Hybrid long term performance

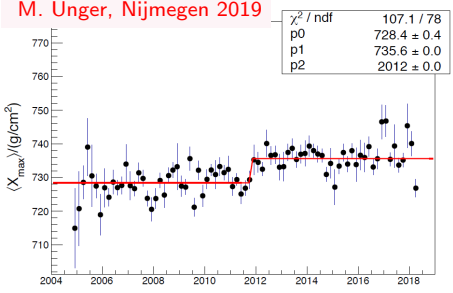
collection of plots

Alexey Yushkov

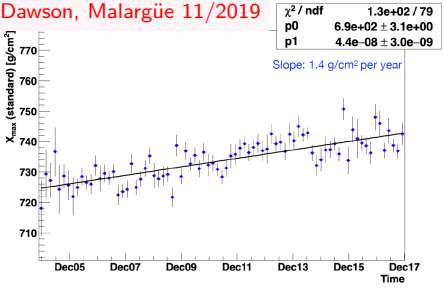
Fyzikální ústav AV ČR

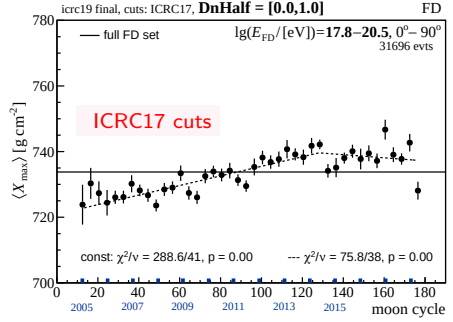
$X_{\max}$, $\lg(E/\mathrm{eV}) = 17.8 - 20.5$

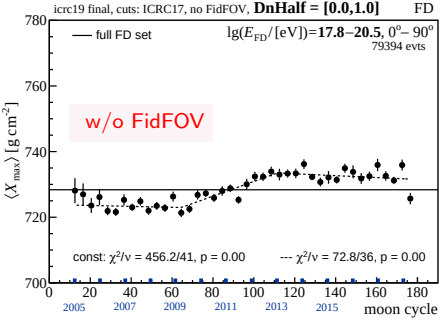
M. Unger, Nijmegen 2019



B. Dawson, Malargüe 11/2019



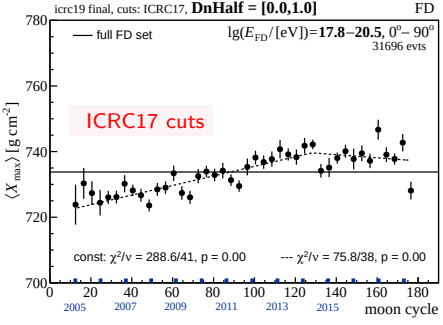


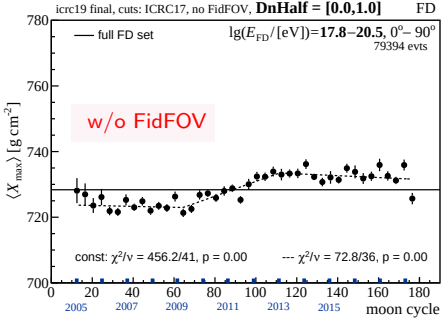


$X_{\max}$, $\lg(E/\mathrm{eV}) = 17.8 - 20.5$

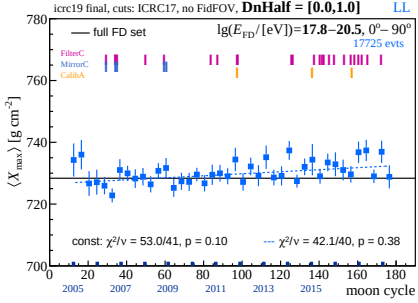
w/o FidFOV: $\langle X_{\max} \rangle$ is $\approx 5\ \mathrm{g\,cm^{-2}}$ smaller, but similar trend

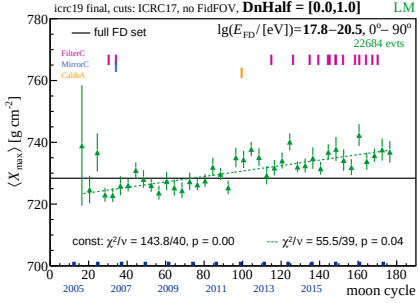
w/o FidFOV set is used further, 2.5 times more events

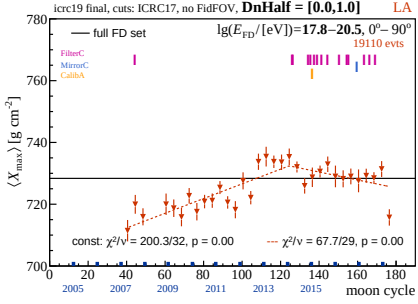


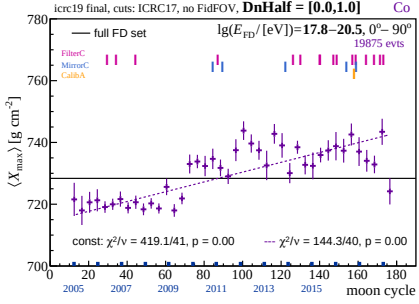


X_{max}, individual FD sites



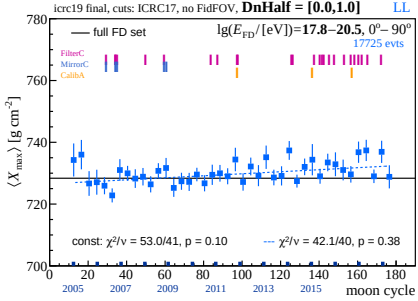


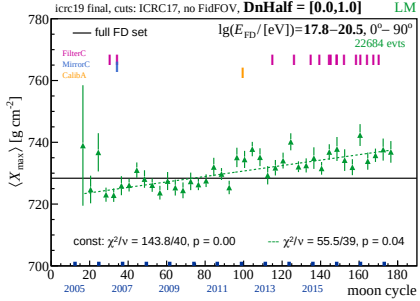




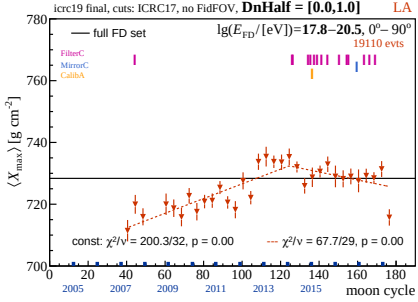
Marks:
Filter cleanings
Mirror cleanings
CalA changes

X_{max}, individual FD sites

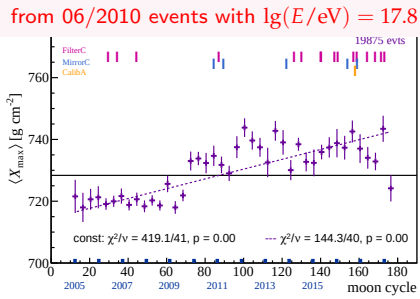




Marks:
Filter cleanings
Mirror cleanings
CalA changes

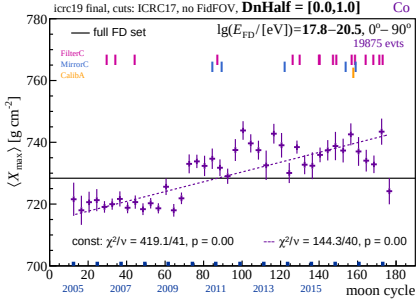


from 06/2010 events with $\lg(E/\mathrm{eV}) = 17.8 - 18.1$ are in HeCo!

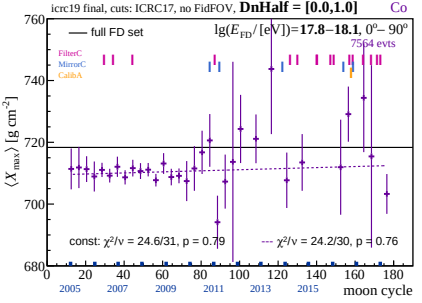


Co: individual energy bins

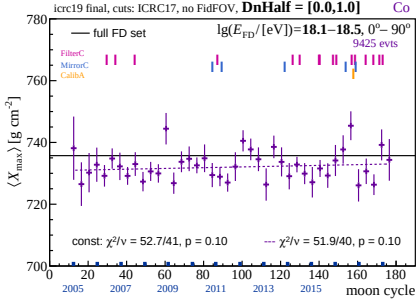
17.8 – 20.5



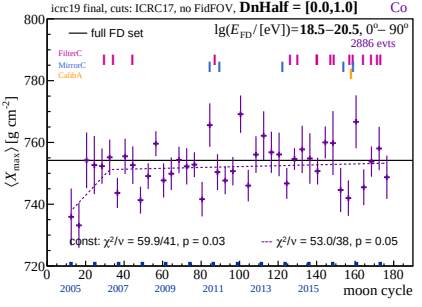
17.8 – 18.1



18.1 – 18.5

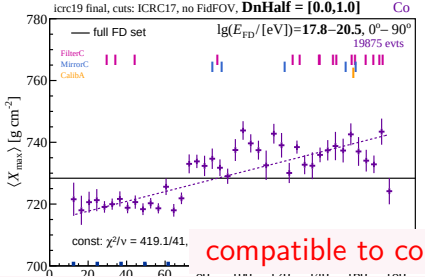


18.5 – 20.5

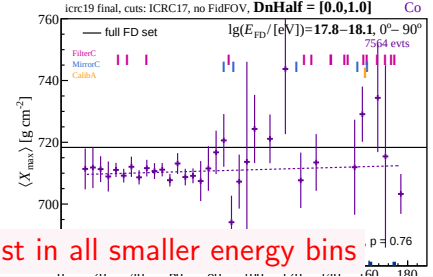


Co: individual energy bins

17.8 – 20.5



17.8 – 18.1



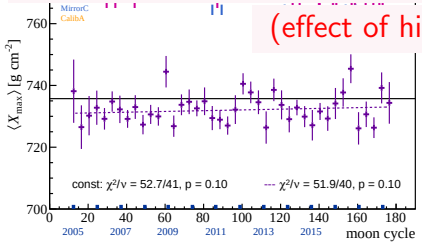
compatible to const in all smaller energy bins

'jump' is just due to removal of events with $\lg(E/\mathrm{eV}) = 17.8 - 18.1$ after 06/2010

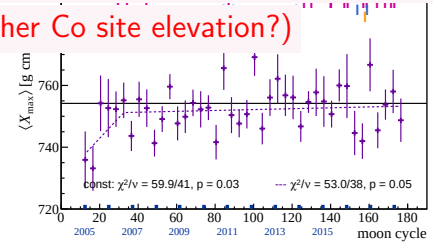
at lower energies $\langle X_{\mathrm{max}} \rangle$ is systematically below the mean of the full FD

(effect of higher Co site elevation?)

18.1 – 18.5

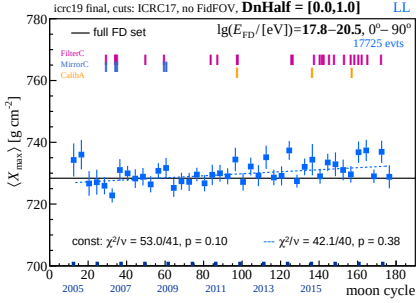


18.5 – 20.5

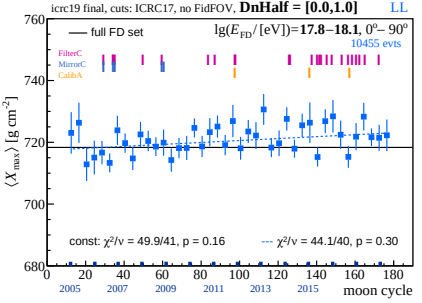


LL: individual energy bins

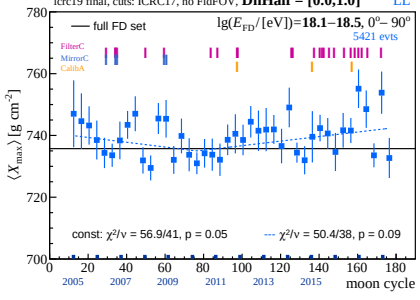
17.8 – 20.5



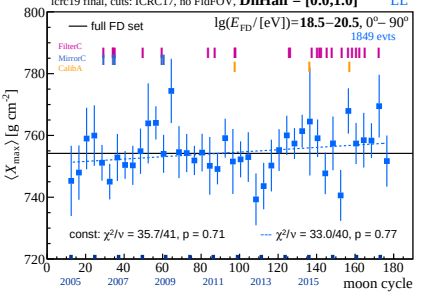
17.8 – 18.1



18.1 – 18.5

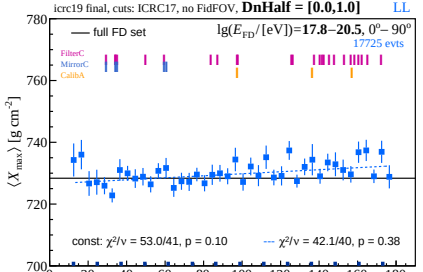


18.5 – 20.5

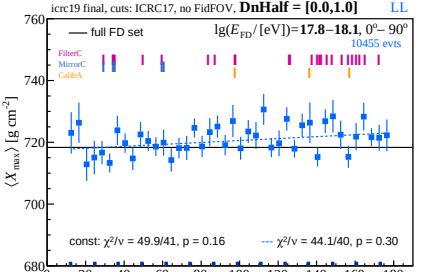


LL: individual energy bins

17.8 – 20.5

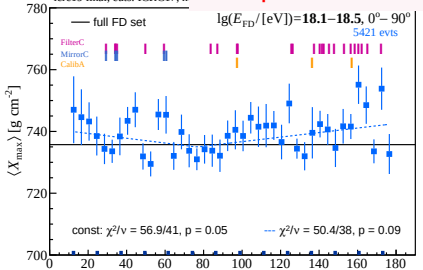


17.8 – 18.1

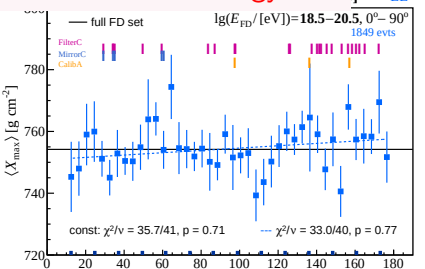


compatible to const in all smaller energy bins

18.1 – 18.5

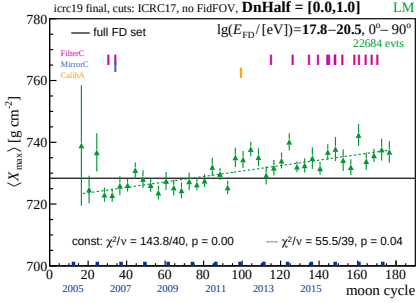


18.5 – 20.5

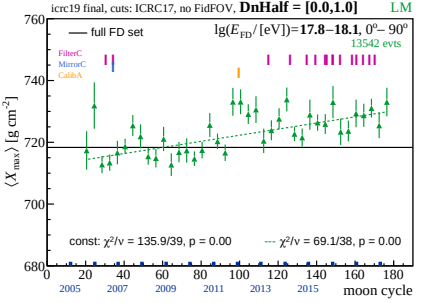


LM: individual energy bins

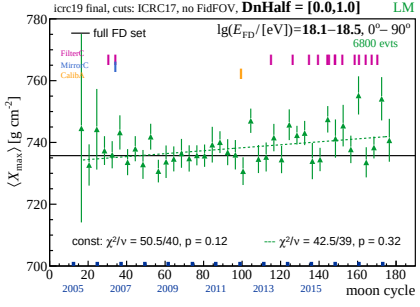
17.8 – 20.5



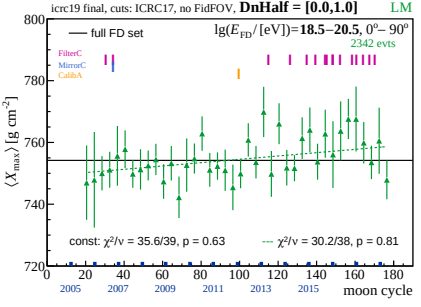
17.8 – 18.1



18.1 – 18.5

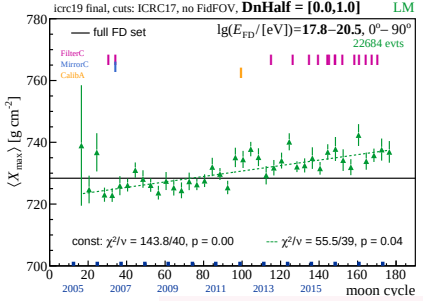


18.5 – 20.5

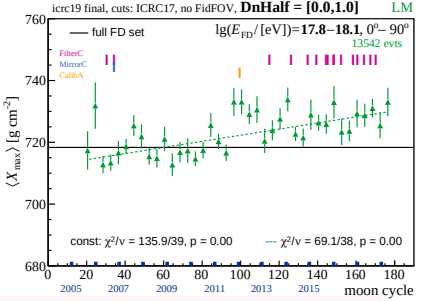


LM: individual energy bins

17.8 – 20.5

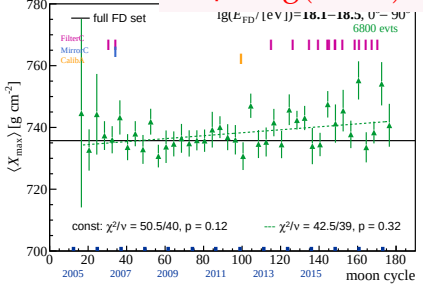


17.8 – 18.1

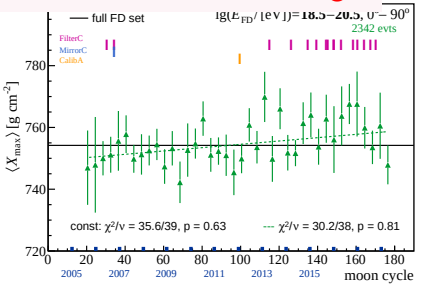


step in $\lg(E/\mathrm{eV}) = 17.8 - 18.1$ at CalA change?

18.1 – 18.5

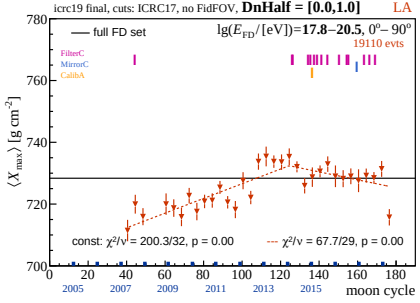


18.5 – 20.5

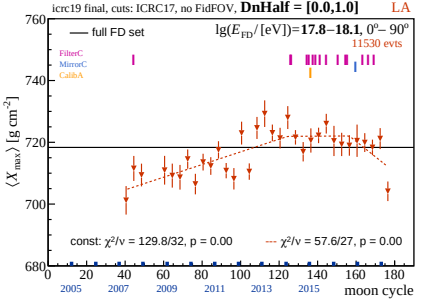


LA: individual energy bins

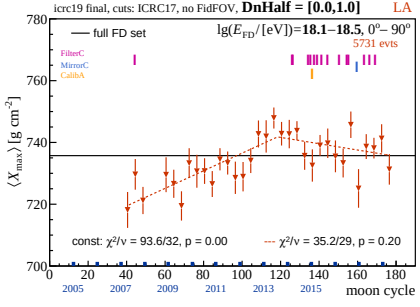
17.8 – 20.5



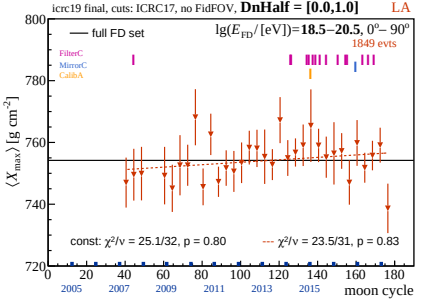
17.8 – 18.1



18.1 – 18.5

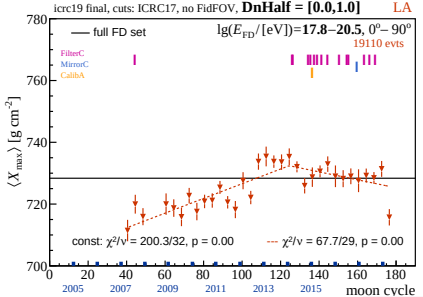


18.5 – 20.5

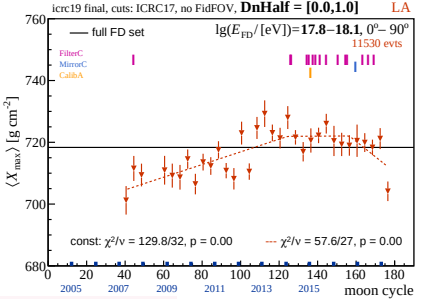


LA: individual energy bins

17.8 – 20.5

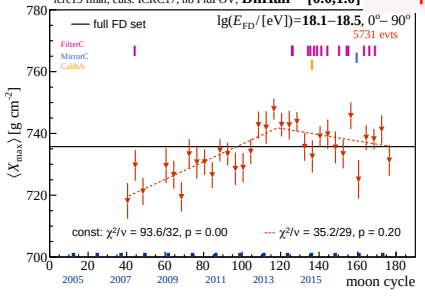


17.8 – 18.1

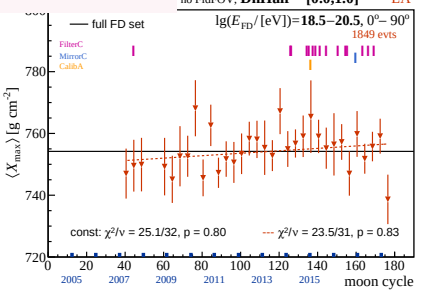


step around 2013?

18.1 – 18.5

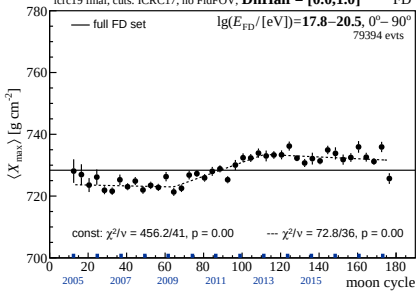


18.5 – 20.5

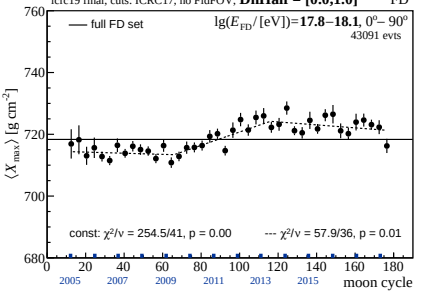


FD: individual energy bins

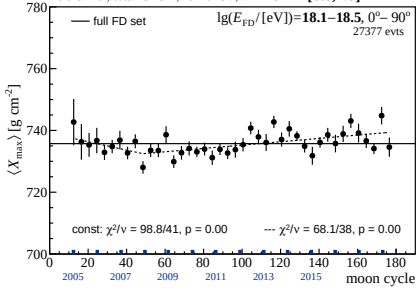
17.8 – 20.5



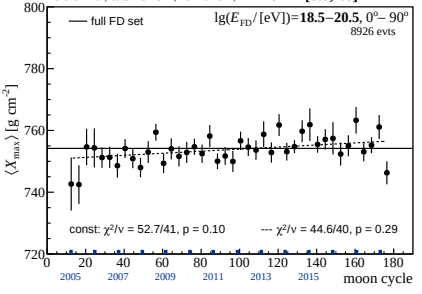
17.8 – 18.1



18.1 – 18.5

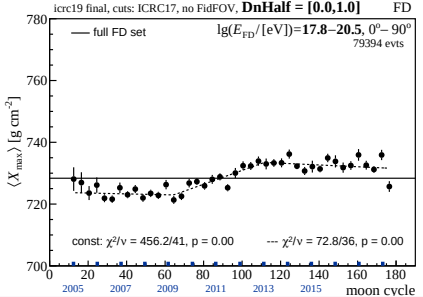


18.5 – 20.5

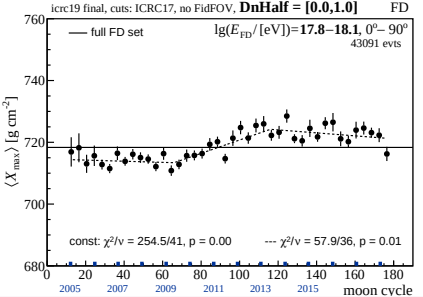


FD: individual energy bins

17.8 – 20.5



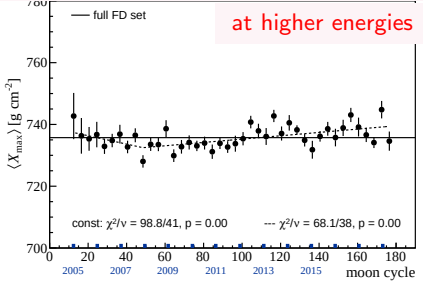
17.8 – 18.1



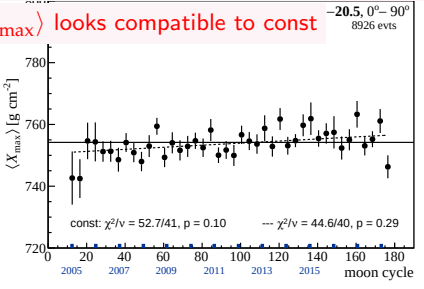
$\lg(E/\mathrm{eV}) = 17.8 - 18.1$: step-like (?) LA & LM contributions, plus removal of Co events with lower $\langle X_{\max} \rangle$

at higher energies $\langle X_{\max} \rangle$ looks compatible to const

18.1 – 18.5



18.5 – 20.5

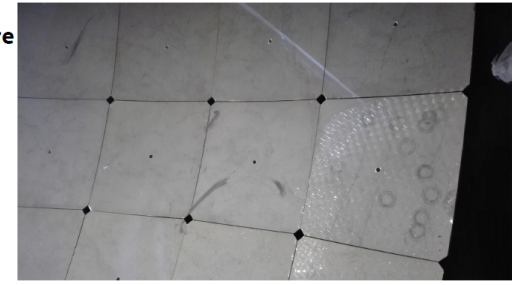


another one bites the dust

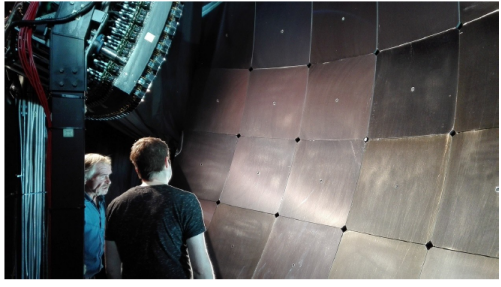
Mirror Cleaning at LL #4

5th April 2019

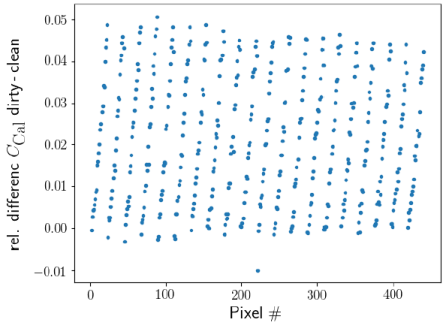
Before

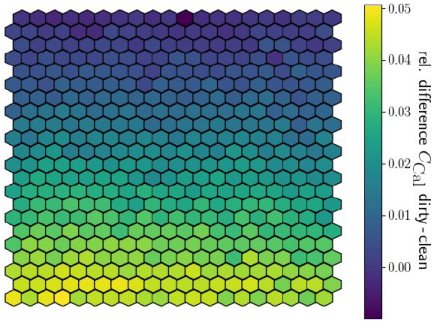


After



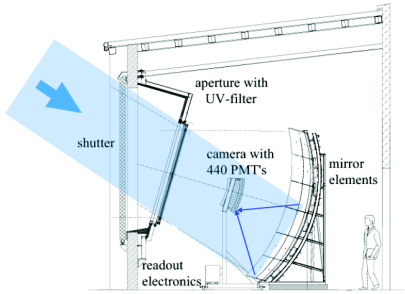
Mirror Cleaning

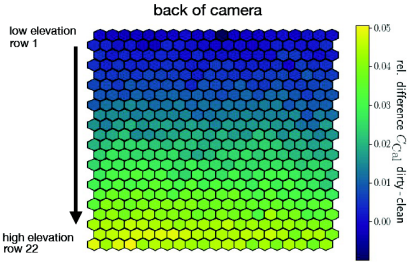




Up to 5% effect

Predominantly sensitive to absorption





To correct for the dust effect, impose a correction to the calibration constants, increasing their value (photons/ADC) with increasing elevation.

Imposing a universal calibration constant correction of 2% (0%) per year for row 22 (row 1) we correct the

- 1% per year drift in energy (Lorenzo, Phong)
- 1.4 g/cm^2 per year drift in X_{max}

Dust effects in data: few naive ideas

Energy scale evolution

are events in cleaner (upper) mirror parts more stable?

$X_{\max}$ evolution (though there might be none at higher energies)

are there subsets with different evolution? (systematics for Galactic plane anisotropy?)

Method

Separate events using fraction of charge deposited in top 11 camera rows

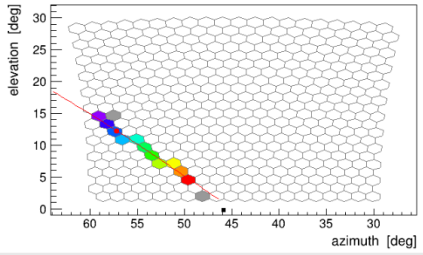
Camera top = Mirror top = Lower elevations

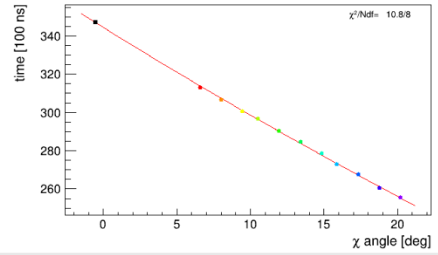
Variable DnHalf: fraction of charge deposited in lower elevation

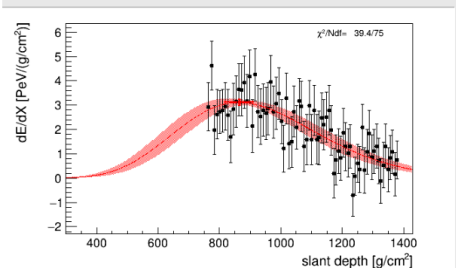
3 classes of events with DnHalf $< 20\%$ (high), $40 - 60\%$ (cross), $> 80\%$ (low)

(using reconstructed pixels `ePulseRecPix`)

Events with DnHalf= 1 (fully in lower elevations)



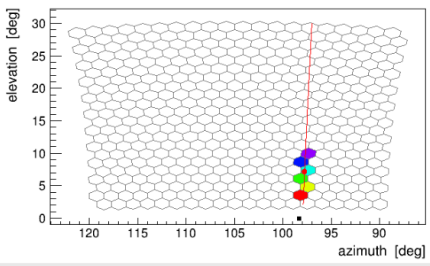


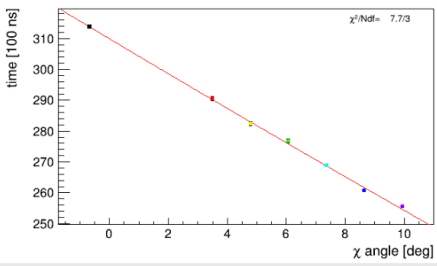


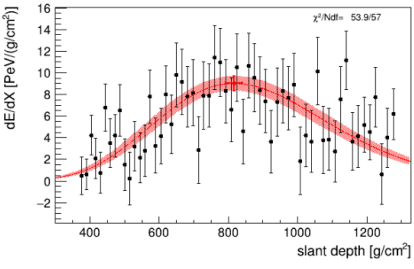
Event Info | Pixels | PCGF

run 864, event 1056
time stamp: 827292608 s 130171826 ns
Trigger: 'Physics - Int or L/R trigger', 'Shower Candidate'
in Los Morados mirror 2 (in DAQ: 1 2 3 4 5 6)
geometry: hybrid, station 1005 (ToT), showerPlaneDistance = 504 m
(θ, ϕ) = (53.1±1.1, 151.9±0.7) deg
(x, y) = (17.77±0.14, 10.00±0.11) km
R_p = 12.72 ± 0.10 km
profile: 4-parameter Gaisser-Hillas (type: USP)
E = (2.09 ± 0.12 ± 0.12) × 10^{18} eV
X_{max} = 865 ± 46 g/cm^2
$(dE/dX)_{max}$ = 3.11 ± 0.13 PeV/(g/cm^2)
(λ, X_0, L) = (58, -31, 229±8) g/cm^2, R = 0.26±0.04
Cherenkov-fraction = 20%, rmva=37 deg.
databases:
Mie attenuation: measured (h<9.6 km, VAOD at 3km: 0.04)
LIDAR: no data ; CloudCam: max(ζ)=(0/0)% (elev>5.5^o); CloudMap: max=0%
molecular profile: GDAS; time correction: good

Events with DnHalf= 1 (fully in lower elevations)



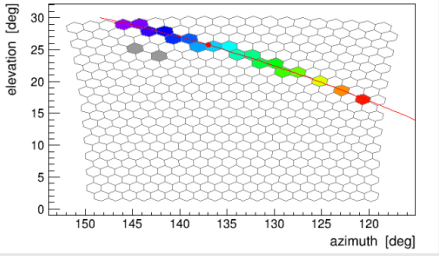


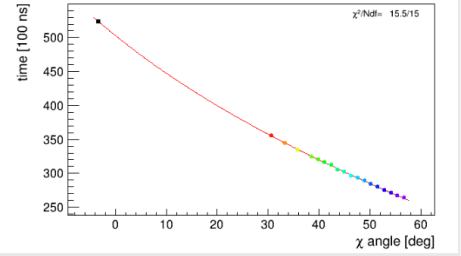


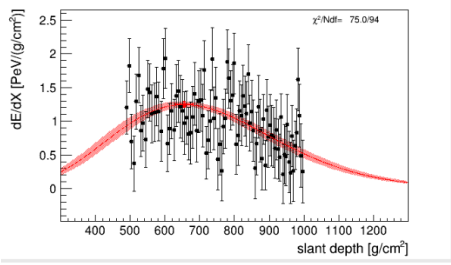
Event Info | Pixels | PCGF

run 910, event 1001
time stamp: 801967288 s 772785674 ns
Trigger: 'Physics - Int or L/R trigger', 'Shower Candidate'
in Los Leones mirror 4 (in DAQ: 1 2 3 4 5 6)
geometry: hybrid, station 817 (ToT), showerPlaneDistance = 361 m
(θ, φ) = (54.1±0.7, 66.8±2.1) deg
(x, y) = (-6.78±0.23, 0.9±0.23) km
R_p = 17.78 ± 0.35 km
profile: 4-parameter Gaisser-Hillas (type: USP)
E = (6.48 ± 0.44 ± 0.41) × 10^{18} eV
X_{max} = 816 ± 25 g/cm²
$(dE/dX)_{max}$ = 9.01 ± 0.67 PeV/(g/cm²)
(λ, X_0, L) = (62, -162, 247±10) g/cm², R = 0.25±0.05
Cherenkov-fraction = 19%, mva=23 deg.
databases:
Mie attenuation: measured (h<16.4 km, VAOD at 3km: 0.00)
LIDAR: no data ; CloudCam: max(ζ)=(0/0)% (elev>5.5^°); CloudMap: no data
molecular profile: GDAS; time correction: good

Events with DnHalf= 0 (fully in higher elevations)



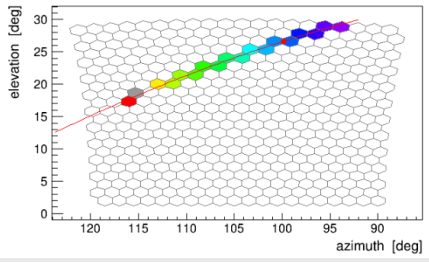


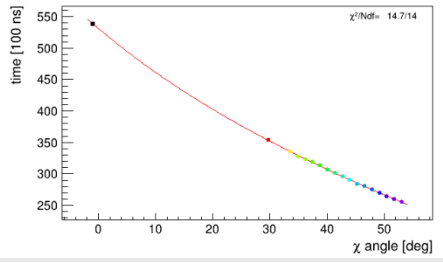


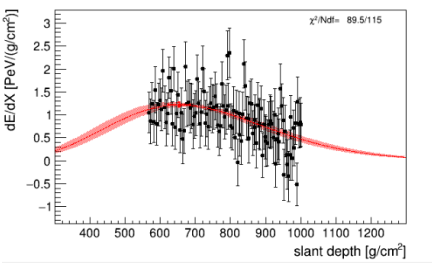
Event Info | Pixels | PCGF

run 1469, event 21792
time stamp: 866089299 s 367026472 ns
Trigger: 'Physics - Int or L/R trigger', 'Shower Candidate'
in Los Morados mirror 5 (in DAQ: 1 2 3 4 5 6)
geometry: hybrid, station 726 (ToT), showerPlaneDistance = 603 m
(θ, ϕ) = (54.4±0.5, 247.2±1.2) deg
(x, y) = (12.57±0.07, -0.38±0.13) km
R_p = 10.04 ± 0.04 km
profile: 4-parameter Gaisser-Hillas (type: USP)
$E = (8.73 \pm 0.46 \pm 0.44) \times 10^{17}$ eV
$X_{max} = 655 \pm 25$ g/cm^2
$(dE/dX)_{max} = 1.25 \pm 0.04$ PeV/(g/cm^2)
(λ, X_0, L) = (61, -236, 232±9) g/cm^2, R = 0.26±0.05
Cherenkov-fraction = 8%, mva=36 deg.
databases:
Mie attenuation: measured (h<8.4 km, VAOD at 3km: 0.00)
LIDAR: h(cloud)=100.0 km, 0%; CloudCam: max(ζ)=(0/0)% (elev>5.5°); CloudMap: no data
molecular profile: GDAS; time correction: good

Events with DnHalf= 0 (fully in higher elevations)



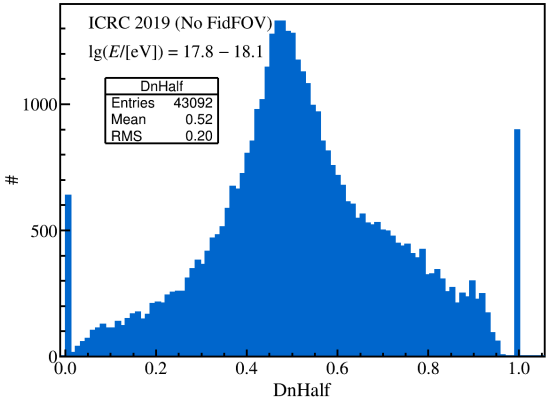


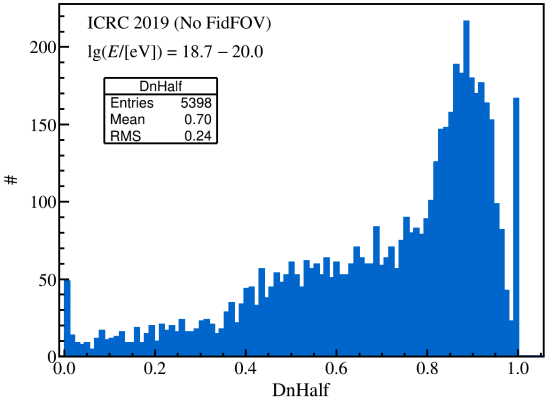


Event Info | Pixels | PCGF

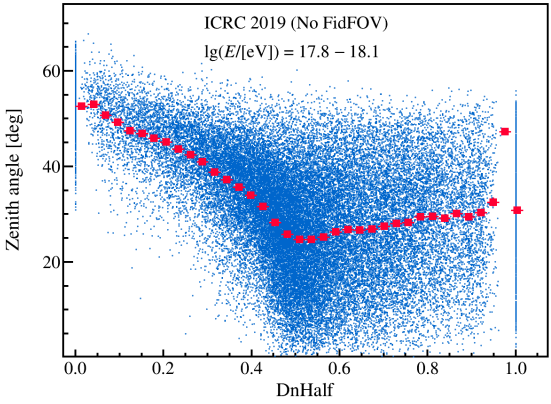
run 1519, event 5849
time stamp: 868583370 s 879036288 ns
Trigger: 'Physics - Int or L/R trigger', 'Shower Candidate'
in Los Morados mirror 4 (in DAQ: 1 2 4 5 6)
geometry: hybrid, station 541 (ToT), showerPlaneDistance = 338 m
(θ, ϕ) = (53.1±0.6, 97.7±1.4) deg
(x, y) = (11.25±0.08, -8.56±0.16) km
R_p = 10.92 ± 0.05 km
profile: 4-parameter Gaisser-Hillas (type: USP)
$E = (8.23 \pm 0.53 \pm 0.42) \times 10^{17}$ eV
X_{max} = 655 ± 31 g/cm^2
$(dE/dX)_{max}$ = 1.22 ± 0.05 PeV/(g/cm^2)
$(\lambda, X_\circ, L)$ = (57, -231, 225±10) g/cm^2, R = 0.25±0.05
Cherenkov-fraction = 7%, mva=48 deg.
databases:
Mie attenuation: measured (h<10.1 km, VAOD at 3km: 0.00)
LIDAR: h(cloud)=10.2 km, 79%; CloudCam: max(ζ)=(100/0)% (elev>5.5^°); CloudMap: no data
molecular profile: GDAS; time correction: good

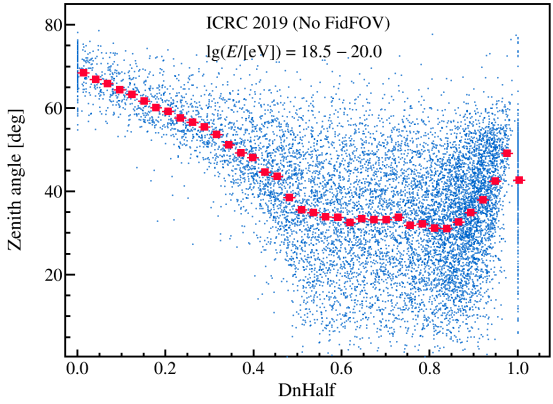
DnHalf distributions



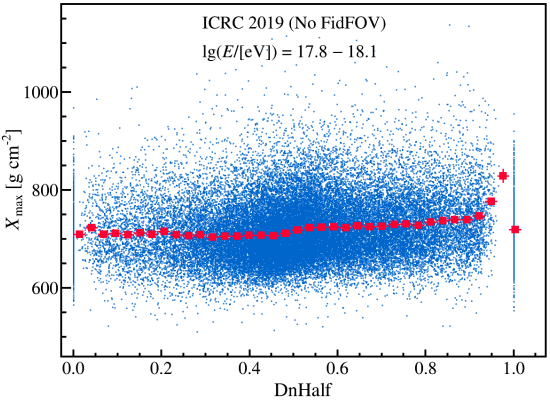


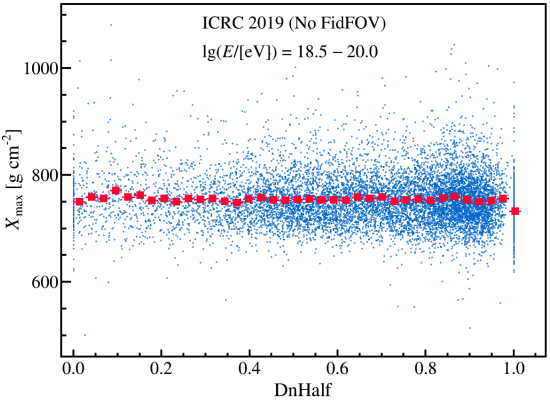
DnHalf distributions



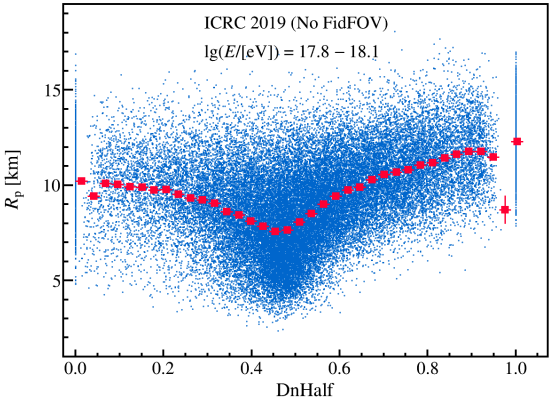


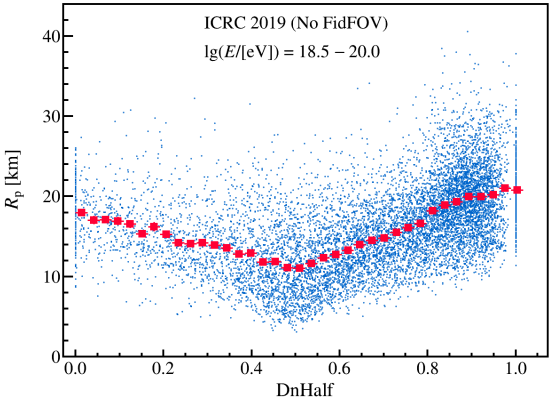
DnHalf distributions





DnHalf distributions

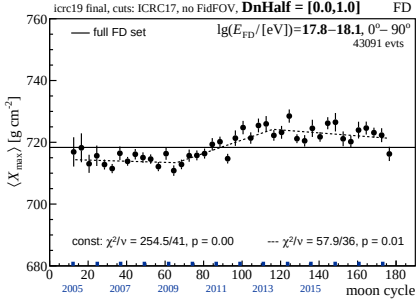




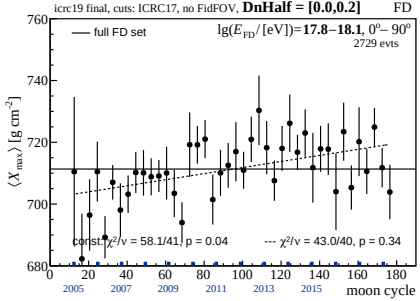
FD: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

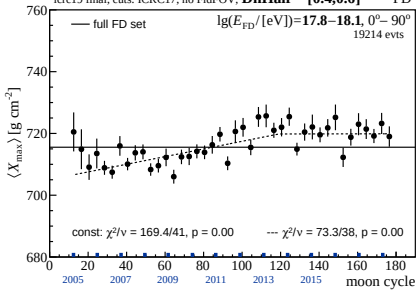
full



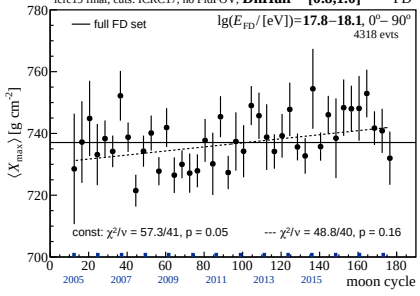
high



cross



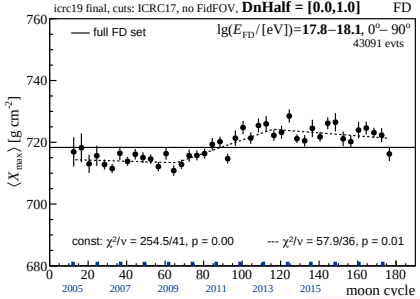
low



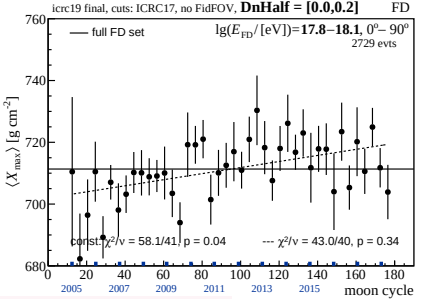
FD: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

full

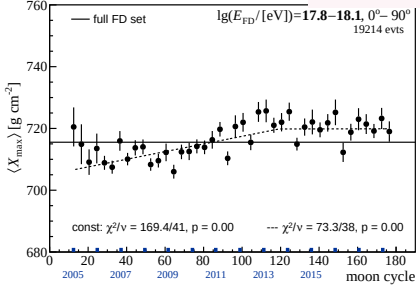


high

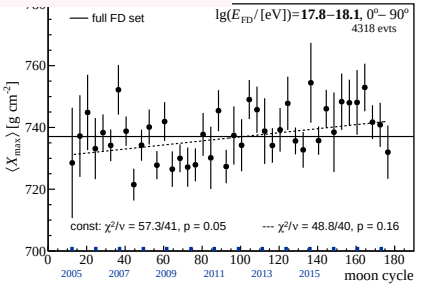


all subsets look compatible

cross



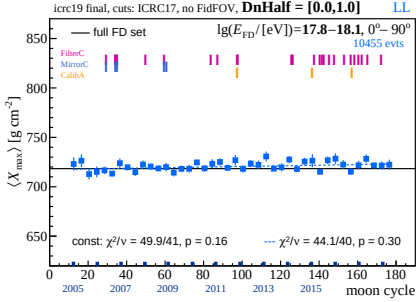
low



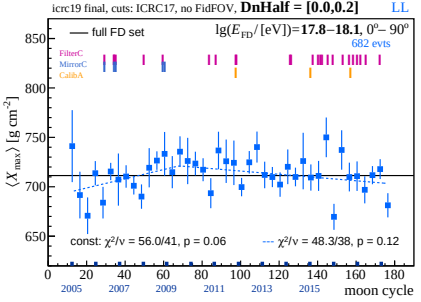
LL: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

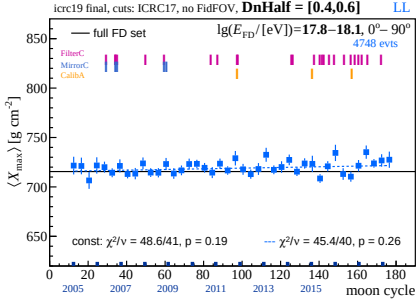
full



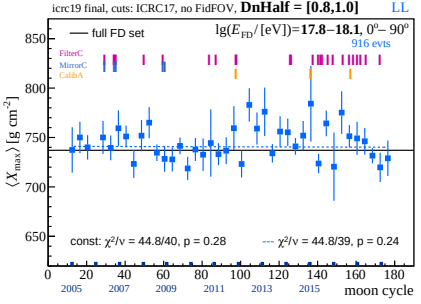
high



cross



low



LL: full mirror, high-, cross-, low-elevation events

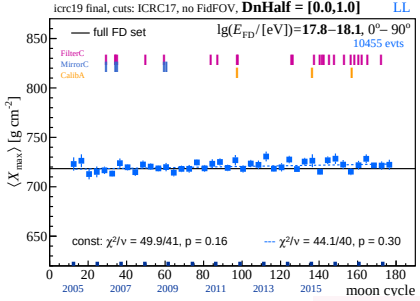
$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

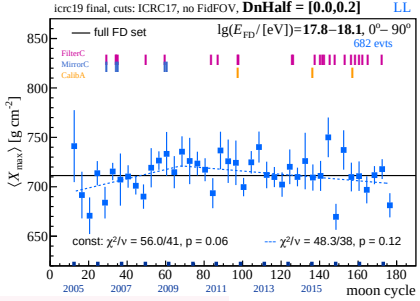
full

high

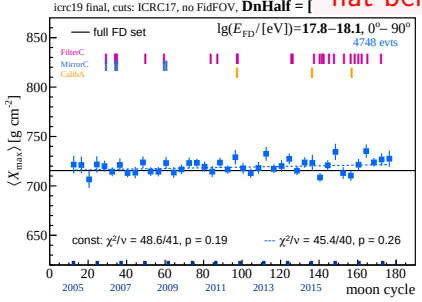
cross

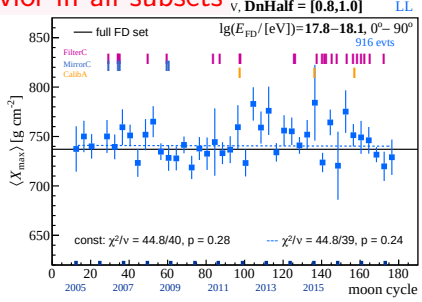
low





flat behavior in all subsets

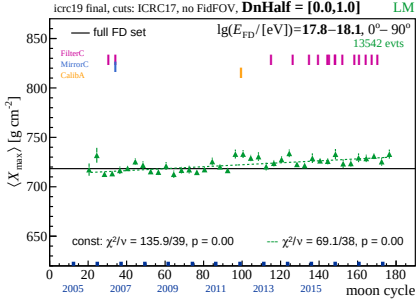




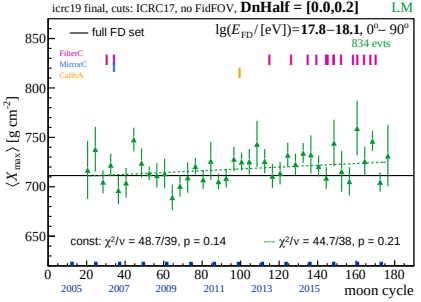
LM: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

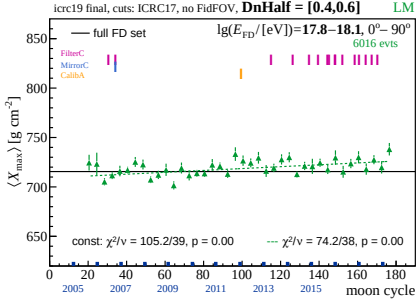
full



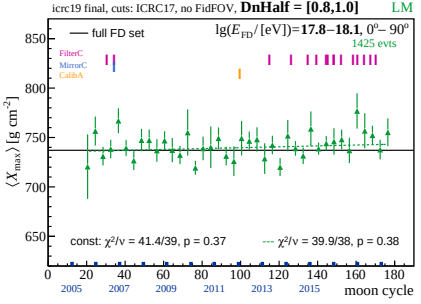
high



cross



low



LM: full mirror, high-, cross-, low-elevation events

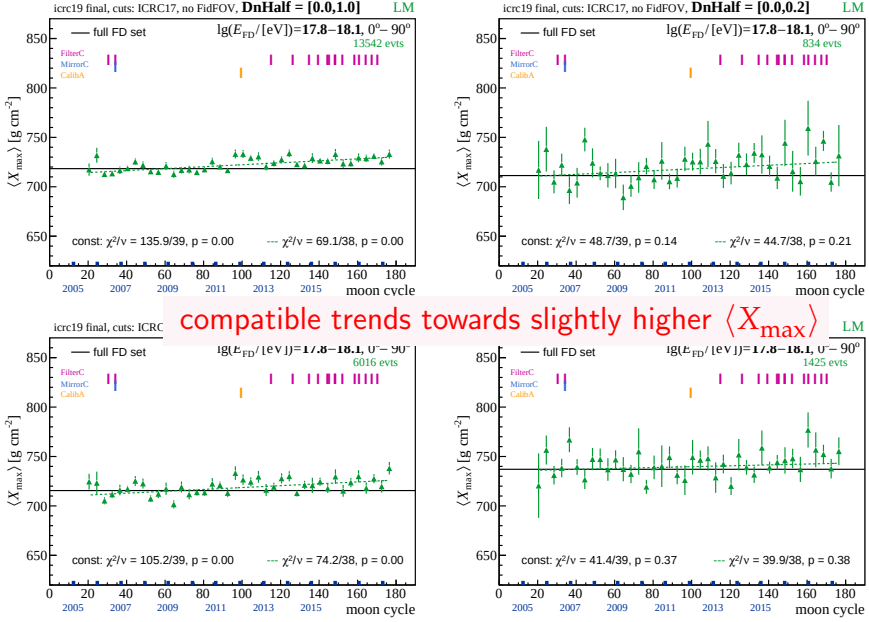
$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

full

high

cross

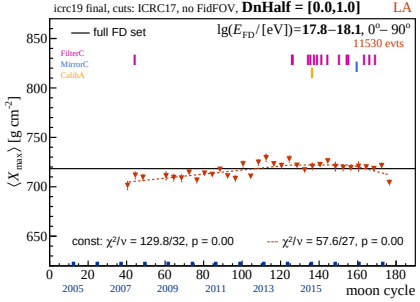
low



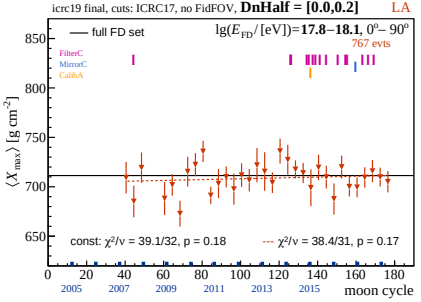
LA: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

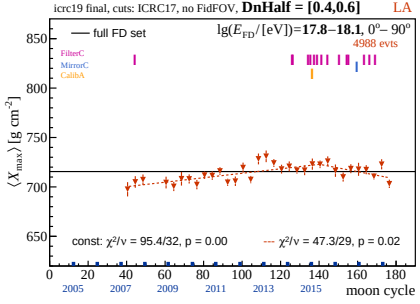
full



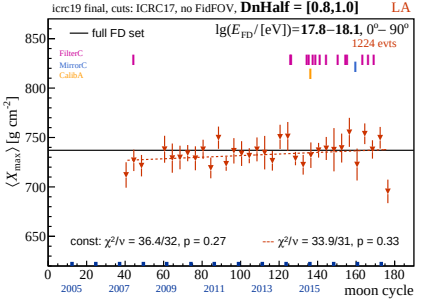
high



cross



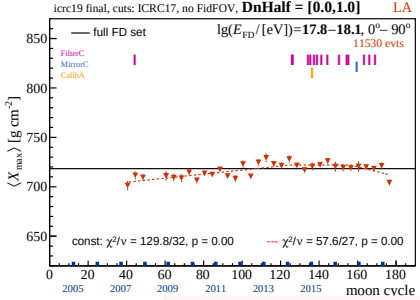
low



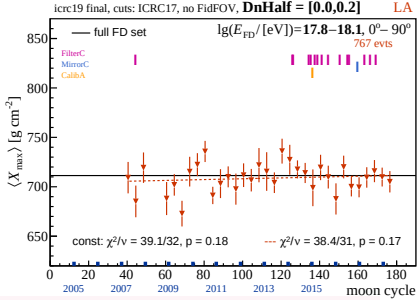
LA: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

full

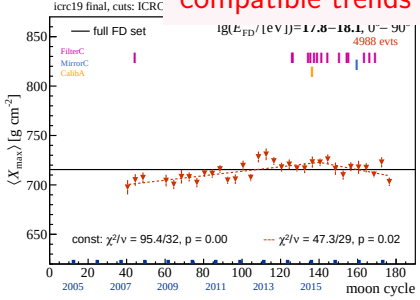


high

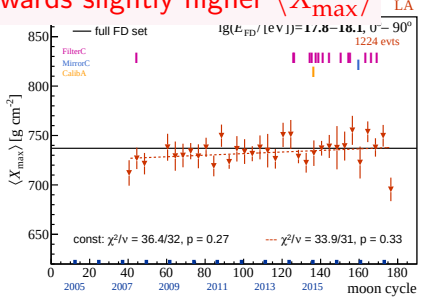


compatible trends towards slightly higher $\langle X_{\mathrm{max}} \rangle$

cross



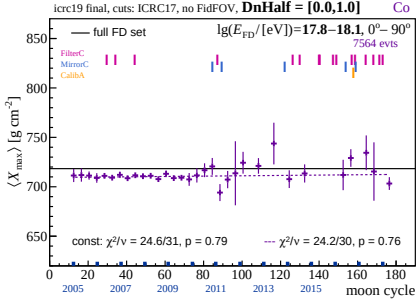
low



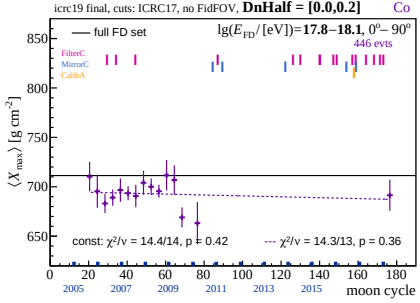
Co: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

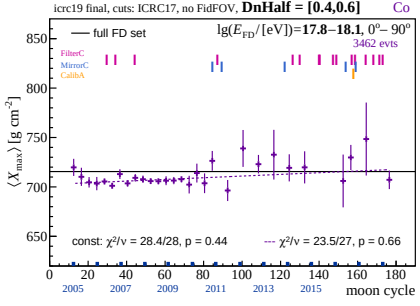
full



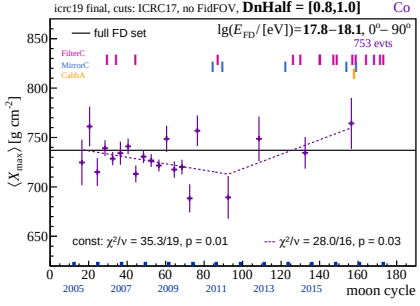
high



cross



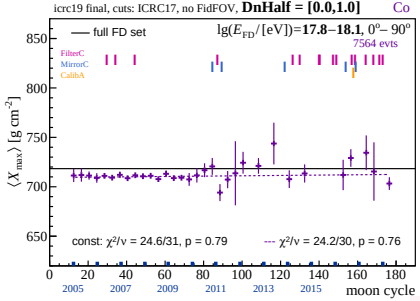
low



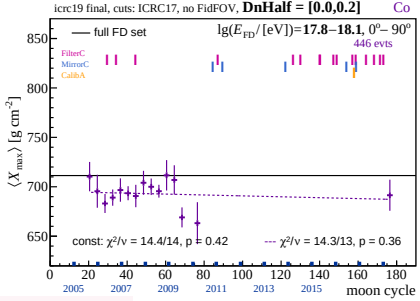
Co: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

full

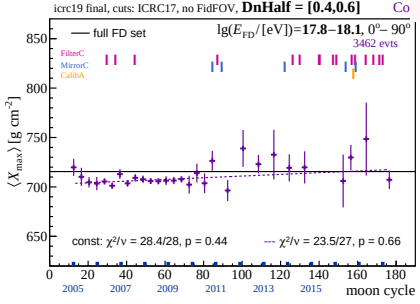


high

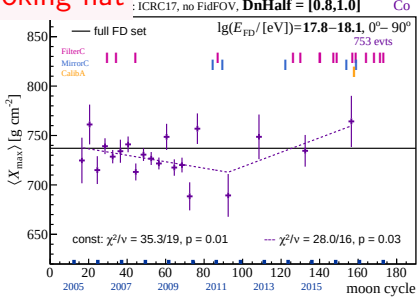


looking flat

cross



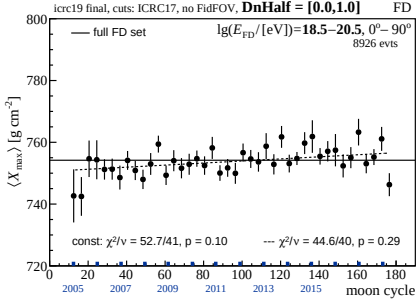
low



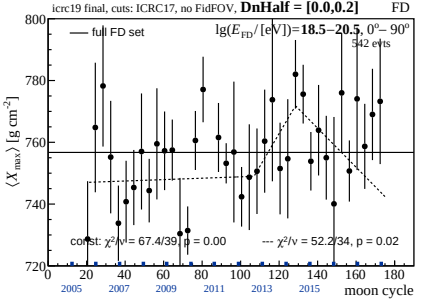
FD: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

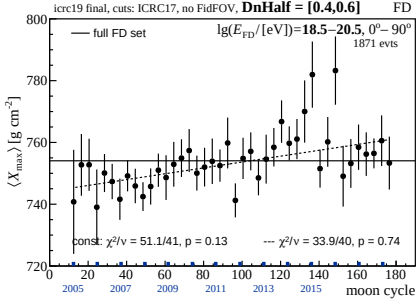
full



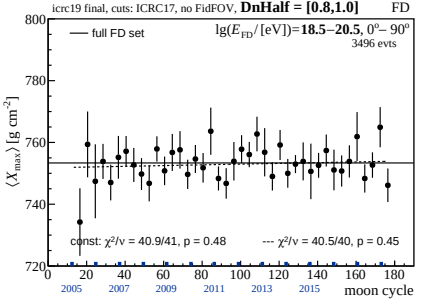
high



cross



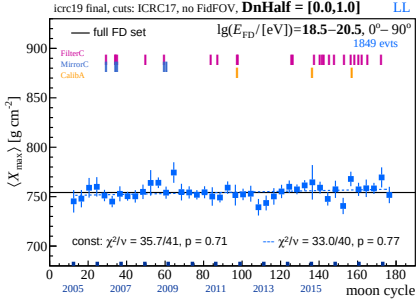
low



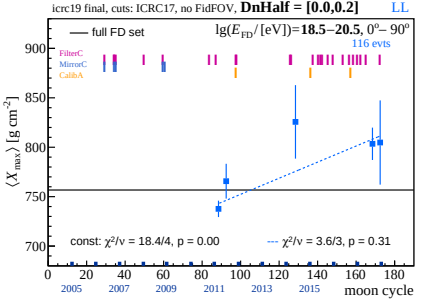
LL: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

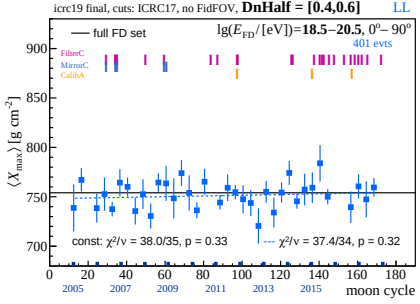
full



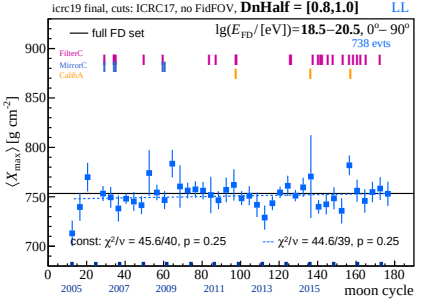
high



cross



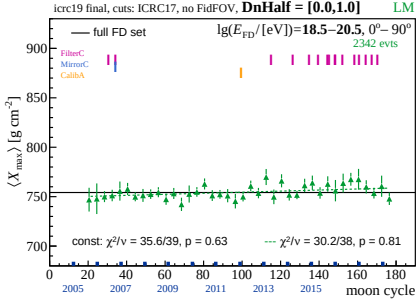
low



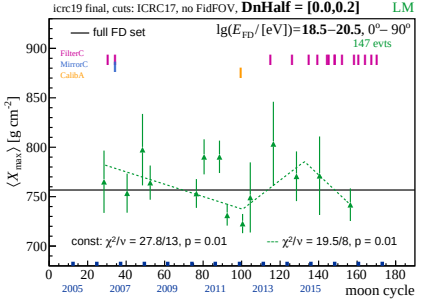
LM: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

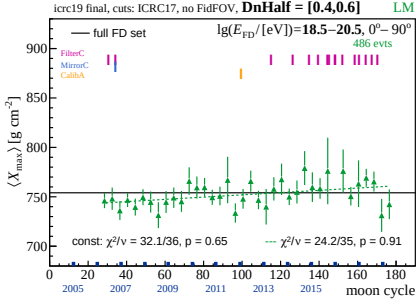
full



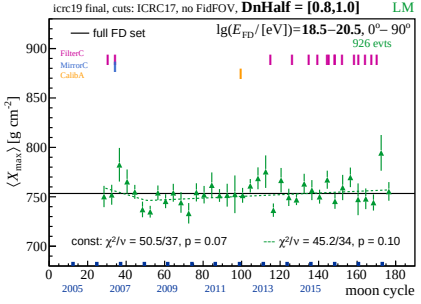
high



cross



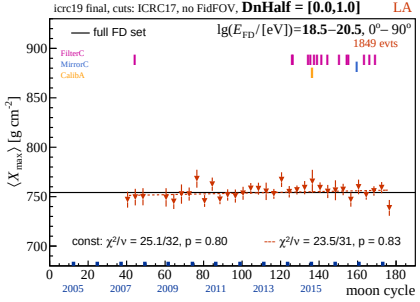
low



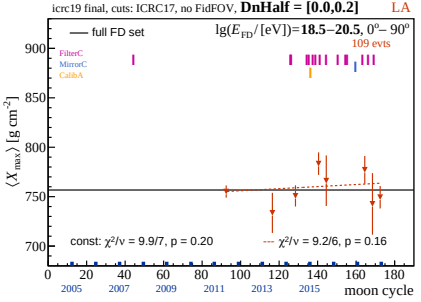
LA: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

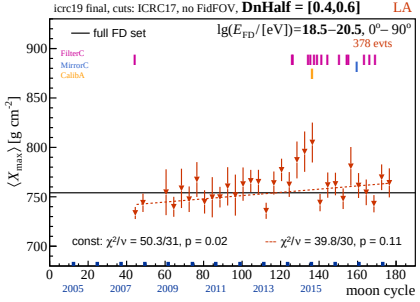
full



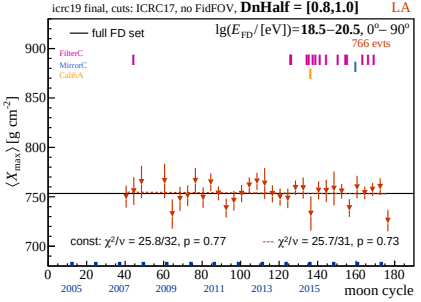
high



cross



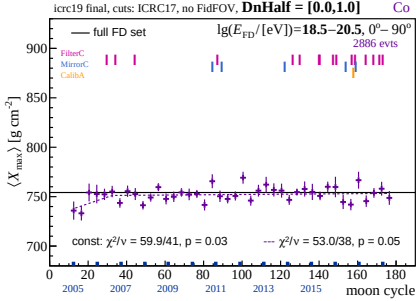
low



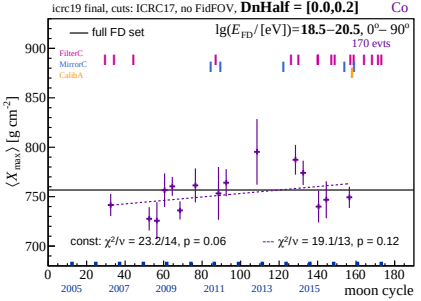
Co: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

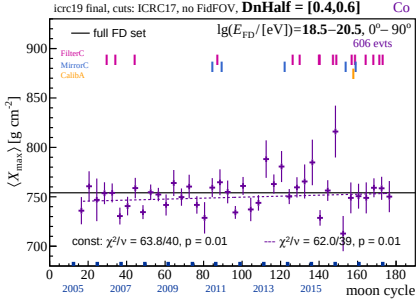
full



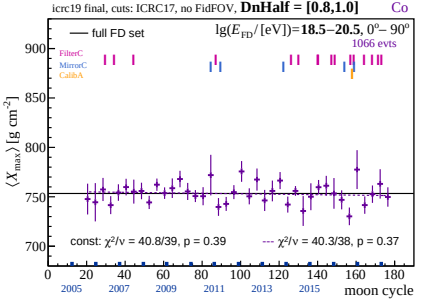
high



cross



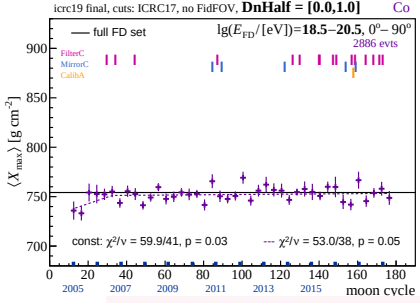
low



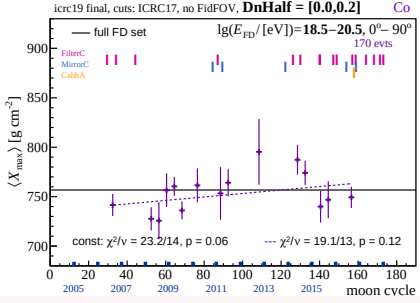
Co: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

full

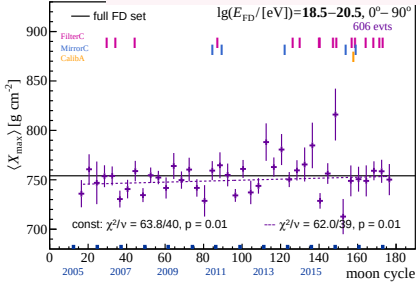


high

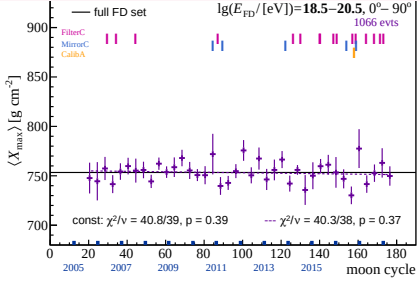


all FD sites look good, no troubles for Galactic anisotropy

cross



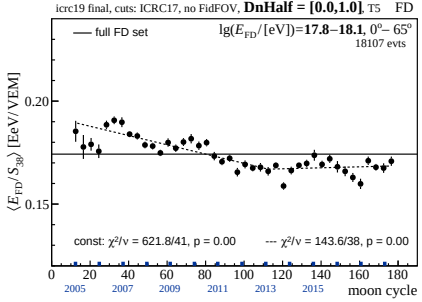
low



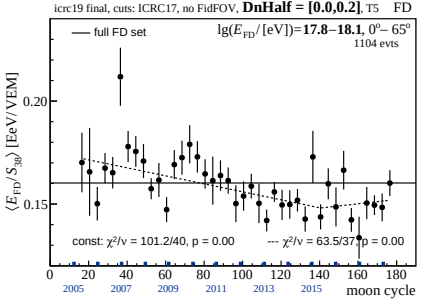
FD: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

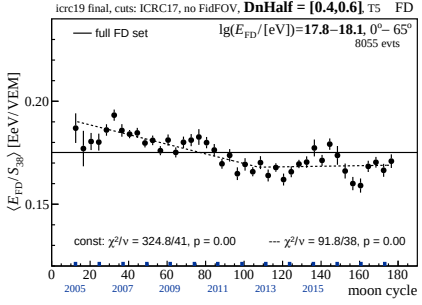
full



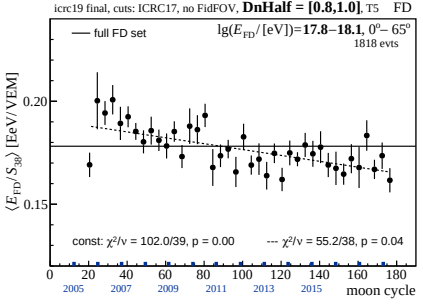
high



cross



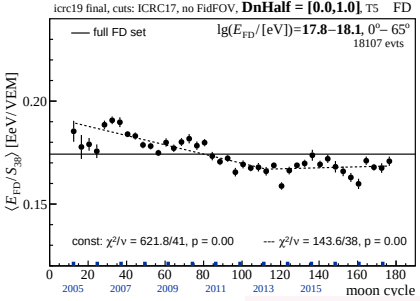
low



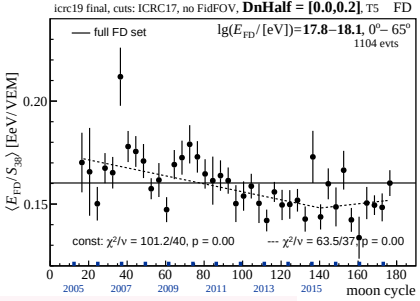
FD: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

full



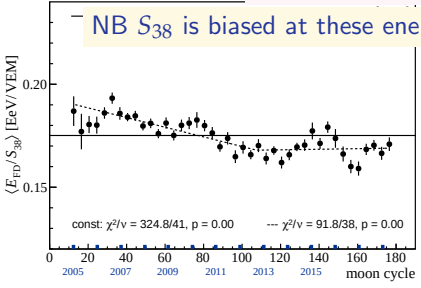
high



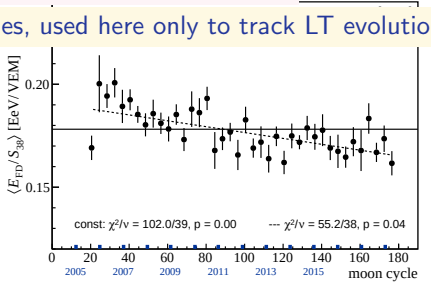
trends of all subsets look compatible

NB S_{38} is biased at these energies, used here only to track LT evolution

cross



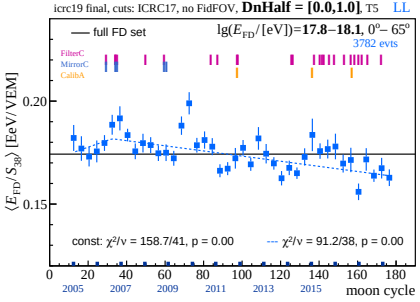
low



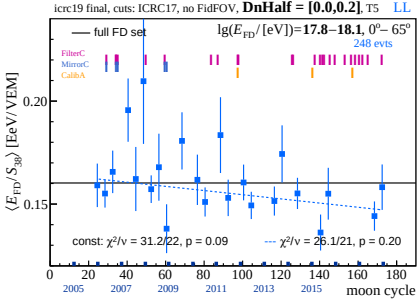
LL: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

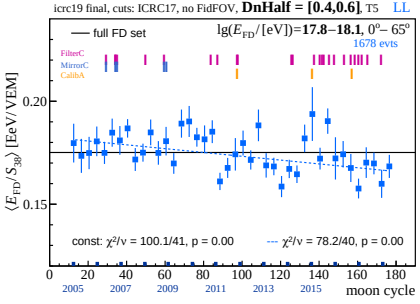
full



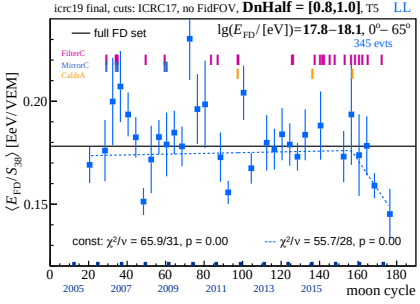
high



cross



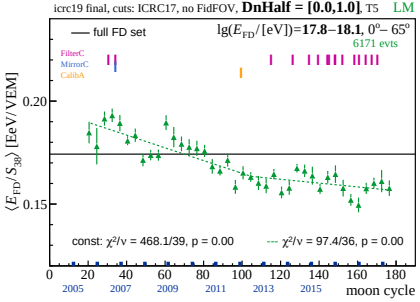
low



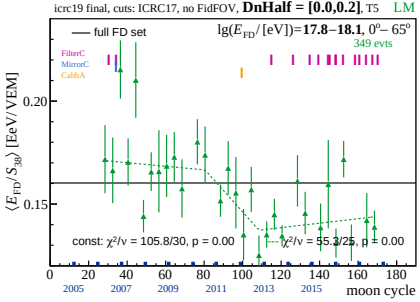
LM: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

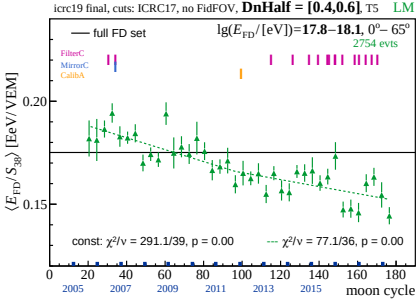
full



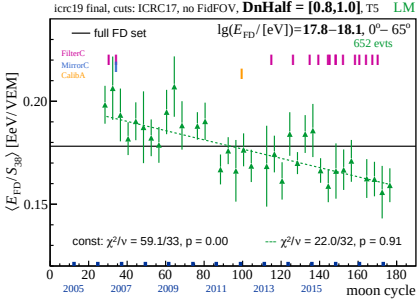
high



cross



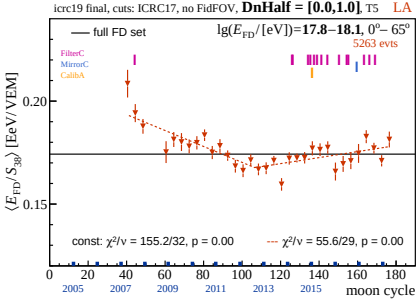
low



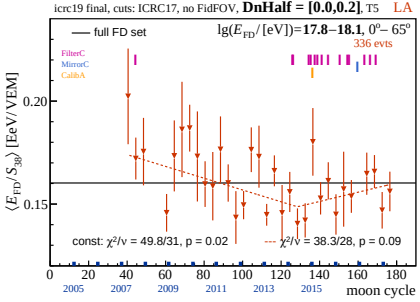
LA: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

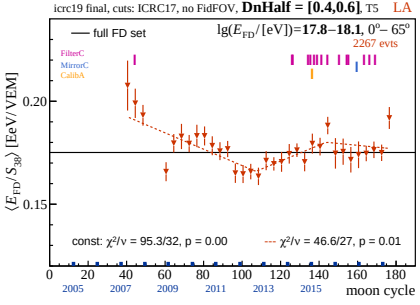
full



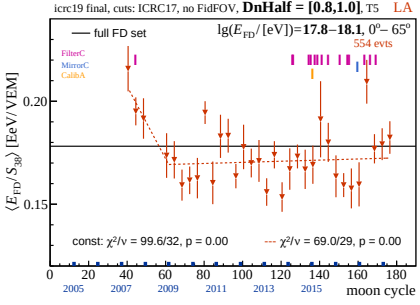
high



cross



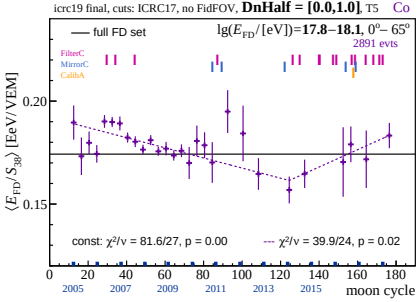
low



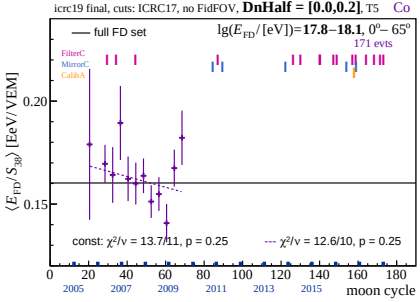
Co: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 17.8 - 18.1$

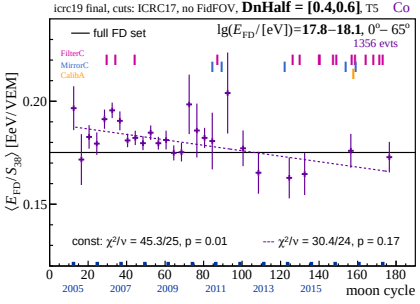
full



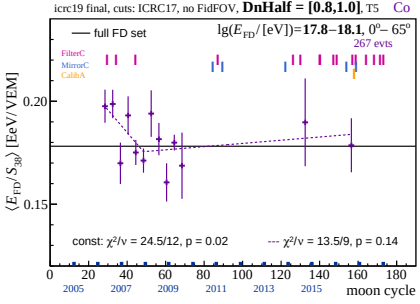
high



cross



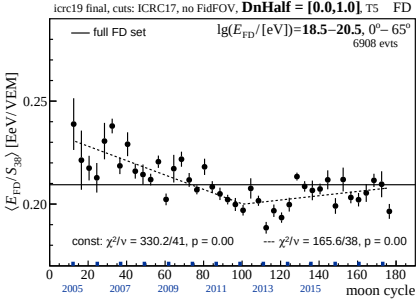
low



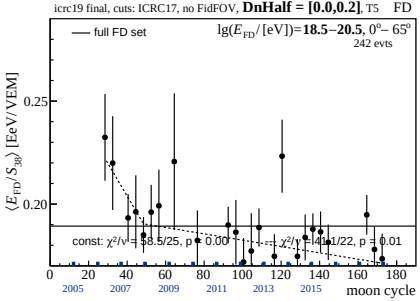
FD: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

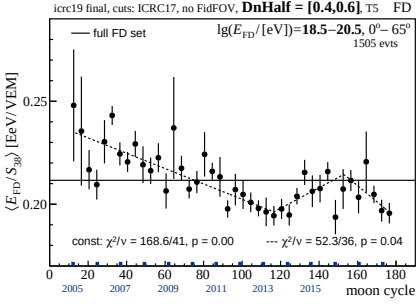
full



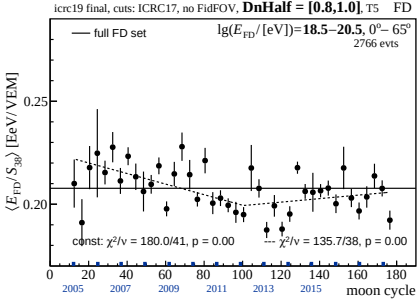
high



cross



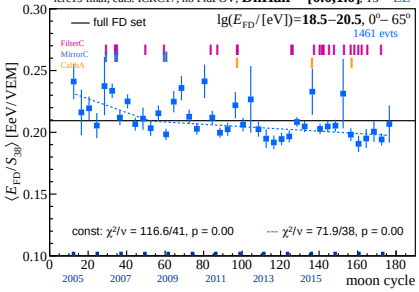
low



LL: full mirror, high-, cross-, low-elevation events

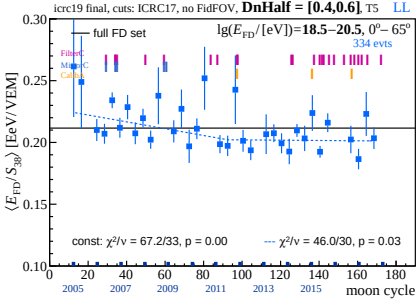
$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

full

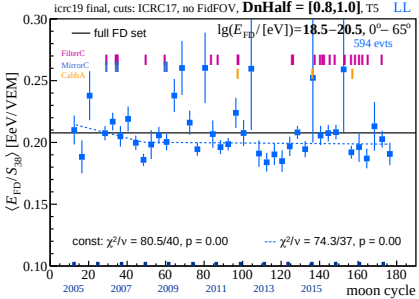


high

cross



low



LM: full mirror, high-, cross-, low-elevation events

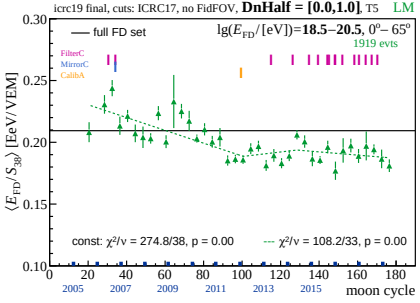
$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

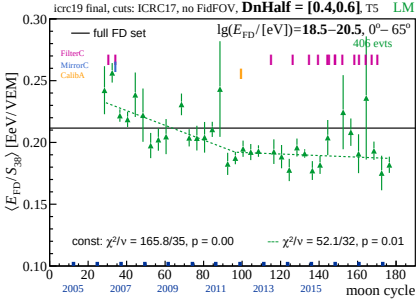
full

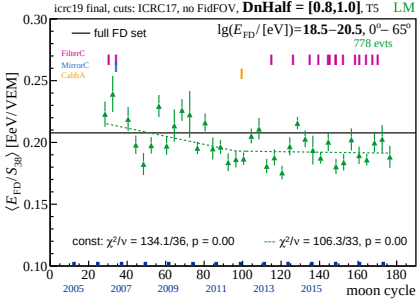
high

cross

low







LA: full mirror, high-, cross-, low-elevation events

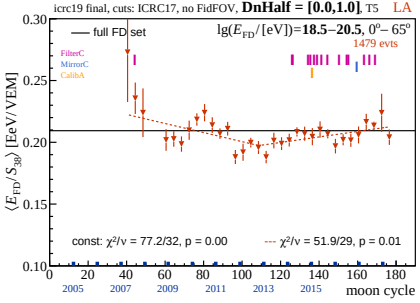
$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

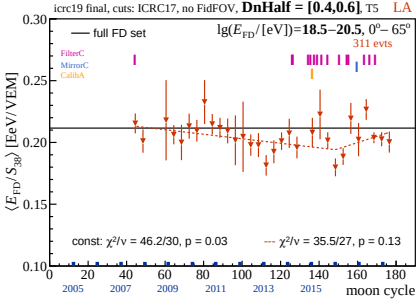
full

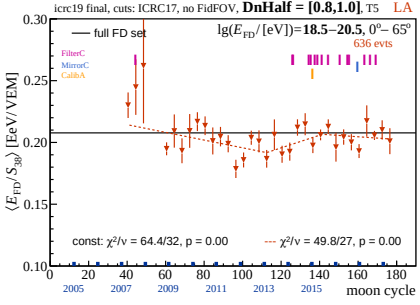
high

cross

low







Co: full mirror, high-, cross-, low-elevation events

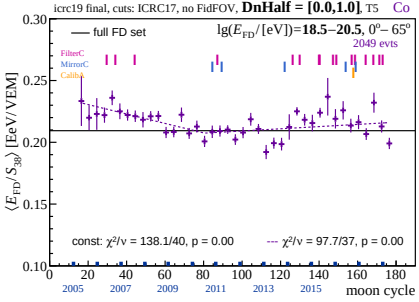
$\lg(E/\mathrm{eV}) = 18.5 - 20.5$

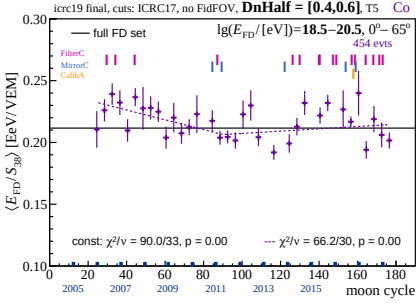
full

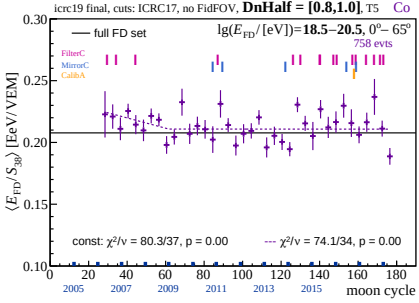
high

cross

low







Summary

$\langle X_{\mathrm{max}} \rangle$ evolution

stronger trends in $\lg(E/\mathrm{eV}) = 17.8 - 18.1$ range

(possibly overlay of step-like changes at different FD sites at different times and Co removal)

at higher energies compatible to const (and also to small increase) for all FD sites/elevation subsets

Energy scale evolution

no indications of more stable ('cleaner') subsets

elevation subsets seem to have similar absolute scale

(comparison is applicable only to $\lg(E/\mathrm{eV}) = 18.5 - 20.5$, for lower energies S_{38} is biased)

possibly the dust effects are too smooth (and mild) for such a coarse analysis

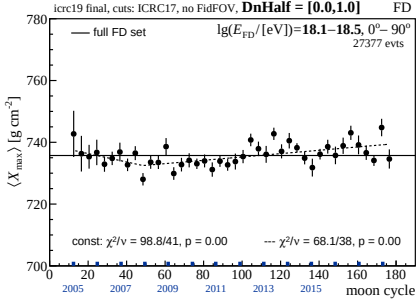
More studies including FD energy scale correction: my talk in mass composition call on 15/05/2019

plots for $\lg(E/\mathrm{eV}) = 18.1 - 18.5$

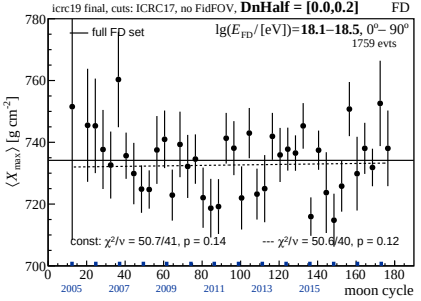
FD: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

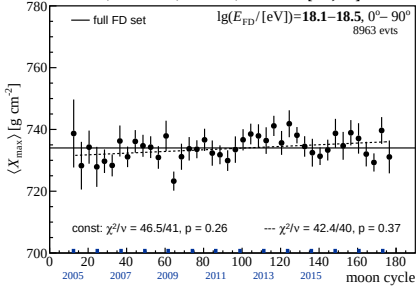
full



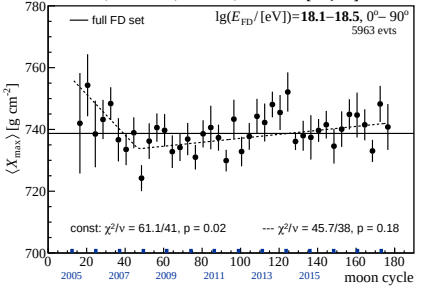
high



cross



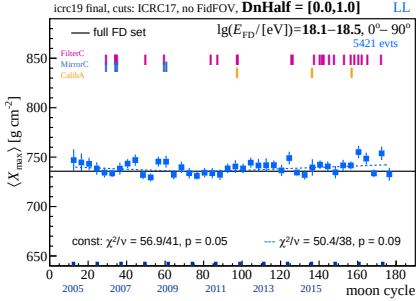
low



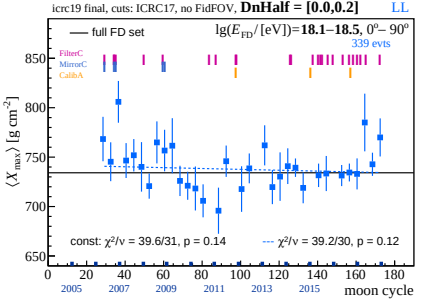
LL: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

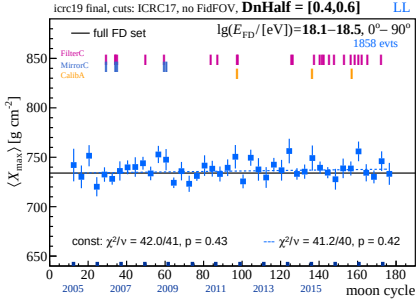
full



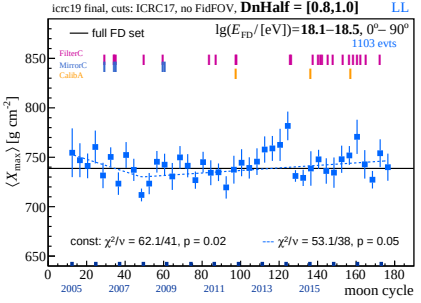
high



cross



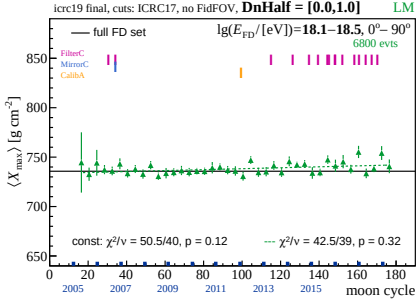
low



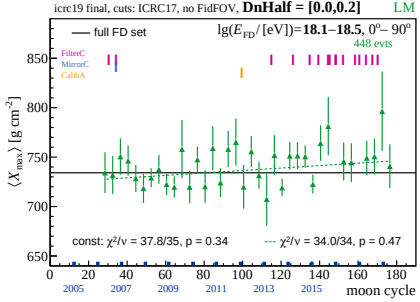
LM: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

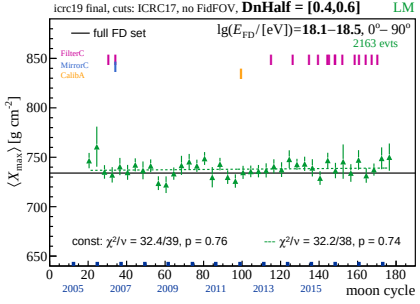
full



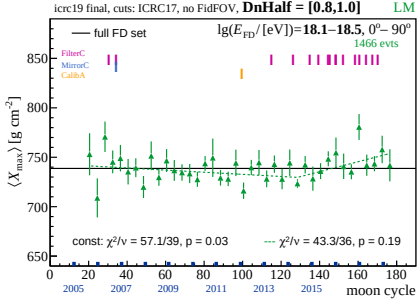
high



cross



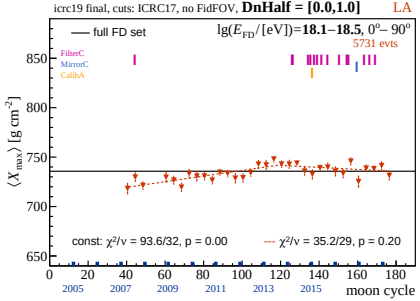
low



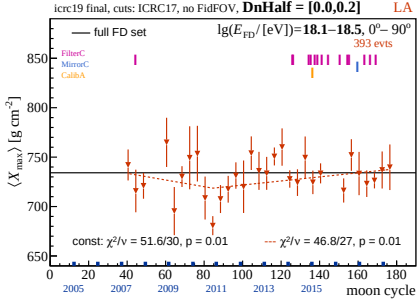
LA: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

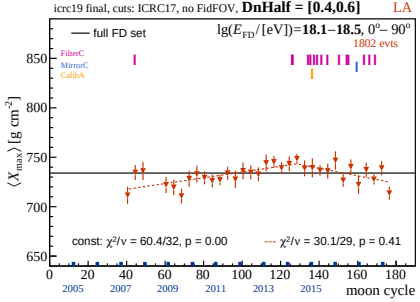
full



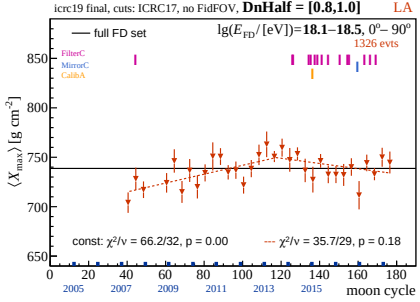
high



cross

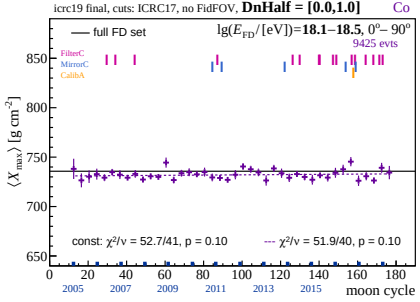


low

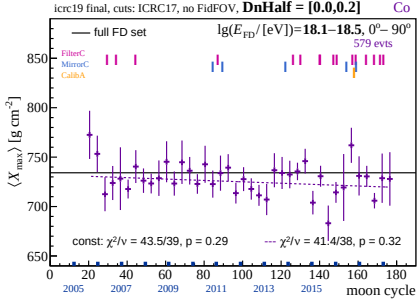


Co: full mirror, high-, cross-, low-elevation events $\lg(E/\mathrm{eV}) = 18.1 - 18.5$

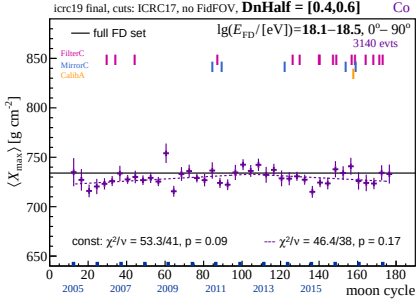
full



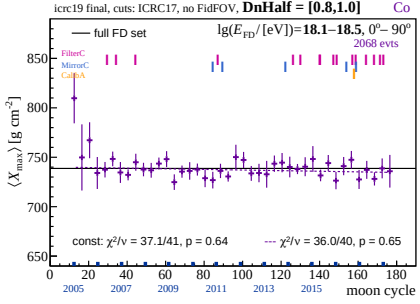
high



cross



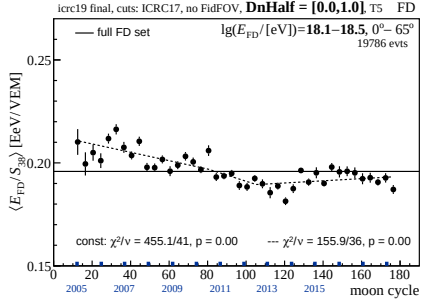
low



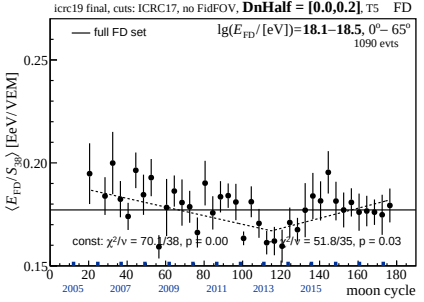
FD: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

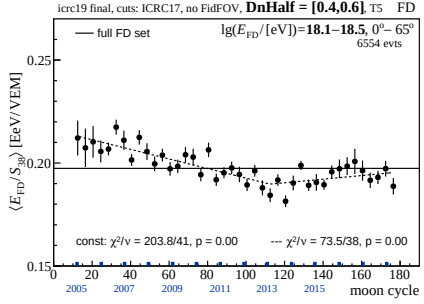
full



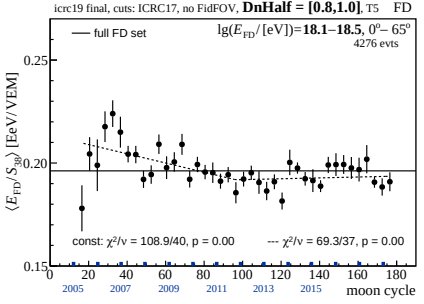
high



cross



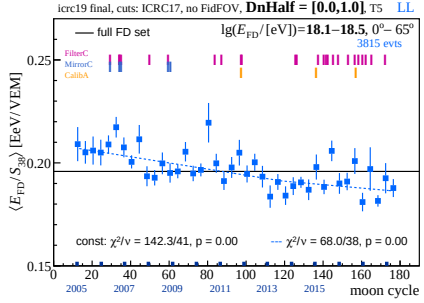
low



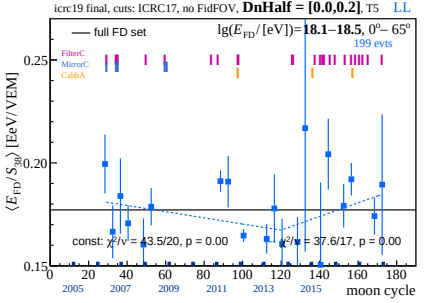
LL: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

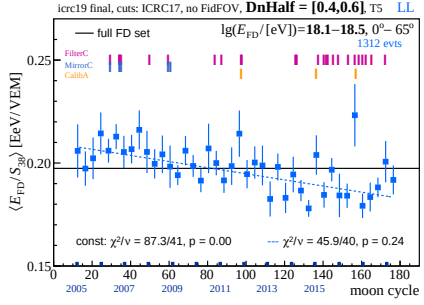
full



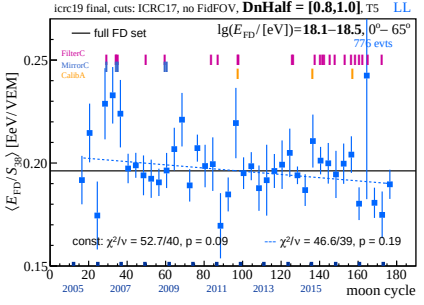
high



cross



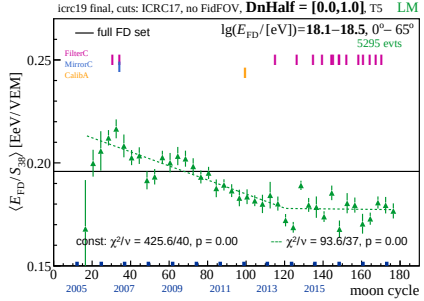
low



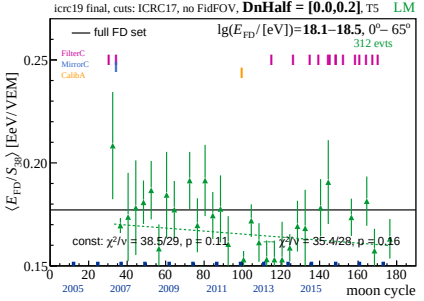
LM: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

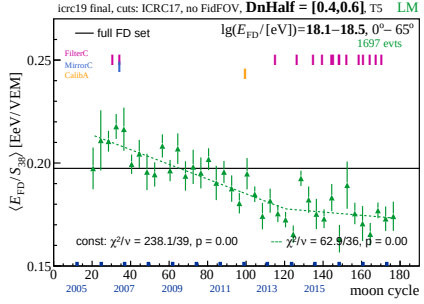
full



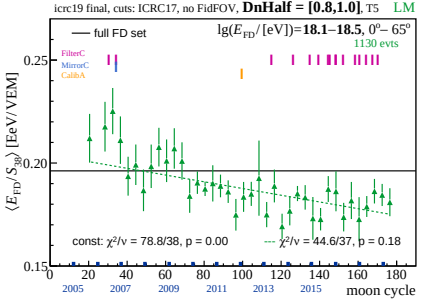
high



cross



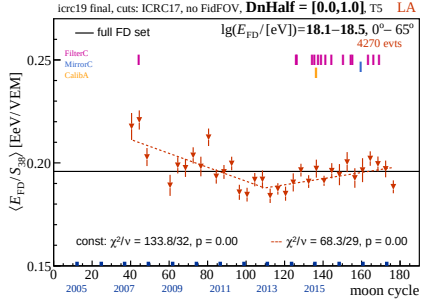
low



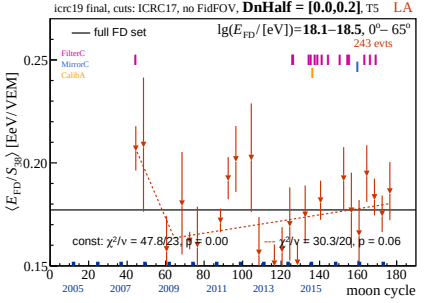
LA: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

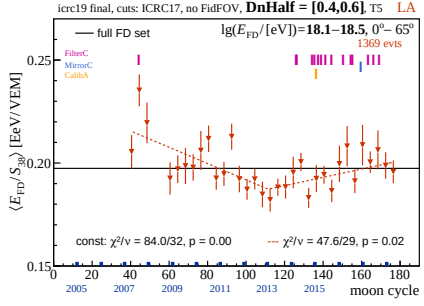
full



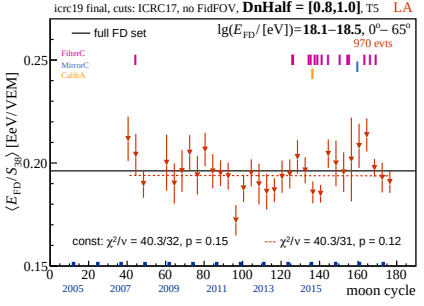
high



cross



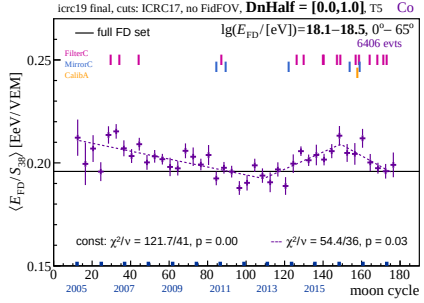
low



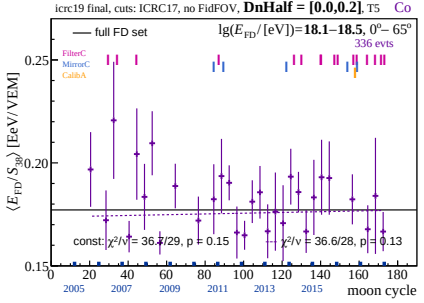
Co: full mirror, high-, cross-, low-elevation events

$\lg(E/\mathrm{eV}) = 18.1 - 18.5$

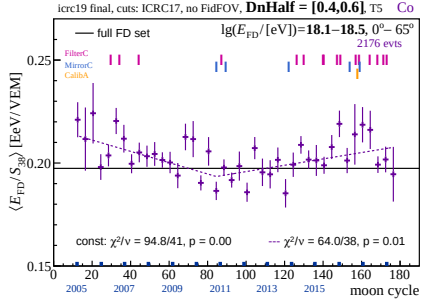
full



high



cross



low