Updates on Si, P, S, Ar, Ca fluxes

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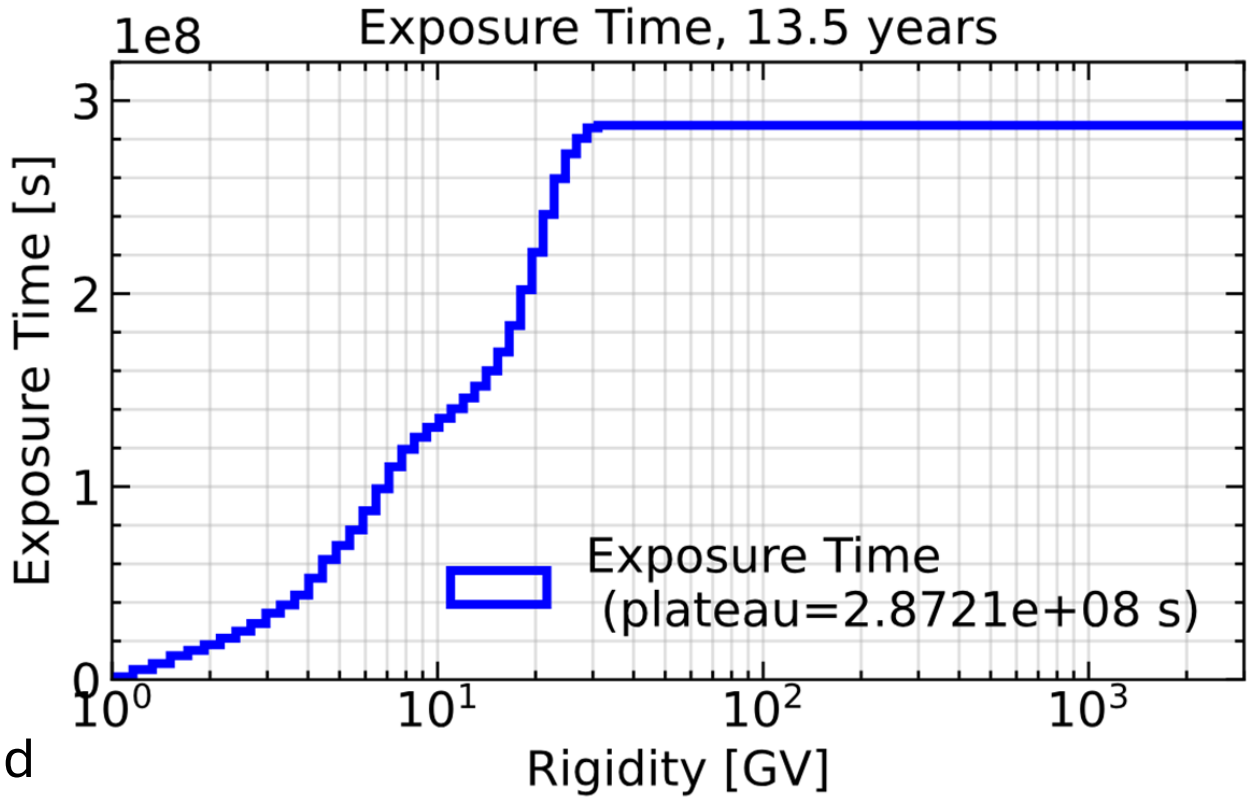
AMS-Italy at La Sapienza, 09 October 2025

Updates since SDIAT analysis meeting

1. 13.5 years, exclude photon-polarization trigger period
2. Efficiency:
   - Bug fix for L1 pick-up efficiency (no visible difference)
   - Update tracker efficiency (P tracker charge efficiency for data improved)
   - P Data/MC fit:
     - L1 BZ directly from P fit
     - Trigger and DAQ: from average of Si and S fits
     - Others: from Si fit
3. Template fit:
   - MC truth for P
   - Refine fitting for Si, S, Ar, Ca
4. TOI: S and P add sub-irons
5. Unfolding: constraint on spectral index at high Rigidity
6. Flux check and comparison with other groups

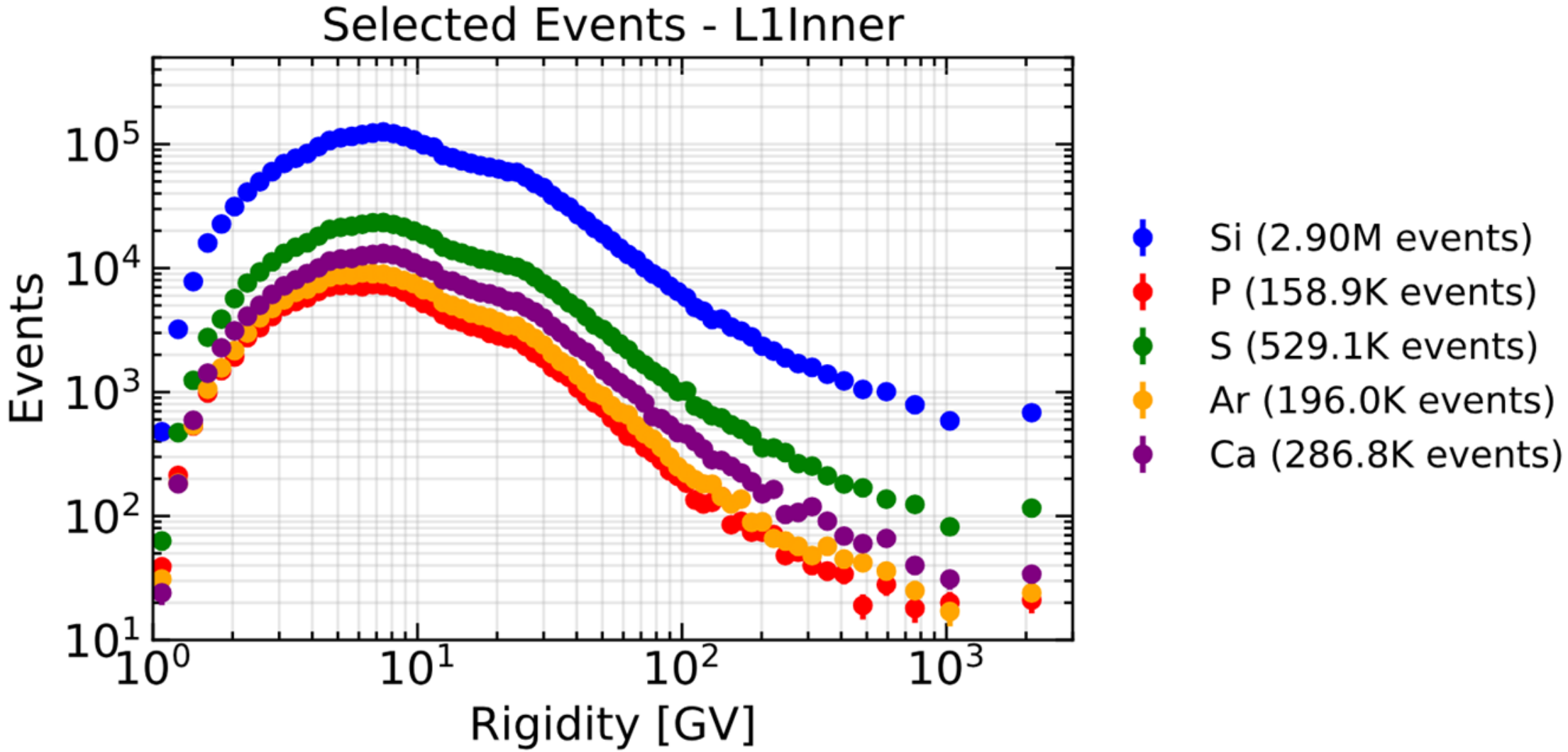
Sample

- Si, P, S, Ar, Ca
- Italian dataset
- Data:
  - 13.5 years (May 20 2011 to Nov 16 2024)
  - ISS.B1236
- MC:
  - B1315: Si, P, S
  - B1236: Cl, Ar, K, Ca, Sc, Ti, V, Fe
- L1Inner Geometry
- Event selection:
  - Pass8 common selection (https://twiki.cern.ch/twiki/bin/view/AMS/Pass8)
  - excluding photon-polarization trigger period
- Rigidity bin:
  - high Z bins, same as Ne Mg and Si binning

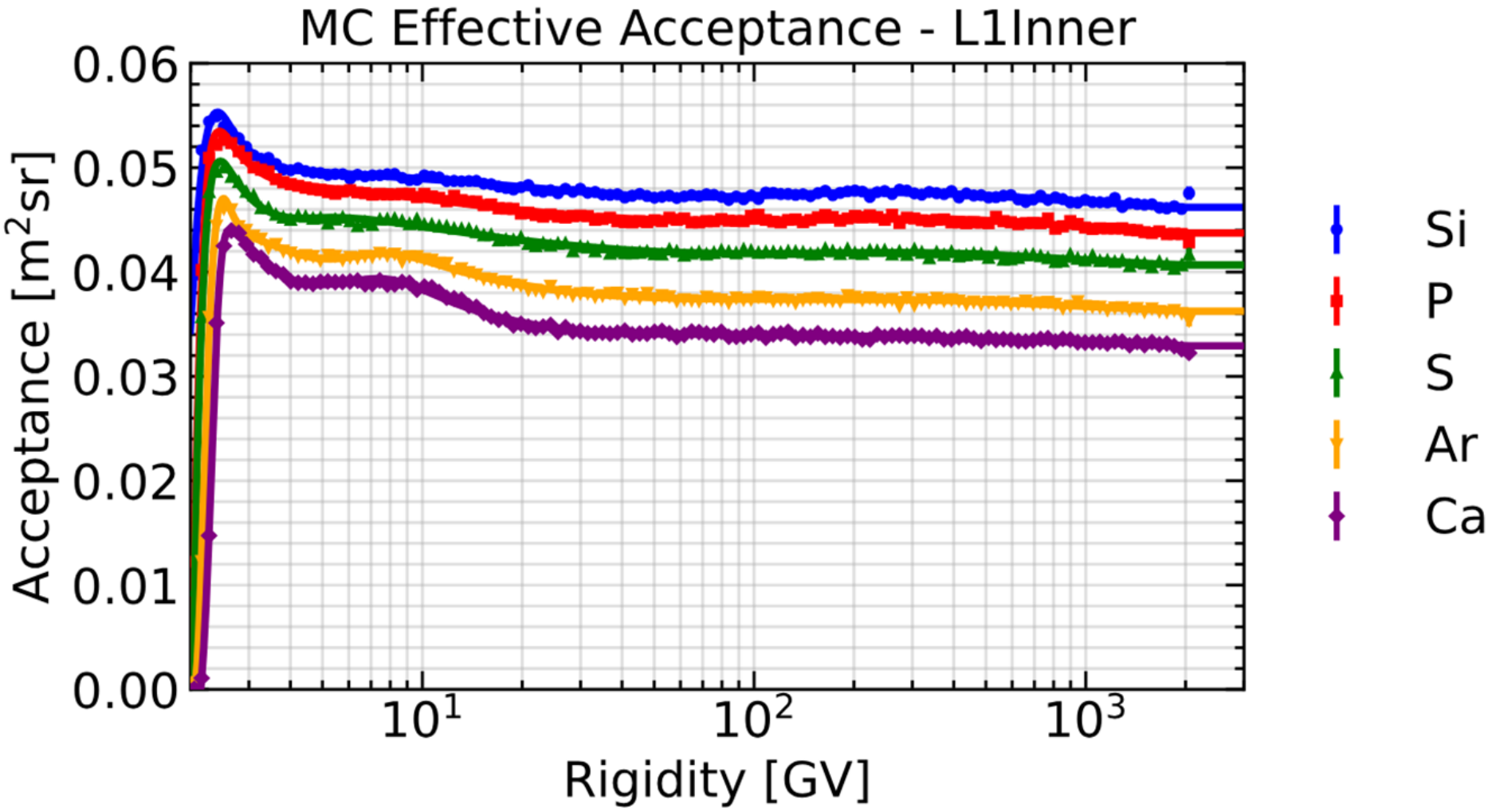


Selected Events (13.5 years)

- https://twiki.cern.ch/twiki/bin/view/AMS/Pass8
- excluding photon-polarization trigger period



L1Inner Effective Acceptance



Data/MC efficiency corrections

MC acceptance needs to be corrected by data/MC efficiency ratios:

- L1 large-charge hit efficiency
- L1 pick-up efficiency
- Inner tracker reconstruction efficiency
- Inner tracker Charge efficiency
- TOF Charge efficiency
- Trigger efficiency

- **Due large contamination in P, some of the P data/MC efficiency ratios are estimated from Si or Si and S.**

L1 large-charge hit efficiency (BZ efficiency)

Denominator:

- SAA cut, RTI cut, Remove bad runs
- Physical trigger
- tracker track: itrtrack >= 0
- beta cuts: beta > 0.4, tof btype == 1
- TrTrack selection
  - InnerNHitY >= 5&&L2&(L3 | L4)&(L5 |L6)&(L7 | L8),
  - InnerNormChisqY < 10
  - L9XY (for FS analysis)
  - InnerL9NormChisqY < 10 (for FS analysis)
- Inner track in L1Inner fiducial volume
- Q selection:
  - UTOF common Q cuts
  - Inner common Q cuts

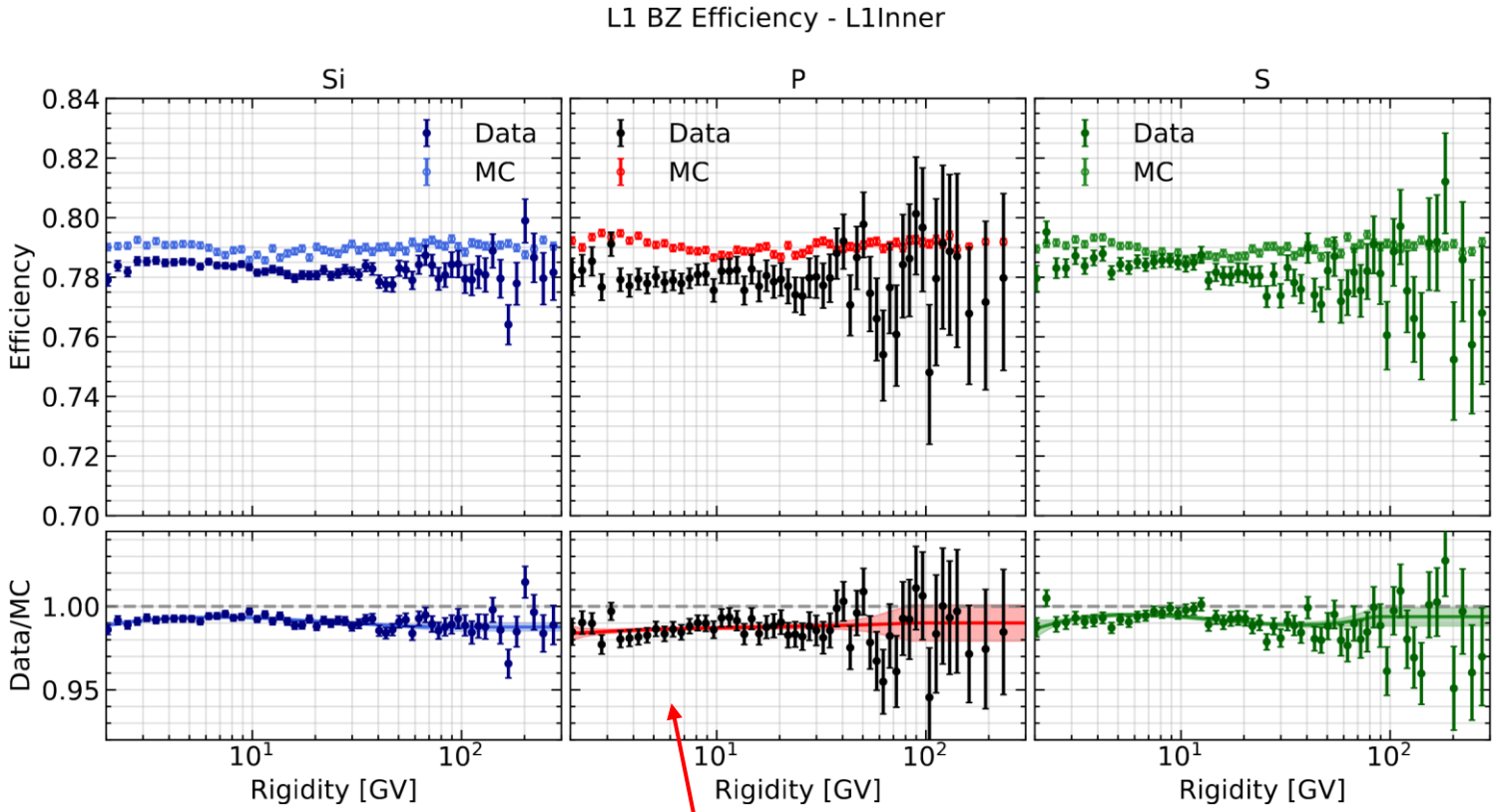
Numerator:

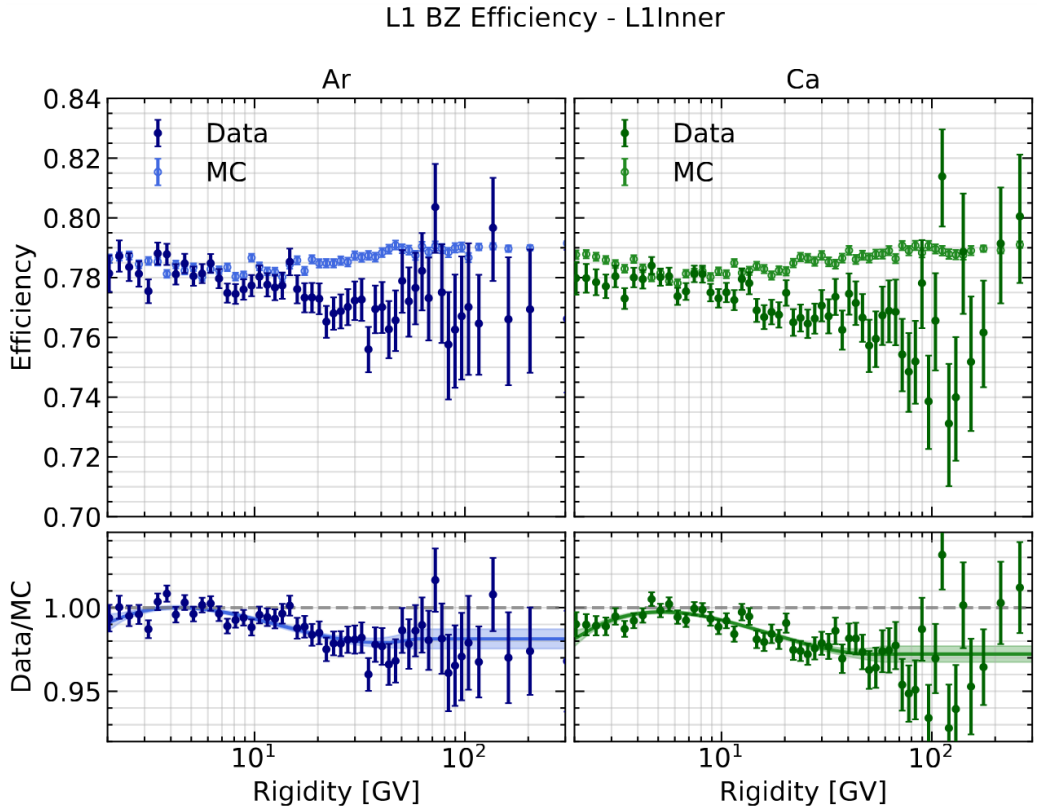
- Denominator
- L1XY (unbiased external HitPos within L1)
- unbiased L1 Q status
- unbiased L1 Q lower charge cut

Q cuts	Si (Z=14)	P (Z=15)	S (Z=16)
Inner Q	[13.5,14.5]	[14.5, 15.5]	[15.5, 16.5]
UTOF Q	[13.26,15.50]	[14.24,16.50]	[15.22,17.50]
Unbiased L1 Q	**>12.43**	**>13.33**	**>14.23**

Q cuts	Ar (Z=18)	Ca (Z=20)
Inner Q	[17.5, 18.5]	[19.5, 20.5]
UTOF Q	[17.17, 19.50]	[19.13, 21.50]
Unbiased L1 Q	**>16.03**	**>17.82**

L1 large-charge hit efficiency (BZ efficiency)





P Data/MC fit: directly from P.

L1 pick-up efficiency

Denominator:

- L1 BZ efficiency numerator

+ Unbiased L1 Q in L1 common Q cut range

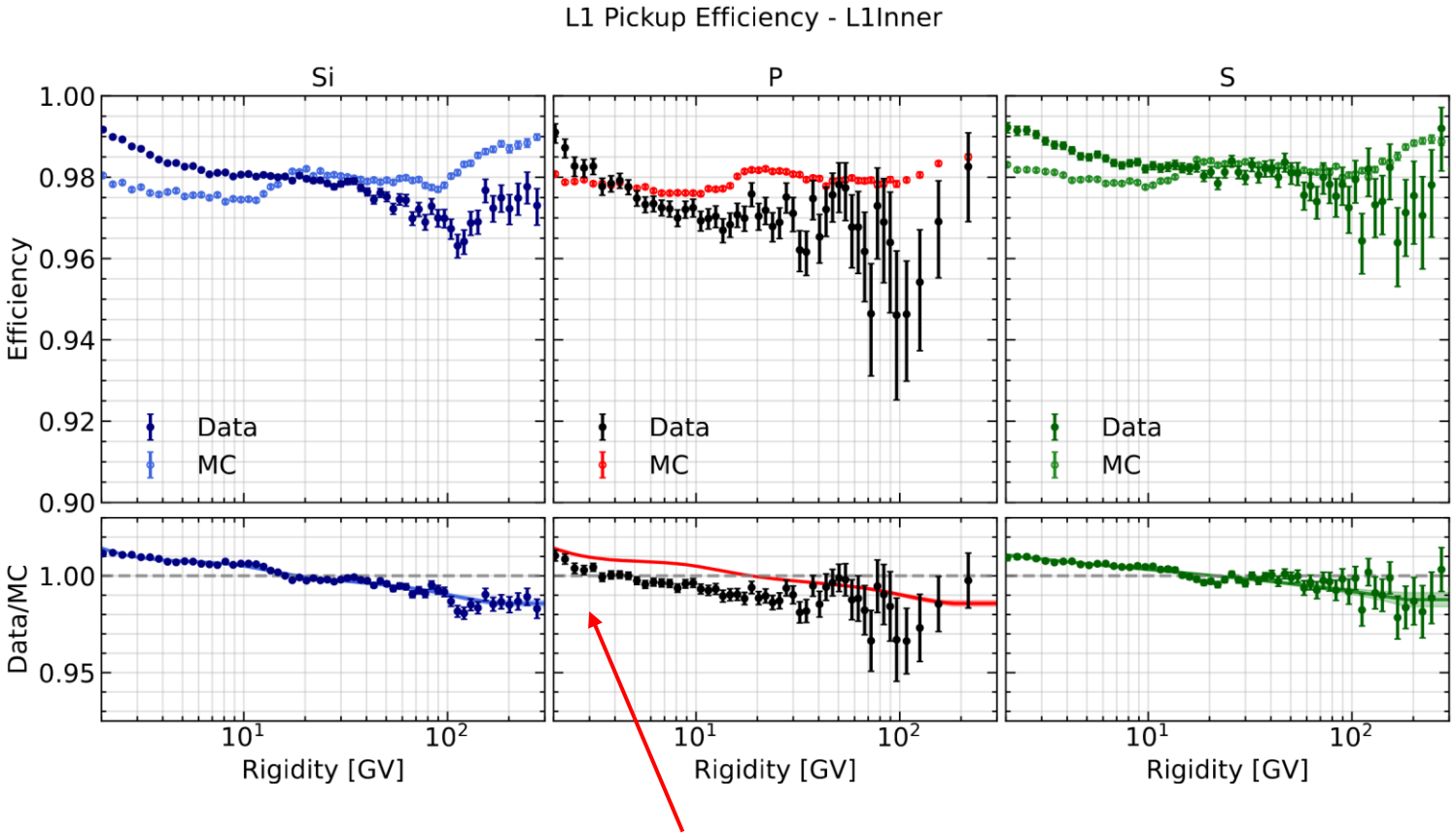
Q cuts	Si (Z=14)	P (Z=15)	S (Z=16)
Unbiased L1 Q	[12.433, 14.90]	[13.333, 15.95]	[14.231, 17.01]
L1 Q	**>12.43**	**>13.33**	**>14.23**

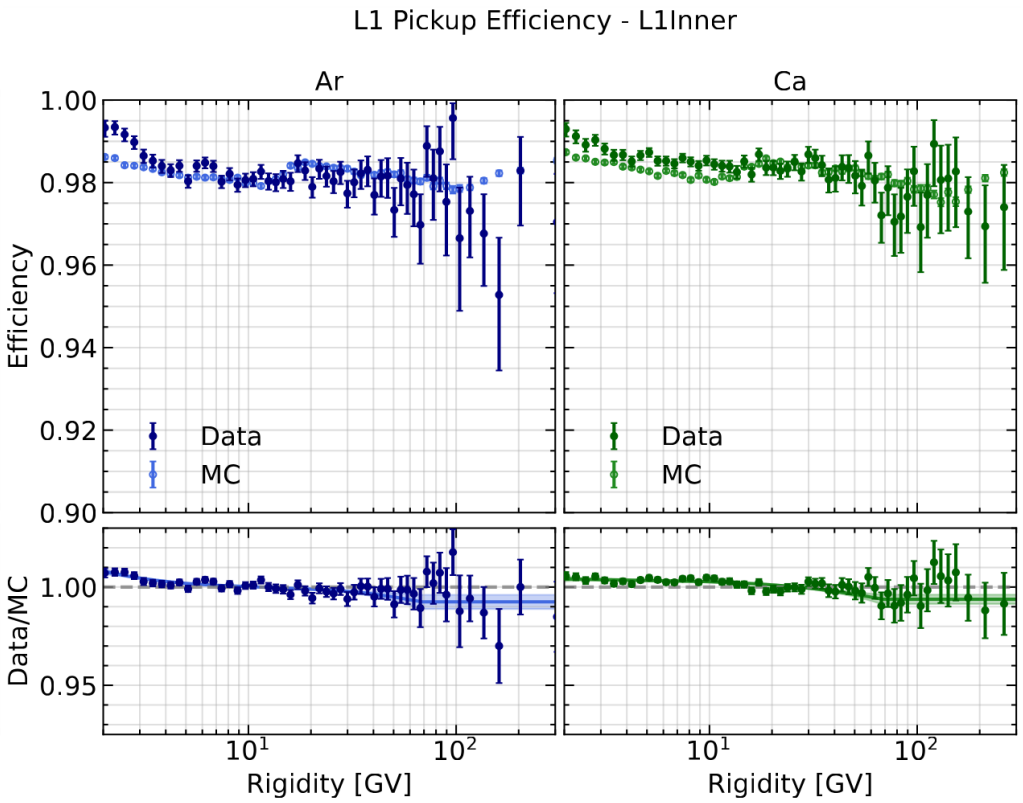
Q cuts	Ar (Z=18)	Ca (Z=20)
Unbiased L1 Q	[16.026, 19.128]	[17.816, 21.247]
L1 Q	**>16.03**	**>17.82**

Numerator:

- Denominator
- TrTrack selection
  - L1InnerNormChisqY < 10&&L1InnerChisqY − InnerChisqY < 10 (for L1Inner analysis)
  - L1XY
- L1 Q > common lower Q range,
- L1 Q asymmetry
- L1 Q status
- L1 Fiducial volume

L1 pick-up efficiency





P Data/MC fit: from Si.

Inner tracker reconstruction efficiency

Denominator:

- SAA cut, RTI cut, Remove bad runs, Physical trigger
- unbiased beta cuts: betahs > 0.4, tof chists < 20&&tof chiscs < 20
- TOF and TRD track extrapolation within the tracker L1+Inner fiducial volume
- Unbiased L1XY (unbiased external HitPos within L1)
- Q selection:
  - Unbiased L1 Q [Z-0.5, Z+0.5],
  - Unbiased L1 Q status
  - Unbiased UTOF, LTOF and total Q in [Z-0.5, Z+0.5]
  - Unbiased TOF Q: |TOF_S1-TOF_S2| < 0.86, |TOF_S3-TOF_S4| < 0.86

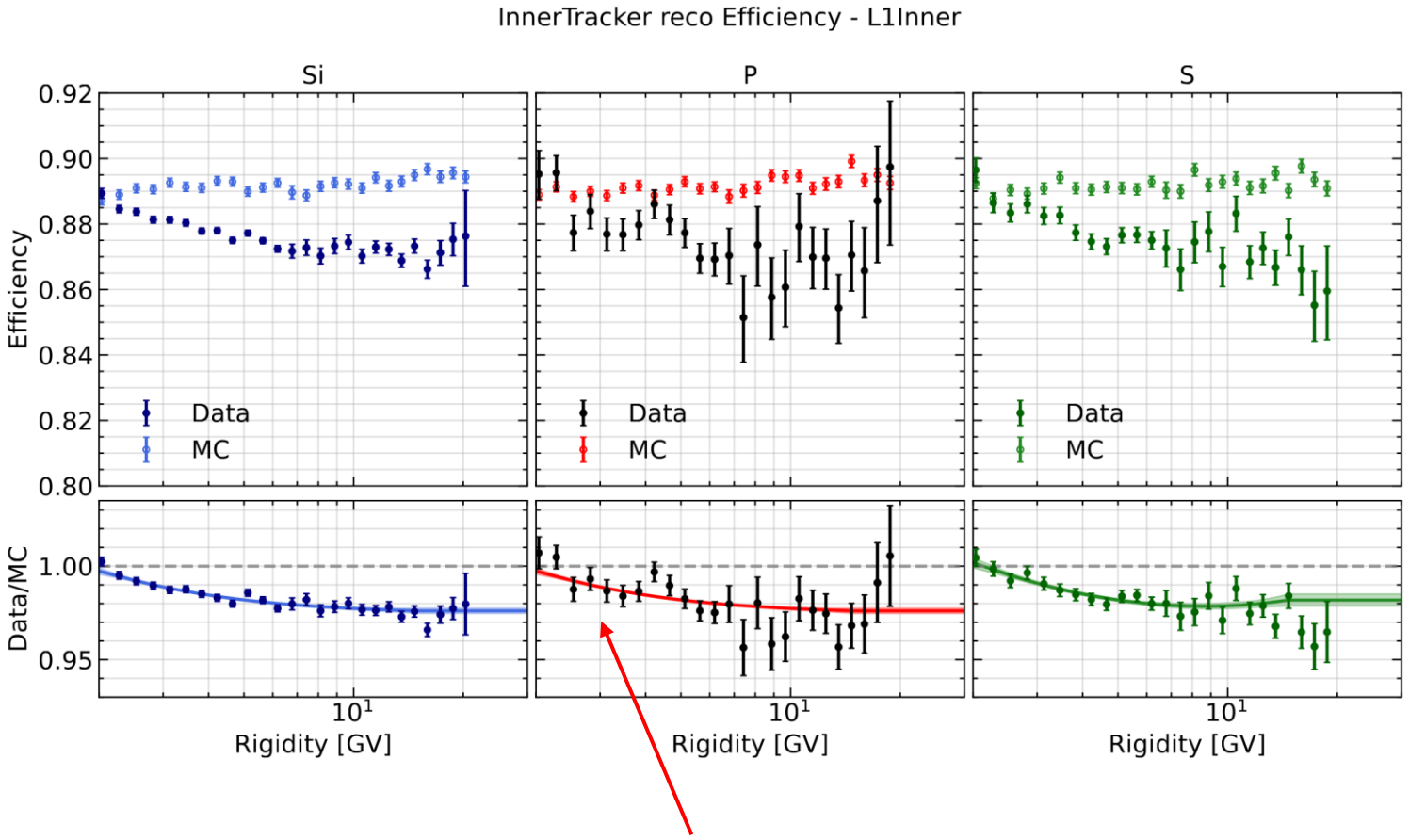
Numerator:

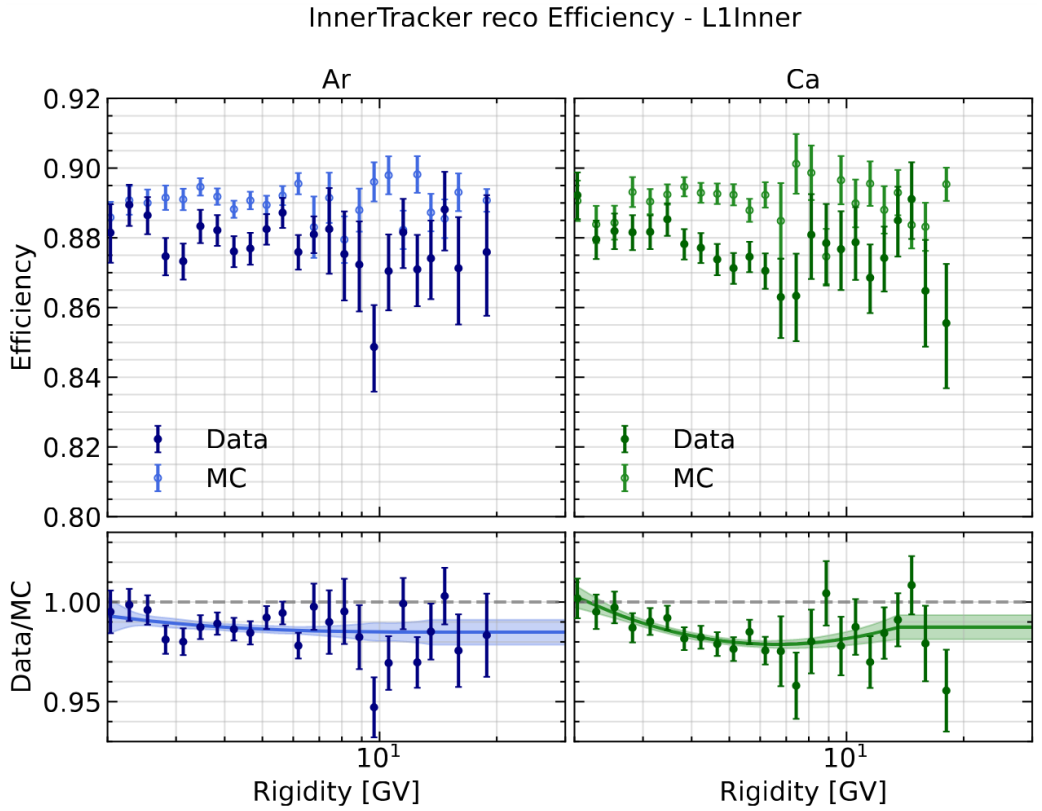
- Denominator
- tracker track: itrtrack >= 0
- ~~beta cuts: beta > 0.4~~
- TrTrack selection
  - InnerNHitY >= 5&&L2&(L3 | L4)&(L5 | L6)&(L7 | L8)
  - InnerNormChisqY < 10
- Inner Q > Z – 2.5

Q cuts	Si (Z=14)	P (Z=15)	S (Z=16)	Ar (Z=18)	Ca (Z=20)
Unbiased L1 Q	[13.5, 14.5]	[14.5, 15.5]	[15.5, 16.5]	[17.5,18.5]	[19.5, 20.5]
Unbiased TOF Q	**[13.5, 14.5]**	**[14.5, 15.5]**	**[15.5, 16.5]**	**[17.5, 18.5]**	**[19.5, 20.5]**
Inner Q	**>11.5**	**>12.5**	**>13.5**	**>15.5**	**>17.5**

Inner tracker reconstruction efficiency

TOF Beta estimator: R<6.60 GV, R_cutoff Mode estimator: R>6.6GV



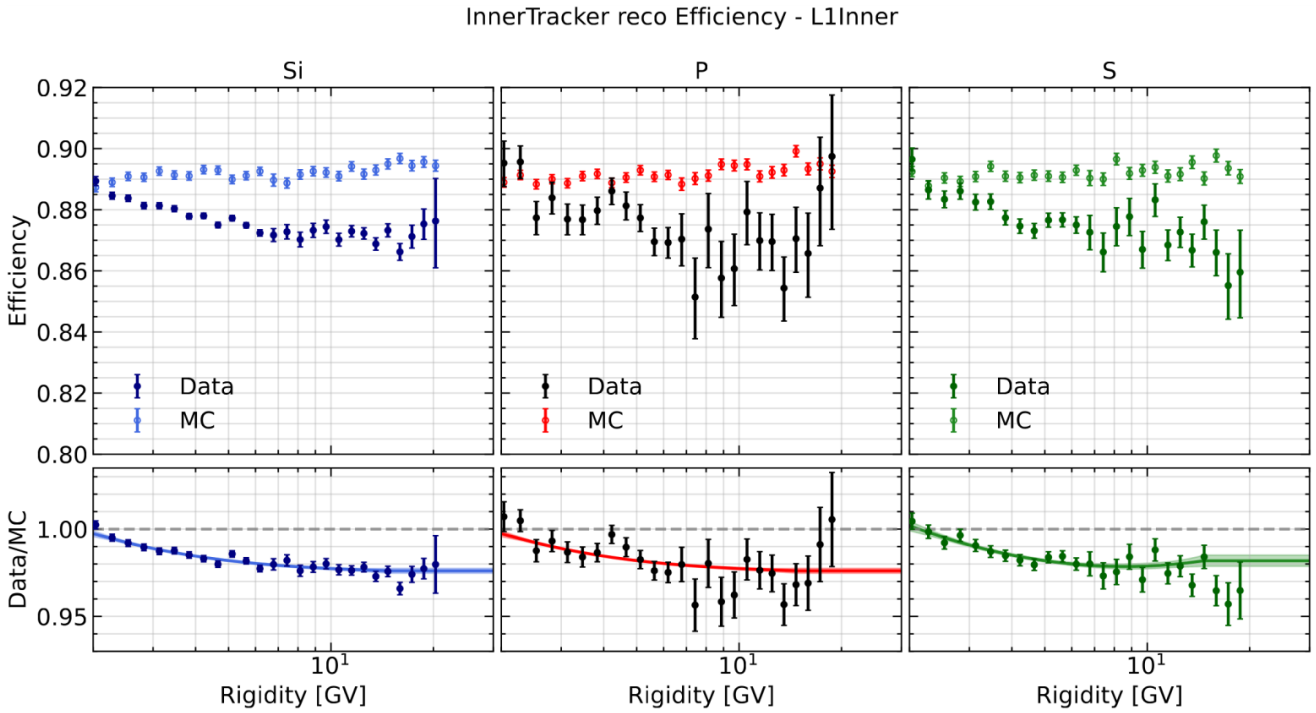


P Data/MC fit: from Si.

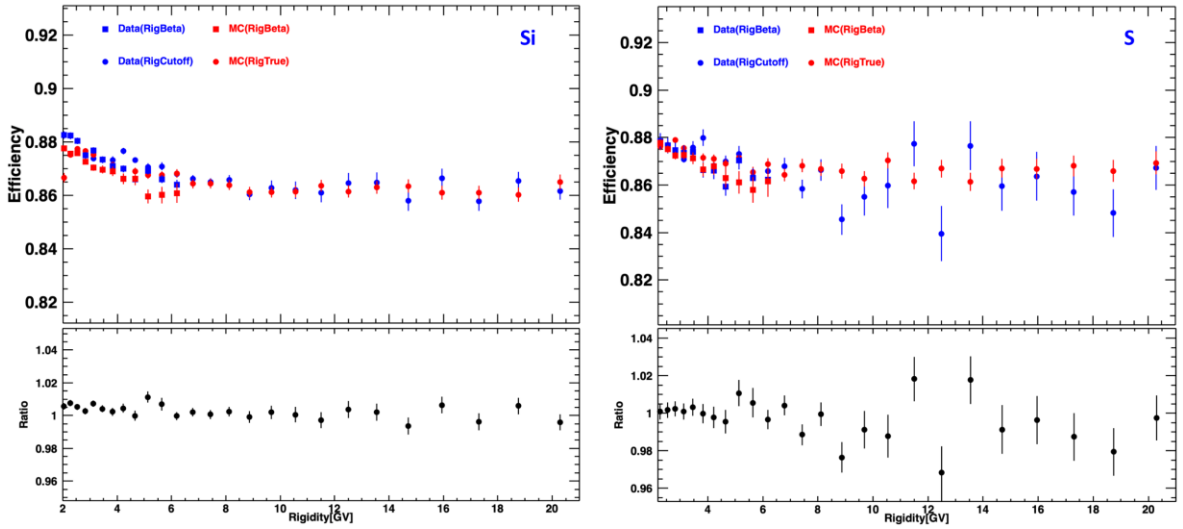
- similar as previous result
- **Large discrepancy between Data and MC**

Discrepancy with the other groups

This result:

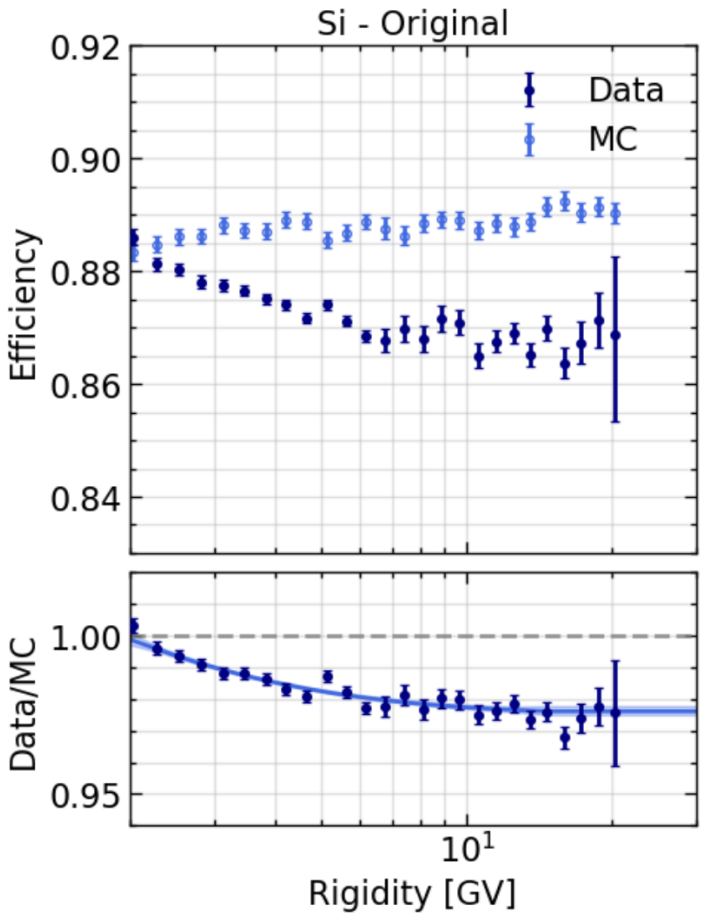


SDIAT result:

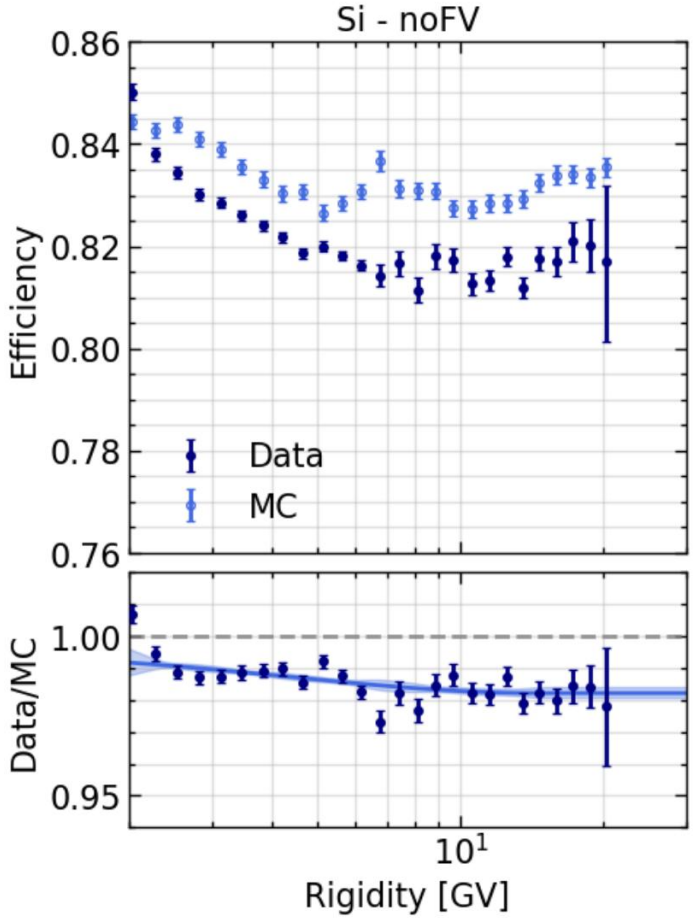


Inner tracker reconstruction efficiency **denominator breakdown:**

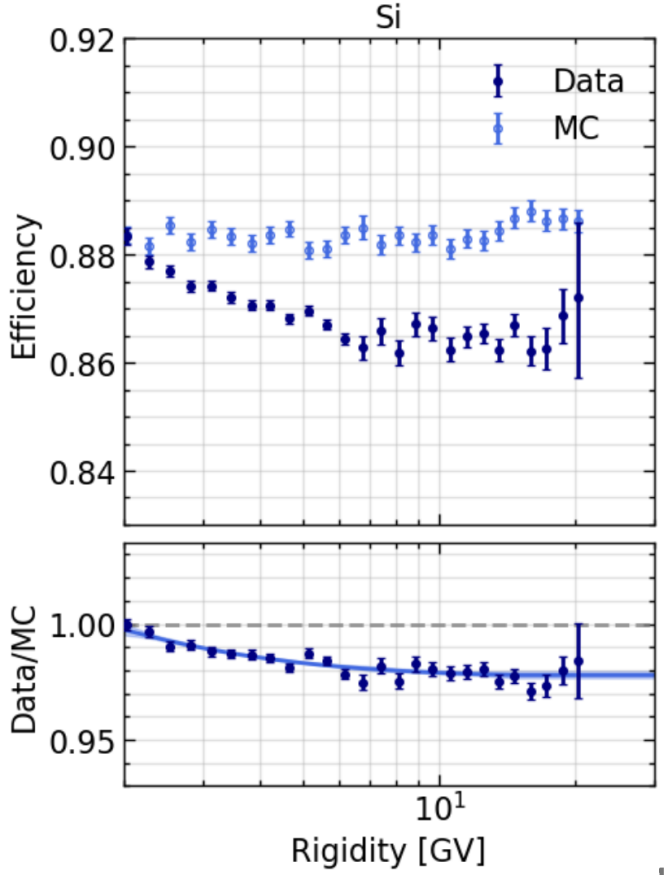
Original result:



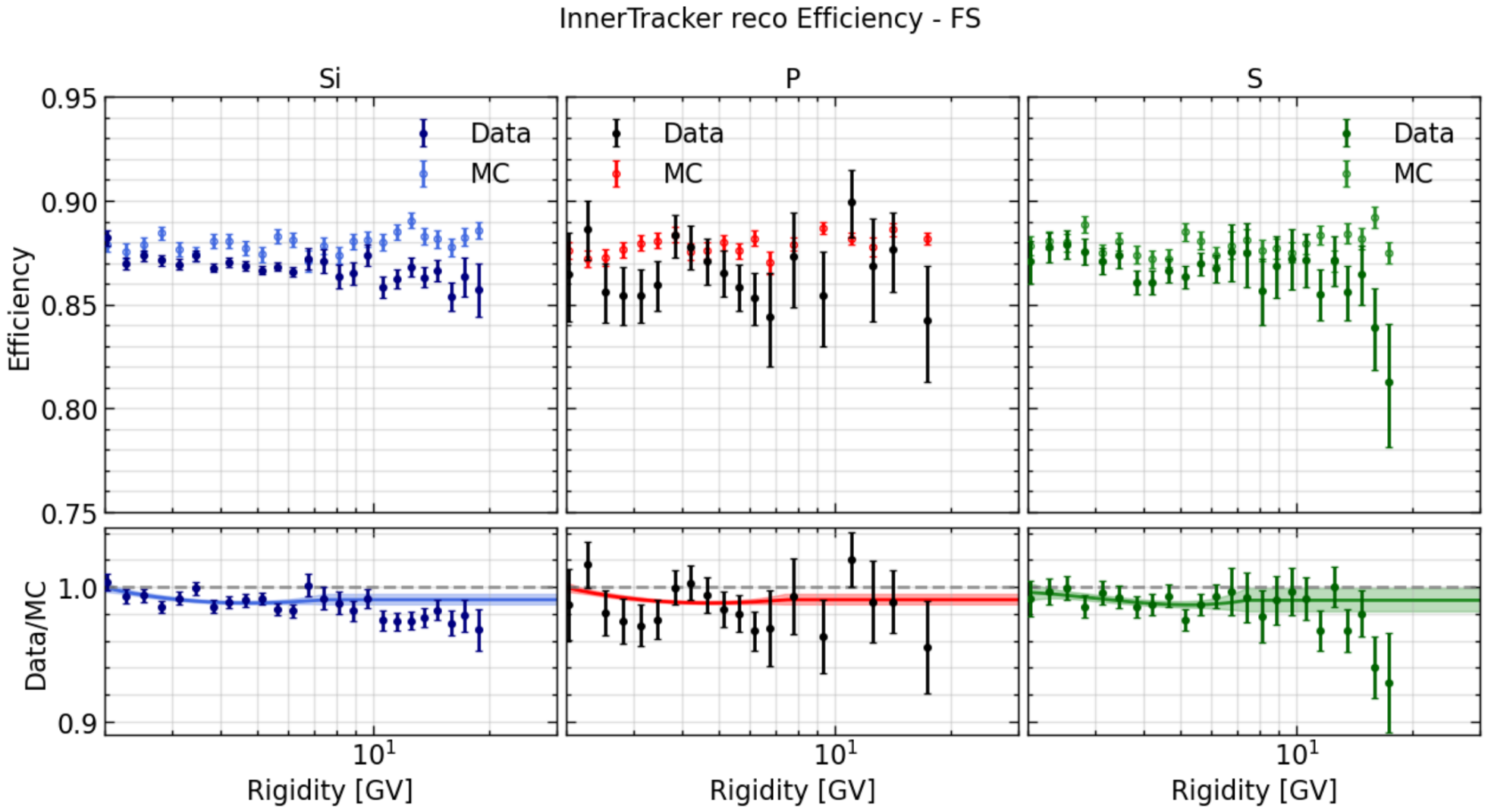
Denominator, remove fiducial volume cut: TOF track extrapolation within the tracker L1+Inner fiducial volume



Denominator, fiducial volume cut: replace TOF track extrapolation with TRD track extrapolation



Inner tracker reconstruction efficiency: check FS



On-going: Further investigation

Inner tracker charge efficiency

Denominator:

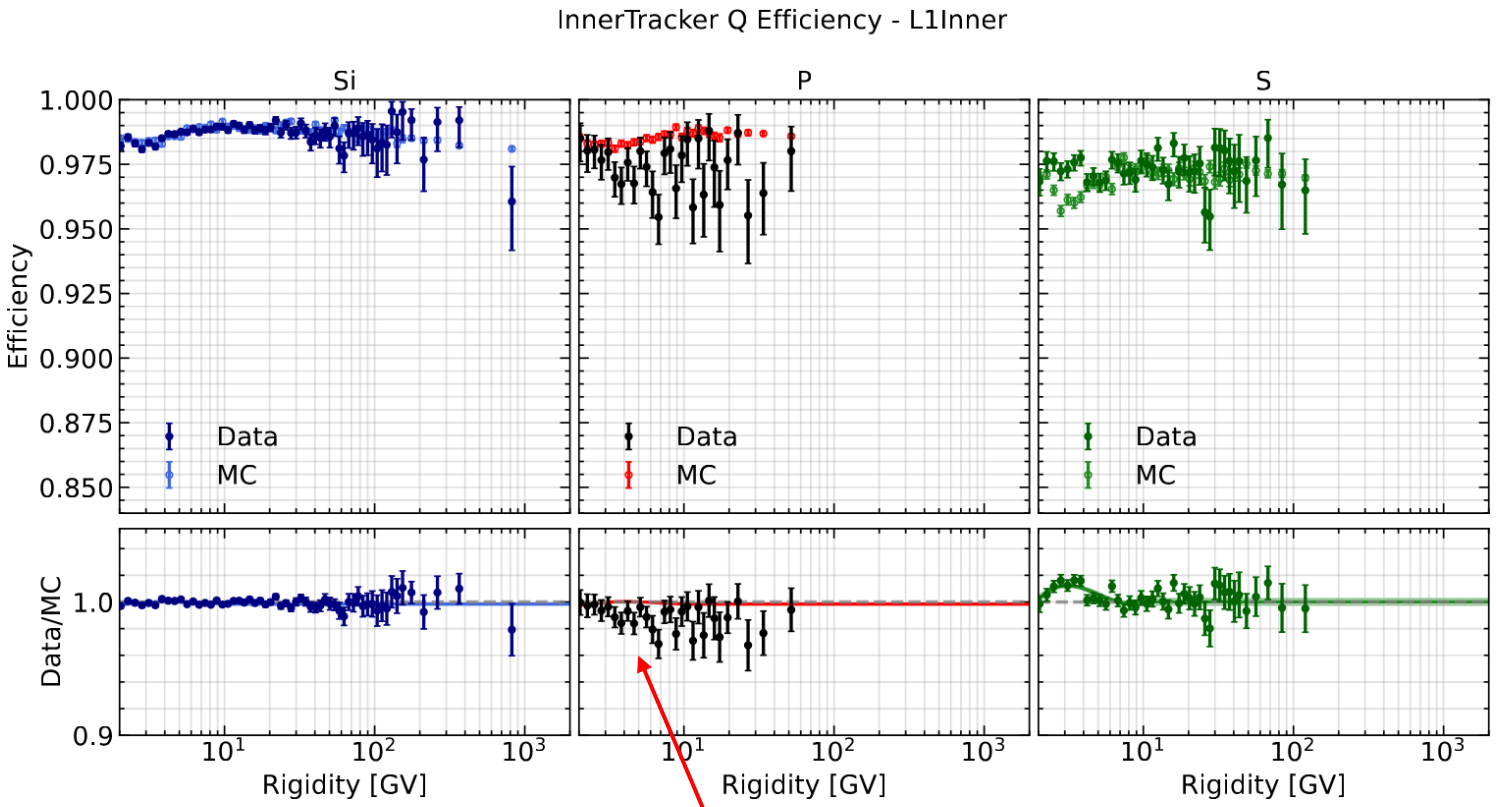
- SAA cut, RTI cut, Remove bad runs, Physical trigger;
- tracker track
- beta cuts: beta > 0.4
- TrTrack selection
- fiducial volume cut
- Q selection:
  - L1 Q [Z-0.5, Z+0.5], Q asymmetry,
  - L1 Q status
  - Inner Q > Z − 2.5,
  - UTOF, LTOF and total [Z-0.4, Z+0.4]
  - Unbiased TOF Q: |TOF_S1-TOF_S2| < 0.86, |TOF_S3-TOF_S4| < 0.86
  - Unbiased L9 charge > Z-0.5

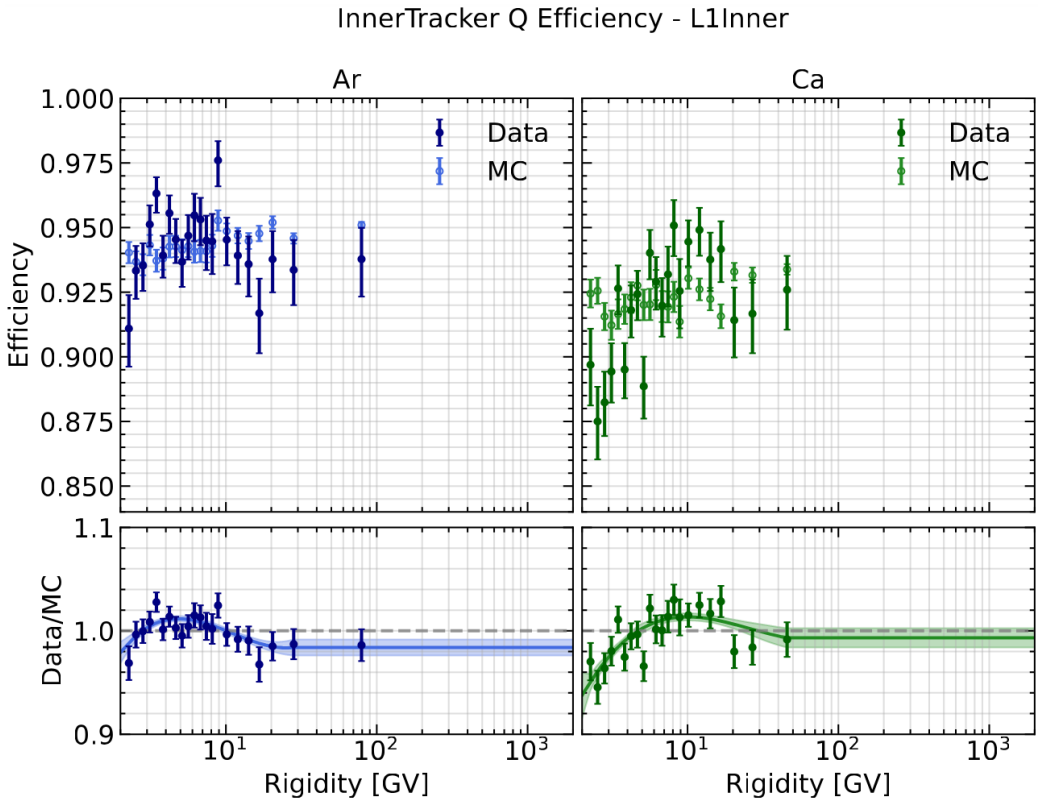
Numerator:

- Denominator
- Inner Q in common Q range

Q cuts	Si (Z=14)	P (Z=15)	S (Z=16)	Ar (Z=18)	Ca (Z=20)
L1 Q	[13.5, 14.5]	[14.5, 15.5]	[15.5, 16.5]	[17.5,18.5]	[19.5, 20.5]
TOF Q	**[13.6, 14.4]**	**[14.6, 15.4]**	**[15.6, 16.4]**	**[17.6, 18.4]**	**[19.6, 20.4]**
Unbiased L9	**>13.5**	**>14.5**	**>15.5**	**>17.5**	**>19.5**
Inner Q	[13.5, 14.5]	[14.5, 15.5]	[15.5, 16.5]	[17.5, 18.5]	[19.5, 20.5]

Inner tracker charge efficiency





P Data/MC fit: from Si.

TOF charge efficiency

Denominator:

- SAA cut, RTI cut, Remove bad runs
- Physical trigger
- tracker track
- TrTrack selection
- fiducial volume cut
- Q selection:
  - L1 Q [Z-0.5, Z+0.5] Q asymmetry, Q status
  - inner Q [Z-0.5, Z+0.5]
  - ***LTOF common Q range for L1Inner analysis***
  - Good second TrTrack in Inner
  - secondTrTrack R ≤ 0.2 GV or hit ≤ 3 layers

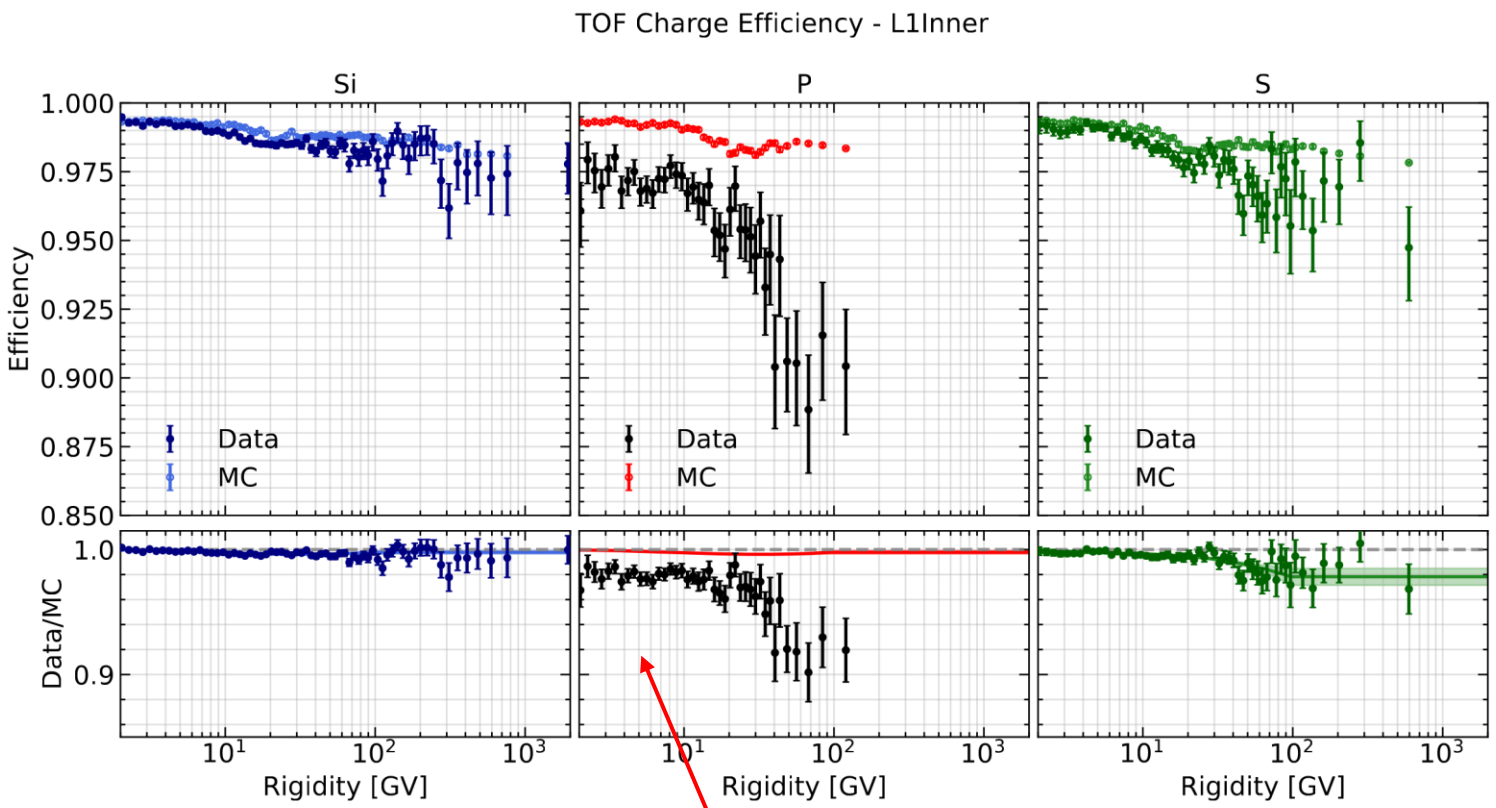
Numerator:

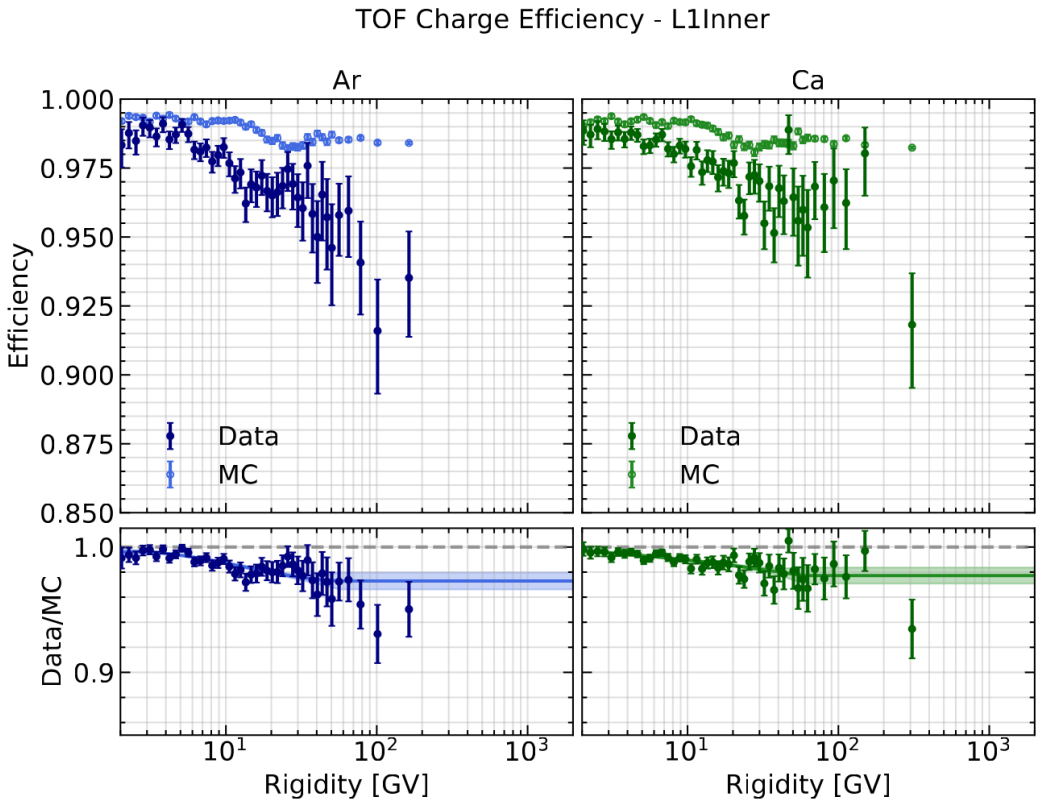
- Denominator
- beta > 0.4
- UTOF Q in common Q range

Common Q cuts	Si (Z=14)	P (Z=15)	S (Z=16)
UTOF Q	[13.26, 15.50]	[14.24, 16.50]	[15.22, 17.50]
LTOF Q for L1Inner	>13.26	>14.24	>15.22

Common Q cuts	Ar (Z=18)	Ca (Z=20)
UTOF Q	[17.17, 19.50]	[19.13, 21.50]
LTOF Q for L1Inner	>17.17	>19.13

TOF charge efficiency

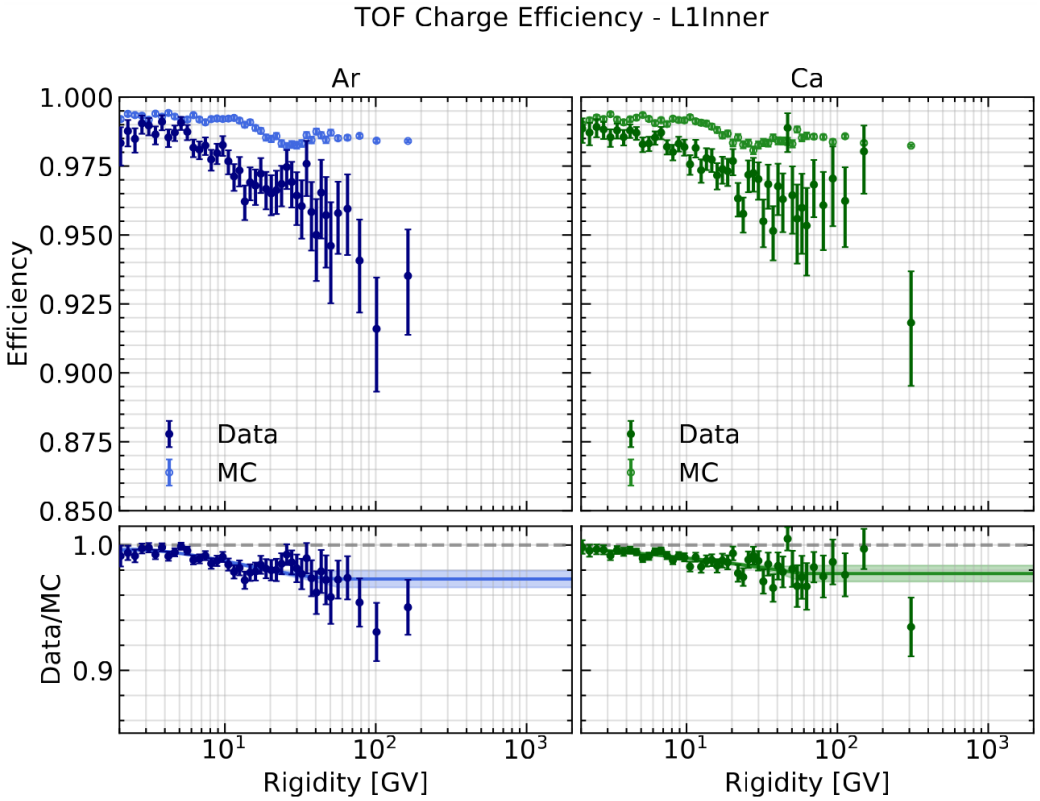


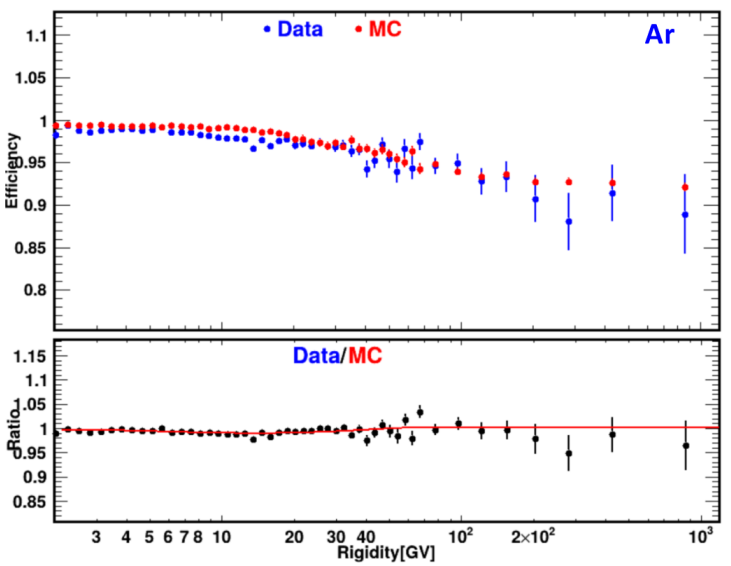


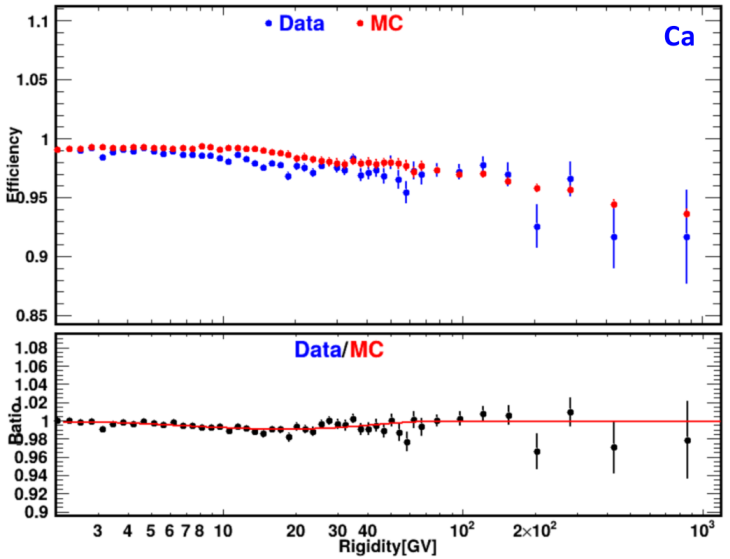
P Data/MC fit: from Si.

TOF charge efficiency

SDIAT

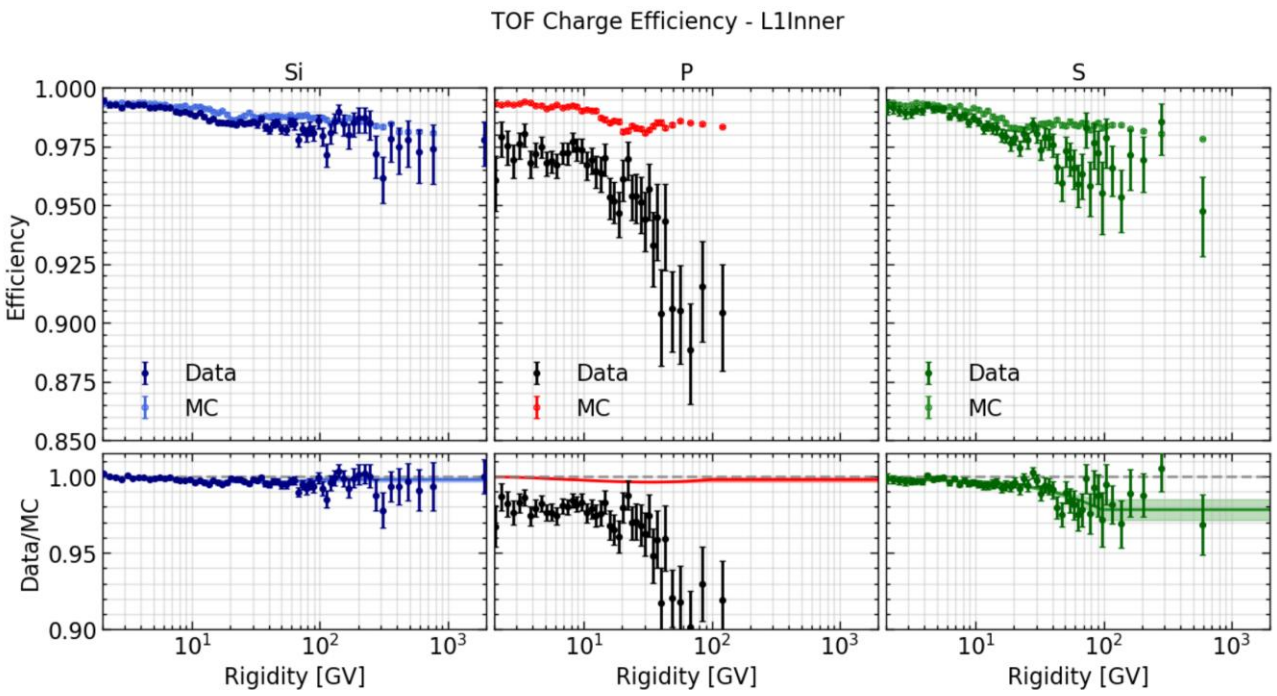


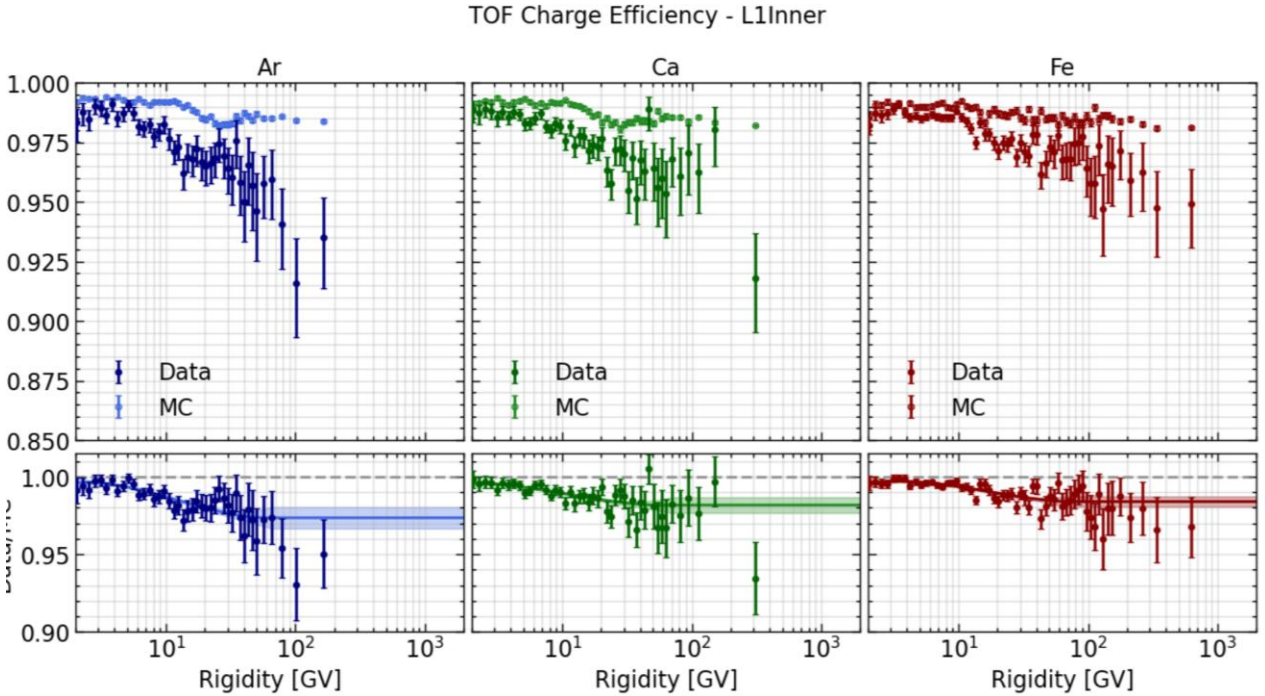




- **The MC sample include Si to Fe, and are weighted according to their fluxes**
- **With multiple MC nuclei sample used, the efficiency differences are within 1%.**

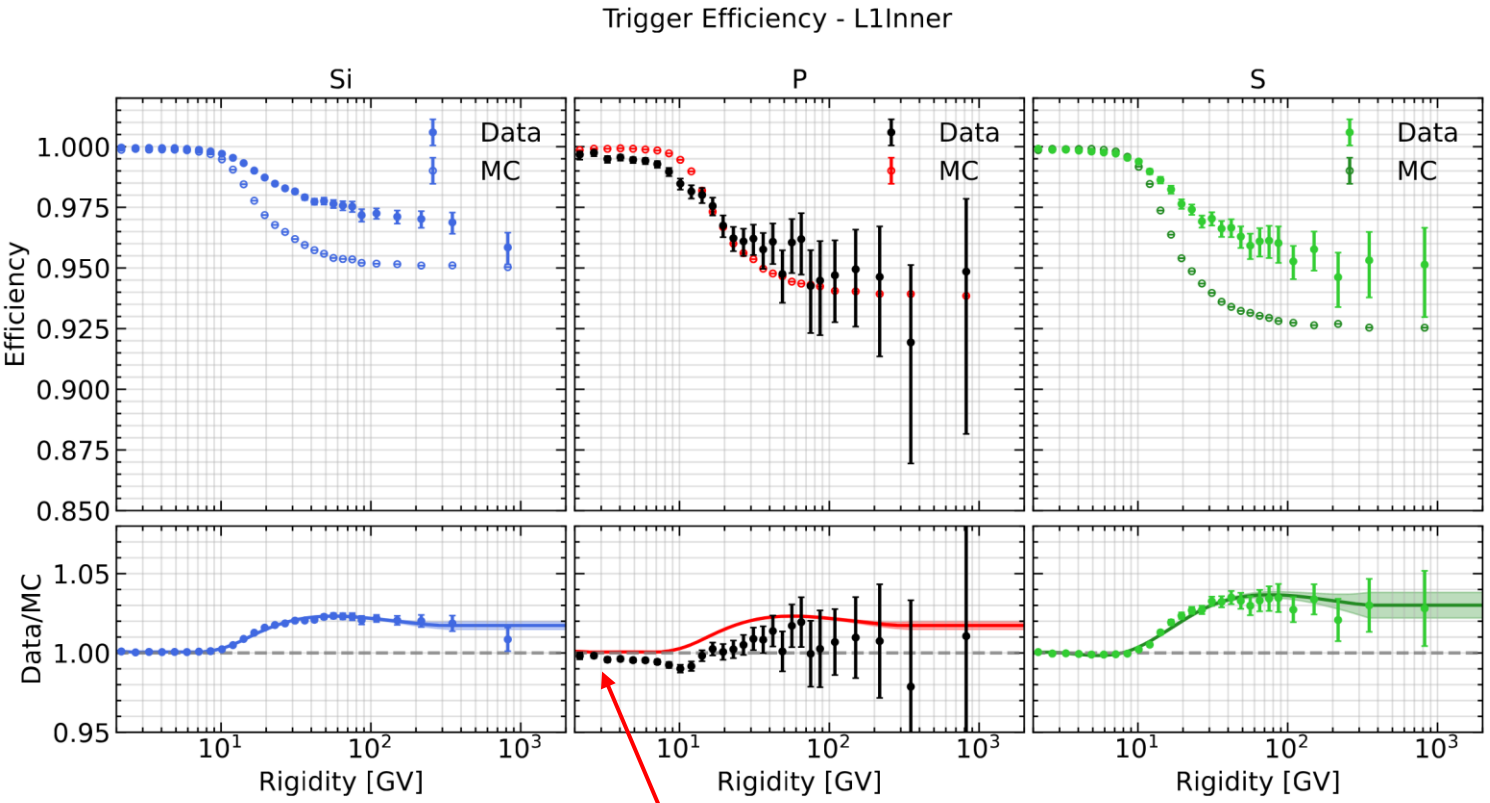
TOF charge efficiency

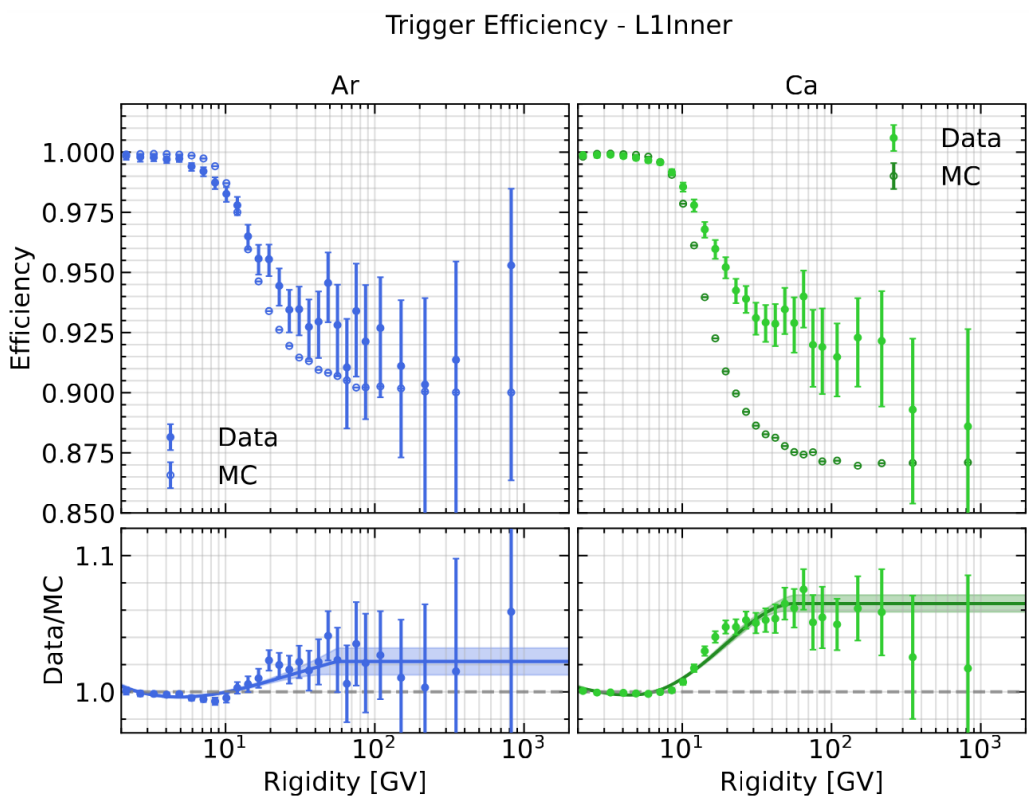




Total trigger efficiency

$$\varepsilon_{\text{Data}}^{\text{total}} \approx \frac{n^{(1)}_{NACC<5} + n^{(2)}_{NACC<8}}{n^{(1)}_{NACC<5} \times \frac{n^{(2)}_{NACC<8}}{n^{(2)}_{NACC<5}} + n^{(2)}_{NACC<8}} \qquad \varepsilon_{MC} = \frac{n_{physical}}{n_{tot}} = \frac{n_{physical}}{n_{physical} + n_{non\text{-}physical}}$$





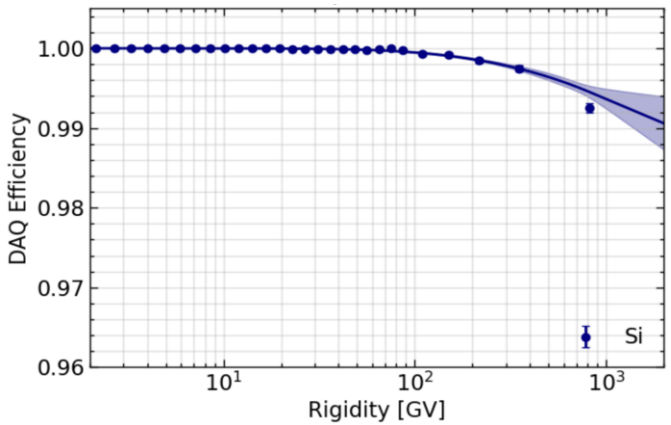
P Data/MC fit: Average of Si and S.

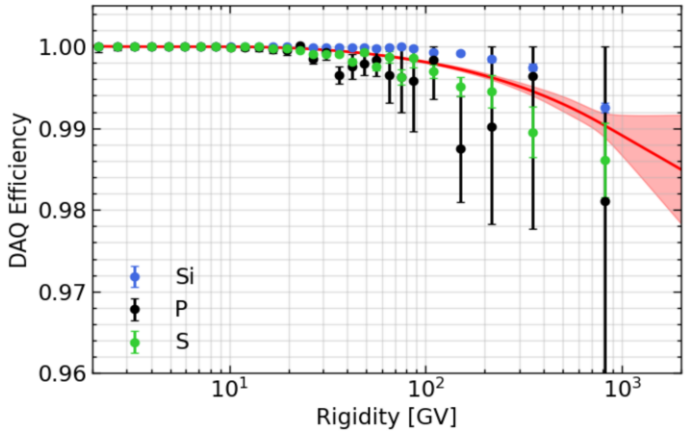
DAQ efficiency

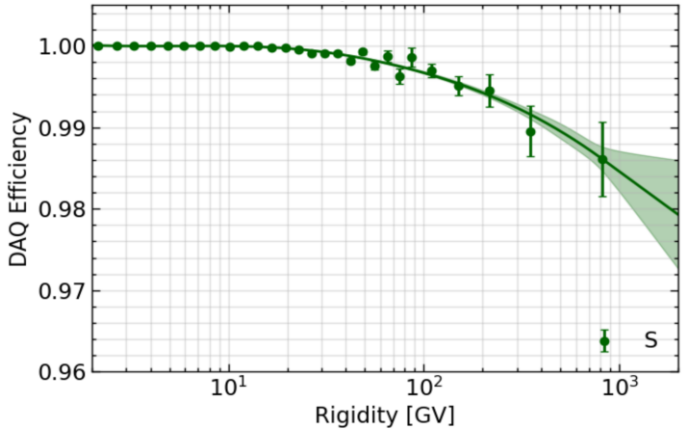
$$\varepsilon^{tot}_{DAQ} = \frac{N^{(1)}_{<=24500} + N^{(1)}_{>24500} + N^{(2)}_{<=24500} + N^{(2)}_{>24500}}{N^{(1)}_{<=24500} + N^{(1)}_{<=24500}\frac{N^{(2)}_{>24500}}{N^{(2)}_{<=24500}} + +N^{(2)}_{<=24500} + N^{(2)}_{>24500}}$$

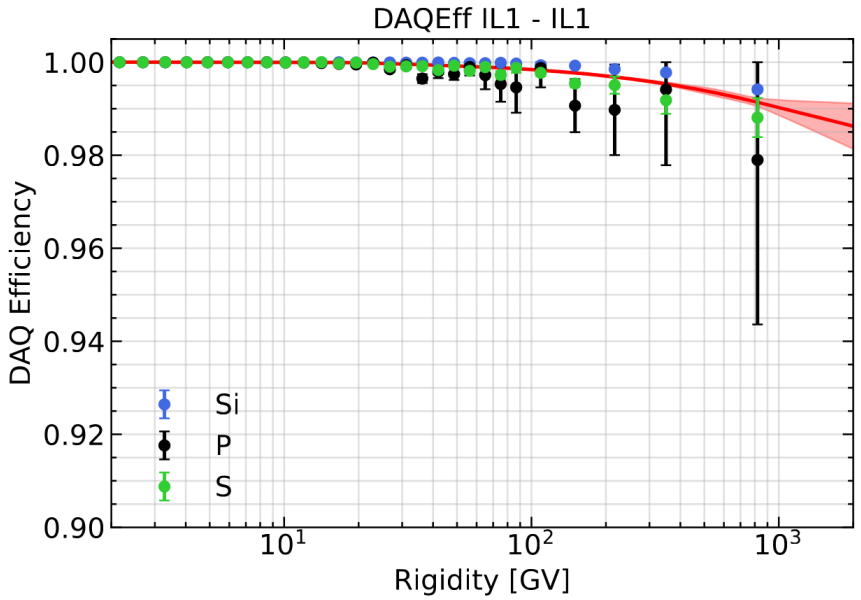
$$= \frac{(N^{(1)}_{<=24500} + N^{(1)}_{>24500})/N^{(1)}_{<=24500} + (N^{(2)}_{<=24500} + N^{(2)}_{>24500})/N^{(1)}_{<=24500}}{(N^{(2)}_{<=24500} + N^{(2)}_{>24500})/N^{(2)}_{<=24500} + (N^{(2)}_{<=24500} + N^{(2)}_{>24500})/N^{(1)}_{<=24500}}$$

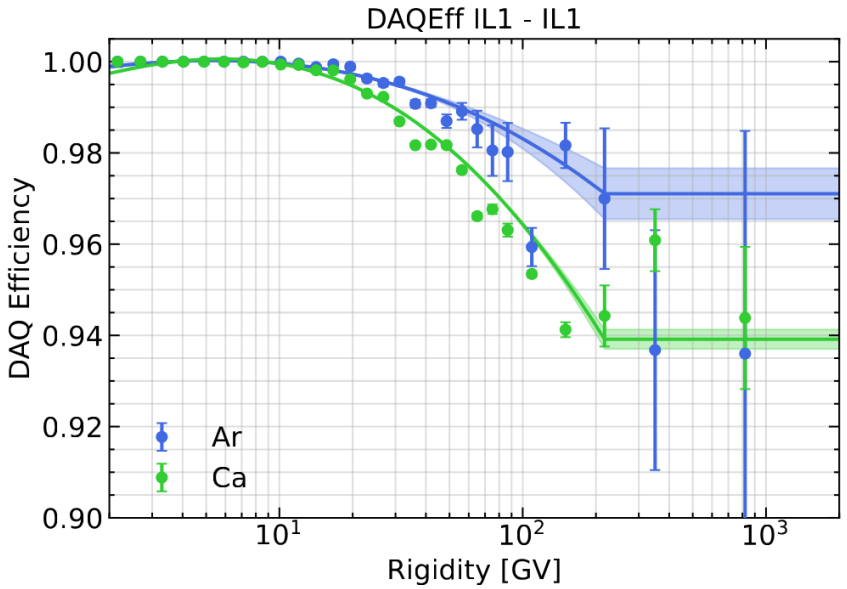
Total DAQ efficiency: 1JINJ time period estimated from >1JINJ:





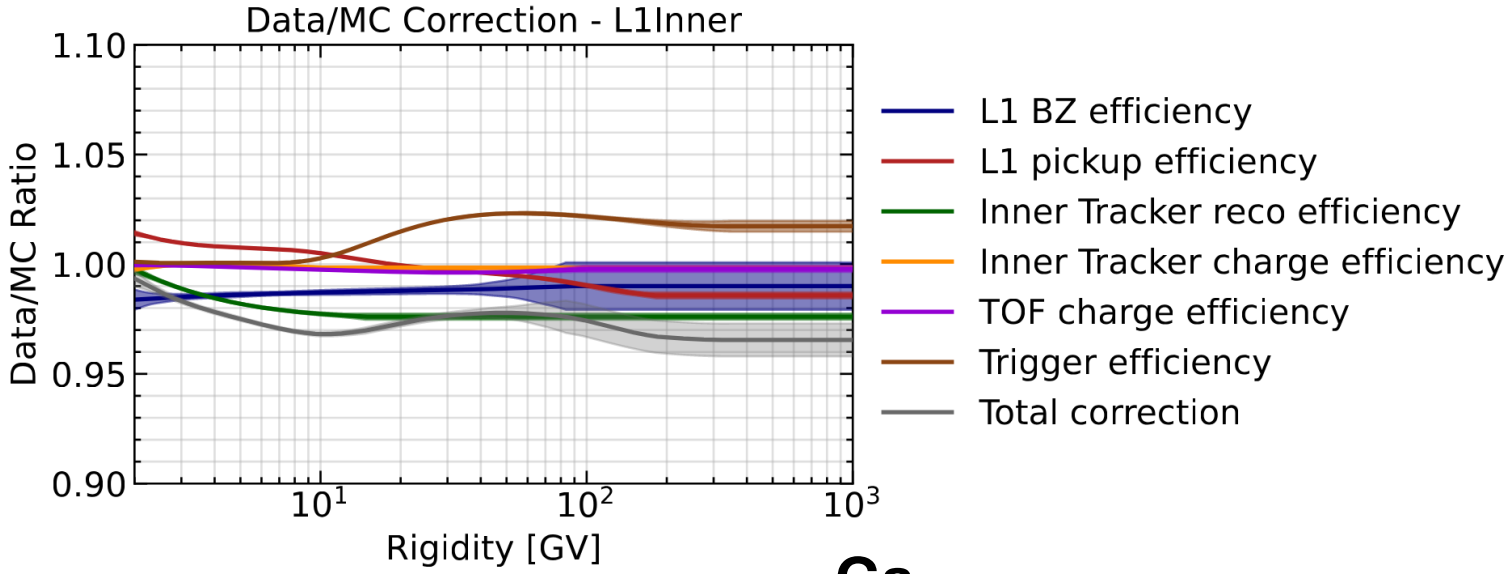




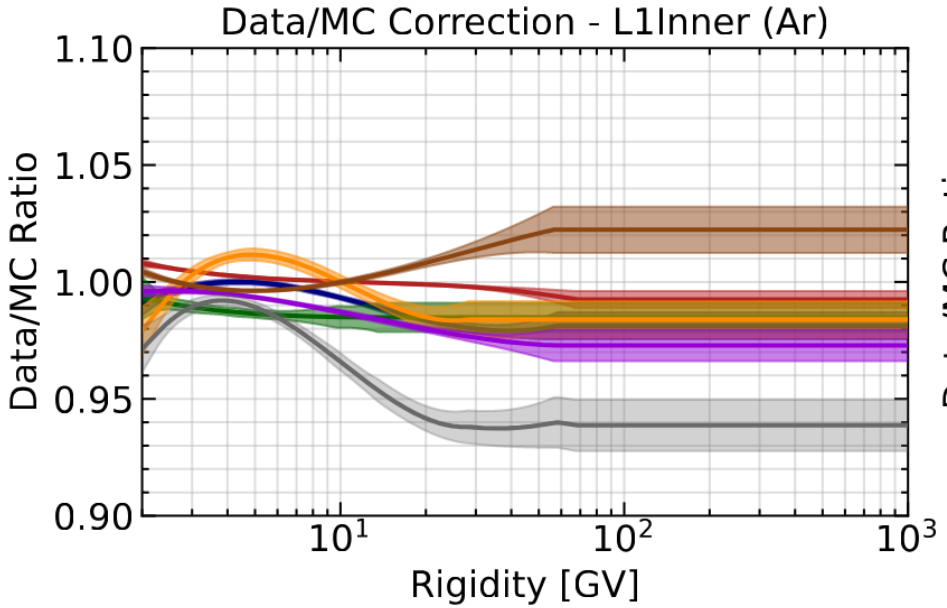


Total Data/MC efficiency correction

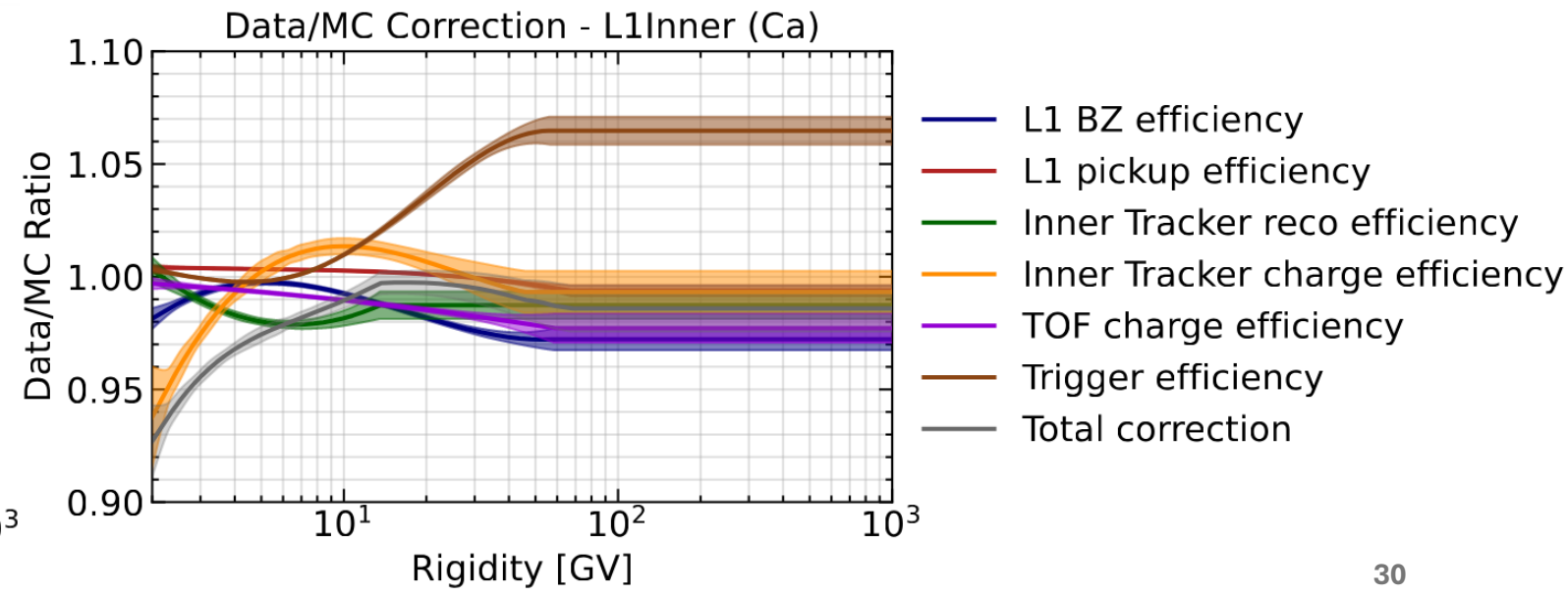
P



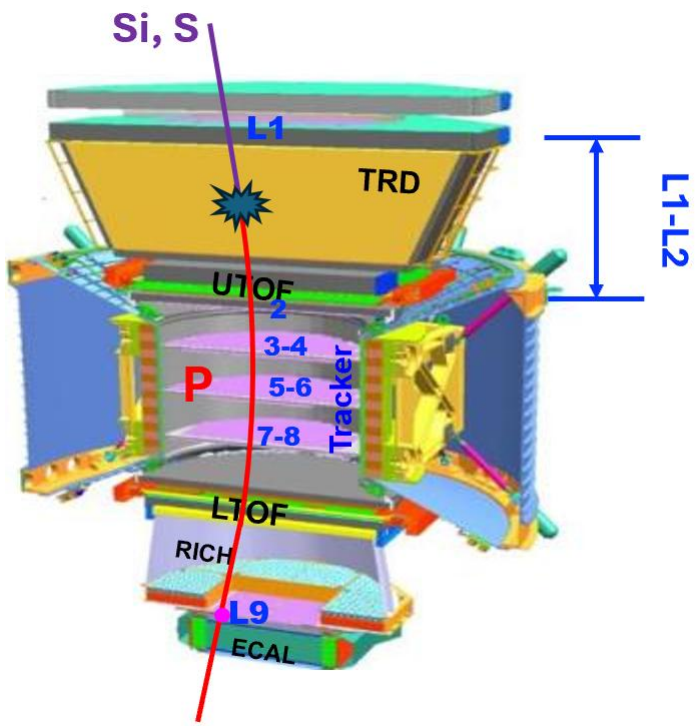
Ar



Ca



P Below L1 background (L1 charge background due to interactions between Tracker L1 and L2)



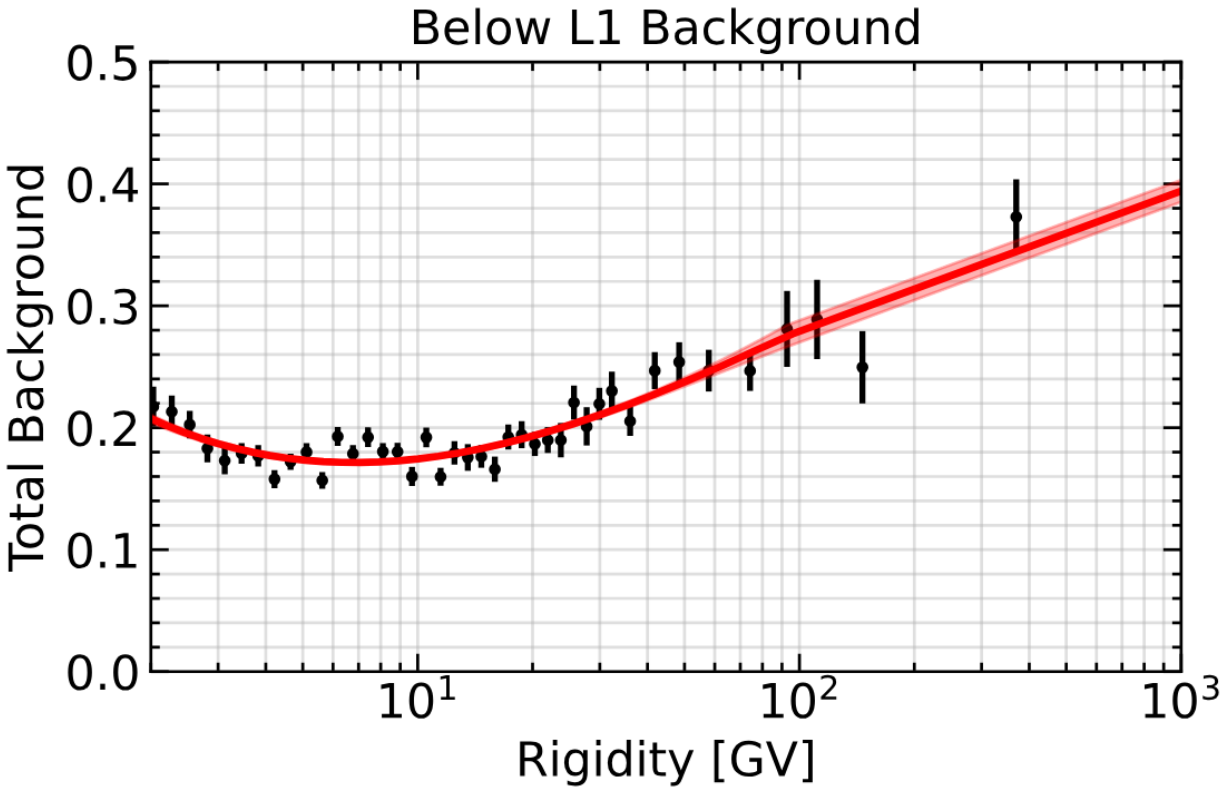
The background is estimated by fitting the L1 charge distribution with Si, P and S templates derived from Si and S L1 charge.

Template fit method: Same as shown in last AMS meeting

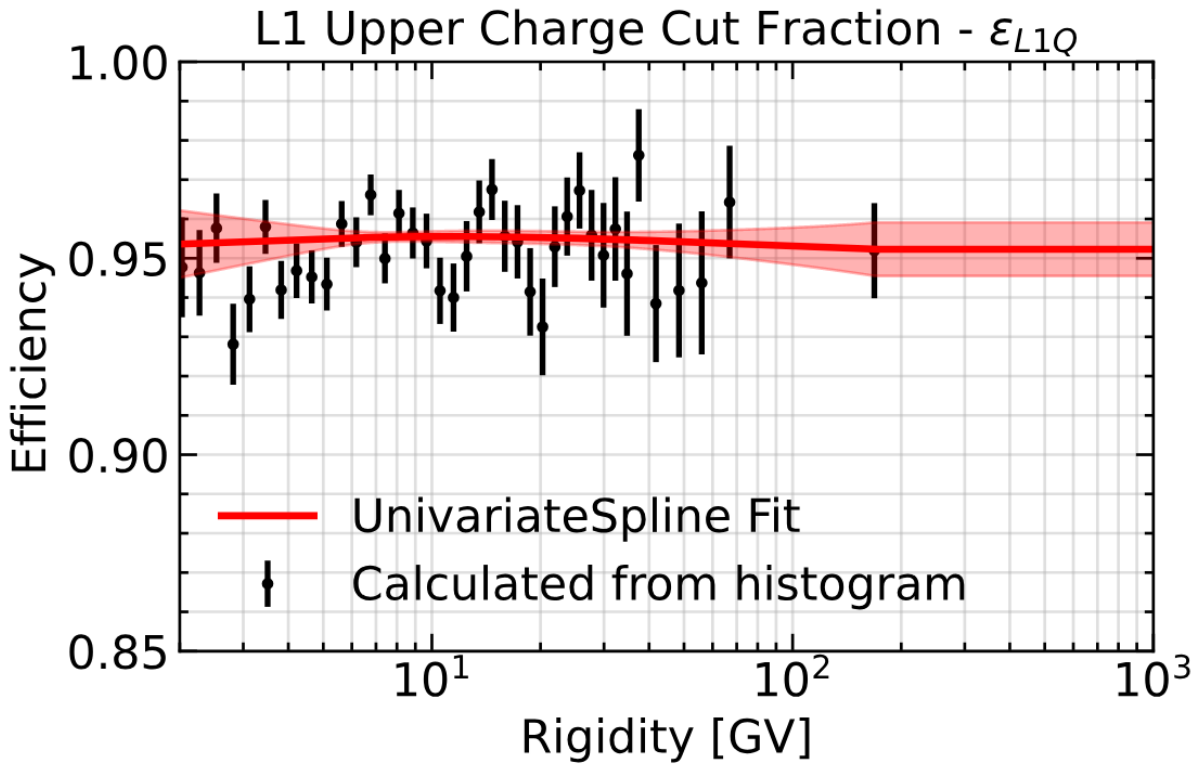
- **Si and S L1 templates:** smooth PDFs built directly from Si and S data.
- **P Template:** smooth PDF built from L1 Si and S interpolated data.
- Fit parameter: fractions, and P charge shift.
  - Allow a small shift in P template (as penalty term in fit loss) to account for a residual bias since template is built from Si and S.
- **Error estimation:**
  1. Fit error: correlation between fractions and shift has been taken into account.
  2. Template statistical error:
     - Build several versions of templates according to the limited statistics.
     - Perform the fits many times to properly account for the template uncertainties.

P Below L1 background: Template fit results

Below L1 background calculated from template fit:



- In event selection, the L1 upper charge cut is applied to data but not to MC.
- ε_{L1Q} applied to correct for the resulting event loss.

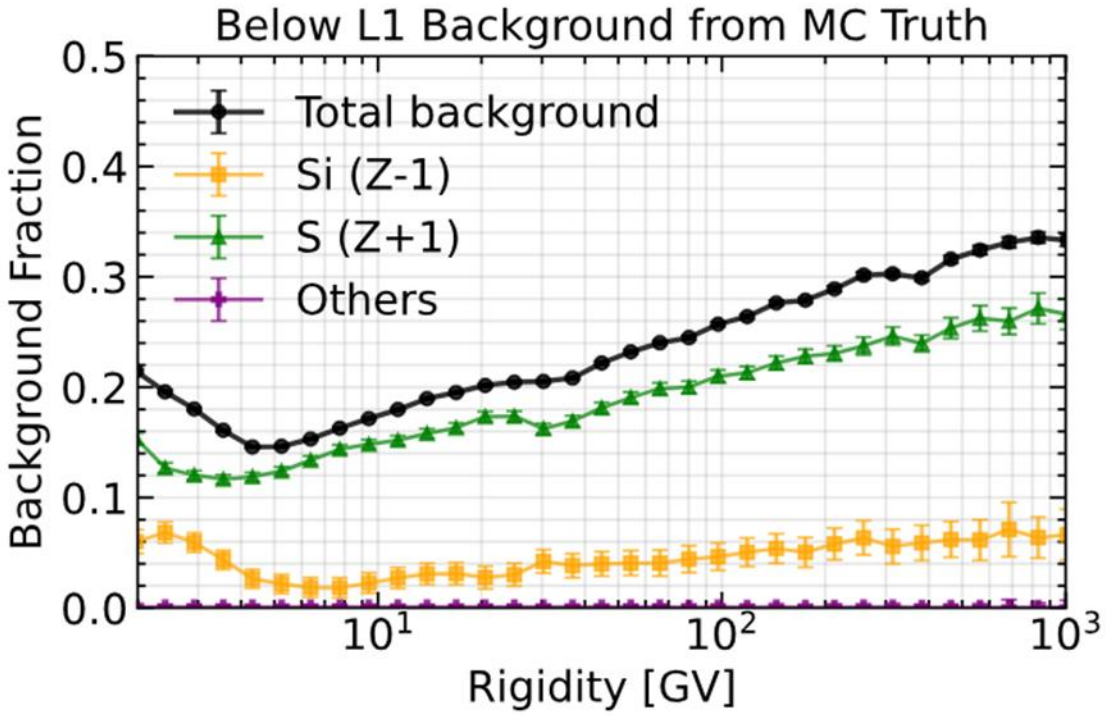


P below L1 background: check with MC

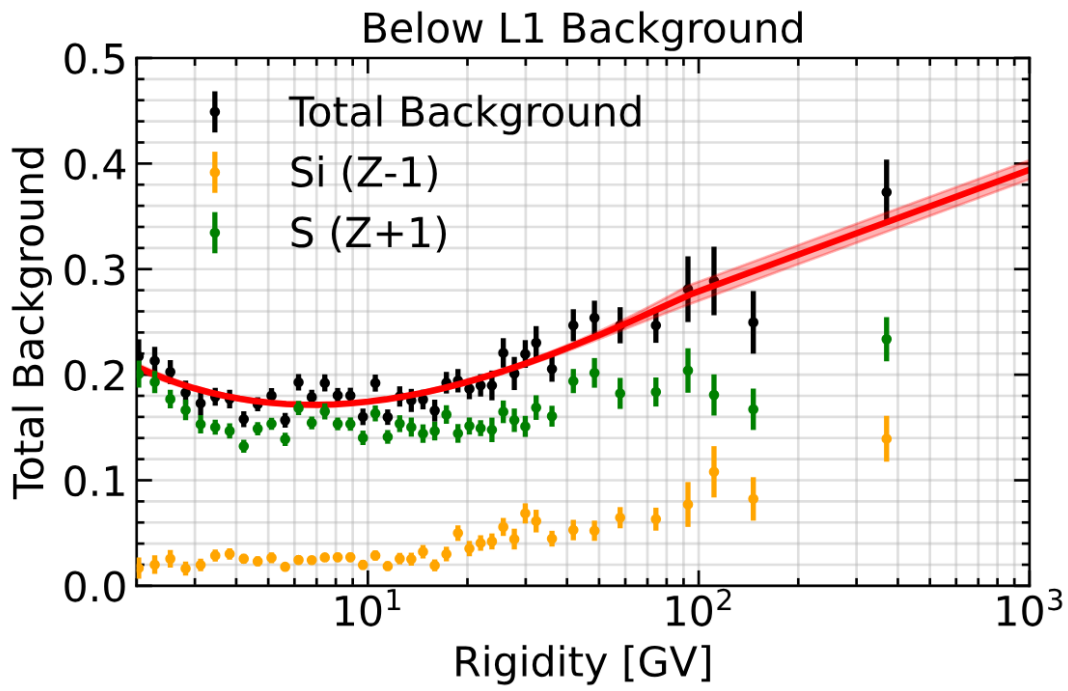
P global MC (Z=14,15,16-20, 26), event selection:

- P event selection,
- For Z>15: Select events survived on L1.

Background calculated from MC truth.

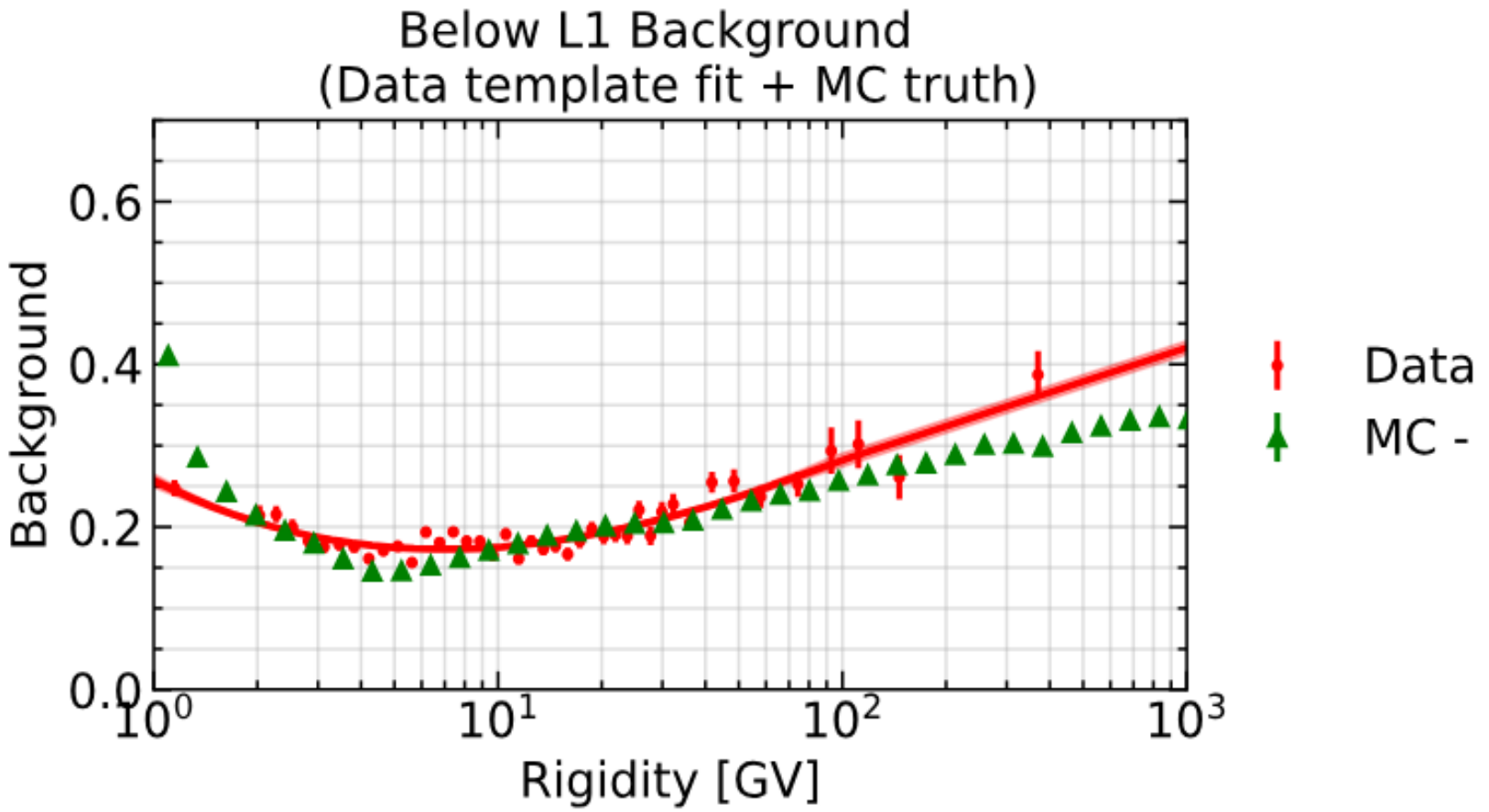


Template fit result from data:

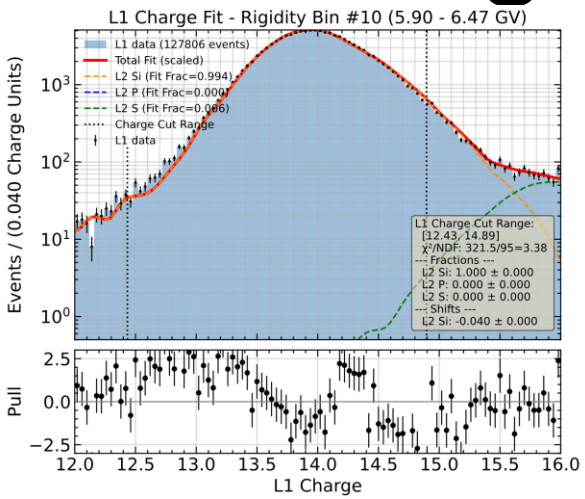


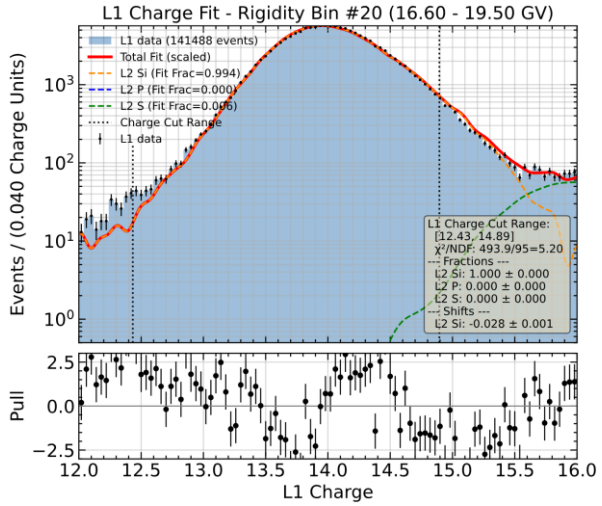
Below L1 background: P

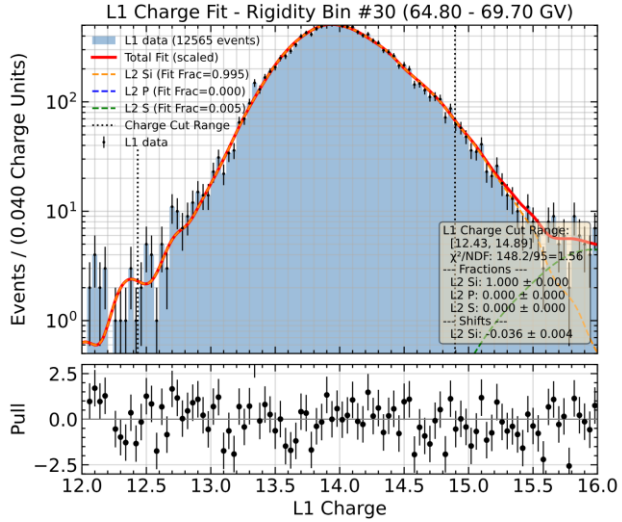
Comparison between MC truth from global MC and template fit result from Data:

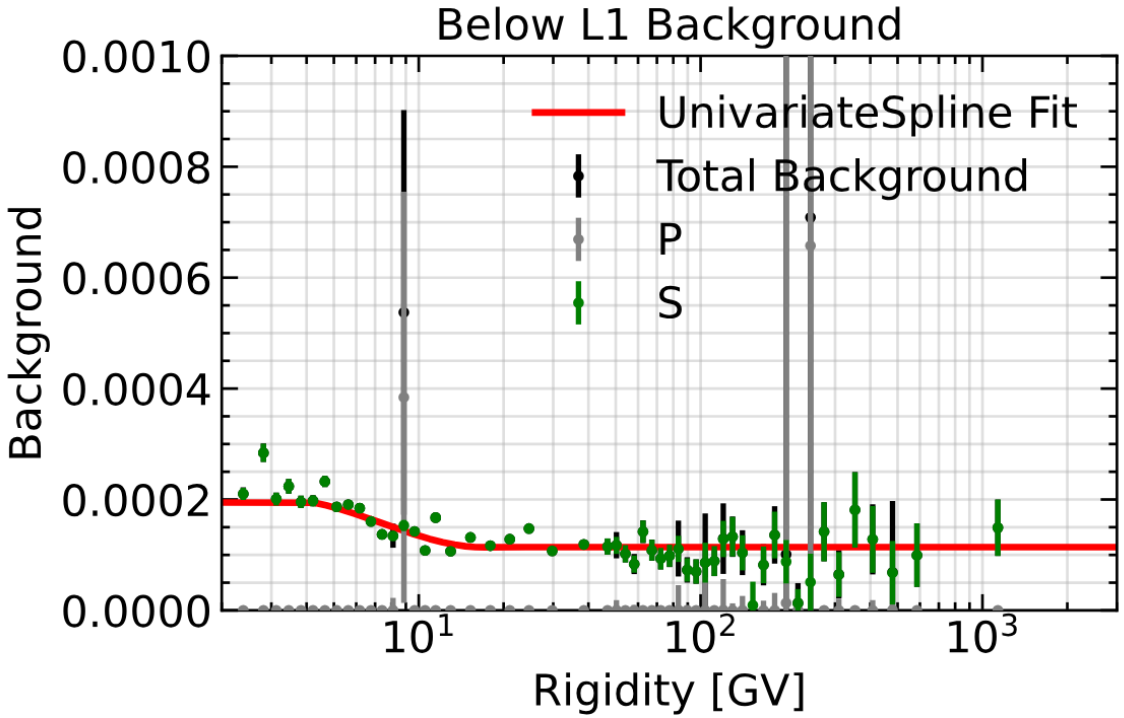


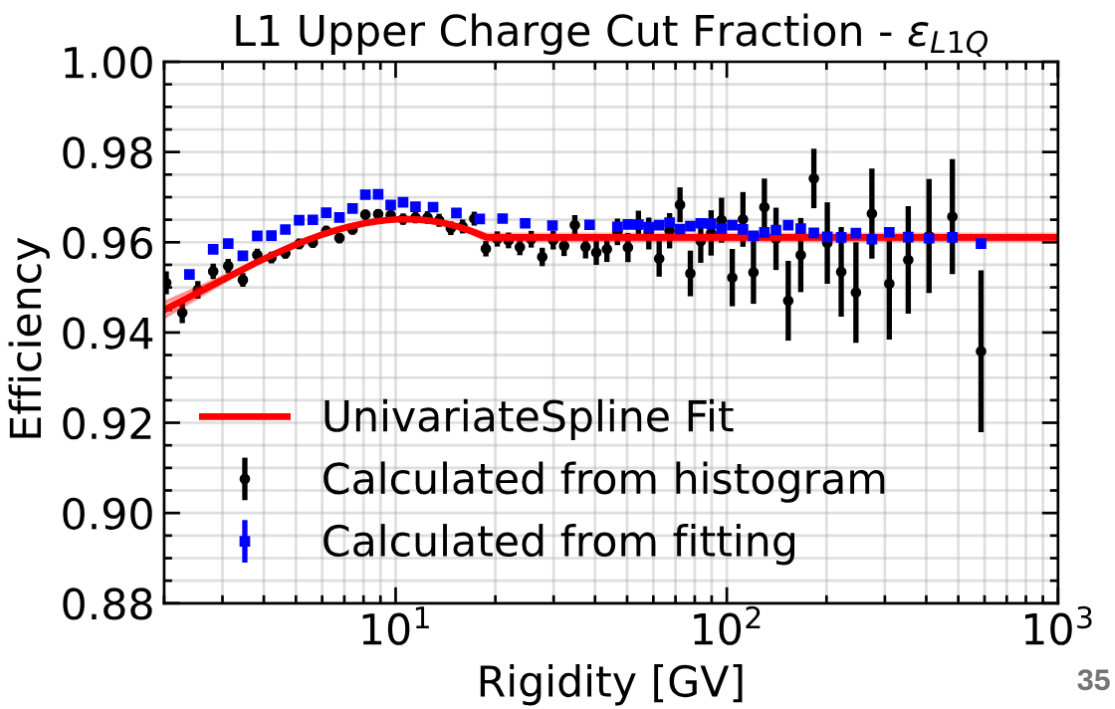
Below L1 background: Si



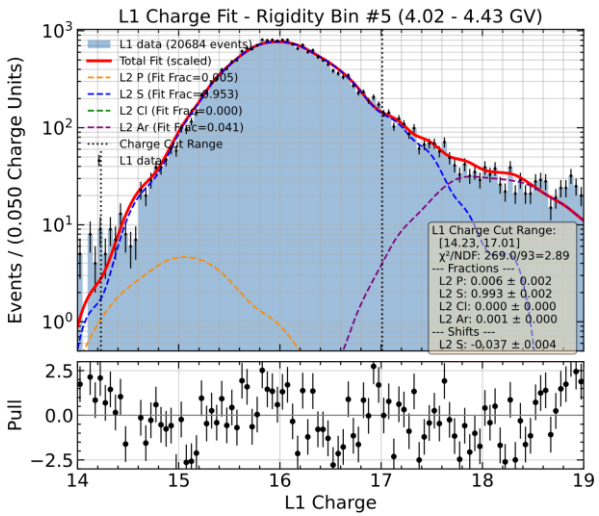


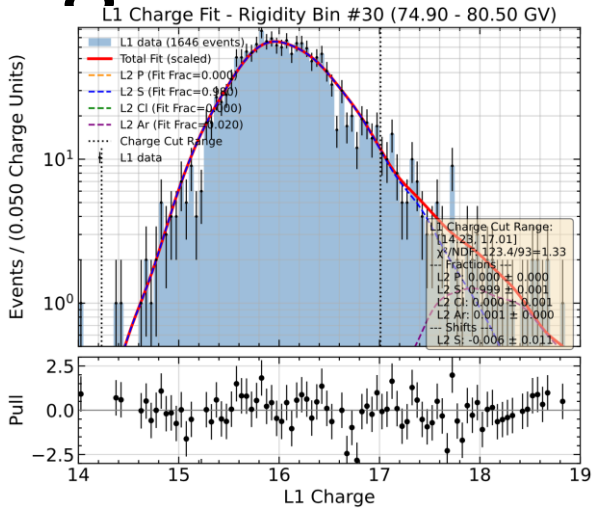


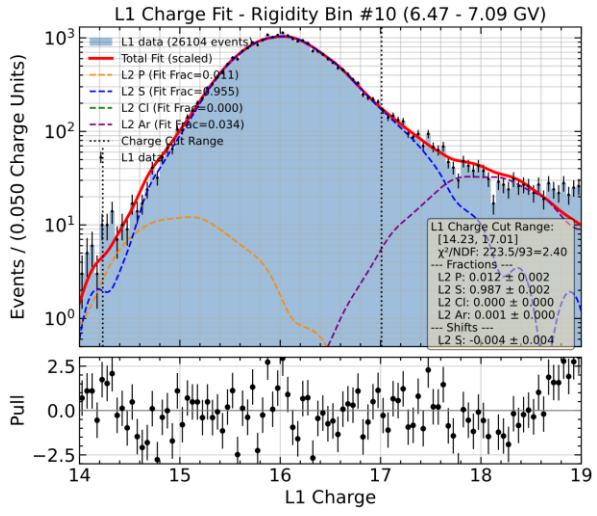


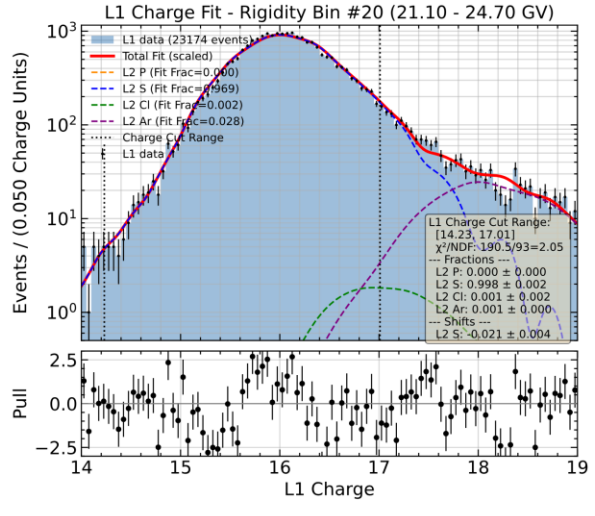


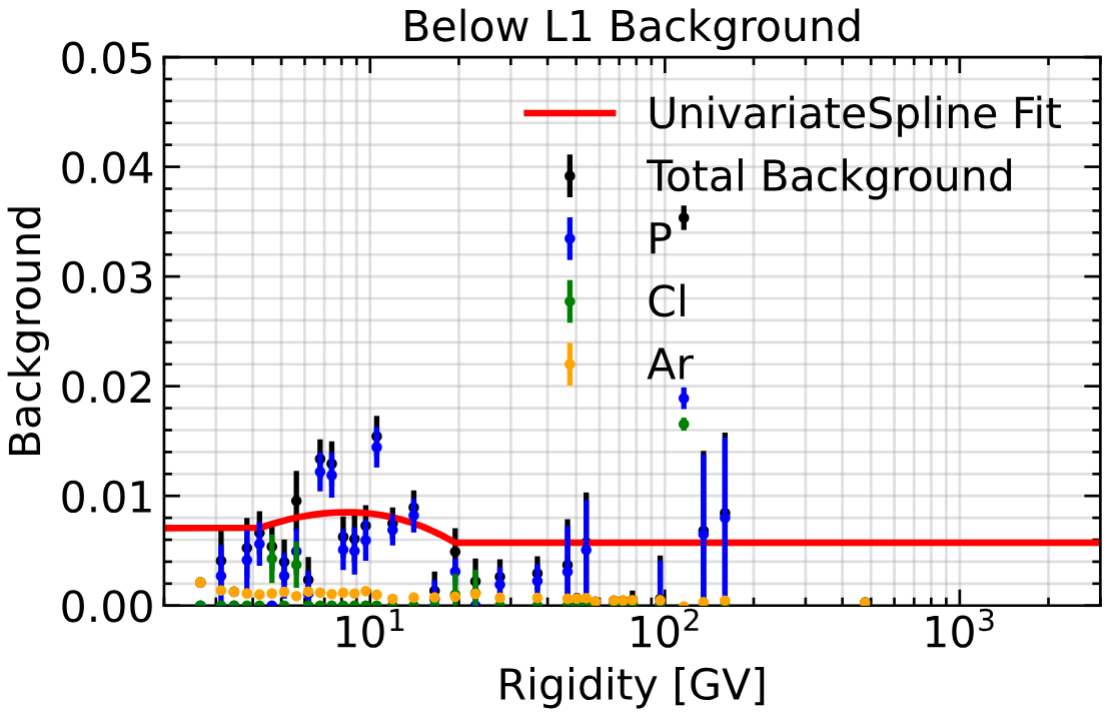
Below L1 background: S

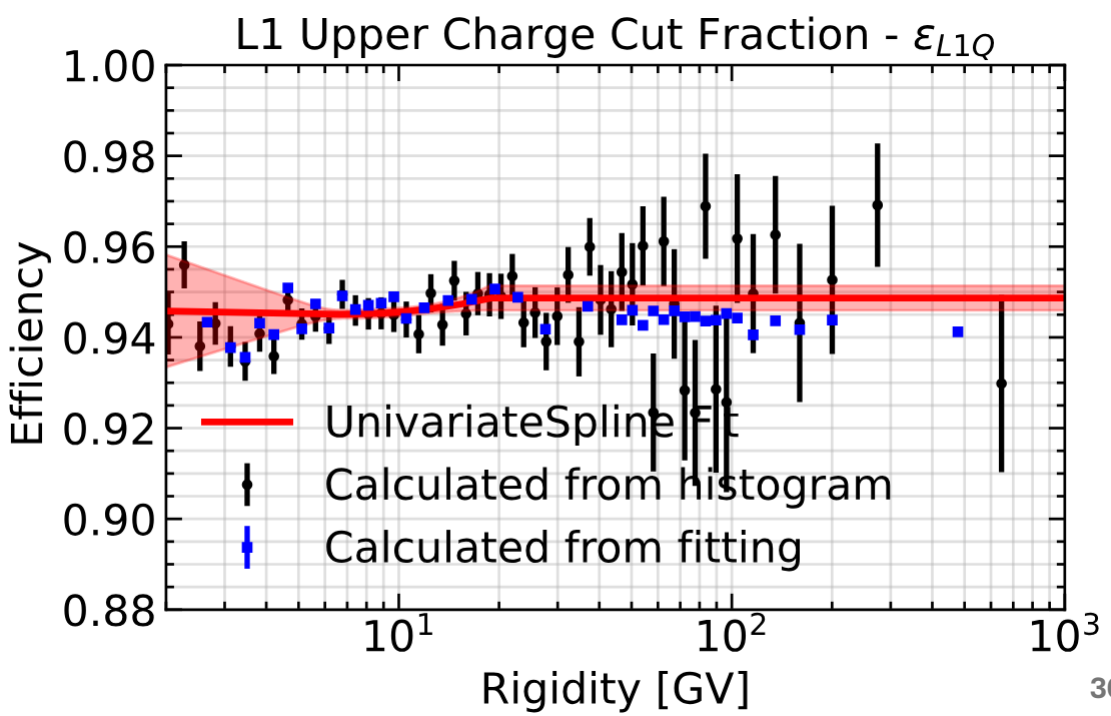




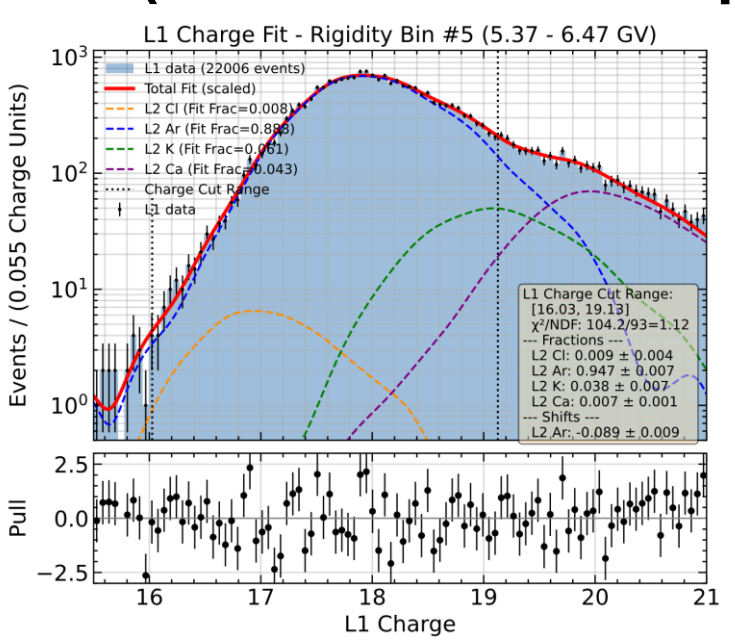


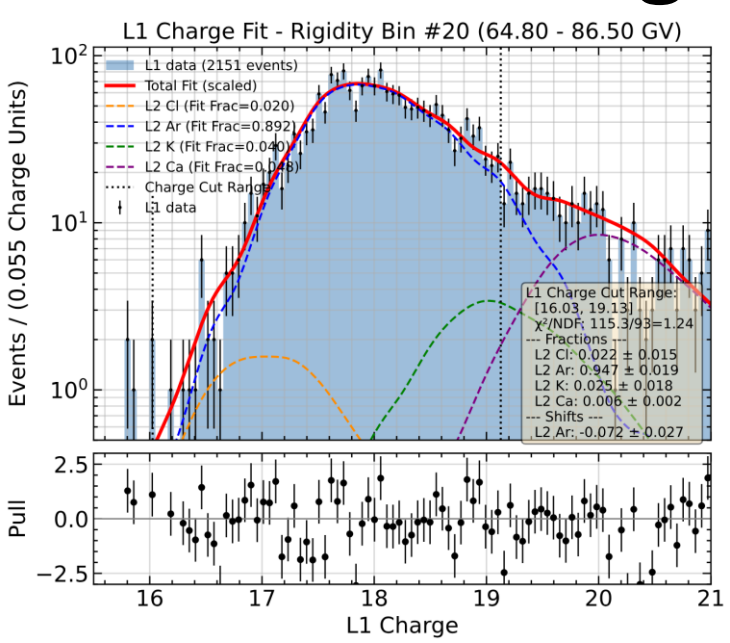


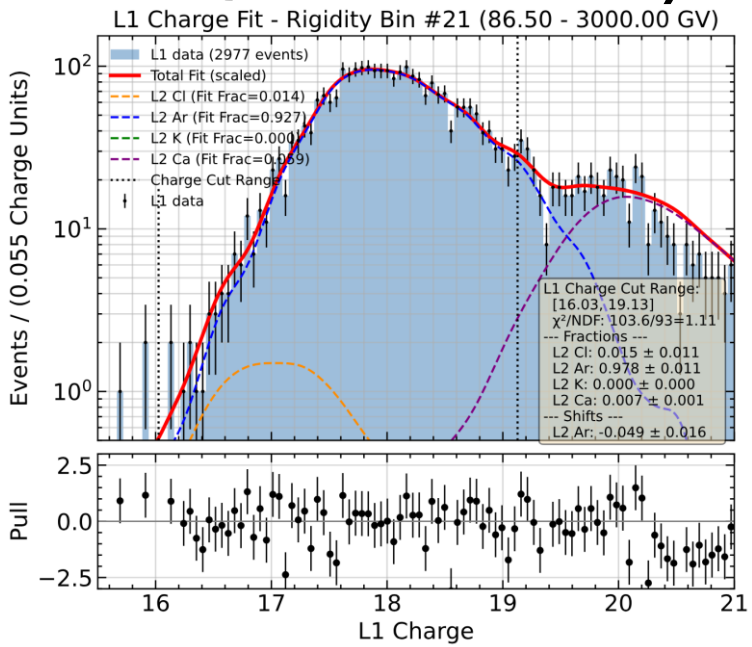


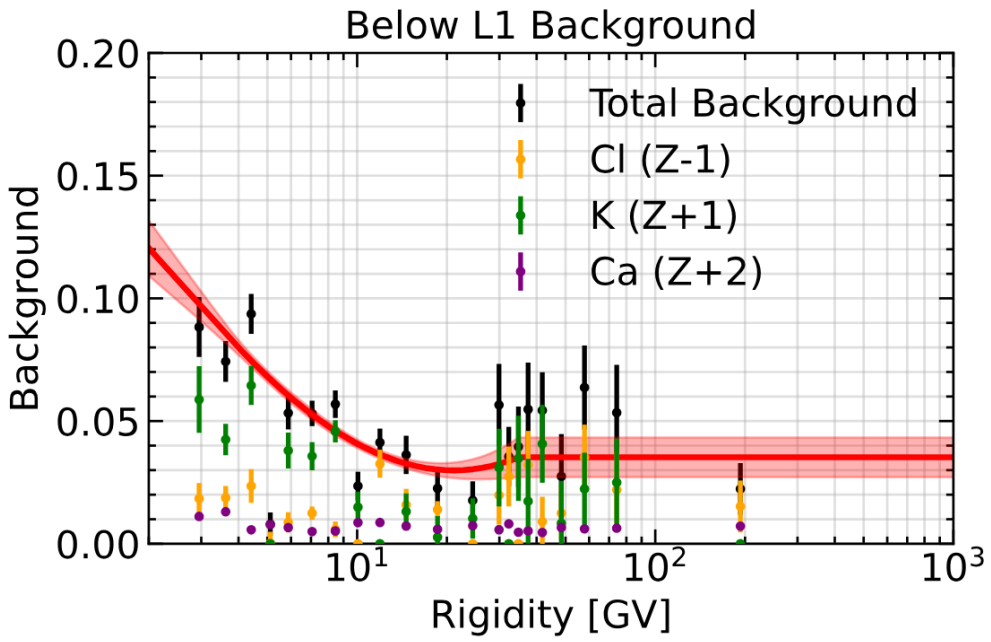


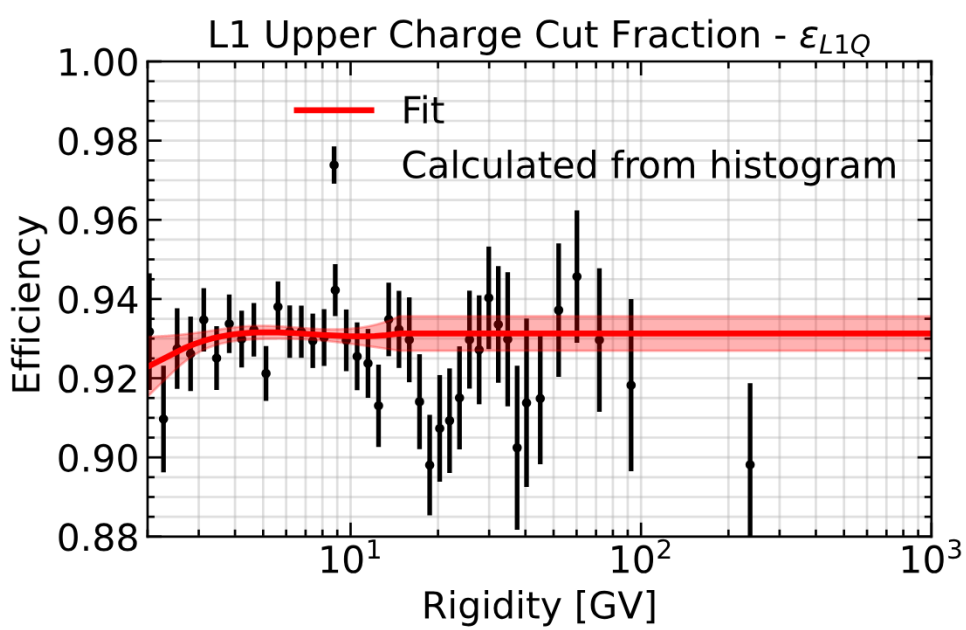
Ar (shifts all templates according to L1 Q, rebinned)



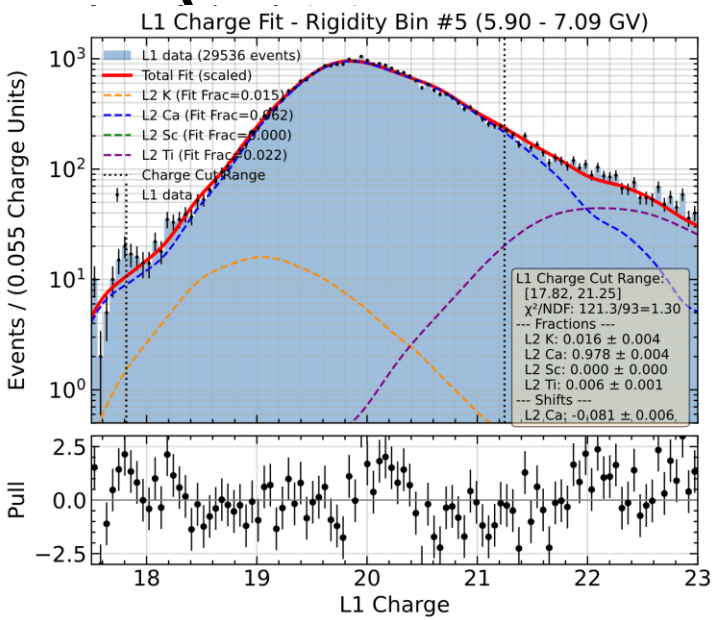


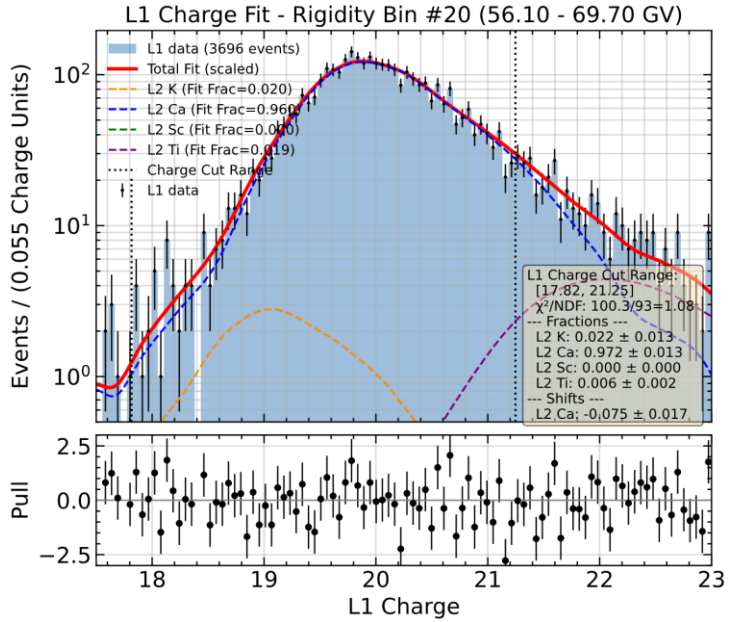


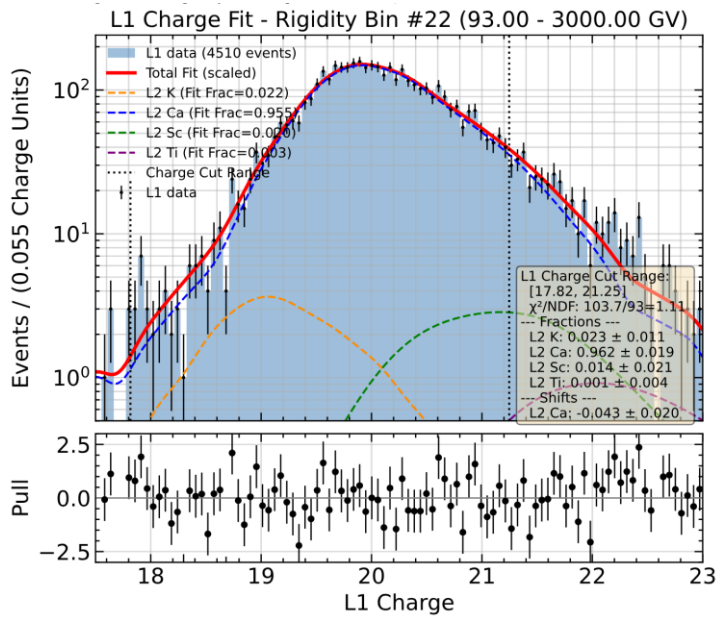


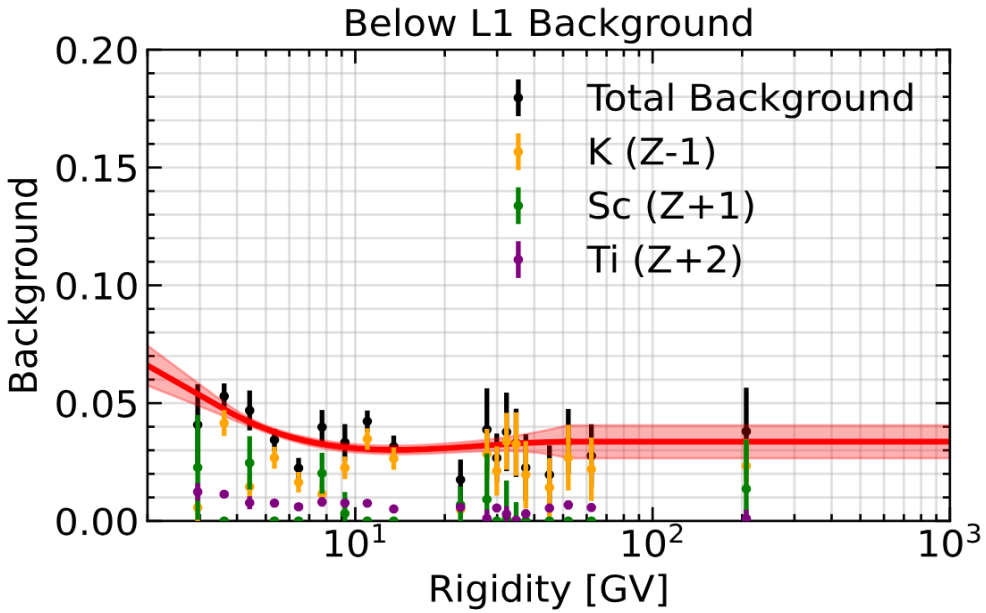


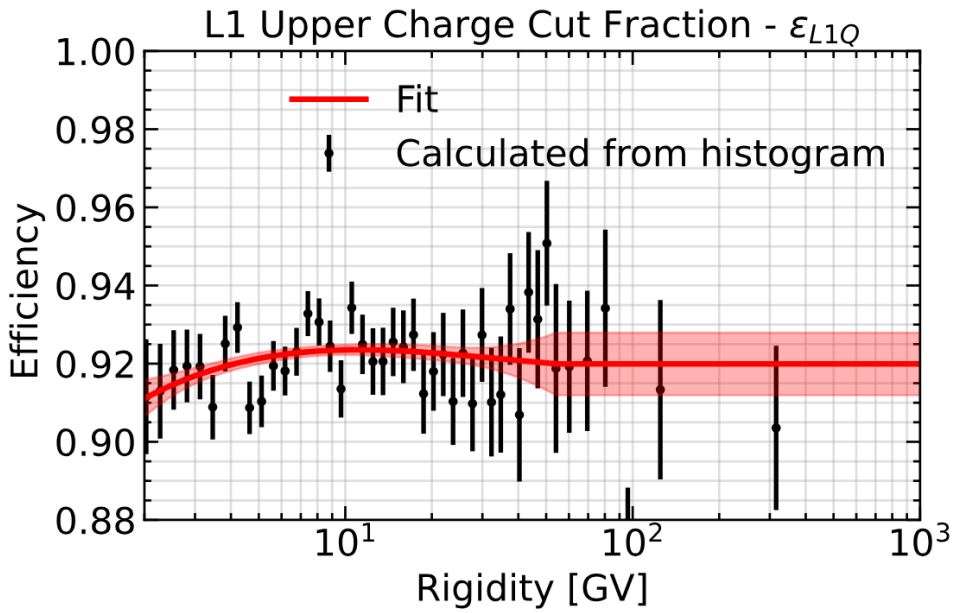
Ca (shift Z and Z+2. rebinned)





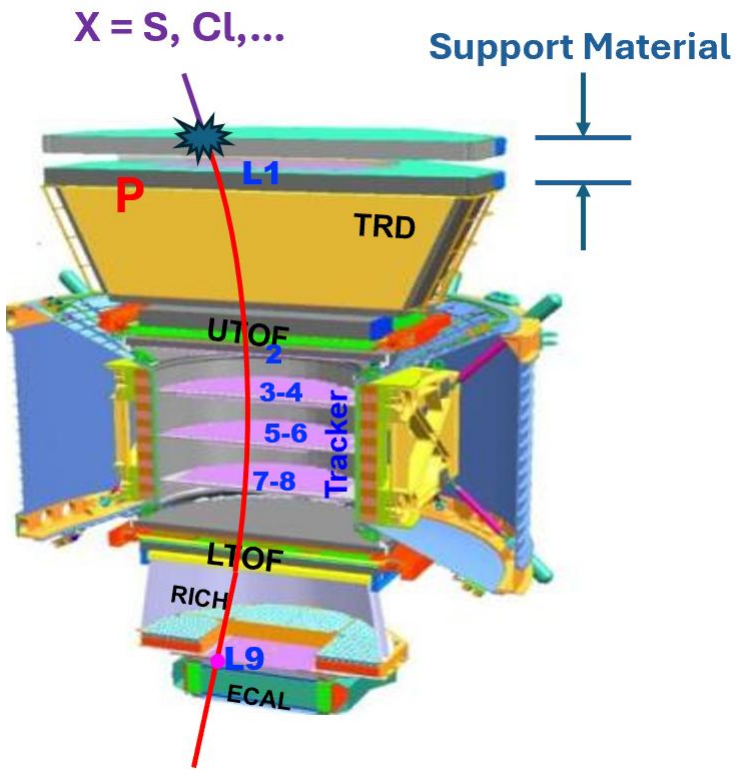






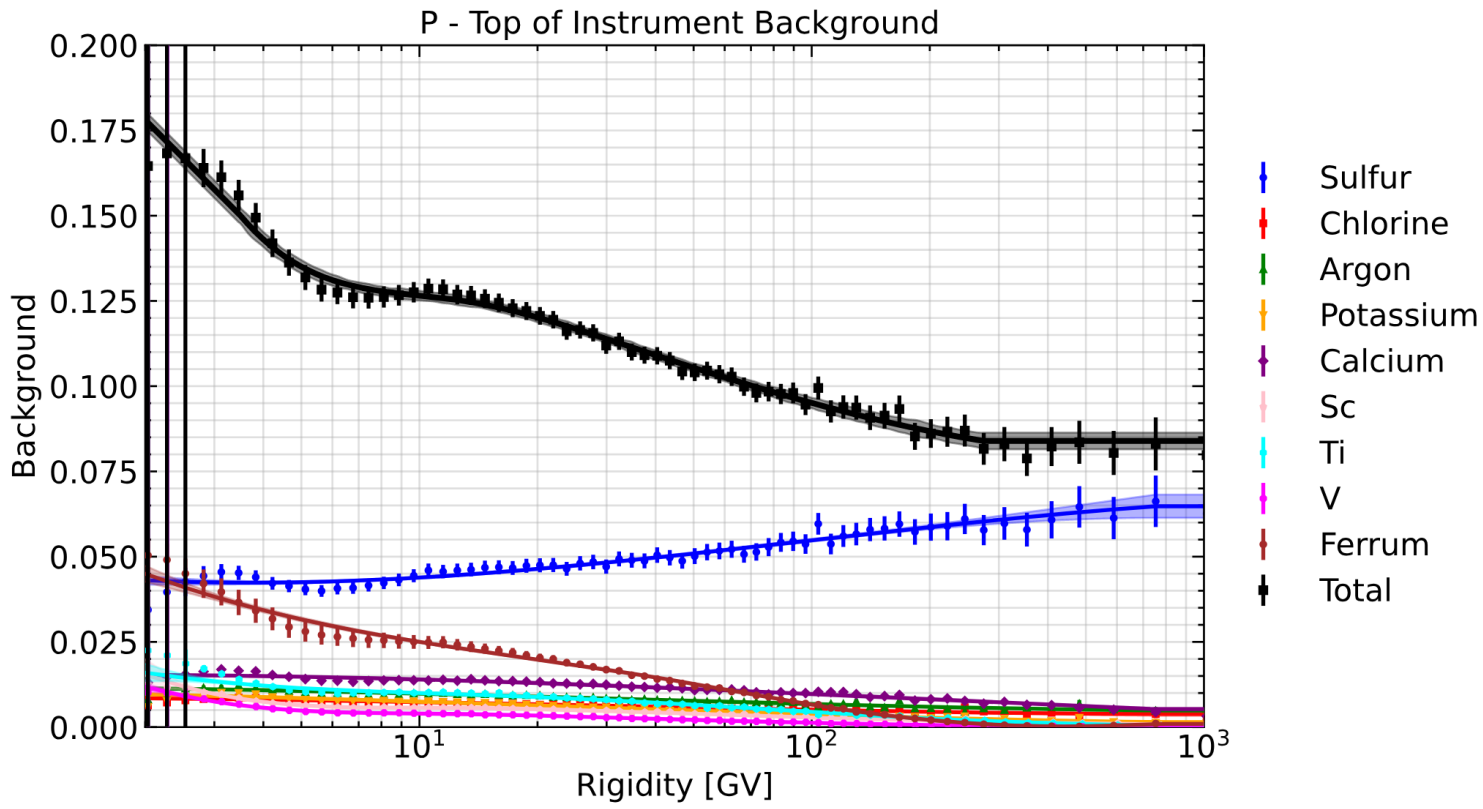
On-going:
check Z-1
contribution

Top of Instrument Background (background due to heavier nuclei interacting above Tracker L1)

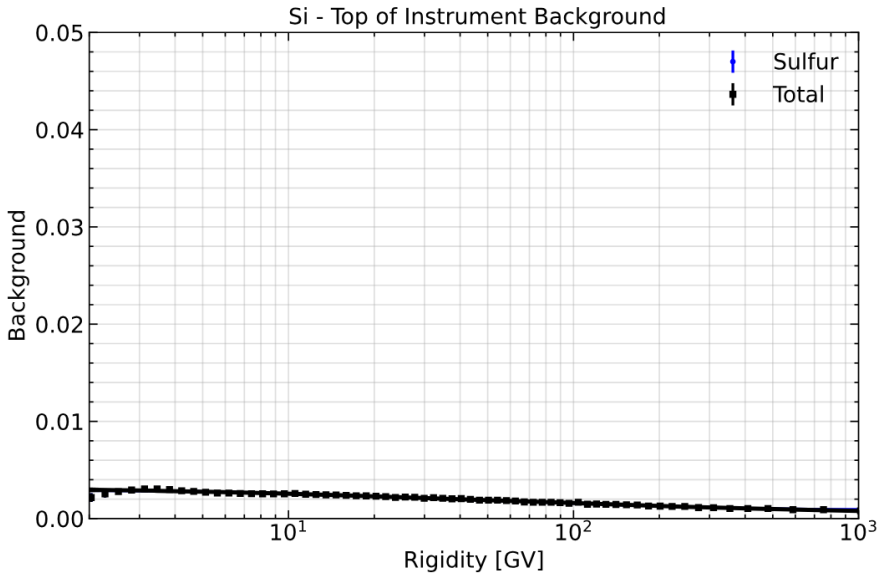


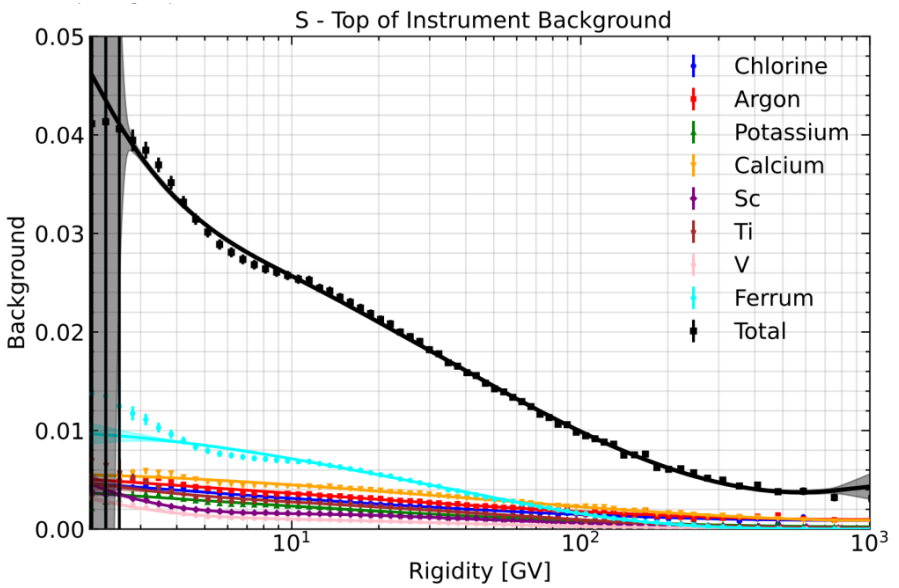
$$\Phi_P = \frac{N'_P - \sum N^{aboveL1}_{X\to P}}{A_P \times T \times \Delta R} = \Phi'_P \left(1 - \sum_{X=S,Cl,..} \delta\right)$$

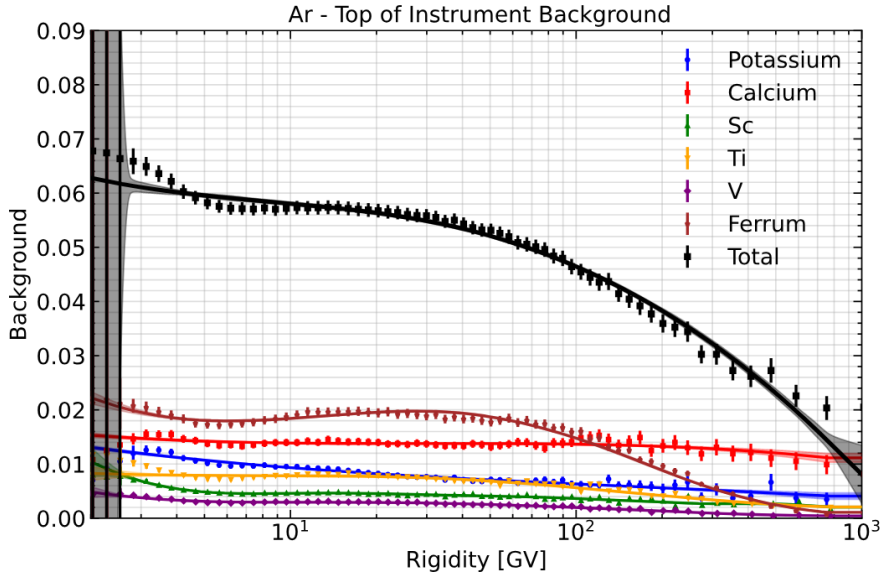
$$\text{where} \quad \sum_{X=S,Cl,..} \delta = \sum_{X=S,Cl,..} \frac{A^{aboveL1}_{X\to P}}{A_P} \times \frac{\Phi_X}{\Phi'_P}$$

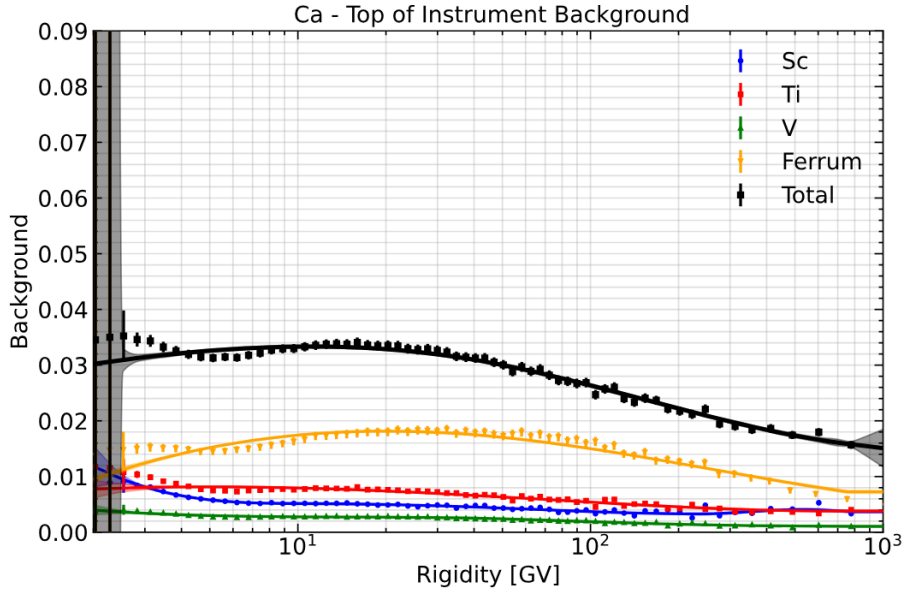


Top of Instrument Background: Si, S, Ar, Ca



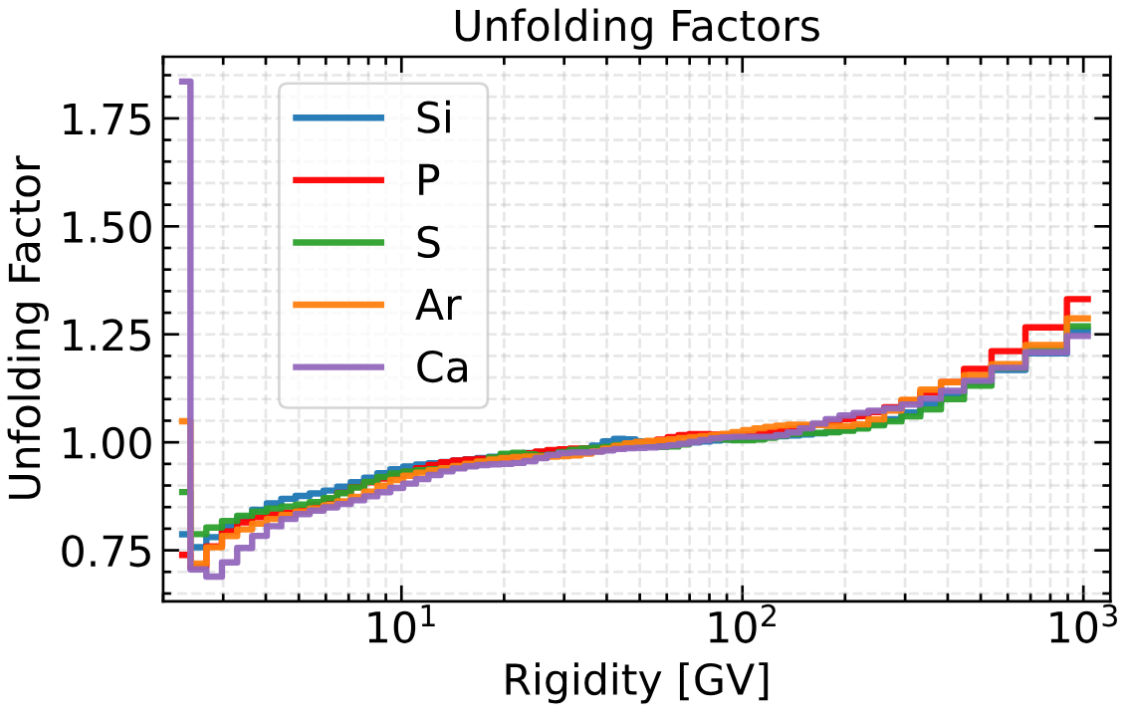


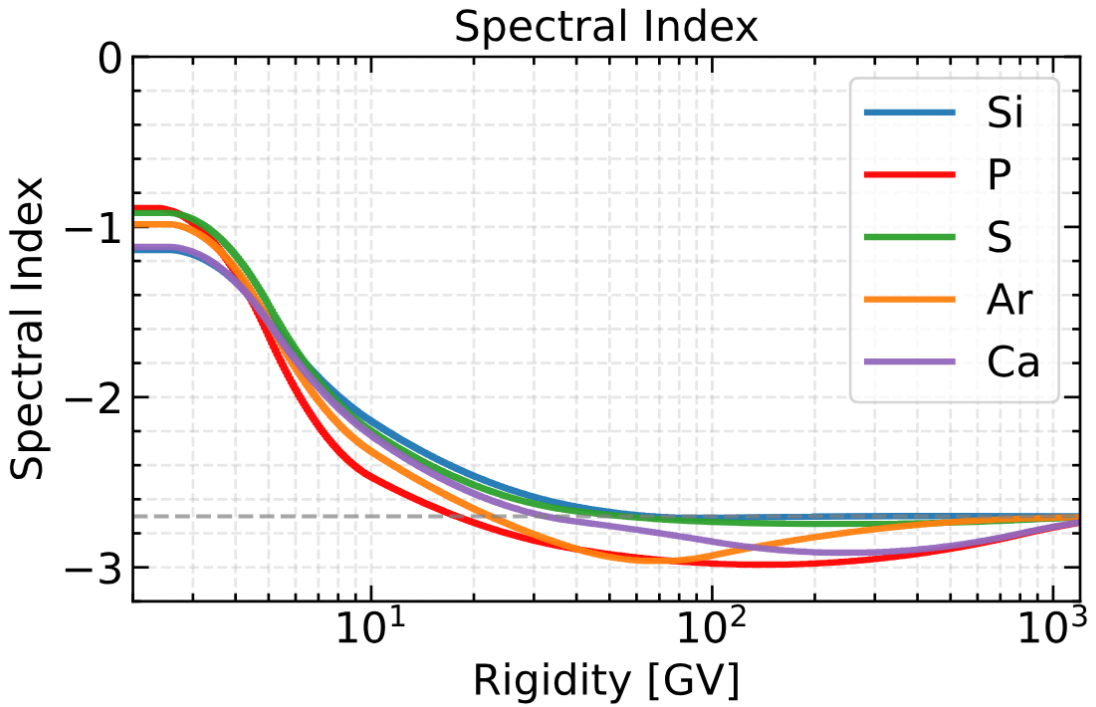




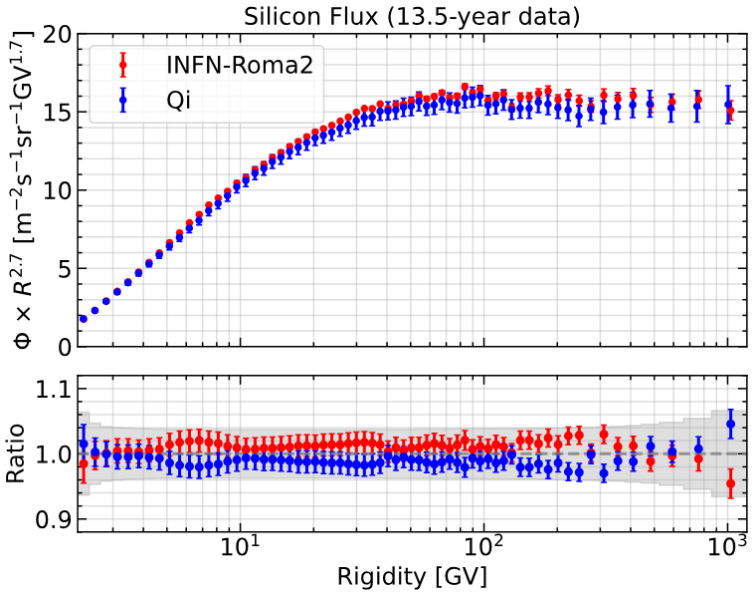
Unfolding factor from forward unfolding

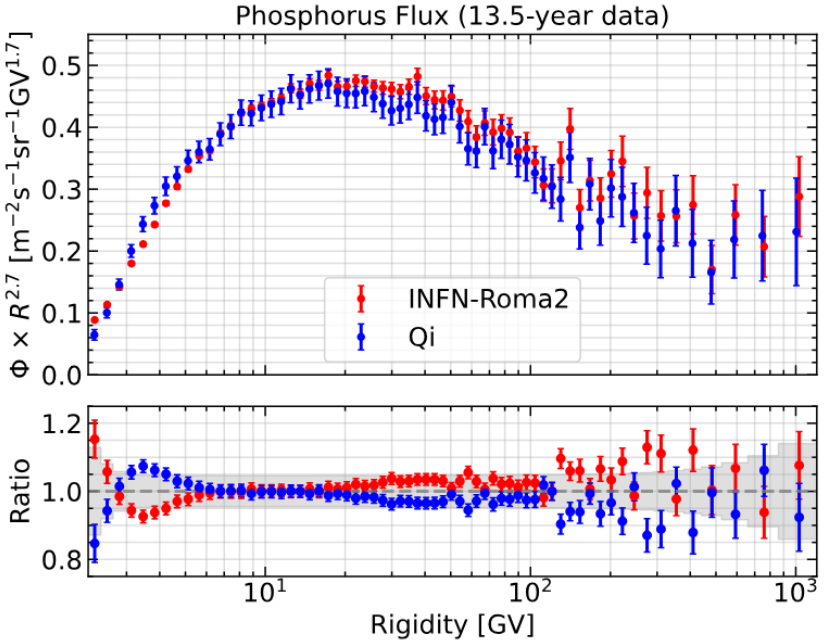
Constrain for flux model: spectral index~-2.7 above some rigidity between 2 and 6TV

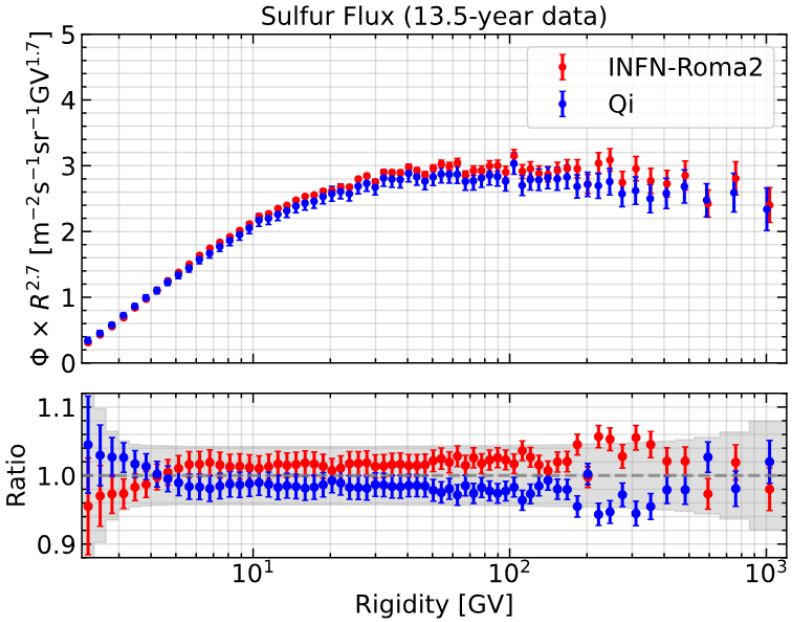


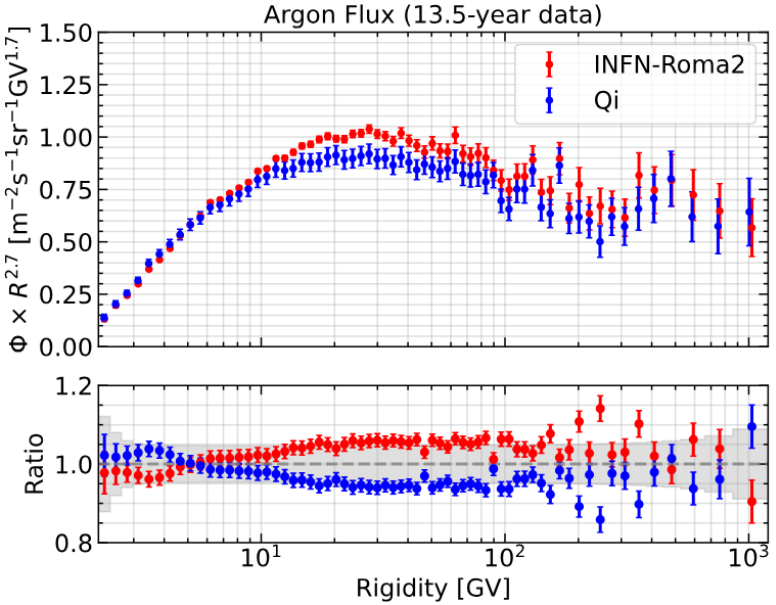


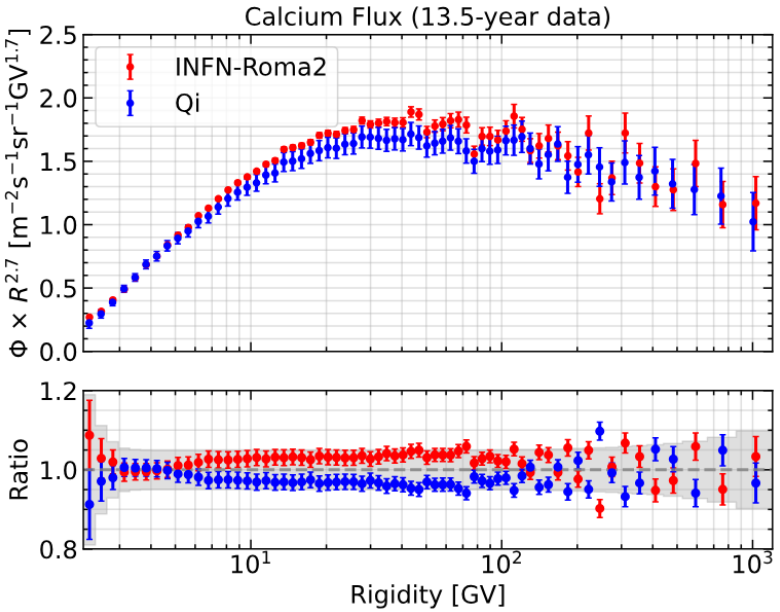
Si, P, S, Ar, Ca L1Inner fluxes, comparison with Qi





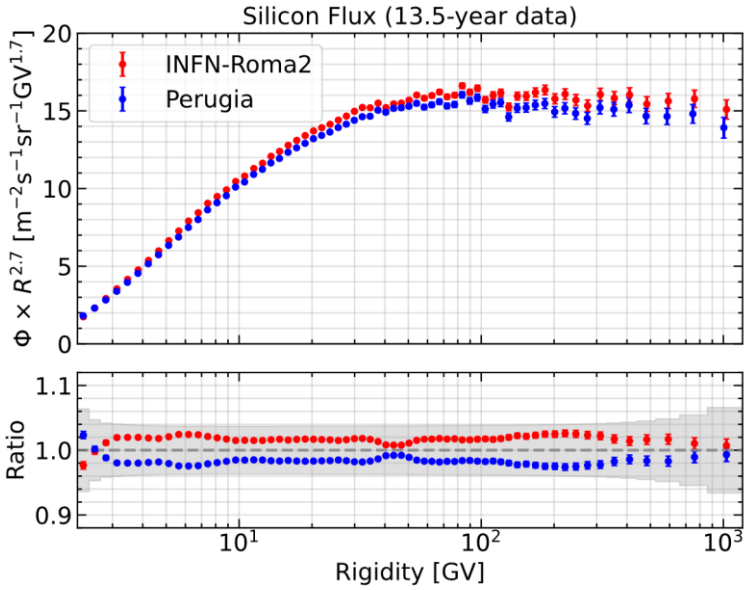


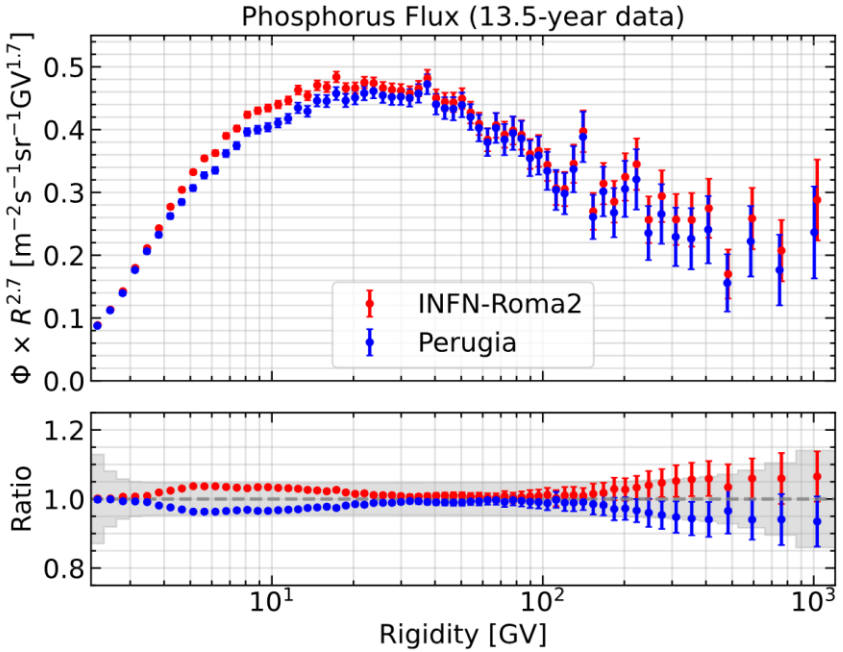


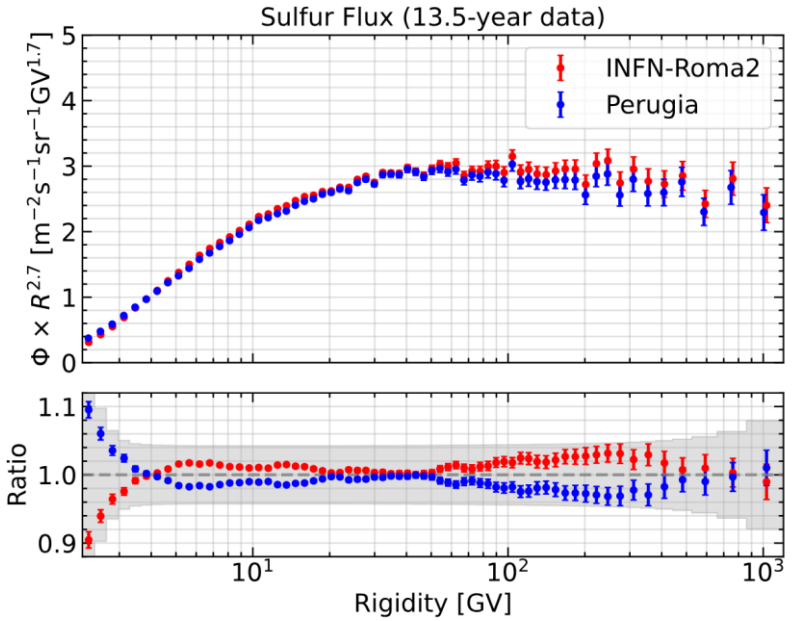


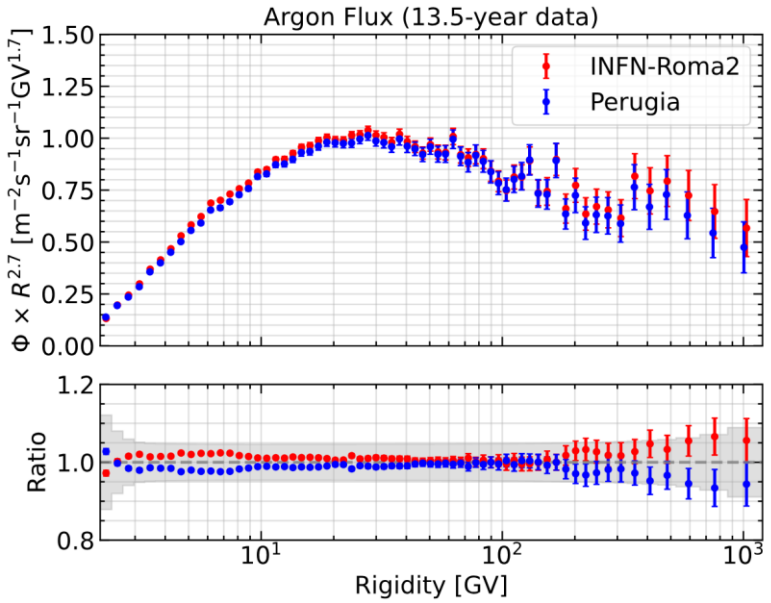
Error band: Qi's total systematic error;
Rome results: statistical error only.

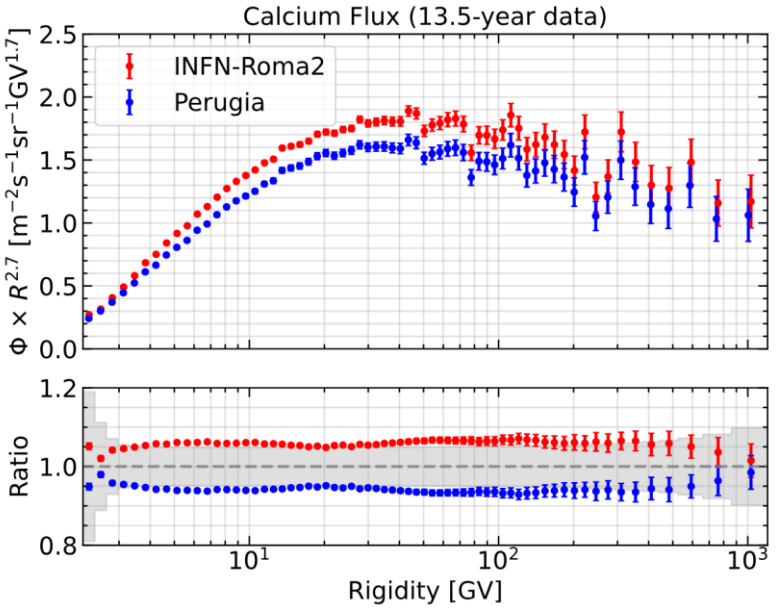
Si, P, S, Ar, Ca L1Inner fluxes, comparison with Alessio





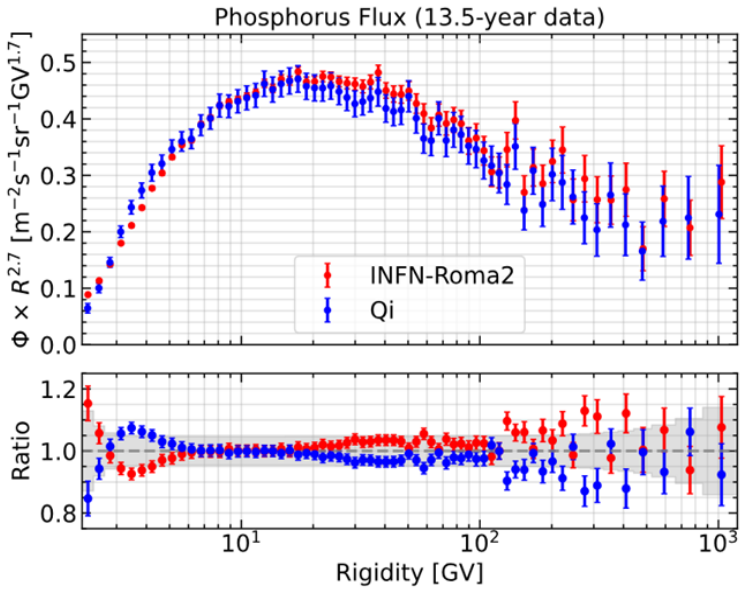


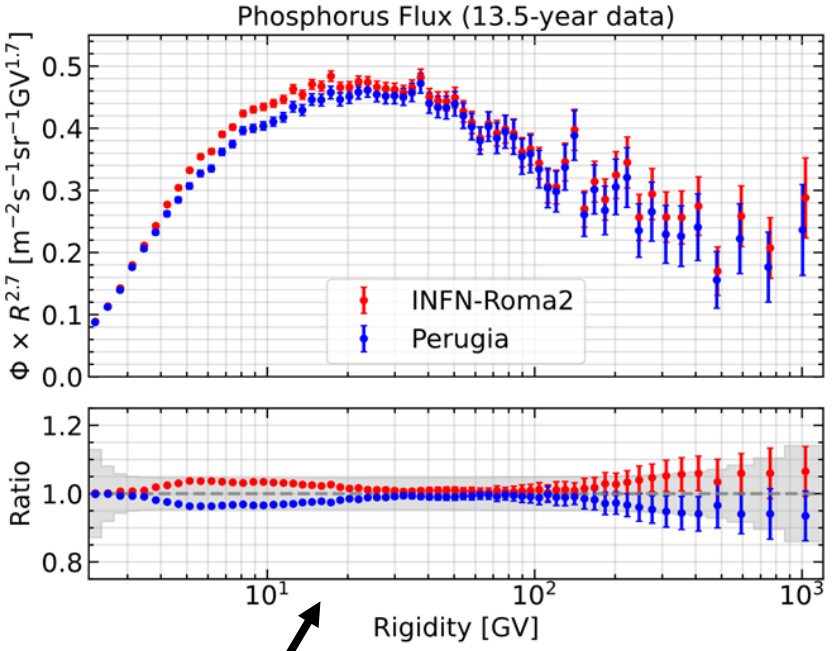


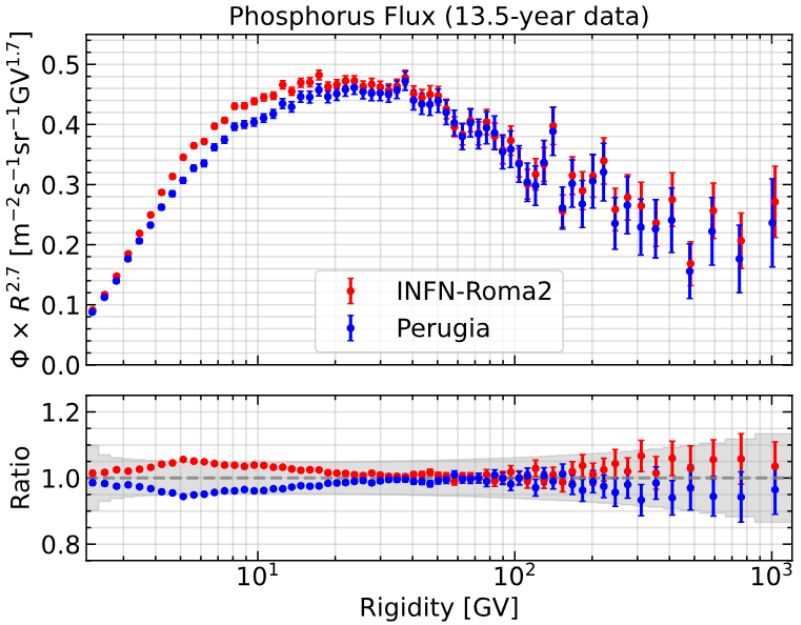


Error band: Qi's total systematic error;

P flux comparison with Qi, SDIAT, and Perugia

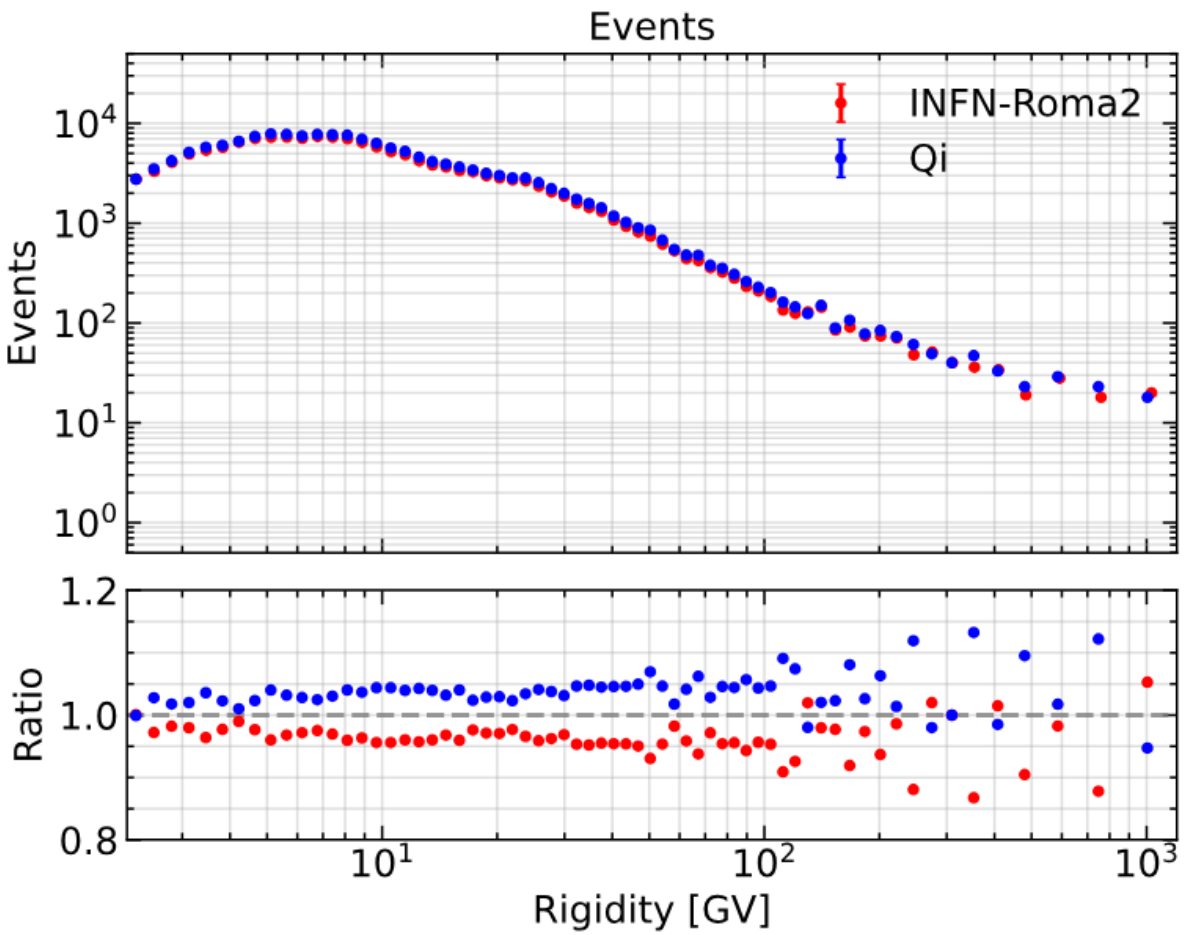


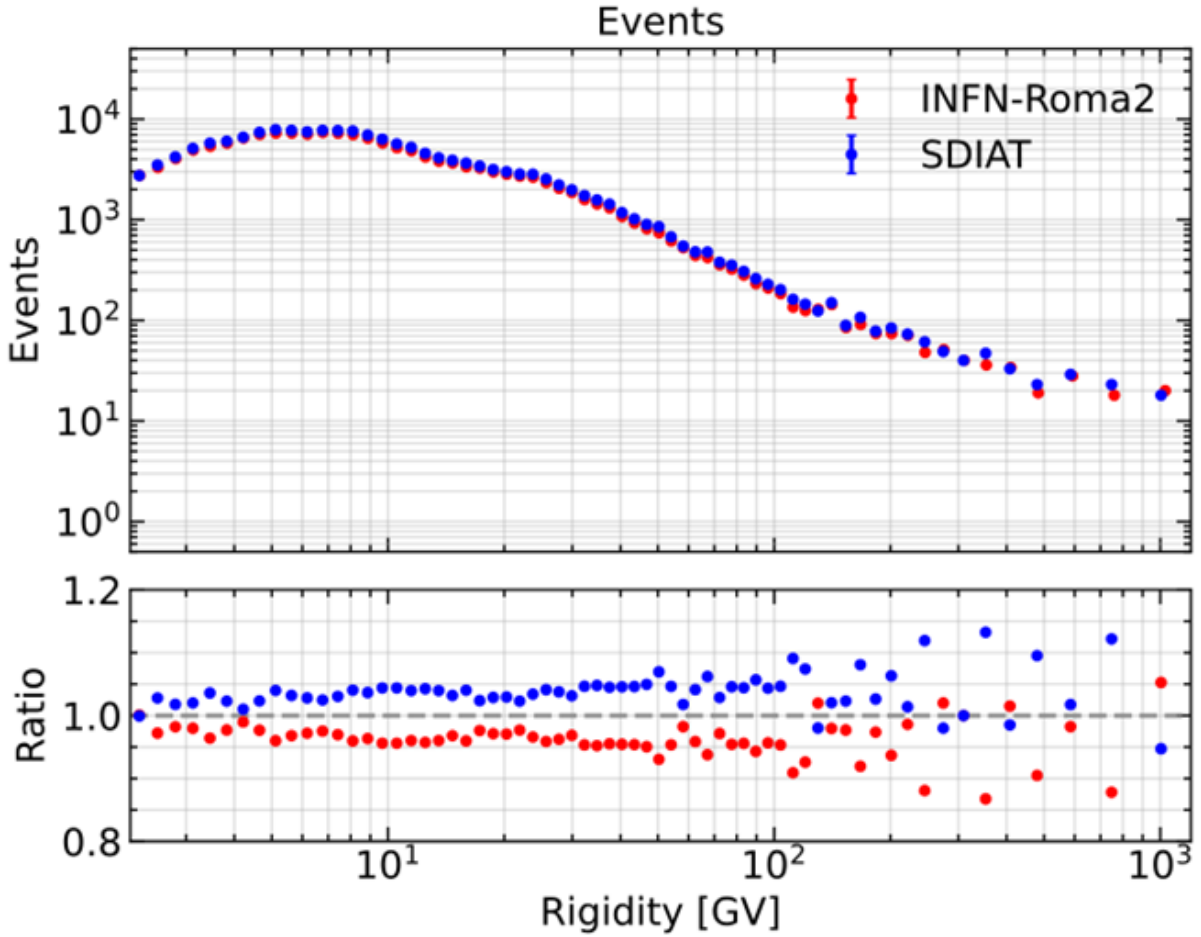




1. **High Rigidity: difference in event selection**
2. **Low Rigidity: TOI**
3. **Overall discrepancy:**
    1. **Tracker reconstruction efficiency (3%)**
    2. **TOF efficiency**
    3. **Background: below × above L1**

P selected events: compare with Qi and SDIAT

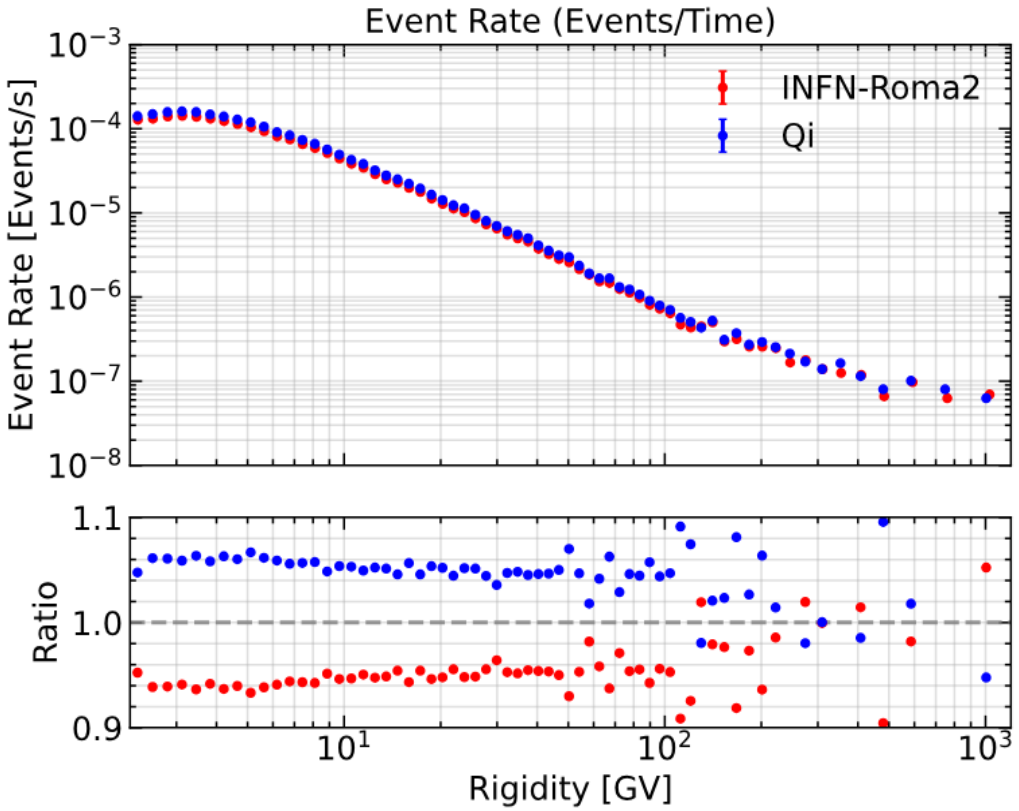




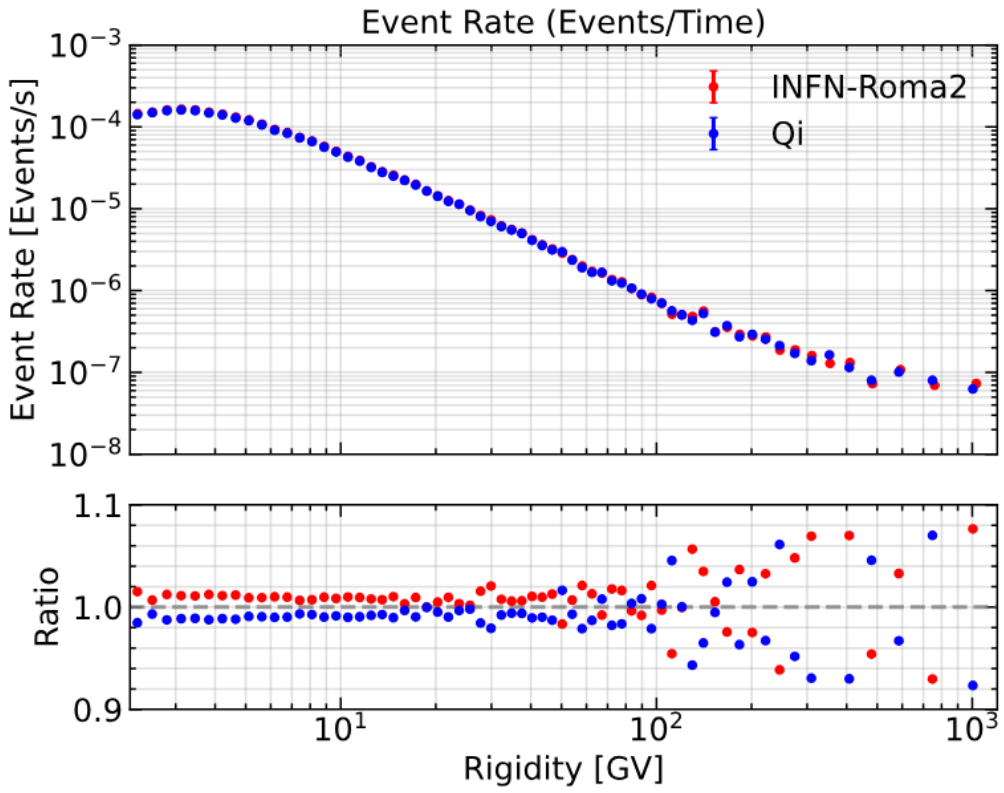
- **Qi and SDIAT have identical selected events**
- **Qi and SDIAT are using loose (L1 only) fiducial volume cut**

P event rate: compare with SDIAT

Rome: L1+Inner Fiducial volume
Qi/SDIAT: L1 Fiducial volume



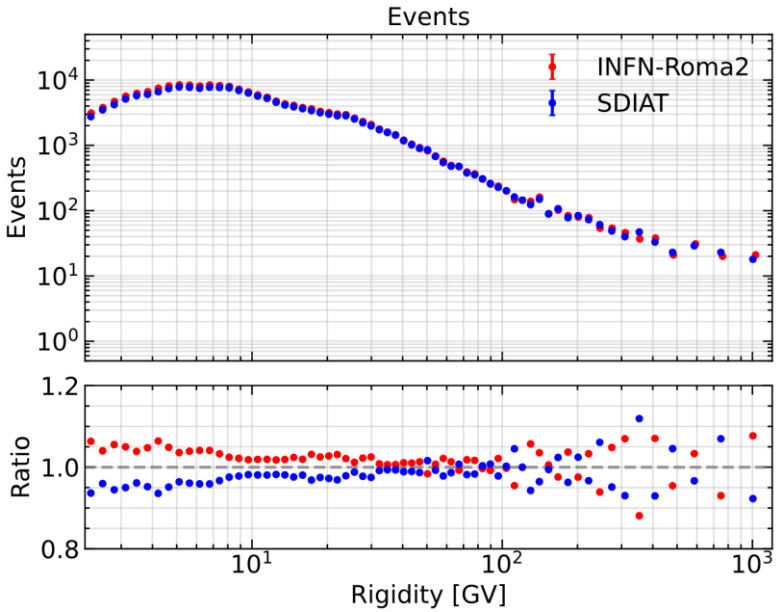
L1 Fiducial volume

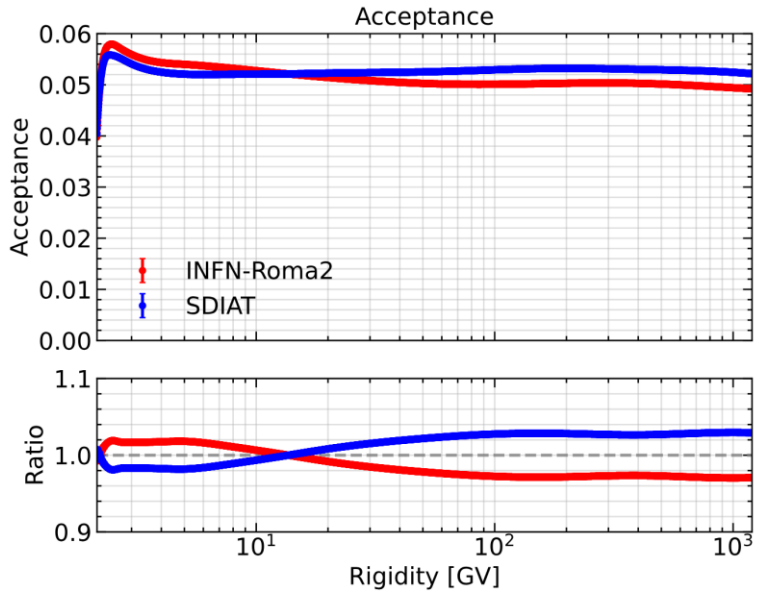


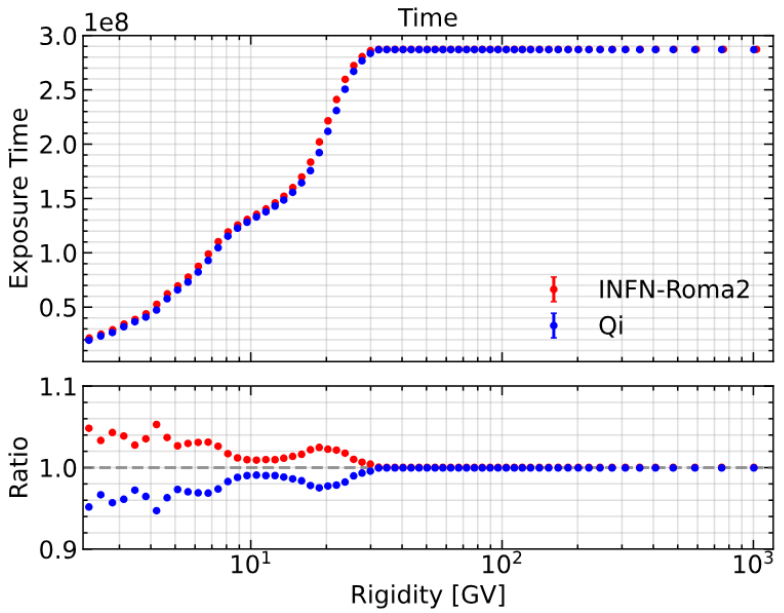
With the same event selection, we still have event fluctuation at high rigidities.

P event selection comparison

Using L1 only Fiducial volume:







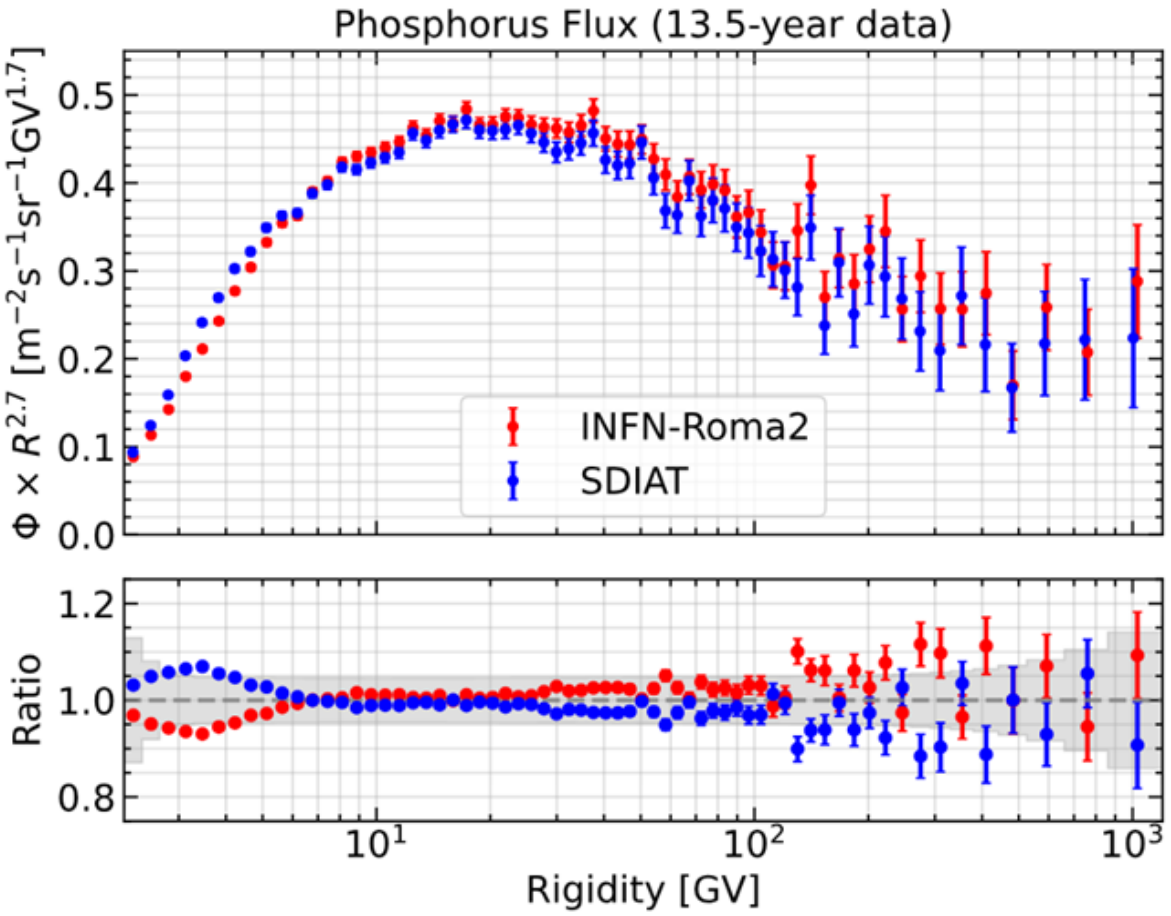
- **With the same event selection, we still have event fluctuation at high rigidities.**

Acceptance selections are different:
SDIAT removes trigger selection

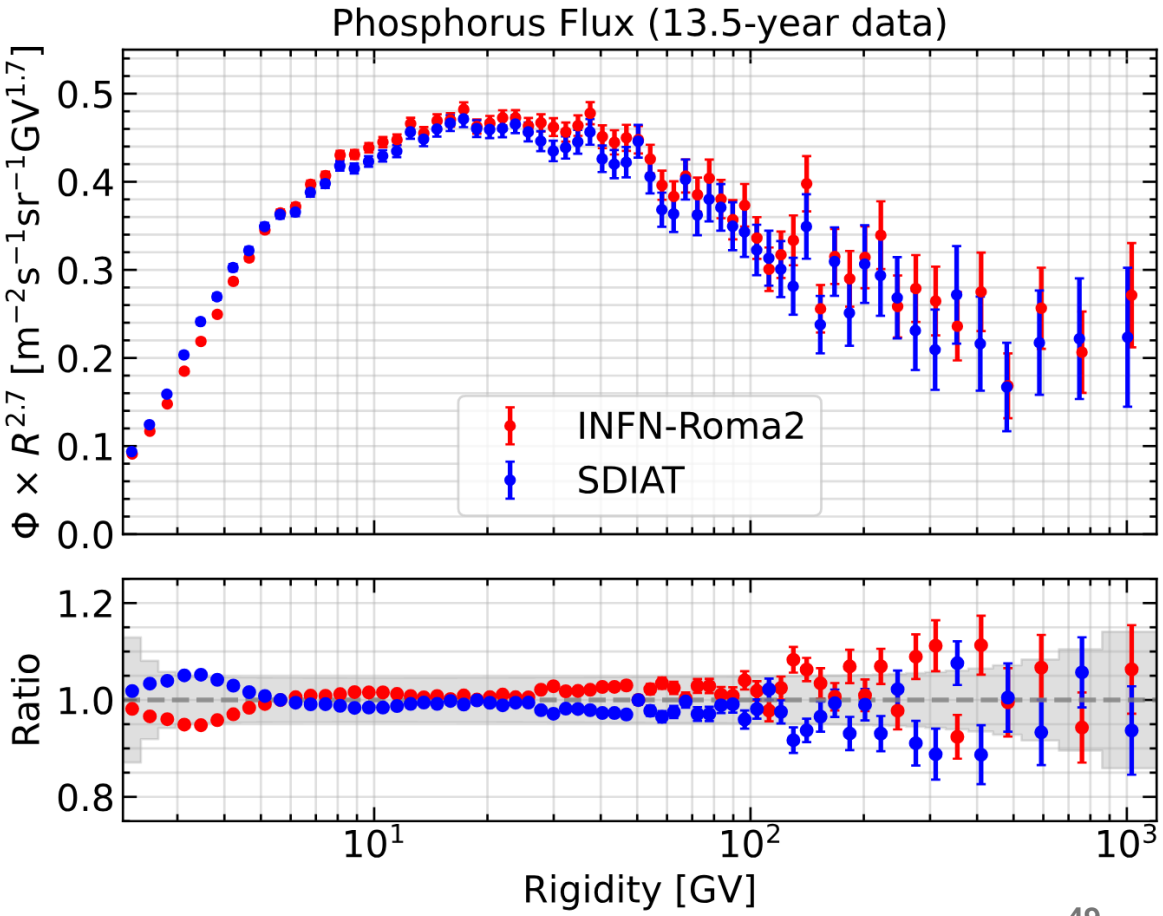
- This work: IGRF 30 deg (https://twiki.cern.ch/twiki/bin/view/AMS/Pass8)
- SDIAT is using the same exposure time as Qi

P flux: Fiducial volume

Rome: L1Inner Fiducial volume
SDIAT: L1 Fiducial volume



L1 Fiducial volume



Detailed comparison with Alessio

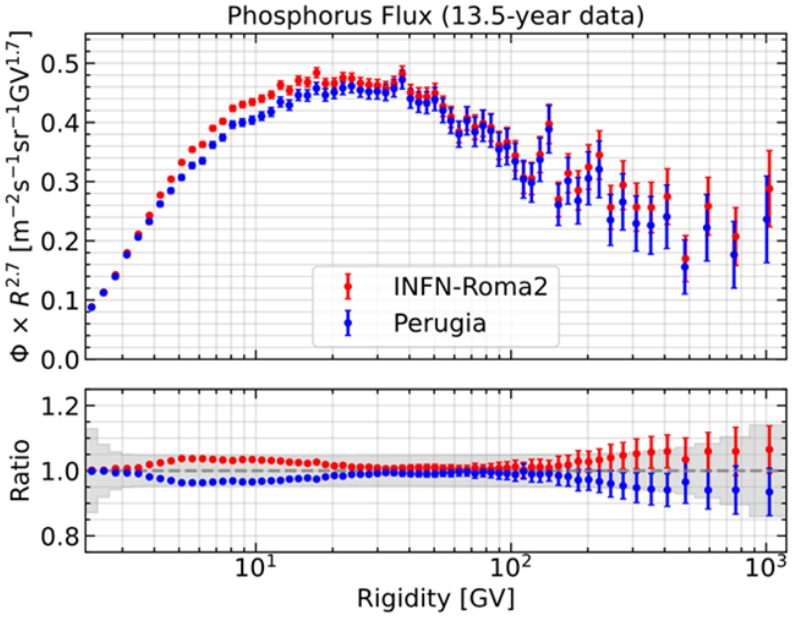
$$\Phi(R_i) = \frac{(N_{count}(R_i) - N_{bkg}) \times (1 - \sum_{Z>12} \delta)}{A^{MC}_{\text{effective}}(R_i) \prod \varepsilon_{Data/MC}(R_i) \varepsilon_{DAQ} \varepsilon_{L1Q} \Delta T(R_i) \Delta R_i}$$

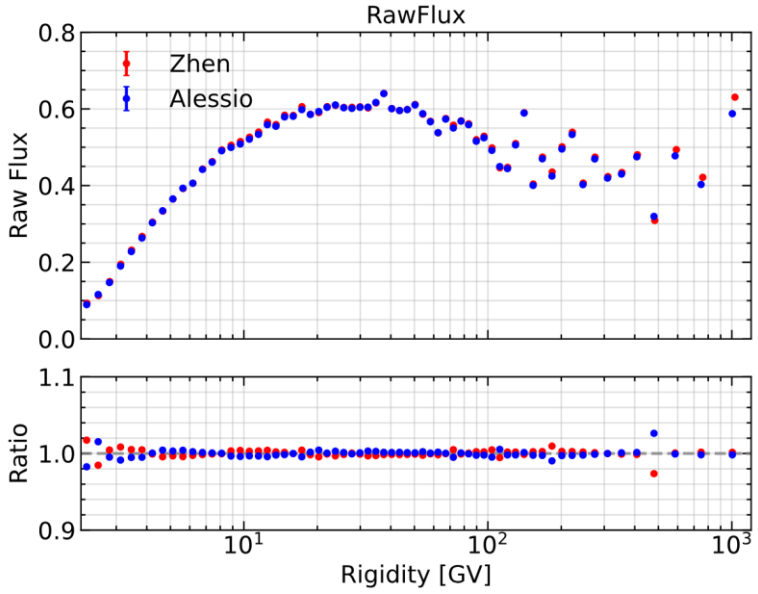
Compare flux and flux components:

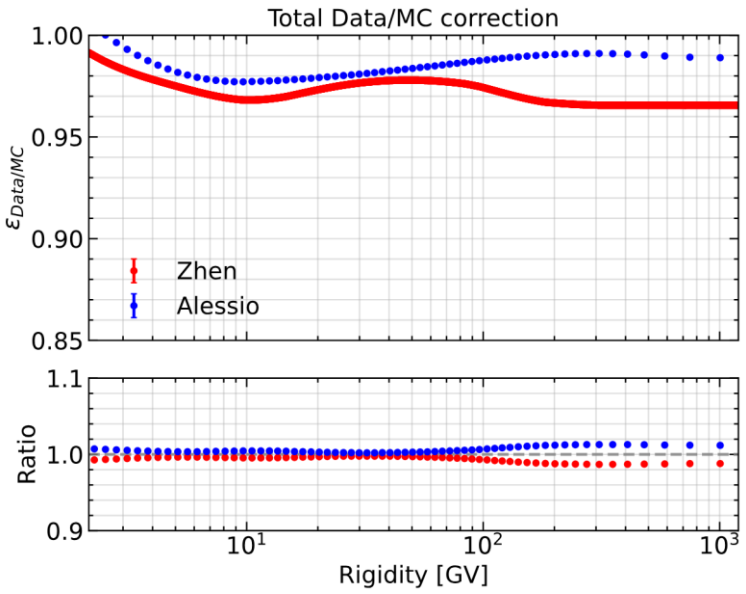
1. Raw flux without efficiency and background correction
2. Efficiency correction: total Data/MC
3. Purity from below L1 background
4. L1 chare cut efficiency
5. Top of instrument background
6. Unfolding factor

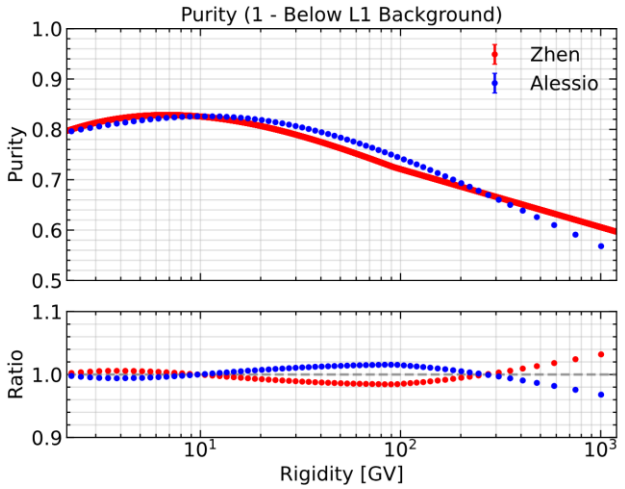
Preliminary, need further checks

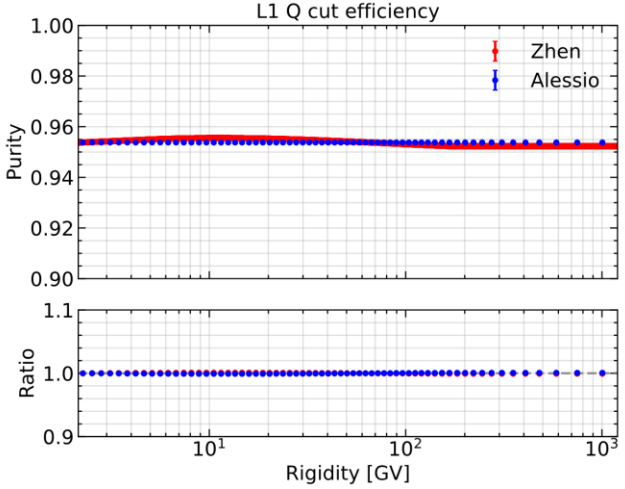
P flux components: comparison with Perugia (Alessio)

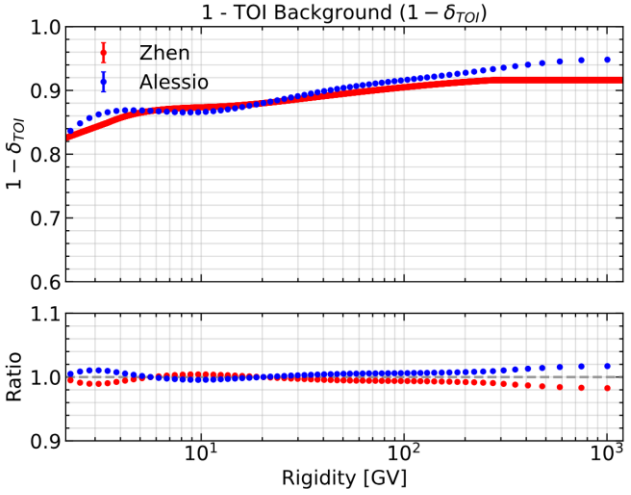


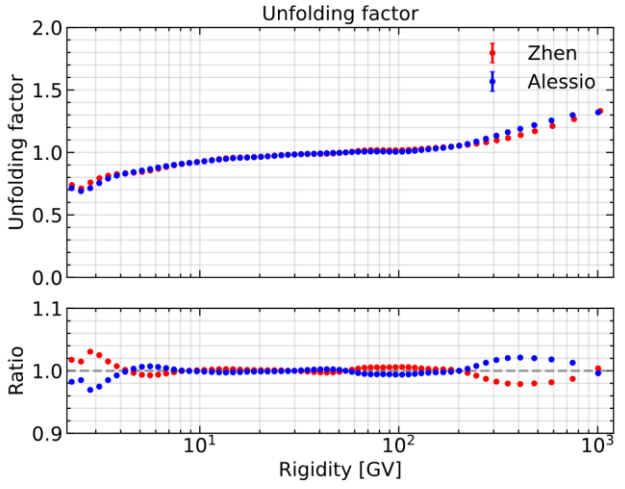




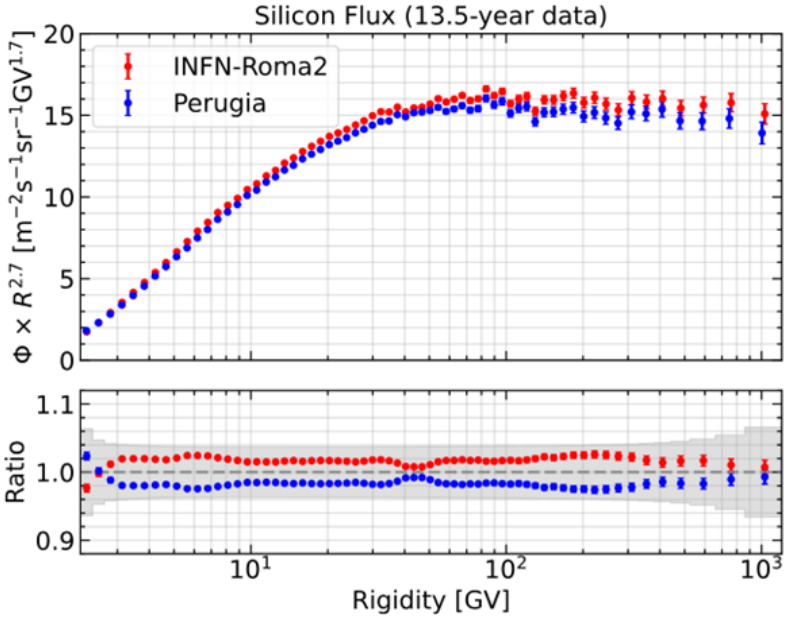


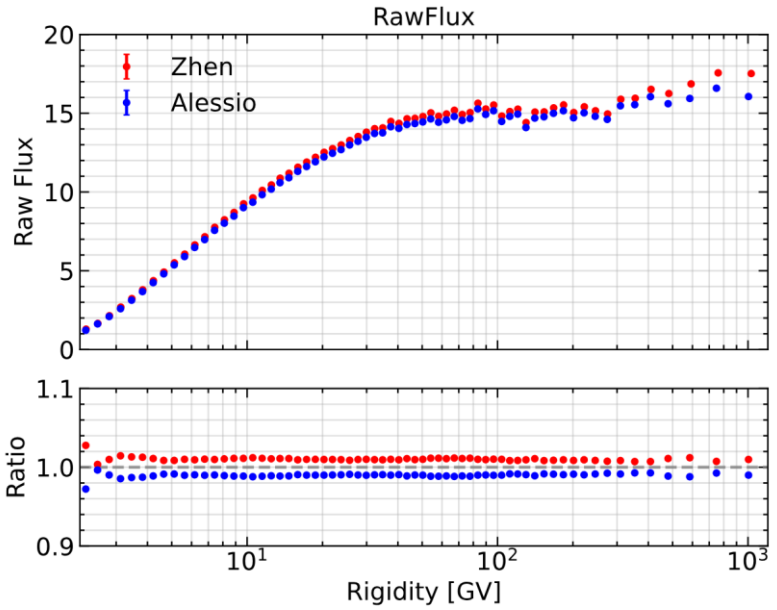


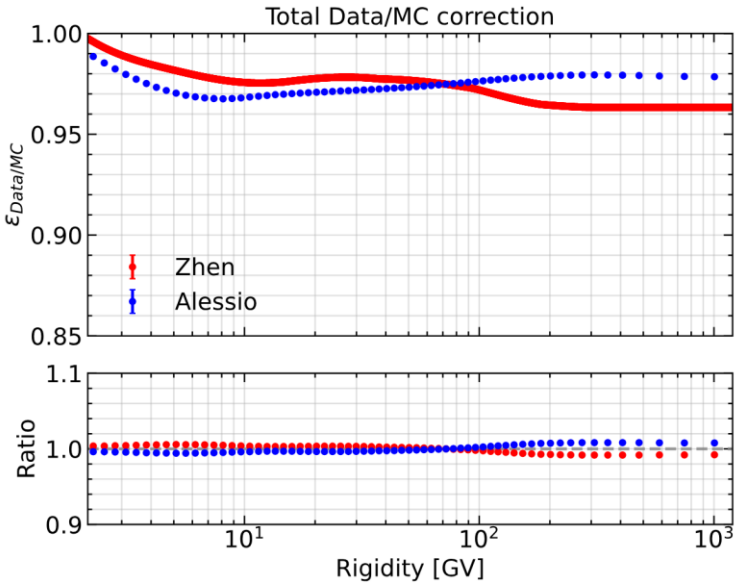


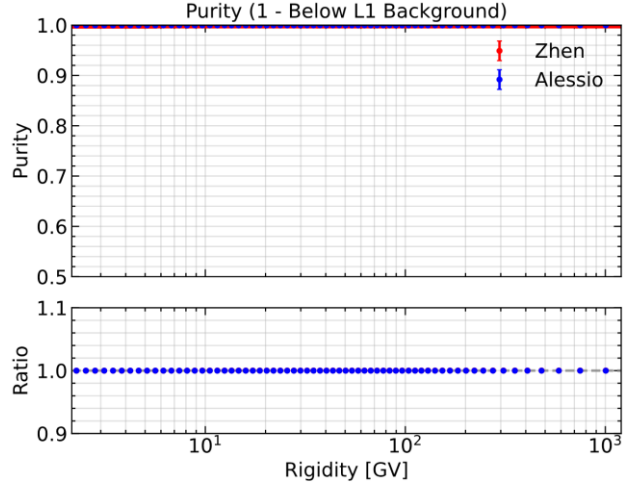


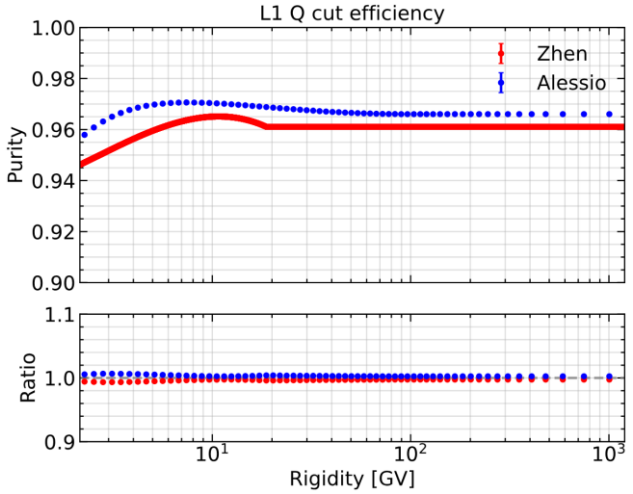
Si flux components: comparison with Perugia (Alessio)

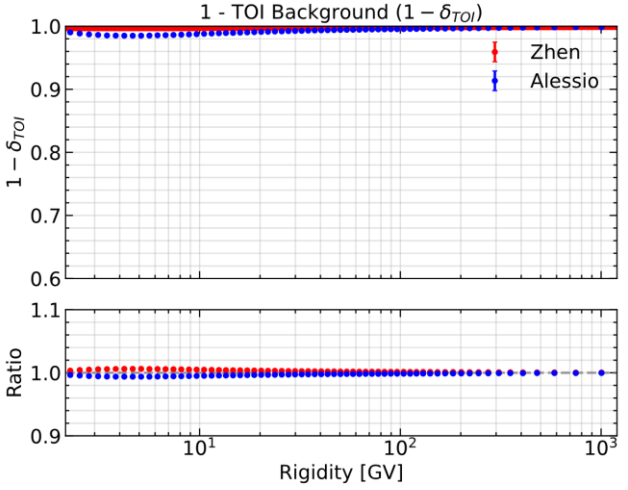


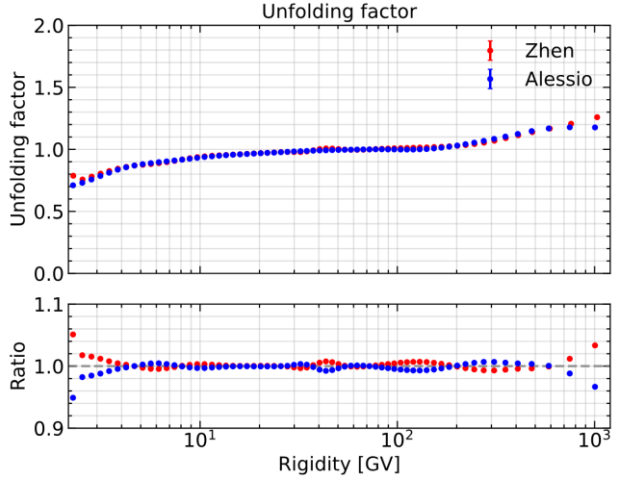




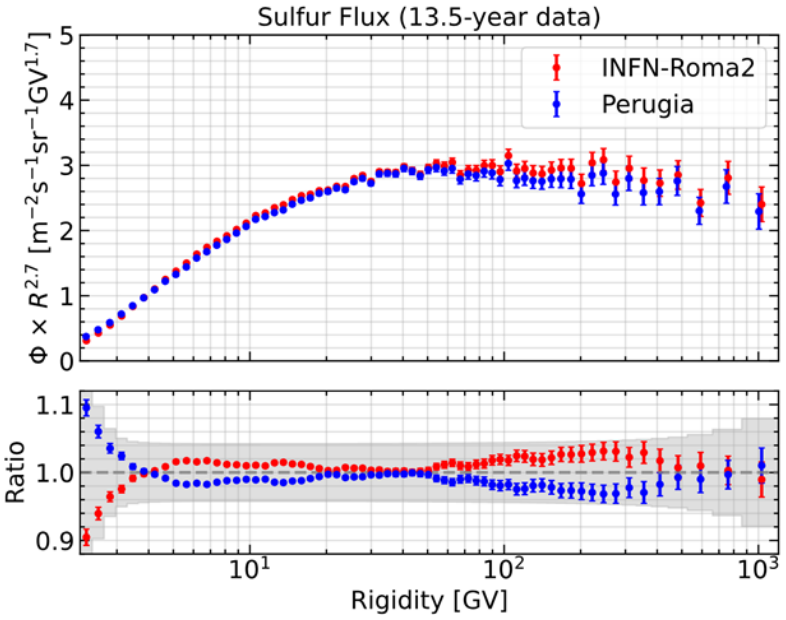


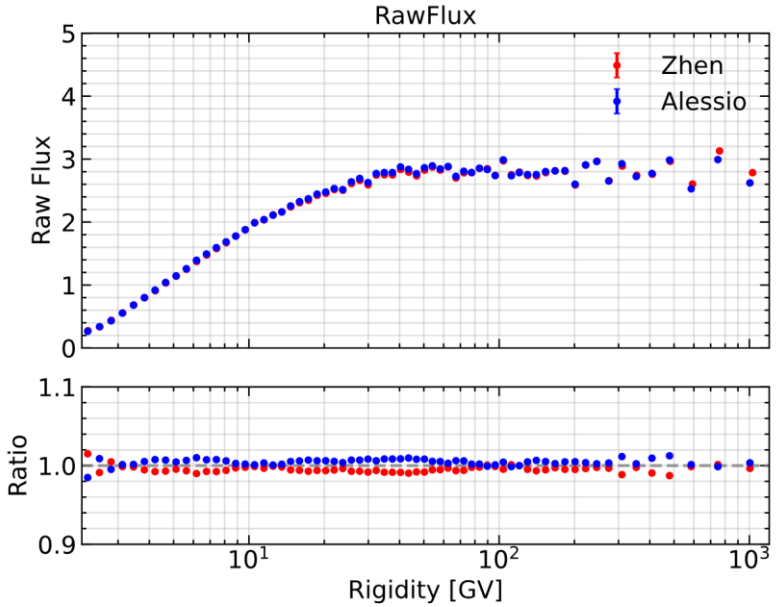


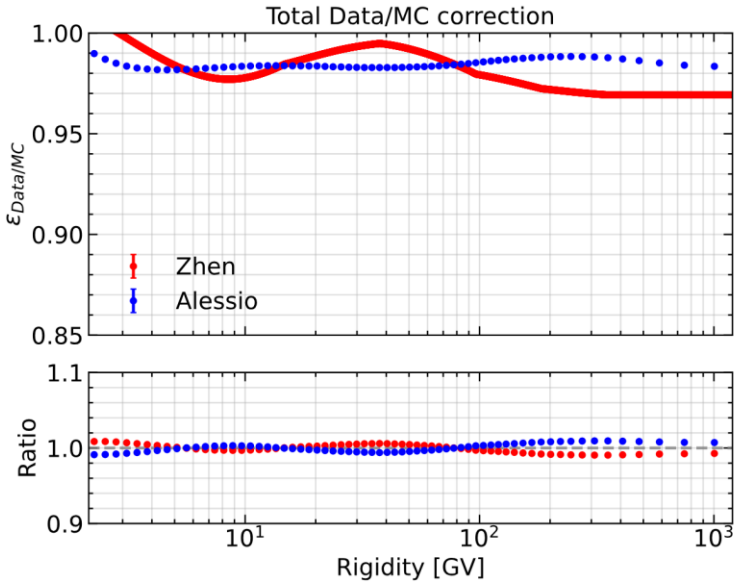


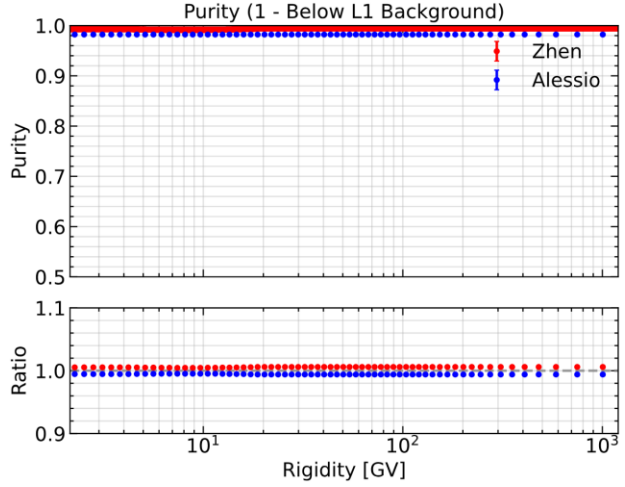


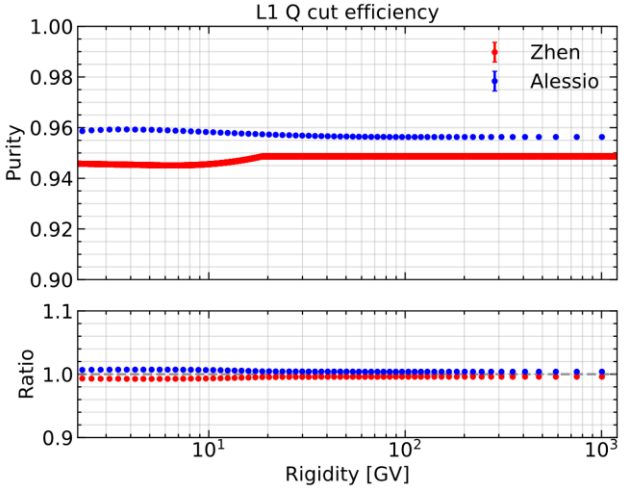
S flux components: comparison with Perugia (Alessio)

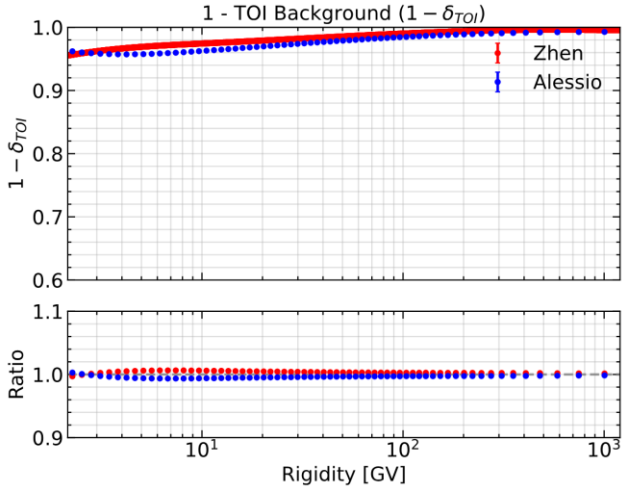


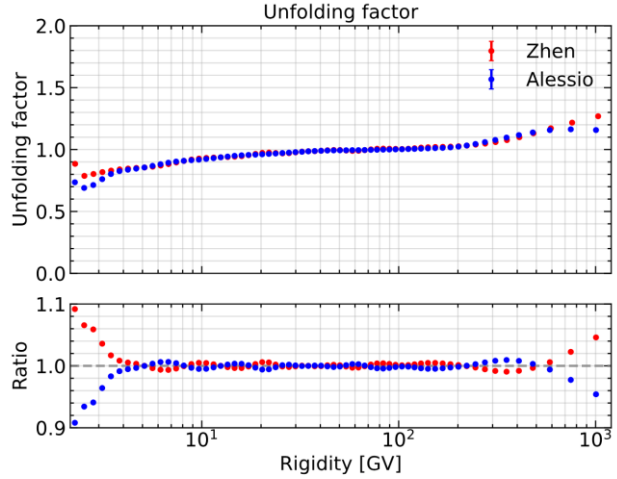




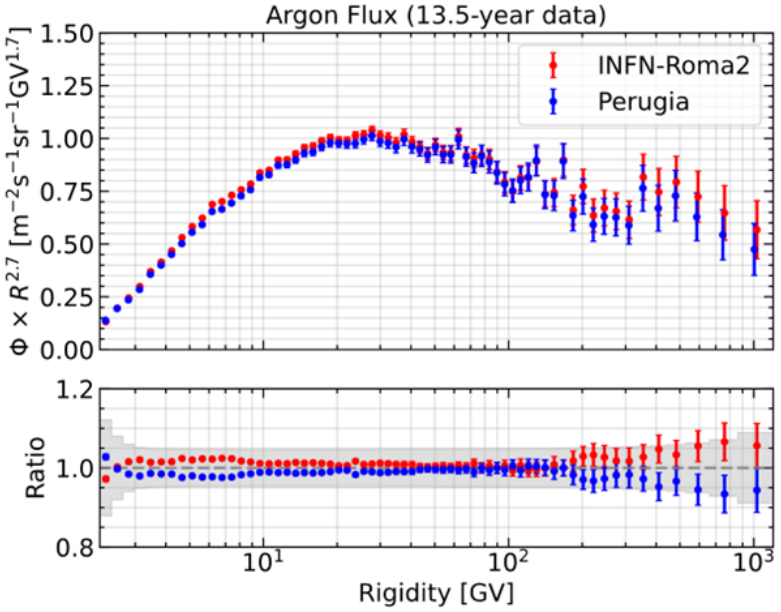


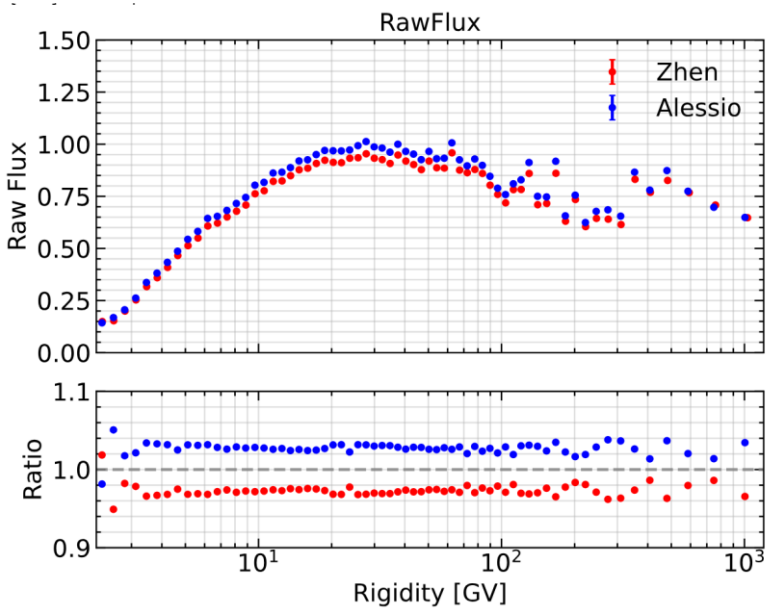


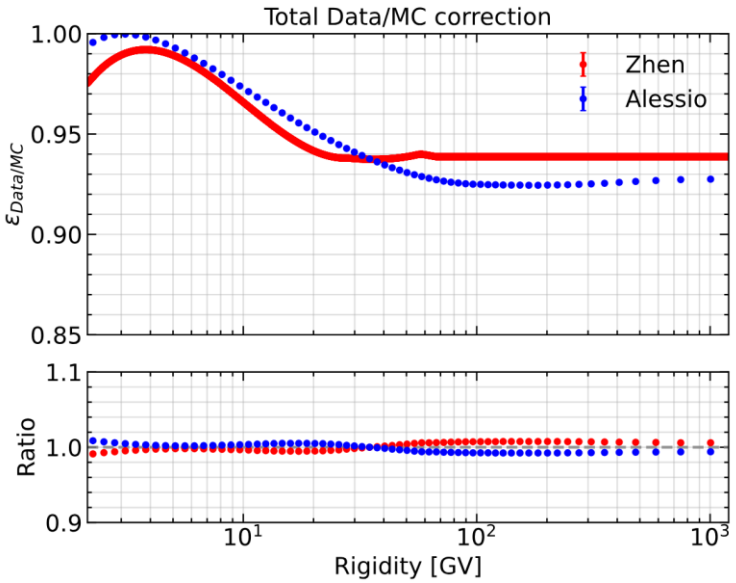


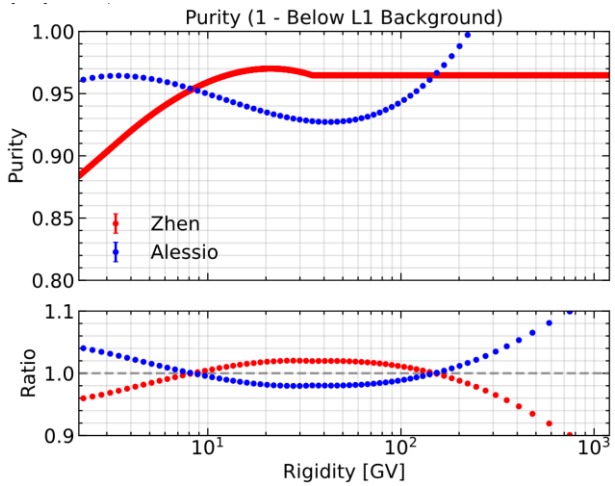


Ar flux components: comparison with Perugia (Alessio)

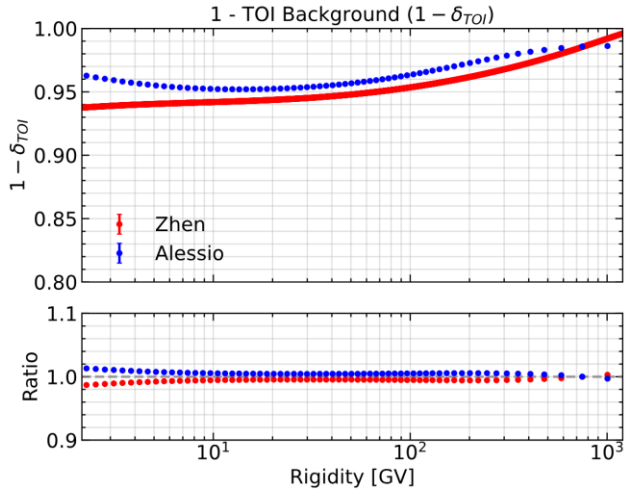


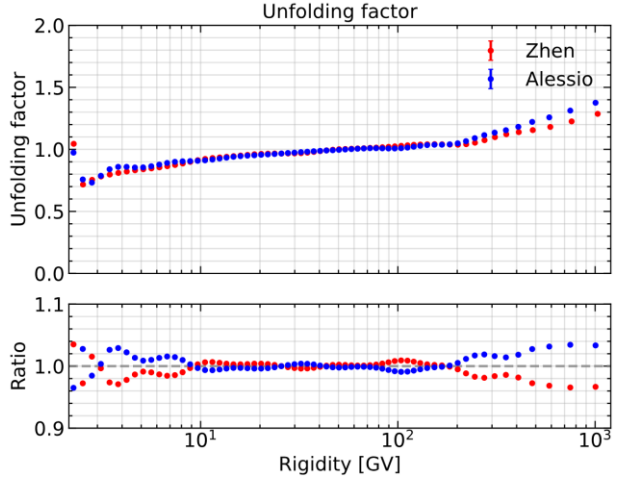




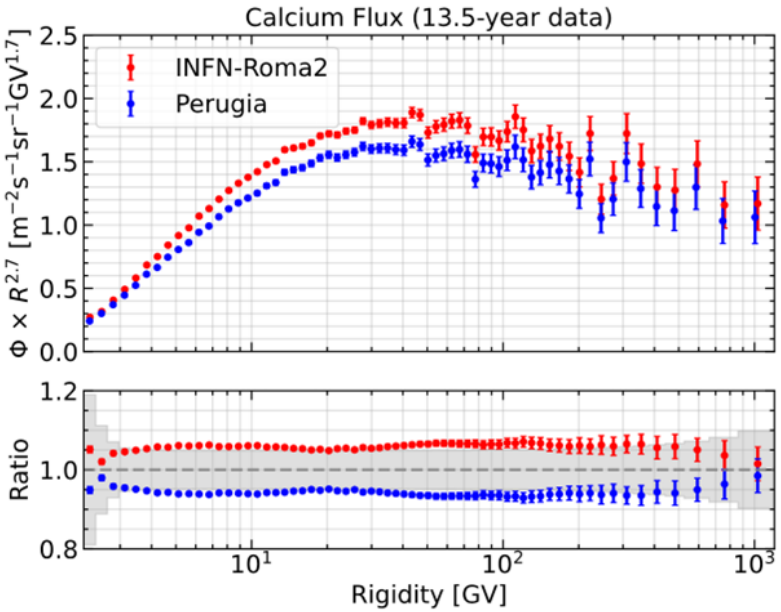


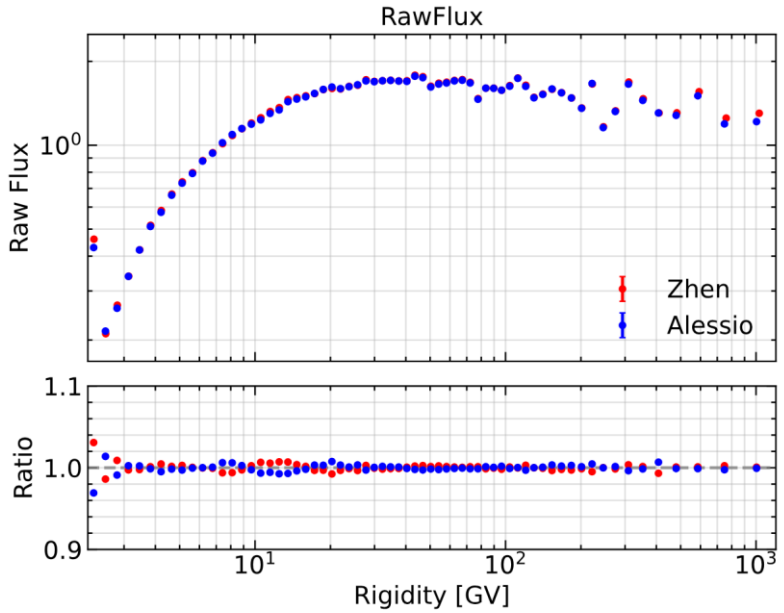
missing

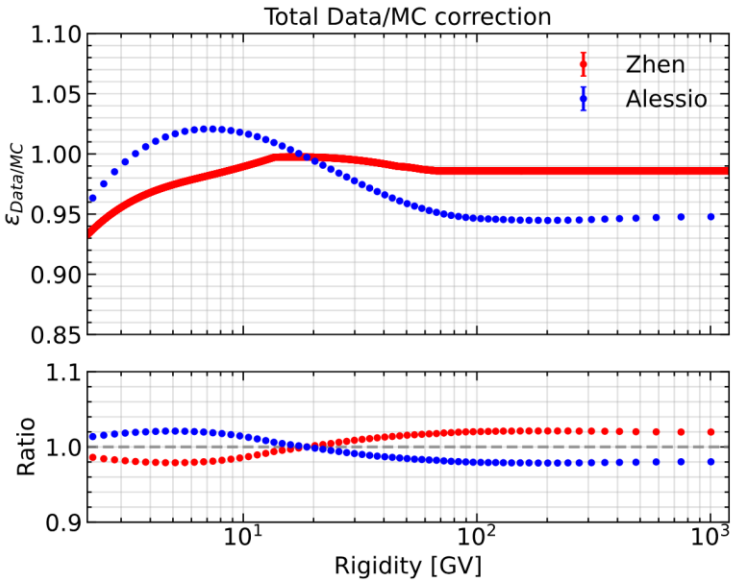


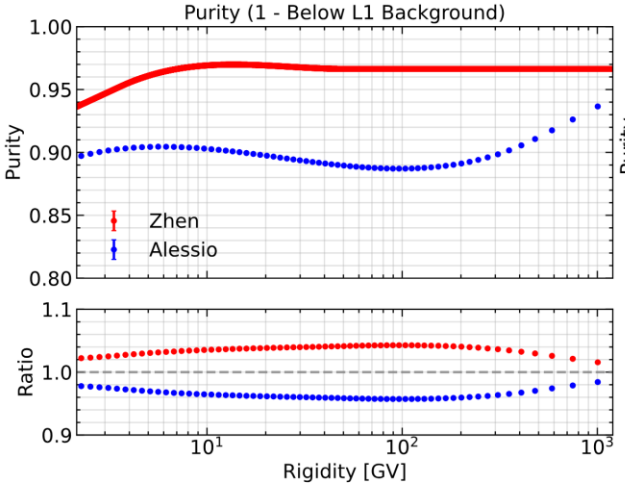


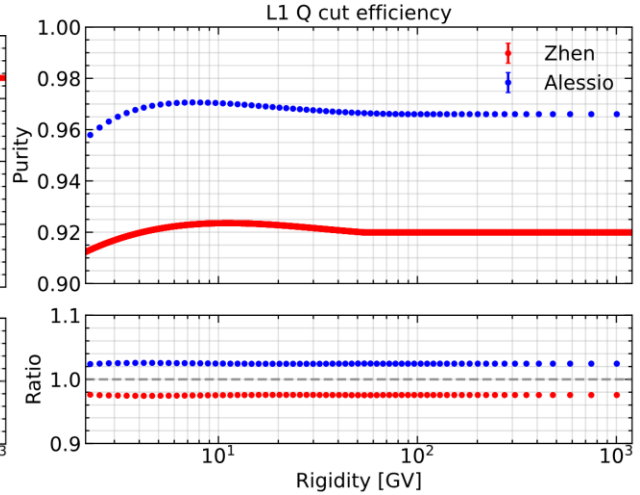
Ca flux components: comparison with Perugia (Alessio)

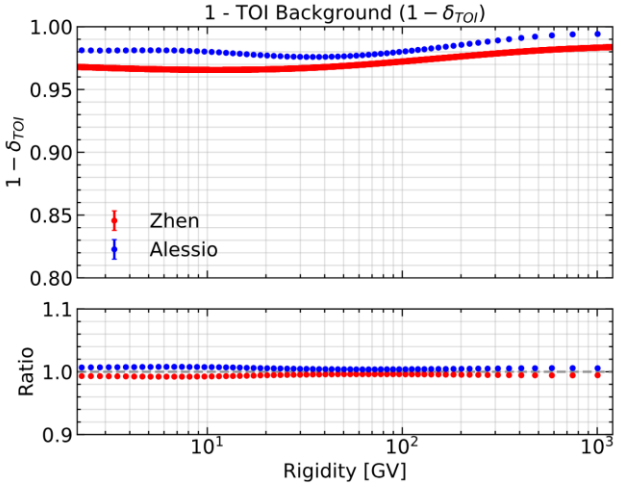


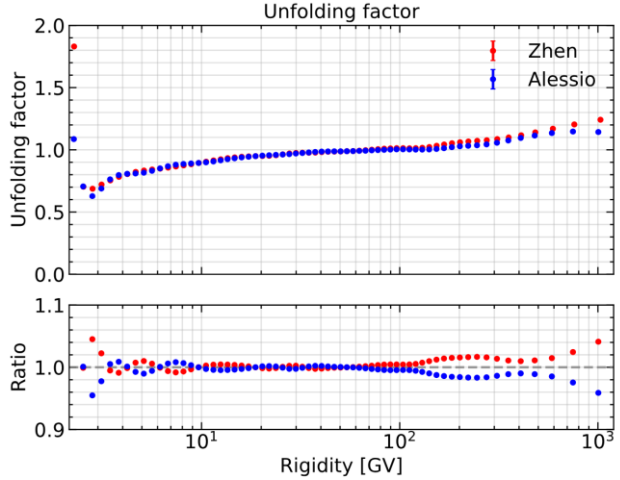












Summary

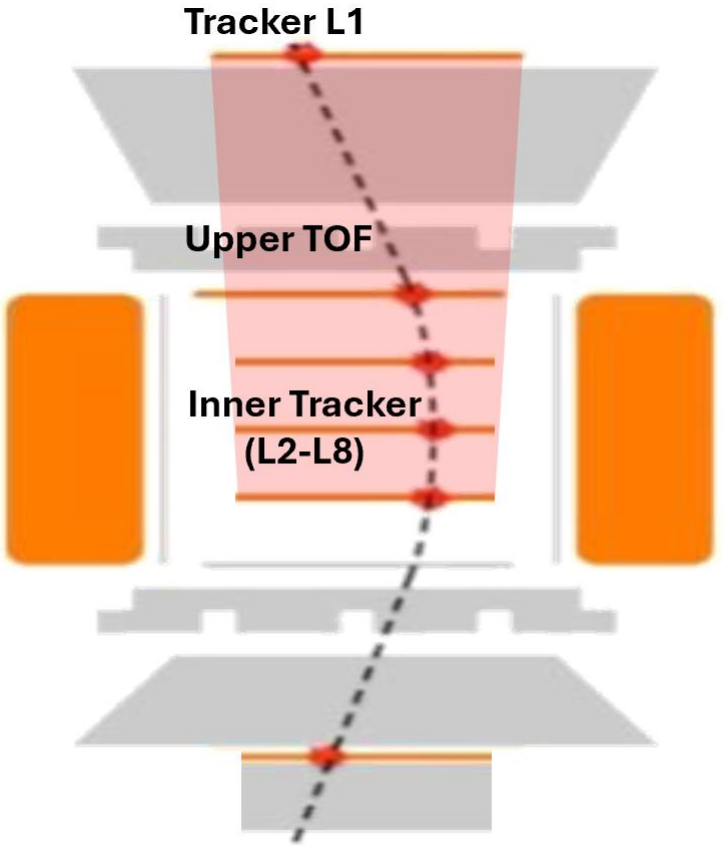
- Si, P, S, Ar, and Ca fluxes based on 13.5 years data with statistical error have been obtained.

- To-do:
  - Check Inner Tracker reconstruction efficiency
  - Update TOF efficiency
  - Update DAQ efficiency
  - Improve Ca L1 template fit
  - Check Top of instrument background
  - Detailed flux comparison for Ar and Ca

Backups

Flux measurements

- L1Inner Geometry
- Event selection:
  - Pass8 Phosphorus (charge = 15) common selection (https://twiki.cern.ch/twiki/bin/view/AMS/Pass8)
  - excluding photon-polarization trigger period
- Rigidity bin:
  - high Z bins, same as Ne Mg and Si binning
- GBL track fitting
- YJ charge



L1Inner geometry

Flux Formula

The differential flux in the i_{th} rigidity bin (R_i, R_i + ΔR_i):

$$\Phi(R_i) = \frac{(N_{count}(R_i) - N_{bkg}) \times (1 - \sum_{Z>12} \delta)}{A^{MC}_{\text{effective}}(R_i) \prod \varepsilon_{Data/MC}(R_i) \varepsilon_{DAQ} \varepsilon_{L1Q} \Delta T(R_i) \Delta R_i}$$

- N_{count}: the number of events
- N_{bkg}: L1 charge residual background
- δ: top of the instrument background due to interactions above Tracker L1 from heavier nuclei
- $A_{effective}$: effective acceptance evaluated from MC events
- $\varepsilon_{Data/MC}$: Data/MC correction
- ε_{DAQ}: data acquisition efficiency evaluated from Data
- ε_{L1Q}: L1 upper charge cut fraction for Data
- ΔT: exposure time

Event Selection (Pass8 common selection)

- RTI cuts:
  - Normal detector operating conditions:
    - a.ntrig/a.nev>0.98
    - a.npart/a.ntrig> (isphorun?0.02:0.07/1600*a.ntrig) && a.npart/a.ntrig<0.25
    - a.nerr>=0 && a.nerr/a.nev<0.1
    - a.npart>0 && a.nev<1800
    - (a.good&0x3F)==0
  - Further selection on normal detector operating conditions:
    - (nexl[0][0]>700 && nexl[1][0]>500); //require number of events (within 90 secs) of having L1 hit to be >700 and having L9 hit to be >500
  - SAA cut (remove SAA by geographic coordinates):
    - a.IsInSAA()==0
  - AMS live-time and attitude cuts:
    - a.lf > (isphorun?0.35:0.5)
    - a.zenith < 40
  - Events with rigidity of track above geomagnetic cutoff (IGRF 30 deg)

Event Selection (Pass8 common selection)

- TrTrack selection (V6 alignment+GBL track fitting algorithm)
  - InnerNHitY>=5 && L2&(L3|L4)&(L5|L6)&(L7|L8)
  - L1XY
  - L9XY (for FS analysis)
  - InnerNormChisqY < 10
  - L1InnerNormChisqY < 10 && L1InnerChisqY-InnerChisqY < 10 (for L1Inner analysis)
  - L1InnerL9NormChisqY < 10 && (L1InnerL9ChisqY-InnerChisqY)/2<10 (for FS analysis)

Event Selection (Pass8 common selection)

- Beta cuts
  - BetaHR->GetBeta()>0.4 && BetaHR->GetBuildType()==1
- Charge selection Z>=9 with tracker charge based on YJ's calibration:
  - Inner Q: fabs(q_inn-Z) < (Z>=14)? 0.5 : 0.0075*pow(Z,1.414)+0.198;
  - L1 Q: Z-0.0585*pow(Z,1.15)-0.35 < q_l1 < Z+0.0334*pow(Z,1.15)+0.20
  - L1 Q asymmetry: fabs(q_l1x-q_l1y)/(q_l1x+q_l1y) < 0.2
  - L1 Q status: (qstatus_l1&0x10013D)==0
  - L9 Q: Z-0.0284*pow(Z,1.15)-0.17 < q_l9 < Z+0.0585*pow(Z,1.15)+0.35
  - L9 Q asymmetry: fabs(q_l9x-q_l9y)/(q_l9x+q_l9y) < 0.2 (for FS analysis)
  - UTOF Q: Z-0.625-0.0225*(Z-9) < q_utof < Z+1.5
  - LTOF Q: q_ltof > Z-0.625-0.0225*(Z-9) (for FS analysis)
- Tracker fiducial volume cut:
  - L1&L2&(L3|L4)&(L5|L6)&(L7|L8)&L9 (>=5 InnerLays) for FS analysis
  - L1&L2&(L3|L4)&(L5|L6)&(L7|L8) (>=5 InnerLays) for L1Inner analysis
  - L1: |R|<62cm, |Y|<47cm; L2: |R|<62cm, |Y|<40cm; L3: |R|<46cm, |Y|<44cm;
  - L4: |R|<46cm, |Y|<44cm; L5: |R|<46cm, |Y|<36cm; L6: |R|<46cm, |Y|<36cm;
  - L7: |R|<46cm, |Y|<44cm; L8: |R|<46cm, |Y|<44cm; L9: |X|<43cm, |Y|<29cm

Charge cuts (Pass8 common selection)

Common Q cuts	Si (Z=14)	P (Z=15)	S (Z=16)	Ar (Z=18)	Ca (Z=20)
L1 Q*	[12.433, 14.895]	[13.333, 15.952]	[14.231, 17.01]	[16.026, 19.128]	[17.816, 21.247]
UTOF Q	[13.26, 15.50]	[14.24, 16.50]	[15.22, 17.50]	[17.17, 19.50]	[19.13, 21.50]
Inner Q	[13.5, 14.5]	[14.5, 15.5]	[15.5, 16.5]	[17.5, 18.5]	[19.5, 20.5]

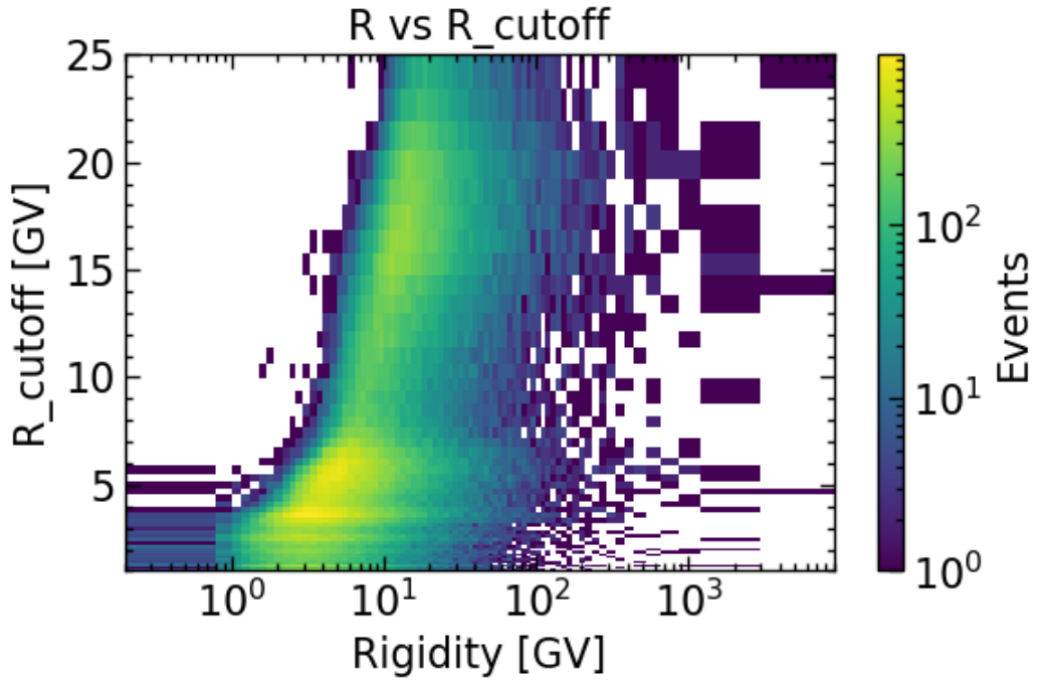
*** L1 upper Q cut applied only to Data**

Inner tracker reconstruction efficiency: rigidity estimator

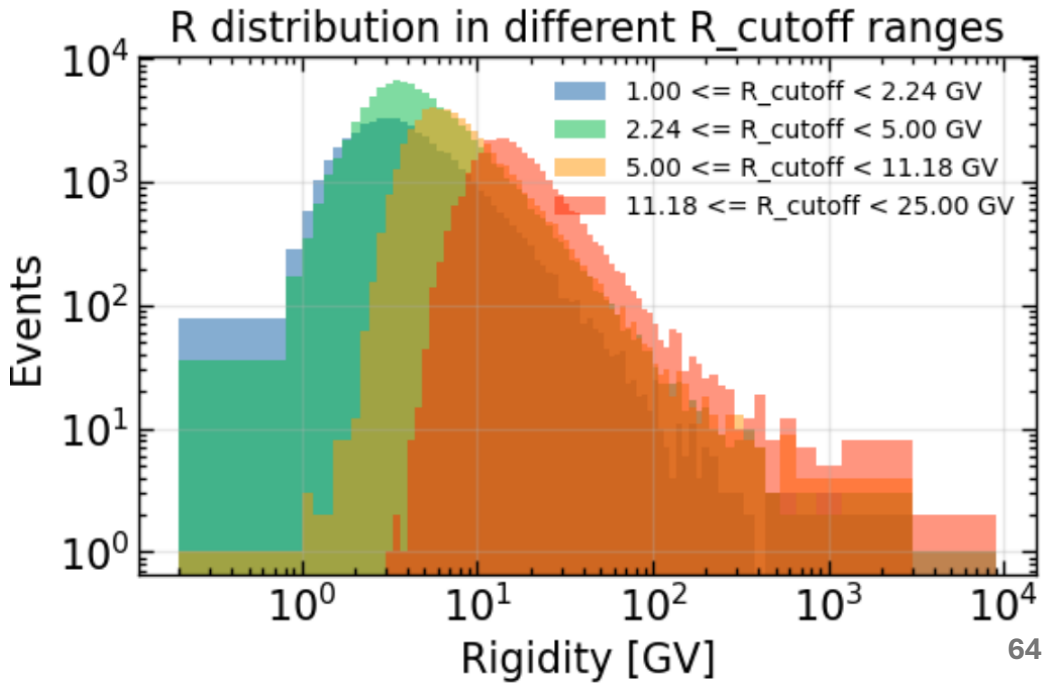
R estimator calculated from R_cutoff (R>6.6GV) :

1. P(R|R_cutoff) = P(R, R_cutoff) / P(R_cutoff)
2. P(R, R_cutoff): non-parametric KDE
3. Estimate R from: E[R|Rcutoff]=∫R·P(R|Rcutoff)dR, Mode, median, etc., and pdf (on-going).

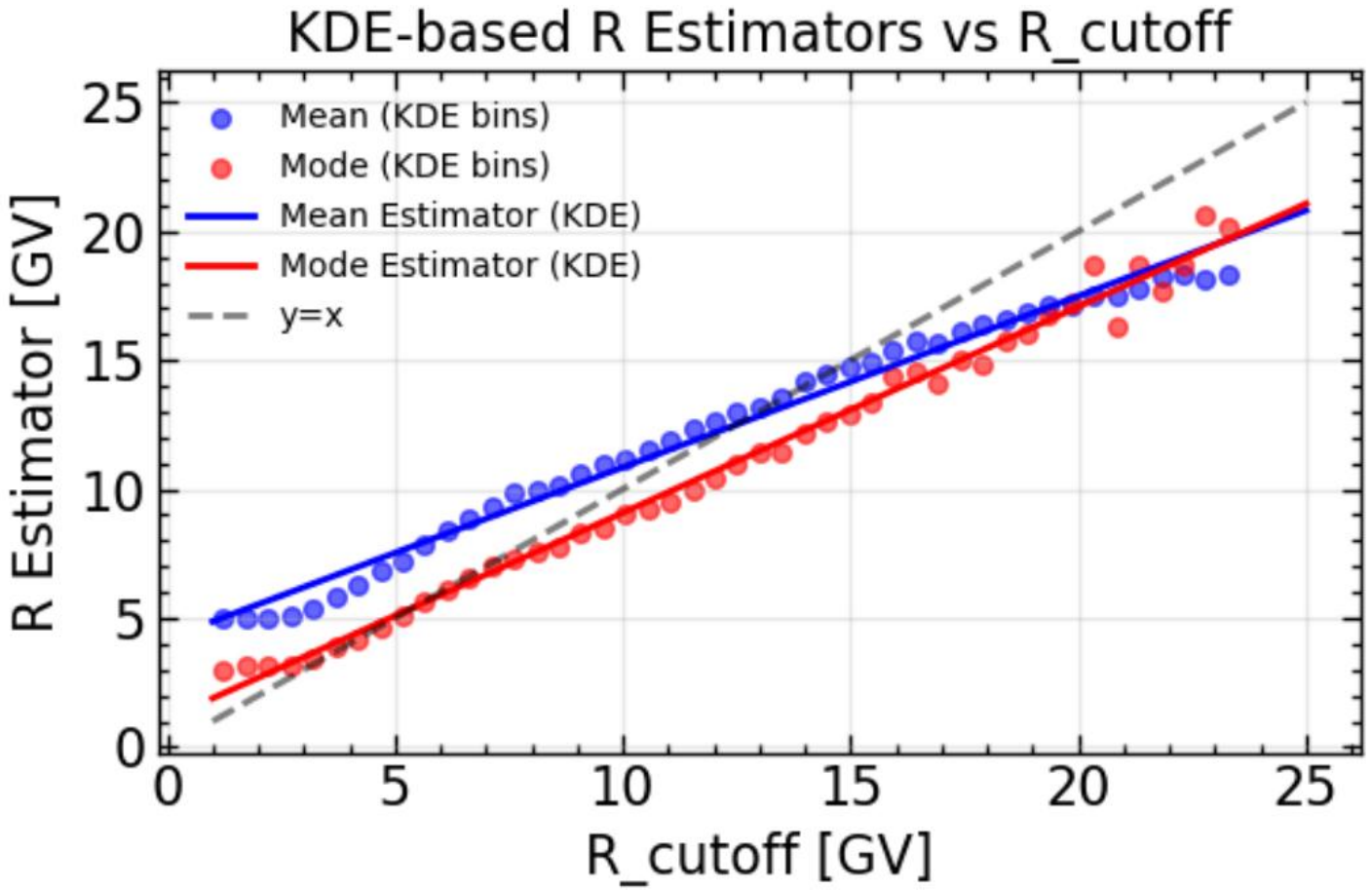
P(R, R_cutoff)



P(R|R_cutoff) → KDE smooth



R Estimator for R>6.6GV



Mean Estimator:

R = 0.5809 * R_cutoff + 4.3931

Mode Estimator:

R = 0.6660 * R_cutoff + 1.6134

Total trigger efficiency

- Time period 1: before February 2016, NACC<5 was used.
- Time period 1 unbiased (non-physical) data events are few, but they can be estimated in time period 2 by requiring NACC<5 from NACC<8.

So the **total Trigger efficiency for Data** can be calculated with ACC<5 time period estimated from ACC<8:

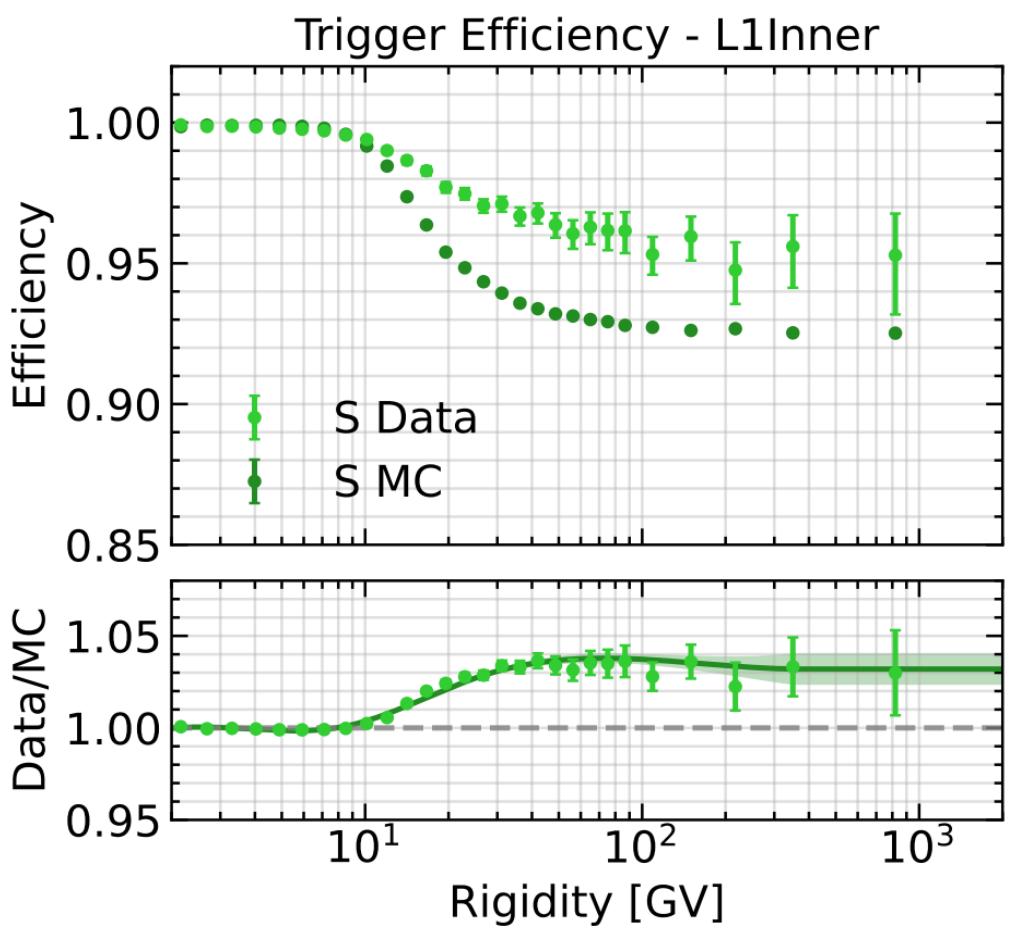
$$\varepsilon_{trig\_total} = \frac{(n_{physics1} + n_{physics2})/100}{(n_{physics1} + n_{physics2})/100 + (n_{unbiased1} + n_{unbiased2})}$$

(time period 1: physical trigger $n_{physics1}$; time period 2: $ACC < 8$)

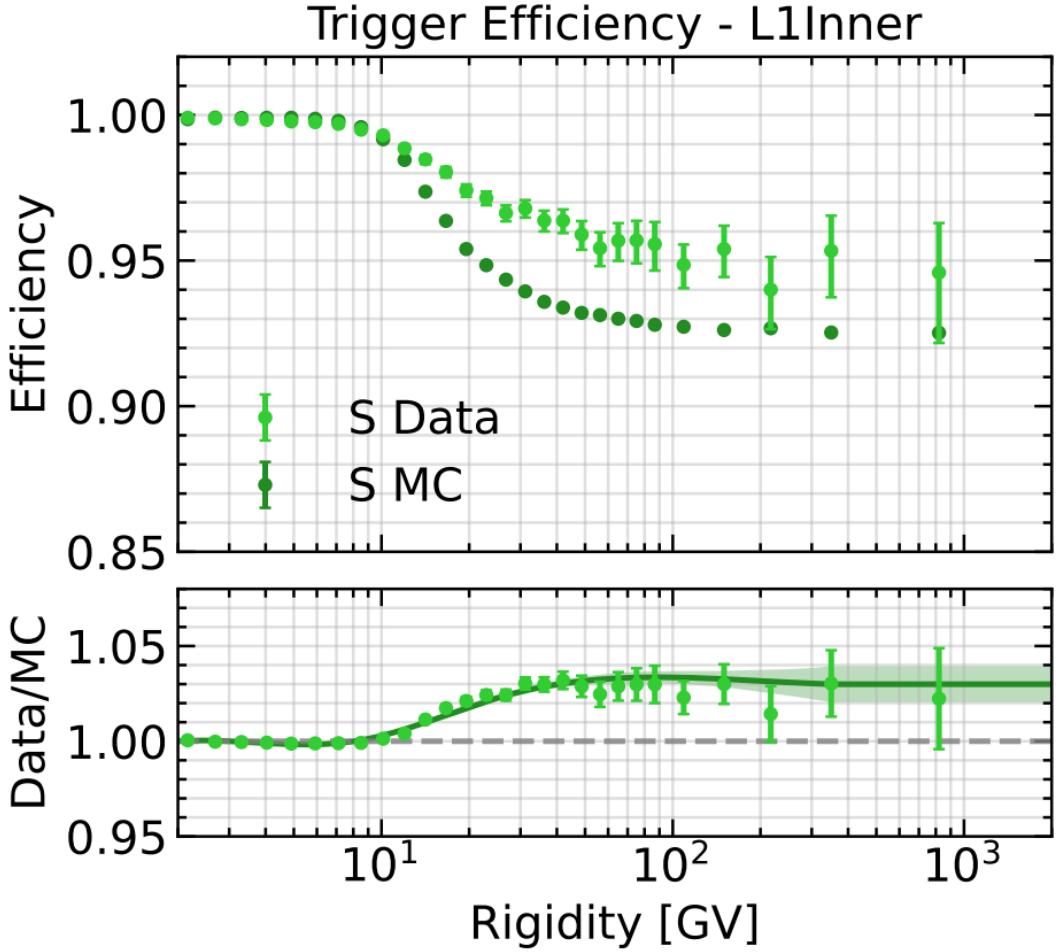
$$\begin{aligned}
\varepsilon_{trig} &= \varepsilon_{trig2} \times Corr \\
&= \varepsilon_{trig2} \times \frac{n_{physics1} + n_{physics2}}{n_{physics1}/factor1 + n_{physics2}/factor2} \\
&\approx 1 \times \frac{n_{physics1} + n_{physics2}}{n_{physics1} \Big/ \frac{n_{physics2}^{ACC<5}}{n_{physics2}} + n_{physics2} \Big/ \frac{n_{physics2}^{ACC<8}}{n_{physics2}}} \\
&\approx \frac{n_{physics1} + n_{physics2}}{n_{physics1} \Big/ \frac{n_{physics2}^{ACC<5}}{n_{physics2}} + n_{physics2}}
\end{aligned}$$

Total trigger efficiency: polarization-photon trigger runs

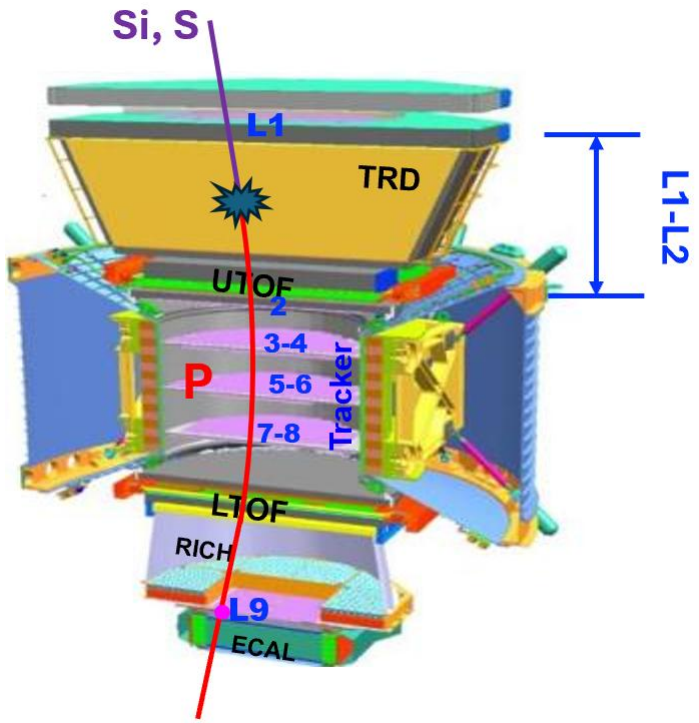
With polarization-photon trigger runs



Without polarization-photon trigger runs



P Below L1 background (L1 charge background due to interactions between Tracker L1 and L2)



The background is estimated by fitting the L1 charge distribution with Si, P and S templates derived from Si and S L1 charge.

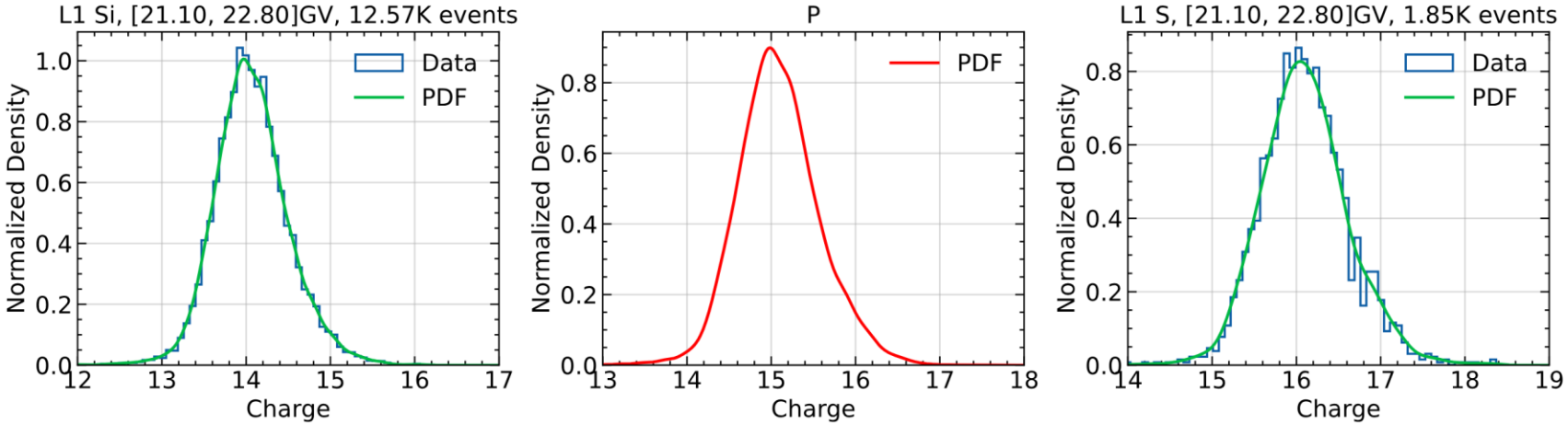
Template fit method:

- **Si and S L1 templates:** smooth PDFs built directly from Si and S data.
- **P Template:** smooth PDF built from L1 Si and S interpolated data.
- Fit parameter: fractions, and P charge shift.
  - Allow a small shift in P template to account for a residual bias since template is built from Si and S.
- **Error estimation:**
  1. Fit error: correlation between fractions and shift has been taken into account.
  2. Template statistical error:
     - Build several versions of templates according to the limited statistics.
     - Perform the fits many times to properly account for the template uncertainties.

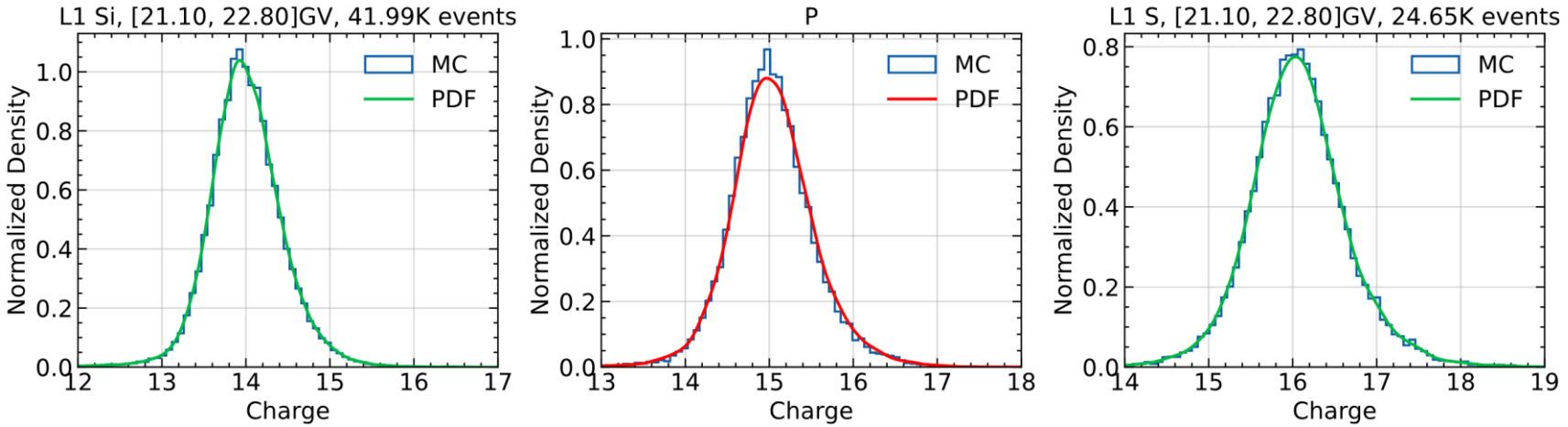
P Below L1 background: template building

- **Si and S PDFs** are built from tightly selected L1 charge distributions.
- **P PDF** is built from synthetic data generated via interpolation of Si and S.
- **Interpolation:** P synthetic data = (0.5 × Si+ 0.5 × S) × (average std) + (average mean)
  1. Standardize Si and S (mean=0, std=1), mix 1:1,
  2. Rescale mixed data to average mean and std.

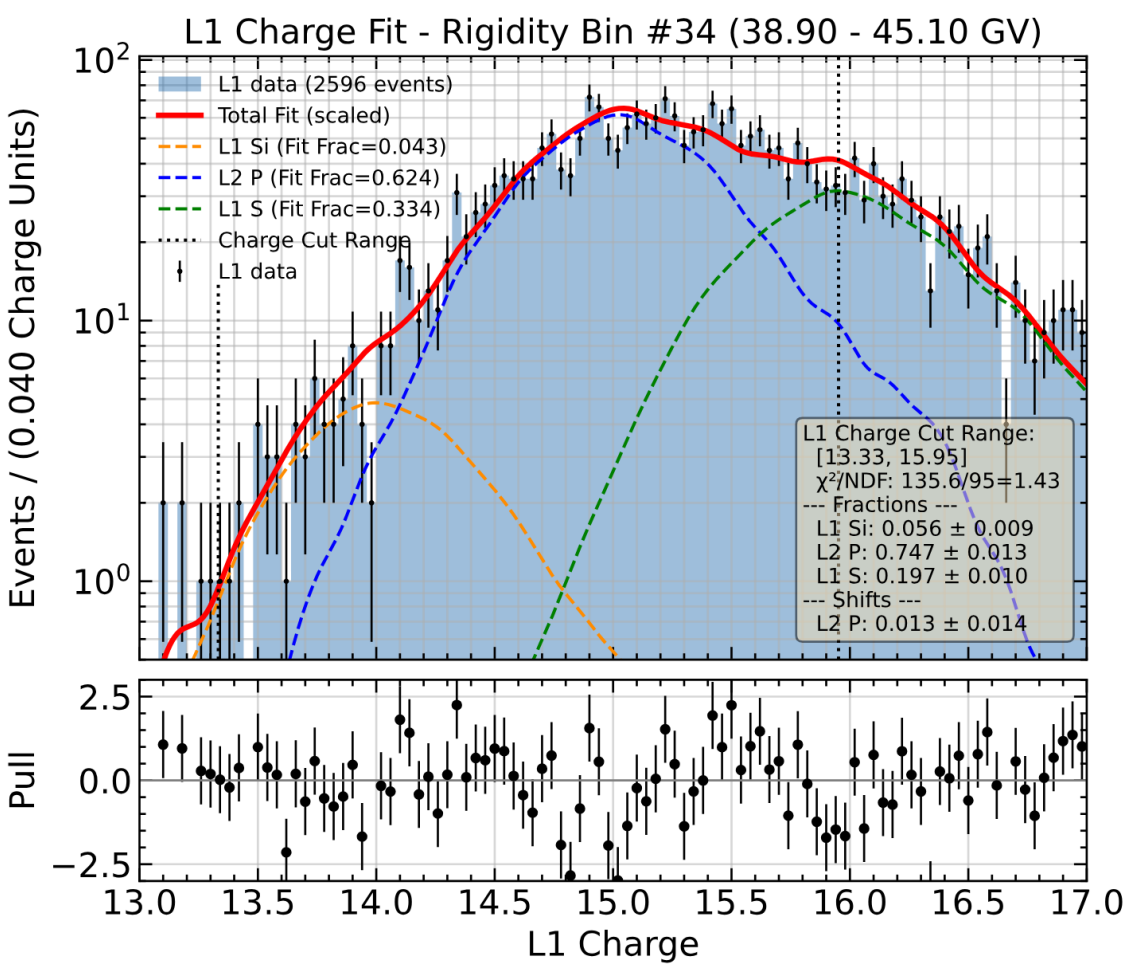
Data:

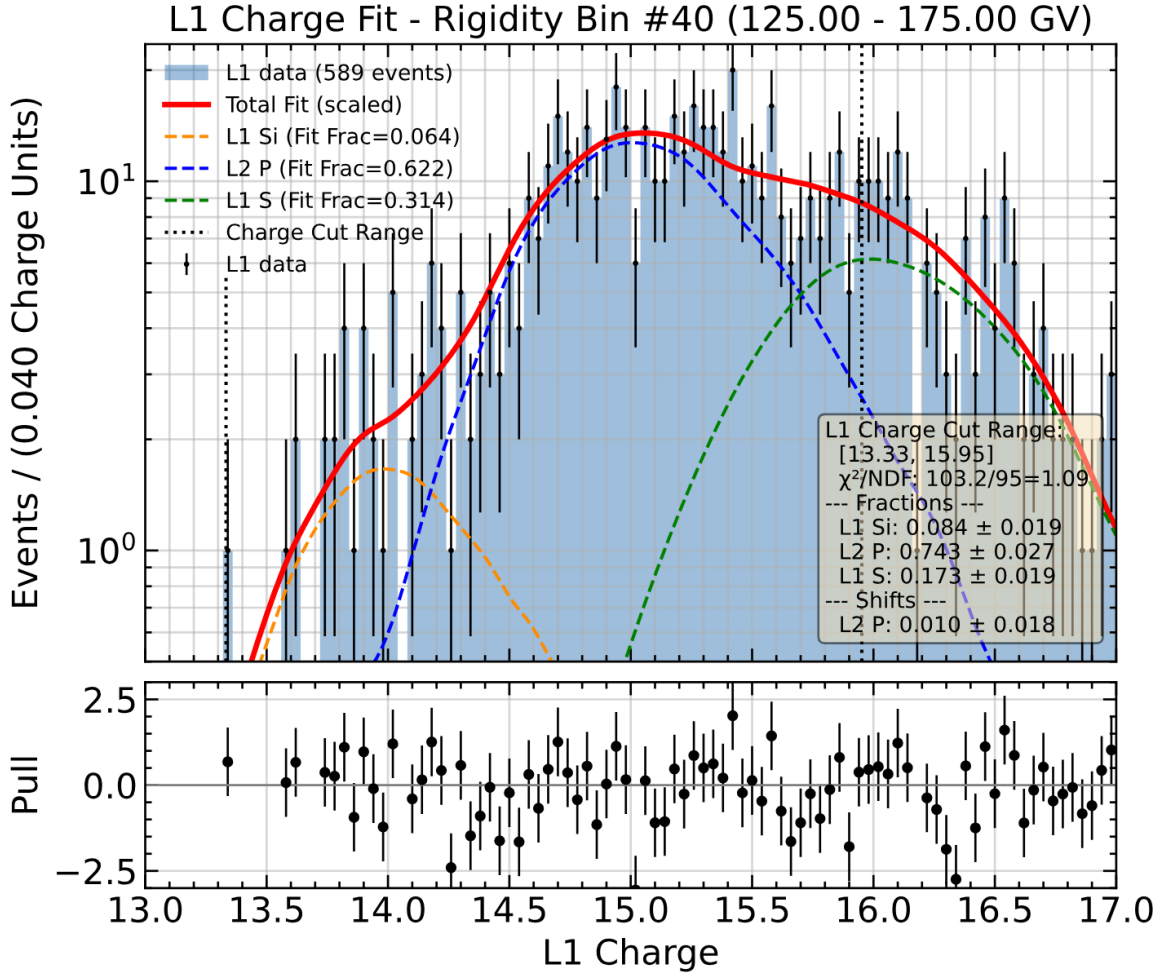


Template building **validated with MC:**



P Below L1 background: Template fit

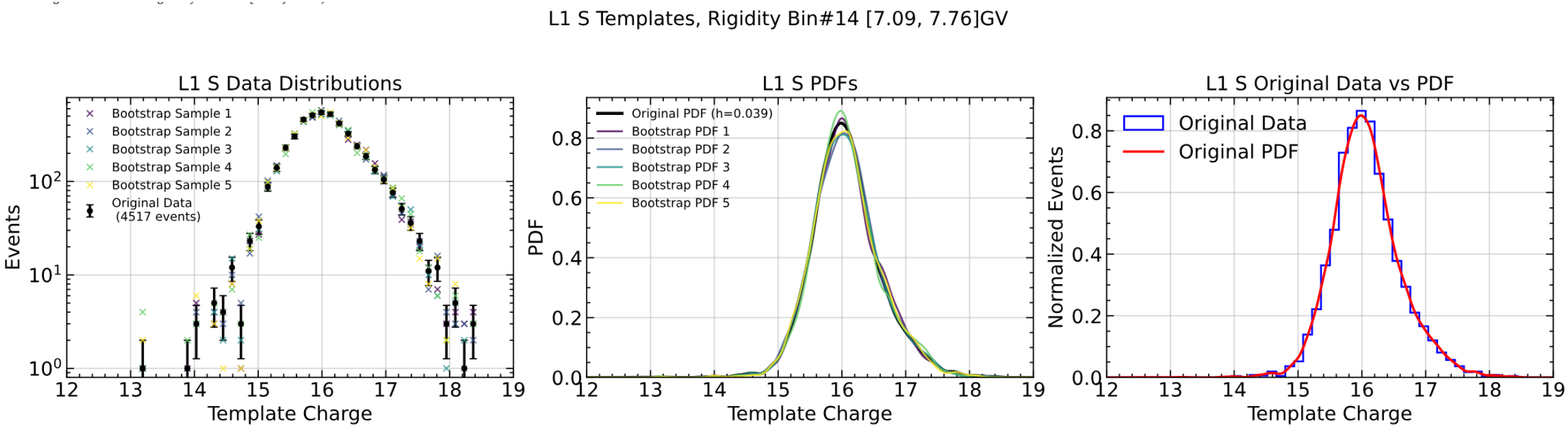




For Rigidity above ~86.5GV, fit quality is limited by the statistics of P sample.

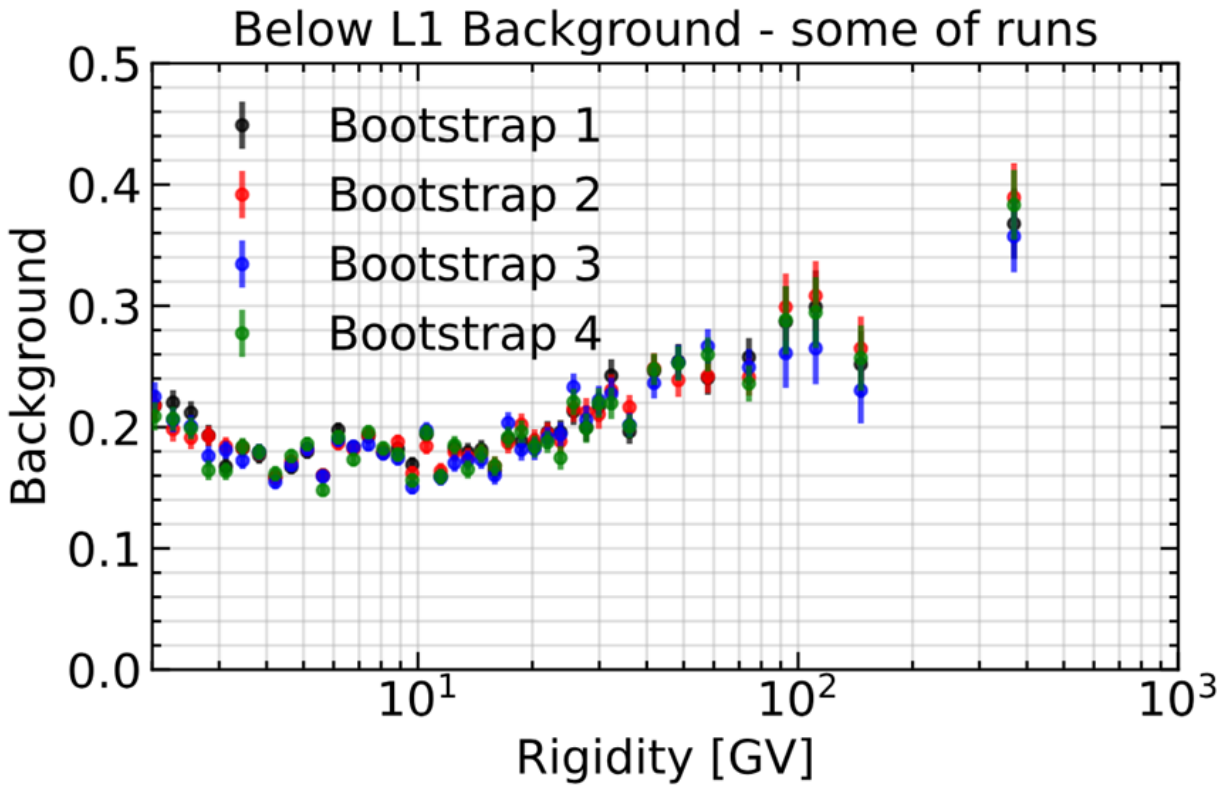
P Below L1 background: error from template statistics

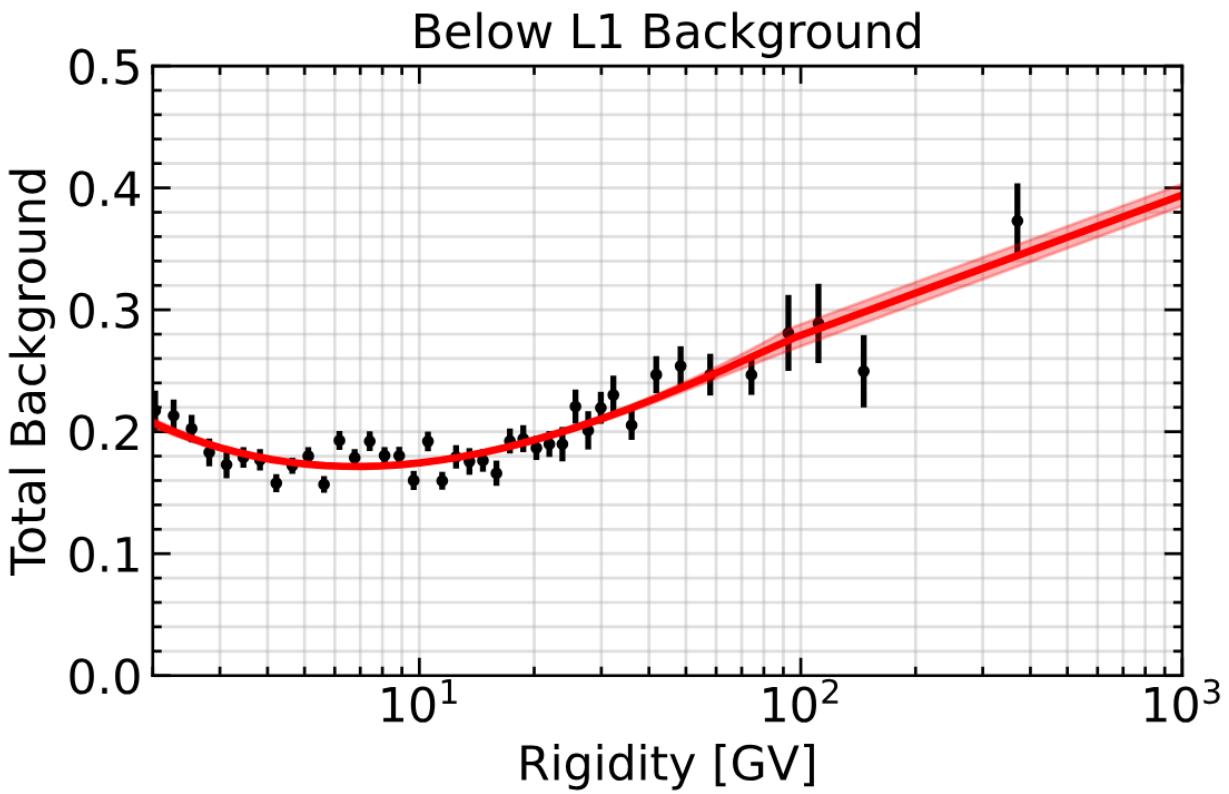
PDF built from template distribution with replacement sampling:



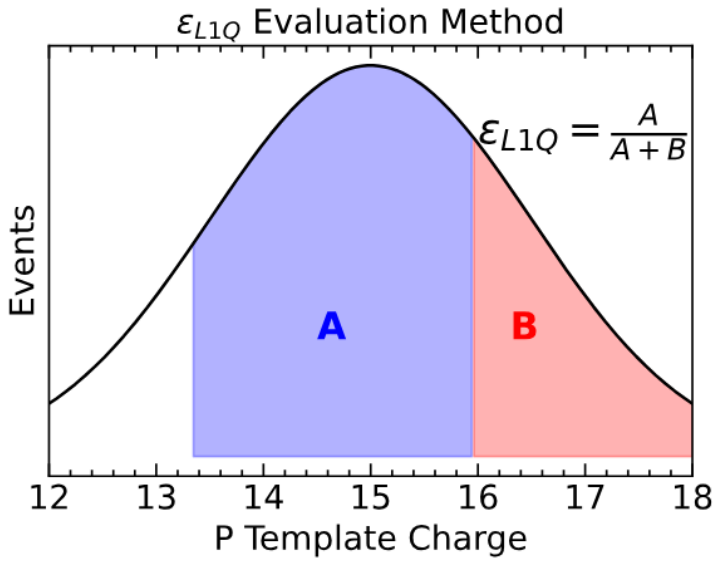
After PDF obtained, bootstrap method is used to perform multiple fits to estimate the error.

P Below L1 background: Template fit results

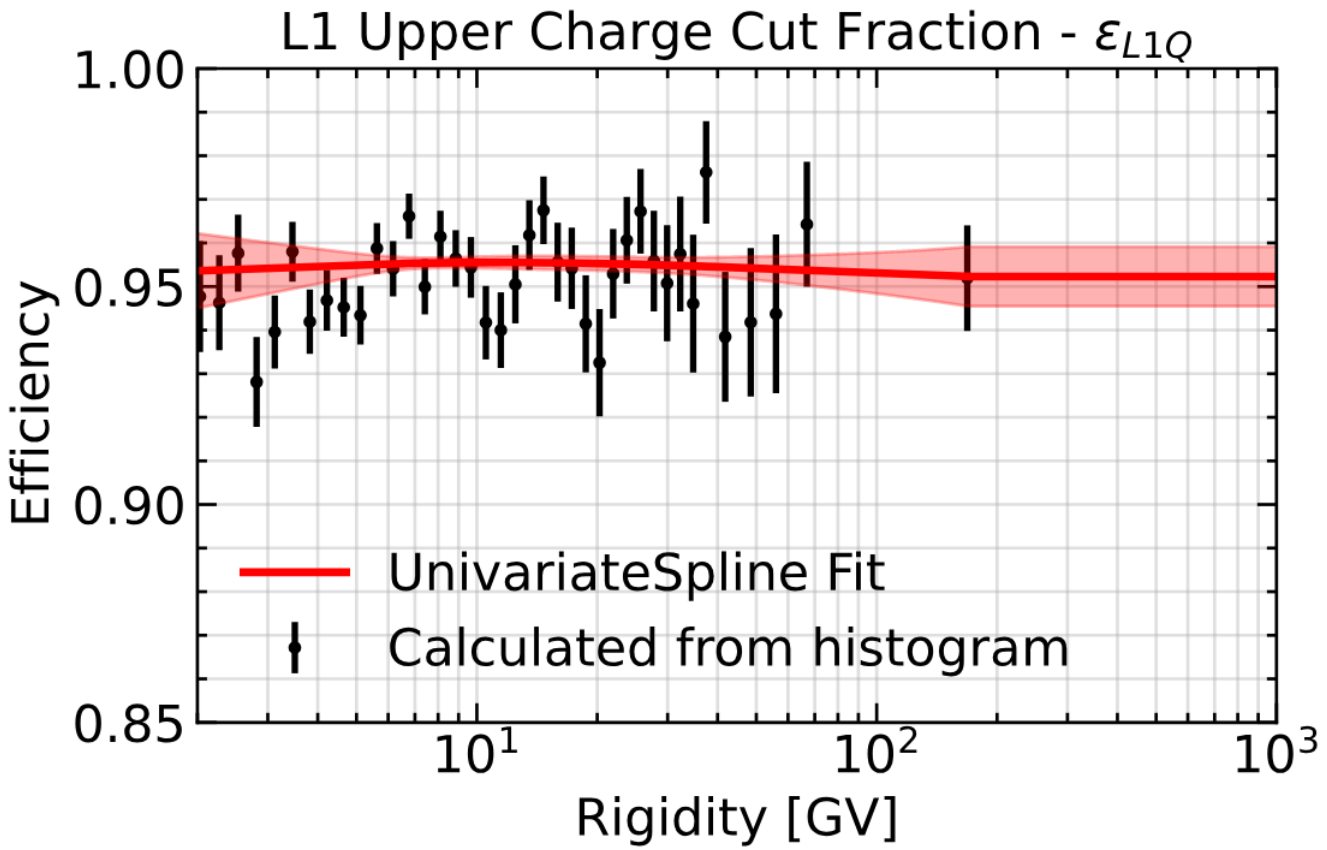




Template fit results: L1 upper charge cut fraction



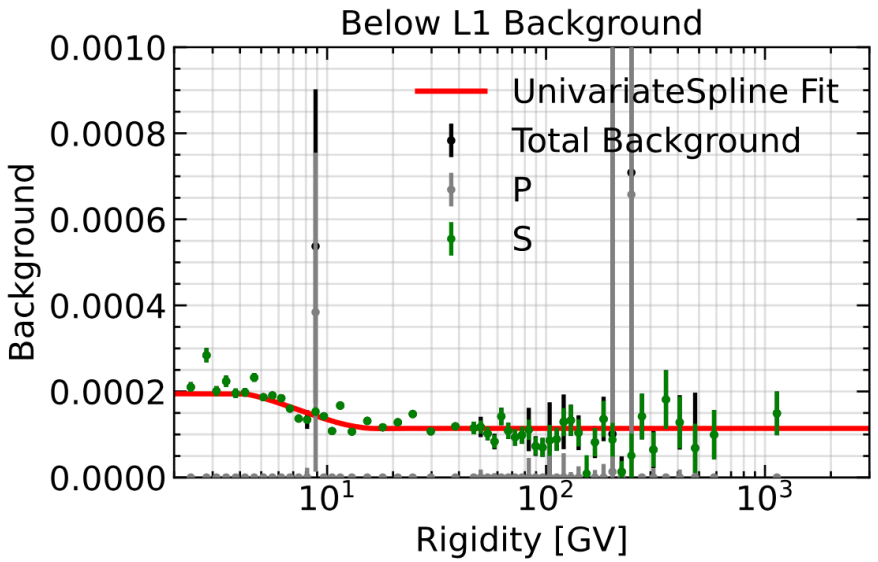
- In event selection, the L1 upper charge cut is applied to data but not to MC.
- To correct for the resulting event loss, ε_{L1Q} is applied to data.



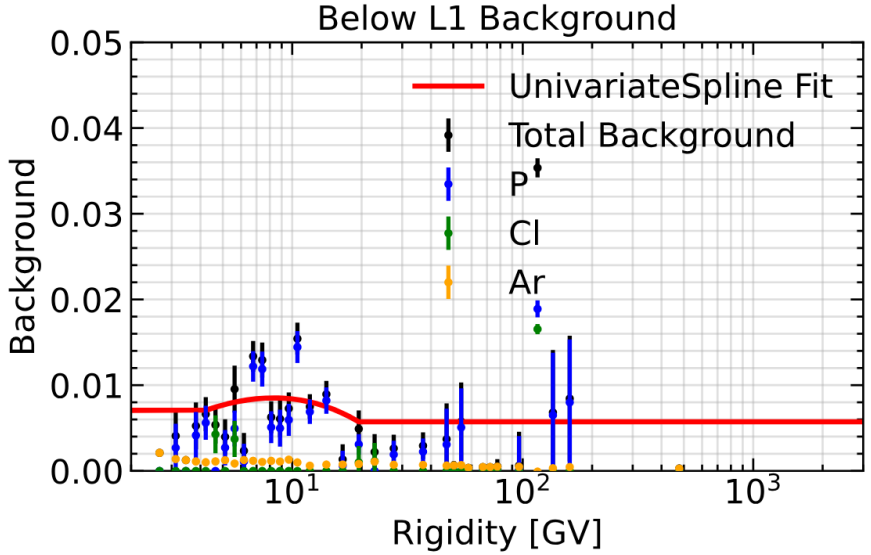
(Points are placed along the abscissa at R calculated for a flux ∝ R^−2.7)

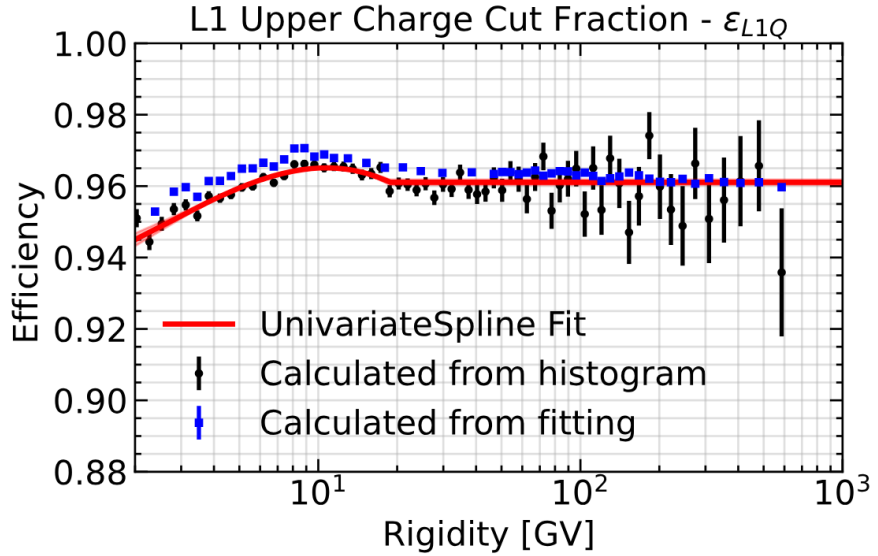
Below L1 background: Si and S

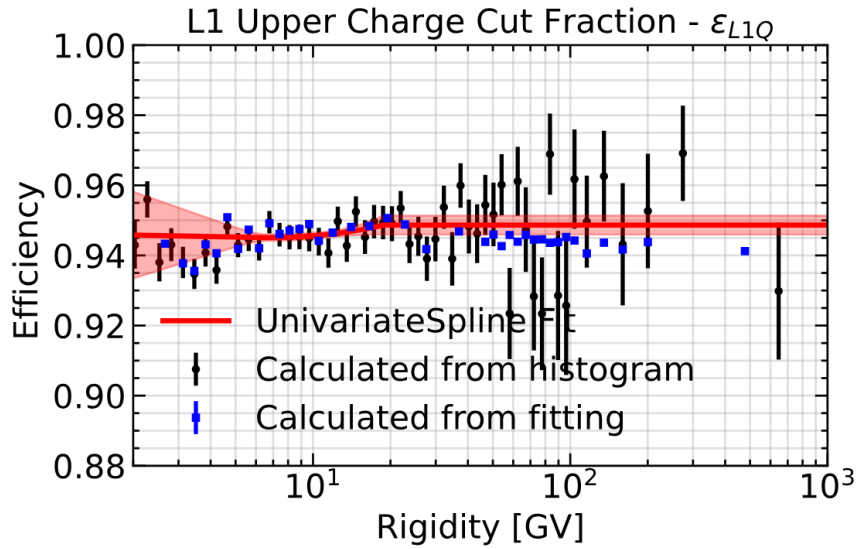
Si



S

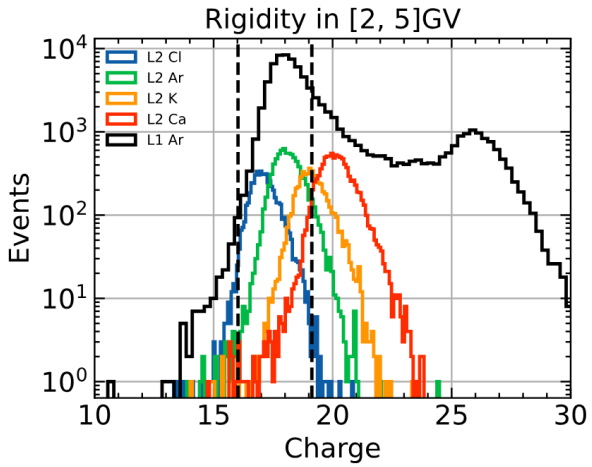


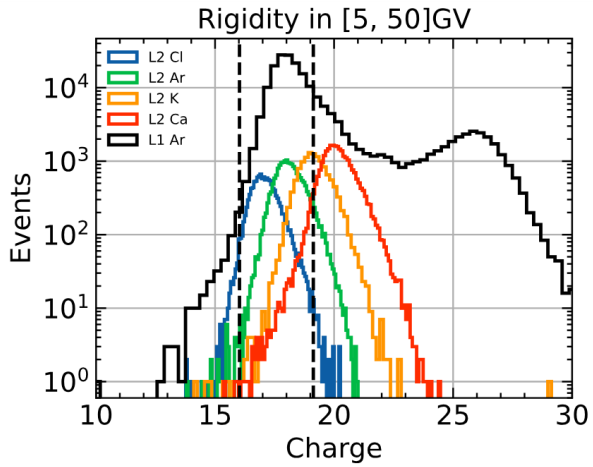


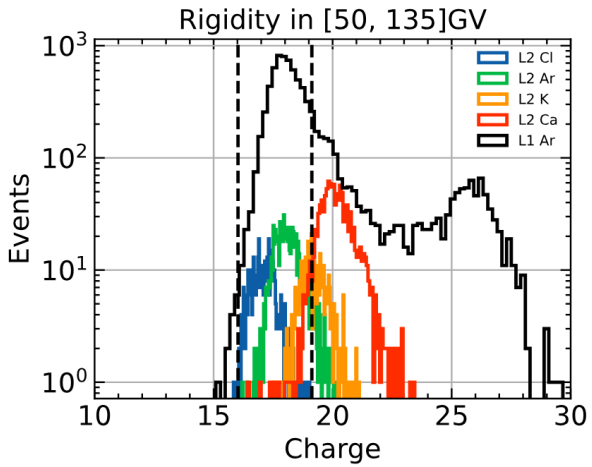


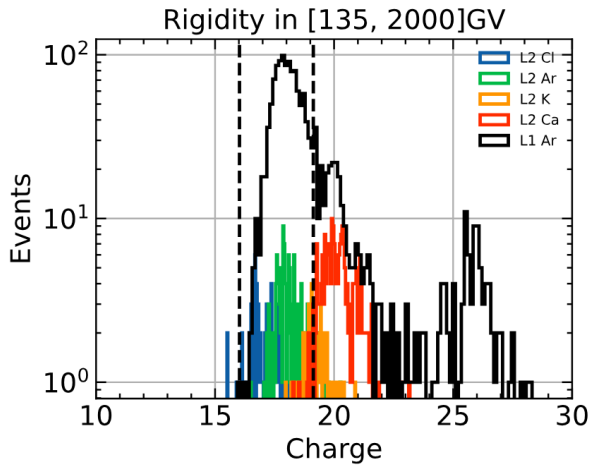
Charge distribution for Ar and Ca

Ar

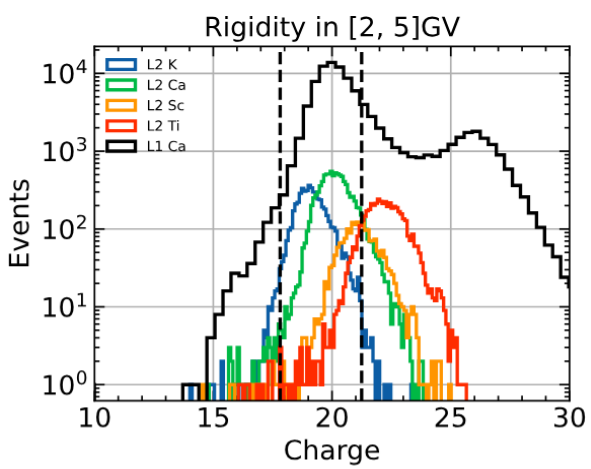


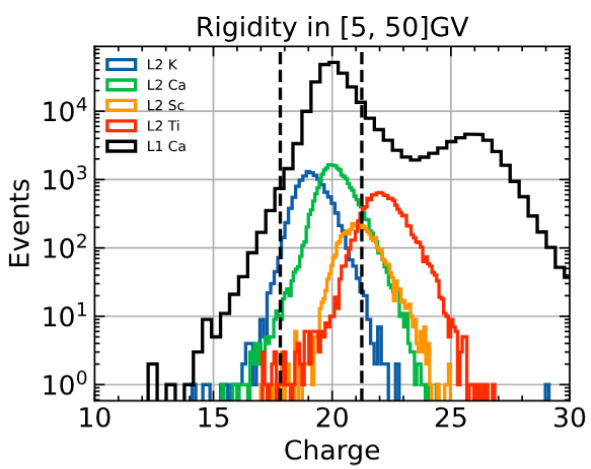


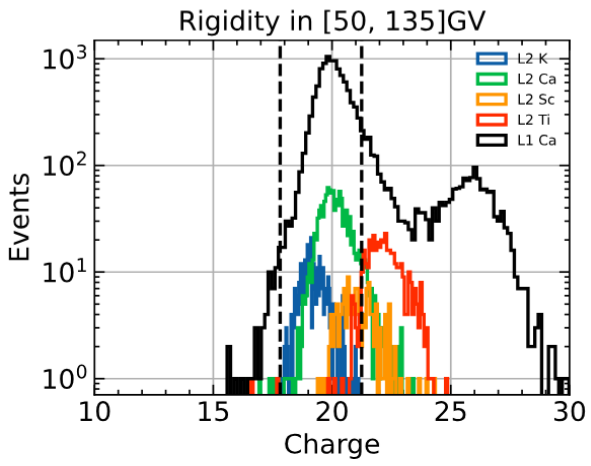


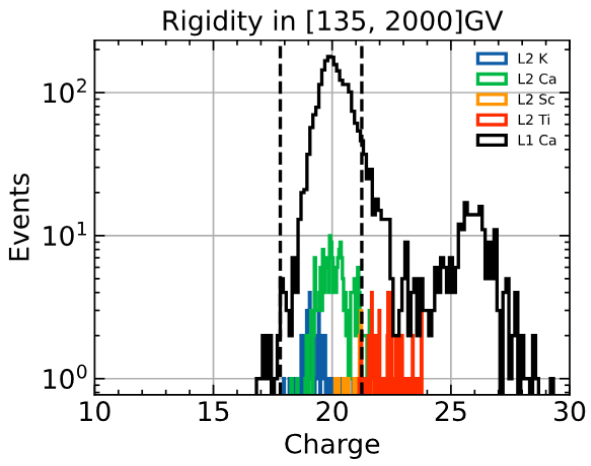


Ca









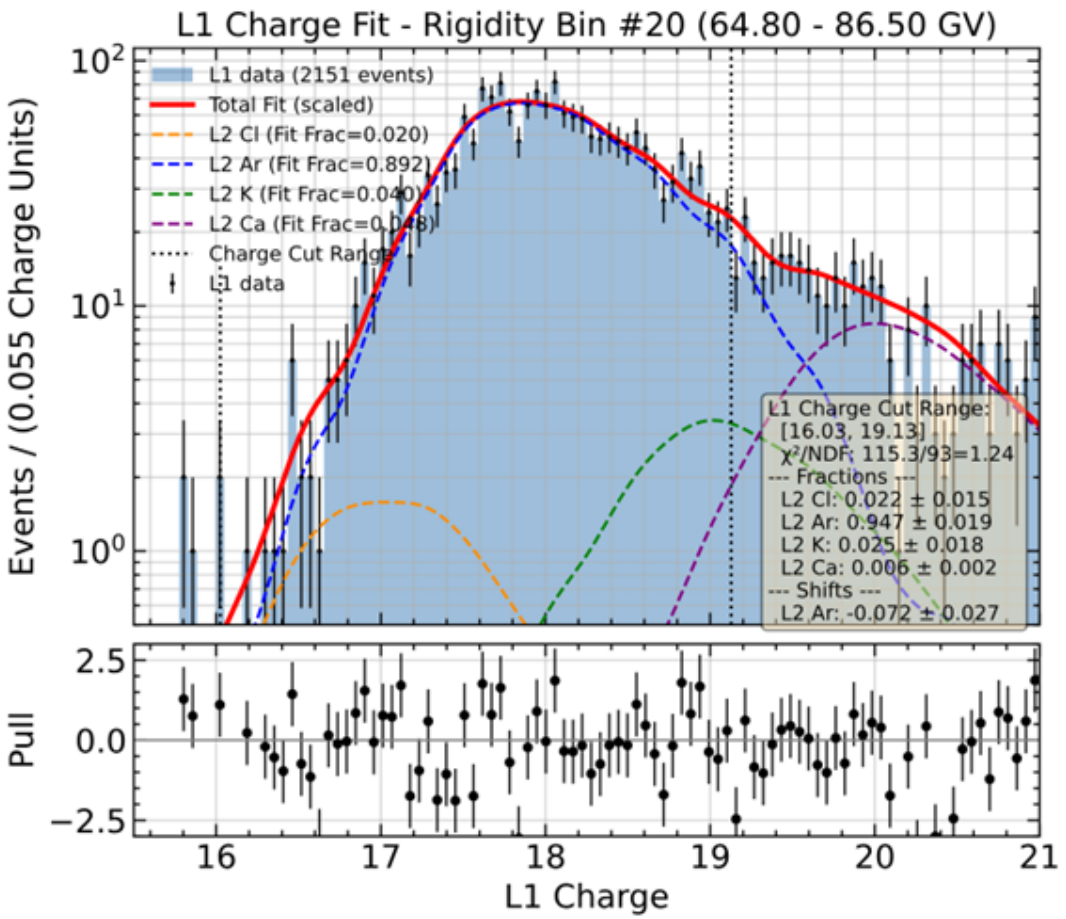
Background contribution:

- Ar: mostly from nuclei Z>18
- Ca: mostly from Z=20-1

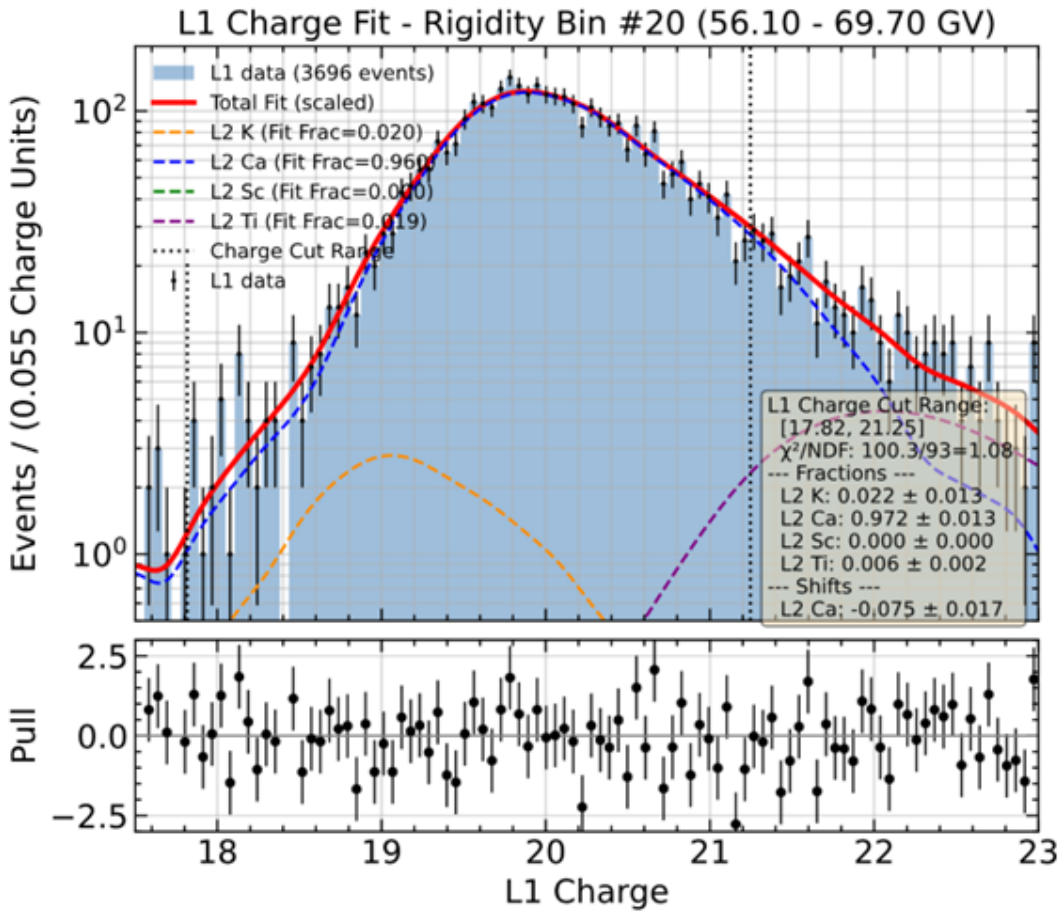
Ar and Ca Below L1 background: Template fit

Ar and Ca: templates built from L2 charge distributions

Ar

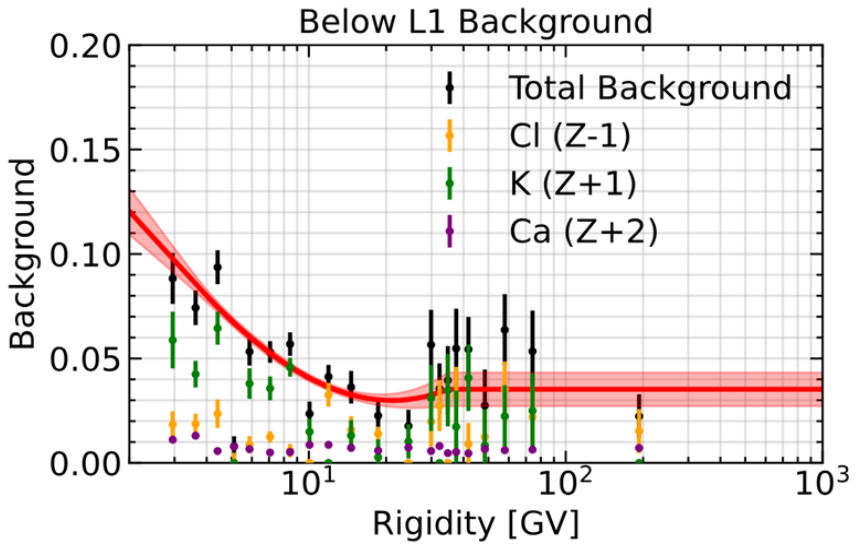


Ca

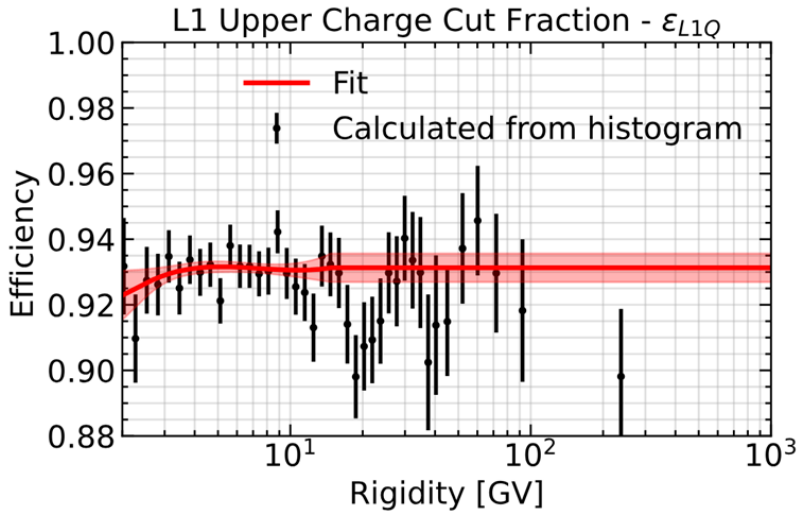


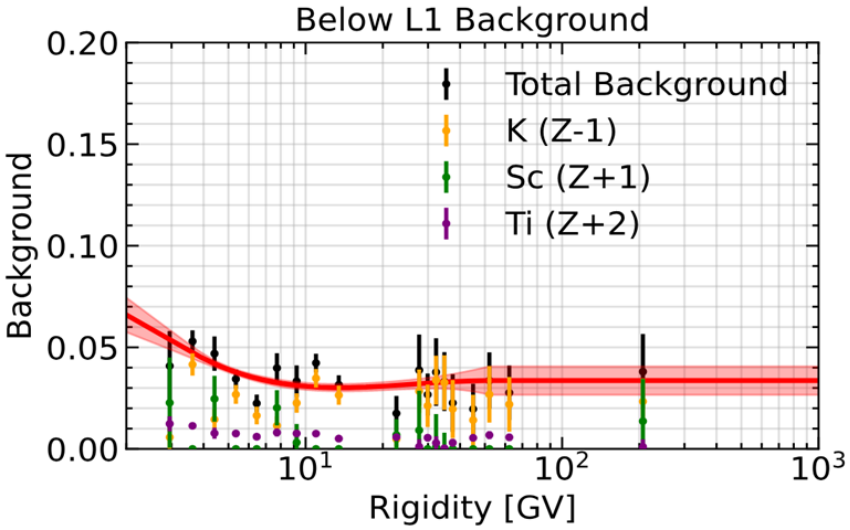
Below L1 background: Ar, Ca

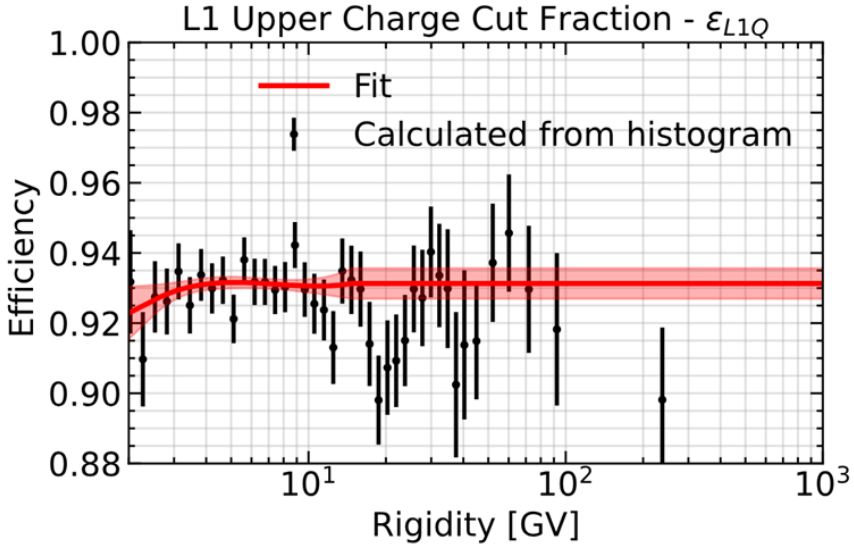
Ar



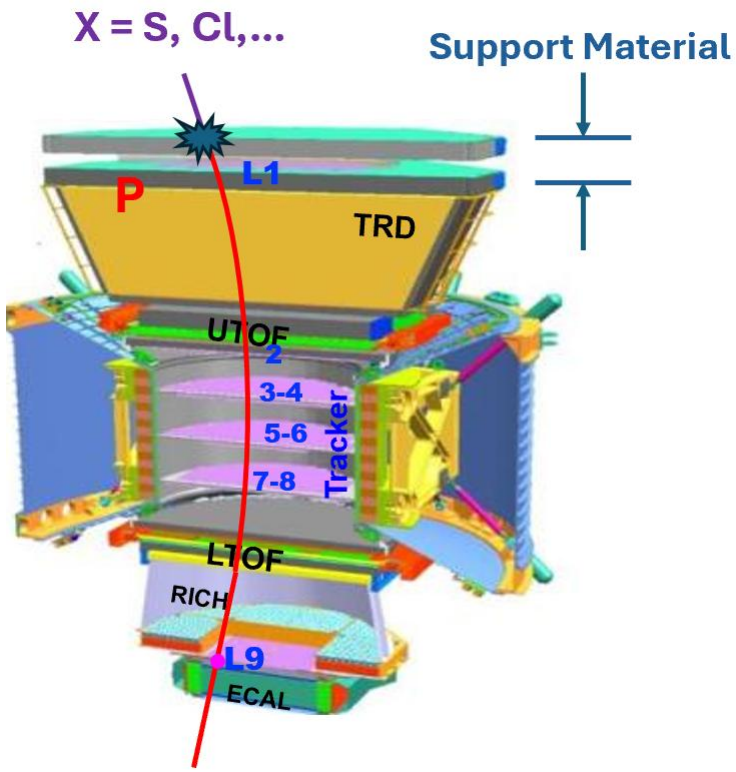
Ca







Top of Instrument Background (background due to heavier nuclei interacting above Tracker L1)



$$\Phi_P = \frac{N'_P - \sum N^{aboveL1}_{X\to P}}{A_P \times T \times \Delta R} = \Phi'_P - \sum \frac{\Phi_X A^{aboveL1}_{X\to P} T\Delta R}{\Phi_P A_P T \Delta R}$$

$$= \Phi'_P \left(1 - \sum \frac{A^{aboveL1}_{X\to P}}{A_{P\to P}} \times \frac{\Phi_X}{\Phi'_P}\right)$$

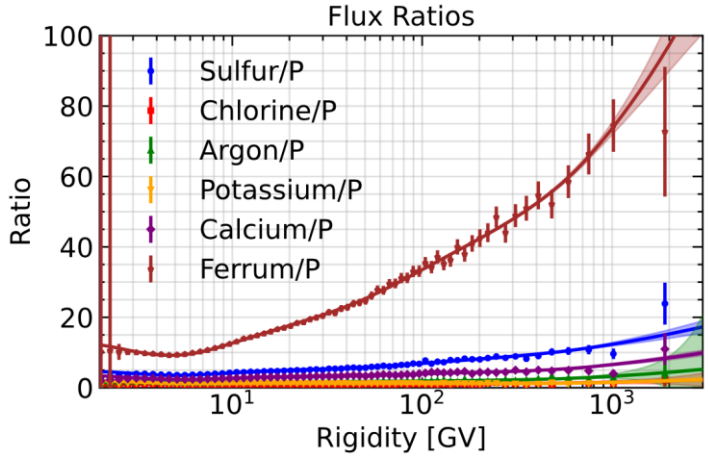
$$= \Phi'_P \left(1 - \sum_{X=S,Cl,..} \delta\right)$$

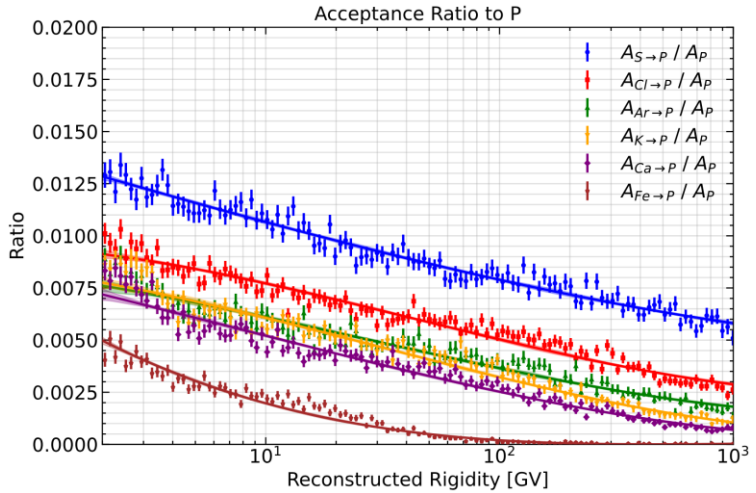
$$\text{where} \quad \sum_{X=S,Cl,..} \delta = \sum_{X=S,Cl,..} \frac{A^{aboveL1}_{X\to P}}{A_P} \times \frac{\Phi_X}{\Phi'_P}$$

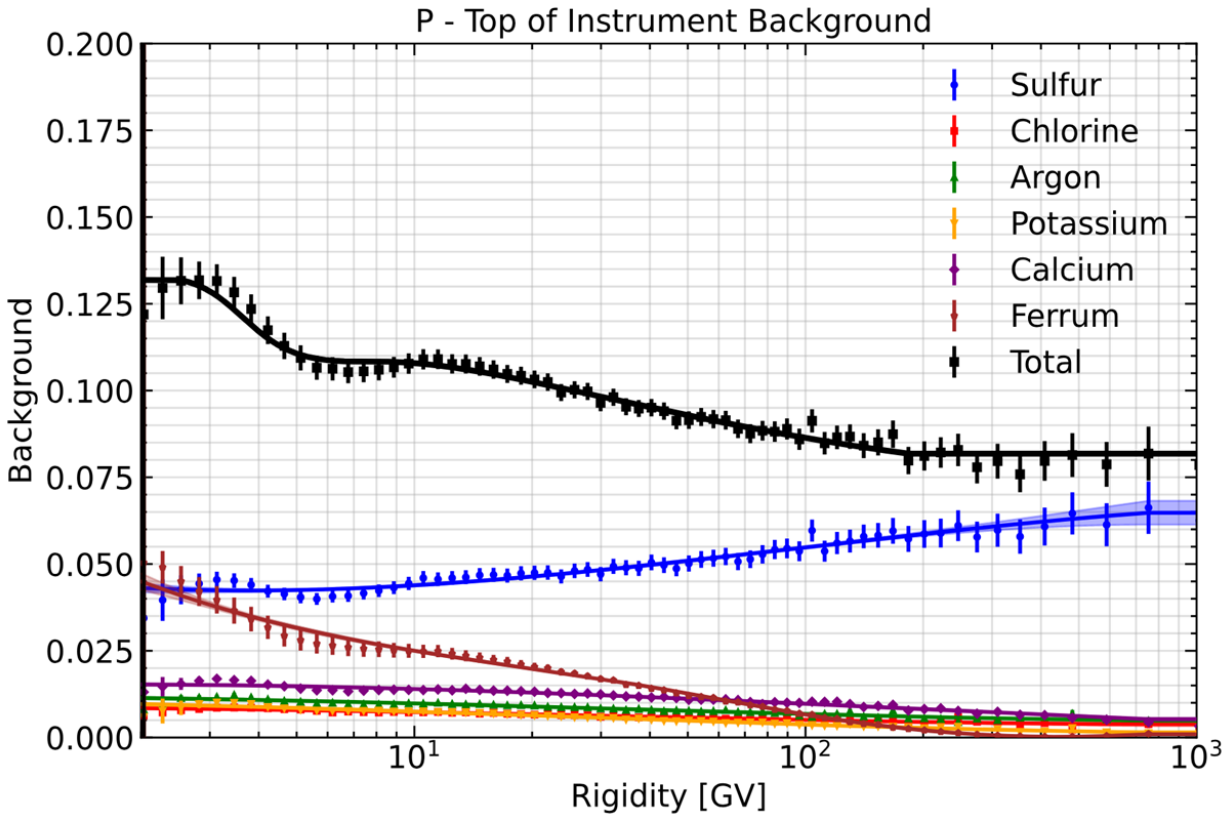
Top of Instrument Background: P

Selection for numerator of $A_{X\to P}$ (X: S,Cl,…,Fe)

1. P event selection
2. MC truth: TrackMCHits on L1 Charge != Primary Z
3. MC truth: Primary particle Position is not in L1 fiducial volume

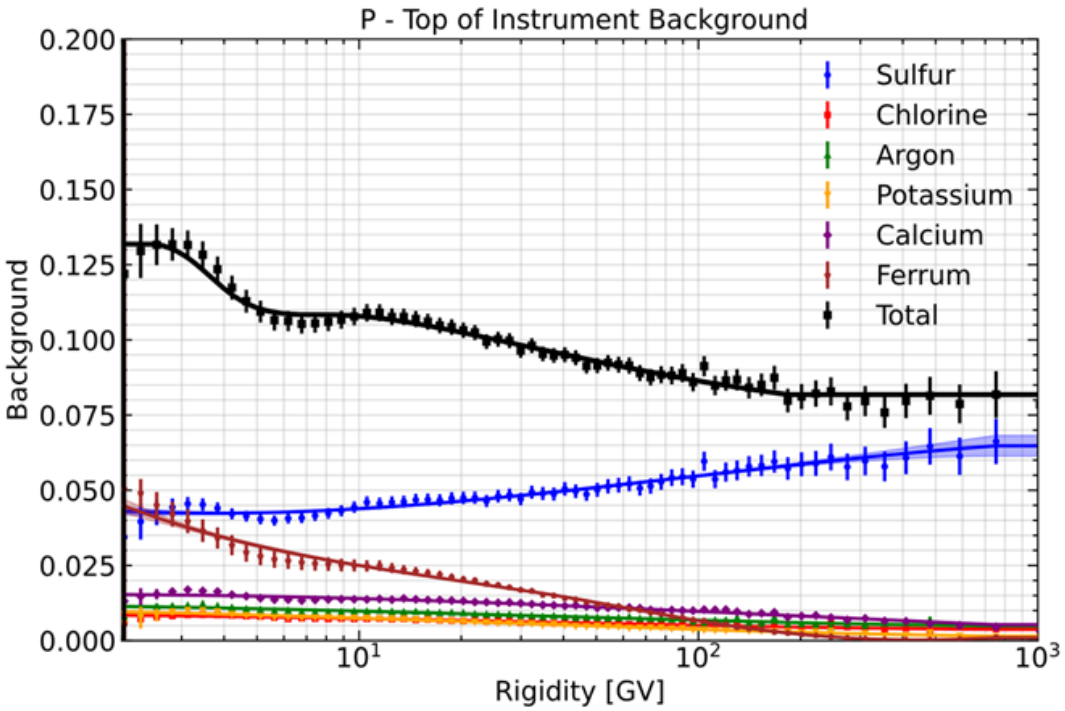




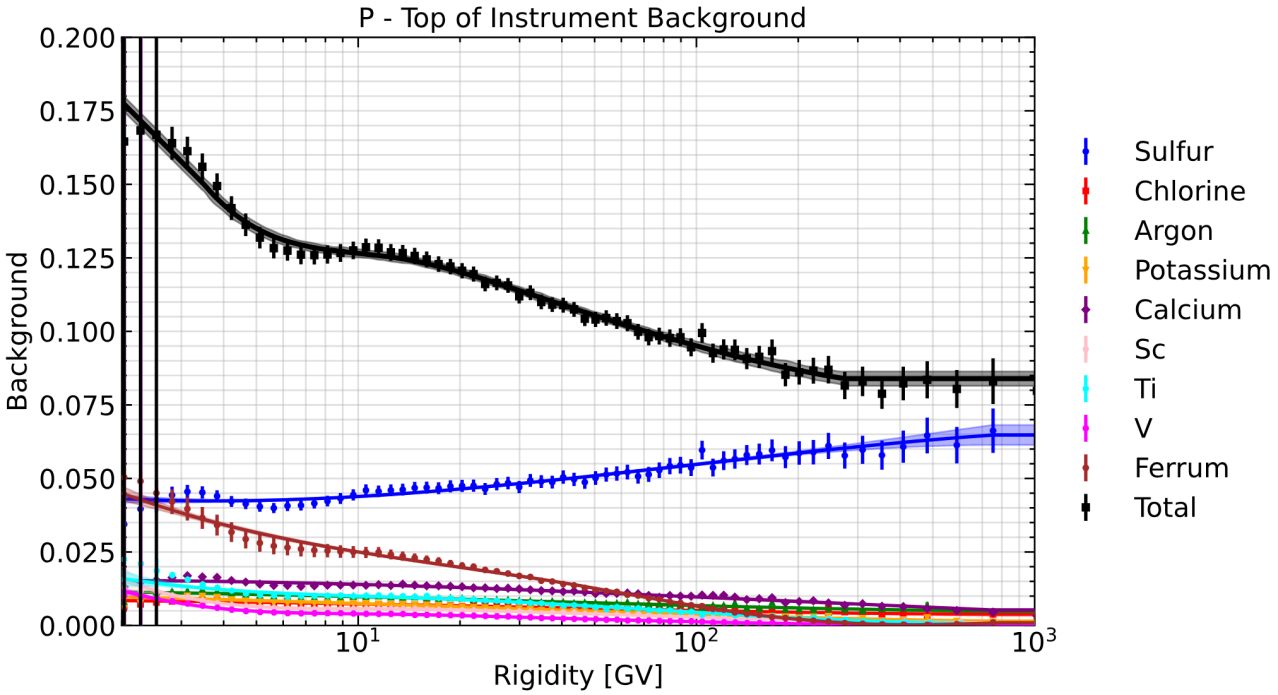


TOI: P

Without sub-irons

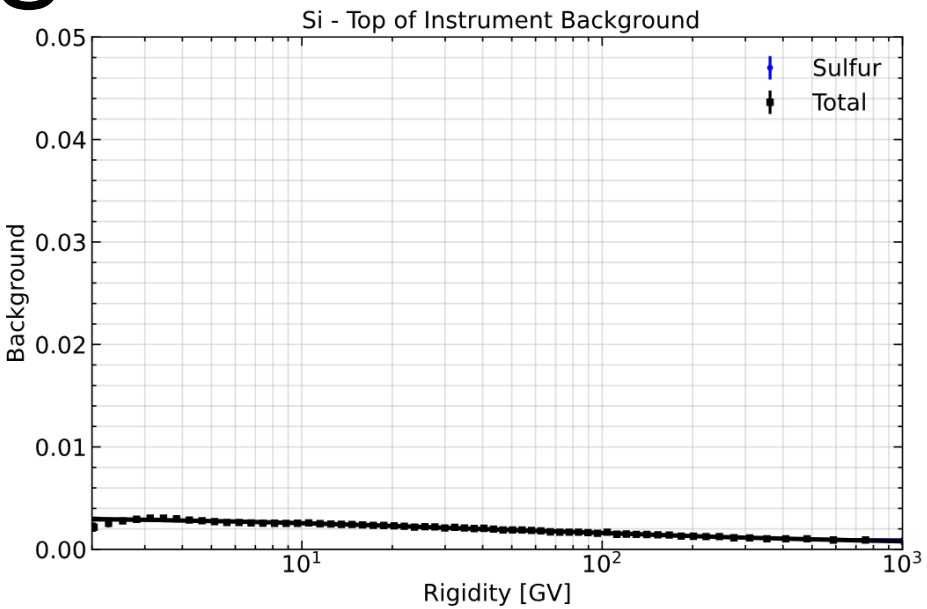


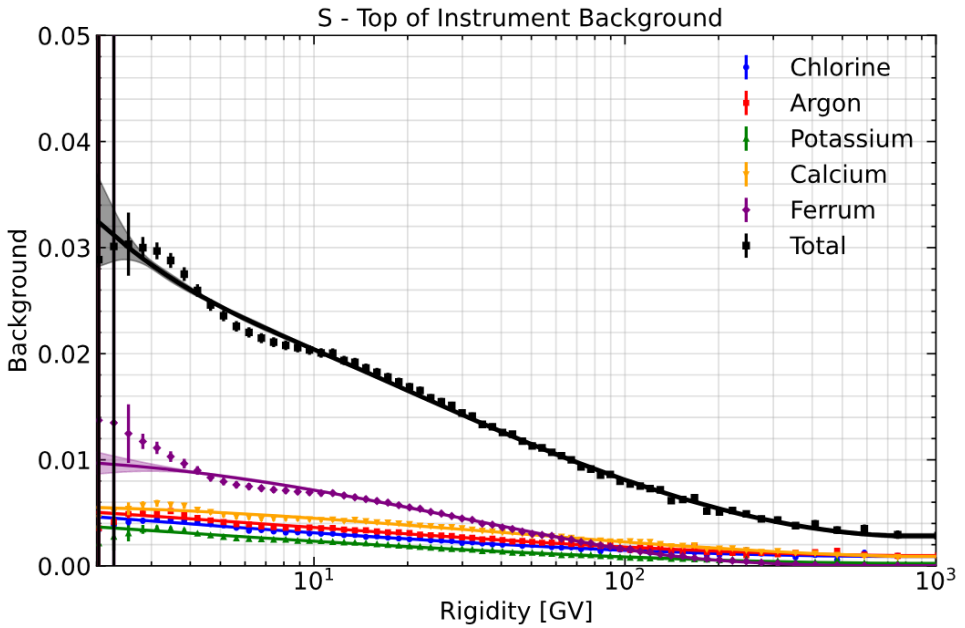
With sub-irons
(Sc, Ti, V)



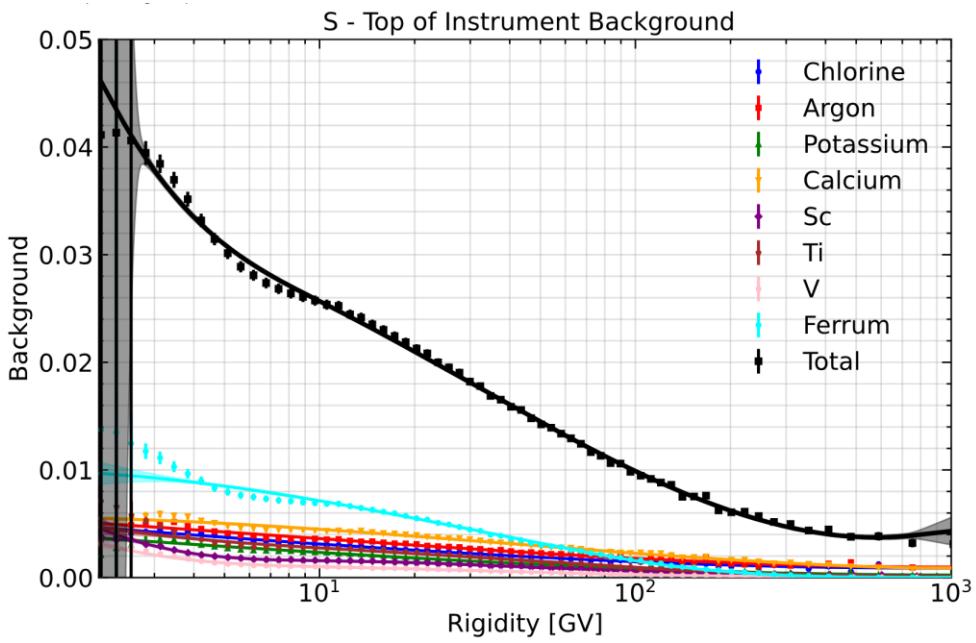
TOI: Si, S

Without sub-irons

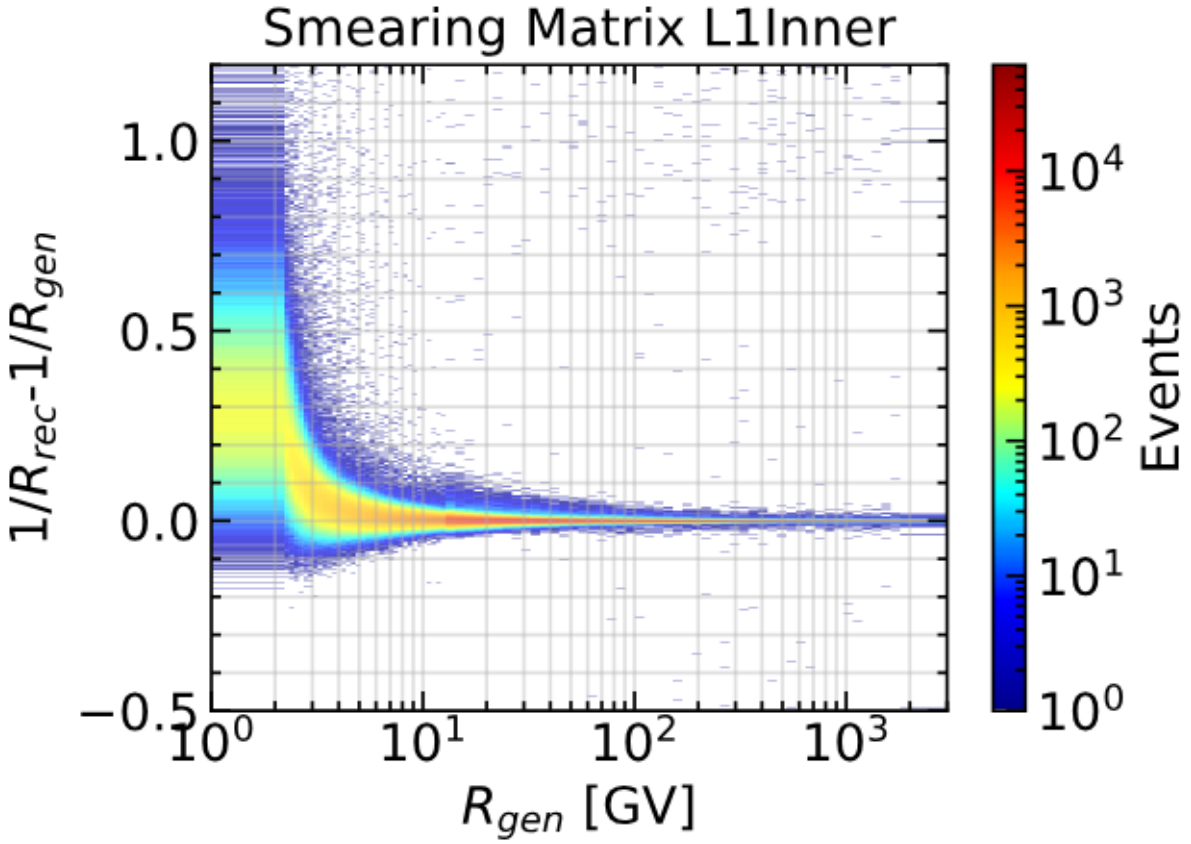




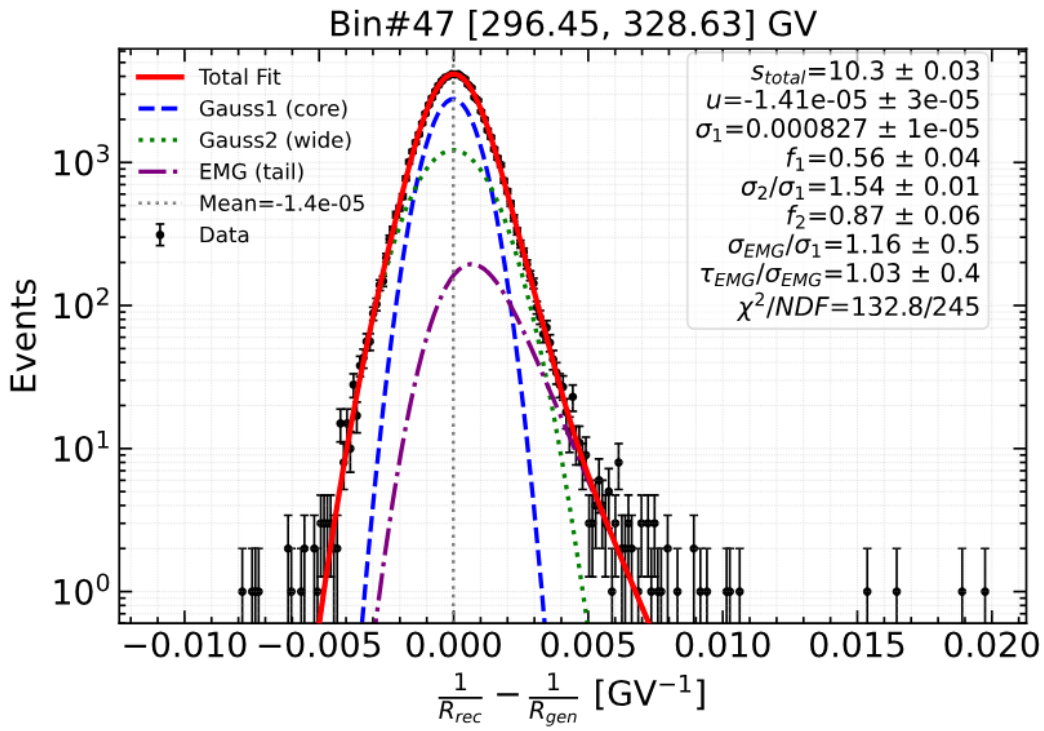
S:
with sub-irons
(Sc, Ti, V)



P rigidity resolution function: $M(R_{gen}, \frac{1}{R_{rec}} - \frac{1}{R_{gen}})$

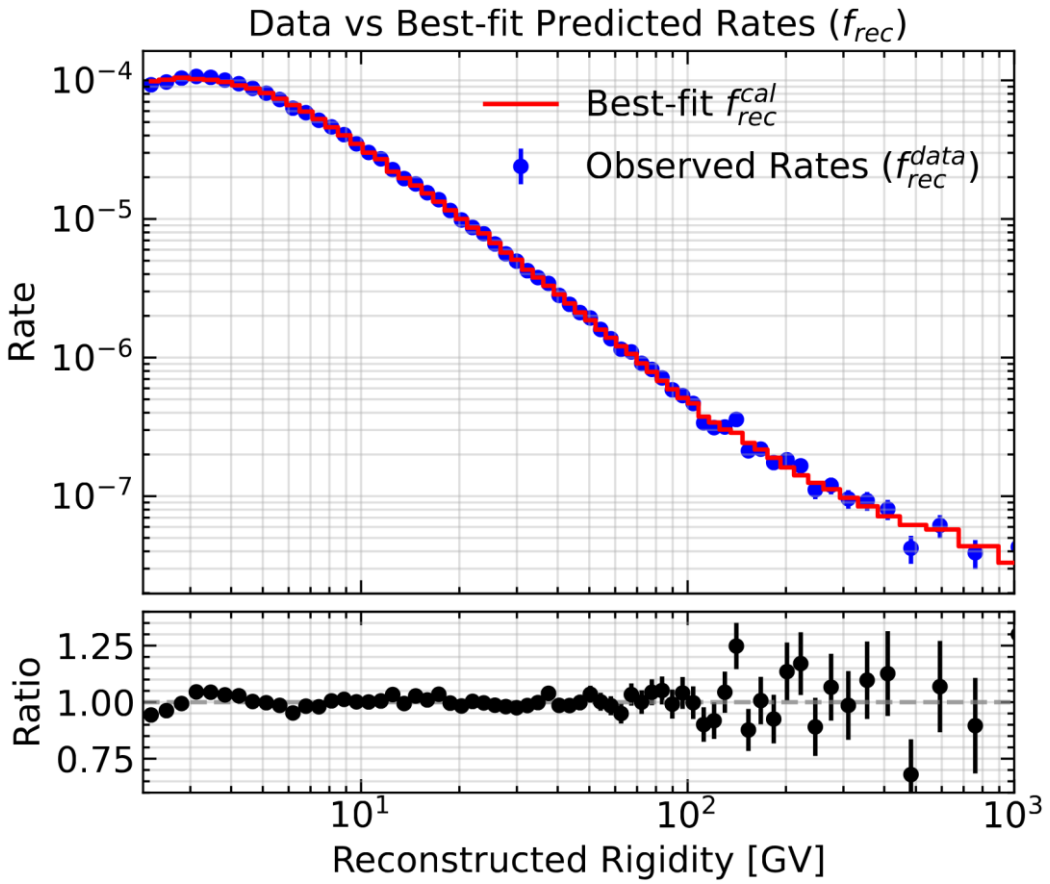


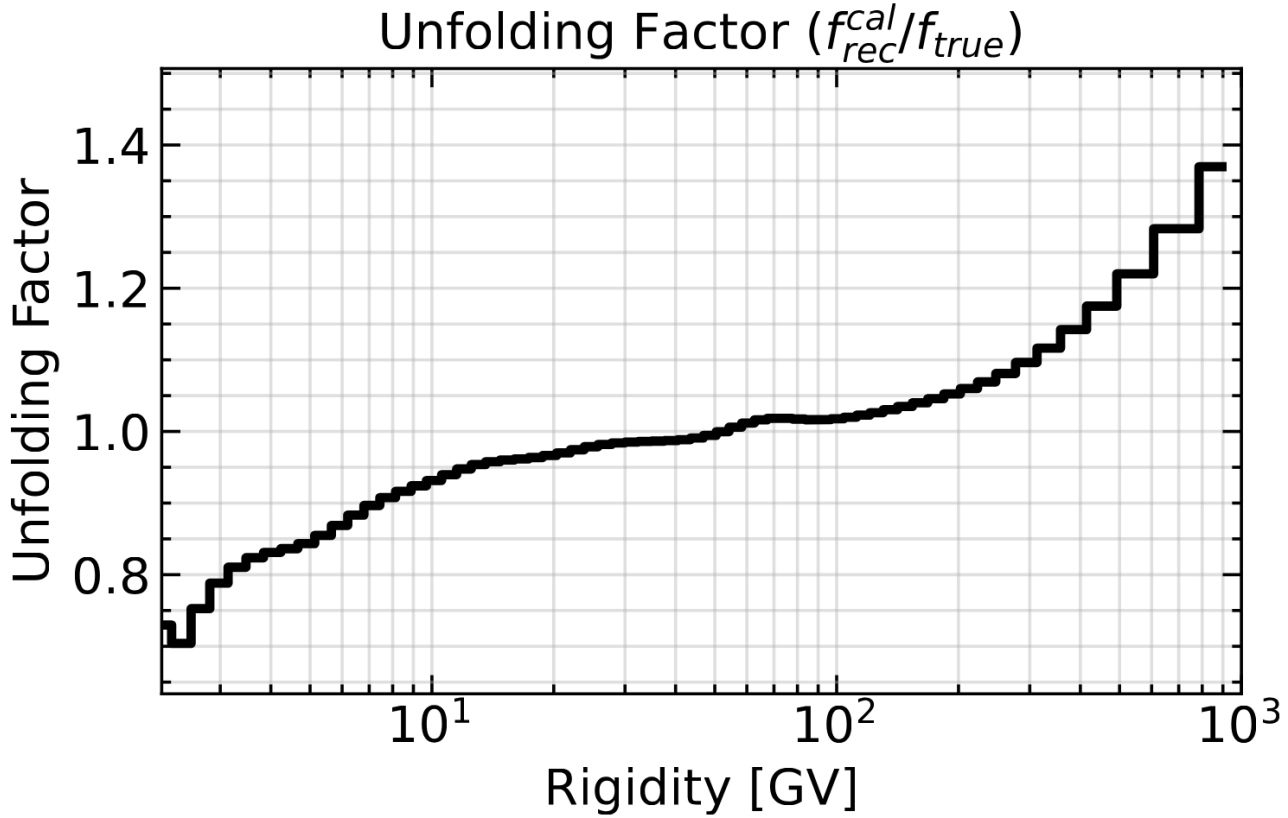
In each R_{gen} bin, f($\frac{1}{R_{rec}} - \frac{1}{R_{gen}}$) is parametrized by 2 Gaussian and 1 Exponentially modified Gaussian



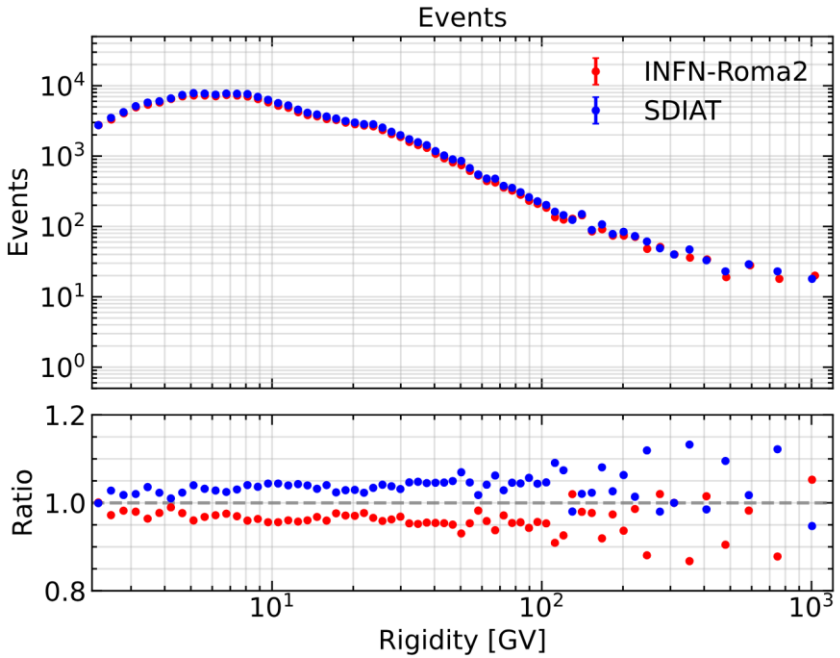
Forward Unfolding (P)

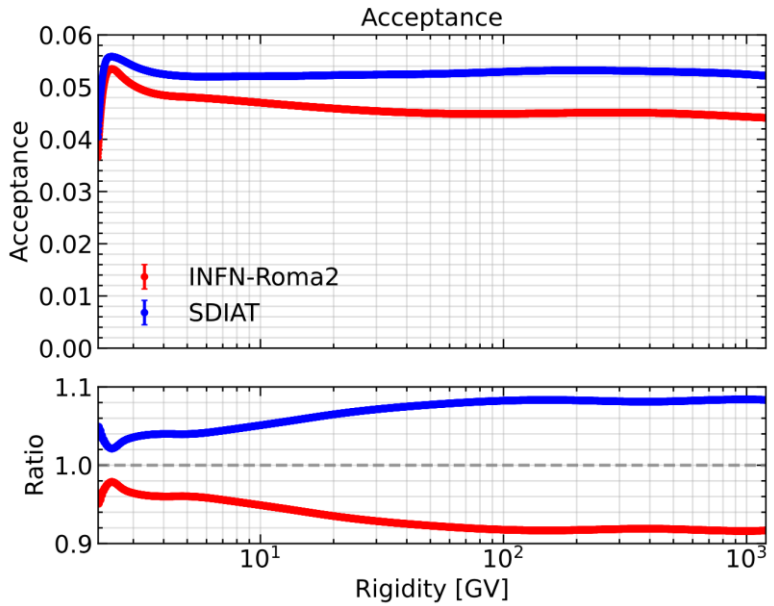
1. On one hand, the event rate in reconstructed rigidity bins is obtained from data: $\boldsymbol{f_{rec}^{\mathrm{data}}}$;
2. On the other hand, with a proper flux model $\boldsymbol{\Phi}(R)$ assumed, the $\boldsymbol{f_{rec}^{cal}}$ is obtained by the integration of $\boldsymbol{\Phi}(R)$ and rigidity resolution smearing matrices $\boldsymbol{M}(R_{rec}, R)$;
3. By minimizing the difference between $\boldsymbol{f_{rec}^{\mathrm{data}}}$ and $\boldsymbol{f_{rec}^{cal}}$, the unfolding factor and unfolded flux $\boldsymbol{\Phi}(R)$ are obtained.

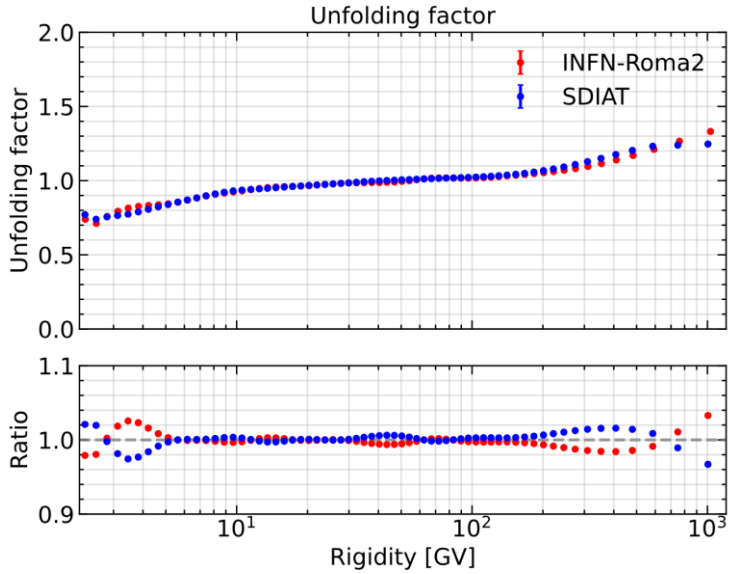




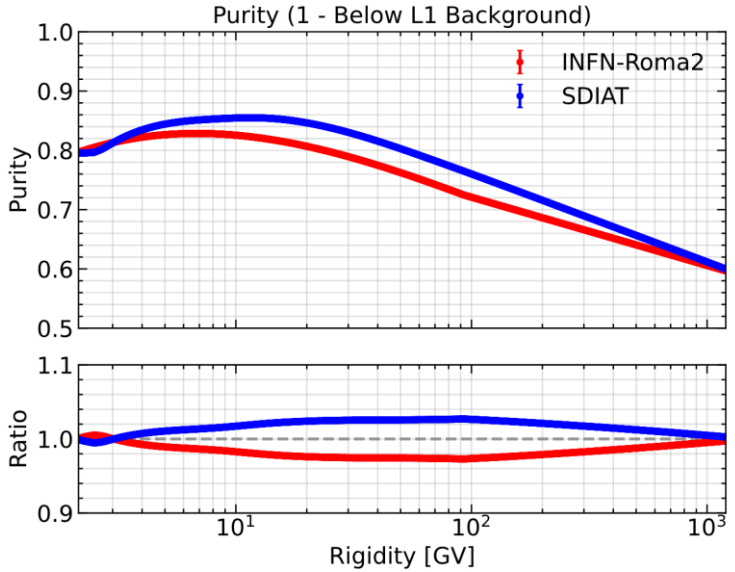
P

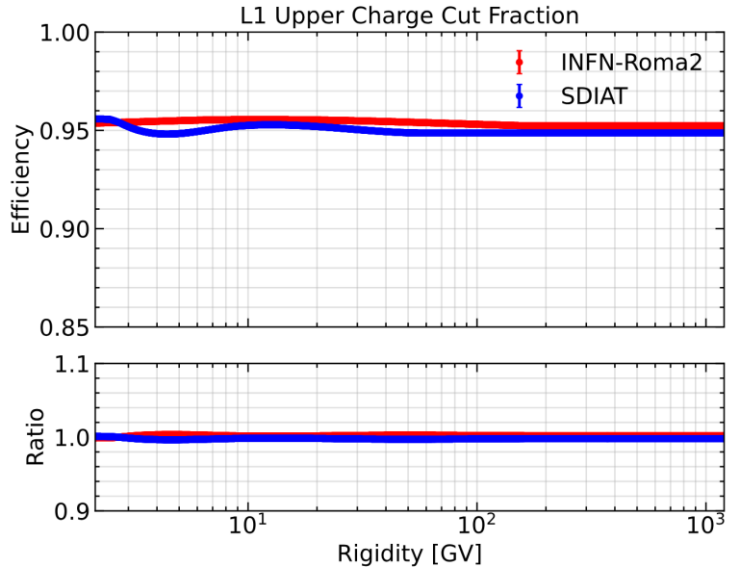


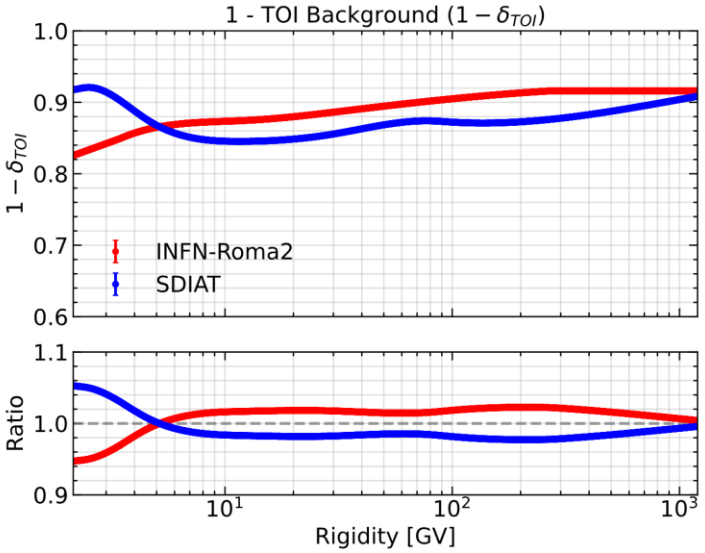




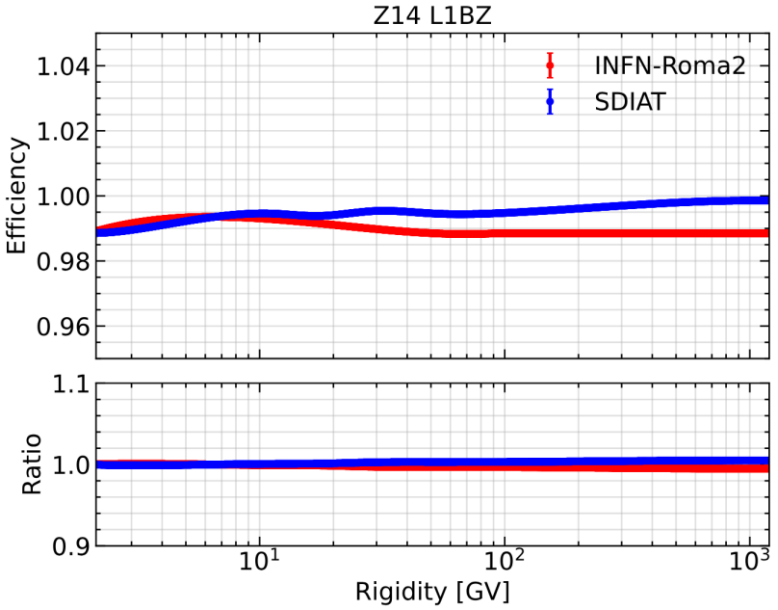
To be added: Time or event rate

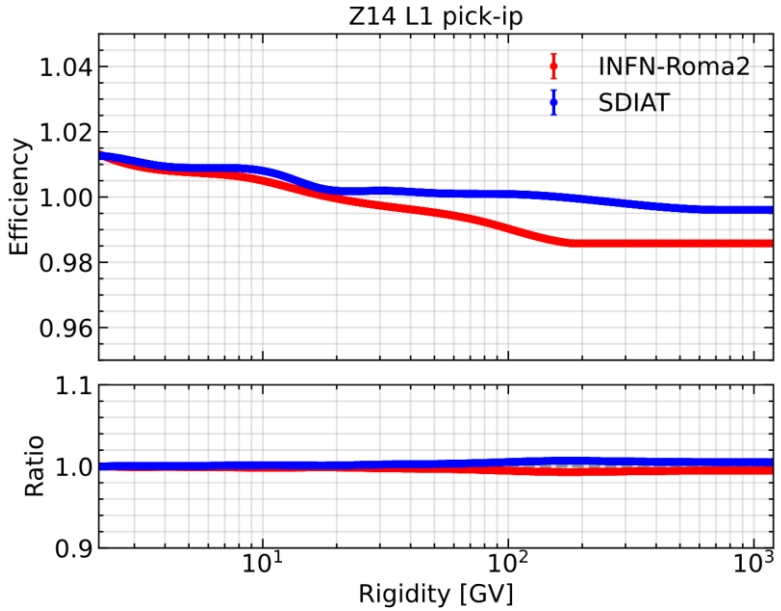


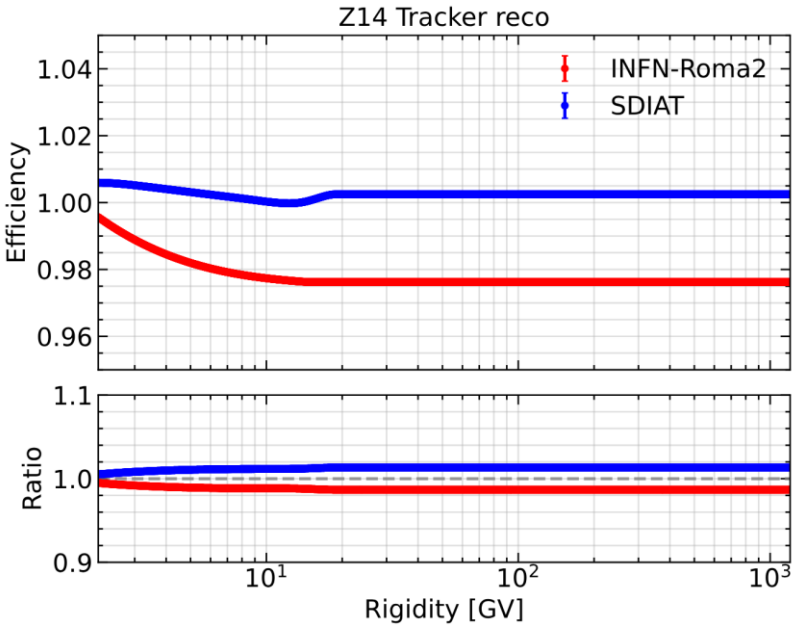


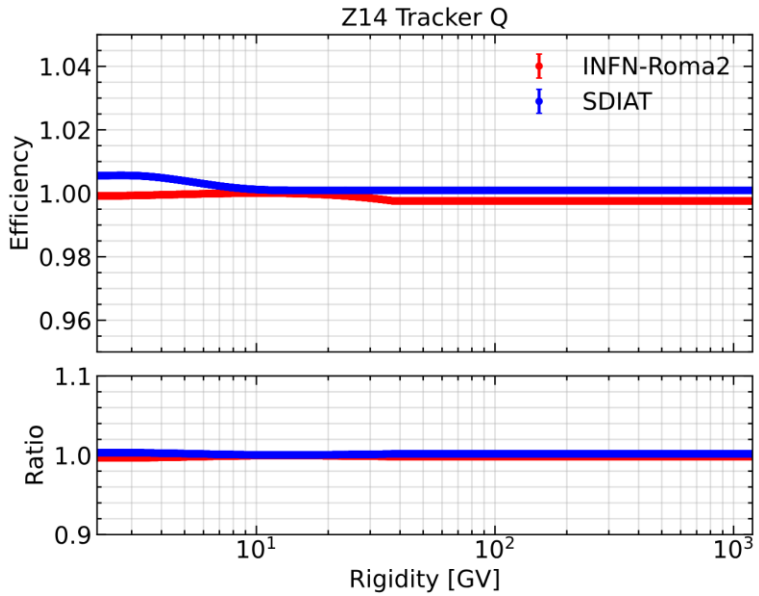


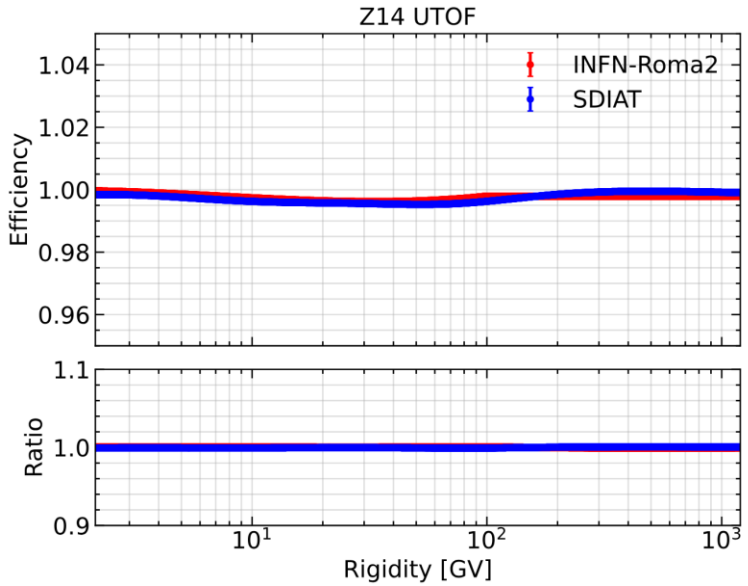
Si Data/MC efficiency ratio











Missing: trigger