Higgs pair production in a Photon Collider

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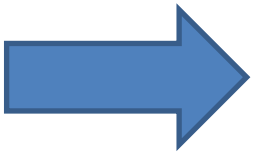
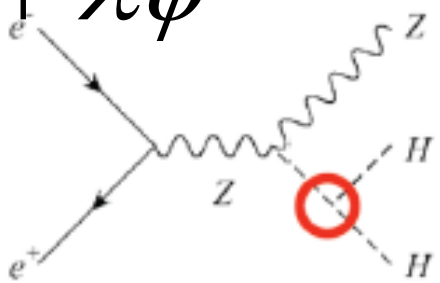
Higgs selfcoupling

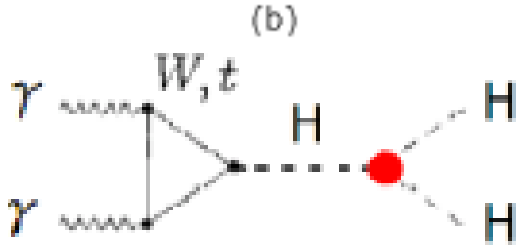
- A Higgs like particle found at LHC!
- Higgs?, SM Higgs or ….
  - coupling to fermions, gauge bosons
    - mass generation
  - selfcoupling
    - symmetry breaking

$$V(\phi) = \mu\phi^2 + \lambda\phi^4$$



even tough with the e+e-





How can the PLC do ?

This study

S.Kawada.. et.al, Phys. Rev. D 85, 113009 (2012)

Final goal: Study of Higgs self-coupling

$$\lambda = \lambda^{SM}(1+\delta\kappa)$$

Self-coupling constant in the SM

Parameter of deviation from the SM

See feasibility of the measurement of Higgs pair creation in PLC.

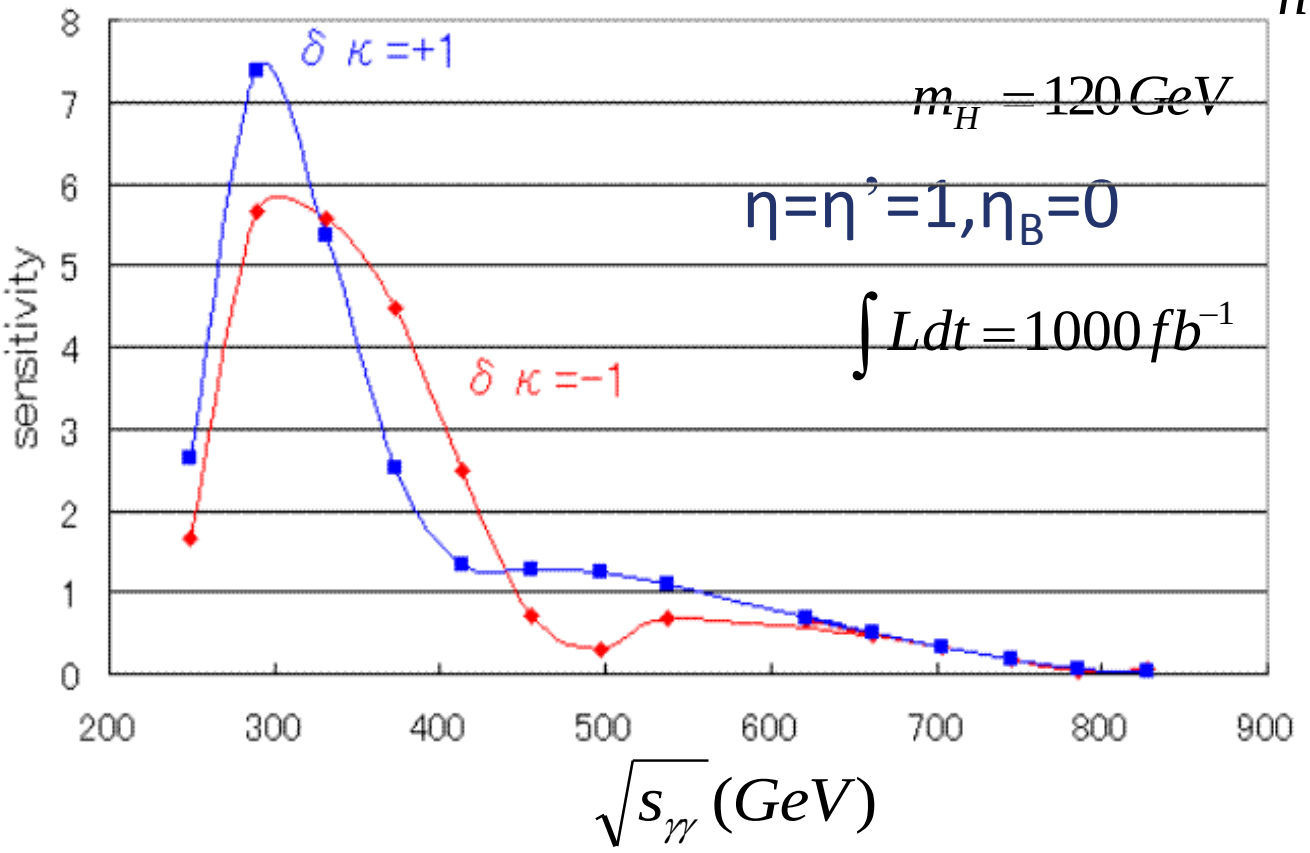
how may events expected?

possible to suppress background?

Sensitivity vs energy

$$sensitivity \equiv \frac{N(\delta\kappa) - N_{SM}}{\sqrt{N_{obs}}} = \frac{L\left|\eta\sigma(\delta\kappa) - \eta'\sigma_{SM}\right|}{\sqrt{L(\eta\sigma + \eta_B\sigma_B)}}$$

$$m_h = 120GeV$$

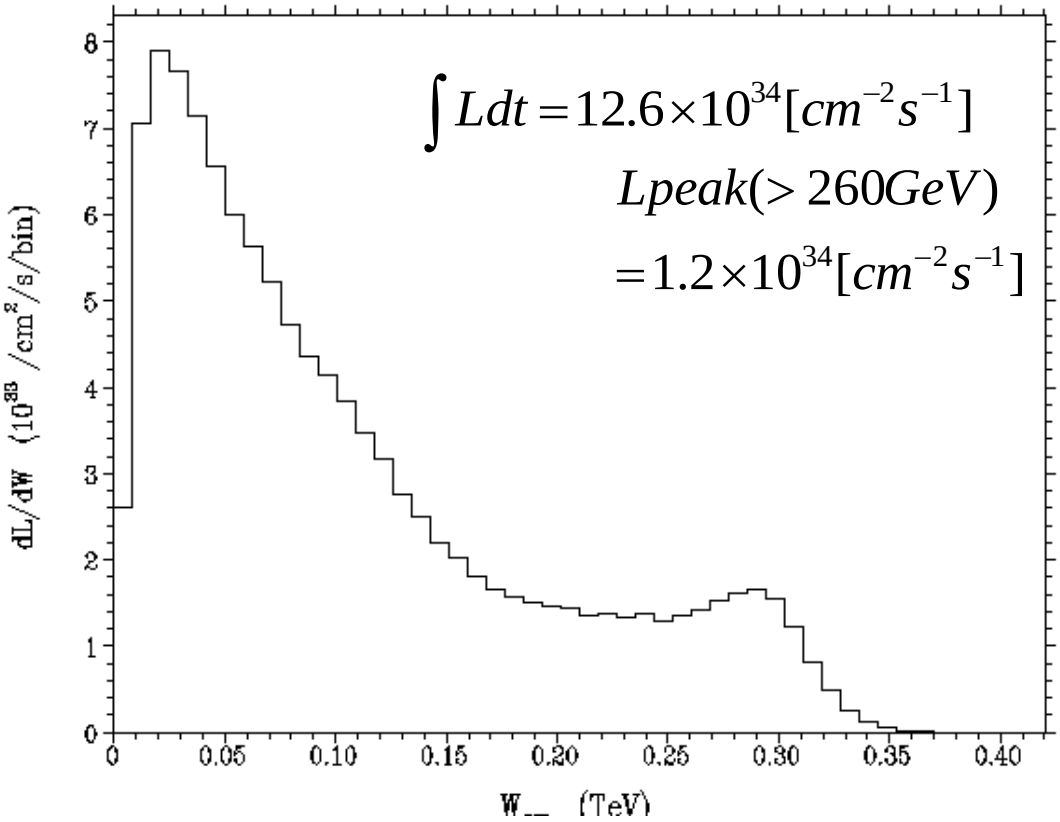


Beam parameters $\sqrt{s_{\gamma\gamma}(peak)} \sim 270GeV$ (based on TESLA optimistic)

	x3.7	x4.8
Ee[GeV]	210	195
n(10^{10})	2	2
σ_z(mm)	0.35	0.35
$\gamma\varepsilon_{x/y}$[m rad]	2.5/0.03	2.5/0.03
$\beta_{x/y}$[mm]@IP	1.5/0.3	1.5/0.3
$\sigma_{x/y}$[nm]	96/4.7	99/5.5
λ_L[nm]	1054	770
x	3.76	4.8
Pulse Energy[J]	10	10
Lgeo(e-e-) [$10^{34}cm^{-2}s^{-1}$]	8.7	8.1
Lpeak($\gamma\gamma$) [$10^{34}cm^{-2}s^{-1}$]	1.2	0.7
Ltot($\gamma\gamma$)[$10^{34}cm^{-2}s^{-1}$]	12.6	5.88

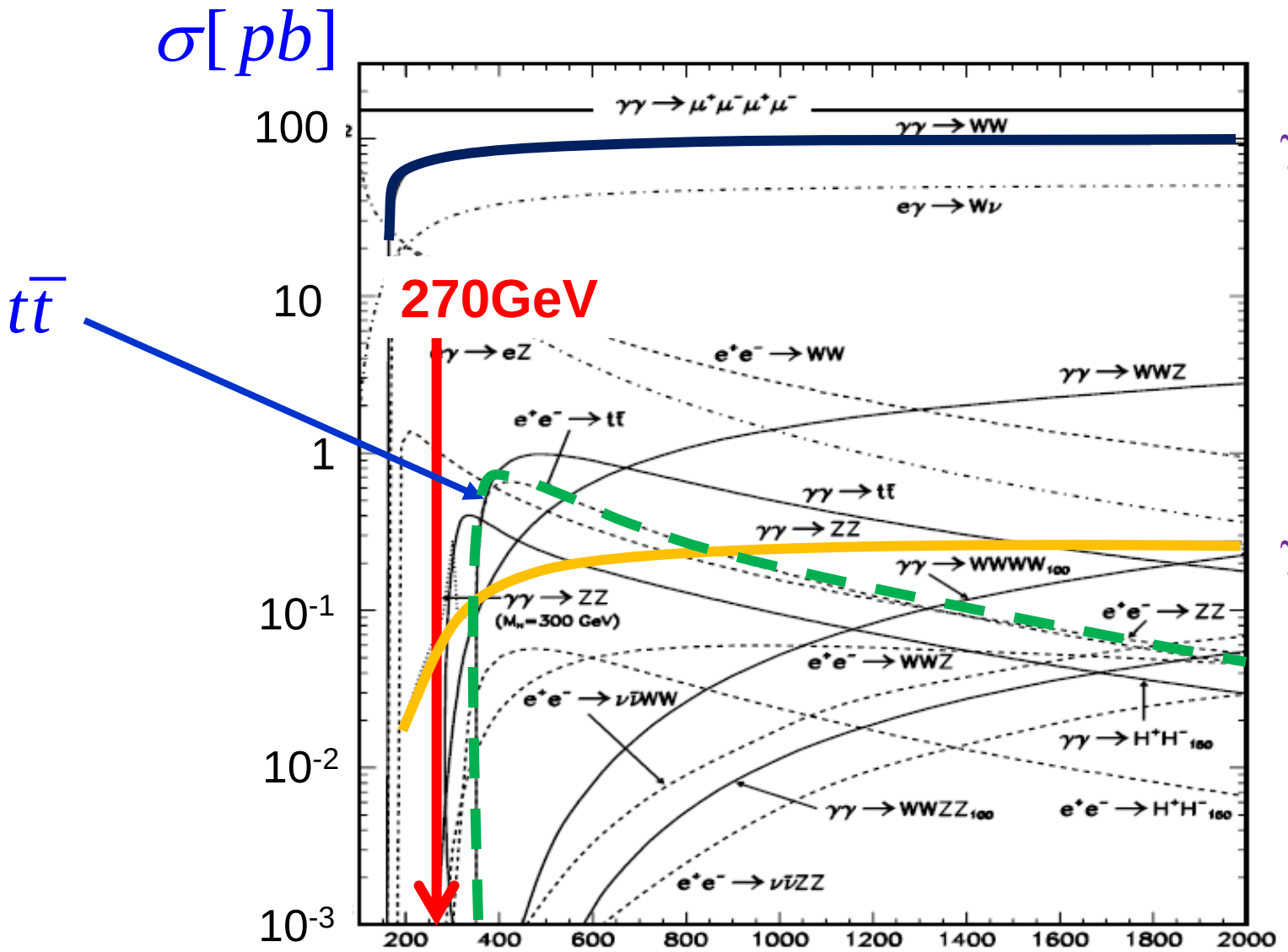
Luminosity Distribution(CAIN)

x=3.76



$$N = \int \sigma\left(s_{\gamma\gamma}\right)\frac{dL}{ds_{\gamma\gamma}}ds_{\gamma\gamma}dt$$

Signal backgrounds



Signal & Backgrounds

$$\int \sigma\left(s_{\gamma\gamma}\right)\frac{dL}{ds_{\gamma\gamma}}ds_{\gamma\gamma}dt$$

Signal

$\gamma\gamma$->HH(－＞bbbb) **16.4events/year**

Backgrounds

10^6

- $\gamma\gamma$->WW **1.462*10^{7}events/year)**
- $\gamma\gamma$->ZZ **1.187*10^{4}events/year**
- $\gamma\gamma$->bbbb **1.187*10^{4}events/year**

Assumption for the study
integrated luminosity of 5 years of PLC run

Event generation and Detector simulation

- detector simulation

Detector	Resolution
Vertex detector	$\sigma_b = 7.0 \oplus (20.0/p \sin^{3/2}\theta)\ \mu\text{m}$
Drift chamber	$\sigma_{p_T}/p_T = 1.1 \times 10^{-4} p_T \oplus 0.1\%$
ECAL	$\sigma_E/E = 15\%/\sqrt{E} \oplus 1\%$
HCAL	$\sigma_E/E = 40\%/\sqrt{E} \oplus 2\%$

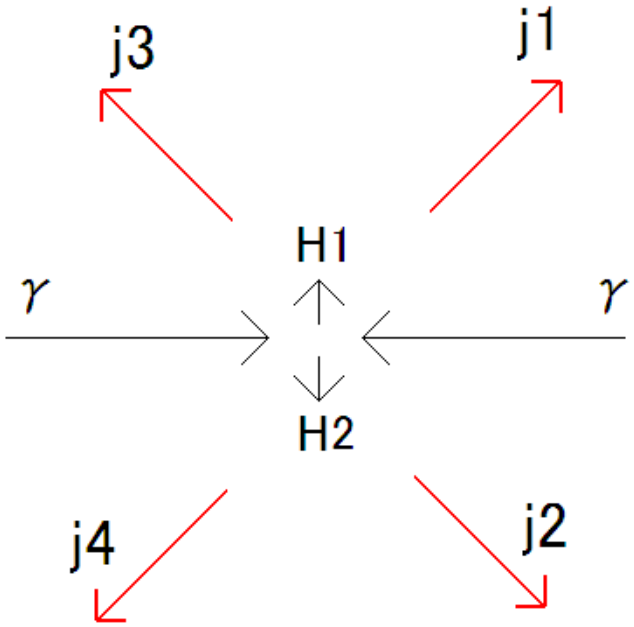
$\theta < 7.2^\circ$ dead

- MC events
  - HH 5×10^4
  - WW 7.5×10^7 ← !
  - zz 1×10^6
  - bbbb 1×10^6

Analysis

- Signal
  - $\gamma\gamma$->HH->$b\bar{b}b\bar{b}$
- Kinematics and flavor information
  - Jet clustering
    - forced 4 Jets
  - Jet pairing
  - b tagging
- Event selection
  - pre-selection to reduced number of events
  - optimization with Neural Net

jet paring



The jet of the least χ^2 was chosen to be the most probable combination.

$$\chi_H{}^2 = \frac{(M_1 - M_H)^2}{\sigma_{2j}^2} + \frac{(M_2 - M_H)^2}{\sigma_{2j}^2}$$

M_1, M_2 : reconstructed mass

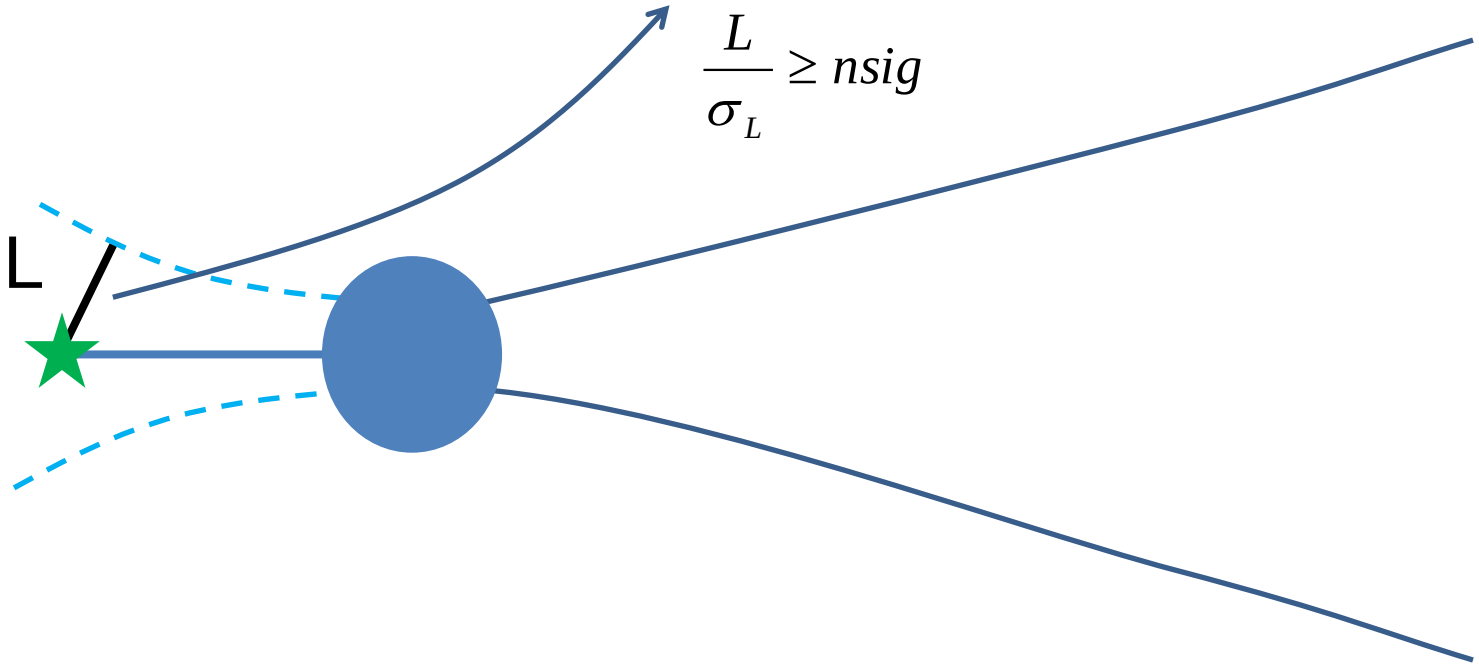
M_H : Higgs mass

$\chi_Z{}^2$ $\chi_W{}^2$ $\chi_{bb}{}^2$ are defined the same way (M_{bb}=10GeV)

Analysis
~ b tagging~

- impact parameter <- simple !

Nsig: Number of displaced tracks in a jet



Selection (1)

pre-selection: cut tacks to forward/backward region
loose b- tagging

$$\beta \geq 0.05, |\cos\theta| \leq 0.99$$

b-tagging
- # Jet w/ more 0 off-vertex(>3s) tracks > 3
- # Jet w/ more than 1 off-vertex(>3s) tracks > 2

	HH	WW	ZZ	bbbb
Total	80	7.3×10^7	59400	260000
Pre-selecttion	47.7	81300	51270	80000

β : Lorentz factor of a particle

θ : Angle between a particle and the beam

Selection (2) --- Neural Network (NN)

- parameters :
  - χ_H^2 , χ_Z^2, χ_{bb}^2
  - transverse (longitudinal) momentum,
  - # of jets with displaced vertex jets,
  - visible energy,
  - Y_{cut} value of jet clustering,
  - # of tracks
- Maximize statistical significance

$$S_{stat} \equiv \frac{N_{Sig} * \eta_{Sig}}{\sqrt{N_{Sig} * \eta_{Sig} + N_{BG} * \eta_{BG}}}$$

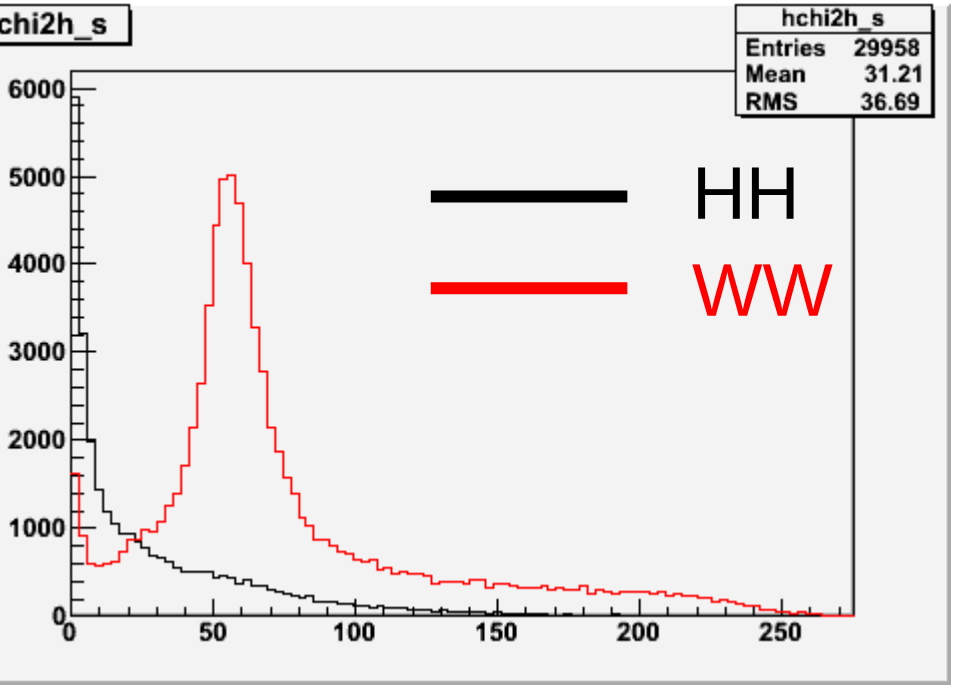
N: # of events occurring in 5 years

η: selection efficiency

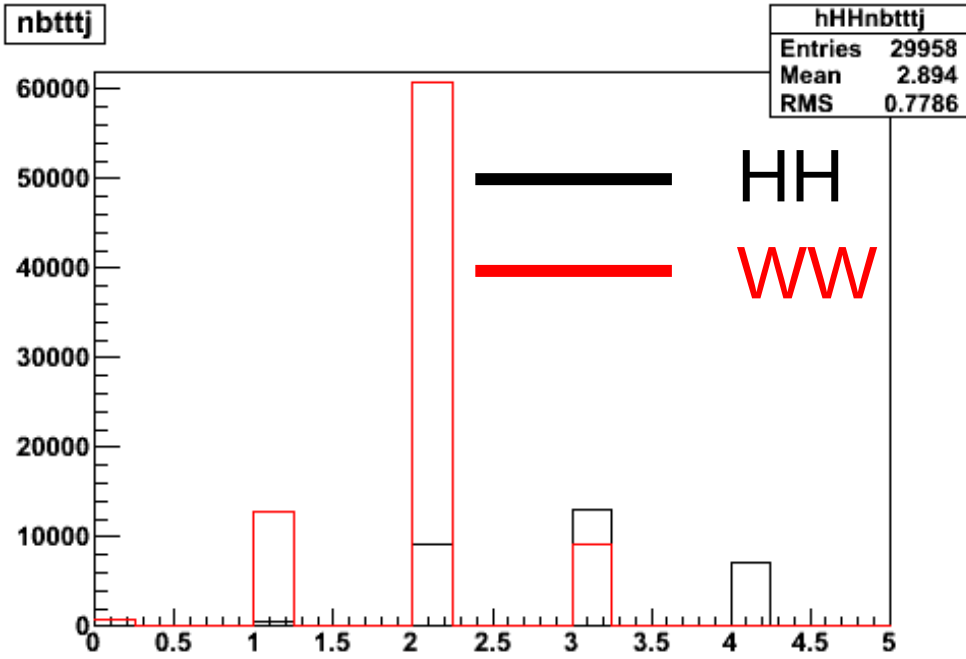
Sig: signal

BG: background

Example parameters For WW

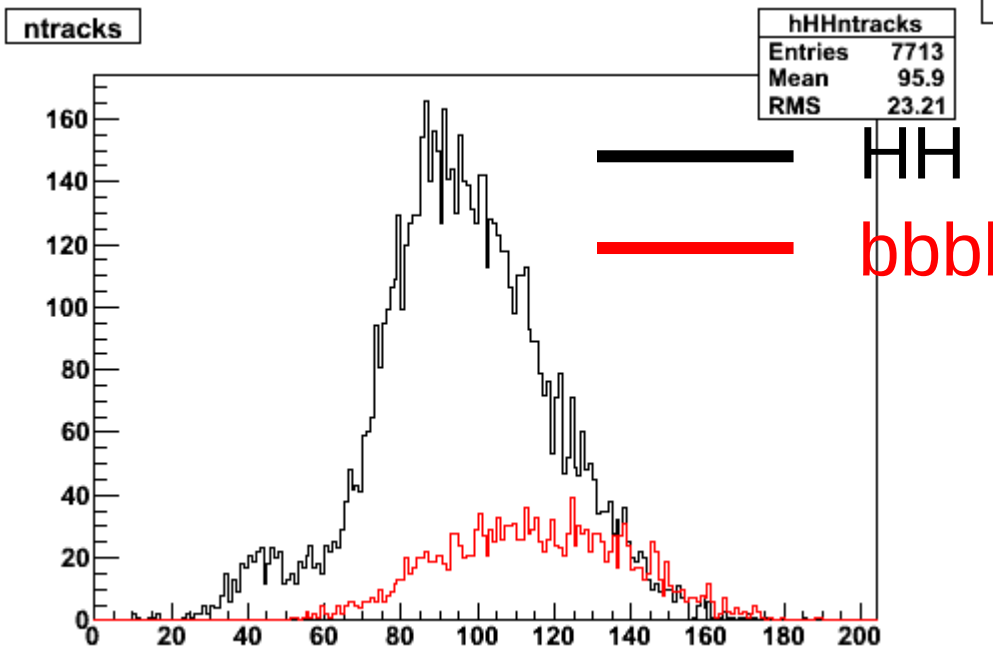


χ^2_H

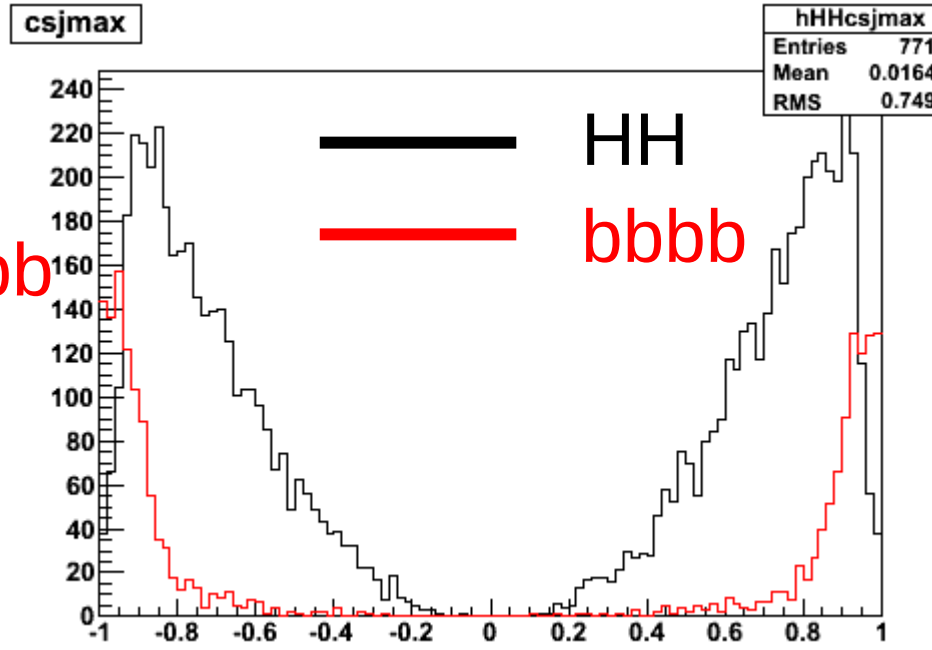


$Njets((Noff = 2))$

Example of parameters for 4b

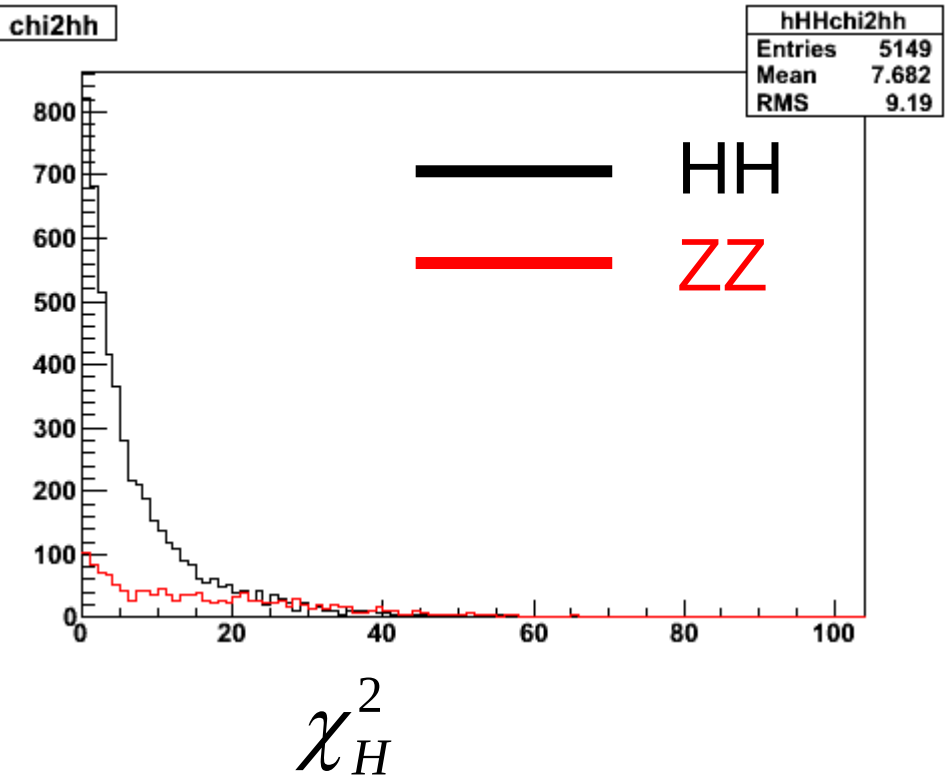


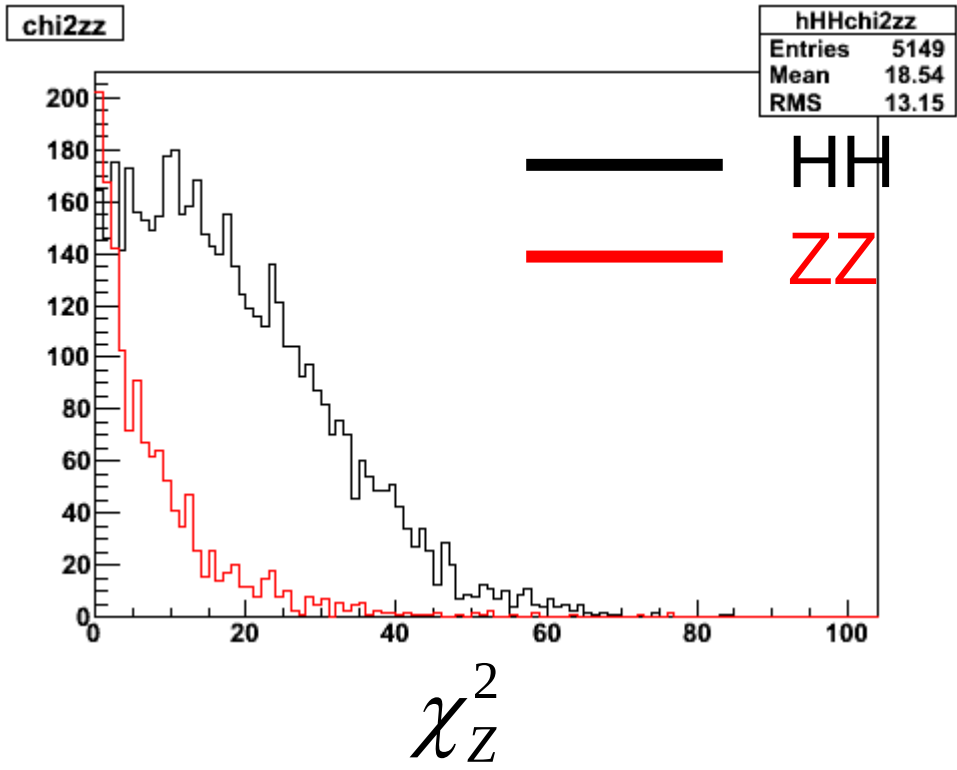
$\#\,tracks$



$\max[\cos\theta_{jet}]$

example parameters for ZZ





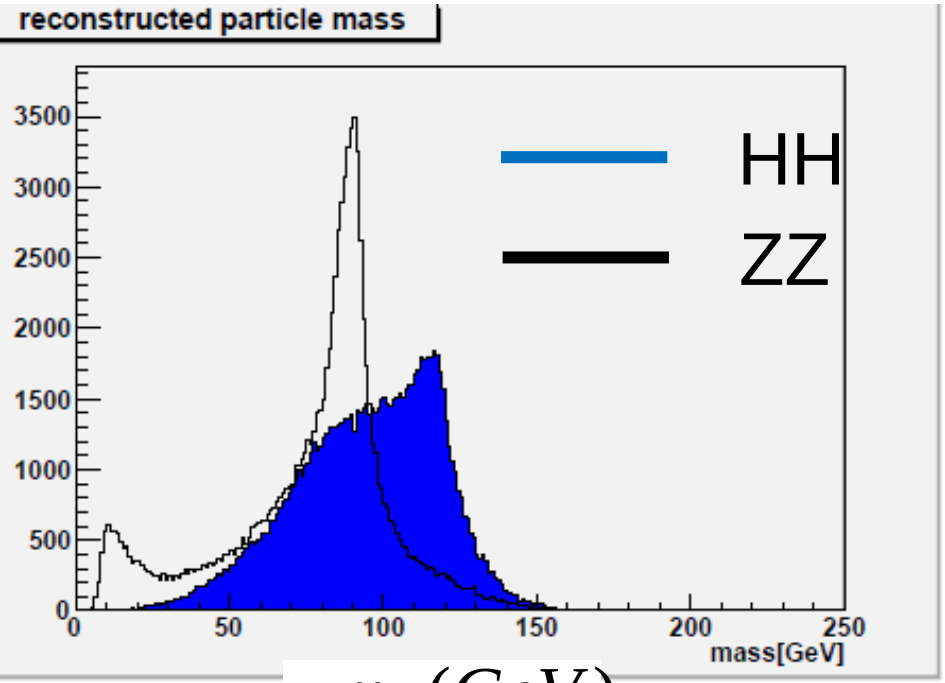
Cut statictics

	HH	WW	ZZ	bbbb
Total	80	7.3×10^7	59400	260000
Pre-selecttion	47.7	81300	51270	80000
WW filter	12.3	24	234	380
ZZ filter	5.90	2	59	13
bbbb filter	3.77 ± 0.08	0+1.8	5.4 ± 0.6	7 ± 1

$$S_{JADE} = \frac{N_{Sig}}{\sqrt{N_{total}}} = 0.92$$

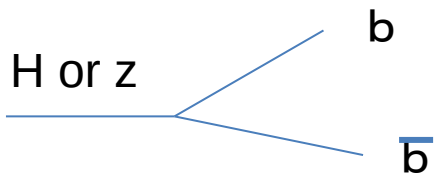
jet clustering

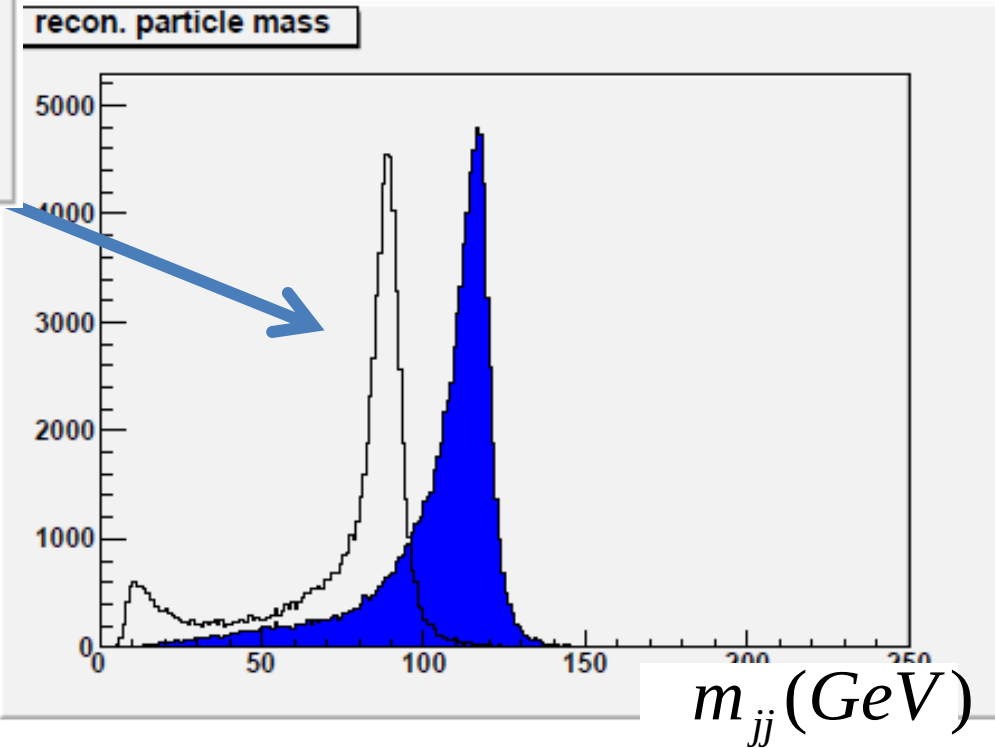
Ideal clustering



$m_{jj}(GeV)$

ideal clustering using color singlet information





$m_{jj}(GeV)$

for HH, WW,ZZ

not for $b\bar{b}b\bar{b}$ as color singlet is not trivial

Cut statictics

	HH	WW	ZZ	bbbb
Total	80	7.3×10^7	59400	260000
Pre-selecttion	47.7	55800	4170	77800
WW filter	40	8	46	1826
ZZ filter	36	8	19	8
bbbb filter	34.7 ± 0.2	5 ± 2	5.2 ± 0.6	6 ± 1

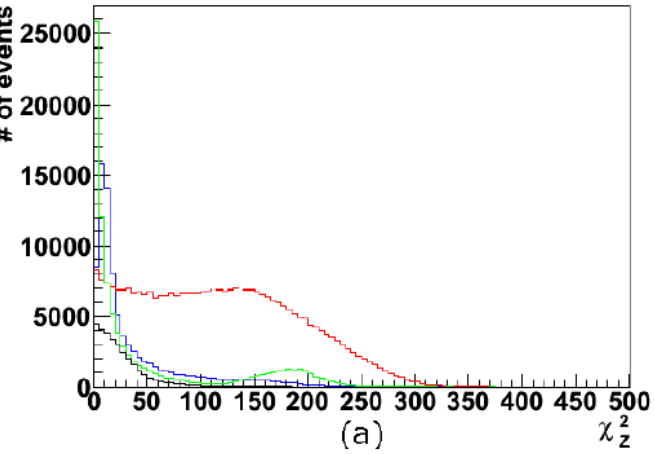
$$S_{Ideal} = \frac{N_{Sig}}{\sqrt{N_{total}}} = 4.9$$

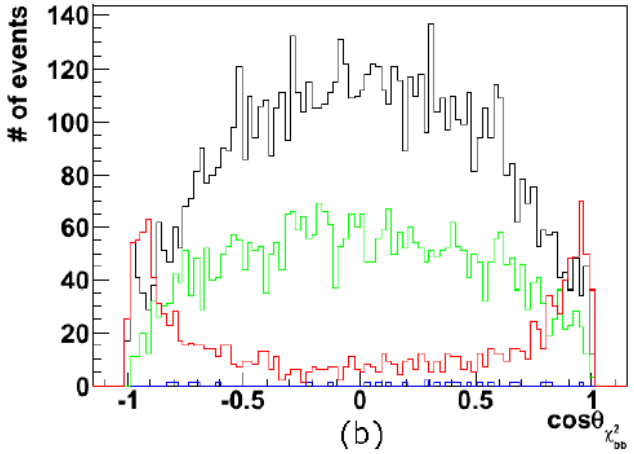
Summary

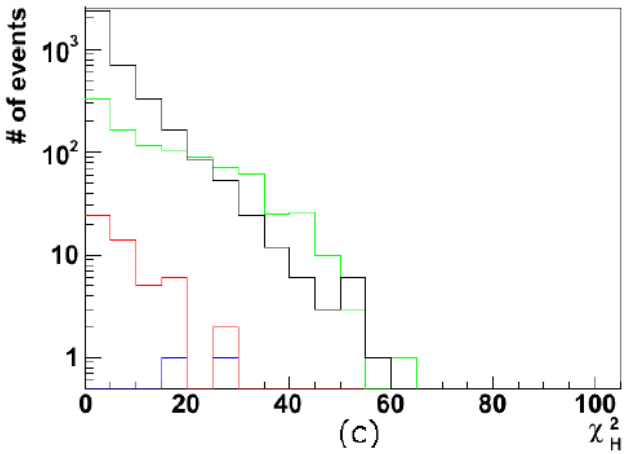
- We tried to see $\gamma\gamma$ -> HH in a photon collider based on TESLA optimistic parameters.
- $\gamma\gamma$ CM energy of 270GeV is optimum for mh =120GeV
- It is possible to suppress backgrounds with improved jet clustering technique.
  - statistical significance of 4.9 with integrated luminosity corresonds to 5 years of PLC run

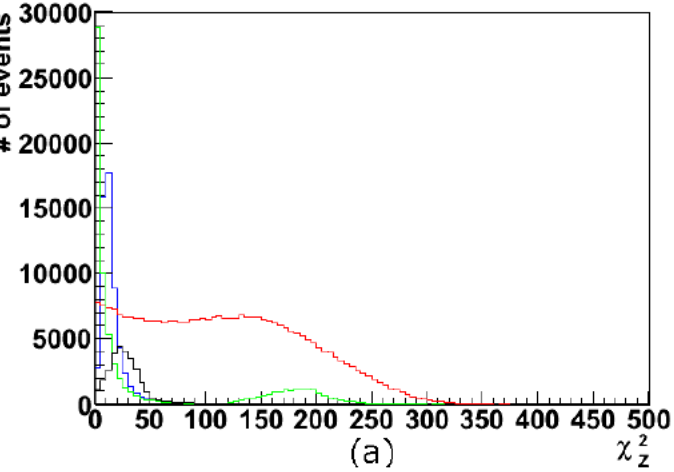
Backup slide

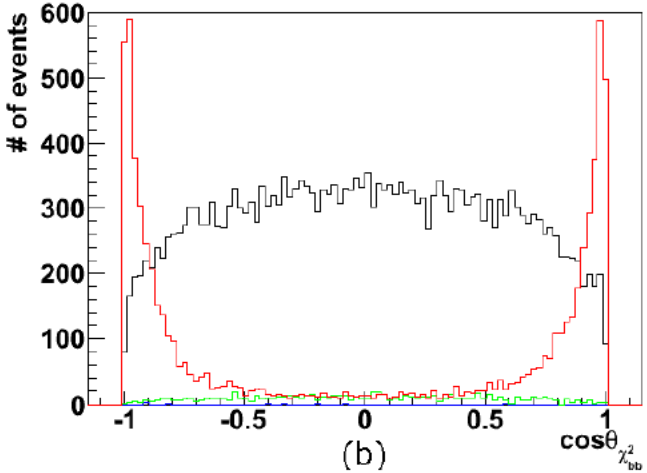
Ideal clustering

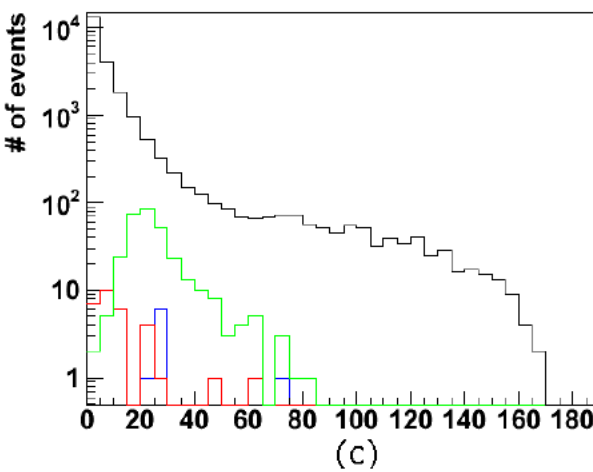












$$S_{Ideal} = \frac{N_{Sig}}{\sqrt{N_{total}}} = 4.9$$