Limits to Performance For Imaging Cherenkov Detectors at a Super B Factory.

Blair Ratcliff
1/20/04

- General Considerations
- Some physics examples
- Defining Performance Metrics
- Thinking about performance: Simple Models
- Summary
• **PID detector requirements may be sensitive to**

1. Backgrounds....both pattern recognition and robustness.
2. Machine Asymmetry (The larger the boost, the harder to do PID.)
3. Good tracking. Existence of reasonable $\frac{1}{\beta^2} \frac{dE}{dx}$.
4. Physics Needs:
   • B Physics Channels?
   • Run on 5s?
   • Charm or $\tau$ physics?

• **For now, assume that**

1. Backgrounds can be handled. (Detectors and radiators proposed are likely to be sufficiently radiation hard. Pattern recognition must be carefully simulated.)
2. Boost ~same as Belle (or less than BaBar)
3. $\frac{dE}{dx}$ and tracking ~ like now .
4. So what about the physics needs?
How well do present PID systems work (a few BaBar examples)?

- From inclusive qqbar studies. Calibrated with control samples.
- Performance reasonably well understood. Limited in many cases by physics processes (scattering, decays, interactions, delta rays, etc.)
- ID efficiency limited by resolution at higher momenta for K-pi.
- ~0.1% Mis-id at low momenta...1-2% in Cherenkov region.
Example II- $B$ to $\rho\gamma$

- $B$ to $\rho\gamma$ topology identical to $K^*\gamma$, which is expected to have \( \sim 20 \times \) the BF. Need to reject Kaons by positive pion ID.

- Optimized cuts give \( \sim \)1/2-1 percent K mis-id for most of the events.

- Mis-Id not the dominant source background for the BF limit on $\rho\gamma$ of $1.6 \times 10^{-6}$.

- Unless BF of “signal/background” ratio is very small, the present Mis-Id is probably sufficient… Would be useful to have some specific channels that require better Mis-Id performance.
Defining the PID Performance Metric

Conceptual Issues

- Often characterized as “Nσ”

\[ N_\sigma \approx \frac{(m_1^2 - m_2^2)}{2p^2 \sqrt{n^2 - 1} \sigma[\theta_c(tot)]} \]

- In a simple model, the total resolution on Cherenkov angle scales as:

\[ \sigma[\theta_c(tot)] = \frac{\sigma[\theta_c]}{\sqrt{N_{pe}}} + \sigma[\theta(tracking)] + \sigma[\theta(cor)] \]

\[ \sigma[\theta_c] = \sqrt{\sigma[\theta_{production}]^2 + \sigma[\theta_{Transport}]^2 + \sigma[\theta_{Imaging}]^2 + \sigma[\theta_{Detection}]^2} \]

In practice, the correlated and tracking pieces are \sim 1.5 \text{ mrad} in BaBar.
Defining the PID Performance Metric $N_\sigma$

• Improving $N_\sigma$ is often taken as improving PID performance and/or momentum range. However, once an adequate separation is attained, it is not clear how much this really improves physics.

• Cherenkov Central tracking is a large component of the overall separation ….to do much better than now need $\ll$ 1 mrad, including alignment and multiple scattering components

• Improving $\sigma(\theta_c)$ for each Cherenkov photon tends to cost pixels (and $\$ or Y)

MIS-ID

• Not Gaussian…

• Physics effects produce separation tails (decays, scattering, delta rays, interactions)

• May be able to “improve” with post DIRC tracking…Needs more study
The BaBar Detector

Silicon Vertex Tracker

DIRC PID

p/K/π

e−

9 GeV

Drift Chamber tracking, dE/dx

Instrumented Flux Return
muon, neutral hadron ID

1.5T Solenoid

Electromagnetic Calorimeter:
good resolution, low energy
reach for photons

e+

3.1 GeV
Thinking about Performance Metrics - Very Simplified

Model I

Gaussian Probability (Model I)-Shown for 4 Sigma Separation

1E-18 1E-17 1E-16 1E-15 1E-14 1E-13 1E-12 1E-11 1E-10 0.000000001 0.00000001 0.0000001 0.000001 0.00001 0.0001 0.001 1

-6 -4 -2 0 2 4 6 8

Separation parameter

Probability Value

Particle Type 1
Particle Type 2

Gaussian PDFs for Both Particles

Equal Particle Populations
Model I - Performance

Gaussian Fractional Mis-id Rate (Equal Particle Populations)

1.00E-14 to 1.00E+00

Efficiency for Wanted Particle

1 Sigma separation
2 sigma separation
3 sigma separation
4 sigma separation
5 sigma separation
6 sigma separation

Gaussian Mis-id Rate (Equal Particle Populations)

Efficiency for Unwanted Particle

1 Sigma separation
2 sigma separation
3 sigma separation
4 sigma separation
5 sigma separation
6 sigma separation

Efficiency for Wanted Particle

0 to 1

1.00E-14 to 1.00E+00
Model III

98% of each particle type has a measured Gaussian at the correct central value with width 1

+ 

2% of each particle type has a measured Gaussian at the correct central value but with a width of 10.

Equal populations for type 1 and type 2 particles
Model III-Performance

Model III Fractional Mis-id Rate (Equal Particle Populations)

![Fractional Mis-id Rate Graph](image)

Model III Mis-Id Rate (Equal Particle Populations)

![Mis-Id Rate Graph](image)
Summary

• Although there will be many challenges in handling the high luminosity at a Super-B Factory, it is not clear that improving physics performance (wrt to BaBar) is especially helpful. …..would be very useful to have clearer physics examples.

• Distinguish between better \((N_\sigma)\) separation (giving a larger momentum range), and better Mis-id performance.

• Reducing Mis-id could likely benefit from post-PID tracking. Should understand this better.

➔ There are some useful areas for careful simulation studies.