

Updates on seasonal variation of the muon rate

Pantelis Melas, Niki Saoulidou
28/5/2020



National and Kapodistrian
University of Athens



Outline

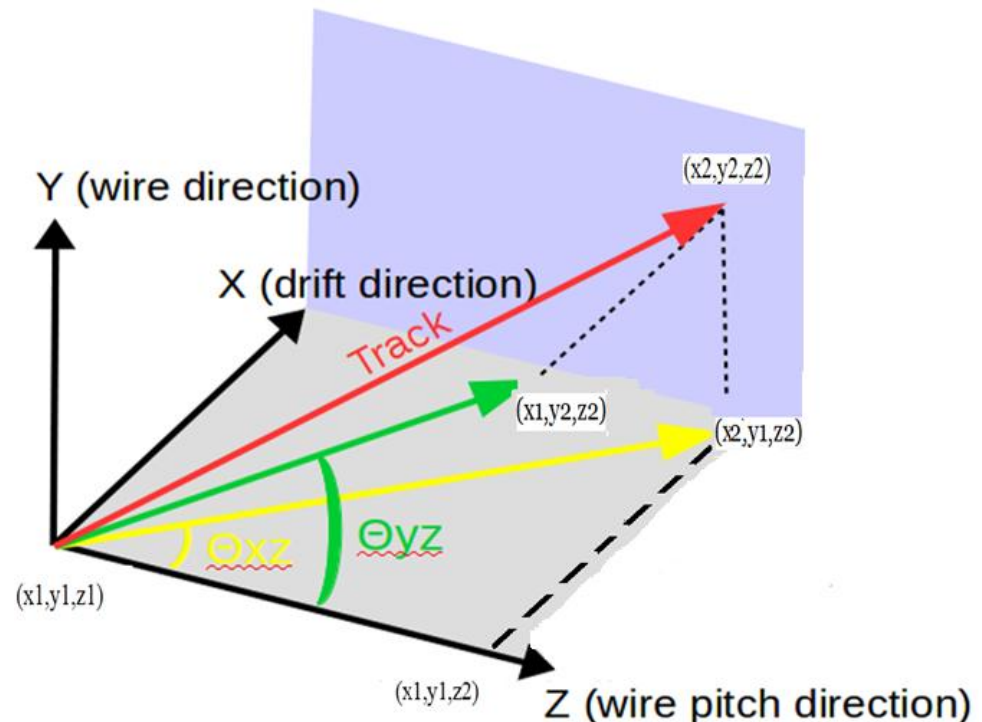
- Preliminary selection of good quality muon tracks
- Preliminary results on :
 - Zenith Distribution
 - Azimuth Distribution
 - Seasonal Variation of Muon Rate

with and without signal selection tracks.

- Summary – Future plans

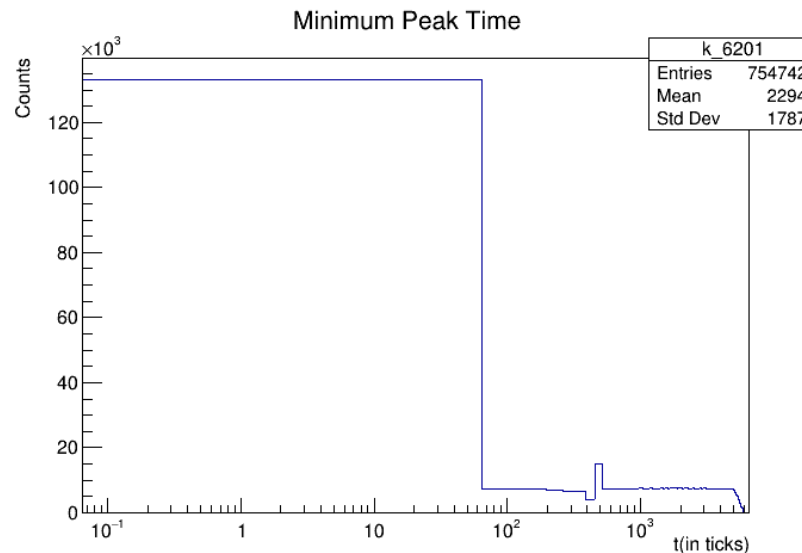
Muon Selection

- **Length Cut** : Perform a selection of tracks ($100\text{cm} < \text{length} < 1140\text{cm}$) such that delta-rays are reduced
- **Angular Cuts** : Tracks which are parallel to the wire planes or moving straight towards the wire planes are not reconstructed well. So, we remove those tracks based on the angle made by the projection of the track on the XZ and YZ planes with Z axis $115\text{deg} > \text{abs}(\theta_{\text{XZ}}) > 65\text{deg}$ and $-110\text{deg} < \text{abs}(\theta_{\text{YZ}}) < -70\text{deg}$



Muon Selection

- **APA Boundaries Cuts** : The majority of the tracks, which start or end around the APA boundaries, are broken. So, we removed the tracks with, **$226\text{cm} < Z < 236\text{cm}$** , for $Z=Z_{\text{end}}$ or Z_{start} Or **$456\text{cm} < Z < 472\text{cm}$** , for $Z=Z_{\text{end}}$ or Z_{start}
- **Removing Early Tracks** : Tracks present in the TPC before the beginning of the time window are removed based on the minimum value of hit peak Time (< 100 ticks) for all hits in a track

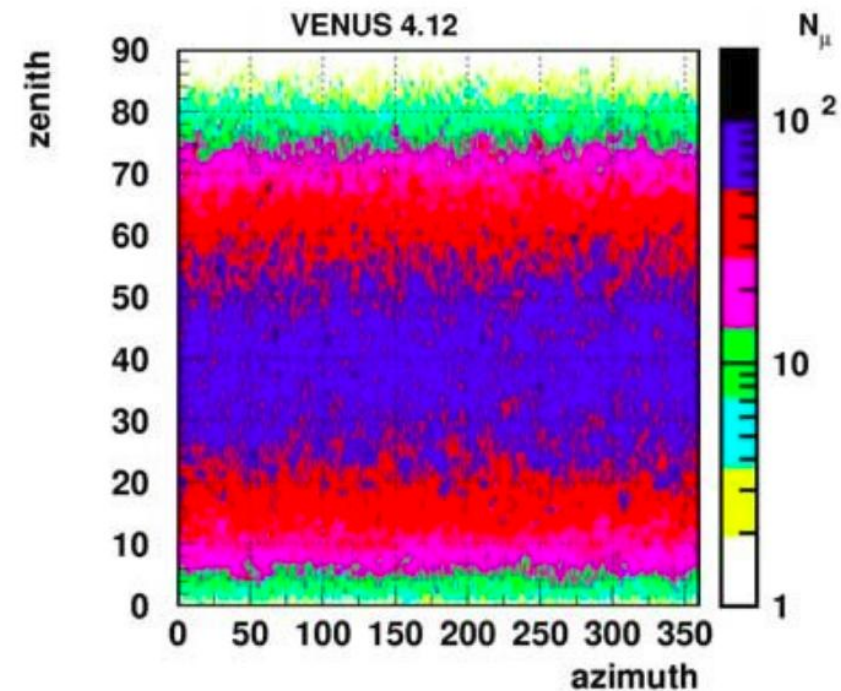
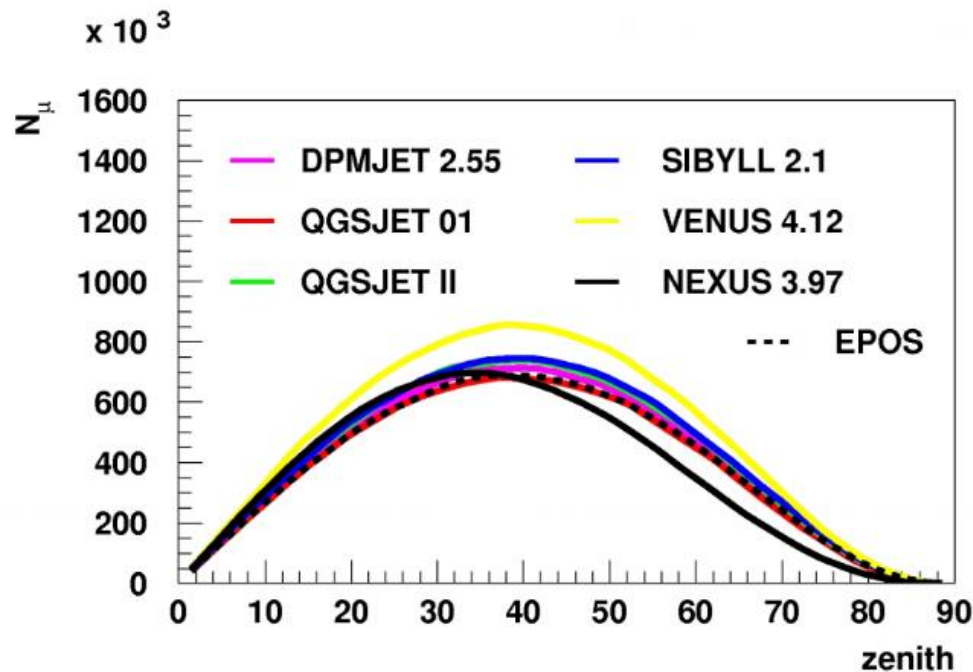


Additional criteria we will consider

- We will consider the following suggestions from the previous meeting, have not done so yet:
 - i) Voltage Stability
 - ii) Purity Variations
 - iii) APA3 issue
 - iv) Percentage of active FEMBs
 - v) Working on reconnecting broken tracks

Distribution of Zenith and Azimuth Angle

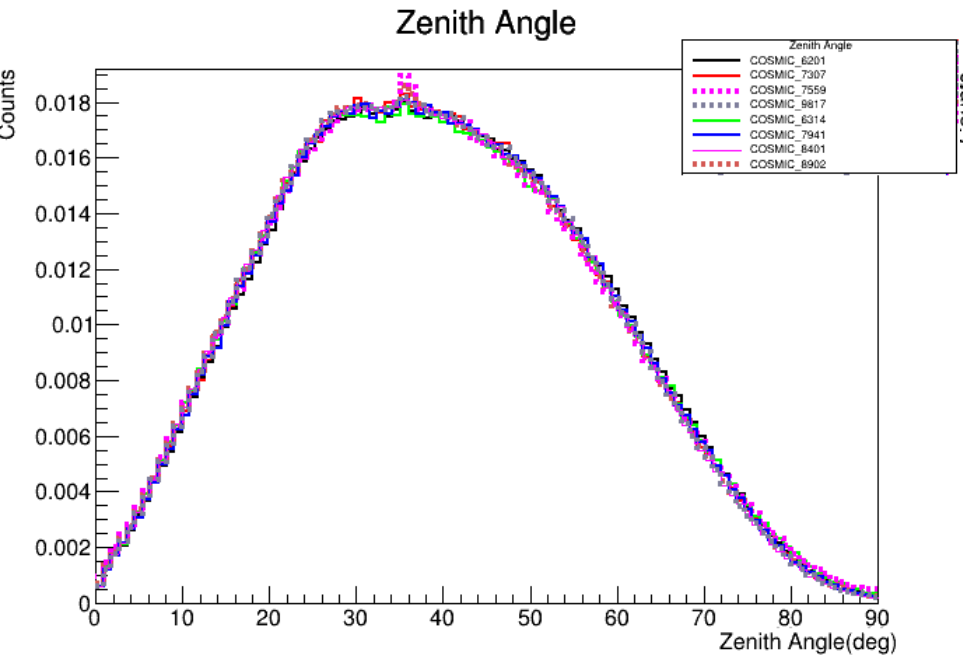
- Simulated zenith and azimuth distribution of cosmic ray muons **at the Earth's surface**



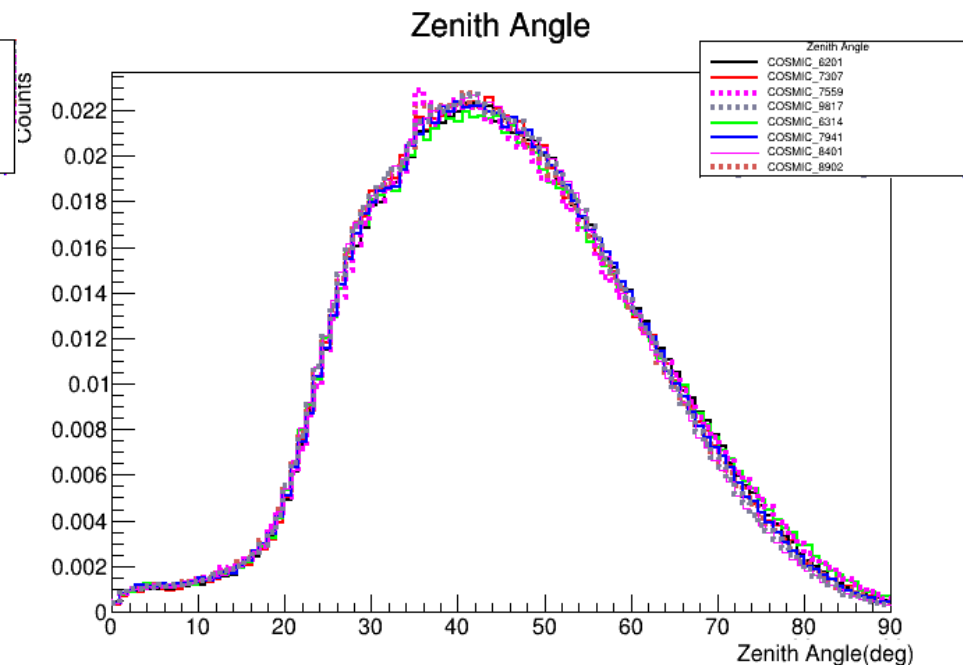
**Hashim, N. & Grupen, Claus. CERN-THESIS 2007-047 (22/06/2007)*

Distribution of Zenith Angle

Length cut only



All selection cuts imposed

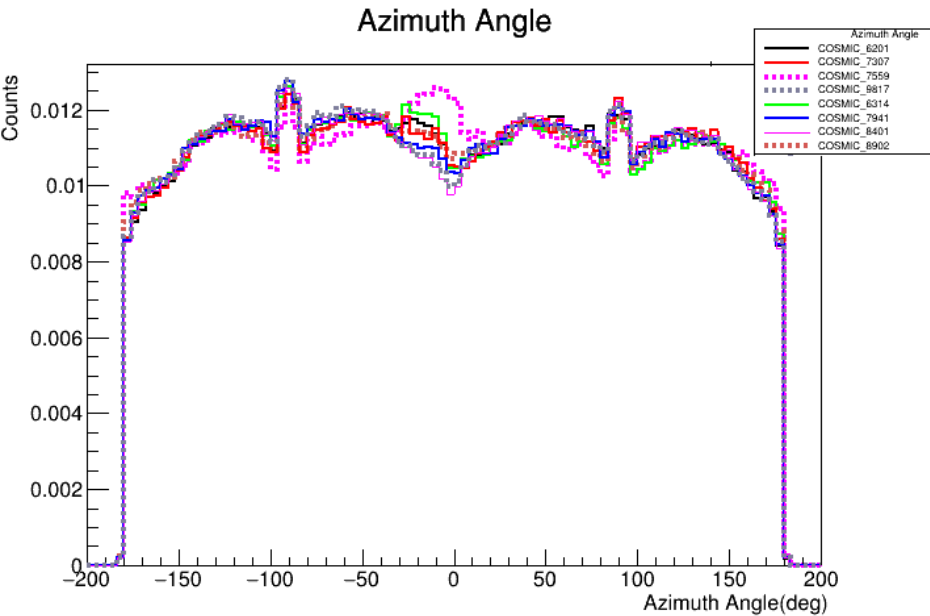


- The tracks, which had 0-25 degrees zenith angle, are reduced after performing the selection cuts additional to the track length.
- We see a similar distributions as the previous published results.

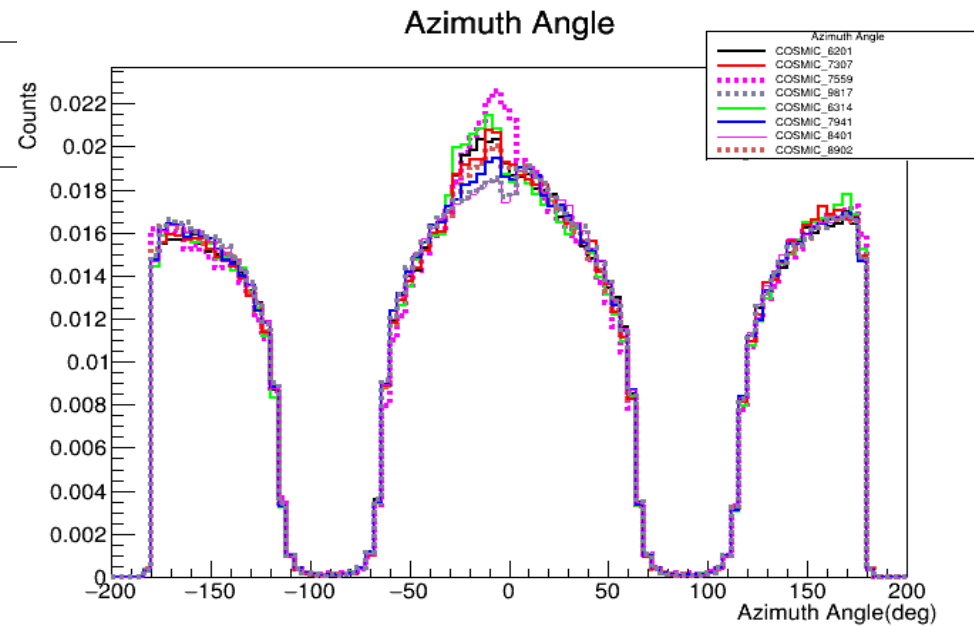
We used ***recob::Track::ZenithAngle ()***

Distribution of Azimuth Angle

Length cut only



All selection cuts imposed

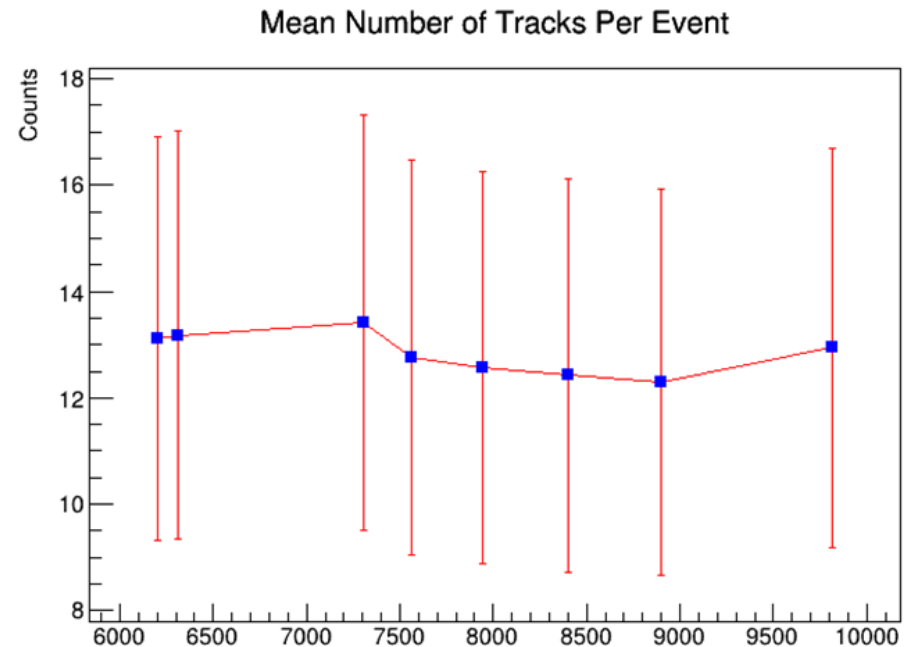
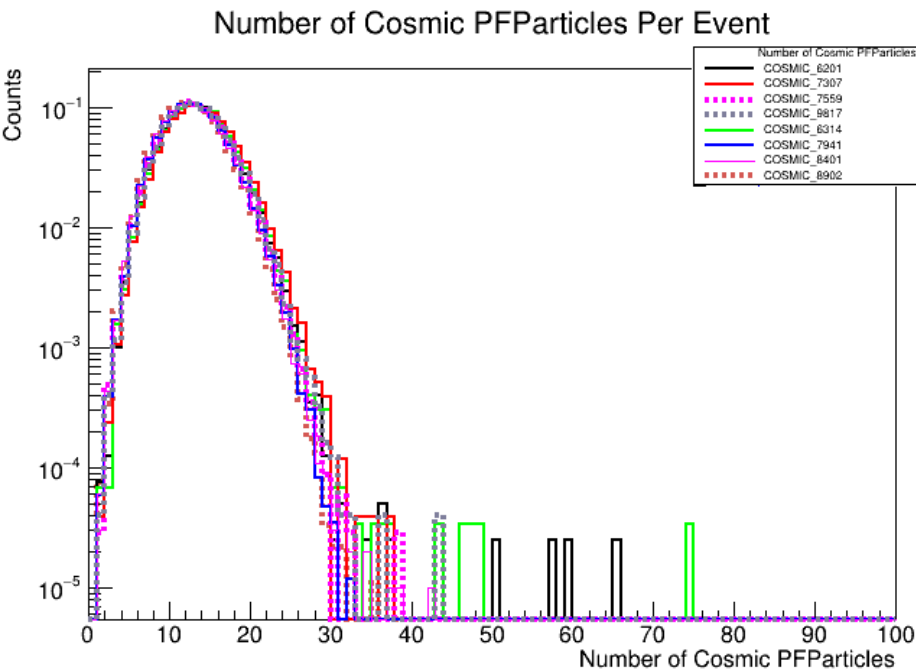


- The tracks, which had $\text{abs}(70-110)$ degrees azimuth angle, are removed by the angular cuts, and the distribution is severely shaped.
- We see a similar distributions as the previous published results.

We used ***recob::Track::AzimuthAngle ()***

Distribution of Number of Tracks

All criteria imposed

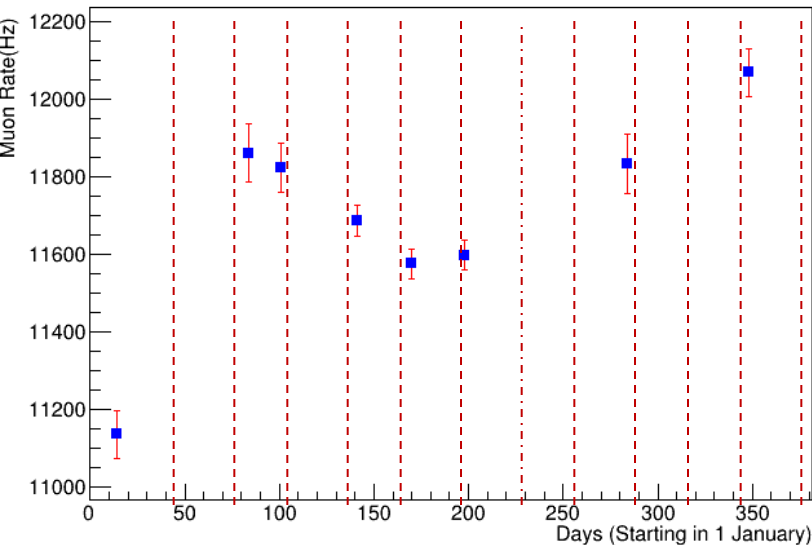


- The Error = RMS
- The X-axis represents the run's number

Seasonal Variation of Muon Rate

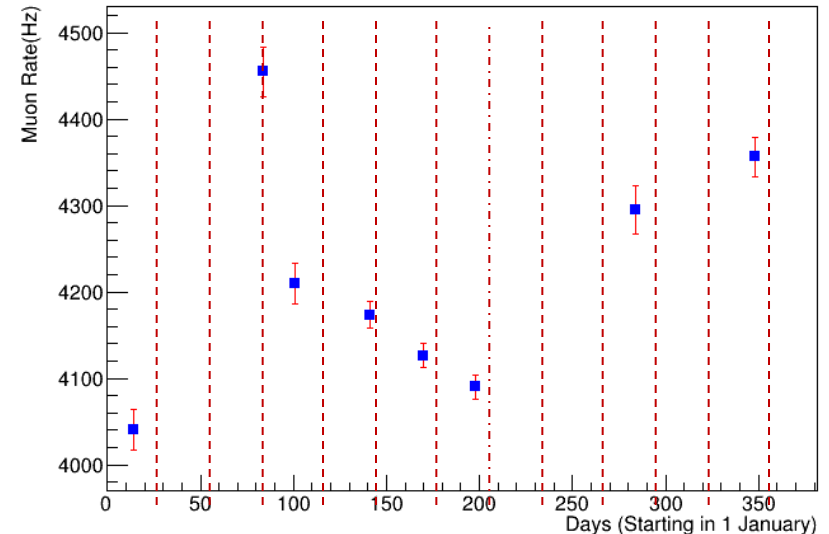
Length cut only

Seasonal Variation of Muon Rate



All selection cuts imposed

Seasonal Variation of Muon Rate



Muon Rate

Number of Tracks

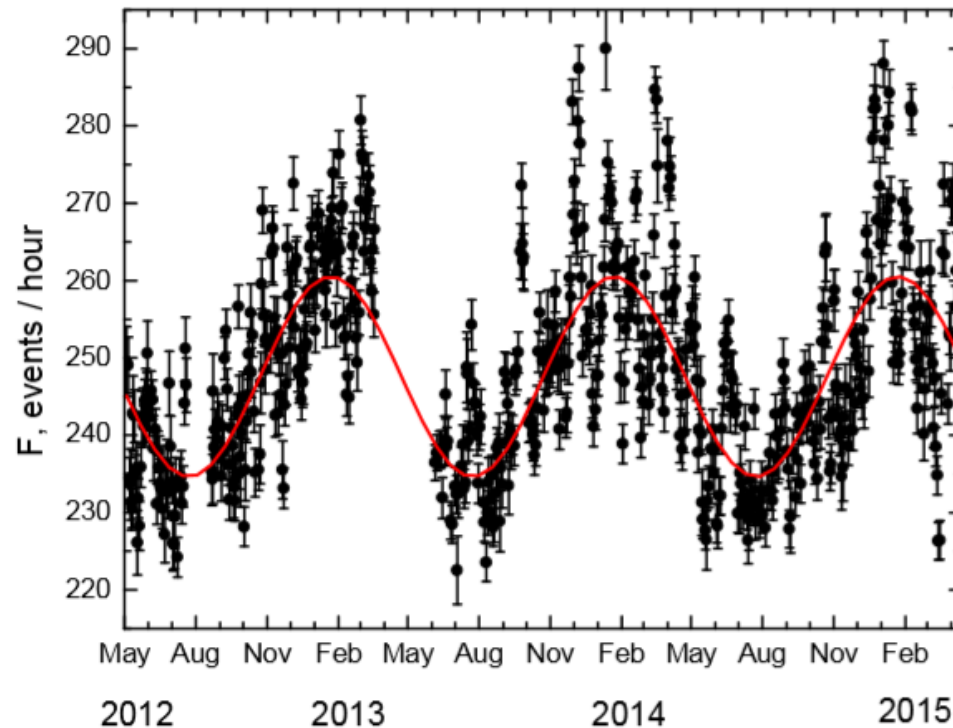
$(Time\ window) * (Number\ of\ Events)$

- The seasonal variation is similar to what other surface experiments have seen (see next slide) but we are still far from understanding especially January.

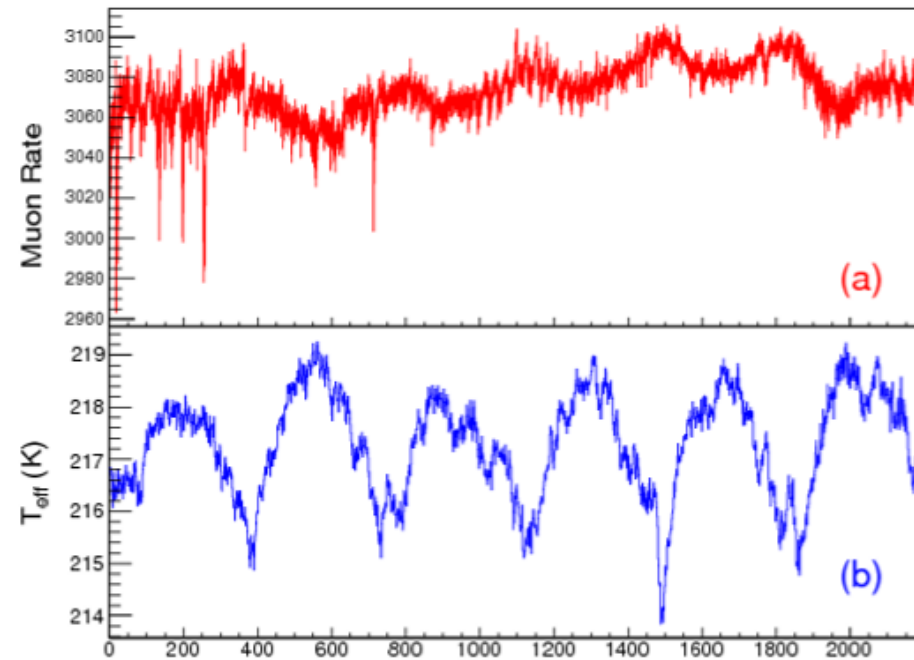
Error = Statistical

Seasonal Variation From Other Experiments

DECOR



GRAPES-3



DÉCOR : *J.Phys.Conf.Ser.* 675 (2016) 3, 032034
 GRAPES-3: PoS(ICRC2017)304

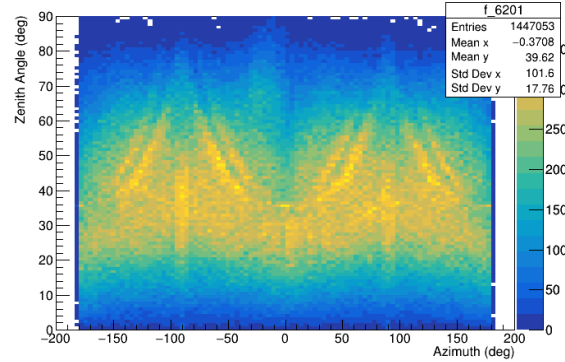
Summary – Future plans

- The preliminary azimuth and zenith angle distribution of cosmic muons in ProtoDUNE agree with expectations (published results).
- Preliminary studies of cosmic events, indicate seasonal variation in muon rate.
- In the future we will check several detector conditions: Purity variations, APA3 issue, ...
- We will also work on reconnecting broken tracks
- Any suggestions, comments, corrections would be more than welcome !

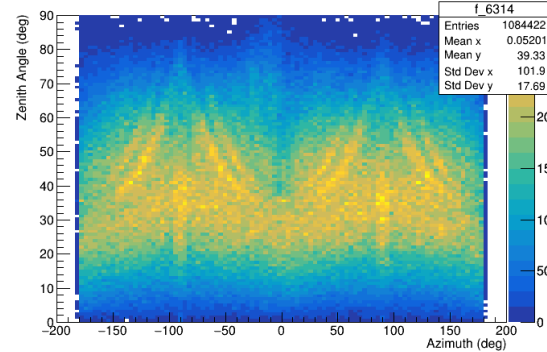
Back Up

Zenith vs Azimuth

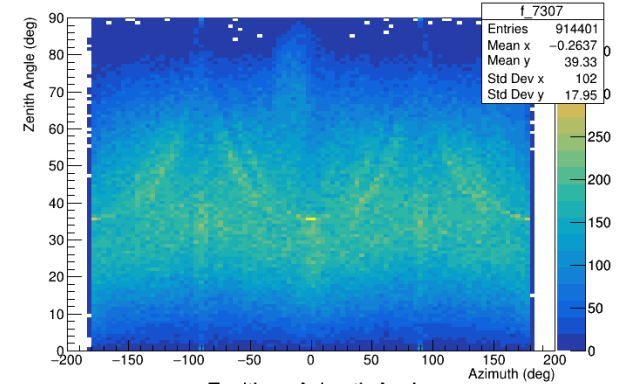
Zenith vs Azimuth Angle



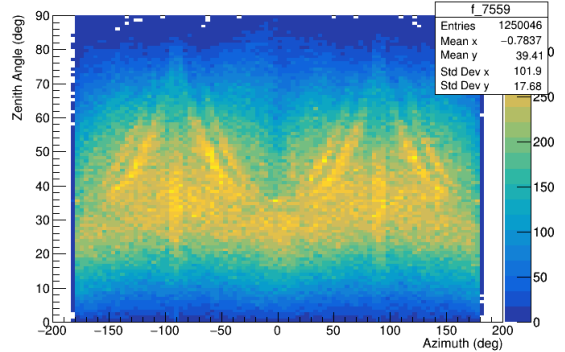
Zenith vs Azimuth Angle



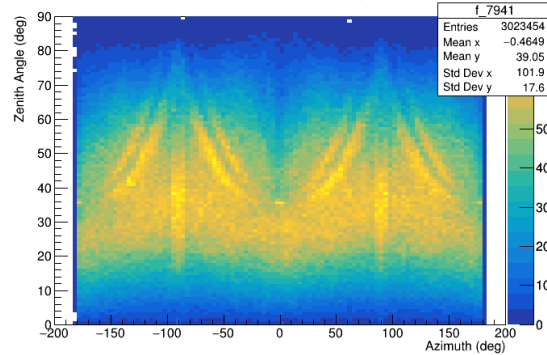
Zenith vs Azimuth Angle



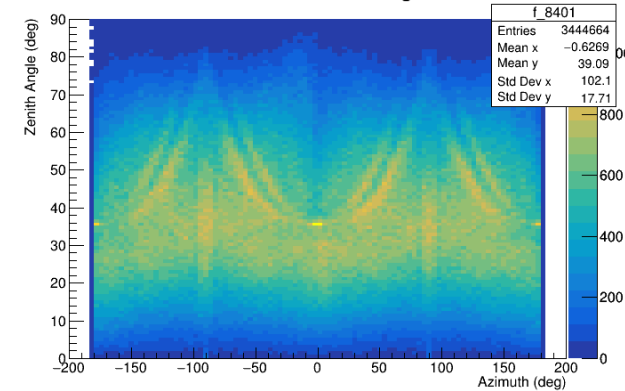
Zenith vs Azimuth Angle



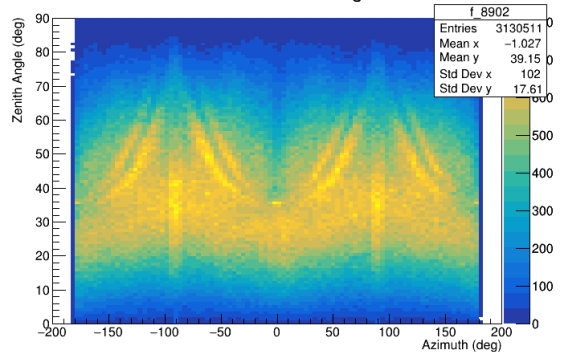
Zenith vs Azimuth Angle



Zenith vs Azimuth Angle



Zenith vs Azimuth Angle



Zenith vs Azimuth Angle

