The New H1 Luminosity System For HERA II

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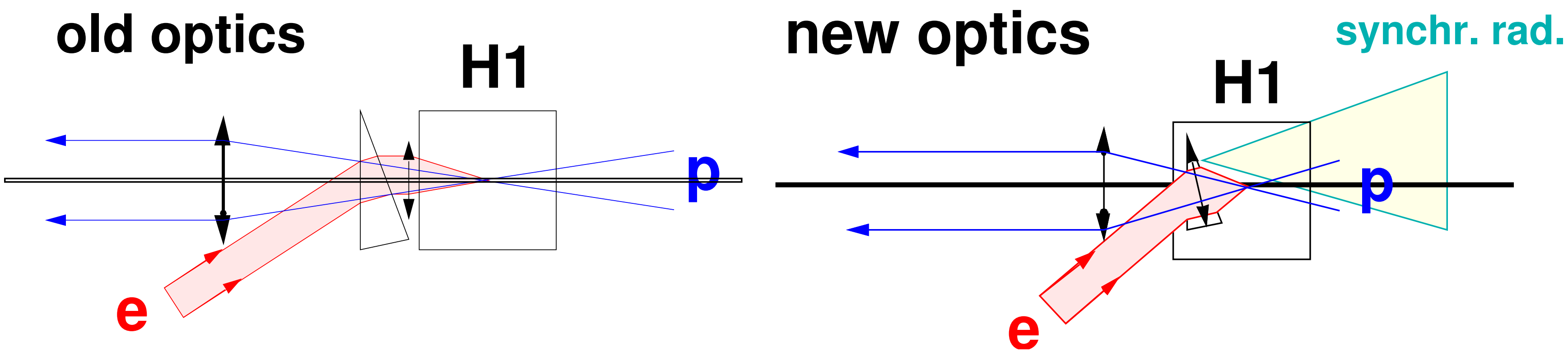
for the H1 Luminosity Group

- Luminosity measurement at HERA II
- Overview of the New H1 Luminosity System
  - Fibre detectors
  - Fast Electronics and DAQ
- first HERA beam as seen by the Lumi system

The HERA II Luminosity upgrade

- HERA II running: 2002–2006
- goal: $L = 7.6 \times 10^{31}\ \mathrm{cm}^{-2}\mathrm{s}^{-1}$ (equivalent 250 pb^{-1}/year)
- How? stronger beam focusing at interaction points



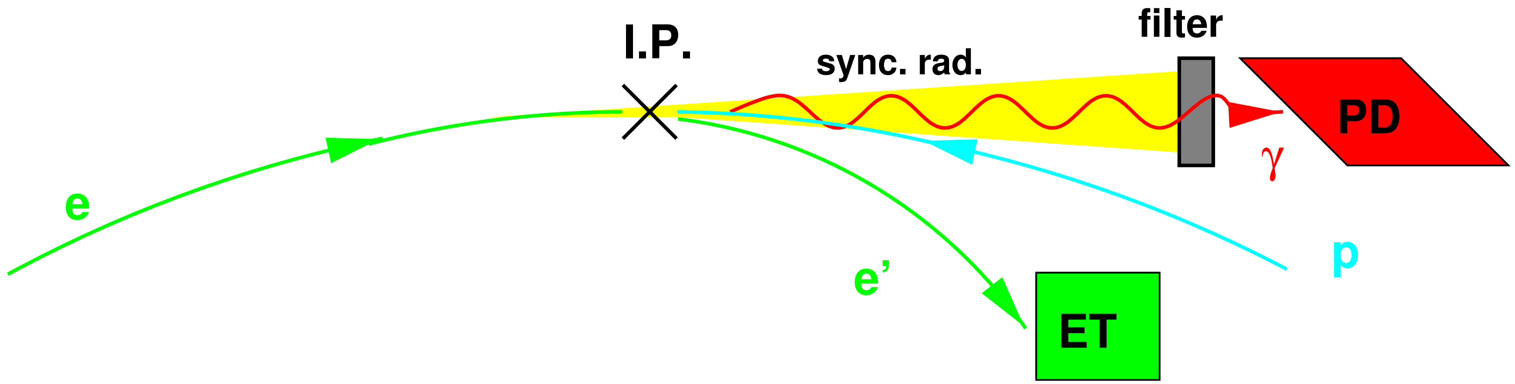
- SC combined function magnets in H1 (and ZEUS)

⇒ *longitudinal polarization "for all or for none"*

⇒ *stronger bending ⇒ increased synchrotron radiation levels*

The Luminosity Measurement Method

- **Principle: bremsstrahlung process $e\ p \rightarrow e'\ p\ \gamma$**

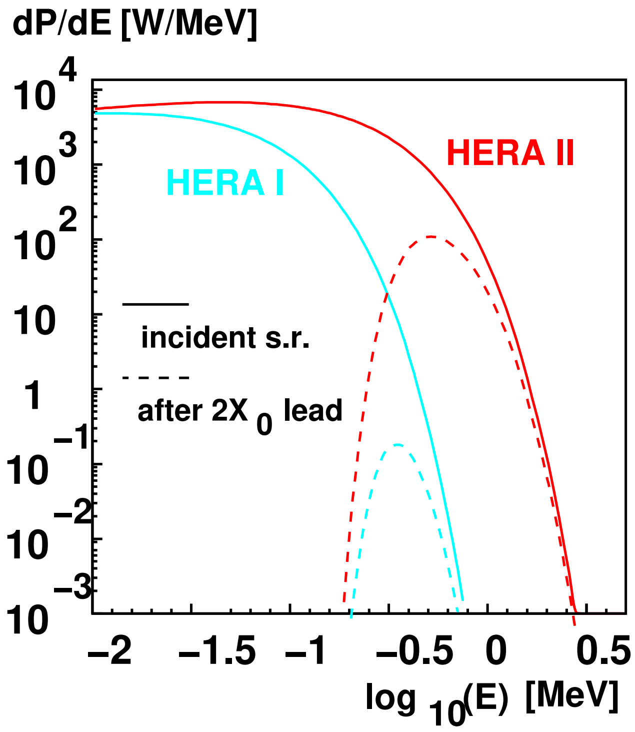


- **γ counting and Bethe–Heitler Cross–section**

$$L = \frac{\Delta N(E > E_T)}{\Delta t} \div \int_{E_T}^{E_0} \frac{d\sigma_{BH}^{vis}}{dE}\, dE$$

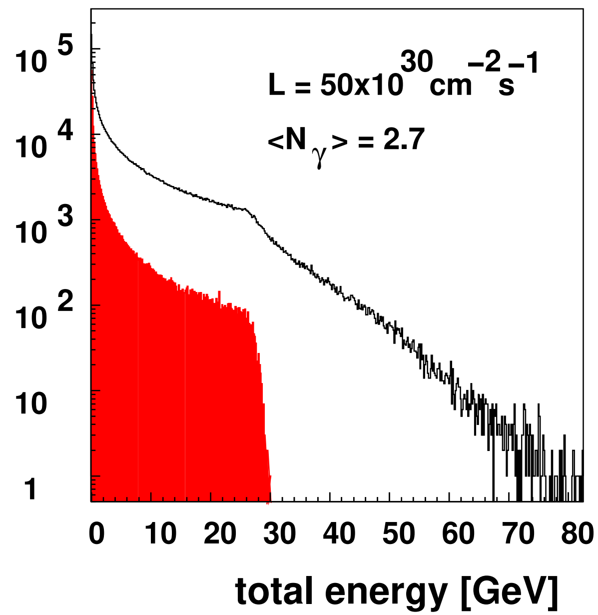
- **beam gas background subtraction, acceptance correction**
- **pile–up effect correction at high rates**

Impact of the HERA Upgrade on the H1 Lumi System



Synchrotron radiation

- higher total power: P = 400W $\rightarrow$ 3.8kW
- harder spectrum: EC = 35keV $\rightarrow$ 160keV
- Dose = O(Trad/year) if unshielded



High event rate $\rightarrow$ pile–up

- BH edge washed out
- $L \neq N / \sigma$

Requirements for the New Luminosity System

Photon Detector

- synchrotron radiation filter ➔ 2 X0 of Be: dose reduced by ~ 10^{-4}
- fast response ➔ Cherenkov calorimetry
- radiation hardness ➔ sampling calorimetry with quartz fibres
- good energy resolution ➔ maximal light yield + fine sampling
- position measurement of γ beam ➔ fine granularity in x and

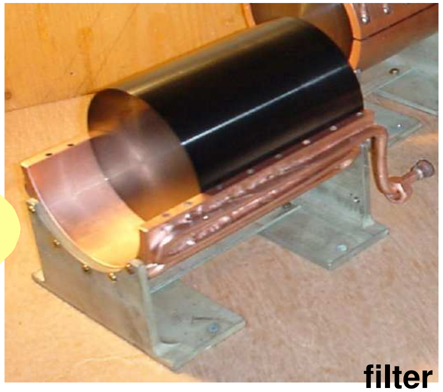
Electron Tagger

- inside GI1 (1st warm) quadrupole magnet gap ➔ compactness
- good energy and position resolution ➔ scintillating fibre calorimetry

Electronics and Data Acquisition System

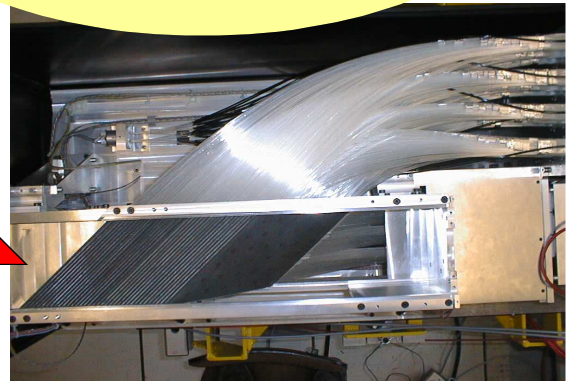
- fast pulse shaping (<96ns) and digitization ➔ avoid pulse overlap
- dual read–out ➔ H1 main DAQ (slow) and Lumi–DAQ (fast)
- fast histogramming DAQ ➔ Online/Offline Luminosity
- event readout ➔ position measurement + monitoring

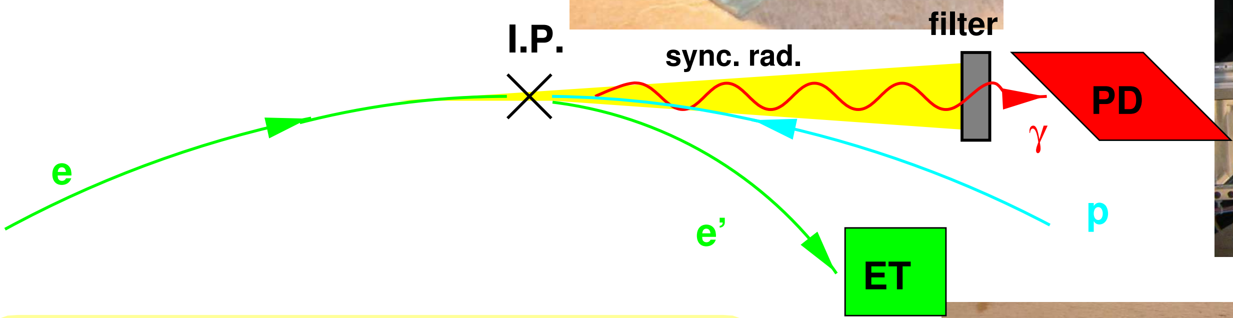
Overview of the New H1 Luminosity System

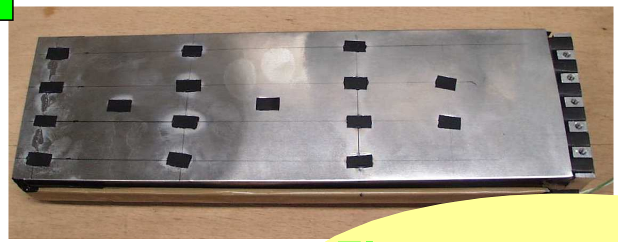


Synchrotron radiation filter: 2 X_0 Beryllium

Photon Detector at 103m: tungsten/quartz–fibre sampling calorimeter

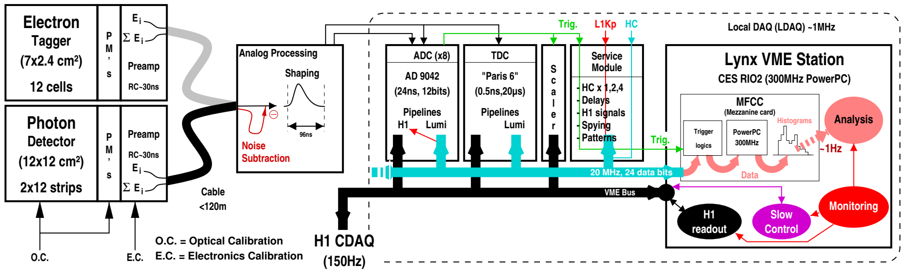




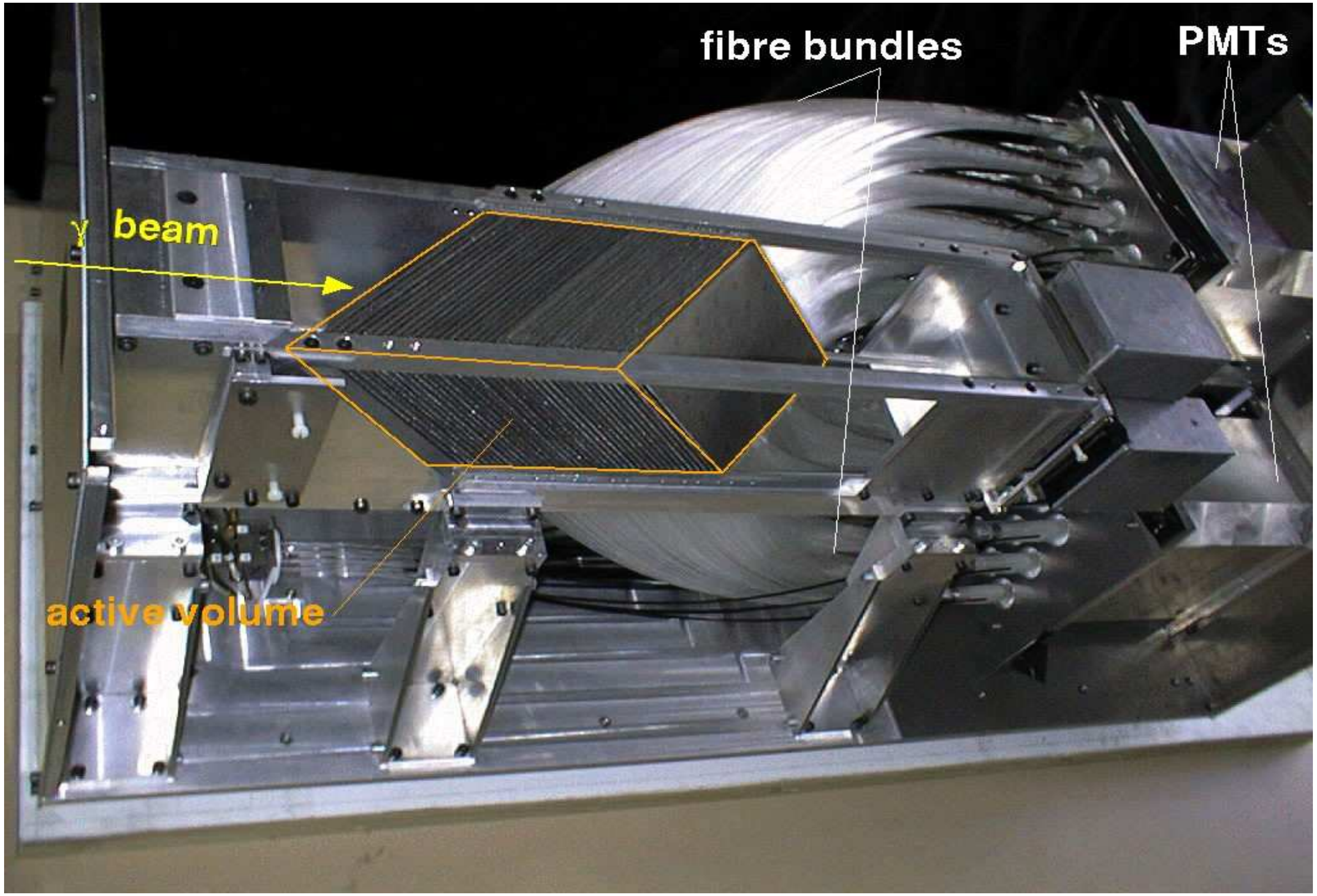


Electron tagger at 6m: compact lead/scintilling fibre SpaCal

Fast electronics and histogramming DAQ



Photon Detector: W/Quartz–fibre Calorimeter



Key Parameters

- 15422 quartz fibres
- (total length ~11km)
- **W/fibre V ratio: 1.68**
- total depth: 25 X_0
- **sampling freq.: 0.36**
- average $X_{0::}$ 7.8mm
- Moliere radius: 17mm

Geometry

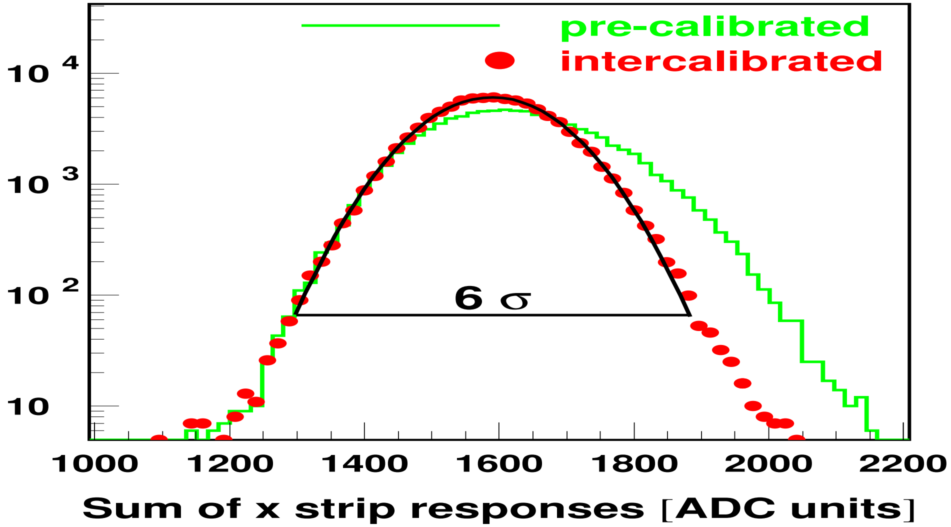
- **12(x)+12(y) 1cm strips**
- **alternating layers**
  ⇒ indep. sampling

Design Performance

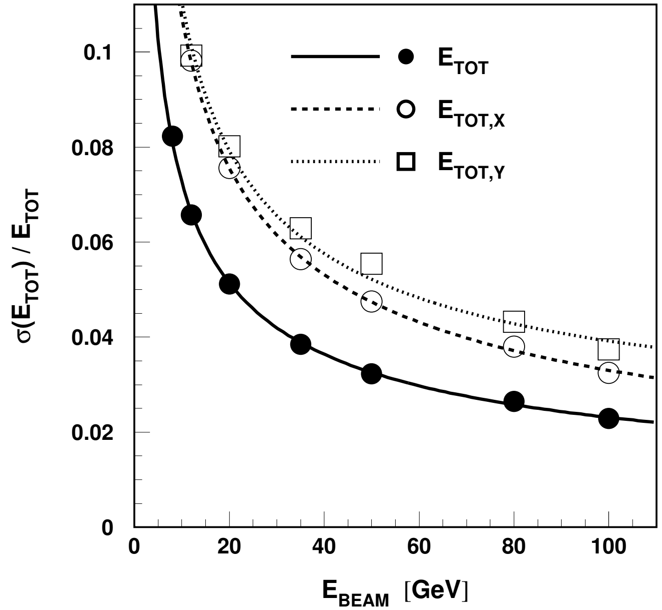
stoch. term: 19.8%/ $\sqrt{E}$
sampling: 16.4%/ $\sqrt{E}$
photostat.: 11.1%/ $\sqrt{E}$

Photon Detector Performance: Energy Response

in CERN test beam 1999 + 2000 electrons 6–100GeV



E-Sum	stoch. term A	const. term B
x strips	27.58(47)%	0.1(3.5)%
y strips	27.37(26)%	0.65(23)%
all strips	19.24(12)%	0.52(10)%



- intercalibration by iterative method
- linearity: 1% for 8 GeV < E < 100 GeV
- energy resolution compatible with design value
- independent sampling by x and y layers
- photostatistics measured with LED calibration system: 130 p.e./GeV

Photon Detector Performance: Position measurement

- **high sensitivity to the shower core**

  ➔ narrow apparent showers

- **reconstructed impact point position:**

  E weighted sum of strip centres

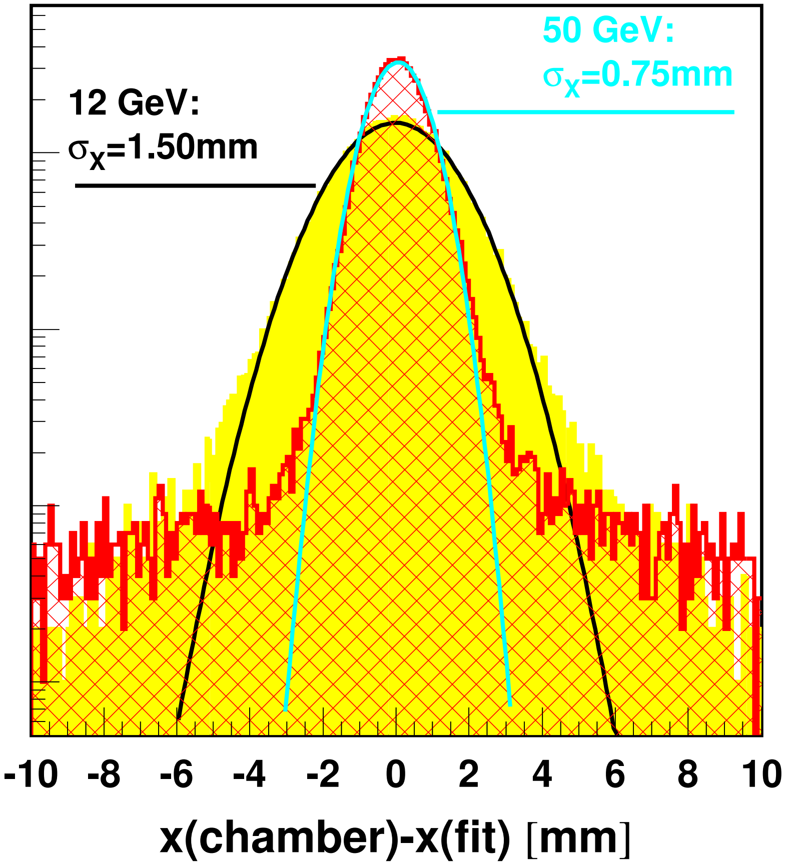
- **in CERN test beam:**

  reco'd *x* v/s drift chamber *x*

- **fit of a correlation function**

  residues ➔ position resolution

$$\sigma_x = \frac{5mm}{\sqrt{E[GeV]}}$$

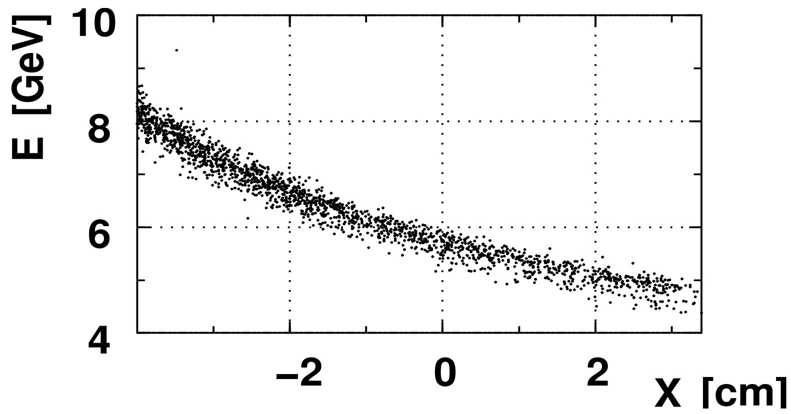


Electron Tagger: Pb/Scintillating Fibre SpaCal

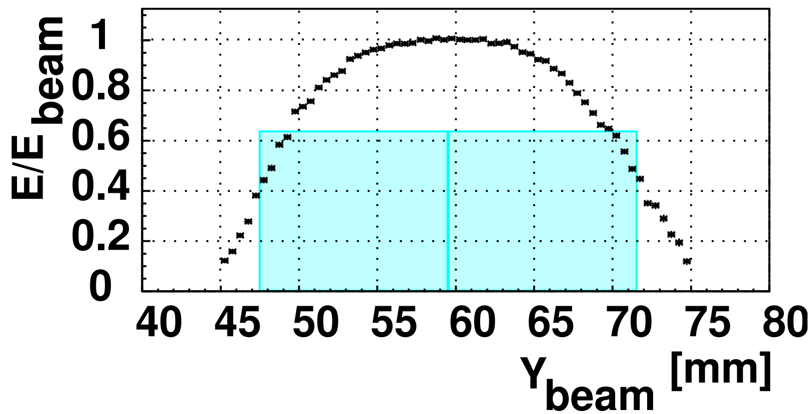
➔ measure scattered electron energy and position (γp and BH)

➔ photon detector cross calibration: E(γ)+E(e)=E(e–beam)

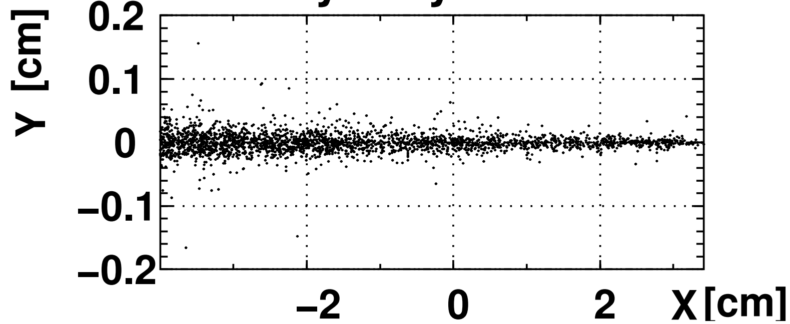
- lead/scintillating fibre spaghetti calorimeter (1:2.26 Vol. ratio)
- 6(*x*) x 2(*y*) cells 13x12x200mm^3
- total depth: 22 Xo
- located inside the gap of GI1 HERA quadrupole magnet at 6 m from IP



Main issue: vertical E leakage



BUT: vertically very narrow beam

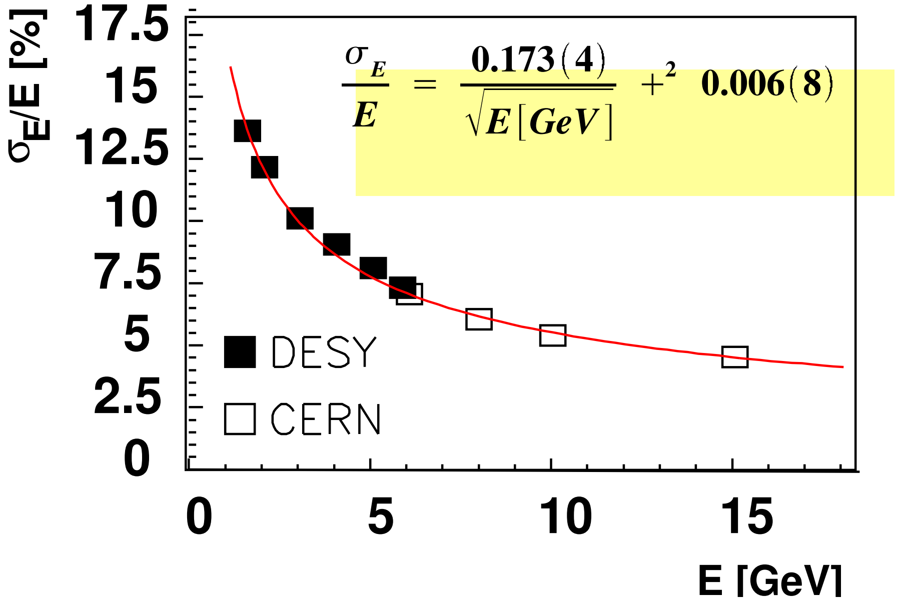


e Tagger Performance: Energy and Position Resolution

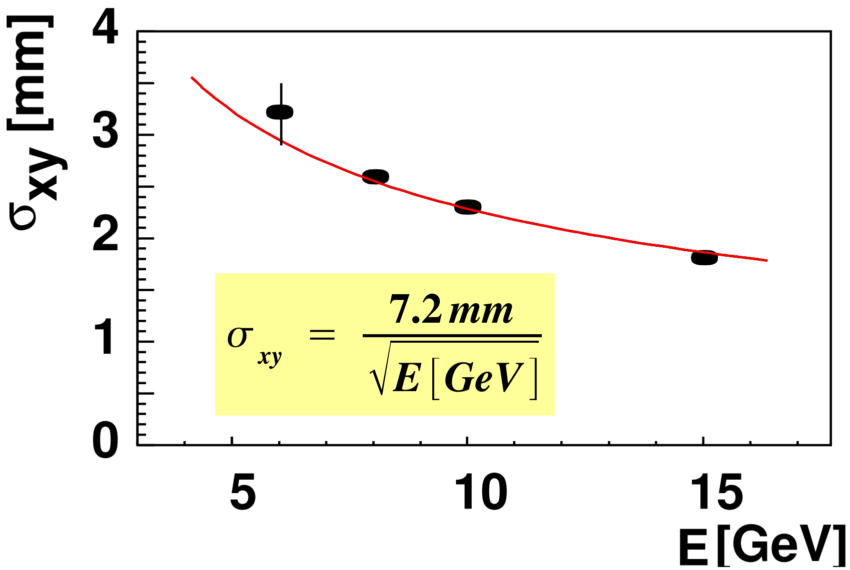
CERN test beam data:

- **linearity: 1% for 6 GeV < E < 15 GeV**
- **energy resolution depending on photomultiplier tubes:**
  higher E resolution and good agreement achieved in DESY test beam with Philips PMTs

Energy resolution



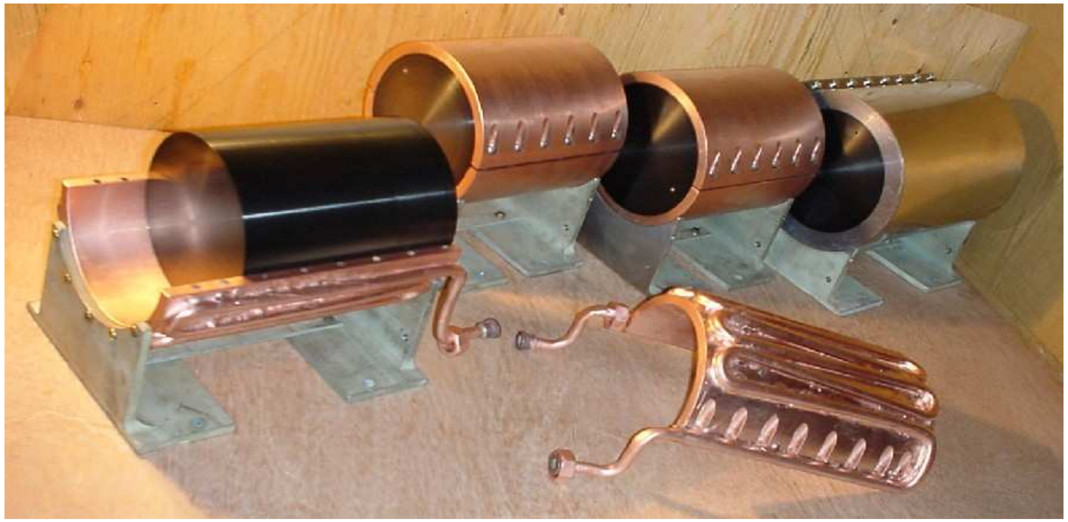
Position resolution

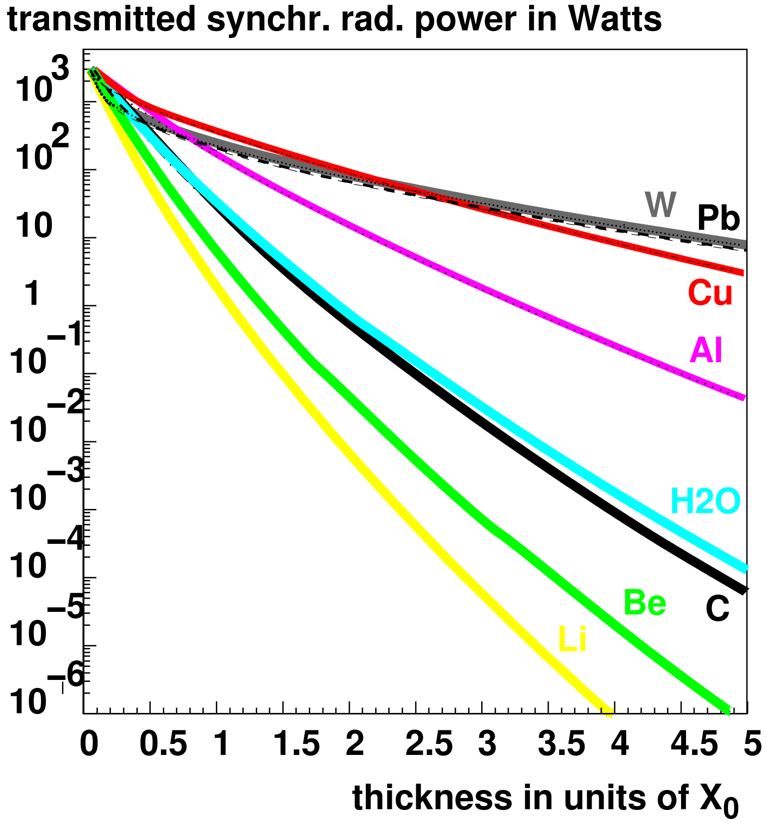


Beryllium Synchrotron Radiation Shield

- reduce radiation dose on photon detector by 10^{-4}
- acceptable dose on fibres: $\mathcal{O}$(50 Mrad/year)

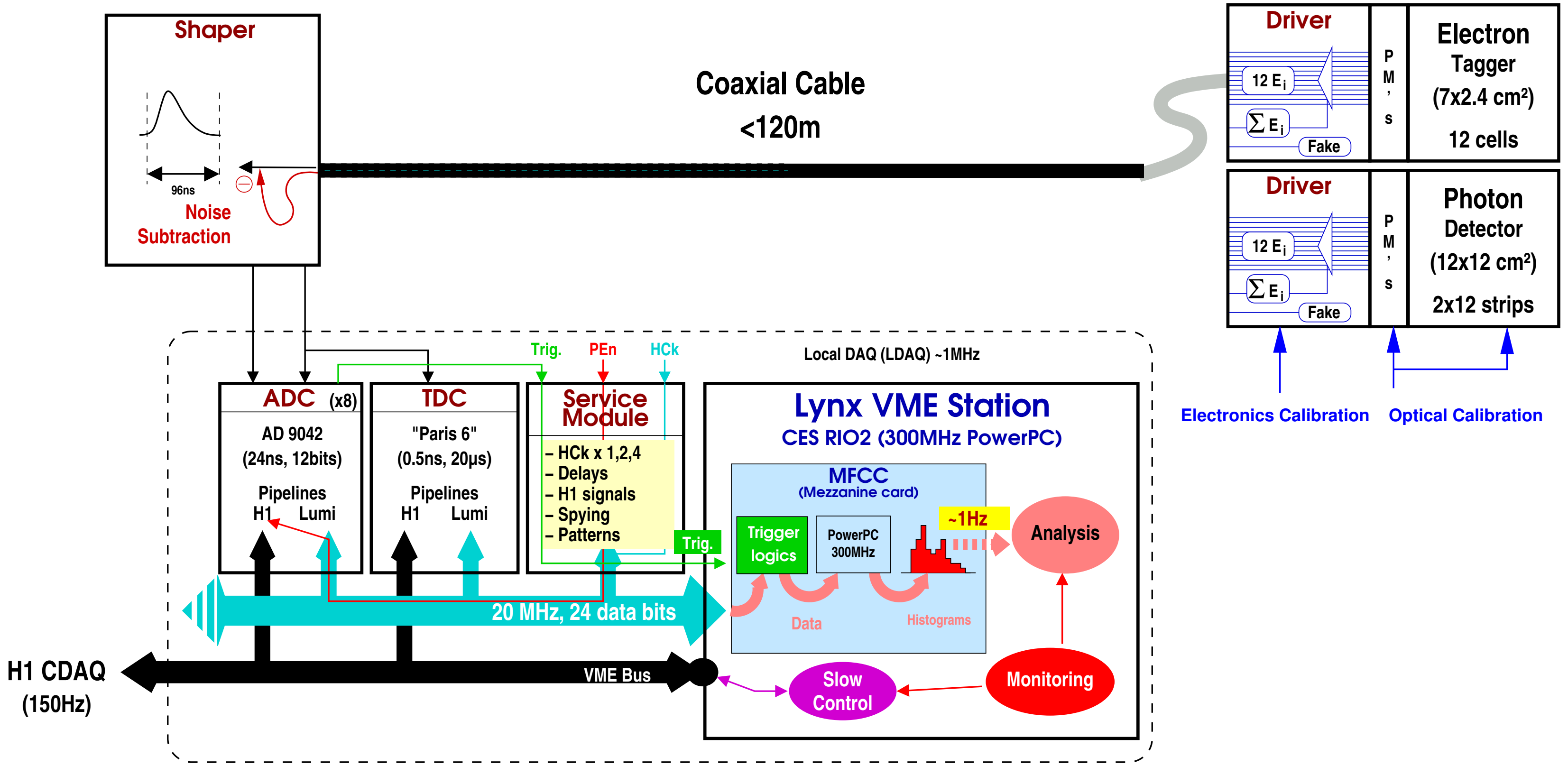
low Z material more efficient to absorb penetrating 500keV~2MeV component of synchrotron radiation with a given "X0–Budget"





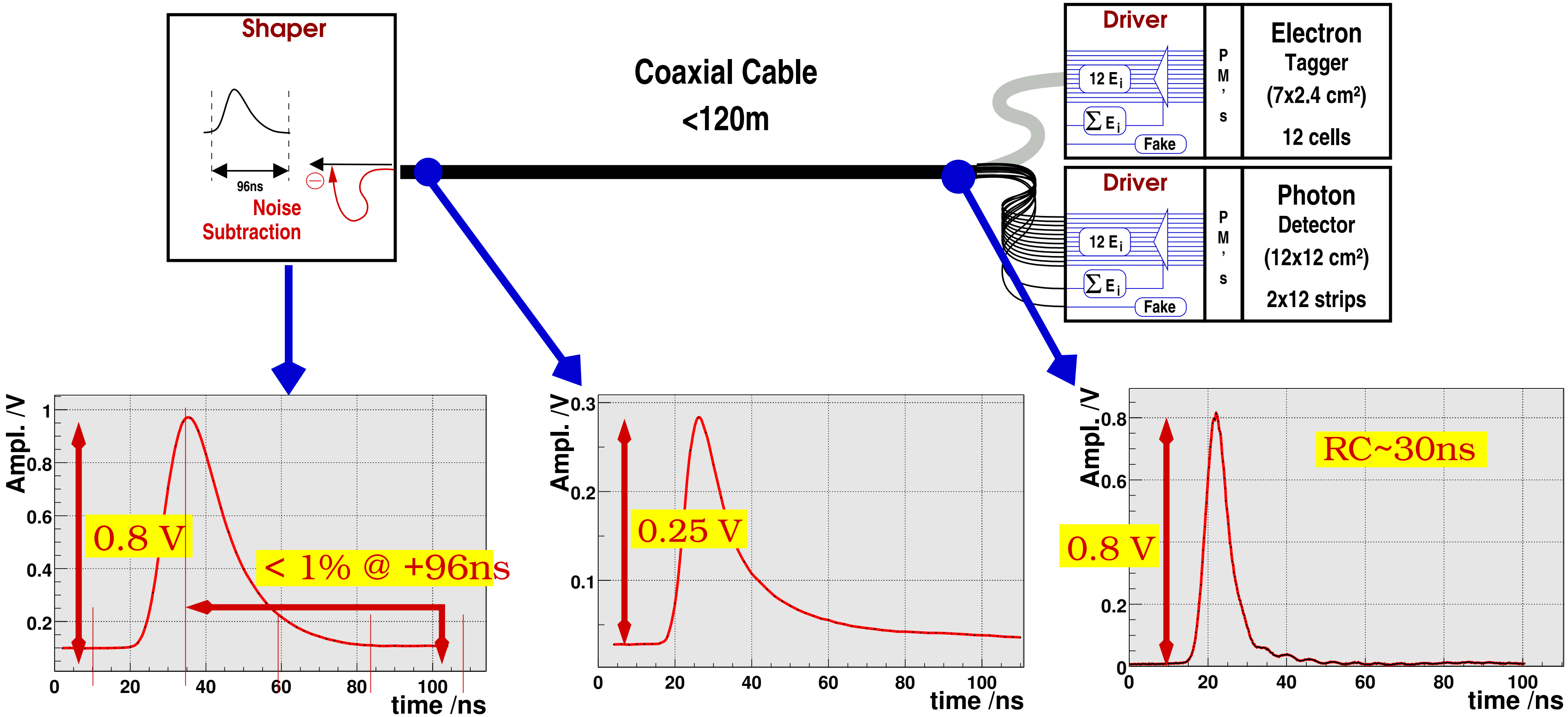
Electronics and Data Aquistion Overview

- fast analog electronics and digitization, noise suppression
- dual pipelined readout of ADCs
- fast histogramming DAQ (Mhz)



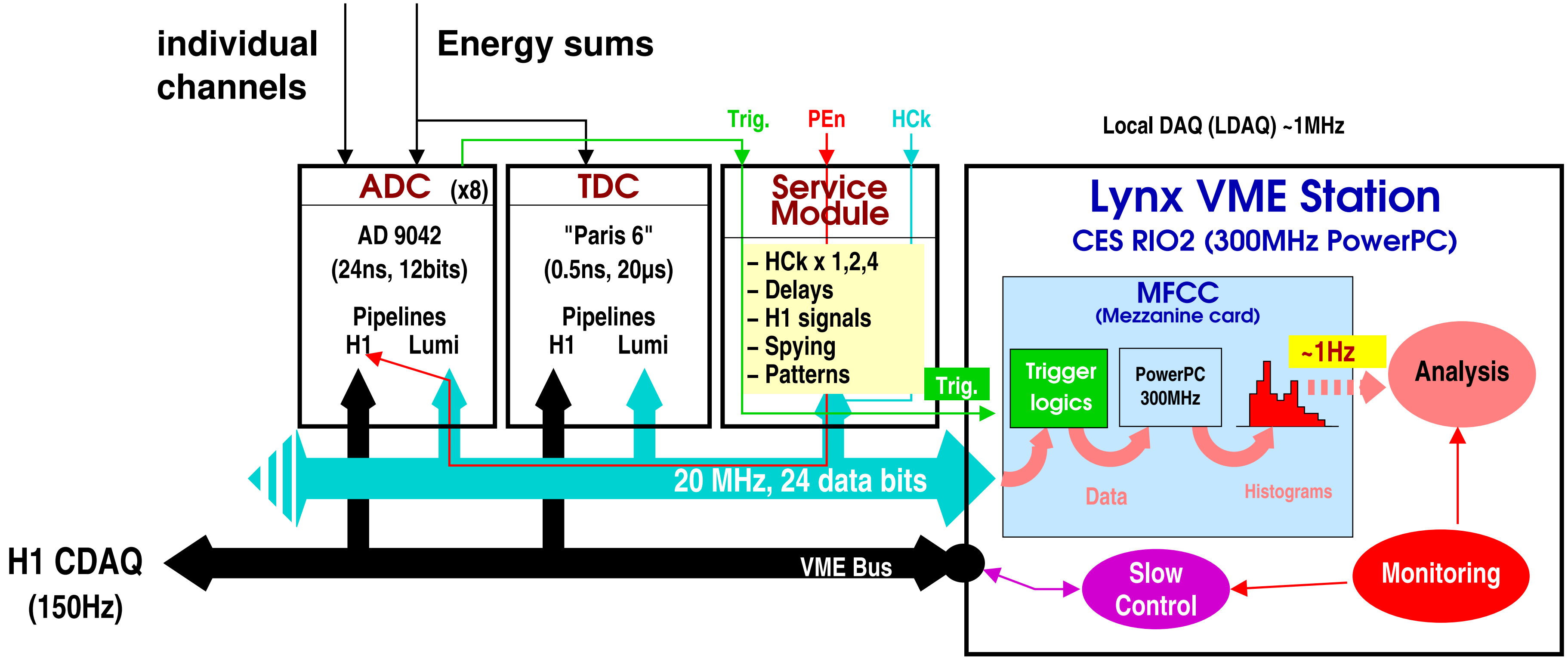
Fast Pulse Shaping and Digitization

- amplification, fast shaping + compensation of coax. cable
- VFE summation + common mode subtraction (fake channel)



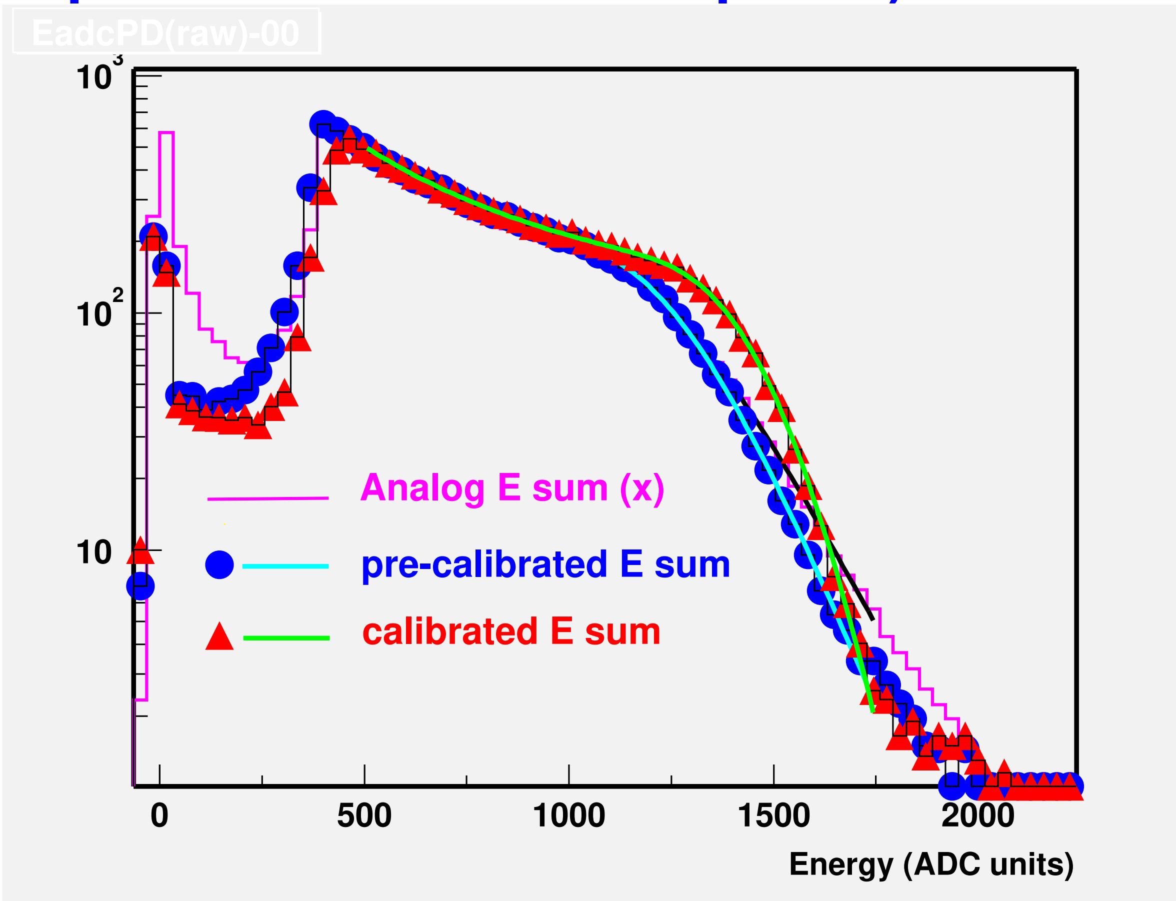
Fast Histogramming DAQ via Dedicated Bus

- ADC: 24ns (4 samples per bunch crossing), 12 bits
- dual pipeline read–out: H1 DAQ (VME) and LumiDAQ (Altera Bus)
- 2 acq. modes: bunch train (unbiased, E sums, high statistics,1MHz)
  triggered event (all channels, monitoring)



First HERA Beam: Photon Detector Calibration

- channel intercalibration by iterative method
- fit of (BH spectrum ⊗ detector response) to E sums



Summary and Outlook

- completely new H1 Luminosity system designed to meet harsh requirements of the HERA II environment
- radiation hard photon detector
- dedicated Data Acquisition system
- system has been installed in 2001
- now in commissioning phase:
  - detector calibration
  - high current (= high rate) operation
  - development of monitoring tools