MARTA

Muon Auger RPC for the Tank Array

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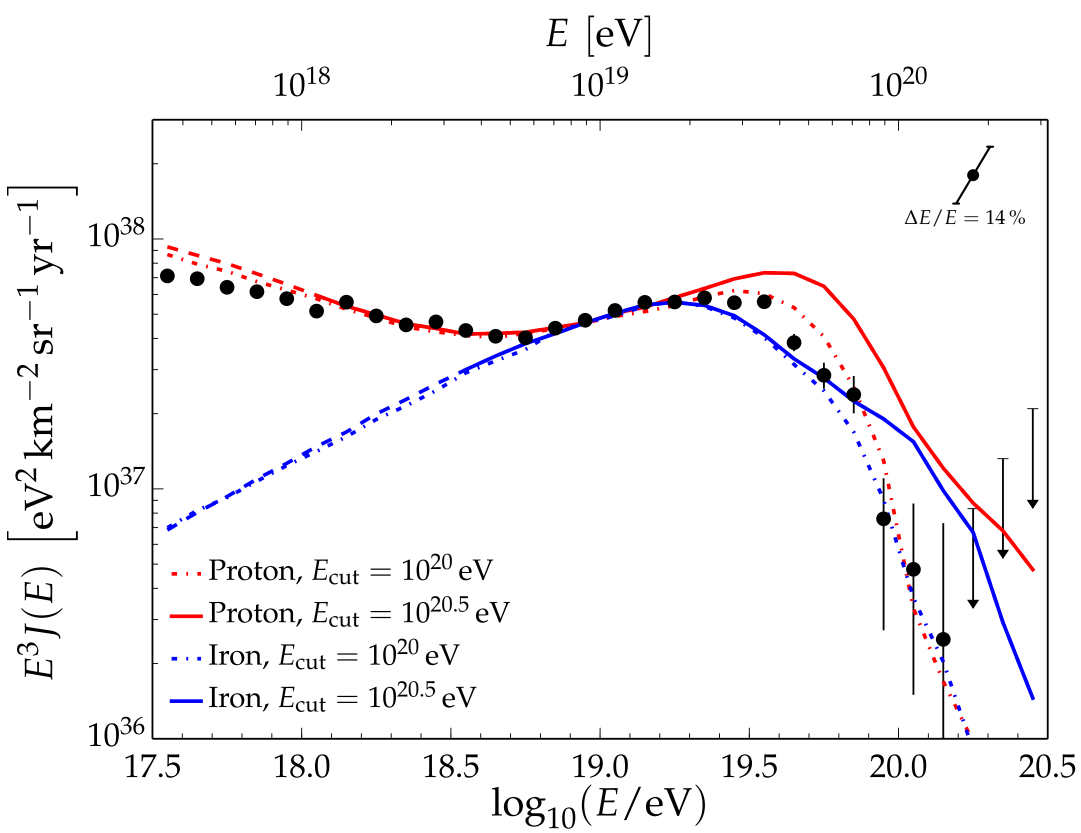
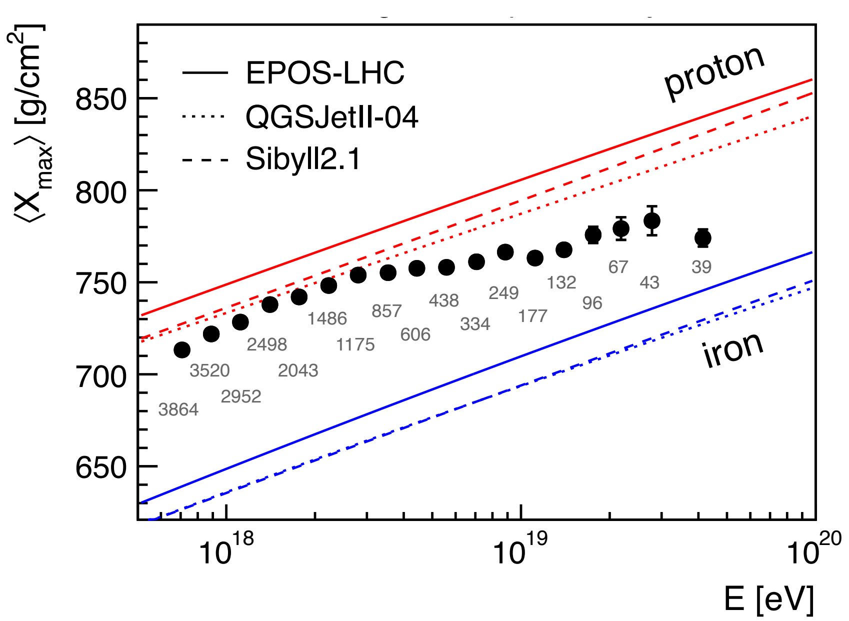
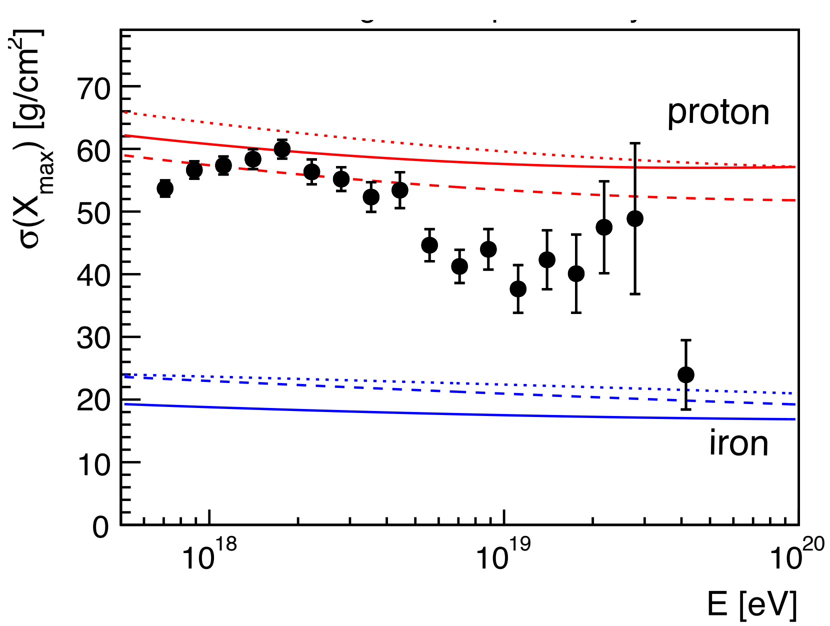
The Pierre Auger Observatory - Beyond 2015



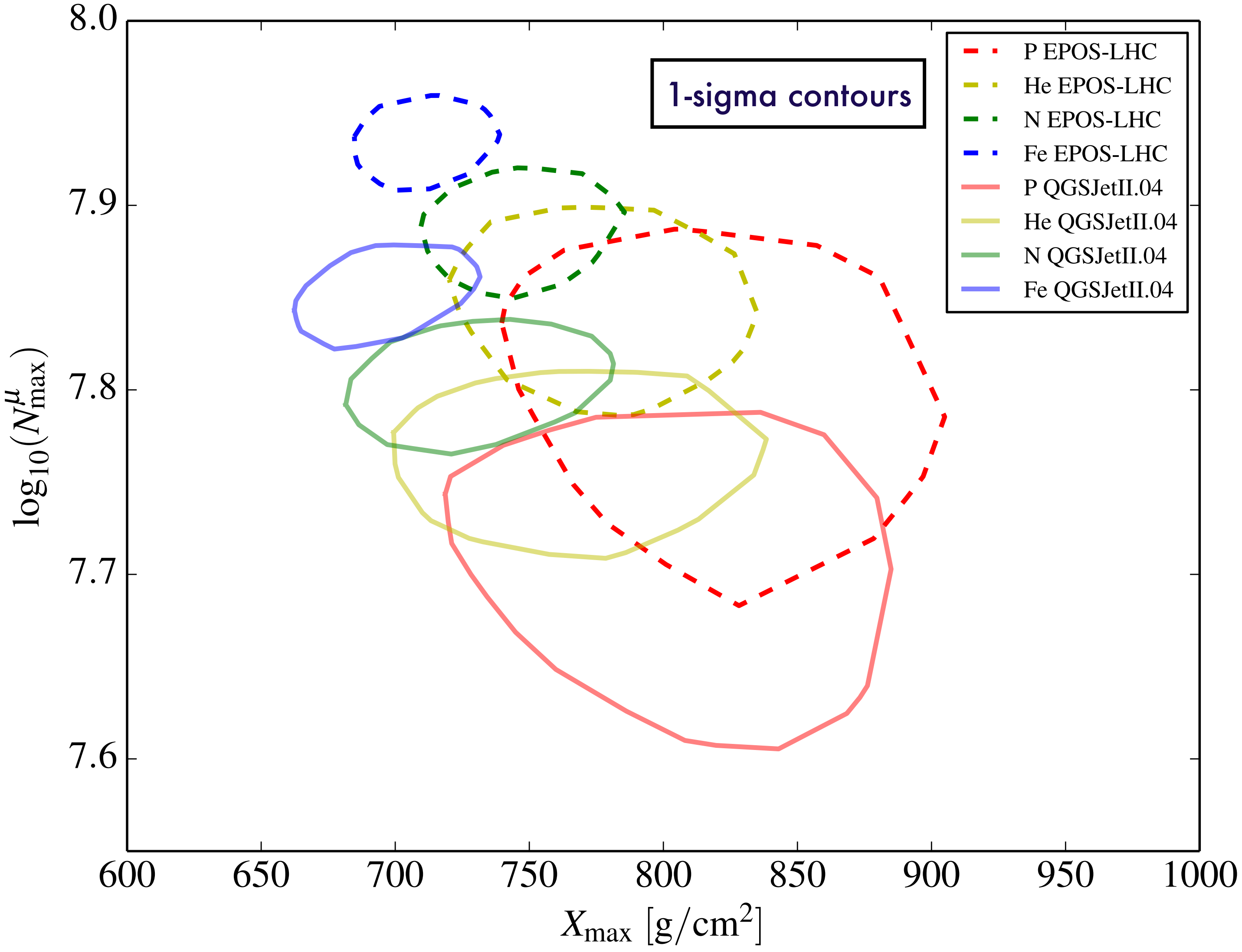
Measurements up to 2023 with upgraded detectors!

- Elucidate the origin of the flux suppression and the mass composition at the highest energies
- Sensitivity to 10% proton flux contribution
- Understand hadronic interactions above 60 TeV and constrain new physics phenomena





The importance of determining the muonic shower component



E=10^{19} eV, zenith angle θ=38°

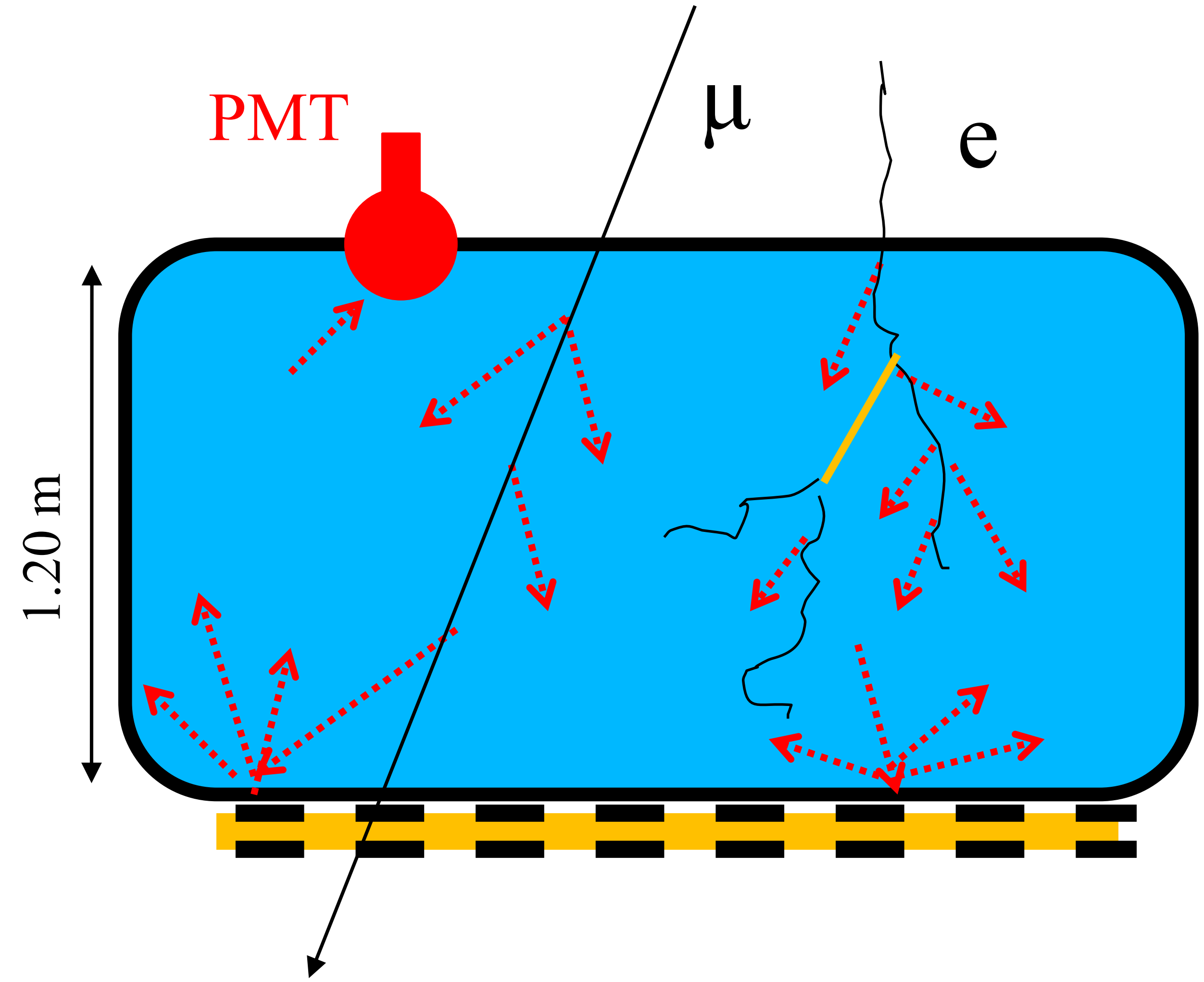
However at fixed energy! Energy resolution ~15% ...

New muonic variables are needed for disentangling mass composition scenarios from hadronic models!

<N_μ> and RMS, X^μmax, ...

The concept of MARTA

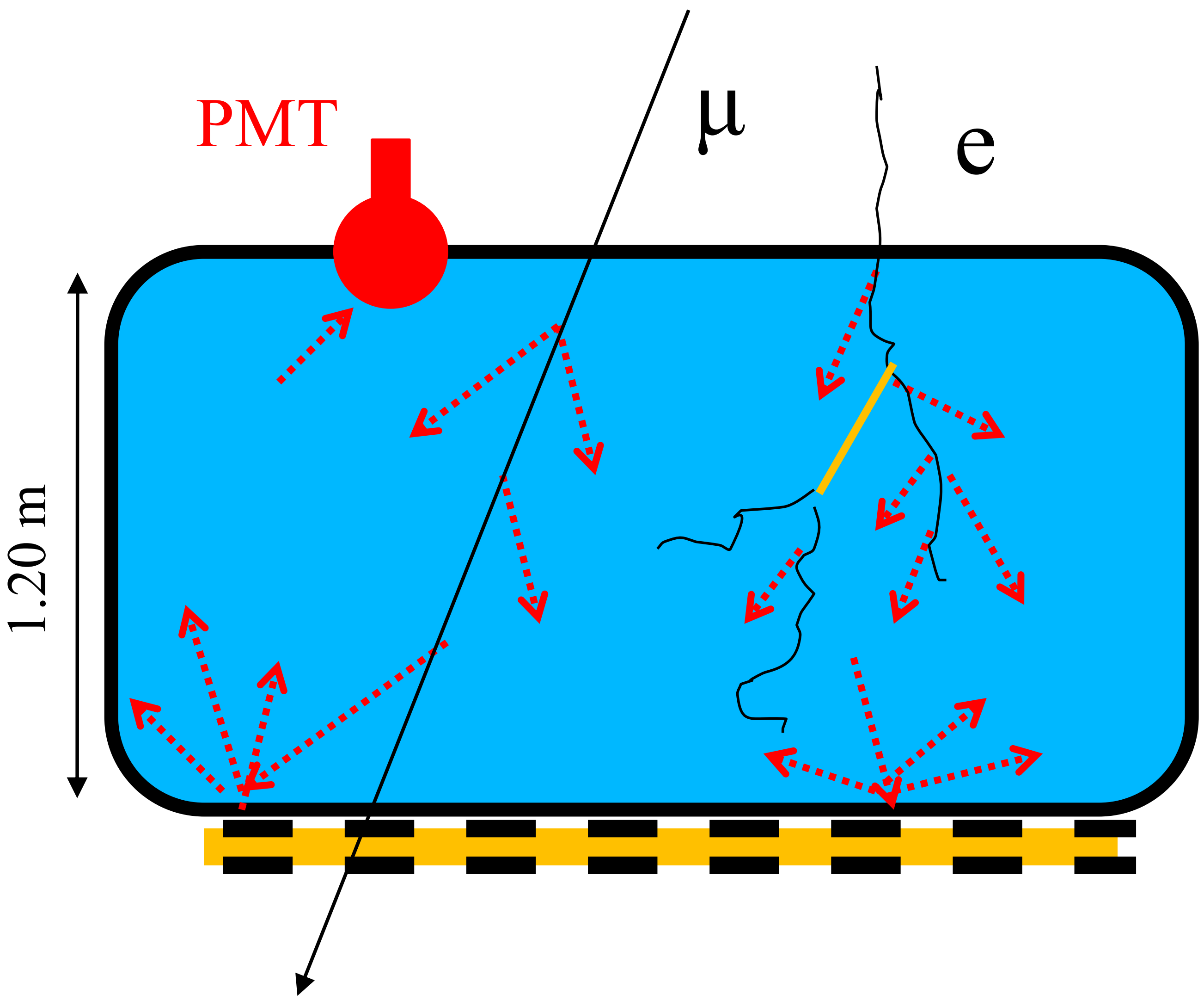
Add a second independent μ sensitive detector with good space and time resolution



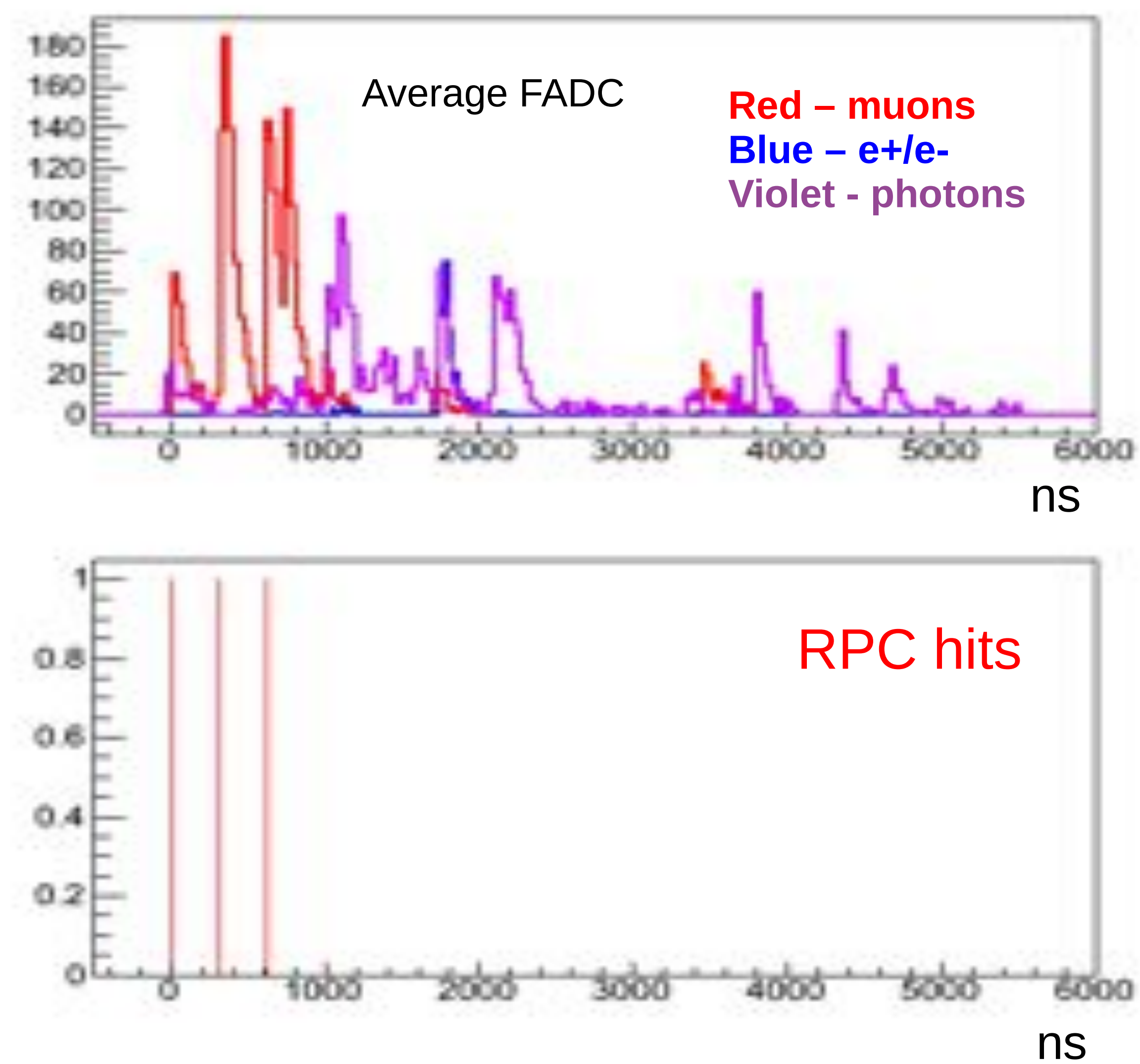
- independent and precise measurements of N_μ (mean and RMS) and E
- Muon Transversal (LDF) and Longitudinal (X^μ_{max}) profiles
- Control of Systematics (cross-calibrations)

RPCs under the tanks

The concept of MARTA

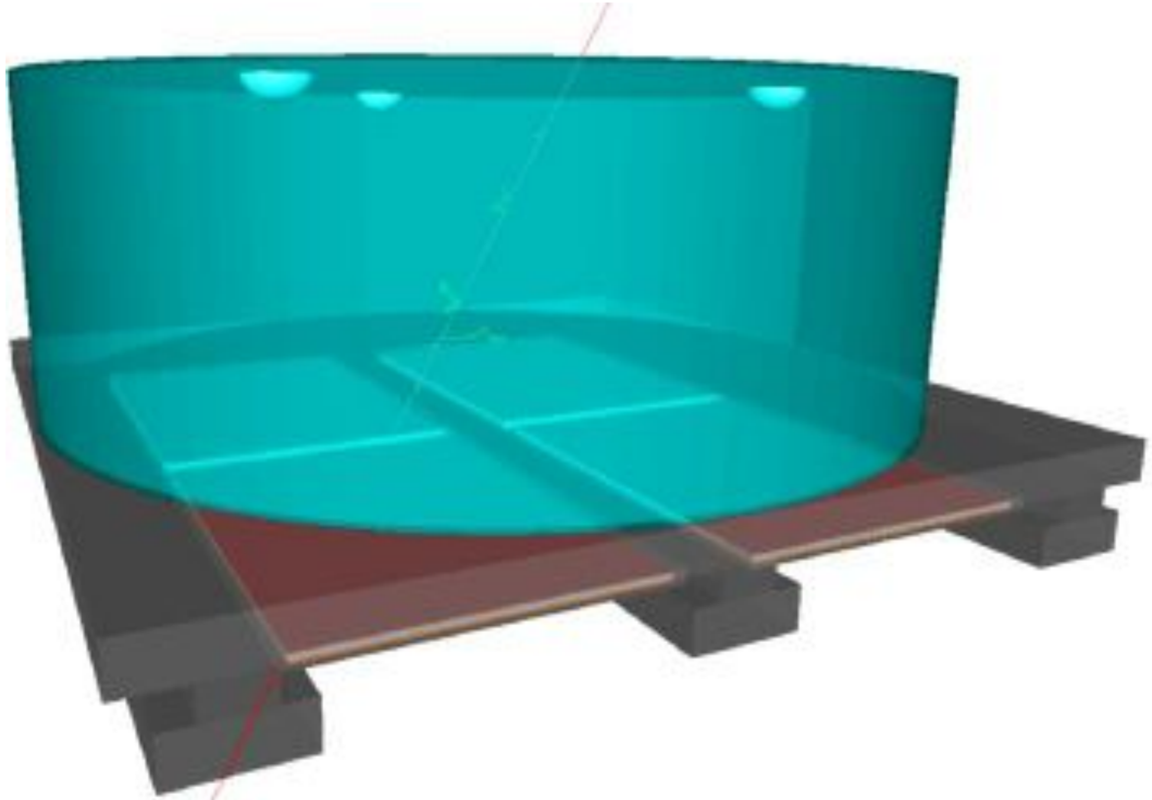


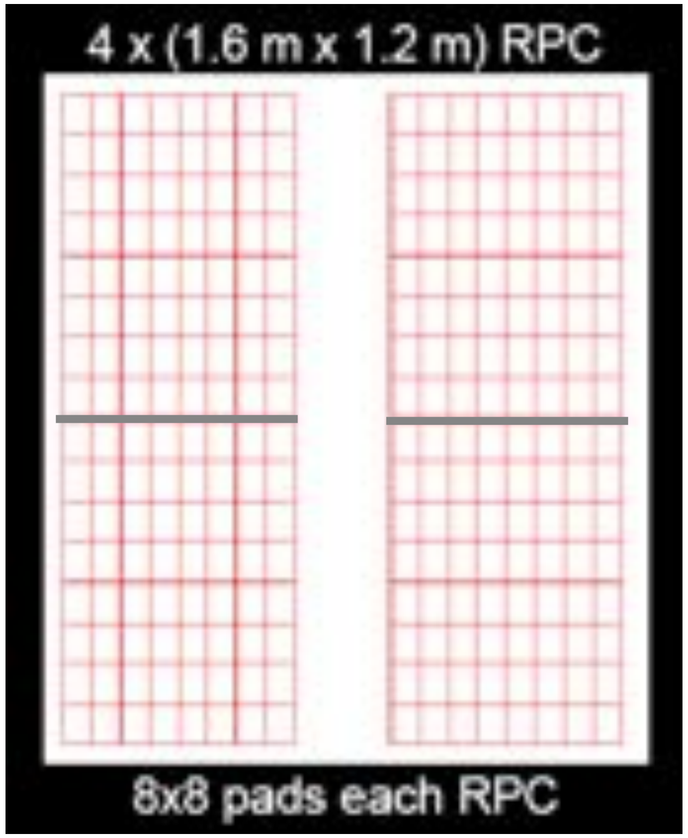
RPCs under the tanks



Absorption of the electromagnetic component in the tank, assessing the muonic component by digital counting of hits in the RPCs

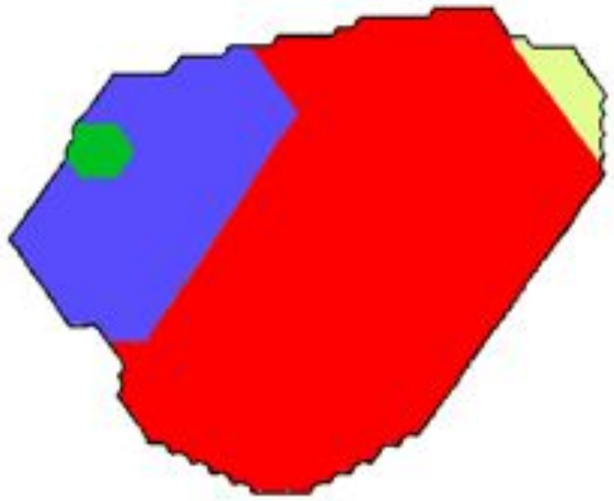
Baseline configuration





Precast + 4 RPC modules below each tank

MARTA in the Auger map



800 stations covering an area of around 2800 km^2:

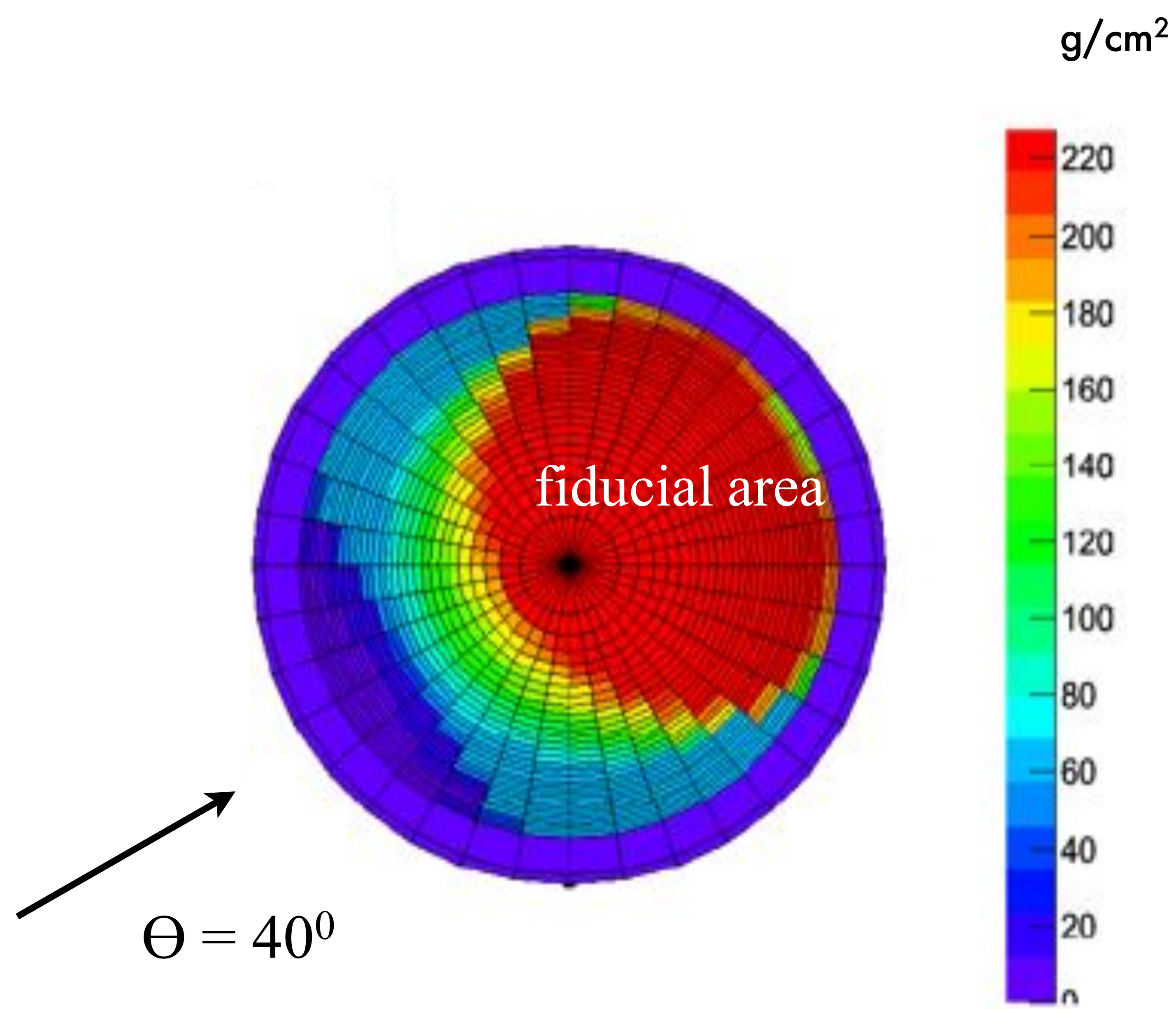
- 71 stations with 750 m spacing (27 km^2)
- 380 stations with 1500 m spacing (750 km^2)
- 350 stations with 2600 m spacing (2000 km^2)

Segmentation

256 segments per MARTA station!

Segmentation allows for:

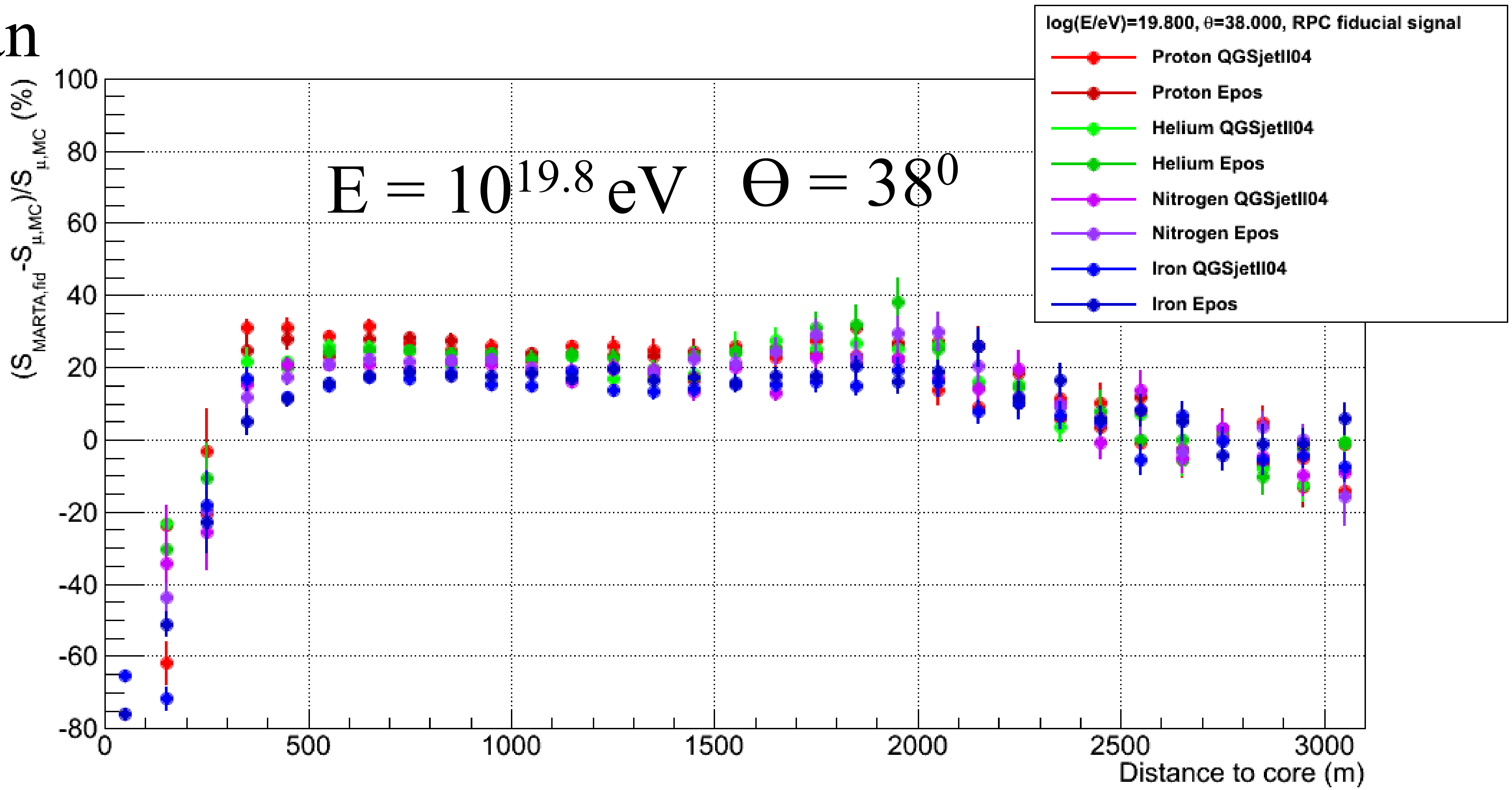
- digital muon counting (with high time resolution)
- definition of fiducial areas (with reduced e.m bkg)
- Definition of control regions (with increased e.m. bkg)
- Powerful methods of calibration and cross-calibration



The amount of material crossed can be accurately computed for each pad and each shower geometry

Expected performance

Mean

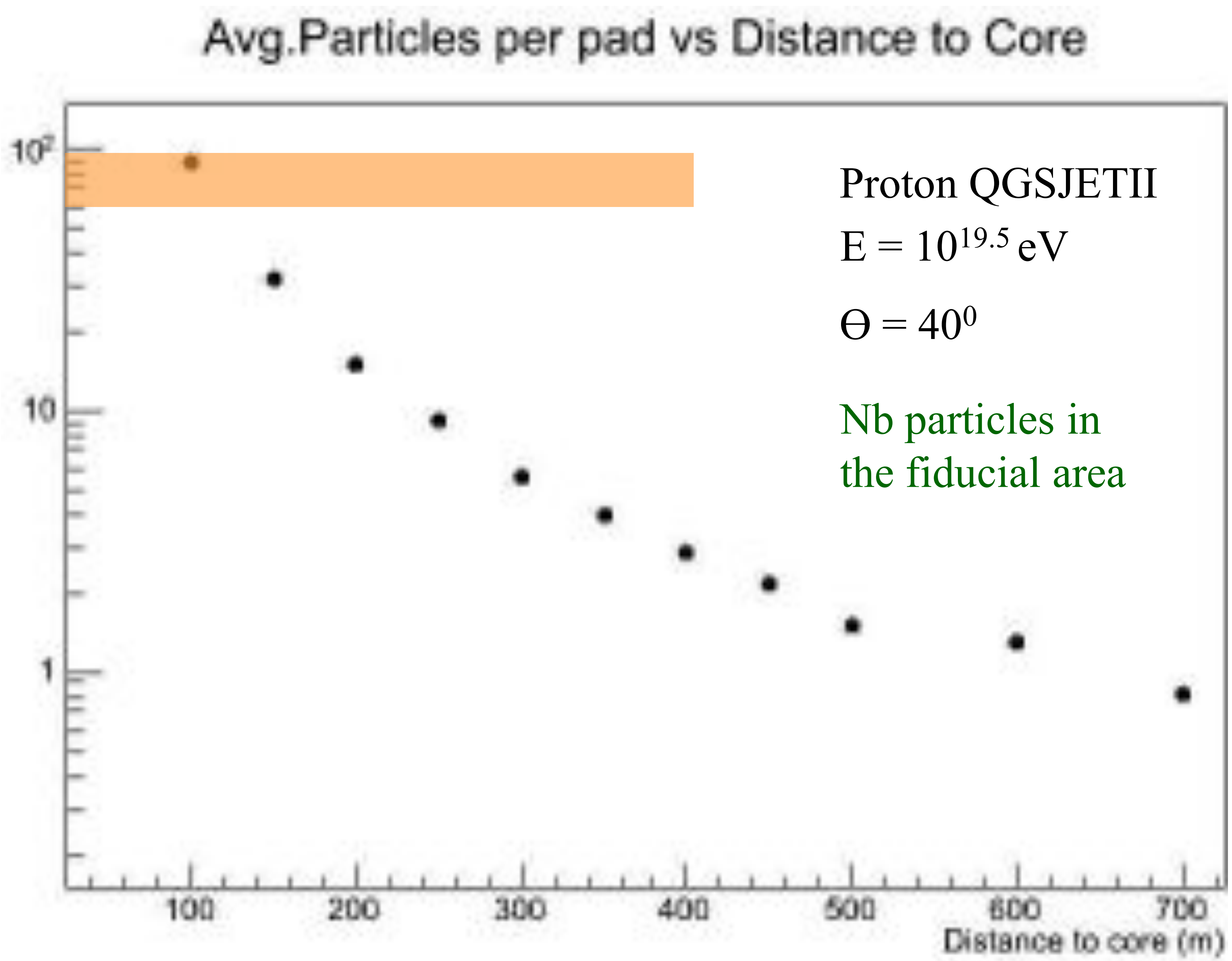


Station level: digitally counting the number of muons

For 500m < r < 2000m :
~20% e.m signal (as foreseen)

Resolutions between 10% and 25%

MARTA ultimate saturation: analogic mode for first 100 ns



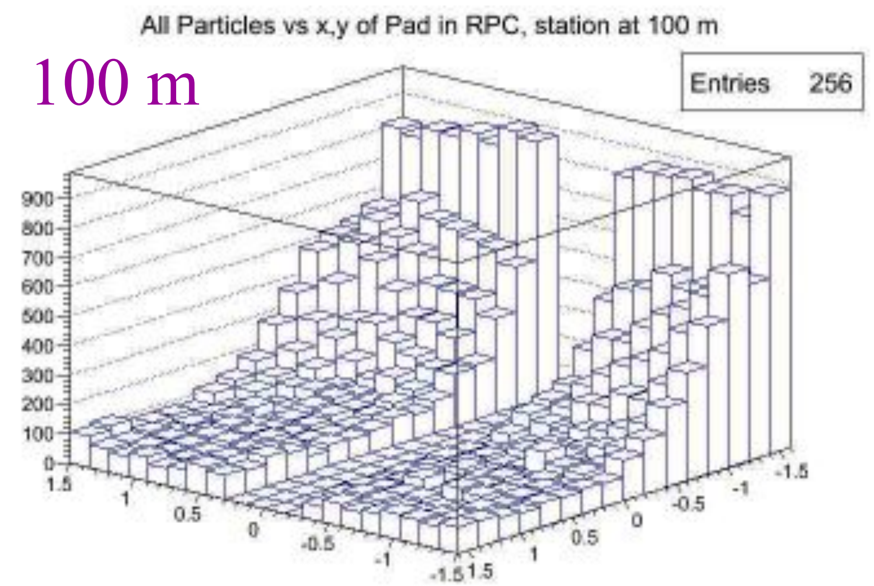
Proton QGSJETII

$E = 10^{19.5}$ eV

$\Theta = 40^0$

Nb particles in the fiducial area

100 m



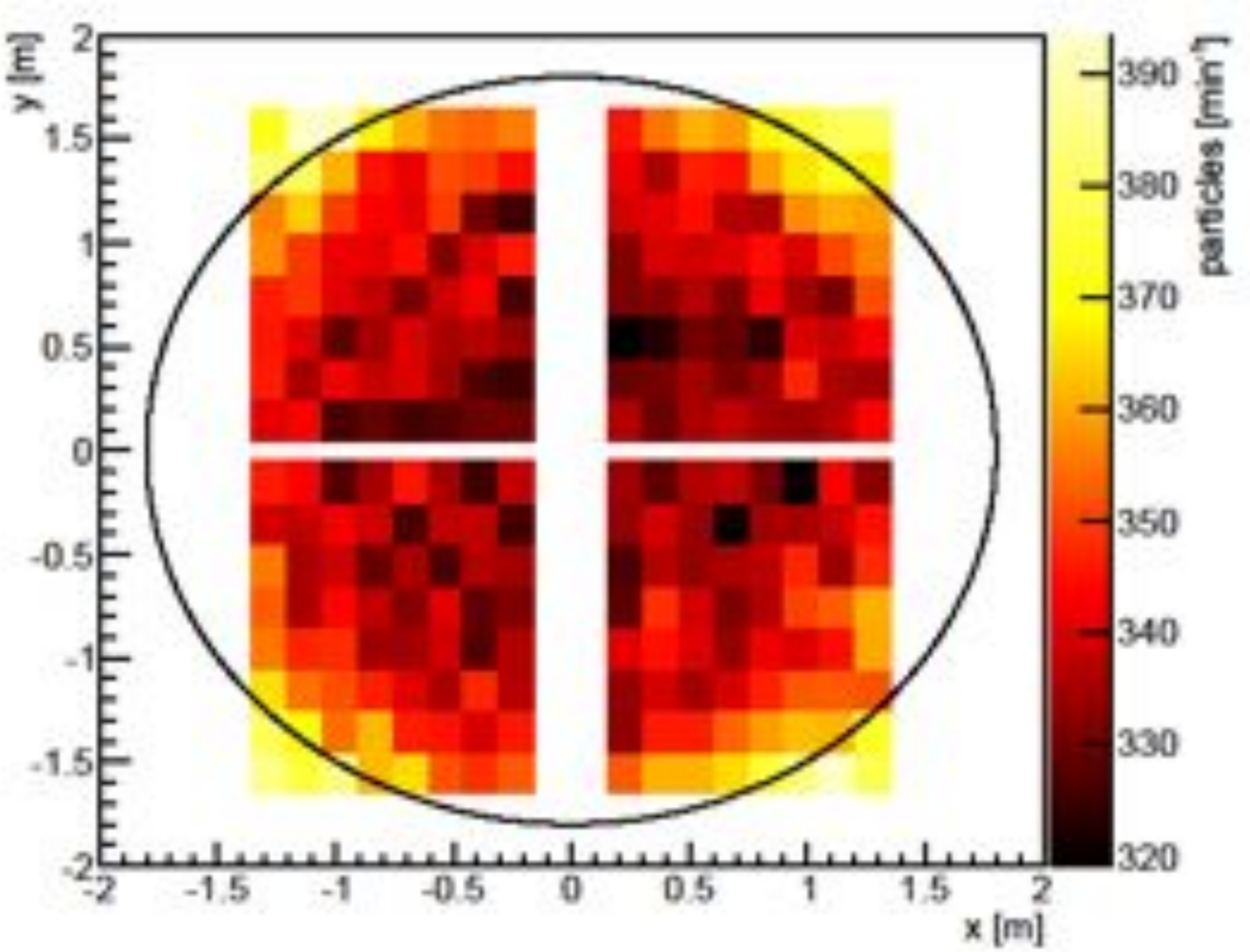
Physics near the Core!

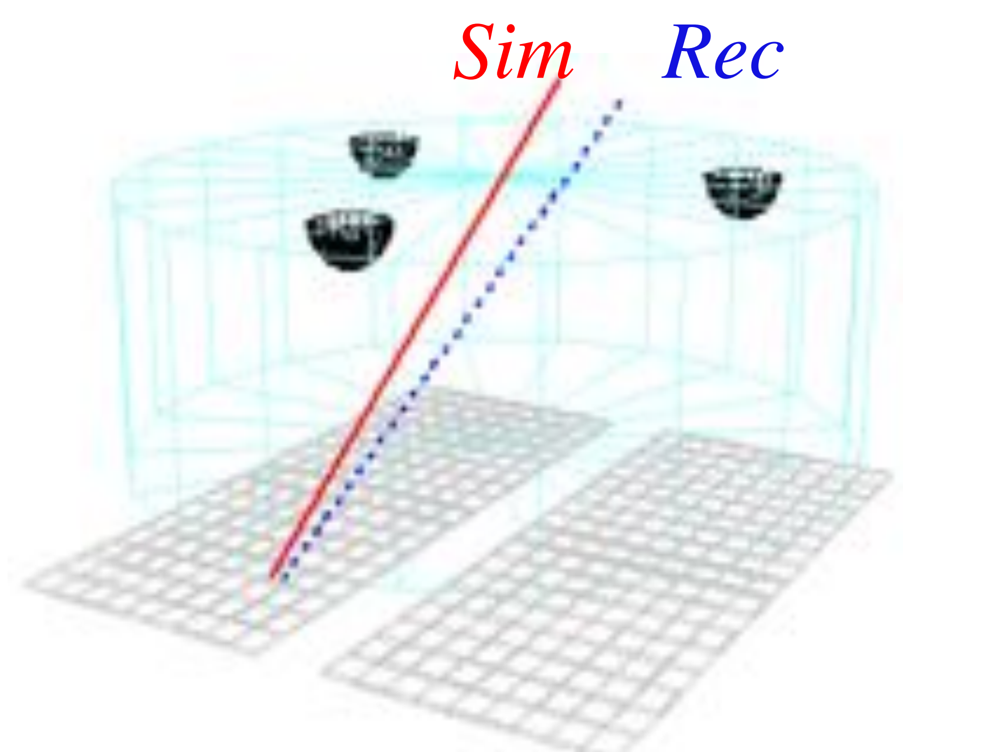
Saturation with analogic mode for $E= 10^{19.5}$ eV $\theta=40^{o}$, R_{sat}=100 -150 m

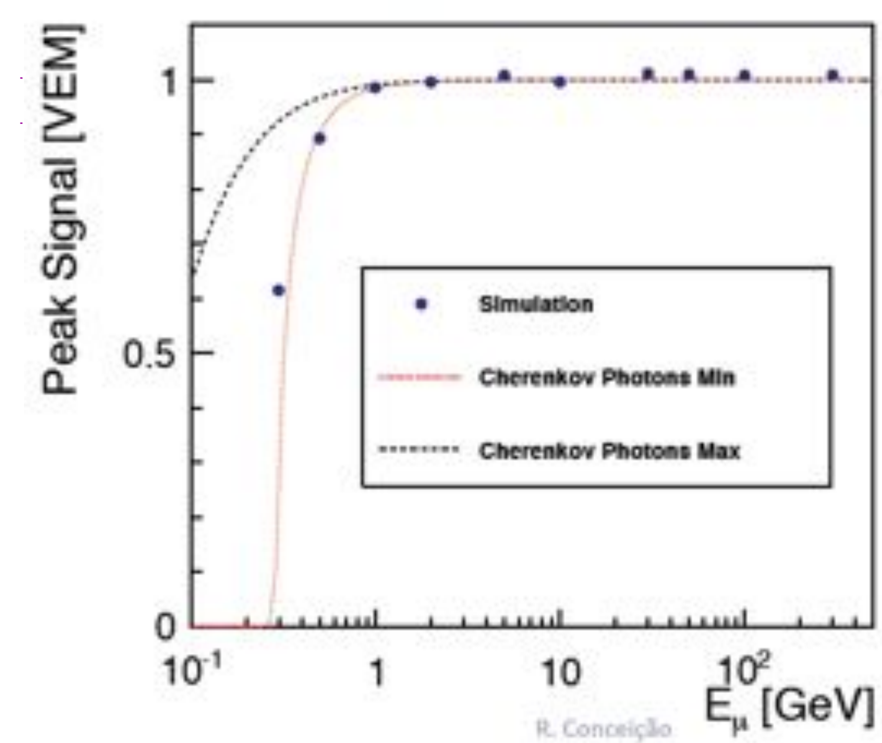
Calibration, cross-calibration and assessing the EAS muon low energy spectrum

Use a MPD like algorithm to reconstruct shower muon trajectories in the tank thanks to a fine segmentation

Particles per pad per min

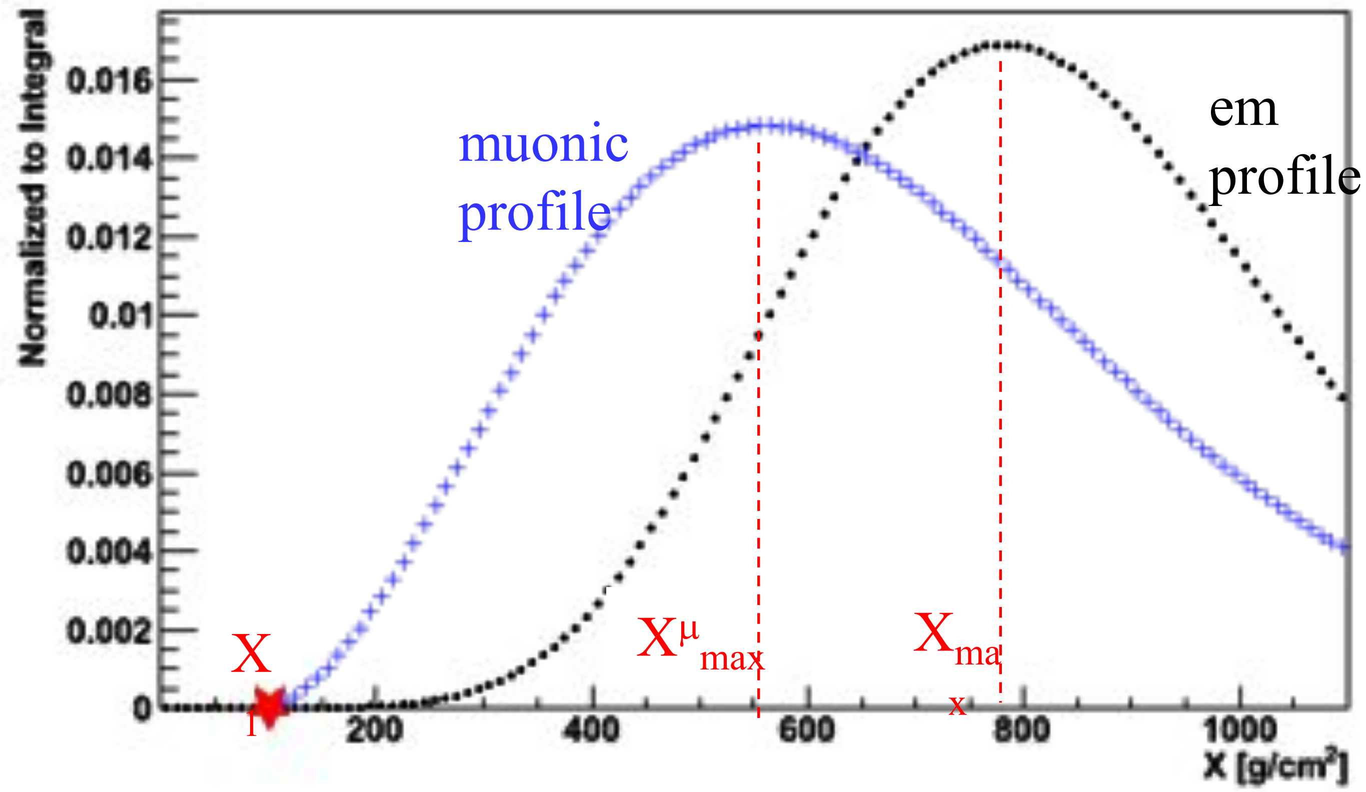






It is possible to follow the number of hits in each pad (ε and flux variations) at 1% level every 30 m

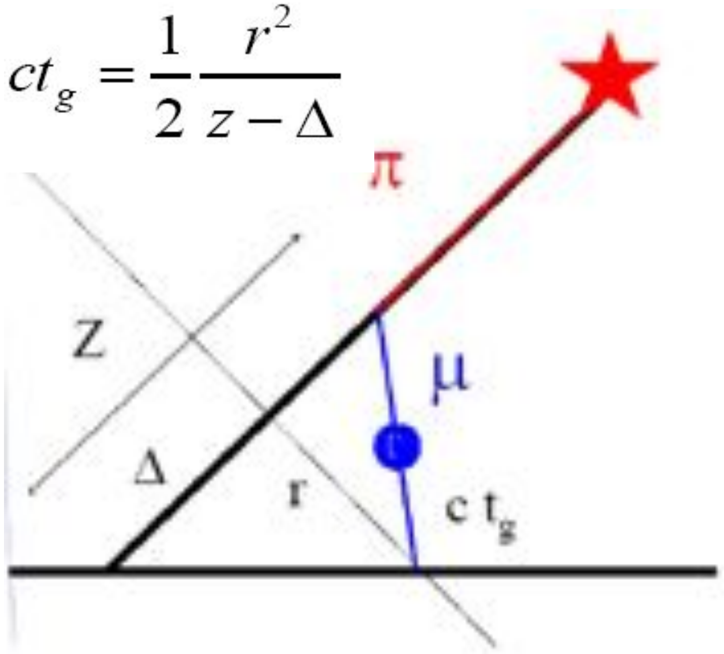
X^{μ}_{max}

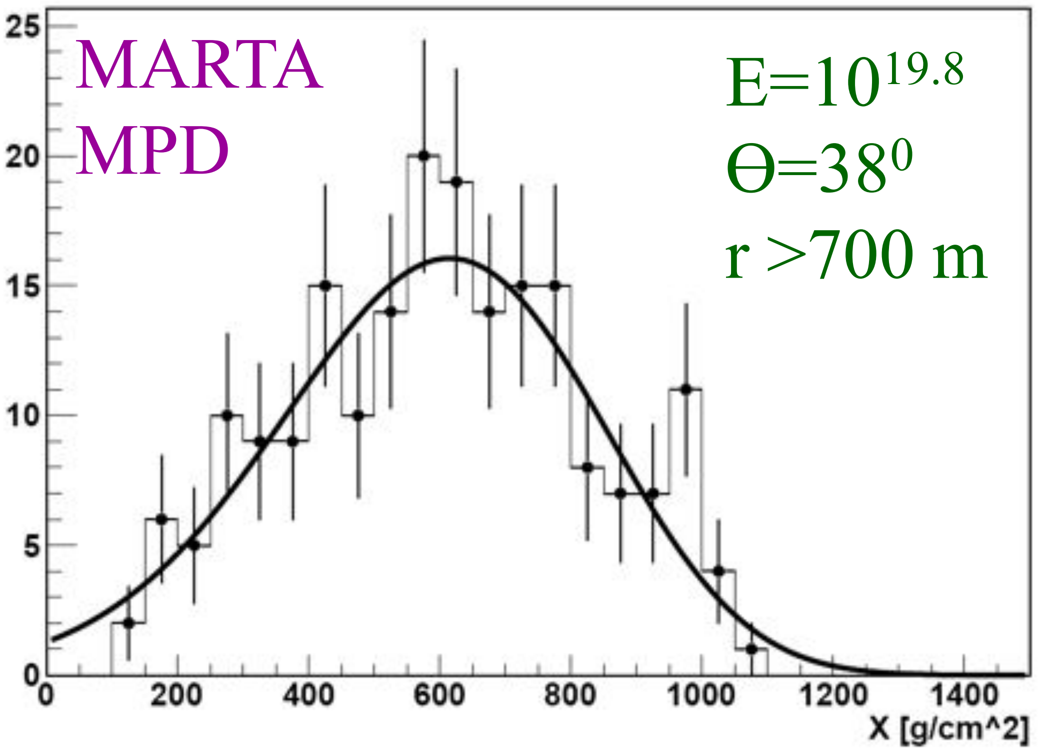


The MARTA Muon Production Depth (MPD) for determining X^{μ}_{max}

Geometrical reconstruction

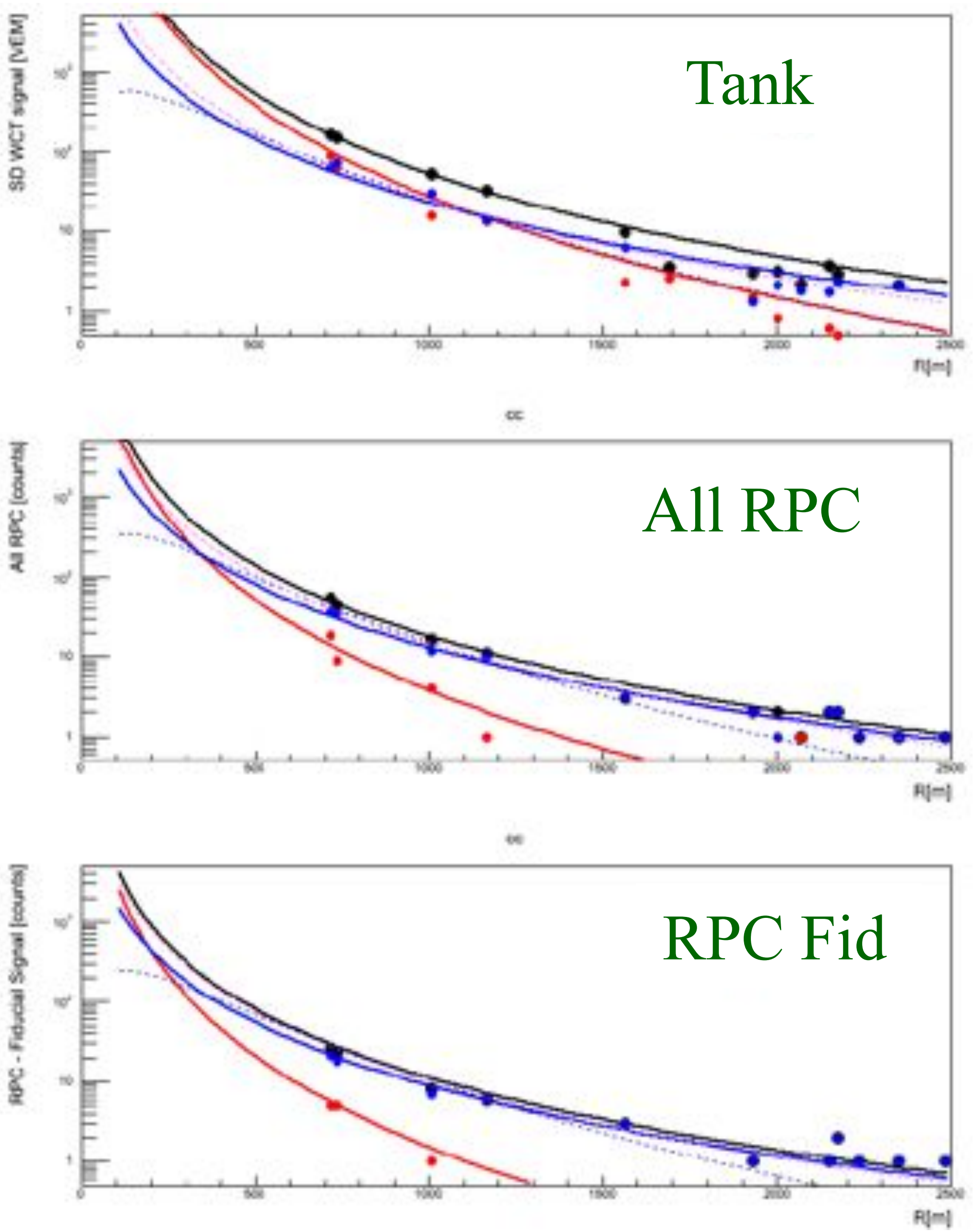
$$ct_g = \frac{1}{2}\frac{r^2}{z-\Delta}$$



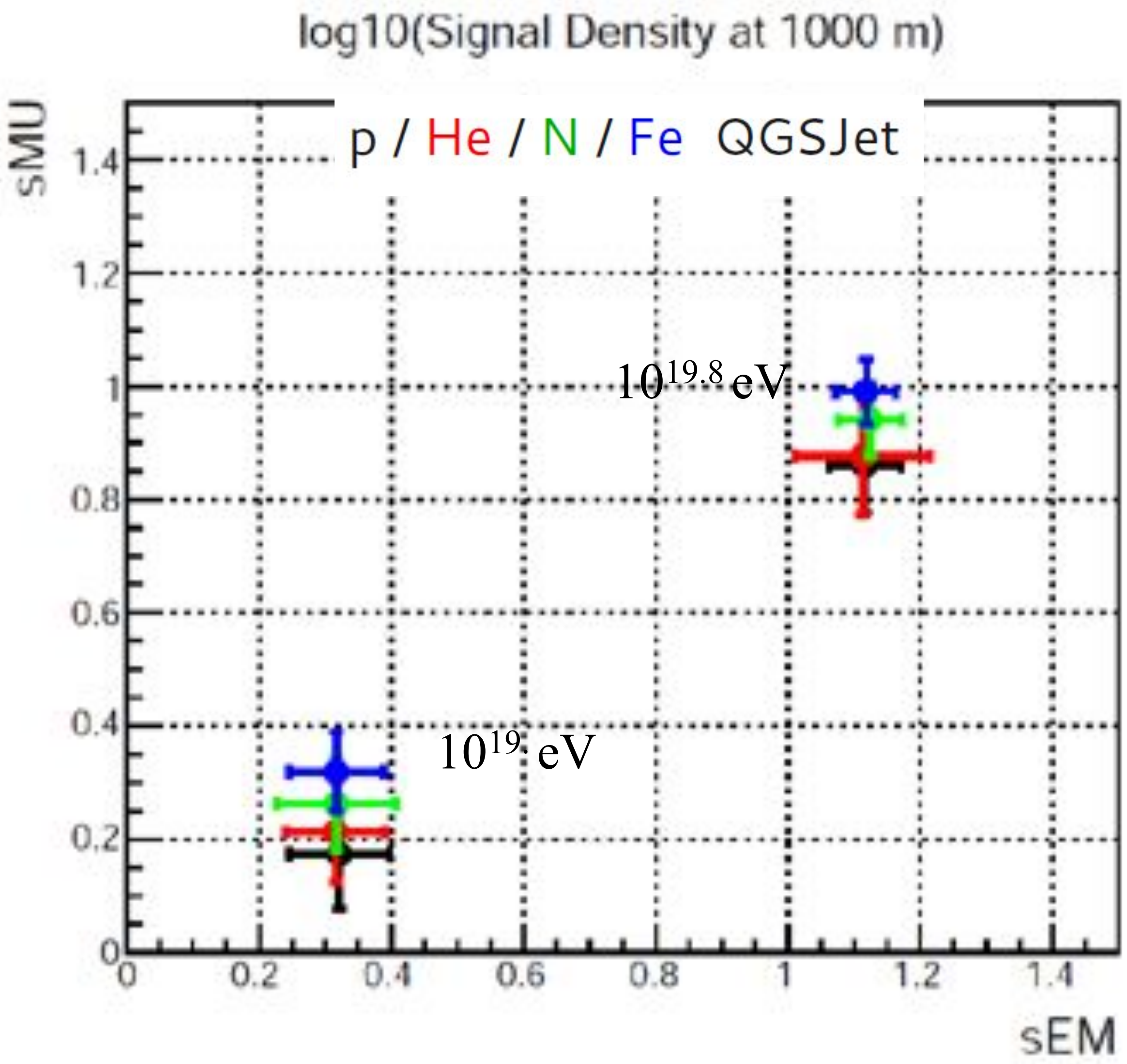


Combined MARTA and Tank
Lateral Distribution Functions (LDFs)

Event by event (β fixed)



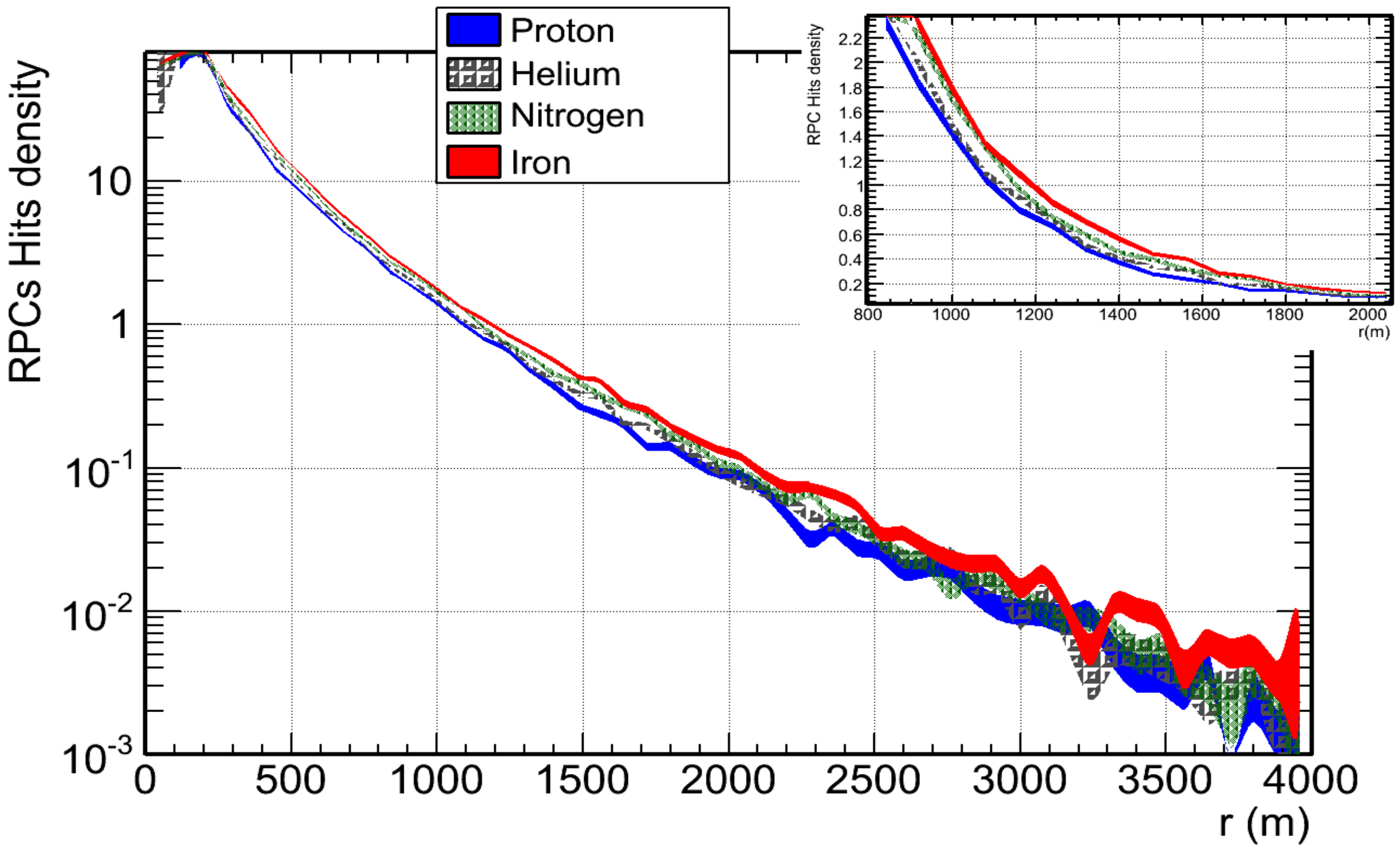
$S_{\mu1000}$ and S_{em1000}



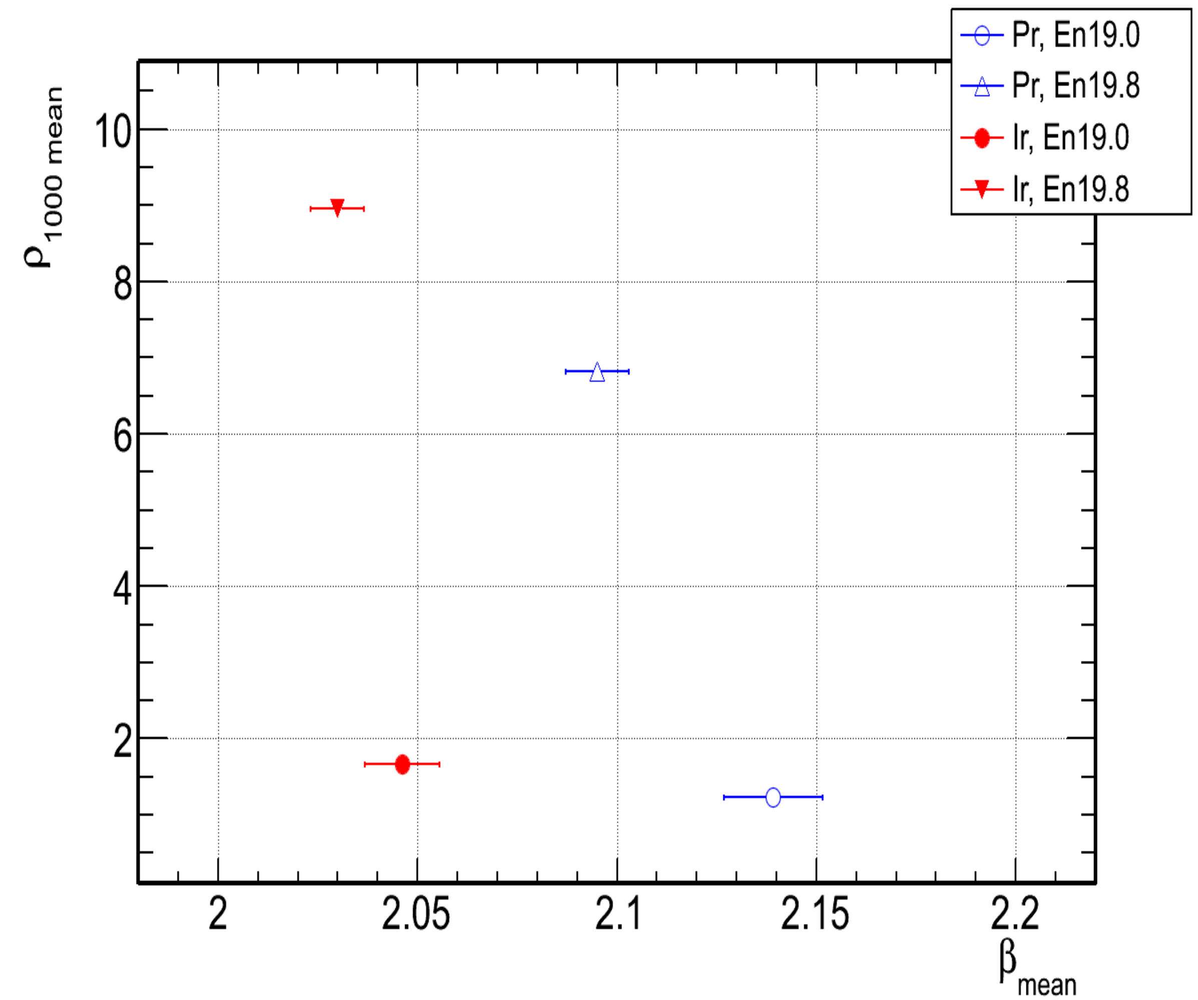
Preliminary resolutions of the order 15% both for $S_{\mu1000}$ and S_{em1000}

MARTA LDFs

Mean over 300 events



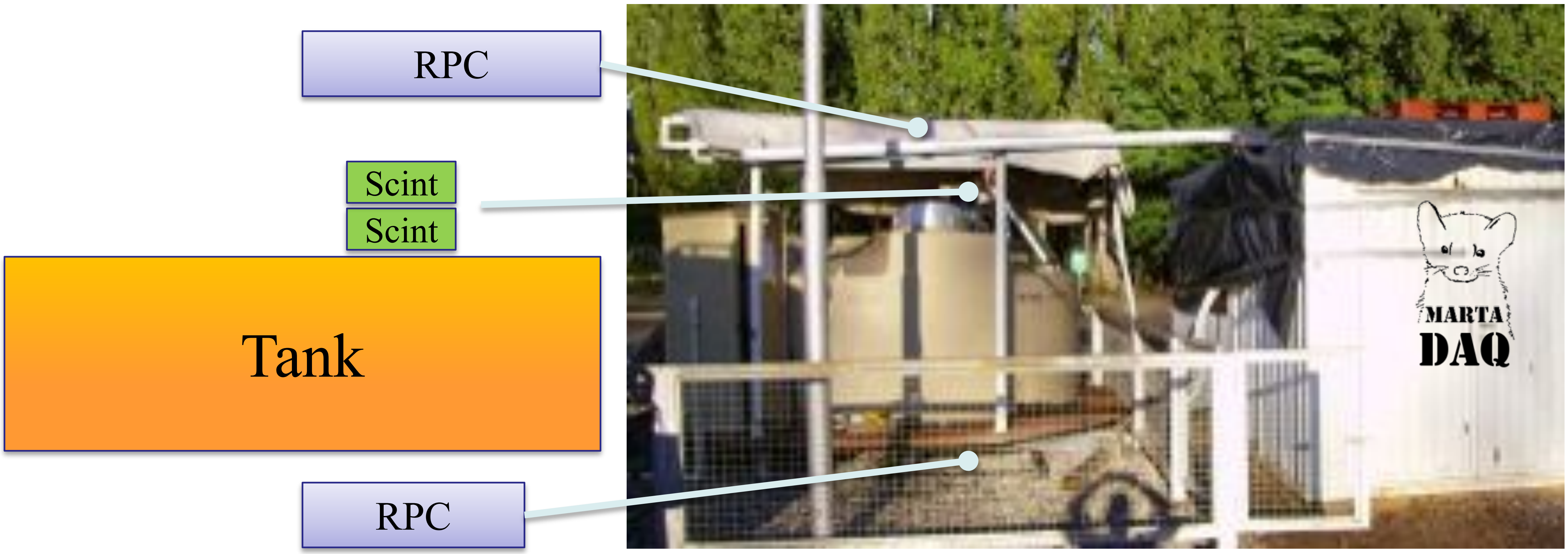
Mean LDF (ρ and β free!)



Normalization ρ_{1000} and shape β parameters of the muon LDFs: additional for assessing the beam composition!

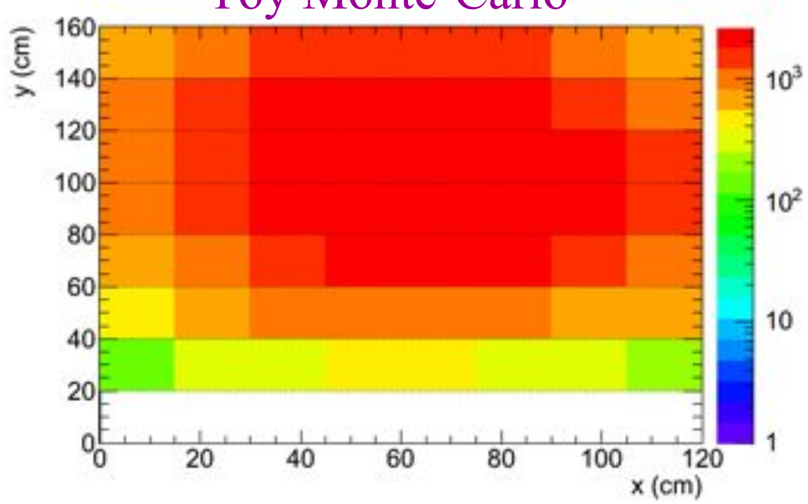
MARTA @ Malargue

RPC telescope in test tank

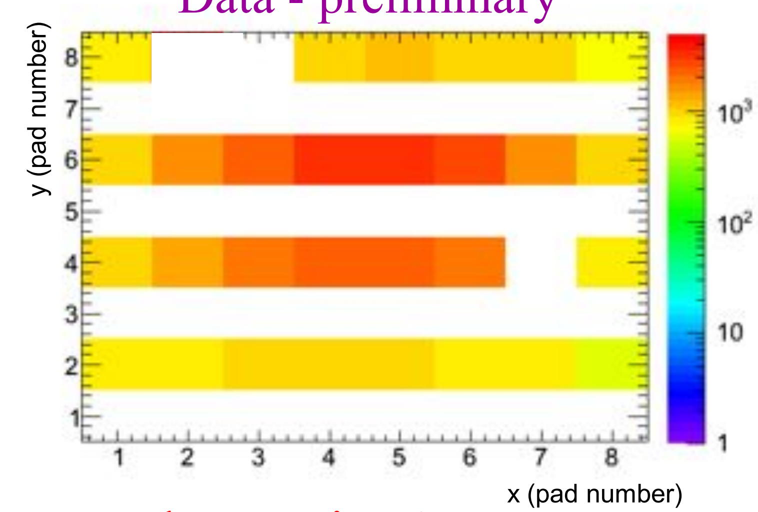


Events taken asking coincidence of scintillators:

Toy Monte-Carlo



Data - preliminary



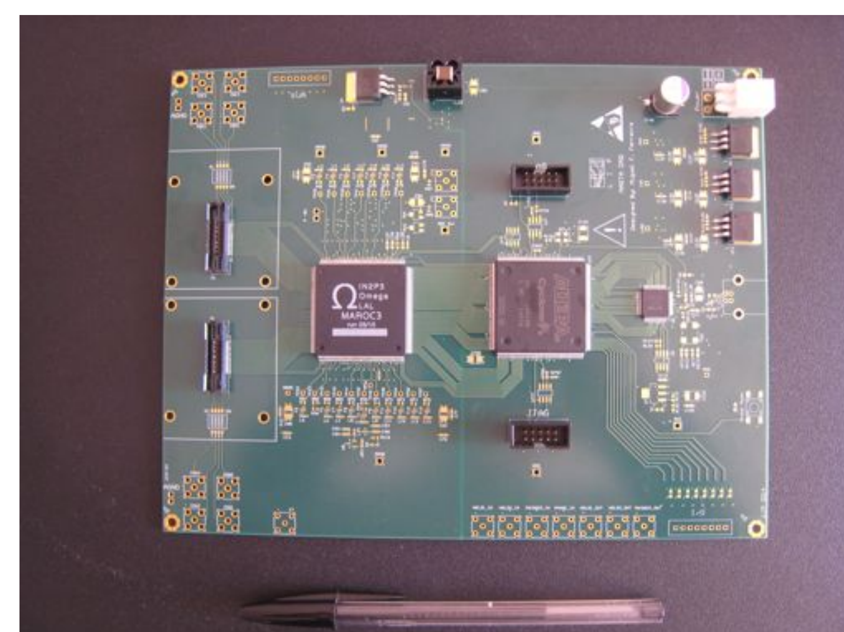
Acquisition with trigger from tank running!

MARTA @ Malargue

Precast + RPC modules installed on the field

Next steps:

- Continue with data taking and analysis
- Install 2 more MARTA stations to measure muon LDFs
- Move to integrated electronics

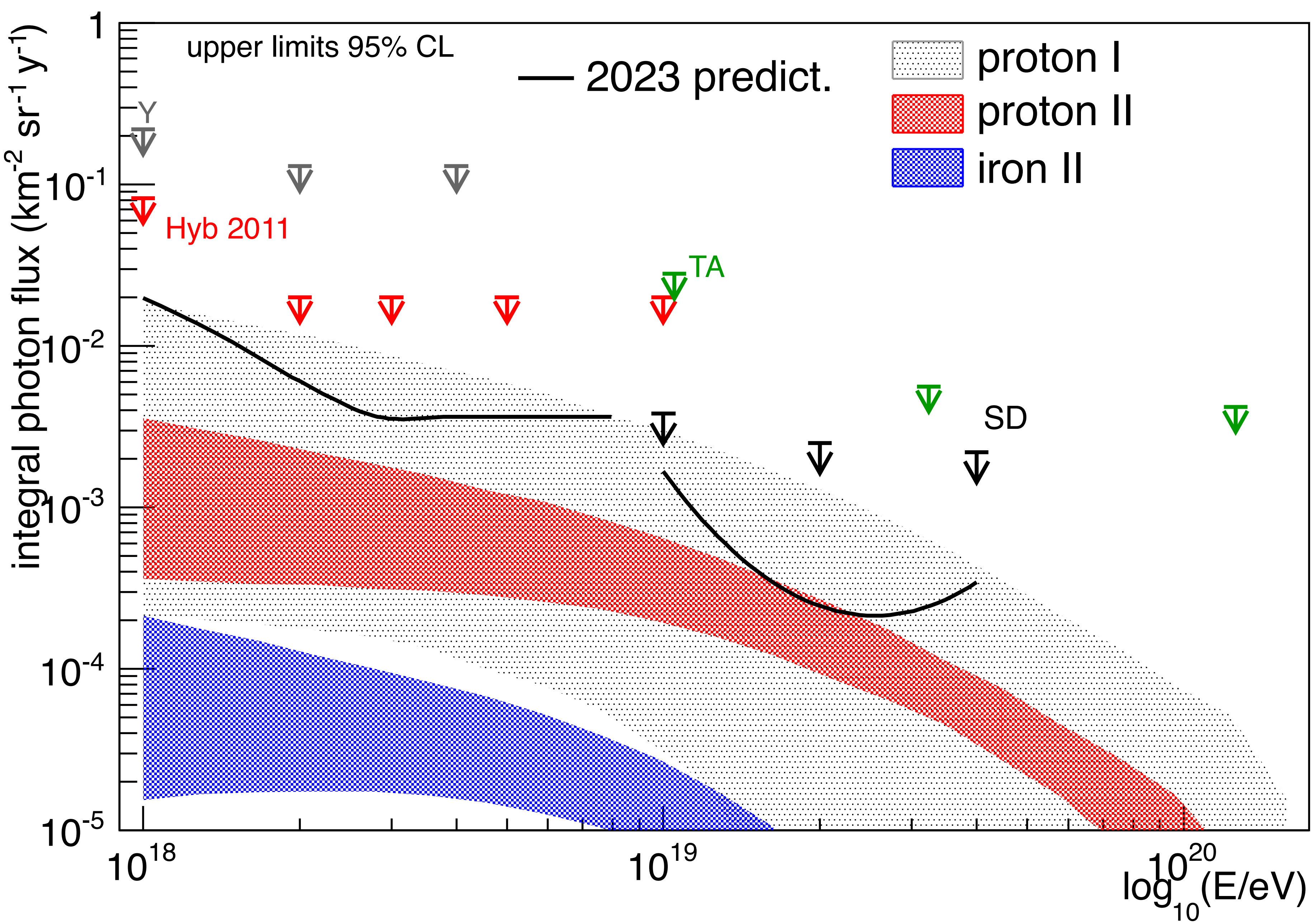


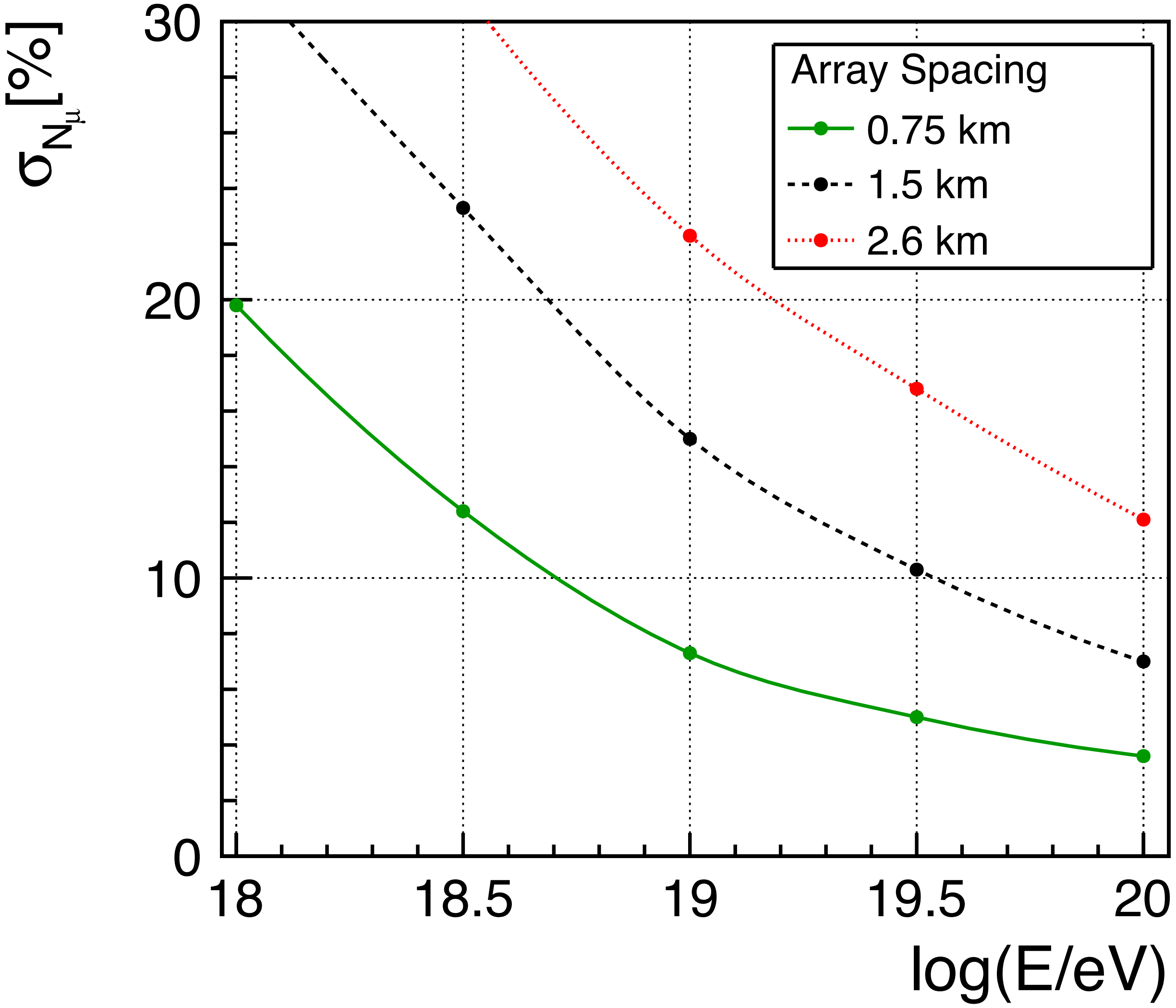
MARROC 3

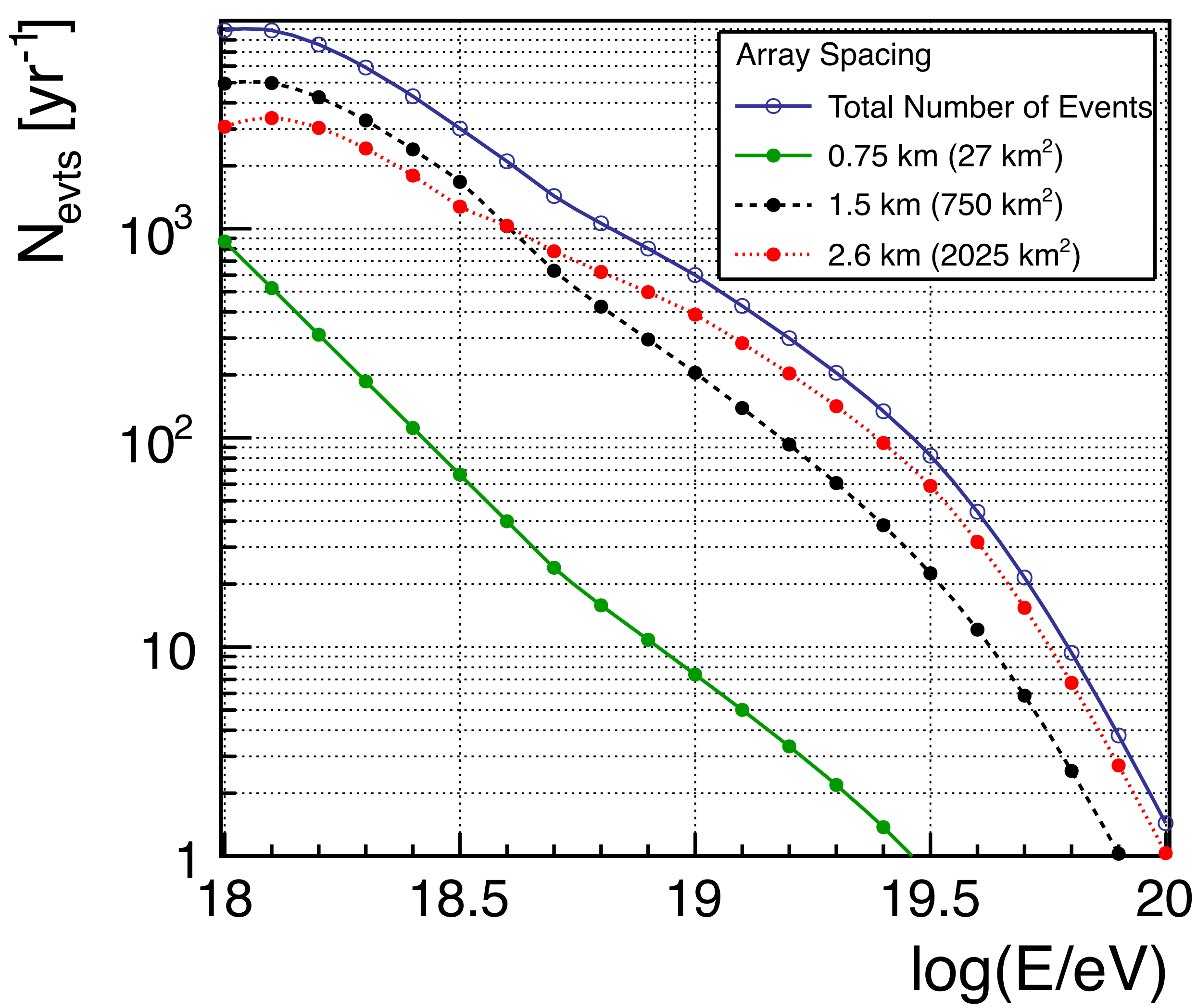
Thanks for your attention!

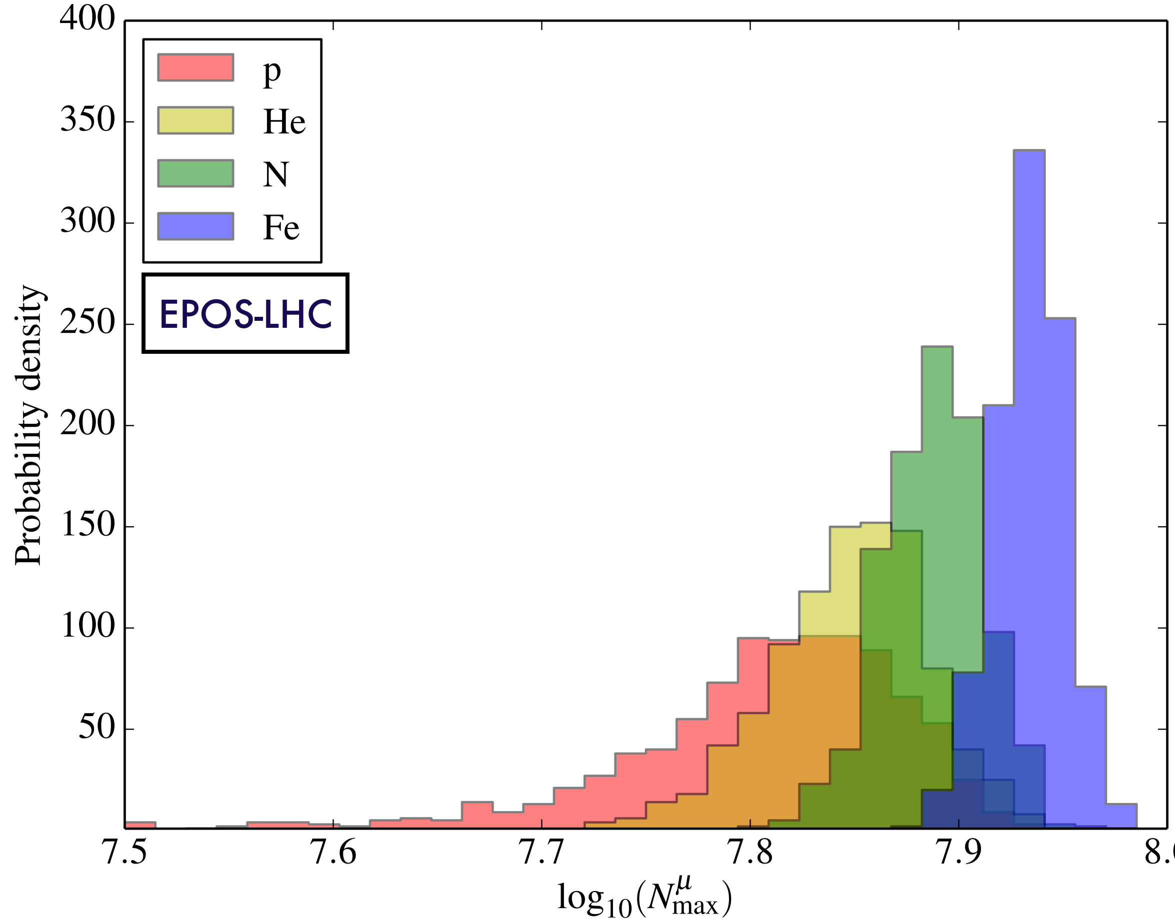
Backup slides

- **Increase the sensitivity to primary photons!**




σ_{N_μ} [%]
Array Spacing
0.75 km
1.5 km
2.6 km
log(E/eV)


N_{evts} [yr^{-1}]
Array Spacing
Total Number of Events
0.75 km (27 km^2)
1.5 km (750 km^2)
2.6 km (2025 km^2)
log(E/eV)


p
He
N
Fe
EPOS-LHC
Probability density
400
350
300
250
200
150
100
50
7.5
7.6
7.7
7.8
7.9
8.0
$\log_{10}(N^{\mu}_{\mathrm{max}})$