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Test of Hadronic Models in GEANT4 using the BESIII Data

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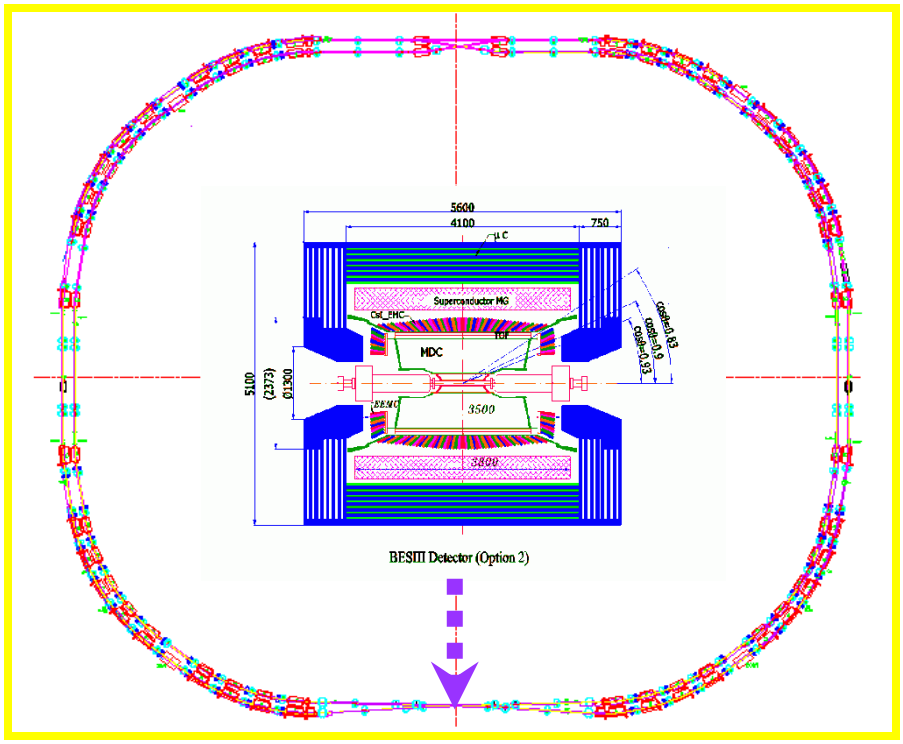
Outline

- **The Experiment – Collider and Detector**
- **BESIII Commissioning and Data Taking**
- **MC Simulation**
- **Validation of Hadronic Models in GEANT4**
  - **Hadronic Models in GEANT4**
  - **Data Sample**
  - **EM Validation**
  - **Hadronic Models Validation**
- **Summary**

BEPCII Project
(Beijing Electron Positron Collider)



- Beam energy: 1~2.3 GeV
- Designed peak luminosity: $10^{33}cm^{-2}\ s^{-1}$ at Ecm=3.77GeV
- Energy spread: 5.16×10^{-4}
- Cross angle: 22mrad
- No. of bunches: 93
- Bunch length: 1.5cm
- Physics: tau-charm physics, charmonium physics, light hadron, QED, new physics

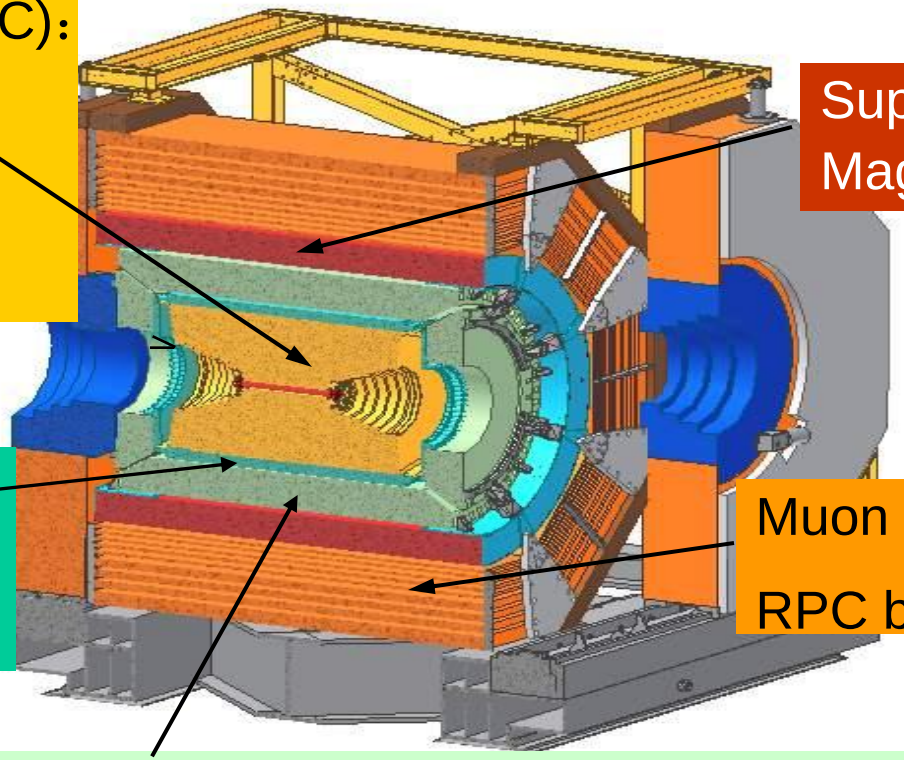
The BESIII Experiment
(BES - BEijing Spectrometer)

Main Drift Chamber (MDC):

σ_{xy} = 130 μm

△P/P = 0.5 %@1 GeV

$\sigma_{dE/dx}$ = 6-7 %



Super-conducting Magnet：1.0 Tesla

TOF System:

σ_T = 90 ps barrel

110 ps endcap

Muon Chamber (MUC):

RPC based

EM Calorimeter (EMC)： △E/E = 2.5 % @ 1 GeV

$\sigma_{z,\phi}$ = 0.6 cm @ 1 GeV

BESIII Commissioning and data taking milestones

Mar. 2008: First full cosmic-ray event

April 30, 2008: Move the BESIII to IP

July 19, 2008: First e^+e^- collision event in BESIII

Nov. 2008: ~ 14M ψ(2S) events collected

April 14, 2009: ~110M ψ(2S) events collected(4×CLEOc)

May 30, 2009: 42 pb^{-1} at continuum collected (Ecm = 3.65 GeV)

July 28, 2009: ~200M J/ψ events collected(4×BESII)

Peak Lumi. @ Nov. 2008:
$1.2\times10^{32}cm^{-2}s^{-1}$
Peak Lumi. @ May 2009:
$3.2\times10^{32}cm^{-2}s^{-1}$ ➔
×5 CESRc
×30 BEPC

BESIII MC Software

BOOST Project

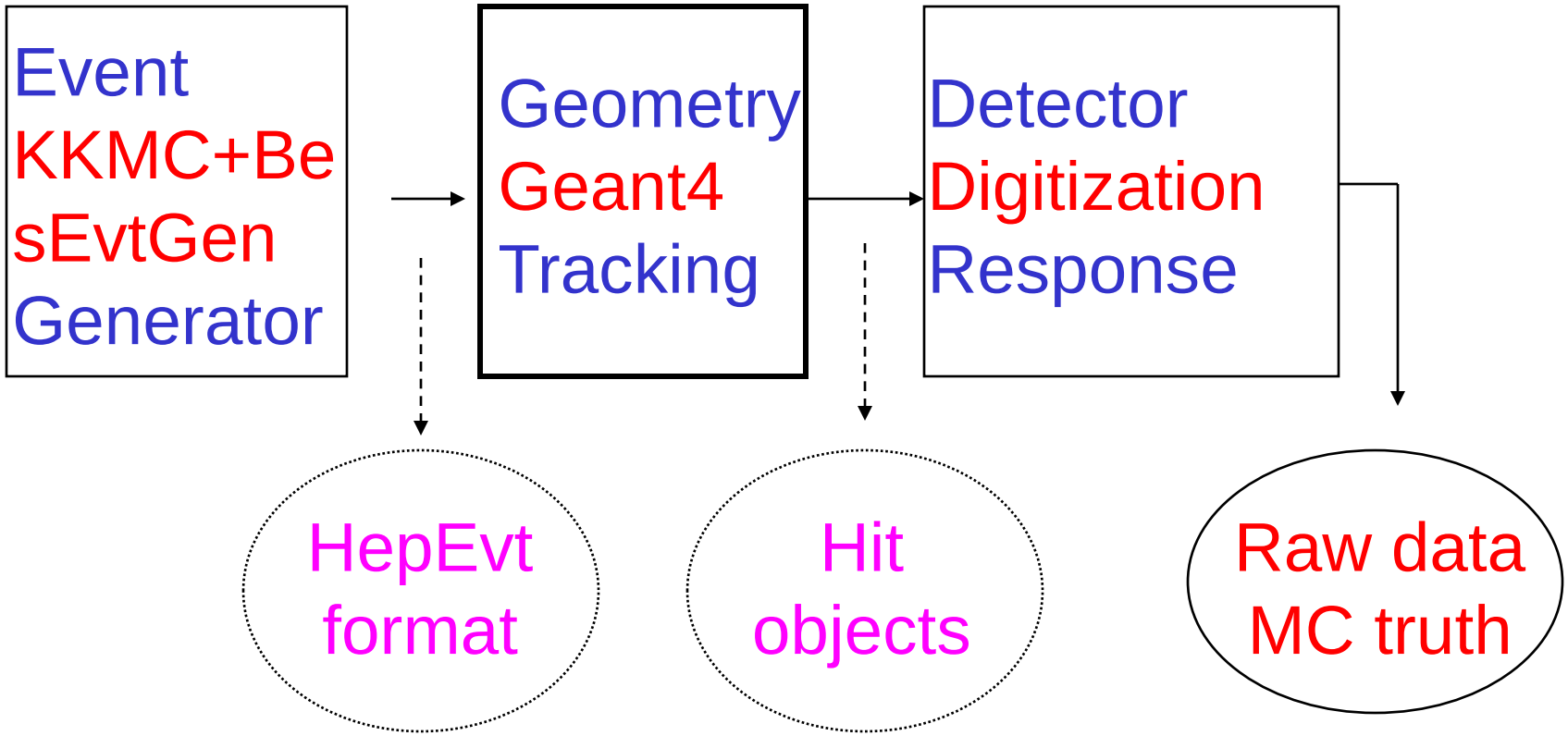
BESIII **O**bject **O**riented **S**imulation **T**ool

(proposal: August, 2002)

BES MC Software Evolution

BESI	BESII	BESIII
SOBER	**SIMBES**	**BOOST**
EGS	*G3*	*G4*
1980s	*1990s*	*2000s*

BOOST Architecture



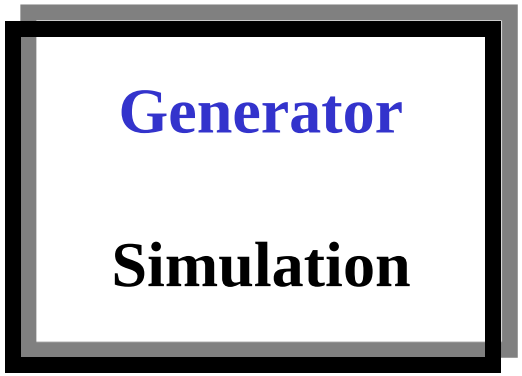
BESIII MC – main components

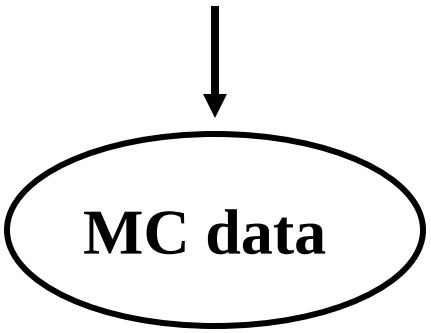
- Detector Description (based on GDML)
- Event Generator
- Physics processes
- Magnetic field
- Digitization
- MC truth
- Data I/O
- Trigger simulation
- Background mixing

BOOST Working in BOSS

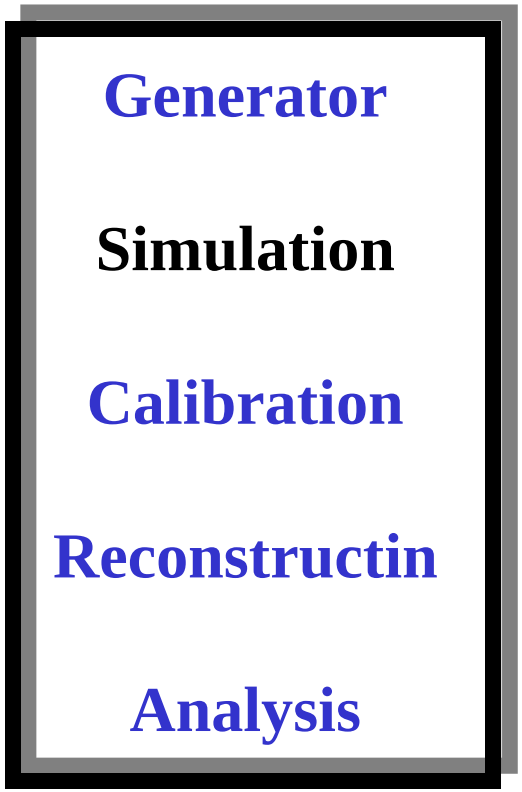
BOSS – BESIII Offline Software System

BOOST based on GEANT4





BOSS based on GAUDI



Current status of MC software

- The geometry, material and magnetic field have been well described.
- Digitization, trigger simulation and background mixing have been seriously considered and tuned by experimental data.
- Billions of MC samples have been generated and used for MC tuning and physics analysis.
- The comparisons between MC and data are generally satisfactory.

Validation of Hadronic Models in GEANT4

Hadronic Models in GEANT4

GEANT4.9.0.p01

Physics lists	π^+/π^-	Proton	Anti-proton
QBBC	BERT (0-4GeV)	BIC (0-4GeV)	CHIPS (0-4GeV)
QGSP_BERT_HP	BERT (0-9.9GeV)	BERT (0-9.9GeV)	LE_GHEISHA (0-25GeV)
QGSP_BERT	BERT (0-9.9GeV)	BERT (0-9.9GeV)	LE_GHEISHA (0-25GeV)
QGSP_BIC	LE_GHEISHA (0-25GeV)	BIC (0-9.9GeV)	LE_GHEISHA (0-25GeV)
QGSP	LE_GHEISHA (0-25GeV)	LE_GHEISHA (0-25GeV)	LE_GHEISHA (0-25GeV)

The same EM and decay process

Data Sample Selection

~10M ψ(2S) data taken in 2008

- **Need to be considered in data sample selection:**
  - **Data sample purity is of the top priority.**
  - **More stringent selection criteria should be applied, even lose some efficiency.**
  - **Least EMC information should be used in event selection.**
- **So, we select π+/π-, e+/e- from**

$$\psi(2S) \to \pi^+\pi^- J/\psi(J/\psi \to e^+e^-)$$

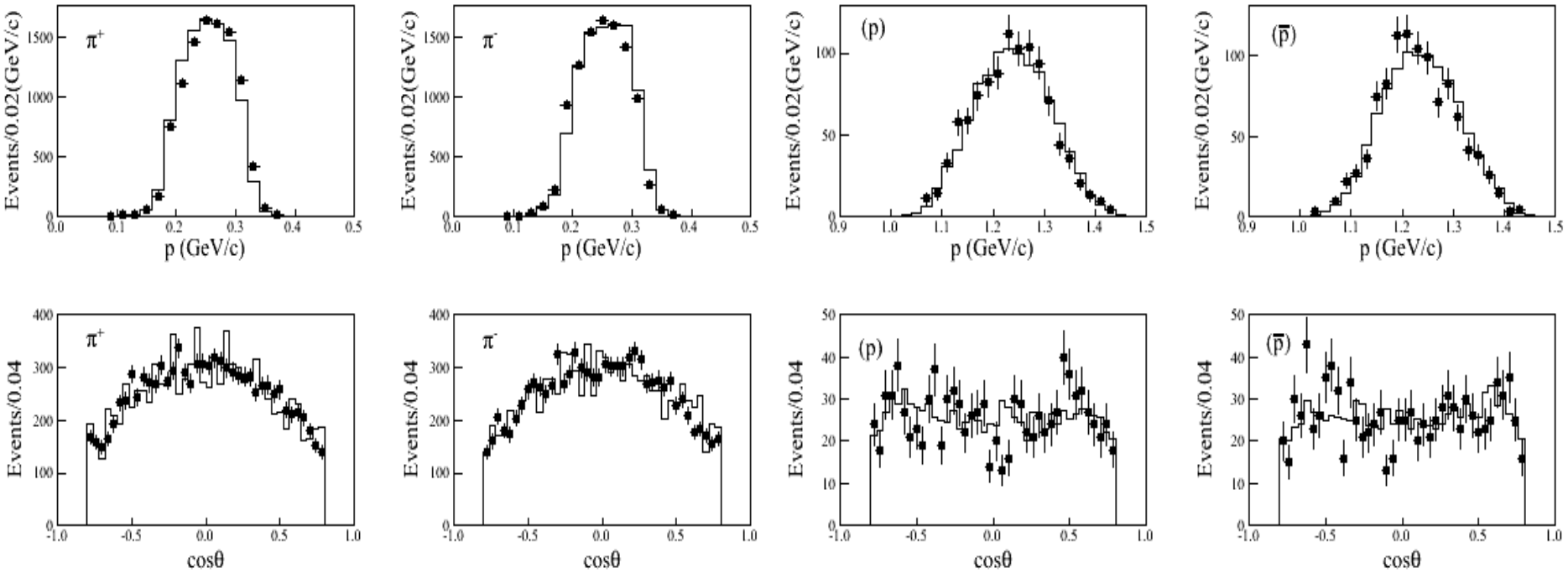
Background level ~ 0.1%

- **And we select proton and anti-proton from**

$$\psi(2S) \to \pi^+\pi^- J/\psi(J/\psi \to p\bar{p})$$

Background level ~ 0.7%

p and cosθ distributions of π^+/π^-, $p/\bar{p}$ samples



Monte Carlo samples are normalized to the number of events in data.

Dots: Data Histo.: MC (QGSP_BERT)

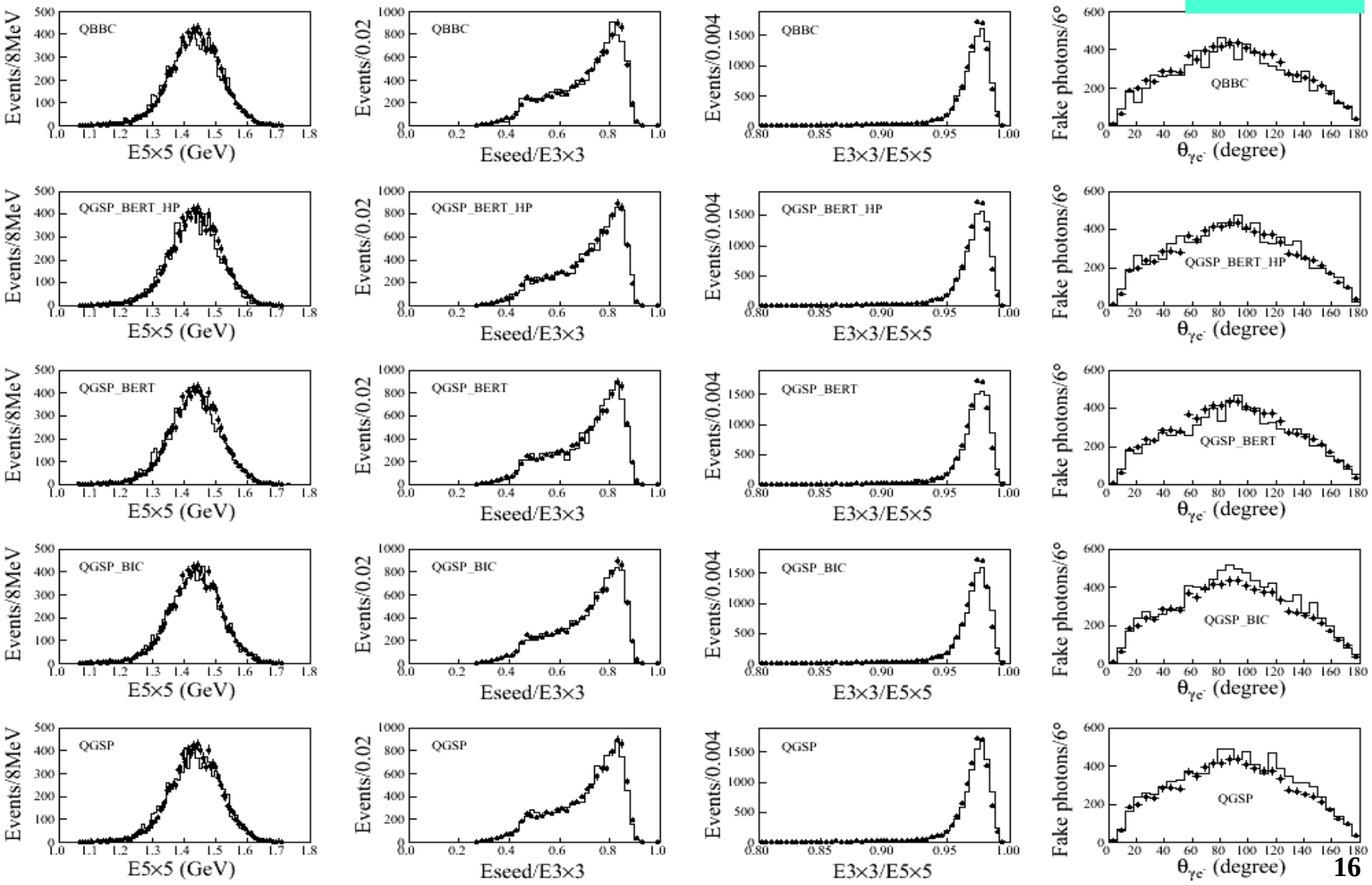
Compared variables

Behavior of hadrons in EM calorimeter, CsI(TI) crystals

- **Basic variables**
  - **E5×5: Energy deposited in 5×5 crystals around the seed in a shower.**
  - **Eseed/E3×3: The ratio of the energy deposited in the seed and the energy deposited in 3×3 crystals.**
  - **E3×3/E5×5: The ratio of the energy deposited in 3×3 crystals and 5×5 crystals.**
  - **θ_{fc}: Angle between fake photons and charged tracks, and a shower is defined as a fake photon if it can not match any charged tracks.**
- **Others**
  - **Energy of fake photons around hadrons ($\theta_{fc} < 30^\circ$)**
  - **CPU time**

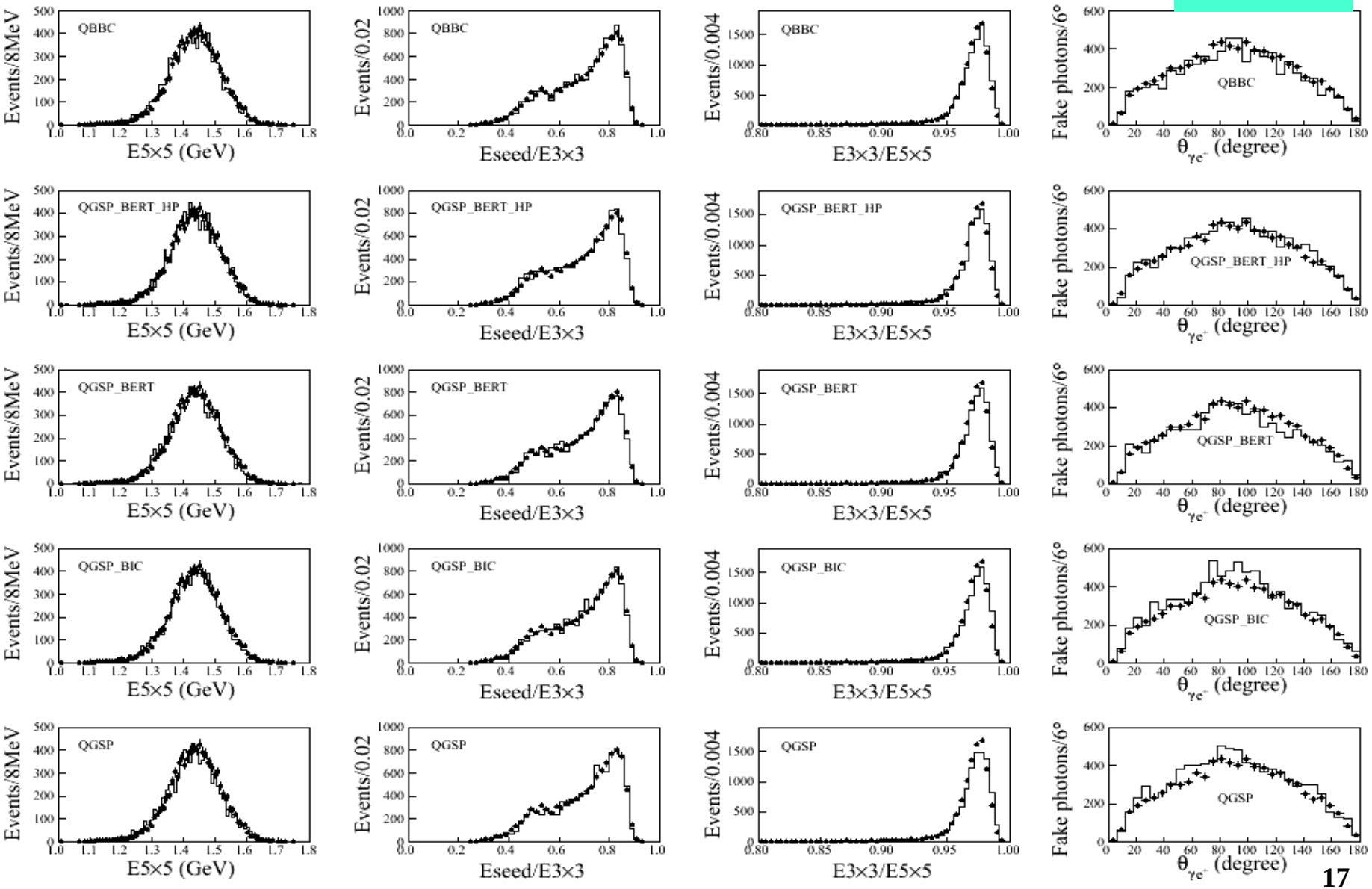
EM comparison (1)

Electron

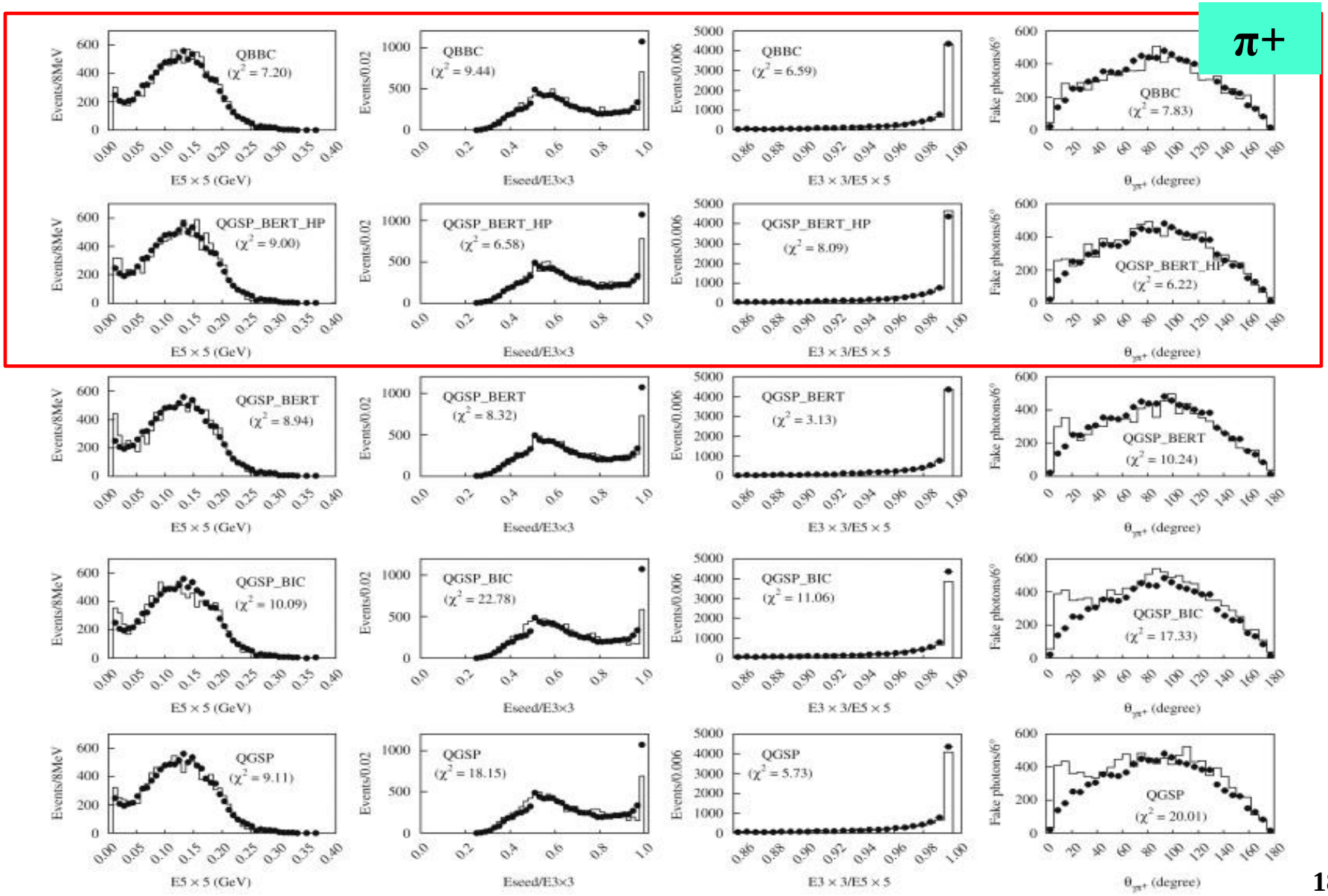


EM comparison (2)

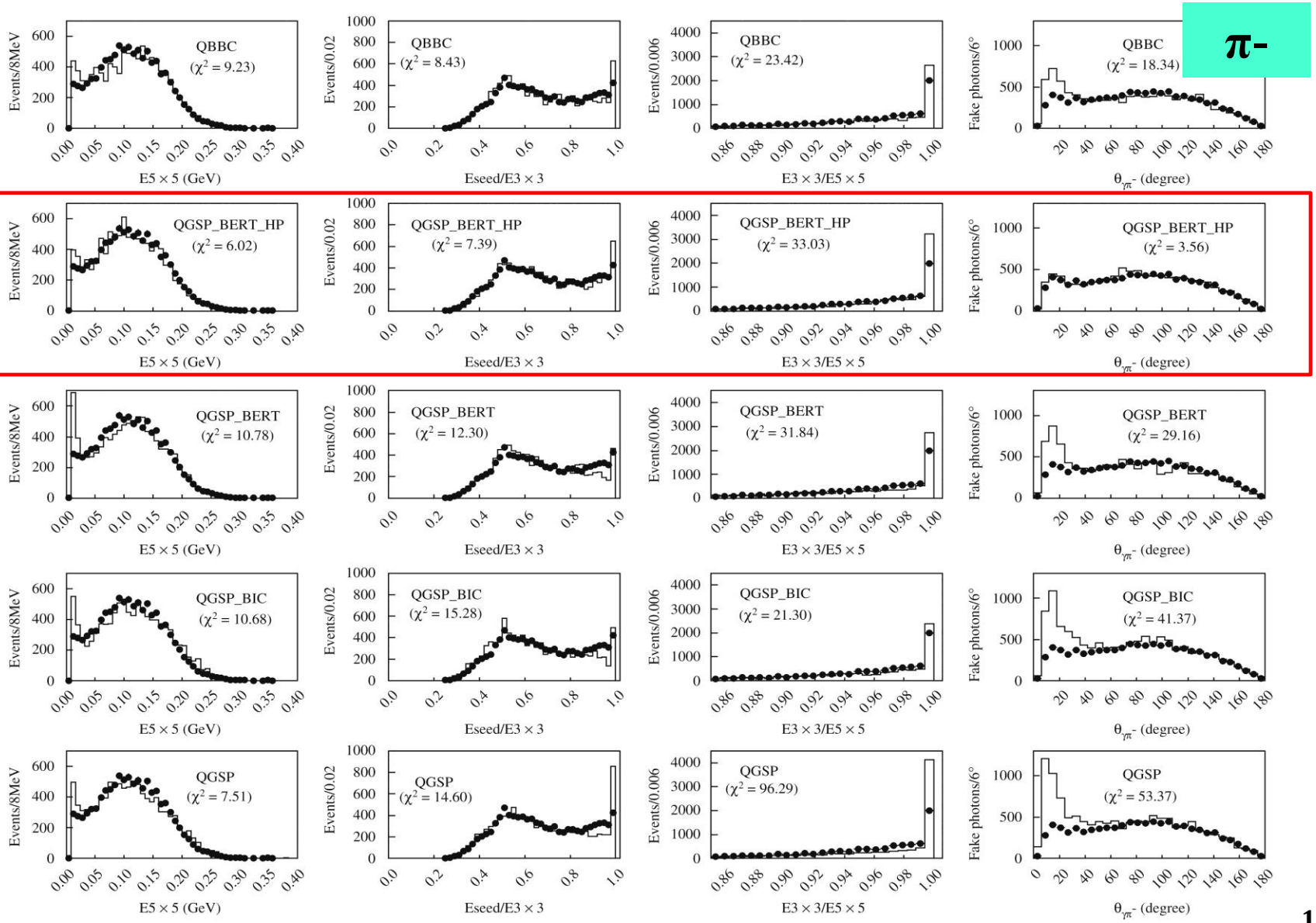
Positron



Hadronic models comparison (1)

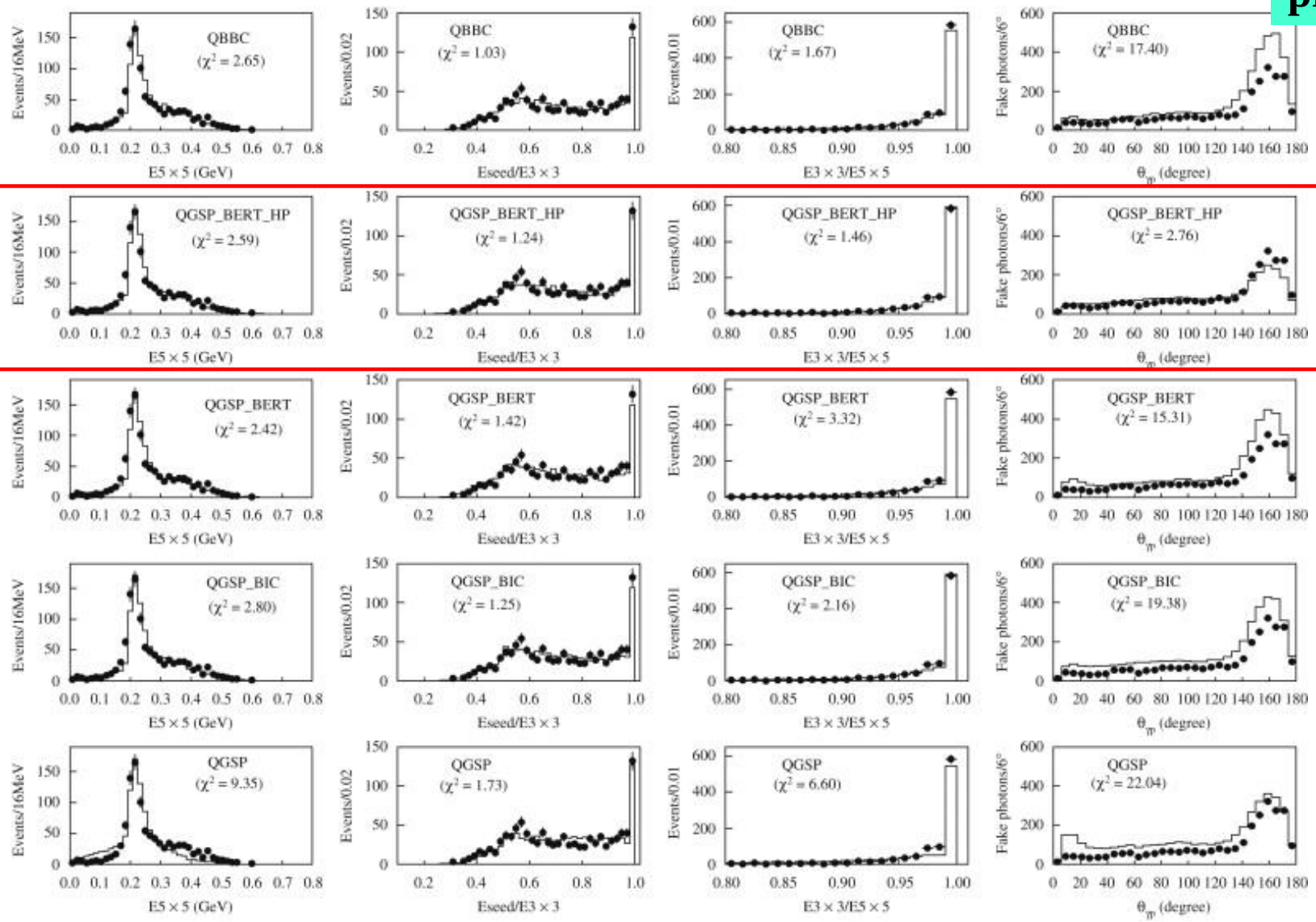


Hadronic models comparison (2)



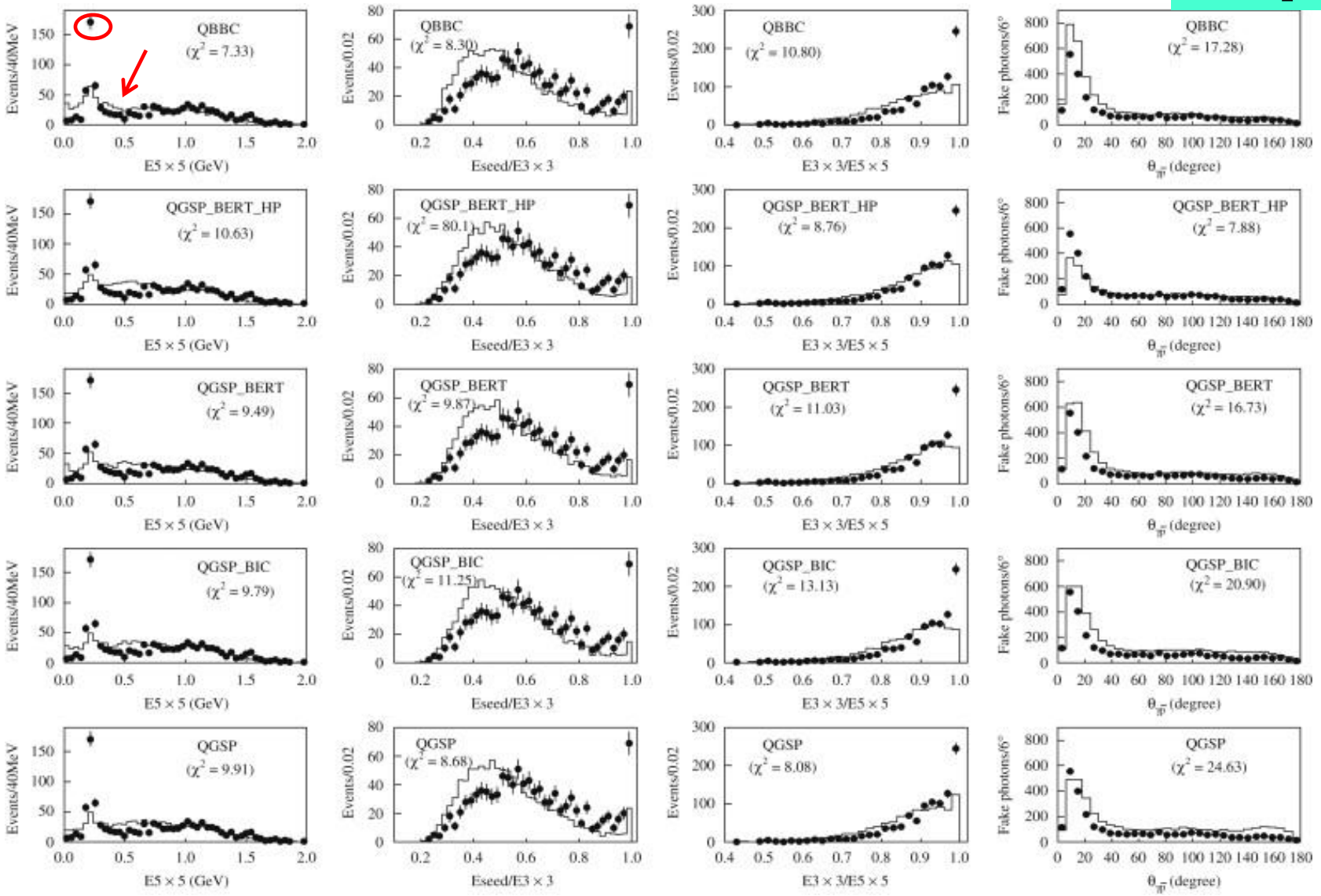
Hadronic models comparison (3)

proton



Hadronic models comparison (4)

Anti-proton



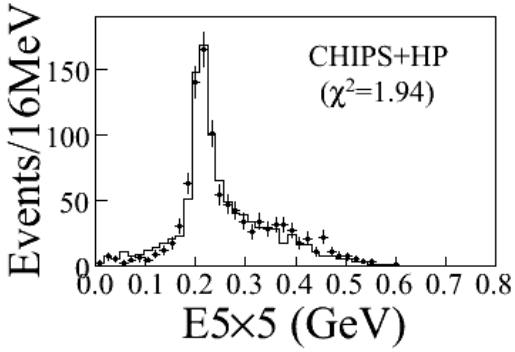
Hadronic Models in GEANT4

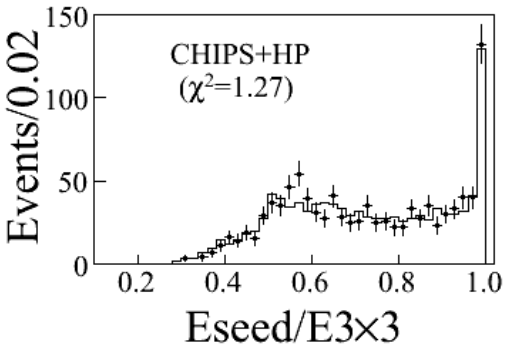
GEANT4.9.2.patch01

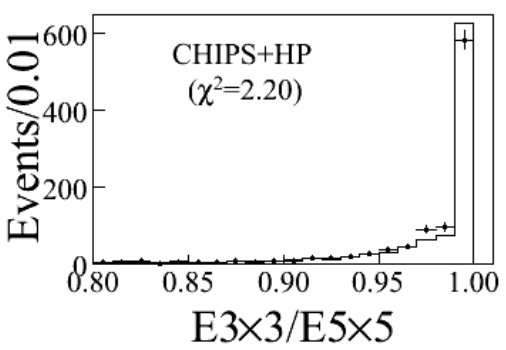
Physics lists	π^+/π^-	Proton	Anti-proton
QBBC	BERT (0-4GeV)	BIC (0-4GeV)	CHIPS (0-7.5GeV)
QGSP_BERT_HP	BERT (0-9.9GeV)	BERT (0-9.9GeV)	LE_GHEISHA (0-25GeV)
QGSP_BERT	BERT (0-9.9GeV)	BERT (0-9.9GeV)	LE_GHEISHA (0-25GeV)
QGSP_BIC	LE_GHEISHA (0-25GeV)	BIC (0-9.9GeV)	LE_GHEISHA (0-25GeV)
QGSP	LE_GHEISHA (0-25GeV)	LE_GHEISHA (0-25GeV)	LE_GHEISHA (0-25GeV)

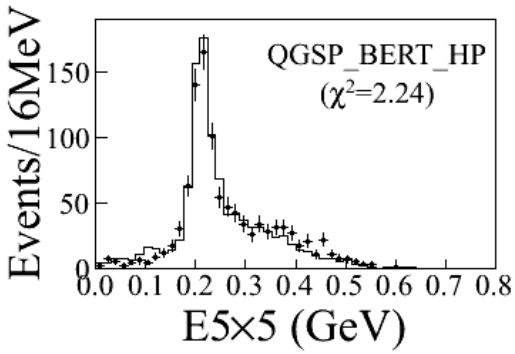
New hadronic models comparison (1)

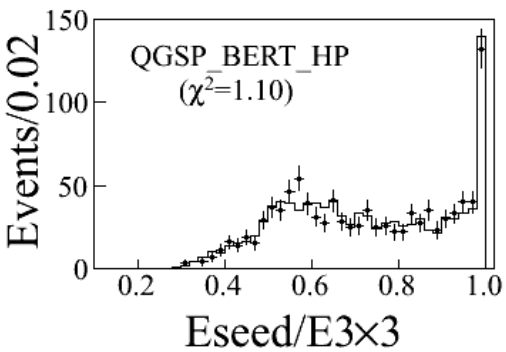
Proton

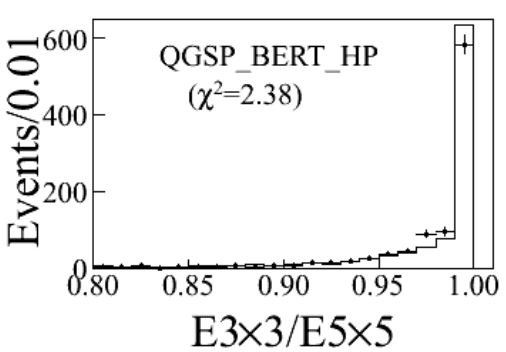


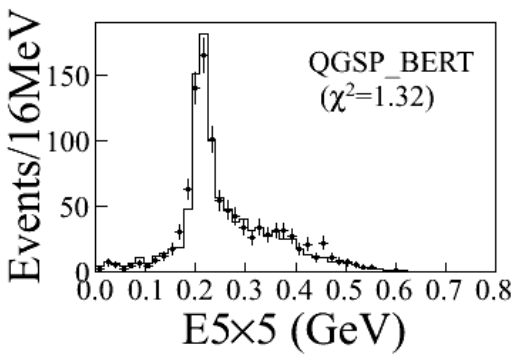


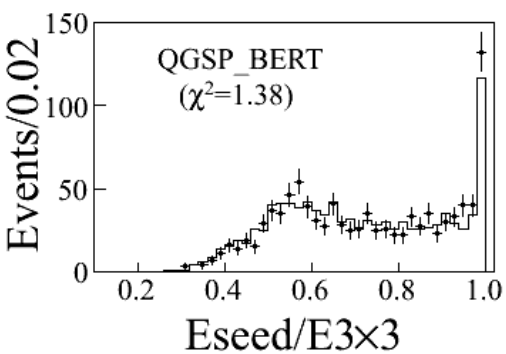


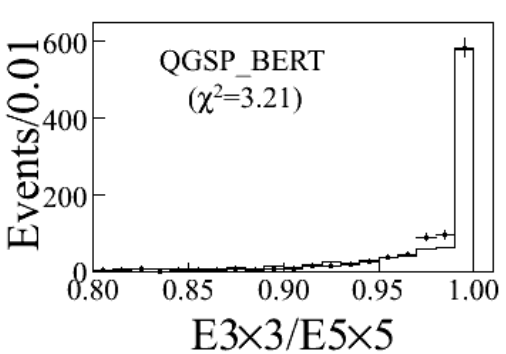






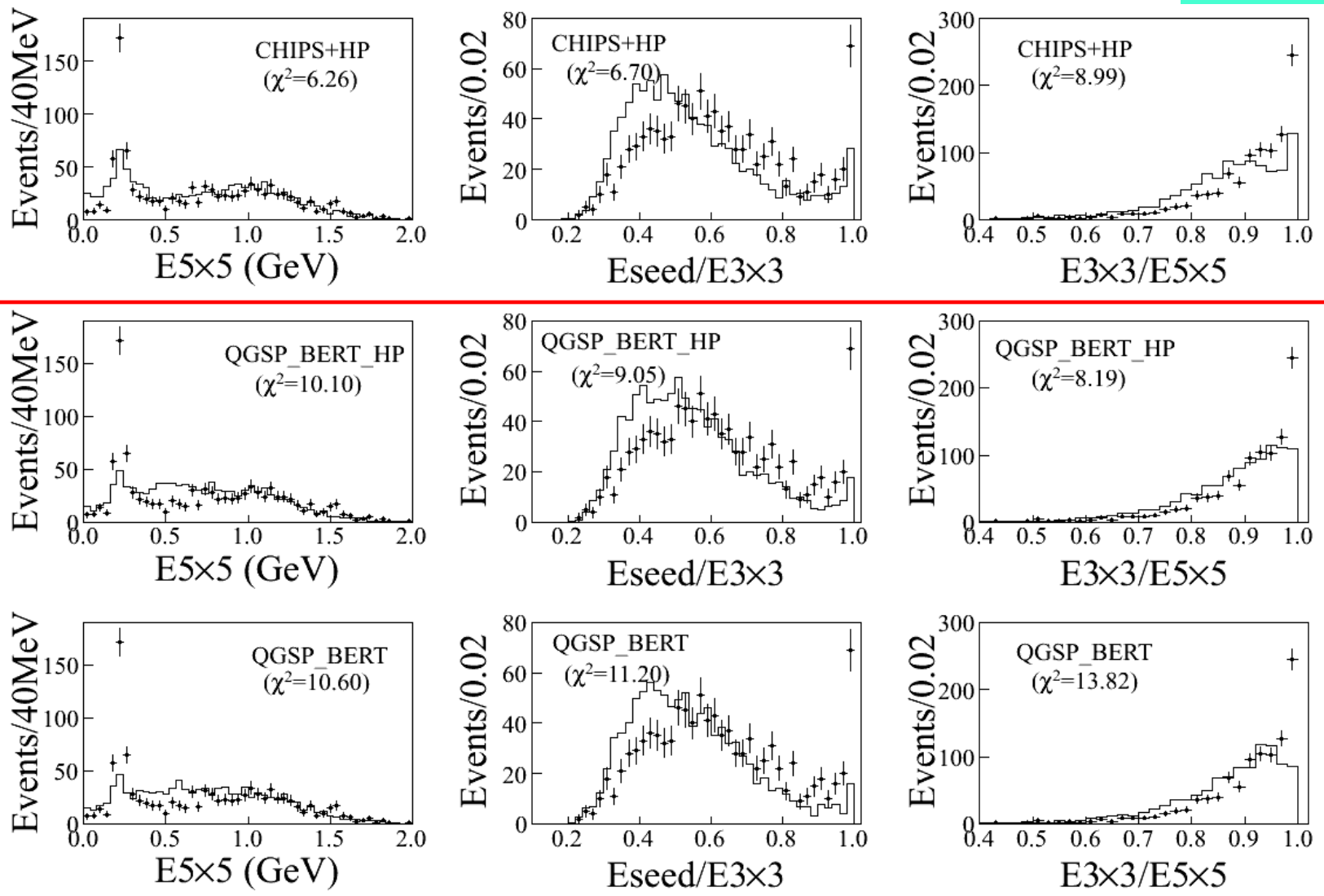




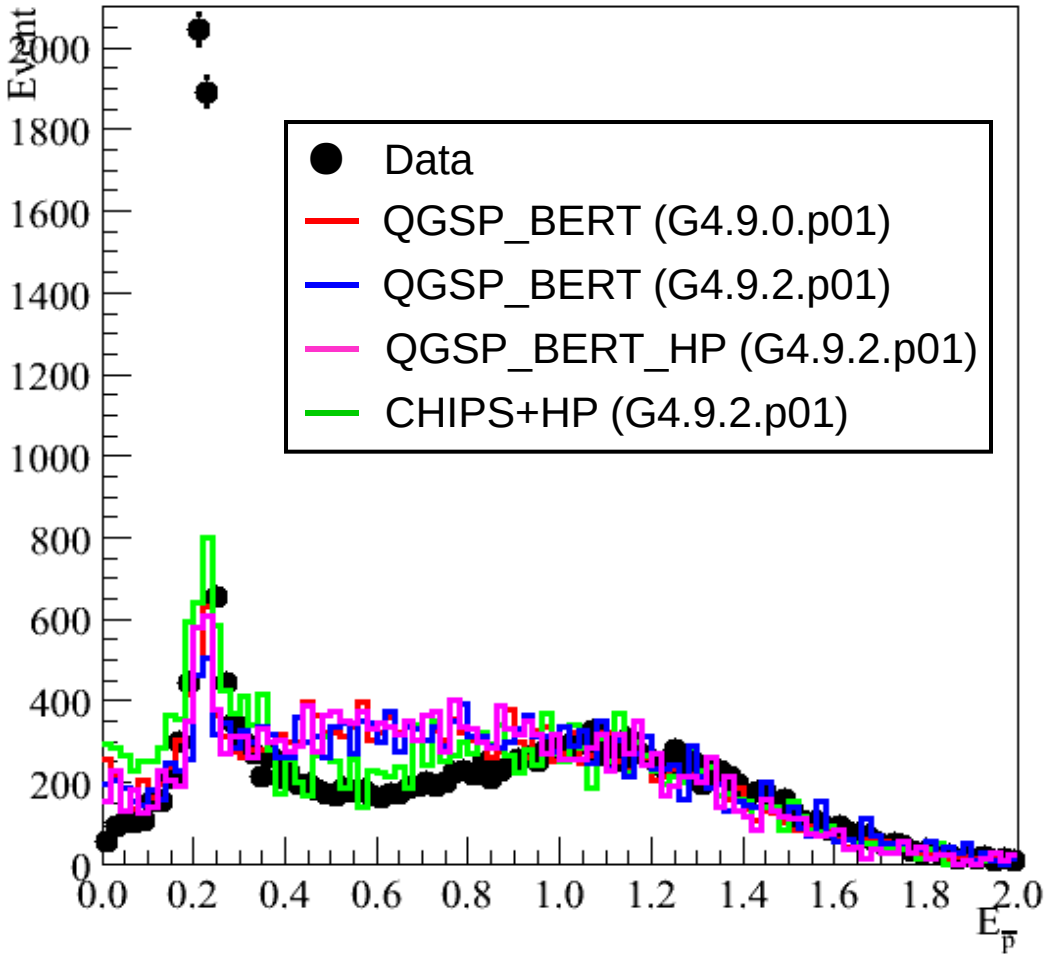


New hadronic models comparison (2)

Anti-proton



Cross Check for Anti-proton



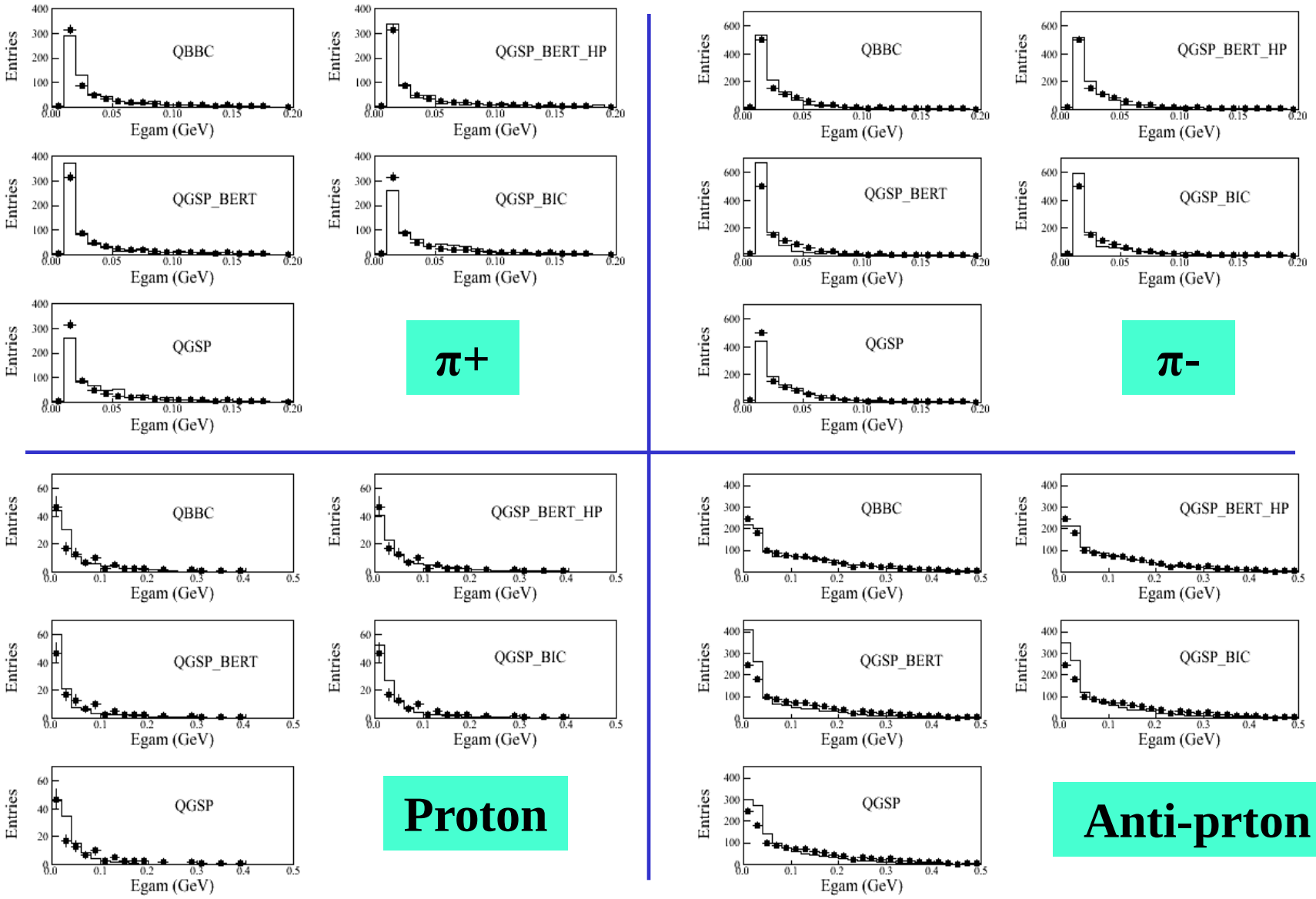
Another pure anti-proton sample is selected from $J/\psi \to p\bar{p}$, the momentum is about 1.2 GeV/c.

1. Cross section of inelastic or elastic is not precise?
2. Some other reasons?
3. How to improve it?

Deposited energy of anti-proton

Any suggestions are welcome.

Energy of fake photons around hadrons (< 30°)



CPU time

IBM PC(2.33GHz/2GB), s/event

Physics lists	$\psi(2S)\to\pi^+\pi^- J/\psi(J/\psi\to e^+e^-)$	$\psi(2S)\to\pi^+\pi^- J/\psi(J/\psi\to p\bar{p})$
QBBC	0.67	0.84
QGSP_BERT_HP	1.06	2.89
QGSP_BERT	0.69	0.85
QGSP_BIC	0.69	0.82
QGSP	0.67	0.57

Summary

- For electromagnetic interaction, we can get good agreement between MC and data.
- For π+/π-, most of models agree in energy deposit and shower shape, but some models tend to produce more tracks around the hadrons.
- For proton, all models can give acceptable agreement except QGSP.
- In general, QGSP_BERT_HP is the best one for pions and protons.
- Anti-proton can not be well simulated, but CHISP+HP is slightly better than others. It seems cross sections need to be improved at low energy.

THANKS