SCEP: a cosmic magnetic monopole search experiment using coincidence measurement between quantum sensor and plastic scintillators

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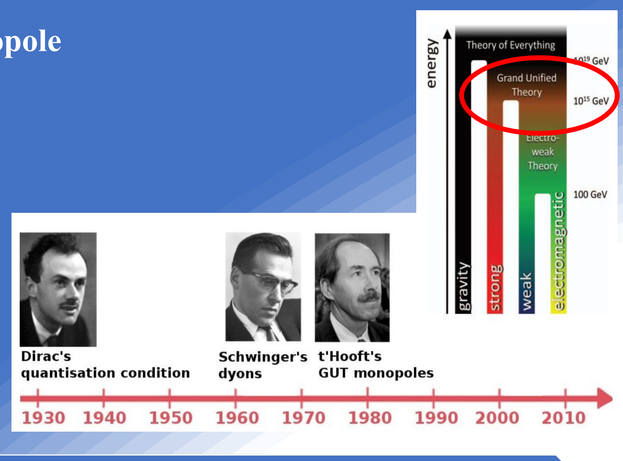
Magnetic Monopole: a hypothesis from GUT

Theoretical motivations of Magnetic monopole

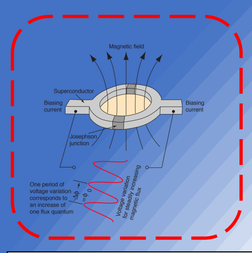
1. Unsymmetric of Maxwell's equations
2. Electron's quantization
3. Grand unification theory's prediction
4. Evidence for inflation theory

A massive, exotic particle that might have been produced during the evolution of the early universe



Past Efforts & Challenges

Superconductivity



Underground experiments: MACRO,IceCube..

	Underground Experiments	Superconductivity
Signal	Ionization	Induction
Advantages	• Low background • Easy to scale up	• Unique feature of signal • No limits on speed
Disadvantages	• No unique feature of signal • Limited mass and speed range	• Hard to scale up

Experimental challenges:

- **Large scale**
- **Low background**
- **Unique signal feature**

Our Proposal

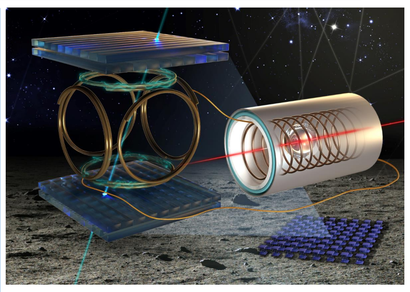
Coincidental measurement between plastic scintillators and the atomic magnetometers

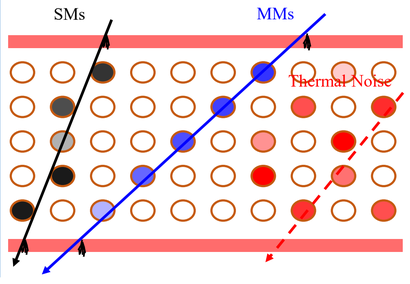
Basic Concept:

- **Plastic scintillator: a highly ionization signal**
- **Atomic magnetometer: a pulse like magnetic signal**

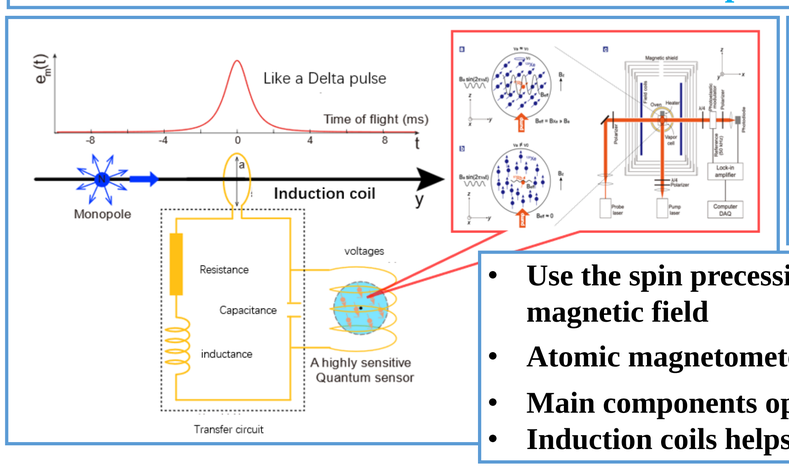
Advantages:

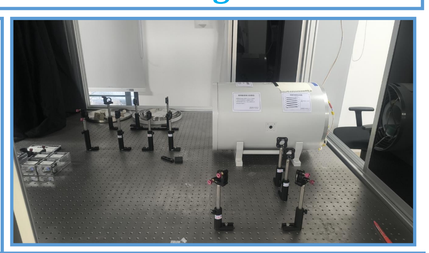
- **Easy to scale up by using induction coils**
- **Low background events thanks to the coincidental measurement**
- **Unique signal feature: a track-like pattern in the induction coils array**





Induction detection module: induction coils coupled to atomic magnetometers





- **Use the spin precession of Rb^{87} atoms to detect RF magnetic field**
- **Atomic magnetometers have ~10 $\frac{fT}{\sqrt{Hz}}$ sensitivity**
- **Main components operate at room temperature**
- **Induction coils helps to search with large area**

Simulation & validation of the induction detection module

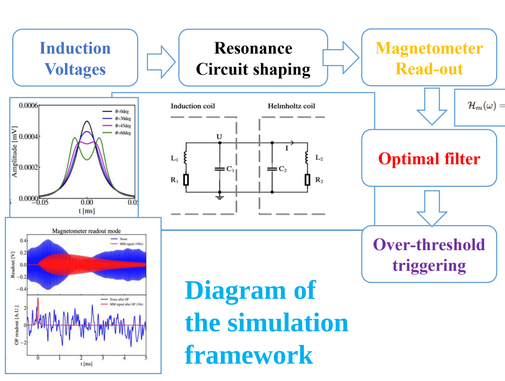
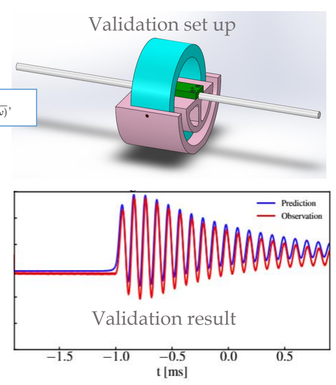


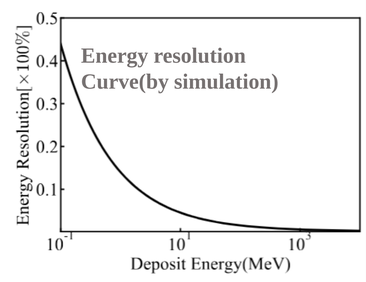
Diagram of the simulation framework

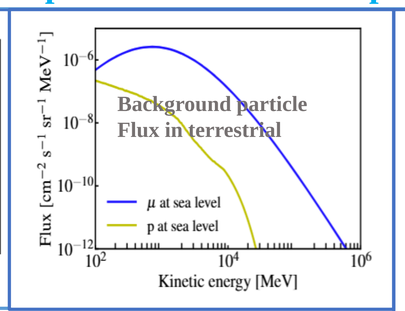


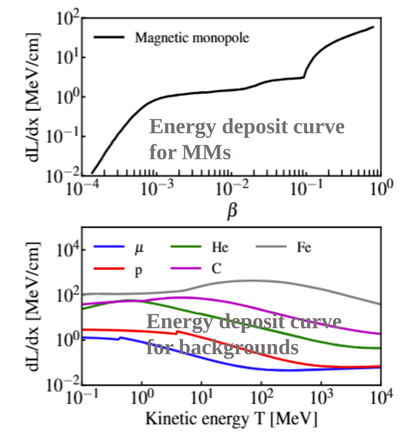
- **Long solenoid to simulate MM signal**
- **Simulation and validation test signals match well. The total difference is within 10%.**
- **Noise was also validated. The total difference is also within 10%**

Background Estimation

Ionization detection module: plastic scintillator coupled to SiPMs



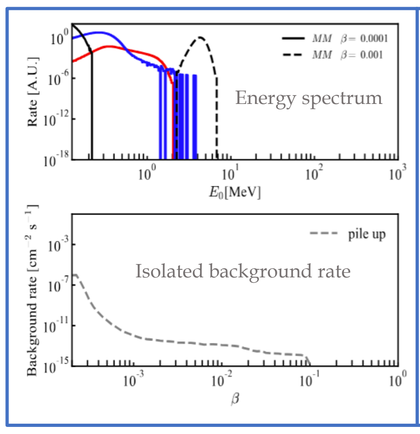


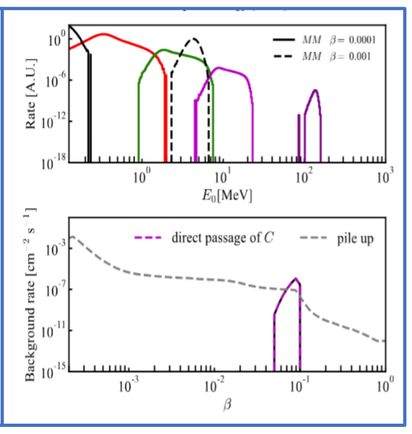


Preliminary parameters from simulation:

- **Energy resolution ~ 7%@1MeV**
- **Time resolution ~ 10ns**
- **Light yield of MM ~ 1MeV/cm @ $\beta = 0.01$**

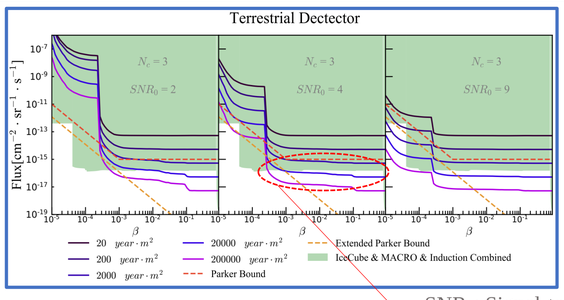
Terrestrial | **Moon-based**

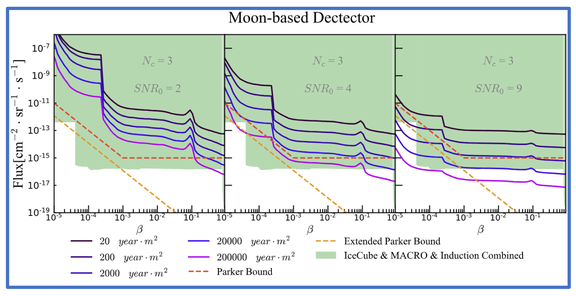


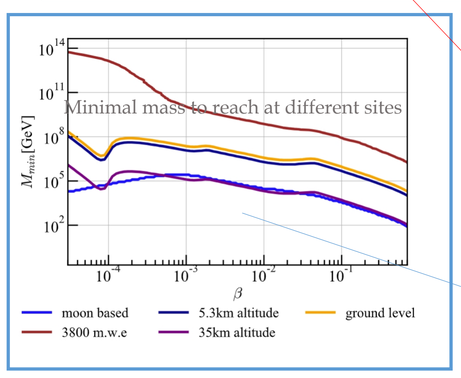


- Two layers of PSs helps to measure energy and velocity at the same time
- Environmental particles such as proton in cosmic ray, muon from the atmosphere are the main background
- Background rate in moon environment is 3 order of magnitude larger than that of terrestrial environment due to the absence of the atmosphere

Projected Sensitivity







SNR_0: Signal-to-Noise Ratio of induction module

N_c: Number of layers of the induction module

- Reach the best constrain with ~20000 $m^2 \cdot year$ exposure and sufficient Signal-to-Noise Ratio(SNR) for a terrestrial detector.
- Realize background free search with higher layers of induction coils
- A steep appears at β~2×10^{-5} is due to MM lower than that speed cannot produce enough light in PSs, an induction-only search is performed then
- Although a moon-based detector suffers from higher background rate, it is still proposed due to its potential to probe into lower cosmic monopole mass

Future

	Induction module	Plastic Scintillator
Current	• Signal to noise ratio (SNR) ~ 1.92 • Single module sensitive area ~ $5cm^2$	• Time resolution ~10ns • Energy resolution ~7%@1MeV • Position resolution ~5cm
Requirement	• Signal to noise ratio (SNR) ~ 4.2 • Single module sensitive area ~ $50cm^2$	• Time resolution ~1ns • Energy resolution ~5%@1MeV • Position resolution ~1cm
Solutions	• Use Iron core to enhance signal • Reduce alternating resistance to lower background • Read-out circuit optimization	• Optical fiber helps to improve light collection • Better arrangement • SiPM base circuit optimization

Single Module optimization

Array design & optimizati-on

Single module physical run

Array-like physical run