EPOS LHC

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Introduction

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EPOS LHC: Test of collective hadronization with data measured at the CERN Large Hadron Collider

EPOS LHC

EPOS is a Monte-Carlo event generator for minimum bias hadro nic interactions, used for both heavy ion interactions and cosmic ray air shower simulations.

EPOS LHC

- E : Energy conserving quantum mechanical multiple scattering approach,
- P : Partons(Partons Ladders)
- O : Off-shell remnants, and
- S : Splitting of parton ladders.

Hadronic Interaction Models

- **Theoretical Basis**:
  - EPOS is based on the Parton-Based Gribov Regge Theory (cross section with multiple scattering).
  - pQCD (large p_T), Cosmic Rays physics dominated by soft interactions
- **Phenomenology (models)** :
  - string fragmentation,
  - beam remnants,
  - diffraction (Good-Walker, ...), Need Parameters !
  - higher order effects. From Experiments !

Hadronic Interaction Models

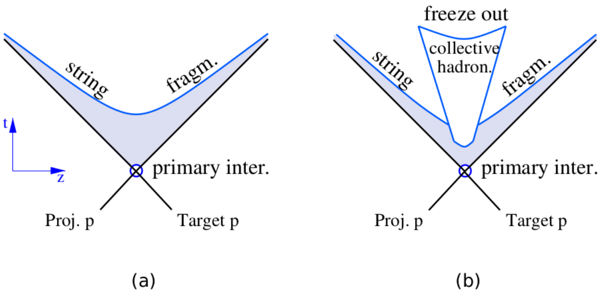


Figure: Simplified pictures of hadronisation in standard high-energy interaction models: EPOS 1.99 (a), EPOS LHC (b).

Hadronic Multi-Particle Production

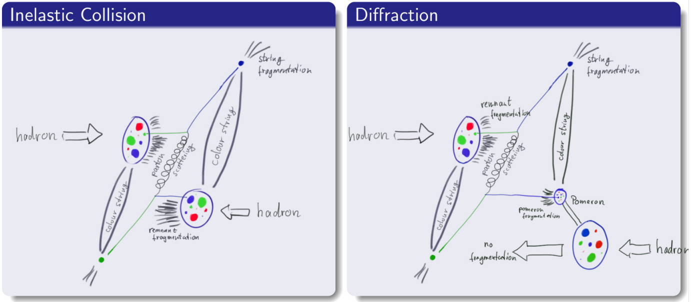


Figure: The initial scatterings lead to the formation of strings, which break into segments, which are usually identified with hadrons.

Cosmic Ray Monte Carlo Program (CRMC)

Cosmic Ray Monte Carlo interface, CRMC

Is designed to give experimental physicists easy access to many different hadronic interaction models used in air shower simulations.

Quick start...

Once the program is started the compiled dynamic library of the selected model is linked and the model is initialised to the set collision parameters.

https://web.ikp.kit.edu/rulrich/crmc.html (Download)
https://github.com/alisw/crmc (Install Linux)

Schematic overview of functionality of CRMC

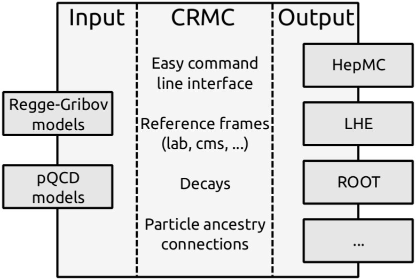


Figure: The program takes various input formats of various hadronic interaction models (left column) and outputs the generated events to formats often used in particle physics (right column).

To generate 1000 collisions p-C in in LAB frame with EPOS LHC:

bin/crmc -o root -p100000 -P-0 -n1000 -m0 -i2112 -I12

The hadronic interaction models used to simulate air showers are linked to CRMC

Model	Version	p-p	p-A & A-A	$\gamma\ p$	π, K_L^0	$\sqrt{s}$ Range [eV]
DPMJET	3.06	✓	✓	✓	✓	5×10^9 to 443×10^{12}
EPOS	1.99 and LHC	✓	✓	✗	✓	6×10^9 to 443×10^{12}
QGSJETII	03 and 04	✓	✓	✗	✓	3×10^9 to 443×10^{12}
SIBYLL	2.1	✓	$A{<}56$ [4]	✗	✓	10×10^9 to 443×10^{12}
HIJING	1.35	✓	✓	✗	✗	$<14\times10^{12}$
PHOJET	1.12	✓	✗	✓	✓	5×10^9 to 443×10^{12}
PYTHIA	6.1 and 6.4	✓	✗	✗	✓	$<50\times10^{12}$

Figure: Features of models as included in CRMC. In some cases they might differ from the standalone versions of the models.

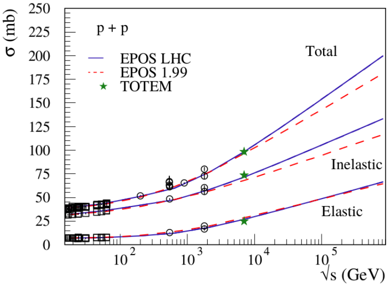
Possible Decays

The decay routine of EPOS reads in a list of possible decays for each type (src/epos/epos-dky.f) with its associated ratio to occur.

LHC data can be described by EPOS LHC

Cross Section

The most fundamental parameters of the EPOS model are fixed by comparing the cross sections calculated from the single scattering amplitude with the measured data. Thanks to the TOTEM experiment, total, inelastic and elastic cross-sections are known now with a high precision and can be used to constrain the model at high energy.



Measurement of the Production Cross Section

Production Cross Section

Determines the probability for a projectile particle to interact and produce secondary particles with a given target particle. It is a useful quantity for collider experiments like the LHC but also for extensive air showers. The measurement of σ_{prod} is crucial since the cross section cannot be calculated from first-principles by the theory of the strong interaction.

When the number of all events with hadronic particle production, N prod , and the integrated luminosity, L , are determined, the cross sec- tion is calculated as

$$\sigma_{\text{prod}} = \frac{N_{prod}}{\mathcal{L}}$$

The acceptance to detect inelastic particle production is much larger in the forward region.

Results on the Production Cross Section

Table 12: Summary of cross sections obtained by the two different event selections.

	Selection	σ_{vis} **[mb]**	$\sigma_{\text{vis,had}}$ **[mb]**	σ_{prod} **[mb]**
Data	Single-arm	2003±76	1937±82	2063±89
	Double-arm	1873±66	1872±68	2059±84
EPOS-LHC	Single-arm	-	1947	2082
	Double-arm	-	1883	
QGSJETII-04	Single-arm	-	2059	2181
	Double-arm	-	1998	
DPMJET3.06	Single-arm	-	2116	2166
	Double-arm	-	2055	

Finally, the σ_{prod} values measured with both selections are combined by taking the central value. The statistical uncertainties and the uncertainty on the luminosity are correlated. For the remaining systematic uncertainties the correlation is less direct and they are taken to be uncorrelated. This yields a final result for the hadronic production cross section of

$$\sigma_{\text{prod}} = (2061 \pm 3\,(\text{stat}) \pm 34\,(\text{syst}) \pm 72\,(\text{lumi}))\ \text{mb}\ .$$