Event Generation of $\gamma\gamma \rightarrow hadrons$

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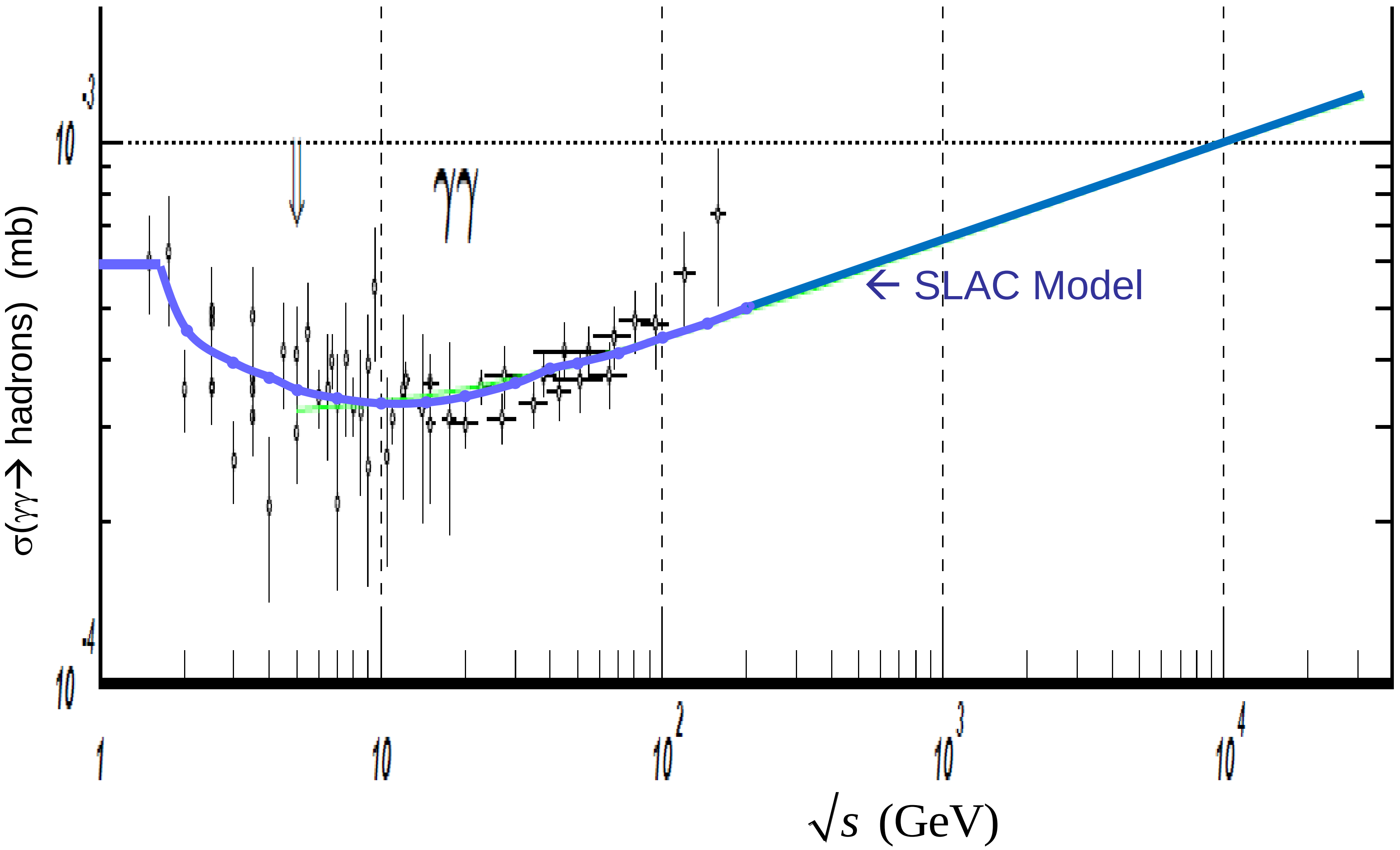
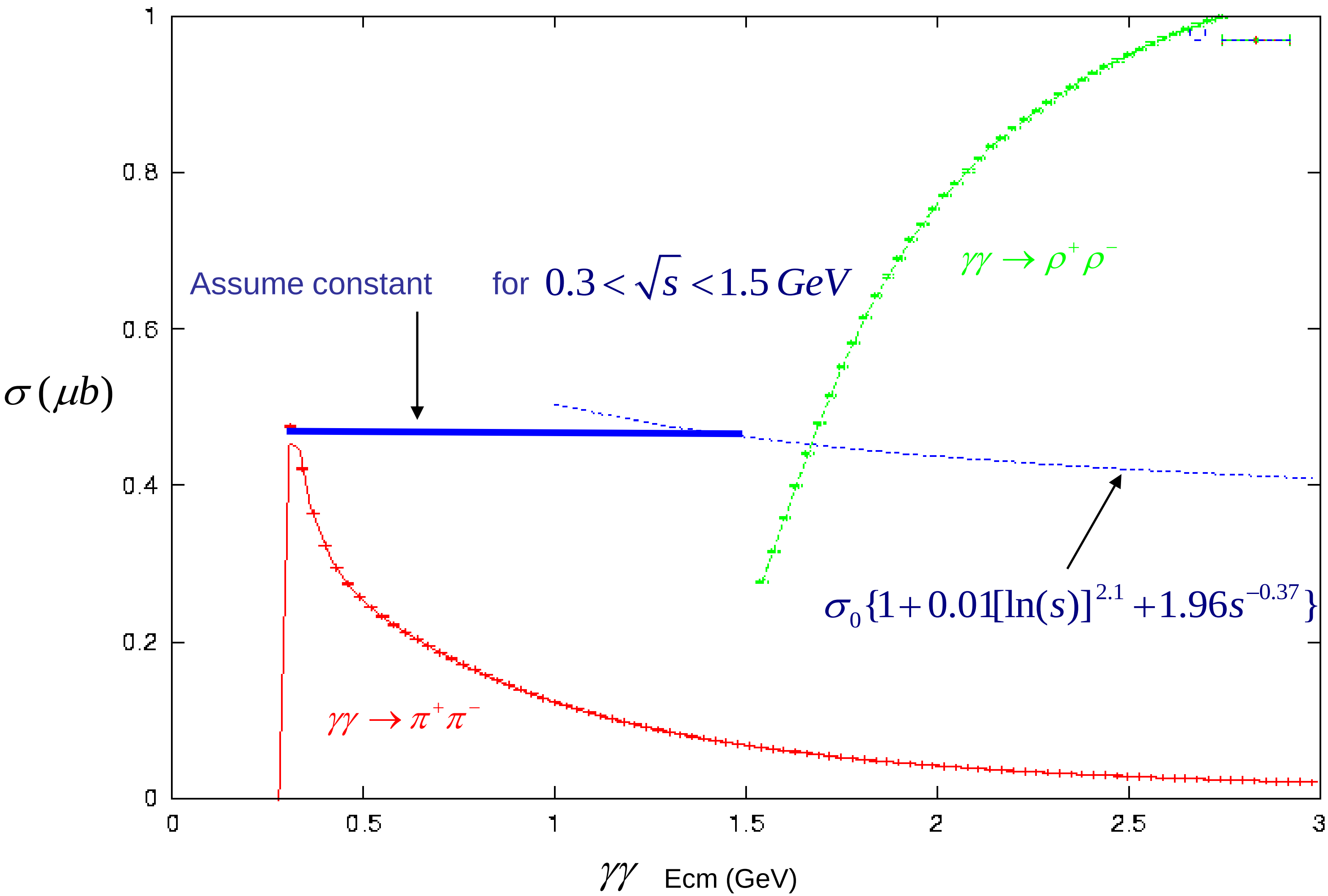
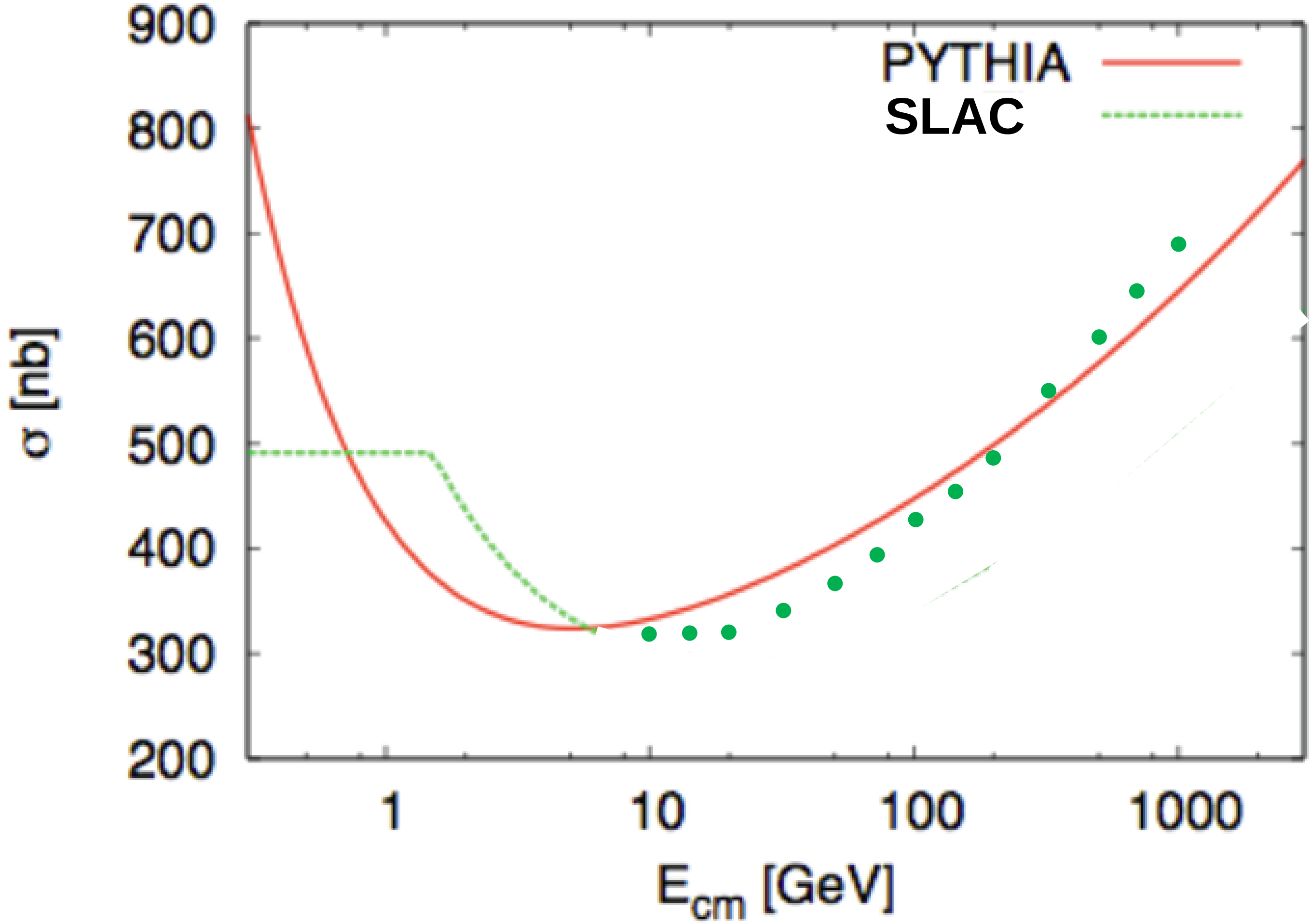
Measured $\sigma(\gamma\gamma \to hadrons)$ from PDG



Model for $\sigma(\gamma\gamma \rightarrow hadrons)$ used at SLAC



SLAC Model vs. PYTHIA Model



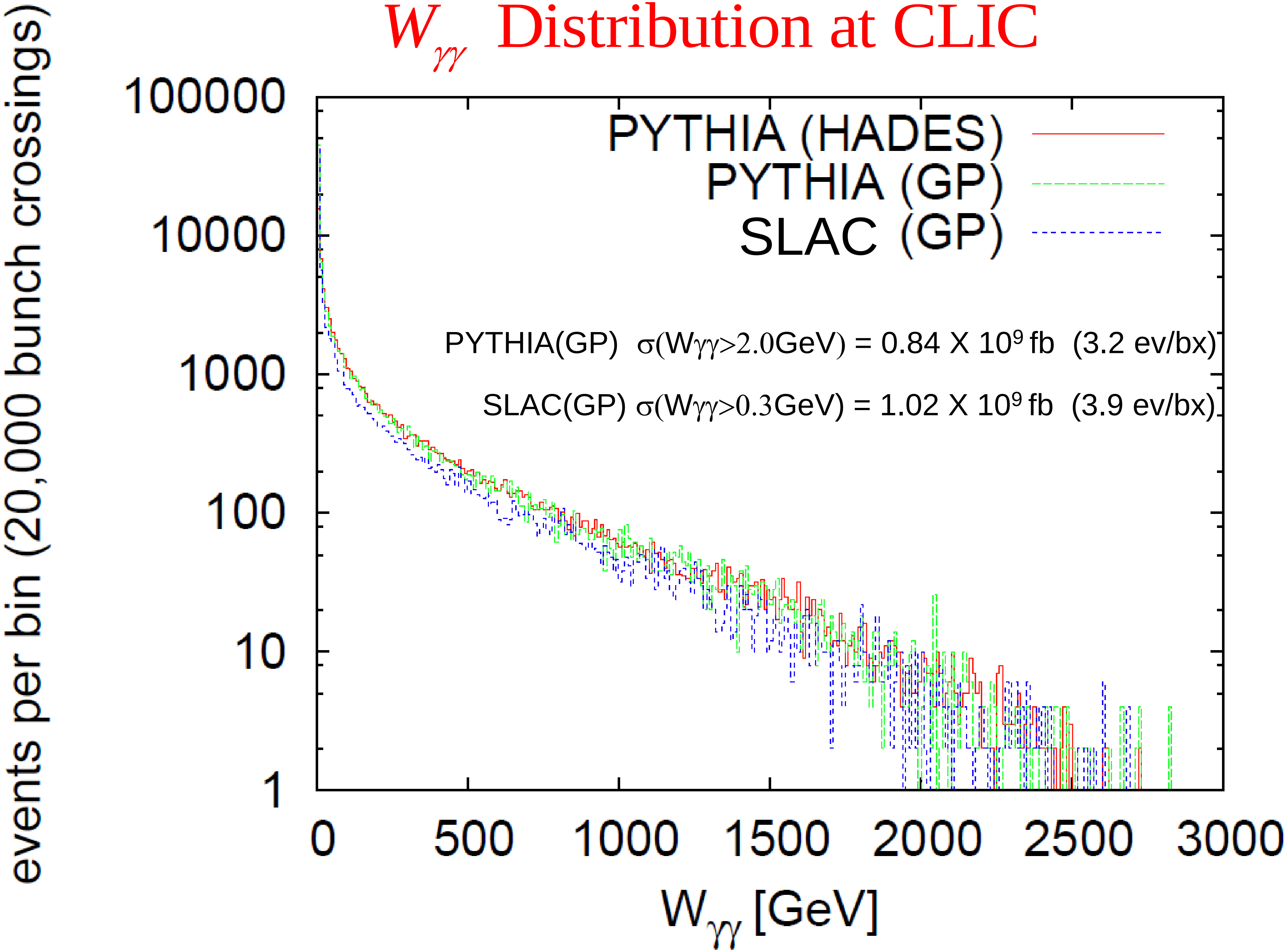
Simulating Hadronic Events

- WHIZARD or comparable is used to simulate virtual photon flux
- Guinea-Pig simulates beamstrahlung flux.
- Total hadronic cross section given by a canonical formula for Ecm > 1.5 GeV and by a constant 490 nb for 0.3 < Ecm < 1.5 GeV
- PYTHIA is used to model low and high-pt hadronic events for Ecm > 2 GeV
- Isotropic production of 2, 3, or 4 pions for 0.3<Ecm < 2 GeV. ←SLAC samples only

PYTHIA Simulation of $\gamma\gamma \rightarrow hadrons$

- Both CERN and SLAC use MSTP(14)=10 which means a mixture of classes 0,2,3,5,6,7:
  0) Both photons are pointlike (direct) in $\gamma\gamma \rightarrow f\bar{f}$
  2) Both photons are VMD-like
  3) Both photons are anomalous (General VMD-like)
  5) One photon direct, the other VMD-like
  6) One photon direct, the other anomalous
  7) One photon VMD-like, the other anomalous

$W_{\gamma\gamma}$ Distribution at CLIC



Samples of $\gamma\gamma \to hadrons$ with <<1 ev/bx

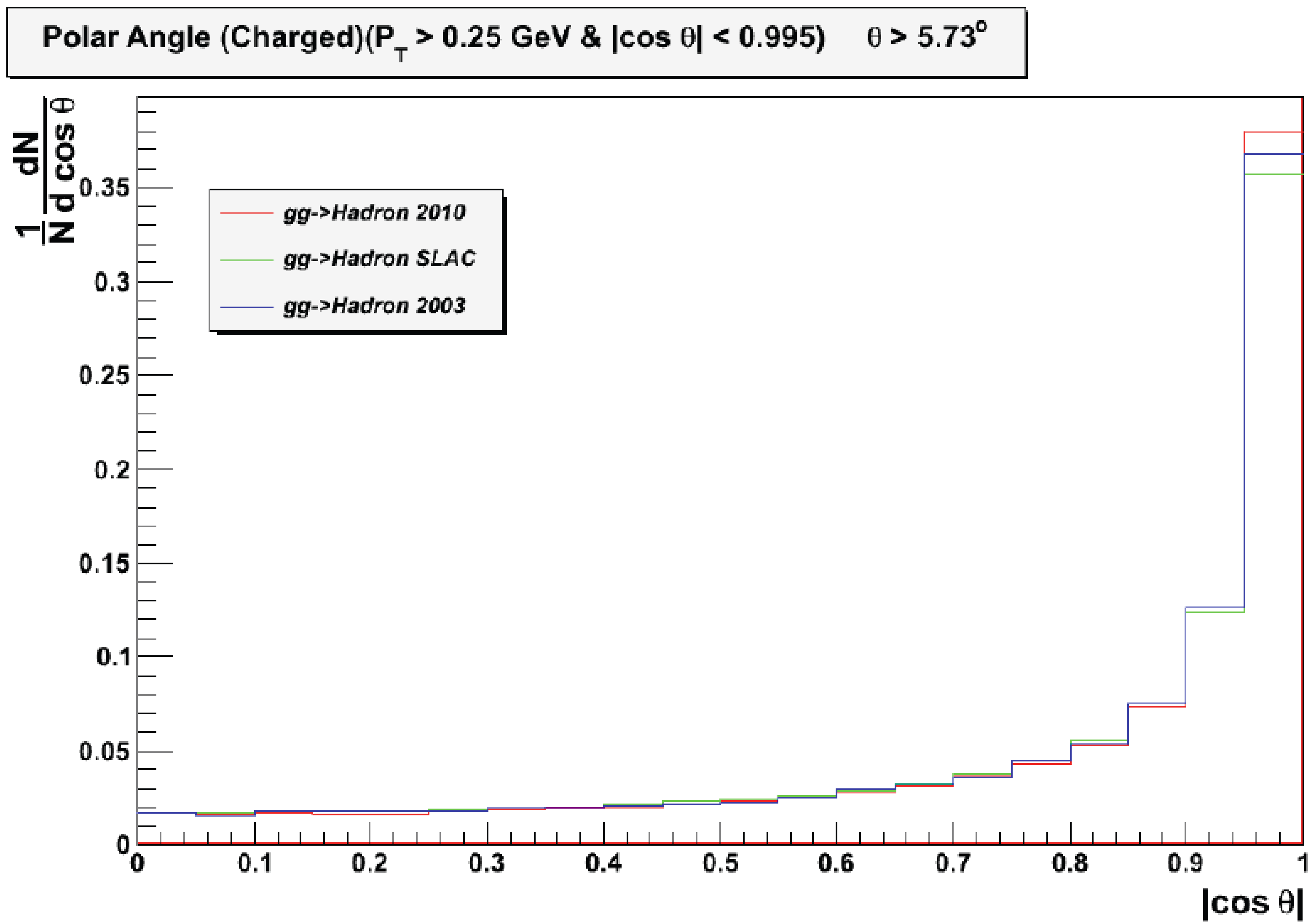
- PYTHIA with MSTP(14)=10 is a mixture of classes 0,2,3,5,6,7:
  0) Both photons are pointlike (direct) in $\gamma\gamma \to f\bar{f}$
  2) Both photons are VMD-like
  3) Both photons are anomalous (Generalized VMD-like)
  5) One photon direct, the other VMD-like
  6) One photon direct, the other anomalous
  7) One photon VMD-like, the other anomalous
- Most events in inclusive overlay samples have small $W_{\gamma\gamma}$. Events with larger $W_{\gamma\gamma}$ appear with low statistics or are missing altogether if there was no event overlay (the usual case for the ILC LOI).
- Independent class 0 samples with $W_{\gamma\gamma} > 10\ \mathrm{GeV},\ \mathrm{P}_T > 4\ \mathrm{GeV}$ were produced for the ILC LOI as part of SM bkgd generation.
- Class 2,3,5,6,7 events only appeared in the LOI overlay sample, however. Current ILC/CLIC studies may want to generate class 2,3,5,6,7 samples with $W_{\gamma\gamma} > 10\ \mathrm{GeV},\ \mathrm{P}_T > 4\ \mathrm{GeV}$

γ γ-> Hadron BACKGROUND EVENTS

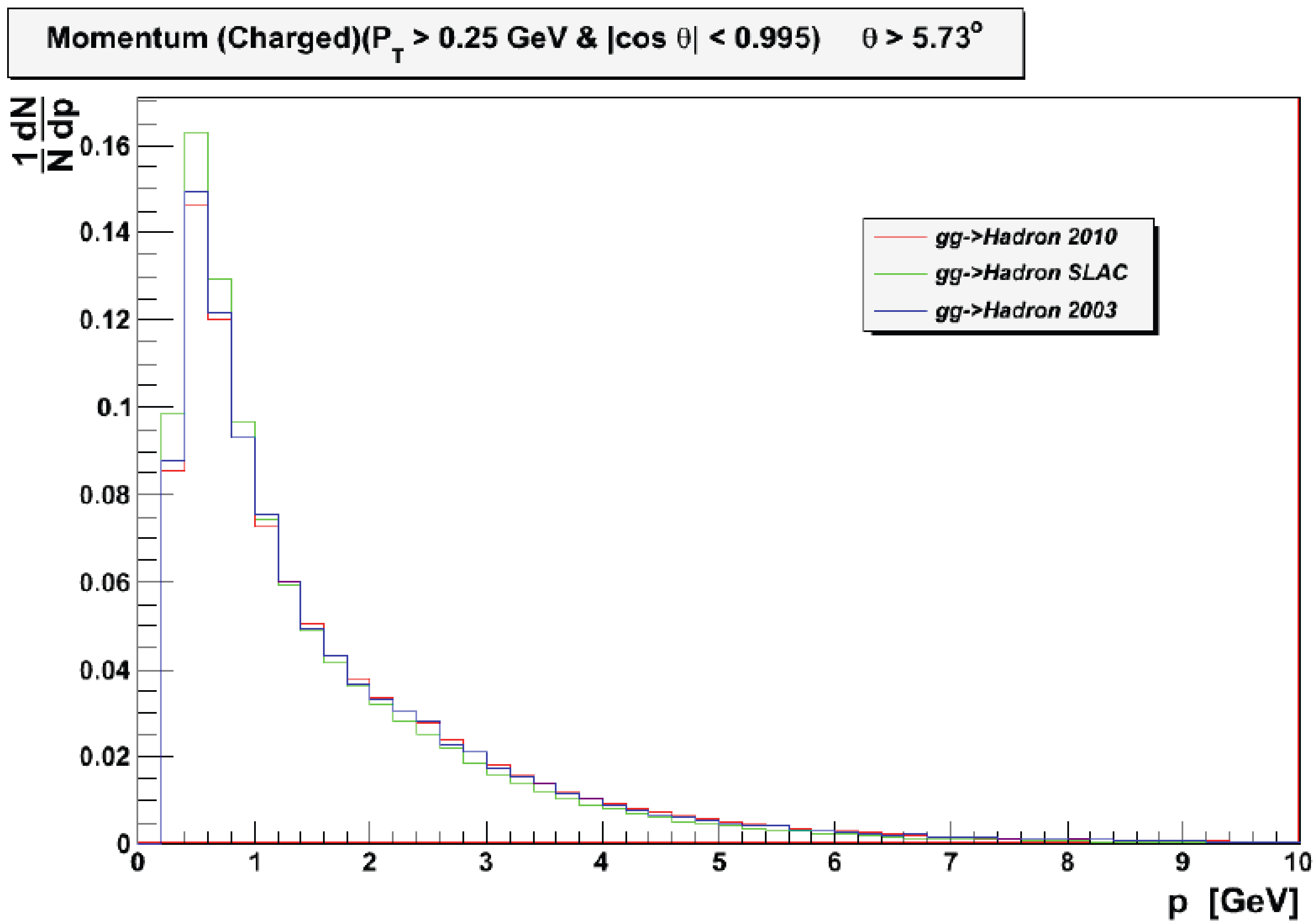
Ozgur Sahin- Dominik Dannheim

- 2010 Schulte Sample
  - Generated with PYTHIA / GUINEA-PIG Monte Carlo generators
  - Number of events: 67 587
  - Invariant Mass Cut: 2 GeV
  - Event / BX : 3.2

- 2010 Barklow Sample
  - Generated with PYTHIA / GUINEA-PIG (WHIZARD) Monte Carlo generators
  - Number of events: 418 888
  - Invariant Mass Cut: ~0.27 GeV
  - Event / BX : 4.1

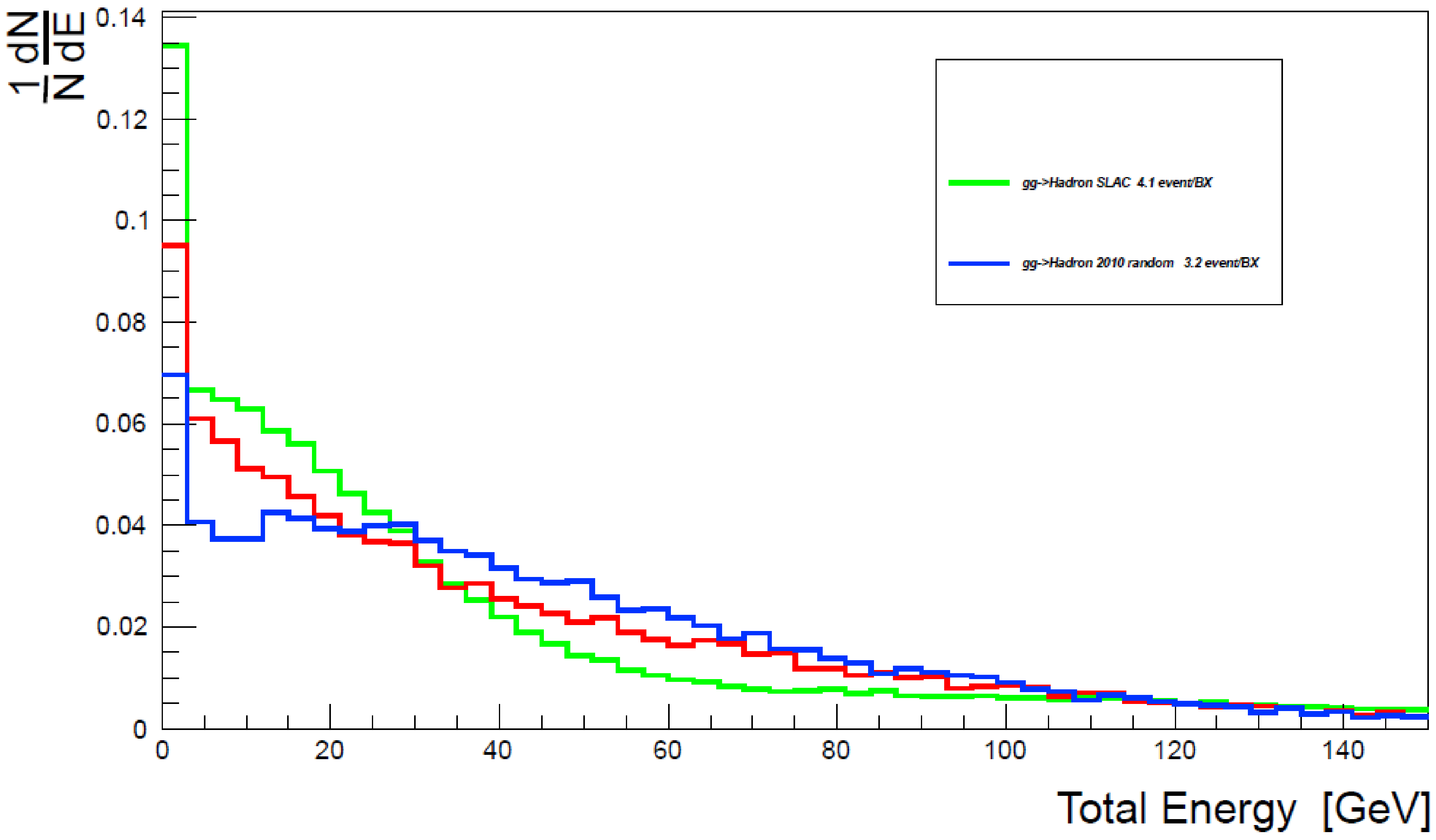


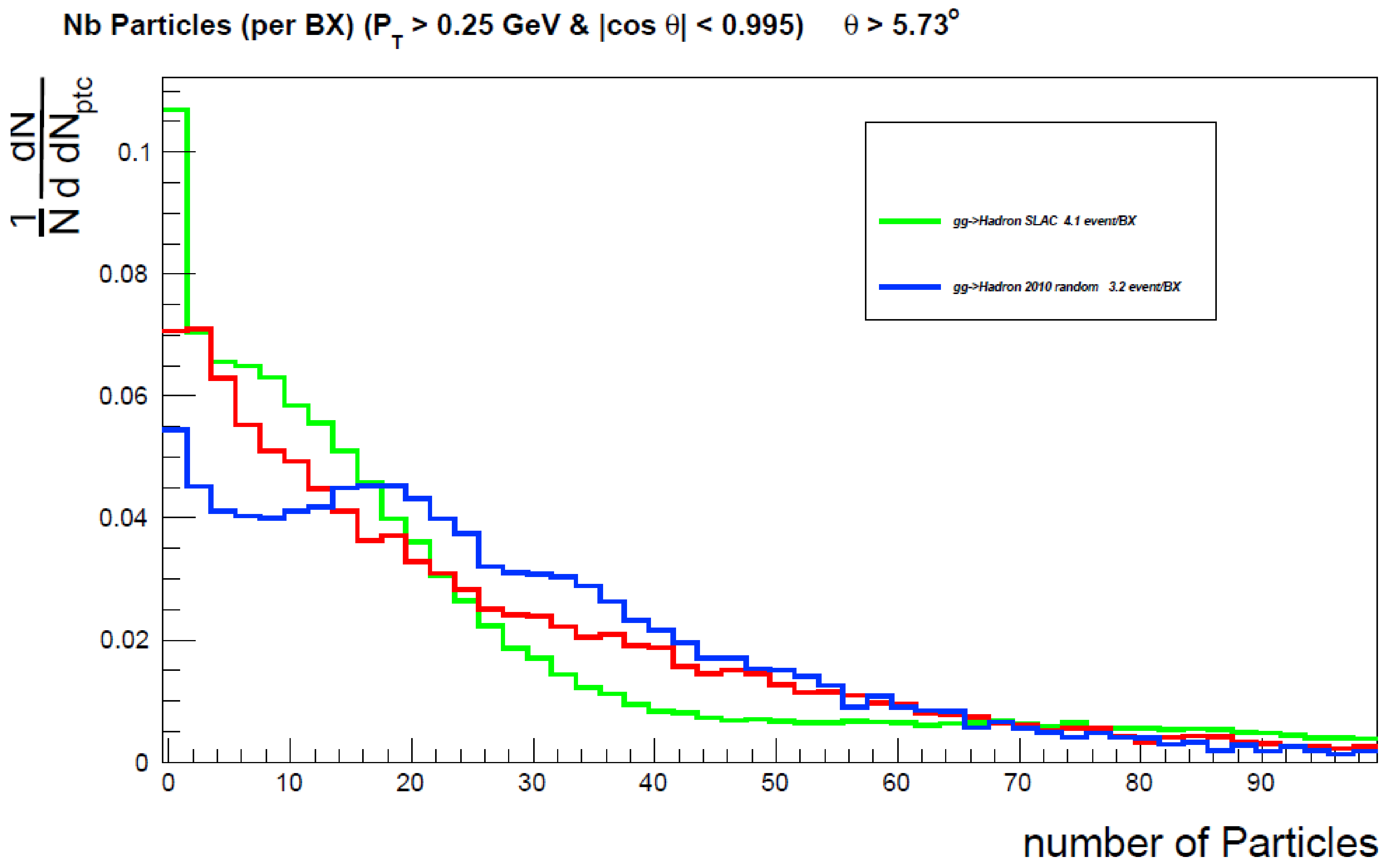
Polar Angle (Charged)(P_T > 0.25 GeV & |cos θ| < 0.995)   θ > 5.73°
$\frac{1}{N}\frac{dN}{d\cos\theta}$
gg->Hadron 2010
gg->Hadron SLAC
gg->Hadron 2003
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0
0.1
0.2
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
|cos θ|



Momentum (Charged)(P_T > 0.25 GeV & |cos θ| < 0.995) θ > 5.73°
1/N dN/dp
0.16
0.14
0.12
0.1
0.08
0.06
0.04
0.02
0
gg->Hadron 2010
gg->Hadron SLAC
gg->Hadron 2003
0 1 2 3 4 5 6 7 8 9 10
p [GeV]

E_{Tot}(per BX) (P_T > 0.25 GeV & |cos θ| < 0.995) θ > 5.73°





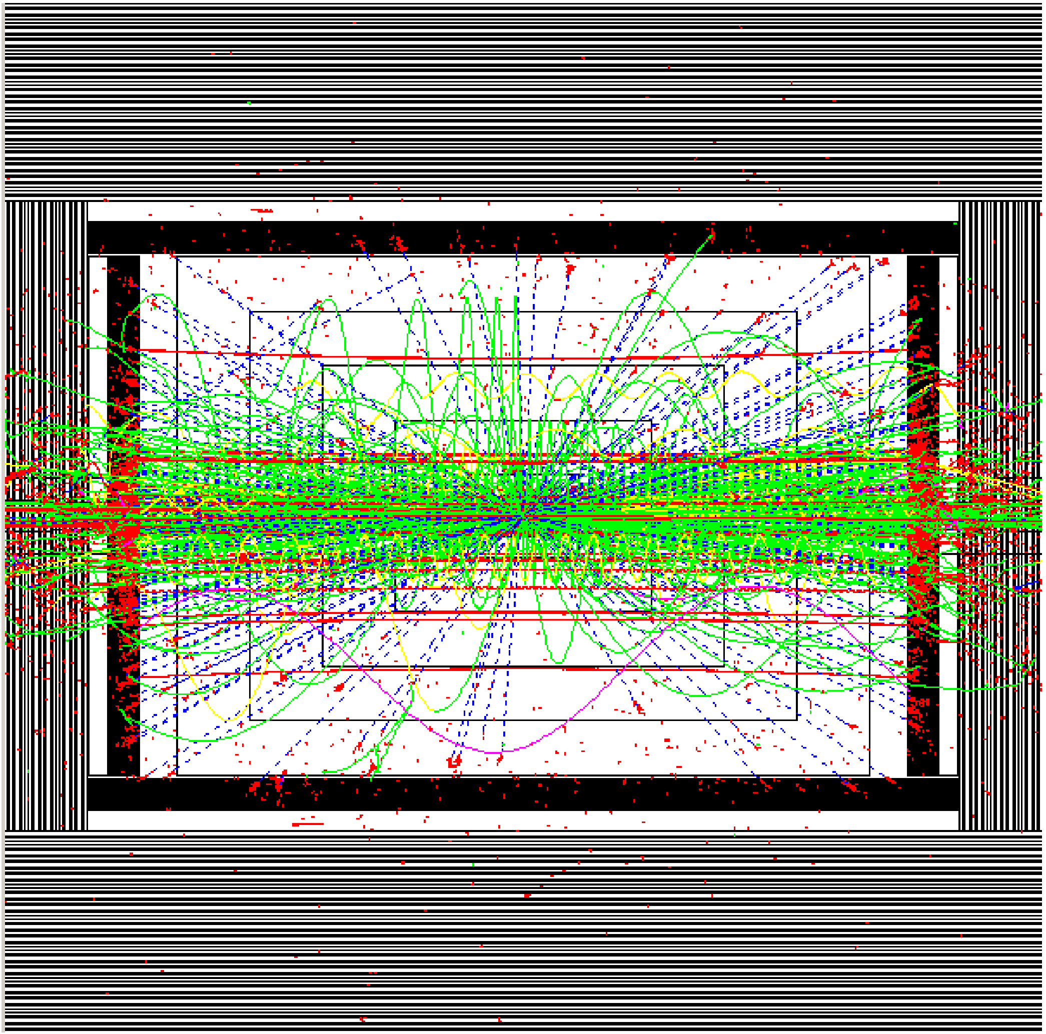
Nb Particles (per BX) (P_T > 0.25 GeV & |cos θ| < 0.995) θ > 5.73°
$\frac{1}{N}\frac{dN}{d\,dN_{ptc}}$
0.1
0.08
0.06
0.04
0.02
0
0
10
20
30
40
50
60
70
80
90
gg->Hadron SLAC 4.1 event/BX
gg->Hadron 2010 random 3.2 event/BX
number of Particles

Comparison CERN vs SLAC Samples

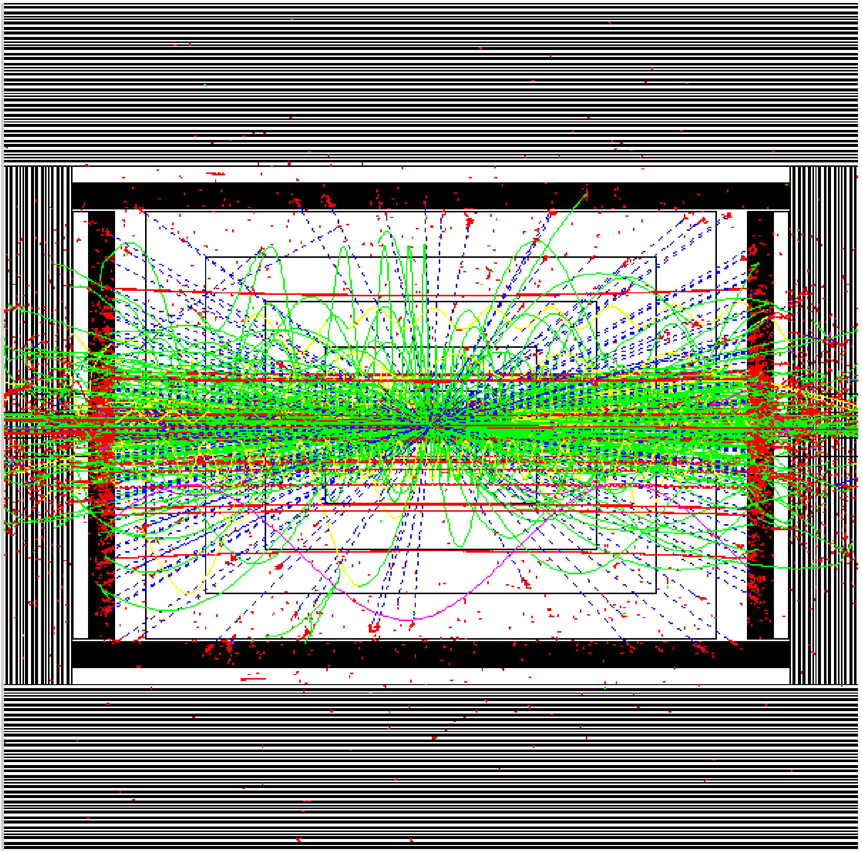
	Schulte 2010	Barklow 2010
Invariant Mass Cut	2 GeV	~0.27 GeV
Events per Bunch Crossing	3.2	4.1
#Particles (charged) per Bunch Crossing $\|\cos\theta\| < 0.92$ & $P_T > 0.25$ GeV ($\theta > 23.07°$)	5.9 (4.2)	5.6 (4.1)
#Particles (charged) per Bunch Crossing $\|\cos\theta\| < 0.98$ & $P_T > 0.25$ GeV ($\theta > 11.49°$)	21.9 (14.3)	23.1 (15.2)
#Particles (charged) per Bunch Crossing $\|\cos\theta\| < 0.995$ & $P_T > 0.25$ GeV ($\theta > 5.73°$)	28.1 (18.4)	29.0 (19.1)
Energy per Bunch Crossing $\|\cos\theta\| < 0.92$ & $P_T > 0.5$GeV ($\theta > 23.07°$)	7.4 GeV	6.4 GeV
Energy per Bunch Crossing $\|\cos\theta\| < 0.98$ & $P_T > 0.25$ GeV ($\theta > 11.49°$)	25.7 GeV	24.6 GeV
Energy per Bunch Crossing $\|\cos\theta\| < 0.995$ & $P_T > 0.25$ GeV ($\theta > 5.73°$)	49.5 GeV	45.1 GeV

Effect of Different Invariant Mass Cuts

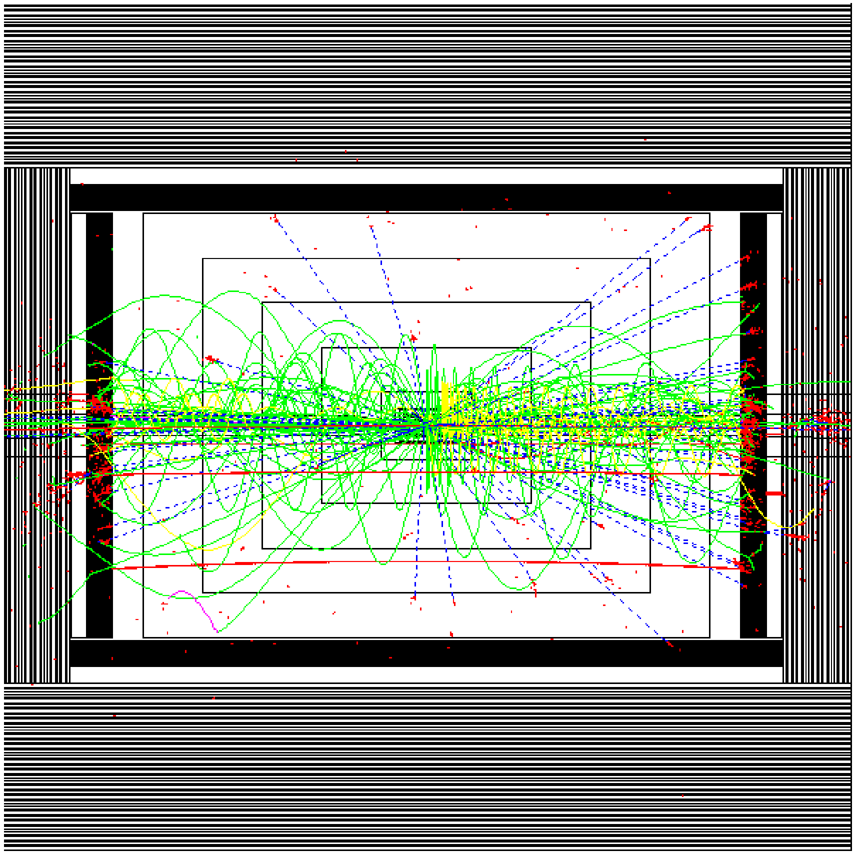
Invariant Mass Cut	$\lvert\cos\theta\rvert < 0.995$ & $P_T > 0.25$ GeV ($\theta > 5.73°$)	Schulte 2010	Barklow 2010
~0.27 GeV	Energy / BX	-	45.1 GeV
	# Particles / BX	-	29.0
2 GeV	Energy / BX	49.4 GeV	44.5 GeV
	# Particles / BX	28.1	28.4
5 GeV	Energy / BX	48.4 GeV	43.2 GeV
	# Particles / BX	27.5	27.6
10 GeV	Energy / BX	47.0 GeV	41.6 GeV
	# Particles / BX	26.6	26.6



56 hadronic events integrated
over 7.3 ns at CLIC (5% of train)
no pt cut; Ecm down to $\pi^+\pi^-$ threshold
660 GeV detected energy
420 detected charged tracks



5.0% train (56 events) at CLIC
integrated over 7.3 ns
660 GeV detected energy
420 detected charged tracks



1.6% train (19 events) at CLIC
integrated over 2.5 ns
220 GeV detected energy
140 detected charged tracks

Summary

- $\gamma\gamma \to hadrons$ events for $W_{\gamma\gamma} > 2\ \mathrm{GeV}$ are simulated using Guinea-Pig + PYTHIA . On average these events contribute 50 GeV energy and 30 particles per bunch crossing at CLIC. Good detector timing required to reduce the impact of these events on physics analyses.
- Events for $0.3\ \mathrm{GeV} < W_{\gamma\gamma} < 2\ \mathrm{GeV}$ are simulated with Guinea-Pig + isotropic 2,3,4 pion production. Such events don't contribute much to average energy or multiplicity per bx once pt and cosθ cuts are applied. However, they might impact forward occupancy and low visible mass analyses.
- Recent 3 TeV $\gamma\gamma \to hadrons$ samples generated at CERN (Schulte) and SLAC (Barklow) show good agreement in various distributions
- Independent high pt pointlike $\gamma\gamma \to q\bar{q}$ background samples should be augmented with high pt resolved photon background samples.