PID performace of a dual radiator RICH using a 2D likelihood function on simulated data

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Results: performace vs configuration, refractive index choice, angle, background level

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The method

For each hypothesis calculate the expected hit probability for each pad on the photon detector -> discussed already by Samo a year ago (meeting of July 17, 2004), will show again two of his slides ->

Calculate likelihood for each hypothesis.

Determine the efficiencies and fake probabilities.

PROBABILITY DENSITIES

- probability density for particular hypothesis $(m=m_e, m_\mu, m_\pi, m_K, m_p)$

$$p(\vartheta,\varphi,m)=n_{cf}(\vartheta,\varphi,m)+n_{bf}(\vartheta,\varphi)$$

$$\iint p(\vartheta,\varphi,m)=N_{cf}+N_{bf}$$

- distribution of Cherenkov photons from both radiators and uniform background can be approximated by

$$n_{cf}(\vartheta,\varphi,m)\approx\frac{1}{2\pi}\left(\frac{1}{\sqrt{2\pi}\sigma_1}e^{-\frac{(\vartheta-\vartheta_1(m))^2}{2\sigma_1^2}}+\frac{1}{\sqrt{2\pi}\sigma_2}e^{-\frac{(\vartheta-\vartheta_2(m))^2}{2\sigma_2^2}}\right)$$

$$n_{bf}(\vartheta,\varphi,m)\propto\vartheta$$

- average number of photons on i-th pixel $\bar{n}_i$ is integral of $p(\vartheta,\varphi,m)$ over pixel area

$$\bar{n}_i(m)=\iint_i p(\vartheta,\varphi,m) \qquad \sum_i \bar{n}_i(m)=N_{cf}+N_{bf}=\bar{N}(m)$$

LIKELIHOOD

- number of photons hitting pixel obeys Poissonian statistics

$$P(n_i;\bar{n}_i)=\frac{\bar{n}_i^{n_i}\mathrm{e}^{-\bar{n}_i}}{n_i!}$$

- probability for i-th pixel to be hit or not

$$P(n_i=0;\bar{n}_i)=\mathrm{e}^{-\bar{n}_i} \qquad P(n_i>0;\bar{n}_i)=1-\mathrm{e}^{-\bar{n}_i}$$

- likelihood function

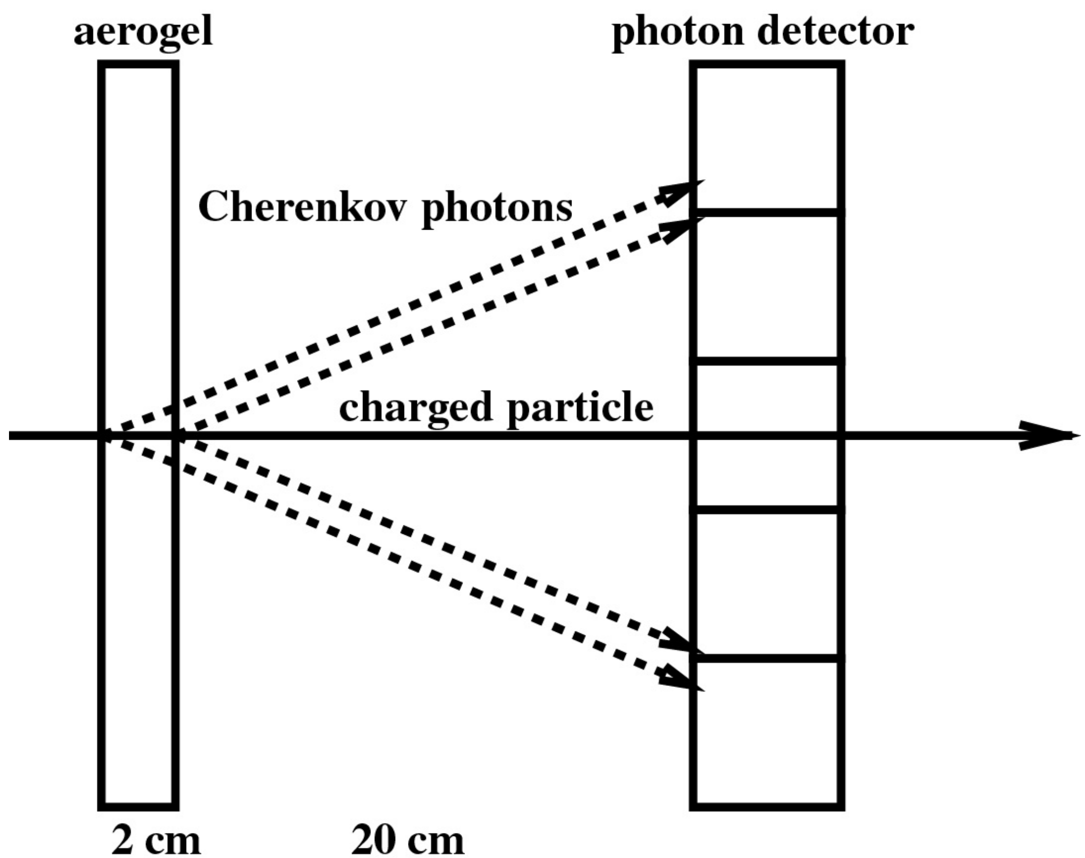
$$L(m)=\prod_{no\ hit\ i}\mathrm{e}^{-\bar{n}_i(m)}\prod_{hit\ i}(1-\mathrm{e}^{-\bar{n}_i(m)})$$

$$\ln L(m)=-\sum_{no\ hit\ i}\bar{n}_i(m)+\sum_{hit\ i}\ln(1-\mathrm{e}^{-\bar{n}_i(m)})=$$

$$=-\bar{N}(m)+\sum_{hit\ i}(\bar{n}_i(m)+\ln(1-\mathrm{e}^{-\bar{n}_i(m)}))$$

- average number of photons is needed only for pixels with hit

Set-up 1



Fix total length, i.e. the distance between the entry point into the first (upstream radiator) and the photon detector surface, to 20cm.

Set-up 2

Vary:

- Configuration (focusing, defocusing)
- Background level
- Angle
- Exact refractive index choice

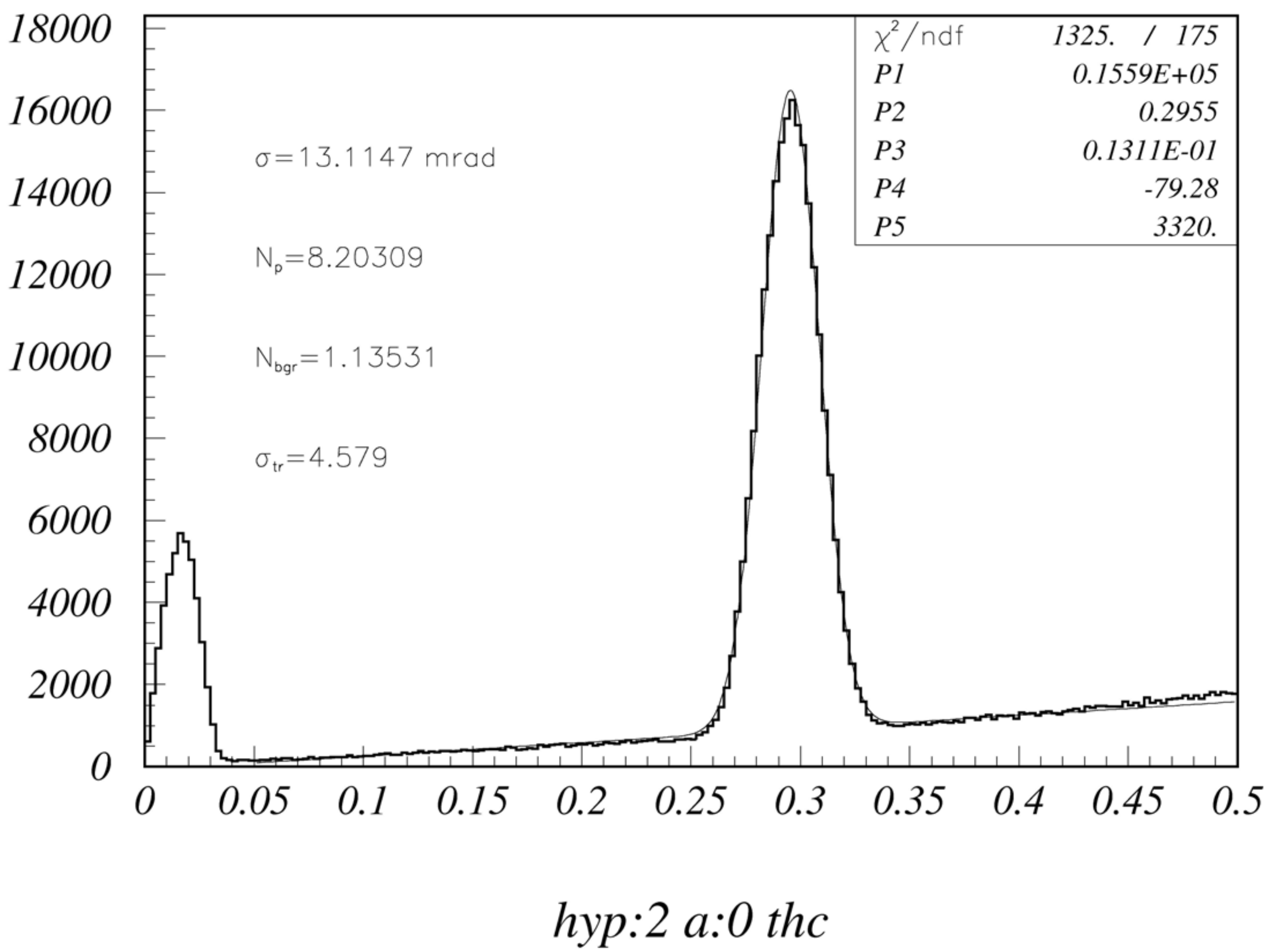
Up to now only two radiators – to avoid too many varied parameters...

Simulation

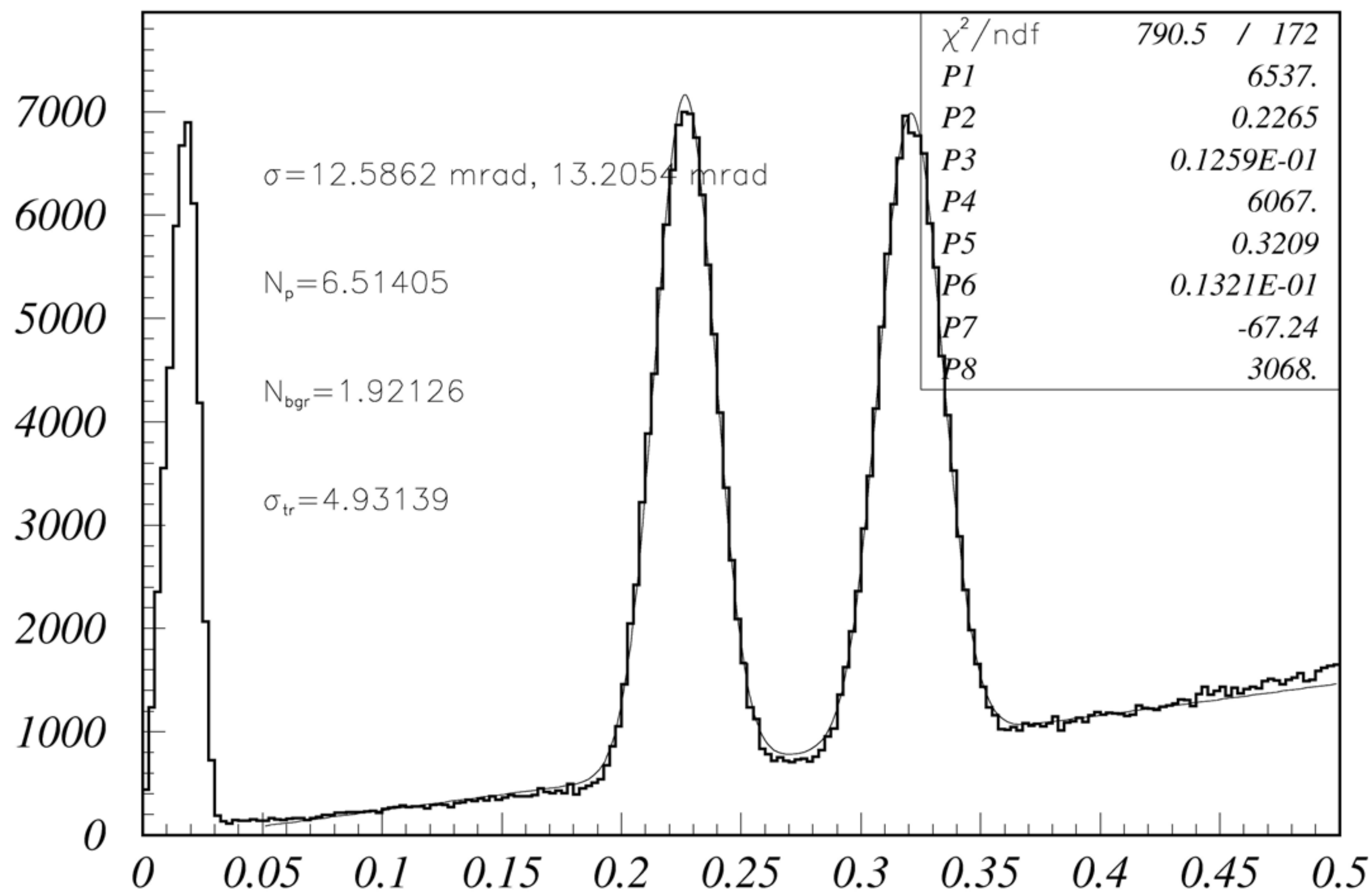
- Use the same code in Geant4 Rok has prepared for the Super-Belle MC.
- Background: generated uniformly over the photon detector.
- Only 50k single track events per set-up, half of it pions, half kaons, uniformly distributed up to 5GeV/c.

  -> statistics has to be increased for in-depth studies

Cherenkov angle distribution, focusing configuration



Cherenkov angle distribution, defocusing configuration



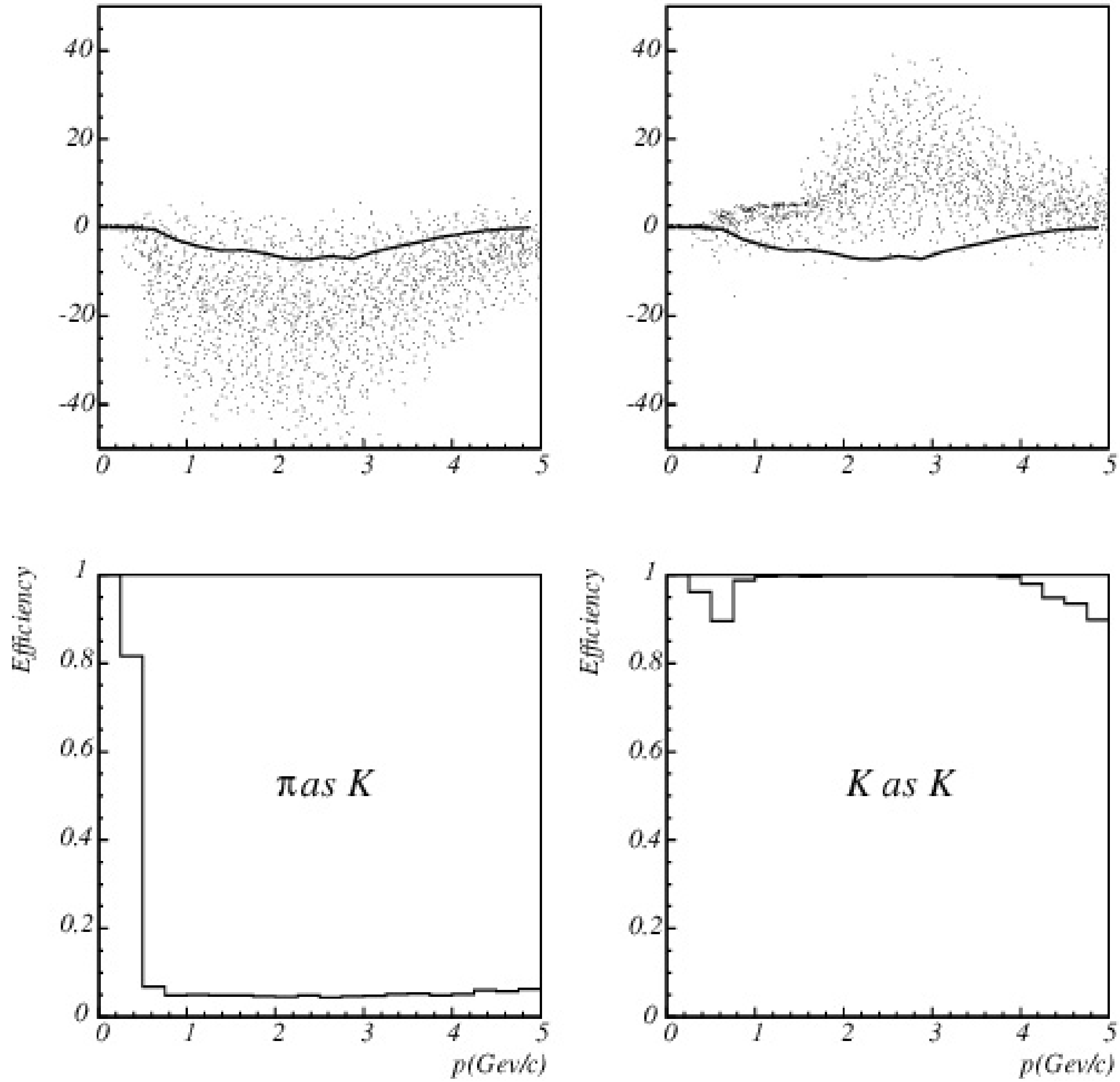
hyp:2 a:0 thc

Likelihoods – typical example 1

Focusing configuration 15mm n=1.043, 15mm n=1.05

Kaon efficiency at 4% pion fake probability

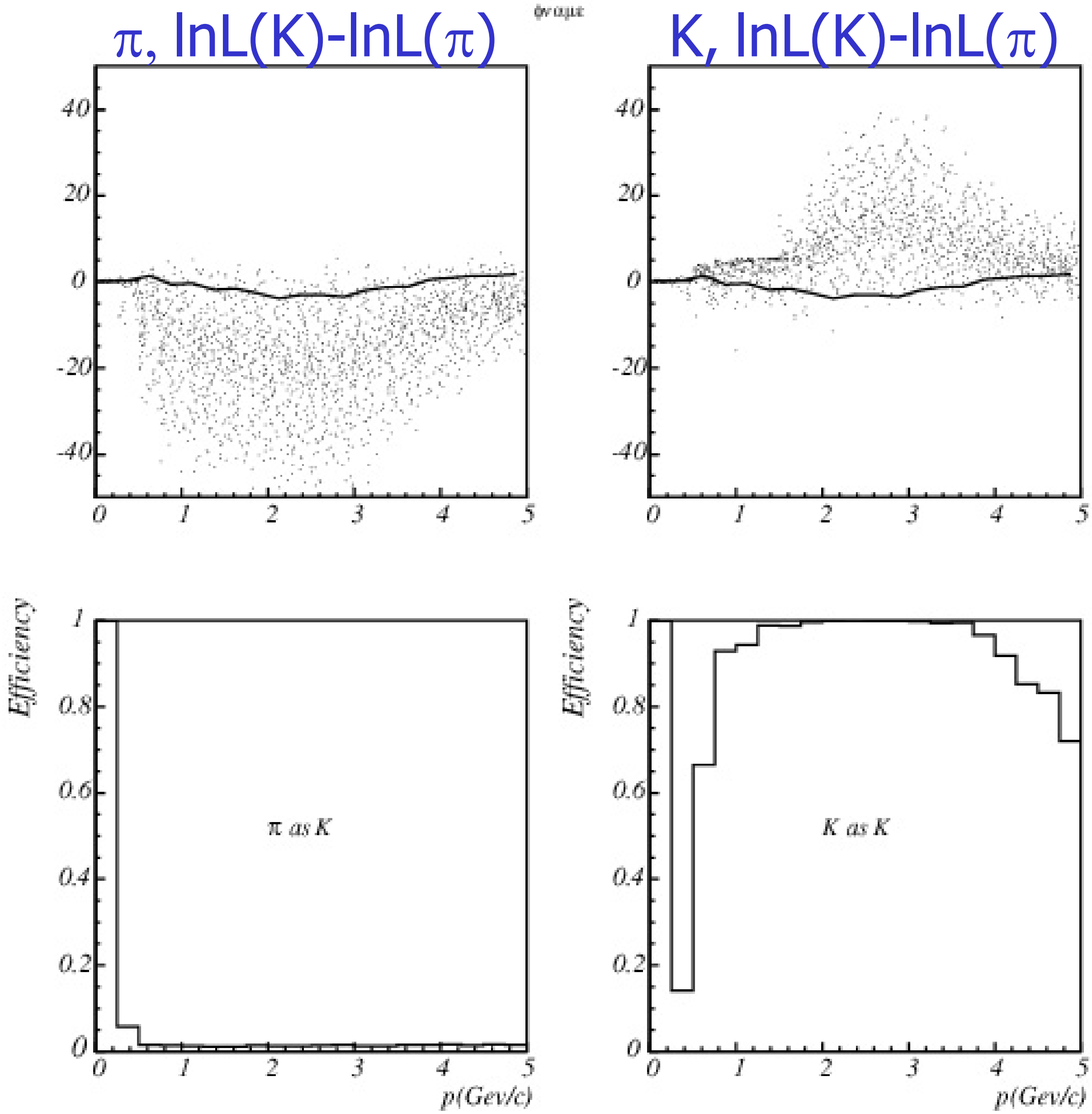
π, lnL(K)-lnL(π) K, lnL(K)-lnL(π)



Likelihoods – typical example 2

Focusing configuration 15mm n=1.043, 15mm n=1.05

Kaon efficiency at 1% pion fake probability

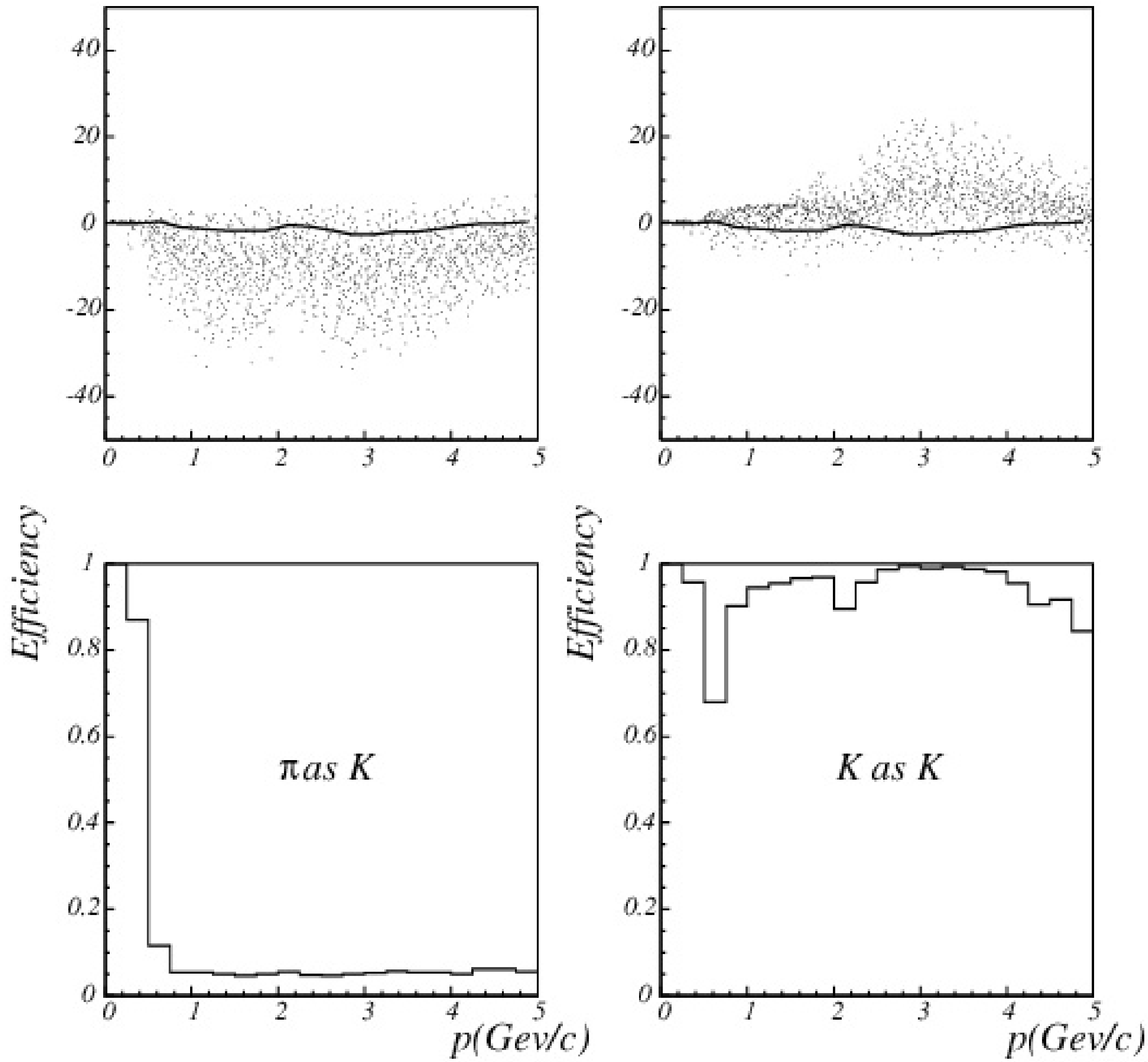


Likelihoods – typical example 3

π, lnL(K)-lnL(π) K, lnL(K)-lnL(π)

Defocusing configuration 15mm n=1.050, 15mm n=1.030

Kaon efficiency at 4% pion fake probability

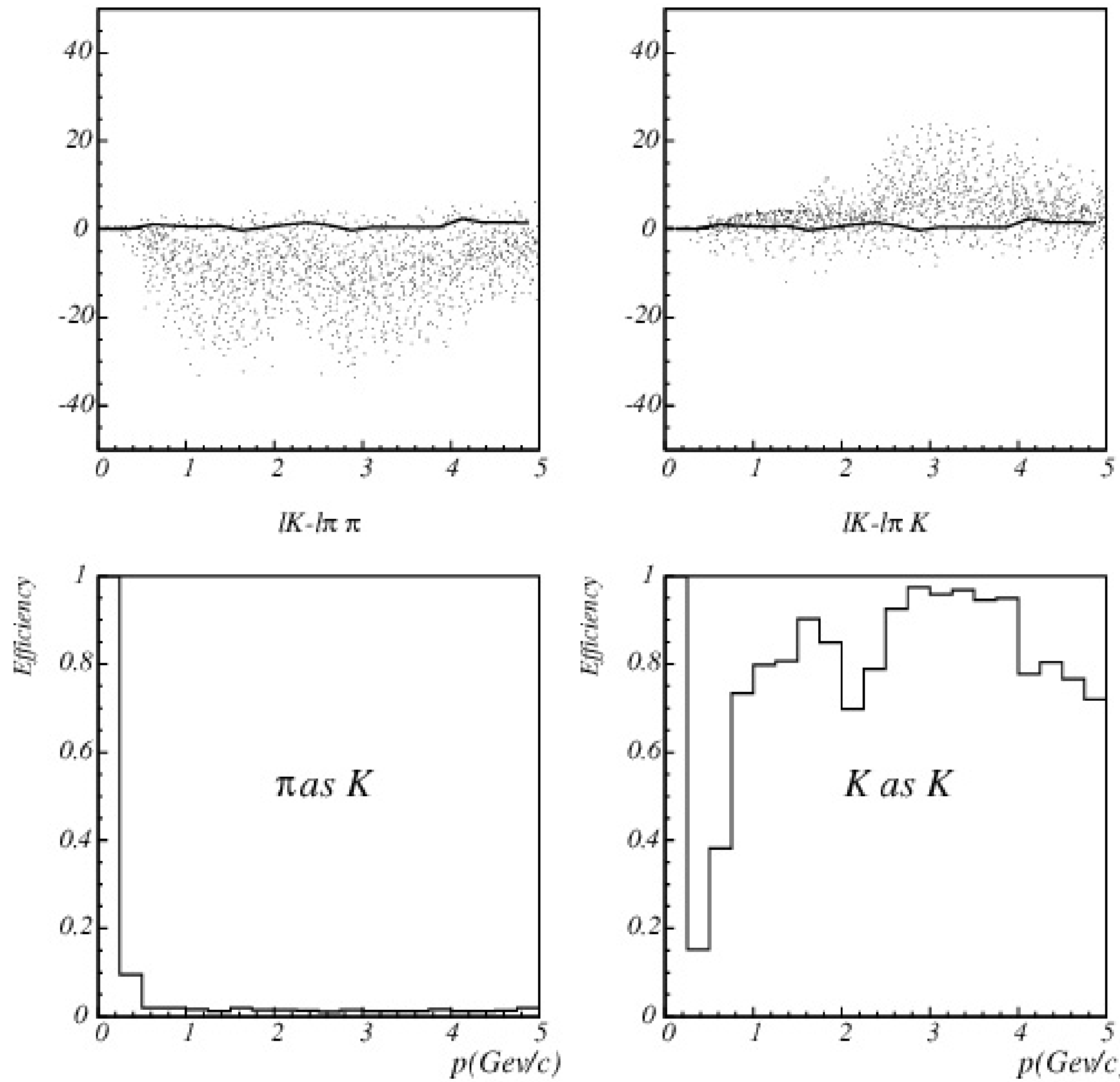


Likelihoods – typical example 4

Defocusing configuration 15mm n=1.050, 15mm n=1.030

Kaon efficiency at 1% pion fake probability

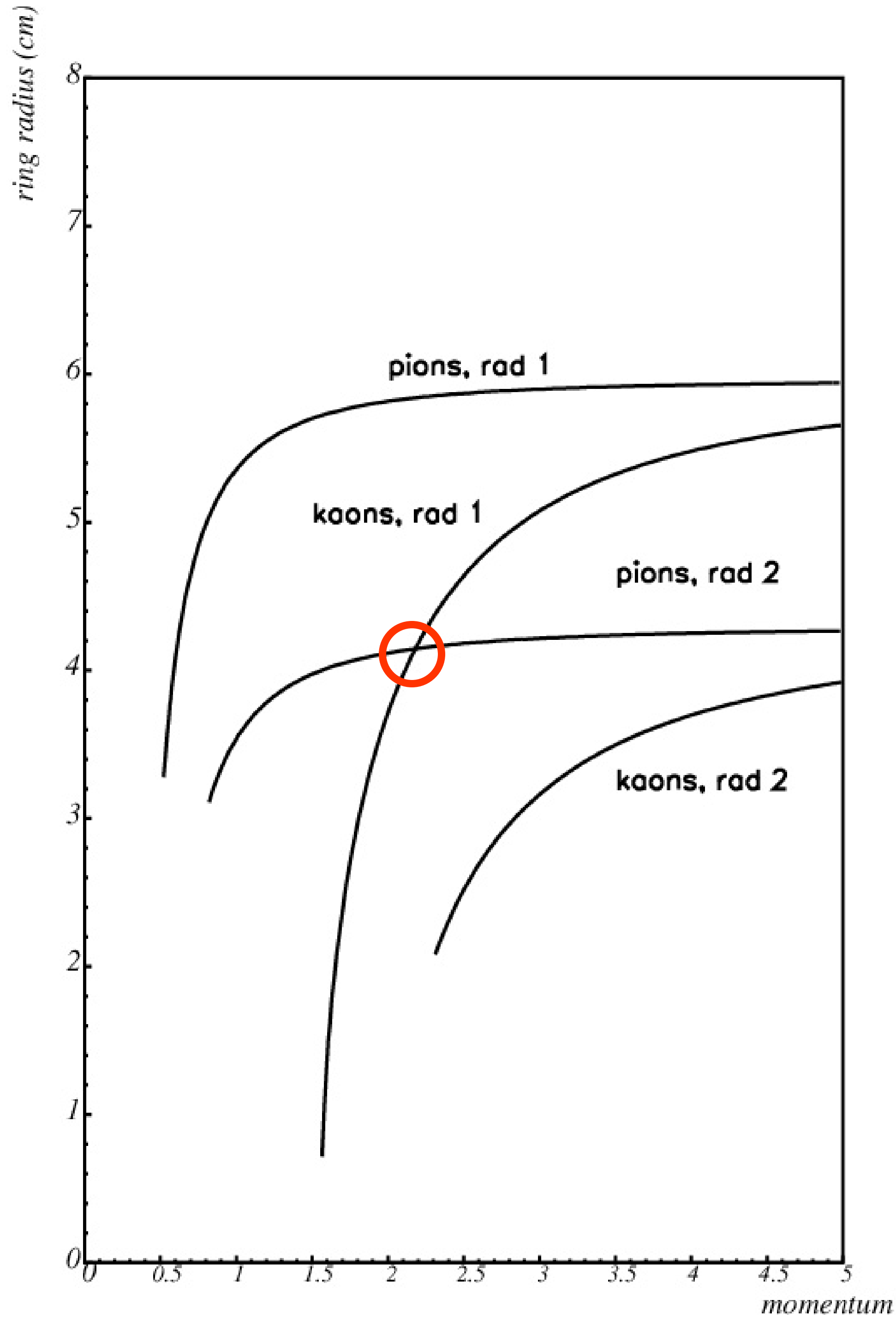
π, lnL(K)-lnL(π) K, lnL(K)-lnL(π)



Do we understand the plots?

What is the dip at 2GeV/c in the defocusing case?

It is related to the overlap of kaon ring from radiator 1 with the pion ring from radiator 2.

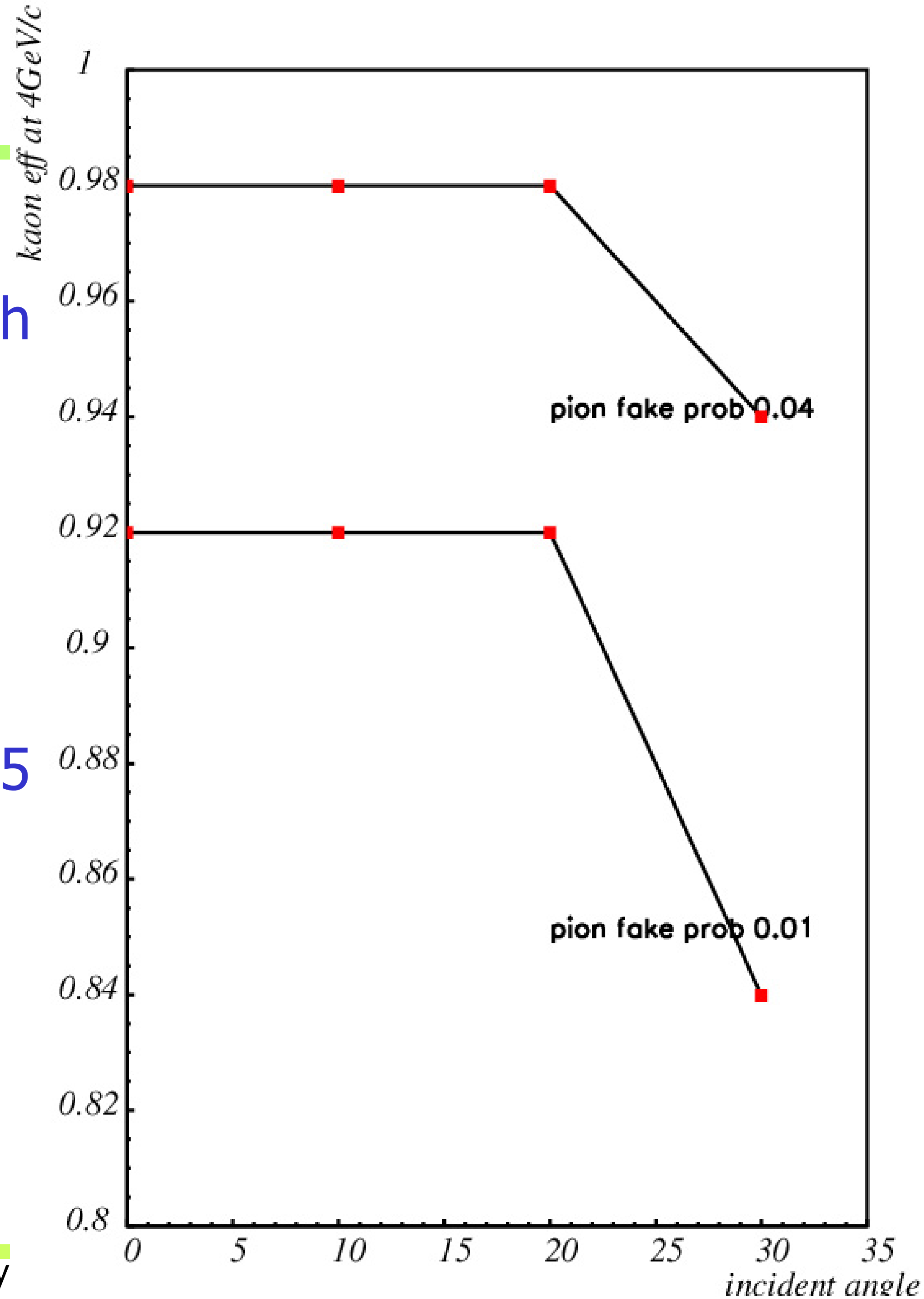


Variation vs angle of incidence

Kaon efficiency at 4GeV/c, with 1% and 4% pion fake probability

Focusing configuration

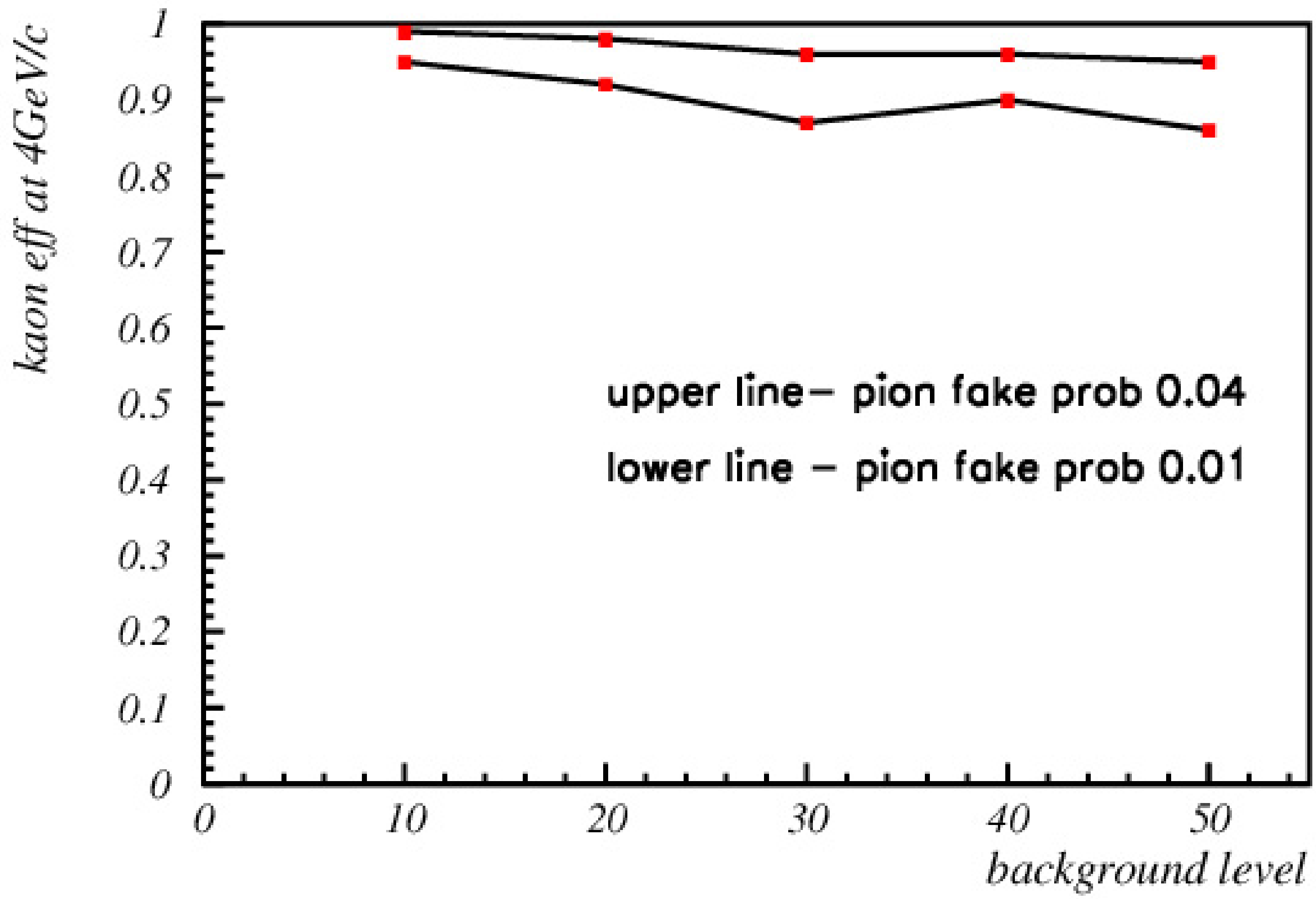
15mm n=1.043, 15mm n=1.05



Variation vs background level

Kaon efficiency at 4GeV/c, with 1% and 4% pion fake prob.

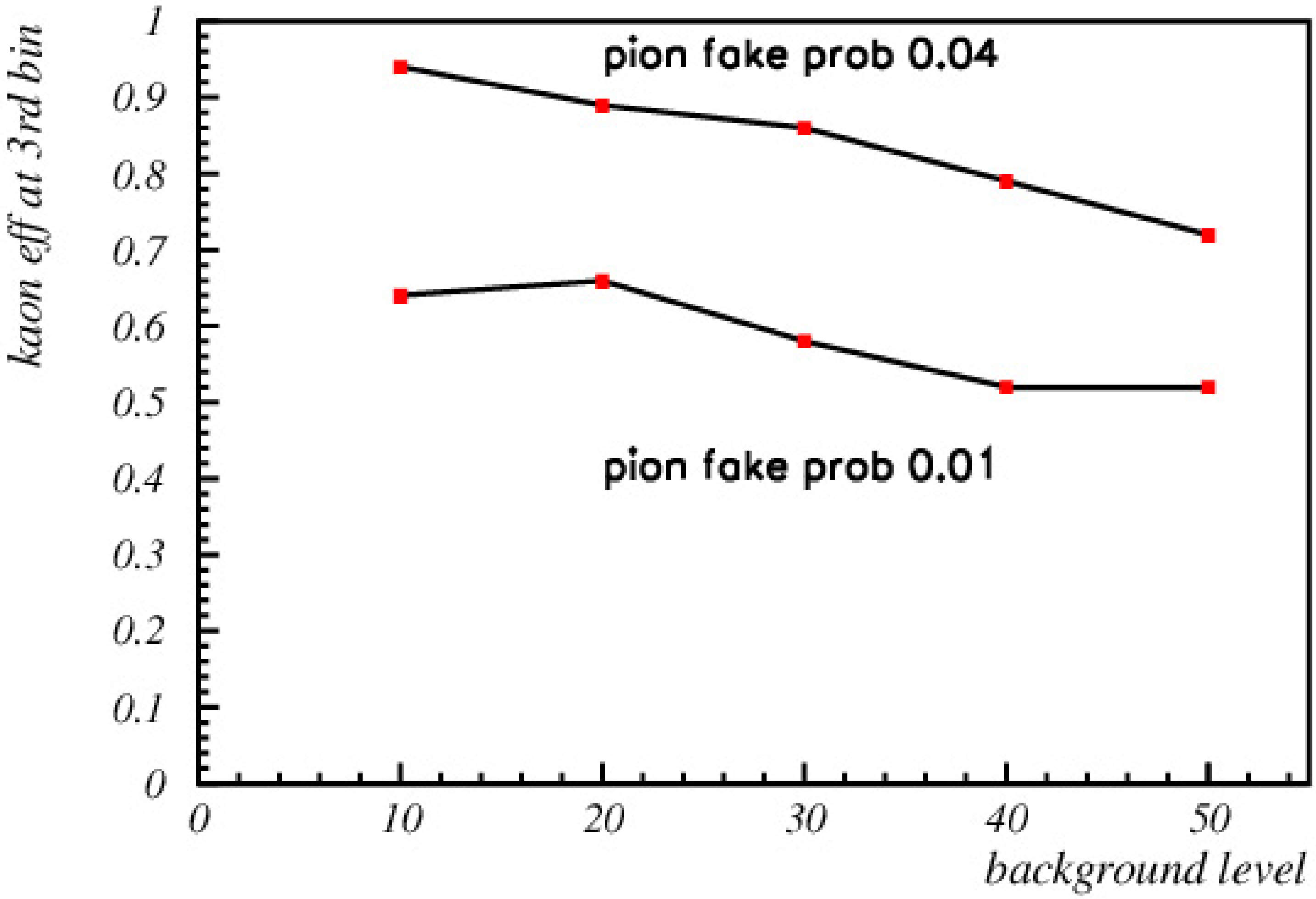
Focusing configuration, 15mm n=1.043, 15mm n=1.05



Variation vs background level

Kaon efficiency at just above threshold, with 1% and 4% pion fake prob.

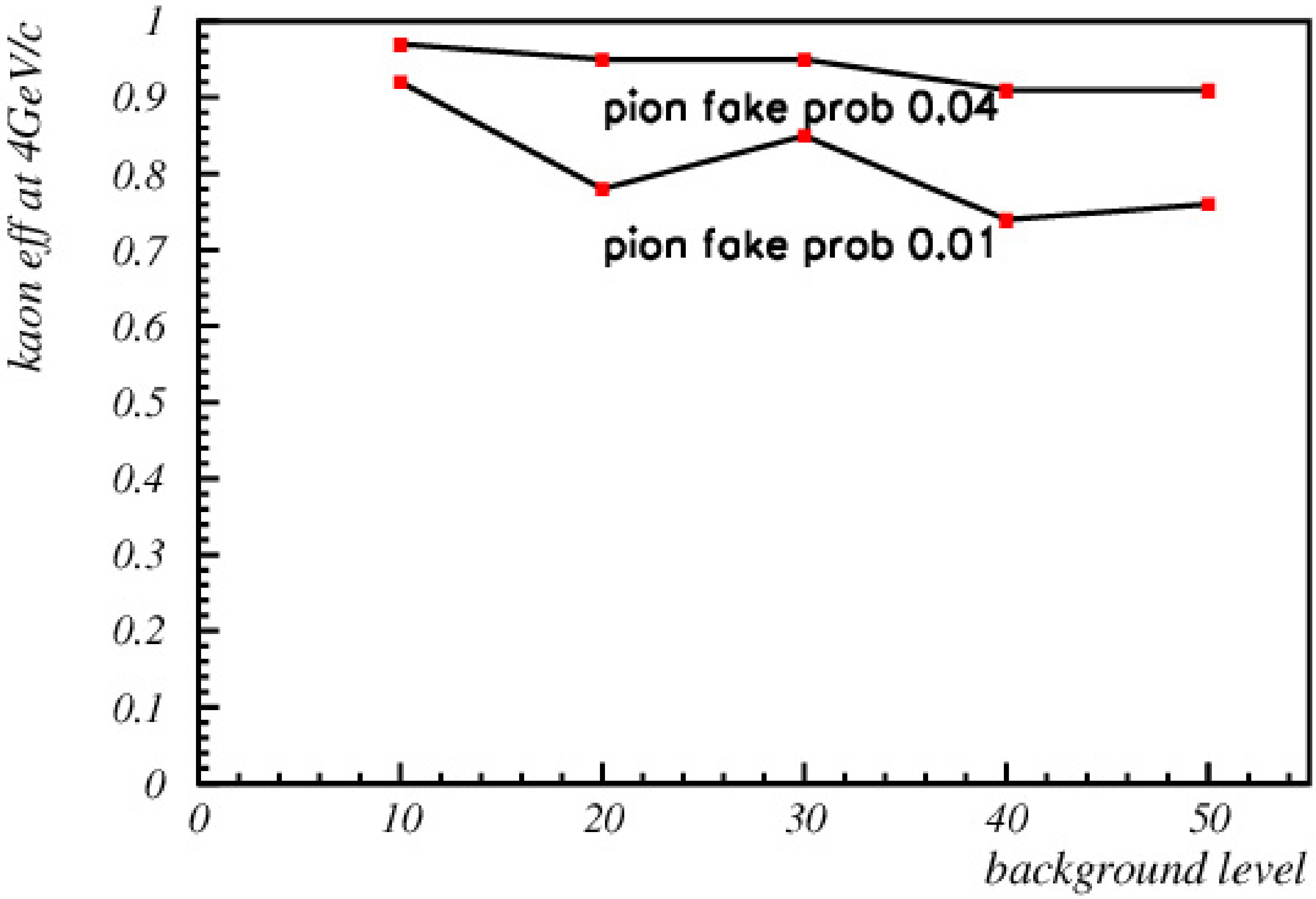
Focusing configuration, 15mm n=1.043, 15mm n=1.05



Variation vs background level

Kaon efficiency at 4GeV/c, with 1% and 4% pion fake prob.

Defocusing configuration, 15mm n=1.050, 15mm n=1.030

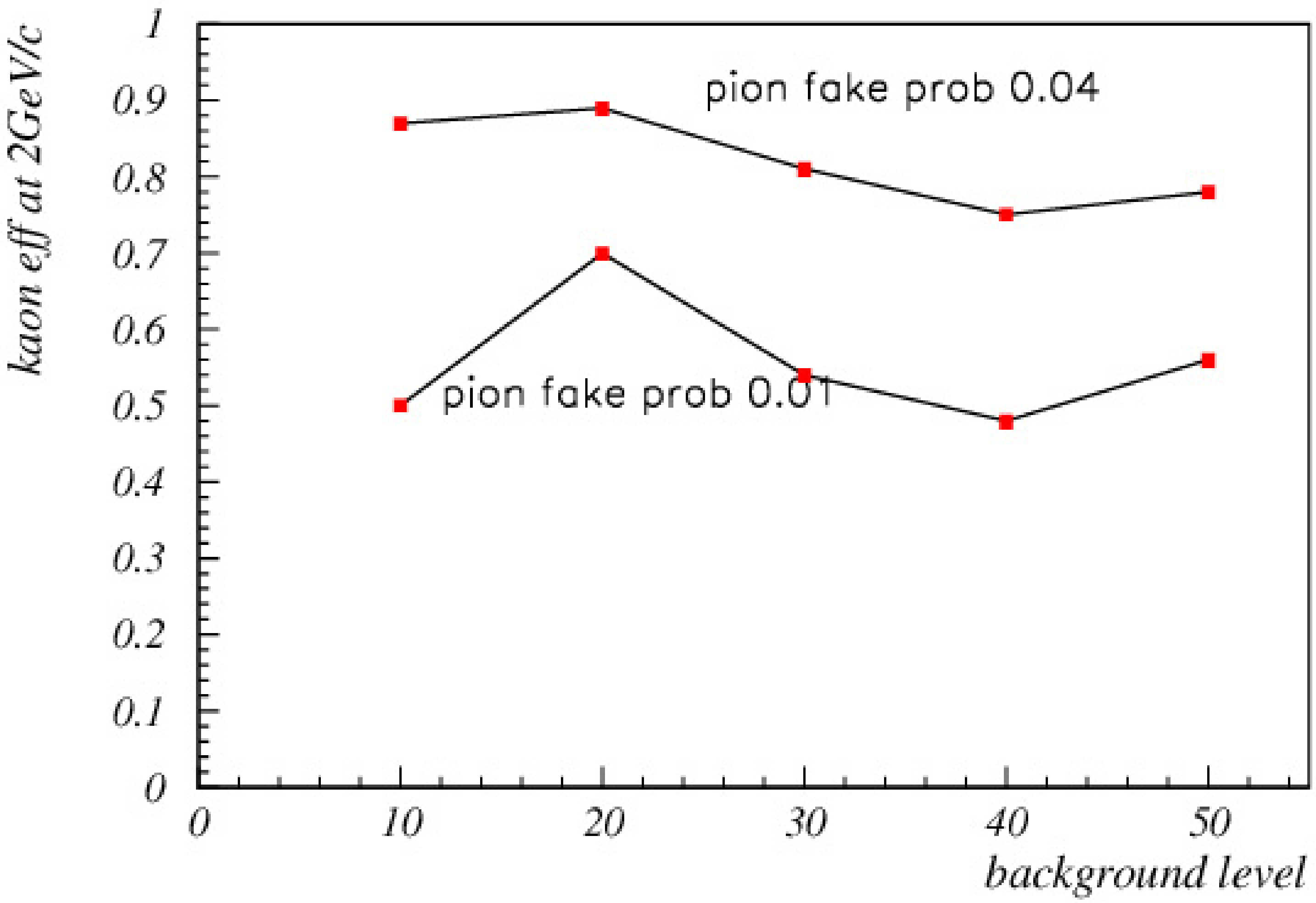


J

Variation vs background level

Kaon efficiency at 2GeV/c, with 1% and 4% pion fake prob.

Defocusing configuration, 15mm n=1.050, 15mm n=1.030

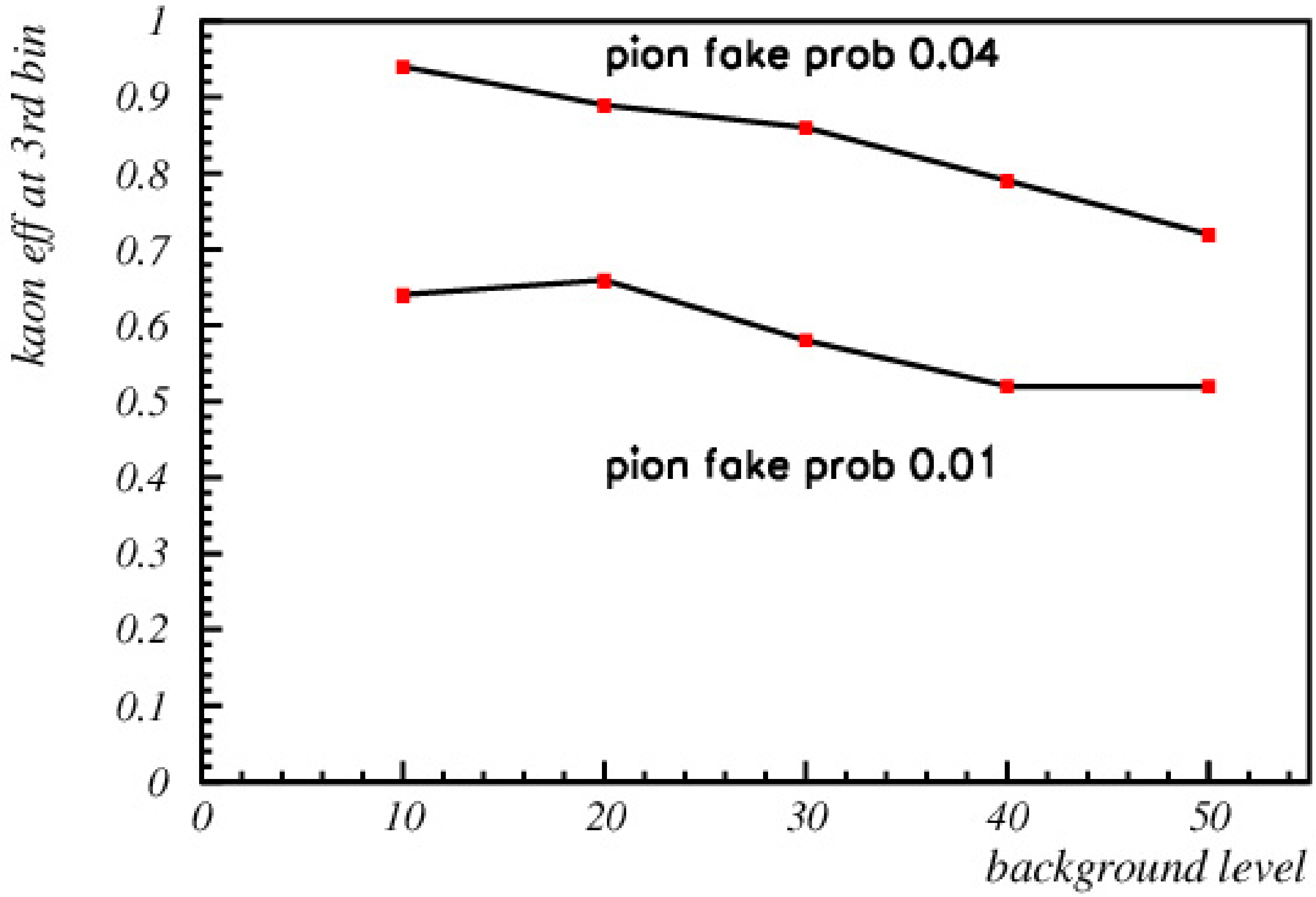


J

Variation vs background level

Kaon efficiency at just above threshold, with 1% and 4% pion fake prob.

Defocusing configuration, 15mm n=1.050, 15mm n=1.030



Summary, plan

Varied:

- Configuration (focusing, defocusing)
- Background level
- Angle

Next:

- Increase statistics

Vary:

- Exact refractive index choice
- Multiple radiator combinations