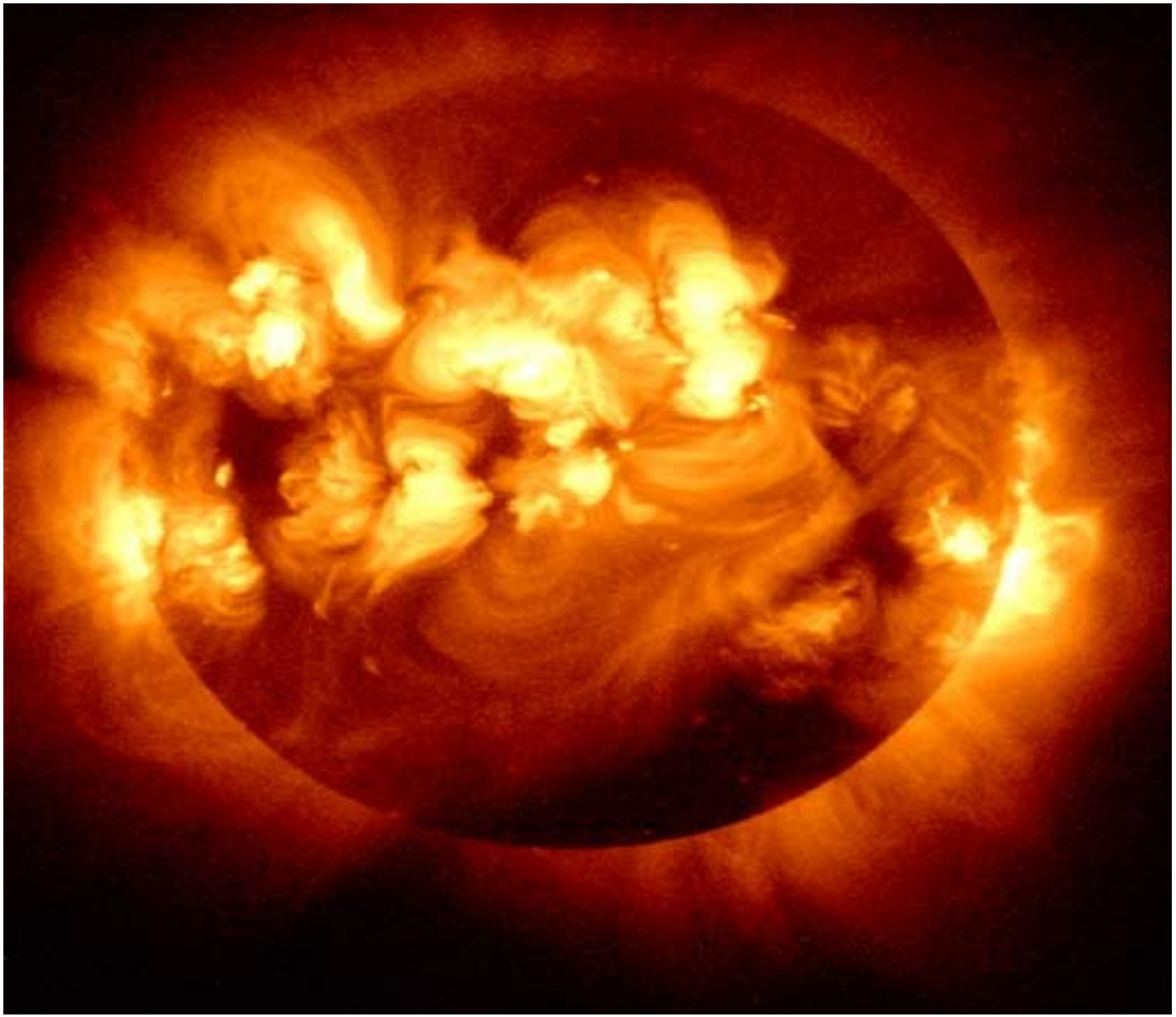
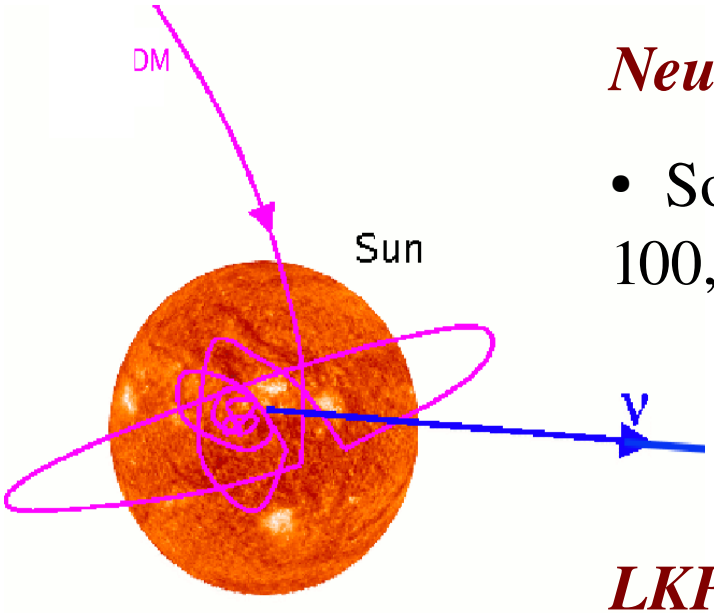
Solar WIMP Studies with *IceCube* and *DeepCore*



Overview

- WIMP searches with IceCube and DeepCore
- Differences to initial study (done by Gustav Wikström)
- Reconstruction and higher level filtering
- Effective Volume
- Expected sensitivities on muon flux from WIMP-annih. in the Sun and SD WIMP-proton cross-section
- Explanation of Result

WIMP Search with IC80+DC6



Investigated WIMP models:

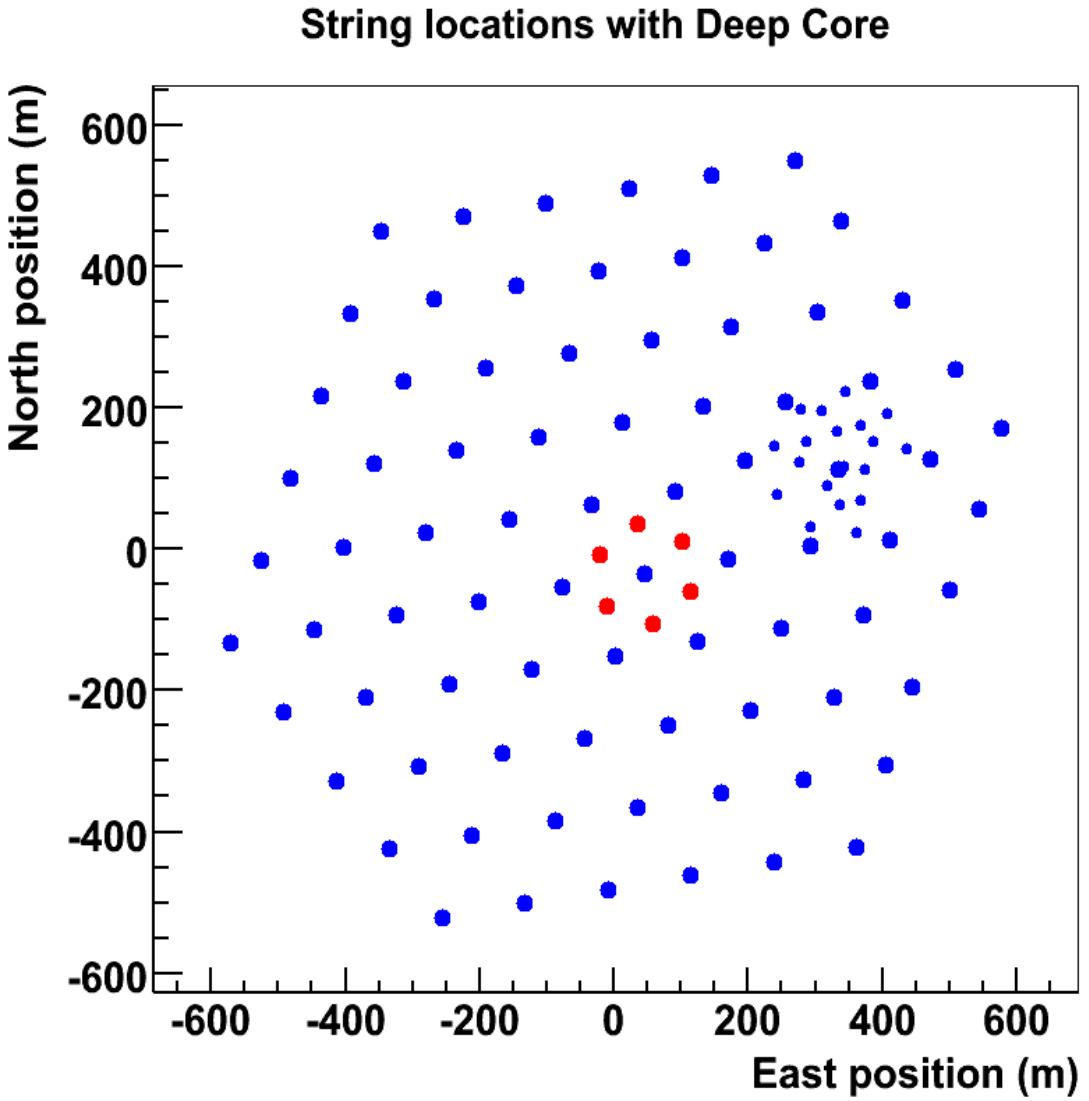
Neutralino:

- Soft (bb) and hard (W+W-/τ+τ–) for energies (50, 100, 250, 500, 1000, 3000, 5000) in GeV

LKP:

- 'true' composition from LKP annihilations (fixed branching ratios) for energies (300, 500, 700, 900, 1100, 1300, 1500) in GeV

WIMP Search with IC80+DC6



Simulated DataSets

2 Detector Configurations:

- **IC80+DC6-case**, all 80 IceCube strings, DeepCore strings (81,82,83,84,85,86) and additionally the HighQE-DOMs deployed on IC-string 36 are used.
- **IC80-case** uses 80 'ordinary' IceCube strings without any extensions or HighQE-DOMs on string 36. (reference Detector)

	Single Muon	Coincident Muon	Triple Coin. Muon	atm. Nu
Livetime	~ 1 h	4 h	~ 1 d	~180 d
Simprod Datasets	1509	1511	1550	1560

Differences to Initial Study

- IceCube-80 remains the same configuration
- Decreased DOM spacing on DeepCore strings
- HighQE DOMs for DeepCore strings and parts of string 36
- 10 times more single muon and atmospheric neutrino background
- Coincident and triple coincident muon background
- Different Trigger and Reconstruction settings

  → (SMT8 + StringTrigger(5/7;1000ns) + LETrigger(SMT4 for DC+1layer of strings))

  → (reconstruction → as close as possible to current standart processing)

- SLC not used so far, only HLC

Level L0 and L1 filtering

(Reconstruction version *IceRecV02-02-00* is used)

L0:

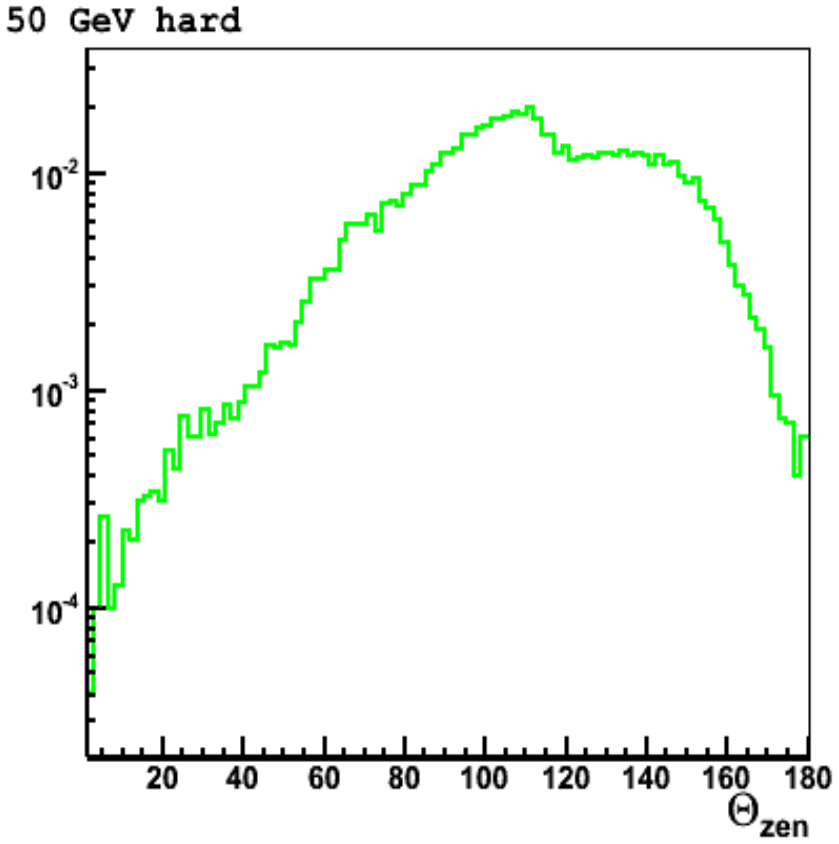
- Broken DOM cleaning
- HLC
- Event time-window of 4500ns

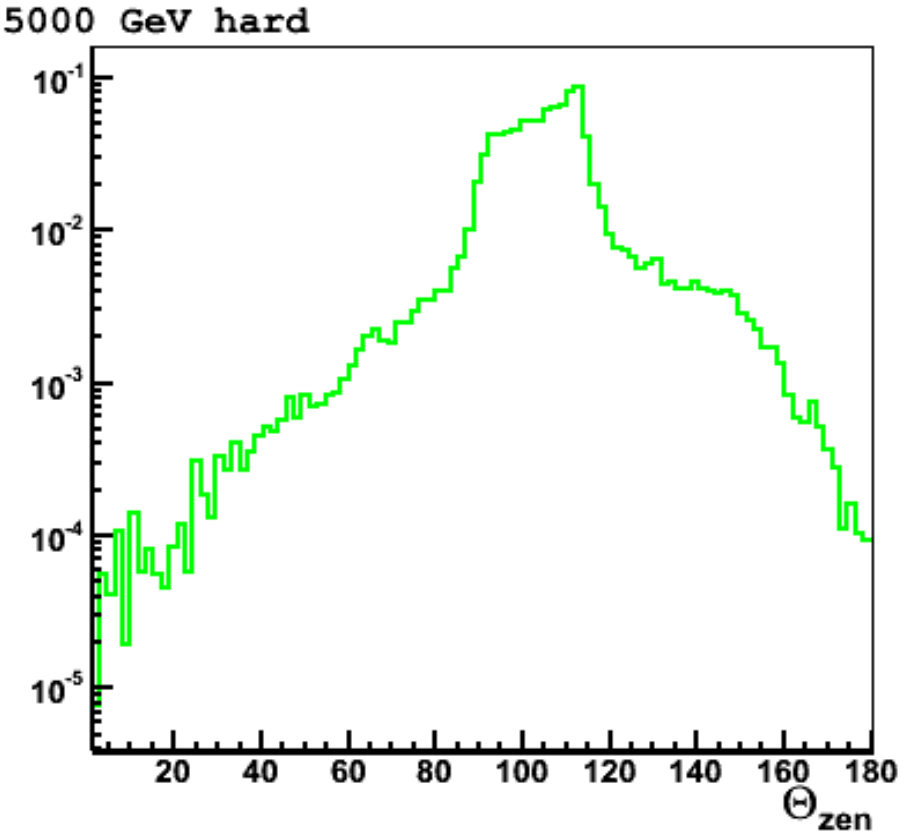
L1:

- *IceCube-Muon-Filter* (only track > 70°)
- *IceCube-Contained-Filter* with a new (IC80+DC6 veto file)
- *IceCube-LowUp-Filter*

Level L2 filtering

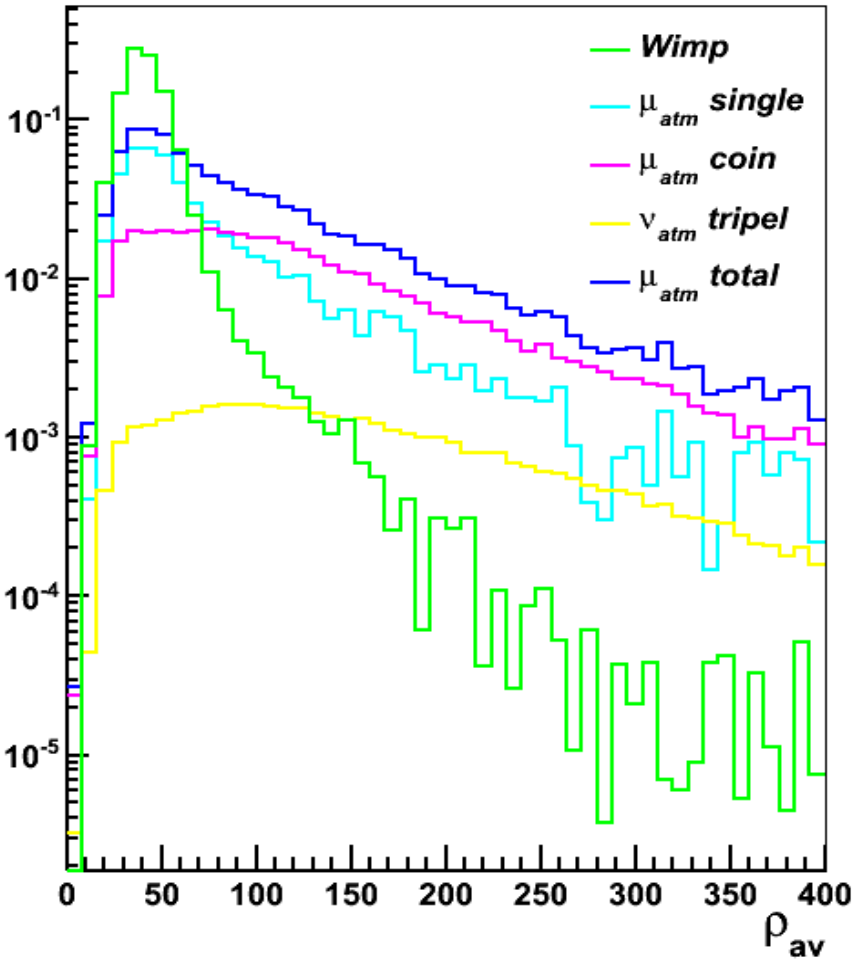
- LLH reconstructed zenith angle **[86° < Θ < 120°]**
- z_travel **> -30**
- Single string events are neglected nstring **>1**

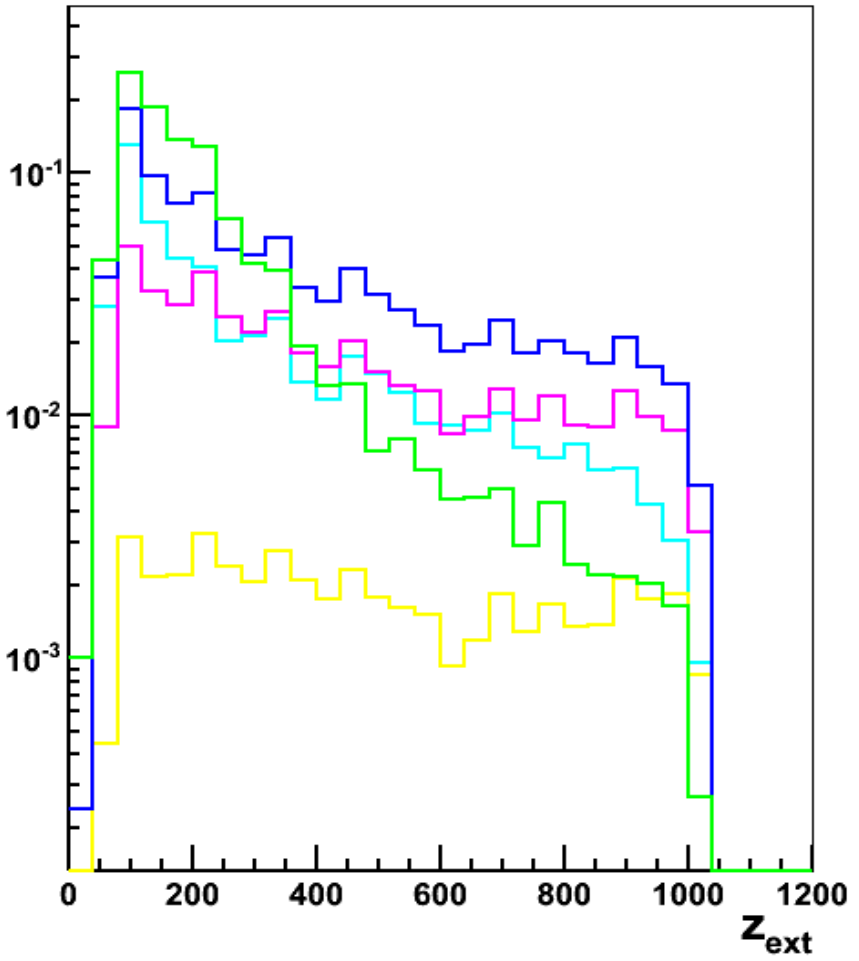




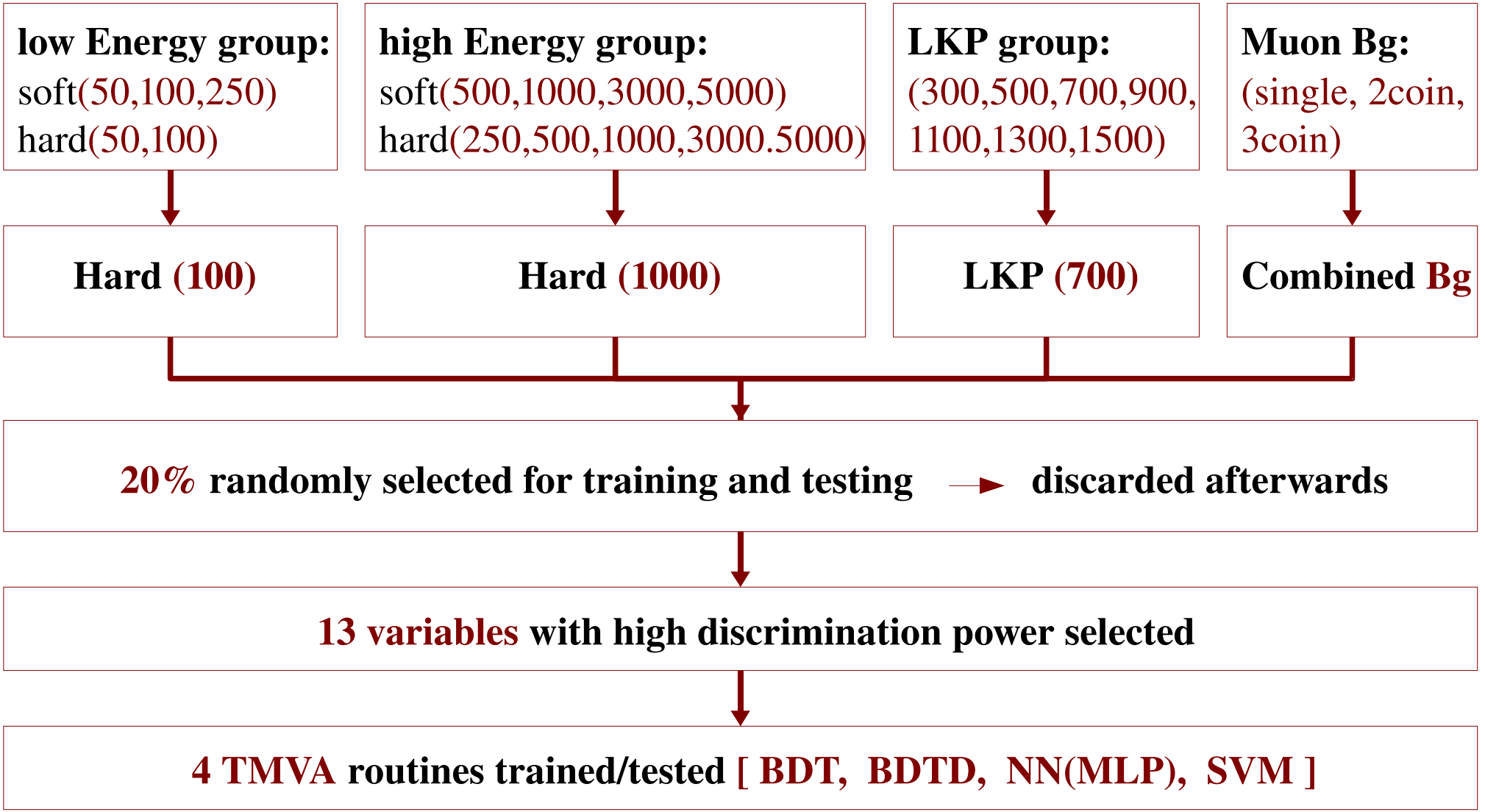
Level L3 filtering

- ρ_av **< 100m** Sum all strings (Sum of shortest distance from track to string/nchan)
- z_extern **< 400m** Extension of muon track in z direction in metre (z[max]-z[min])





Level L4 filtering (multivariate)



Level L4 filtering

- var1 = Θ_llh
- var2 = ndir[a]+ndir[b]+ndir[c]+ndir[d]
- var3 = separation
- var4 = z_travel
- var5 = time_ext
- var6 = cog_z
- var7 = ρ_av
- var8 = rllh
- var9 = 3*nchf-nchv-nchvetolid
- var10 = ndirstr[a]+ndirstr[b]+ndirstr[c]
- var11 = smoothness_[a+b+c+d]
- var12 = ldir[a]
- var13 = σ_paraboloid

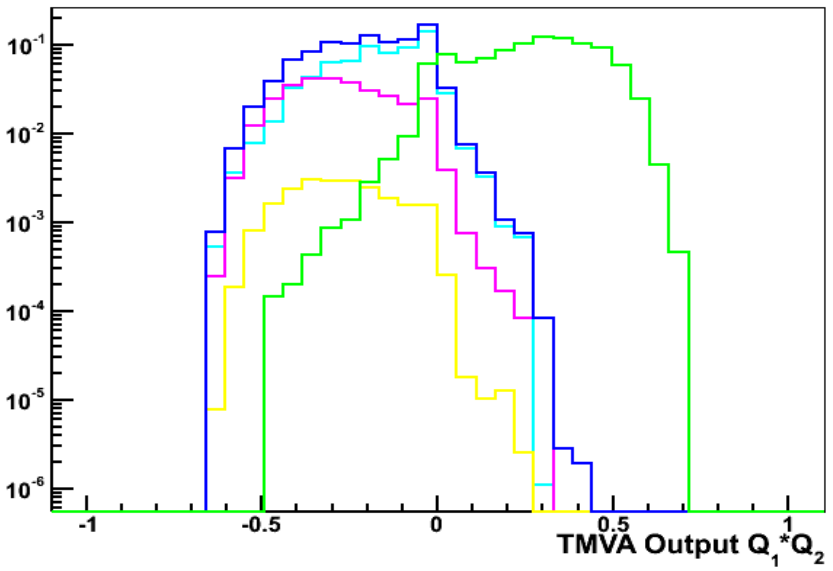
- For each sample (Detector config./WIMP model)

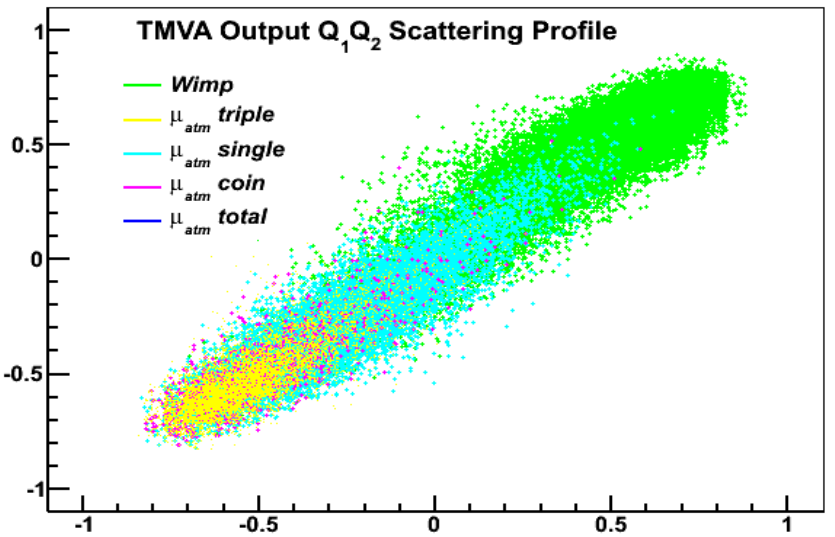
  -> try to find best cut on any combination of Q^1*Q^2
- MRF used to find optimum cut value and method for fixed Ψ [6°(high E)/10°(low E)]
- Additional cuts for (DeepCore/high E)-configuration to remove muon-Bg

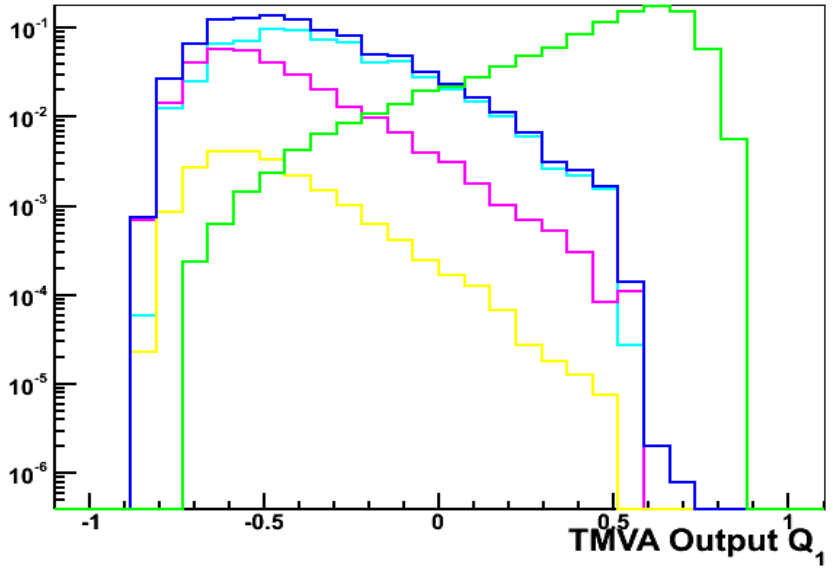
  (ldir[a+b+c+d] > 500m, nstr > 2)
- In the (DC/low E) sample also further cuts on atm. Neutrino Bg

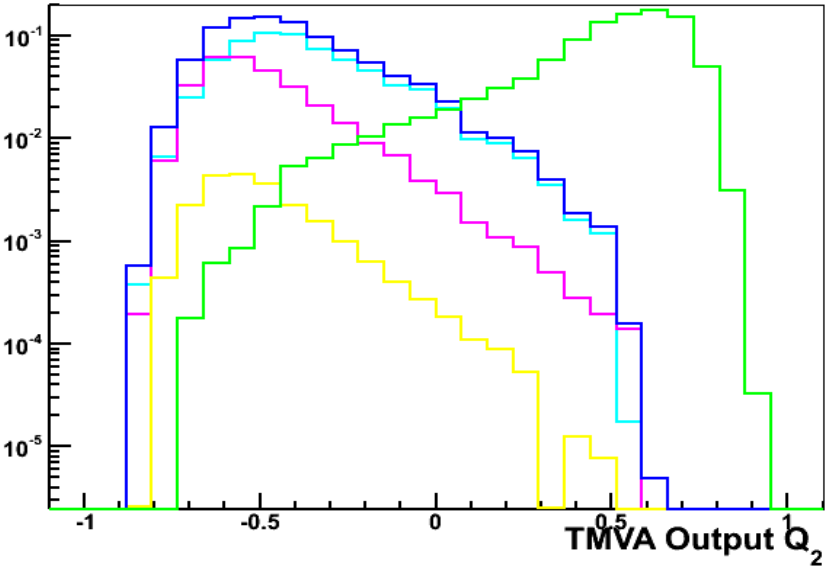
  (ldir[a/b/c/d] < 300m, smooth[a+b+c+d] > - 0.6, nstr < 8, nveto_str < 3, ndir[a+b+c+d] < 180)

Level L4 filtering









Expected rates (high Energy group)

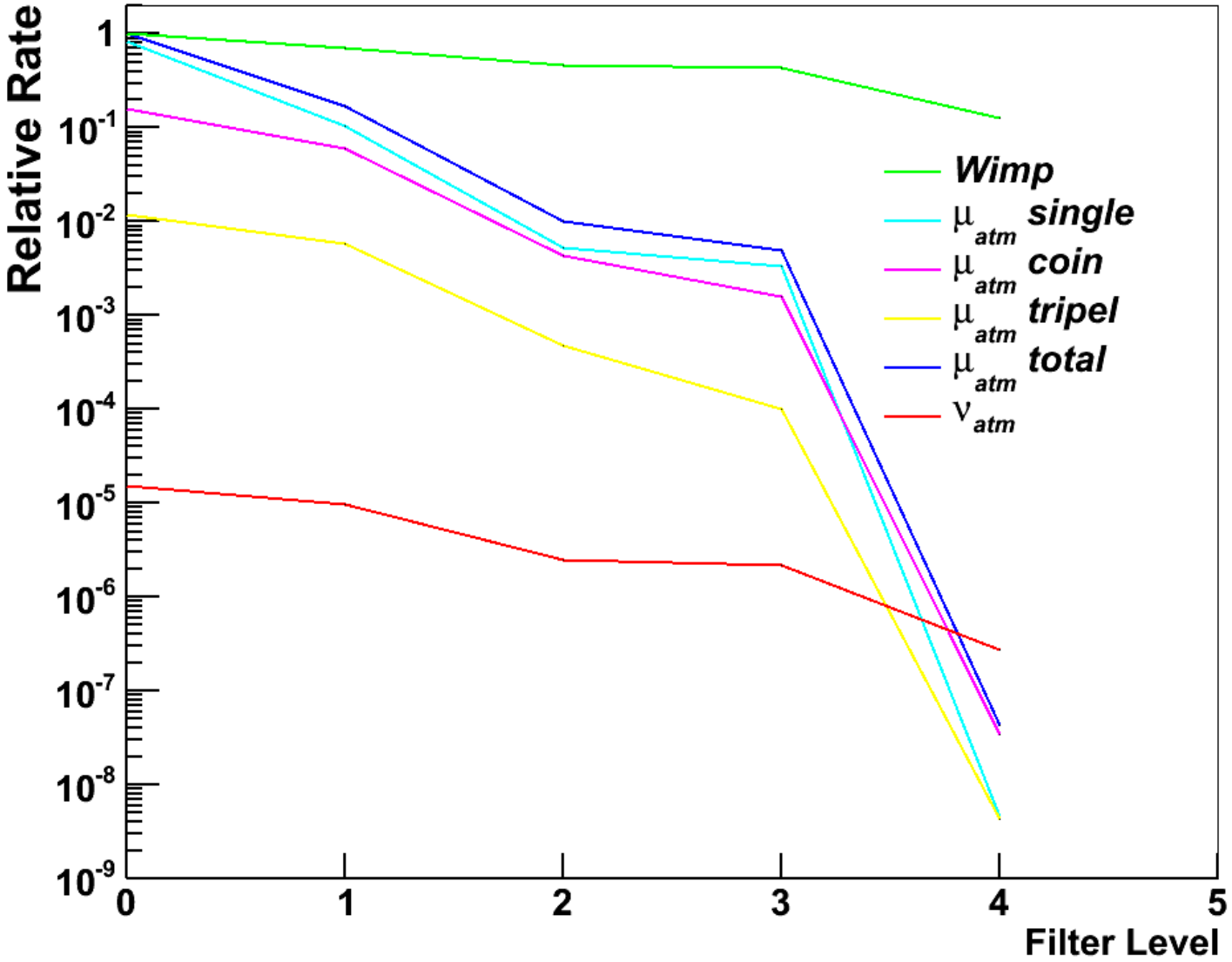
To ensure **'good'** muon background reduction (relative short samples)

→ cuts are set harder than maybe necessary (cut until 0 coin. Events left)

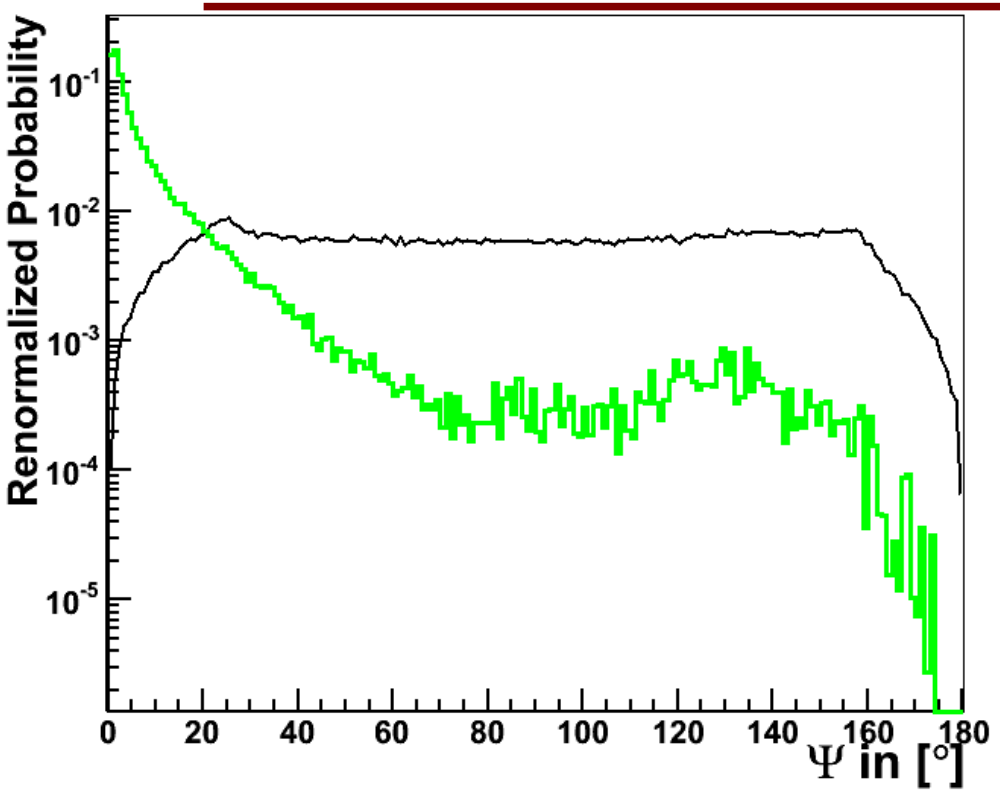
Expected rates for simulated background-samples:

Level	Muon bkg sum	Single Muon	Coin. Muon	Tripel Coin. Mu	atm. Nu
Trig. level	2303 Hz	1903 Hz	372.5 Hz	27.1 Hz	35.2 mHz
Level 1	396 Hz	242.9 Hz	140.3 Hz	13.3 Hz	22.6 mHz
Level 2	23.3 Hz	12.1 Hz	10.1 Hz	1.1 Hz	5.65 mHz
Level 3	11.5 Hz	7.7 Hz	3.6 Hz	0.23 Hz	5.04 mHz
Level 4	<0.12 mHz	0.01 mHz	<0.1 mHz	<0.01 mHz	0.64 mHz

Filter Efficiency (hard 1000)



Solar Search L5



Probability density functions for signal and Bg of finding a certain event x within a search cone Ψ

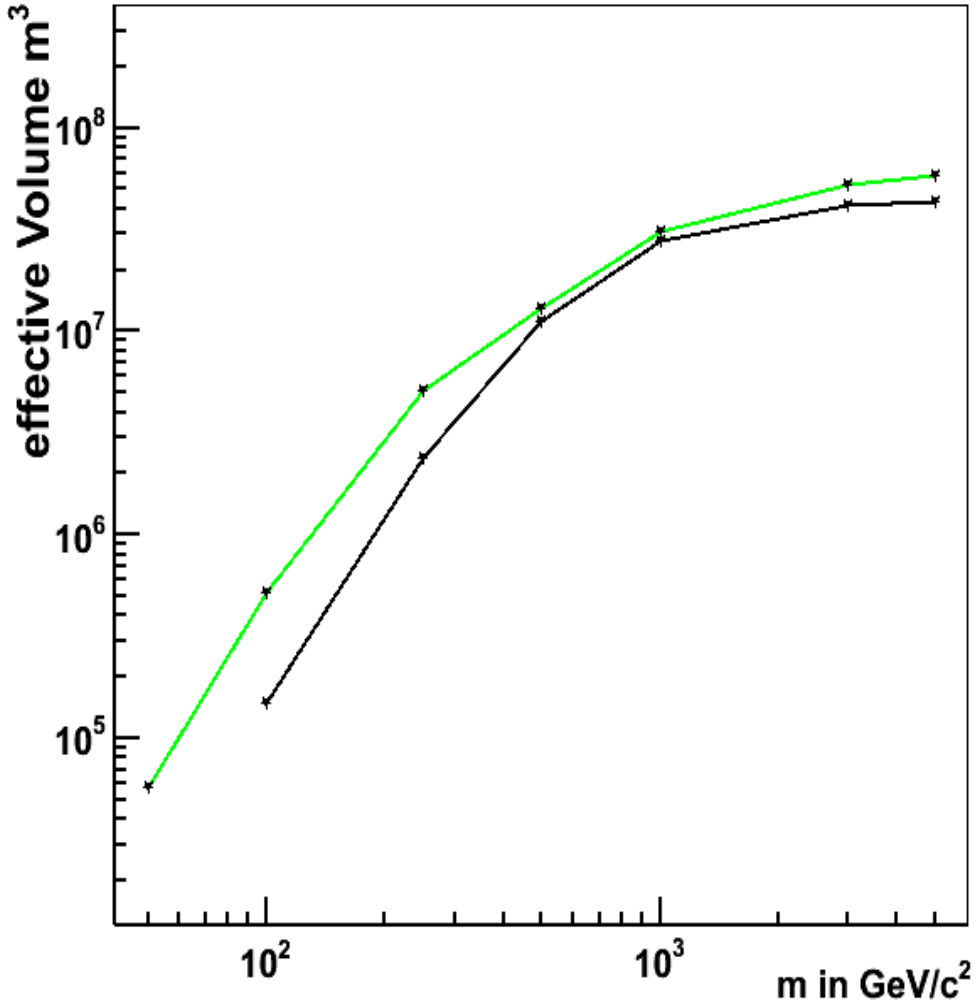
$$\epsilon_1(\Psi) = \frac{\sqrt{n_{Bg}}}{n_s}$$
$$\epsilon_2(\Psi) = \frac{\sqrt{eff_{Bg}}}{eff_s}$$
$$MRF = \frac{\overline{\mu}_s^{90\%}}{n_s}$$

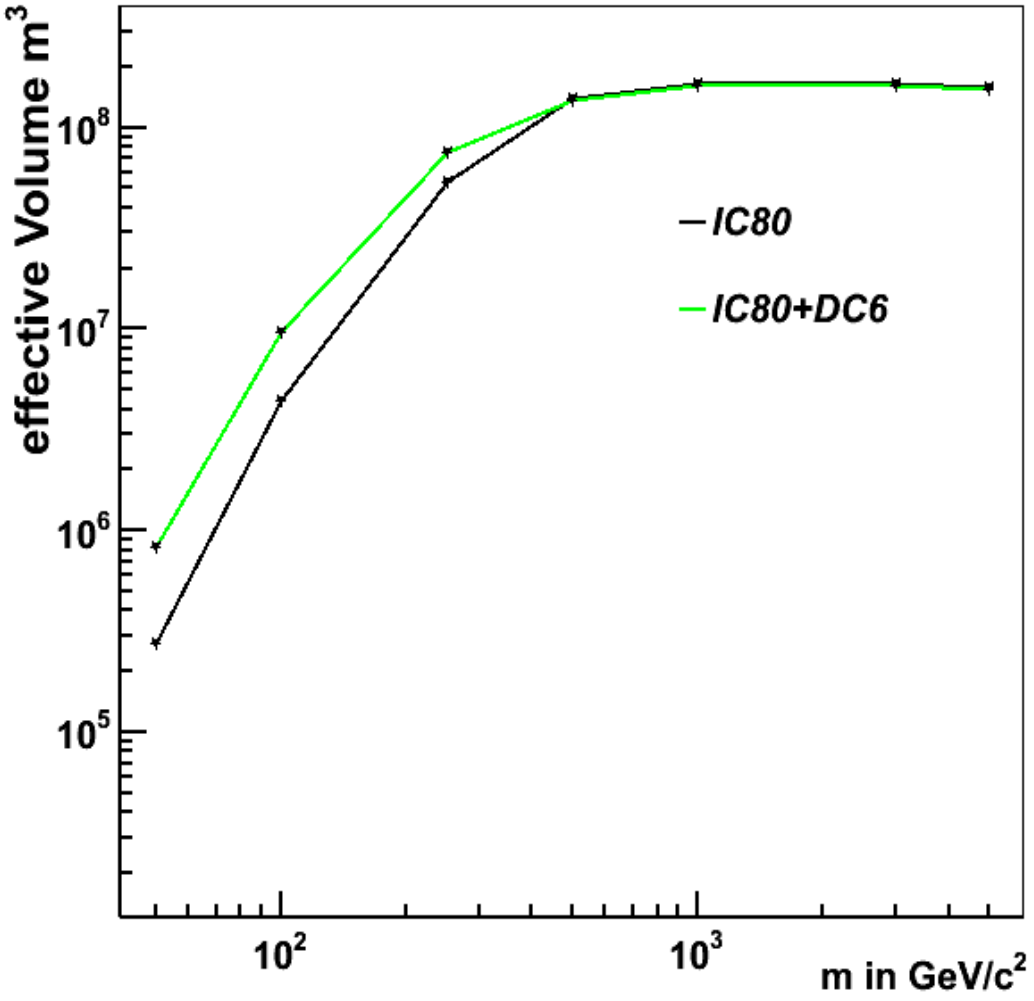
3 methods are tested for Ψ

WIMPmodel	LKP	high Energy	low Energy
Ψ in deg	3	3	7

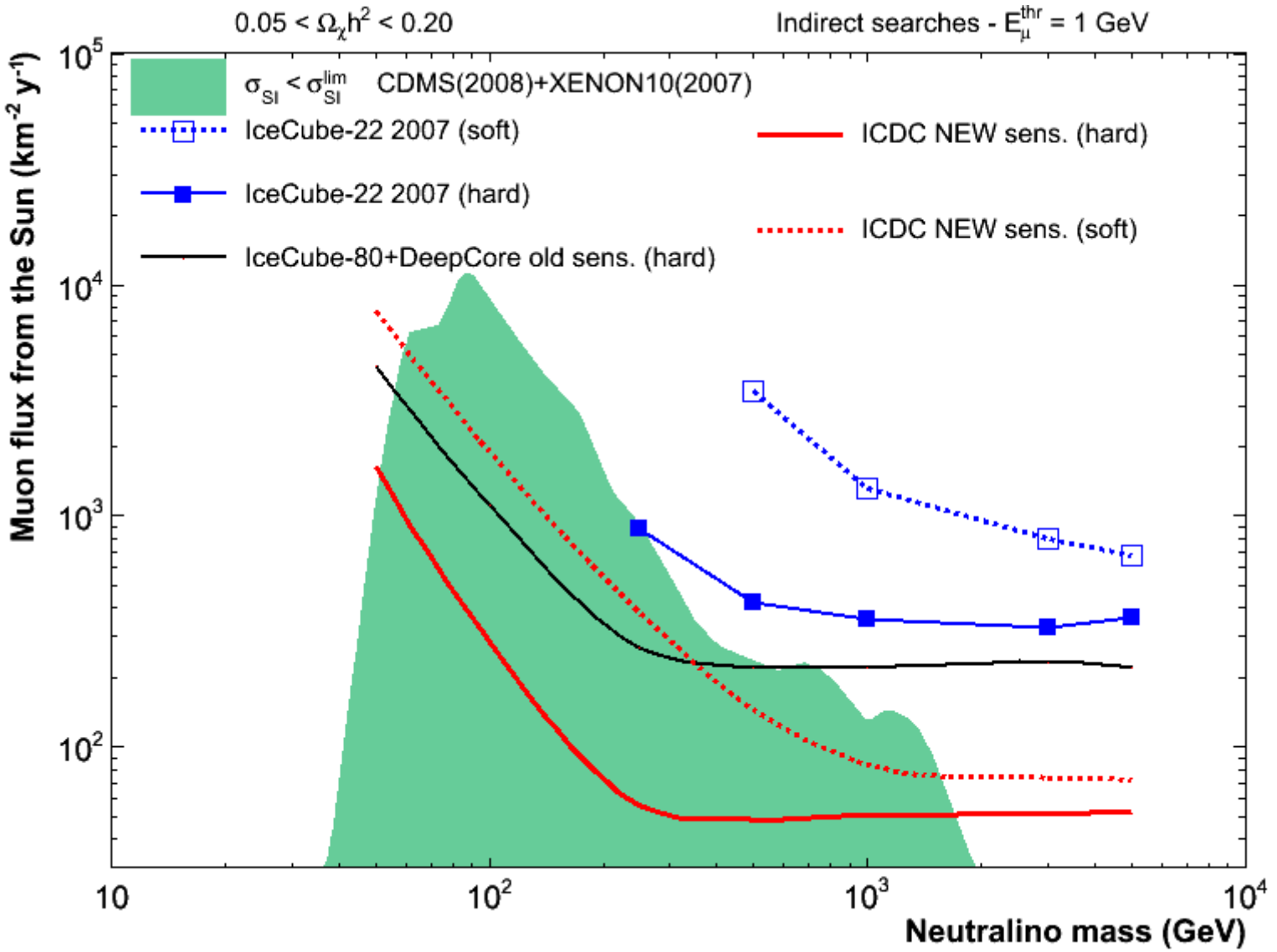
MRF gives the minimum values for the nu-to-muon conversion rate

Effective Volume (Neutralino)

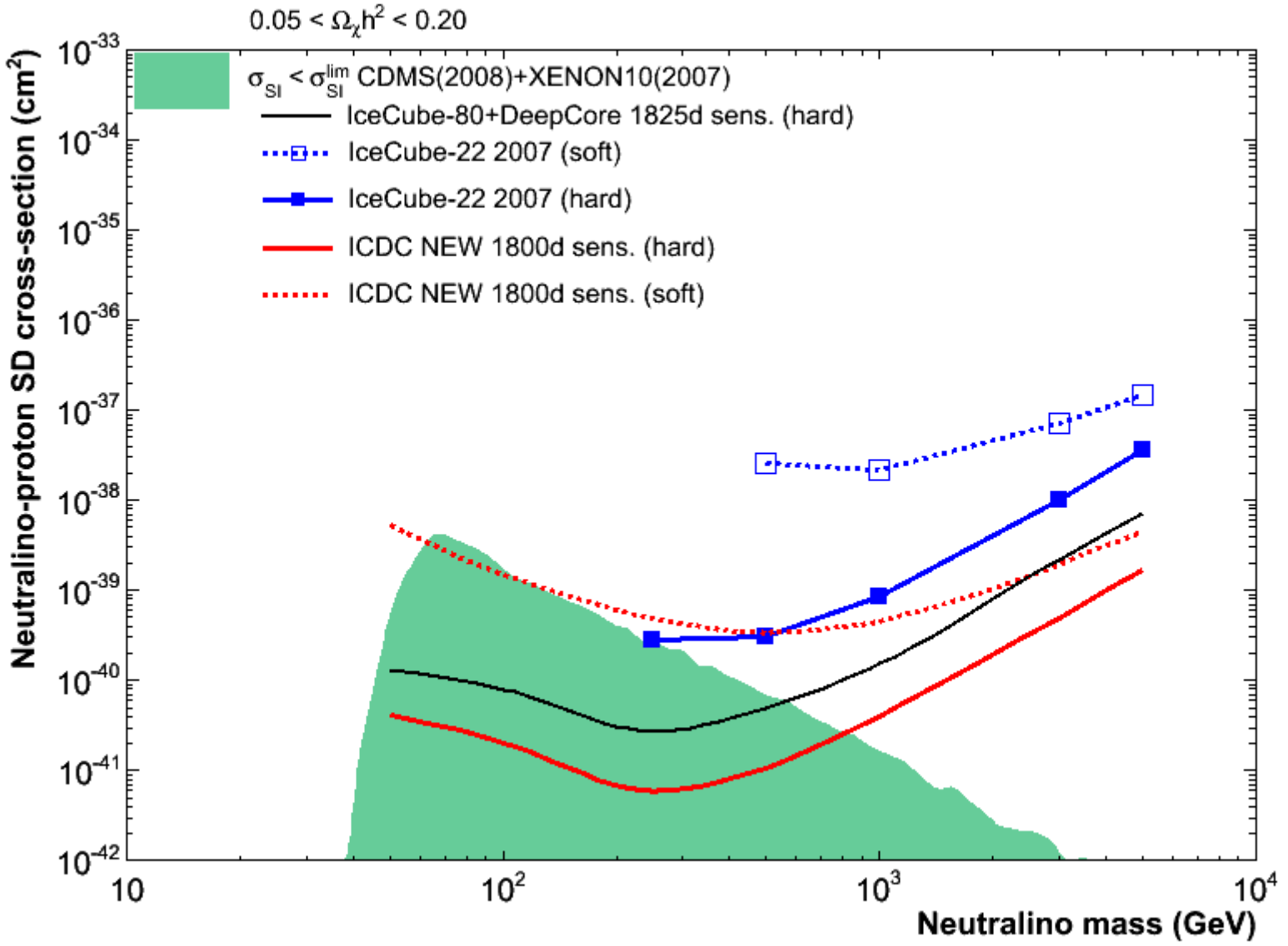




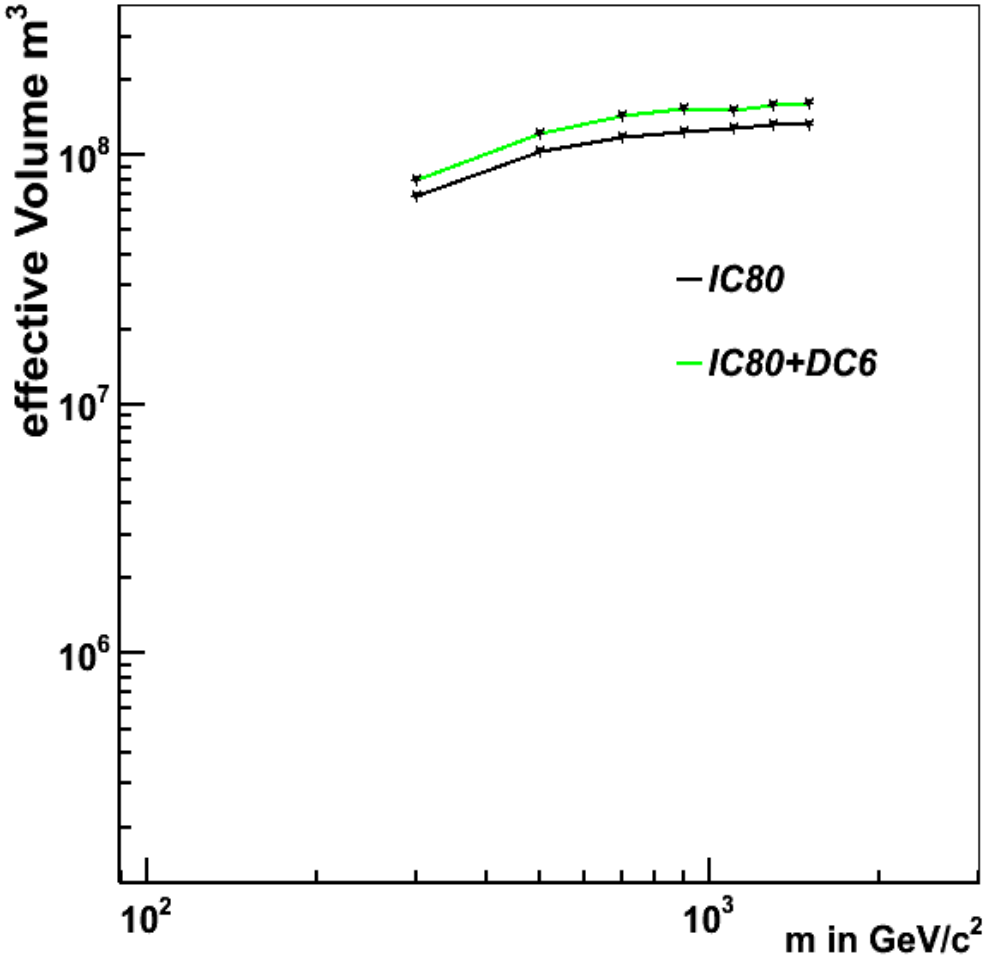
Muon Flux Sensitivity (Neutralino)

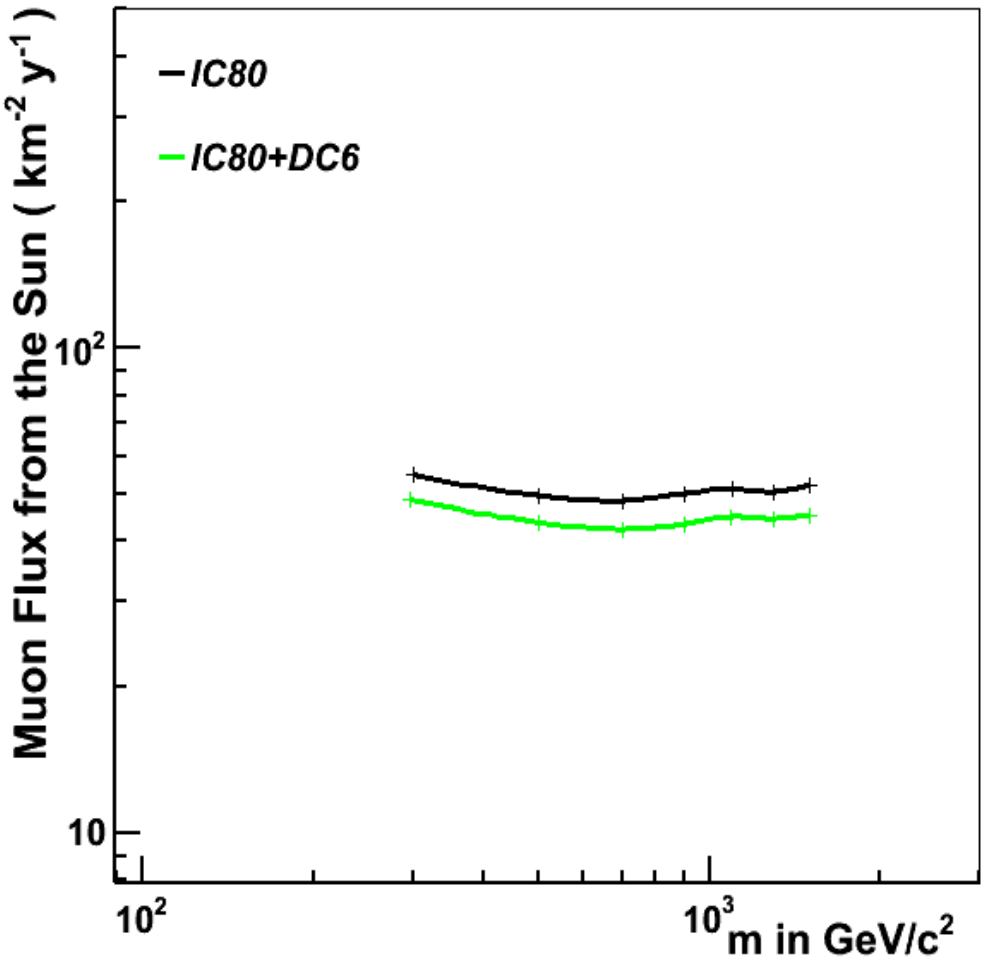


SD Cross-Section Sensitivity (Neutralino)



Effective Volume and muon Flux (LKP)





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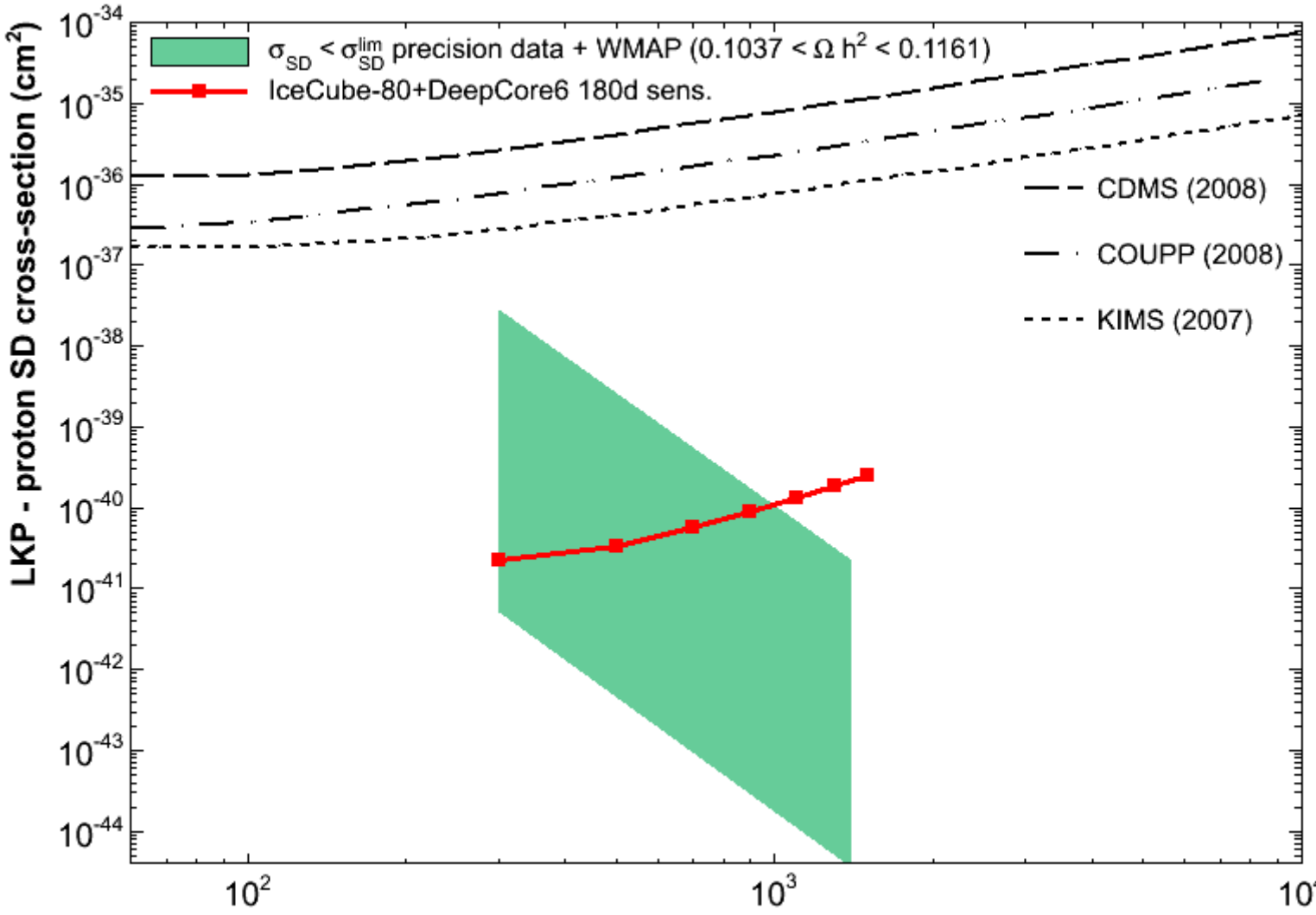


$$0.01 \leq r = \left(m_{q^{(1)}} - m_{B^{(1)}}\right)/m_{B^{(1)}} \leq 0.5$$

Theoretical predictions for cross-sections depend on predictions for the mass of the KK-quark

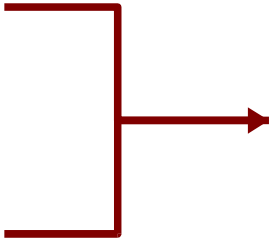
Explanation of Improvement

I. Cross-check of numbers and methods with Gustav

II. Change from AHA07v1ice → AHA07v2ice — gain: **1.4**

III. Difference in Reconstruction and L1-Filtering

IV. Difference in Analysis method
(only linear cuts → linear + multivariate)



gain: **2.13**

total gain: **~3**

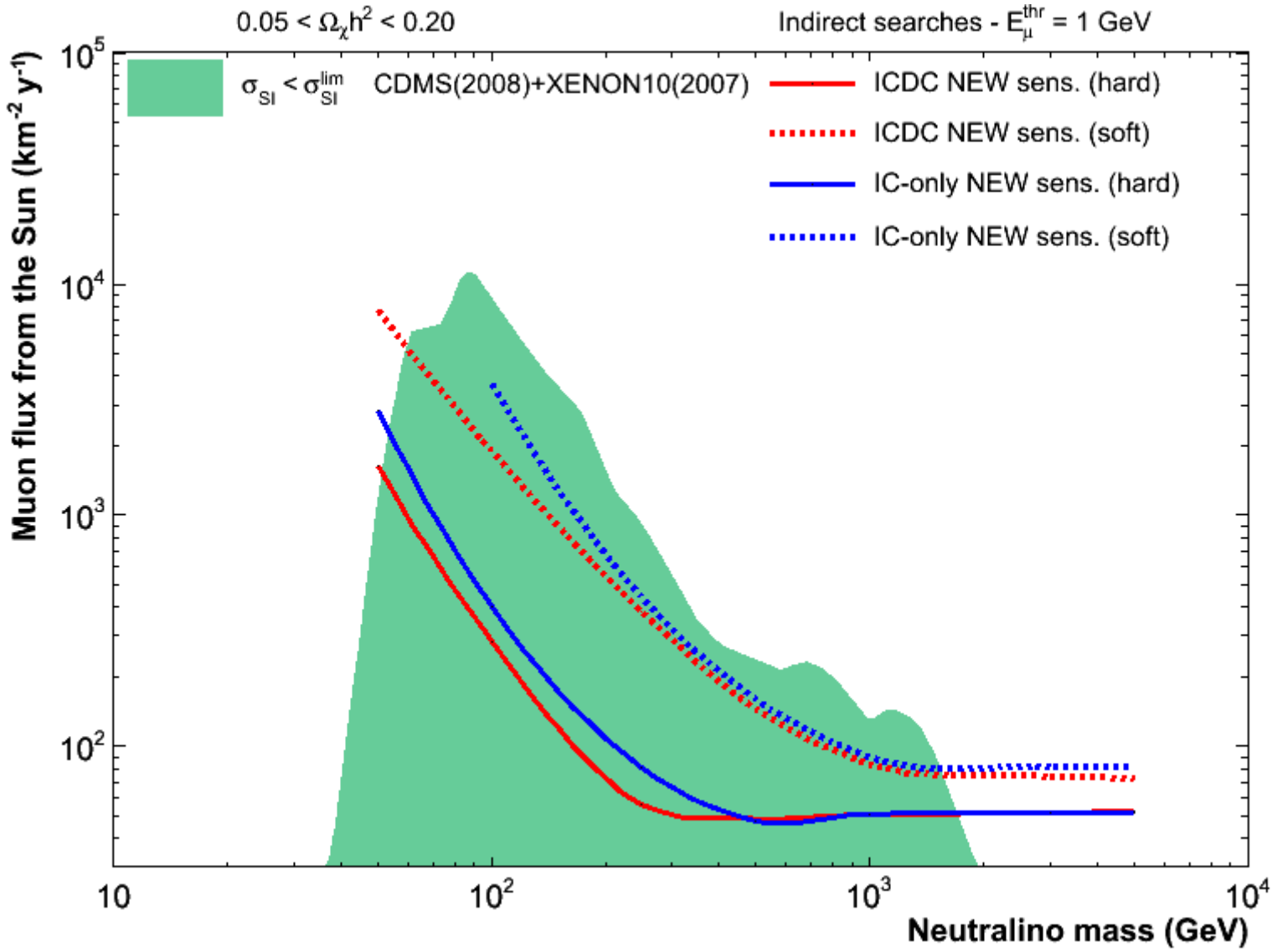
V. Including SLC — gain: **?**

VI. Bonus of StringTrigger with SLC (without: L2 60% → L5 2%) — gain: **?**

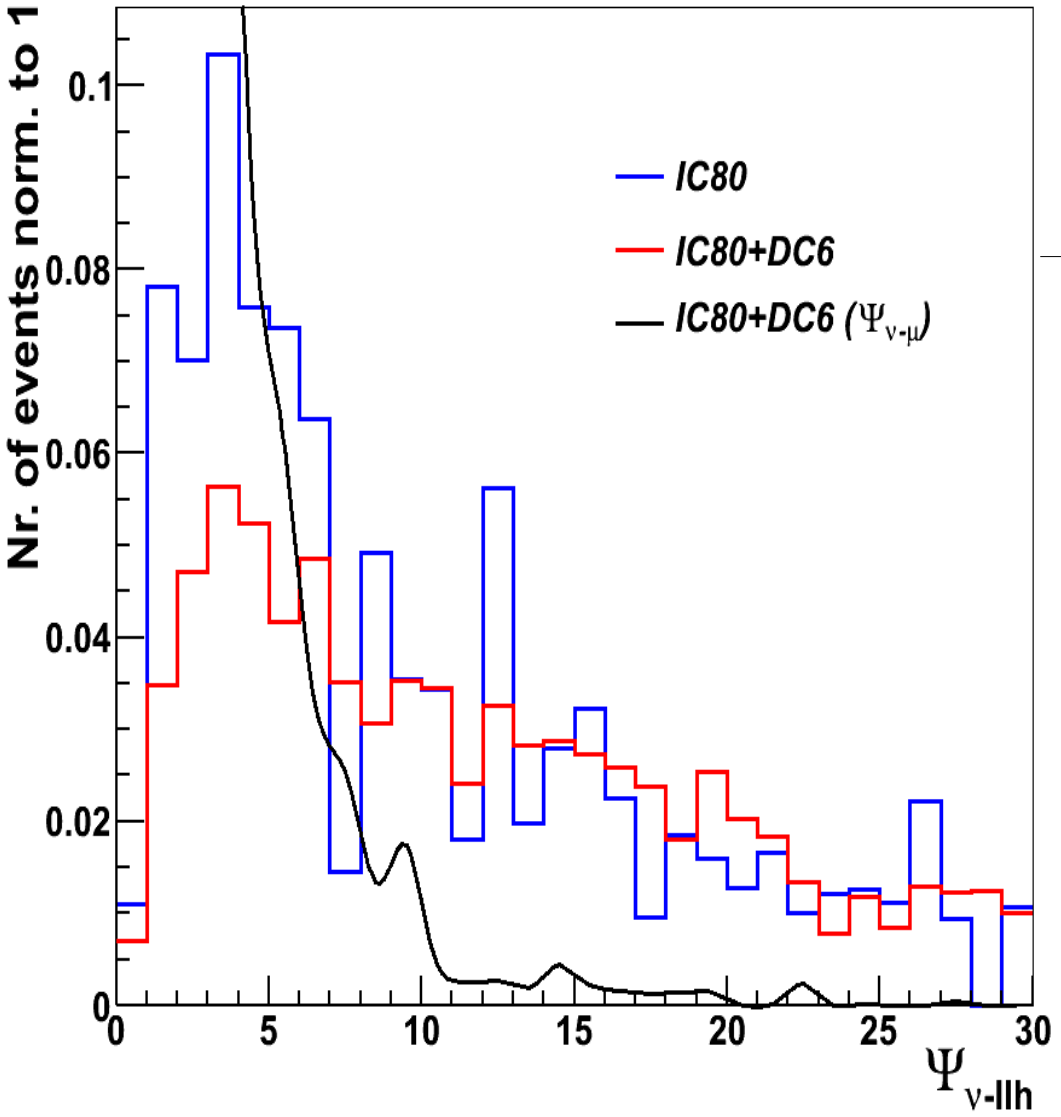
VII. New parameters and ideas — gain: **?**

VIII. Improvement in track-reconstruction in *ICDC* (esp. lowE) — gain: **?**

IC80DC6 vs *IC80*



IC80DC6 vs *IC80*



Comparison of hard 50 GeV **(L4)**

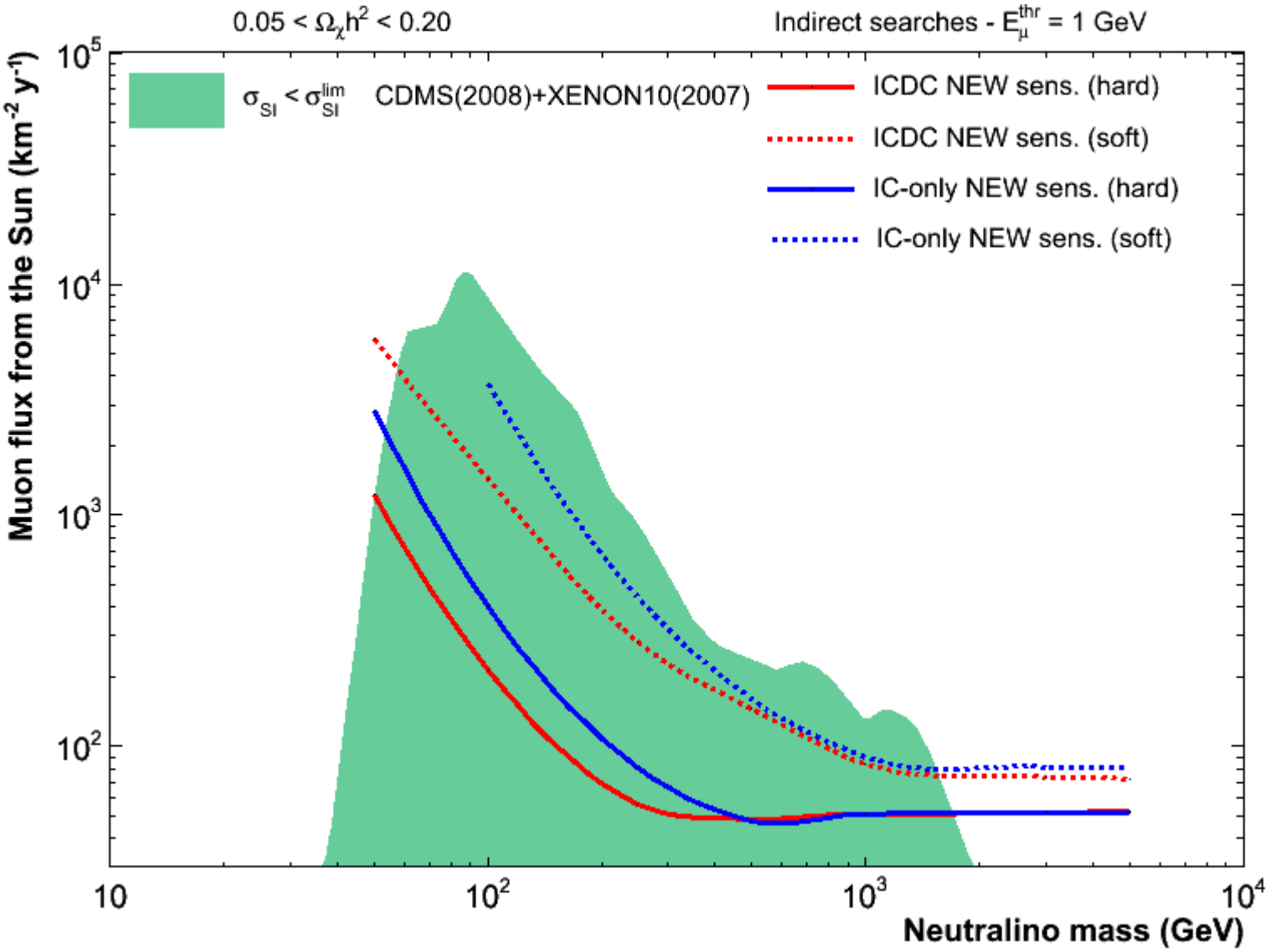
Level	IC 80 + DC 6	IC 80	Ratio
atm.ν L4	0.37 mHz	0.083 mHz	4.4
L4	1717	286	6
L5	459	132	3.47

Improvement in reconstruction

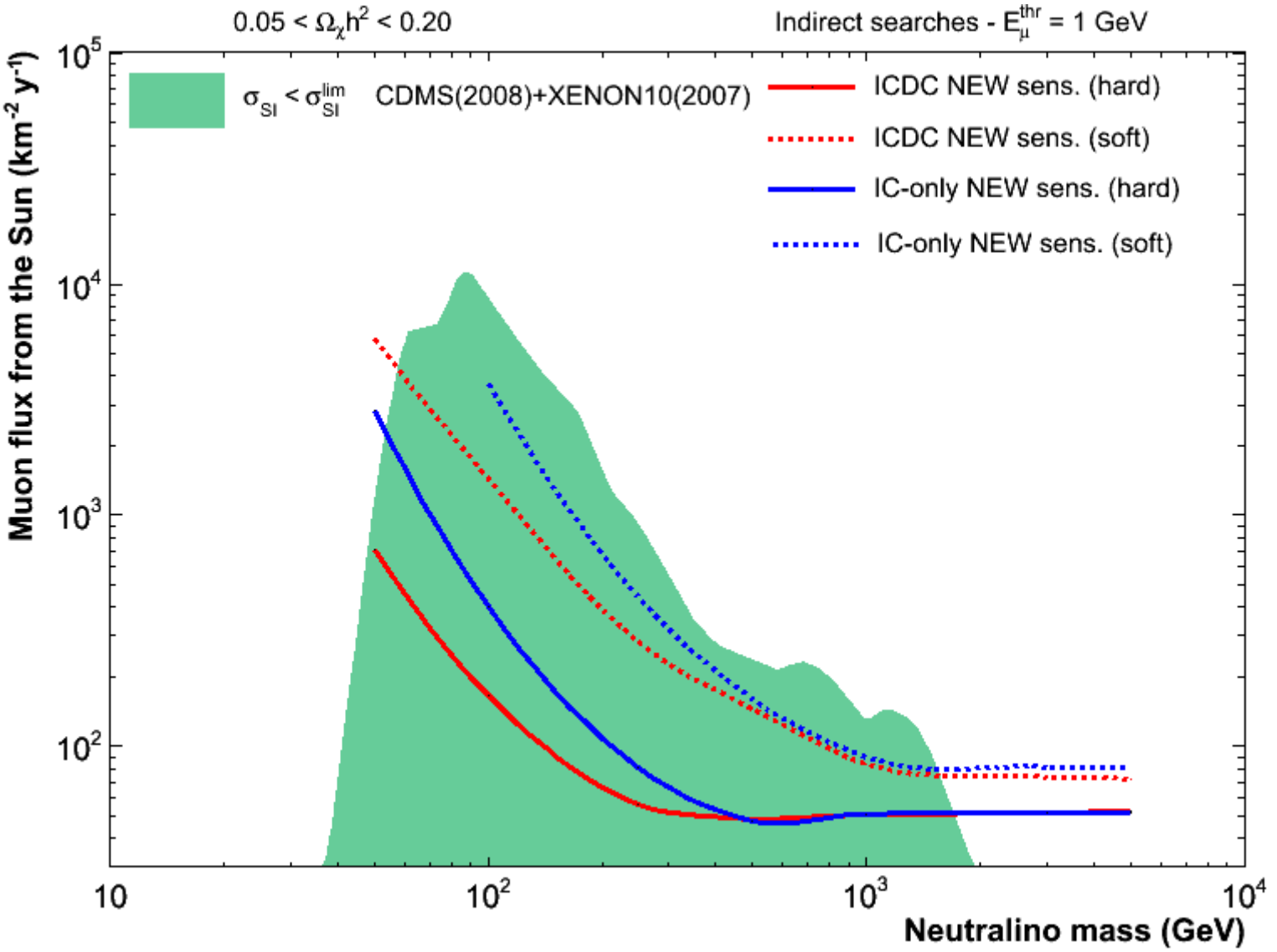
→ keep signal ratio

→ decrease Ψ → reduce Bg(ν)

Improving Ψ 7° → 5°



Improving Ψ + signal ratio



Conclusion + Outlook

- More 'stable' study with actual geometry settings
- Only using established analysis steps
- Markedly improvement in sensitivities (**10 y**. observation → **1 y**.)
- Room for plenty of improvement:

  (SLC, new/changed parameters and analysis ideas incl. DeepCore)
- **But**, to really utilize the full DeepCore potential

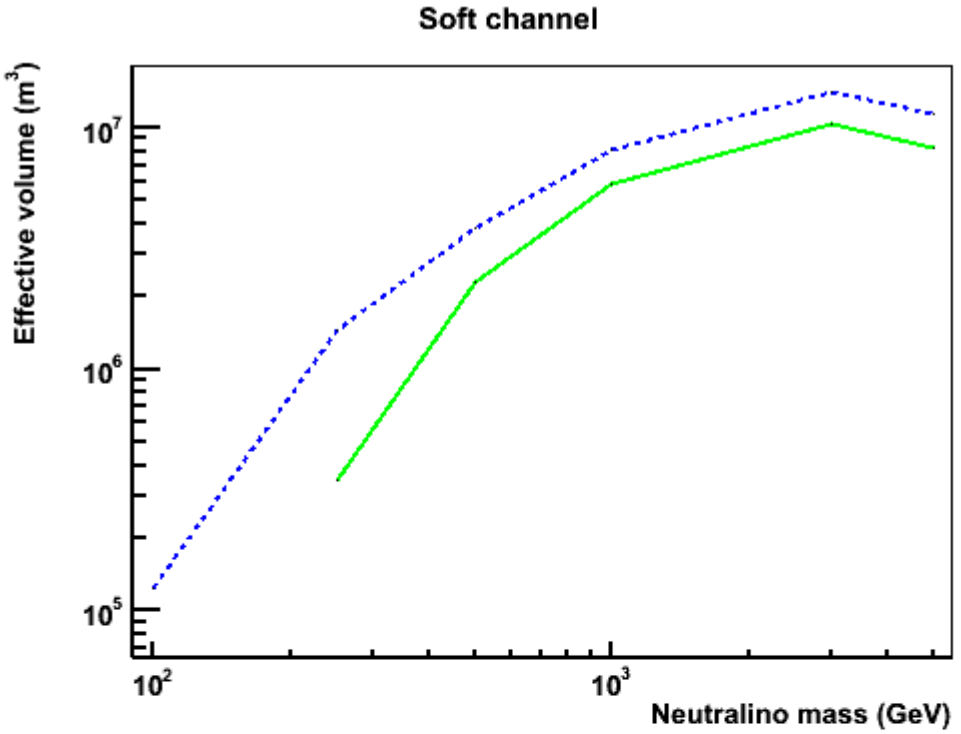
  → improvement in track-reconstruction for combined *IC80-DC6* essential

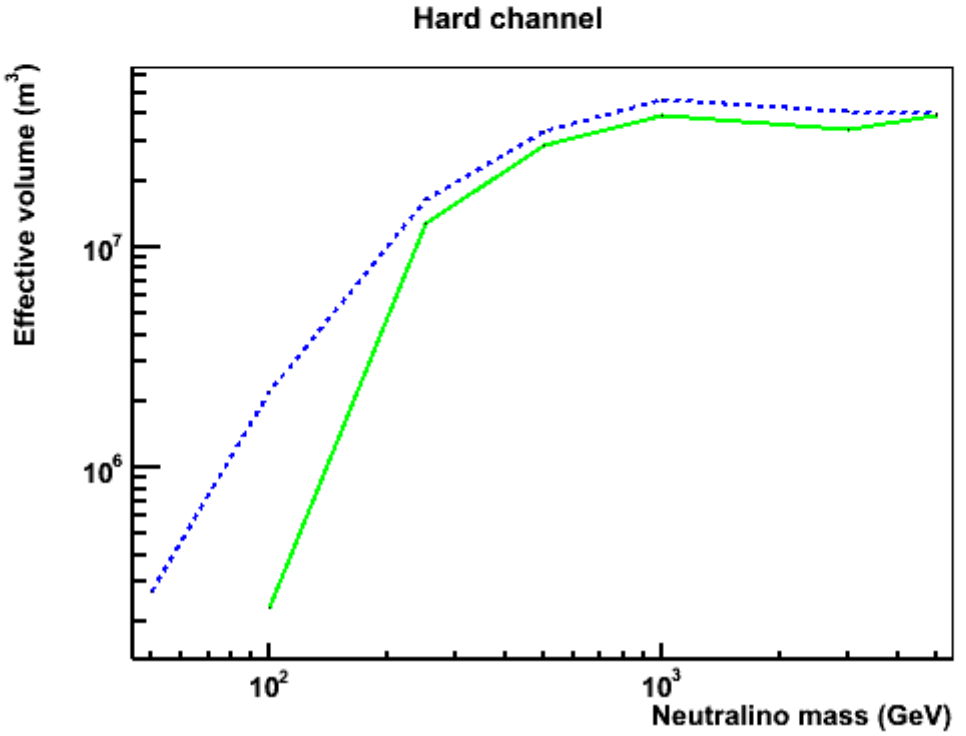
End

Thank You

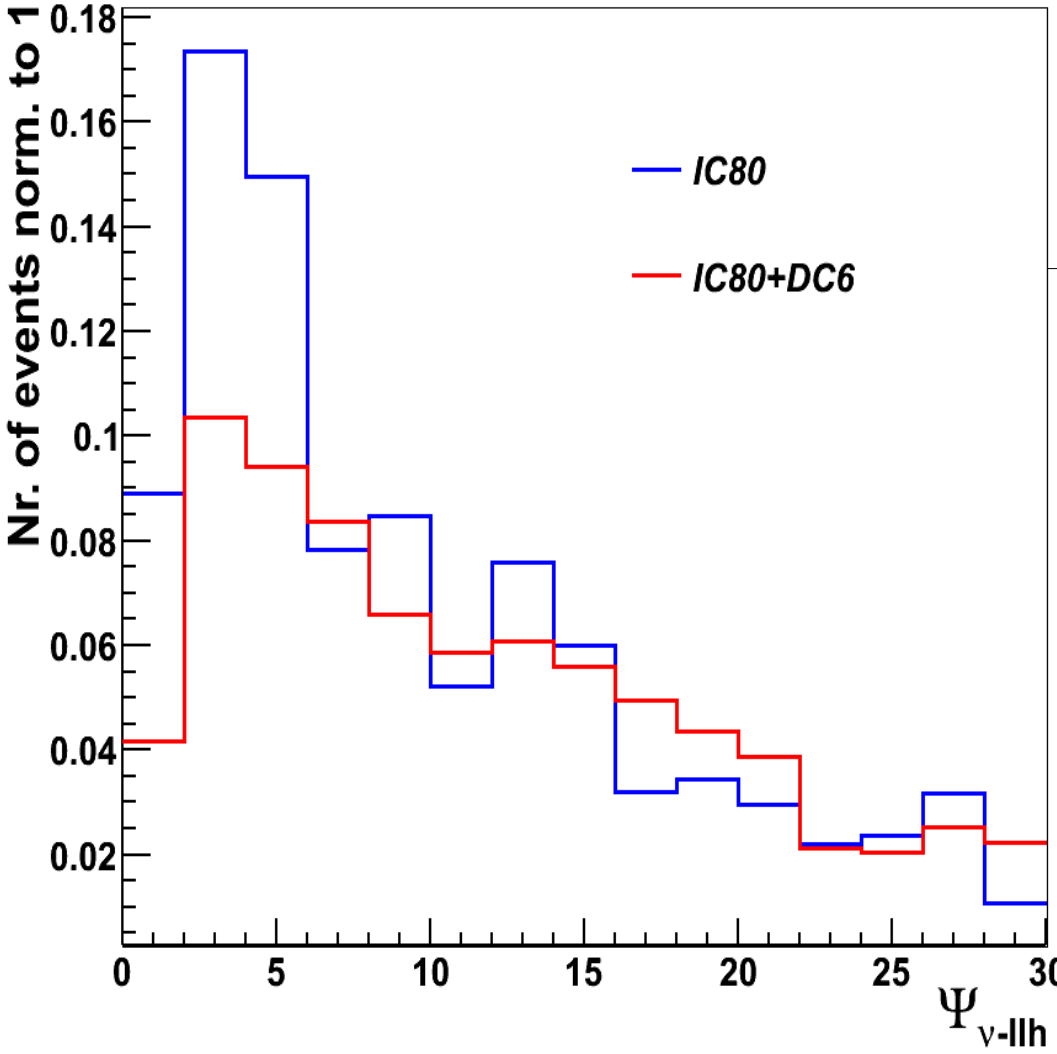
http://icecube.wisc.edu/~mda65/IC80DC6

Additional Slides





IC80DC6 vs *IC80*



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