

Mono-Photon WIMP prospects at the ILC from $\sqrt{s}=250$ GeV to 1 TeV

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21.04.2015



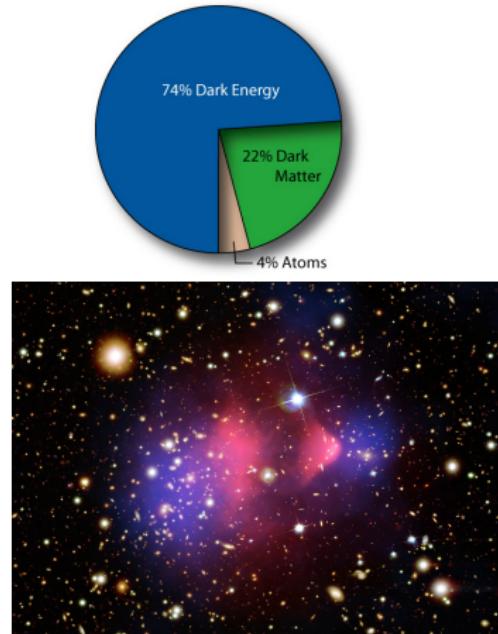
Mono-Photon WIMP prospects at the ILC from $\sqrt{s} = 250$ GeV to 1 TeV

Introduction

Extrapolation of results at 500 GeV
to different \sqrt{s} , $\int L$, polarisation config's

Influence of beamspectrum

Summary

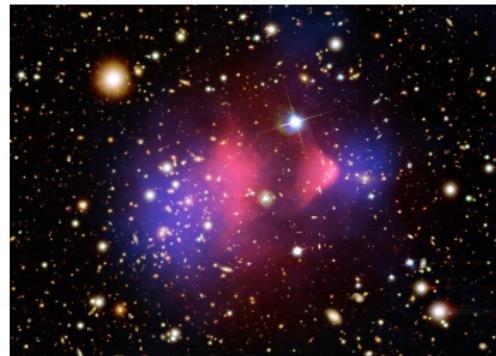
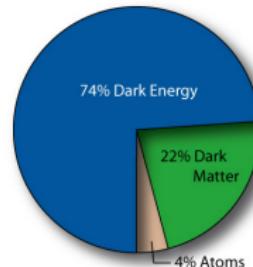


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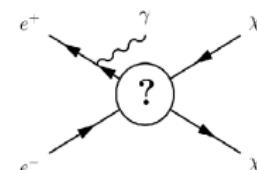
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Summary



Motivation

- Weakly Interacting Massive Particles (WIMPs, χ)
 - Dark Matter Candidate
 - Collider search:
- ILC: $e^+ e^- \rightarrow \chi\chi$
- WIMPs not visible in detector
 \Rightarrow Tag particle needed: **Mono-Photon search**
- Initial State Radiation (ISR)
 \rightarrow quasi model-independent / general approach

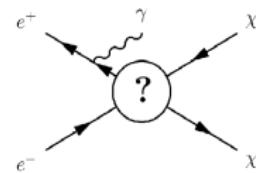


Signal: single photon in an "empty" detector: $\gamma + \not{E}$

- Observables: E_γ , θ_γ



Effective operator approach



- $M_{mediator} \gg \sqrt{s}$
⇒ interaction can be described by a few parameters
- Λ : energy scale of new physics ($\sigma \propto 1/\Lambda^4$)
- types of mediator: vector, axial-vector,...

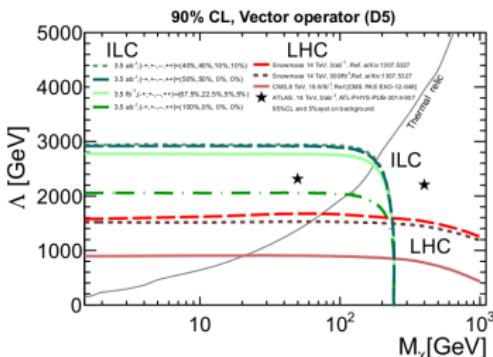
$$\frac{d^2\sigma}{dz d \cos \theta} \approx \frac{\alpha}{12\pi^2} \frac{s}{\Lambda^4} \frac{1}{z \sin^2 \theta} (1 - z)[4(1 - z) + z^2(1 + \cos^2 \theta)]$$

Chae and Perelstein 2013

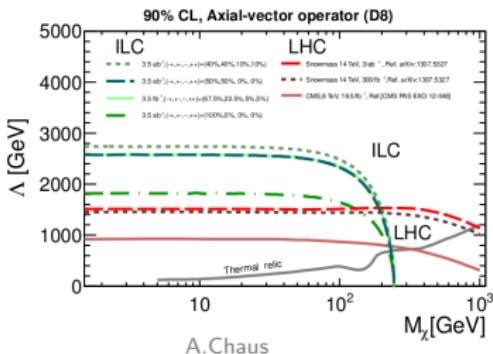
$$(z = \frac{2E_\gamma}{\sqrt{s}}, M_\chi \ll \sqrt{s})$$



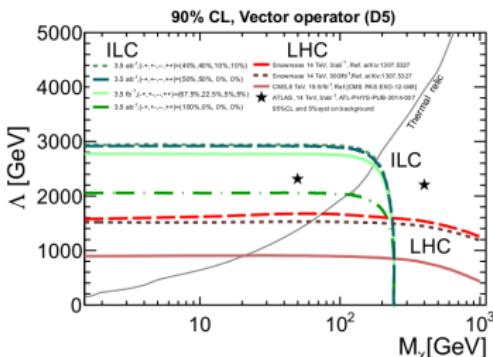
Status



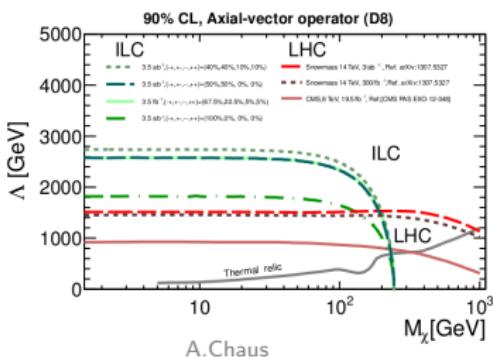
- Geant4 based full detector analysis (C.Bartels)
 - $\sqrt{s} = 500 \text{ GeV}$
 - $1 \text{ GeV} \leq M_\chi < \sqrt{s}/2$
- ILC can test smaller σ than LHC



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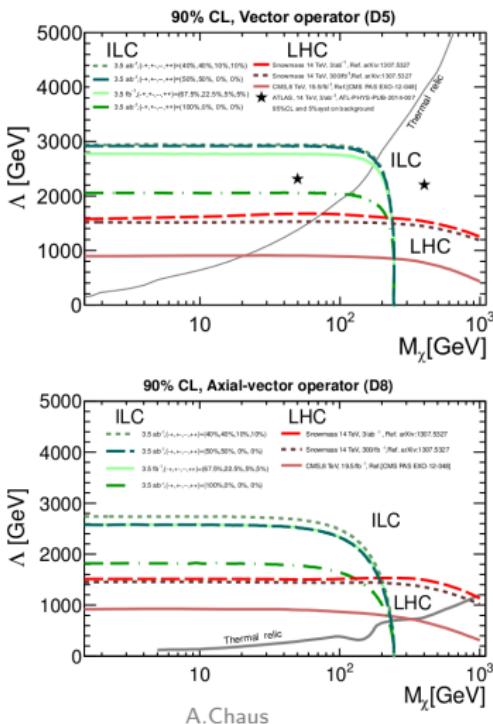


Now:

- What about other \sqrt{s} ?



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Now:

- What about other \sqrt{s} ?
 ⇒ extrapolation of reachable Λ

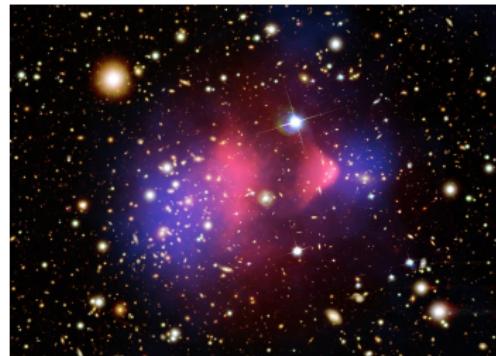
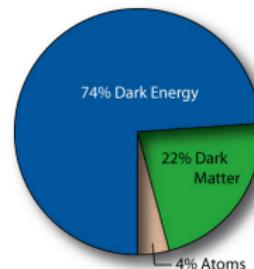


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Strategy for an extrapolation of Λ^{reach}

- find approximation $\Lambda \sim F(S, B)$
 - S : # signal events, B : # background events
 - $\Lambda \sim F(S, B) \Rightarrow \Lambda \sim F(\sqrt{s}, \int L, pol)$
- energy dependence of
 - signal: $S = \sigma_S \cdot \int L \cdot \epsilon$
 \Rightarrow analytical formula for $\frac{d^2\sigma_S}{dz d \cos \theta}(\sqrt{s}, pol, \Lambda)$ with $\sigma \sim 1/\Lambda^4$
 - background: $B = \sigma_B \cdot \int L \cdot \epsilon$
 $\Rightarrow \sigma_B$ calculated with WHIZARD 2
main contributions: $\nu\nu\gamma$, $e^+e^-\gamma$

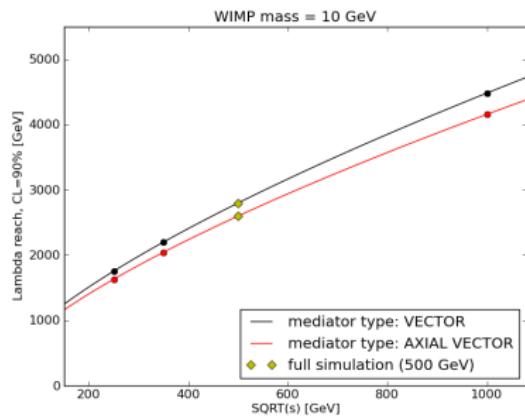


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- change of sensitivity:
$$\Lambda^{reach, CL} = \Lambda_0^{reach, CL} \frac{F(\sqrt{s}, \int L, pol)}{F(\sqrt{s_0}, \int L_0, pol_0)}$$



Λ^{reach} at different center-of-mass energies

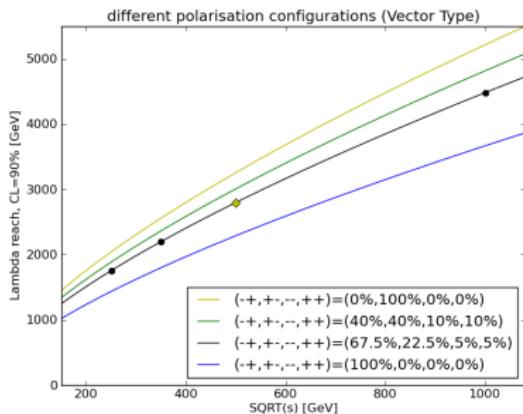


- accessible Λ rises with energy
($=\sigma$ becomes smaller)
- assumptions:
 - polarisation configuration:
 $(-+,+-,--,++) = (67.5\%, 22.5\%, 5\%, 5\%)$
 - $\int L \propto \sqrt{s}$
(e.g. at $\sqrt{s} = 500$: $\int L = 500 \text{ fb}^{-1}$)
- vector (axial-vector) mediator
only possible for LR,RL (LL,RR)
 $\Rightarrow \Lambda_{vector}^{reach} > \Lambda_{axial-vector}^{reach}$



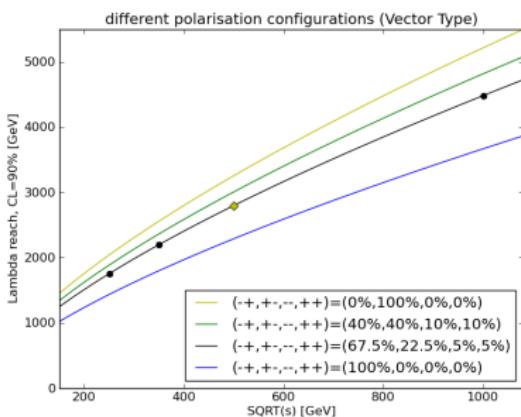
Λ^{reach} for different polarisation configurations

- mediator type: vector
- e^- : 80% polarised,
 e^+ : 30% polarised
- signal and background depend on polarisation of electron and positron
 - Vector: only possible for LR, RL

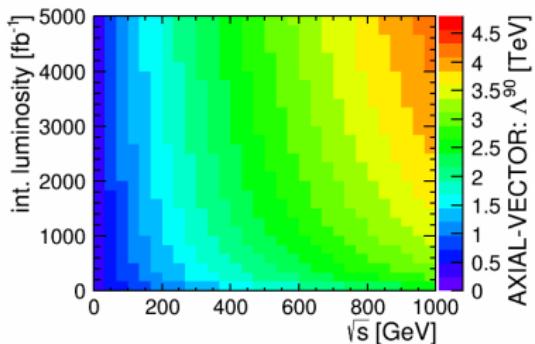


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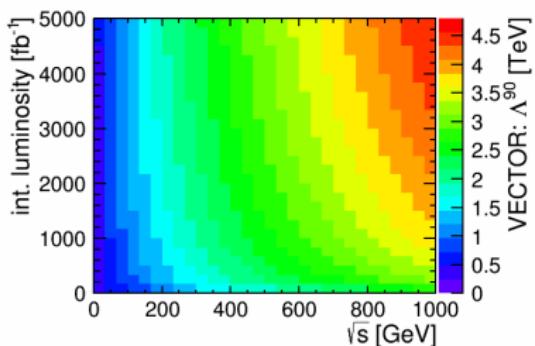
- mediator type: vector
- e^- : 80% polarised,
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- signal and background depend on polarisation of electron and positron
 - Vector: only possible for LR, RL
 - Background: suppressed for RL
- crucial part is RL
- best case: $(-, +, -, -, +, +) = (0\%, \textbf{100}\%, 0\%, 0\%)$
- extrapolation of $\int L_{RL}$ only



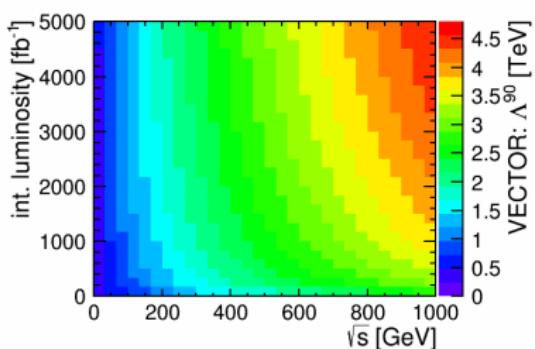
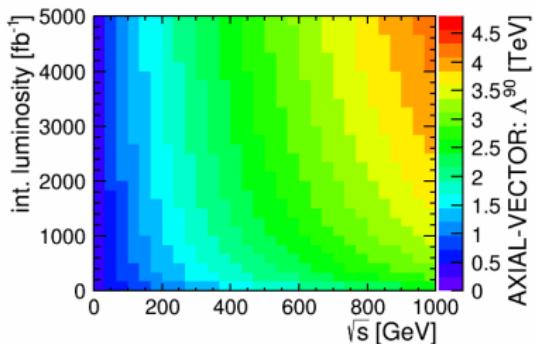
Λ^{reach} at different \sqrt{s} and integrated luminosities



- allows to give estimates for Λ^{reach}
 - for different time scales
 - (- for different running scenarios)
- e.g.: after 4 years (500 fb^{-1}) at $\sqrt{s}=250 \text{ GeV}$: $\Lambda^{reach} \approx 1.5 \text{ TeV}$

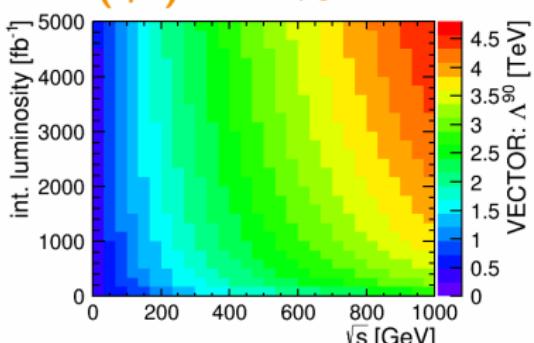
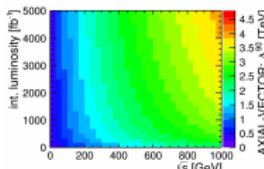
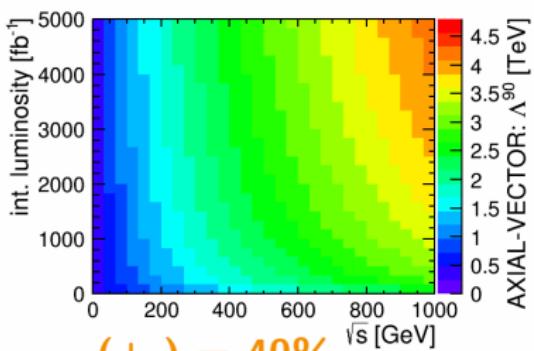


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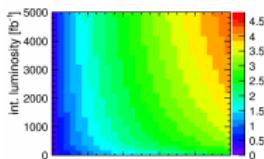


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- more LR/RL
 $\Rightarrow \Lambda_{\text{vector}}^{reach} > \Lambda_{\text{axial-vector}}^{reach}$
- (40%, 40%, 10%, 10%) better than (67.5%, 22.5%, 5%, 5%)



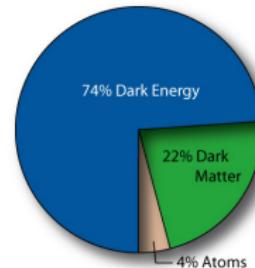
(+/-) = 22.5%

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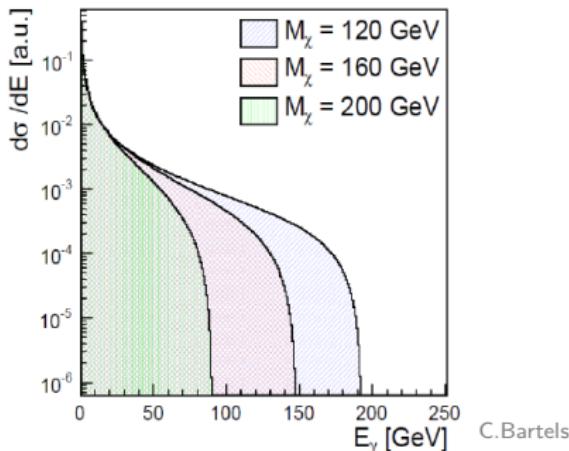
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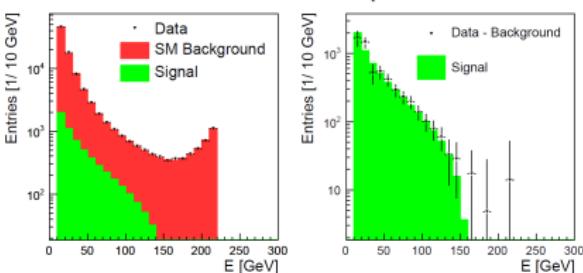
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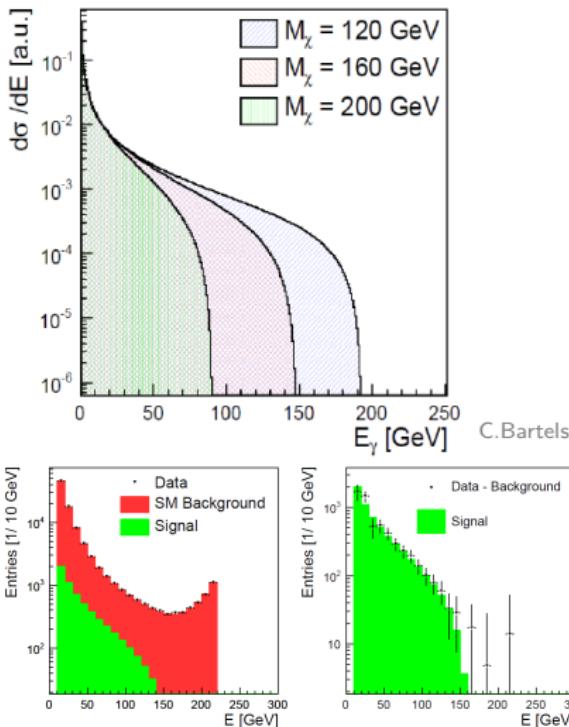
Influence of beamspectrum: Motivation



- E_γ : shape information is used
- range depends on M_χ
- $\frac{d\sigma}{dE_\gamma} = f(\sqrt{s})$
- only if \sqrt{s} is known precisely $\rightarrow M_\chi$



Influence of beamspectrum: Motivation

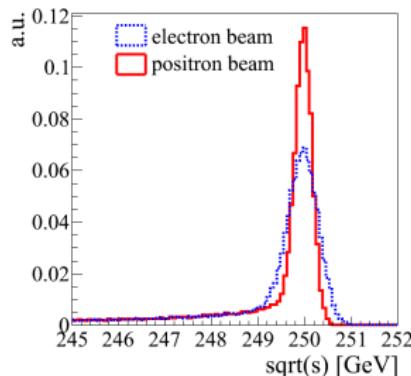
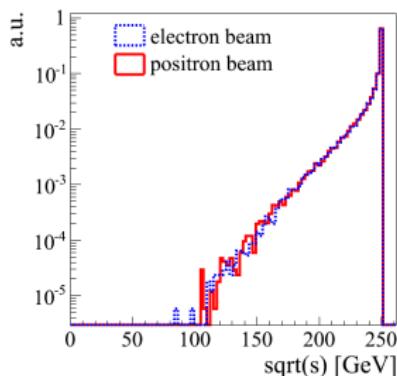


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 - only if \sqrt{s} is known precisely $\rightarrow M_\chi$
 - So far: beam spectrum largest source of systematic uncertainties
- ⇒ **beamspectrum has to be understood**
 ⇒ especially around nominal beam energy



Influence of Beamspectrum

- TDR beamspectrum (DBD)
- generated with GuineaPig

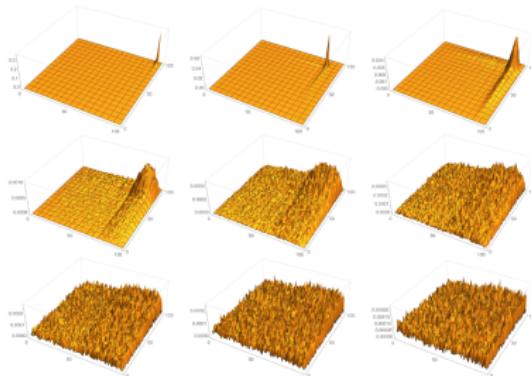


- WHIZARD 2 offers two possibilities
 - beamspectrum can be read in directly
 - parametrization (CIRCE2)



Parametrization in WHIZARD: CIRCE2

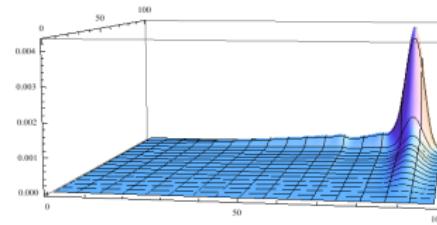
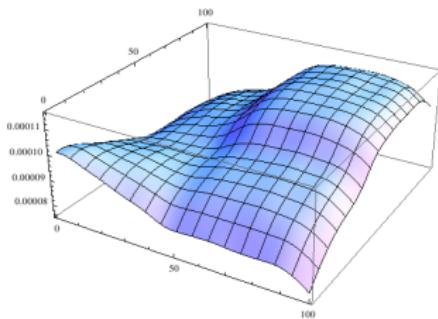
- 2D grid: electron and positron distributions depend on each other
- bin size is adapted to variance
⇒ describes well part around nominal beam energy
⇒ huge bins in tail



Two different beamspectrum parametrizations

- same GuineaPig output used for both
- one describes the peak well, the other one the tail

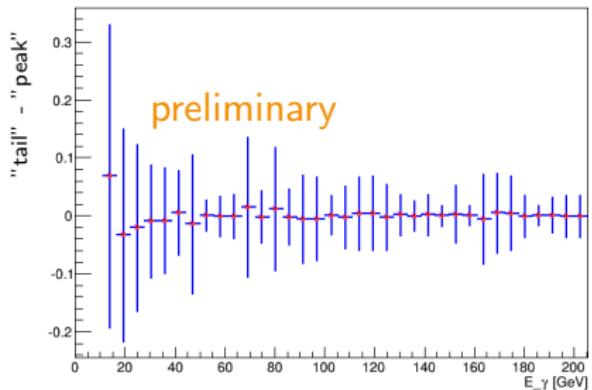
CIRCE2 options	PEAK	TAIL
iterations	10	2
smooth	5	1



Influence of beamspectrum

- two test samples ($\nu\nu\gamma$), using the two parametrizations of the beam spectrum
- rough estimation of the influence of the beamspectrum: subtract the distributions of E_γ

Neutrino pair production: photon energy



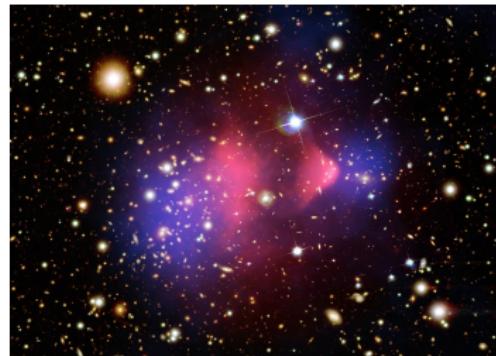
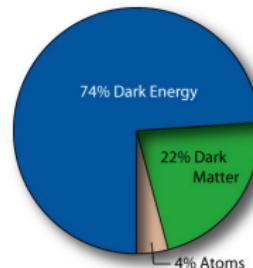
- huge effect at low energies (6%)
⇒ most important range!
- Status
 - Small statistics
 - Monte Carlo level

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- Effective operator approach
 - Λ : suppression scale
 - full simulation at 500 GeV



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 - full simulation at 500 GeV
- Extrapolation of reachable Λ for different running scenarios:
 - full ILC energy range (250 GeV - 1 TeV)
 - integrated luminosities
 - polarisation configurations
 - ⇒ P_{e^-} : R, P_{e^+} : L best case
 - (background suppression more important than signal enhancement)



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- Effective operator approach
 - Λ : suppression scale
 - full simulation at 500 GeV
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 - integrated luminosities
 - polarisation configurations
 - ⇒ P_{e^-} : R, P_{e^+} : L best case
(background suppression more important than signal enhancement)
- Crucial to understand luminosity spectrum
 - largest source of systematic uncertainty for M_χ determination
 - first (rough) estimate shown



Thank you !

