Test Beam Results
of the
Quartz Fibre Calorimeter
for the
H1 luminosity

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- The new luminometer : motivations and description
- Calibration procedure and uniformity
- Photostatistics
- Energy linearity and resolution
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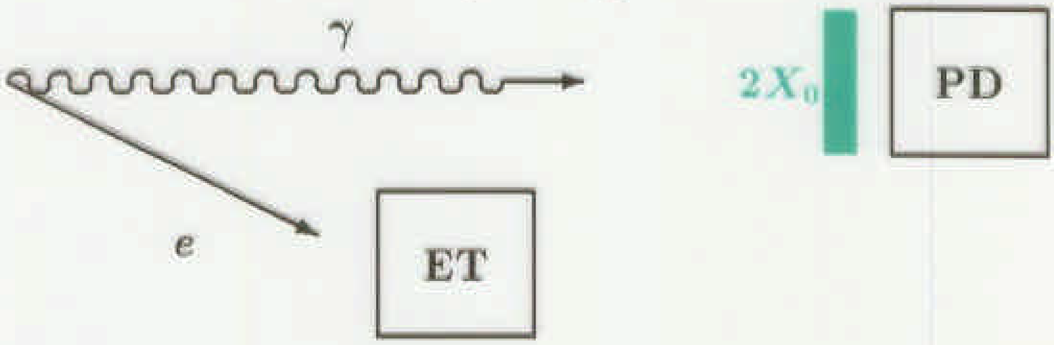
- Summary

A new luminometer for H1

Luminosity measurement at HERA based on bremsstrahlung process :

$$ep \rightarrow e\gamma p$$



HERA upgrade in 2000/2001

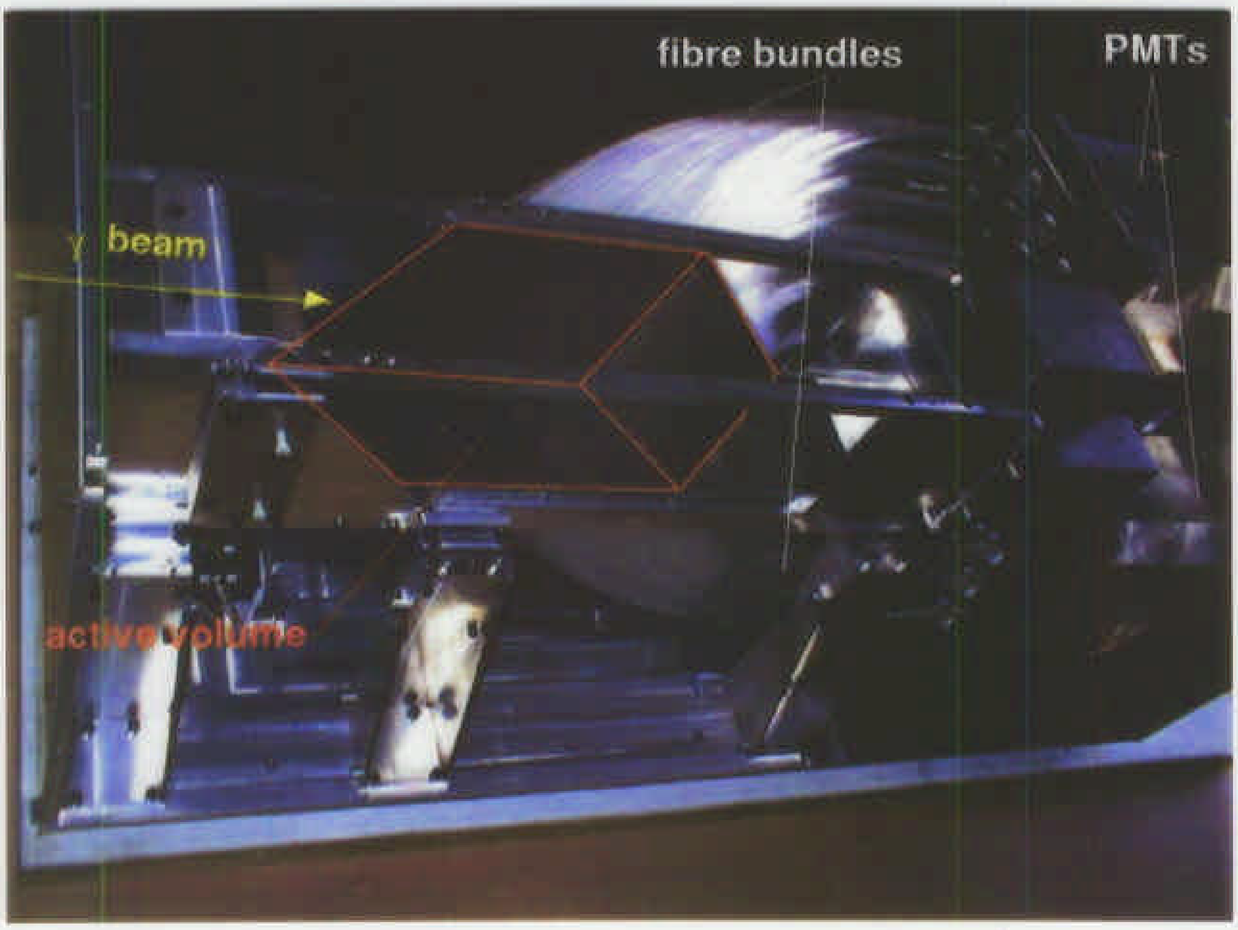
- Luminosity $\times 5$ using low-β focalisation magnets
  ⇒ Huge synchrotron radiation background (doses up to GigaRad)
- Longitudinal polarisation
  ⇒ Bunch by bunch luminosity (and polarisation) measurement with precision of 1 % /bunch/minute

⟹ Choice of quartz-fiber Čerenkov calorimetry for H1 luminosity measurement after HERA upgrade

- Radiation hardness tested in lab.
  ⇒ quartz core/polymer cladding optimal choice performance/cost
- Čerenkov threshold = 0.7 MeV
  ⇒ natural cut-off to low-energy particles
- Limited space available in HERA tunnel
  ⇒ choice of tungsten as absorber for maximum compactness
- Fibre angle w.r.t. beam = 45°
  ⇒ close to Čerenkov angle, for maximum light collection
  ⇒ unsensitivity to background from the proton side (halo muons)

A new luminometer for H1

- 69 layers, each with 224 fibres (diameter = 0.6 mm)
- 70 tungsten plates (thickness = 0.7 mm)
- orientation of fibres in each layer : 45° angle w.r.t. beam alternatively in horizontal or vertical plane (along x and y in the transverse plane)
- fibres grouped in 12 bundles in each direction
- 12 x + 12 y strips (width = 1 cm) $\Longleftrightarrow$ square cell segmentation
- 24 light mixers + 24 Photonics XP2978 phototubes
- 4 LEDs for optical monitoring of PMs (gain) and fibres (light yield)



- active volume : 12 x 12 x 17 cm^3
- W/fibre volume ratio : 1.68
- average $X_0 = 7.8$ mm
- Molière radius = 17.2 mm

Energy calibration and spatial uniformity

Results of tests at CERN-SPS H4 beam in 1999 with e (8 to 100 GeV), μ (225 GeV) and γ (e bremsstrahlung on Cu target)

Calibration procedure

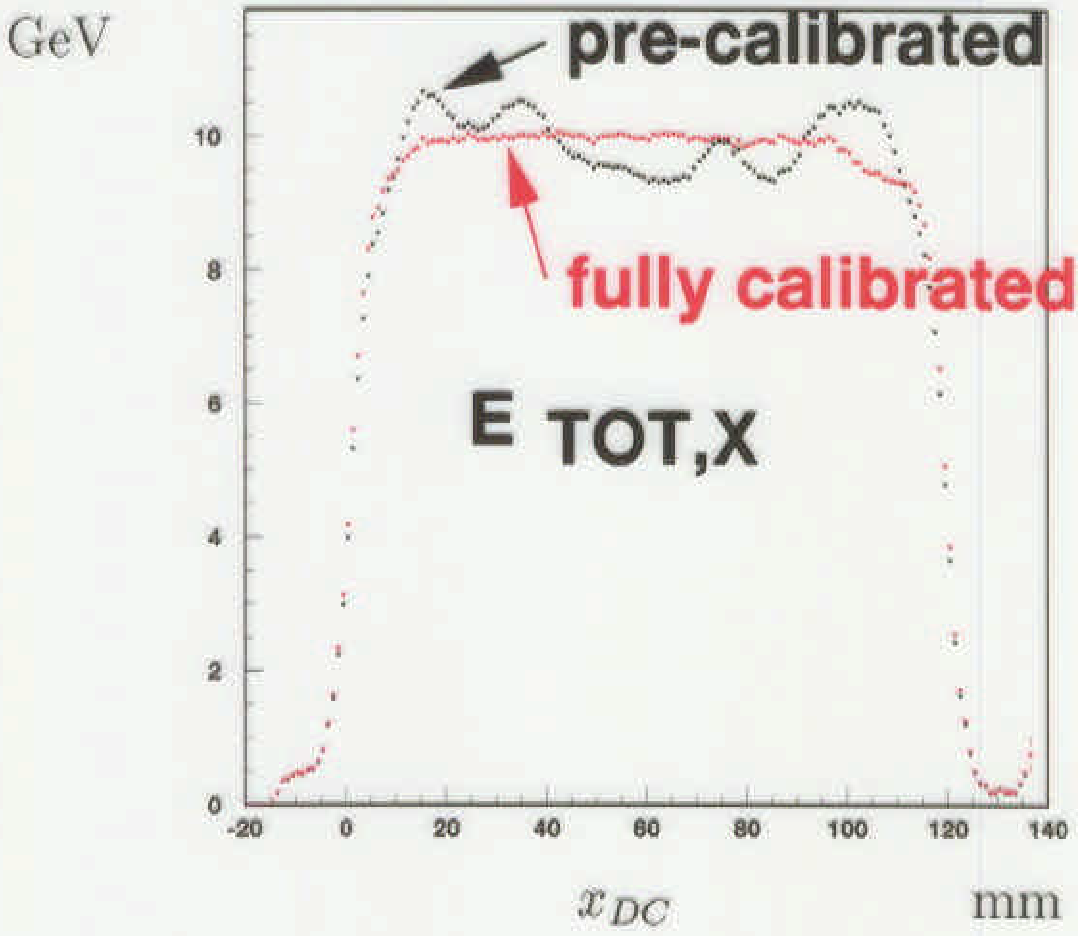
- Electrons at fixed energy (20 GeV), position scan
- Intercalibrate strips in each direction separately

Step 1) Select narrow showers (i.e. 75 % energy in one strip)

Step 2) Gaussian fit ($\pm 2\sigma$)

Step 3) Adjust calibration coefficients to equalize energy response

Iterate until convergence (obtained after 3 iterations)



$\Rightarrow$ Uniformity better than 1 %

Photostatistics

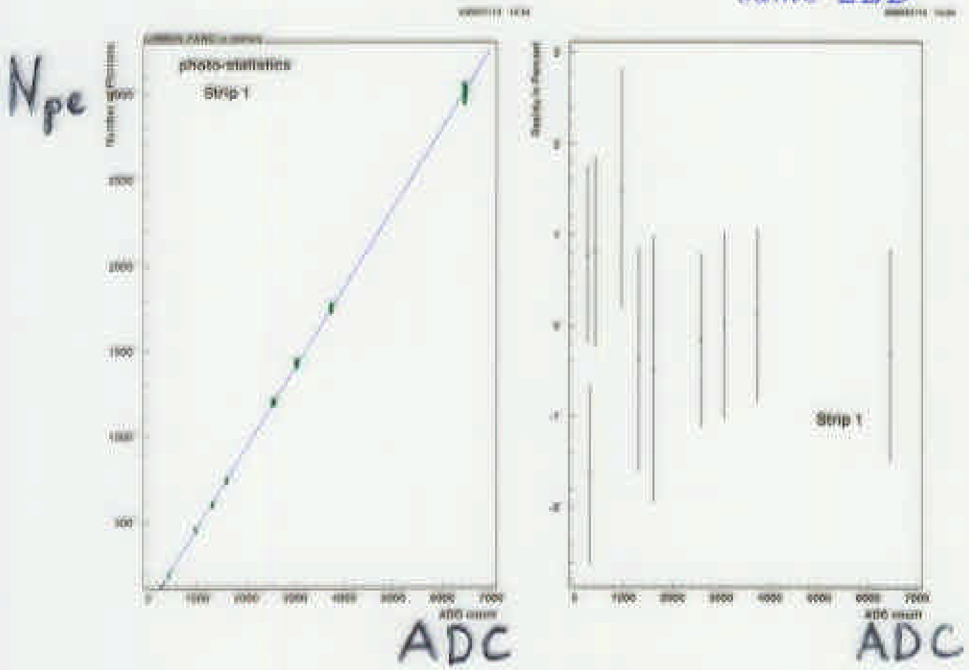
LED calibration events with adjustable light amplitude

- Light injected at each PM i, S_i measured at output
- Each of the 4 LEDs pulses 6 channels at a time
- Electronics noise negligible
- Assume LED light pulses fluctuations only statistical

$$\Rightarrow N^i_{pe} = \frac{1+V_G}{V_{S_i}} \quad \begin{cases} -V_G \text{ relative variance } (\equiv \frac{\sigma^2}{<>^2}) \text{ of gain of PM (measured } V_G = 0.36) \\ -V_{S_i} \text{ relative variance of channel } i \end{cases}$$

Problem : systematic variations of LED

Solution : use $X_i = S_i/(\sum_{j\neq i, \text{ same LED}} S_j)$ instead of S_i



Example of results for one channel :

$N_{pe} \leftrightarrow$ ADC linear within $\pm 1\%$

- Determination of "optical" calibration : N_{pe}/ADC count
- Coefficients ADC$\rightarrow$GeV known from energy calibration

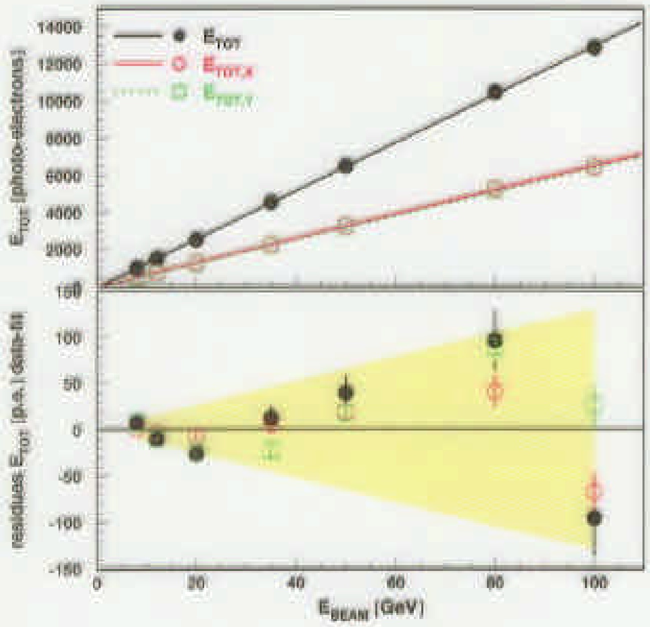
$$< N_{pe} >= 130 \pm 5 \text{ photo-electrons/GeV}$$

$\Rightarrow$ Photostatistics contribution to the resolution :

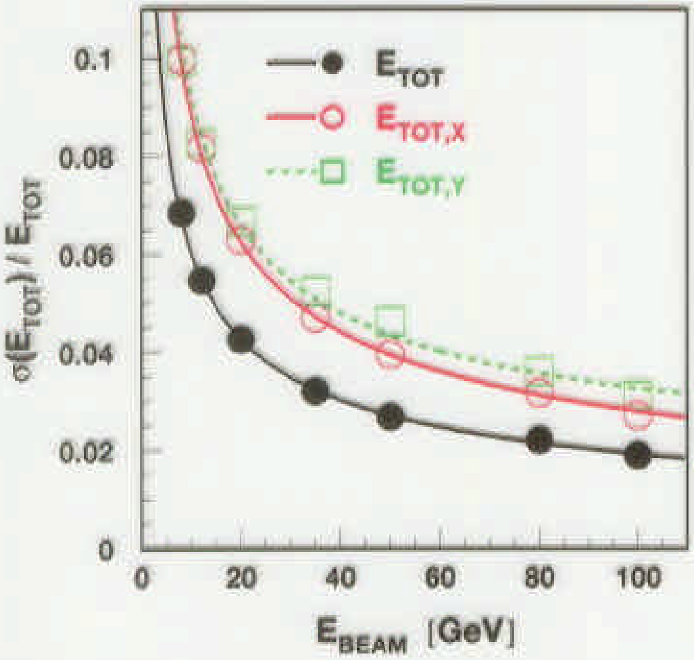
$$\sigma_E^{photostat.}/E = 8.8\%/\sqrt{E} \;(E \text{ in GeV})$$

Energy linearity and resolution

Electrons from 8 to 100 GeV



Energy response linear within ±1%



Energy resolution

$\sigma_E/E = 19\%/\sqrt{E}$

(E in GeV)

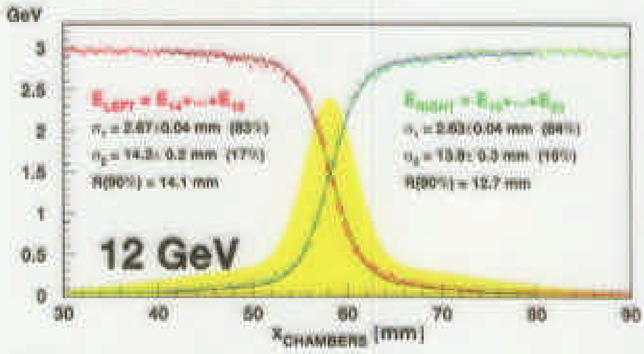
- Constant term compatible with 0
- Photostatistics term = $8\%/\sqrt{E}$ ⇒ Sampling term = $16\%/\sqrt{E}$

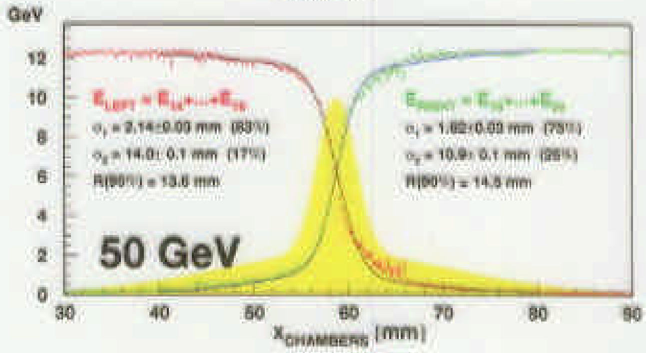
⟹ Even if light yield is divided by 2, resolution will only increase to $20\%/\sqrt{E}$

Shower profiles and position resolution

Shower profiles

Fit $\int$(sum of 2 gaussians) on $E_{L,R}$ function of x_{DC} (drift chambers)





$\Rightarrow$ 2 components :

- "core" $\sigma_1 \simeq 2$ mm

("core" energy fraction $\simeq 80\%$)

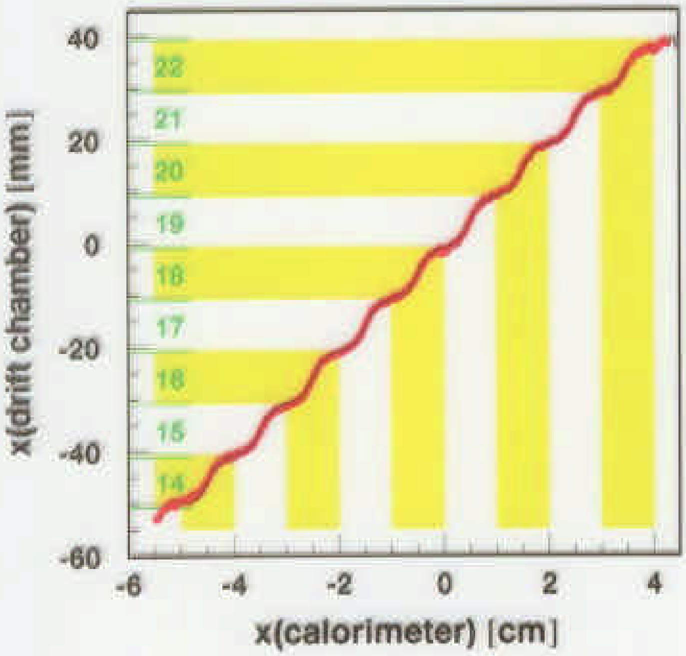
- "cloud" $\sigma_2 \simeq 14$ mm

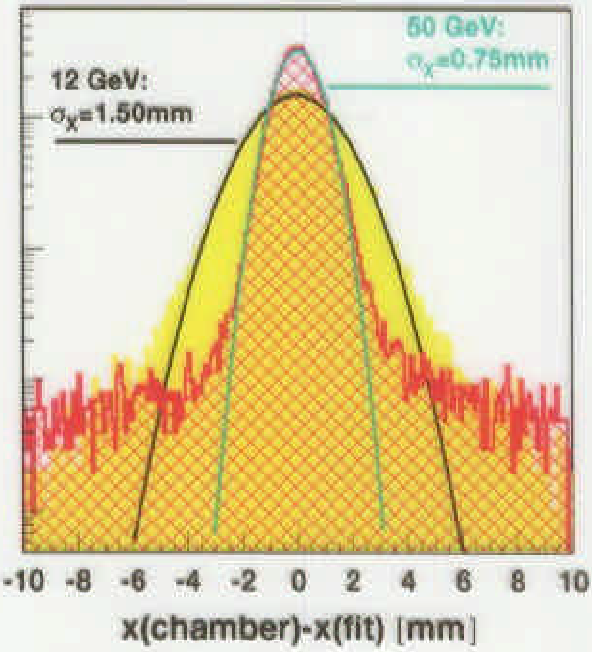
("cloud" energy fraction $\simeq 20\%$)

Position reconstruction

Fit $x_{DC} = f(x_{calo})$ (f = arctan by intervals)

$\sigma_{x_{DC}} = 0.2$ mm, x_{calo} energy weighted strip center position





$\Rightarrow$ Position resolution $\sigma_x \simeq 5\ \mathrm{mm}/\sqrt{E}$ (E in GeV)

Summary

• A tungsten/quartz-fibre Čerenkov calorimeter for H1 luminosity measurement has been successfully built and tested in beam at CERN-SPS

• Its peculiar geometry allows the detection of the core of the electromagnetic shower, as well as a transverse segmentation equivalent to cells

• Its performances are in agreement with expectations
→ Uniformity of energy response within ±1%
→ Linearity of energy response within ±1%
→ Resolution in energy $\sigma_E/E = 19\%/\sqrt{E}$
→ Resolution in position $\sigma_x \simeq 5$ mm$/\sqrt{E}$

• The sampling contribution to the resolution has been indirectly measured as $16\%/\sqrt{E}$, which will ensure that resolution will almost not change even if light yield degrades by a factor of 2