Steriles@νSTORM In a Nutshell

C.D. Tunnell (Oxford)

1. The World of Steriles
2. Our ‘new’ approach
3. The Experiment
4. Performance
5. Sensitivity

Forest

Trees

1. The World of Steriles
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Disclaimer: I am focusing on my appearance analysis, but see Walter Winter's disappearance (arXiv:1204.2671) analysis. This talk is the 'tip of the iceberg' of work that's been done and most of it is written down.

I like to be interrupted when I talk.

1. The World of Steriles

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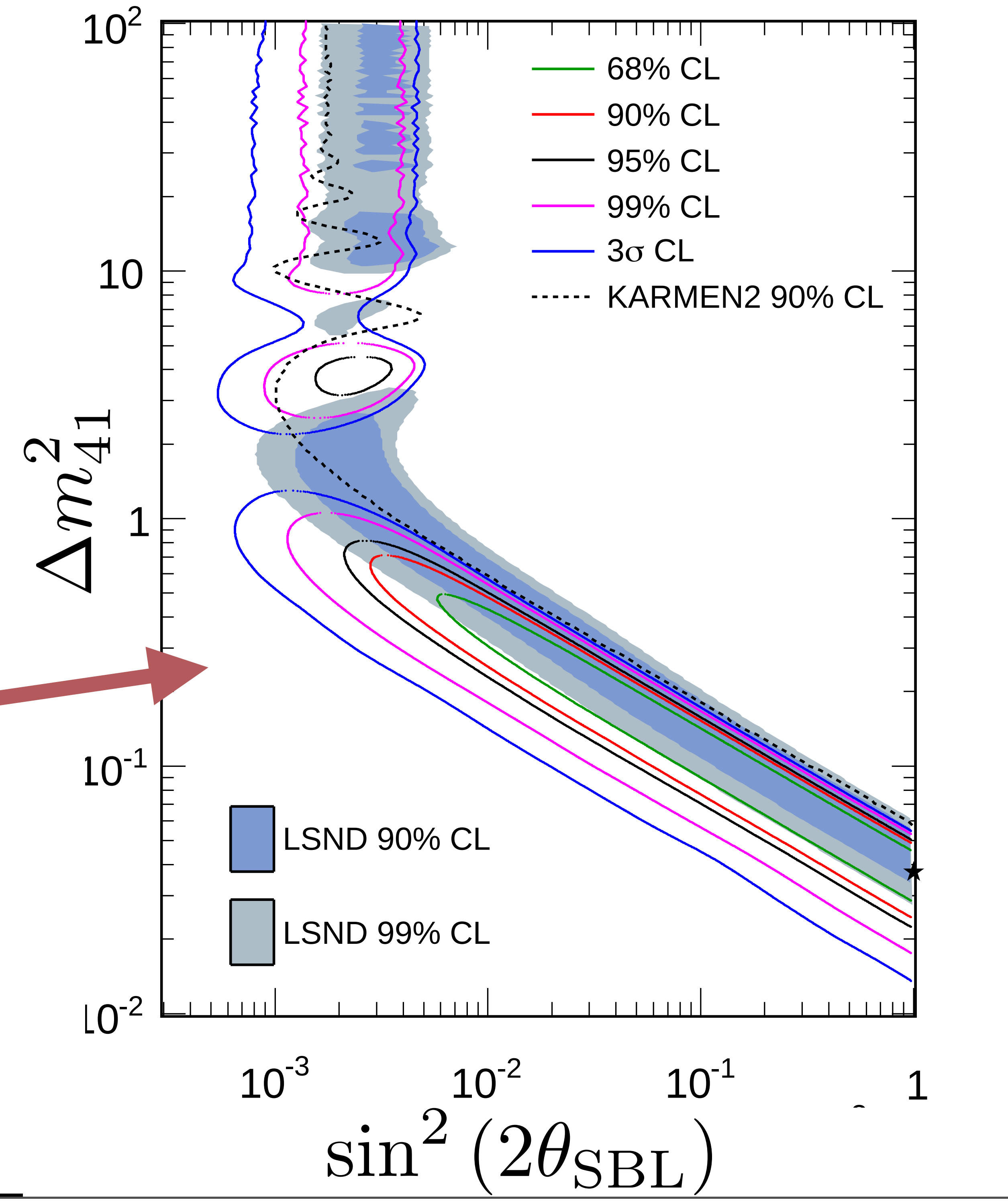
- Boris: "steriles are interesting"
- My reason
- Tension in fits: one or more experiments wrong

arXiv:1207.4809 with axis label change



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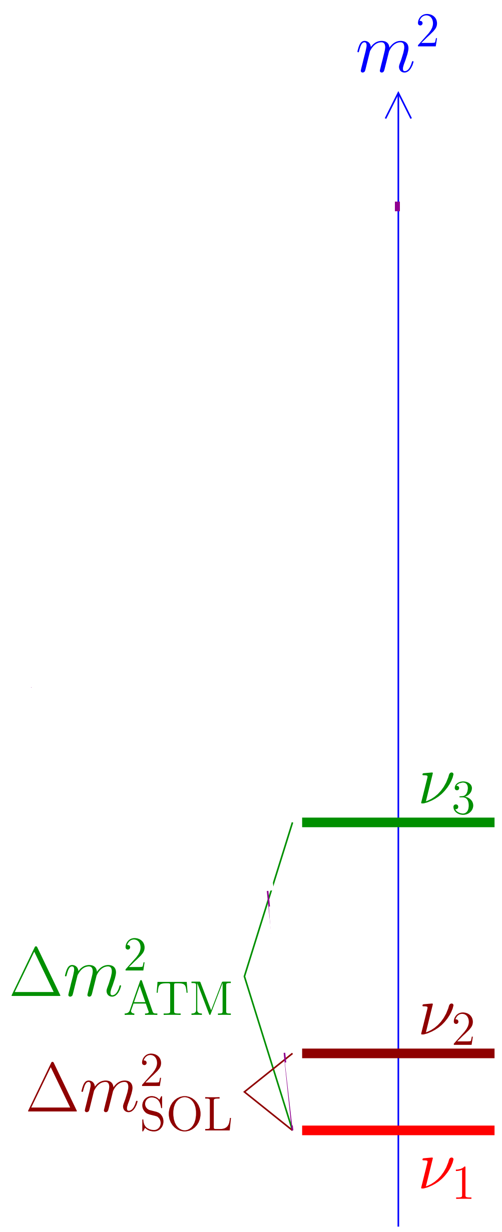
$$U_{3\times 3} = R_{23} R_{13}^{*} R_{12}$$

$$= \begin{array}{c c} & \begin{array}{ccc} \nu_1 & \nu_2 & \nu_3 \end{array} \\ \begin{array}{c} e \\ \mu \\ \tau \end{array} & \begin{bmatrix} U_{e1} & U_{e2} & U_{e3} \\ U_{\mu 1} & U_{\mu 2} & U_{\mu 3} \\ U_{\tau 1} & U_{\tau 2} & U_{\tau 3} \end{bmatrix} \end{array}$$

cartoon from arXiv:1106.4479



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$$U_{4\times 4} = R_{34} R^*_{24} R^*_{14} U_{3\times 3}$$

$$R_{ij} = \begin{pmatrix} 1 & \dots & 0 & \dots & 0 & \dots & 0 \\ \vdots & & \vdots & & \vdots & & \vdots \\ 0 & \dots & \cos\theta_{ij} & \dots & \sin\theta_{ij} & \dots & 0 \\ \vdots & & \vdots & & \vdots & & \vdots \\ 0 & \dots & -\sin\theta_{ij} & \dots & \cos\theta_{ij} & \dots & 0 \\ \vdots & & \vdots & & \vdots & & \vdots \\ 0 & \dots & 0 & \dots & 0 & \dots & 1 \end{pmatrix}$$

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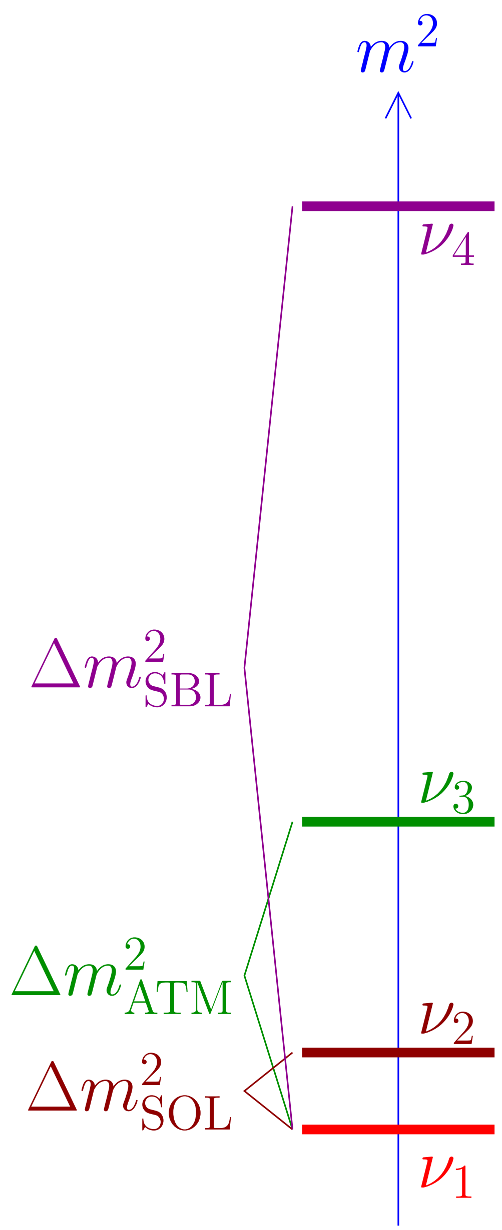

$$U_{4\times 4} = R_{34} R^*_{24} R^*_{14} U_{3\times 3}$$

$$= \begin{pmatrix} \cos(\theta_{14}) & 0 & 0 & \sin(\theta_{14}) \\ -\sin(\theta_{14})\sin(\theta_{24}) & \cos(\theta_{24}) & 0 & \sin(\theta_{24})\cos(\theta_{14}) \\ -\sin(\theta_{14})\sin(\theta_{34})\cos(\theta_{24}) & -\sin(\theta_{24})\sin(\theta_{34}) & \cos(\theta_{34}) & \sin(\theta_{34})\cos(\theta_{14})\cos(\theta_{24}) \\ -\sin(\theta_{14})\cos(\theta_{24})\cos(\theta_{34}) & -\sin(\theta_{24})\cos(\theta_{34}) & -\sin(\theta_{34}) & \cos(\theta_{14})\cos(\theta_{24})\cos(\theta_{34}) \end{pmatrix}$$

Thus: $U_{e4} = \sin(\theta_{14})$

$$U_{\mu 4} = \cos(\theta_{24})\sin(\theta_{14})$$

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Assume:

$$m_4 >> m_3 \simeq m_2 \simeq m_1$$

Then:

$$P_{\nu_e \to \nu_e} = 4\left(1 - |U_{e4}|^2\right)|U_{e4}|^2 \sin^2\left(\frac{m_{14}^2 L}{4E}\right)$$

$$P_{\nu_\mu \to \nu_\mu} = 4\left(1 - |U_{\mu 4}|^2\right)|U_{\mu 4}|^2 \sin^2\left(\frac{m_{14}^2 L}{4E}\right)$$

$$P_{\nu_e \leftrightarrow \nu_\mu} = 4|U_{e4}|^2|U_{\mu 4}|^2 \sin^2\left(\frac{m_{14}^2 L}{4E}\right)$$

$|U_{e4}|^2, |U_{\mu 4}|^2$ small

double suppressed

Define:

$$\sin^2(2\theta_{\mathrm{SBL}}) := 4|U_{e4}|^2|U_{\mu 4}|^2$$

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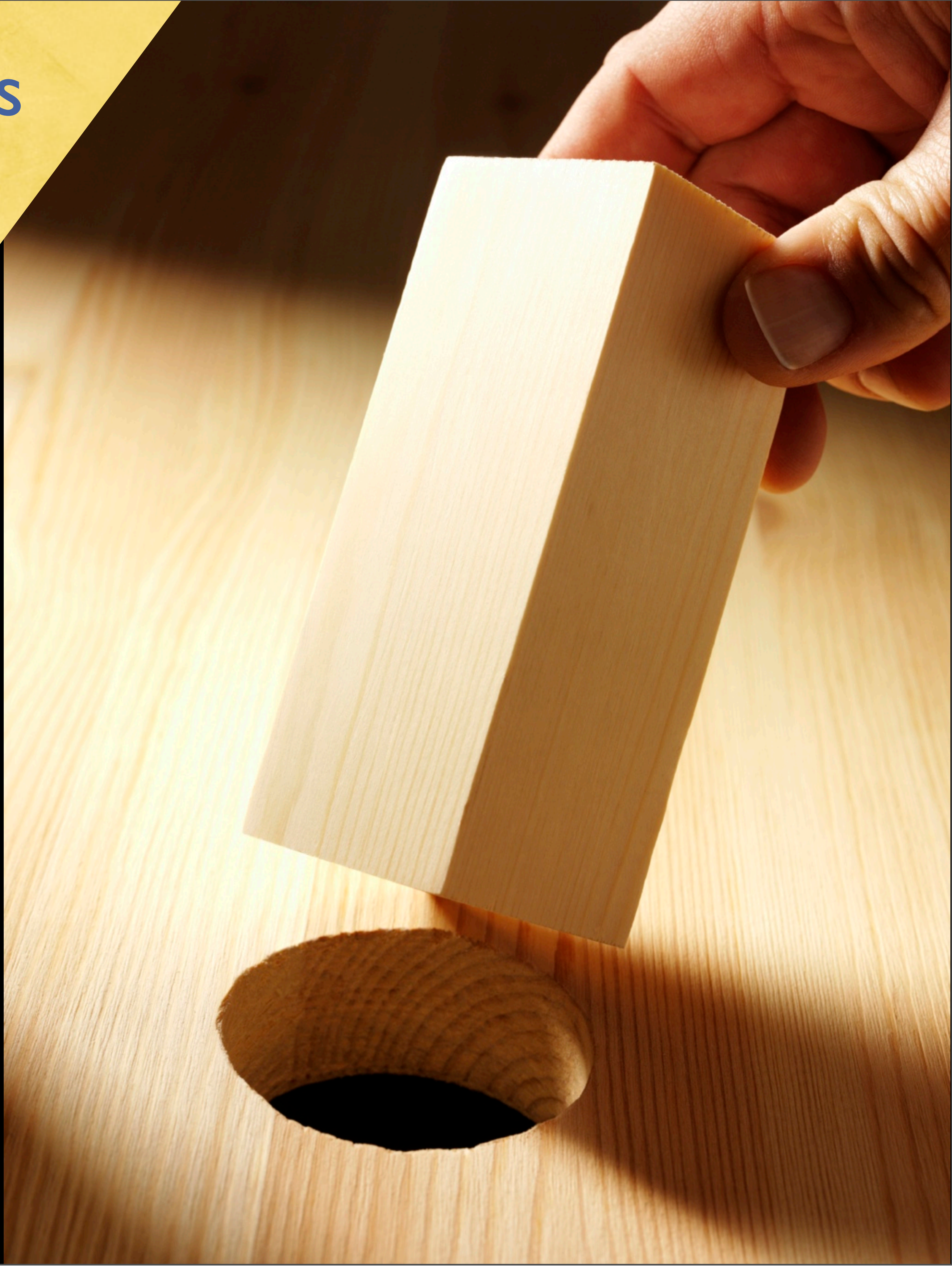
Sometimes
it's worth
considering
new ideas



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LSND:

$$\bar{\nu}_\mu \rightarrow \bar{\nu}_e$$

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LSND:

$$\mathrm{CPT}(\bar{\nu}_\mu \rightarrow \bar{\nu}_e)$$

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LSND:

νSTORM:

$$\mathrm{CPT}(\bar{\nu}_\mu \to \bar{\nu}_e) = \nu_e \to \nu_\mu$$

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"Why is this *better?*"

LSND:

νSTORM:

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"Why is this *better?*"

LSND:

νSTORM:

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Hard

Easy

Detection

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"Why is this *better?*"

Flux Uncertainty*

Hard

Easy

LSND:

νSTORM:

$$\mathrm{CPT}(\bar{\nu}_\mu \to \bar{\nu}_e) = \nu_e \to \nu_\mu$$

Hard

Easy

Detection

* if using NF beam

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νSTORM:

$$\nu_e \rightarrow \nu_\mu$$

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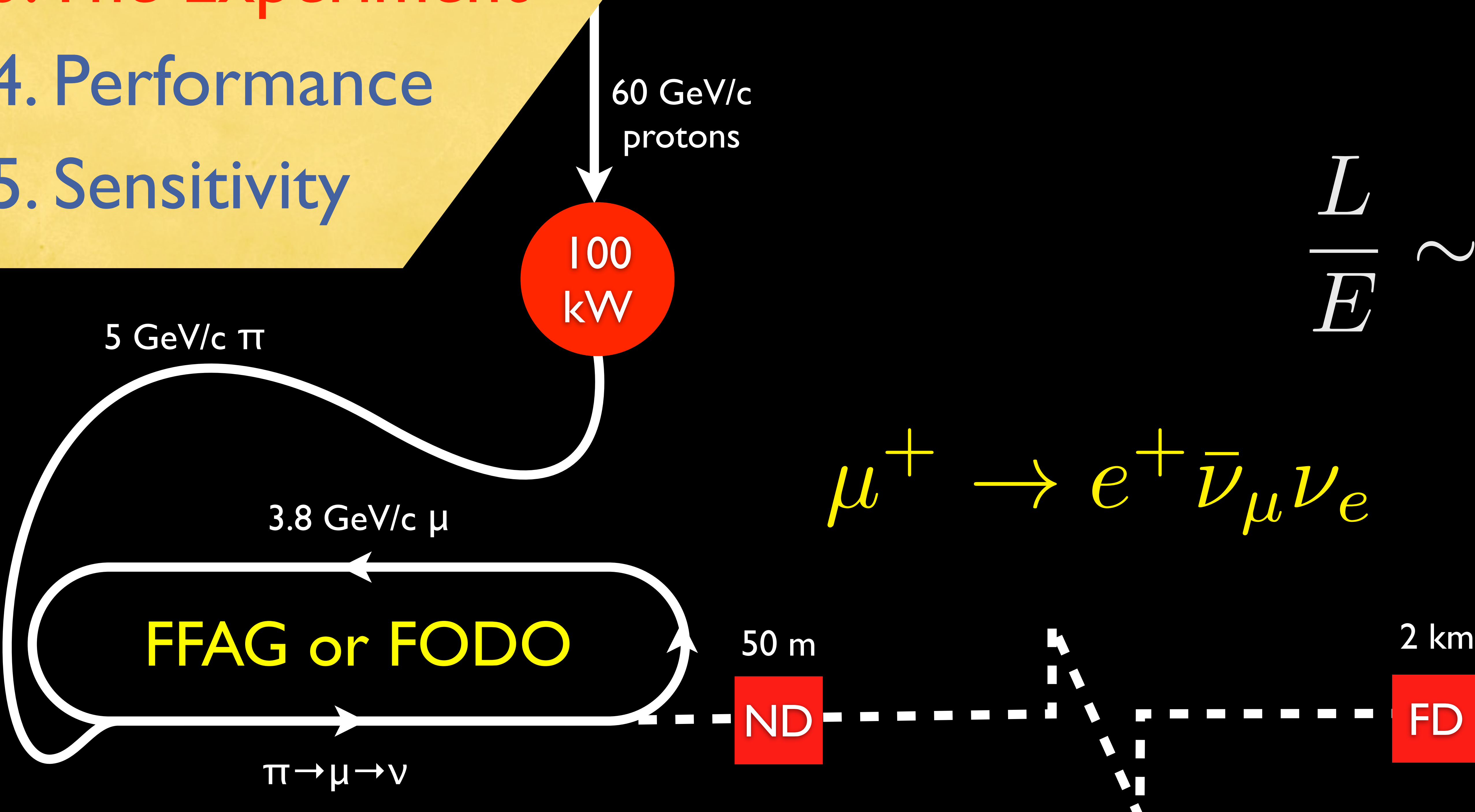
No New Technology
Neuffer @ Telemark (1980)



$$\frac{L}{E} \sim 1$$

$$\mu^+ \to e^+ \bar{\nu}_\mu \nu_e$$

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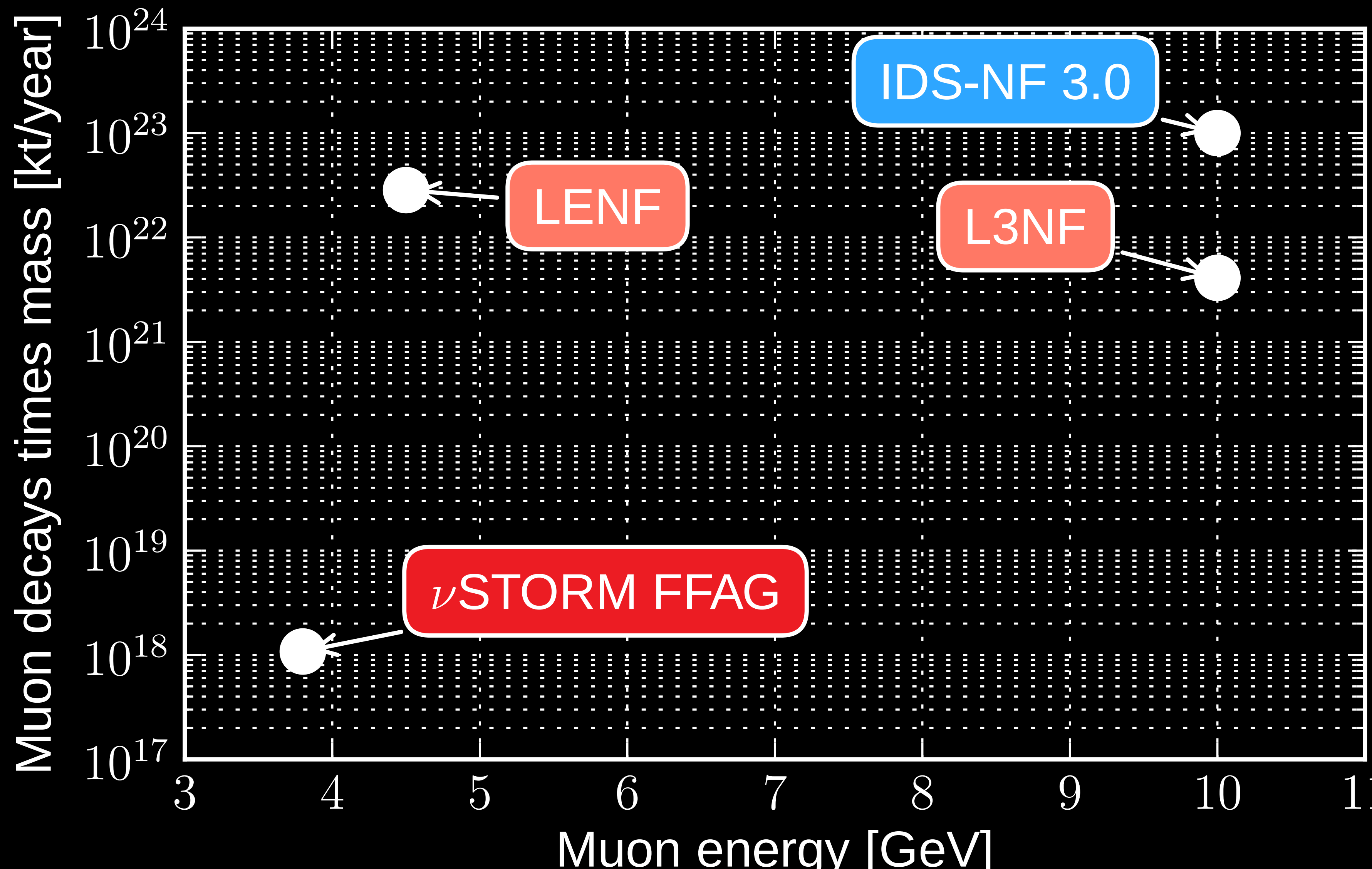
Why is νSTORM so different from a NF?



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	$\nu_e \to \nu_e$ CC	216657	230766	-6.1%	-29.4
π^+	$\nu_\mu \to \nu_\mu$ CC	?	?	?	?
	$\nu_\mu \to \nu_e$ CC	?	?	?	?
μ^-	$\bar{\nu}_e \to \bar{\nu}_\mu$ CC	117	0	∞	∞
	$\bar{\nu}_e \to \bar{\nu}_e$ NC	30511	32481	-6.1%	-10.9
	$\nu_\mu \to \nu_\mu$ NC	66037	69420	-4.9%	-12.8
	$\bar{\nu}_e \to \bar{\nu}_e$ CC	77600	82589	-6.0%	-17.4
	$\nu_\mu \to \nu_\mu$ CC	197284	207274	-4.8%	-21.9
π^-	$\bar{\nu}_\mu \to \bar{\nu}_\mu$ CC	?	?	?	?
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Cut by injecting only one sign

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Cut by timing

Cut by injecting only one sign

Interaction rates @ 2 km for 1 kt

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Two cuts for finding 300 events in 500000:

- How do you tell a muon from a NC or ν_e event?
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(Note: R. Bayes did the first performance analysis)

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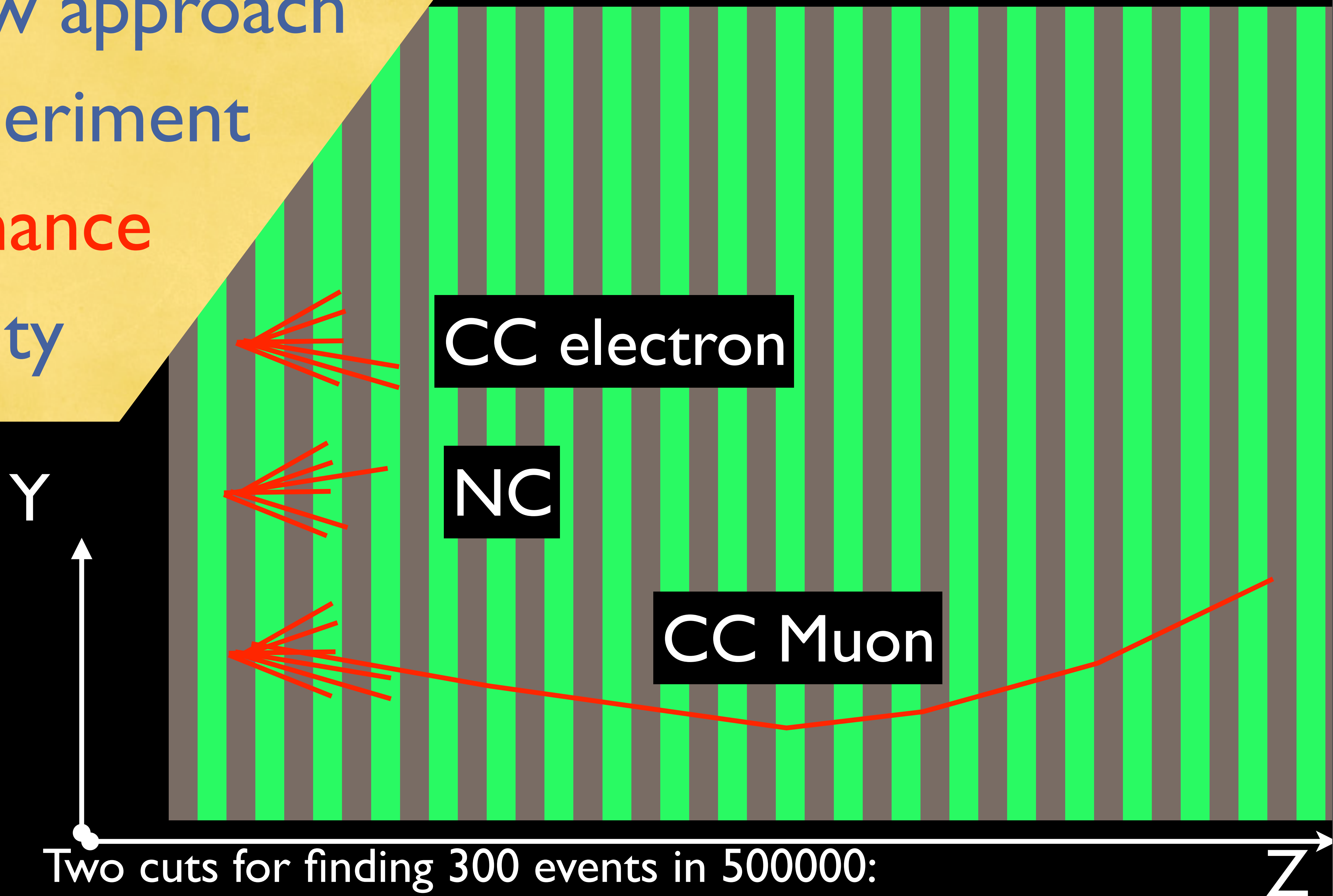
~MINOS



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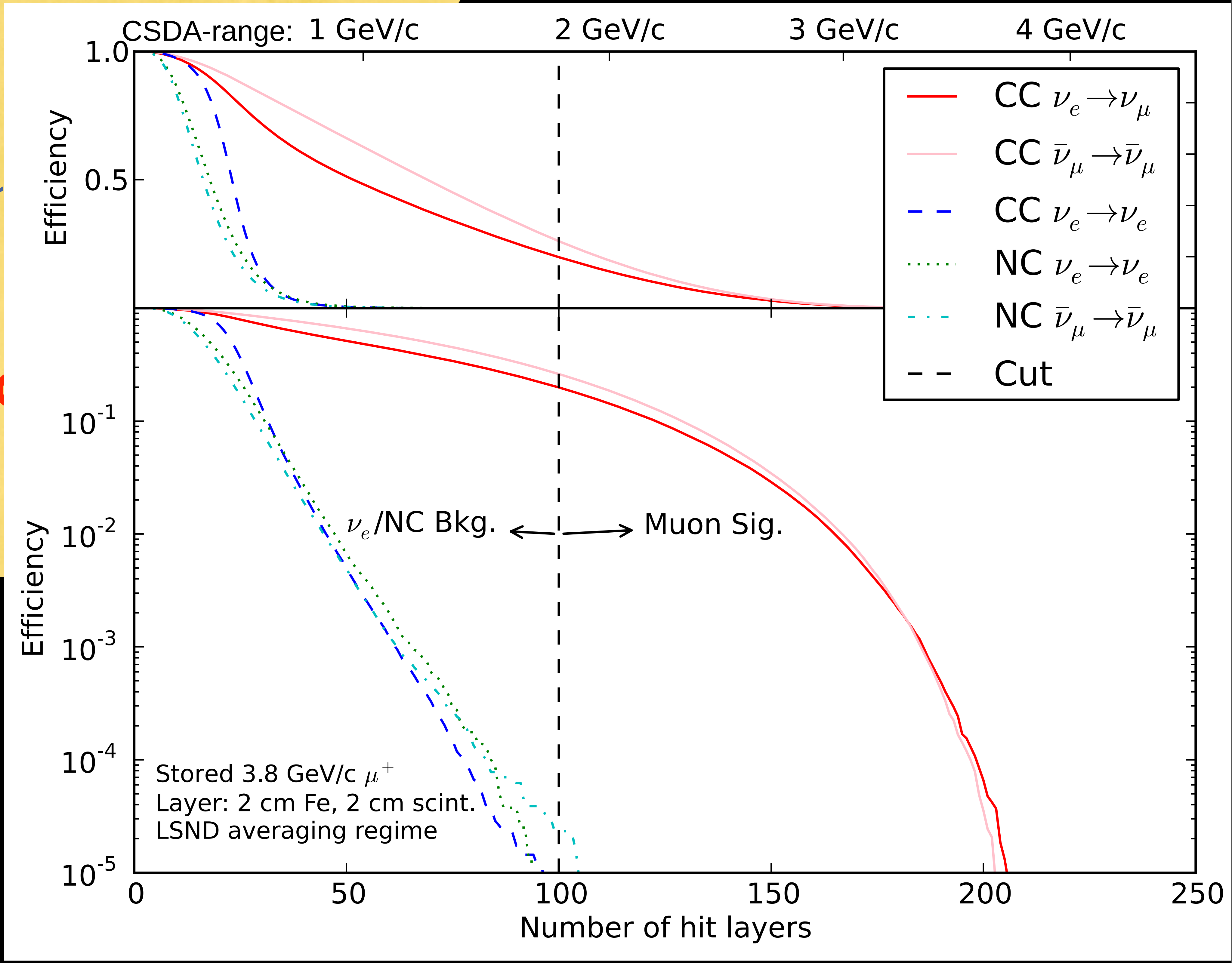

$\sim 10 \times \lambda_{\text{Pion Int.}}$

$\sim 100 \times \lambda_{\text{Radiation}}$

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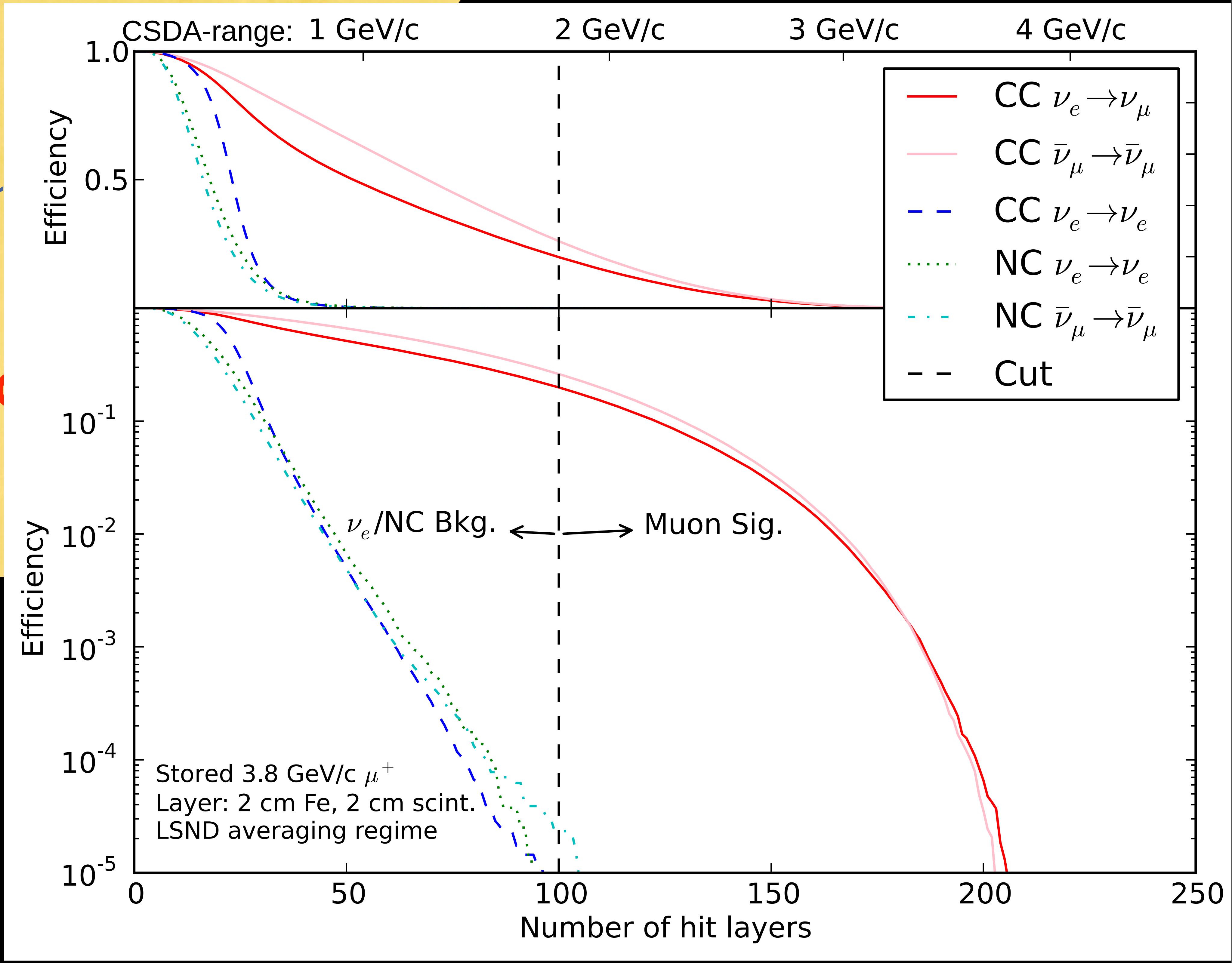

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Cut by timing

Cut by injecting only one sign

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Cut by length
Cut by timing

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Cut by length

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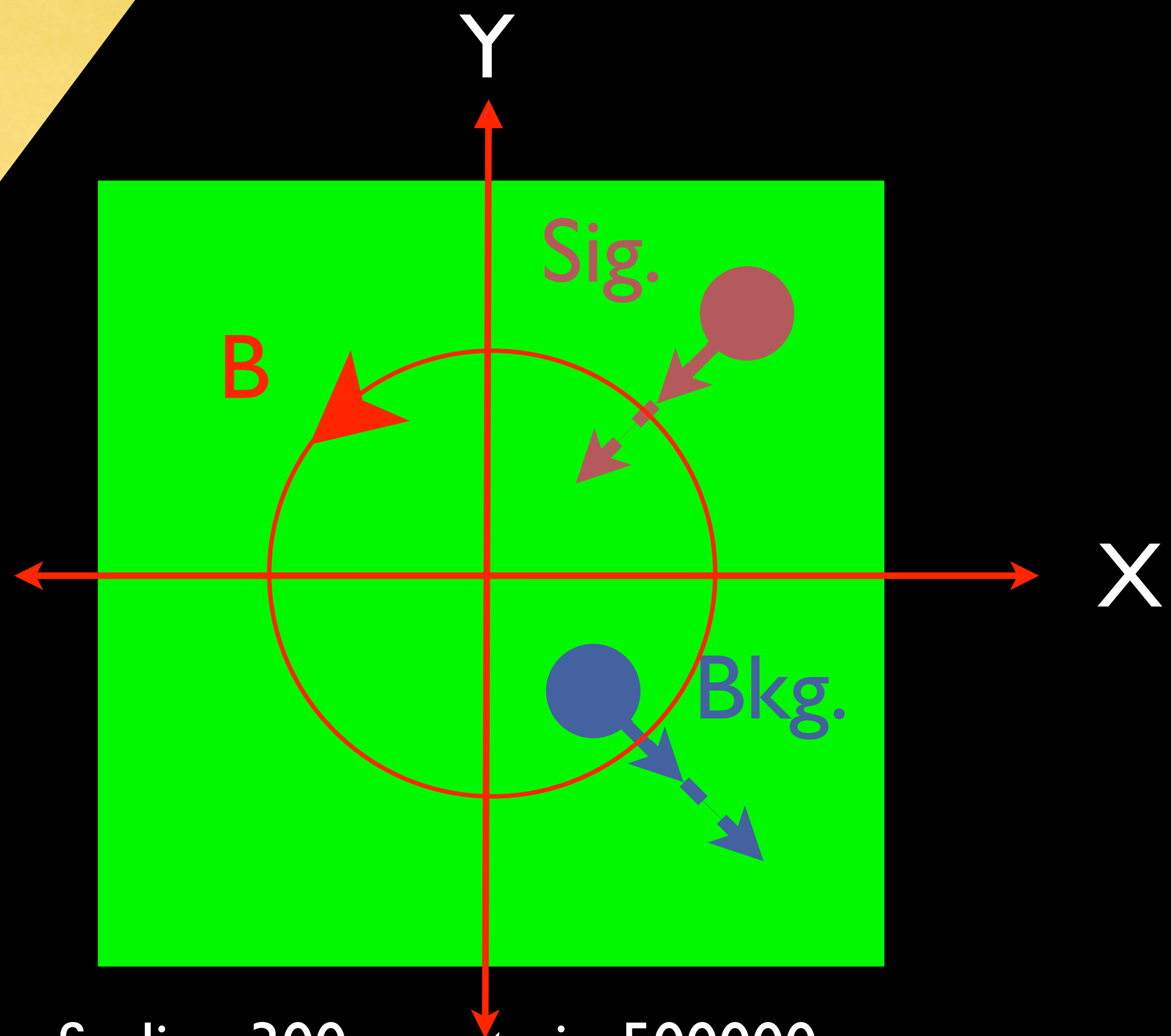
Magnetize!
Focus signal,
defocus backgrounds



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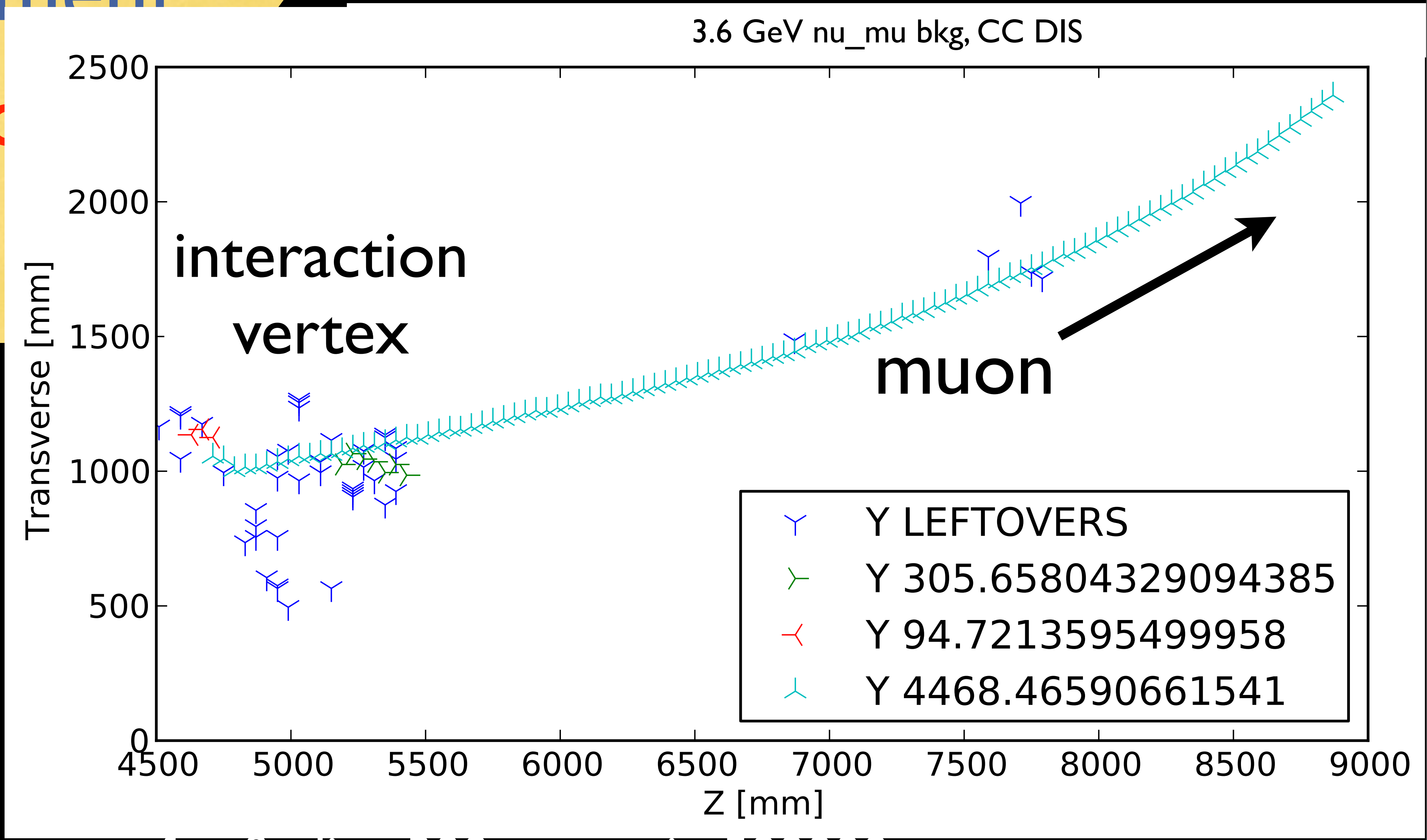
Does radius increase?



GENIE and Geant4. Form a graph then take minimal spanning tree to find muon

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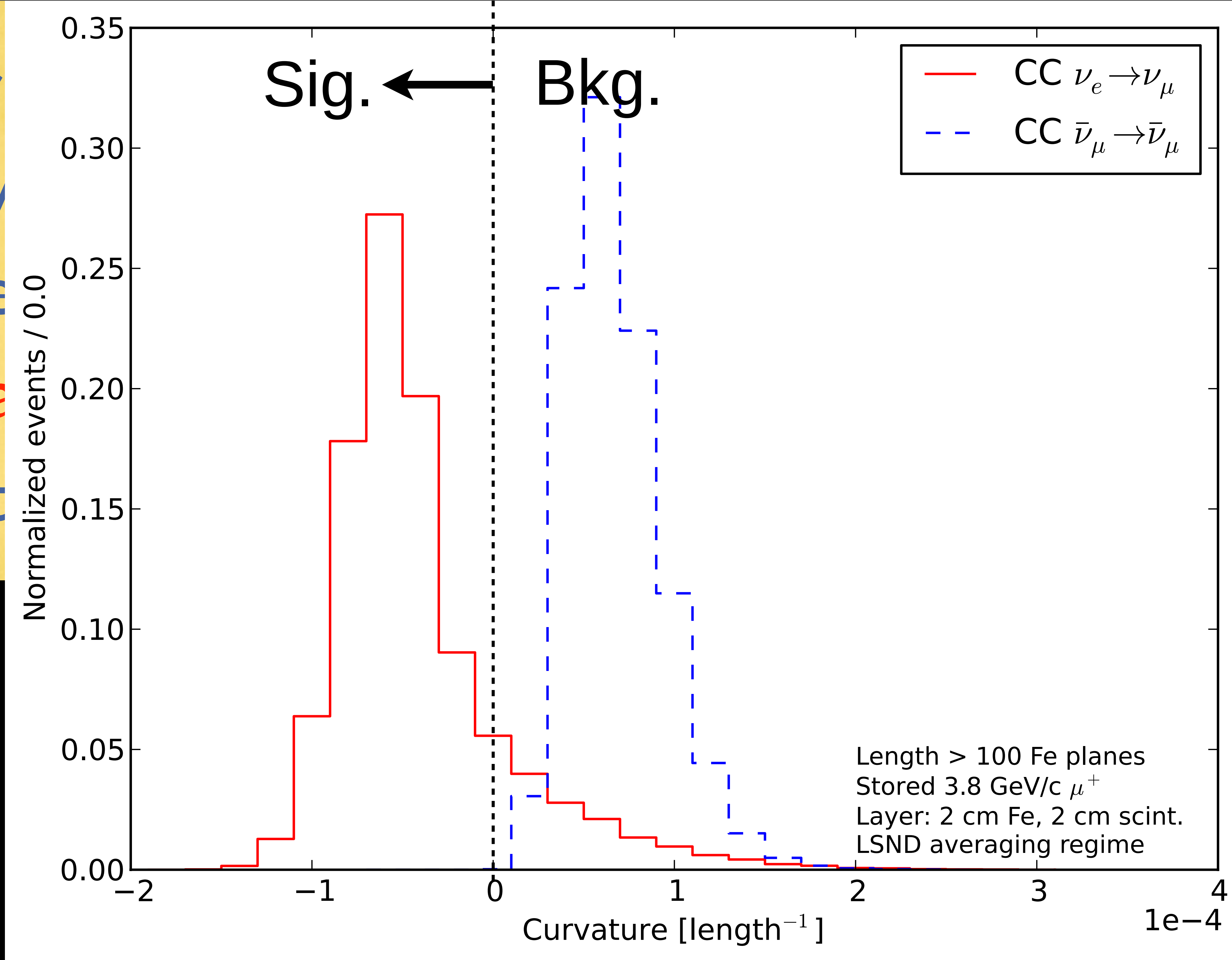

The tail is due to 'swimming' near superconducting coil and only goes one way.

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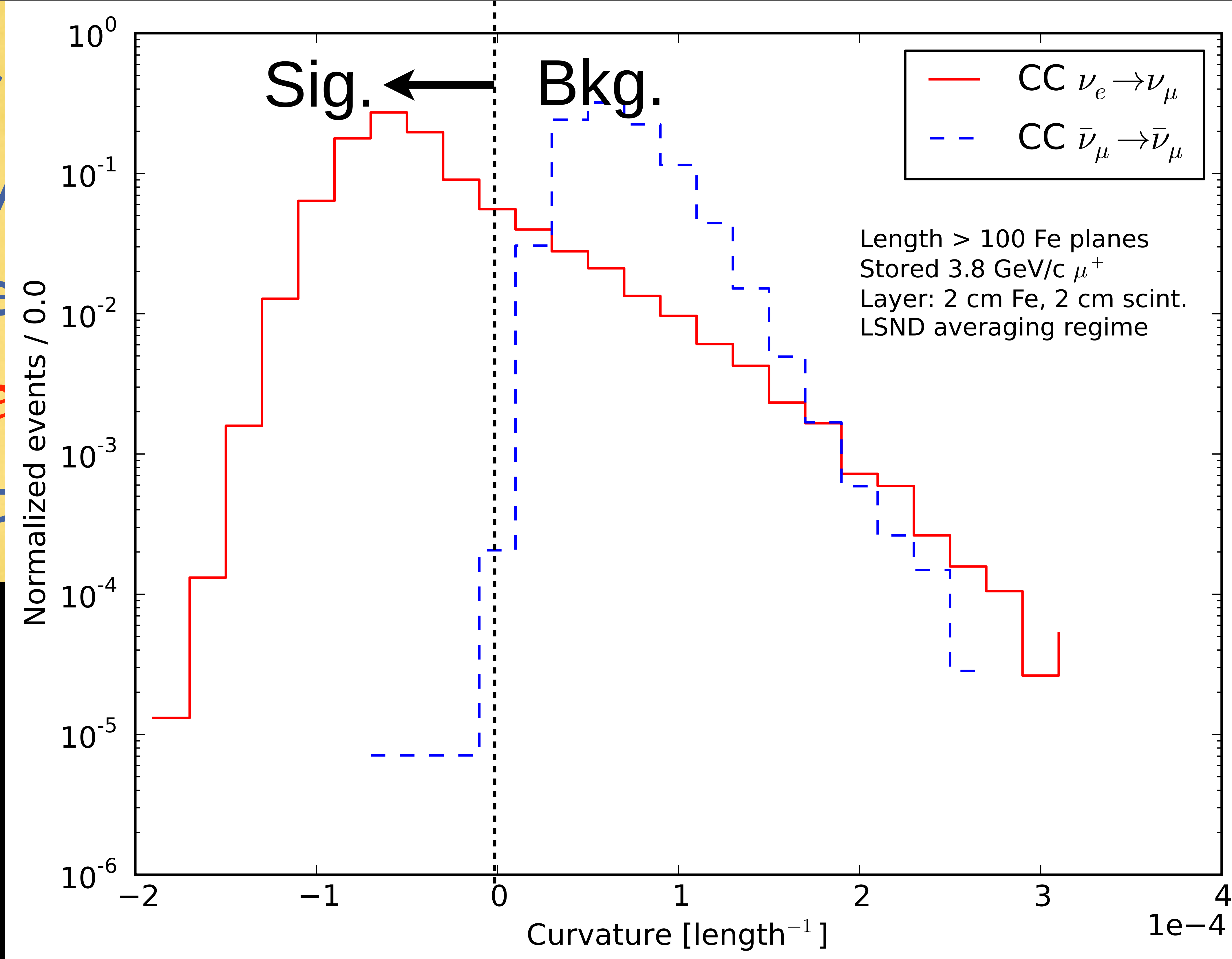

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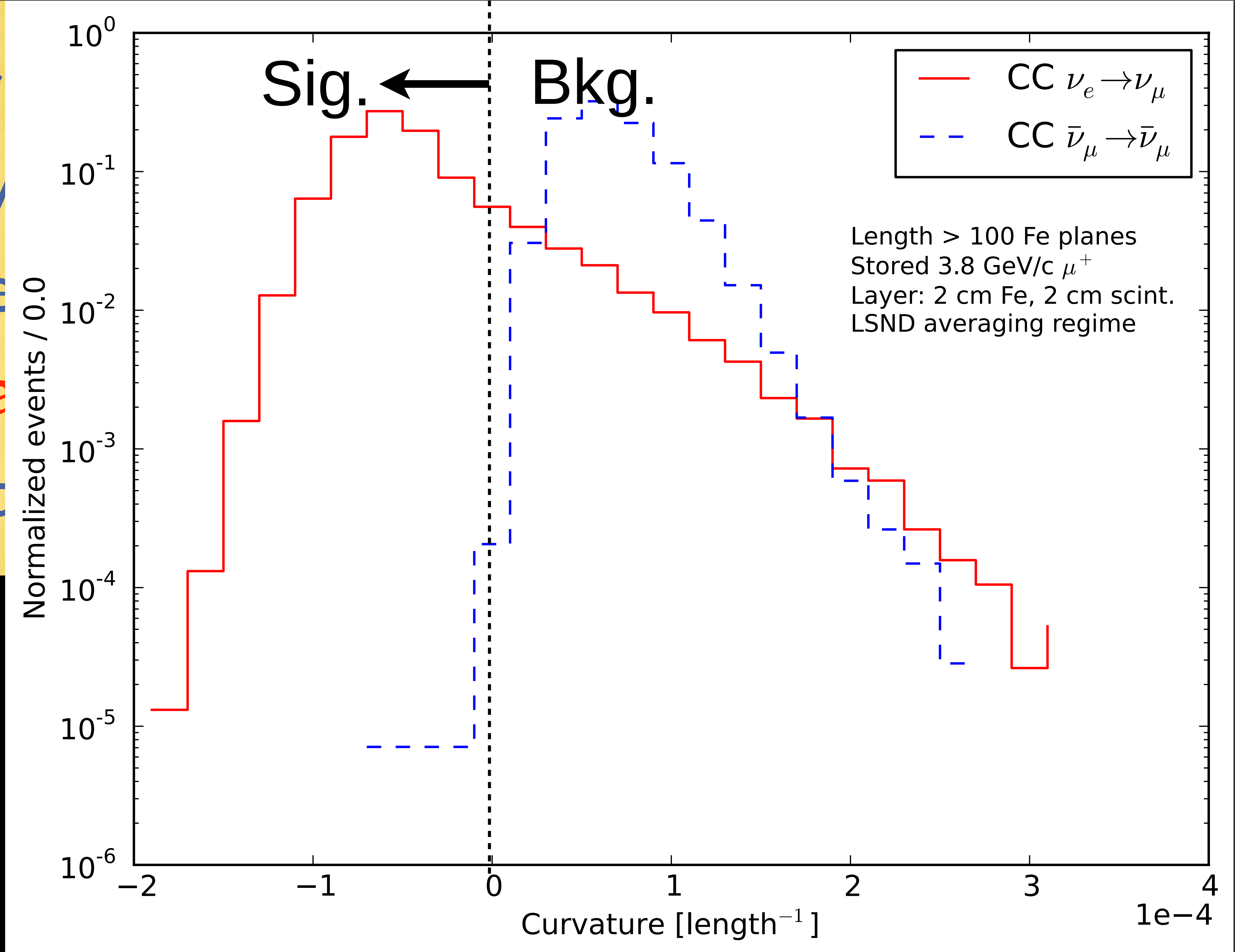

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Cut by length
Cut by timing

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Cut by length

Cut by curvature

Cut by length

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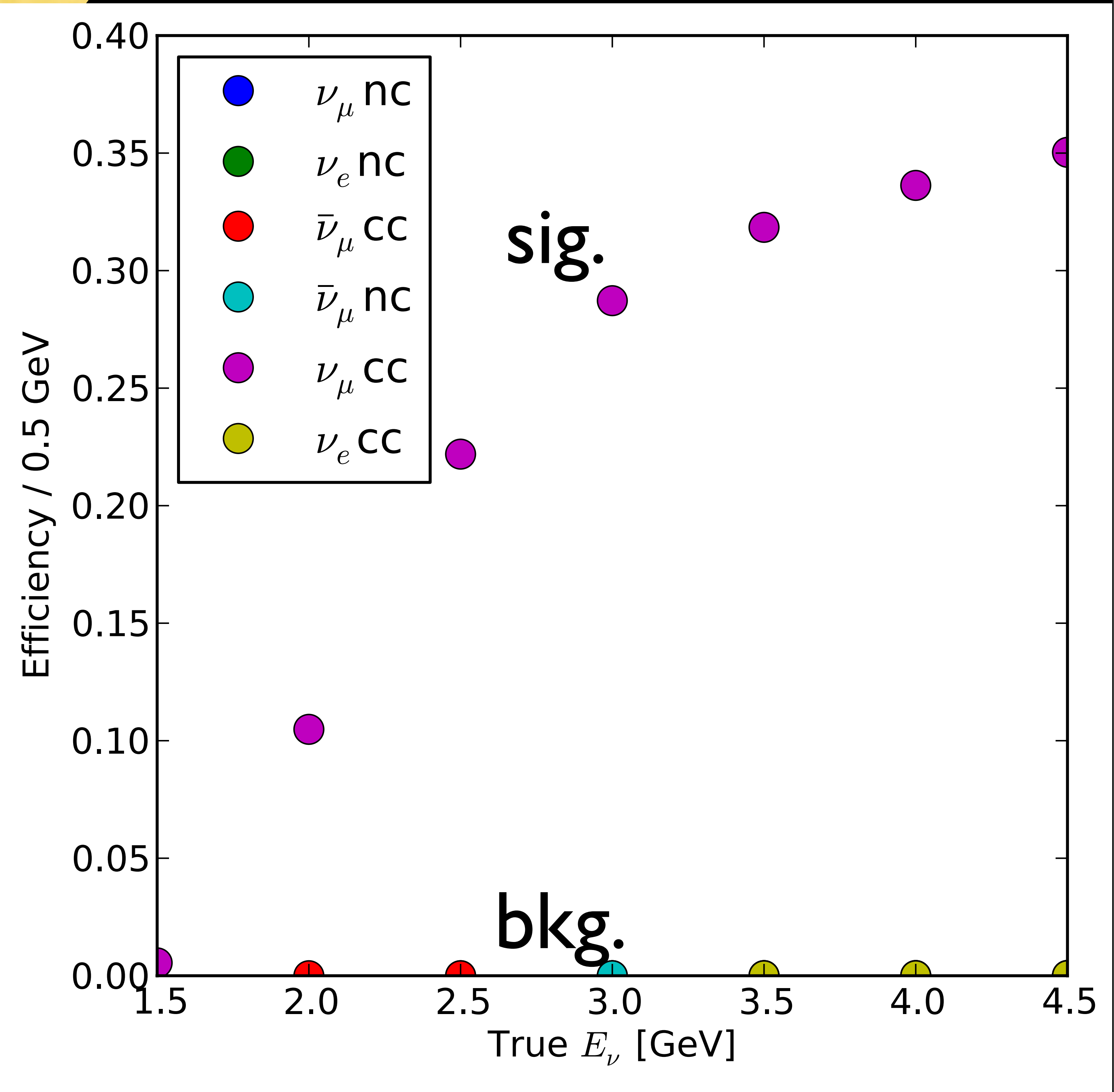

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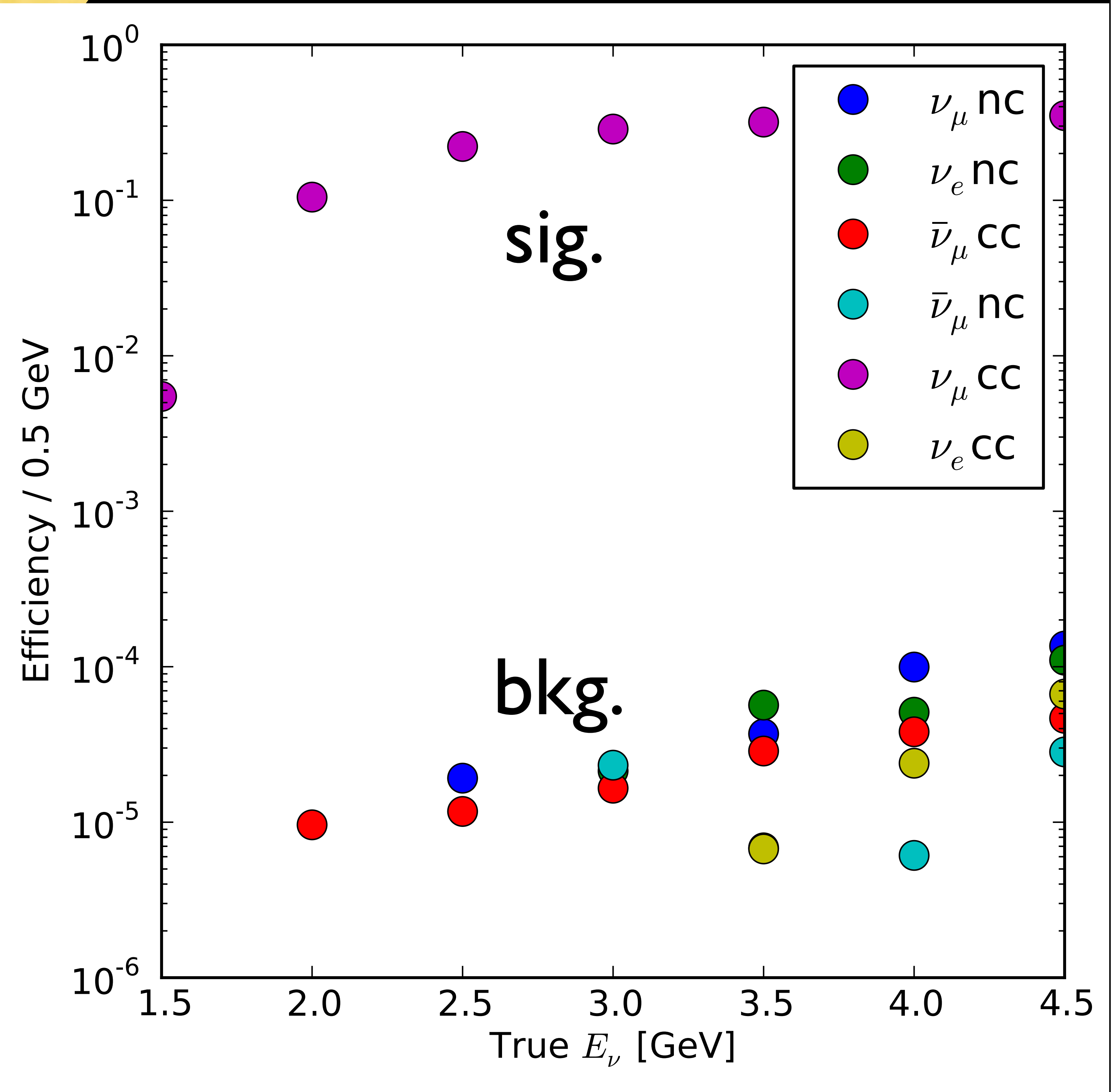

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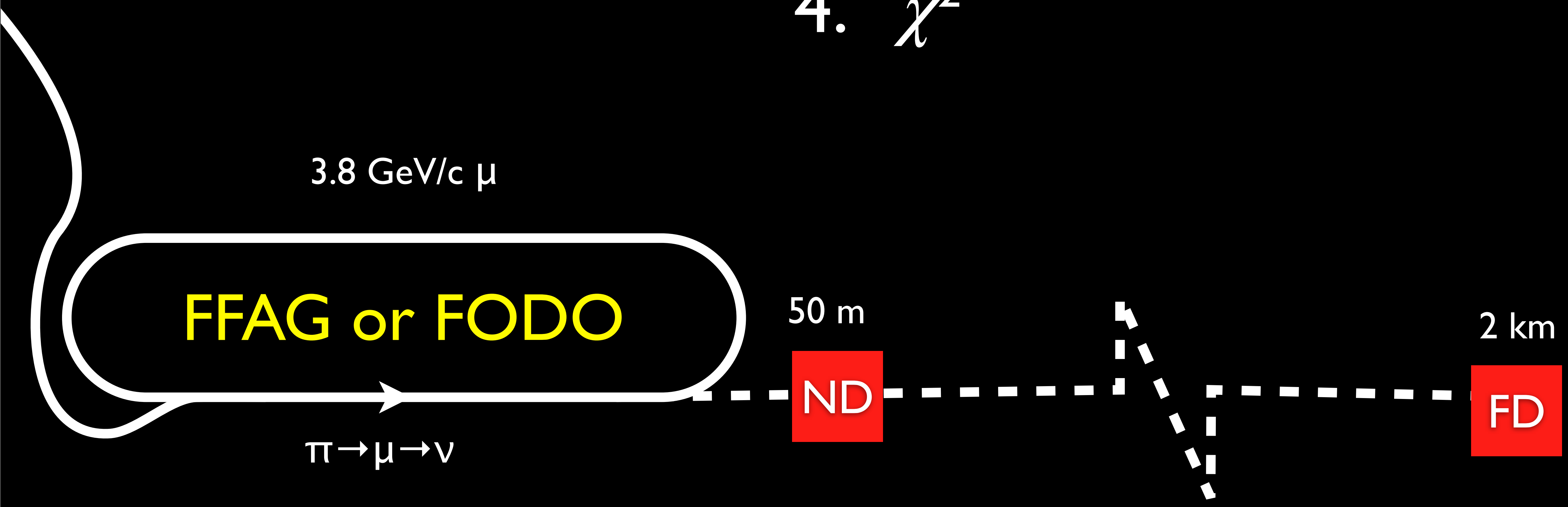
Sensitivity Steps:

1. Flux
2. Interactions
3. Efficiency
4. χ^2



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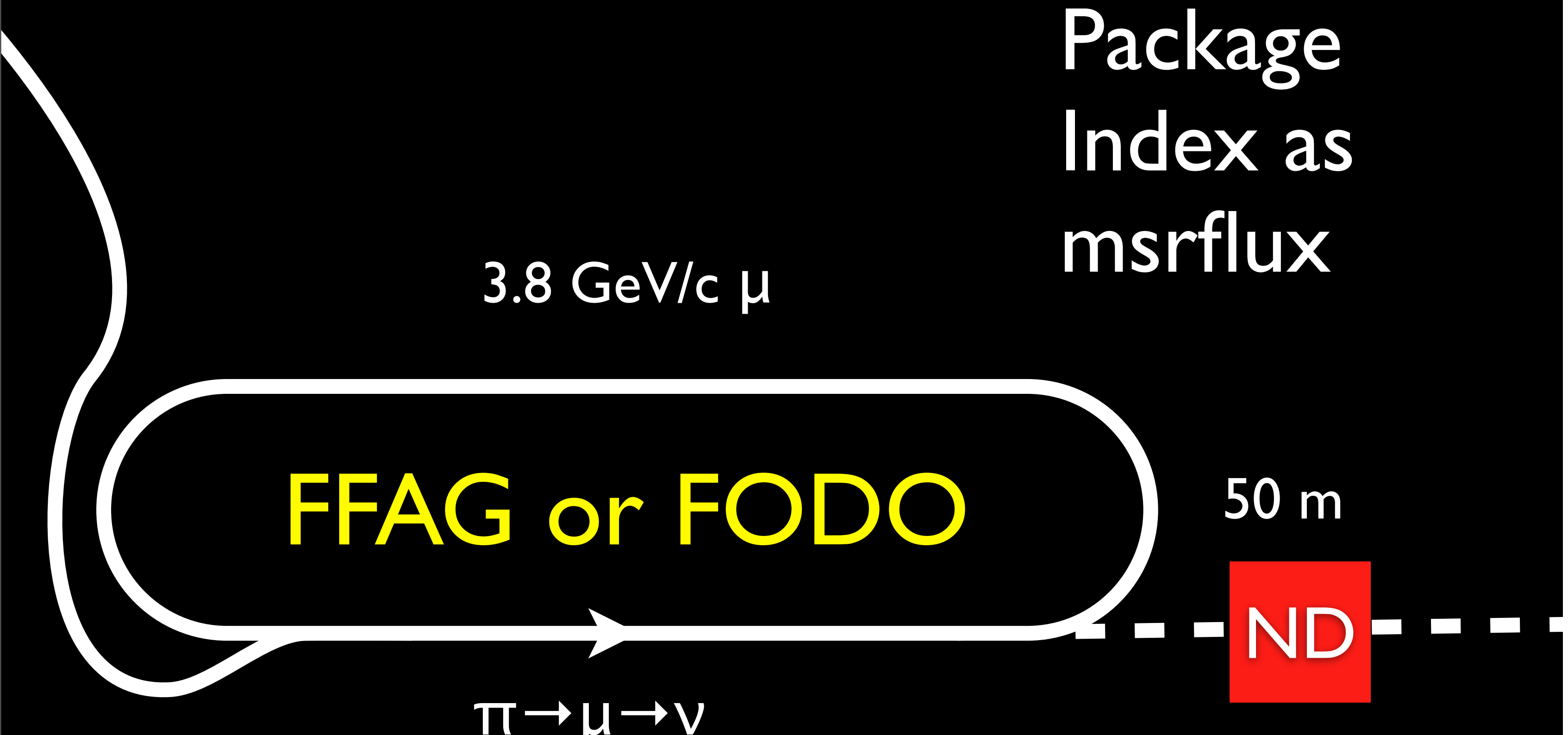
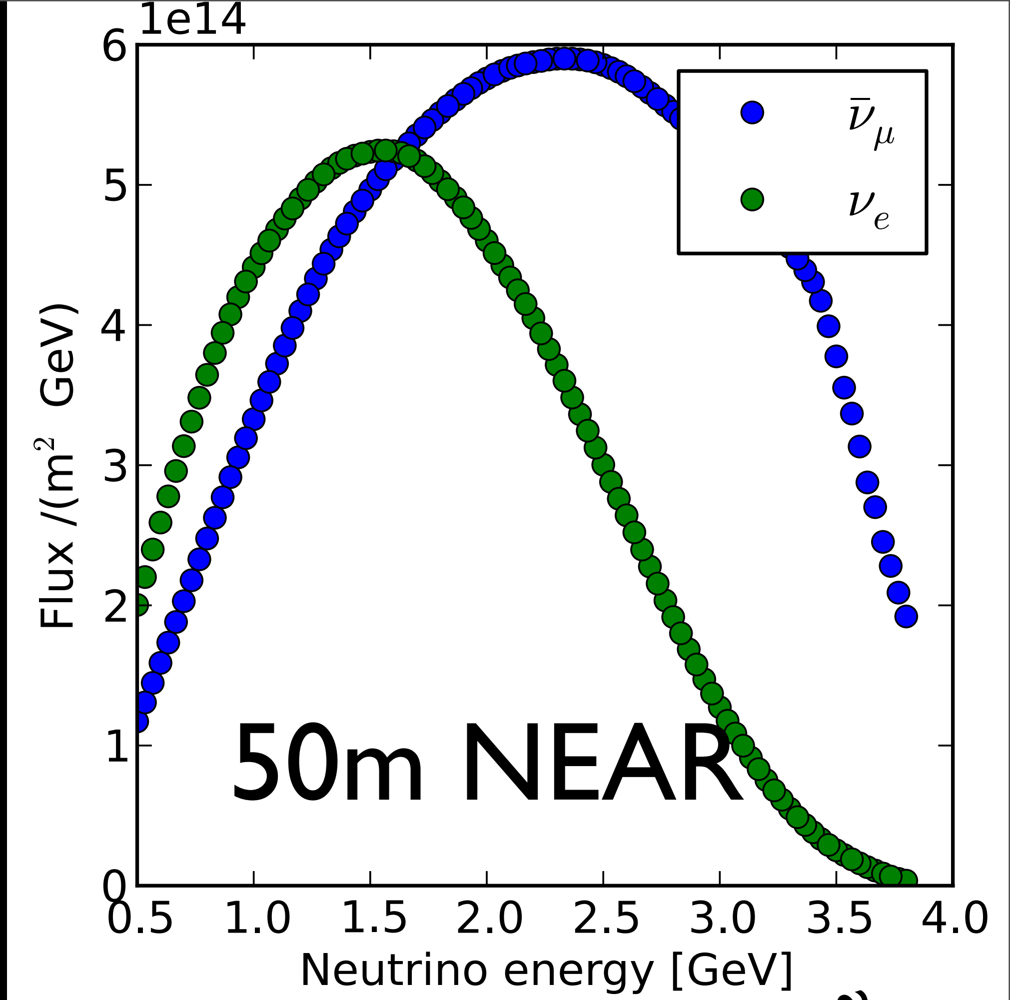
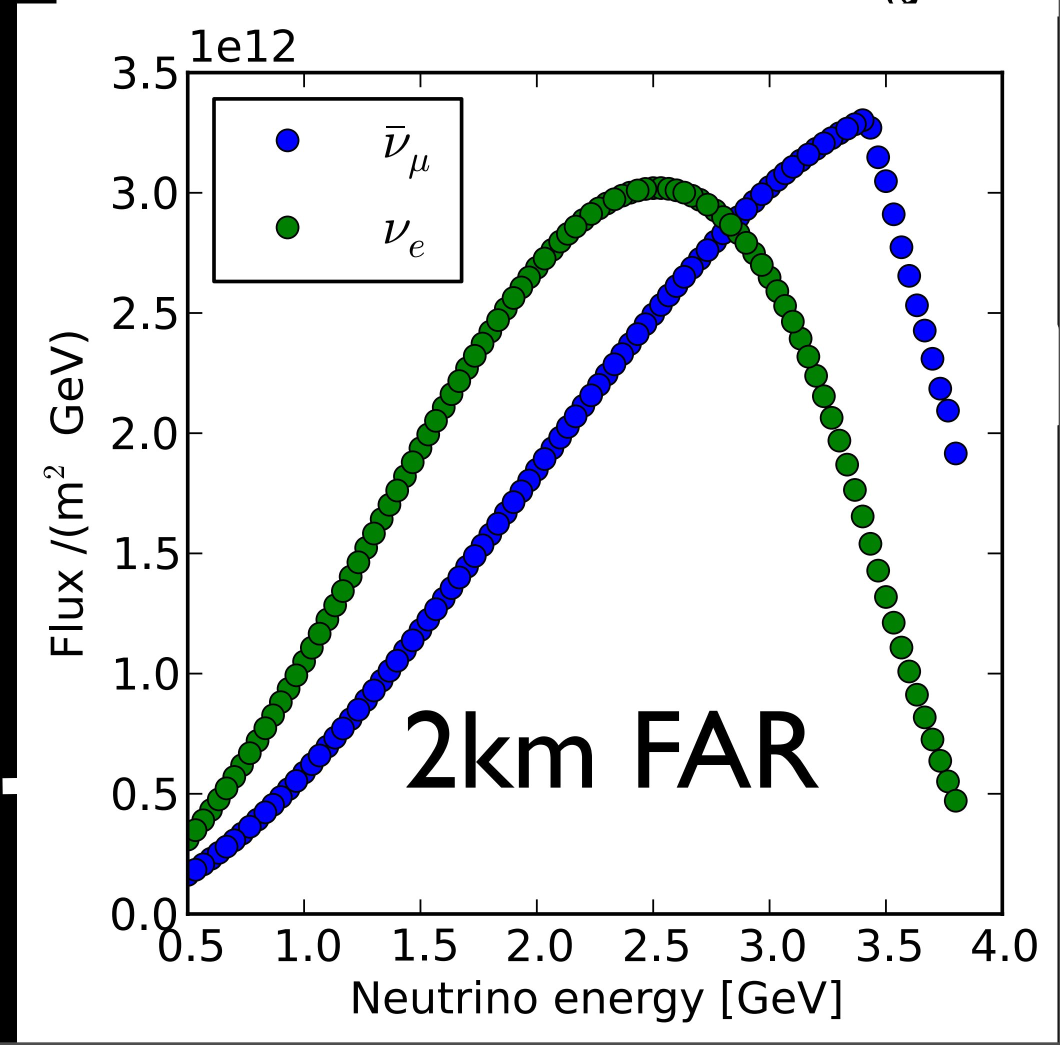
Flux

- Integrate decay straight
- Available in Python Package Index as msrflux







1. The World of Steriles
2. Our new approach
3. The Experiment
4. Performance
5. Sensitivity

Event rates

- 1.3 kt Sampling Iron Calorimeter
- Raw interactions
- No SM backgrounds
- Need 10^-5 bkg rej

Decaying Particle	Channel	$N_{\text{osc.}}$	N_{null}	Diff.	$(N_{\text{osc.}} - N_{\text{null}})/\sqrt{N_{\text{null}}}$
μ^+	$\nu_e \to \nu_\mu$ CC	332	0	∞	∞
	$\bar{\nu}_\mu \to \bar{\nu}_\mu$ NC	47679	50073	-4.8%	-10.7
	$\nu_e \to \nu_e$ NC	73941	78805	-6.2%	-17.3
	$\bar{\nu}_\mu \to \bar{\nu}_\mu$ CC	122322	128433	-4.8%	-17.1
	$\nu_e \to \nu_e$ CC	216657	230766	-6.1%	-29.4

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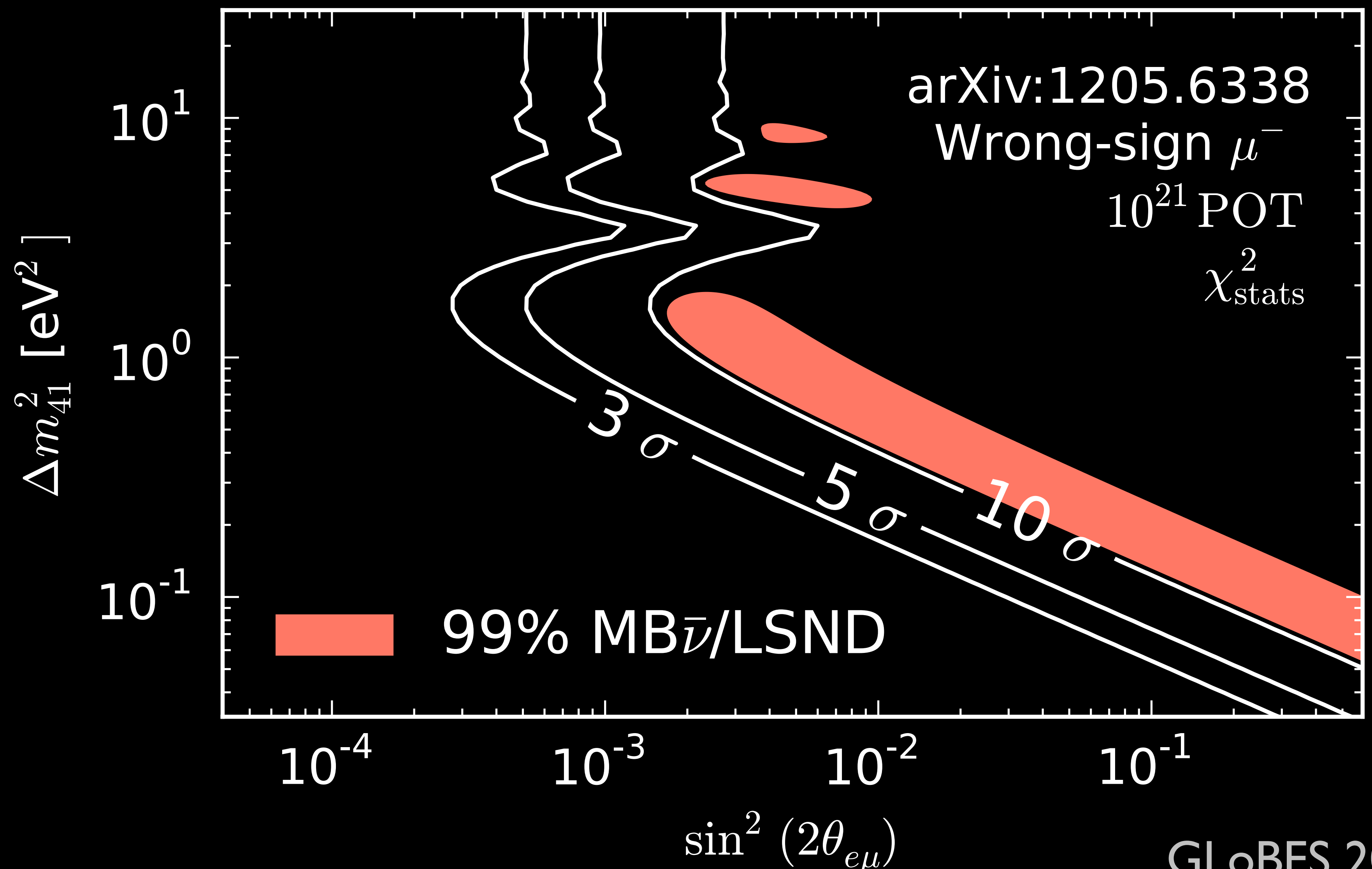
Stephen Parke:
"Don't show me plots until it's 10 sigma!"



(Backgrounds don't oscillate)

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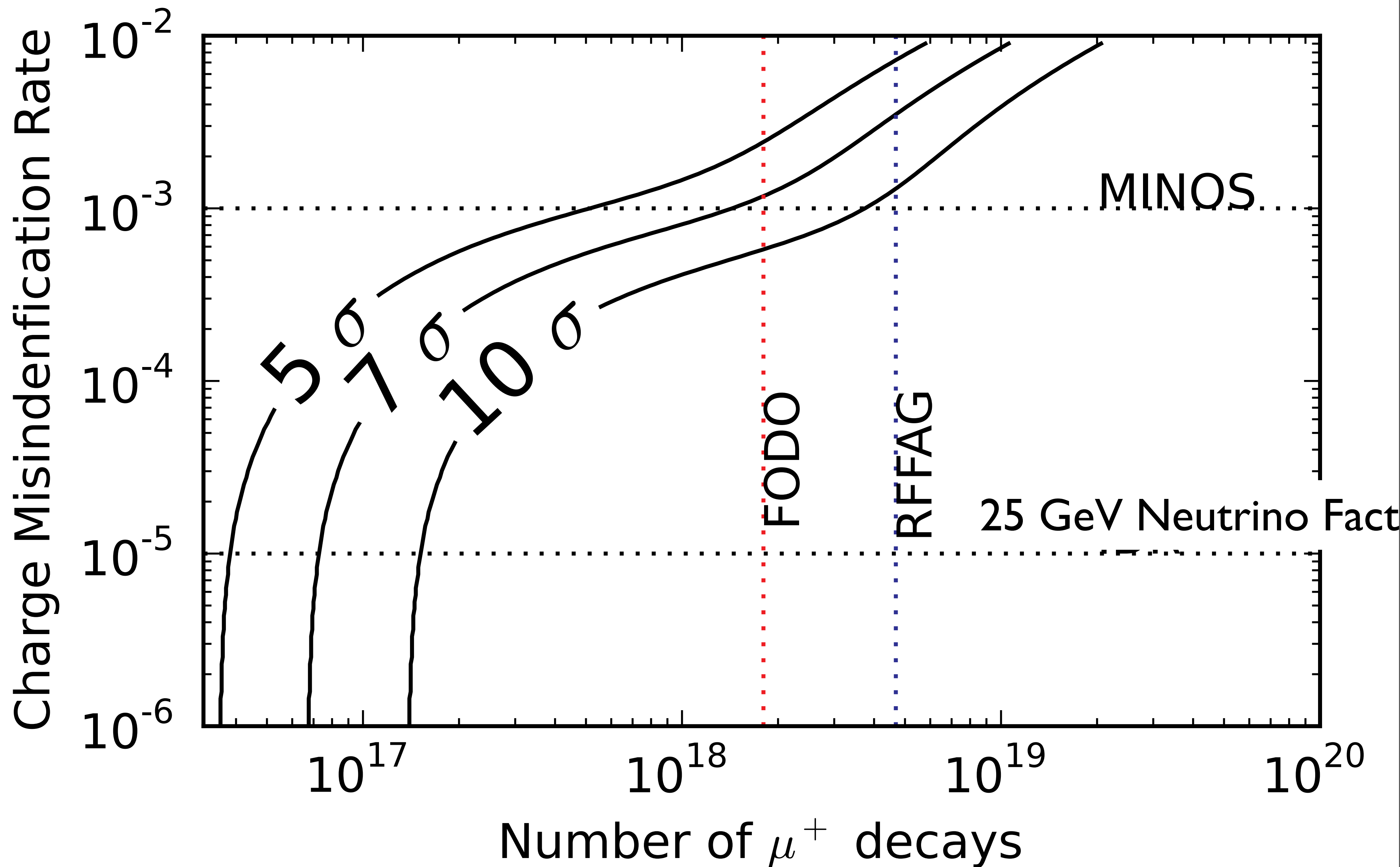
Optimizing accelerator performance versus detector performance



Numerous other optimizations in LOI

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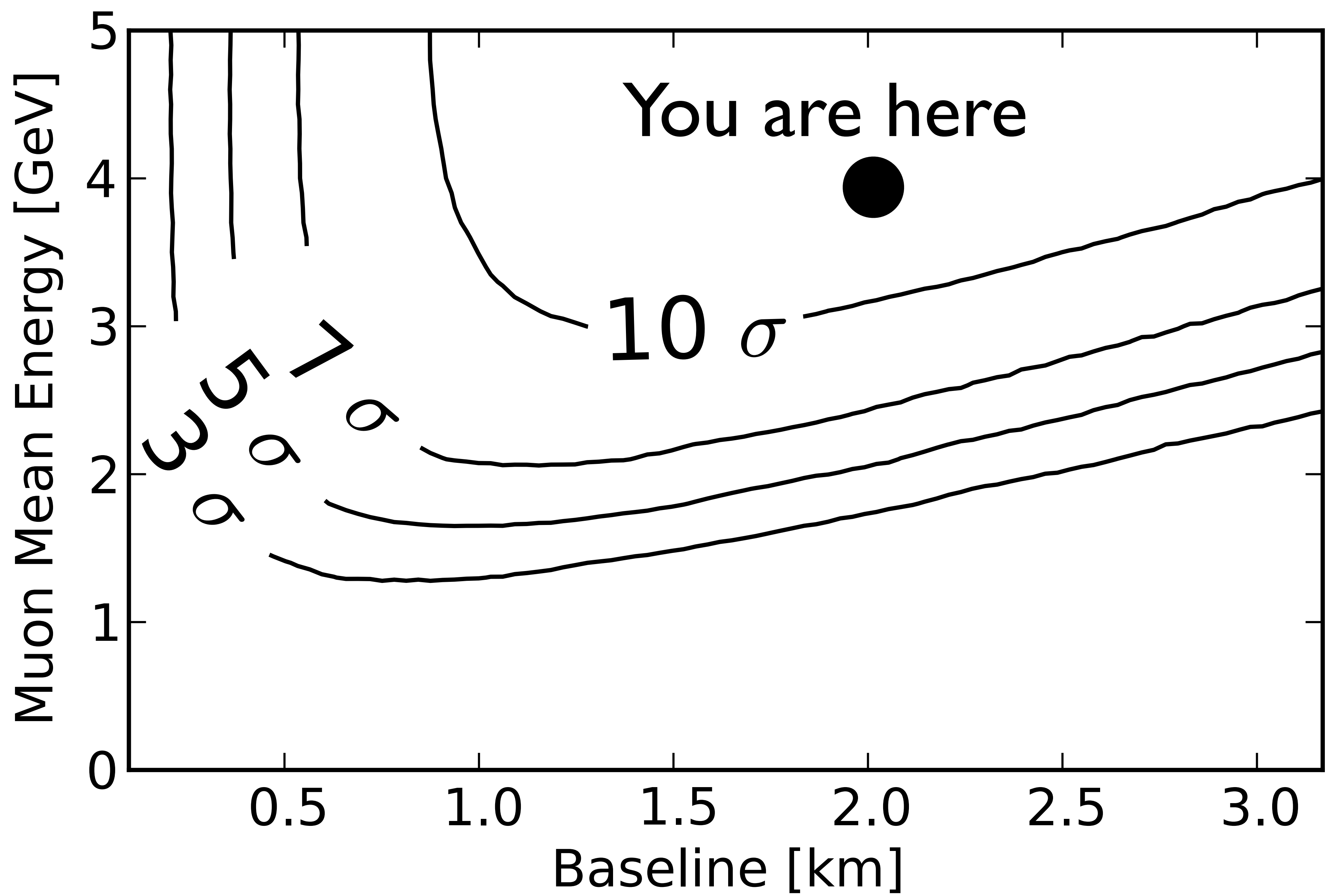
Optimizing Baseline and Energy



Numerous other optimizations in LOI

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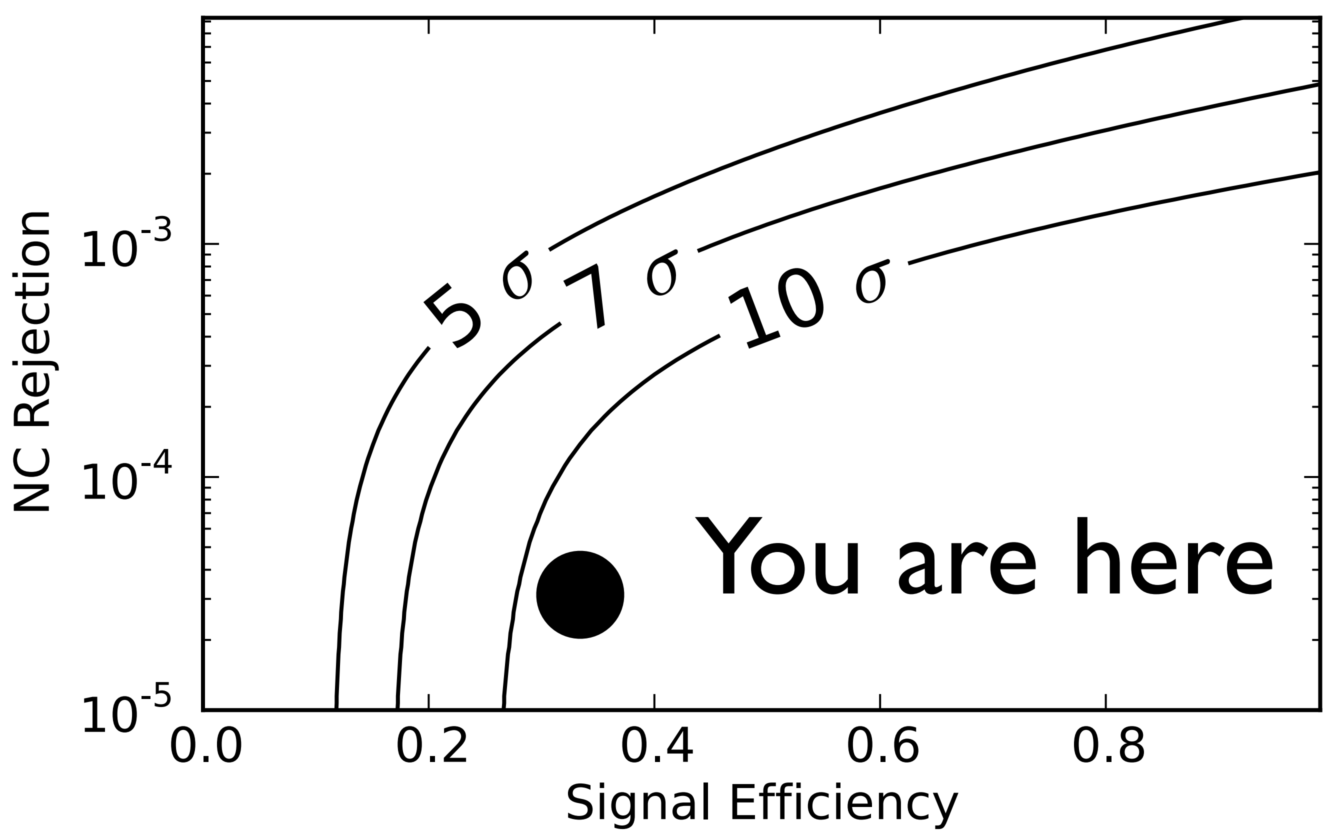
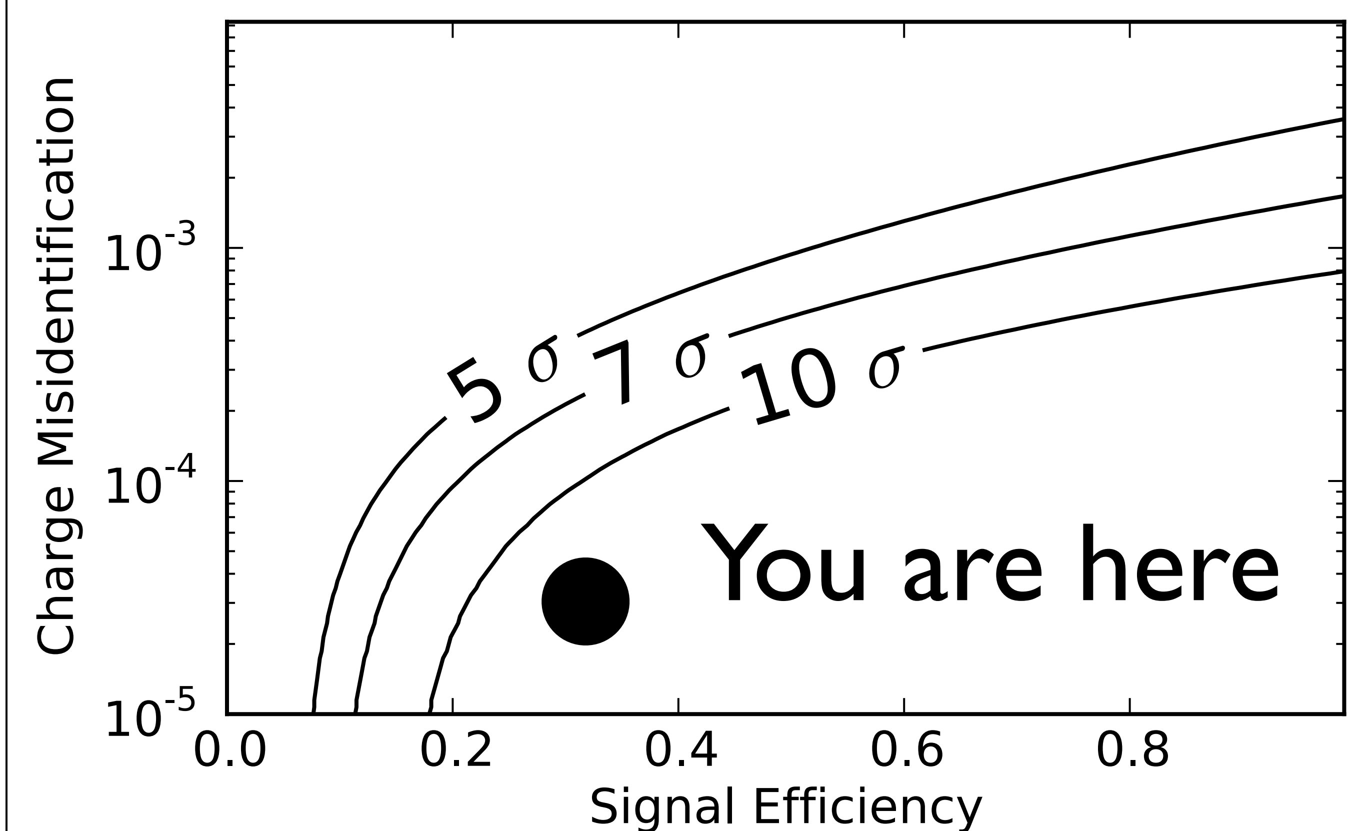
Optimizing cuts

Backgrounds at 1e-4 if unspecified





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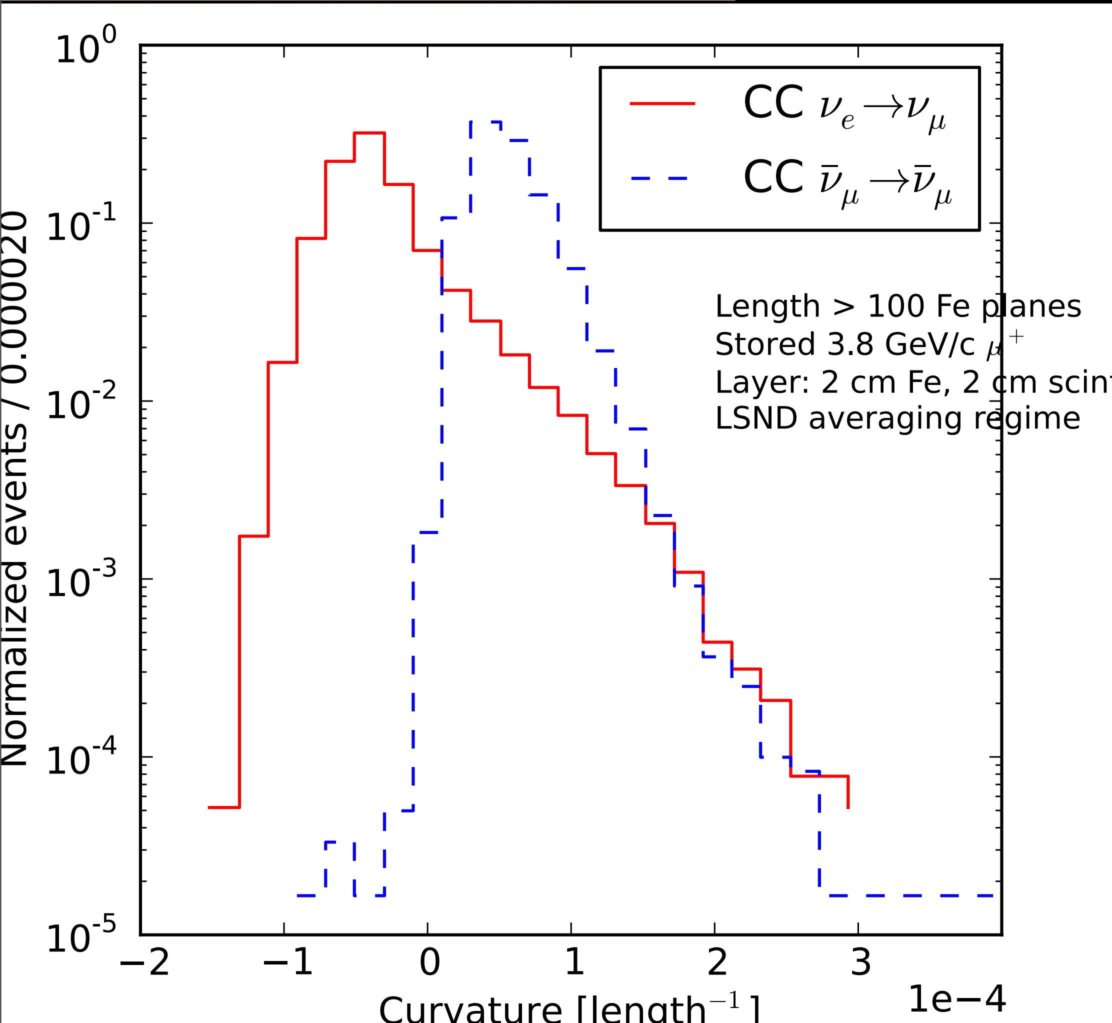
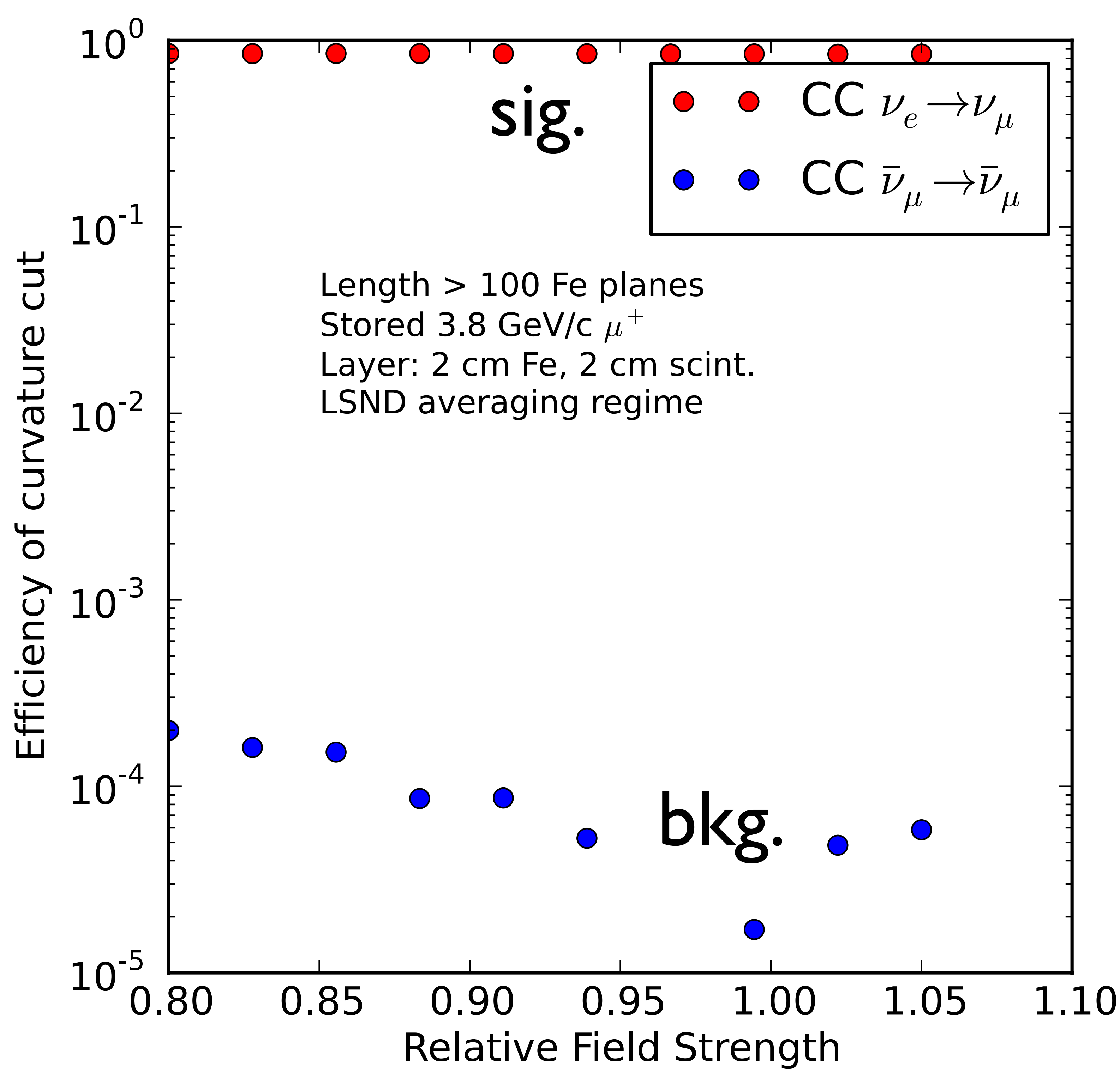
Vary field strength?





The 10σ seems fairly robust

- When varying cuts
- When varying field
- When varying POT
- When varying detector performance
- When varying muon energy and baseline

Simple physical cuts allow for systematic studies. Promising start...

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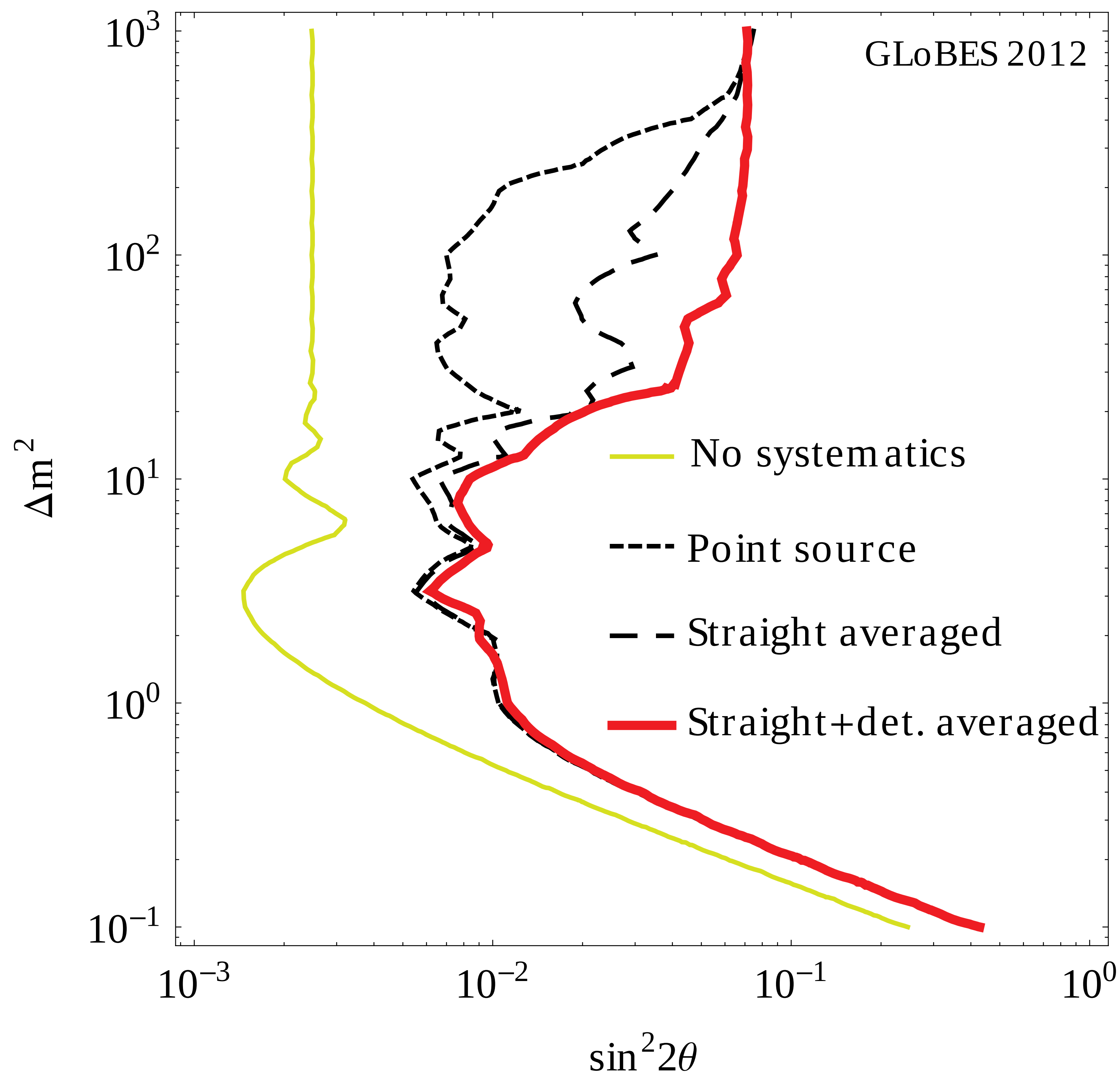
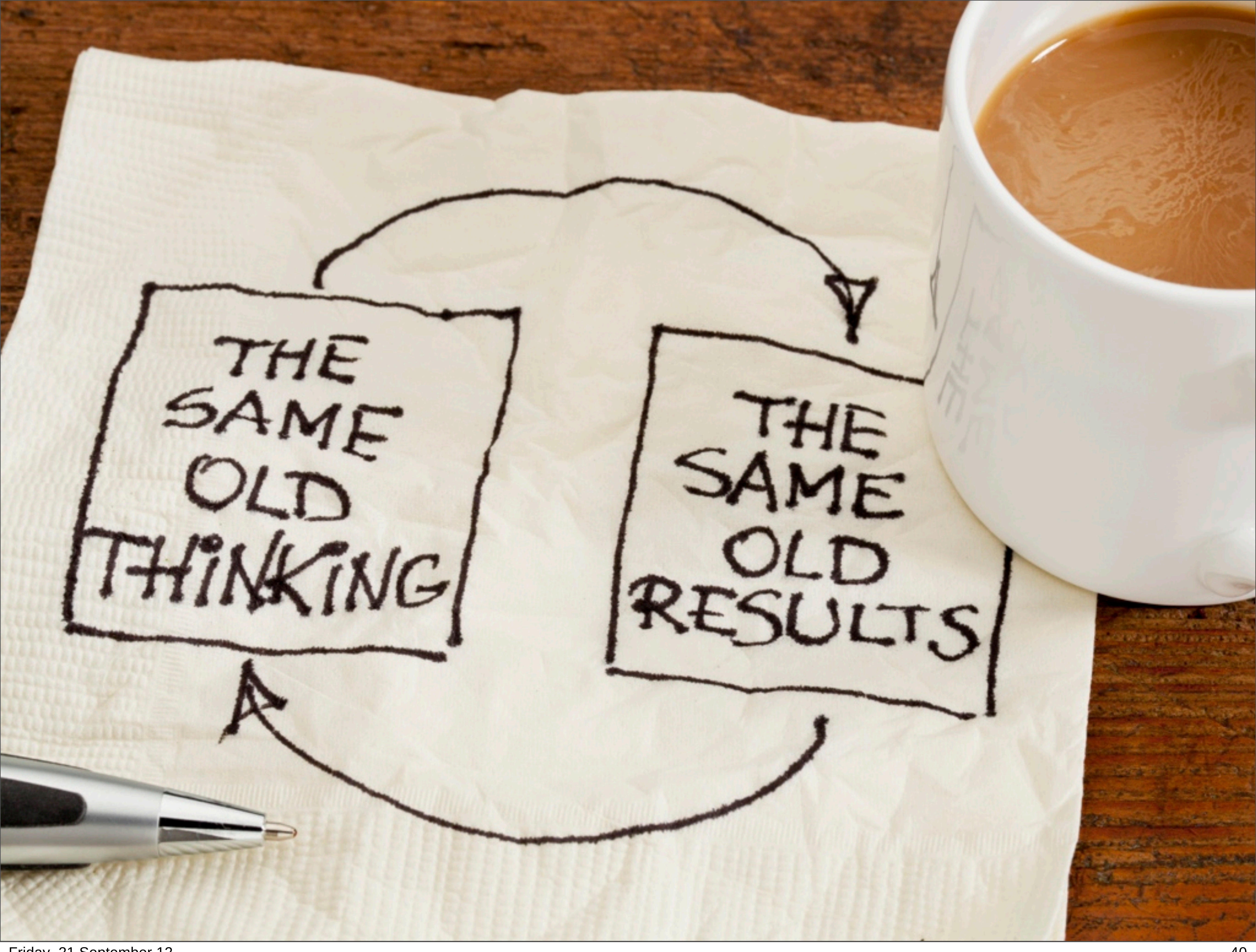
Non-sequiter

work of Walter Winter



Conclusions

- Sterile neutrinos rock.
- One of the twelve channels was presented; feel free to ask me about getting involved with other channels
- Simple detector performance study @ 10σ
- With this sensitivity to LSND, it's the SNO of sterile neutrinos


THE SAME OLD THINKING
THE SAME OLD RESULTS


WILL WORK
FOR
FOOD


WILL
post doc
FOR
FOOD


WILL
post doc
FOR
FOOD
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