# Charge non-conservation in Herwig and Pythia 5.3.3 MC samples

(studies on dijet event samples
with Pt = 18, 150 GeV)

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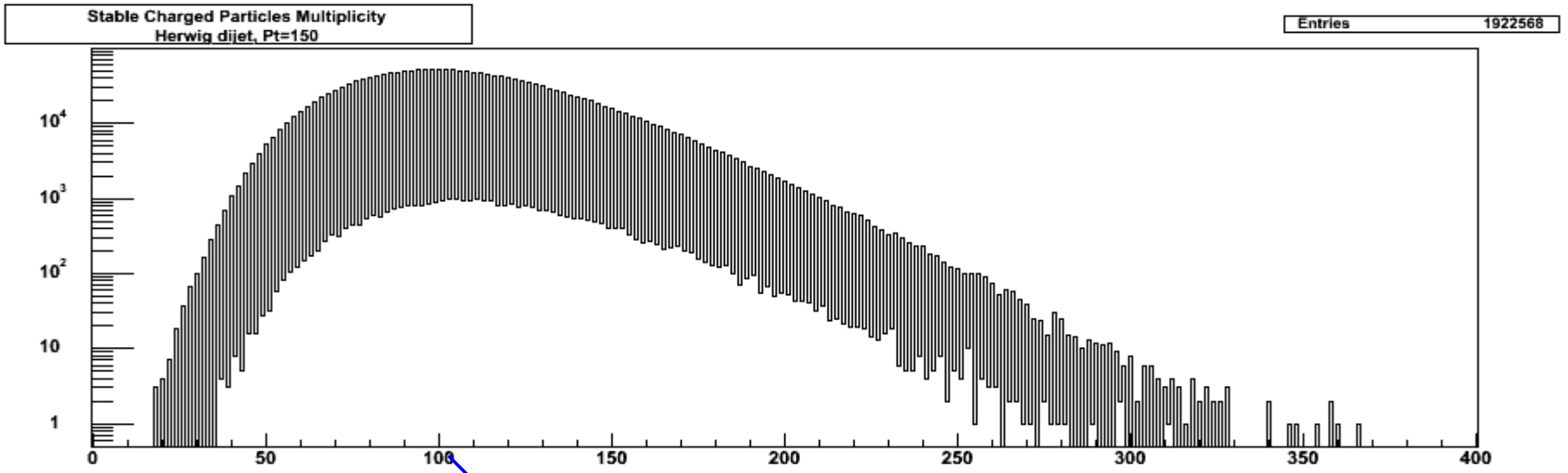
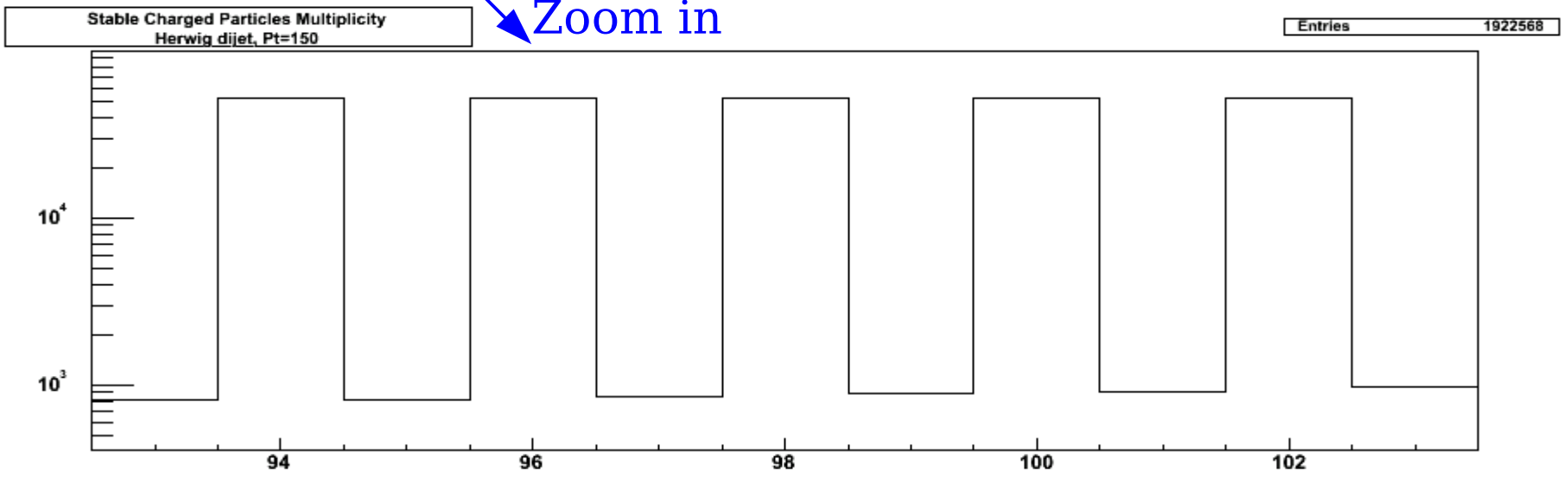
QCD meeting 06/24/05

# Illustration of the problem(Herwig case, hwdj150)

Electric & Baryon charges have to be conserved in the *final state*:
=> Only even number of charged, stable particles in the HEPG bank




Zoom in



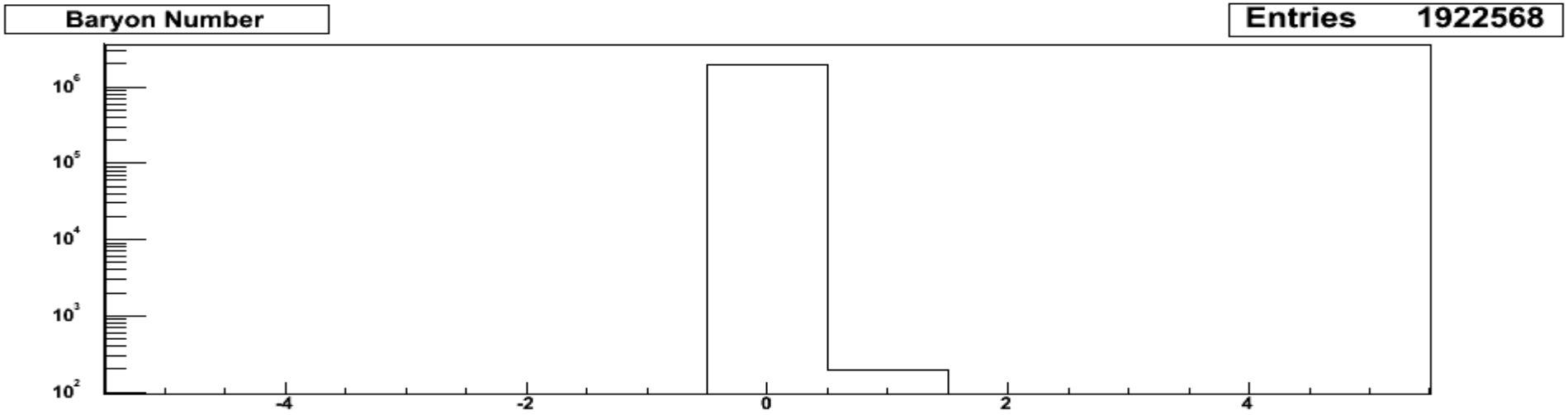
# Illustration of the problem(Herwig Case, hwdj150)

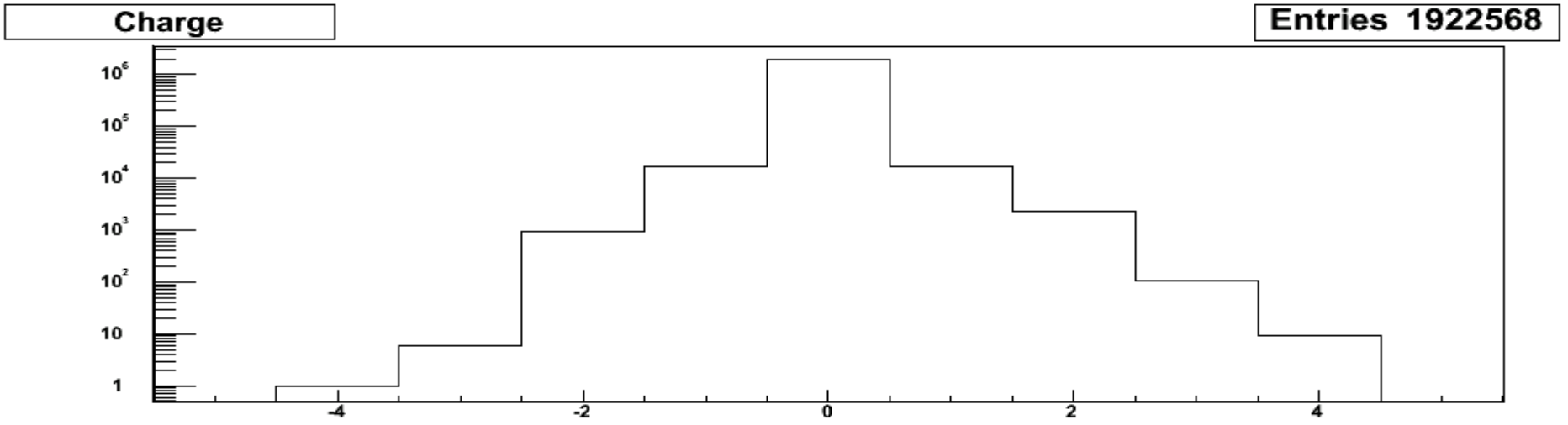
Electric & Baryon charges have to be conserved in the *final state*:

=> Baryon number must be 0

=> Electric charge must be 0

=> Leptonic number must be 0

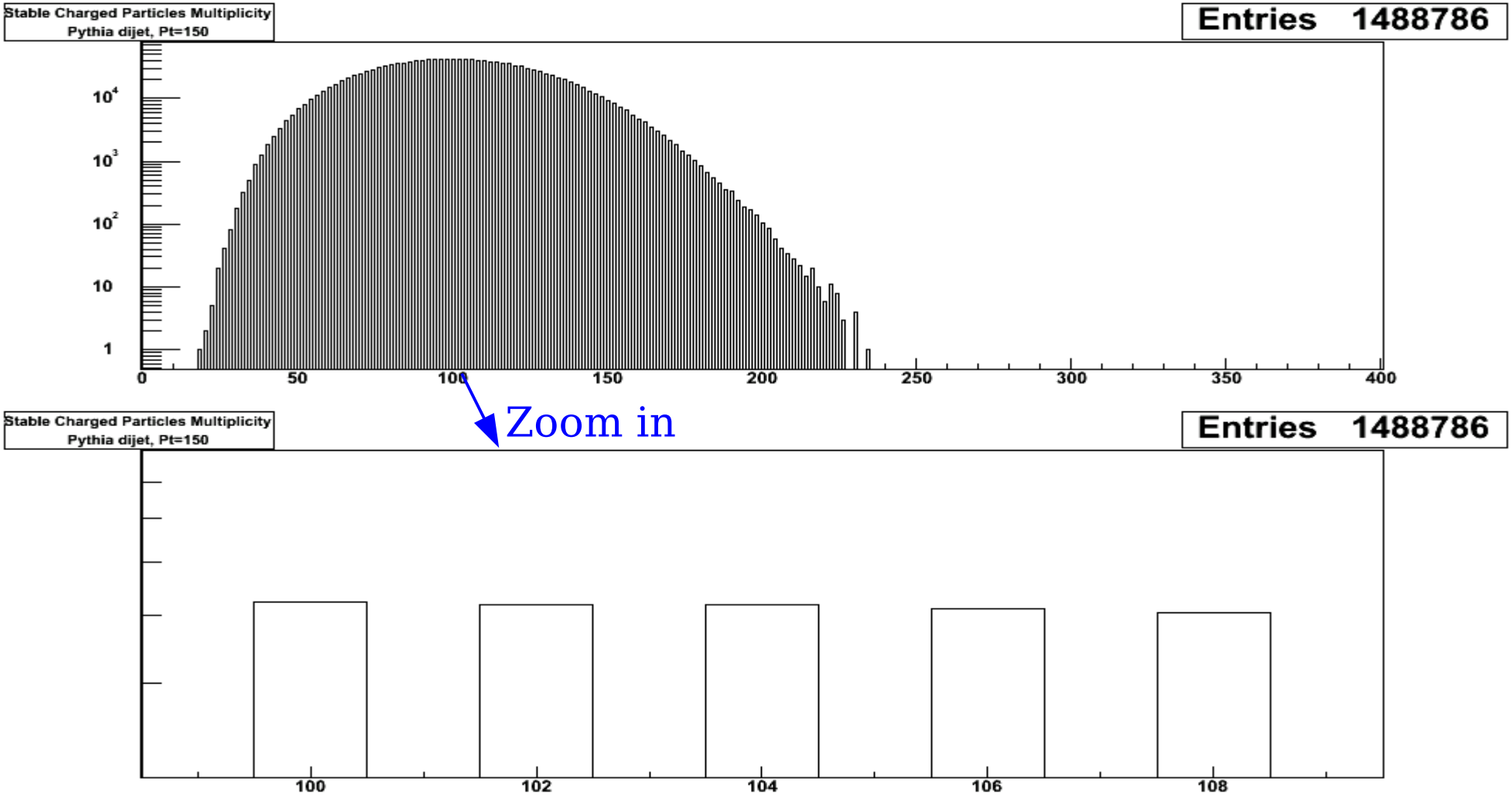


# Illustration of the problem(Pythia case, pydj150)

Electric & Baryon charges have to be conserved in the *final state*:

- Only even number of charged, stable particles in the HEPG bank

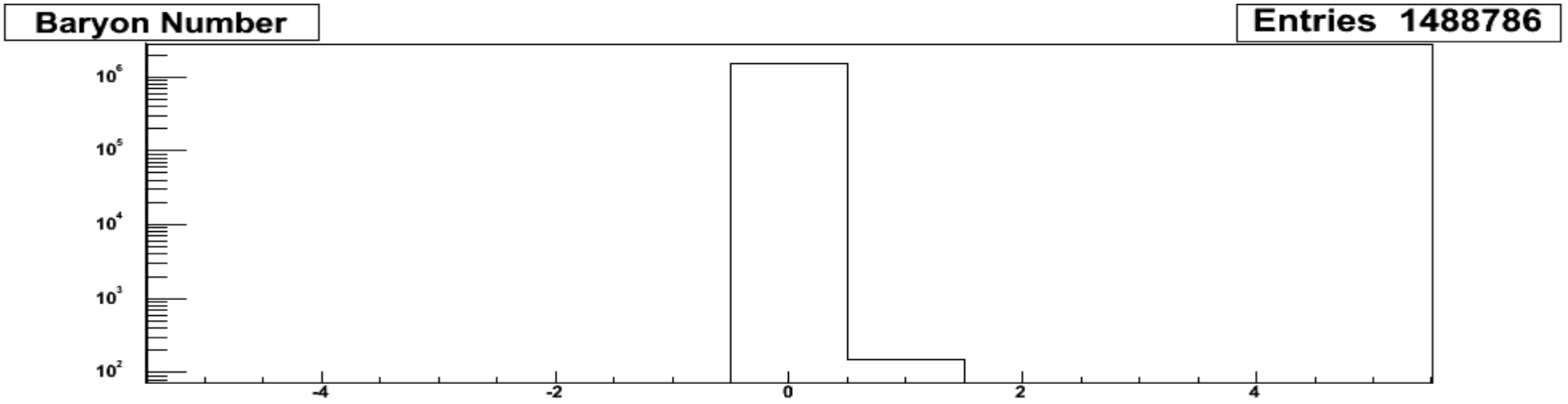


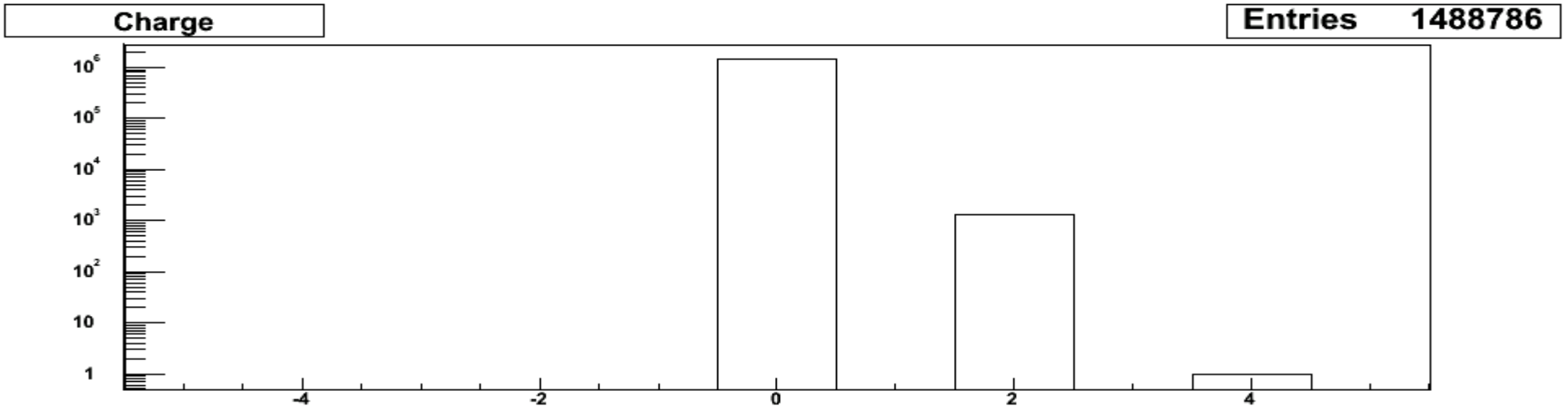

- Even though multiplicity looks OK, there are still problems with …

# Illustration of the problem(Pythia Case, pydj150)

Electric & Baryon charges have to be conserved in the *final state*:

- Baryon number must be 0
- Electric charge must be 0
- Leptonic number must be 0



# Searching for the source of the problem

- Select events where Charge and Baryon number are not conserved
- Look on these events for “bad decays”
- Trace the origin of the problems to the following decays

Pythia

Electric charge:

$$\overline{D}_0 \rightarrow K^+ \pi^+ \eta'$$

$$B_s^0 \rightarrow D_s^{*-} \pi^+ \pi^+ \pi^+$$

Baryon number:

$$\overline{\Lambda}_b^0 \rightarrow \Lambda_c^+ , \pi^- \bar{p}, \pi^+$$

Don't see correct decays for these channels

# Searching for the source of the problem

- Select events where Charge and Baryon number are not conserved
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- Trace the origin of the problems to the following decays

## Herwig

- The same problematic decays as Pythia, plus:

$B_0^{*0} \to B^+,\pi^0;\ B^0,\pi^+$
$B_0^{*+} \to B^0,\pi^0;\ B^+,\pi^-$

$B_1(L)^0 \to B^{*+},\pi^0;\ B^{*0},\pi^+$
$B_1(L)^+ \to B^{*0},\pi^0;\ B^{*+},\pi^-$

$B_1(H)^0 \to B^{*+},\pi^0;\ B^{*0},\pi^+$
$B_1(H)^+ \to B^{*0},\pi^0;\ B^{*+},\pi^-$

$B_2^{*0} \to B^{*+},\pi^0;\ B^{*0},\pi^+;\ B^+,\pi^0;\ B^0,\pi^+$
$B_2^{*+} \to B^{*0},\pi^0;\ B^{*+},\pi^-;\ B^0,\pi^0;\ B^+,\pi^-$

*...and their antiparticles*

→ “Bad b-mesons”

# Cross-check of Hypothesis

Baryon number

- Baryon number is violated by +1 per decay
- Count number of events which violate baryon number conservation
- Count number of decays which violate baryon number conservation
- These two numbers in a perfect agreement

Electric Charge($B_s^0$, $D_0$)

- Electric charge is violated by +2 per decay
- Count number of events which violate charge conservation
- Count number of decays which violate charge conservation
- These two numbers in a perfect agreement
- In Herwig case select events with no “bad b-mesons”

Electric Charge(“bad b-mesons”)

- Electric charge is violated with +1 or -1
- Select events with “bad b-mesons”. Look at total charge distribution
- Look at total charge distribution without any selection
- We expect these two distributions to be exactly the same in negative region
- They are the same

# Typos in the decay table

Particles decay via QQ module, which uses a decay table for this purpose

- We can find all problematic decays there.
- There are two versions of tables on QQ module web-page: old and new one
- Old version of the decay table has typos and it was used in the samples above
- In each MC sample we have to check which decay table was used.

## Old version of decay table:

http://mit1.fnal.gov/~fkw/QQ/decay.dbt

Example of: $B_0^{*0} \to B^+,\pi^0$; $B^0,\pi^+$

```
PDG      B3P0P     10511
....

DECAY  B3P0P
CHANNEL 0  0.33 B+ PI0
CHANNEL 0  0.67 B0 PI+
ENDDECAY
```

## New version of decay table:

http://cdfcodebrowser.fnal.gov/CdfCode/source/qq_i/decay.CDF

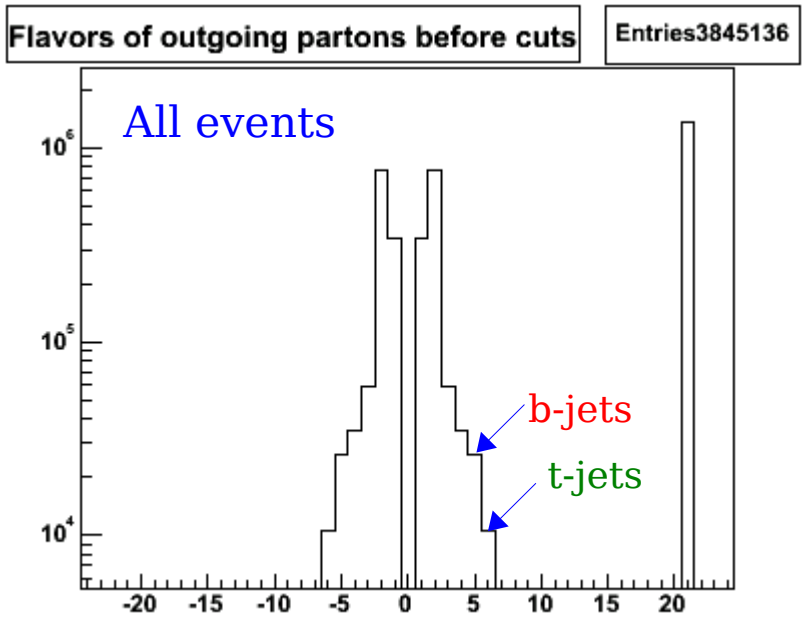
Example of: $B_0^{*0} \to B^0,\pi^0$; $B^+,\pi^-$

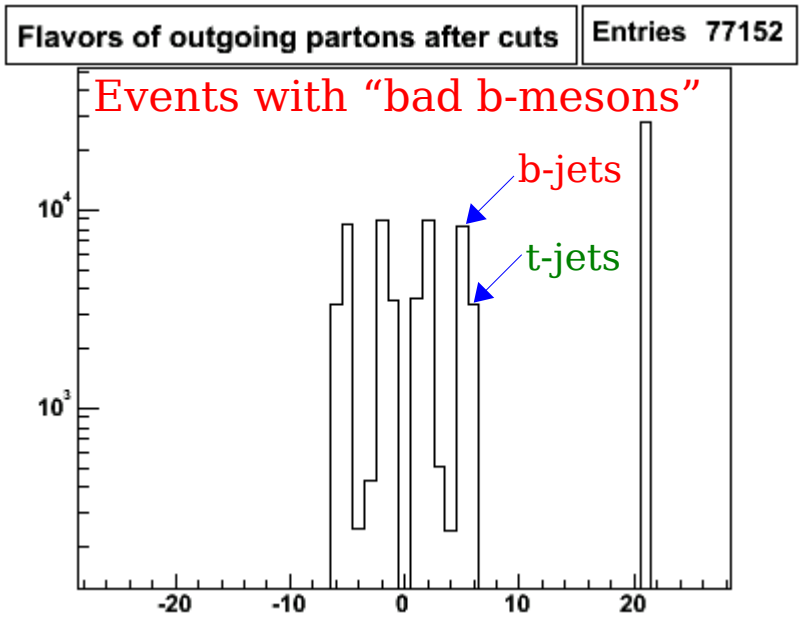
```
PDG      B3P00     10511
....

DECAY  B3P00
CHANNEL 0  0.33 B0 PI0
CHANNEL 0  0.67 B+ PI-
ENDDECAY
```

# Effect of these bugs

| | Herwig018(%) | Herwig150(%) | Pythia150(%) |
|---|---|---|---|
| (Number of ev.)/$N_{tot}$ with $\overline{\Lambda}_b^0$ bad decays | 0.006 | 0.01 | 0.01 |
| (Number of ev.)/$N_{tot}$ with $B_s^0$ or $\overline{D}_0$ bad decays | 0.06 | 0.08 | 0.09 |
| (Number of ev.)/$N_{tot}$ with „bad b-mesons” | 1.3 | 2.0 | 0.0 |




~32% of b-jets are affected by this bug!

Larger multiplicity in b-jets. Can it affect b-tagging?

# Conclusion

All 5.3.3 MC Samples(Herwig and Pythia) generated with old decay tables have wrong decays violating charge and baryon number.

Affected decays: $\overline{D}_0$, $\overline{\Lambda}_b^0$, $B_s^0$, class of “bad b-mesons”

~30% of b-jets in Herwig dijet150 have problematic decays. Smaller effect in Pythia.

Use extra care in analyzes involving b-jets, $\Lambda_b$ and $B_s$ mesons

Problem is easy to fix – check and fix the decay table

Should wider audience be notified?

# Badly decaying B-mesons(Appendix)

| | | $L=0$ | | $L=1$ | | | | |
|---|---|---|---|---|---|---|---|---|
| | | $S=0$ | $S=1$ | $S=0$ | $S=1$ | | | |
| | | $J=0$ | $J=1$ | $J=1$ | $J=0$ | $J=1$ | $J=2$ | |
| $q_1$ | $\overline{q}_2$ | $**1$ | $**3$ | $10**3$ | $10**1$ | $20**3$ | $**5$ | |
| d | $\overline{d}$ | $\pi^0$ | $\rho^0$ | $b_1^0$ | $a_0^0$ | $a_1^0$ | $a_2^0$ | 11 |
| | $\overline{u}$ | $\pi^-$ | $\rho^-$ | $b_1^-$ | $a_0^-$ | $a_1^-$ | $a_2^-$ | −21 |
| | $\overline{s}$ | $K^0$ | $K^{*0}$ | $K_1^0(1270)$ | $K_0^{*0}$ | $K_1^0(1400)$ | $K_2^{*0}$ | 31 |
| | $\overline{c}$ | $D^-$ | $D^{*-}$ | $D_1^-(2420)$ | $D_0^{*-}$ | $D_1^-(H)$ | $D_2^{*-}$ | −41 |
| | $\overline{b}$ | $B^0$ | $B^{*0}$ | $B_1^0(L)$ | $B_0^{*0}$ | $B_1^0(H)$ | $B_2^{*0}$ | 51 |
| u | $\overline{u}$ | $\eta$ | $\omega$ | $h_1(1170)$ | $f_0(980)$ | $f_1(1285)$ | $f_2(1270)$ | 22 |
| | $\overline{s}$ | $K^+$ | $K^{*+}$ | $K_1^+(1270)$ | $K_0^{*+}$ | $K_1^+(1400)$ | $K_2^{*+}$ | 32 |
| | $\overline{c}$ | $\overline{D}^0$ | $\overline{D}^{*0}$ | $\overline{D}_1^0(2420)$ | $\overline{D}_0^{*0}$ | $\overline{D}_1^0(H)$ | $\overline{D}_2^{*0}$ | −42 |
| | $\overline{b}$ | $B^+$ | $B^{*+}$ | $B_1^+(L)$ | $B_0^{*+}$ | $B_1^+(H)$ | $B_2^{*+}$ | 52 |
| s | $\overline{s}$ | $\eta'$ | $\phi$ | $h_1(1380)$ | $f_0(1300)$ | $f_1(1510)$ | $f_2'(1525)$ | 33 |
| | $\overline{c}$ | $D_s^-$ | $D_s^{*-}$ | $D_{s1}^-(2536)$ | $D_{s0}^{*-}$ | $D_{s1}^-(H)$ | $D_{s2}^{*-}$ | −43 |
| | $\overline{b}$ | $B_s^0$ | $B_s^{*0}$ | $B_{s1}^0(L)$ | $B_{s0}^{*0}$ | $B_{s1}^0(H)$ | $B_{s2}^{*0}$ | 53 |
| c | $\overline{c}$ | $\eta_c$ | $J/\psi$ | $h_c$ | $\chi_{c0}$ | $\chi_{c1}$ | $\chi_{c2}$ | 44 |
| | $\overline{b}$ | $B_c^+$ | $B_c^{*+}$ | $B_{c1}^+(L)$ | $B_{c0}^{*+}$ | $B_{c1}^+(H)$ | $B_{c2}^{*+}$ | 54 |
| b | $\overline{b}$ | $\eta_b$ | $\Upsilon(1S)$ | $h_b$ | $\chi_{b0}$ | $\chi_{b1}$ | $\chi_{b2}$ | 55 |