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Cosmic Ray Monte Carlo Simulation Models and Strange Hadron Production in High-Multiplicity Hadronic Collisions: simulation study

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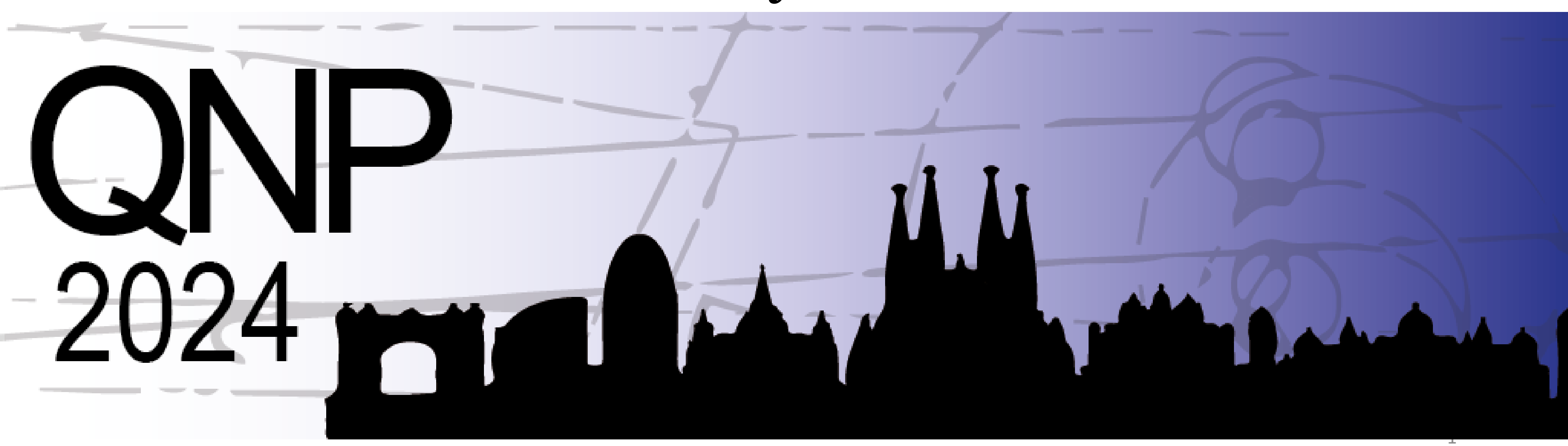


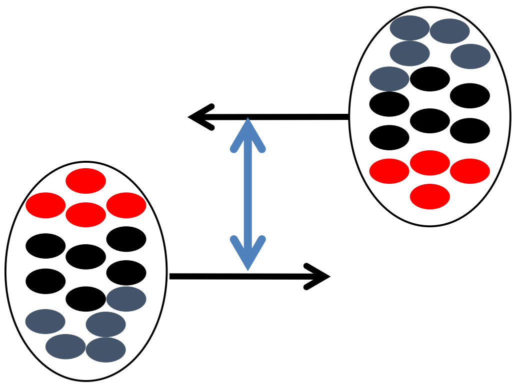
Outline:

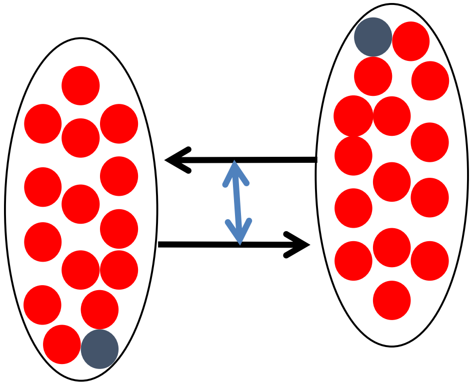
- Motivation
- Strange Hadrons
- Cosmic Rays
- Simulation Models
- Comparison
- Outlook

Motivation:

- The production of strange hadrons in high-energy hadronic interactions provides a way to investigate the properties of quantum chromodynamics (QCD), the theory of strongly interacting matter.
- Unlike up (u) and down (d) quarks, which form ordinary matter, strange (s) quarks are not present as valence quarks in the initial state, yet they are sufficiently light to be abundantly created during the course of the collisions.
- String fragmentation models tend to suppress the production of strange hadrons relative to those with only light quarks. The suppression of strangeness in elementary collisions is an important parameter in Monte Carlo models. Measuring strange hadron production can therefore help constrain these models.

Motivation:





- Peripheral collision
  - Large distance between the centers of the nuclei
  - Small number of participants
  - Few charged particles produced (low multiplicity)

- Central collision
  - Small distance between the centers of the nuclei
  - Large number of participants
  - Many charged particles produced (high multiplicity)

Motivation:

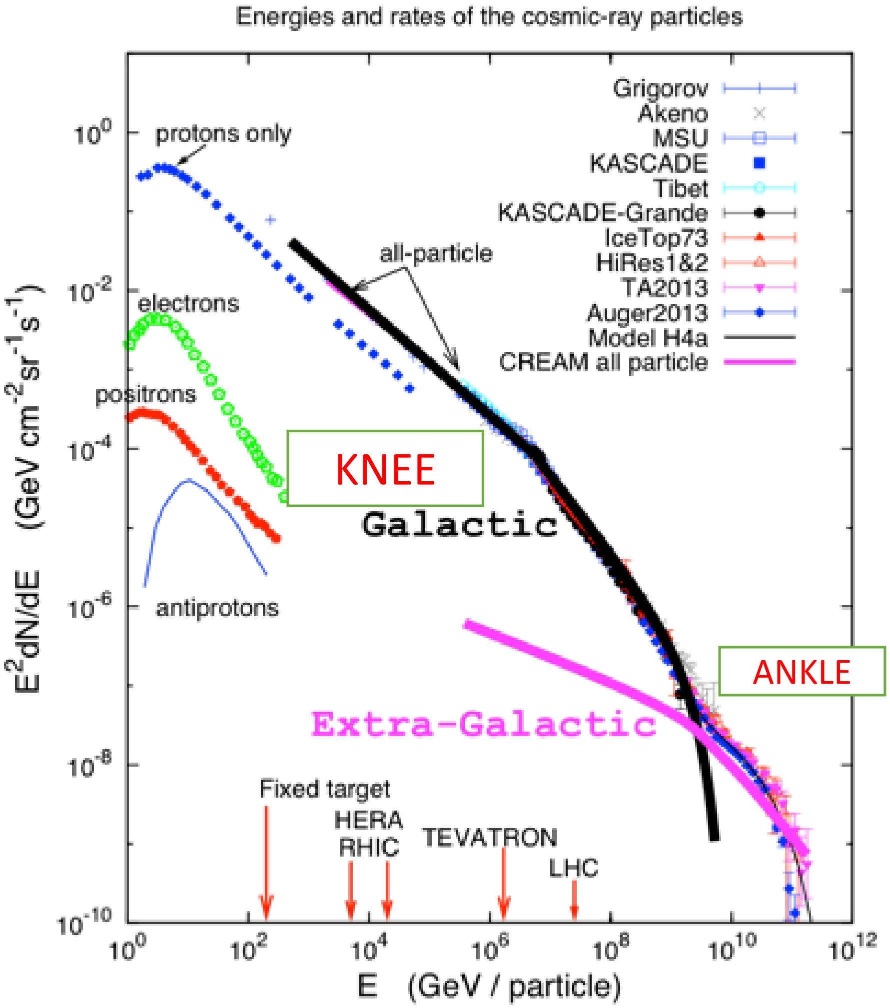
- One million pp collision at 7 TeV are simulated with the same setting in the ALICE data
- Primary strange particles: K_S^0, Λ, Ξ and Ω
- Multiplicity classes: MC1 – MC10 from high to low multiplicity

$K_S^0 \rightarrow \pi^+ + \pi^-.$ $\quad$ $\pi^+ \rightarrow \mu^+ + \nu_\mu$ and $\pi^- \rightarrow \mu^- + \bar{\nu}_\mu$

$\Lambda \rightarrow p + \pi^-.$ $\quad$ $p \rightarrow n + \mu^+ + \nu_\mu.$

$\Xi \rightarrow \Lambda + \pi^-.$

Cosmic Rays:



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Simulation:

- EPOS-LHC:
  - Used for hadron–hadron and nucleus–nucleus interactions, and for cosmic ray air shower simulation
- Pythia:
  - An event generator developed to generate interactions of high-energy particles to produce their properties in strong interaction.
  - Successful in explaining macroscopic flow features in pp collisions
- QGSJETII
  - Based on Quark Gluon model using Gribov–Regge theory
  - It encompasses interactions such as nucleus-nucleus collisions and semi-hard processes via the ”semi-hard Pomeron”
- SIBYLL:
  - It’s captures fundamental aspects of multi-particle production, encompassing phenomena like the leading particle effect, the formation of high-transverse momentum jets predicted by Quantum Chromodynamics (QCD), production of diffractively excited states of projectile and target, and the approximate scaling of leading particle distributions with interaction energy.

PYTHIA8 and EPOS have been widely used to model collision systems in QCD

QGSJETII and SIBYLL are known as standard hadronic event generator for simulating extensive air showers induced by high-energy cosmic rays

Simulation:

- Tsallis distribution function:
  - Used to fit the experimental data ALICE 2017, and extract the properties of the medium formed during collisions.

$$\frac{1}{N_{ev}}\frac{1}{2\pi p_T}\frac{d^2N}{dydp_T} = Cm_T\left(1+(q-1)\frac{m_T}{T_{eff}}\right)^{-q/(q-1)}$$

this distribution incorporates parameters like C for normalization, q for non-extensivity, mT for transverse mass, and Teff for effective temperature

- Temperatures:
  - Initial temperature: The initial temperature describes the excitation degree of interacting system at the initial stage of collisions.
  - Chemical freeze-out temperature: The chemical freeze out temperature describes the excitation degree of interacting system at the stage of chemical equilibrium
  - Effective Temperature: Effective temperature is not a real temperature. It includes the kinetic freeze-out temperature and flow velocity
  - Kinetic freeze out temperature: The kinetic freeze out temperature describes the excitation degree of interacting system at the stage of thermal equilibrium
- Flow velocity: describes the kinetic expansion charactersitics of the interacting system
- Volume: The volume occupied by such ejectiles source where the mutual nuclear interactions become negligible (they only feel the coulombic repulsive force and are free from the attractive force)

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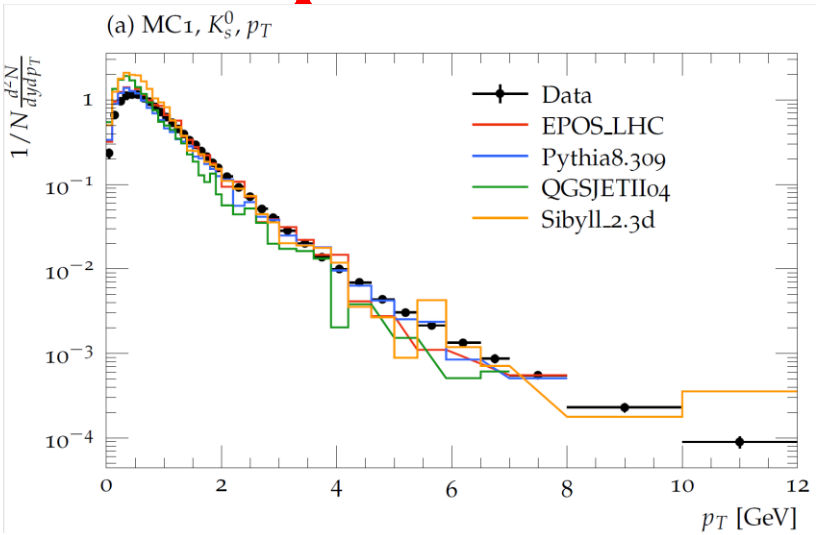
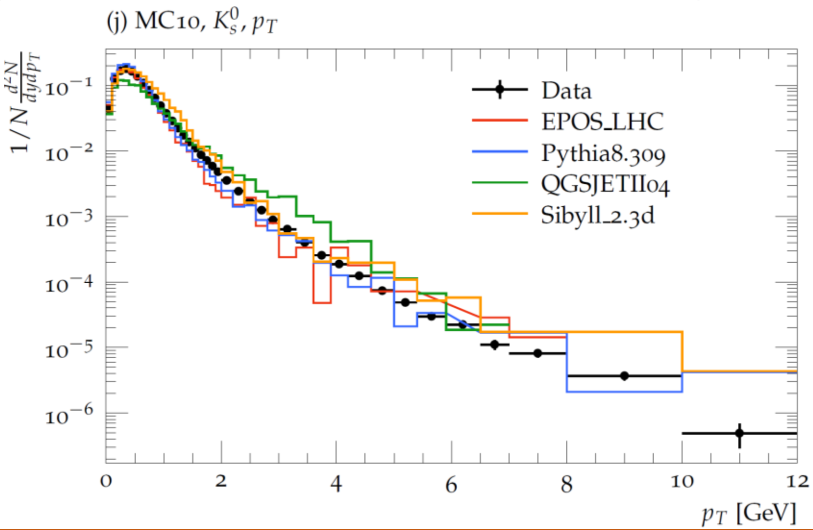
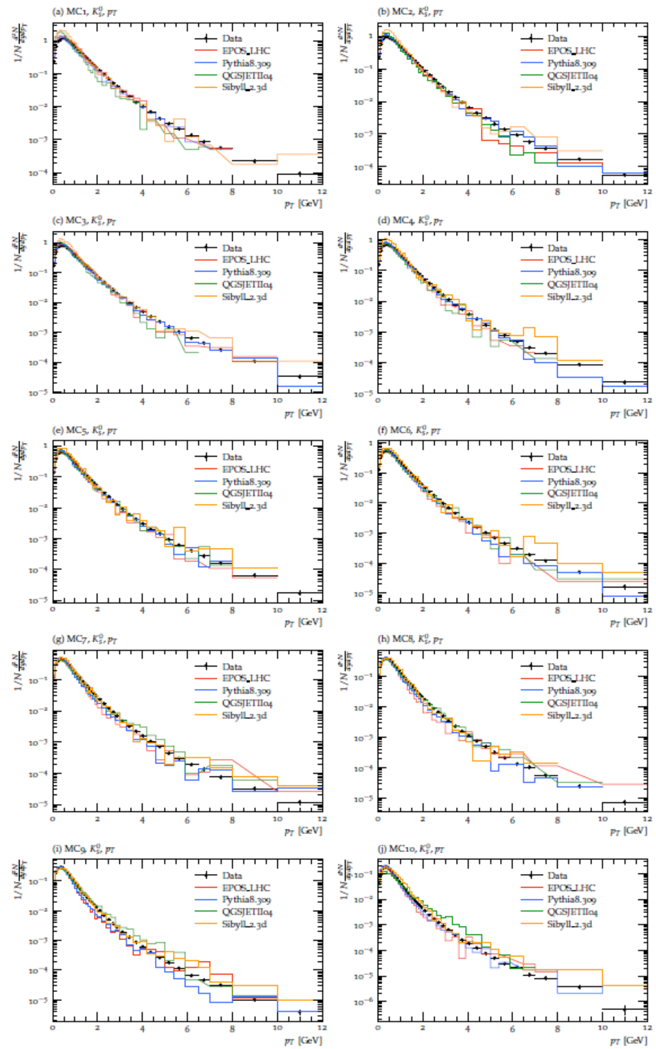
Comparison:







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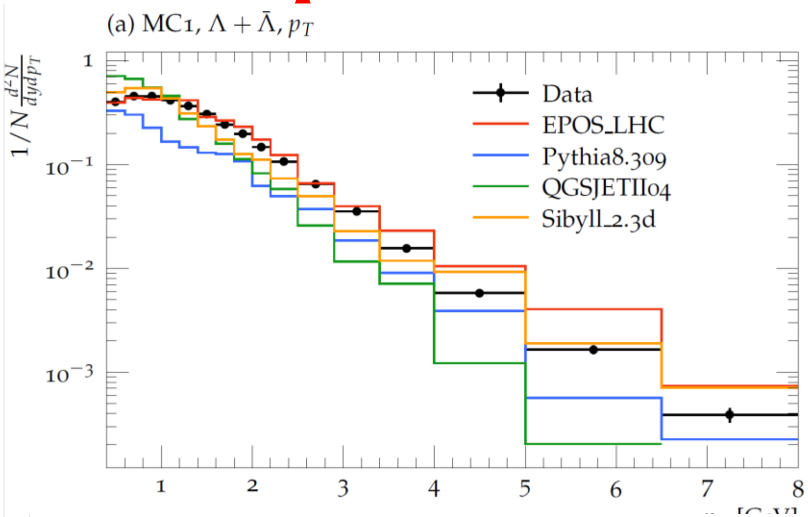
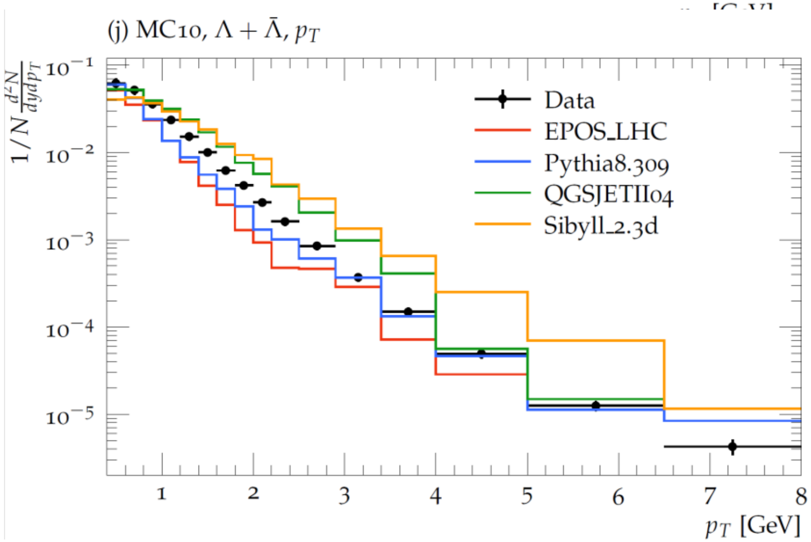
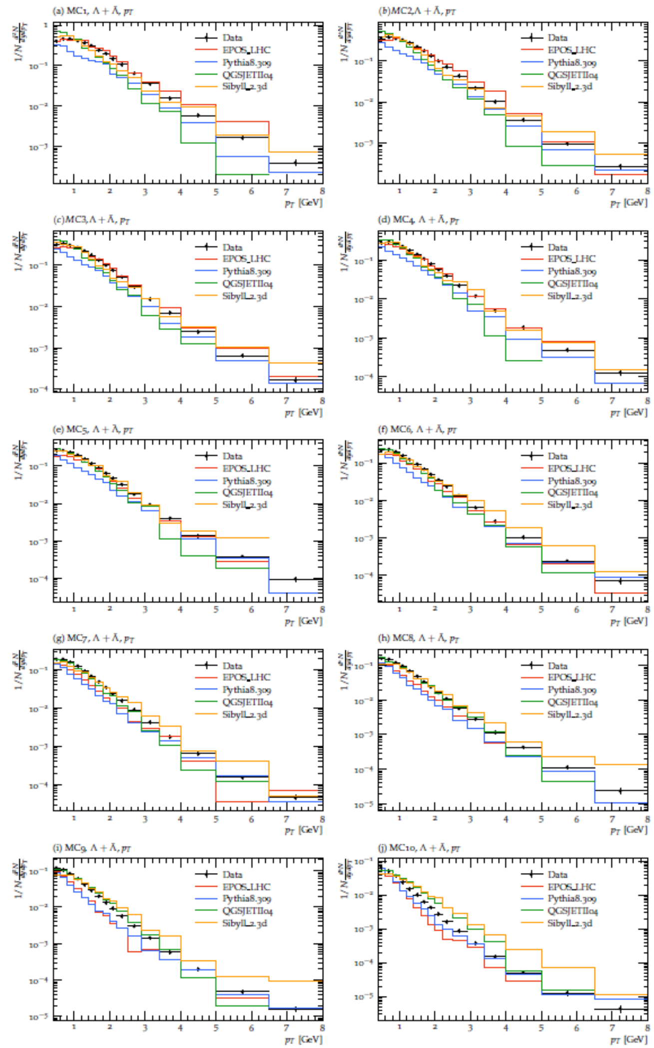

(a) MC1, $\Lambda + \bar{\Lambda}$, p_T
$1/N \frac{d^2N}{dydp_T}$
Data
EPOS_LHC
Pythia8.309
QGSJETII04
Sibyll_2.3d


(j) MC10, $\Lambda + \bar{\Lambda}$, p_T
$1/N \frac{d^2N}{dydp_T}$
Data
EPOS_LHC
Pythia8.309
QGSJETII04
Sibyll_2.3d
p_T [GeV]



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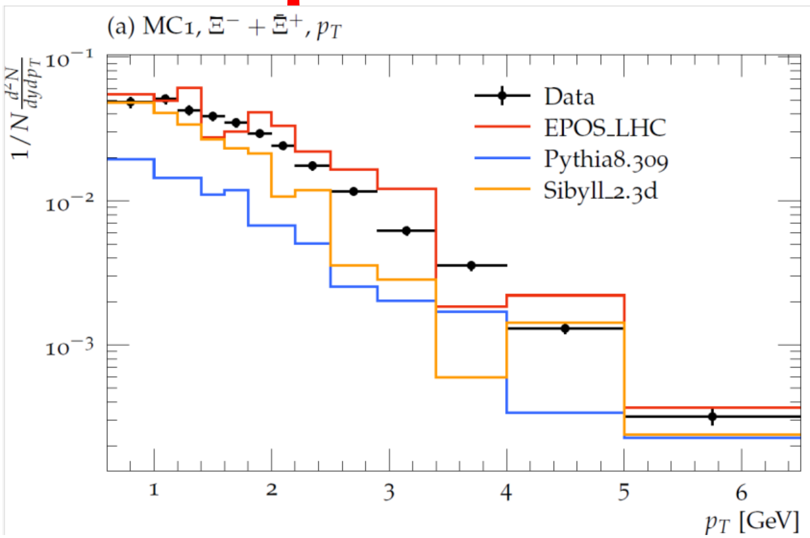

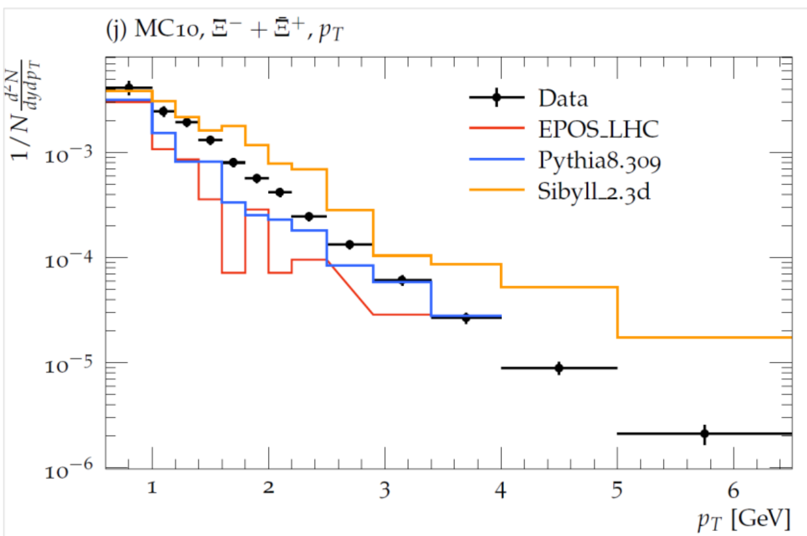

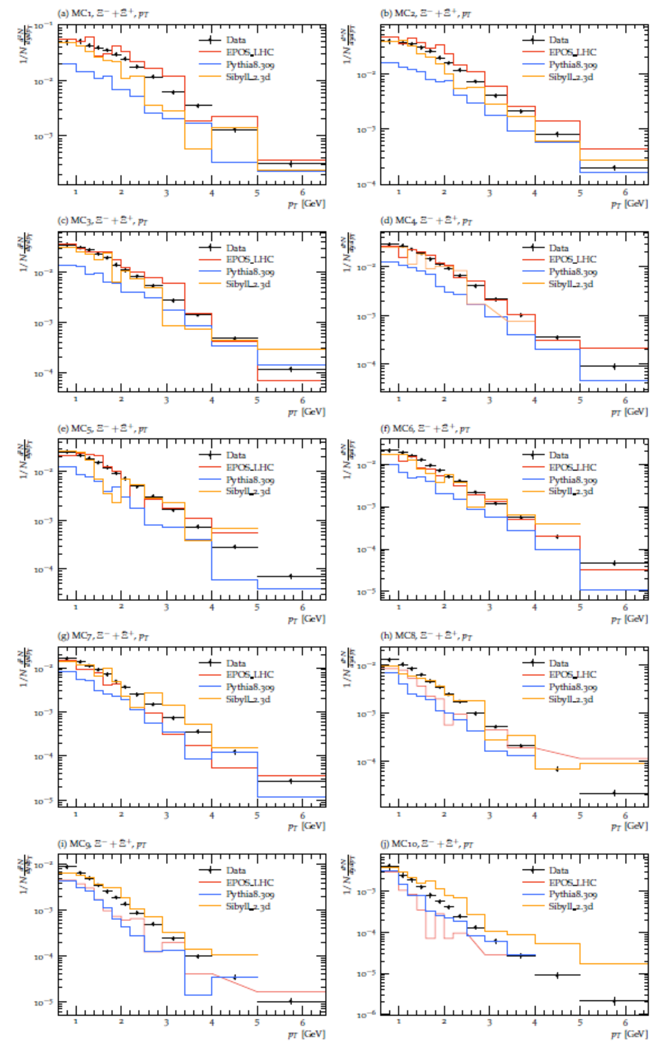

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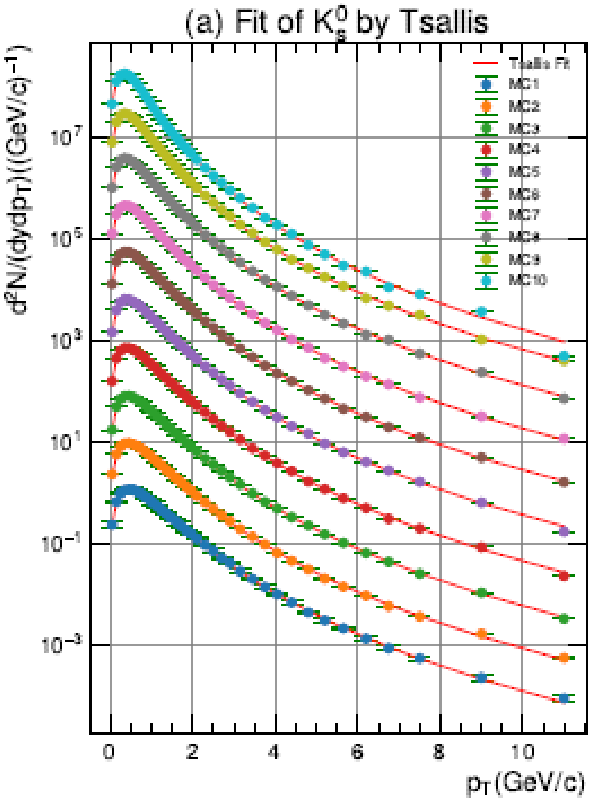

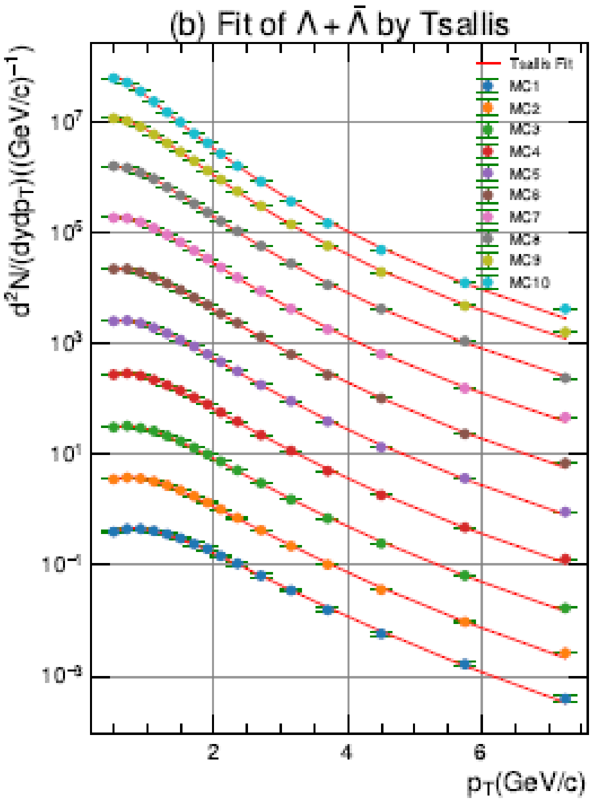

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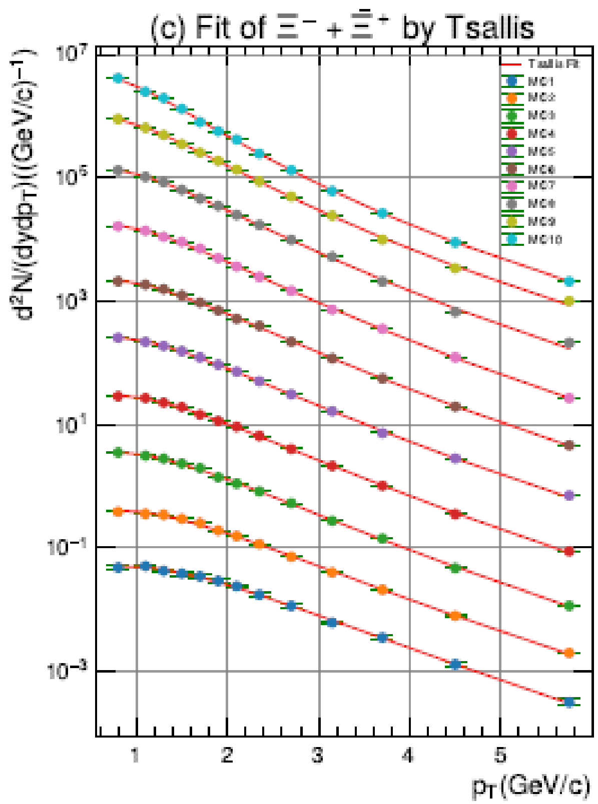

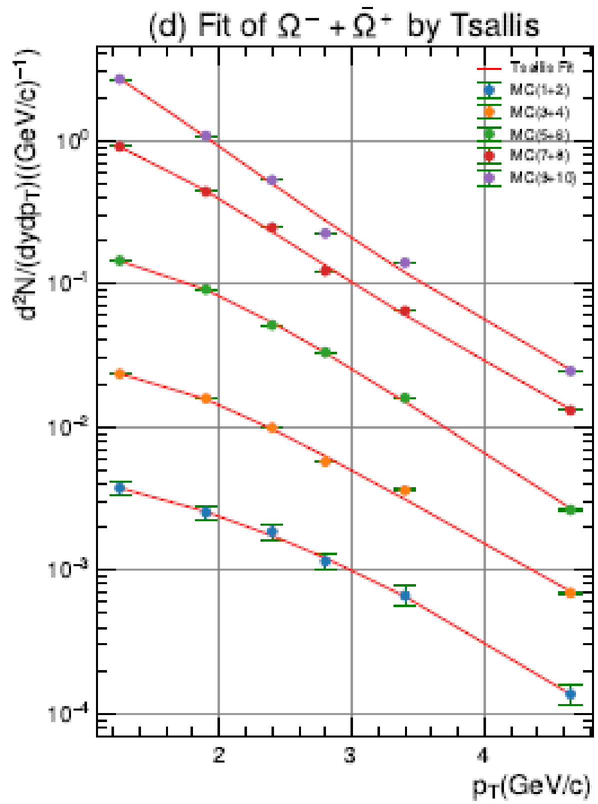

Outlook:

- Different performance for different models
  Preference for EPOS-LHC

- Comparison at different energies in required

- Try other distribution functions to extract the parameters.

THANK YOU