Workshop on luminosity measurement in Tel Aviv
3th to 5th Oct 2010

Luminosity measurement by ZEUS at HERA-II

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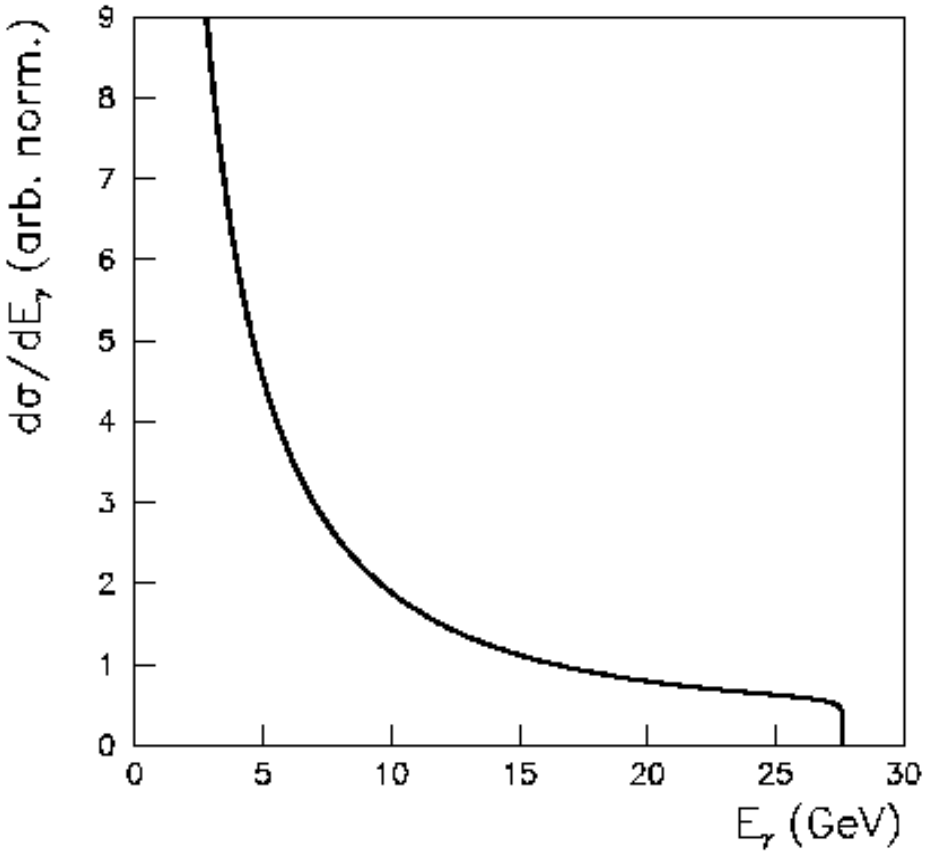
Technique process: ep→epγ

γ energy spectrum



***ep* bremsstrahlung**

accurately calculable cross-section

- σ known to 0.2%
  (*arXiv:1009.2451v1 [hep-ph]*)

high rate

- sufficient for real-time monitoring

sharply forward-peaked

- θ_γ dominated by *e*-beam p_T spread at IP

Photon measurement requirements

E_γ range:

- few GeV — 27 GeV

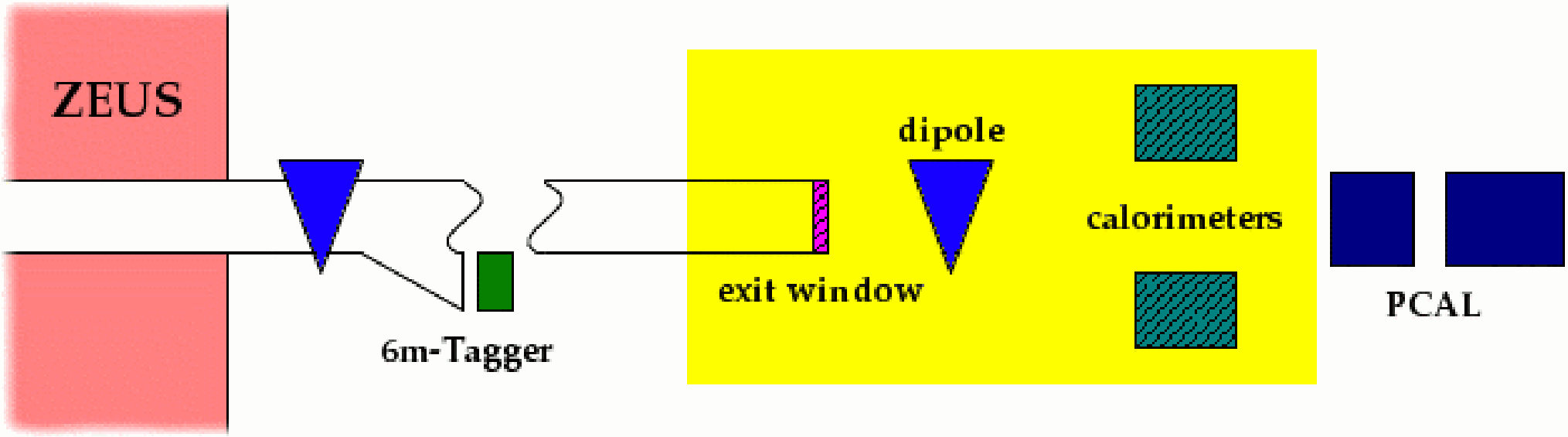
pile-up:

- several γ with $E_\gamma > 0.5\ GeV$ per BC

radiation hardness:

- SR + low energy bremsstrahlung

Technique luminosity system



e-tagger at 6m from IP

- measure scattered e
- check photon acceptance *(work in progress)*
- W-scintillator spaghetti calorimeter

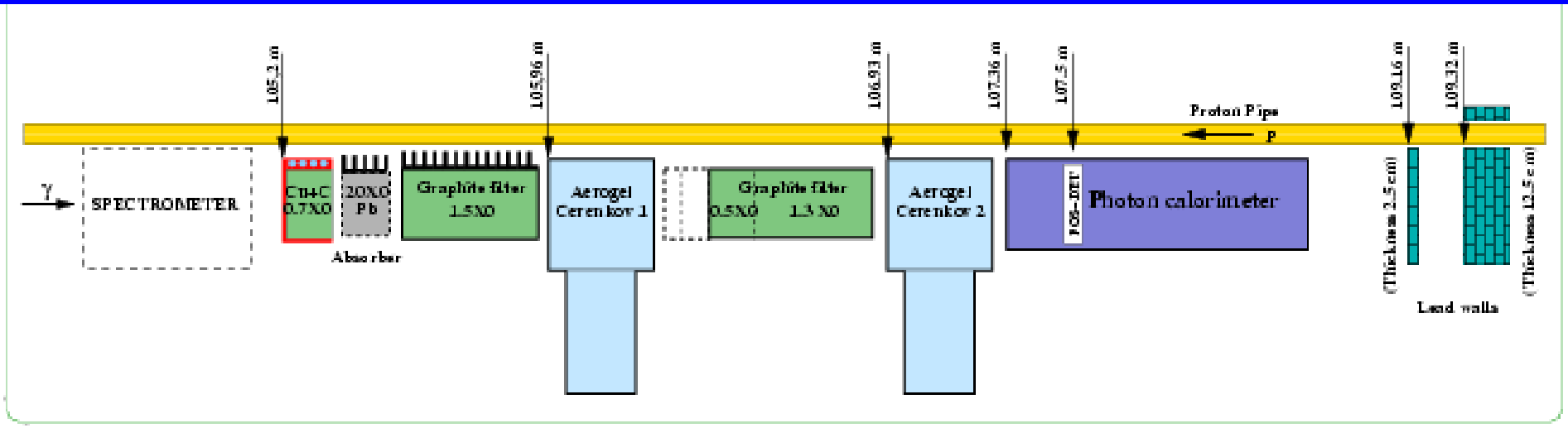
Pair spectrometer (*SPEC*)

- measure pairs from $\gamma \rightarrow e^+e^-$ in exit window (~9%)

Photon calorimeter (*PCAL*)

- direct measure photons

PCAL setup



filters

- graphite ~3-4 X0
- Cerenkov detectors

(not used for LUMI, used for physics)

PCAL

- Pb-scintillator sandwich
- Scint. hodoscope for position recon

features

***PCAL* sits in direct γ-beam & primary SR fan**

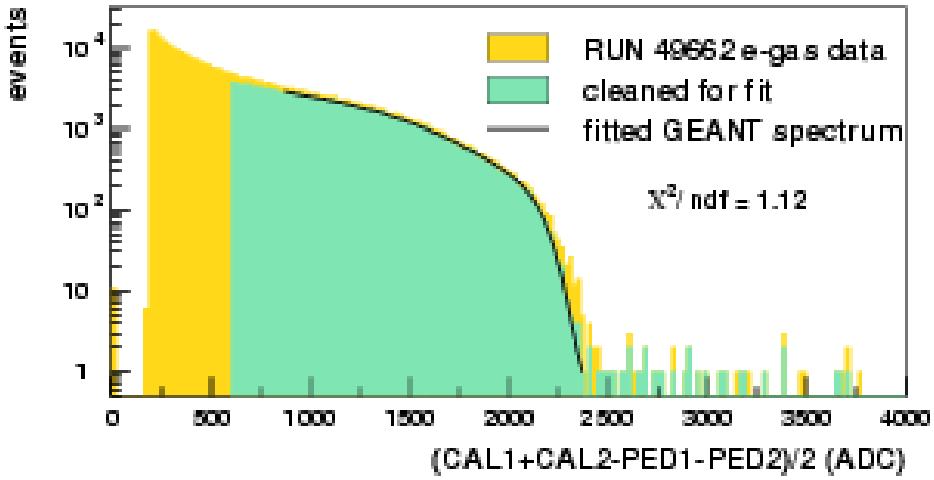
⇒ *PCAL* must be shielded: graphite filters

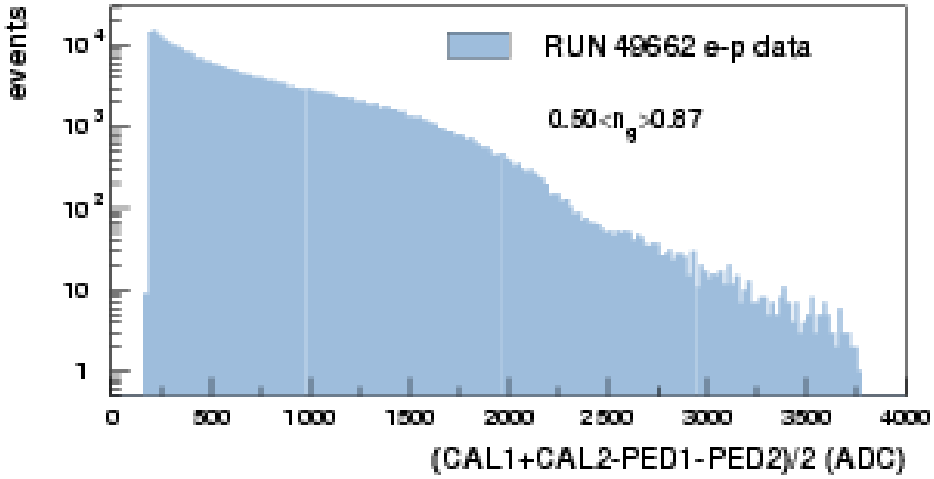
⇒ serious resolution degradation; must be MC simulated

detect E_γ > few hundred MeV

PCAL calibration

γ-spectra for ep, e-bunches





fit MC to data

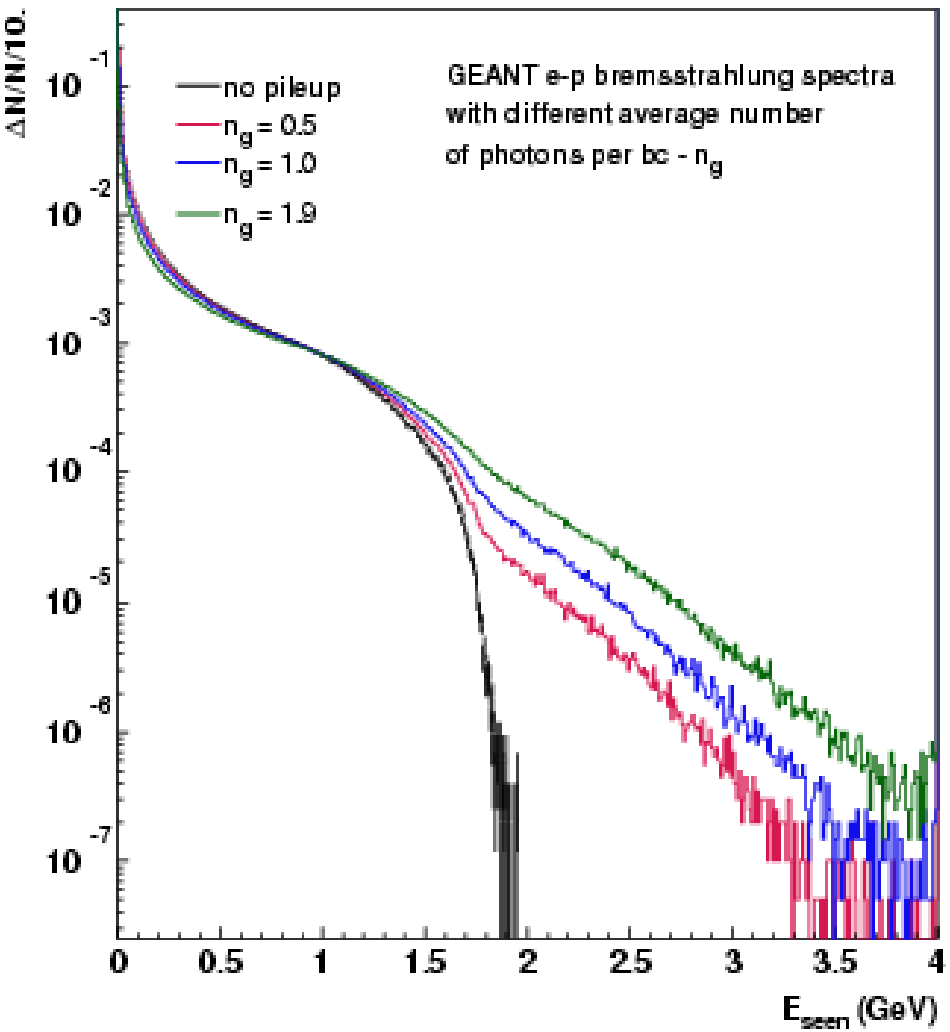
***ep*-bunch endpoint smeared**

use unpaired *e*-bunches

- *e*-gas rate ~10^{-2} *ep*-rate
- *γ*-spectrum ~ undistorted
- MC fit to endpoint

PCAL luminosity measurement

MC γ-spectra for various L_{inst}



LUMI measurement

E_γ-spectrum distorted by pile-up

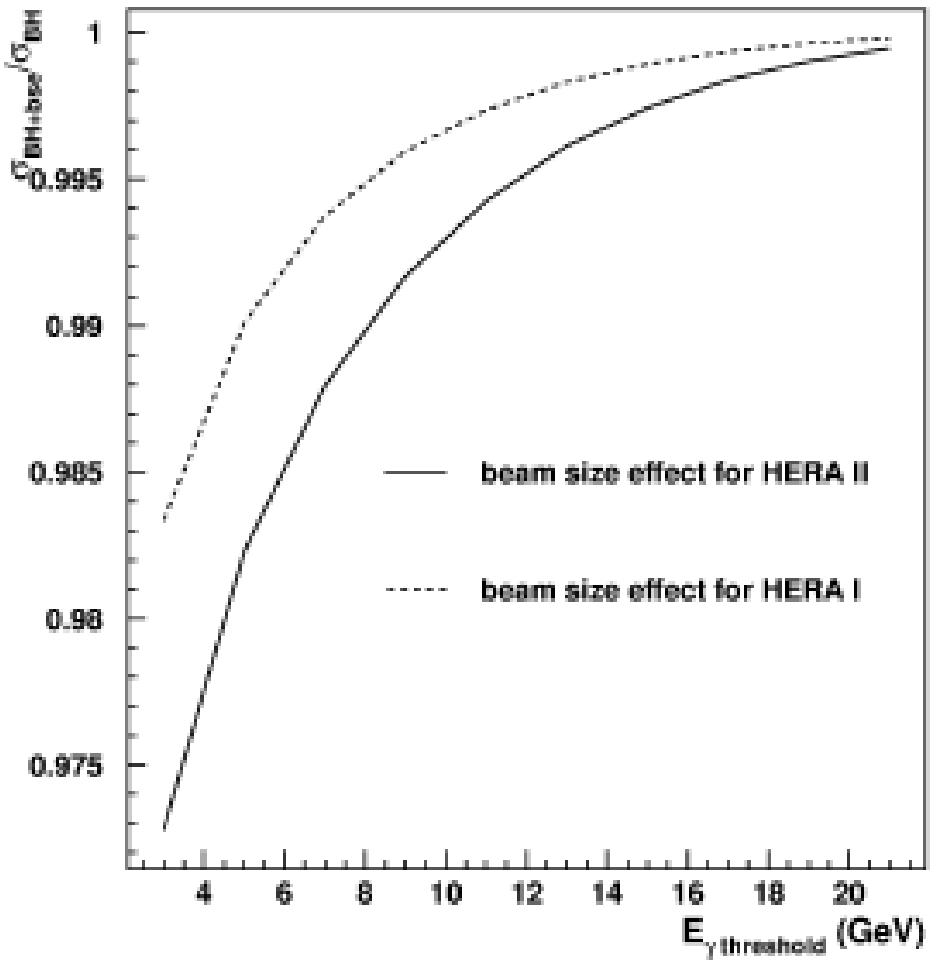
- count γ's with E_γ > threshold
- compare to MC for various N_γ
- use several thresholds

correction ~ several %

- requires precise *PCAL* simulation

other luminosity corrections

σ_γ shift due to 'beam-size effect'



Beam-size effect

- impact parameter limited by transverse beam size ⇒ low E_γ suppressed
- observed e.g. *VEPP* e^+e^-, *HERA-I ep*
- *HERA-II* smaller beam size

⇒ stronger effect: >2%

Other effects, corrections:

- electronics pileup (pulse overlaps)
- pedestal shift from SR

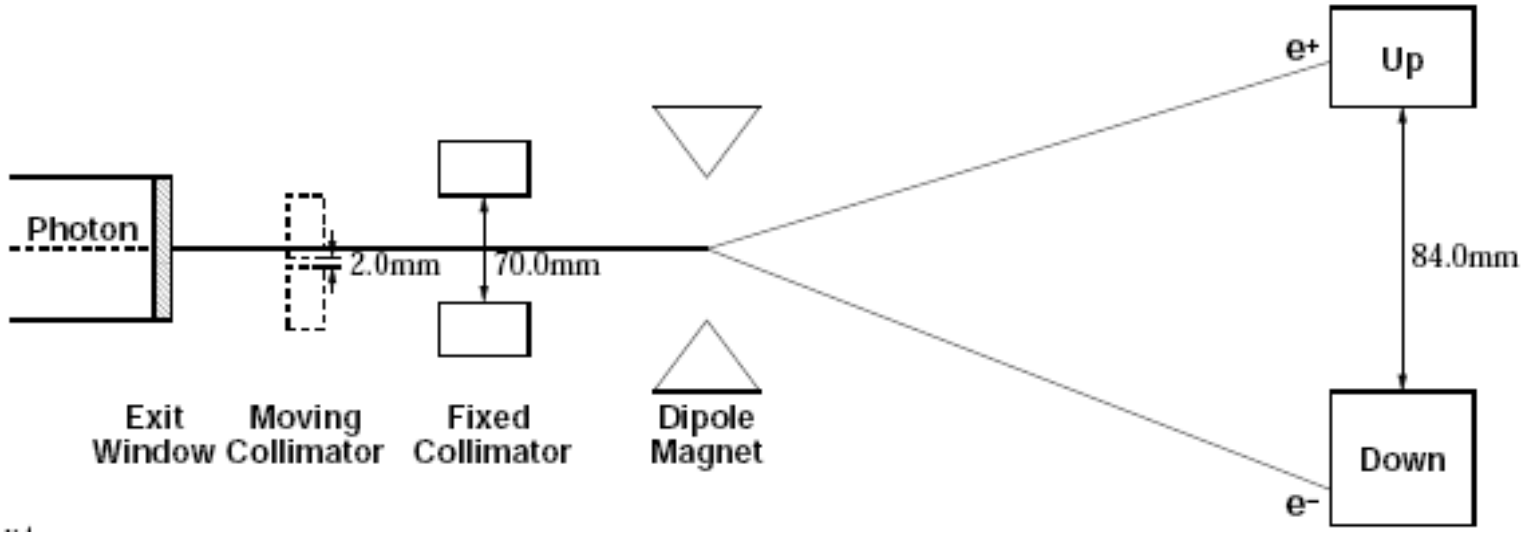
PCAL summary

concept & detector simple

complications: shielding, high rates, low Eγ

large (several %) corrections require accurate MC modeling

Spectrometer setup



Components:

exit window:

~9% γ-conversions ⇒ 10x rate reduction

dipole:

- pair separated vertically, $p_T = 0.1\ GeV$

***Up, Down* calorimeters:**

- $e^{\pm}$ measurements
- W-scintillator sandwich; x,y - segmented
- out of direct γ-beam & sync. rad. fan

Calibration:

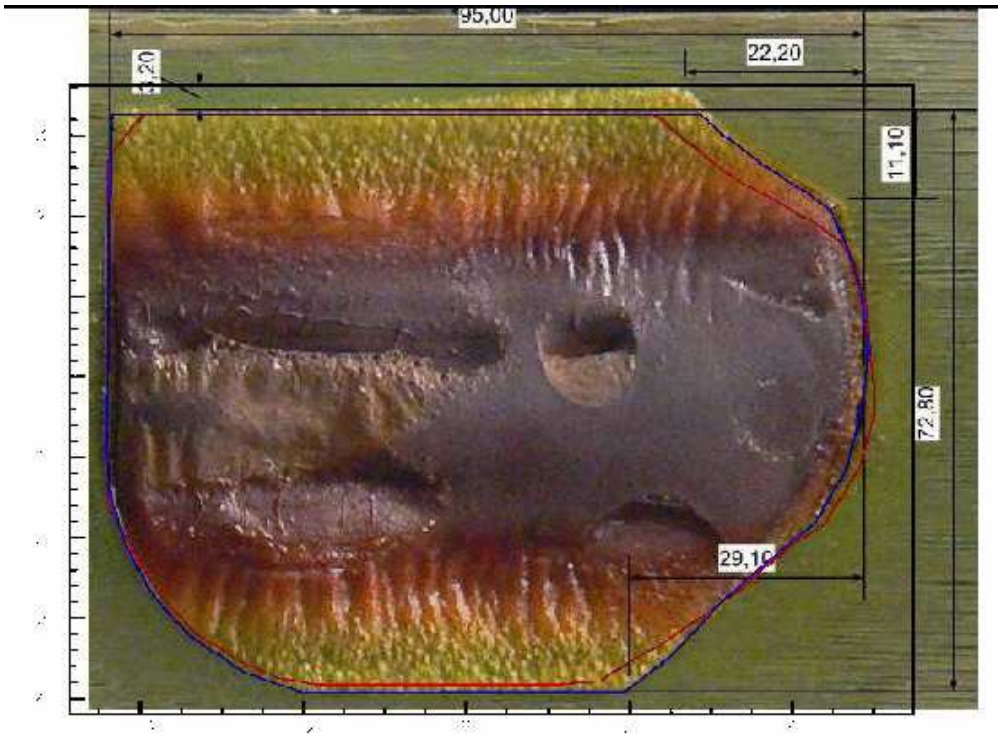
- insert *moving collimator*
  ⇒ defines vertical position of pair

- $e^{\pm}$ energies are directly related to vertical position of shower in calor.

- was done about once a day

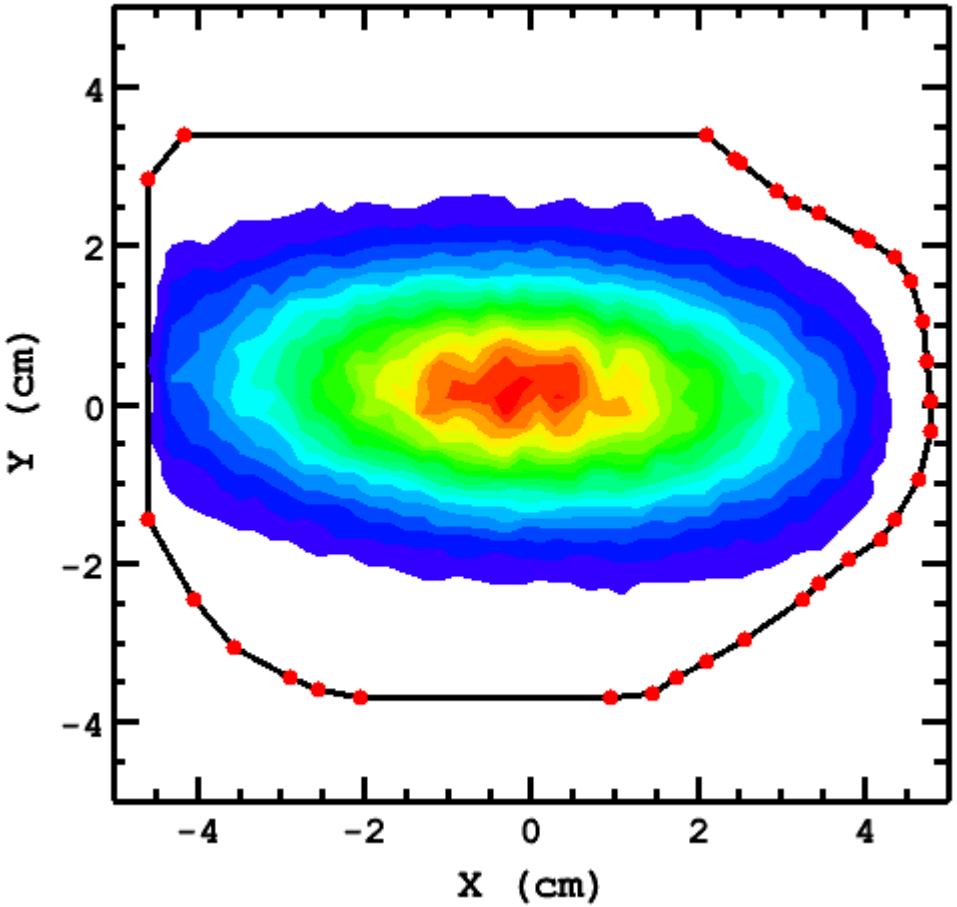
Spectrometer aperture

foil irradiated by SR;
located at SPEC calorimeters



The effects of aperture restrictions between the IP and the foil are clearly visible

measured γ-beam

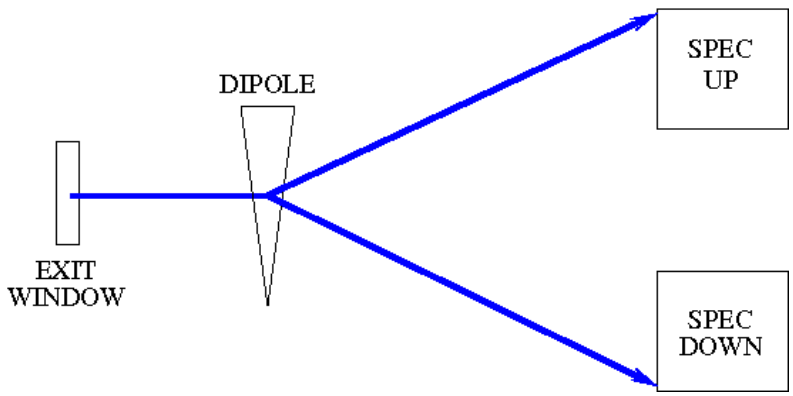


γ-loss at left side is visible

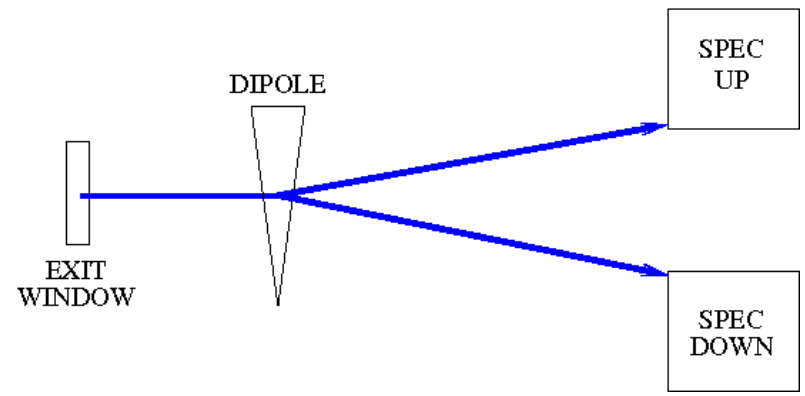
Spectrometer γ energy range

Consider pair midway between calorimeters, with equal shared energy

min E_γ which will produce a coincidence

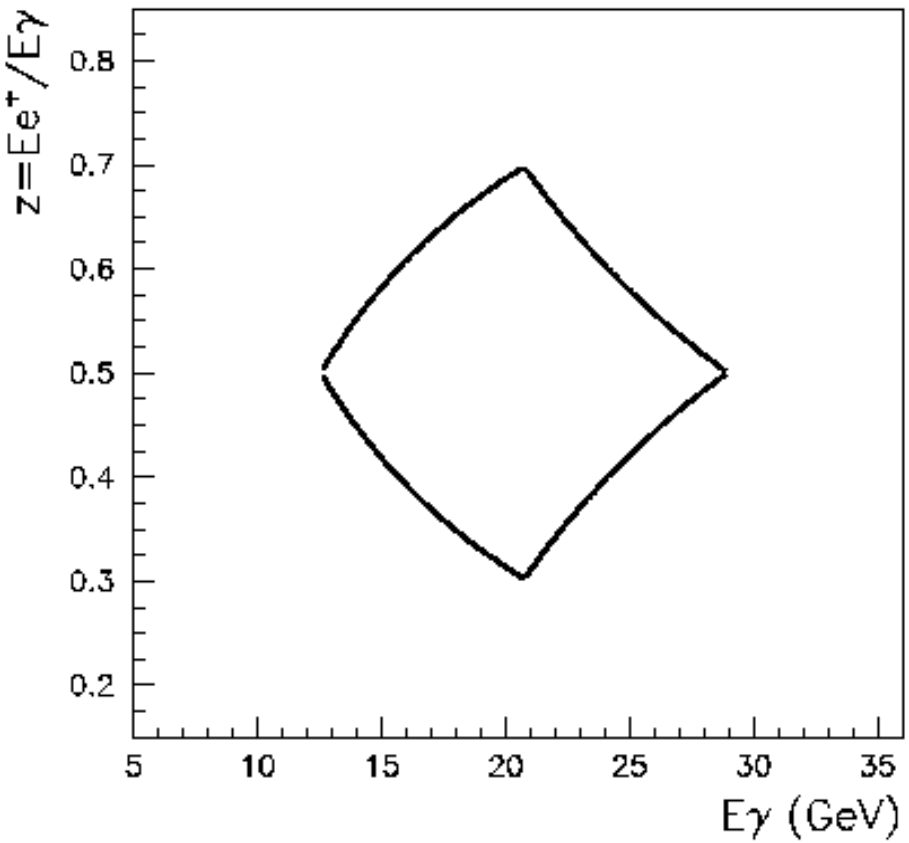


max E_γ which will produce a coincidence

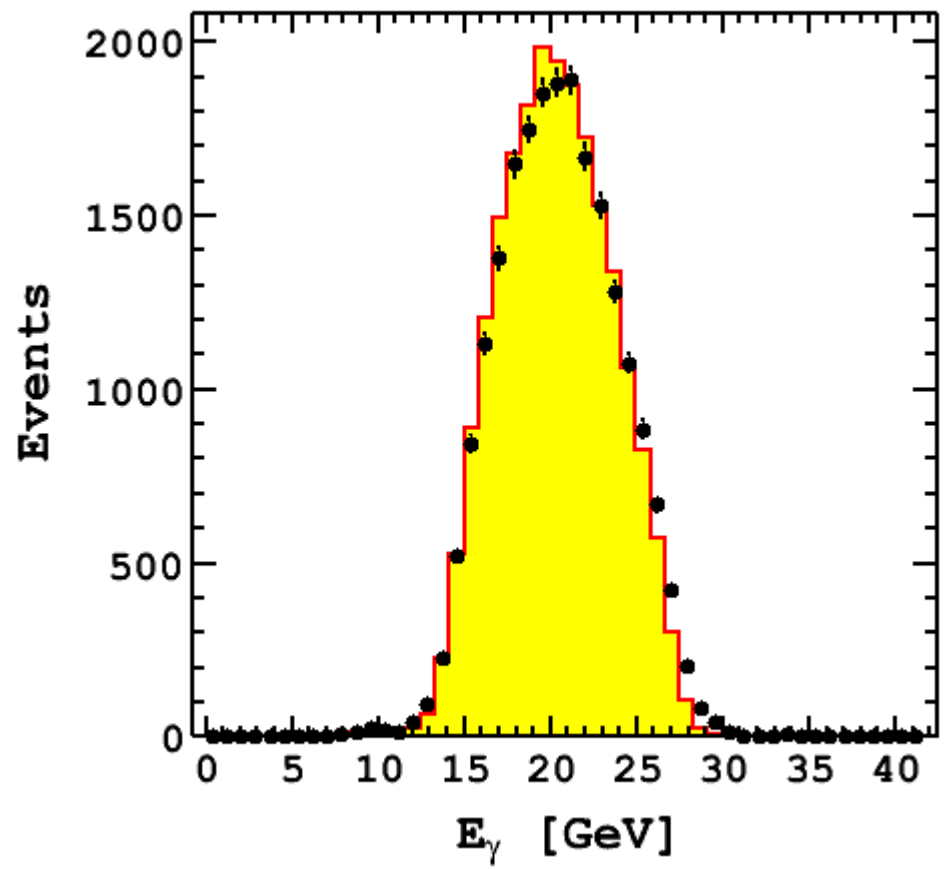


Spectrometer γ energy range

acceptance region in e, γ - energy range

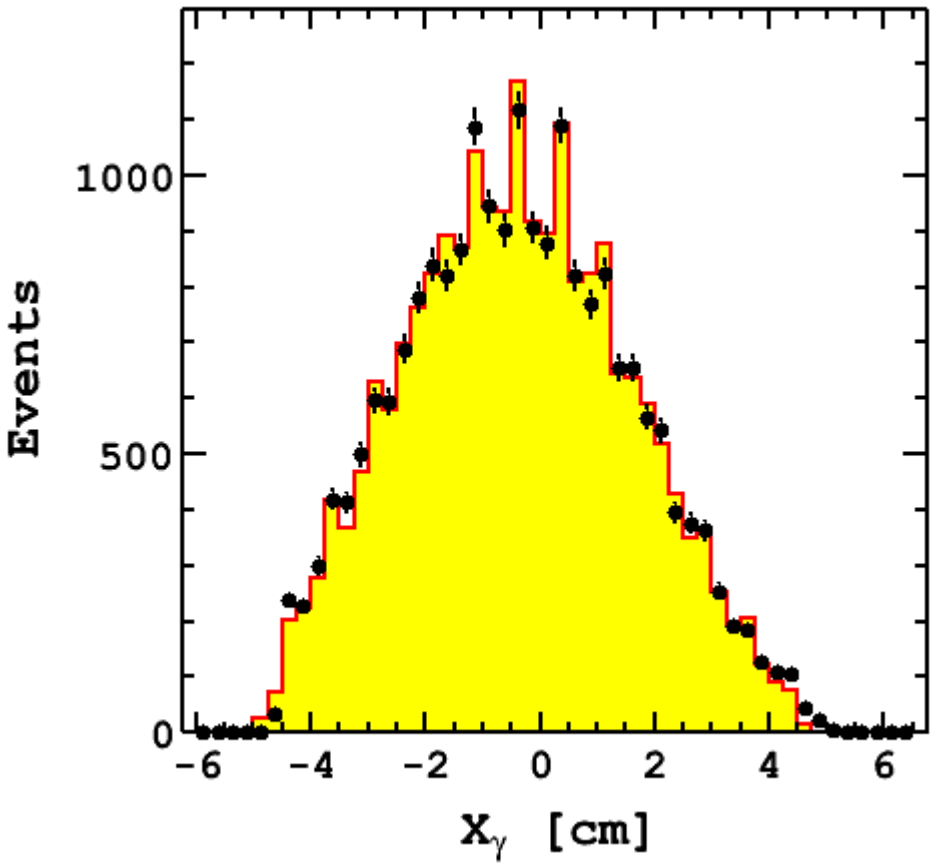


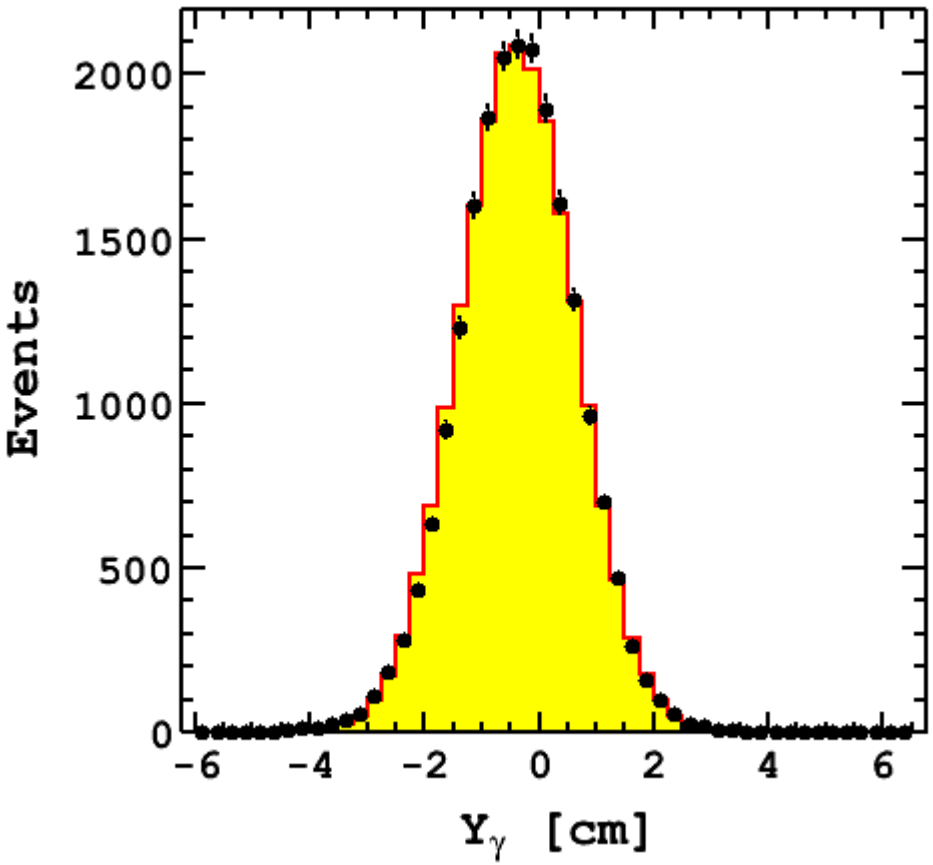
γ energy spectrum



spectrometer geometry and dipole field define an acceptance region in the *e*, *γ* - energy range

Spectrometer luminosity measurement





good data & MC agreement

Data:

- count coincidences for ~16 sec. (ZEUS int. time)
- accumulate E_γ, X_γ, Y_γ, histograms

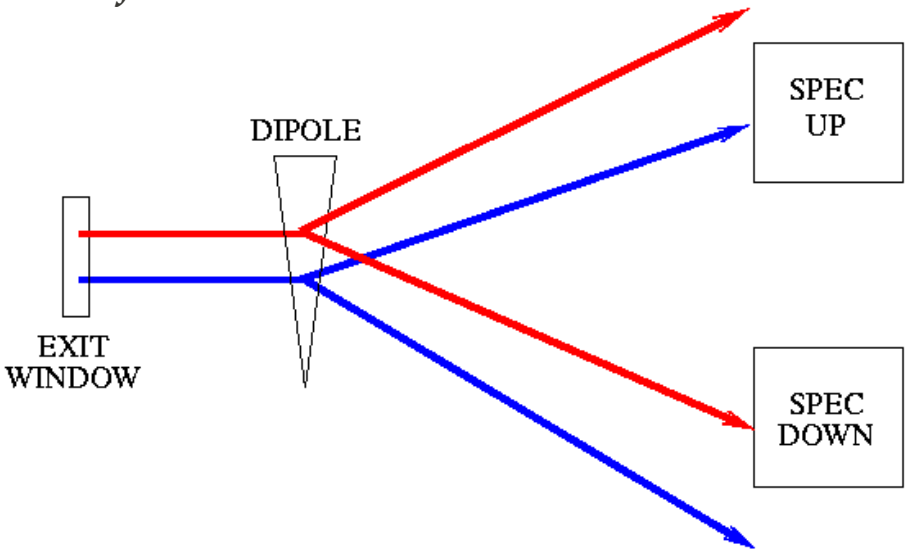
Offline analysis:

- fit MC for photon beam to X_γ, Y_γ - histograms

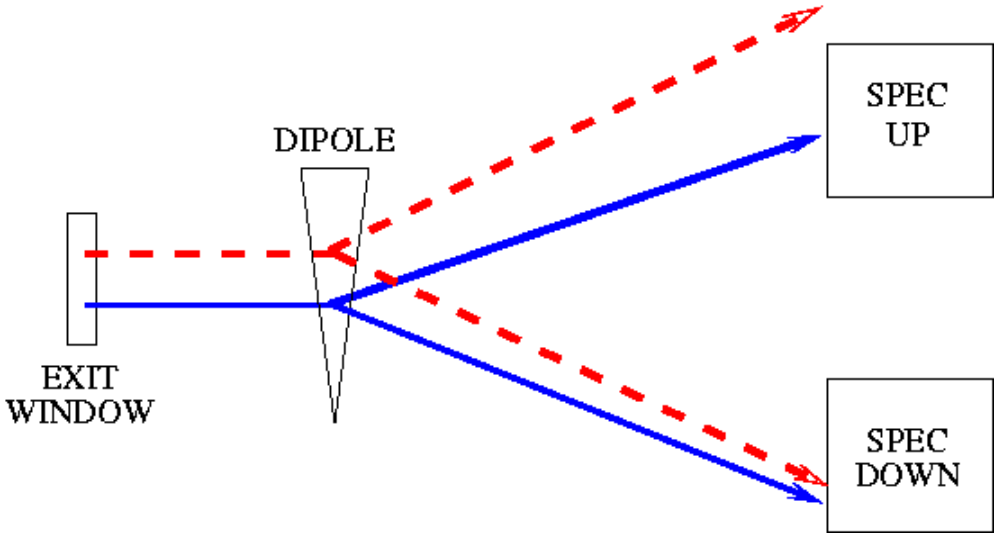
$\Rightarrow$ acceptance correction

Spectrometer pile-up

fake coincidence



lost coincidence



2 pairs that would not each make a coincidence could make one

This leads to over-counting of coincidences

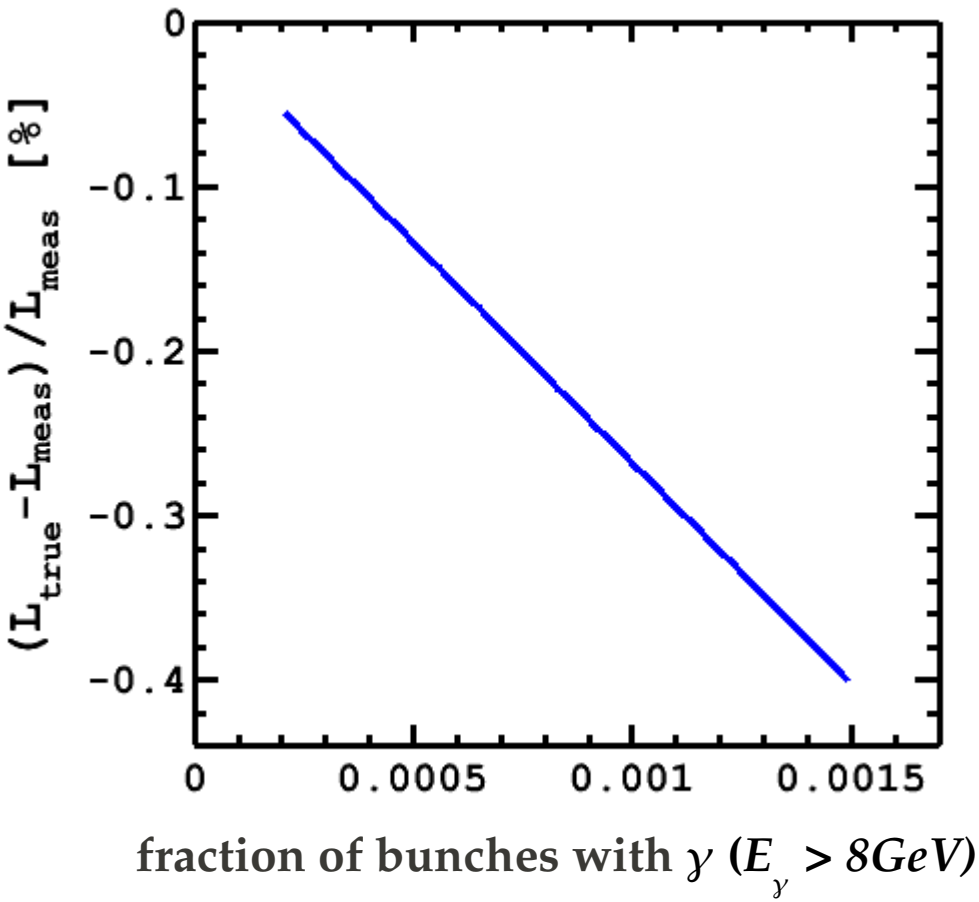
DAQ subtracted channel energies from previous HERA bunch

A single from a previous bunch (- - - -) could overlap a valid coincidence, stealing its energy and failing cuts

This leads to under-counting of coincidences

Spectrometer pile-up

luminosity shift due to pile-up



effect:
- determined using MC simulation
- 2 effects opposite sign, and nearly cancel

total pileup correction:
< 0.5% at highest HERA L_{inst}

Spectrometer summary

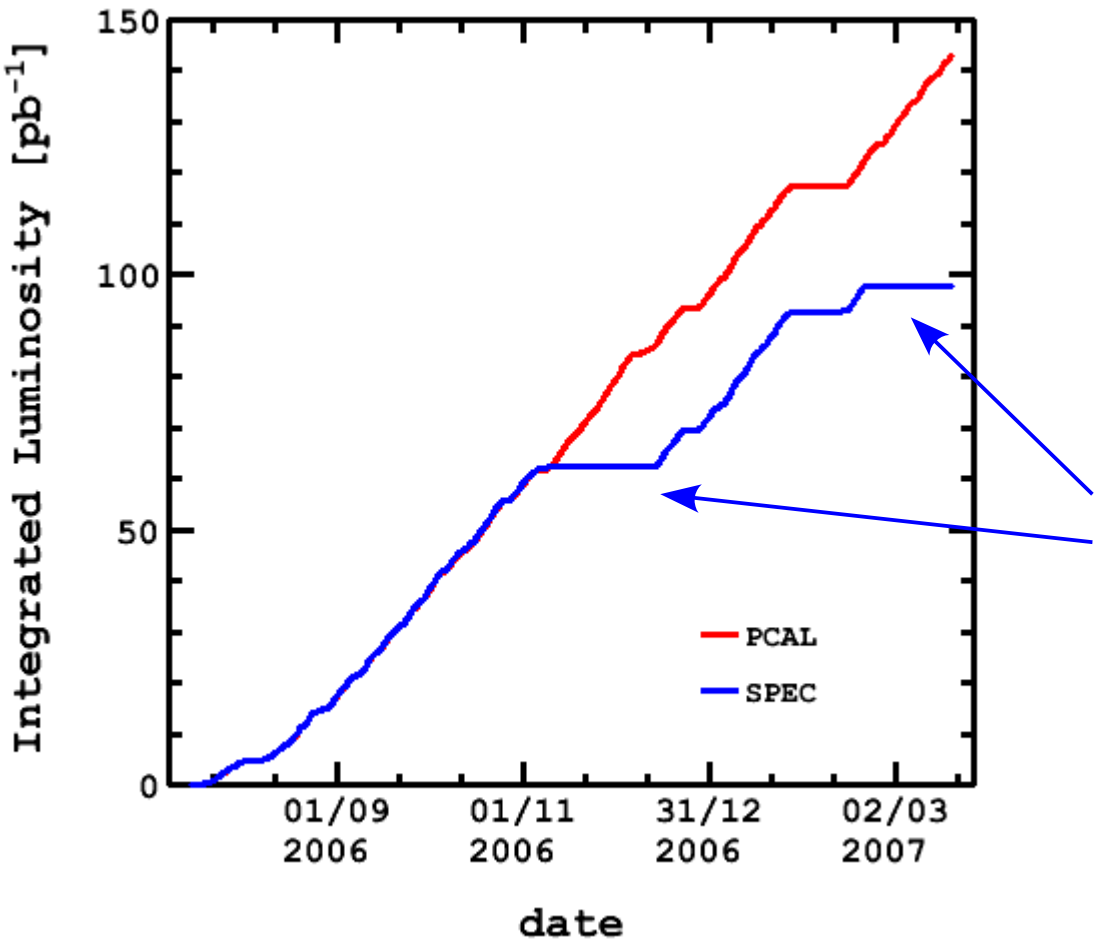
concept & detector more complex than PCAL, but:

straightforward calibration

natural E_γ range: no low E_γ complications

negligible pile-up correction

Running experiences *SPEC* hardware



***SPEC* problem**

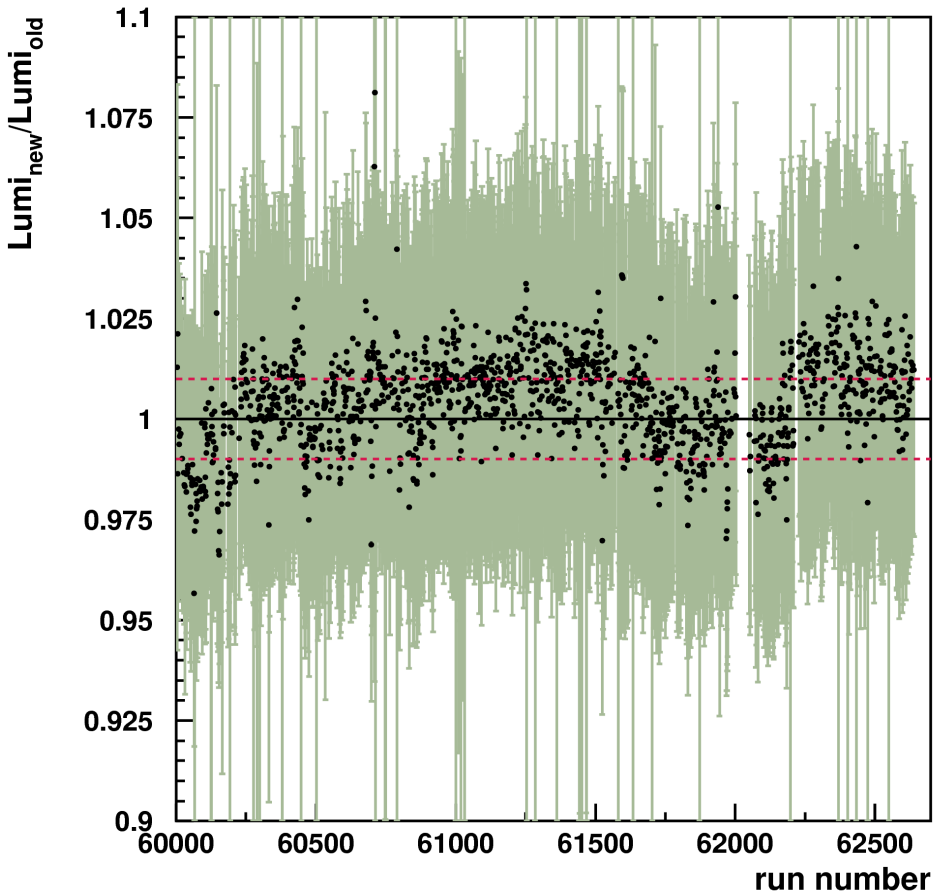
recycled hardware

HV failed several periods

- lost ~ 45 pb^{-1} (30%)

Running experiences *PCAL & SPEC* cross check

PCAL luminosity correction



cross check

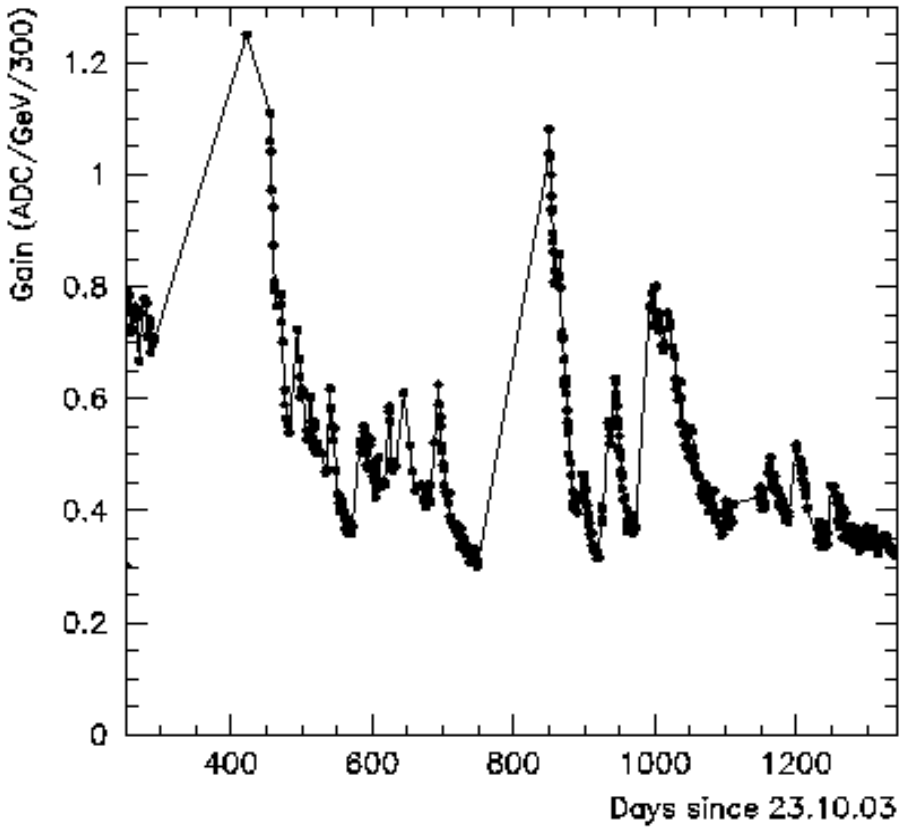
- indicate biases

- ensures measurement if one system failed

- shown PCAL correction developed after discrepancy with SPEC was found

Running experiences radiation damage

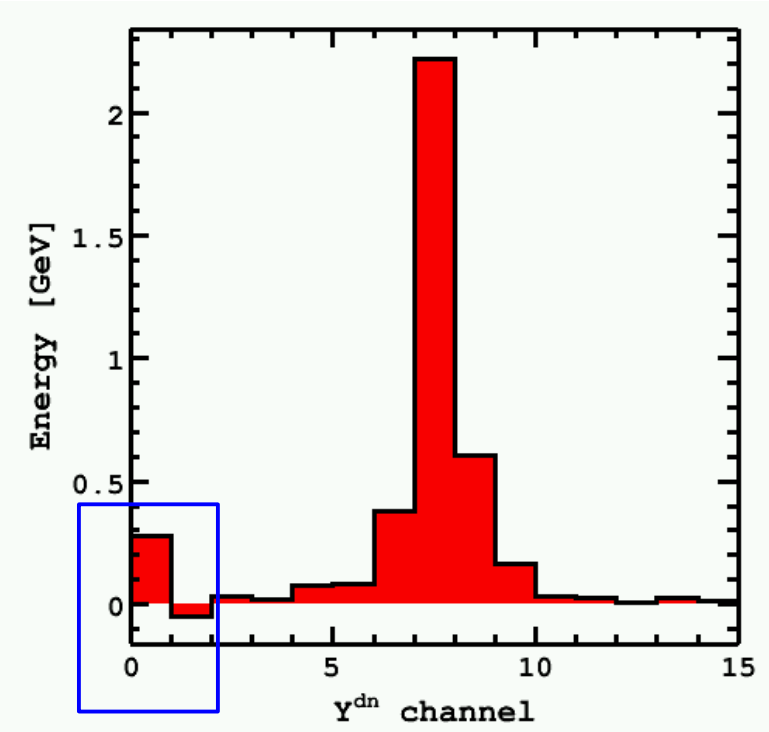
gain variation with time
(worst channel)

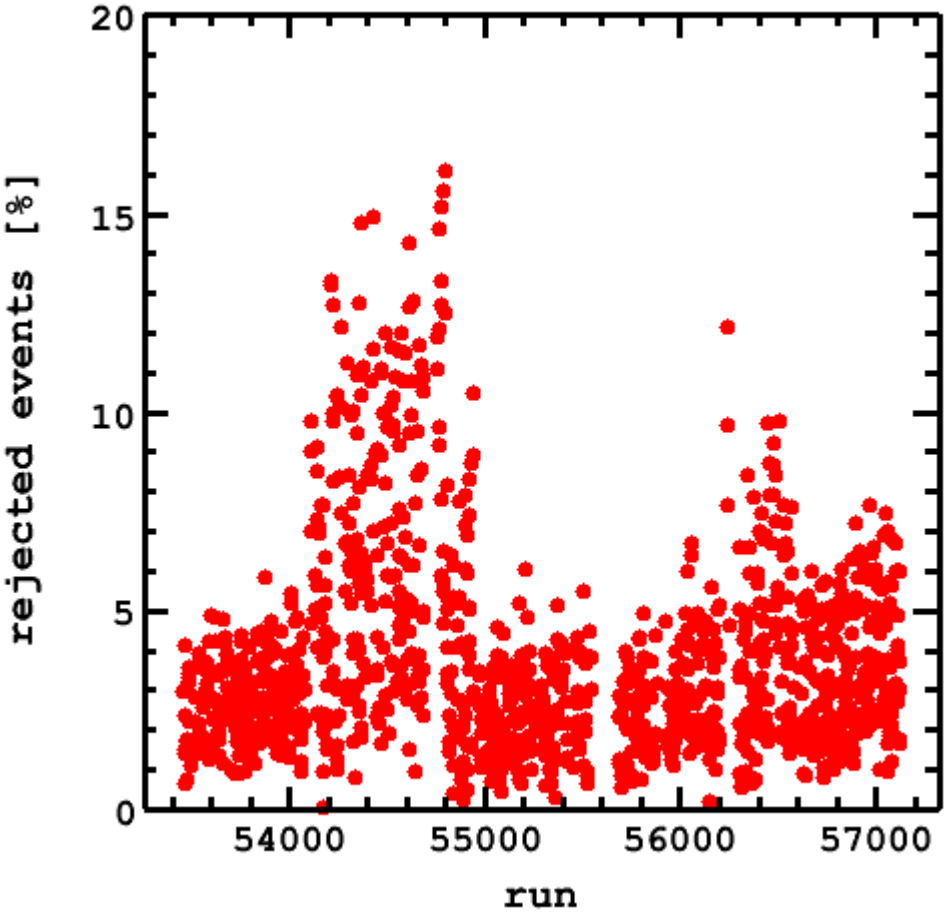


gains variation
- dropped in HERA operation
- recovered in HERA shutdowns

problem
- calorimeters were not well shielded
- damage in WLS from secondary SR

Running experiences trigger





Fails rms cut:
rms = 0.5 → 1.6
rms cut is 1

DAQ must be immune to bad beam conditions and detector problems

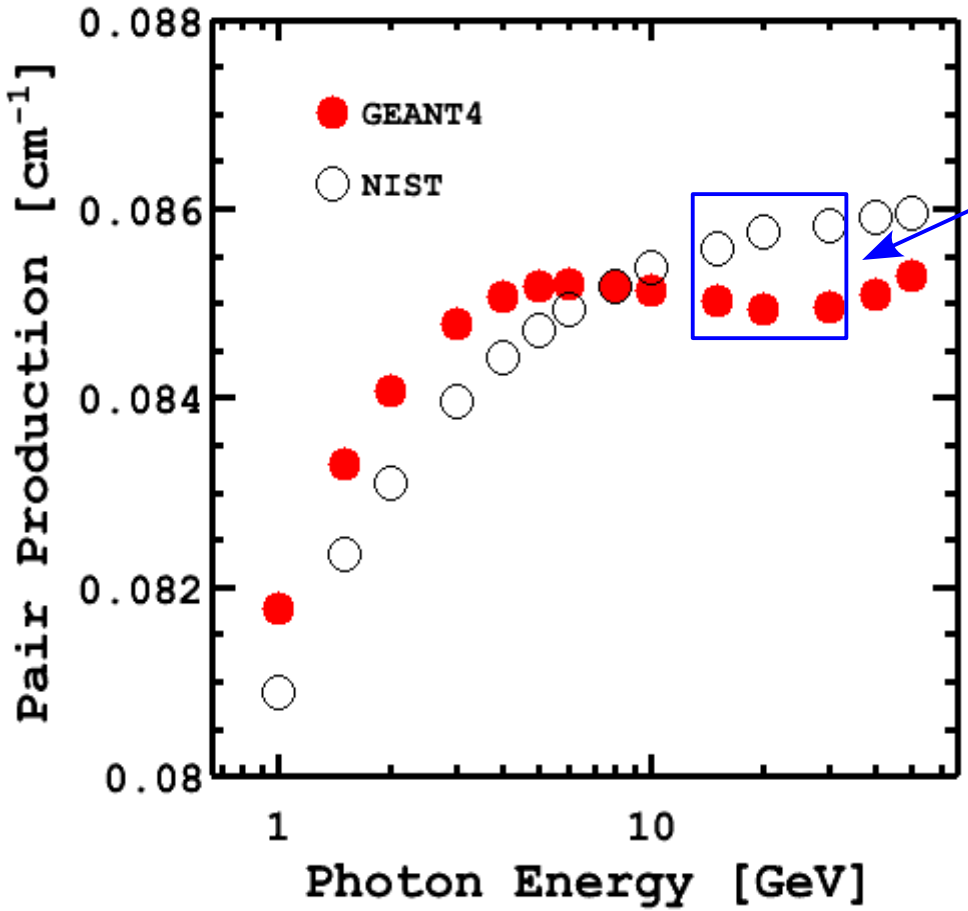
Running experiences draft

new measurements (U. Schneekloth)

	Z	σ 20 GeV [cm^{-1}]	alloy specification [%]	spare @ DESY [%]	original @ DESY [%]	original @ MAN [%]
Mg	12	0.0528	0.27	0.336	0.318	0.344
Al	13	0.0858	86.22	85.320	81.790	86.200
Si	14	0.0815	10.80	10.894	14.765	10.300
Fe	26	0.4385	0.21	0.281	0.227	0.260
Cu	29	0.5342	2.50	2.741	2.433	2.400
Zn	30	0.4397		0.315	0.338	0.365
σ_{window} [cm^{-1}]				0.10000	0.09841	0.09864

New measurement lead to luminosity correction of 1.4%

γ attenuation coefficient for Al



Acceptance region

- ε = 1 % at 20 GeV

***NIST* database**

- best knowledge of photon cross sections

GEANT

- parametrization
- fit to the NIST values
- fit accuracy better than 5% (*GEANT* manual)

Running experiences literature

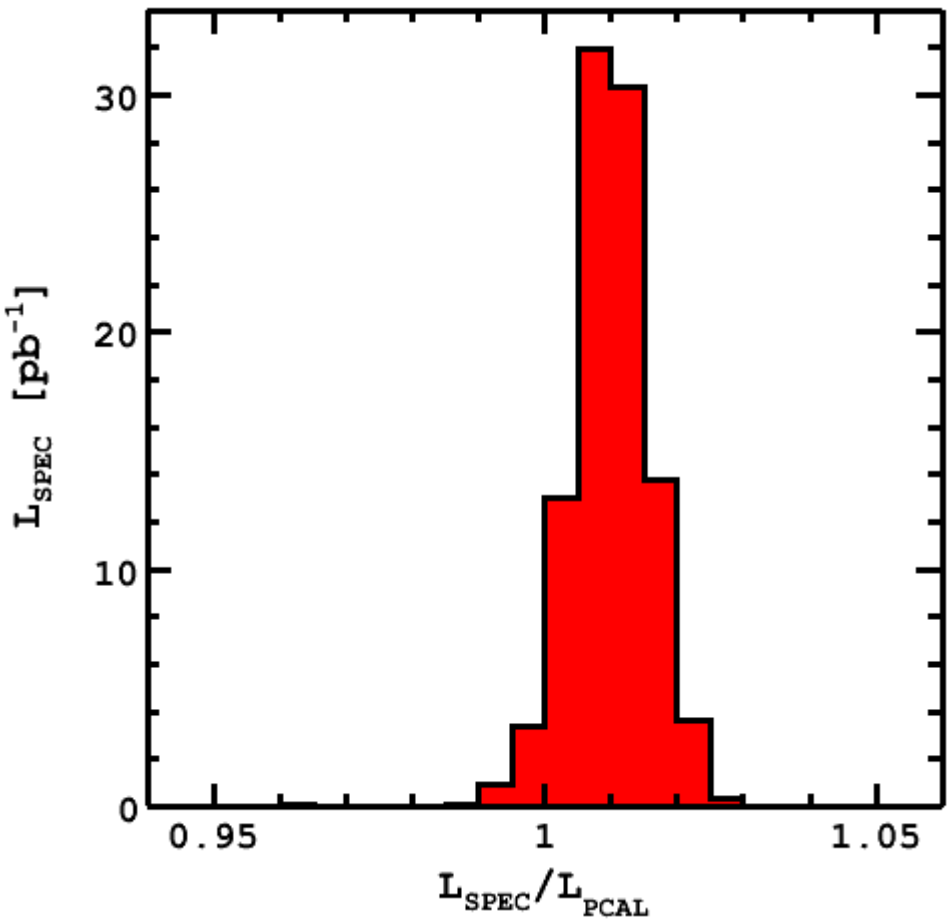
'An accurate determination of the total pair production cross section in carbon, aluminium, copper and lead for photons from 1.200 to 4.050 GeV'
Physics Letters B, Volume 27, Issue 2, 1968, Pages 103-105

Al	1.2 GeV	0.4 %
	1.5 GeV	0.7 %
Cu	1.2 GeV	0.3 %
	1.5 GeV	0.1 %

No measurement for *Al, Cu* above 1.5 GeV

Results draft

weighted luminosity ratio



PCAL & SPEC comparison:

- they operated and analyzed by two independent groups

- they agree within 1%

Systematic uncertainties:

PCAL

- total systematics: ±2.5%

- comes equally from the several corrections, probably irreducible

SPEC

- total systematics: ±1.8%

- hope to improve further with *e*-tagger studies