Data reconstruction at Compass for endusers

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Compass Seminar 08.05.09
Aim: Search for new short living states ($X$) with final states of the outgoing particles. → Invariant mass of $X$ has to be determined.
What do we need to measure?

Invariant masses
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Particles and their kinematical properties in collisions
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Dynamics best described with Lorentzvectors $(E/p, p)^T$
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momentum – energy – mass - charge
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Invariant masses

Particles and their kinematical properties in collisions

Dynamics best described with Lorentzvectors \((E/p, p)^T\)

momentum – energy – mass – charge

Determined by:
particle position – particle time – particle speed
Measure the momentum of outgoing charged particles: The Spectrometer

SM1 bending power = 1 Tm
SM2 bending power = 4 Tm
Measure the momentum of outgoing charged particles:
The Spectrometer

Trackers:
- VSAT (very small area trackers)
- SAT (small area trackers)
- LAT (large area trackers)

Measure the momentum of incoming charged particles: The Beam Momentum Station

**µ beam**: BMS (beam momentum station) at the bending magnet station

Scintillating fibers for track position measurement

**hadron beam**: no measurement! Exclusivity is just an approximation.
Measure the momentum of the recoiling particles: The Recoil Particle Detector

Measure the momentum of neutral particles: Case they decay into charged particles ($V^0$)

$V^0 (\Lambda^0 \bar{\Lambda}^0 K^0)$

reconstructed by user measured

$\bar{p} \pi^-$

$p \pi^+$
Measure the momentum of neutral particles: Case they decay into γ's ($\pi^0 \eta$)

π₀ → γ → measured
reconstructed by user

Energy and position in the electromagnetic calorimeters
Measure the momentum of neutral particles: Case they decay into $\gamma$'s ($\pi^0 \eta$)
Determination of charged particle energies

Energy resolution of ECALs (and HCALs) is too poor for precise energy determination!

Thus we use the energy - momentum relation for energy determination. $E^2 = m^2 c^4 - p^2 c^2$

Particle identification is needed → PDG mass for well known particles is used.
Particle identification for incoming beamparticles:
CEDAR
Incoming beam momentum is fixed
→ the velocity for different masses differs.
→ the cherenkov angles differ.
Particle identification for outgoing charged beamparticles: The RICH Detector

Realized only for the first stage of spectrometer
Mainly for separation of pions, Kaons and protons
Particle identification for outgoing charged beamparticles: The RICH Detector
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By knowing the beam momentum and the Cherencov cone angle we know the mass but identification of Kaons only possible up to 50 – 60 GeV.
How do we obtain the physical values out of the RAW data (TDC, ADC, position)?

Main steps of the RAW data decoding are provided by the experts of the detectors as a c++ library.
From the RAW data stored on CASTOR tapes to Enduser data stored as mini DSTs

ROOT Framework (library for data treatment, histogramming, fitting, …)
From the RAW data stored on CASTOR tapes to Enduser data stored as mini DSTs

Tracking
Wires - scintillators - foils
TDC

RICH/CEDAR
PMTs
TDC

ECALs
PMTs
SADC

... RAW data

ROOT Framework (library for data treatment, histogramming, fitting, ...)

Database
time calibration
Position ...
From the RAW data stored on CASTOR tapes to Enduser data stored as mini DSTs

- Tracking
  - Wires - scintillators - foils
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- ECALs
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- ... RAW data

ROOT Framework

CORAL

- Event reconstruction with decoding library
- Also MC detector signal simulation Containing COOOL for online monitoring

Database

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- Position ...

Library for data treatment, histogramming, fitting, ...
From the RAW data stored on CASTOR tapes to Enduser data stored as mini DSTs

**ROOT Framework**

- **Tracking**
  - Wires - scintillators - foils
  - TDC

- **RICH/CEDAR**
  - PMTs
  - TDC

- **ECALs**
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  - SADC

- ... [RAW data]

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**Database**

- time calibration
- Position ...

**PHAST**

- mDST creator
- Enduser analysis tool

**mDSTs**

- Mini Data Storage Tapes
  - Tracks-Vertices-Particles-Charge-
  - ECAL Cluster-Energies-
  - Cherenkov Angles-etc.
The Configuration for the Enduser

ROOT Framework (library for data treatment, histogramming, fitting, ...)

**mDSTs**
Mini Data Storage Tapes
Tracks-Vertices-Particles-Charge-
ECAL Cluster-Energies-
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**PHAST**
mDST creator
Enduser analysis tool

**UserEvent**
A method called by Phast
Phast transfers Event by Event
User has to treat the data

**Histograms - Trees - Graphs**
Typical work of an Enduser

• Eventselection:
  mDST-run-spill selection, Triggerselection
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  mdST-run-spill selection, Triggerselection

• **Vertexselection:**
  primary/secondary - inside/outside the target
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  Search for Cluster with no associated charged tracks
  Computation of Lorentzvectors starting from the vertex
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Lot of background due to noisy channels

[Graph showing mass fit and analysis results]
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  - Having a charged track one retrieves a Lorentzvector by definition of the mass of the particle.
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![Invariant mass of π⁺π⁻ system](hist_k0_mass)

<table>
<thead>
<tr>
<th>hist_k0_mass</th>
<th>Entries</th>
<th>Mean</th>
<th>RMS</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>4307</td>
<td>0.4948</td>
<td>0.1347</td>
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</tbody>
</table>
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Reduced background due to PID of protons and antiprotons
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• **Cutselection for background reduction:**
  combinatorial background by particle misidentification,
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• **Computation of invariant masses:**
  Find the short living particles in the mass spectra (Example on the next page)
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•**Computation of invariant masses:**
  Find the short living particles in the mass spectra

•**Comparison with Monte Carlo:**
  Test the code on Monte Carlo data.
  Determine systematic errors and background.
void UserEvent1(PaEvent& e){
    // create a histogram to fill only when this
    // method is called the first time
    static TH1F* mass_hist;
    bool first(true);
    if (first){
        mass_hist = new TH1F("mass_hist", "invariant mass distr", 1000, 0, 5);
        first = false;
    }
    // go through all vertices in this event
    for(int ivertex = 0; ivertex < e.NVertex(); ivertex++){
        const PaVertex& vertex = e.vVertex(ivertex); // copy vertex
        if (!vertex.IsPrimary()) continue; // take only primaries
        if ((-65 < vertex.Z()) && (vertex.Z() < -30)) continue; // only target region
        if (vertex.NOutParticles() != 3) continue; // number of outgoing particles must fit
        // get the indexes of the particles in the vector
        int index_pi1 = vertex.iOutParticle(0);
        int index_pi2 = vertex.iOutParticle(1);
        int index_pi3 = vertex.iOutParticle(2);
        // retrieve the particle themselves
        const PaParticle& particle_pi1 = e.vParticle(index_pi1);
        const PaParticle& particle_pi2 = e.vParticle(index_pi2);
        const PaParticle& particle_pi3 = e.vParticle(index_pi3);
        // calculate the Lorentz vectors in the specific position of the vertex
        TLorentzVector LzVec_pi1 = particle_pi1.ParInVtx(ivertex).LzVec(0.139);
        TLorentzVector LzVec_pi2 = particle_pi2.ParInVtx(ivertex).LzVec(0.139);
        TLorentzVector LzVec_pi3 = particle_pi3.ParInVtx(ivertex).LzVec(0.139);
        mass_hist->Fill((LzVec_pi1+LzVec_pi2+LzVec_pi3).M());
    }
}
Output of UserEvent Analysis

3 outgoing particles assigned with masses of pions

from analysis by haas
Output of UserEvent Analysis

3 outgoing particles assigned with masses of pions

from analysis by haas
Thank you