Method for High Accuracy Multiplicity Correlation Measurements

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LUND UNIVERSITY

VILLUM FONDEN

Outline

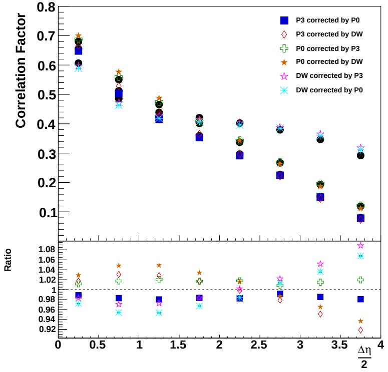
1. Introduction
2. Measuring Multiplicity Correlations with High Accuracy
   - The Simple Assumption
   - Achieving High Accuracy
   - Results from Simulations
3. Summary

Motivation ...

... to develop a high accuracy and model independent method for measuring multiplicity correlations.

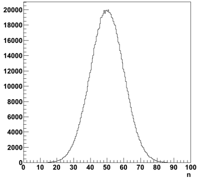
Especially forward-backward correlations since:

- Tuning of event-generators
- MPI play an important role
- Important for understanding the underlying event
- Interesting for Heavy-Ion collisions

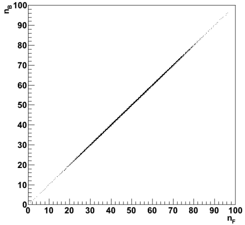


The Correlation Factor

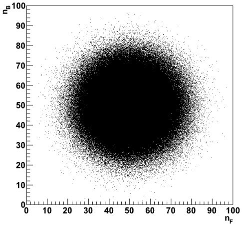
$$b = \mathrm{Cor}(N_f, N_b) = \frac{\mathrm{Cov}(N_f, N_b)}{\sqrt{\mathrm{Var}(N_f)\mathrm{Var}(N_b)}}$$
$$= \frac{\langle N_f N_b \rangle - \langle N_f \rangle \langle N_b \rangle}{\sqrt{\left(\langle N_f^2 \rangle - \langle N_f \rangle^2\right)\left(\langle N_b^2 \rangle - \langle N_b \rangle^2\right)}}$$



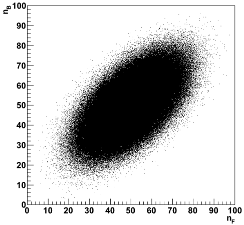
$b = 1$



$b = 0$



$b = 0.6$



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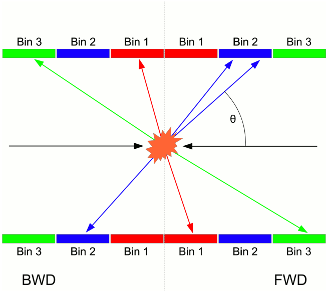
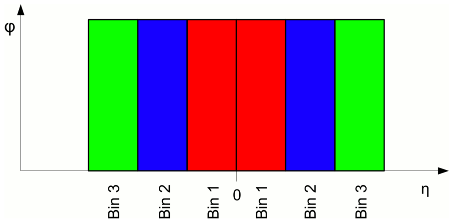
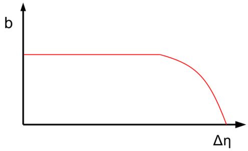
$$\eta = -\ln\left[\tan\left(\frac{\theta}{2}\right)\right]$$

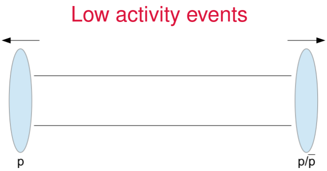




The Origin of Long Range Correlations

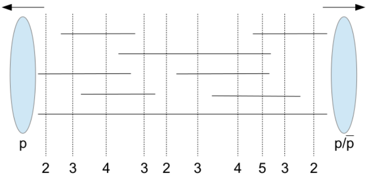
- Correlations occur due to (colour) connections between the receding participants.
- QCD predicts the formation of colour strings between the receding partons.
- Strings radiate off particles - flat b-distribution in this picture.

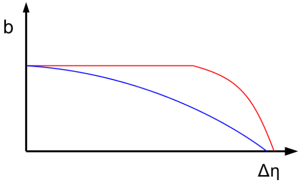




A More Realistic Picture

- Strings do not span the full region between the beam-remnants.
- Shorter strings between participants at different rapidities
- Reduced and varying number of possible interactions between the strings - b-distribution not flat.





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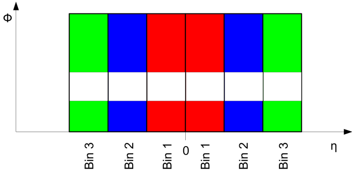
The Simple Assumption

Assume equal probability ε that any given particle is accepted
- equivalent to uniform distribution of particles across the bin.

In this case the moments of the bi-variate distribution become:



$$\widehat{\langle N \rangle} = \langle N \rangle \varepsilon$$

$$\widehat{\langle N_f N_b \rangle} = \langle N_f N_b \rangle \varepsilon_f \varepsilon_b$$

$$\widehat{\langle N^2 \rangle} = \langle N^2 \rangle \varepsilon^2 + \langle N \rangle \varepsilon (1 - \varepsilon)$$

$$\widehat{\mathrm{Cov}}(N_x, N_y) = \left(\langle N_x N_y \rangle - \langle N_x \rangle \langle N_y \rangle\right) \varepsilon_x \varepsilon_y + \delta_{x,y} \langle N \rangle \varepsilon (1 - \varepsilon)$$

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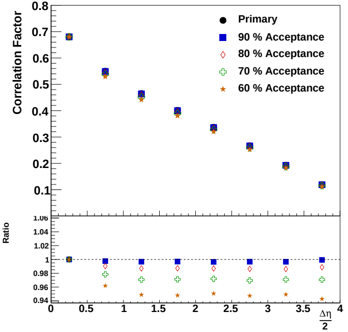

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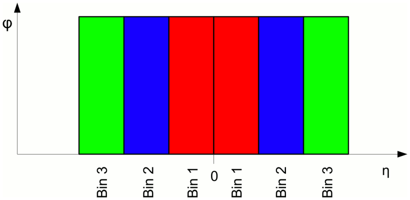
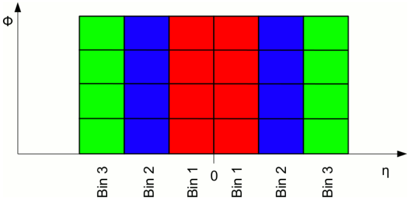
Achieving High Accuracy

Need to take the event shape into account, ie. the azimuthal distribution of particles.
Divide the bins into segments of equal size in φ.





Achieving High Accuracy

Realising that the covariance of the total set is the double sum of covariances between the N subsets:

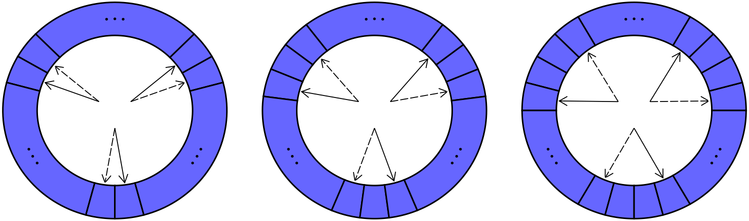
$$\mathrm{Cov}(X, Y) = \sum_{i=1}^{N} \sum_{j=1}^{N} \mathrm{Cov}(X_i, Y_j)$$

we can use the symmetry of the experiment to "fill in the missing pieces".

Equally sized segments will on average and over many events measure the same multiplicity.

Exploiting the Rotational Invariance

The covariances between all segments are all identical for equal separations when considering the primary particle distribution.

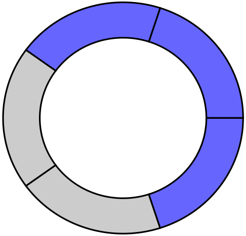


The rotational invariance can be exploited to calculate the covariance for 2π in azimuth in the presence of reduced acceptance and imperfect detection efficiency.

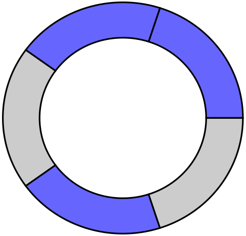
The Formula

$$\mathrm{Cov}(N^P_{r_1}, N^P_{r_2}) =$$
$$m_\varphi \cdot \frac{\sum_{i_\varphi=1}^{m_\varphi} \mathrm{Cov}(N^D_{r_1,i_\varphi}, N^D_{r_2,i_\varphi})}{\sum_{i_\varphi=1}^{m_\varphi} \varepsilon_{r_1,i_\varphi}\varepsilon_{r_2,i_\varphi}}$$
$$+ m_\varphi \cdot \sum_{s=1}^{m_\varphi-1} \left\{ \frac{\sum_{i_\varphi=1}^{m_\varphi-s} \mathrm{Cov}(N^D_{r_1,i_\varphi}, N^D_{r_2,i_\varphi+s}) + \sum_{i_\varphi=1}^{s} \mathrm{Cov}(N^D_{r_1,m_\varphi+i_\varphi-s}, N^D_{r_2,i_\varphi})}{\sum_{i_\varphi=1}^{m_\varphi-s} \varepsilon_{r_1,i_\varphi}\varepsilon_{r_2,i_\varphi+s} + \sum_{i_\varphi=1}^{s} \varepsilon_{r_1,m_\varphi+i_\varphi-s}\varepsilon_{r_2,i_\varphi}} \right\}$$
$$- \delta_{r_1 r_2} \cdot m_\varphi \cdot \frac{\sum_{i_\varphi=1}^{m_\varphi} \varepsilon_{r_1,i_\varphi}\left(1 - \varepsilon_{r_1,i_\varphi}\right)}{\sum_{i_\varphi=1}^{m_\varphi} \varepsilon^2_{r_1,i_\varphi}} \cdot \frac{\sum_{i_\varphi=1}^{m_\varphi} \langle N^D_{r_1,i_\varphi} \rangle}{\sum_{i_\varphi=1}^{m_\varphi} \varepsilon_{r_1,i_\varphi}}$$

Scaling Factors



Sep.	0	1	2	3	4
	↓	↓	↓	↓	↓
Contr.	3	2	1	1	2
Scale	$\frac{5}{3}$	$\frac{5}{2}$	$\frac{5}{1}$	$\frac{5}{1}$	$\frac{5}{2}$



Sep.	0	1	2	3	4
	↓	↓	↓	↓	↓
Contr.	3	1	2	2	1
Scale	$\frac{5}{3}$	$\frac{5}{1}$	$\frac{5}{2}$	$\frac{5}{2}$	$\frac{5}{1}$

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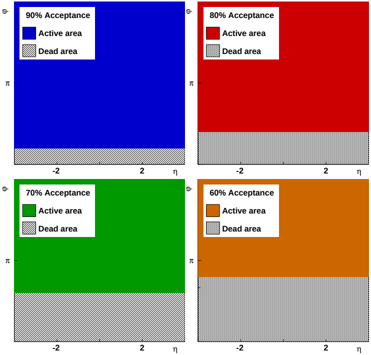
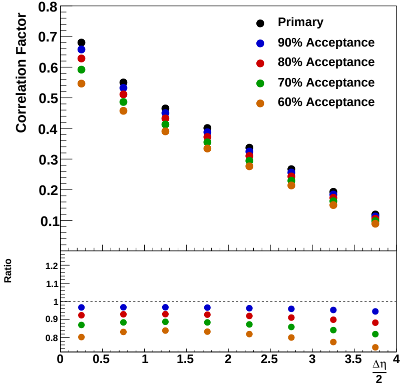
'Holes' in φ-regions

Method tested on a simulation using Pythia6 tuned with Perugia0 using 10 segments along φ.





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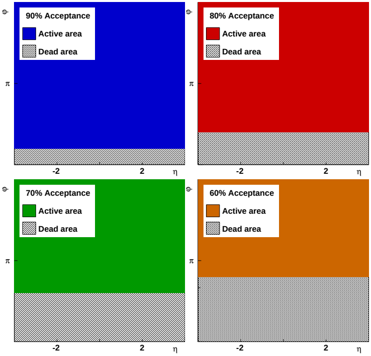
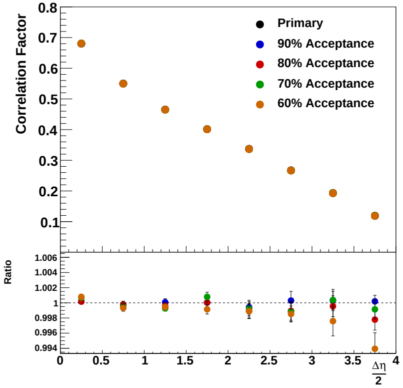
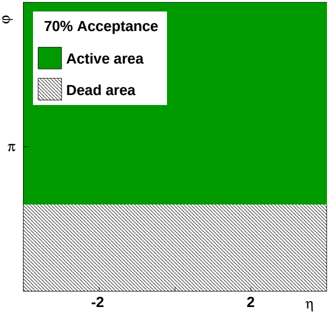
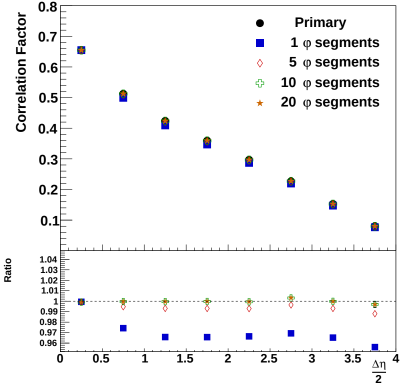


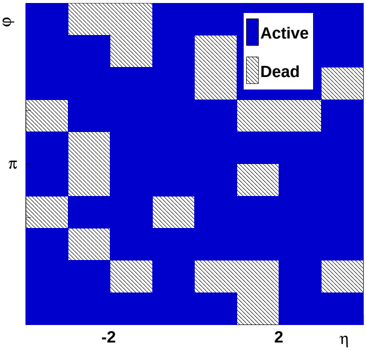


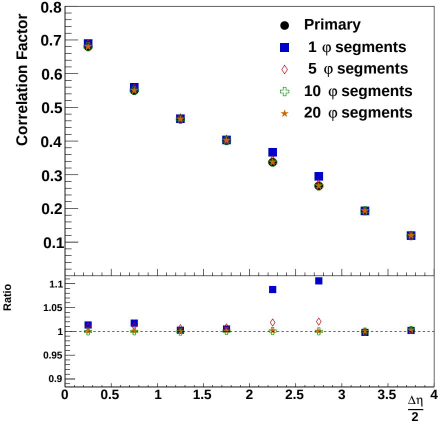
The Effect of Varied Segmentation





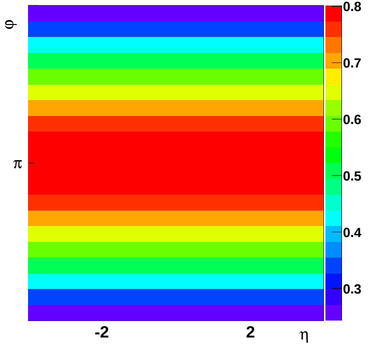
"Holes" at Random Locations



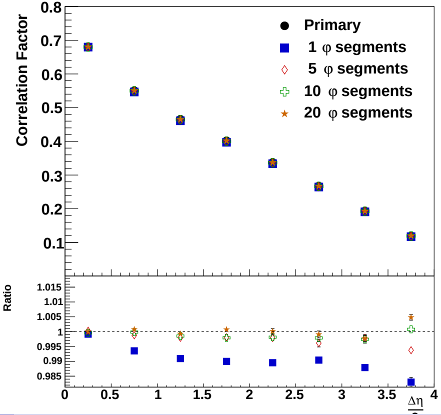


Efficiency Gradient

$20\% < \varepsilon < 80\%$



Results with varied φ segmentation

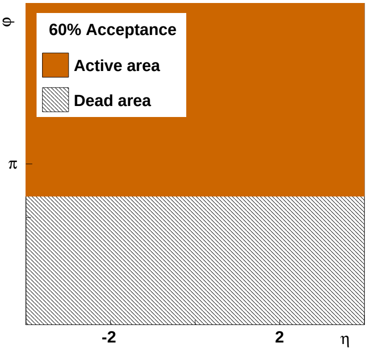


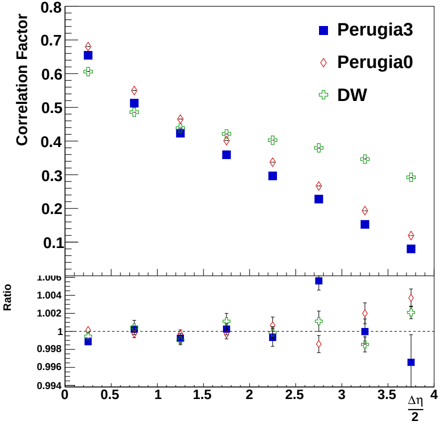
Summary

- The presented method provides a framework to correct for detection efficiency (almost) without bias
- Work in progress on a method to correct for secondary particle contamination
- Fwd-Bwd correlations can be measured with separations of up to 7 units in η by using data from the ITS and FMD of ALICE
- Method paper on arxiv at http://arxiv.org/abs/arXiv:1408.3391 where the formulas and the full derivation can be found

Backup slides

Model Comparisons

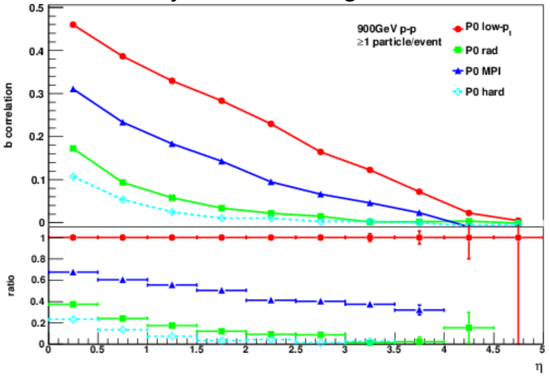




MPI and Fwd-Bwd Correlations

low-p_t	All
MPI	Multiple Parton Interactions
rad	Parton showers
hard	Hard two–particle scatterings

Pythia 6 : Perugia0



P.Z. Skands & K. Wraight

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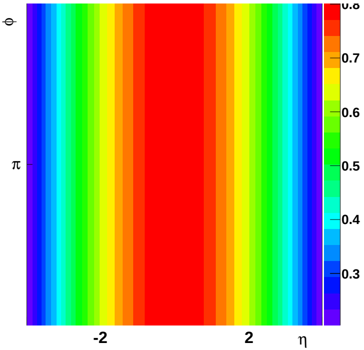

Results with varied η segmentation