QED Background Event Generators

- „New“ insight into background for PXD:

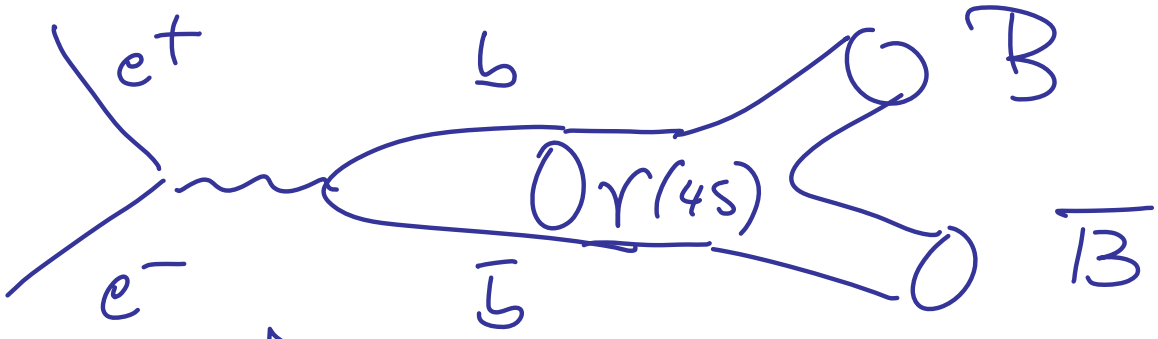
  Machine background may not be the real problem
  → background ~ current (factor 2-3 more?)

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

- Several generators under study

  differences may be significant (?)

Cross Sections for Physics at SuperKEKB



$$s = \left(E_{e^+} + E_{e^-}\right)^2$$

$$\sigma \sim \frac{1}{s} = R \cdot \frac{87}{s}\ [nb]$$

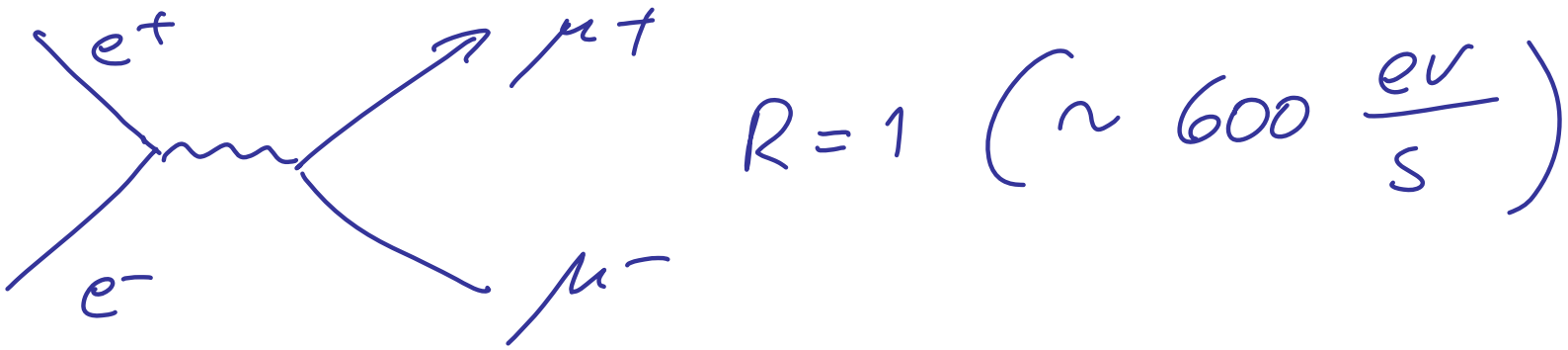
$$\frac{87}{s} \approx 0.8$$

$$\rightsquigarrow R(\Upsilon(4S)) \sim 8$$

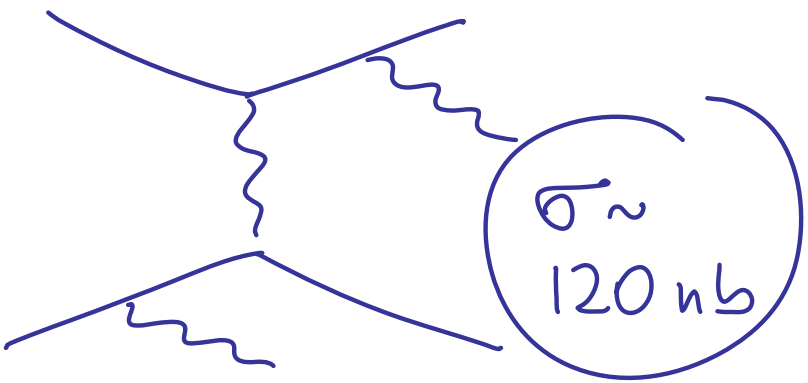
$$\dot{N} = \mathcal{L} \cdot \sigma_{\Upsilon} \sim 6\,kHz \;@\; 10^{36}\ \left[\frac{1}{cm^2 s}\right]$$

QED Processes at SuperKEKB

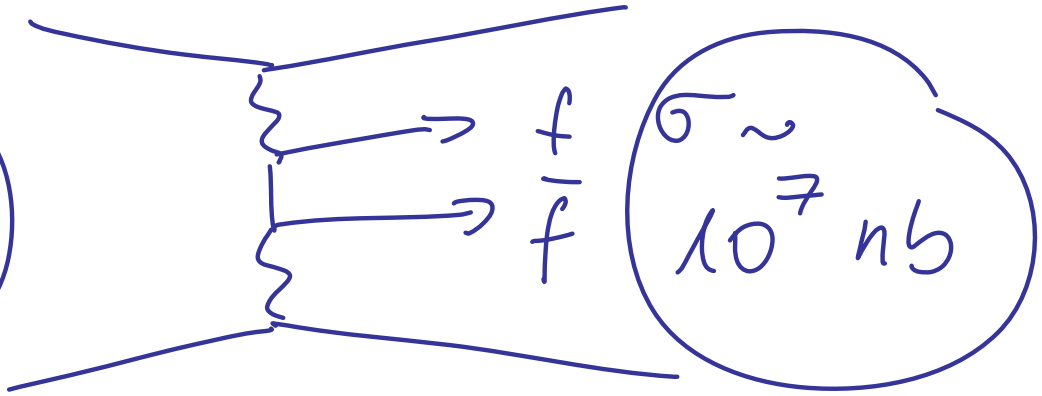
Cross sections for s-channel processes fall like 1/s



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



Bhabha scattering



2-photon-processes

QED Processes of Importance

2-photon processes dominate by far

Several generators:

Diag36 (Berends-Daverfeldt-Kleiss, 1985)

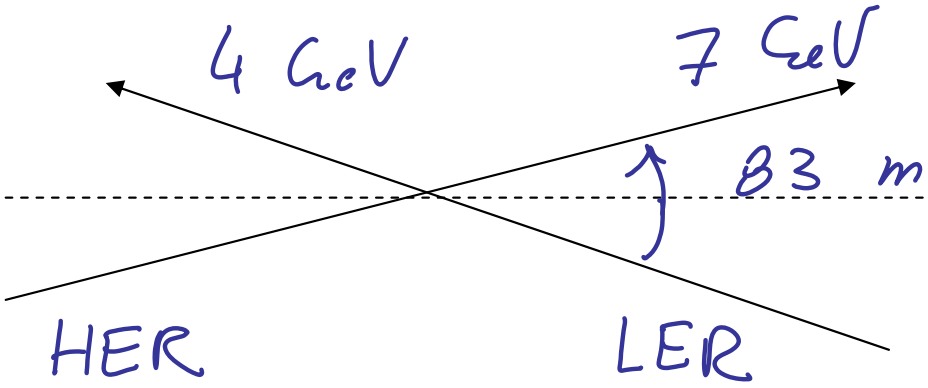
Grace (J.Fujimoto, et.al. Comp.. Phys. Comm. 100 (1997) 128

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)

QED at SuperKEKB



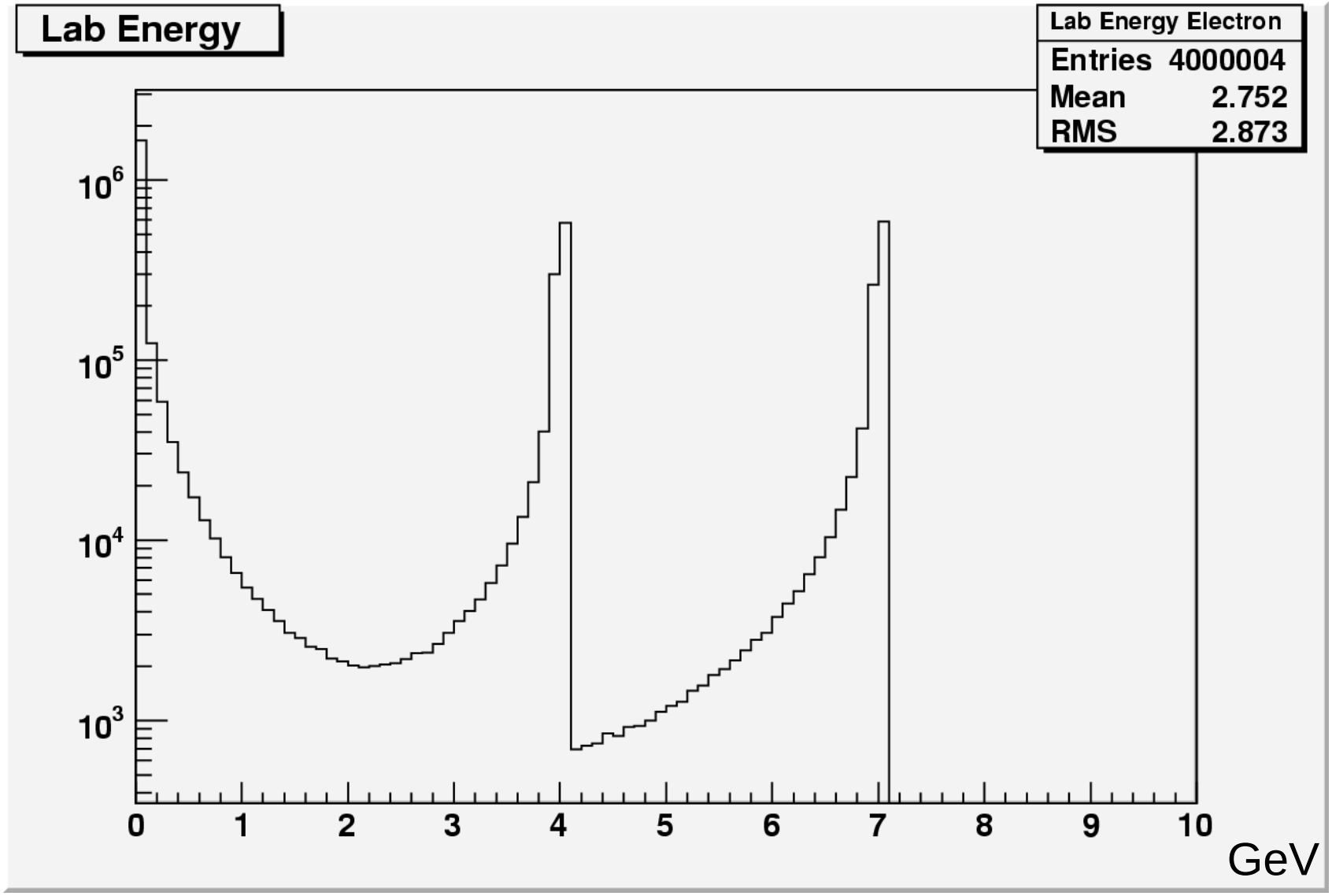
$\vec{B}$-Field of Belle II (symmetry axis)

Procedure:

- generate events in cm system (1M events each)
- calculate boost from Lab to CMS (→ method by Bushard)
- boost cms to lab
- make acceptance cuts (P_T, θ)

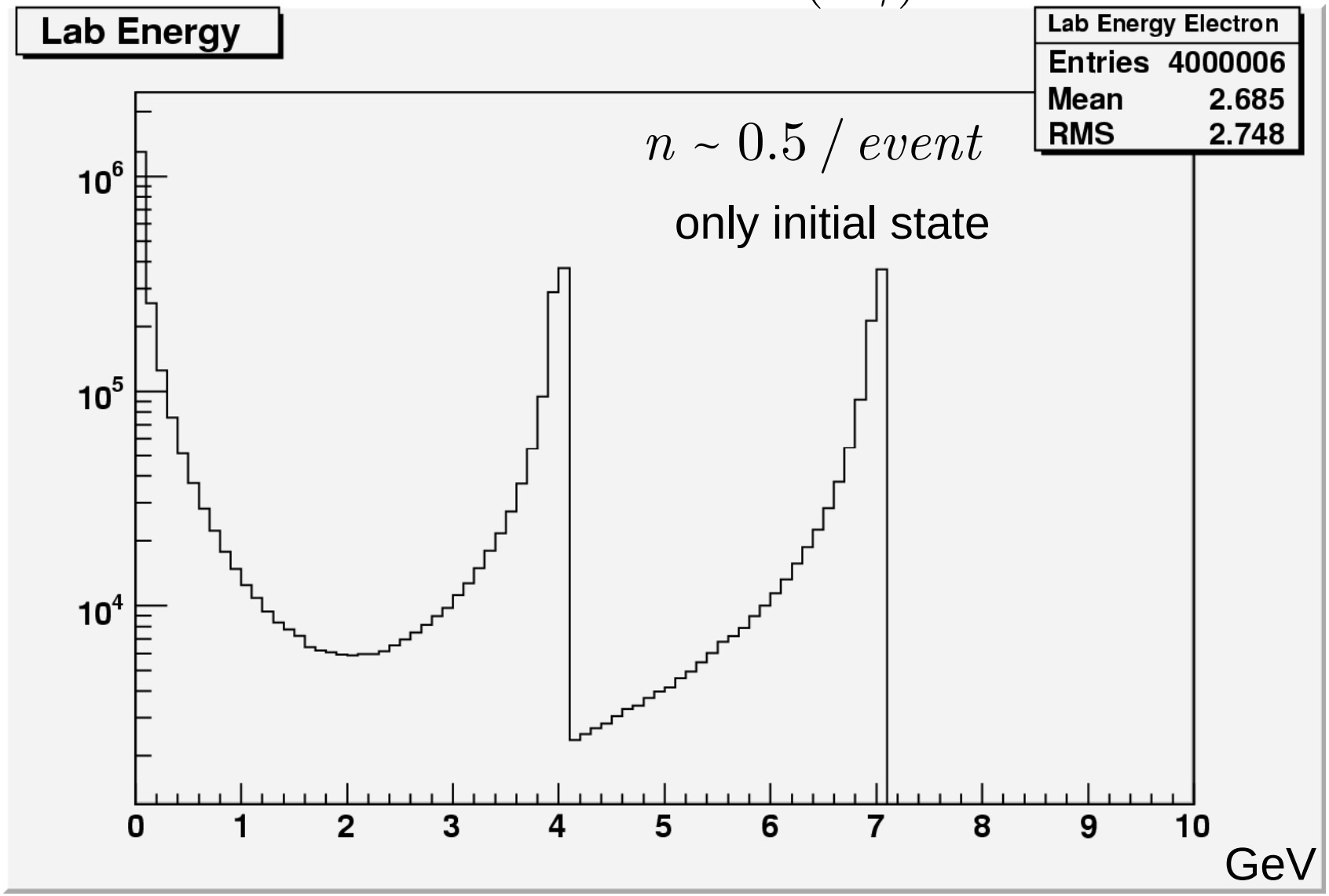
Berends-Daverfeldt-Kleiss (BDK)

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



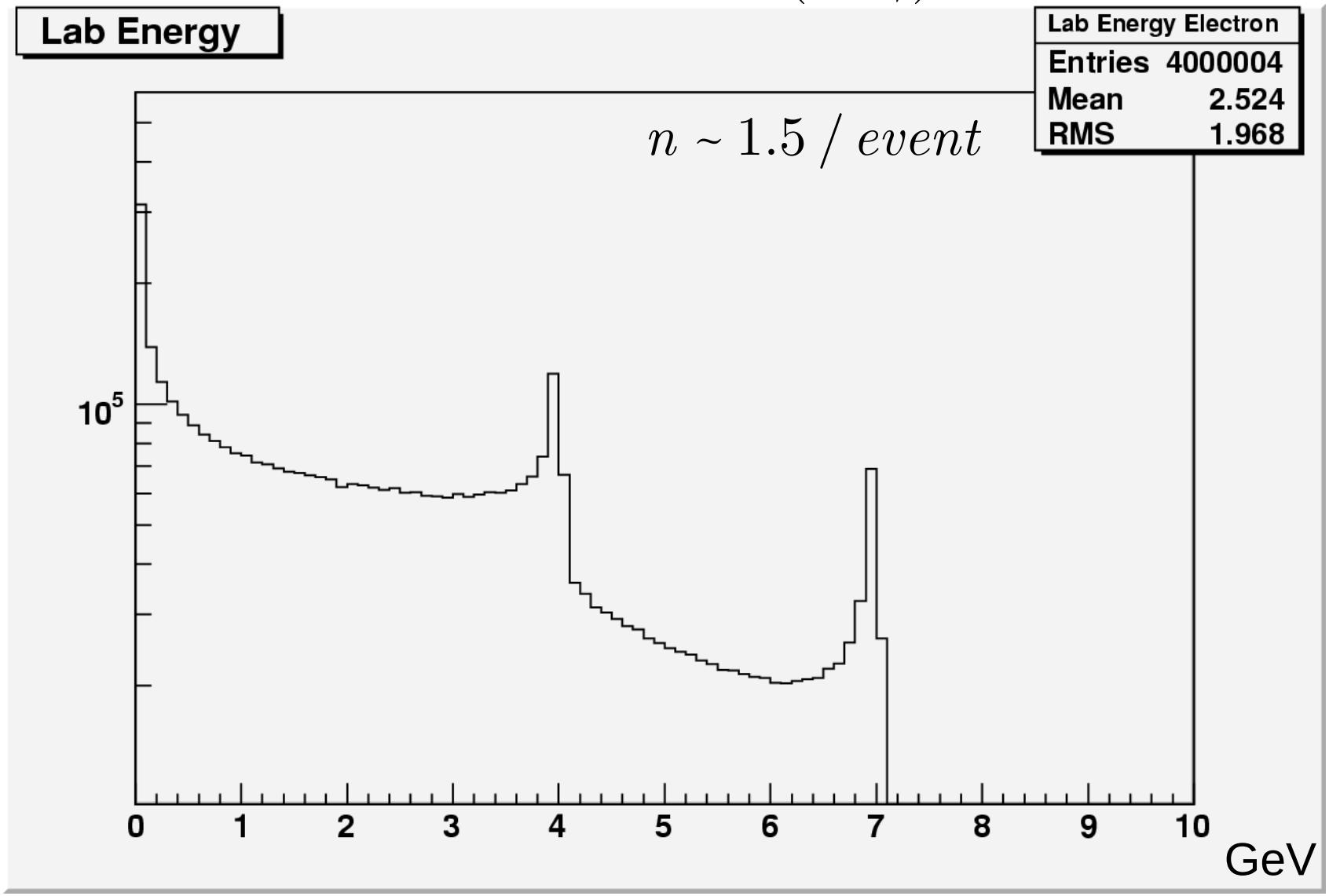
Grace (GR)

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

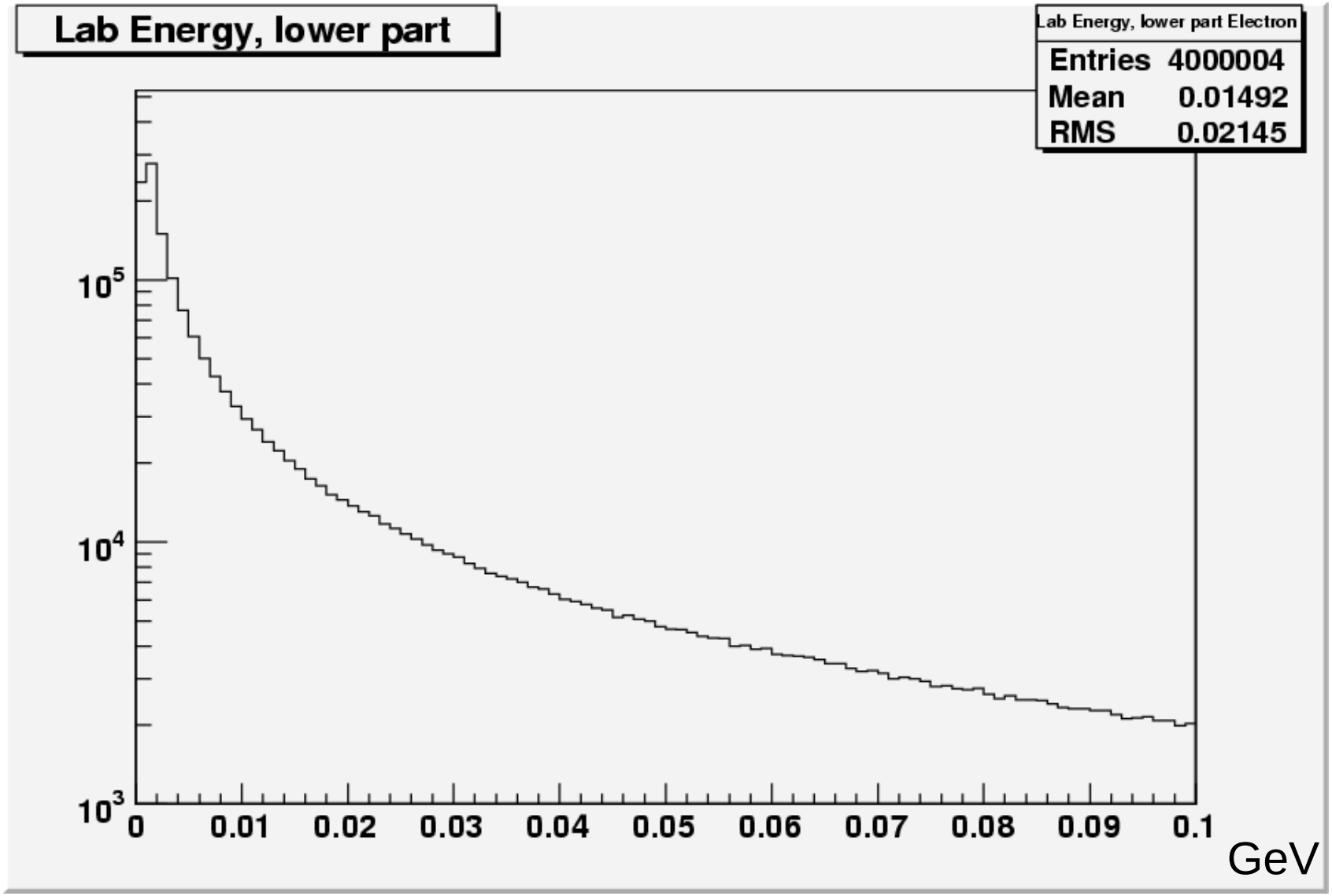


KoralW (KW)

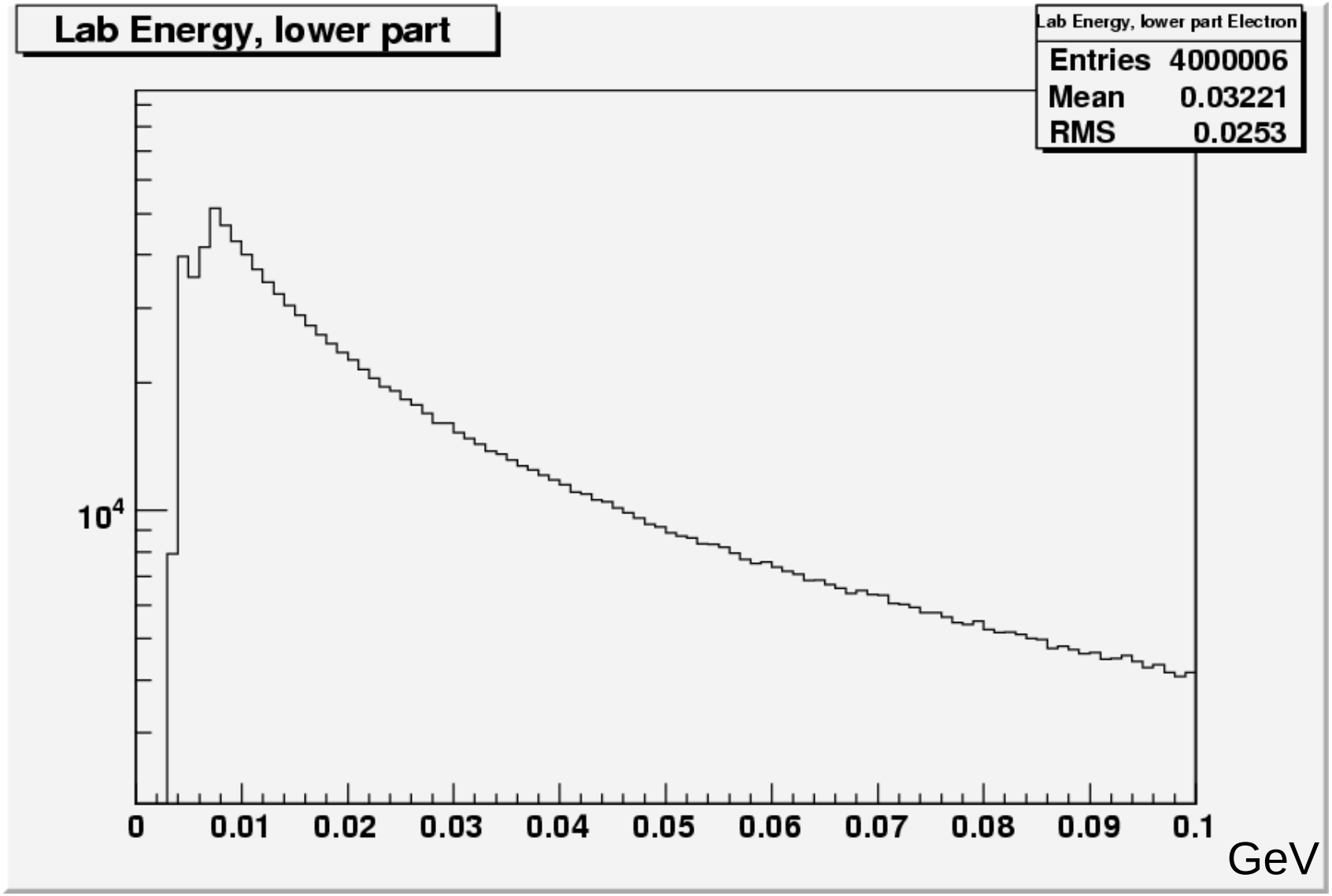
$$e^+e^- \rightarrow e^+e^-e^+e^-(+n\gamma)$$



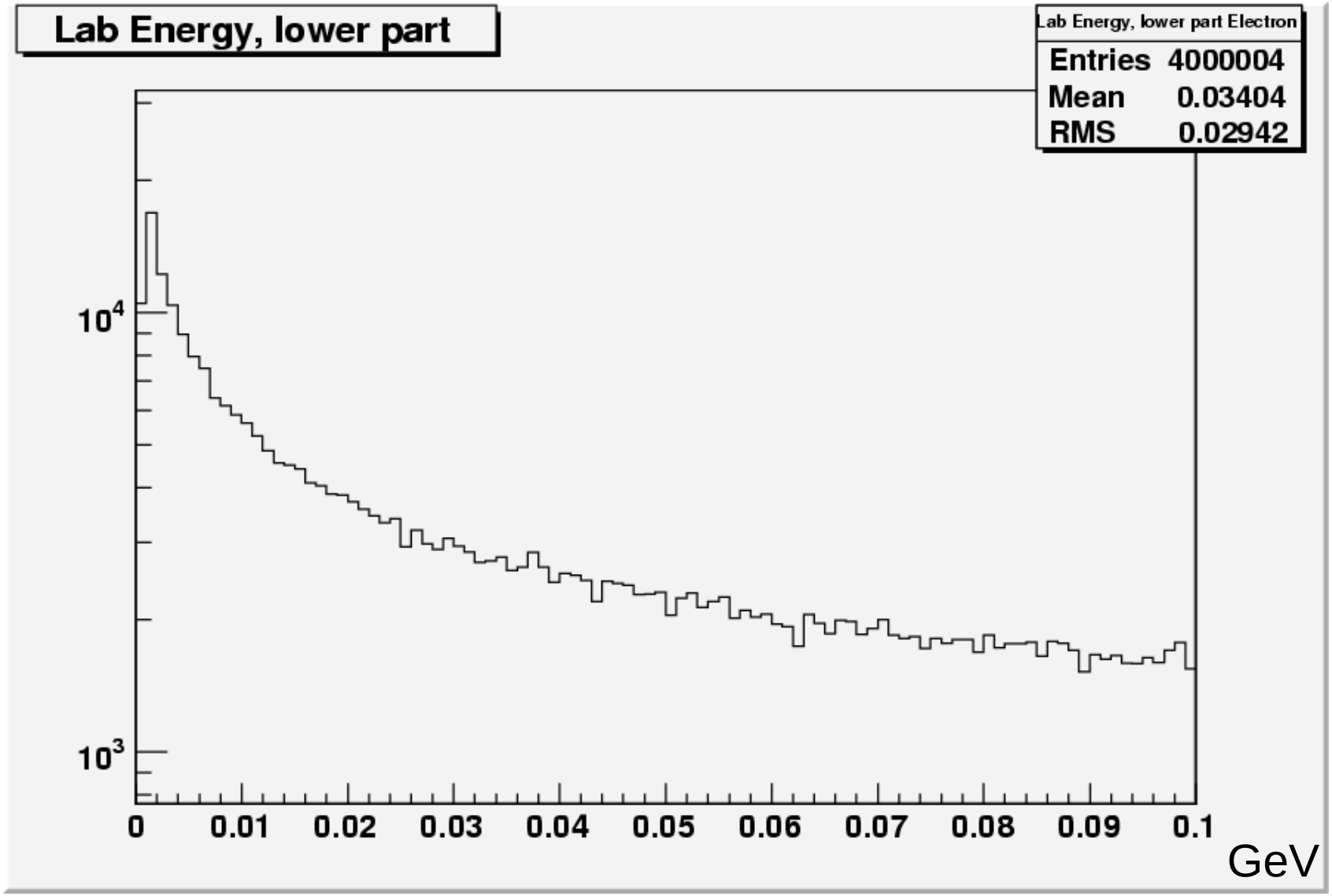
BDK


Lab Energy, lower part
Lab Energy, lower part Electron
Entries 4000004
Mean 0.01492
RMS 0.02145
10^5
10^4
10^3
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
GeV

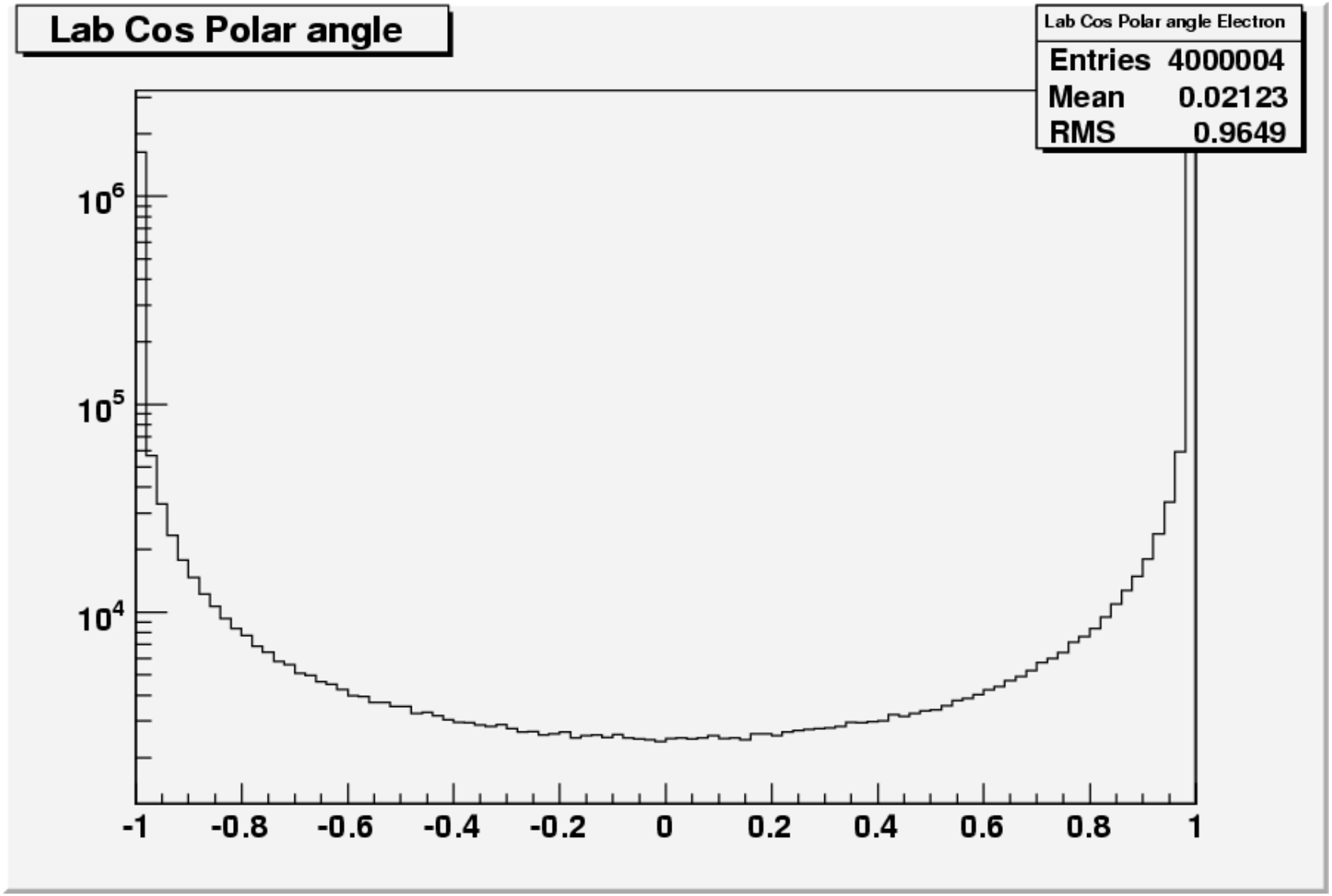
GR


Lab Energy, lower part
Lab Energy, lower part Electron
Entries 4000006
Mean 0.03221
RMS 0.0253
10^4
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
GeV

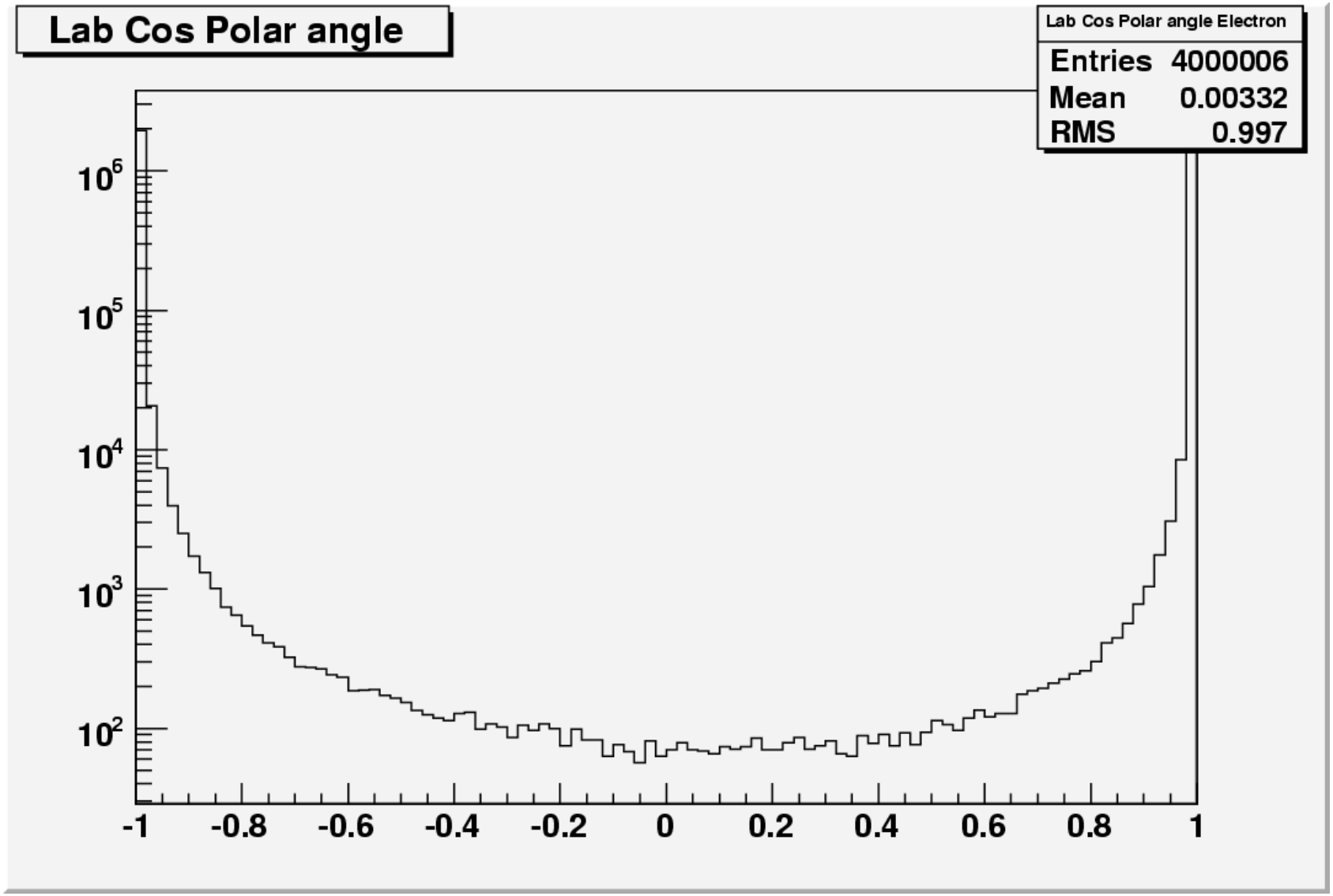
KW


Lab Energy, lower part
Lab Energy, lower part Electron
Entries 4000004
Mean 0.03404
RMS 0.02942
10^4
10^3
0
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
GeV

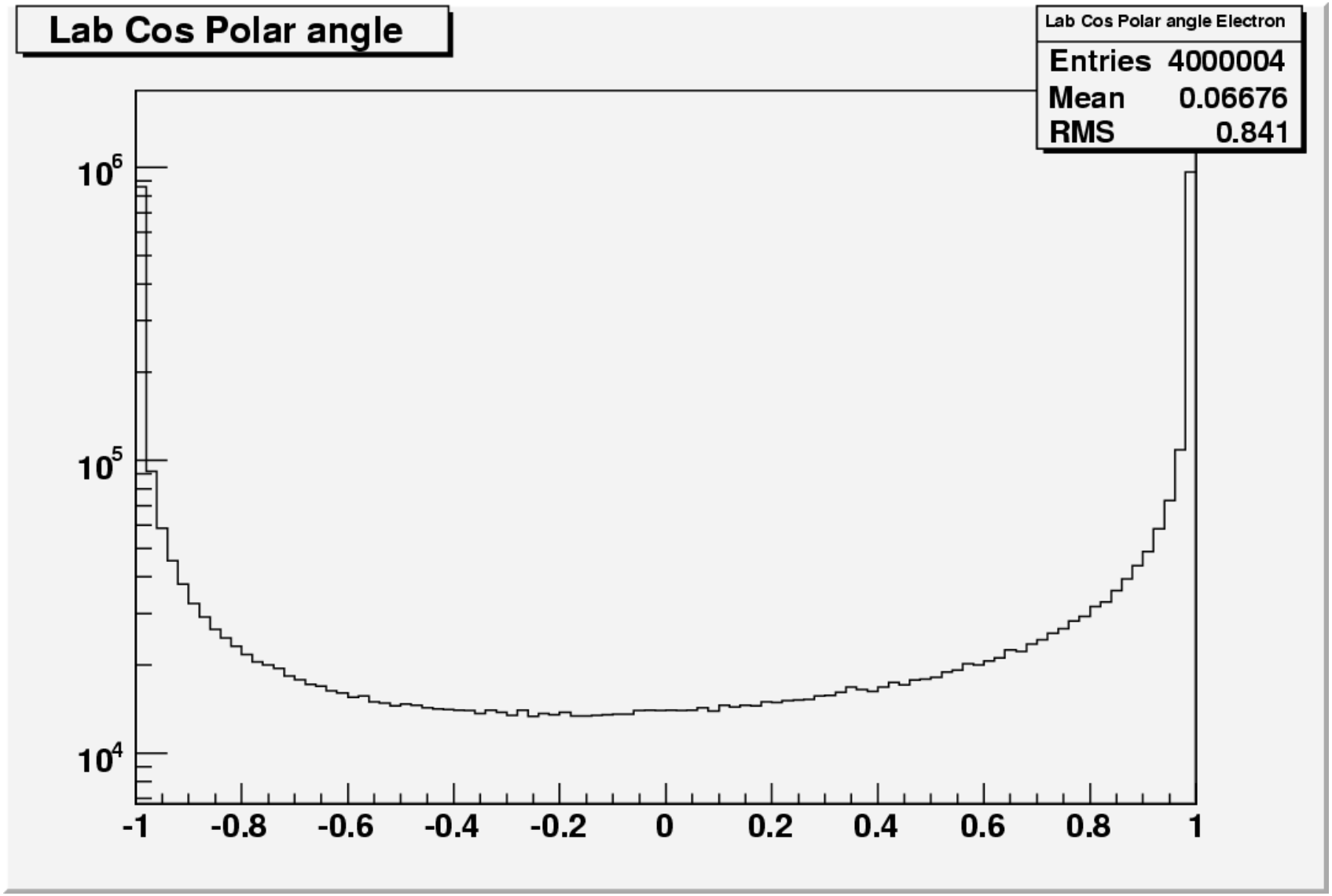
BDK


Lab Cos Polar angle
Lab Cos Polar angle Electron
Entries 4000004
Mean 0.02123
RMS 0.9649
10^6
10^5
10^4
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

GR

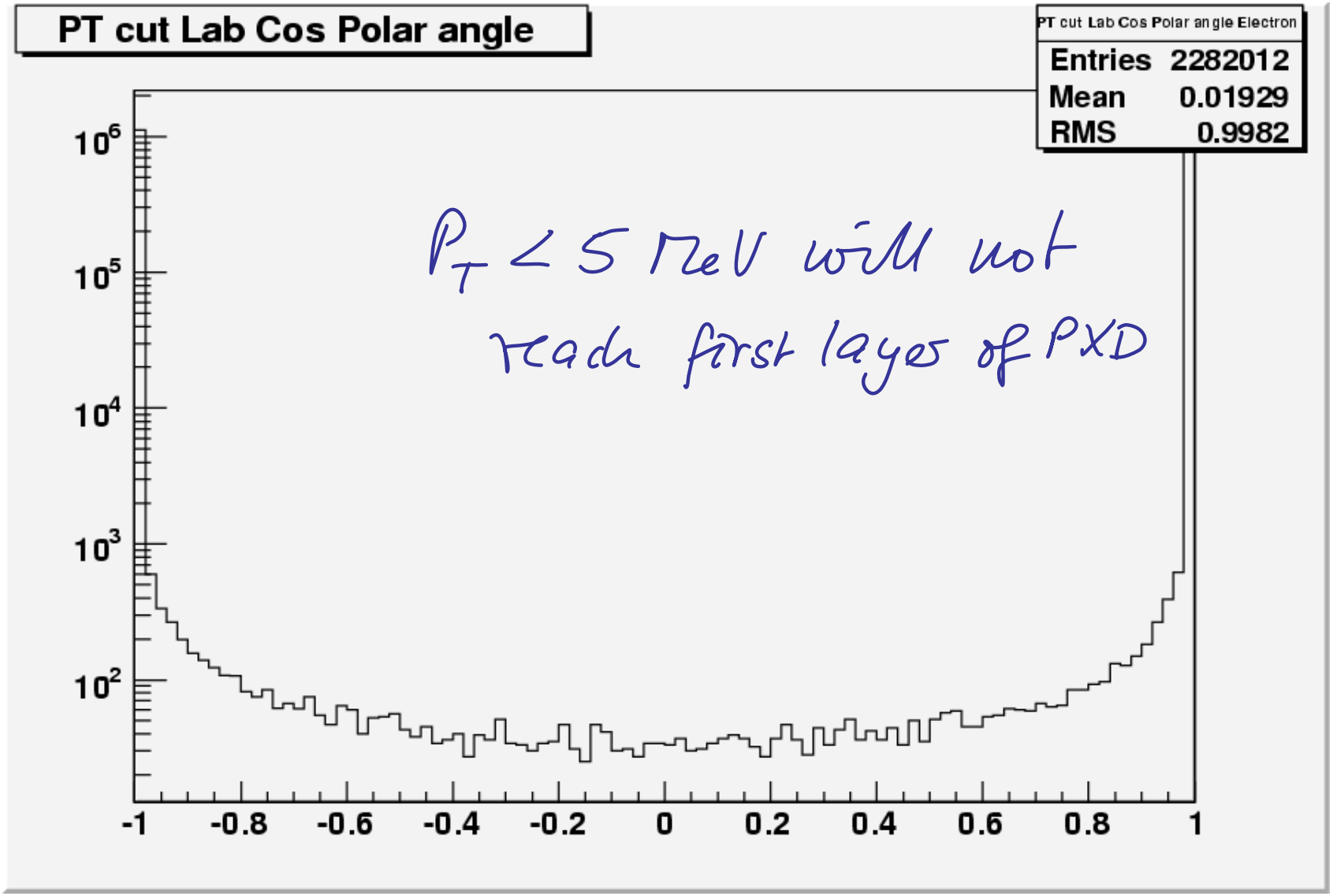

Lab Cos Polar angle
Lab Cos Polar angle Electron
Entries 4000006
Mean 0.00332
RMS 0.997
10^6
10^5
10^4
10^3
10^2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

KW

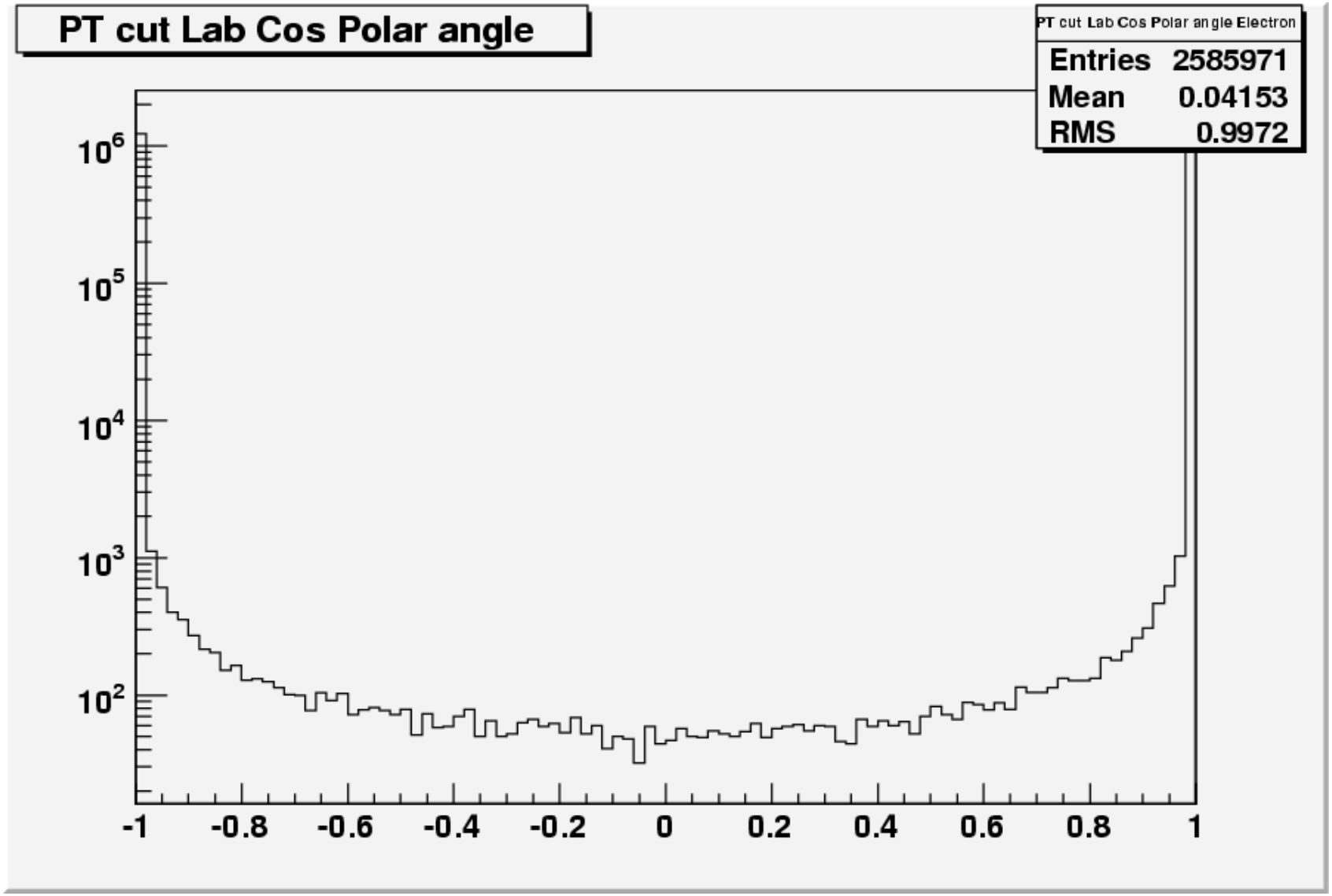

Lab Cos Polar angle
Lab Cos Polar angle Electron
Entries 4000004
Mean 0.06676
RMS 0.841
10^6
10^5
10^4
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

BDK

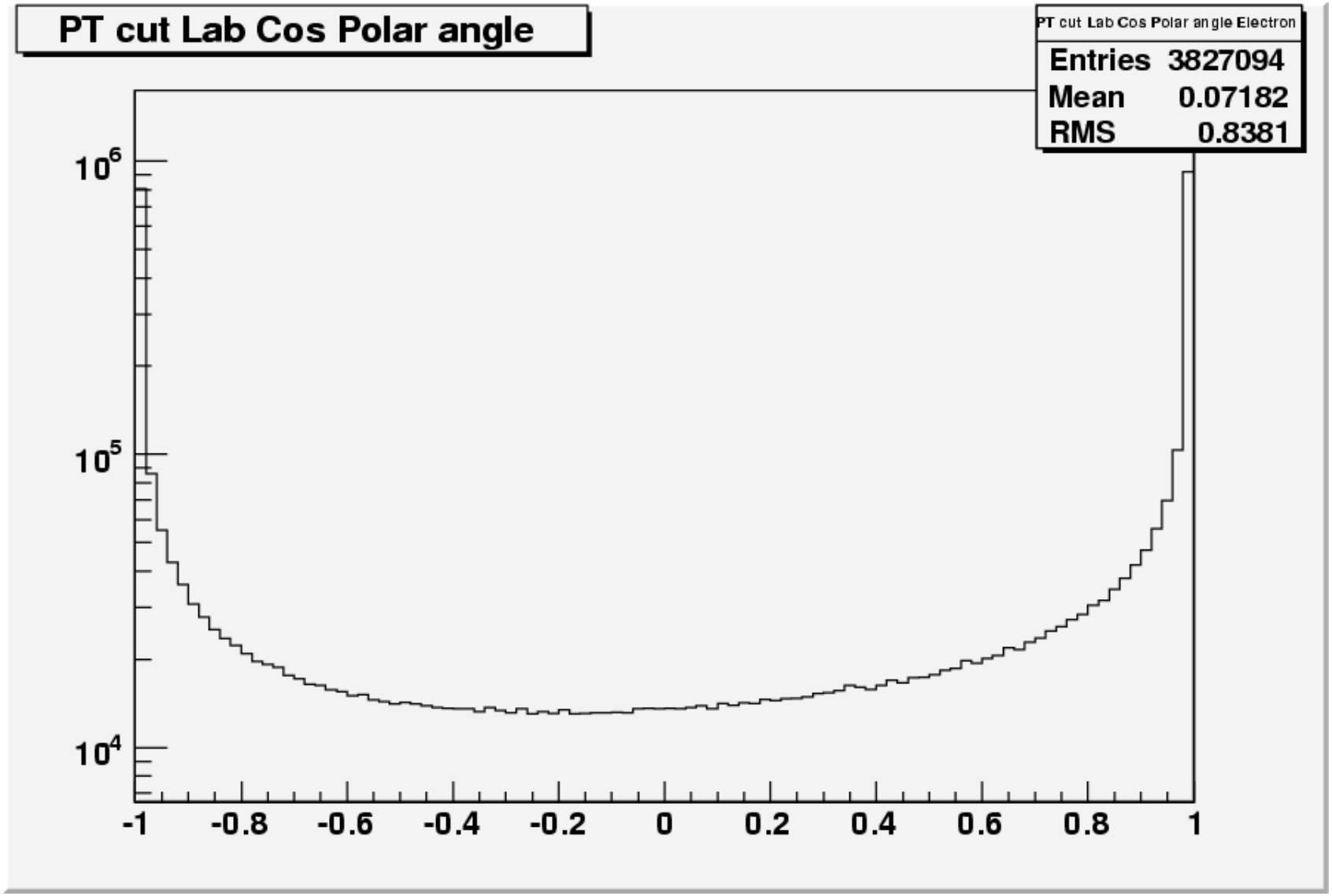
$P_T > 5$ MeV


PT cut Lab Cos Polar angle
PT cut Lab Cos Polar angle Electron
Entries 2282012
Mean 0.01929
RMS 0.9982
10^6
10^5
10^4
10^3
10^2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
$P_T < 5$ MeV will not
reach first layer of PXD

GR

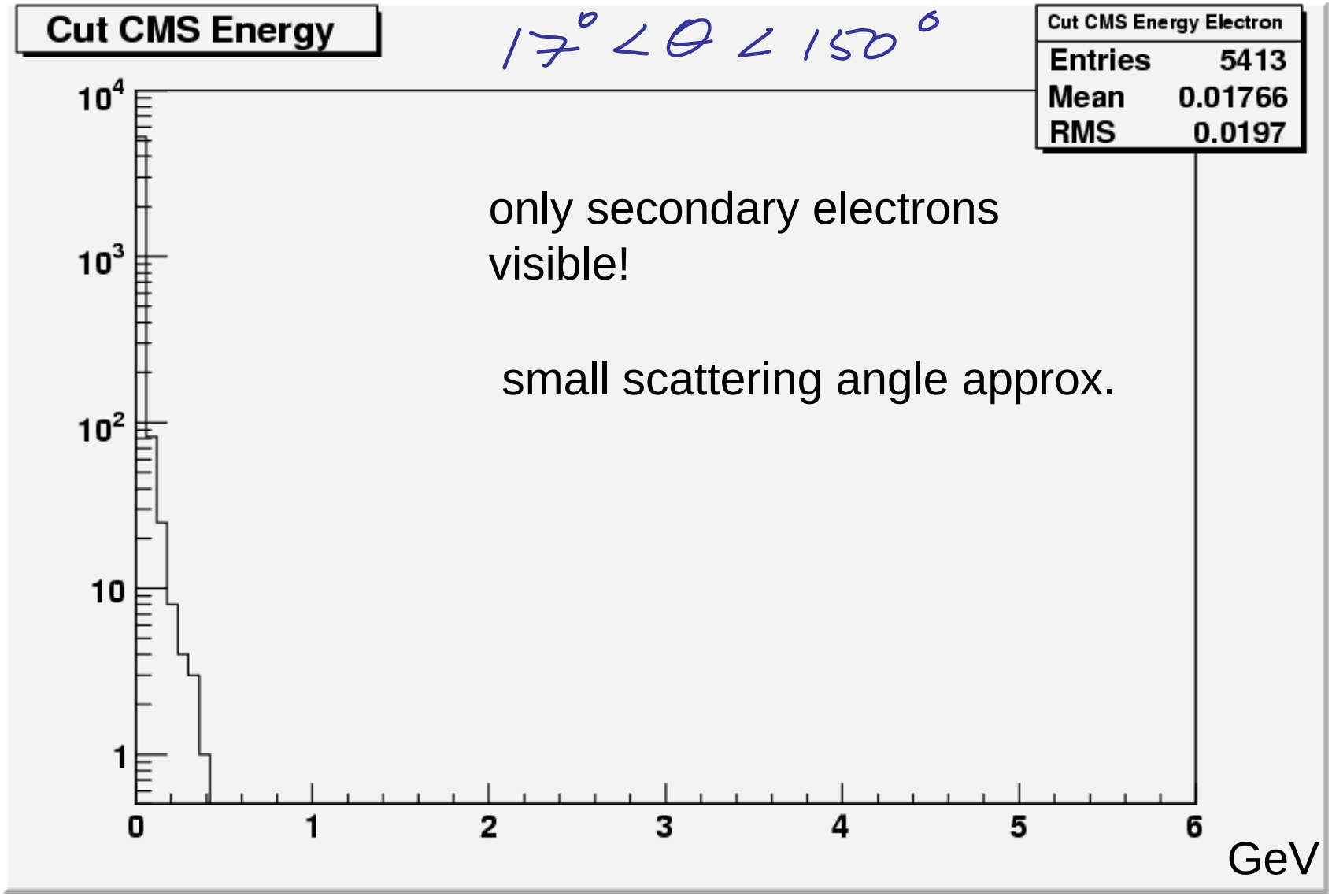

PT cut Lab Cos Polar angle
PT cut Lab Cos Polar angle Electron
Entries 2585971
Mean 0.04153
RMS 0.9972
10^6
10^5
10^4
10^3
10^2
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

KW

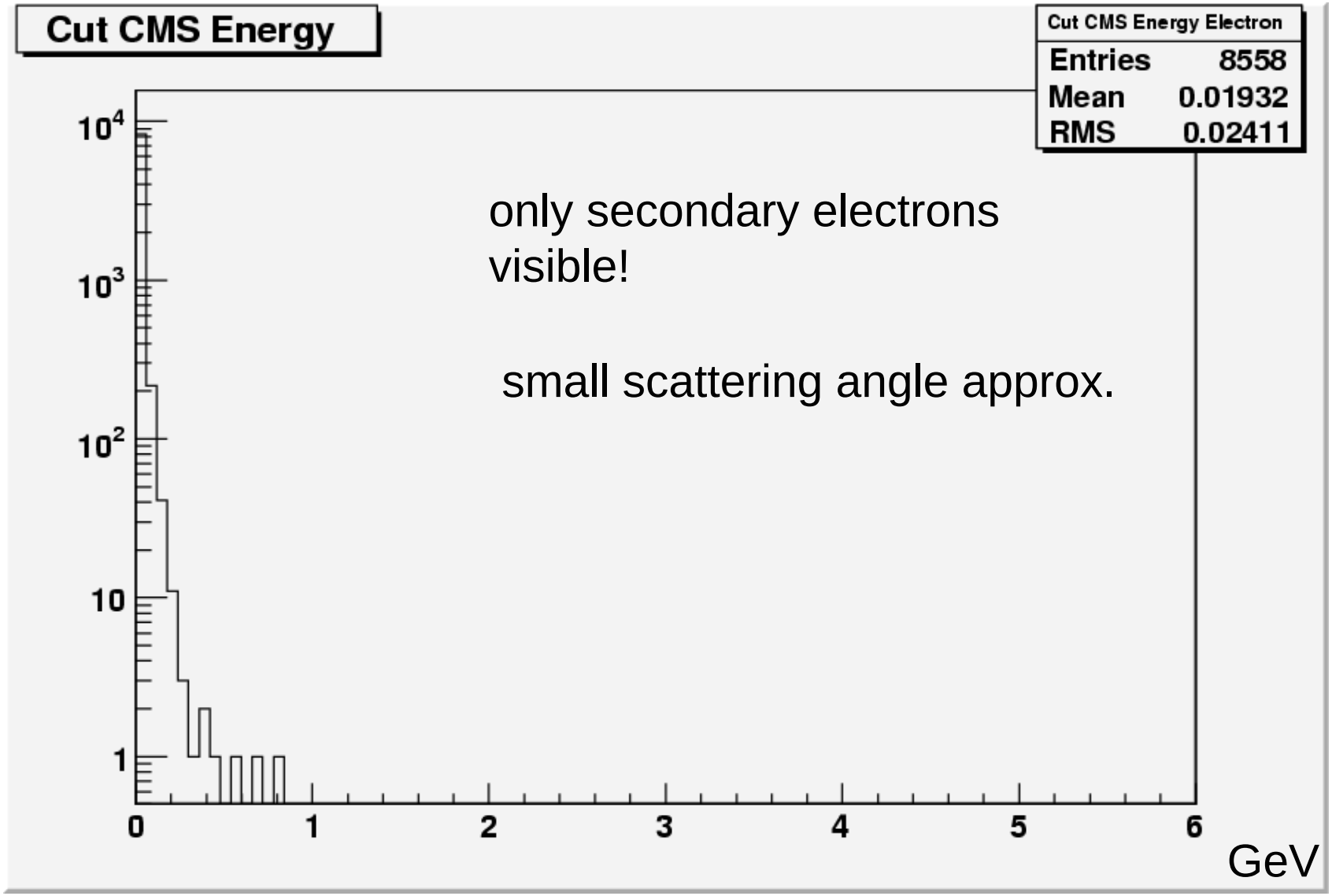

PT cut Lab Cos Polar angle
PT cut Lab Cos Polar angle Electron
Entries 3827094
Mean 0.07182
RMS 0.8381
10^6
10^5
10^4
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

BDK (after acc. cuts)

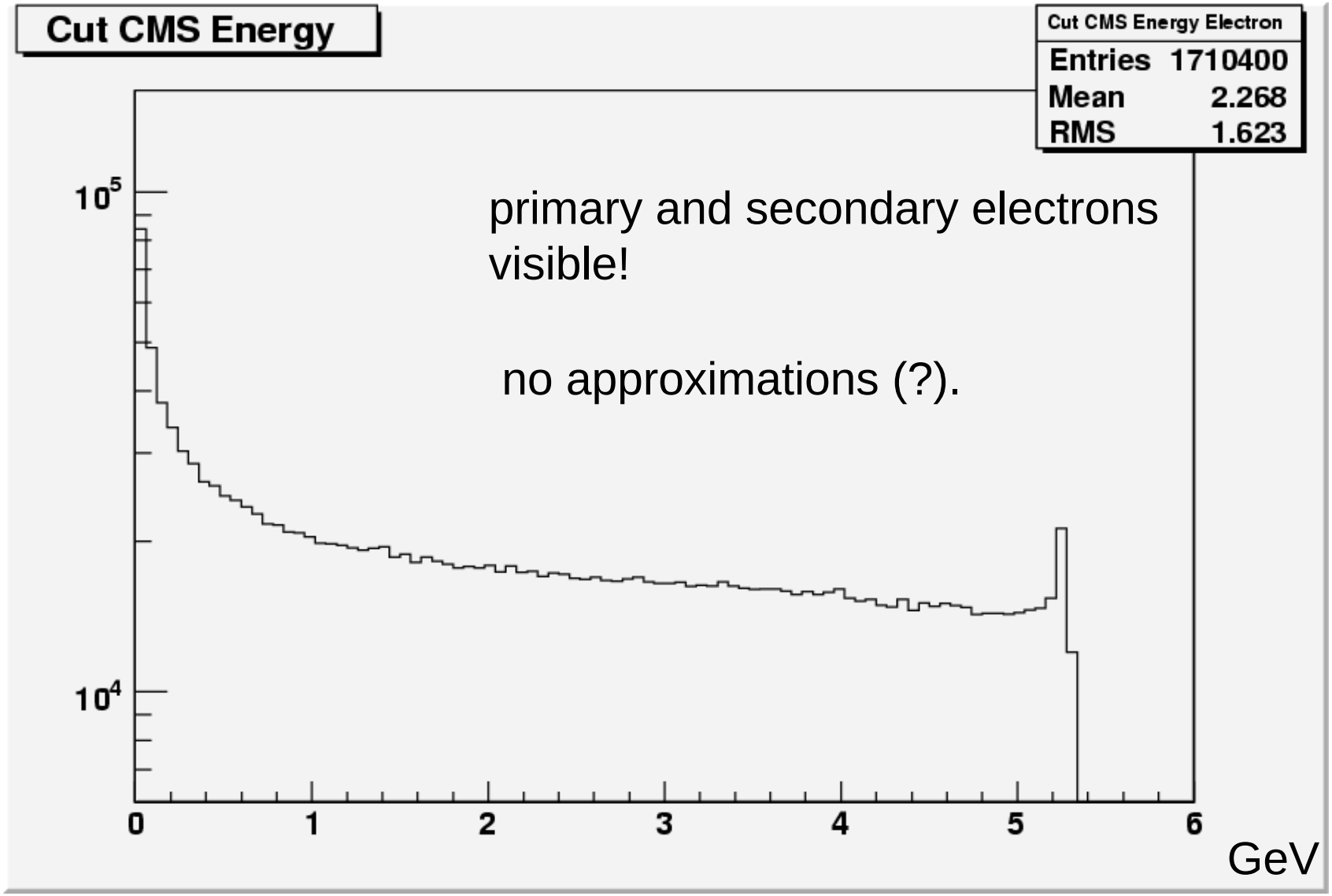
+ angulas acceptance in lab



GR (after acc. cuts)



KW (after acc. cuts)



First attempt to calculate rates (I)

BDK: $\sigma = 7.3 \times 10^6$ [nb]

KW: $= 1.6 \times 10^5$ "

‖ some inkrud cuts exist!

$\dot{N} = L \cdot \sigma \cdot \varepsilon$ ← cut efficiency

$\varepsilon_{BDK} = 1.35 \times 10^{-3}$

$\varepsilon_{GR} = 2.14 \times 10^{-3}$

$\varepsilon_{KW} = 4.23 \times 10^{-1}$

$\varepsilon = \frac{N_{acc}}{N_{total\ gen}}$

[σ(GR) not avail., Racoon cannot be used ($m_\ell = 0$)

First attempt to calculate rates (II)

How many BG ev. do we have to overlay?

$N = \int L dt \cdot \sigma \cdot \varepsilon$ $\quad \int dt = 20\,\mu s$

BDK: $N = 1000 \frac{1}{nbs} \times 7.3 \times 10^{6}\,[nb] \times 1.35 \times 10^{-3} \times 2 \times 10^{-5}\,[s]$

$= 200 \rightarrow$ total ~ 400 tracks

KW: $N = 1000 \frac{1}{nbs} \times 1.6 \times 10^{5} \times 4.23 \times 10^{-1} \times 2 \times 10^{-5}$

$= 1400 \rightarrow$ total of ~ 3000 tracks

(+ 2000 γ's)

KW occupancy: 5000 tr. x 3 px/tr. = 15000 px
250 x 1600 x 8 px in 1st layer = 3.5 Mpx

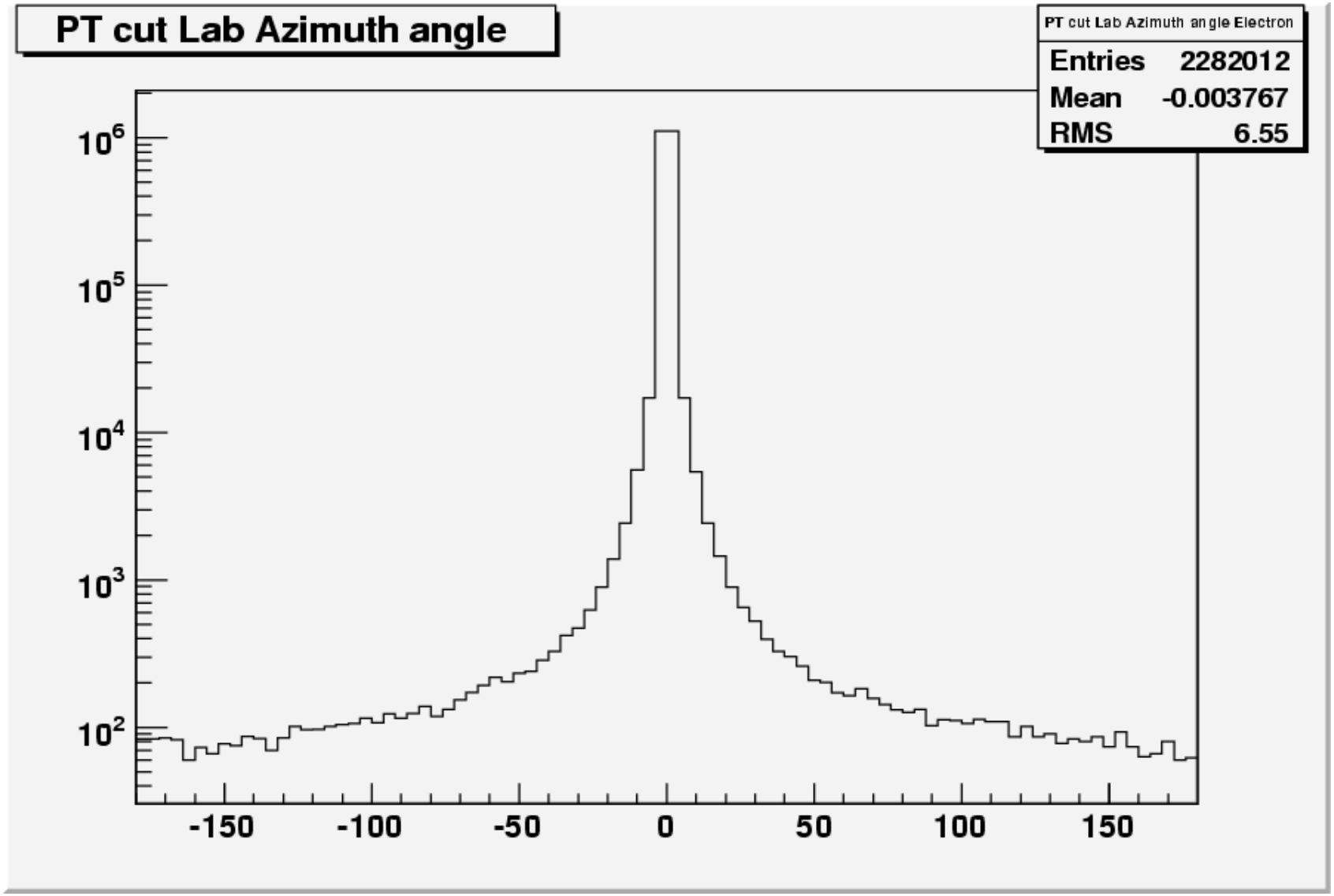
0.5 %

Conclusions

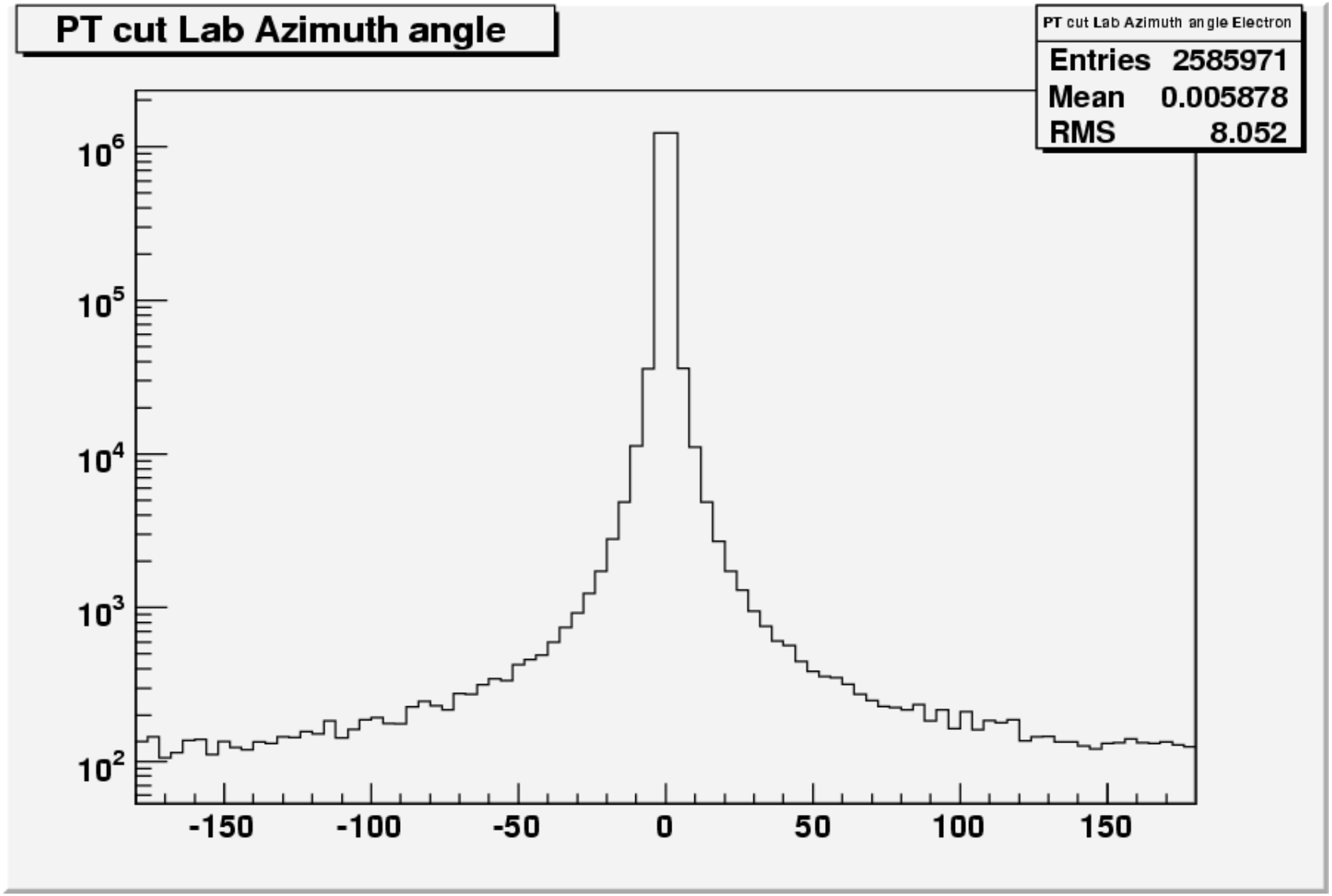
- SuperKEKB: Current will rise by factor 2, lumi by factor 40
- Background likely to be dominated by QED (2 photon reactions) at SuperKEKB
- Final states in e electrons give largest contribution
- Generator (BDK; Grace) used by Belle may not be adequate (approximations doubtful: e.g. radiation from leptons)
- Present estimate of bg rate in physics event seems low using BDK (what is wrong? Do we have to open cuts even more?)
- KoralW yields much larger contribution, is it realistic?
- Further study needed and ongoing (contact with authors), hopefully trustful results for TDR

Backup

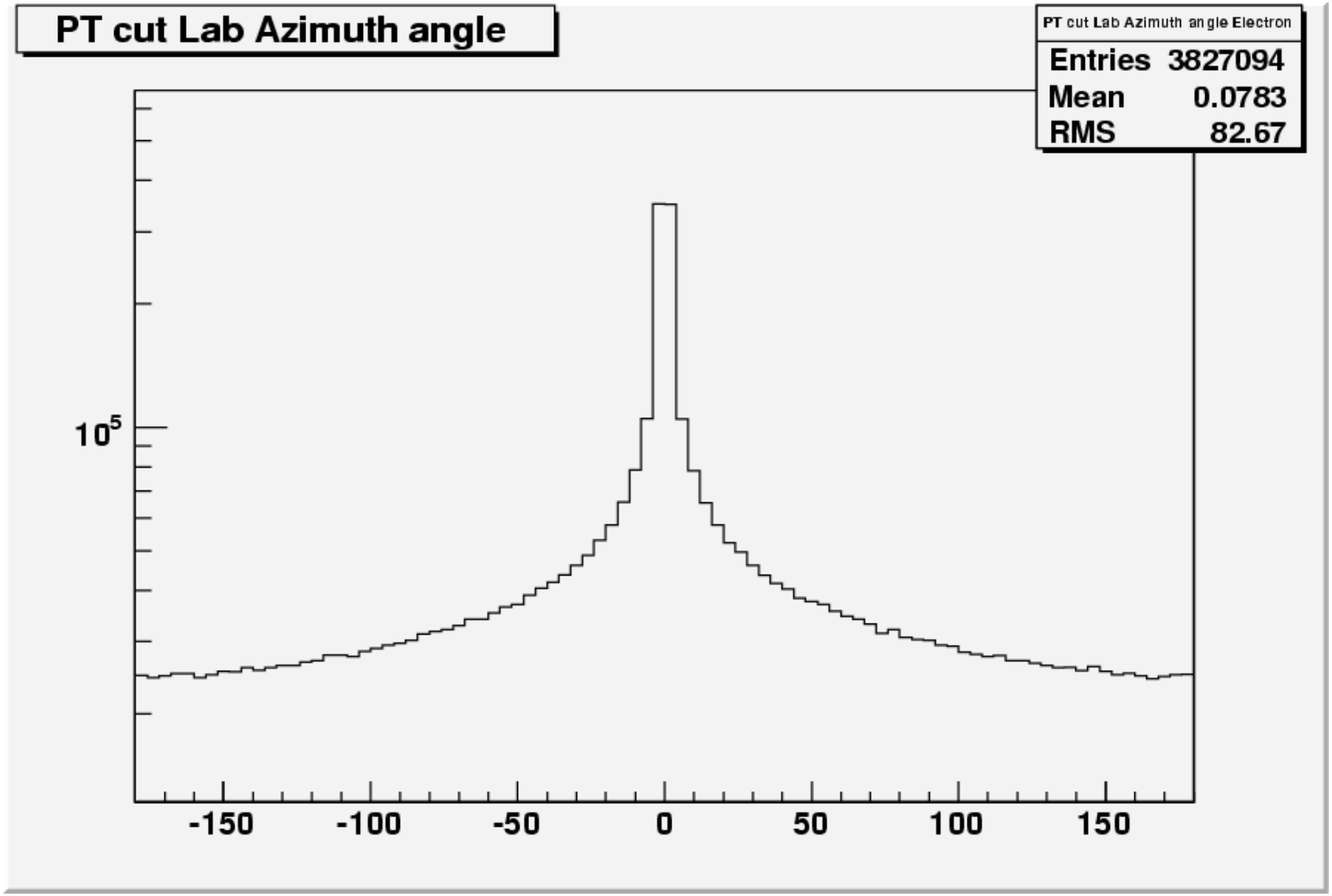
BDK


PT cut Lab Azimuth angle
PT cut Lab Azimuth angle Electron
Entries 2282012
Mean -0.003767
RMS 6.55
10^6
10^5
10^4
10^3
10^2
-150
-100
-50
0
50
100
150

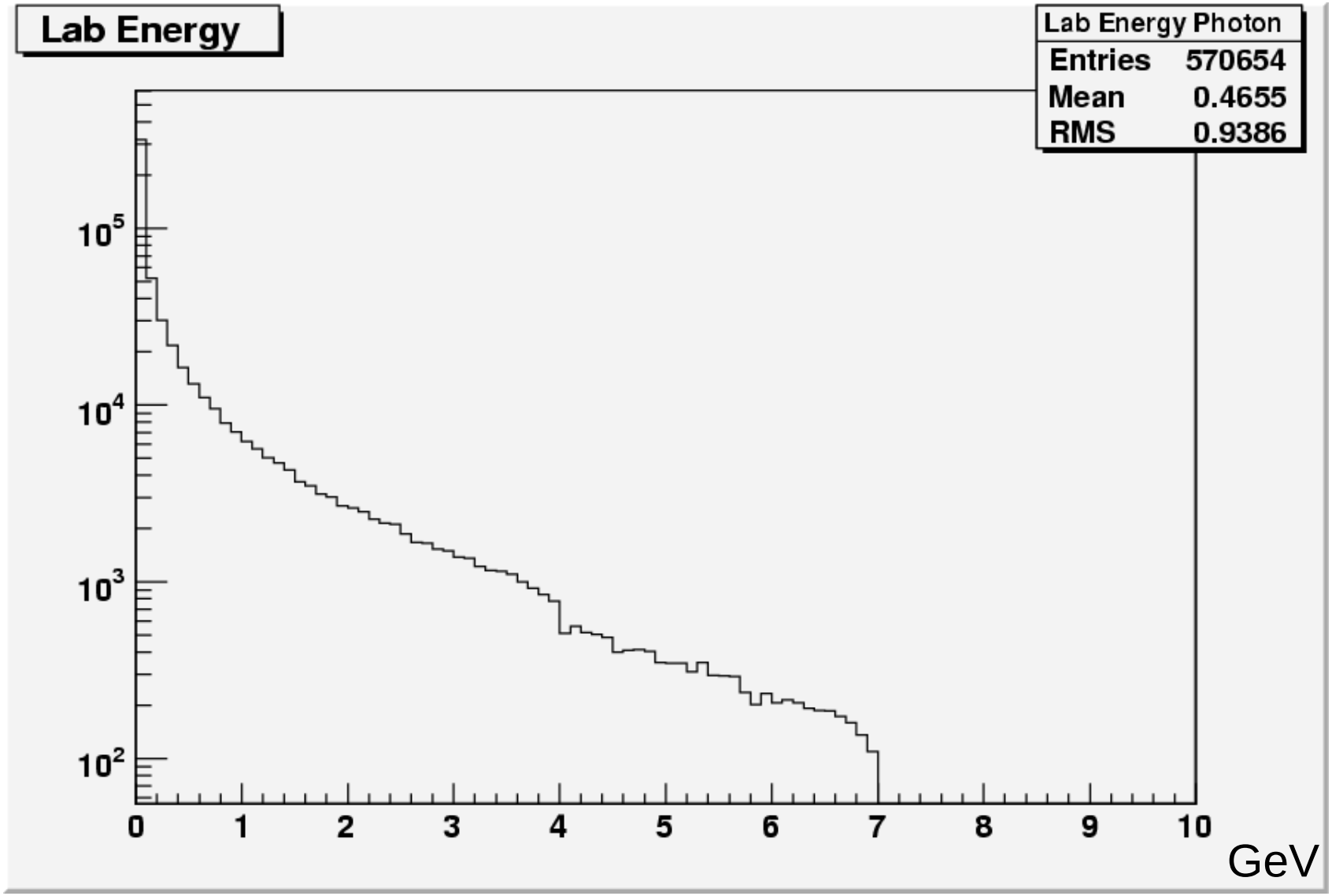
GR


PT cut Lab Azimuth angle
PT cut Lab Azimuth angle Electron
Entries 2585971
Mean 0.005878
RMS 8.052
10^6
10^5
10^4
10^3
10^2
-150
-100
-50
0
50
100
150

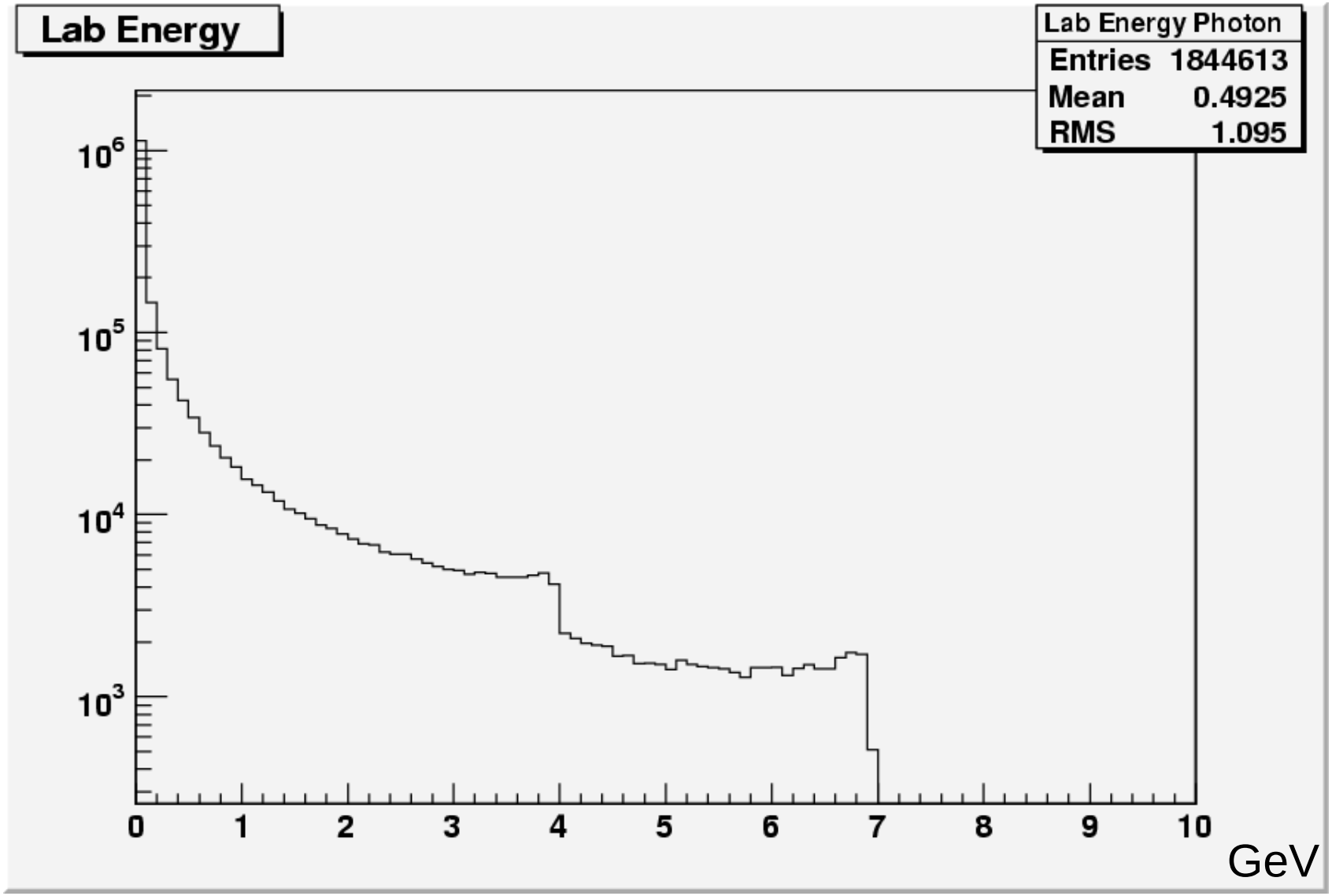
KW


PT cut Lab Azimuth angle
PT cut Lab Azimuth angle Electron
Entries 3827094
Mean 0.0783
RMS 82.67
10^5
-150
-100
-50
0
50
100
150

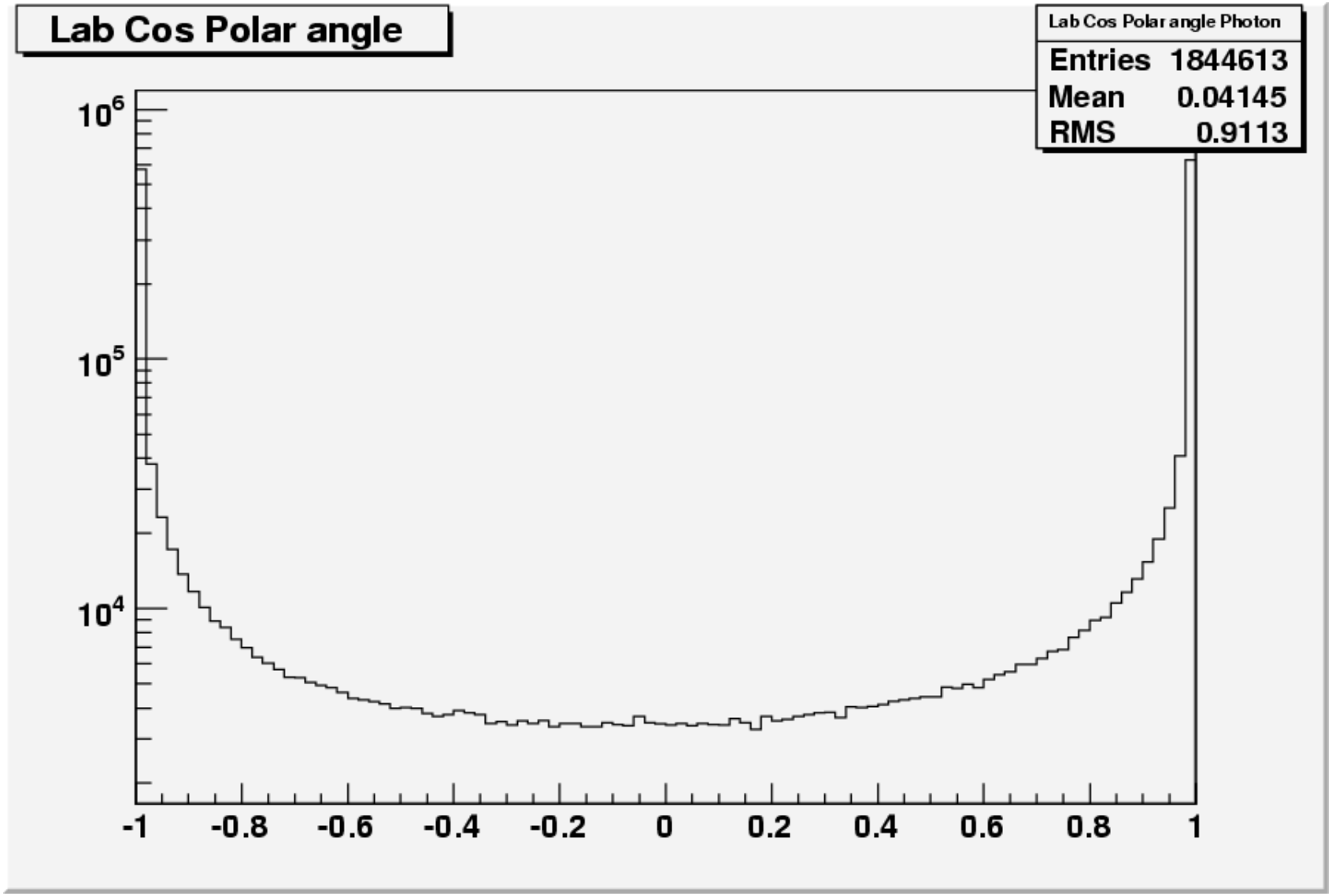
GR


Lab Energy
Lab Energy Photon
Entries 570654
Mean 0.4655
RMS 0.9386
10^5
10^4
10^3
10^2
0 1 2 3 4 5 6 7 8 9 10
GeV

KW


Lab Energy
Lab Energy Photon
Entries 1844613
Mean 0.4925
RMS 1.095
10^6
10^5
10^4
10^3
0 1 2 3 4 5 6 7 8 9 10
GeV

KW


Lab Cos Polar angle
Lab Cos Polar angle Photon
Entries 1844613
Mean 0.04145
RMS 0.9113
10^6
10^5
10^4
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1