Natural cuts in seeking of New Physics phenomena. Example: $e\gamma \to W\nu \to \mu\bar{\nu}\nu$

- Simulated and experimental cross sections
- Statistical significance - parameters of New Physics
- Phase space cuts - better results

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Study of triple anomalous interactions of the gauge bozons

$\boxed{\mathbf{e^+e^-}}$–mode has been studied quite well, both γWW and ZWW anomalies influence, mixed.

$\boxed{\gamma\gamma}$ $\boxed{\mathbf{e}\gamma}$–modes – weakly explored potential.

Process $e\gamma \to W\nu$

only anomalous $WW\gamma$ interactions influence.

Effective lagrangian

$$\begin{aligned}\mathcal{L}_{WW\gamma} &= ie({W^\dagger}_{\mu\nu}W^\mu F^\nu - {W^\dagger}_\mu F_\nu W^{\mu\nu} + \\ &(1+\Delta\varkappa){W^\dagger}_\mu W_\nu F^{\mu\nu} + \\ &\frac{\lambda}{m_W^2}{W^\dagger}_{\lambda\mu}{W^\mu}_\nu F^{\nu\lambda})\end{aligned}$$

$\Delta\varkappa$ – anomalous magnetic momentum,
λ–quadruple momentum

Process $e\gamma \to W\nu \to \mu\bar{\nu}\nu$

- **observable** final states ($W \to \mu\nu$)
- non-trivial photon and electron **spectra**
- **polarization** of photon and electron
- **TESLA** detector parameters and luminosity
- **one** observed particle - **loss** of information

Effects of New Physics are to be small $\Rightarrow$

linear dependencies should be considered

Statistical Significance

$$SS = \frac{N_{(SM+anom)} - N_{SM}}{\sqrt{N_{SM}}},$$

$$\lambda_{exp} \le CL\frac{\lambda_{sim}}{SS}$$

(we use $\lambda_{sim} = 0.1$ and $\Delta\varkappa_{sim} = 0.1$)

Final numbers for $CL = 1\sigma$ — to compare with TESLA TDR estimates.

Estimation of photons spectrum uncertainty contribution to statistical error is presented at the respective **poster** session.

Simulation is performed using **CompHEP** (SINP MSU) software package for symbolic calculations and Monte Carlo integration.

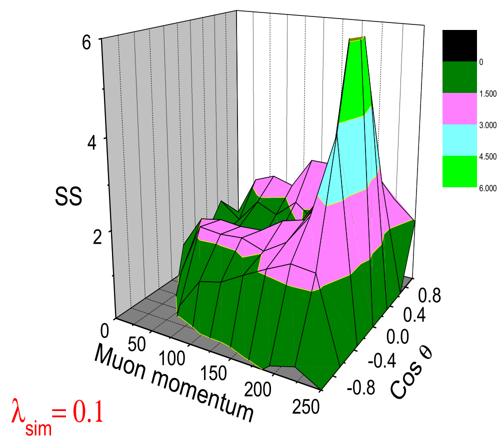
The $\frac{\partial^2\sigma}{\partial p \partial \cos\theta_{\mu e}}$ and $\frac{\partial^2\sigma}{\partial p_{\|}, \partial p_{\perp}}$ distributions are evaluated.

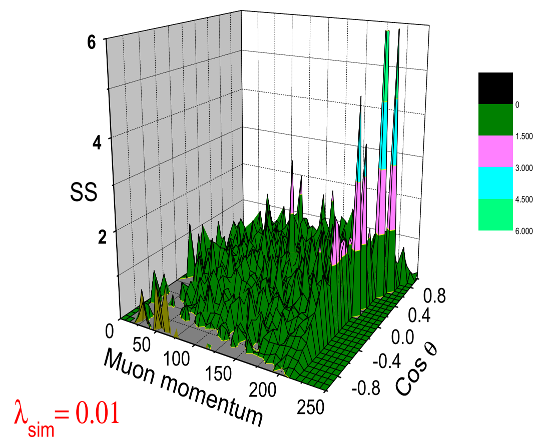
Simulation parameters

1. Total phase space is divided into cells.
2. Monte Carlo events $\sim 5 \cdot 10^3$ per cell,
3. total cross section ratio error $\leq 0.05\%$,
4. cross section ratio error per cell $\leq 5\%$.

Statistical Significance distribution

Simulate huge number of MC events or
Use unlikely big λ and $\Delta\varkappa$ values
leaving only linear effects*
in the calculated "cross sections".





Areas "most sensitive" to anomalous interactions?

*CompHEP version adapted by Alexander Pukhov
$\lambda^n, \Delta\varkappa^n := 0, n > 1$

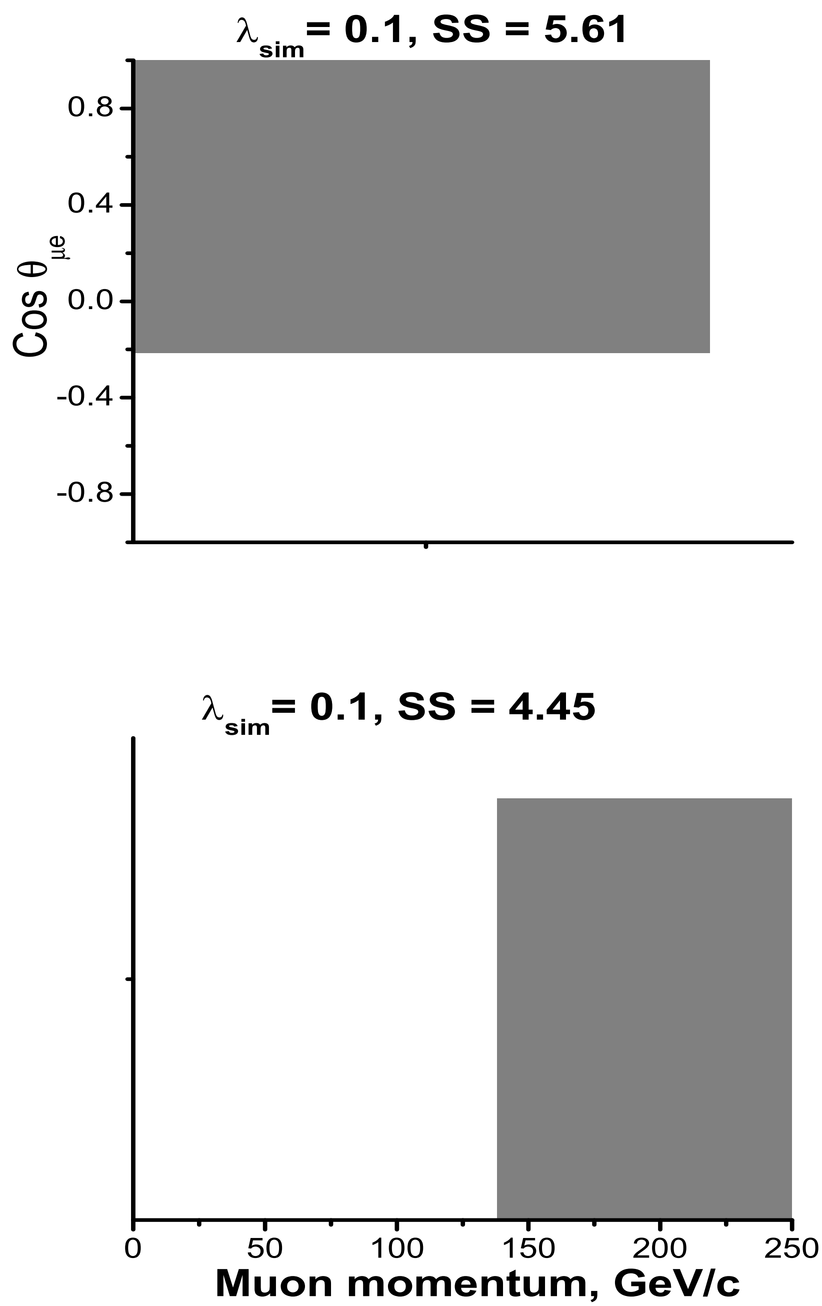
The maximum SS value can be obtained by considering a certain group of phase space cells instead of the entire phase space.

Algorithm used for area selection

1. Random choice of a new cell.
2. SS recalculation for the area with/without the concerned cell.
3. Area changes confirmation in case of SS increase.

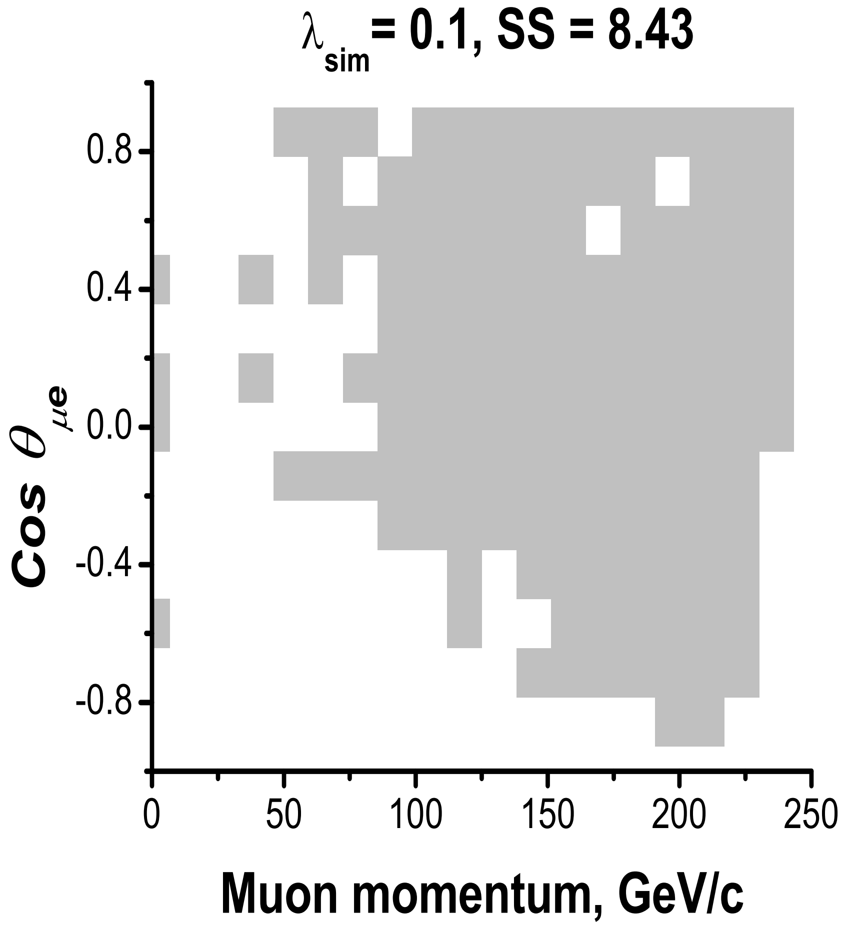
Areas examples - "right-handed" photons

1-dimensional distributions



Areas examples - "right-handed" photons

2-dimensional distributions



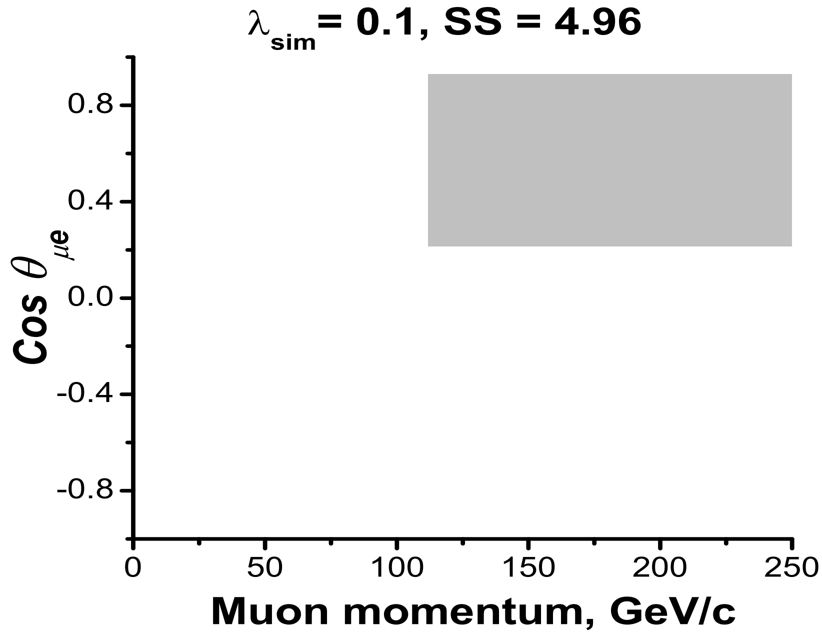
Compare with total cross section SS = 2.12

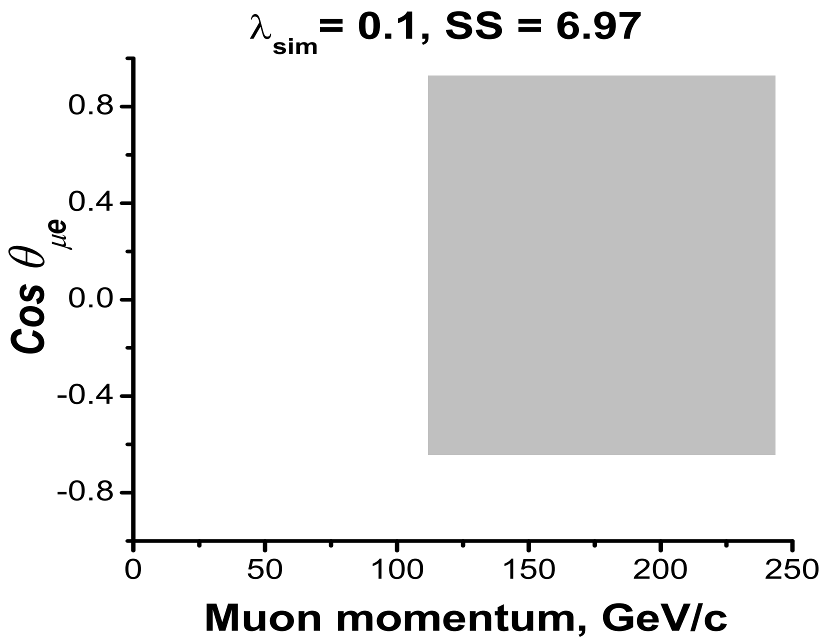
"Left-handed" photons give best SS = 12.20

Areas in $p_{\|}, p_{\perp}$ plane bring the same SS

Areas for $\Delta\varkappa$ - entire phase space

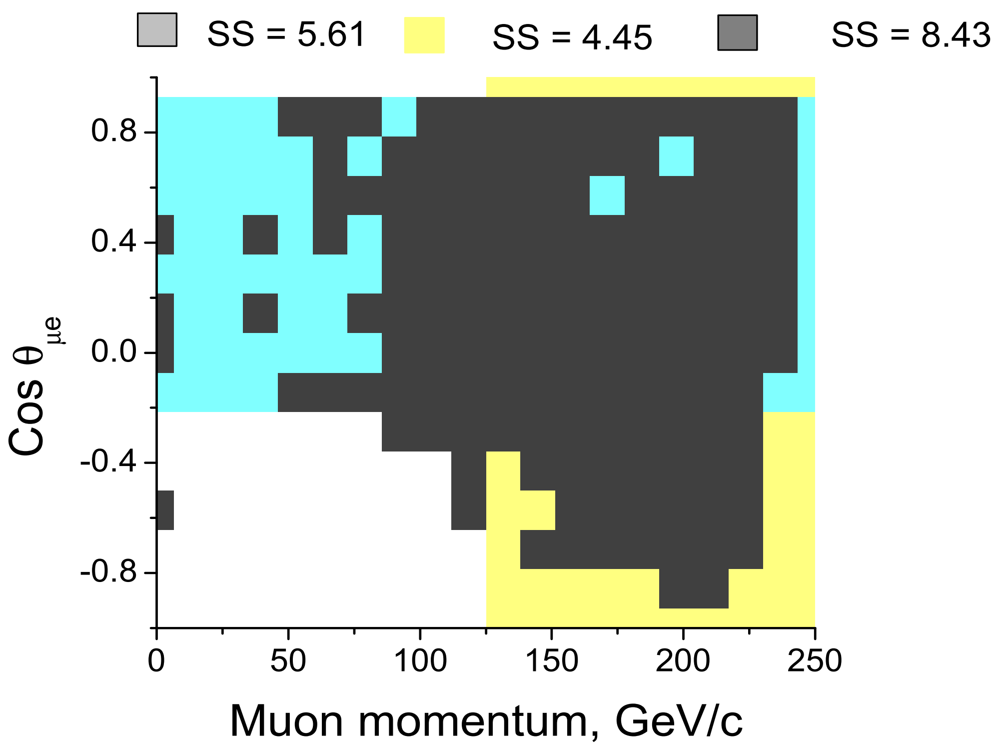
Reduced areas - "right-handed" photons





May suppress background contribution.

Compare distributions



More observed particles ($W \to q\bar{q}$) and more complex processes - more variables

How to choose variables?

For the e-channel calculations give
the same results as for the μ-channel.
$\Delta\varkappa$, λ upper limits (μ and e–channels)

$\sqrt{s_{ee}}$/GeV		$\int \mathcal{L}dt, fb^{-1}$	λ	$\Delta\varkappa$
500	$\mathbf{e}\gamma$	125	$5.8 \cdot 10^{-3}$	$1.0 \cdot 10^{-3}$
	$\mathbf{e}^+\mathbf{e}^-$	500	$5.9 \cdot 10^{-4}$	$3.3 \cdot 10^{-4}$

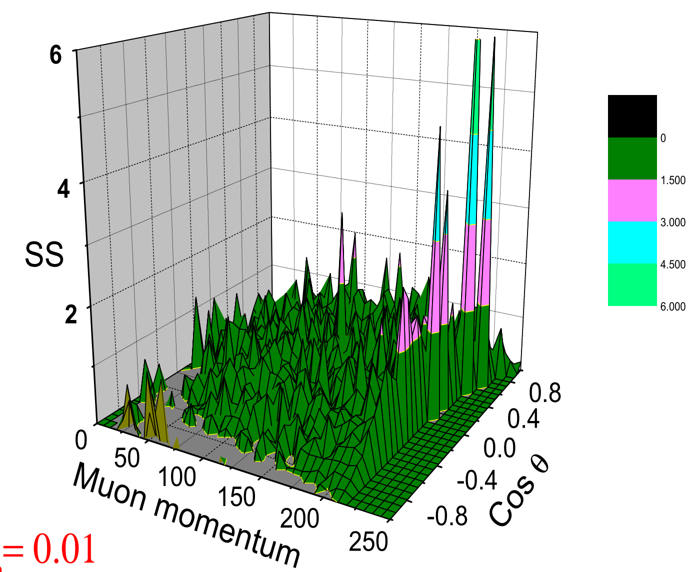
numerical innacuracy$\leq$ 10%
e^+e^- data from TESLA TDR

Conclusion

☐ *Phase space areas selection may improve results significantly.*
☐ One can find *the natural cuts* bounding the areas in the final phase space, which give better SS value while background contribution is suppressed.

Questions

Multidimensional phase space - large uncertainty due to huge number of cells, $\Rightarrow$ simple MC approach is not applicable.



$\lambda_{sim} = 0.01$

How to choose physical variables and less-dimensional projections?

Problems

Reasonable criterion for areas search is not easy formalizable. There are multiple solutions with relatively small SS deviations:

$\Rightarrow$ Use some fuzzy approaches

$\Rightarrow$ Evaluate some kernel function for convolution with simulated data. Use to calculate

$$SS = \frac{\int \frac{d\Delta\sigma}{d\Gamma} \cdot Ker(\Gamma)}{\sqrt{\int \frac{d\sigma}{d\Gamma} \cdot Ker^2(\Gamma)}},$$

Now $Dom(Ker) = \{0, 1\}$.

Kernel also can give a cell relevancy map.

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Thanks for your attention!

Photon spectrum

$$\frac{\partial L_{e\gamma}}{\partial x} = F(x_0, x)\exp(-\rho^2 g^2(x_0, x)/8),$$

$$x = \frac{\omega}{E}, r = \frac{x}{x_0(1-x)}, x_0 = \frac{4E\omega_0}{{m_e}^2},$$

$$x_{max} = \frac{x_0}{x_0+1}, g(x_0, x) = \sqrt{x_0/x - x_0 - 1},$$

$$F(x, x_0) = \begin{cases} N(\frac{1}{1-x} - x + (2r-1)^2 - \\ \lambda_e P_l x_0 r(2r-1)(2-x)) & , \quad (I) \\ 0 & \quad\quad (II) \end{cases}$$

$$(I) - 0.7x_{max} \le x \le x_{max} \quad ,$$

$$(II) - 0 \le x \le 0.7x_{max}$$

$$\lambda_e = 0.85, P_l = -1, \rho = 1$$

Electron effective spectrum

$$F(x) = \exp\left[\beta(3/4 - C)\right]\beta(1-x)^{\beta-1}\cdot$$

$$\cdot\frac{4(1+x^2) - \beta[(1+3x^2)\ln(x) + 2(1-x)^2]}{8\Gamma(1+\beta)},$$

$$\beta = \alpha\ln(4E_e^2/m_e^2) - \alpha/\pi$$

Muon spectrum in τ − decay

$$dN = \frac{1}{N_{tot}} {p_\mu}^\alpha {p_\tau}^\beta (2g^{\alpha\beta}(p_\mu - p_\tau)^2$$

$$-(p_\mu - p_\tau)^\alpha (p_\mu - p_\tau)^\beta)\frac{d^3\vec{p}_\mu}{\epsilon_\mu}$$

Observed channels

muon (electron) channels	
1	2
$e\gamma \to W^- \nu_e$ $\downarrow$ $\mu(e)\bar{\nu}_\mu \nu_e$	$e\gamma \to W^- \nu_e$ $\downarrow$ $\tau \bar{\nu}_\tau \nu_e$ $\downarrow$ $\mu(e)\bar{\nu}_\mu \nu_\tau \bar{\nu}_\tau \nu_e$

τ–channel	hadronic channel
$e\gamma \to W^- \nu_e$ $\downarrow$ $\tau \bar{\nu}_\tau \nu_e$ $\downarrow$ $\nu_\tau + hadrons + \bar{\nu}_\tau + \nu_e$	$e\gamma \to W^- \nu_e$ $\downarrow$ $q\bar{q}\nu_e$

Muon channels (1) and (2) are studied.

E_{tot} (CMS, e^+e^-) = 130, 500, 800 GeV,
$2\lambda_e = -0.85$,
$\int \mathcal{L}_{e\gamma} dt = \frac{1}{4} \int \mathcal{L}_{e^+e^-} dt$

Photon circular polarization taken into account.

Photon effective spectrum - *I.F. Ginzburg, G.L. Kotkin, V.G. Serbo, V.I. Telnov* (1983), *I.F. Ginzburg, G.L. Kotkin (2000)*,

ISR - *E.A. Kurayev, V.S. Fadin (1985), S. Jadach, M. Skrzypek (1991)*.

Event selection

Single observed muon at

1. $\pi - \theta_0 \geq \theta \geq \theta_0 = 10$ mrad (detector).
2. $\sqrt{s}/2 > p_\perp > p_{\perp 0} = 10$ GeV.