Particle Identification
for a
Linear Collider Detector

How do we decide what we need?

Linear Collider Detector Workshop
University of Michigan
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PID in Europe & Japan studies?

✔ Chris Damerell:
  – “The European regional workshop has just ended, with no work done on particle ID.”
  – “My understanding is that the Japanese (like the Europeans) have not yet done anything on this.”

✔ PID has dropped below the event horizon in physics studies and overall detector optimisation.

✔ Are they right?
Keystone PID Summary

Hitoshi outlined two philosophies:

A  Identify physics requiring PID.

B  Plan for PID, if it is there we will use it.

In practice: \[ \Psi = \alpha A + \beta B \]

In a perfect world: \[ \alpha \approx 1, \beta \approx 0 \]

Hitoshi’s summary \[ \Rightarrow \alpha >> \beta \]

Experience indicates uses for PID that we will not think of until we have data. Or at least, not for quite a while yet. \[ \Rightarrow \alpha \approx \beta \]
What does this mean in practice?

✓ We *do* need to keep searching for specific examples to justify PID explicitly
  – we may even find a “golden” mode

✓ The PID “group” is so small that we could not possibly cover the phase space of LC physics, thoroughly and in reasonable time.

✓ The existing physics groups should be primed to ask PID questions.
What should the PID group do?

- Select a few particularly promising topics to give practical examples.
- Provide the physics groups with guidelines on plausible PID capabilities.
- PID class for simulation/reconstruction.
Promising topics for PID

✓ Strange, charm, bottom tagging

\[ e^+ e^- \rightarrow t\bar{t} \rightarrow W^+ b W^- \bar{b} \]

\[ e^+ e^- \rightarrow HA \rightarrow bbbb, bb\tau\tau \]

\[ W^+ \rightarrow c\bar{s} \quad above \quad ud \]

\[ t \rightarrow W^+ s, \quad \Rightarrow V_{ts} \]

Asymmetries

✓ Multi-jet analysis - net flavor?

✓ Your favorite process here!
PID Technology Review

✔ What do we get for “free” i.e. from the required sub-systems?
  - e, μ, h from calorimetry
  - e, μ, π, K, p from tracker (dE/dx)

✔ What could we get from a PID subsystem?
  - Transition Radiation Detector
  - Scintillator Time-of-flight
  - Threshold Cerenkov
  - Ring imaging Cerenkov
PID Sub-system impact?

- Material in front of the calorimeter
  - How much is tolerable? What is the spec.?
- Calorimeter $ vs. inner radius
- Track resolution (BL^2)
- The goal is the best LC physics
  \[ \Rightarrow \text{coherent design optimization of all sub-systems together} \]
Example: Cerenkov Ring Imaging

**✓ Basic formulae:**

\[ \cos \theta = \frac{1}{\beta n} \quad \Rightarrow \quad p = \beta \gamma m \]

\[ N_\gamma = N_0 L z^2 \sin^2 \theta \quad \gamma_{\text{threshold}} = \left(1 - \frac{1}{n^2}\right)^{-\frac{1}{2}} \]

**✓ In practice need** \( <N_\gamma> \approx 10 \)

**✓ DIRC -- the most compact Cerenkov option**

– quartz radiator, \( n=1.474, L=1.8\text{cm} \)

\[ \beta_{\text{threshold}} = 0.68, \gamma_{\text{threshold}} = 1.36 \quad \Rightarrow \quad p_{\text{threshold}} = 0.92 m_{\mu, \pi, K, p} \]

\[ N_\gamma (\beta \approx 1, \text{normal, pmf}) \approx 30 \]
Angular resolution & PID

✓ Maximum momentum for separation by $n_\sigma$ standard deviations

\[
  p_{\text{max}} = \left( \frac{\beta^2 \Delta m^2 \beta_t \gamma_t N^{1/2} \gamma}{2n_\sigma \sigma_\theta} \right)^{1/2}
\]

✓ For $3\sigma$ $\pi$-K separation in 18 mm quartz

\[
  p_{\text{max}} = \frac{0.14}{\sigma_\theta^{1/2}} N^{1/4} \gamma
\]

✓ About 4 GeV/c for BaBar-DIRC
  - double radiator thickness $\Rightarrow$ 20% increase
  - 1/2 resolution $\Rightarrow$ 40% increase
PID R&D proposals pending

✔ H. Yamamoto: Identify specific processes -
  - Heavy, long-lived, charged particles (c.f. Fermilab workshop)
  - Other SUSY? Other?

✔ RJW: Detector capabilities review + specific process -
  - Top studies - discrimination from WW, new physics, t→Ws, polarization? (cf M. Peskin)
  - Flavor asymmetries: A_{s,c,b} ?
  - B tag, à la B-factories - Higgs studies?