WIMP Search: Update

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ILD Software / Analysis Meeting

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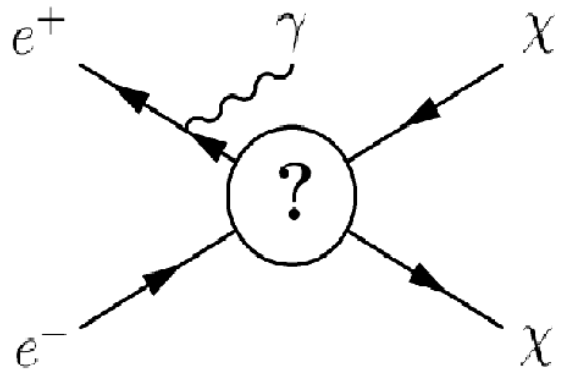
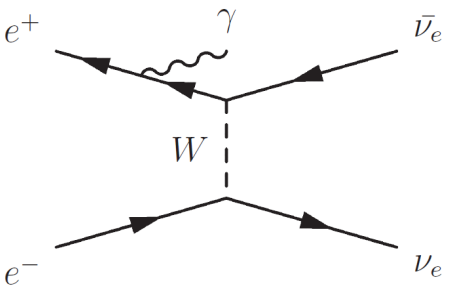
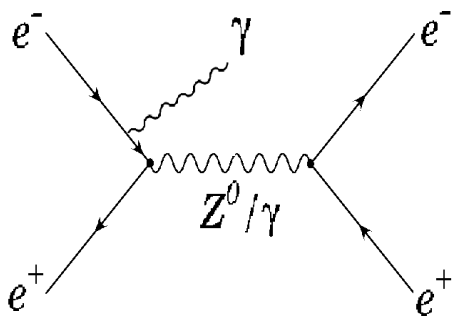
WIMPs in the Mono-Photon Channel

- **Signal**
  - **WIMP pair production with a photon from initial state radiation** $e^+e^- \to \chi\chi\gamma$
  - quasi model-independent
  - single photon in an "empty" detector $\to$ missing four-momentum
  - observables: E_γ, θ_γ



- **Main Background Processes**
  - **Neutrino pairs** $e^+e^- \to \nu\bar{\nu}\gamma$
    - irreducible
    - polarisation: enhance or suppress
  - **Bhabha scattering** $e^+e^- \to e^+e^-\gamma$
    - huge cross section
    - mimics signal if leptons are undetected $\Rightarrow$ requires best possible hermeticity in the forward region of the detector

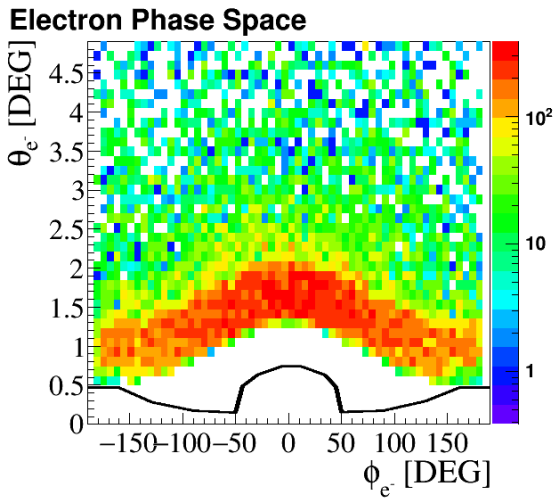


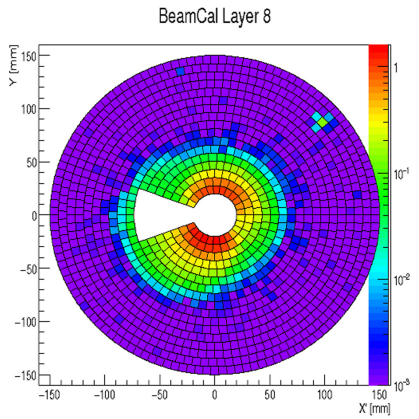


Closing the Gap in the Bhabha Phase Space

- Bhabha samples used so far:
  Whizard (1) default cut:
  - invariant mass of all possible particle pairs $> 4\,\text{GeV}$
  - $\rightarrow \theta_e \approx 1$ DEG (on MC level)
  - (ϕ dependence due to crossing angle boost)

  $\Rightarrow$ at low θ: some part of BeamCal phase space is not covered





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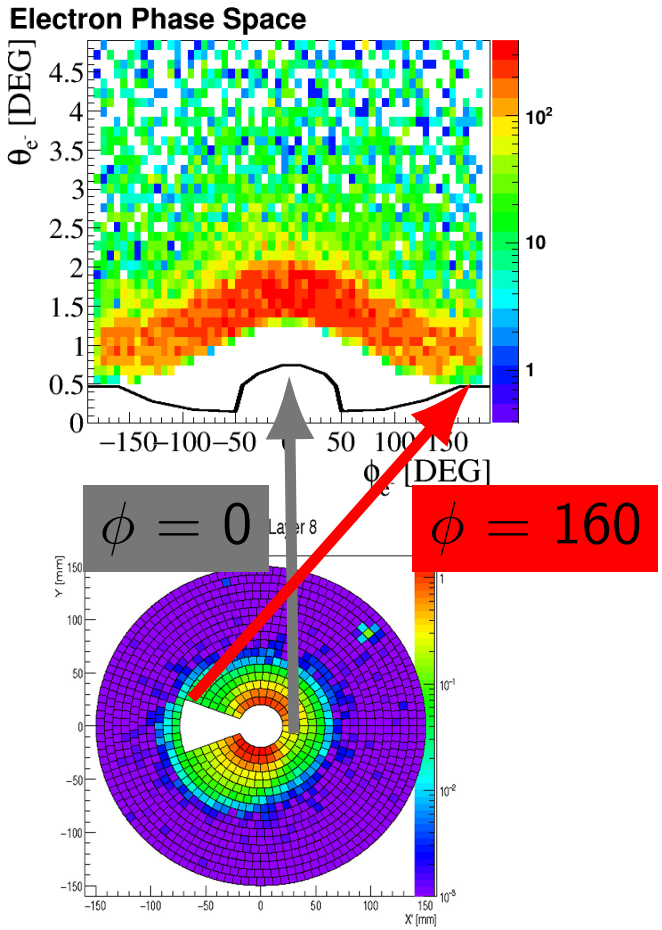

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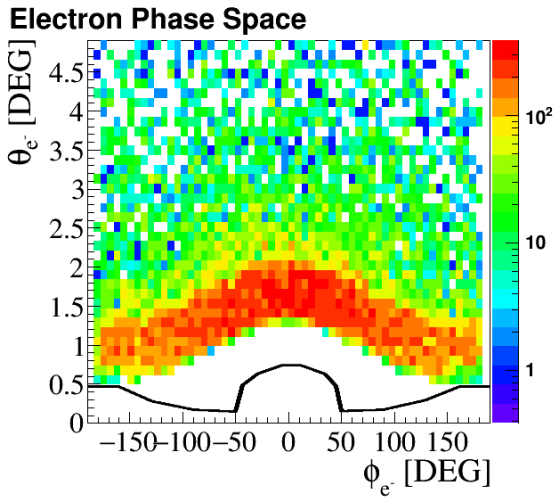
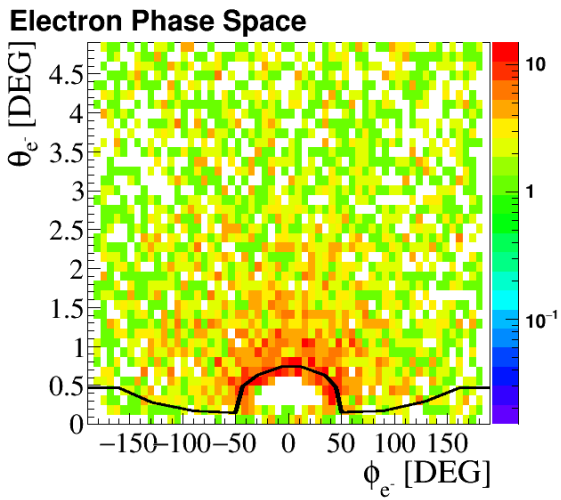
- new sample with $M_{inv} > 1\,\text{GeV}$
  $\Rightarrow$ gap is closed





Signal Definition: Motivation

- observables: E_γ, θ_γ
- motivation for signal defining conditions
  - distinguish photon from noise: **minimum E_γ**
  - avoid large backgrounds at Z return ($242\,\text{GeV}$ for $\sqrt{s} = 500\,\text{GeV}$): **maximum E_γ**
  - distinguish photon from e^-/e^+
    $\rightarrow$ need tracker: **maximum $\cos(\theta)$**
  - ensure that one e^-/e^+ in Bhabha events is detected: **minimum $p_{T,\gamma}$**

Signal Definition: Motivation

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$E_\gamma > 10\,\text{GeV}$

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- $p_{T,\gamma}$ only indirectly via $E_{\gamma,min}$ and $\cos\theta_\gamma$: 2 GeV
  $\Rightarrow$ parameter space can be enlarged by requiring
  - a certain $p_{T,\gamma}$
  - and loosening the $E_{\gamma,min}$ and $\cos\theta_\gamma$ conditions

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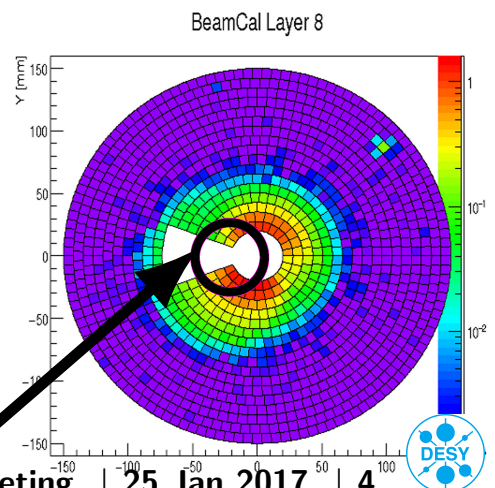
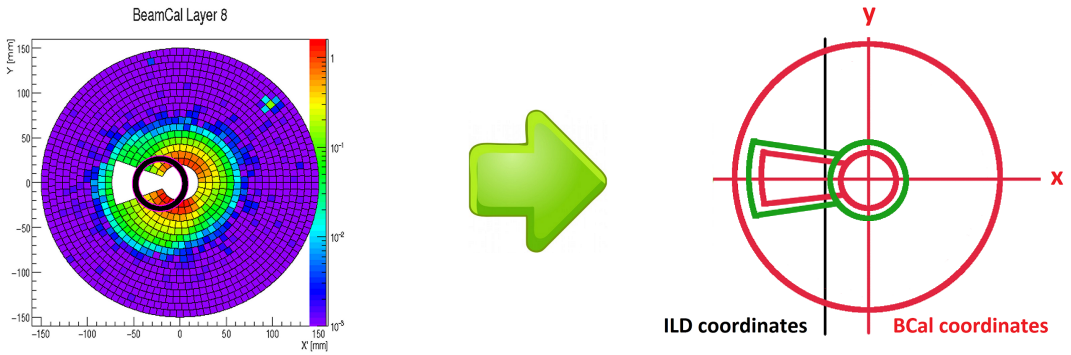
  $\Rightarrow$ BUT: $p_{T,e^-/e^+}$ does not cover BCal opening:
  $p_{T,e^-/e^+} > 2\,\text{GeV}$ translates into $\theta_{e,min} = 0.42\,\text{deg}$



Phi Dependent Signal Definition

- in order to describe BeamCal hole best:
  go to **phi dependent** signal definition



- cuts can be easiest defined in BeamCal coordinate system
  - $p_{T,e} > 5.2\,\text{GeV}$ for $|\phi| \geq 141.5$

    $\Leftrightarrow$ $p_{T,\gamma} > 5.2\,\text{GeV}$ for $|\phi| \leq 38.5$
  - $p_{T,e} > 2.06\,\text{GeV}$ for $|\phi| < 141.5$

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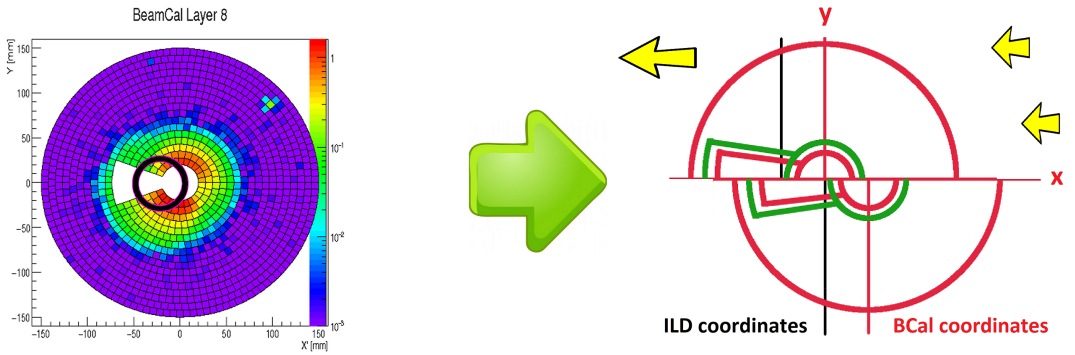

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- for signal definition boost photon into BeamCal frame
  (7 mrad along negative x axis)
  - a possible p_T shift during the boost is taken into account

Signal Definition: Efficiency

- look at $\nu\bar{\nu}\gamma$ with e^-: L, e^+: R
  - loosen conditions: $E_\gamma > 9\,\text{GeV}$ and $|\cos\theta_\gamma| < 0.9$
  - at moment constraint by preselection cuts
  - preselection cuts $E_\gamma > 8\,\text{GeV}$ and $|\cos\theta_\gamma| < 0.995$

	signal definition	fiducial cross-section
previously	$E_\gamma > 10\,\text{GeV}$ $\|\cos\theta_\gamma\| < 0.98$ $E_\gamma < 220\,\text{GeV}$ no explicit $p_{T,\gamma}$	8011 fb
now	$E_\gamma > 9\,\text{GeV}$ $\|\cos\theta_\gamma\| < 0.99$ $E_\gamma < 220\,\text{GeV}$ $p_{T,\gamma}$: 5.2 GeV for $\|\phi\| \leq 38.5$ 2.06 GeV for $\|\phi\| > 38.5$	9342 fb

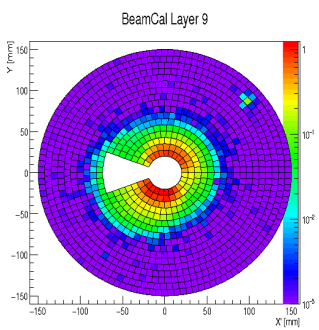
Bhabha Background Suppression

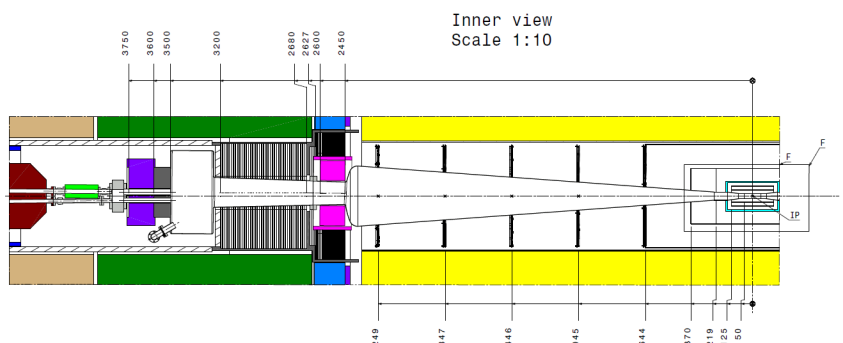
- selection criteria
  - veto events with track with $p_T > 3$ GeV
  - additional visible energy < 20 GeV (PFOs)
  - no cluster in BeamCal
- suppression efficiency
  - preliminary ! (partially only small test samples)
  - all normalised to signal definition of "invariant mass > 4 GeV" sample

$e^+e^-\gamma$	$M_{inv} > 4$ GeV Christoph Bartels ilcsoft v01-06	$M_{inv} > 4$ GeV old sig def ilcsoft v01-16	$M_{inv} > 1$ GeV old sig def	$M_{inv} > 1$ GeV new sig def (p_T, ϕ-dep.)
sig.def.	100%	100%	235%	375%
p_T	21.1%	26.1%	14.7%	161.0%
E_{vis}	16.0%	1.9%	3.6%	37.3%
BCal	0.29%	0.02%	0.07%	0.45%

BeamCal and L* I

- How does the L* change request influence the Bhabha suppression ?
- How does the number of missed Bhabhas change if BeamCal is moved along the z axis ?
  $\rightarrow$ **rough estimate**
- idea: apply a hard theta cut: inside nothing is reconstructed, outside everything
- which θ_{eff} cut mimics the BeamCal reconstruction ?
- with $\theta_{eff} = 8.62\,\text{mrad}$ the same rate is obtained as in full analysis



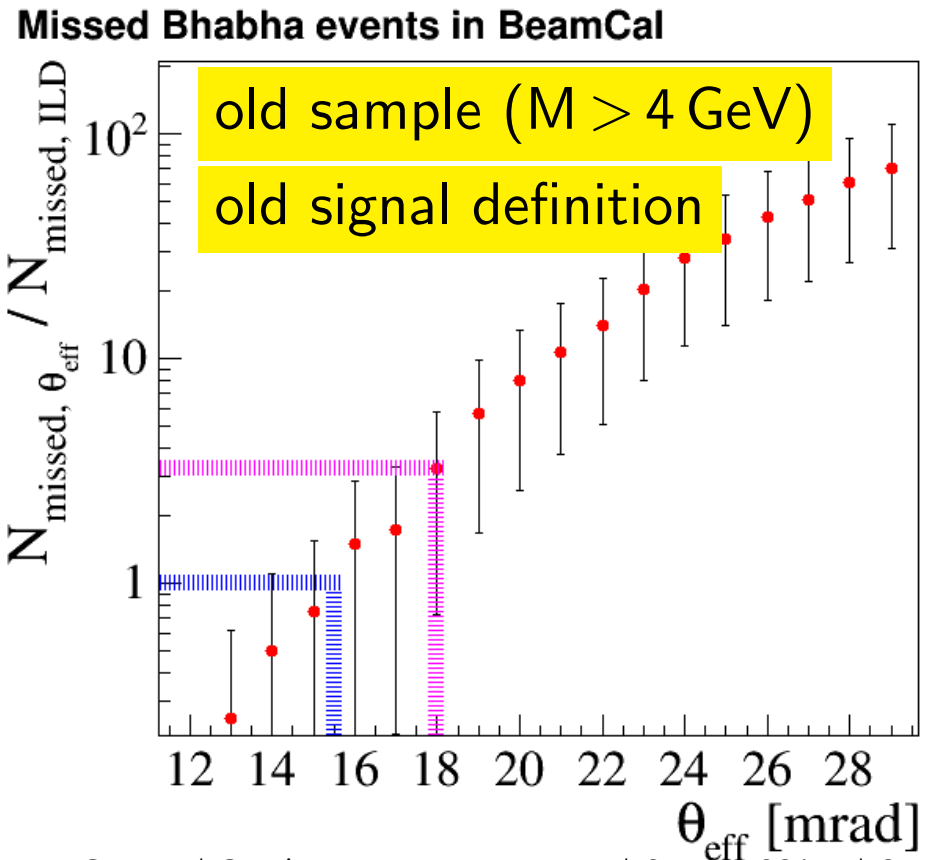


BeamCal and L*: Old Results

- assume purely geometrical dependence (i.e. ignore shape of Beamstrahlung pair cone)
- θ_{eff} grows when BeamCal is moved closer to IP

- ILD_o1_V05
  - $\theta_{eff,ILD} =$ 15.94 mrad
  - $z_{BCal,ILD} = 3486$ mm
- if BeamCal is moved in by 40 cm
  - $z_{BCal,L*} = 3086$ mm
  - $\theta_{eff} =$ 18.01 mrad

approx. 3-4 times more Bhabhas are missed



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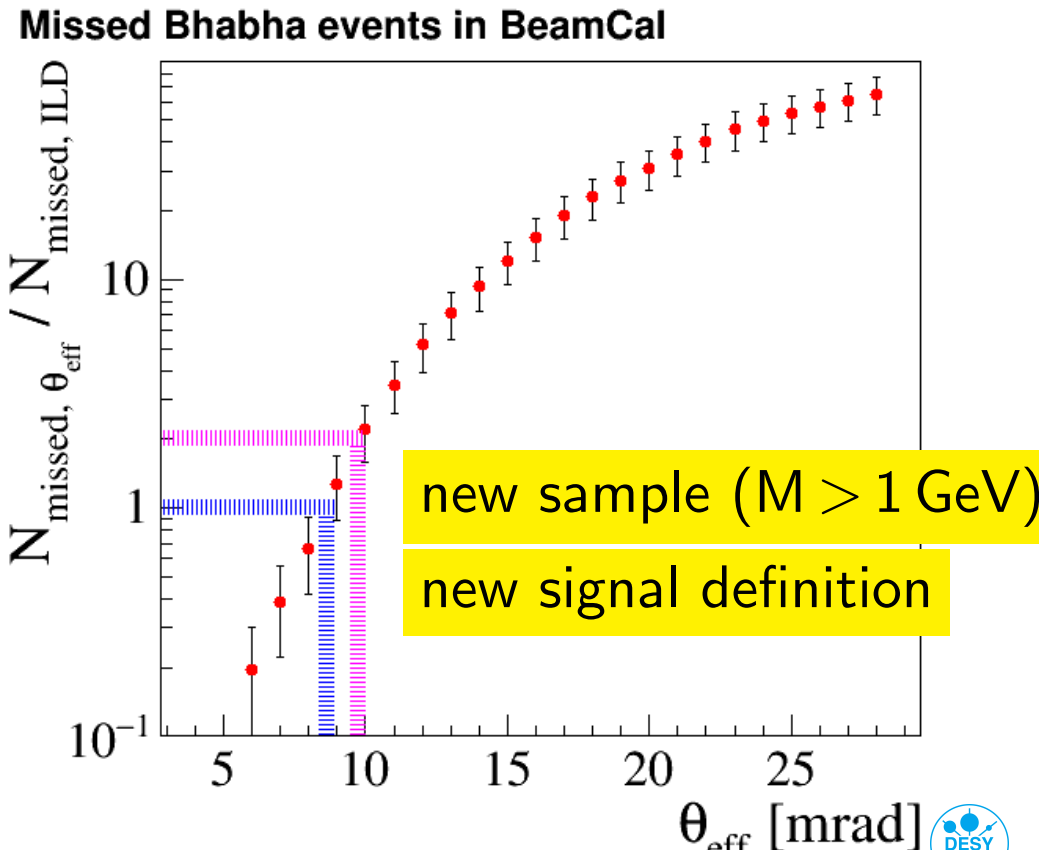
  - $\theta_{eff,ILD} =$ 8.62 mrad
  - $z_{BCal,ILD} = 3486$ mm
- if BeamCal is moved in by 40 cm
  - $z_{BCal,L*} = 3086$ mm
  - $\theta_{eff} =$ 9.74 mrad

approx. 2 times more Bhabhas are missed



Conclusions

- with the new Bhabha sample...
  - the gap in phase space is closed
  - a realistic estimate of the Bhabha background is possible
- with the new signal definition...
  - Bhabhas really hit the detector
  - a realistic estimate of the Bhabha background is possible
- with a signal definition based on $p_{T,\gamma}$...
  - more signal ($\nu\bar{\nu}\gamma$) events can be regained
  - the Bhabha suppression level is (only) a bit worse
- beware: this is preliminary
  and the full impact of all this is under study