Update on the software trigger scheme

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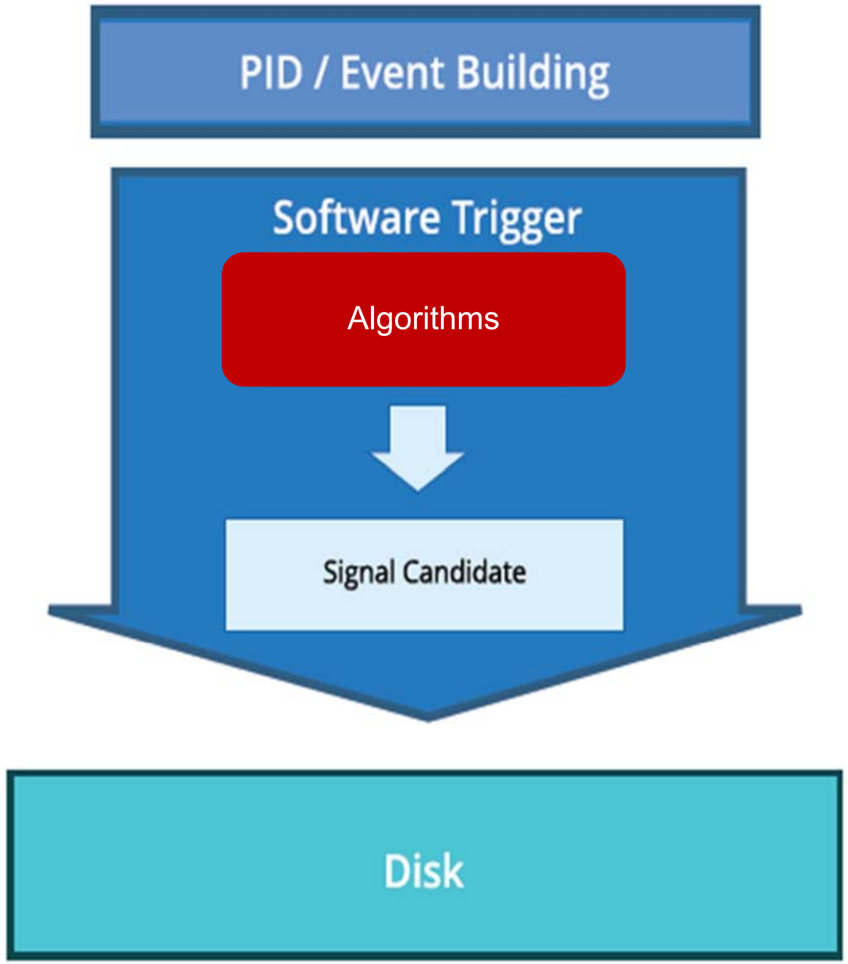
- Introduction
- Test with full chain MC simulation
- Summary & Outlook

Ingredients for trigger algorithms

- Track reconstruction is the important key
- PID for charged/neutral track
- Event Shape variables
- Most of physics benchmark channels contain J/ψ, D^0, $D^\pm$, D_s mesons, light Mesons (π^0,ϕ), baryons (Λ, Λ_c), l^+l^- pair
- Kinematic cuts, depends on each physics channel
- POCA / Vertex finding, if it is possible



Determination of events rate

MC simulation data

Signal MC : EvtGen
Background MC : DPM

Production	
$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-(\mu^+\mu^-)\pi^+\pi^-$	h_c,ψ(2S),X,Y
$\bar{p}p \to J/\psi\pi^0\pi^0 \to e^+e^-(\mu^+\mu^-)4\gamma$	Y
$\bar{p}p \to \chi_{c1}\gamma \to J/\psi\gamma\gamma \to e^+e^-(\mu^+\mu^-)\gamma\gamma$	ψ(2S),X,Y
$\bar{p}p \to \chi_{c2}\gamma \to J/\psi\gamma\gamma \to e^+e^-(\mu^+\mu^-)\gamma\gamma$	ψ(2S),X,Y
$\bar{p}p \to J/\psi\gamma \to e^+e^-(\mu^+\mu^-)\gamma$	χ_{c1},χ_{c2},X
$\bar{p}p \to J/\psi\eta \to e^+e^-(\mu^+\mu^-)\gamma\gamma$	η_c(2S),ψ(2S),X,Y
$\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$	
$\bar{p}p \to \pi^+\pi^-\pi^0\pi^0 \to \pi^+\pi^-\gamma\gamma\gamma\gamma$	
$\bar{p}p \to J/\psi\eta\pi^0 \to e^+e^-\gamma\gamma\gamma\gamma$	
$\bar{p}p \to J/\psi\omega\pi^0 \to e^+e^-\pi^0\gamma\gamma\gamma$	
$\bar{p}p \to \pi^+\pi^-\pi^0 \to \pi^+\pi^-\gamma\gamma$	
$\bar{p}p \to \pi^+\pi^-\eta \to \pi^+\pi^-\gamma\gamma$	
$\bar{p}p \to J/\psi\pi^0\gamma \to e^+e^-\gamma\gamma\gamma$	
$\bar{p}p \to J/\psi\eta\gamma \to e^+e^-\gamma\gamma\gamma$	
$\bar{p}p \to J/\psi\eta\eta \to e^+e^-\gamma\gamma\gamma\gamma$	
$\bar{p}p \to \eta_c(2S)\gamma \to \gamma\gamma\gamma$	h_c
$\bar{p}p \to \pi^0\pi^0 \to \gamma\gamma\gamma\gamma$	
$\bar{p}p \to \pi^0\gamma \to \gamma\gamma\gamma$	
$\bar{p}p \to \pi^0\eta \to \gamma\gamma\gamma\gamma$	
$\bar{p}p \to \eta\eta \to \gamma\gamma\gamma\gamma$	
$\bar{p}p \to \pi^0\eta^{(\prime)} \to \gamma\gamma\gamma\gamma$	
$\bar{p}p \to \eta_c\gamma \to \phi\phi\gamma \to K^+K^-K^+K^-\gamma$	h_c
$\bar{p}p \to K^+K^-K^+K^-\pi^0 \to K^+K^-K^+K^-\gamma\gamma$	
$\bar{p}p \to \phi K^+K^-\pi^0 \to K^+K^-K^+K^-\gamma\gamma$	
$\bar{p}p \to \phi\phi\pi^0 \to K^+K^-K^+K^-\gamma\gamma$	
$\bar{p}p \to K^+K^-\pi^+\pi^-\pi^0 \to K^+K^-K^+K^-\gamma\gamma$	
$\bar{p}p \to D^+D^- \to K^-\pi^+\pi^+K^+\pi^-\pi^-$	ψ(3770)
$\bar{p}p \to D^{*+}D^{*-} \to D^0\pi^+\overline{D^0}\pi^- \to K^-\pi^+\pi^+K^+\pi^-\pi^-$	ψ(4040)
$\bar{p}p \to$ generic DPM	
$\bar{p}p \to 3\pi^+3\pi^-\pi^0$	
$\bar{p}p \to 3\pi^+3\pi^-$	
$\bar{p}p \to K^+K^-2\pi^+2\pi^-$	
$\bar{p}p \to \tilde{\eta}_{c1}\eta \to \chi_{c1}\pi^0\pi^0\eta \to J/\psi\gamma\pi^0\pi^0\eta$	$\tilde{\eta}_{c1}(4286)$
$\bar{p}p \to \chi_{c0}\pi^0\pi^0\eta \to J/\psi\gamma\pi^0\pi^0\eta$	
$\bar{p}p \to \chi_{c1}\pi^0\eta\eta \to J/\psi\gamma\pi^0\eta\eta$	
$\bar{p}p \to \chi_{c1}\pi^0\pi^0\pi^0\eta \to J/\psi\gamma\pi^0\pi^0\pi^0\eta$	
$\bar{p}p \to J/\psi\pi^0\pi^0\pi^0\eta$	
$\bar{p}p \to \tilde{\eta}_{c1}\eta \to D^0\overline{D}^{*0}\eta \to K^-\pi^+\pi^0K^+\pi^-\pi^0\pi^0\eta$	$\tilde{\eta}_{c1}(4286)$
$\bar{p}p \to D^0\overline{D}^{*0}\pi^0 \to K^-\pi^+\pi^0K^+\pi^-\pi^0\pi^0\pi^0$	
$\bar{p}p \to D^0\overline{D}^{*0}\eta \to K^-\pi^+\pi^0\pi^0K^+\pi^-\pi^0\pi^0\eta$	
$\bar{p}p \to D^0\overline{D}^{*0}\eta \to K^-\pi^+\pi^0\pi^0K^+\pi^-\pi^0\pi^0\pi^0\eta$	

15 algorithms

$D^0(K\pi)$
$D^0(K\pi\pi^0)$
$D^\pm(K\pi\pi)$
$J/\psi(e^+e^-)$
$J/\psi(\mu^+\mu^-)$
$J/\psi(\pi^+\pi^-\pi^0)$
$D^0(\mu^\pm e^\mp)$
$D^\pm(\pi^\pm e^\mp \mu^\pm)$
$D^0(\mu^+\mu^-)$
e^+e^-
$\phi(K^+K^-)$
$D_s(\phi\pi)$
$\eta_c(\gamma\gamma)$
$\Lambda(p\pi)$
$\Lambda_c^+(pK^-\pi^+)$
$h_c(\gamma\gamma\gamma)$

Decision

select event
if one of 15 algorithms
is fulfilled

reject event
if none of 15 algorithms
are satisfied

- 15 selection algorithms according to resonances scan data/events in parallel
- For each algorithm data samples pass through invariant mass filtering

Determination of events rate

Test on software trigger scheme with full chain MC simulation

- EvtGen signal data and DPM background data using PANDAroot ver.oct12

$\bar{p}p \to X(3872) \to J/\psi\pi^+\pi^- \to l^+l^-\pi^+\pi^-$

$\bar{p}p \to e^+e^-$

$\bar{p}p \to \psi(4040) \to D^{*+}D^{*-} \to D^0\pi^+\overline{D}^0\pi^- \to K^-\pi^+\pi^+K^-\pi^-\pi^-$

$\bar{p}p \to f(2230) \to \phi\phi \to K^+K^-K^+K^-$

$\bar{p}p \to \tilde{\eta}_{c1}\eta \to \chi_{c1}\eta\pi^0\pi^0 \to J/\psi\gamma\eta\pi^0\pi^0 \to e^+e^-\gamma\gamma\gamma\gamma\gamma\gamma$

$\bar{p}p \to D_s^{\pm}D_s^{0*\mp} \to D_s^{\pm}D_s^{\mp}\pi^0 \to \phi\pi^{\pm}\phi\pi^{\mp}\pi^0 \to K^+K^-\pi^{\pm}K^+K^-\pi^{\mp}\gamma\gamma$

$\bar{p}p \to \tilde{\eta}_{c1}\eta \to \overline{D}^{*0}D^0\eta \to \overline{D}^0\pi^0D^0\eta \to K^-\pi^+\pi^0K^+\pi^-\pi^0\pi^0\eta$

$\bar{p}p \to \overline{\Lambda}_c\Lambda_c \to \bar{p}K^+\pi^-pK^-\pi^+$

$\bar{p}p \to h_c(3526) \to \eta_c\gamma \to \gamma\gamma\gamma$

……

DPM background

- inelastic event only corresponding to ~ 10 MHz rate
- min beam mom. = 2.230 GeV/c
  max beam mom. = 5.474 GeV/c
- 22 data sets

- online tracking resolution and PID efficiency are the same as like offline values

- apply global PID probability for each charged track

$$\mathrm{Prob.}(k) = \frac{\prod_i \mathrm{Prob.}_i(k)}{\sum_j \prod_i \mathrm{Prob.}_i(j)}$$

$i =$ subdetectors

$j = e, \mu, \pi, K, p$

$k =$ particle

PID selection :

loose

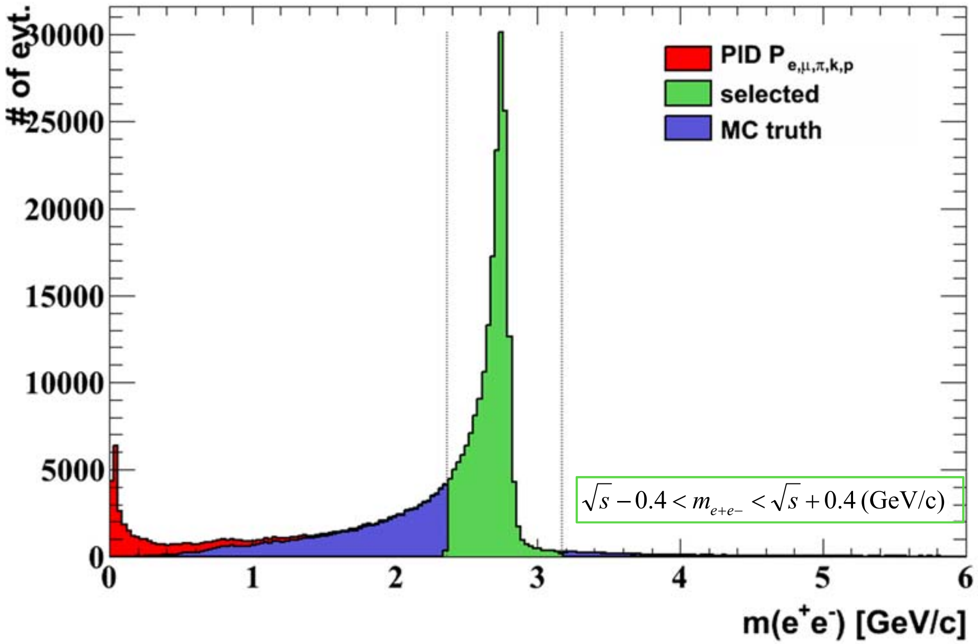
$\mathrm{Prob.}(e,\mu) > 0.01,\ \mathrm{Prob.}(\pi, p) > 0.1,\ \mathrm{Prob.}(K) > 0.2$

tight

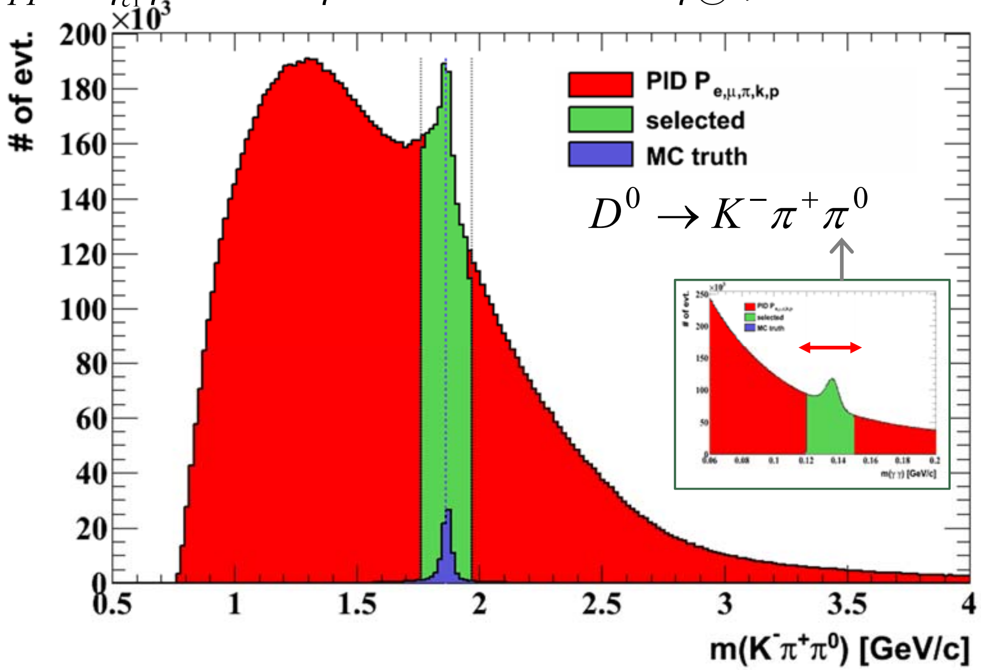
$\mathrm{Prob.}(e,\mu,\pi,K,p) > 0.5$

MC simulation e^+e^-, D^0, D_s, Λ_c

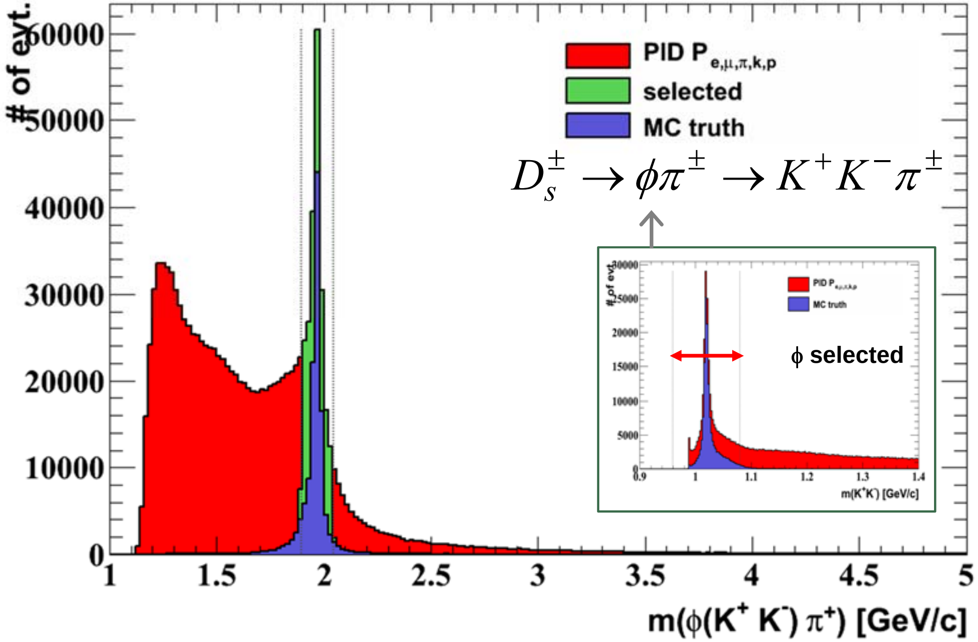
$\bar{p}p \to e^+e^- @ \sqrt{s} = 2.768\,\mathrm{GeV}$



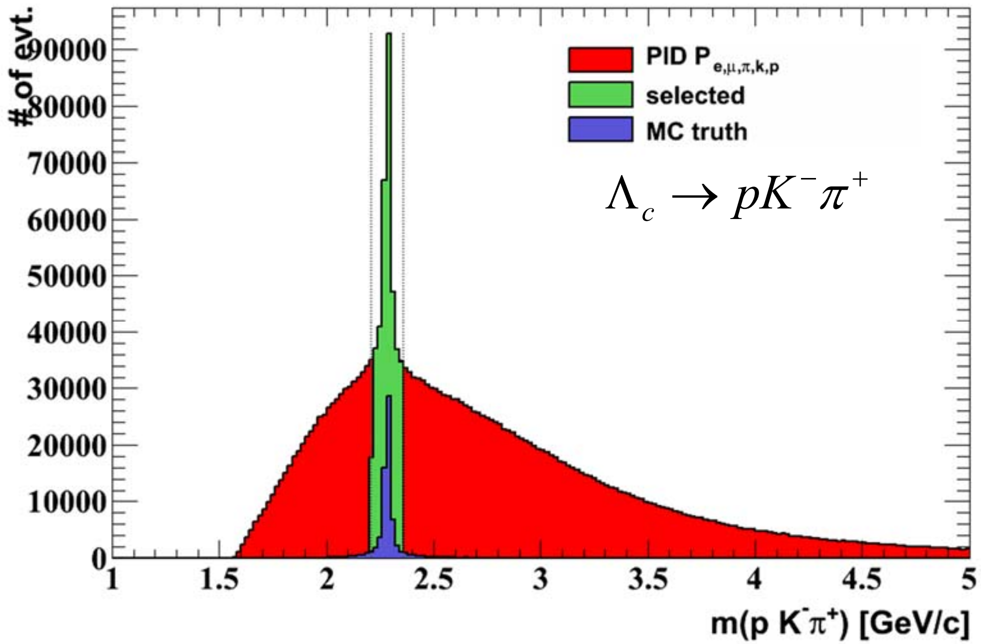
$\bar{p}p \to \tilde{\eta}_{c1}\eta \to \overline{D}^{*0}D^0\eta \to K^-\pi^+\pi^0 K^+\pi^-\pi^0\pi^0\eta @ \sqrt{s} = 5.380\,\mathrm{GeV/c}$



$\bar{p}p \to D_s^{\pm}D_s^{0*\mp} \to D_s^{\pm}D_s^{\mp}\pi^0 \to \phi\pi^{\pm}\phi\pi^{\mp}\pi^0 @ \sqrt{s} = 4.286\,\mathrm{GeV/c}$

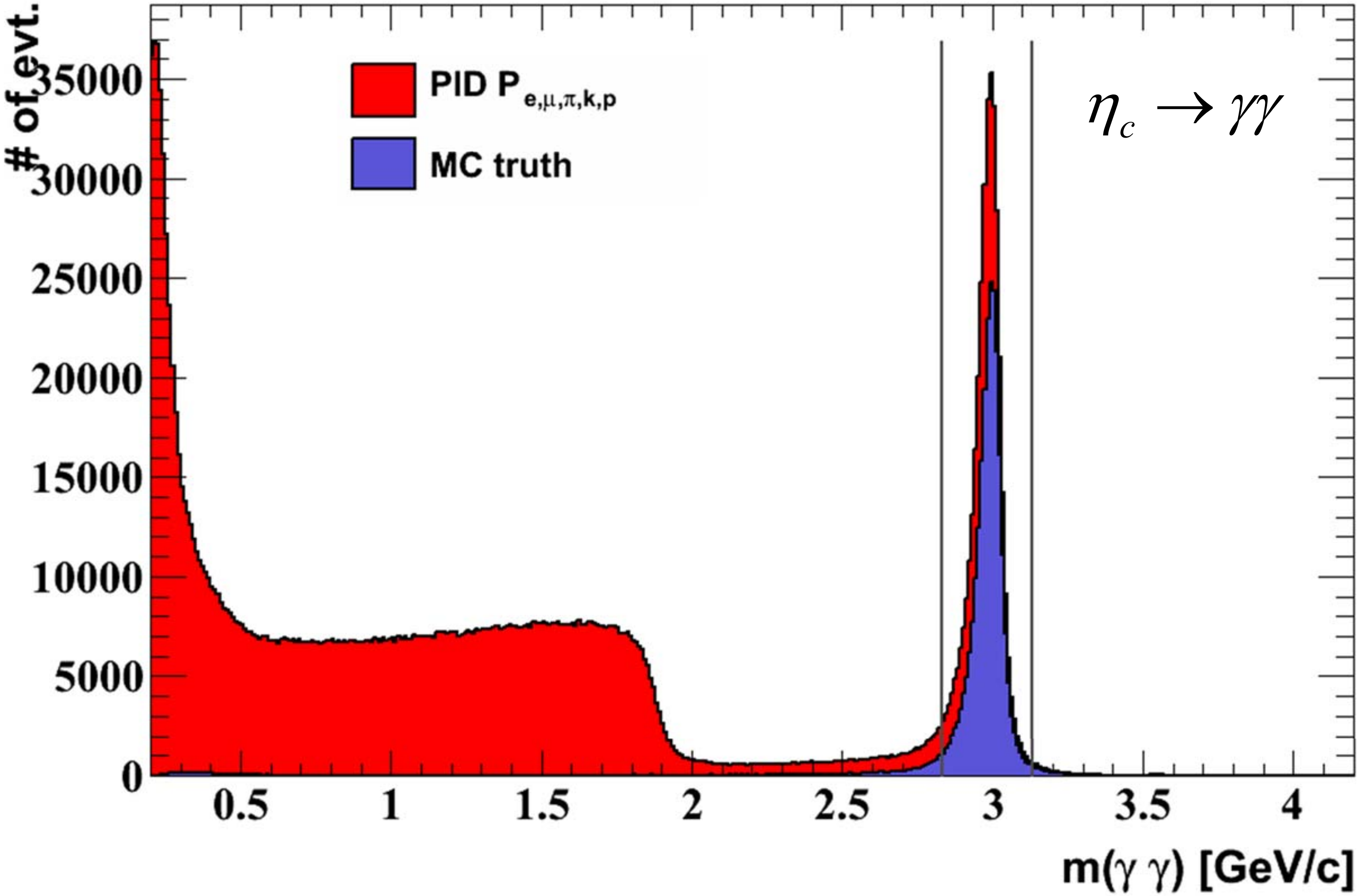


$\bar{p}p \to \overline{\Lambda}_c\Lambda_c \to \bar{p}K^+\pi^- pK^-\pi^+ @ \sqrt{s} = 5.474\,\mathrm{GeV/c}$



MC simulation η_c

$$\bar{p}p \to h_c(3526) \to \eta_c\gamma \to \gamma\gamma\gamma$$

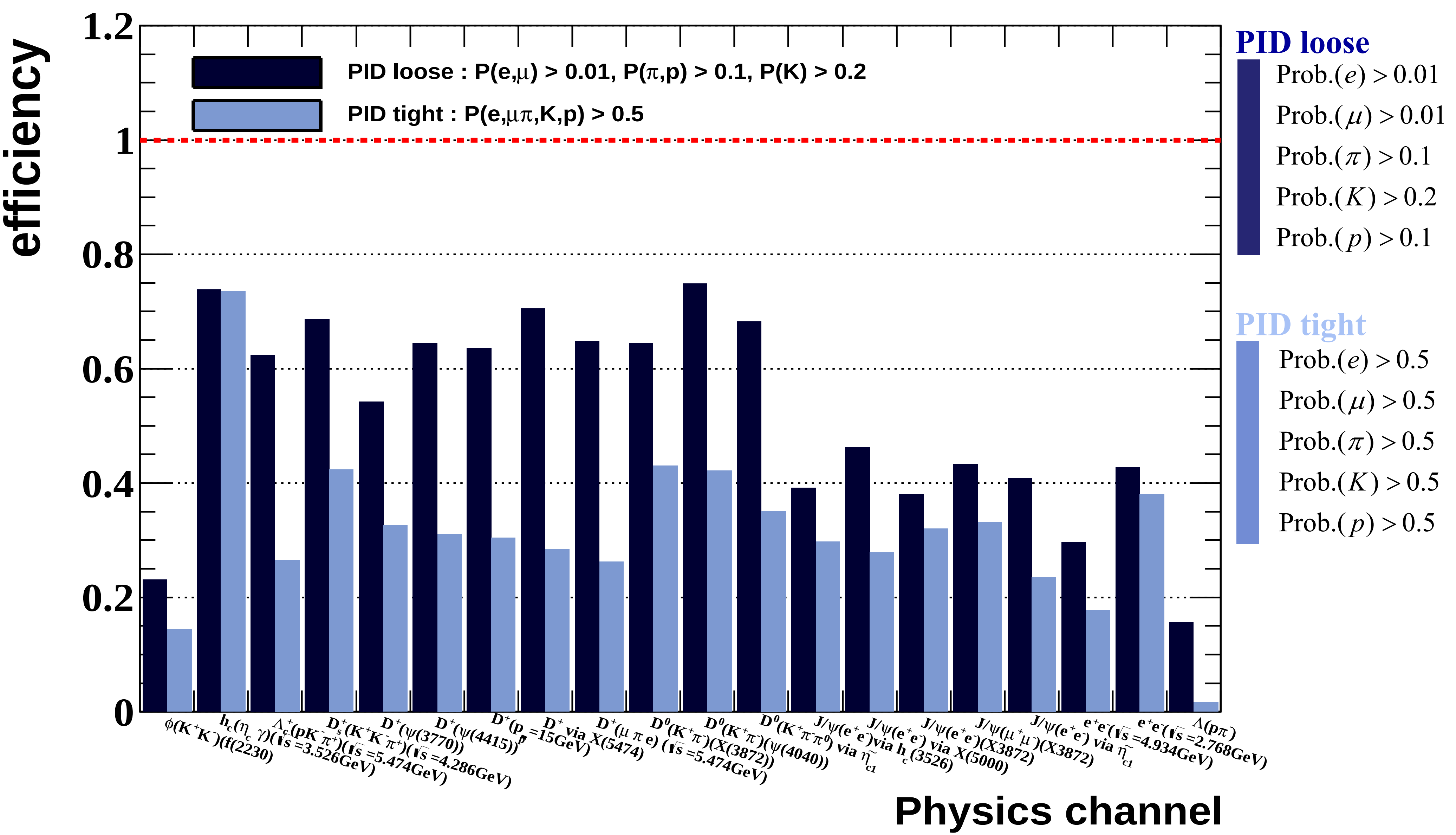


$E_{EMC} > 10$ MeV for γ candidates

Blue distribution : MC truth matched reconstructed η_c mass

Red distribution : reconstructed η_c from the combination of all neutral candidates

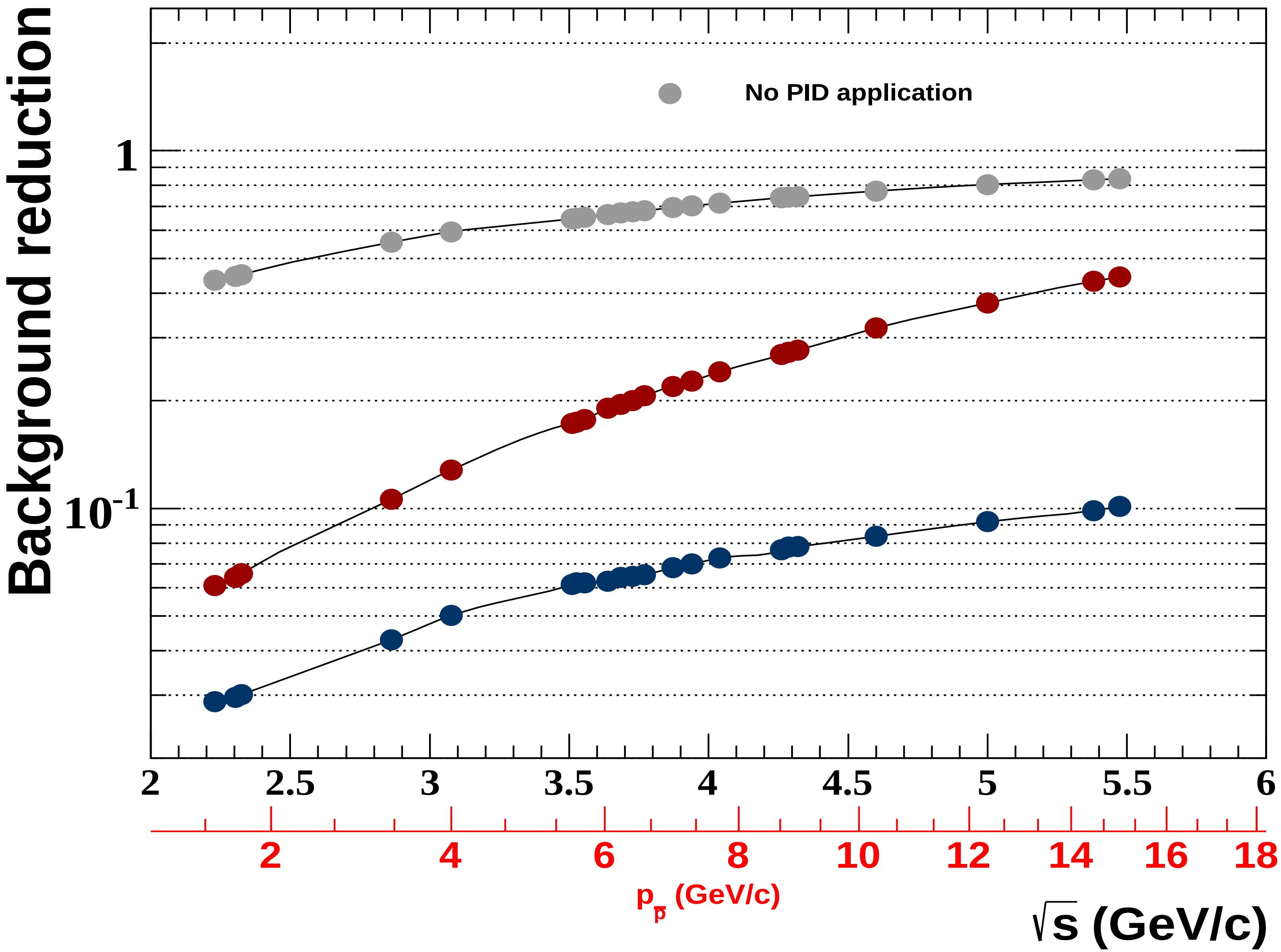
Physics trigger efficiency



$$\varepsilon = \frac{N_{rec.event,MC}}{N_{gen.event,MC}}$$

$N_{rec.event,MC}$ is the number of selected signal event accepted by one of 15 algorithms

Background reduction



No PID

PID loose

Prob.$(e) > 0.01$

Prob.$(\mu) > 0.01$

Prob.$(\pi) > 0.1$

Prob.$(K) > 0.2$

Prob.$(p) > 0.1$

PID tight

Prob.$(e) > 0.5$

Prob.$(\mu) > 0.5$

Prob.$(\pi) > 0.5$

Prob.$(K) > 0.5$

Prob.$(p) > 0.5$

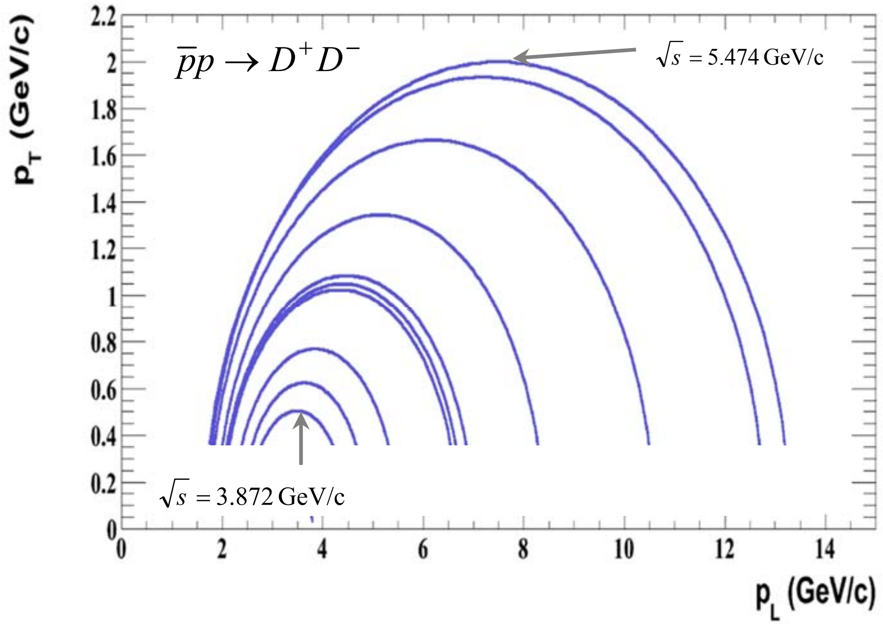
$$\eta = \frac{N_{rec.event,MC}}{N_{gen.event,MC}}$$

$N_{rec.event,MC}$ is the number of background event accepted by one of 15 algorithms

p_T application

- p_T threshold of the open charm production

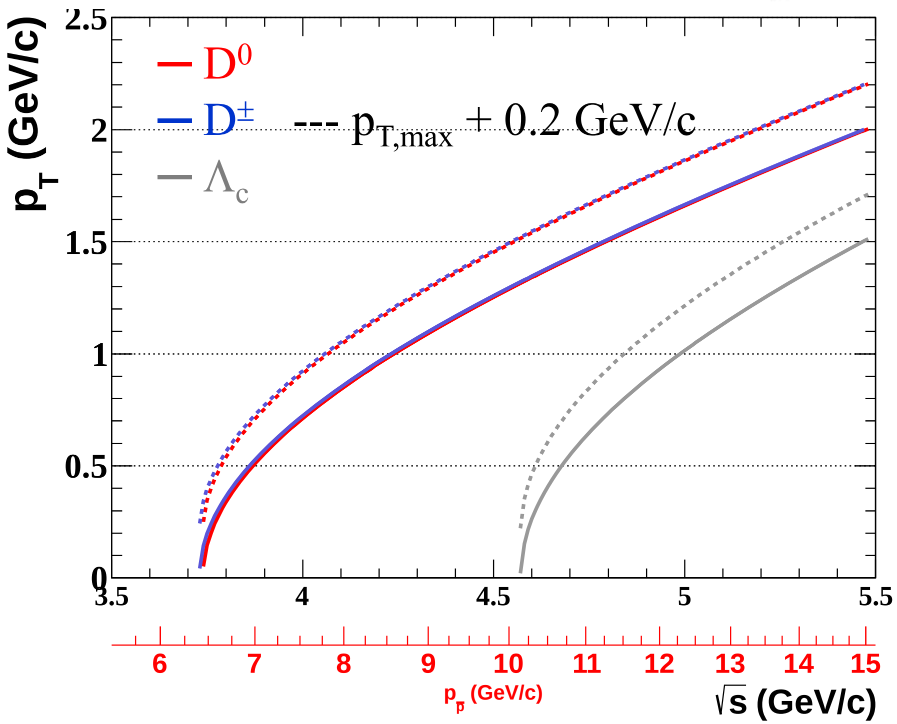
$$\bar{p}p \rightarrow D^0 \overline{D}^0$$
$$\bar{p}p \rightarrow D^+ D^-$$
$$\bar{p}p \rightarrow \Lambda_c \overline{\Lambda}_c$$



- p_T distribution :

$$p_T^{\max}(\sqrt{s};m) = \frac{\sqrt{s^2 - 4\cdot s\cdot m^2}}{2\sqrt{s}}$$

where m = mass of particle



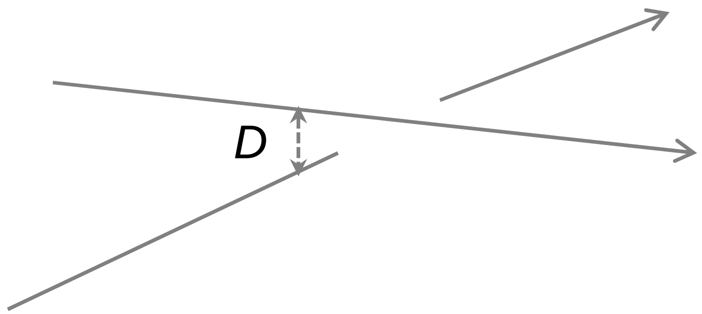
- apply the cut on p_T :

$$p_T^{\max} + 0.2(\mathrm{GeV/c}) < p_T$$

POCA application

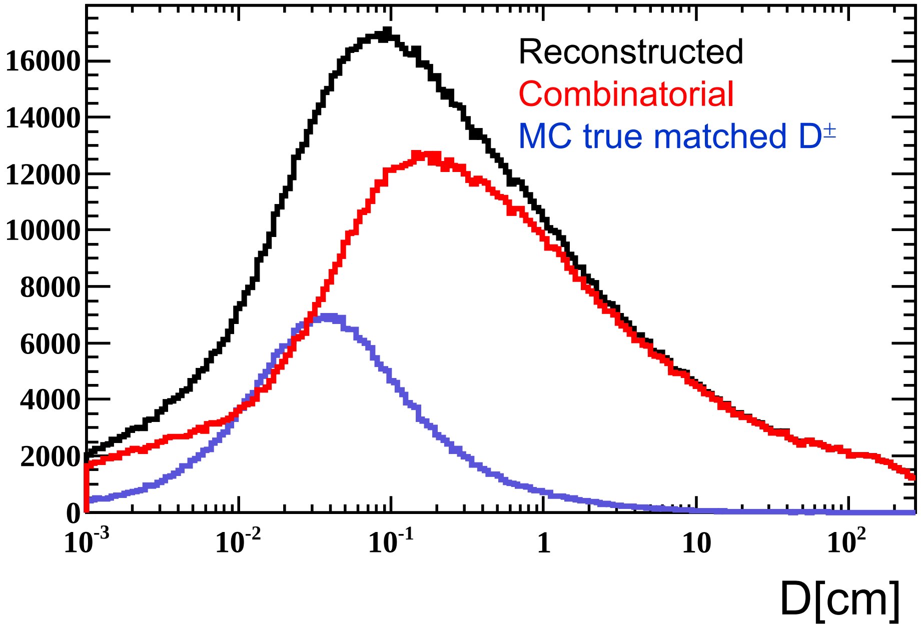
Point Of Closest Approach

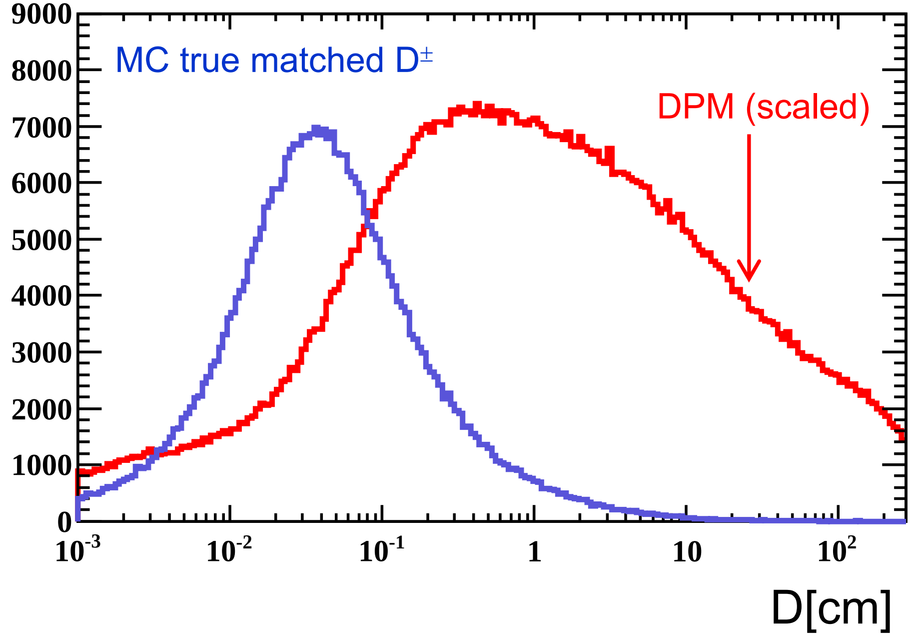
- Validity of the assumption of same origin for trajectories
- Considering two/three charged particle in a homogeneous field
- No fitting, analytical calculation of closest distance between tracks
  Output : POCA closest distance & vertex position



D = closest distance between tracks in 3 dimension

$$\bar{p}p \to D^+D^- \to K^-\pi^+\pi^+K^+\pi^-\pi^- \ @\sqrt{s} = 5.474\,\mathrm{GeV/c}$$





Closest D from POCA

Signal efficiency and background reduction after POCA cut

- starting from the event selected by mass window :

$$eff.(red.) = \frac{N_{\text{event selected by POCA}}}{N_{\text{event within the mass window}}}$$

		No PID		PID loose	
	Closest D [cm]	Siganl MC	DPM	Siganl MC	DPM
$D^{\pm}(K\pi\pi)$	1	95 %	76 %	82 %	42 %
$\Lambda_c(pK^-\pi^+)$	1	95 %	82 %	79 %	33 %
$D^0(K\pi)$	50	99 %	86 %	97 %	63 %
$D^{\pm}(\pi^{\pm}e^{\mp}\mu^{\pm})$	1	91 %	73 %	86 %	45 %
$\phi(K^+K^-)$	10	91 %	86 %	79 %	56 %

not possible to use for the decay $D_s(\phi\pi)$ & $D^0(K\pi\pi^0)$
due to the intermediate state such as ϕ^0 & π^0 neutral decay

Vertex finder at online

Fast/Full Vertex Fitter as an online vertex finder

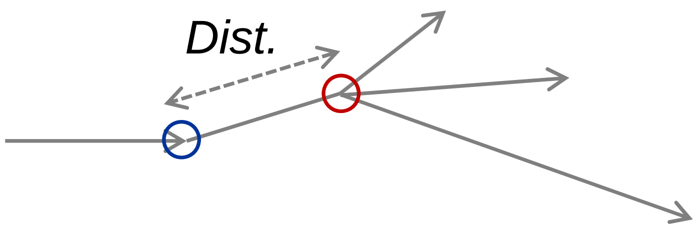
- based on the Billoir's method
- track parameterization by perigee description $(p,V)_i \rightarrow (\varepsilon, z_p, \theta, \varphi_p, \rho)_i$

ϵ	–	signed distance of the perigee point to the z axis
z_p	–	z position of the perigee point
θ	–	polar angle of the particle momentum
ϕ_p	–	azimutal angle of the particle momentum at the perigee point
ρ	–	circular curvature in the x–y plane, radius $R_c = 1/\lvert\rho\rvert$

- (5X5)n covariant matrix dimensions are reduced to 3X3 during linearization leads a fast calculation/finding of the vertex
- two approaches are available, implemented by Ralf Kleimt

Simple fitting (Fast Fitter) | Extended fitting (Full Fitter)

- distance between interaction point and decay vertex

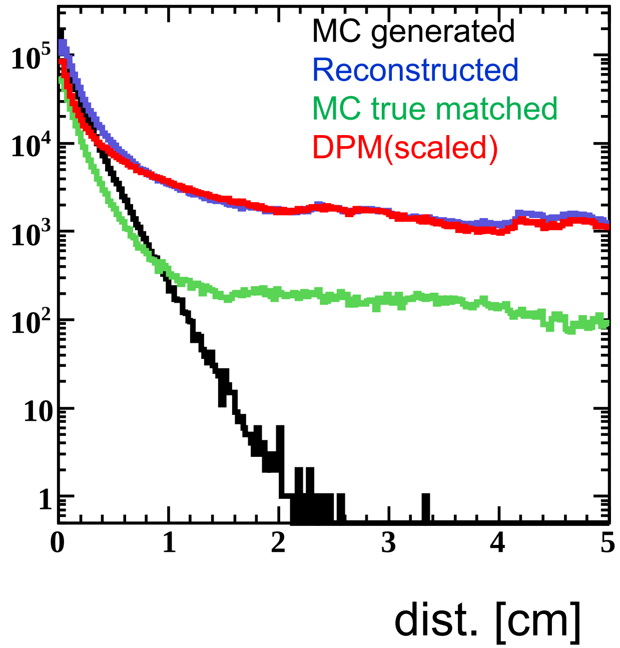


Vertex cut by distance

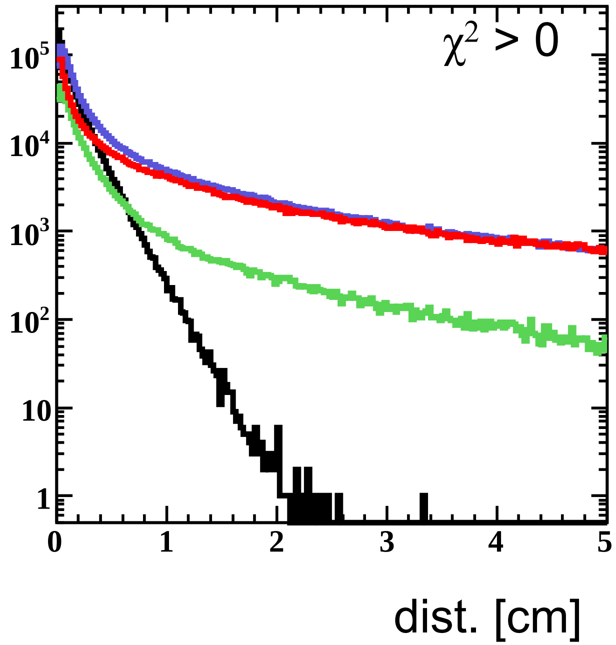
$$\bar{p}p \to D^+D^- \to K^-\pi^+\pi^+K^+\pi^-\pi^- \ @\sqrt{s} = 5.474\,\mathrm{GeV/c}$$

distribution with **linear** scale at x

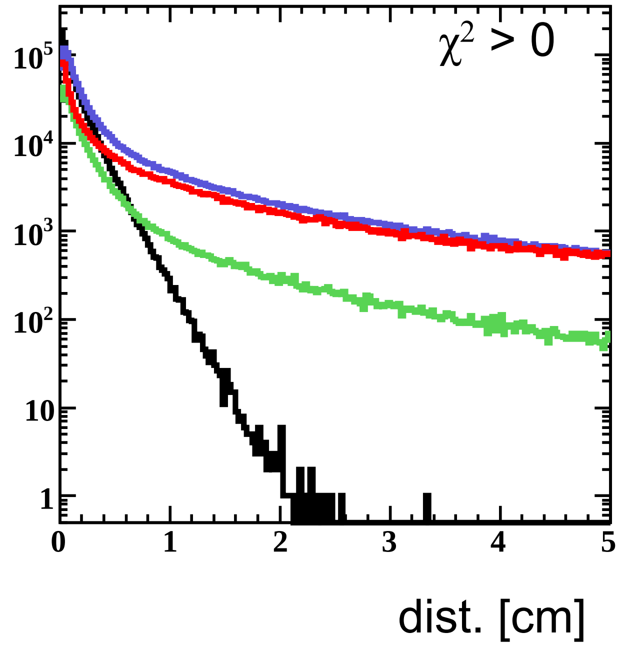
POCA

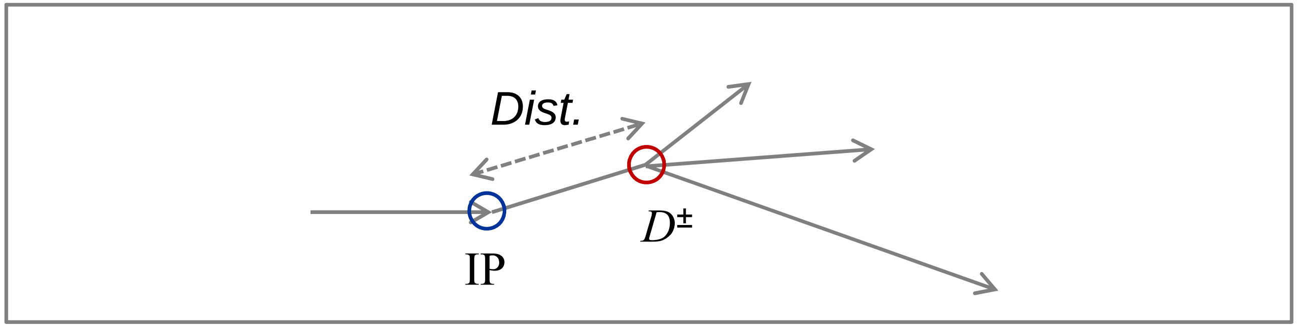


Fast Vertex



Full Vertex

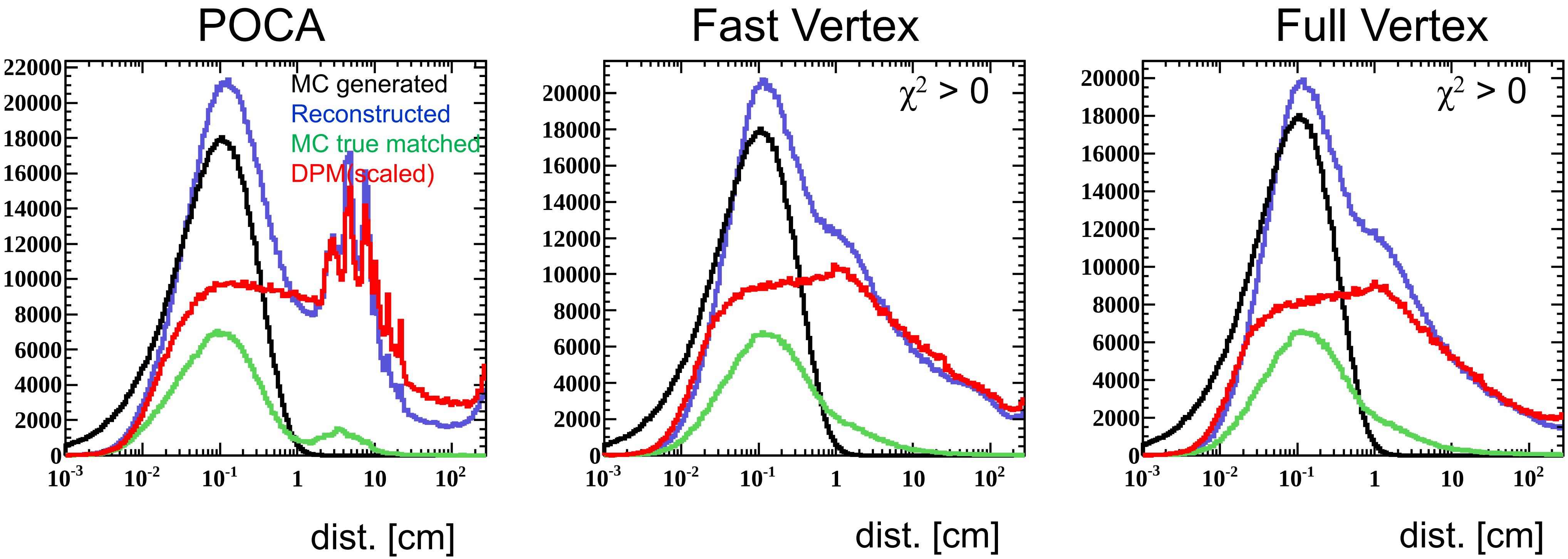


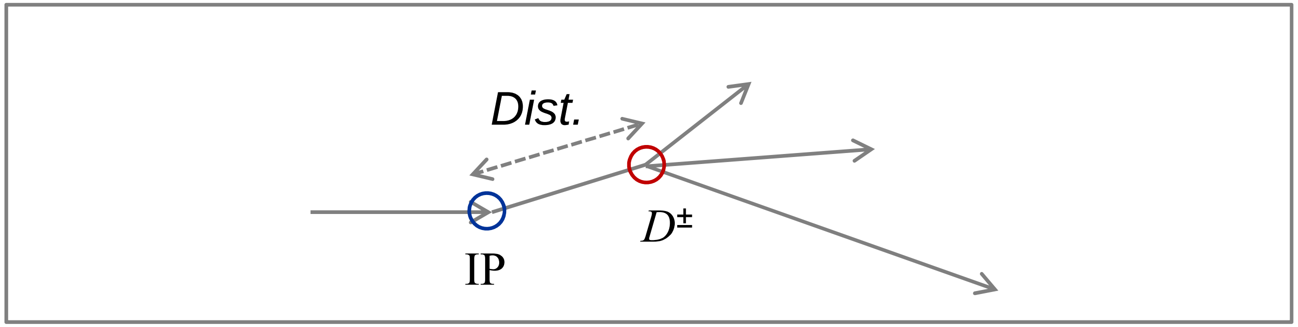


Vertex cut by distance

$$\bar{p}p \rightarrow D^+D^- \rightarrow K^-\pi^+\pi^+K^+\pi^-\pi^- \; @\sqrt{s} = 5.474\,\mathrm{GeV/c}$$

distribution with **logarithmic** scale at x





Preliminary vertex cut

Preliminary cuts on the vertex finding for the online application

	POCA	Fast Vertex Finding	Full Vertex Fitter
	Closest D [cm]	Distance D [cm] $0 < \chi^2 < 200$	Distance D [cm] $0 < \chi^2$
$D^{\pm}(K\pi\pi)$	1	1	1
$\Lambda_c(pK^-\pi^+)$	1	5	5
$\phi(K^+K^-)$	10	2	2
$D^0(K\pi)$	50	1	1
$D^{\pm}(\pi^{\pm}e^{\mp}\mu^{\pm})$	1	1	1

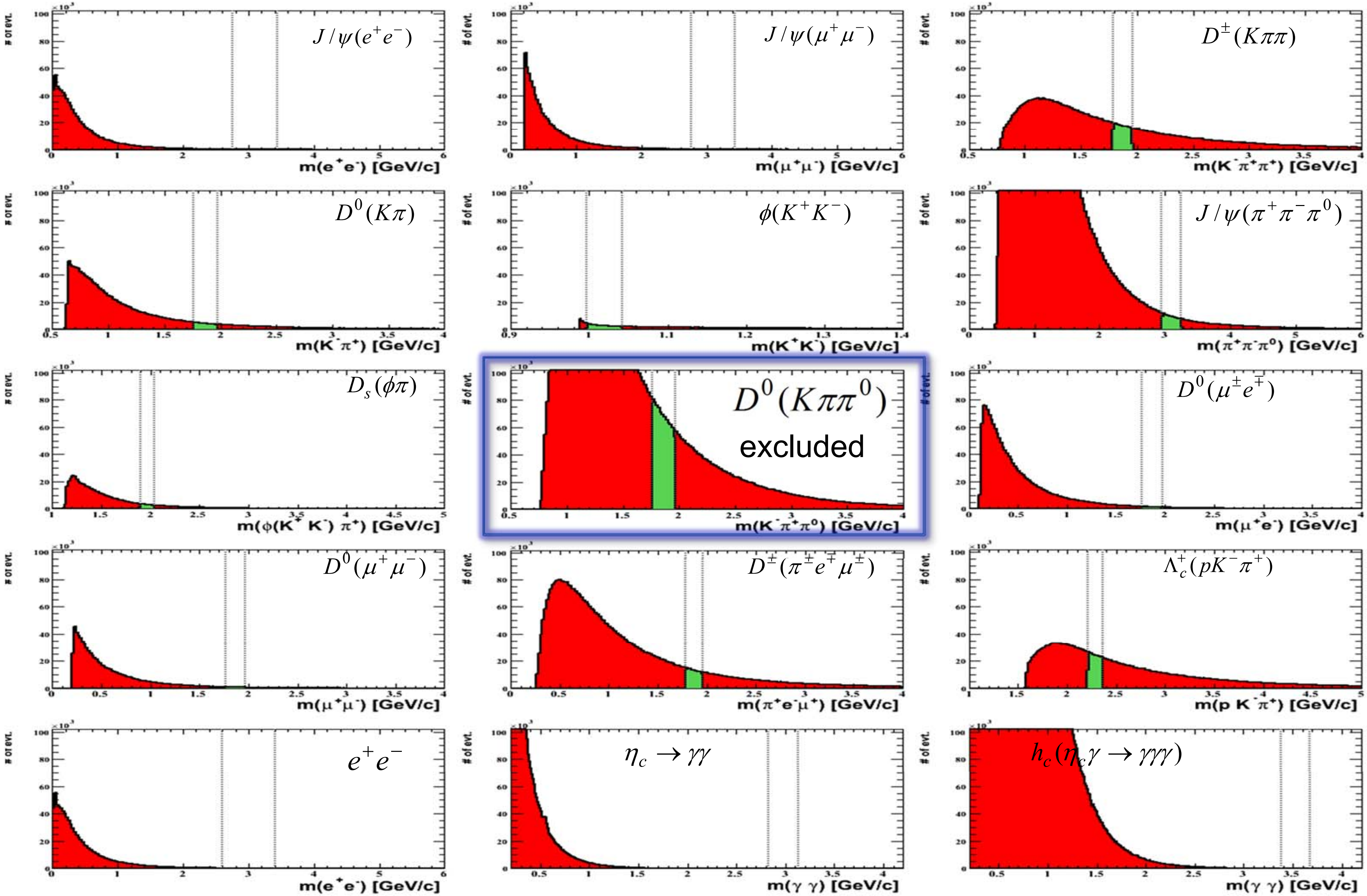
- will be optimized values of closest D and distance D for each section

- other parameters like minimum D and/or vertex χ^2 can also be applied

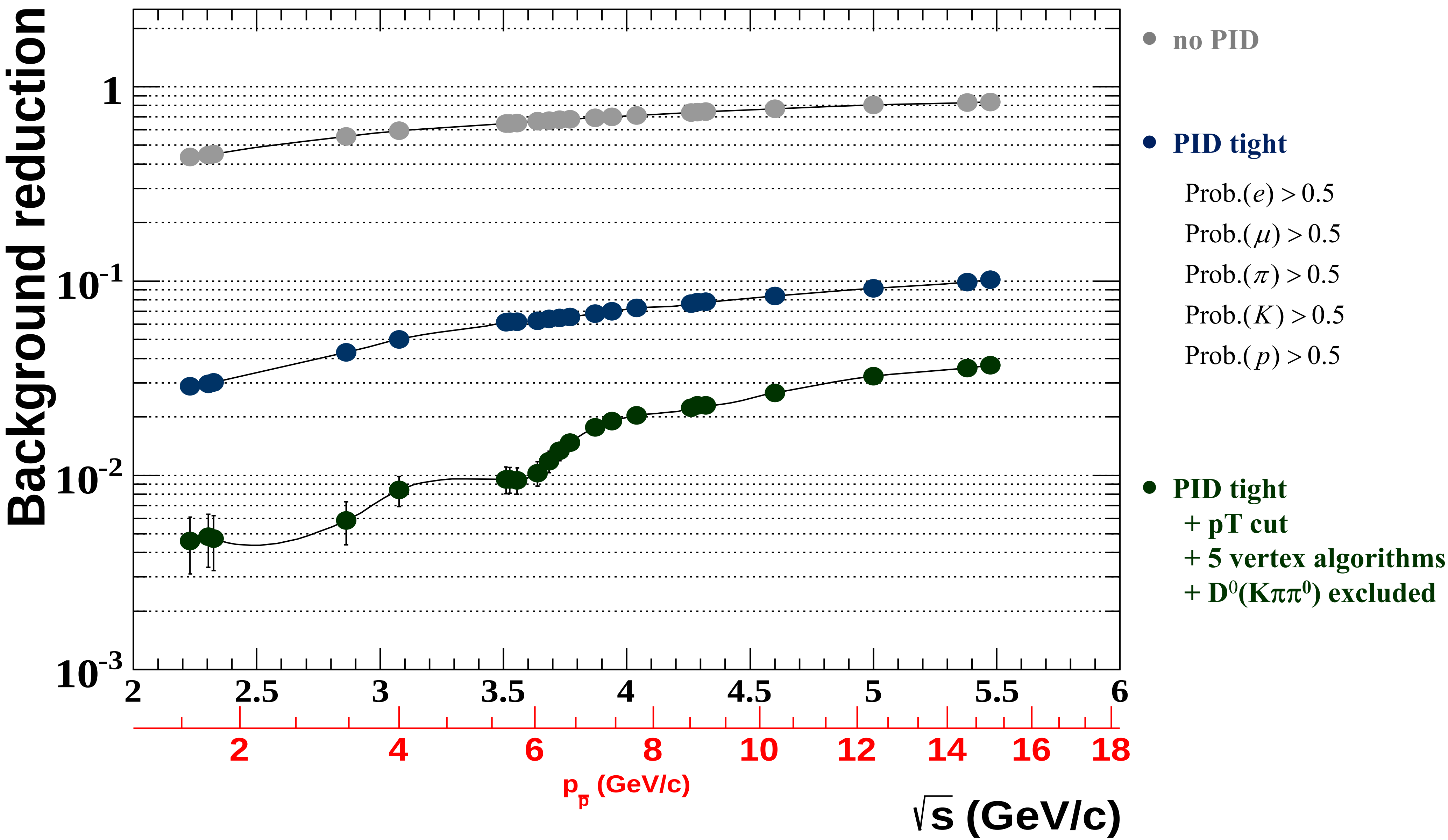
- for full vertex fitter, χ^2 values are too small, have to be checked

DPM background

Selection for DPM data @ $\sqrt{s} = 5.474\,\mathrm{GeV/c}$ normalized! selected



Background reduction



$$\eta = \frac{N_{rec.event,MC}}{N_{gen.event,MC}}$$

$N_{rec.event,MC}$ is the number of background event accepted by one of 14 algorithms

Summary & Outlook

Some studies have been done …

• at present 14 selection algorithms with kinematic cuts in the full chain MC simulation

background reduction ~ 0.004 @ 1.5 GeV/c & 0.04 @ 15GeV/c

• POCA and Fast Vertex Finder can basically be used in the online trigger

• p_T cut for $D^{\pm}$, D^0 and Λ_c (open charm production)

• $D^0 \rightarrow K\pi\pi^0$ selection is temporally excluded, necessary a vertex finder for neutral decay

Next step …

• new MC production for inclusive production

$$\bar{p}p \rightarrow D^{+}D^{-} \rightarrow K\pi\pi + Any, \text{ etc...}$$

• study on the event shape variables using the data from new production

• test of background reduction with new track reconstruction code

Backup

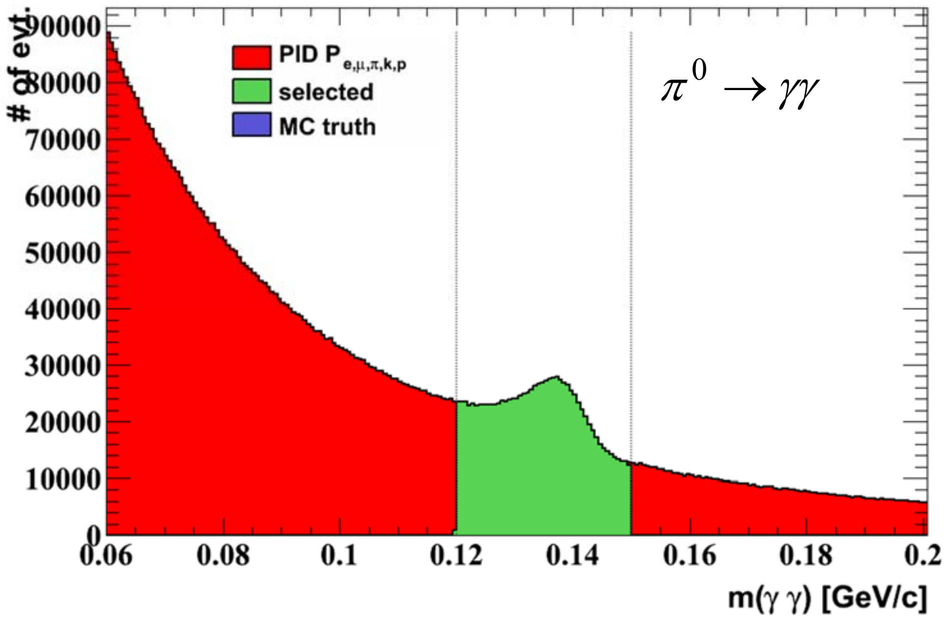
π^0 selection

- wide mass window for π^0

  Δm_π=0.13498 ± 0.015 GeV

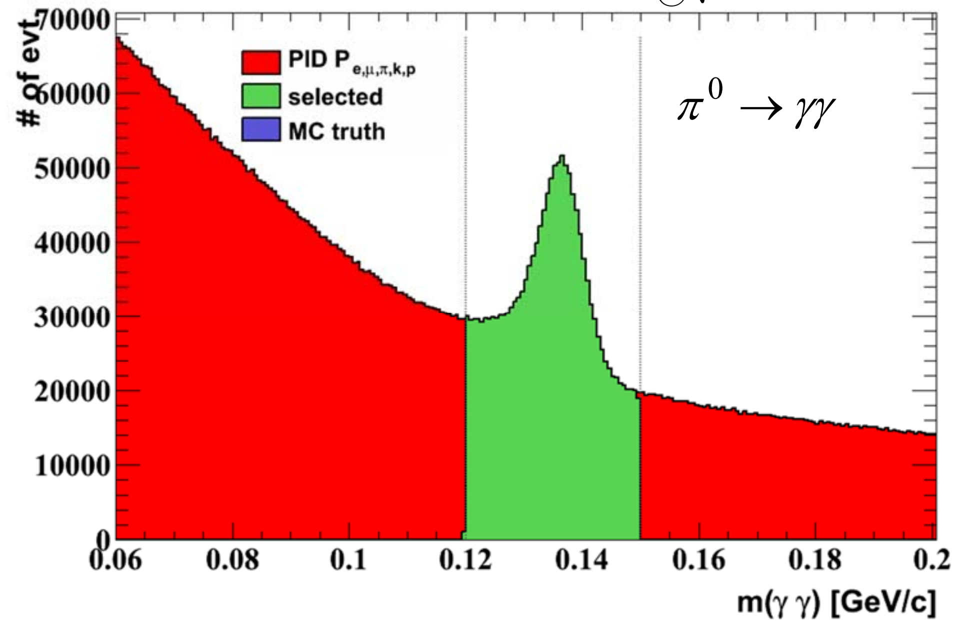
- at this moment, no MC true matched info about γ i.e., neutral candidates

$\bar{p}p \to X(3872) \to \bar{D}^{*0}D^0 \to \bar{D}^0\pi^0 D^0 \to K^-\pi^+K^+\pi^-\gamma\gamma$



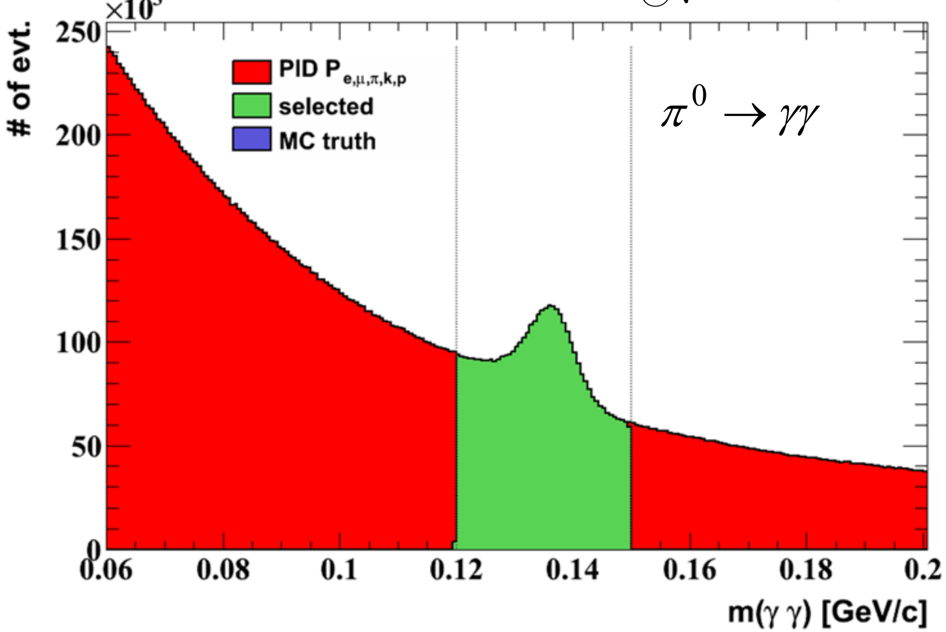
$\bar{p}p \to \tilde{\eta}_{c1}\eta \to \chi_{c1}\eta\pi^0\pi^0 \to J/\psi\gamma\eta\pi^0\pi^0 \to e^+e^-\gamma\gamma\gamma\gamma\gamma\gamma$

$@\sqrt{s} = 5.380\text{GeV}$



$\bar{p}p \to \tilde{\eta}_{c1}\eta \to \bar{D}^{*0}D^0\eta \to \bar{D}^0\pi^0 D^0\eta \to K^-\pi^+\pi^0K^+\pi^-\pi^0\pi^0\eta$

$@\sqrt{s} = 5.380\text{GeV}$



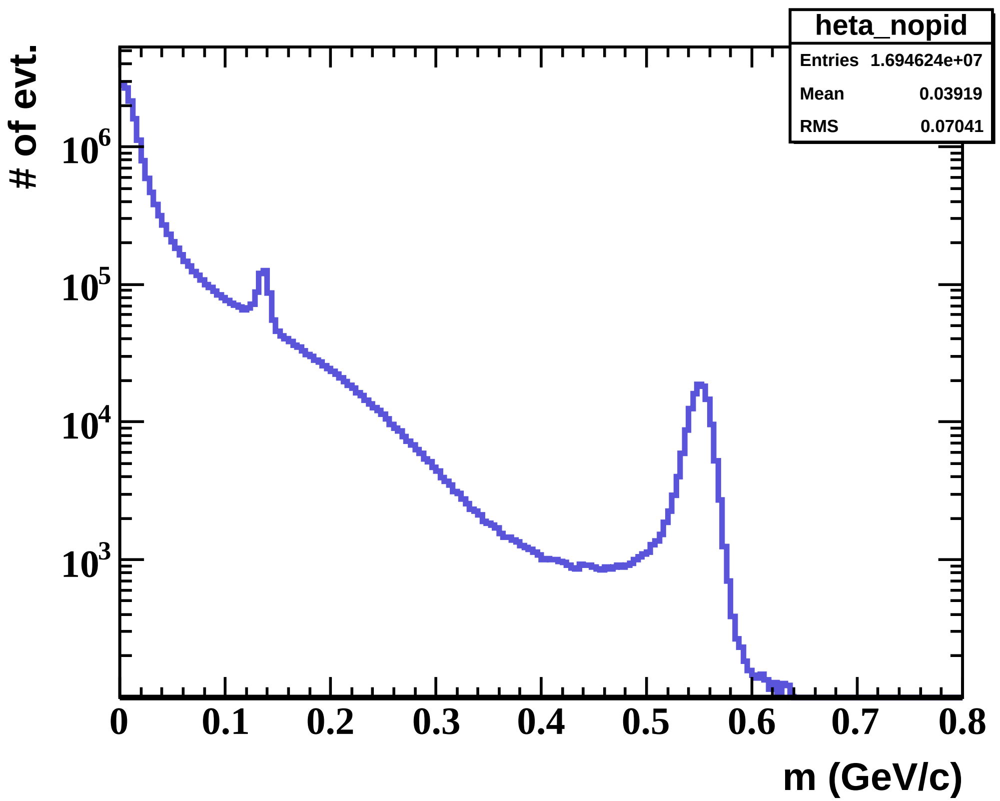
η selection

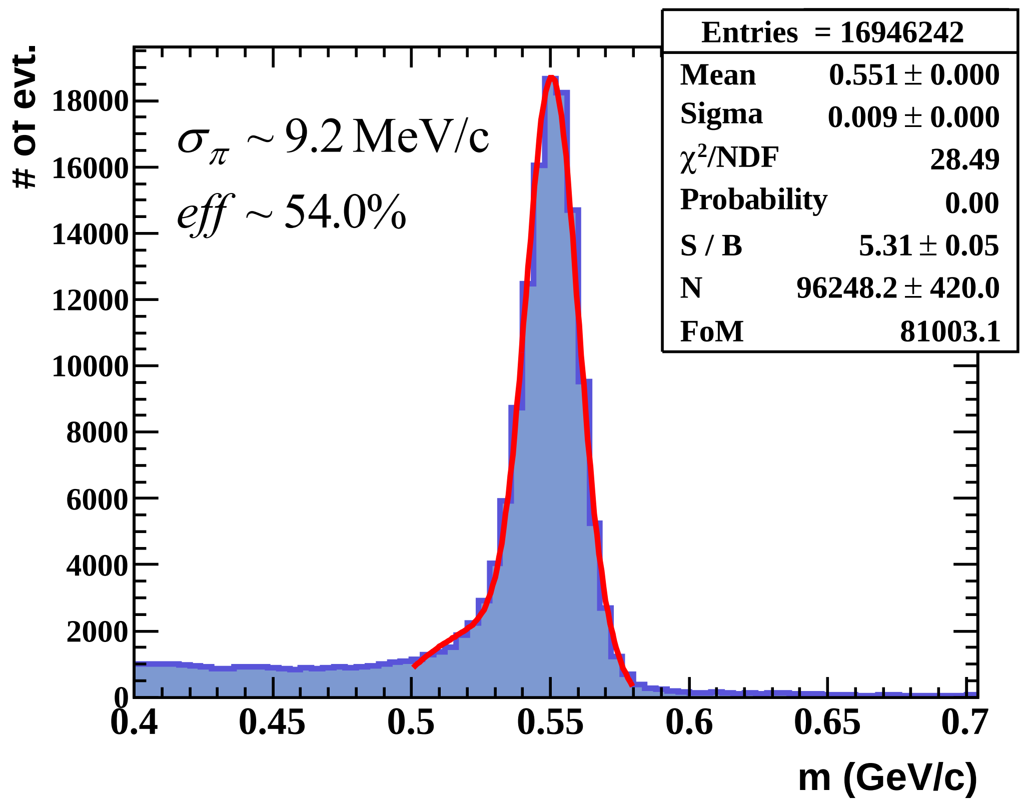
Study on $\eta \to \gamma\gamma$ 0.453M events in the full simulation

$$0.2 < p < 5.0\,(\mathrm{GeV/c})\ ;\ 1^\circ < \theta < 148^\circ$$

neutral track combinations without cut on E_{emc} > 10 MeV

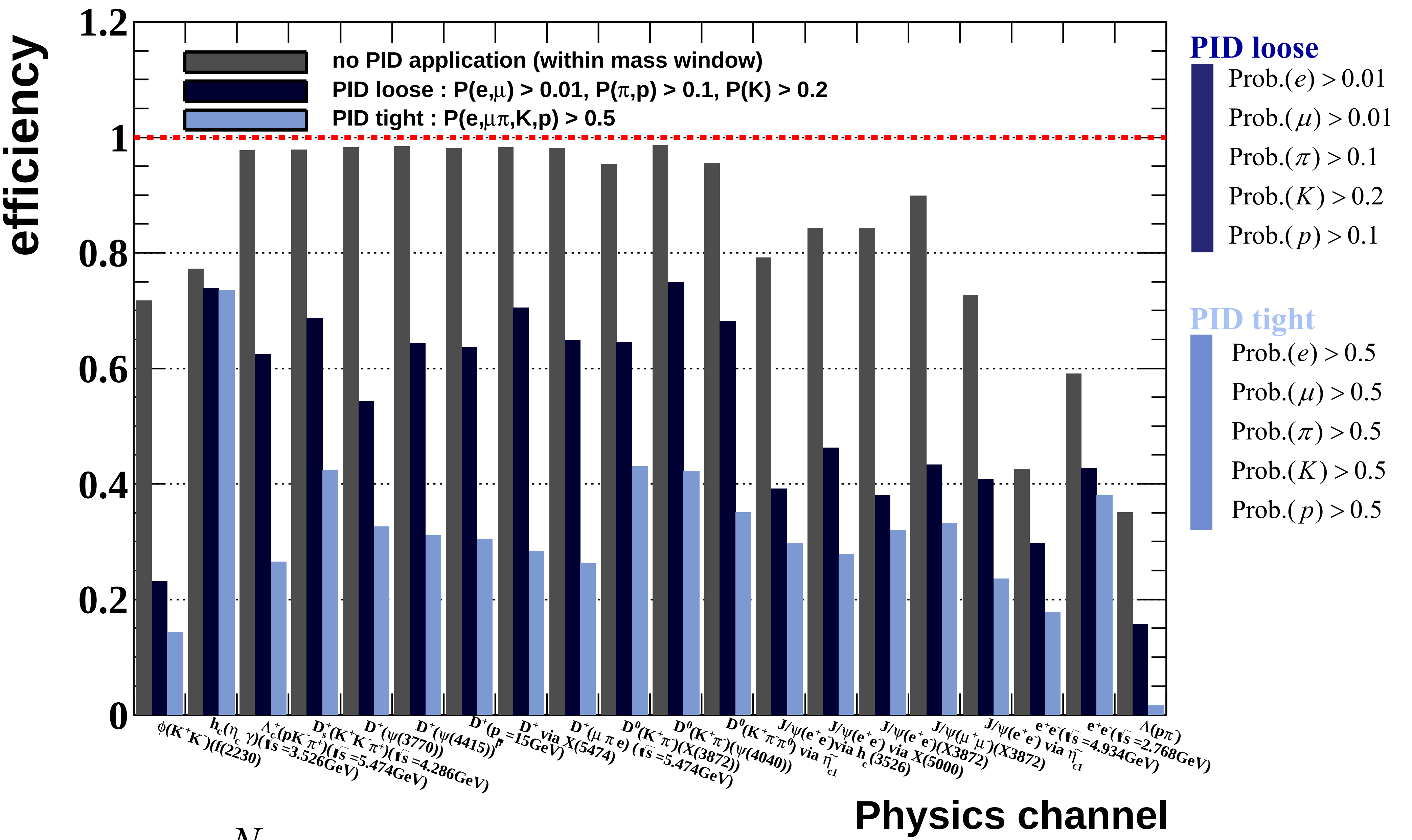
$\eta \to \gamma\gamma$	39.3%
$\eta \to \pi^0\pi^0\pi^0$	32.5%
$\eta \to \pi^+\pi^-\pi^0$	22.7%
$\eta \to \pi^+\pi^-\gamma$	4.6%





η selection is presently not used in the trigger algorithms

Physics trigger efficiency

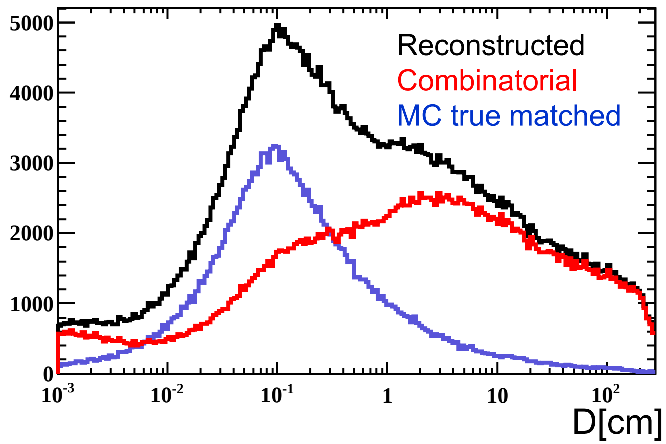


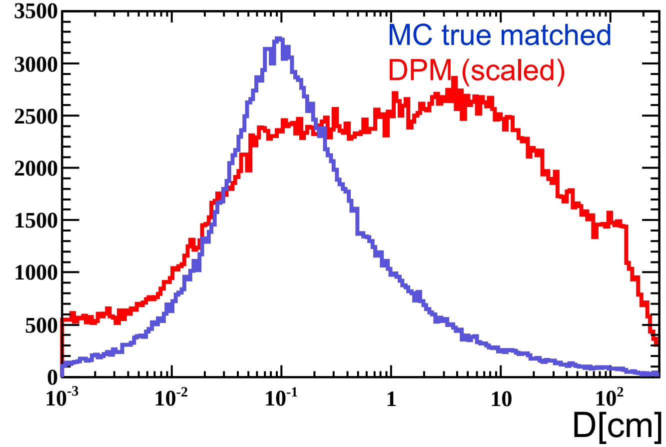
$$\varepsilon = \frac{N_{rec.event,MC}}{N_{gen.event,MC}}$$

$N_{rec.event,MC}$ is the number of selected signal event accepted by one of 15 algorithms

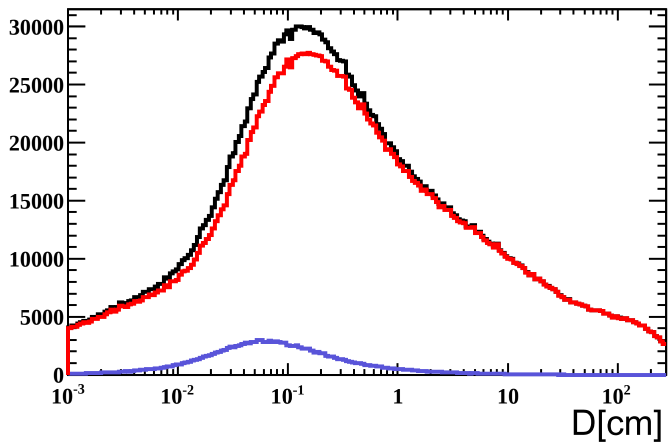
Closest D from POCA

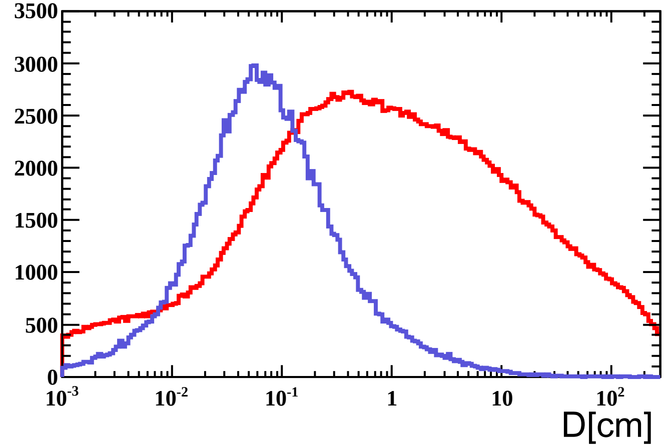
$\phi \to K^+K^-$



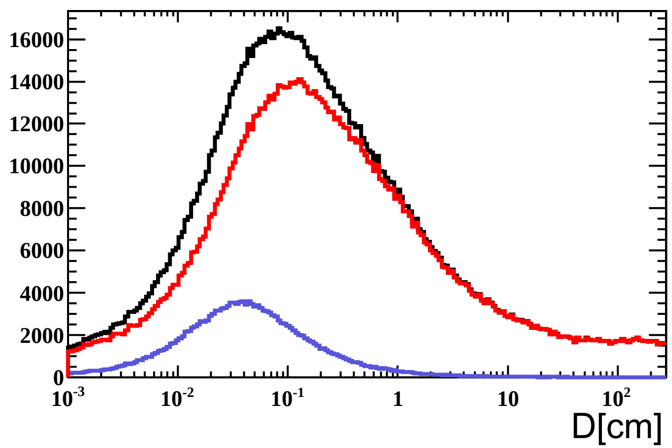


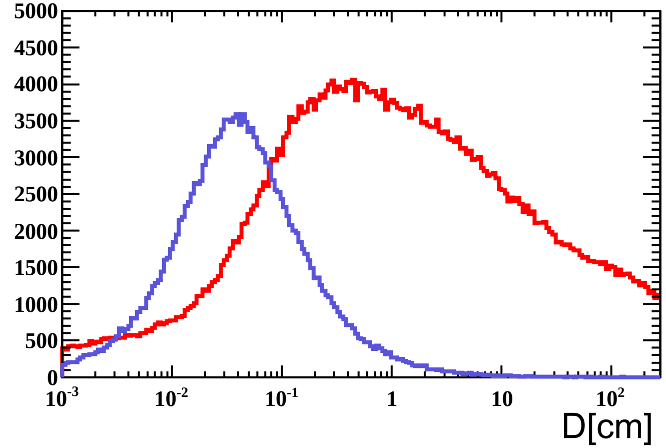
$\Lambda_c \to pK^-\pi^+$





$D^{\pm} \to \pi e \mu$

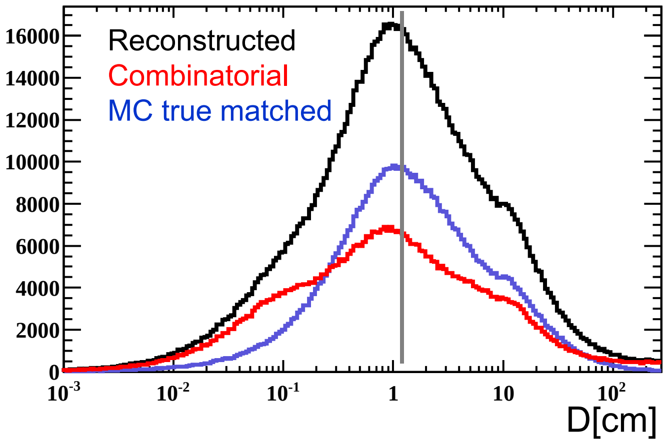


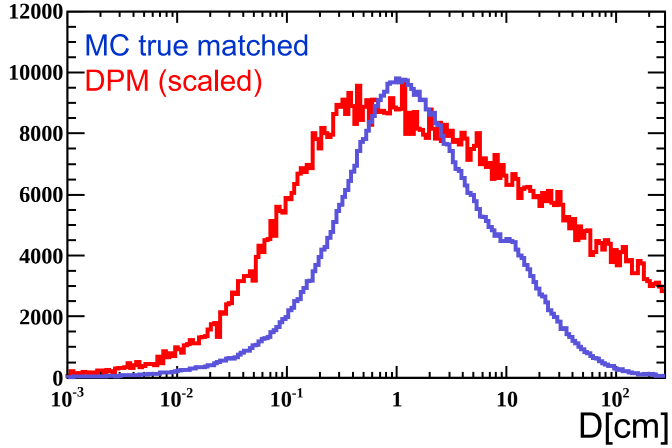


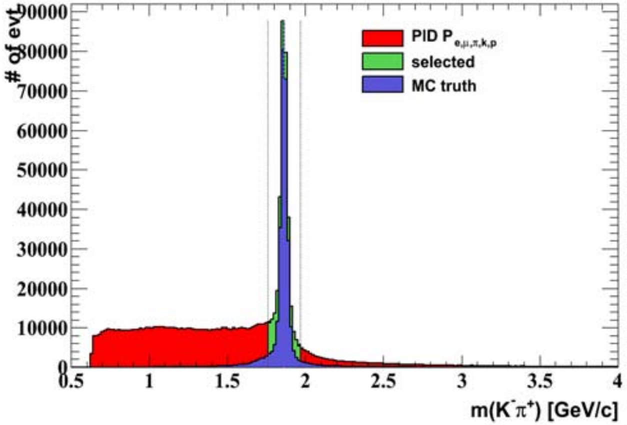
Closest D from POCA

$$D^0 \to K^-\pi^+$$

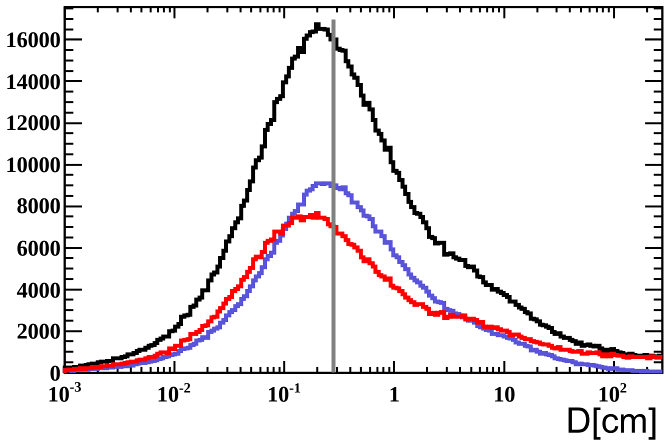
$$\bar{p}p \to X(3872) \to \overline{D}^{*0}D^0 \to \overline{D}^0\pi^0 D^0 \to K^-\pi^+K^+\pi^-\gamma\gamma$$

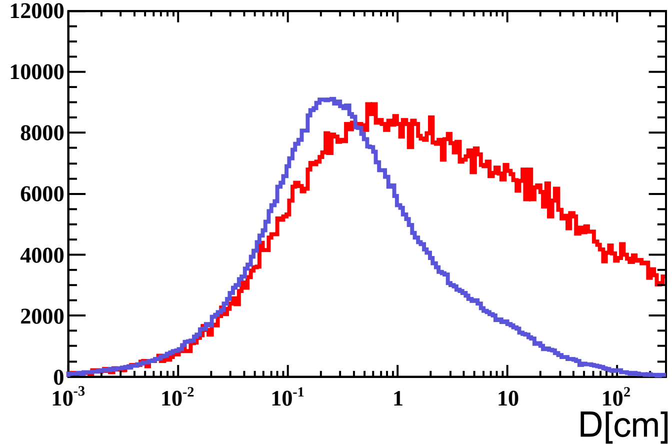


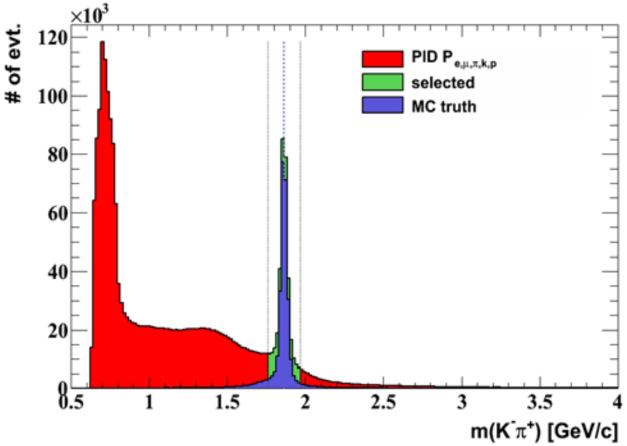




$$\bar{p}p \to \psi(4040) \to D^{*+}D^{*-} \to D^0\pi^+\overline{D}^0\pi^- \to K^-\pi^+\pi^+K^-\pi^-\pi^-$$

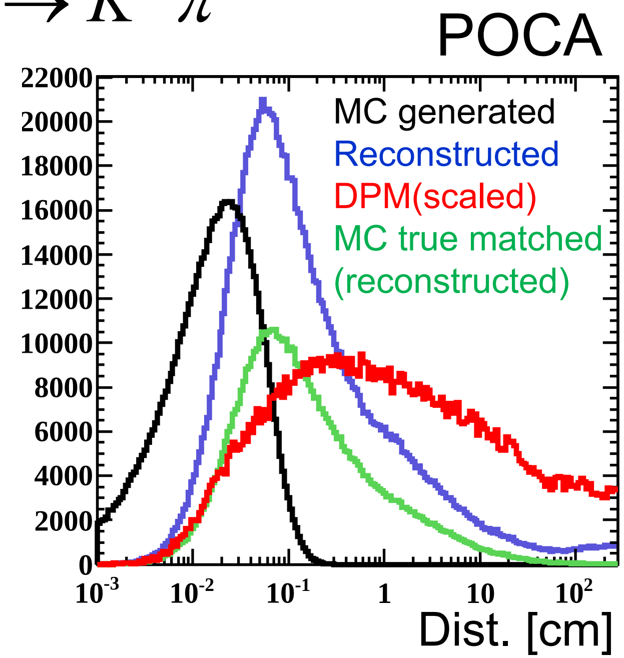


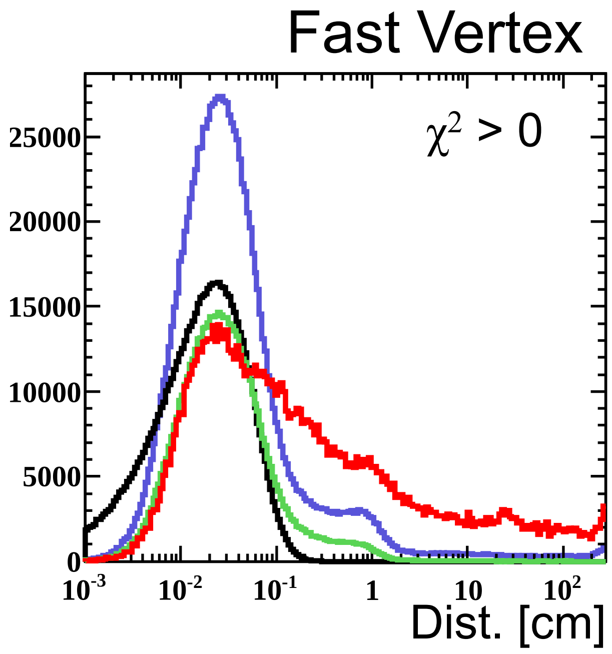


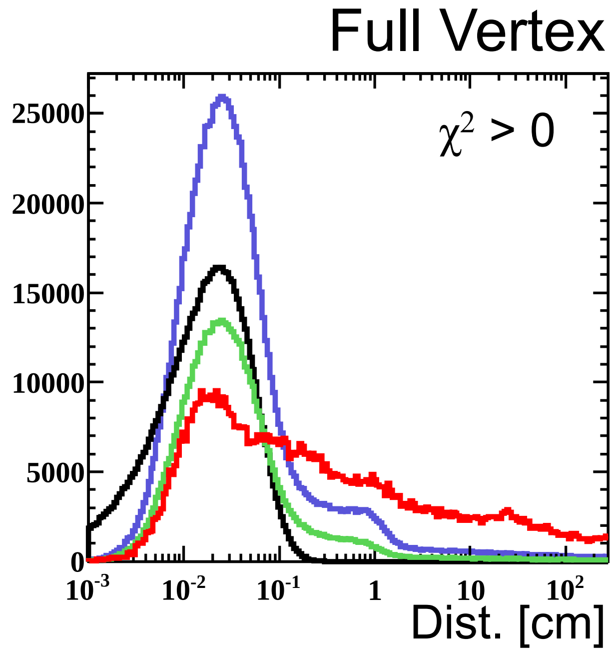


Vertex cut by distance

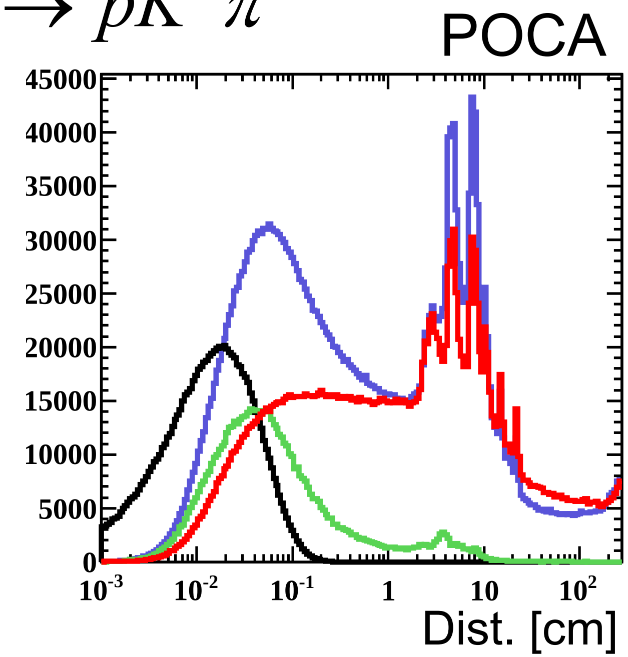
$D^0 \to K^- \pi^+$

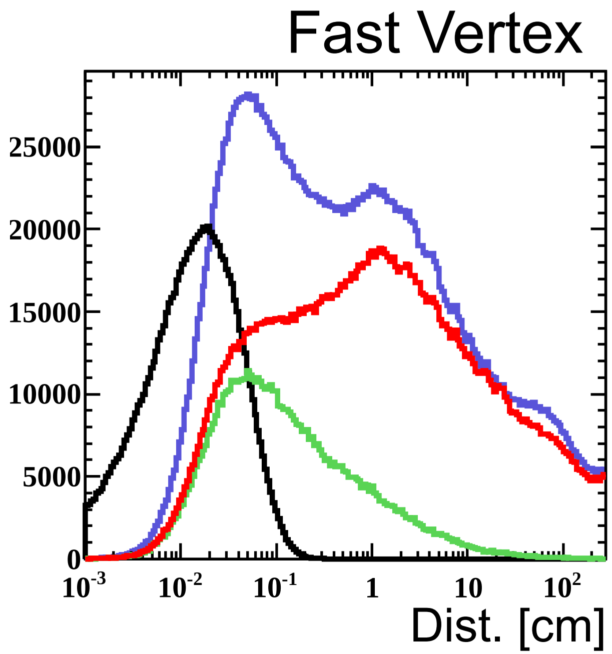


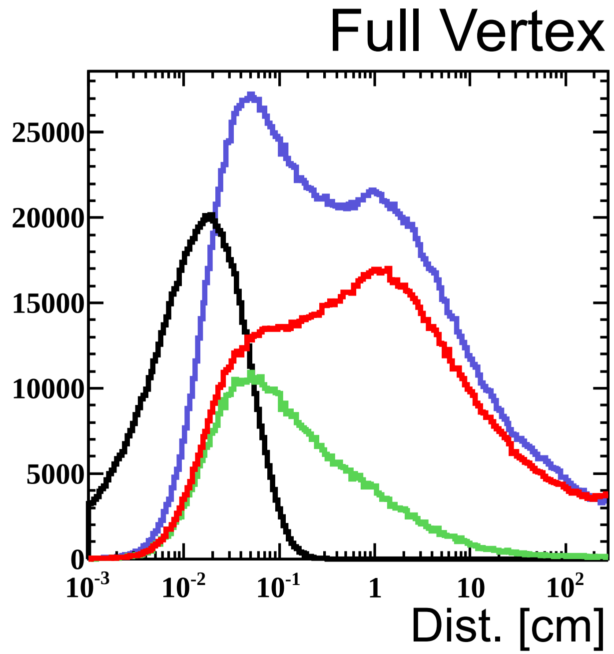




$\Lambda_c \to p K^- \pi^+$



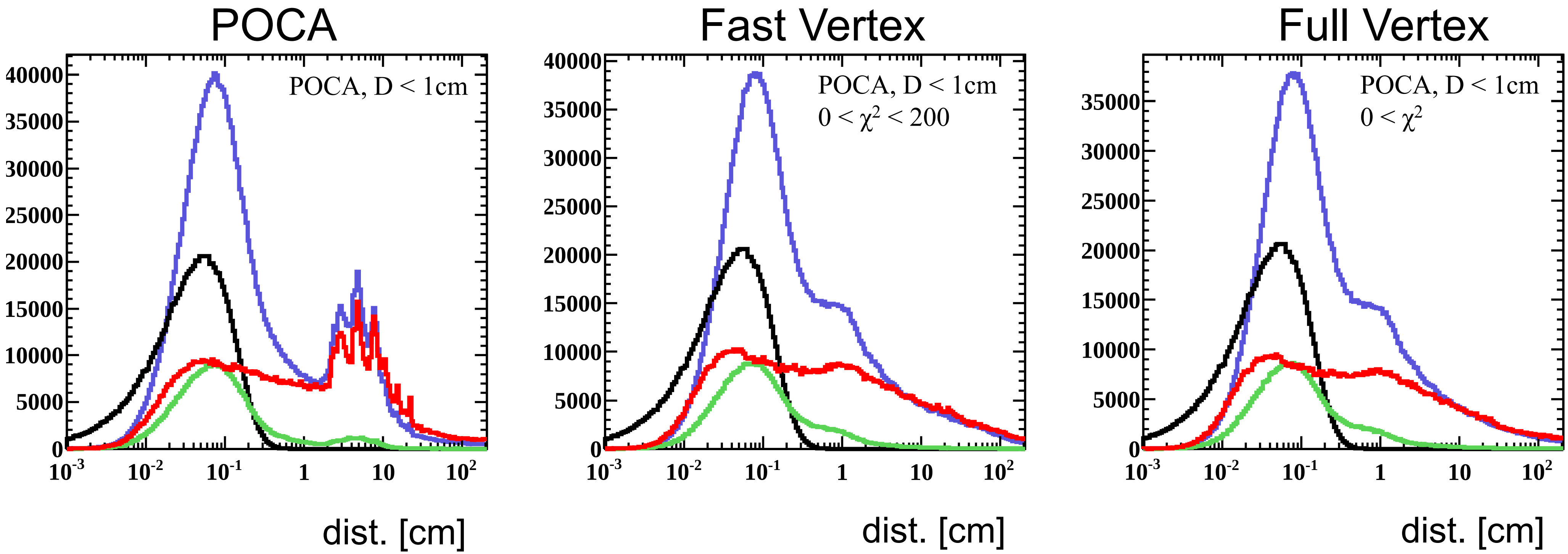


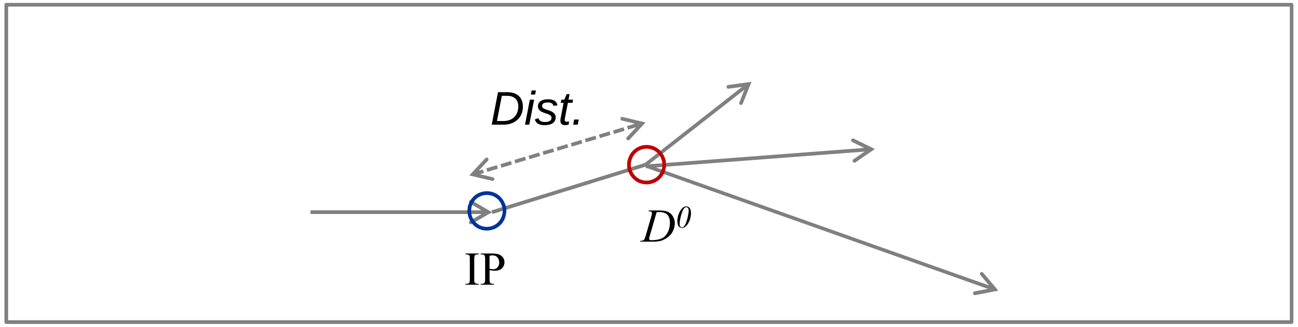


Vertex cut by distance

$$\bar{p}p \to D^+D^- \to K^-\pi^+\pi^+K^+\pi^-\pi^- \,@\sqrt{s} = 5.474\,\mathrm{GeV/c}$$

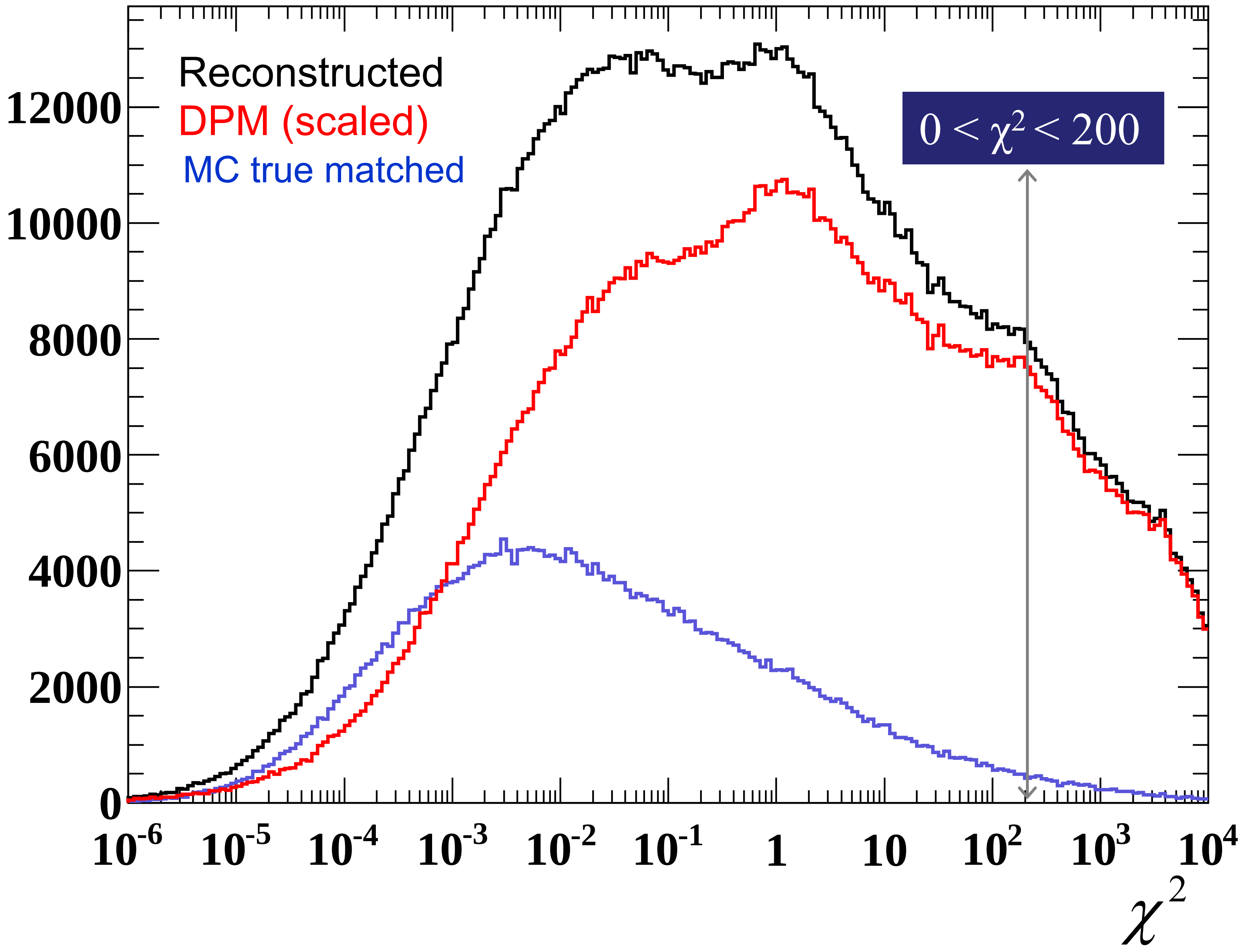
distribution with **logarithmic** scale at x





χ^2 distribution

Fast Vertex Finder for $D^{\pm}$ @ 15GeV



kinematic cut

Application of p_T cut in D selection