

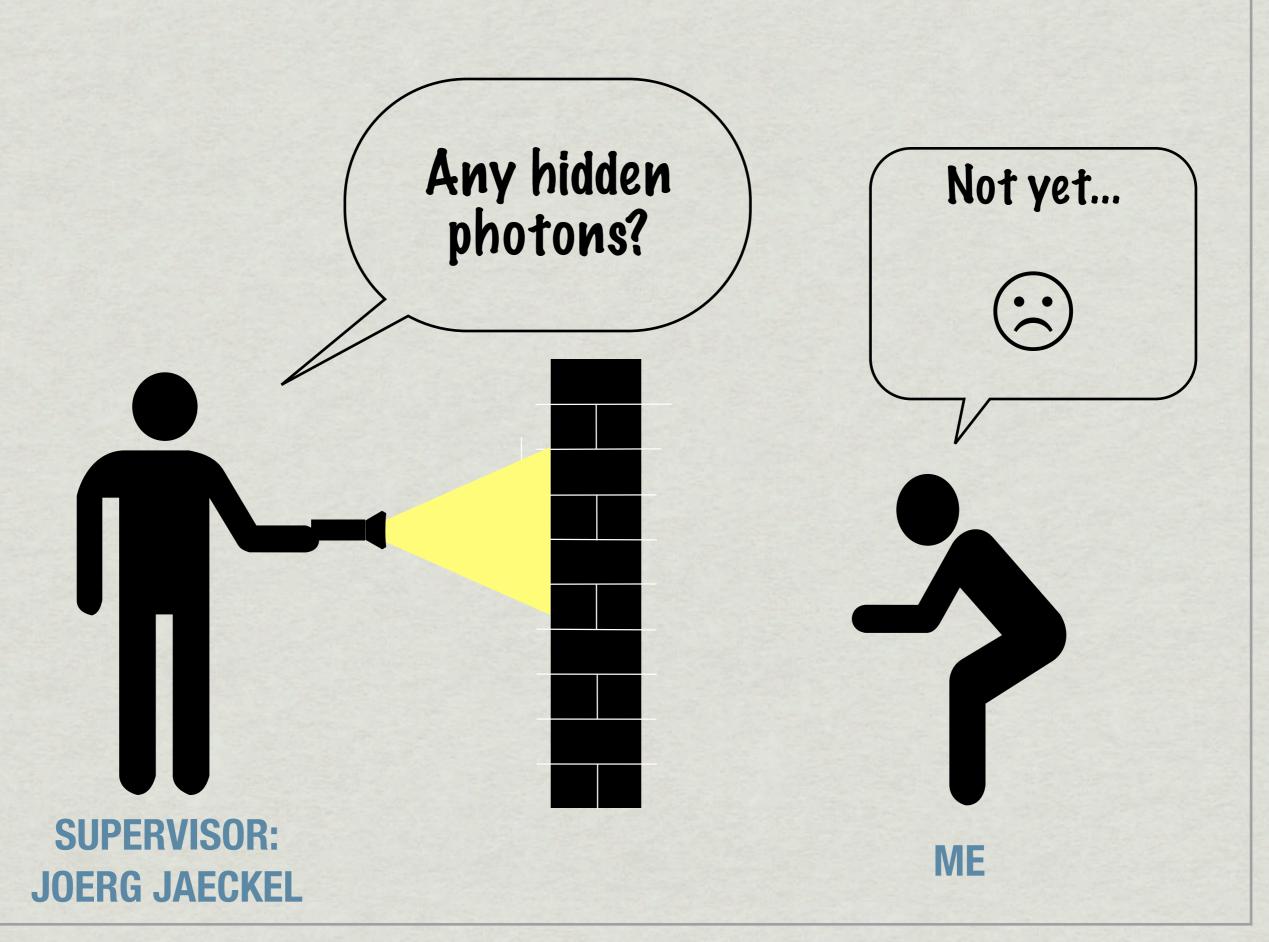
MINOS as a WIMP Cannon

Chris J Wallace IPPP, Durham



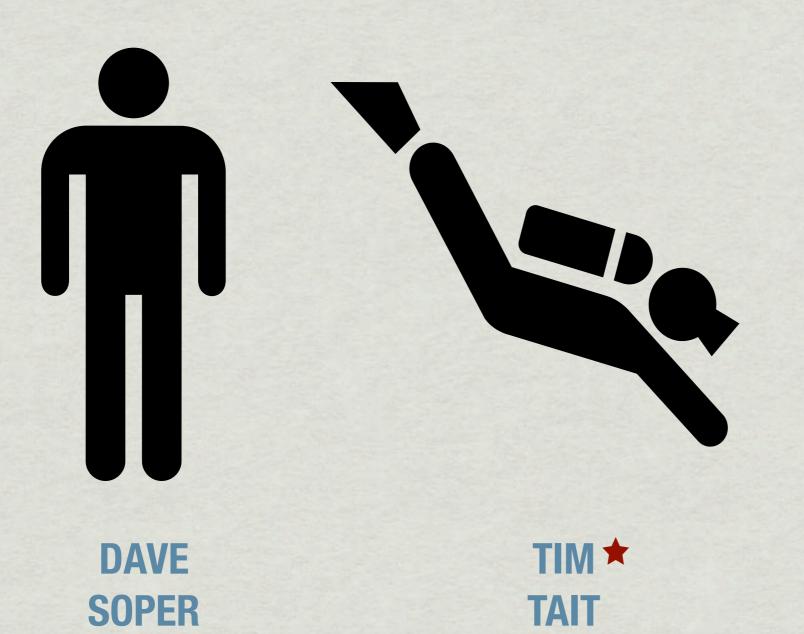


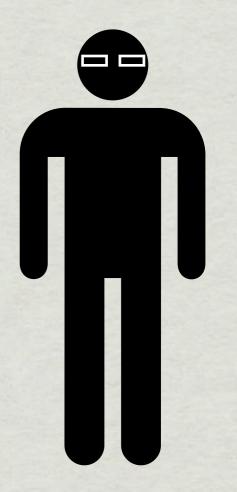
NORMALLY...



BUT TODAY...

WORK IN COLLABORATION WITH:





MICHAEL SPANNOWSKY

* AS SEEN ON TV!

Outline

* A little on WIMPs and a simple model.

- * Accessing WIMPs and hidden physics.
 - ▶ The Energy Frontier LHC bounds.
 - ▶ The Intensity Frontier MINOS bounds.

* Very light mediators - a dipole model.

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 The Intensity Frontier MINOS bounds.

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Hidden sectors are well motivated!

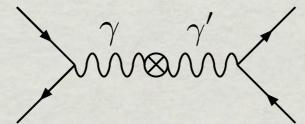
- * There is a well motivated search for BSM physics.
- * String theory, strong CP problem, Susy, dark matter, ...
 - ▶ Hidden sectors!
- * Weakly Interacting Massive Particles are a good generic DM candidate.
- * Popular paradigm WIMPs interact with the SM via a hidden sector mediator.

Looking for WIMPs

* Several approaches to try:

* Portals - Higgs, vector, neutrino.





* Effective theories/contact interactions. [Fox, Harnik...]

$$\frac{1}{M_*^2} \left[\bar{\chi} \gamma_\mu \chi \right] \sum_q \left[\bar{q} \gamma^\mu q \right] \Leftrightarrow$$

[Goodman, Tait...]

* Direct coupling.

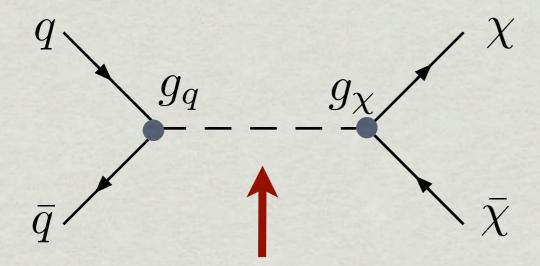
[deNiverville, McKeen, Ritz]

* Many interactions already tightly constrained.

MUCH MORE WORK, MANY MORE AUTHORS. BUT THESE GUYS COULD BE IN THE AUDIENCE ... :P

A simple model

- * Dirac fermion WIMPs in a hidden sector.
- * Light mediator that only allows WIMP quark couplings.

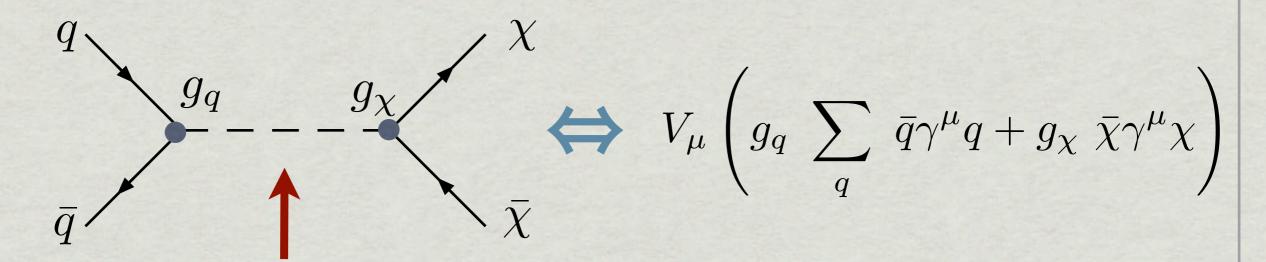


Scalar, pseudoscalar, vector, axial vector

- * Particular paradigm Light WIMPs (MeV GeV).
- * Light mediator always off-shell: $m_V < 2 m_\chi$

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WIMPs are difficult to detect!

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COLLIDERS: LHC, TEVATRON

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FIXED TARGETS: LSND, T2K, MINOS

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FIXED TARGETS: LSND, T2K, MINOS COSMOLOGICAL

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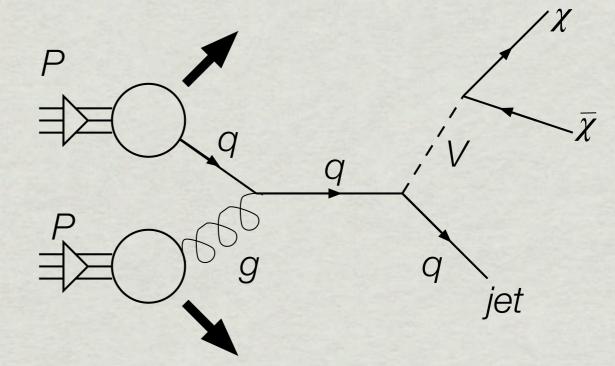
FIXED TARGETS: LSND, T2K, MINOS



The energy frontier

- * High energy to probe small scales/couplings and large masses.
- * LHC monojet search (not the only way!).

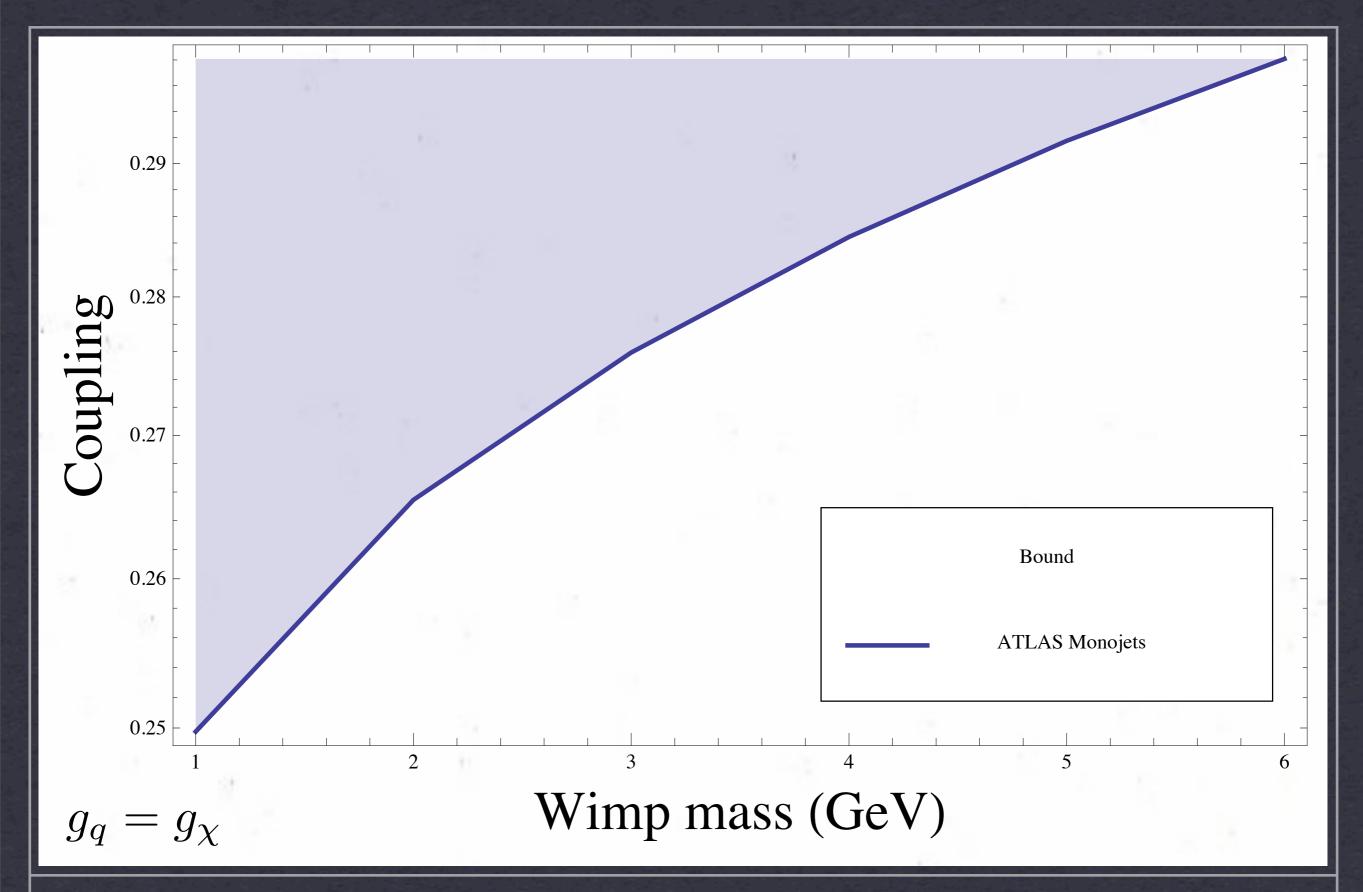
SINGLE JET SCATTERS
BACK TO BACK WITH...
WHAT?



*** ICHEP data:**

- ▶ Predicted 124,000 ± 4000 monojets.
- Observed 124,700 monojets.

[Tomorrow: Bjoern Penning]



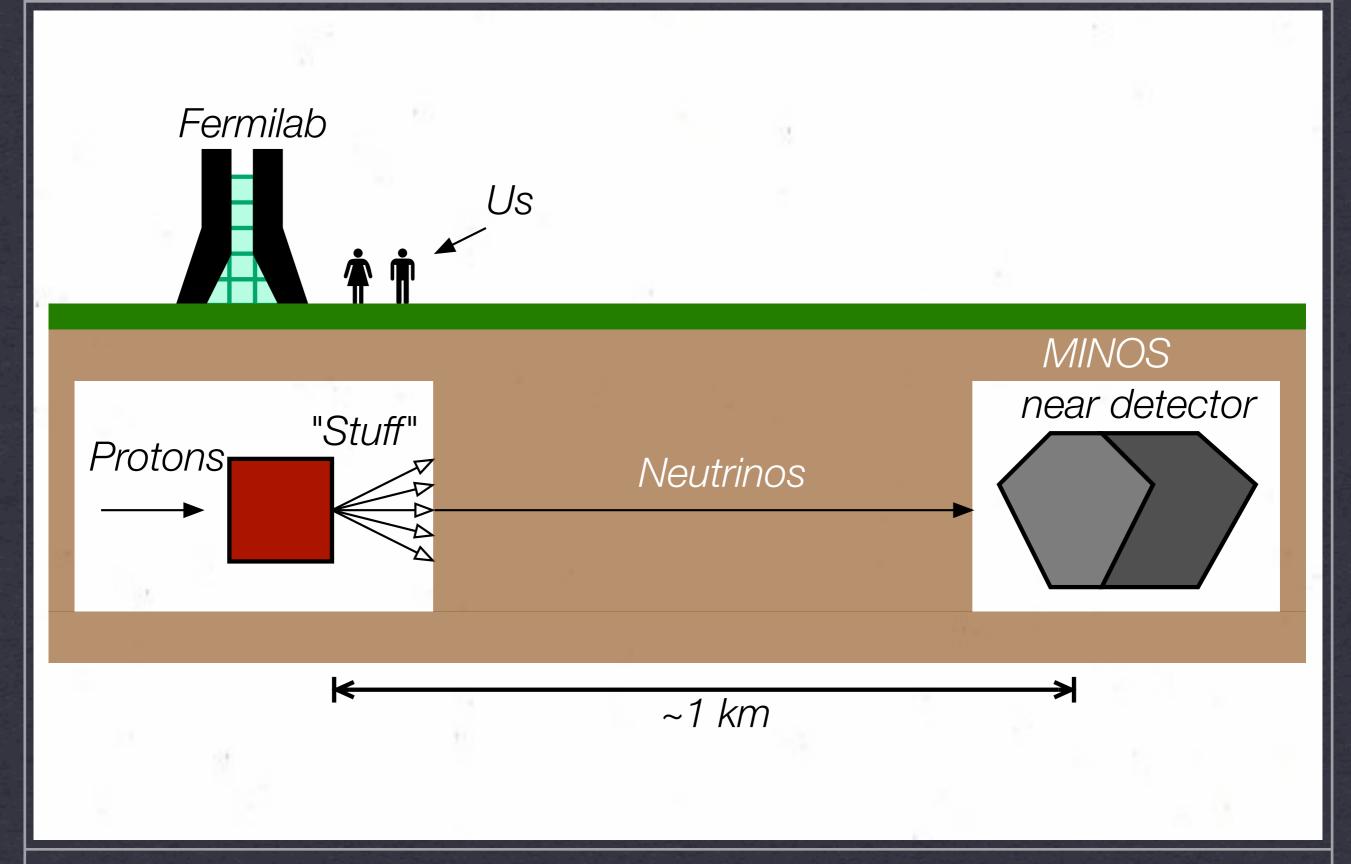
MONOJET BOUNDS

COUPLING ENTERS TO FOURTH POWER IN CROSS SECTION.

The intensity frontier

- * Access small couplings using large data sets.
- * Fixed targets probe of new physics. [Bjorken, Essig...]
- * Proton fixed targets good for light DM. [Batell, Pospelov, Ritz]
- * Of the proton fixed target machines, MINOS has the highest beam energy.

WHAT'S A FIXED TARGET EXPERIMENT ANYWAY?



MINOS

A NEUTRINO FIXED TARGET EXPERIMENT

WIMP creation

- * 120 GeV proton beam. ~10^21 POT.
- * Stationary graphite target.
- * Strong rapidity cut (angle on target ~0.0025 rad).

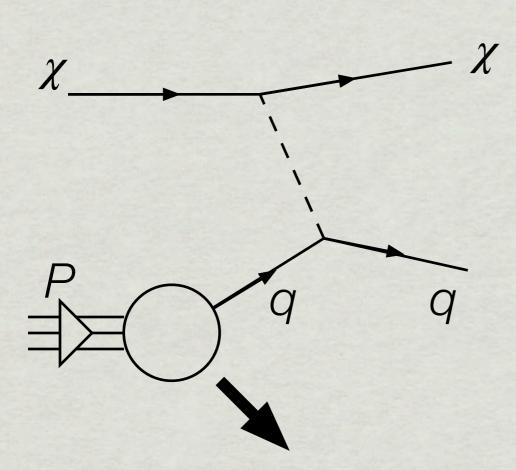
* Process:

$$\begin{array}{c|c}
P & & \chi \\
\hline
 & & \chi \\
\hline
 & & \bar{q} \\
\hline
 & & \bar{\chi} \\
\end{array}$$

$$N_{\rm prod} = 2 \times \sigma(pp \to \chi\bar{\chi}) \times L_T \times n_T \times {\rm POT}$$

WIMP Rescattering

- * Lots of stuff in between target and detector.
- * Deep inelastic scattering type process.



MEAN FREE PATH

$$\lambda = \frac{A}{N_A \rho \sigma \left(\chi N \to \chi N\right)}$$

RESCATTERING PROBABILITY

$$P = \int_0^L dx \, \frac{1}{\lambda} \, e^{-\frac{x}{\lambda}}$$

FINALLY DETECT:

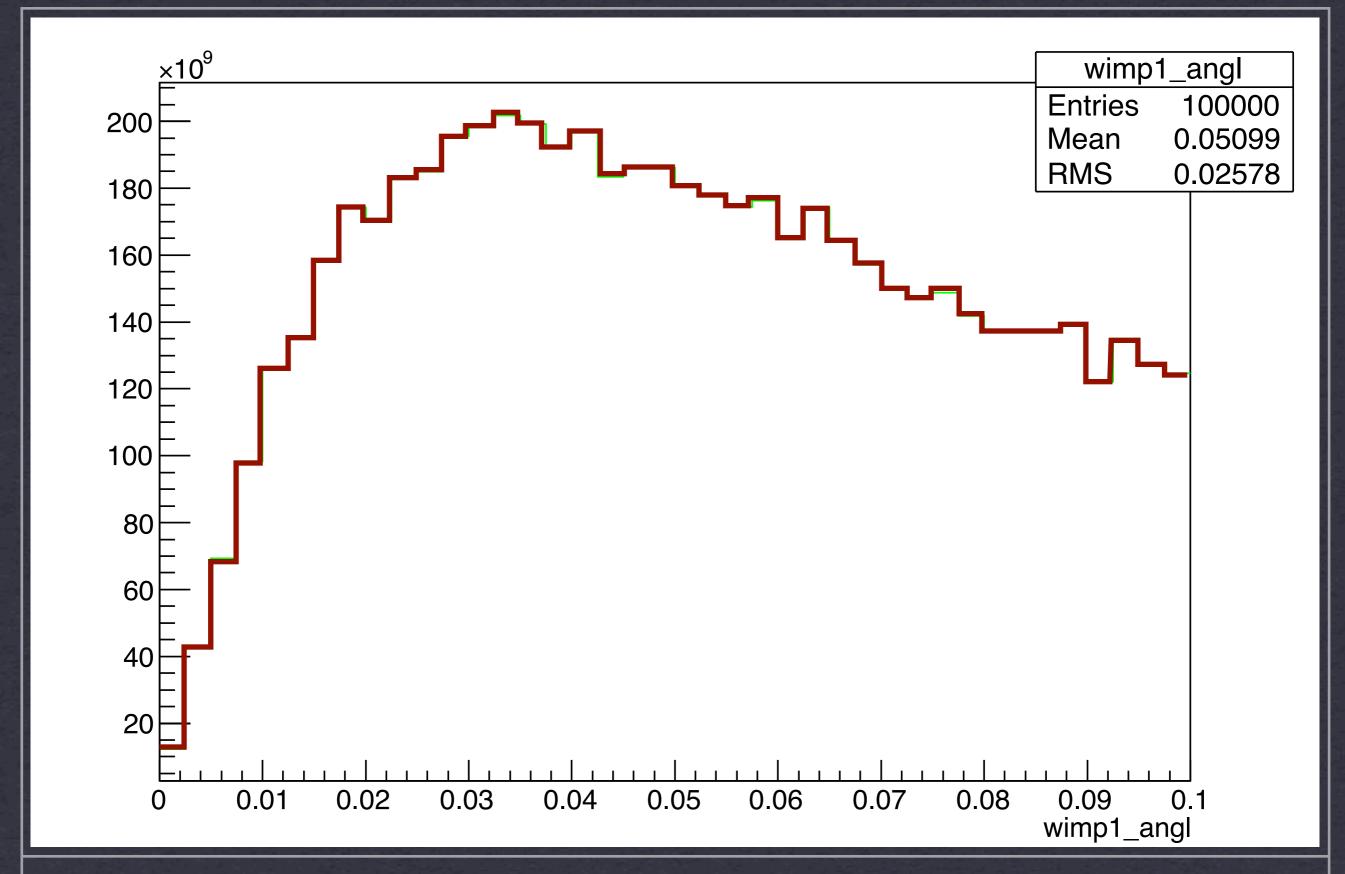
$$N_{\rm detected} = \epsilon \times (1 - P_{\rm Si}) \times P_{\rm Fe} \times N_{\rm prod}$$

SO IS MINOS REALLY A WIMP CANON?



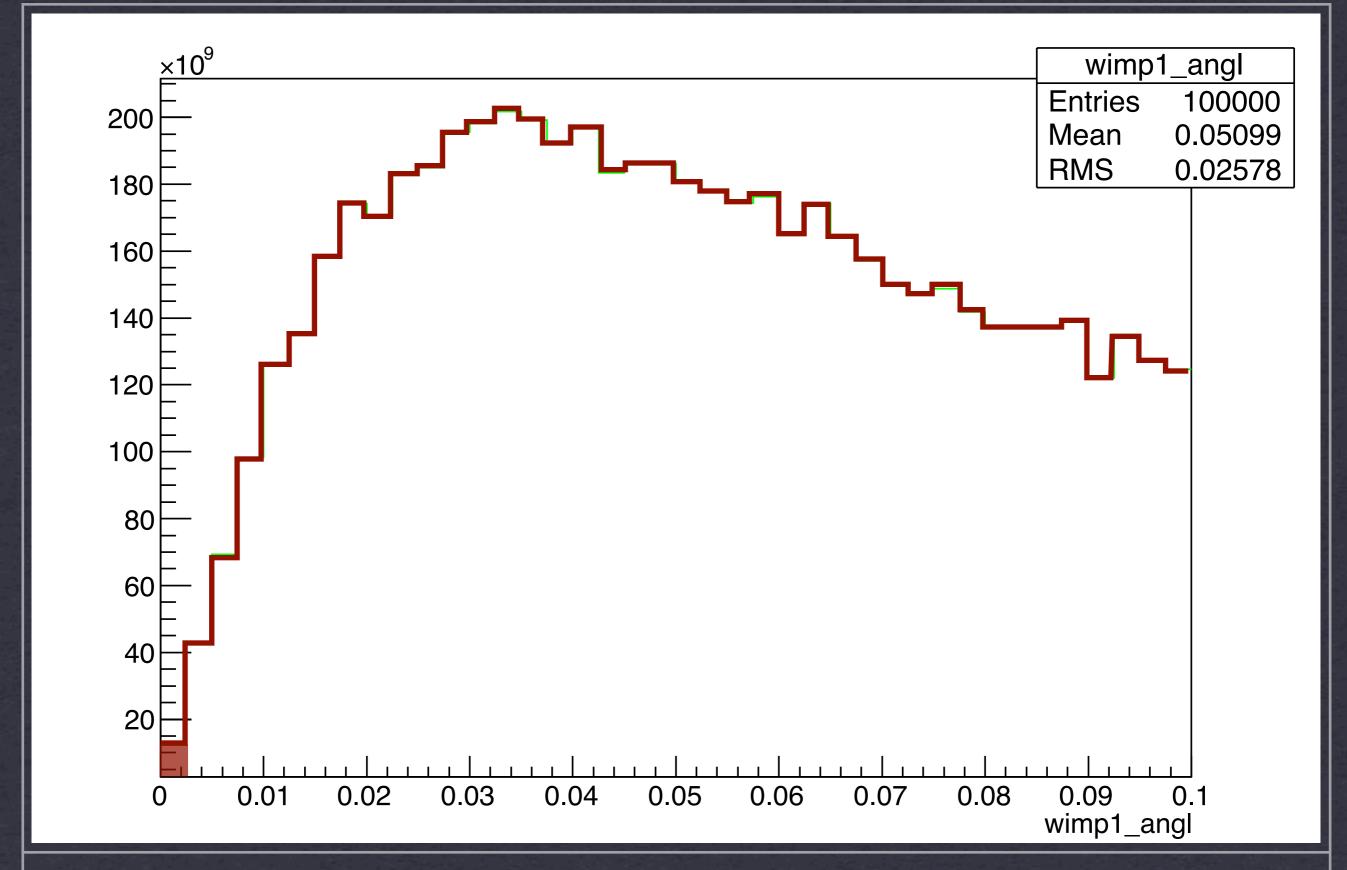
FIRST GOOGLE IMAGE HIT FOR "MINOS CANNON"

DOES NOT BODE WELL.



ANGULAR DISTRIBUTION OF HARDEST WIMP (g=1)

BUT HOW MANY DO WE CATCH?



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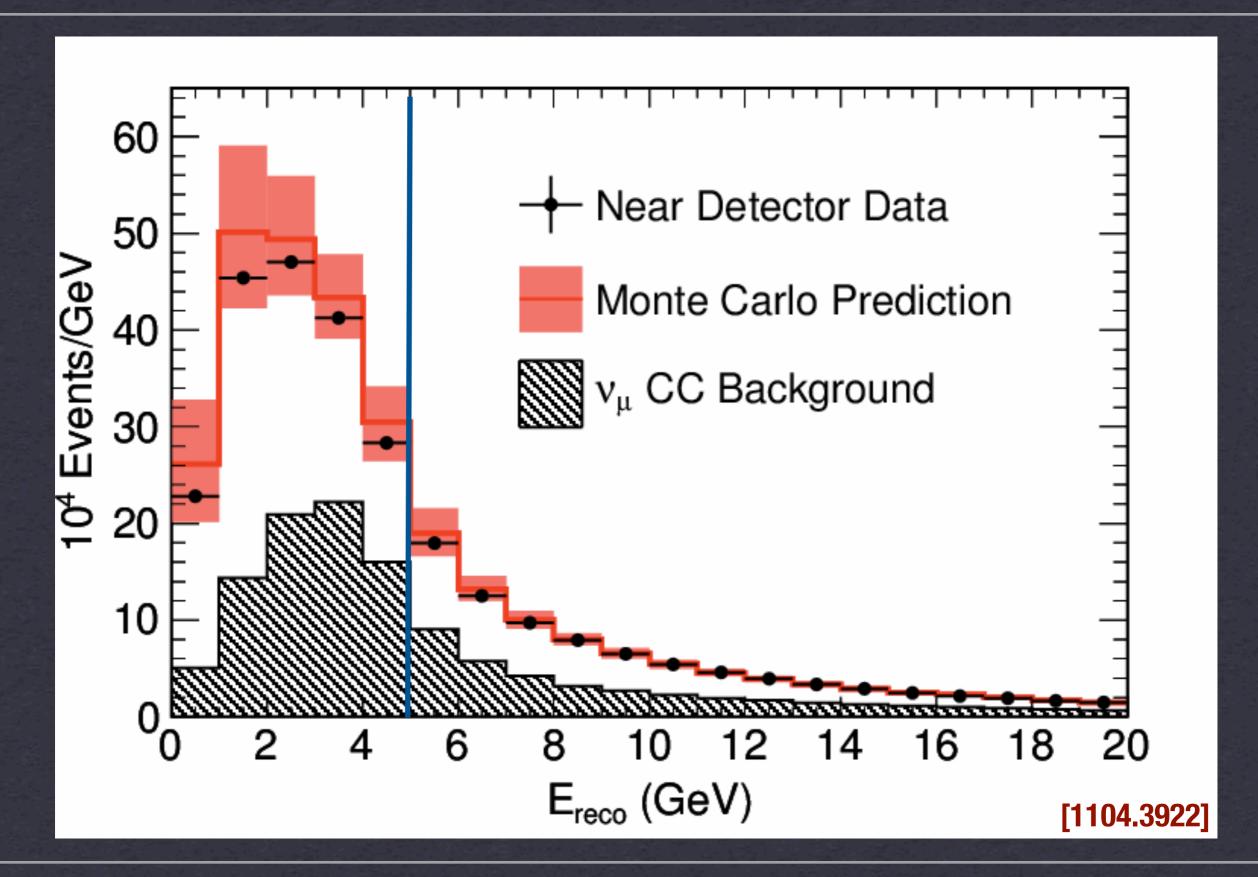


MINOS as a WIMP Cairion

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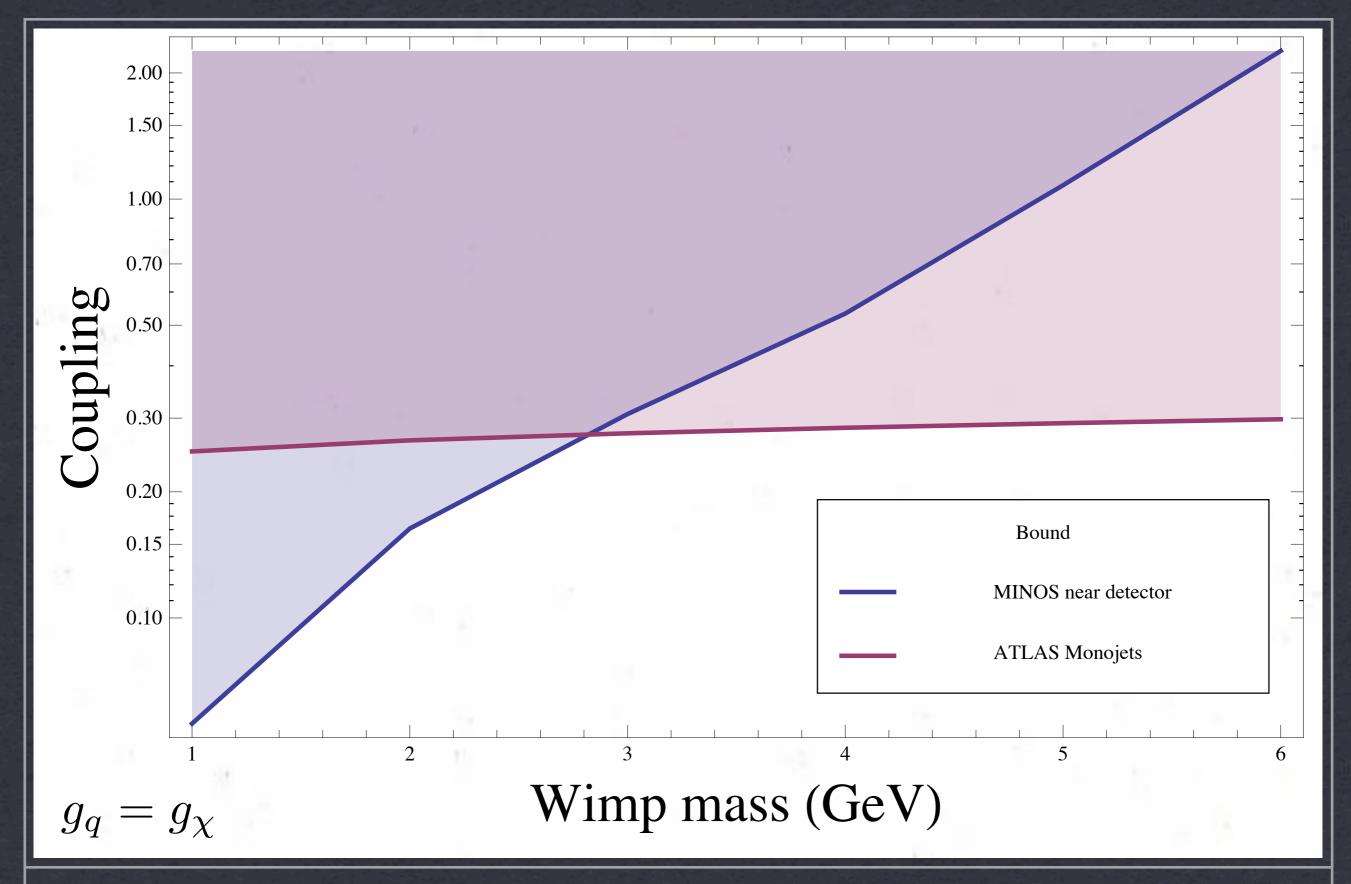


University of Durham



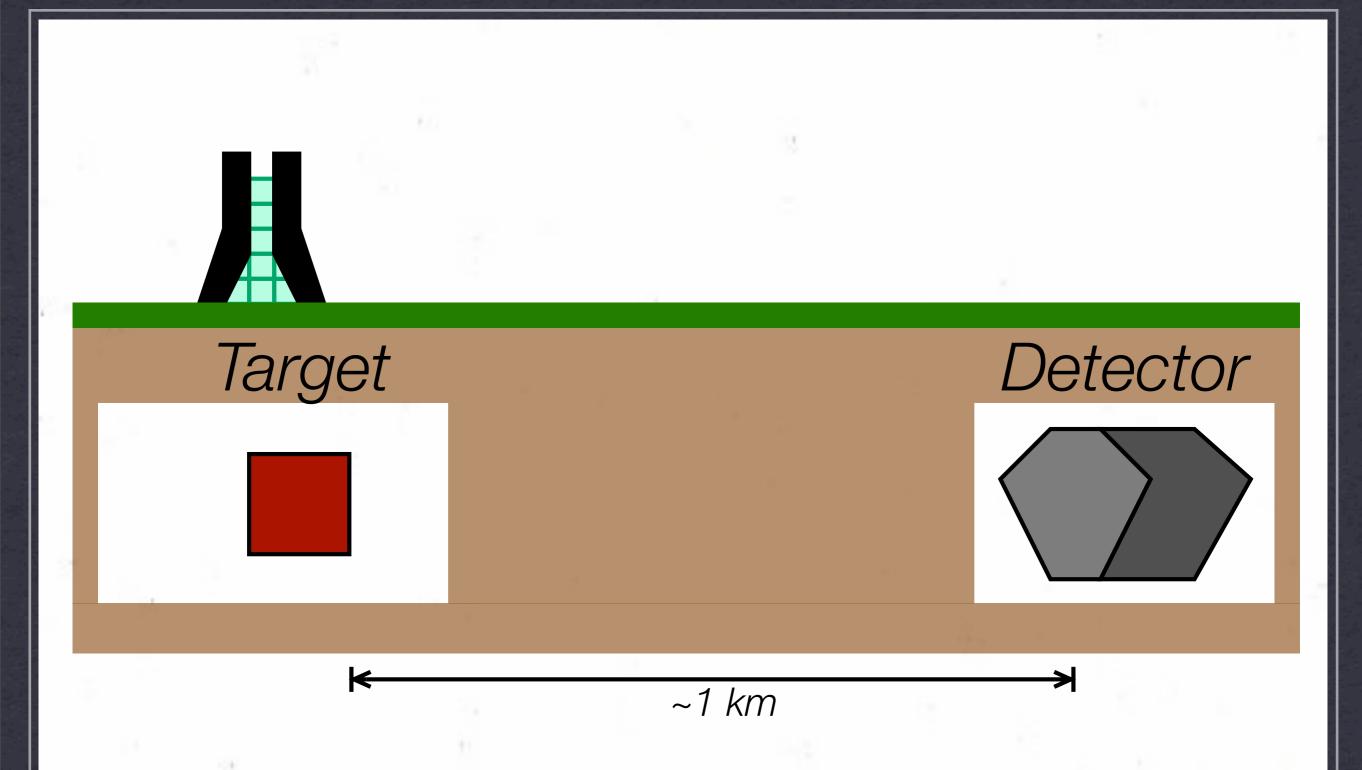
NEUTRAL CURRENTS IN MINOS NEAR DETECTOR

REALLY NEED TO KNOW THE NUMBERS FOR THE BACKGROUND



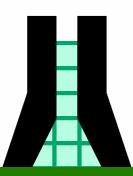
MONOJET VS MINOS BOUNDS

COUPLING ENTERS TO FOURTH POWER IN CROSS SECTION.



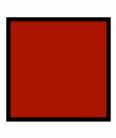
REAL SET UP

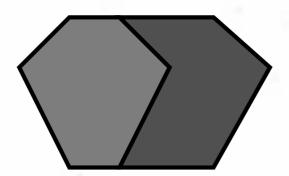
A NEUTRINO FIXED TARGET EXPERIMENT

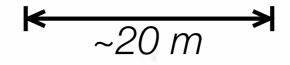


Target



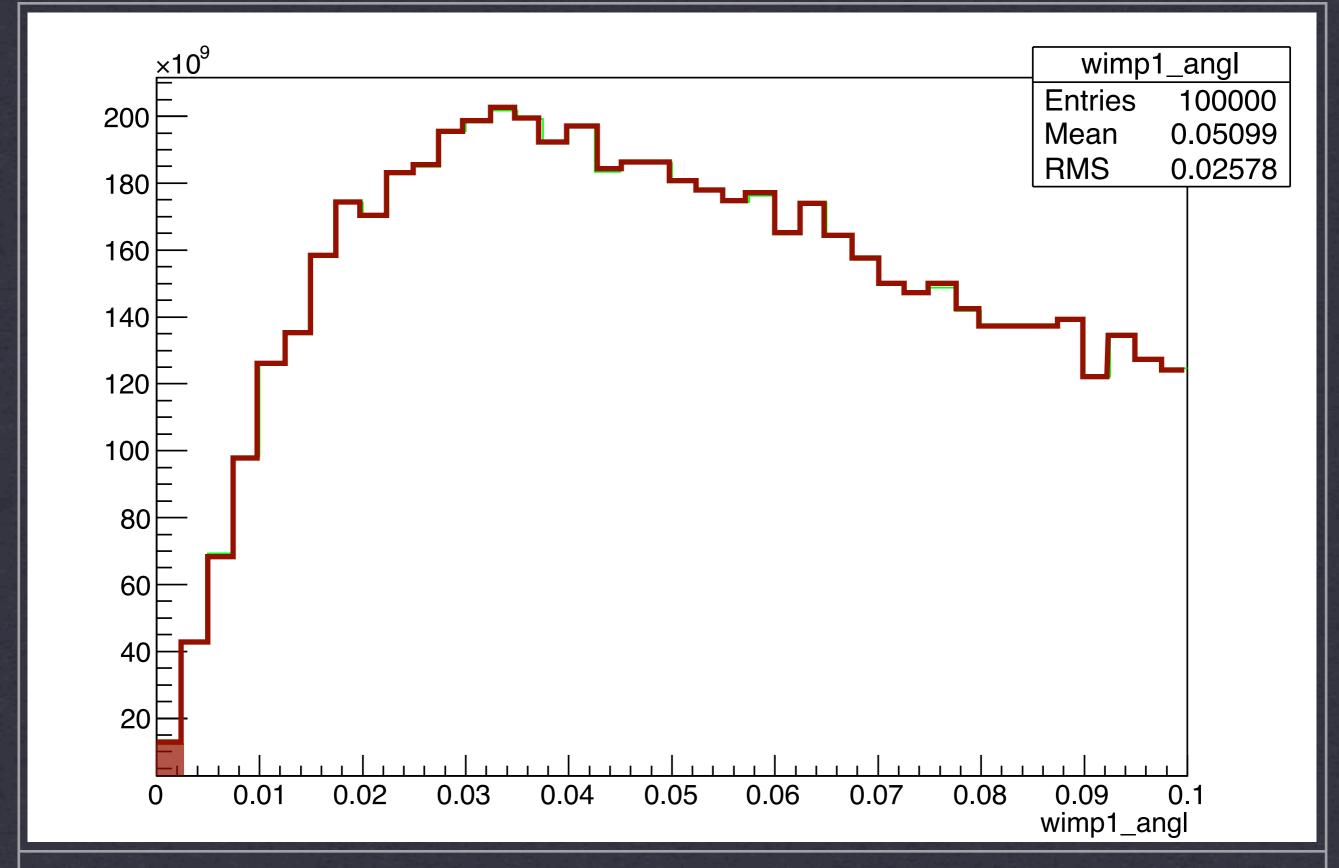






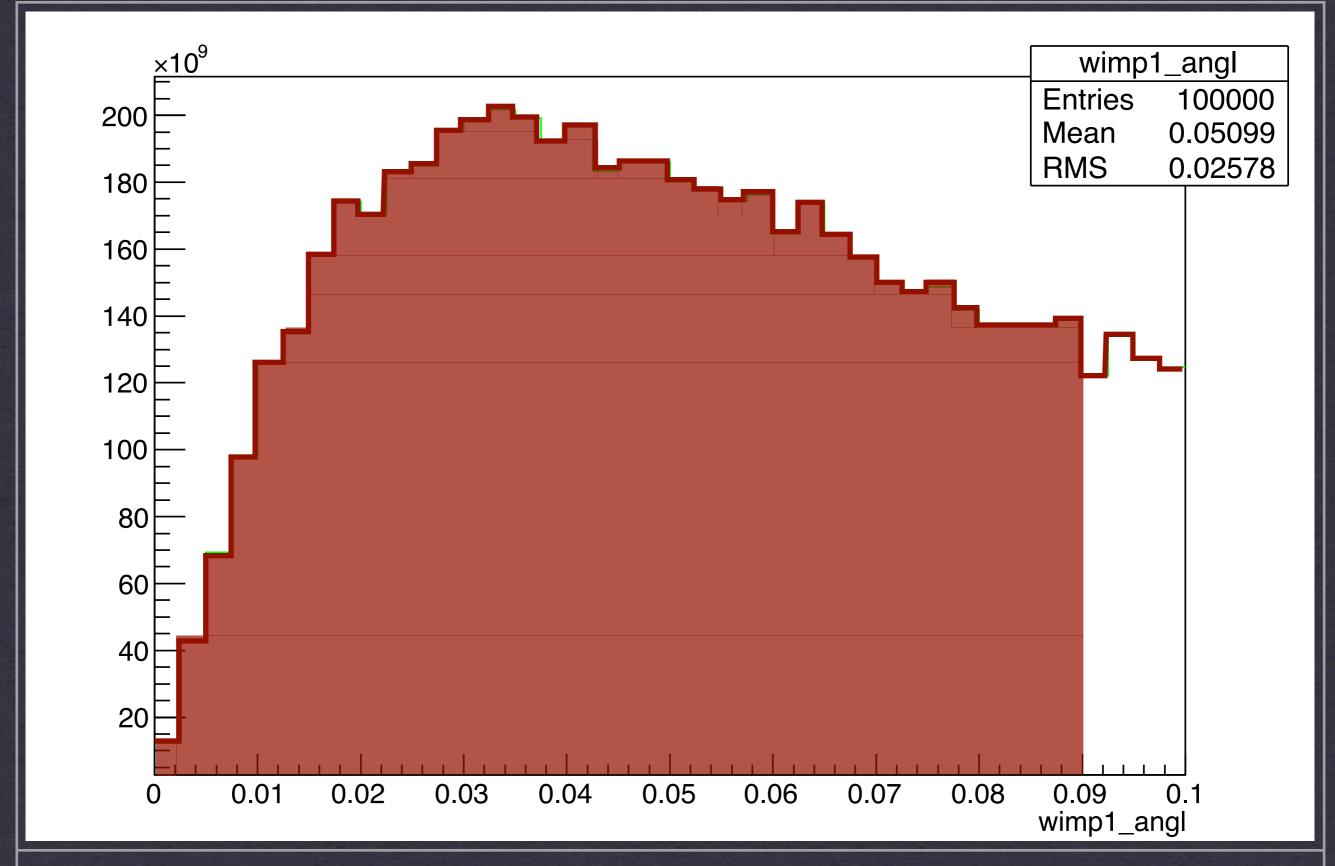
FANTASY SET UP

A NEUTRINO FIXED TARGET EXPERIMENT



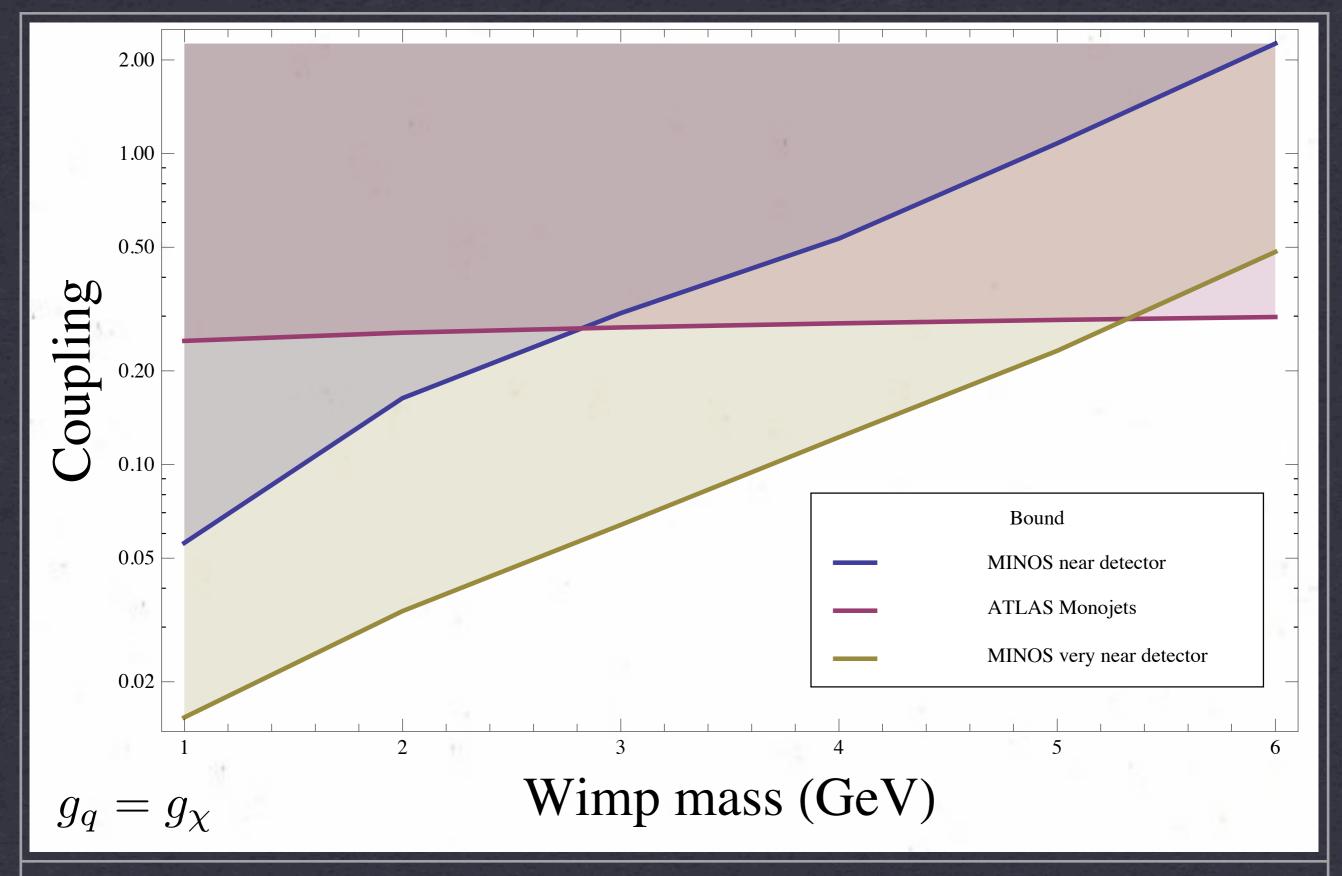
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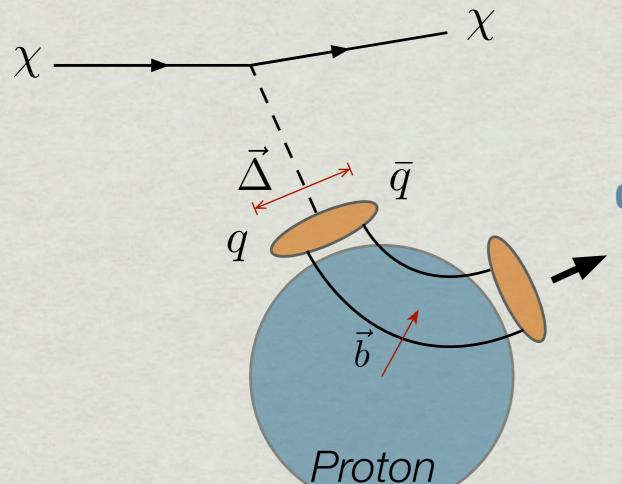


MONOJET VS "PIE IN THE SKY" MINOS BOUNDS

COUPLING ENTERS TO FOURTH POWER IN CROSS SECTION.

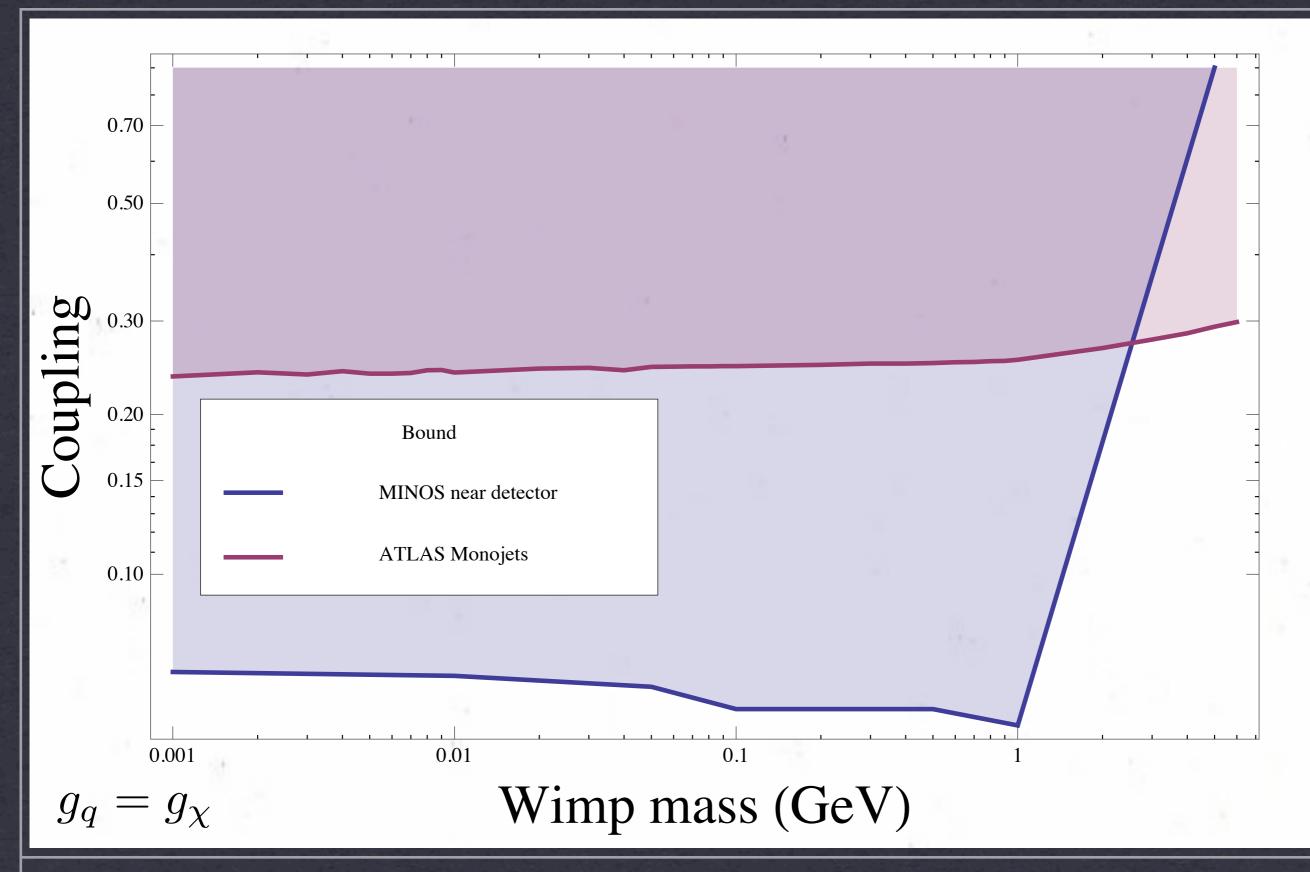
Very light mediators

- * We can consider MeV "WIMPs".
- * To maintain kinematic regime, use 1 MeV mediator. $m_V < 2m_\chi$
- * Nontrivial! Must introduce dipole picture:



Nice physical picture dipole scattering.
Regulates potential collinear
divergence for low mediator masses.

$$\sigma \propto \int d\vec{b} \int d\vec{\Delta} \theta (\Delta^2 Q^2 > a^2) \frac{\Xi(\vec{b}, \vec{\Delta})}{\Delta^4}$$



PRELIMINARY BOUNDS FOR LOW MASSES

BOUND SHOULD GET STRONGER FOR LOWER MASS, MAYBE A PROBLEM AT 1 GEV?

To do:

- * Finish (pseudo)scalar, axial vector cases.
- * Much testing of dipole model.
- * Alternative couplings/portals/models.
- * Other QCD production mechanisms (meson decay).
- * Other DM constraints (micrOMEGAS for DM properties, e.g.)

Message

- * Can consider very light mediators in this context (some testing required).
- * The specific bounds on our (toy) model are not so important.
- * MINOS (and similar) is a good testing ground for WIMPs, can compete with LHC.
- * Good new physics opportunities with proton fixed target experiments.



THANKS!