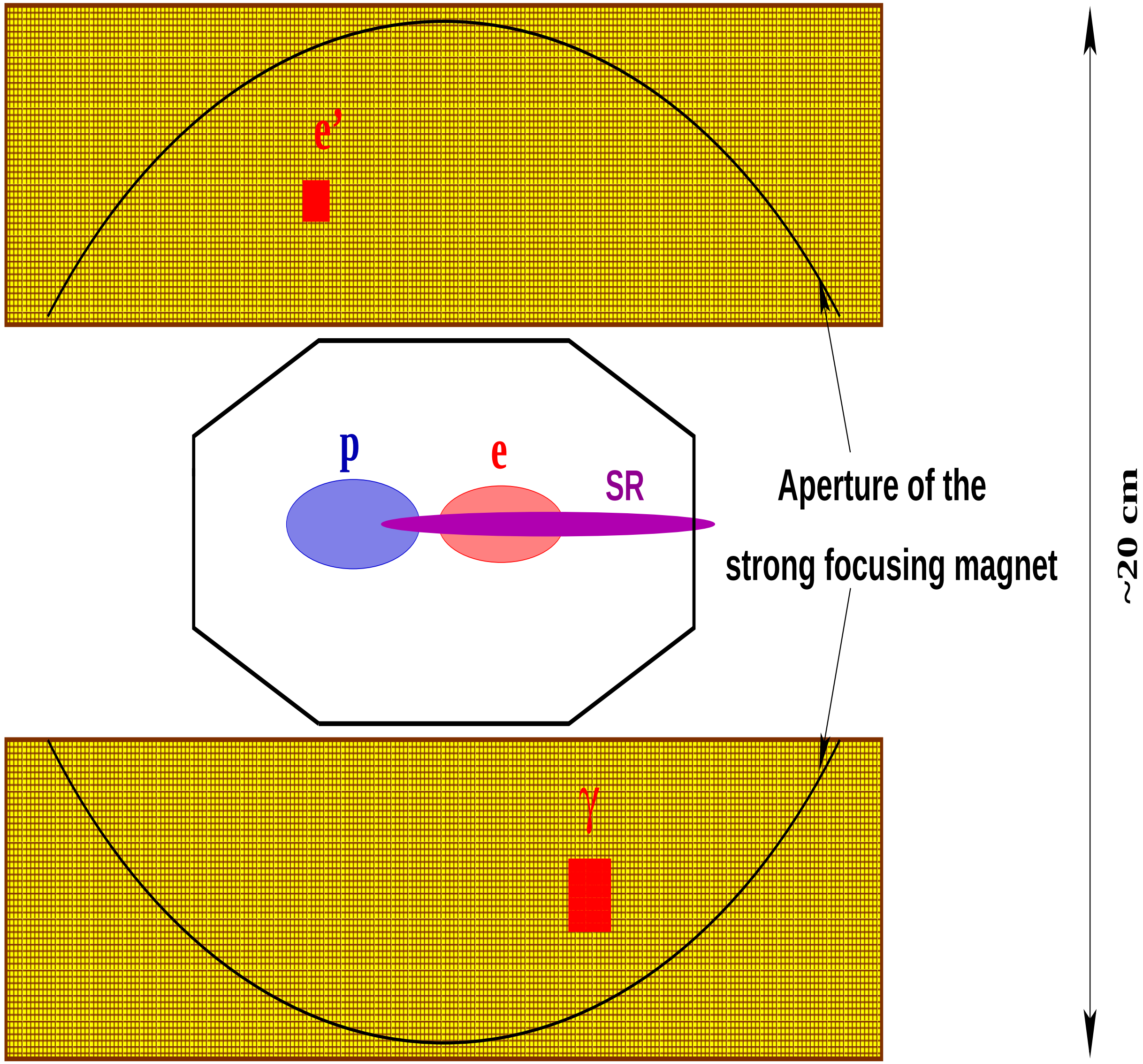
**+ VLQ (6m)?**

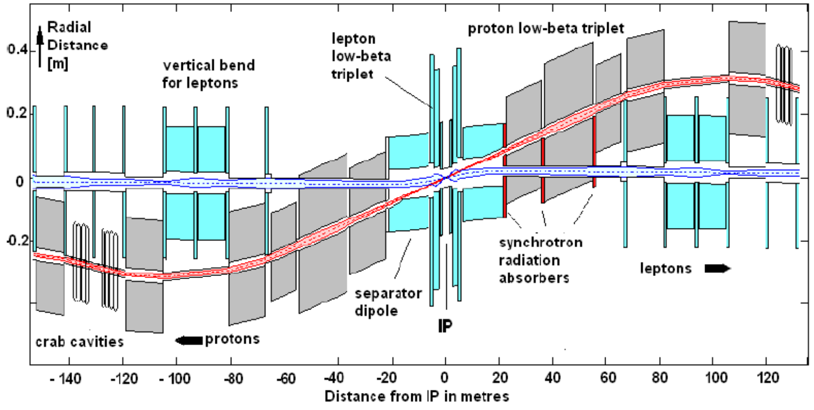
# An option of VLQ/BPC at 6m ?




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

# Challenges in Linac-Ring and Ring-Ring options

IR Layout



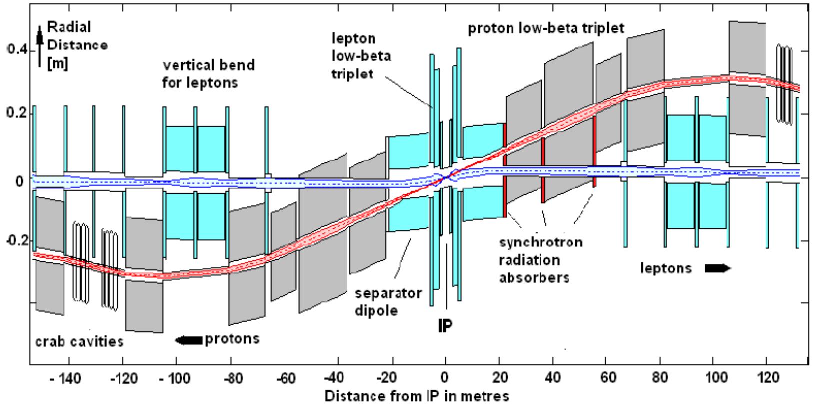

- crossing angle at IP
- large SR flux

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

**RR scheme**

# Challenges in Linac-Ring and Ring-Ring options

## IR Layout

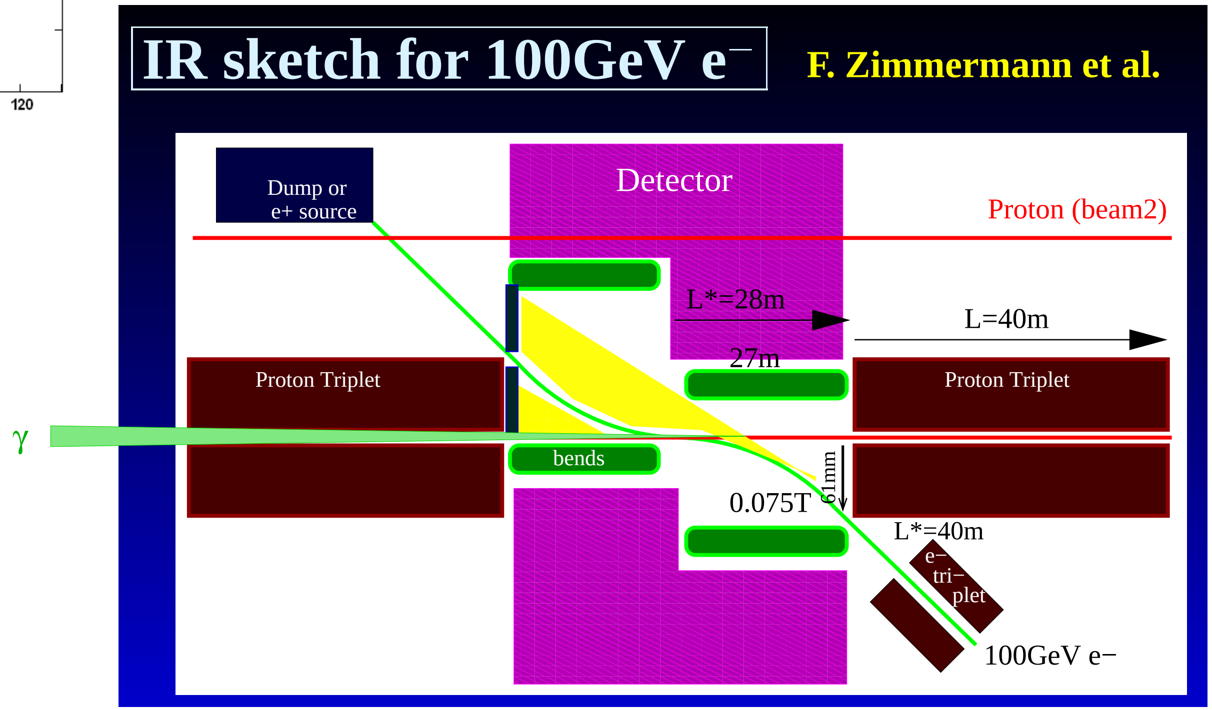



- crossing angle at IP
- large SR flux

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

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

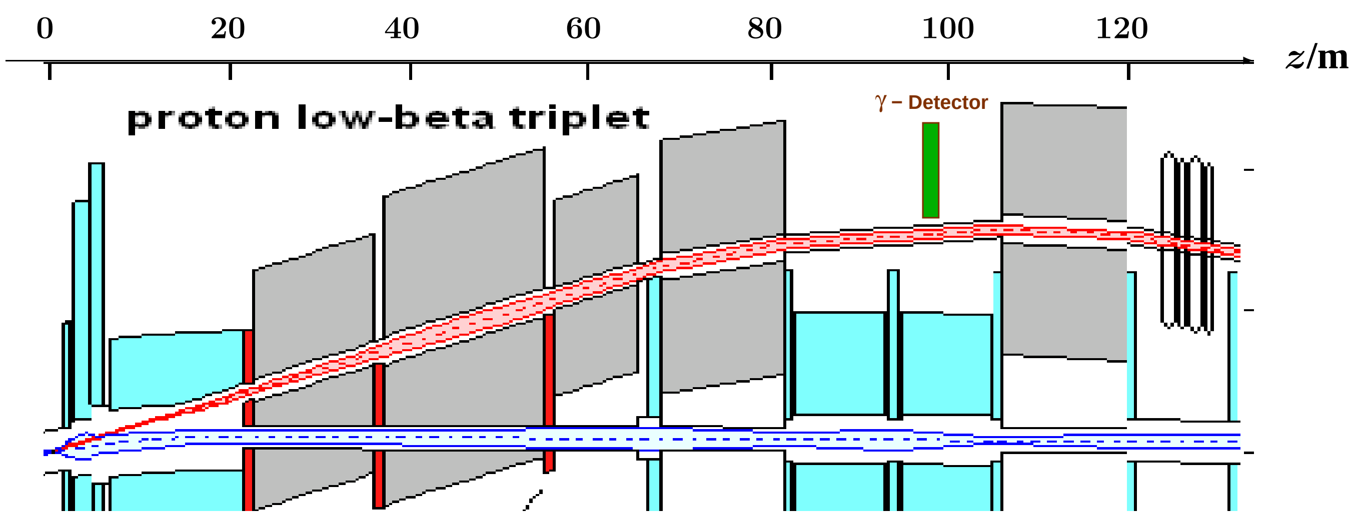
  $\Rightarrow$ Challenge: large aperture required for proton magnets at $z = 60 - 80$m

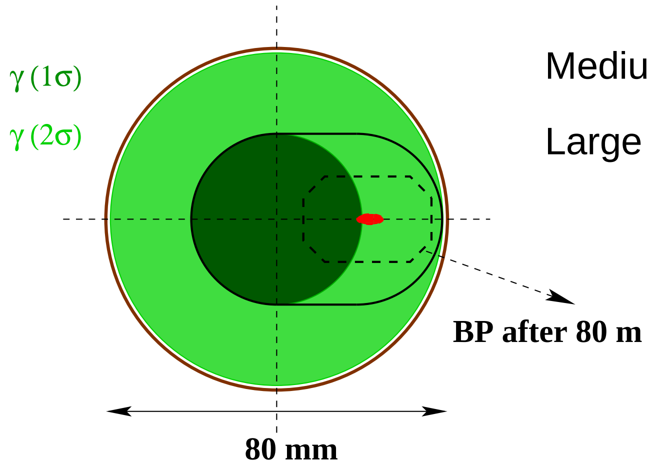



**RR scheme**

**LR scheme**

# LR option



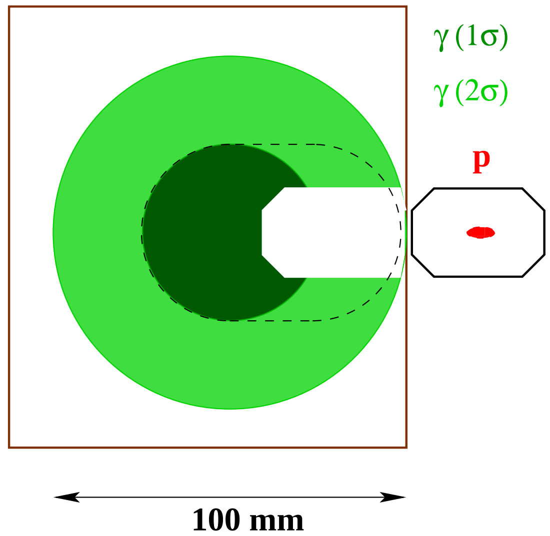




Beampipe at z=80m

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

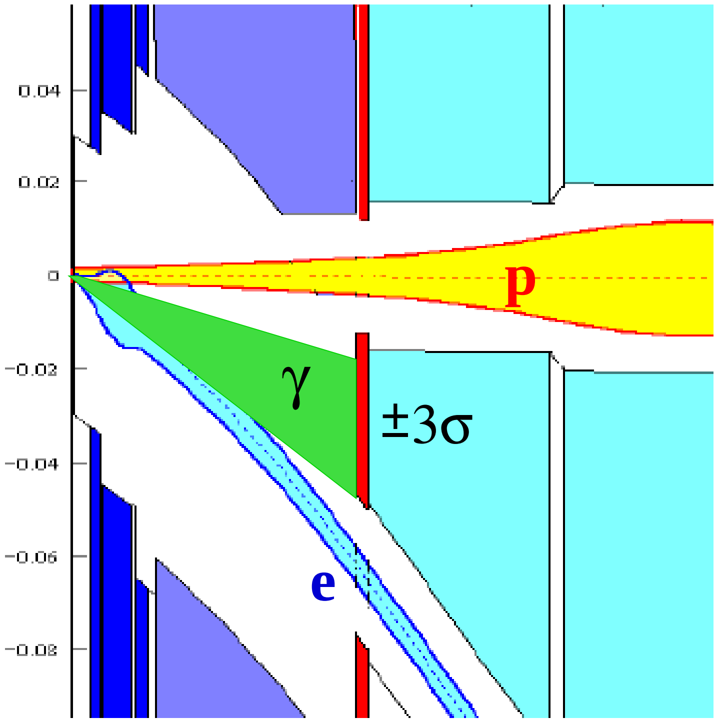
$\Rightarrow$ $60$ mm beam separation at $22$m

**B**

Crossing angle $= 1.5$ mr

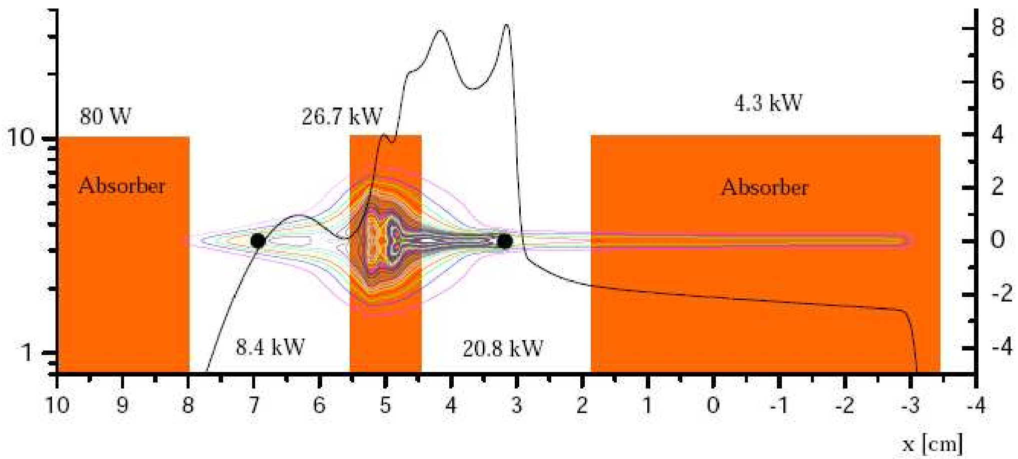
Magnetic separation $= 0.75$ mr

$\Rightarrow$ $40$ mm beam separation at $22$m




F. Willeke, May 2008

**SR power profile at 22m**



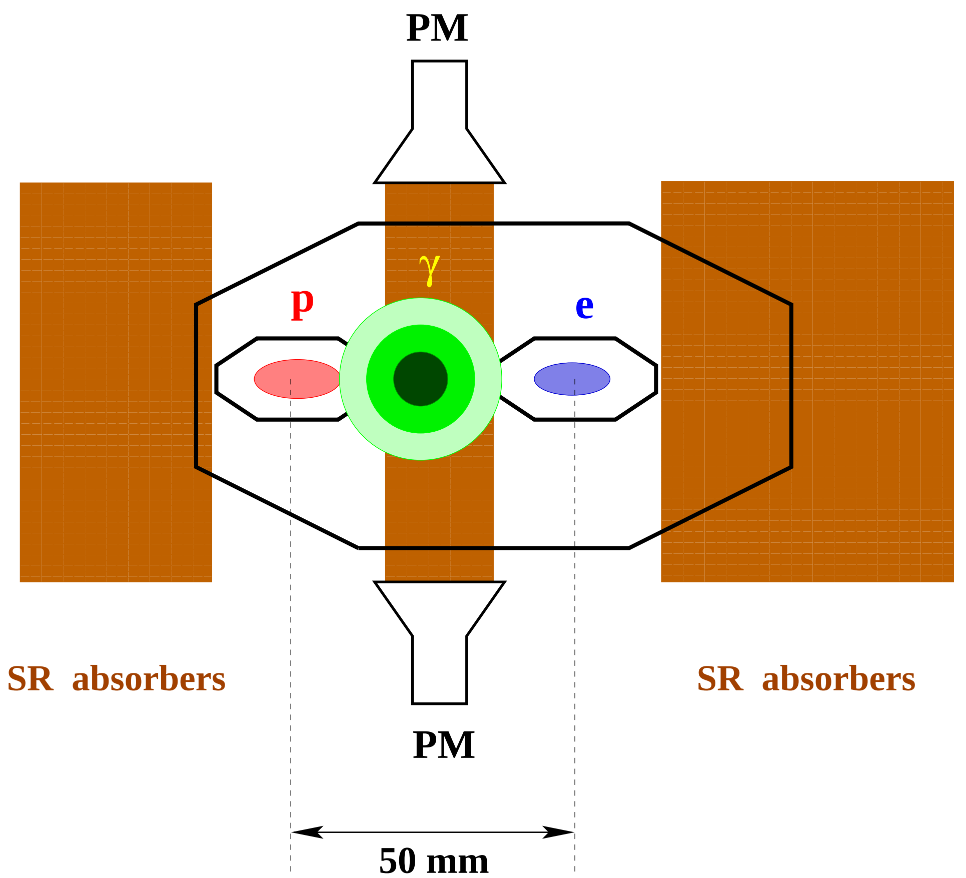

B. Holzer / B. Nagorny, Sept 2008

BH spot at the hottest place!

# Active SR absorber

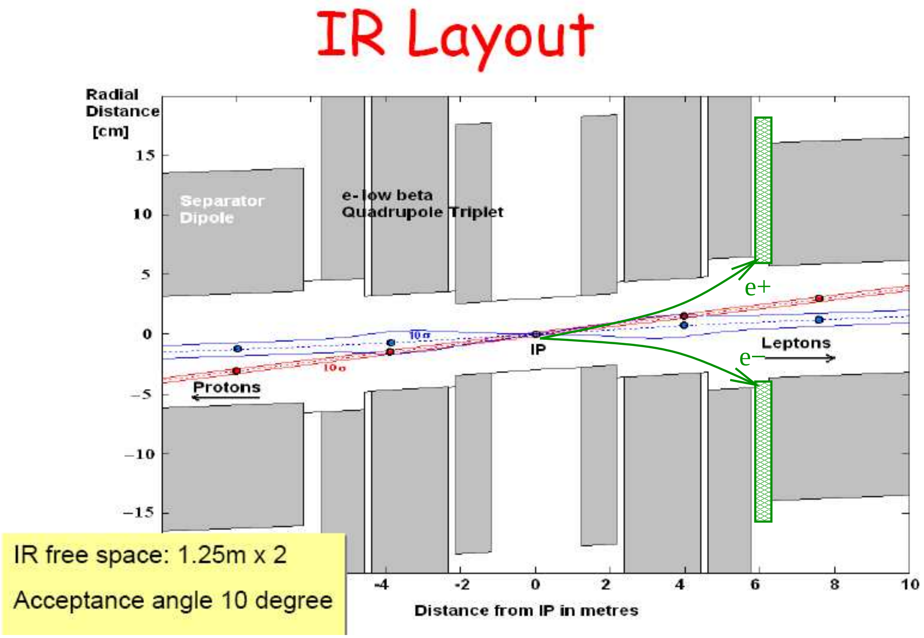
## BH-photon detector integrated into SR absorber

- 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)

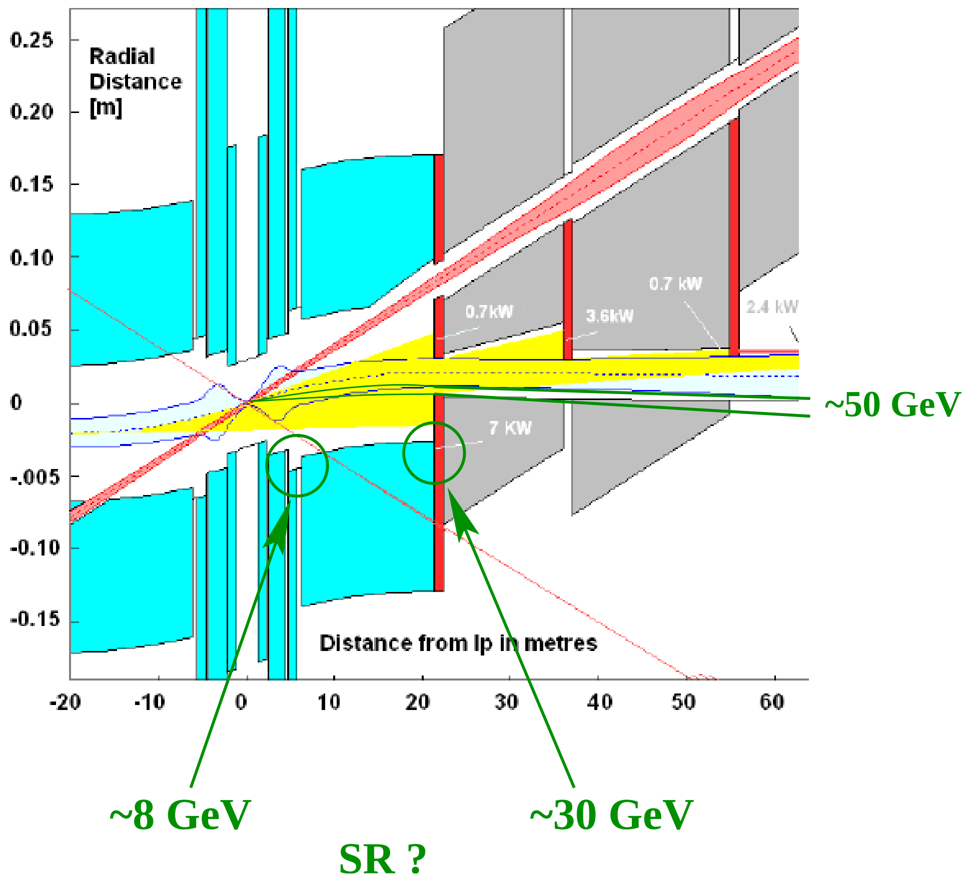



$\delta L = 3\%$ within reach

# Options for Electron Taggers



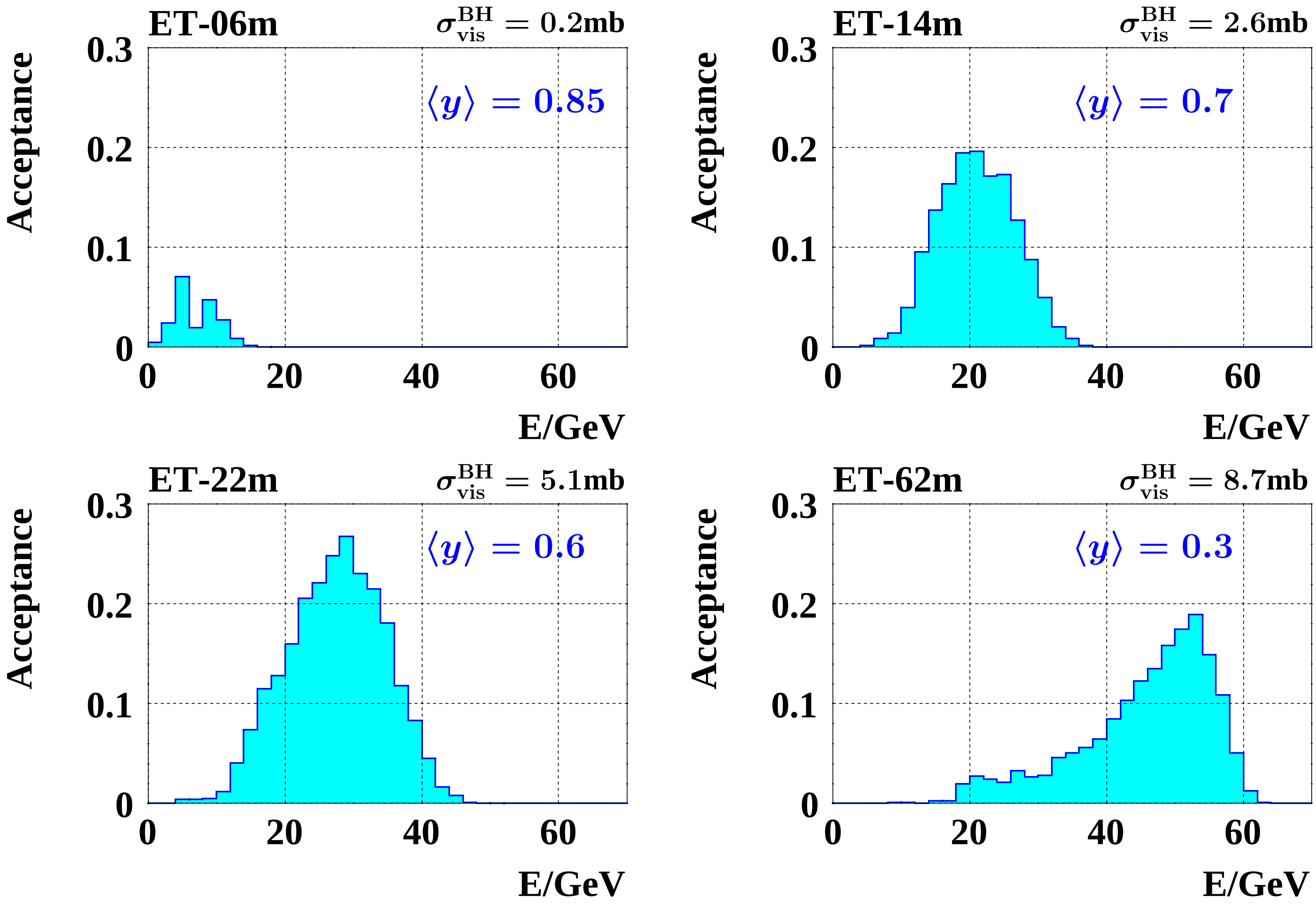

- An option: split separator dipole and position ET at $z = 13 - 14$m ?



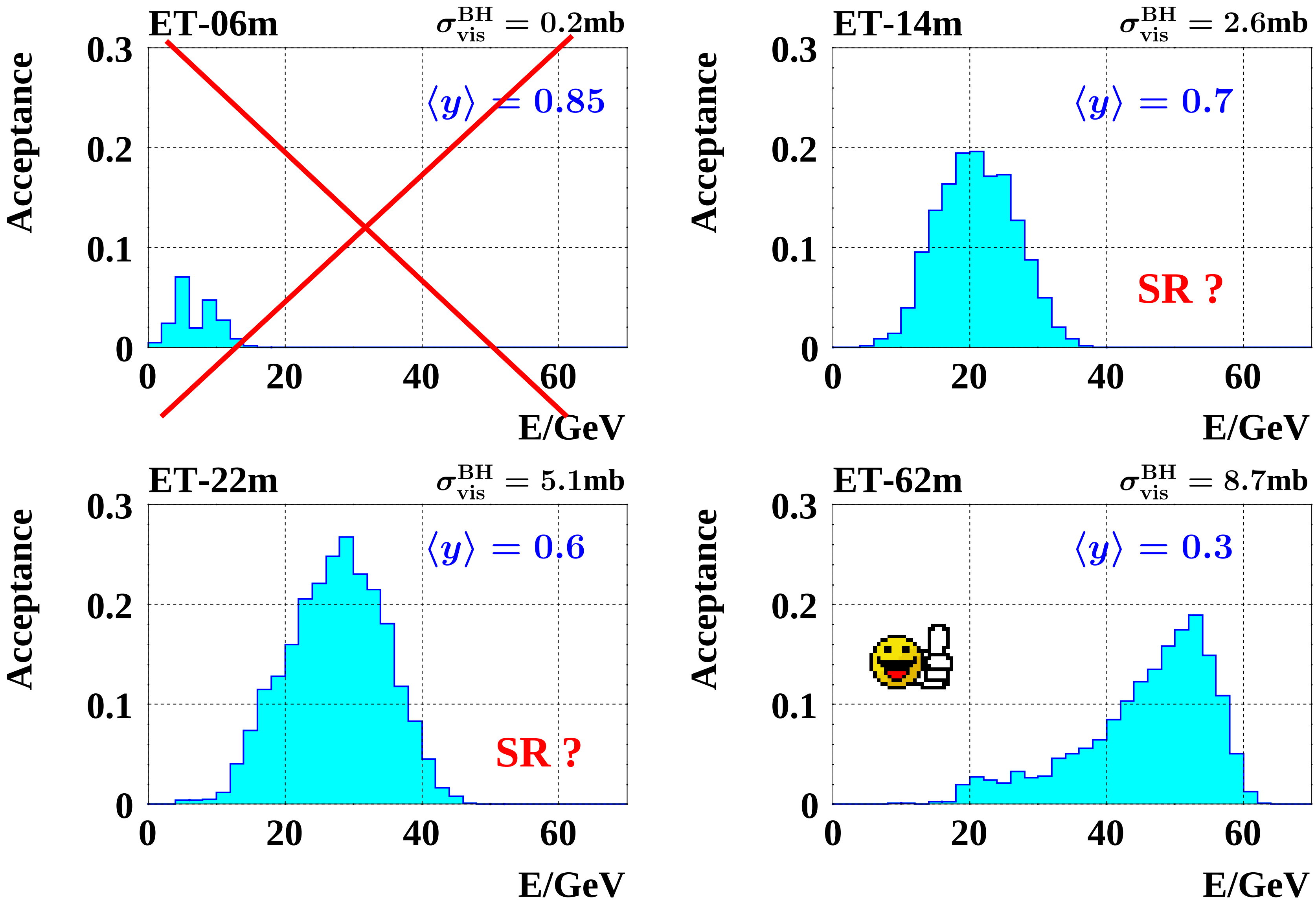

- ET-6m requires some dipole field $\Rightarrow$ not possible for low luminosity setup

- This place perhaps better siuted for vertical VLQ stations ("QEDC tagger")

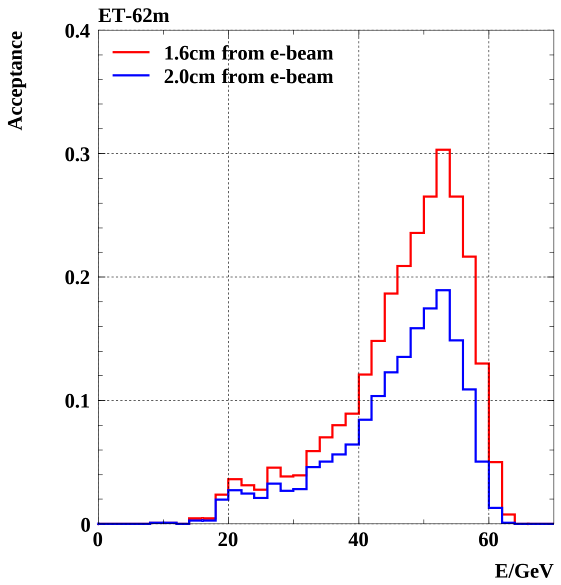
# e-Tagger Acceptances (70 GeV case)

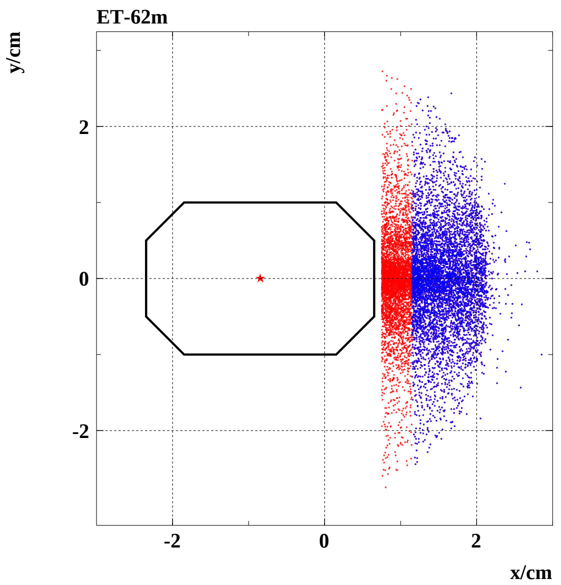


# e-Tagger Acceptances (70 GeV case)



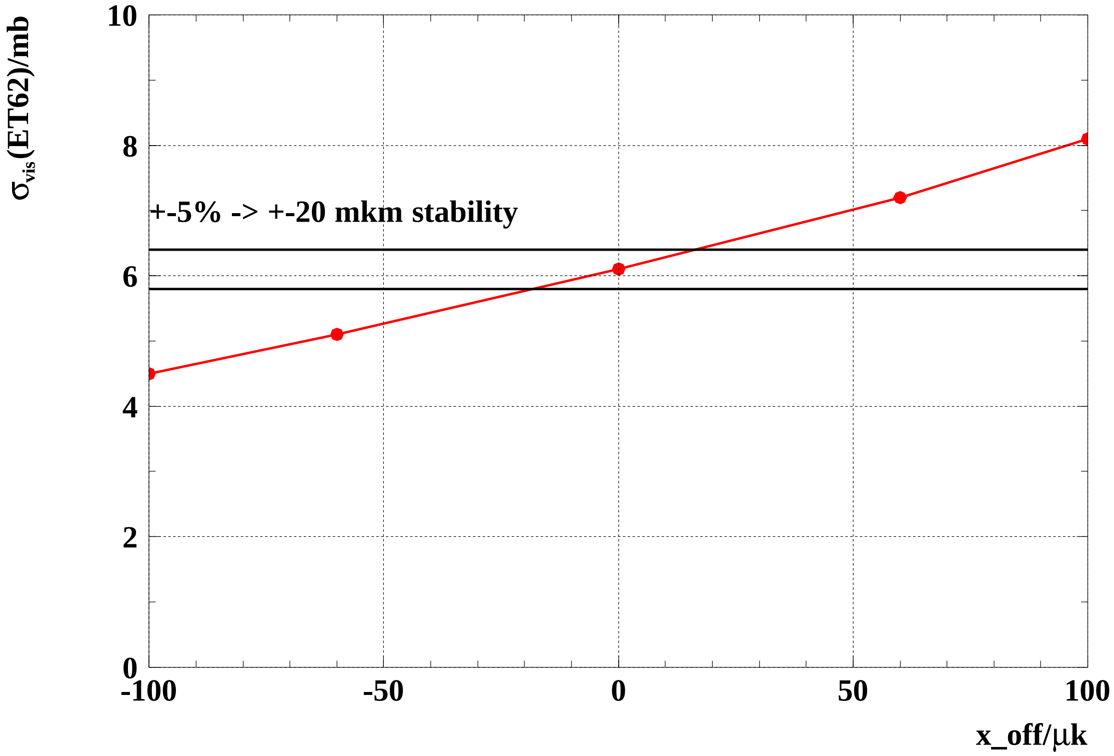
# ET-62m Acceptance variations




## Acceptance control requirements

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

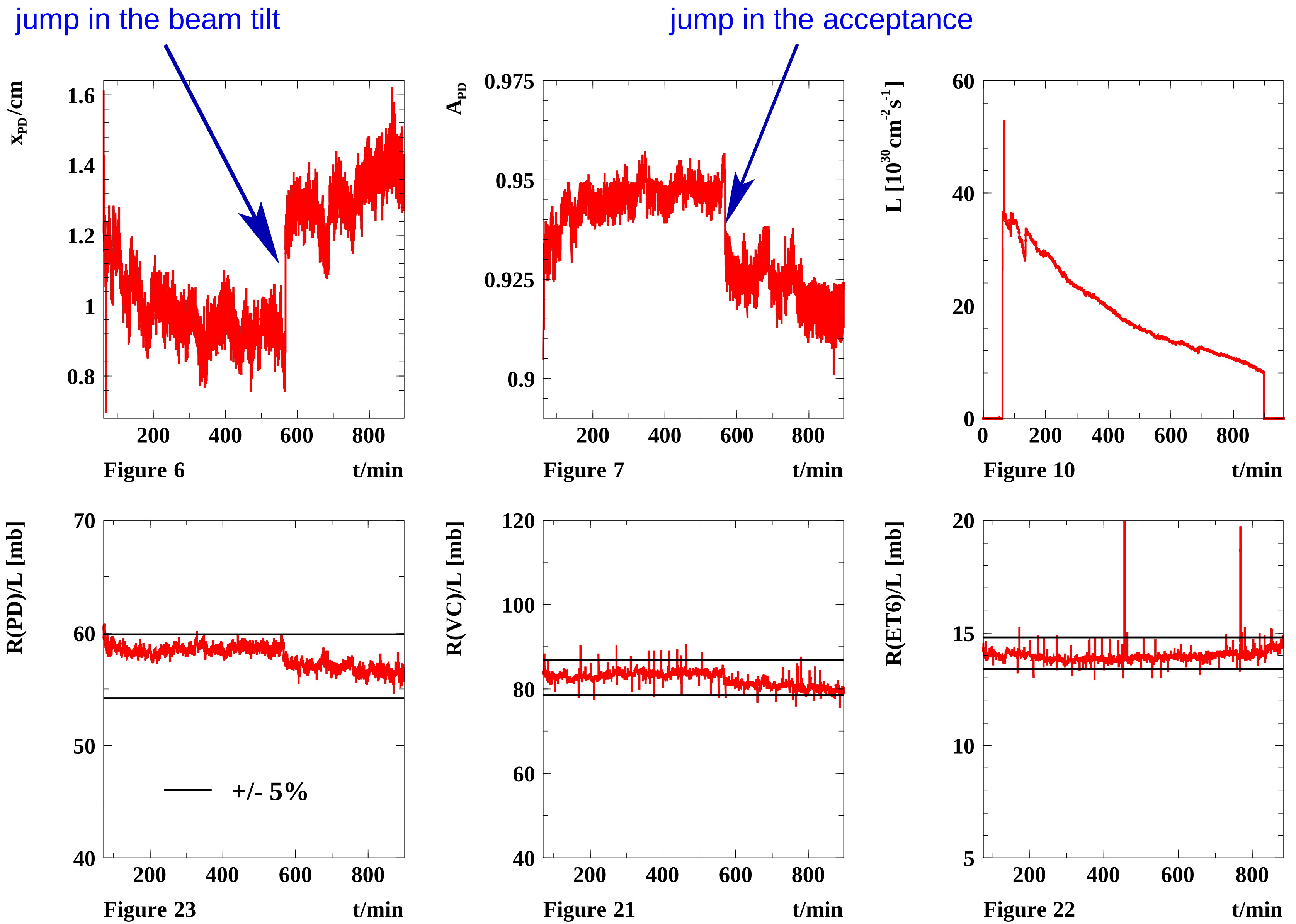


# Further remarks about Electron Taggers

- $e-$taggers are also useful to enhance physics programme (tagged $\gamma p$). 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**

# Rates at HERA (H1 Lumi system)



# Dominant systematics

| Method | Stat. error | Syst.error | Systematic error components | | | Application |
|---|---|---|---|---|---|---|
| BH ($\gamma$) | $0.1\%$/sec | $3-6\%$ | x-section | = | $0.5\%$ | Monitoring, tuning, |
| | | | acceptance, $A$ | = | $10\%(1-A)$ | Absolute $L$ (?), |
| | | | $E$-scale, pileup | = | $1-4\%$ | 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 normalization |
| | | | 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 at $22$m
  - $\triangleright$ 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

# Work for CDR and beyond

- Update ET-$62$m 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) && !$\gamma$(PD/ASRF)
- Continue to look for bright ideas capable of $\delta\mathcal{L} \leq 1\%$