First Measurement of Monoenergetic Muon Neutrino Charged Current Interactions

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on behalf of the **MiniBooNE Experiment**

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Why KDAR? $K^+ \rightarrow \mu^+ \nu_\mu \quad [\mathrm{BR} = 64\%]$

A monoenergetic neutrino at 236 MeV.

Standard candle for muon kinematics.

High-Δm^2 (sterile) oscillation search.

Precision measurement of Δs.

Signature of dark matter annihilation in the Sun.

- Which model of the nucleus, relevant for future neutrino experiments, is correct?
- What is the correct way to treat the transition from on-nucleus to on-nucleon scattering?
- How many final state neutrons are there as a function of energy transfer?
- How large are the contributions of short-range correlations?

KDAR @ MiniBooNE

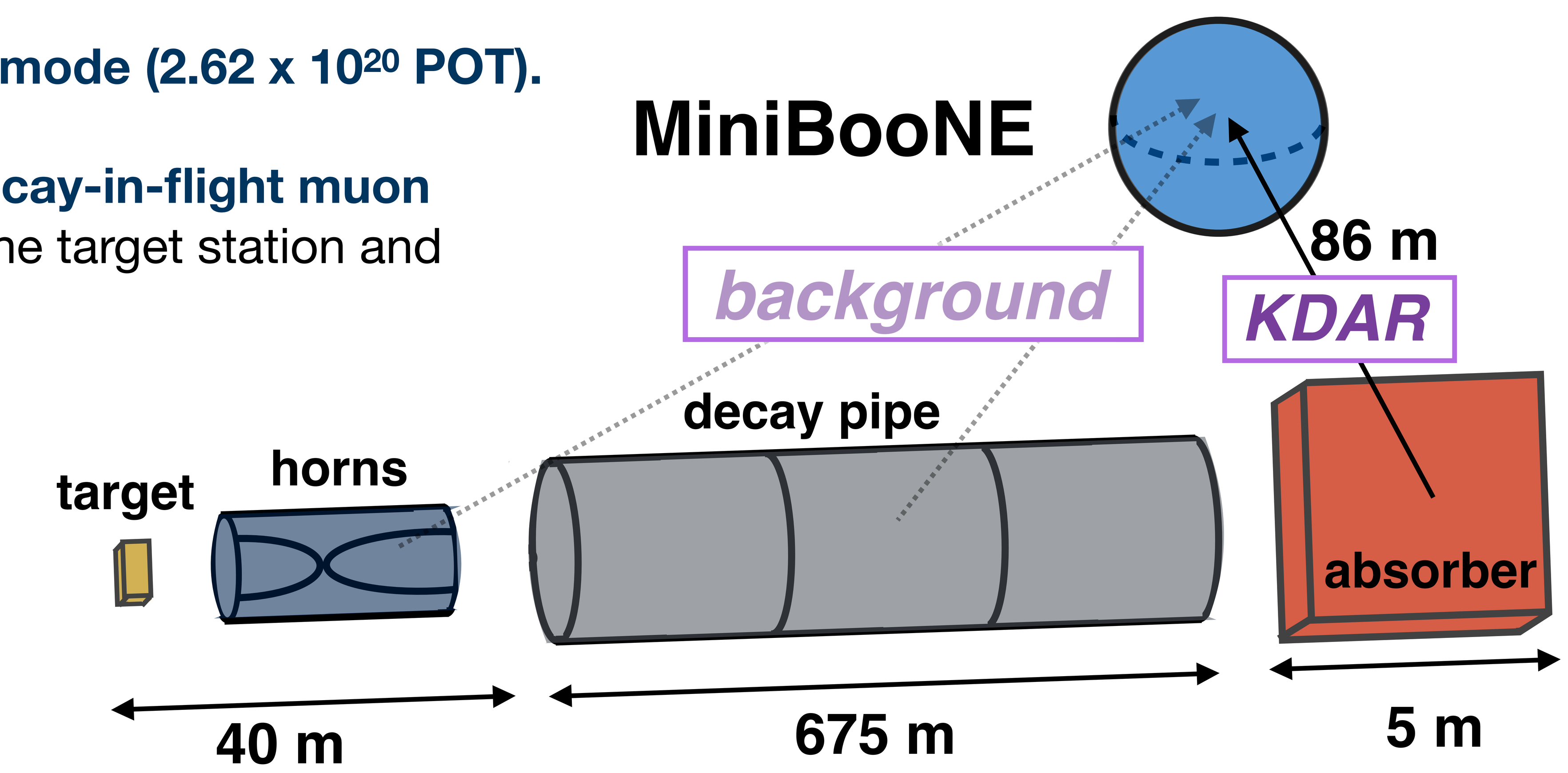
About one-sixth of the primary NuMI beam power makes it all the way to the absorber, where the protons interact to produce kaons that come to rest and decay.

We use NuMI LE antineutrino mode (2.62 x 10^{20} POT).

The **primary background is decay-in-flight muon neutrinos** produced mainly in the target station and upstream-most decay pipe.

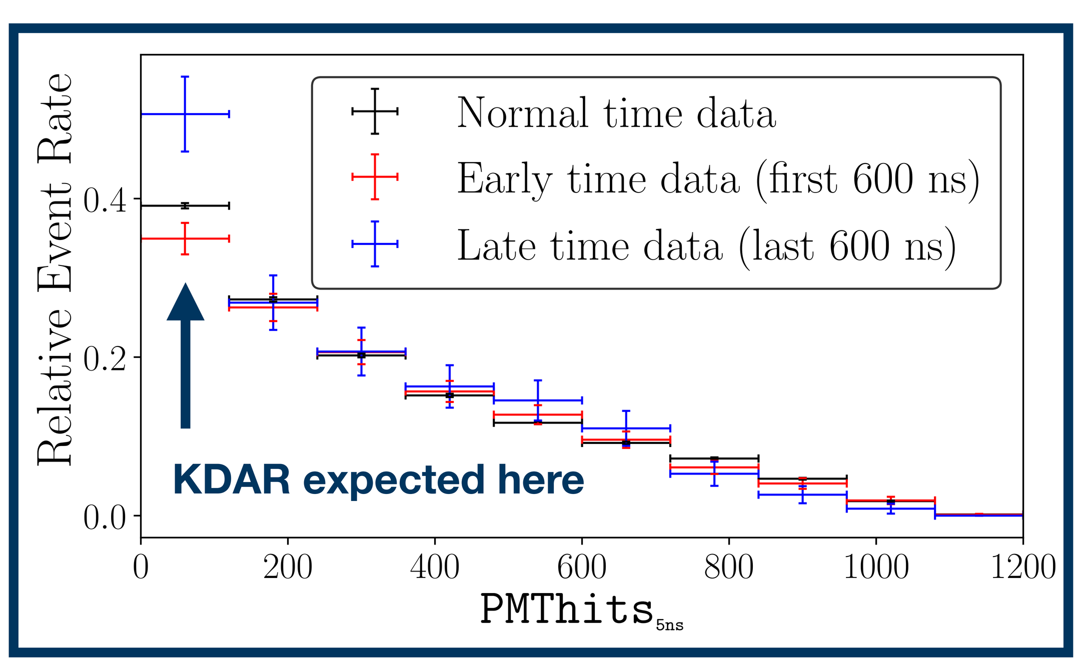
Energy reconstruction isolates muon Cherenkov light:

$\mathrm{PMThits}_{5ns}$ = number of PMT hits multiplied by fraction of light collected in first 5 ns.



Published in: Phys. Rev. Lett. **120** 141802 (2018) as an **Editors' Suggestion**.

Timing to the Rescue!



We expect:

- a *background-enhanced* ("early time") region;
- a *signal-enhanced* ("late time") region.

Observe:

2.1σ deficit at early times

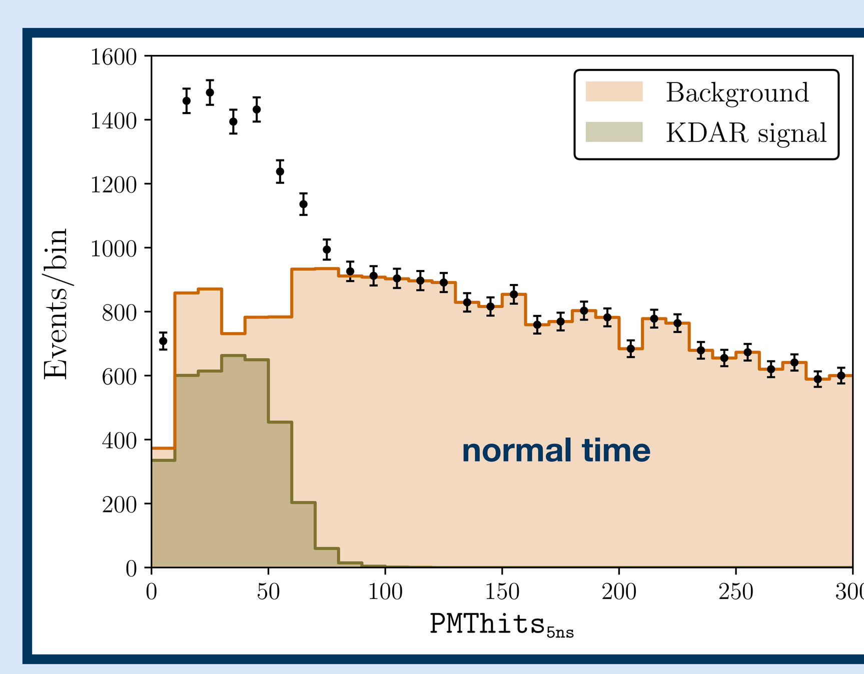
2.4σ excess at late times

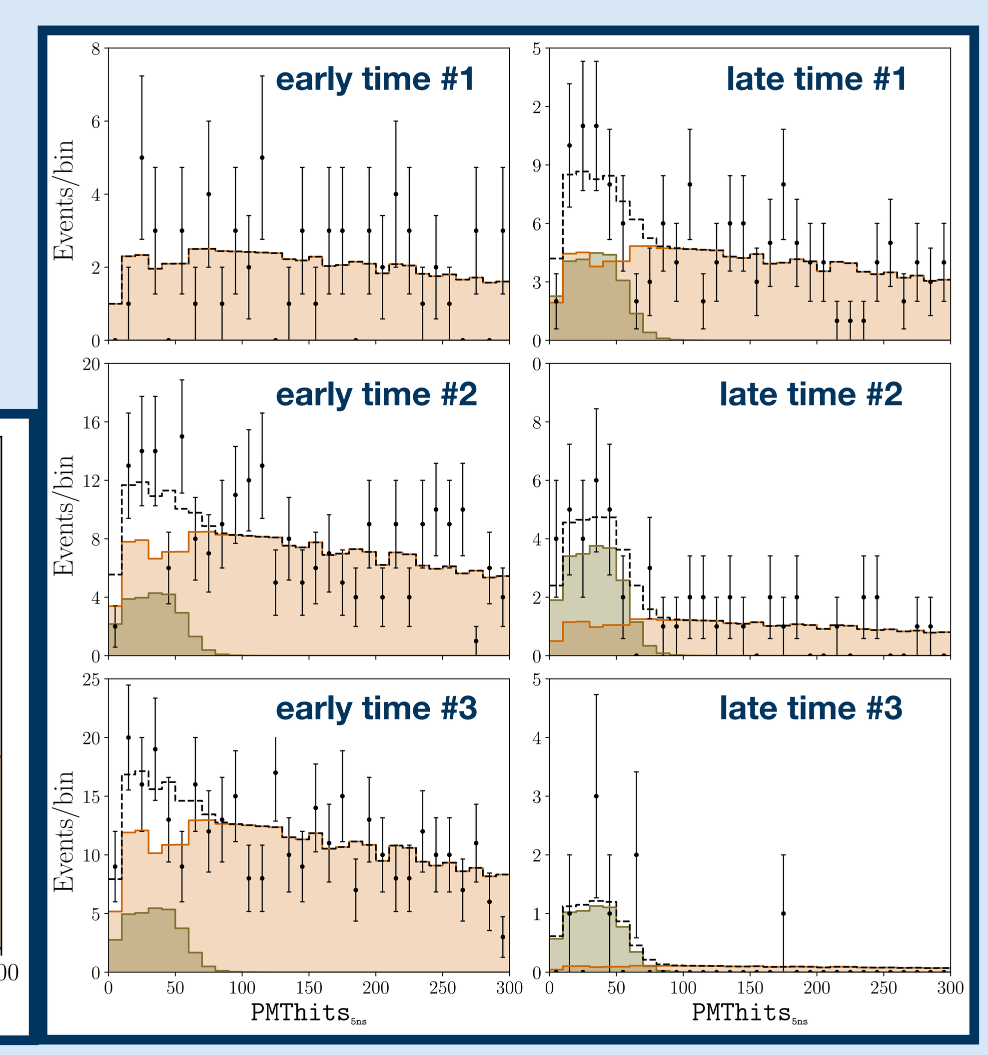
Evidence of the KDAR signal!

Analysis Procedure

We split data into **seven time bins** and study the evolution of **signal** and **background** over time. The analysis then proceeds as follows:

1. Form a **signal** hypothesis.
2. Define a **background** hypothesis such that **signal+background** = **data** in **normal time**.
3. Compare **signal** and **background** hypotheses to **data** at **early** and **late times**.
4. **Background** scaled to region where no **signal** is expected.
5. Marginalize over **signal** normalization in **each time bin**.
6. Test many thousands of models to find best fit.





Results and Outlook

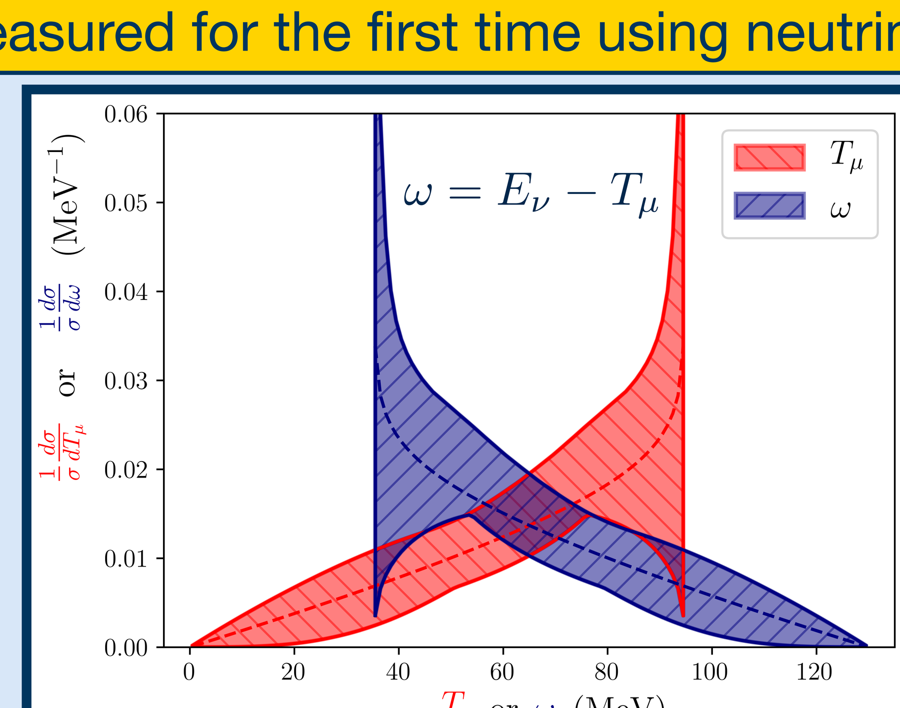
ω measured for the first time using neutrinos!

KDAR events collected: 3700 ± 1250

Significance: 3.9σ

In the near future (precision measurements):

- **MicroBooNE** will use LArTPC technology to better remove background from the NuMI KDAR signal.
- **JSNS²**, expected to begin taking data in 2019, will collect 10-20k KDAR events per year.



$$\text{Total } \nu_\mu \text{ CC cross section at } E_\nu = 236 \text{ MeV} \;:\; \sigma = (2.7 \pm 0.9 \pm 0.8) \times 10^{-39} \mathrm{cm}^2/\mathrm{neutron}$$

https://www-boone.fnal.gov/for_physicists/data_release/kdar/

Data release allows comparison between any arbitrary theoretical model and the KDAR data!