RS RESPONSE DEPENDENCE ON GEANT4 HADRONIC INTERACTION MODELS
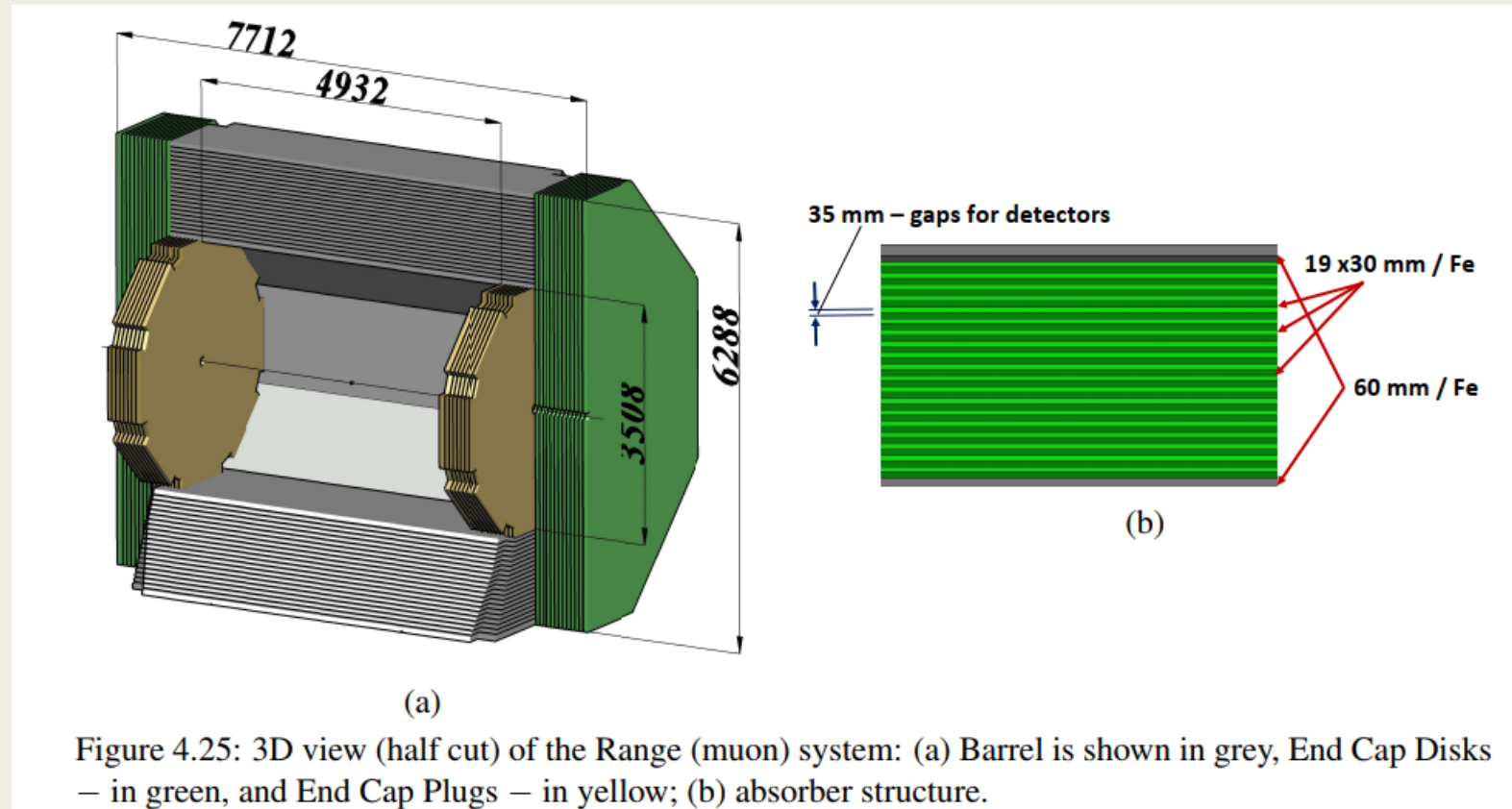
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The Summer Students Program 2020 at JINR

INTRODUCTION

- The polarized gluon content of proton and deuteron at intermediate will be investigated (SPD NICA) using among other **inclusive production of charmonia** as a probe.

- The inclusive J/ψ-production has a large cross-section and clear experimental signature, and thus is a powerful probe of the internal structure of proton and deuteron.

- Also production of prompt J/ψ-mesons looks most attractive, since large data set of $J/\psi \to \mu^-\mu^+$ (the branching fraction is 0.06) events is accumulated in beam-dump experiments. At pp collision energy of $27\ GeV$, $10^7\ s$ time of data taking (one year) with the maximum luminosity - one expects about 12 million $J/\psi \to \mu^-\mu^+$ decays in the SPD detector.

RANGE (MUON) SYSTEM

- The Range System of the SPD detector serves to identify muons in presence of a hadronic background.

- The system is expected to separate showers from strongly interacting pions and muon tracks.

Figure 4.25: 3D view (half cut) of the Range (muon) system: (a) Barrel is shown in grey, End Cap Disks – in green, and End Cap Plugs – in yellow; (b) absorber structure.
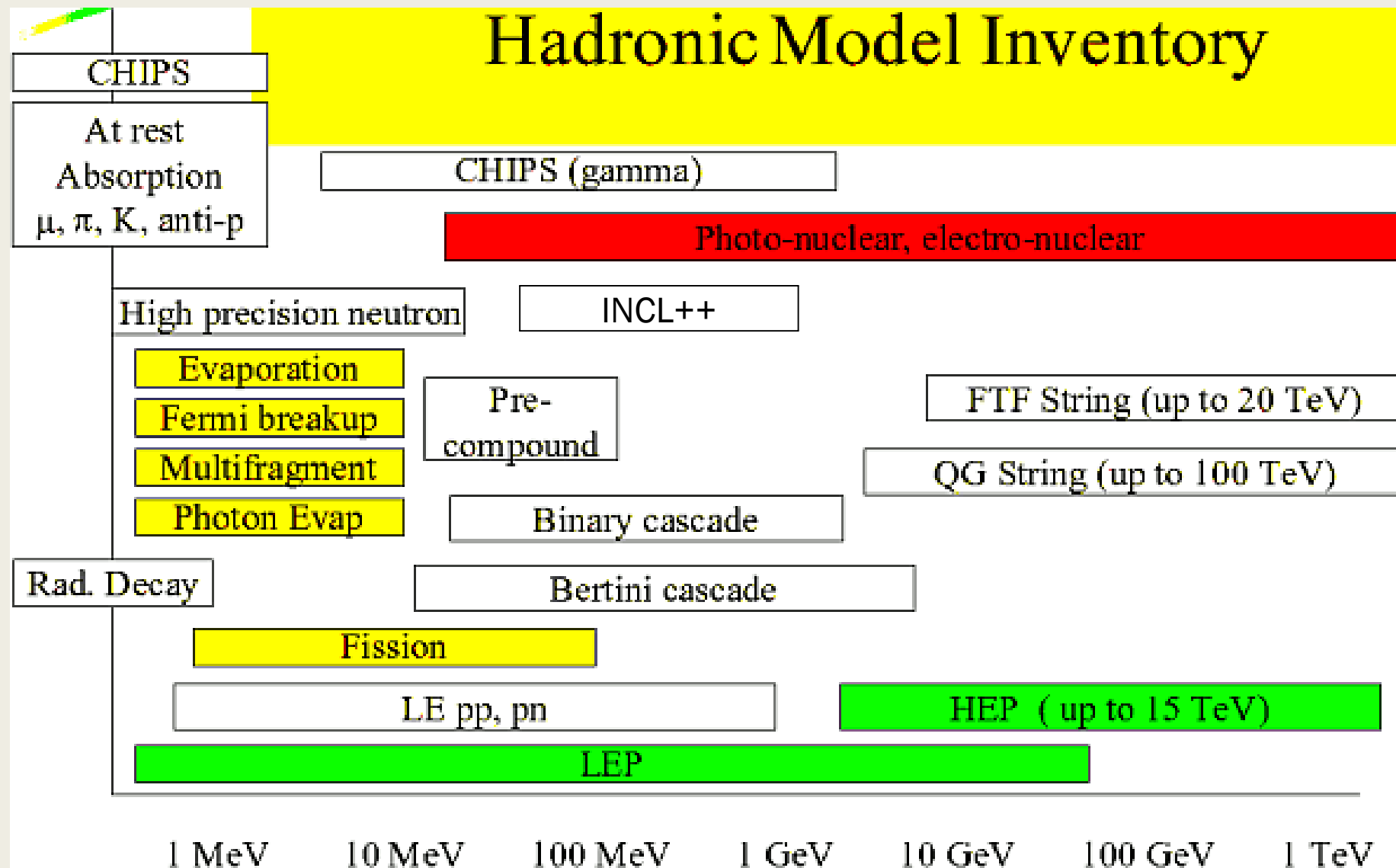
MUONS/HADRONS SEPARATION

- There are three sources of muon background giving the same (muon-like) signal in RS:

- pions (and other hadrons) traversing (a large distance) the iron absorber with ionization energy losses only;

- decay muons from pions.

- Variables:

- **hit multiplicity in an event;**

- last fired layer;

- shower starting layer number (first layer out of 3 with ≥ 2 hits per layer);

- first fired layer;

- number of hits in last layer.

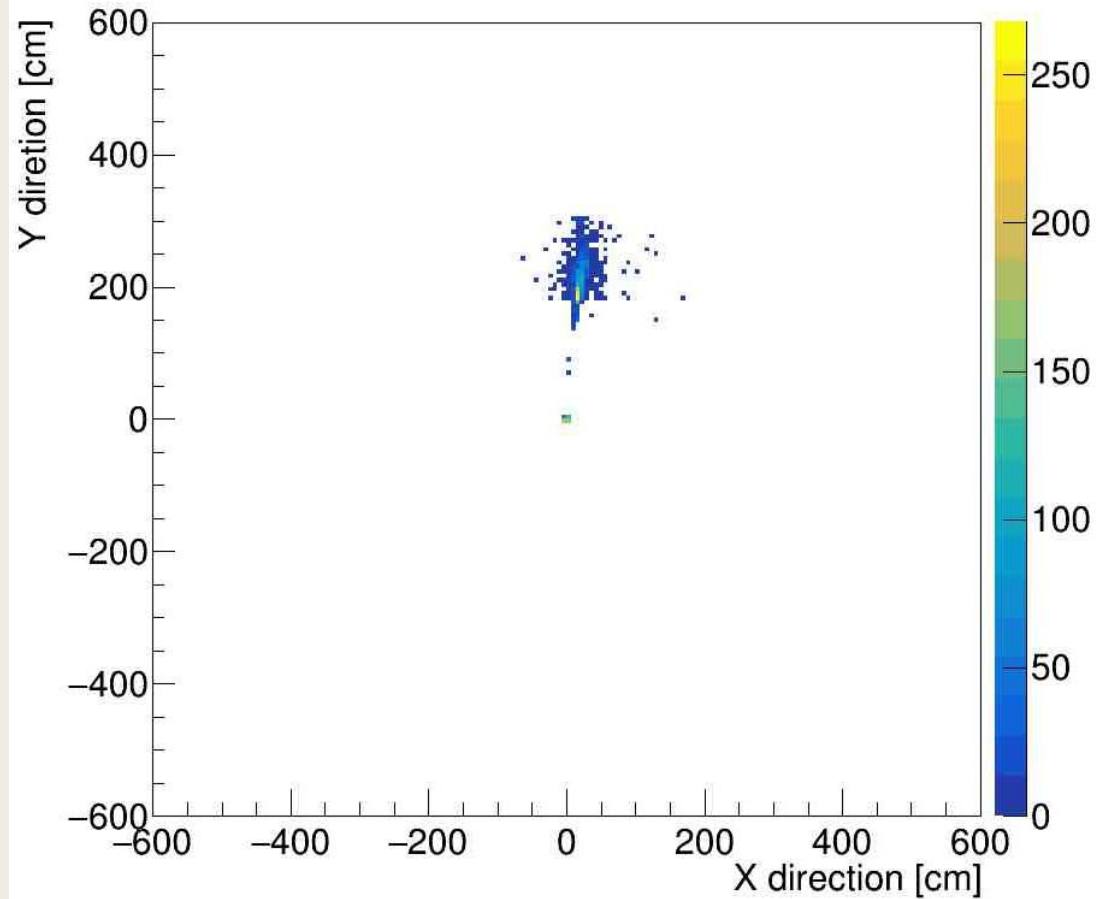# HADRONIC INTERACTIONS IN GEANT4

- The simulated energy range (from 0.1 to 1 GeV) requirement follows from the kinematic range of secondary particles, which are produced in a collision of protons with energy up to 27 GeV and emitted into 4π solid angle

- The **INCL++** is the Liège intranuclear cascade model («QGSP_INCLXX», «FTFP_INCLXX») for $\sim 200\ MeV$. The strategy adopted by the INCL++ is to improve the quasi-classical treatment of physics without relying on too many free parameters.

- Interactions are between a primary or secondary particle and an individual nucleon of the nucleus, leading to the name **BInary Cascade** «FTF_BIC» in range from $10\ MeV$ to $1200\ MeV$

- The **BERT**ini intra-nuclear cascade model treats nuclear reactions initiated by long-lived hadrons with energies between 0 and $10\ GeV$ («FTFP_BERT»).

- The **FTF** group based on the FRITIOF (like string model) for $p, n, \pi^{\pm}$.

- The **QGS** lists group based on a modeling using Quark Gluon String model for high energy hadronic interactions of $p, n, \pi^{\pm}$.

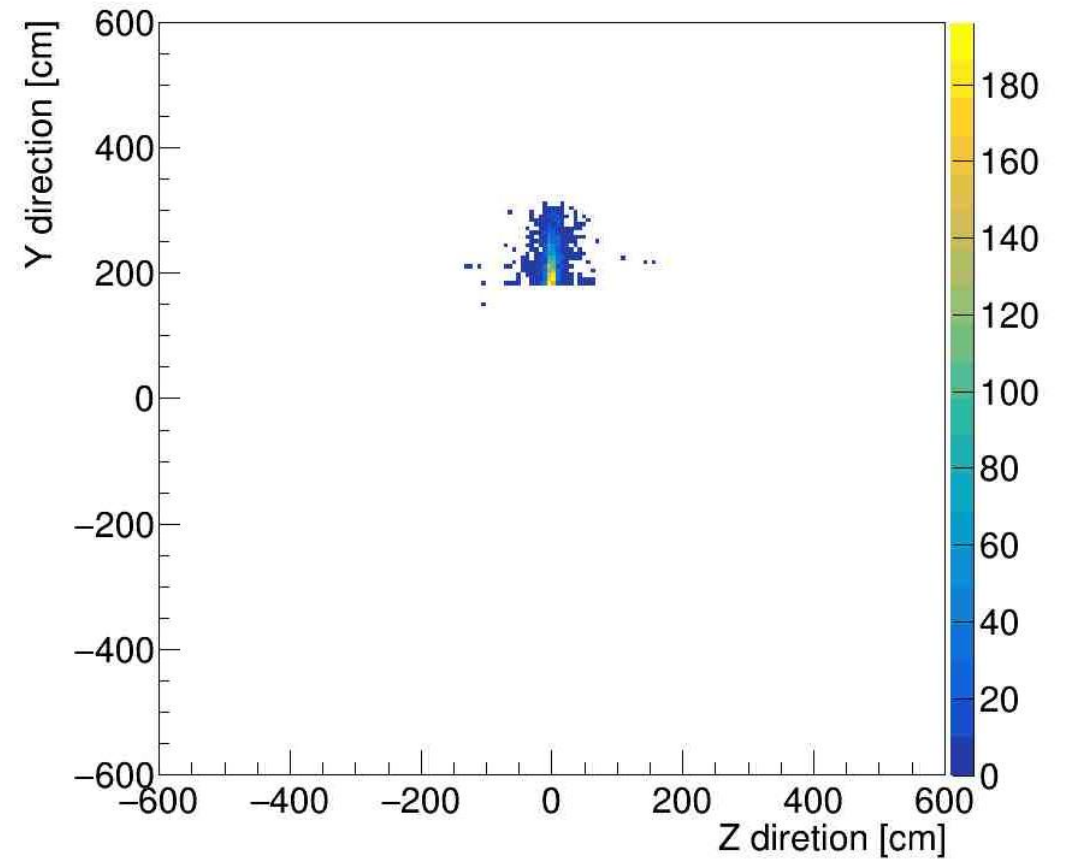- «QBBC» - QGSC_BIC for p, n and QGSC_BERT for $\pi^{\pm}$.

HADRONIC MODELS IN GEANT4

Hadronic Model Inventory

| | CHIPS | | | | | | |

At rest
Absorption
μ, π, K, anti-p

CHIPS (gamma)

Photo-nuclear, electro-nuclear

High precision neutron   INCL++

Evaporation

Fermi breakup

Multifragment   Pre-compound

Photon Evap

Binary cascade

FTF String (up to 20 TeV)

QG String (up to 100 TeV)

Rad. Decay

Bertini cascade

Fission

LE pp, pn   HEP (up to 15 TeV)

LEP

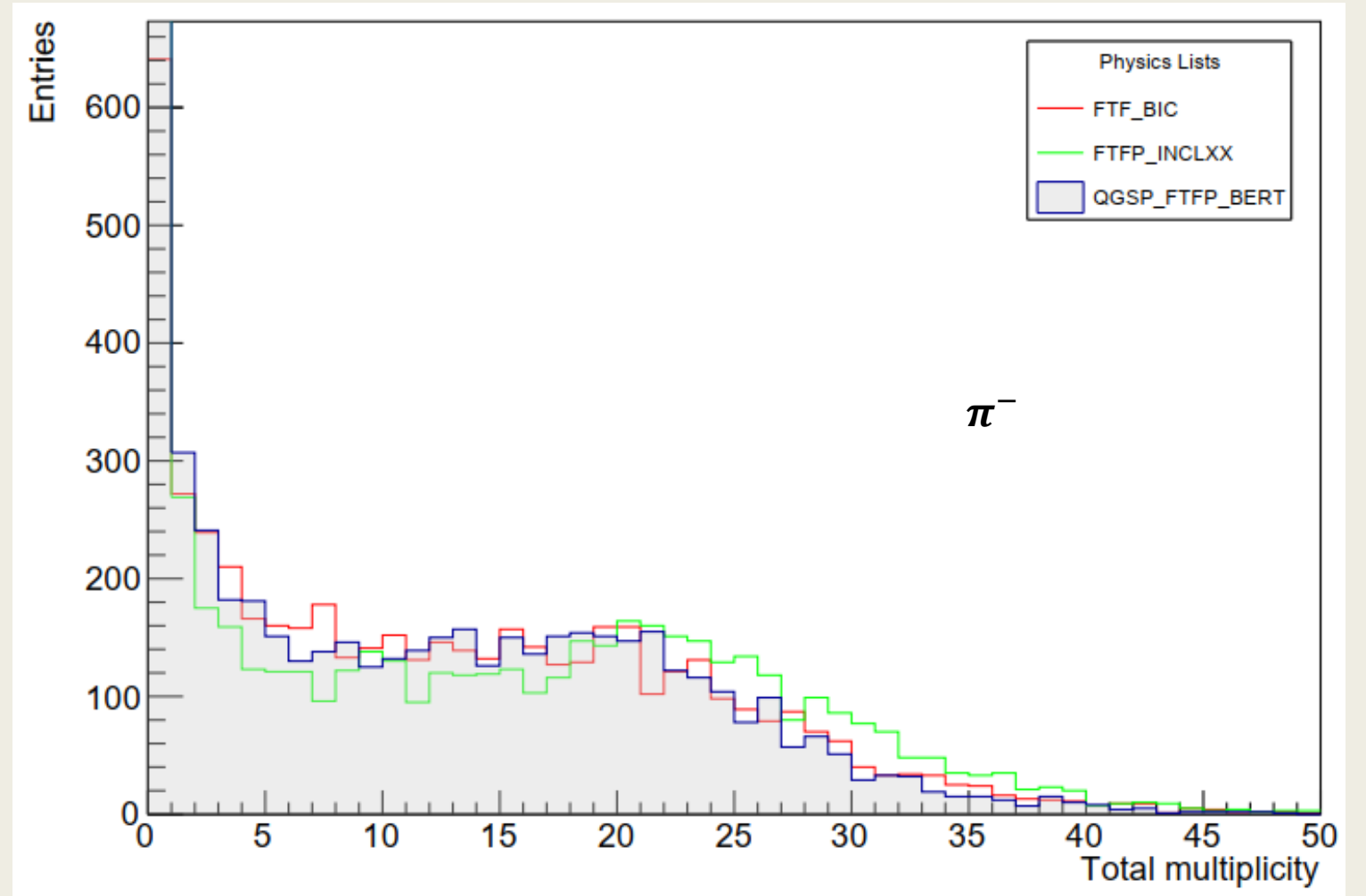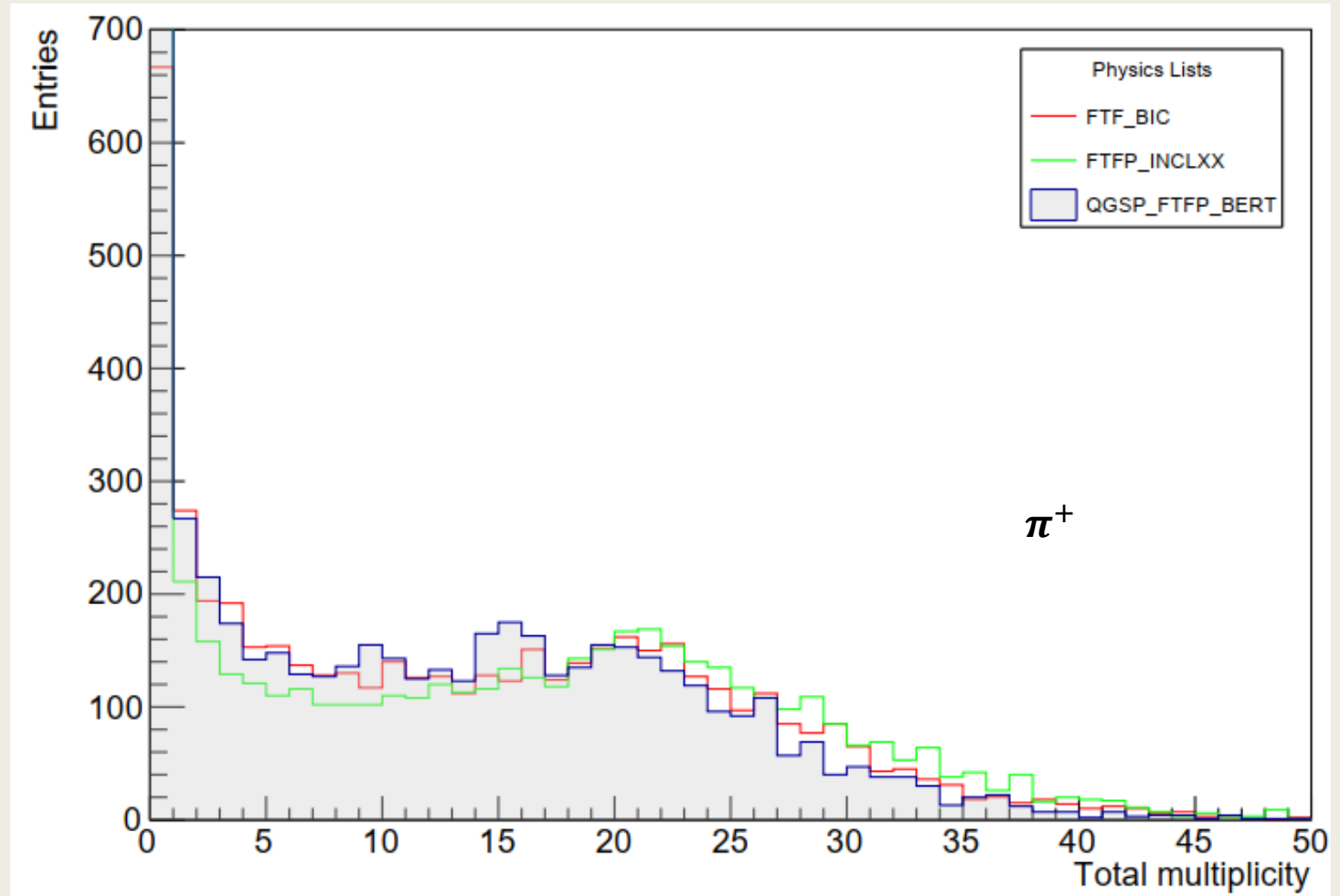| 1 MeV | 10 MeV | 100 MeV | 1 GeV | 10 GeV | 100 GeV | 1 TeV |

SIMULATION DETAILS

RESULTS

Hits multiplicity for a π^-

Total 5000 events

The reference model is filled in gray.

Weighted mean of hits multiplicity	
FTF_BIC	13.2
FTF_INCLXX	15.1
QGSP_FTFP_BERT	12.8

RESULTS

Hits multiplicity for a π^+

Total 5000 events

The reference model is filled in gray.

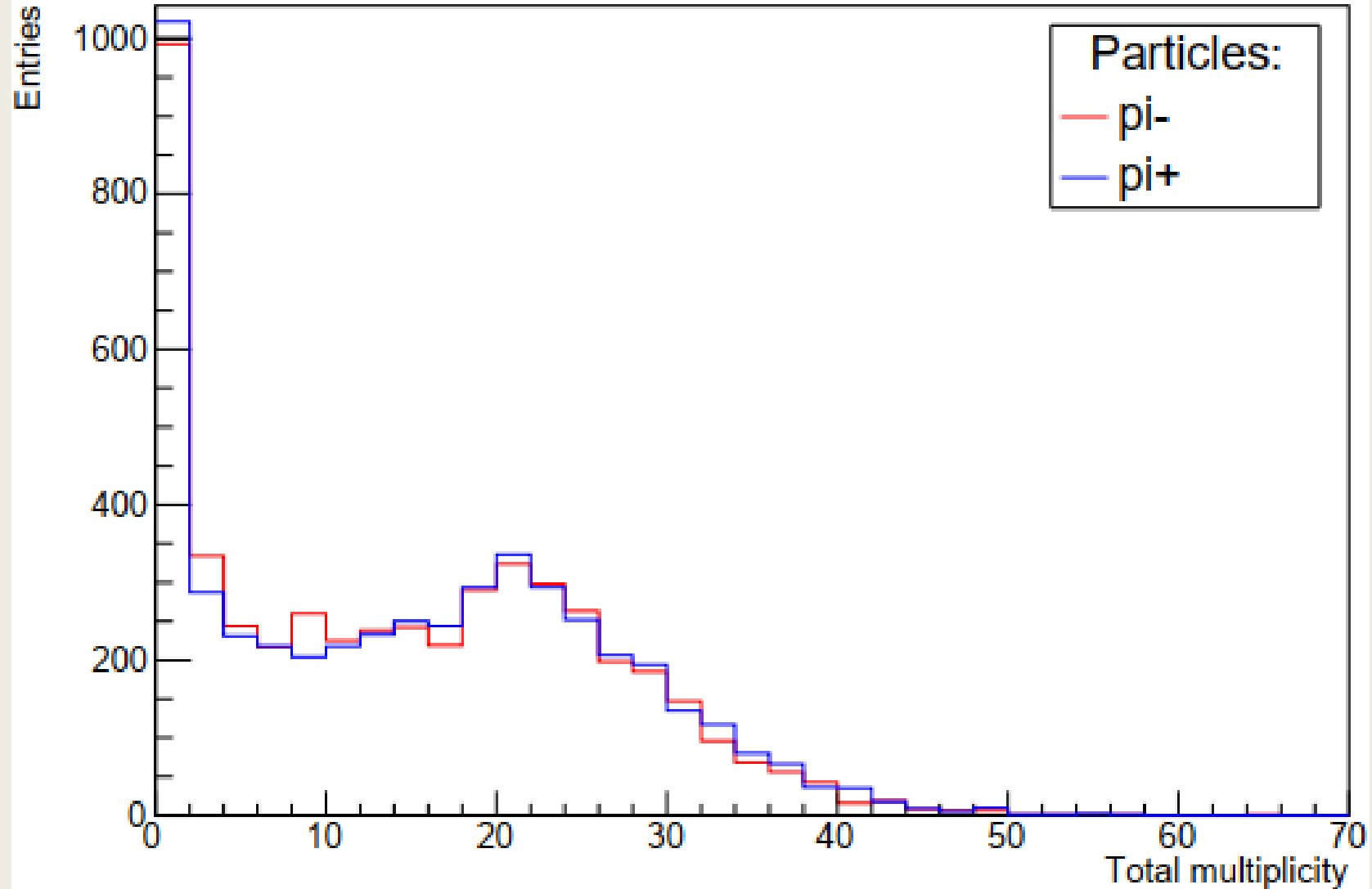| Weighted mean of hits multiplicity	
FTF_BIC	14.2
FTF_INCLXX	15.4
QGSP_FTFP_BERT	13.1

RESULTS

Comparison of results for a π^- and π^+
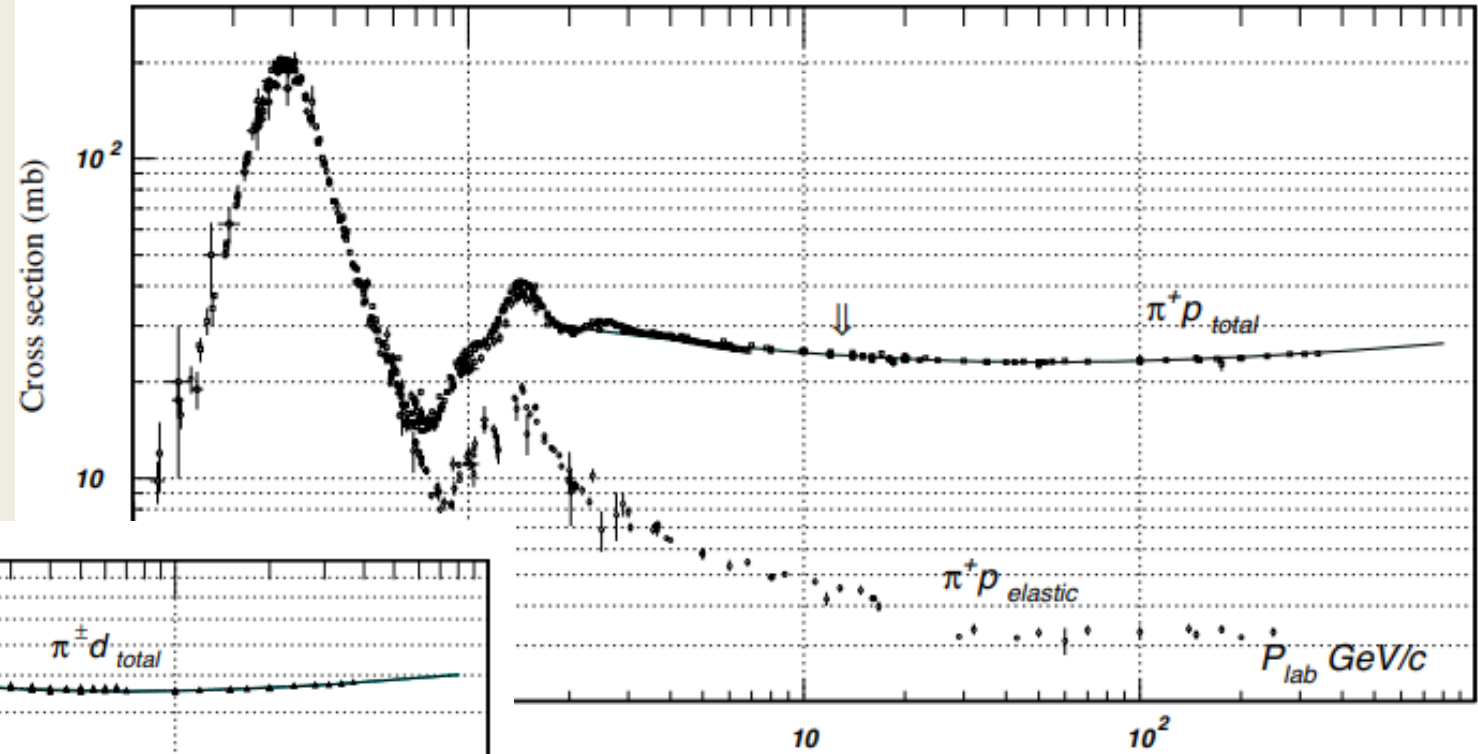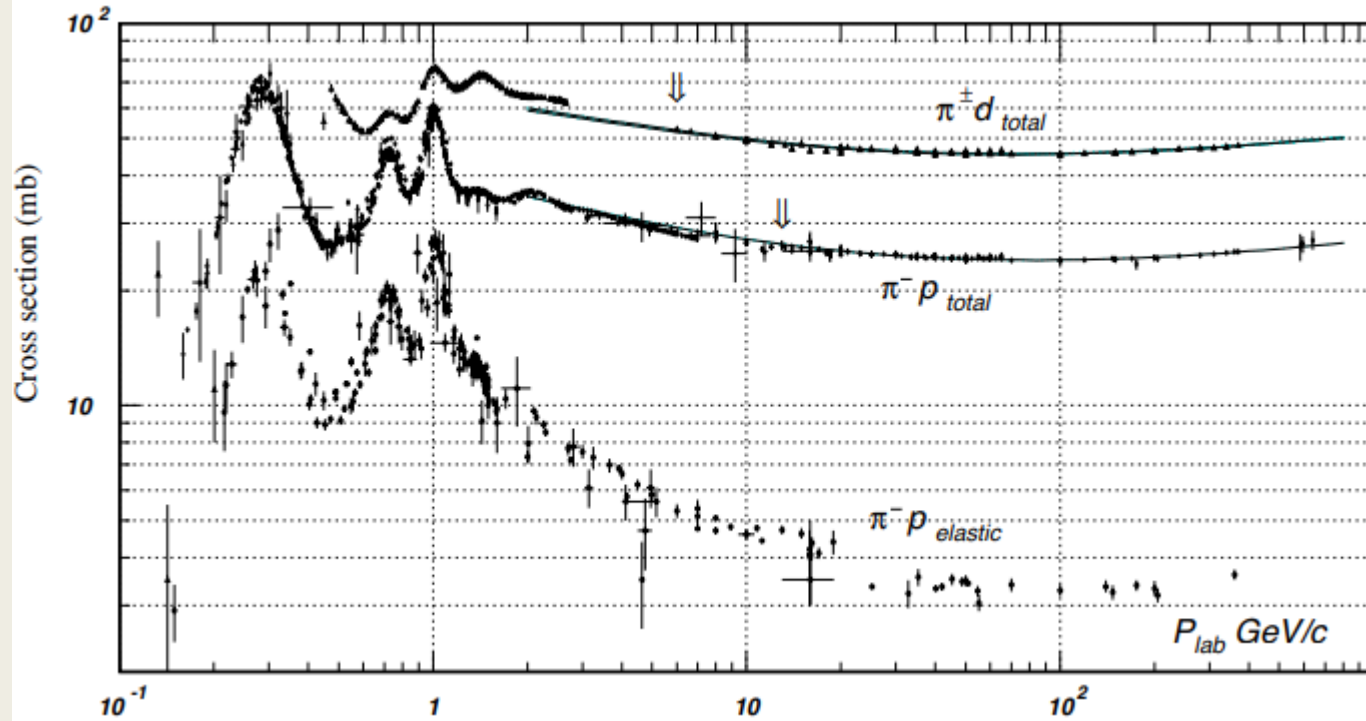
Hits multiplicity for a π^- and π^+
(for 5000 events, reference model - QGSP_FTFP_BERT).

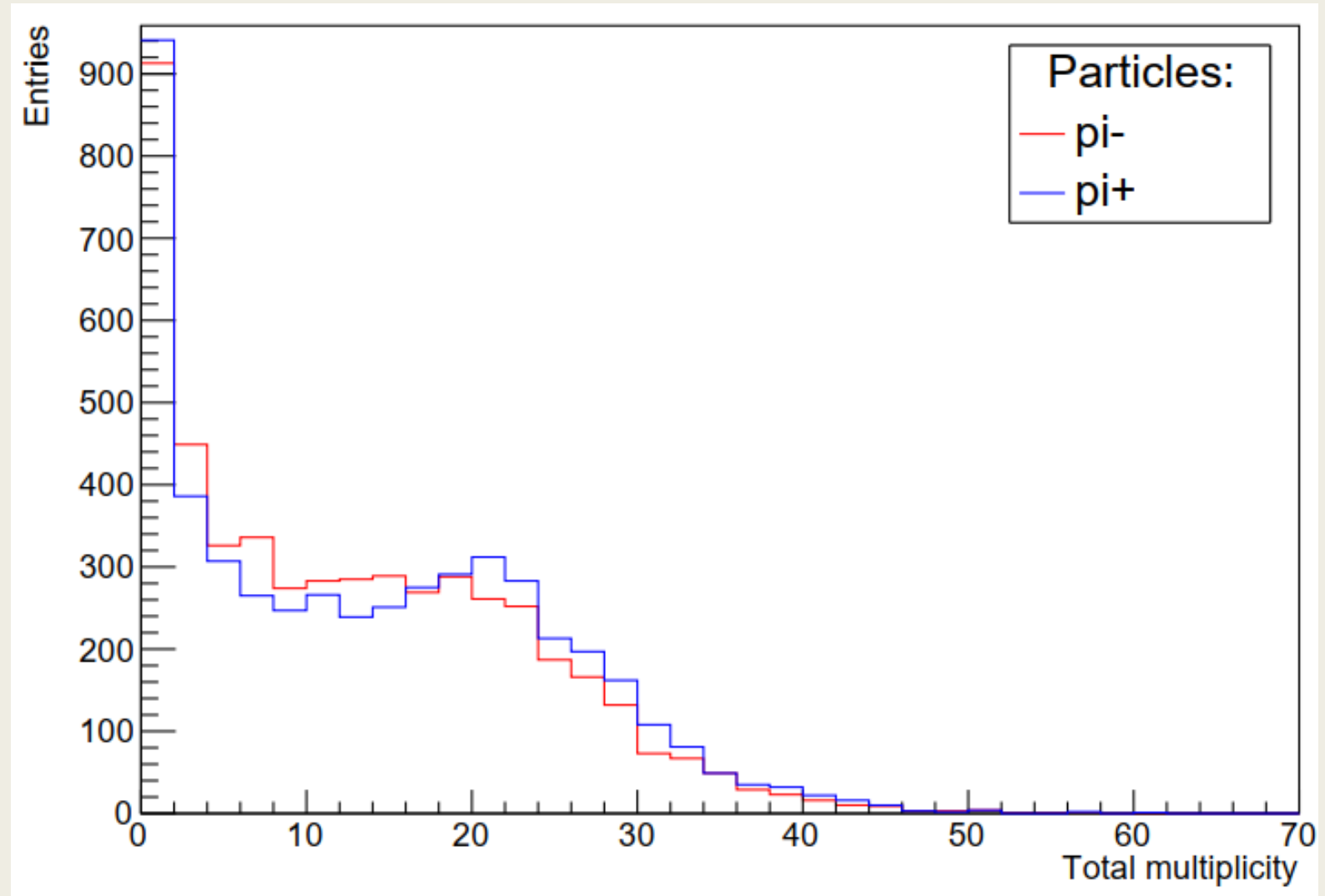| Weighted mean of hits multiplicity	
π^+	12.8
π^-	13.1

RESULTS

Total and elastic cross sections for $\pi^{\pm}p$ and $\pi^{\pm}d$ (total only) collisions as a function of laboratory beam momentum.
(Courtesy of the COMPAS Group, IHEP, Protvino, April 2012)

RESULTS

Comparison of results for a π^- and π^+

Hits multiplicity for a π^- and π^+
(for 5000 events, model name - FTFP_BIC).

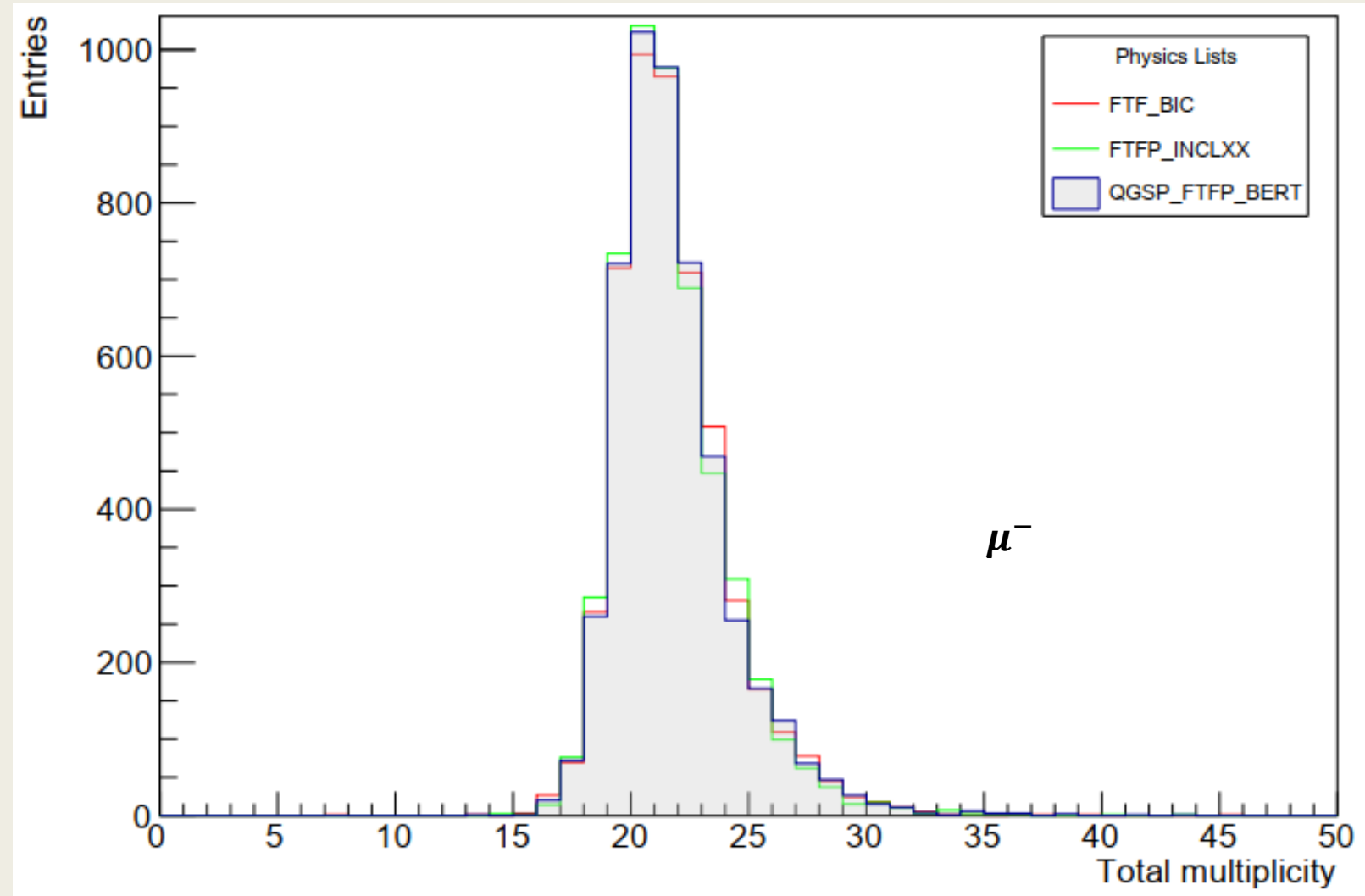| Weighted mean of hits multiplicity	
π^+	14.2
π^-	13.2

RESULTS

Hits multiplicity for a μ^-

Total 5000 events

The reference model is filled in gray.

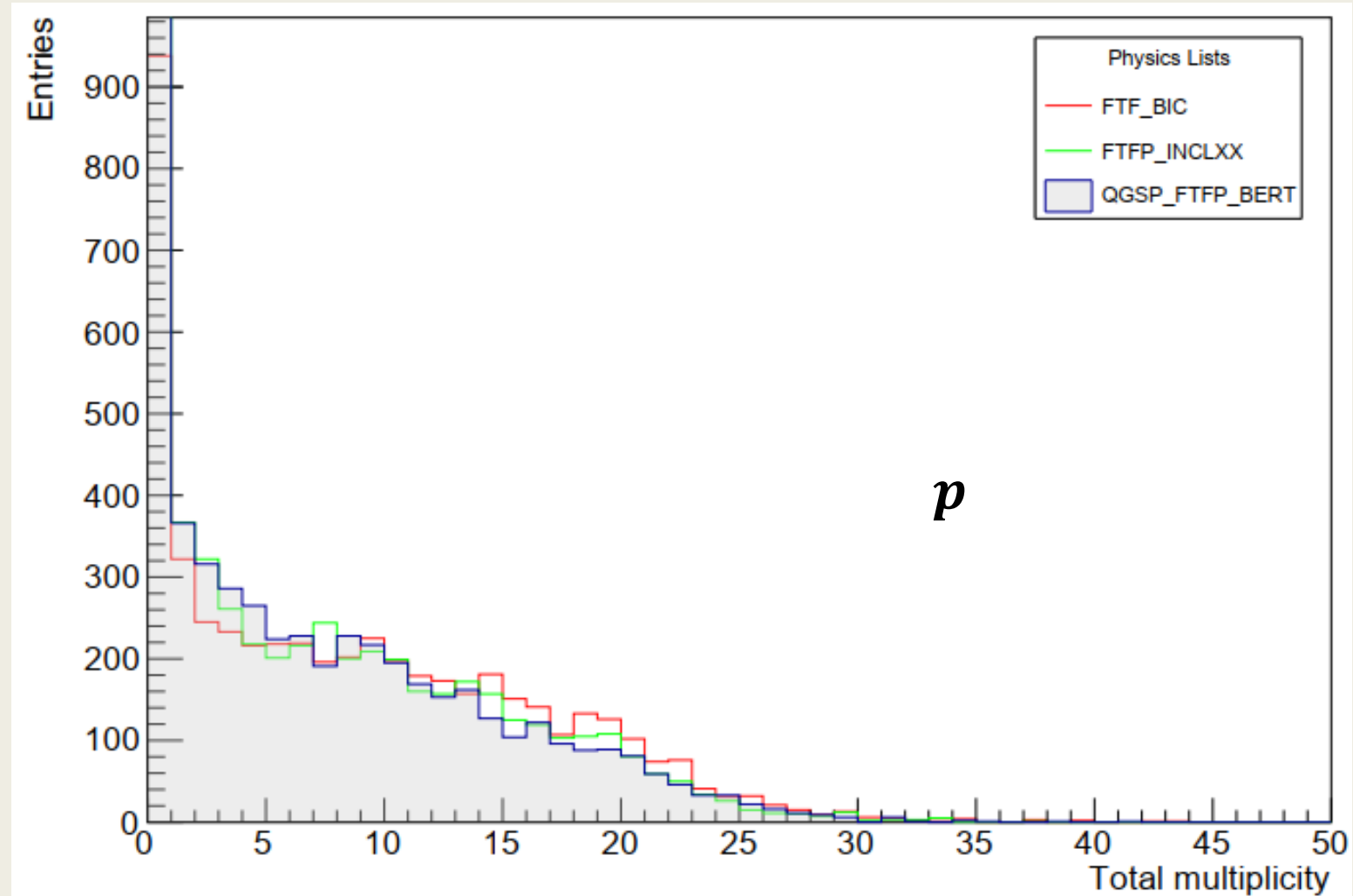| Weighted mean of hits multiplicity	
FTF_BIC	22.3
FTF_INCLXX	22.243
QGSP_FTFP_BERT	22.3114

RESULTS

Hits multiplicity for a *p*

Total 5000 events

The reference model is filled in gray.

Weighted mean of hits multiplicity	
FTF_BIC	9.4
FTF_INCLXX	8.4
QGSP_FTFP_ BERT	8.2

RESULTS

The response patterns of the Range System for p, π^-, π^+, μ^-

p – the blue line
π^+ – the green line
π^- - the red line
μ^- - the gray line

Total - 5000 entries

number of hits in an event

CONCLUSION

For 5000 generated events:

- there is **no** significant difference in the detector response to protons for all models;

- there is **no** significant difference in the detector response to muons for all models;

- there is **no** difference between the response to π^+ and π^- for the reference model;

- there is **no** significant difference in the detector response to pions for all models except _INCLXX (**a weak** model dependence);

- there is **no** difference between the response to π^+ and π^- for the reference model;

- there is **a weak difference** between the response to π^+ and π^- for the FTFP_BIC model.

Comparison of other variable characteristics of hadron showers in the RS, error analysis and a more detailed interpretation of the results will be performed in the next steps of my work.

Thanks for your attention!