Baryonspektroskopie bei COMPASS

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Trigger Meeting Bonn
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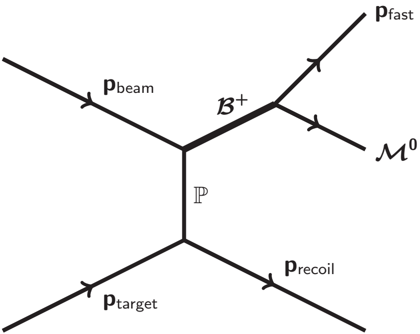
JOHANNES GUTENBERG UNIVERSITÄT MAINZ

Inhalt

Idee

- 2009 Datennahme mit Protonstrahl ($\mathbf{h}^+$-Strahl)
- Untersuchung diffraktiver Anregungen des Strahlprotons
- Beschränkung auf 2-Teilchen Endzustände (hier $\mathbf{p}\boldsymbol{\pi}^\mathbf{0}$ und $\mathbf{p}\boldsymbol{\eta}$)



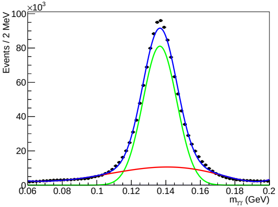
Basisselektion

1. DT0-Trigger
2. genau ein primärer Vertex im Target
3. einlaufendes Proton in mind. einem CEDAR registriert (kein Pion in beiden CEDARs)
4. rekonstruiertes Rückstoßproton
5. ein auslaufendes geladenes Teilchen
6. mit Ladung $+1$
7. genau zwei Photonen in den ECALs
    - Energie mindestens (1,2) $\mathbf{GeV}$ in ECAL (1,2)
    - LED/Laser Korrekturen
    - weitere Korrekturen aus der OZI Analyse (J. Bernhard, K. Schoenning)
    - runs 77594, 77595 und 77598 haben keine Korrekturen und werden ausgelassen

π^0/η Selektion

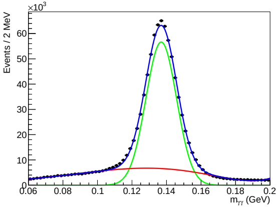
- invariante $\gamma\gamma$ Masse innerhalb 2σ um die PDG Masse
- skaliere Photonenergie um π^0/η auf die PDG Masse zu schieben

π^0 in ECAL (1,1)



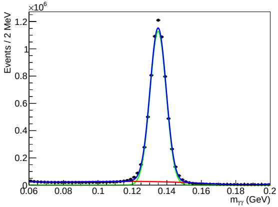
$\sigma = 9.79$ MeV

π^0 in ECAL (1,2)/(2,1)



$\sigma = 8.87$ MeV

π^0 in ECAL (2,2)



$\sigma = 4.68$ MeV

$$f(m) = n_{sig} \cdot \exp\left(-\frac{(m-m_0)^2}{2\sigma^2}\right) + n_{bkg} \cdot \mathrm{Pol}(m)$$

π^0/η Selektion

- invariante $\gamma\gamma$ Masse innerhalb 2σ um die PDG Masse
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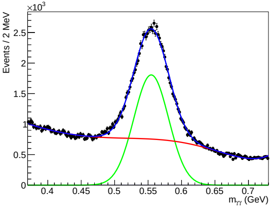
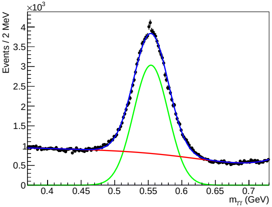
η in ECAL (1,1)



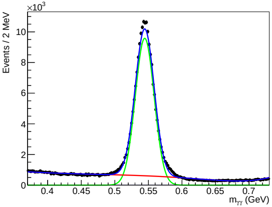
$\sigma = 26.0$ MeV

η in ECAL (1,2)/(2,1)



$\sigma = 25.8$ MeV

η in ECAL (2,2)

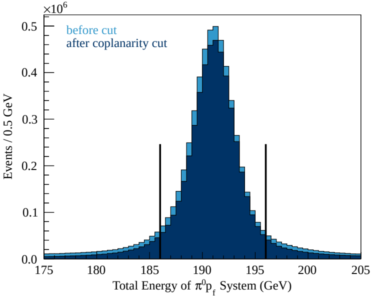


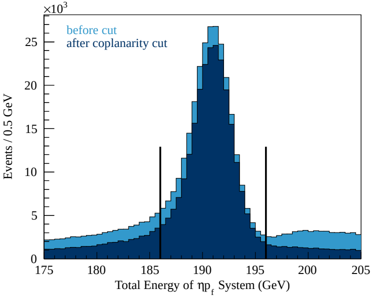
$\sigma = 14.1$ MeV

$$f(m) = n_{sig} \cdot \exp\left(-\frac{(m - m_0)^2}{2\sigma^2}\right) + n_{bkg} \cdot \mathrm{Pol}(m)$$

Finale Selektion

8. rekonstruiertes π^0 oder η
9. Exclusivität ((191 ± 5) GeV)
10. Koplanarität (± 0.26 rad)
11. Impulsübertrag $0.1\ \mathrm{GeV}^2/c^2 < t' < 1.0\ \mathrm{GeV}^2/c^2$





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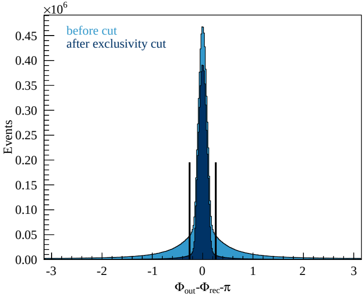

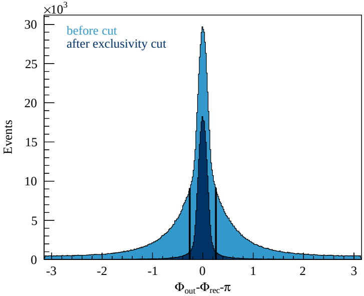

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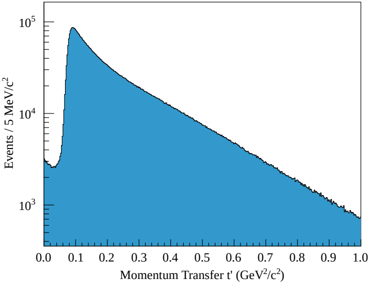
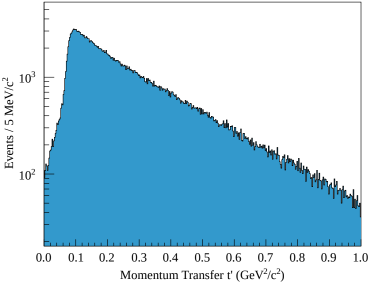
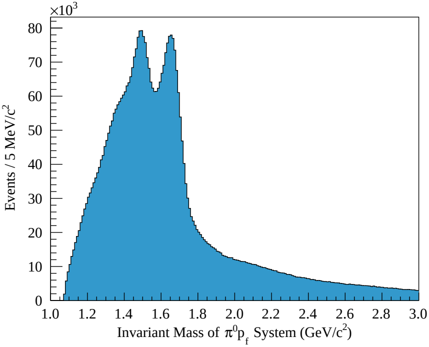


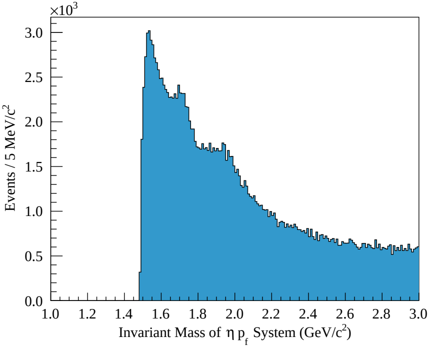


Invariante Massen nach allen Schnitten

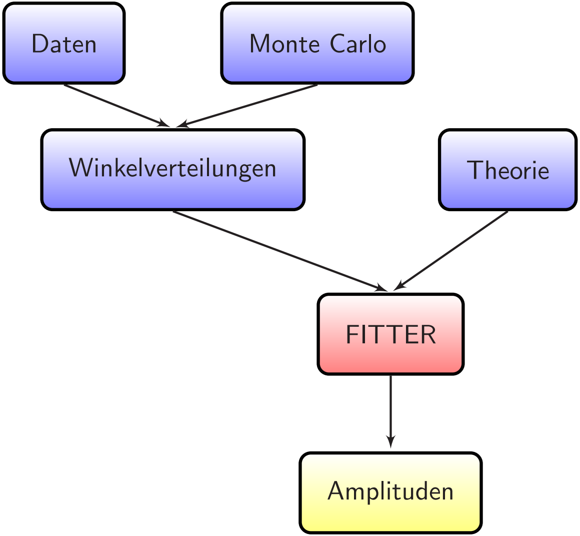
π^0



η

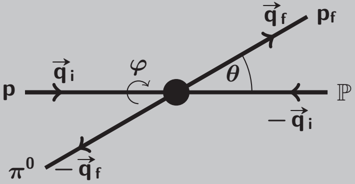


Konzept


Daten
Monte Carlo
Winkelverteilungen
Theorie
FITTER
Amplituden

Theorie

Produktion

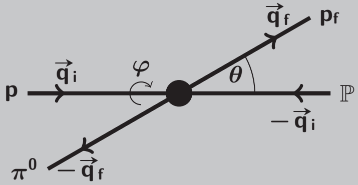


$$\frac{d\sigma}{d\Omega}(s,\theta) = \frac{1}{8\,|\vec{q}_f|^2} \sum_{\substack{\lambda_i=\pm\frac{1}{2}\\ \lambda_f=\pm\frac{1}{2}}} \left| \sum_{J=0}^{\infty} (2J+1) T^J_{\lambda_i\lambda_f}(s) d^{*J}_{\lambda_i\lambda_f}(\theta) \right|^2$$

Keine φ-Abhängigkeit (unpolarisiert)

Theorie

Produktion



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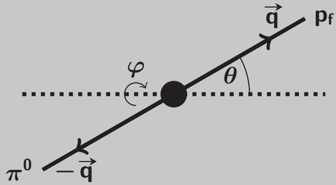
Keine φ-Abhängigkeit (unpolarisiert)

Zerfall



$$\frac{d\Gamma}{d\Omega}(s,\theta,\varphi) = \frac{1}{32\pi^2}\frac{|q|}{M^2} \sum_{\lambda} \left| \sum_{J,M_J} \sqrt{\frac{2J+1}{4\pi}} T^J_{M_J\lambda}(s) D^{*J}_{M_J\lambda}(\theta,\varphi) \right|^2$$

φ-Abhängigkeit in Verteilungen sichtbar (echt?)

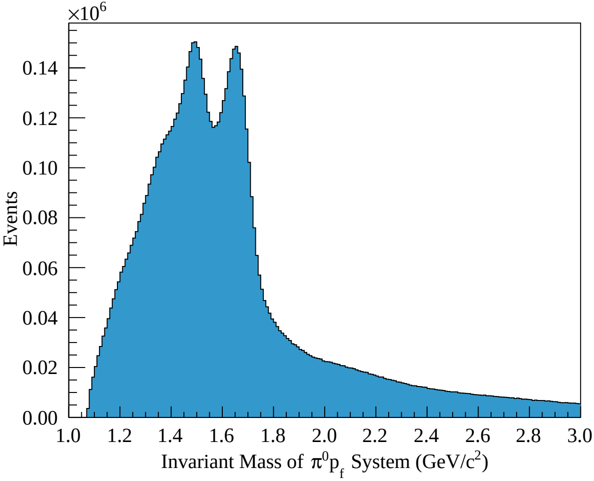
Status

- Akzeptanzkorrektur für $\mathbf{p}\boldsymbol{\pi}^{\mathbf{0}}$ und $\mathbf{p}\boldsymbol{\eta}$ für beide Parametrisierungen
- PWA Fitter entwickelt
  - beide Parametrisierungen möglich
  - Fit in (beliebigen) Massenbins
  - verschiedene Fitalgorithmen möglich
- Gespräch mit Spezialisten in Mainz
  - welche Parametrisierung ist die vernünftigste?
  - wie geht man mit Ambiguitäten um?
  - wie erklärt sich die φ-Abhängigkeit bei einer unpolarisierten Messung?
  - Antwort im Januar erwartet

BACKUP

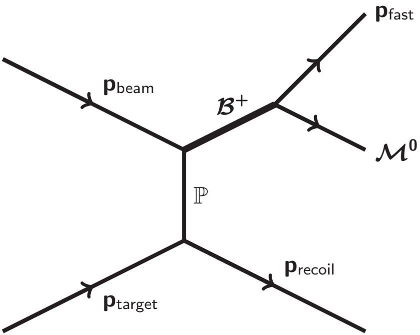
Starting Point

2009 **pp** $\rightarrow$ **p**π^0**p** data released in May 2013



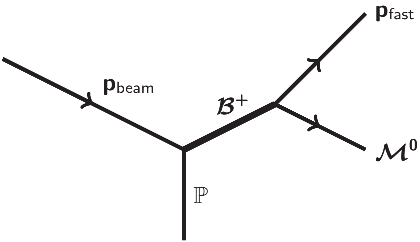
Simplifying the Process

- target/recoil proton does not participate in the reaction



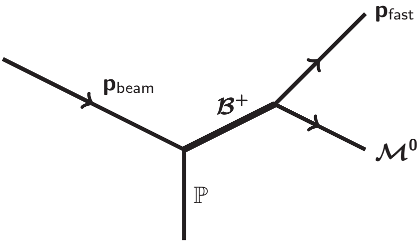
Simplifying the Process

- target/recoil proton does not participate in the reaction
- switch to 'target pomeron'



Simplifying the Process

- target/recoil proton does not participate in the reaction
- switch to 'target pomeron'
- transform to $\mathcal{B}^+$ rest frame



Simplifying the Process

- target/recoil proton does not participate in the reaction
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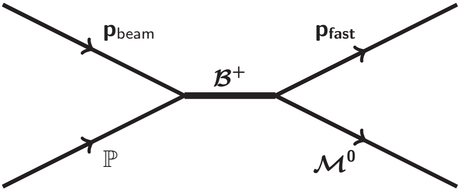

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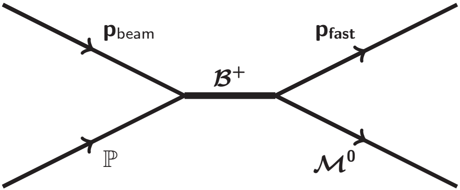
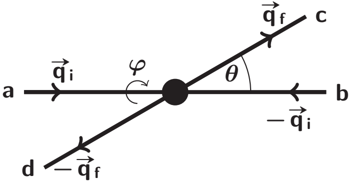


Some Constraints

- Neglect everything but spin-0 pomeron exchange
- Concentrate on spin-0 mesons (π^0, η)

2-Particle Scattering

$$\frac{d\sigma}{d\Omega}(s, \theta, \varphi) = \frac{1}{64\pi^2 s} \frac{|\vec{q}_i|}{|\vec{q}_f|} |\langle f|T|i\rangle|^2$$



with

- $s = M_{ab}^2 = M_{cd}^2$
- $|i\rangle = |q_i, \theta_i, \phi_i, \lambda_a, \lambda_b\rangle$

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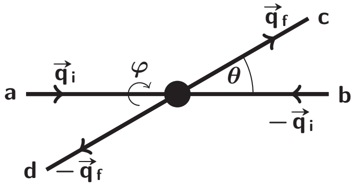


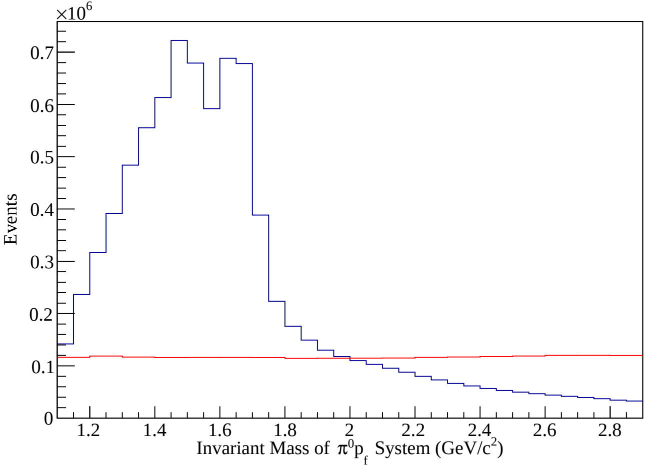
Unpolarised Measurement

- No φ dependence
- Only two remaining variables: $\mathbf{M_{p\pi^0}}$ and $\mathbf{cos(\theta)}$

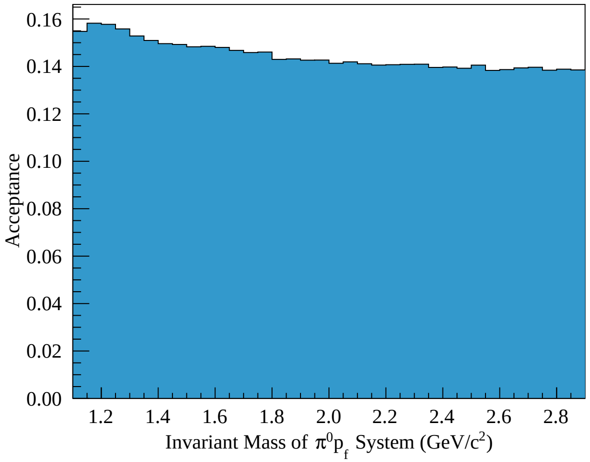
$\rightarrow$ Do acceptance correction in these variables

Monte Carlo

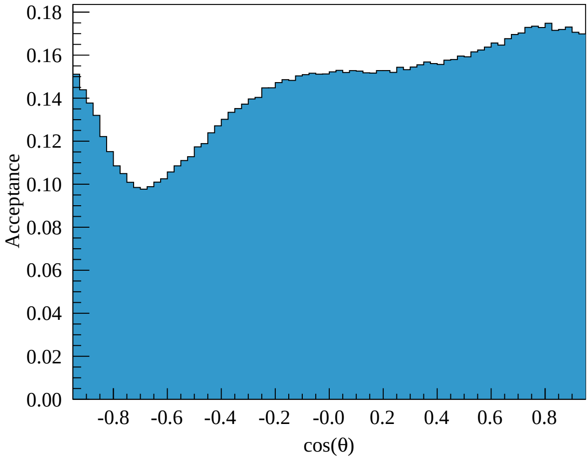
- Same Monte Carlo chain as in OZI analysis (Thanks to Karin)
- So far 17M events generated
- 2.5M events accepted



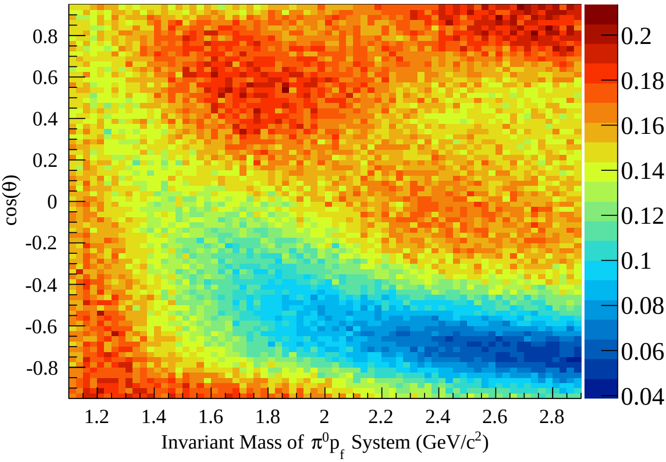
Acceptance in $\mathbf{M_{p\pi^0}}$



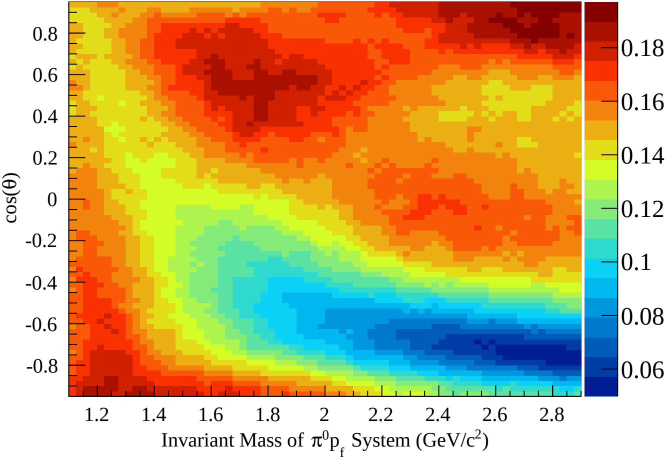
Acceptance in $\cos(\theta)$



Acceptance in $\mathbf{M_{p\pi^0}}$ vs. $\mathbf{cos(\theta)}$



Acceptance in $\mathbf{M_{p\pi^0}}$ vs. $\mathbf{cos(\theta)}$

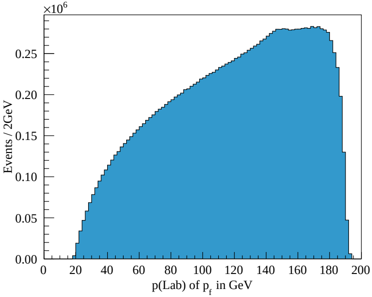


Explaining the Structures

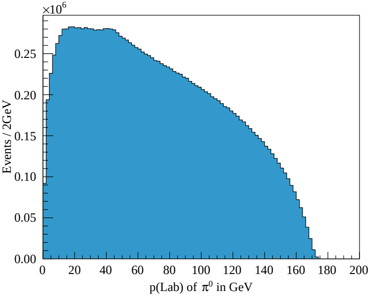
Look at momentum of $\mathbf{p}_{\text{fast}}$ and $\boldsymbol{\pi}^0$:

Full Data

$\mathbf{p}_{\text{fast}}$



$\boldsymbol{\pi}^0$



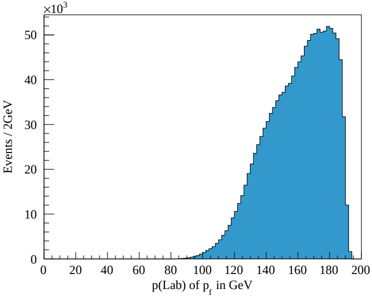
18.1% of events have reconstructed $\boldsymbol{\pi}^0$

Explaining the Structures

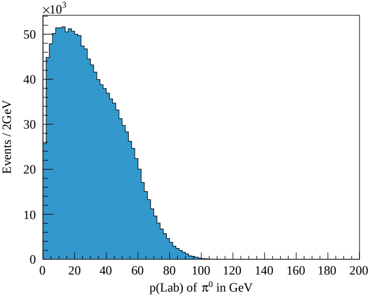
Look at momentum of $\mathbf{p}_{\text{fast}}$ and π^0:

$$\mathbf{0.5} < \mathbf{cos(}\theta\mathbf{)} < \mathbf{0.9} \text{ (good acceptance)}$$

$\mathbf{p}_{\text{fast}}$



π^0

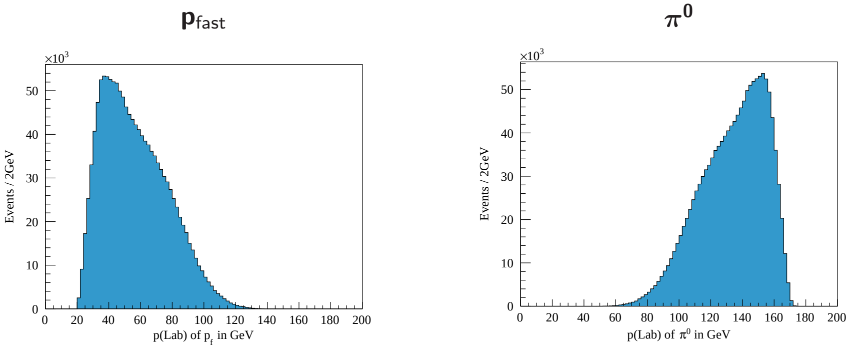


22.9% of events have reconstructed π^0

Explaining the Structures

Look at momentum of $\mathbf{p}_{\text{fast}}$ and π^0:

$$-0.5 > \cos(\theta) > -0.9 \text{ (bad acceptance)}$$

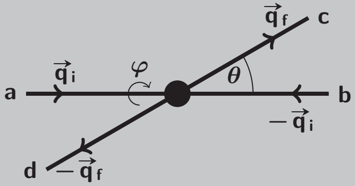


12.7% of events have reconstructed π^0

2-Particle Scattering Amplitudes

Cross Section

$$\frac{d\sigma}{d\Omega}(s,\theta,\varphi) = \frac{1}{64\pi^2 s}\frac{|\vec{q}_i|}{|\vec{q}_f|}\left|\langle f|T|i\rangle\right|^2$$



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- $|i\rangle = |q_i, \theta_i, \phi_i, \lambda_a, \lambda_b\rangle$

Partial Wave Decomposition

$$\langle f|T|i\rangle = 4\pi\sqrt{\frac{s}{q_i q_f}}\sum_{J=0}^{\infty}(2J+1){D^*}^J_{\lambda_i\lambda_f}(\varphi,\theta,0)T^J_{\lambda_a\lambda_b\lambda_c\lambda_d}(s)$$

with $\lambda_i = \lambda_a - \lambda_b$ and $\lambda_f = \lambda_c - \lambda_d$

2-Particle Scattering Amplitudes

Partial Wave Decomposition

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with $\lambda_i = \lambda_a - \lambda_b$ and $\lambda_f = \lambda_c - \lambda_d$

For $p\mathbb{P} \rightarrow p\pi^0$:

- $\lambda_b = \lambda_d = 0 \Rightarrow \lambda_i = \lambda_a$ and $\lambda_f = \lambda_c$
- $\lambda_{i,f} = \pm\frac{1}{2}$
- $J = L \pm \frac{1}{2}$

$$\langle f|T|i\rangle = 4\pi\sqrt{\frac{s}{q_i q_f}}\sum_{J=0}^{\infty}(2J+1){D^*}^J_{\lambda_i\lambda_f}(\varphi,\theta,0)T^J_{\lambda_i\lambda_f}(s)$$

2-Particle Scattering Amplitudes

- unpolarized beam and target ⇒ average over initial state spins
- final state spins not measured ⇒ sum over final state spins

Full Cross Section

$$\frac{d\sigma}{d\Omega}(s,\theta,\varphi) = \frac{1}{4}\frac{1}{|\vec{q}_f|^2}\frac{1}{2}\sum_{\substack{\lambda_i=\pm\frac{1}{2}\\ \lambda_f=\pm\frac{1}{2}}}\left|\sum_{J=0}^{\infty}(2J+1){D^*}^{J}_{\lambda_i\lambda_f}(\varphi,\theta,0)T^{J}_{\lambda_i\lambda_f}(s)\right|^2$$

⇒ Four complex amplitudes for each **J**

2-Particle Scattering Amplitudes

Full cross section in single mass bin (simplified notation):

$$\frac{d\sigma}{d\Omega}(s,\theta,\varphi) = \frac{1}{4}\frac{1}{|\vec{q}_f|^2}\frac{1}{2}\sum_{\substack{\lambda_i=\pm\frac{1}{2}\\ \lambda_f=\pm\frac{1}{2}}}\left|\sum_{J=0}^{\infty}(2J+1){D^*}^{J}_{\lambda_i\lambda_f}(\varphi,\theta,0)T^J_{\lambda_i\lambda_f}(s)\right|^2$$

Single mass bin (simplified notation):

$$\frac{d\sigma}{d\Omega}(\theta,\varphi) = \frac{1}{8|\vec{q}_f|^2}\sum_{\lambda}\left|\sum_{J=0}^{\infty}(2J+1){D^*}_{J\lambda}(\varphi,\theta,0)T_{J\lambda}\right|^2$$

Work out modulus square

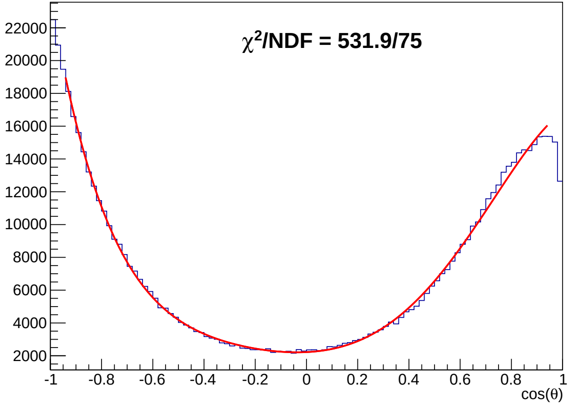
Write amplitude as $T_{JK} = t_{JK}\exp(i\phi_{JK})$:

$$\frac{d\sigma}{d\Omega}(\theta) = \frac{1}{8|\vec{q}_f|^2}\sum_{J,J',\lambda}(2J+1)(2J'+1)d_{J\lambda}(\theta)d_{J'\lambda}(\theta)t_{J\lambda}t_{J'\lambda}\cos(\phi_{J\lambda}-\phi_{J'\lambda})$$

First Tests

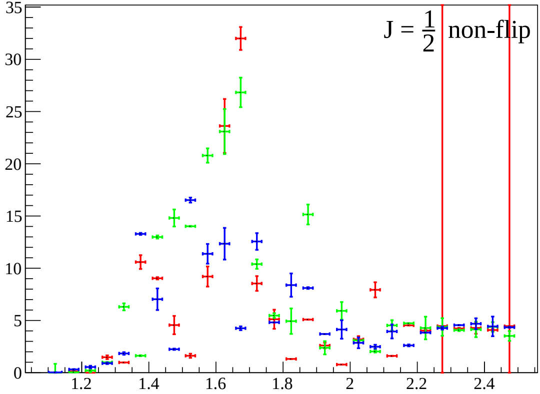
- Fit on uncorrected histograms in 50 $\mathbf{MeV}$mass bins
- Fit up to $\mathbf{J} = \frac{5}{2}$
- Look at amplitudes with and without spin-flip of the proton

Example for Fit: 1450 $\mathbf{MeV}$mass bin



First Tests

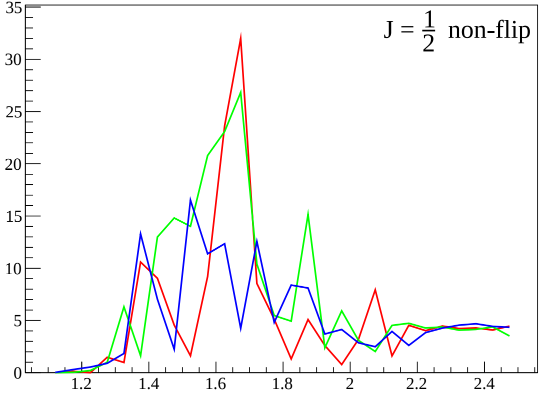
Do 3 fits using different starting values and compare outcome



Difficult to see anything → Draw lines

First Tests

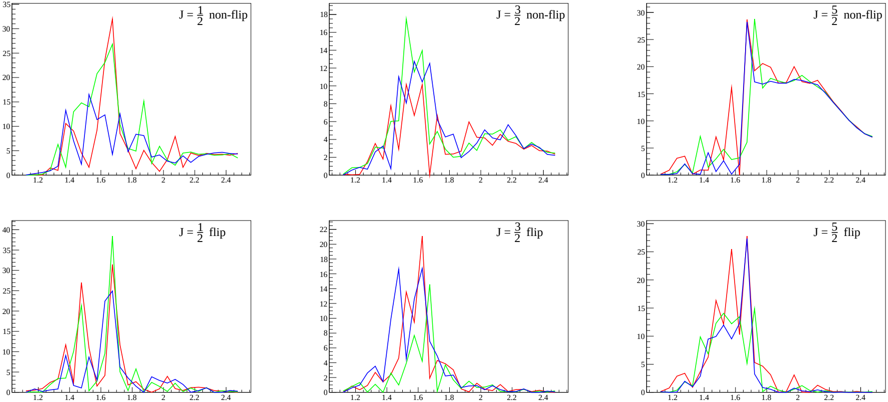
Do 3 fits using different starting values and compare outcome



Difficult to see anything → Draw lines

First Tests

All 6 amplitudes

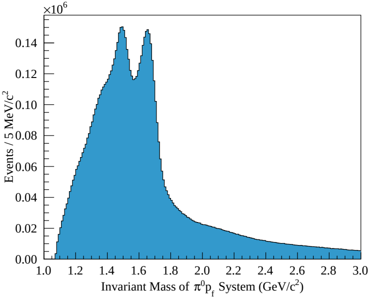


Fit ambiguities or fit instabilities?

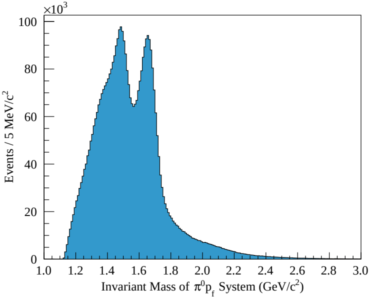
Central Production

What is the contribution from central production?
$\longrightarrow$ Use central production cut by Alex as an anticut: $\mathbf{p(p_f) < 140\ GeV}$

Without cut



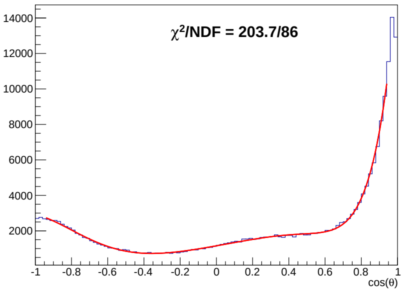
With cut



Central Production

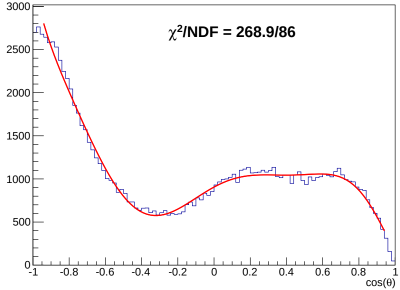
What is the contribution from central production?
$\longrightarrow$ Use central production cut by Alex as an anticut: $\mathbf{p(p_f) < 140\ GeV}$

Without cut



$\mathbf{1750\ MeV}$ mass bin

With cut

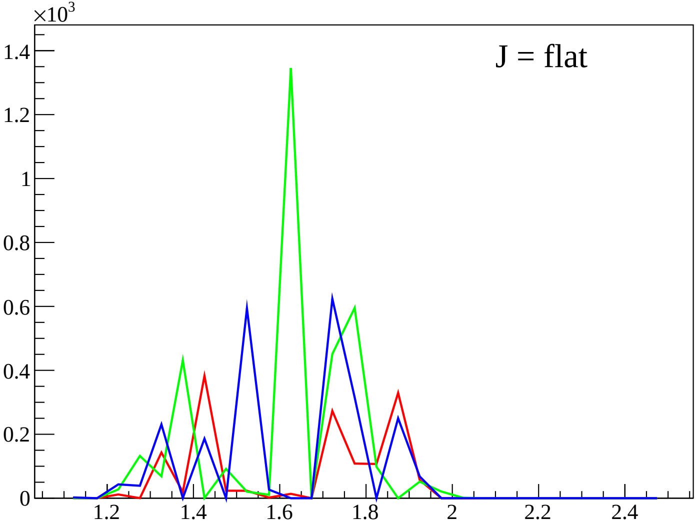


$\mathbf{1750\ MeV}$ mass bin

Next Steps

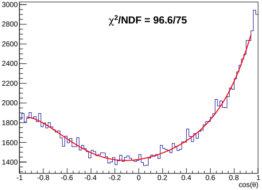
- Finish and include acceptance correction (extended likelihood fit)
- Get handle on fit ambiguities
- Control contribution from central production

Flat Wave

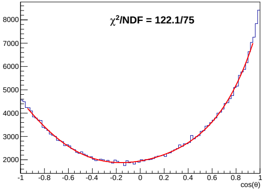


All Fits

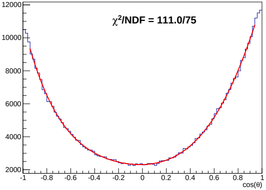
1100 MeV



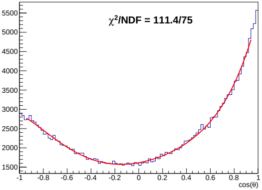
1200 MeV



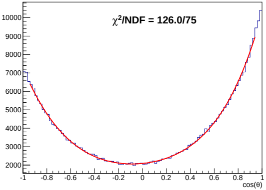
1300 MeV



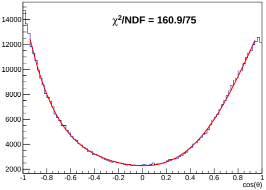
1150 MeV



1250 MeV

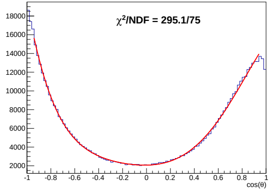


1350 MeV

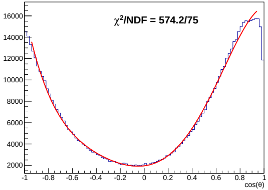


All Fits

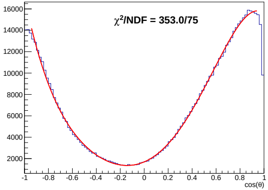
1400 MeV



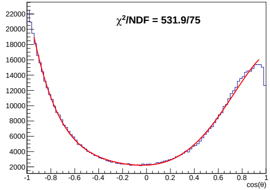
1500 MeV



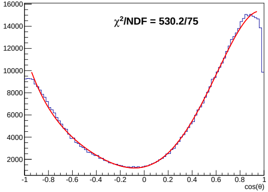
1600 MeV



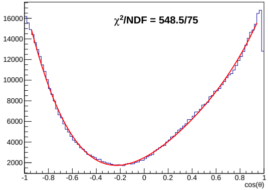
1450 MeV



1550 MeV

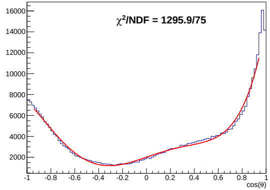


1650 MeV

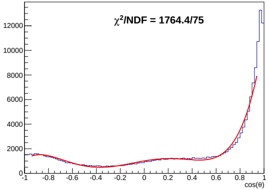


All Fits

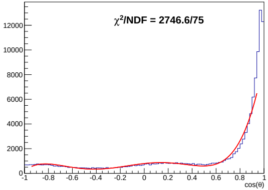
1700 MeV



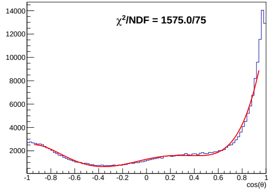
1800 MeV



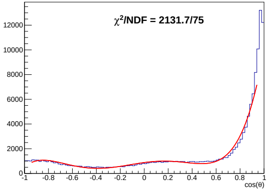
1900 MeV



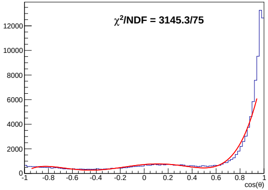
1750 MeV



1850 MeV

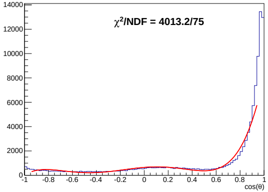


1950 MeV

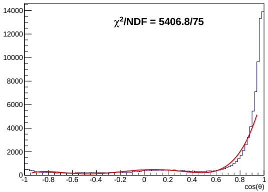


All Fits

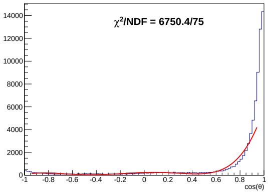
2000 MeV



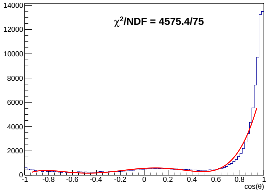
2100 MeV



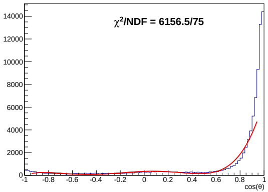
2200 MeV



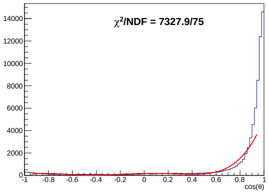
2050 MeV



2150 MeV

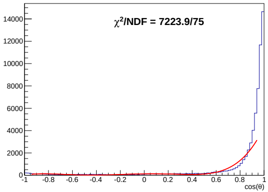


2250 MeV

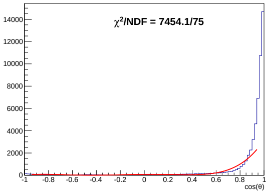


All Fits

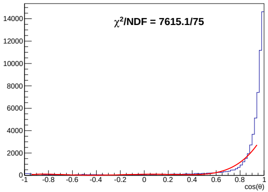
2300 MeV



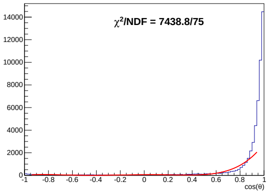
2400 MeV



2350 MeV



2450 MeV

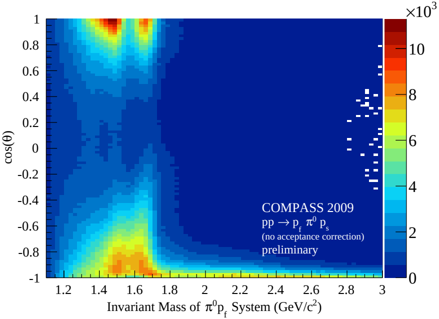


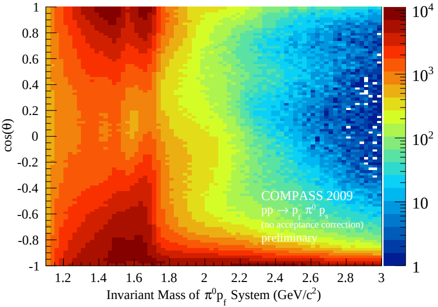
Gottfried-Jackson Frame

- Rest frame of $\mathbf{p_f}\boldsymbol{\pi}^{\mathbf{0}}$;
- y-axis: orthogonal to production plane (beam $\times$ $\mathbf{p_f}\boldsymbol{\pi}^{\mathbf{0}}$)
- z-axis: along beam direction
- x-axis: follows from right-handed coordinate system

$pp \to p_{rec}\pi^0 p_f$ – Gottfried-Jackson Angles

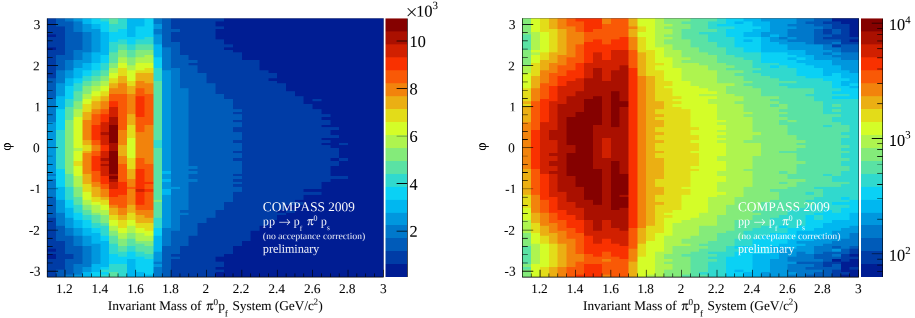
Polar angle $\cos(\theta)$ vs. invariant mass





$pp \rightarrow p_{rec}\pi^0 p_f$ – Gottfried-Jackson Angles

Azimuthal angle φ vs. invariant mass



Parametrisierung

- Wir betrachten nur $\mathbf{X} \longrightarrow \mathbf{p}\pi^0$
- Zerfall im Schwerpunktsystem

$$\frac{d\Gamma}{d\Omega} = \frac{1}{32\pi^2} \frac{|p|}{M^2} |\mathcal{M}|^2$$

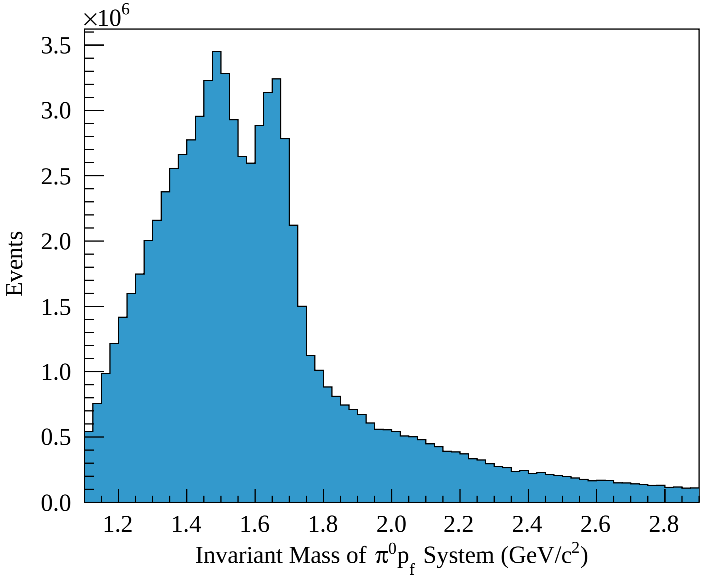
- Partialwellenzerlegung

$$|\mathcal{M}|^2 = \sum_{\lambda} \left| \sum_{J,M_J} \sqrt{\frac{2J+1}{4\pi}} A_{JM_J\lambda} D^{J}_{M_J\lambda}{}^{*}(\Omega) \right|^2$$

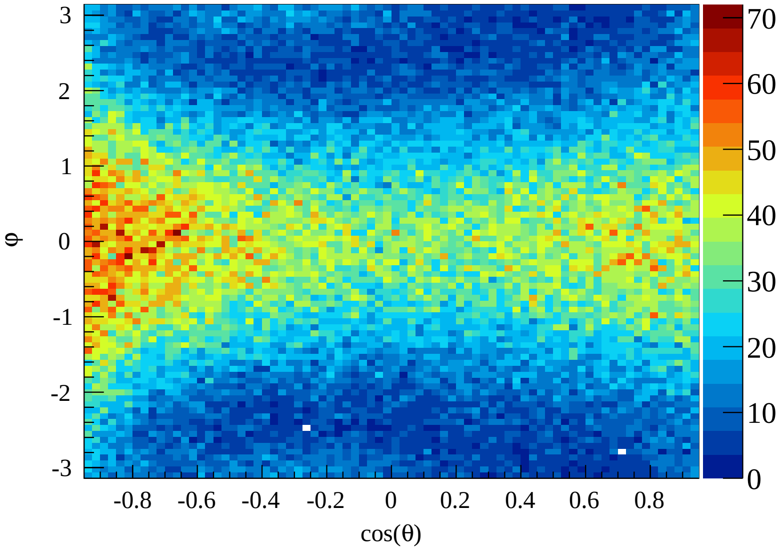
mit

$$D^{J}_{JM_J\lambda}{}^{*}(\Omega) = e^{iM_J\varphi} d^{J}_{JM_J\lambda}(\theta)$$

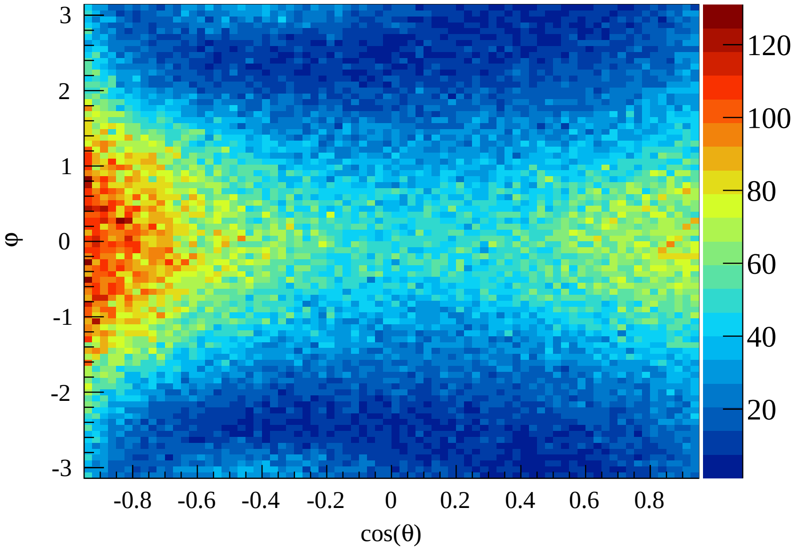
- Abhängigkeit von φ und θ (keine Mittelung über Spins der einlaufenden Teilchen)


×10^6
3.5
3.0
2.5
2.0
1.5
1.0
0.5
0.0
Events
1.2
1.4
1.6
1.8
2.0
2.2
2.4
2.6
2.8
Invariant Mass of π^0 p_f System (GeV/c^2)

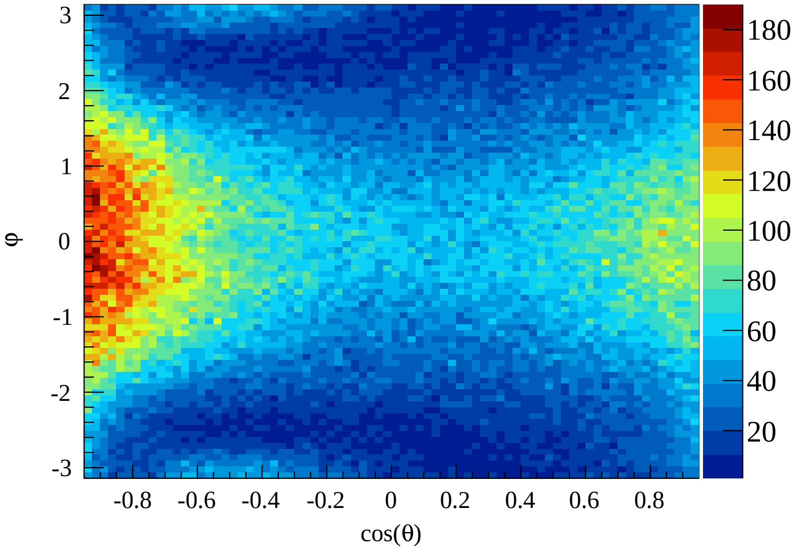
1100 MeV



1150 MeV

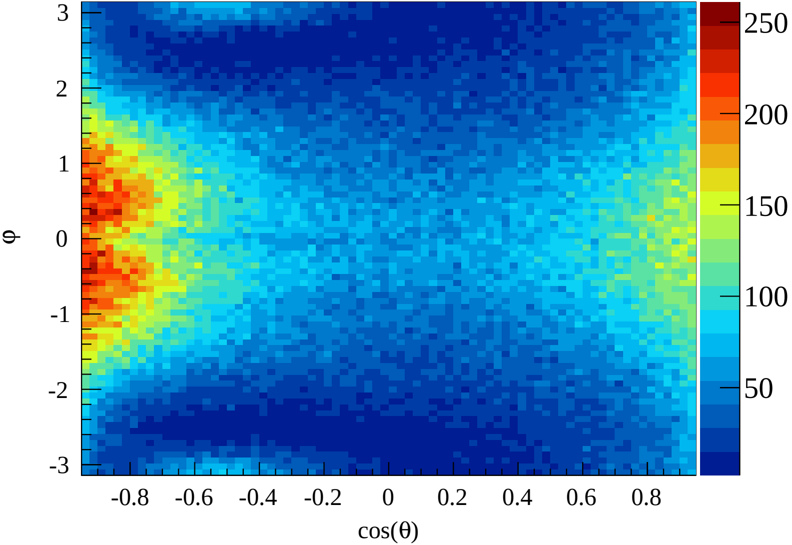


1200 MeV

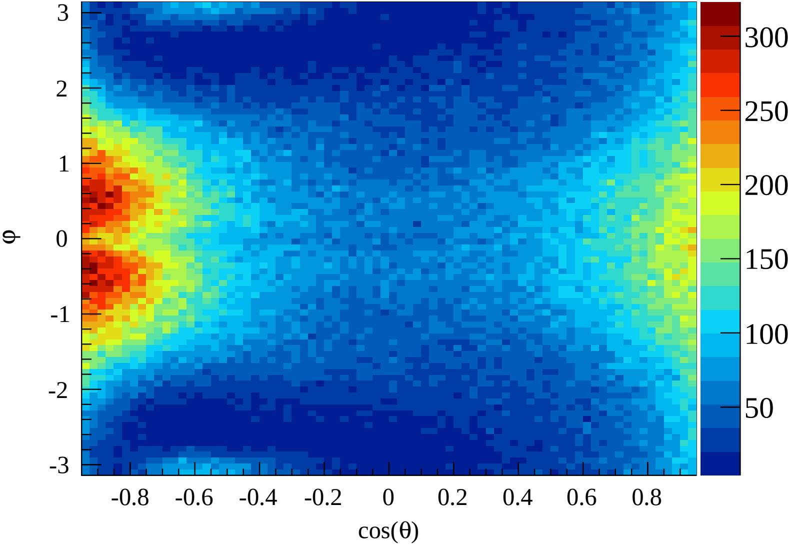


3
2
1
0
-1
-2
-3
φ
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
180
160
140
120
100
80
60
40
20

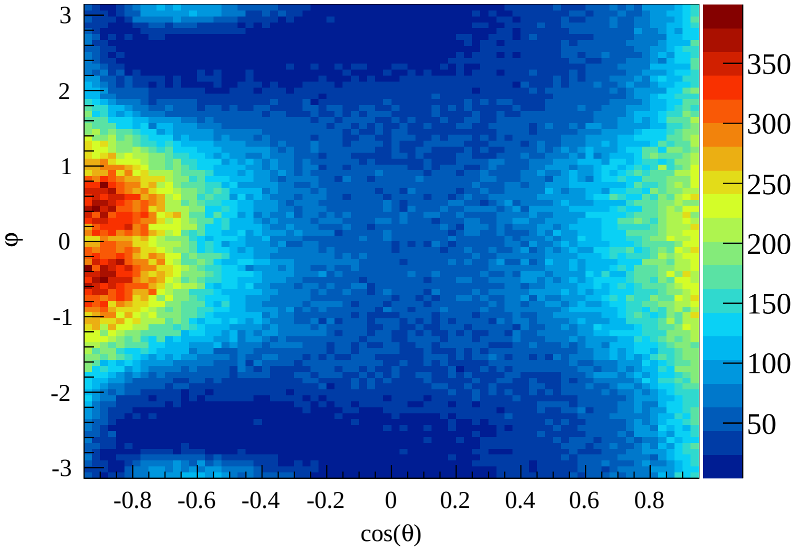
1250 MeV



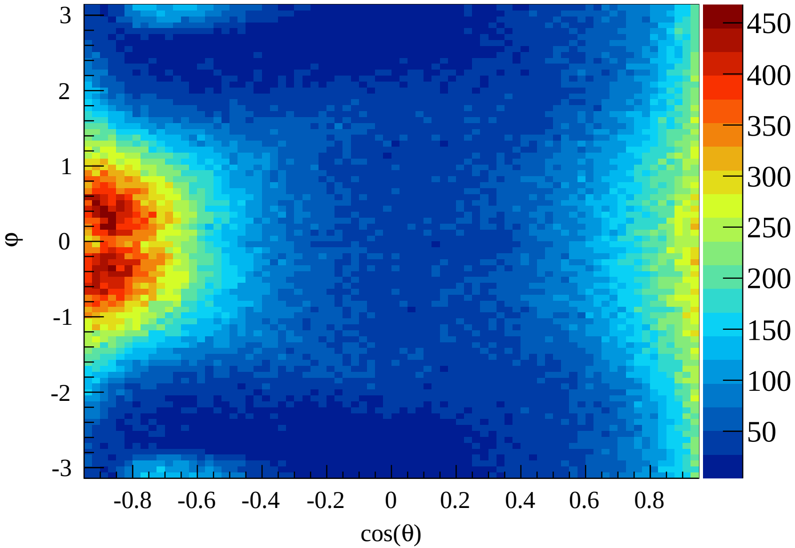
1300 MeV



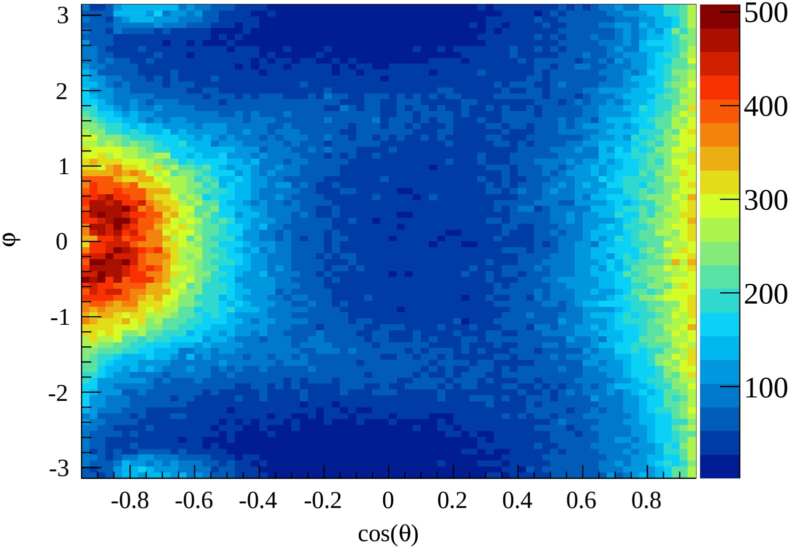
1350 MeV



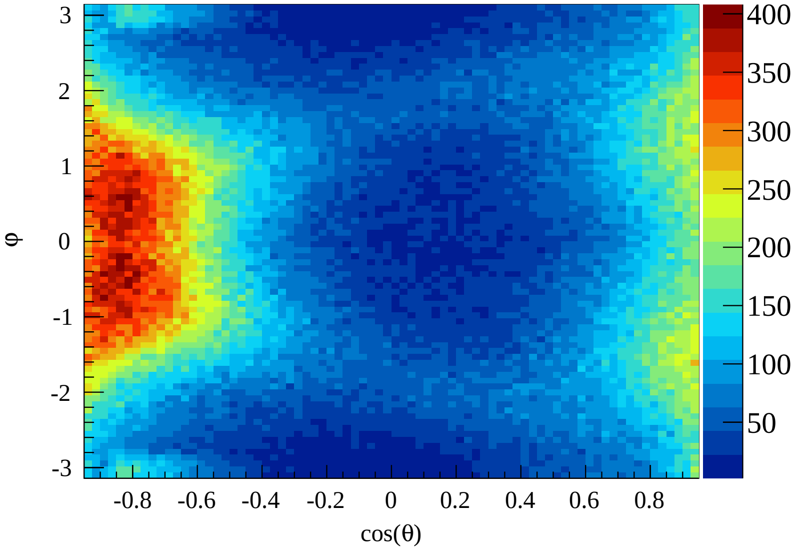
1400 MeV


φ
3
2
1
0
-1
-2
-3
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
450
400
350
300
250
200
150
100
50

1450 MeV



1500 MeV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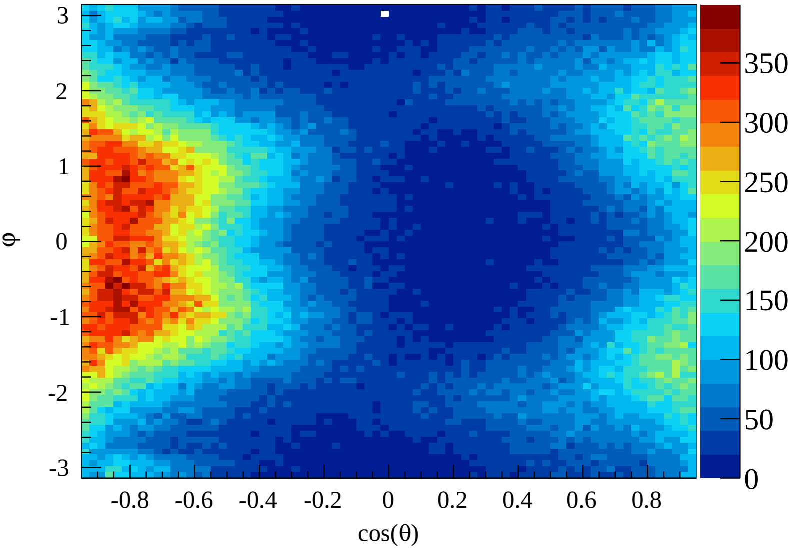
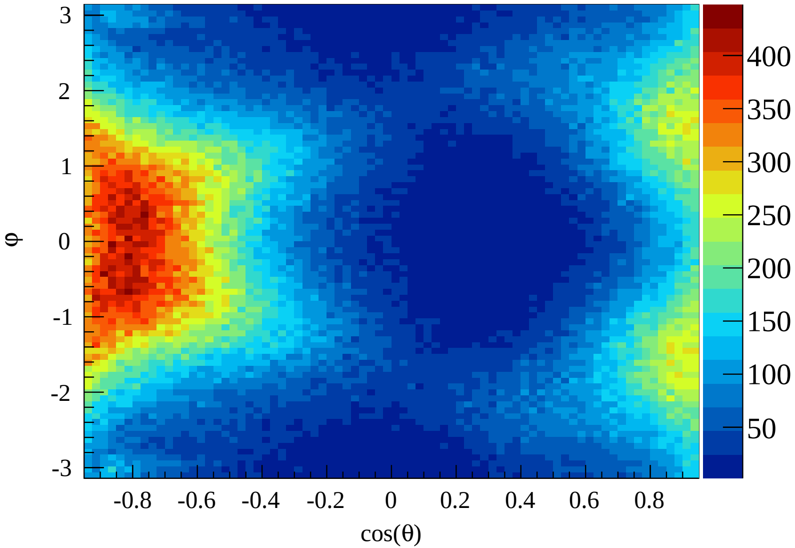
2
1
0
-1
-2
-3
φ
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
400
350
300
250
200
150
100
50

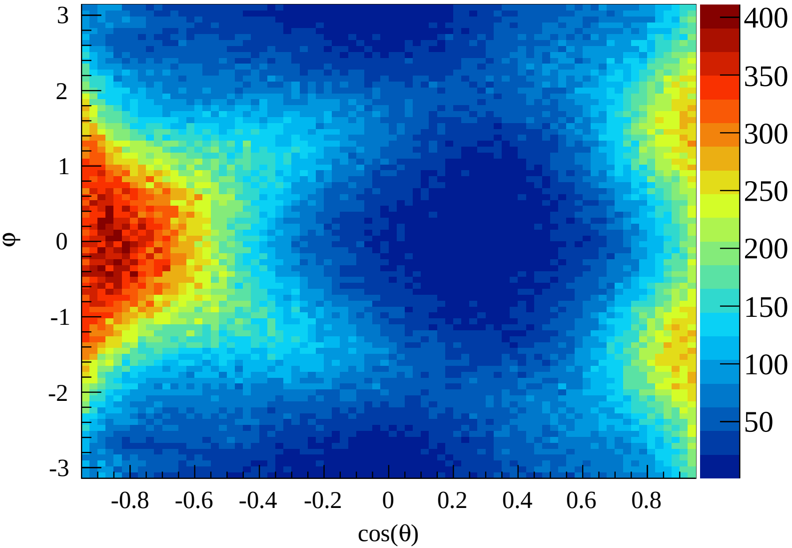
1550 MeV


φ
3
2
1
0
-1
-2
-3
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
350
300
250
200
150
100
50
0

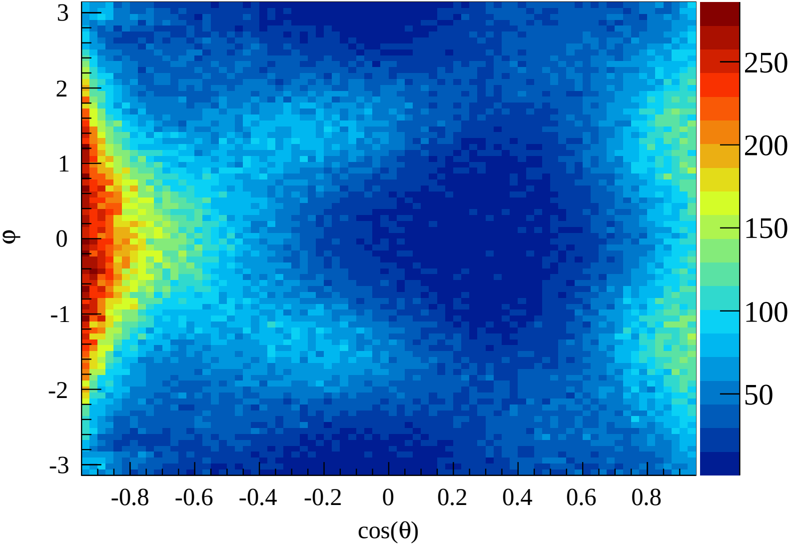
1600 MeV


3
2
1
0
-1
-2
-3
φ
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
400
350
300
250
200
150
100
50

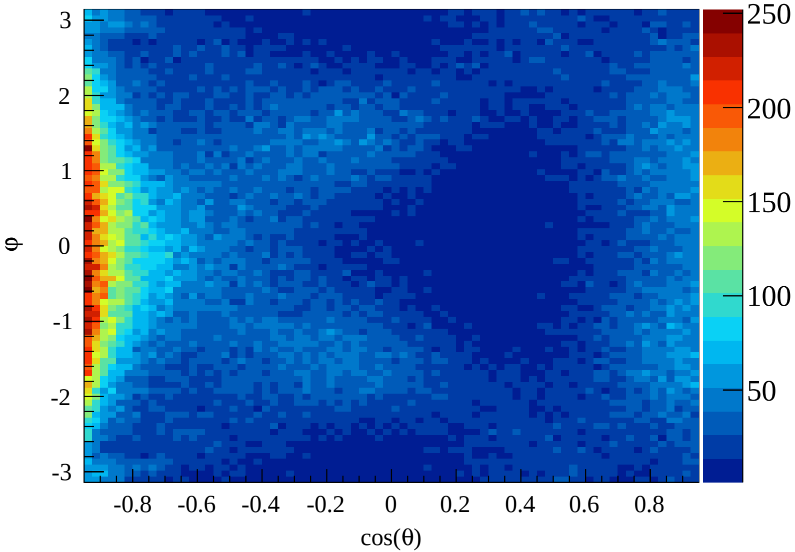
1650 MeV


φ
3
2
1
0
-1
-2
-3
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
400
350
300
250
200
150
100
50

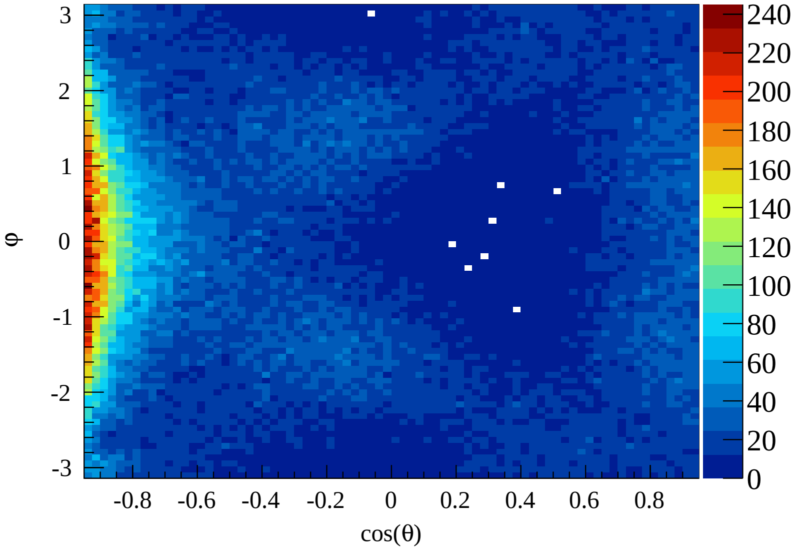
1700 MeV



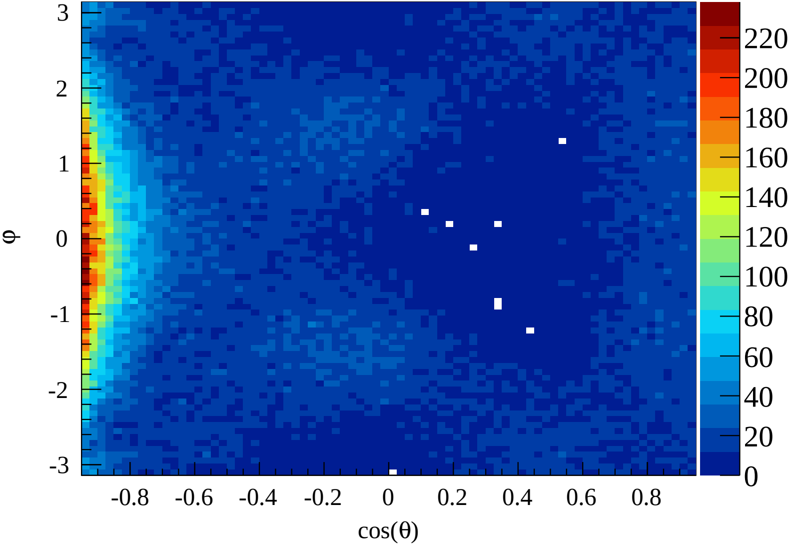
1750 MeV



1800 MeV


φ
3
2
1
0
-1
-2
-3
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
240
220
200
180
160
140
120
100
80
60
40
20
0

1850 MeV



φ
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2
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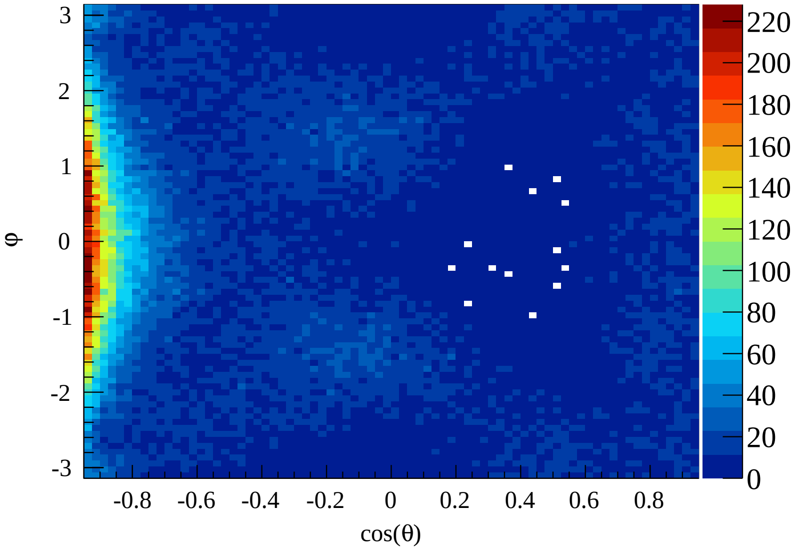
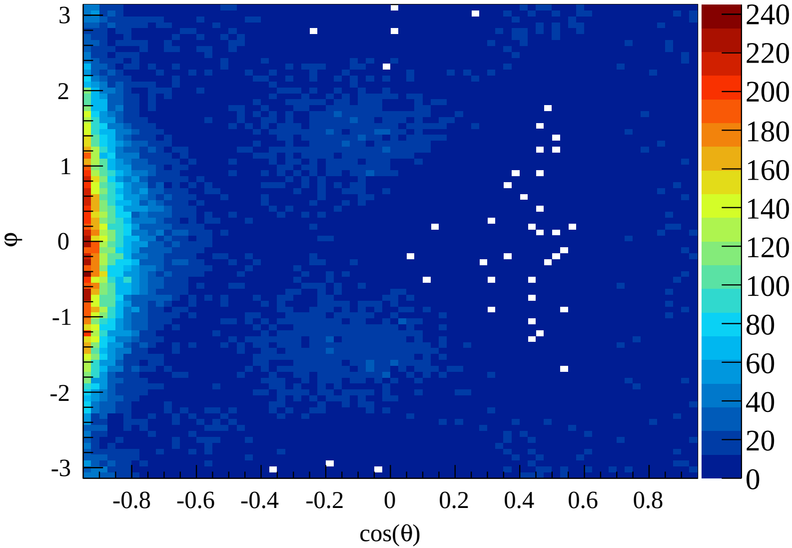
-1
-2
-3
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
220
200
180
160
140
120
100
80
60
40
20
0

1900 MeV


3
2
1
0
-1
-2
-3
φ
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
220
200
180
160
140
120
100
80
60
40
20
0

1950 MeV



3
2
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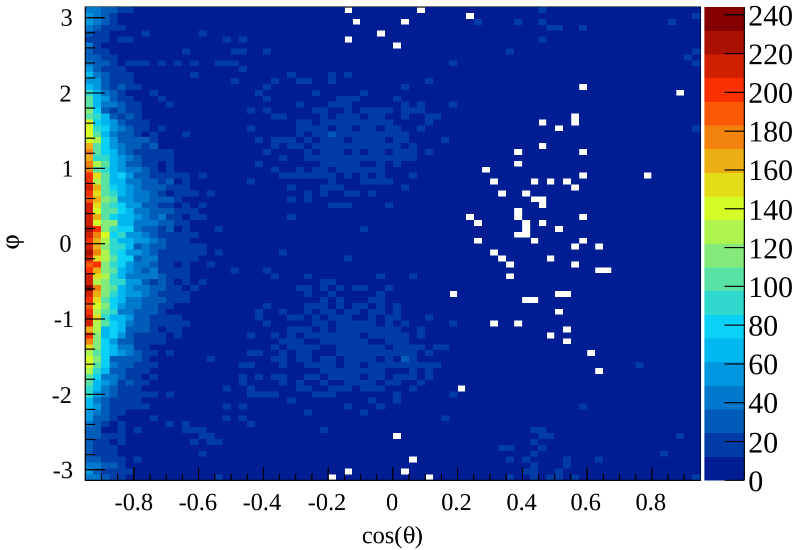
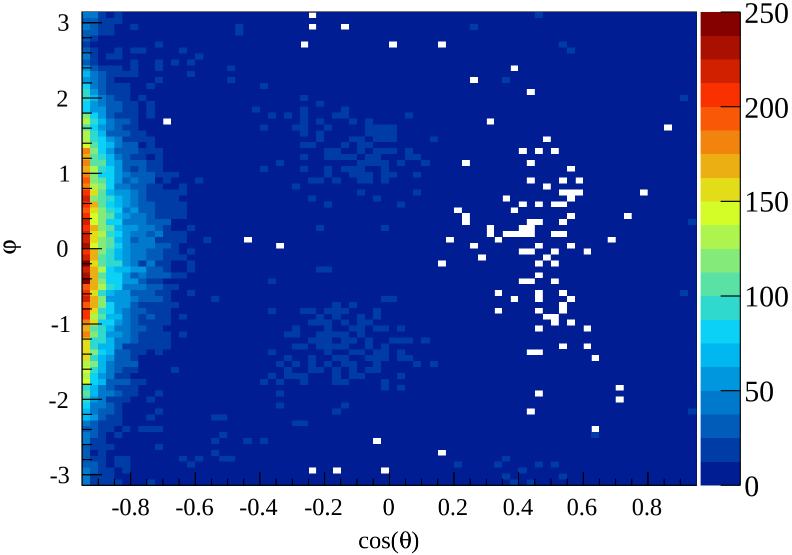
-1
-2
-3
φ
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
240
220
200
180
160
140
120
100
80
60
40
20
0

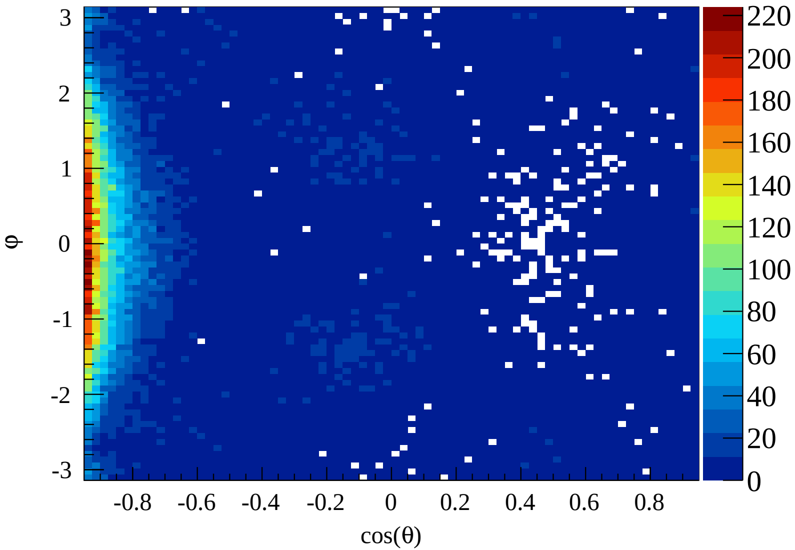
2000 MeV


3
2
1
0
-1
-2
-3
φ
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
240
220
200
180
160
140
120
100
80
60
40
20
0

2050 MeV

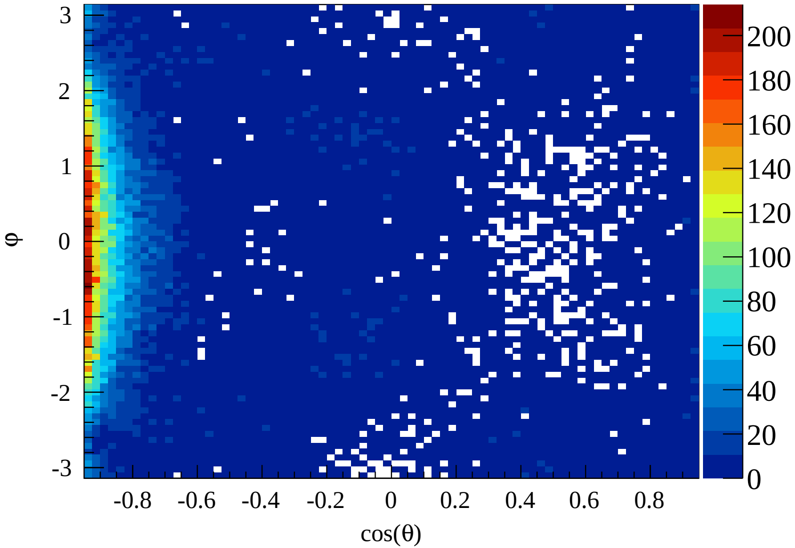


2100 MeV

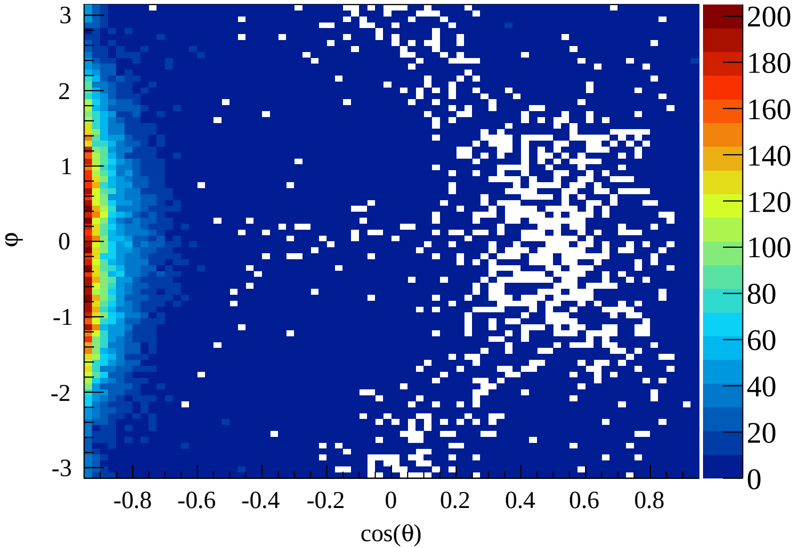


φ
3
2
1
0
-1
-2
-3
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
220
200
180
160
140
120
100
80
60
40
20
0

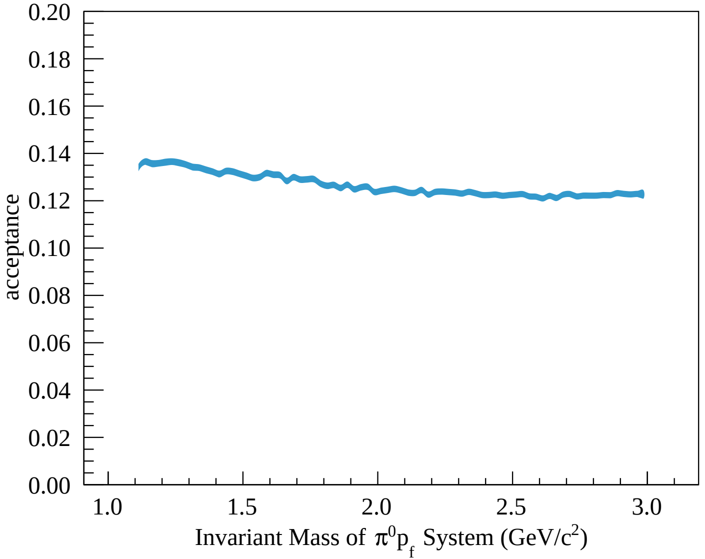
2150 MeV


φ
3
2
1
0
-1
-2
-3
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
cos(θ)
200
180
160
140
120
100
80
60
40
20
0

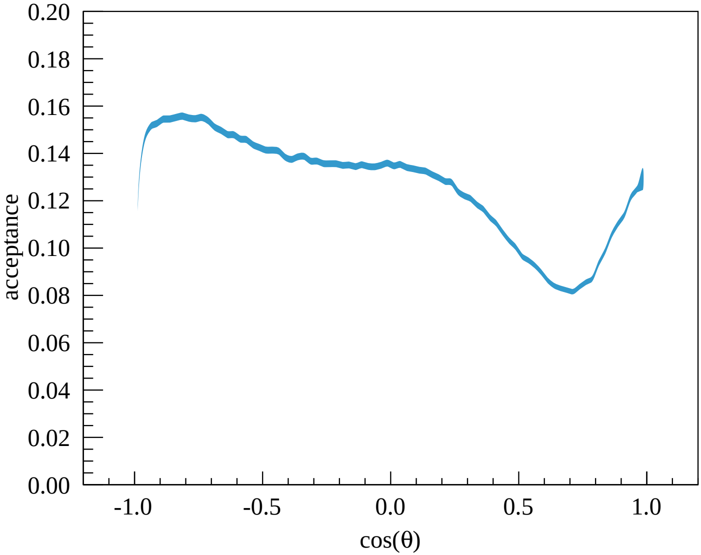
2200 MeV


φ
cos(θ)
3
2
1
0
-1
-2
-3
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
200
180
160
140
120
100
80
60
40
20
0

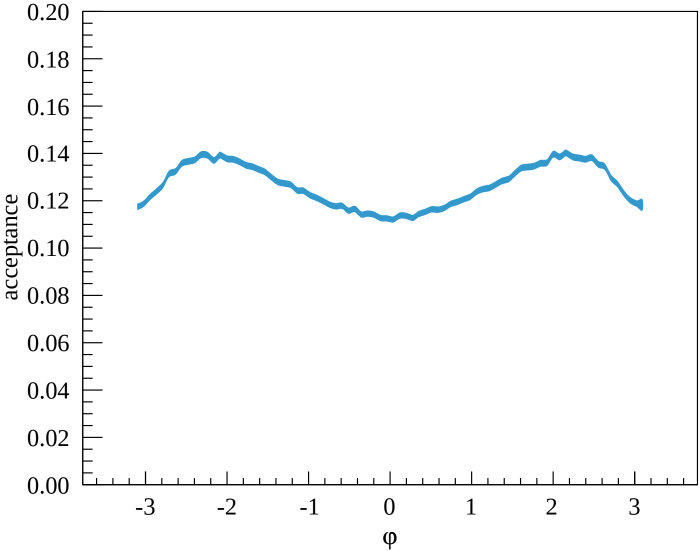
Akzeptanzen π^0



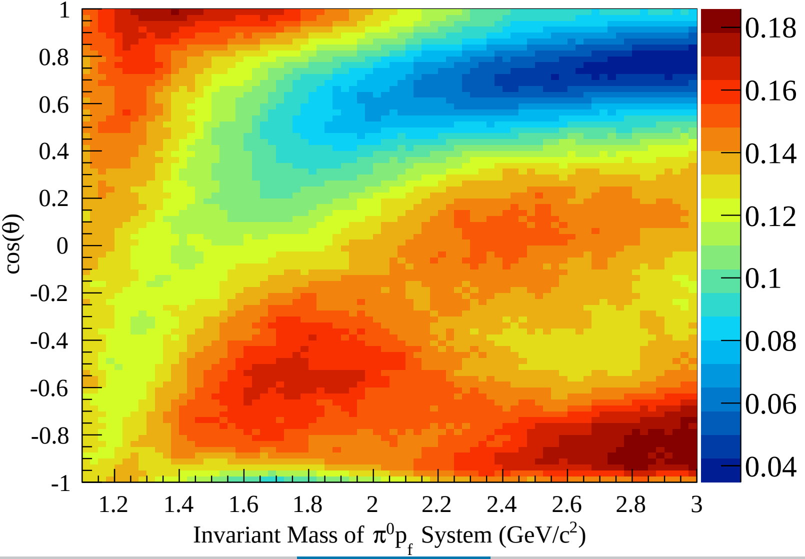
Akzeptanzen π^0



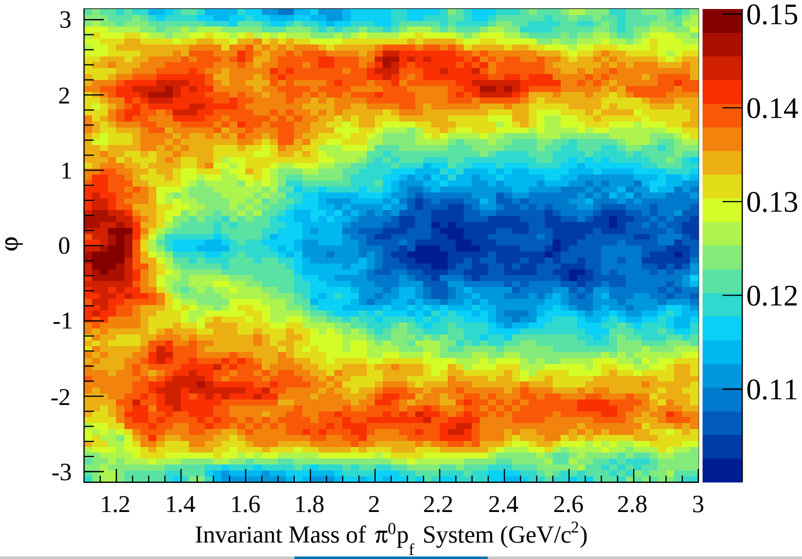
Akzeptanzen π^0



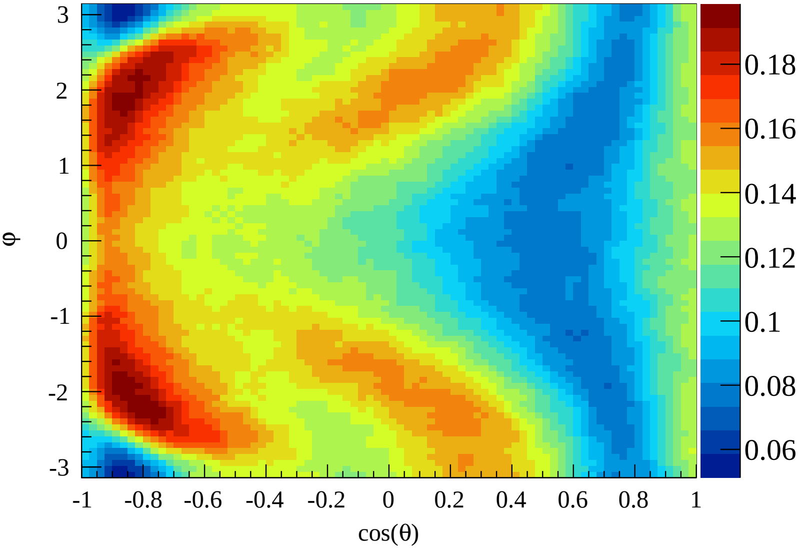
Akzeptanzen π^0



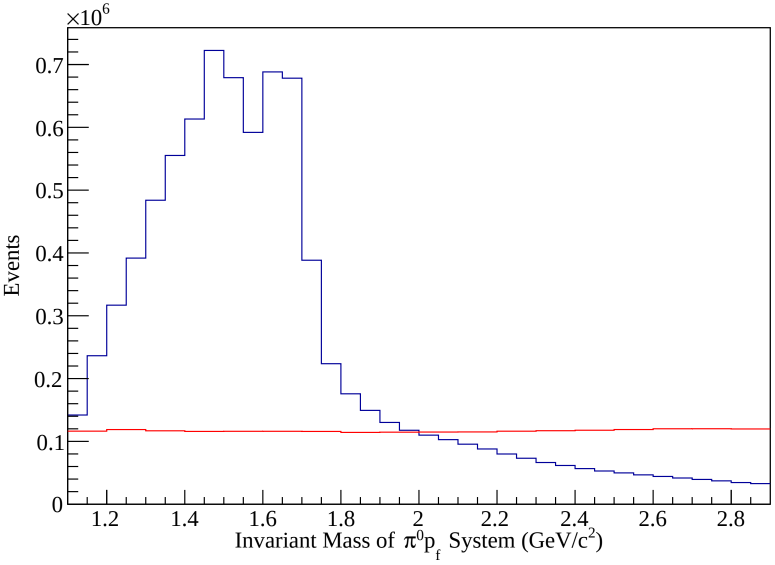
Akzeptanzen π^0



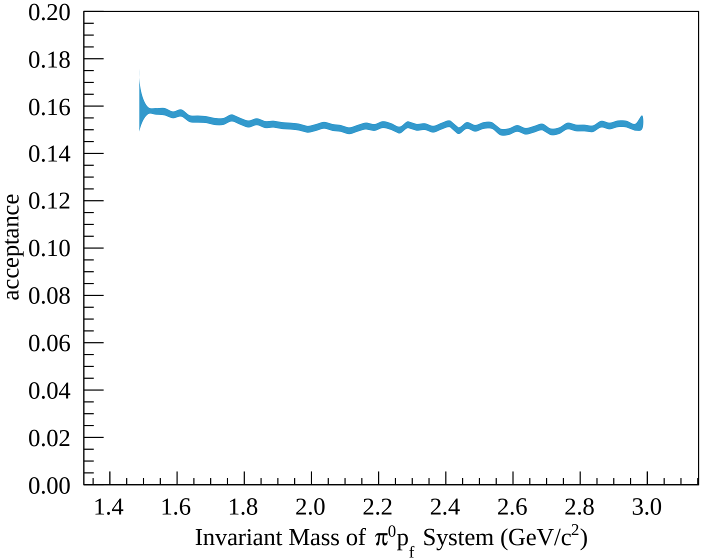
Akzeptanzen π^0



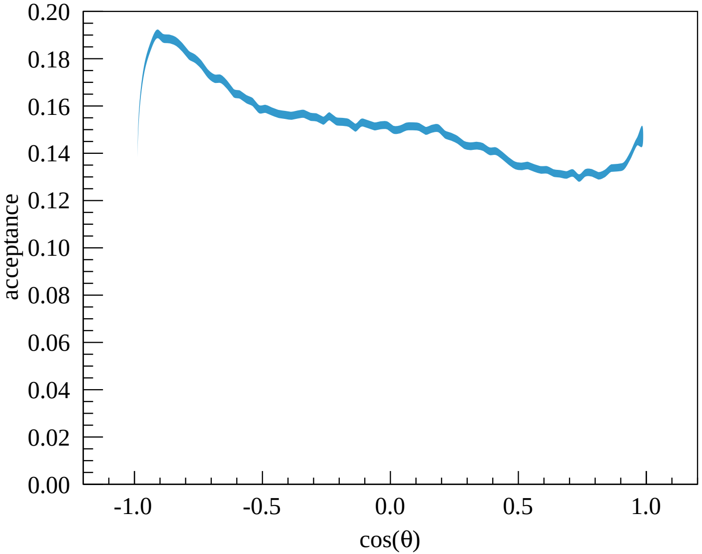
Akzeptanzen π^0



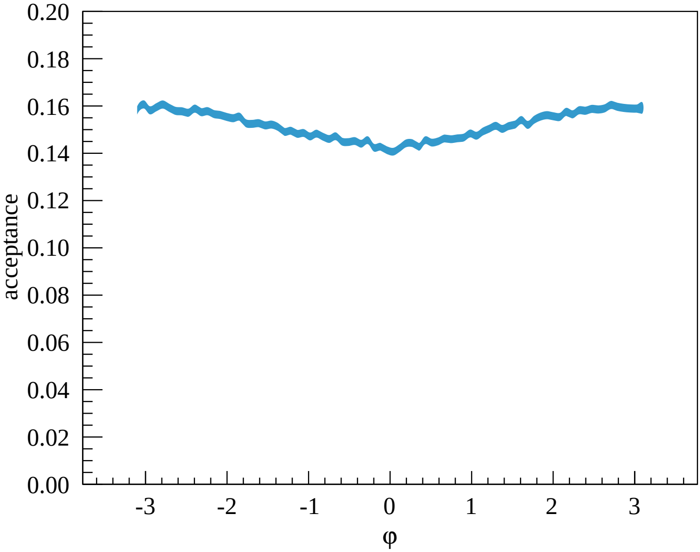
Akzeptanzen η



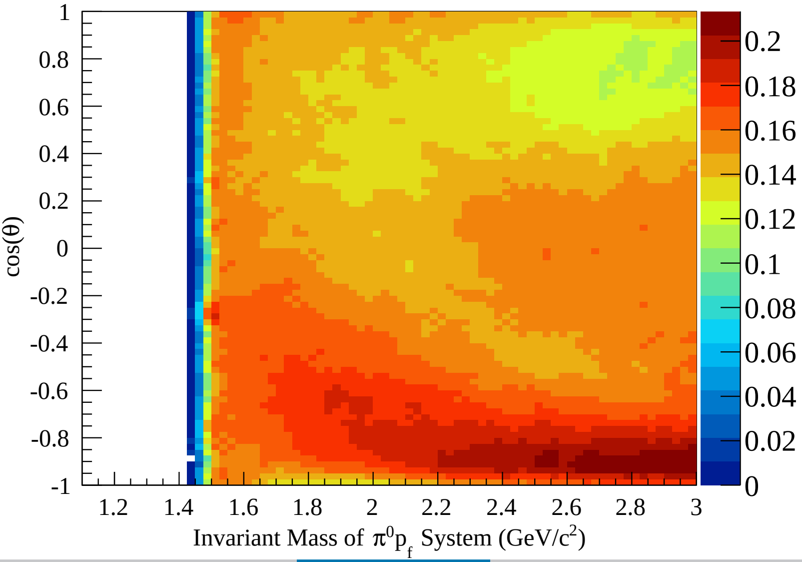
Akzeptanzen η



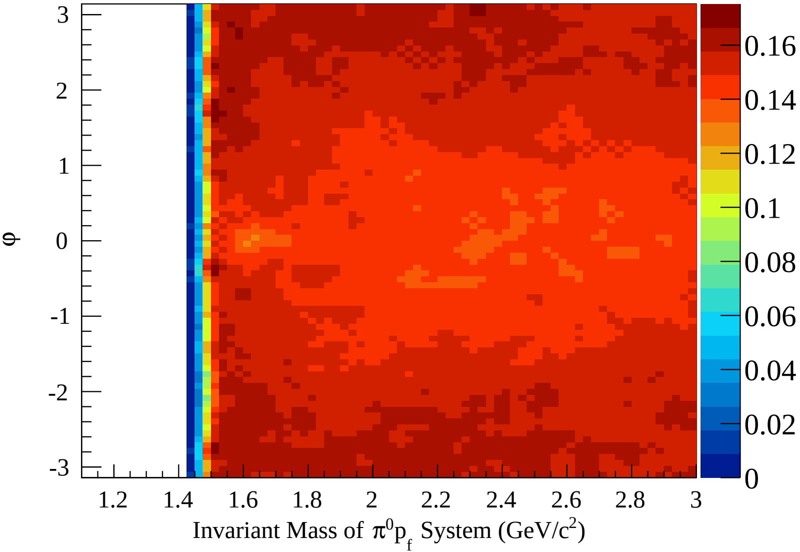
Akzeptanzen η



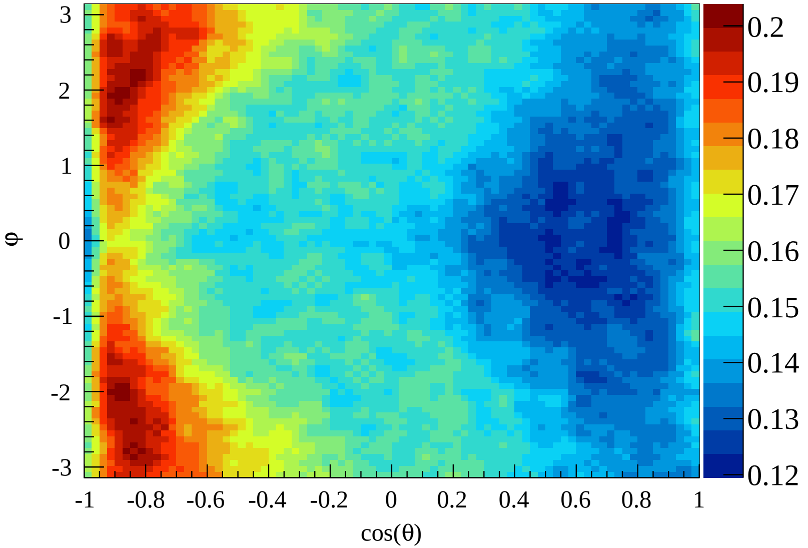
Akzeptanzen η



Akzeptanzen η



Akzeptanzen η



Akzeptanzen η