Separation power – again...

- slide shown at GSI PID-TAG

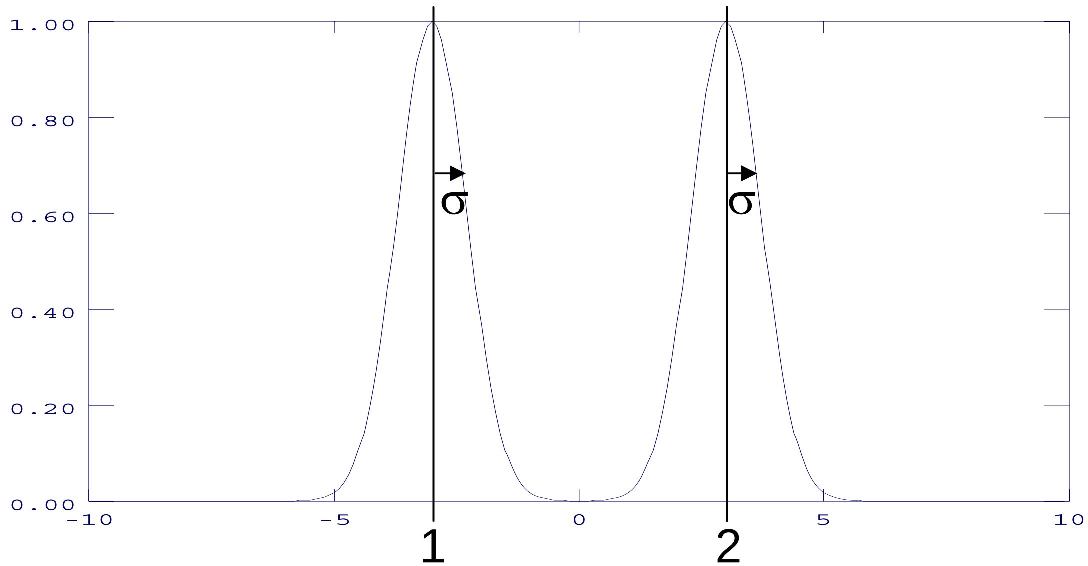
- key formulae from overview talks at the two past RICH conferences
- definition as worded in BaBar paper

- looking ahead

Klaus Föhl 2007-10-05 VRVS PID-TAG meeting

Definition of σ_{RES}

$$N_\sigma = \frac{|p_1 - p_2|}{\sigma_{RES}}$$



what do we do if distribution widths are not the same?

$$\sigma_{RES} := (\sigma_1 + \sigma_2)/2$$

CLEO

TAG definiton agreed at GSI

consistent with formula in B. Seitz talk

$$N_\sigma \approx \frac{|m_1^2 - m_2^2|}{2p^2\sigma(\vartheta_C)\sqrt{n^2-1}}$$

(Particle Data Book)

N.B. $\beta = \frac{p}{\sqrt{p^2+m^2}} \approx 1 - 1/2\frac{m^2}{p^2}$

$$\sigma_{RES} := \sqrt{\sigma_1^2 + \sigma_2^2}$$

COMPASS

came up in Erlangen

error value for (p_1+p_2) or for (p_1-p_2), but we measure **one single value** p_i

p_1 and p_2 define the scale

$|p_1-p_2|$ determined accurately (high statistics or by calculations)

$$\sigma_{RES} := \sigma_1 + \sigma_2$$

same information content as formula on the left

Klaus Föhl
PANDA PID-TAG
GSI 2007-09-20

Ypsilantis and Seguinot

Nuclear Instruments and Methods in Physics Research A 343 (1994) 30–51
North-Holland

Theory of ring imaging Cherenkov counters

T. Ypsilantis *, J. Seguinot
College de France, Paris, France

2.1. Resolution and particle identification

The resolution of a RICH detector for a single photoelectron is given by Eq. (7). For N photoelectrons it becomes

$$\frac{\sigma_\beta}{\beta} = \tan\theta \frac{\sigma_\theta}{\sqrt{N}}, \qquad (9)$$

where σ_θ is the total angular error per detected photon. This differs from Eq. (8) because a RICH counter measures θ directly whereas in threshold counters it is

The particle identification capability of a RICH counter may be obtained by considering the variable $u = \sin^2\theta$ which, from Eq. (1), may be written as

$$u = 1 - (1/n)^2 - (m/pn)^2, \qquad (10)$$

where p and m are the particle momentum and mass. The number of standard deviations n_σ to discriminate mass m_2 from m_1 is then obtained from Eq. (10) as

$$n_\sigma = \frac{u_2 - u_1}{(\sigma_u/\sqrt{N})} = \frac{m_2^2 - m_1^2}{p^2 n^2}\left(\frac{\sqrt{N}}{\sigma_u}\right), \qquad (11)$$

where σ_u is the error in u per single photoelectron and $\sigma_u/\sqrt{N}$ is the error for N photoelectrons. By combining Eqs. (4) and (9) and noting that $\sigma_u = (2\sin\theta\cos\theta)\sigma_\theta = (2\sin\theta/n\beta)\sigma_\theta$, particle ID with n_σ standard deviations may be attained at momentum

$$p = \sqrt{\frac{m_2^2 - m_1^2}{2k_r n_\sigma}}, \qquad (12)$$

where the quantity k_r is the RICH detector constant, defined as

$$k_r = \frac{n\beta\sigma_\theta}{\sqrt{N_0 L}} = \frac{\tan\theta\,\sigma_\theta}{\sqrt{N}} \qquad (13)$$

and σ_θ is the total angular error per detected photon.

Glässel at RICH 2004

Nuclear Instruments and Methods in Physics Research A 433 (1999) 17–23

For $\beta \to 1$ the Cherenkov angle approaches the *asymptotic* value θ_{max} related to threshold as

$$\sin^2\theta_{max} = \frac{1}{\gamma_t^2} = \frac{1}{\eta_t^2 + 1} \quad (5)$$

Here the quantity $\eta = \beta\gamma$ has been introduced, trivially related to the Lorentz factor as $\eta^2 = \gamma^2 - 1$. It directly relates to particle momentum ($p = \beta\gamma m$).

9. Angular resolution and particle identification

Particle identification with the RICH is based on distinguishing the Cherenkov angle for particles with known momentum. If one considers the quantity $\sin^2\theta_c$, its difference for two masses m_1 and m_2 at momentum p is

$$\Delta\sin^2\theta_c = \frac{m_2^2 - m_1^2}{n^2 p^2} = \frac{\Delta m^2}{n^2 p^2}. \quad (17)$$

The quality of the separation is described by the number of standard deviations in this quantity, it can be calculated to be

$$n_\sigma = \frac{\beta^2 \Delta m^2}{2p^2} \Big/ \frac{\sigma_\beta}{\beta} = \frac{\beta^2 \Delta m^2}{2p^2 \tan\theta_c \sigma_{\theta_c}} \quad (18)$$

leading to an upper momentum limit for n_σ standard deviation separation of

$$p_{max} = \left(\frac{\beta^2 \Delta m^2 \eta_t}{2 n_\sigma \sigma_{\theta_c}}\right)^{1/2}. \quad (19)$$

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Performance of the BABAR-DIRC*

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Representing the BABAR-DIRC Collaboration ‡

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The pion-kaon separation power is defined as the difference of the mean Cherenkov angles for pions and kaons assuming a Gaussian-like distribution, divided by the measured track Cherenkov angle resolution. As shown in Figure 6, the separation between kaons and pions is about 4 σ at 3 GeV/c declining to about 2.5 σ at 4.2 GeV/c.

Looking ahead

- reasonable collection of candidate detectors
- ideas on inividual and combined detector performances

- need to formulate: physics implications of particular detector decisions...