Pass8 - 7 Year Flux
NAIA 1.02

Summary:
- Integral Flux (7 year)
- Daily Flux (7 year), updated L1 correction
- SEP Daily Flux, background subtraction (new)

AMS Italy - April 2024
Francesco Faldi

Proton Flux VS Rigidity

$$\Phi_i(t) = \frac{N_{selected,i}(t)}{\Delta R_i \cdot T_{exp,i}(t) \cdot A_{eff,i}(t)} \qquad i = i^{th} rigidity\ interval$$

$N_{selected}$ → **Selected counts corresponding to proton events**

T_{exp} → **Exposure Time in seconds**

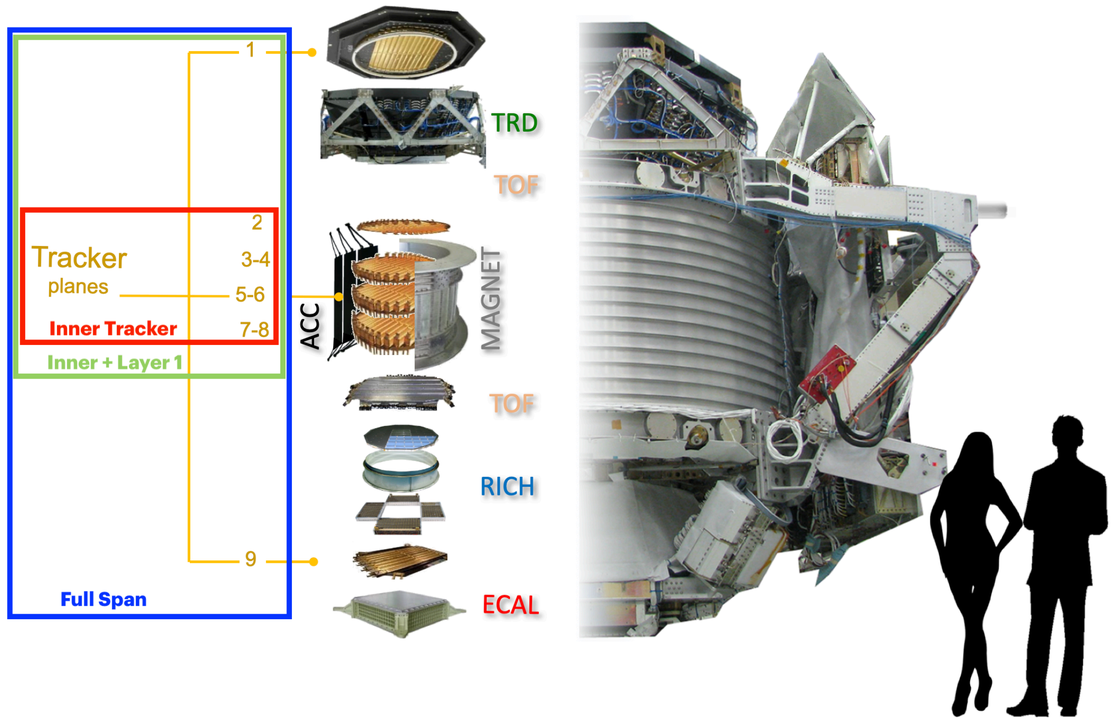
$A_{eff} = A_{MC} \cdot DA/MC\ Corr$ → **Effective Acceptance: Montecarlo Acceptance multiplied by corrections**

$DA/MC\ Corr$ → **Efficiencies on Data / Efficiencies on Montecarlo**

Event Selection Cuts - Inner+L1 Analysis

Charge Reconstruction Type: Yi Jia
Fit Type: GBL

Orange: Only Pass8
Black: Pass8 & MC



RTI Cuts

- Livetime Fraction > 0.05
- Zenith Angle < 25
- Not in SAA
- Mean Difference PG-CIEMAT Trk Calibration

Physical Cuts

- Any Physical trigger
- Chi2Y < 10 (Inner rigidity)
- Hits on: L2 & (L3|L4) & (L5|L6) & (L7|L8)
- At least 5 Hits in Inner Tracker
- Chi2Y < 10 (InnerL1 rigidity)
- 0.7 < Inner Charge < 1.5
- Inner Charge / Inner Charge RMS < 0.4
- 0.6 < L1 Charge < 2
- Inside Inner Fiducial (InnerL1 rigidity)
- Inside L1 Fiducial (InnerL1 rigidity)
- L1 Normalized Residual < 10
- Beta > 0.4
- 0.5 < Upper ToF Charge < 2.5
- Mass Cut
- Inner Rigidity > SafetyFactor(R) * IGRF Cutoff

Event Selection Cuts - Inner+L1 Analysis - NAIA Code

NAIA Version: 1.02

From NAIA Standard Library (NSL)

My Selection cut

```
auto selection =
    ns::Trigger::HasPhysicsTrigger()                &&
    ns::Tof::BetaInRange(0.4, infinity, BTH)        &&
    ns::Tof::ChargeInRange(0.5, 2.5, UTC)           &&
    ns::Track::ChiSquareLessThan(10, YSD, FIT, INN) &&
    ns::InnerTracker::HitPattern()                  &&
    ns::InnerTracker::NHitsGreaterThan(4, YSD)      &&
    ns::Track::ChiSquareLessThan(10, YSD, FIT, IL1) &&
    ns::InnerTracker::ChargeInRange(0.7, 1.4, CRT)  &&
    ns::InnerTracker::ChargeRMSLessThan(0.4, CRT)   &&
    ns::TrackerLayer::ChargeInRange(1, 0.6, 2, CRT) &&
    ns::Track::InnerFiducialVolume(FIT, IL1)        &&
    ns::Track::L1FiducialVolume(FIT, IL1)           &&
    ns::Track::L1NormResidualLessThan(10, FIT)      &&
    ms::MassCut(IL1);
```

Inner Tracker Efficiency - NAIA Code

NAIA Version: 1.02

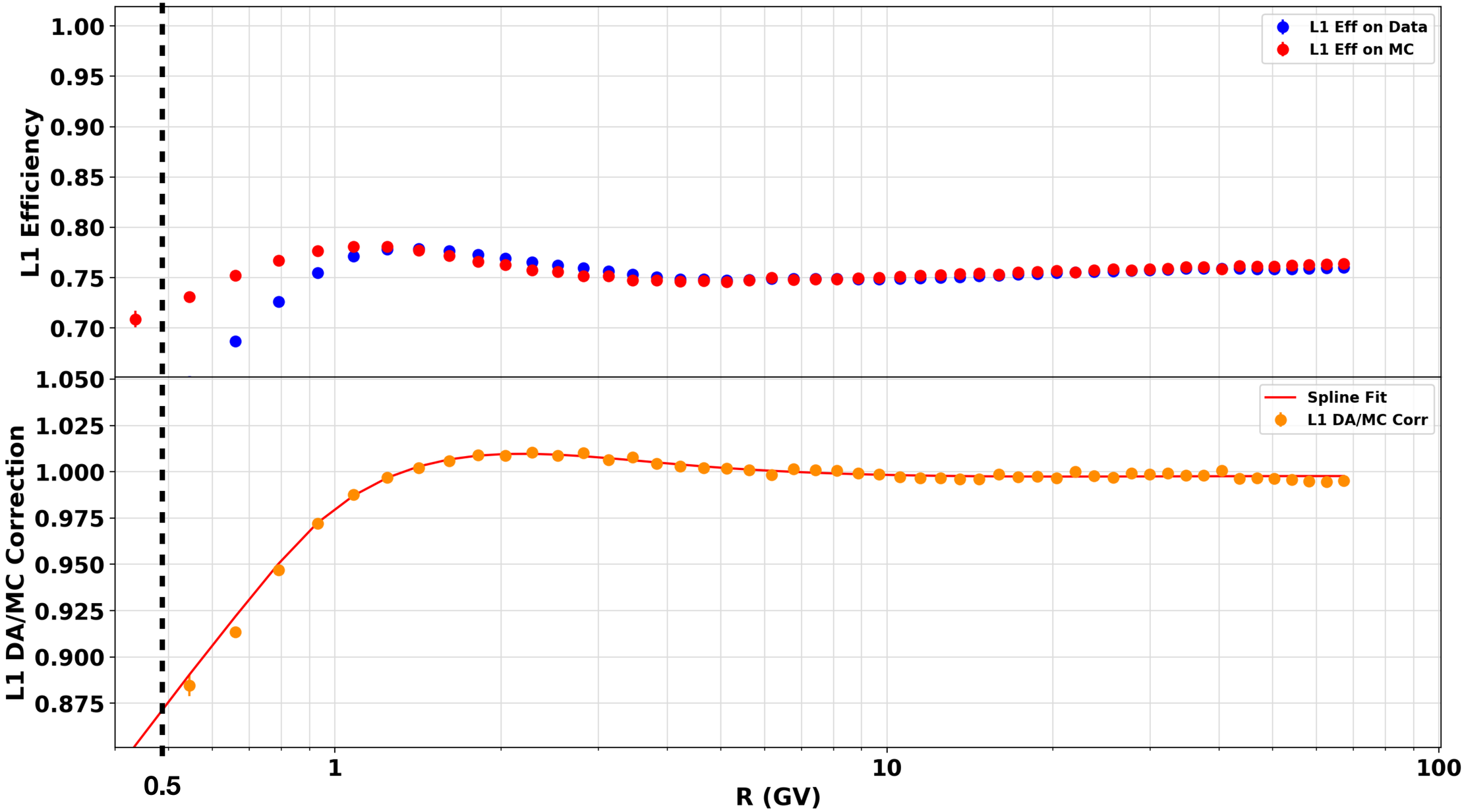
My Selection cut

From NAIA Standard Library (NSL)

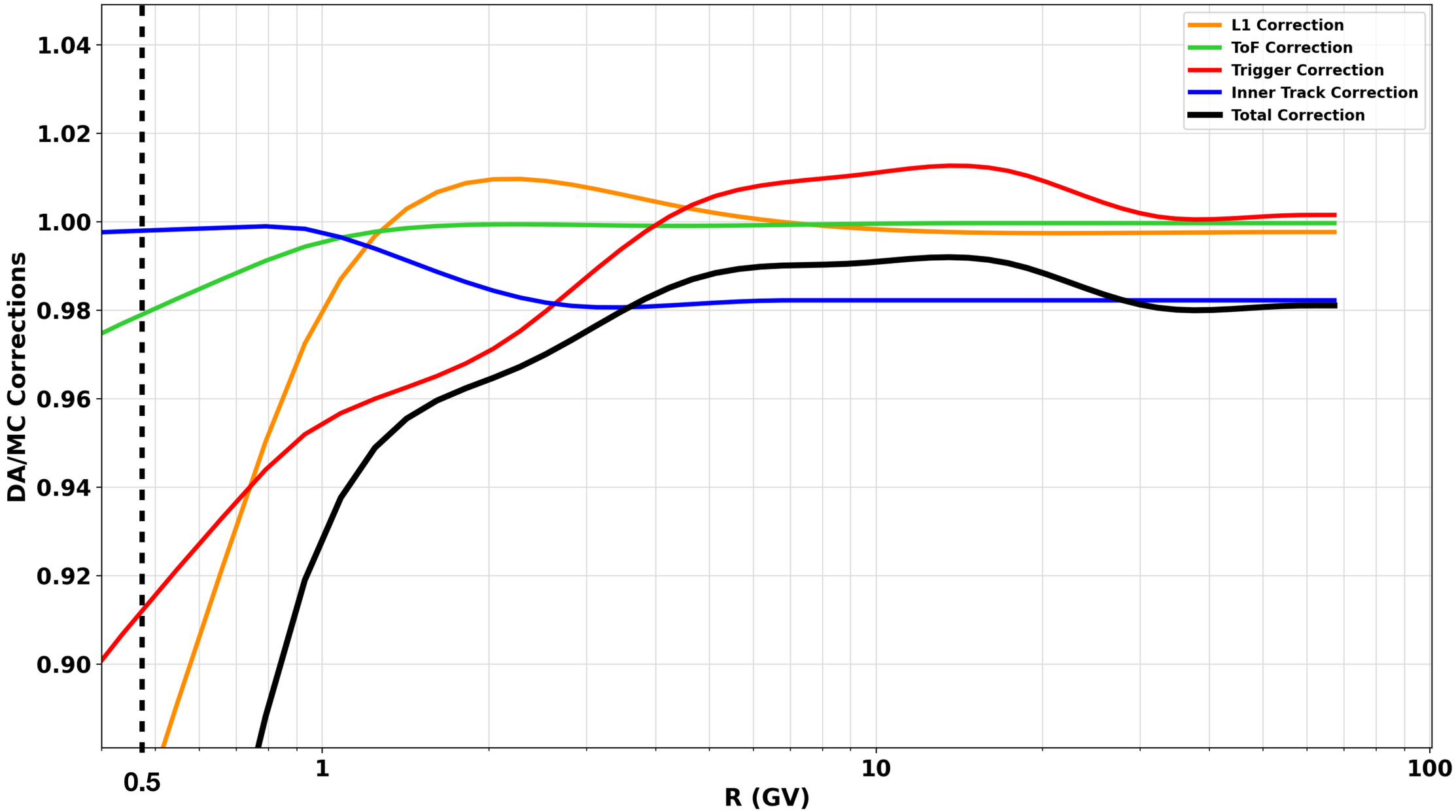
```
auto den_track =
  ns::Trigger::HasPhysicsTrigger()                  &&
  ms::TofSt::tofBetaInRange(0.4, infinity, BTH)     &&
  ms::TofSt::tofChi2TimeLessThan(2)                 &&
  ms::TofSt::tofChi2CooLessThan(2)                  &&
  ms::TofSt::tofChargeInRange(0.5, 1.5, UTC)        &&
  ms::TofSt::tofChargeInRange(0.5, infinity, LTC)   &&
  ms::TofSt::tofInnerFiducialVolume()               &&
  ms::TofSt::tofL1FiducialVolume()                  &&
  ms::TrdSt::trdL1FiducialVolume()                  &&
  ms::NTofClusterLessThan(5)                        &&
  ms::ExtChargeInRange(0.6, 2, EL1, CRT);
auto num_track =
  ns::Track::ChiSquareLessThan(10, YSD, FIT, INN)   &&
  ns::InnerTracker::ChargeInRange(0.7, 1.4, CRT)    &&
  ns::InnerTracker::ChargeRMSLessThan(0.4, CRT)     &&
  ns::InnerTracker::HitPattern()                    &&
  ns::InnerTracker::NHitsGreaterThan(4, YSD);
```

NOTE: NAIA code for examples of my selection cuts in backup!

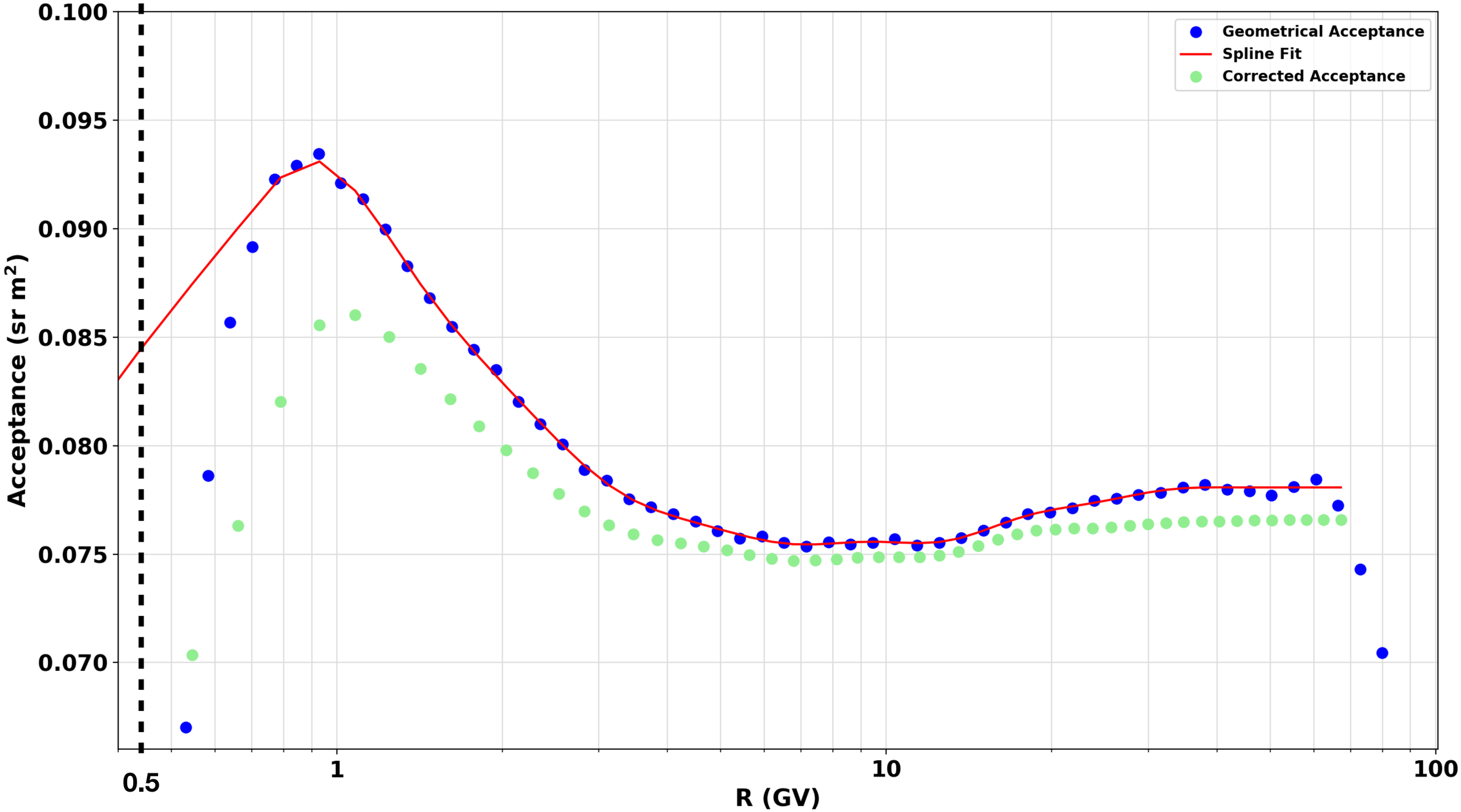
Layer 1 Pickup Efficiencies And Correction - [21/05/2011, 28/05/2018]



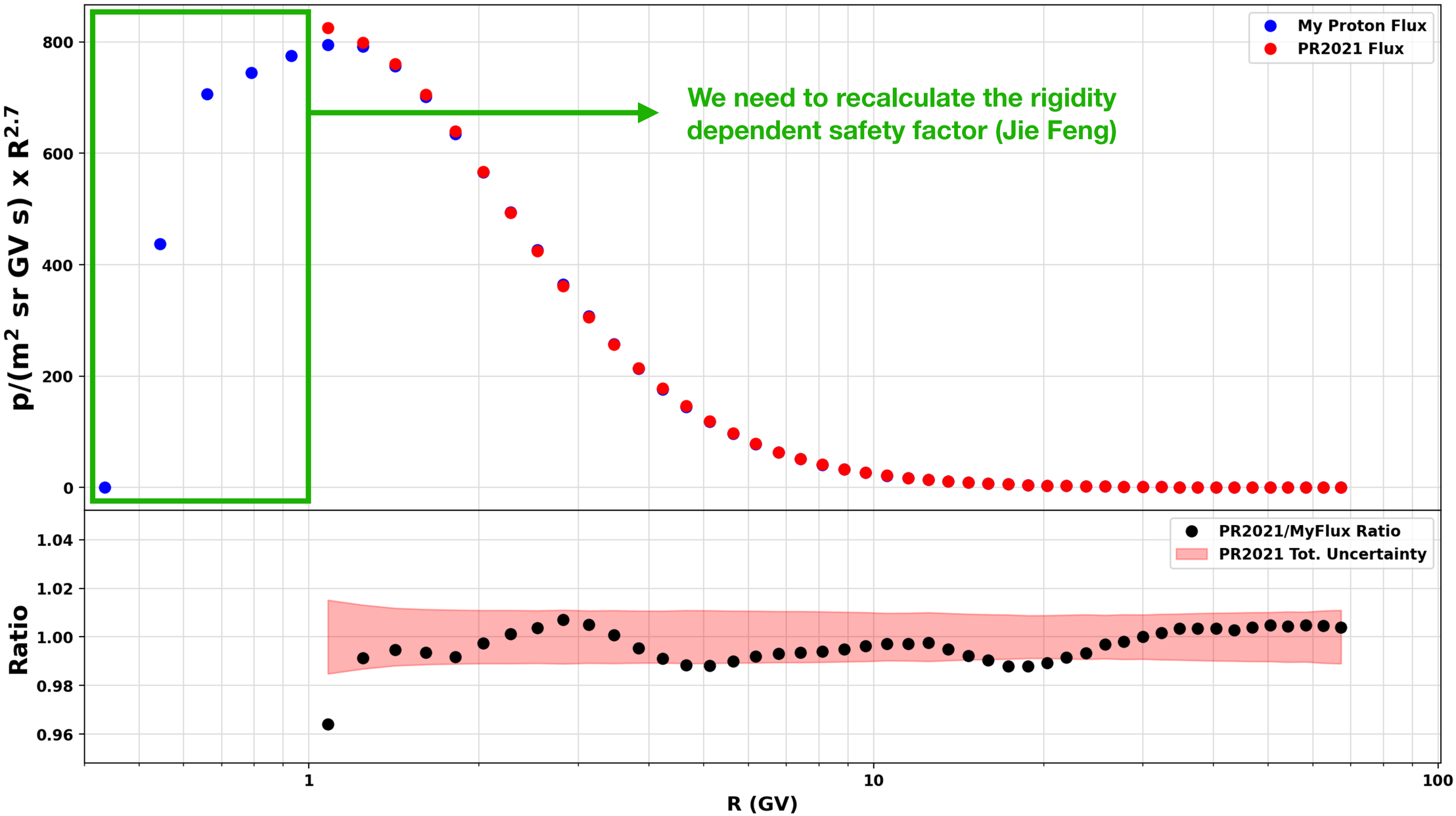
Integral Corrections - [21/05/2011, 28/05/2018]



Integral Corrections - [21/05/2011, 28/05/2018]



Integral Proton Flux - [21/05/2011, 28/05/2018]

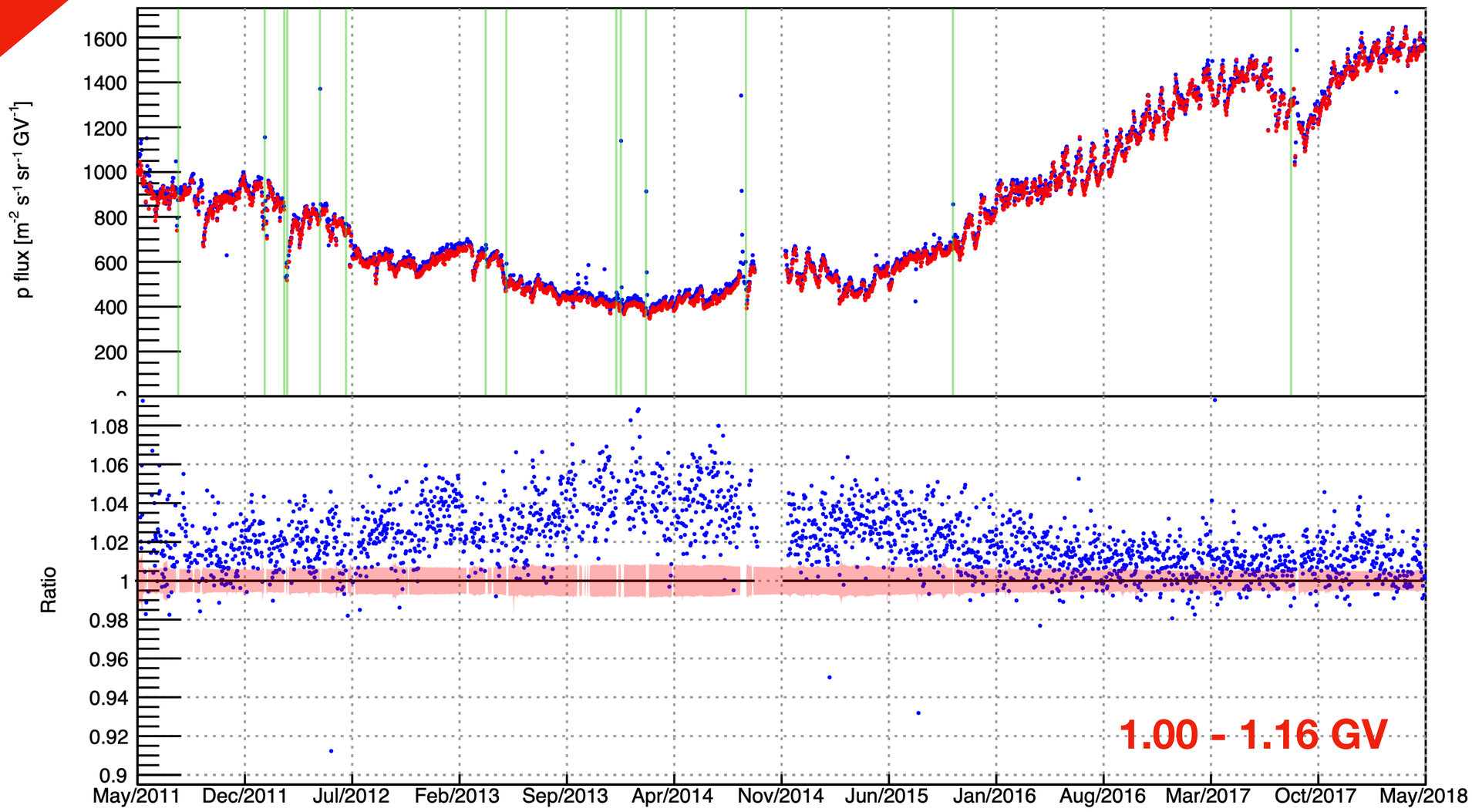


Pass8 - Daily Flux

Comparison with PRL 2021 Pass8 - Daily Flux

As Presented Last NAIA Meeting!

Daily Proton Flux: My Flux - PRL2021



- **Time dependence** of the **flux** was due the **Layer 1 Pickup Efficiency**.
- **Updated efficiency** by introducing **new cut** on **Inner Only Extrapolation** to Layer 1.

New Cut On L1 Efficiency Denominator - Inner TRD fit Match

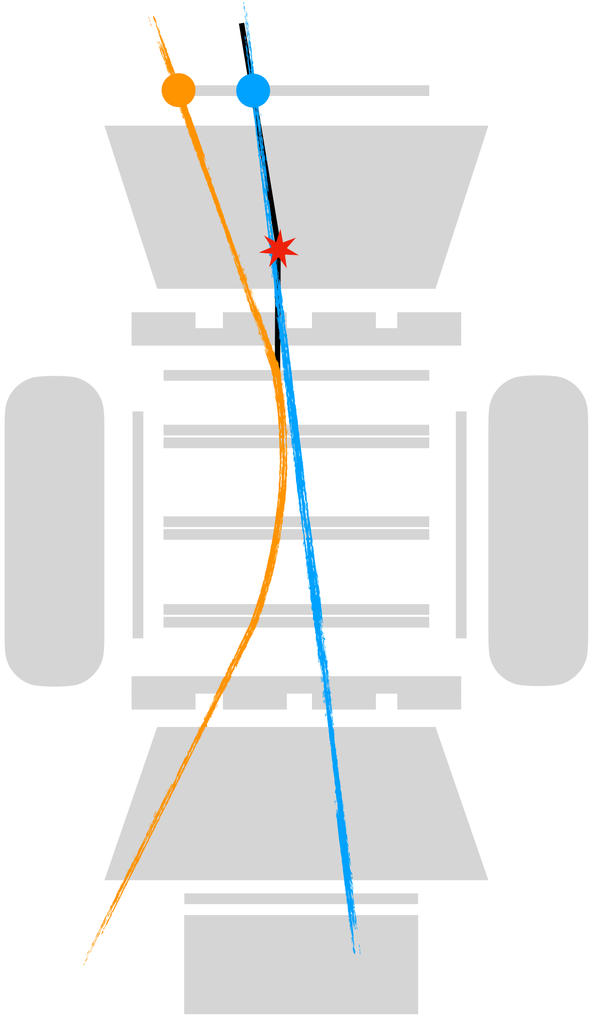
TRD Fit

Inner Fit

True Track

Interaction

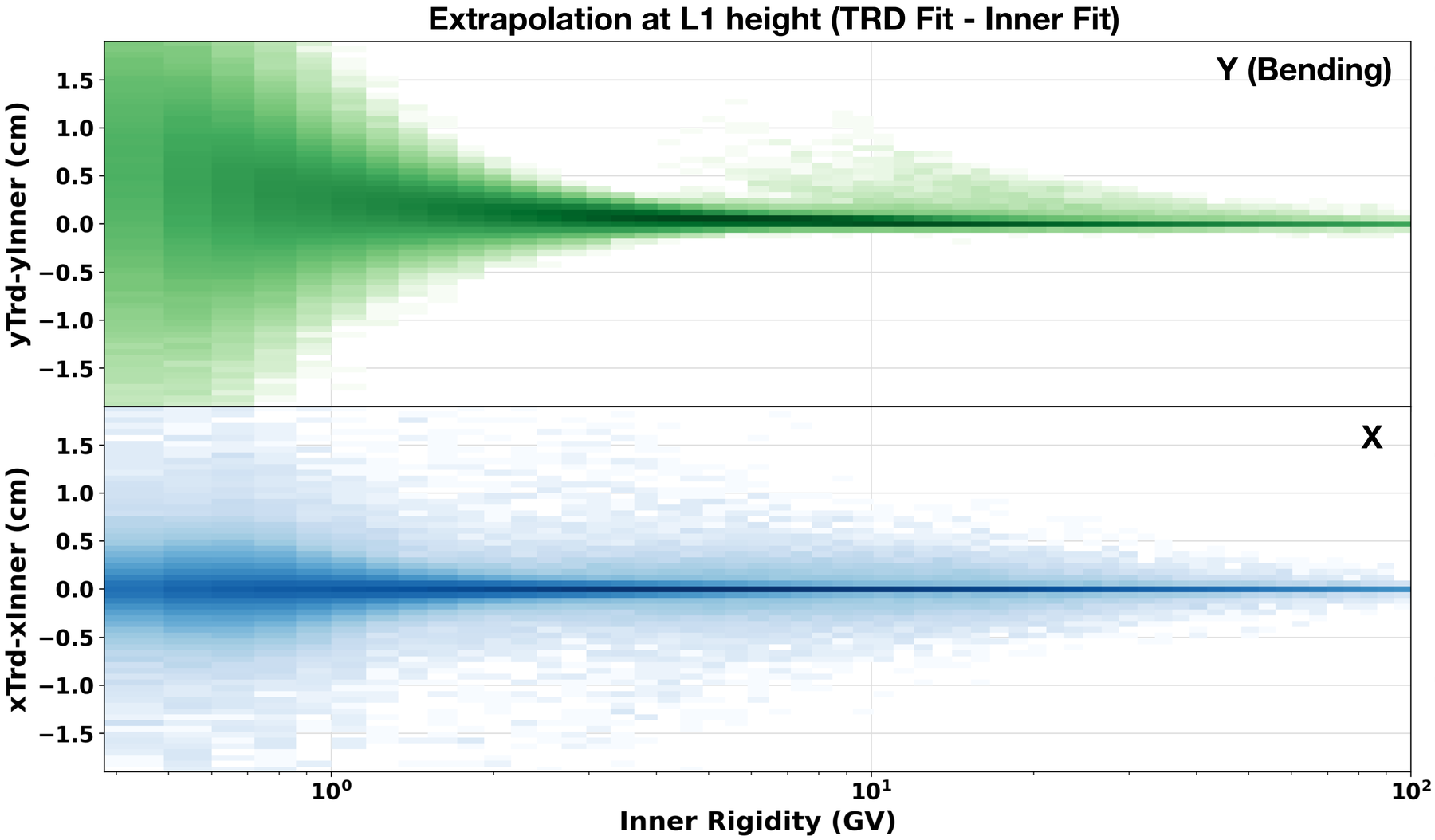
●-● = TRD - Inner Residual



- Calculate **residual distribution** in rigidity of the two fit extrapolations at L1 height: **TRD - Inner** (for both x and y directions).
- **Slice** the distribution along **rigidity bins** and find **μ** and **σ** (next slide).
- For each event: (**TRD-Inner**) - **μ**(R) < **σ**(R)

NOTE: NAIA code for this cut in backup!

New Cut On L1 Efficiency Denominator - Inner TRD fit Match



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- **Slice** the distribution along **rigidity bins** and find **μ** and **σ** (next slide).
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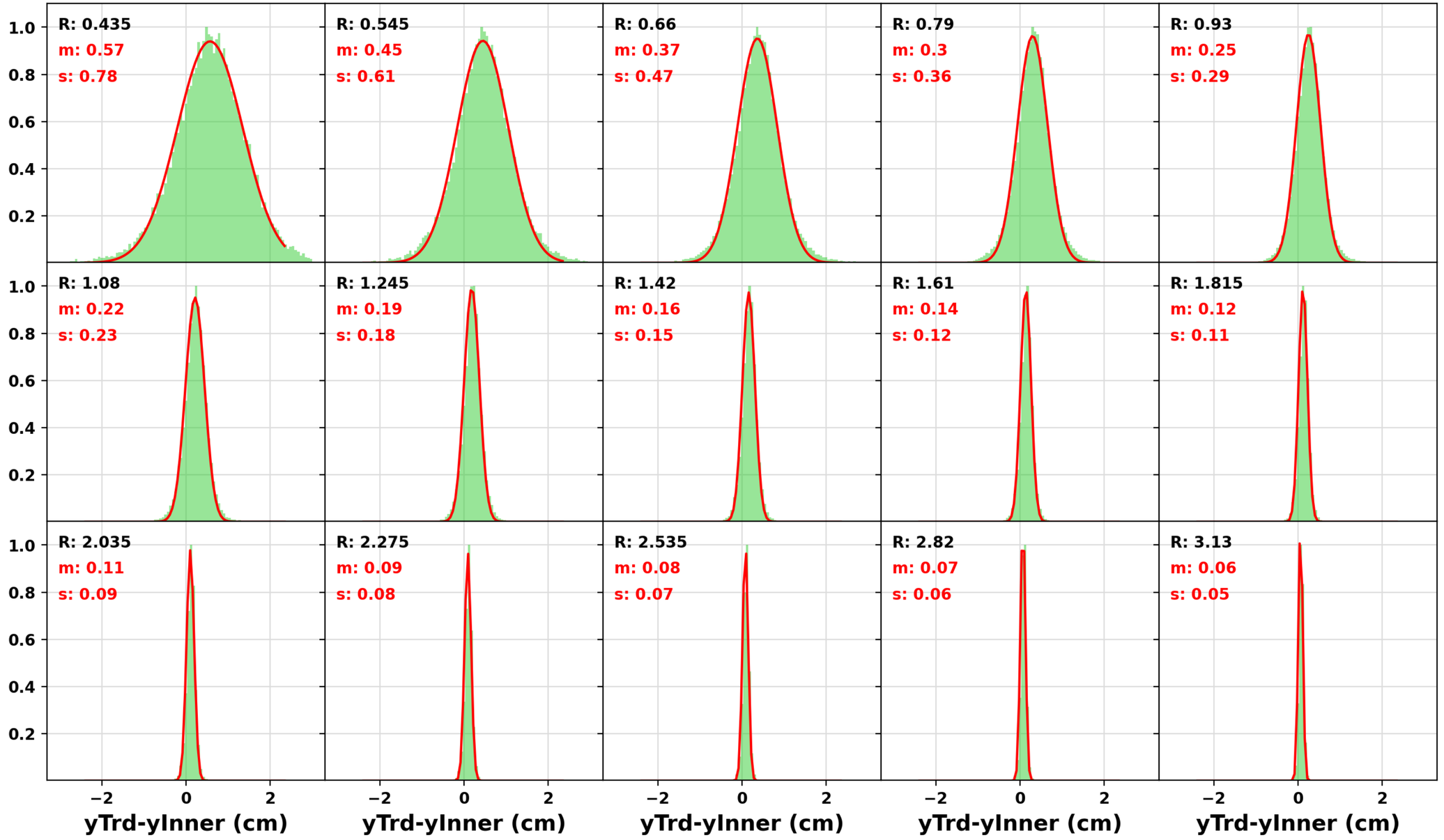
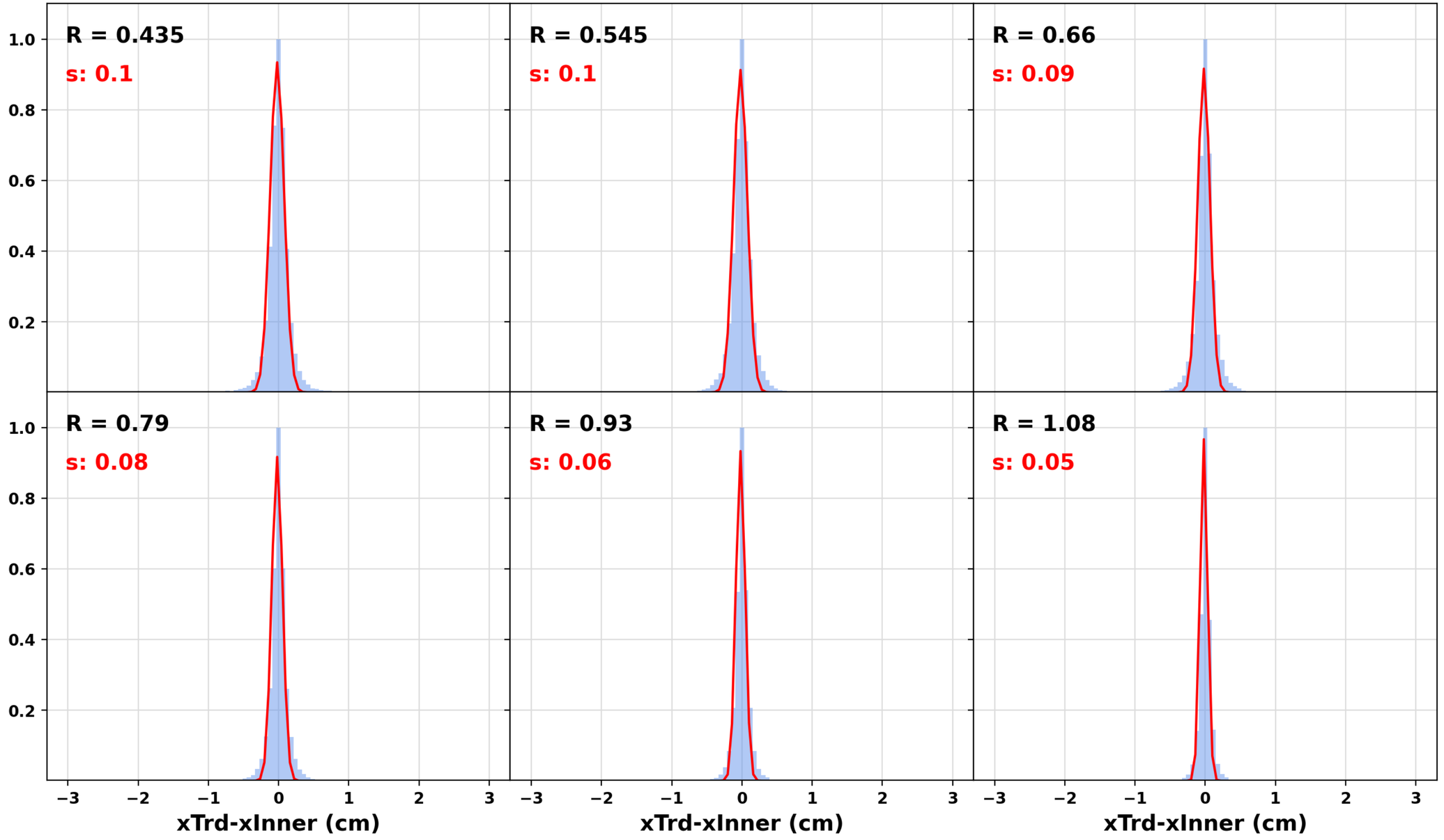
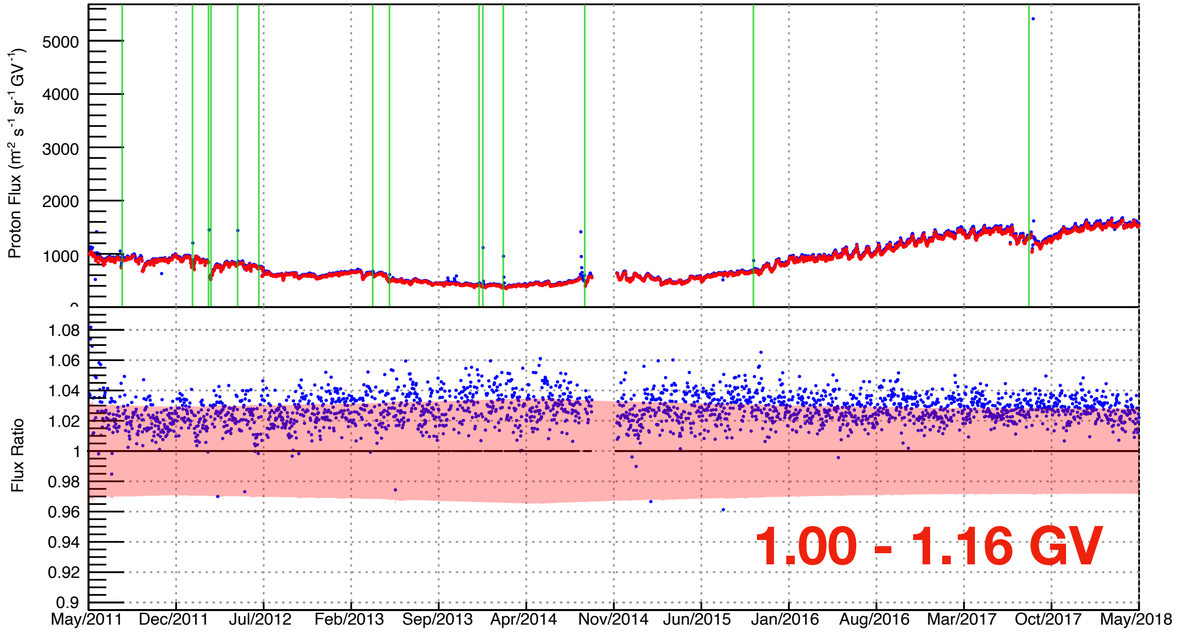
New Cut On L1 Efficiency Denominator - Inner TRD fit Match

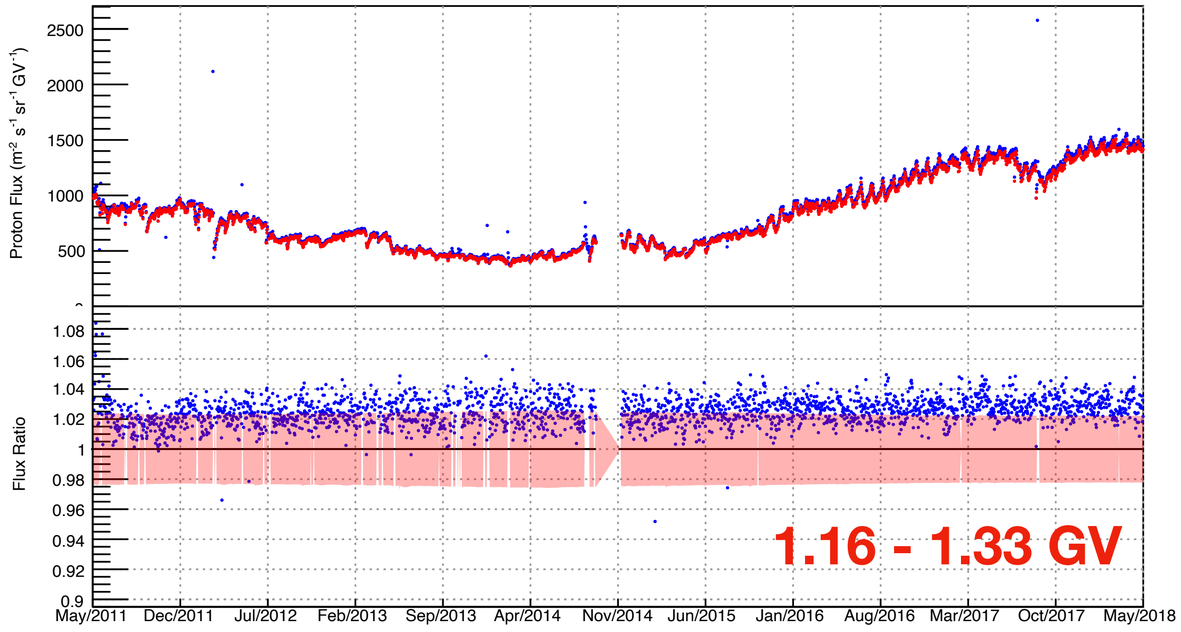


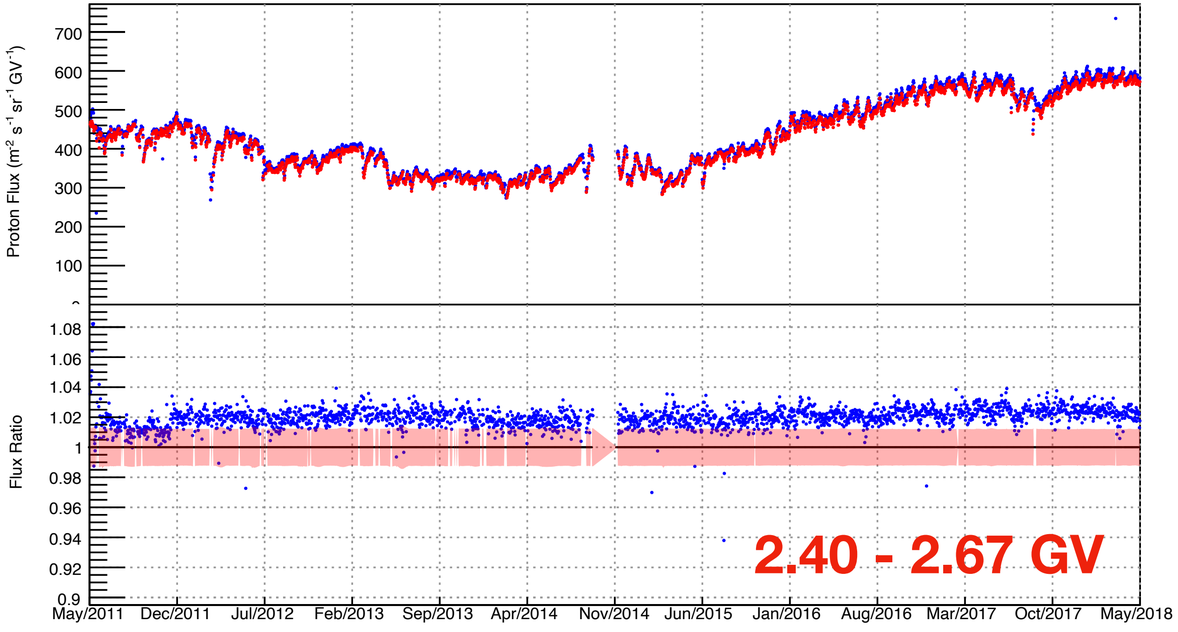
New Cut On L1 Efficiency Denominator - Inner TRD fit Match

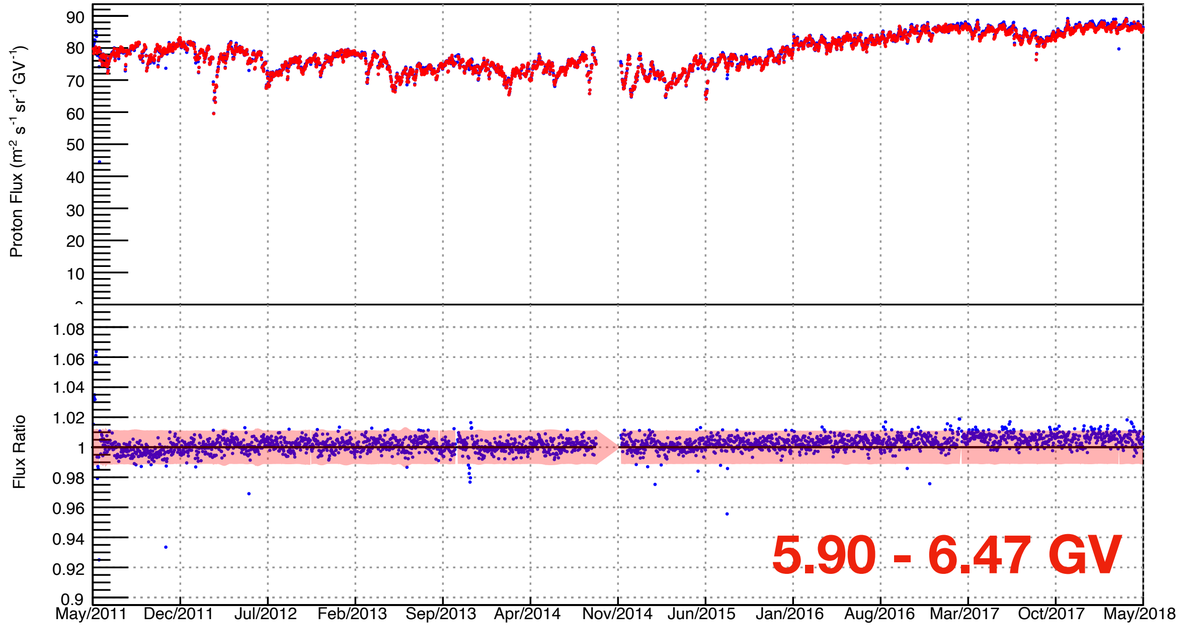


Daily Proton Flux: My Flux - PRL2021







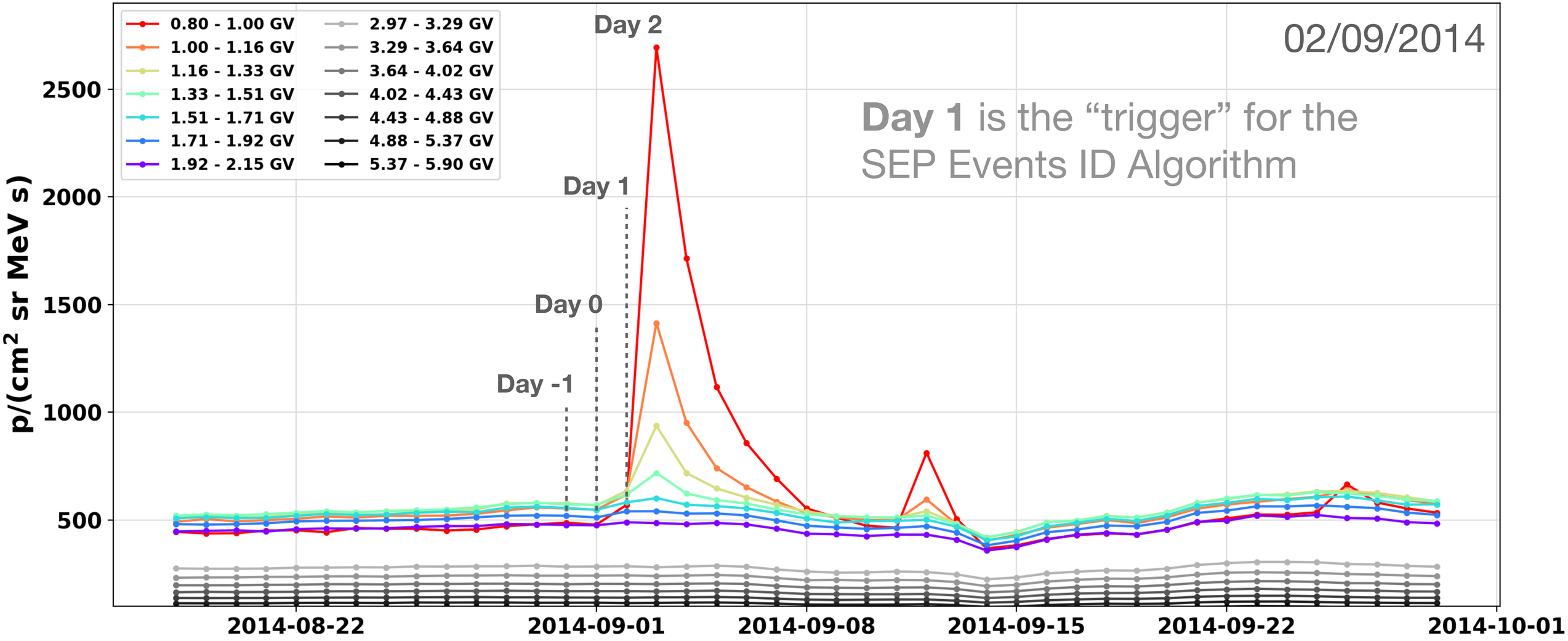


SEP Daily Proton Flux

CR Background Subtraction

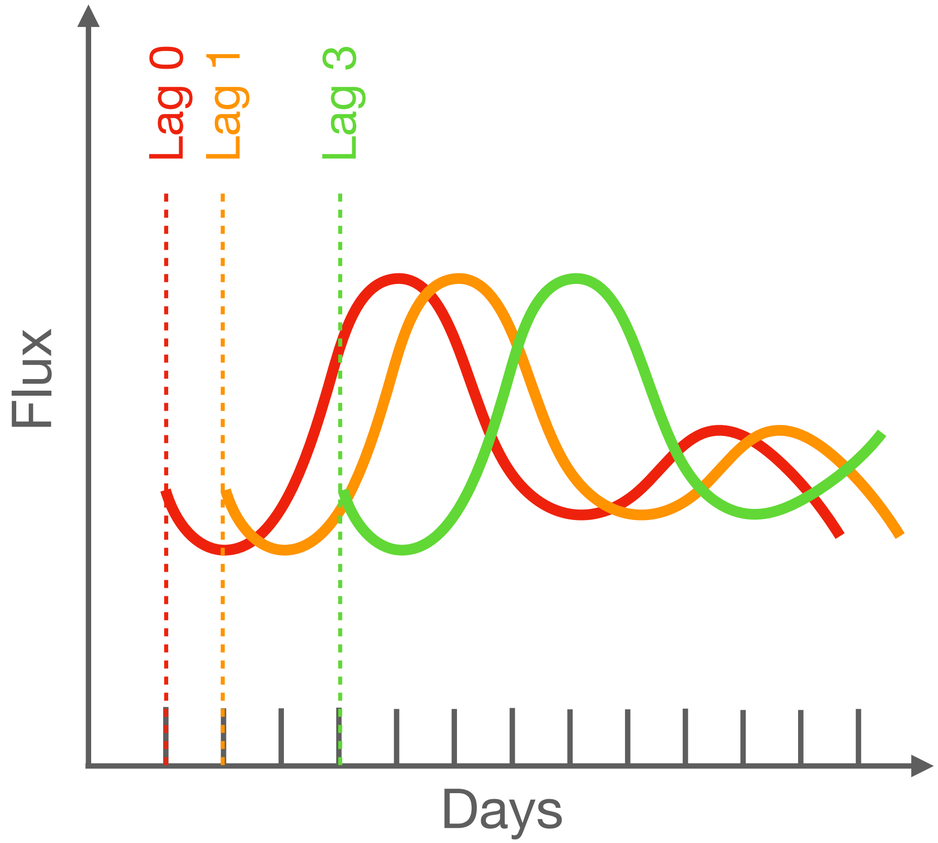
Francesco Faldi

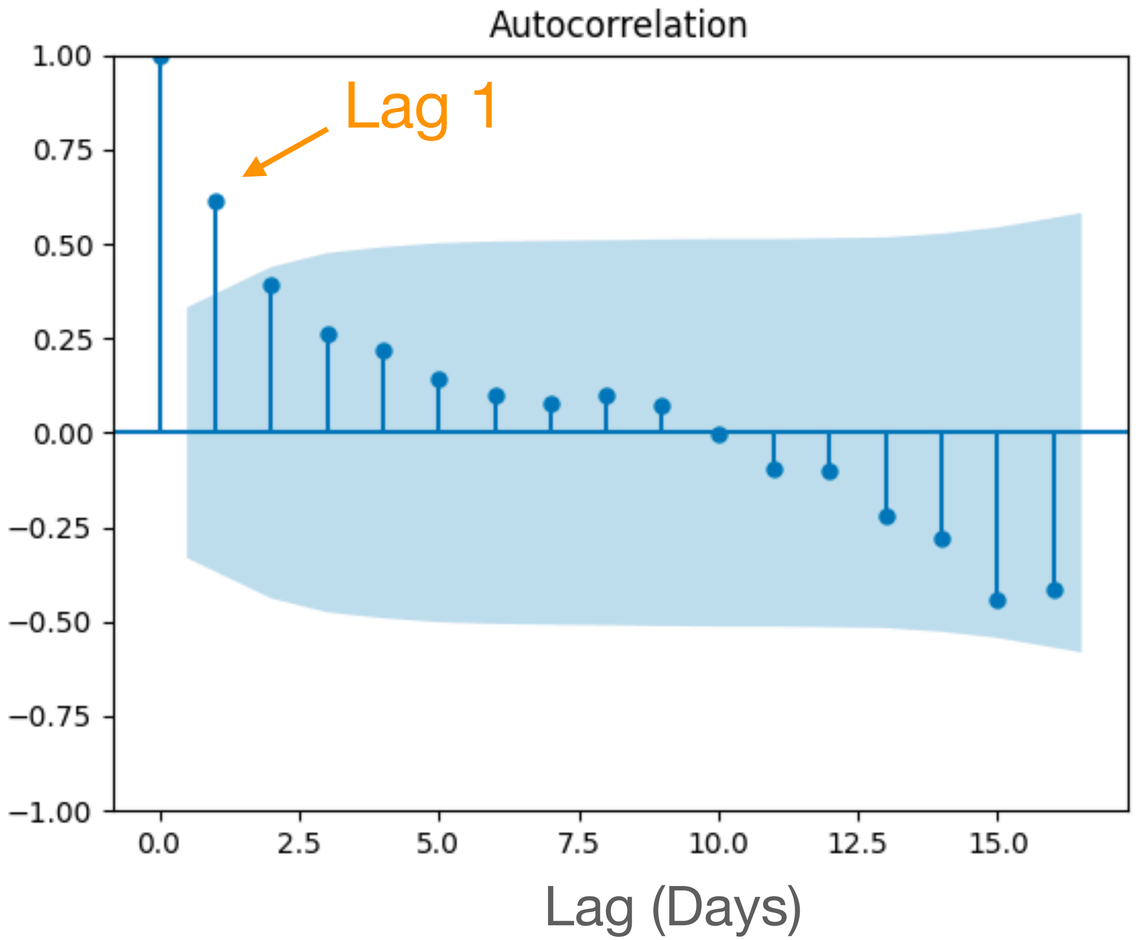
Daily Proton Fluxes



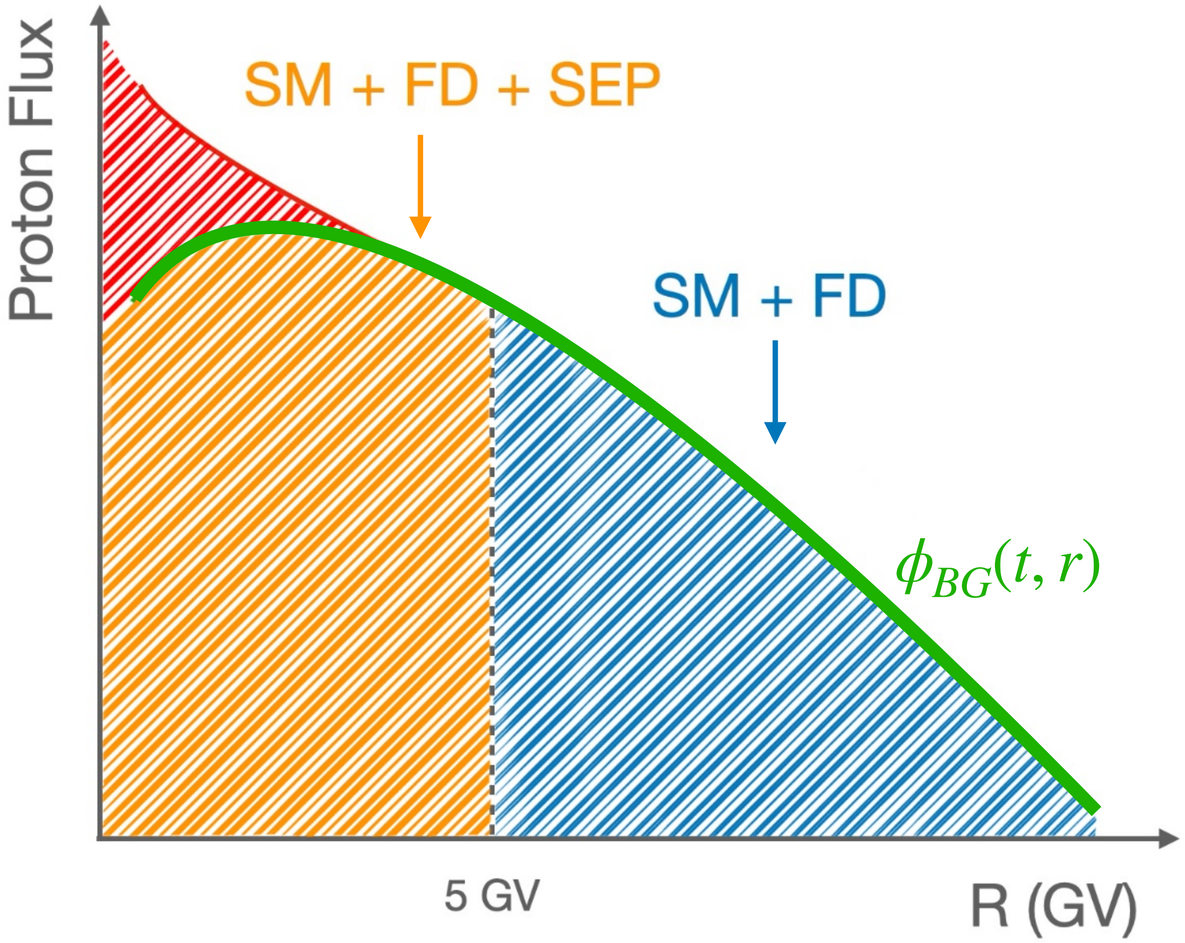
Daily Proton Fluxes

The proton flux, at a given day, is strongly correlated to the flux of the day before.





CR Background Forecast



The CR **background** can then be described as **proportional** to its **previous value**
(starting from a non SEP day):

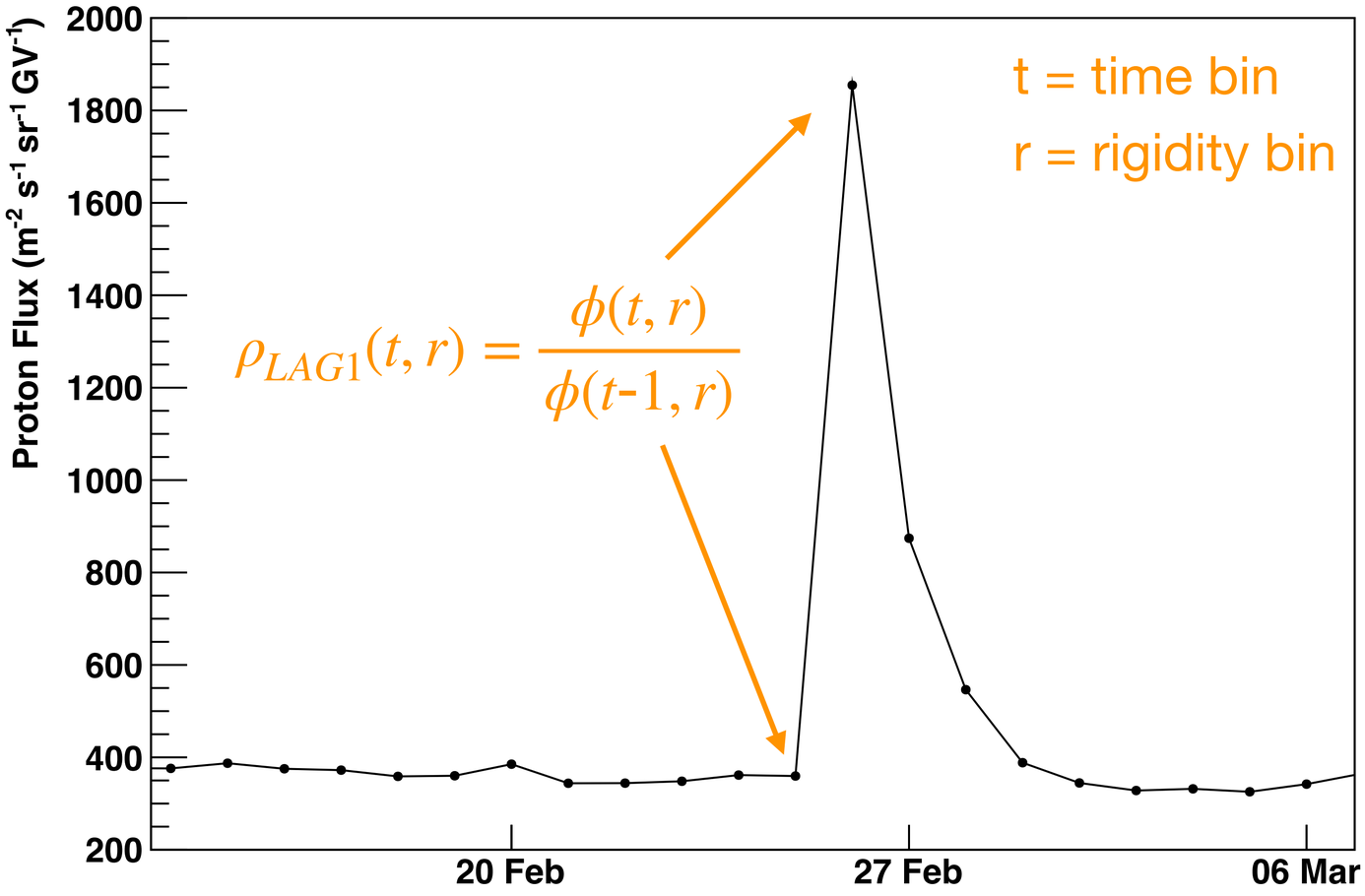
Day -1 $\phi_{BG}(t\text{-}1, r) = \phi(t\text{-}1, r)$

Day 0 $\phi_{BG}(t, r) = N \times \phi_{BG}(t\text{-}1, r)$

The **normalization N** can be calculated from the flux at **higher rigidities** (i.e. > 5GV), excluding the SEP contribution.

SM = Solar Modulation, FD = Forbush Decrease, SEP = Solar Energetic Particles

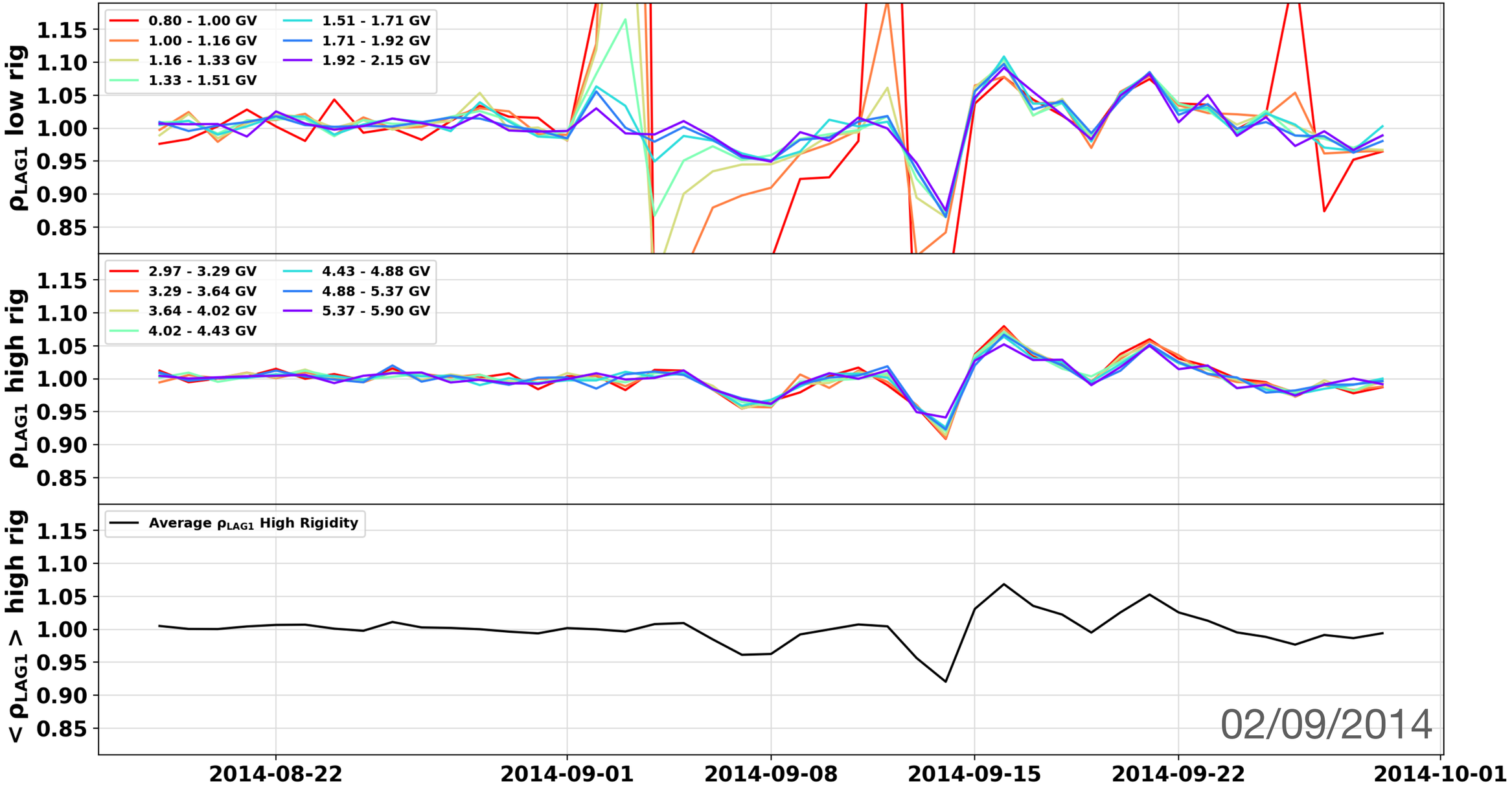
ρ_{LAG1} Forecast Parameter: Ratio with Lag1 Flux



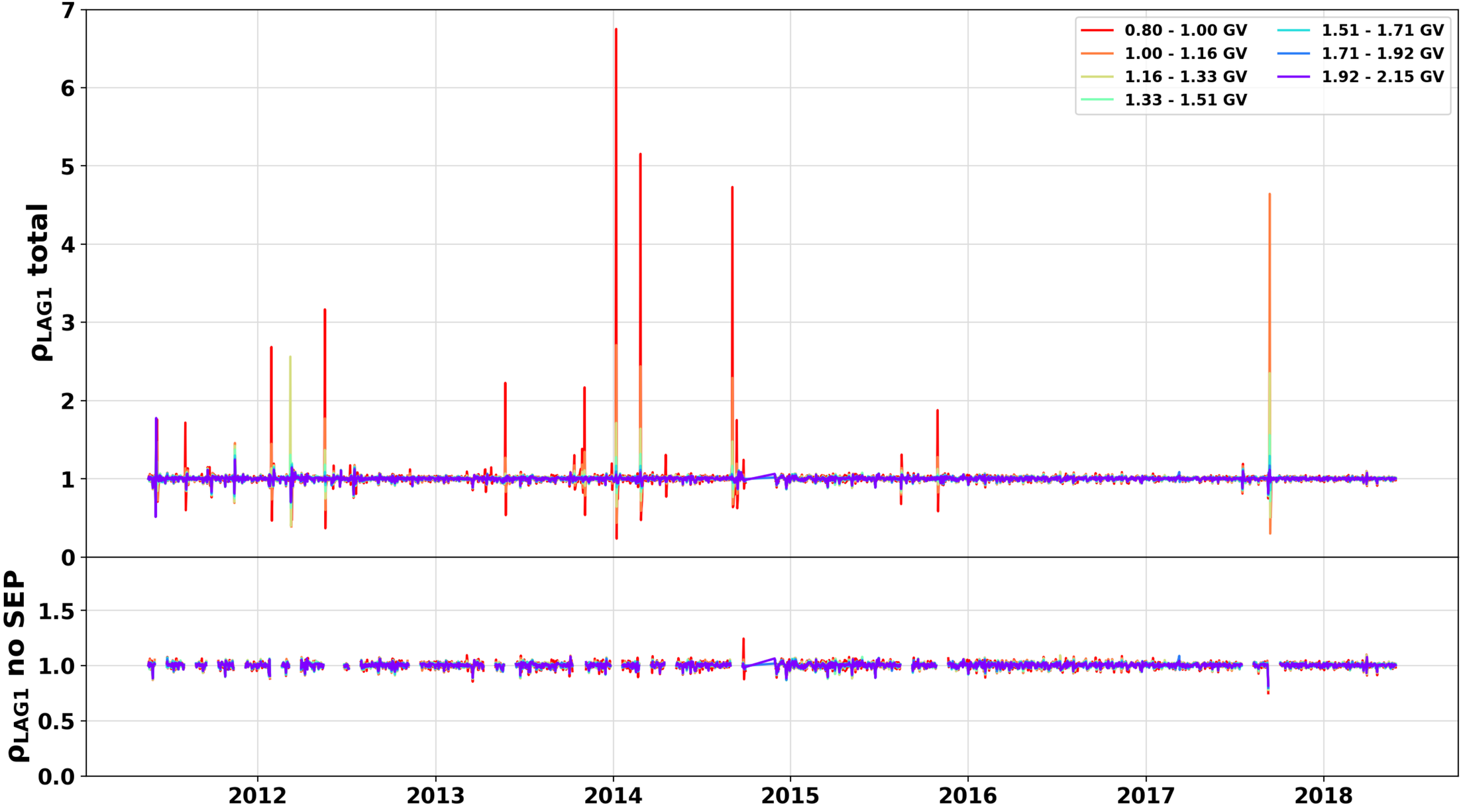
For each time (day) and rigidity bin, ρ_{LAG1} is defined as the **ratio** of the **current** daily flux with the flux of the **previous** day.

- **Stationary**: removes temporal trend. Still time dependent (e.g. Forbush Decreases), but with “random” fluctuations in the baseline and no seasonality.
- **Rigidity independent** during quiet periods.

ρ_{LAG1} Forecast Parameter: Ratio with Lag1 Flux



ρ_{LAG1} Forecast Parameter: Ratio with Lag1 Flux



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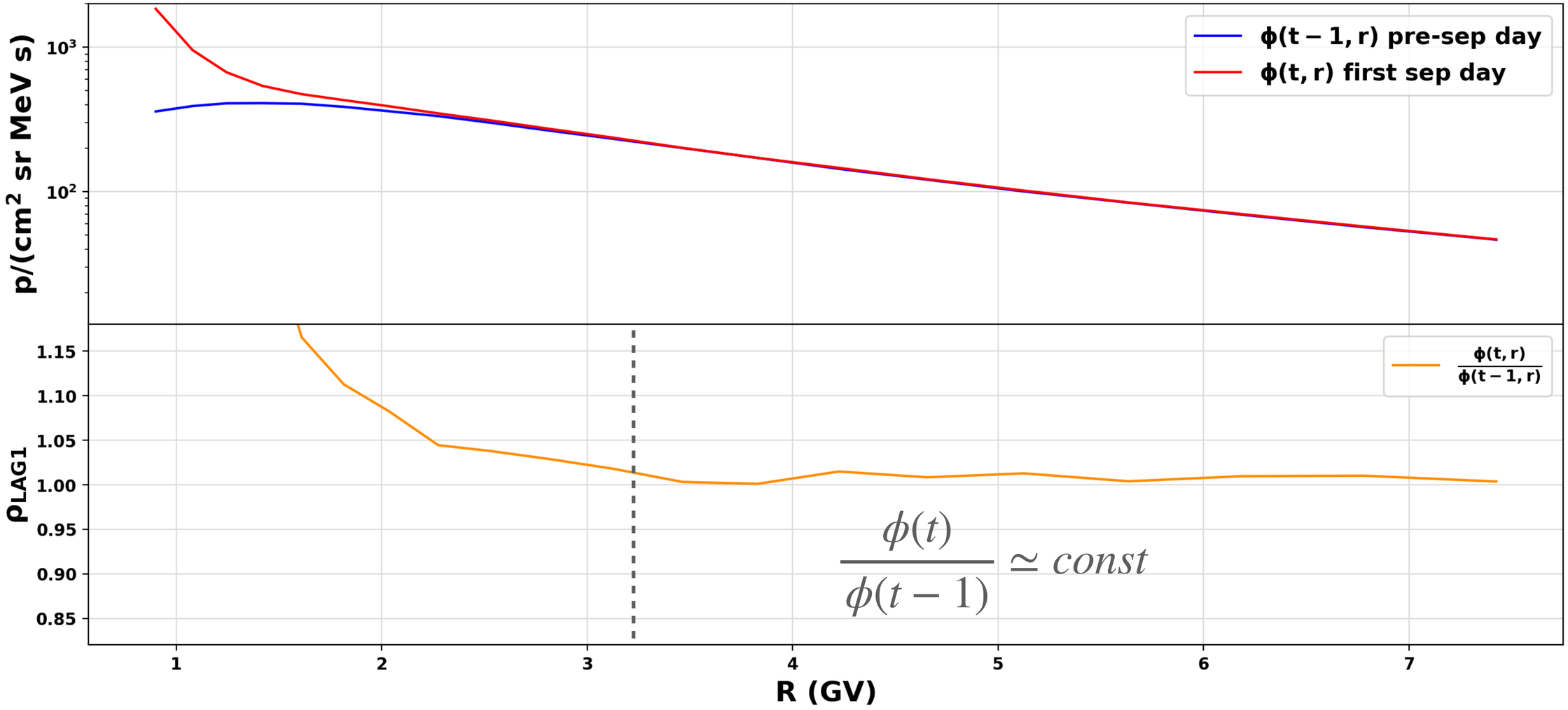
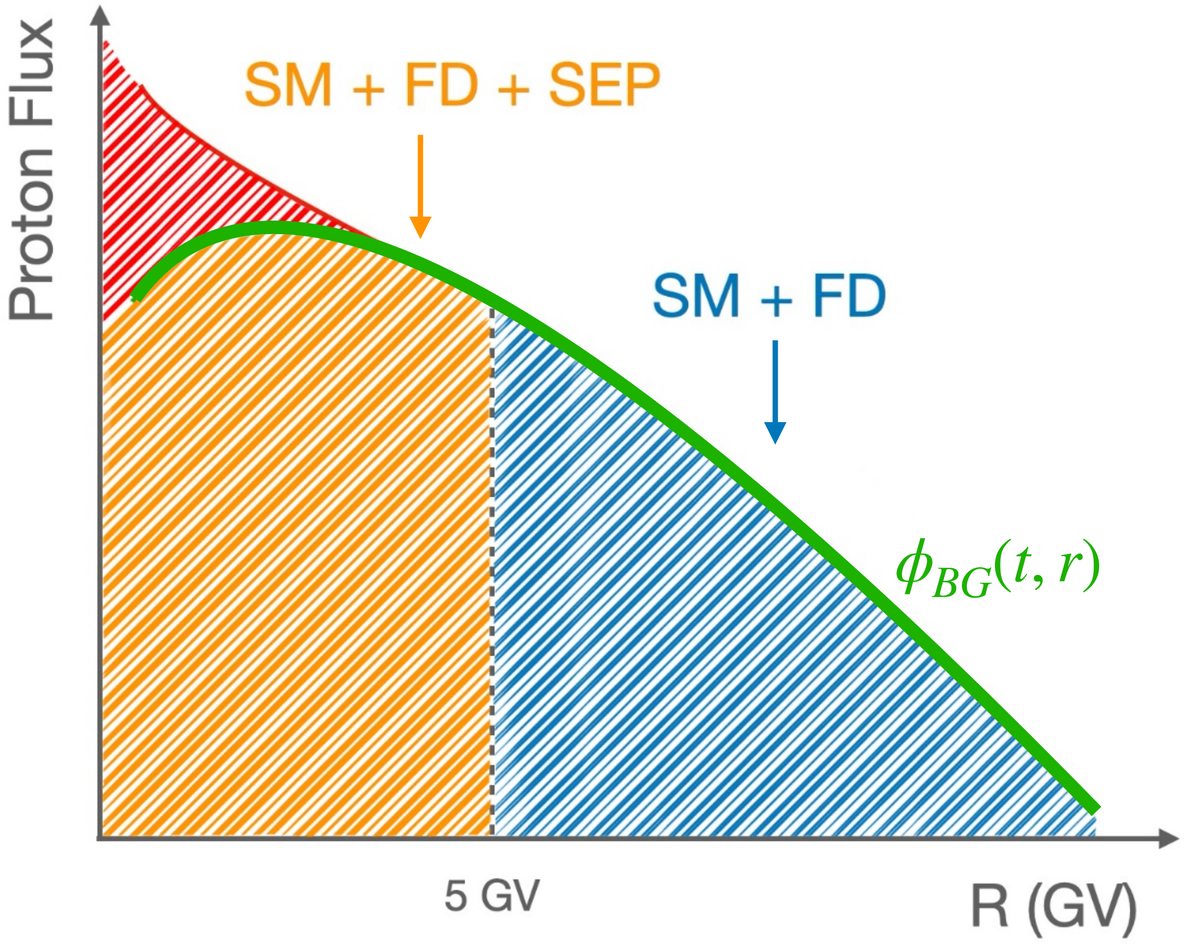


CR Background Forecast



Thanks to **rigidity independence**, the **normalization N**, for every rigidity bin, is given by:

$$N = < \rho_{LAG1}(t) > = \frac{1}{10} \sum_{r=10}^{20} \frac{\phi(t, r)}{\phi(t\text{-}1, r)}$$

The **CR background** is calculated **iteratively**, starting with the total flux value as background.

Day -1 $\phi_{BG}(t\text{-}1, r) = \phi(t\text{-}1, r)$

Day 0 $\phi_{BG}(t, r) = < \rho_{LAG1}(t) > \times \phi_{BG}(t\text{-}1, r)$

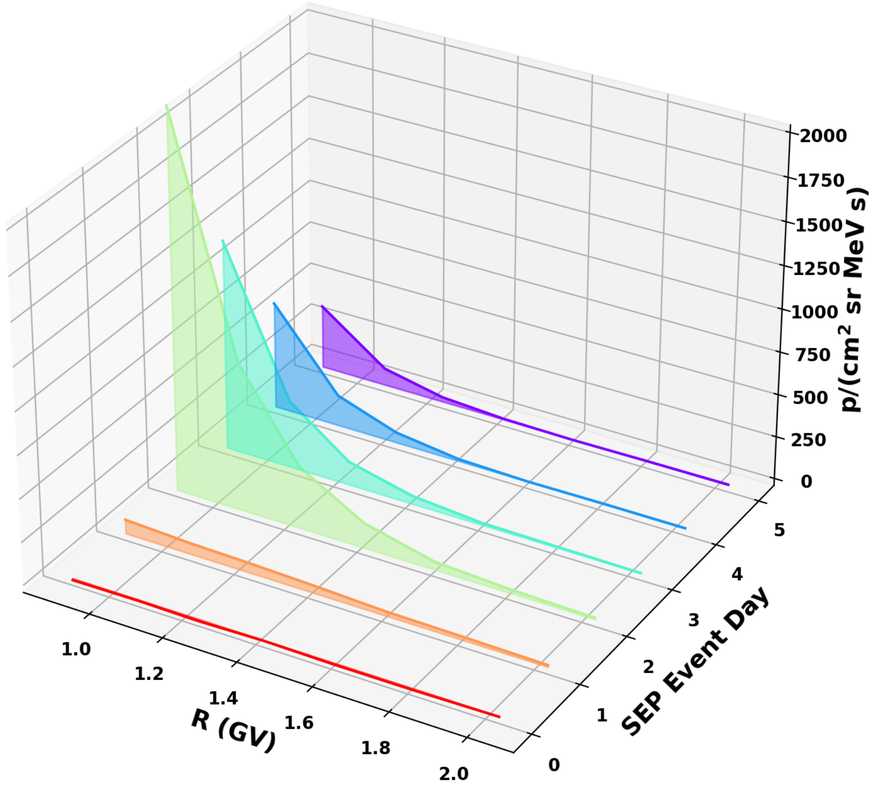
SM = Solar Modulation, FD = Forbush Decrease, SEP = Solar Energetic Particles

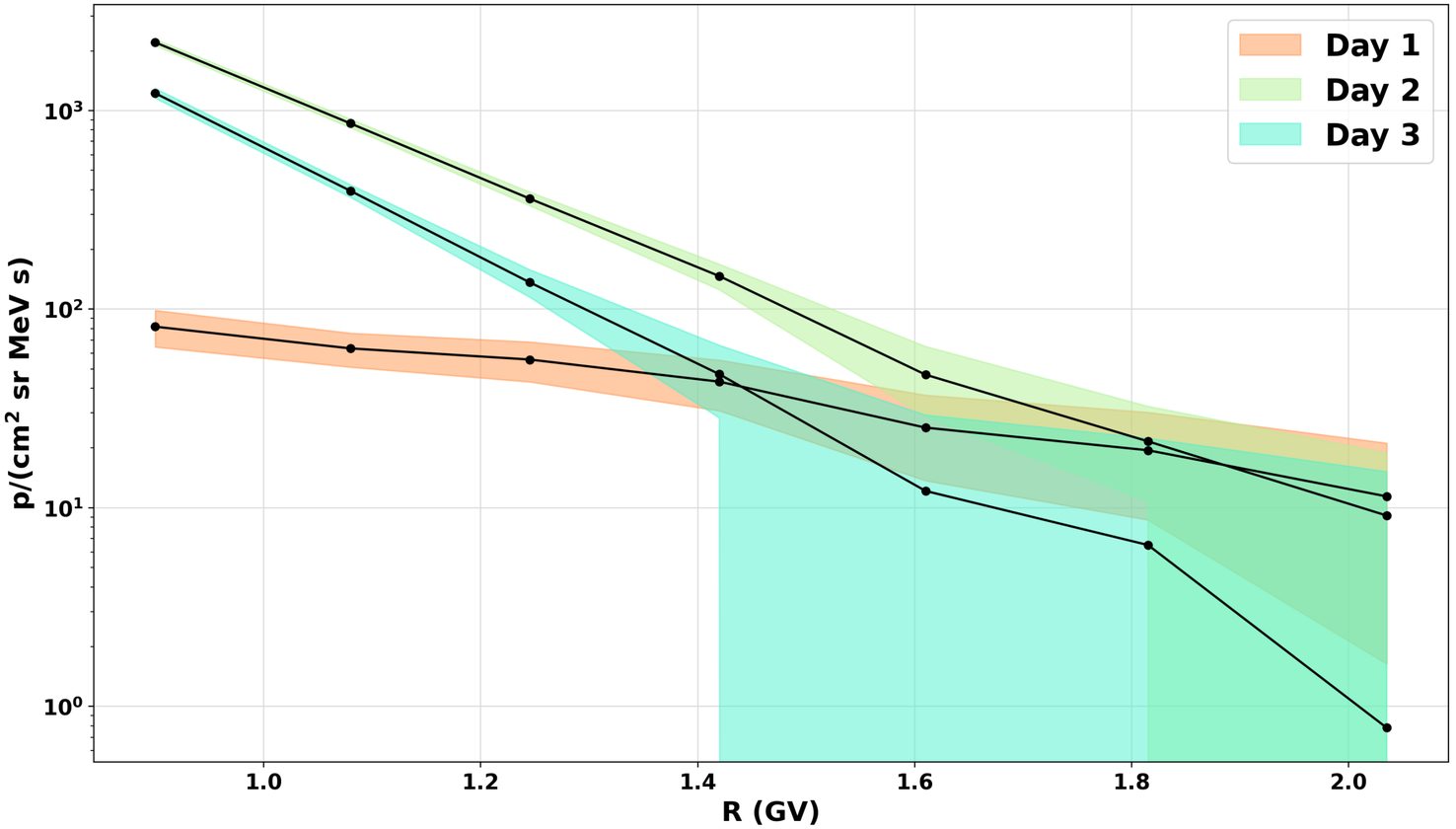
Background-subtracted SEP Flux

The **SEP only** flux is the **subtraction** of the **background** from the **total** flux.

$$\phi_{SEP}(t, r) = \phi(t, r) - \phi_{BG}(t, r)$$

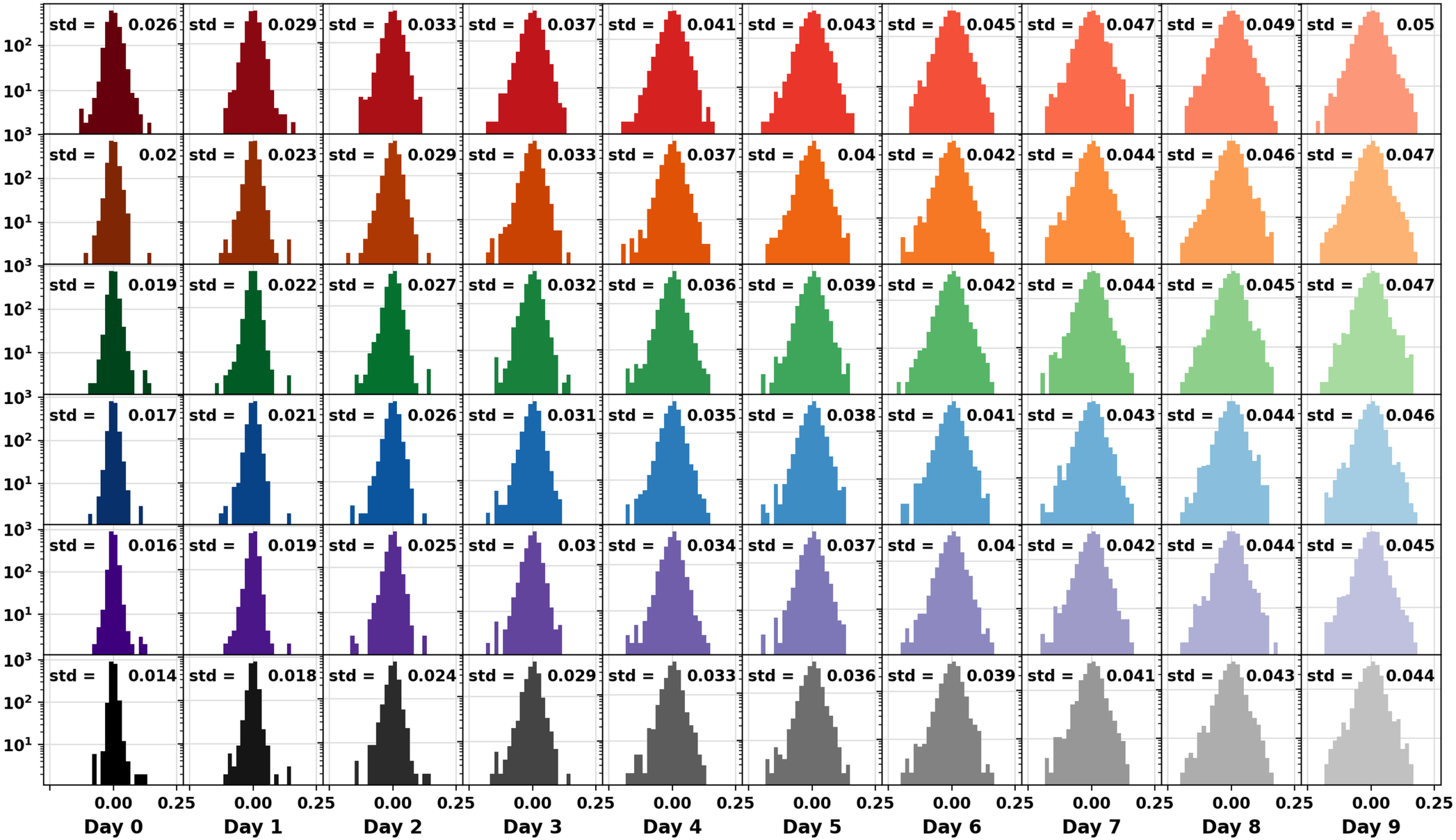
02/09/2014





Forecasted Background - Non-SEP Flux

$$\frac{\phi_{BG} - \phi}{\phi}$$



SEP Flux Finding Algorithm - GOES vs AMS

✔ Seen by AMS, (✔) Partially seen / Forbush only NOAA Database: https://umbra.nascom.nasa.gov/SEP/

Start Time	Flare Class (X-ray)	AMS
2011 Jun 07	M2	✔
2011 Aug 04	M9	✔
2011 Aug 09	X6	(✔)
2011 Sep 23	X1	(✔)
2011 Nov 26	C1	
2012 Jan 23	M8	(✔)
2012 Jan 27	X1	✔
2012 Mar 07	X5	✔
2012 Mar 13	M7	(✔)
2012 May 17	M5	✔
2012 Jun 16	M1	(✔)
2012 Jul 07	X1	✔

Start Time	Flare Class (X-ray)	AMS
2012 Jul 12	X1	(✔)
2012 Jul 17	M1	(✔)
2012 Sep 01	C8	
2012 Sep 28	C3	
2013 Mar 16	M1	(✔)
2013 Apr 11	M6	✔
2013 May 15	X1	
2013 May 22	M5	✔
2013 Jun 23	M2	
2013 Sep 30	C1	
2013 Dec 28	C9	
2014 Jan 06	X1	✔

Start Time	Flare Class (X-ray)	AMS
2014 Feb 20	M3	
2014 Feb 25	X4	✔
2014 Apr 18	M7	✔
2014 Sep 11	X1	✔
2015 Jun 18	M1	
2015 Jun 21	M2	
2015 Jun 26	M7	
2016 Jan 02	M2	
2017 Jul 14	M2	(✔)
2017 Sep 05	M5	(✔)
2017 Sep 10	X8	✔

Backup

Additional Cuts In NSL - NAIA Code

From NSL repository

```
#include "NSL/Tof/BetaInRange.h"

NSL::Selections::Tof::BetaInRange::BetaInRange(float min, float max, NAIA::Tof::BetaType type) {
  m_matcher = std::make_shared<boolMatcher>([=](Event &event) {
    auto charge = event.tofBase->Beta[type];
    return (charge > min && charge < max);
  });
}
```

My own definition (ToF Standalone)

```
namespace TofSt{ // ToF Standalone
class tofBetaInRange : public NSL::Selection{
public:
  tofBetaInRange(double min, double max, NAIA::Tof::BetaType type){
    m_matcher = make_shared<NSL::boolMatcher>([=](Event &event) {
      auto charge = event.tofBaseSt->Beta[type];
      return (charge > min && charge < max);
    });
  }
};
```

- Standalone cuts are missing in NSL (at least in v1.02).
- Easy implementation, following the non-standalone counterpart.
- Useful for any flux analysis that require Inner Tracker efficiency evaluation.

Inner TRD Extrapolation Match Cut - NAIA Code

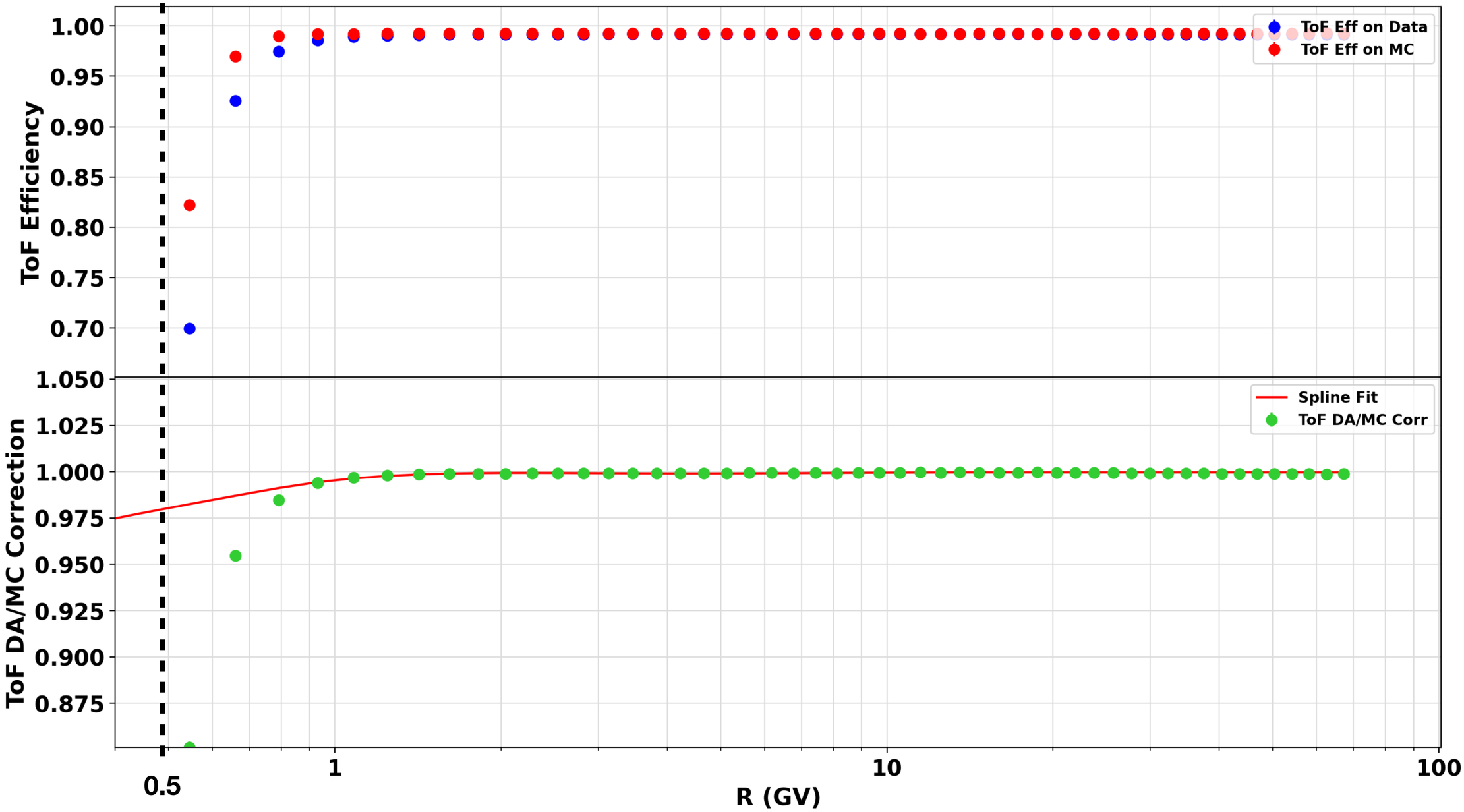
```
class MatchInnerTrd : public NSL::Selection{
public:
  MatchInnerTrd(){
    m_matcher = make_shared<NSL::boolMatcher>([=](Event &event) {
      if(!event.CheckMask(NAIA::Category::HasTrd)) return false;
      auto l1_height = NAIA::TrTrack::fitPositionHeightZ[L1];
      auto trd_l1 = event.trdKBase->InterpolateAtZ(l1_height);
      auto inn_l1 = event.trTrackBase->TrTrackFitPos[L1][FIT][INN];
      double rig = fabs(event.trTrackBase->Rigidity[FIT][INN]);
      bool match = true;
      if(fabs(trd_l1[1]-inn_l1[YSD]-muY->Eval(rig))>sigmaY->Eval(rig)) match = false;
      if(fabs(trd_l1[0]-inn_l1[XSD])>sigmaX->Eval(rig)) match = false;
      return match;
    });
  }
};
```

Example Of User Defined Cuts - NAIA Code

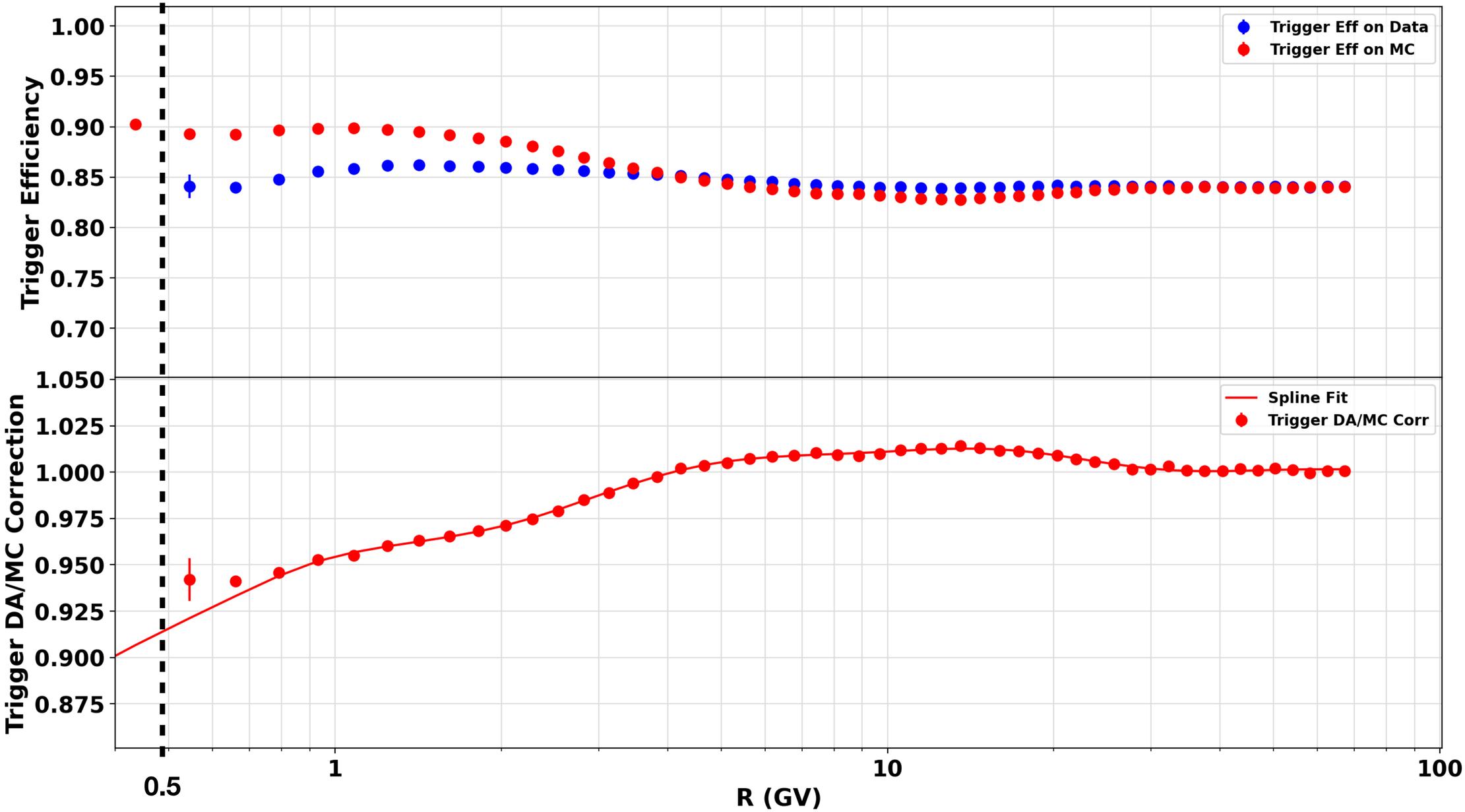
```
namespace ms{ //my selection

class NAccLessThan : public NSL::Selection{
public:
  NAccLessThan(int max){
    m_matcher = make_shared<NSL::boolMatcher>([=](Event &event) {
      return event.evSummary->NAcc < max;
    });
  }
};
class NTrackLessThan : public NSL::Selection{
public:
  NTrackLessThan(int max){
    m_matcher = make_shared<NSL::boolMatcher>([=](Event &event) {
      return event.evSummary->NTrTrack < max;
    });
  }
};
class NTofClusterLessThan : public NSL::Selection{
public:
  NTofClusterLessThan(int max){
    m_matcher = make_shared<NSL::boolMatcher>([=](Event &event) {
      return event.evSummary->NTofCluster < max;
    });
  }
};
```

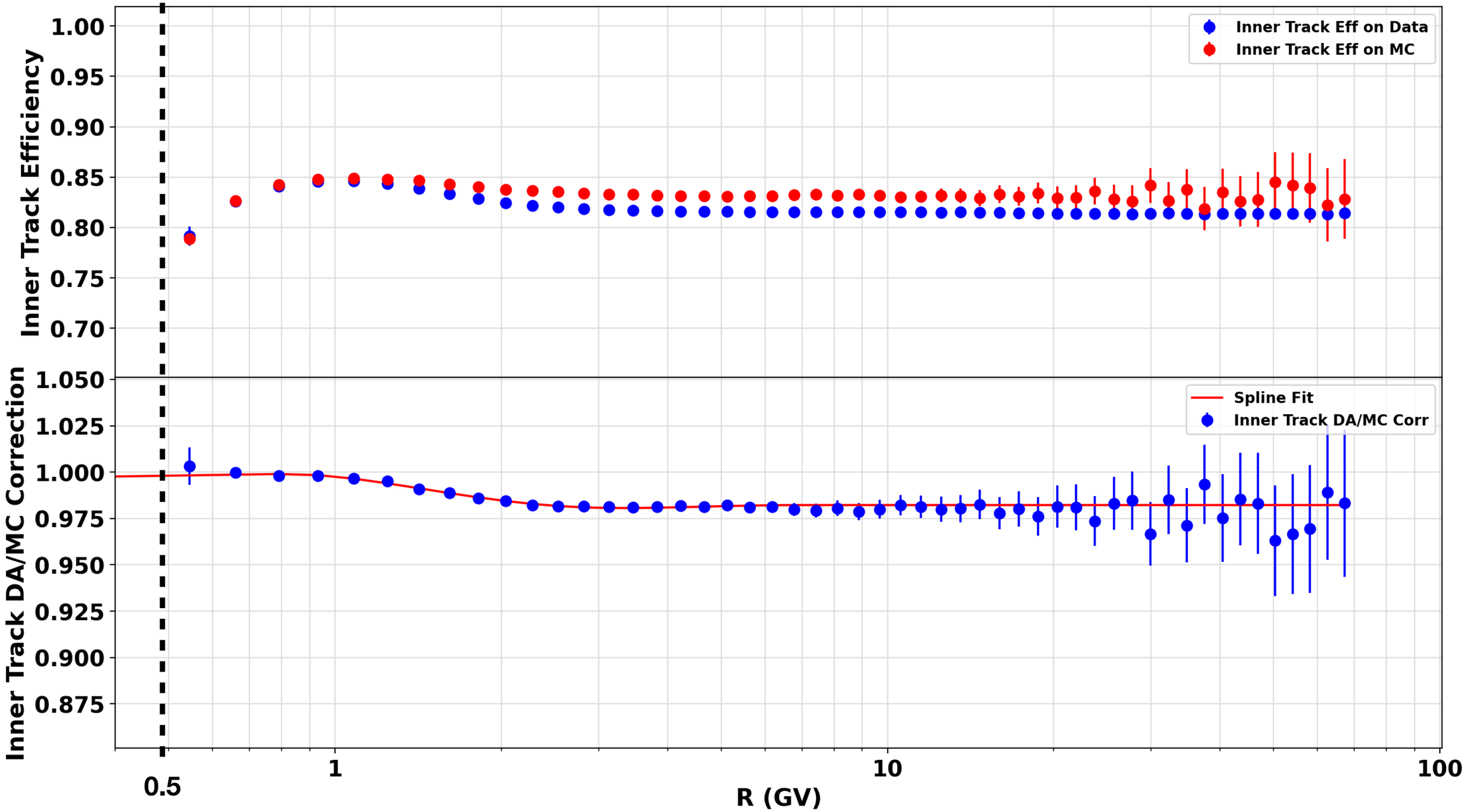
ToF Efficiencies And Correction - [21/05/2011, 28/05/2018]



Trigger Efficiencies And Correction - [21/05/2011, 28/05/2018]

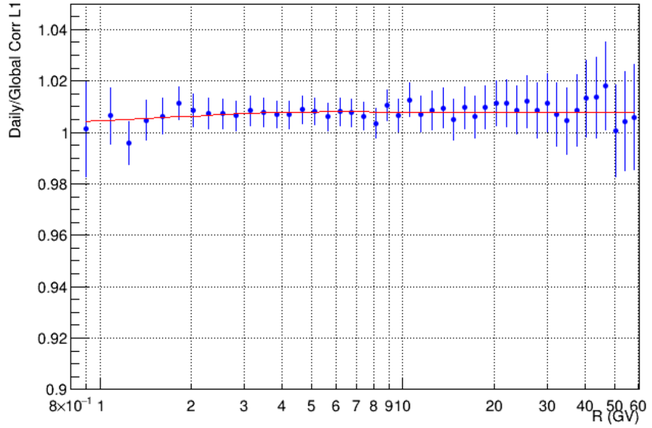


Inner Track Efficiencies And Correction - [21/05/2011, 28/05/2018]



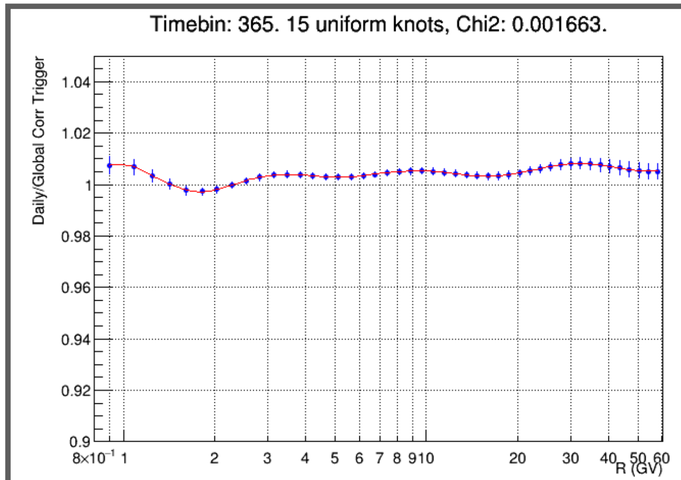
Daily Efficiencies and Corrections

L1, TOF, TRACK



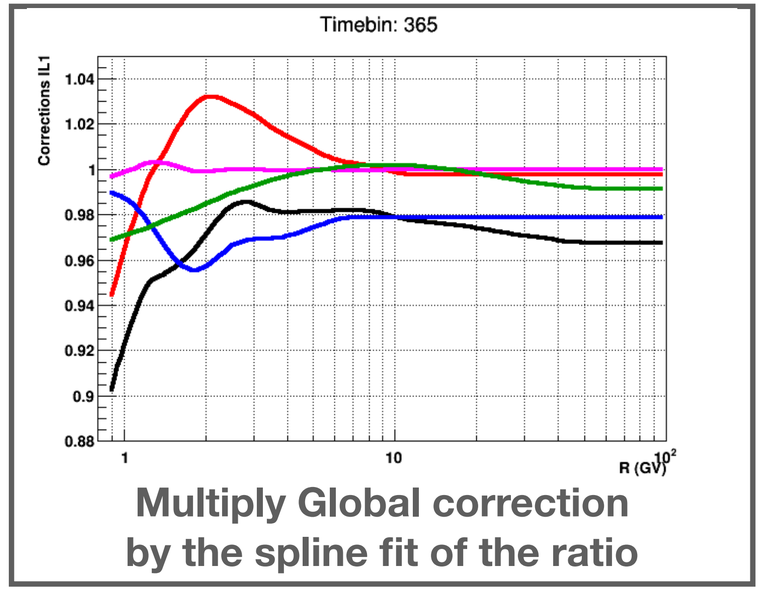
Compute Daily/Global ratio and fit with spline (3 knots) up to 20 GV

TRIGGER



Compute 15Days/Global ratio and fit with spline

Normalise by the daily trigger correction (Pol0 fit)



Multiply Global correction by the spline fit of the ratio

L1
Track
Tof
Trigger
Total

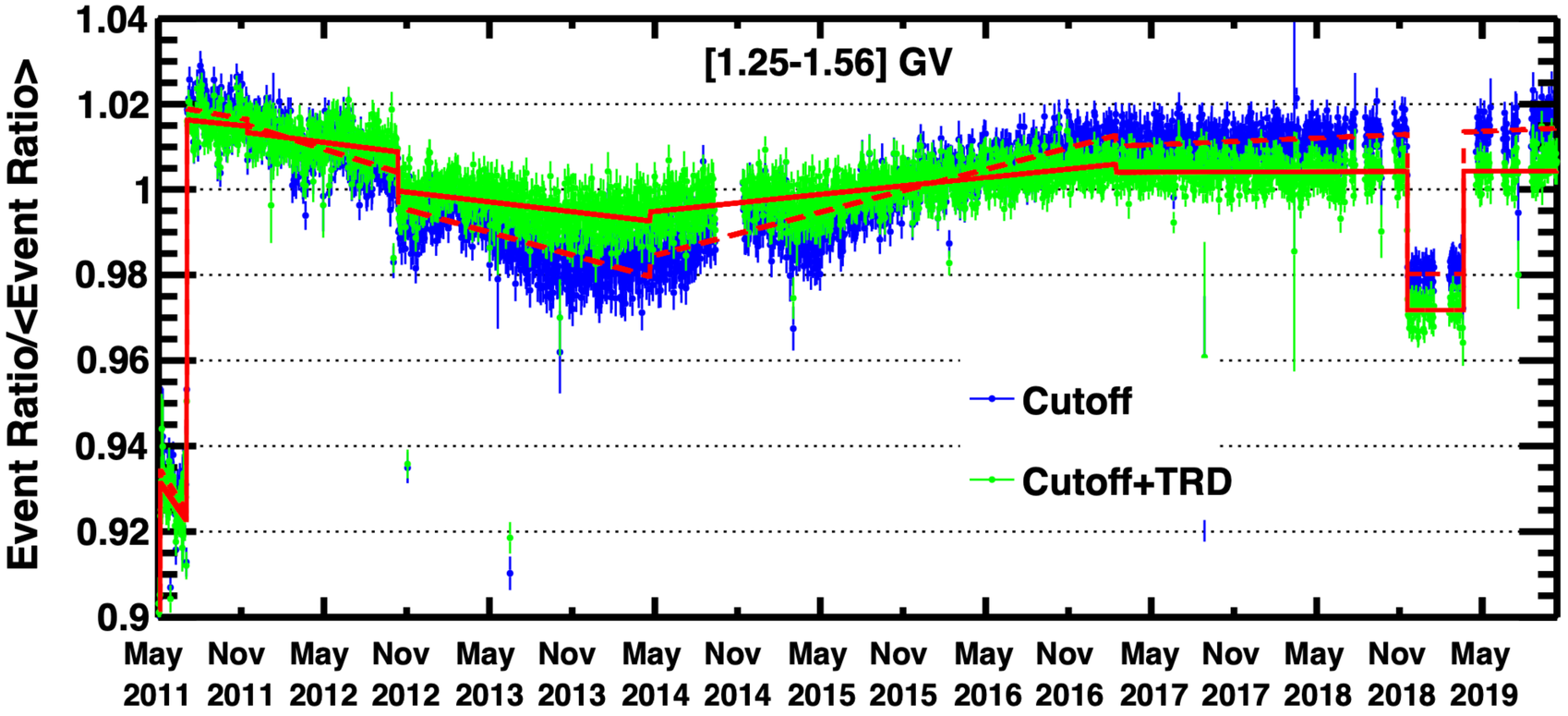
Worst variance and bias

From
YI Jia's
on
Nuclei
Analisys

L1Inner Geometry Proton Event ratio

Event ratio definition: Numerator: L1Inner events after L1Inner selection with inner rigidity
Denominator: Inner events after Inner selection with inner rigidity

Tighter cuts: nTOFClusterH<=4, TOF chis2, TRD, mass cut, ntrack=1, nacc=0



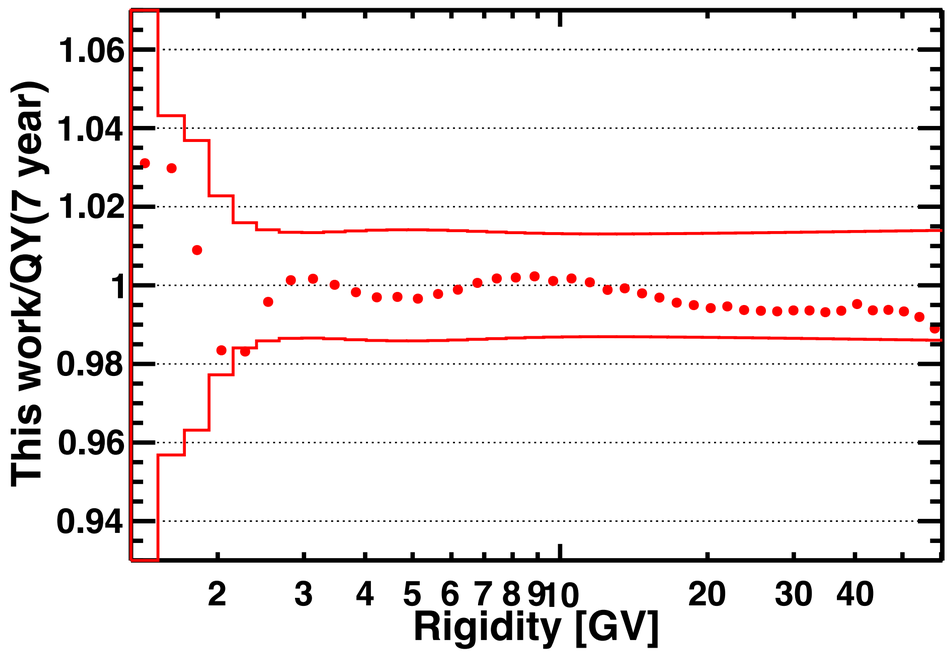
TRD cut: March L1 positions extrapolated from TRD coordinates and tracker track

From YI Jia's on Nuclei Analisys

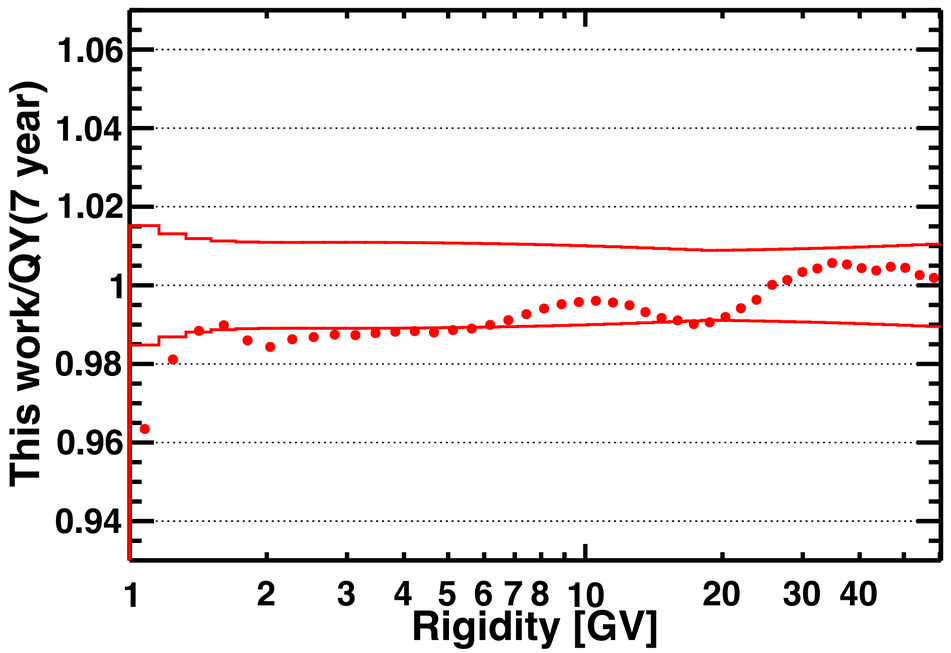
Integrated Flux Comparison

Same period for 7 year flux: May 2011 to May 2018.

Helium



Proton



Integrated by exposure time.