WIMP Search in the Mono-Photon Channel

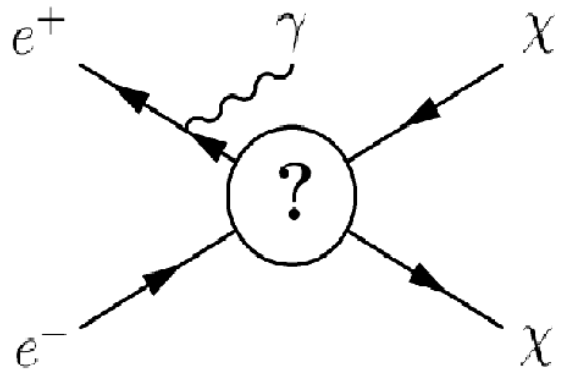
Moritz Habermehl

ILD Software / Analysis Meeting

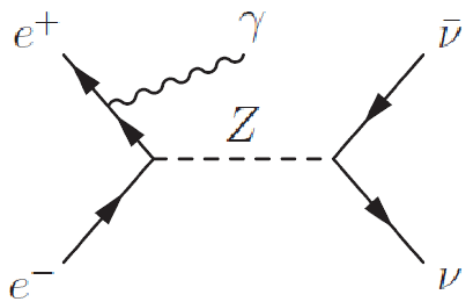
13 July 2016

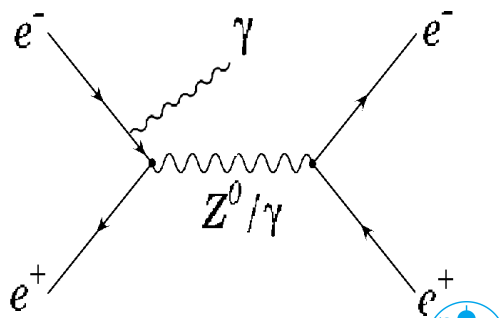
WIMPs in the Mono-Photon Channel

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



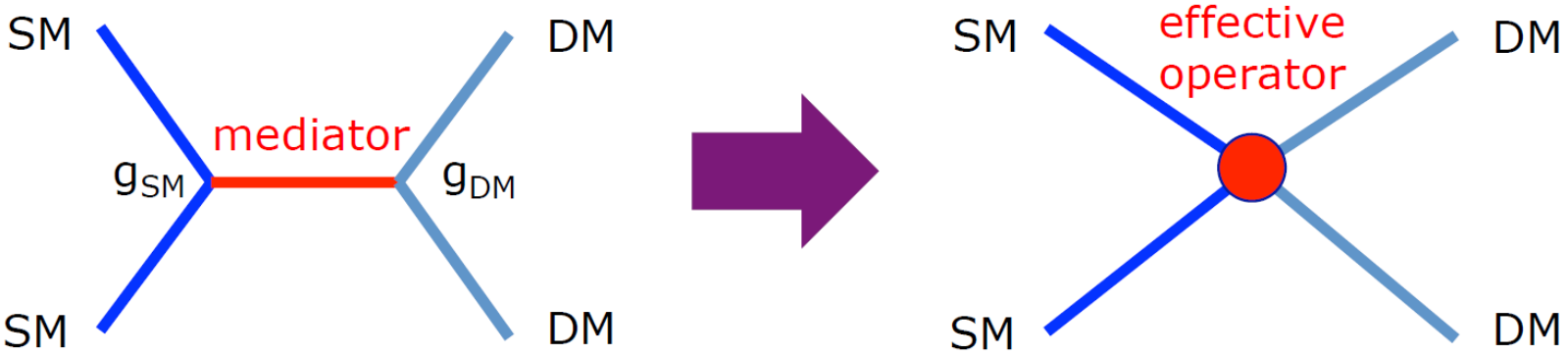
- **Main Background Processes**
  - **Neutrino pairs** $e^+e^- \to \nu\bar{\nu}\gamma$
    - irreducible
    - but polarisation: switch on/off
  - **Bhabha scattering** $e^+e^- \to e^+e^-\gamma$
    - if leptons are undetected
    - huge cross section $\Rightarrow$ forward region





Effective Operators

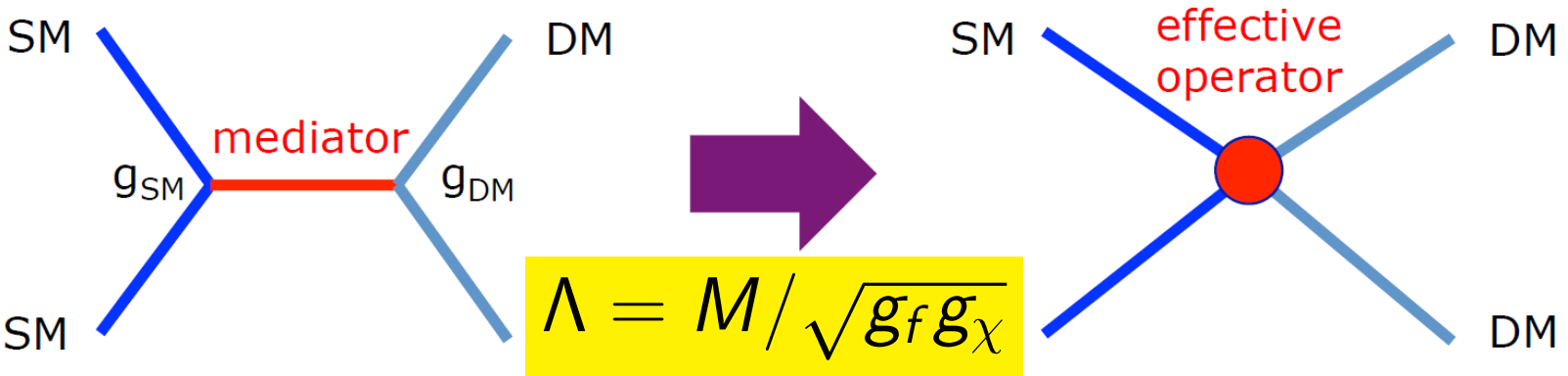
- assumption:
  new physics interaction is mediated by a **heavy** particle
- interaction can be integrated out



$$\left(\frac{g_f g_\chi}{q^2 - M^2}\right)(\overline{f}\gamma_\mu f)(\overline{\chi}\gamma^\mu \chi) \qquad \frac{1}{\Lambda^2}(\overline{f}\gamma_\mu f)(\overline{\chi}\gamma^\mu \chi)$$

Effective Operators

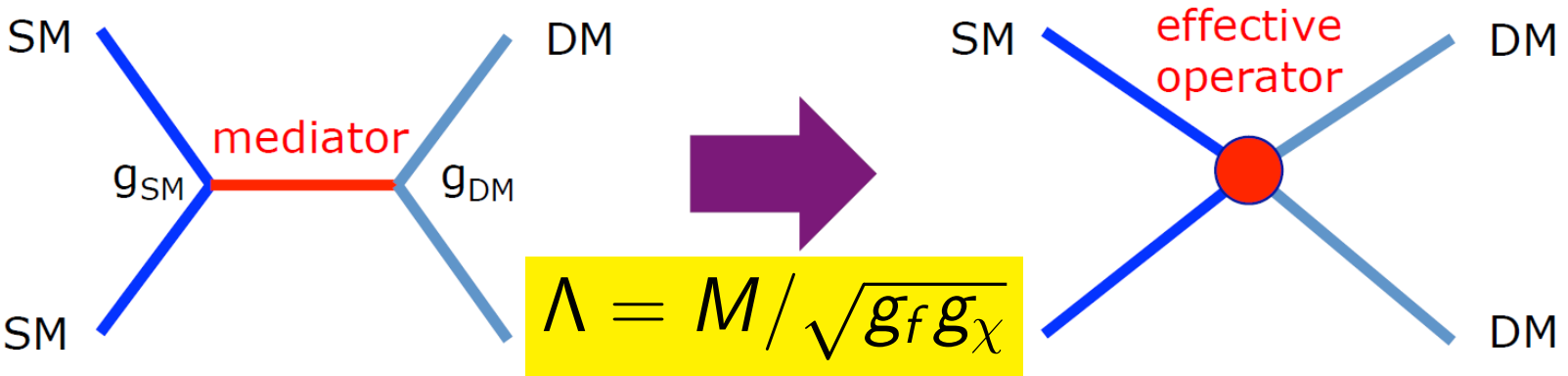
- assumption:
  new physics interaction is mediated by a **heavy** particle
- interaction can be integrated out



$$\left(\frac{g_f g_\chi}{q^2 - M^2}\right)(\overline{f}\gamma_\mu f)(\overline{\chi}\gamma^\mu \chi) \qquad \frac{1}{\Lambda^2}(\overline{f}\gamma_\mu f)(\overline{\chi}\gamma^\mu \chi)$$

Effective Operators

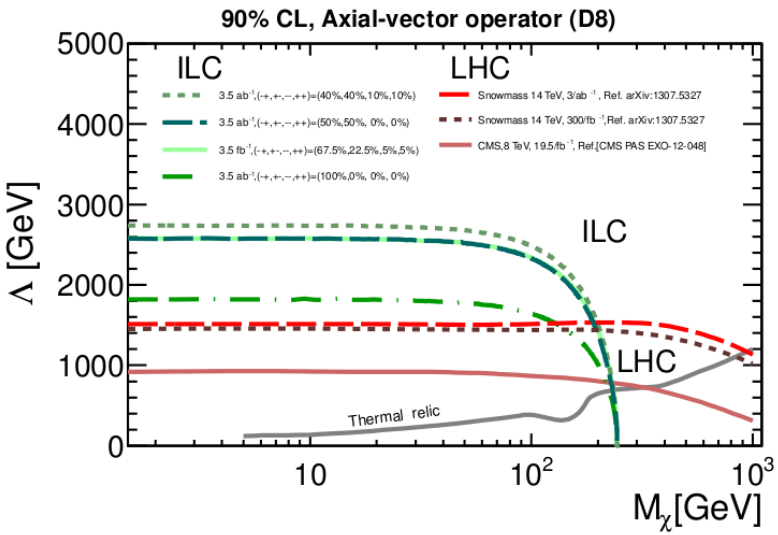
- assumption:
  new physics interaction is mediated by a **heavy** particle
- interaction can be integrated out

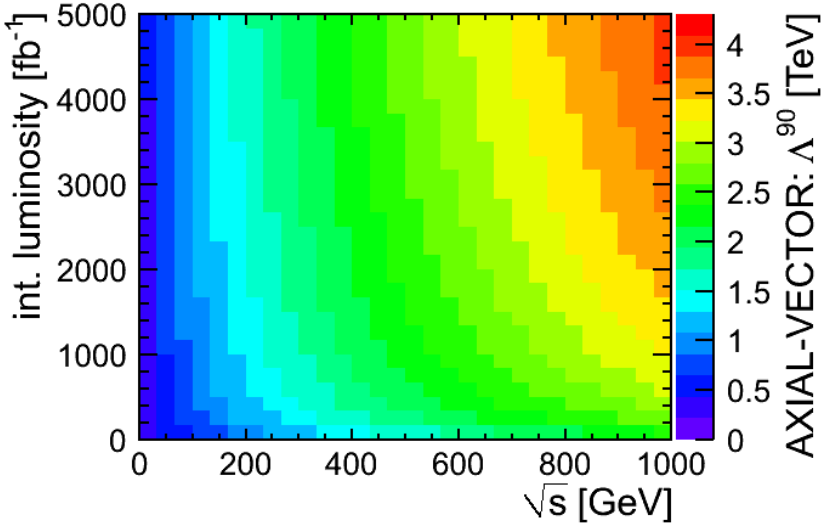


$$\left(\frac{g_f g_\chi}{q^2 - M^2}\right)(\overline{f}\gamma_\mu f)(\overline{\chi}\gamma^\mu \chi) \qquad \frac{1}{\Lambda^2}(\overline{f}\gamma_\mu f)(\overline{\chi}\gamma^\mu \chi)$$

- validity
  - $M_{mediator} \gg \sqrt{s}$
  - pertubativity: g_f, $g_\chi \lesssim \sqrt{4\pi}$
  - ILC suitable for exclusion of allowed phase space

Some (Old) Results





BeamCalClusterReco: Overview

- Marlin processor BeamCalClusterReco by Andre Sailer and Andrei Sapronov
- four modes (to overlay background):
  - **Pregenerated**:
    - random background samples are directly overlaid
    - root files for single BX's
  - **Average**:
    - calculate average and stdev in each pad,
    - generate background accordingly
    - input `bg_aver...root` $\Rightarrow$ allows to compare to old setup
  - **Gaussian** (in v01-17-08: called Parametrised)
    - same as Averaged
    - but with BeamCal_bg_E500-TDR_ws.root
  - **Parametrised**:
    - parametrisation for each pad
    - also: BeamCal_bg_E500-TDR_ws.root

BeamCalClusterReco: Tuning of Parameters

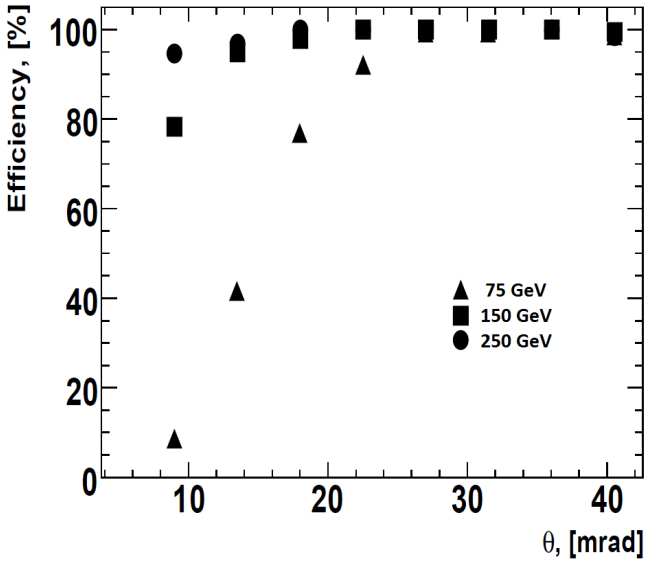
- Particle Gun sample:
  electrons, 50 GeV / 200 GeV
- after subtraction of pair background in each pad (average + 1σ)...

BeamCalClusterReco: Tuning of Parameters

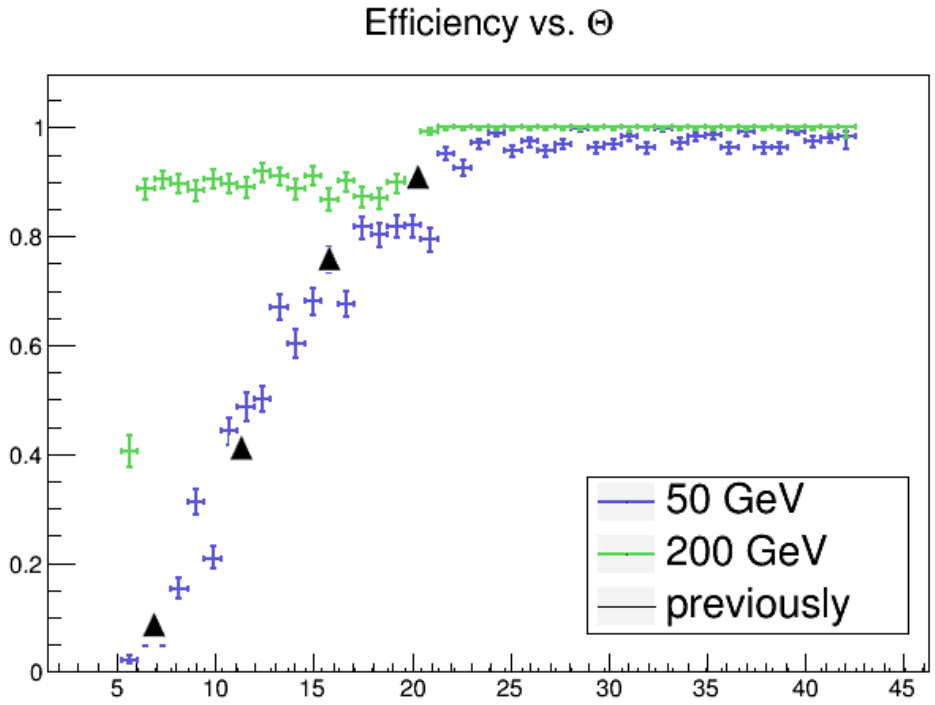
- Particle Gun sample:
  electrons, 50 GeV / 200 GeV
- after subtraction of pair background in each pad (average + 1σ)...
- ... events have to fulfill the following to be considered as Bhabha event:
  - **SigmaCut**:
    energy in pad: **2**·σ above the average
  - **ETPadMin**:
    energy in pad has to be higher than **0.01**
  - **MinimumTowerSize**:
    pads in **6** consecutive layers
  - **StartLookingInLayer**:
    first layers contain most overlay
    $\rightarrow$ ignore them and start looking in layer **2**

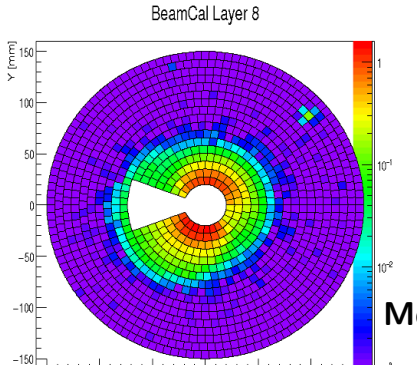
BeamCalClusterReco: Reconstruction Efficiencies

- previously ...



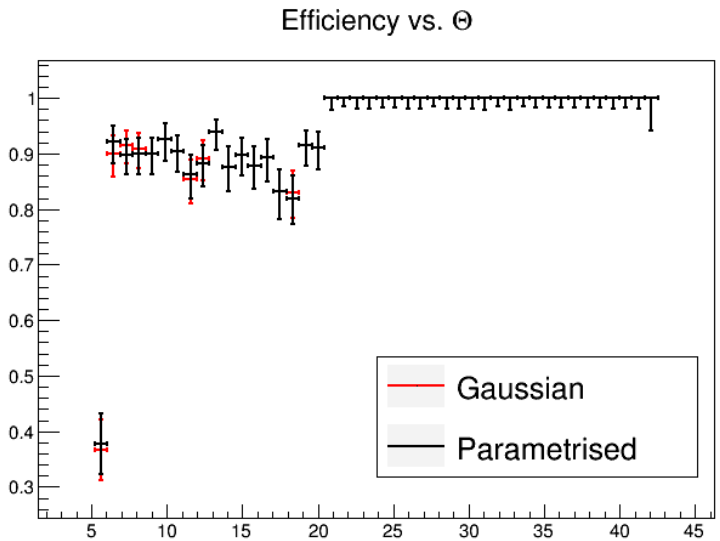
- now...

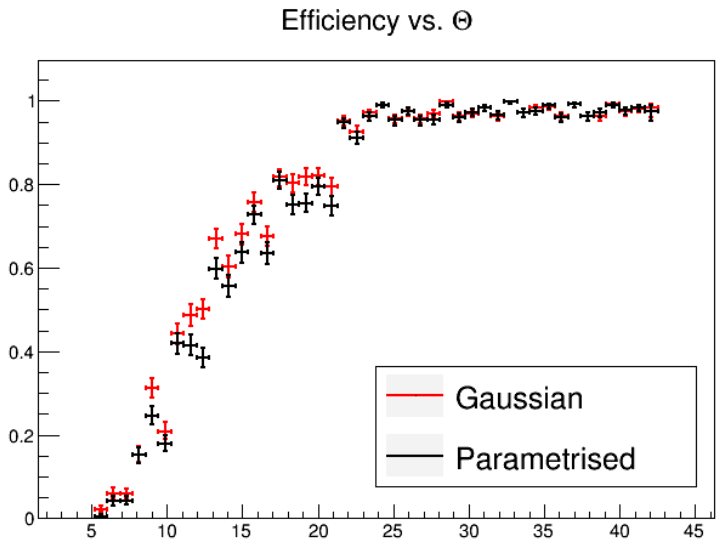


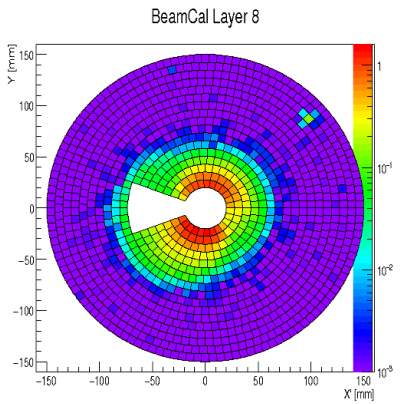


- tuned parameters are included in
  /ILDConfig/v01-17-09/StandardConfig/current/ bbudsc_3evt_stdreco.xml

Parametrised vs. Gaussian vs. Averaged

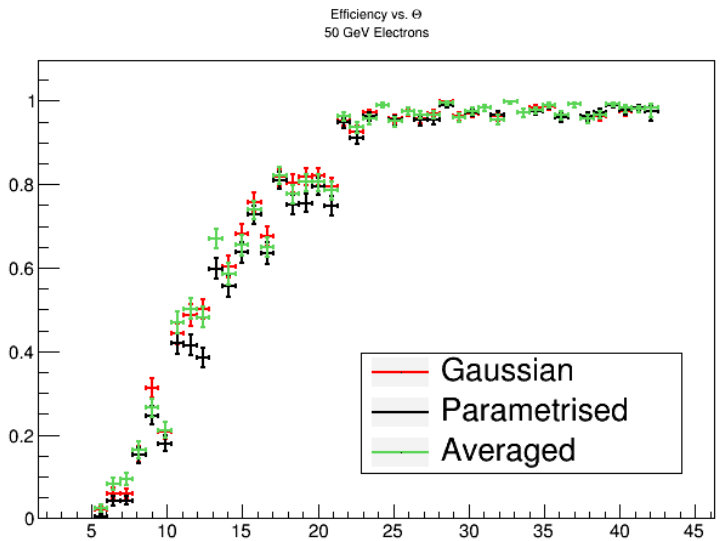


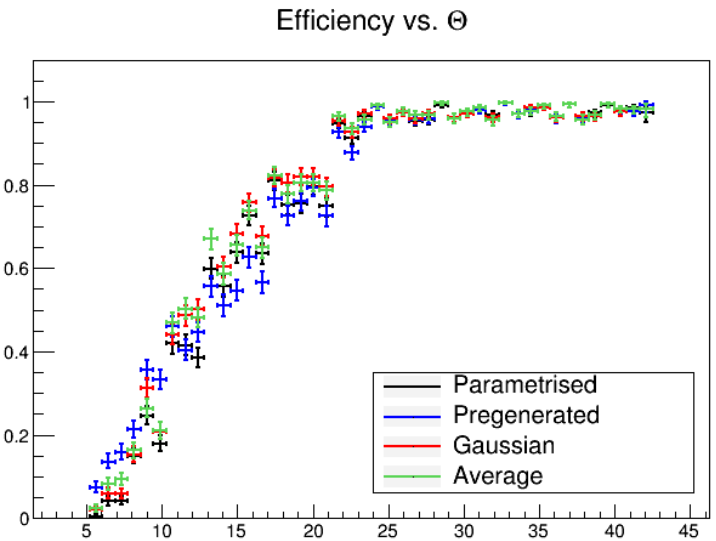


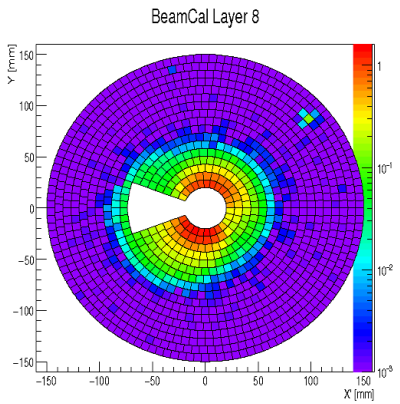


- "Parametrised" is most realistic approach
- efficiencies are very similar to "Gaussian" and "Average"
- small deviations in transition region
  $\Leftrightarrow$ energy distribution not well descibed by Gaussian

Parametrised vs. Gaussian vs. Averaged

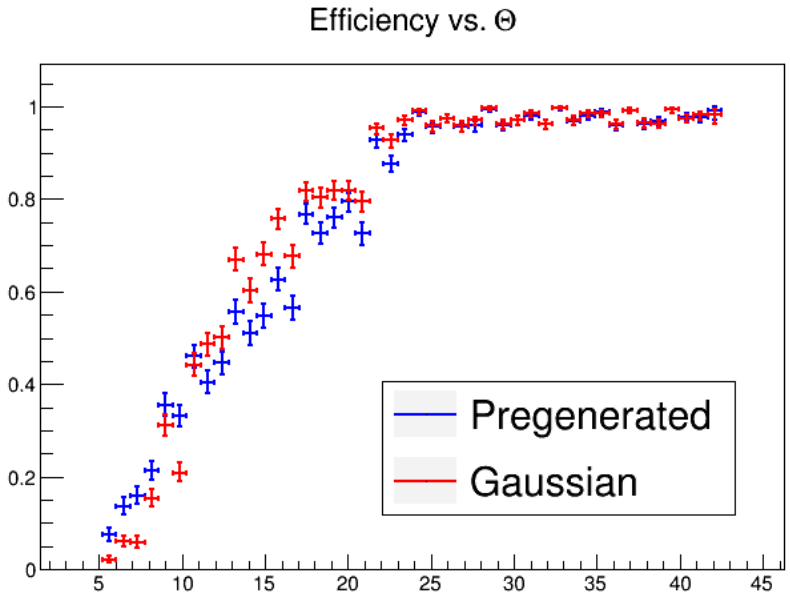


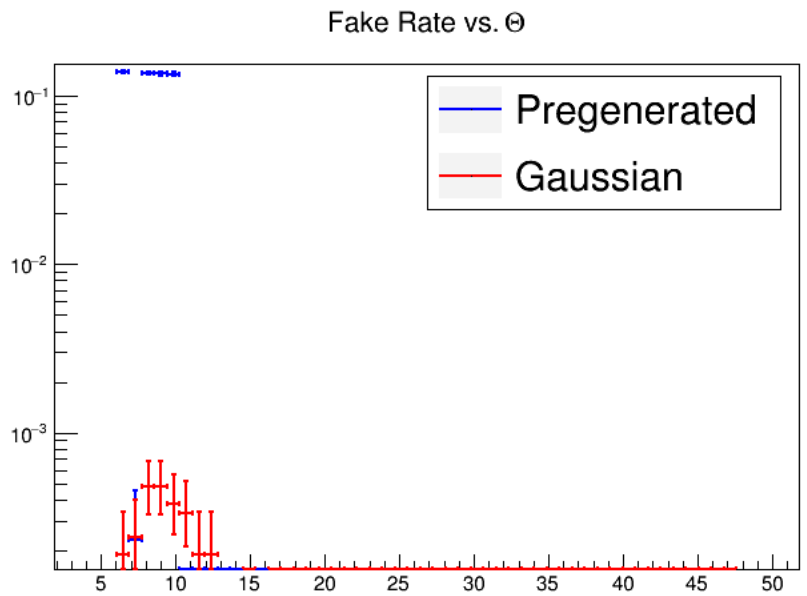




- "Parametrised" is most realistic approach
- efficiencies are very similar to "Gaussian" and "Average"
- small deviations in transition region
  $\Leftrightarrow$ energy distribution not well descibed by Gaussian

Pregenerated





- huge fake rate (maybe correlationsin neighbouring cells)
- Pregenerated Method Needs Further Testing

Event Selection I

- signal definition ($\chi\chi\gamma \rightarrow$ single photon plus missing energy)
  - $E_\gamma > 10$ GeV
  - $E_\gamma < 220$ GeV (Z return at 242 GeV: large background)
  - $|\cos\theta_\gamma| < 0.98$ (tracking needed for photon identification)
    $\rightarrow$ Bhabhas: hard photon boosts leptons in detector
- transverse momentum: $p_T > 3$ GeV rejected
  - $\chi\chi\gamma$: no charged particles
  - allow for beam-induced background with low p_T
- empty detector: visible energy of >10 GeV rejected
- BeamCal cluster $\rightarrow$ rejected
  - old analysis: no reconstruction $\rightarrow$ tagging efficiency
  - now BeamCalClusterReco: reconstruction $\rightarrow$ fakes are possible

Event Selection II

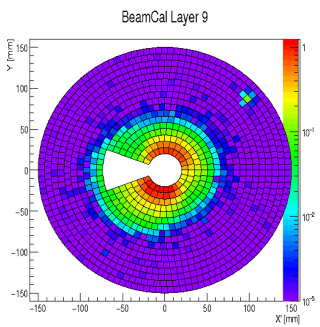
- signal definition: 10 GeV $< E_\gamma <$ 220 GeV, $|\cos\theta_\gamma| < 0.98$
- transverse momentum: $p_T > 3$ GeV rejected
- empty detector: visible energy of >10 GeV rejected
- BeamCal cluster $\rightarrow$ rejected

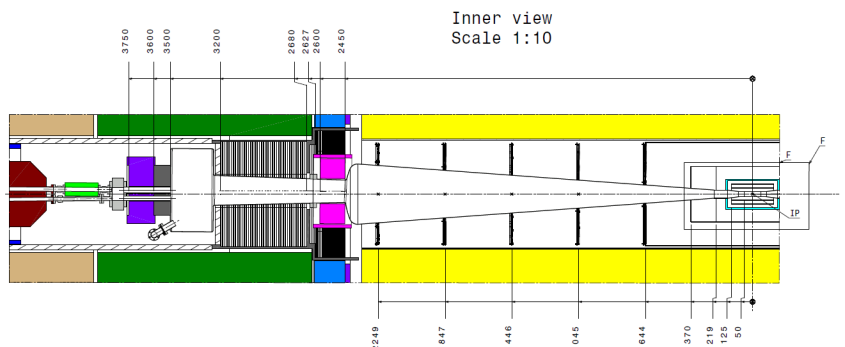
- preliminary cut flow
  - small test samples
  - no low p_T overlay

$\nu\nu\gamma$	new sample	old analysis
p_T	99.3%	97.7%
E_{vis}	91.7%	91.6%
BeamCal	90.8%	89.8%
$e^+e^-\gamma$	new sample	old analysis
p_T	26.1%	21.1%
E_{vis}	1.9%	16.0%
BeamCal	0.02%	0.29%

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 mimicks the BeamCal reconstruction ?
- with $\theta_{eff} = 15.94$ the same rate is obtained as in full analysis



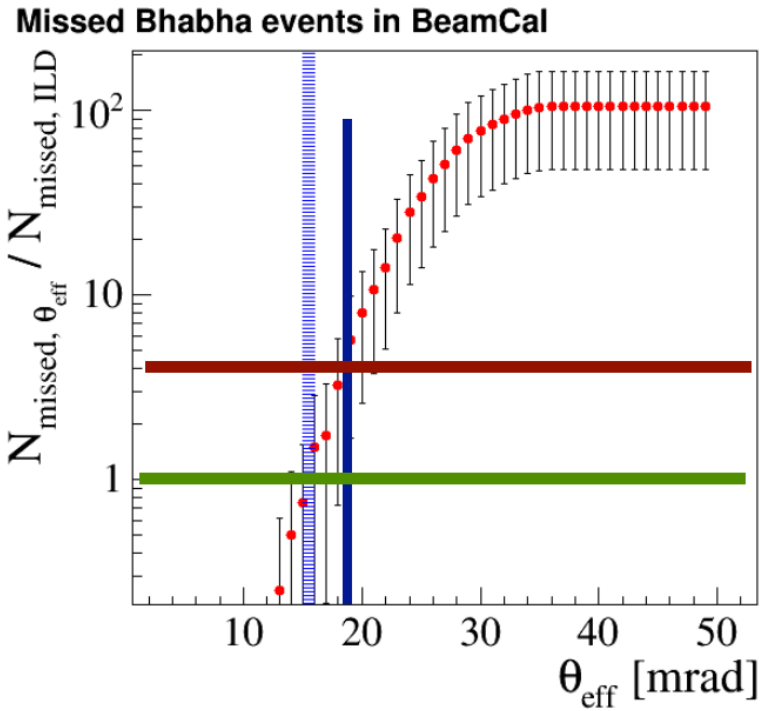


BeamCal and L* II

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

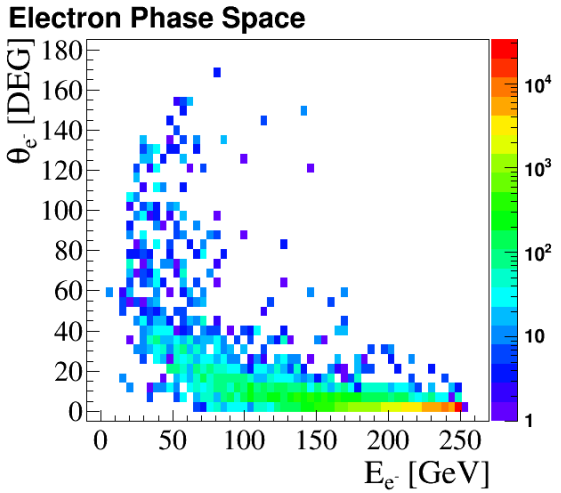
- ILD_o1_V05
  - $\theta_{eff,ILD} = 15.94$ mrad
  - $z_{BCal,ILD} = 3486$ mm
- if BeamCal is moved in by 40 cm
  - $z_{BCal,L*} = 3086$ mm
  - $\theta_{eff} = 18.01$ mrad

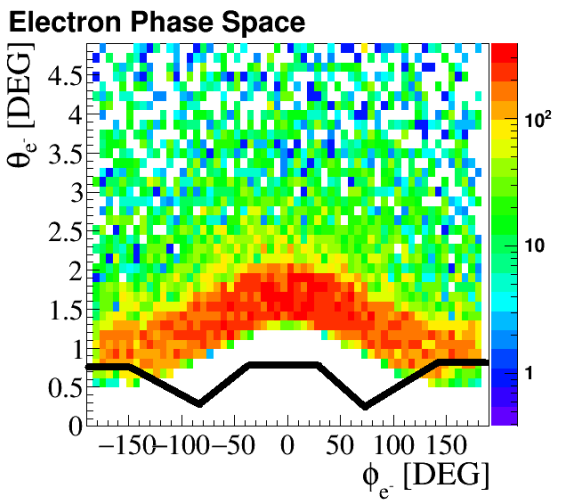
approx. 3-4 times more Bhabhas are missed



Bhabha phase space

- Bhabha samples used so far:
  Whizard (1) default cut:
  - invariant mass of all possible particles pairs > 4 GeV
  - $\rightarrow \theta \approx 1$ DEG (on MC level)
  - (ϕ dependence due to crossing angle boost)
  - BUT: (photon) signal definition translates to $\theta_{e,min} = 0.42$ DEG
- at low θ: some part of BeamCal phase space is not covered
- Whizard: cross section calculation diverges for $\theta \rightarrow 0$
- Bhabha: hard ISR photon very unlikely

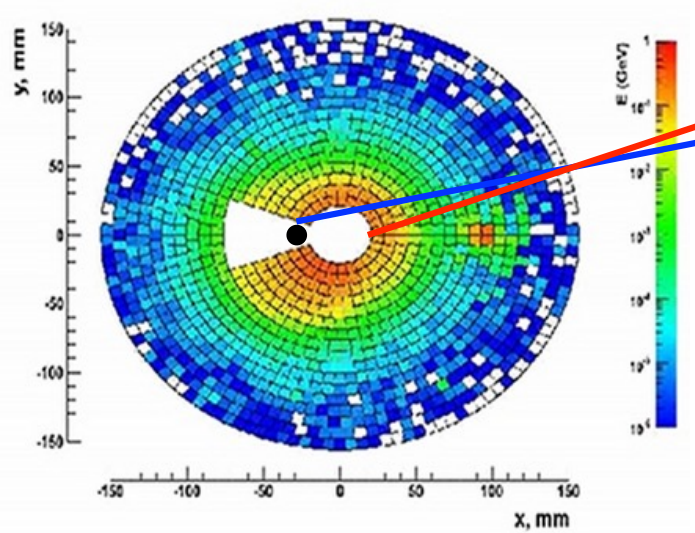


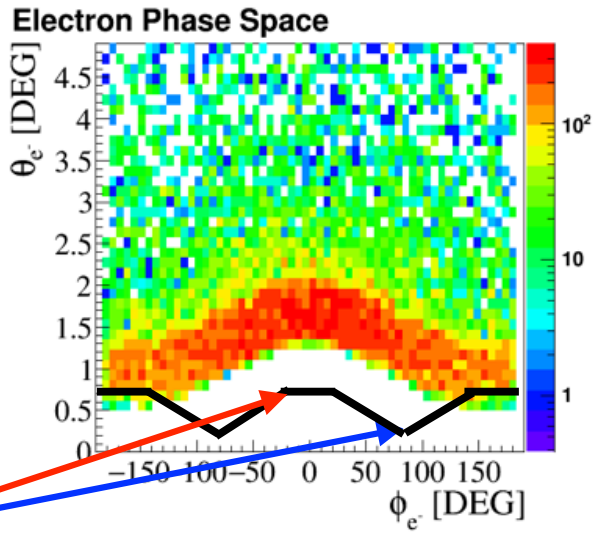


Jenny's Backup Silde from Santander

Bhabha veto in BeamCal

- background f. WIMPs: radiative Bhabha's with photon E >10 GeV, θ >7 deg
- e+e- angles after crossing angle boost
- Whizard chokes to get to smaller angles
- **=> need to get suitable MC samples first before meaningful studies of L* / anti-DID issues can be done**



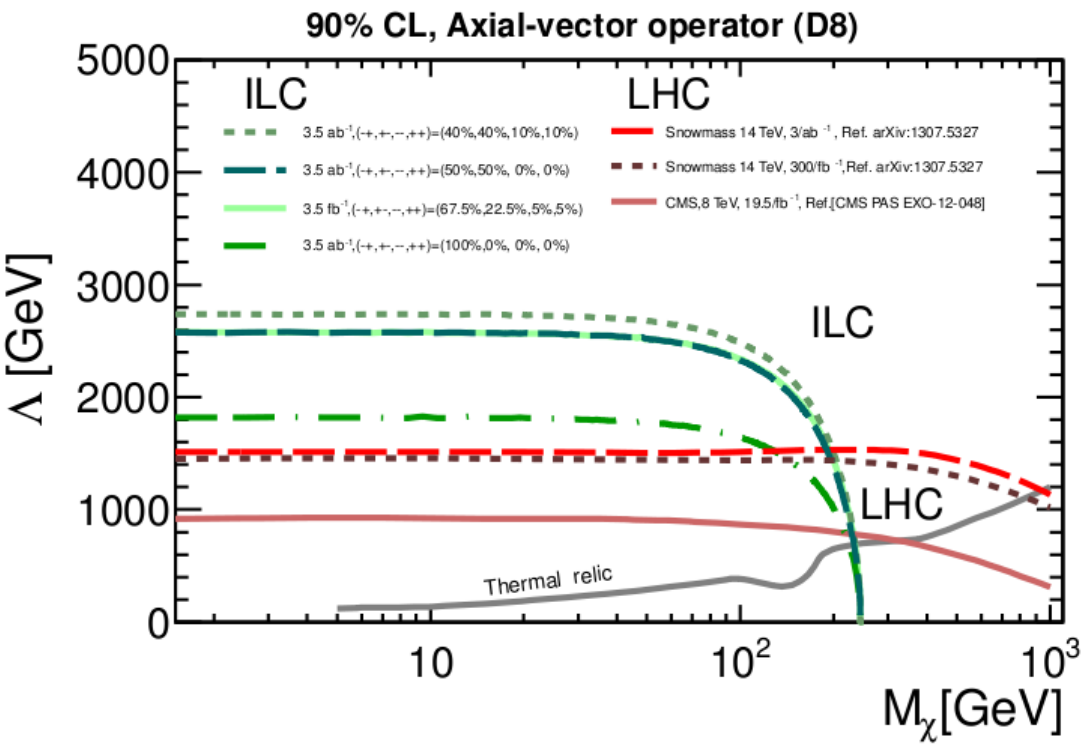


Summary: BeamCal and Bhabhas

- Bhabha background is significantly reduced using BeamCalClusterReco
- L*: moving BeamCal in results in loss of sensitivity for Bhabhas
  (no full simulation, only rough estimate)
- phase space of Bhabha samples cuts out forward region
  $\rightarrow$ trying to improve cuts in Whizard
- outlook: with TDR BeamCal and current Bhabha samples
  $\rightarrow$ expect WIMP sensitivity to increase

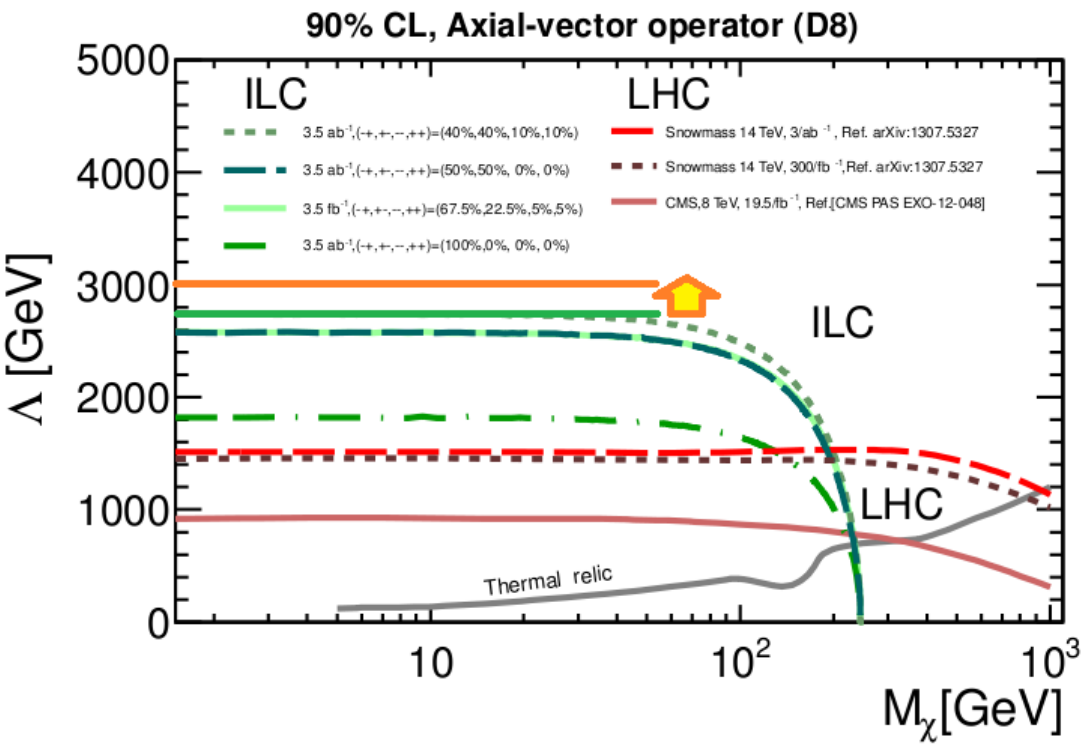
Outlook: Estimate of WIMP Sensitivity

- improvement due to better Bhabha reconstruction
- plot shows estimate
- I'm producing new limits for ICHEP ...



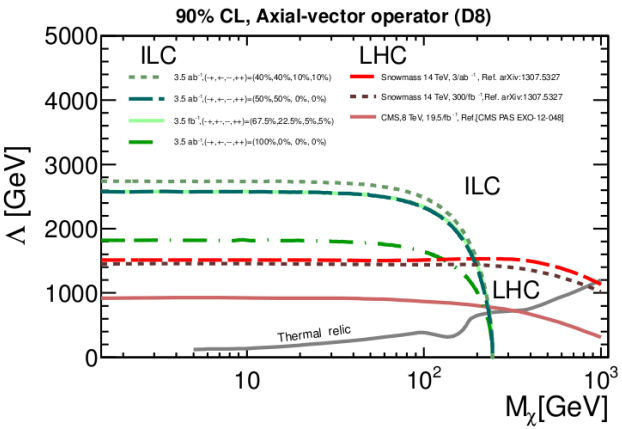
Outlook: Estimate of WIMP Sensitivity

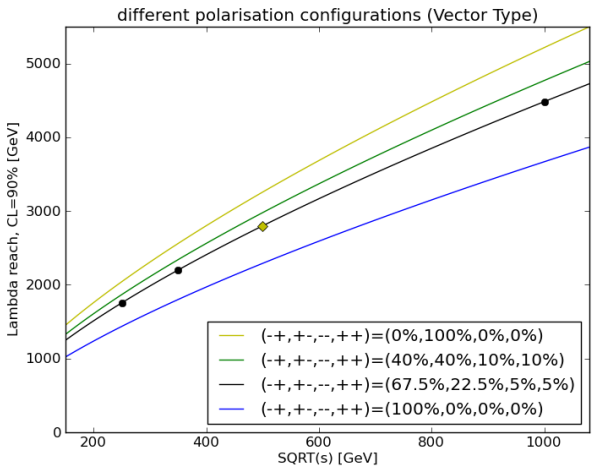
- improvement due to better Bhabha reconstruction
- plot shows estimate
- I'm producing new limits for ICHEP ...

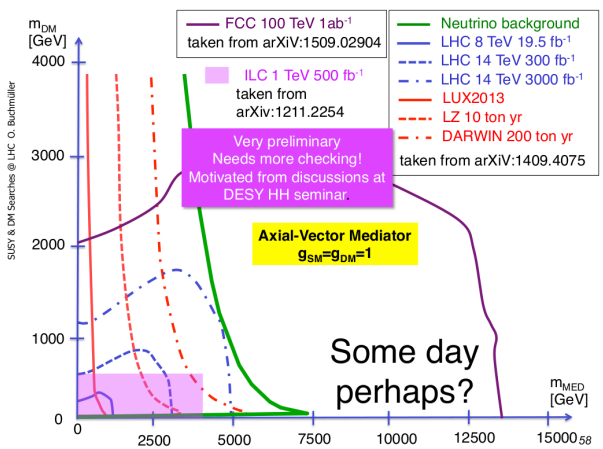


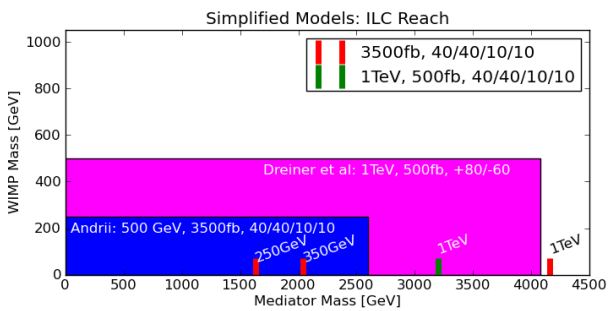
additional material

Interpretation: Outlook: Simplified Models: Translating EFT Results into Simplified Models









BeamCal and L*: Discussion

- BeamCal is centered around outgoing beam pipe
- with a crossing angle of 14 mrad $\rightarrow$ centered around 7 mrad
- inner rim at 5 mrad (BeamCal coordinates)
  $\rightarrow$ 2 - 12 mrad in detector coordinates