Pythia tuning of Minimum Bias for LHCb

Paul Szczypka

Overview

- Reasons for Re-Tune
- Tuning method
- Review Settings
- Results
- Results at $\sqrt{s}$ = 14. TeV and 1800. GeV
- Summary
- References

Reasons to Produce Tune

- Excited Meson states included
  - ~12% of b-mesons are expected to be produced in excited states
  - B** states decay strongly via pion emission
  - Multiplicity is increased
- Prompt J/ψ processed included
  - Important for calculating J/ψ X backgrounds (see Vincenzo Vagnoni's talk – LHCb week Wed 1st Dec)

paul.szczypka@cern.ch

Introduction

- Using Pythia v6.224 in standalone mode
  - Default settings are taken from Tune A
  - Additional settings taken from the LHCb simulation program "Gauss"
  - No use of EVTGEN

Pythia Settings from Gauss

MSEL = 0
MSUB(11) = 1
MSUB(12) = 1
MSUB(13) = 1
MSUB(28) = 1
MSUB(53) = 1
MSUB(68) = 1
MSUB(91) = 1
MSUB(92) = 1
MSUB(93) = 1
MSUB(94) = 1
MSUB(95) = 1
MSUB(86) = 1
MSUB(87) = 1
MSUB(88) = 1
MSUB(89) = 1
MSUB(106) = 1
MSUB(107) = 1
MSUB(108) = 1

Prompt J/ψ (important for J/ψX background studies)

CKIN(3) = 0.

MSTP(2) = 2
MSTP(33) = 3
MSTP(51) = 4032
MSTP(52) = 2
MSTP(81) = 1
MSTP(82) = 3
MSTP(128) = 2

PARP(82) = 3.45
PARP(89) = 14000.
PARP(90) = 0.
PARP(85) = 0.33
PARP(86) = 0.66
PARP(31) = 1.5

Excited Meson Settings

PARJ(13) = 0.75
PARJ(14) = 0.162
PARJ(15) = 0.018
PARJ(16) = 0.054
PARJ(17) = 0.09

PARJ(21) = 0.36
PARJ(55) = -0.005

MSTJ(11) = 4
MSTJ(30) = 0
MSTJ(31) = 0
MSTJ(32) = 0
MSTJ(33) = 0
MSTJ(34) = 0

MSTU(130) = 0
MSTU(131) = 0
MSTU(132) = 0

Pythia Settings at sub-LHC energies

MSEL = 0
MSUB(11) = 1
MSUB(12) = 1
MSUB(13) = 1
MSUB(28) = 1
MSUB(53) = 1
MSUB(68) = 1
MSUB(91) = 0
MSUB(92) = 0
MSUB(93) = 0
MSUB(94) = 1
MSUB(95) = 1
MSUB(86) = 1
MSUB(87) = 1
MSUB(88) = 1
MSUB(89) = 1
MSUB(106) = 1
MSUB(107) = 0
MSUB(108) = 0

CKIN(3) = 0.

MSTP(2) = 2
MSTP(33) = 3
MSTP(51) = 4032
MSTP(52) = 2
MSTP(81) = 1
MSTP(82) = 3
MSTP(128) = 2

PARP(82) = 3.45
PARP(89) = 14000.
PARP(90) = 0.
PARP(85) = 0.33
PARP(86) = 0.66
PARP(31) = 1.5

Set to Non-single Diffractive Events for sub-LHC energies (MSUB(91)–MSUB(94))

Prompt J/ψ (MSUB(106)–MSUB(108))

Excited Meson Settings

PARJ(13) = 0.75
PARJ(14) = 0.162
PARJ(15) = 0.018
PARJ(16) = 0.054
PARJ(17) = 0.09

PARJ(21) = 0.36
PARJ(55) = -0.005

MSTJ(11) = 4
MSTJ(30) = 0
MSTJ(31) = 0
MSTJ(32) = 0
MSTJ(33) = 0
MSTJ(34) = 0

MSTU(130) = 0
MSTU(131) = 0
MSTU(132) = 0

Tuning Method

Multiplicity data from:

http://oschneid.home.cern.ch/oschneid/minbias_data/cdf_eta.txt

(Both UA5 and CDF data)

Method: *(LHCb note: LHCb 99-028 PHYS)*

• In the multiple interaction models available in Pythia, P_{Tmin} is the minimum transverse momentum of the parton – parton collisions.

• At each √s, the P_{Tmin} parameter, PARP(82) , is adjusted to reproduce the average multiplicity from the measured data.

• Linear fit performed on the average multiplicity difference to calculate best PARP(82) value at each √s

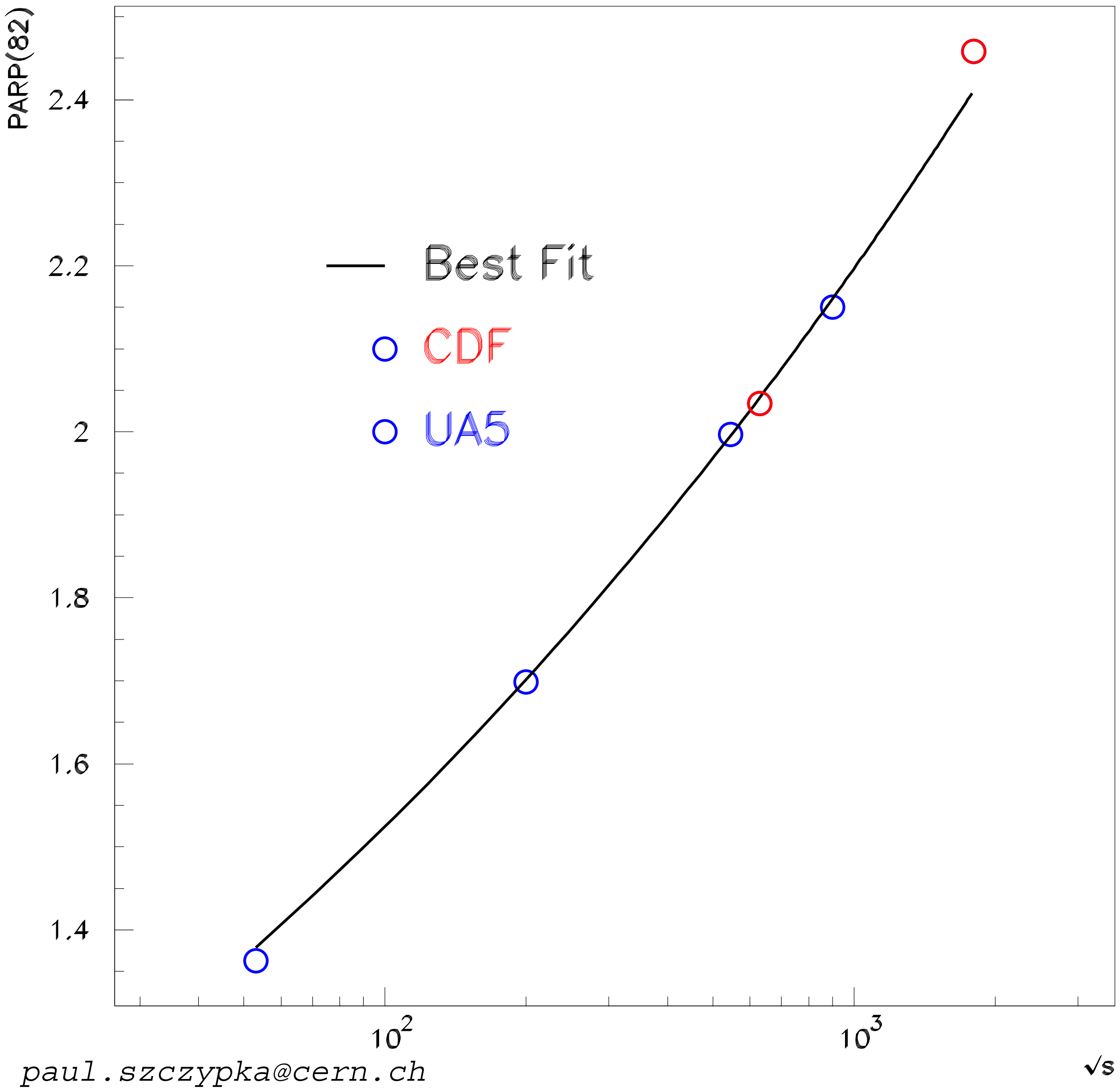
paul.szczypka@cern.ch

Results

Energy/GeV	P_T Min	$<dN_{ch}/d\eta>_{\eta=0}$ Simulated	$<dN_{ch}/d\eta>_{\eta=0}$ Data
53	1.36 ± 0.05	1.95 ± 0.02	1.96 ± 0.10
200	1.70 ± 0.04	2.45 ± 0.03	2.48 ± 0.07
546	2.00 ± 0.01	3.03 ± 0.03	3.05 ± 0.03
630	2.03 ± 0.12	3.19 ± 0.03	3.18 ± 0.15
900	2.15 ± 0.02	3.46 ± 0.03	3.48 ± 0.07
1800	2.46 ± 0.15	3.97 ± 0.04	3.95 ± 0.15

Extrapolation of P_T_min I

Fitting to: $$P_{T_{min}}(\sqrt{s}) = P_{T_{min}}^{\mathrm{LHC}} \left(\frac{\sqrt{s}}{14\ \mathrm{TeV}} \right)^{2\epsilon}$$



$P_{T\,Min}^{LHC} = 3.34 \pm 0.13$

$\varepsilon = 0.079 \pm 0.006$

These values give:

$\langle dN_{ch}/d\eta \rangle_{\eta=0}^{LHC} = 6.45 \pm 0.25$

in Single-Diffractive Events

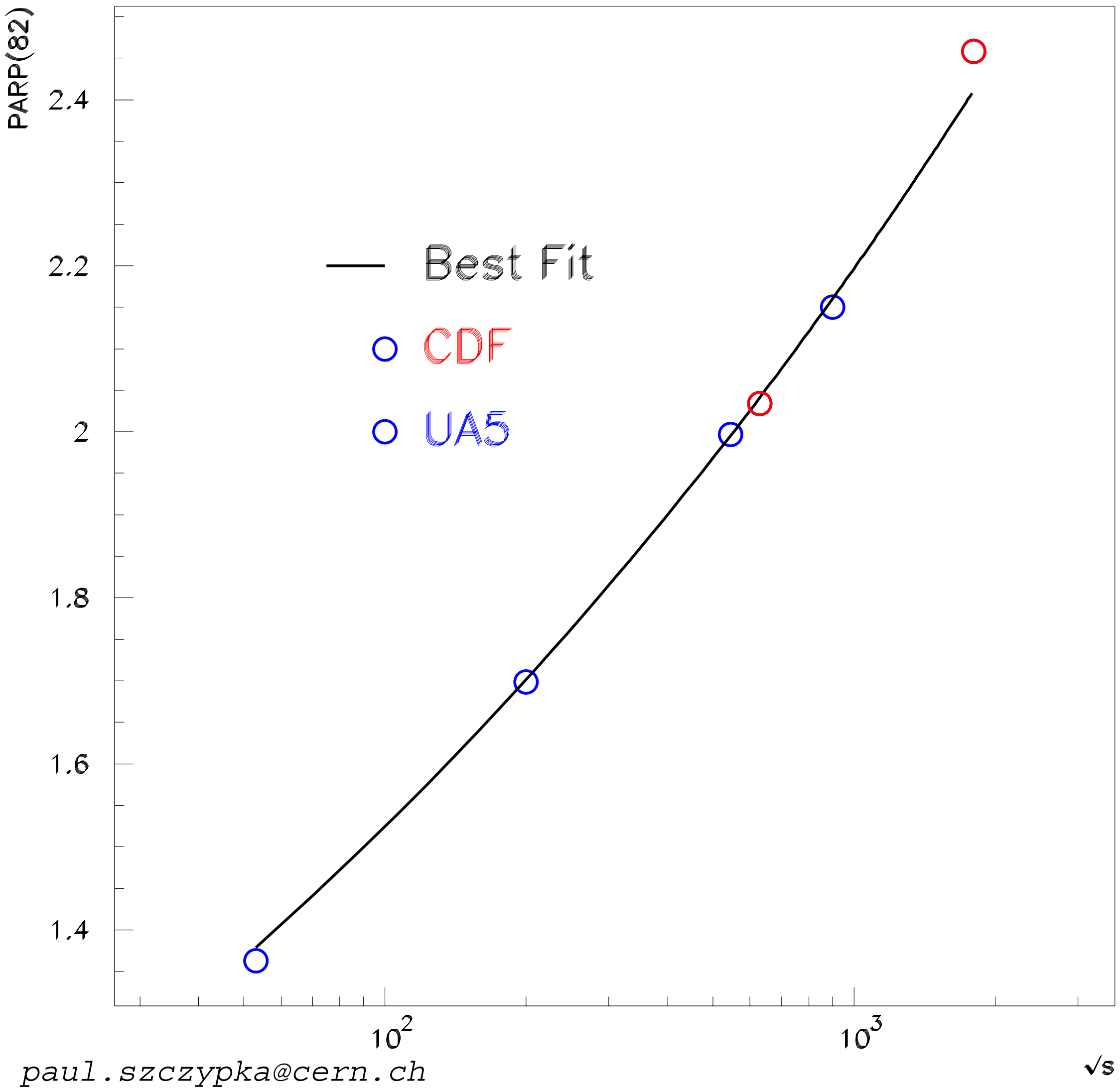
Compared to the phenomenological extrapolation of:

$\langle dN_{ch}/d\eta \rangle_{\eta=0}^{LHC} = 6.27 \pm 0.50$

→ **Compatible**

Extrapolation of P_T_min II

Evaluating $P_{T\,min}$ at 1800. GeV:



$$P_{T\,Min}^{1800.} = 2.42 \pm 0.04$$

This value gives:

$$\langle dN_{ch}/d\eta\rangle_{\eta=0}^{1800.} = 4.05 \pm 0.06$$

Compared to the measured data:

$$\langle dN_{ch}/d\eta\rangle_{\eta=0}^{1800.} = 3.95 \pm 0.15$$

→ **Compatible**

Summary

- Pythia v6.224 tuned to reproduce multiplicity values from UA5 & CDF data at energies of 53, 200, 546, 630, 900 and 1800 GeV
- Prompt J/ψ and B** turned on
- Tuning gives $P_T Min^{LHC} = 3.34 \pm 0.13$
- Which produces $\langle dN_{ch}/d\eta \rangle^{LHC}_{\eta=0} = 6.45 \pm 0.25$ compatible with the extrapolated value.

References

[1]. P. Bartalini et al. LHCb note: LHCb 99-028

[2]. http://oschneid.home.cern.ch/oschneid/minbias_data/cdf_eta.txt

[3]. Observation of orbitally excited B mesons in p-pbar collisions at $\sqrt{s}$ = 1800. GeV - Phys Review D, Vol 64, 072002

Any questions?

Settings used for mult. calculation at 14 TeV

MSEL = 0
MSUB(11) = 1
MSUB(12) = 1
MSUB(13) = 1
MSUB(28) = 1
MSUB(53) = 1
MSUB(68) = 1
MSUB(91) = 0
MSUB(92) = 1
MSUB(93) = 1
MSUB(94) = 0
MSUB(95) = 1
MSUB(86) = 1
MSUB(87) = 1
MSUB(88) = 1
MSUB(89) = 1
MSUB(106) = 1
MSUB(107) = 0
MSUB(108) = 0

Set to Single Diffractive Events for LHC energies

Prompt J/ψ

CKIN(3) = 0.

MSTP(2) = 2
MSTP(33) = 3
MSTP(51) = 4032
MSTP(52) = 2
MSTP(81) = 1
MSTP(82) = 3
MSTP(128) = 2

PARP(82) = 3.45
PARP(89) = 14000.
PARP(90) = 0.
PARP(85) = 0.33
PARP(86) = 0.66
PARP(31) = 1.5

Excited Meson Settings

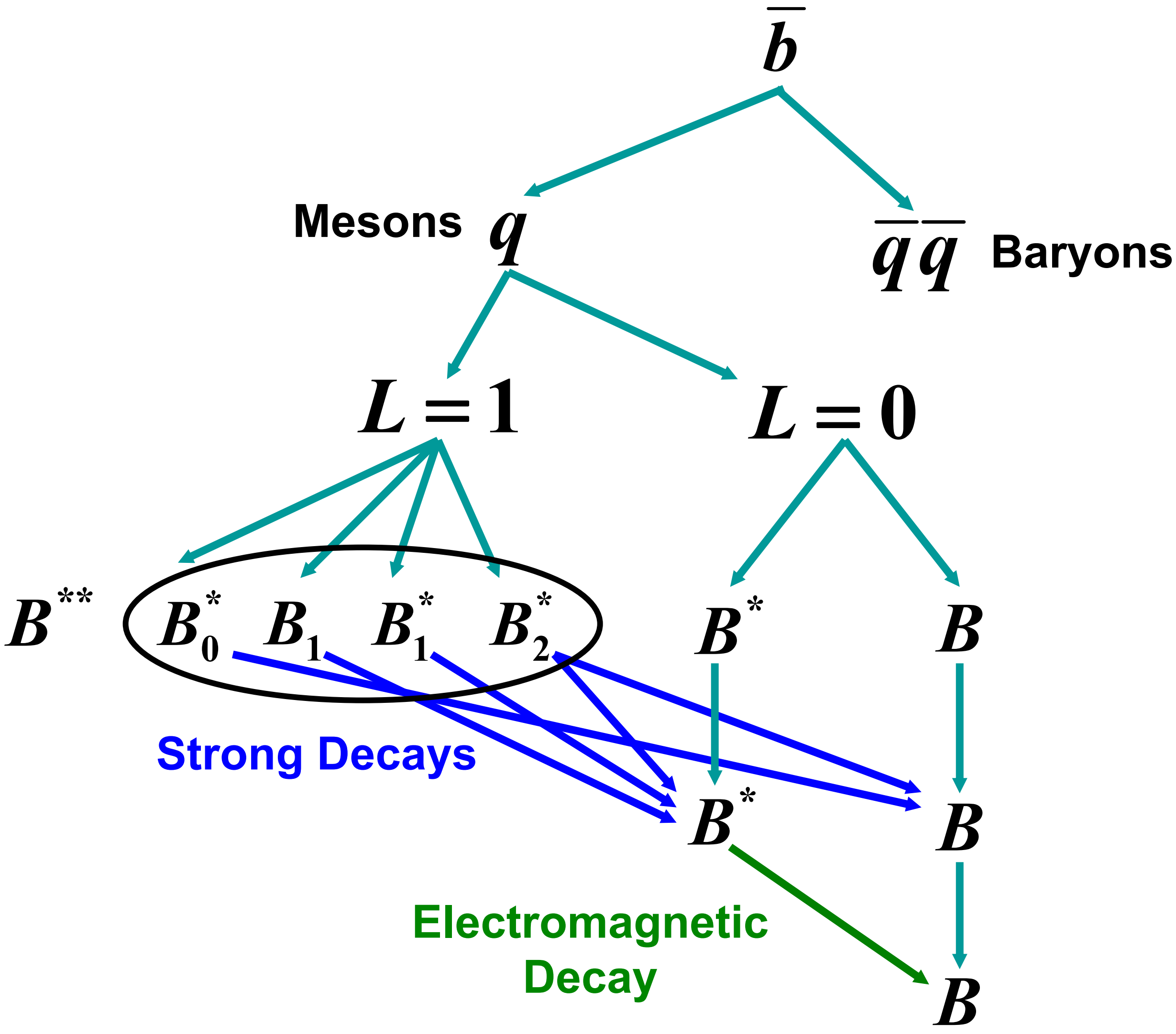
PARJ(13) = 0.75
PARJ(14) = 0.162
PARJ(15) = 0.018
PARJ(16) = 0.054
PARJ(17) = 0.09

PARJ(21) = 0.36
PARJ(55) = -0.005

MSTJ(11) = 4
MSTJ(30) = 0
MSTJ(31) = 0
MSTJ(32) = 0
MSTJ(33) = 0
MSTJ(34) = 0

MSTU(130) = 0
MSTU(131) = 0
MSTU(132) = 0

Excited B meson states



$$B_s^{**} \not\to B_s^{(*)}\pi$$

Forbidden from Isospin conservation

Slide taken from Vincenzo's talk, LHCb week, 1st Dec

paul.szczypka@cern.ch

PARJ settings explained

Pythia parameter	meaning	Default value
PARJ(1)	Meson, baryon fraction	0.10
PARJ(2)	Strangeness production	0.30
PARJ(11)	*P*(light meson has spin 1)	0.5
PARJ(12)	*P*(strange meson has spin 1)	0.6
PARJ(13)	*P*(S=1 (b, c))	0.75
PARJ(14)	*P*(S=0,L=1,J=1)	0.0
PARJ(15)	*P*(S=1,L=1,J=0)	0.0
PARJ(16)	*P*(S=1,L=1,J=1)	0.0
PARJ(17)	*P*(S=1,L=1,J=2)	0.0

Excited Meson Ratios

- Tried to match HFAG averages on B meson fractions
  - This was done by reducing the amount of B** production wrt e.g. CDF settings
- but keeping some clear LEP measurements and spin counting rule for B** states
  - $\sigma(B^*)/(\sigma(B^*)+\sigma(B)) = 75\%$
  - $\sigma(B^*0):\sigma(B1):\sigma(B^*1):\sigma(B^*2) = 1:3:3:5$
- The side effect in reducing the B** production is that also the increase in charged multiplicity is reduced

- Adopted Pythia settings:
  - PARJ(13)=0.75
  - PARJ(14)=0.162
  - PARJ(15)=0.018
  - PARJ(16)=0.054
  - PARJ(17)=0.09

Slide taken from Vincenzo's talk, LHCb week, 1st Dec

- The experimental data are fitted with the phenomenological trend
  $(0.023\pm0.008)\ln^2(s)+(0.24\pm0.18)\ln(s)+(2.42\pm0.98)$

- Extrapolating at 14 TeV we obtain
  $\langle dN_{ch}/d\eta\rangle_{\eta=0} = 6.27\pm0.50$