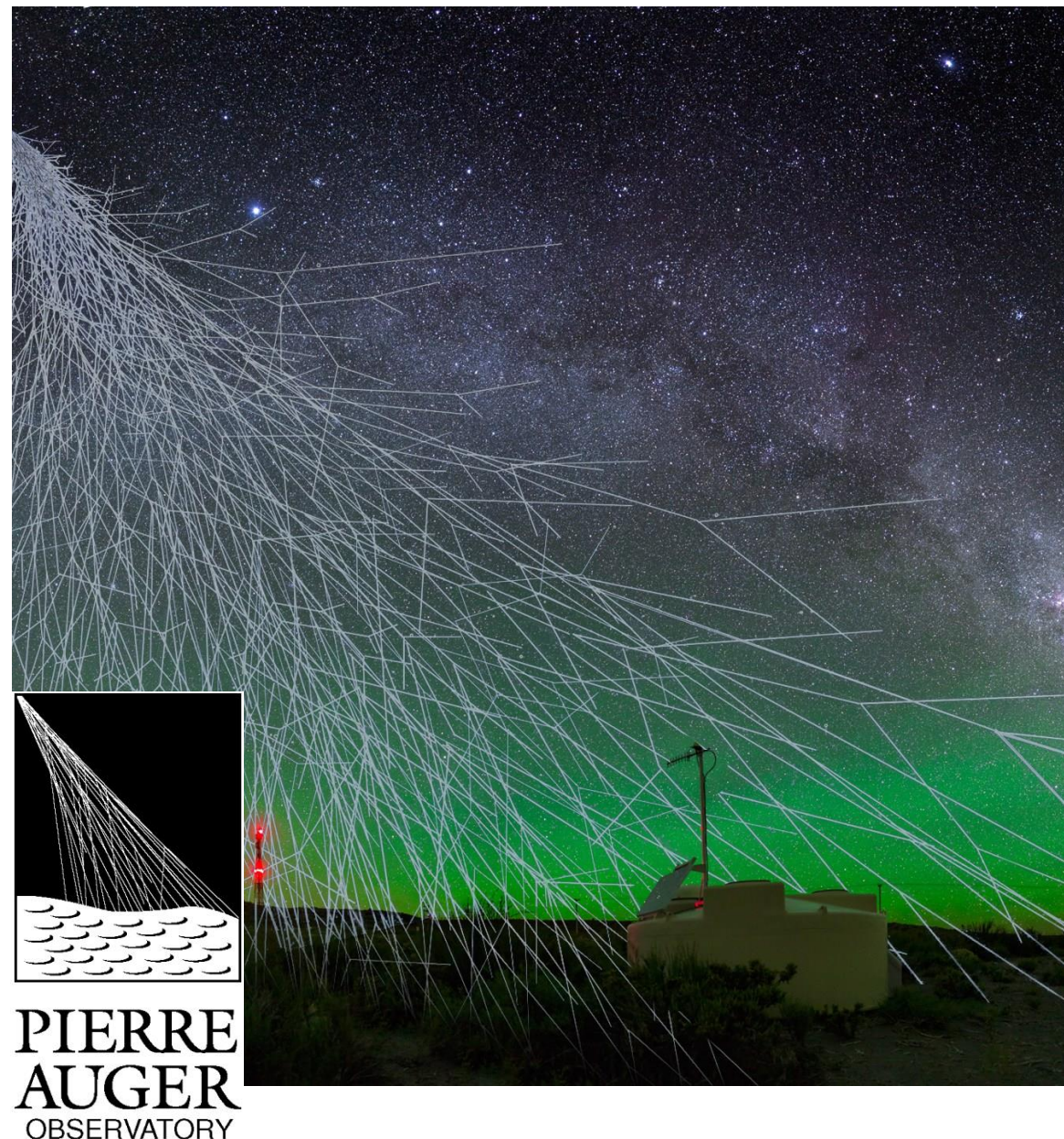




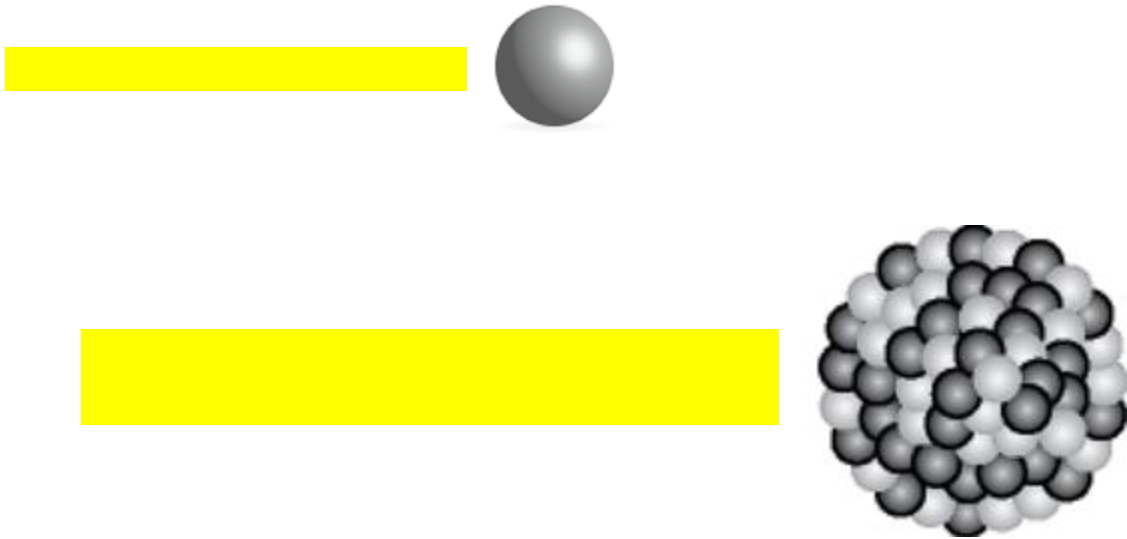
Inner Structure of Ultra-High-Energy Air Showers

2026 LIP Internship

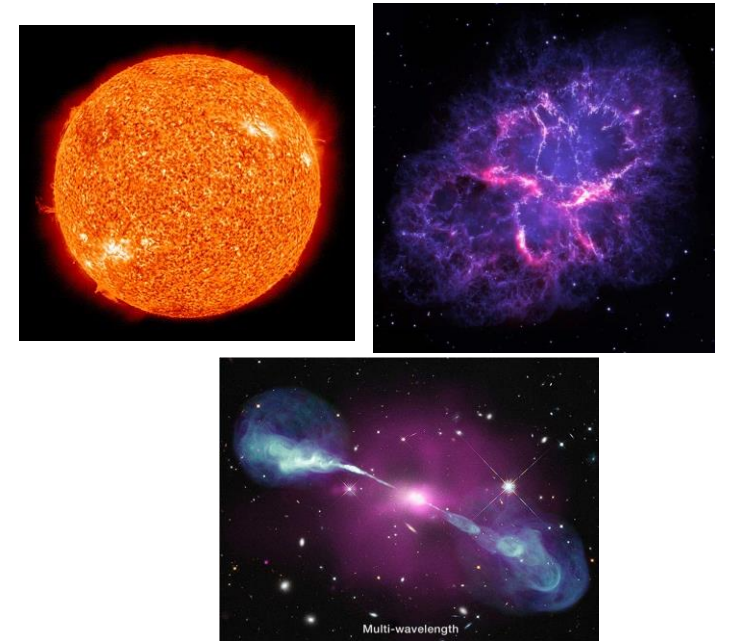
Interns: Filipa Canaria e Francisco Vasconcelos
Supervisors: Ruben Conceição e Milton Freitas



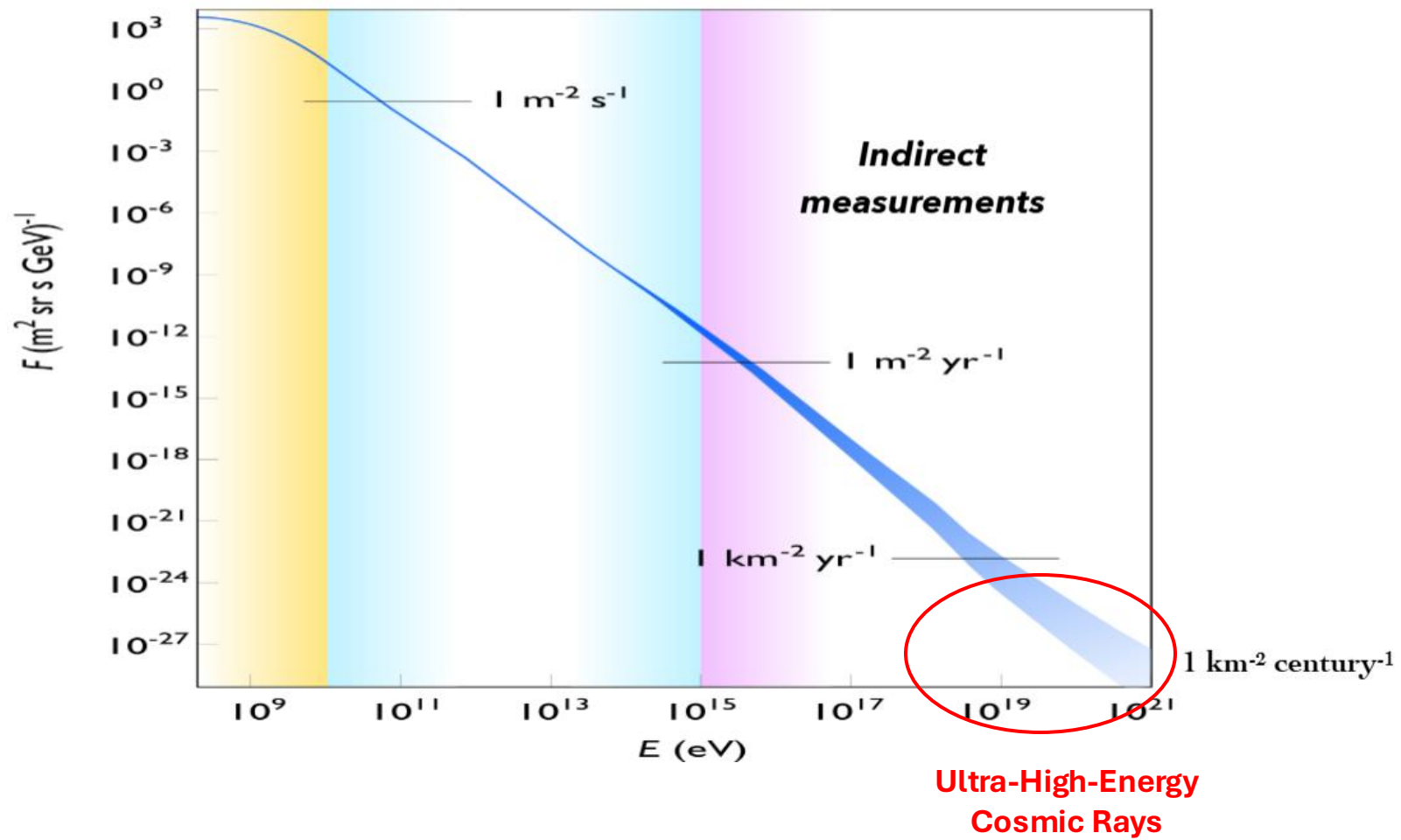
Cosmic Rays



Possible origins:

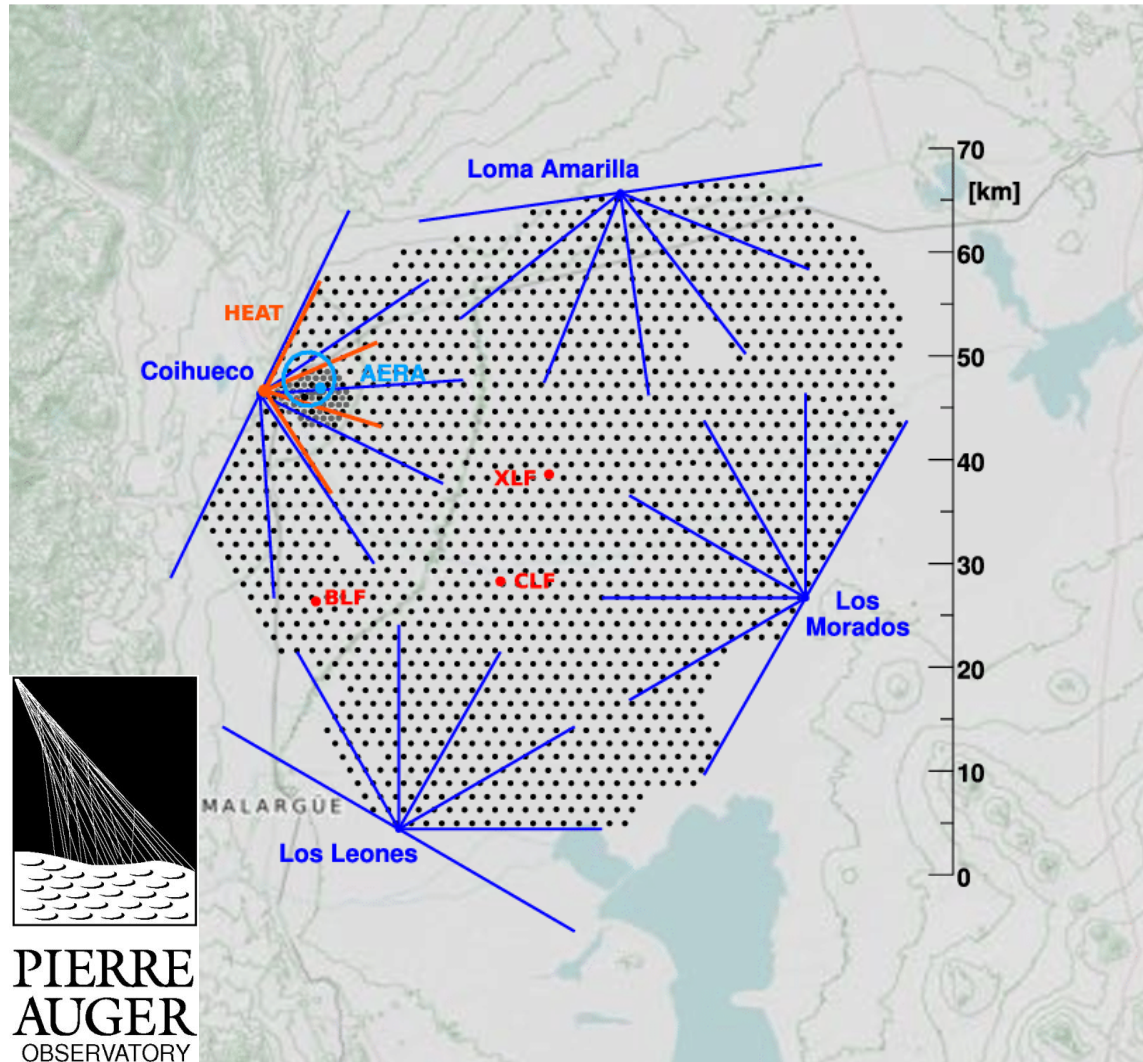


$10^9 \text{ eV} - 10^{21} \text{ eV}$



Cosmic Ray energy spectrum

Pierre Auger Observatory



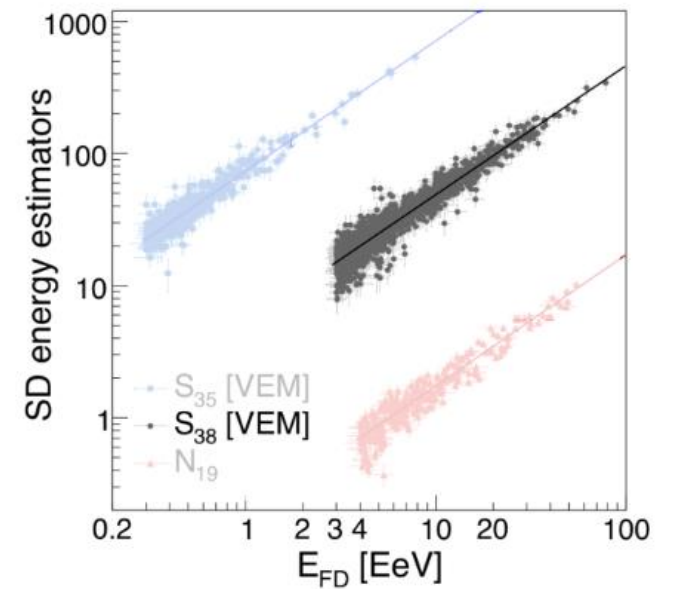
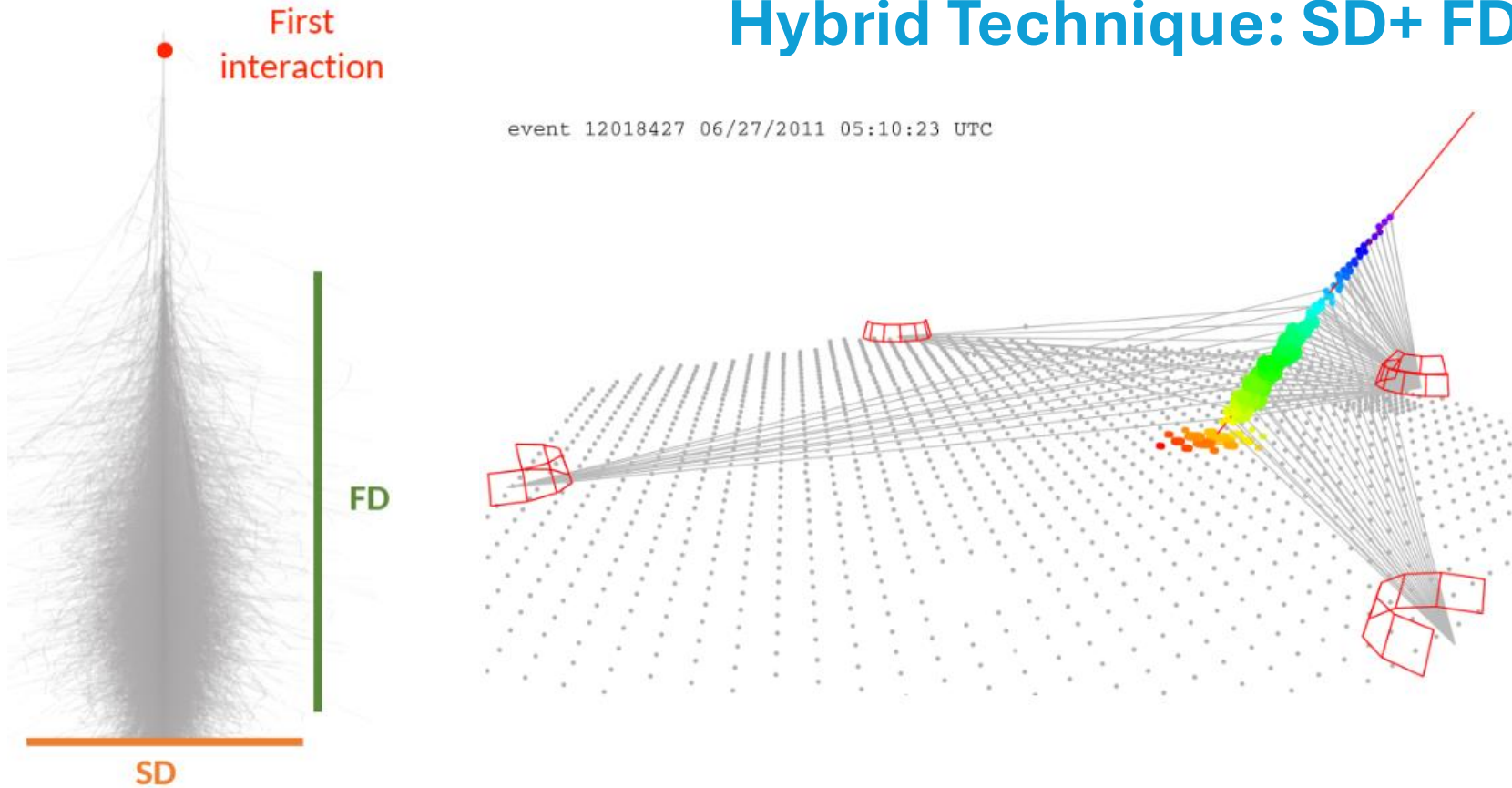
Fluorescence Detector- **FD**



Surface Detector- **SD**

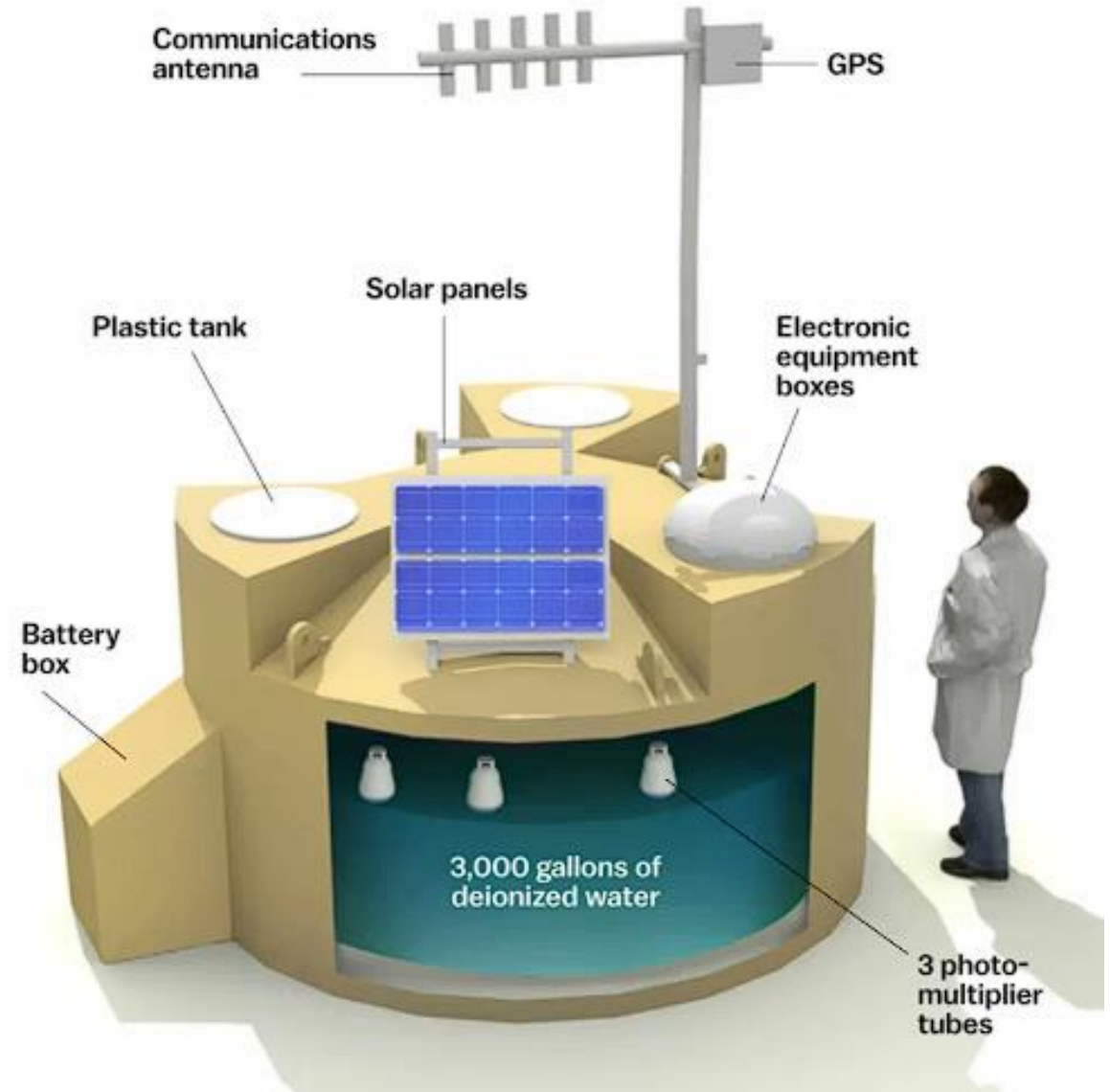
Why explore SD data close to shower core?

Hybrid Technique: SD+ FD

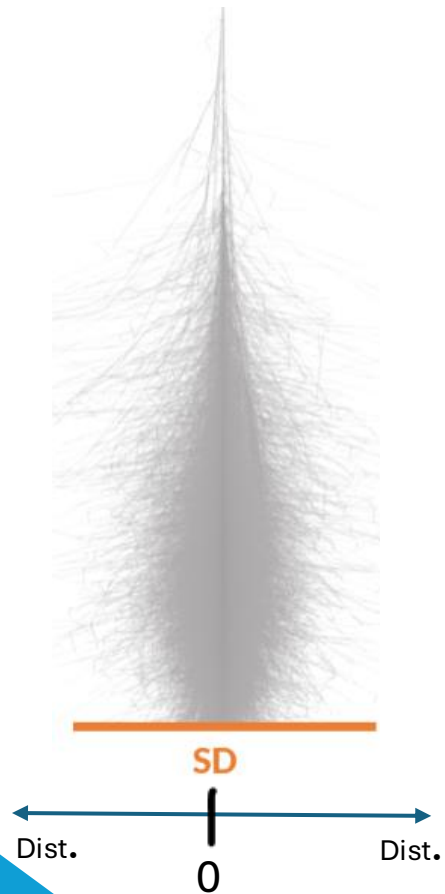


Access with SD the same region to which the FD is sensitive.

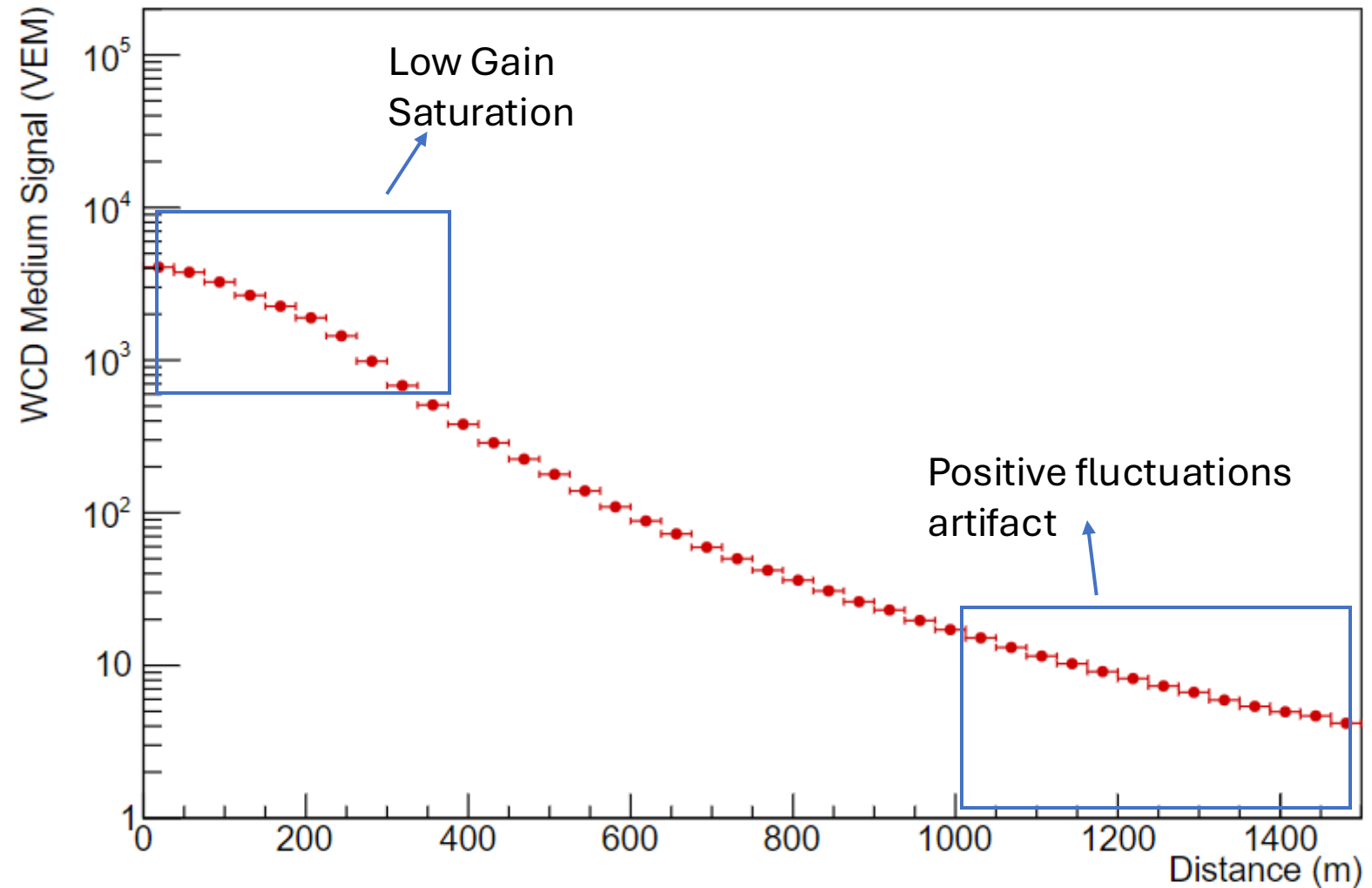
WCD Water Cherenkov Detector



LPMT

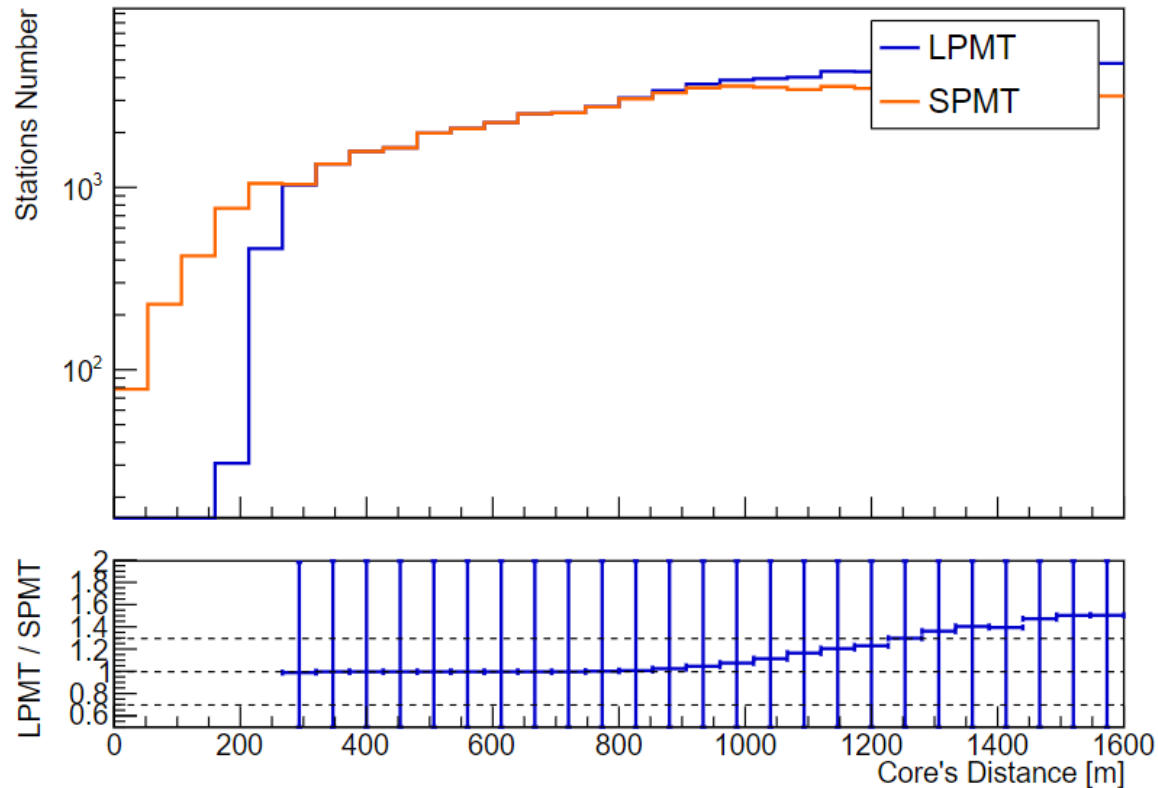


Lateral Distribution Function LPMT

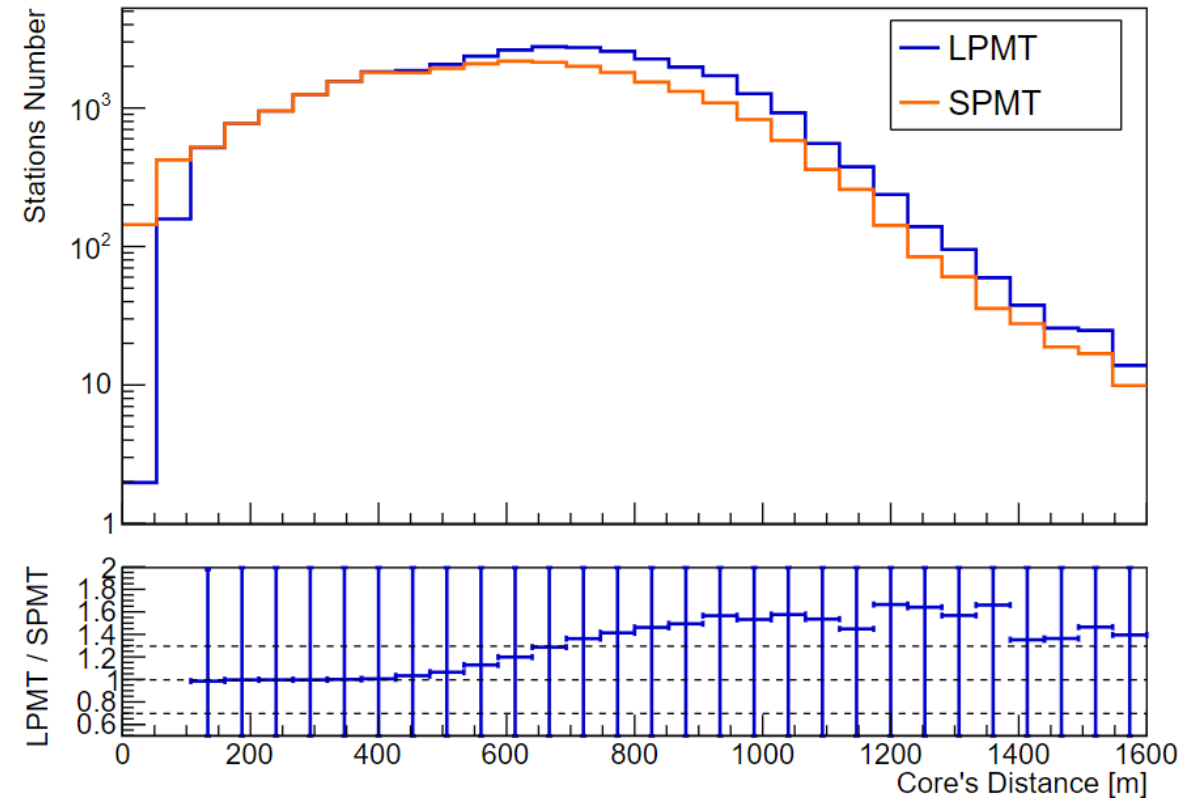


SPMT (Small Photo-Multiplier Tube)

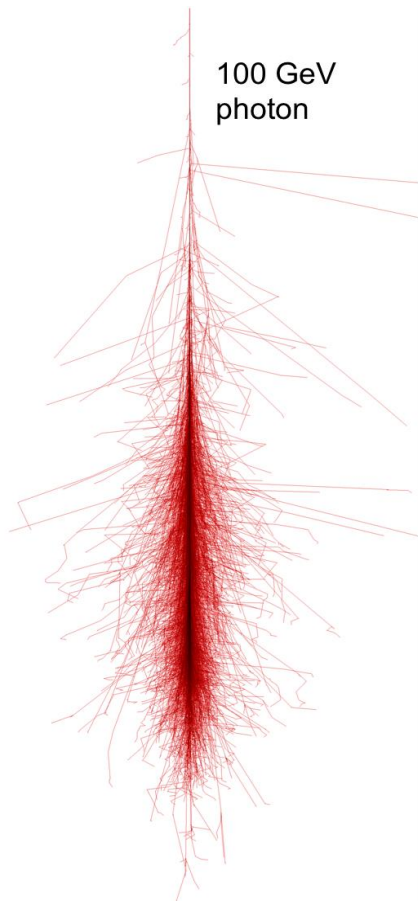
High Energy ($10^{18,7}$ eV)



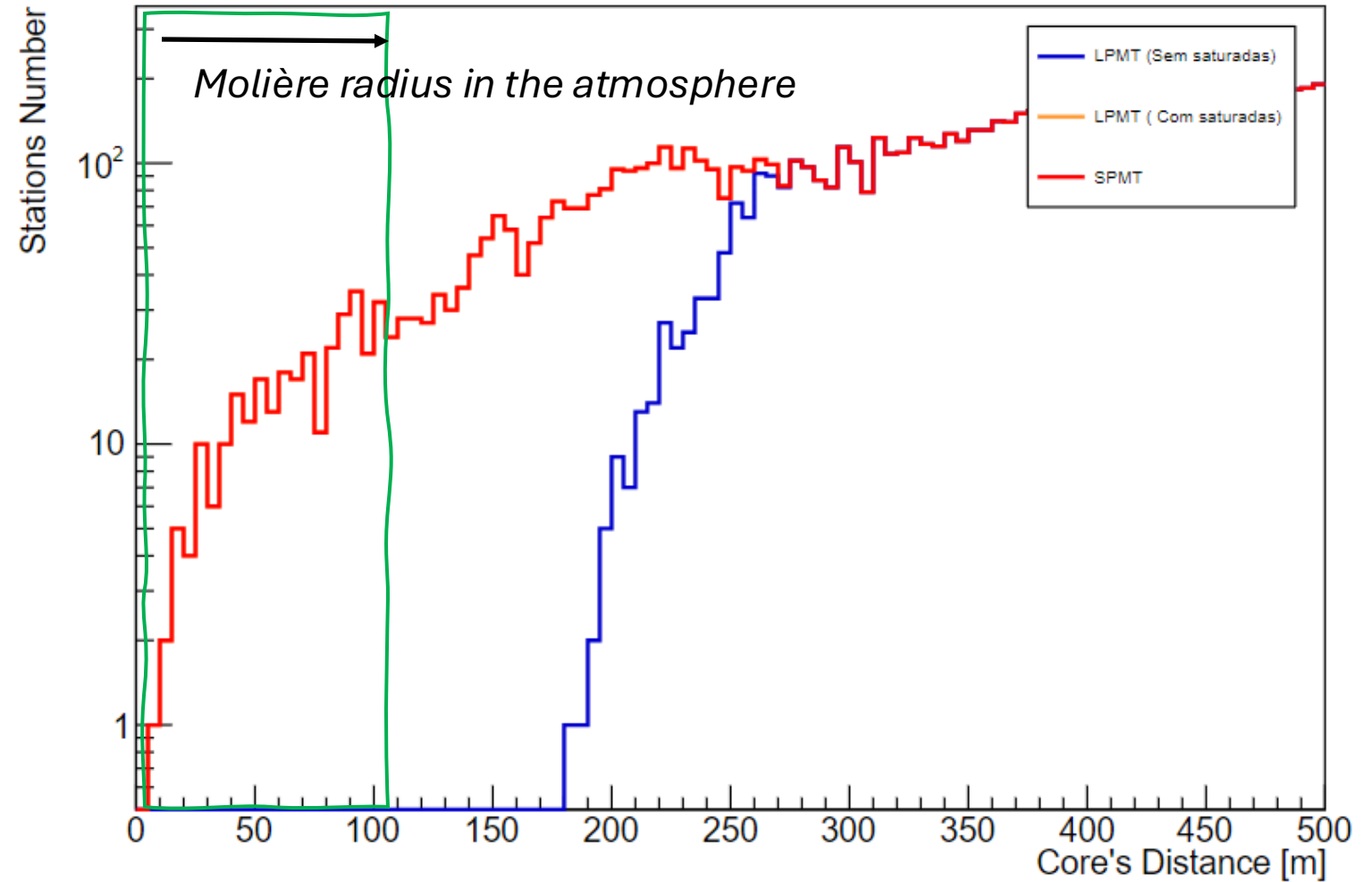
Low Energy ($10^{17,7}$ eV)



SPMT

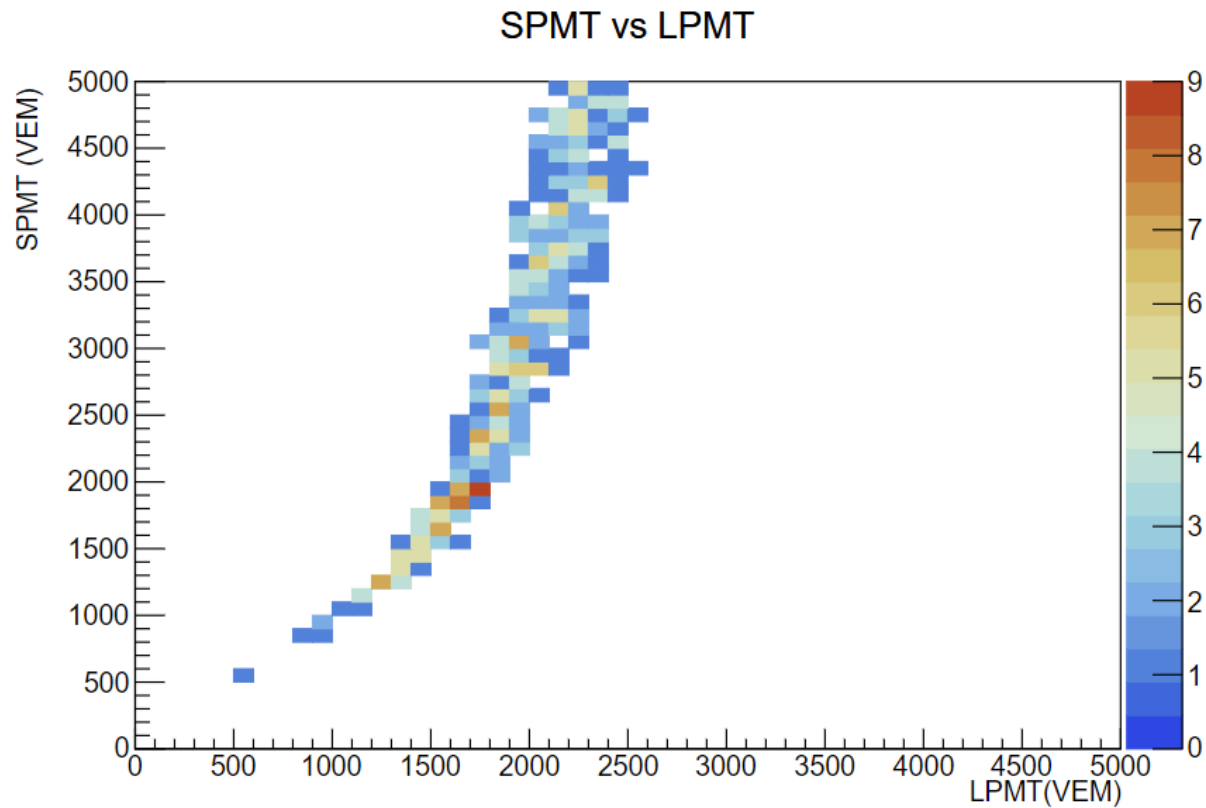


Stations vs Core's Distance

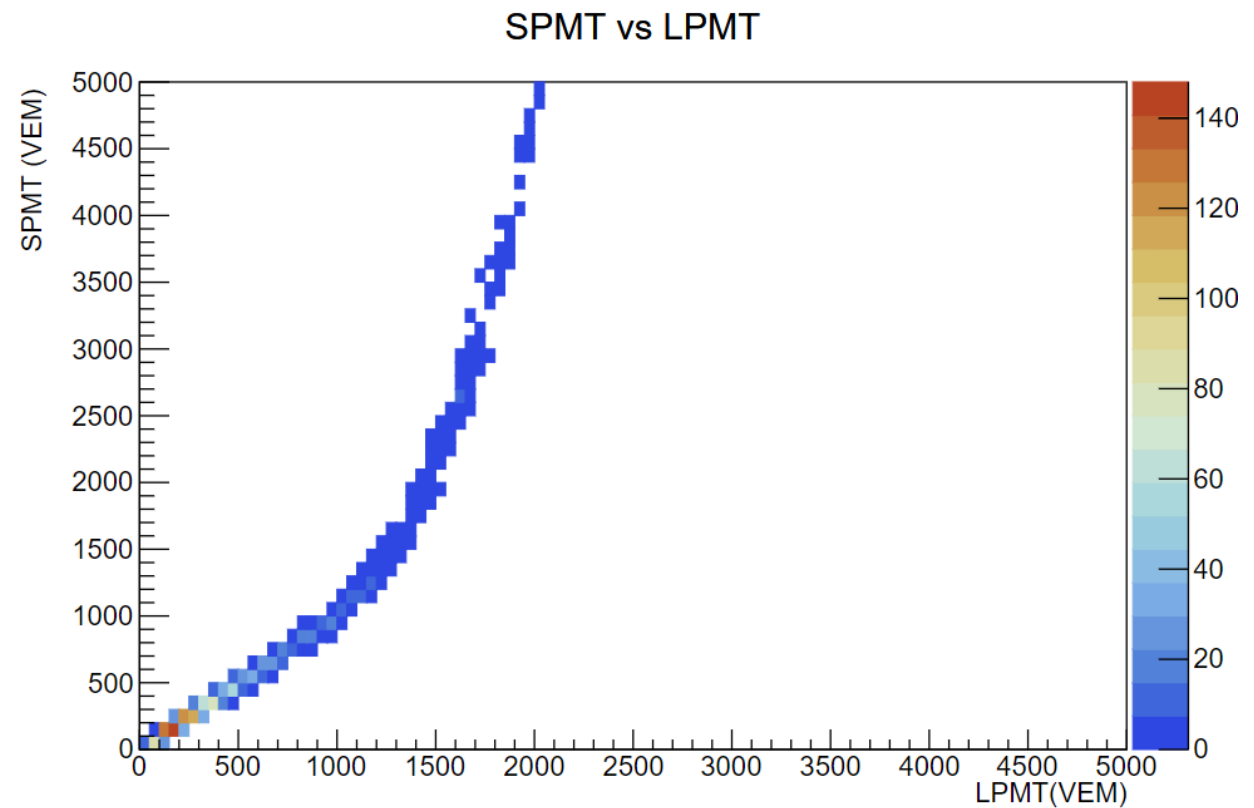


SPMT

High Energy ($10^{18,7}$ eV)



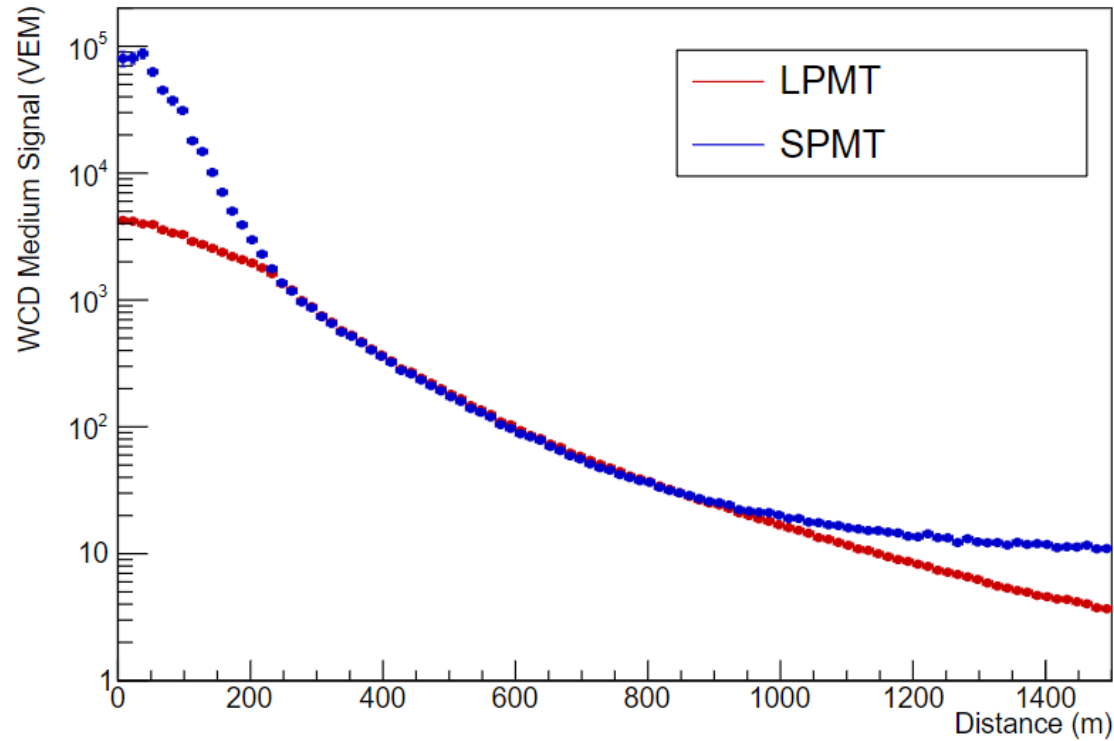
Low Energy ($10^{17,7}$ eV)



SPMT

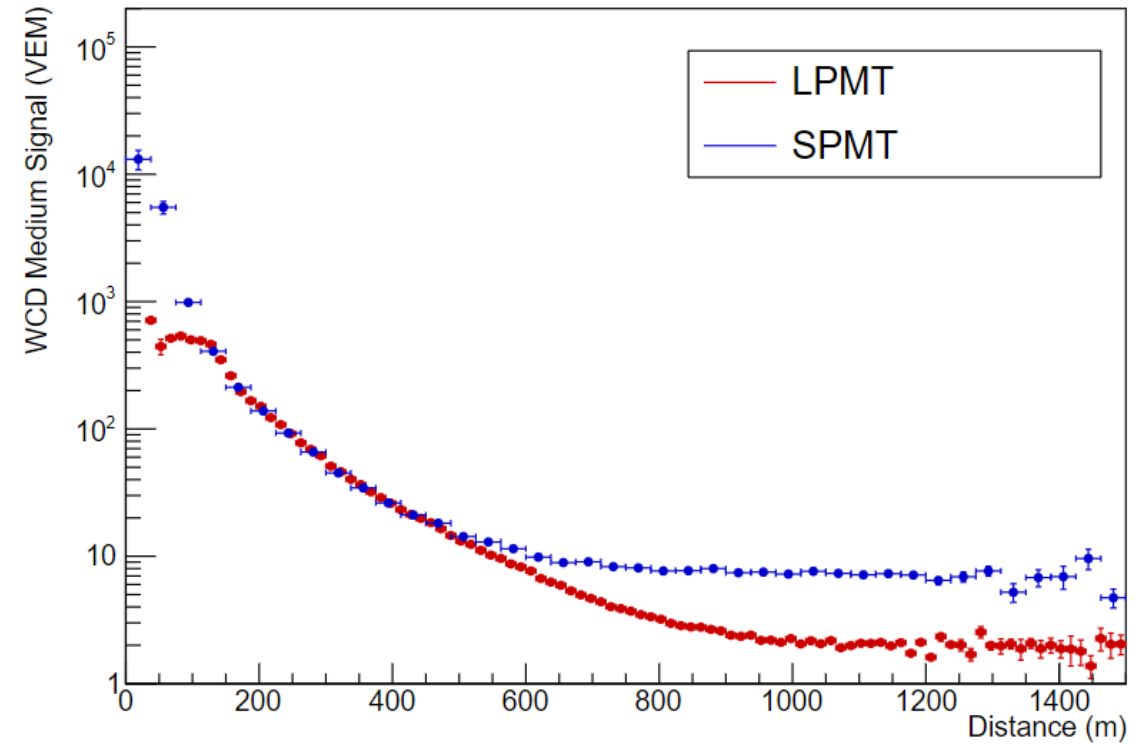
High Energy ($10^{18,7}$ eV)

Lateral Distribution Function LPMT



Low Energy ($10^{17,7}$ eV)

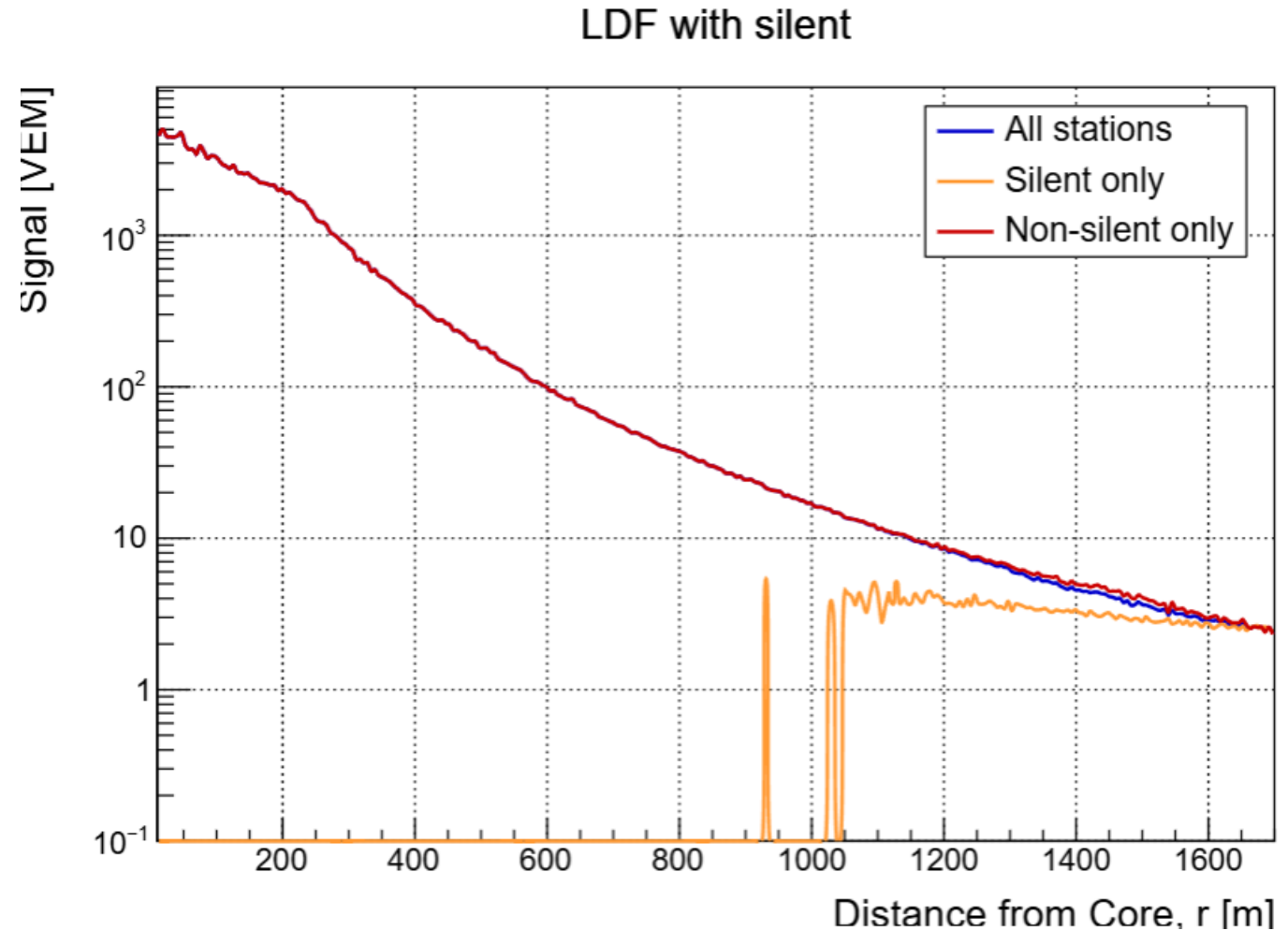
Lateral Distribution Function LPMT



Silent Stations

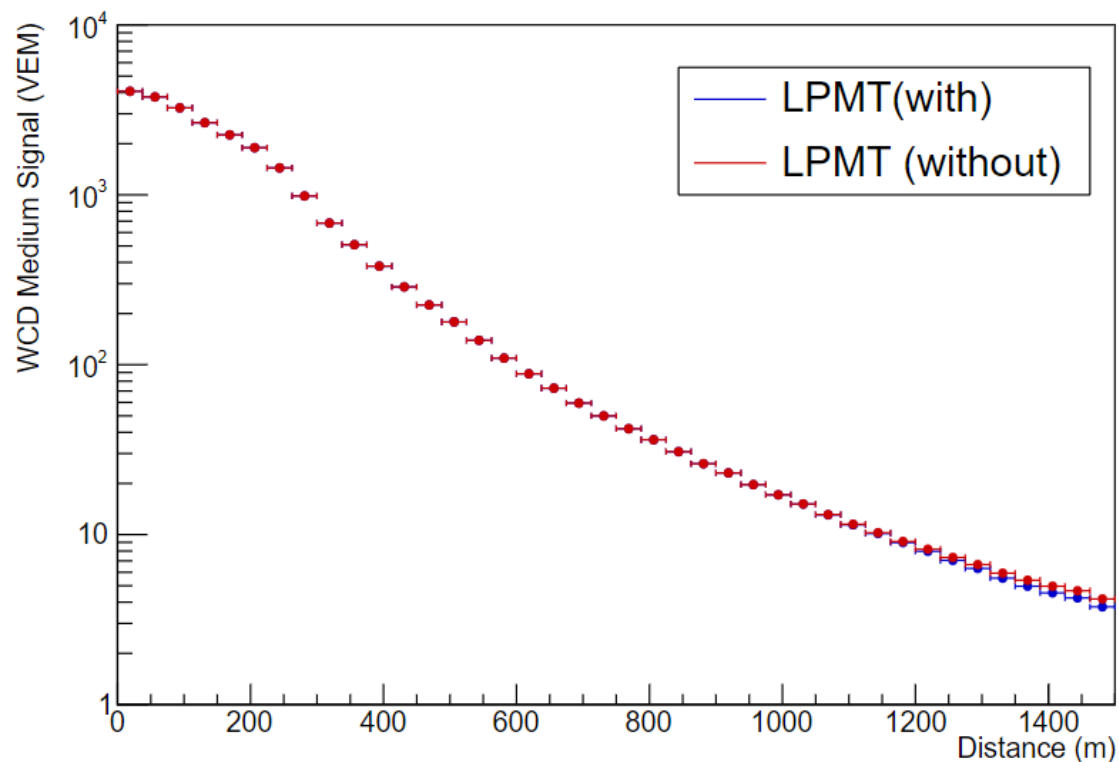
Stations crossed by shower particle but did not triggered

Should be dominant at large distances from shower core where number of shower particles is highly reduced

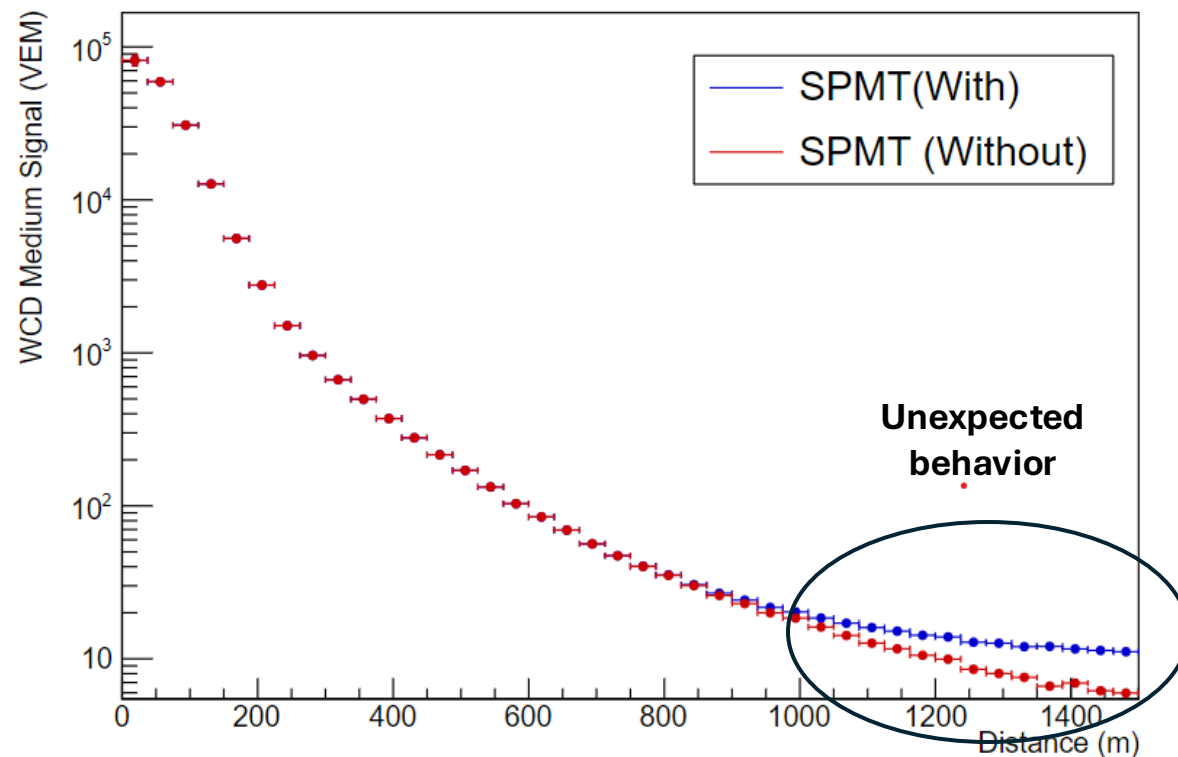


Including silent stations

Lateral Distribution Function LPMT



Lateral Distribution Function SPMT

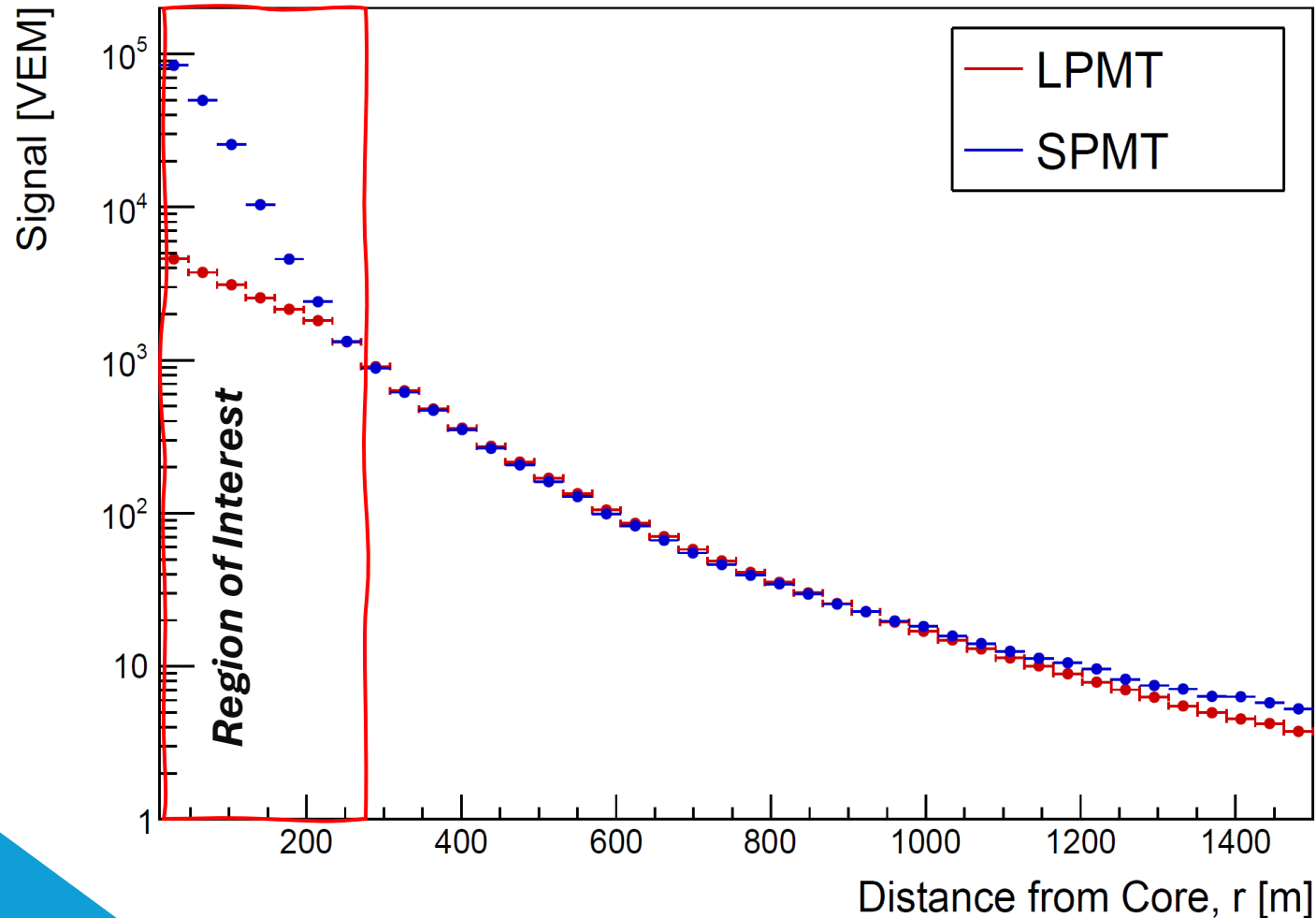


Large distance to shower core found artifact of SPMT calibration w.r.t. LPMT

To be reported soon in a Foundation task call

Conclusion

LDF with silent



It is **possible** to access the **inner region** of the shower core with **SPMT**.

The results of this internship enables future test between FD and SD.