SPD meeting,
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Reconstruction of short-lived particles in SPD experiment

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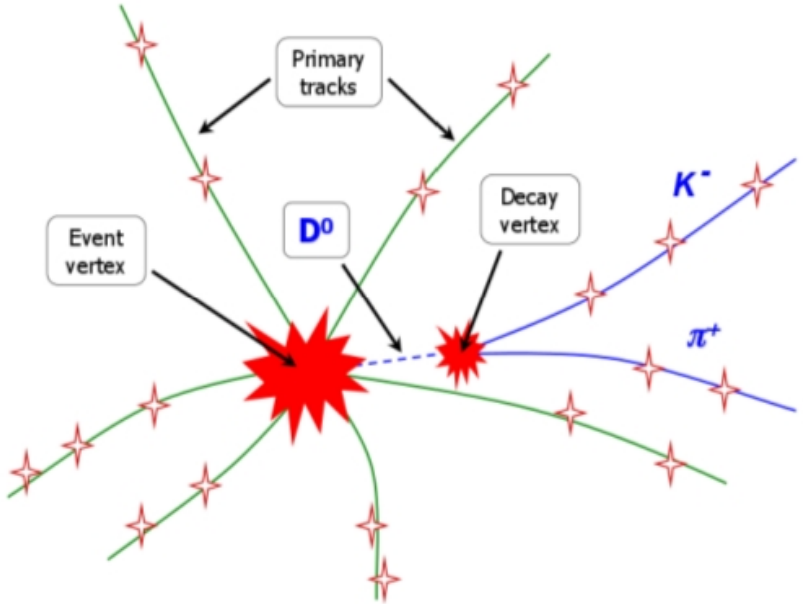
Introduction

- Particles, which are produced in a collision, can be divided into two groups: long-lived particles and short-lived particles.

- Long-lived particles have a lifetime large enough to cross the tracking detector system of the experiment and to be registered directly (e ± , p ± and particles with a large decay length $c\tau$, like muons, pions and K± mesons).

- Short-lived are those particles, which decay before or inside the tracking system and can be registered only indirectly: strange hyperons (Λ, Ξ, Ω), low mass vector mesons (ρ, ω, φ), charmed particles (D mesons, J/ ψ) end etc.



Introduction(2)

- General scheme of short-lived particles reconstruction:

  - fit tracks with Kalman filter methods (in our case);

  - select primary and secondary particles on the base of DCA (distance of closest approach) to PV or another methods;

  - reconstruct secondary vertex (as point of DCA between daughter particles trajectories)

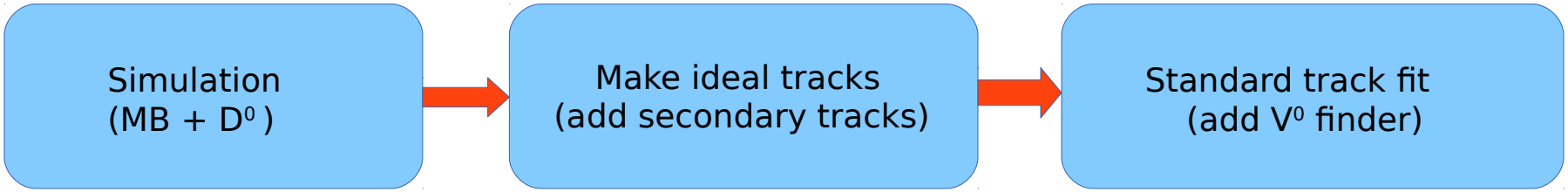
  - finally, reconstruct of mother particle parameters based on parameters of daughter particles

  - the special KF Particle package has been developed for the complete reconstruction of short-lived particles with their momentum, energy, mass, lifetime, decay length, rapidity, etc. Used in ATLAS, STAR, CBM and others experiments

  - now this KF Particle package is installed in SPD (thanks Artur)

  - the new ideal V0 finder is also prepared for SPD software

General schema of V^0 finder in SPD



Parameters of ideal V^0 finder:

1. userOutFile = " IdelV0finder.root" - name of user output file

2. SetFirstDaughter (321) => K - meson

3. SetSecondDaughter (211) => pi - meson

4. SetUsedTypeOfPV (1) => 0 – simulated and 1 – reconstructed primary vertex

5. SetMinTrackPVchi2 (1.0) => min chi2 of track relatively PV

6. SetMinDistDaughter (0.075) => minimum distance between daughter particles

7. SetMinimumMass (0.0) => minimum value of mass widow

8. SetMaximumMass (2.5) => maximum value of mass window

Output root file contains next parameter reconstructed secondary particles:

mass, massErr, momentum, energy, eta, theta, phi, decay length

Ideal V^0 finder

Selection criterion in KF Particle package:

1. select tracks (primary and secondary) on the base of chi2 of track and primary vertex (rec and sim)

$$\chi^2_{prim} = \Delta\mathbf{r}^T (C_{track} + C_{PV})^{-1} \Delta\mathbf{r},$$

where Δr – distance between track and the primary vertex position, C_{track} is covariance matrix of a track and C_{PV} is a covariance matrix of primary vertex

2. consider only combination of 2 particles with different charge (q1*q2 < 0) for 2 particles decay case

3. check the distance between 2 daughter particles

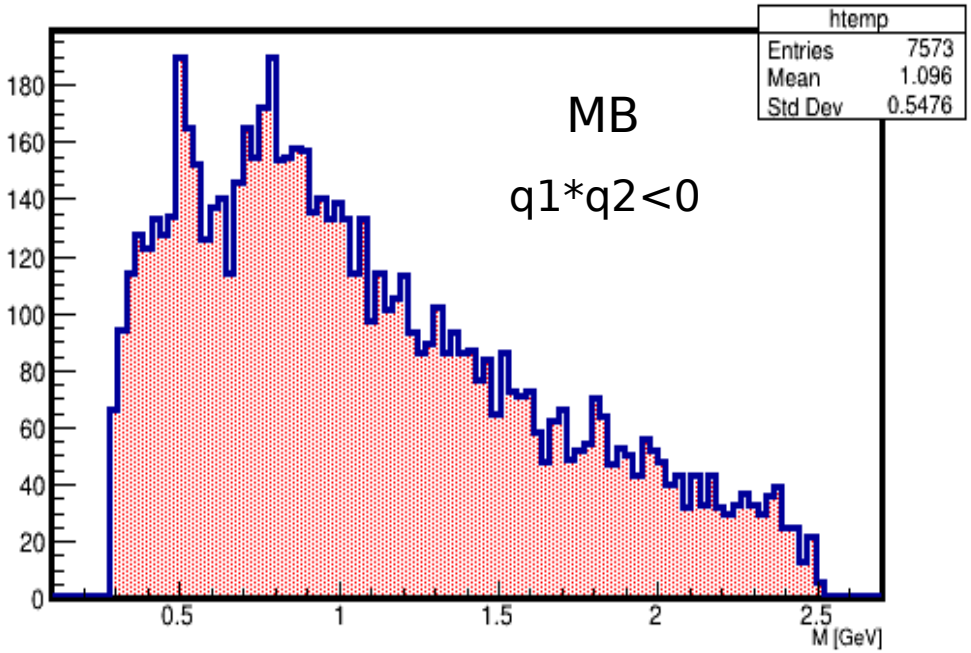
4. check L / dL - decay length normalized on the error

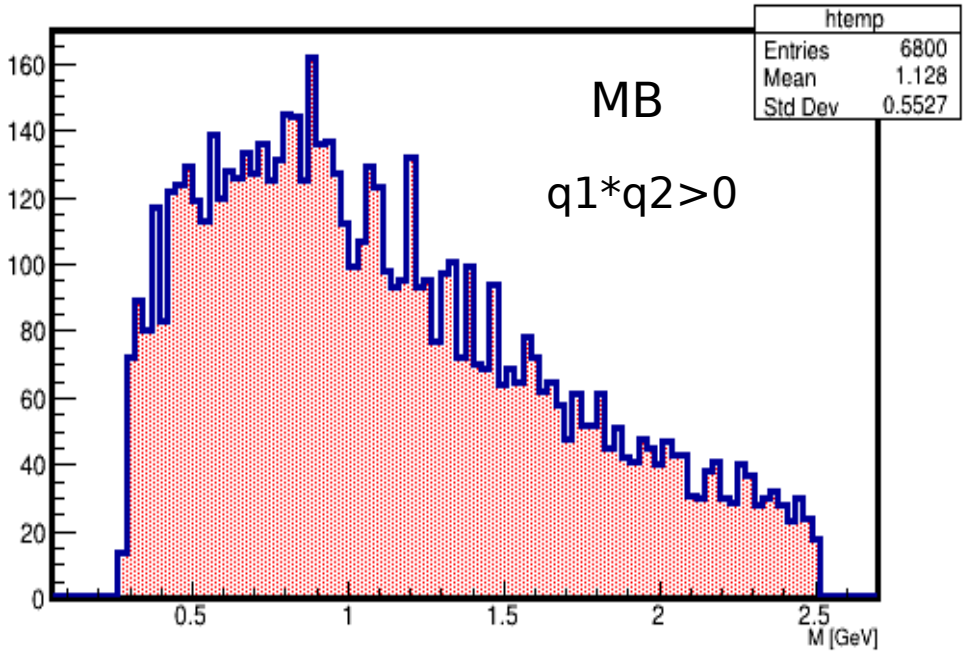
5. check χ^2_{topo} - of mother particle to primary vertex

6. check some kinematic variables (θ of mother particle, P_T mother or daughter particles)

Ideal V^0 finder (K^0_s)

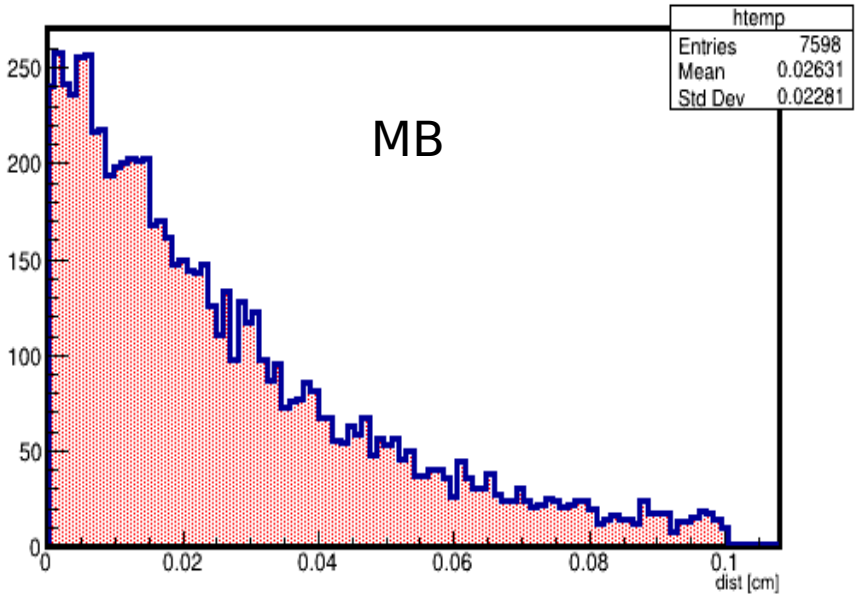
1. consider $K^0_s \to \pi^+ \pi^-$ decay (68,6 %) and $\tau = 0.895*10^{-10}$ => $c\tau = 2.7$ cm
2. simulate Minimum Bias (MB) events with Pythia6 and $\sqrt{s} = 27$ GeV
3. additionally simulate 5000 K^0_s events, uniform θ and φ (~1800 reconstructed)
4. consider 2 pions combination with different charge (q1*q2 < 0) in each event

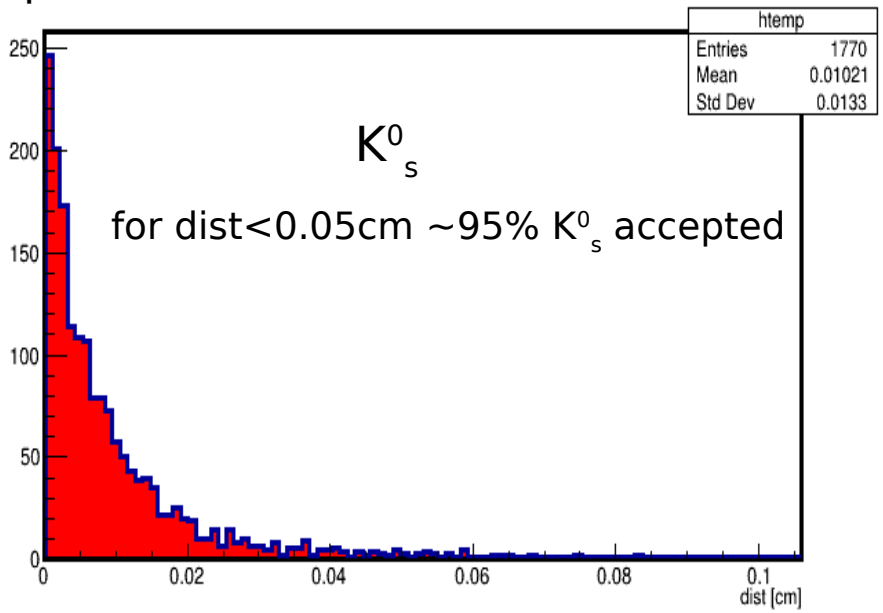




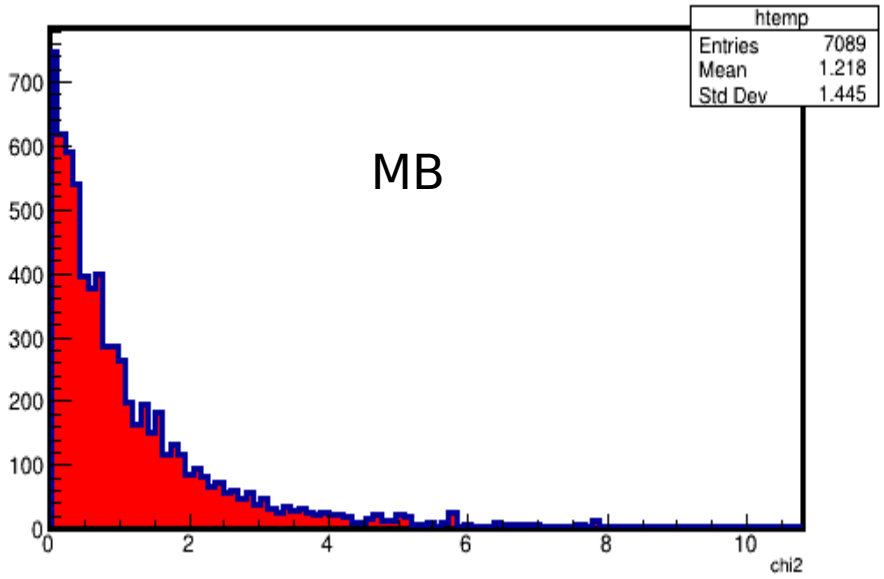
Ideal V^0 finder (K^0_s)

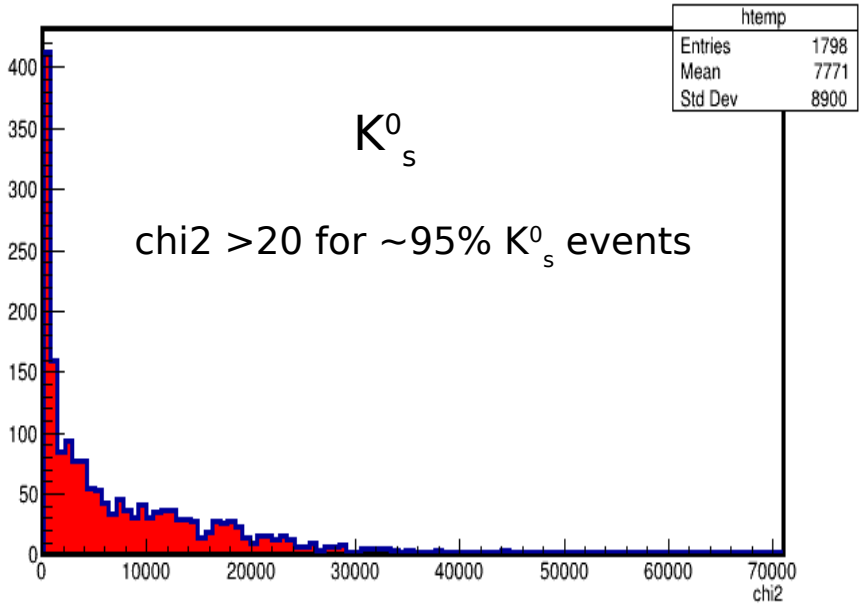
Distance between 2 particles





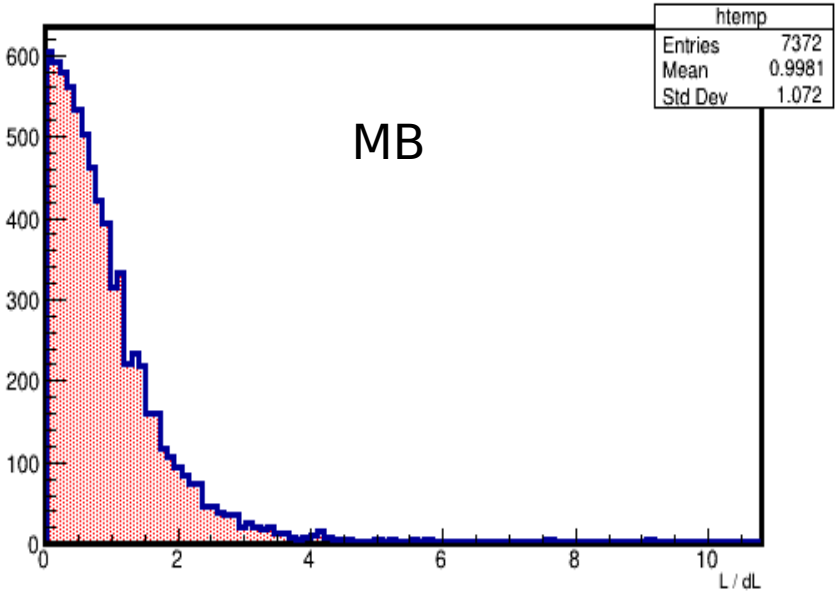
chi2 of track to PV

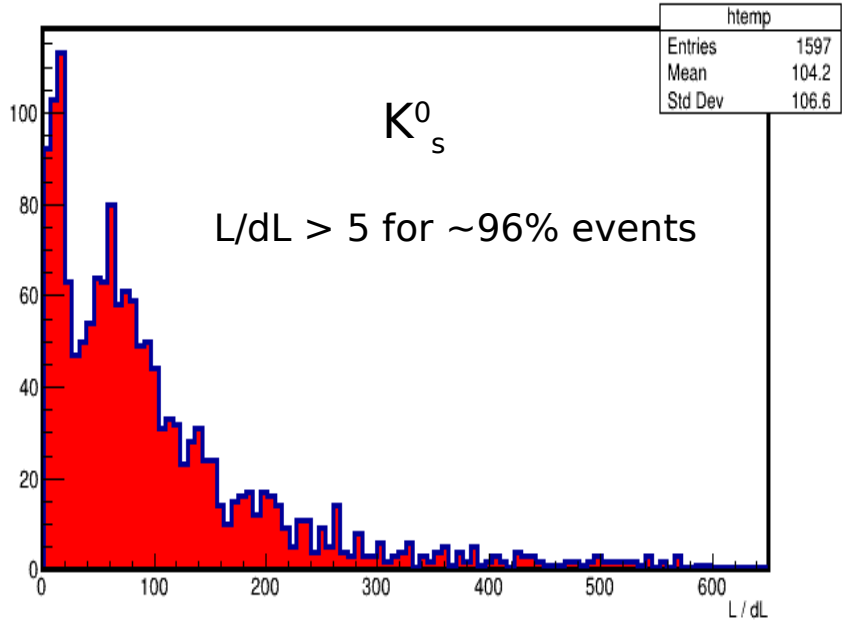




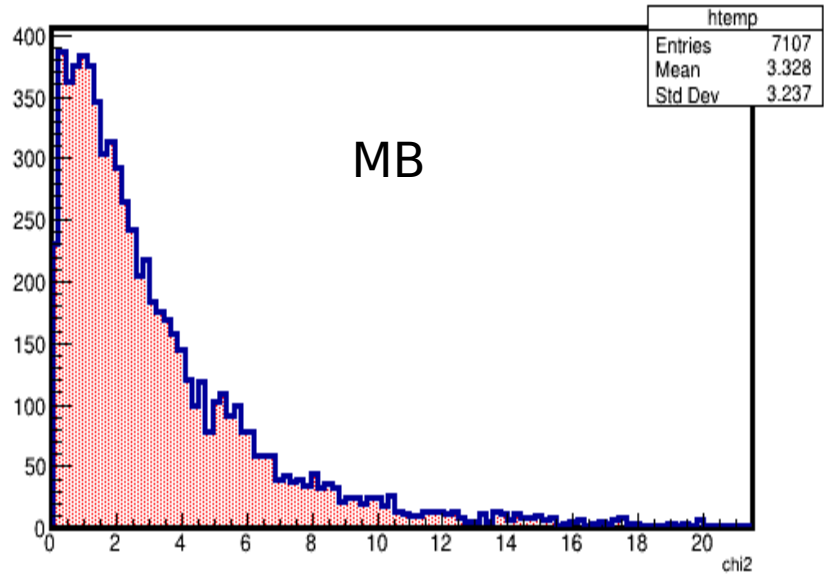
Ideal V^0 finder (K^0_s)

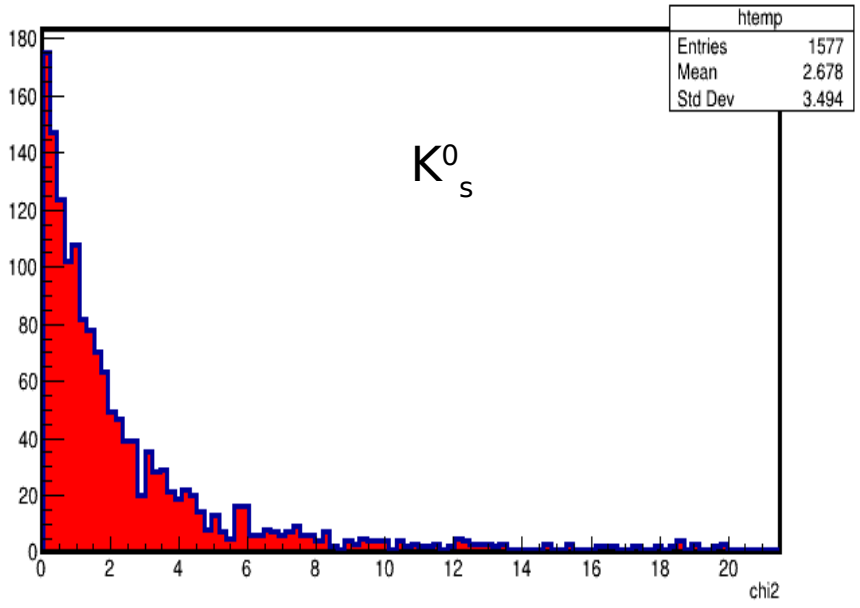
Normalize distance L/dL of V^0 particle to PV



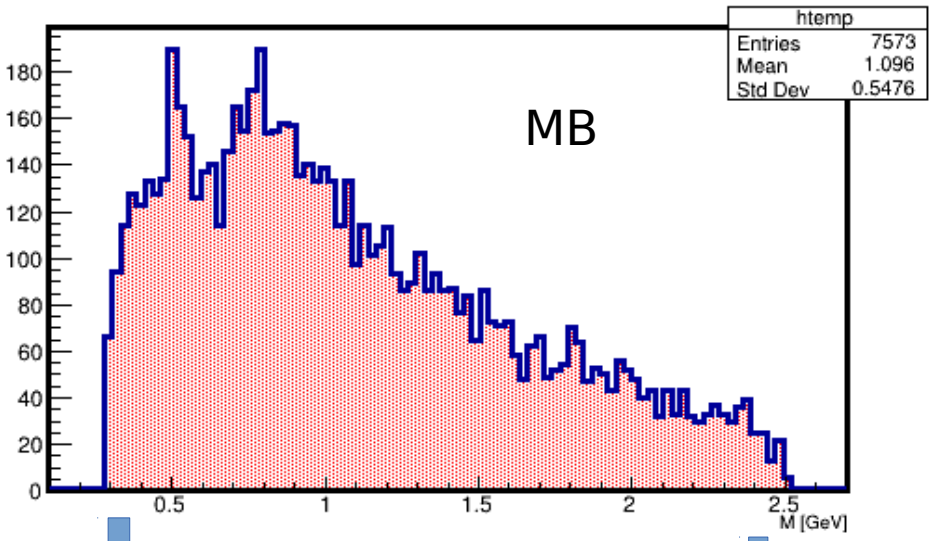


chi2 link V^0 particle with PV

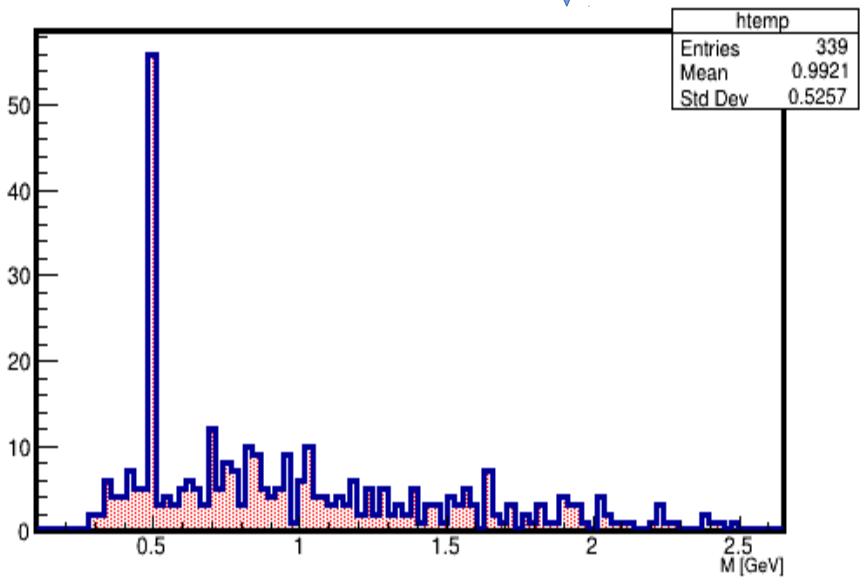




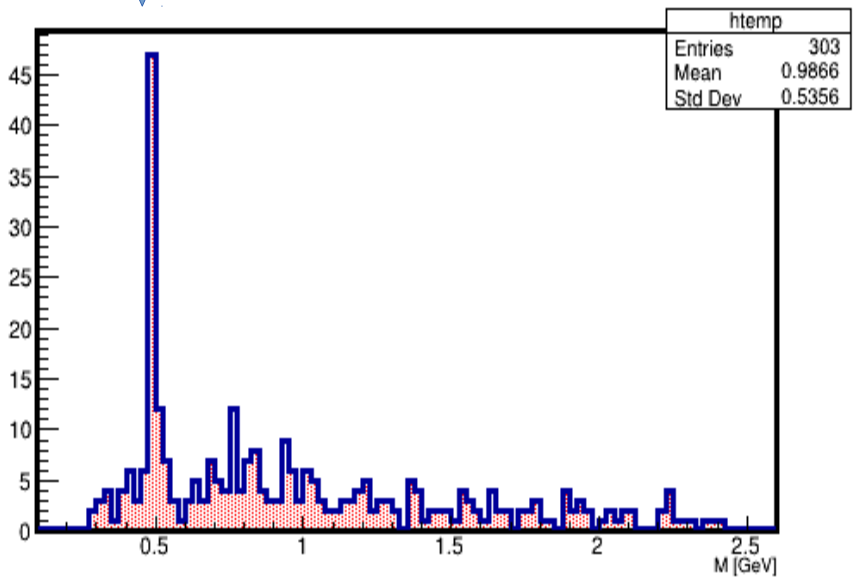
Ideal V⁰ finder (K^0_s)



chi2 > 20



L/dL > 10



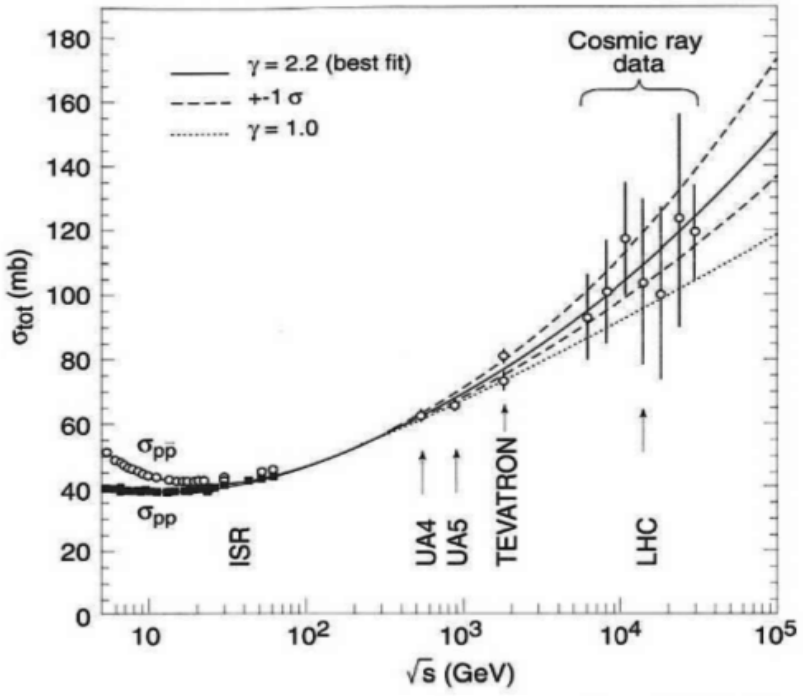
Ideal V^0 finder (D^0)

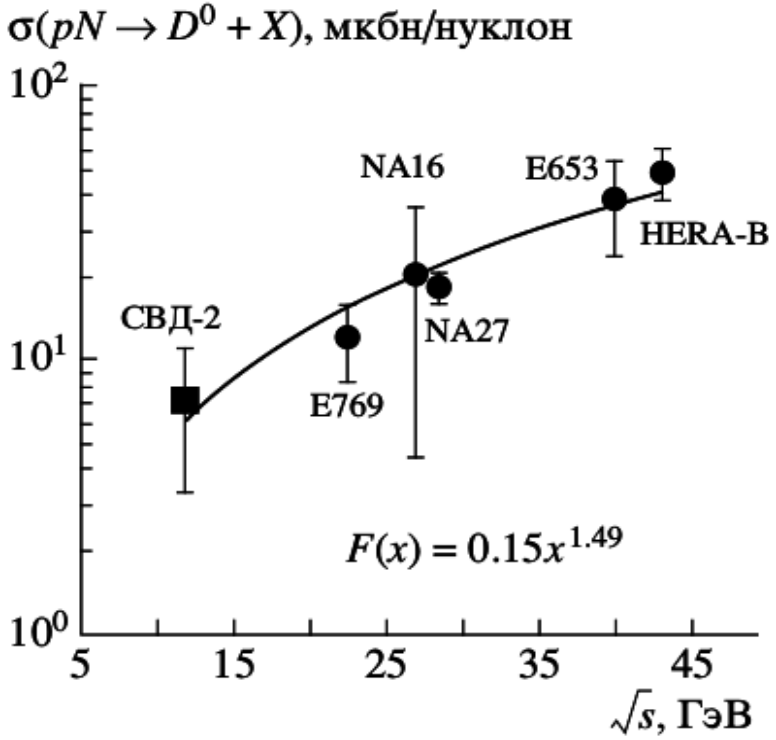
1. consider $D^0 \to K^- \pi^+$ decay (3.9 %) => cτ = 122.9 μm

2. simulate 10000 Minimum Bias (MB) events with Pythia6, √s = 27 GeV

3. additionally simulate 20000 D^0 events, uniform θ and φ (~15240 reconstructed, ~76%)

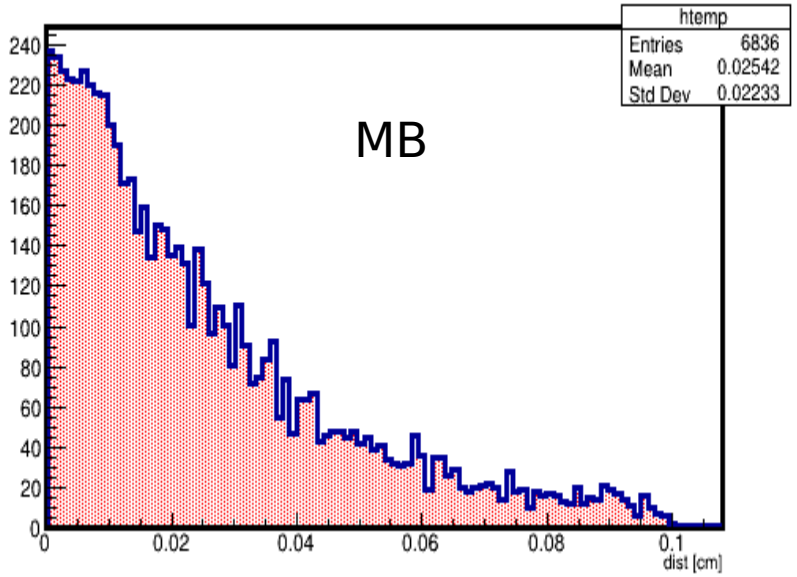
4. consider $K^- \pi^+$ combination with different charge (q1*q2 < 0) in each event

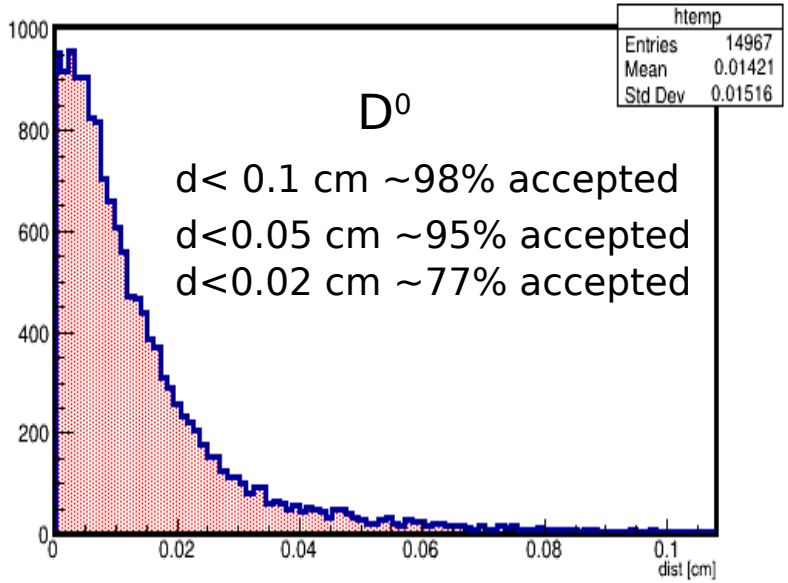




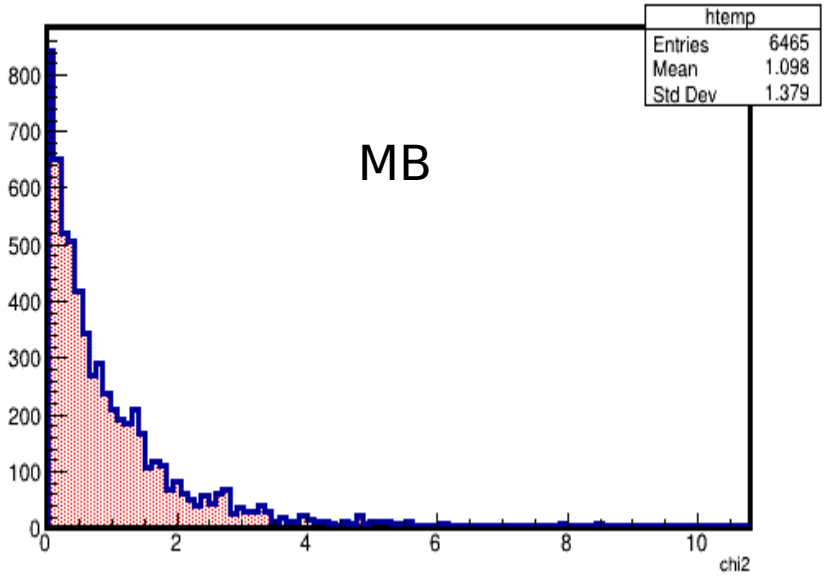
Ideal V^0 finder (D^0)

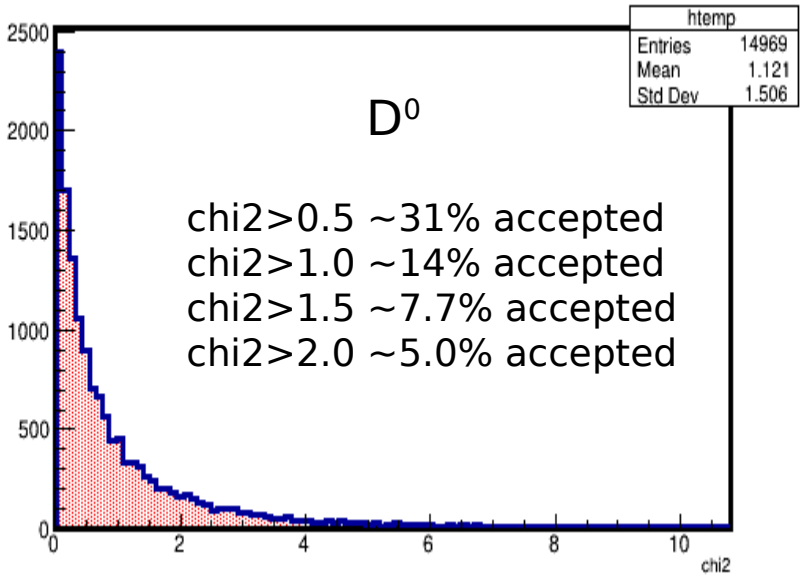
Distance between 2 particles





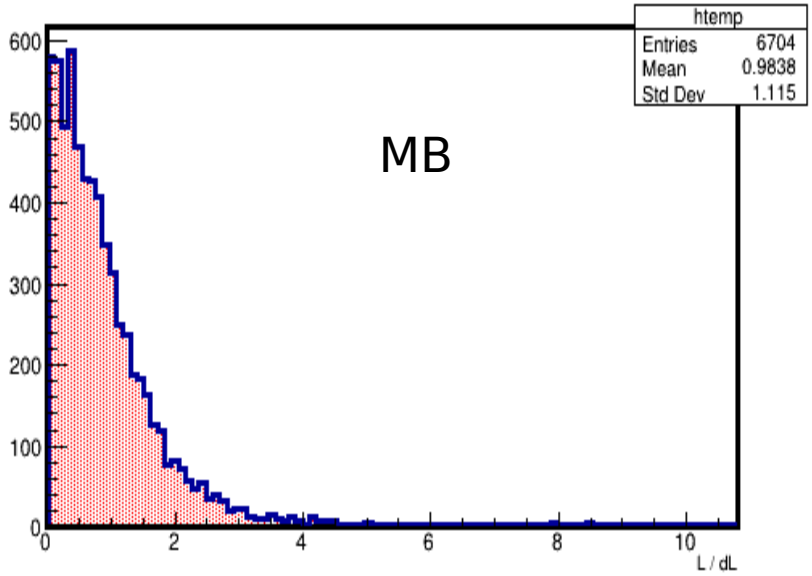
chi2 of track to PV

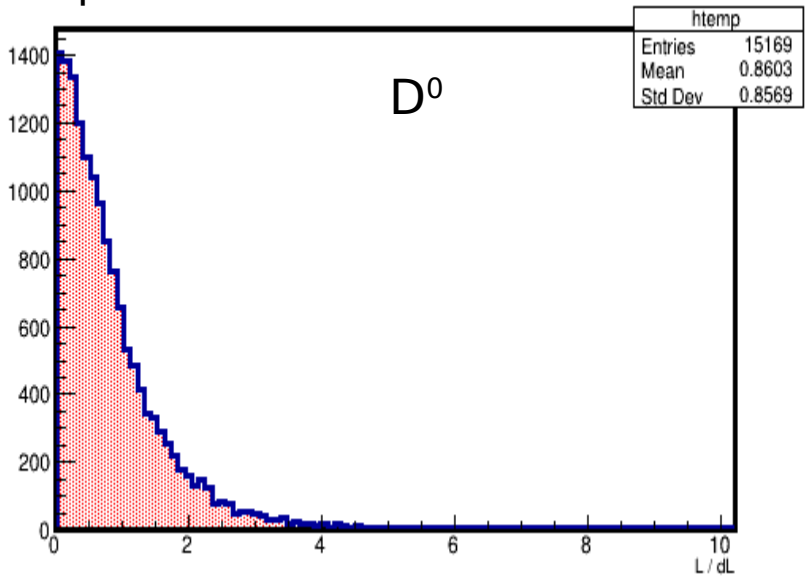




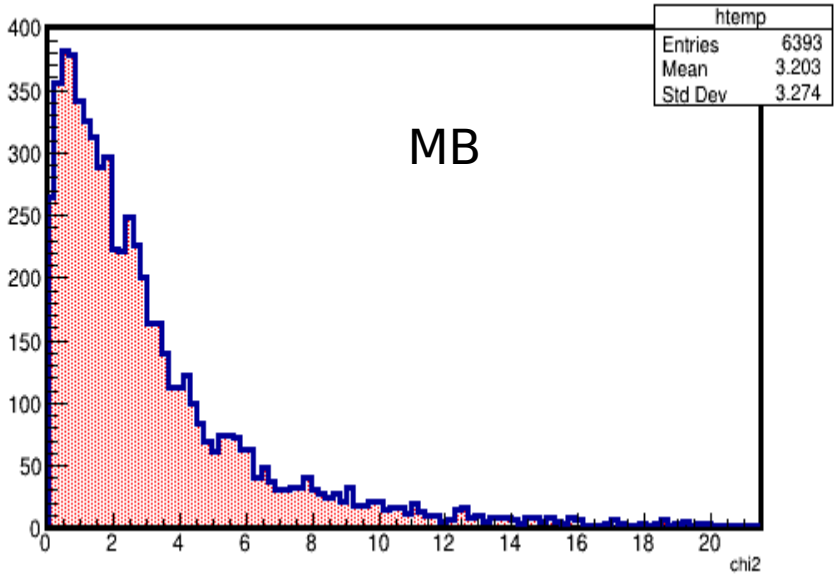
Ideal V^0 finder (D^0)

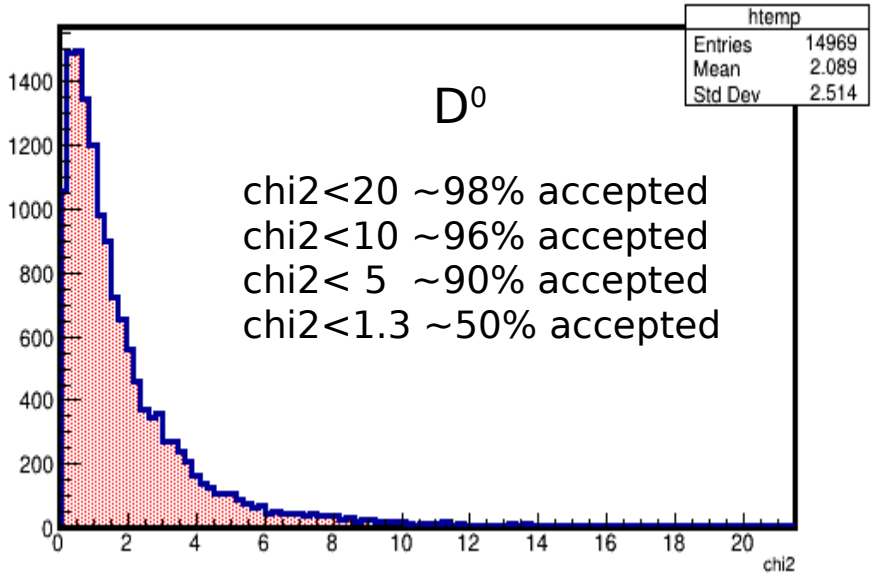
Normalize distance L/dL of V^0 particle to PV





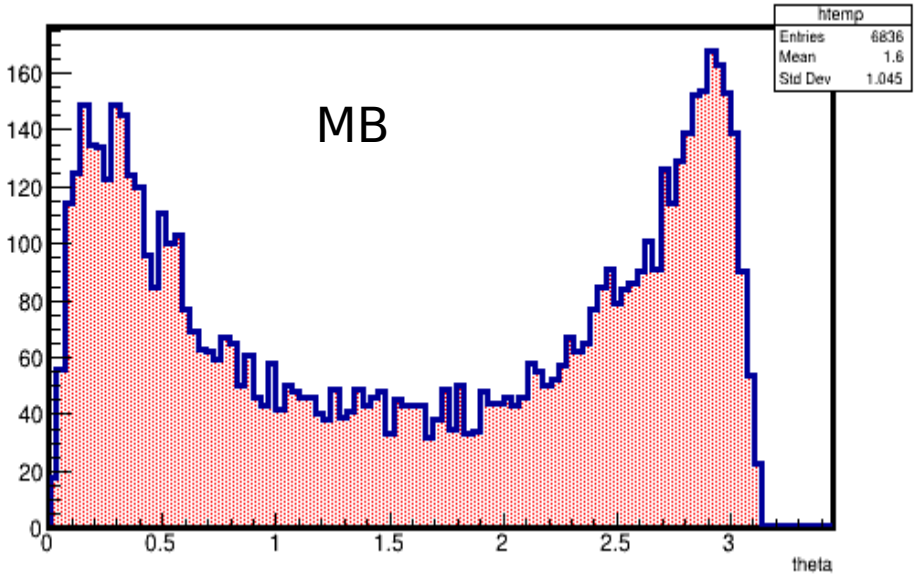
chi2 link V^0 particle with PV

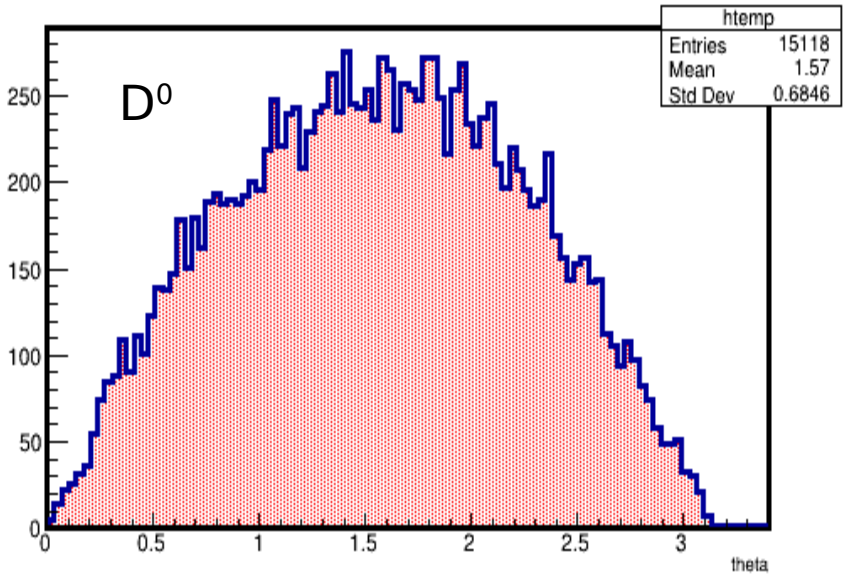




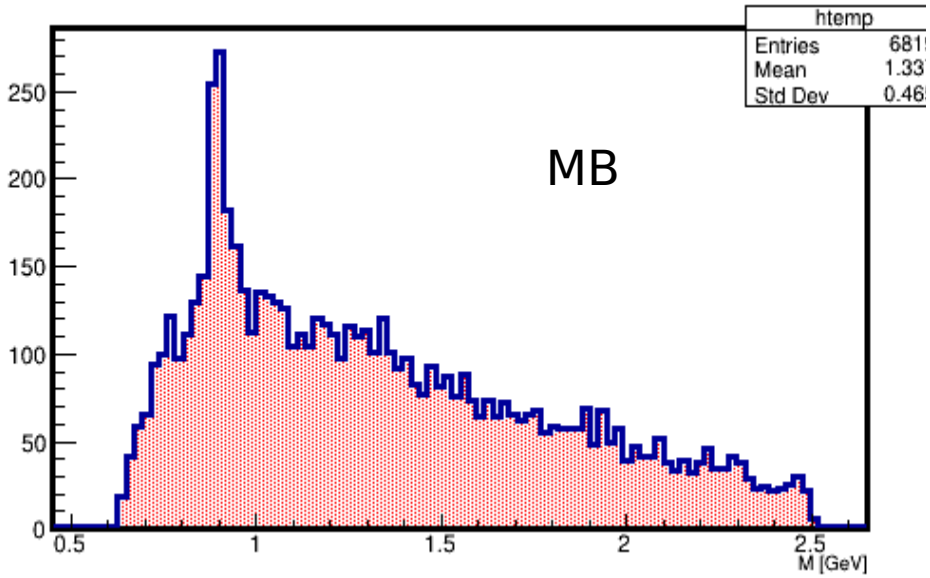
Ideal V^0 finder (D^0)

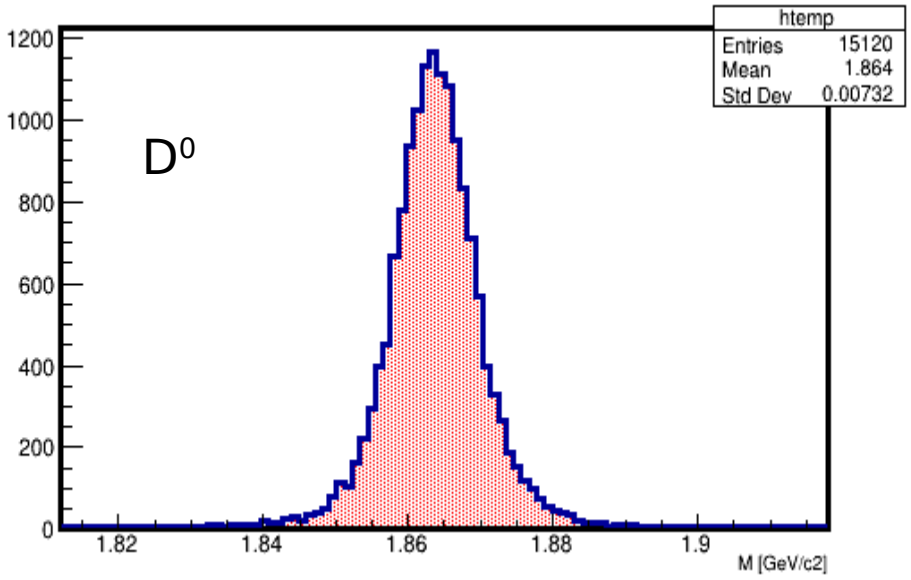
θ distribution of V^0 particle





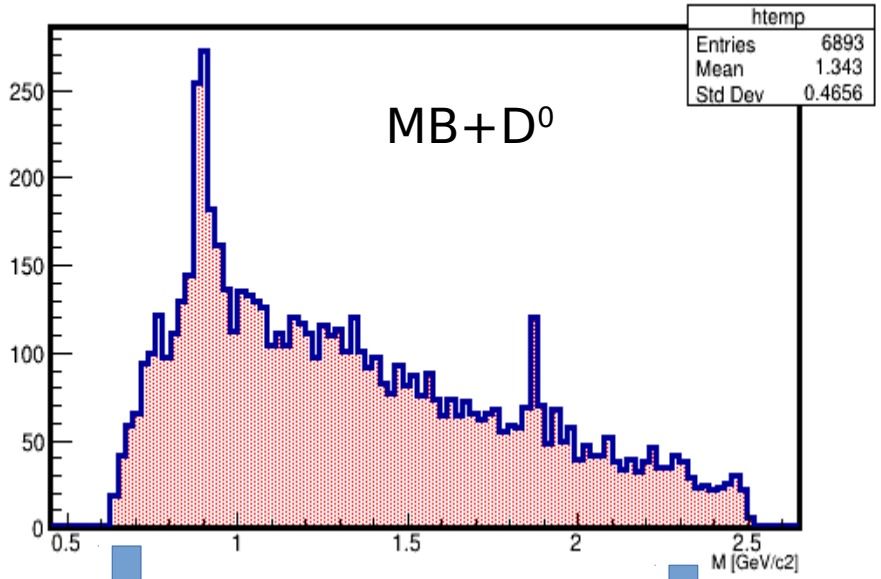
invariant mass of V^0 particle



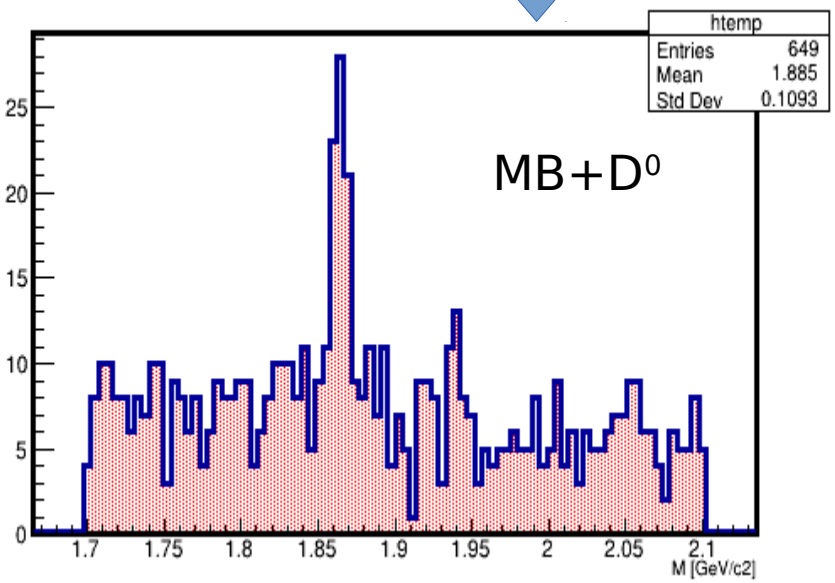


Ideal V^0 finder (D^0)

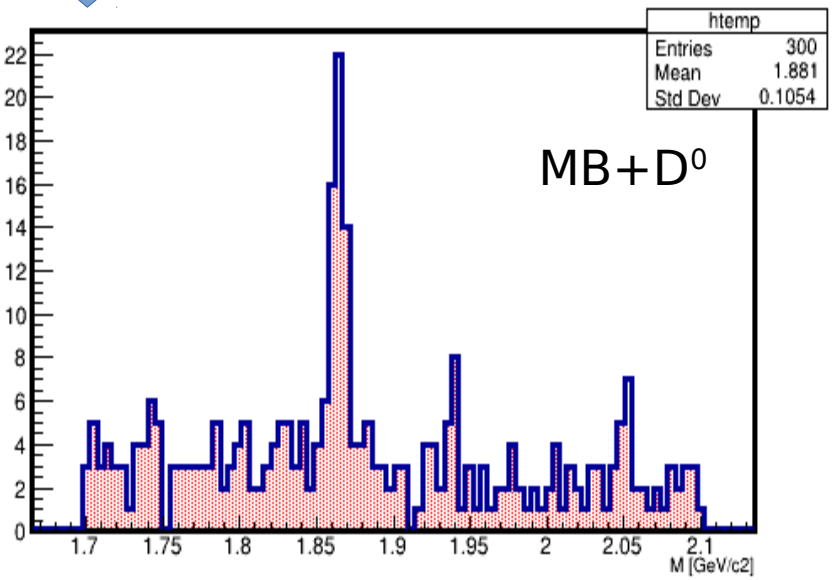
1. simulate 10000 MB events + 100 D^0 events



dist < 0.02 cm

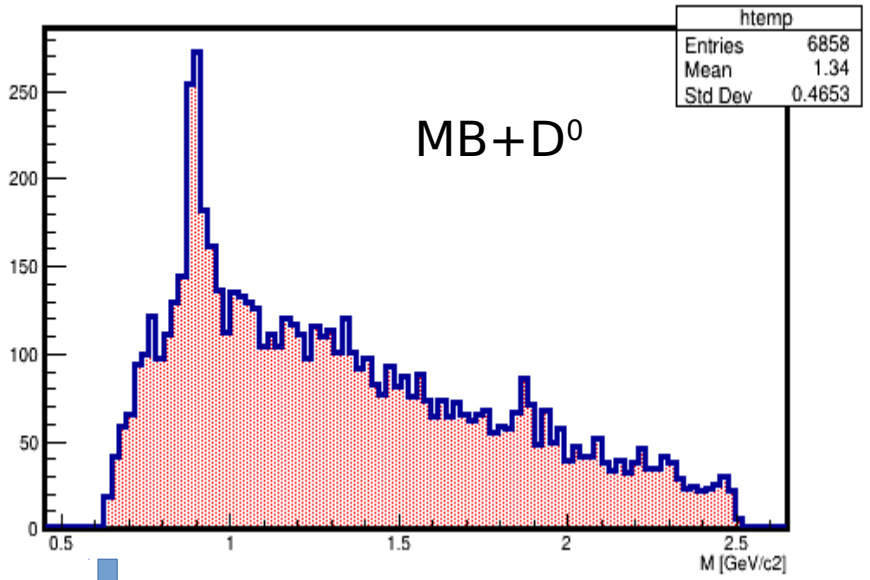


d<0.02 cm + Δθ

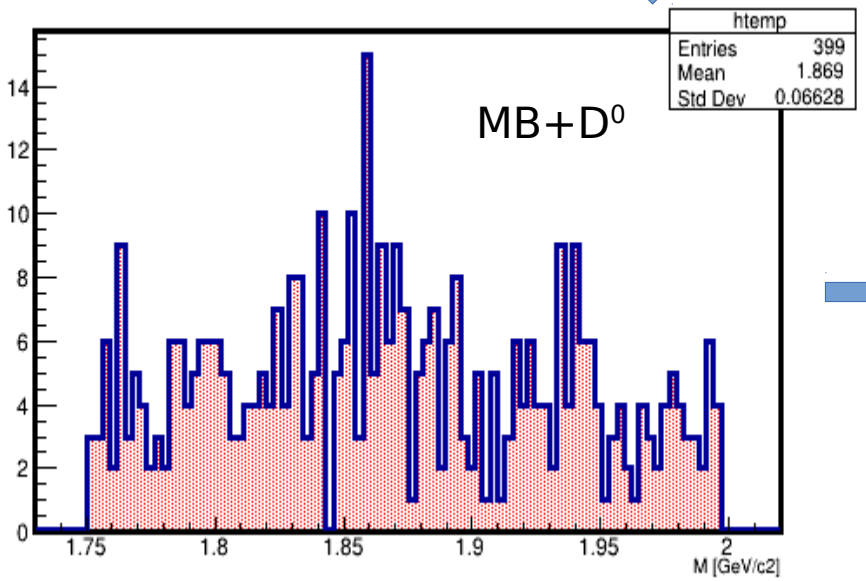


Ideal V^0 finder (D^0)

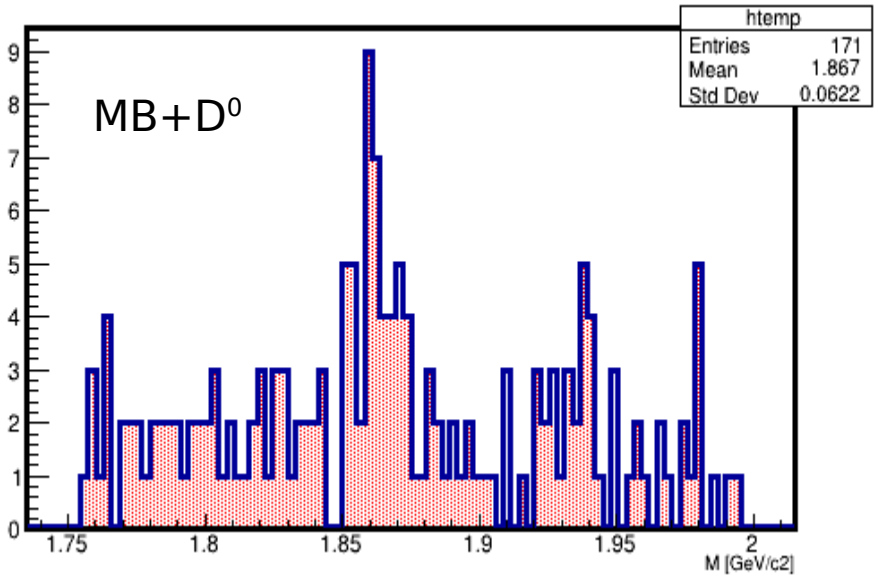
1. simulate 10000 MB events + 30 D^0 events



dist < 0.02 cm



d<0.02 cm + Δθ



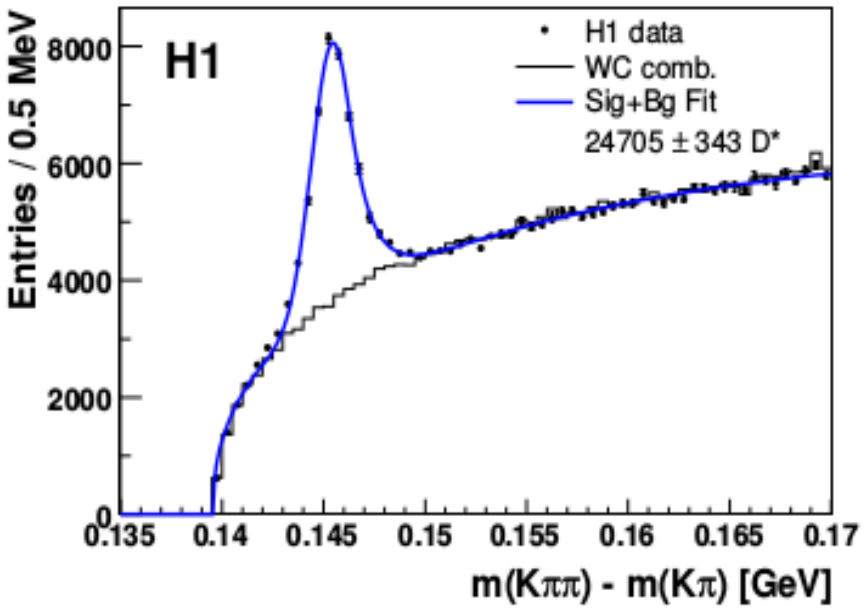
Summary

1) KF Particle package for finding and reconstruction of short-lived particles is available in SPDroot

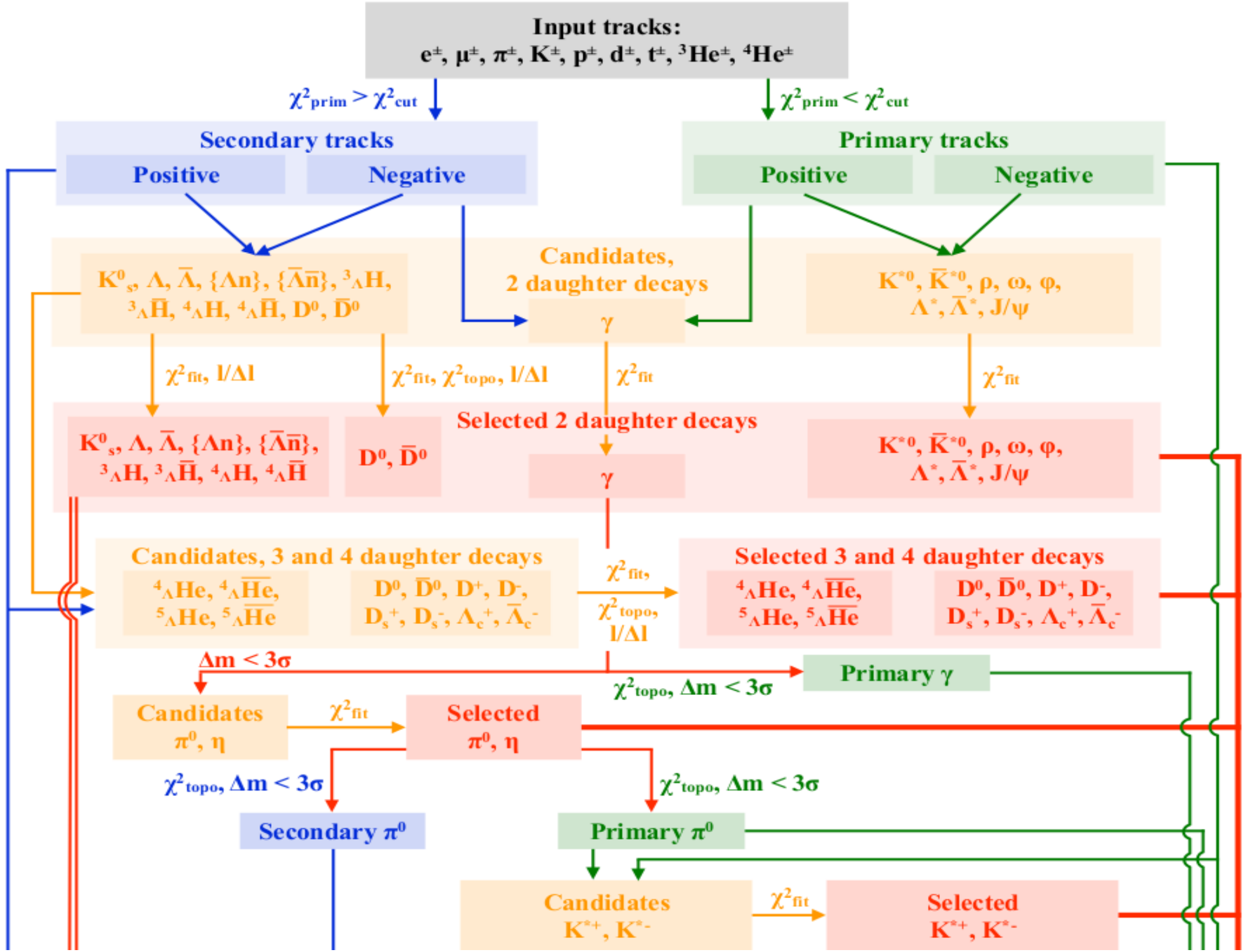
2) first version of ideal V^0 finder is also available

3) need special study and adjust the cuts for separation each type of short-live particle candidates

4) as example => find D^0 using $D^{*+} \rightarrow D^0 pi^+$ channel



Backup slides


Input tracks:
e±, μ±, π±, K±, p±, d±, t±, ³He±, ⁴He±
χ²prim > χ²cut
χ²prim < χ²cut
Secondary tracks
Positive
Negative
Primary tracks
Positive
Negative
K⁰s, Λ, Λ̄, {Λn}, {Λ̄n̄}, ³ΛH, ³ΛH̄, ⁴ΛH, ⁴ΛH̄, D⁰, D̄⁰
Candidates, 2 daughter decays
γ
K*0, K̄*0, ρ, ω, φ, Λ*, Λ̄*, J/ψ
χ²fit, l/Δl
χ²fit, χ²topo, l/Δl
χ²fit
χ²fit
Selected 2 daughter decays
K⁰s, Λ, Λ̄, {Λn}, {Λ̄n̄}, ³ΛH, ³ΛH̄, ⁴ΛH, ⁴ΛH̄
D⁰, D̄⁰
γ
K*0, K̄*0, ρ, ω, φ, Λ*, Λ̄*, J/ψ
Candidates, 3 and 4 daughter decays
⁴ΛHe, ⁴ΛHe, ⁵ΛHe, ⁵ΛHe
D⁰, D̄⁰, D⁺, D⁻, Ds⁺, Ds⁻, Λc⁺, Λ̄c⁻
χ²fit, χ²topo, l/Δl
Selected 3 and 4 daughter decays
⁴ΛHe, ⁴ΛHe, ⁵ΛHe, ⁵ΛHe
D⁰, D̄⁰, D⁺, D⁻, Ds⁺, Ds⁻, Λc⁺, Λ̄c⁻
Δm < 3σ
χ²topo, Δm < 3σ
Primary γ
Candidates π⁰, η
χ²fit
Selected π⁰, η
χ²topo, Δm < 3σ
χ²topo, Δm < 3σ
Secondary π⁰
Primary π⁰
Candidates K*+, K*-
χ²fit
Selected K*+, K*-

KF Particle package

Package has following properties:

- is based on Kalman filter mathematics;
- daughter and mother particles are described with the same set of parameters and are treated in exactly the same way;
- the package is geometry independent;
- daughter particles are added to the mother particle absolutely independently from each other
- the package allows reconstruction of decay chains
- the state vector of the particle includes 8 parameters => **r** = (*x, y, z, Px, Py, Pz, E, s*), where $s = l/p$ (distance normalized on the momentum, when a production point of particle is known, x,y,z – coordinates of first hit position)