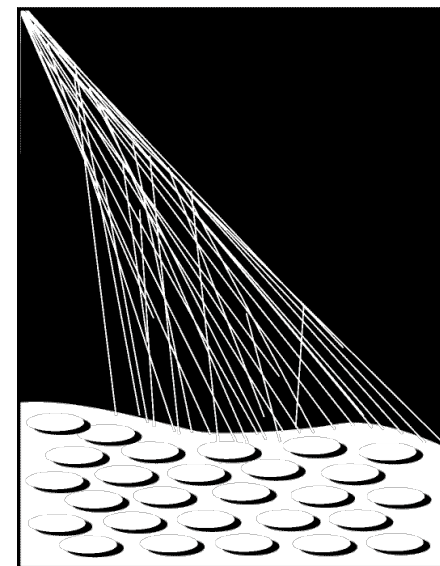


# AugerPrime: Expectations and first results

David Schmidt () on behalf of the Pierre Auger Collaboration

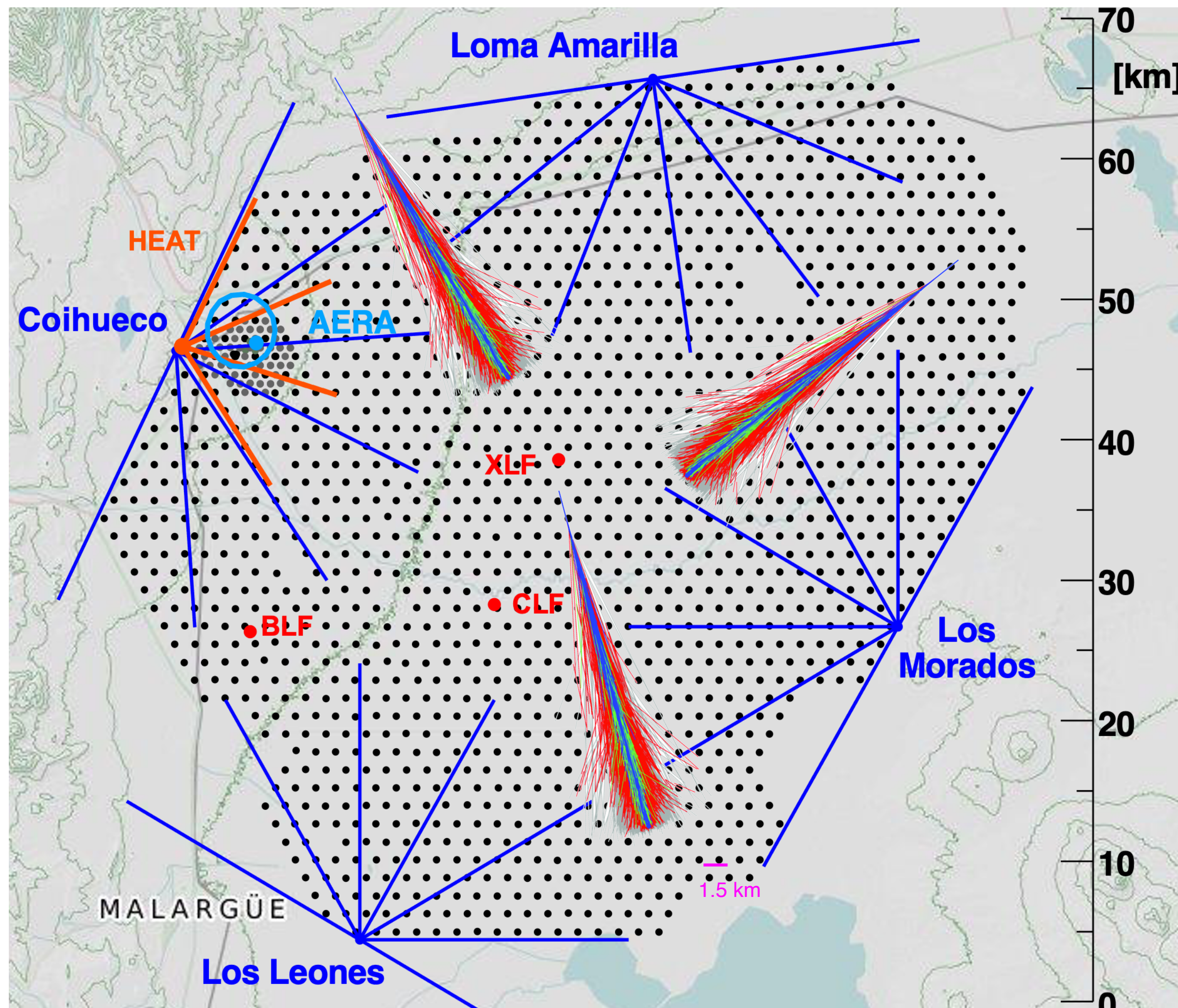


PIERRE  
AUGER  
OBSERVATORY



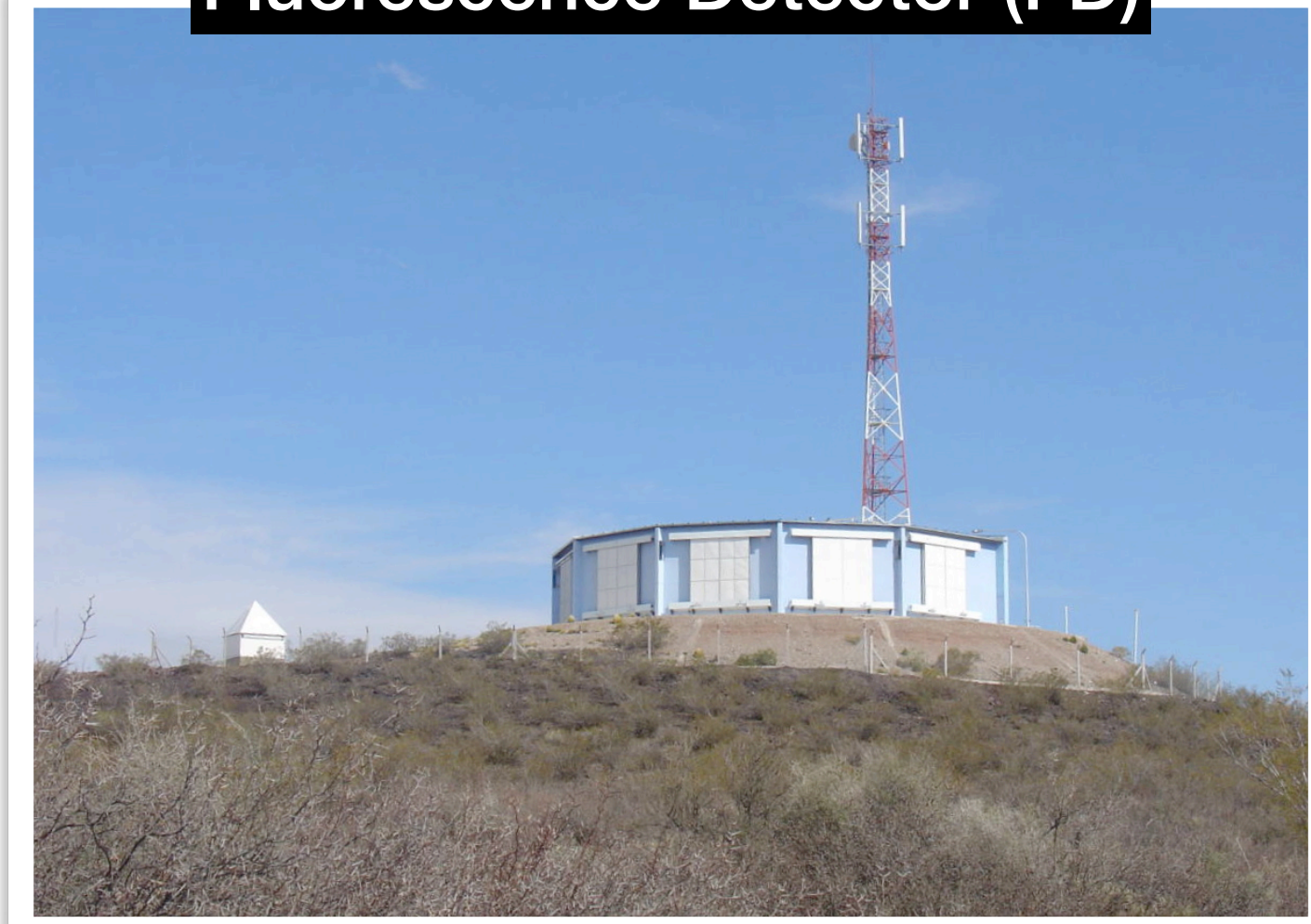
# The Pierre Auger Observatory | Ultra-high-energy cosmic rays

Physics data taking since 2004



**Location:** Malargüe, Mendoza, Argentina  
**Height:** 1450 meters  
**Atm. Depth:** 860 g/cm<sup>2</sup>  
**Energy Threshold:** 10<sup>16.7</sup> eV

Fluorescence Detector (FD)



27 telescopes distributed between 4 locations

Surface Detector (SD)

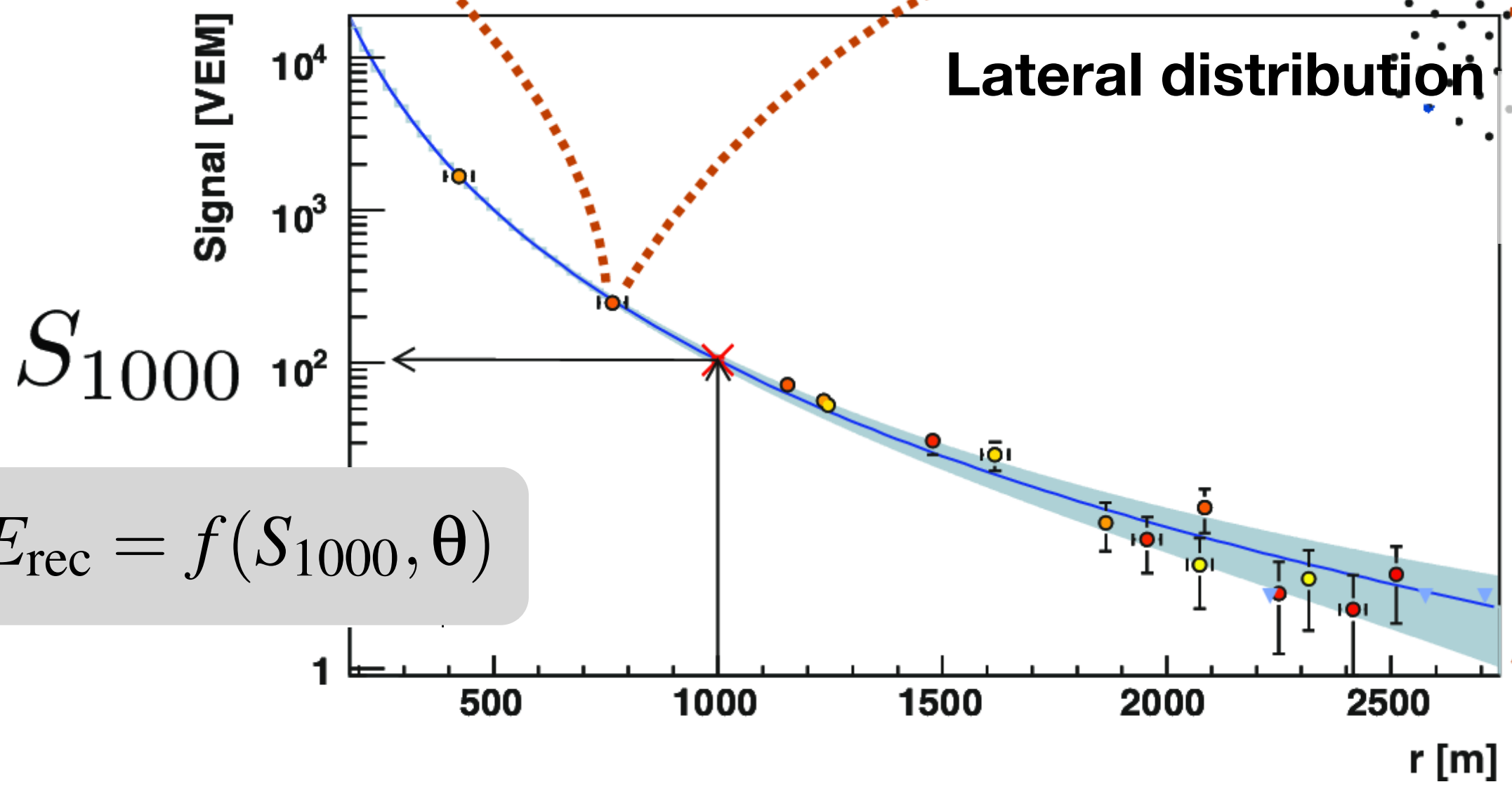
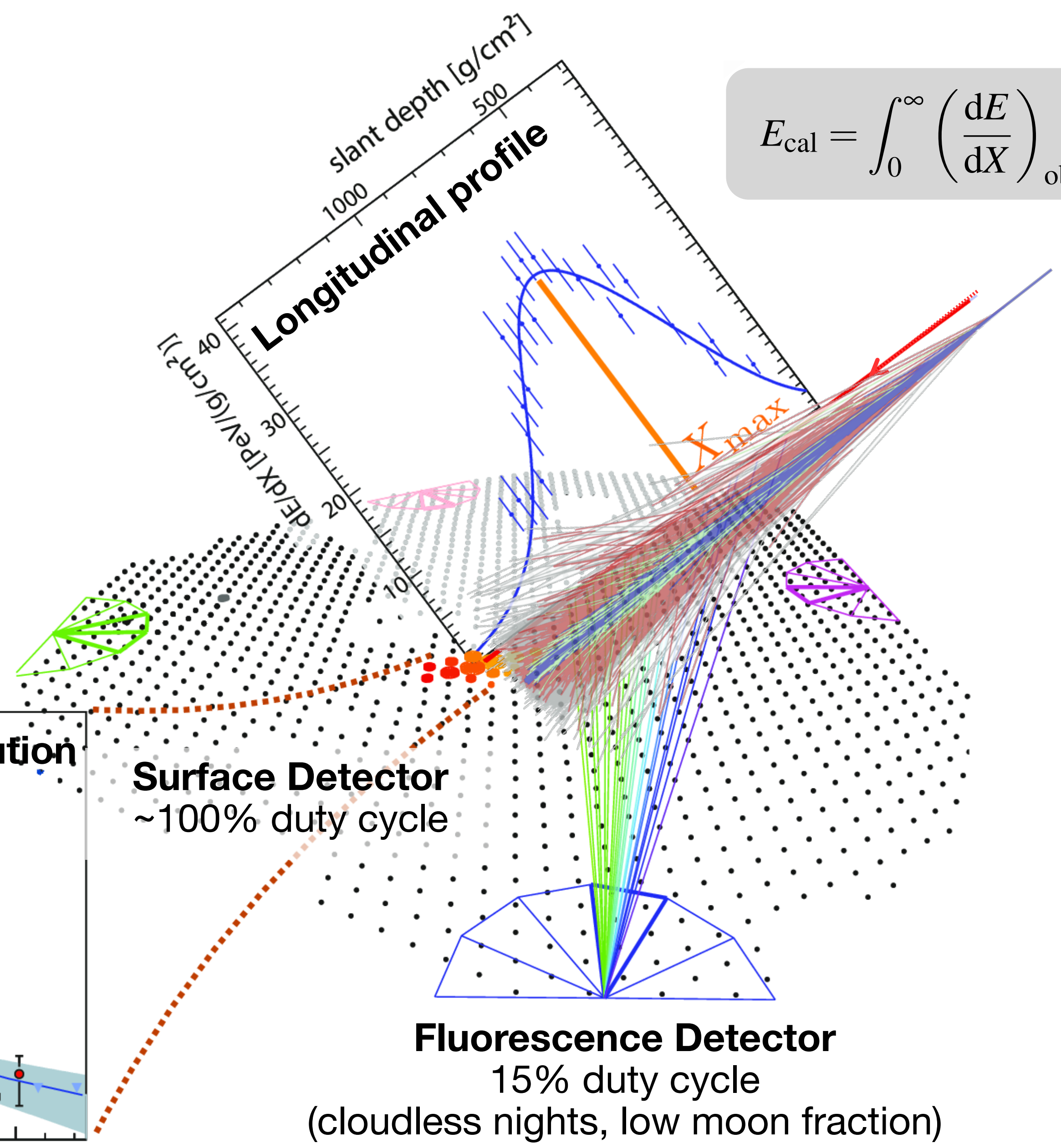
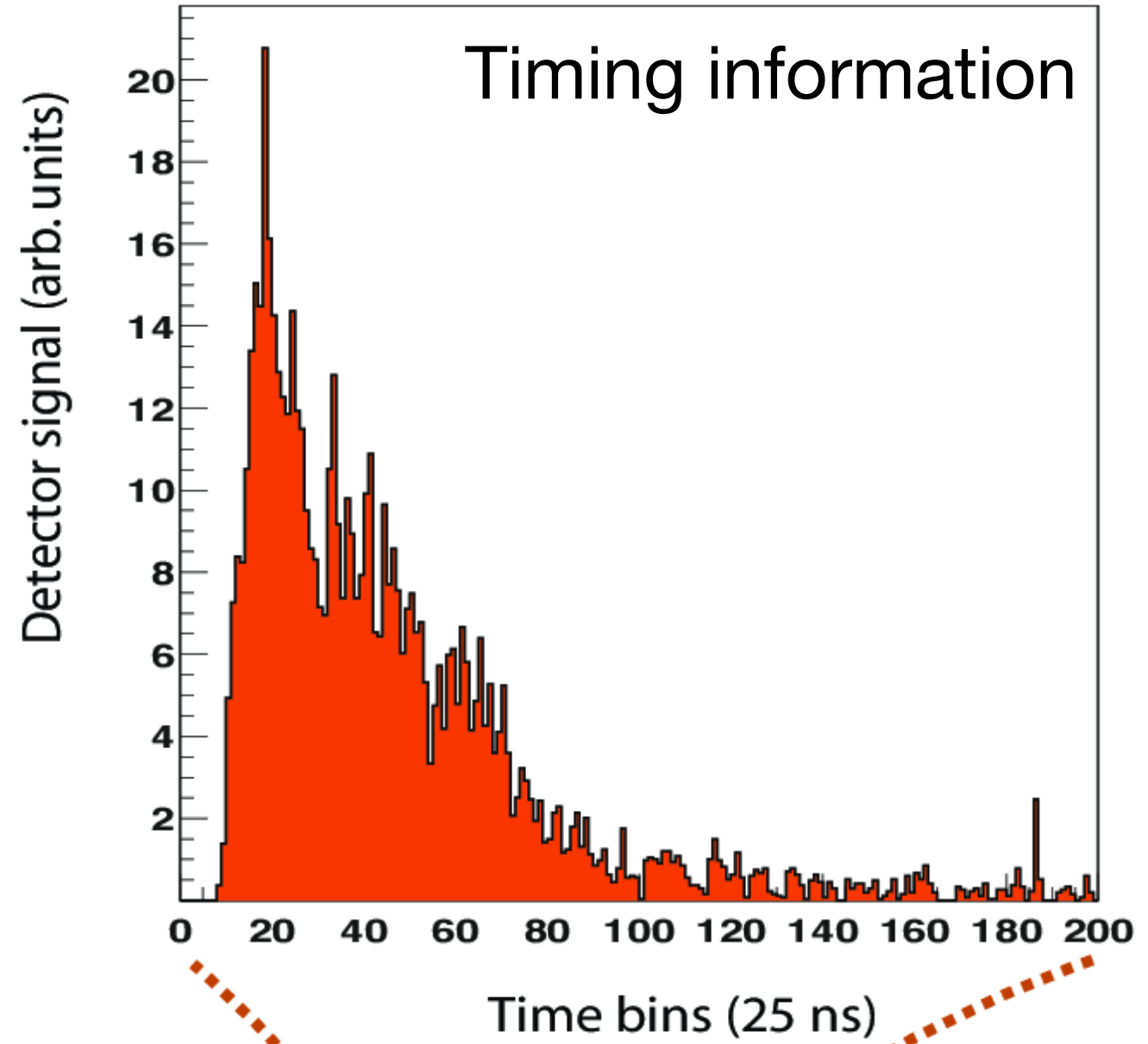


1660 water-Cherenkov detectors  
1500 m, 750 m, and 433 m grids



# Measurement principle

$$E_{\text{cal}} = \int_0^{\infty} \left( \frac{dE}{dX} \right)_{\text{obs}} dX$$





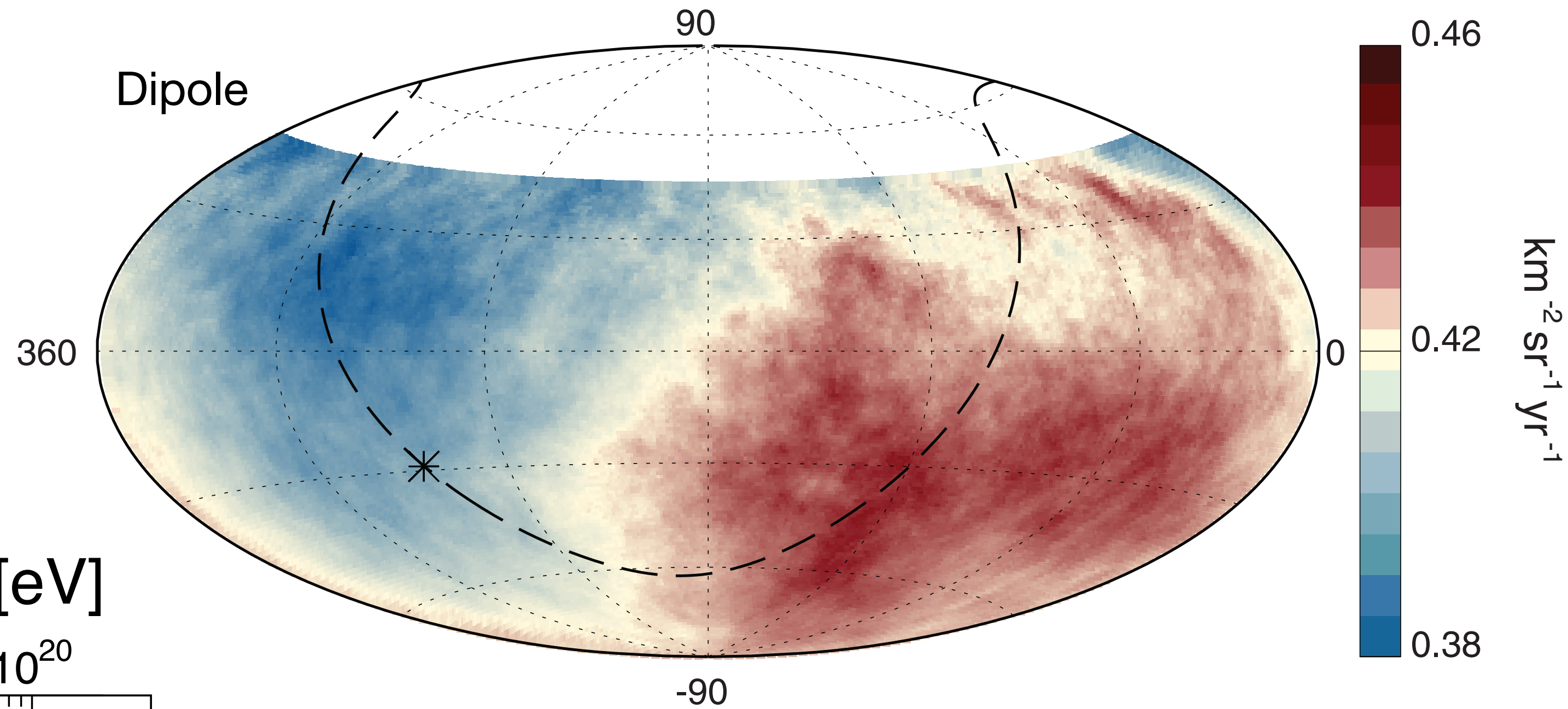
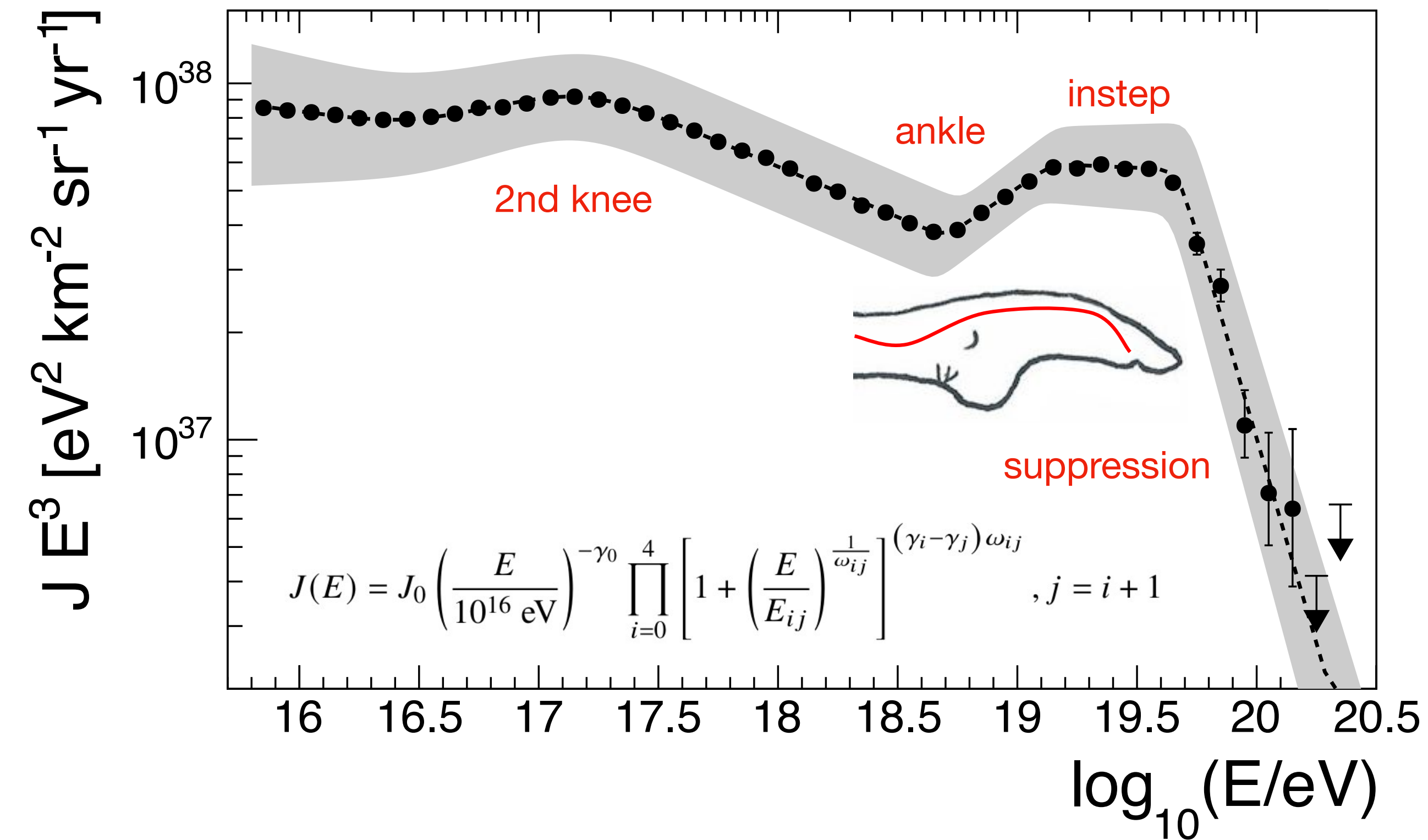
# A couple of Phase I Results

For more: contribution by Vitor de Souza from Aug. 28

Unprecedented exposure of more than  
80,000 km<sup>2</sup> sr yr

13 TeV (equivalent c.m.)  
LHC (p-p)

E [eV]



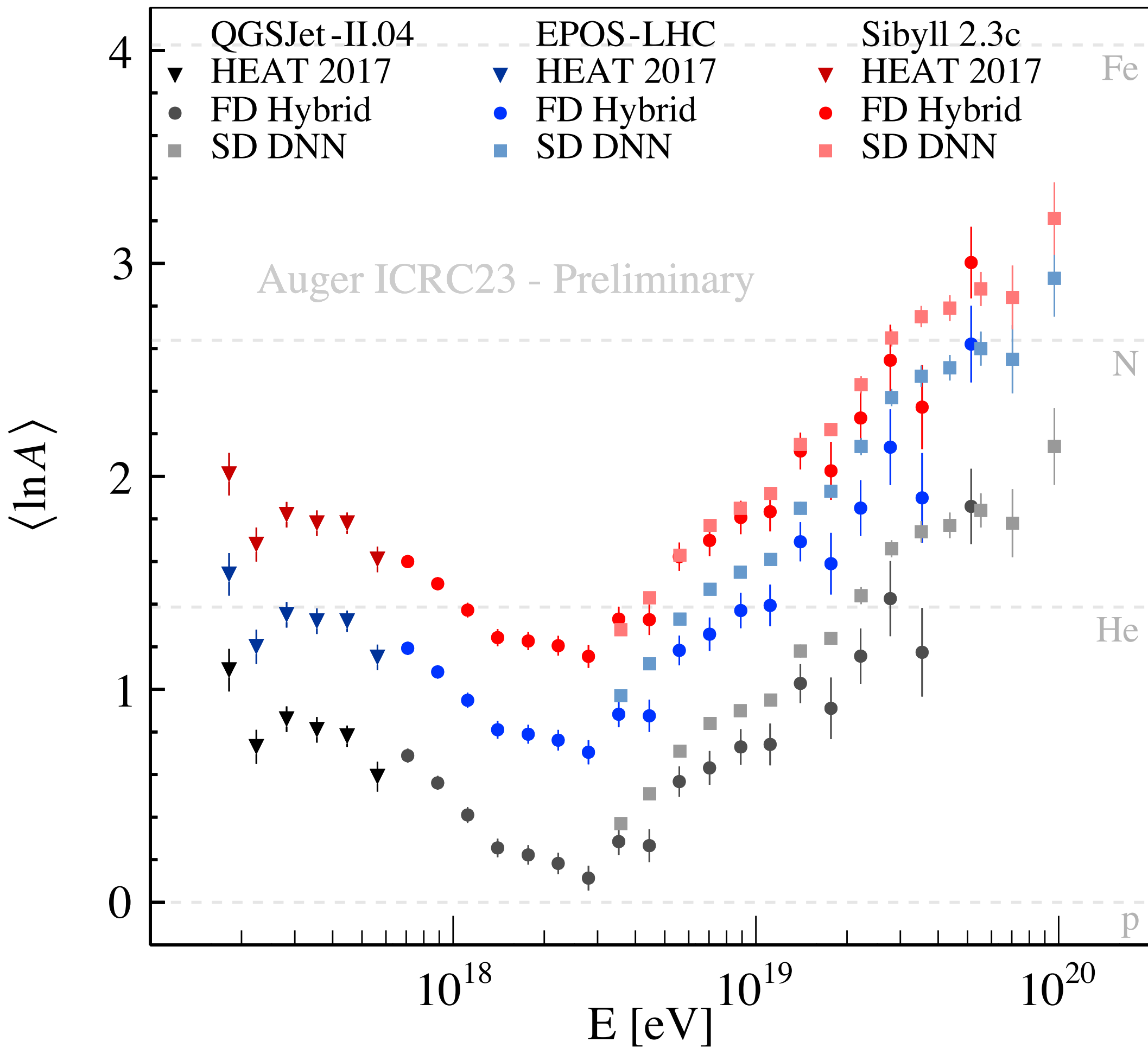
Auger Coll., Science 357 (2017) 1266  
 Auger Coll., Astrophys. J. 868 (2018) 4  
 G.Golup, PoS(ICRC2023) 252, subm.ApJ

Auger Coll., Phys.Rev.D102 (2020) 062005  
 Auger Coll., Phys.Rev.Lett. 125 (2020) 121106  
 Auger Coll., Eur. Phys. J. C 81 (2021) 966  
 V.Novotny, PoS(ICRC2021) 324  
 A.Brichetto, PoS(ICRC2023) 398



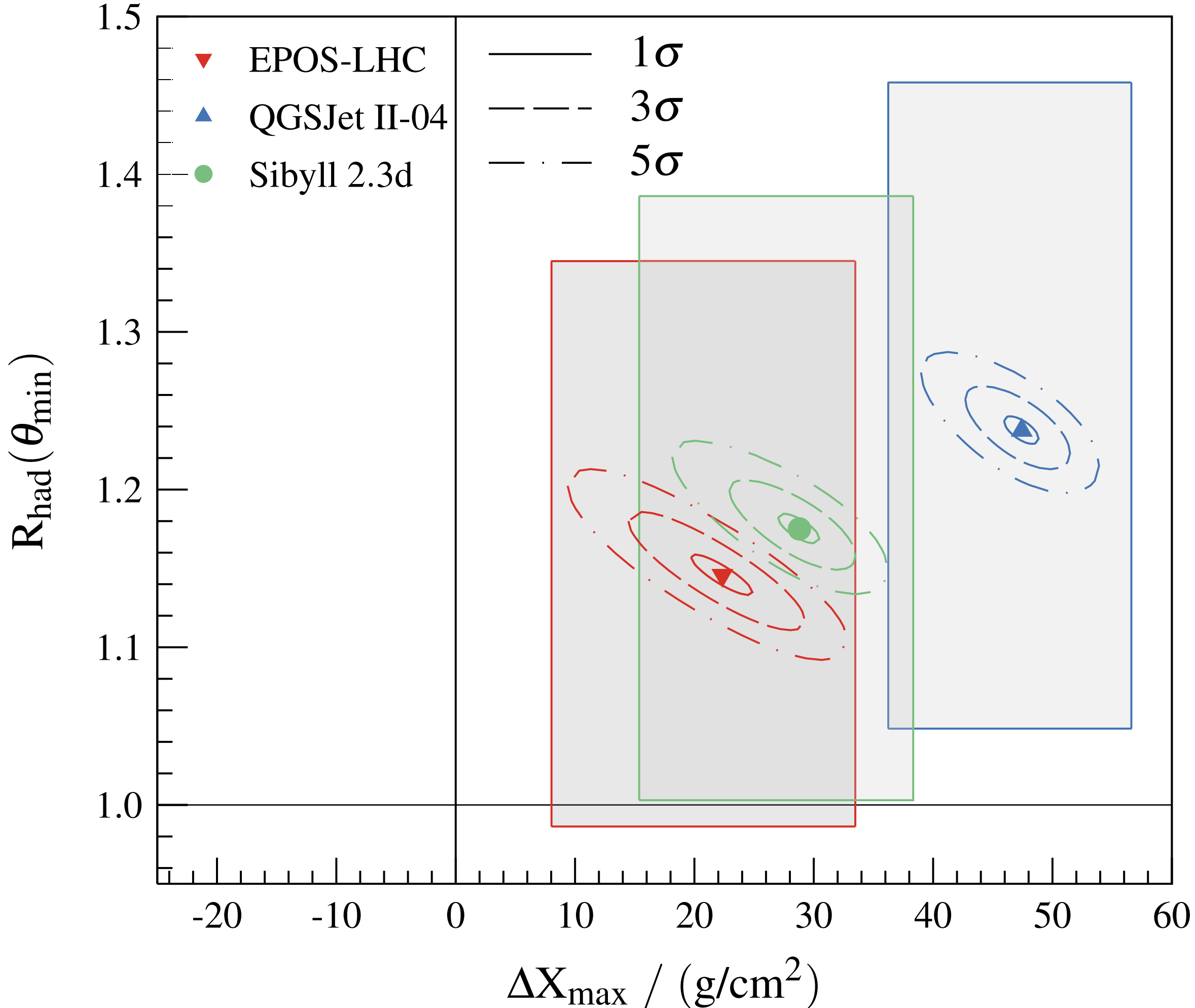
# Unveiled complexity

Composition getting heavier with energy



- ▶ Rigidity factors into large, medium, and point source anisotropy studies
- ▶ Source of flux suppression at highest energies still unclear

Inadequacies in hadronic interactions models



- ▶ Complicates composition measurements

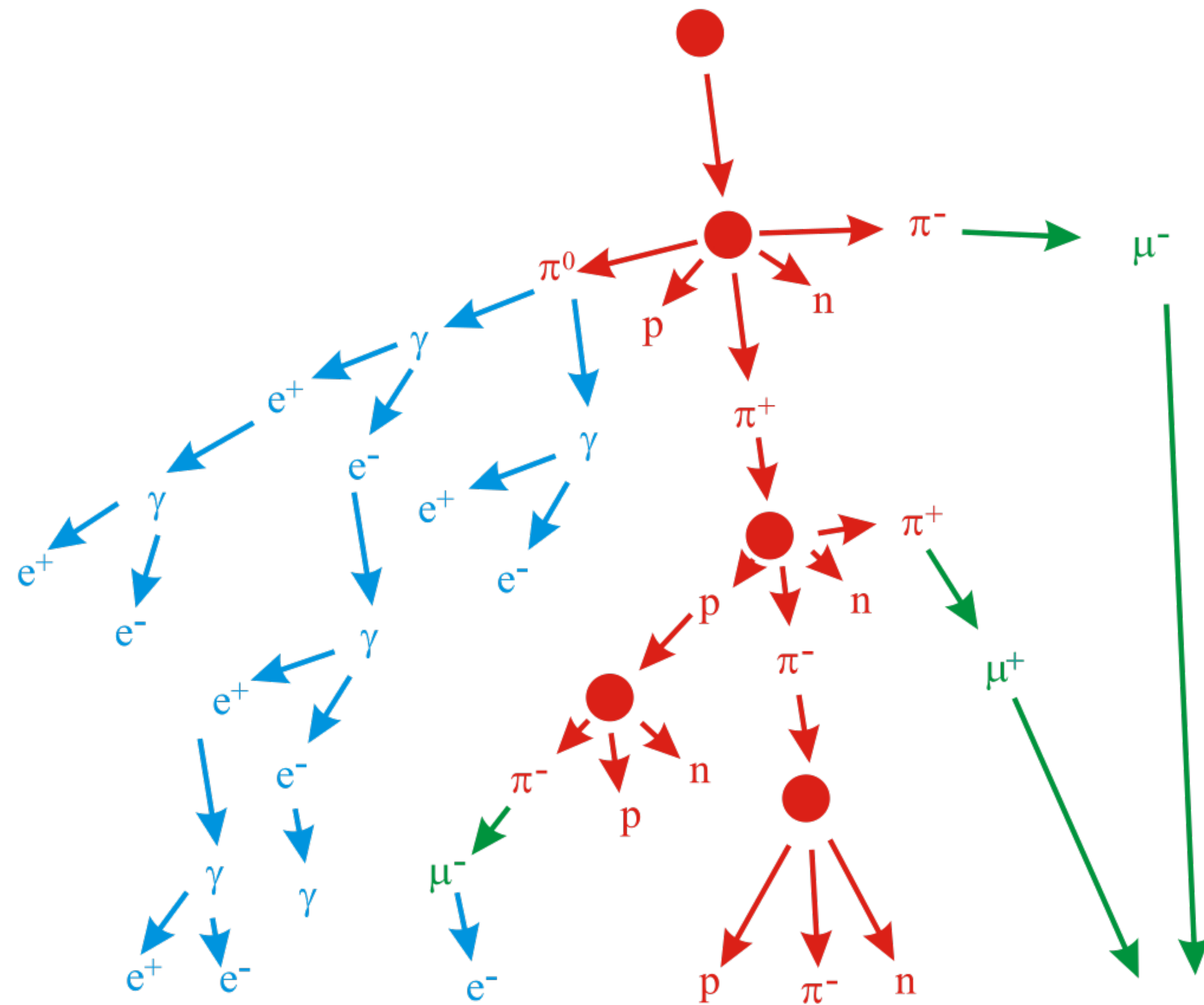
For more: contribution by Tobias Schulz from Aug. 29

Auger Collab., Phys. Rev. D 109 (2024) 102001



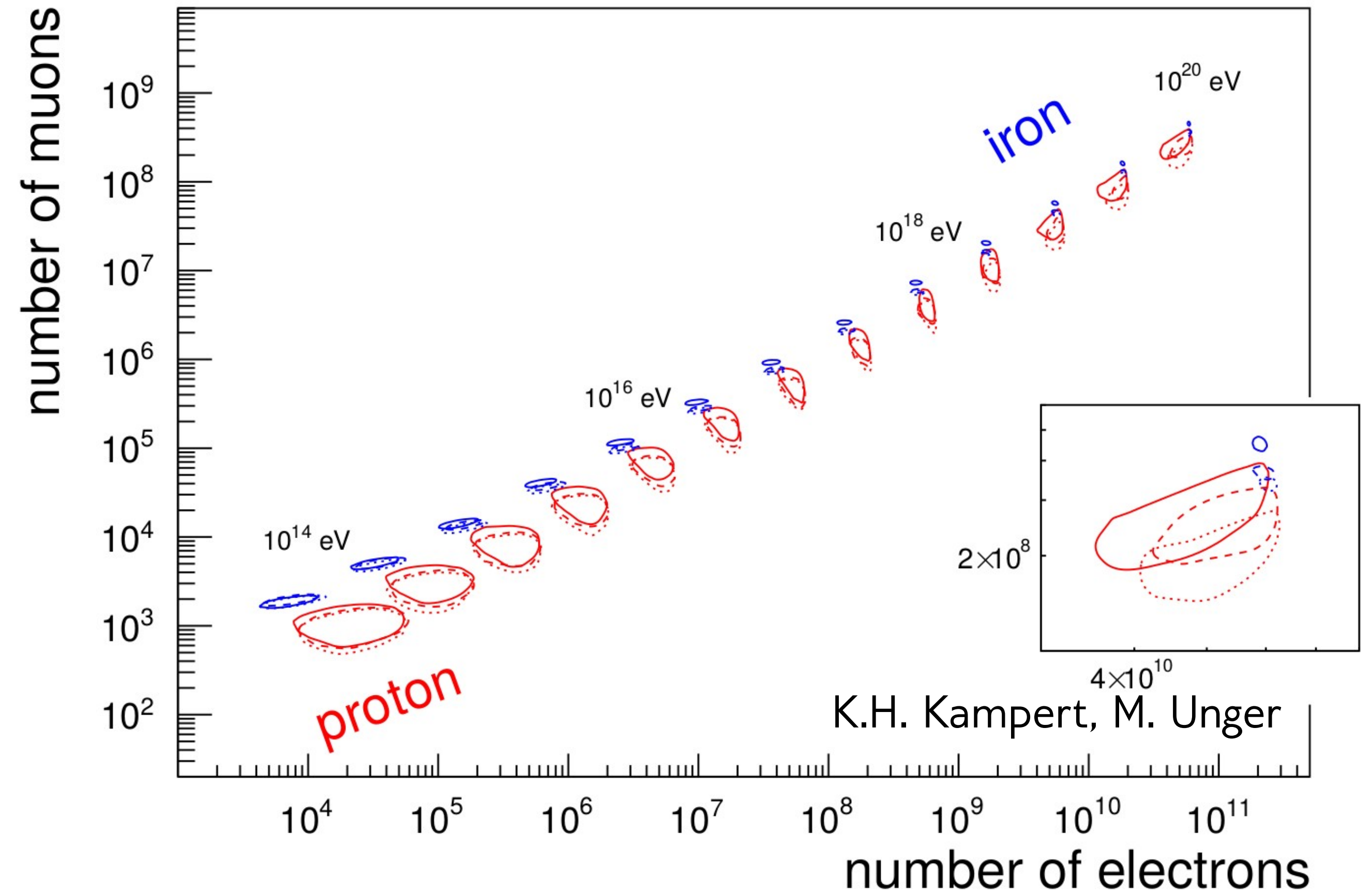
# AugerPrime | Introduction

**Need** access to **primary mass** on event-by-event basis **with large exposure**



## Goals:

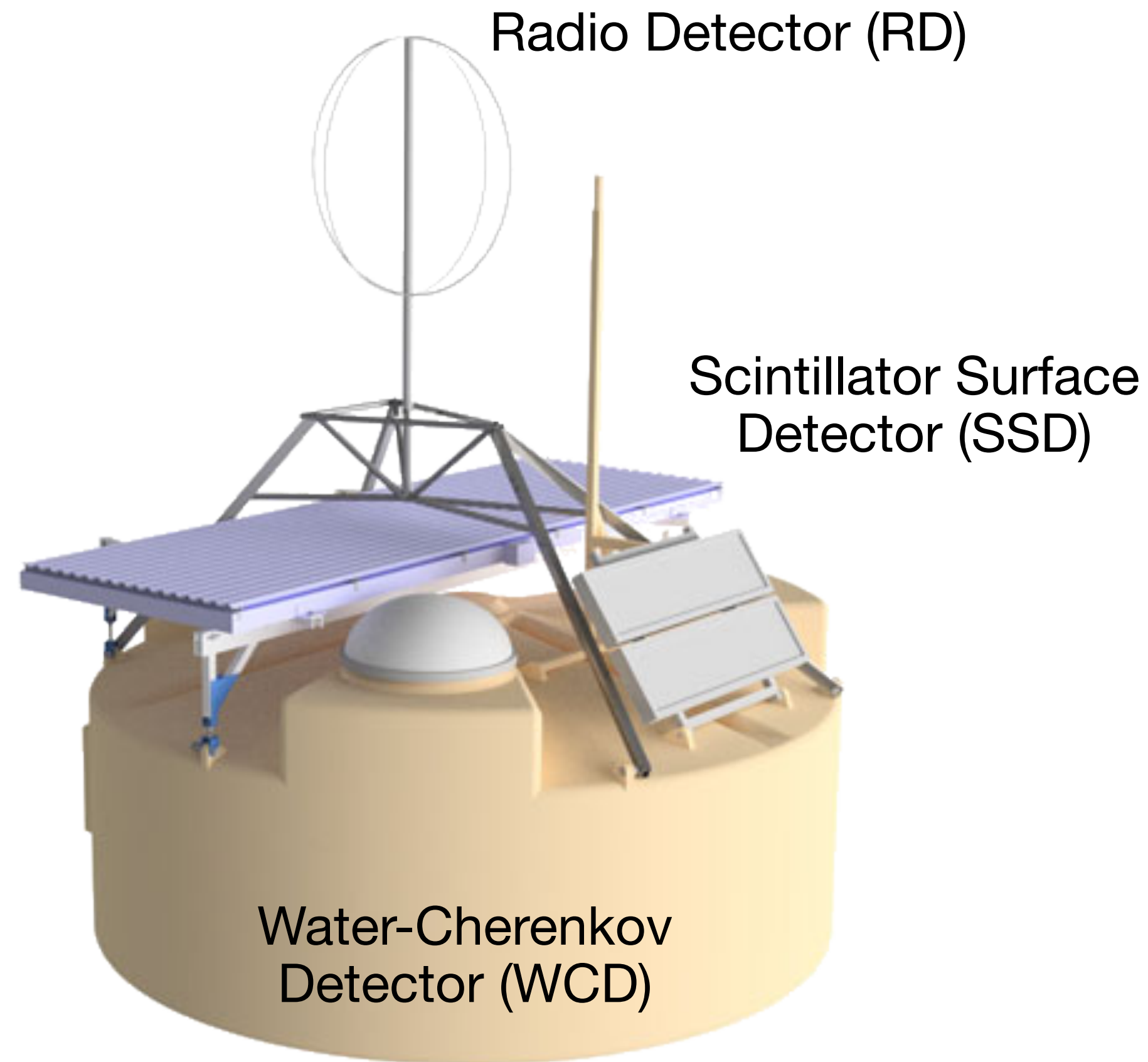
- Understand nature and origin of UHECR
- Unravel origin of flux suppression
- Search for UHE photons and neutrinos
- Constrain/understand hadronic interactions at UHE
- Look for indications of BSM physics





# AugerPrime | Introduction

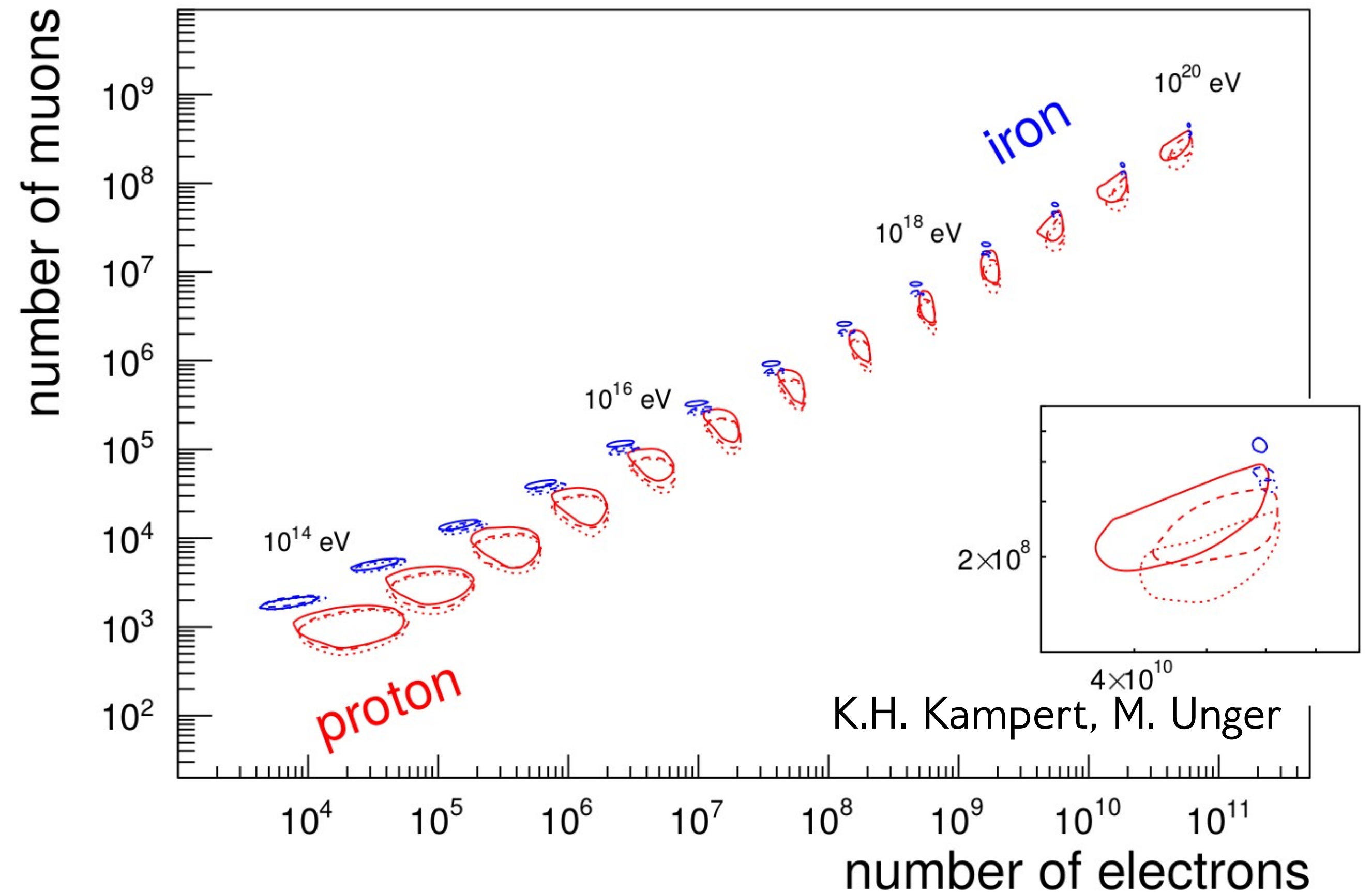
**Need** access to **primary mass** on event-by-event basis **with large exposure**



Provides composition sensitivity for near full sky with 100% duty cycle

## Goals:

- Understand nature and origin of UHECR
- Unravel origin of flux suppression
- Search for UHE photons and neutrinos
- Constrain/understand hadronic interactions at UHE
- Look for indications of BSM physics

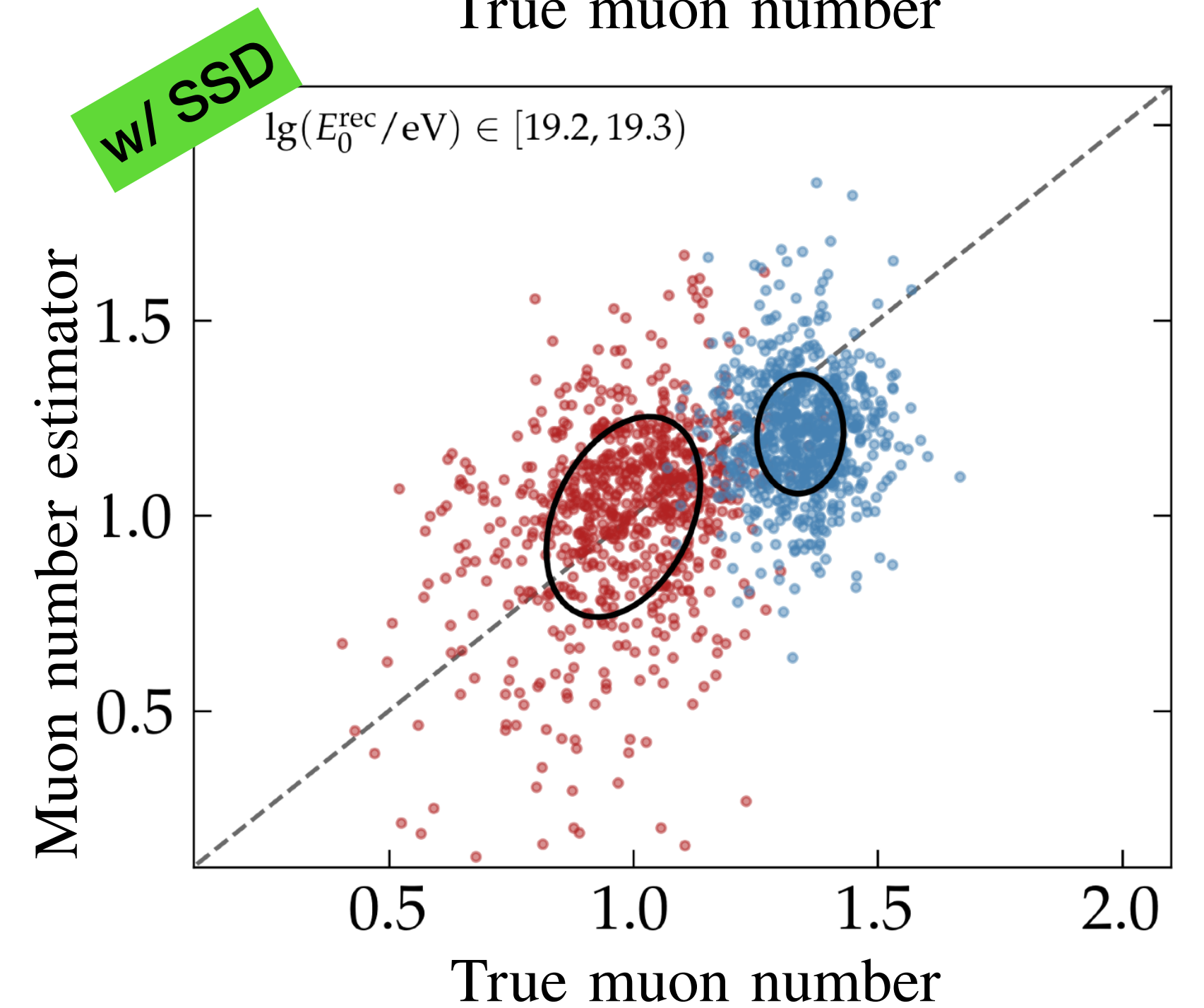
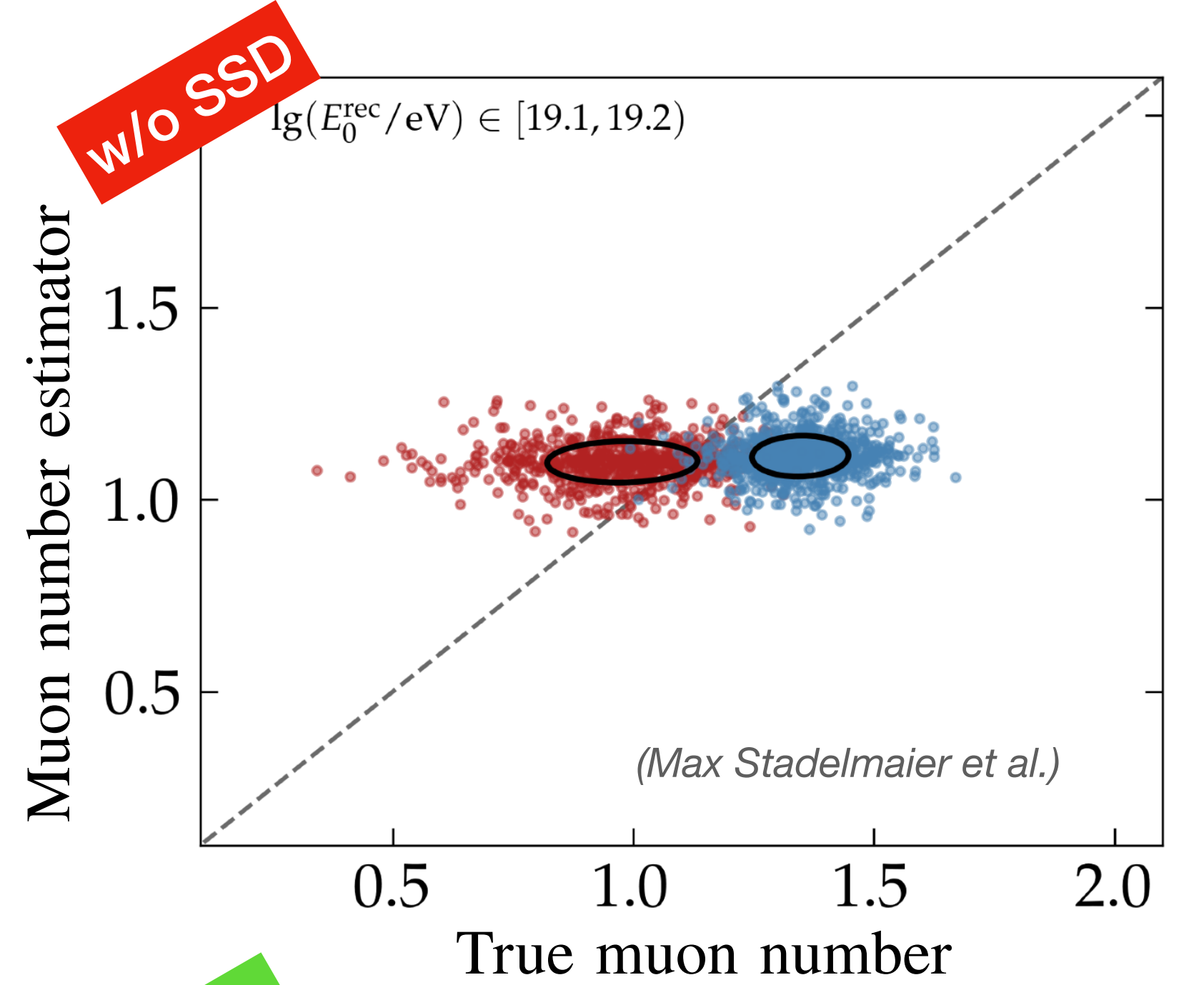
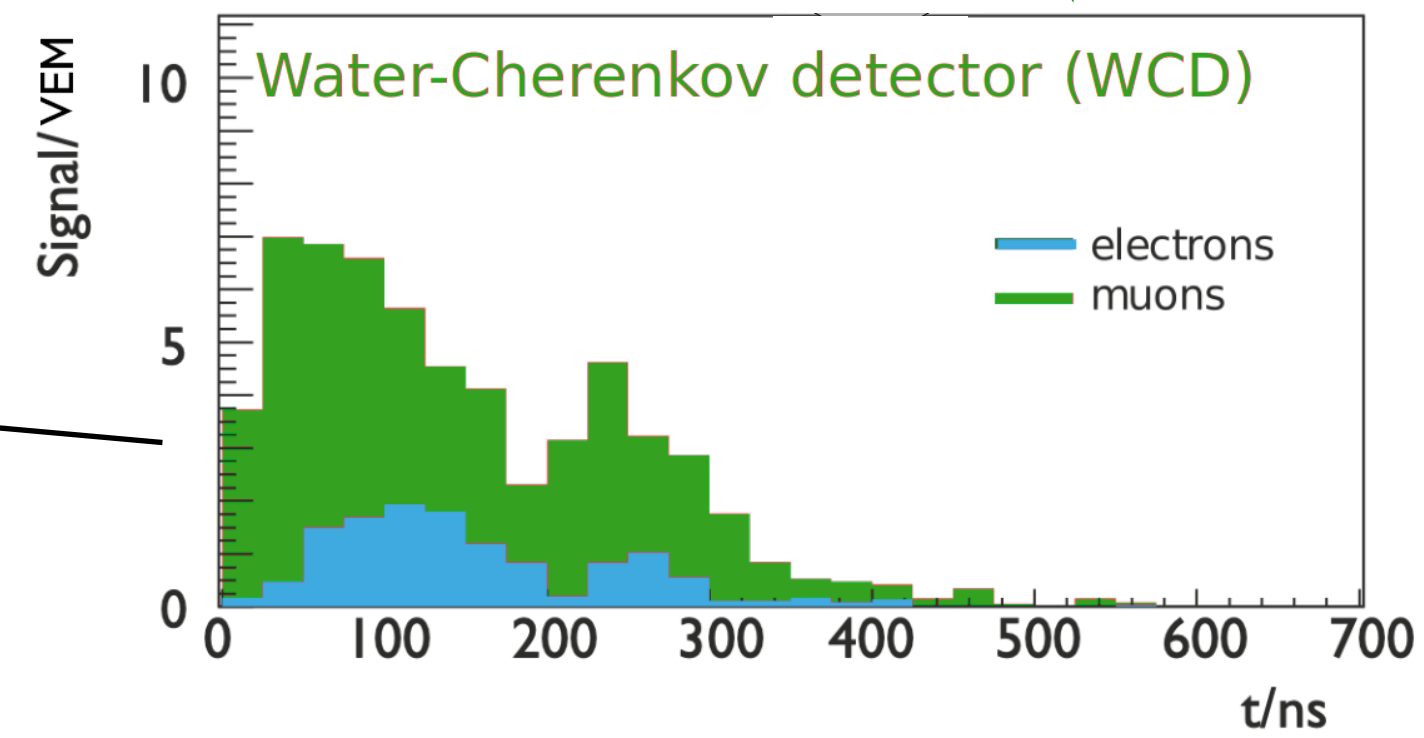
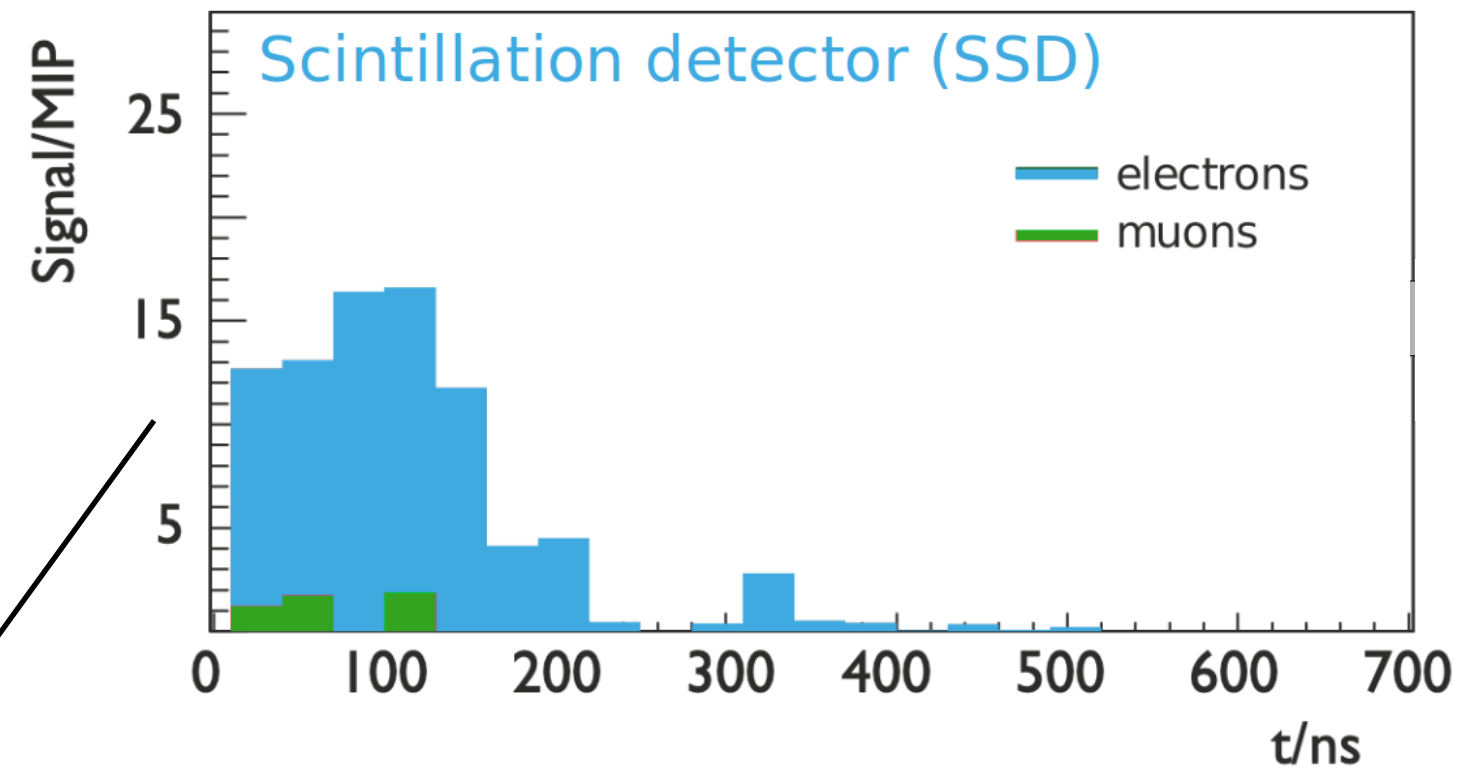
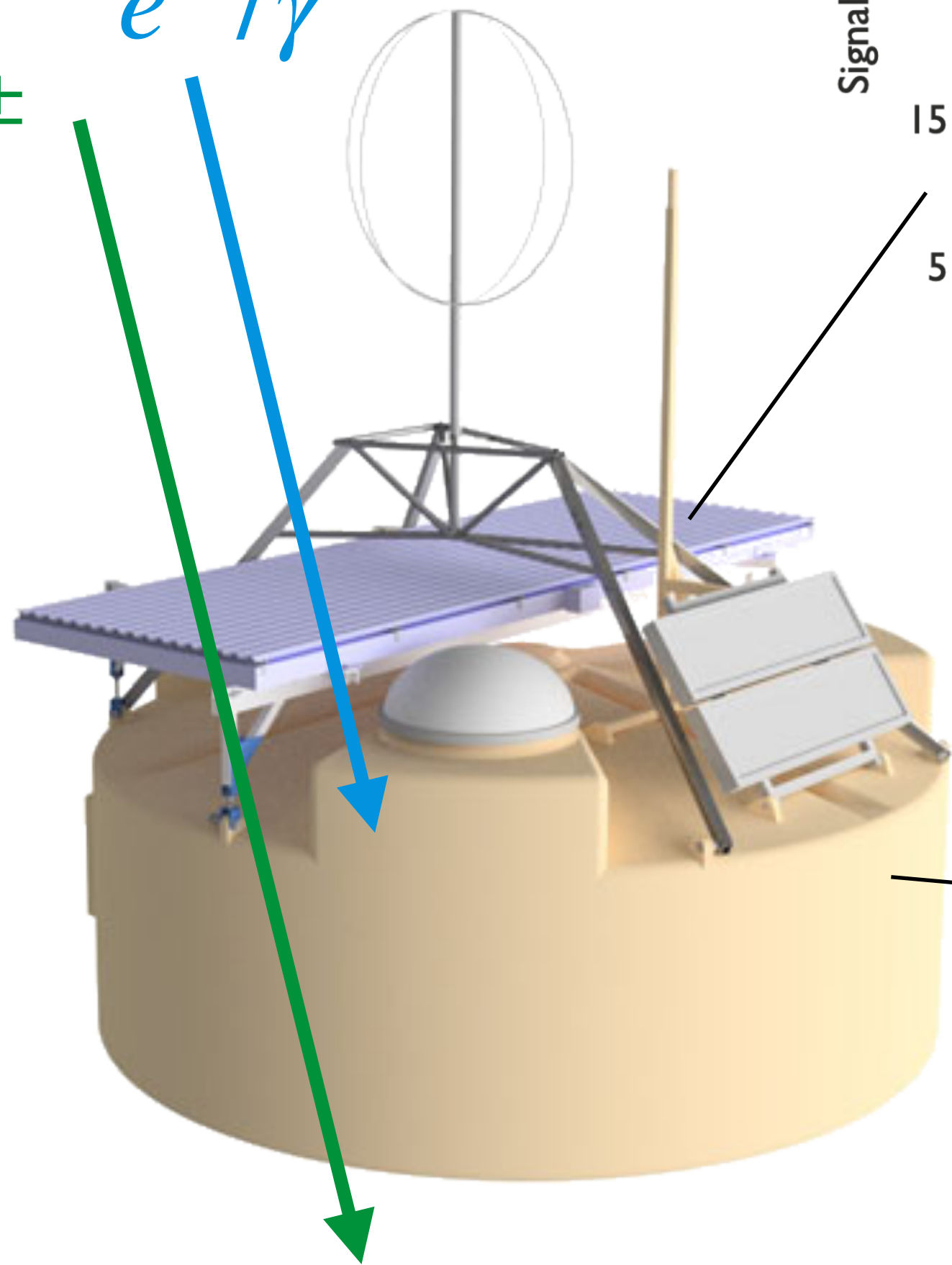




# “Vertical” events | $\theta < 60^\circ$

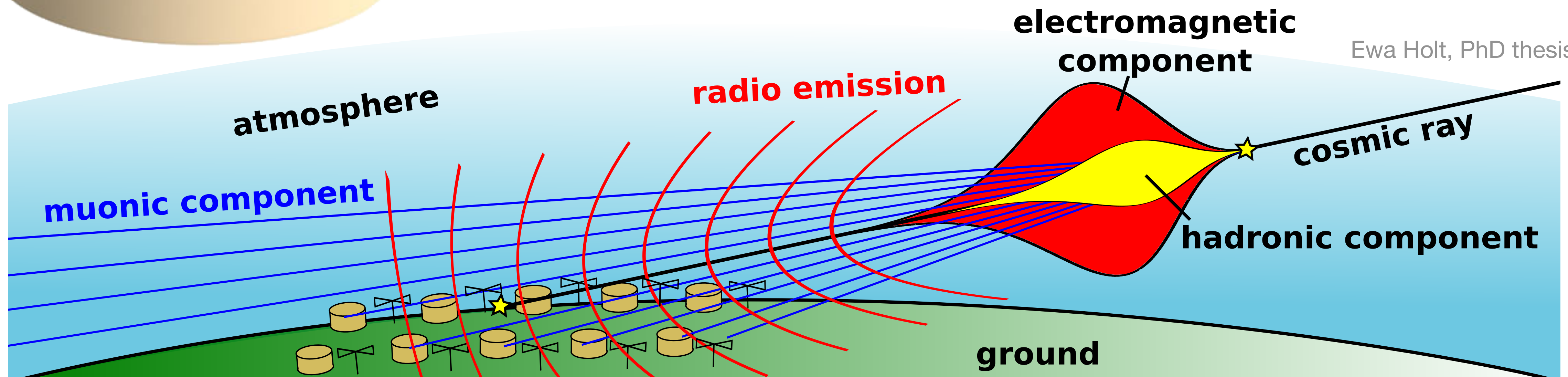
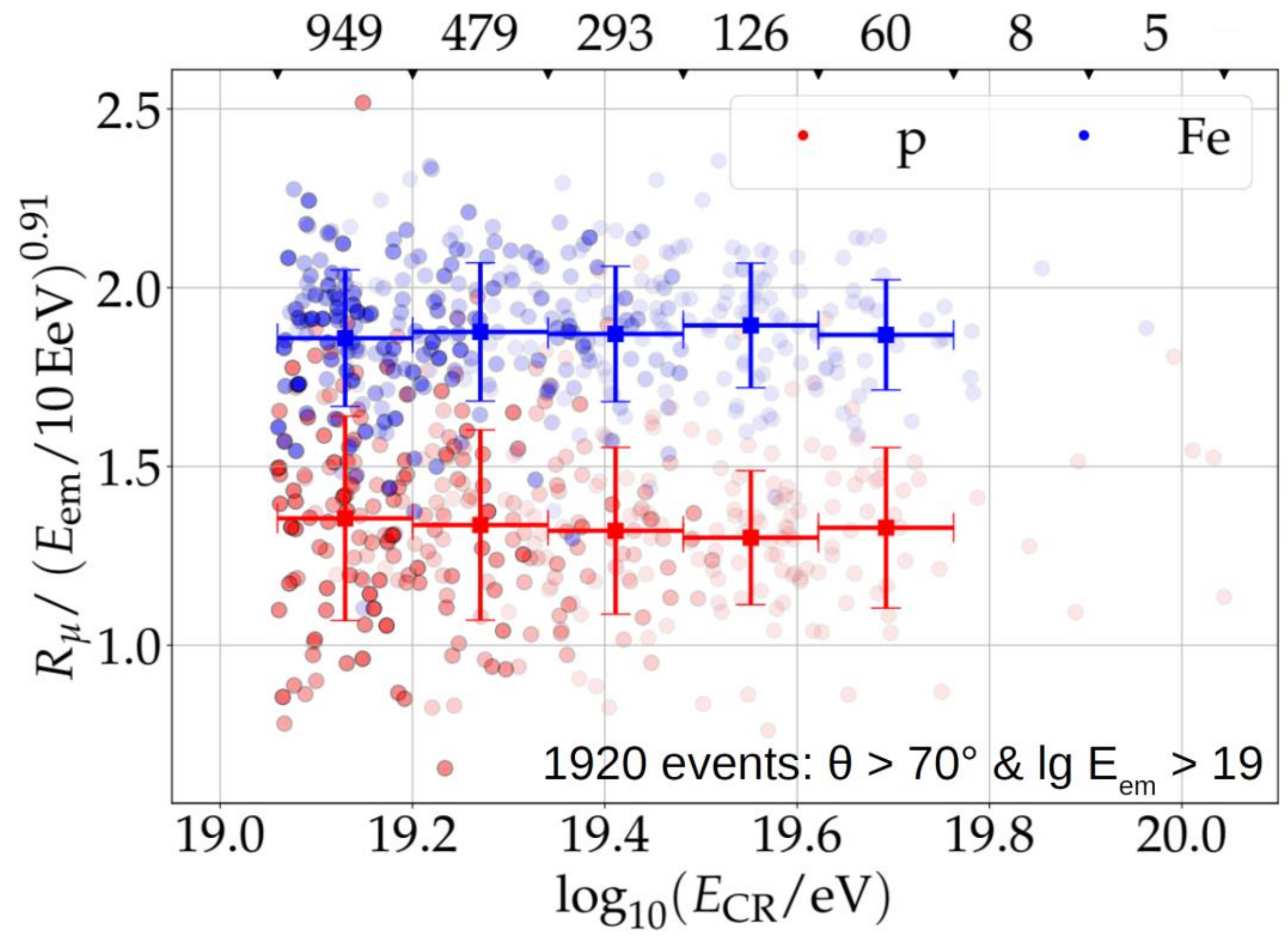
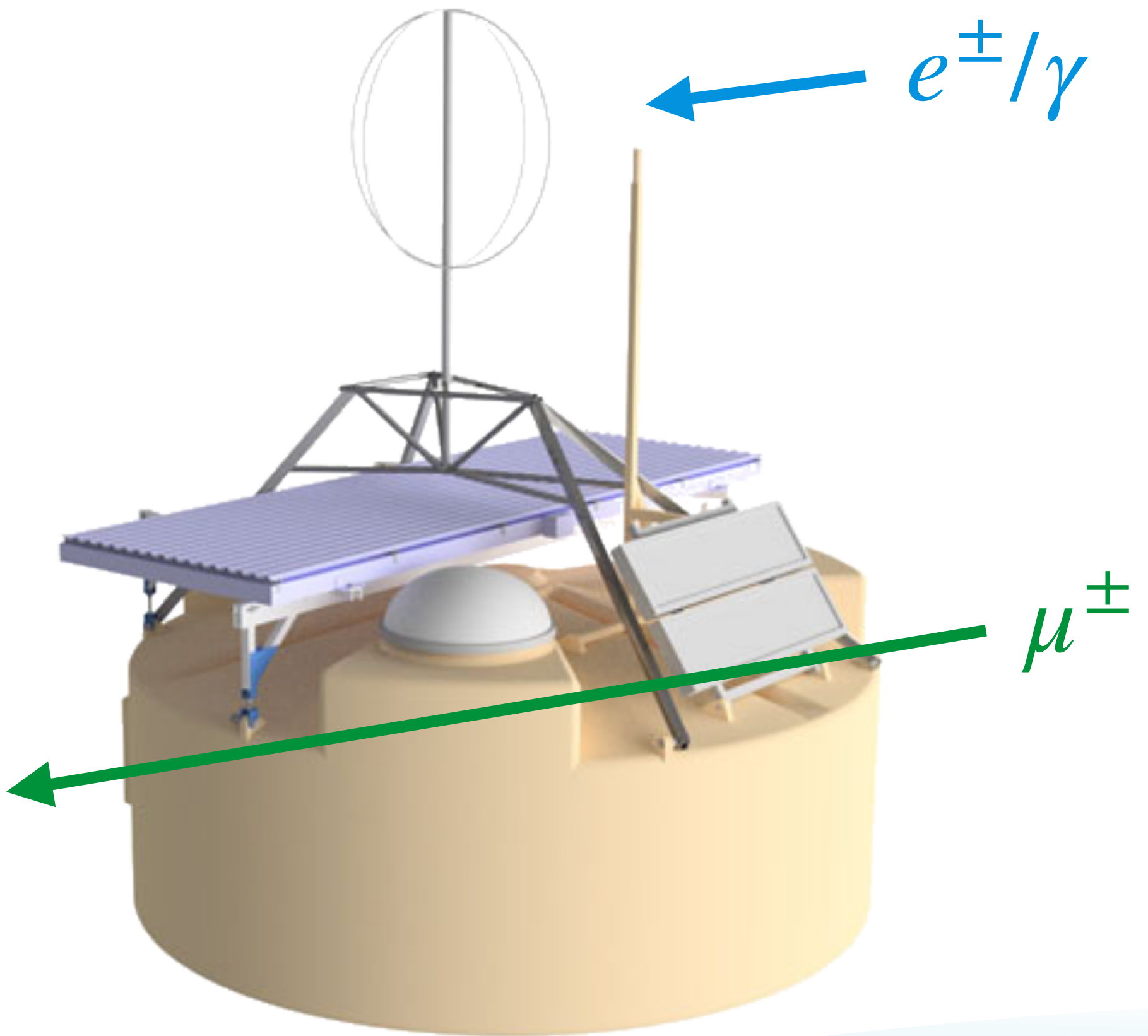
$\mu^\pm$

$e^\pm/\gamma$





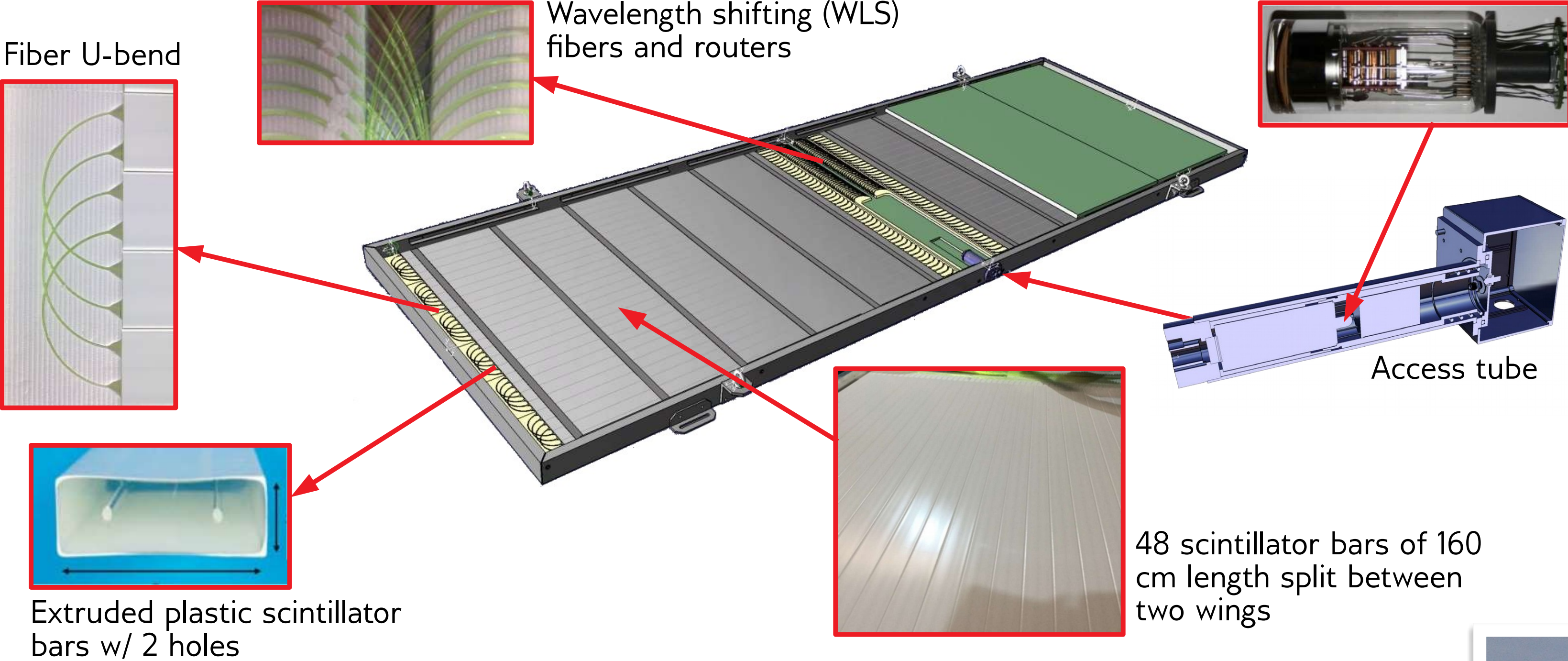
# “Inclined” events | $\theta > 60^\circ$



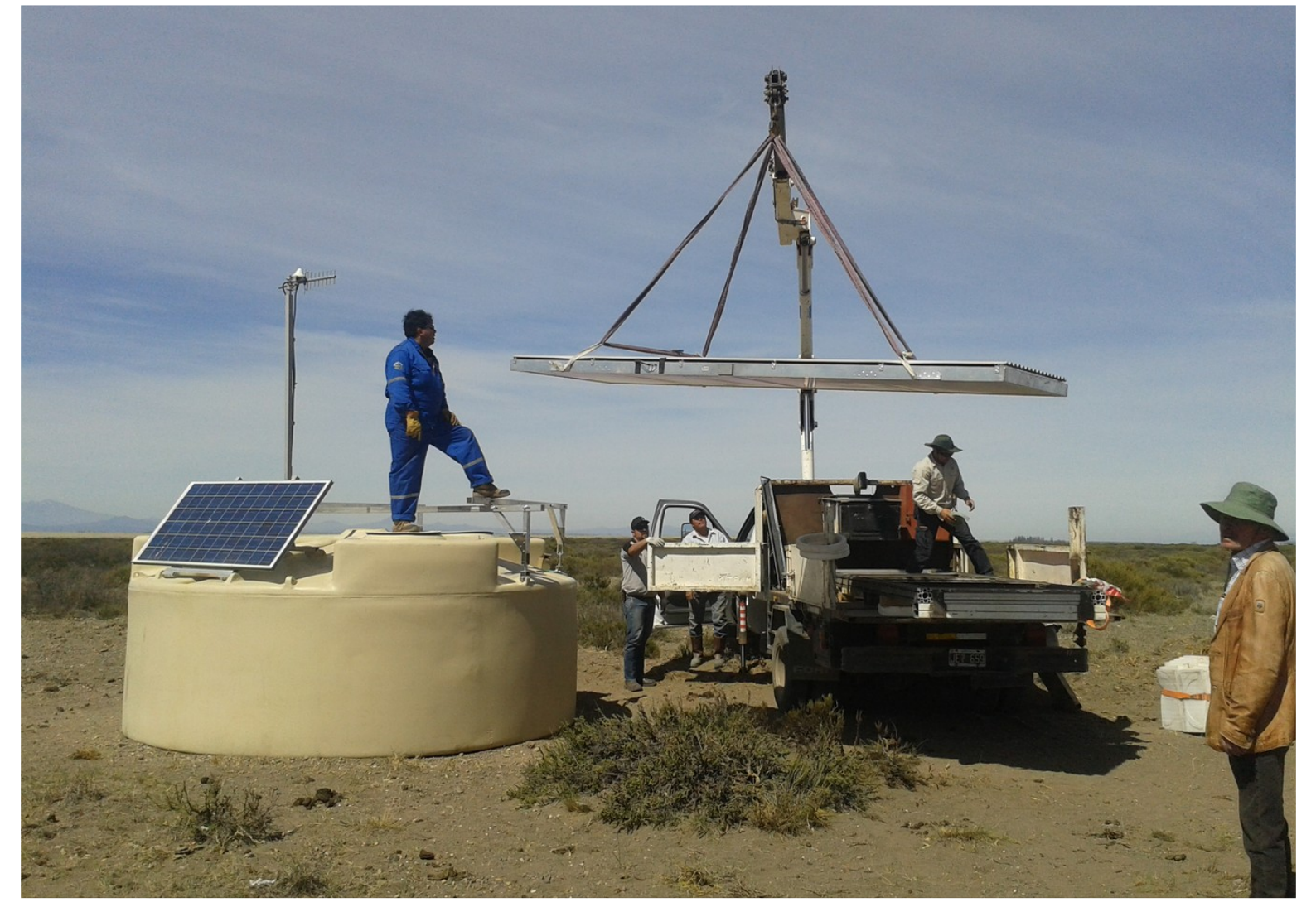
Ewa Holt, PhD thesis, 2018



# Realization | Scintillator Surface Detector (SSD)



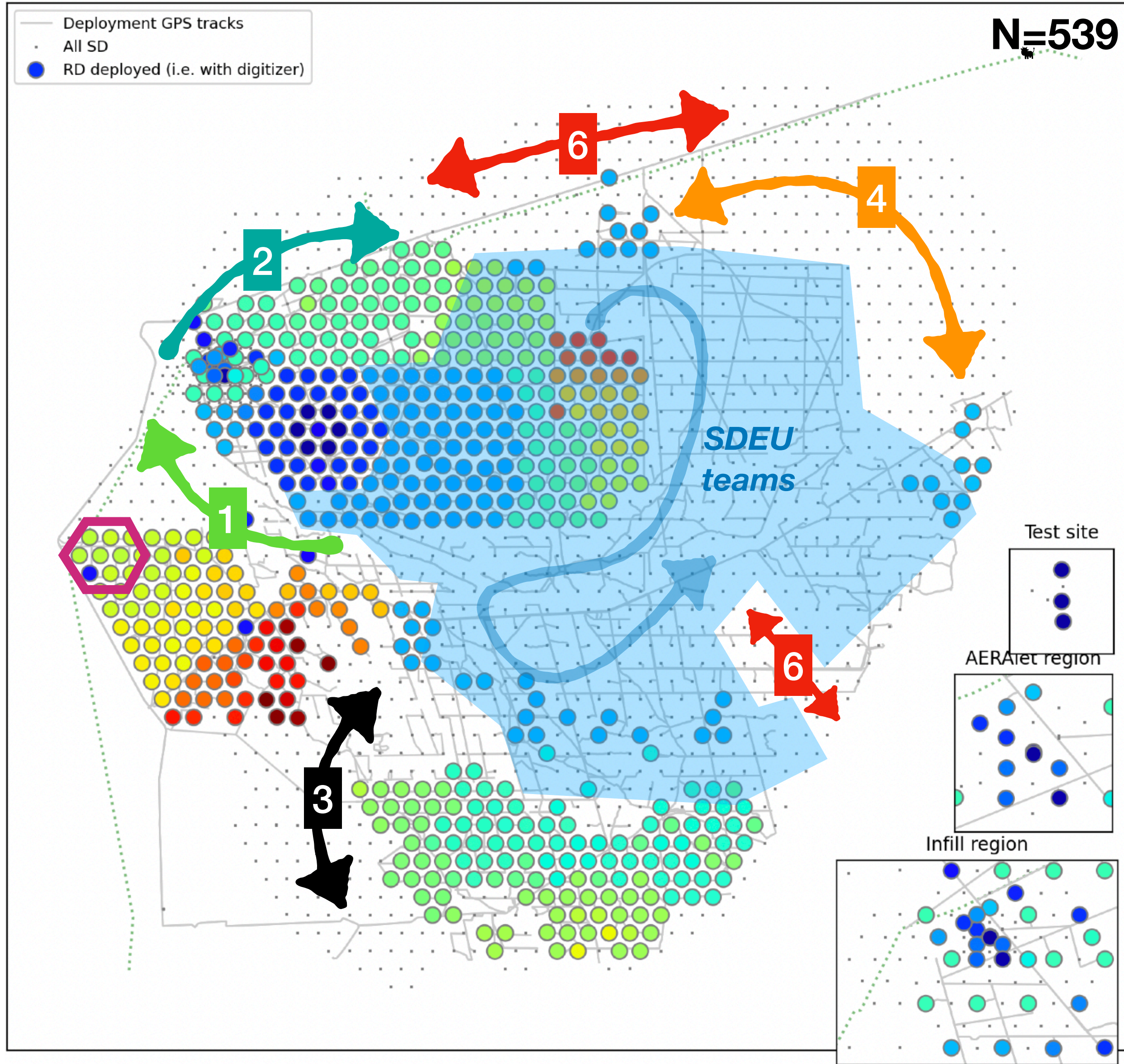
Active area of 3.84 m<sup>2</sup>  
Constructed and tested at 5 locations across Europe





# Realization | Radio Detector (RD)

timeline of commissioning up to 2024-03-16 17:20:11 (UTC)



Now This week this moth | 2023 | 2022 ...

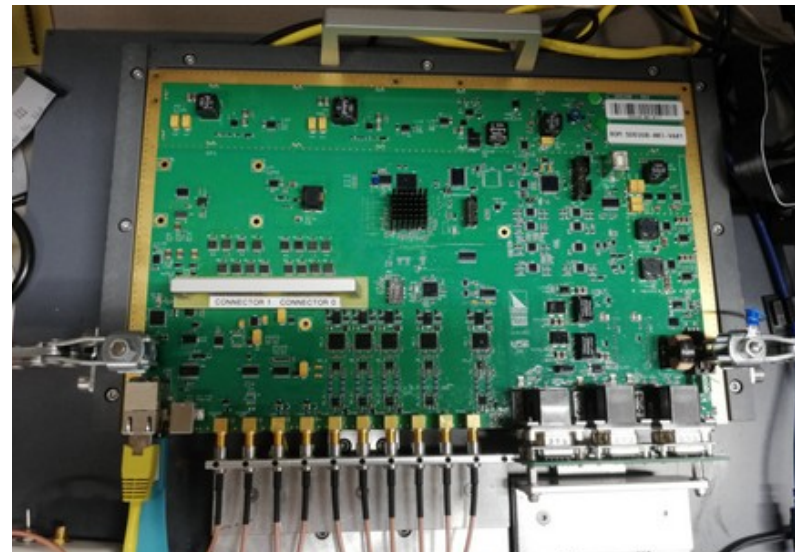




# Upgrade electronics (UUB)

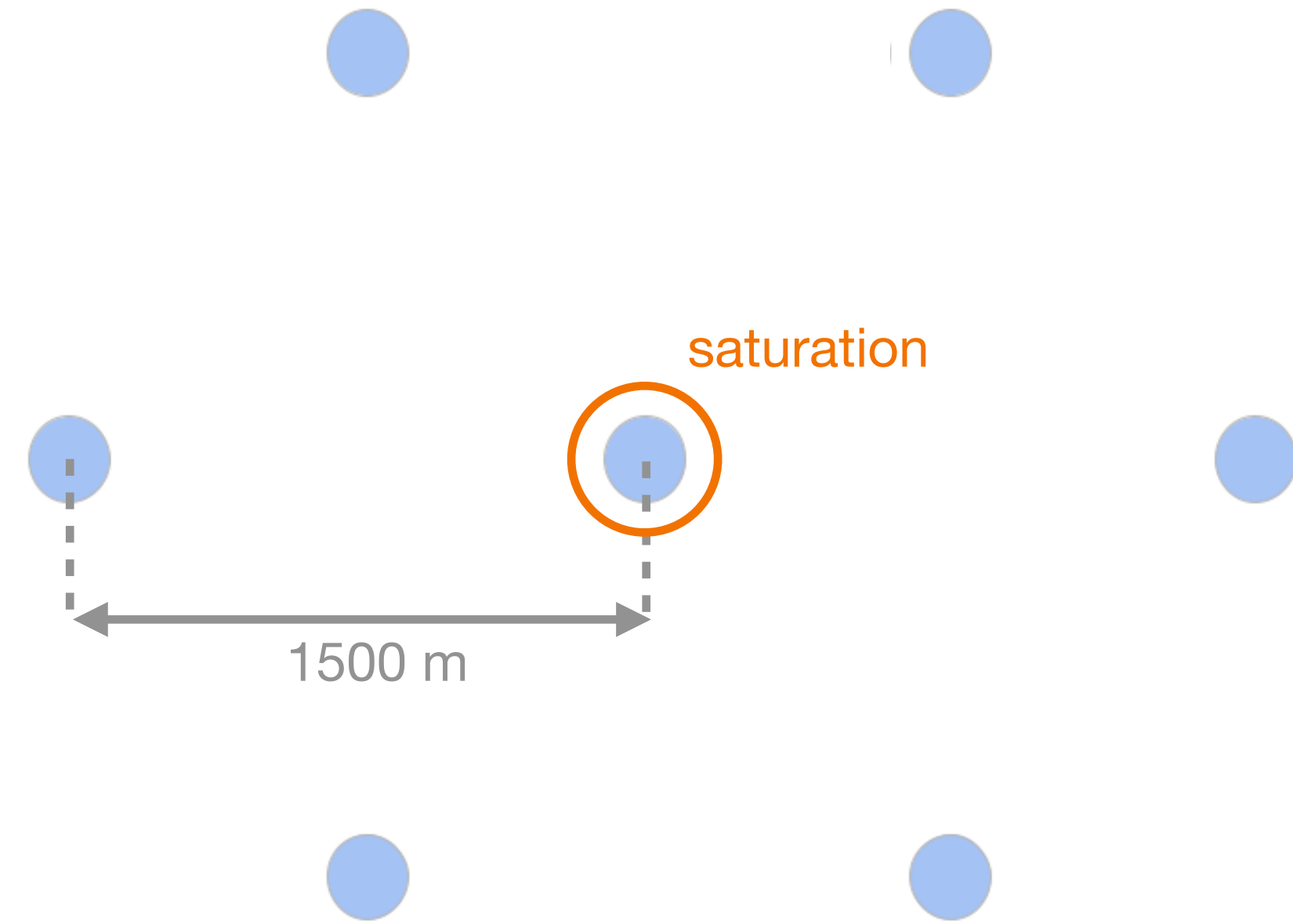
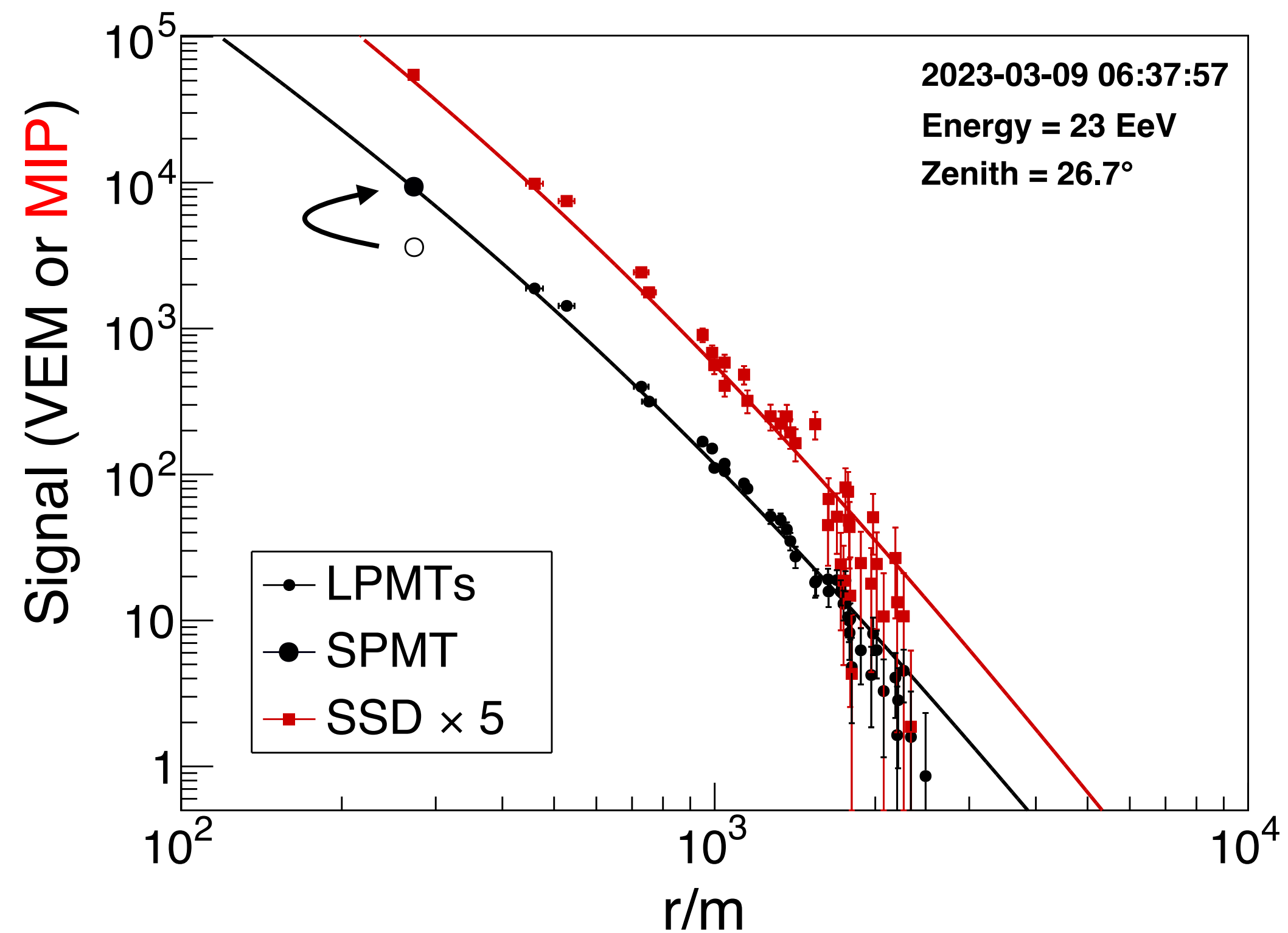
## Improved timing/signal resolution

- 120 MHz sampling (previously 40 MHz)
- 5 ns GPS resolution (previously 8 ns)
- 12 bits (previously 10 bits)





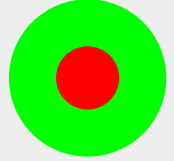

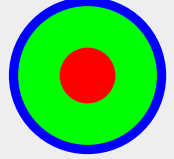
## Improved dynamic range

- small area PMT
- allows for measurement 200 m at 100 EeV (previously saturated ~500 m)



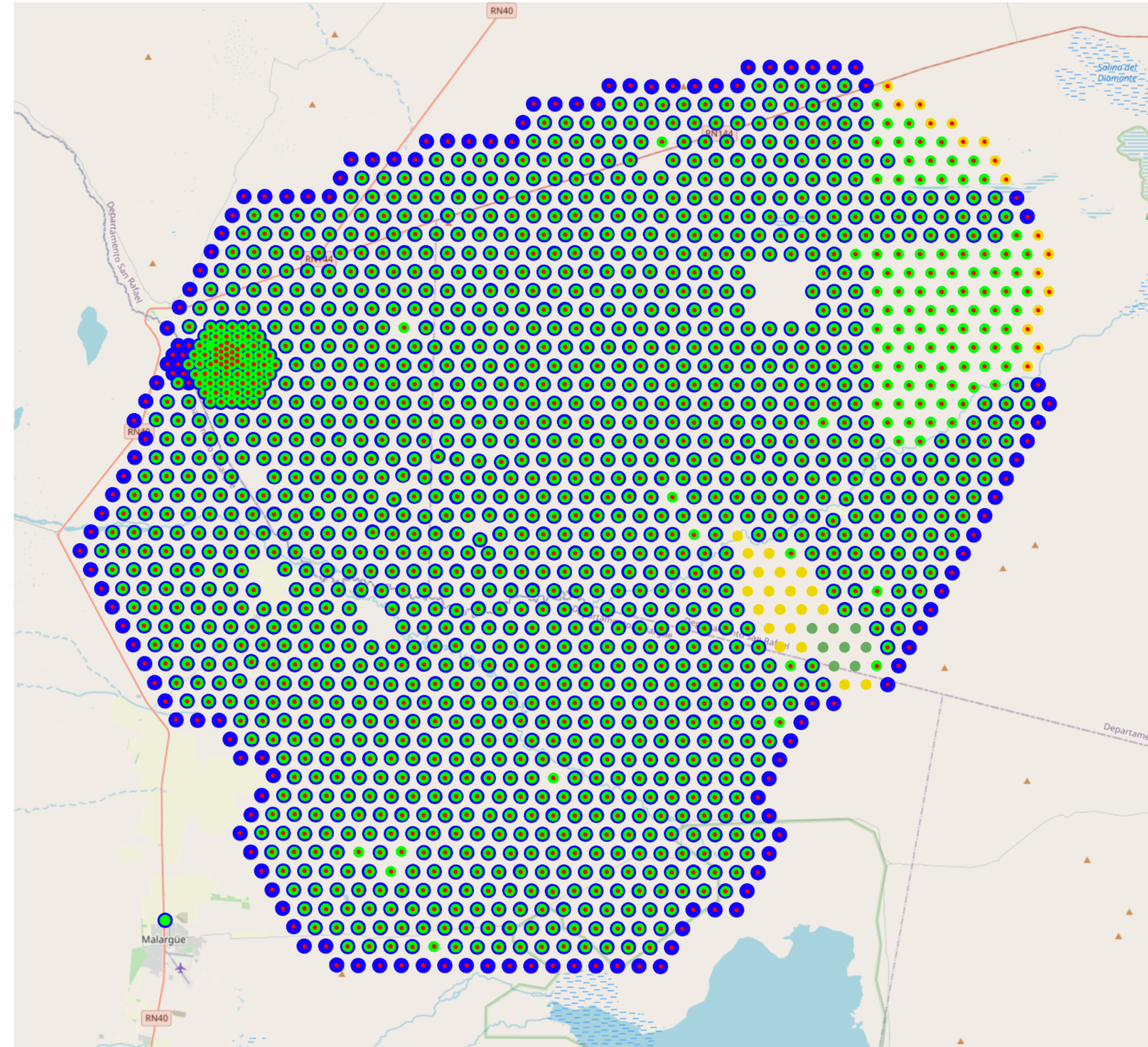


# Deployment Status

-  Phase I station
-  Stations w/ UUB (deployment complete)
-  Stations w/ UUB + SSD (deployment complete)
-  Stations w/ UUB + RD
-  Stations w/ UUB + SSD + RD

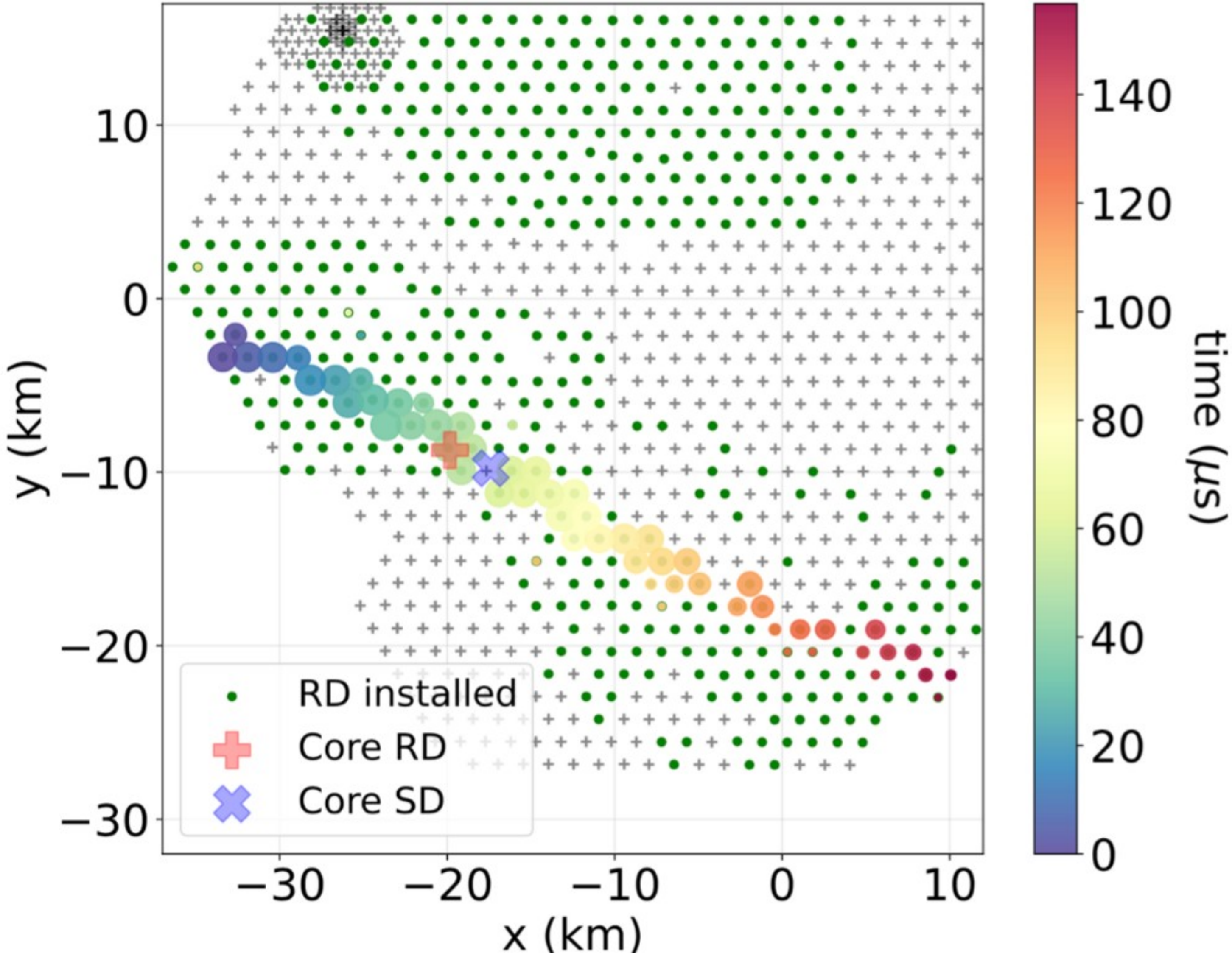
UUB + SSD deployment  
completed in mid-2023

RD deployment to be completed  
on timescale of weeks

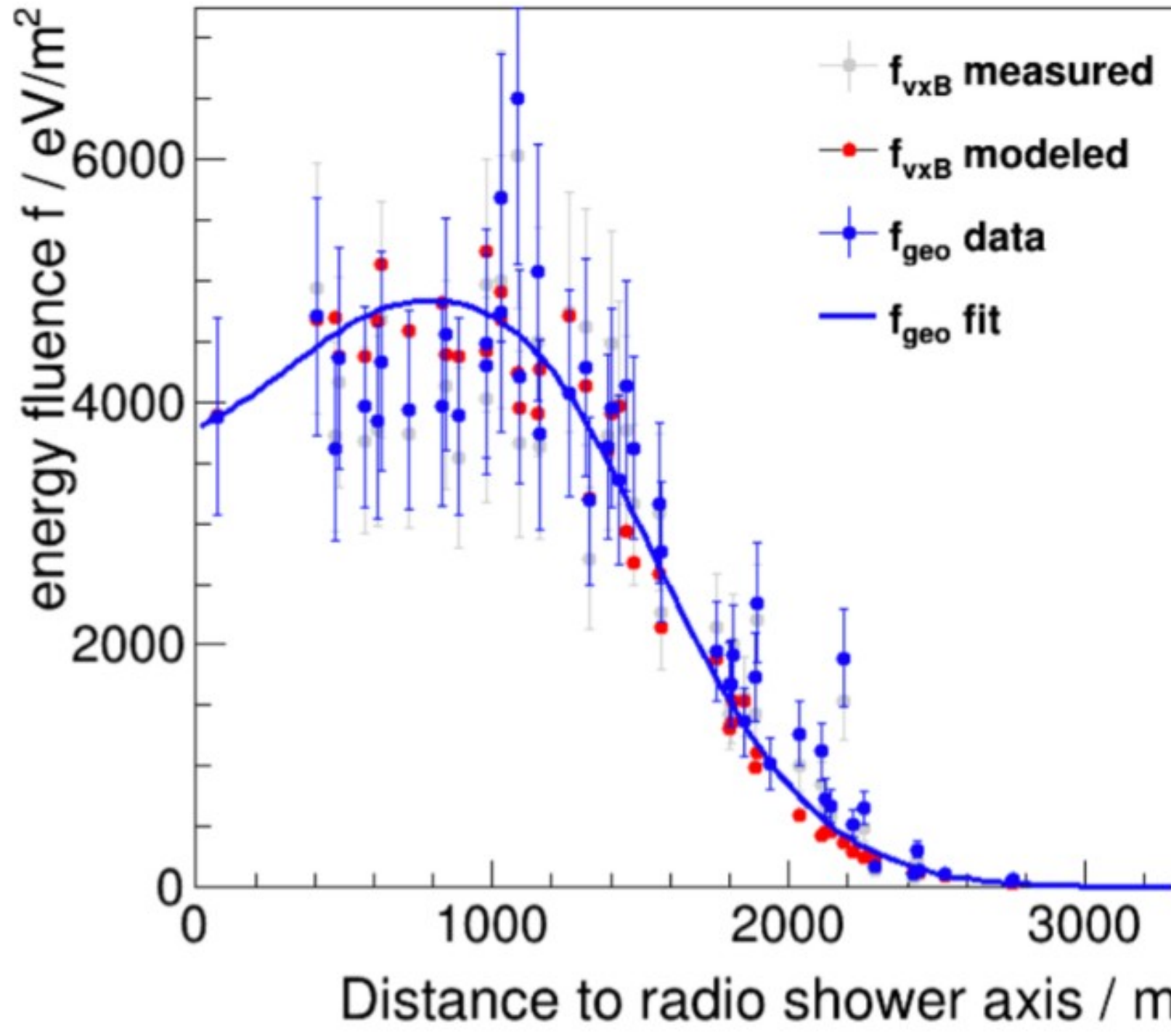




# Coming online | Sample “inclined” event



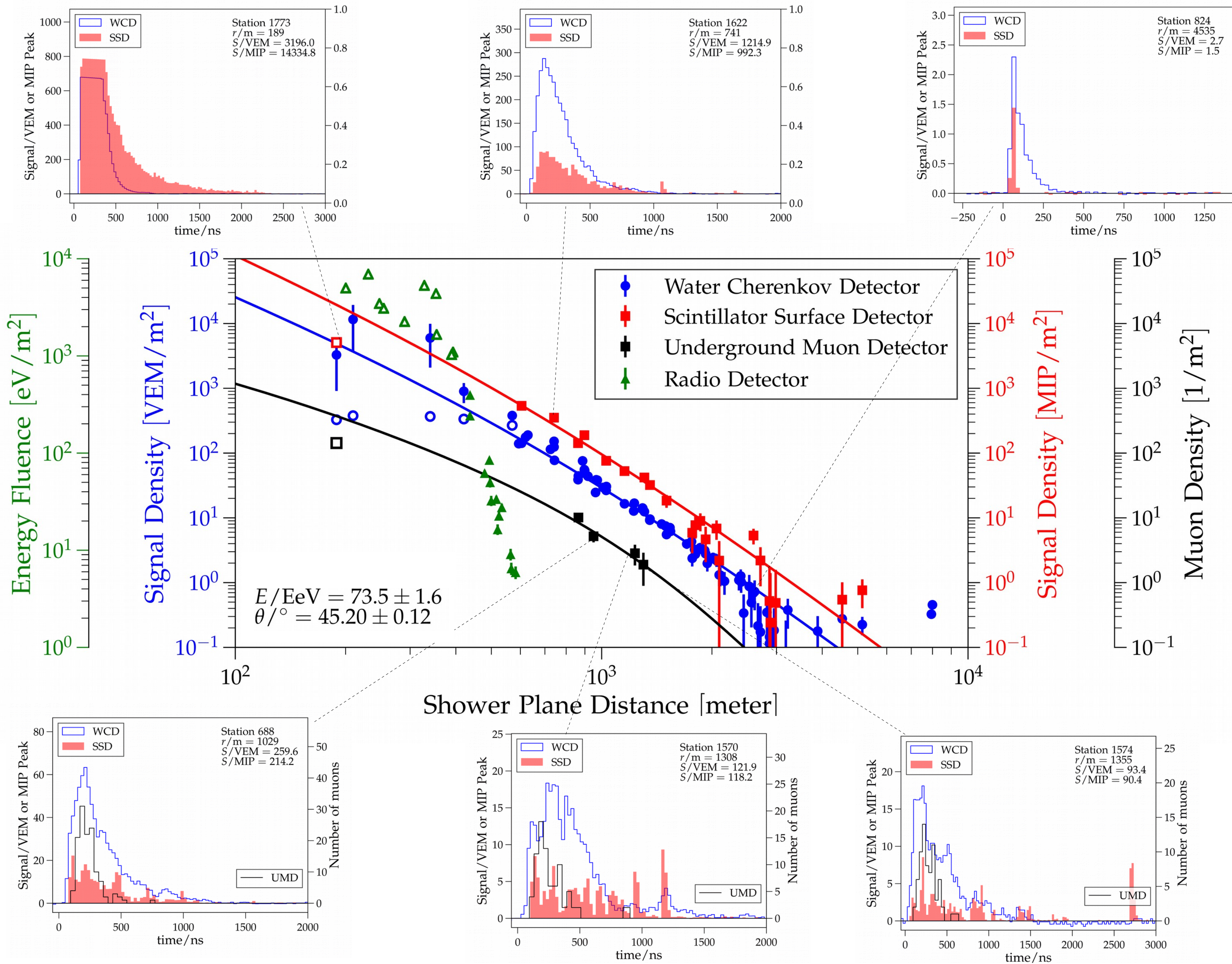
Event at 84.7 degree  
36  $\pm$  3 EeV





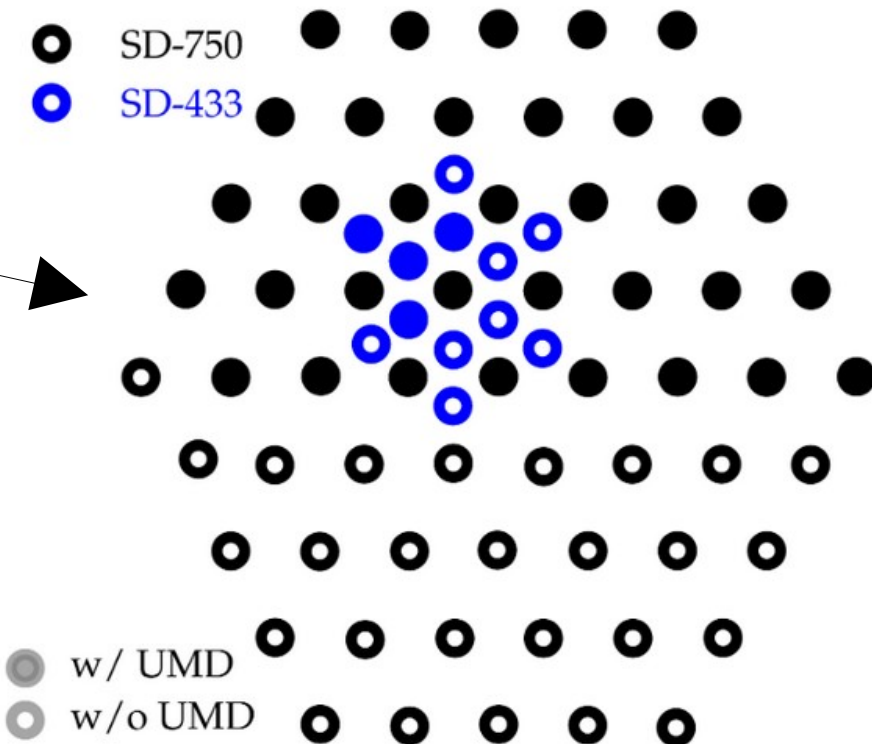
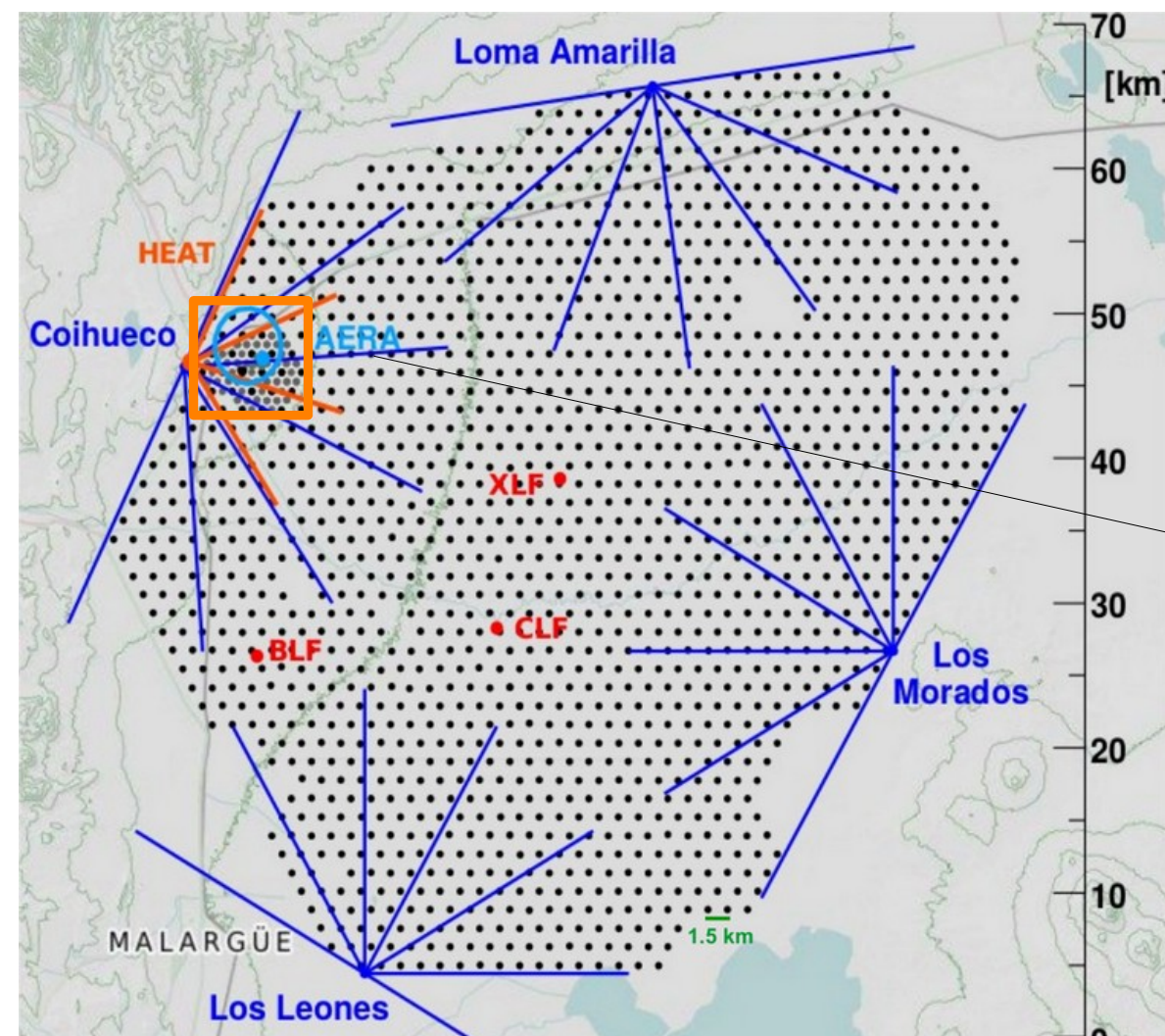
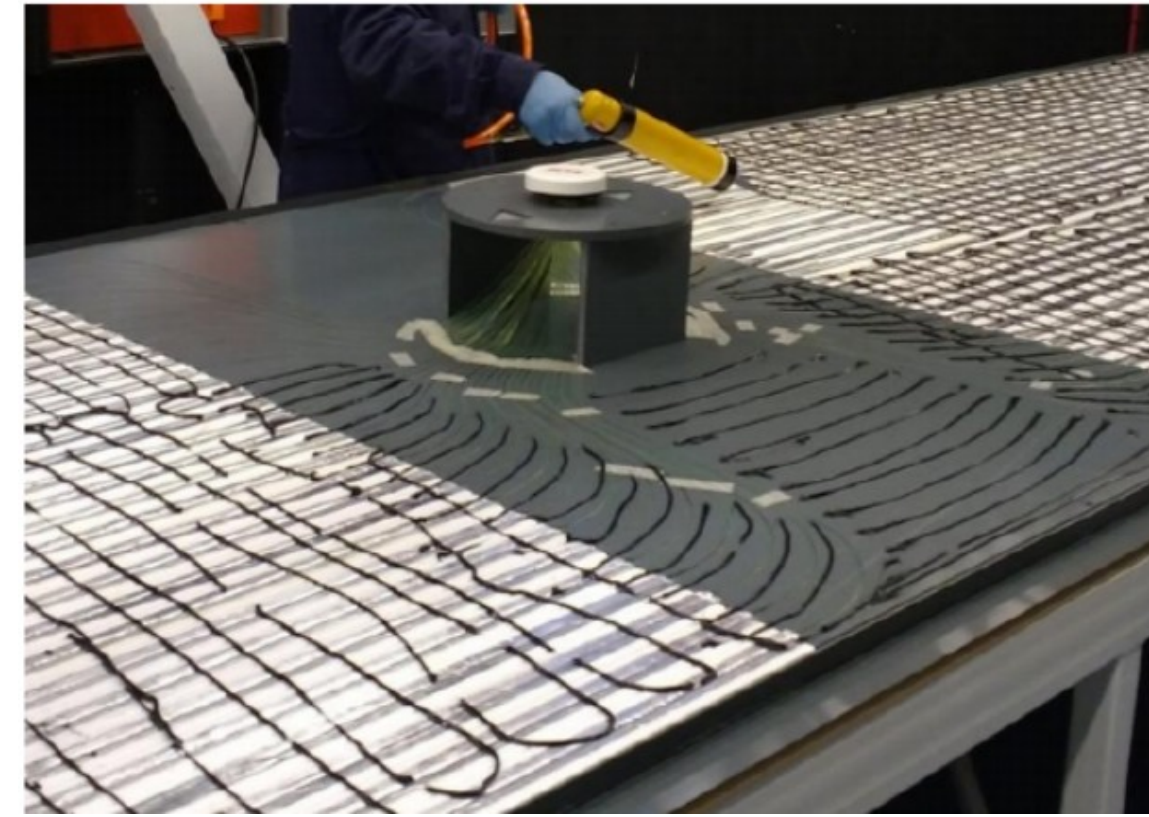
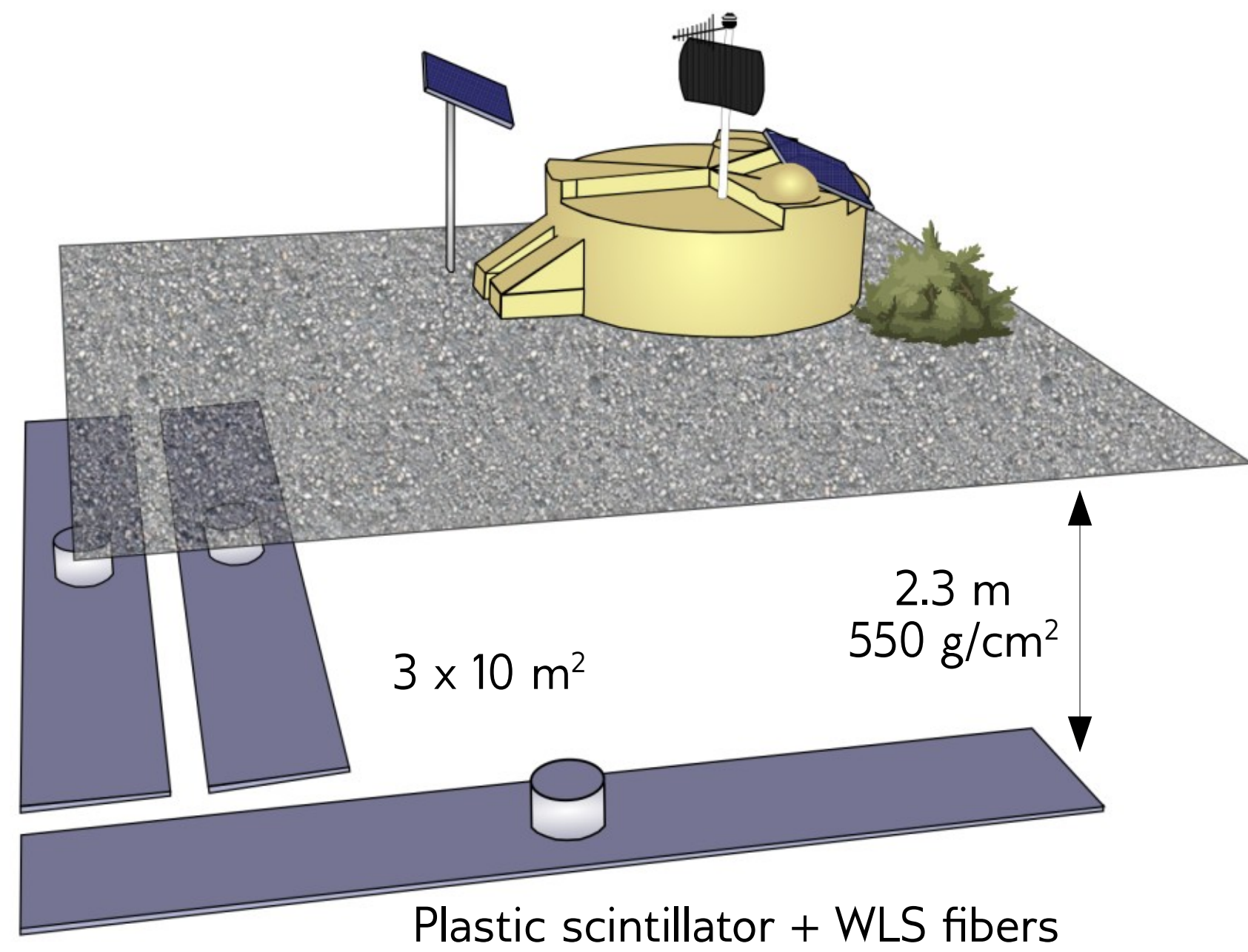
# Coming online

## Sample “vertical” event





# Underground Muon Detector (UMD)





# Summary & Outlook

- AugerPrime upgrade combines composition sensitivity with massive aperture of surface detector array
- AugerPrime will operate until at least 2035
- Auger remains largest observatory for next decade
- Deployment is reaches its conclusion

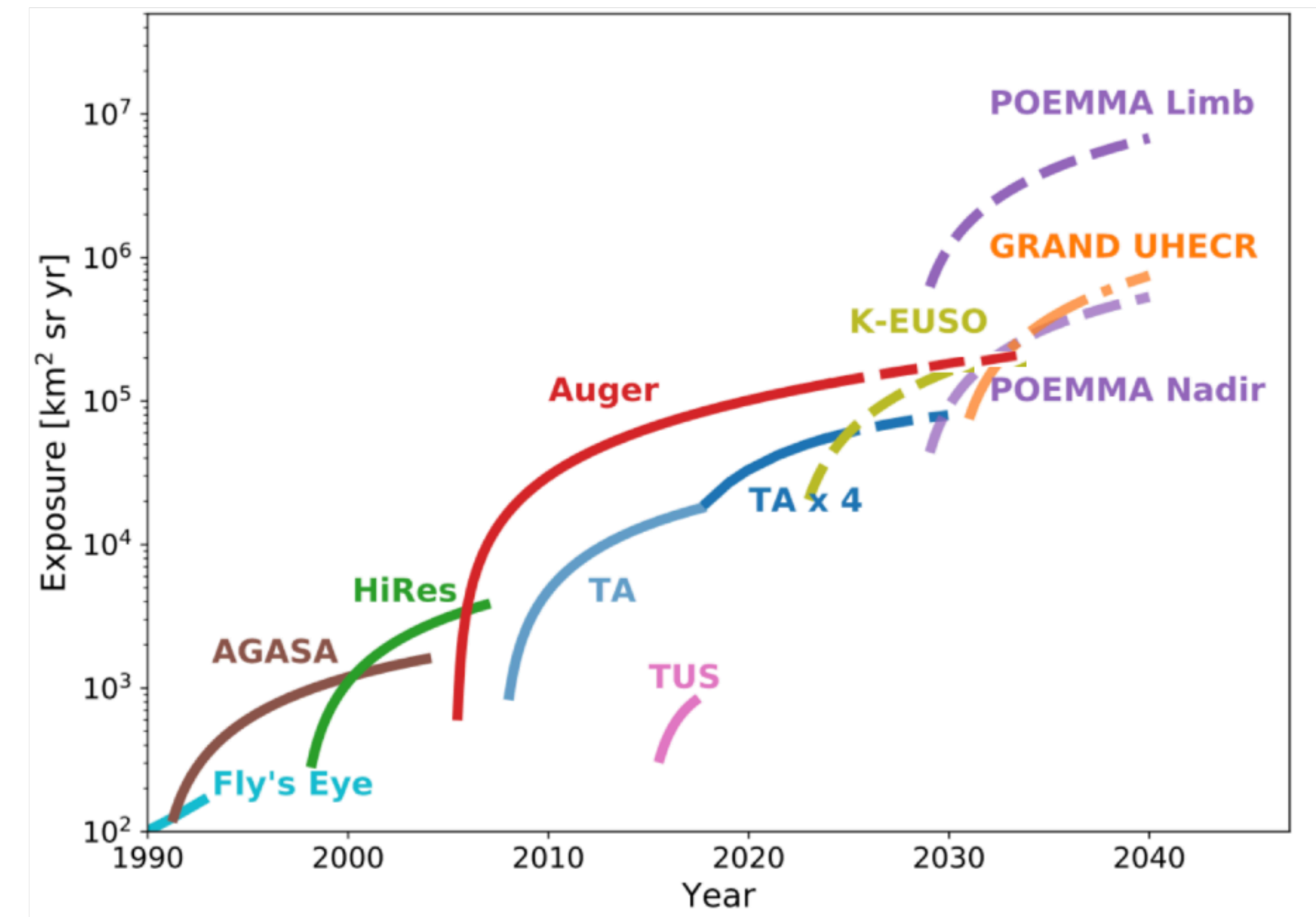
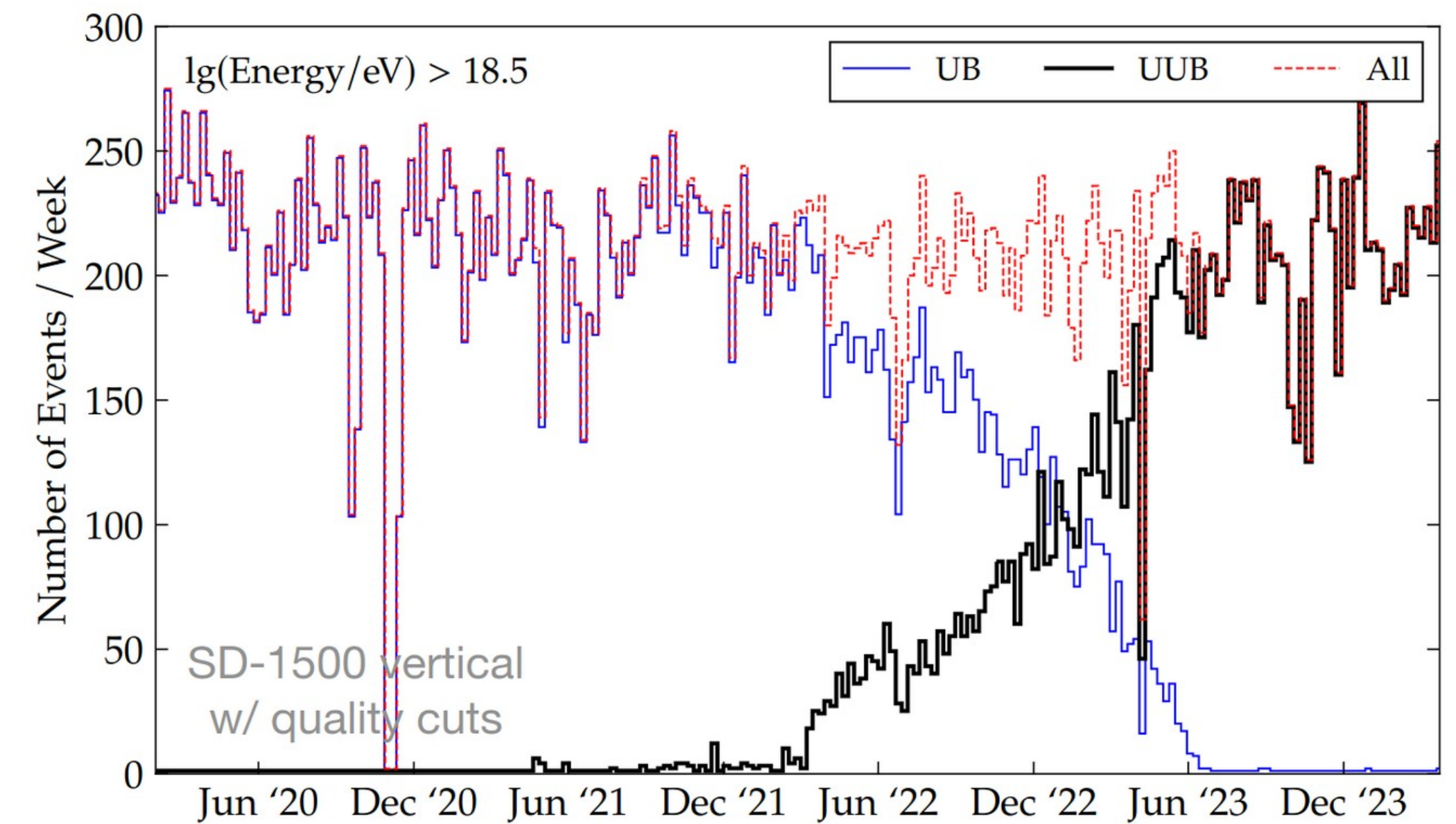
## Current activities

- Finalizing trigger commissioning and calibration procedures
- Finalizing data processing and reconstruction pipelines
- Working on first physics results with AugerPrime

## Next decade:

- Reduced systematics in hadronic interaction models
- Composition sensitivity in the region of flux suppression
- Enhanced sensitivity to UHE photons and neutrinos
- Composition enhanced anisotropy studies
- Search for new phenomena in hadronic interactions
- Test bed for next generation observatories

*(For more: contribution by Sonja Mayotte today)*





# **Supplementary material**



