



PIERRE
AUGER
OBSERVATORY

Correlation $r_G(X_{\max}^*, S_{38}^*)$

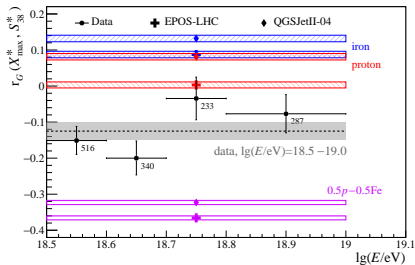
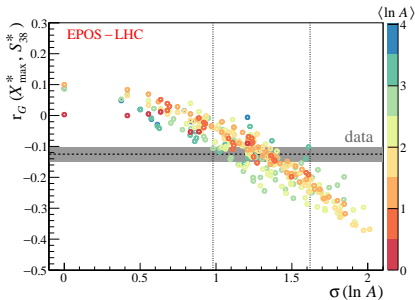
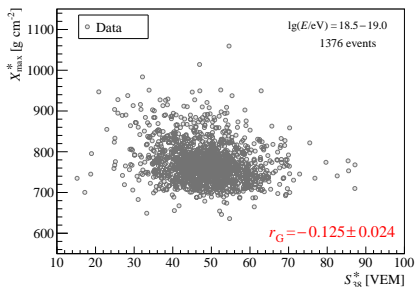
MASS1 ICRC 2019

all plots are preliminary

Alexey Yushkov

Fyzikální ústav AV ČR

Published results: PLB 762 (2016) 288



data period: 2004 – 2012 (X_{\max} PRD 2014 data)

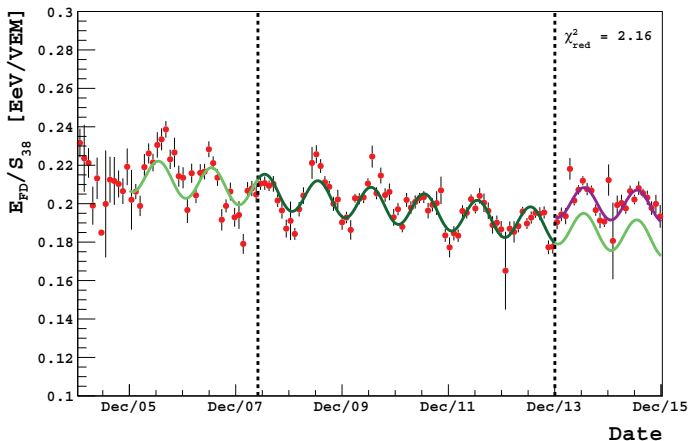
data explained by mixed composition including nuclei $A > 4$

spread of masses $\sigma(\ln A) \simeq 1.35 \pm 0.35$

energy dependence: inconclusive

S_{38}^* is S_{38} scaled to 10 EeV: $S_{38}^* \sim S_{38} / E_{\text{FD}}^{1/1.025}$; X_{\max}^* is X_{\max} scaled to 10 EeV

Detector: energy scale evolution (for $E > 3$ EeV)



Phong Huy Nguyen, PhD thesis, GAP 2018 – 011

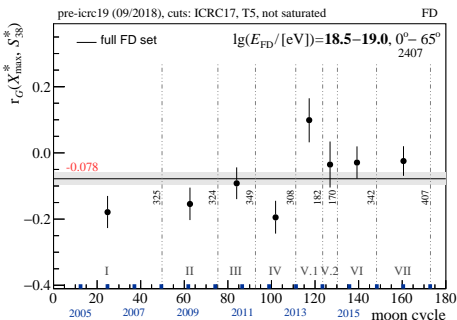
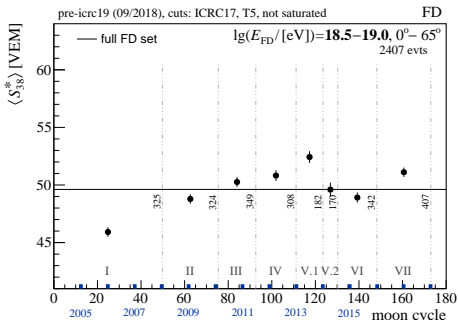
E_{FD}/S_{38} jump: related to the UV filter cleaning at all FD sites in 03/2014? Probably no.
<https://www.auger.unam.mx/AugerWiki/ListOfCleanings>

Split period V around E_{FD}/S_{38} jump (01/2014)

More positive correlation comes from V.1 before the jump, where S_{38}^* is also larger

Closer look to V.1 needed:

cal B fiber replacements, filter cleaning campaigns in 03-04/2013, CLF upgrade



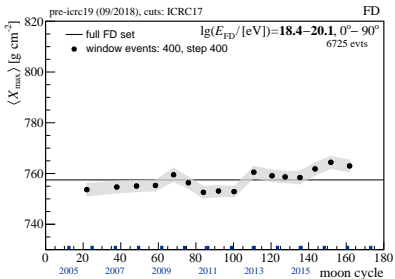
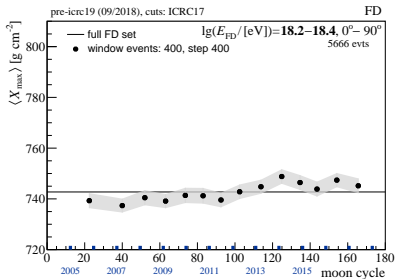
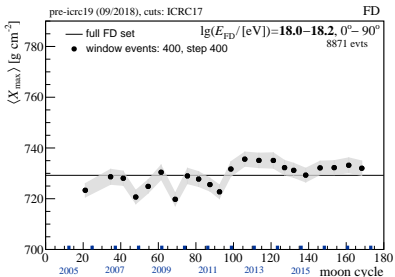
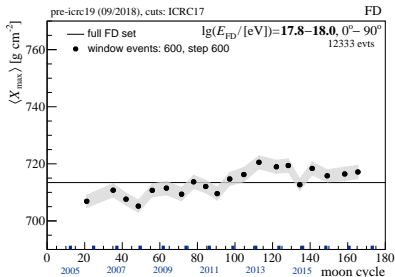
pre-production from 09/2018: aerosol, clouds, calibration DBs are far from final!

weather correction applied

Many thanks to Lorenzo Perrone for providing the data

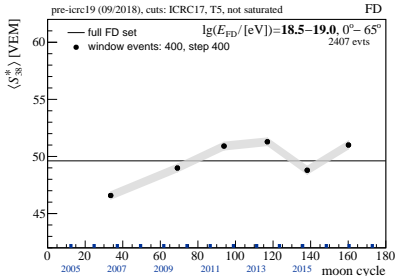
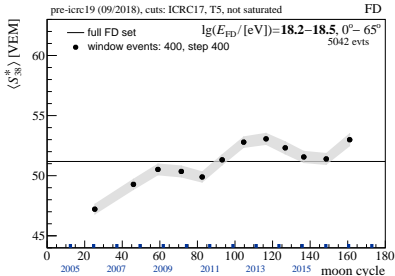
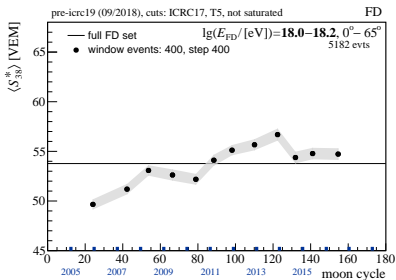
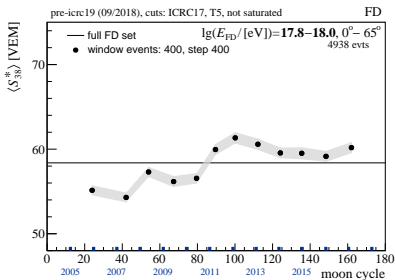
$\langle X_{\max} \rangle$ stability: full FD, 4 energy bins

ICRC 2017 cuts



S_{38}^* stability: full FD, 4 energy bins

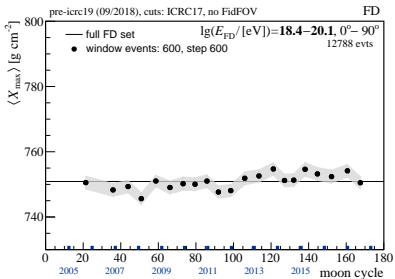
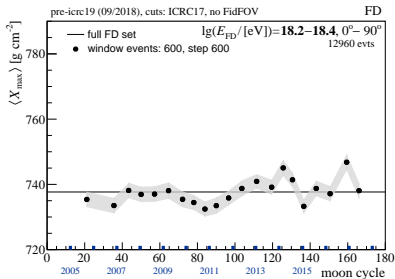
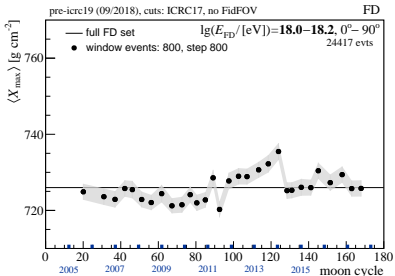
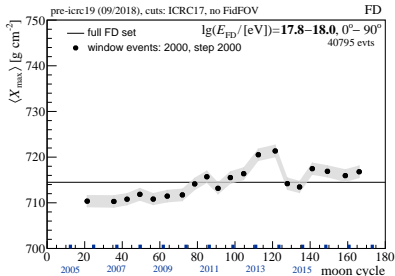
PLB 2016 cuts (ICRC 2017, T5, no saturated events)



for low energies S_{38}^* is biased, used here only for stability studies

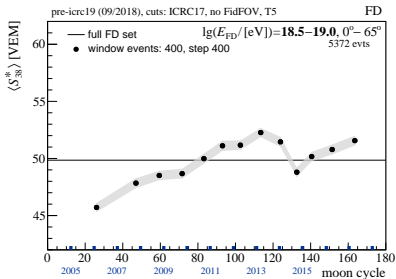
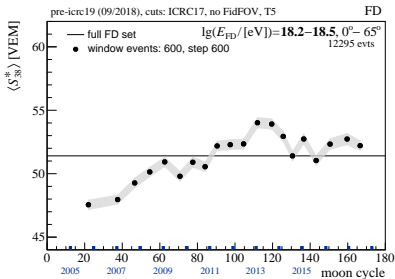
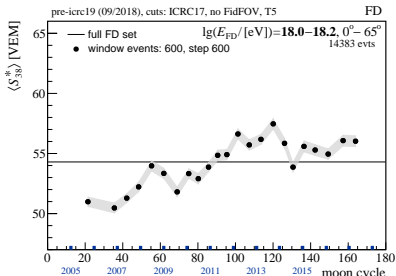
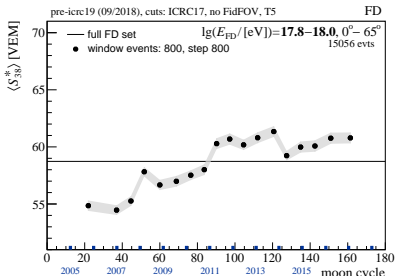
$\langle X_{\max} \rangle$ stability: full FD, 4 energy bins

ICRC 2017 cuts without FidFOV



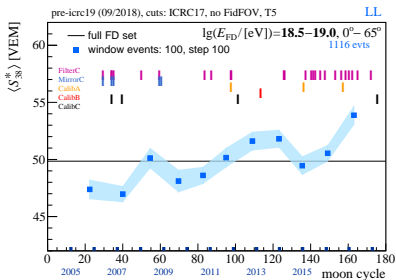
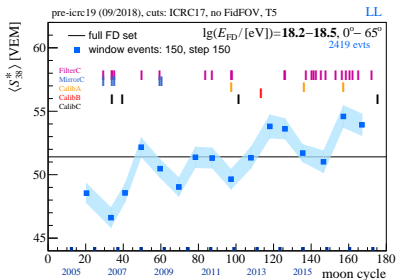
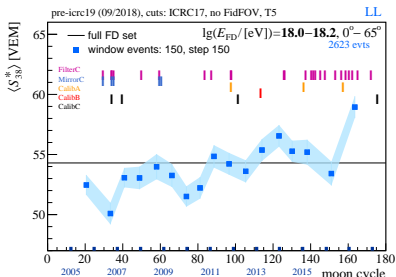
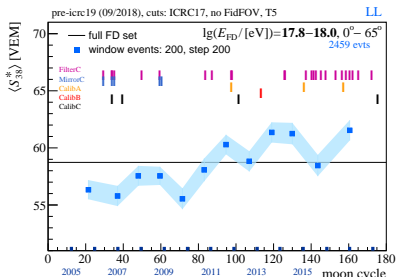
S_{38}^* stability: full FD, 4 energy bins

ICRC 2017 cuts without FidFOV, T5



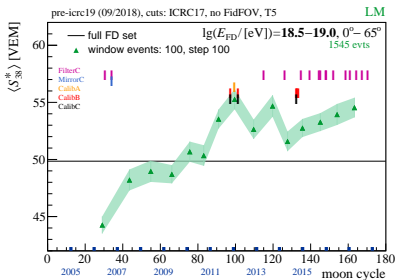
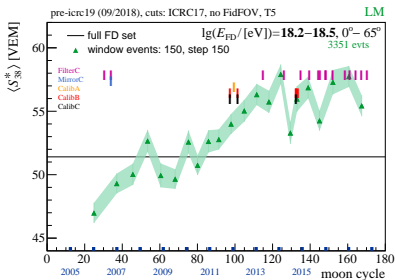
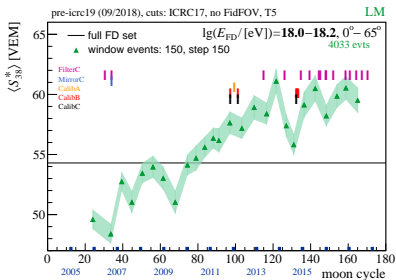
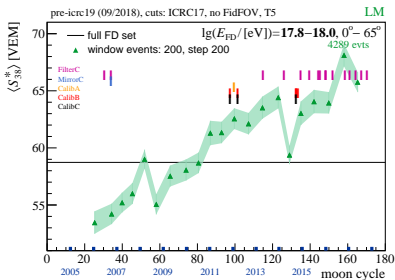
S_{38}^* stability vs FD interventions

ICRC 2017 cuts without FidFOV, T5



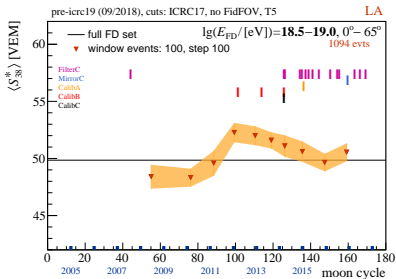
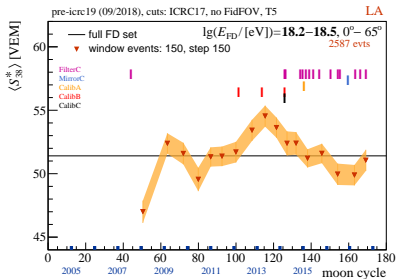
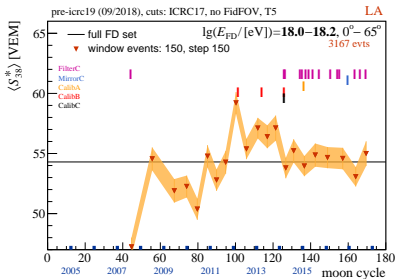
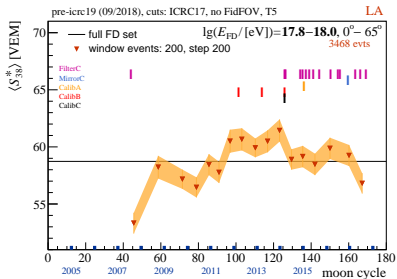
S_{38}^* stability vs FD interventions

ICRC 2017 cuts without FidFOV, T5



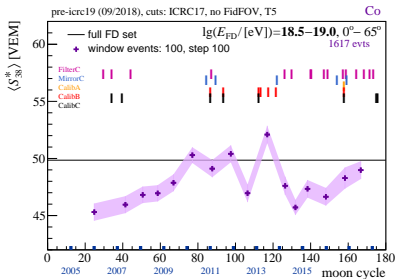
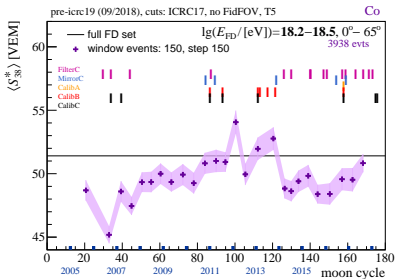
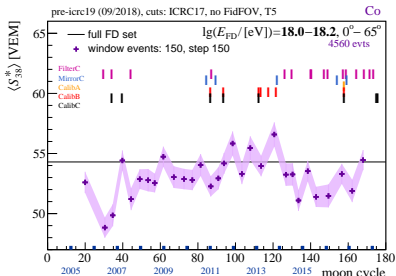
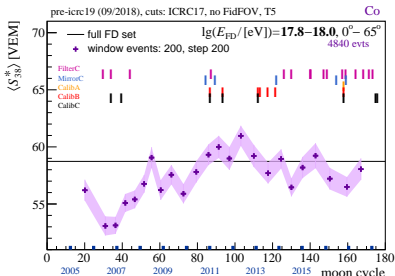
S_{38}^* stability vs FD interventions

ICRC 2017 cuts without FidFOV, T5



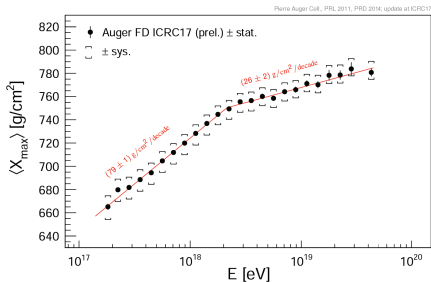
S_{38}^* stability vs FD interventions

ICRC 2017 cuts without FidFOV, T5



X_{\max} and energy scale evolutions

- S_{38}^* evolution is mostly due to the evolution of E_{FD} (see thesis of Phong)
- another evidence: FD sites have different energy scales
- S_{38}^* evolution is similar in all energy bins
- X_{\max} evolution is stronger at lower energies

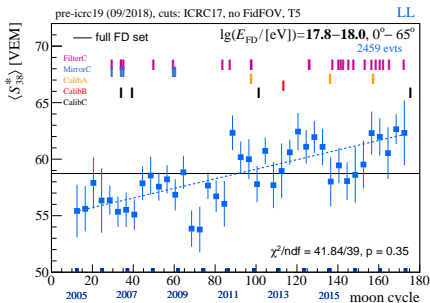


with time same value E_0 is assigned to showers of higher true energies: higher X_{\max} are sampled
effect is stronger for $E < 2 \text{ EeV}$ where $ER = 79 \text{ g cm}^{-2}/\text{decade}$
mild effect: e.g. 15% decrease in energy ($\Delta \lg(E/\text{eV}) = 0.06$) is equivalent to 5 g cm^{-2} increase of X_{\max}

Correction for the energy evolution, $\lg(E/\text{eV}) = 17.8 - 18.0$

previously S_{38}^* was corrected using $\text{fit}/\langle S_{38}^* \rangle$, E_{FD} was not corrected, there was no events migration

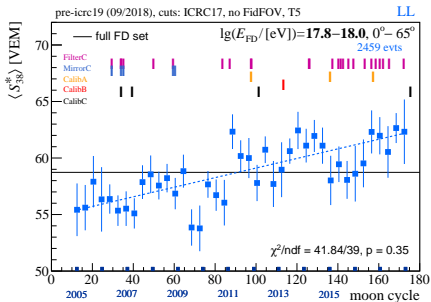
- fit S_{38}^* time dependence for each eye



for migration regarding this bin data were selected with threshold $\lg(E/\text{eV}) = 17.5$ (cross-checks needed)

Correction for the energy evolution, $\lg(E/\text{eV}) = 17.8 - 18.0$

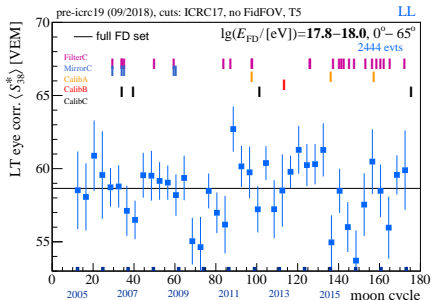
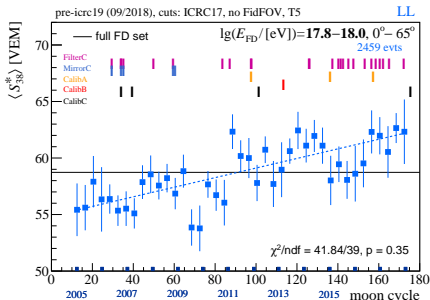
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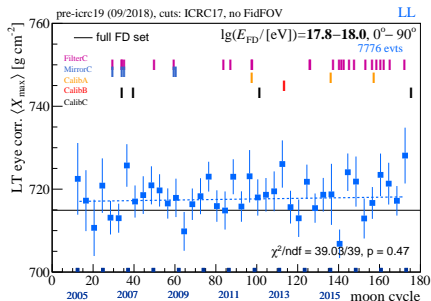
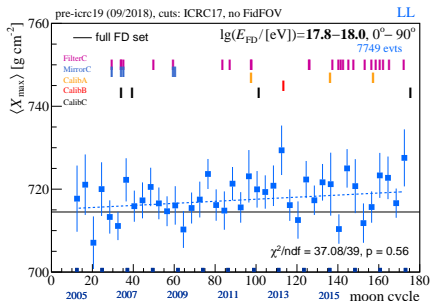
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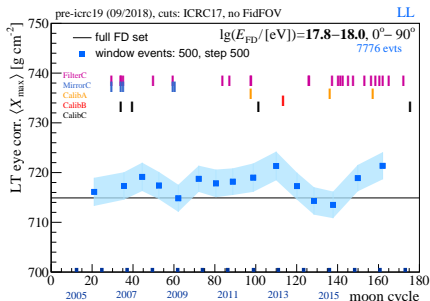
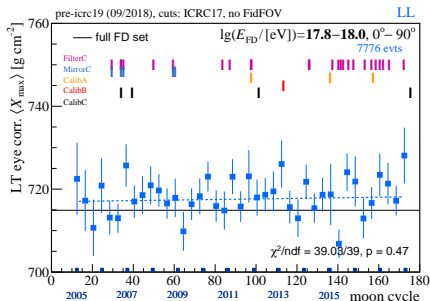
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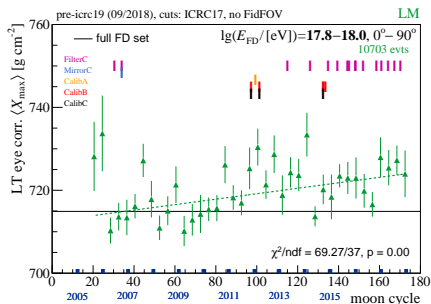
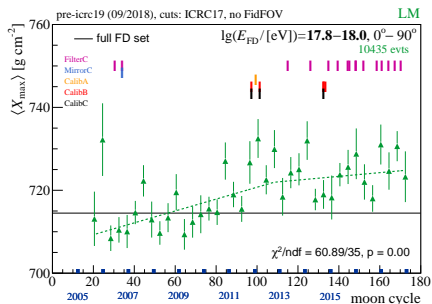
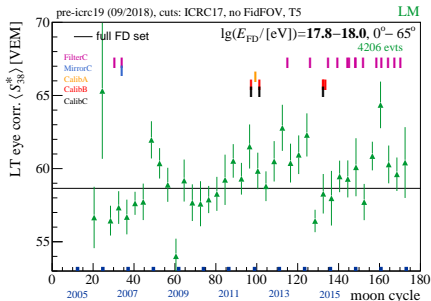
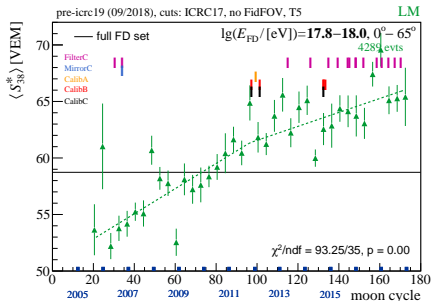
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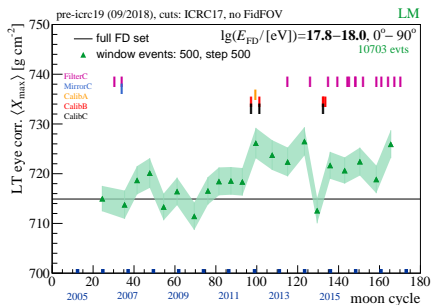
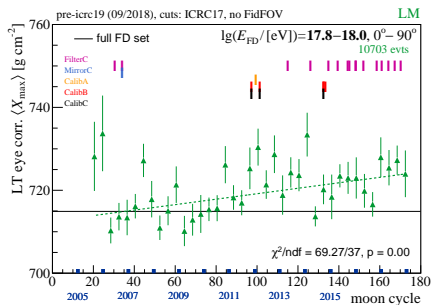
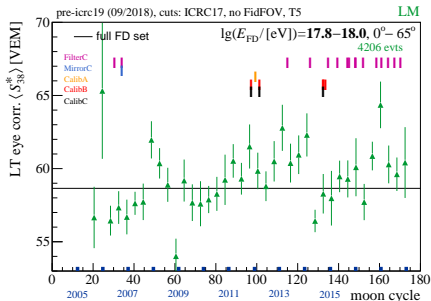
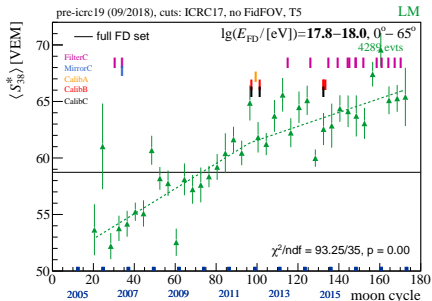
note 'jumps' around year 2013 in the following slides

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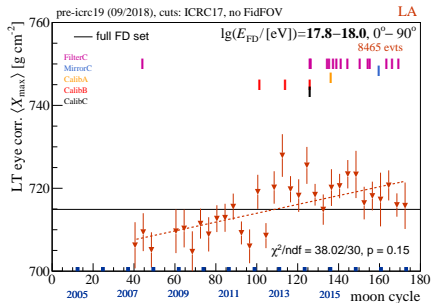
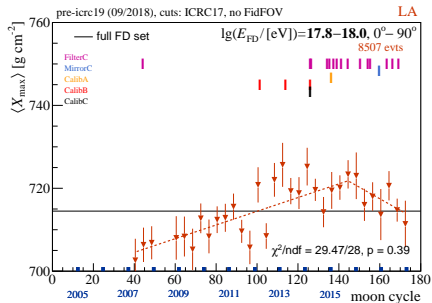
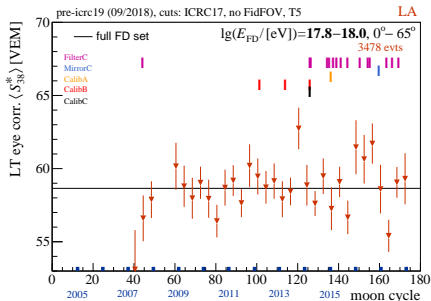
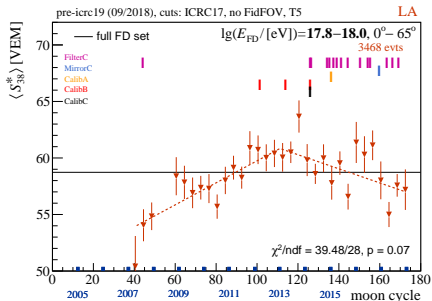
Correction for the energy evolution, $\lg(E/\text{eV}) = 17.8 - 18.0$



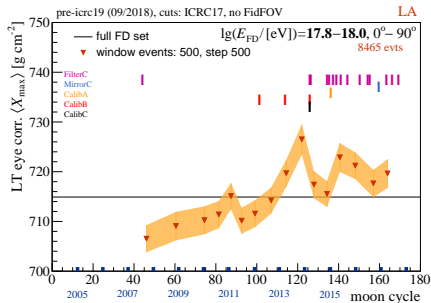
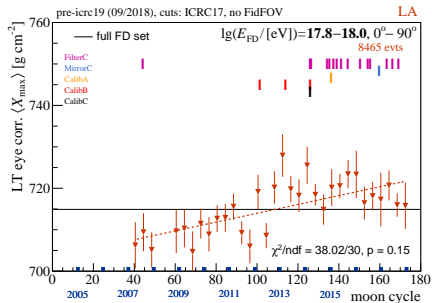
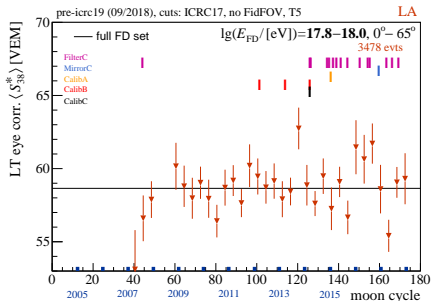
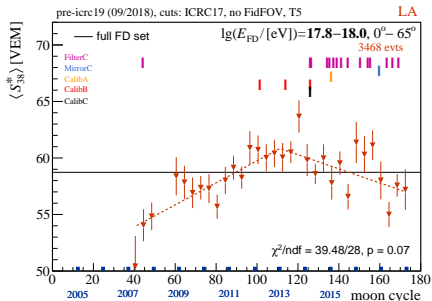
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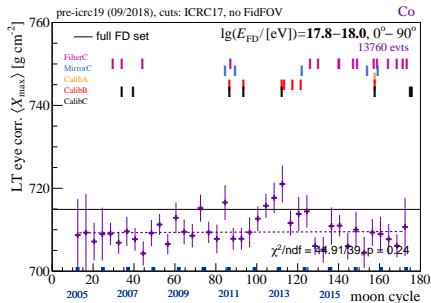
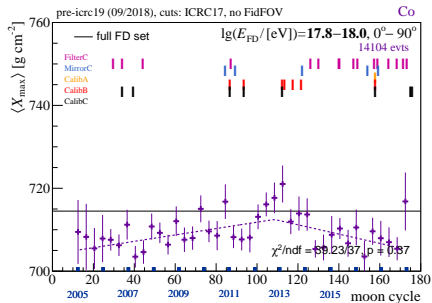
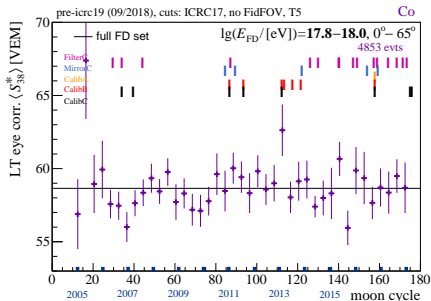
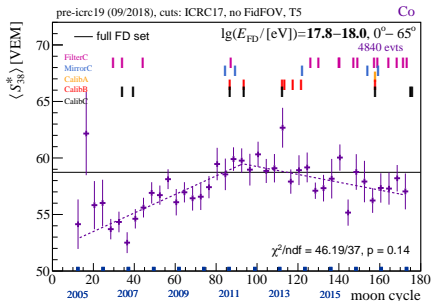
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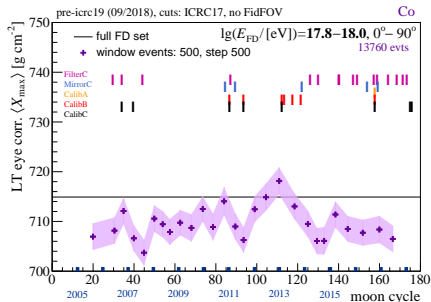
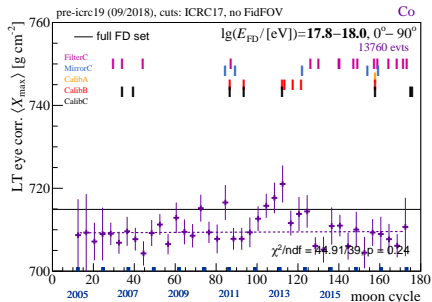
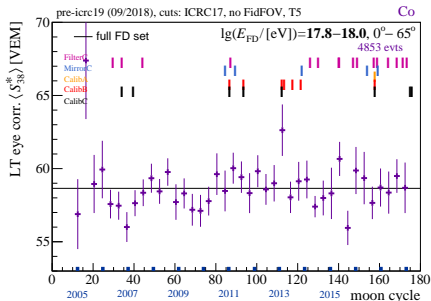
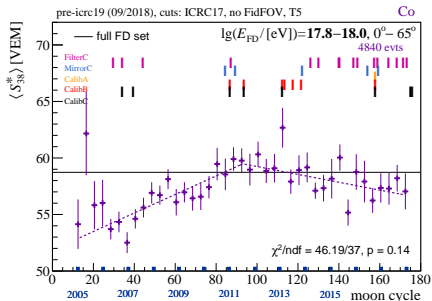
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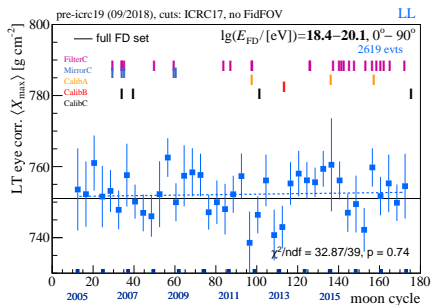
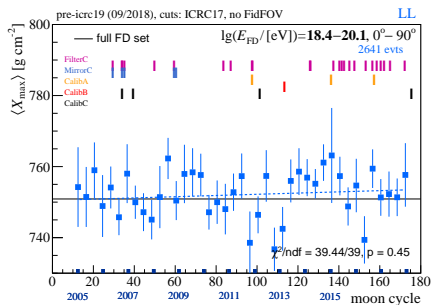
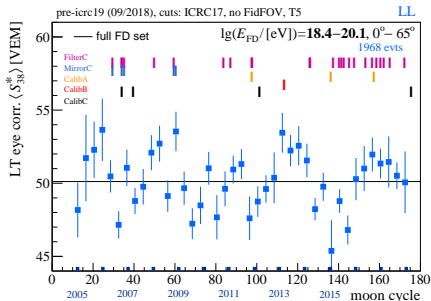
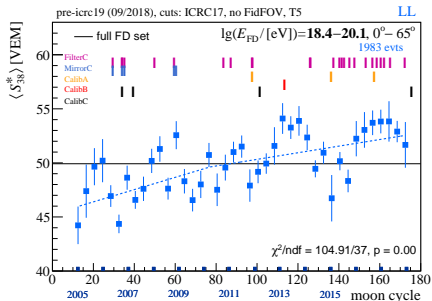
Correction for the energy evolution, $\lg(E/\text{eV}) = 17.8 - 18.0$



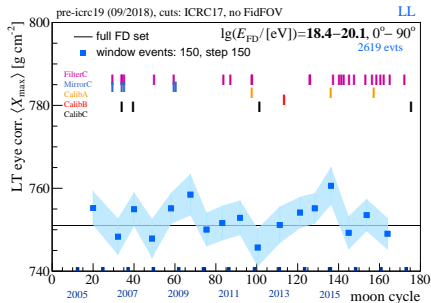
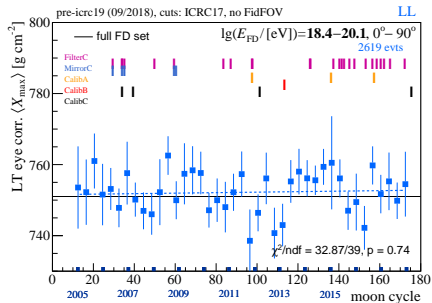
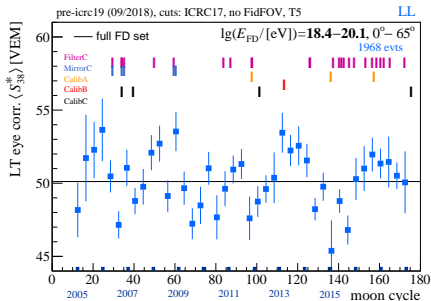
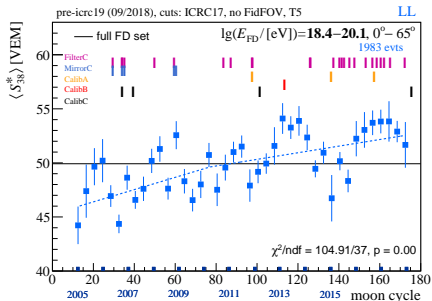
Correction for the energy evolution, $\lg(E_{\text{FD}}/\text{eV}) = 17.8 - 18.0$



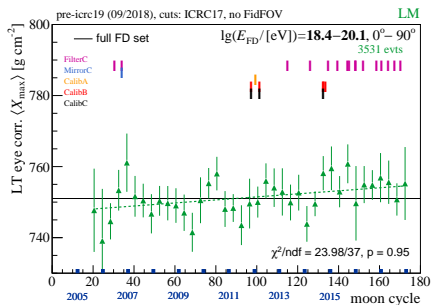
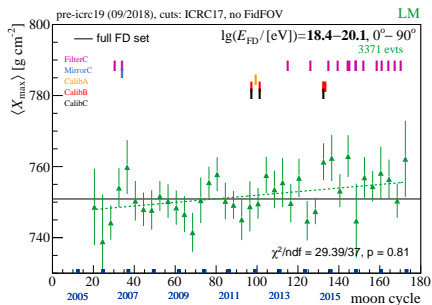
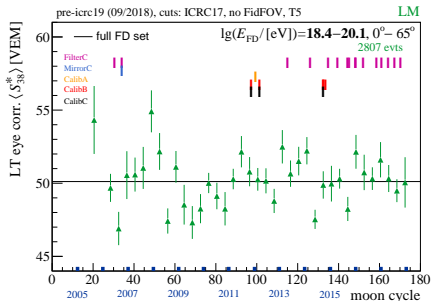
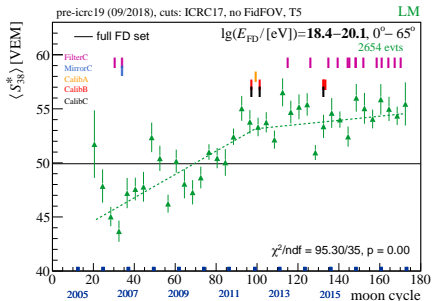
Correction for the energy evolution, $\lg(E/\text{eV}) = 18.4 - 20.1$



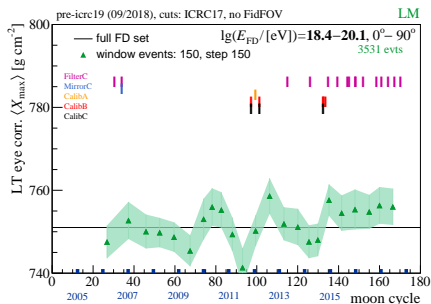
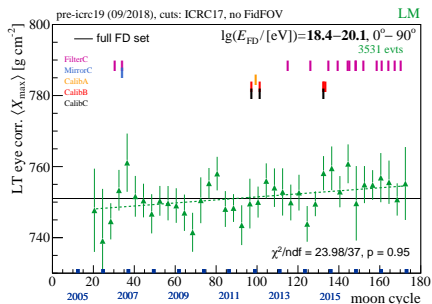
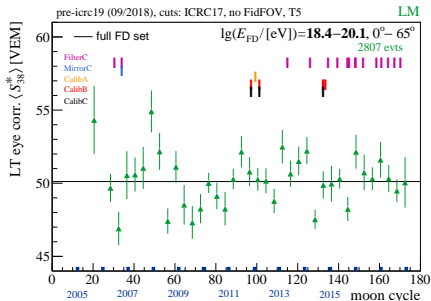
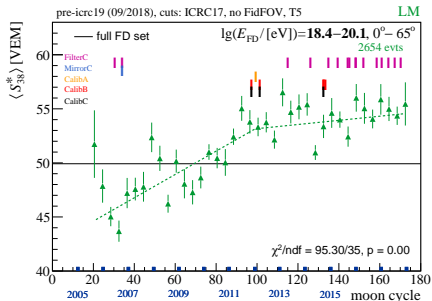
Correction for the energy evolution, $\lg(E_{\text{FD}}/\text{eV}) = 18.4 - 20.1$



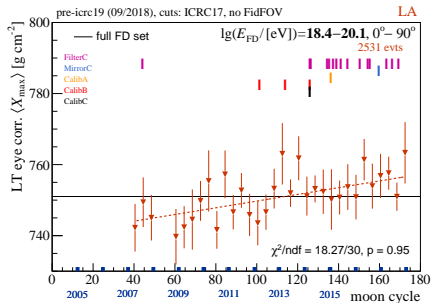
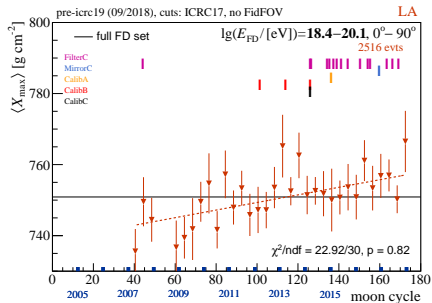
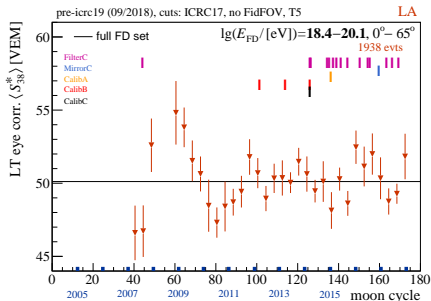
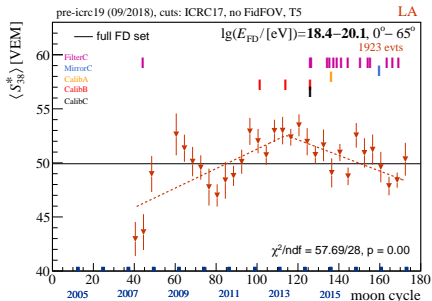
Correction for the energy evolution, $\lg(E/\text{eV}) = 18.4 - 20.1$



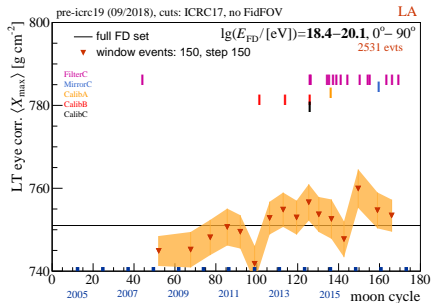
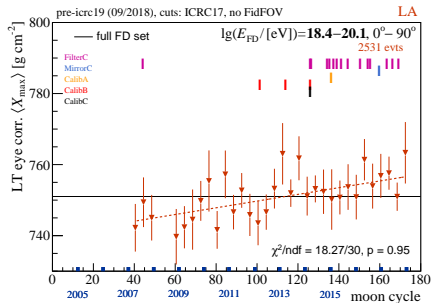
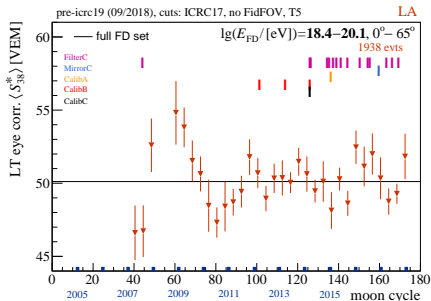
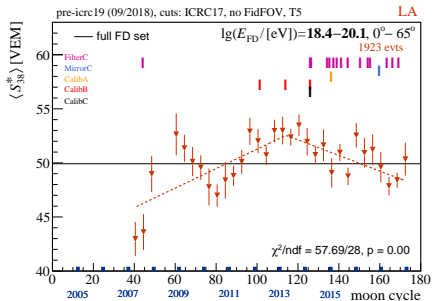
Correction for the energy evolution, $\lg(E_{\text{FD}}/\text{eV}) = 18.4 - 20.1$



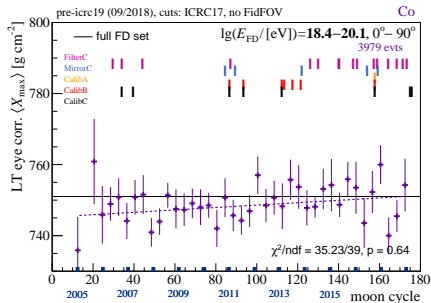
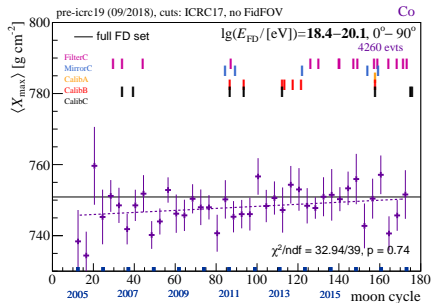
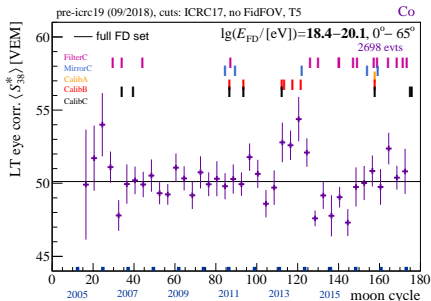
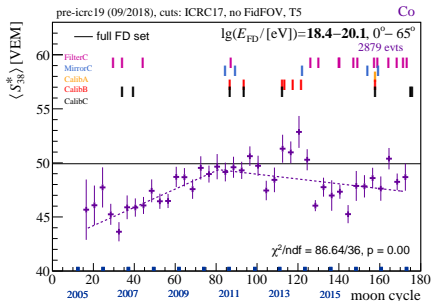
Correction for the energy evolution, $\lg(E/\text{eV}) = 18.4 - 20.1$



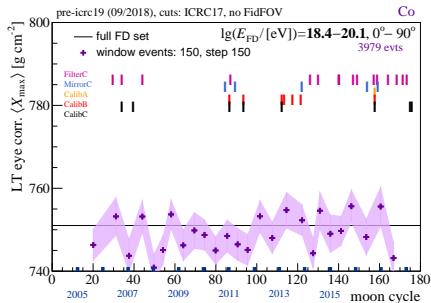
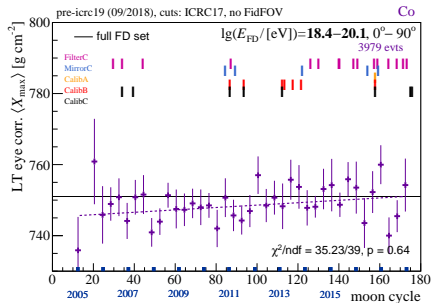
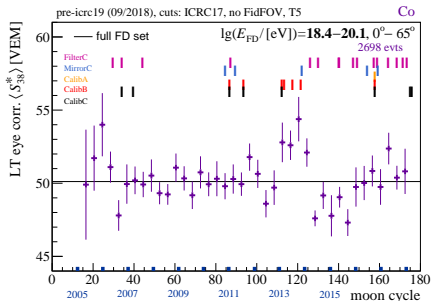
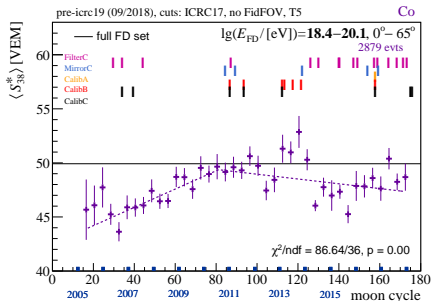
Correction for the energy evolution, $\lg(E/\text{eV}) = 18.4 - 20.1$



Correction for the energy evolution, $\lg(E_{\text{FD}}/\text{[eV]}) = 18.4 - 20.1$

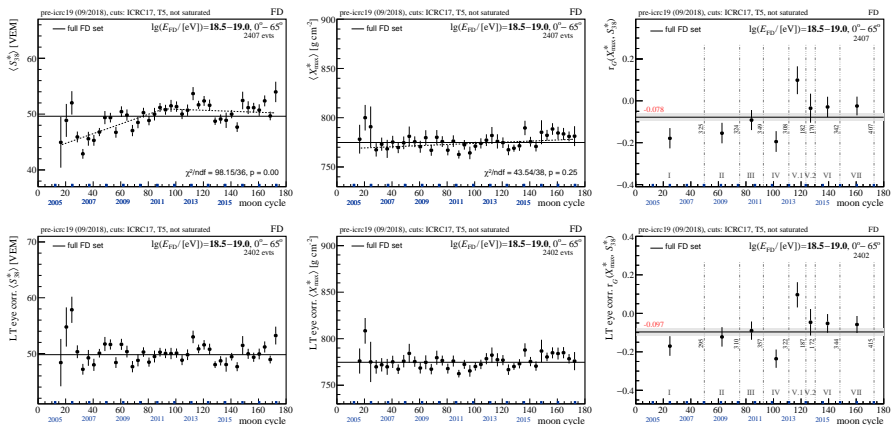


Correction for the energy evolution, $\lg(E_{\text{FD}}/\text{[eV]}) = 18.4 - 20.1$



Correlation: FD, $\lg(E/\text{eV}) = 18.5 - 19.0$

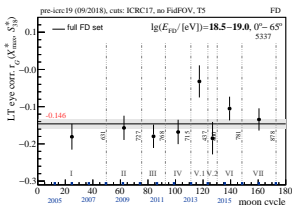
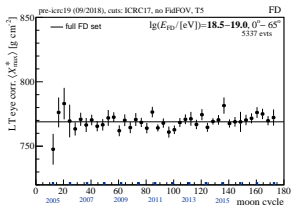
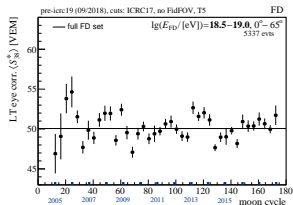
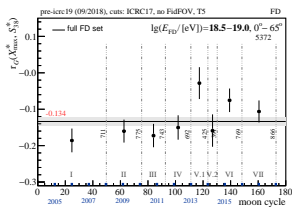
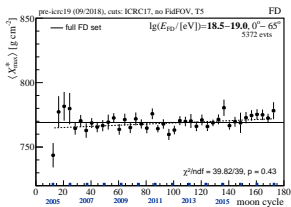
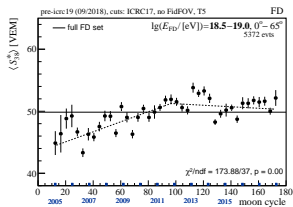
PLB 2016 cuts (ICRC 2017, T5, no saturated events)



top row — measured values, bottom row — values corrected for long term

Correlation: FD, $\lg(E/\text{eV}) = 18.5 - 19.0$

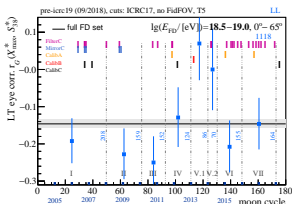
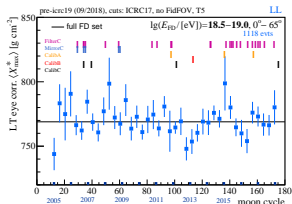
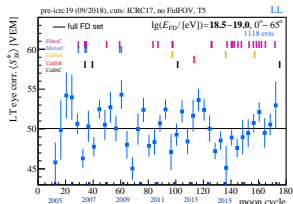
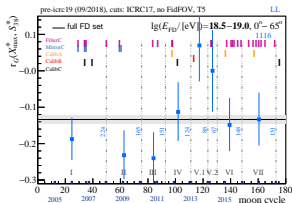
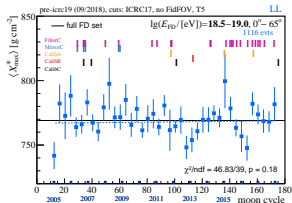
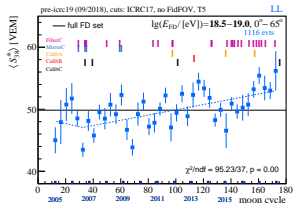
ICRC 2017 cuts without FidFOV



note jump in S_{30}^* near 2013, also in the next slides

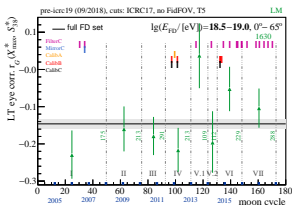
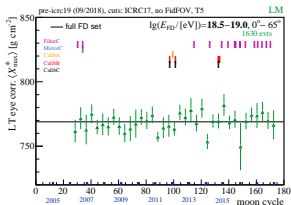
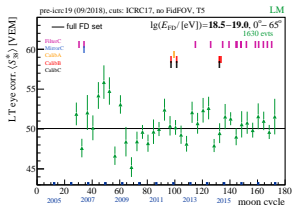
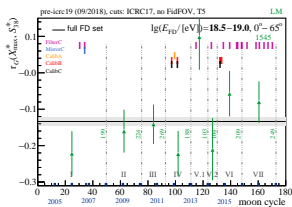
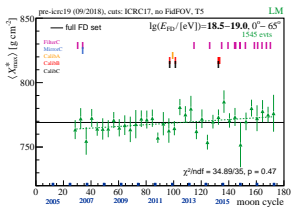
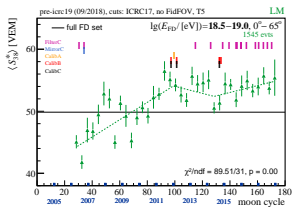
Correlation: LL, $\lg(E/eV) = 18.5 - 19.0$

ICRC 2017 cuts without FidFOV



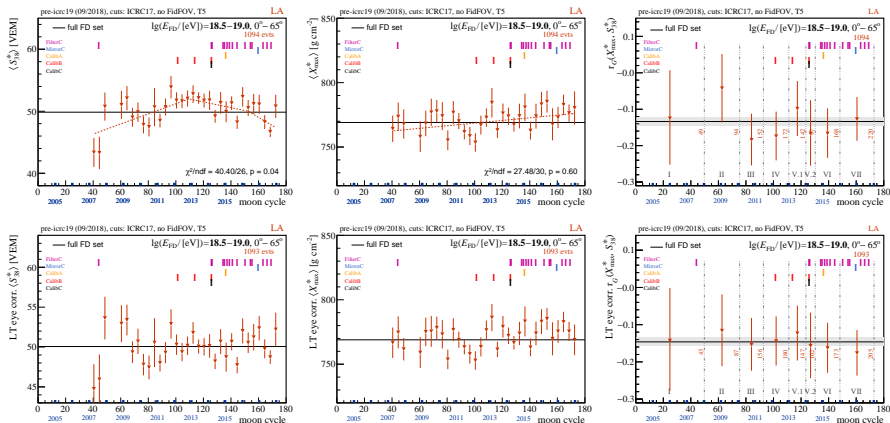
Correlation: LM, $\lg(E/\text{eV}) = 18.5 - 19.0$

ICRC 2017 cuts without FidFOV



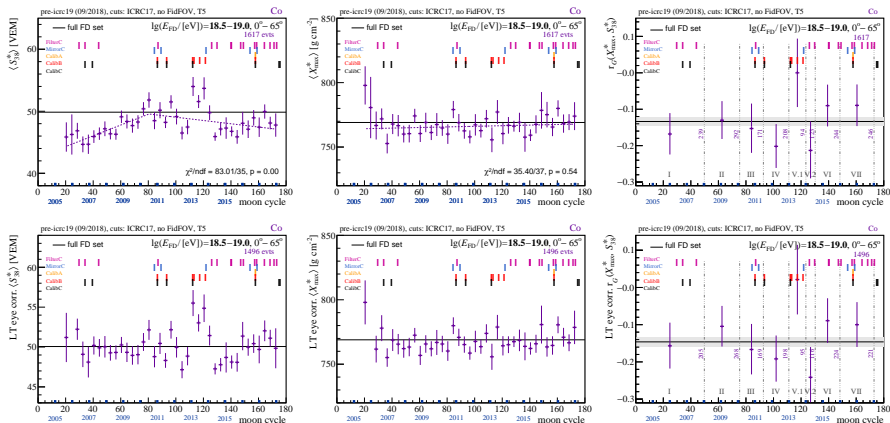
Correlation: LA, $\lg(E/eV) = 18.5 - 19.0$

ICRC 2017 cuts without FidFOV



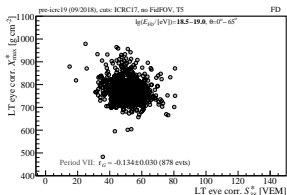
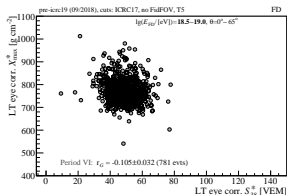
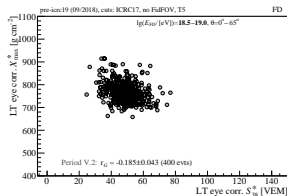
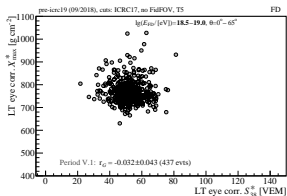
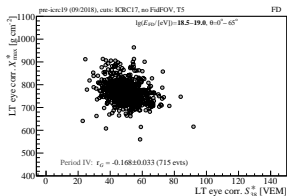
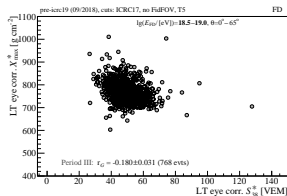
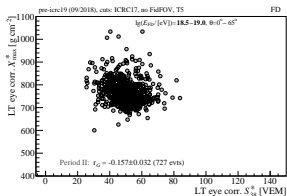
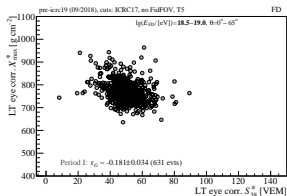
Correlation: Co, $\lg(E/eV) = 18.5 - 19.0$

ICRC 2017 cuts without FidFOV



LL, LM, Co: S_{38}^* and r_G near/in 2013 are above mean

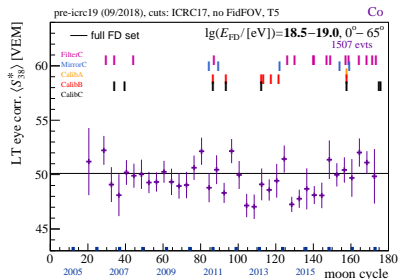
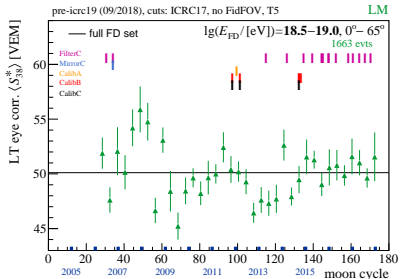
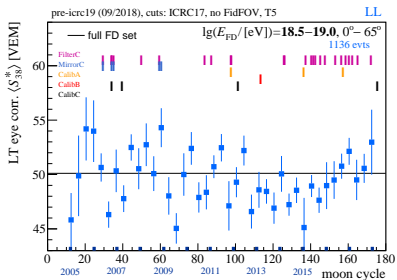
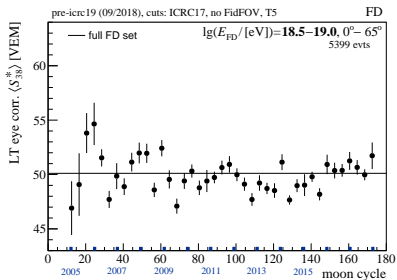
Correlation in all periods: FD, $\lg(E/eV) = 18.5 - 19.0$



Period V.1 (center)
 looks different?

Correlation: ad-hoc change of E_{FD} , $\lg(E/\text{eV}) = 18.5 - 19.0$

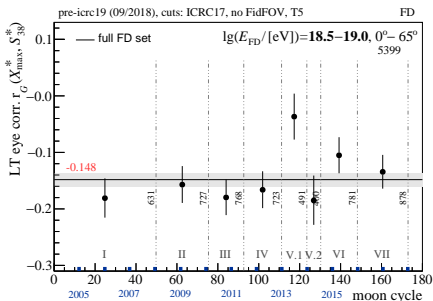
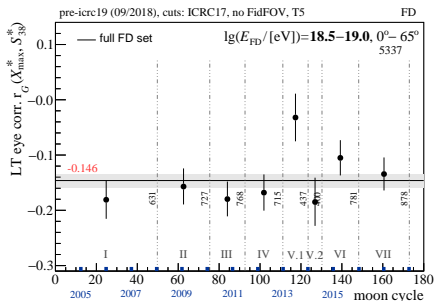
$E_{\text{FD}}^{\text{corr}}$ is additionally (ad-hoc) increased by 10% for LL, LM, Co for 2013



Correlation: ad-hoc change of E_{FD} , $\lg(E/eV) = 18.5 - 19.0$

Correlation unchanged

left: r_G with LT correction; right: same but with ad-hoc 10% increase of E_{FD} for LL, LM, Co for 2013



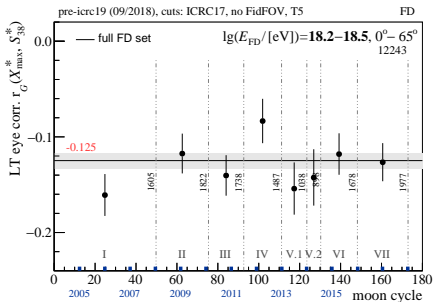
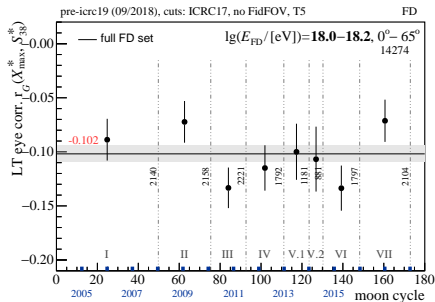
correlation could change due to migration of events from lower energies where composition should be more mixed

note increase in statistics in V.1 from 437 to 491 events,

this is why it is important to apply correction to E_{FD} and re-bin events

Correlation: $\lg(E/\text{eV}) = 18.0 - 18.2$ and $\lg(E/\text{eV}) = 18.2 - 18.5$

Period V.1 looks fine



Despite of jumps in S_{38}^* happening around 2013 (period V.1) it looks like for r_G we just got a fluctuation?

further checks and MC studies are underway. . .