Large collider experiments like **ATLAS** can detect high-energy neutrinos from **galactic supernovae.**

Detecting High-Energy Neutrinos from Galactic Supernovae with ATLAS

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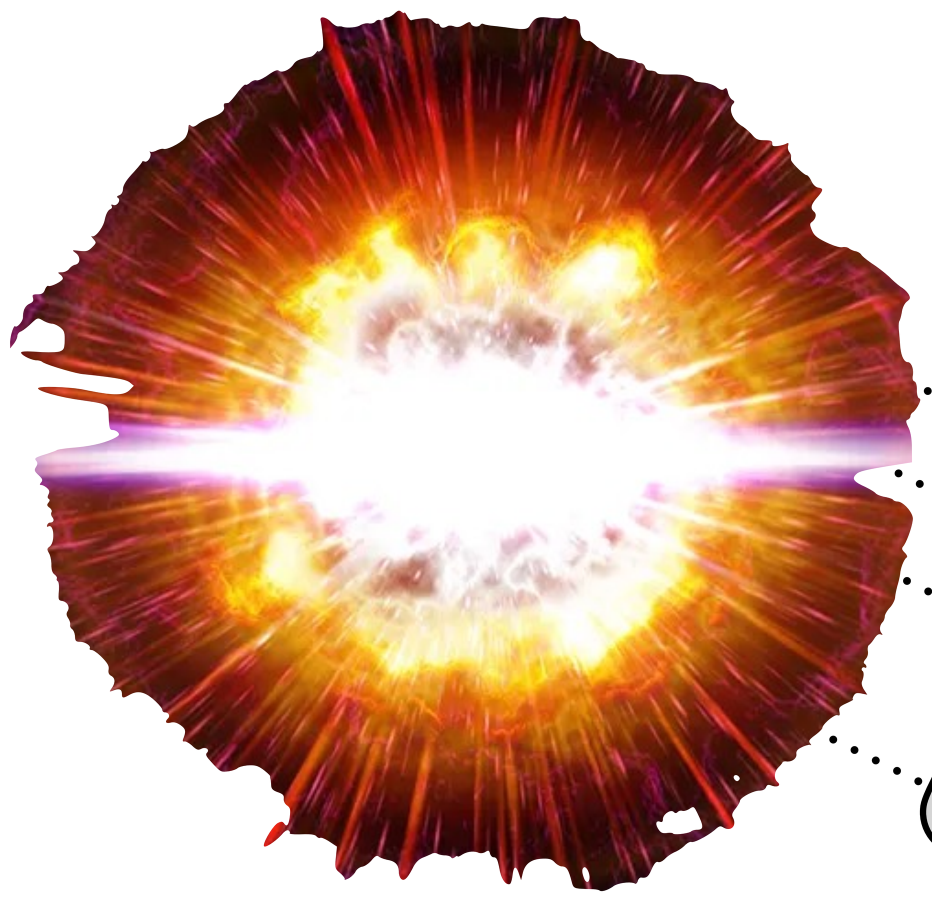
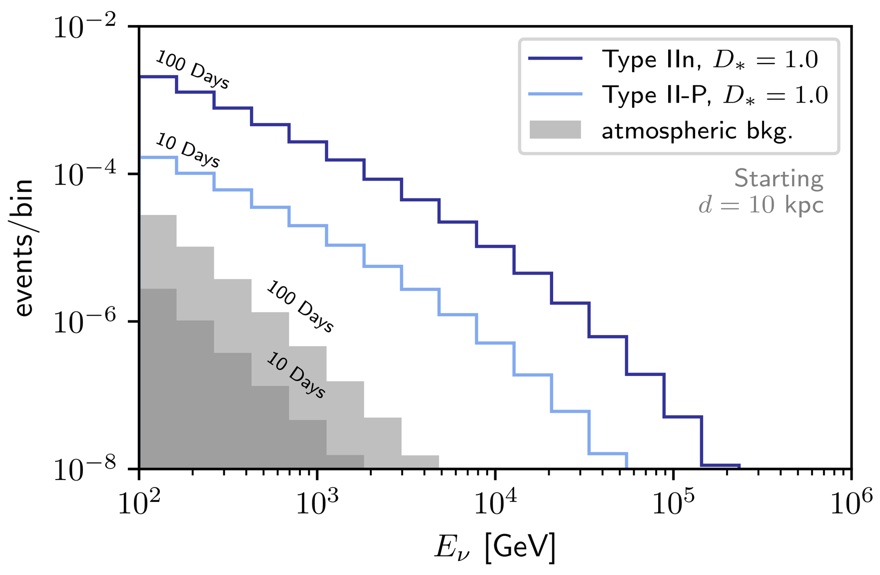
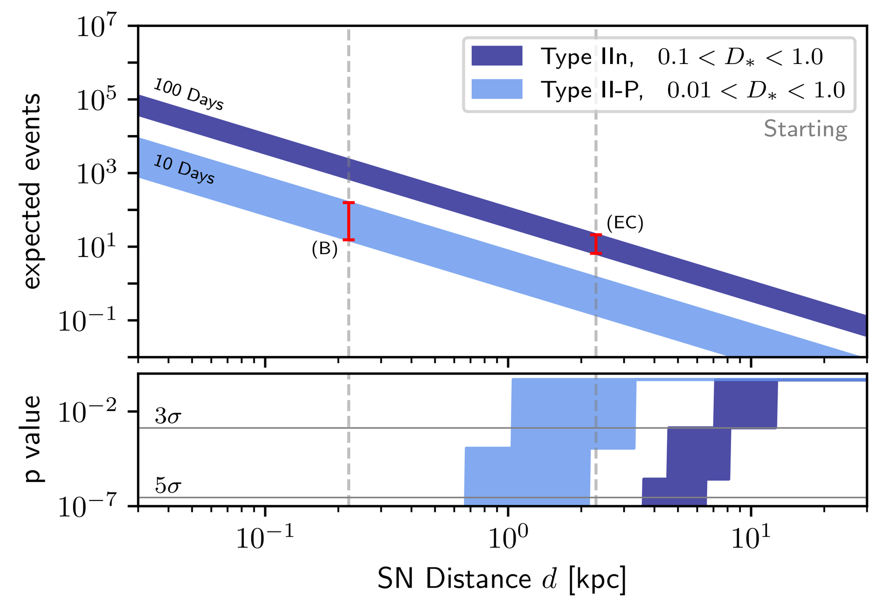
1 **High energy neutrino emission from supernovae.** Type IIn and II-P supernovae emit a significant neutrino flux in the range $1 - 10^6$ GeV due to high-energy proton-proton collisions in the circumstellar medium [1]. This flux may last for tens to hundreds of days depending on the SN type, and the flux varies with a CSM density parameter D_* [1]. In our galaxy, these types make up around 50-60% of all supernovae. Measuring this neutrino flux can test new neutrino and supernova physics. In this work, we show that the measurement is possible.



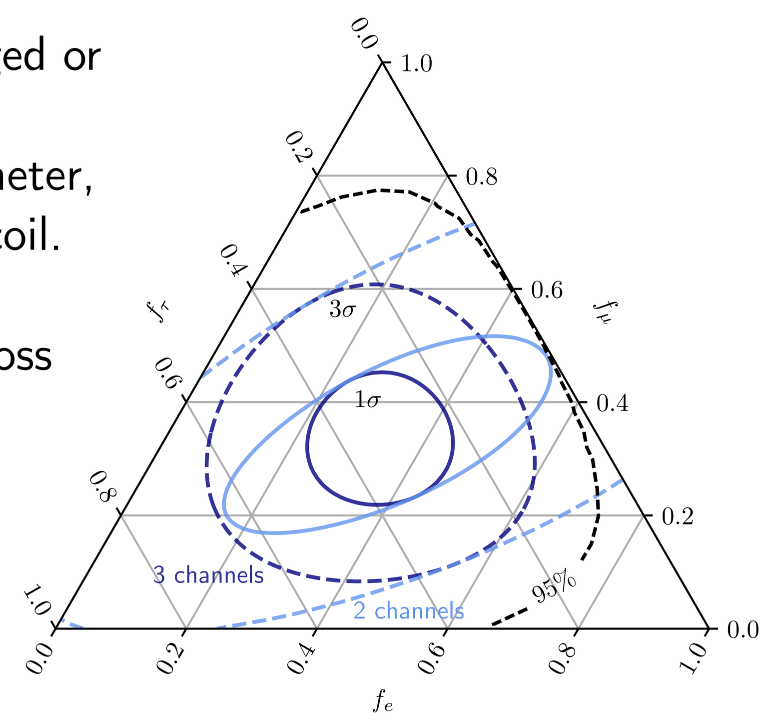
↓ **Estimated neutrino energy distribution of starting events** for different supernovae at 10 kpc, compared to atmospheric background.



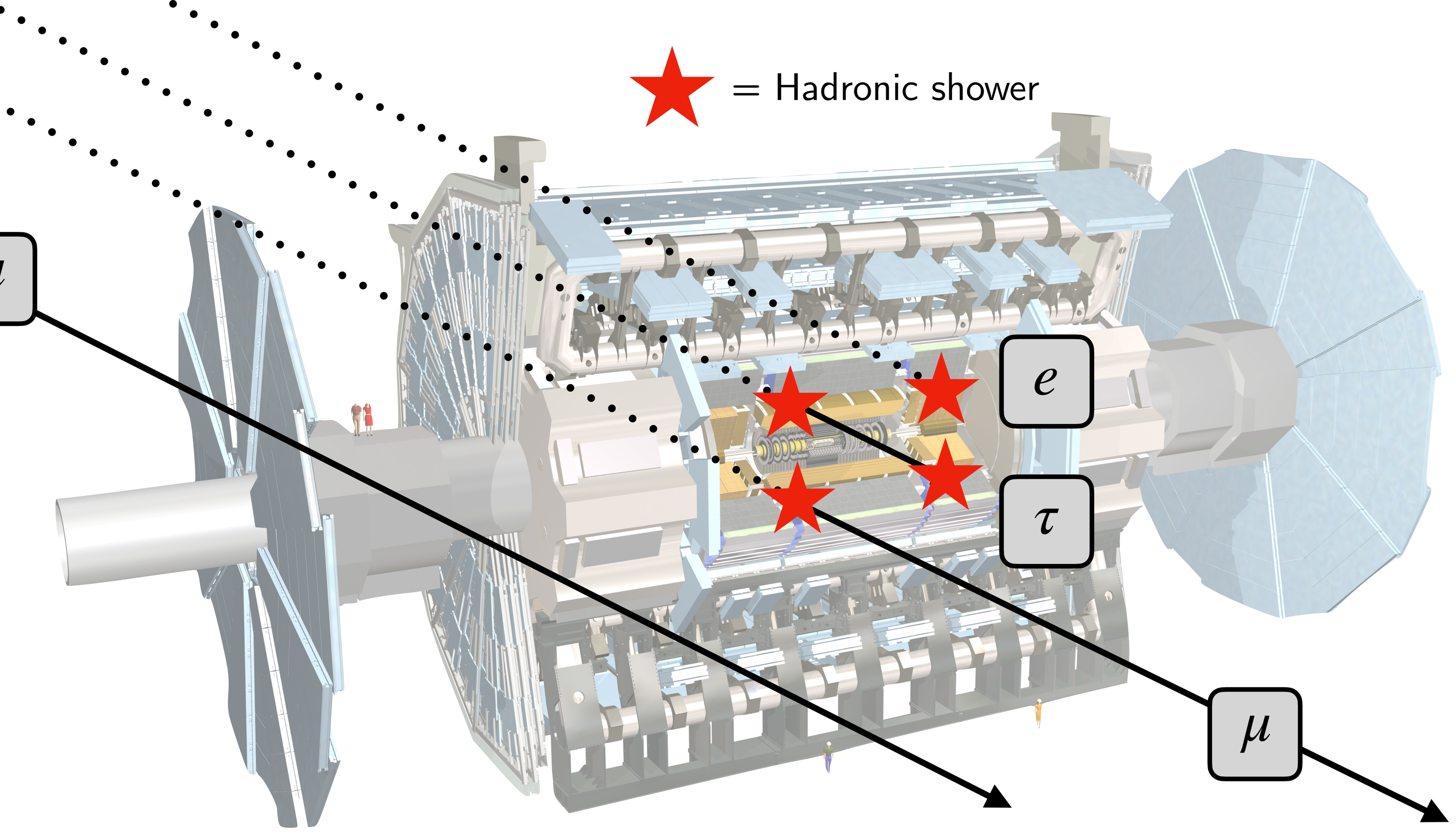


← **Number of expected starting events** varying with distance, integrated over their characteristic timescales, for different supernovae and the corresponding statistics-only discovery p-value. (B) and (EC) are supernova candidates Betelgeuse and Eta Carinae. The width of the galaxy is around 30 kpc.

3 **Starting events** Starting events may cause a charged or neutral current neutrino-nucleon interaction in the hadronic calorimeter, producing a detectable nuclear recoil. The rate is calculated analytically integrating flux, detector mass, cross section, and timescale.



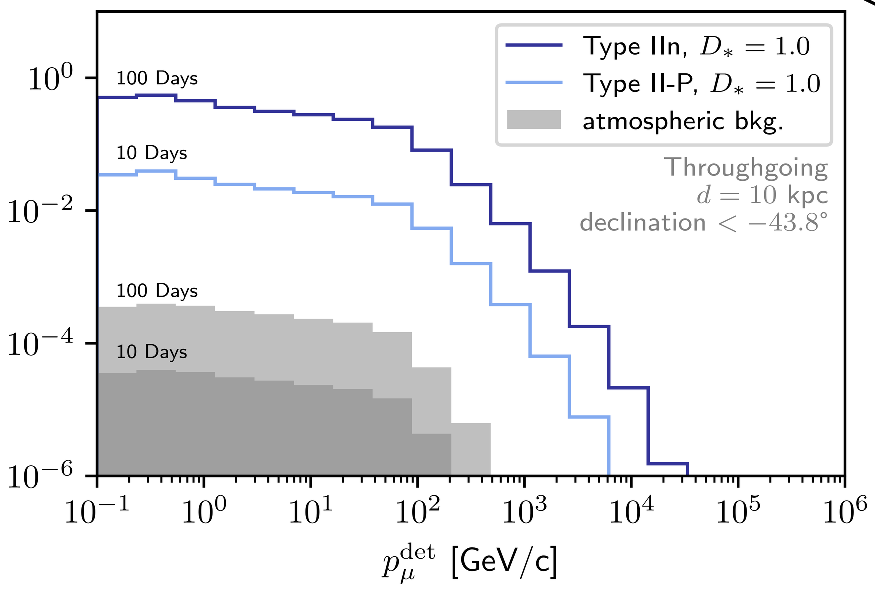
← **Flavor ratio 1σ / 3σ confidence allowed regions for starting events.** ATLAS would be sensitive to the hadronic shower from all charged and neutral current events. Taus may then decay hadronically, making another shower, and muons may be detected by the muon system. Hence there are three channels to infer the flavor ratio. We also show the allowed regions without the tau channel. The 95% confidence set by IceCube HESE [3] is shown in the black dashes.

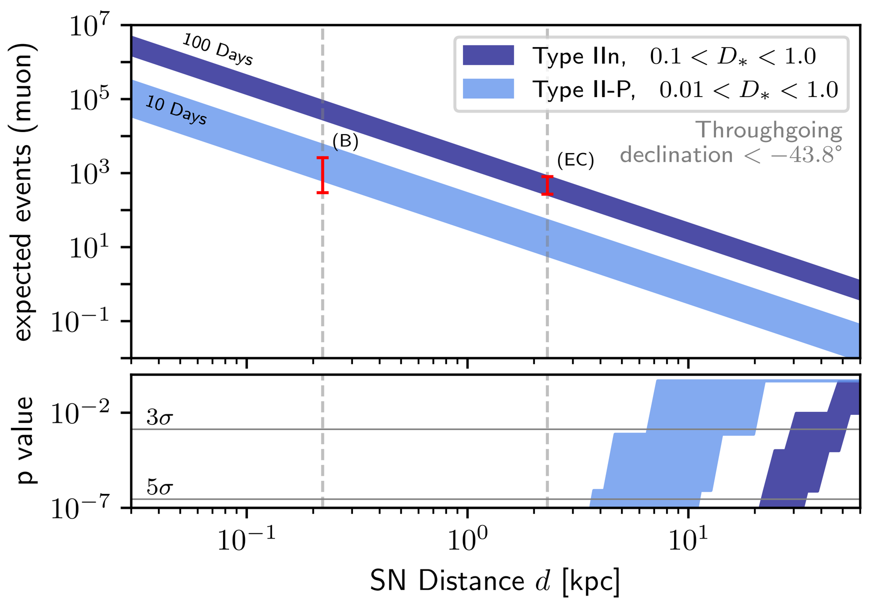


Throughgoing events come from charged current muon neutrino interactions in the bedrock, producing a muon which is detected by ATLAS. We compute the rate by injecting neutrino interaction vertices according to the supernova flux and cross section with `LeptonInjector` [4], and propagating the resulting muon to the detector with `PROPOSAL` [5].

4 **Throughgoing events**

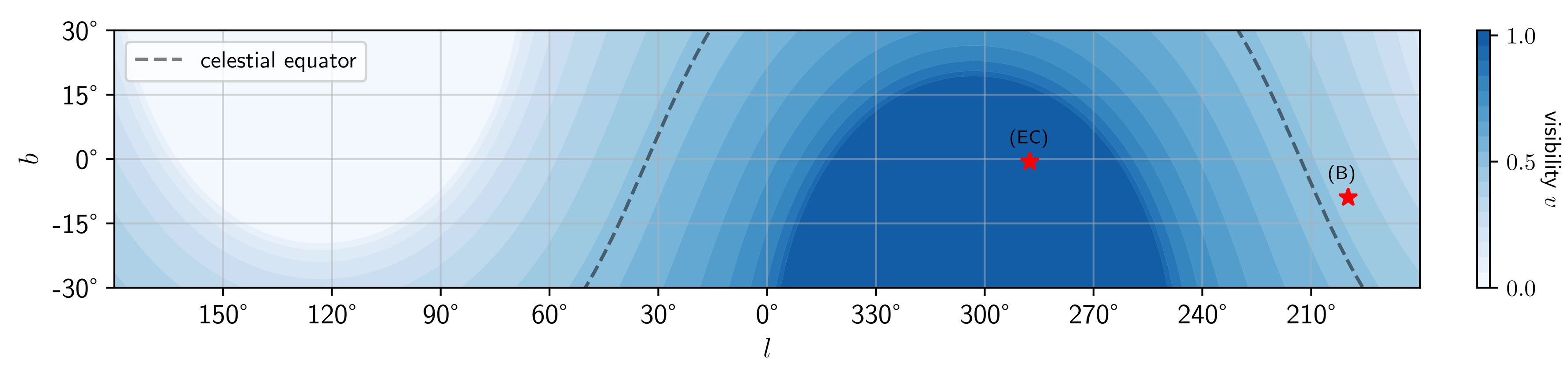
→ **Estimated momentum distribution of muons at the detector.** These muons originate from the neutrino interaction in the bedrock, and lose some energy as they propagate to the detector. We assume supernovae of different types at 10 kpc and integrate over its characteristic timescale. The flat part below 100 GeV is due to higher energy events cascading down.





← **Number of expected throughgoing events** integrated over their characteristic timescales, for different supernovae varying with distance, and the corresponding statistics-only discovery p-value. In comparison to starting events, there can be sensitivity to almost the whole galaxy. Throughgoing events must originate from below the horizon; therefore, not all parts of the sky will be throughgoing all of the time.

→ **Skymap, in galactic coordinates,** showing the visibility of throughgoing events. The visibility v corresponds to the fraction of time that part of the sky is below the horizon at the ALTAS latitude, as the earth spins.



2 **ATLAS** is a currently-running large accelerator experiment located at the LHC at CERN, designed to detect particles from proton-proton collisions [2]. It features a 4000 ton iron hadronic calorimeter surrounded by a muon system. It is located in a cavern around 100 m underground.

5 **Other highlights.**

- ATLAS can discriminate muon charge (therefore neutrino/antineutrino identification) due to its toroidal magnet
- ATLAS has better hadronic shower energy resolution compared to neutrino telescopes
- Beam & cosmic muon backgrounds can be reduced by timing and direction correlation to supernova

References:

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Images: CERN; Getty Images Plus

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