Parameters Tuning of Hadronic Generator LUARLW

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Abstract The measurements of R value needs Monte Carlo hadronization generator to determine the hadronic efficiency. The generator LUARLW based on the Lund area law can simulates the productions and decays of the continuous and resonant hadronic states from $2m_\pi$ up to 5 GeV. The related phenomenological parameter set in LUARLW are tuned using the data samples between 2.0-4.6 GeV taken at BESIII. The some important distributions of final states particles of data and MC are compared at the detector level. The estimated systematic error of hadronic efficiency are about 2%.

Key words Monte Carlo generator, Lund area law, hadronic efficiency.

1 Motivation

The directly measured hadronic cross section from the data analysis is the so-called observed cross section written in following formula

$$\sigma^{tot}_{obs}(s) = \frac{N_{obs} - N_{bg}}{L} \tag{1}$$

where N_{obs} is the number of hadronic event selected from the dada sample with the integrated luminosity L, and N_{bg} the number of the remnant backgrounds. the quantity of $\sigma^{tot}_{obs}(s)$ is experiment dependent and is not physics cross section. If one may know the efficiency factor $\bar{\epsilon}$ which reflect the ratio that of number of hadronic event produced at the collision vertex and the number of the observed hadronic event after raw data reconstruction and event selection, the quantity presented by

$$\sigma^{tot}(s) \equiv \sigma^{tot}_{phys}(s) = \frac{N_{obs} - N_{bg}}{L\bar{\epsilon}} \tag{2}$$

is the physics and experiment independent cross section which corresponds to the value calculated in theoretic calculation. In principle, the hadronic efficiency $\bar{\epsilon}$ is unknown in data analysis, but it can be estimated by the Monte Carlo method. The Monte Carlo consists two parts, the simulation of hadronic production at collision vertex and all processes of the long-life particles in detector. It is always assume that the detector simulations are perfect, and the difference between data and MC simulations are caused by the faultiness of event generator, and the coincidence between data and MC can be improved by tuning the phenomenological parameters of the event generator. In the experimental measurements of R value at BESII, the hadronic generator LUARLW which based on the Lund string fragmentation area law was used and the parameters has been tuned, the combined systematic errors of event selection and hadronic detection efficiency were estimated as about 2%. But in BESIII R value measurement, the detector simulation adopts the GEANT4 scheme instead of the BGS scheme in BESII. So the parameters in LUARLW need to tune again using BESIII data. In addition, the LUARLW itself has also some improvements.

2 The Lund string fragmentation hadronization model

In the modern point of view, the hadron production in the high energy electron-positron collision may be described as the following processes depicted in Fig.1: the electron and positron (e^+ and e^-) annihilate into a virtual photo γ^* (Z^0 can be neglected at BEPC energies), then the γ^* splits into a pair of initial quark-antiquark pairs $q\bar{q}$, and follows a series of perturbative QCD cascade evolutions of quarks and gluons (the parton shower), finally the preliminary hadrons produce via nonperturbative hadronization processes, the unstable hadrons (if have) will decay into the stable final state. The inclusive hadronization processes (the stage represented by the gray region in the Fig.1) are usually described by phenomenological models.

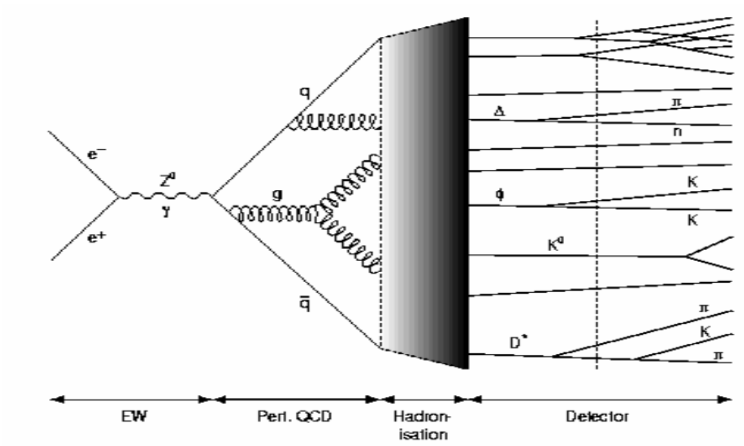


Fig.1 The hadron production processes via virtual photo annihilation in the electron-positron collision.

In the R value measurement at BESII and BESIII, the Lund string fragmentation model is studied and used. The well-known Monte Carlo simulation packet JETSET is not built in order to describe few-body states (in particular at the few GeV level in e^+e^- annihilation as in BEPC energy region). For the purpose of R value measurement with BEPC/BES, the formalism of the Lund model was tried to solve strictly starting from the basic assumptions (relativity, quantum mechanics, causality) and did not adapt the extreme high energy approximation $s \to \infty$ in the derivation of the formula like did in JETSET, the obtained form of the string fragmentation function is the Lund area law, instead of the fragmentation function $f(z)$ which is used in JETSET. So the Monte Carlo packet LUARLW is an hadronic generator based on the Lund Model area law directly[2].

In general, any hadronic generator contains a few phenomenological parameters which have definite physical meaning reflecting the dynamical mechanisms of the hadronization, but their values are unknown and need to tune using the experimental data. The tactic to tune these parameters is to choose a set of distributions of the hadronic final states (such as, the charged and neutral multiplicities, the fractions of the all preliminary and final hadrons produced in the simulation, momentum, etc.), compare the corresponding distributions between data and generator at detector level and tune the related values of the parameters iteratively, untill all the chosen distributions of data and MC are acceptable agreement. In the parameters tuning, one always assume that the detector simulations are perfect, and any difference between data and simulation are due to the shortcoming of the hadronization model and/or the values of the parameters are unreasonable.

In the R value measurement with the BESII and BESIII data, the generator LUARLW is used. Historically, the LUARLW was ever tuned twice. The first time, the data samples with small statistics (about 1000 hadronic events for each energy point)cbetween 2-5 GeV at about 100 energy points taken in 1999 are used, the error of the hadronic efficiency ϵ_{had} are about $2 \sim 5\%$[3, 4]. Later on, LUARLW was tuned again using the data samples with larger statistics taken at four energy points below open charm threshold collected in 2004, these large data samples provided more information and small statistic fluctuation, which are helpful to tune the parameters of LUARLW effectively, the error of the ϵ_{had} decreased to about 3%[5]. Now, the higher luminosity of BEPCII provides data samples with even large statistics, and the better performance of BESIII detector and more accurate detector simulations with GEANT4 will be helpful to tune the parameters of LUARLW.

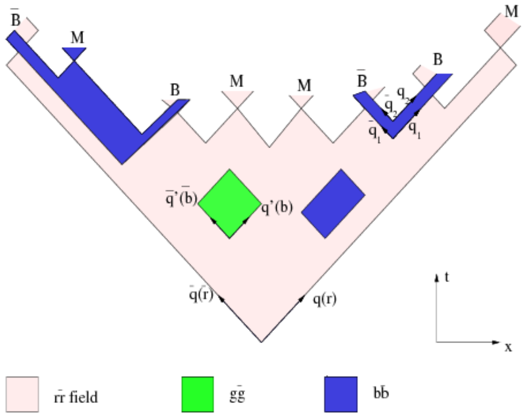


Fig.2 The hadron production processes in string fragmentation.

3 The formalism of Lund area law

The inclusive hadronic generator LUARLW are used for BEPCII/BESIII experiments, the nominal center of mass energy E_{cm} range is 2-4.6 GeV, due to the bremmsstrahlung of the initial beam, the effective energy $E^{'}_{cm}$ may decrease to the lowest hadronic production threshold (i.e. the state $\pi^+\pi^-$). The resonances with quantum number $J^{PC}=1^{--}$ will be produced except for the continuous states.

In BEPC/BESII running period, the processes can be simulated by LUARLW are not complete, they are described in Ref.[4] [3] and listed below

In Lund area law, the lowest cross section for an exclusive process $e^+e^-\to\text{string}\to m_1+m_2...+m_n$ can be written as

$$d\sigma(e^+e^-\to m_1,m_2...m_n)=d\sigma(e^+e^-\to q\bar{q})\cdot d\mathcal{P}(q\bar{q}\to m_1,m_2...m_n;s), \tag{3}$$

the differential cross section for $e^+e^-\to q\bar{q}$ can use QED expression

$$d\sigma(e^+e^-\to q\bar{q})=N_c\frac{\alpha^2}{4s}\sum_q\beta_q[1+\cos^2\theta+(1-\beta_q^2)\sin^2\theta]=N_c\frac{\alpha^2}{4s}\sum_q\beta_q[(2-\beta_q^2)+\beta_q^2\cos^2\theta], \tag{4}$$

and the probability for string fragmentation into n hadrons reads

$$d\mathcal{P}(q\bar{q}\to m_1,m_2...m_n;s)=\delta(1-\sum_{j=1}^{n}\frac{m_{\perp j}^2}{sz_j})\delta(1-\sum_{j=1}^{n}z_j)\delta^{(2)}(\sum_{j=1}^{n}\vec{k}_j)\overline{\sum}|\mathcal{T}^{(n)}|^2d\Phi_n, \qquad d\Phi_n=\prod_{j=1}^{n}d^2\vec{k}_j\frac{dz_j}{z_j} \tag{5}$$

where, the factor like the element of matrix in Lund area law can be written as

$$\mathcal{T}^{(n)}=N^n\mathcal{T}_{\perp}^{(n)}\cdot\mathcal{T}_{//}^{(n)} \tag{6}$$

the part corresponding to the transverse momentum has the Gaussiann form

$$\mathcal{T}_{\perp}^{(n)}=\exp(-\sum_{j=1}^{n}\vec{k}_j^2) \qquad \vec{k}_j=\frac{\vec{p}_{j\perp}}{2\sigma}, \tag{7}$$

and the part corresponding to the longitudinal momentum takes the Lund area law

$$\mathcal{T}_{//}^{(n)}=\exp(i\xi\mathcal{A}_n) \qquad \xi=\frac{1}{2\kappa}+i\frac{b}{2} \tag{8}$$

where $\mathcal{A}_n$ is the light-cone area enclosed by the light-cone of the n hadrons.

Starting from the Lund area law, one may obtain a approximation expression of a poisson-like multiplicity distribution of the fragmentation hadron

$$P_n(s)=\frac{\mu^n}{n!}\exp[c_0+c_1(n-\mu)+c_2(n-\mu)^2], \tag{9}$$

where, n is the number of the fragmentation hadron, μ can be understood as the average multiplicity which can quote the QCD prediction

$$\mu=\alpha+\beta\exp(\gamma\sqrt{s}), \tag{10}$$

where, c_1, c_2, c_3, α, β and γ are free parameters and to be tuned by experimental data.

For the following string fragmentation and n hadrons production process

$$e^+e^-\Rightarrow q\bar{q}\Rightarrow \text{string}\Rightarrow m_1+m_2+\cdots+m_n,$$

the total matrix element can be written as

$$\mathcal{M}\equiv\mathcal{M}_{\text{QED}}(e^+e^-\to q\bar{q})\mathcal{M}_{\text{LUND}}(q\bar{q}\to string\to m_1,m_2,\cdots m_n), \tag{11}$$

where M_{QED} is for the pure QED process $e^+e^-\to q\bar{q}$, and gives the differential cross section

$$\frac{d\sigma(e^+e^-\to q\bar{q})}{d\Omega_{q\bar{q}}}=\frac{3\alpha^2}{4s}e_q^2\beta[1+\cos^2\theta+(1-\beta^2)\sin^2\theta]. \tag{12}$$

The matrix element for the string fragmentation into n hadrons can be factorized as two factors

$$\mathcal{M}_{\text{LUND}}(q\bar{q}\to string\to m_1,m_2,\cdots m_n)=C_n\mathcal{M}_\perp\mathcal{M}_{//}, \tag{13}$$

where $\mathcal{M}_\perp$ for the transverse momentum of the fragmentation hadrons and has the Gaussian form

$$\mathcal{M}_\perp=\exp(-\sum_{j=1}^{n}{\mathbf{k}_j}^2), \tag{14}$$

and $\mathcal{M}_{//}$ for the longitudinal momentum has the Lund area law form

$$\mathcal{M}_{//}=\exp(i\xi\mathcal{A}_n), \tag{15}$$

where $\mathcal{A}_n$ is the light-cone area in Fig.2, and ξ is the complex parameter reflecting the dynamics properties of the string fragmentation

$$\xi=\frac{1}{2\kappa}+i\frac{b}{2}. \tag{16}$$

The probability of n hadrons in the element of phase space $d\Phi_n$ is

$$d\mathcal{P}(q\bar{q}\to m_1,m_2,\cdots m_n)=(2\pi)^4\delta(1-\sum_{j=1}^{n}\frac{m_{\perp j}^2}{sz_j})\delta(1-\sum_{j=1}^{n}z_j)\delta^2(\sum_{j=1}^{n}\mathbf{k}_j)\sum|\mathcal{M}_{LUND}|^2d\Phi_n, \tag{17}$$

where

$$d\Phi_n=\prod_{j=1}^{n}d^2\mathbf{k}_j\frac{dz_j}{z_j}, \tag{18}$$

and the transverse mass of hadron j with mass m_j is

$$m_{\perp j}=\sqrt{m_j^2+p_{\perp j}^2}=\sqrt{m_j^2+4\sigma_\perp^2\mathbf{k}_j^2},\qquad (j=1,2,\cdots n). \tag{19}$$

The probability given in Eq.(17) can be solved for n=,2,3$\cdots$6 respectively[2], which determine the momentum distribution of the n preliminary hadrons with masses $(m_1,m_2\cdots m_n)$ in the string fragmentation. Finally, the total cross section of n hadrons production in the Lund area law reads

$$\sigma(e^+e^-\to m_1,m_2,\cdots m_n)=\int d\Omega_{q\bar{q}}\frac{d\sigma(e^+e^-\to q\bar{q})}{d\Omega_{q\bar{q}}}\cdot d\mathcal{P}_n(q\bar{q}\to string\to m_1,m_2,\cdots m_n). \tag{20}$$

$$Z_n=s\int d\Phi_n\exp(-b\mathcal{A}_n), \tag{21}$$

$$P_n=Z_n/\sum Z_n, \tag{22}$$

In the Monte Carlo simulation of an inclusive hadronic sample, the multiplicity of the preliminary hadrons is determined by following distribution

$$P_n(s)=\frac{\mu^n}{n!}\exp[c_0+c_1(n-\mu)+c_2(n-\mu)^2]. \tag{23}$$

where could be understood as the average multiplicity, and expressed as the form predicted by QCD

$$\mu=\alpha+\beta\exp(\gamma\sqrt{s}), \tag{24}$$

the values of the free parameters c_0, c_1, c_2, α, β and γ can be obtained by match the data.

4 Functions of LUARLW

The inclusive hadronic generator LUARLW are used for BEPCII/BESIII experiments, the nominal center of mass energy E_{cm} range can be 2-4.6 GeV, due to the bremsstrahlung of the initial beam, the effective energy E'_{cm} may decrease to the lowest hadronic production threshold (i.e. the state $\pi^+\pi^-$). The resonances with quantum number $J^{PC}=1^{--}$ will be produced except for the continuous states. In addition, the leading order QCD correction is also considered. In order to simulate the hadronic production processes more completely, LUARLW are extended and improved compared to the version used in BESII work. The basic processes can be simulated by LUARLW are summarized below.

$$e^+e^-\Rightarrow\gamma^*\Rightarrow\begin{cases} q\bar{q}\Rightarrow\text{string}\Rightarrow\text{hadrons}\\ gq\bar{q}\Rightarrow\text{string + string}\Rightarrow\text{hadrons}\end{cases}$$

The vector mesons with $J^{PC}=1^{--}$ can directly couple to virtual photon and production in ISR return process

$$e^+e^-\to\gamma^*\to\rho(770),\omega(782),\phi(1020)\cdots\rho(1700). \tag{25}$$

The production and decay of the charmonium adopt the standard pictures[4].

$$e^+e^-\Rightarrow\gamma^*\Rightarrow J/\psi\Rightarrow\begin{cases} \gamma^*\Rightarrow e^+e^-,\ \mu^+\mu^-\\ \gamma^*\Rightarrow\bar{q}\Rightarrow\text{string}\Rightarrow\text{hadrons}\\ ggg\Rightarrow\text{string + string + string }\Rightarrow\text{hadrons}\\ \gamma gg\Rightarrow\text{string + string }\Rightarrow\text{hadrons}\\ \gamma\eta_c\Rightarrow gg\Rightarrow\text{string + string }\Rightarrow\text{hadrons}\\ \gamma+\text{exclusive radiative decay channels}\end{cases}$$

$$e^+e^-\Rightarrow\gamma^*\Rightarrow\psi(3686)\Rightarrow\begin{cases} \gamma^*\Rightarrow e^+e^-,\ \mu^+\mu^-,\ \tau^+\tau^-\\ \gamma^*\Rightarrow q\bar{q}\Rightarrow\text{string}\Rightarrow\text{hadrons}\\ ggg\Rightarrow\text{string + string + string }\Rightarrow\text{hadrons}\\ \gamma gg\Rightarrow\text{string + string }\Rightarrow\text{hadrons}\\ \gamma\eta_c\Rightarrow gg\Rightarrow\text{string + string }\Rightarrow\text{hadrons}\\ \gamma+\text{exclusive radiative decay channels}\\ \pi\pi J/\psi,\ \eta J/\psi,\ \pi^0 J/\psi\end{cases}$$

$$e^+e^- \Rightarrow \gamma^* \Rightarrow \psi(3770) \Rightarrow \begin{cases} \gamma^* \Rightarrow e^+e^-,\ \mu^+\mu^-,\ \tau^+\tau^- \\ \gamma^* \Rightarrow q\bar{q} \Rightarrow \text{string} \Rightarrow \text{hadrons} \\ ggg \Rightarrow \text{string + string + string} \Rightarrow \text{hadrons} \\ \gamma gg \Rightarrow \text{string + string} \Rightarrow \text{hadrons} \\ \pi\pi J/\psi,\ \eta J/\psi,\ \pi^0 J/\psi \\ \gamma + \text{exclusive radiative decay channels} \\ D\bar{D} \end{cases}$$

$$e^+e^- \Rightarrow \gamma^* \Rightarrow \begin{cases} \psi(4040) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, D^*\bar{D}, D_s\bar{D}_s, \text{other decay modes} \\ \psi(4160) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, D^*\bar{D}, D_s\bar{D}_s, D_s\bar{D}_s^*, \text{other decay modes} \\ \psi(4415) \Rightarrow D\bar{D}, D^*\bar{D}^*, D\bar{D}^*, D^*\bar{D}, D_s\bar{D}_s, D_s\bar{D}_s^*, D_s^*\bar{D}_s^*, \text{other decay modes} \\ X(4260) \Rightarrow \text{possible decay modes} \\ X(4360) \Rightarrow \text{possible decay modes} \end{cases}$$

5 Parameters tuning

The generator LUARLW is used to determine the hadronic efficiency in R value measurement. In BEPCII energy region, R values are measured with inclusive scheme, so it is enough that LUARLW agree with data inclusively, no need request it agree with data exclusively. There are some phenomenological parameters in LUARLW. In the BEPC energy, the main parameters are those which determine the ratios of mesons and baryons with different quantum number (s,L,J) in the string fragmentation process. In LUARLW these parameters are stored in array $PARJ(1-20)$ as did in JETSET[6], their default values were set by fitting the data collected at LEP[7]. The values of PARJ(1-20) are tuned to make the MC agree with the experimental data taken with BESIII. It is found that some parameters are not constants in BEPCII energy region, some experiential and smooth functions (no physics bases, just for fit data well) are adopted to give the values of parameters. Table 1 lists the tuned parameters and their tuned values.

In the processes of LUARLW's parameters tuning, one may find the earlier version of LUARLW code can not agree data well by tuning the parameters only. At this issue, one has to add some new mechanism and functions, i.e, modify the code. As the preliminary stage of parameters tuning, the parameters are tuned by hand, and compare the MC with data. After many many time manually tuning, MC agree with data for most of the important distributions generally, which mean the values of the related parameters of LUARLW are generally reasonable. When arriving at this stage, the parameters of LUARLW should be optimized by fitting all distributions again by the way described in reference [7].

6 Comparison of data and MC

The main principle of parameters tuning is requesting MC agree data well as many as possible for those final state distributions which related to the event selection criteria, especially for those distributions which are sensitive to the efficiency, such as charged multiplicity, polar angle $\cos\theta$, charged track momentum, deposit energy of charged and neutral tacks in EMC, angle between isolate photon and charged track for 2-prong events. The single particle (mesons and baryons) fraction in final states are also compared, which reflect whether the tuned values of parameter sets $PARJ(1-17)$ are reasonable or not. It is noticed that the generator LUARLW is not perfect yet, which certainly can not describe entire and intricate hadron production very well, it needs further modification when simply tuning of parameters can not improve the agreement between MC and data.

Table 1: The parameters tuned with BESIII data.

parameter	default	tuned	meaning
c_0	-	5.0	parameter in preliminary hadron multiplicity distribution $P_n(s)$
c_1	-	0.05	parameter in preliminary hadron multiplicity distribution $P_n(s)$
c_2	-	-0.25	parameter in preliminary hadron multiplicity distribution $P_n(s)$
α	-	0.80	parameter α in $\mu = \alpha + \beta \exp(\gamma\sqrt{s})$
β	-	0.25	parameter β in $\mu = \alpha + \beta \exp(\gamma\sqrt{s})$
γ	-	1.10	parameter γ in $\mu = \alpha + \beta \exp(\gamma\sqrt{s})$
$\sigma_\perp$	-	Ecm-dependent	effective transverse momentum width in like-Gaussian form
PARJ(01)	0.10	Ecm-dependent	diquark/quark production ratio, baryon suppression (B/M)
PARJ(02)	0.30	Ecm-dependent	s/(u,d) production ratio, strange meson suppression (K/π)
PARJ(03)	0.40	Ecm-dependent	strange diquark suppression, strange baryon suppression (Λ/p)
PARJ(04)	0.05	0.05	suppression of spin 1 diquark compared to spin 0 ones
PARJ(05)	0.50	0.50	relative occurence of baryon produced by $BM\bar{B}$ and by $B\bar{B}$
PARJ(06)	0.50	0.50	suppression for having $s\bar{s}$ shared by B and $\bar{B}$ of $BM\bar{B}$ situation
PARJ(07)	0.50	0.50	suppression for having strange meson M in $BM\bar{B}$ configuration
PARJ(11)	0.50	Ecm-dependent	suppression of light meson has spin 1 compared to spin 0 (ρ/π)
PARJ(12)	0.60	0.60	suppression of strange meson of spin 1 compared to spin 0 ($K^\star/K$)
PARJ(13)	0.75	0.75	suppression of charm meson of spin 1 compared to spin 0 ($D^\star/D$)
PARJ(14)	0.00	0.09	probability that spin $s=0$ and orbital $L=1$ with total $J=1$ meson
PARJ(15)	0.00	0.07	probability that spin $s=1$ and orbital $L=1$ with total $J=0$ meson
PARJ(16)	0.00	0.08	probability that spin $s=1$ and orbital $L=1$ with total $J=1$ meson
PARJ(17)	0.00	0.10	probability that spin $s=1$ and orbital $L=1$ with total $J=2$ meson

A objective standard that the values of the tuned parameters are optimized are to see the quantities χ^2 about the differences between MC data for above mentioned distributions and $\Delta(N_{had}/\bar{\epsilon})$ are acceptable small.

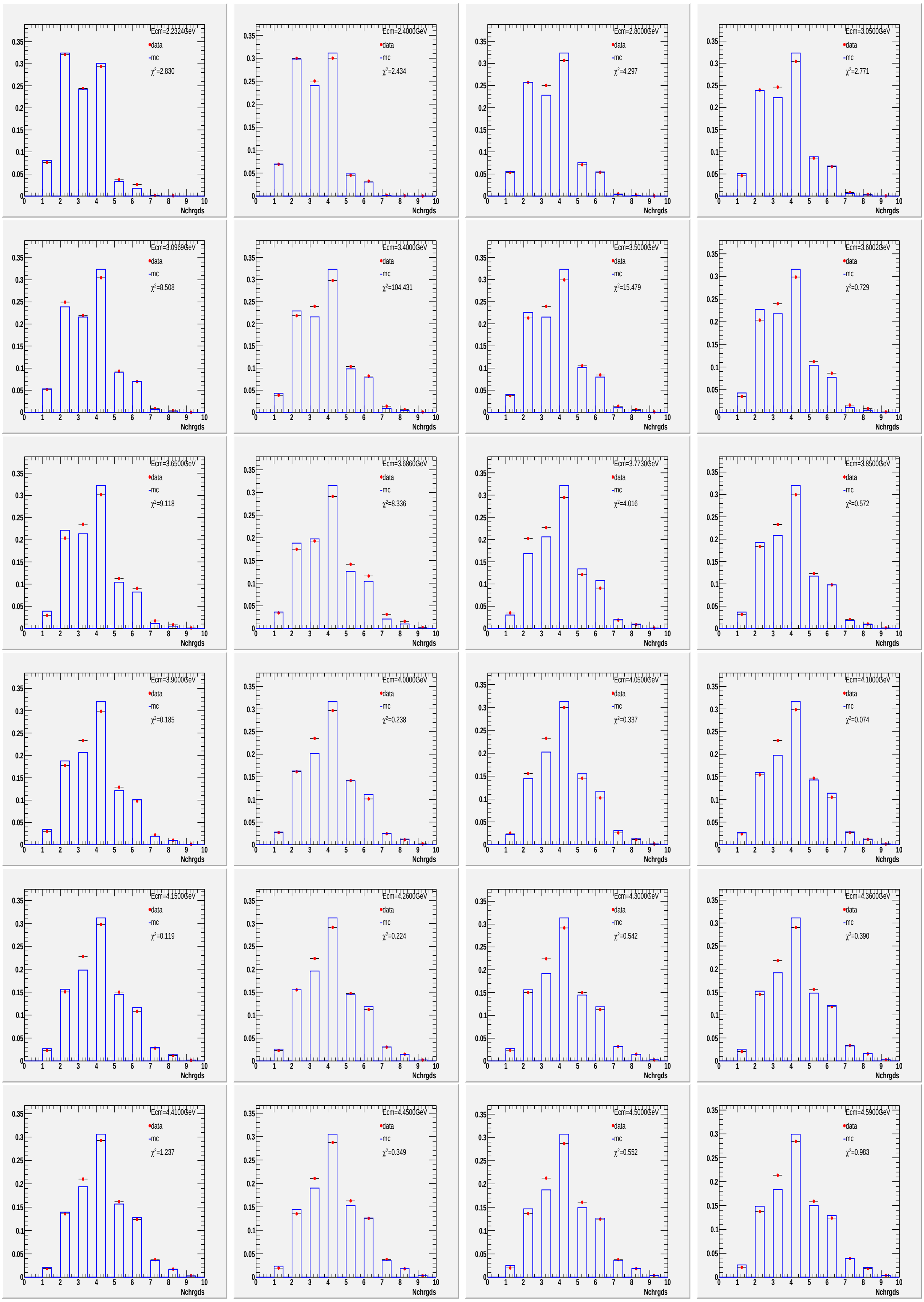


Fig. The multiplicity of charged tack distribution.

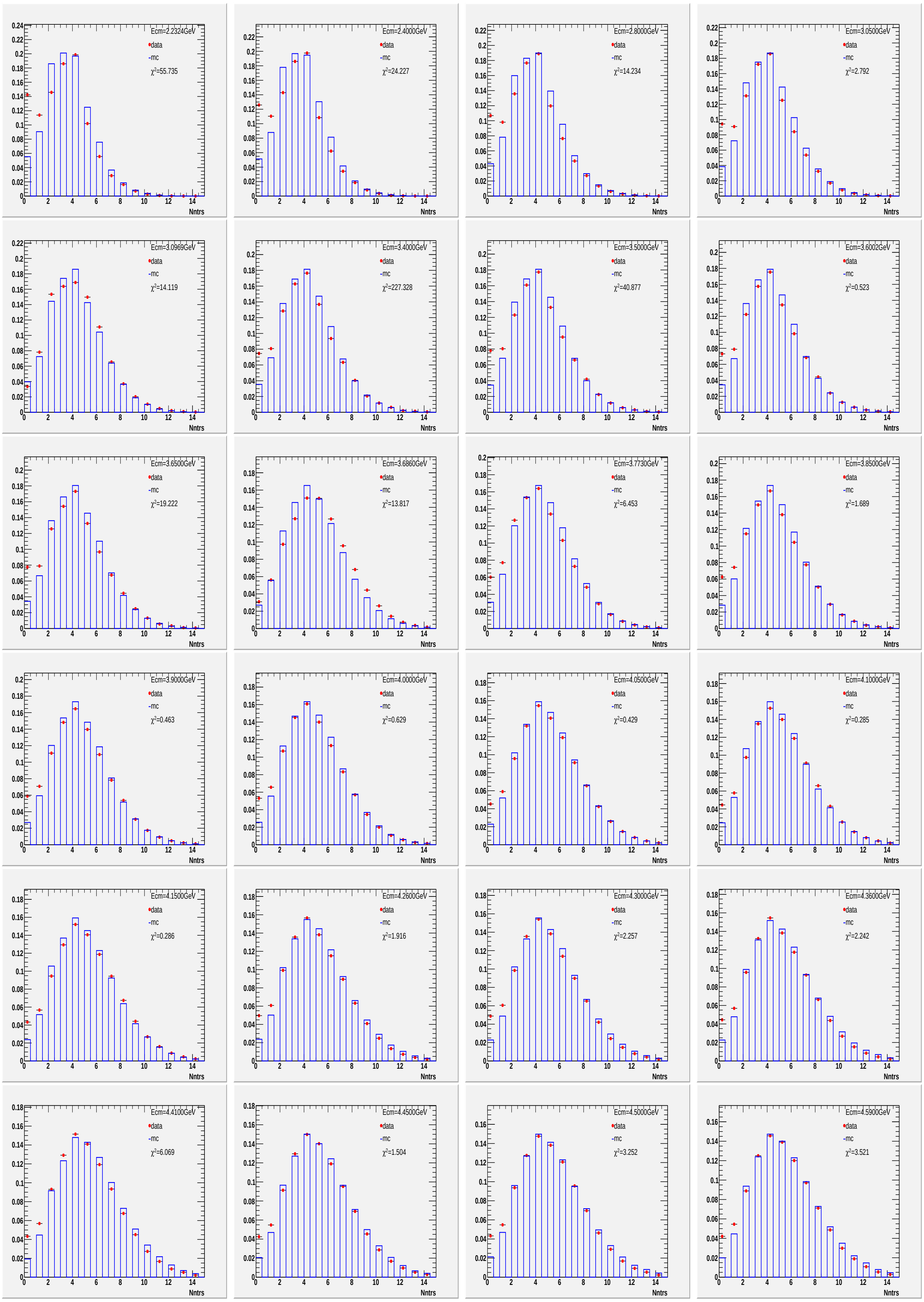


Fig. The multiplicity of neutral tack distribution.

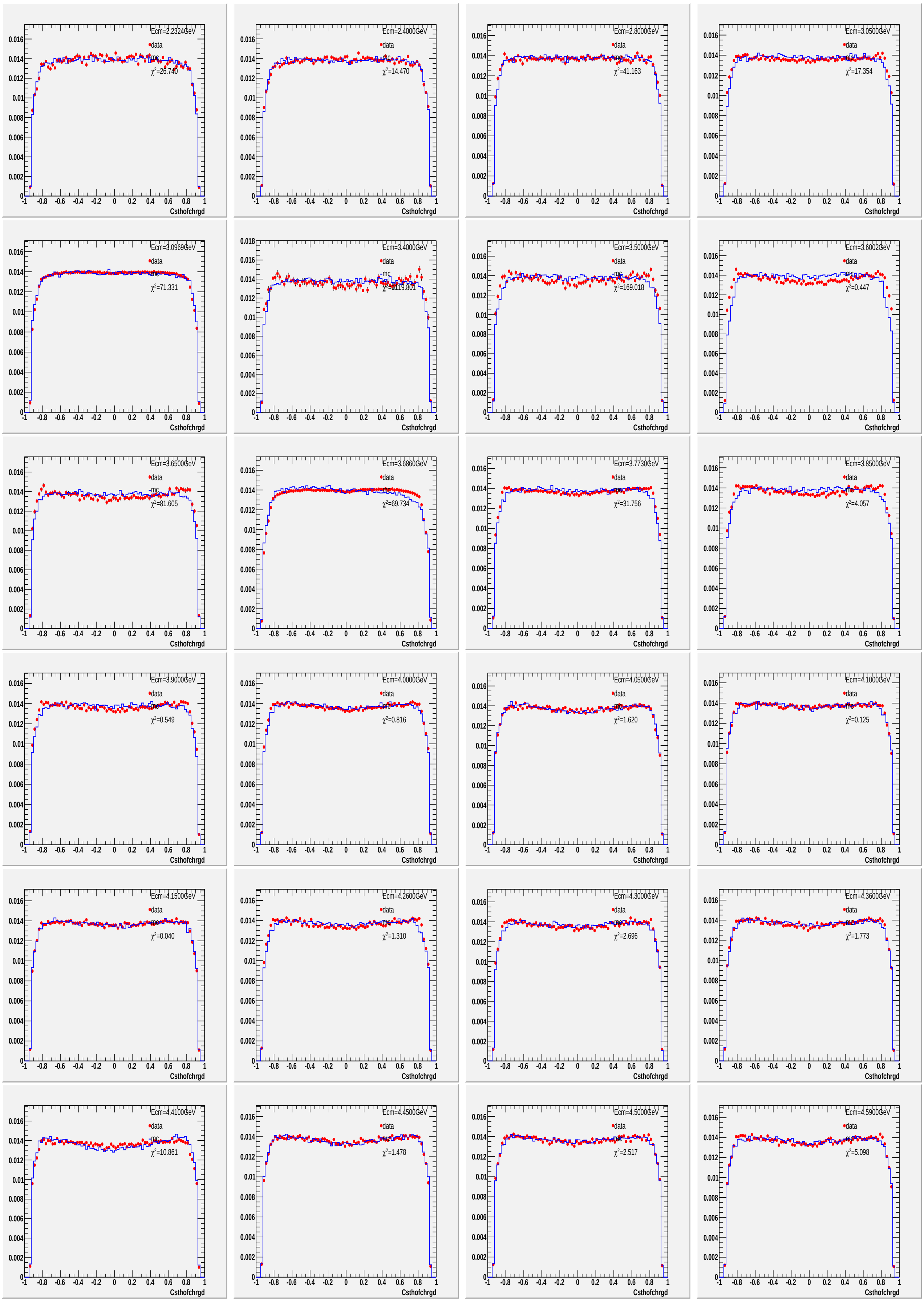


Fig. The polar angle $\cos\theta$ of charged tack distribution.

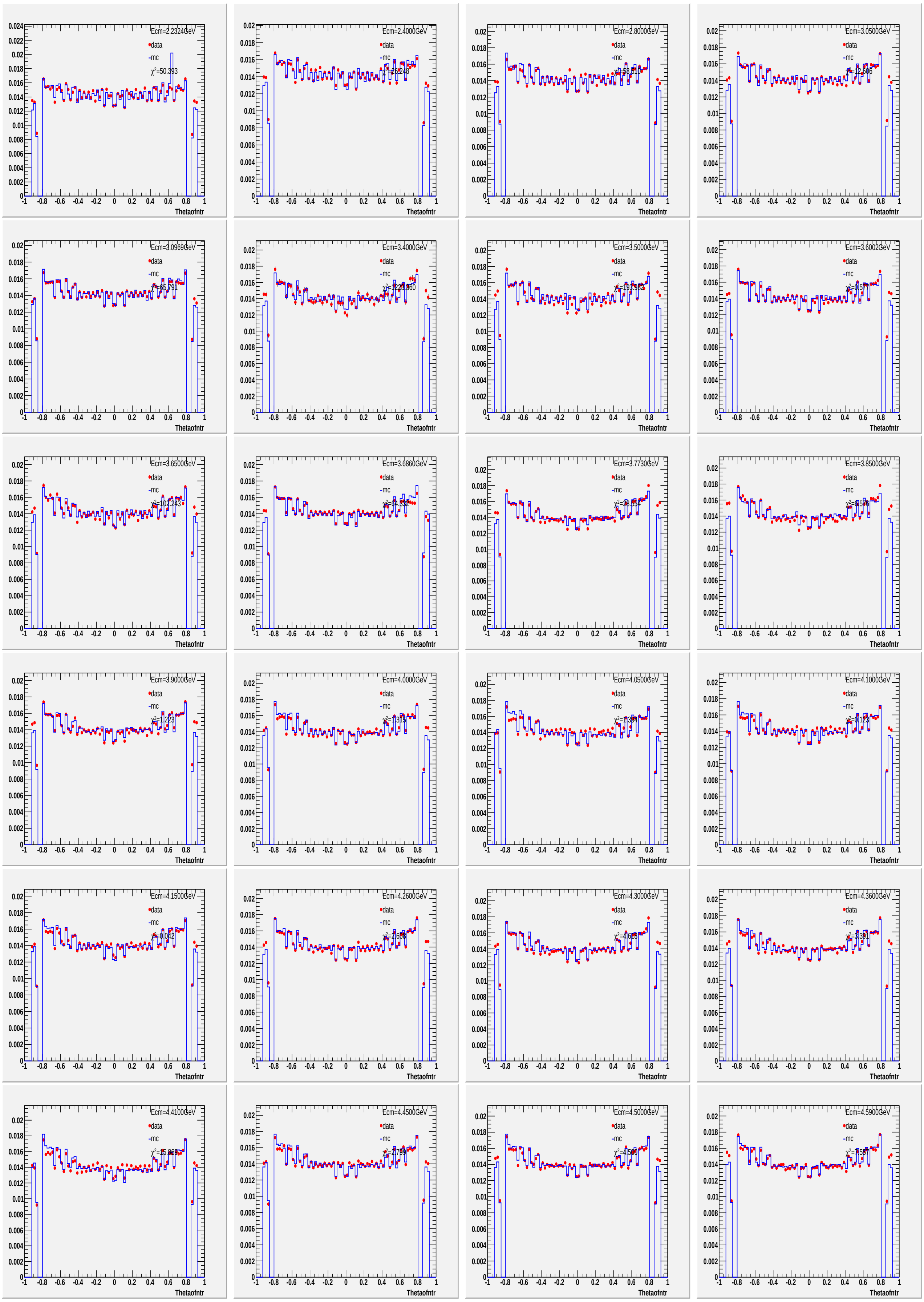


Fig. $\cos\theta$ of neutral tracks.

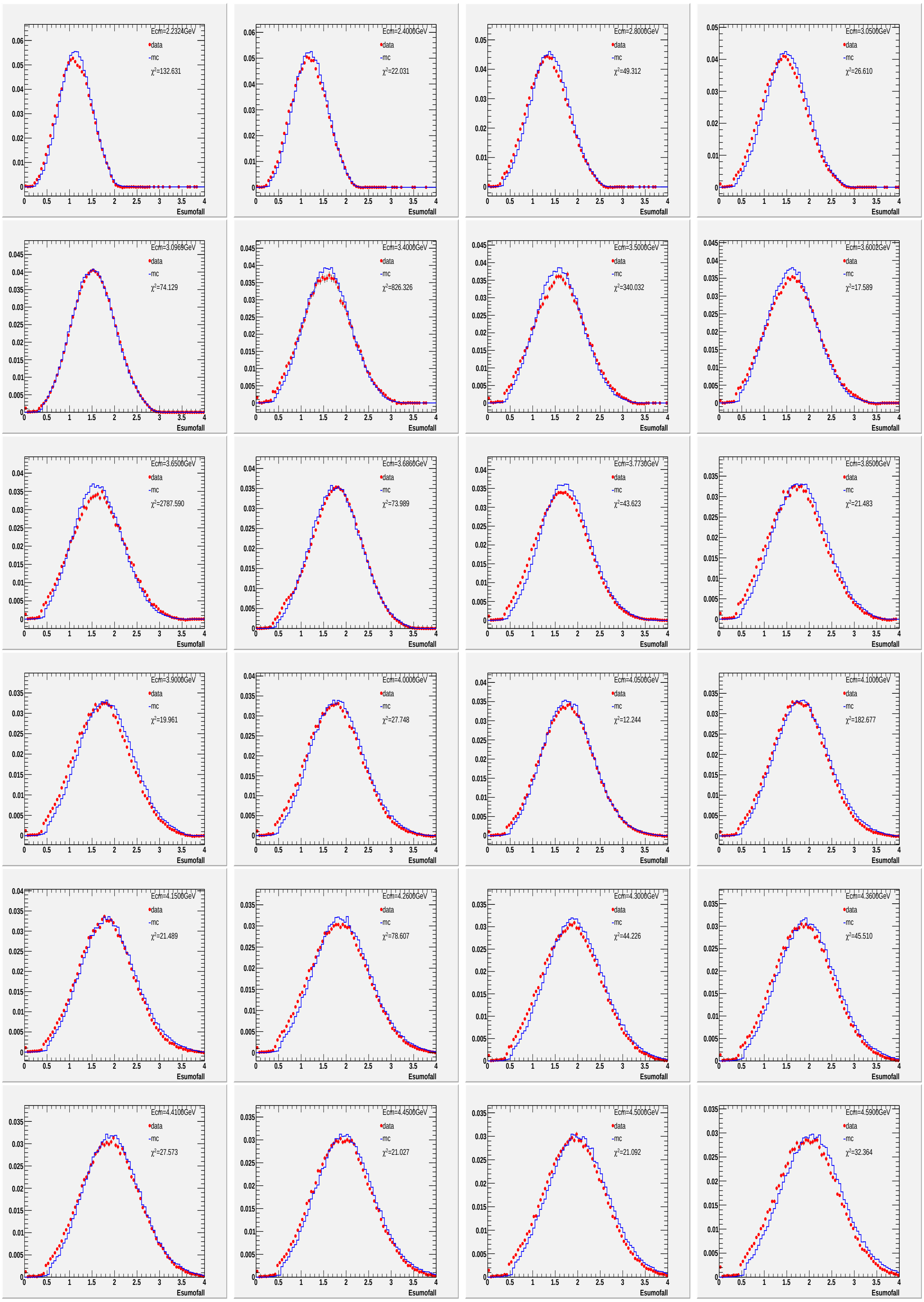


Fig. The deposit energy in ECM of charged and neutral tracks.

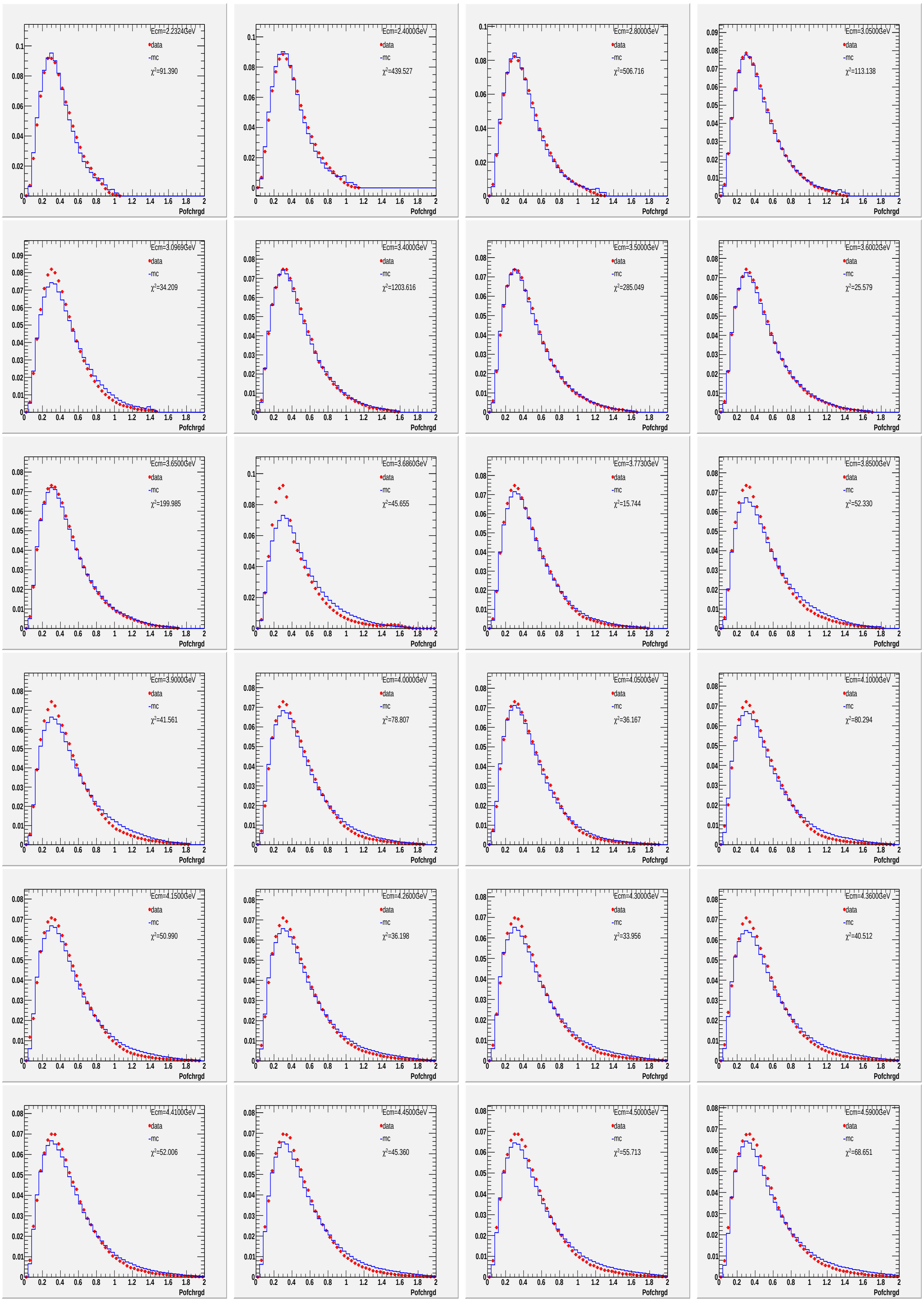


Fig. The momentum of charged tracks.

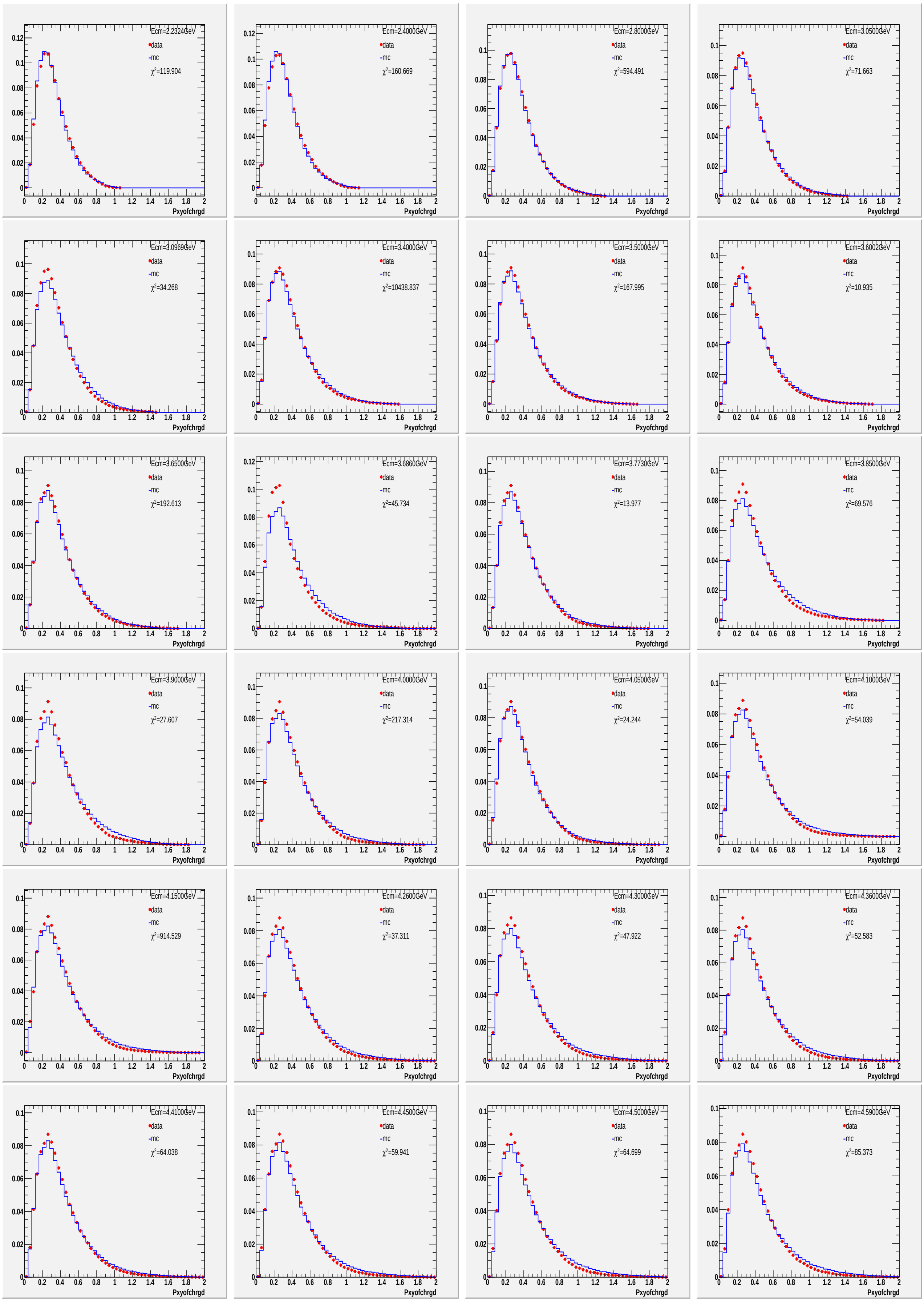
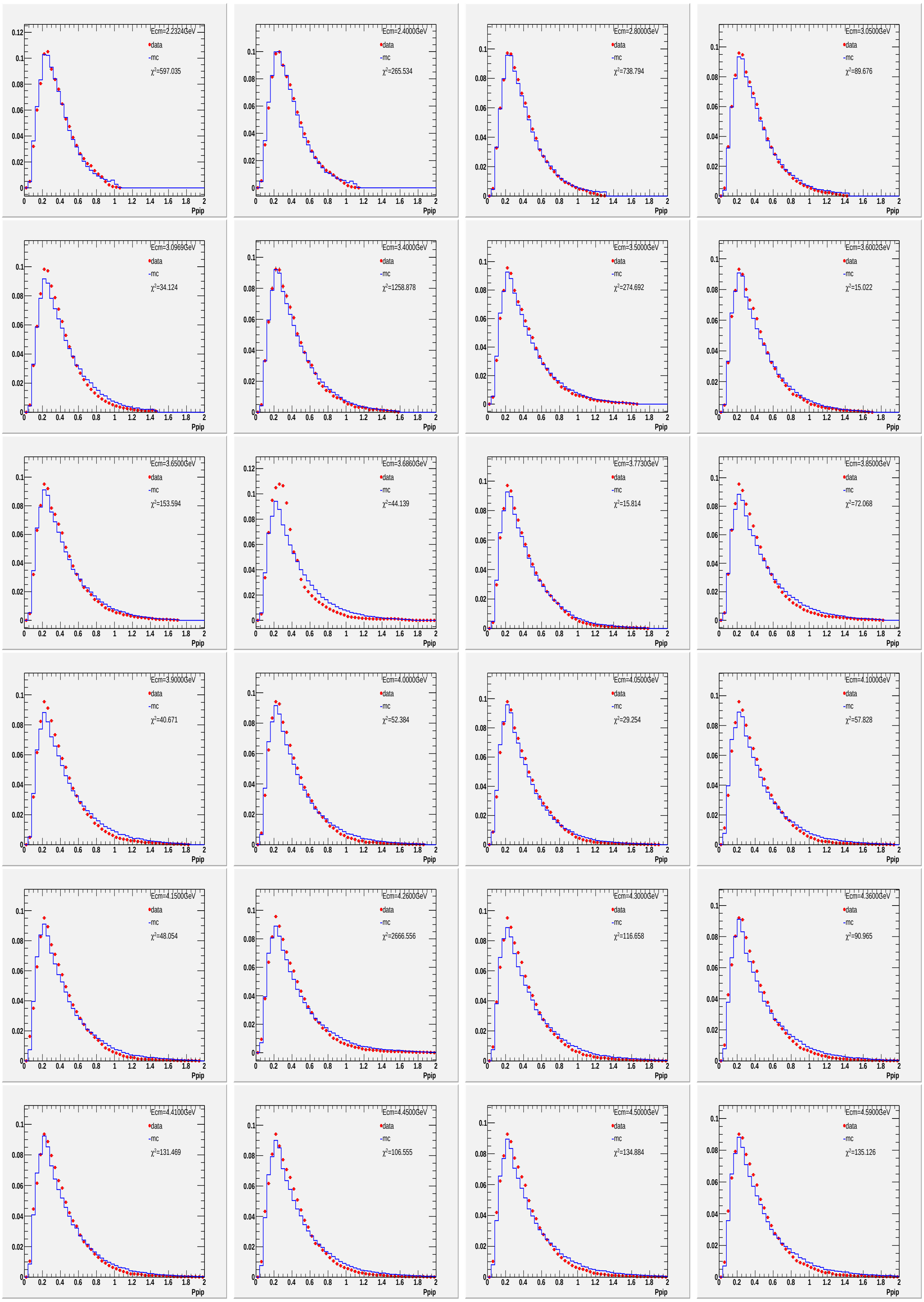


Fig. The transverse momentum P_{xy} of charged tracks.



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data
mc
χ2=597.035
Ppip
Ecm=2.4000GeV
data
mc
χ2=265.534
Ppip
Ecm=2.8000GeV
data
mc
χ2=738.794
Ppip
Ecm=3.0500GeV
data
mc
χ2=89.676
Ppip
Ecm=3.0969GeV
data
mc
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data
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Ecm=4.5000GeV
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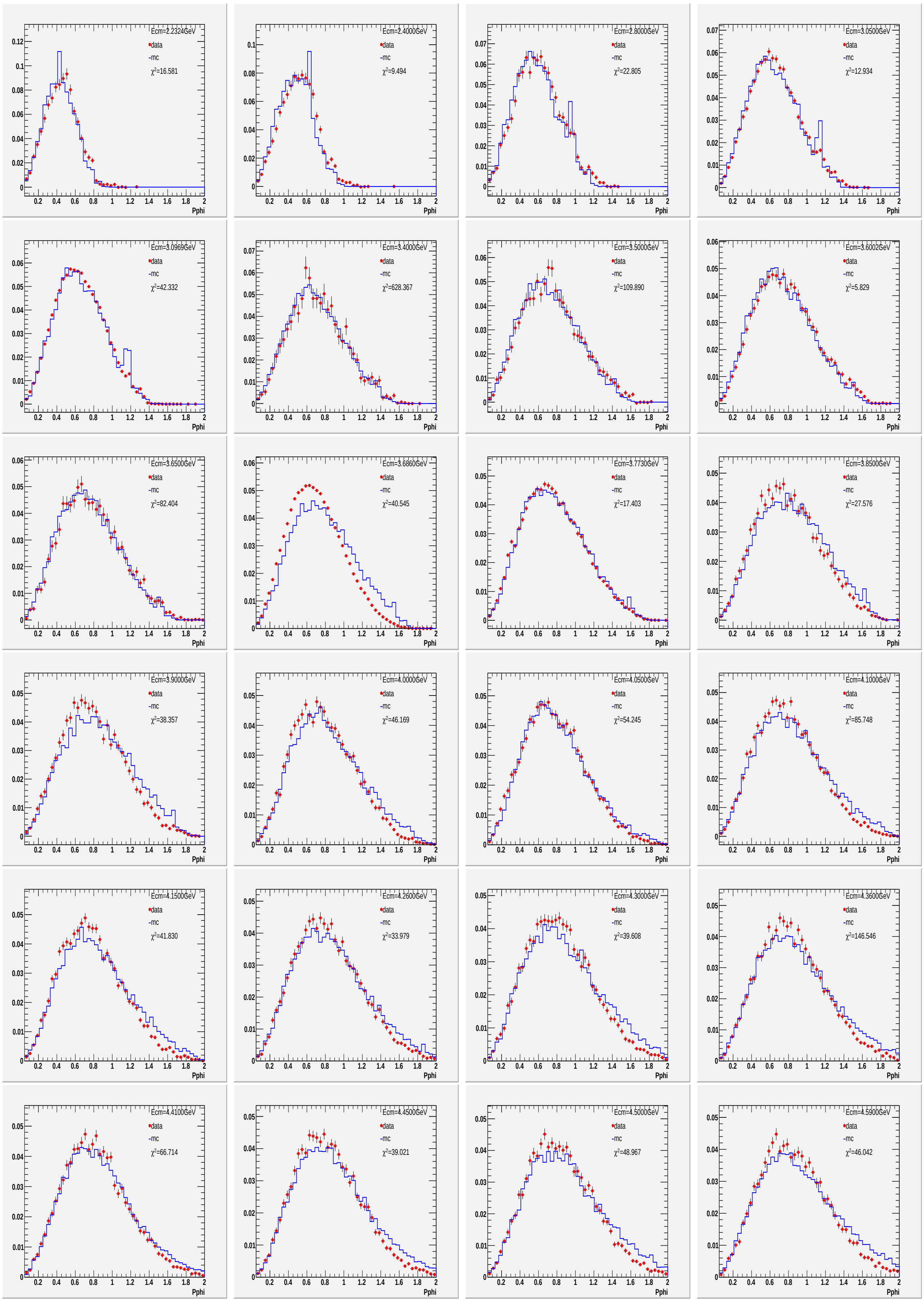
data
mc
χ2=135.126
Ppip

Fig. P of π^+.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mc
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Ecm=2.4000GeV
χ^2=9.494
Ecm=2.8000GeV
χ^2=22.805
Ecm=3.0500GeV
χ^2=12.934
Ecm=3.0969GeV
χ^2=42.332
Ecm=3.4000GeV
χ^2=628.367
Ecm=3.5000GeV
χ^2=109.890
Ecm=3.6002GeV
χ^2=5.829
Ecm=3.6500GeV
χ^2=82.404
Ecm=3.6860GeV
χ^2=40.545
Ecm=3.7730GeV
χ^2=17.403
Ecm=3.8500GeV
χ^2=27.576
Ecm=3.9000GeV
χ^2=38.357
Ecm=4.0000GeV
χ^2=46.169
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χ^2=39.021
Ecm=4.5000GeV
χ^2=48.967
Ecm=4.5900GeV
χ^2=46.042
Pphi

Fig. P of ϕ.

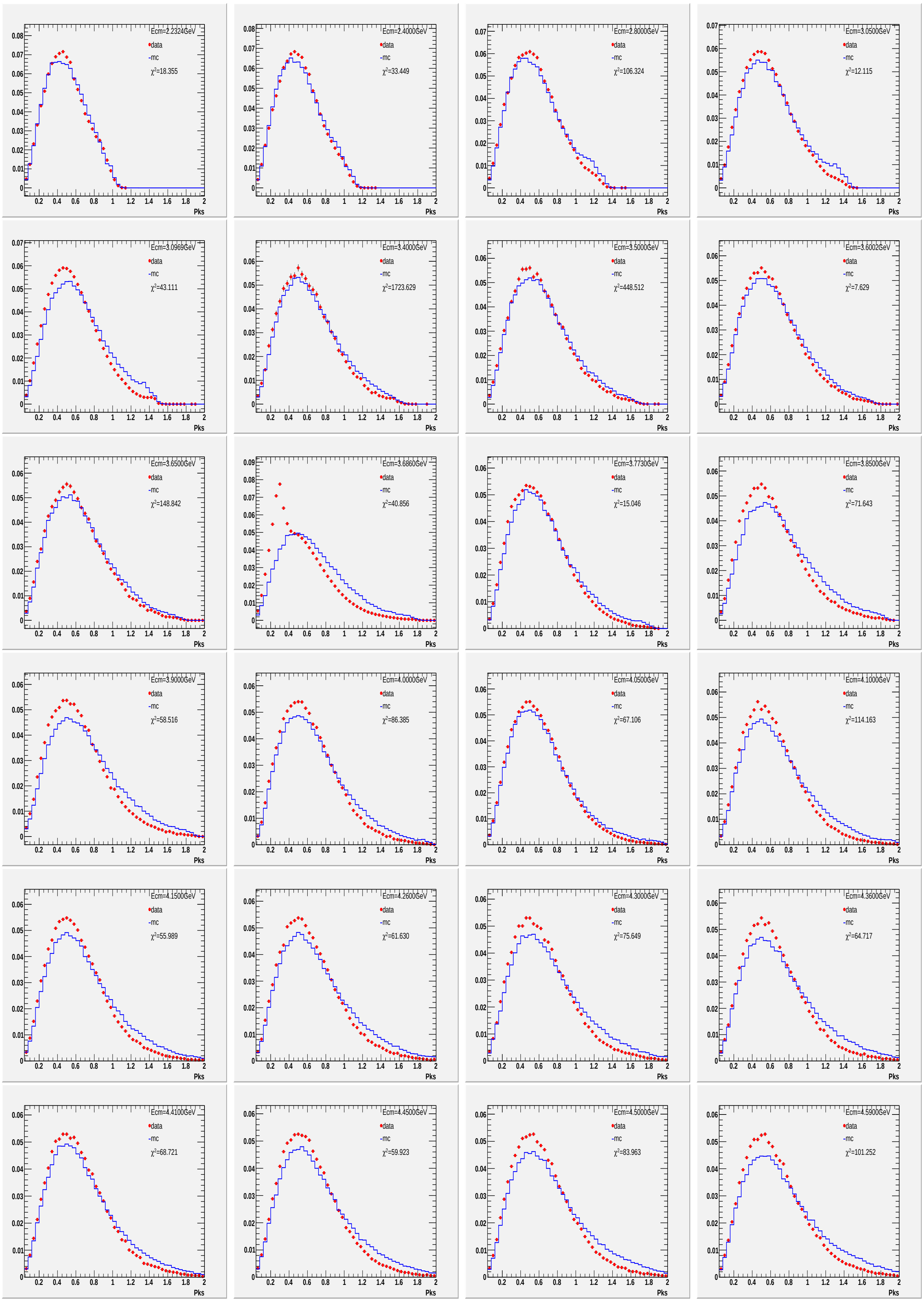

Ecm=2.2324GeV
data
mc
χ^2=18.355
Pks
Ecm=2.4000GeV
data
mc
χ^2=33.449
Pks
Ecm=2.8000GeV
data
mc
χ^2=106.324
Pks
Ecm=3.0500GeV
data
mc
χ^2=12.115
Pks
Ecm=3.0969GeV
data
mc
χ^2=43.111
Pks
Ecm=3.4000GeV
data
mc
χ^2=1723.629
Pks
Ecm=3.5000GeV
data
mc
χ^2=448.512
Pks
Ecm=3.6002GeV
data
mc
χ^2=7.629
Pks
Ecm=3.6500GeV
data
mc
χ^2=148.842
Pks
Ecm=3.6860GeV
data
mc
χ^2=40.856
Pks
Ecm=3.7730GeV
data
mc
χ^2=15.046
Pks
Ecm=3.8500GeV
data
mc
χ^2=71.643
Pks
Ecm=3.9000GeV
data
mc
χ^2=58.516
Pks
Ecm=4.0000GeV
data
mc
χ^2=86.385
Pks
Ecm=4.0500GeV
data
mc
χ^2=67.106
Pks
Ecm=4.1000GeV
data
mc
χ^2=114.163
Pks
Ecm=4.1500GeV
data
mc
χ^2=55.989
Pks
Ecm=4.2600GeV
data
mc
χ^2=61.630
Pks
Ecm=4.3000GeV
data
mc
χ^2=75.649
Pks
Ecm=4.3600GeV
data
mc
χ^2=64.717
Pks
Ecm=4.4100GeV
data
mc
χ^2=68.721
Pks
Ecm=4.4500GeV
data
mc
χ^2=59.923
Pks
Ecm=4.5000GeV
data
mc
χ^2=83.963
Pks
Ecm=4.5900GeV
data
mc
χ^2=101.252
Pks

Fig. P of K_s.

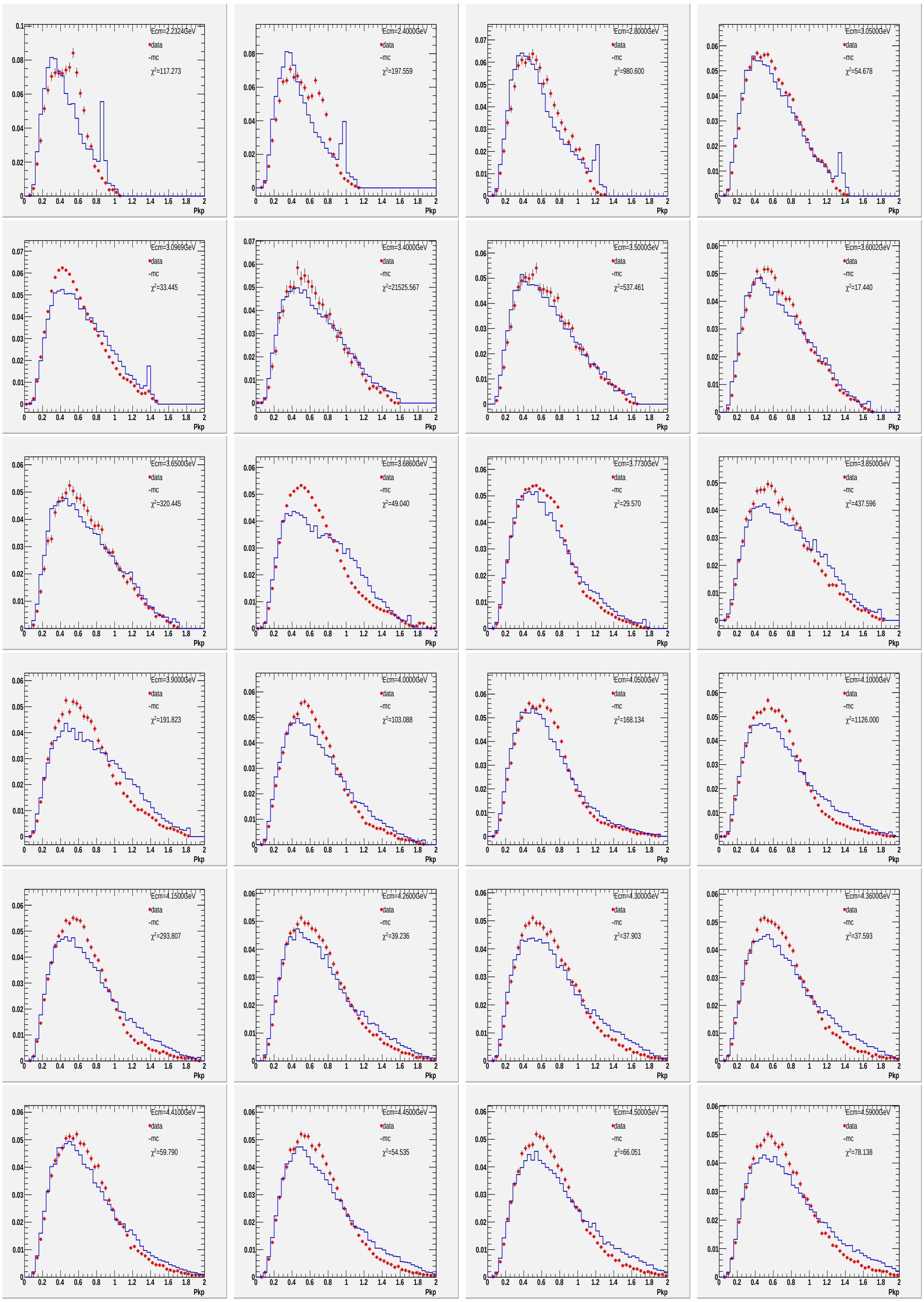

Ecm=2.2324GeV
data
mc
χ^2=117.273
Ecm=2.4000GeV
χ^2=197.559
Ecm=2.8000GeV
χ^2=980.600
Ecm=3.0500GeV
χ^2=54.678
Ecm=3.0969GeV
χ^2=33.445
Ecm=3.4000GeV
χ^2=21525.567
Ecm=3.5000GeV
χ^2=537.461
Ecm=3.6002GeV
χ^2=17.440
Ecm=3.6500GeV
χ^2=320.445
Ecm=3.6860GeV
χ^2=49.040
Ecm=3.7730GeV
χ^2=29.570
Ecm=3.8500GeV
χ^2=437.596
Ecm=3.9000GeV
χ^2=191.823
Ecm=4.0000GeV
χ^2=103.088
Ecm=4.0500GeV
χ^2=168.134
Ecm=4.1000GeV
χ^2=1126.000
Ecm=4.1500GeV
χ^2=293.807
Ecm=4.2600GeV
χ^2=39.236
Ecm=4.3000GeV
χ^2=37.903
Ecm=4.3600GeV
χ^2=37.593
Ecm=4.4100GeV
χ^2=59.790
Ecm=4.4500GeV
χ^2=54.535
Ecm=4.5000GeV
χ^2=66.051
Ecm=4.5900GeV
χ^2=78.138
Pkp

Fig. P of K^+.

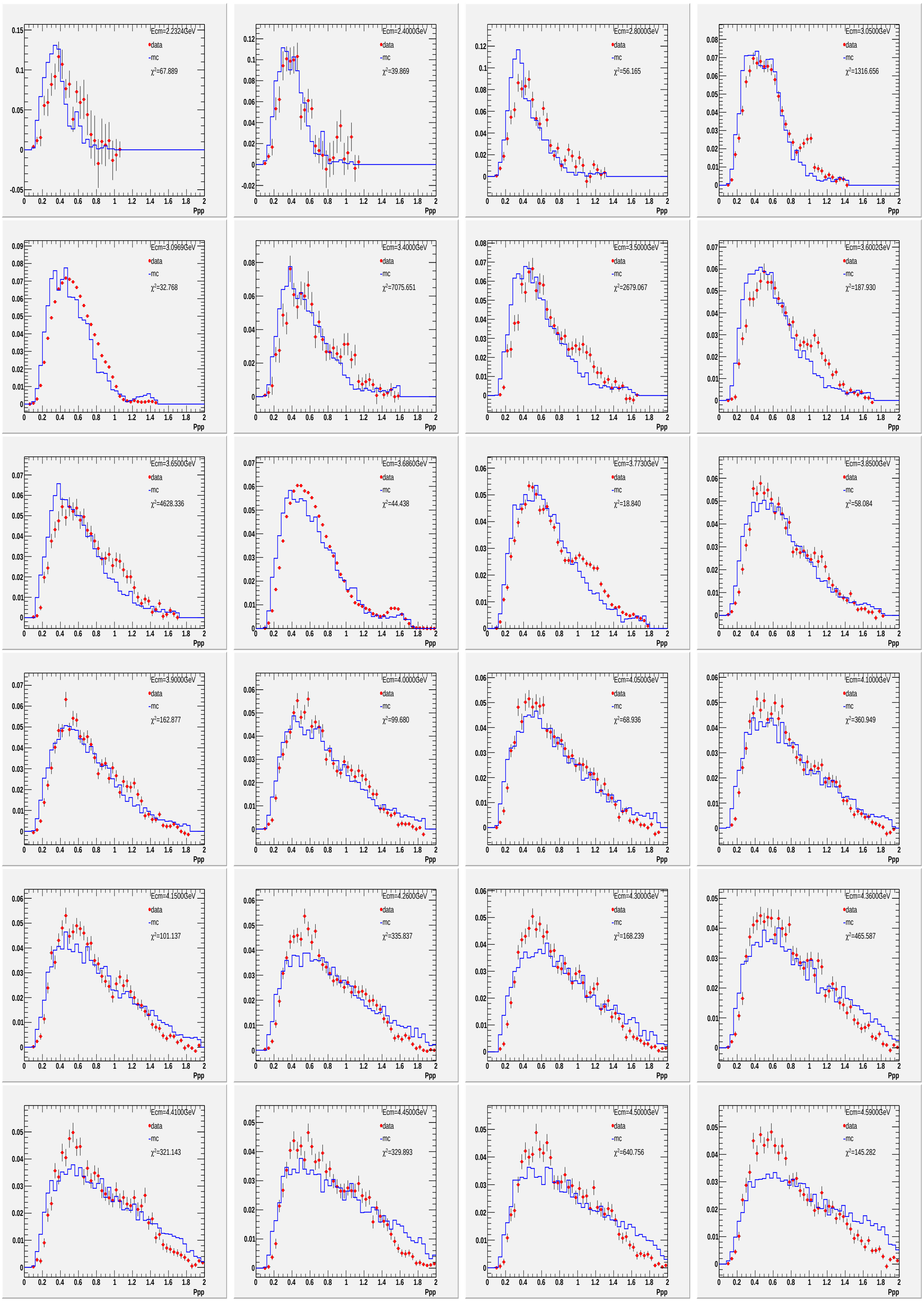

Ecm=2.2324GeV
data
mc
χ^2=67.889
Ecm=2.4000GeV
data
mc
χ^2=39.869
Ecm=2.8000GeV
data
mc
χ^2=56.165
Ecm=3.0500GeV
data
mc
χ^2=1316.656
Ecm=3.0969GeV
data
mc
χ^2=32.768
Ecm=3.4000GeV
data
mc
χ^2=7075.651
Ecm=3.5000GeV
data
mc
χ^2=2679.067
Ecm=3.6002GeV
data
mc
χ^2=187.930
Ecm=3.6500GeV
data
mc
χ^2=4628.336
Ecm=3.6860GeV
data
mc
χ^2=44.438
Ecm=3.7730GeV
data
mc
χ^2=18.840
Ecm=3.8500GeV
data
mc
χ^2=58.084
Ecm=3.9000GeV
data
mc
χ^2=162.877
Ecm=4.0000GeV
data
mc
χ^2=99.680
Ecm=4.0500GeV
data
mc
χ^2=68.936
Ecm=4.1000GeV
data
mc
χ^2=360.949
Ecm=4.1500GeV
data
mc
χ^2=101.137
Ecm=4.2600GeV
data
mc
χ^2=335.837
Ecm=4.3000GeV
data
mc
χ^2=168.239
Ecm=4.3600GeV
data
mc
χ^2=465.587
Ecm=4.4100GeV
data
mc
χ^2=321.143
Ecm=4.4500GeV
data
mc
χ^2=329.893
Ecm=4.5000GeV
data
mc
χ^2=640.756
Ecm=4.5900GeV
data
mc
χ^2=145.282
Ppp

Fig. P of p^{+}.

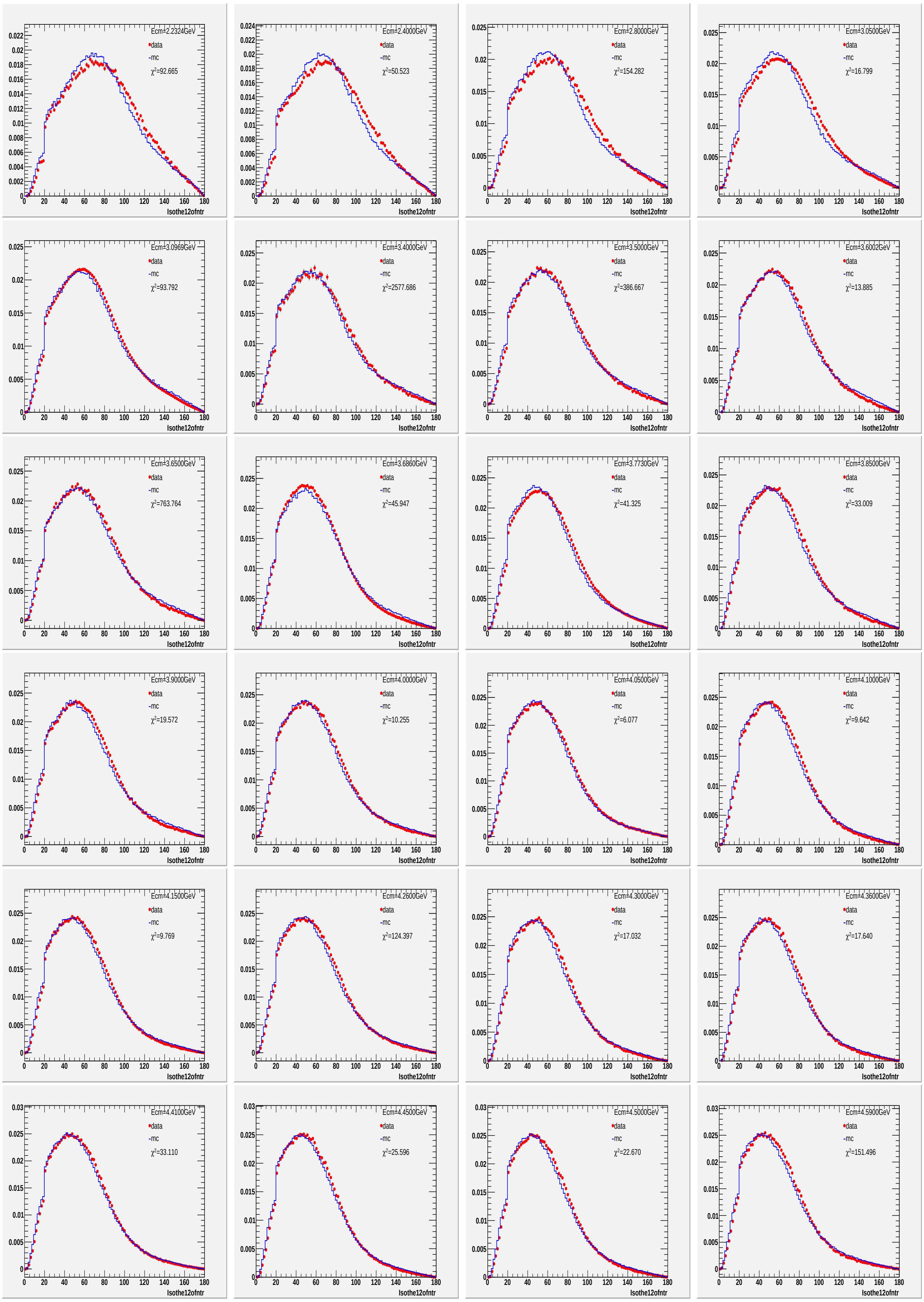
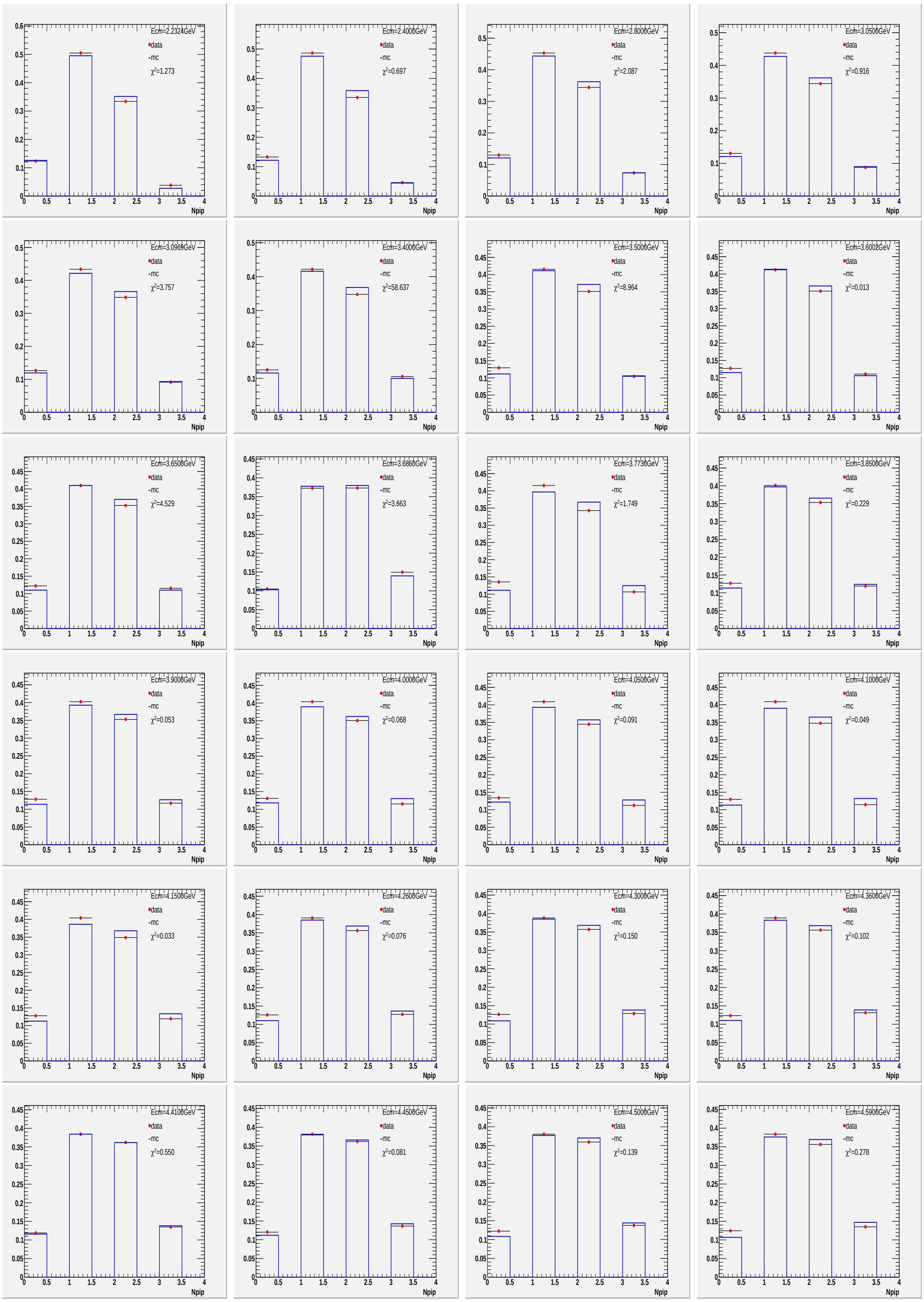
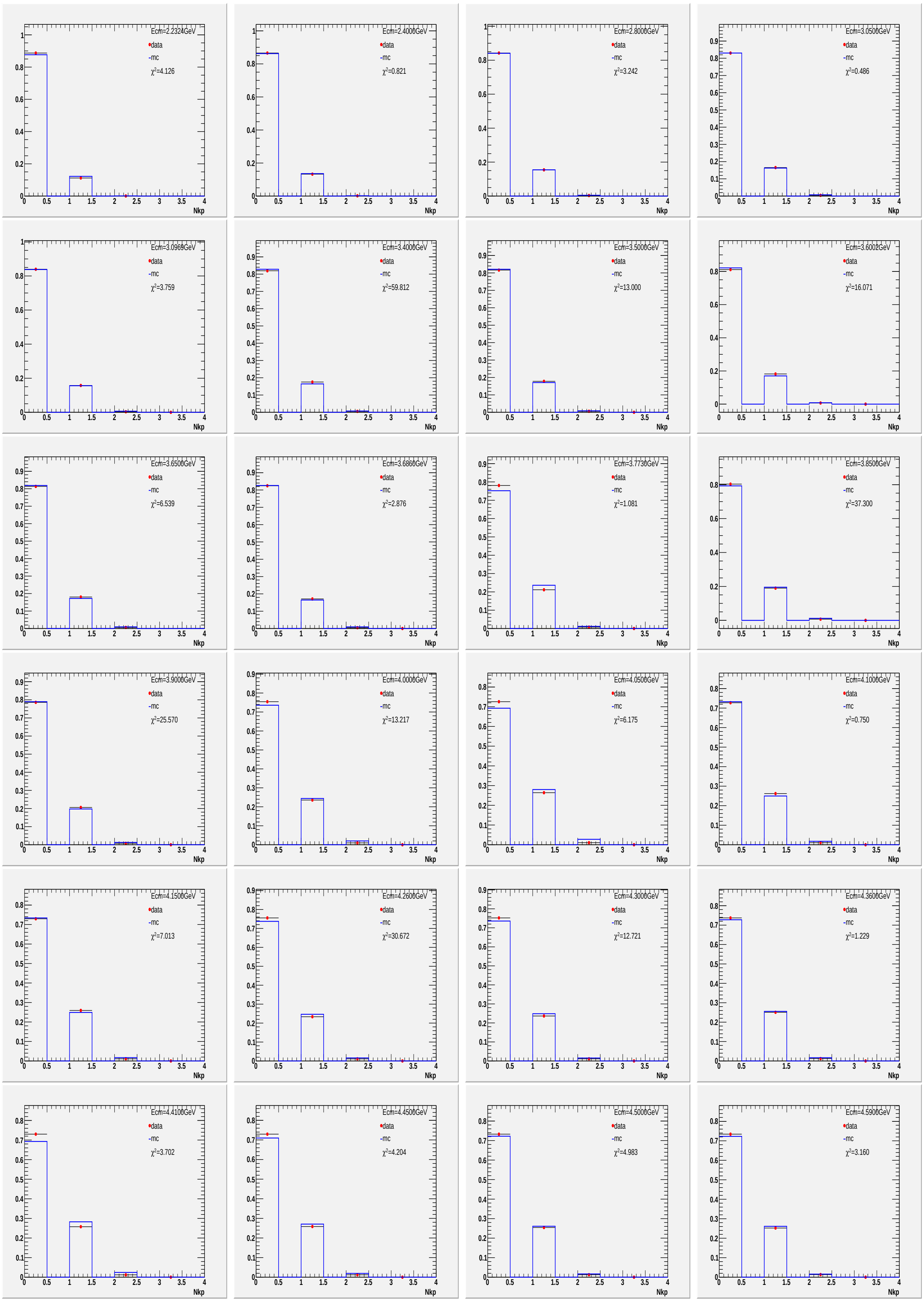


Fig.2 The angle between photon and charged track in 2-prong event.



Ecm=2.2324GeV
data
mc
χ^2=1.273
Npip
Ecm=2.4000GeV
data
mc
χ^2=0.697
Npip
Ecm=2.8000GeV
data
mc
χ^2=2.087
Npip
Ecm=3.0500GeV
data
mc
χ^2=0.916
Npip
Ecm=3.0969GeV
data
mc
χ^2=3.757
Npip
Ecm=3.4000GeV
data
mc
χ^2=58.637
Npip
Ecm=3.5000GeV
data
mc
χ^2=8.964
Npip
Ecm=3.6002GeV
data
mc
χ^2=0.013
Npip
Ecm=3.6500GeV
data
mc
χ^2=4.529
Npip
Ecm=3.6860GeV
data
mc
χ^2=3.663
Npip
Ecm=3.7730GeV
data
mc
χ^2=1.749
Npip
Ecm=3.8500GeV
data
mc
χ^2=0.229
Npip
Ecm=3.9000GeV
data
mc
χ^2=0.053
Npip
Ecm=4.0000GeV
data
mc
χ^2=0.068
Npip
Ecm=4.0500GeV
data
mc
χ^2=0.091
Npip
Ecm=4.1000GeV
data
mc
χ^2=0.049
Npip
Ecm=4.1500GeV
data
mc
χ^2=0.033
Npip
Ecm=4.2600GeV
data
mc
χ^2=0.076
Npip
Ecm=4.3000GeV
data
mc
χ^2=0.150
Npip
Ecm=4.3600GeV
data
mc
χ^2=0.102
Npip
Ecm=4.4100GeV
data
mc
χ^2=0.550
Npip
Ecm=4.4500GeV
data
mc
χ^2=0.081
Npip
Ecm=4.5000GeV
data
mc
χ^2=0.139
Npip
Ecm=4.5900GeV
data
mc
χ^2=0.278
Npip

Fig.2 N_{π^+}.



Ecm=2.2324GeV
data
mc
χ²=4.126
Nkp
Ecm=2.4000GeV
data
mc
χ²=0.821
Nkp
Ecm=2.8000GeV
data
mc
χ²=3.242
Nkp
Ecm=3.0500GeV
data
mc
χ²=0.486
Nkp
Ecm=3.0969GeV
data
mc
χ²=3.759
Nkp
Ecm=3.4000GeV
data
mc
χ²=59.812
Nkp
Ecm=3.5000GeV
data
mc
χ²=13.000
Nkp
Ecm=3.6002GeV
data
mc
χ²=16.071
Nkp
Ecm=3.6500GeV
data
mc
χ²=6.539
Nkp
Ecm=3.6860GeV
data
mc
χ²=2.876
Nkp
Ecm=3.7730GeV
data
mc
χ²=1.081
Nkp
Ecm=3.8500GeV
data
mc
χ²=37.300
Nkp
Ecm=3.9000GeV
data
mc
χ²=25.570
Nkp
Ecm=4.0000GeV
data
mc
χ²=13.217
Nkp
Ecm=4.0500GeV
data
mc
χ²=6.175
Nkp
Ecm=4.1000GeV
data
mc
χ²=0.750
Nkp
Ecm=4.1500GeV
data
mc
χ²=7.013
Nkp
Ecm=4.2600GeV
data
mc
χ²=30.672
Nkp
Ecm=4.3000GeV
data
mc
χ²=12.721
Nkp
Ecm=4.3600GeV
data
mc
χ²=1.229
Nkp
Ecm=4.4100GeV
data
mc
χ²=3.702
Nkp
Ecm=4.4500GeV
data
mc
χ²=4.204
Nkp
Ecm=4.5000GeV
data
mc
χ²=4.983
Nkp
Ecm=4.5900GeV
data
mc
χ²=3.160
Nkp

Fig.2 N_{K+}.

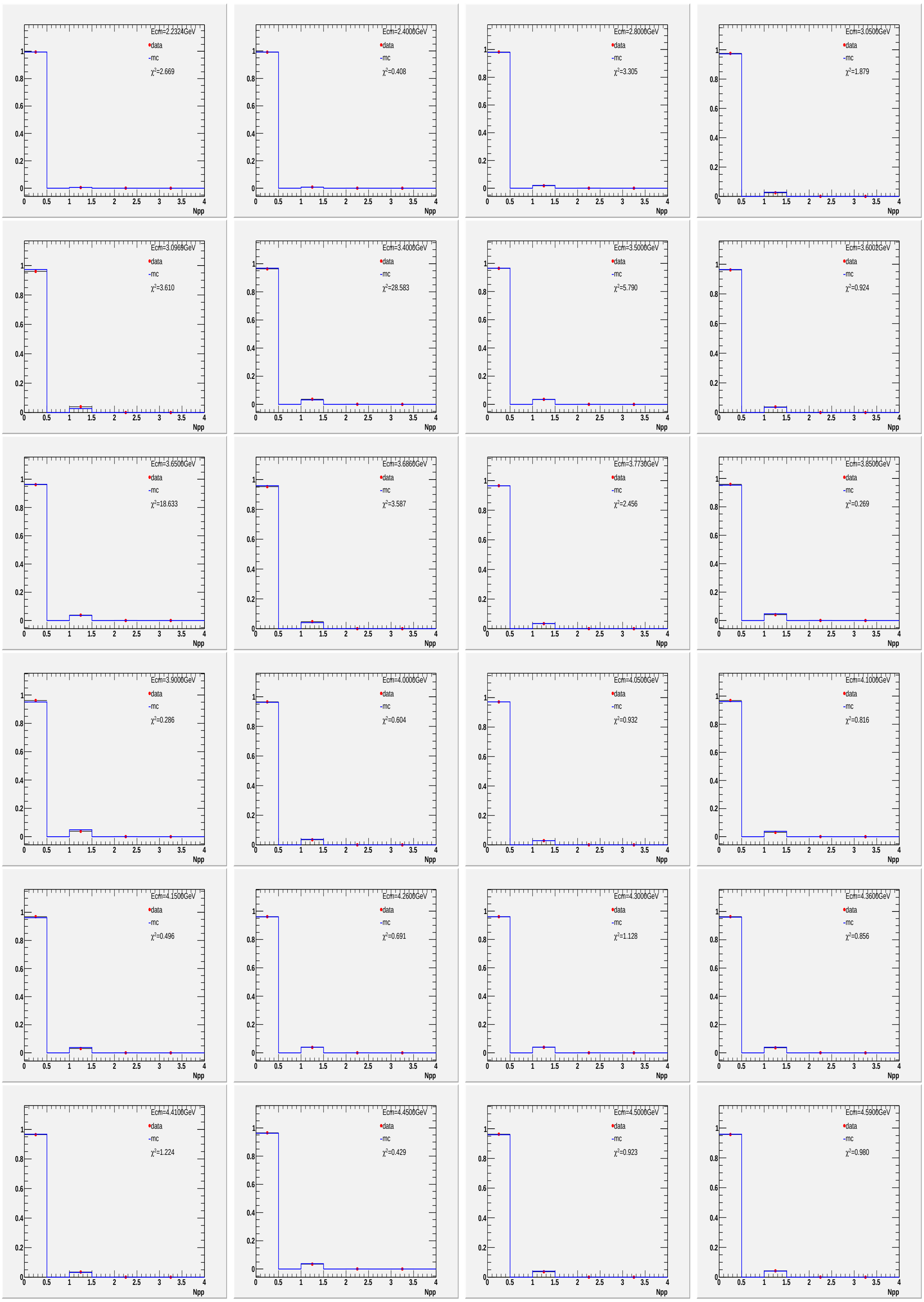
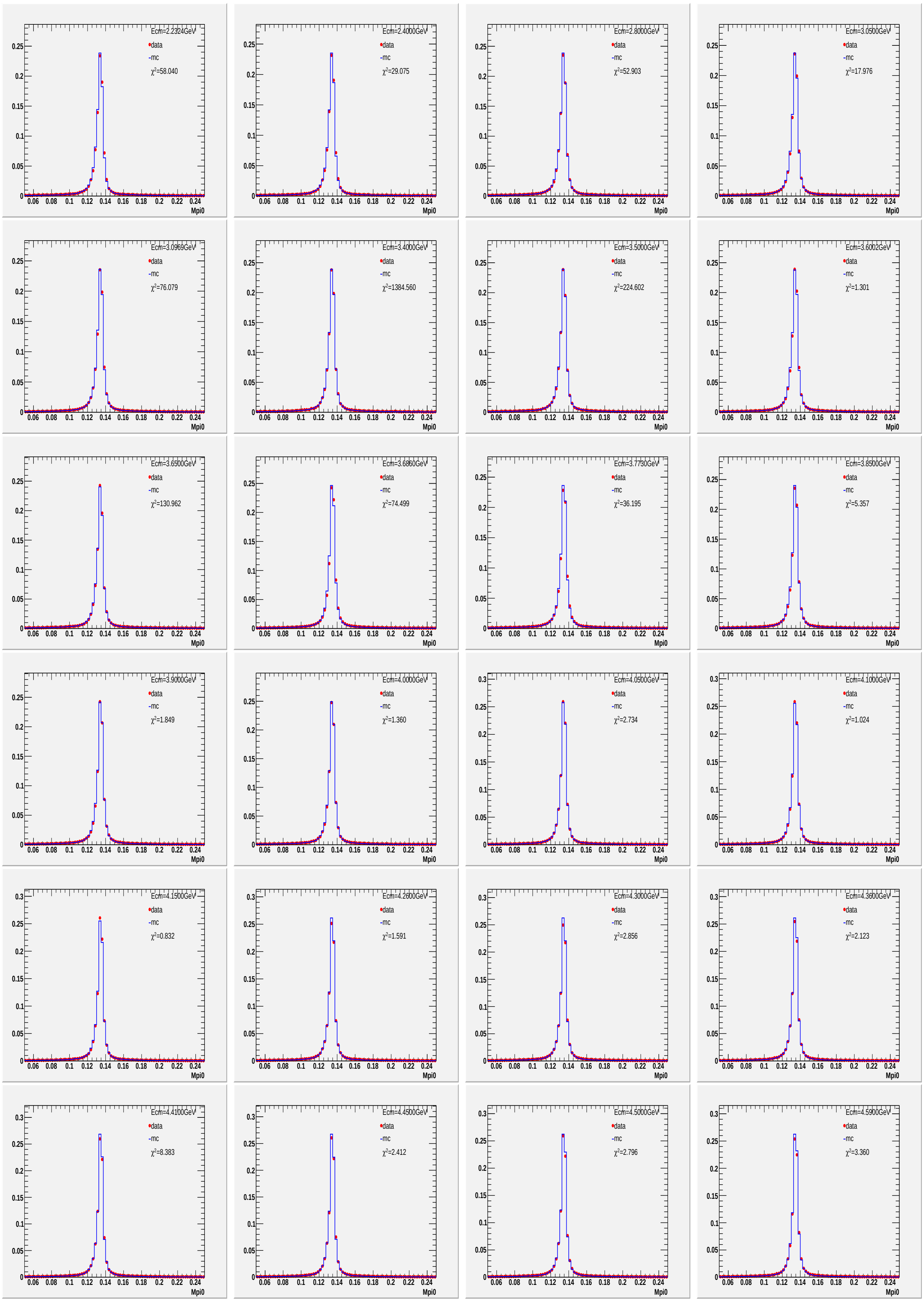

Ecm=2.2324GeV
data
mc
χ²=2.669
Npp
Ecm=2.4000GeV
data
mc
χ²=0.408
Npp
Ecm=2.8000GeV
data
mc
χ²=3.305
Npp
Ecm=3.0500GeV
data
mc
χ²=1.879
Npp
Ecm=3.0969GeV
data
mc
χ²=3.610
Npp
Ecm=3.4000GeV
data
mc
χ²=28.583
Npp
Ecm=3.5000GeV
data
mc
χ²=5.790
Npp
Ecm=3.6002GeV
data
mc
χ²=0.924
Npp
Ecm=3.6500GeV
data
mc
χ²=18.633
Npp
Ecm=3.6860GeV
data
mc
χ²=3.587
Npp
Ecm=3.7730GeV
data
mc
χ²=2.456
Npp
Ecm=3.8500GeV
data
mc
χ²=0.269
Npp
Ecm=3.9000GeV
data
mc
χ²=0.286
Npp
Ecm=4.0000GeV
data
mc
χ²=0.604
Npp
Ecm=4.0500GeV
data
mc
χ²=0.932
Npp
Ecm=4.1000GeV
data
mc
χ²=0.816
Npp
Ecm=4.1500GeV
data
mc
χ²=0.496
Npp
Ecm=4.2600GeV
data
mc
χ²=0.691
Npp
Ecm=4.3000GeV
data
mc
χ²=1.128
Npp
Ecm=4.3600GeV
data
mc
χ²=0.856
Npp
Ecm=4.4100GeV
data
mc
χ²=1.224
Npp
Ecm=4.4500GeV
data
mc
χ²=0.429
Npp
Ecm=4.5000GeV
data
mc
χ²=0.923
Npp
Ecm=4.5900GeV
data
mc
χ²=0.980
Npp

Fig.2 N_{p^+}.



Ecm=2.2324GeV
data
mc
χ^2=58.040
Ecm=2.4000GeV
χ^2=29.075
Ecm=2.8000GeV
χ^2=52.903
Ecm=3.0500GeV
χ^2=17.976
Ecm=3.0969GeV
χ^2=76.079
Ecm=3.4000GeV
χ^2=1384.560
Ecm=3.5000GeV
χ^2=224.602
Ecm=3.6002GeV
χ^2=1.301
Ecm=3.6500GeV
χ^2=130.962
Ecm=3.6860GeV
χ^2=74.499
Ecm=3.7730GeV
χ^2=36.195
Ecm=3.8500GeV
χ^2=5.357
Ecm=3.9000GeV
χ^2=1.849
Ecm=4.0000GeV
χ^2=1.360
Ecm=4.0500GeV
χ^2=2.734
Ecm=4.1000GeV
χ^2=1.024
Ecm=4.1500GeV
χ^2=0.832
Ecm=4.2600GeV
χ^2=1.591
Ecm=4.3000GeV
χ^2=2.856
Ecm=4.3600GeV
χ^2=2.123
Ecm=4.4100GeV
χ^2=8.383
Ecm=4.4500GeV
χ^2=2.412
Ecm=4.5000GeV
χ^2=2.796
Ecm=4.5900GeV
χ^2=3.360
Mpi0

Fig.2 M_{π^0}.

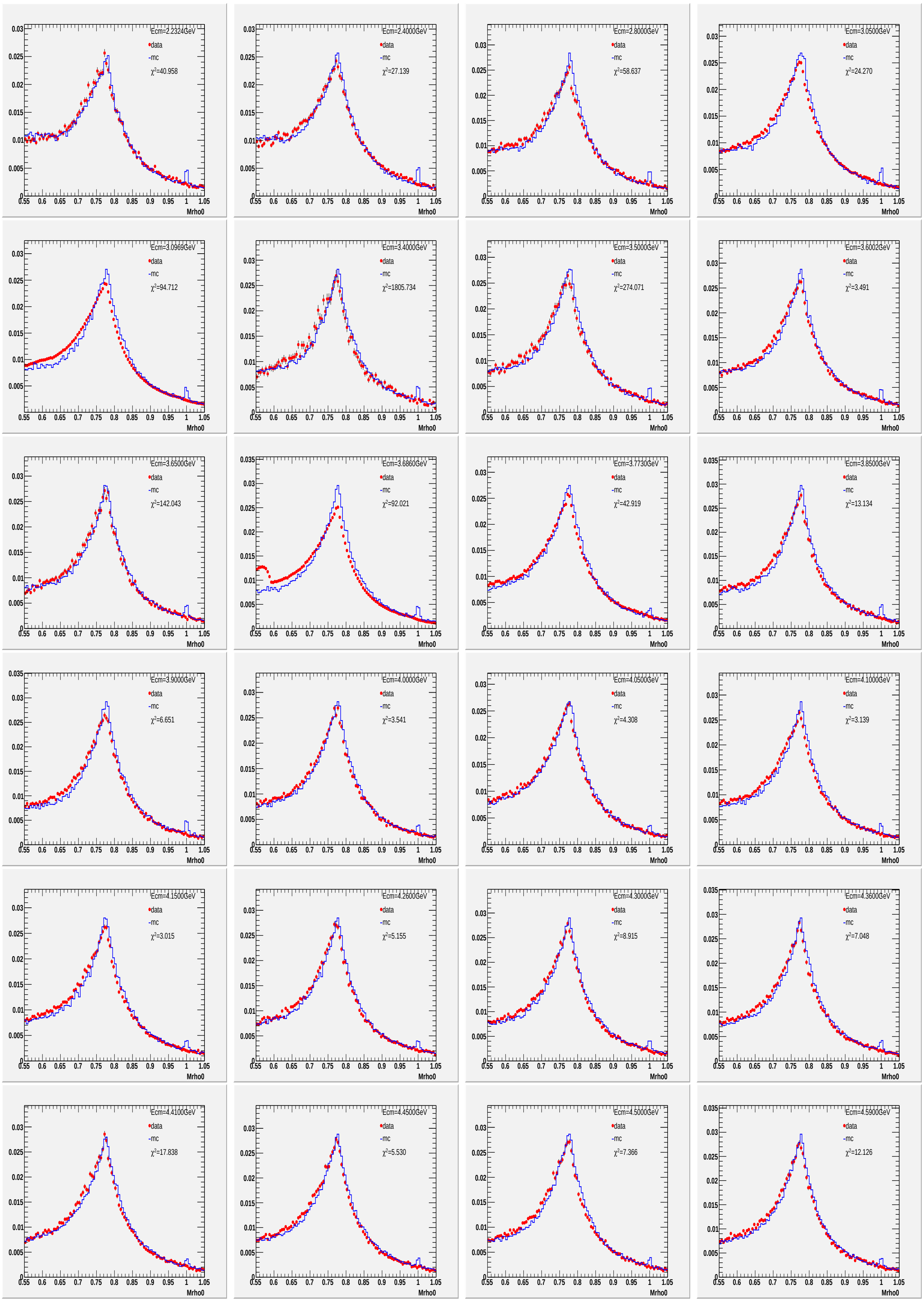

Ecm=2.2324GeV
data
mc
χ^2=40.958
Ecm=2.4000GeV
χ^2=27.139
Ecm=2.8000GeV
χ^2=58.637
Ecm=3.0500GeV
χ^2=24.270
Ecm=3.0969GeV
χ^2=94.712
Ecm=3.4000GeV
χ^2=1805.734
Ecm=3.5000GeV
χ^2=274.071
Ecm=3.6002GeV
χ^2=3.491
Ecm=3.6500GeV
χ^2=142.043
Ecm=3.6860GeV
χ^2=92.021
Ecm=3.7730GeV
χ^2=42.919
Ecm=3.8500GeV
χ^2=13.134
Ecm=3.9000GeV
χ^2=6.651
Ecm=4.0000GeV
χ^2=3.541
Ecm=4.0500GeV
χ^2=4.308
Ecm=4.1000GeV
χ^2=3.139
Ecm=4.1500GeV
χ^2=3.015
Ecm=4.2600GeV
χ^2=5.155
Ecm=4.3000GeV
χ^2=8.915
Ecm=4.3600GeV
χ^2=7.048
Ecm=4.4100GeV
χ^2=17.838
Ecm=4.4500GeV
χ^2=5.530
Ecm=4.5000GeV
χ^2=7.366
Ecm=4.5900GeV
χ^2=12.126
Mrho0

Fig. M_{π^0}.

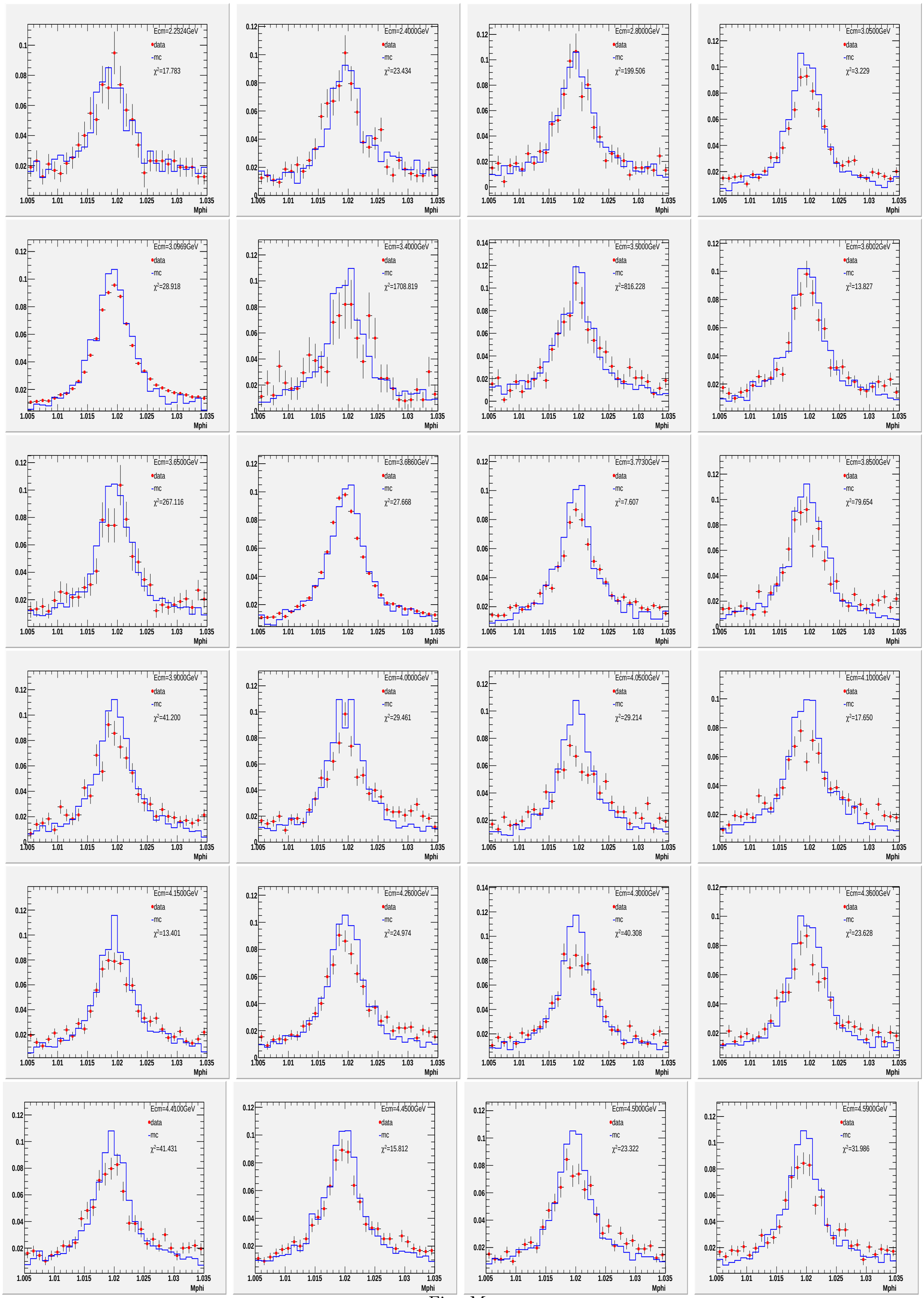
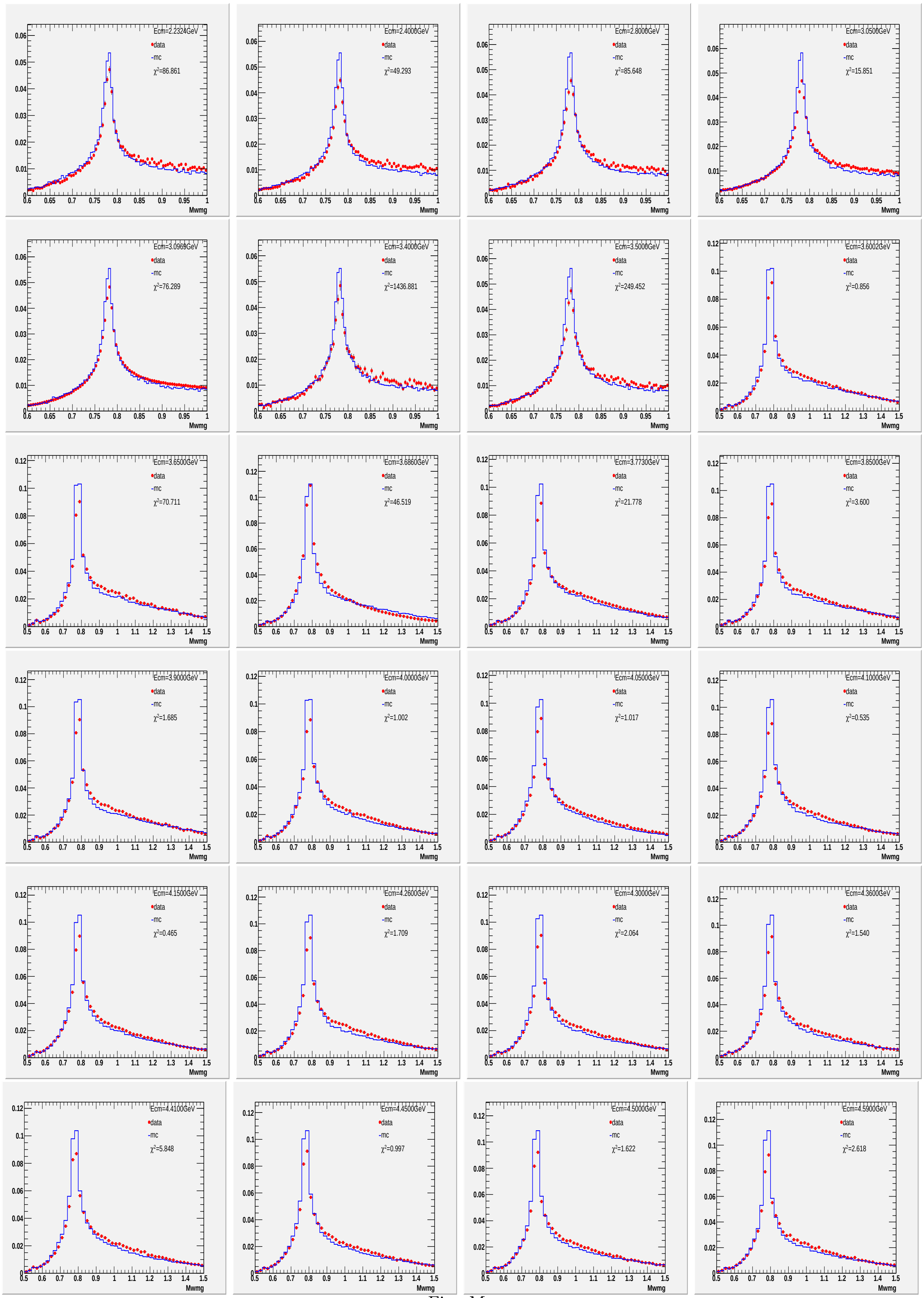
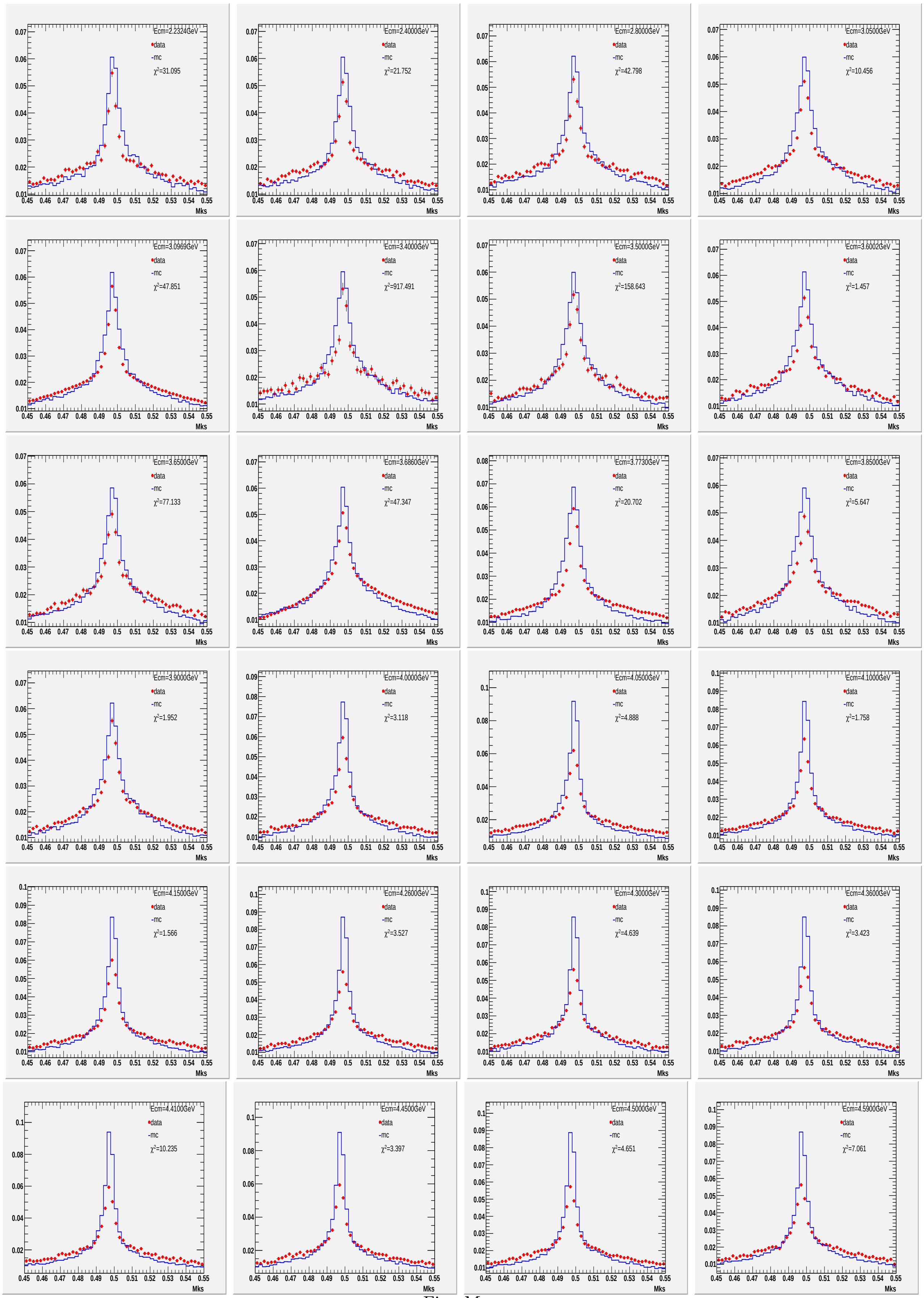

Ecm=2.2324GeV
data
mc
χ^2=17.783
Ecm=2.4000GeV
χ^2=23.434
Ecm=2.8000GeV
χ^2=199.506
Ecm=3.0500GeV
χ^2=3.229
Ecm=3.0969GeV
χ^2=28.918
Ecm=3.4000GeV
χ^2=1708.819
Ecm=3.5000GeV
χ^2=816.228
Ecm=3.6002GeV
χ^2=13.827
Ecm=3.6500GeV
χ^2=267.116
Ecm=3.6860GeV
χ^2=27.668
Ecm=3.7730GeV
χ^2=7.607
Ecm=3.8500GeV
χ^2=79.654
Ecm=3.9000GeV
χ^2=41.200
Ecm=4.0000GeV
χ^2=29.461
Ecm=4.0500GeV
χ^2=29.214
Ecm=4.1000GeV
χ^2=17.650
Ecm=4.1500GeV
χ^2=13.401
Ecm=4.2600GeV
χ^2=24.974
Ecm=4.3000GeV
χ^2=40.308
Ecm=4.3600GeV
χ^2=23.628
Ecm=4.4100GeV
χ^2=41.431
Ecm=4.4500GeV
χ^2=15.812
Ecm=4.5000GeV
χ^2=23.322
Ecm=4.5900GeV
χ^2=31.986
Mphi

Fig. M_ϕ.



Ecm=2.2324GeV
data
mc
χ²=86.861
Ecm=2.4000GeV
data
mc
χ²=49.293
Ecm=2.8000GeV
data
mc
χ²=85.648
Ecm=3.0500GeV
data
mc
χ²=15.851
Ecm=3.0969GeV
data
mc
χ²=76.289
Ecm=3.4000GeV
data
mc
χ²=1436.881
Ecm=3.5000GeV
data
mc
χ²=249.452
Ecm=3.6002GeV
data
mc
χ²=0.856
Ecm=3.6500GeV
data
mc
χ²=70.711
Ecm=3.6860GeV
data
mc
χ²=46.519
Ecm=3.7730GeV
data
mc
χ²=21.778
Ecm=3.8500GeV
data
mc
χ²=3.600
Ecm=3.9000GeV
data
mc
χ²=1.685
Ecm=4.0000GeV
data
mc
χ²=1.002
Ecm=4.0500GeV
data
mc
χ²=1.017
Ecm=4.1000GeV
data
mc
χ²=0.535
Ecm=4.1500GeV
data
mc
χ²=0.465
Ecm=4.2600GeV
data
mc
χ²=1.709
Ecm=4.3000GeV
data
mc
χ²=2.064
Ecm=4.3600GeV
data
mc
χ²=1.540
Ecm=4.4100GeV
data
mc
χ²=5.848
Ecm=4.4500GeV
data
mc
χ²=0.997
Ecm=4.5000GeV
data
mc
χ²=1.622
Ecm=4.5900GeV
data
mc
χ²=2.618
Mwmg

Fig. M_ω.



Ecm=2.2324GeV
data
mc
χ^2=31.095
Ecm=2.4000GeV
data
mc
χ^2=21.752
Ecm=2.8000GeV
data
mc
χ^2=42.798
Ecm=3.0500GeV
data
mc
χ^2=10.456
Ecm=3.0969GeV
data
mc
χ^2=47.851
Ecm=3.4000GeV
data
mc
χ^2=917.491
Ecm=3.5000GeV
data
mc
χ^2=158.643
Ecm=3.6002GeV
data
mc
χ^2=1.457
Ecm=3.6500GeV
data
mc
χ^2=77.133
Ecm=3.6860GeV
data
mc
χ^2=47.347
Ecm=3.7730GeV
data
mc
χ^2=20.702
Ecm=3.8500GeV
data
mc
χ^2=5.647
Ecm=3.9000GeV
data
mc
χ^2=1.952
Ecm=4.0000GeV
data
mc
χ^2=3.118
Ecm=4.0500GeV
data
mc
χ^2=4.888
Ecm=4.1000GeV
data
mc
χ^2=1.758
Ecm=4.1500GeV
data
mc
χ^2=1.566
Ecm=4.2600GeV
data
mc
χ^2=3.527
Ecm=4.3000GeV
data
mc
χ^2=4.639
Ecm=4.3600GeV
data
mc
χ^2=3.423
Ecm=4.4100GeV
data
mc
χ^2=10.235
Ecm=4.4500GeV
data
mc
χ^2=3.397
Ecm=4.5000GeV
data
mc
χ^2=4.651
Ecm=4.5900GeV
data
mc
χ^2=7.061
Mks

Fig. M_{K_s}.

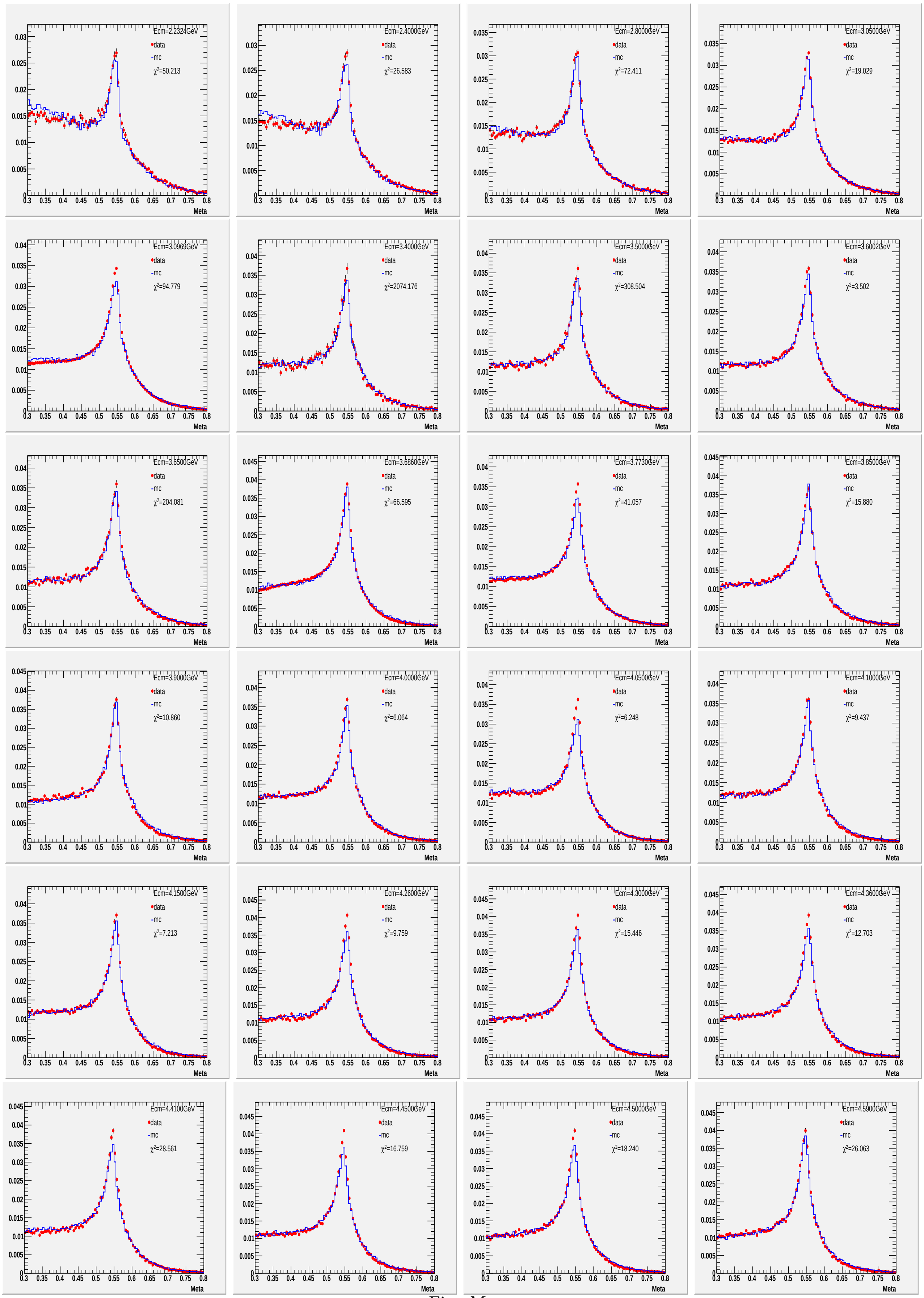

Ecm=2.2324GeV
data
mc
χ^2=50.213
Ecm=2.4000GeV
χ^2=26.583
Ecm=2.8000GeV
χ^2=72.411
Ecm=3.0500GeV
χ^2=19.029
Ecm=3.0969GeV
χ^2=94.779
Ecm=3.4000GeV
χ^2=2074.176
Ecm=3.5000GeV
χ^2=308.504
Ecm=3.6002GeV
χ^2=3.502
Ecm=3.6500GeV
χ^2=204.081
Ecm=3.6860GeV
χ^2=66.595
Ecm=3.7730GeV
χ^2=41.057
Ecm=3.8500GeV
χ^2=15.880
Ecm=3.9000GeV
χ^2=10.860
Ecm=4.0000GeV
χ^2=6.064
Ecm=4.0500GeV
χ^2=6.248
Ecm=4.1000GeV
χ^2=9.437
Ecm=4.1500GeV
χ^2=7.213
Ecm=4.2600GeV
χ^2=9.759
Ecm=4.3000GeV
χ^2=15.446
Ecm=4.3600GeV
χ^2=12.703
Ecm=4.4100GeV
χ^2=28.561
Ecm=4.4500GeV
χ^2=16.759
Ecm=4.5000GeV
χ^2=18.240
Ecm=4.5900GeV
χ^2=26.063
Meta

Fig. M_η.

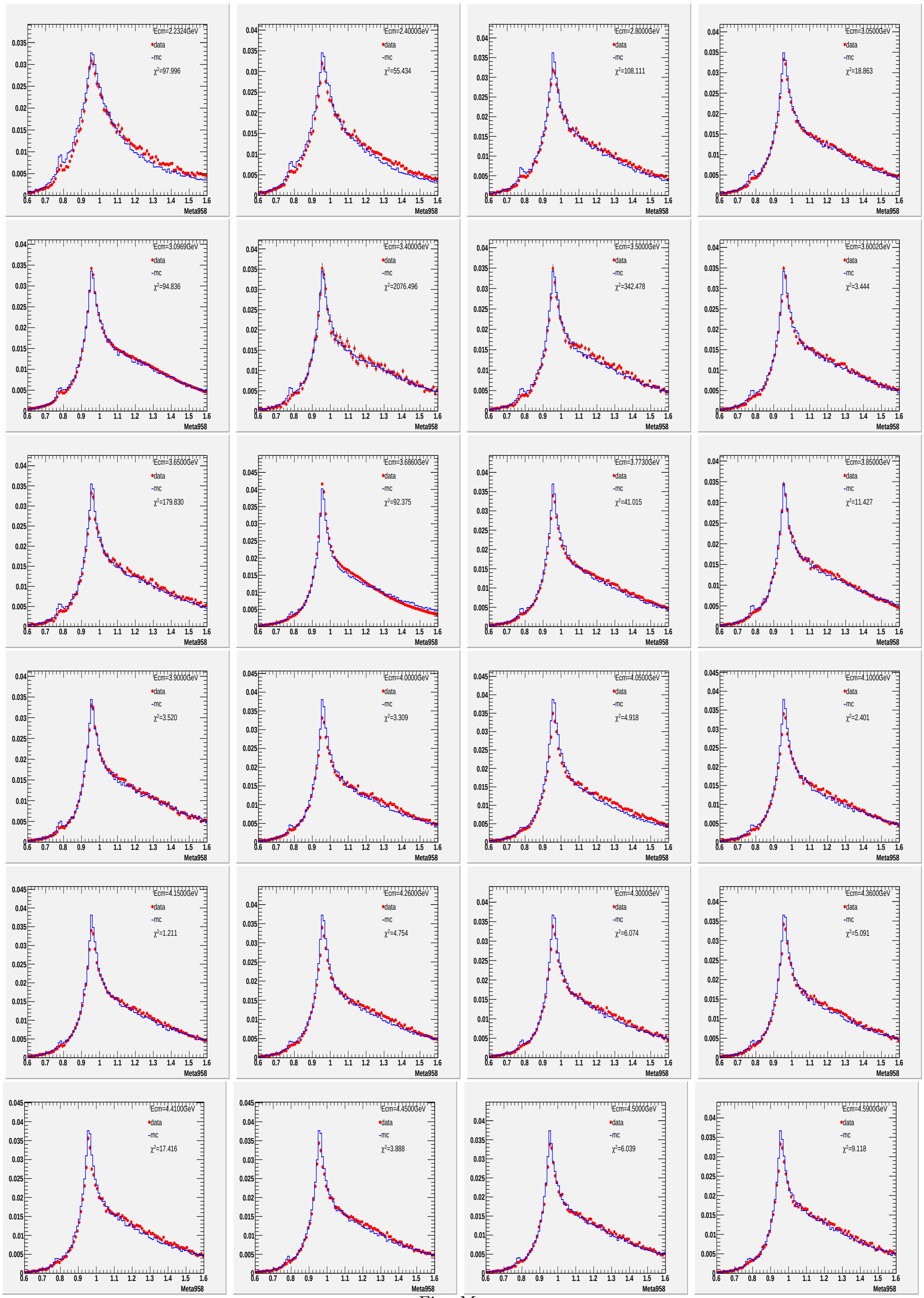

Ecm=2.2324GeV
data
mc
χ^2=97.996
Meta958
Ecm=2.4000GeV
data
mc
χ^2=55.434
Meta958
Ecm=2.8000GeV
data
mc
χ^2=108.111
Meta958
Ecm=3.0500GeV
data
mc
χ^2=18.863
Meta958
Ecm=3.0969GeV
data
mc
χ^2=94.836
Meta958
Ecm=3.4000GeV
data
mc
χ^2=2076.496
Meta958
Ecm=3.5000GeV
data
mc
χ^2=342.478
Meta958
Ecm=3.6002GeV
data
mc
χ^2=3.444
Meta958
Ecm=3.6500GeV
data
mc
χ^2=179.830
Meta958
Ecm=3.6860GeV
data
mc
χ^2=92.375
Meta958
Ecm=3.7730GeV
data
mc
χ^2=41.015
Meta958
Ecm=3.8500GeV
data
mc
χ^2=11.427
Meta958
Ecm=3.9000GeV
data
mc
χ^2=3.520
Meta958
Ecm=4.0000GeV
data
mc
χ^2=3.309
Meta958
Ecm=4.0500GeV
data
mc
χ^2=4.918
Meta958
Ecm=4.1000GeV
data
mc
χ^2=2.401
Meta958
Ecm=4.1500GeV
data
mc
χ^2=1.211
Meta958
Ecm=4.2600GeV
data
mc
χ^2=4.754
Meta958
Ecm=4.3000GeV
data
mc
χ^2=6.074
Meta958
Ecm=4.3600GeV
data
mc
χ^2=5.091
Meta958
Ecm=4.4100GeV
data
mc
χ^2=17.416
Meta958
Ecm=4.4500GeV
data
mc
χ^2=3.888
Meta958
Ecm=4.5000GeV
data
mc
χ^2=6.039
Meta958
Ecm=4.5900GeV
data
mc
χ^2=9.118
Meta958

Fig. $M_{\eta958}$.

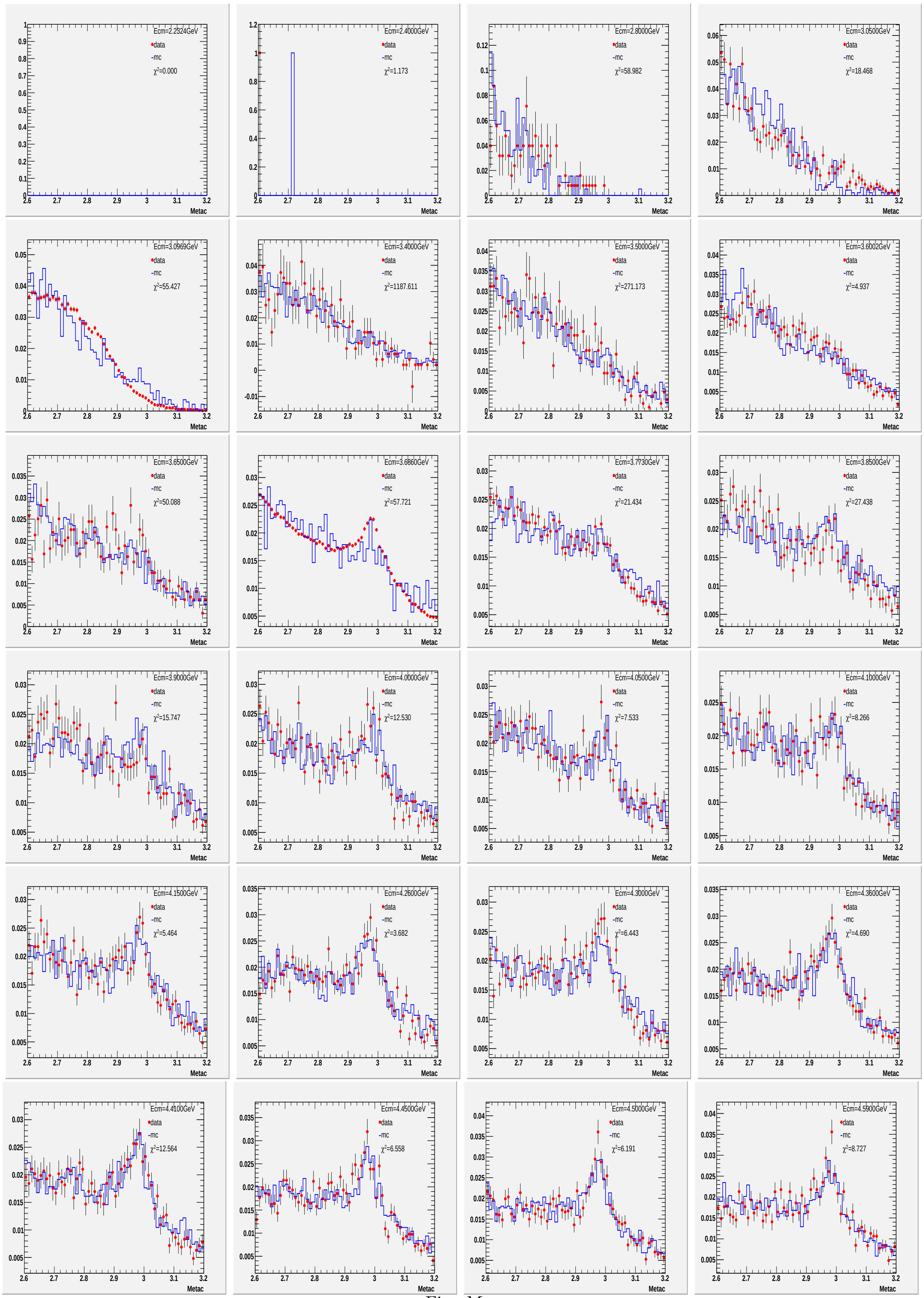

Ecm=2.2324GeV
χ²=0.000
Ecm=2.4000GeV
χ²=1.173
Ecm=2.8000GeV
χ²=58.982
Ecm=3.0500GeV
χ²=18.468
Ecm=3.0969GeV
χ²=55.427
Ecm=3.4000GeV
χ²=1187.611
Ecm=3.5000GeV
χ²=271.173
Ecm=3.6002GeV
χ²=4.937
Ecm=3.6500GeV
χ²=50.088
Ecm=3.6860GeV
χ²=57.721
Ecm=3.7730GeV
χ²=21.434
Ecm=3.8500GeV
χ²=27.438
Ecm=3.9000GeV
χ²=15.747
Ecm=4.0000GeV
χ²=12.530
Ecm=4.0500GeV
χ²=7.533
Ecm=4.1000GeV
χ²=8.266
Ecm=4.1500GeV
χ²=5.464
Ecm=4.2600GeV
χ²=3.682
Ecm=4.3000GeV
χ²=6.443
Ecm=4.3600GeV
χ²=4.690
Ecm=4.4100GeV
χ²=12.564
Ecm=4.4500GeV
χ²=6.558
Ecm=4.5000GeV
χ²=6.191
Ecm=4.5900GeV
χ²=8.727
data
mc
Metac

Fig. M_{η_c}.

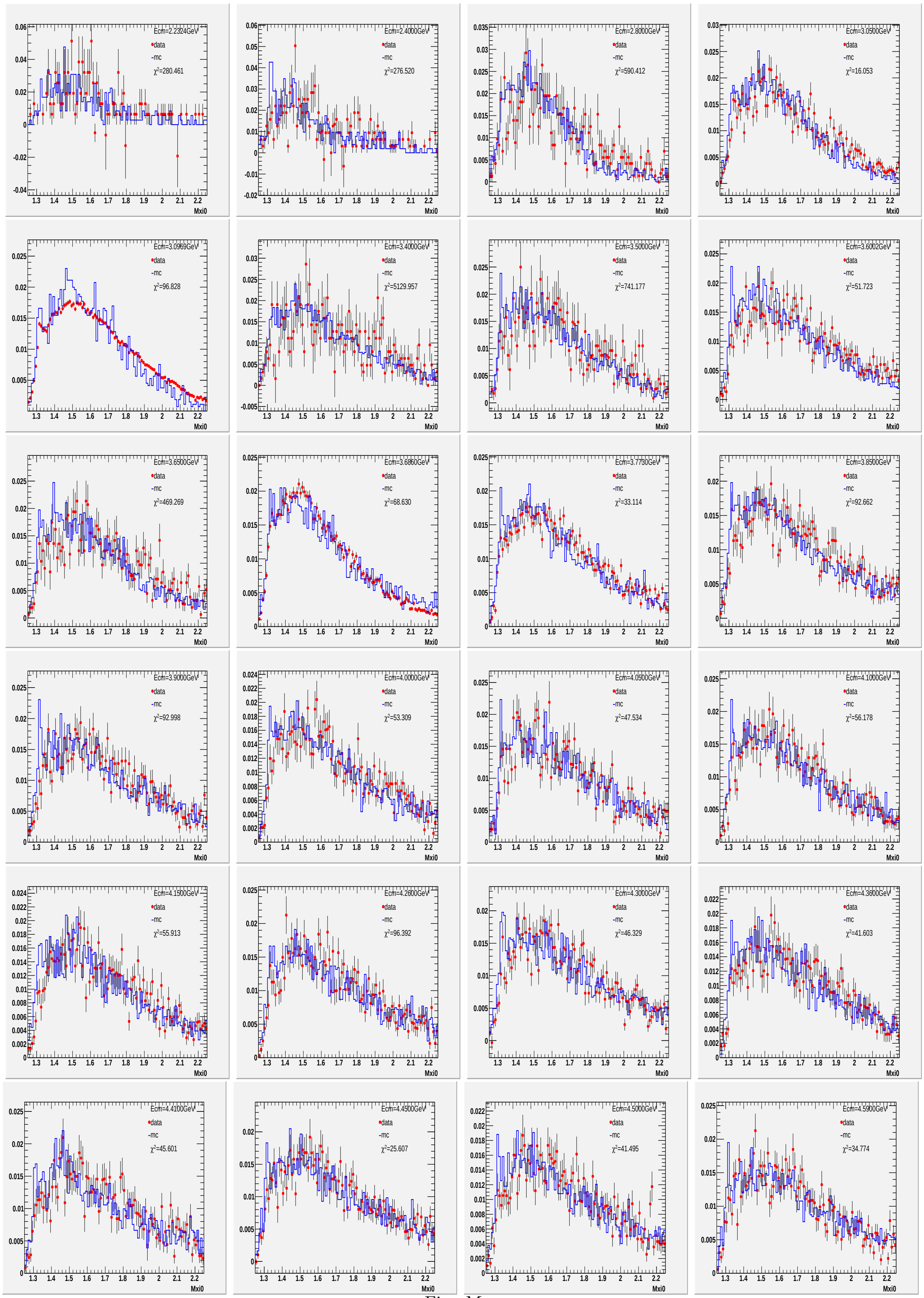

Ecm=2.2324GeV
data
mc
χ²=280.461
Ecm=2.4000GeV
χ²=276.520
Ecm=2.8000GeV
χ²=590.412
Ecm=3.0500GeV
χ²=16.053
Ecm=3.0969GeV
χ²=96.828
Ecm=3.4000GeV
χ²=5129.957
Ecm=3.5000GeV
χ²=741.177
Ecm=3.6002GeV
χ²=51.723
Ecm=3.6500GeV
χ²=469.269
Ecm=3.6860GeV
χ²=68.630
Ecm=3.7730GeV
χ²=33.114
Ecm=3.8500GeV
χ²=92.662
Ecm=3.9000GeV
χ²=92.998
Ecm=4.0000GeV
χ²=53.309
Ecm=4.0500GeV
χ²=47.534
Ecm=4.1000GeV
χ²=56.178
Ecm=4.1500GeV
χ²=55.913
Ecm=4.2600GeV
χ²=96.392
Ecm=4.3000GeV
χ²=46.329
Ecm=4.3600GeV
χ²=41.603
Ecm=4.4100GeV
χ²=45.601
Ecm=4.4500GeV
χ²=25.607
Ecm=4.5000GeV
χ²=41.495
Ecm=4.5900GeV
χ²=34.774
Mxi0

Fig. $M_{\chi0}$.

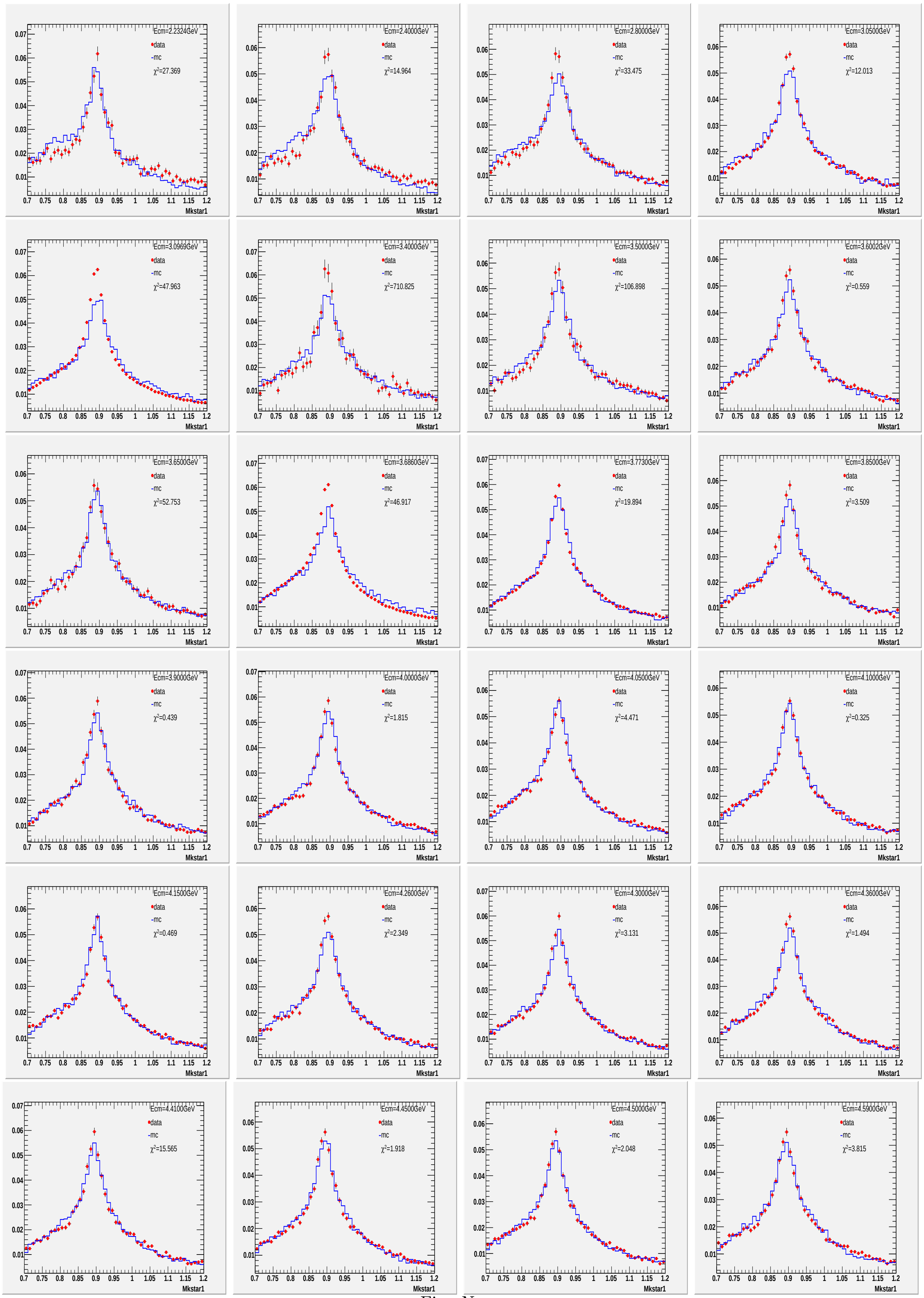


Fig. $N_{K_1^{\star}1}$.

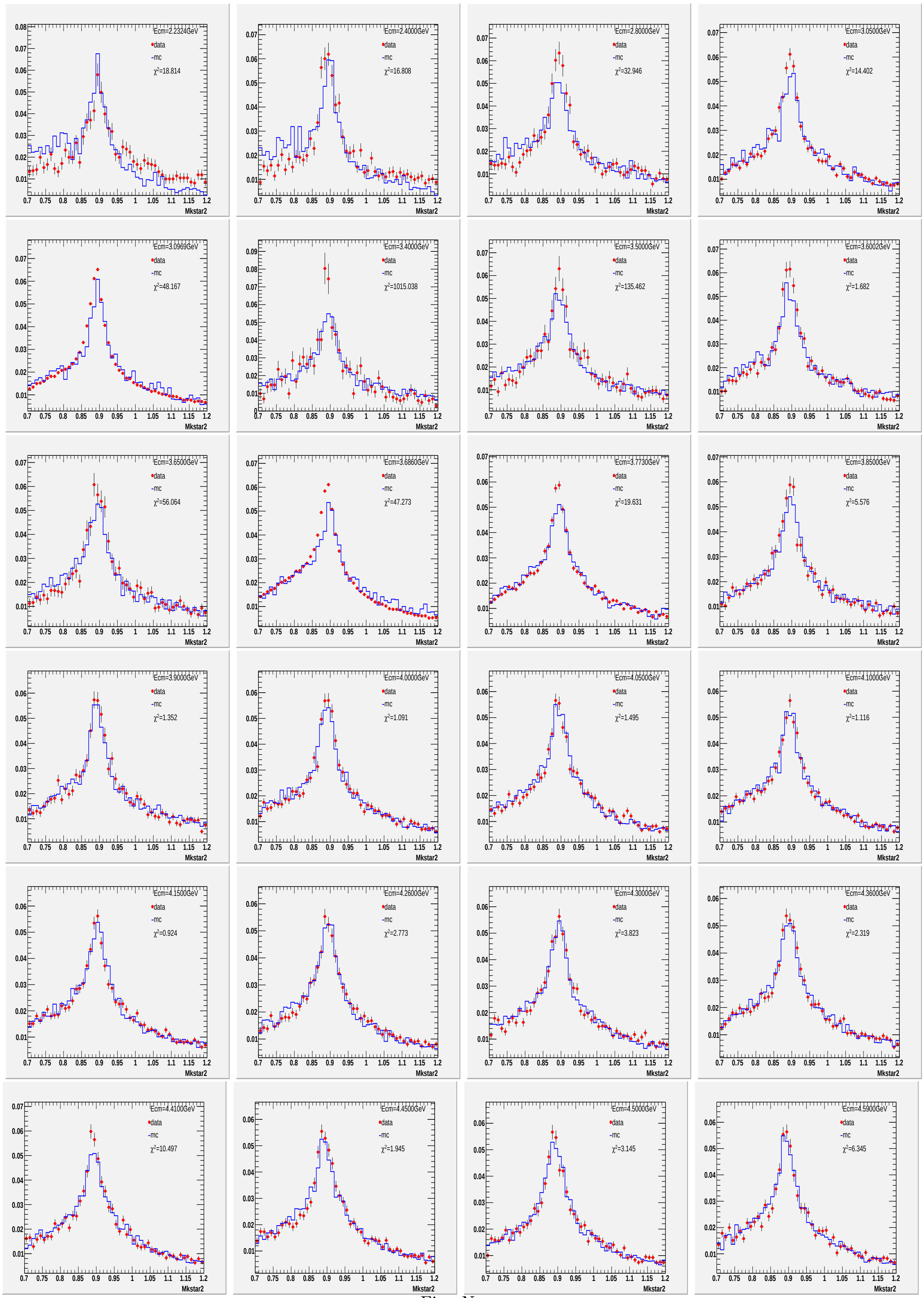


Fig. $N_{K_k^\star 2}$.

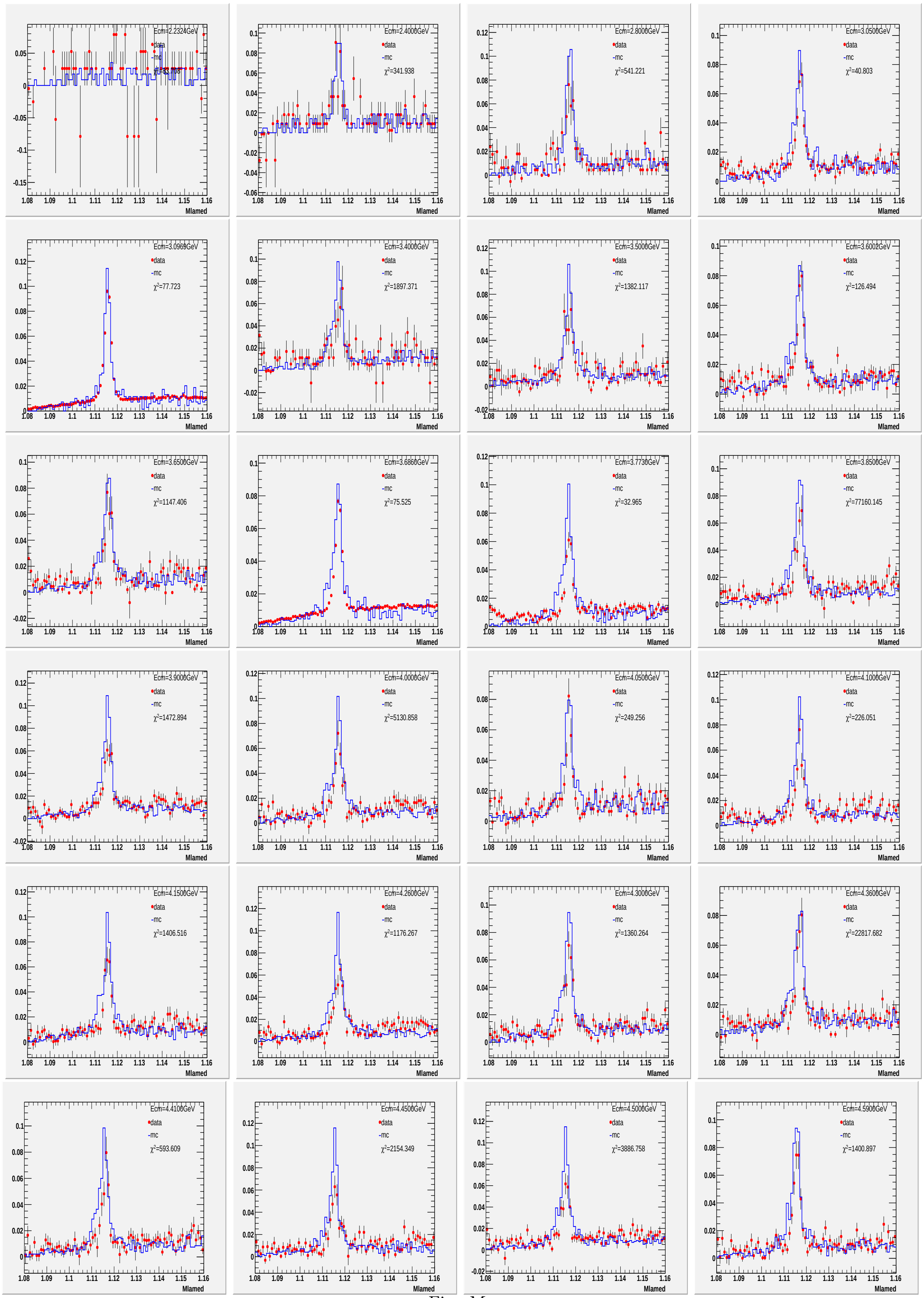
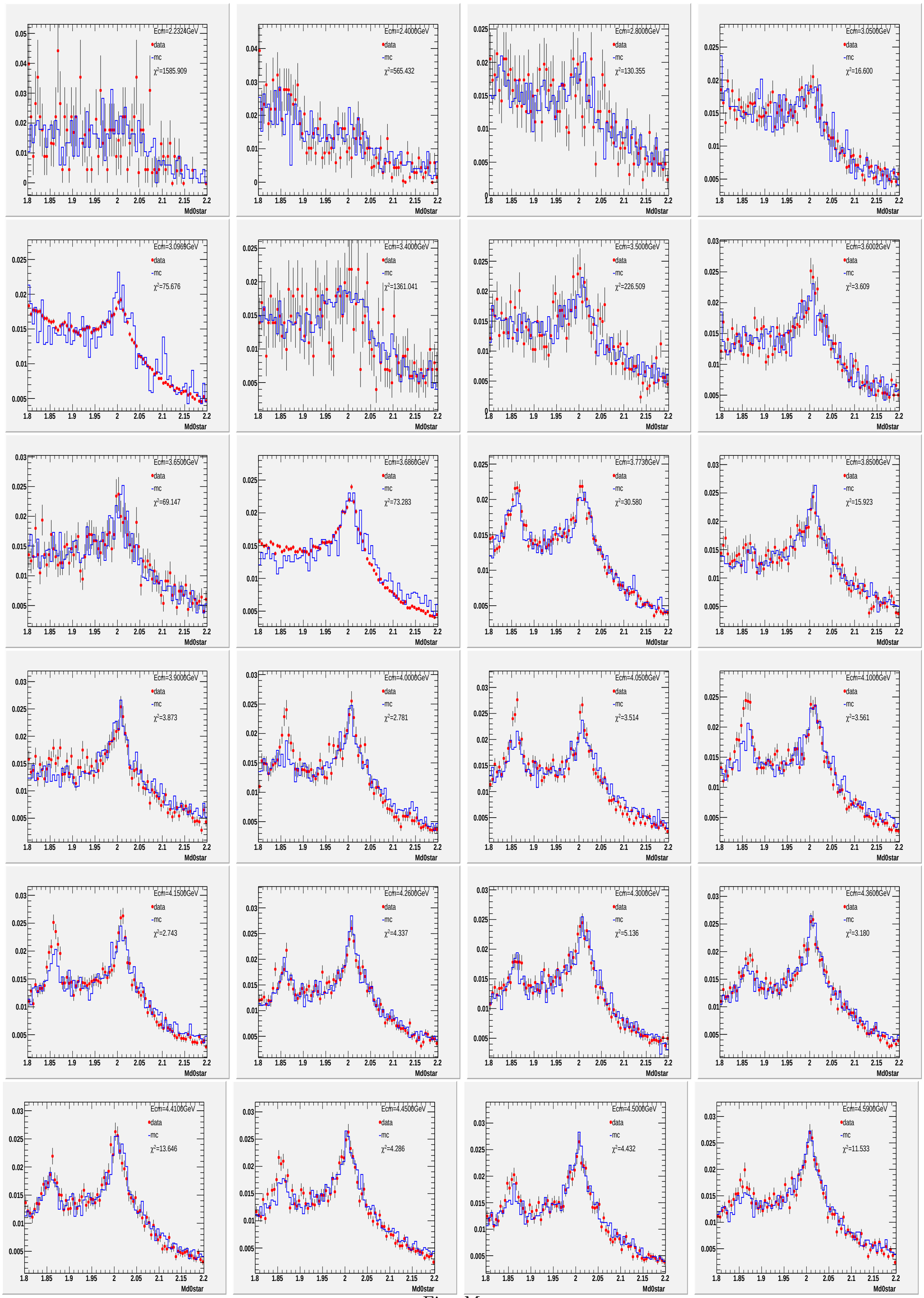

Ecm=2.2324GeV
data
mc
Ecm=2.4000GeV
χ²=341.938
Ecm=2.8000GeV
χ²=541.221
Ecm=3.0500GeV
χ²=40.803
Ecm=3.0969GeV
χ²=77.723
Ecm=3.4000GeV
χ²=1897.371
Ecm=3.5000GeV
χ²=1382.117
Ecm=3.6002GeV
χ²=126.494
Ecm=3.6500GeV
χ²=1147.406
Ecm=3.6860GeV
χ²=75.525
Ecm=3.7730GeV
χ²=32.965
Ecm=3.8500GeV
χ²=77160.145
Ecm=3.9000GeV
χ²=1472.894
Ecm=4.0000GeV
χ²=5130.858
Ecm=4.0500GeV
χ²=249.256
Ecm=4.1000GeV
χ²=226.051
Ecm=4.1500GeV
χ²=1406.516
Ecm=4.2600GeV
χ²=1176.267
Ecm=4.3000GeV
χ²=1360.264
Ecm=4.3600GeV
χ²=22817.682
Ecm=4.4100GeV
χ²=593.609
Ecm=4.4500GeV
χ²=2154.349
Ecm=4.5000GeV
χ²=3886.758
Ecm=4.5900GeV
χ²=1400.897
Mlamed

Fig. M_λ.



Ecm=2.2324GeV
data
mc
χ^2=1585.909
Md0star
Ecm=2.4000GeV
data
mc
χ^2=565.432
Md0star
Ecm=2.8000GeV
data
mc
χ^2=130.355
Md0star
Ecm=3.0500GeV
data
mc
χ^2=16.600
Md0star
Ecm=3.0969GeV
data
mc
χ^2=75.676
Md0star
Ecm=3.4000GeV
data
mc
χ^2=1361.041
Md0star
Ecm=3.5000GeV
data
mc
χ^2=226.509
Md0star
Ecm=3.6002GeV
data
mc
χ^2=3.609
Md0star
Ecm=3.6500GeV
data
mc
χ^2=69.147
Md0star
Ecm=3.6860GeV
data
mc
χ^2=73.283
Md0star
Ecm=3.7730GeV
data
mc
χ^2=30.580
Md0star
Ecm=3.8500GeV
data
mc
χ^2=15.923
Md0star
Ecm=3.9000GeV
data
mc
χ^2=3.873
Md0star
Ecm=4.0000GeV
data
mc
χ^2=2.781
Md0star
Ecm=4.0500GeV
data
mc
χ^2=3.514
Md0star
Ecm=4.1000GeV
data
mc
χ^2=3.561
Md0star
Ecm=4.1500GeV
data
mc
χ^2=2.743
Md0star
Ecm=4.2600GeV
data
mc
χ^2=4.337
Md0star
Ecm=4.3000GeV
data
mc
χ^2=5.136
Md0star
Ecm=4.3600GeV
data
mc
χ^2=3.180
Md0star
Ecm=4.4100GeV
data
mc
χ^2=13.646
Md0star
Ecm=4.4500GeV
data
mc
χ^2=4.286
Md0star
Ecm=4.5000GeV
data
mc
χ^2=4.432
Md0star
Ecm=4.5900GeV
data
mc
χ^2=11.533
Md0star

Fig. $M_{D_0^\star}$.

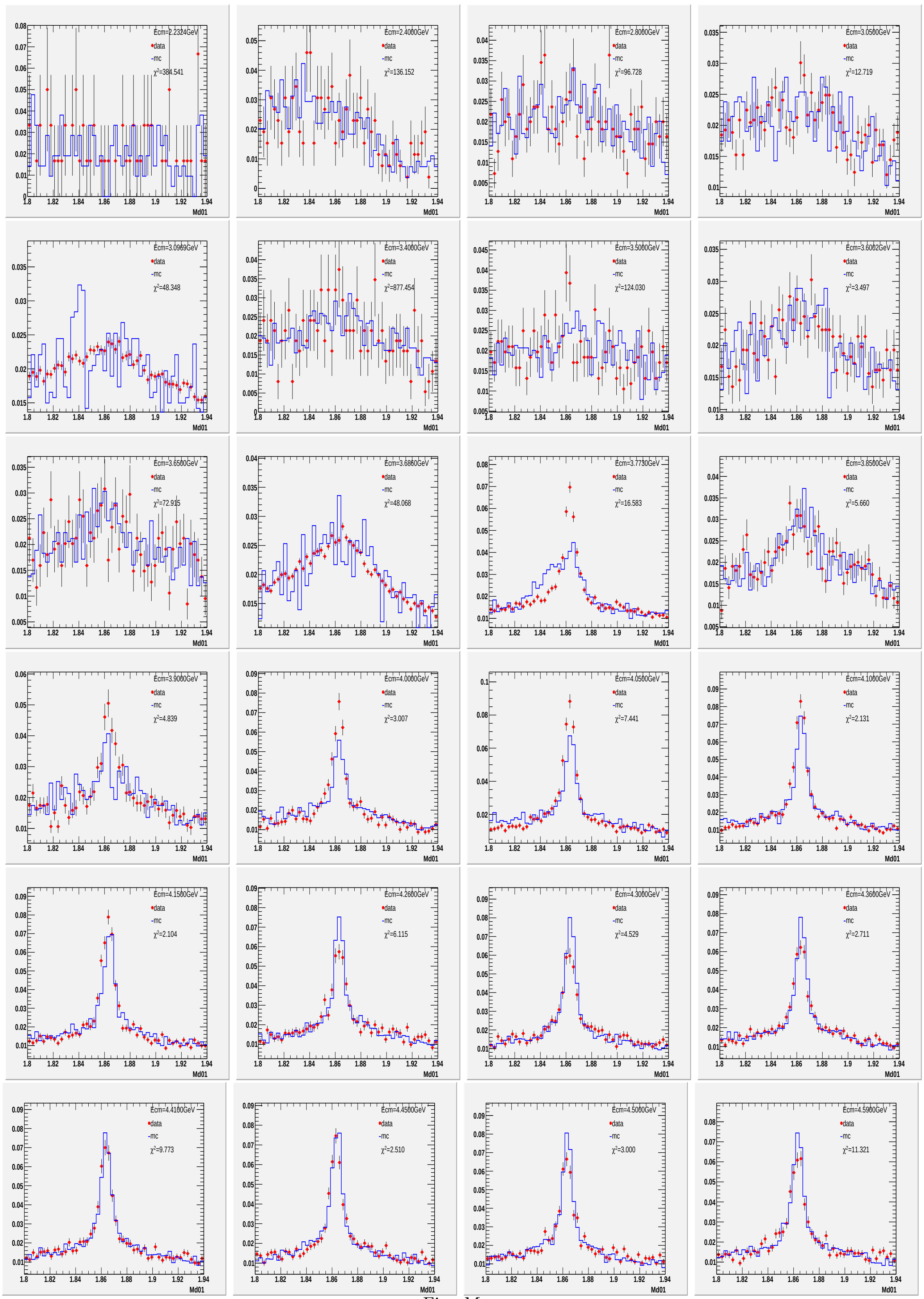
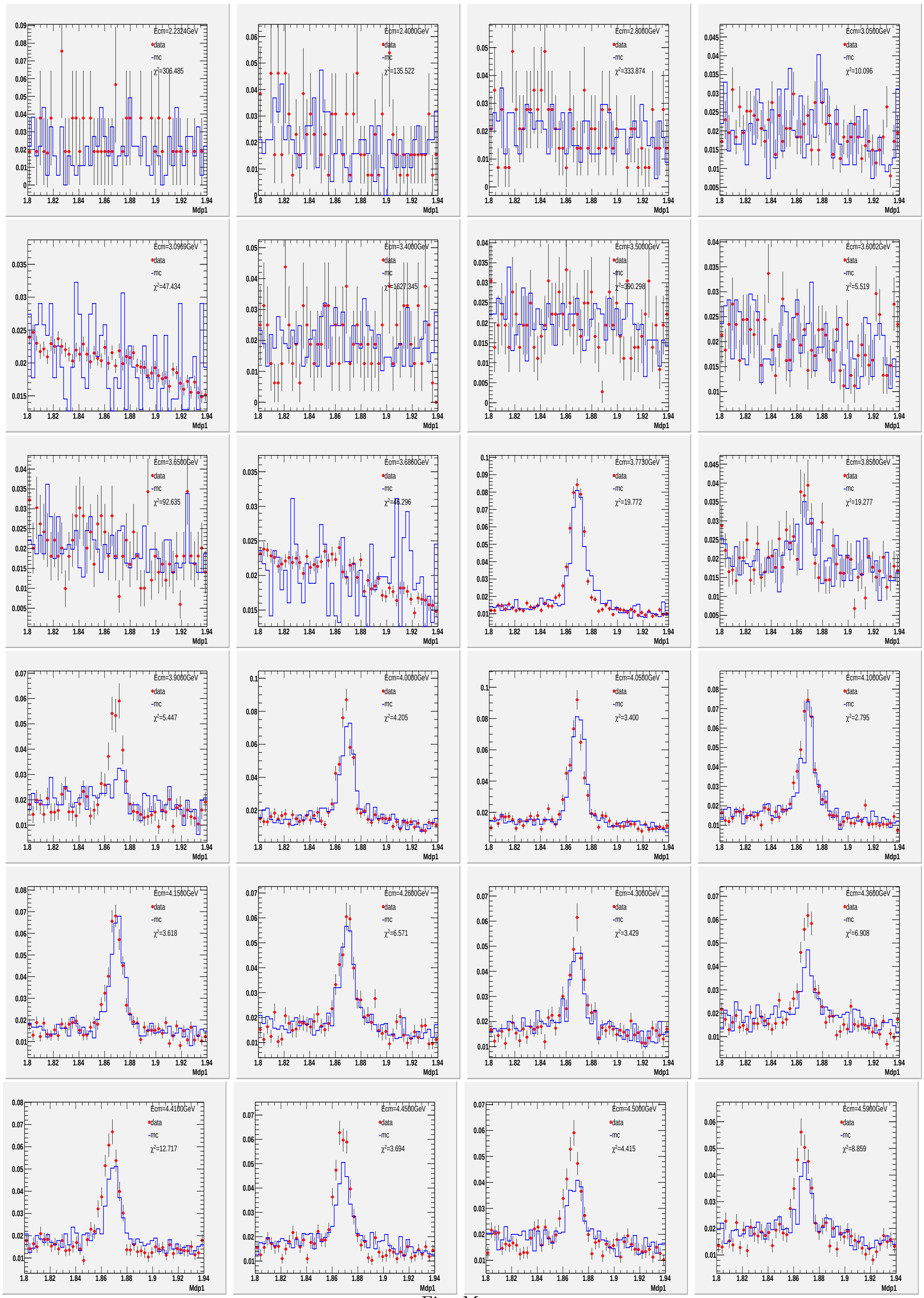

Ecm=2.2324GeV
data
mc
χ^2=384.541
Ecm=2.4000GeV
χ^2=136.152
Ecm=2.8000GeV
χ^2=96.728
Ecm=3.0500GeV
χ^2=12.719
Ecm=3.0969GeV
χ^2=48.348
Ecm=3.4000GeV
χ^2=877.454
Ecm=3.5000GeV
χ^2=124.030
Ecm=3.6002GeV
χ^2=3.497
Ecm=3.6500GeV
χ^2=72.915
Ecm=3.6860GeV
χ^2=48.068
Ecm=3.7730GeV
χ^2=16.583
Ecm=3.8500GeV
χ^2=5.660
Ecm=3.9000GeV
χ^2=4.839
Ecm=4.0000GeV
χ^2=3.007
Ecm=4.0500GeV
χ^2=7.441
Ecm=4.1000GeV
χ^2=2.131
Ecm=4.1500GeV
χ^2=2.104
Ecm=4.2600GeV
χ^2=6.115
Ecm=4.3000GeV
χ^2=4.529
Ecm=4.3600GeV
χ^2=2.711
Ecm=4.4100GeV
χ^2=9.773
Ecm=4.4500GeV
χ^2=2.510
Ecm=4.5000GeV
χ^2=3.000
Ecm=4.5900GeV
χ^2=11.321
Md01

Fig. $M_{D_0^1}$.



Ecm=2.2324GeV
χ²=306.485
Ecm=2.4000GeV
χ²=135.522
Ecm=2.8000GeV
χ²=333.874
Ecm=3.0500GeV
χ²=10.096
Ecm=3.0969GeV
χ²=47.434
Ecm=3.4000GeV
χ²=1627.345
Ecm=3.5000GeV
χ²=390.298
Ecm=3.6002GeV
χ²=5.519
Ecm=3.6500GeV
χ²=92.635
Ecm=3.6860GeV
Ecm=3.7730GeV
χ²=19.772
Ecm=3.8500GeV
χ²=19.277
Ecm=3.9000GeV
χ²=5.447
Ecm=4.0000GeV
χ²=4.205
Ecm=4.0500GeV
χ²=3.400
Ecm=4.1000GeV
χ²=2.795
Ecm=4.1500GeV
χ²=3.618
Ecm=4.2600GeV
χ²=6.571
Ecm=4.3000GeV
χ²=3.429
Ecm=4.3600GeV
χ²=6.908
Ecm=4.4100GeV
χ²=12.717
Ecm=4.4500GeV
χ²=3.694
Ecm=4.5000GeV
χ²=4.415
Ecm=4.5900GeV
χ²=8.859
data
mc
Mdp1

Fig. $M_{D_1^+}$.

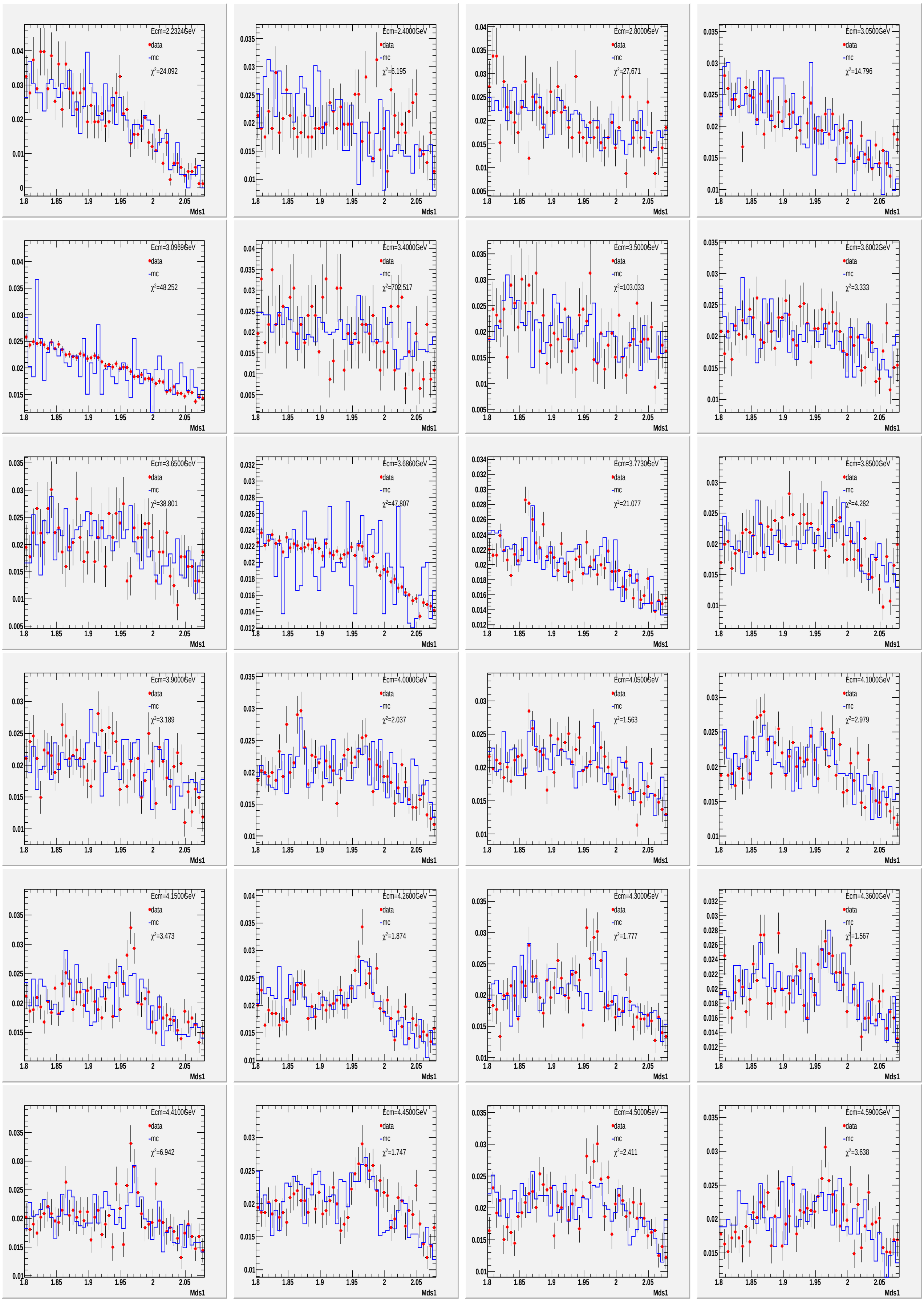

Ecm=2.2324GeV
data
mc
χ^2=24.092
Mds1
Ecm=2.4000GeV
χ^2=6.195
Ecm=2.8000GeV
χ^2=27.671
Ecm=3.0500GeV
χ^2=14.796
Ecm=3.0969GeV
χ^2=48.252
Ecm=3.4000GeV
χ^2=702.517
Ecm=3.5000GeV
χ^2=103.033
Ecm=3.6002GeV
χ^2=3.333
Ecm=3.6500GeV
χ^2=38.801
Ecm=3.6860GeV
χ^2=47.807
Ecm=3.7730GeV
χ^2=21.077
Ecm=3.8500GeV
χ^2=4.282
Ecm=3.9000GeV
χ^2=3.189
Ecm=4.0000GeV
χ^2=2.037
Ecm=4.0500GeV
χ^2=1.563
Ecm=4.1000GeV
χ^2=2.979
Ecm=4.1500GeV
χ^2=3.473
Ecm=4.2600GeV
χ^2=1.874
Ecm=4.3000GeV
χ^2=1.777
Ecm=4.3600GeV
χ^2=1.567
Ecm=4.4100GeV
χ^2=6.942
Ecm=4.4500GeV
χ^2=1.747
Ecm=4.5000GeV
χ^2=2.411
Ecm=4.5900GeV
χ^2=3.638

Fig. $M_{D_s^1}$.

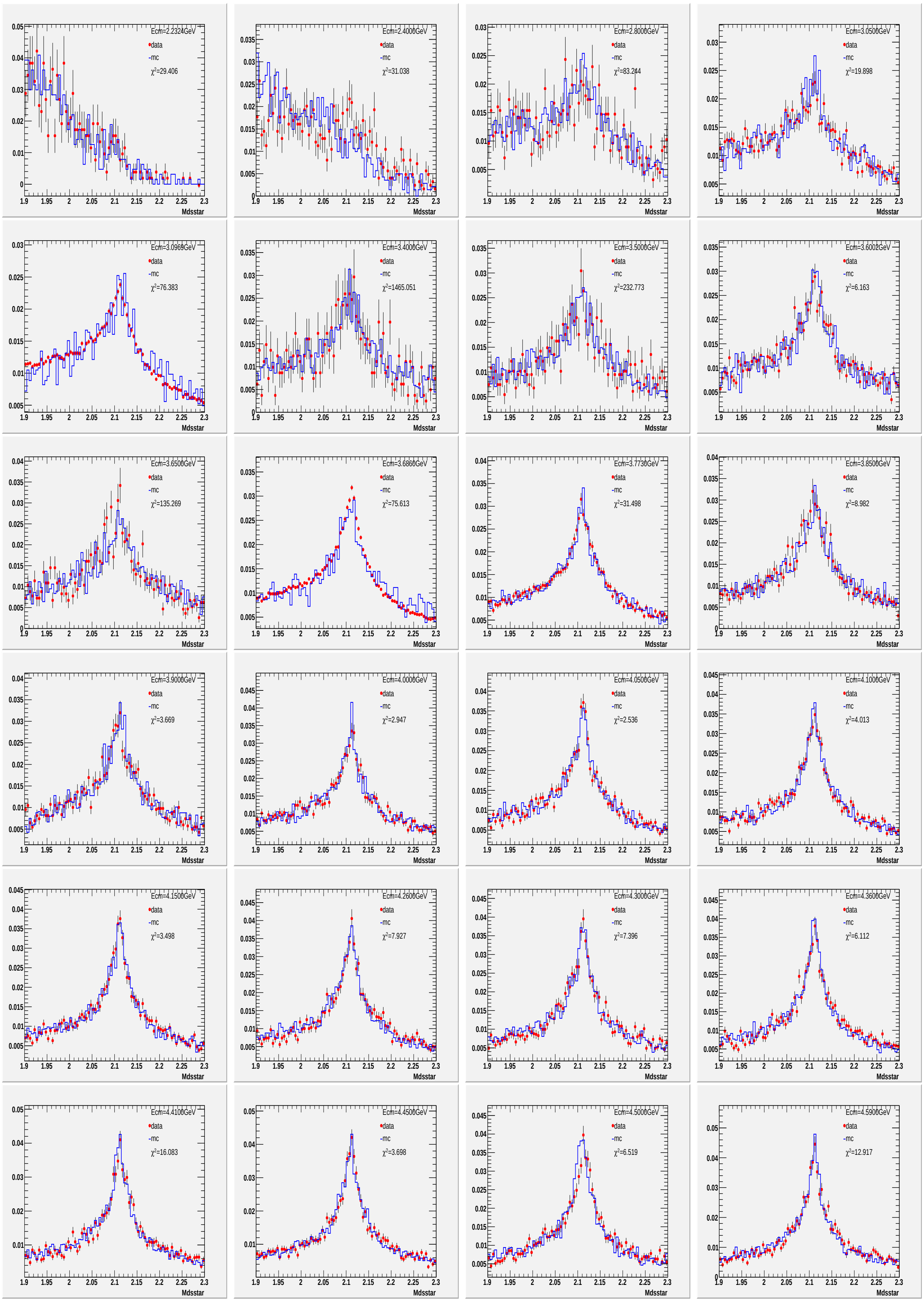
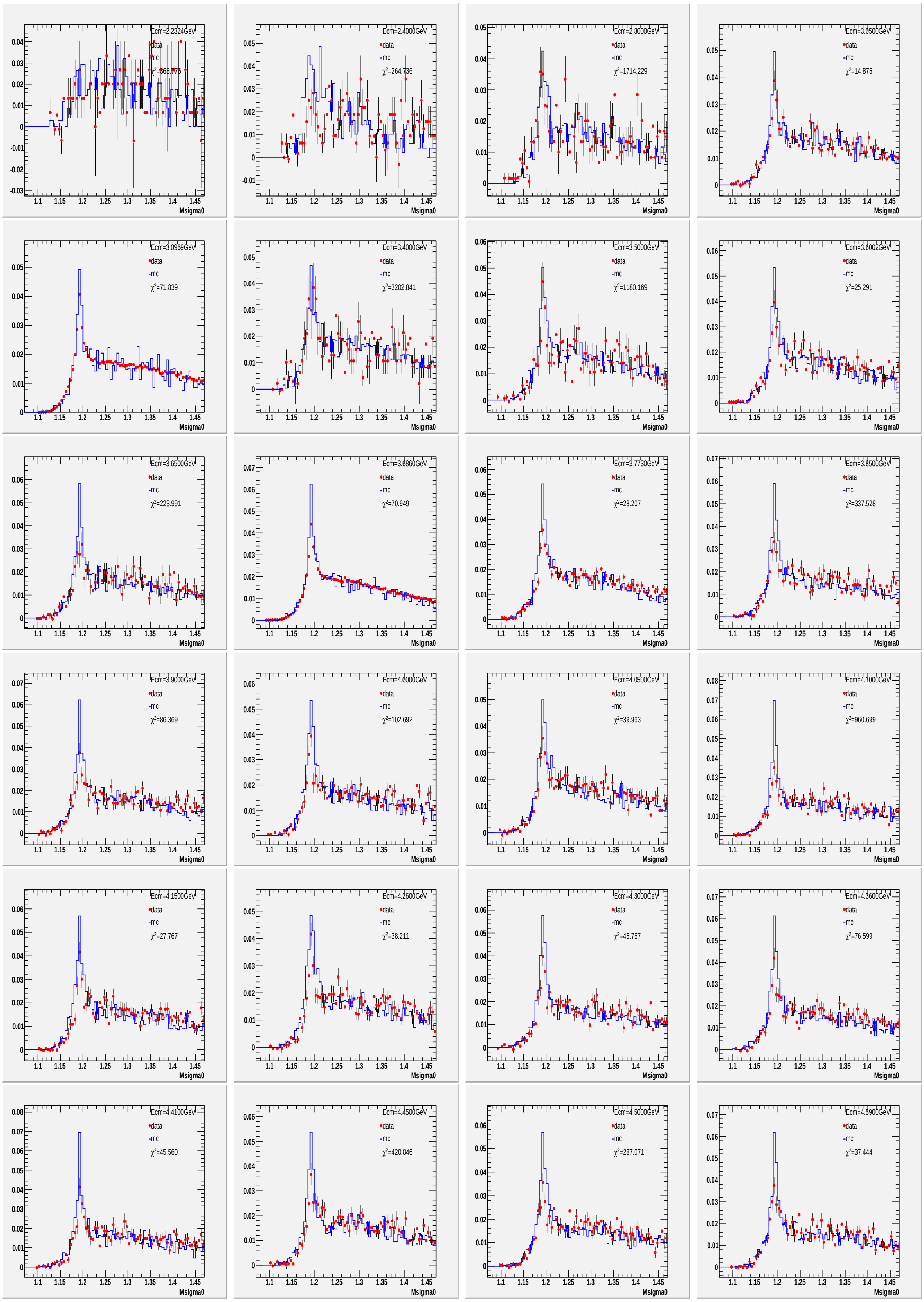


Fig. $M_{D_s^\star}$.



Ecm=2.2324GeV
Ecm=2.4000GeV
χ^2=264.736
Ecm=2.8000GeV
χ^2=1714.229
Ecm=3.0500GeV
χ^2=14.875
Ecm=3.0969GeV
χ^2=71.839
Ecm=3.4000GeV
χ^2=3202.841
Ecm=3.5000GeV
χ^2=1180.169
Ecm=3.6002GeV
χ^2=25.291
Ecm=3.6500GeV
χ^2=223.991
Ecm=3.6860GeV
χ^2=70.949
Ecm=3.7730GeV
χ^2=28.207
Ecm=3.8500GeV
χ^2=337.528
Ecm=3.9000GeV
χ^2=86.369
Ecm=4.0000GeV
χ^2=102.692
Ecm=4.0500GeV
χ^2=39.963
Ecm=4.1000GeV
χ^2=960.699
Ecm=4.1500GeV
χ^2=27.767
Ecm=4.2600GeV
χ^2=38.211
Ecm=4.3000GeV
χ^2=45.767
Ecm=4.3600GeV
χ^2=76.599
Ecm=4.4100GeV
χ^2=45.560
Ecm=4.4500GeV
χ^2=420.846
Ecm=4.5000GeV
χ^2=287.071
Ecm=4.5900GeV
χ^2=37.444
data
mc
Msigma0

Fig. M_{Σ^0}.

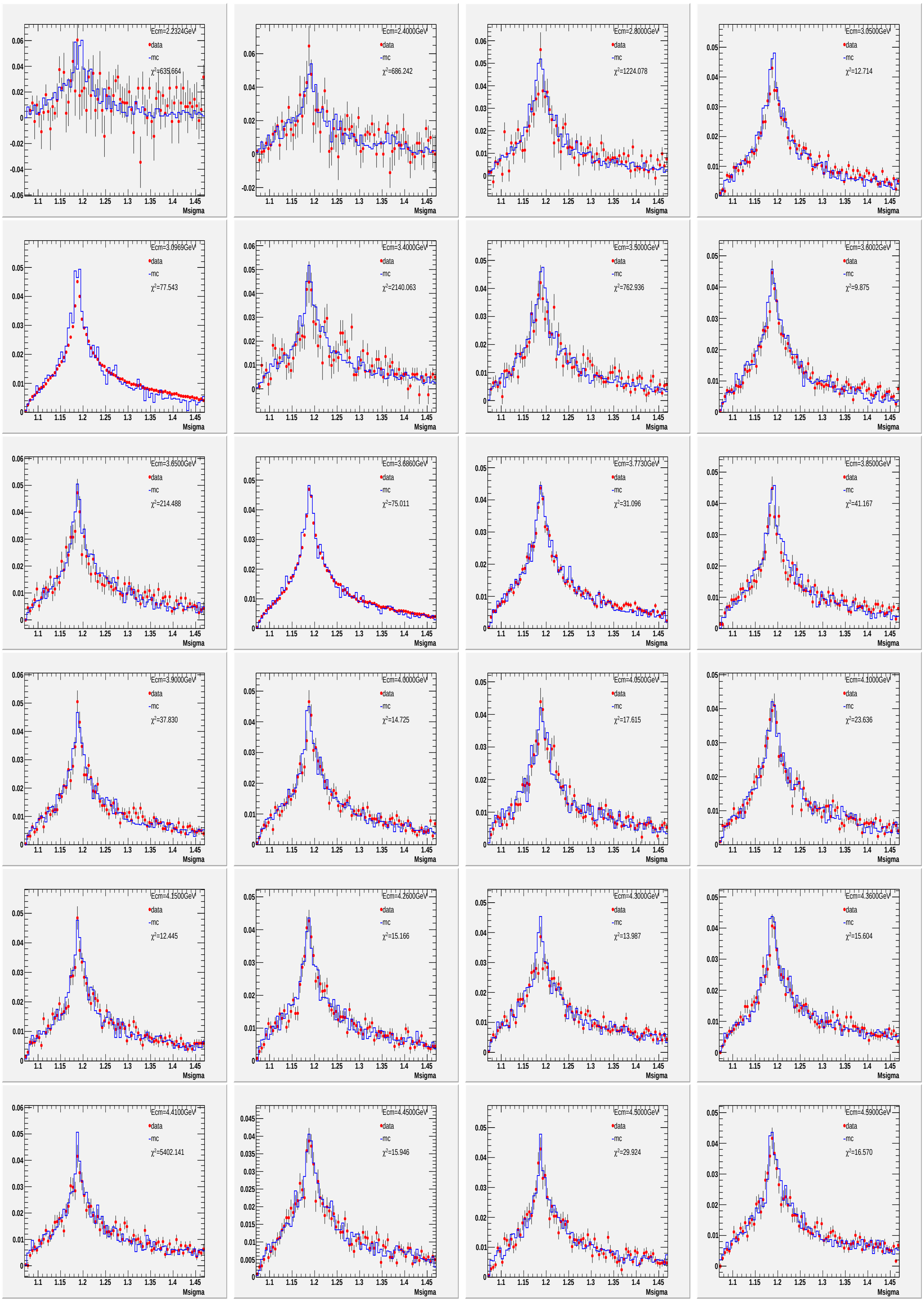
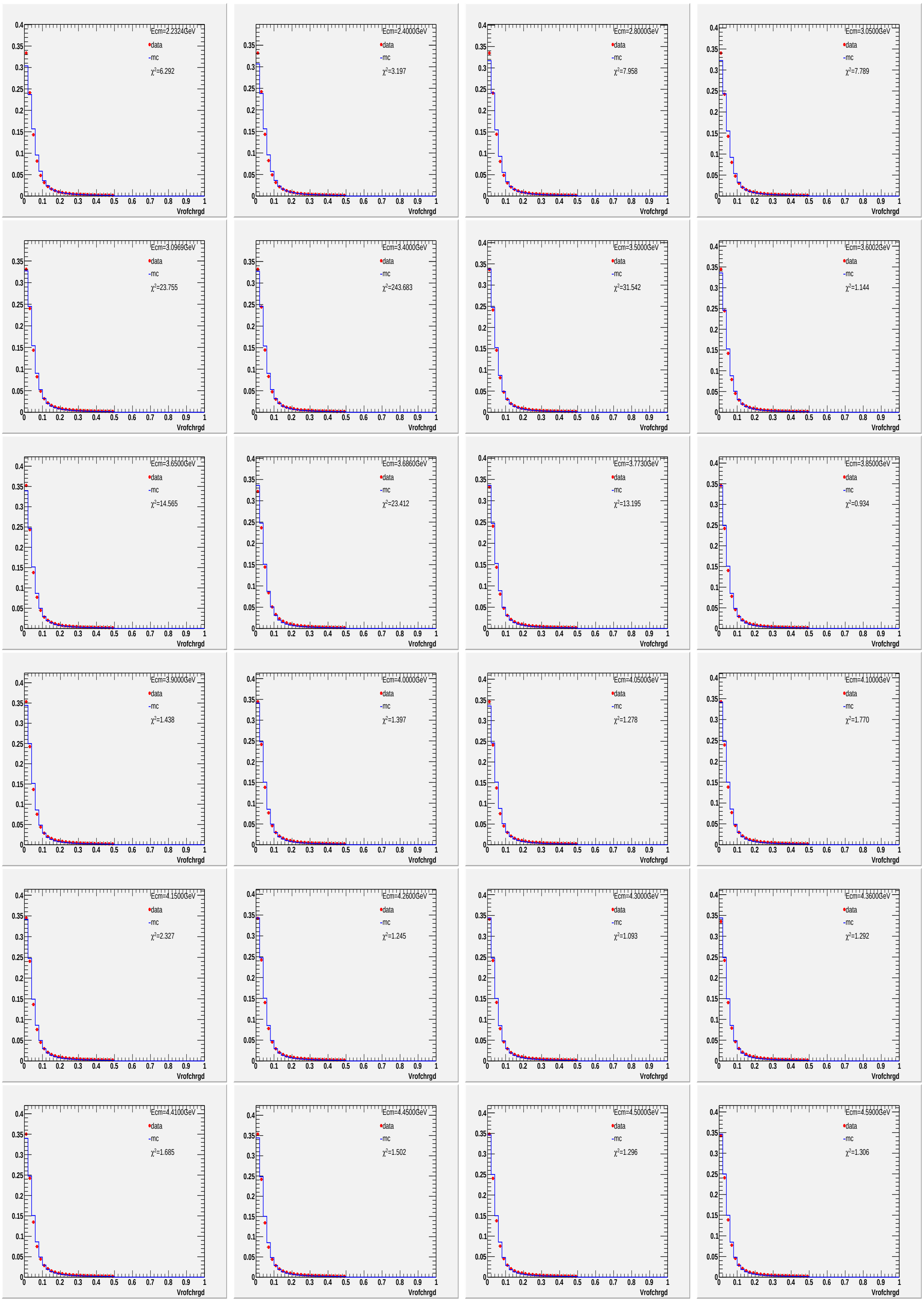

Ecm=2.2324GeV
data
mc
χ^2=635.664
Ecm=2.4000GeV
χ^2=686.242
Ecm=2.8000GeV
χ^2=1224.078
Ecm=3.0500GeV
χ^2=12.714
Ecm=3.0969GeV
χ^2=77.543
Ecm=3.4000GeV
χ^2=2140.063
Ecm=3.5000GeV
χ^2=762.936
Ecm=3.6002GeV
χ^2=9.875
Ecm=3.6500GeV
χ^2=214.488
Ecm=3.6860GeV
χ^2=75.011
Ecm=3.7730GeV
χ^2=31.096
Ecm=3.8500GeV
χ^2=41.167
Ecm=3.9000GeV
χ^2=37.830
Ecm=4.0000GeV
χ^2=14.725
Ecm=4.0500GeV
χ^2=17.615
Ecm=4.1000GeV
χ^2=23.636
Ecm=4.1500GeV
χ^2=12.445
Ecm=4.2600GeV
χ^2=15.166
Ecm=4.3000GeV
χ^2=13.987
Ecm=4.3600GeV
χ^2=15.604
Ecm=4.4100GeV
χ^2=5402.141
Ecm=4.4500GeV
χ^2=15.946
Ecm=4.5000GeV
χ^2=29.924
Ecm=4.5900GeV
χ^2=16.570
Msigma

Fig. M_{Σ}.



Ecm=2.2324GeV
data
mc
χ^2=6.292
Vrofchrgd
Ecm=2.4000GeV
data
mc
χ^2=3.197
Vrofchrgd
Ecm=2.8000GeV
data
mc
χ^2=7.958
Vrofchrgd
Ecm=3.0500GeV
data
mc
χ^2=7.789
Vrofchrgd
Ecm=3.0969GeV
data
mc
χ^2=23.755
Vrofchrgd
Ecm=3.4000GeV
data
mc
χ^2=243.683
Vrofchrgd
Ecm=3.5000GeV
data
mc
χ^2=31.542
Vrofchrgd
Ecm=3.6002GeV
data
mc
χ^2=1.144
Vrofchrgd
Ecm=3.6500GeV
data
mc
χ^2=14.565
Vrofchrgd
Ecm=3.6860GeV
data
mc
χ^2=23.412
Vrofchrgd
Ecm=3.7730GeV
data
mc
χ^2=13.195
Vrofchrgd
Ecm=3.8500GeV
data
mc
χ^2=0.934
Vrofchrgd
Ecm=3.9000GeV
data
mc
χ^2=1.438
Vrofchrgd
Ecm=4.0000GeV
data
mc
χ^2=1.397
Vrofchrgd
Ecm=4.0500GeV
data
mc
χ^2=1.278
Vrofchrgd
Ecm=4.1000GeV
data
mc
χ^2=1.770
Vrofchrgd
Ecm=4.1500GeV
data
mc
χ^2=2.327
Vrofchrgd
Ecm=4.2600GeV
data
mc
χ^2=1.245
Vrofchrgd
Ecm=4.3000GeV
data
mc
χ^2=1.093
Vrofchrgd
Ecm=4.3600GeV
data
mc
χ^2=1.292
Vrofchrgd
Ecm=4.4100GeV
data
mc
χ^2=1.685
Vrofchrgd
Ecm=4.4500GeV
data
mc
χ^2=1.502
Vrofchrgd
Ecm=4.5000GeV
data
mc
χ^2=1.296
Vrofchrgd
Ecm=4.5900GeV
data
mc
χ^2=1.306
Vrofchrgd

Fig. V_r

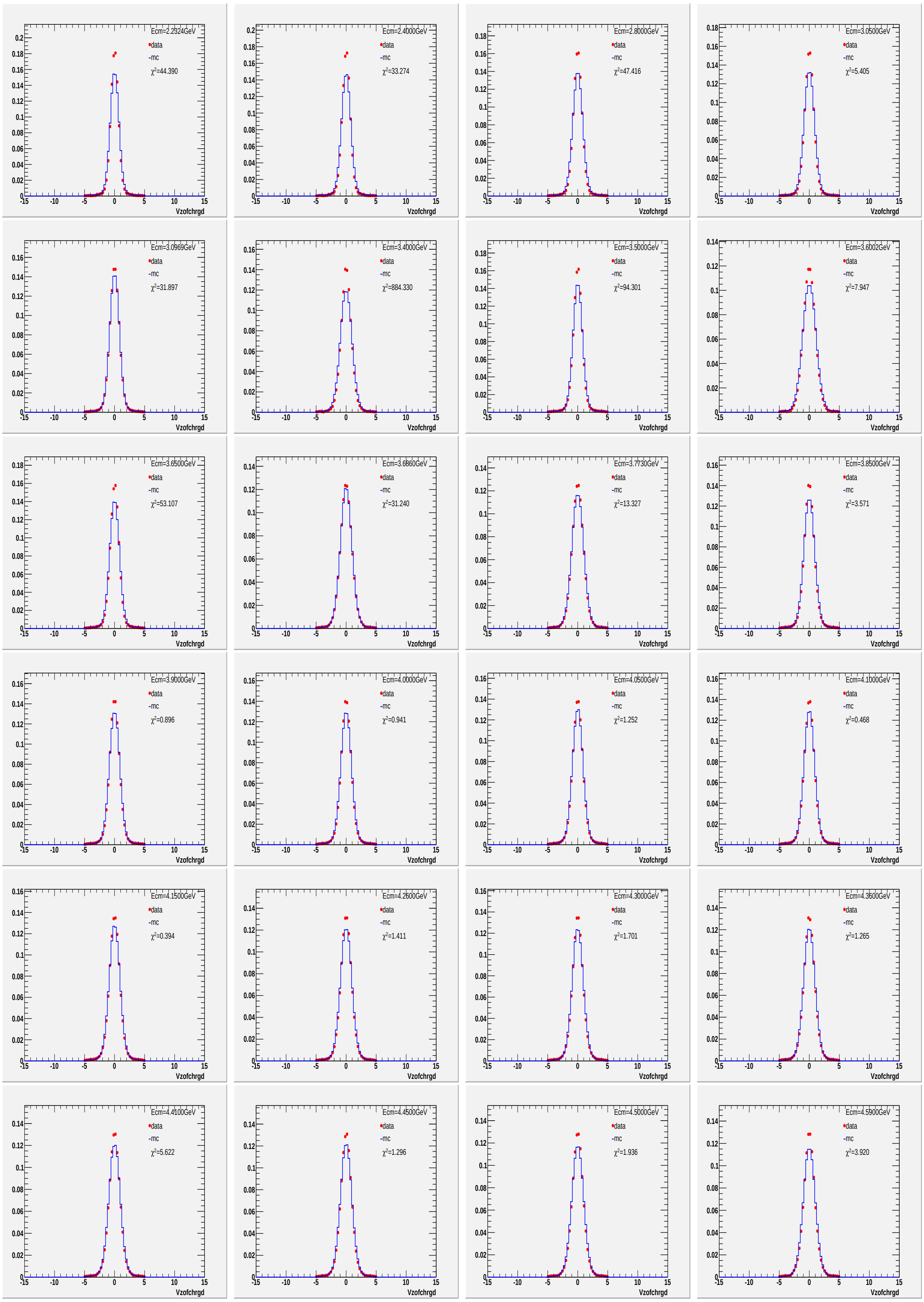

Ecm=2.2324GeV
data
mc
χ^2=44.390
Ecm=2.4000GeV
χ^2=33.274
Ecm=2.8000GeV
χ^2=47.416
Ecm=3.0500GeV
χ^2=5.405
Ecm=3.0969GeV
χ^2=31.897
Ecm=3.4000GeV
χ^2=884.330
Ecm=3.5000GeV
χ^2=94.301
Ecm=3.6002GeV
χ^2=7.947
Ecm=3.6500GeV
χ^2=53.107
Ecm=3.6860GeV
χ^2=31.240
Ecm=3.7730GeV
χ^2=13.327
Ecm=3.8500GeV
χ^2=3.571
Ecm=3.9000GeV
χ^2=0.896
Ecm=4.0000GeV
χ^2=0.941
Ecm=4.0500GeV
χ^2=1.252
Ecm=4.1000GeV
χ^2=0.468
Ecm=4.1500GeV
χ^2=0.394
Ecm=4.2600GeV
χ^2=1.411
Ecm=4.3000GeV
χ^2=1.701
Ecm=4.3600GeV
χ^2=1.265
Ecm=4.4100GeV
χ^2=5.622
Ecm=4.4500GeV
χ^2=1.296
Ecm=4.5000GeV
χ^2=1.936
Ecm=4.5900GeV
χ^2=3.920
Vzofchrgd

Fig. V_r

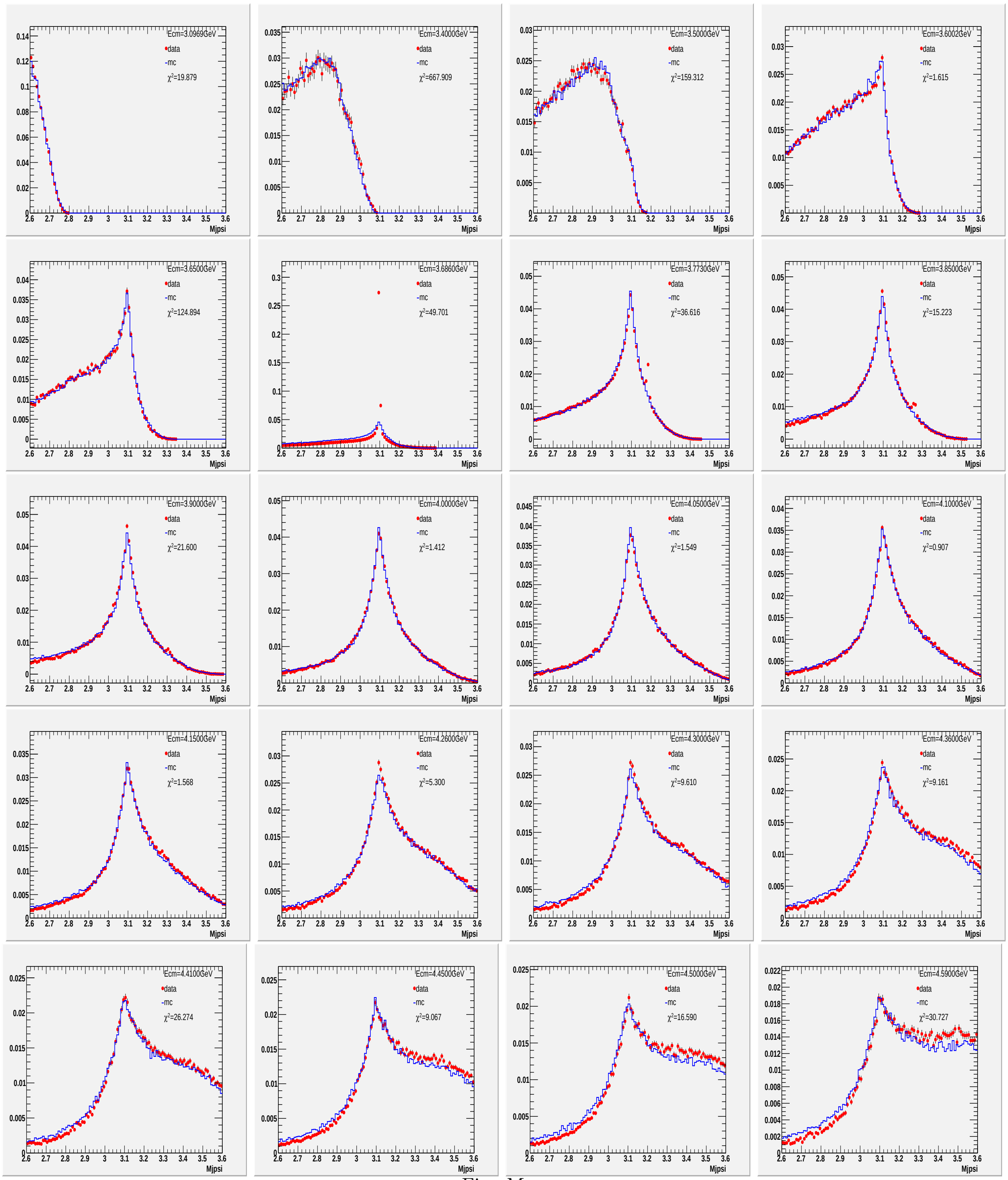


Fig. $M_{J\psi}$.

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