Discrimination Potential of Event (Shape) Variables

K. Götzen

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Toy MC Setup

All following studies done with Toy MC

- 4-vectors taken from generator level
- Full geometric acceptance of 4π
- Tracks
  - Detection efficiency $\varepsilon_{trk} = 100\%$
  - Momentum smearing $\Delta p/p = 3\%$
  - Angle smearing $\Delta\theta = \Delta\varphi = 1$ mrad
  - PID efficiency $\varepsilon_{PID} = 95\%$ (all particle species)
  - PID mis-ID $mis_{PID} = 5\%$ (all particle species)
- Neutrals
  - Detection efficiency $\varepsilon_{neut} = 100\%$
  - Energy smearing $\Delta E/E = 5\%$
  - Angle smearing $\Delta\theta = \Delta\varphi = 3$ mrad

Channels under investigation

Channel (+c.c.)/sqrt(s) [GeV]	BR[%]	2.4	3.77	4.28	5.0	5.5
$\varphi (\rightarrow K^+ K^-) \varphi$	49.8	x	x	x	x	x
$\Lambda(\rightarrow p \pi^-) \bar{\Lambda}$	63.9	x	x	x	x	x
$J/\psi (\rightarrow \ell^+\ell^-) \pi^+\pi^-$	11.9		x	x	x	x
$D^0 (\rightarrow K^-\pi^+) \bar{D}^0$	3.9		x	x	x	x
$D^+ (\rightarrow K^- \pi^+ \pi^+) D^-$	9.4		x	x	x	x
$D_s^+ (\rightarrow K^+K^-\pi^+) D_s^-$	5.5			x	x	x
$\Lambda_c(\rightarrow p K^- \pi^+) \bar{\Lambda}_c$	5.0				x	x
$D^0 (\rightarrow K^-\pi^+\pi^0) \bar{D}^0$	13.9		x	x	x	x
$D^0 (\rightarrow K^-\pi^+\pi^+\pi^-) \bar{D}^0$	8.1		x	x	x	x
$D^+ (\rightarrow K^- \pi^+ \pi^+\pi^0) D^-$	6.1		x	x	x	x
$D^+ (\rightarrow K_S \pi^+ \pi^0) D^-$	6.9		x	x	x	x
$D^+ (\rightarrow K_S \pi^+ \pi^+\pi^-) D^-$	3.1		x	x	x	x
$D_s^+ (\rightarrow K^+K^-\pi^+\pi^0) D_s^-$	5.6			x	x	x

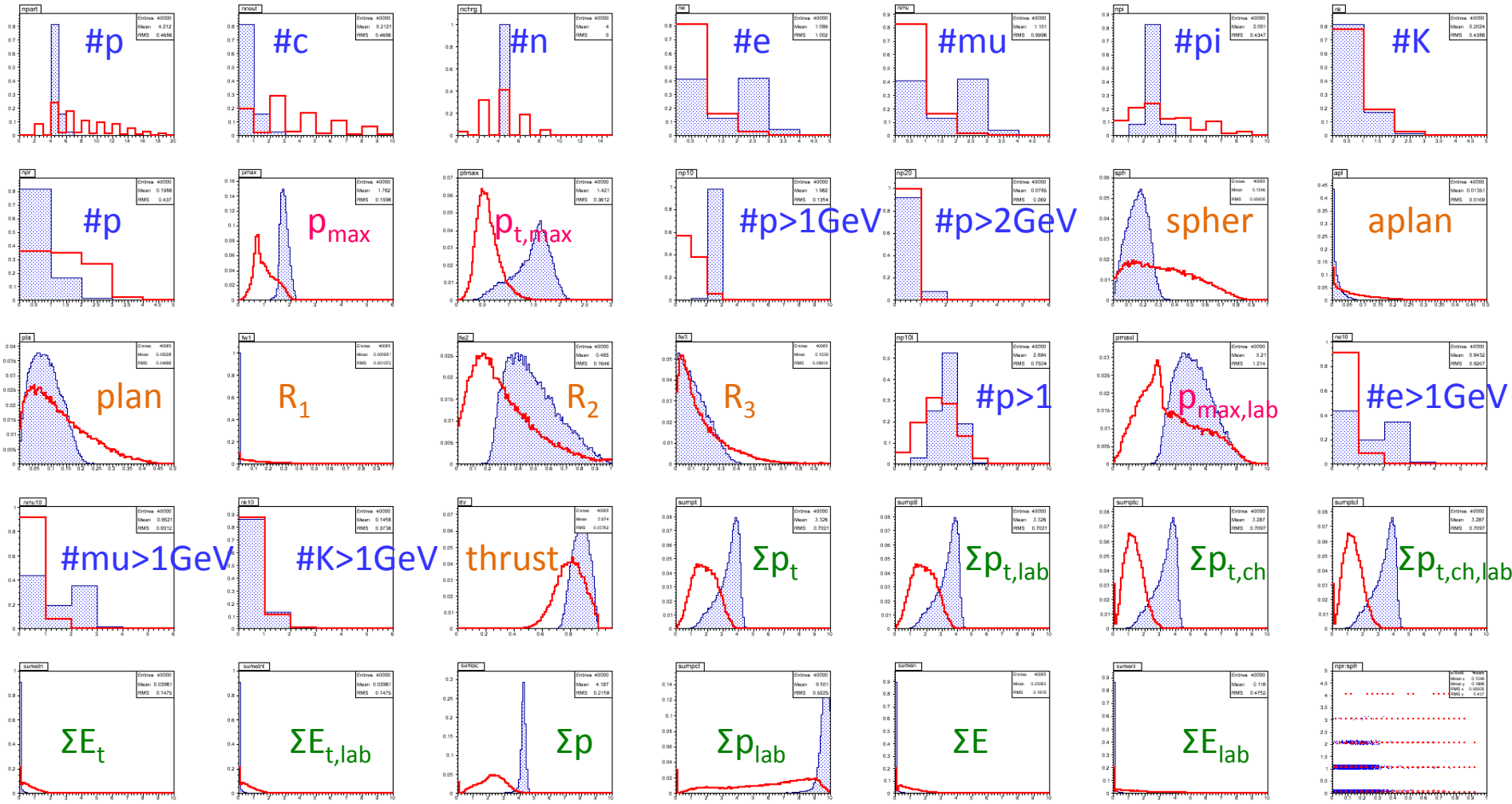
in preparation

Event variables

- Quantities computable without combinatorics and specific assumption about decay channel

- Multiplicities of all, charged, neutrals, above a certain momentum threshold, with certain PID quality,...
- Maximum/Minimum momenta, transverse momenta, cluster energy, transvers energy *(cms and lab system)*
- Sums of momenta, transverse momenta, energies, transverse energies *(cms and lab system)*
- Event shape variables like sphericity, aplanarity, planarity, thrust, Fox Wolfram moments *(usually cms system)*

Some event variables

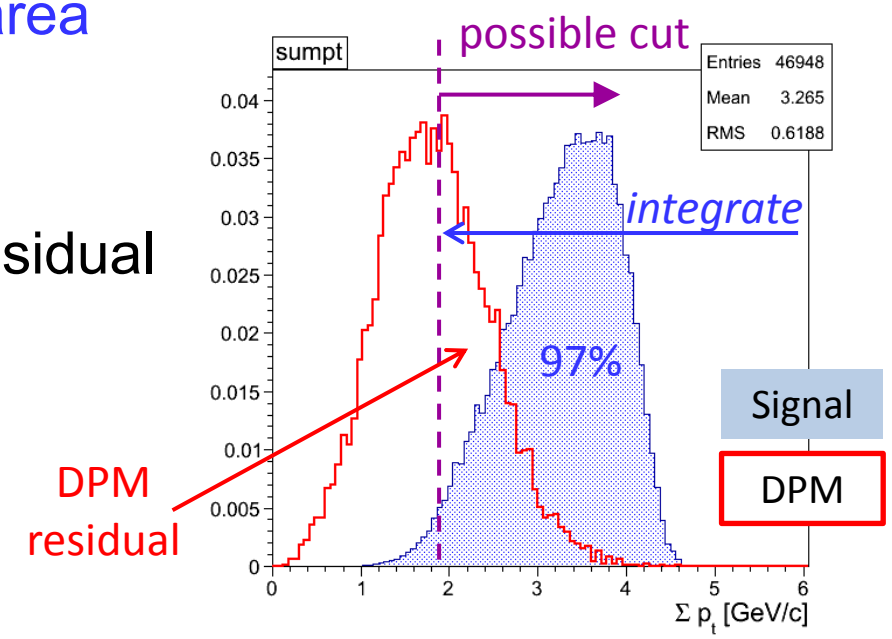


Signal: J/psi -> ll

Background: DPM

Optimization Approach

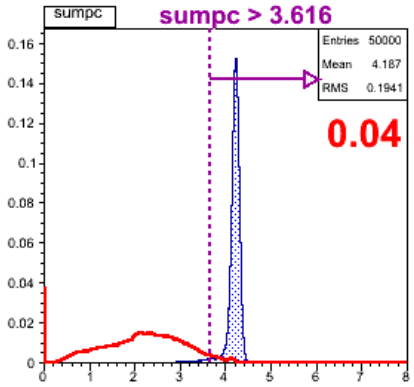
- For every signal channel and every variable do the following:
  - Integrate up to 97% signal area (from both sides)
  - Determine DPM residual
  - Find cut with lowest DPM residual
  - Apply and find next variable
  - Do, until total eff ≈ 90%

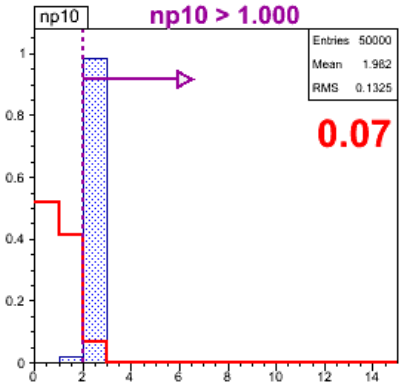


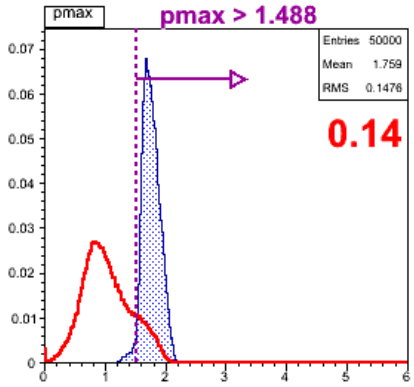
- For total performance determination
  - Apply event cuts in addition to mass window cut
  - Determine DPM suppression for simultaneous tagging of all channels

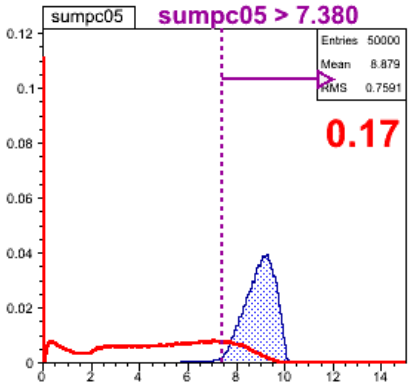
Example J/ψ

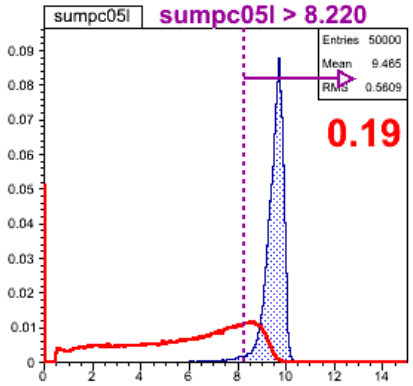
- The best 8 cuts for J/psi selection
- Red numbers = DPM residual

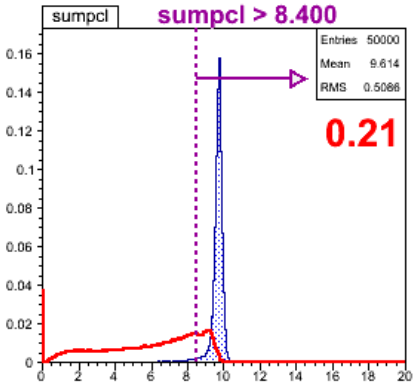


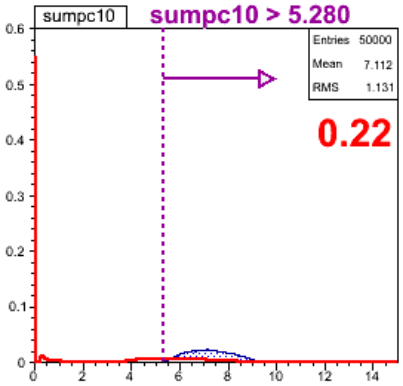


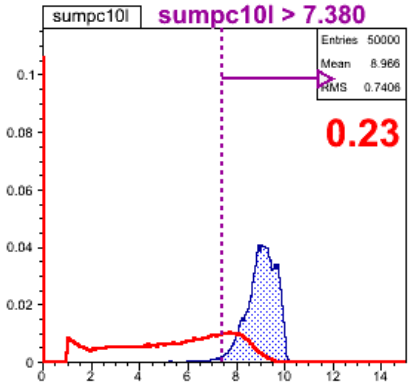








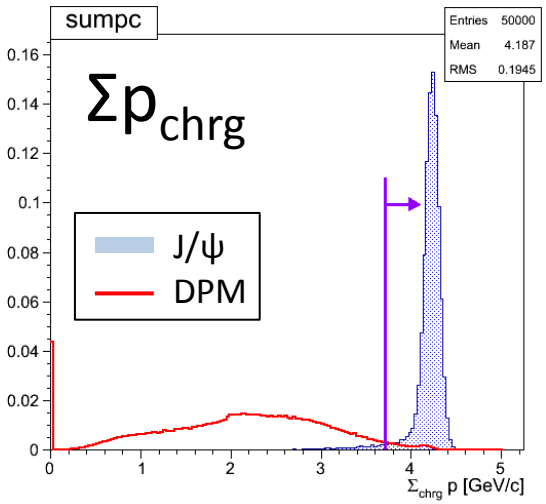


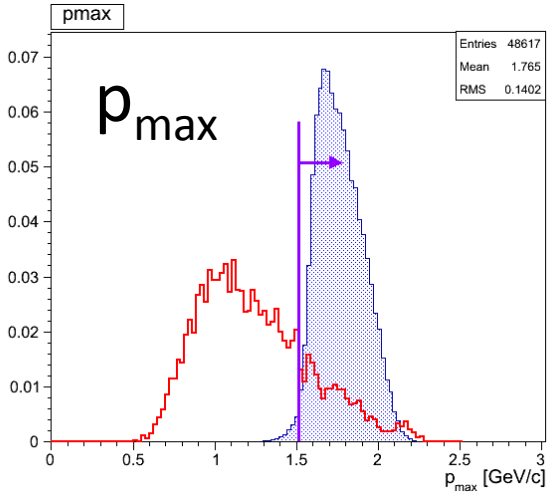


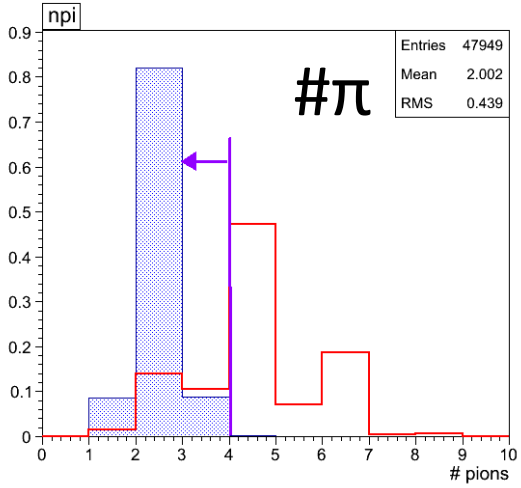
Criteria Examples: J/ψ

$p\bar{p} \rightarrow J/\psi(\rightarrow \ell^+\ell^-)\,\pi^+\pi^-$ @ 4.28 GeV

$\Sigma p_{chrg} > 3.6$ GeV/c & $p_{max} > 1.5$ GeV/c & #π<4







$\epsilon_{J/\psi}$ = 97.2%

ϵ_{DPM} = 3.8%

$\epsilon_{J/\psi}$ = 95.9%

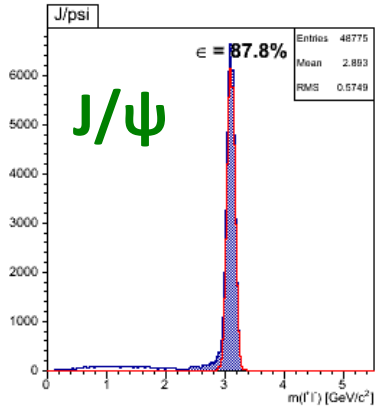
ϵ_{DPM} = 0.8%

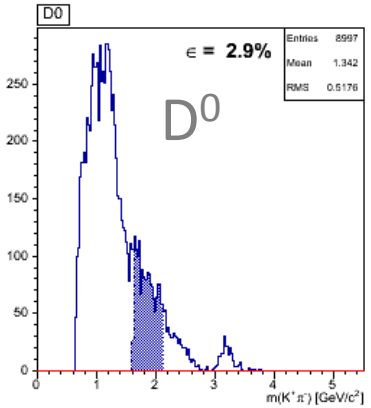
$\epsilon_{J/\psi}$ = 95.7%

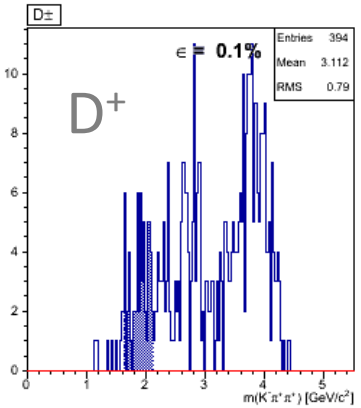
ϵ_{DPM} = 0.2%

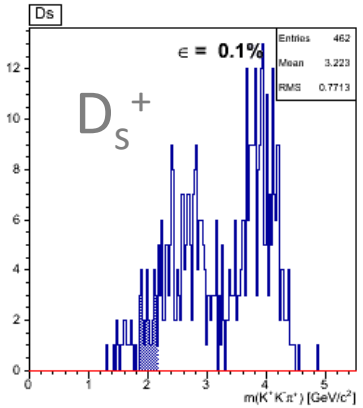
Simultaneous tagging for J/ψ events

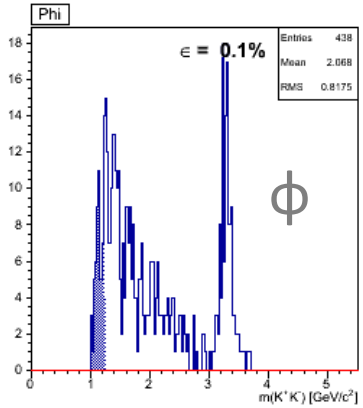
J/ψ events: No event cut applied

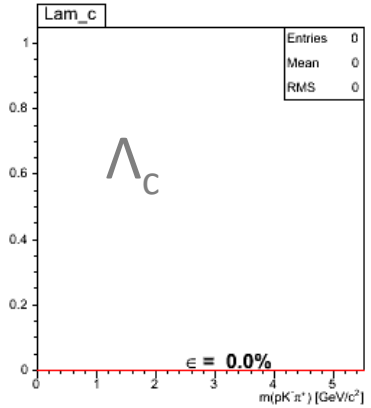


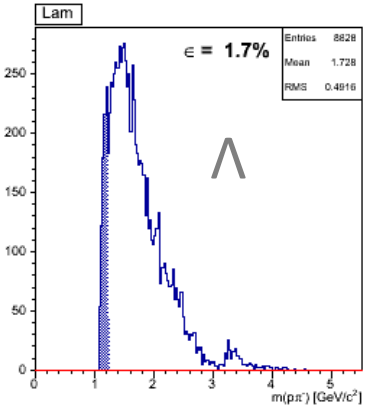








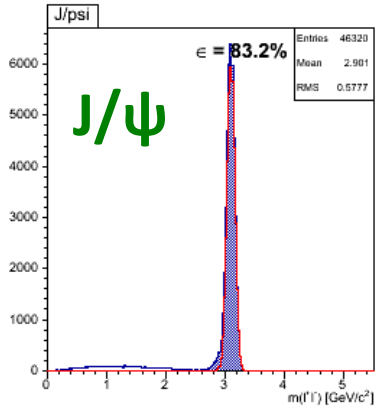


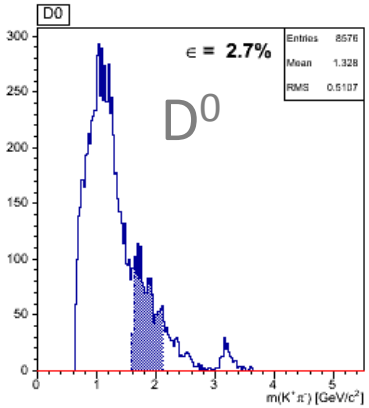


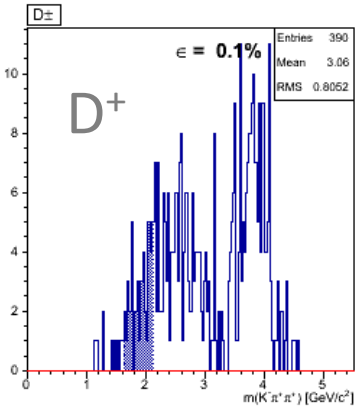
$\varepsilon_{tot} = 88.4\%$

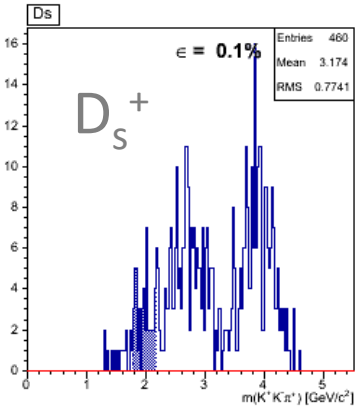
Simultaneous tagging for J/ψ events

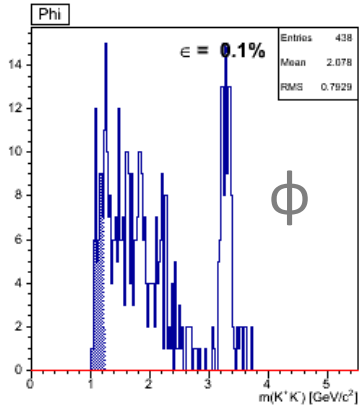
J/ψ events: Event cuts applied (all channels)

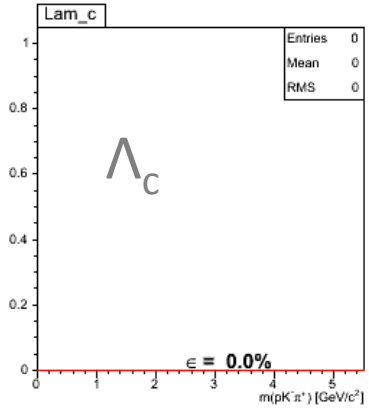


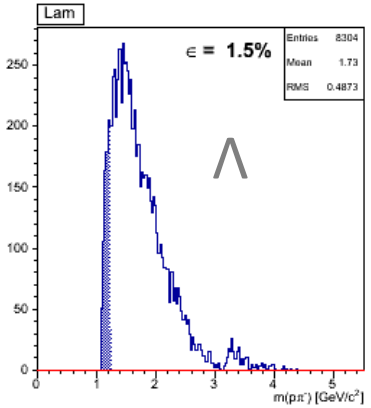








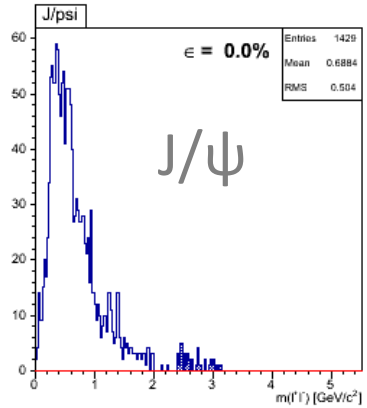


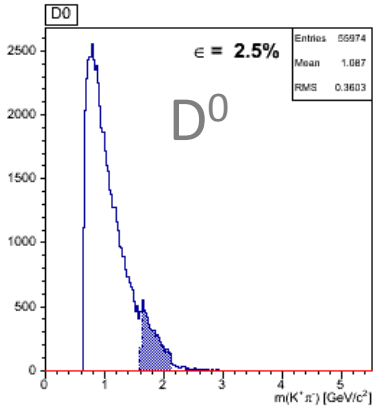


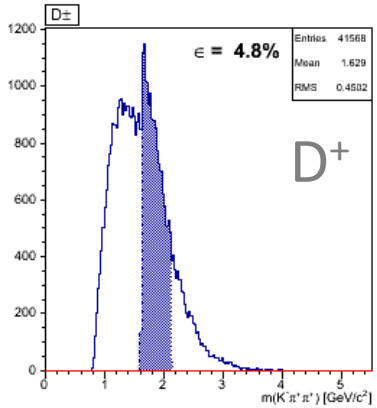
$\varepsilon_{tot} = 83.5\%$

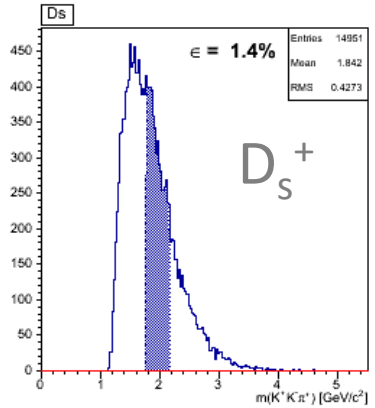
Simultaneous tagging for DPM events

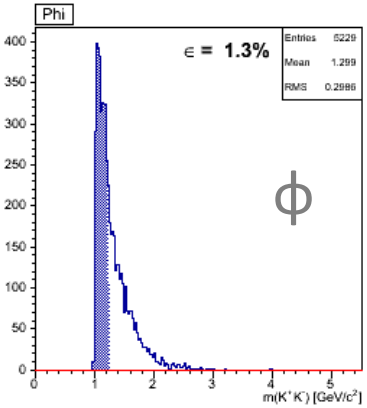
DPM: No event cut applied

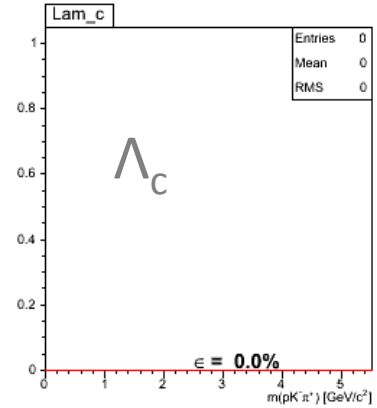


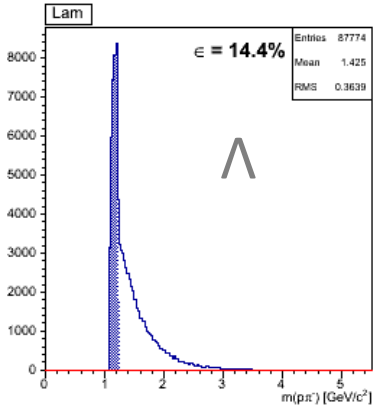








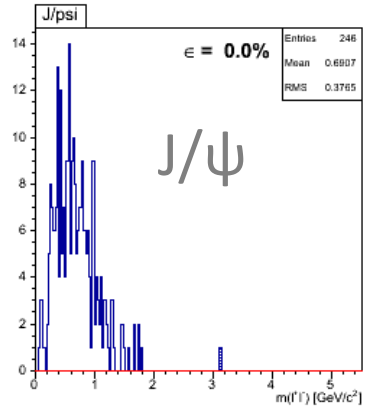


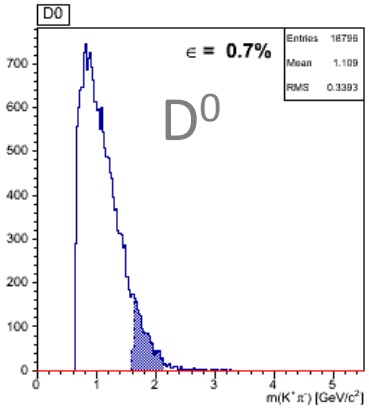


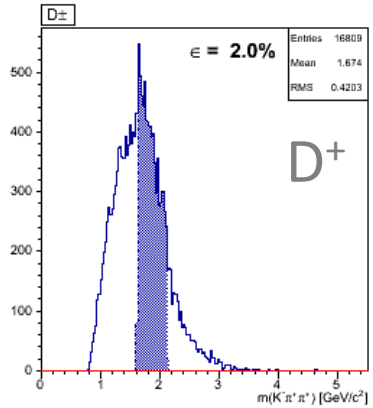
ε_{tot} = 20.9%

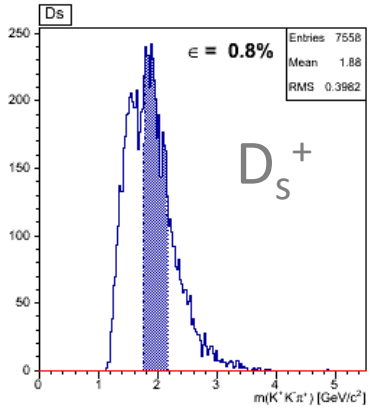
Simultaneous tagging for DPM events

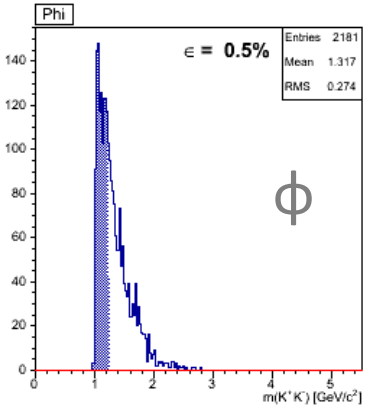
DPM: Event cuts applied (all channels)

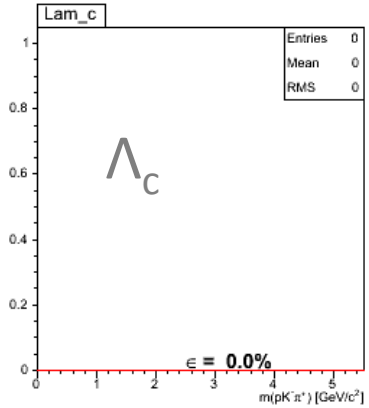


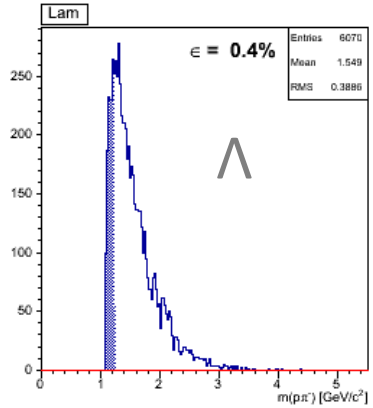












$\varepsilon_{tot} = 2.7\%$

Factor 7.8 improvement!

Performance of Event Cuts

Energy/channel	Pure eventshape cut		Combined with simultaneous cut			
2.4 GeV	sig eff	dpm eff	eff	eff w/ cut	rel eff	cut
phi (KK) phi	90%	0,6%	95%	90%	*94%*	nk>1 & sumpc<1.632 & pmax<0.6
Lam(ppi) Lamb	93%	0,2%	96%	91%	*95%*	npr>0 & npart>3 & npi<4 & fw1>0.132 & fw4>0.2112
DPM			9%	1%	*6%*	**Faktor 16,04**
3.77 GeV	sig eff	dpm eff	eff	eff w/ cut	rel eff	cut
phi (KK) phi	93%	0,2%	96%	93%	*98%*	nk>1 & npart>3 & fw2>0.5456
Lam(ppi) Lamb	92%	0,2%	96%	91%	*94%*	npr>0 & npart>3 & fw2>0.6248 & fw4>0.3784 & fw5>0.22
J/psi(ll) pipi	91%	0,0%	89%	83%	*93%*	np10>1 & npi<4 & pmax>1.464 & sumpc>3.424 & fw2<0.8976
D0(Kpi) D0b	91%	2,1%	92%	80%	*86%*	nk>0 & sumptl>1.38 & pmax>0.768 & pmax<1.056 & fw3<0.1848
D+-(Kpipi) D-+	90%	4,3%	91%	78%	*85%*	nk>0 & sumptl>1.5 & pmax<0.936
DPM			18%	2%	*12%*	**Faktor 8,52**
4.28 GeV	sig eff	dpm eff	eff	eff w/ cut	rel eff	cut
phi (KK) phi	91%	0,1%	96%	90%	*94%*	nk>1 & sumptl>0.96 & fw2>0.6424
Lam(ppi) Lamb	93%	0,1%	96%	91%	*95%*	npr>0 & npart>3 & fw2>0.7216 & fw4>0.484 & fw5>0.1408
J/psi(ll) pipi	92%	0,0%	89%	83%	*94%*	npi<4 & np05>2 & sumpc>3.904 & ptmax>0.612
D0(Kpi) D0b	91%	1,9%	93%	74%	*80%*	nk>0 & pmax>0.936 & sumptl>2.1
D+-(Kpipi) D-+	90%	5,3%	92%	79%	*86%*	nk>0 & ptmax>0.516 & sumptl>1.8
Ds+-(KKpi) Ds-+	92%	1,5%	93%	80%	*86%*	nk>1 & npi<7 & sumptl>1.62
DPM			21%	3%	*13%*	**Faktor 7,74**
5.0 GeV	sig eff	dpm eff	eff	eff w/ cut	rel eff	cut
phi (KK) phi	91%	0,1%	96%	90%	*94%*	nk>1 & sumptl>1.14 & fw2>0.7392
Lam(ppi) Lamb	95%	0,1%	96%	91%	*95%*	npart>3 & ptmax>0.504 & fw1>-0.0176 & fw2>0.8008
J/psi(ll) pipi	92%	0,0%	89%	84%	*94%*	npi<4 & sumpc>4.608 & ptmax>0.828
D0(Kpi) D0b	91%	1,4%	93%	75%	*81%*	nk>0 & pmax>1.152 & sumptl>2.4
D+-(Kpipi) D-+	91%	5,2%	92%	81%	*88%*	nk>0 & ptmax>0.6 & sumptl>2.04
Ds+-(KKpi) Ds-+	92%	1,6%	94%	82%	*87%*	nk>1 & npi<7 & sumptl>1.92
Lc (pKpi) Lcb	91%	2,8%	95%	82%	*86%*	nk>0 & npr>0 & npart>5 & sumpt>1.5 & fw1>-0.0176
DPM			26%	3%	*13%*	**Faktor 7,82**

Performance of Event Cuts

Energy/channel	Pure eventshape cut		Combined with simultaneous cut			
2.4 GeV	sig eff	dpm eff	eff	eff w/ cut	rel eff	cut
phi (KK) phi	90%	0,6%	95%	90%	*94%*	nk>1 & sumpc<1.632 & pmax<0.6
Lam(ppi) Lamb	93%	0,2%	96%	91%	*95%*	npr>0 & npart>3 & npi<4 & fw1>0.132 & fw4>0.2112
DPM			9%	1%	*6%*	**Faktor 16,04**
3.77 GeV	sig eff	dpm eff	eff	eff w/ cut	rel eff	cut
phi (KK) phi	93%	0,2%	96%	93%	*98%*	nk>1 & npart>3 & fw2>0.5456
Lam(ppi) Lamb	92%	0,2%	96%	91%	*94%*	npr>0 & npart>3 & fw2>0.6248 & fw4>0.3784 & fw5>0.22
J/psi(ll) pipi	91%	0,0%	89%	83%	*93%*	np10>1 & npi<4 & pmax>1.464 & sumpc>3.424 & fw2<0.8976
D0(Kpi) D0b	91%	2,1%	92%	80%	*86%*	nk>0 & sumptl>1.38 & pmax>0.768 & pmax<1.056 & fw3<0.1848
D+-(Kpipi) D-+	90%	4,3%	91%	78%	*85%*	nk>0 & sumptl>1.5 & pmax<0.936
DPM			18%	2%	*12%*	**Faktor 8,52**
4.28 GeV	sig ef					
phi (KK) phi	91%					
Lam(ppi) Lamb	93%					84 & fw5>0.1408
J/psi(ll) pipi	92%					>0.612
D0(Kpi) D0b	91%					
D+-(Kpipi) D-+	90%					
Ds+-(KKpi) Ds-+	92%					
DPM			21%	3%	*13%*	**Faktor 7,74**
5.0 GeV	sig eff	dpm eff	eff	eff w/ cut	rel eff	cut
phi (KK) phi	91%	0,1%	96%	90%	*94%*	nk>1 & sumptl>1.14 & fw2>0.7392
Lam(ppi) Lamb	95%	0,1%	96%	91%	*95%*	npart>3 & ptmax>0.504 & fw1>-0.0176 & fw2>0.8008
J/psi(ll) pipi	92%	0,0%	89%	84%	*94%*	npi<4 & sumpc>4.608 & ptmax>0.828
D0(Kpi) D0b	91%	1,4%	93%	75%	*81%*	nk>0 & pmax>1.152 & sumptl>2.4
D+-(Kpipi) D-+	91%	5,2%	92%	81%	*88%*	nk>0 & ptmax>0.6 & sumptl>2.04
Ds+-(KKpi) Ds-+	92%	1,6%	94%	82%	*87%*	nk>1 & npi<7 & sumptl>1.92
Lc (pKpi) Lcb	91%	2,8%	95%	82%	*86%*	nk>0 & npr>0 & npart>5 & sumpt>1.5 & fw1>-0.0176
DPM			26%	3%	*13%*	**Faktor 7,82**

One order of magnitude *additional* suppression might be achieved with event cuts!

BACKUP

Optimization Approach

- For every signal channel do the following:
  1. Determine distributions for signal and DPM events
  2. For each event variable distribution
     - Find threshold from both sides for 97% signal area
     - Determine DPM residual for each threshold
  3. Choose event variable, where least DPM events survive
  4. Apply cut and find the next best variable
  5. Iterate, until total signal efficiency ≈ 90%

- For total performance determination
  - Apply event cuts in addition to mass window cut
  - Determine DPM suppression for simultaneous tagging of all channels