Pile-Up at ALICE

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Definition

- Whem the proton bunches of the LHC cross there can be zero or more p-p interactions.
- When more than one collision is recorded in an event we talk about **pile-up**.

Introduction

- The multiplicity that we are determining can come from multiple interactions.
- We are looking for the **multiplicity distritbution in a single interaction**.
- Main assumptions:
  - the interactions are completely independent of each other,
  - the number of collisions have a Poisson-distribution:

$$E_k = e^{-\mu} \frac{\mu^k}{k!}.$$

- The amount of pile-up is characterized by the expectation value of the number of simultaneous collisions: μ.

Determining μ

- We assume that the μ is constant during a single run (approximation).
- The value is accessible from the run condition table at `https://alimonitor.cern.ch/configuration`.

LHC10d	Beam					
Run#	Bunches	Scheme	Fill #	Energy	Intensity per bunch	Mu
126437	1		1,233	3,500	0.90	0.0590
126432	1		1,233	3,500	0.90	0.0600
126425	1		1,233	3,500	0.90	0.0560
126424	1		1,233	3,500	0.90	0.0500
126422	1		1,233	3,500	0.90	0.0520
126421	1		1,233	3,500	0.90	
126420	1		1,233	3,500	0.90	
126419	1		1,233	3,500	0.90	
126416	1		1,233	3,500	0.90	

Determining μ

- The value in the table is determined using beam-pickup counters and trigger rates:

$$\frac{CINT1B}{CBEAMB} = 1 - e^{-\mu} \qquad \mu = \ln(CBEAMB) - \ln(CBEAMB - CINT1B)$$

- We can work with events from runs with $\mu <= 0.05 \Rightarrow$ we can use approximations.
- The μ depends on the trigger $\Rightarrow$ different for inelastic and non-single diffractive events.

Detecting Pile-Up

- Pile-up is detected, when
  - the interactions have at least 0.8 cm distance along the z axis,
  - and there are at least 3 contributors to the vertices.
- These limits have been determined after extensive Monte-Carlo studies to ensure proper efficiency and to avoid fakes.
- We can find about 50% of the pile-up events after this exclusion $\Rightarrow$ we must correct for the remaining pile-up.

Modeling Pile-up

- The number of interactions in a bunch crossing have a distribution E_k.
- The multiplicity distribution in a single interaction is P_k, unknown.
- The multiplicity distribution for k interactions: $P_m^{\Sigma_k}$, a sum of independent P_k distributions:

$$P_m^{\Sigma_0} = 0$$
$$P_m^{\Sigma_k} = \sum_{i_1=0}^{\infty} \cdots \sum_{i_k}^{\infty} P_{i_1} \cdot \cdots \cdot P_{i_k} \delta_{i, \sum_{l=1}^{k} i_l} \ (k > 0)$$

- The measured multiplicity distribution is:

$$Q_m = \sum_{k=0}^{\infty} E_k P_m^{\Sigma_k}.$$

Deconvolution

- In our event sample we don't actually have events with zero collisions, so E_k is a modified Poisson distribution:

$$E'_0 = 0,$$
$$E'_k = E_k \frac{1}{1 - E_0}.$$

- Example reversed formulae:

$$Q_0 = \frac{e^{-\mu}}{1 - e^{-\mu}} \sum_{k=1}^{\infty} \frac{\mu^k}{k!} P_0^k = \frac{e^{-\mu}}{1 - e^{-\mu}} (e^{\mu P_0} - 1),$$
$$Q_1 = \frac{e^{-\mu}}{1 - e^{-\mu}} \sum_{k=1}^{\infty} \frac{\mu^k}{k!} k P_1 P_0^{k-1} = \frac{e^{-\mu}}{1 - e^{-\mu}} \mu e^{\mu P_0} P_1.$$

Complexity

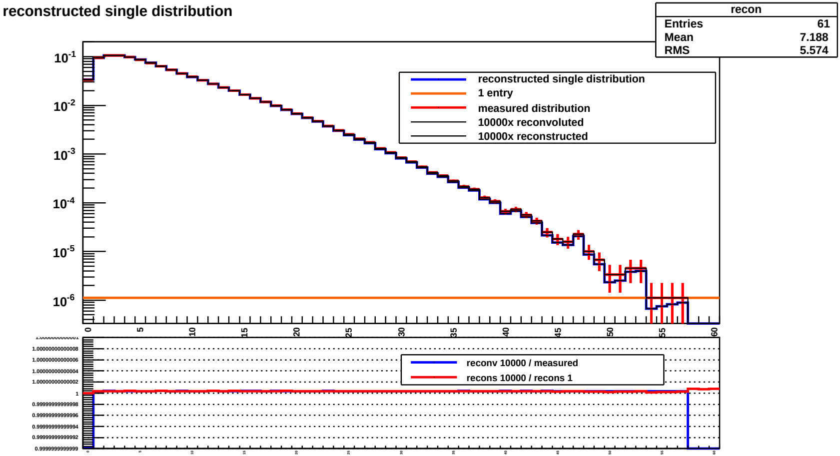
- Mathematical component of the solution: determine every possible way a positive integer can be decomposed into a sum of positive integers.
- Combinatorial complexity: very steep increase of terms.
- I wrote a simple program to calculate the terms in Q_m.
- Derivation of exact formulas beyond P_5 is not practical.

m	# terms
1	1
4	5
5	7
10	42
15	176
20	627
30	5604
50	204226

An approximation

- Currently, the deconvolution is done in two steps.
  1. I generate a code that can perform the deconvolution, which assumes a maximal number of collisions (currently 5). Every other term is discarded from the sums.
  2. The code is used on the measured distribution.
- The code is also capable of performing the convolution, which allows a simple test. I iterated the calculation and its inversion 10^4 times and there is no error accumulated.
- Tested with simple distributions generated with a Monte-Carlo method.

Example Deconvolution



Summary

- Pile-up is present at ALICE and we can measure the expectation value of the number of simultaneous collisions: μ.
- Finite pile-up detection efficiency requires the correction for pile-up.
- A simple model of pile-up can be constructed, but the combinatorial complexity is excessive.
- Working code: maximalising the number of simultaneous collisions. No numerical problem was found in testing.