Update of $\tau \rightarrow$3prongs

07/05/2012

Pablo DEL AMO SANCHEZ

Dominique DUCHESNEAU

Laboratoire d'Annecy-le-Vieux de Physique des Particules

Goals:

- 1st phase: Update existing (Magali and Dominique's 2008) $\tau \rightarrow 3$prongs analysis : nowadays better simulation and backgrounds better understood

- 2nd phase: Improve analysis!

- TODAY: Likelihood Ratio; new efficiencies after preliminary NUMUCC rejection; other decay variables

(2nd-)vertexing in our analysis

- Questions about 2nd-vertexing in our analysis during last Tau Efficiency Mtg
- We use events reconstructed by the OpEmuRec chain after : EleDet reconstruction, brickfinding, CS, Scanback, Total Scan, tracking and vertexing. DECAY SEARCH NOT APPLIED at the moment, T.Strauss' 2nd vertexing not applied either.
- So we use the list of vertices provided by SYSAL/FEDRA «as is». Secondary vertices are extracted from there. Most upstream vertex with at least 2 hadrons is taken to be primary vertex, second most upstream vertex with at least 2 downstream hadron tracks is taken as secondary (~tau decay) vertex. Electron-positron pairs vertices are explicitly rejected.

Hadronic reinteraction bkg status

- A. Sheshukov produces FLUKA ν_μ CC and NC NEGN-like beamfiles for us.
- With the help of S. Dusini, a procedure to reconstruct these beamfiles within the OpEmuRec chain has been defined.
- All different stages of the chain have been tested, a minor units issue left to be corrected
- Should have reconstructed hadronic reinteraction MC by the start of next week
- This method will be available to the Collaboration for other analyses
- Thanks to E. Pennacchio as well, who's been testing the OpEmuRec processing!

Current work: charm bkg MC

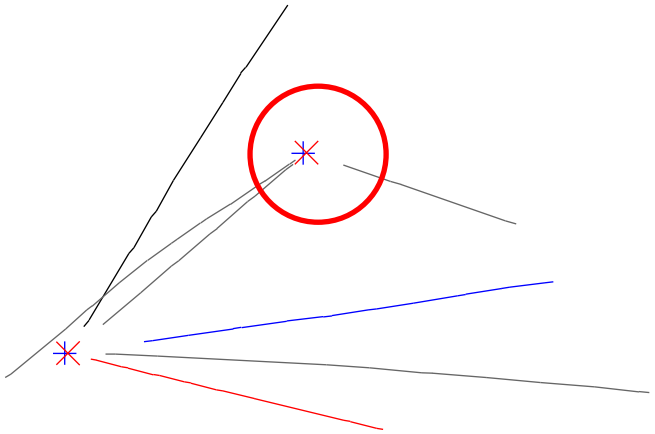
- Using new charm fragmentation fractions in MC
- Weight D^0, D^+, D^+_s and Λ_c separately according to latest CHORUS measurements:

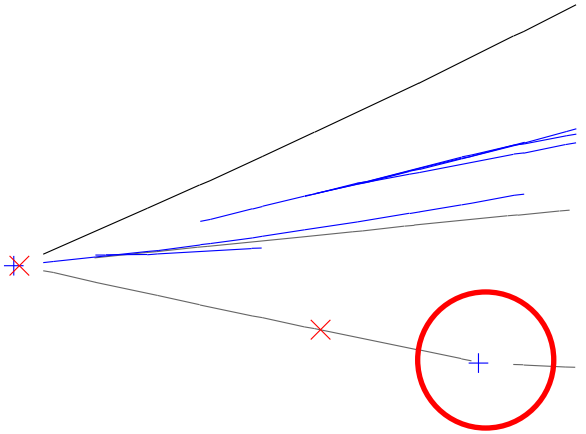
  $f_{D0} = 43.8\%$, $f_{D+} = 21.7\%$, $f_{D+s} = 9.2\%$, $f_{\Lambda c} = 25.3\%$ (D. Auterio)

- Large (10000 evts each, "march2012") used for each species (TAU3P, NUMUCC, NUMUNC, Dzero, Dplus, DplusS, LambdaC) thanks to Elisabetta!

NUMUCC and NUMUNC backgrounds rejection

- Already knew that a small fraction of vertices didn't have all their tracks downstream of the vertex.
- Realized that most of the NUMUCC 2-vertex events are like this:





- Require >= 2 downstream tracks. Big reduction of NUMUCC and NUMUNC bkg :x10 reduction in 2-prongs sub-sample, x5 reduction on 3-prongs. Efficiency reduced by 1/3 in signal.

Changes in selection (II)

- Decrease in signal efficiency all due to 2-prongs. This is expected, 2-prongs is most polluted subsample. 3-prongs eff compatible with previous one within errors : 3.6% → 3.3%
- SYSAL : ~25% short decays, ~75% long decays

  FEDRA: 8% short decays, 92% long decays
- Preliminary TrackFollowDown results from S.Dusini indicate a flat (no dependences) recovery of 38% of muons
- Applied a factor (1 – 38%) to EleDet muon efficiency for Charm and unflavoured NUMUCC and NUMUNC

Signal & bkg abundances

- Signal and background abundances for 3 nominal years:

Species	Osc'd nu_tau CC	Osc'd nu_tau CC	nu_mu CC	nu_mu NC	D0 nu_mu CC	D+ nu_mu CC	Ds+ nu_mu CC	LambdaC nu_mu CC	Charm Sum
	SYSAL	FEDRA	SYSAL	SYSAL	SYSAL	SYSAL	SYSAL	SYSAL	
Expected (2011)	9,683625	9,683625	12000	4000	234,4176	116,1384	49,2384	135,4056	
Eff OpCarac Contained	0,939378	0,939378	0,968336	0,840953	0,977081	0,976012	0,975056	0,977183	
Expected	9,09658429	9,09658429	11620,032	3363,812	229,044983	113,352472	48,0101974	132,31605	522,723703
Eff No ED muon	0,705512	0,705512	**0,03487047**	0,796275	**0,04036479**	**0,03831947**	**0,04518045**	**0,02040048**	
Expected	6,41774937	6,41774937	405,196024	2678,5194	9,24535264	4,34360688	2,16912251	2,69931094	18,457393
Eff Two Vertices	0,19265	0,153614	0,0441373	0,0212067	0,242213	0,213716	0,202082	0,0606993	
Expected	1,23637942	0,98585615	17,8842585	56,8025574	2,2393446	0,92829829	0,43834062	0,16384628	3,76982979
Eff 2 tracks	0,545135	0,570497	0,295609	0,228274	0,56197	0,466739	0,457246	0,407015	
Expected	**0,67399369**	**0,56242798**	**5,28674776**	**12,966547**	**1,25844448**	**0,43327301**	**0,20042949**	**0,0666879**	**1,95883489**
Eff 3 tracks	0,254909	0,221548	0,126061	0,057216	0,0476918	0,274672	0,209122	0,0488855	
Expected	**0,31516424**	**0,21841446**	**2,25450751**	**3,25001512**	**0,10679837**	**0,25497755**	**0,09166667**	**0,00800971**	**0,4614523**

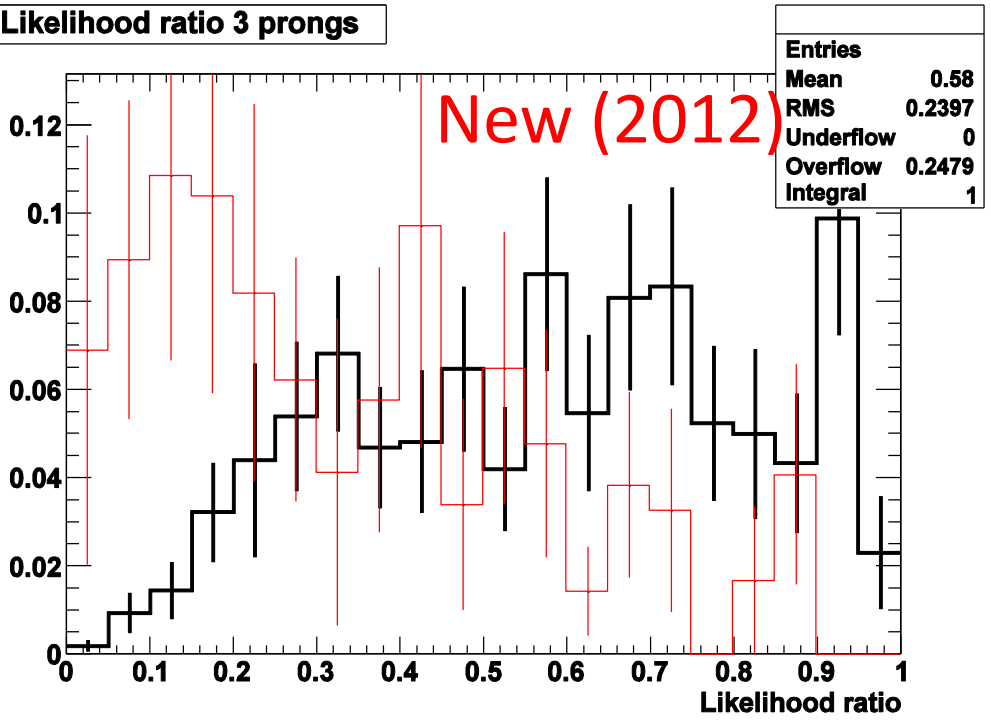
Signal & bkg abundances

- Abundances for 3 nominal years, LONG DECAYS only:

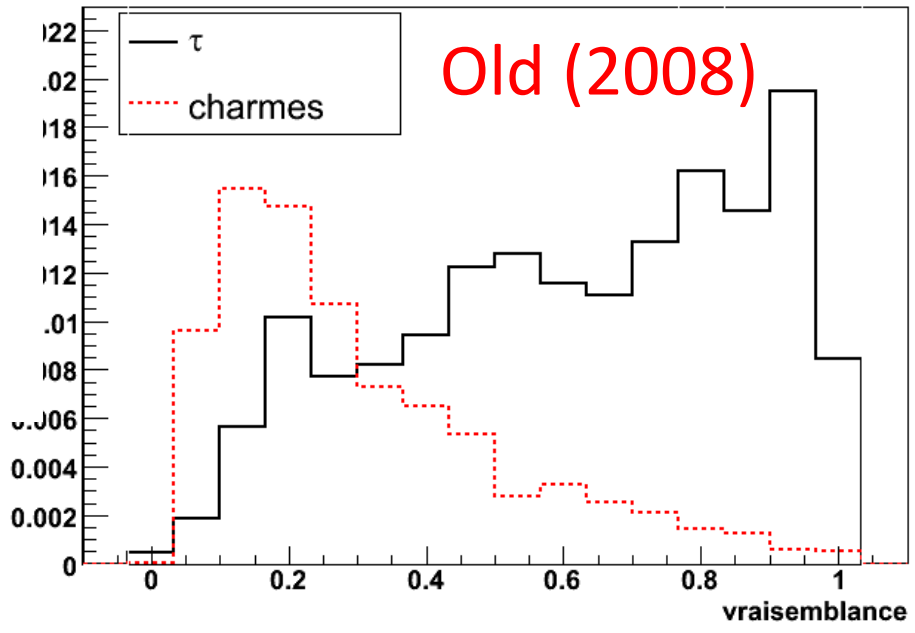
Species	Osc'd nu_tau CC	Osc'd nu_tau CC	nu_mu CC	nu_mu NC	D0 nu_mu CC	D+ nu_mu CC	Ds+ nu_mu CC	LambdaC nu_mu CC	Charm Sum
	SYSAL	FEDRA	SYSAL	SYSAL	SYSAL	SYSAL	SYSAL	SYSAL	
Expected (2011)	9,683625	9,683625	12000	4000	234,4176	116,1384	49,2384	135,4056	
Eff OpCarac Contained	0,939378	0,939378	0,968336	0,840953	0,977081	0,976012	0,975056	0,977183	
Expected	9,09658429	9,09658429	11620,032	3363,812	229,044983	113,352472	48,0101974	132,31605	522,723703
Eff No ED muon	0,705512	0,705512	0,03487047	0,796275	0,04036479	0,03831947	0,04518045	0,02040048	
Expected	6,41774937	6,41774937	405,196024	2678,5194	9,24535264	4,34360688	2,16912251	2,69931094	18,457393
Eff Two Vertices	0,19265	0,153614	0,0441373	0,0212067	0,242213	0,213716	0,202082	0,0606993	
Expected	1,23637942	0,98585615	17,8842585	56,8025574	2,2393446	0,92829829	0,43834062	0,16384628	3,76982979
Eff 2 tracks	0,41432495	0,51779506	0,295609	0,19253382	0,4733153	0,44215679	0,39241492	0,30262827	
Expected	**0,51226284**	**0,51047144**	**5,28674776**	**10,9364136**	**1,05991606**	**0,41045339**	**0,1720114**	**0,04958452**	**1,69196536**
Eff 3 tracks	0,1863005	0,21089376	0,126061	0,057216	0,04080839	0,24179019	0,18083804	0	
Expected	**0,2303381**	**0,20791091**	**2,25450751**	**3,25001512**	**0,09138406**	**0,22445342**	**0,07926866**	**0**	**0,39510614**

Likelihood ratio (3p)

- Defined as: $LR = \prod_i PDF_i^{\tau}(evt) / \left(\prod_i PDF_i^{\tau}(evt) + \prod_i PDF_i^{charm}(evt) \right)$



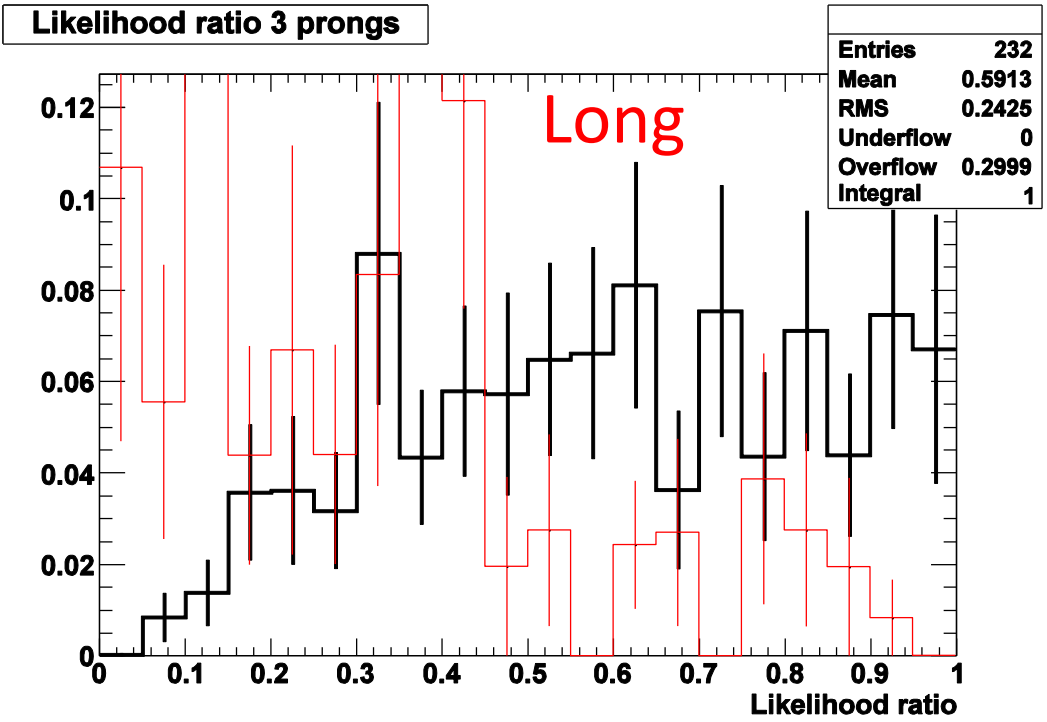
Nice separation of signal & charm background in 3 prongs case



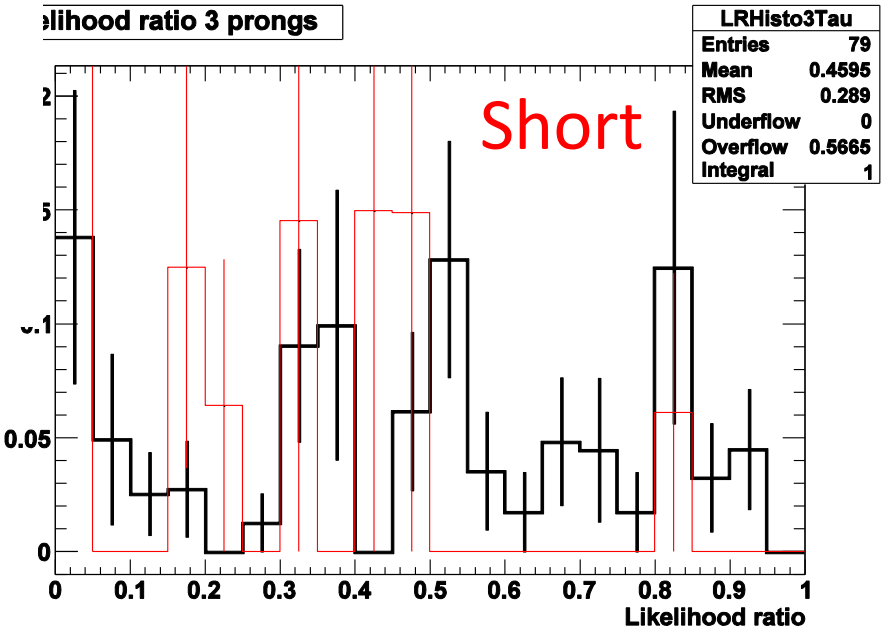
Overtraining due to using same events for PDFS and LR evaluation !!!

Likelihood ratio (3p)

- Separated in long decays (left) and short decays (right)



Not many short decays (~25%)

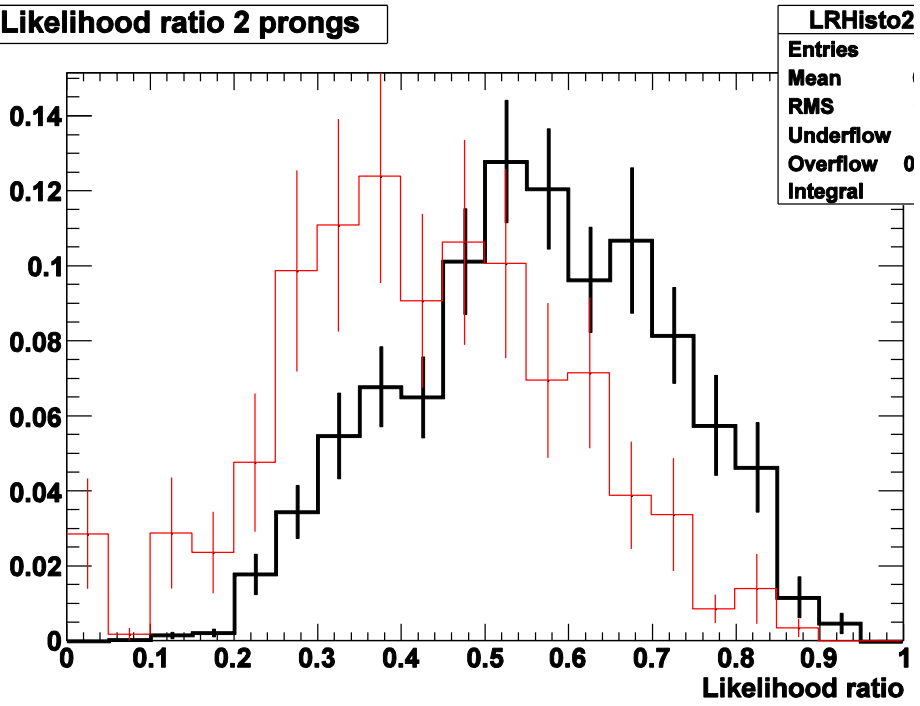


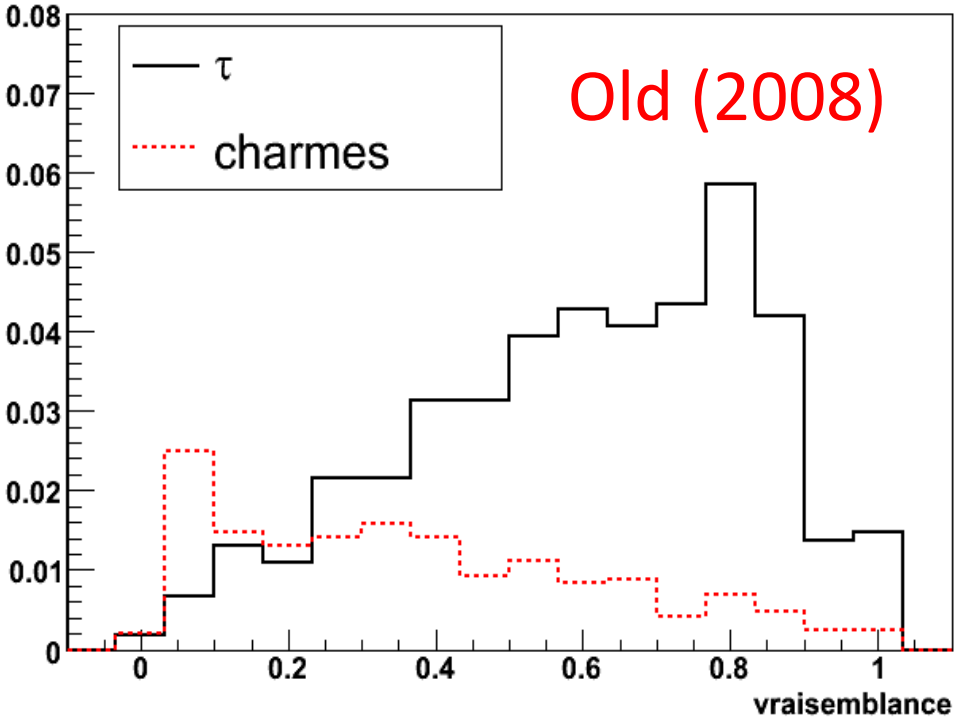
Likelihood ratio (2p)

- Defined as: $LR = \prod_i PDF_i^{\tau}(evt) / \left(\prod_i PDF_i^{\tau}(evt) + \prod_i PDF_i^{charm}(evt) \right)$

New (2012)

Some separation between signal and charm background



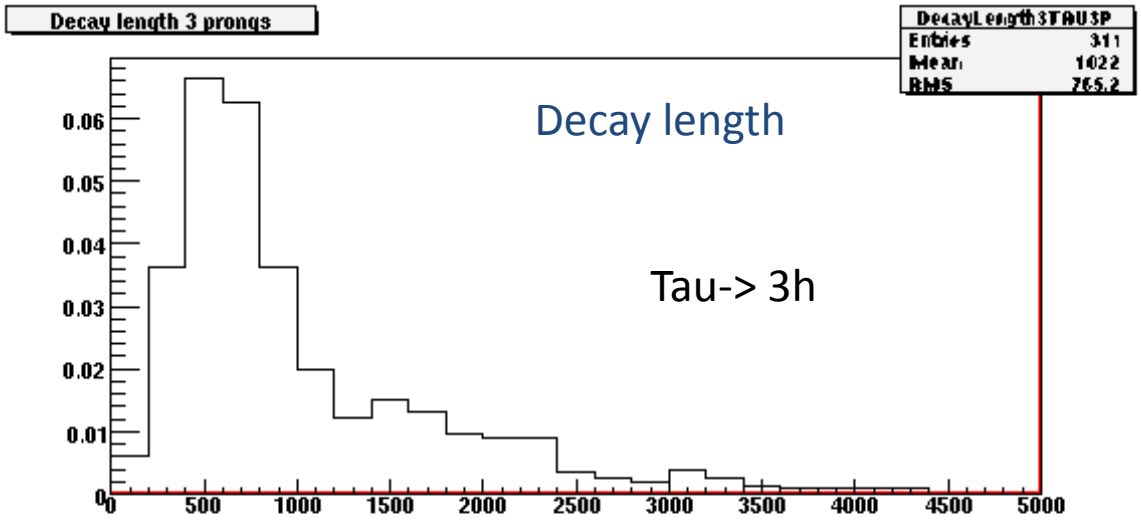


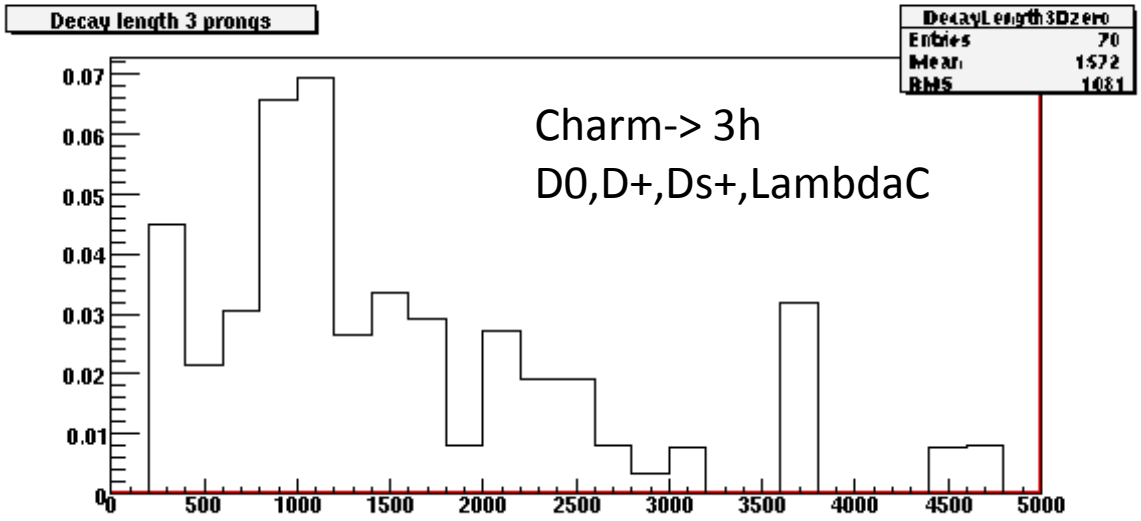
Other topological variables for 3hadron channel:

Decay length: In microns

Selection:
2 vertices with 3 tracks at the second vertex;
Contained event,
No muon,

Ntau expected=0.32
Ncharm exp.: 0.46



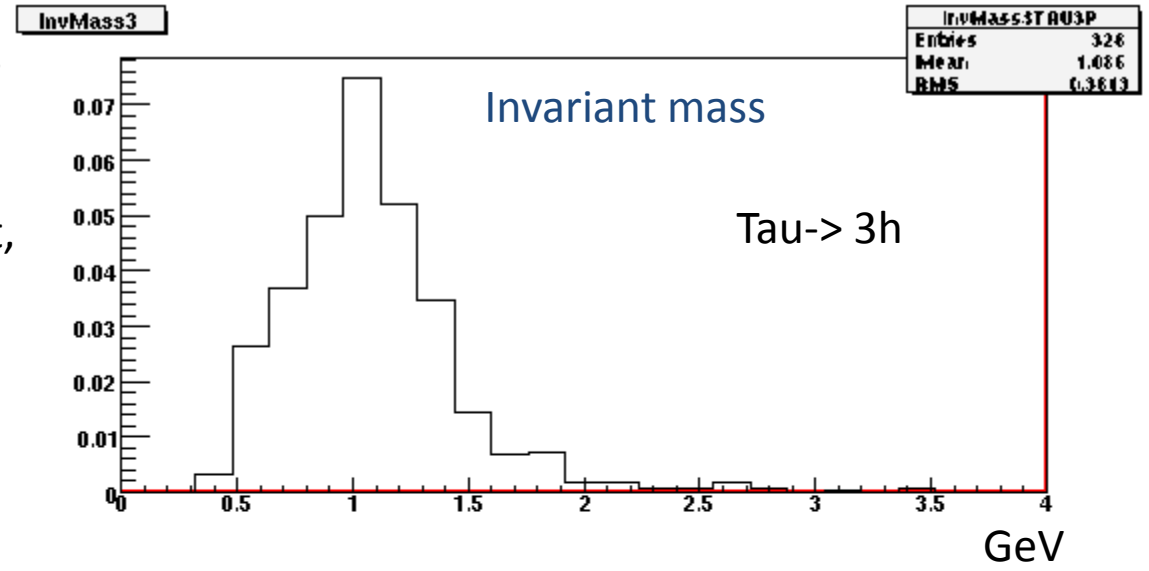


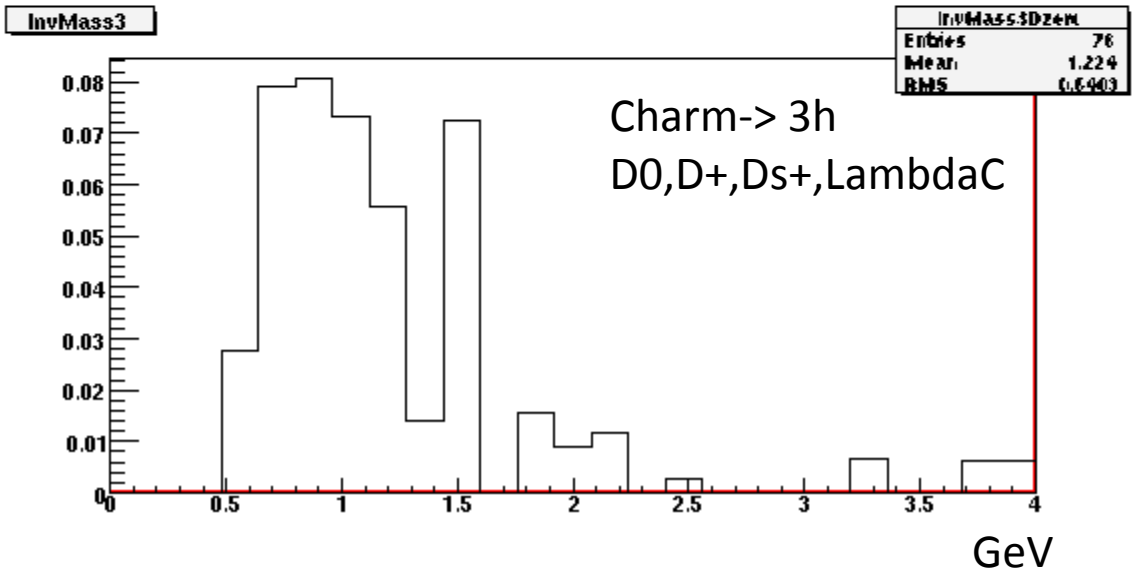
After reconstruction, selection.

Other topological variables for 3hadron channel:

Invariant mass of 3 charged particles (pion assumption) at second vertex

Selection:
2 vertices with 3 tracks at the second vertex;
Contained event,
No muon,



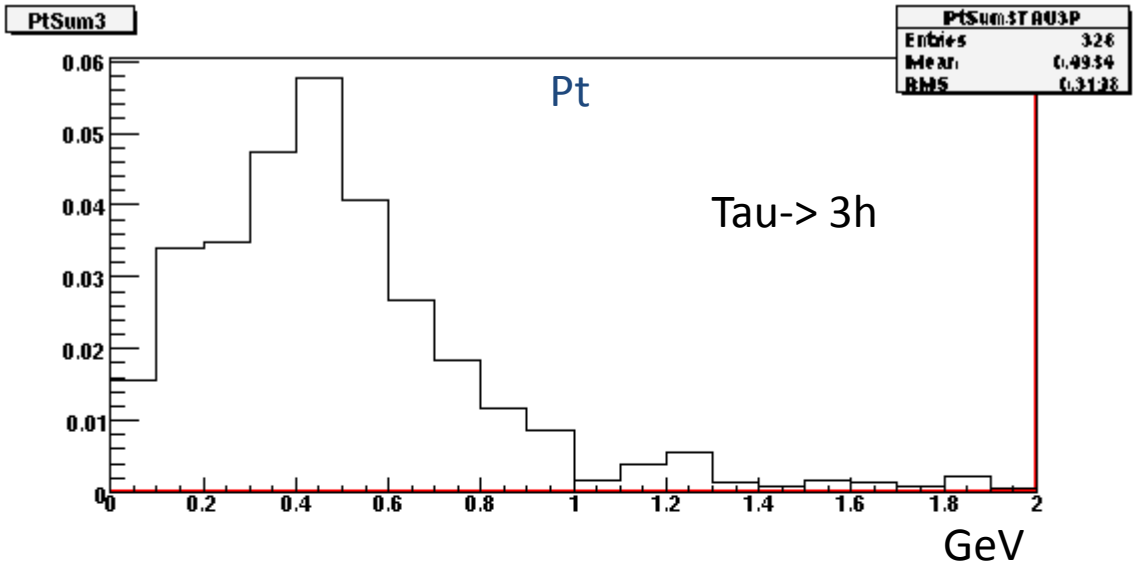


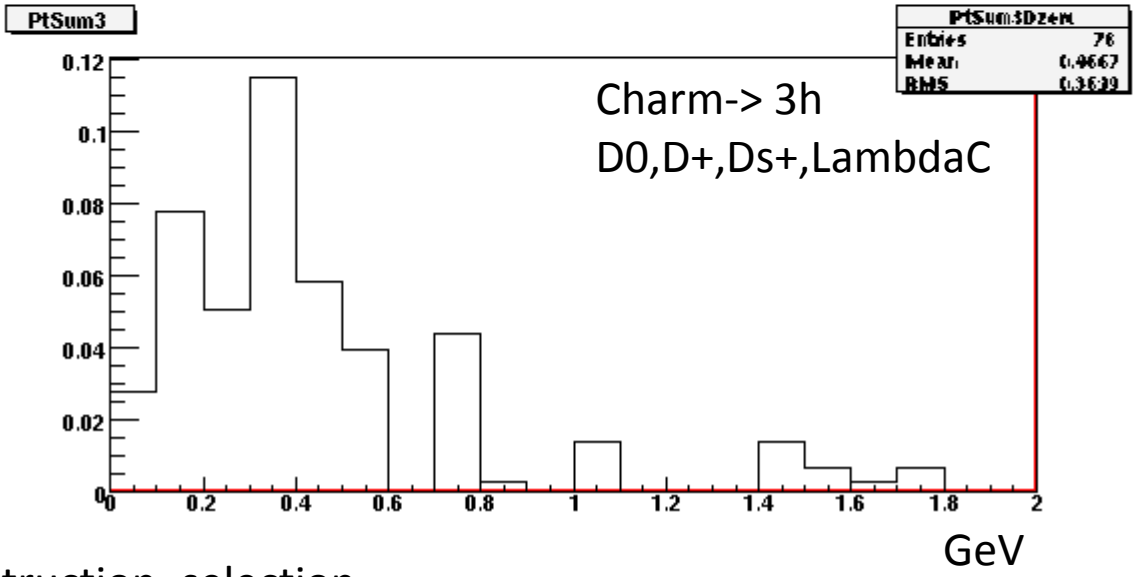
After reconstruction, selection.

Other topological variables for 3hadron channel:

Pt of the sum of 3 charged particles) at second vertex

Selection:
2 vertices with 3 tracks at the second vertex;
Contained event,
No muon,





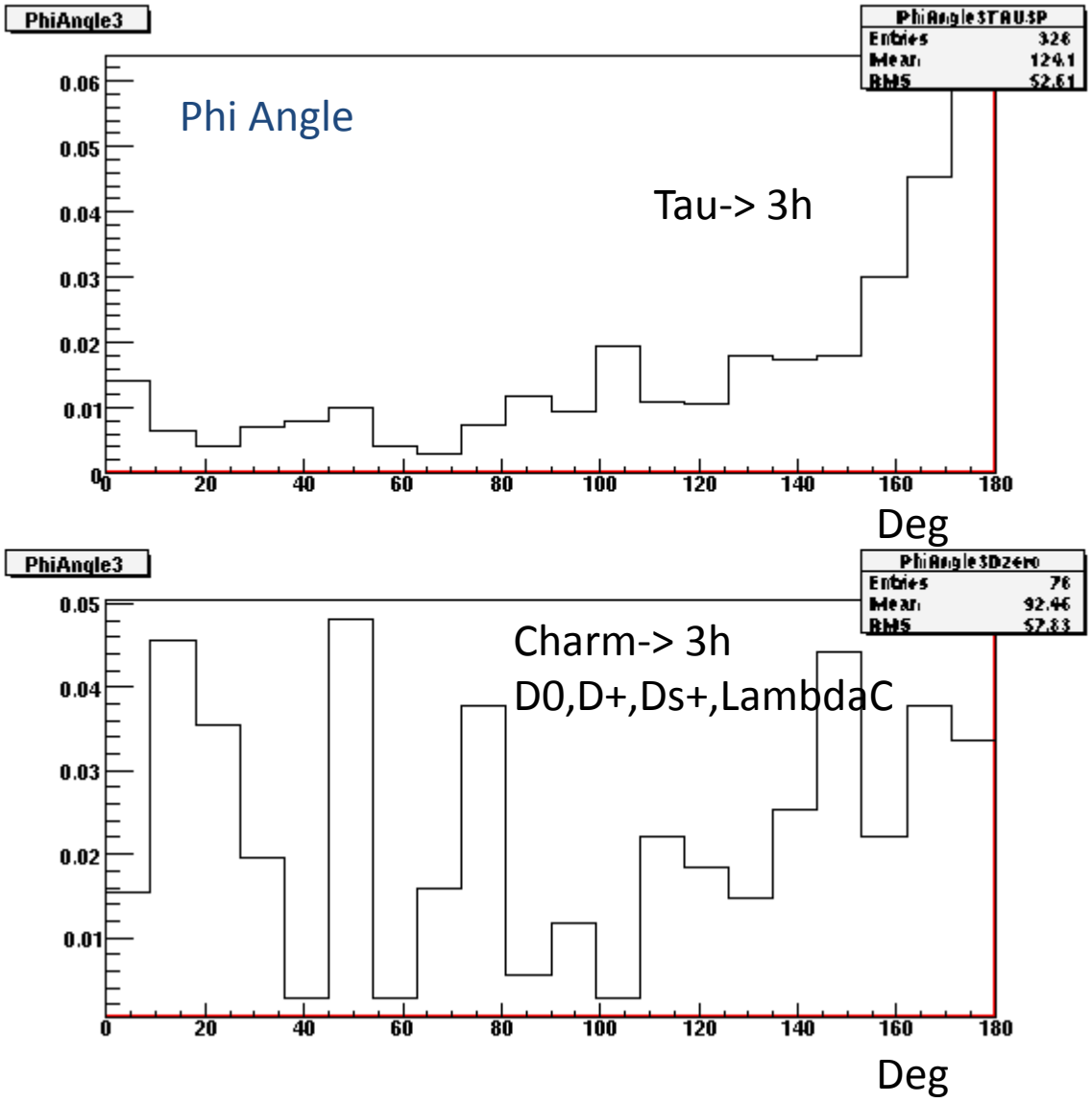
After reconstruction, selection.

Other topological variables for 3hadron channel:

Selection:
2 vertices with 3 tracks at the second vertex;
Contained event,
No muon,

Phi angle between the parent track and momentum direction of charged particle at primary vertex in the transverse plane to the neutrino direction

After reconstruction, selection.



Analysis tool ready; to come: check these variables after likelihood selection

Conclusions and Outlook

- Defined procedure to produce FLUKA hadronic reinteraction MC; testing of procedure finished
- Greatly suppressed ν_μ CC and NC bkg, more to come!
- Have recomputed charm-rejecting likelihood ratio using preliminary estimate of TrackFollowDown by S. Dusini
- Will optimize cut on LR next
- Started implementing variables suggested by O. Sato
- Possibly include decay search if ready soon (not our priority)

Laboratoire d'Annecy-le-Vieux de Physique des Particules

OPERA

BACKUP SLIDES

Laboratoire d'Annecy-le-Vieux de Physique des Particules

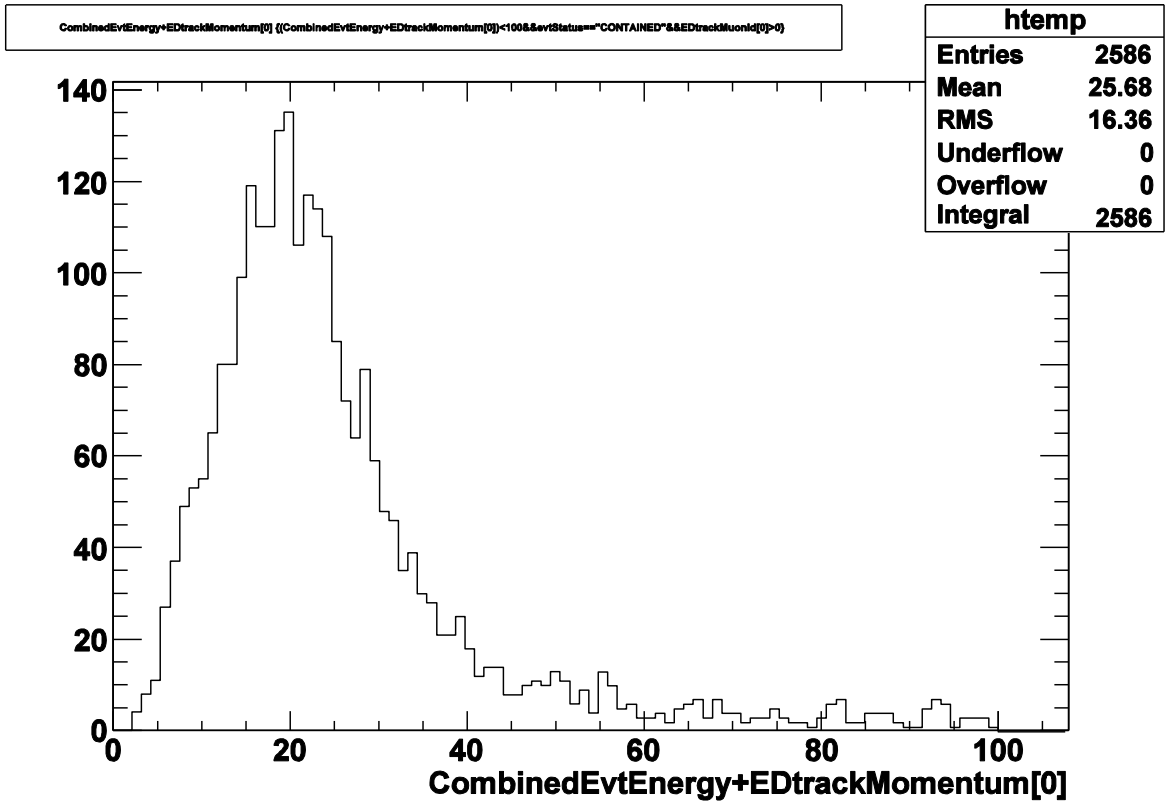
OpNtpWriter

- Goal: out-of-the-box software to write all the relevant information of an OPERA event to a ***numerical*** ROOT file (i.e. floats, ints, bools; NOT Opera objects)
- Emphasis on reconstructed quantities rather than raw detector data

  (e.g. EDtracks vs number of TT photoelectrons)
- Under beta-testing
- Uses Budimir's OpEmuRecReader to access trees

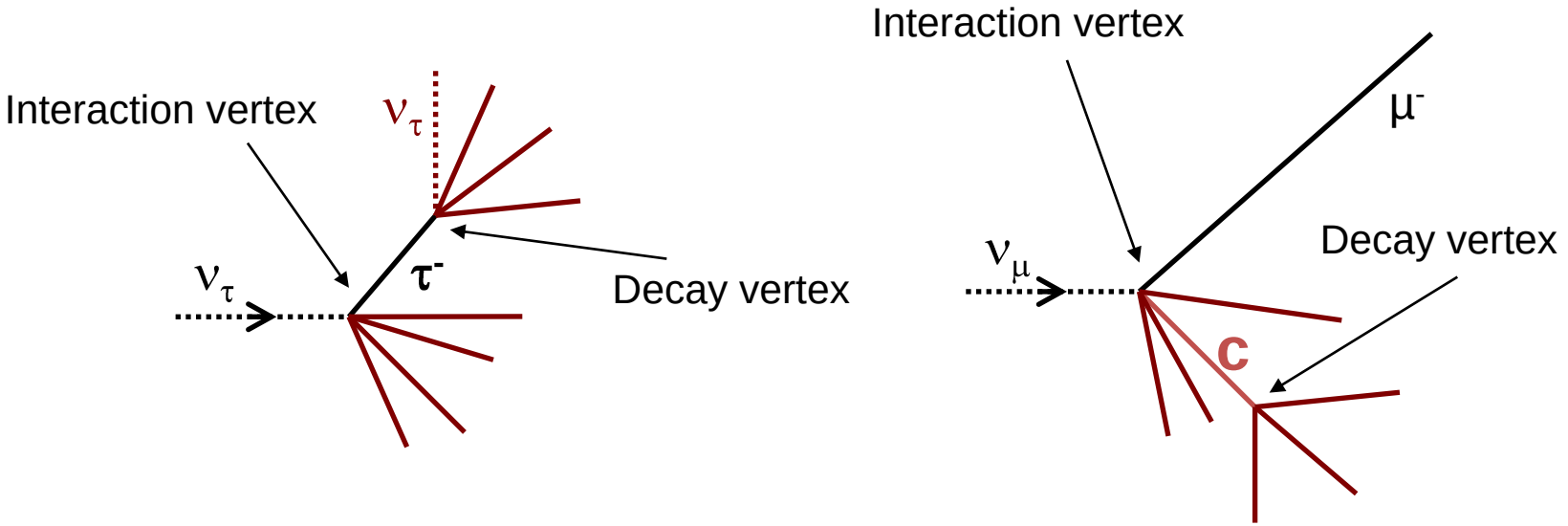
OpNtpWriter

- This simplifies greatly the analysis. E.g. ED paper total event energy plot in one root command




```
ntp->Draw("CombinedEvtEnergy+EDtrackMomentum[0]",
"(CombinedEvtEnergy+EDtrackMomentum[0])<100&&evtStatus=="CONTAINED"&&EdtrackMuonId[0]>0")
```

$\tau \rightarrow 3$prongs in a nutshell



- $\tau \rightarrow 3$prongs → 15% of all τ decays
- Less distinct kink → characteristic 2-vertex topology
- ν_μ charm can easily mimic this topology if we miss the muon
- ν_μ CC and NC bigger stats (signal ×1800) → can also find 2 vertex topology by chance

Current work: framework

- OpRelease 4.1 ("march2011") + OpRelease 4.X ("march2012"?) framework (see Elisbetta's slides)
- MC samples produced by Elisabetta:
  - 3000 DIS $\tau \longrightarrow 3$prongs and 5000 generic charm ("march2011")
  - Produced: D^0, D^+, D^+_s, Λ_c 10000 evts each ("march2012")
  - Asked for 5000 more TAU3P in "march2012"
- "march2012" used for eff calc^{ns}, "march2011+march2012" for PDFs
- Kinematics calculated with smeared MC momentum (resolution from MCS paper)

Selection Criteria

- OpCarac::EvtStatus == CONTAINED
- >=2 reco'ed vertices (e^--e^+ pairs not counted)
- 2 or 3 reco'ed tracks in the 2^{ry} vertex, not e^- or baryons (p, D, T, α) → 2 separate samples

} SIGNAL RECONS-TRUCTION

- Veto events with EleDet tracks tagged as muons
- Cut on likelihood ratio (signal/signal+charm)
- TrackFollowDown (with S.Dusini)

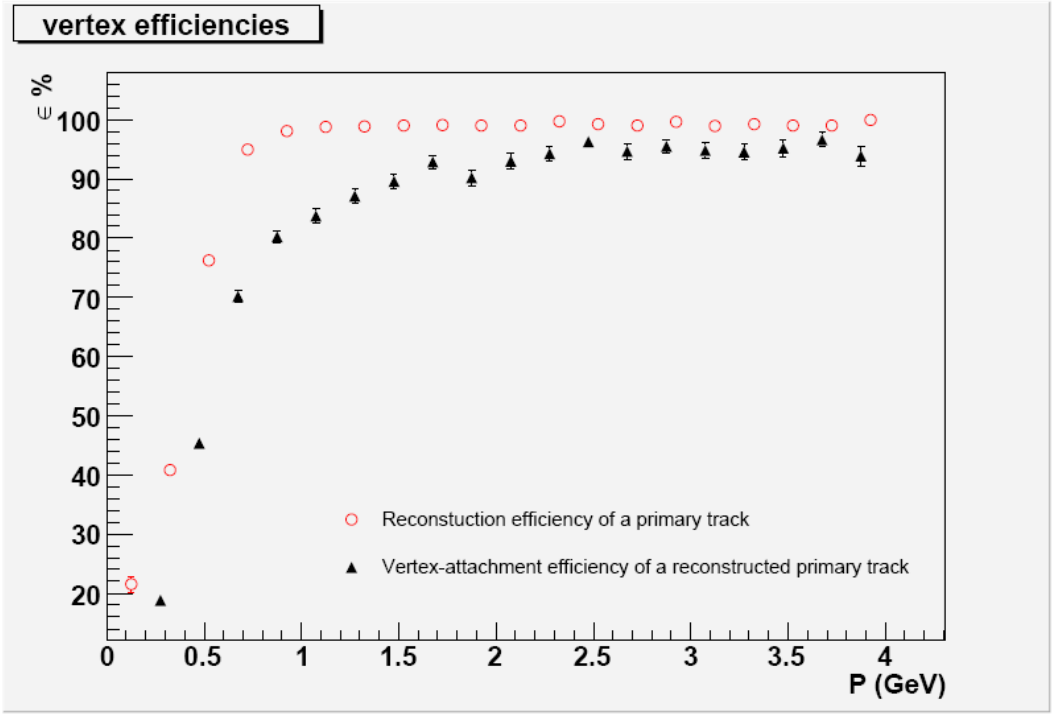
} CHARM BKG REJECTION

- Aperture angle of 2^{ry} vertex: cos(θ)<0.995
- Distance between 1^{ry} and 2^{ry} vertices > 100 μm

} ν_μ CC, NC BKG REJECTION

Vertexing study

- Started looking at track and vertex reconstruction effects
- Magali had found (NUMUCC FEDRA ORFEO 2008):



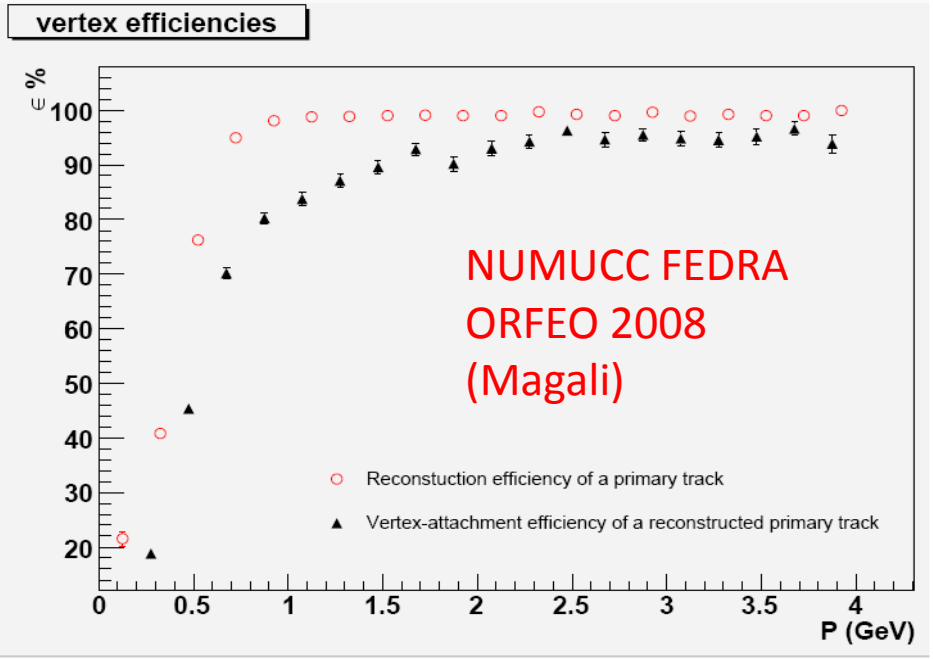
ε(tracking) ~ 100% for P>1GeV, drastically decreases below 1 GeV

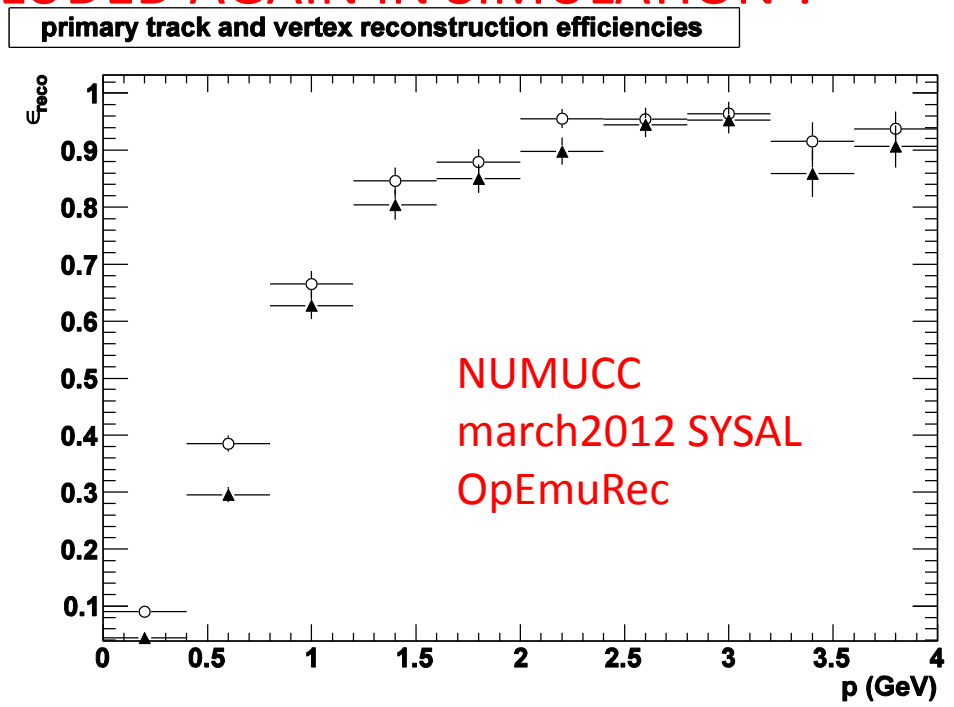
ε(vertexing) ~ 95% for P>2GeV, drastically decreases below 1 GeV

Vertexing study

- Started looking at track and vertex reconstruction effects
- Reevaluation gives less track reconstruction efficiency
- C. Bozza said efficiencies not credible if no bkg in films

→ COULD µTracks BKG BE INCLUDED AGAIN IN SIMULATION ?





Reminder: 2008 $\tau \rightarrow 3$prongs analysis

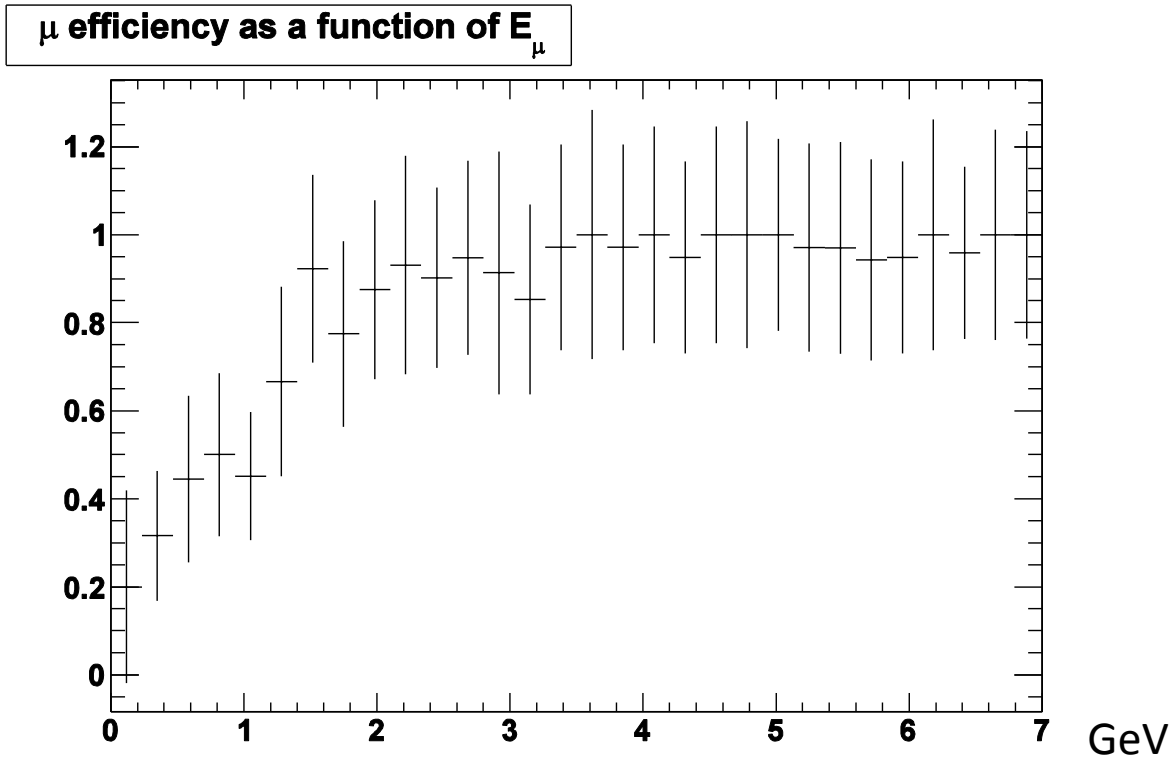
- ORFEO + FEDRA framework
- Big background MC sample (10000 evts signal, 40000 charm)
- Defined selection criteria (see later)
- Studied backgrounds, particularly charm
- Developed likelihood ratio in order to reject charm bkg
- Calculated signal and background abundances
- Started studied vertexing; emphasized its importance!

  (e.g. track migration from 2^{ary} vertex to 1^{ary} vertex, see OPERA note #97 "Vertex reconstruction studies with FEDRA and performances on hadronic multivertex neutrino events")

(Described in Magali's BESNIER PhD thesis, 2008)

Muon veto

- Did 'quick and dirty' check on muon reco' efficiency:



Good agreement with existing parameterisation (used in previous $\tau \rightarrow 3$prongs analysis)

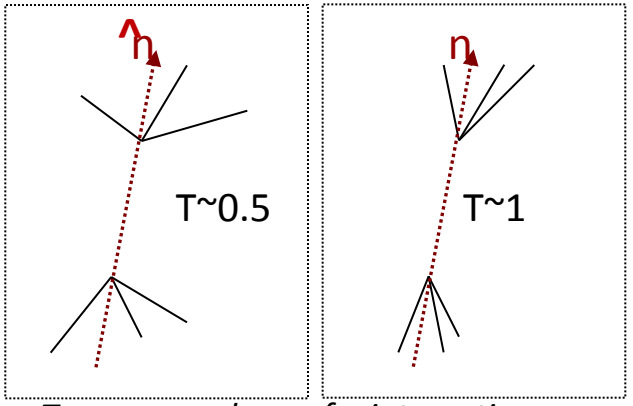
(used OpRelease 4.1, ν_μ CC from march 2011 MC production)

- TrackFollowDown performed on actual data, work ongoing with S. Dusini to include it in $\tau \rightarrow 3$prongs analysis

Likelihood ratio vars

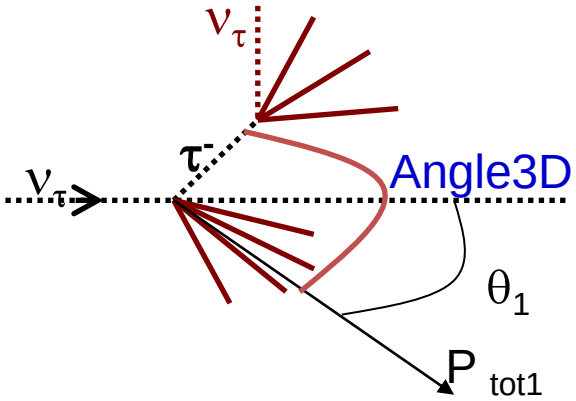
- Four kinematical variables being used to build a charm-rejecting likelihood ratio :
- Thrust. Describes the "jettiness" of the event in the transverse plane

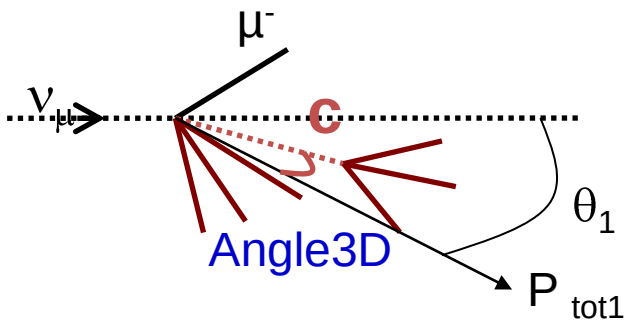
$$T = \max\Big|_{\vec{n}} \left(\frac{\sum_{tracks} |\vec{p}_i \cdot \vec{n}|}{\sum_{tracks} |\vec{p}_i|} \right)$$



Transverse plane of ν interaction

- Etot2. Sum of modulimomenta of tracks attached to 2nd vertex
- angle3D
- θ_1





OLD Signal & bkg abundances

- Signal and background abundances for 3 nominal years:

CAVEAT: stats limited! Short/long classification preliminary!

	TAU3P SYSAL	CHARM SYSAL	NUMUCC SYSAL
Abs eff 2 tracks	13%	0.8%	0.5%
Expected 2 tracks	1.3 evts	4.3 evts	64 evts
Long decay fraction 2 tracks	75%	93%	~100%
Abs eff 3 tracks	3.6%	0.15%	0.10%
Expected 3 tracks	0.35 evts	0.81 evts	11.6 evts
Long decay fraction 3 tracks	74%	85%	~100%

OLD Signal & bkg abundances

- OLD Signal and background abundances for 3 nominal years:

Species	Osc'd nu_tau CC SYSAL	Osc'd nu_tau CC FEDRA	nu_mu CC SYSAL	D0 SYSAL	D+ SYSAL	Ds+ SYSAL	LambdaC SYSAL	Charm Sum
Rate (/yr /kt)	2,5823	2,5823	3200	62,51136	30,97024	13,13024	36,10816	
Expected (2011)	9,683625	9,683625	12000	234,4176	116,1384	49,2384	135,4056	
Eff OpCarac Contained	0,910167	0,913418	0,970333	0,976561	0,983759	0,978988	0,973959	
Expected	8,81371592	8,84519738	11643,996	228,923086	114,252196	48,2038027	131,879503	523,258588
Eff No ED muon	0,769155	0,75479	0,0652951	0,0547222	0,0615315	0,0890121	0,0281495	
Expected	6,77911366	6,67626653	760,295883	12,5271749	7,03010901	4,29072171	3,71234206	27,5603477
Eff Two Vertices	0,310928	0,255681	0,166629	0,355611	0,265453	0,184743	0,104703	
Expected	2,10781625	1,7069945	126,687343	4,45480119	1,86616353	0,7926808	0,38869335	7,50233887
Eff 2 tracks	0,605353	0,646588	0,507194	0,735091	0,3311651	0,562537	0	
Expected	1,27597289	1,10372216	64,2550601	3,27468426	0,61800823	0,44591228	0	4,33860477
Eff 3 tracks	0,163914	0,173188	0,0912813	0,0538726	0,252254	0,124774	0	
Expected	0,34550059	0,29563096	11,5641853	0,23999172	0,47074721	0,09890595	0	0,80964489