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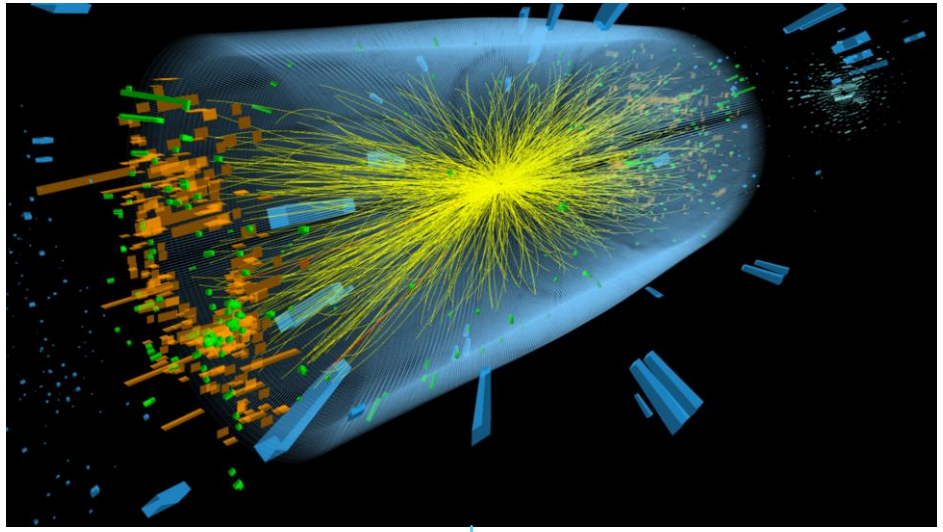
DATA ANALYSIS FROM KASCADE EXPERIMENT WITH EPOS LHC-R

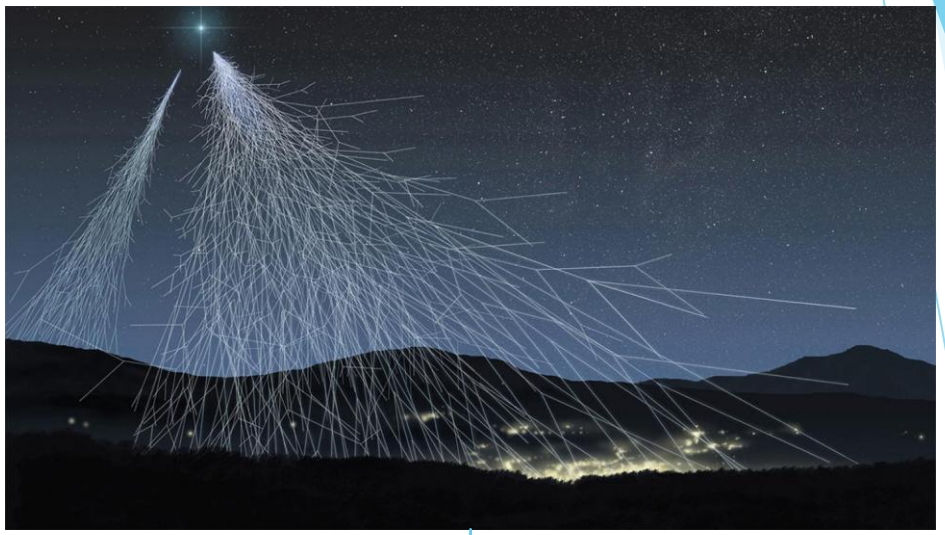
Preliminary evaluation : Data analysis from RIVET with EPOS LHC-R

Delassoud Kamil | 18/06/2024

Collider Physics



Cosmic rays Physics

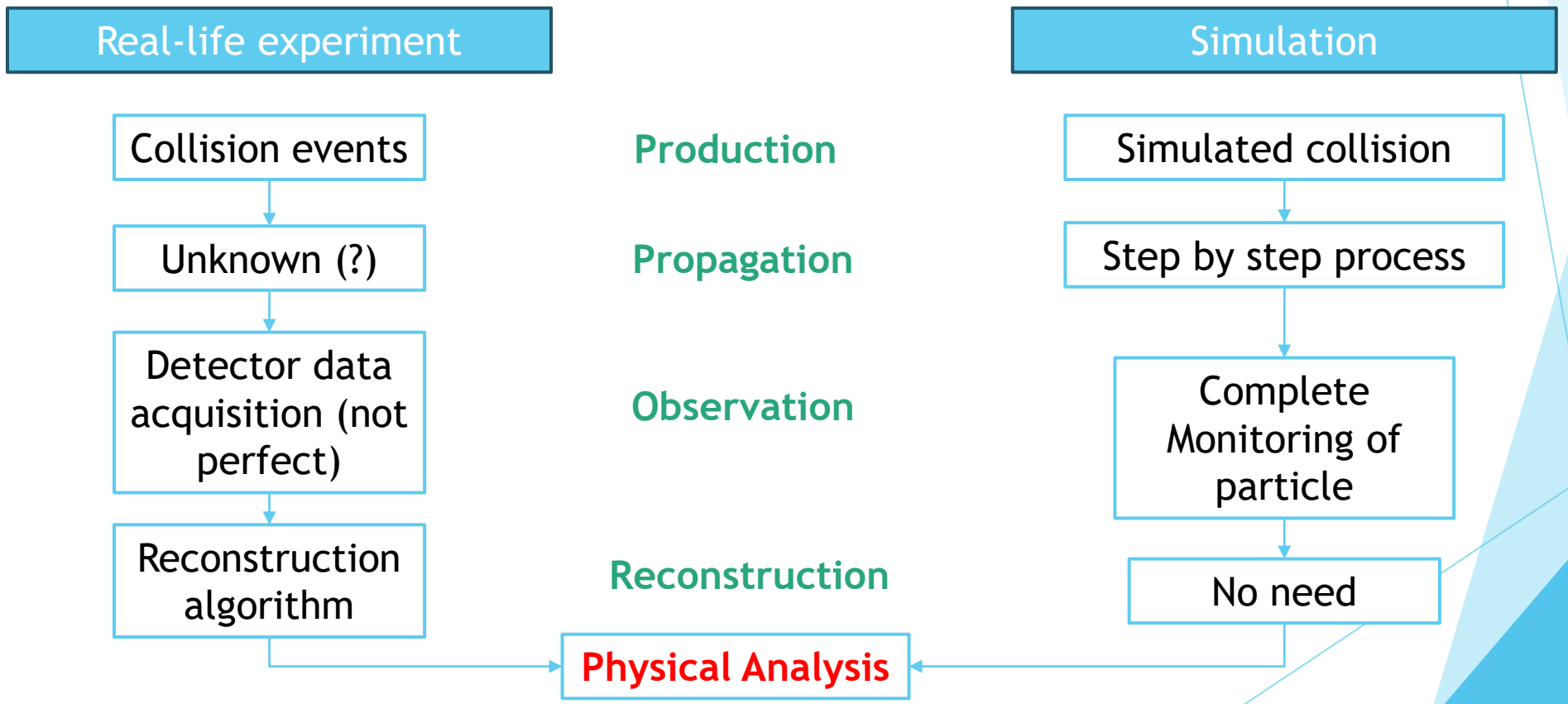


Theoretical Model Construction

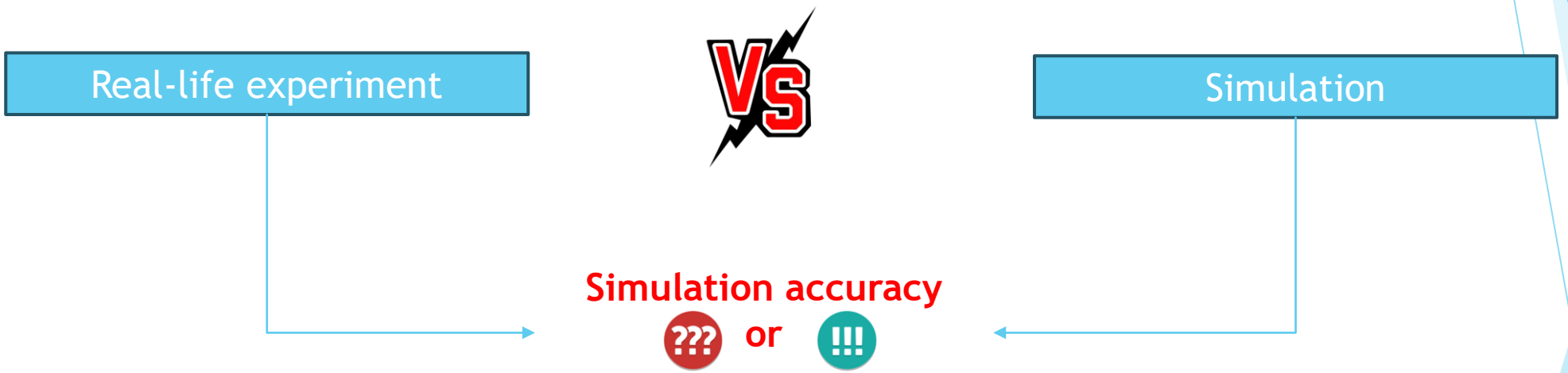
How do we verify it ?

Event Generator (?)

- Code that simulates a particle collision
- Based on a theoretical model



Event Generator usage



- Accuracy influenced by :
  - Chosen theoretical model
  - Usage (energy , projectile & target , etc..)
  - Tuning of model free parameters (won't be considered here)

Motivation

- EPOS LHC-R : **event generator**
- **Updated** version of EPOS LHC for cosmic rays
  1. Evaluate performance of the model on **collider physics**
  2. Evaluate performance on cosmic rays (attenuation of muon puzzle ?)
     - Yet to be done

EPOS Model

- Stands for :

  Energy conserving quantum mechanical approach, based on

  Partons, parton ladders, strings,

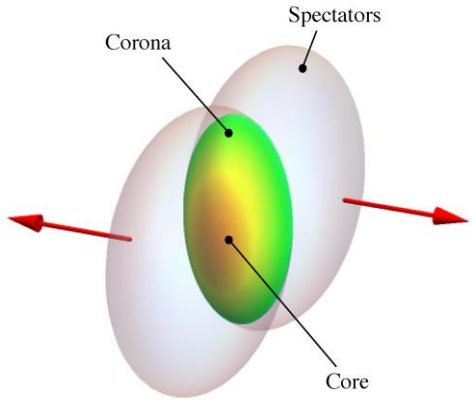
  Off-shell remnants, and

  Saturation of parton ladders

- Based on a mix between **parton model** and **Gribov-Regge Theory :**
  - **Parton based Gribov-Regge Theory**
- **EPOS LHC** tuning with LHC data
- **EPOS LHC-R** updated with recent data for cosmic ray physics

EPOS Core-Corona Structure

- Core-Corona Structure :
  - Corona : low density area
  - Core : high density area → **collective effects (hydrodynamic contribution)**



Models to be compared with

EPOS configurations	Informations
EPOS LHC	
EPOS LHC-R	
EPOS LHC-R_no_rescattering	No hadronic rescattering
EPOS LHC-R_no_rescattering_no_fusion	No Core-Corona

Other models
QGSJETII
QGSJETIII
SIBYLL

Data

- Use of a public toolkit : **RIVET**
  - Regroup ~2000 analyses
  - Covers a large angle of physics
    - Jet Production and properties
    - Underlying event
    - Top and heavy flavour physics
    - And many more … (BSM , EW, not studied here)

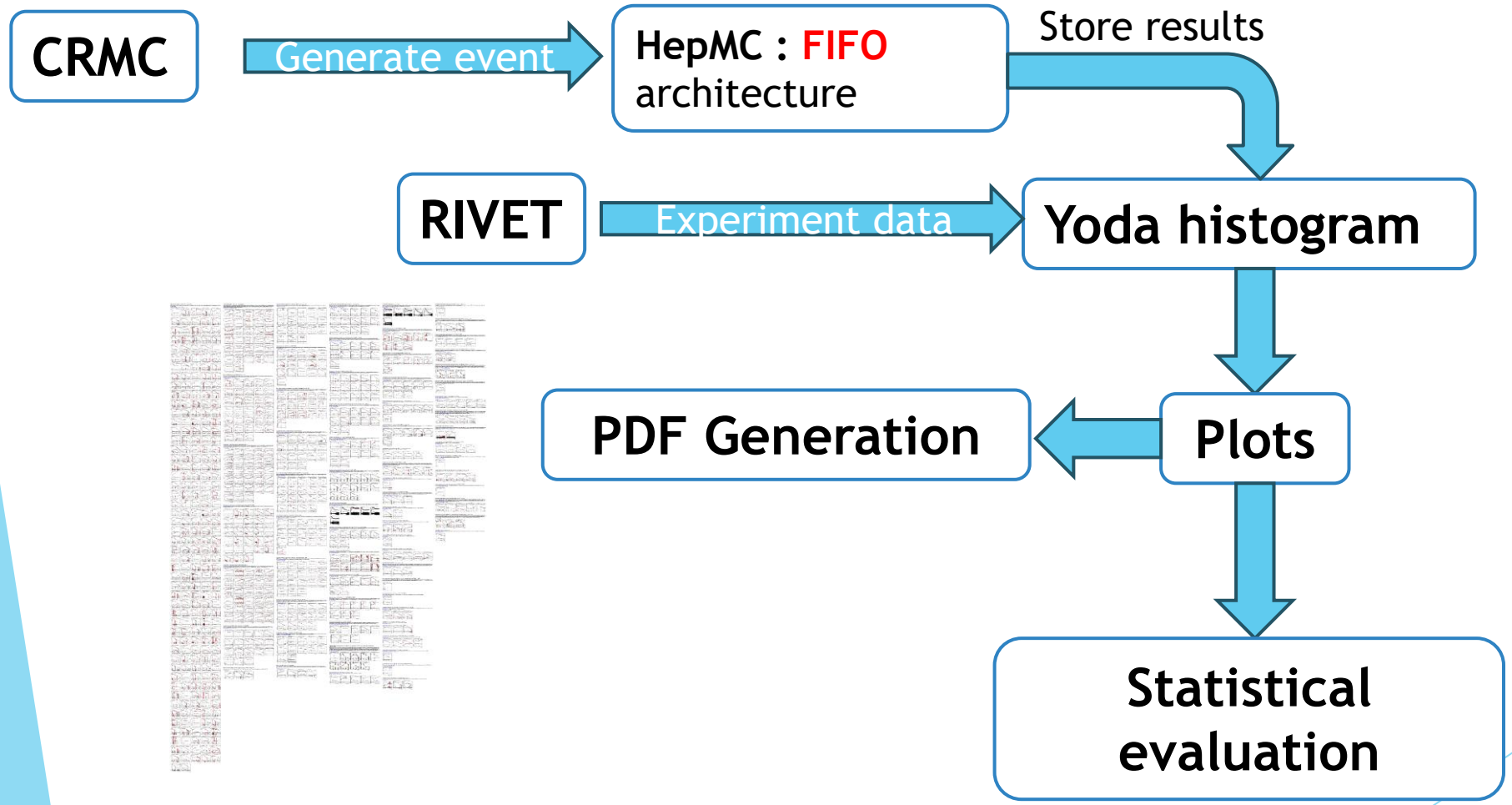
Data for simulations

- Choice of 154 analyses from several experiment :
  - LEP : ALEPH, DELPHI, L3
  - SLAC : PEP (TPC)
  - SPS : UA1, UA5
  - RHIC : STAR
  - LHC : ALICE, ATLAS, CMS, LHCb, LHCf, TOTEM
- Choice of several collision : $e^+e^-, \overline{p}p, pp, pPb$ at different energies.

Beam	Number of collision simulated
e^+e^-	100 000
$\overline{p}p$	100 000
pp	100 000
pPb	10 000

Simulation


FIFO
Data Out
Data In


CRMC
Generate event
HepMC : FIFO architecture
Store results
RIVET
Experiment data
Yoda histogram
PDF Generation
Plots
Statistical evaluation

Statistical evaluation

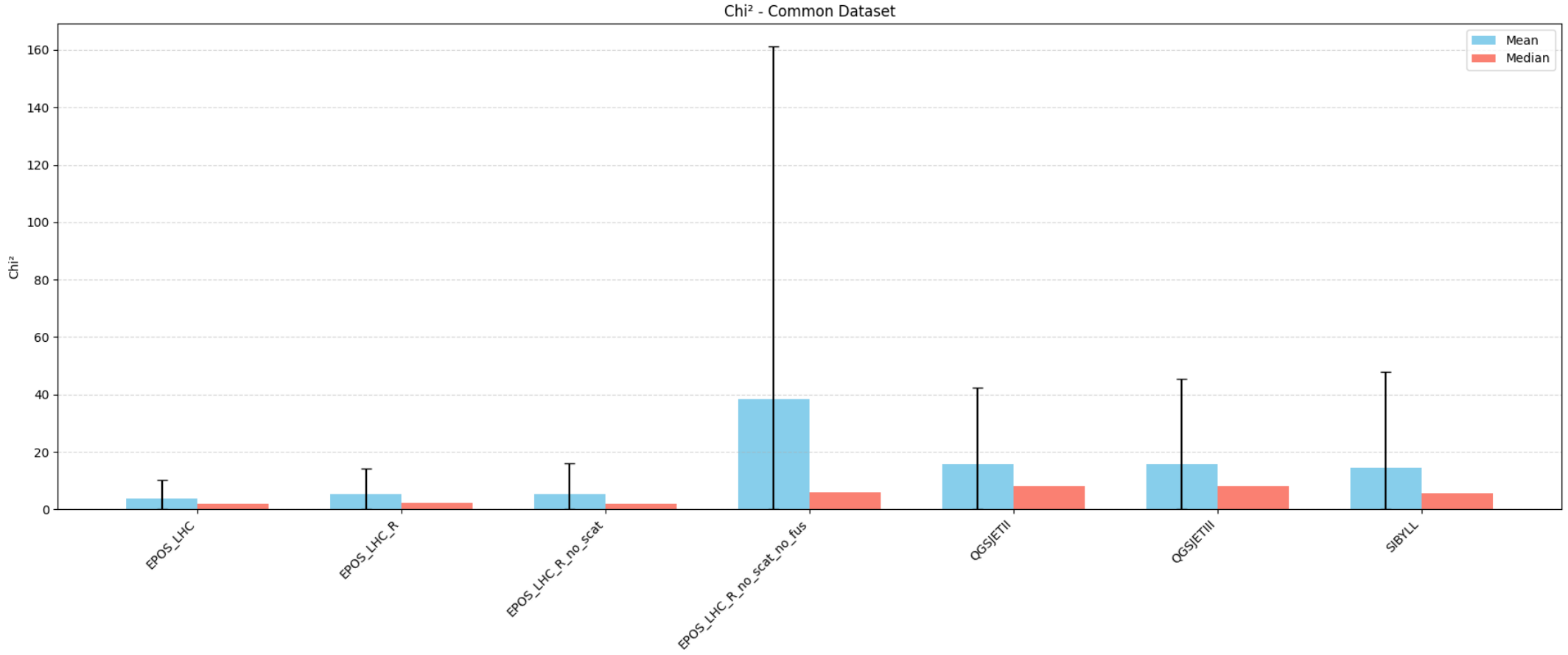
- Criteria :
  - Relative Error

$$\mathrm{RE} = \frac{\sum_i \left| y_i^{\mathrm{model}} - y_i^{\mathrm{data}} \right| \cdot \left| y_i^{\mathrm{data}} \right| \cdot \left| \Delta x_i^{\mathrm{model}} \right|}{\sum_i \left| y_i^{\mathrm{data}} \right| \cdot \left| \Delta x_i^{\mathrm{data}} \right|}$$

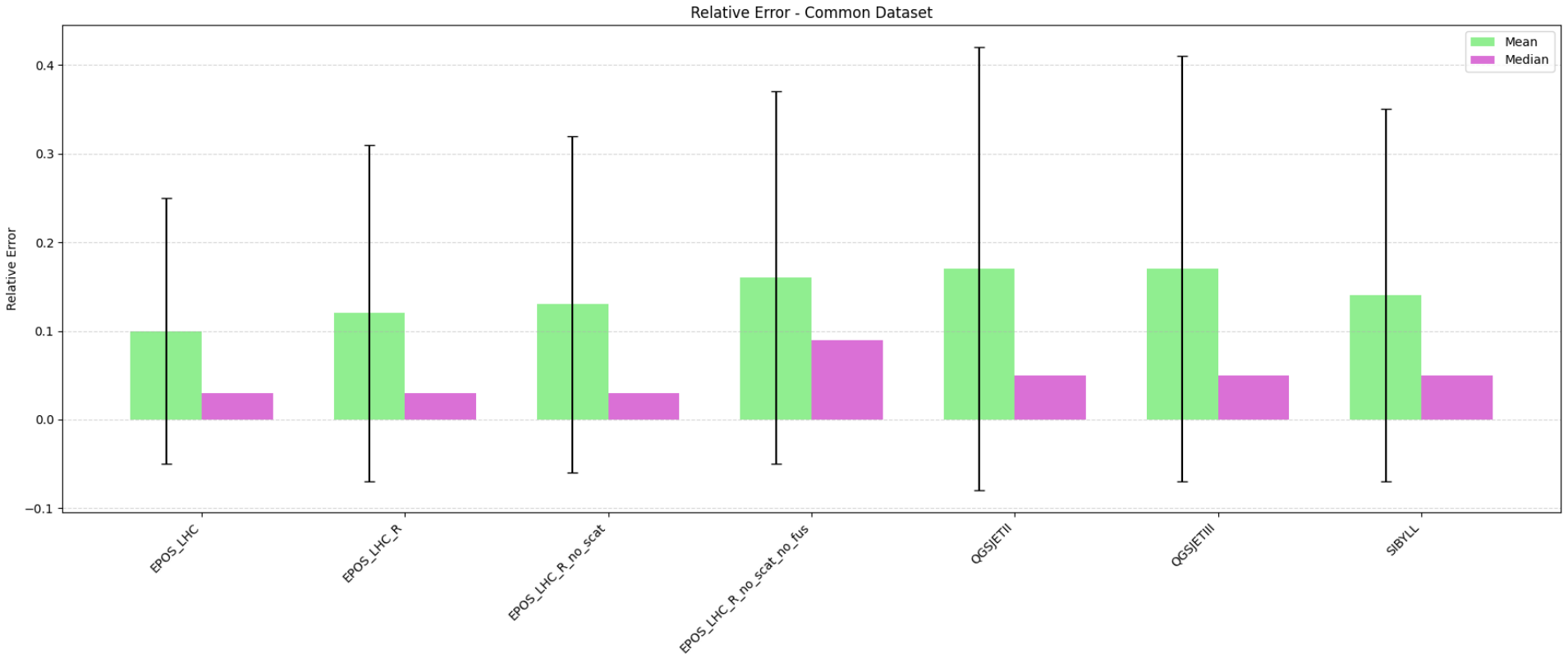
  - χ^2

$$\chi^2 = \frac{1}{N} \sum_i \frac{\left(y_i^{\mathrm{data}} - y_i^{\mathrm{model}} \right)^2}{\left(\sigma_i^{\mathrm{data}} \right)^2 + \left(\sigma_i^{\mathrm{model}} \right)^2}$$

Results : χ^2



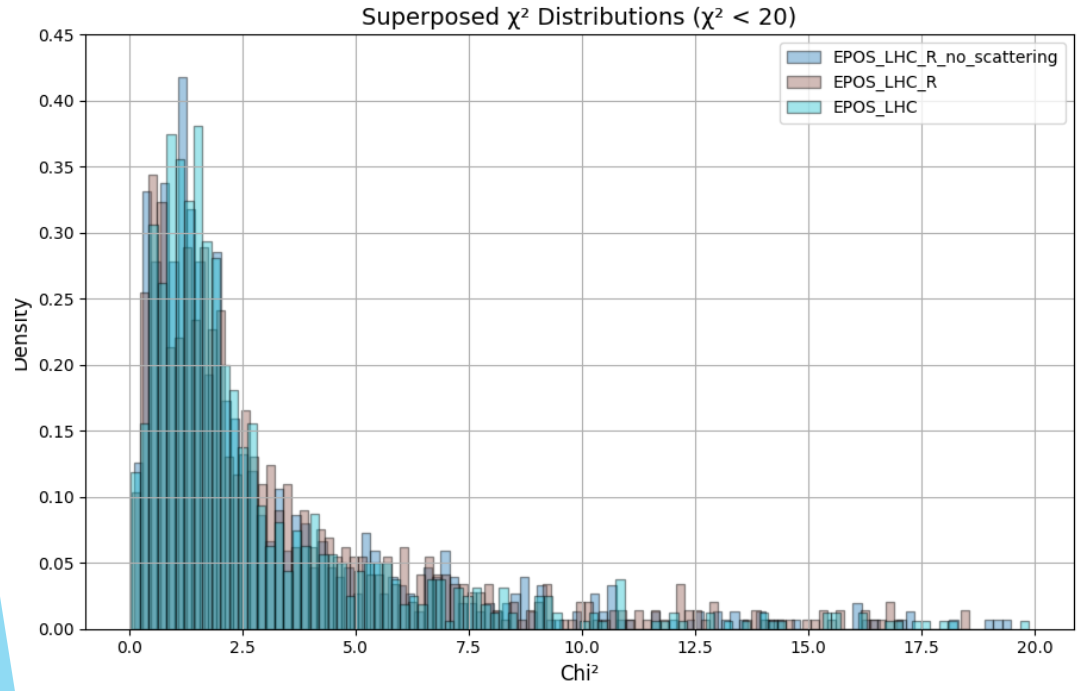
Results : *Relative Error*

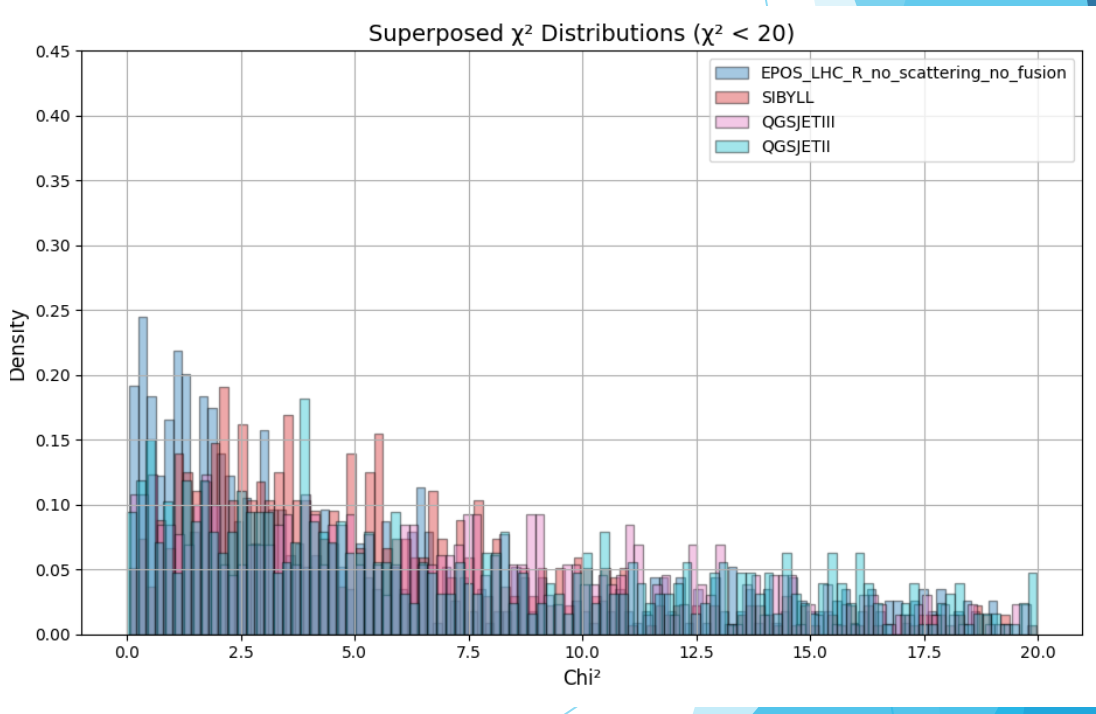


Results : Overall performance

EPOS models

Other model





Overall : EPOS outperforms the other models

Comparison between models

Model 1

$Plot\ 1$ χ_1^2

$Plot\ 2$ χ_1^2

Model 2

$Plot\ 1$ χ_2^2

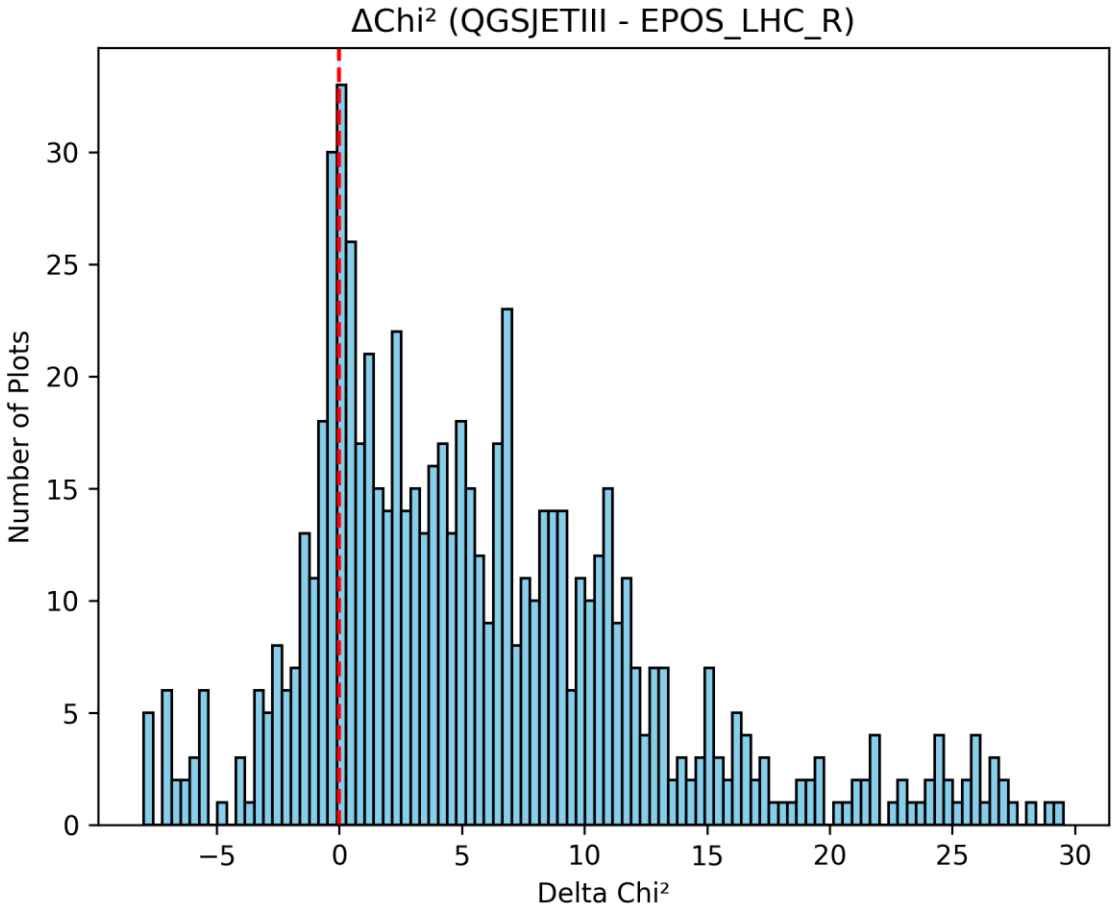
$Plot\ 2$ χ_2^2

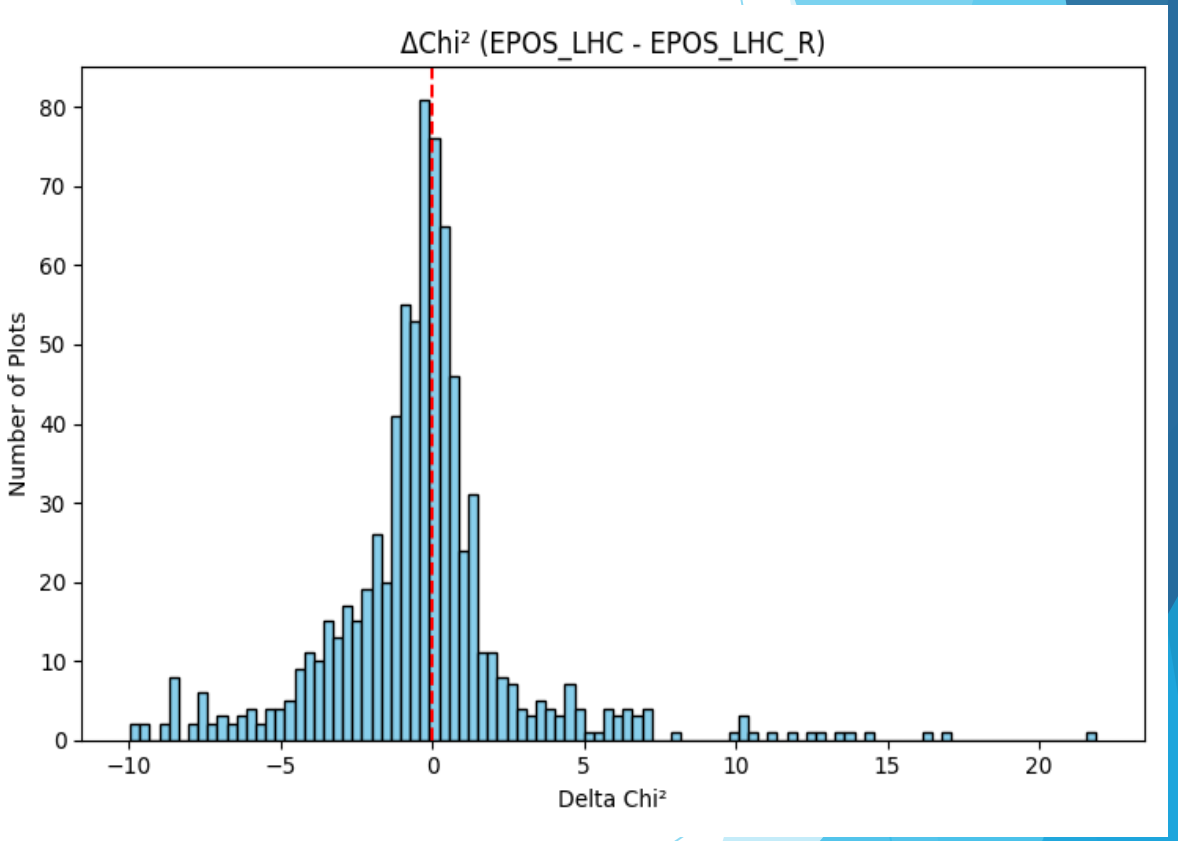
Model 1 – Model 2

$Plot\ 1$ $\chi_1^2 - \chi_2^2$

$Plot\ 2$ $\chi_1^2 - \chi_2^2$

Comparison between models



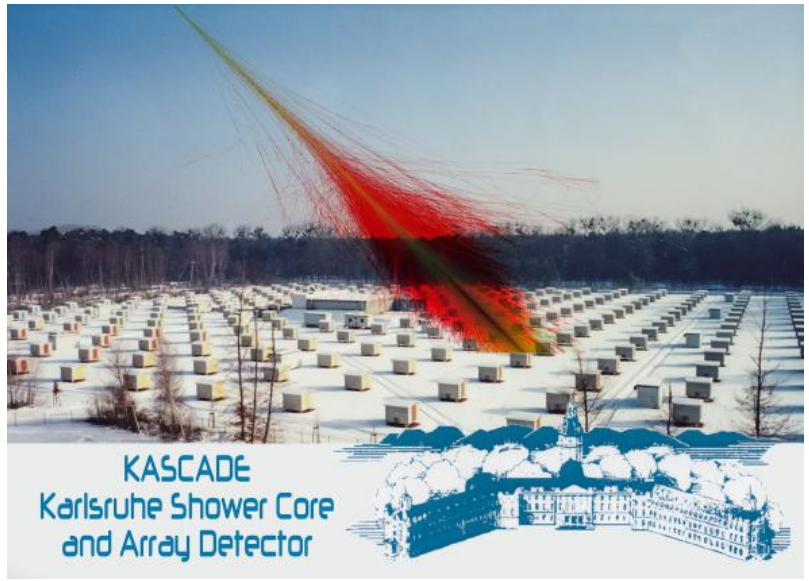


Conclusion

- EPOS LHC-R OVERALL performs better than QGSJETII, QGSJETIII and SIBYLL
- The differences between EPOS LHC-R and EPOS LHC are negligible
- Some phenomenon are less well described by EPOS
  - To check for specific studies on collider physics

- There's now to see the performance of EPOS LHC for cosmic rays with KASCADE-Grande

(yet to come ….)



Annexes

EPOS Description

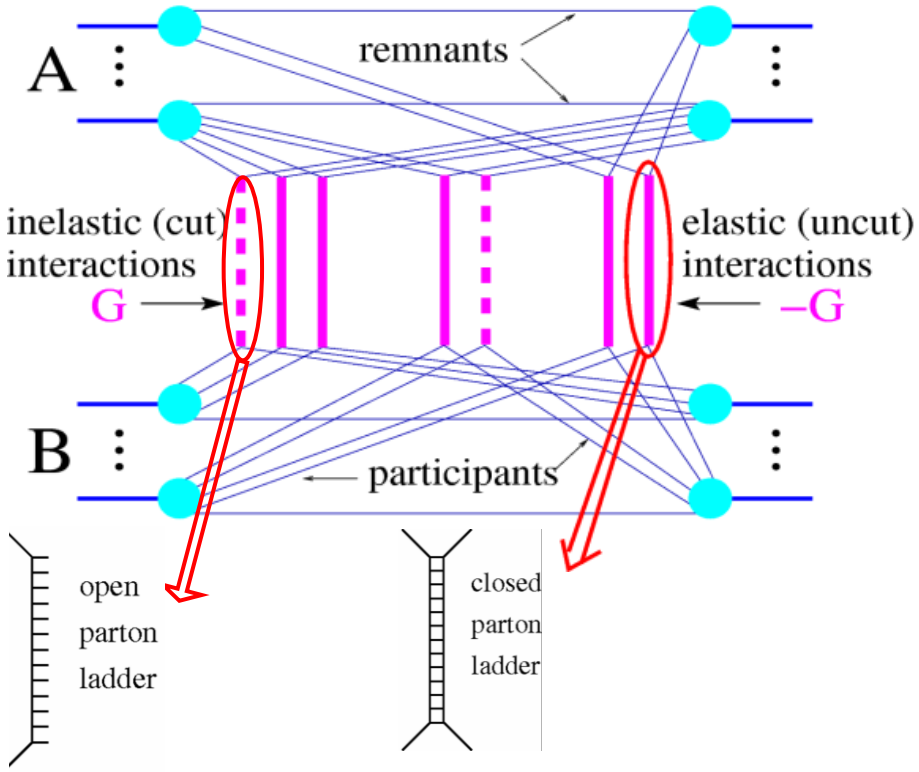
Energy conserving quantum mechanical approach, based on

Partons, **parton ladders**, **strings**

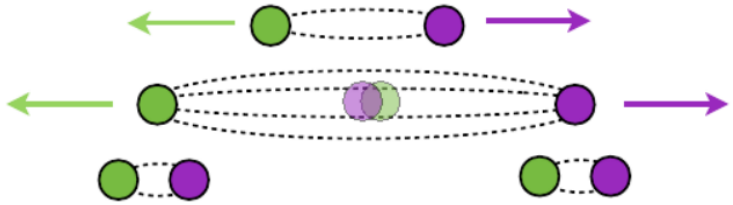
Off-shell remnants, and

Saturation of parton ladders

- **Parton Ladders**
- Modelised by the exchange by an object called **Pomeron**.



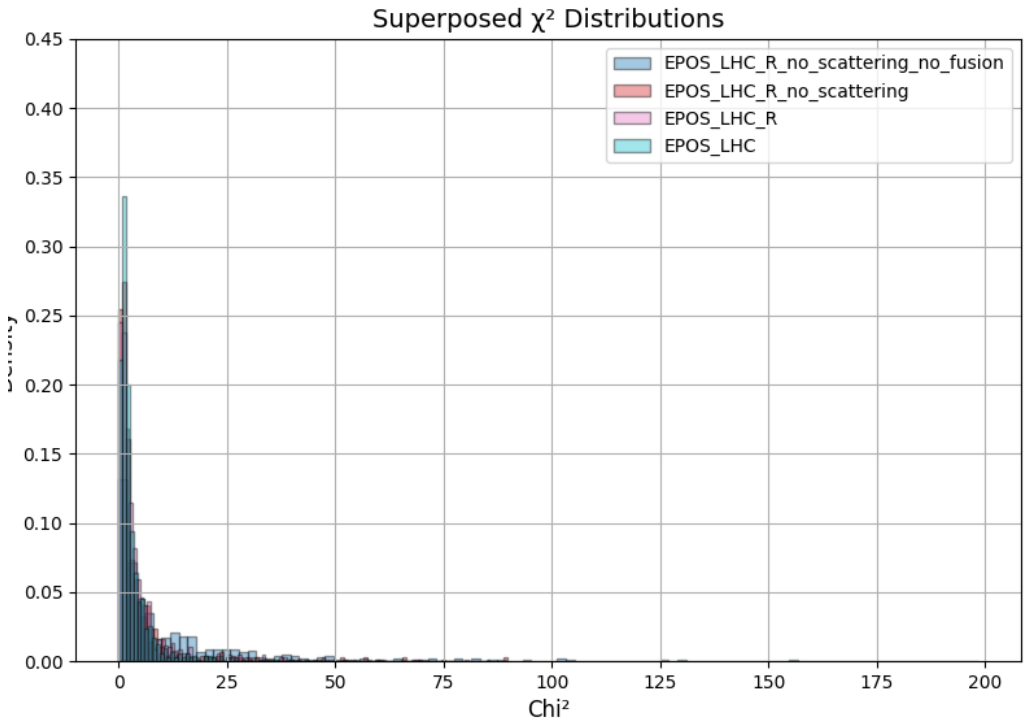
- Treatment of Off-shell remnants
- Strings models

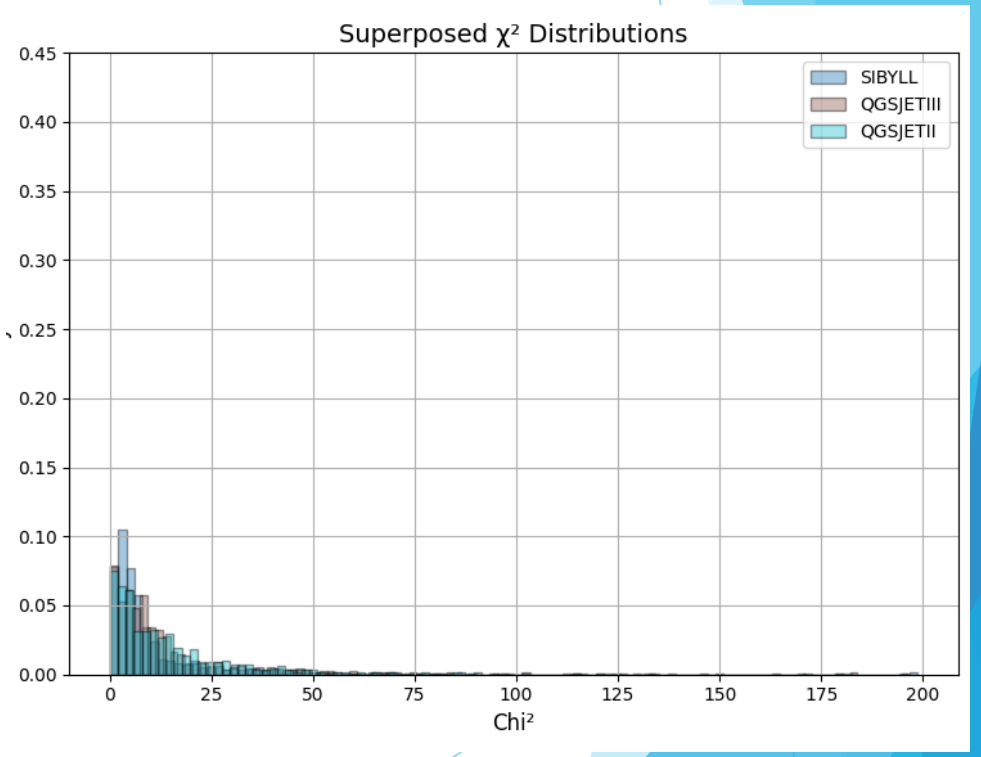


Results : Overall performance on full range

EPOS models

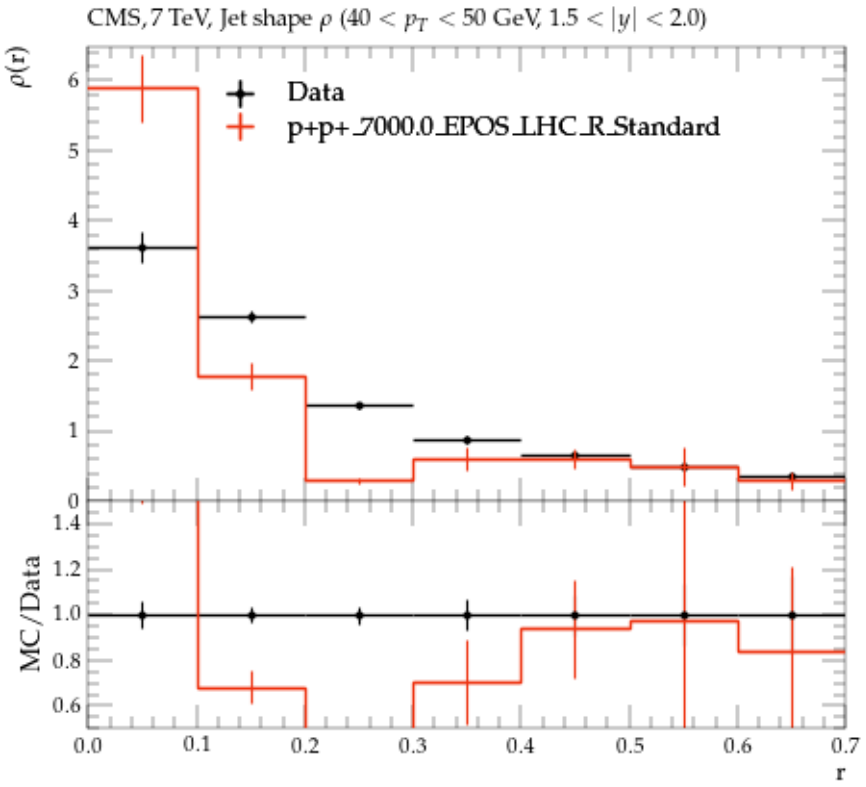
Other model

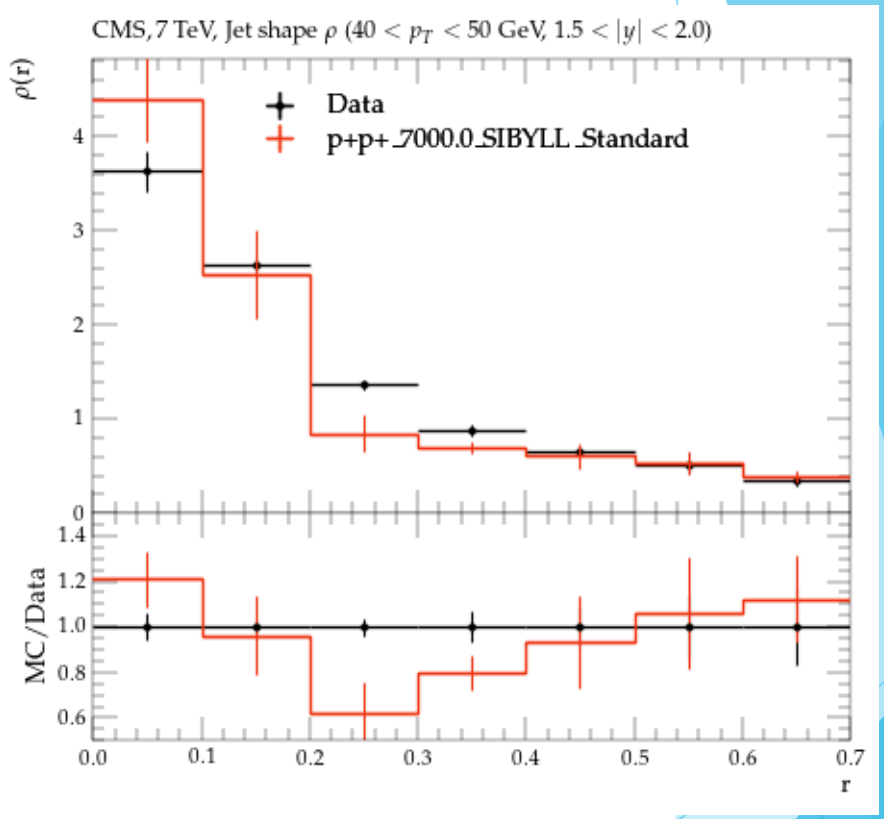




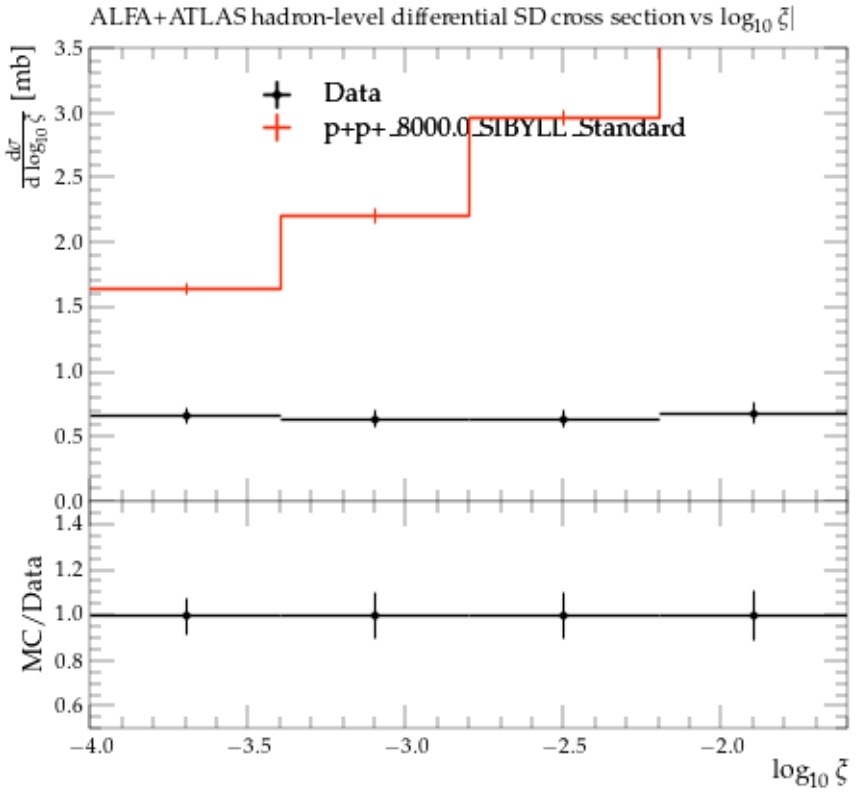
Overall : EPOS outperformes the other models

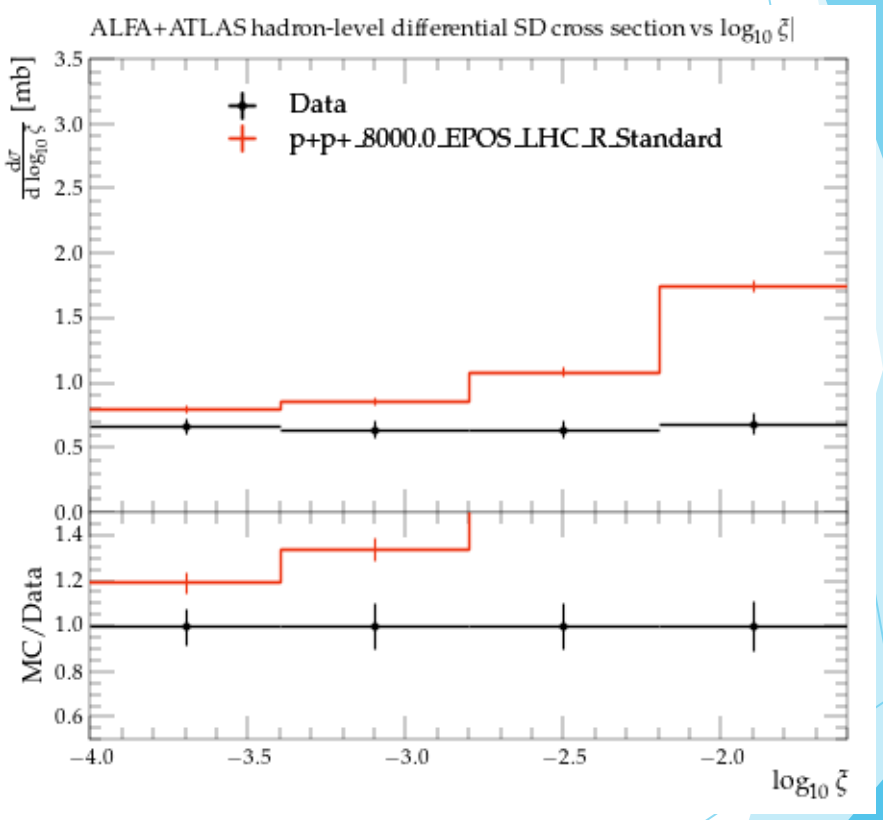
Big χ^2 differences in favor of SIBYLL



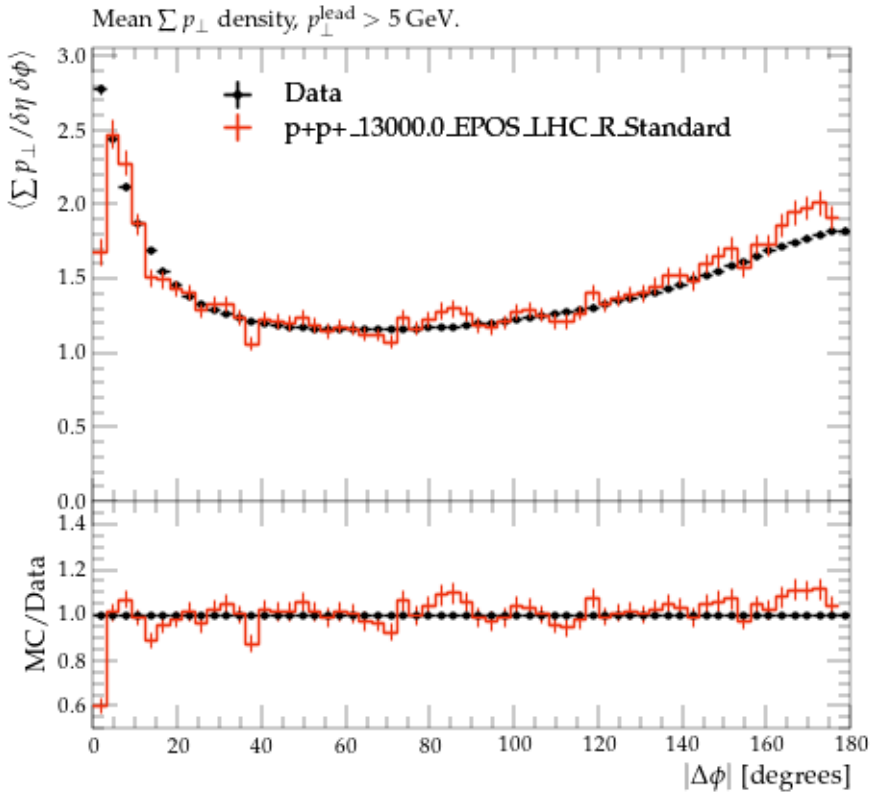


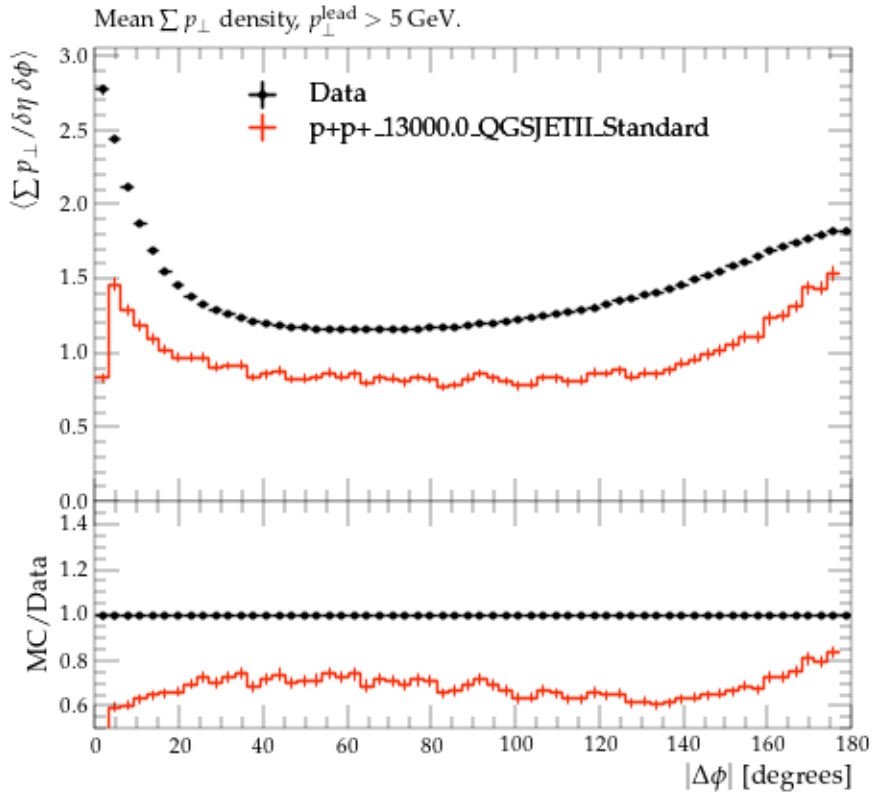
Big χ^2 differences in favor of EPOS



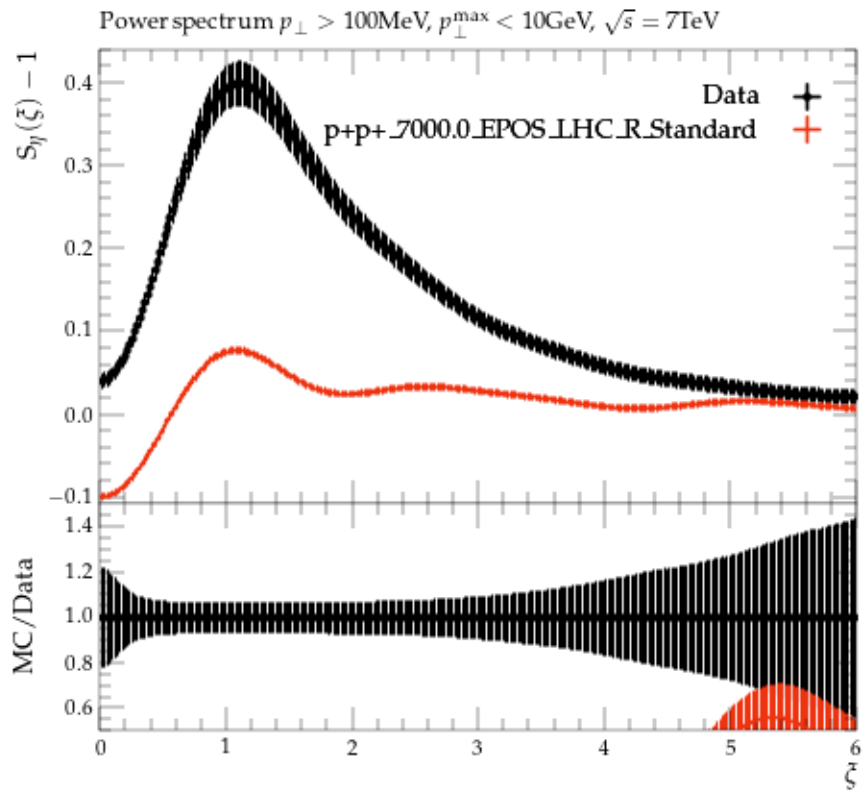


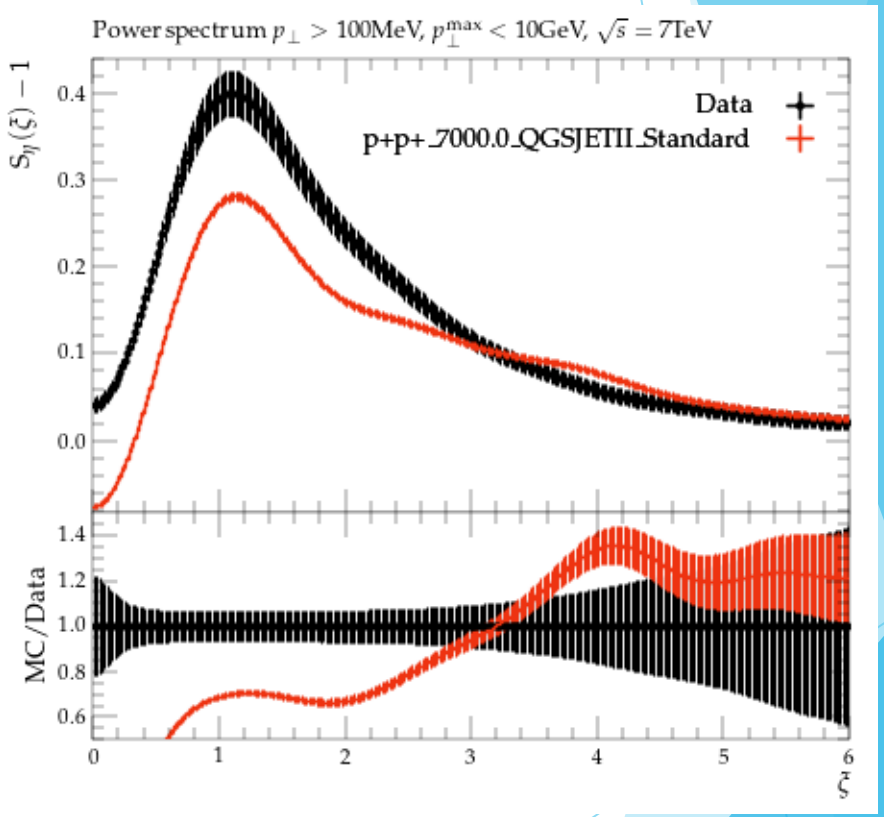
Big χ^2 differences in favor of EPOS

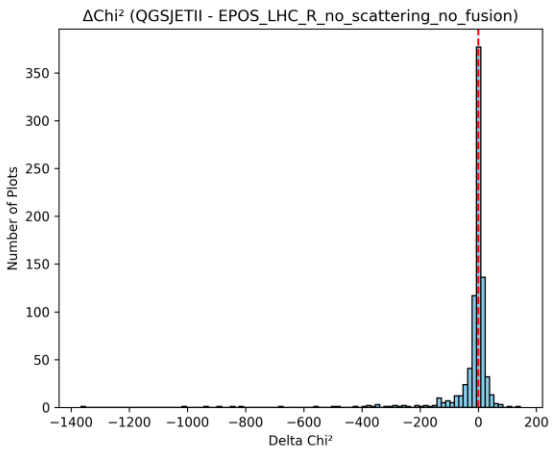


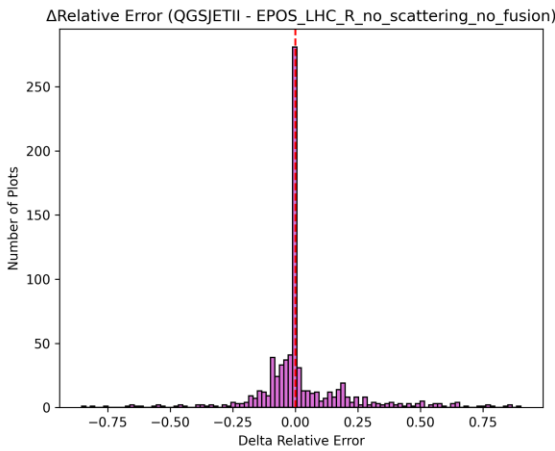


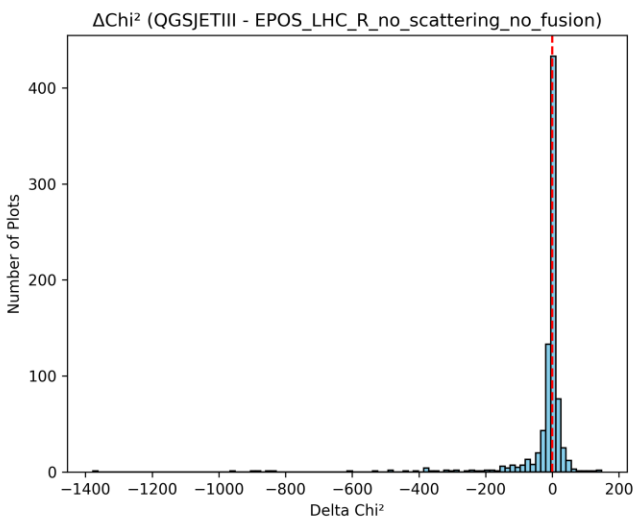
Big χ^2 differences in favor of QGSJETII

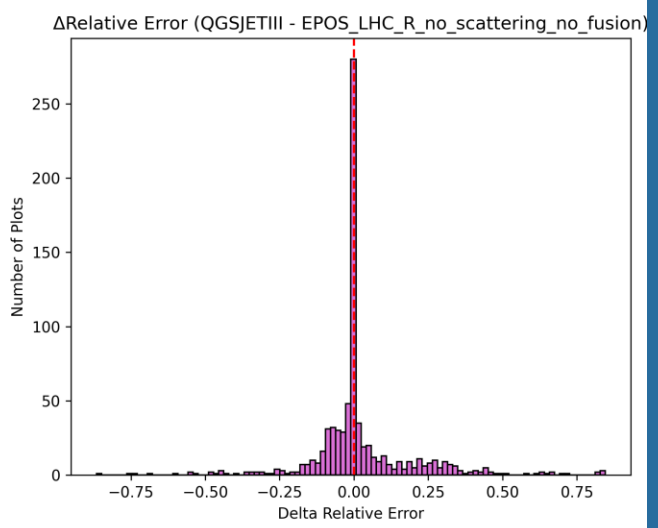


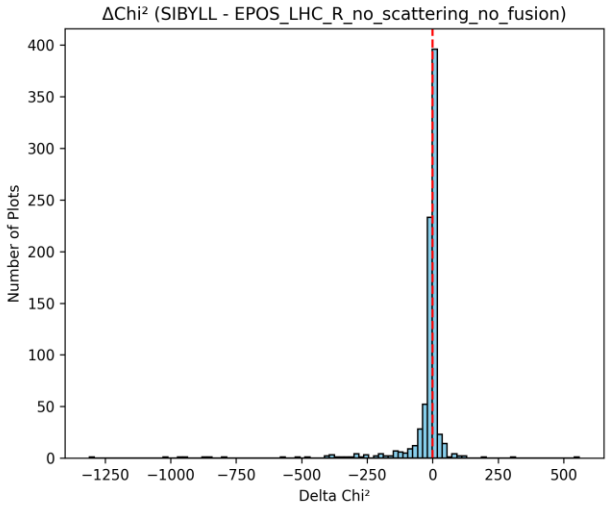


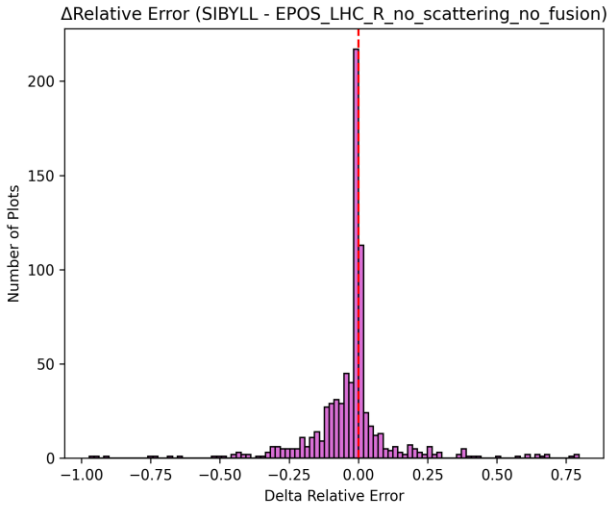

ΔChi² (QGSJETII - EPOS_LHC_R_no_scattering_no_fusion)
Number of Plots
Delta Chi²

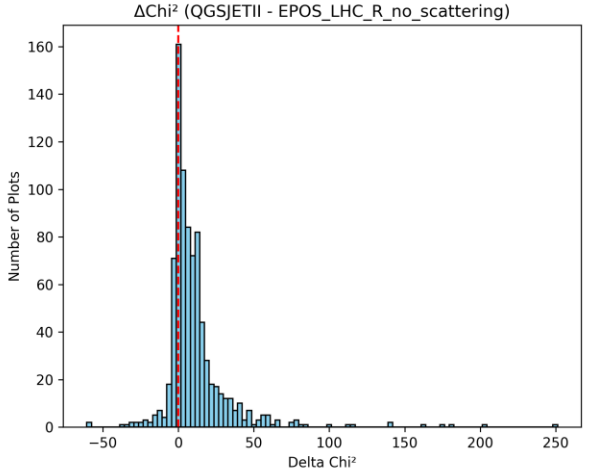

ΔRelative Error (QGSJETII - EPOS_LHC_R_no_scattering_no_fusion)
Number of Plots
Delta Relative Error


ΔChi² (QGSJETIII - EPOS_LHC_R_no_scattering_no_fusion)
Number of Plots
Delta Chi²


ΔRelative Error (QGSJETIII - EPOS_LHC_R_no_scattering_no_fusion)
Number of Plots
Delta Relative Error


ΔChi² (SIBYLL - EPOS_LHC_R_no_scattering_no_fusion)
Number of Plots
Delta Chi²


ΔRelative Error (SIBYLL - EPOS_LHC_R_no_scattering_no_fusion)
Number of Plots
Delta Relative Error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Number of Plots
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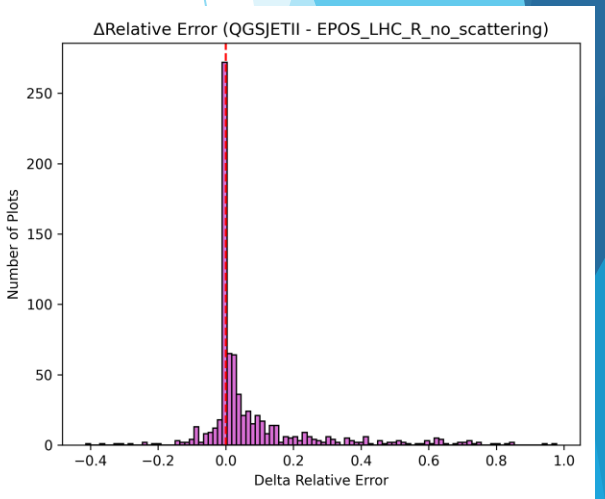
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Number of Plots
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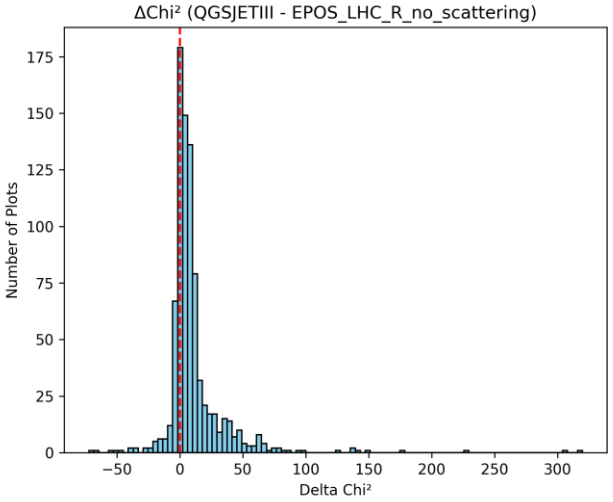
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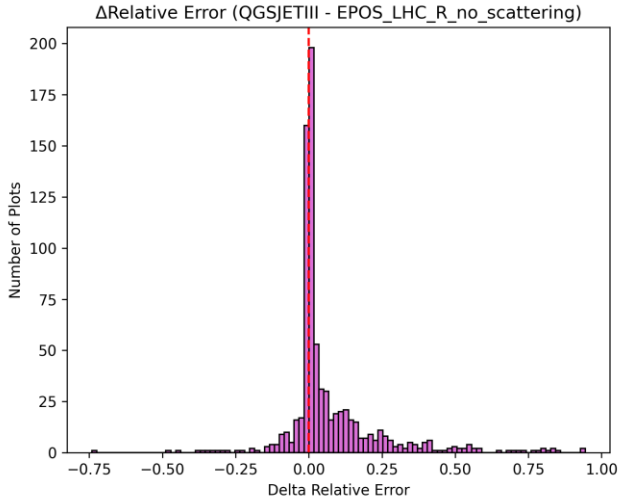
Number of Plots
Delta Chi²


ΔRelative Error (QGSJETIII - EPOS_LHC_R_no_scattering)
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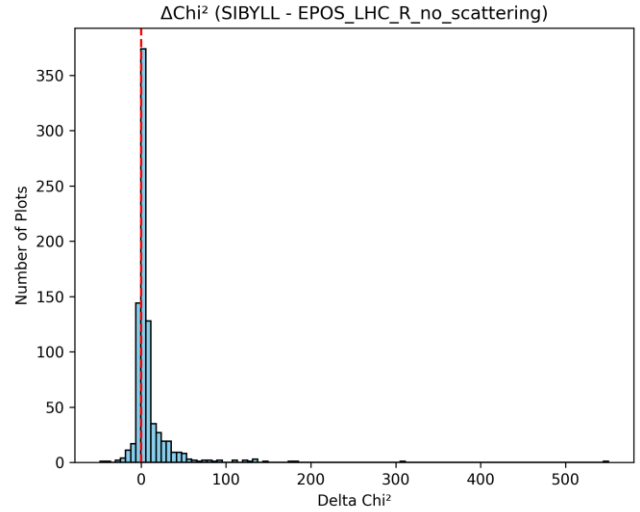
ΔChi² (SIBYLL - EPOS_LHC_R_no_scattering)
Number of Plots
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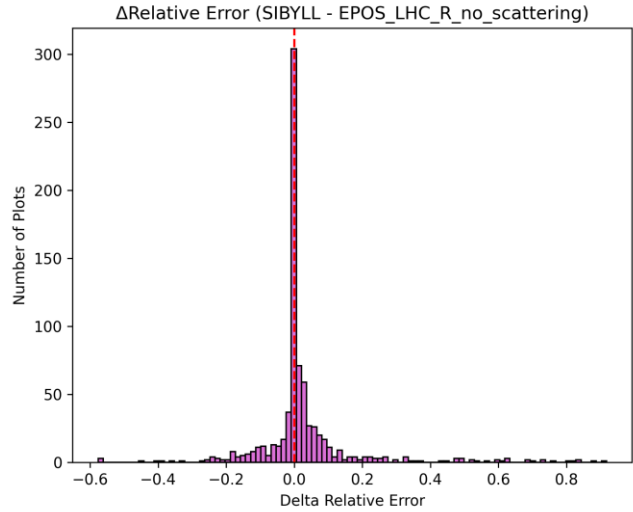
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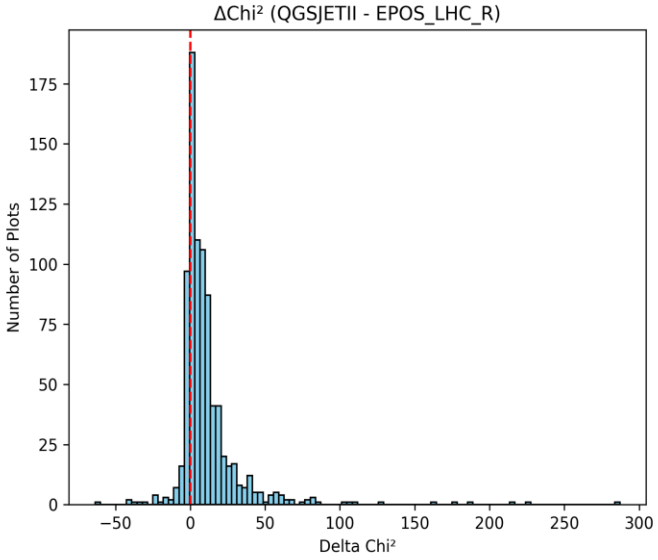
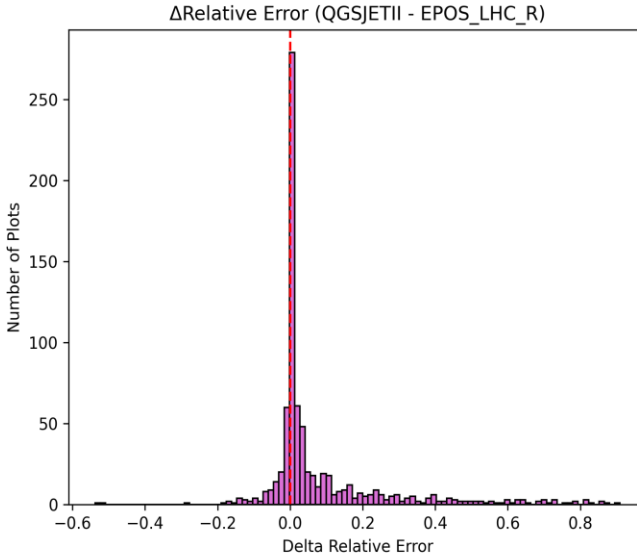

ΔChi² (QGSJETII - EPOS_LHC_R)
Number of Plots
Delta Chi²


ΔRelative Error (QGSJETII - EPOS_LHC_R)
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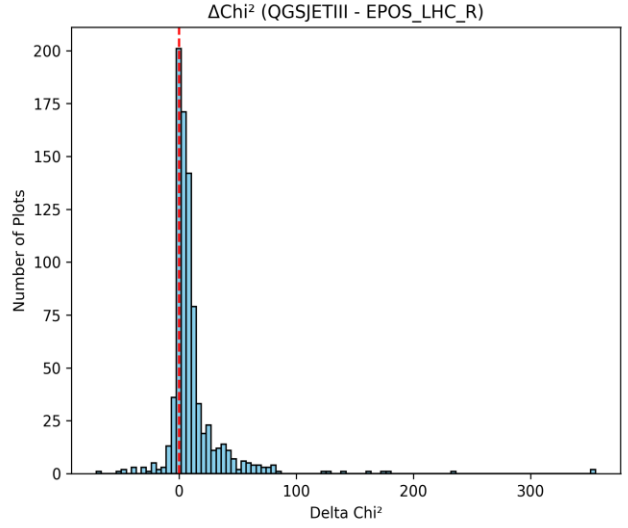
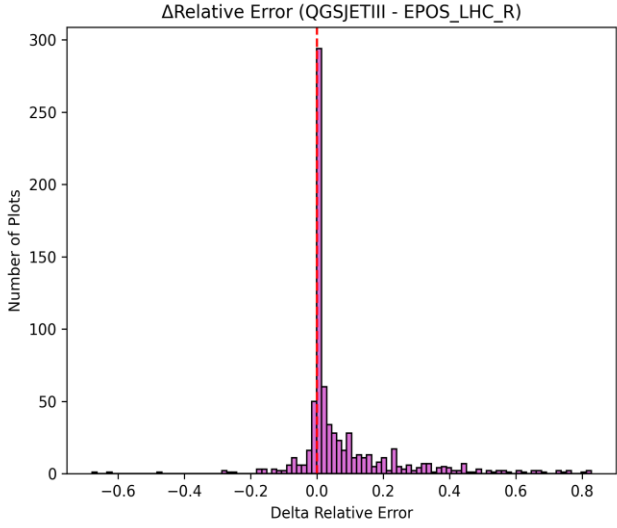
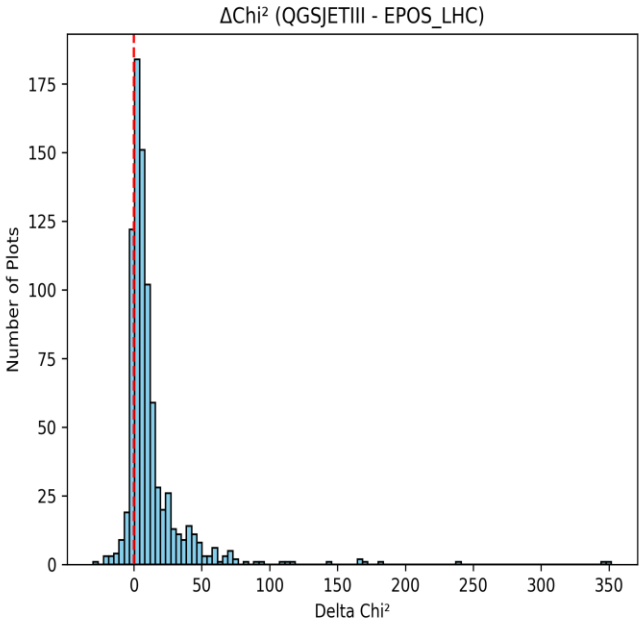
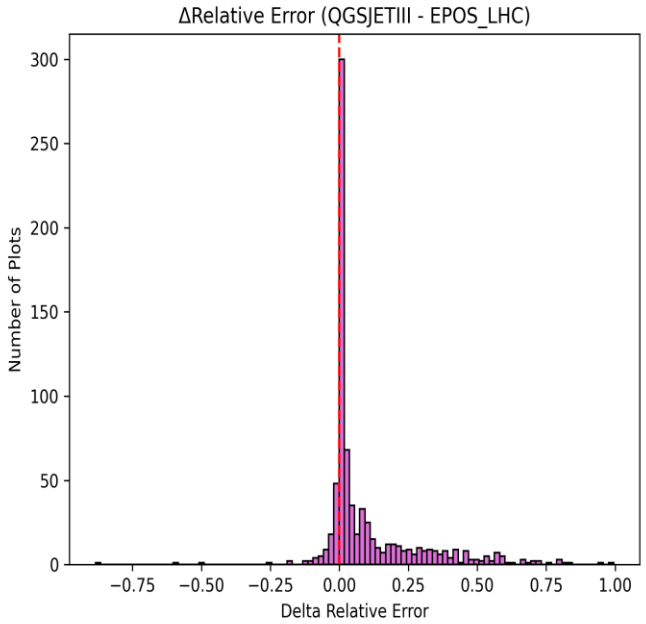
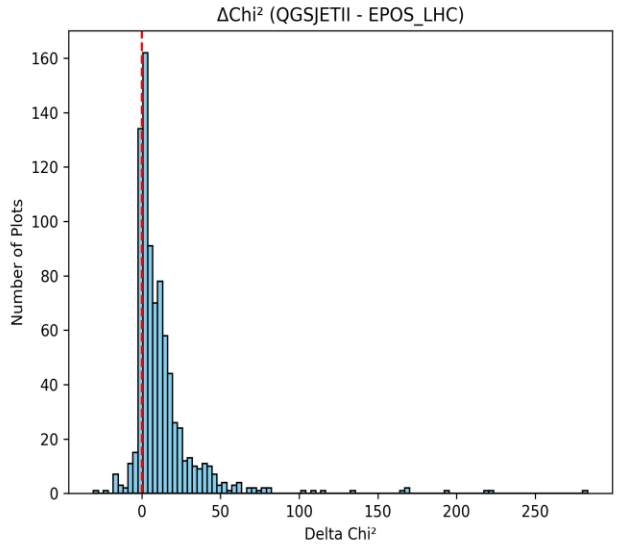
Delta Relative Error

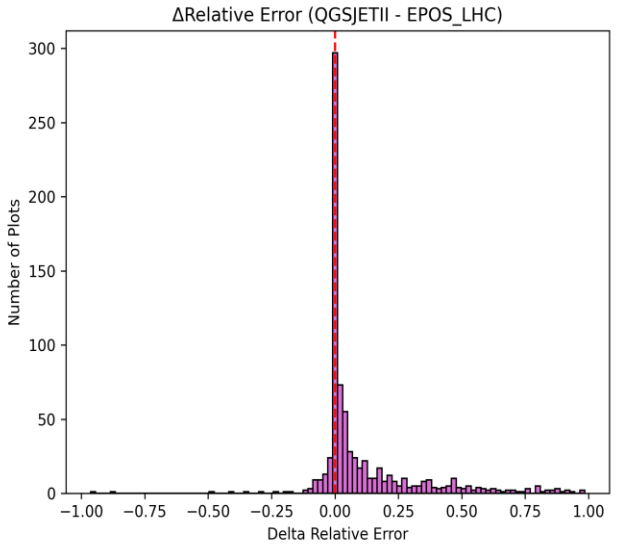

ΔChi² (QGSJETIII - EPOS_LHC_R)
Number of Plots
Delta Chi²

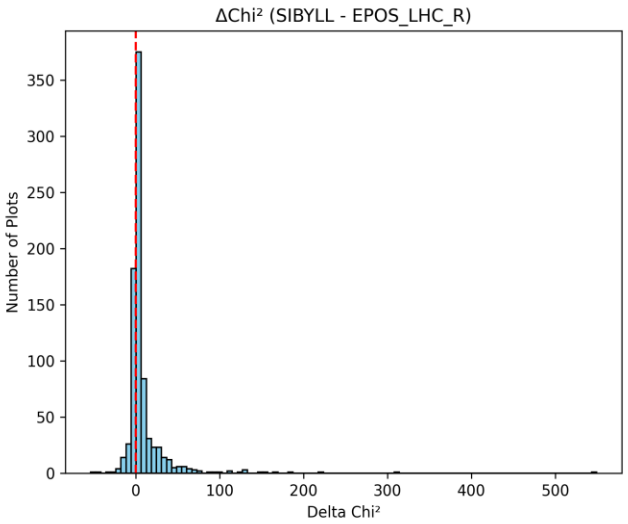

ΔRelative Error (QGSJETIII - EPOS_LHC_R)
Number of Plots
Delta Relative Error

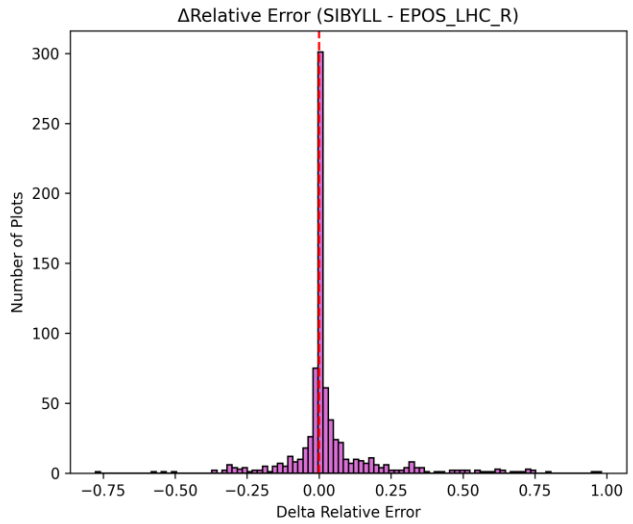

ΔChi² (QGSJETIII - EPOS_LHC)
Number of Plots
Delta Chi²

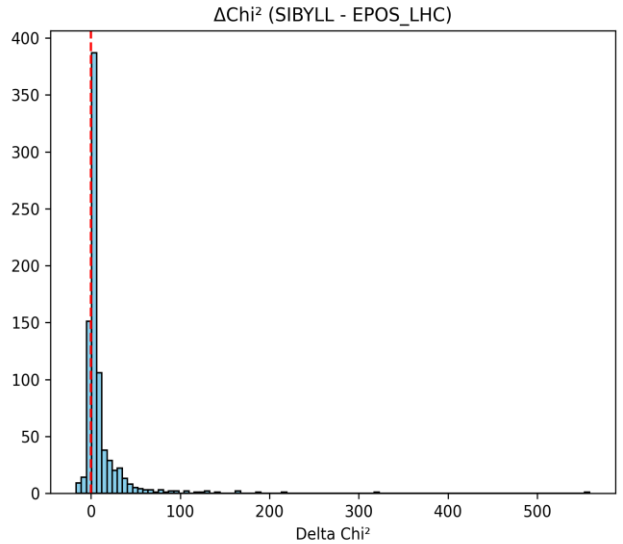

ΔRelative Error (QGSJETIII - EPOS_LHC)
Number of Plots
Delta Relative Error

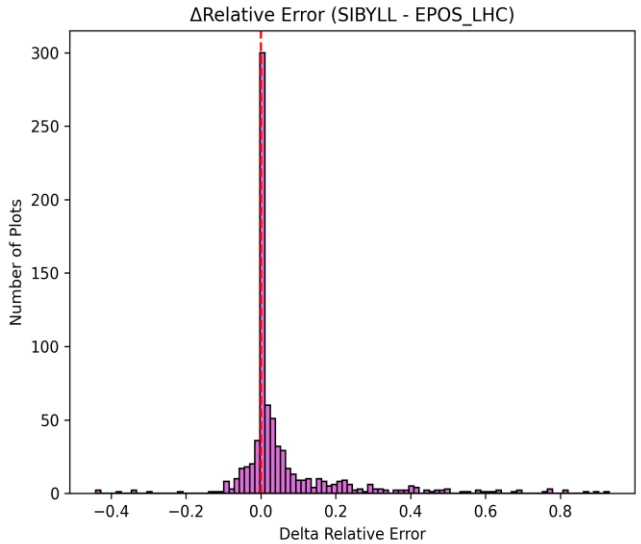

ΔChi² (QGSJETII - EPOS_LHC)
Number of Plots
Delta Chi²


ΔRelative Error (QGSJETII - EPOS_LHC)
Number of Plots
Delta Relative Error


ΔChi² (SIBYLL - EPOS_LHC_R)
Number of Plots
Delta Chi²


ΔRelative Error (SIBYLL - EPOS_LHC_R)
Number of Plots
Delta Relative Error


ΔChi² (SIBYLL - EPOS_LHC)
Number of Plots
Delta Chi²


ΔRelative Error (SIBYLL - EPOS_LHC)
Number of Plots
Delta Relative Error