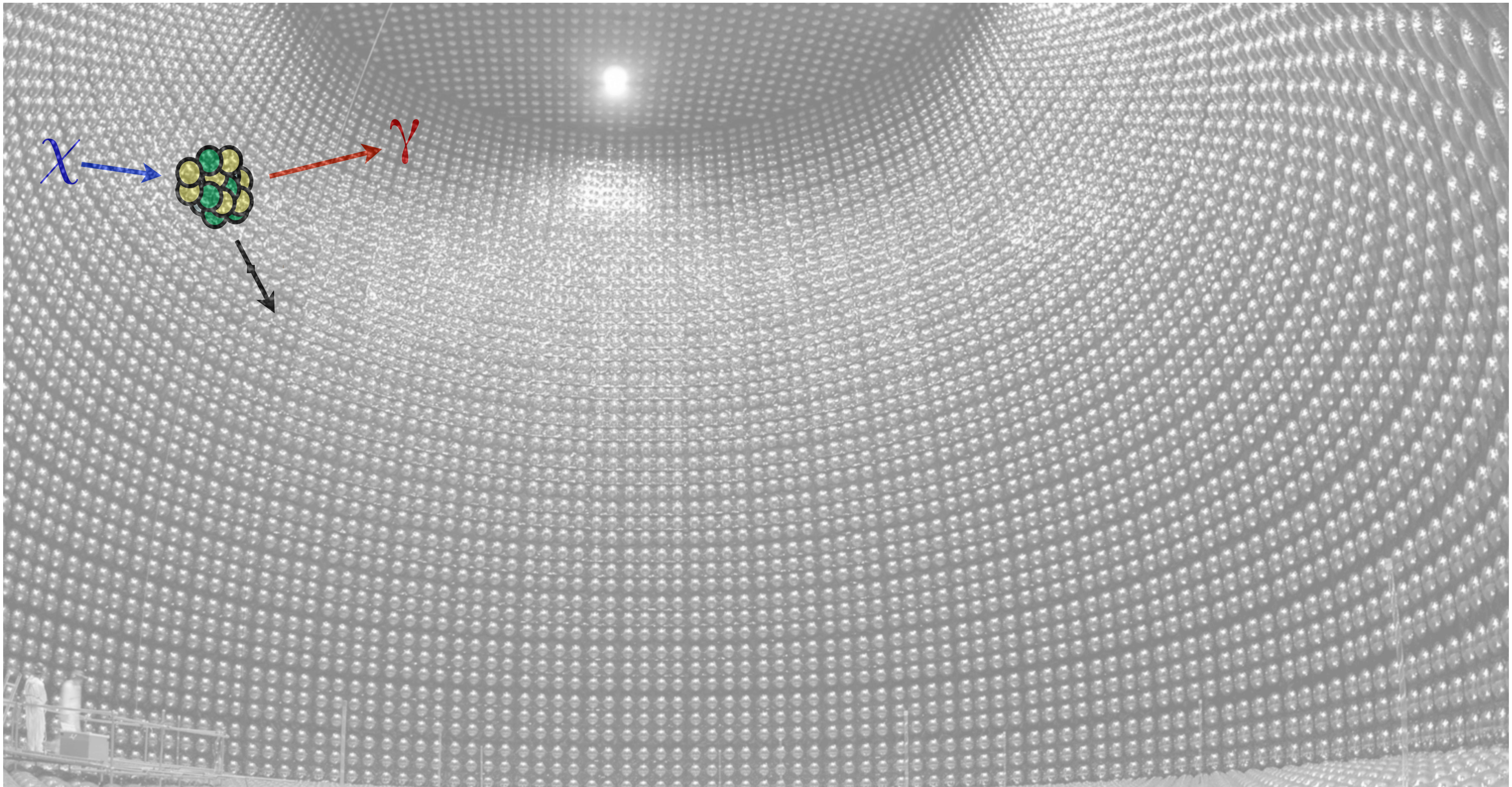
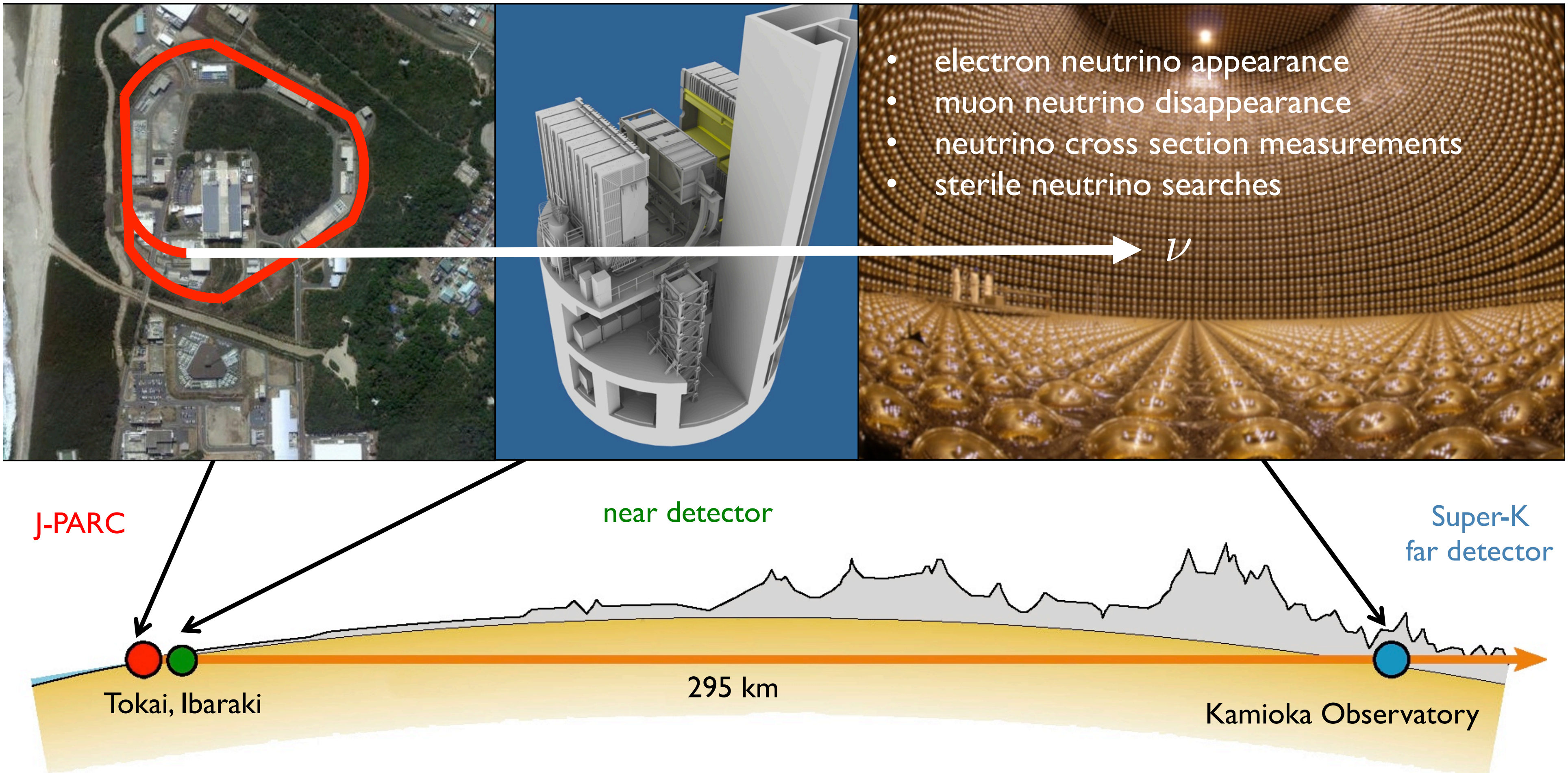


A search at Super-Kamiokande for low mass dark matter candidates in the T2K neutrino beam

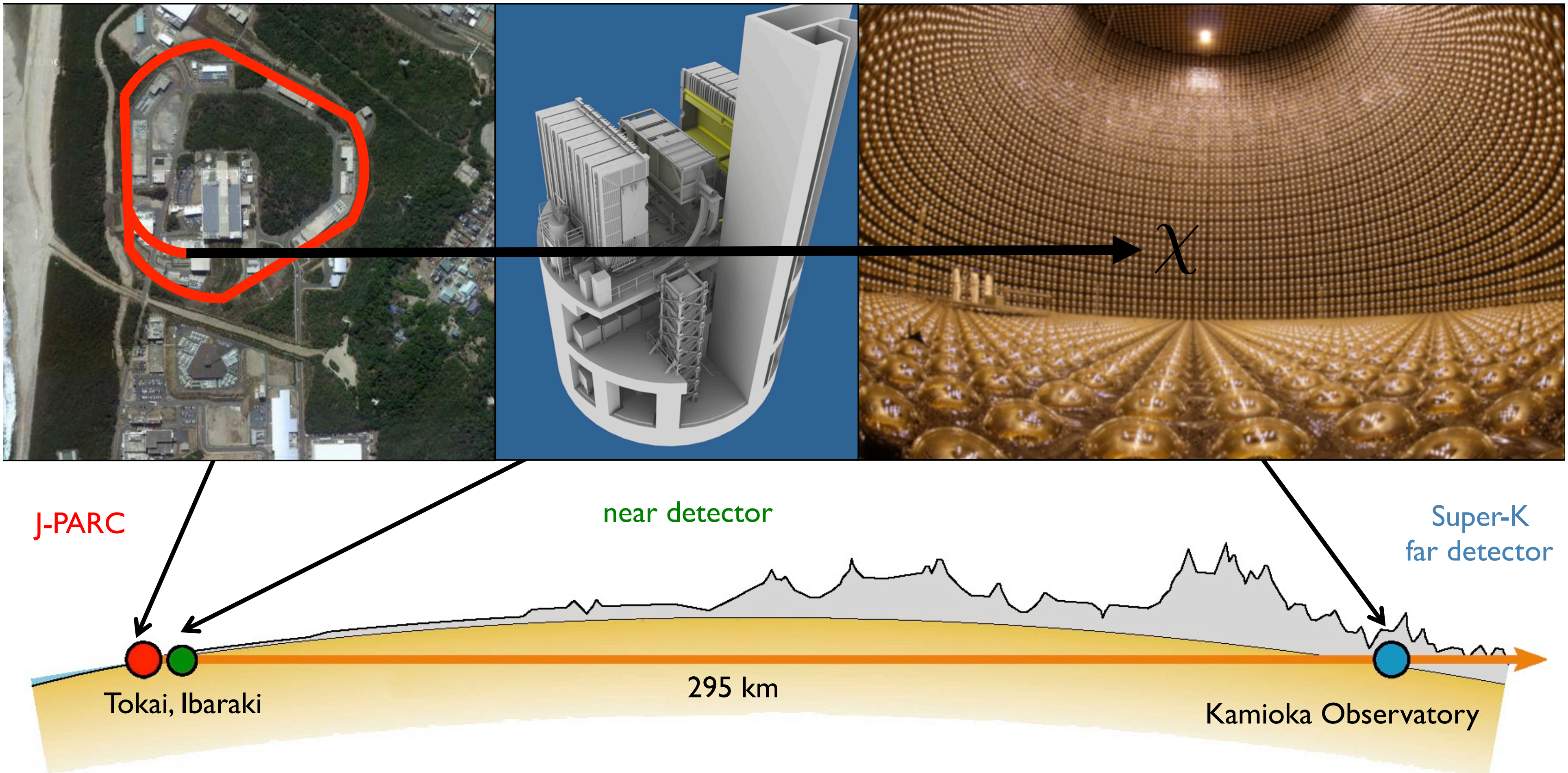
Corina Nantais
University of British Columbia

CAP Congress, Laurentian University, 16-20 June 2014

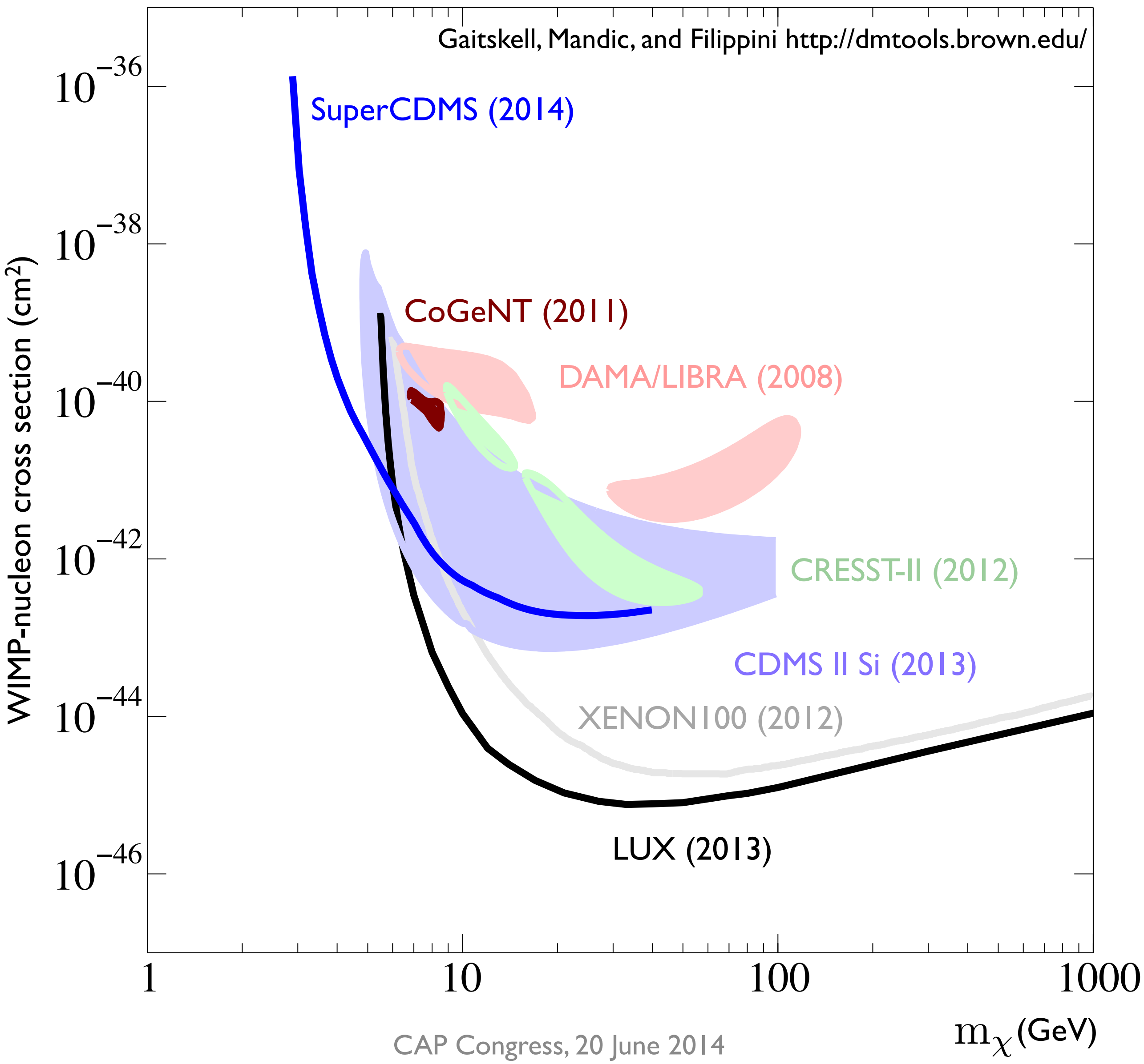
T2K is a long baseline neutrino oscillation experiment



T2K … can be used to produce and then detect WIMPs



Current underground direct detection experiments have poor sensitivity to low mass WIMPs



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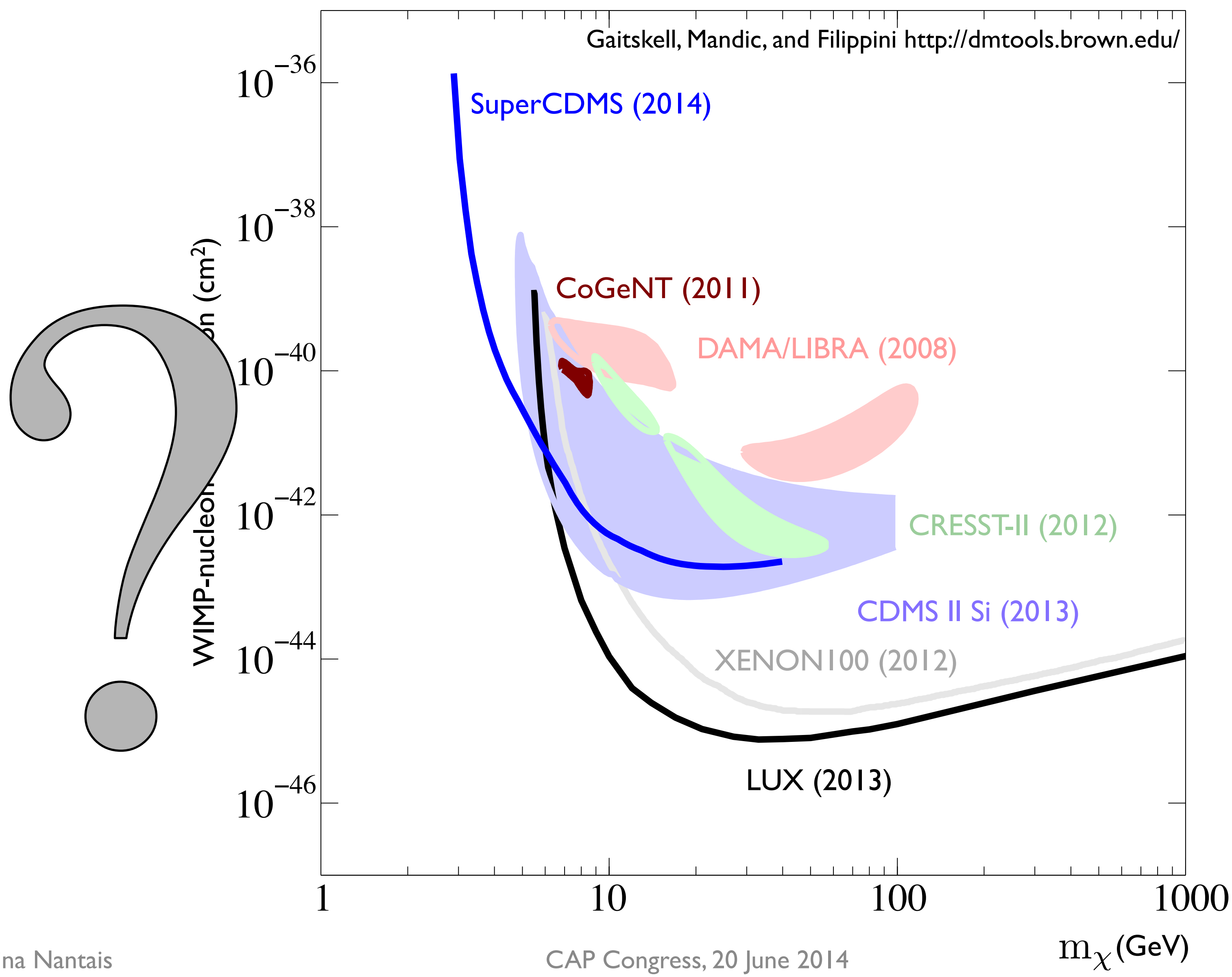
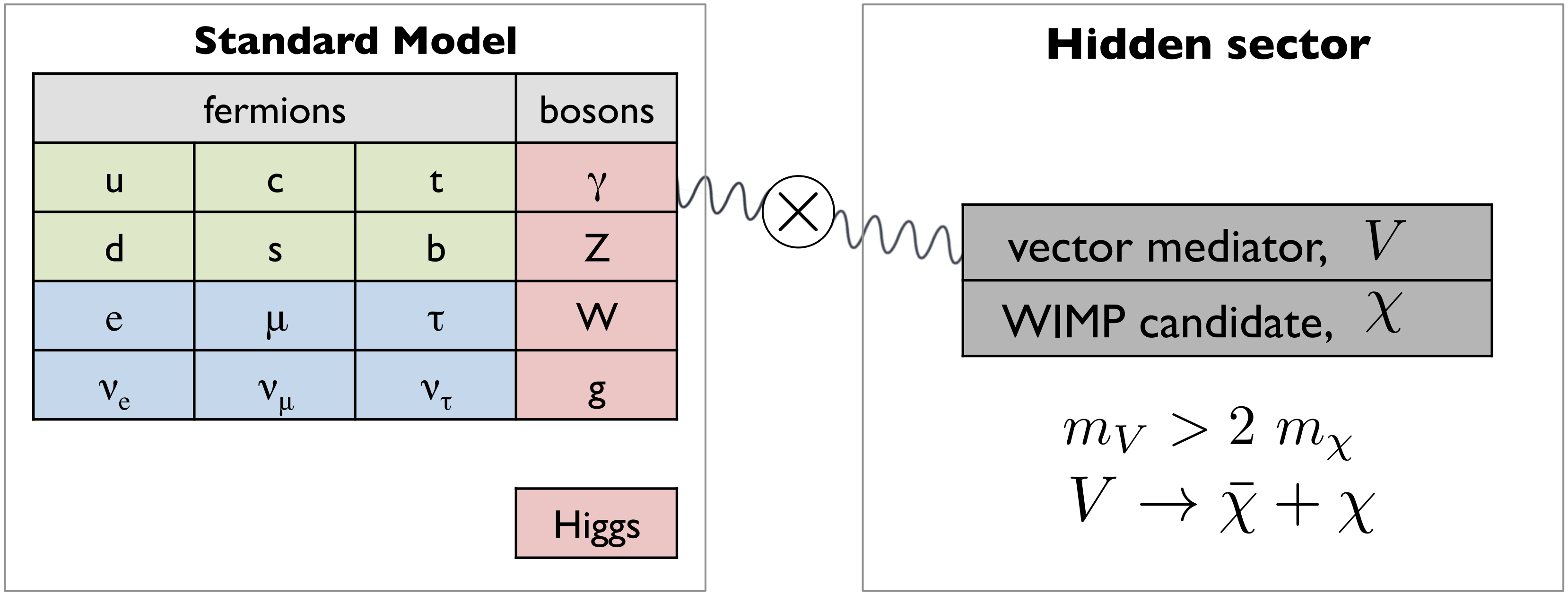


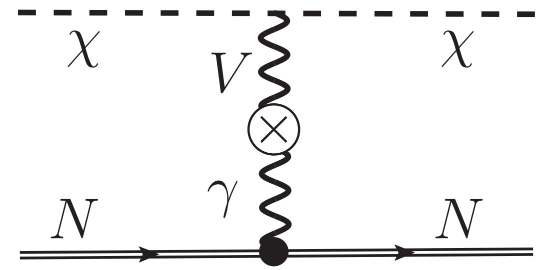
A mediator that decays to low mass WIMPs



Kinetic mixing between Standard Model γ and vector mediator V is one possibility

References
P. deNiverville, D. McKeen, and A. Ritz, "Signatures of sub-GeV dark matter beams at neutrino experiments," *Phys. Rev. D* **86**, 035022 (2012).
A. A. Aguilar-Arevalo *et al.*, "Low mass WIMP searches with a neutrino experiment: A proposal for further MiniBooNE running," arXiv:1211.2258.
P. deNiverville and A. Ritz, private communication.

Production in T2K target, and detection in far detector



direct production

$$p + p(n) \;\rightarrow\; V^* \;\rightarrow\; \bar{\chi}\chi$$

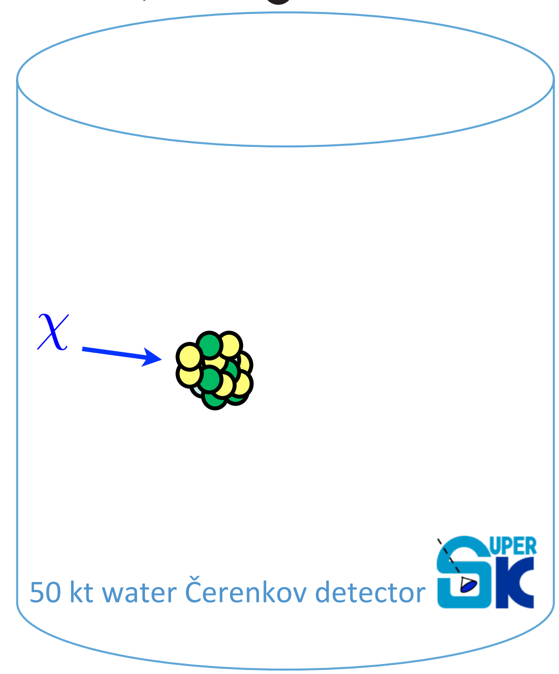
indirect production

$$p + p(n) \rightarrow \pi^0, \eta \rightarrow V\gamma \rightarrow \bar{\chi}\chi\gamma$$

30 GeV protons

graphite target

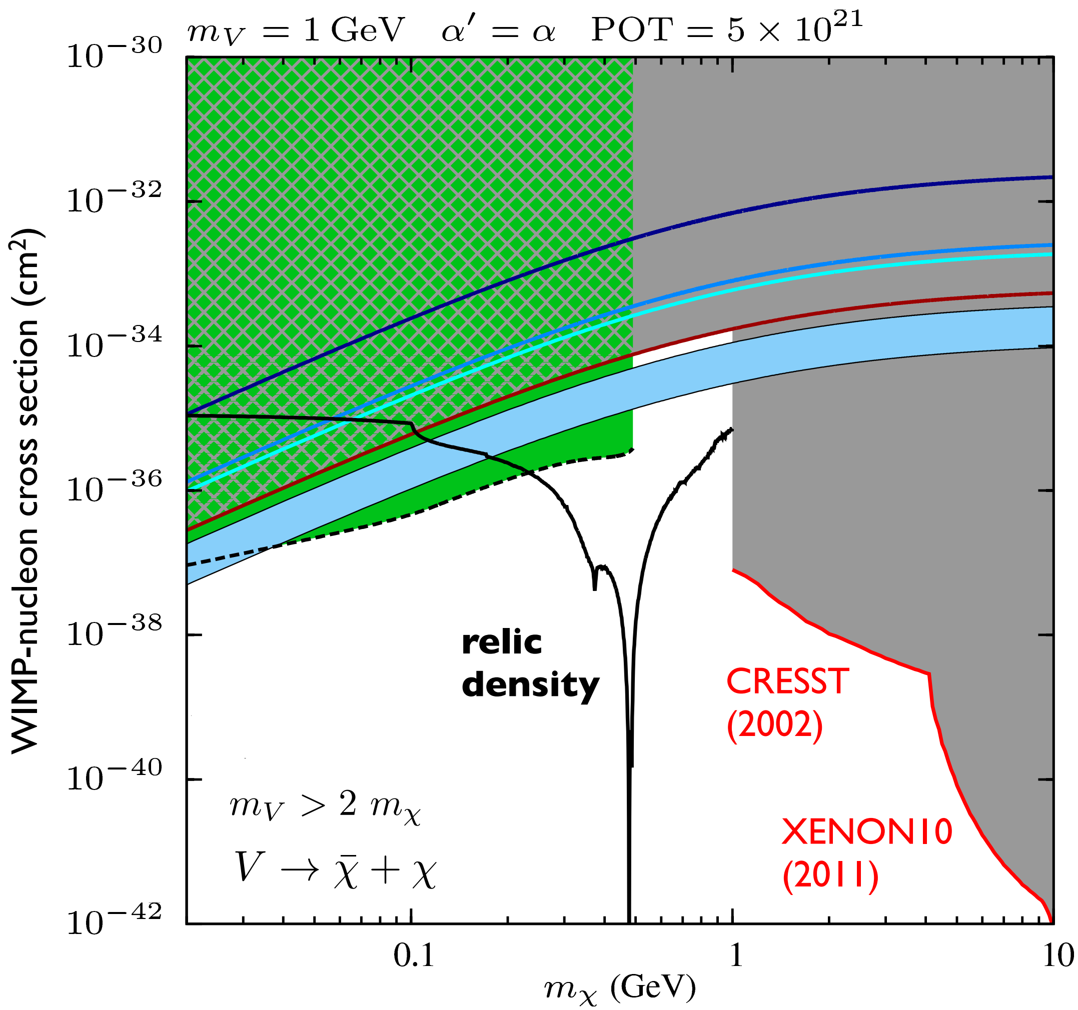
295 km



Theorist estimate of T2K Super-K sensitivity is complementary

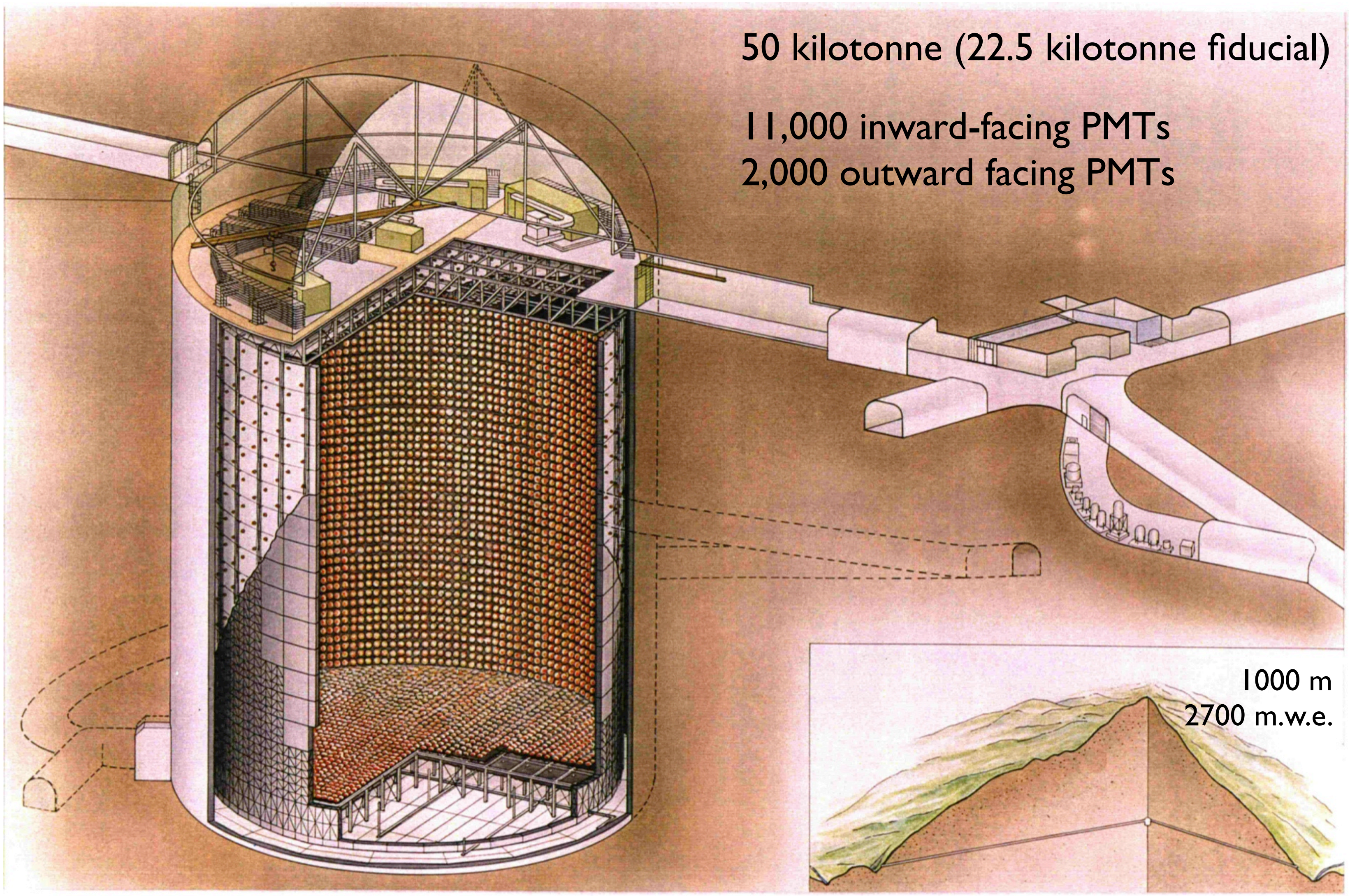
A. Ritz and P. deNiverville, private communication.

T2K Super-K projected sensitivity for 1 event



model-dependent constraints

Super-K water Čerenkov detector is well understood



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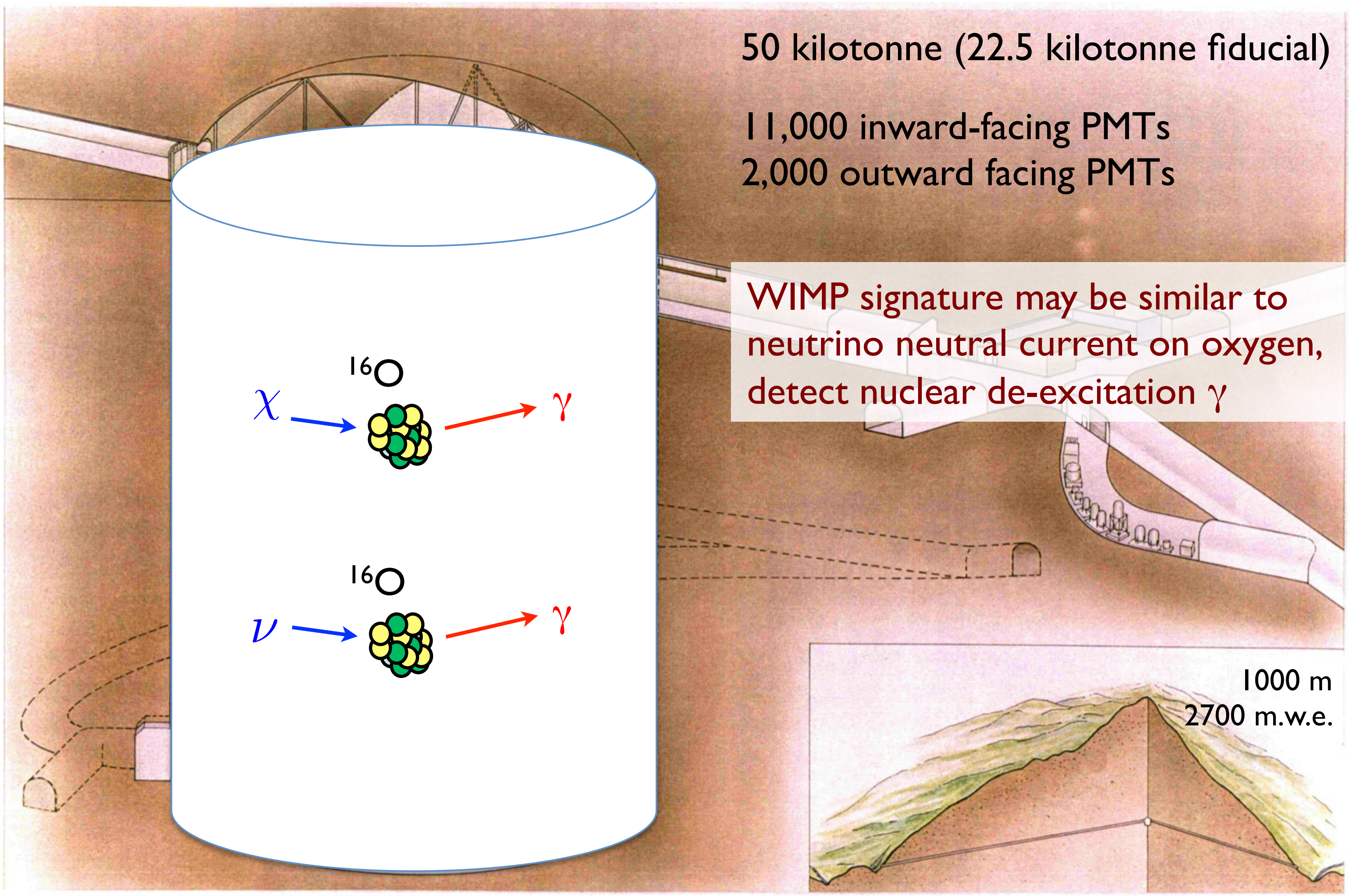
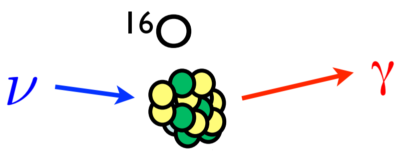


50 kilotonne (22.5 kilotonne fiducial)

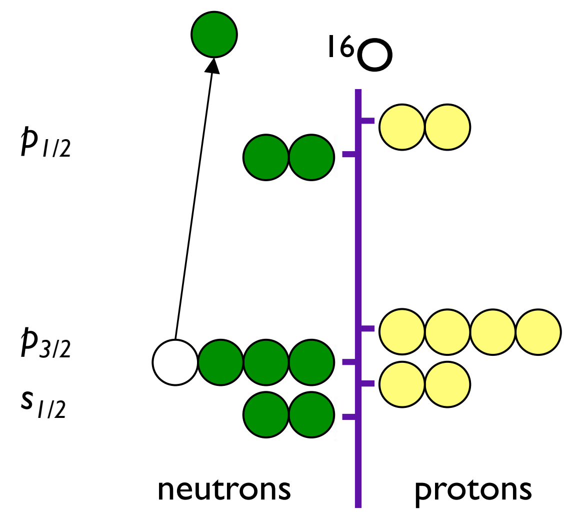
11,000 inward-facing PMTs
2,000 outward facing PMTs

WIMP signature may be similar to neutrino neutral current on oxygen, detect nuclear de-excitation γ

Nuclear de-excitation gammas after the neutrino-oxygen neutral current quasi-elastic (NCQE) interaction



600 MeV, single nucleon emission is dominant mechanism

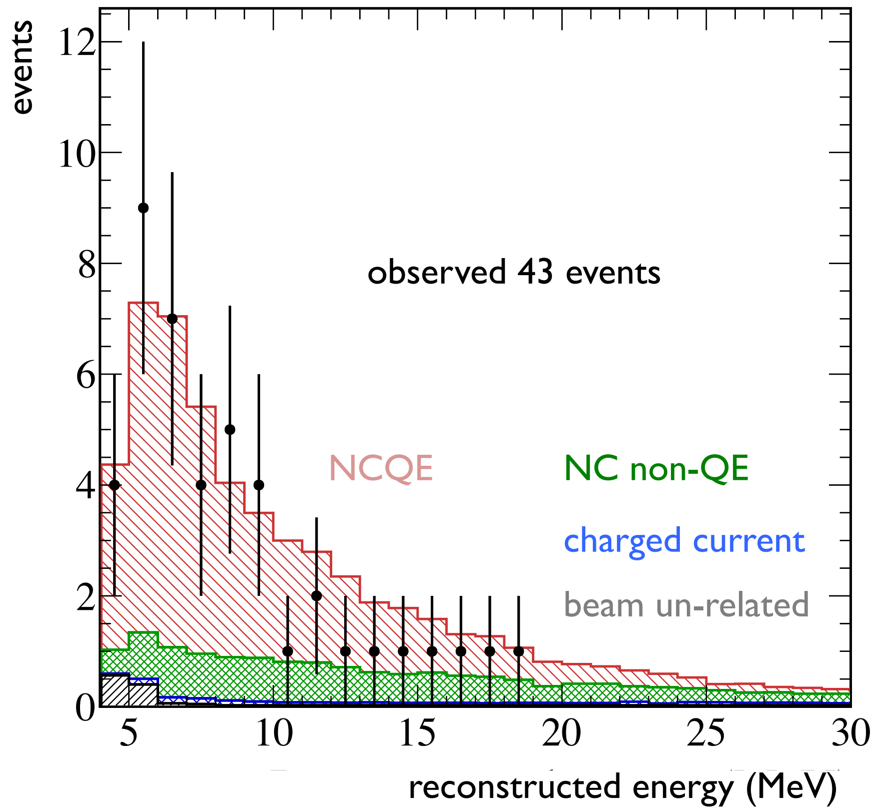


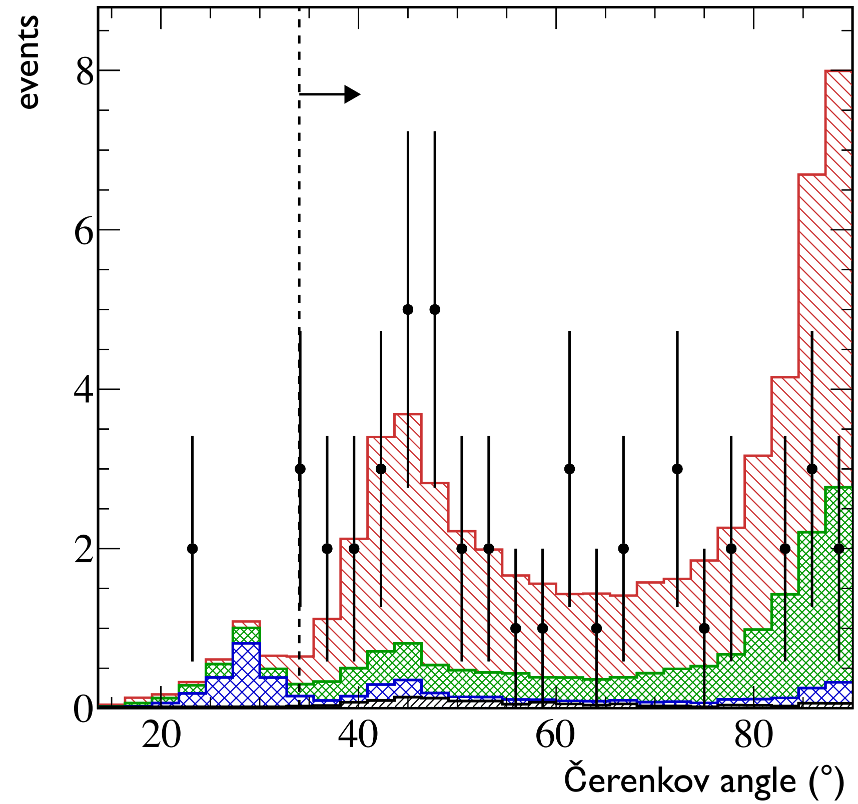
excited nucleus decays by emitting gammas

contribution of $p_{3/2}$ is overwhelming:
6.32 MeV from $(p_{3/2})_p$
6.18 MeV from $(p_{3/2})_n$

PRL **108** 052502 (2012)

Analysis of neutrino-oxygen NCQE events in T2K Super-K



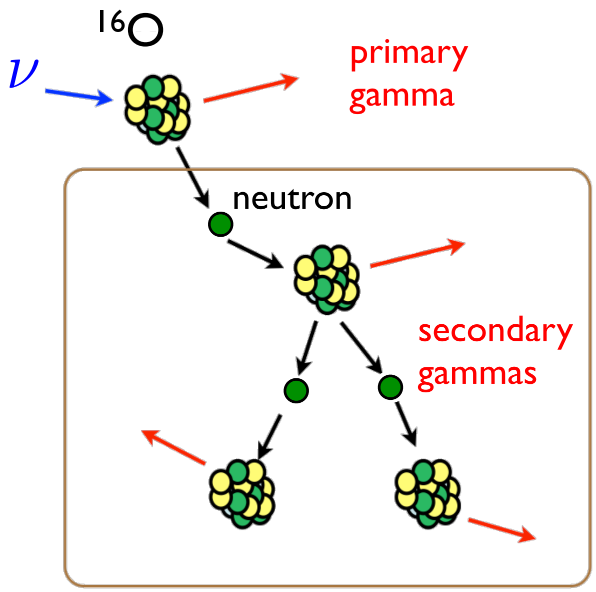


Selection cuts

- 4 – 30 MeV reconstructed energy
- > 34° Čerenkov angle to remove muons
- ±100 ns of beam timing
- …

Improve analysis of neutrino-oxygen NCQE, then apply to WIMPs

Study gamma production from neutrons



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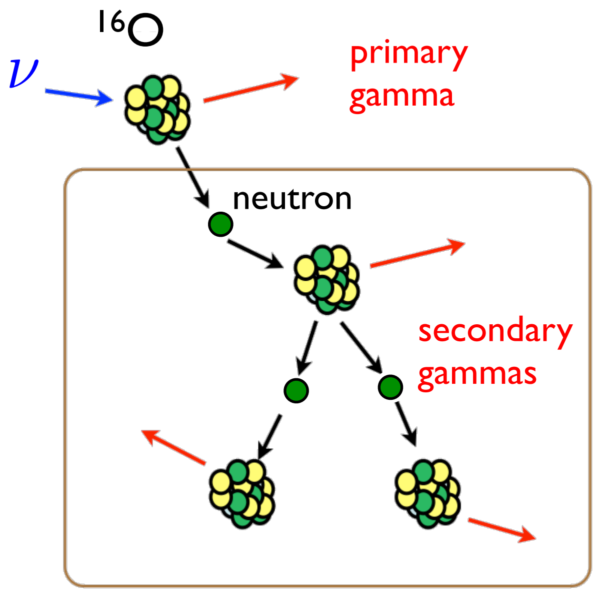
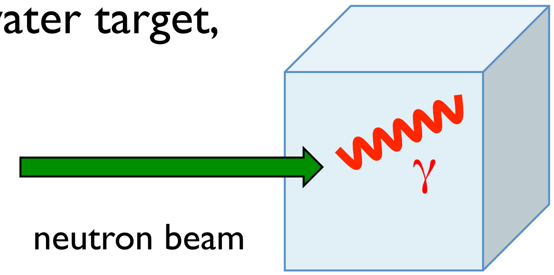


Study gamma production from neutrons

1) simulations of neutrons on a water target, compare FLUKA and Geant3



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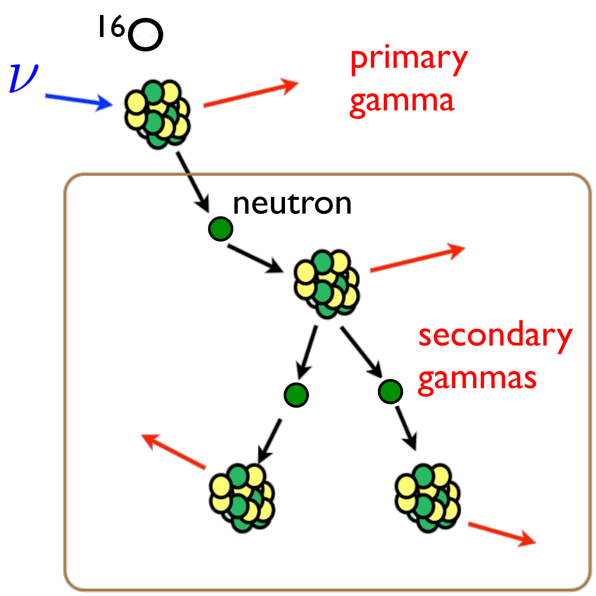

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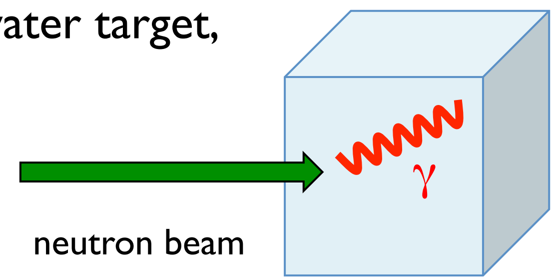
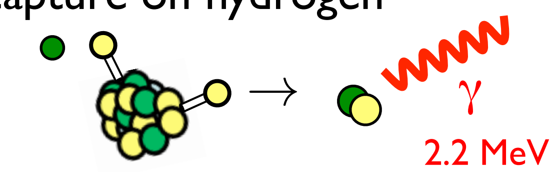


2) 2.2 MeV tag from neutron capture on hydrogen

$$n + p \rightarrow d + \gamma$$



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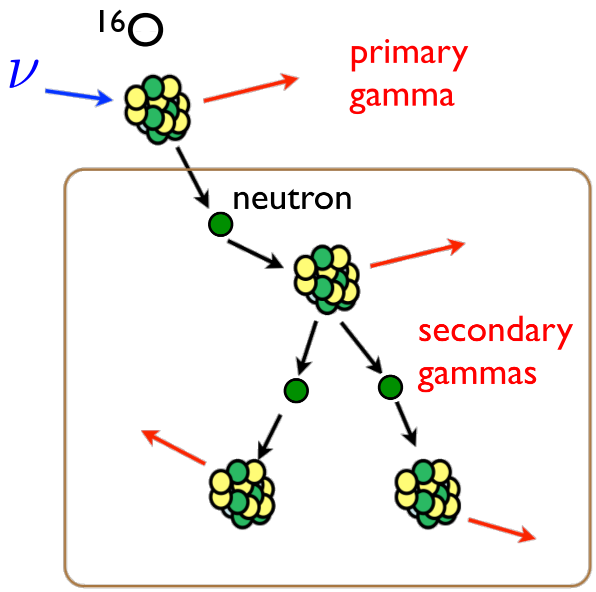

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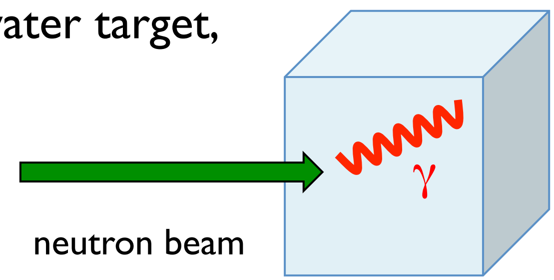

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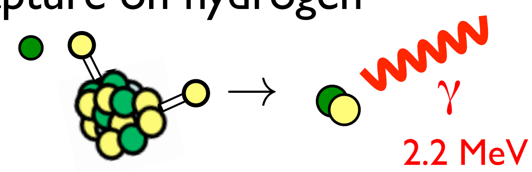
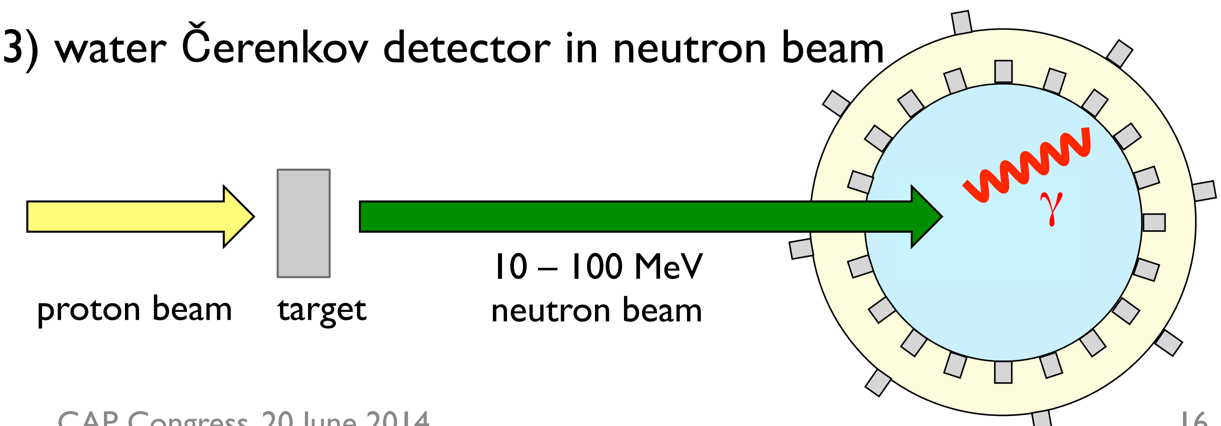
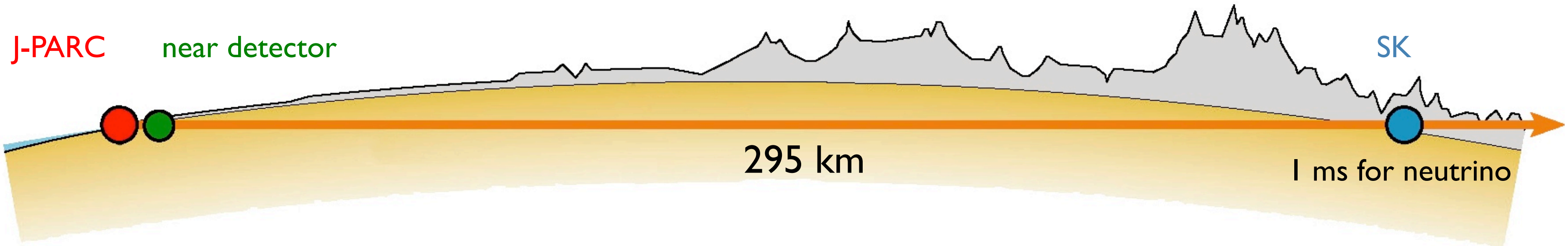


3) water Čerenkov detector in neutron beam



Time of flight to separate WIMP from neutrino



p_χ = 3 GeV
PRD **86** 035022 (2012)

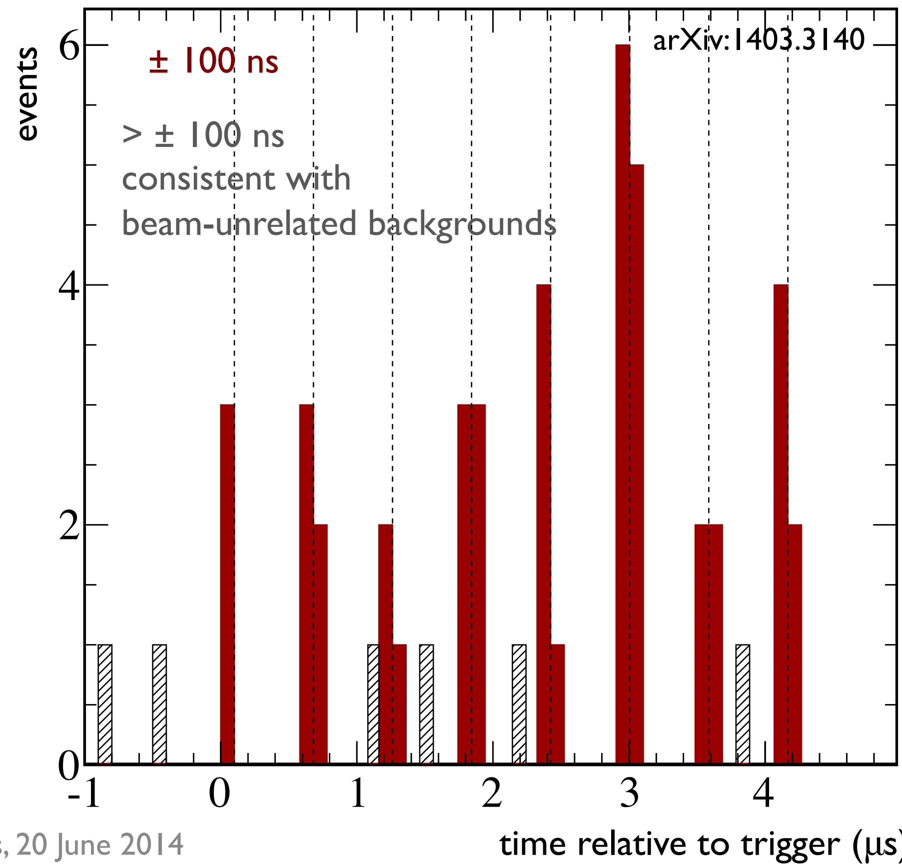
m_χ	TOF delay
30 MeV	50 ns
100 MeV	500 ns
300 MeV	5 µs

Beam structure

- 8 bunches per spill
- bunch is approximately 20 ns wide
- bunches separated by 580 ns gaps
- spill delivered every 2 – 3 s

Mass sensitivity requires a full analysis

neutrino-oxygen NCQE de-excitation gamma events



Conclusion: A competitive and complementary search

Search for low mass dark matter candidate produced in T2K neutrino beam

- understand detection of de-excitation gammas in Super-K after neutrino-oxygen NCQE
- improvements to current analysis, then apply to WIMP search
- WIMP/neutrino discrimination using time of flight