Physics Impact of Beam Beam Hadron Background

- Introduction
- Background Simulation and Characteristics
- Impact on Higgs mass measurement at 500 GeV
- Impact on $H \rightarrow \tau\tau$ selection at 500 GeV
- Impact on $WW \rightarrow H$ selection at 1000 GeV
- Summary

Results are preliminary!

Klaus Desch, University of Hamburg

with Andreas Imhof, Niels Meyer, Alexei Raspereza (DESY)

and including results from Toshinori Abe, Tim Barklow, John Jaros (SLAC)

LCWS04, Paris, 20/04/04

Backgrounds

Effects of colliding beamstrahlung photons:

- produce $e^+ e^-$ pairs in the electric field of the bunch charges
- some will hit machine and detector parts, producing backscattered particles which hit the detector

- collide themselves and produce leptons and hadrons which (apart from their low multiplicity and energy) look like real physics events

$\gamma\gamma \rightarrow$ hadrons

Hadronic Background

from ILC-TRC report:	TESLA		JLC-C		NLC/GLC	
	500	**800**			**500**	**1000**
n_γ [number of γs per e]	1.56	1.51	1.36	1.30	1.26	1.30
$N_{\mathrm{pairs}}(p_T^{\mathrm{min}} = 20\ \mathrm{MeV/c}, \Theta_{\mathrm{min}} = 0.2)$	39.4	37.3	10.7	15.0	11.9	15.0
$N_{\mathrm{hadron\ events}}/\mathrm{crossing}$ (W>5 GeV)	0.248	0.399	0.075	0.270	0.103	0.270

Number of γγ→hadrons events per bunch-crossing (BX) for W>5GeV:

NLC: 0.10/0.27 events at 500/1000 GeV
TESLA: 0.25/0.40 events at 500/800 GeV

Probably not a very big problem if single bunches can be resolved **Battaglia, Schulte (2000)**

Readout of whole detector between two consecutive BX
is very tough within 1.4 ns at NLC

→ detector will integrate the signals over more than one BX at NLC

If detector granularity is fine enough, a single cell will not be hit in two consecutive BX (low occupancy).

→ no need to readout the cell immediately; storing time-info enough (time-stamping).

Very forward region will have high occupancy – effects not considered in this study

Hadronic Background

Need to find out which time-stamping resolution is acceptable without compromising physics performance

TESLA has 337/176 ns bunch spacing → time-stamping possible at 1BX precision

NLC detector goal is 4-5BX (6-8 ns)

We consider the following 5 scenarios:

		events overlaid on average		
	no. of BX	500 GeV	1000 GeV	
No background	0	0	0	
TESLA	1	0.25	0.4	
NLC / 6ns	4	0.4	1.1	
NLC / 25ns	18	1.8	4.9	“LHC”
NLC / 90ns	64	6.4	17.3	“HERA”

Hadronic Background Simulation

GuineaPig to simulate beamstrahlung photon flux

PYTHIA to simulate the $\gamma\gamma \rightarrow$ hadrons events (only $W > 5$ GeV)

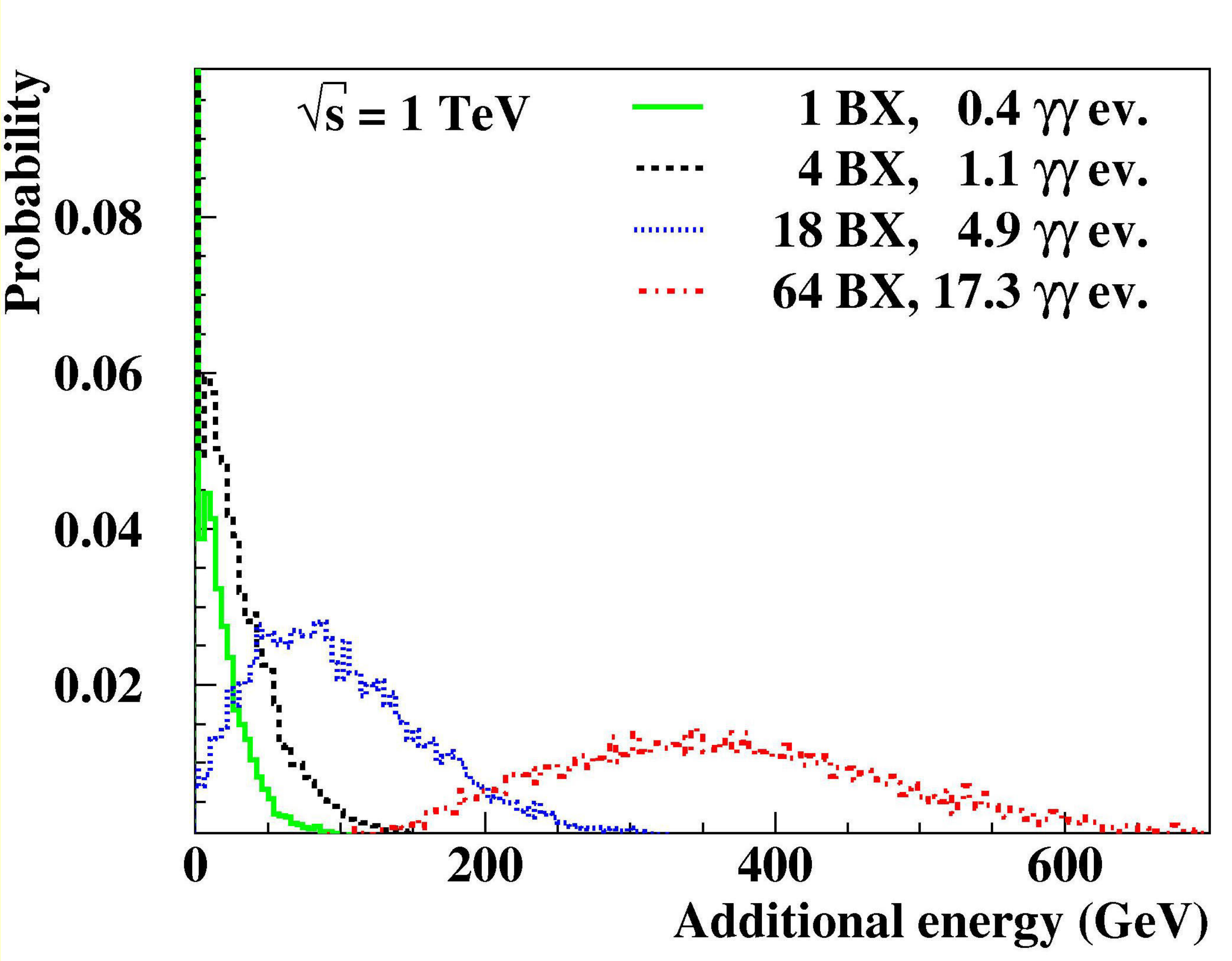
Hades (D.Schulte) to mix the events with the real physics event

SIMDET4 for detector simulation

cross check with BRAHMS

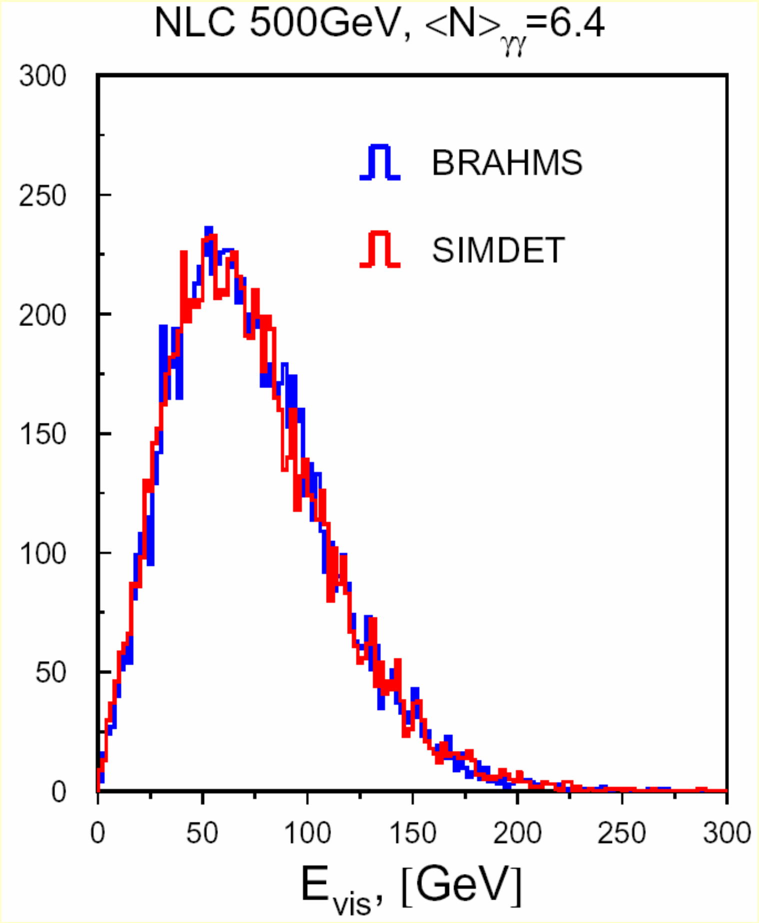
Hadronic Background - Properties

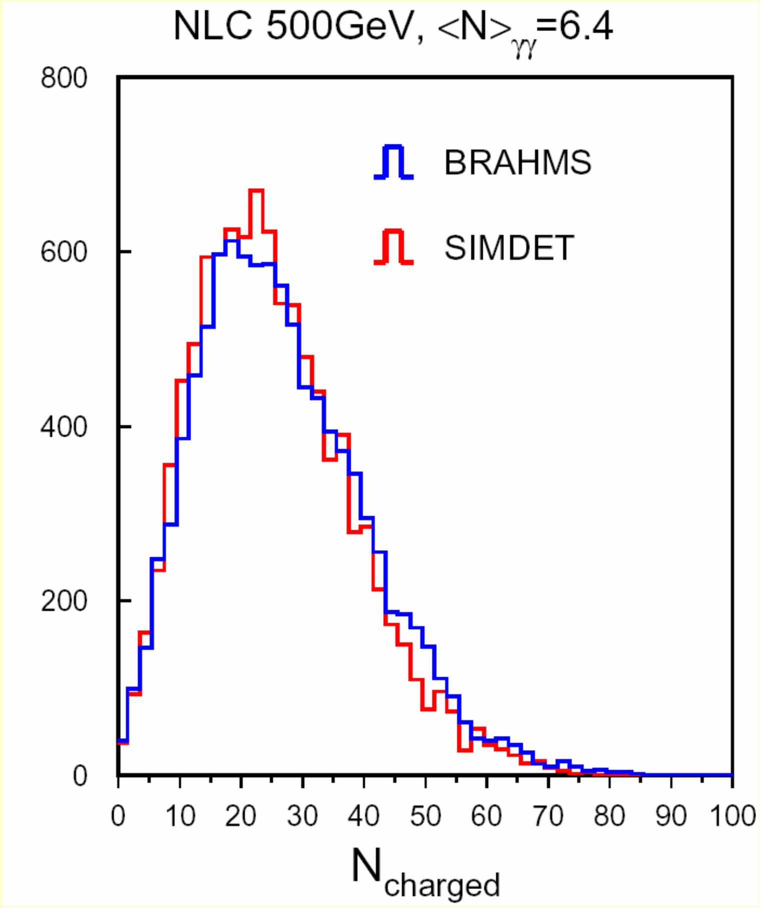
If integrated over several BX, huge amount of energy is deposited in the detector:



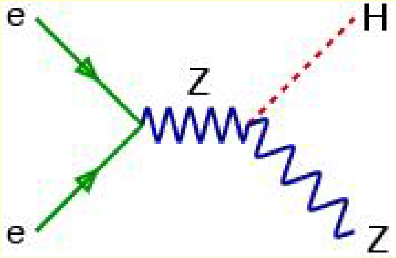
Hadronic Background - Properties

check of fast simulation (SIMDET) with BRAHMS → agreement on global distribution





Physics impact 1: Higgs mass measurement

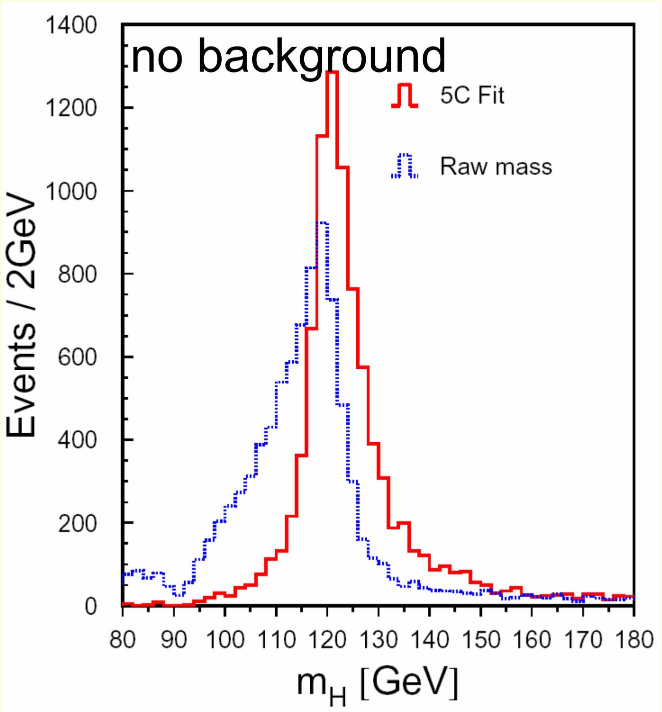


Mass measurement for a light Higgs boson

Higgs-strahlung process

Best final state: H→bb, Z→qq (4 jets)

Improve mass resolution with a kinematic fit (assume 4-momentum conservation)

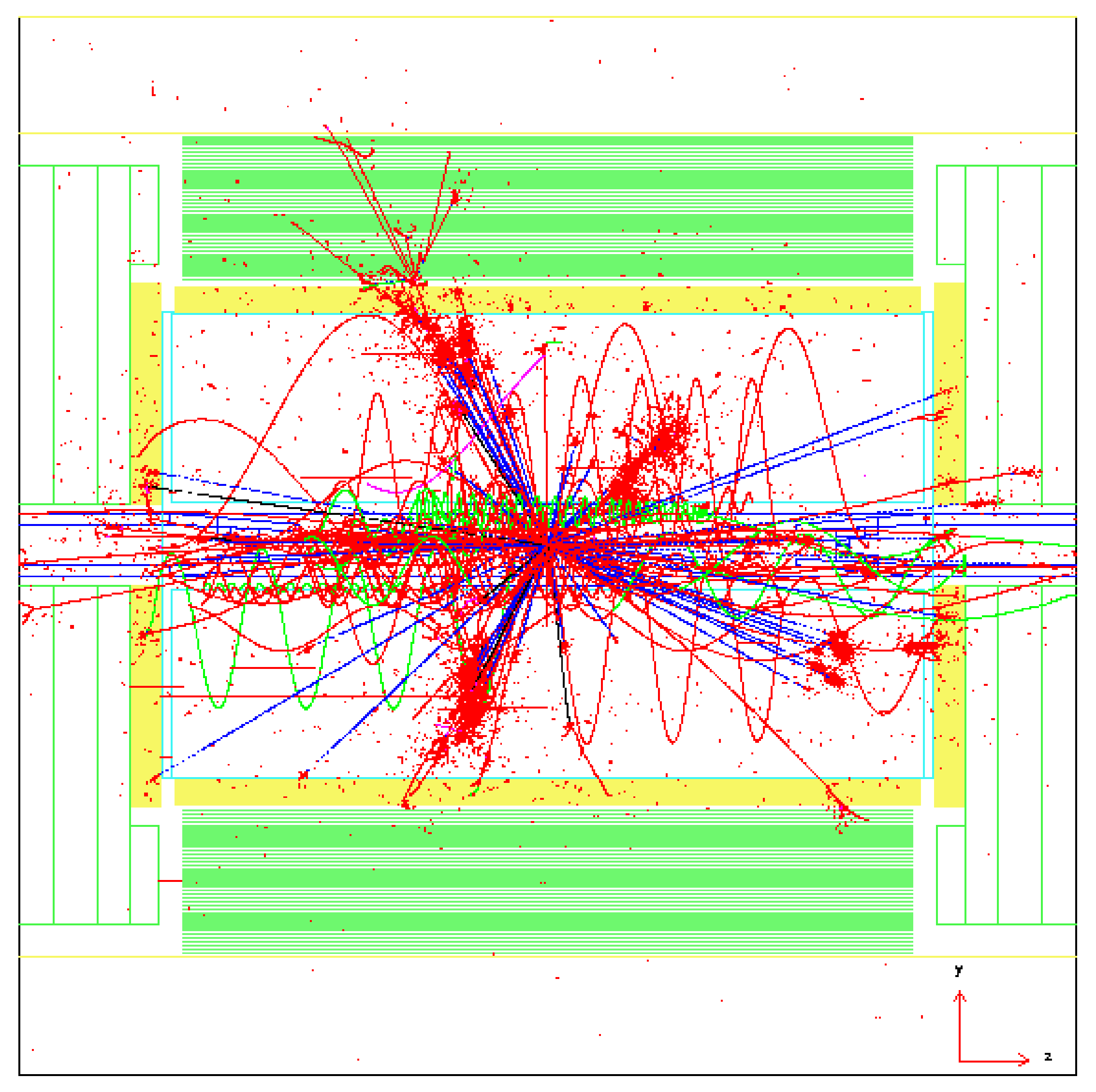


Study at 500 GeV for 500 fb^{-1}

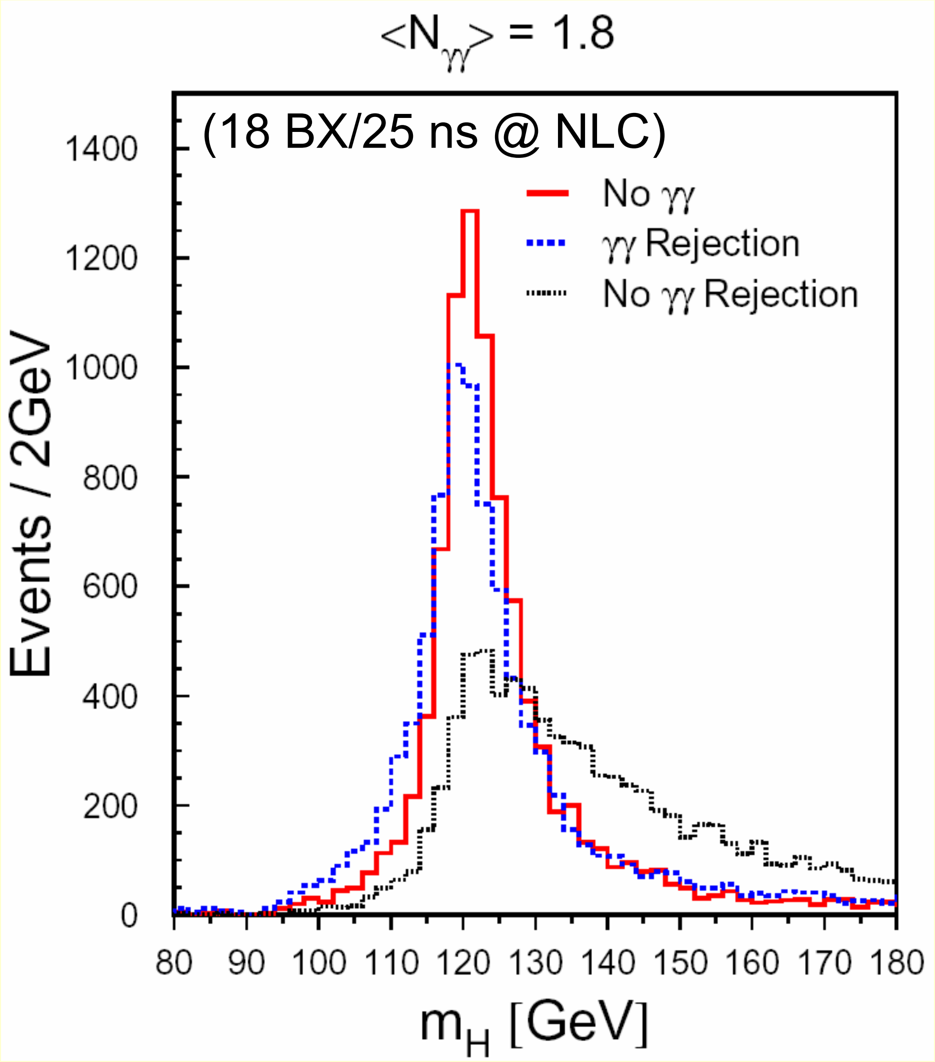
m_h = 120 GeV

Overlaid background will (seemingly) violate 4-momentum conservation
→ expect kinematic fit to fail:

2. Hadronic Background



Physics impact 1: Higgs mass measurement



Hadronic background disastrous if no analysis optimization is performed!

Need to design special cuts to minimize the impact of the hadronic background (blue curve)

Physics Impact 1: Higgs mass measurement

Most particles from hadronic background are low-energetic and forward.

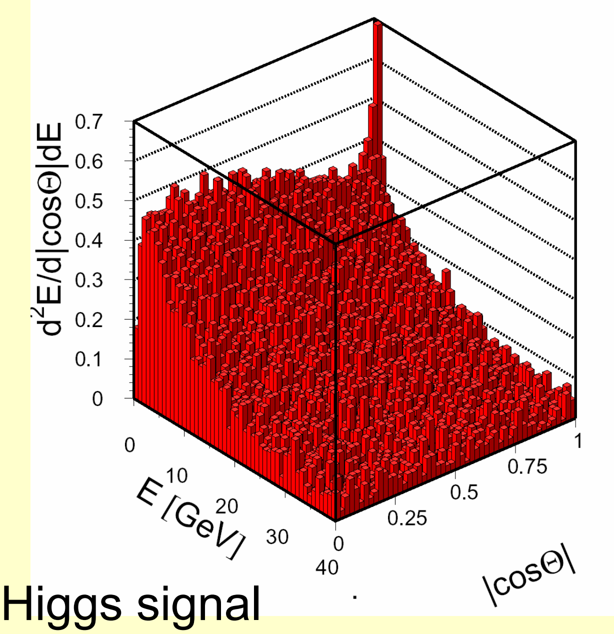
Cuts:

$p_t^{pflow} > 0.5/1$ GeV and energy-dependent cos Θ cut ($|\cos\Theta| < 1 - A \exp(-E/E_0)$)

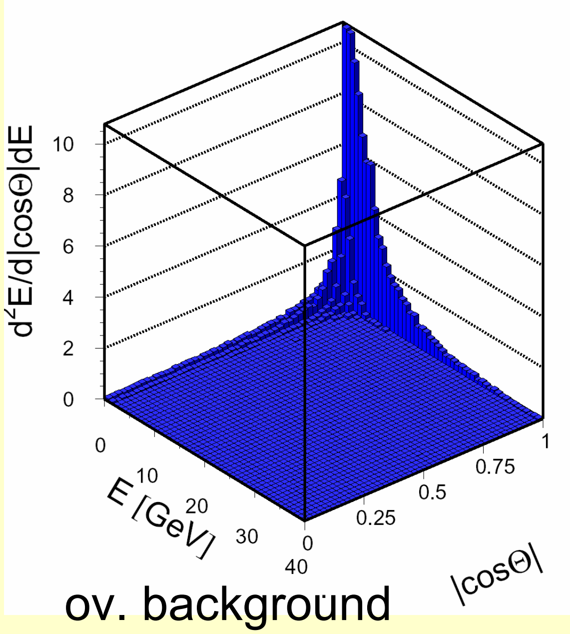
A and E_0 depend on background situation

Note: cuts are process-specific – very forward physics might suffer more than centrally produced Higgses

cut motivation:



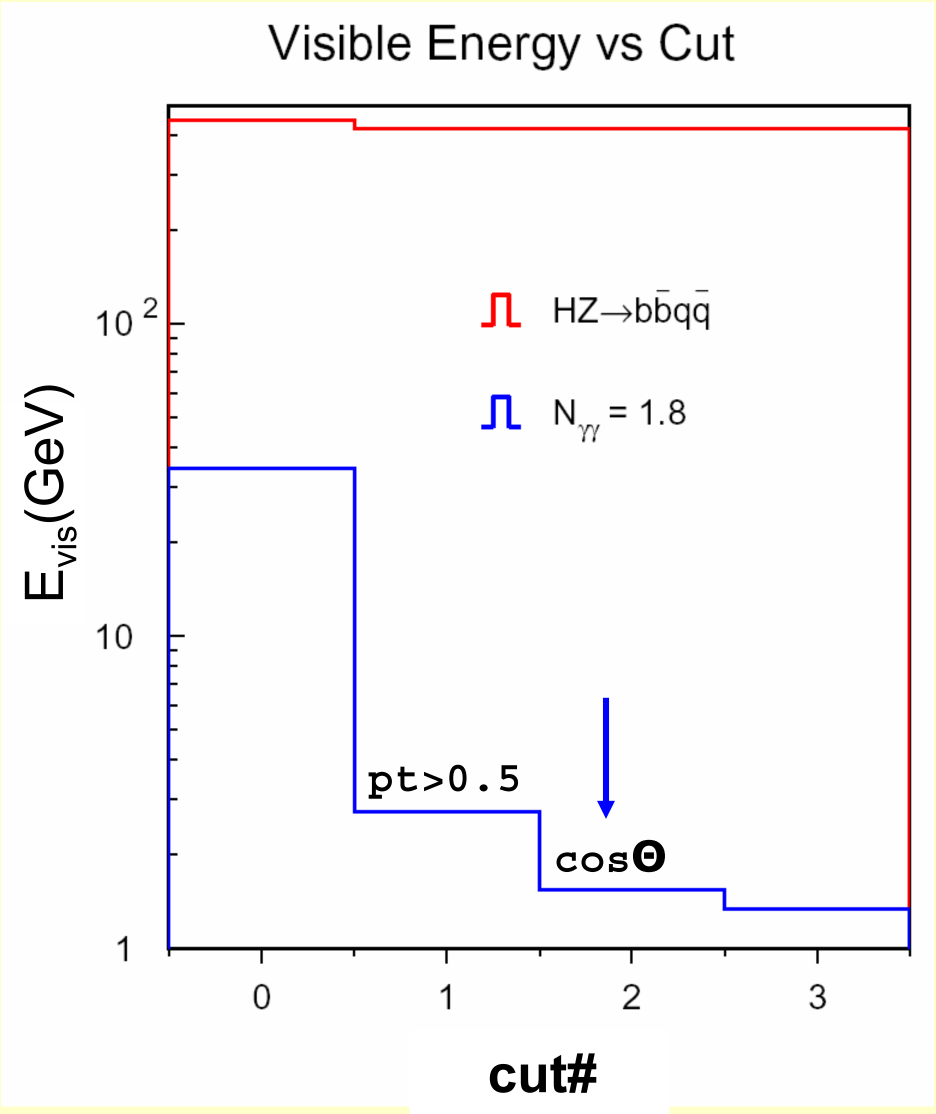
Higgs signal



ov. background

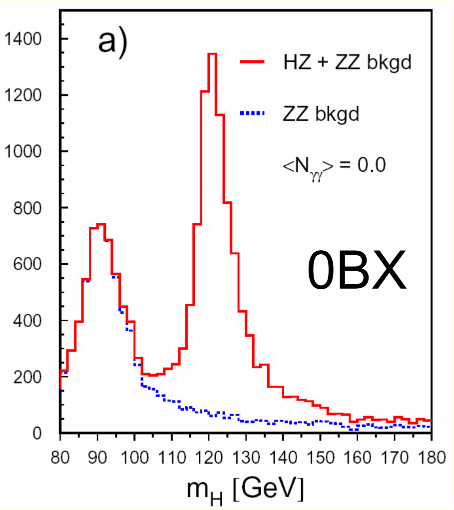
Physics impact 1: Higgs mass measurement

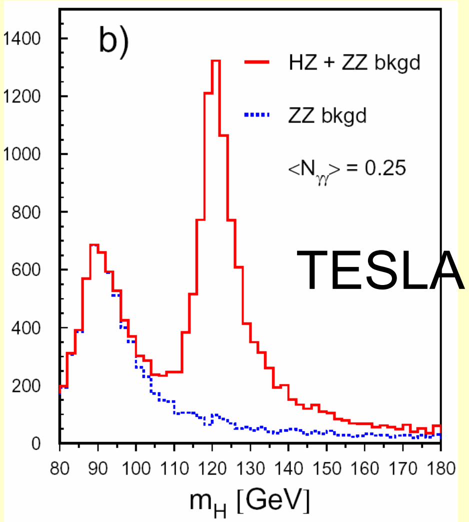
Effect of cuts:

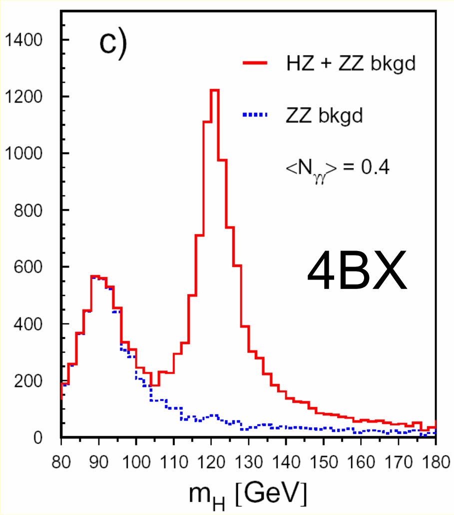


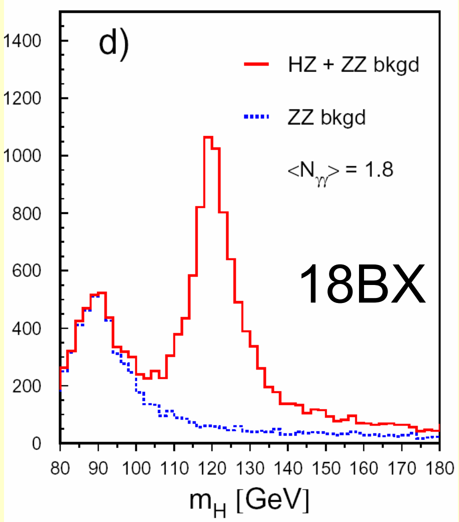
Background energy
reduced by factor 20

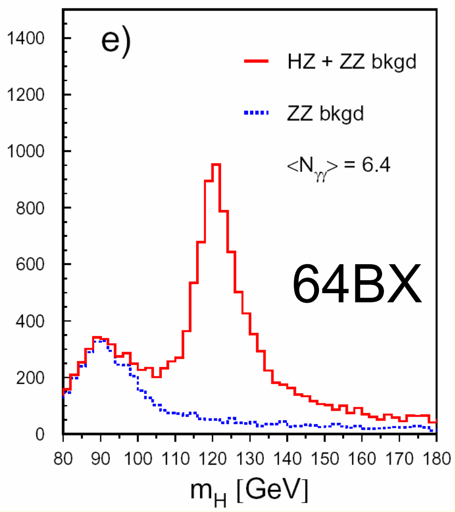
Physics impact 1: Higgs mass measurement











Physics impact 1: Higgs mass measurement

Quantitative results:

# of overlaid events	efficiency (%)	Δm_h(MeV)	Relative Luminosity to get same accuracy
0.00	43.9	68	1.0
0.25 (“TESLA”)	43.3	75	1.2
0.40 (4BX)	41.6	78	1.3
1.80 (18 BX)	40.1	92	1.8
6.40 (64 BX)	36.7	110	2.4

Physics impact 1: Higgs mass measurement

T.Abe et al have started a very similar study in the US

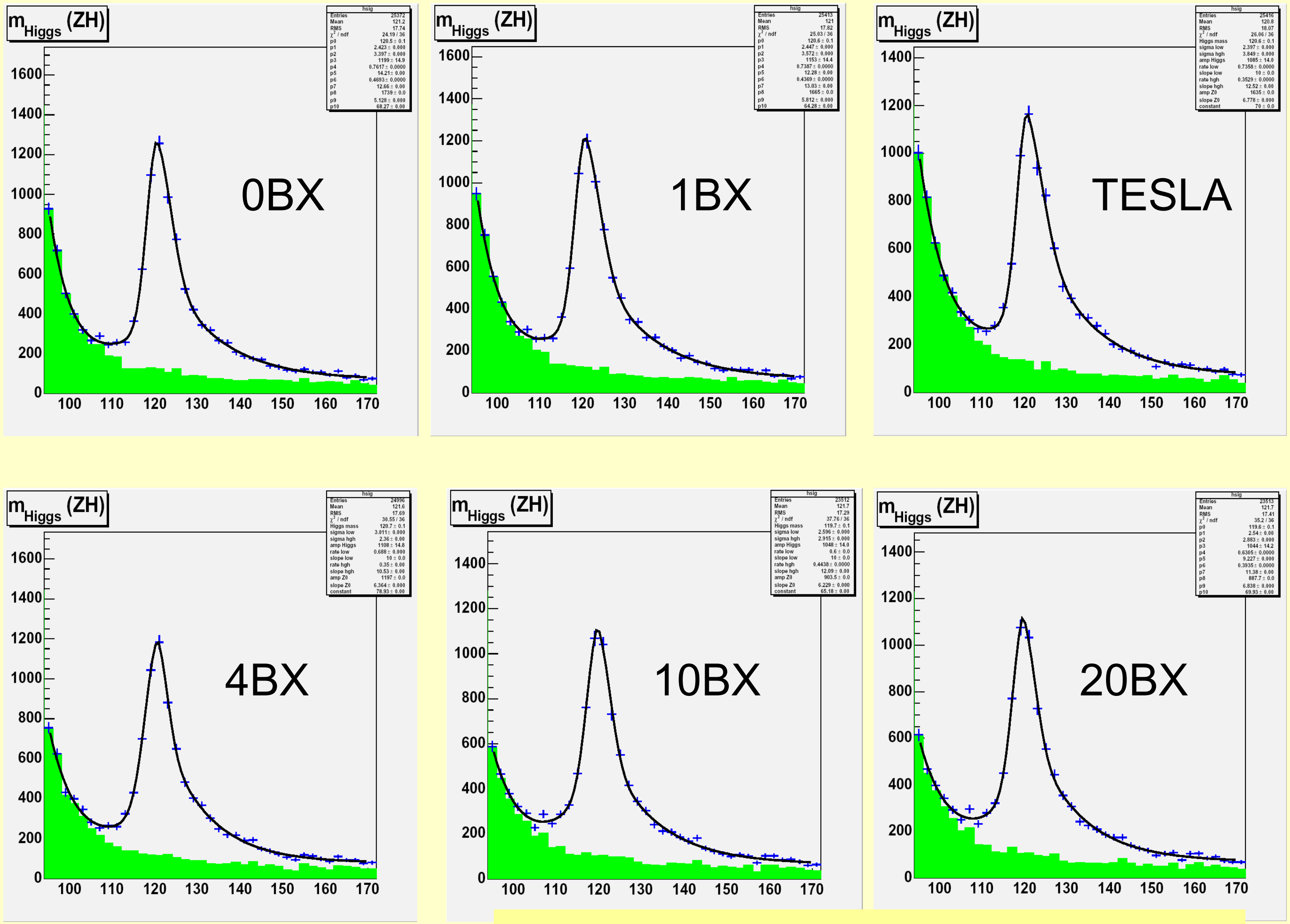
<u>Differences:</u>

- US Si Detector
- Inclusion of background with W<5 GeV:

number of BX	number of $\gamma\gamma$ events at 500 GeV
1	0.291
TESLA	0.808
4	1.164
5	1.455
10	2.910
20	5.820

- two different sets of jet energy resolution parameters in kinematic fit (for < 10 BX, for >= 10 BX)

Physics impact 1: Higgs mass measurement



optimized jet energy resolution parameters

Physics impact 1: Higgs mass measurement

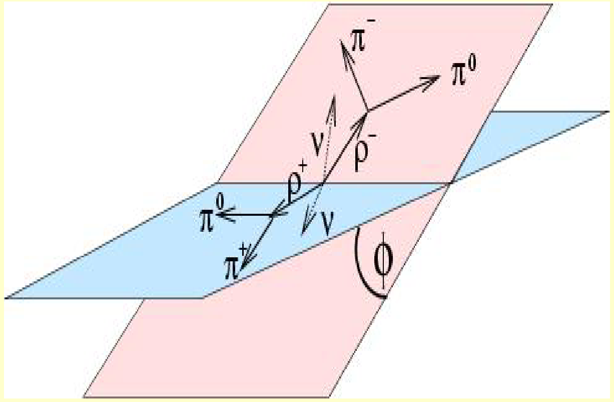
Comparison of results:

# of BX	US/optimized for <10BX	US/optimized for>=10BX	EU/optimized for 1BX
0	71	74	68
1	74	78	
TESLA	77	79	75
4	79	82	78
5	79	82	
10	91	82	
20	92	81	92
64			110

Physics Impact 2: CP study in $H \to \tau\tau$

Select $HZ \to \tau\tau\nu\nu \to \rho^+ \rho^- \upsilon\upsilon\upsilon\upsilon \to \pi^+ \pi^0 \pi^- \pi^0 \nu\nu\nu\nu$ events

Measure $\rho\rho$ acoplanarity



Overlaid events may disturb tau ID and reconstruction of ρ decay products

Simplified selection:

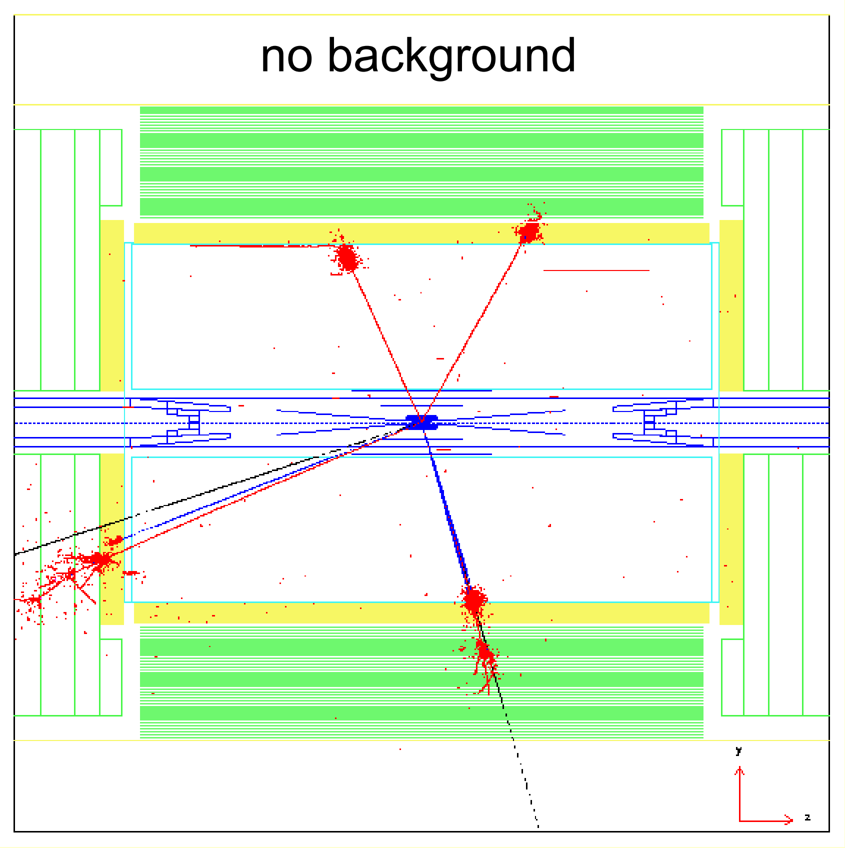
- require 2 cones(15^0) with exactly 1 charged track (not e,μ) with E>2 GeV
- at least 1 GeV neutral energy within 10^0 around charged track
- ρ mass between 0.4 and 4 GeV
- $\rho\rho$ mass between 25 and 125 GeV

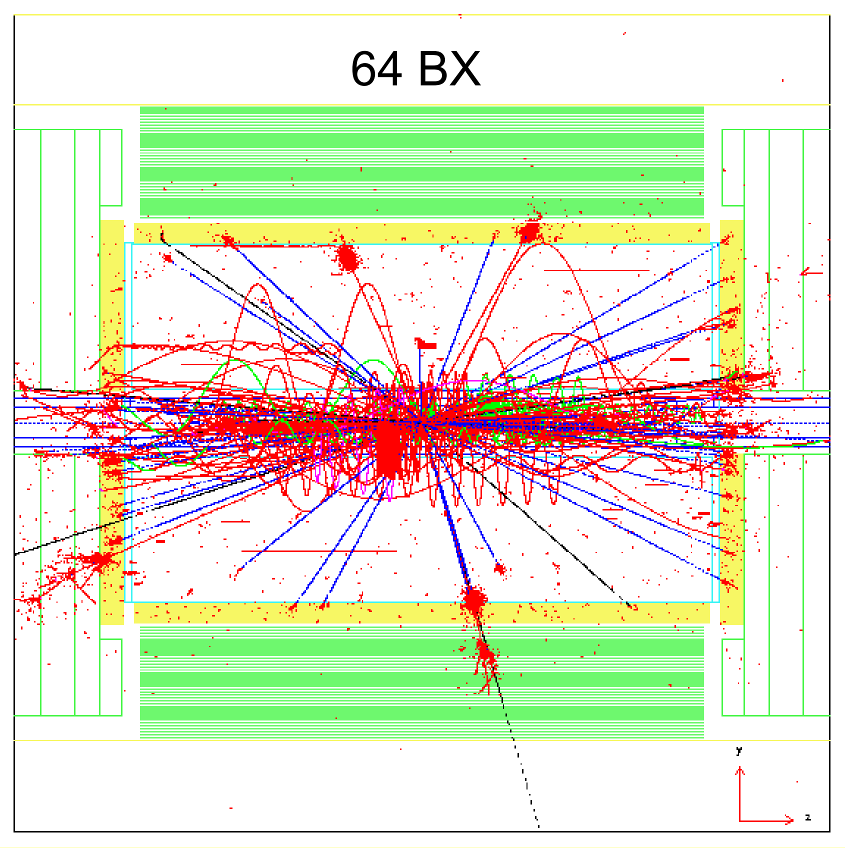
p_t-cut not easily applicable since photons from τ decay often low-energetic

cone size will be varied to reduce impact of background

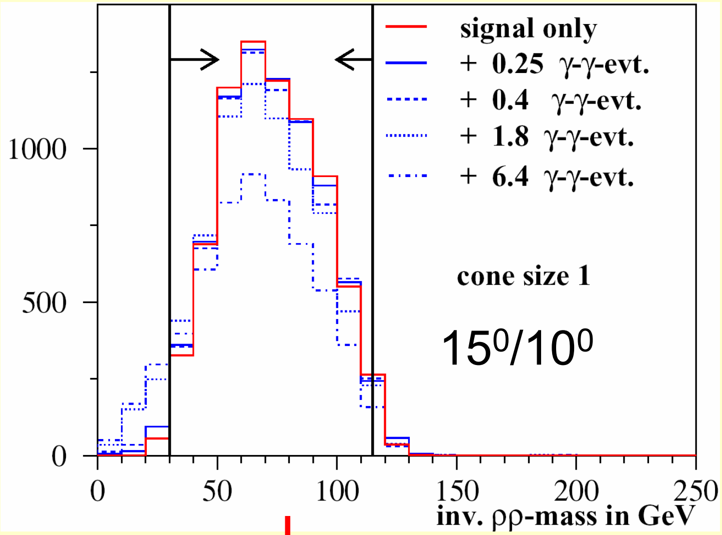
2. Hadronic Background

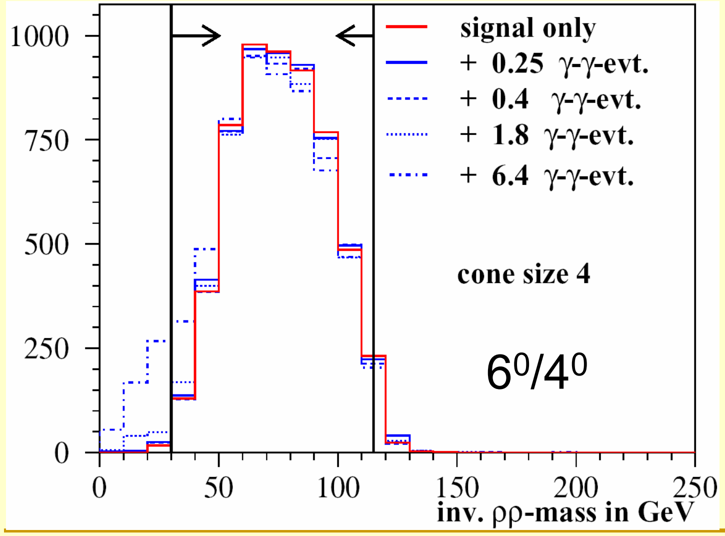
HZ → $\tau\tau ee$ event





Physics Impact 2: CP study in H→ττ

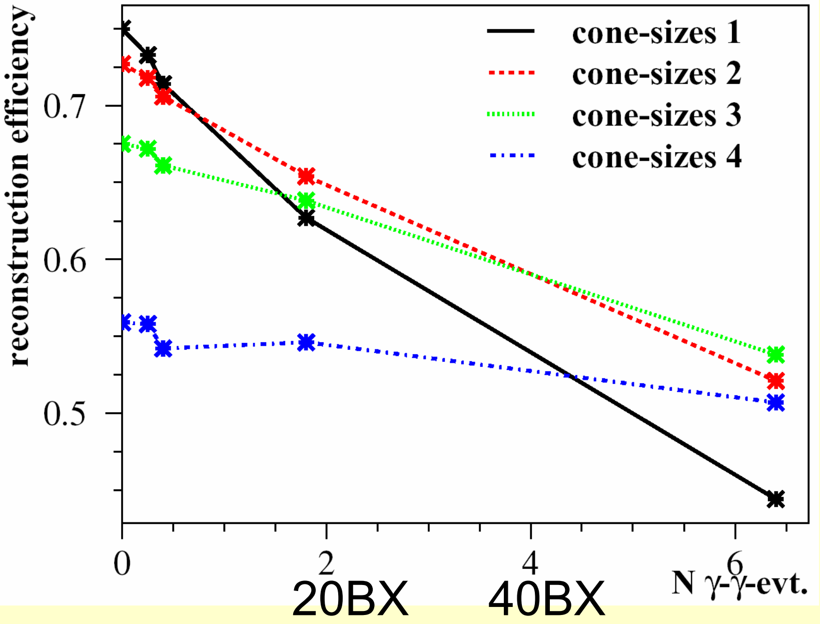




reducing the cone size reduces the fraction of “dirty” tau candidates

but also reduces the efficiency for good tau’s.

Result (efficiency for good tau-pairs):



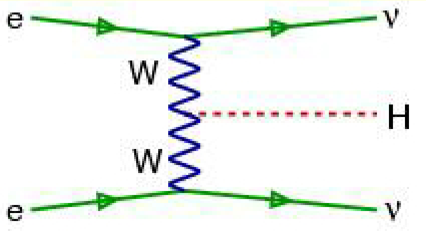
Physics Impact 3: Higgs in WW-fusion @ 1 TeV

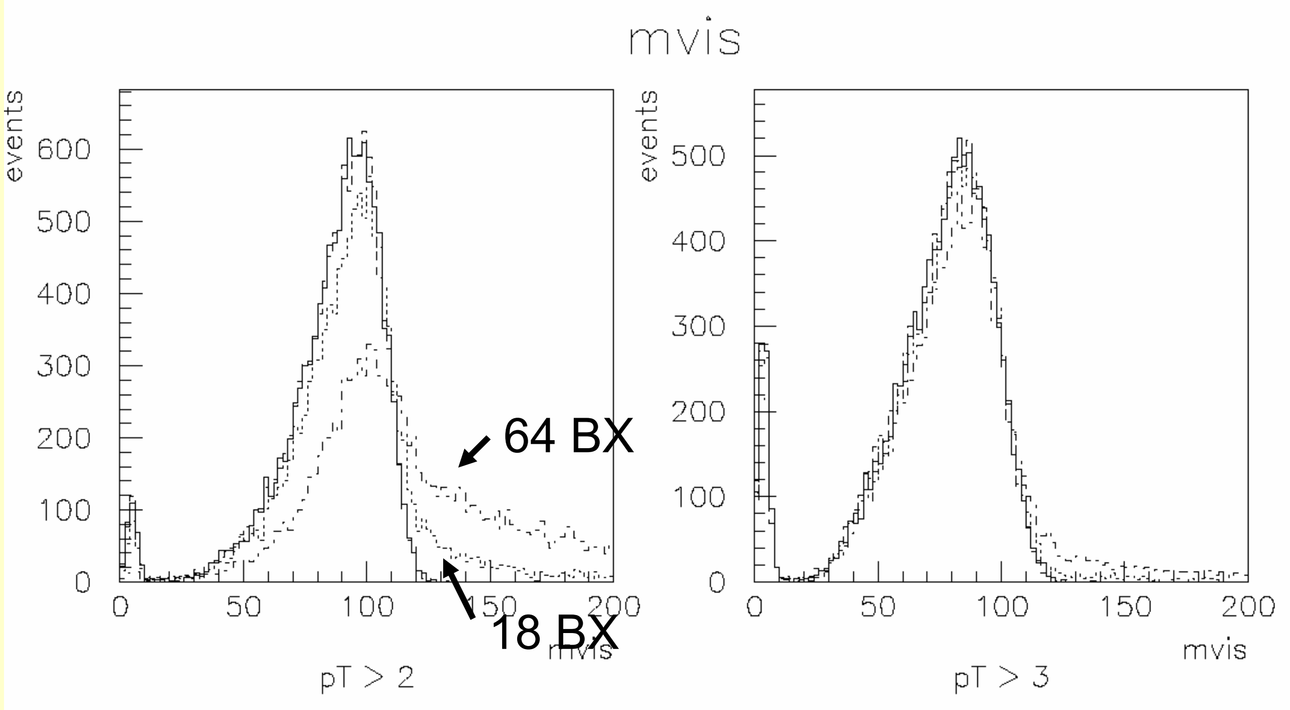
$e^+e^- \rightarrow b b \upsilon \upsilon$

look at visible mass (=m_H)

larger background at 1 TeV

no kinematic constraints in this channel

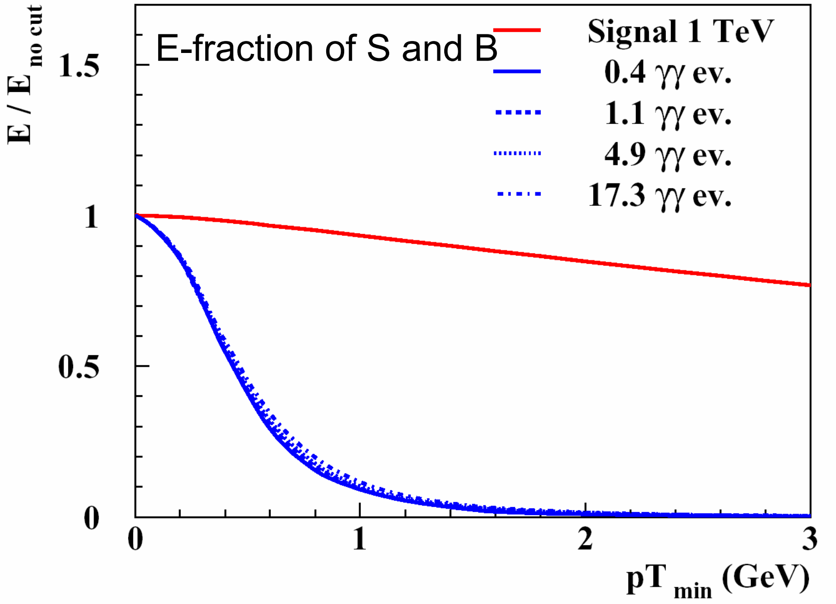


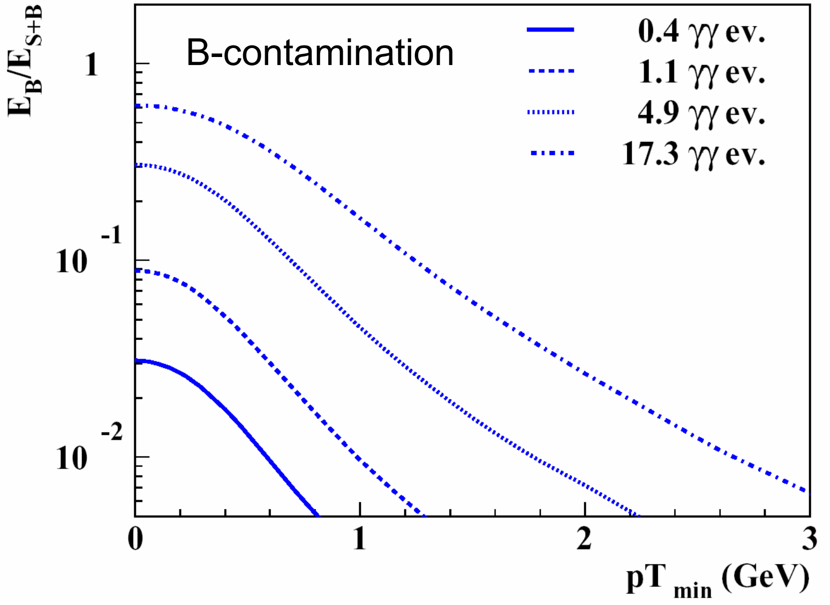


need a significant p_t cut to get m_{vis} distribution back into right ballpark

Physics Impact 3: Higgs in WW-fusion @ 1 TeV

How hard to cut?



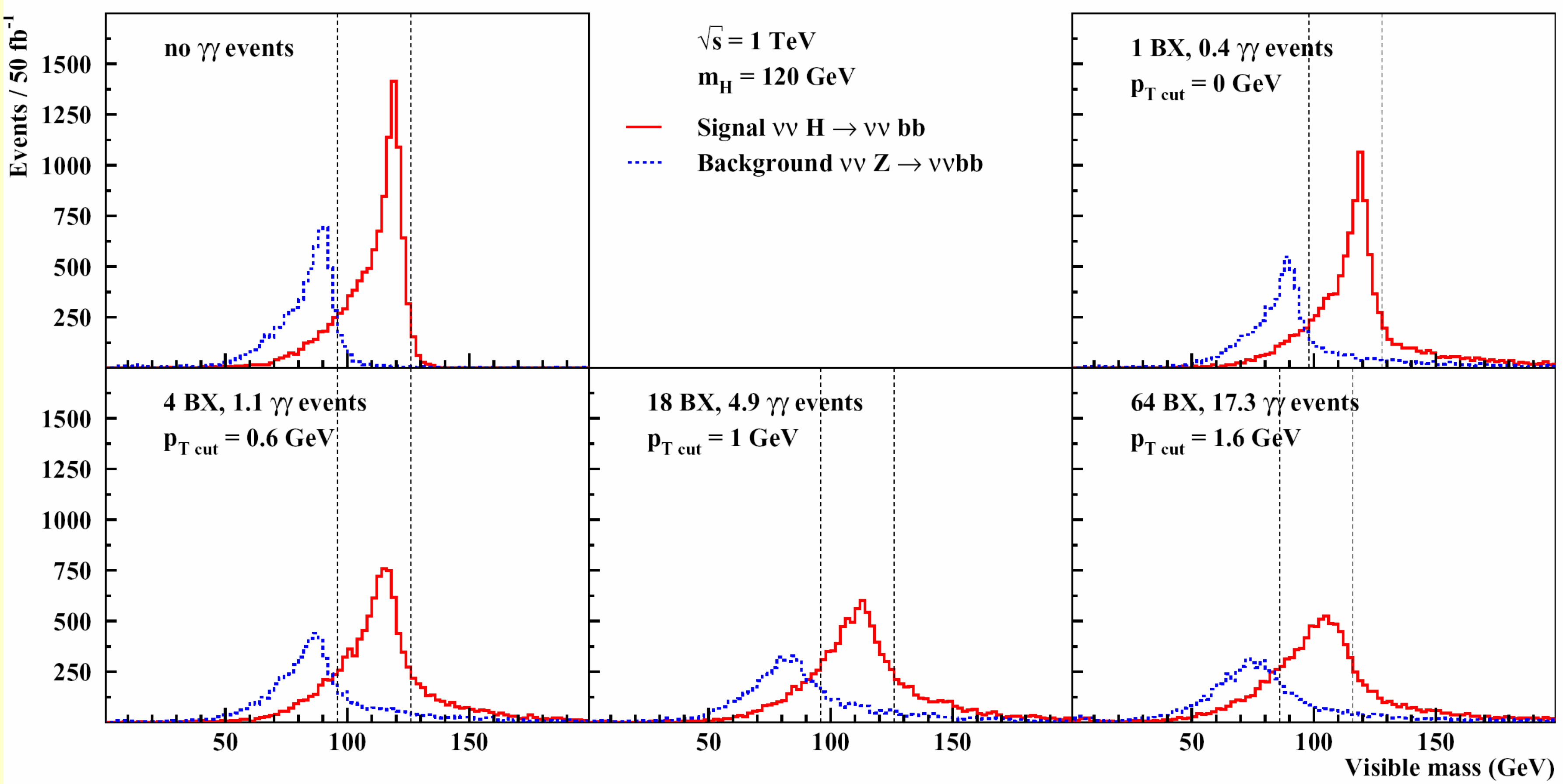


	p_t-cut
TESLA	0.0 GeV
4BX	0.6 GeV
18BX	1.0 GeV
64BX	1.6 GeV

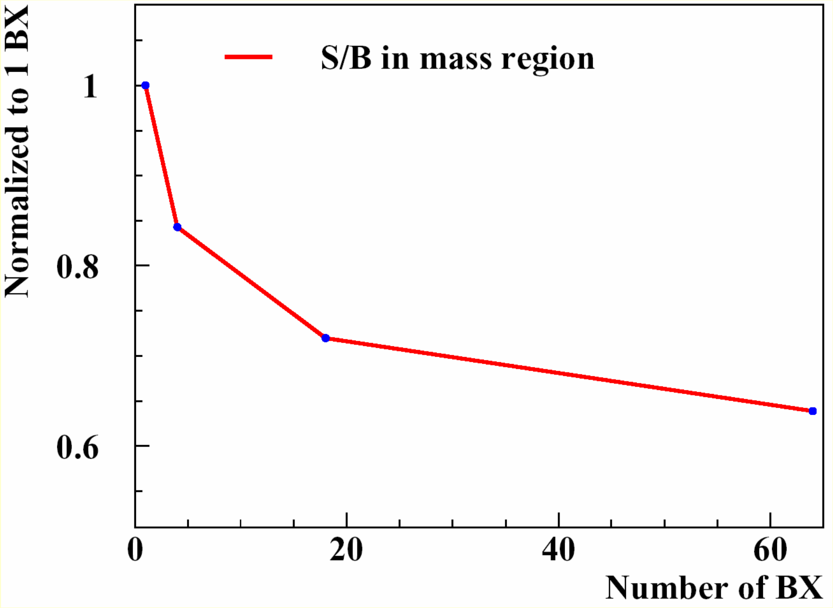
and a global cosΘ > 0.95 cut

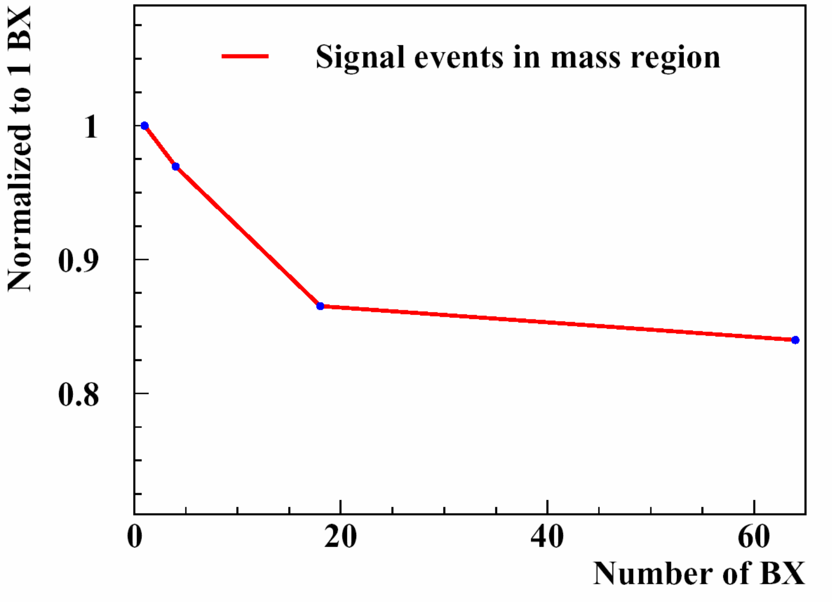
Physics Impact 3: Higgs in WW-fusion @ 1 TeV

Effect of p_t cut on signal and on dominant (ZZ) background:



Physics Impact 3: Higgs in WW-fusion @ 1 TeV





normalized to 1BX@TESLA

Preliminary Summary

Integrating the hadronic background from more than a few bunch-crossings would have a sizeable impact on the physics performance

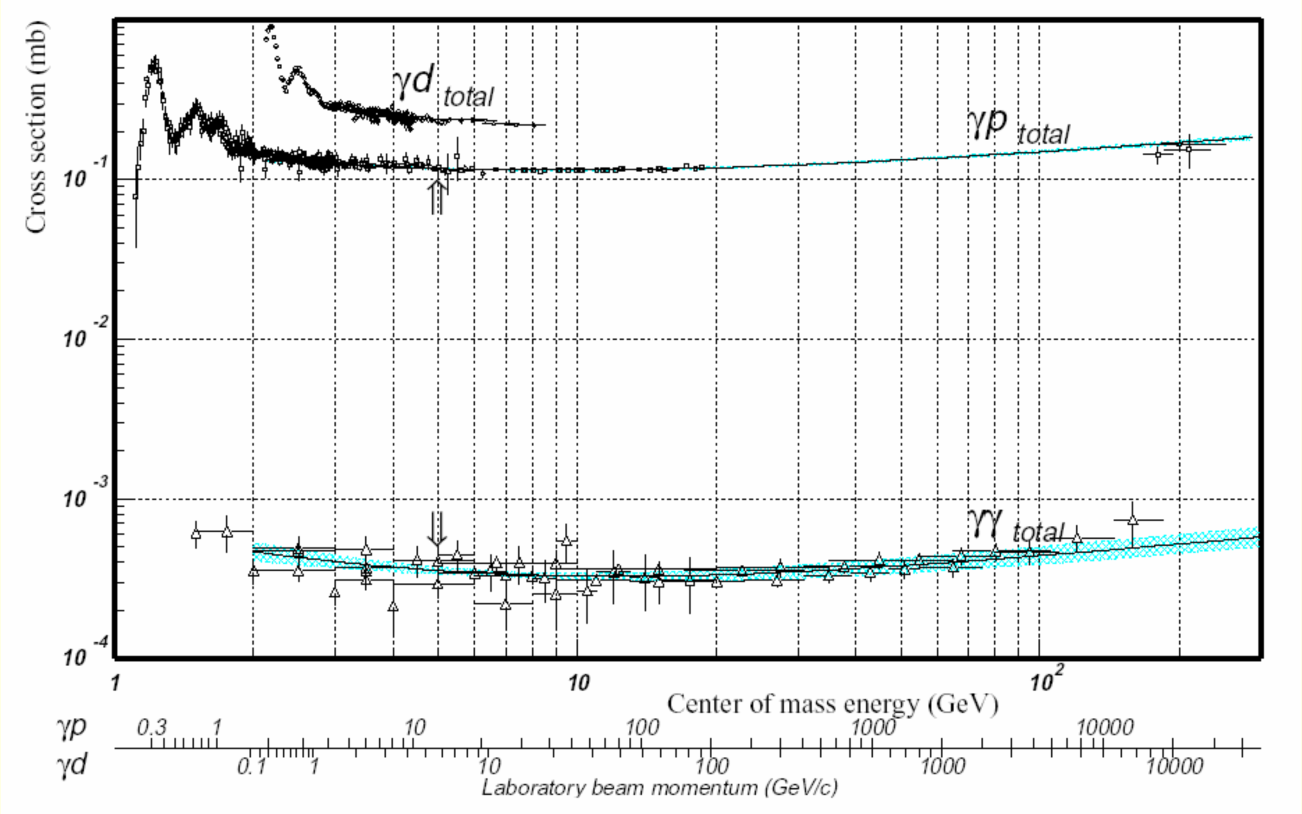
Typically (for the studied cases) 30 – 60% more integrated luminosity needed to get back to precision achievable for1BX bunch tagging when NLC detector would integrate over18 BX (=25 ns @ NLC)

EU and US study on Higgs mass (kin. fit) look consistent – tuning of jet resolution may recuperate some of the resolution loss for larger integration times

At NLC, a bunch tagging of ~6 ns is needed to become comparable to the TESLA situation → R&D on detector timing is vital for warm technology

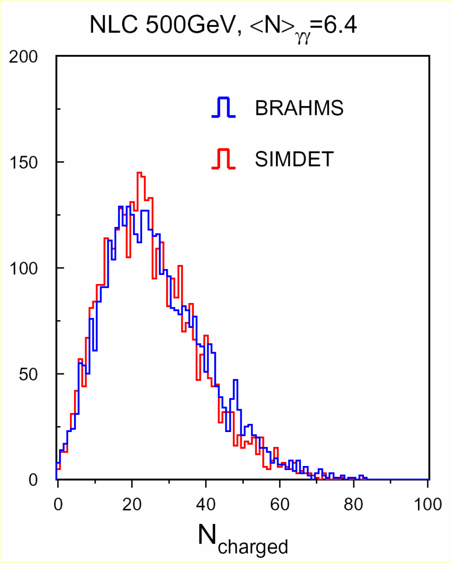
2. Hadronic Background

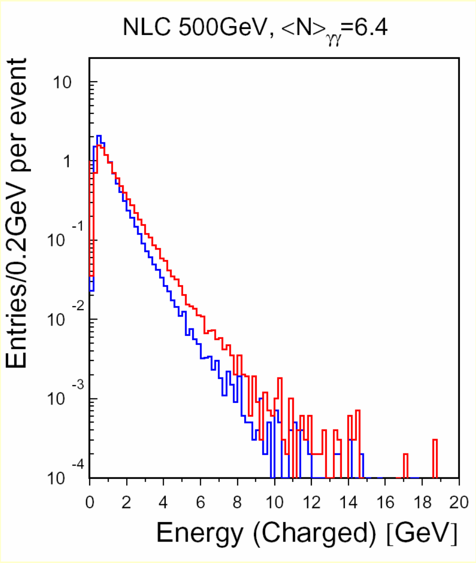
Total cross section for γγ→hadrons is very large (500-1000 nb)

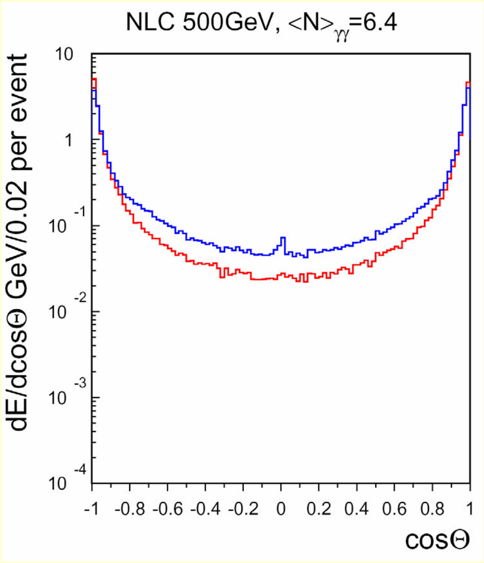


2. Hadronic Background: Properties

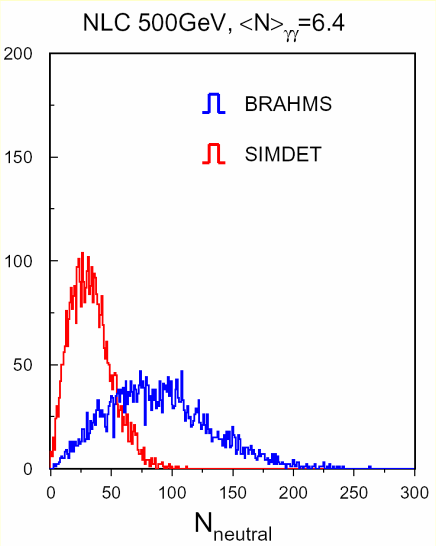
charged

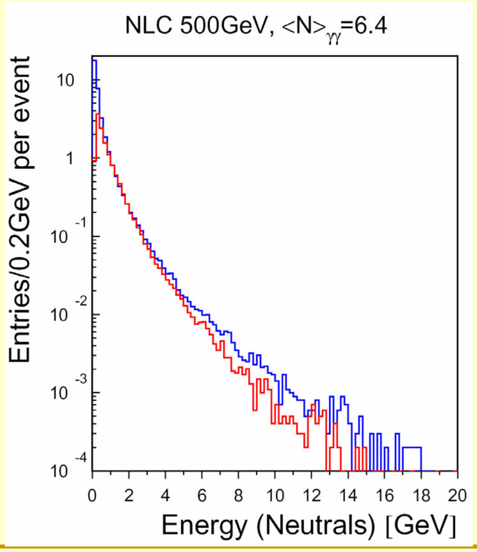


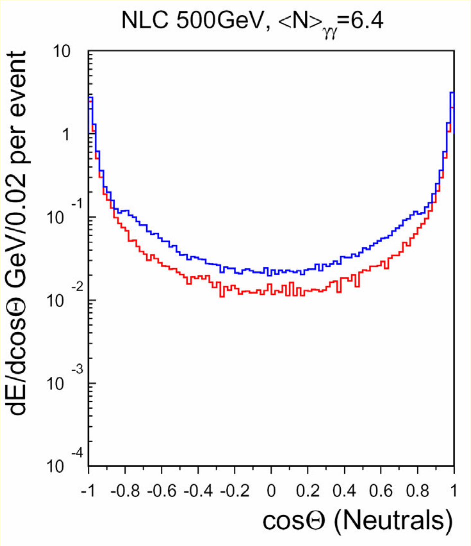




neutral







2. Hadronic Background: Properties ($p_t^{plfow} > 1$ GeV)