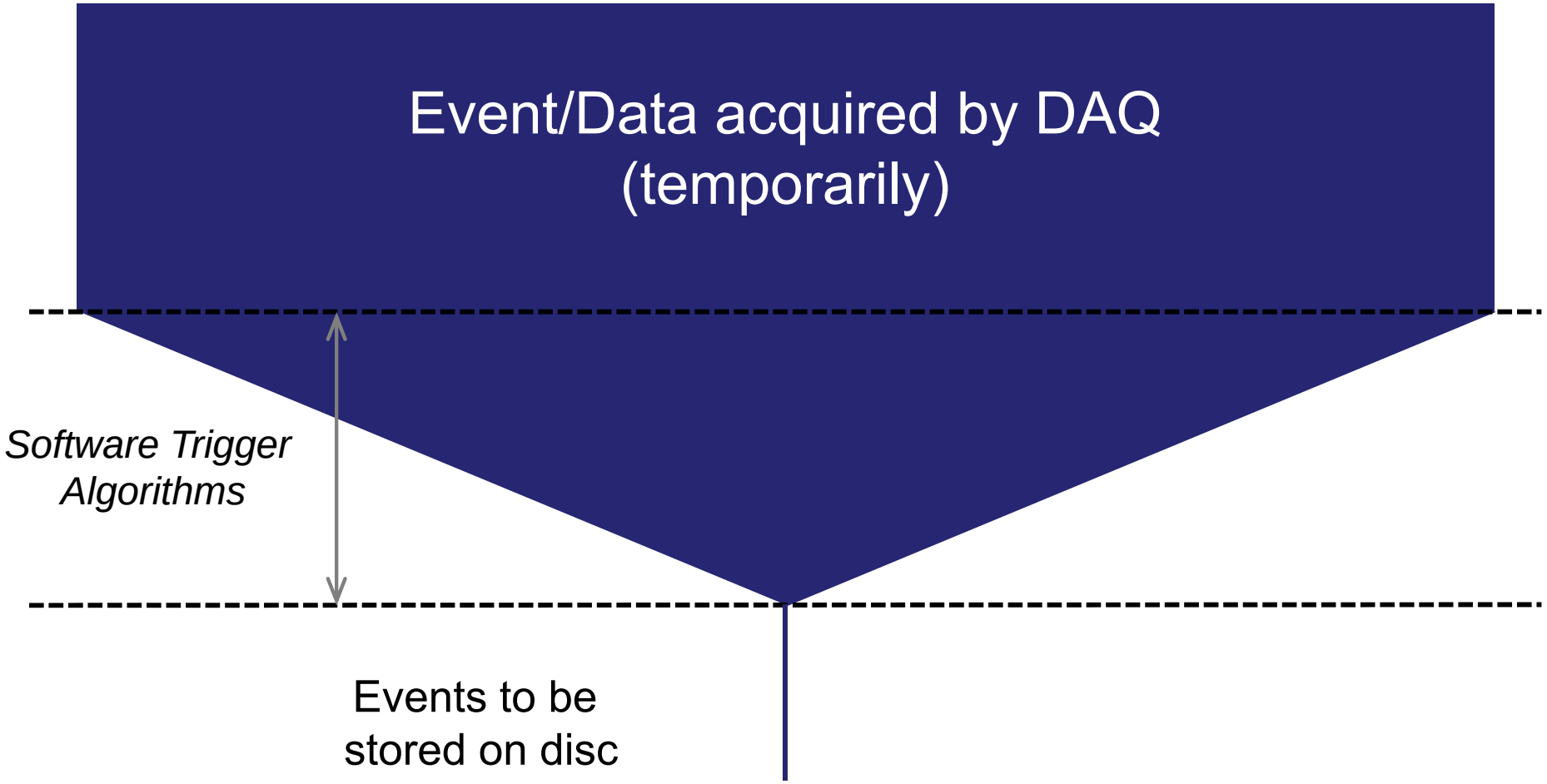
Online Software Trigger @ PANDA

Donghee Kang

Institut für Kernphysik, Universität Mainz

Challenge of online trigger

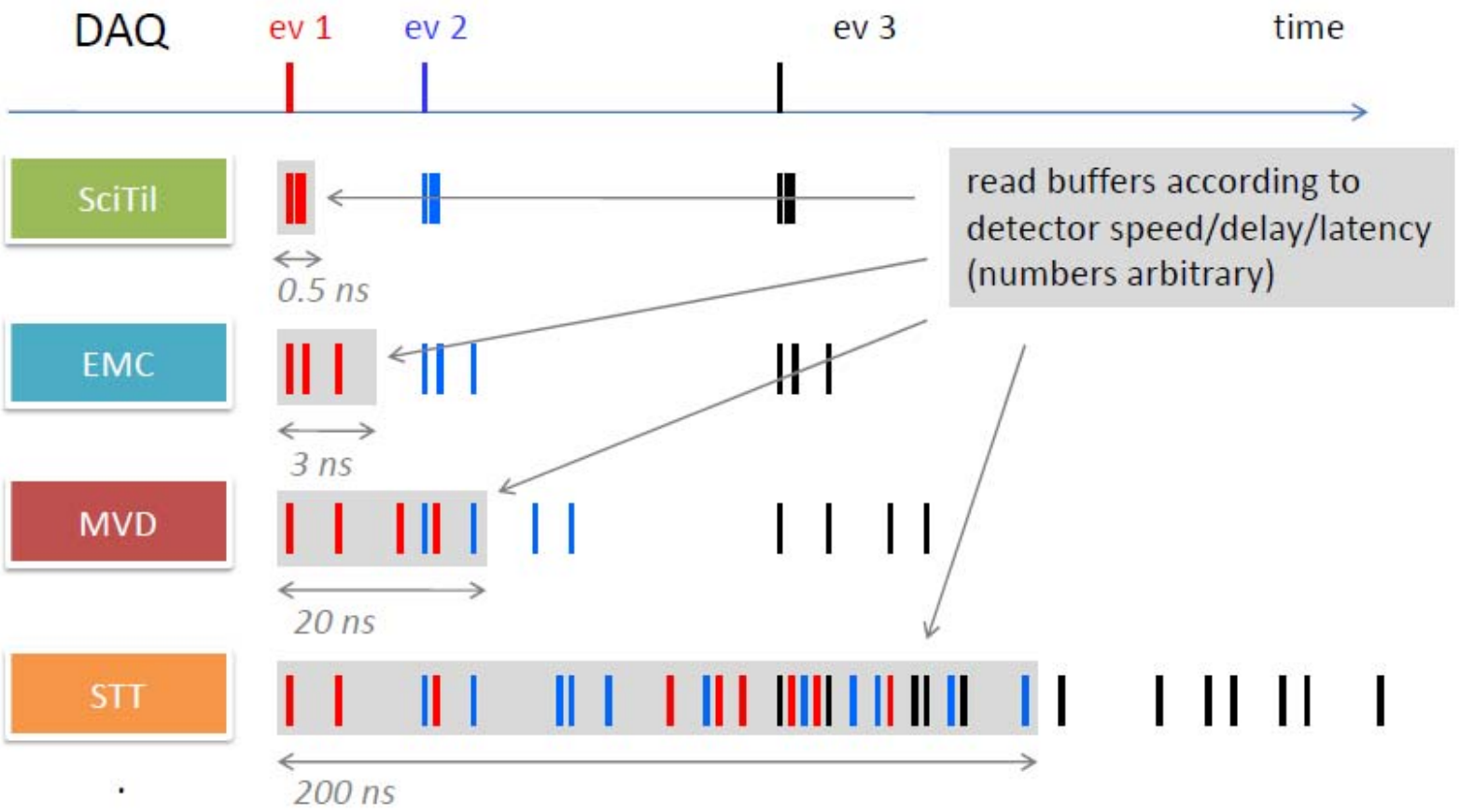


- Required background reduction rate 1/1000 with software trigger in total
- Triggering event rate : 20 MHz → 20 kHz

Online trigger @ PANDA

Consideration of online physics trigger

- need a special event building algorithm based on time
- reco. and pattern recog. algorithm should be different for online



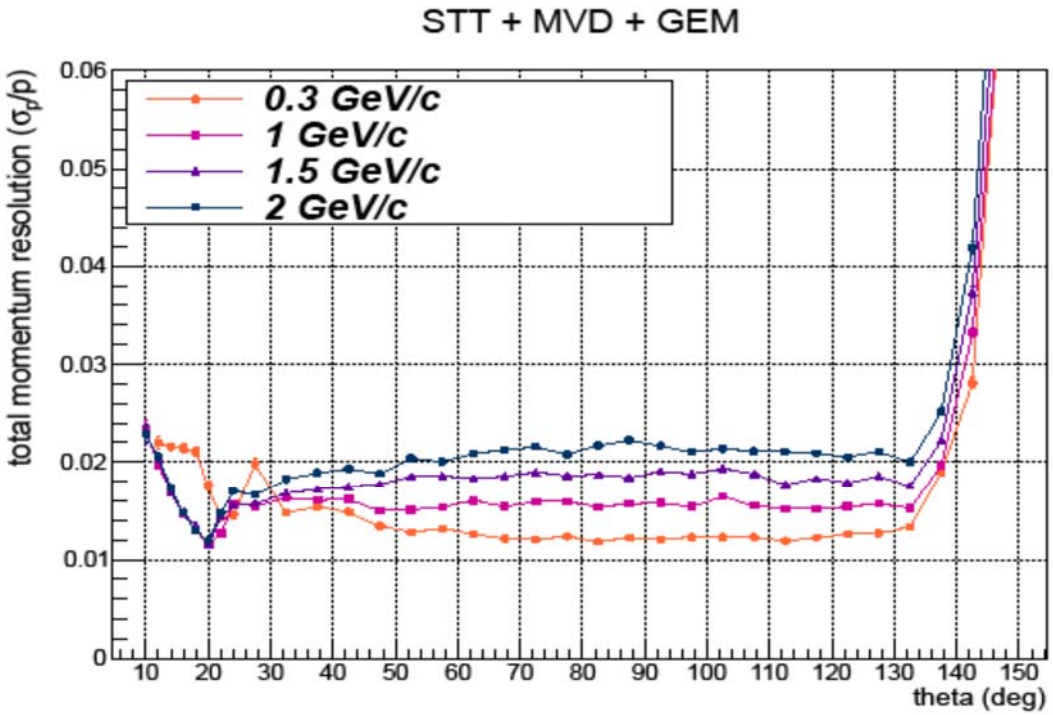
PANDA Software Trigger, online trigger meeting, Oct. 2011, K.Götzen

Online trigger @ PANDA

Consideration of online physics trigger

- need a special event building algorithm based on time
- reco. and pattern recog. algorithm should be different for online
- available informations are limited (maybe no PID(?) & vertex fit)
- expect worse momentum resolution for online reconstruction

mom. resolution
in offline : 2~3%



Online trigger strategy

Online trigger group

- define required information from detector
- answer for what is required precision of mass, momentum resolution and efficiency for interesting physics channel
- find optimal online cut criteria from the kinematic feature of physics & background event

Synchronize

Detector group

- preparing track and PID information for online case, analyzing data streams under real time condition
- implement the concept of physics trigger into

  Local Unit with FPGA (VHDL)
  Computer Node based on FPGA (VHDL)
  Commercial Grid Computer (C++ online)
  GPU parallel computing (CUDA)

investigate the concept of online trigger by studying benchmark channels

Benchmark channels

As an example …

$$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$$

Benchmark channels

Charmonium with a J/ψ in the final state (a la PANDA physics book)

- EvtGen for signal, EvtGen & Dpm for background
- No Resonance & Photos
- $\sqrt{s} = 3.526,\ 3.686,\ 3.872,\ 4.260,\ 4.600,\ 5.000\ \text{GeV}$

signal < nb	main background ~ few hundred μb
$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$	$\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$
$\bar{p}p \to J/\psi\pi^0\pi^0 \to e^+e^-\gamma\gamma\gamma\gamma$	$\bar{p}p \to \pi^+\pi^-\pi^0\pi^0 \to \pi^+\pi^-4\gamma$ $\bar{p}p \to J/\psi\eta\pi^0 \to e^+e^-4\gamma$ $\bar{p}p \to J/\psi\omega\pi^0 \to e^+e^-5\gamma$ } need EMC
$\bar{p}p \to \chi_{c1,c2}\gamma \to J/\psi\gamma\gamma \to e^+e^-\gamma\gamma$	$\bar{p}p \to \pi^+\pi^-\pi^0 \to \pi^+\pi^-\gamma\gamma$
$\bar{p}p \to J/\psi\gamma \to e^+e^-\gamma$	$\bar{p}p \to \pi^+\pi^-\pi^0 \to \pi^+\pi^-\gamma\gamma$
$\bar{p}p \to J/\psi\eta \to e^+e^-\gamma\gamma$	$\bar{p}p \to J/\psi\pi^0\pi^0 \to e^+e^-4\gamma$ $\bar{p}p \to J/\psi\eta\gamma \to e^+e^-3\gamma$ $\bar{p}p \to J/\psi\pi^0\gamma \to e^+e^-3\gamma$ $\bar{p}p \to J/\psi\eta\pi^0 \to e^+e^-4\gamma$ } need EMC $\bar{p}p \to \pi^+\pi^-\pi^0$ $\bar{p}p \to \pi^+\pi^-\eta$

Analysis approach

Mass filtering

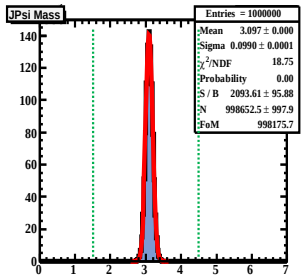
- assumption : complete track finding for all charged particle and no PID
- combining 2 tracks with electron mass hypothesis in each J/ψ event
- tracking resolution $\Delta p/p$ are varying from 5% to 100% (p_T and p_L both)
- applying fixed or varying J/ψ mass window to test efficiency
- find background reduction rate in same condition

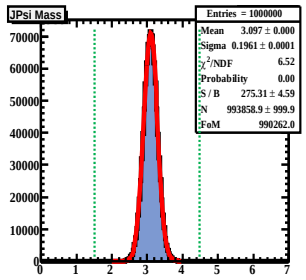
Invariant mass distribution

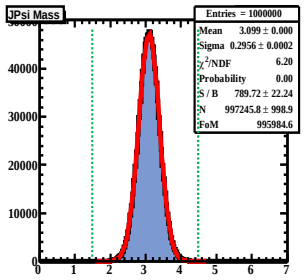
Dependence of J/ψ mass distribution on track momentum resolution

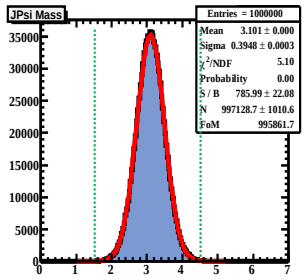
$\sqrt{s} = 3.526$ GeV

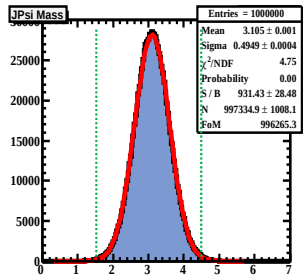
$\frac{\Delta p}{p} = 5\%$





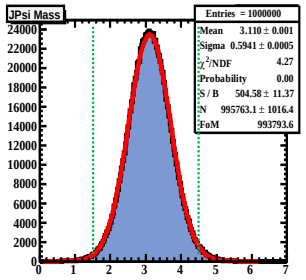


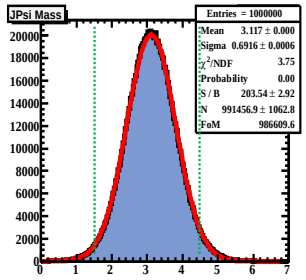


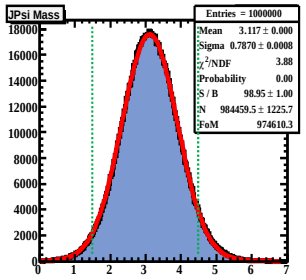


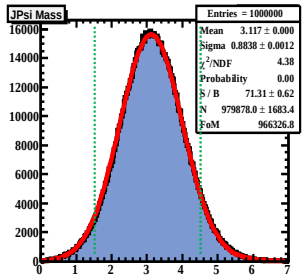
$\frac{\Delta p}{p} = 25\%$

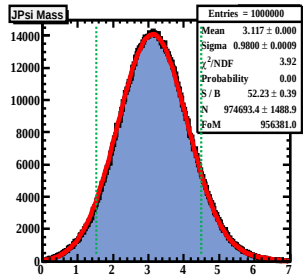
$\frac{\Delta p}{p} = 30\%$











$\frac{\Delta p}{p} = 50\%$

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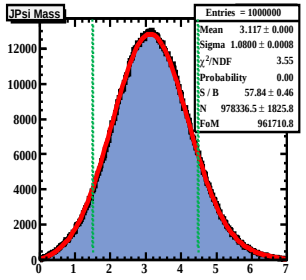

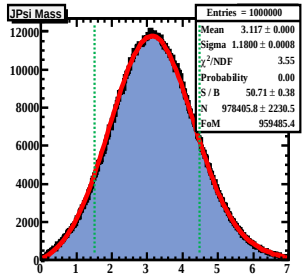

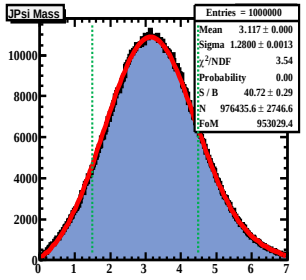

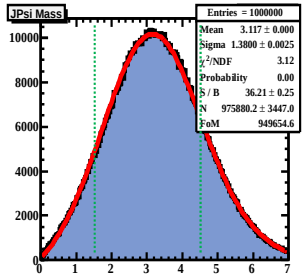

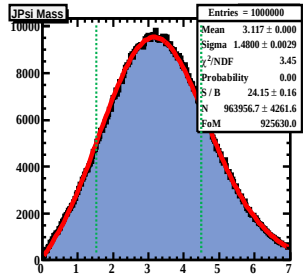

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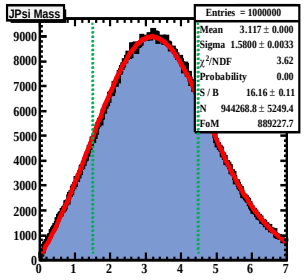
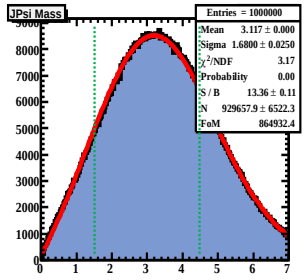
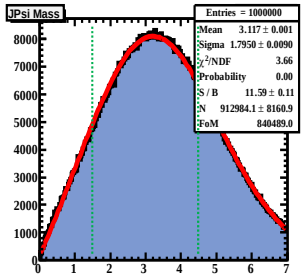
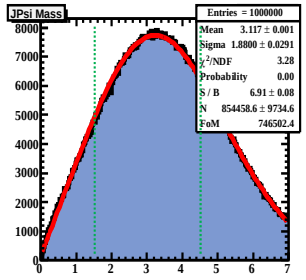
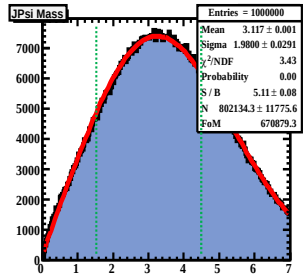








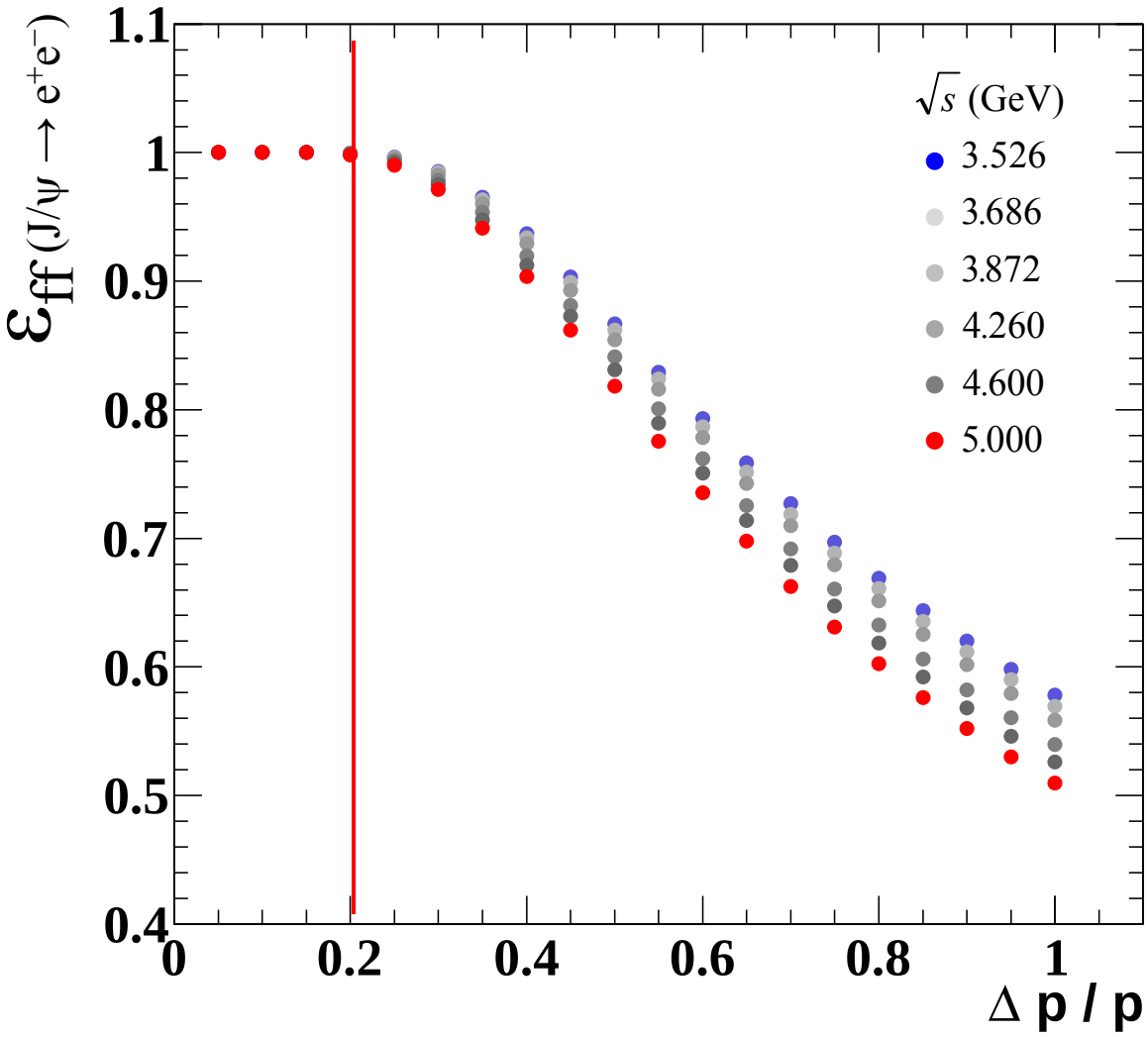


$\frac{\Delta p}{p} = 100\%$

Efficiency

J/ψ mass window fix: $1.596\ \text{GeV/c} < m_{e^+e^-} < 4.596\ \text{GeV/c}$ ($\Delta m = 3\ \text{GeV/c}$)

$$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$$



- efficiency for $J/\psi \to e^+e^-$
- definition of efficiency :

$$\varepsilon_{ff} = \frac{N_{Acc}}{N_{Gen}}$$

- below 20% tracking resolutions are mandatory at online for the case of using fixed mass window

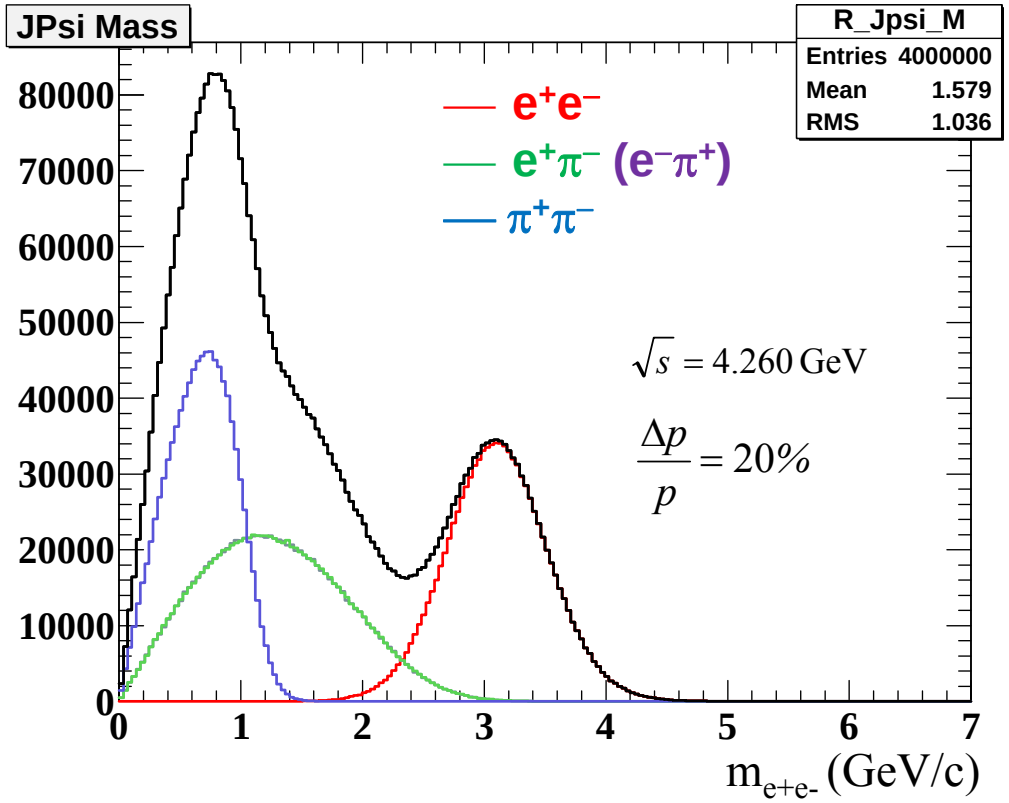
Background study

Combinatorial & background mass distribution with electron hypothesis (EvtGen)

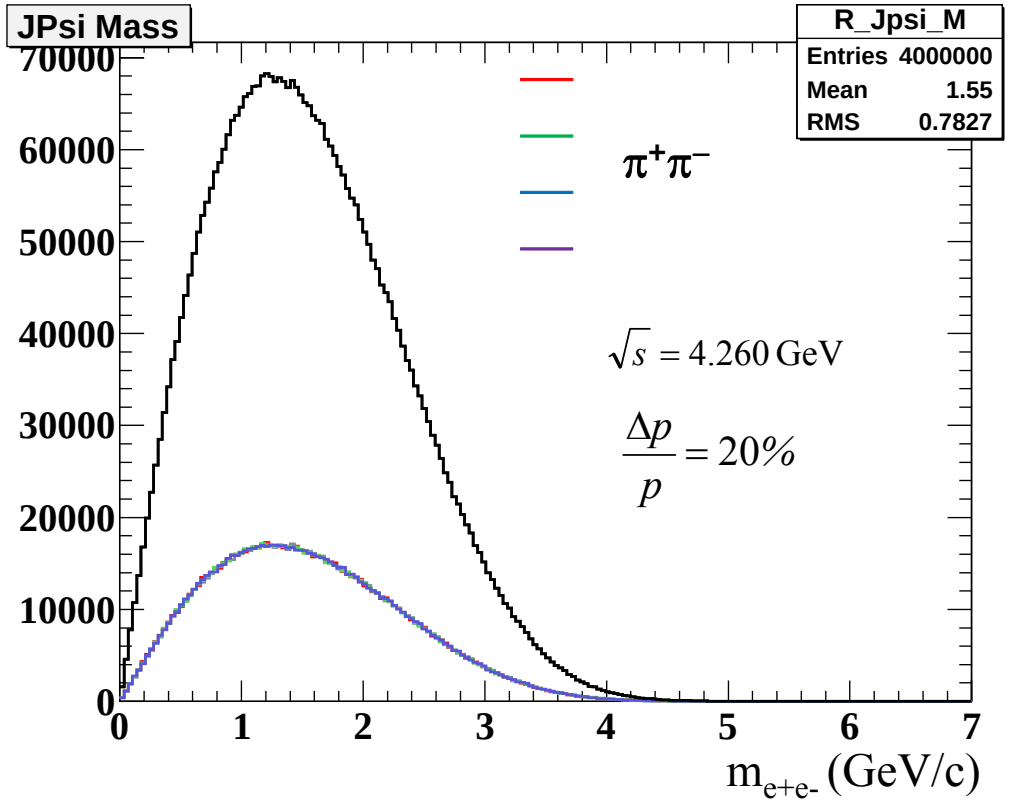
$$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$$

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

combinatorial



4 combinations

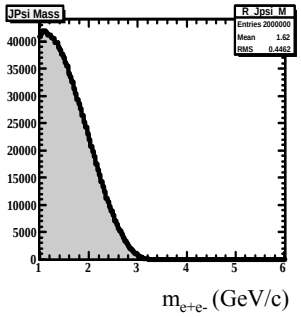


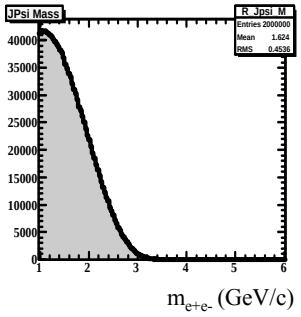
Background study

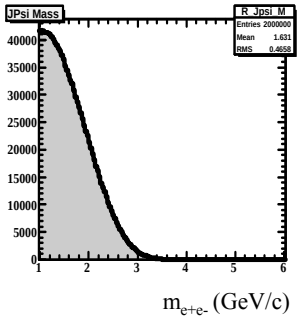
Background mass distribution with electron hypothesis (EvtGen)

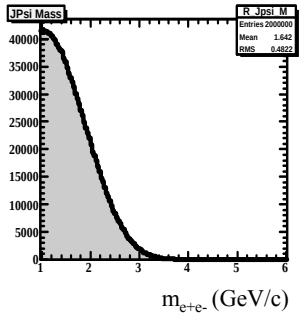
$\sqrt{s} = 3.526$ GeV

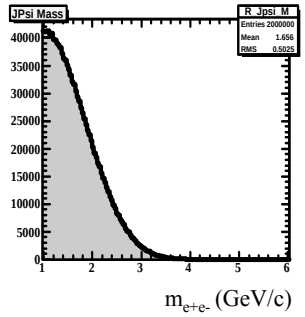
$\frac{\Delta p}{p} = 5\%$











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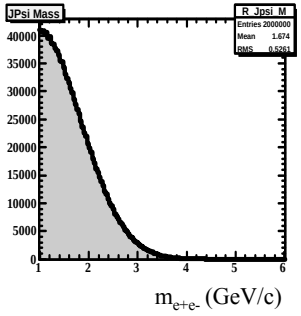

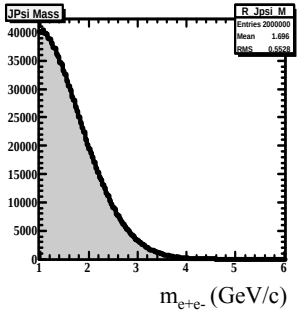

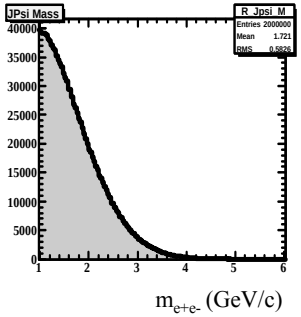

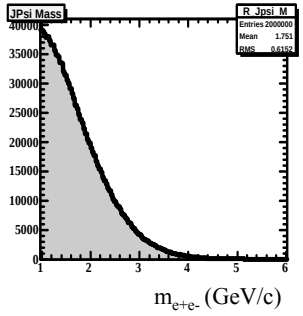

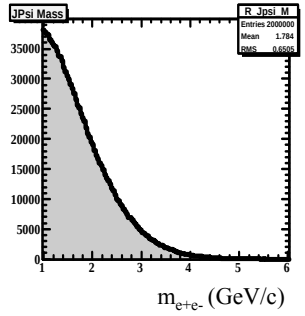

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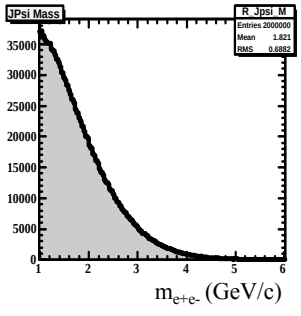

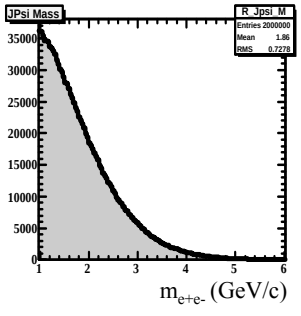

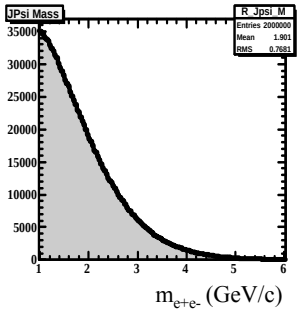

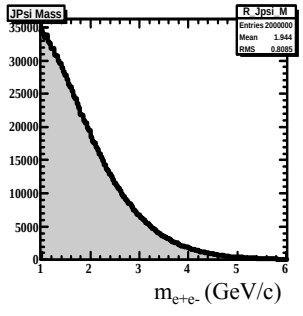

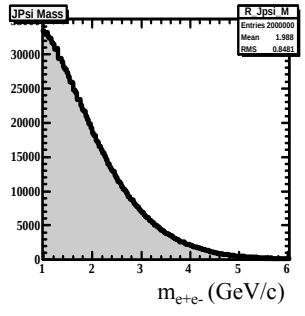

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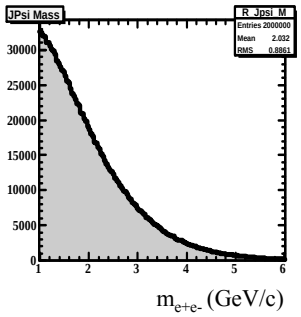
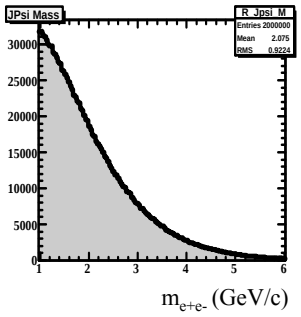
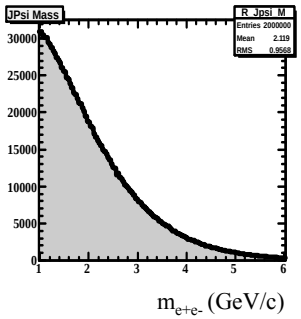
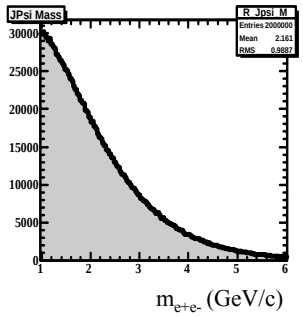
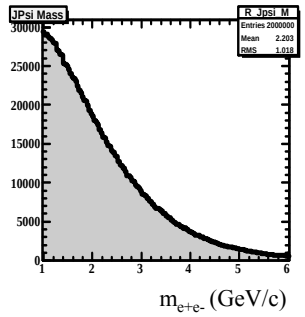










$\frac{\Delta p}{p} = 100\%$

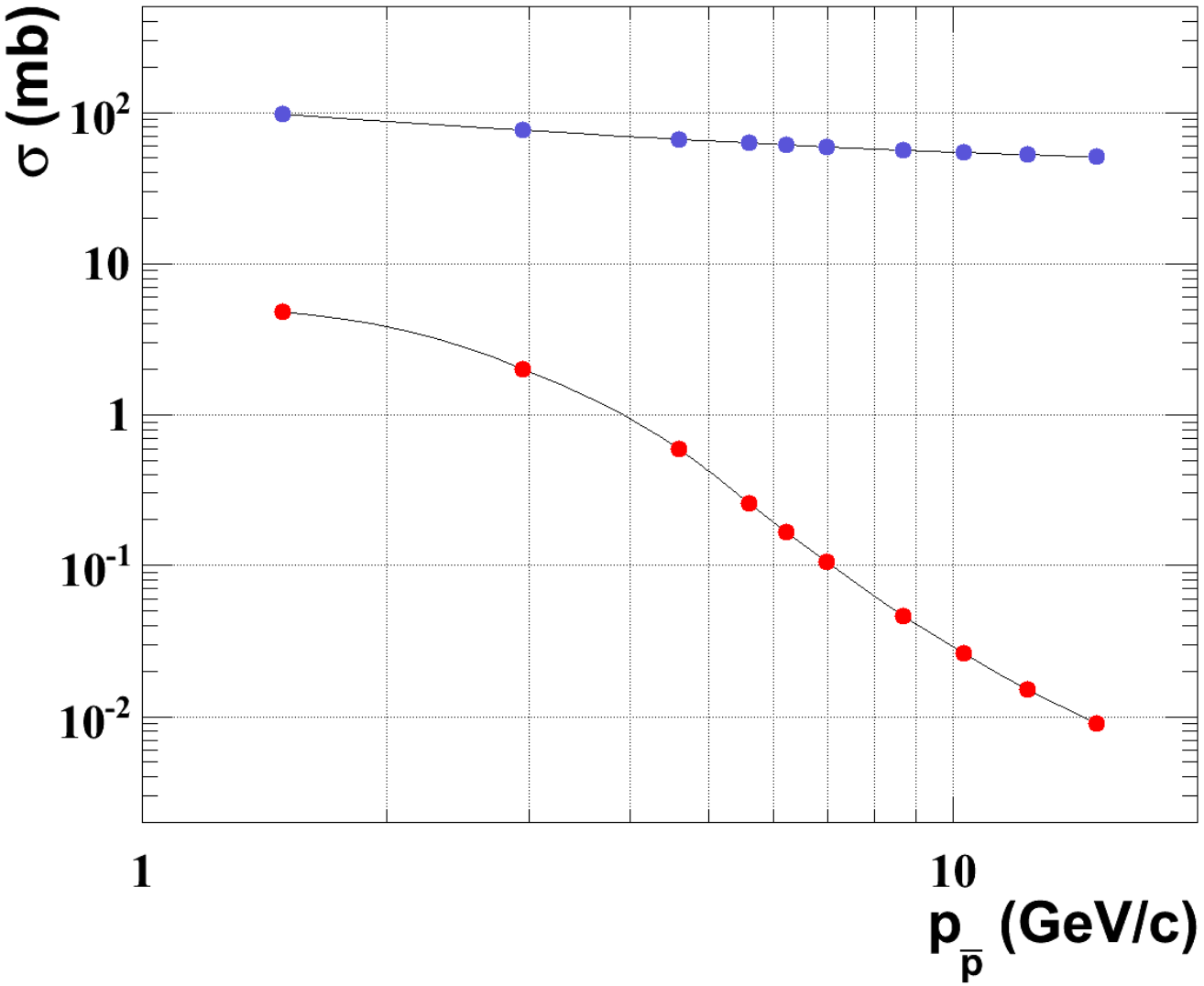
Background study

Background with DPM generator

Inelastic $\pi^+\pi^-\pi^+\pi^-$ event for each beam momentum are selected from DPM generation

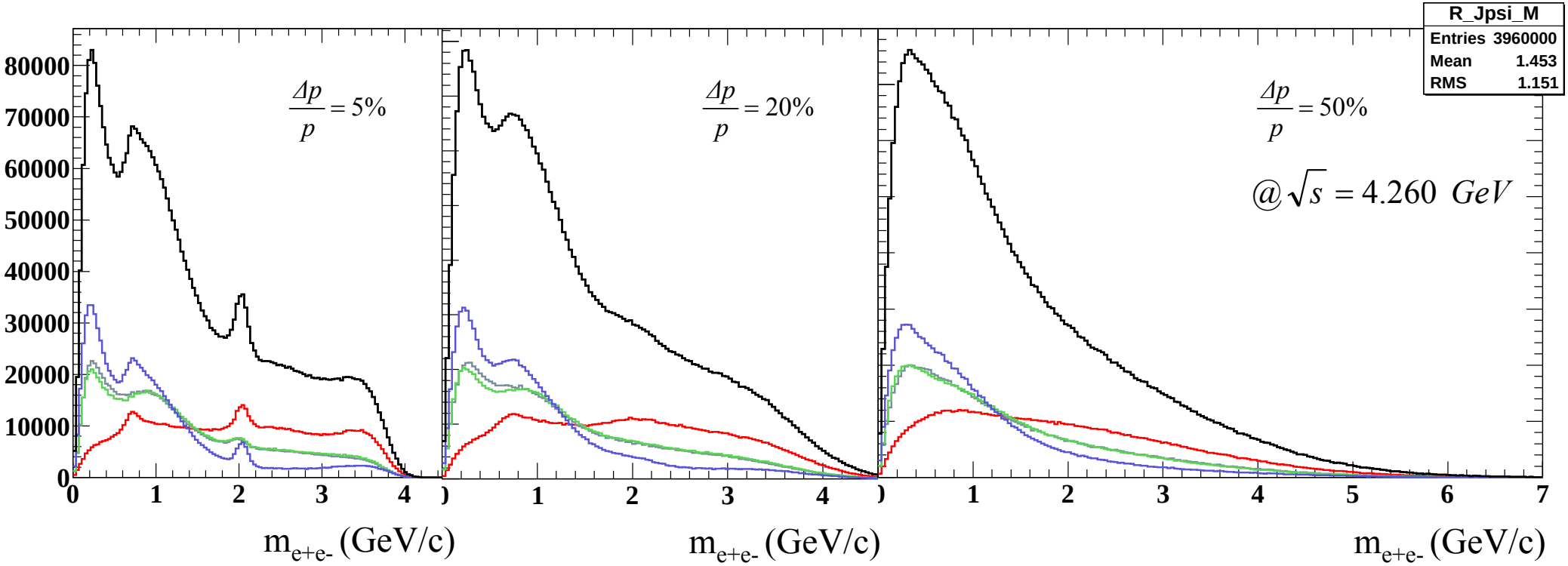
- **total cross section**
- $\pi^+\pi^-\pi^+\pi^-$ cross section

statistics 10^6 events



Background study

Background mass distribution with electron hypothesis (DPM)



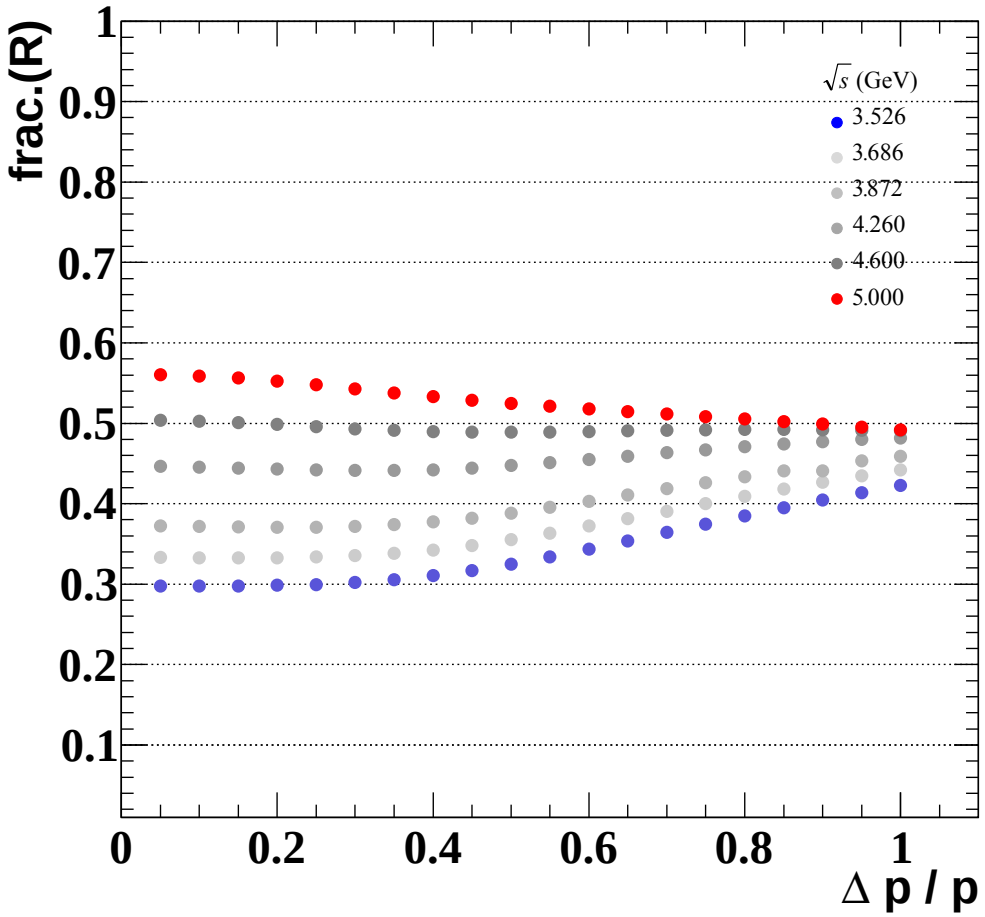
- different color mean different combinations from all π tracks
- no information about resonances and mother particles in DPM

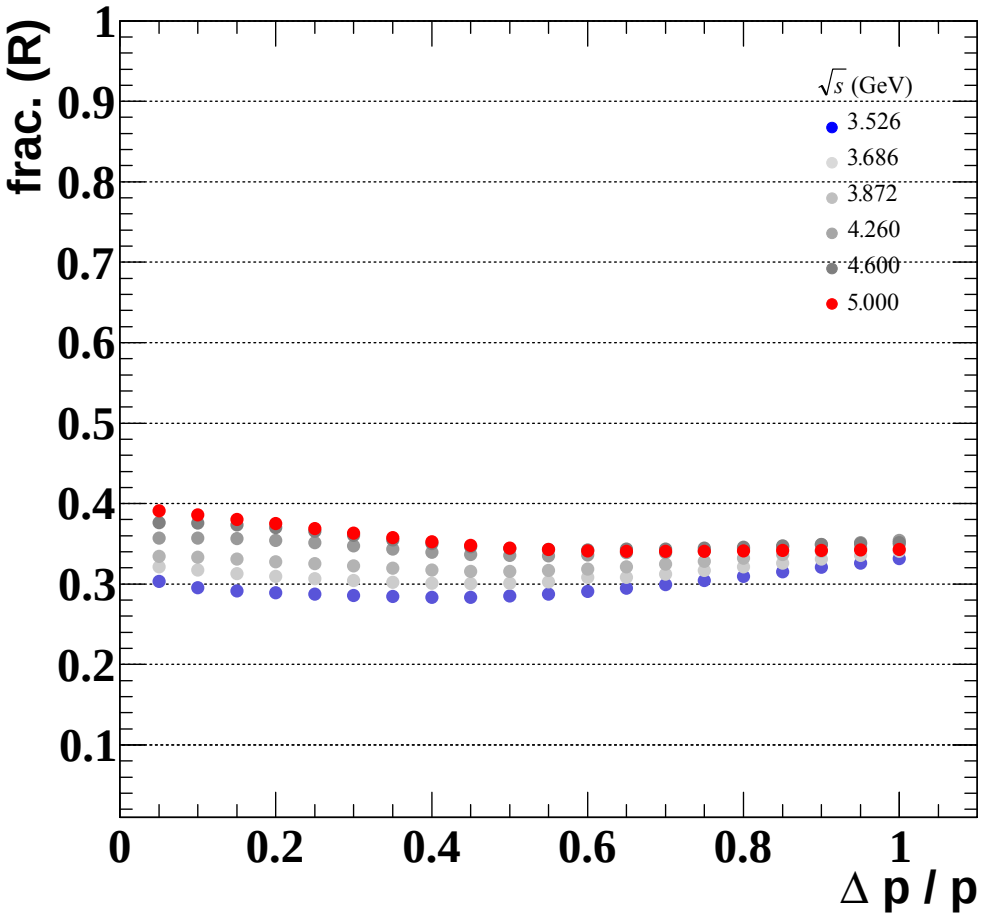
Background study

J/ψ mass window fix: $1.596\ \mathrm{GeV/c} < m_{e^+e^-} < 4.596\ \mathrm{GeV/c}$

EvtGen $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$

DPM $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$





Fraction = accepted combinations / all possible combinations of two tracks

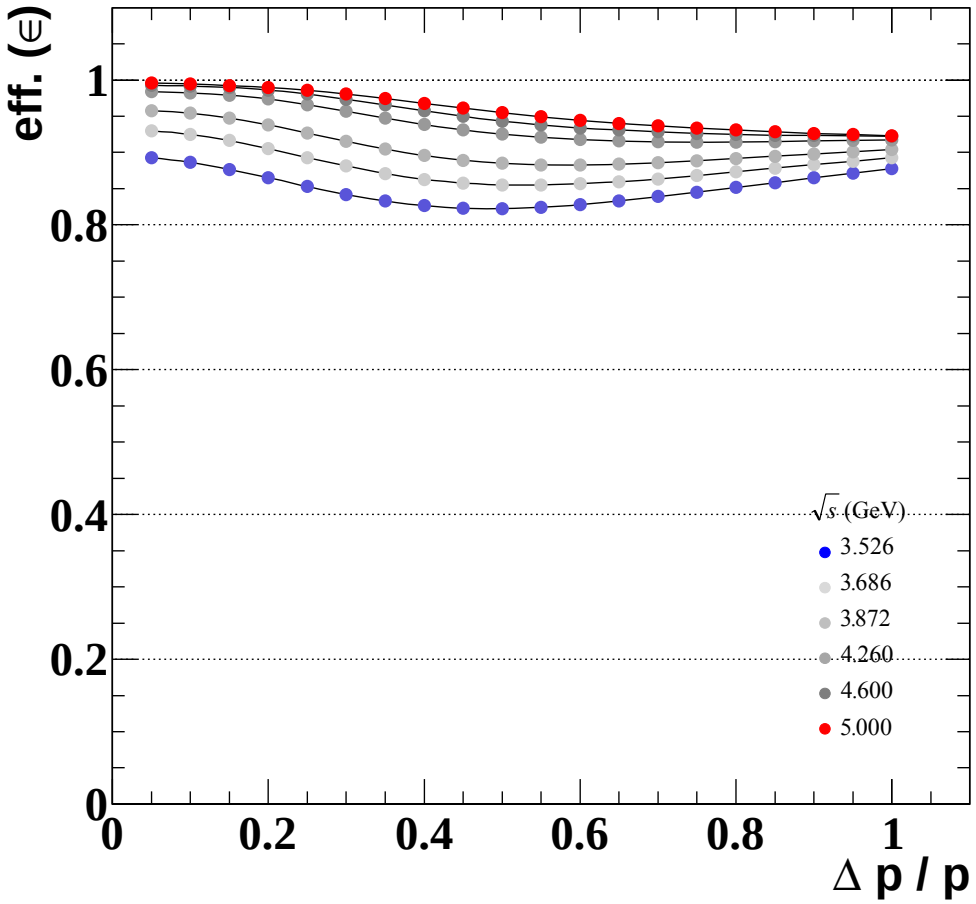
Difference between EvtGen and DPM ~ 20%

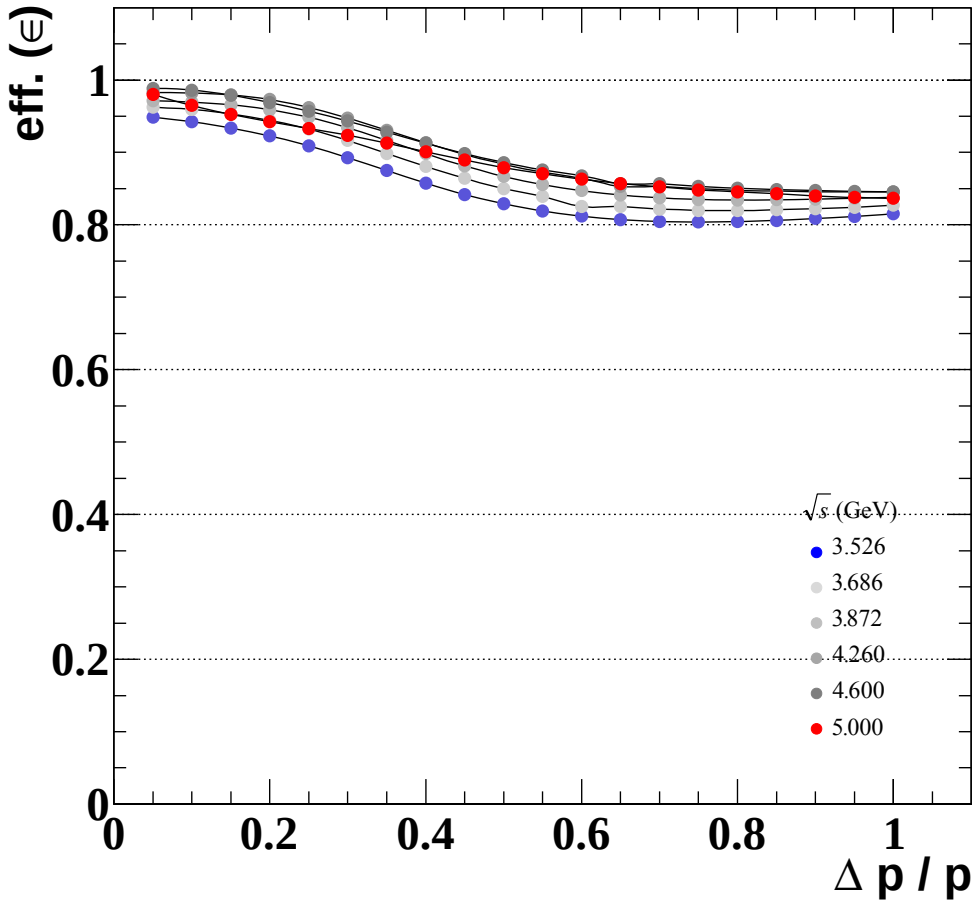
Background study

J/ψ mass window fix: $1.596\ \text{GeV/c} < m_{e^+e^-} < 4.596\ \text{GeV/c}$ ($\Delta m = 3.0\ \text{GeV/c}$)

EvtGen $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$

DPM $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$





Efficiency = accepted event / total generated event

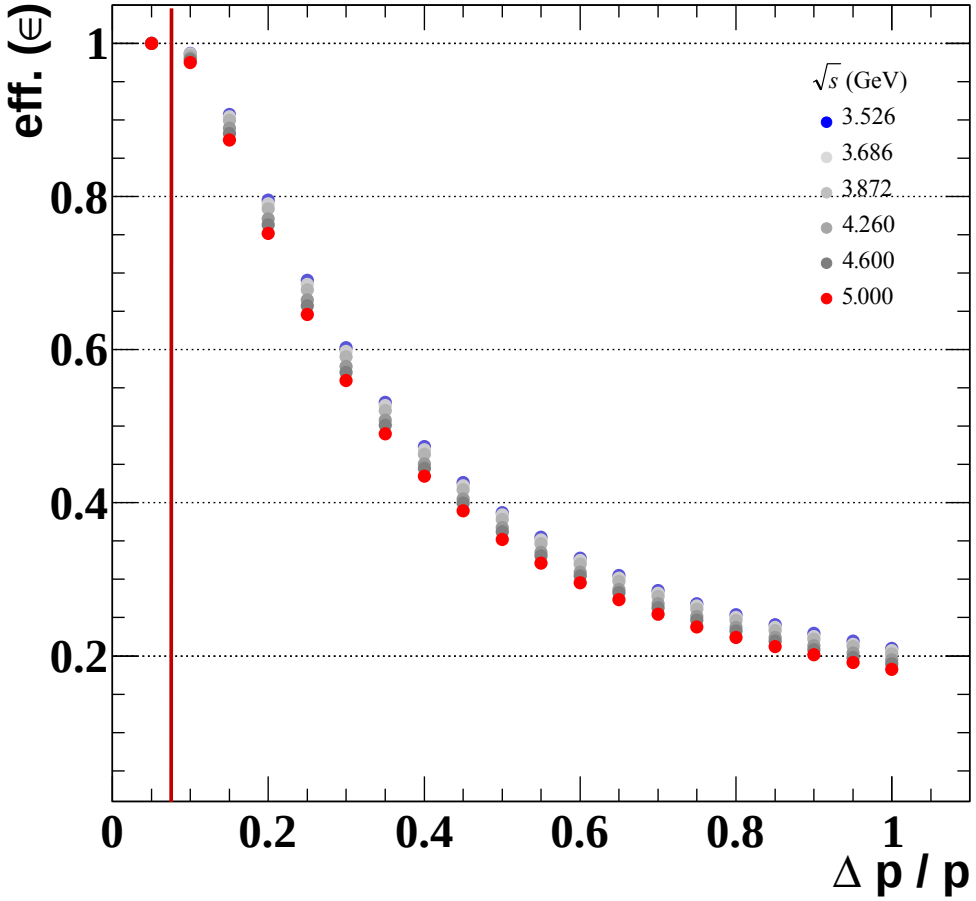
No gain for background reduction ~ few %

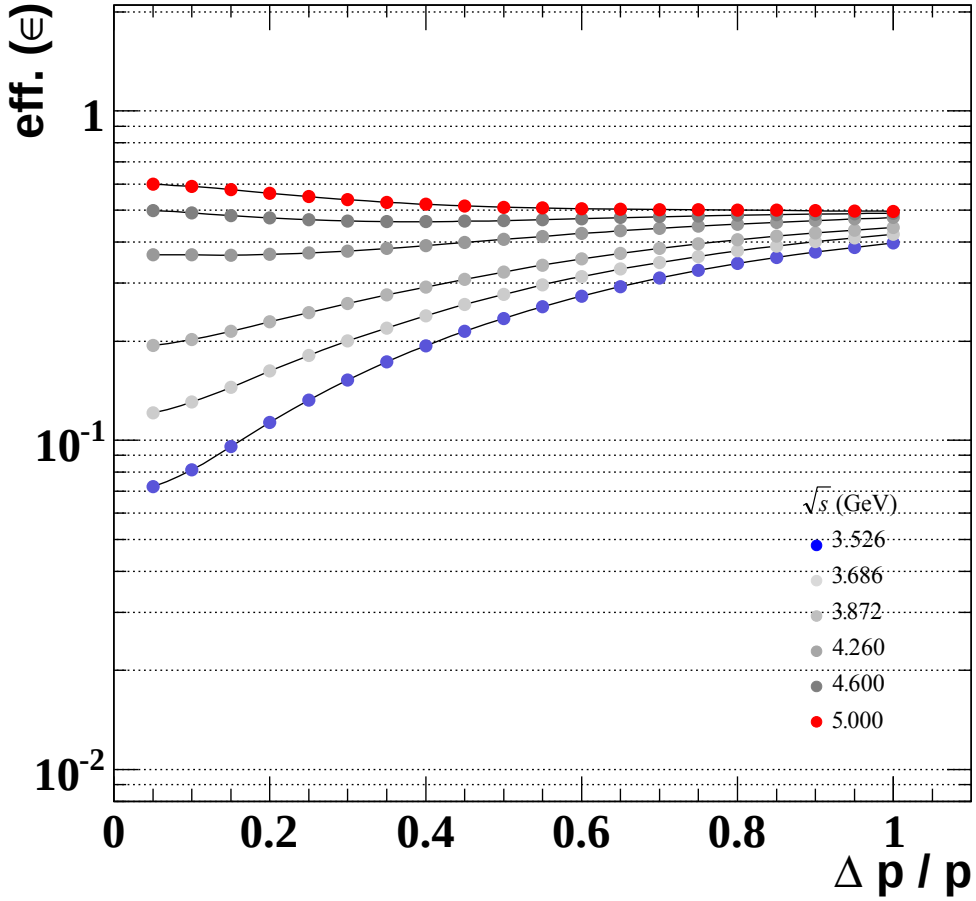
Efficiency

J/ψ mass window fix: 2.596 GeV/c < $m_{e^+e^-}$ < 3.596 GeV/c (Δm = 1.0 GeV/c)

$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$

EvtGen $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$





Efficiency = accepted event / total generated event

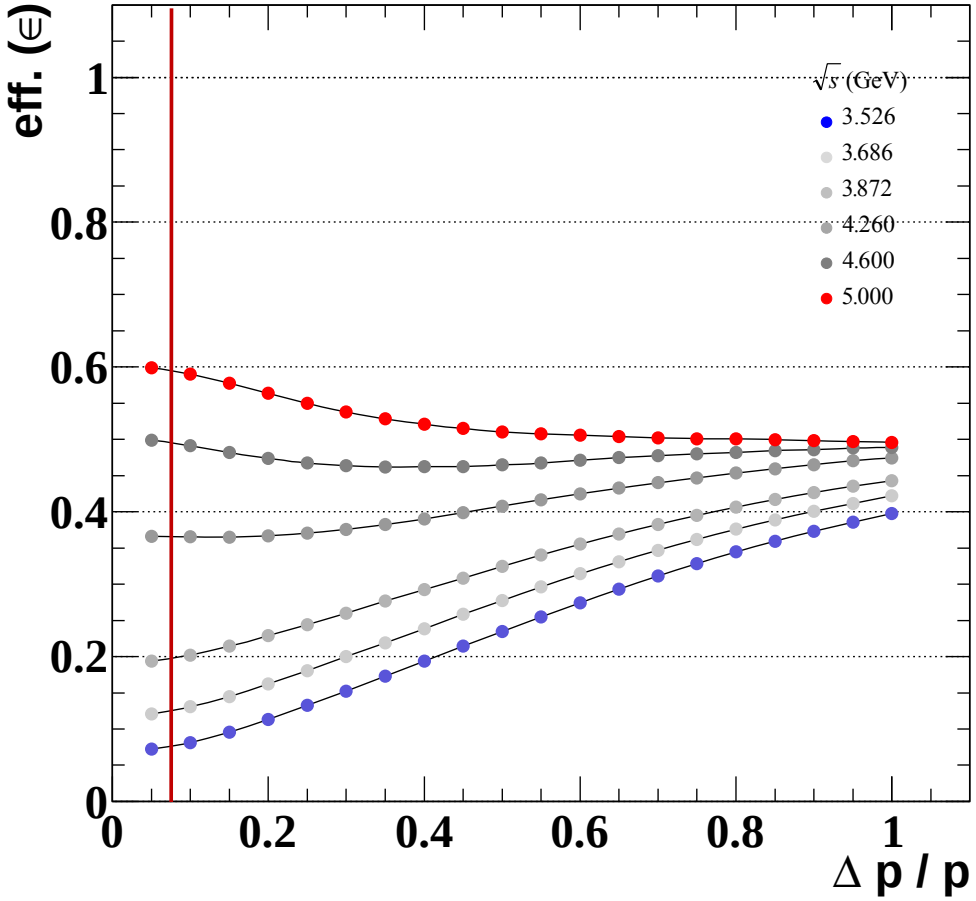
require $\Delta p/p < 5$ % for signal selection

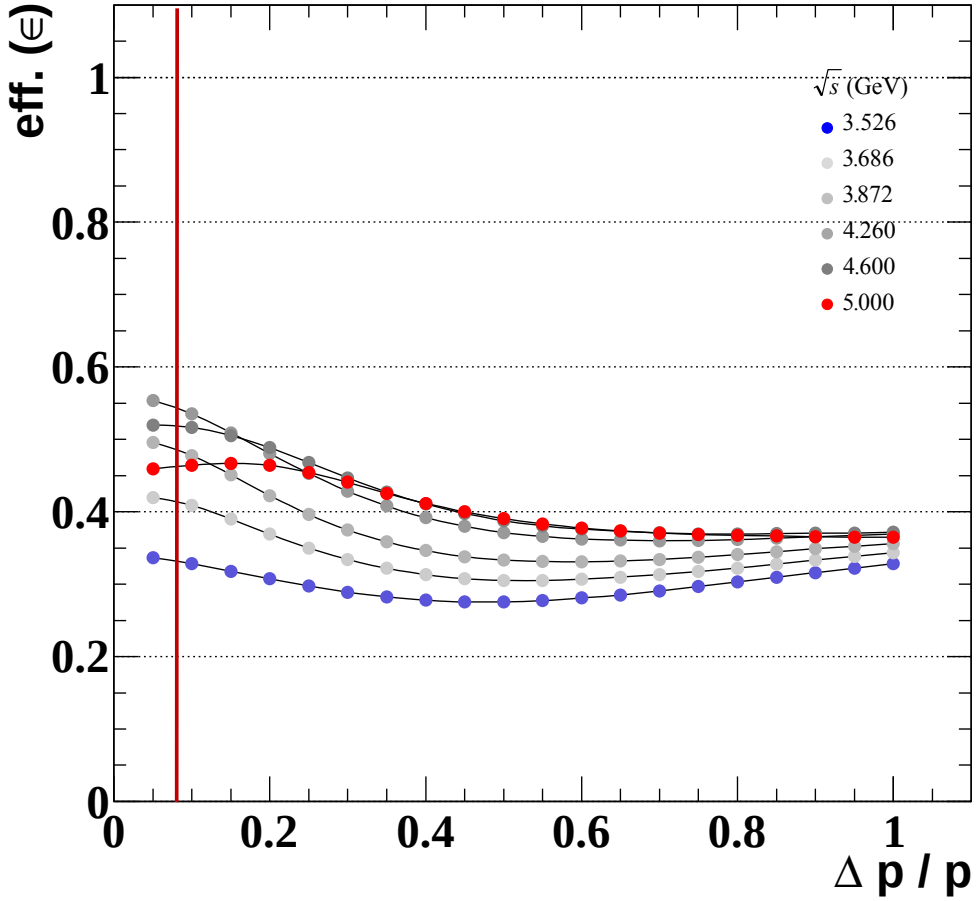
Background study

J/ψ mass window fix: 2.596 GeV/c < $m_{e^+e^-}$ < 3.596 GeV/c (Δm = 1.0 GeV/c)

EvtGen $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$

DPM $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$





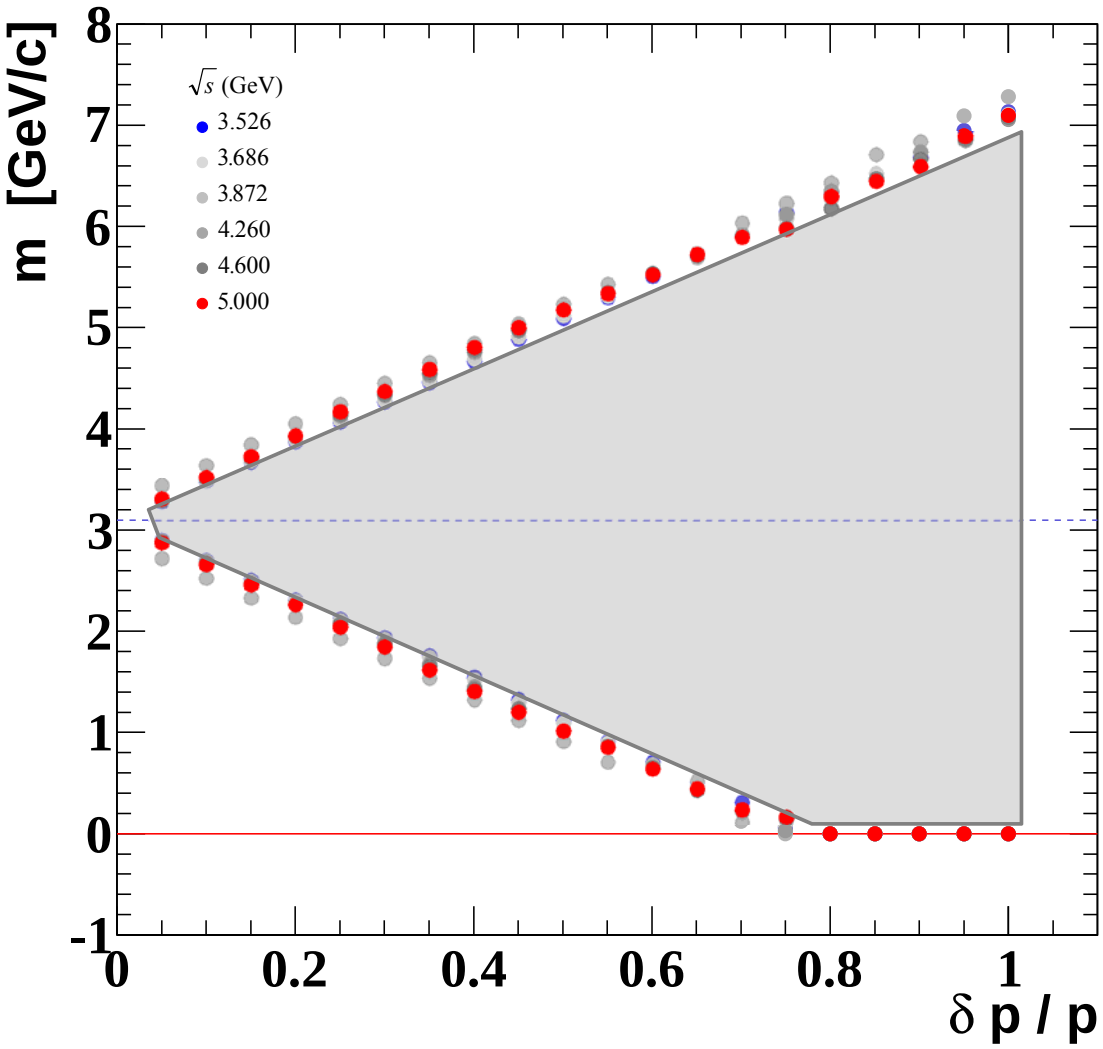
Efficiency = accepted event / total generated event

Background reduction rate ~ 1 / 10

Background study

J/ψ mass window vary: $m_{J/\psi} - 2\sigma_m < m_{e+e-} < m_{J/\psi} + 2\sigma_m$ GeV/c

- select $2\sigma_m$ mass range → signal efficiency > 95 %
- estimate background reduction rate for both EvtGen & DPM



$m_{J/\psi} = 3.097$ (GeV/c)

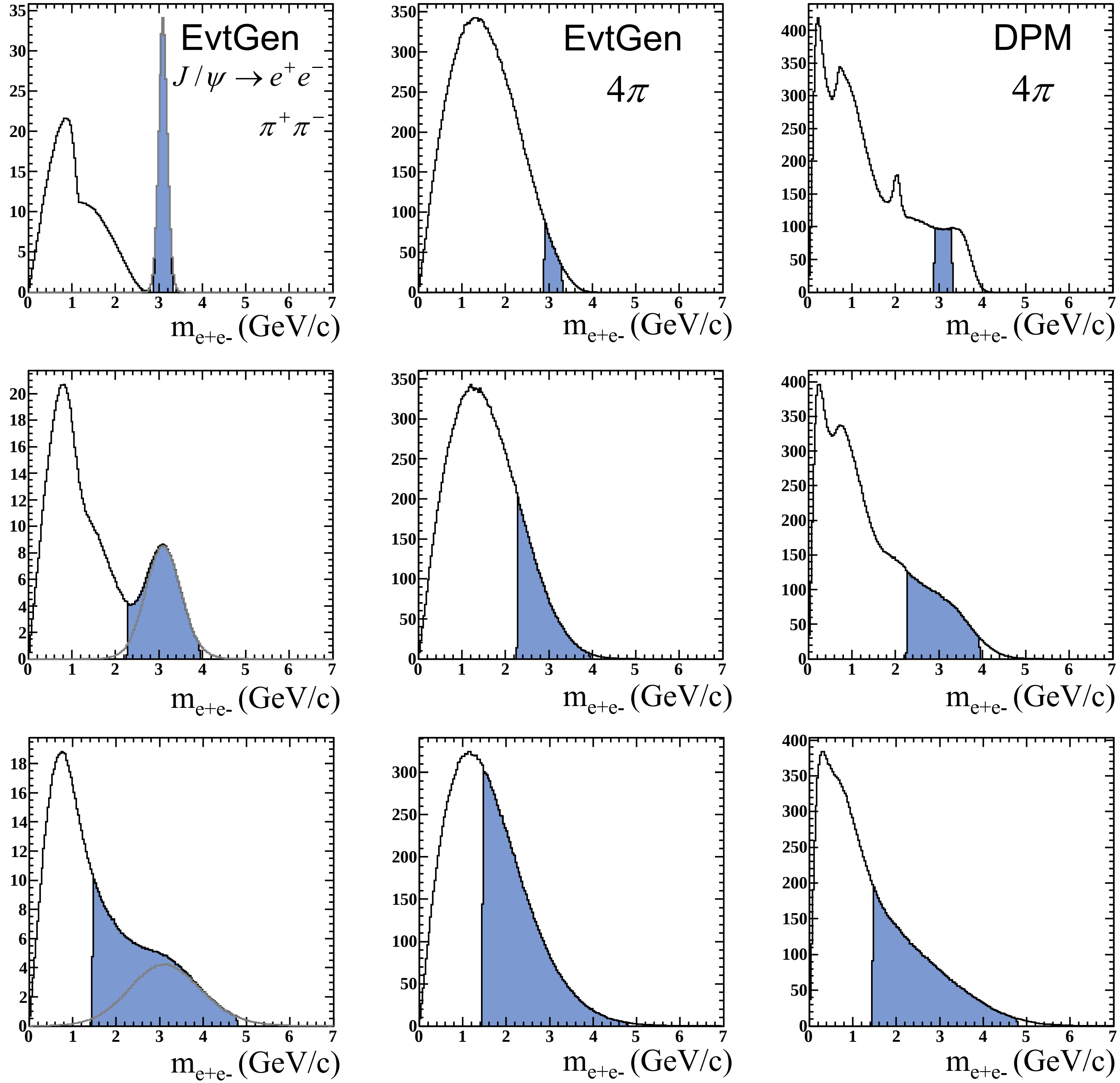
Background study

$$\sqrt{s} = 4.260\ GeV$$

$$\frac{\Delta p}{p} = 5\%$$

$$\frac{\Delta p}{p} = 20\%$$

$$\frac{\Delta p}{p} = 40\%$$

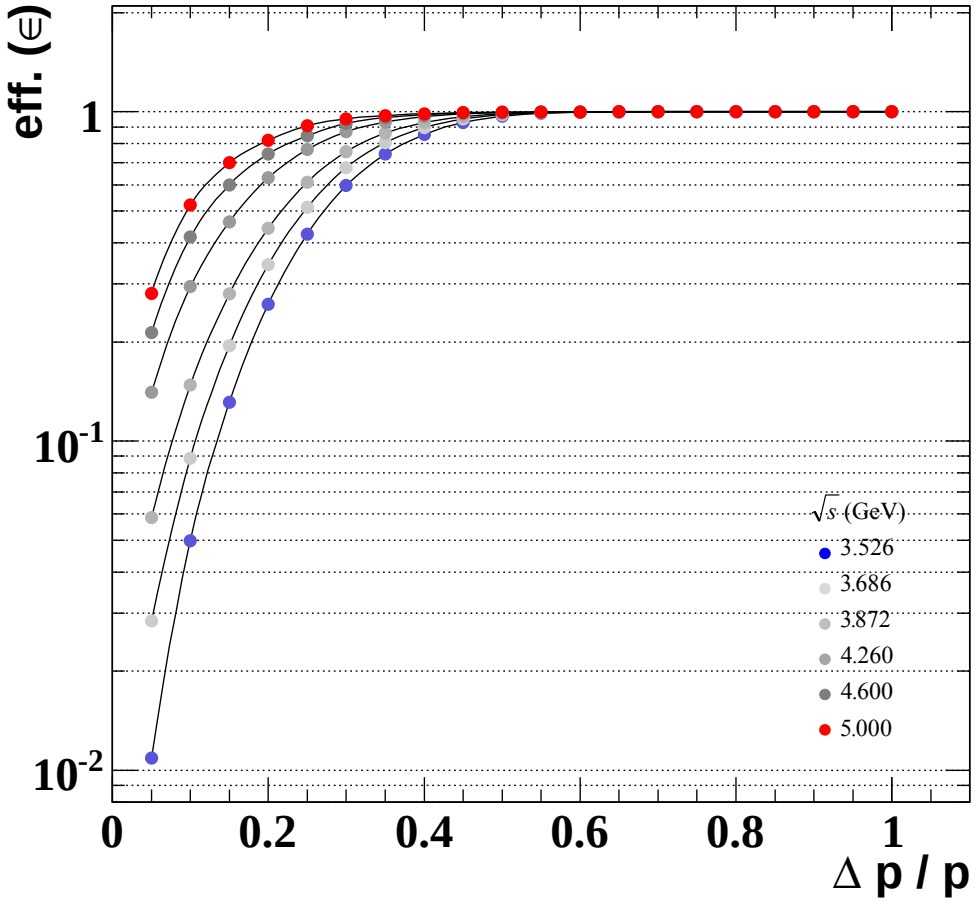


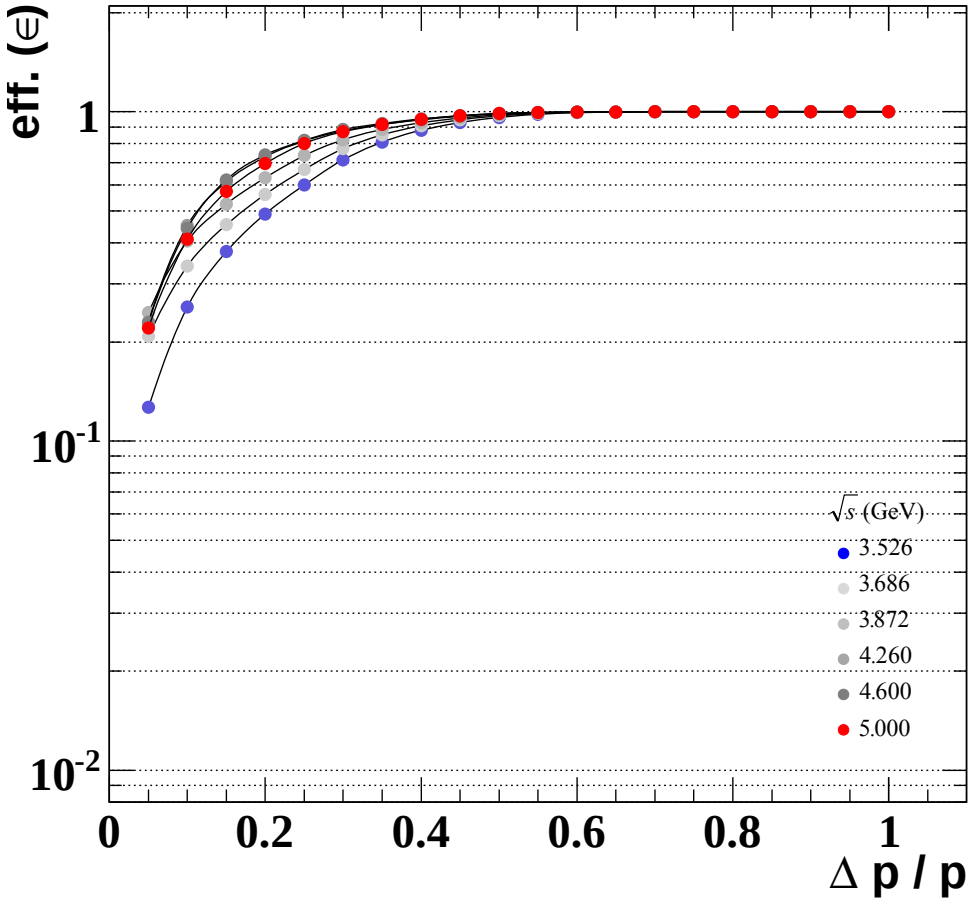
Background study

J/ψ mass window vary: $m_{J/\psi} - 2\sigma_m < m_{e^+e^-} < m_{J/\psi} + 2\sigma_m$ GeV/c

EvtGen $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$

DPM $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$





Efficiency = accepted event / total generated event

Background reduction rate ~ 1 / 100

Background study

Event rate for signal and background using cross section from DPM

c.m.s.	production	σ_{sig}
$\sqrt{s} = 3.526\,\mathrm{GeV}$	$\bar{p}p \to h_c \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$	**not seen**
$\sqrt{s} = 3.686\,\mathrm{GeV}$	$\bar{p}p \to \psi(2s) \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$	σ = 50 nb [1]
$\sqrt{s} = 3.872\,\mathrm{GeV}$	$\bar{p}p \to X(3872) \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$	σ= 50~443 nb
$\sqrt{s} = 4.260\,\mathrm{GeV}$	$\bar{p}p \to X(4260) \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$	σ = 60 pb [2]
$\sqrt{s} = 4.600\,\mathrm{GeV}$	$\bar{p}p \to ? \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$	**new state**
$\sqrt{s} = 5.000\,\mathrm{GeV}$	$\bar{p}p \to ? \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$	**new state**

[1] Measurement of branching ratios J/ψ, ψ' resonance parameters in pbarp annihilation, E760 @ FNAL, PRD47, 772 (1993)
[2] Measurement of branching ratios ψ'→e+e-, ψ'→J/ψπ+π- ψ'→J/ψη, E835 @ FNAL, PRD71, 032006 (2005)

Background study

$X(3872)$

cms:

$\sqrt{s} = 3.872\,\mathrm{GeV}$

$P_B = 6.988\,\mathrm{GeV/c}$

cross section:

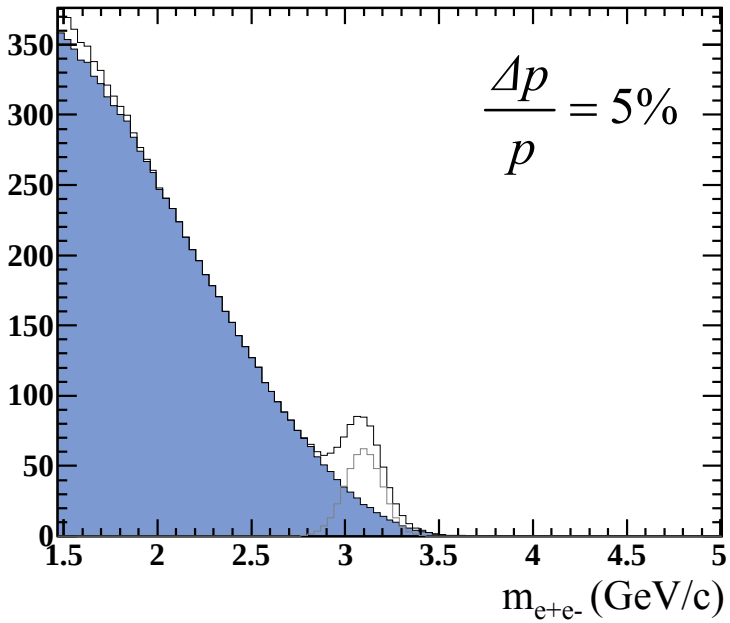
$\sigma_{J/\psi}$ = 50 nb

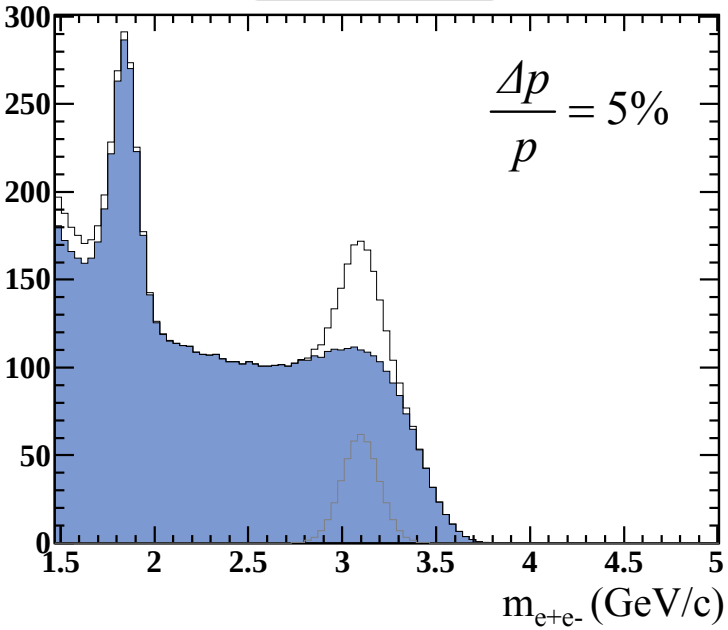
$\sigma_{4\pi}$ = 50 μb

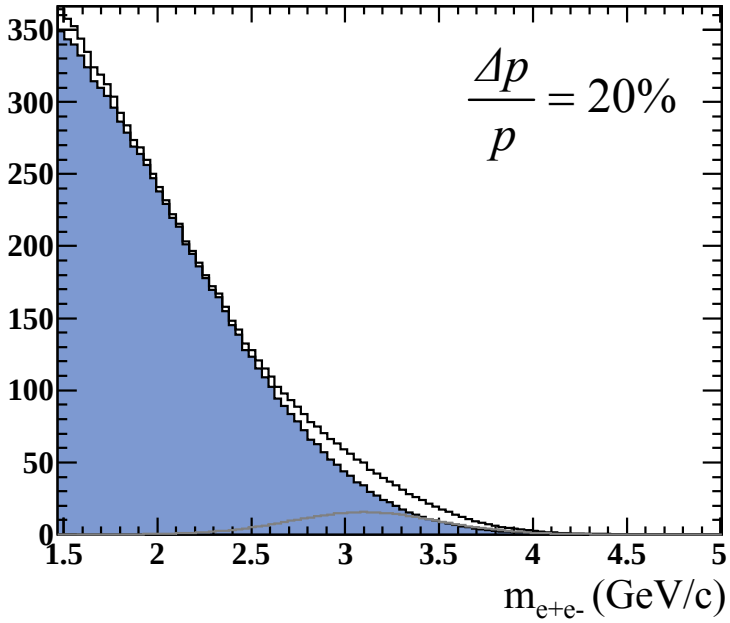
signal scaled by X 100

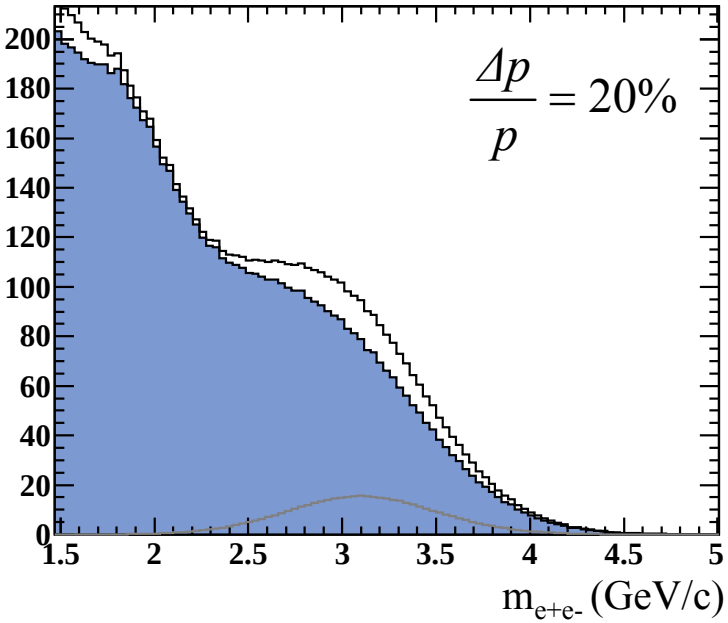
EvtGen

DPM









Benchmark channels

Another example …

$$\bar{p}p \to D^+D^- \to K^-\pi^+\pi^+K^+\pi^-\pi^-$$

$$\bar{p}p \to D^{*+}D^{*-} \to D^0\pi^+\bar{D}^0\pi^- \to K^-\pi^+\pi^+K^+\pi^-\pi^-$$

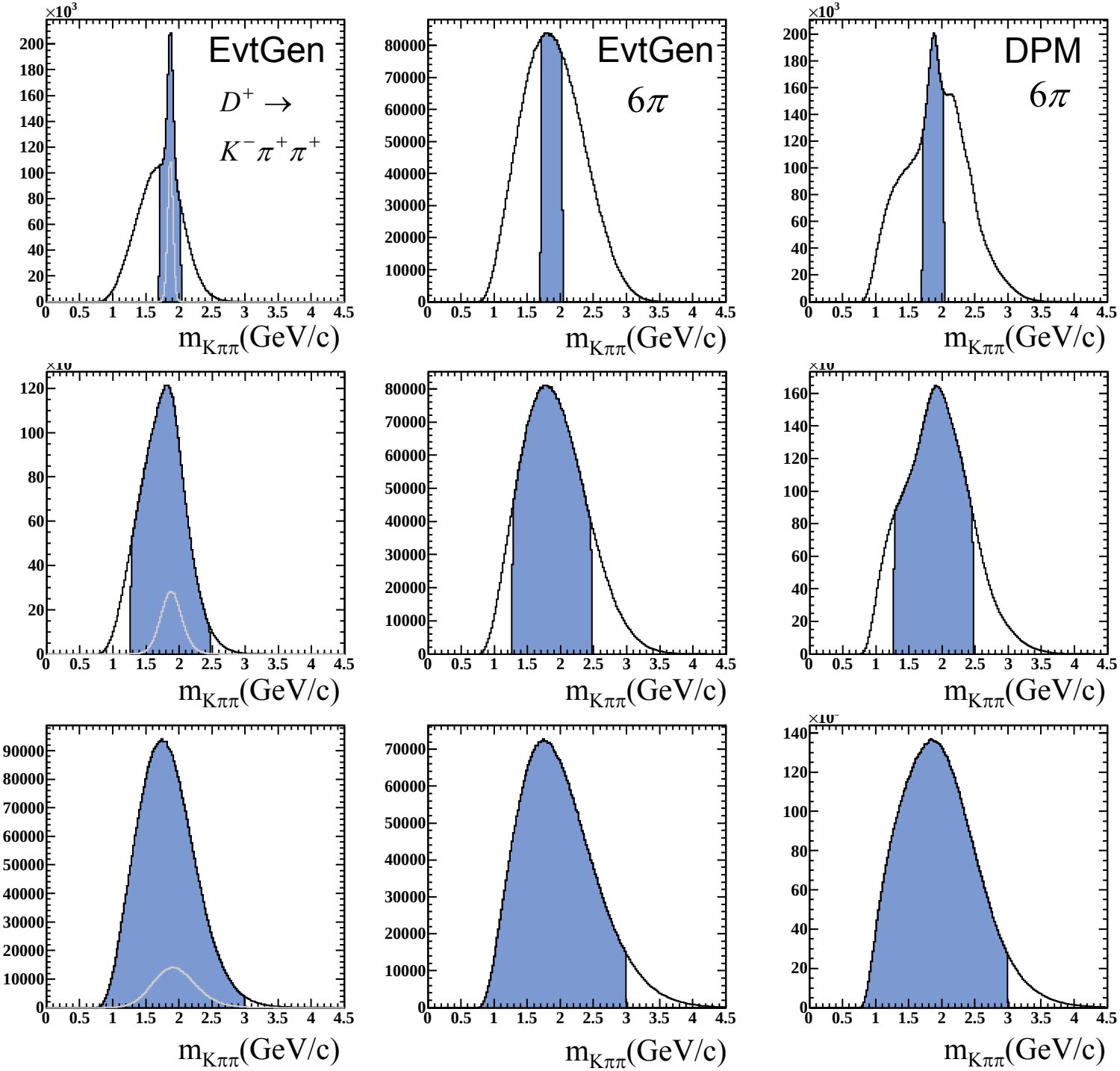
Background study

$\sqrt{s} = 3.770$ GeV

$\frac{\Delta p}{p} = 5\%$ →

$\frac{\Delta p}{p} = 20\%$ →

$\frac{\Delta p}{p} = 40\%$ →

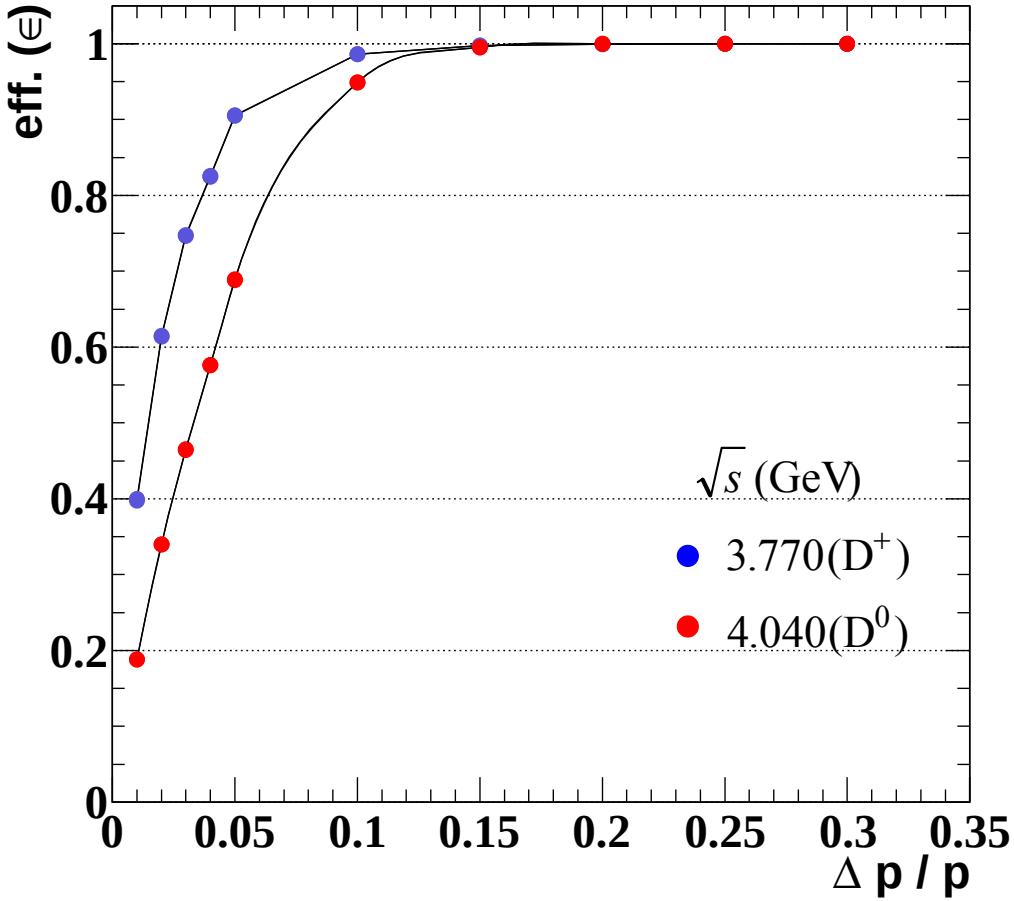


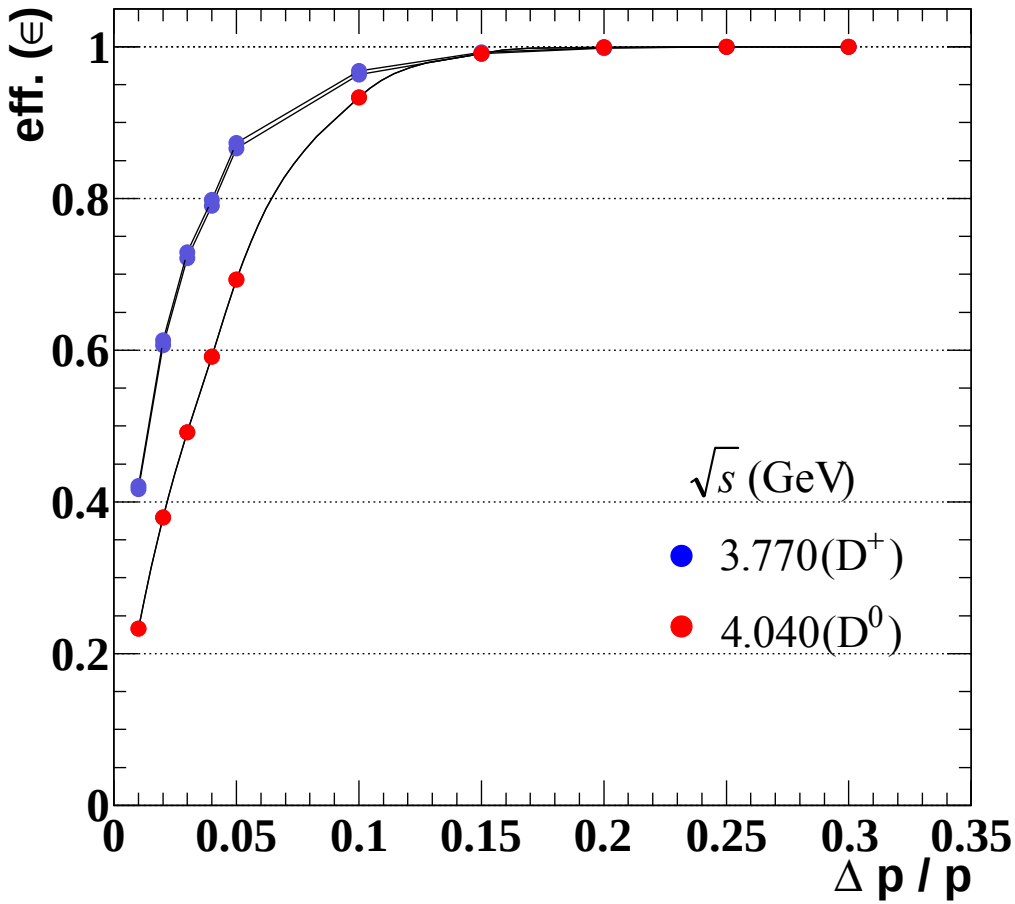
Background study

$D^{\pm}$, D^0 mass window vary: $m_D - 2\sigma_m < m_{K\pi\pi(K\pi)} < m_D + 2\sigma_m$ GeV/c

EvtGen $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$

DPM $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$





Efficiency = accepted event / total generated event

Require $\Delta p/p < 5$ % for background reduction

Summary & Outlook

- The method of mass filtering and requirement of momentum resolution for online have been studied in the ideal situation

  J/ψ : looks promising but other cuts on p_T or opening angle will be necessary

  D meson : much more difficult than J/ψ, the fraction of background is too large

- γ included channels will be tested with using EMC information

- PID information is definitely necessary to achieve 1/1000 background reduction rate in the online

  need to clarify a statement about available PID and its precision from each detector group

Backup

Background reduction

1/1000 reduction rate in software trigger

- At least 20 MHz → 20 kHz, based on available computing power in offline reconstruction
- In very first stage, Information for trigger should be most likely local hits or possibly local tracks
- For this purpose, time resolution of detector should be a critical factor !

Detectors	Time Resolution σ_t
SciTil-ToF	100 ps
EMC for $e^{\pm}$& γ (hadrons)	1.0 (2.0) ns
MVD	~ 5.0 ns
STT (single hit)	5.0 ns (200 ns) †
GEMs	12.0 ns
DIRC	< 20.0 ns
FTS (straw)	> 5.0 ns (200 ns)
MDT (μ)	a few ns (60ns)

† STT, MDT has a drift time …

Status: time order simulation

- Simulation on time ordered events allows to test trigger algo. (including event building)

- Status of time simulation in PANDAroot (Jan 2012)

Detectors	Geometry	Tracking & PID	Time application
MVD	O	O	O
STT	O	O	O
EMC	O	O	X
GEMs	O	O	X
DIRC	O	O	X
FTS	X	X	X
MDT	O	O	X
SciTil	O	X	X

not ready to apply into the study on the online trigger

Event building I

Realistic event building strategy with time gap in SciTil

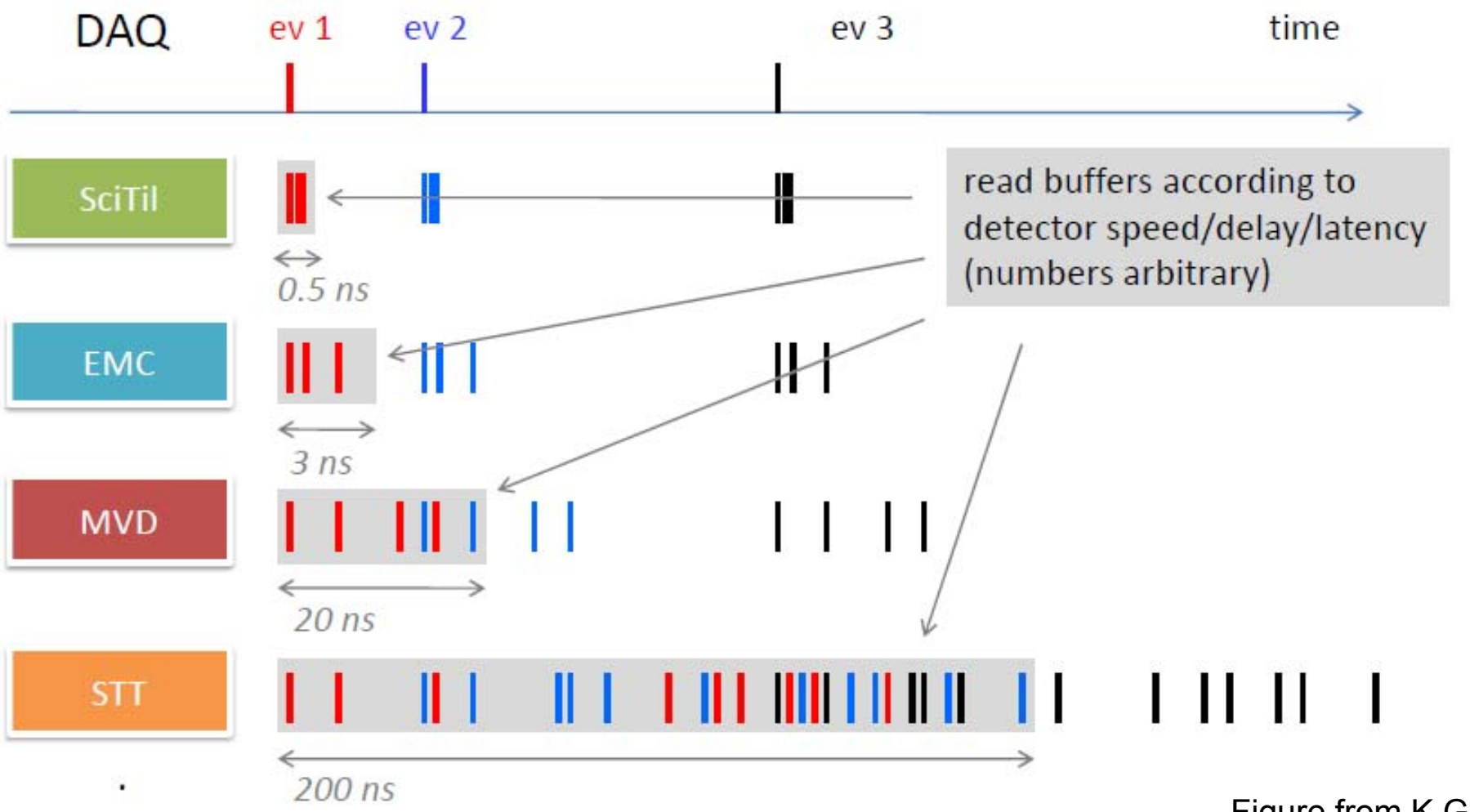
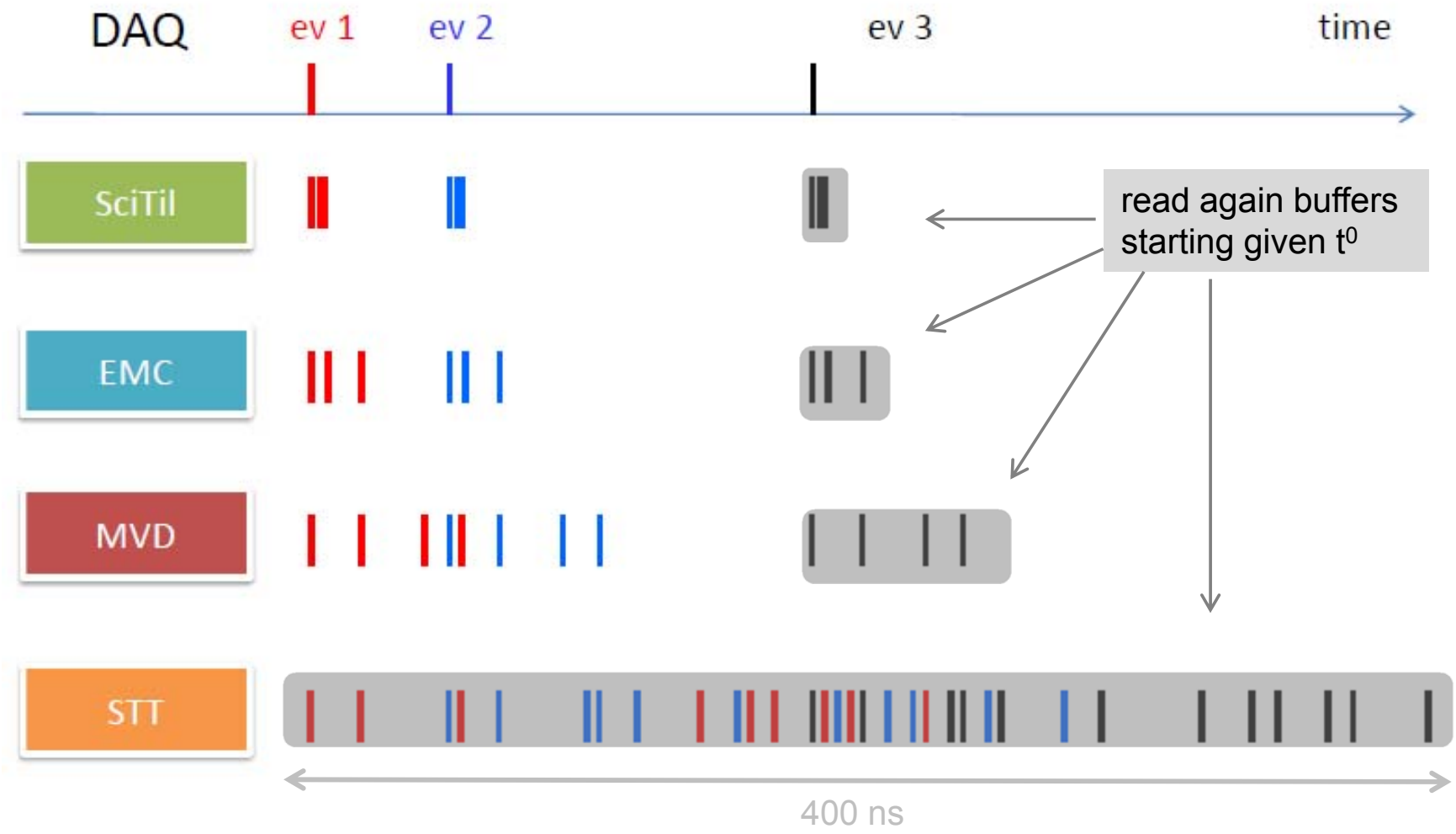


Figure from K.Götzen

Event building II

Realistic event building strategy with time gap in SciTil

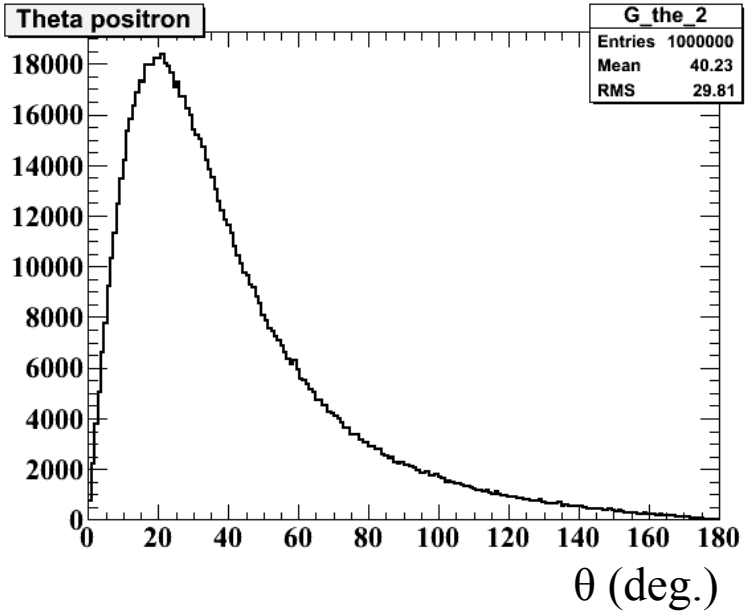


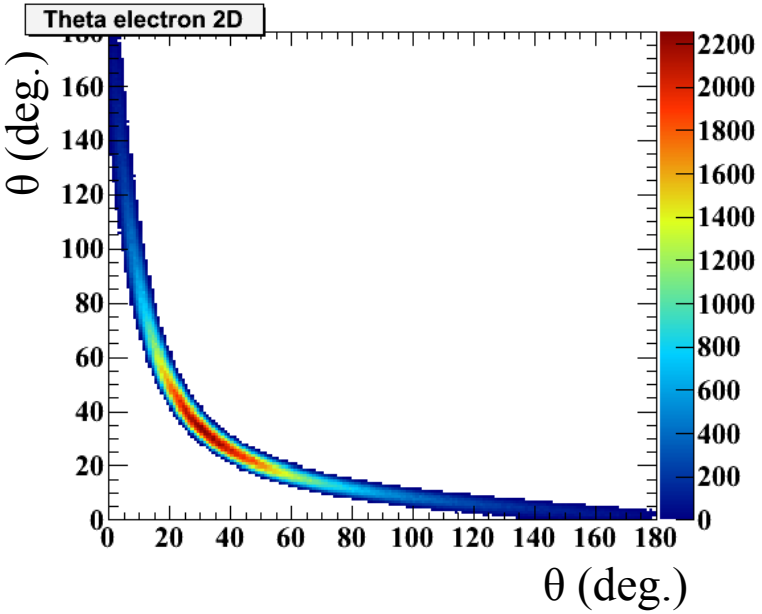
due to drift time of STT

8 events can be mixed in ±200ns and average

Benchmark channels

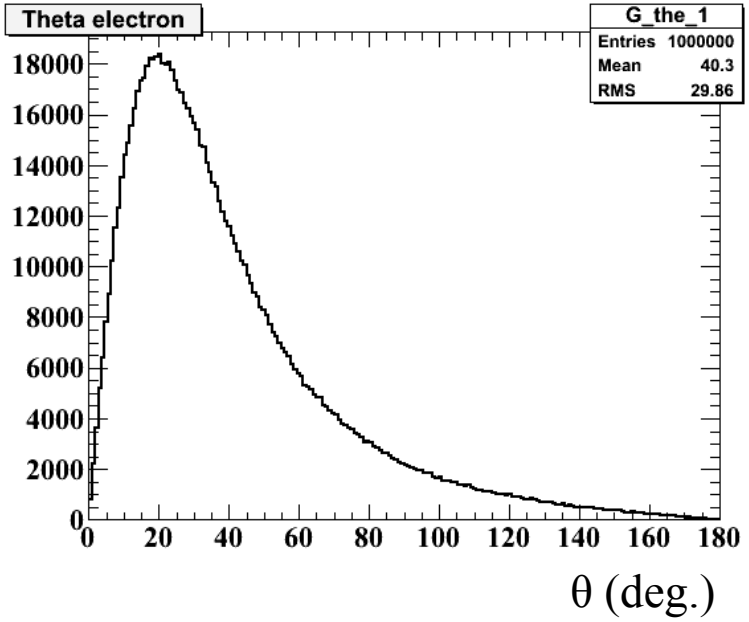
Kinematic feature : θ distribution of $J/\psi \to e^+e^-$





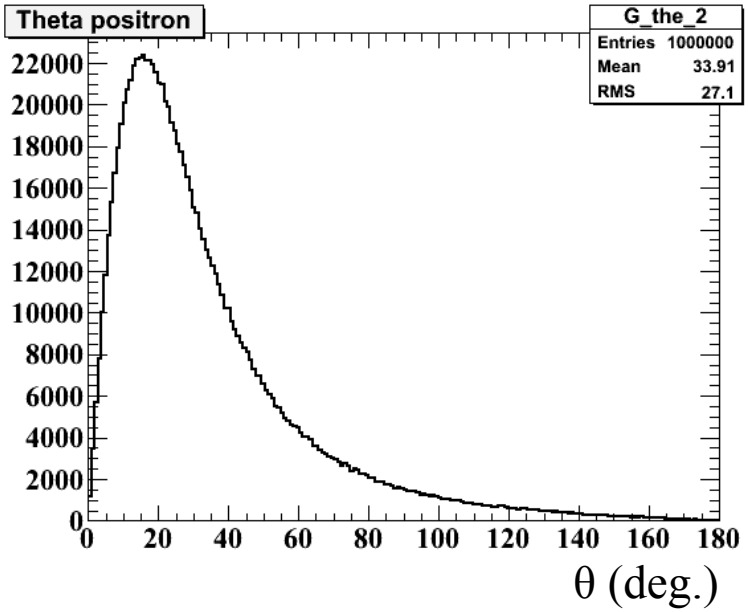
$$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$$

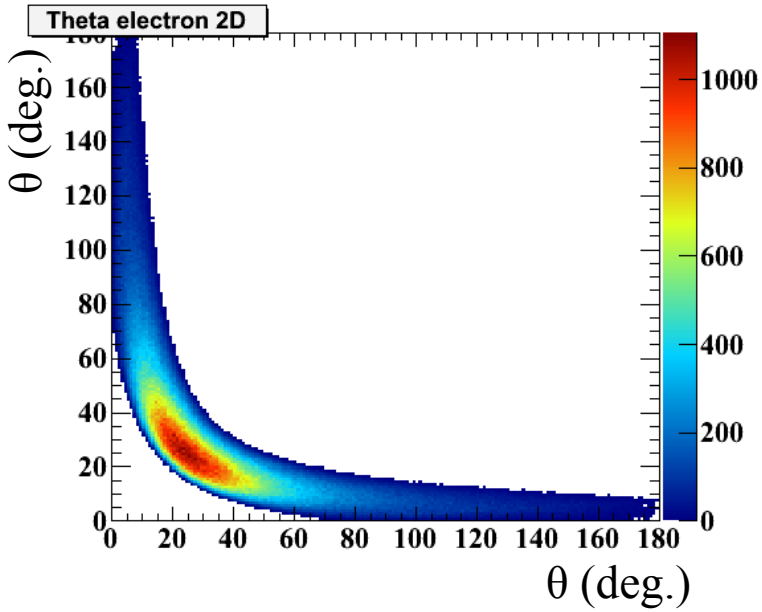
$$\sqrt{s} = 3.526 \text{ GeV}$$



Benchmark channels

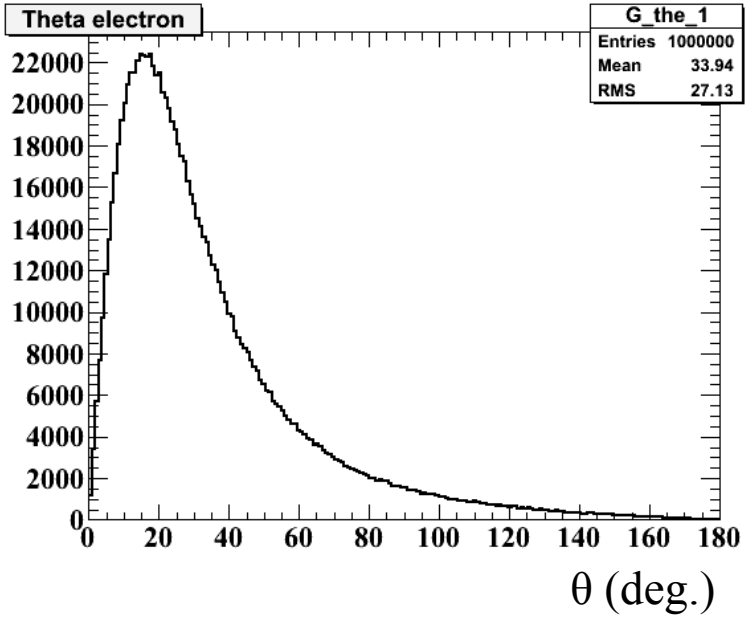
Kinematic feature : θ distribution of $J/\psi \to e^+e^-$





$$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$$

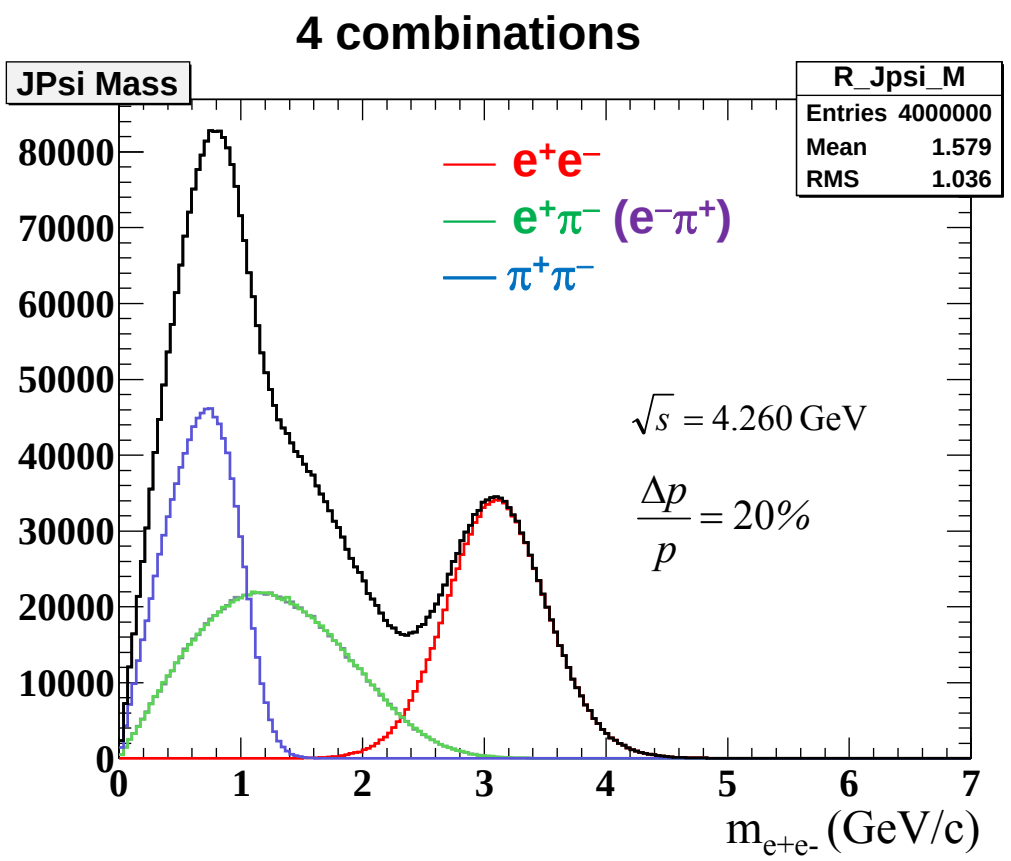
$$\sqrt{s} = 4.260 \text{ GeV}$$

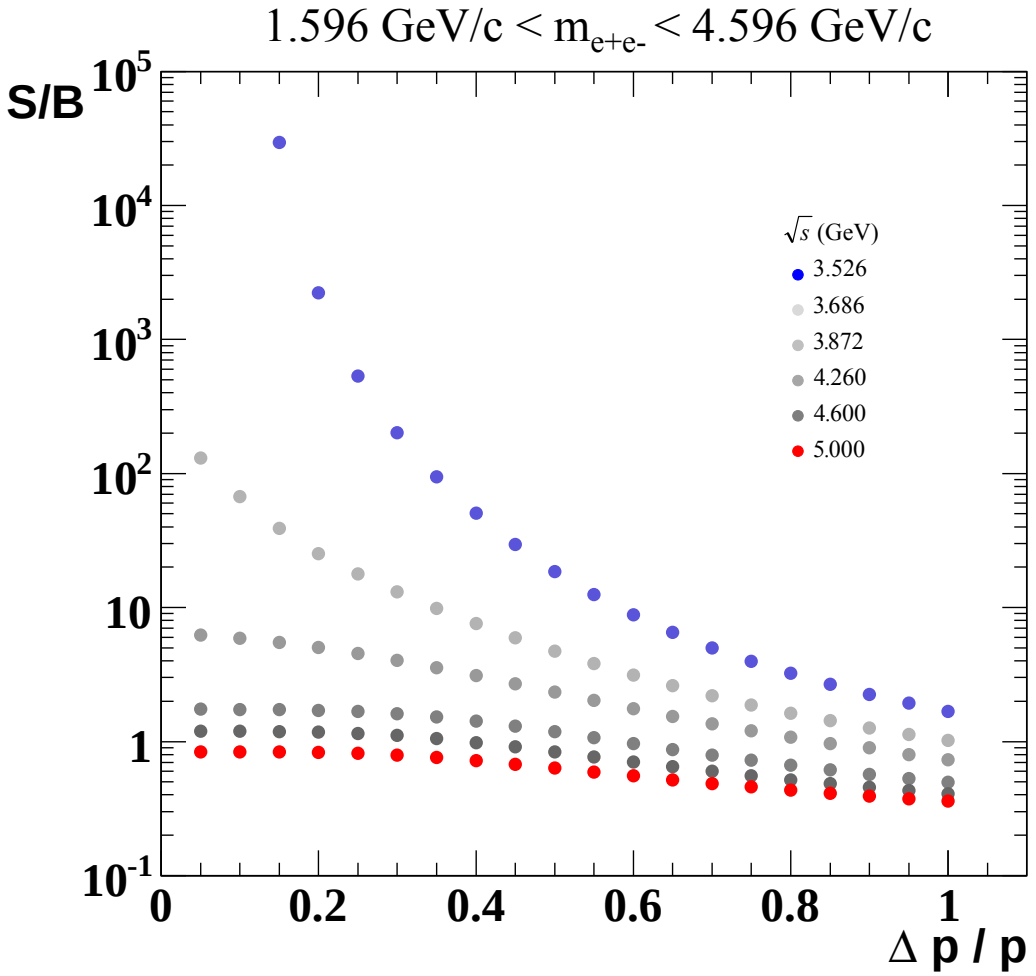


Combinatorial background

Combinatorial background of J/ψ event with electron hypothesis (EvtGen)

$$\bar{p}p \to J/\psi\pi^+\pi^- \to e^+e^-\pi^+\pi^-$$

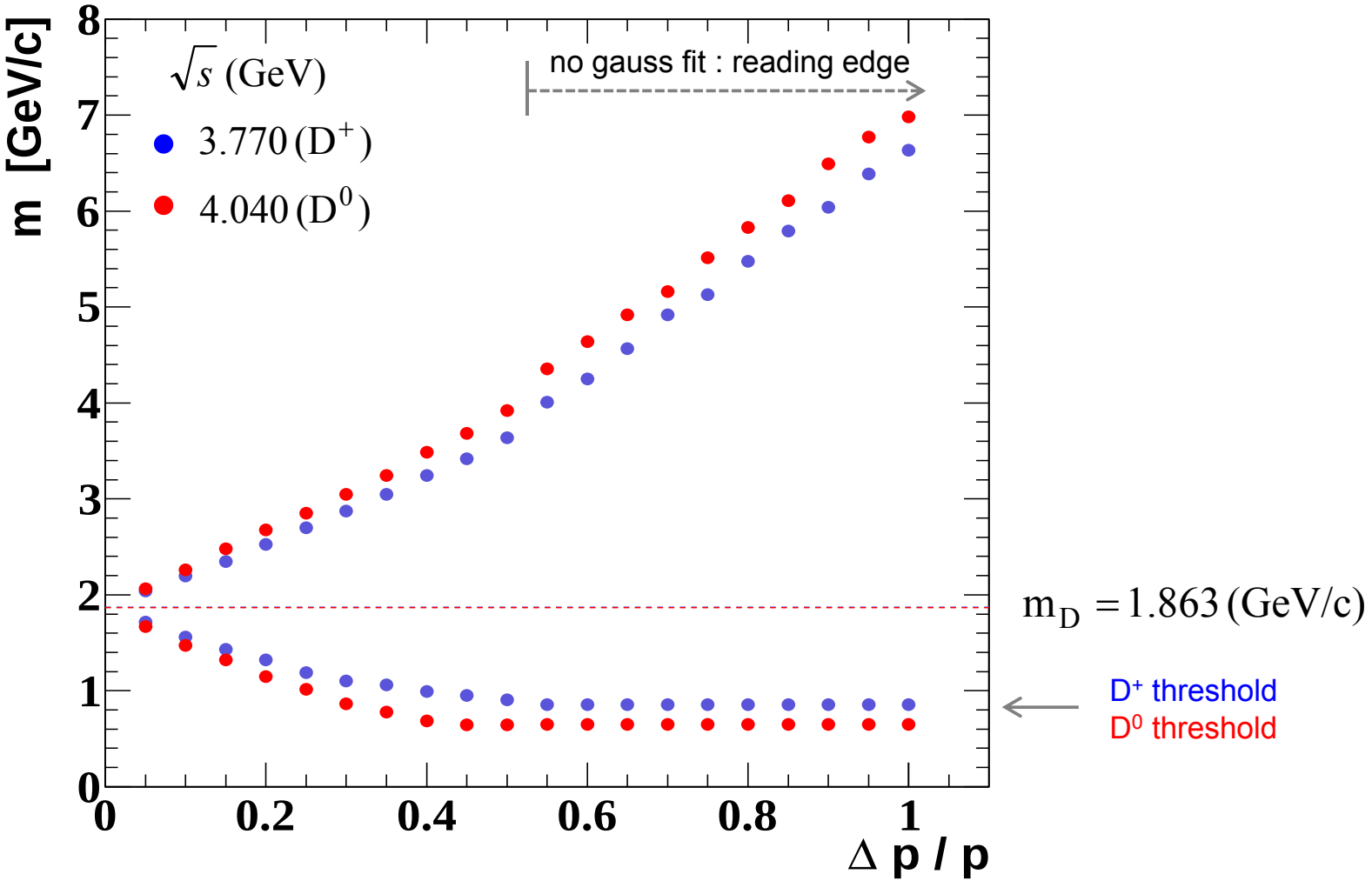




Benchmark channels

$D^{\pm}$, D^0 mass window vary: $m_D - 2\sigma_m < m_{K\pi\pi(K\pi)} < m_D + 2\sigma_m$ GeV/c

- combining 3(2) tracks with K and π mass hypothesis in each $D^{\pm}(D^0)$ event
- total 9 combinations from 6 tracks for both $D^{\pm}$ and D^0 event

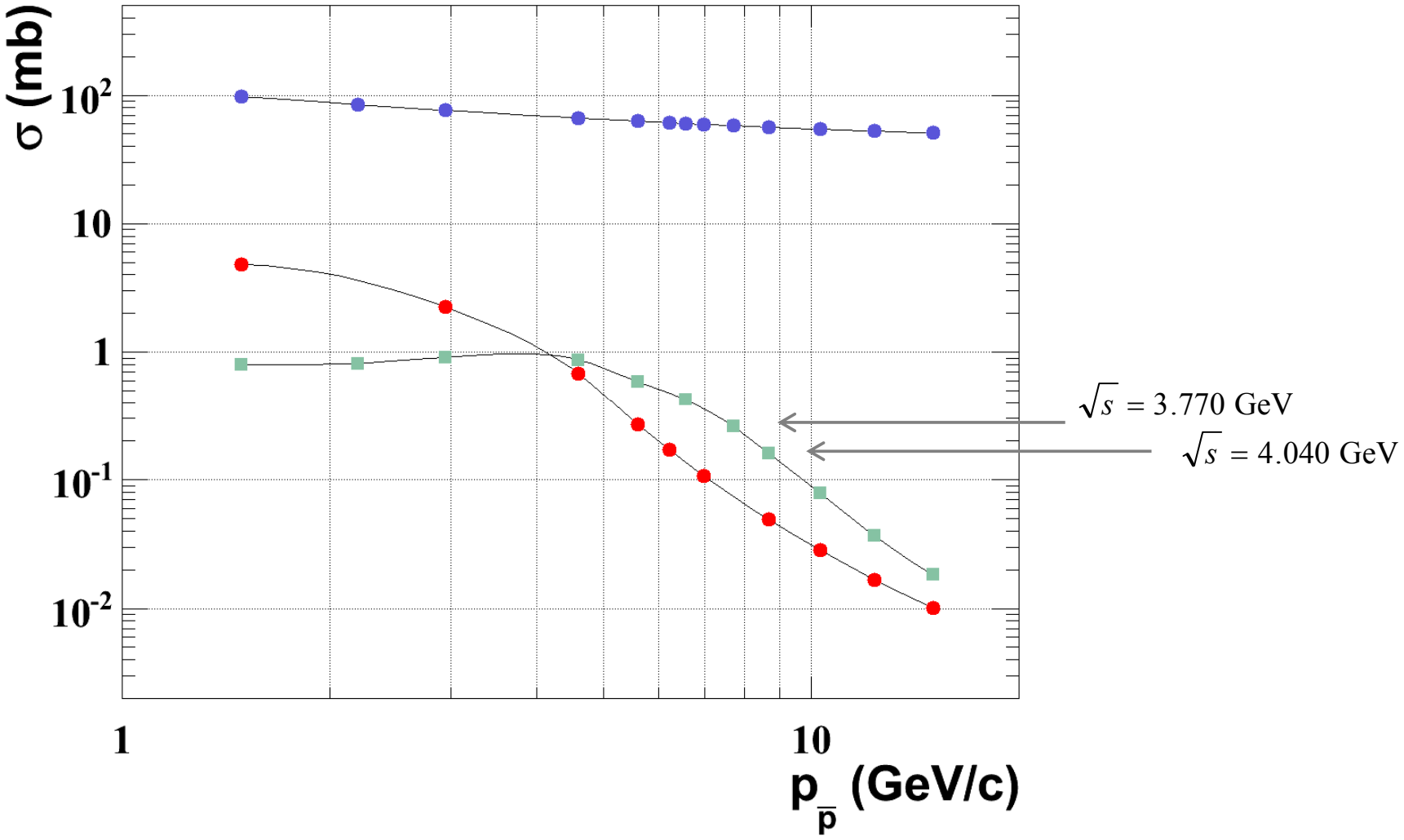


Background study

Background with DPM generator

Inelastic $\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$ event for two beam momentum are selected from DPM generation

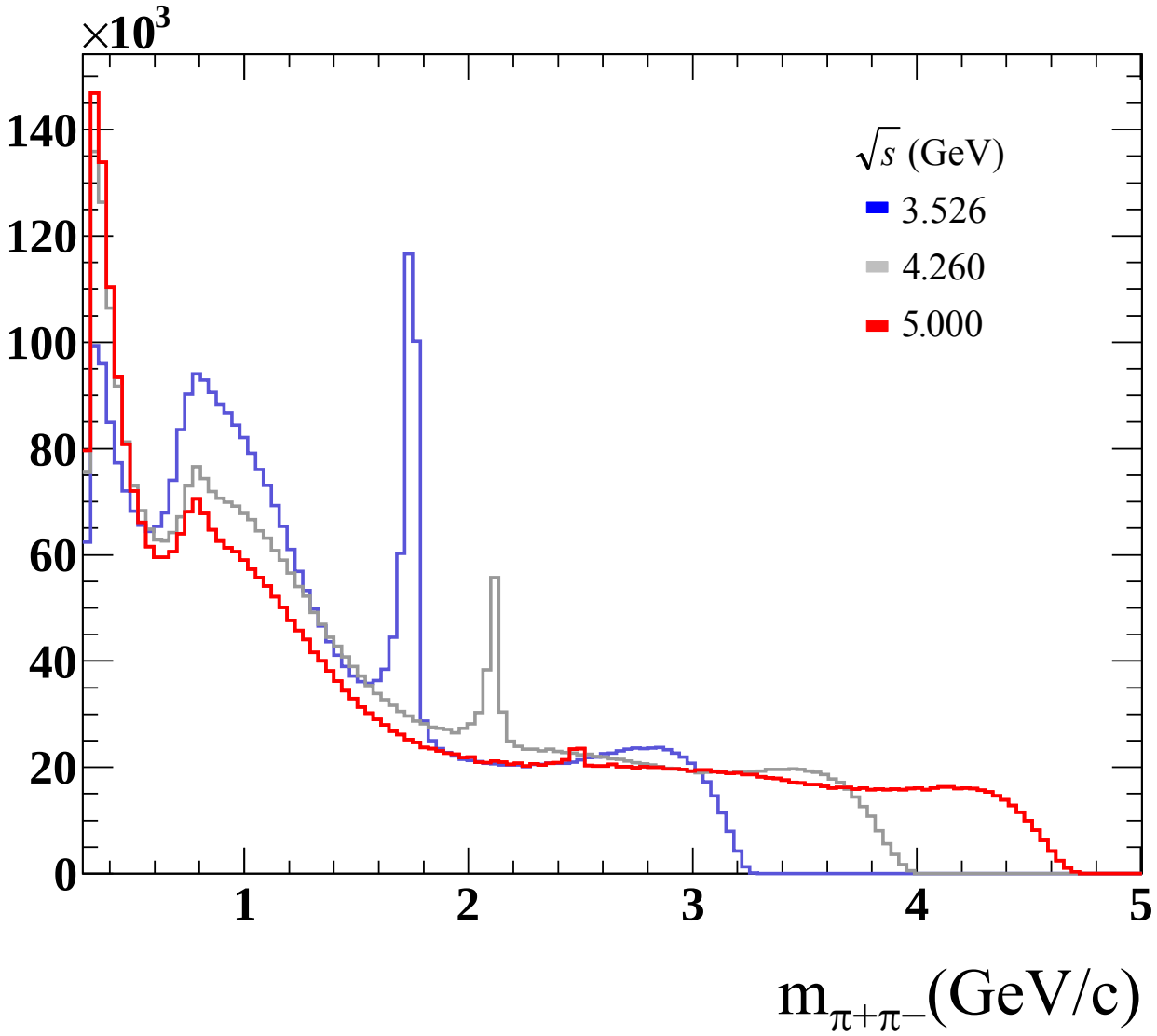
- **total cross section**
- $\pi^+\pi^-\pi^+\pi^-$ cross section
- $\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$ cross section



Background study

Background with DPM generator

DPM $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-$ π mass hypothesis

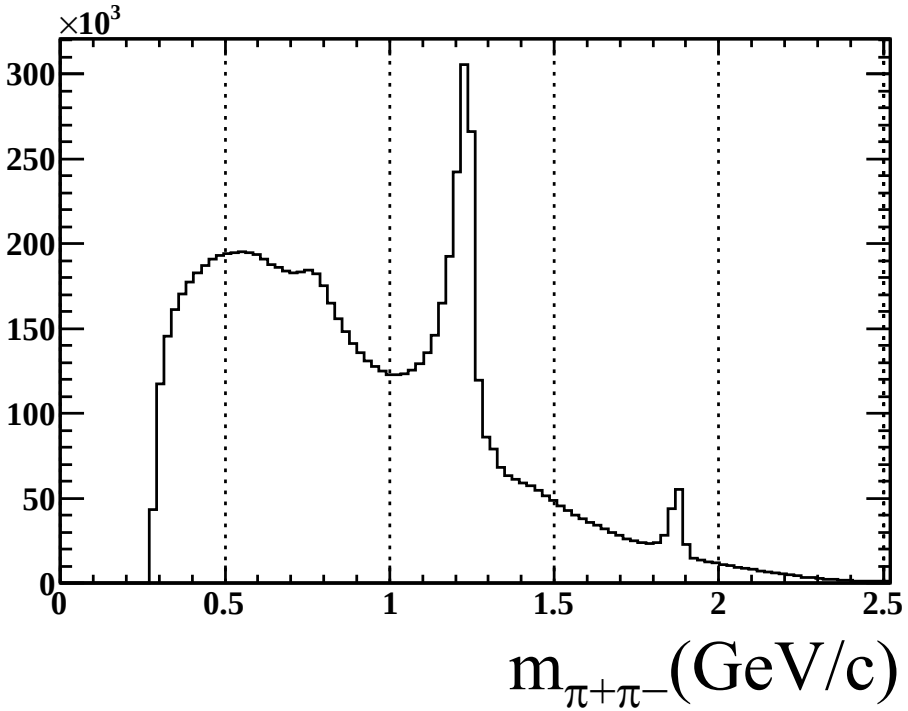


Background study

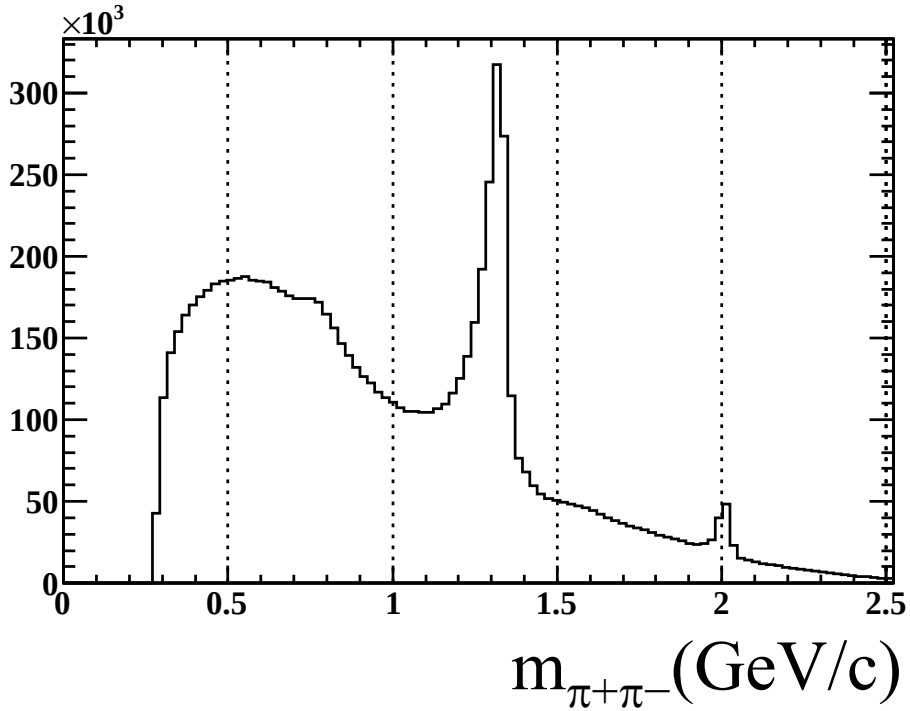
Background with DPM generator

DPM $\bar{p}p \to \pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$ π mass hypothesis

$\sqrt{s} = 3.770$ GeV

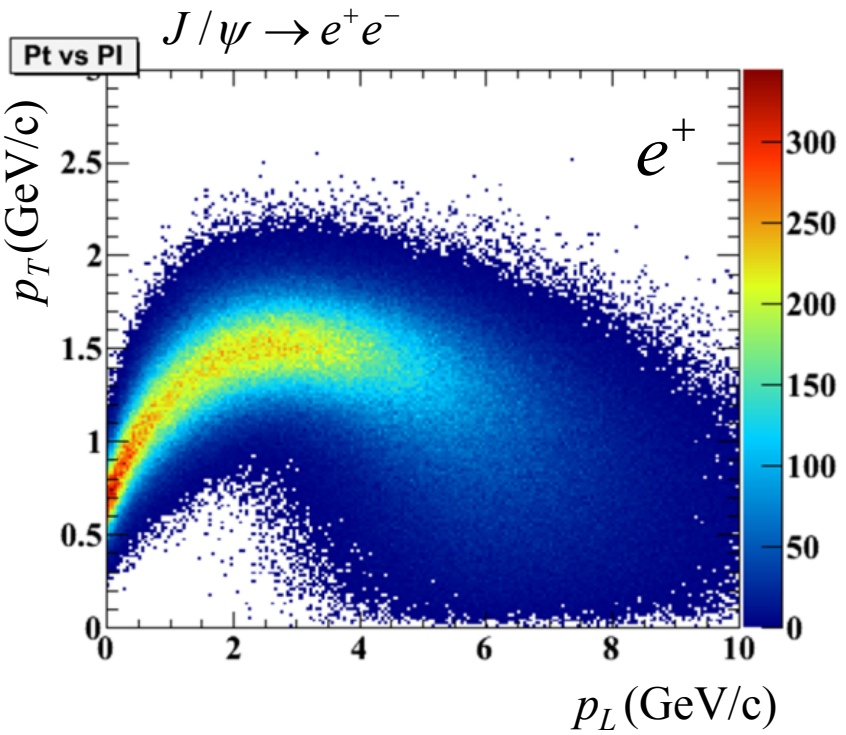


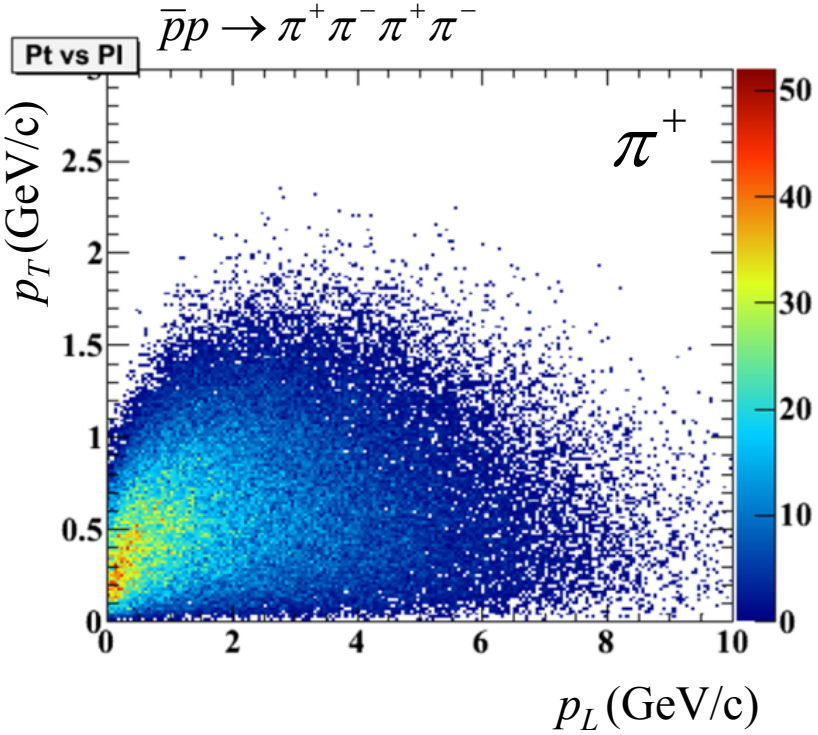
$\sqrt{s} = 4.040$ GeV



Outlook

J/ψ : cuts on p_T or opening angle will be necessary





D meson : much more difficult than J/ψ, the fraction of background is too large
π-K separation from EMC is known to be not optimal (< 25%)
possible solution should be dE/dx from STT, MVD, and DIRC(?)