# QED Background
Event Generators

○ Occupancy of the (inner) DEPFET layer of crucial importance

→ reliable estimates for background needed

○ „New" insight into background for PXD:

Machine background may not be the real problem
background ~ current (factor 2-3 more?)

→

Luminosity-related QED processes will dominate
background ~ luminosity (factor 40 more!)

→

○ Several generators under study
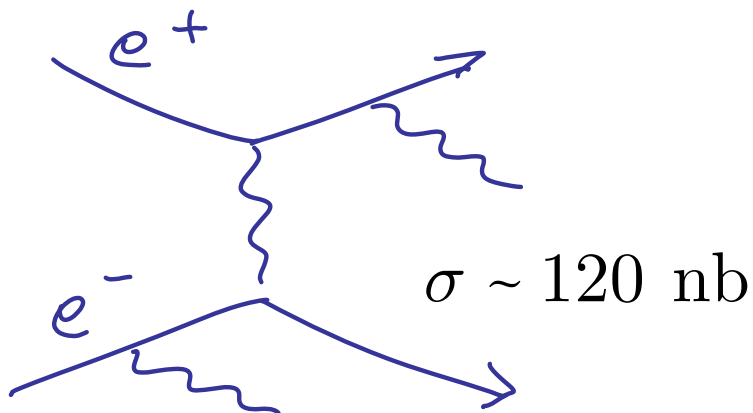
→ differences are significant (!)

QED Processes at SuperKEKB (Belle II)

Cross sections for s-channel processes fall like 1/s

e^+ → μ^+

e^- → μ^-
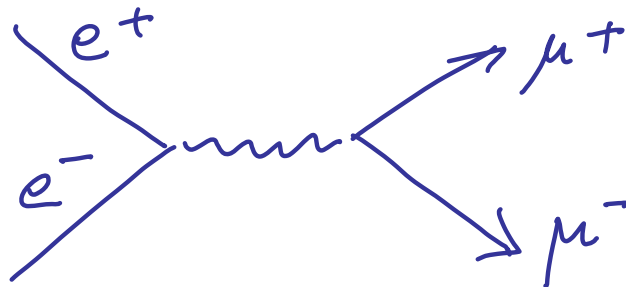
Rate ~ 600 ev/s

@10^3 / nb s

Cross sections for t-channel processes are largely independent of s

e^+

e^-

$\sigma \sim 120 \text{ nb}$

Bhabha scattering

e^+

e^-

$\left. \begin{array}{c} f \\ \overline{f} \end{array} \right\}$ $e^+ e^-$:

$\sigma \sim O(10^7 \text{nb})$

2-photon-processes

QED Processes of Importance
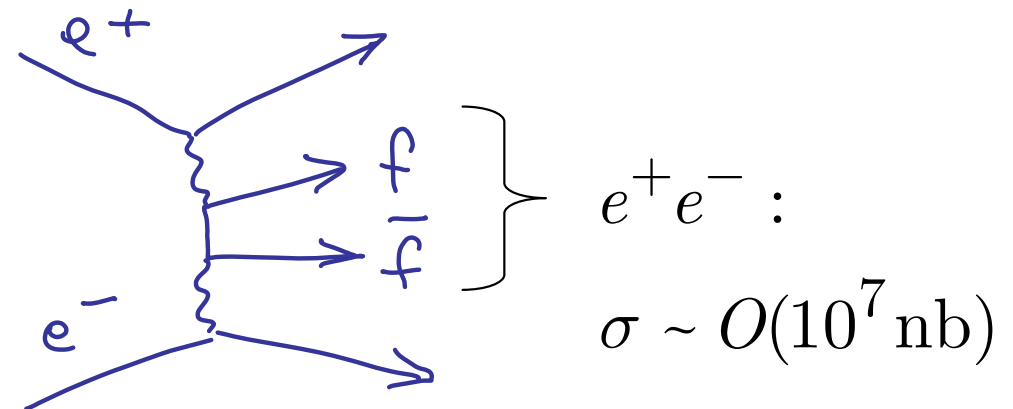
○ 2-photon processes dominate by far
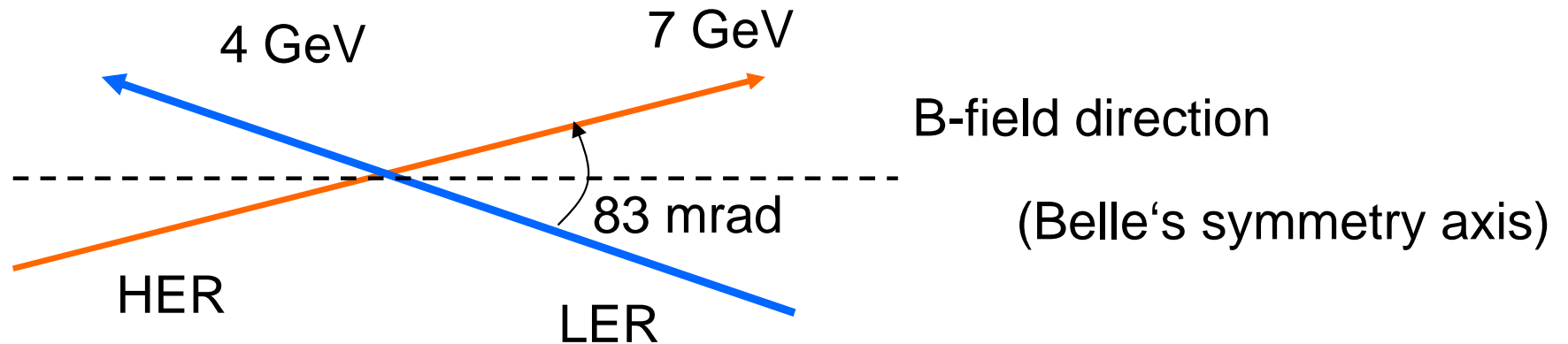
○ Several generators:

Diag36 (Berends-Daverfeldt-Kleiss, 1985)

Grace (J.Fujimoto, et.al. Comp.. Phys. Comm. 100 (1997) 128)

Racoon (A.Denner, S.Dittmaier, M.Roth, D.Wackeroth,
Comp. Phys. Comm.. 153 (2003) 462)

KoralW (S. Jadach, W. Placzek, M. Skrzypek, B.F.L. Ward,
CERN-TH/95-205, Jul 1995, CPC 94 (1996) 216 …)

○ all done for symmetric e+e- machines (PETRA, LEP), all tested there!

QED at SuperKEKB

4 GeV   7 GeV

B-field direction

83 mrad

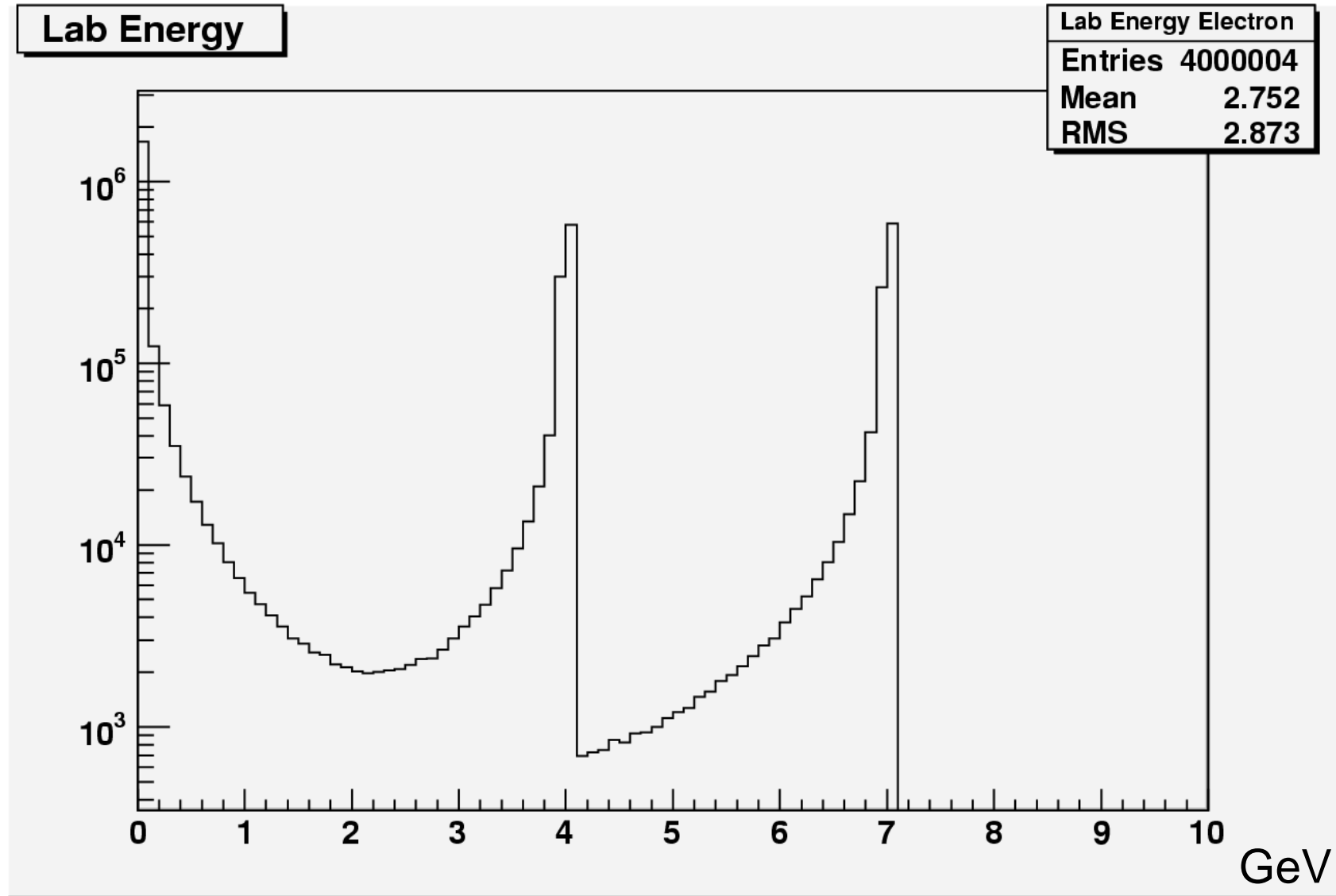(Belle's symmetry axis)
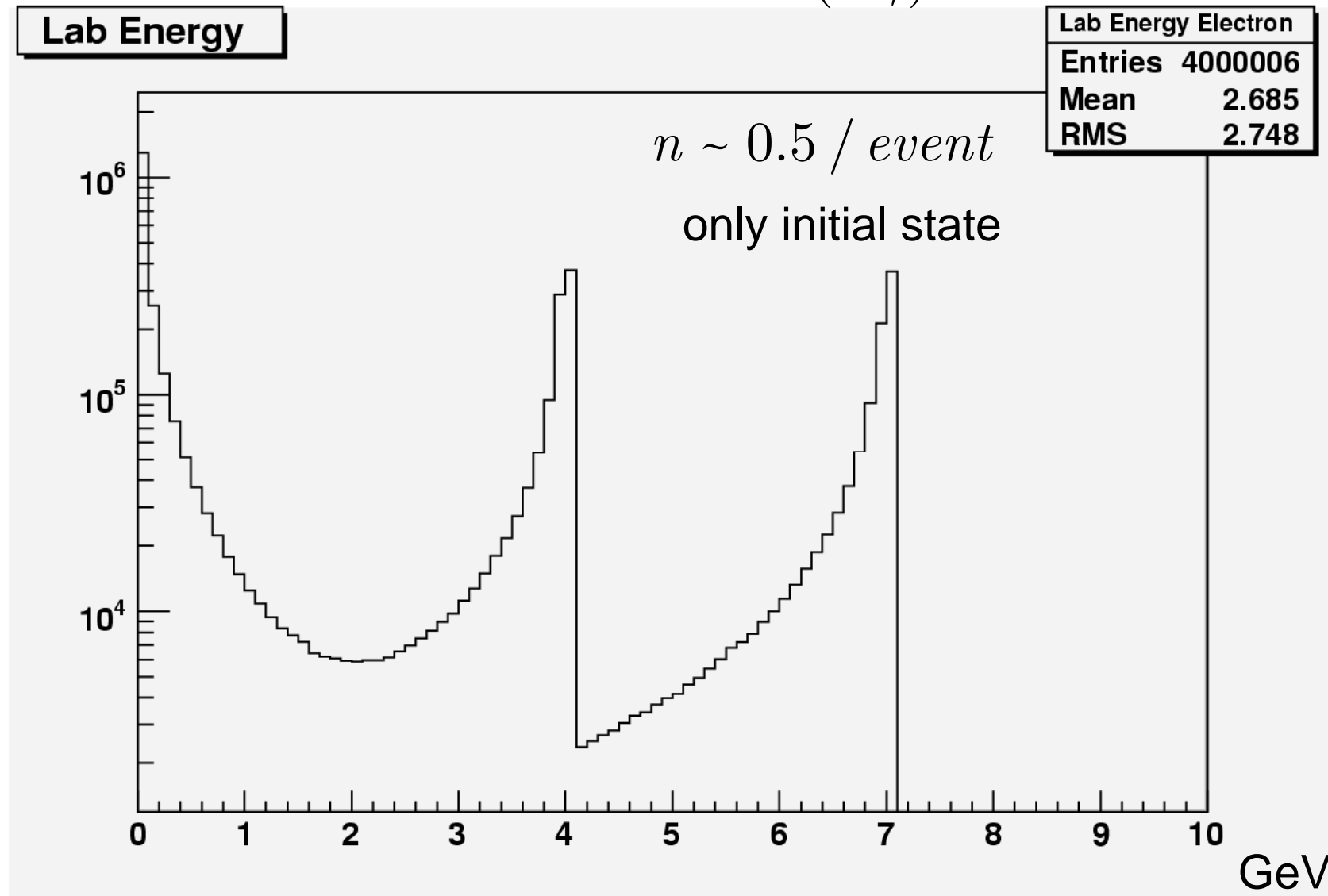
HER

LER

Procedure:

1M events
per generator

○ generate events in CM system

○ calculate boost from lab to CMS (method of Burkard)

○ boost CMS to lab

○ make acceptance cuts (p_T, θ) in the lab

Berends-Daverfeldt-Kleiss (BDK)

$$e^+ e^- \rightarrow e^+ e^- e^+ e^-$$

$$e^+ e^- \rightarrow e^+ e^- e^+ e^- (+\gamma)$$

Lab Energy

Lab Energy Electron	
Entries	4000006
Mean	2.685
RMS	2.748

$$n \sim 0.5 \, / \, event$$

only initial state

GeV

KoralW (KW)

$$e^+e^- \rightarrow e^+e^-e^+e^-(+n\gamma)$$

Lab Energy

Lab Energy Electron	
Entries	4000004
Mean	2.524
RMS	1.968

$n \sim 1.5 \, / \, event$

estimated error on
cross section: 70 % !!

GeV
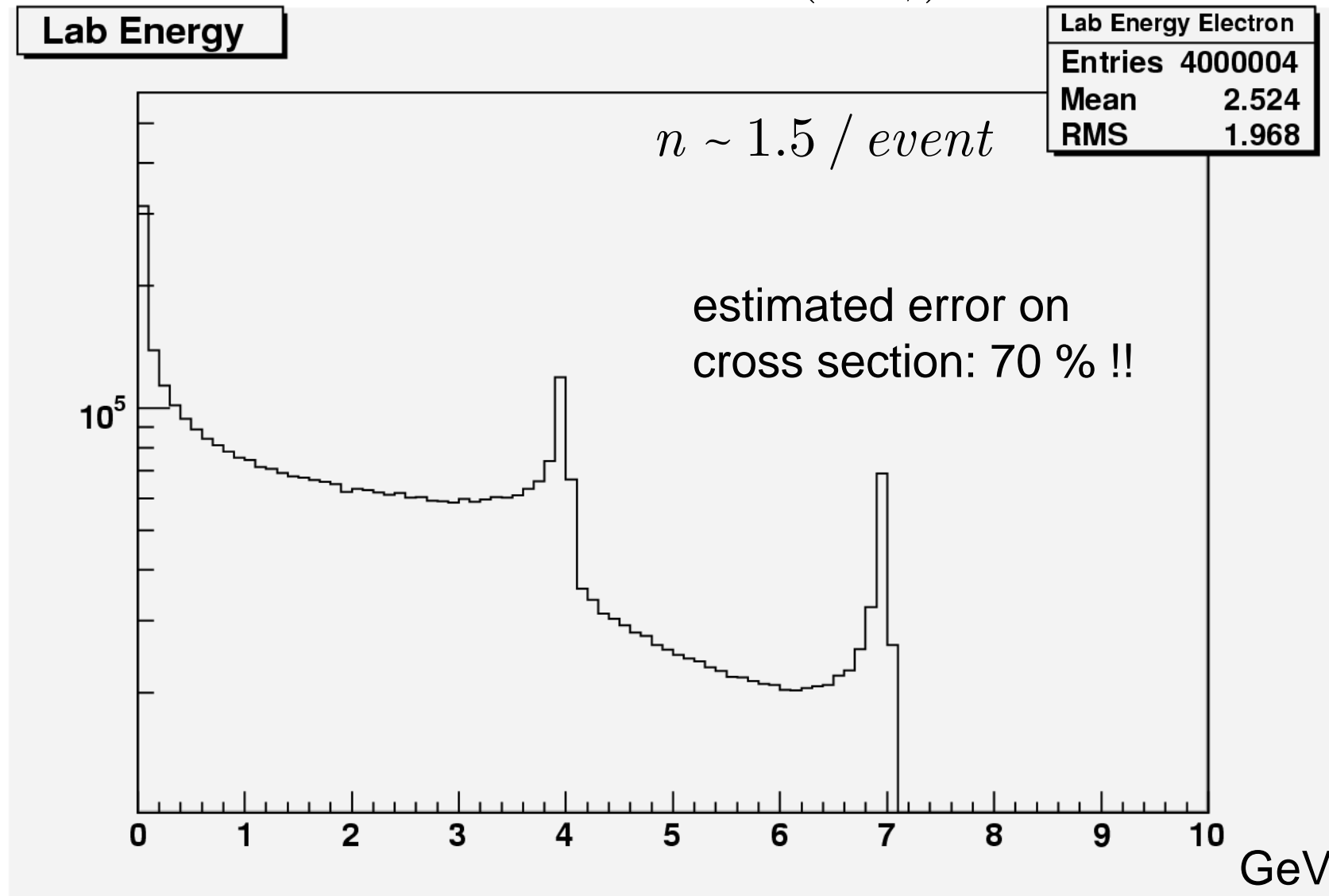
BDK (after acc. cuts)

PT/th cut Lab Energy, lower part

PT/th cut Lab Energy, lower part Electron	
Entries	5413
Mean	0.01684
RMS	0.01194

only secondary electrons
visible!

small scattering angle:
Weizsäcker-Williams approximation

GeV

PT/th cut Lab Energy, lower part

PT/th cut Lab Energy, lower part Electron	
Entries	1710400
Mean	0.04339
RMS	0.0268

primary and secondary electrons visible!

no approximations (?).

GeV

PT/th cut Lab Energy

PT/th cut Lab Energy Electron	
Entries	1710400
Mean	2.361
RMS	1.76

primary and secondary electrons with high energy visible!

GeV

KW (after acc. cuts)

PT/th cut Lab Cos Polar angle

PT/th cut Lab Cos Polar angle Electron	
Entries	1710400
Mean	0.1755
RMS	0.5872

„backward"　　　　　　　　　　　　　　　　　　　　„forward"
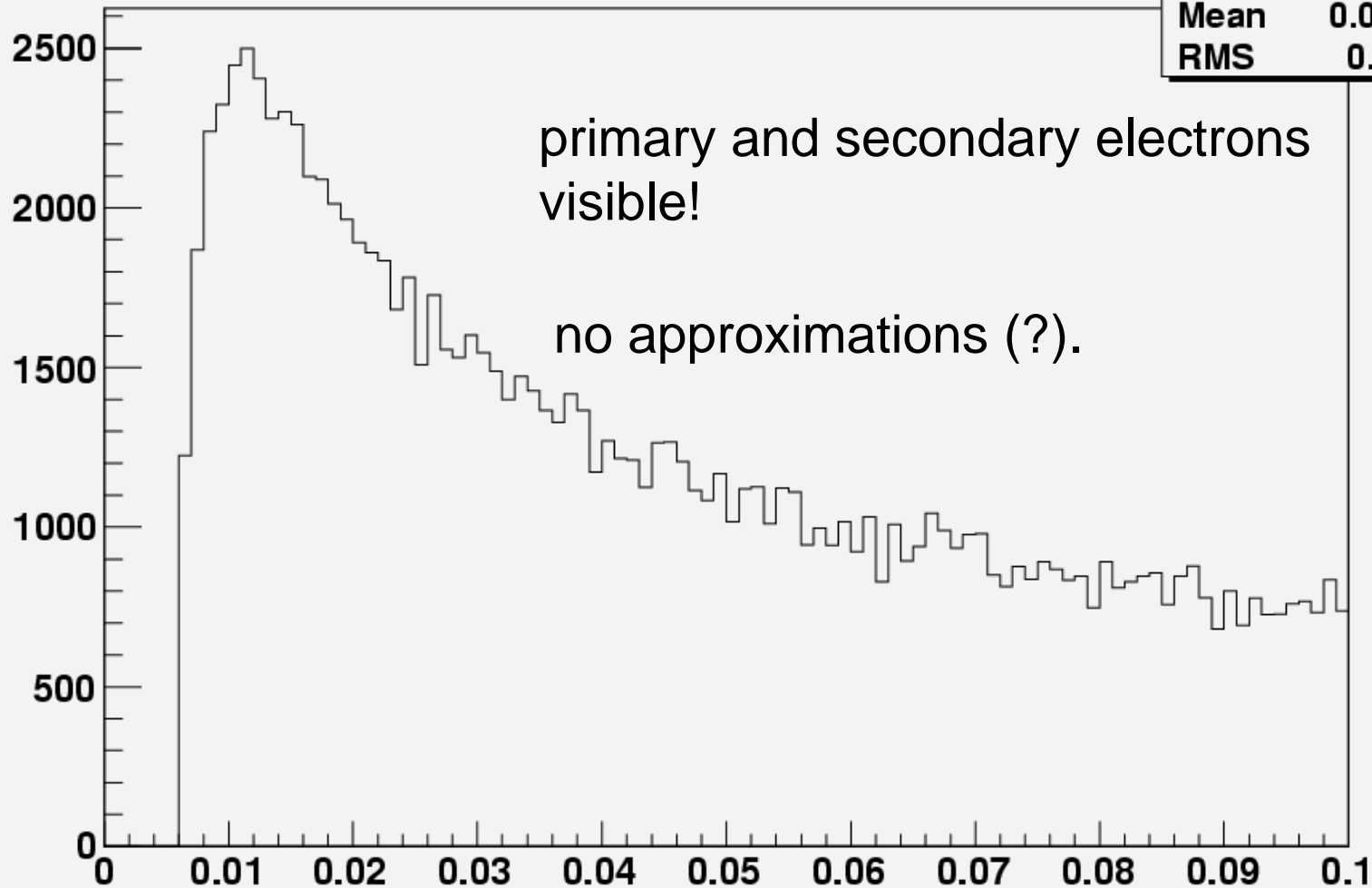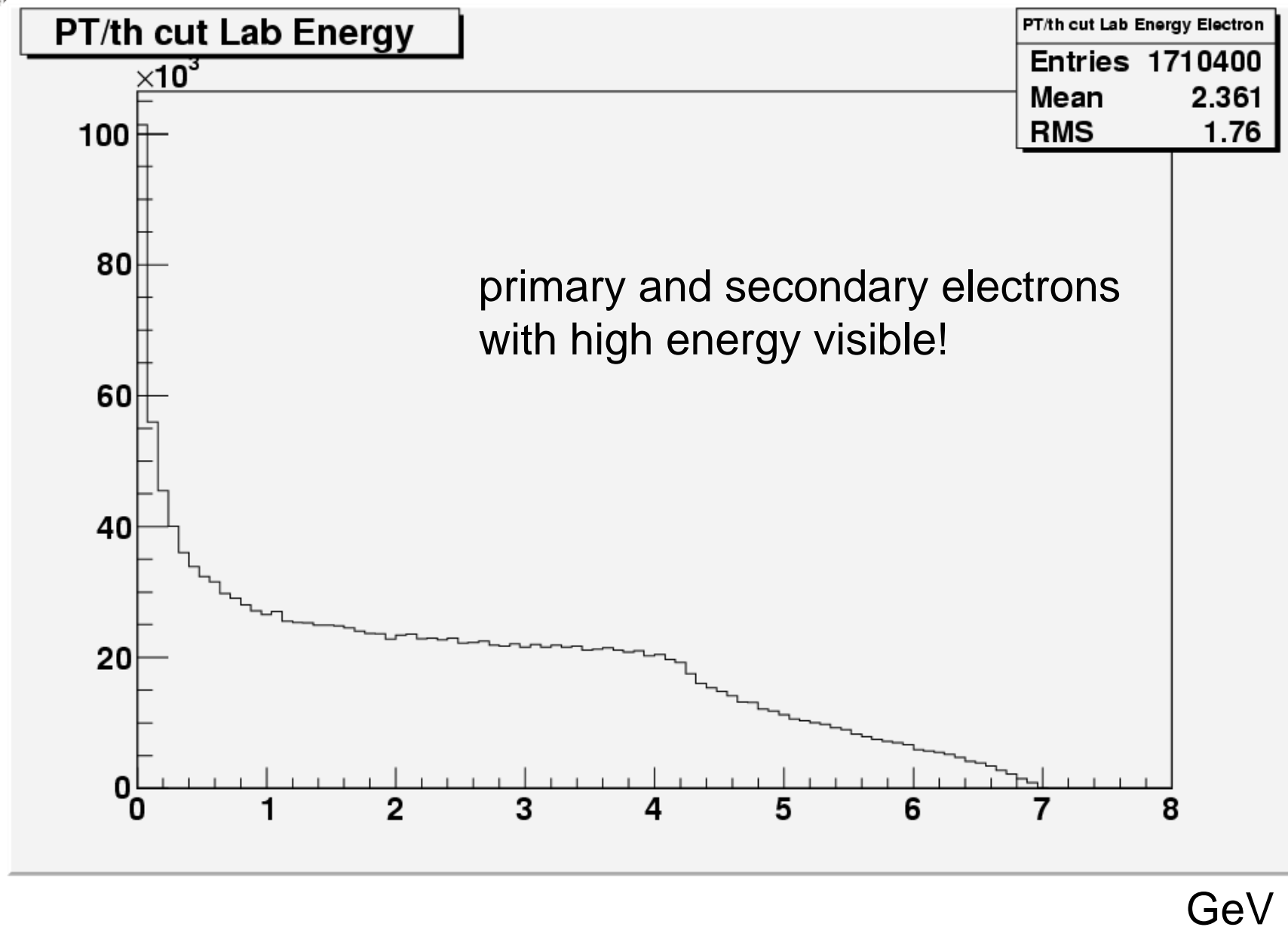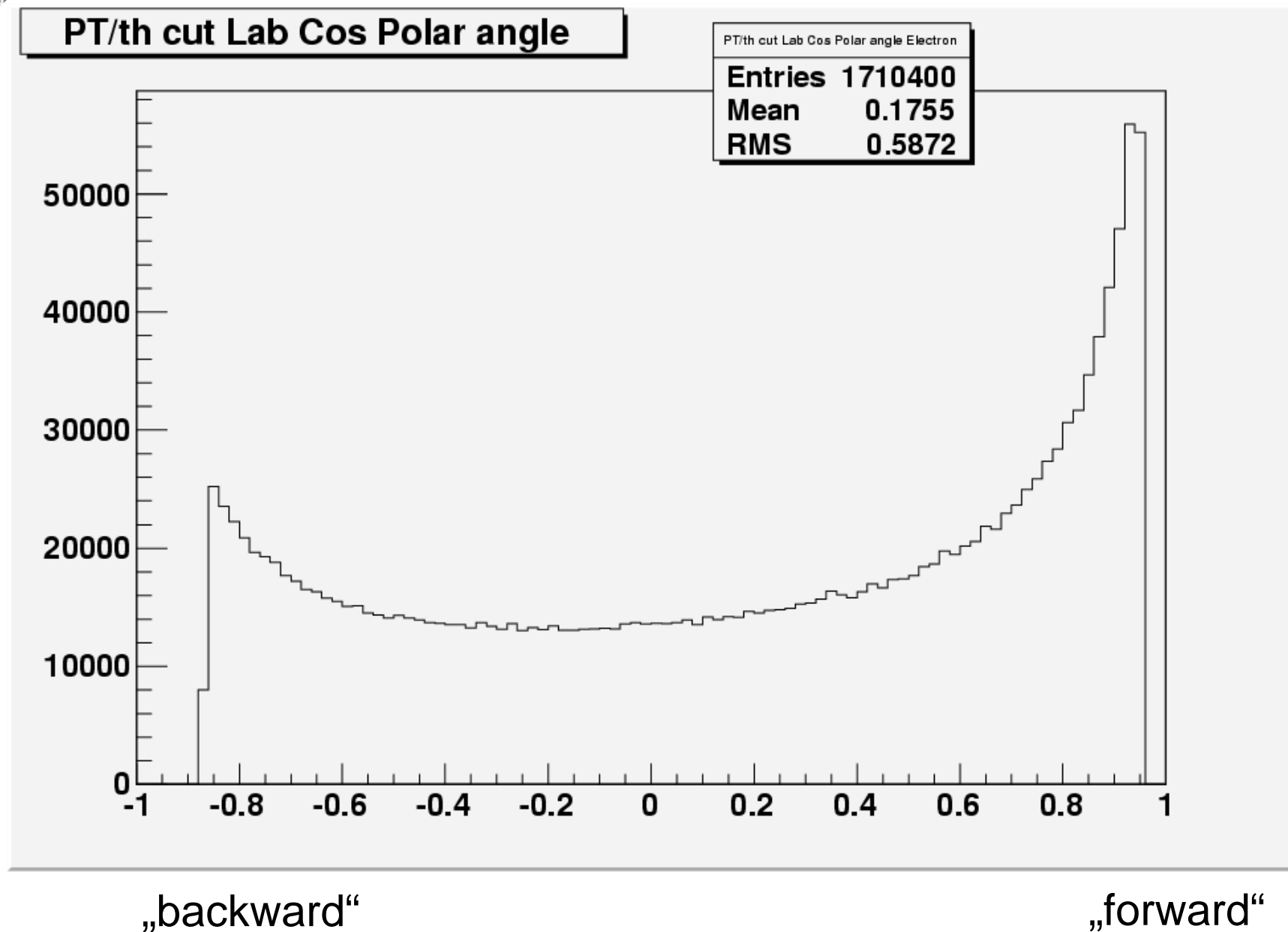
BDK: $\sigma = 7.3 \times 10^6 \left[\mathrm{nb}\right]$

(some „internal" cuts do exist!)

KW: $\sigma = 1.6 \times 10^5 \left[\mathrm{nb}\right]$

$$N_{\mathrm{tr}}(\mathrm{bg}) = N_{\mathrm{tr}}^{\mathrm{acc}}(\mathrm{MC}) \cdot \frac{\sigma_{\mathrm{QED}} \cdot L}{N_{\mathrm{ev}}(\mathrm{MC})}$$

ε

DEPFET readout time

$$L = \int \mathcal{L}\, dt = \mathcal{L} \cdot \Delta t = 10^3 \left[\frac{1}{\mathrm{nb}\, s}\right] \times 2 \times 10^{-5}\, [s]$$

$$N_{\mathrm{ev}}(\mathrm{MC}) = 10^6$$

BDK: $\varepsilon = 0.146$

KW: $\varepsilon = 3.2 \times 10^{-3}$

BDK: $\quad N_{\text{tr}}^{\text{acc}}(\text{MC}) = 5413$

KW: $\quad N_{\text{tr}}^{\text{acc}}(\text{MC}) = 1.71 \times 10^6$

Expected number of background tracks per event:

Occupancy (inner layer):

BDK: $\quad N_{\text{tr}}^{\text{bg}} = 790$ $\qquad\qquad 0.07\,\%$

KW: $\quad N_{\text{tr}}^{\text{bg}} = 5470$ $\qquad\qquad 0.5\,\%$

close to the „limit" of 1 %

Nr of pixels: $\quad 250 \times 1600 \times 8 = 3.2 \times 10^6$
(assume each track lights up 3 pixels)

QED at low momentum transfers (I)

A word of caution:

- QED (higher orders) has been studied in great detail in HEP

  … **but:** only at high momentum transfers!

  e.g. PETRA / LEP:
  single tag, double tag
  no-tag, but with high energy electrons (~GeV)

  ⟶ only triggered events were compared to theory!

- QED never tested in low Q scenarios

- No surprise that theoretical models are in disagreement

QED at low momentum transfers (II)

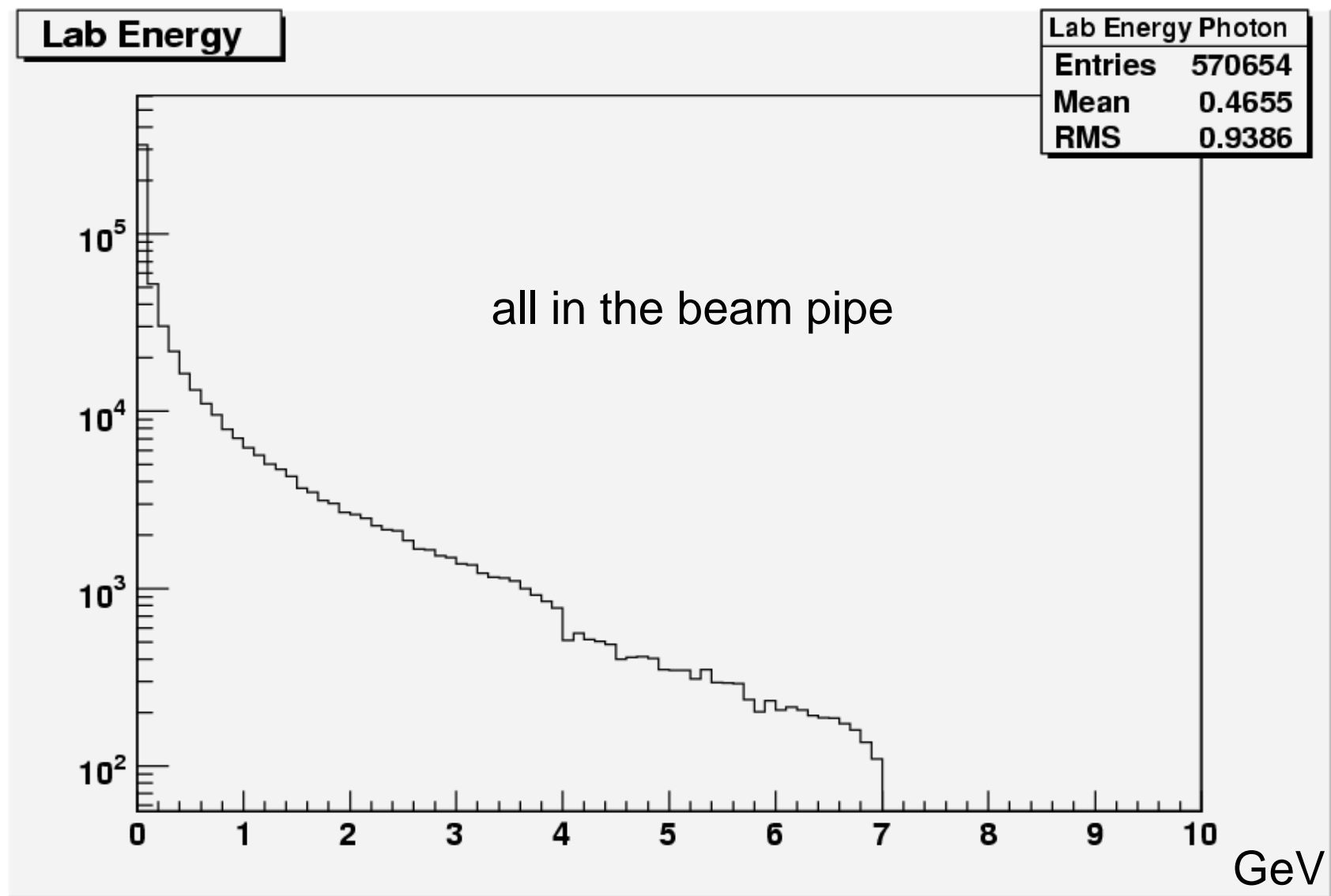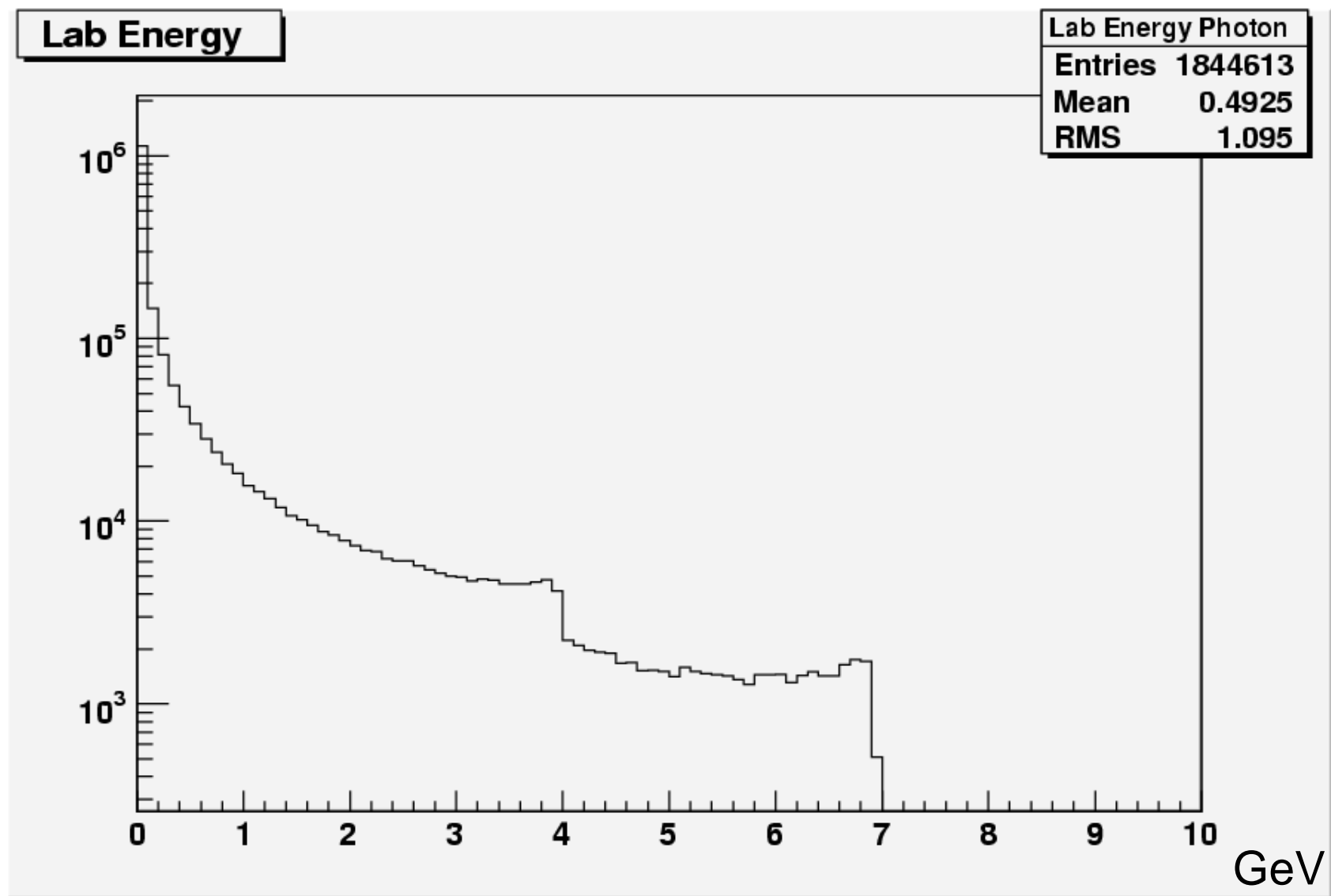➡ Need to MEASURE the low energy-transfer QED

Proposal:

Take random triggers with Belle (this year last chance)

- ⚪ colliding beams (comes with data taking)

    ➡ collects QED and beam gas

- ⚪ with separated beams (special run, to be requested)

    ➡ collects only beam gas

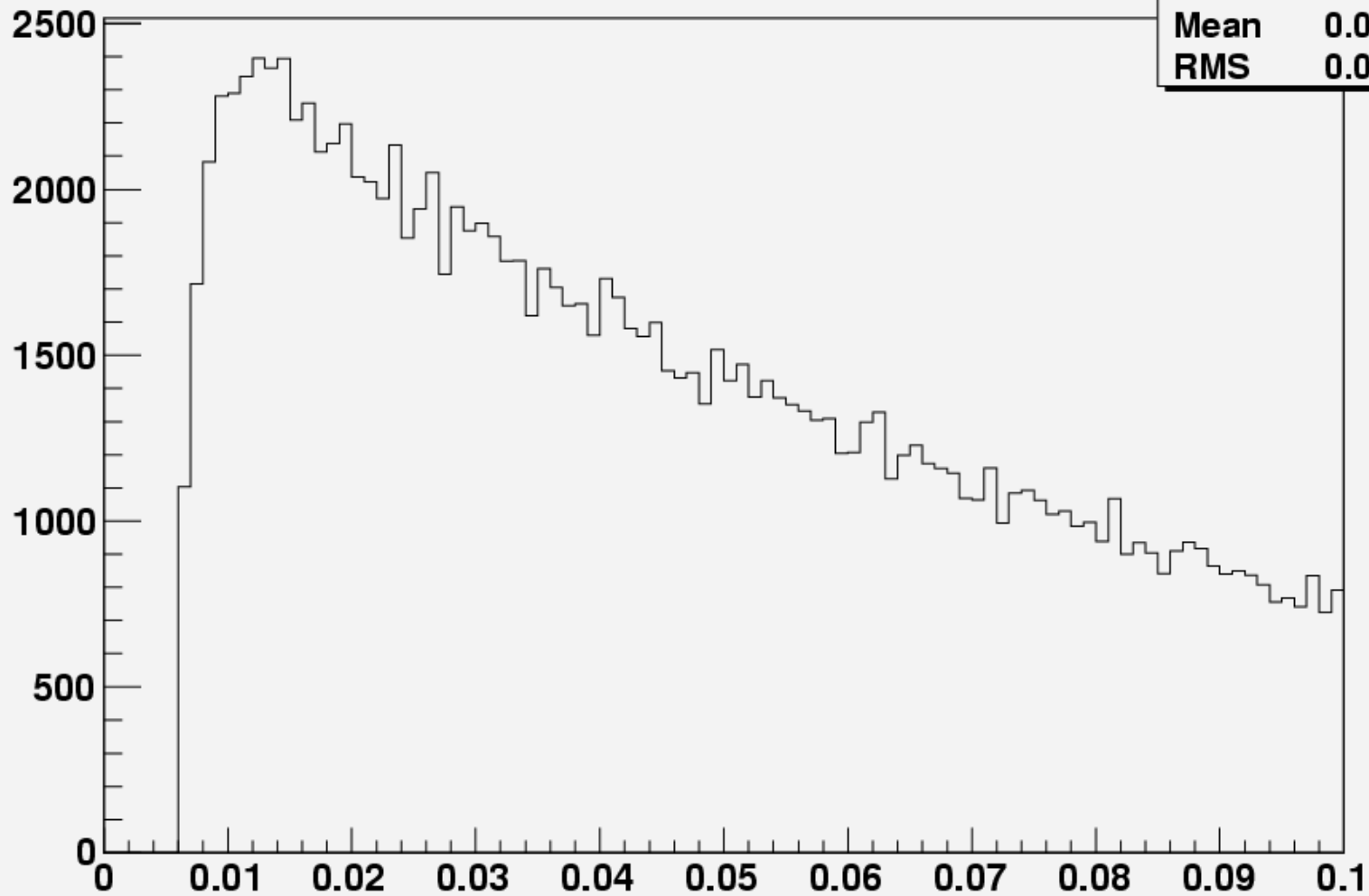- ⚪ Subtract to get estimate of QED bg

Conclusions

- SuperKEKB: Current will rise by factor 2, lumi by factor 40

- Background likely to be dominated by QED (2 photon reactions) at SuperKEKB (also conclusion of the SuperB colleagues)

- Final states in electron pairs give largest contribution

- Generators BDK, Grace (used by Belle?) may not be adequate, approximations doubtful: e.g. radiation from leptons, Racoon is unusable (zero-mass approximation).

- Present estimate of bg rate in physics event seems low using BDK

- KoralW yields much larger contribution, is it real?

- Further study needed and ongoing (contact with authors),
  → put to a test with special runs with Belle this year

Backup

GR

all in the beam pipe

Lab Energy

Lab Energy Photon	
Entries	570654
Mean	0.4655
RMS	0.9386

GeV

PT/th cut Lab Energy, lower part

PT/th cut Lab Energy, lower part Photon	
Entries	350612
Mean	0.04449
RMS	0.02592

GeV

KW

PT/th cut Lab Cos Polar angle

PT/th cut Lab Cos Polar angle Photon

Entries	350612
Mean	0.1736
RMS	0.5998

1γ per $5e$

LER   HER