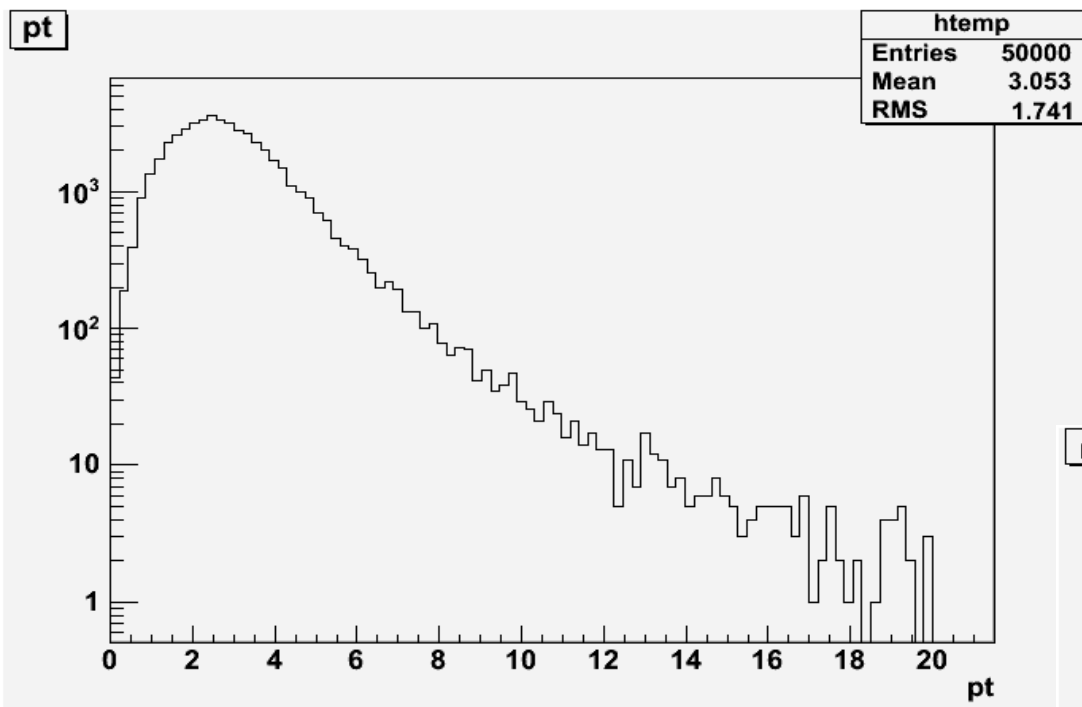
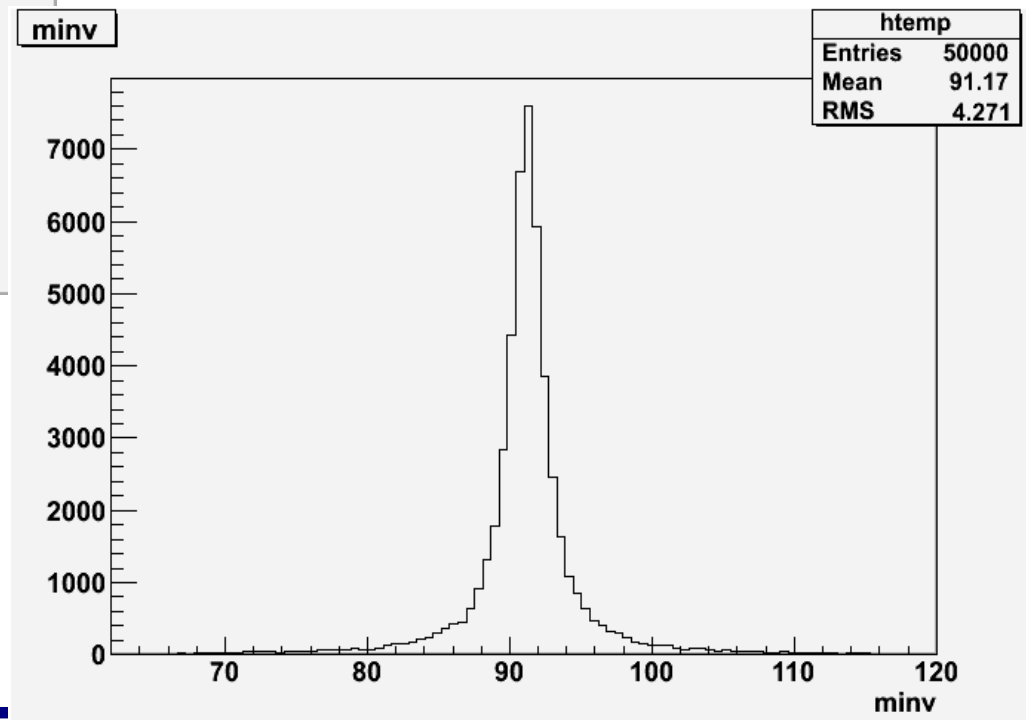


Issue:

Used a PTYHIA gun (Pythia6PtYDistGun) to generate Z0, with $p_T[0.20]\text{GeV}/c$, distributed according to a falling p_T spectrum, and flat in y .

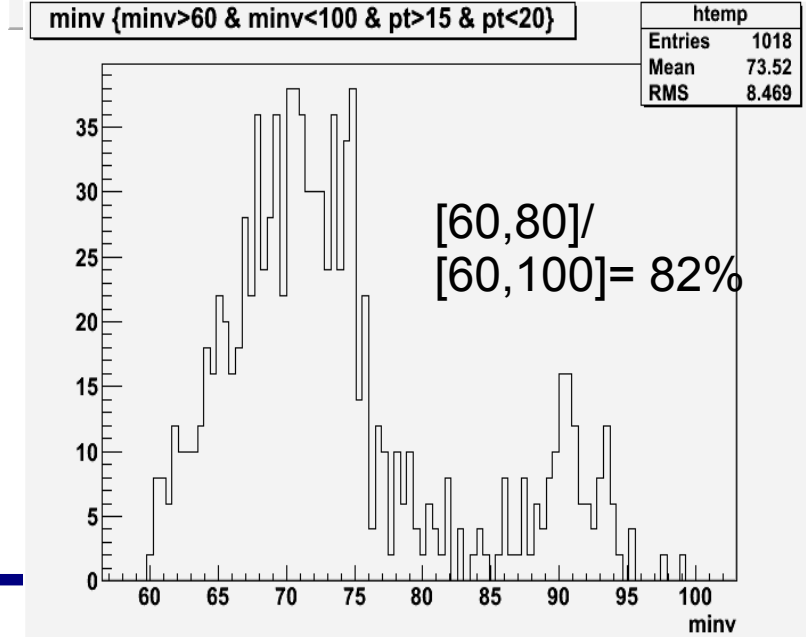
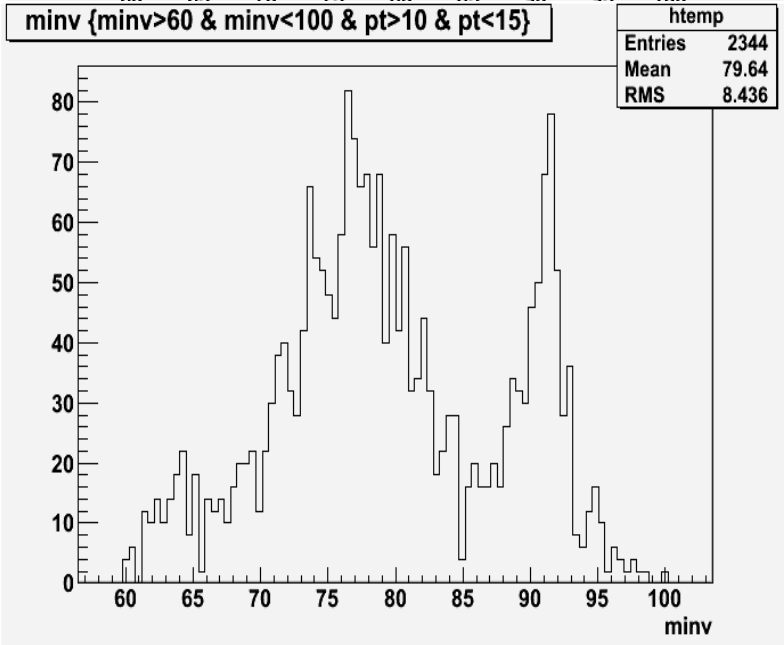
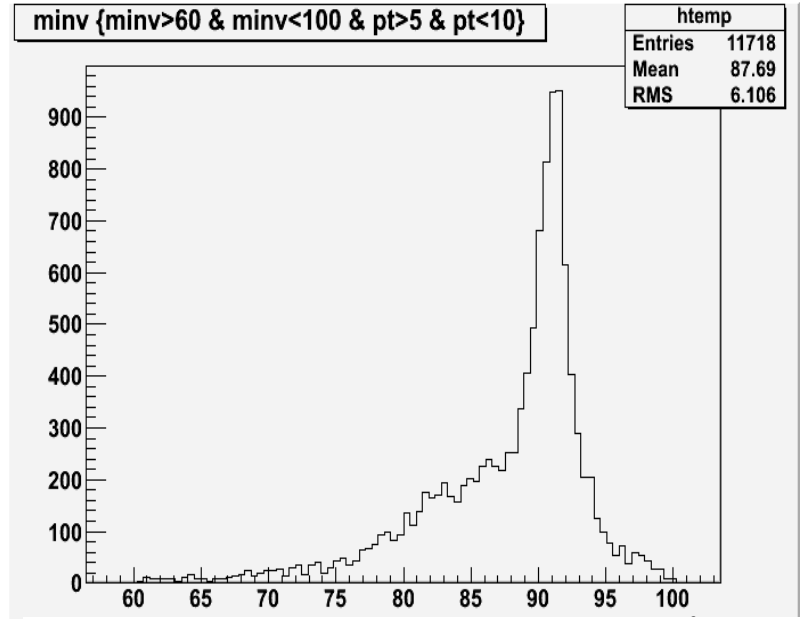
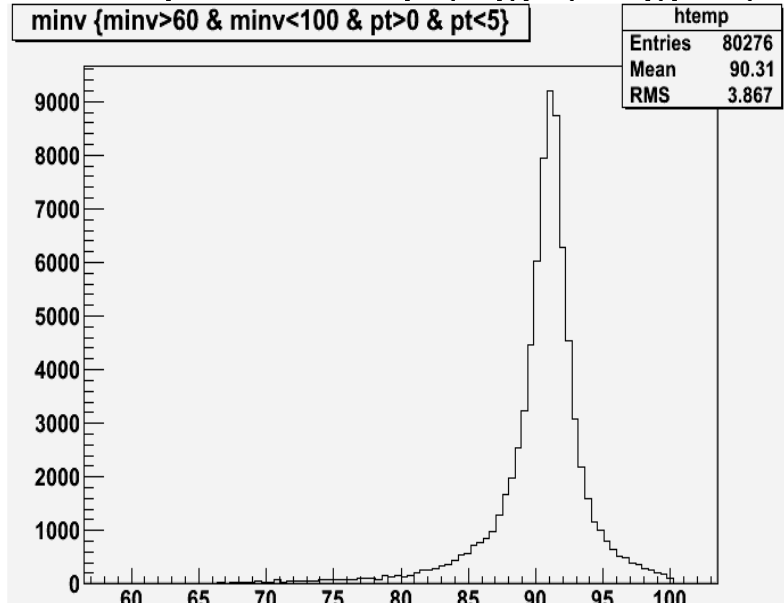


The p_T and M mass of the generated Z0 (pdg_id=23, status=2)



Issue (cont): Secondary peak at $M < M_{Z0}$

Looked at the Z0, rebuilt from the decay muons ($\text{abs}(\text{pdg_id}())=13$, $\text{status}=1$), in different pT slices: $[0,5]$, $[5,10]$, $[10,15]$, $[15,20]$, in the mass window $M[60,100]\text{GeV}$

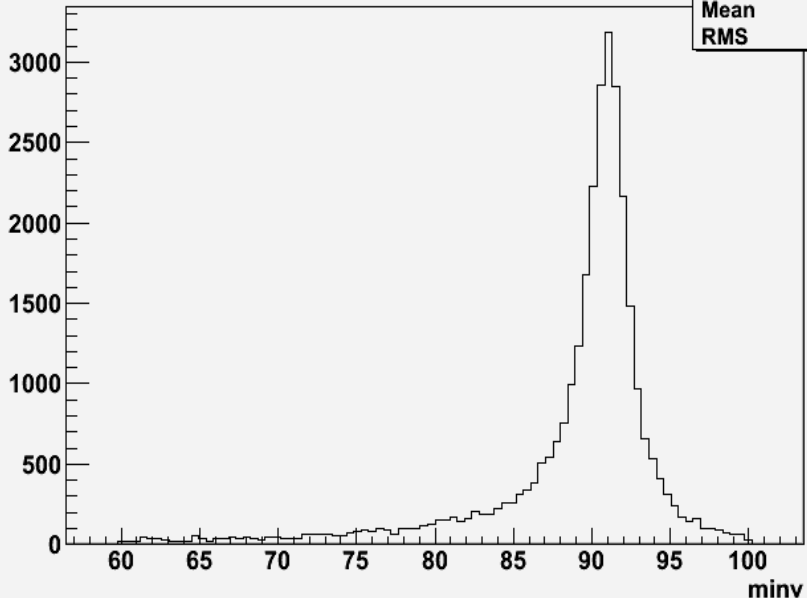


Bug or feature?

Generate a regular PYTHIA Z0 (MSEL=0,MSUB(1)=1,MSTP(43)=2) , pt_hat[0,20, |y|<2.4]

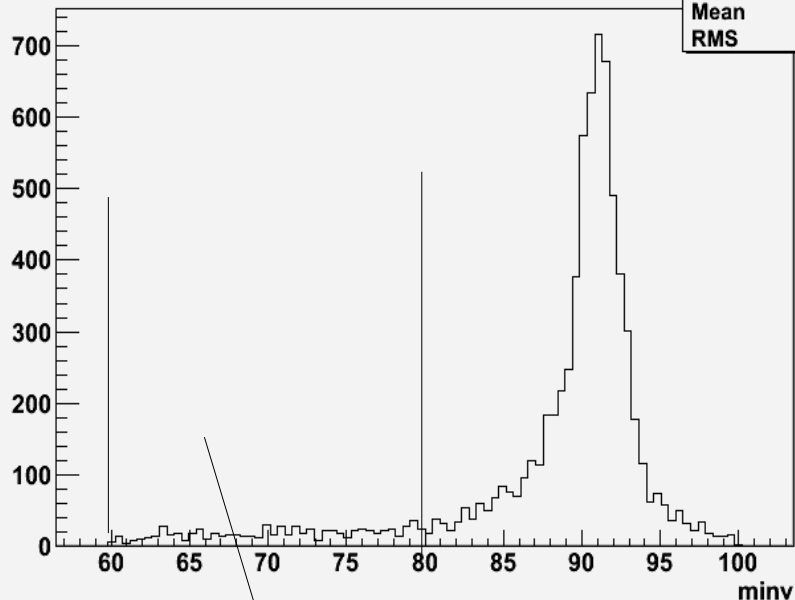
minv {minv>60 & minv<100 & pt>0 & pt<5}

htemp	
Entries	30754
Mean	88.92
RMS	5.801



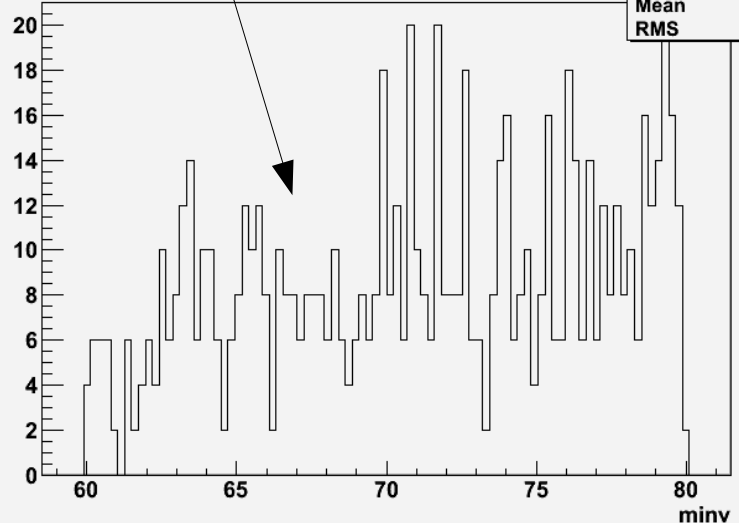
minv {minv>60 & minv<100 & pt>15 & pt<20}

htemp	
Entries	7454
Mean	88.35
RMS	6.751



minv {minv>60 & minv<80 & pt>15 & pt<20}

htemp	
Entries	770
Mean	71.18
RMS	5.62



~10%

The diff between slide 2 and slide 3 is due mostly to the falling of the generated spectra; a bizzare effect is there nevertheless; we investigated further ...

PYTHIA gun, flat pT: all pT, Radiation ON/OFF

Use from now on a flat in pT PYTHIA gun (Pythia6PtGun), pT[0,20];
Switched OFF final state radiation in the gun (MSTP(71)=0 – checked that indeed
this turns OFF all that influences the Z->mumu: col 4 and 5 in the table bellow);

The difference between
==> col 3 and 5: effect of final state radiation only
==> col 2 and 4: 'twin peak'

[60,80]/[60,100]

RADIATION

ON

OFF

pT	mumu(%)	Z0(%)	mumu(%)	Z0(%)
[0,1]	2.8	2.3	2.4	2.4
[1,2]	3.2	2.8	2.4	2.4
[2,5]	4	2.2	1.8	1.8
[5,10]	5.8	2.2	2	2.
[10,15]	6.1	2.1	1.9	1.9
[15,20]	5.7	1.8	2.	2.

Detailed investigation

Printouts: for each Z0, printed its descendents (HePMC::descendents), and for the decayed muons, the parents (HepMC::parents).

Things noticed:

- 1) a gamma (final state radiation) is always among the Z0 descendents and
- 2) an object with pdg_id=94 is always present (slide 6)
- 3) the '94' is **not** present in any of the PYTHIA or gun+radiation_OFF cases; **only** in gun+radiation_ON case; though it exist in PYTHIA code, as a valid, intermediate object in the decay/fragm process, there is no reason for seeing it only in the case of particle_gun_rad_ON case

As I did check that when turning OFF the radiation, MSTP(71)=0, the rebuilt Z0 and the initial Z0 have identical kinematics, and there is no extra contribution to the low mass indeed (previous slide)

=> it is a problem related to how the radiation is dealt with in the gun.

Details: printout (excerpt):

PYTHIA gun, flat pT, radiation ON

Descendants:

GenParticle: 1 ID:23 (P,E)=17.2141,-2.93813,12.0746,95.8837 Stat:2 PV:-1 EV:-2 Pol:(0,0) F:0
GenParticle: 7 ID:-13 (P,E)=29.4191,11.8845,-3.56203,31.9284 Stat:1 PV:-5 EV:0 Pol:(0,0) F:0
GenParticle: 8 ID:22 (P,E)=19.4206,7.73505,-2.55576,21.06 Stat:1 PV:-5 EV:0 Pol:(0,0) F:0
GenParticle: 5 ID:13 (P,E)=-31.6257,-22.5577,18.1924,42.8953 Stat:1 PV:-4 EV:0 Pol:(0,0) F:0
GenParticle: 6 ID:-13 (P,E)=48.8397,19.6195,-6.11778,52.9884 Stat:2 PV:-4 EV:-5 Pol:(0,0) F:0
GenParticle: 4 ID:94 (P,E)=17.2141,-2.93813,12.0746,95.8837 Stat:2 PV:-3 EV:-4 Pol:(0,0) F:0
GenParticle: 2 ID:13 (P,E)=-31.626,-22.5579,18.1926,42.8957 Stat:2 PV:-2 EV:-3 Pol:(0,0) F:0
GenParticle: 3 ID:-13 (P,E)=48.8401,19.6198,-6.11797,52.988 Stat:2 PV:-2 EV:0 Pol:(0,0) F:0

Parents1:

GenParticle: 5 ID:13 (P,E)=-31.6257,-22.5577,18.1924,42.8953 Stat:1 PV:-4 EV:0 Pol:(0,0) F:0
GenParticle: 4 ID:94 (P,E)=17.2141,-2.93813,12.0746,95.8837 Stat:2 PV:-3 EV:-4 Pol:(0,0) F:0

Parents2:

GenParticle: 7 ID:-13 (P,E)=29.4191,11.8845,-3.56203,31.9284 Stat:1 PV:-5 EV:0 Pol:(0,0) F:0
GenParticle: 6 ID:-13 (P,E)=48.8397,19.6195,-6.11778,52.9884 Stat:2 PV:-4 EV:-5 Pol:(0,0) F:0

PYTHIA

Descendants:

GenParticle: 7 ID:23 (P,E)=0.0850366,-0.568962,-279.98,293.125 Stat:3 PV:-5 EV:-6 Pol:(0,0) F:0
GenParticle: 12 ID:13 (P,E)=-12.9387,0.236771,-3.81841,13.4928 Stat:1 PV:-8 EV:0 Pol:(0,0) F:0
GenParticle: 13 ID:22 (P,E)=-4.11408,-0.0113798,-1.4145,4.35047 Stat:1 PV:-8 EV:0 Pol:(0,0) F:0
GenParticle: 11 ID:-13 (P,E)=17.1378,-0.794354,-274.747,275.282 Stat:1 PV:-7 EV:0 Pol:(0,0) F:0
GenParticle: 8 ID:13 (P,E)=-17.0531,0.225406,-5.22774,17.8381 Stat:3 PV:-6 EV:-8 Pol:(0,0) F:0
GenParticle: 9 ID:-13 (P,E)=17.1381,-0.794369,-274.752,275.287 Stat:3 PV:-6 EV:-7 Pol:(0,0) F:0
GenParticle: 10 ID:23 (P,E)=0.0850366,-0.568962,-279.98,293.125 Stat:2 PV:-6 EV:0 Pol:(0,0) F:0

Parents:

GenParticle: 8 ID:13 (P,E)=-17.0531,0.225406,-5.22774,17.8381 Stat:3 PV:-6 EV:-8 Pol:(0,0) F:0
GenParticle: 7 ID:23 (P,E)=0.0850366,-0.568962,-279.98,293.125 Stat:3 PV:-5 EV:-6 Pol:(0,0) F:0

Parents:

GenParticle: 9 ID:-13 (P,E)=17.1381,-0.794369,-274.752,275.287 Stat:3 PV:-6 EV:-7 Pol:(0,0) F:0
GenParticle: 7 ID:23 (P,E)=0.0850366,-0.568962,-279.98,293.125 Stat:3 PV:-5 EV:-6 Pol:(0,0) F:0

Parents:

GenParticle: 11 ID:-13 (P,E)=17.1378,-0.794354,-274.747,275.282 Stat:1 PV:-7 EV:0 Pol:(0,0) F:0
GenParticle: 9 ID:-13 (P,E)=17.1381,-0.794369,-274.752,275.287 Stat:3 PV:-6 EV:-7 Pol:(0,0) F:0

Parents:

GenParticle: 12 ID:13 (P,E)=-12.9387,0.236771,-3.81841,13.4928 Stat:1 PV:-8 EV:0 Pol:(0,0) F:0
GenParticle: 8 ID:13 (P,E)=-17.0531,0.225406,-5.22774,17.8381 Stat:3 PV:-6 EV:-8 Pol:(0,0) F:0

the '94' is not present in any of the PYTHIA or gun+radiation_OFF cases;

only in gun+radiation_ON case.

Details: Summary

Split gun events function of the M_mumuZ0 and M_Z0:

A) (M_mumu_Z0 in [60,80])&& (M_Z0 in [60,80]) mass region – Normal events

B) (M_mumu_Z0 in [60,80]) && !(M_Z0 in [60,80]) – Problem events

Printed the number of photons in the 'descendants' chain of Z0 (col 1), and counted in which E interval they land (column 2->5) ;

Summary: events A)

```
NGamma [ E[0,5] E[5,10] E[10,20] E[20,] ]
1 [ 341 13 9 0 ],
2 [ 305 19 6 0 ],
3 [ 111 8 1 0 ],
4 [ 25 3 0 0 ],
5 [ 9 0 1 0 ],
6 [ 0 0 0 0 ],
7 [ 0 0 0 0 ],
8 [ 0 0 0 0 ],
```

Summary: events B

```
NGamma [ E[0,5] E[5,10] E[10,20] E[20,] ]
1 [ 24 80 521 249 ],
2 [ 724 165 450 169 ],
3 [ 546 65 168 64 ],
4 [ 201 23 41 15 ],
5 [ 74 5 15 1 ],
6 [ 8 1 3 0 ],
7 [ 0 0 0 0 ],
8 [ 7 0 0 1 ],
```

- very high number of high-E emitted photons
- more events with >2 emitted photons
- some events with >5 emitted photons

==> looks like the bug is in how the gun deals with the final state radiation.

Summary of the summary:

1. PYTHIA gun simulations done for Z0 show an inconsistent way of dealing with/accounting for final state radiation;
2. Effect more pronounced when generating a falling Z0 spectrum, as the signal decreases, and hence the 'twin peak' start to be more visible;
3. Checks done with regular PYTHIA simulations, as well with PYTHIA gun with final state radiation OFF seem to confirm the conclusion 1)
4. there is 'object with id 94', valid in pythia manual, but not in regular PYTHIA simulations; not sure if this is a bug, or it's the way the gun keeps tracks and deals with final state radiation;
5. tried to check for other particles (lower scale), but another little problem occurred: for lower masses (tried Jpsi and Upsilon) the gun produces everything with one fixed mass value (the central value); contacted Y.Yarba who is looking into this already.

Extra: configuration file to run: flat-pT gun

```
import FWCore.ParameterSet.Config as cms

from GeneratorInterface.Pythia6Interface.pythiaDefault_cff import *

generator = cms.EDProducer("Pythia6PtGun",
    maxEventsToPrint = cms.untracked.int32(0),
    pythiaHepMCVerbosity = cms.untracked.bool(False),
    pythiaPylistVerbosity = cms.untracked.int32(0),

    PGunParameters = cms.PSet(
        ParticleID = cms.vint32(23),
        AddAntiParticle = cms.bool(False)
        ,MinPt = cms.double(0.0),
        MaxPt = cms.double(20.0),
        MinEta = cms.double(-2.),
        MaxEta = cms.double(2.)
        ,MinPhi = cms.double(-3.14159265359)
        ,MaxPhi = cms.double(3.14159265359)
    ),
    PythiaParameters = cms.PSet(
        pythiaDefaultBlock,
        pythiaZtoMuons = cms.vstring( "MDME(174,1)=0",      # !Z decay into d dbar,
            "MDME(175,1)=0",      # !Z decay into u ubar,
            "MDME(176,1)=0",      # !Z decay into s sbar,
            "MDME(177,1)=0",      # !Z decay into c cbar,
            "MDME(178,1)=0",      # !Z decay into b bbar,
            "MDME(179,1)=0",      # !Z decay into t tbar,
            "MDME(182,1)=0",      # !Z decay into e- e+,
            "MDME(183,1)=0",      # !Z decay into nu_e nu_ebar,
            "MDME(184,1)=1",      # !Z decay into mu- mu+,
            "MDME(185,1)=0",      # !Z decay into nu_mu nu_mubar,
            "MDME(186,1)=0",      # !Z decay into tau- tau+,
            "MDME(187,1)=0"      # !Z decay into nu_tau nu_taubar
        ),
        parameterSets = cms.vstring('pythiaDefault','pythiaZtoMuons')
    )
)
```

Extra: configuration file to run: non-flat pT gun

```
import FWCore.ParameterSet.Config as cms
from GeneratorInterface.Pythia6Interface.pythiaDefault_cff import *
generator = cms.EDProducer("Pythia6PtYDistGun",
    maxEventsToPrint = cms.untracked.int32(0),
    pythiaHepMCVerbosity = cms.untracked.bool(False),
    pythiaPylistVerbosity = cms.untracked.int32(0),

    PGunParameters = cms.PSet(
        ParticleID = cms.vint32(23),
        kinematicsFile = cms.FileInPath('HeavylonsAnalysis/Configuration/data/jpsipbpb.root'),
        PtBinning = cms.int32(100000),
        YBinning = cms.int32(500),
        MinPt = cms.double(0.0),
        MaxPt = cms.double(20.0),
        MinY = cms.double(-2.4),
        MaxY = cms.double(2.4),
        MinPhi = cms.double(-3.14159265359),
        MaxPhi = cms.double(3.14159265359),
        AddAntiParticle = cms.bool(False)),

    PythiaParameters = cms.PSet(
        pythiaDefaultBlock,
        pythiaZtoMuons = cms.vstring( "MDME(174,1)=0",      # !Z decay into d dbar,
            "MDME(175,1)=0",      # !Z decay into u ubar,
            "MDME(176,1)=0",      # !Z decay into s sbar,
            "MDME(177,1)=0",      # !Z decay into c cbar,
            "MDME(178,1)=0",      # !Z decay into b bbar,
            "MDME(179,1)=0",      # !Z decay into t tbar,
            "MDME(182,1)=0",      # !Z decay into e- e+,
            "MDME(183,1)=0",      # !Z decay into nu_e nu_ebar,
            "MDME(184,1)=1",      # !Z decay into mu- mu+,
            "MDME(185,1)=0",      # !Z decay into nu_mu nu_mu_bar,
            "MDME(186,1)=0",      # !Z decay into tau- tau+,
            "MDME(187,1)=0"      # !Z decay into nu_tau nu_tau_bar
        ),
        parameterSets = cms.vstring('pythiaDefault','pythiaZtoMuons')
    )
)
```