Lowering the threshold in the DAMA dark matter search

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Overview

DAMA sees modulation in event rate (8.9σ)

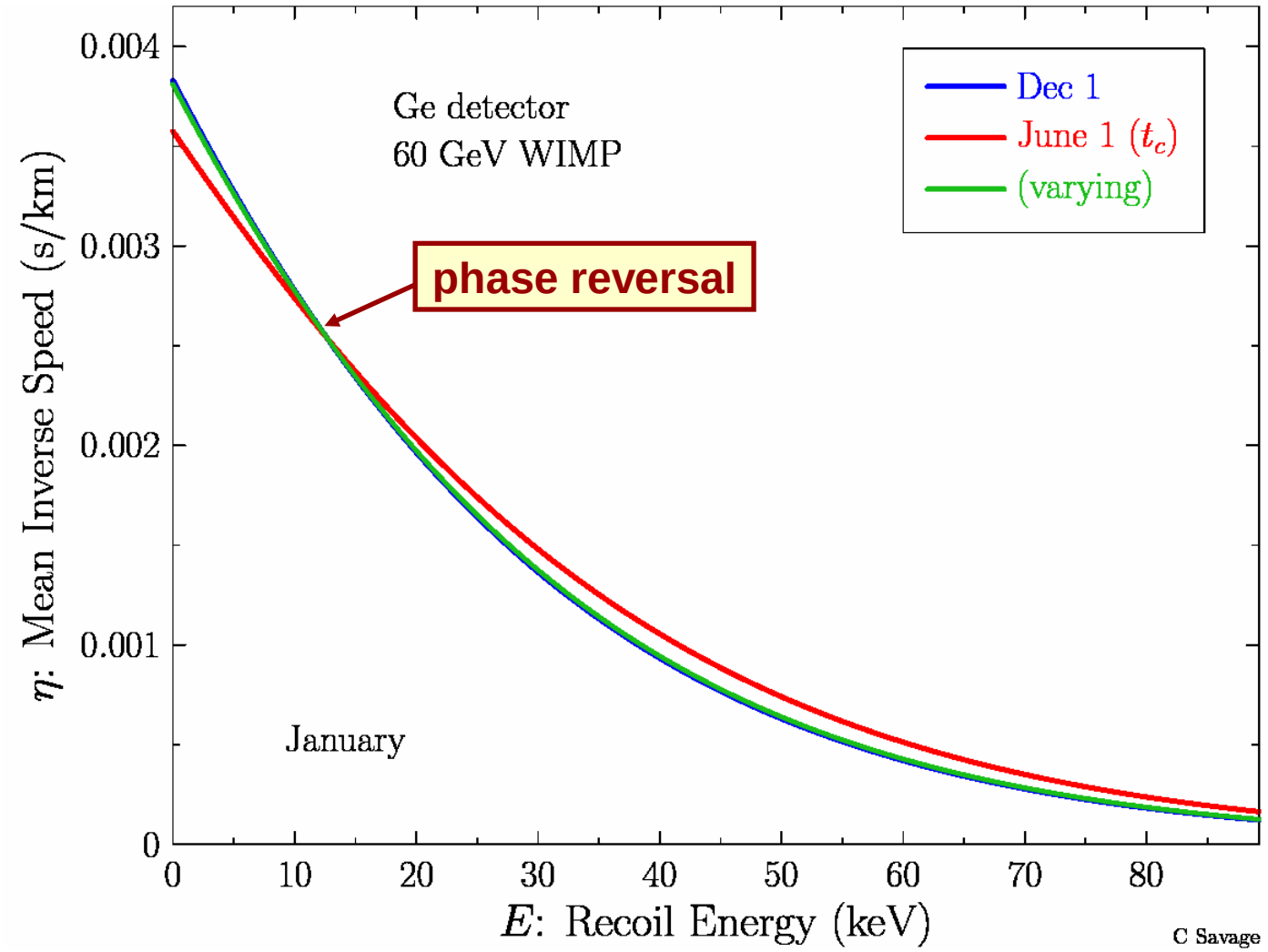
- Consistent with ~ 10 GeV or ~ 70 GeV WIMP
- Consistent with spin-independent (SI) or spin-dependent (SD) interactions

2010: detector upgrades

- Better PMTs allow threshold to be lowered (2 $\rightarrow$ 1 keVee)
- **What will low-threshold results tell us?**

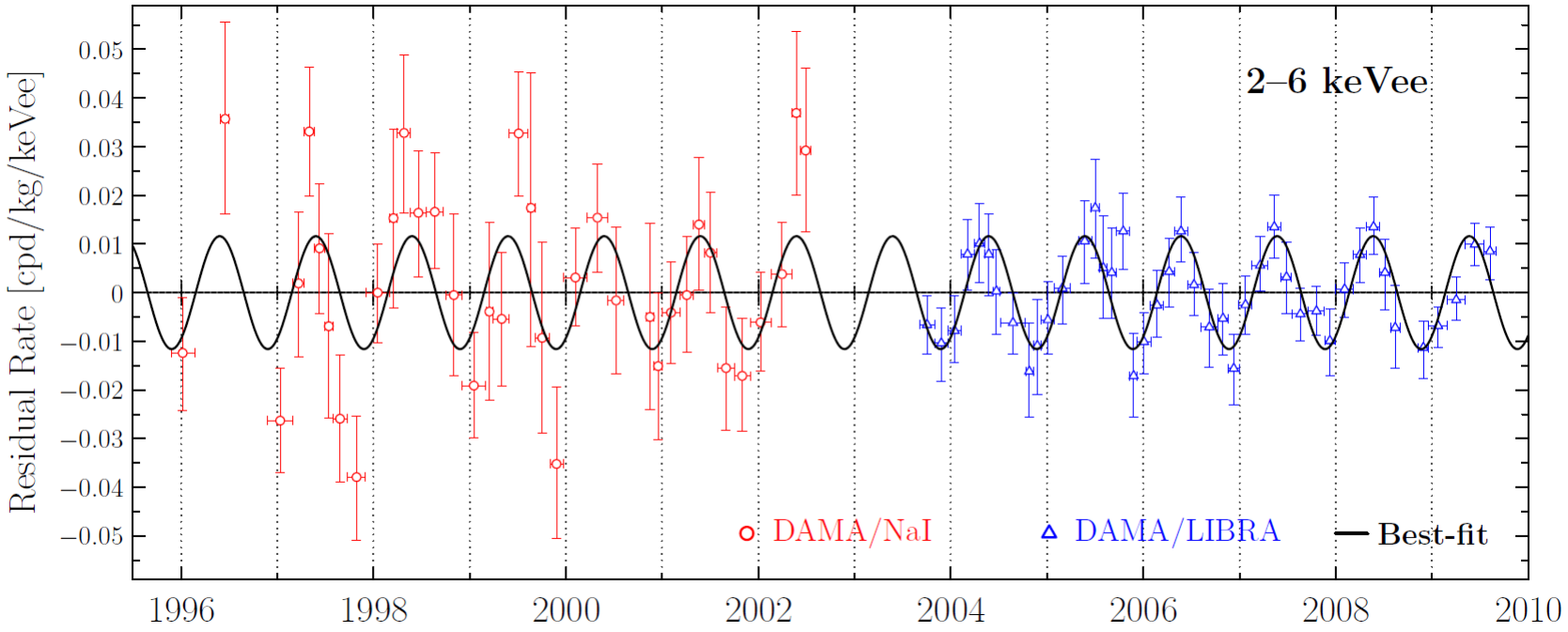
DM-Ice, etc.

Why lower threshold?



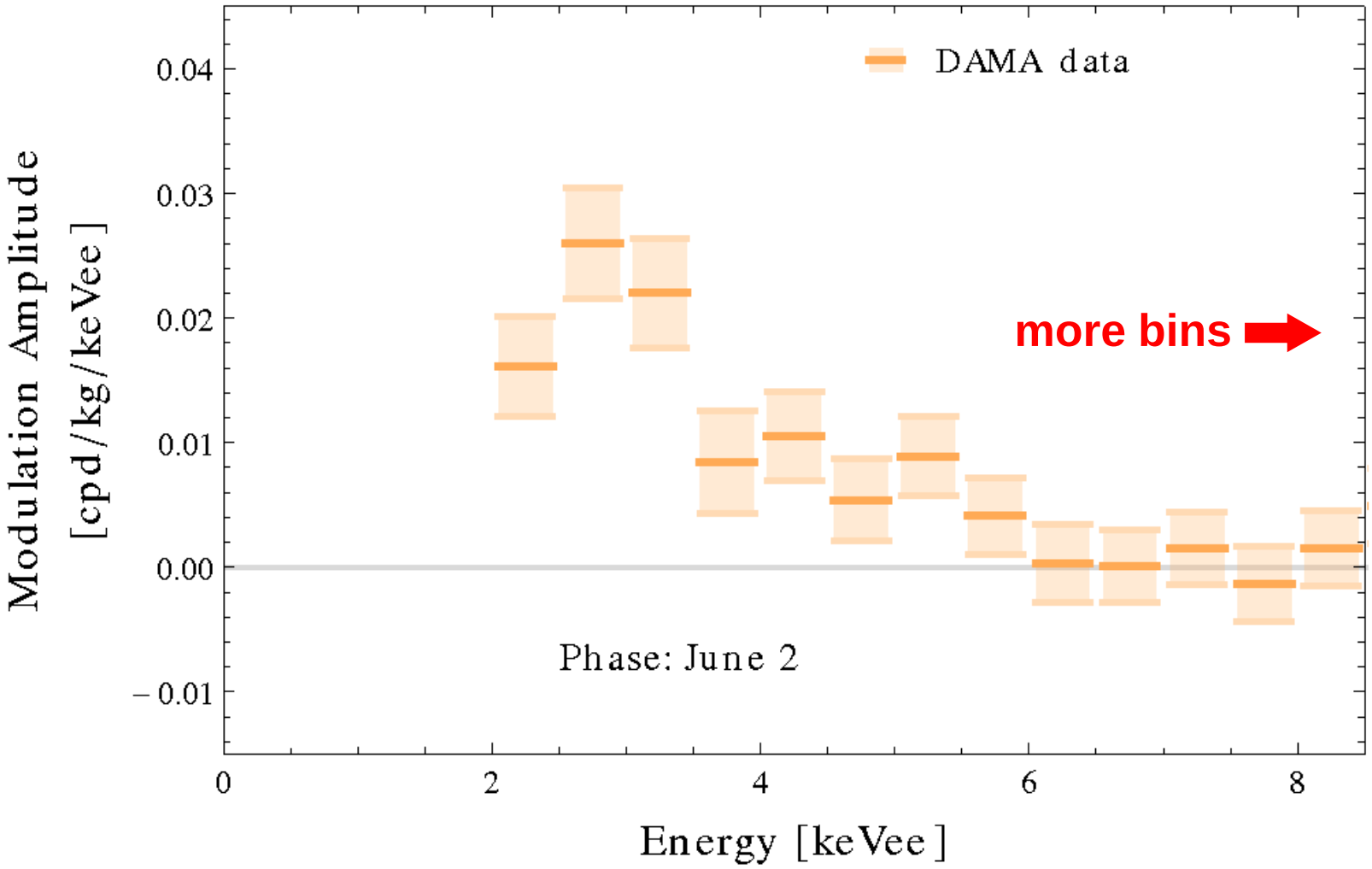
DAMA Results

- Modulation search using NaI crystals (scintillation only)
  - DAMA/NaI: 1996-2002 R. Bernabei *et al.*, Riv. Nuovo Cim. **26N1**, 1 (2003)
  - DAMA/LIBRA: 2003-2009 R. Bernabei *et al.*, Eur. Phys. J. **C67**, 039 (2010)



8.9σ annual modulation

DAMA Results



Lowering the DAMA threshold

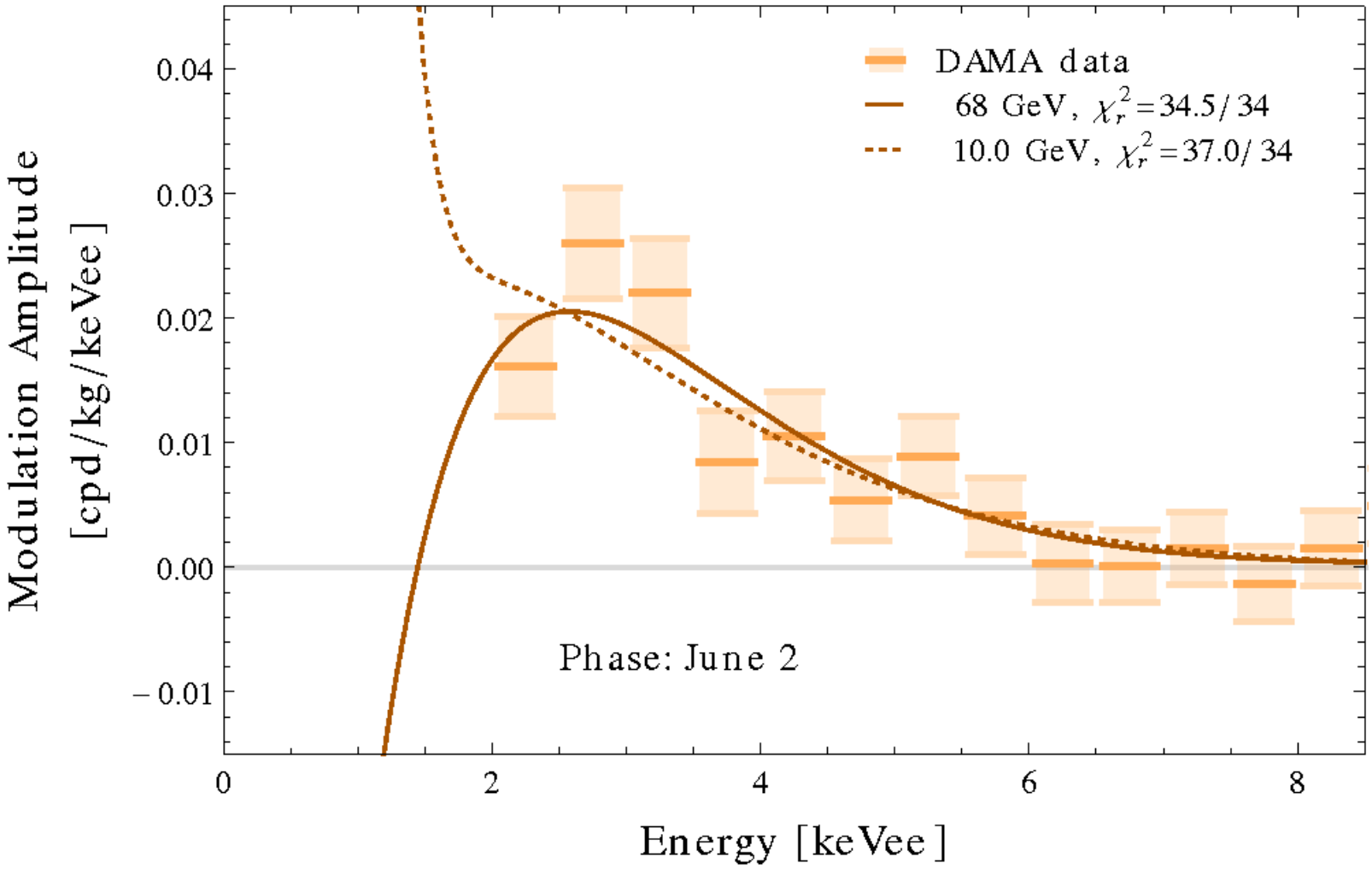
WIMP Fits

Chi-squared analysis

Assumptions:

- Standard Halo Model
- Spin-independent elastic scattering
  (later: spin-dependent)
- Quenching: $Q_I = 0.09$, $Q_{Na} = 0.30$
- Finite energy resolution

DAMA Fits



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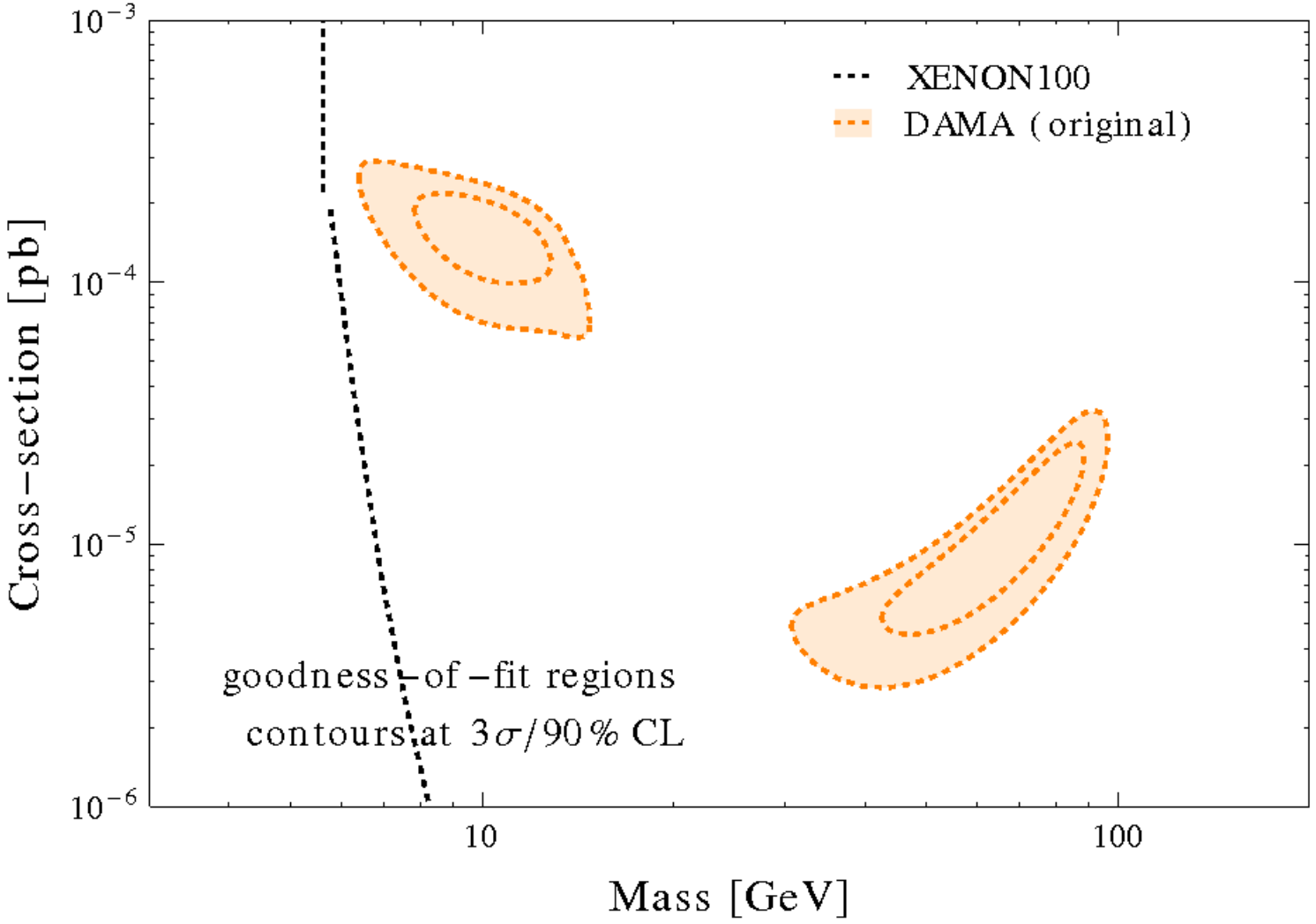
DAMA Fits



Lowering the DAMA threshold

Binning

Original bins (36):

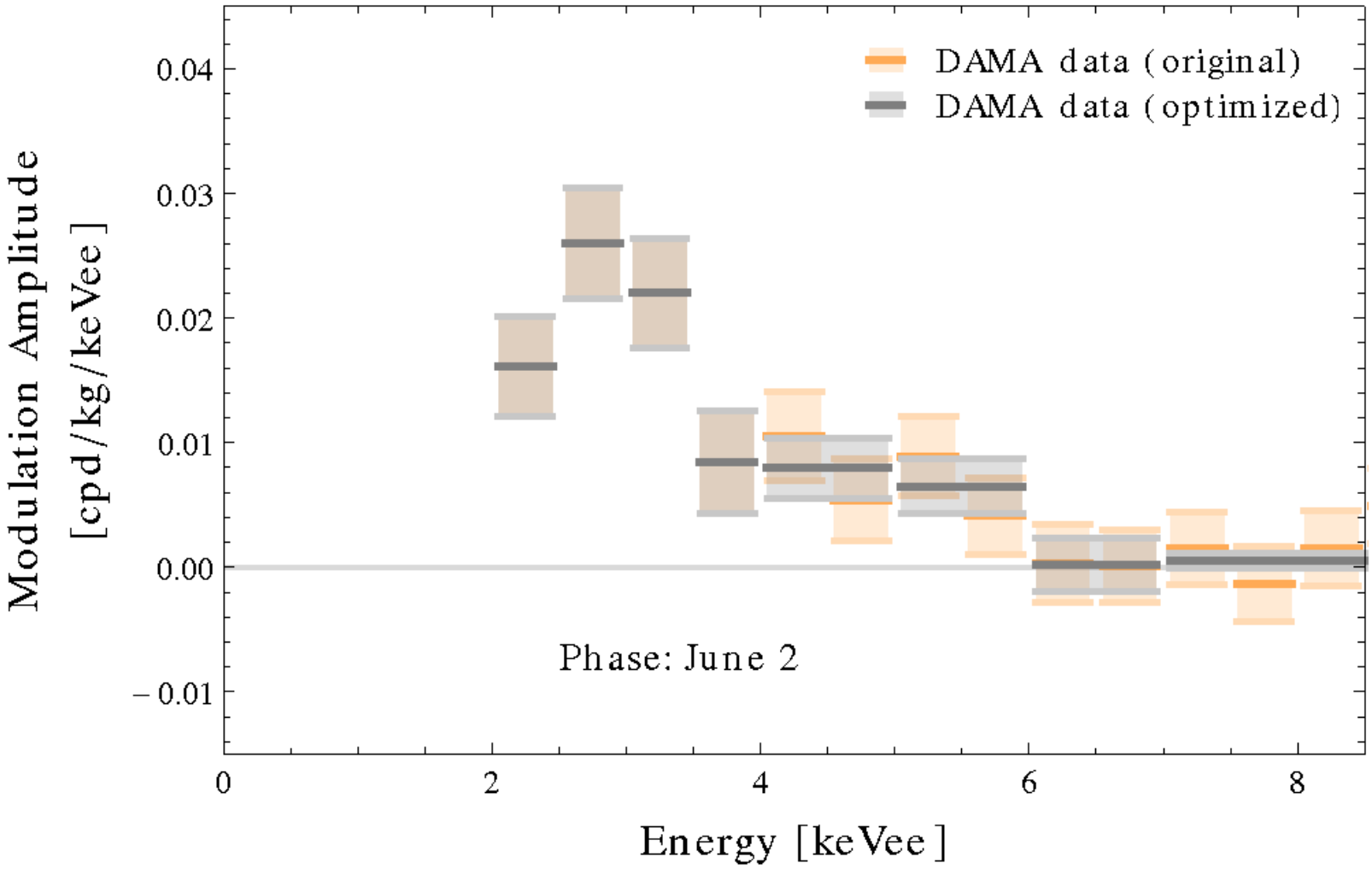
- Most narrower than energy resolution
- Most expected to have negligible signal

$\Rightarrow$ Sensitivity of goodness-of-fit weakened!

More optimal choice of bins (8):

- Combine bins much smaller than energy resolution
- Combine all bins above 7 keVee

Binning



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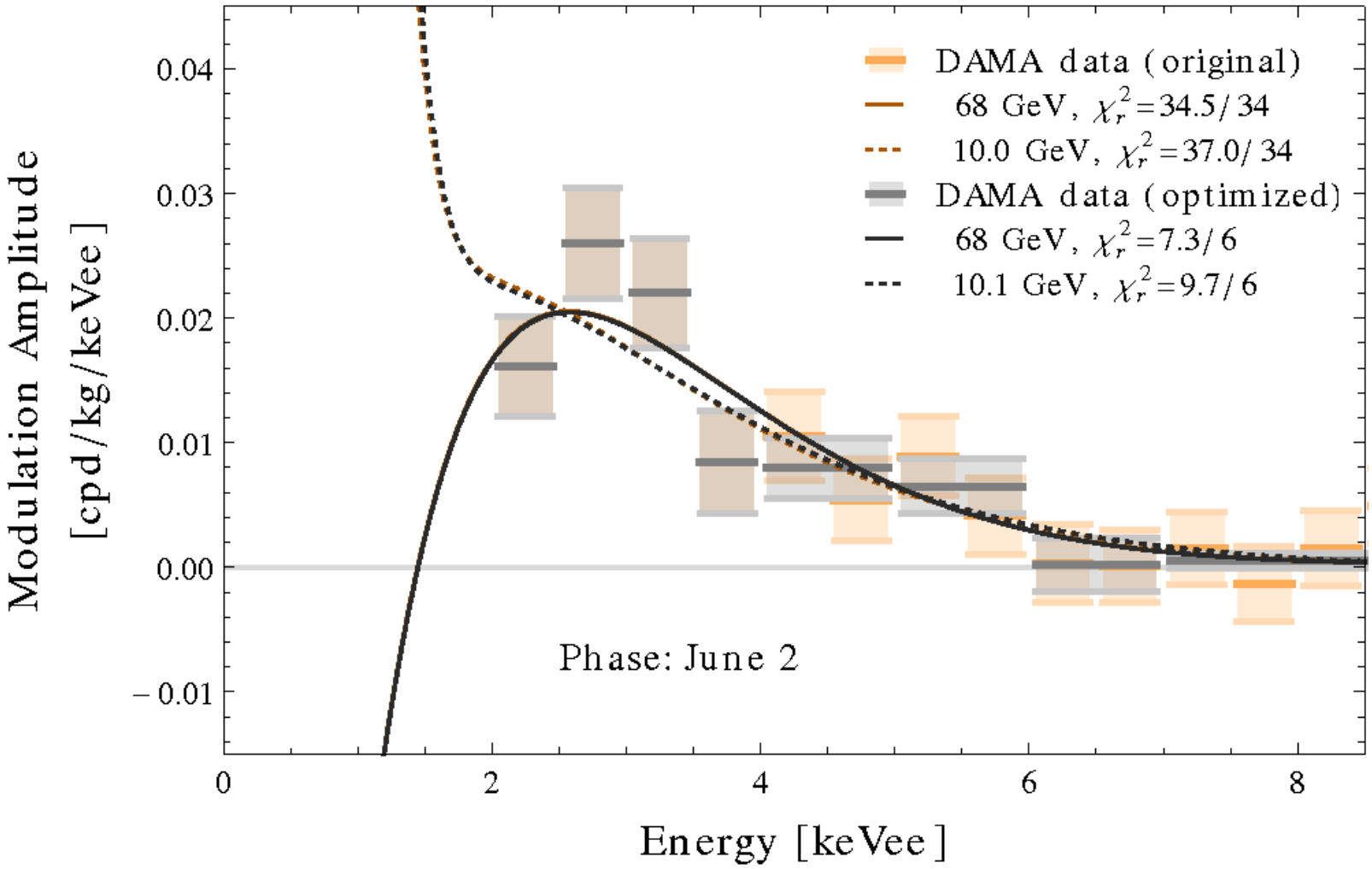
Binning



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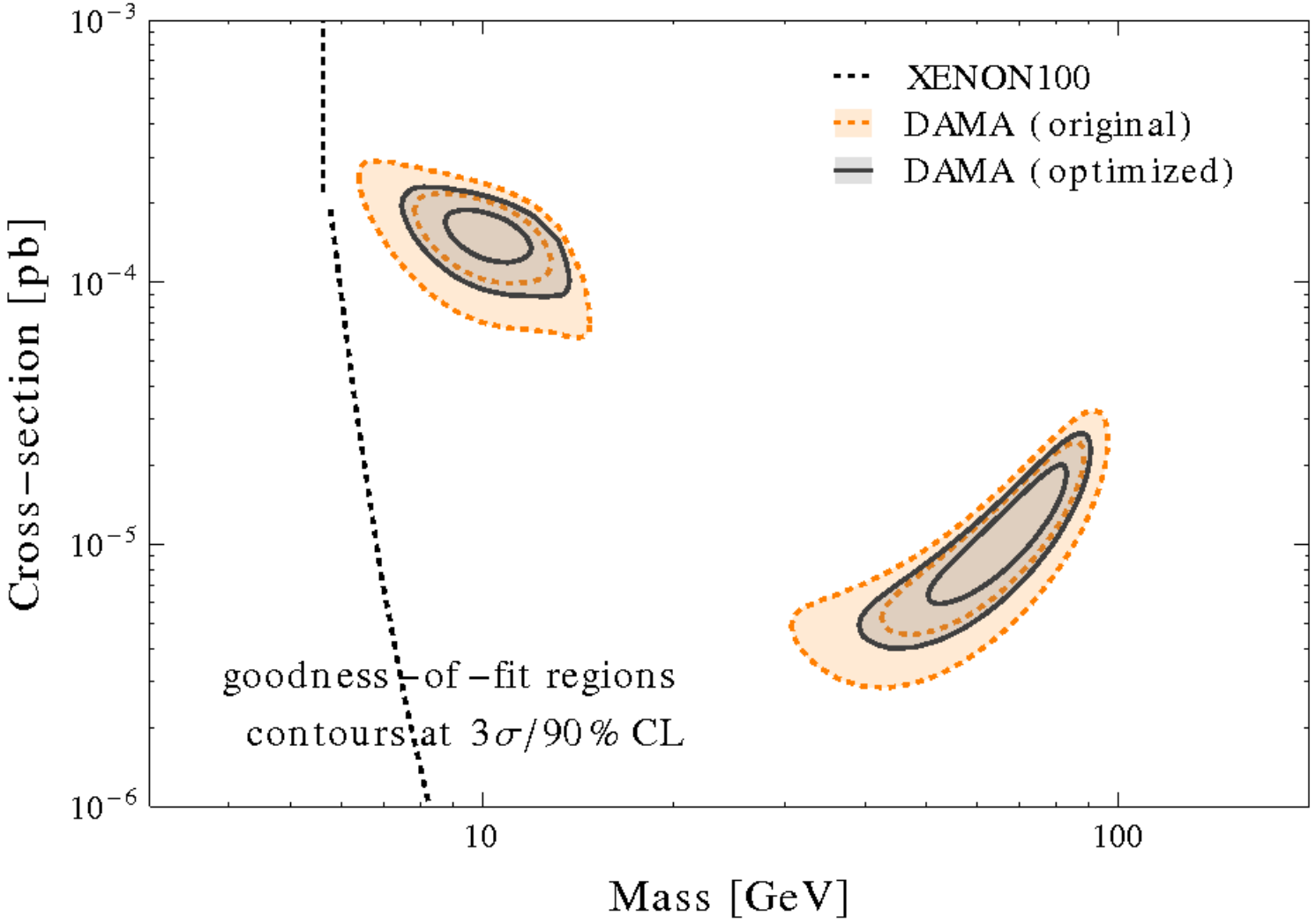
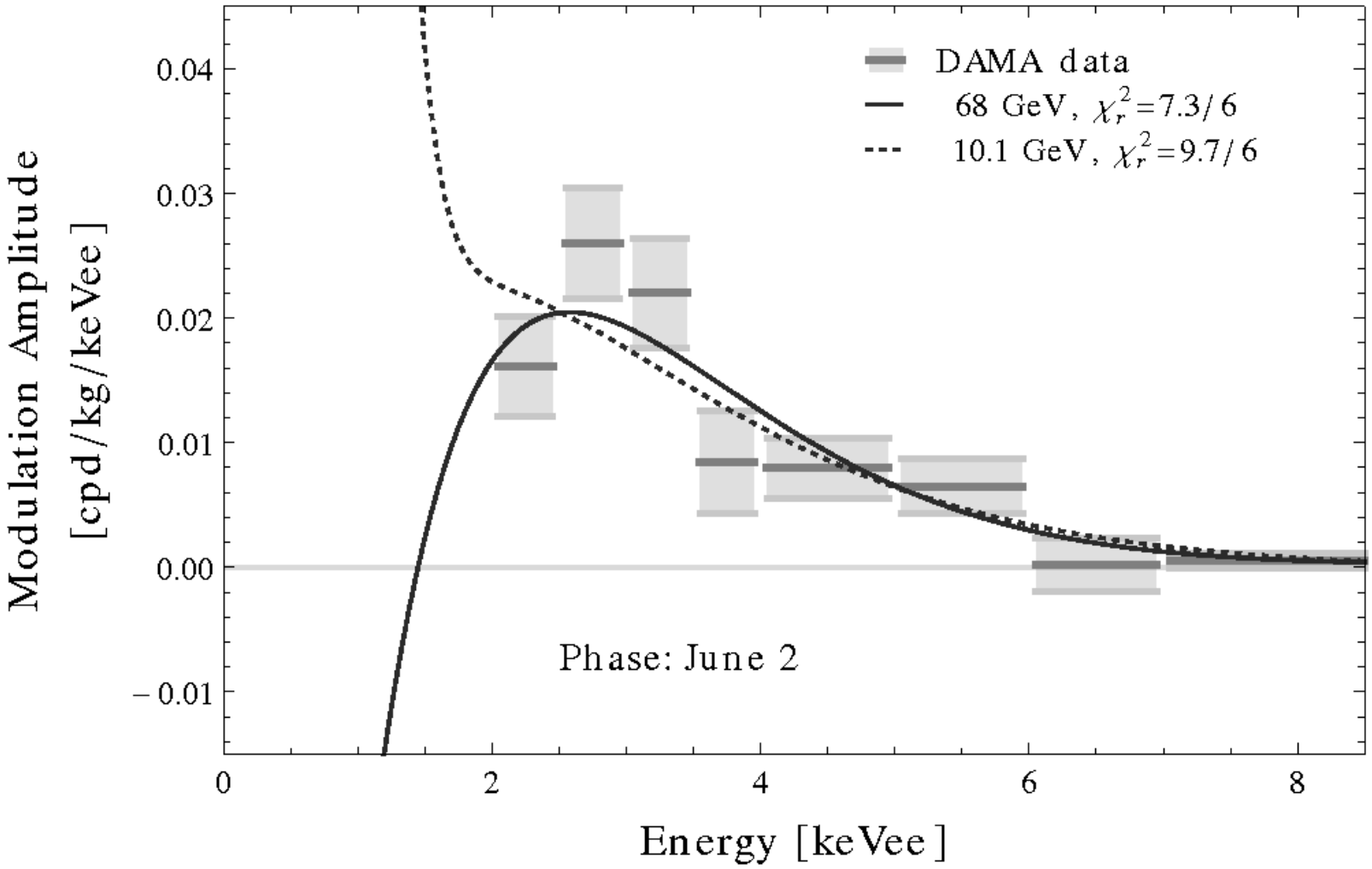


Lowering the DAMA threshold

Low-threshold Models

- Low energy possibilities
  - **Model 1:** Heavy WIMP spectrum (68 GeV)
  - **Model 2:** Light WIMP spectrum (10 GeV)
  - **Model 3:** “flat” spectrum
- Pseudo-data in two new bins over 1-2 keVee
  - Uncertainties consistent with LIBRA-like exposure
- Use existing data over 2-20 keVee

Low-threshold Models



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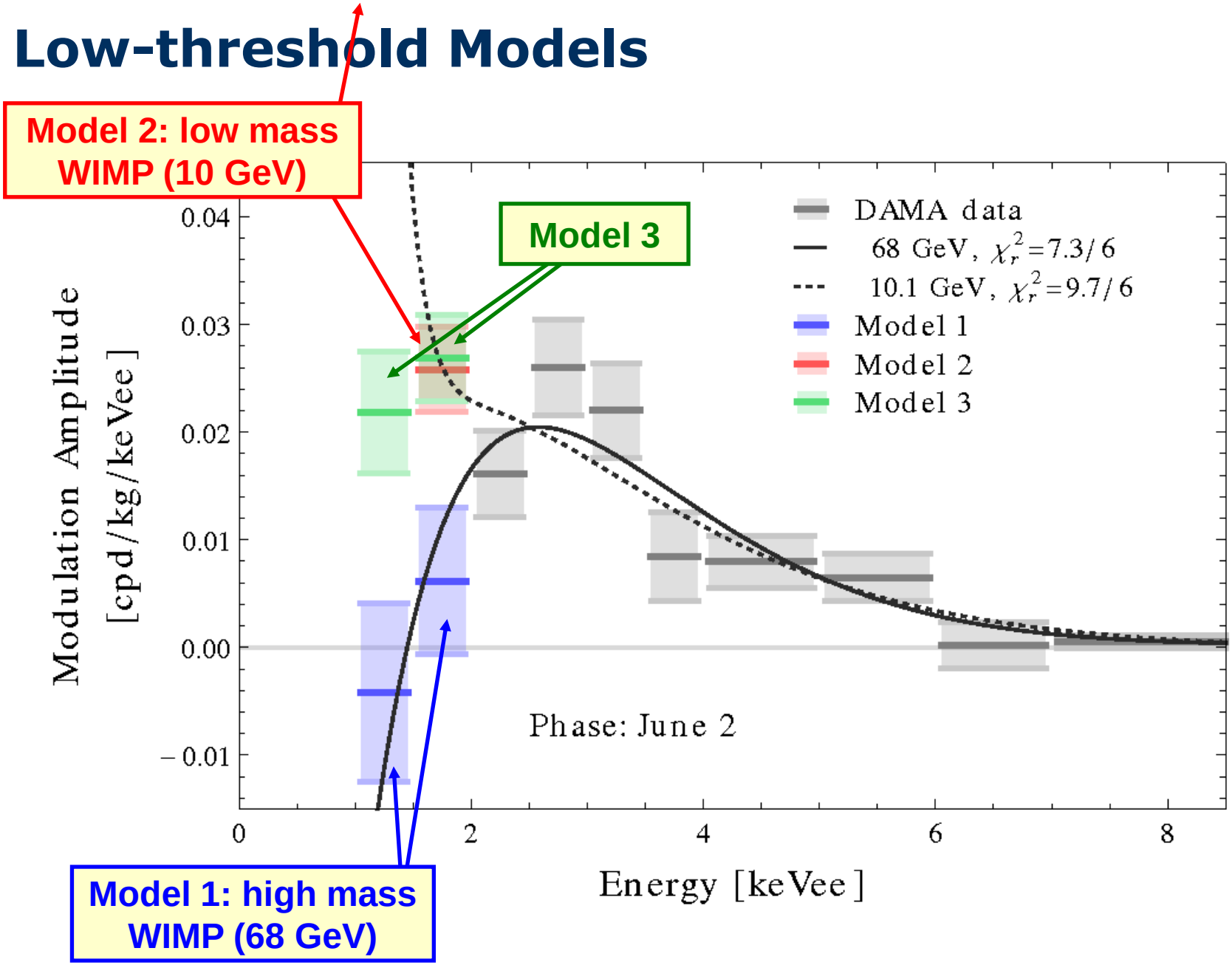
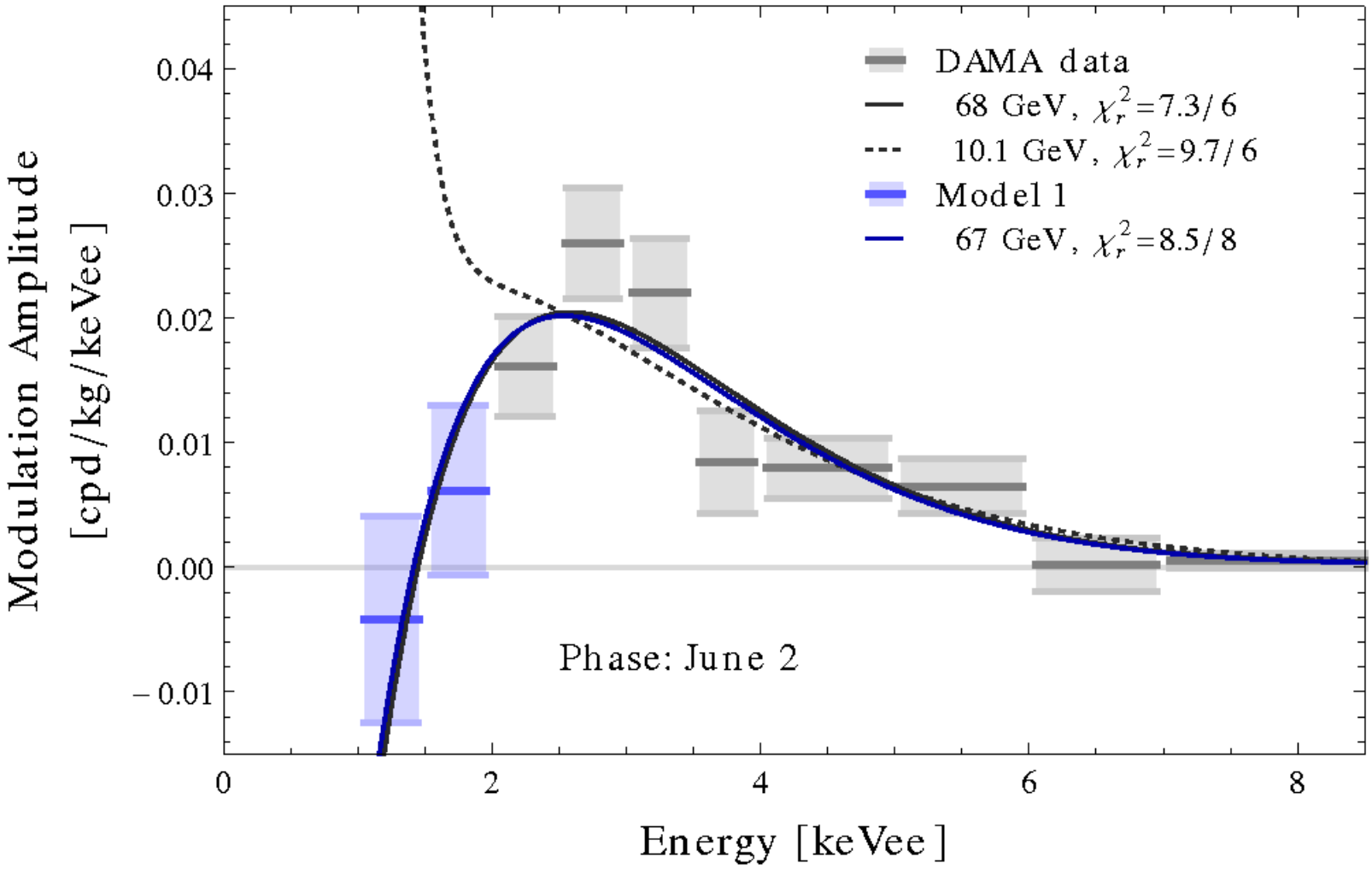
Low-threshold Models



Lowering the DAMA threshold

Model 1 (high mass WIMP)



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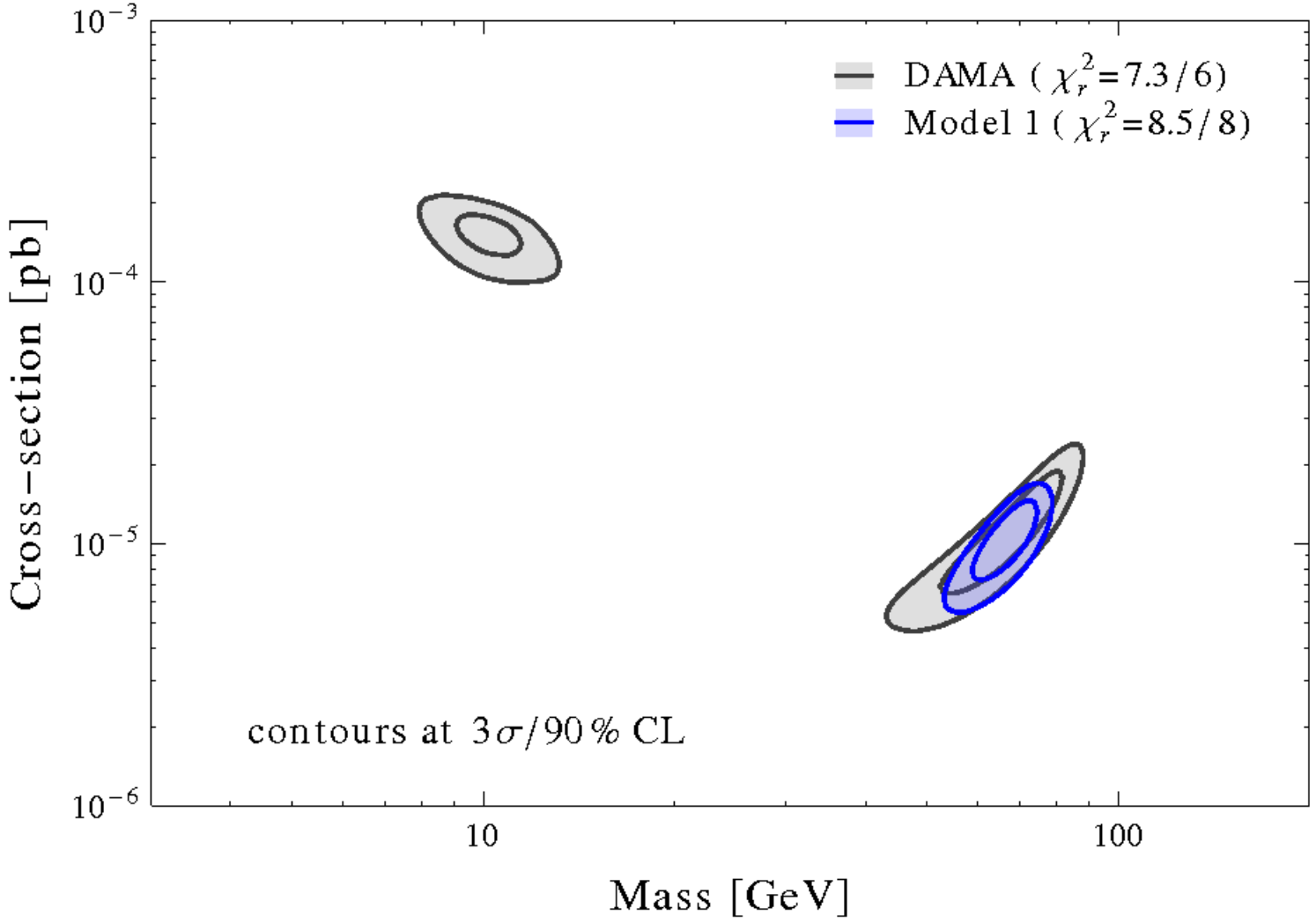

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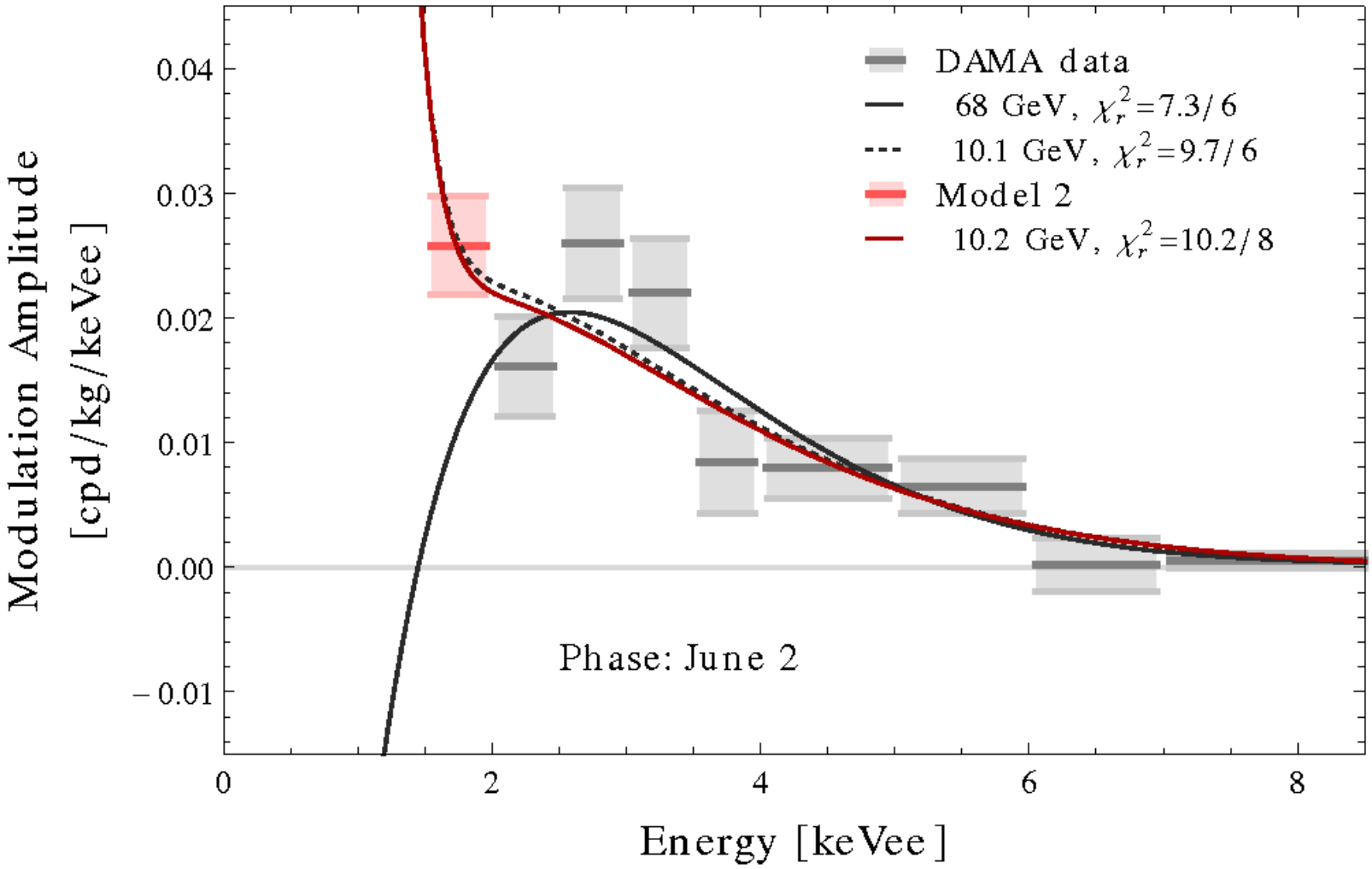
Model 2 (low mass WIMP)



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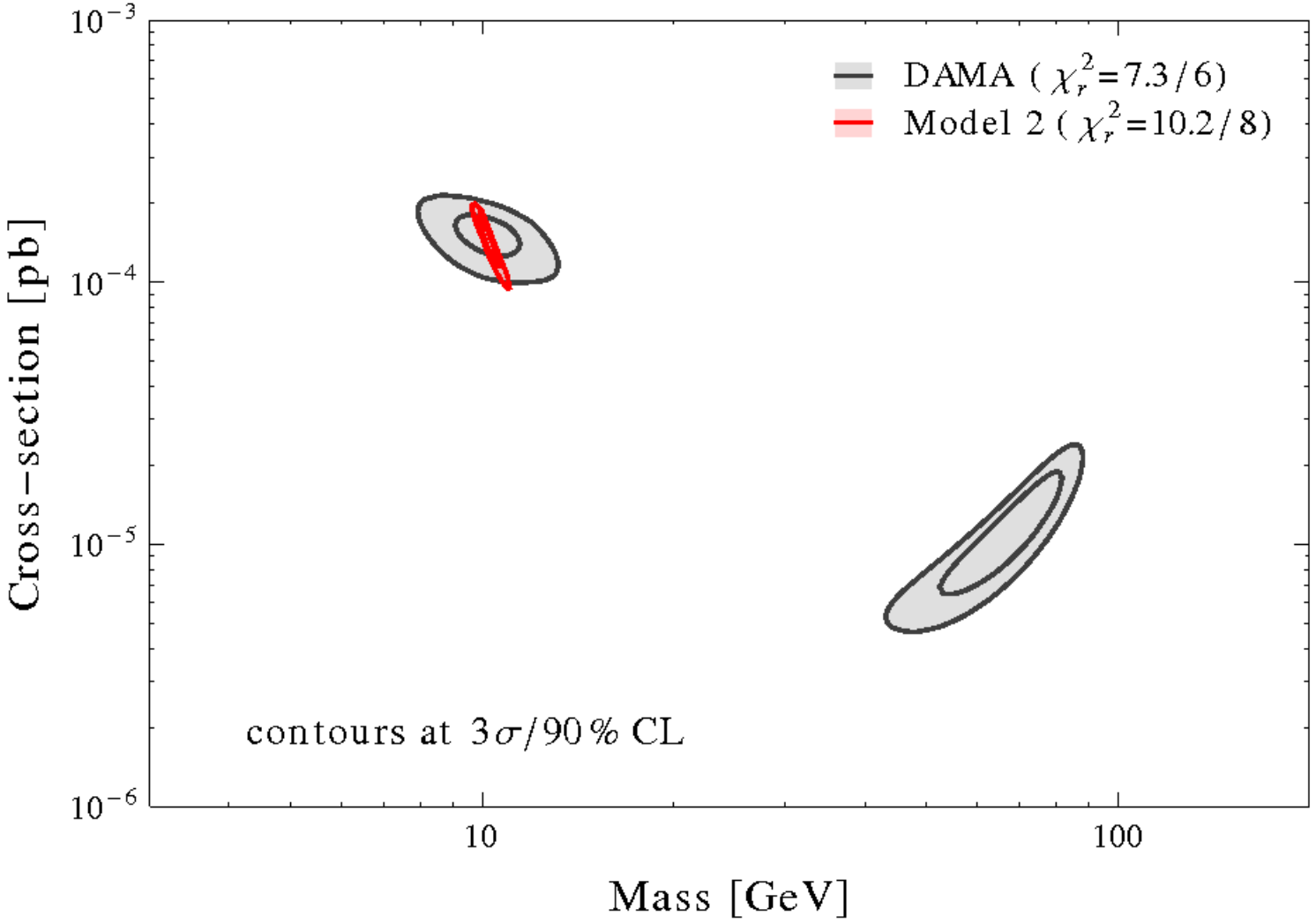

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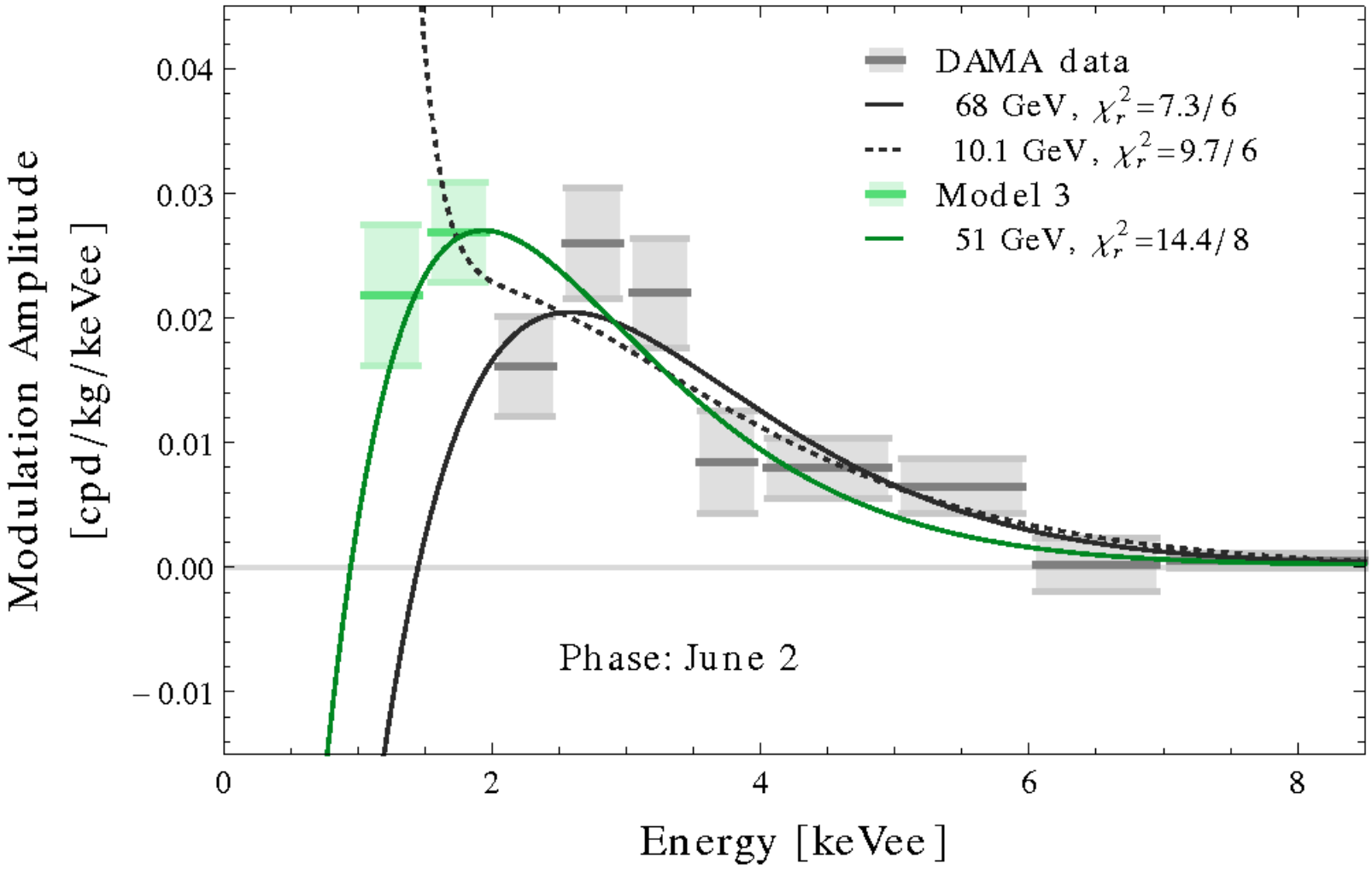
Model 3



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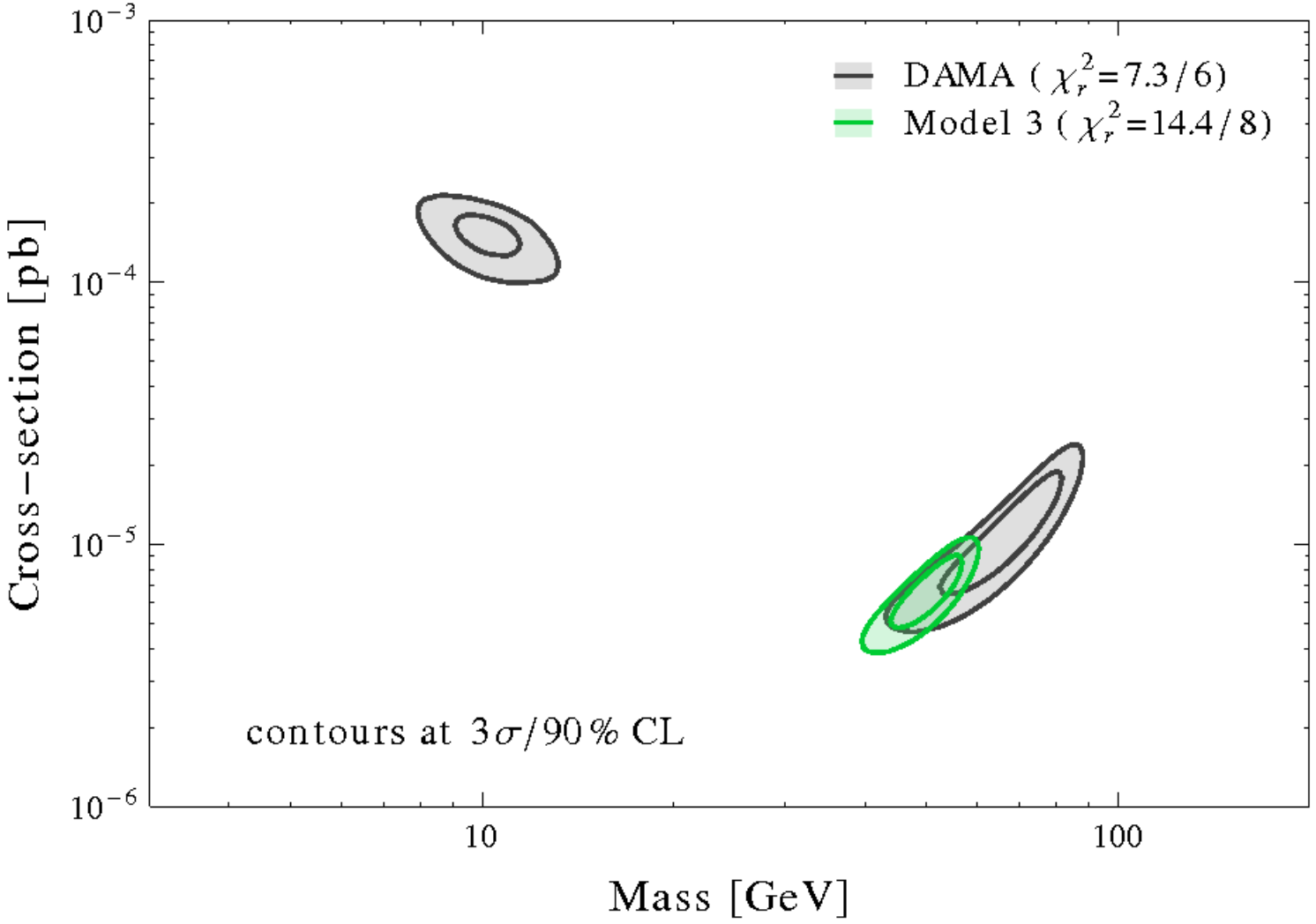

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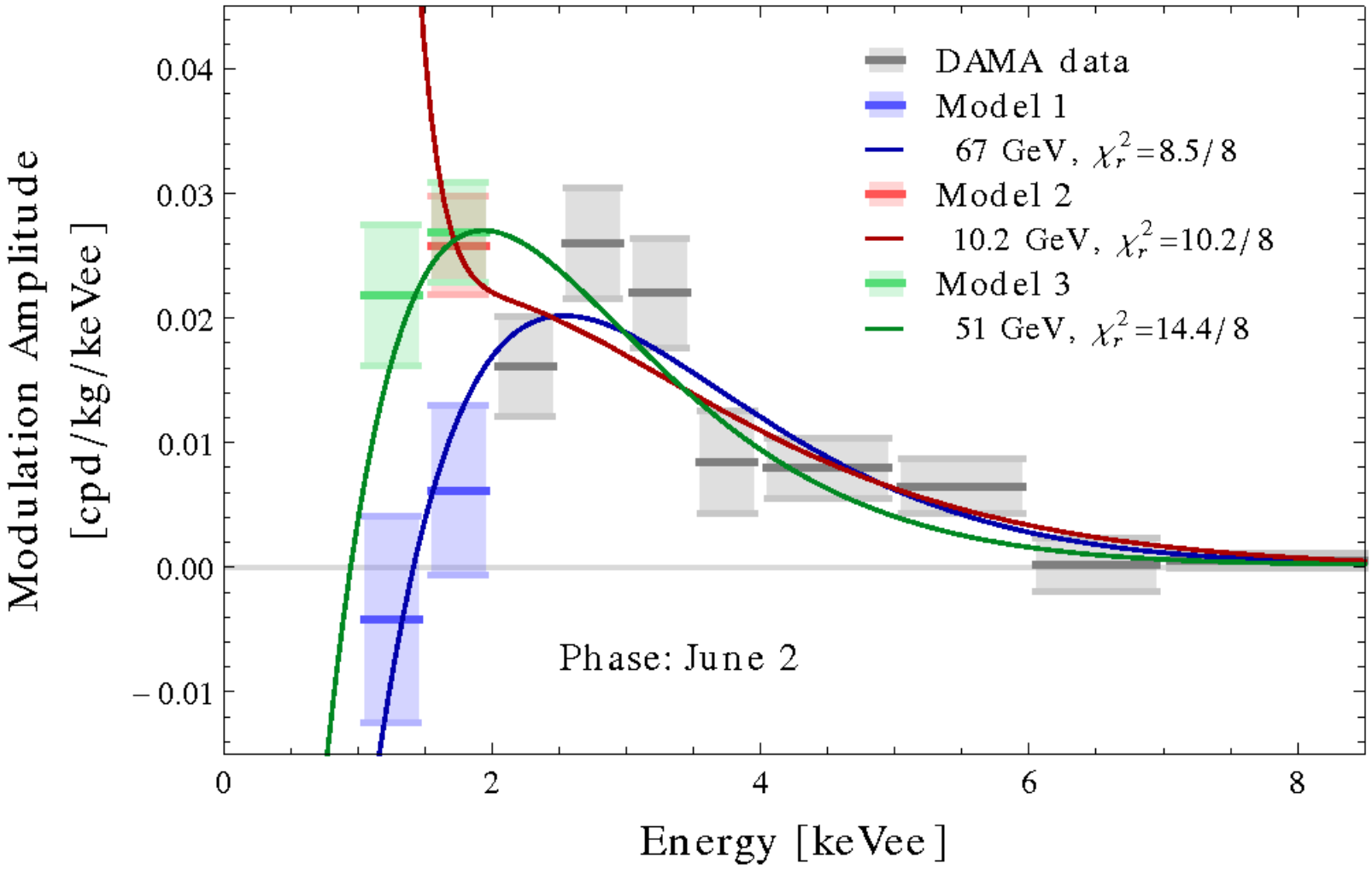
Low-threshold Models



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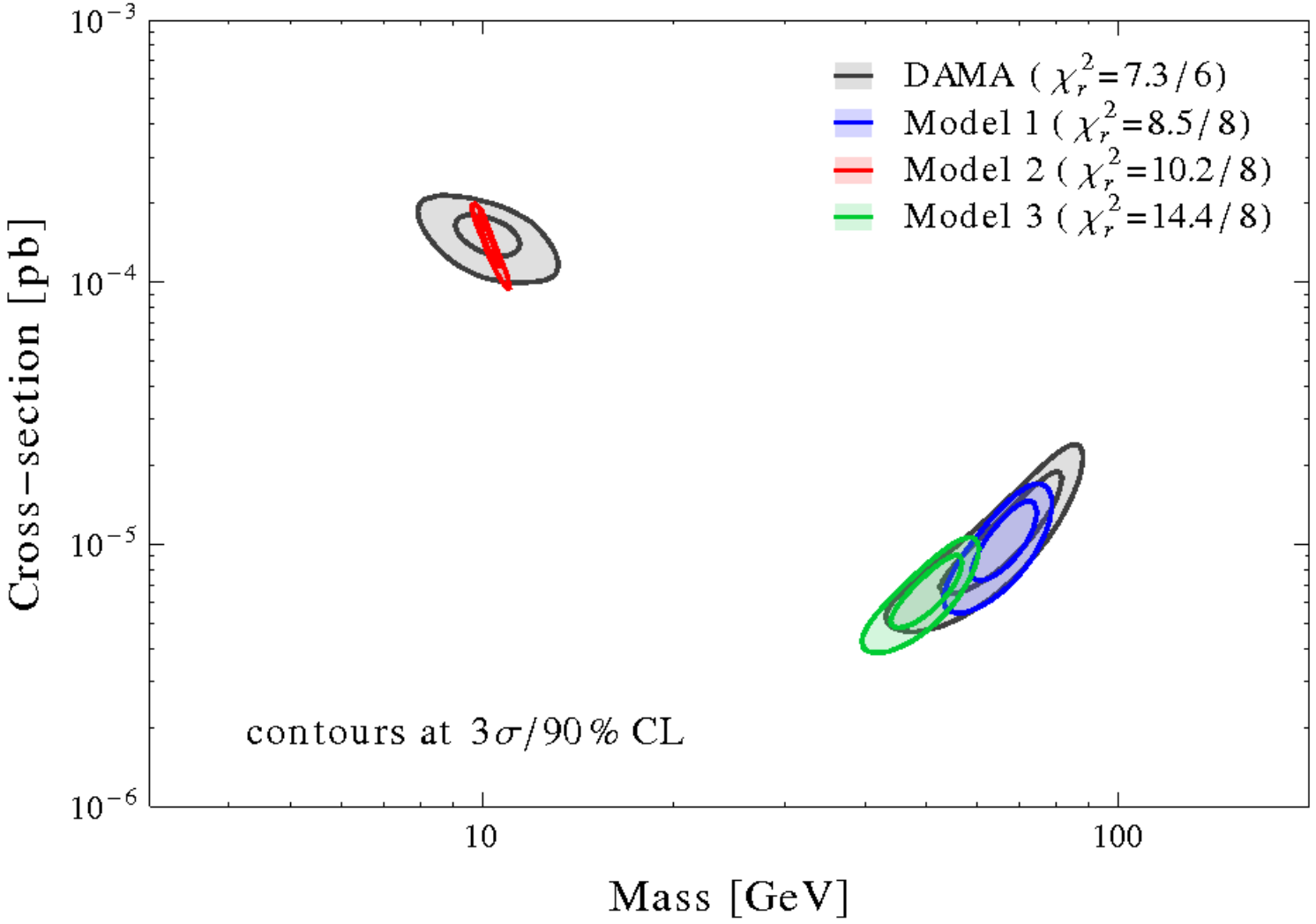

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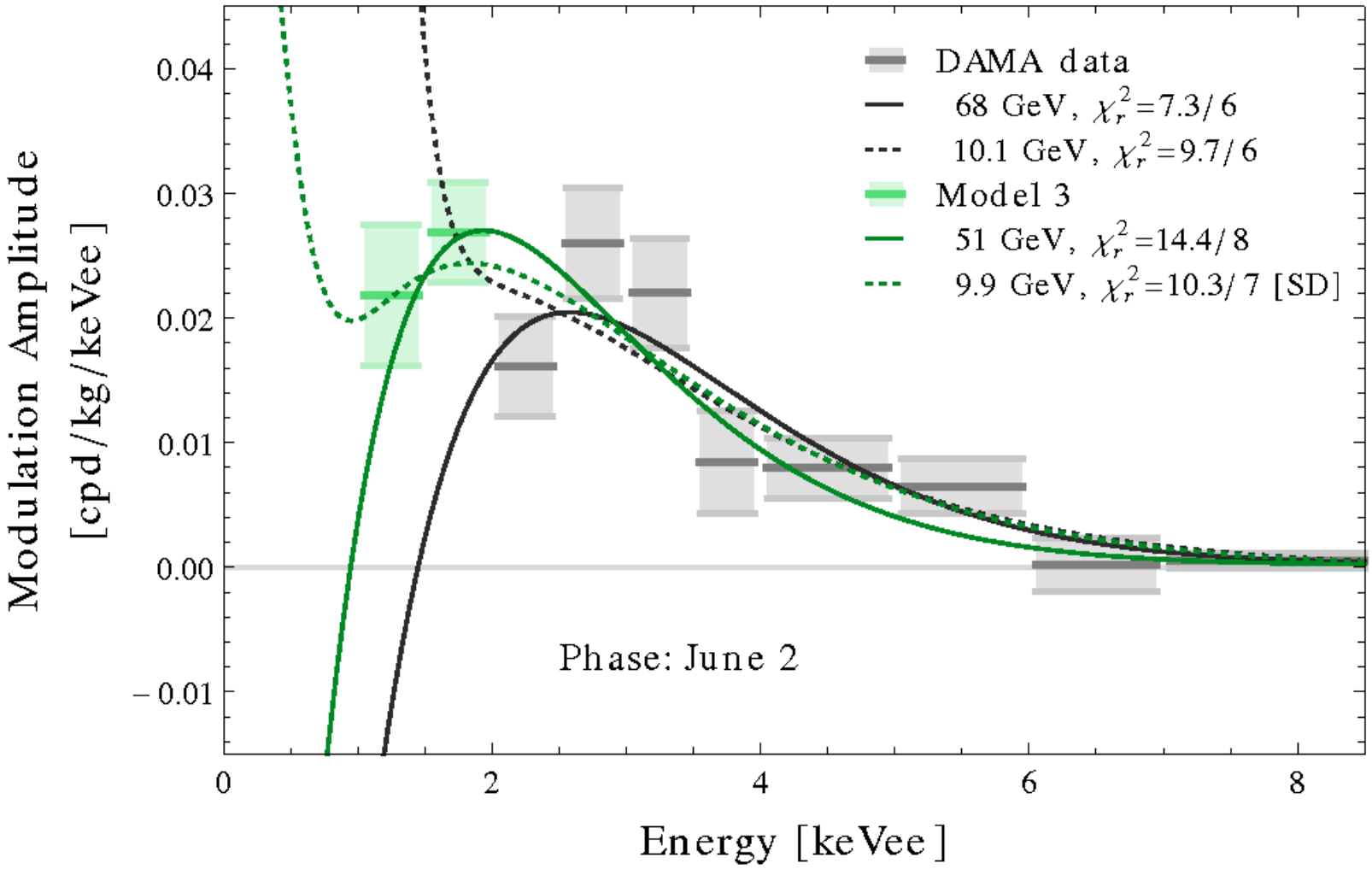
Spin-dependent Scattering

Can low-energy data help distinguish between spin-independent and spin-dependent scatttering?

Spin-dependent (Model 3)



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Spin-dependent (Fits)

	DAMA	Model 1	Model 2	Model 3
	spin-independent			
m_χ [GeV]	68.4 (10.1)	67.3	10.2	50.8
$\sigma_{\rm p,SI}$ [pb]	1.1×10^{-5} (1.5×10^{-4})	1.1×10^{-5}	1.5×10^{-4}	6.7×10^{-6}
$\chi^2_{\rm min}/dof$	7.3/6 (9.7/–)	8.5/8	10.2/8	14.4/8
	spin-dependent, proton-only ($a_{\rm n}=0$)			
m_χ [GeV]	10.3 (43.7)	11.0	3.4	10.0
$\sigma_{\rm p,SD}$ [pb]	0.60 (0.43)	0.50	7.1	0.62
$\chi^2_{\rm min}/dof$	9.5/6 (26.6/–)	22.8/8	91.9/8	10.6/8
	spin-dependent, neutron-only ($a_{\rm p}=0$)			
m_χ [GeV]	10.0 (52.5)	58.7	12.3	47.6
$\sigma_{\rm n,SD}$ [pb]	84. (9.5)	10.3	77.	9.0
$\chi^2_{\rm min}/dof$	9.6/6 (10.0/–)	14.0/8	18.0/8	11.6/8
	spin-dependent, mixed couplings			
m_χ [GeV]	8.3 (52.1)	58.7	9.1	9.9
$a_{\rm p}$	12.0 (0.24)	0.043	3.7	1.8
$a_{\rm n}$	-147. (-6.1)	-5.6	-60.	-4.2
$\chi^2_{\rm min}/dof$	8.6/5 (9.9/–)	14.0/7	9.6/7	10.3/7

Lowering the DAMA threshold

Summary and Remarks

- Modulation:
  - Phase reversal
  - Sodium and Iodine contributions
- Low-threshold modulation data can…
  - Identify if light or heavy WIMP
  - Indicate if spin-independent or spin-dependent interactions
- DAMA
  - Upgraded 2010 (improved PMT efficiency)
  - Attain significant exposure before data release (LIBRA: 4 years)
    …results within next 1-2 years?