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Test of Hadronic Models in GEANT4 using BESIII Data

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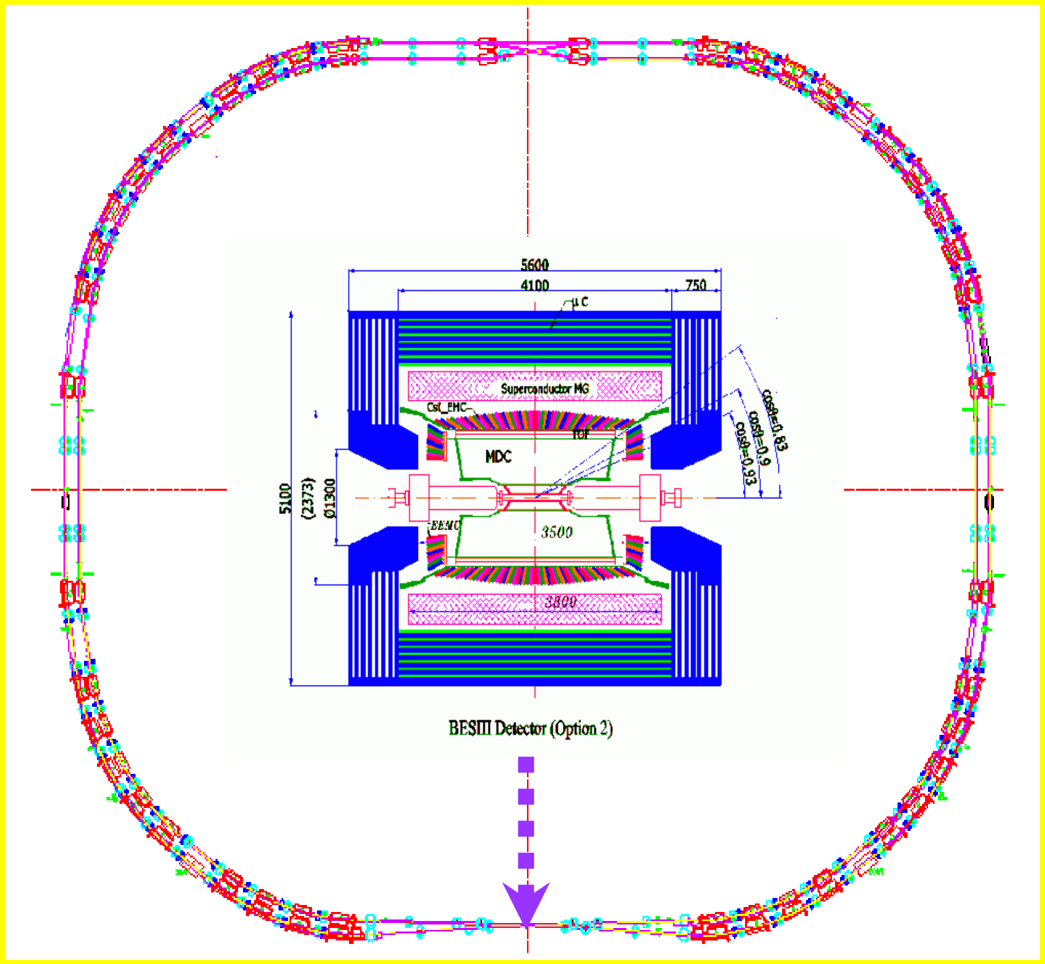
LCG Physics Validation Meeting

7 July, 2010

Outline

- The Experiment – Collider and Detector
- 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**
- **Luminosity: 1×10^{33} cm^{-2} s^{-1}**
- **Optimum energy: 1.89 GeV**
- **Energy spread: 5.16×10^{-4}**
- **Cross angle: 22 mrad**
- **No. of bunches: 93**
- **Bunch length: 1.5 cm**
- **Total current: 0.91 A**
- **SR mode: 0.25 A @ 2.5 GeV**

BES-III

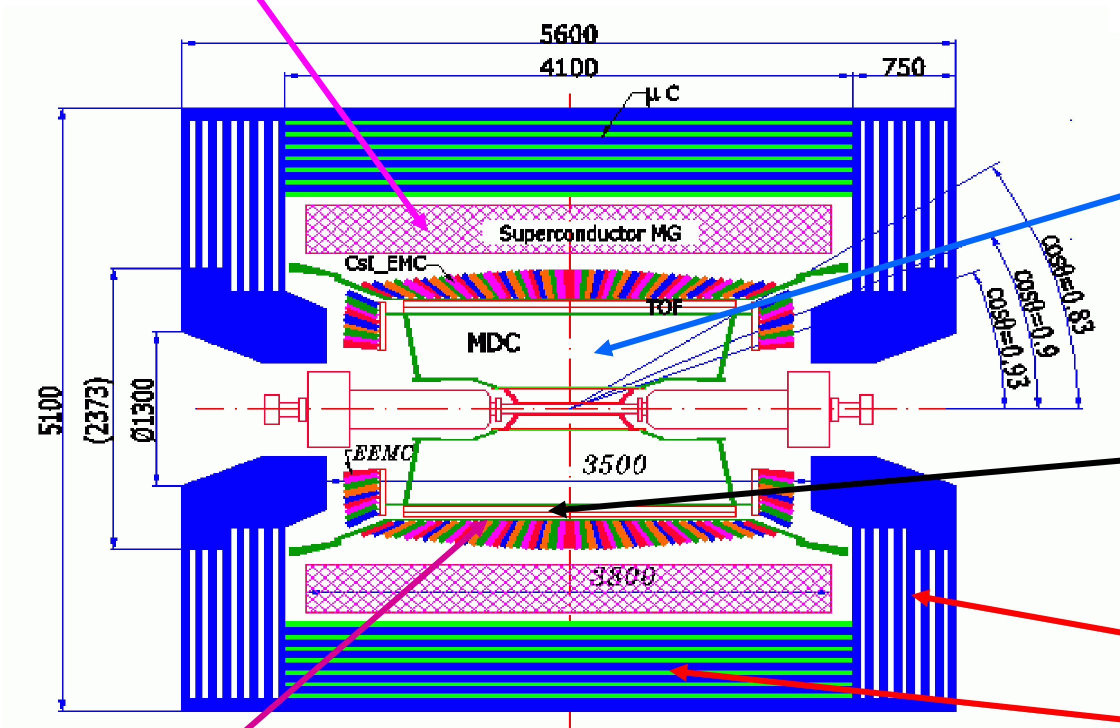
BESIII detector: all new !

CsI calorimeter

Precision tracking

Time-of-flight + dE/dx PID

Magnet: 1 T Super conducting



MDC: small cell & Gas: He/C3H8 (60/40), 43 layers
σ_{xy}=130 μm
s_p/p = 0.5% @1GeV
dE/dx=6%

TOF:
σ_T = 100 ps Barrel
110 ps Endcap

Muon ID: 9 layers RPC
8 layers for endcap

EMC: CsI crystal, 28 cm
ΔE/E = 2.5% @1 GeV
σz = 0.6 cm/√E

Data Acquisition:
Event rate = 4 kHz
Total data volume ~ 50 MB/s

The detector is hermetic for neutral and charged particle with excellent resolution, PID, and large coverage.

Physics Topics at BESIII

- Study of Light hadron spectroscopy
  - Search for non-$q\bar{q}$ or non-qqq states
  - Meson spectroscopy
  - Baryon spectroscopy
- Study of the production and decay mechanisms of charmonium states: J/ψ, $\psi(2S)$, $\eta_c(1S)$, $\chi_{c(0,1,2)}$, $\eta_c(2S)$, $h_c(^1P_1)$, $\psi(3770)$, etc.

New Charmonium states above open charm threshold.

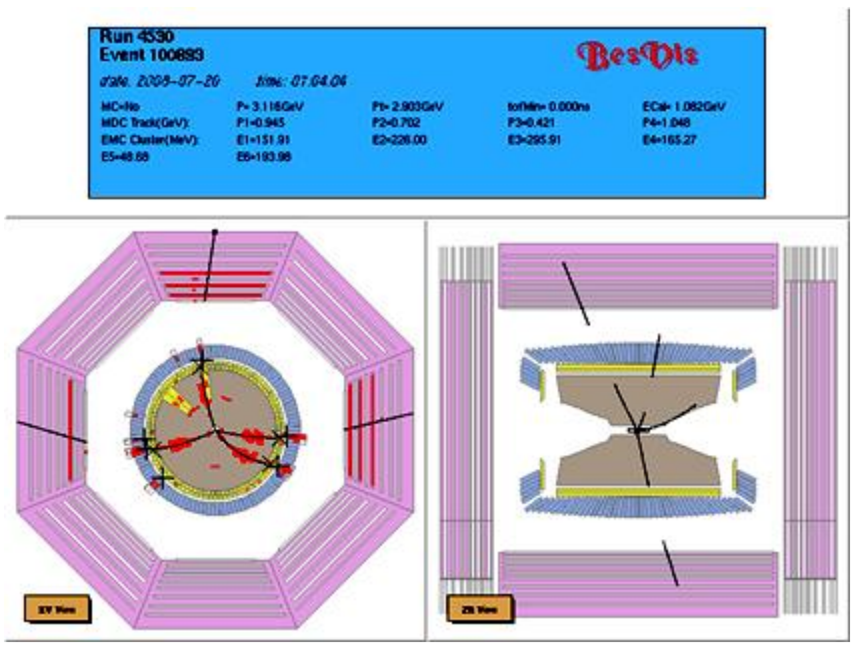
- Precise measurement of R values, τ mass, …
- Precise measurement of CKM matrix.
- Search for DDbar mixing, CP violation and etc.

BEPCII/BESIII Milestones

Record Luminosity
$3.2 \times 10^{32} cm^{-2}s^{-1}$ or
$5 \times$ CESRc
$30 \times$ BEPC

Beginning of 2004, construction starts

Mar. 2008:	**First full cosmic-ray event**
Apr. 30, 2008:	**Move BESIII to IP**
July 19, 2008:	**First e^+e^- collision event in BESIII**
Apr. 14, 2009	**BESIII 106 M $\psi(2S)$ events ($42.3 pb^{-1}$ at 3.65GeV)**
July 28, 2009	**~226 M J/ψ events**
June 27, 2010	**~950 pb^{-1} at $\psi(3770)$, with ~70pb^{-1} scanning in $\psi(3770)$ energy region.**



First collision event

May 15, 2008: detector at IP; installing SC quads and beam pipe.

BESIII MC Software

BOOST Project

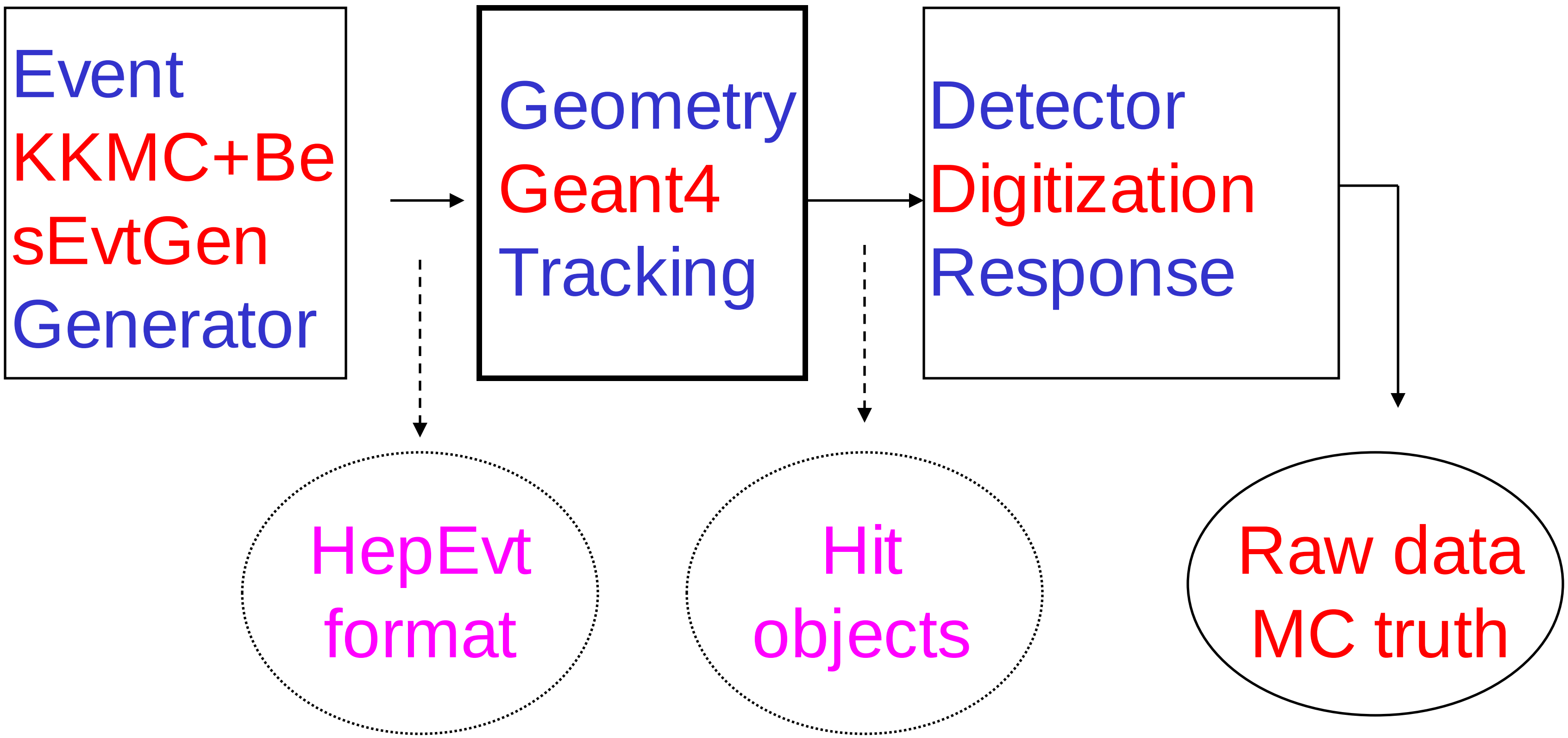
BESIII **O**bject **O**riented **S**imulation **T**ool

(proposal: August, 2002)

BES MC Software Evolution

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

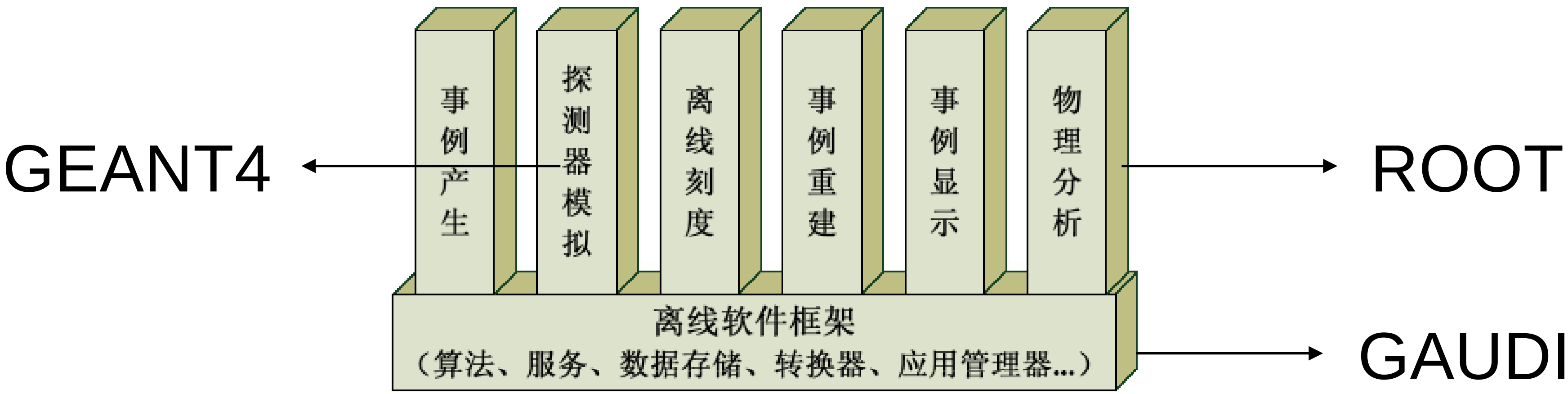
BOOST Architecture



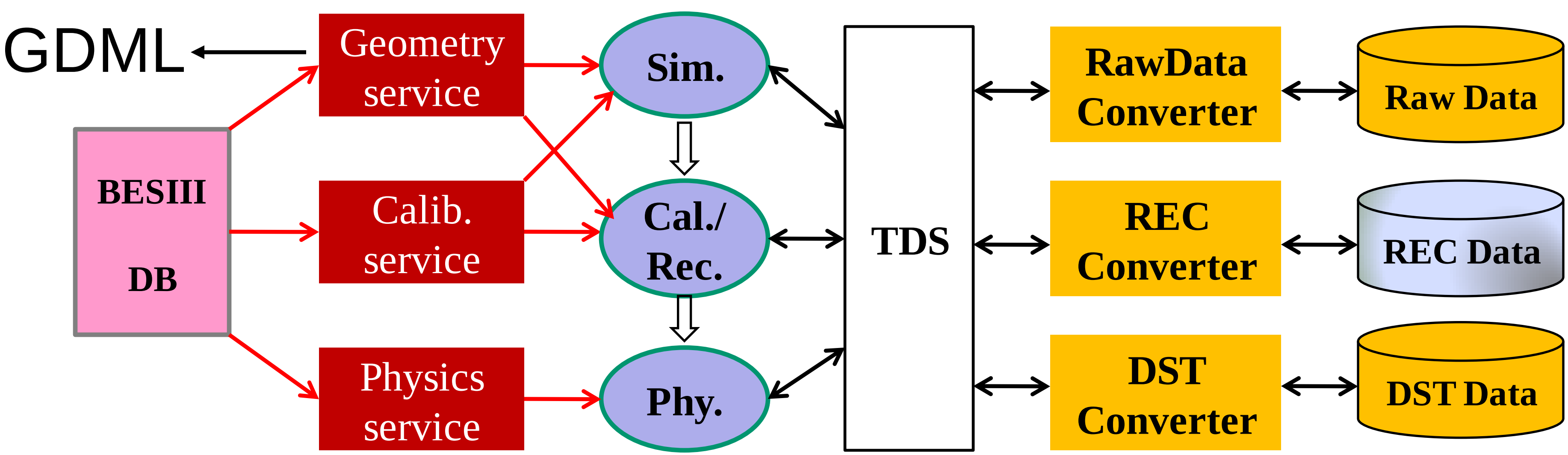
BESIII MC – main components

- 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)



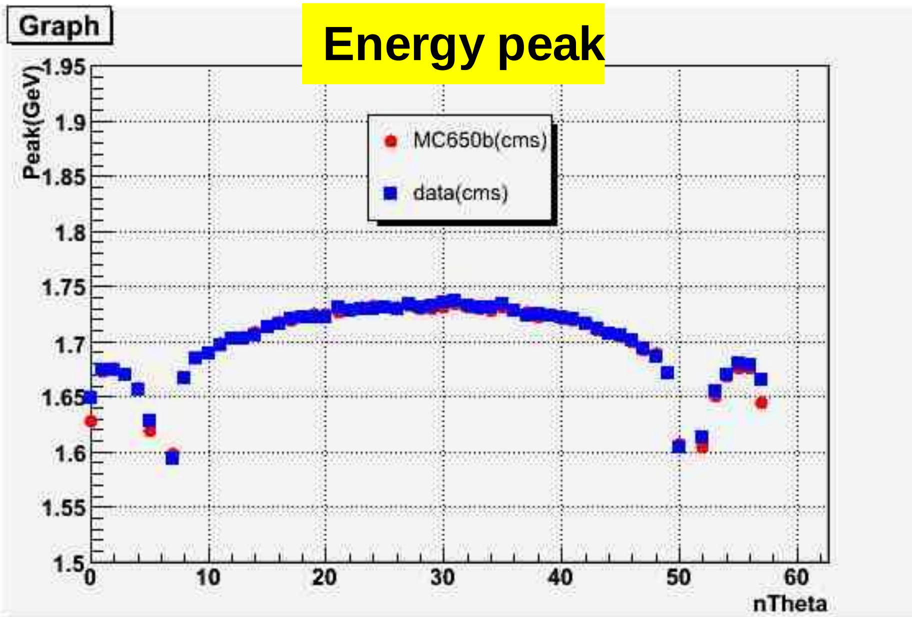
Architecture of BOSS

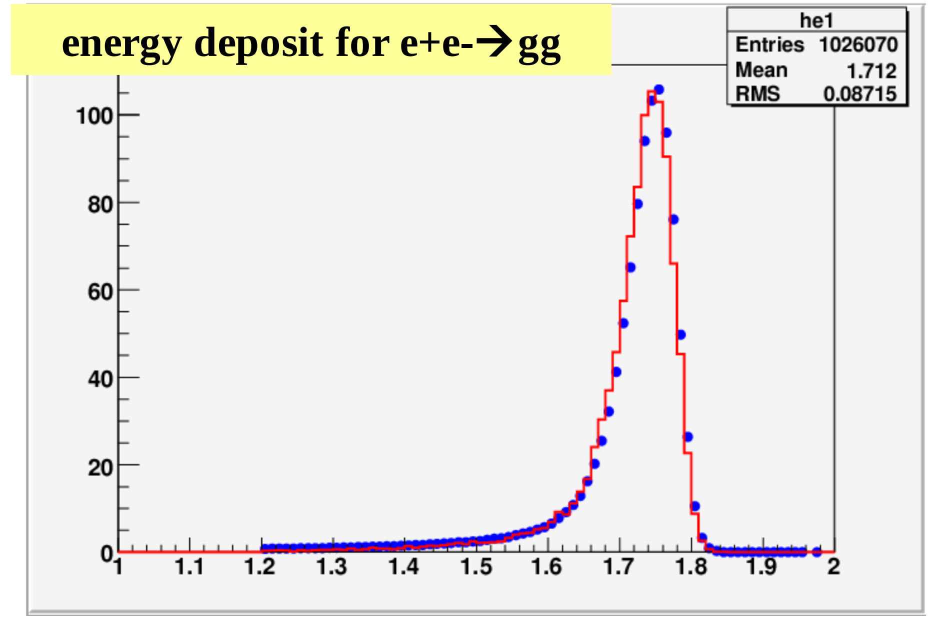


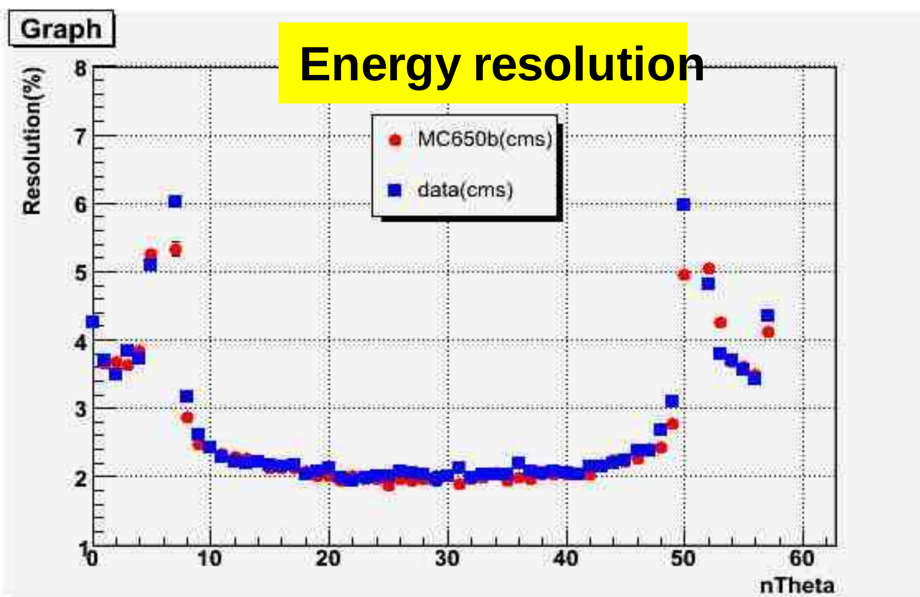
Current status

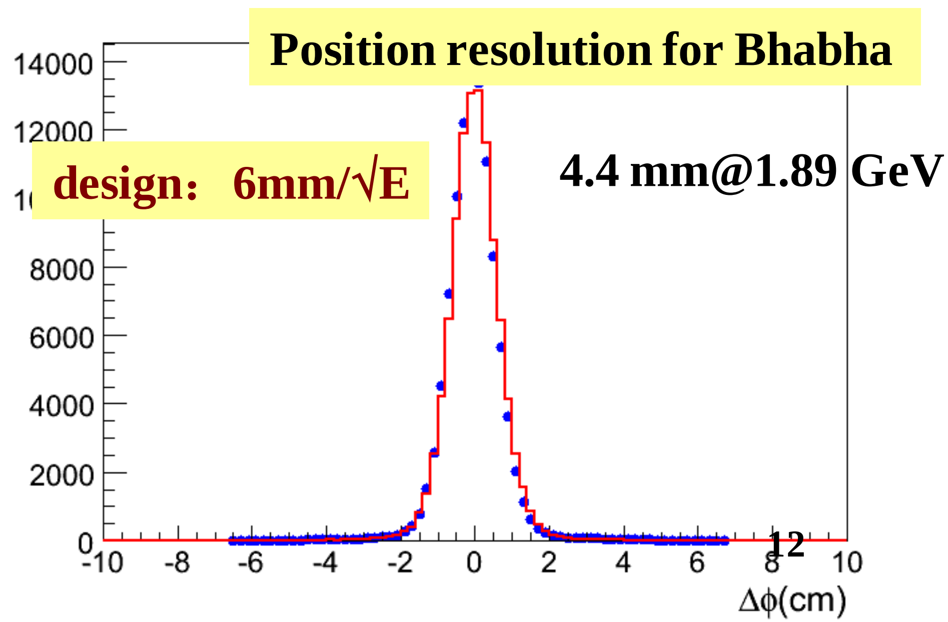
- A stable full simulation program with Geant4 finally works after a long test and bug fix
- One billion MC events have been produced for software tuning and physics study
- Physics results from simulation are quite reasonable and generally consistent with the experimental data
- We are trying hard to tune MC to achieve better agreements

EMC Performance reach/exceed design









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/LHEP	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**

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

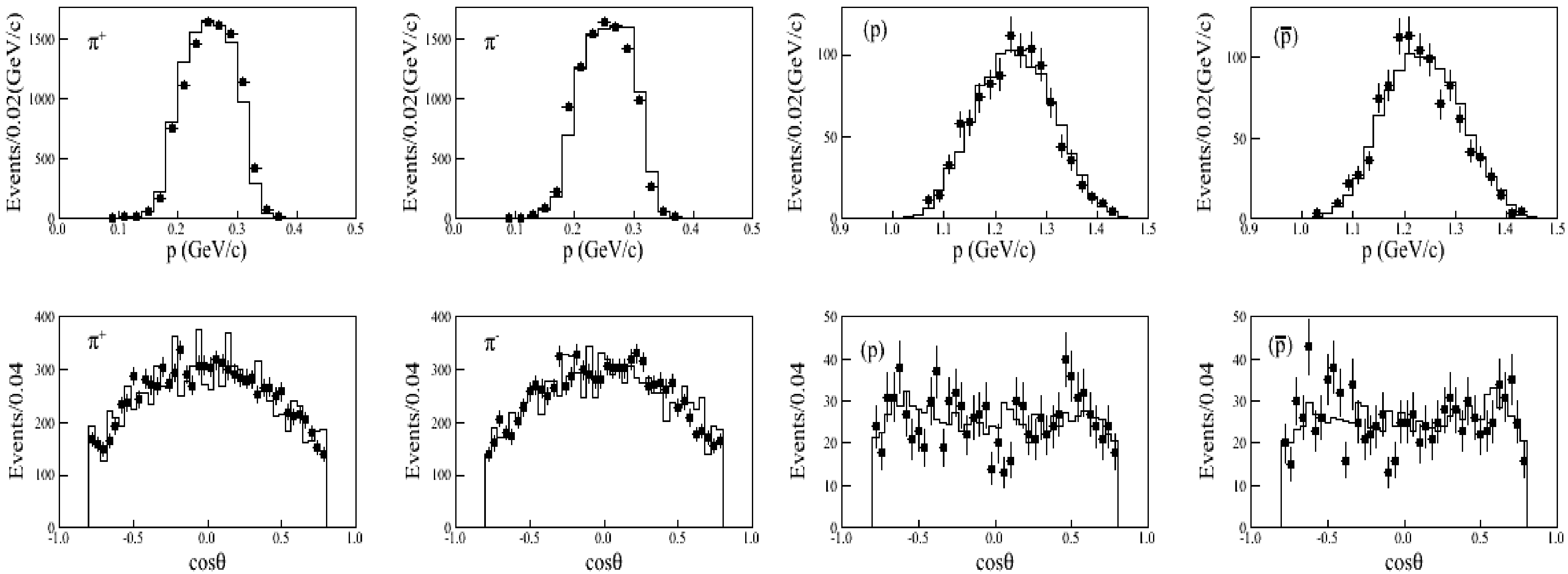
Background level ~ 0.1%

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

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

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)

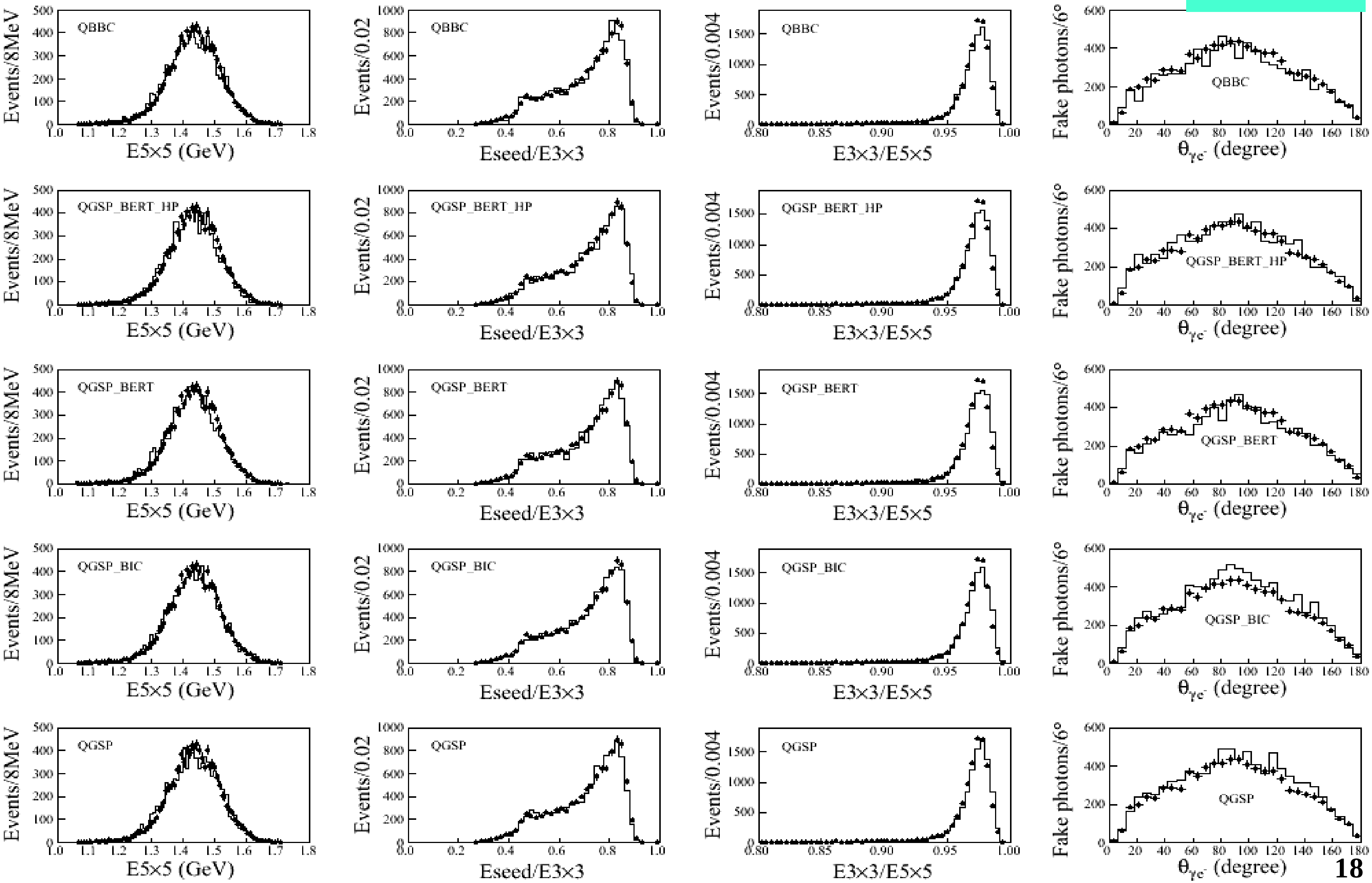
Compared variables

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

- **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.**

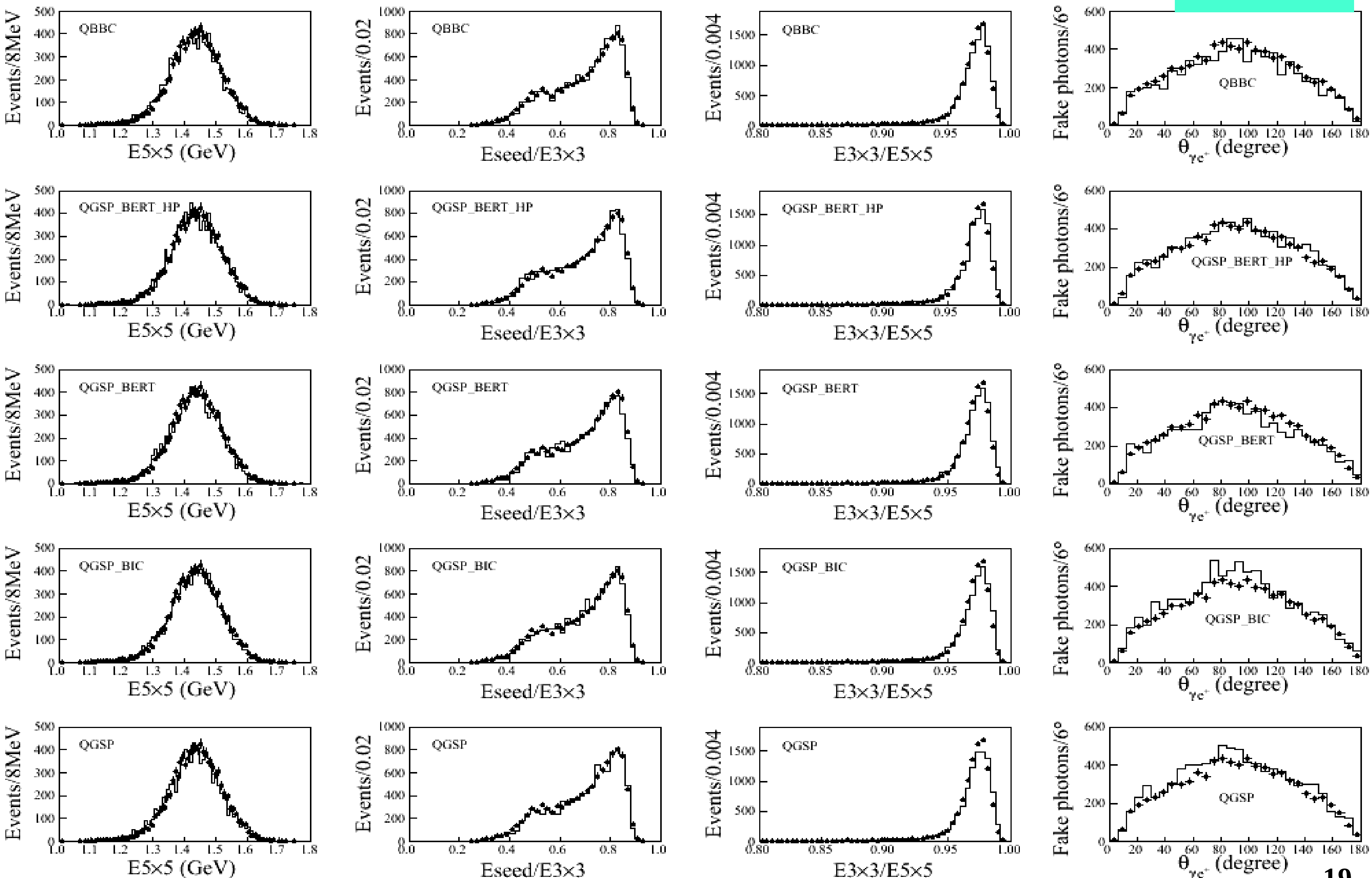
EM comparison (1)

Electron



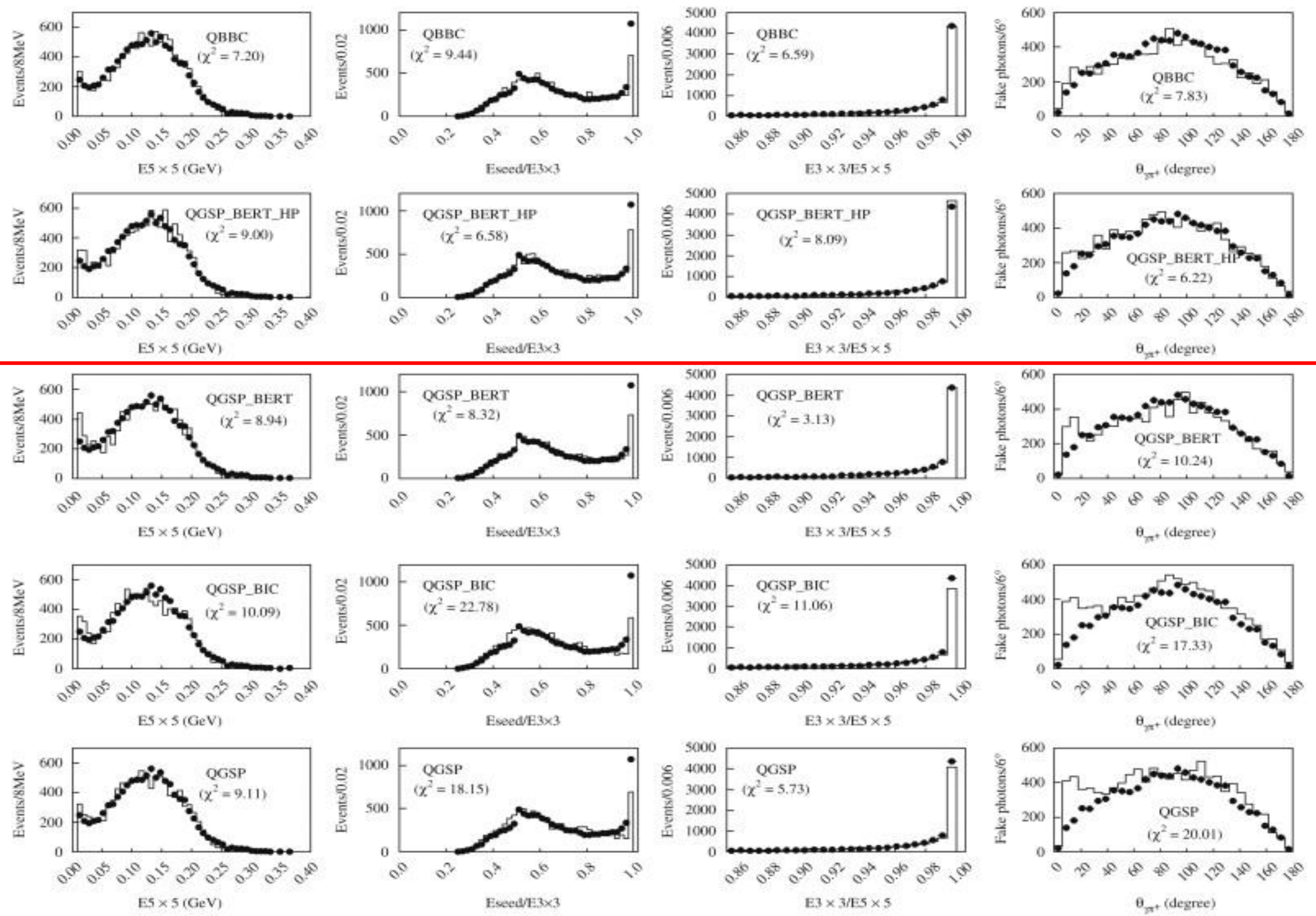
EM comparison (2)

Positron



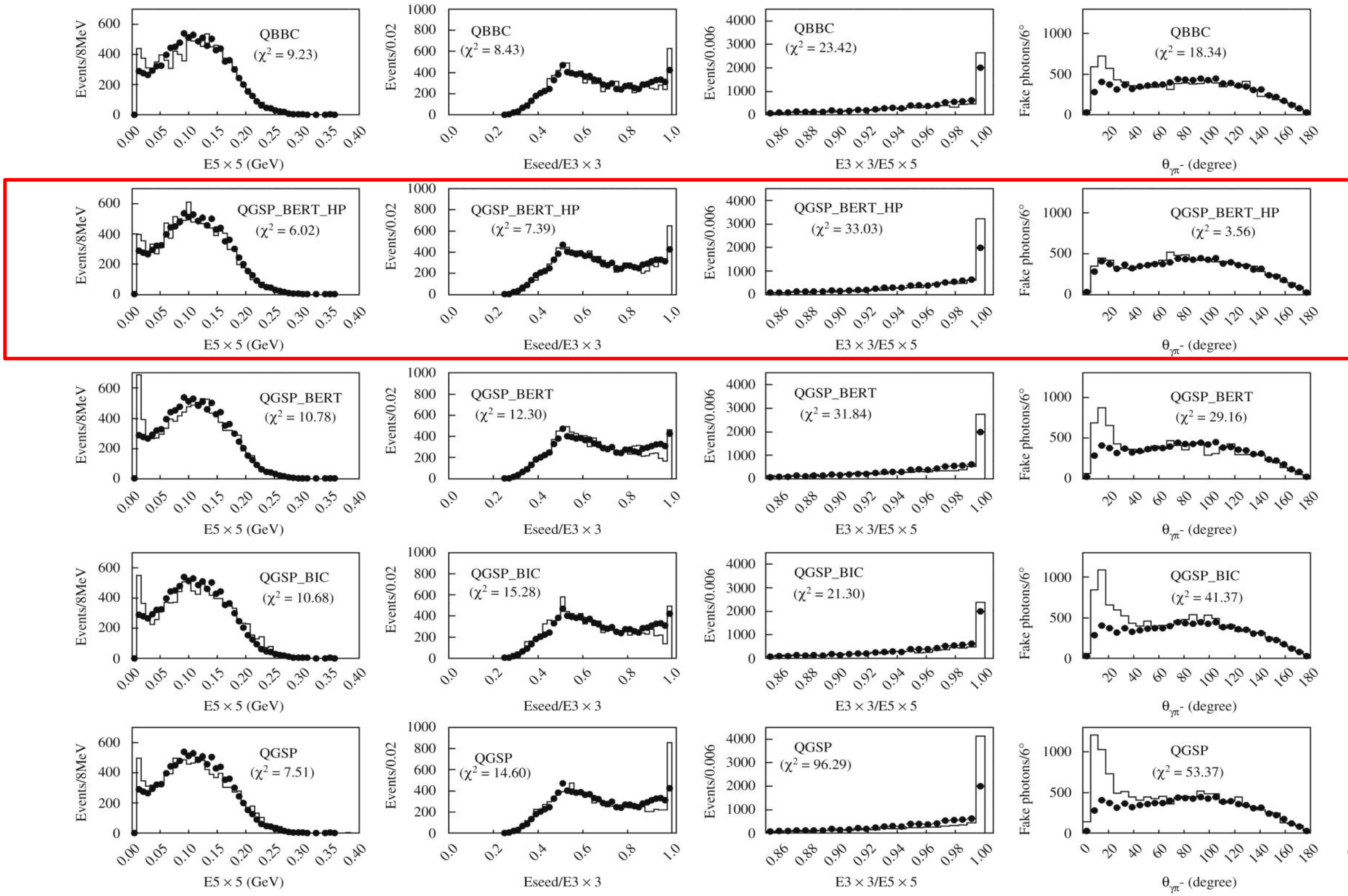
Comparisons with G4.9.0.p01 (1)

π+ [0.1, 0.4GeV/c]



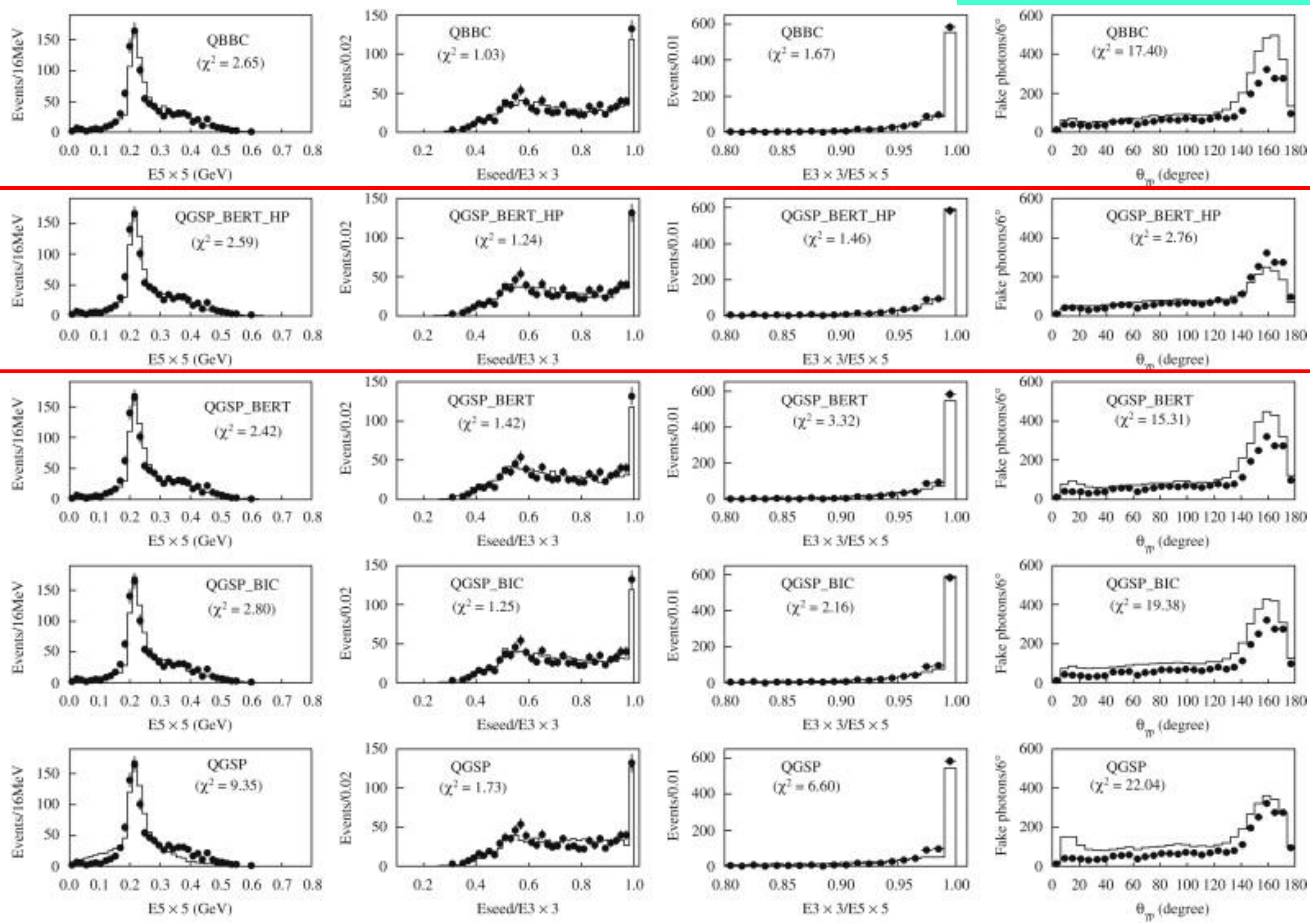
Comparisons with G4.9.0.p01 (2)

π- [0.1, 0.4GeV/c]



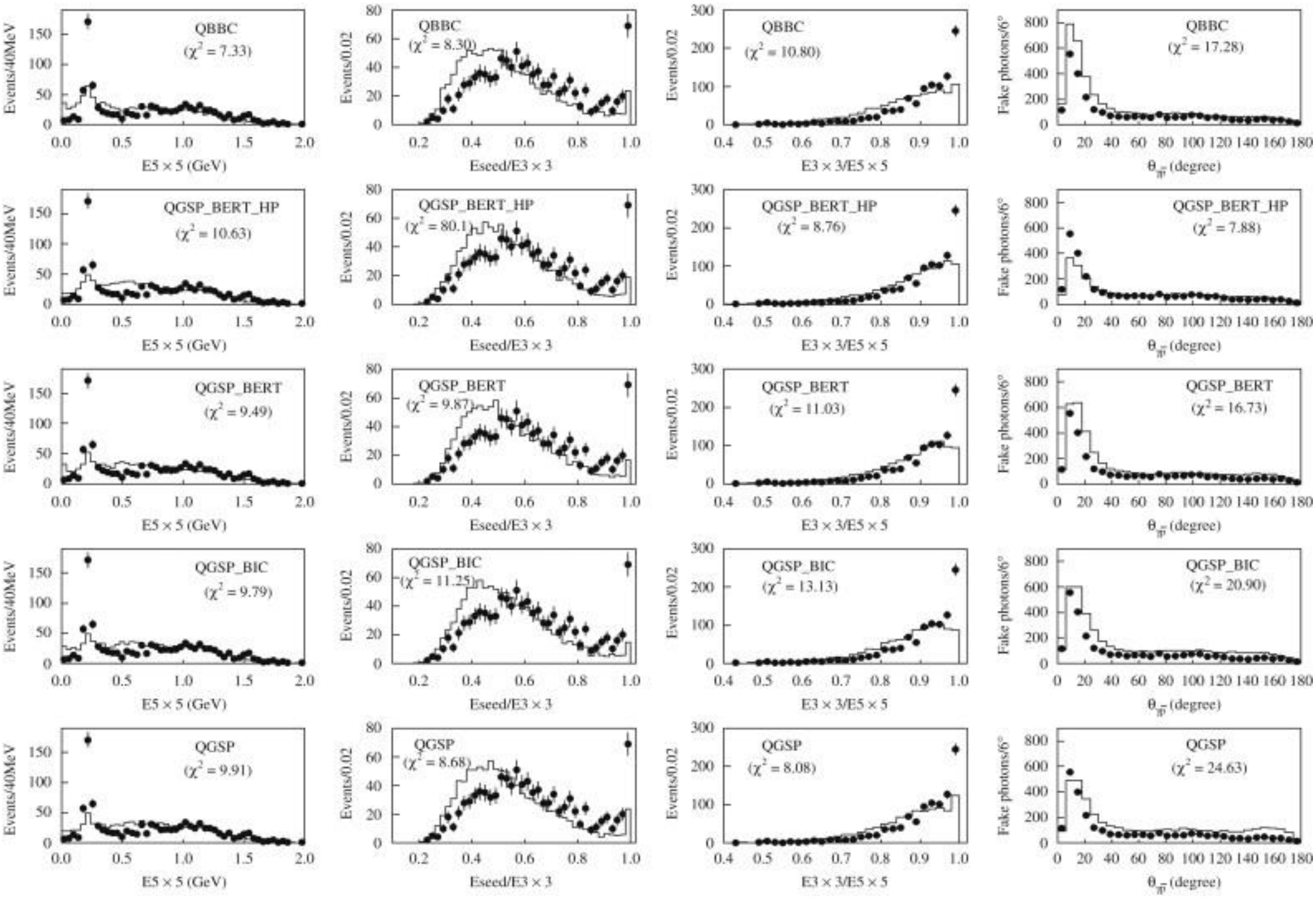
Comparisons with G4.9.0.p01 (3)

proton [1.1, 1.4GeV/c]



Comparisons with G4.9.0.p01 (4)

Anti-proton [1.1, 1.4GeV/c]



Hadronic Models in GEANT4

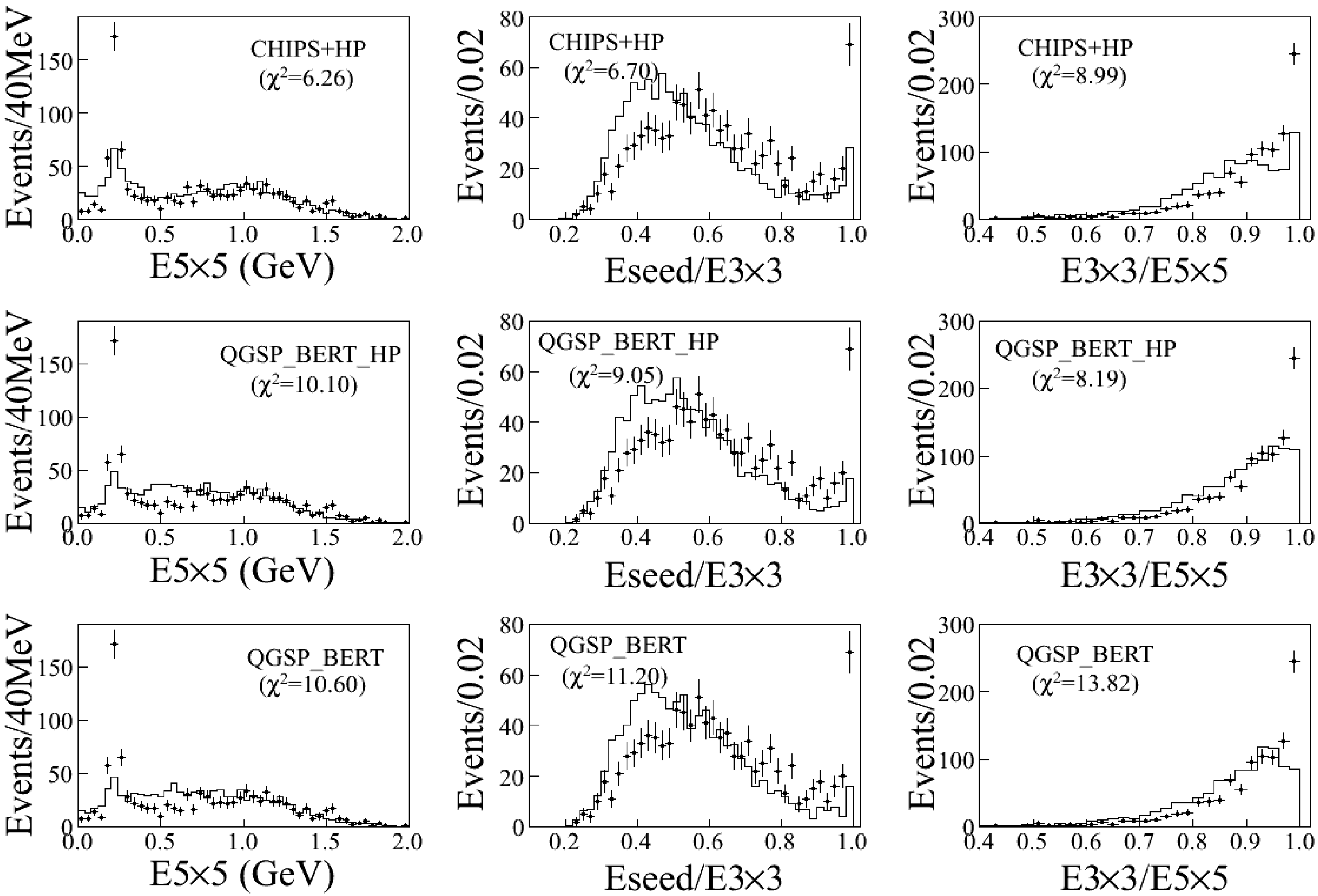
GEANT4.9.2.patch01

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/LHEP	LE_GHEISHA (0-25GeV)	LE_GHEISHA (0-25GeV)	LE_GHEISHA (0-25GeV)

We can get similar results with GEANT4.9.0.p01

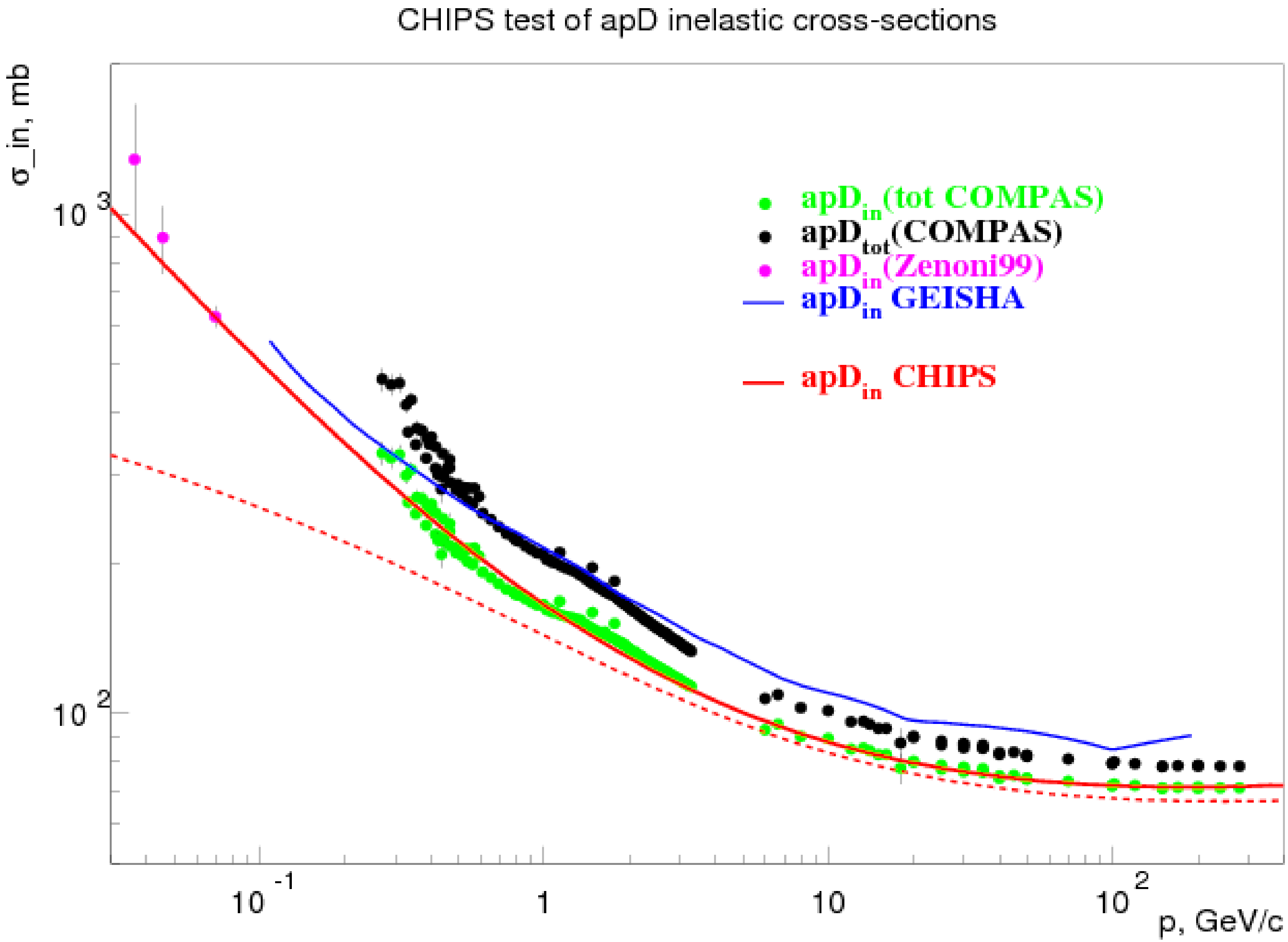
Comparisons with G4.9.2.p01

Anti-proton [1.1, 1.4GeV/c]



We have reported above results in 14th Geant4 workshop

Borrow from Kosov's talk in14th GEANT4 Workshop



Hadronic Models in GEANT4

GEANT4.9.3

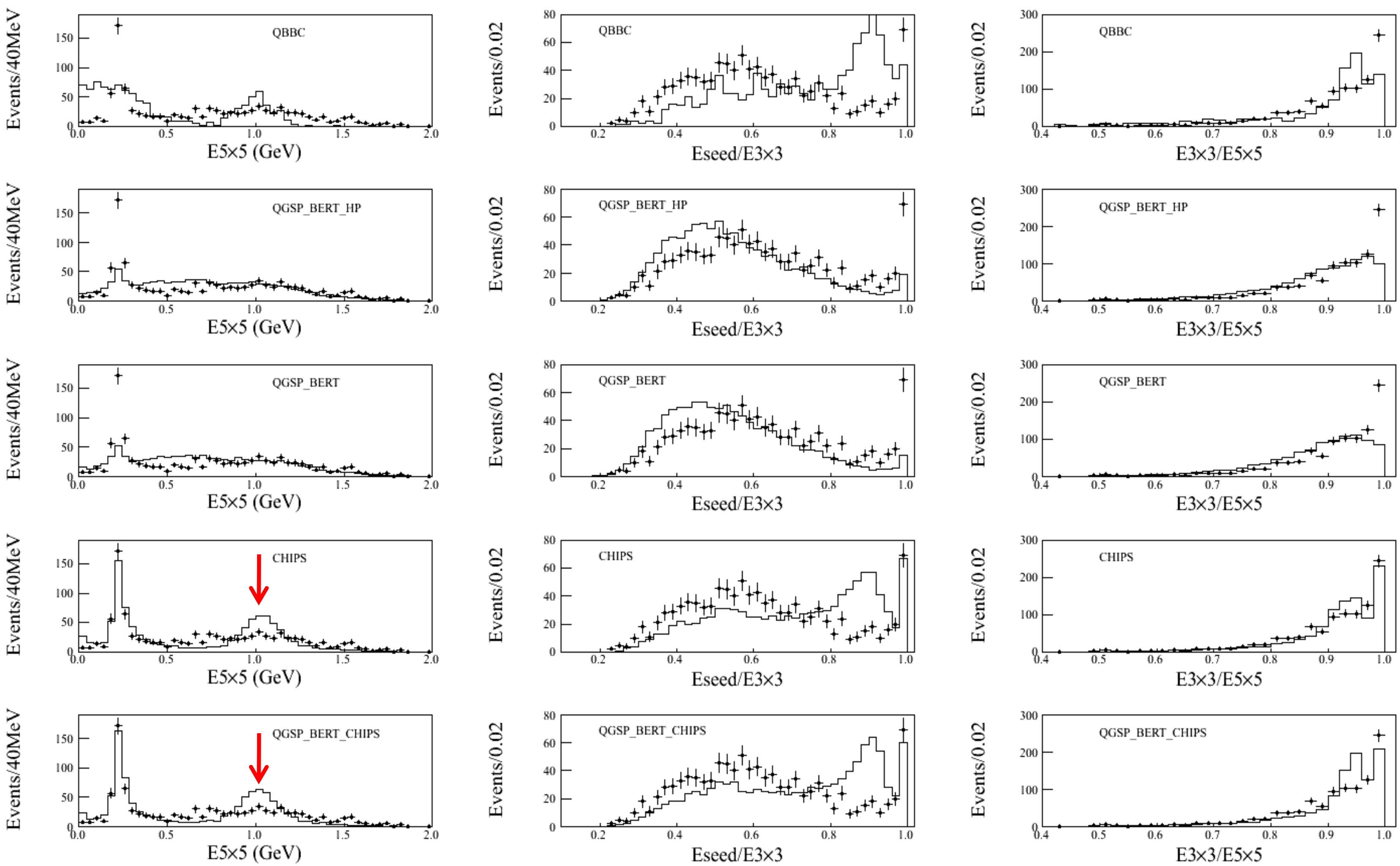
Physics lists	π^+/π^-	Proton	Anti-proton
QBBC	BERT	BIC	CHIPS
QGSP_BERT_HP	BERT	BERT	LE_GHEISHA
QGSP_BERT	BERT	BERT	LE_GHEISHA
CHIPS	CHIPS	CHIPS	CHIPS
QGSP_BERT_CHIPS	BERT	BERT	CHIPS

CHIPS: It's a new physics lists in GEANT4.9.3, CHIPS model is used for all particles at all energy region.

QGSP_BERT_CHIPS: Built by us based on QGSP_BERT, in which we only replaced GHEISHA model by CHIPS model for anti-proton inelastic and no other changes.

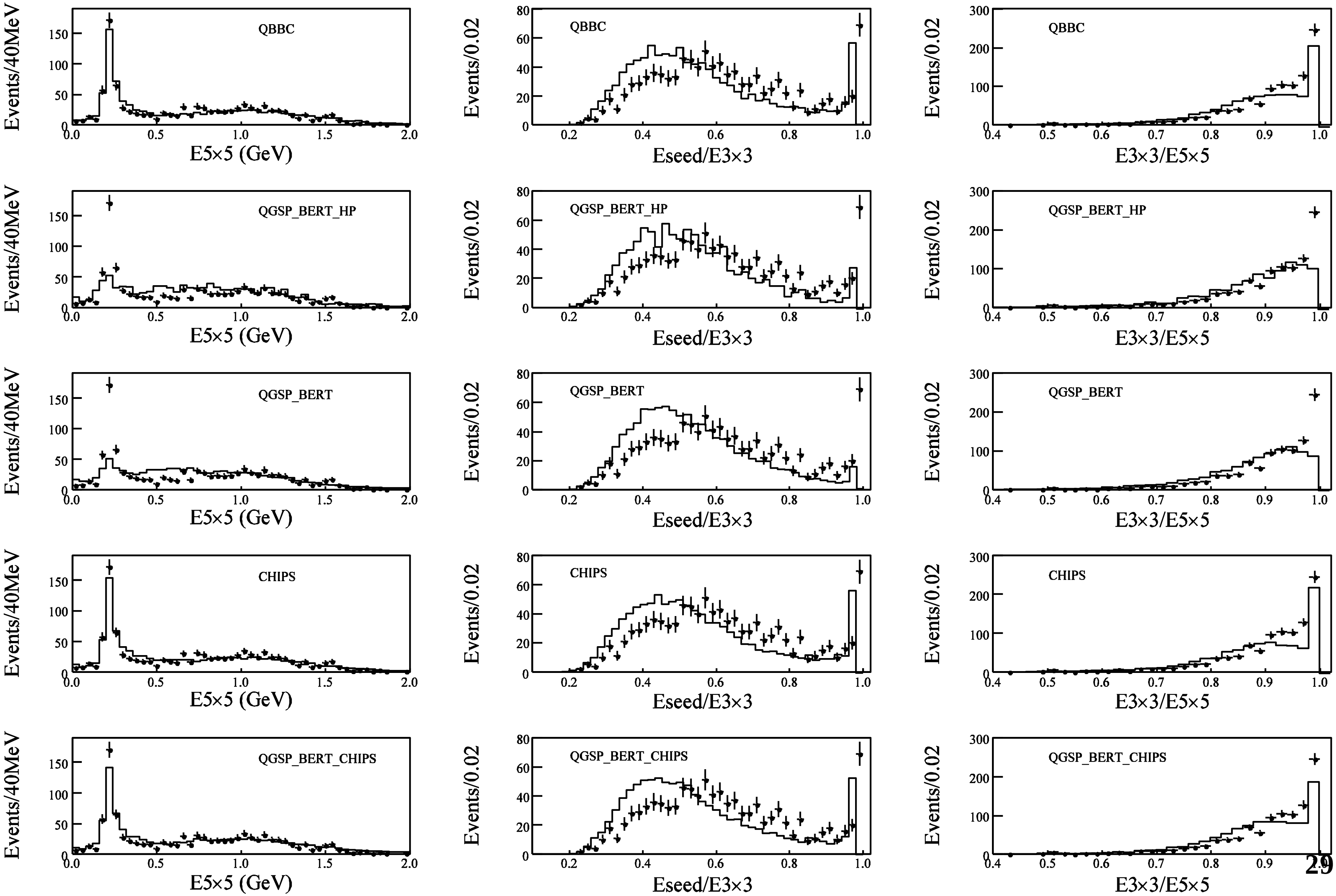
Comparisons with G4.9.3

Anti-proton [1.1, 1.4GeV/c]



Comparisons with G4.9.3.p01

Anti-proton [1.1, 1.4GeV/c]



Summary

- For electromagnetic interaction, we can get excellent agreements between MC and data.
- For $\pi+/\pi-$, 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 good agreements except QGSP/LHEP.
- In general, QGSP_BERT_HP is the best one for pions and protons.
- CHIPS model in G4.9.3.p01 can well simulate deposited energy of anti-proton, and the shower shape is also improved than previous versions.
- We have also selected Kaon and anti-neutron samples with good purity, so more comparison results will come soon.