Two-photon background in DELPHI — an on-going study

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Two generators were used:

TWOGAM 2 .1:
ISR with p_T , massive quarks, QPM+QCD+VDM components. (With polarization bug $\Rightarrow$ $\sim$ 20% too high cross-section)

PHOJET 1.1:
No ISR, no massive quarks,
"realistic" soft interactions, multiple interactions.

Emphasis on 2-photon background to searches

The searches :

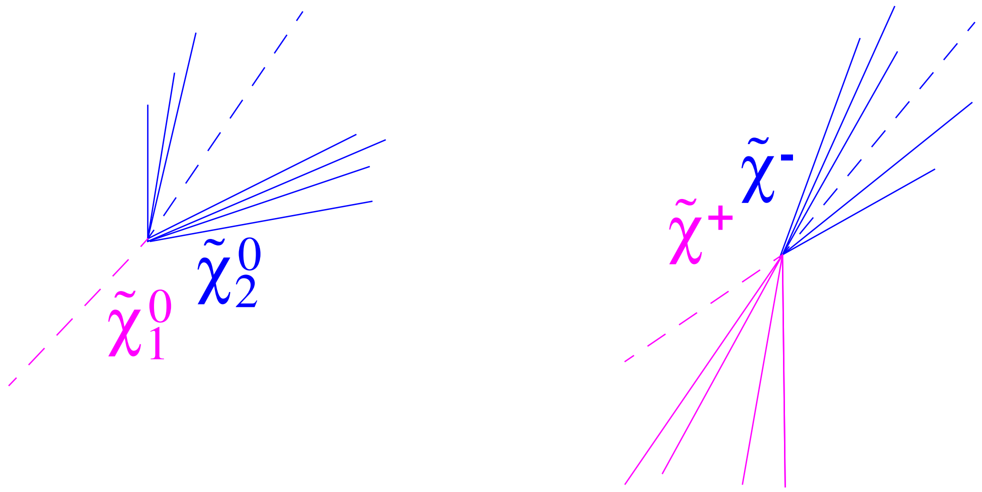
Searches affected by $\gamma\gamma$ background are mainly those in SUSY scenarios with low mass splitting, e.g.

$e^+e^- \to \tilde{\chi}^+\tilde{\chi}^-;\ \tilde{\chi}^\pm \to \tilde{\chi}^0 q\bar{q}$ ($\Delta M = M_{\tilde{\chi}^\pm} - M_{\tilde{\chi}^0}$),

$e^+e^- \to \tilde{q}\bar{\tilde{q}};\tilde{q} \to \tilde{\chi}^0 q$ ($\Delta M = M_{\tilde{q}} - M_{\tilde{\chi}^0}$)

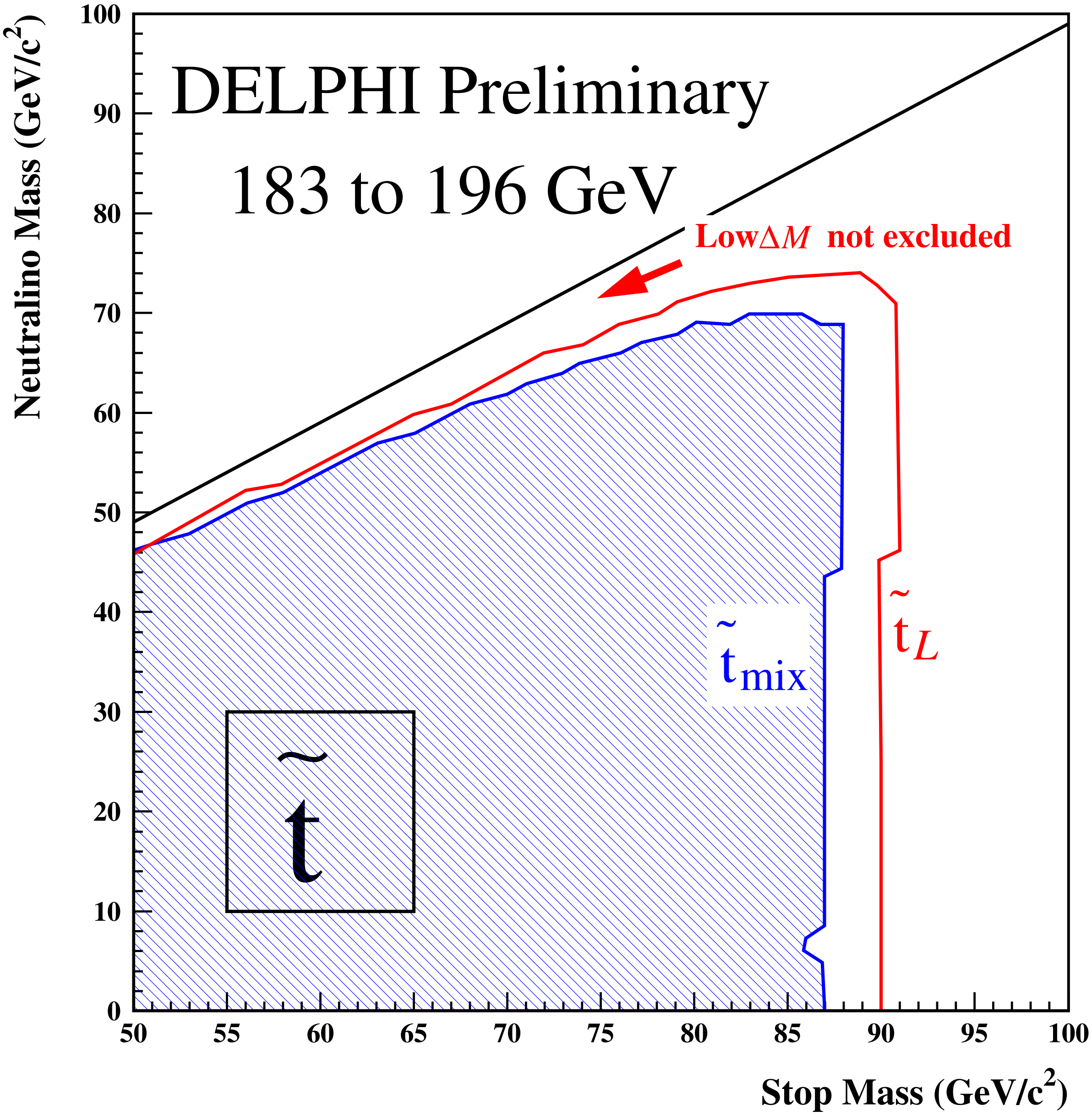
or $e^+e^- \to \tilde{\chi}_1^0\tilde{\chi}_2^0;\tilde{\chi}_2^0 \to \tilde{\chi}_1^0 q\bar{q}$ ($\Delta M = M_{\tilde{\chi}_2^0} - M_{\tilde{\chi}_1^0}$)

where the heavy LSPs ($\tilde{\chi}_1^0$) escape detection:



Such events with large missing energy resemble $\gamma\gamma$ events where both electrons are lost (no-tag events). For discovery we must know the background from low $W_{\gamma\gamma}$ events.

Example exclusion:



Simulation at 189 GeV (from summer '99)

Cross-section for $\gamma\gamma \rightarrow X$ is several hundred nb

$\Rightarrow \sim 5 \cdot 10^7$ events for $\int L dt = 158\ \mathrm{pb}^{-1}$.

$\Rightarrow$ Cuts must be made already at generator level to reduce the number of events to simulate:

"Searches bias" ($\sigma \sim 1\,\mathrm{nb}$)($\sim$ 200 kevents/generator)

$W_{\gamma\gamma} > 3\,\mathrm{GeV}/c^2$ and either one track with $p_T > 1.2\,\mathrm{GeV}/c$ or one seen particle with $E > 0.4 E_{beam}$.

"Doubtful bias" ($\sigma \sim 1\,\mathrm{nb}$) (10 k events):

As "Searches bias", but $1\,\mathrm{GeV}/c^2 < W_{\gamma\gamma} < 3\,\mathrm{GeV}/c^2$

"Low bias" $\sigma \sim 6\mathrm{nb}$ ($\sim$ 700 kevents/generator) :

$W_{\gamma\gamma} > 3\,\mathrm{GeV}/c^2$ and either

Two tracks above $10°$ with $p > 1\,\mathrm{GeV}/c$ or

One seen particle with $E > 0.4 E_{beam}$.

"Hard $\gamma\gamma$" selection

To select two-photon events in the vicinity of the phase-space selected in search analyses. Main cuts:

- $p_{\mathrm{T}} > 1.5\,\mathrm{GeV}/c^2$ for at least one particle
- $p_{\mathrm{T}}^{\mathrm{tot}} < 10\,\mathrm{GeV}/c$
- $E_{\mathrm{T}} < 20\,\mathrm{GeV}$
- $N_{\mathrm{charged}} < 30$
- $E_{\mathrm{had}}/E_{\mathrm{beam}} < 0.3$ for both hemispheres

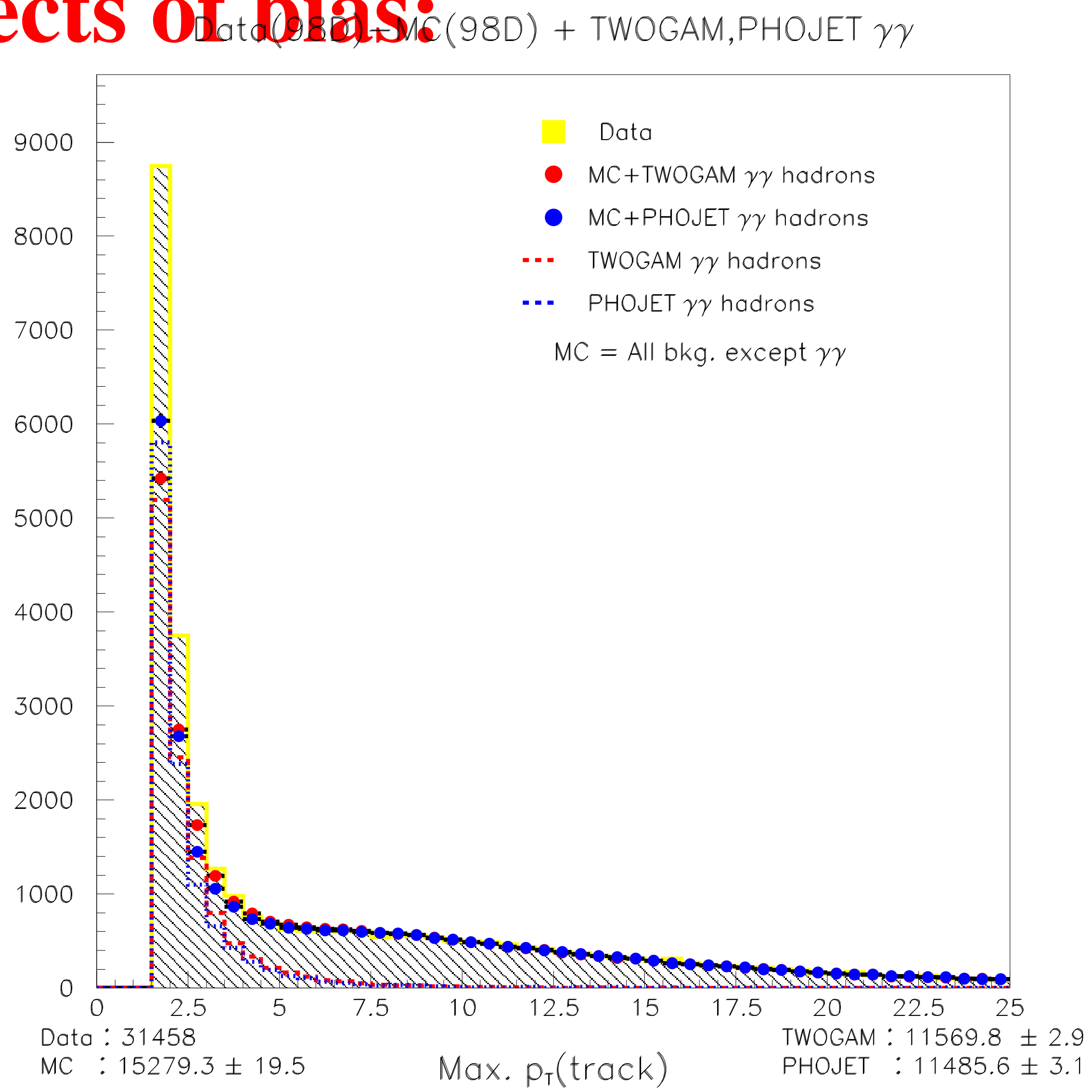
For single-tag:

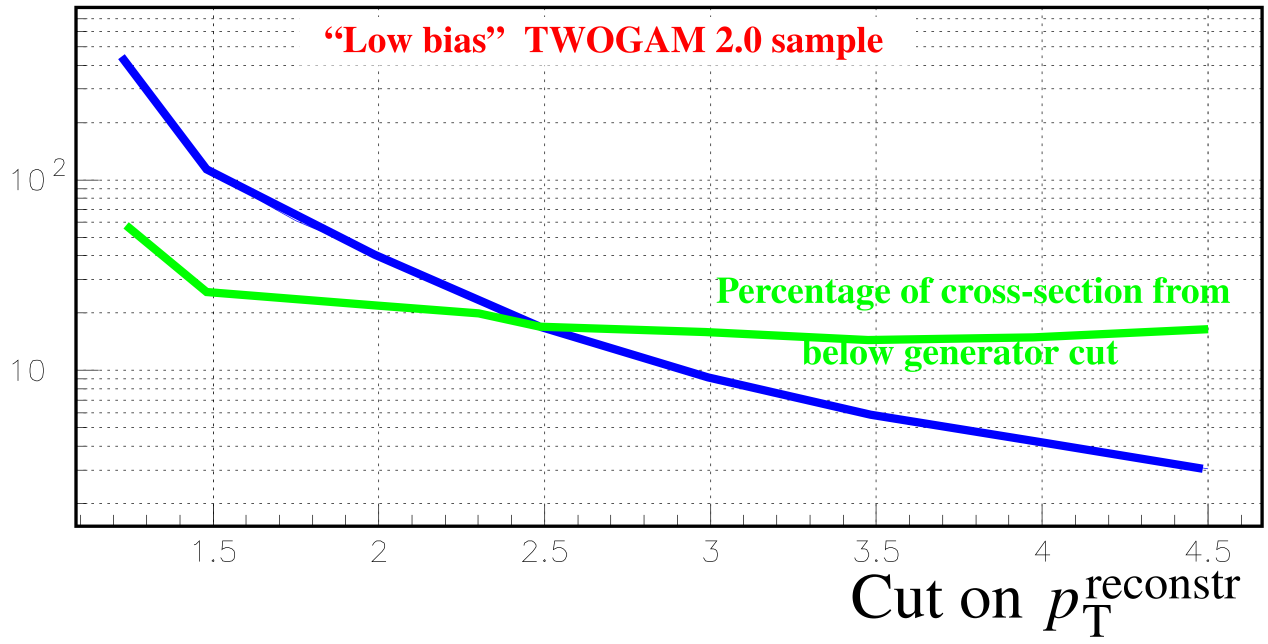
- $p_{\mathrm{missing}} > 70\mathrm{GeV}/c^2$
- $E(\theta < 10°) > 70\mathrm{GeV}$
- $E_{\mathrm{hem}}^{\mathrm{max}}/E_{\mathrm{beam}} > 0.7$ and $E_{\mathrm{hem}}^{\mathrm{min}}/E_{\mathrm{beam}} < 0.4$

For no-tag:

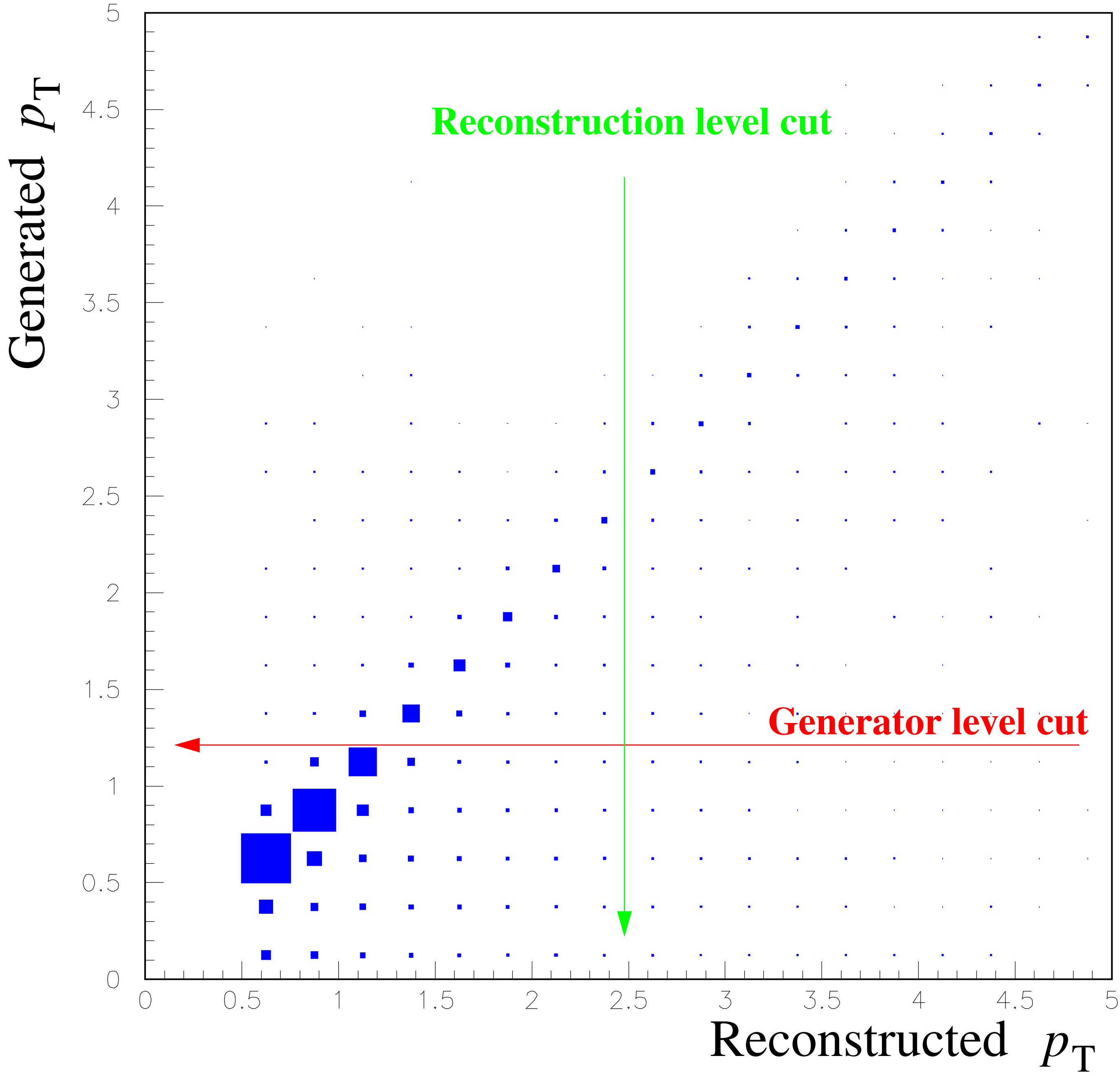
- $p_{\mathrm{T}}^{\mathrm{tot}} < 7\,\mathrm{GeV}/c^2$; $p_{\mathrm{T}}^{\mathrm{max}} < 5\mathrm{GeV}/c$
- $E_{\mathrm{missing}} > 150\mathrm{GeV}$
- $\left(\sqrt{E_{\mathrm{hem1}}^2 + E_{\mathrm{hem2}}^2}\right)/E_{\mathrm{beam}} < 0.4$
- At least four barrel (TPC) tracks with $\sum |p_{\mathrm{T}}| > 4\mathrm{GeV}/c^2$

Effects of bias:





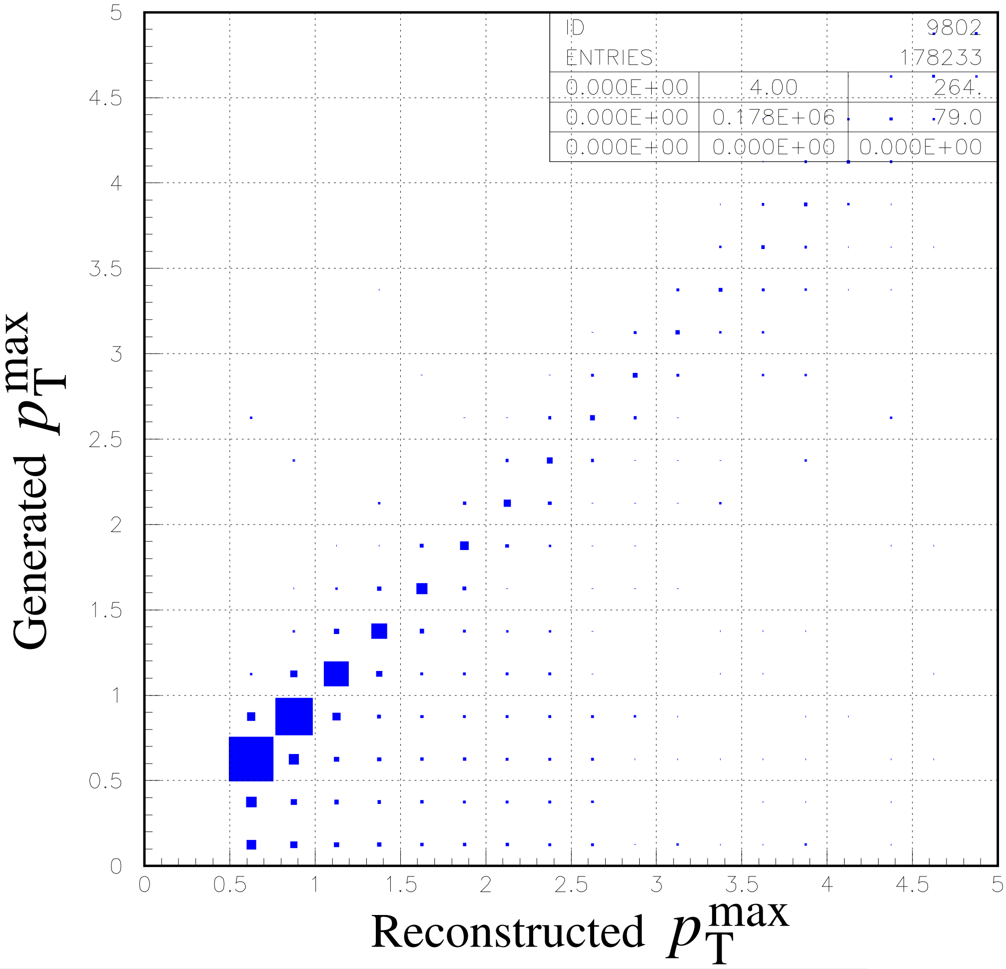
p_T^{max} smearing:

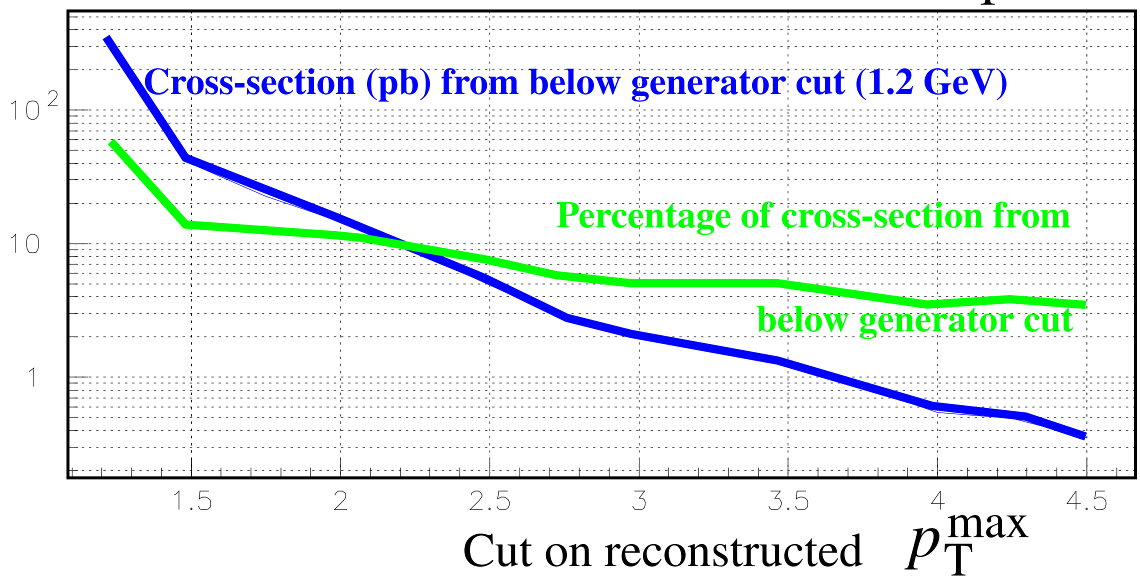


Reconstruction cut 1.3GeV/c above generator threshold $\Rightarrow$ loss of $\sim$ 15% of signal in degenerate chargino search.

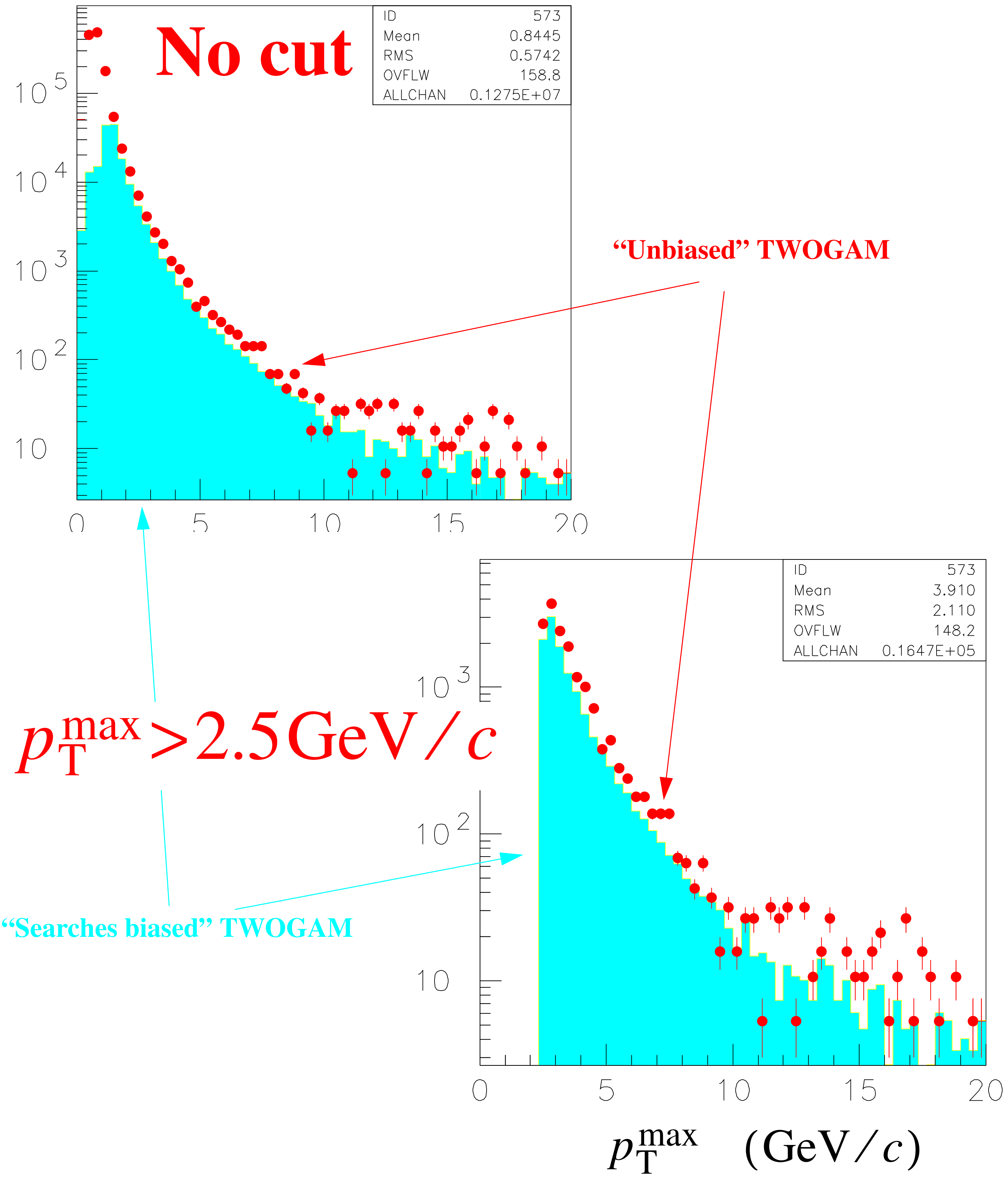
Improvement in migration

Using tighter quality criteria on highest p_T track migration can be reduced:



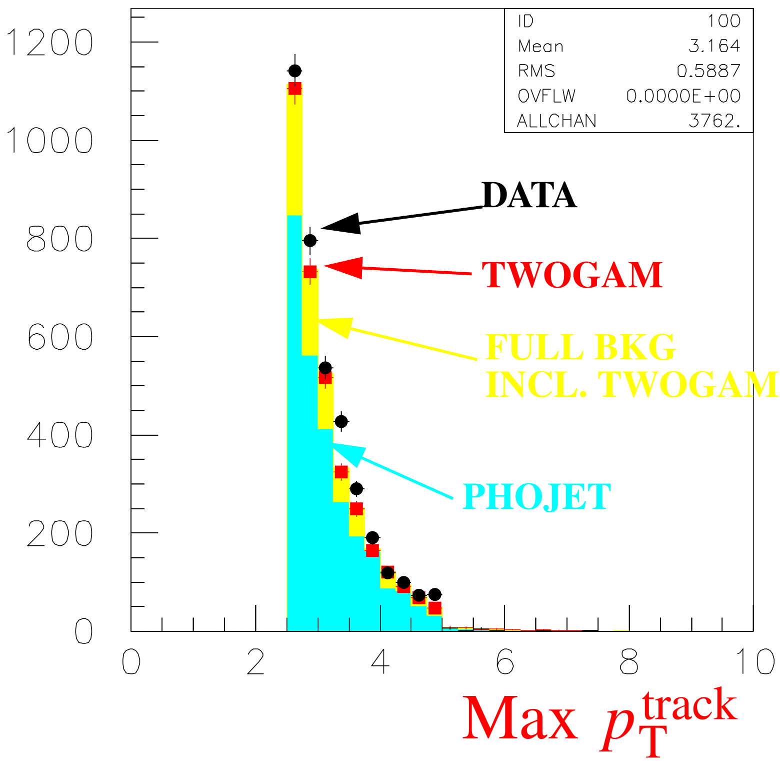


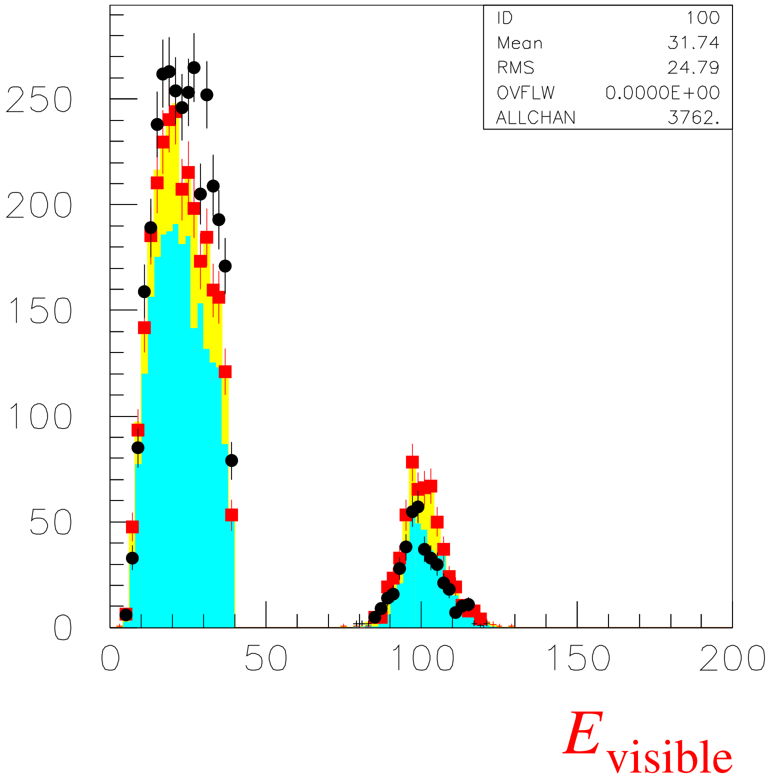
Effect of $p_T^{max} > 2.5\,\mathrm{GeV}$



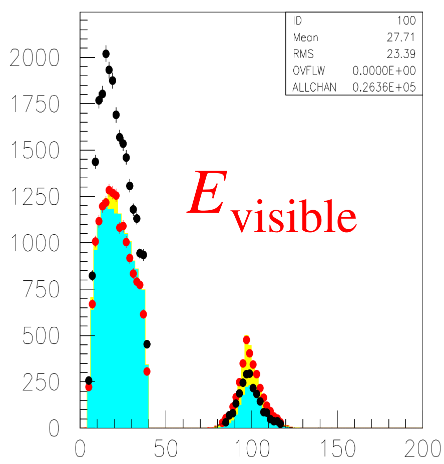
Data vs MC for hard $\gamma\gamma$ selection

$p_T^{track} > 2.5\,\mathrm{GeV}$

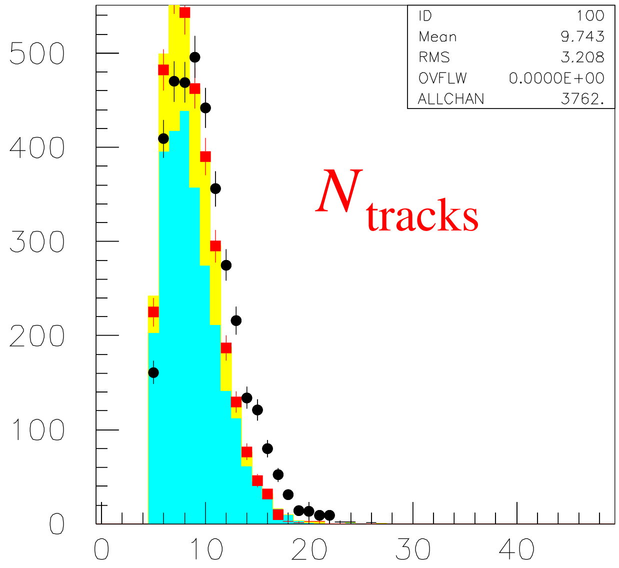


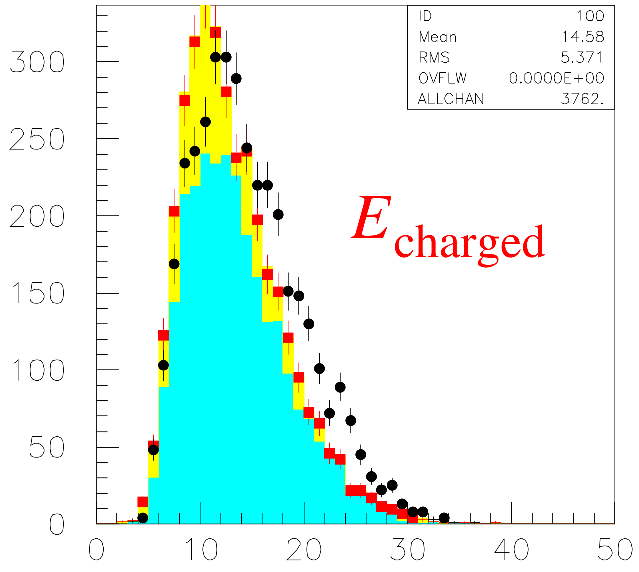


p_T **cut at 1.5 GeV:**

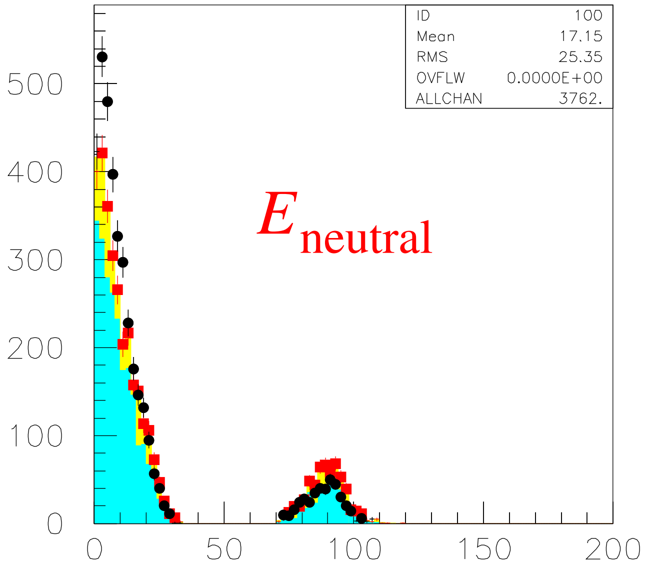


γγ physics ?



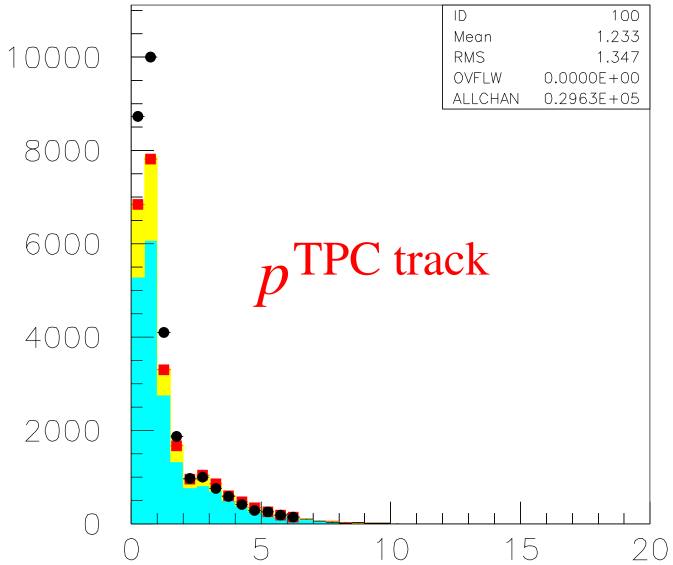


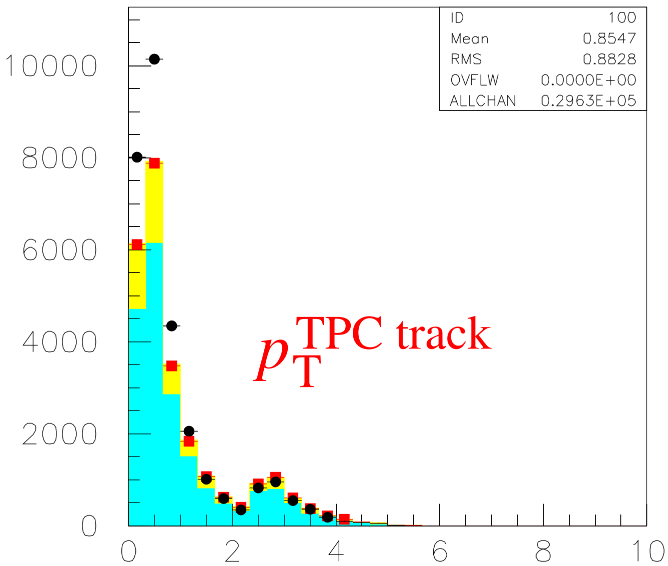
... or detector effects ?

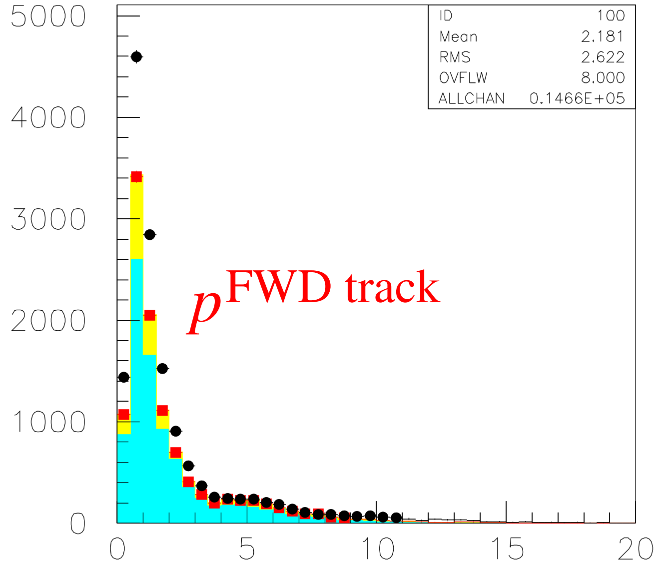


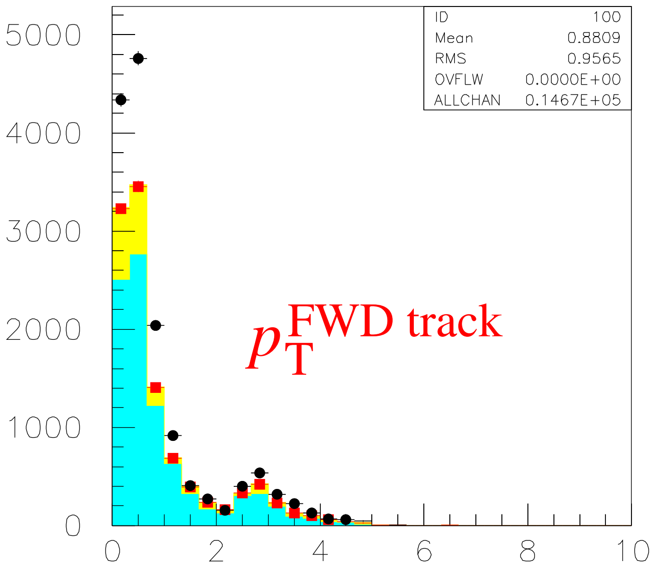
Tracks

Distributions for single tracks show excess at low momenta



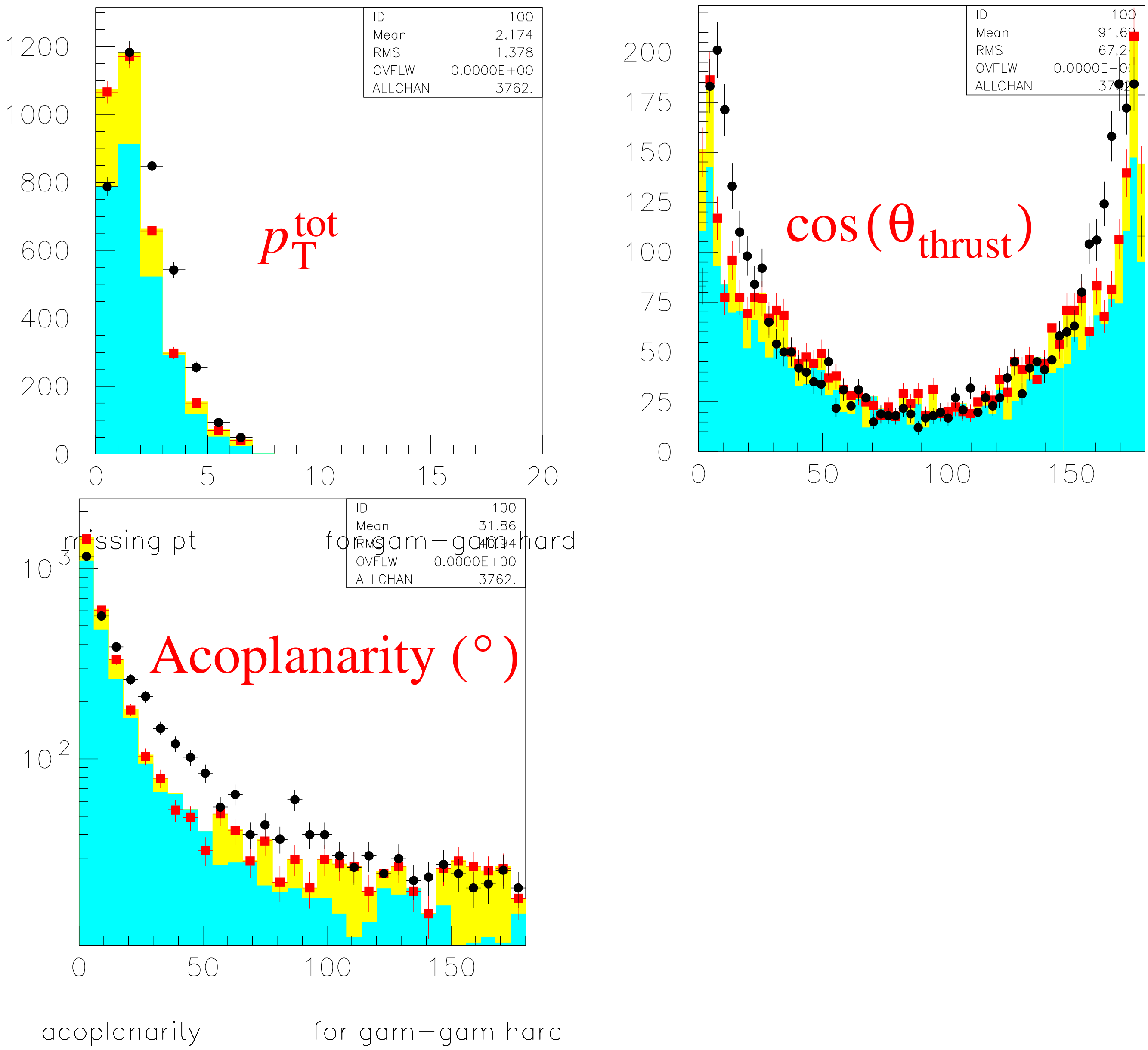






Hard to disentangle detector/biasing and generator effects.

Search-sensitive variables

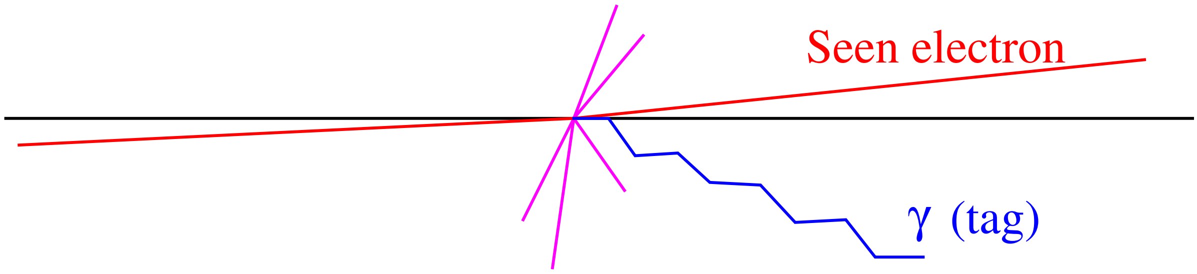


Clearly, there are some discrepancies...

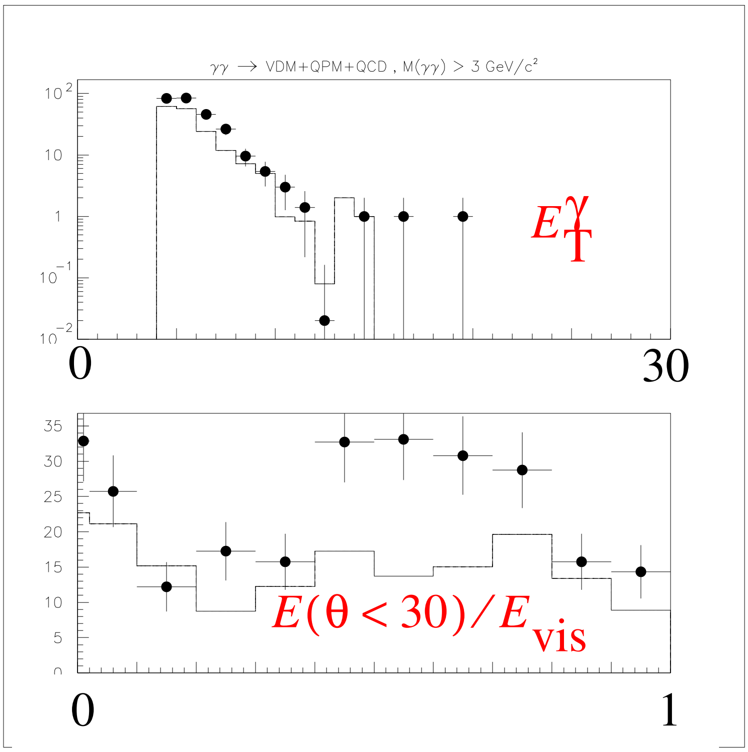
An extreme case

For very small $\Delta M = M_{\tilde{\chi}^{\pm}} - M_{\tilde{\chi}^{0}}$, background to $\tilde{\chi}^{+}\tilde{\chi}^{-}$ is dominated by no-tag two-photon events.

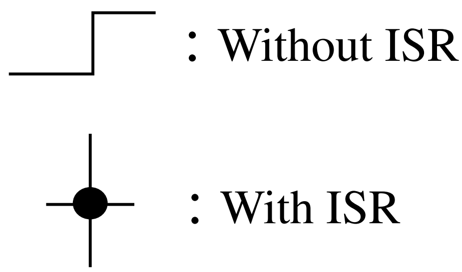
Requiring an ISR photon with $p_T > \sqrt{s}\dfrac{\sin\theta_{acc}}{1 + \sin\theta_{acc}}$ turns "no-tag" into "single-tag" (Chen,Drees,Gunion):



$\Rightarrow$ Analysis rather insensitive to ISR (TWOGAM 2):



Rates after preselection



... but sensitive to detector effects and biasing cuts !

Conclusions

• It's hard to distinguish generator effects from detector/biasing due to the steeply falling spectra.

• For searches, TWOGAM and PHOJET are useable, provided a hard cut can be tolerated ($p_{\mathrm{T}}^{\max} > 2.5\,\mathrm{GeV}/c^2$).

• A better understanding of the low $W_{\gamma\gamma}$ region is needed for discovery in degenerate scenarios (which are not $\sqrt{s}$ — limited).