# NEW POLARIZATION ALGORITHM

SQWG PM3
May 2015

P. Liebing, IUP Bremen

# Outline

- Suggestions for changes to polarization algorithm
- Suggestions for changes to polarization correction
- Implications
- Motivation for changes
- Update on the IB signal

# New Algorithm

- Synchronize and integrate 40 Hz PMD data
- Filter for spikes (Limb)
- Mirror model calibration of virtual sum and PMD signal
- Correct unpolarized ratio for IB(solar) and cluster coverage
- Correct unpolarized ratio with additional IB scale factor
- Compute average $\mu_i$(PMD,DET) (IT dependent!)
- Use PMD 4 and 7 iteratively

# New Algorithm

- Other PMDs, Nadir:
  - Retrieve q,u from RTM LUT, calculate RTM polarization angle
  - Compute polarization sensitivity
  - If sensitivity>X: Apply polarization angle algorithm
  - Else if glint: use RTM value directly
  - Else: use u(R) model
    - Use u(RTM) and calibrated reflectance
    - Apply (possibly cos($\theta$) dependent) parameterization
    - Derive q with u(R)

# New Algorithm

- Other PMDs, Limb:
  - Apply u(R) model
    - Use u(RTM) and calibrated reflectance
    - Apply (possibly cos($\theta$), TH, R dependent) parameterization
    - Derive q with u(R)
    - Reflectance should be calibrated iteratively
- Option: Use effective MMEs from in-flight fits rather than V9 key data
- Above TH=$Z_1$: Use q(R), u(R) (at least PMD 5)
- Above TH=$Z_2$: use last values (even and odd TH steps separately)

# Polarization Correction

- In principle as before
- Improve nadir UV parametrization (between ~300 and 370 nm)
  - Use new GOME approach, i.e., parameters as f(O3 column and effective albedo)
  - Needs O3 columns from previous L2
  - RTM for albedo?
- In principle same is necessary for limb, but no rigorous model yet
  - I think it's less dependent on albedo, but more on O3 and aerosol profiles
  - Study needs to be performed
  - Possibly find parametrization based on reflectance (profile)

# Things to do (IUP)

- Describe/document algorithm
- Provide IB scale factor $f(\alpha,t)$
- Optimize X, $Z_1$, $Z_2$
- Provide SCIATRAN data for LUTs
  - At least 2 different ones
    1. Rayleigh (over land)
    2. BRDF (v=7m/s, over ocean)
- Provide slopes for u(R) as tables or parameterization

# Things to do (DLR)

- Implement algorithm
- Build SCIATRAN LUT and interpolation routines
- Optimize PMD synchronization (w/IUP)
- Limb: Spike filter (?)
- Implement Gome-style polarization correction

# Things to do (SRON)

- Improve IB
- Improve key data for limb
- Alternative for limb: use effective MMEs from in-flight fits
  - Provided by IUP as f($\alpha$,t)

# Motivation For New Algorithm

- For channels 2,3,4 and 6 we only measure 1 Stokes component, but need 2
  - That 1 component is not in the direction we need (i.e., q)
- Need to make assumptions about the polarization angle
- Depending on assumptions and algorithm, large errors can be generated when the polarization angle is in the direction where "*instrument*" is not sensitive
  - That happens more often than you think

# Current Polarization Algorithm

$$R = \frac{S^{PMD}}{S^{DET}}, R = \frac{1 + \mu_2^{PMD} q + \mu_3^{PMD} u}{1 + \mu_2^{DET} q + \mu_3^{DET} u}$$

- Original L0-1 algorithm:

$$R = \frac{1 + \mu_2^{PMD} q \left(1 + \frac{u_0}{q_0} \mu_3^{PMD}\right)}{1 + \mu_2^{DET} q \left(1 + \frac{u_0}{q_0} \mu_3^{DET}\right)} = \frac{1 + \mu^{PMD*} q}{1 + \mu^{DET*} q} \Rightarrow u = q \frac{u_0}{q_0}$$

$$q = \frac{1 - R}{R \mu_2^{DET*} - \mu_2^{PMD*}}$$

- Problem when denominator small and/or $u_0/q_0$ large or $q_0$ small

# New Polarization Algorithm

$$R = \frac{S^{PMD}}{S^{DET}}, R = \frac{1 + \mu_2^{PMD} q + \mu_3^{PMD} u}{1 + \mu_2^{DET} q + \mu_3^{DET} u}$$

- Change polarization frame so that u=0 (assumes known polarization angle)
- Rotate MM:

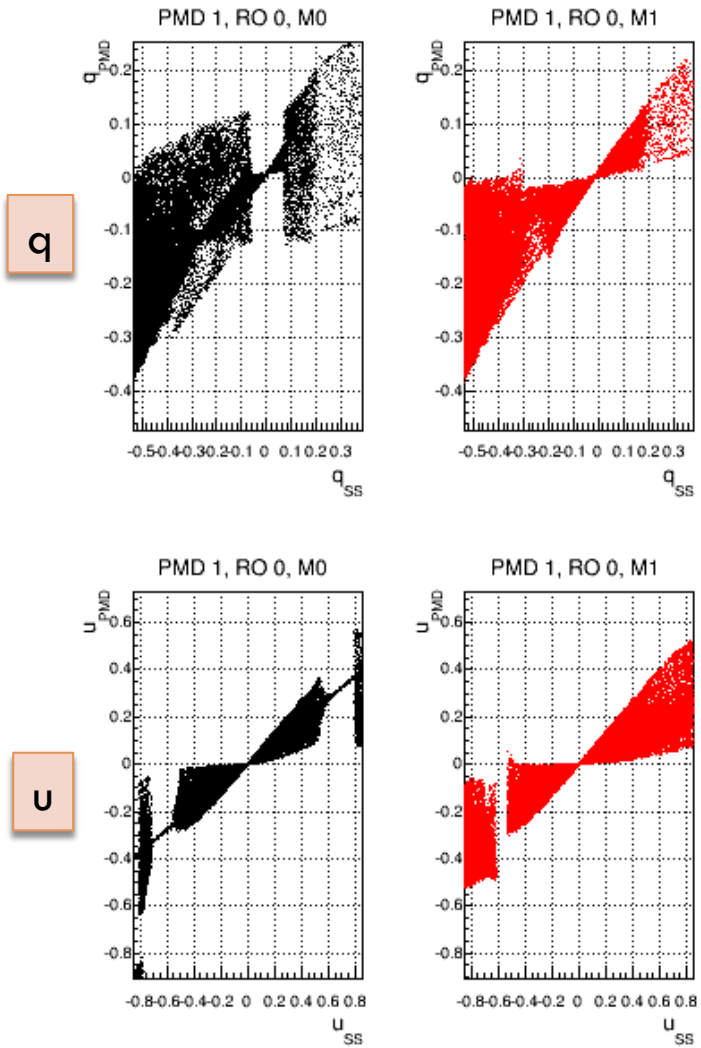
$$\mu_2^{PMD,DET*} = \mu_2^{PMD,DET} \cos(2\chi) + \mu_3^{PMD,DET} \sin(2\chi), \chi = \tan^{-1}\left(\frac{u_0}{q_0}\right)$$

$$R = \frac{1 + \mu_2^{PMD*} q^*}{1 + \mu_2^{DET*} q^*} \Rightarrow q = q^* \cos(2\chi), u = q^* \sin(2\chi)$$

$$q^* = \frac{1 - R}{R\mu^{DET*} - \mu^{PMD*}}$$

- Problem when denominator small (i.e., no polarization sensitivity in this direction)

# Compare Algorithms: PMD 1, Nadir




- q(u)(PMD) vs. q(u) (single scat.)
- For new method: $|\mu^*|>0.1$
- Current L0-1 method, slightly modified, with V9 KD
- New method, with V9 KD
- New method, with V9 KD corrected for unpolarized scale factor (IB-signal)

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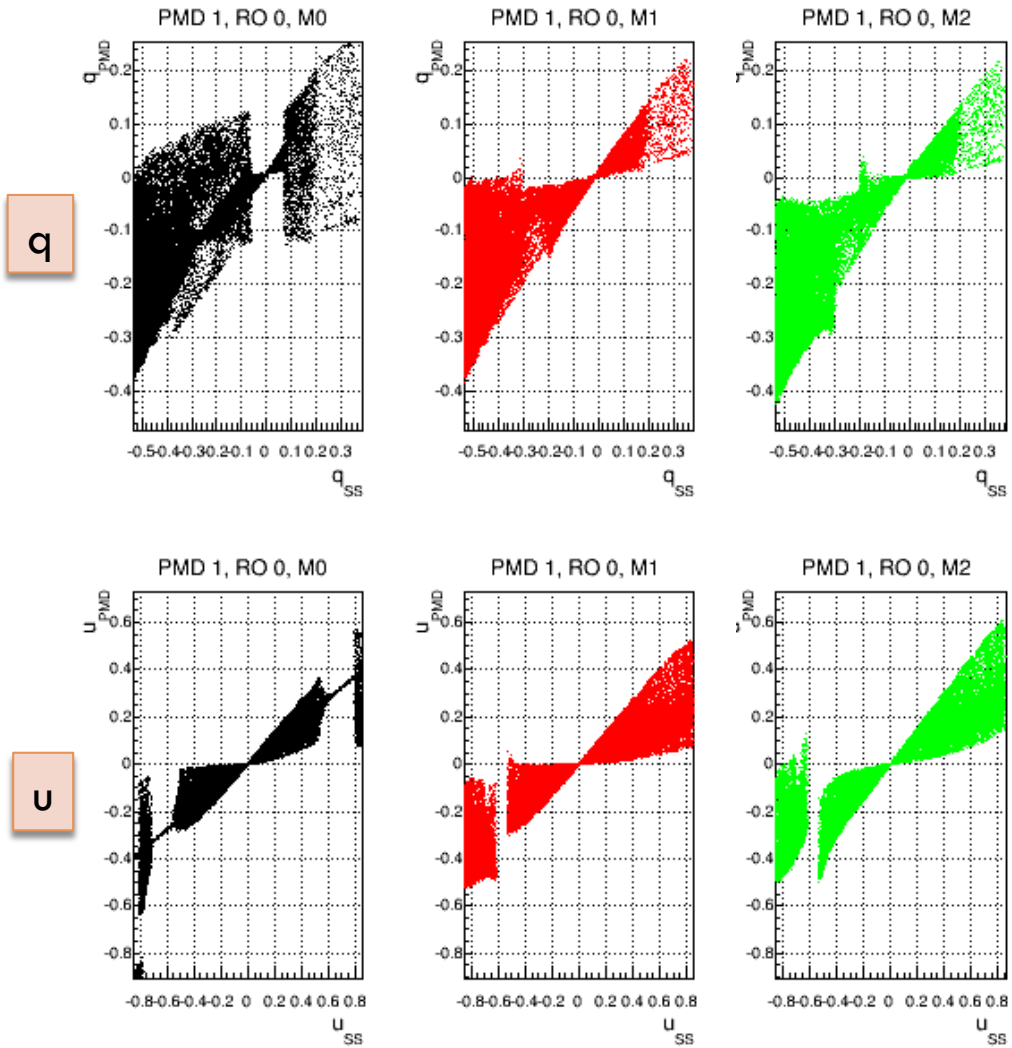


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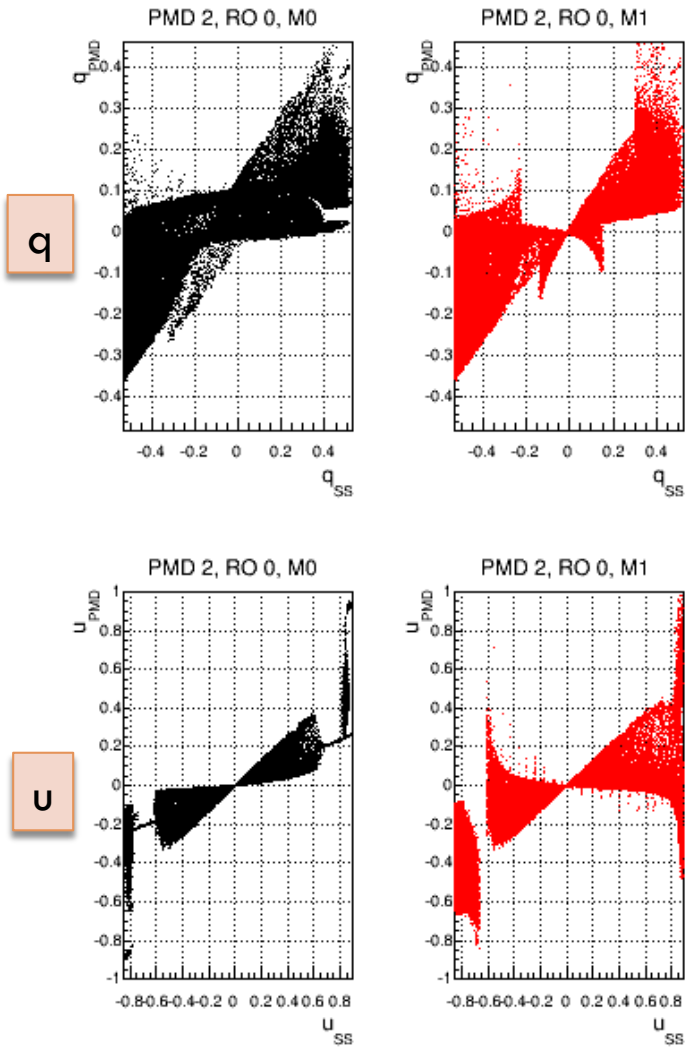


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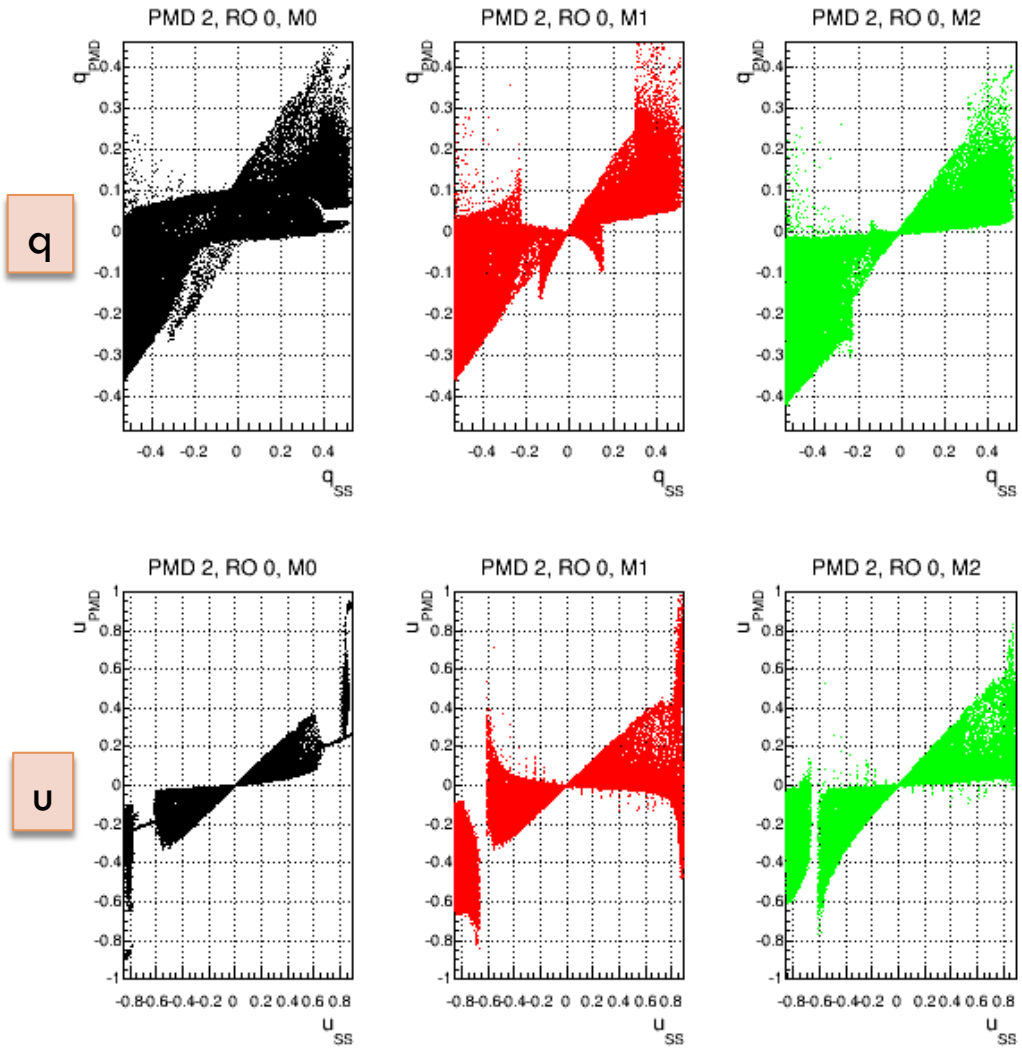


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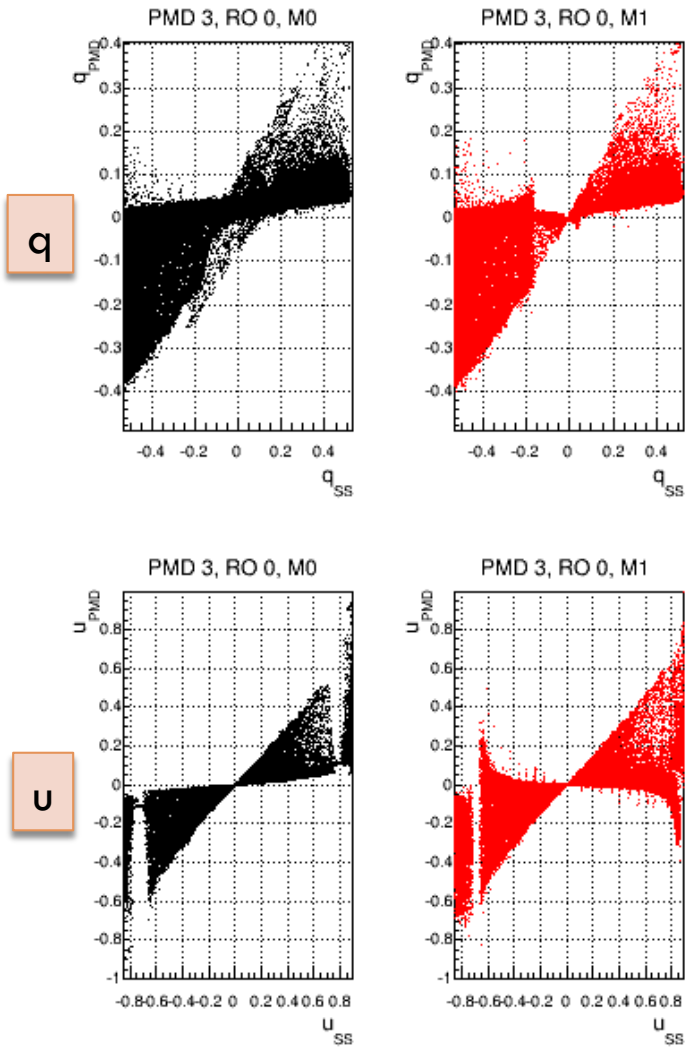


- q(u)(PMD) vs. q(u) (single scat.)
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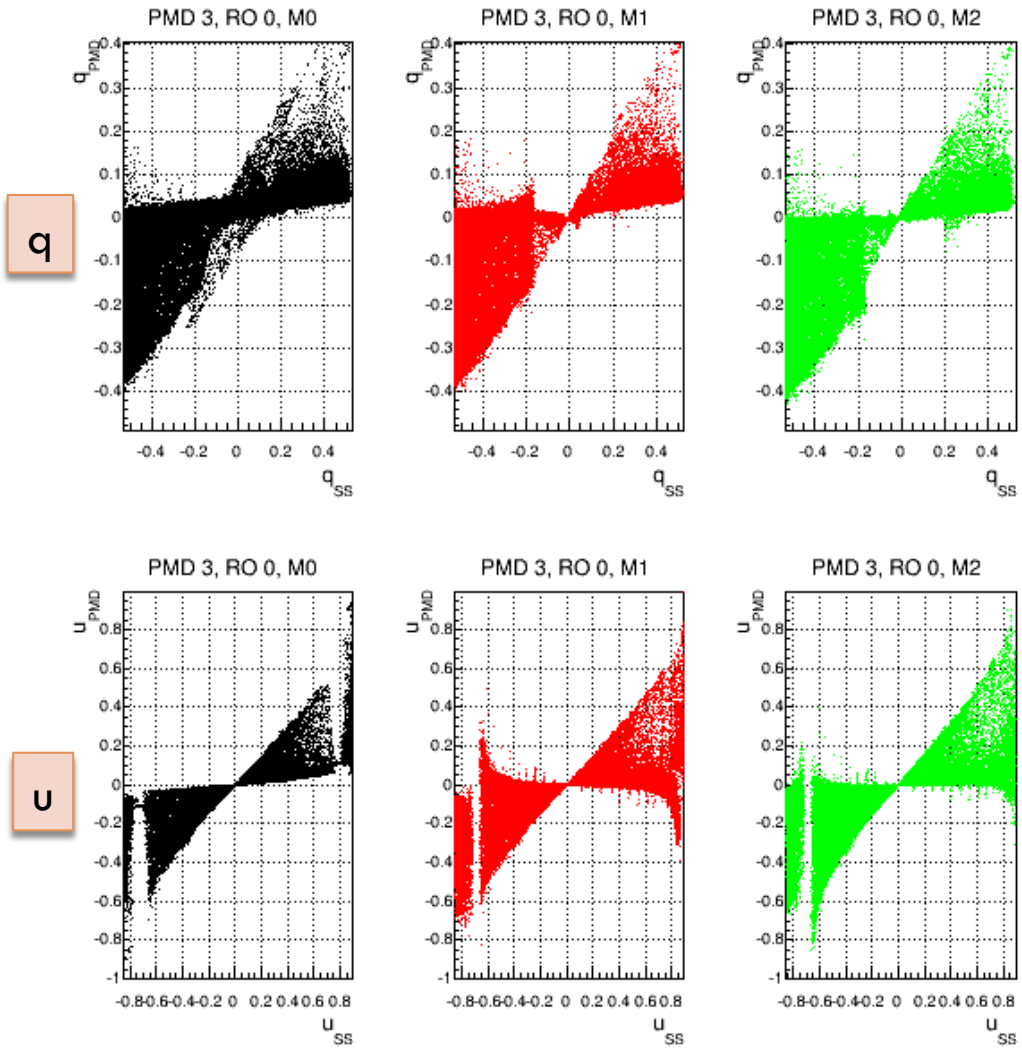


- q(u)(PMD) vs. q(u) (single scat.)
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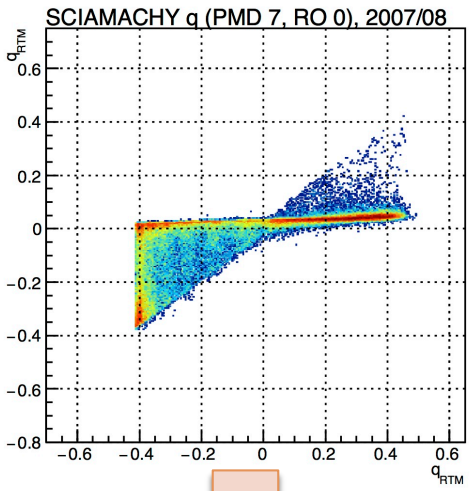
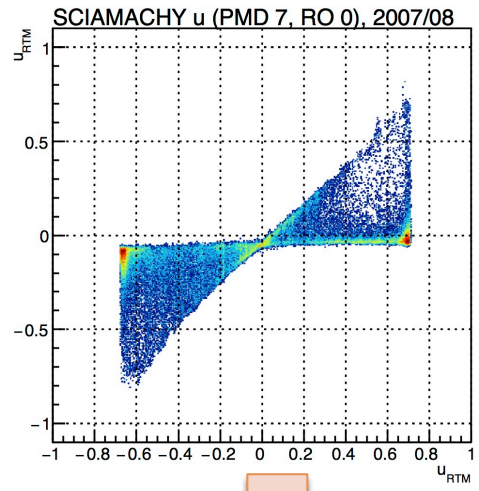
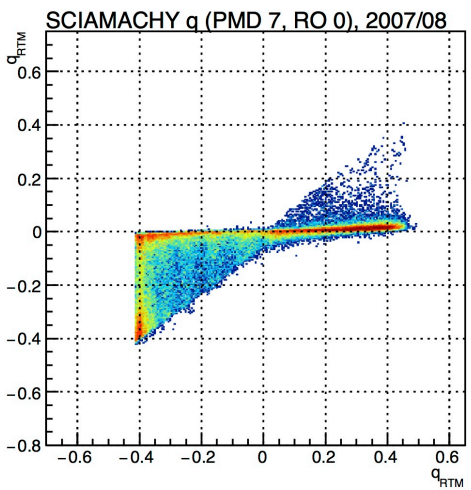
# PMD 4/7 Iteration

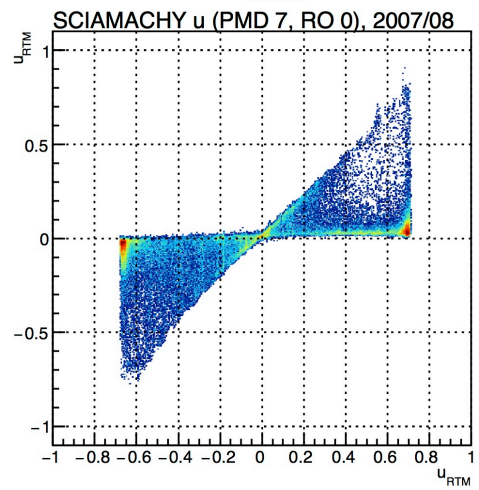



q




u




- q(u)(PMD) vs. q(u) (BRDF)
- Color scale = statistics
- Top: with V9 KD
- Bottom: with V9 KD corrected for unpolarized scale factor (IB-signal)

# Nadir Summary

- Polarization angle algorithm improves both q and u for data with large enough sensitivity
- Other data have to be treated differently:
  - Apply a model for u as a function of reflectance
- In any case, for reference RTM data are necessary:
  - IUP can provide SCIATRAN data, which need to be converted into a LUT to give q, u, and intensity for any given viewing geometry (interpolation+extrapolation may be necessary)
- Wrong unpolarized calibration can generate large artifacts
  - In-Band signal needs to be corrected
  - Time and scan angle dependent correction factor to be provided by IUP

# Limb?

- Polarization angle method does not work for limb
- MMEs are not accurate enough
- Polarization angle is not known well enough
  - Depends on atmospheric composition
- PMD sensitivities + limb geometry result in almost complete polarization insensitivity over most of the orbit for PMDs 1,2

# Alternative for Limb and Insensitive Nadir Regions

- Assume a value for u, e.g., u=u(R)

$$u(R) = \frac{u_{RTM}}{1 + pR}, R = \frac{I / I_0}{(I / I_0)_{RTM}} - 1, p > 0$$

  - P fixed between 0.5 -1.5 or as f(R, TH, cosθ)
- Can in be applied in nadir for data with low sensitivity, too
  - Use PARASOL slopes (?)
  - Possibly slopes derived from yet another fit method of mine
    - That would need yet another RTM reference for thick clouds

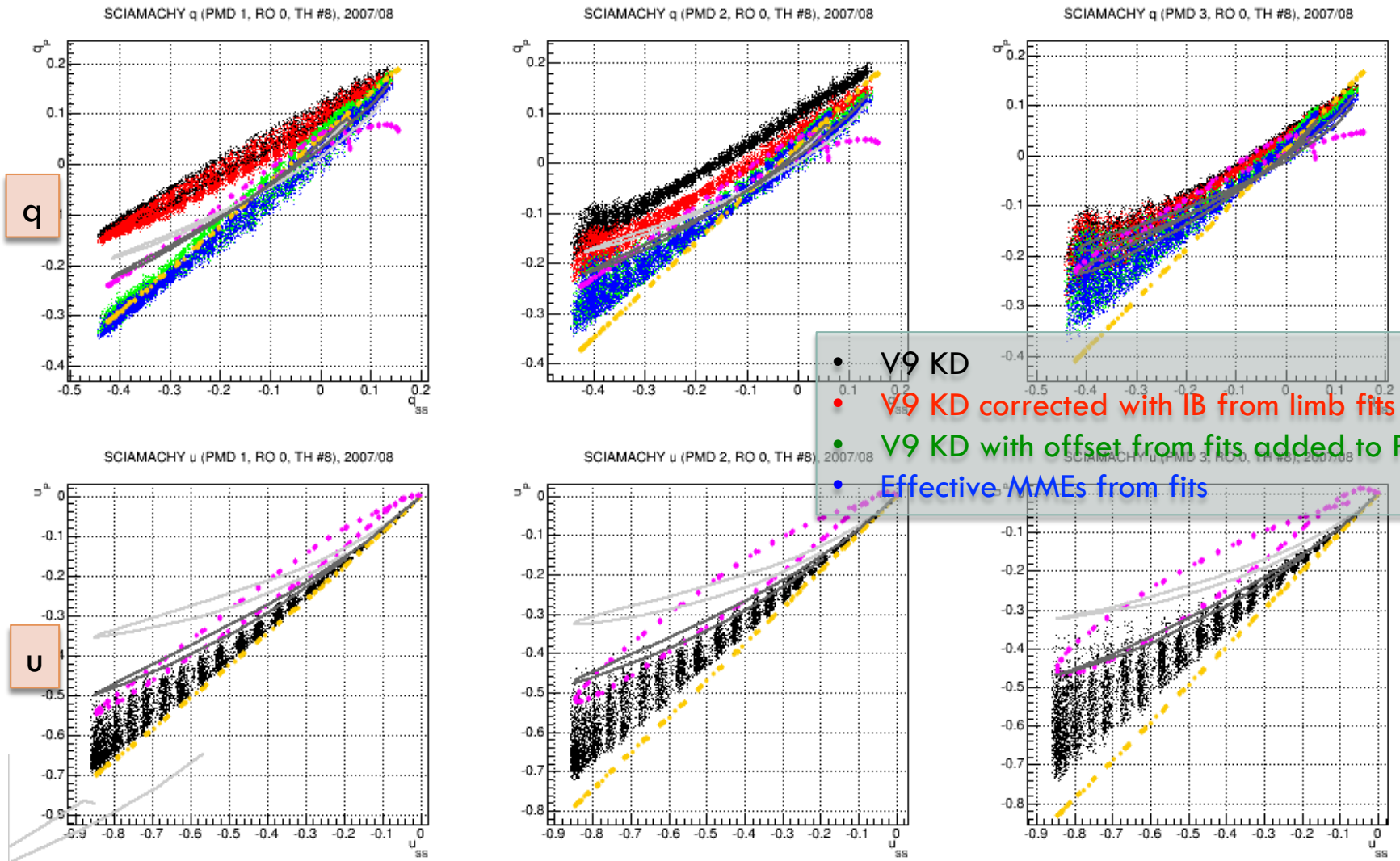
# Limb MMEs

- There are still significant differences between V9 and fits to RTM
- Highly collinear data
- Fits to RTM very model dependent
- Which are the correct MMEs?
  - Check retrieved polarization
- To apply effective MMEs from in-flight fits:

$$R = 1 + \mu_2^{Eff} q + \mu_3^{Eff} u$$

  - For polarization correction, V9 KD have to be trusted

# Limb Compared to RTM, TH=28




- V9 KD
- V9 KD corrected with IB from limb fits
- V9 KD with offset from fits added to PMDs
- Effective MMEs from fits



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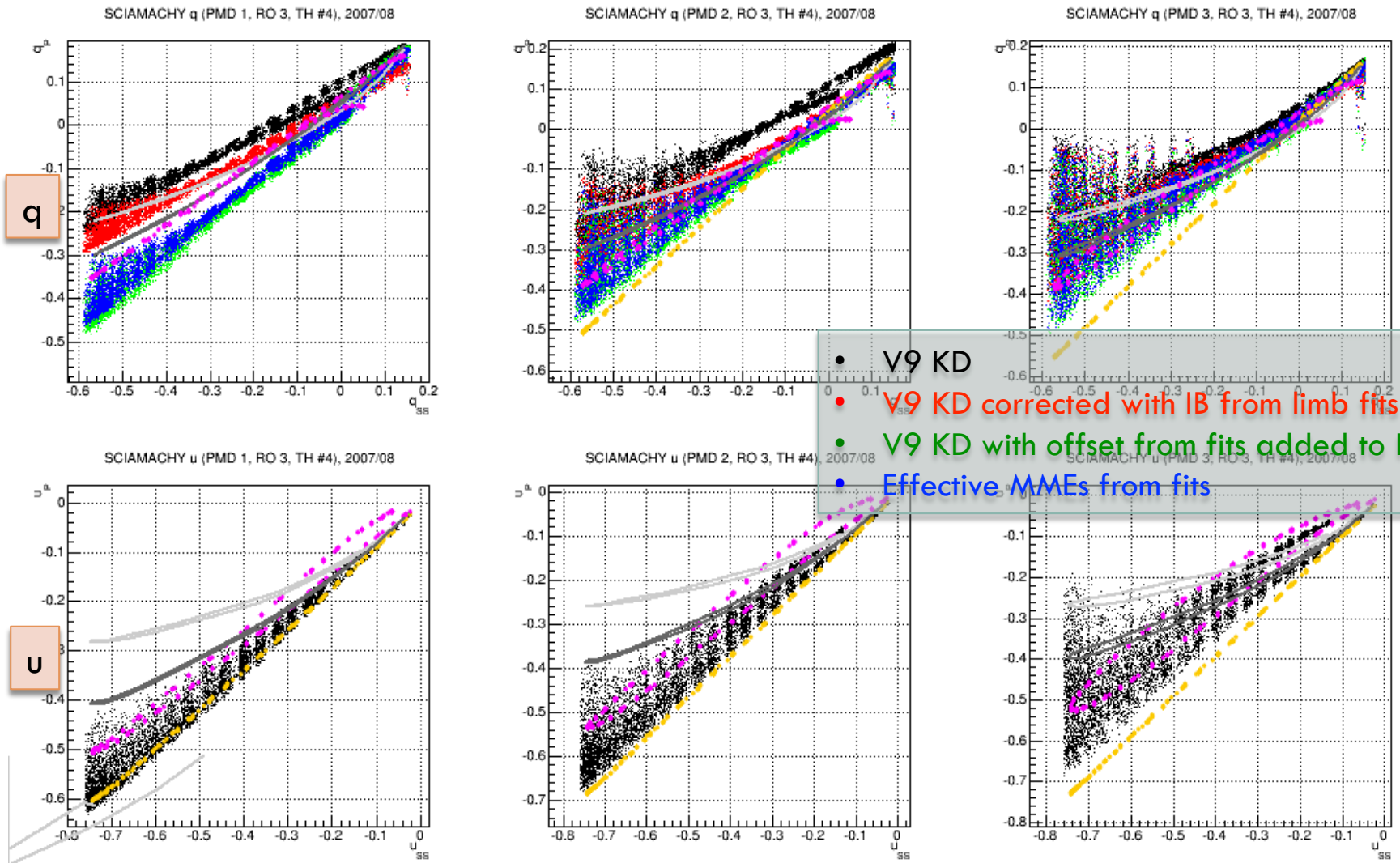
# Limb Compared to RTM, TH=15 km




- V9 KD
- V9 KD corrected with IB from limb fits
- V9 KD with offset from fits added to PMDs
- Effective MMEs from fits



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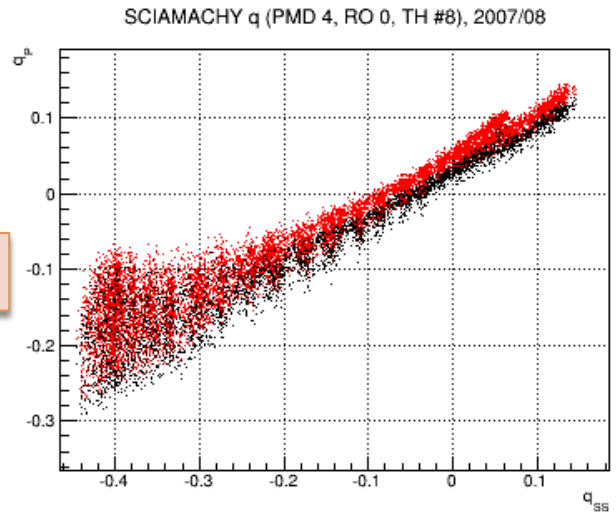
# Limb PMD4/7 Iteration, TH=28 km

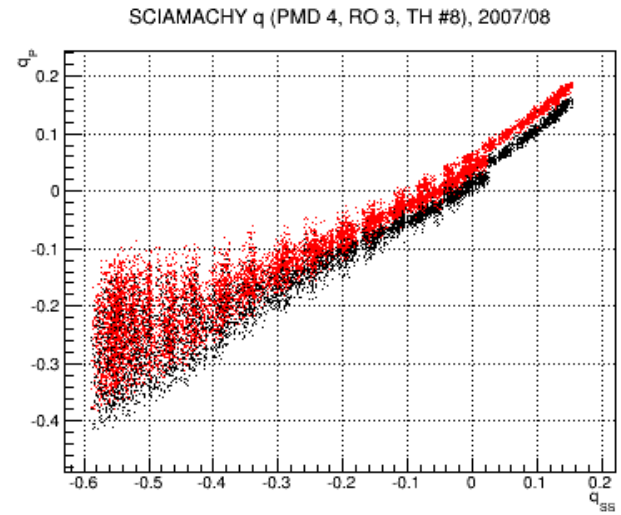
q

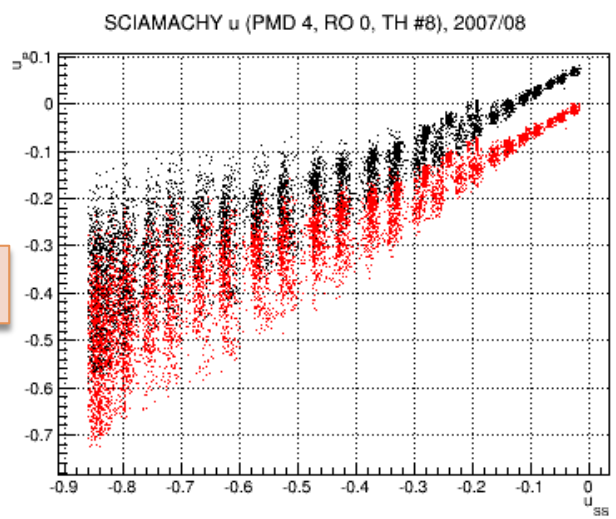
u

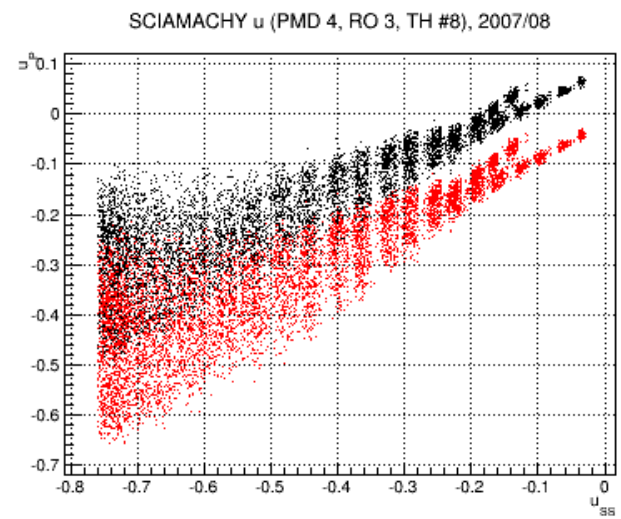
Iter

Iter*$IB_{FIT}$

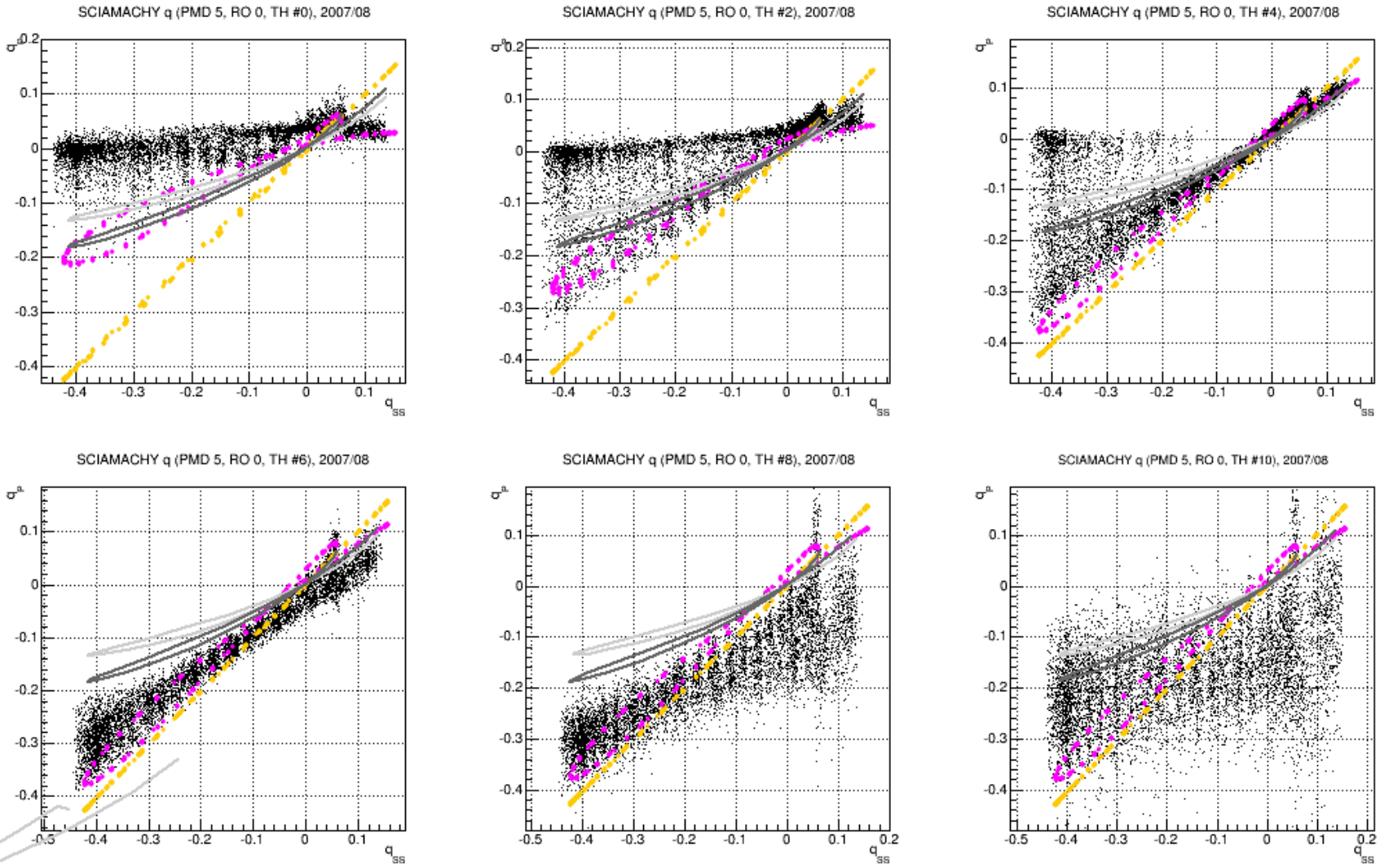


# Limb PMD5, TH -5-28 km



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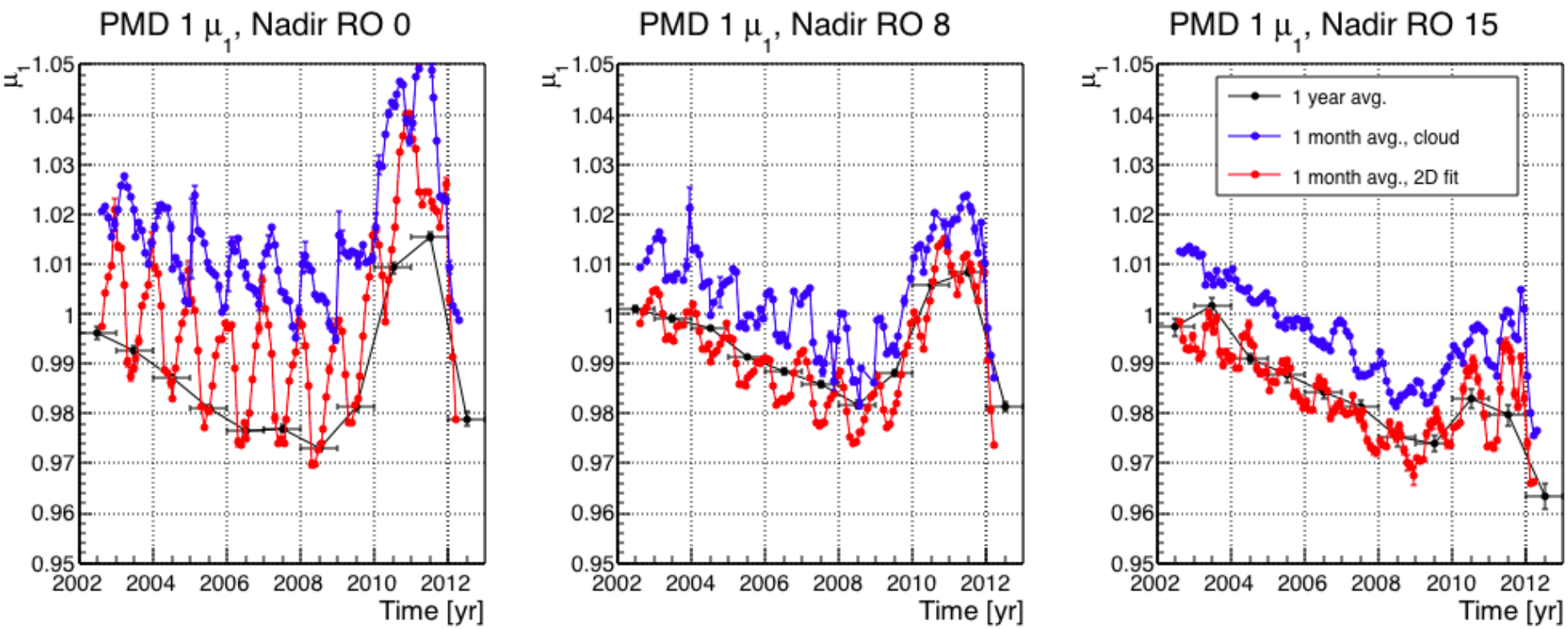
# Limb Summary

- With V9 KD, polarization from PMDs 1,2,3 severely underestimated
- u(R) model works ok
- Optimization possible
  - LUT of u(R,TH,cos($\theta$))
- Again input from RTM necessary
- It seems impossible to retrieve a model-independent IB correction factor
- PMD 4 and 7 have (possibly TH dependent) In-Band signals in limb
  - Significant offsets when uncorrected
- IB of other PMDs also offset, but effect is less obvious

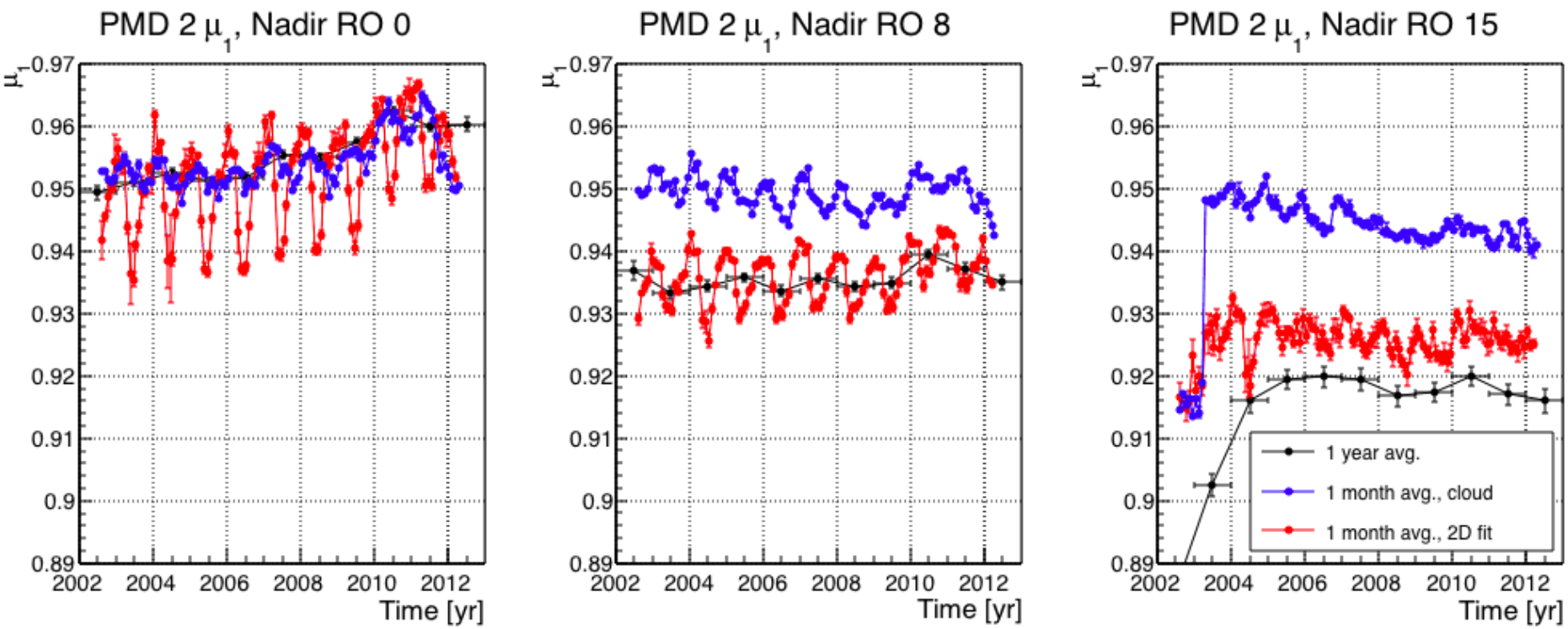
# Schedule? Just One Example: IBs

- PMD 1 IB correction factor vs. time



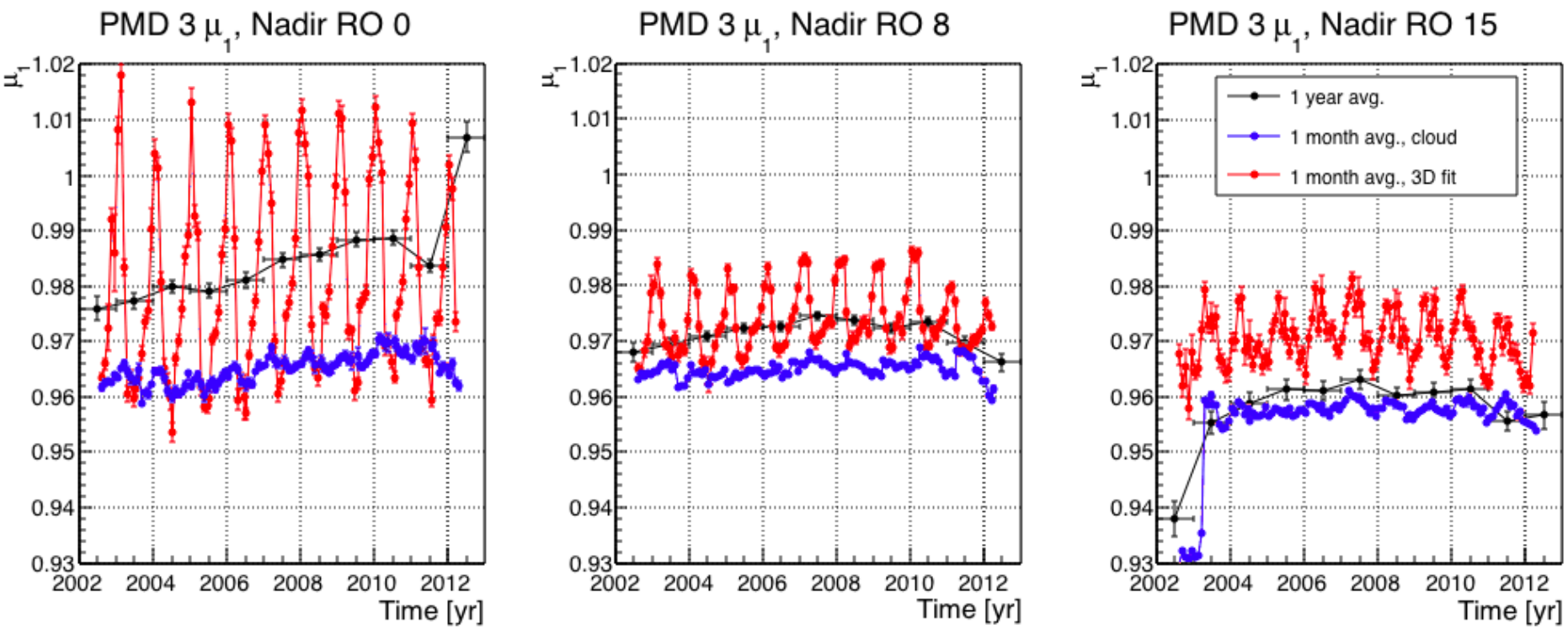
# Schedule? Just One Example: IBs

- PMD 2 IB correction factor vs. time



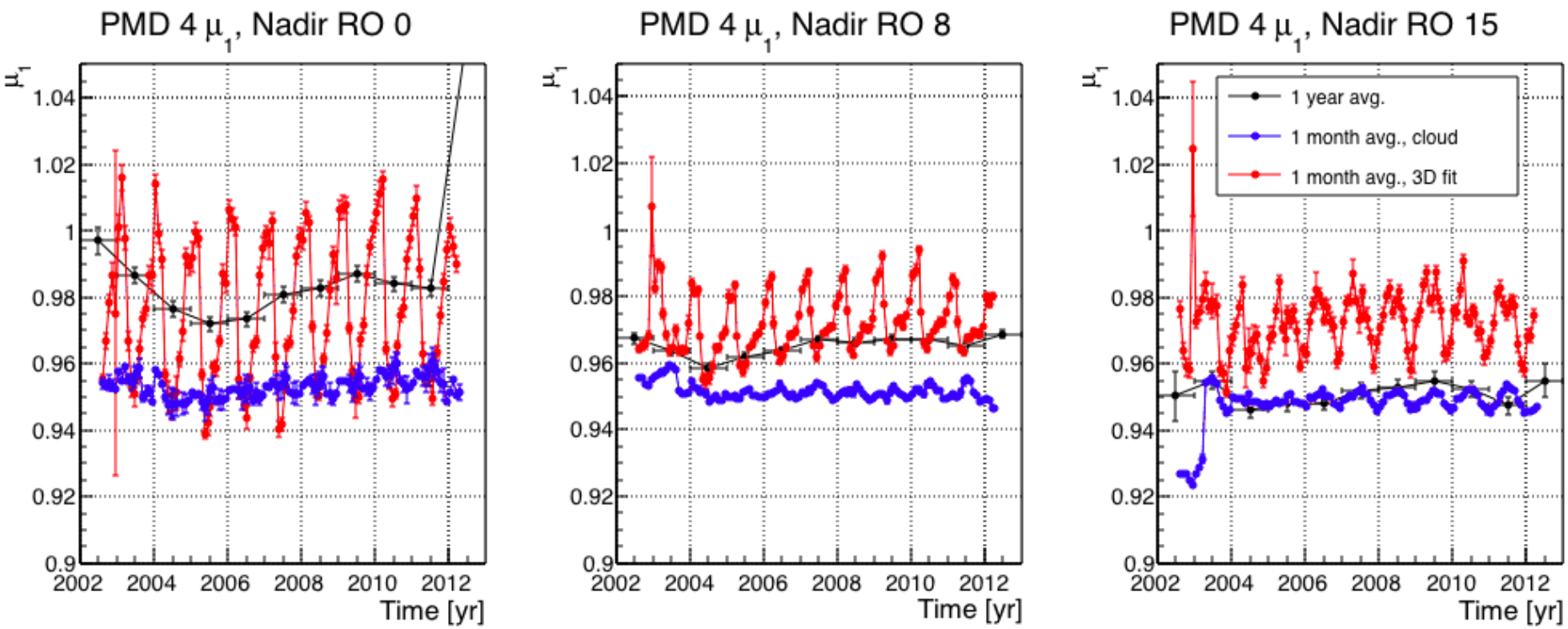
# Schedule? Just One Example: IBs

- PMD 3 IB correction factor vs. time



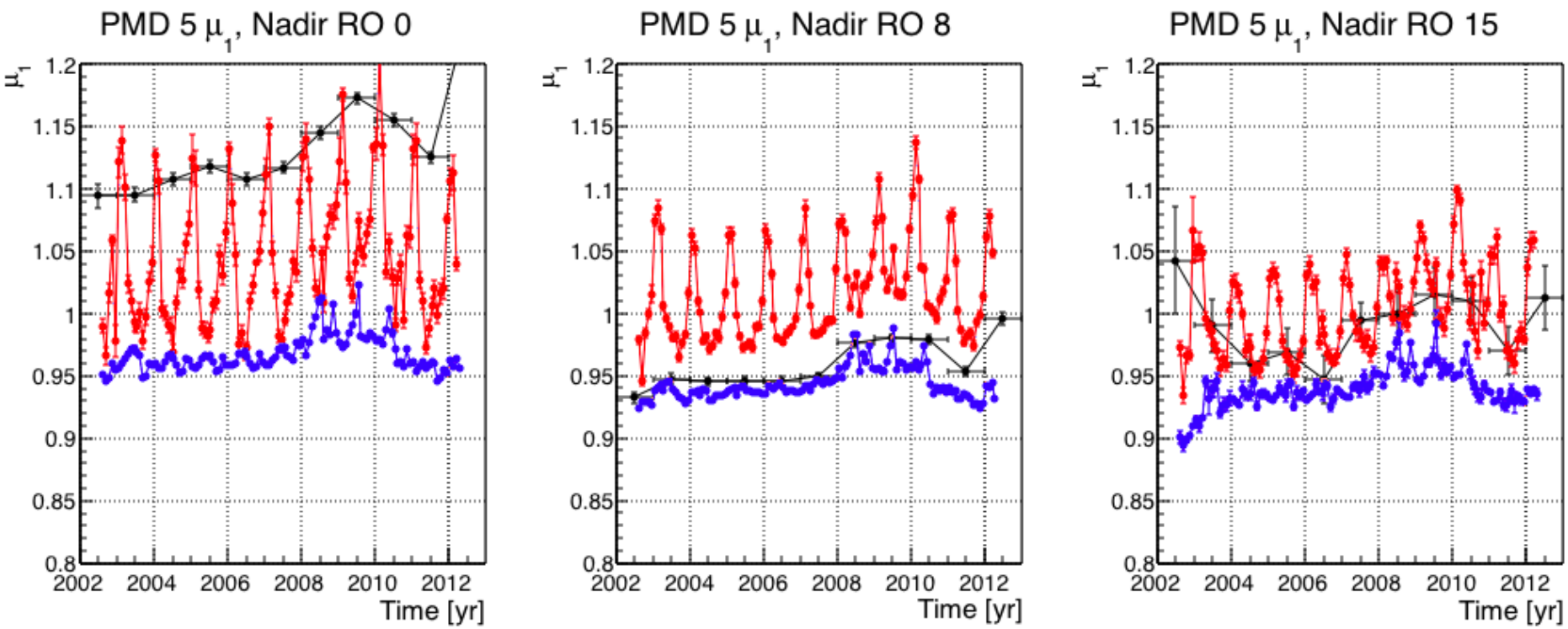
# Schedule? Just One Example: IBs

- PMD 4 IB correction factor vs. time



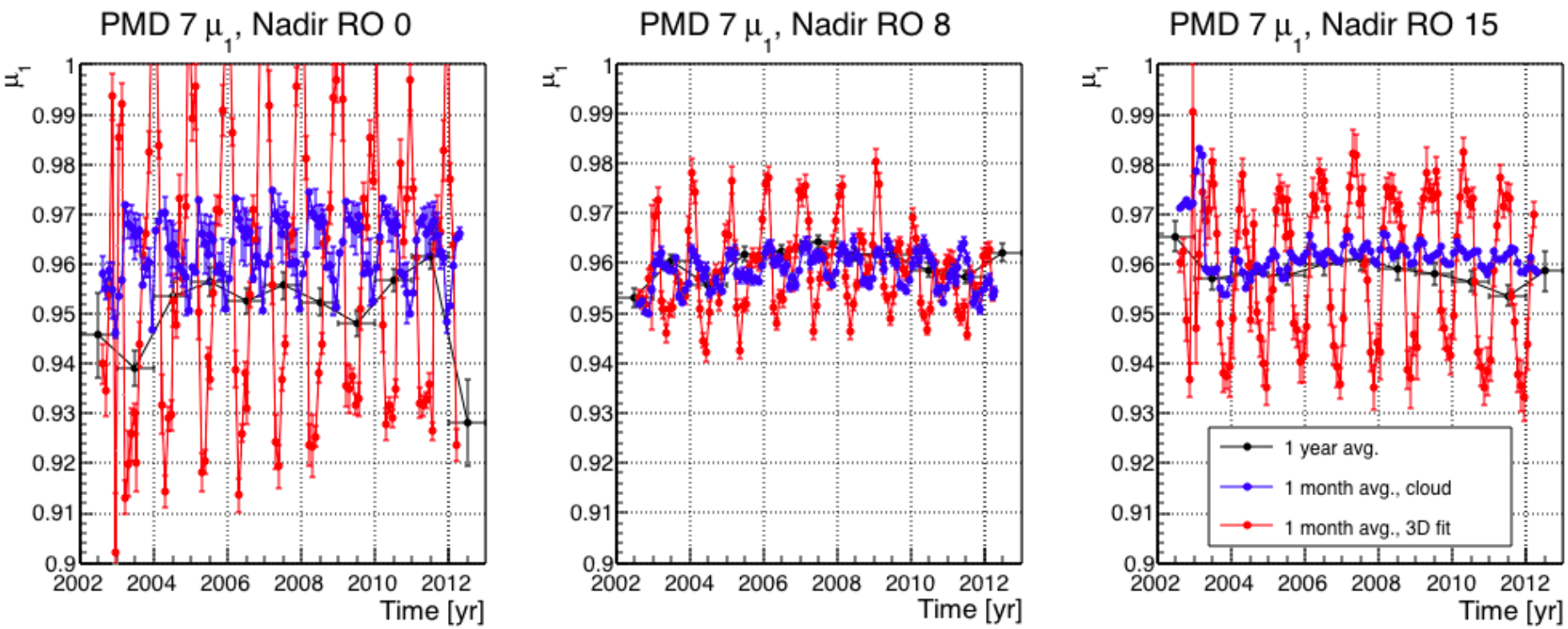
# Schedule? Just One Example: IBs

- PMD 5 IB correction factor vs. time



# Schedule? Just One Example: IBs

- PMD 7 IB correction factor vs. time



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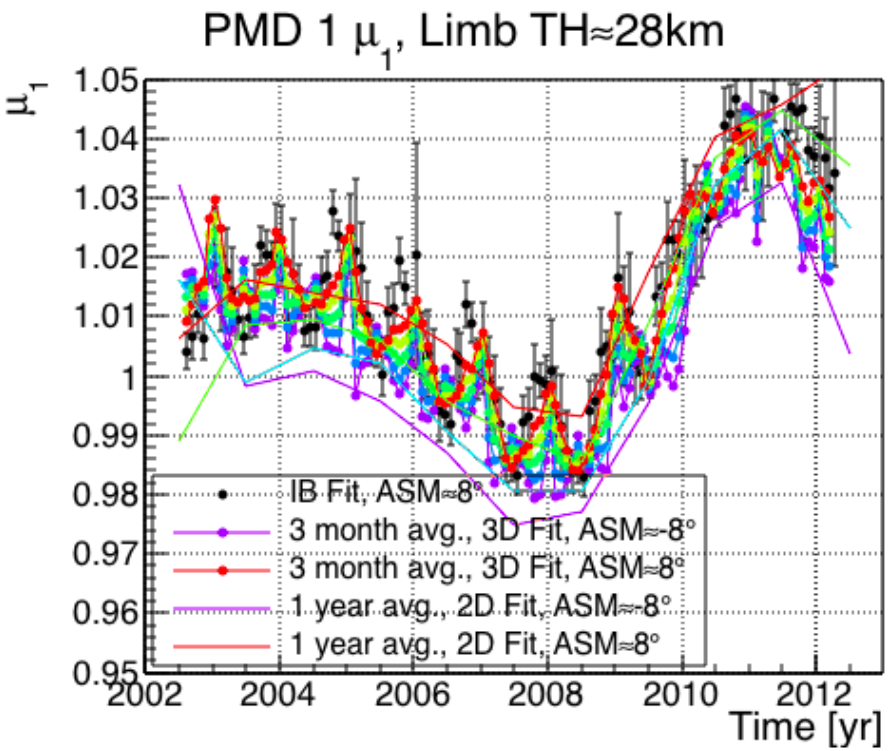
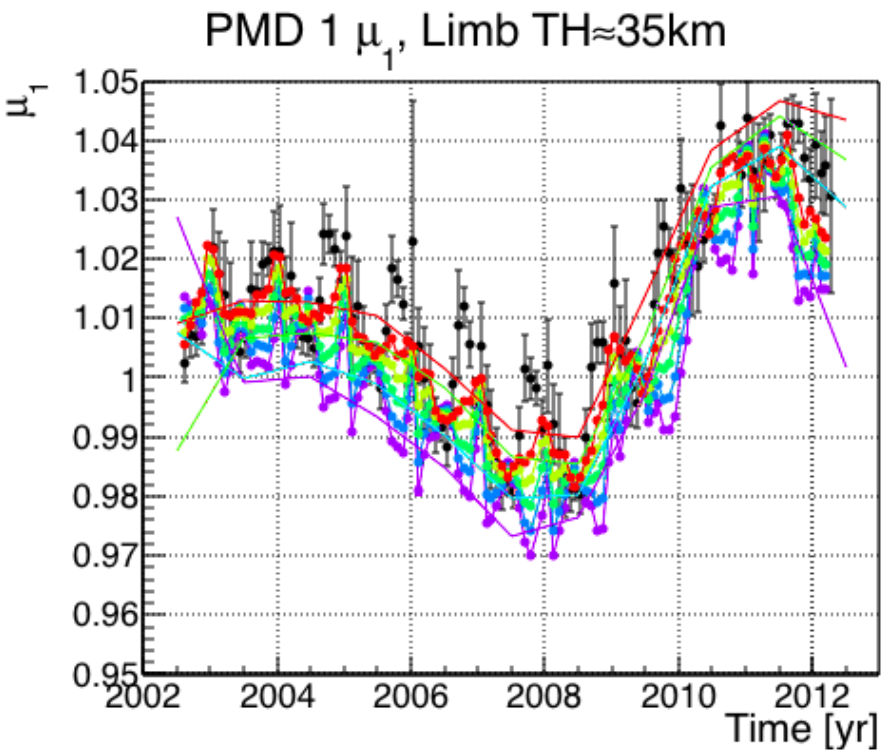
- PMD 1 IB correction factor vs. time (Limb vs. Nadir)



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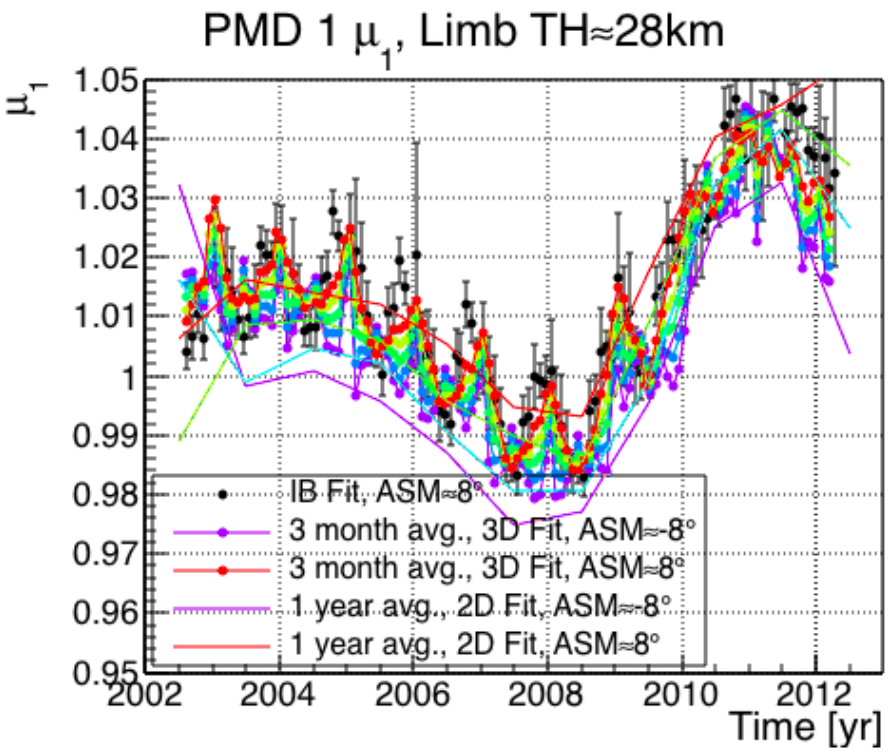


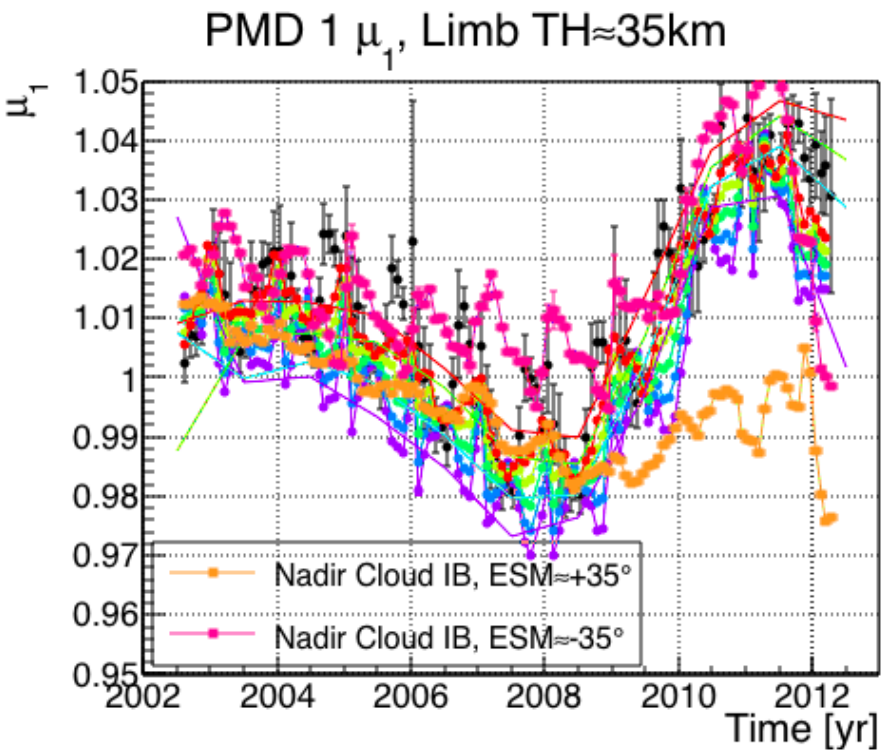

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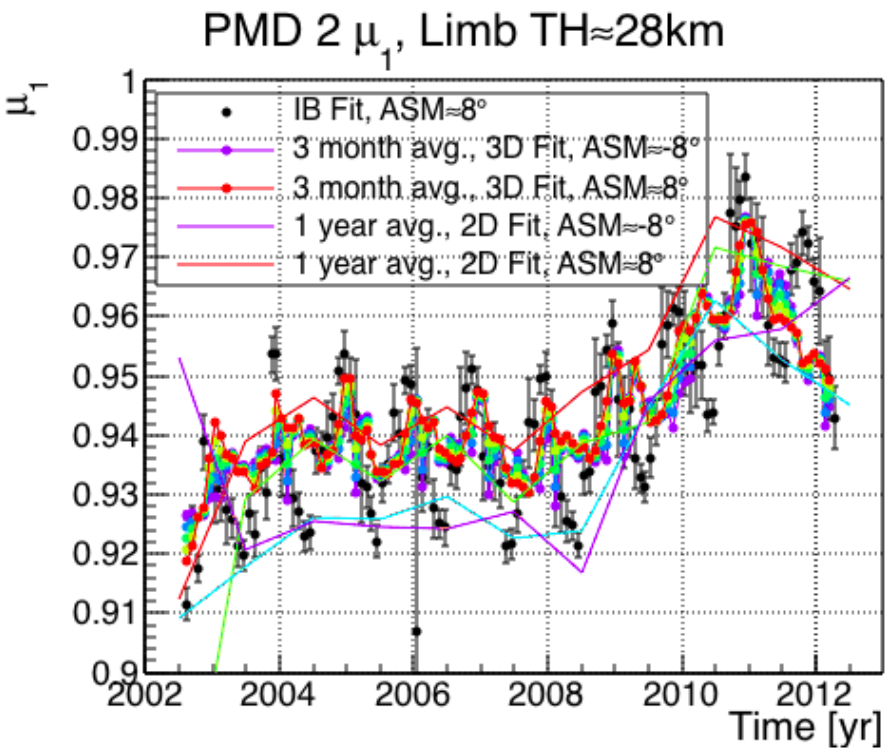


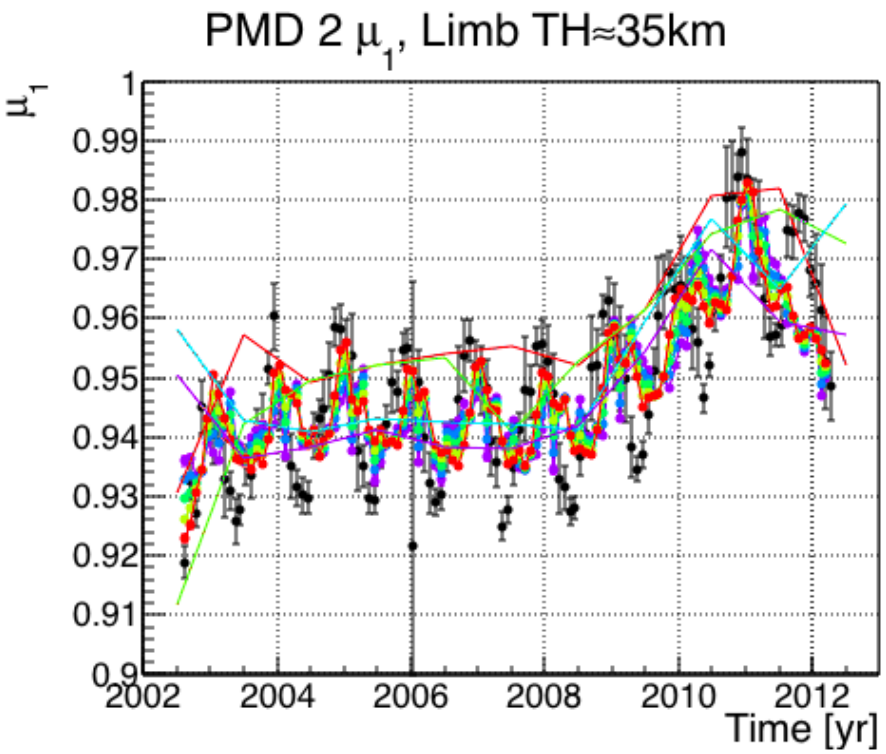

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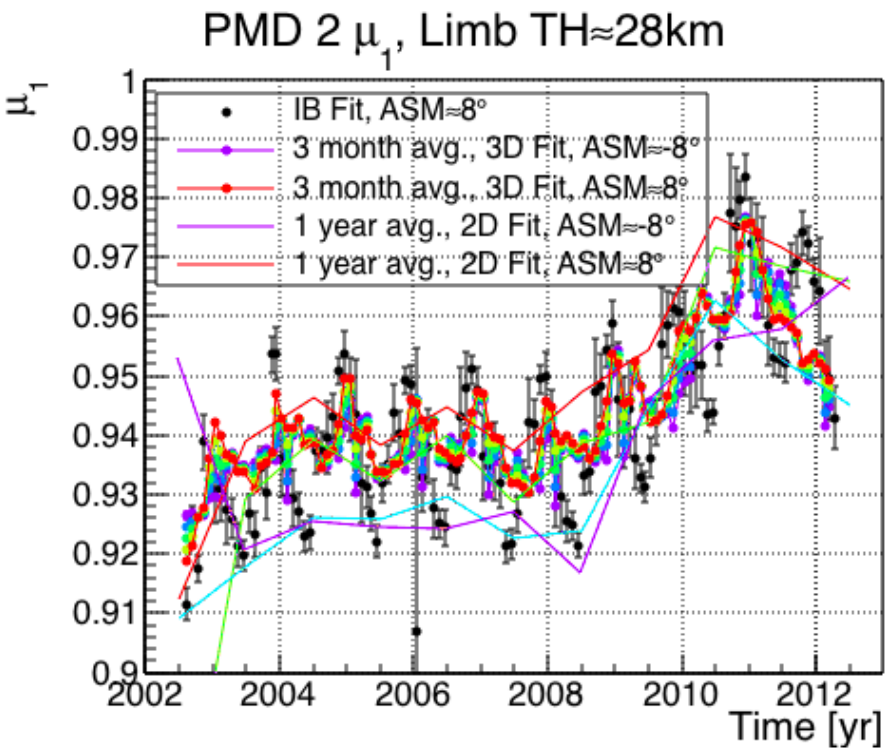


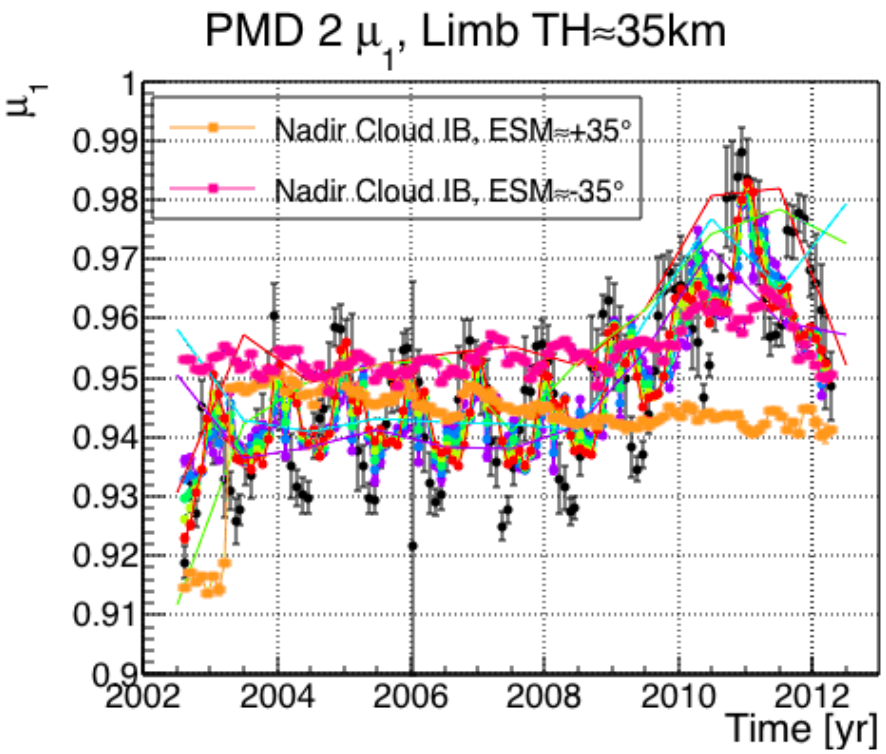

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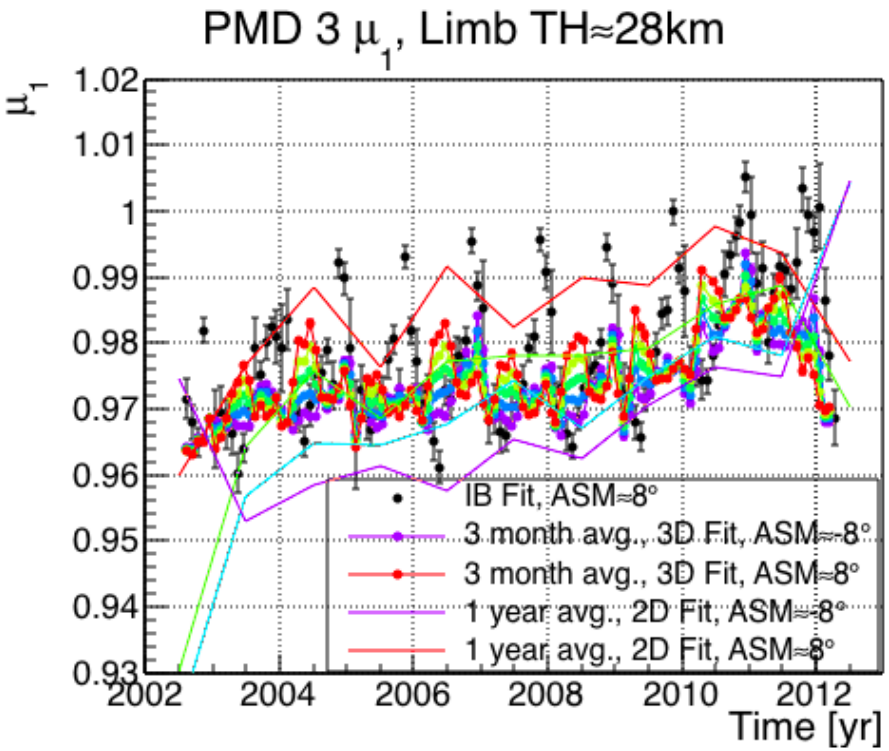
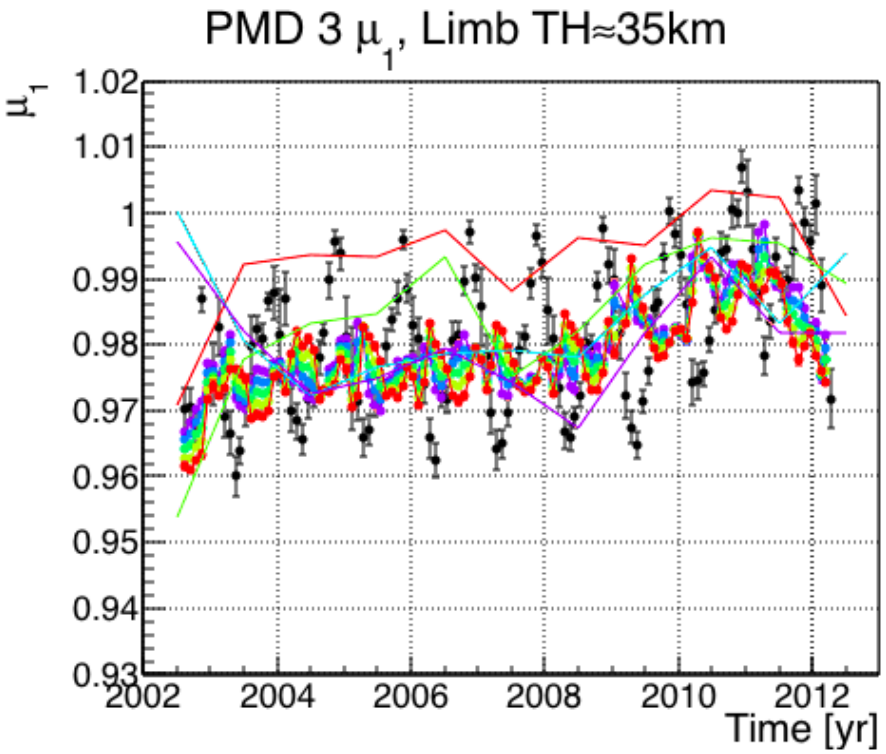
- PMD 3 IB correction factor vs. time (Limb vs. Nadir)



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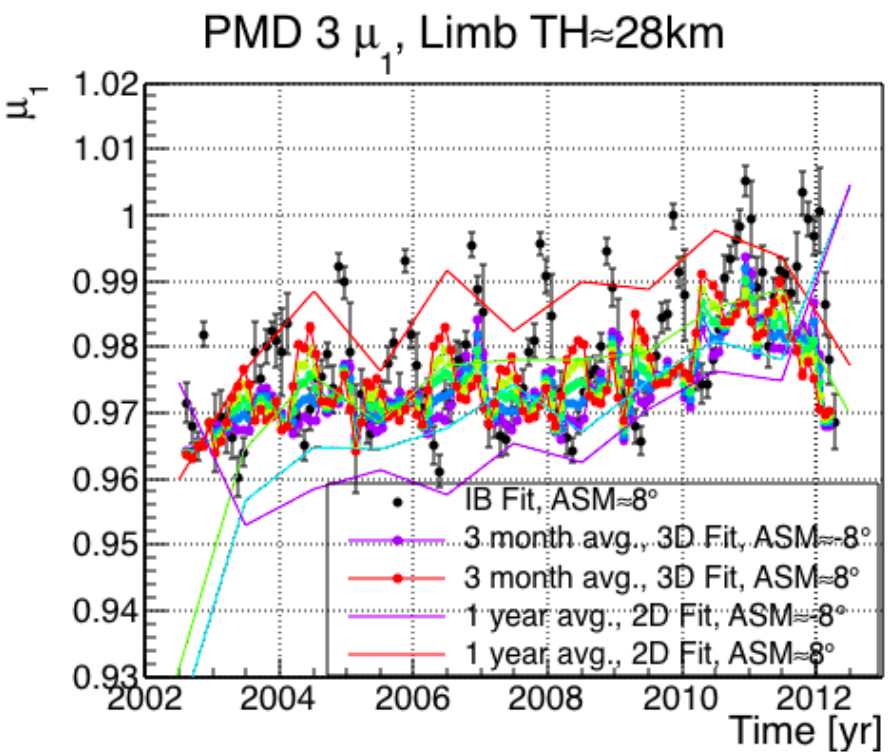


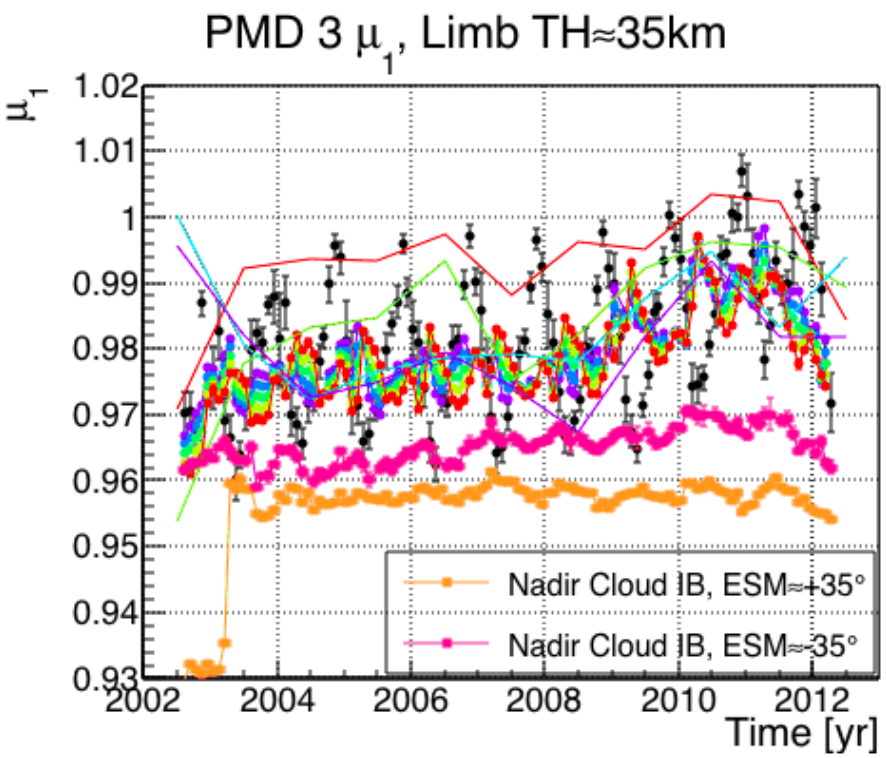

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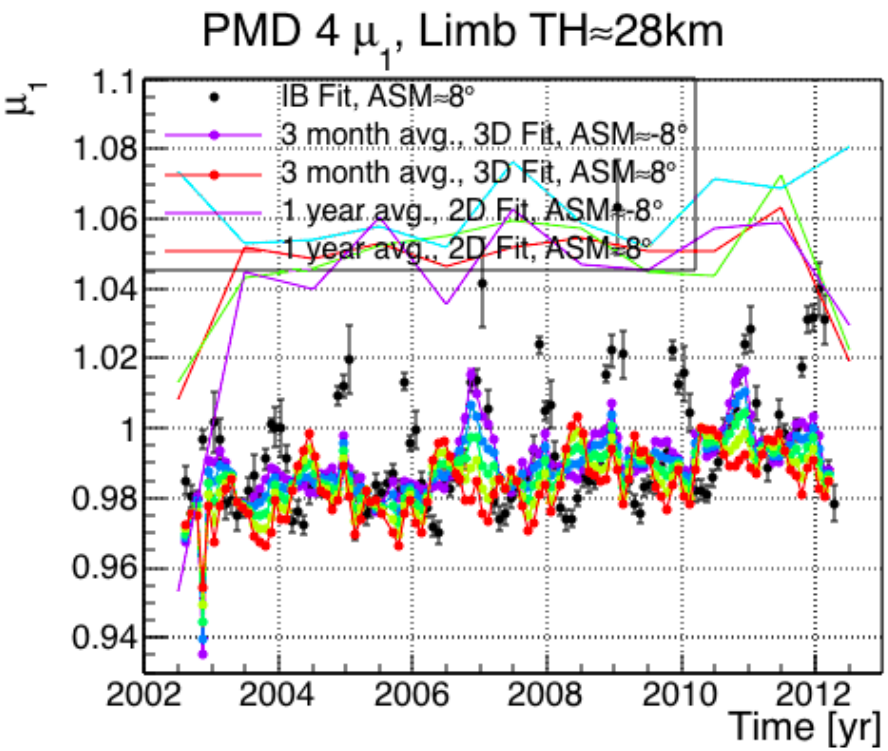
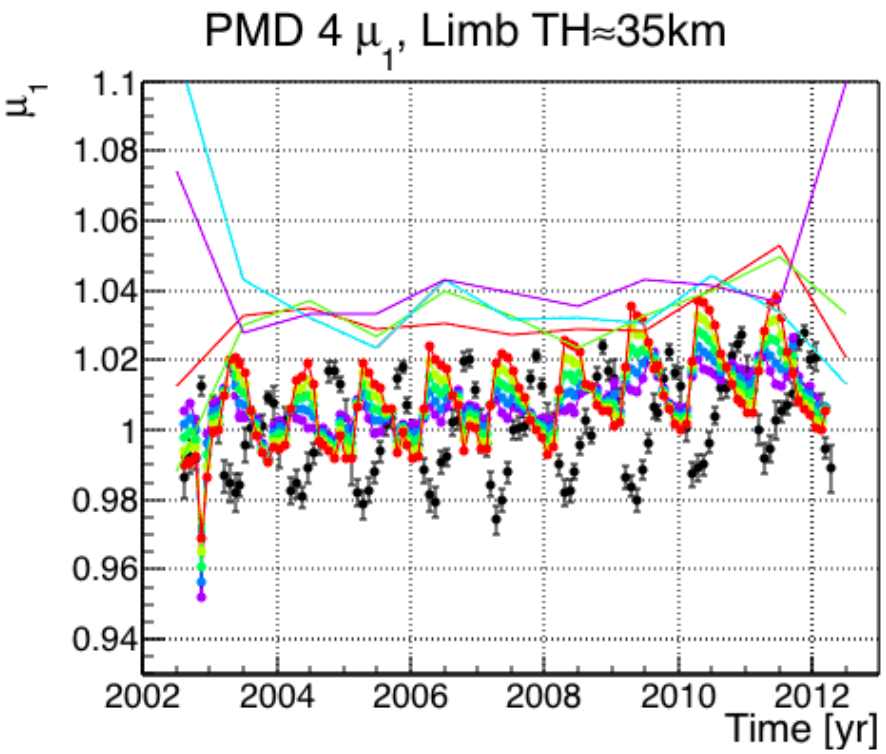
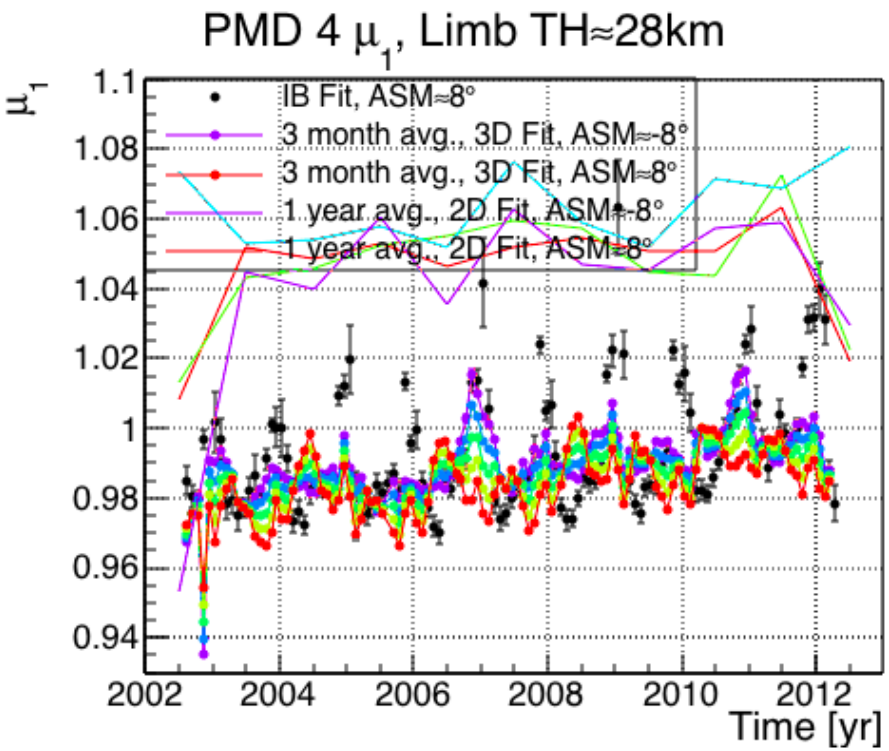
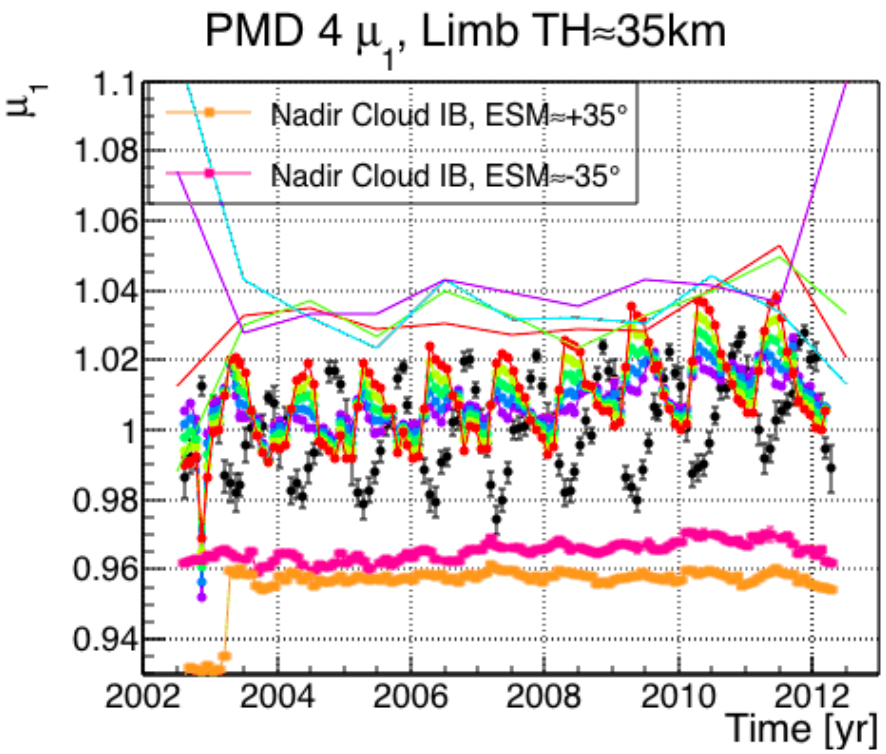


# Schedule? Just One Example: IBs

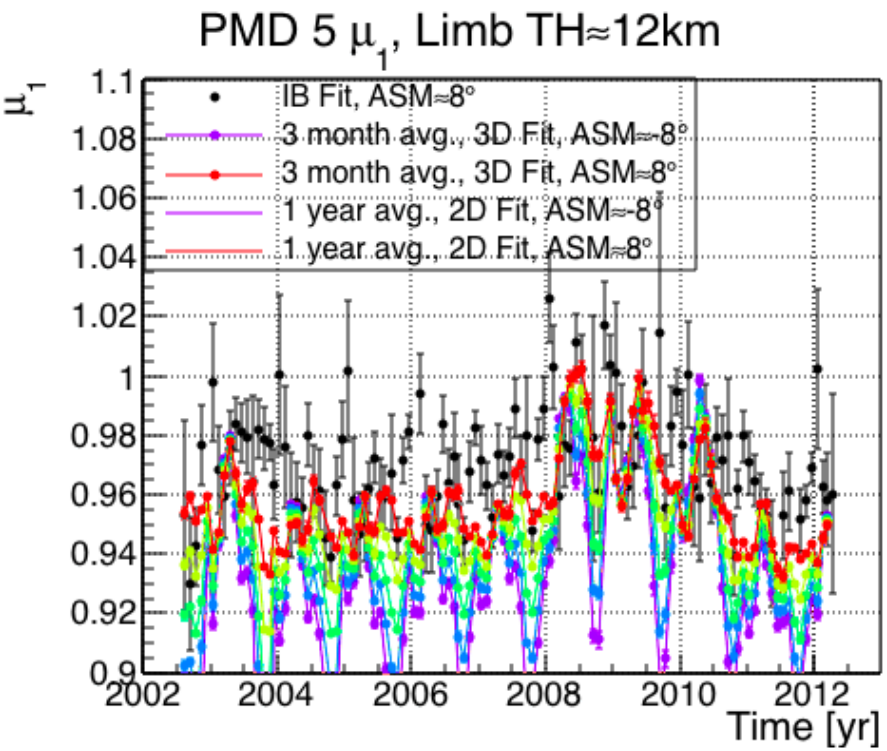
- PMD 4 IB correction factor vs. time (Limb vs. Nadir)

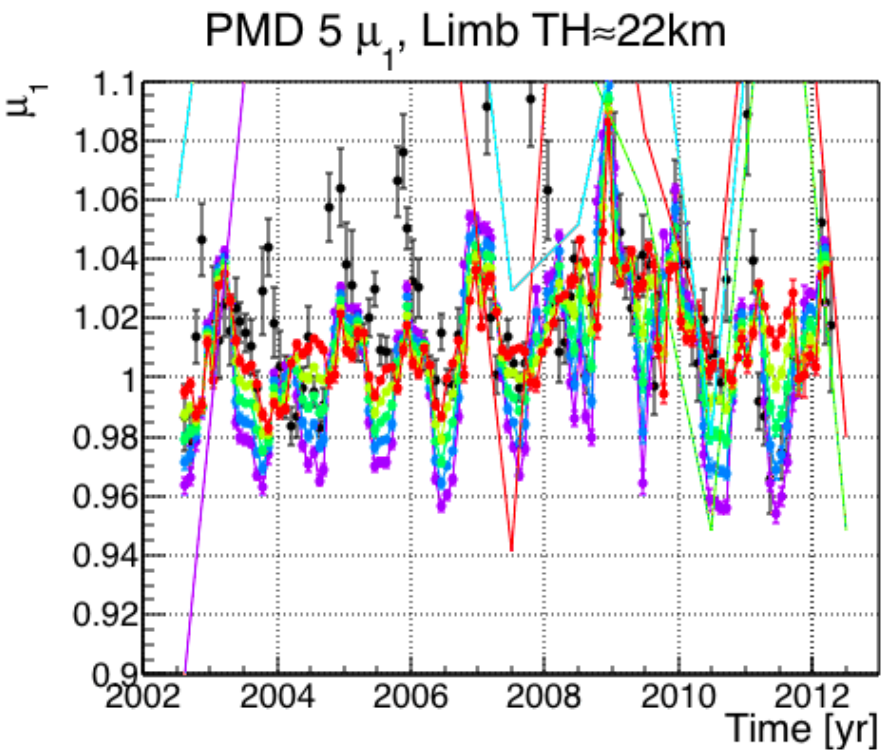


# Schedule? Just One Example: IBs

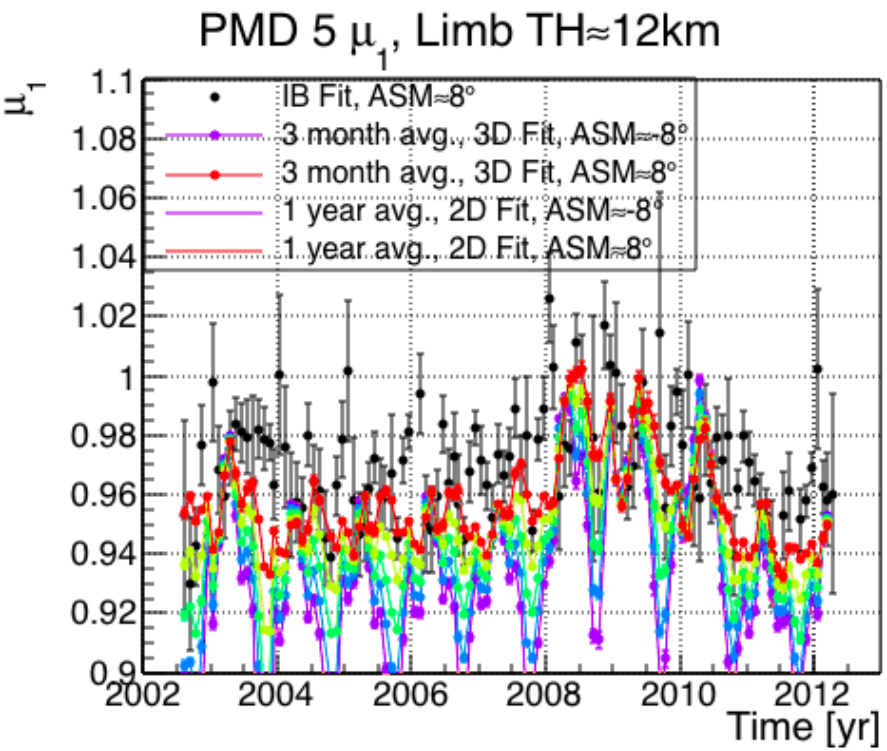
- PMD 5 IB correction factor vs. time (Limb vs. Nadir)

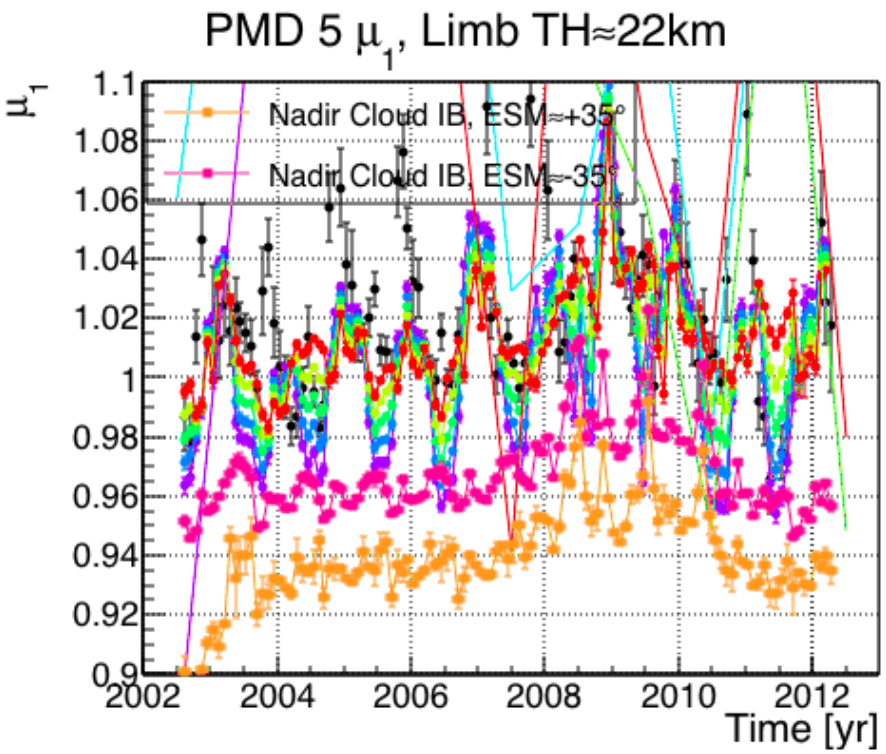


# Schedule? Just One Example: IBs

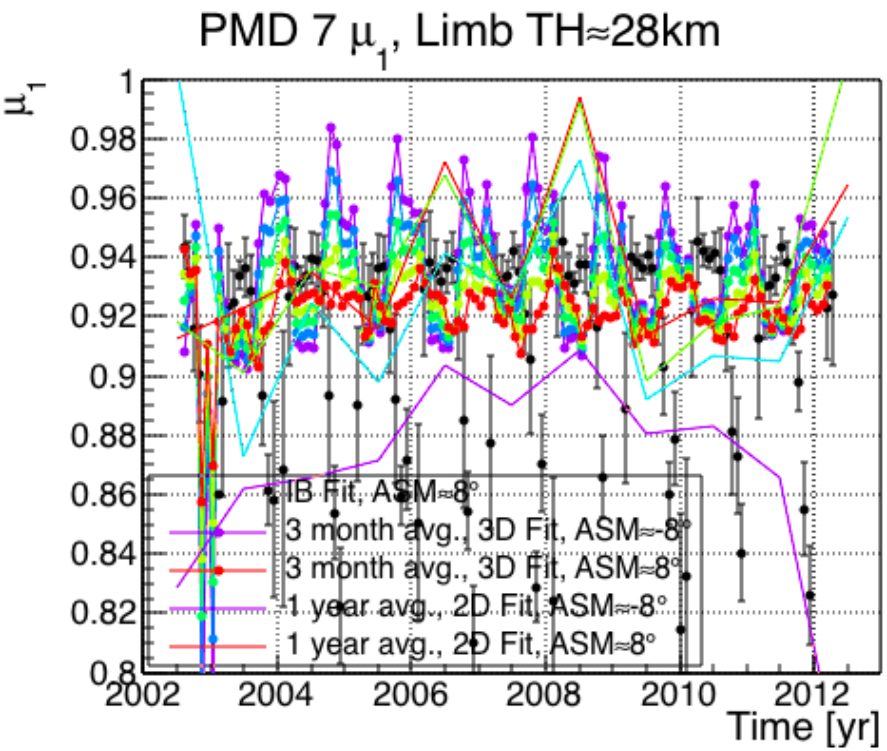
- PMD 5 IB correction factor vs. time (Limb vs. Nadir)

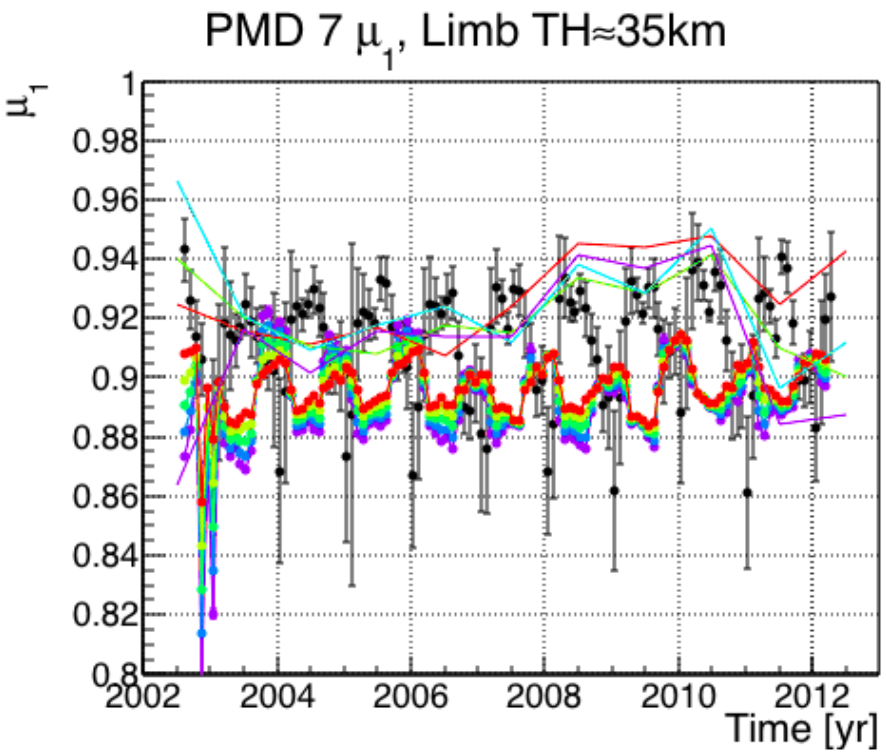


# Schedule? Just One Example: IBs

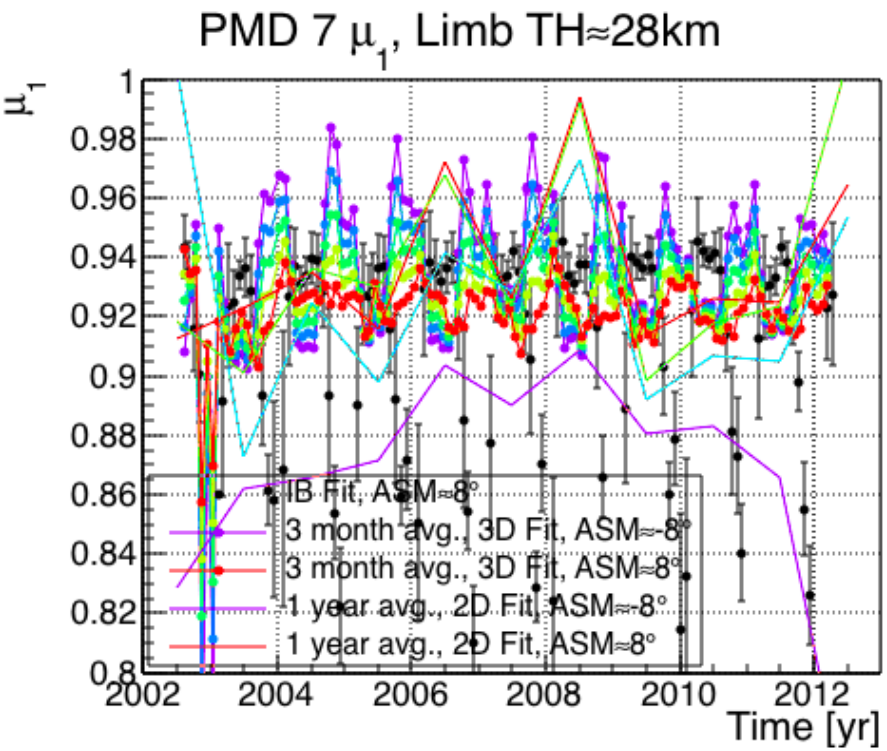
- PMD 7 IB correction factor vs. time (Limb vs. Nadir)

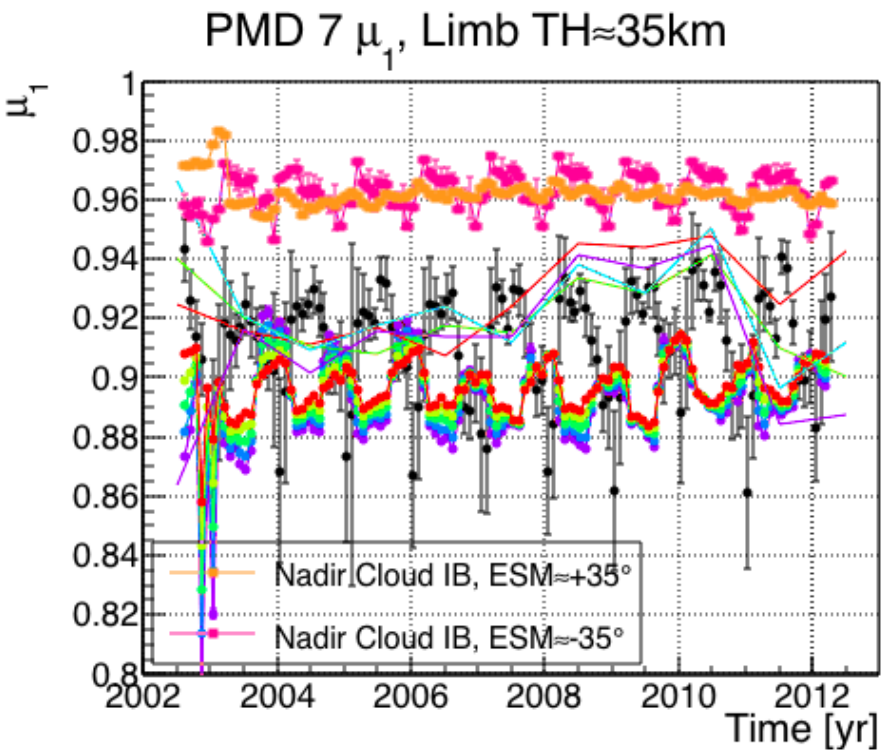


# Schedule? Just One Example: IBs

- PMD 7 IB correction factor vs. time (Limb vs. Nadir)



# Which Is The Correct IB?

- Strong seasonal cycle is clearly an artifact
- Offset between yearly avg. and cloud limit (nadir)?
  - Decide by looking at "butterfly" plots:
    - PMD 1: inconclusive
    - Note: it may be an inaccuracy in $\mu_3$
    - PMD 2,3,4,7: improvement with cloud limit method
- Follow up on cloud method …
- Limb:
  - TH dependence of PMDs 4,5,7
  - Not quite compatible with Nadir IB

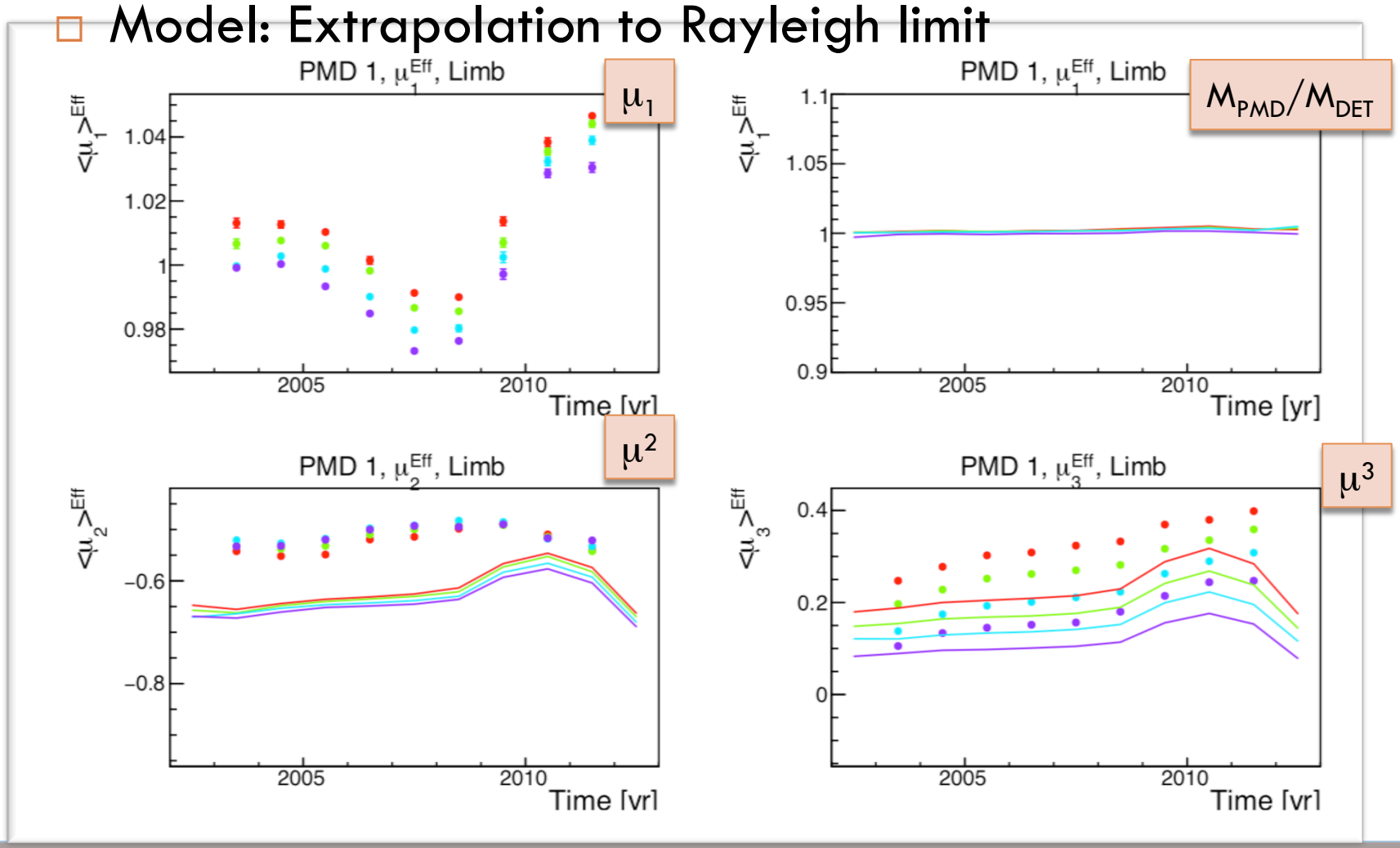
# What to do next?

- All: Settle on algorithm, very soon.
- Me: Write docu
- Me: Finish IB studies:
  - Which time resolution?
  - Select best method.
- SRON/Ralph: deliver “final set” of KD
  - Me: check and
  - If necessary, deliver related IB correction factor
  - If necessary, deliver limb effective MMEs
- DLR:
  - Implementations: Communicate!
  - PMD data synchronization
- Time frame for all this?

# Backup

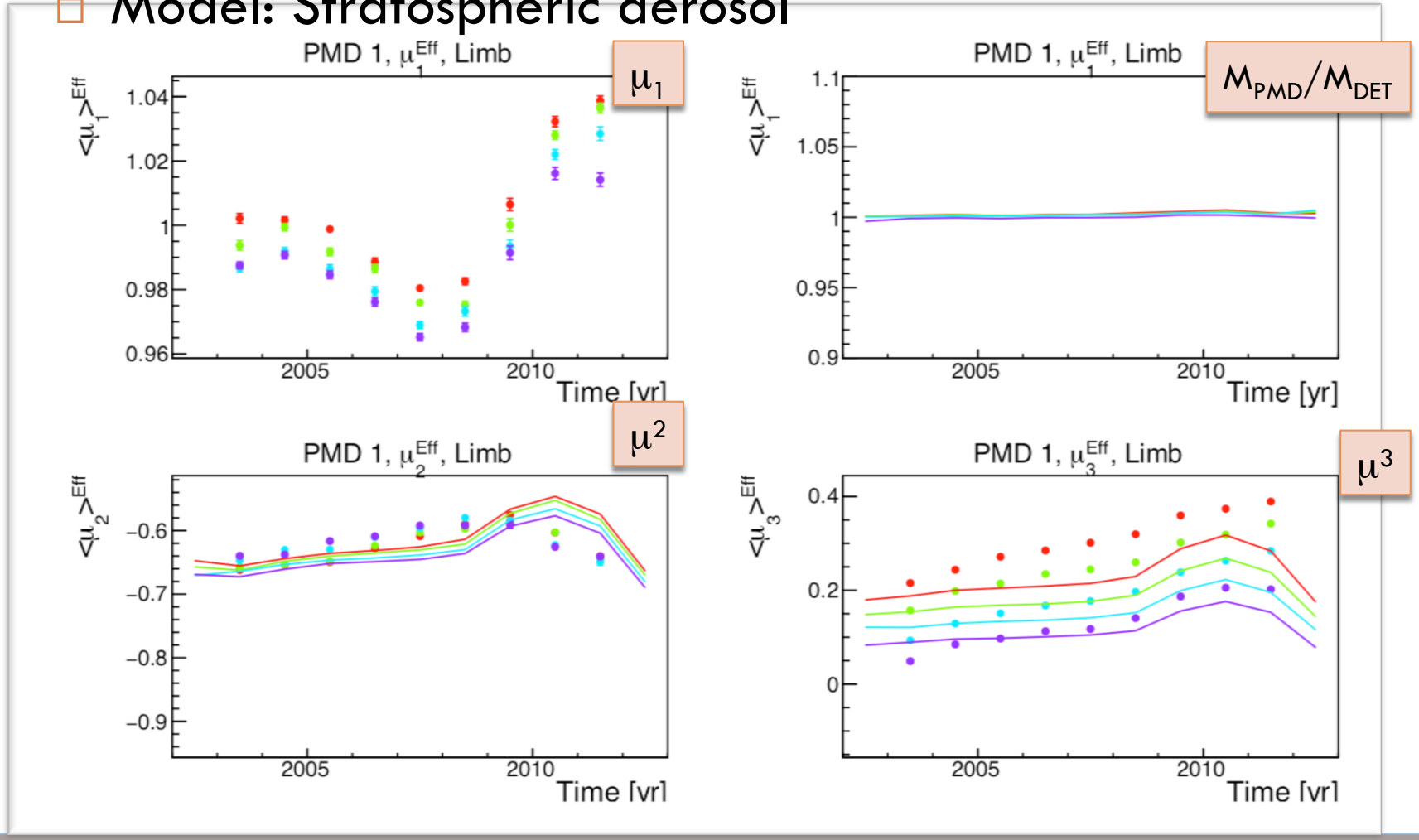
# PMD 1 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Extrapolation to Rayleigh limit



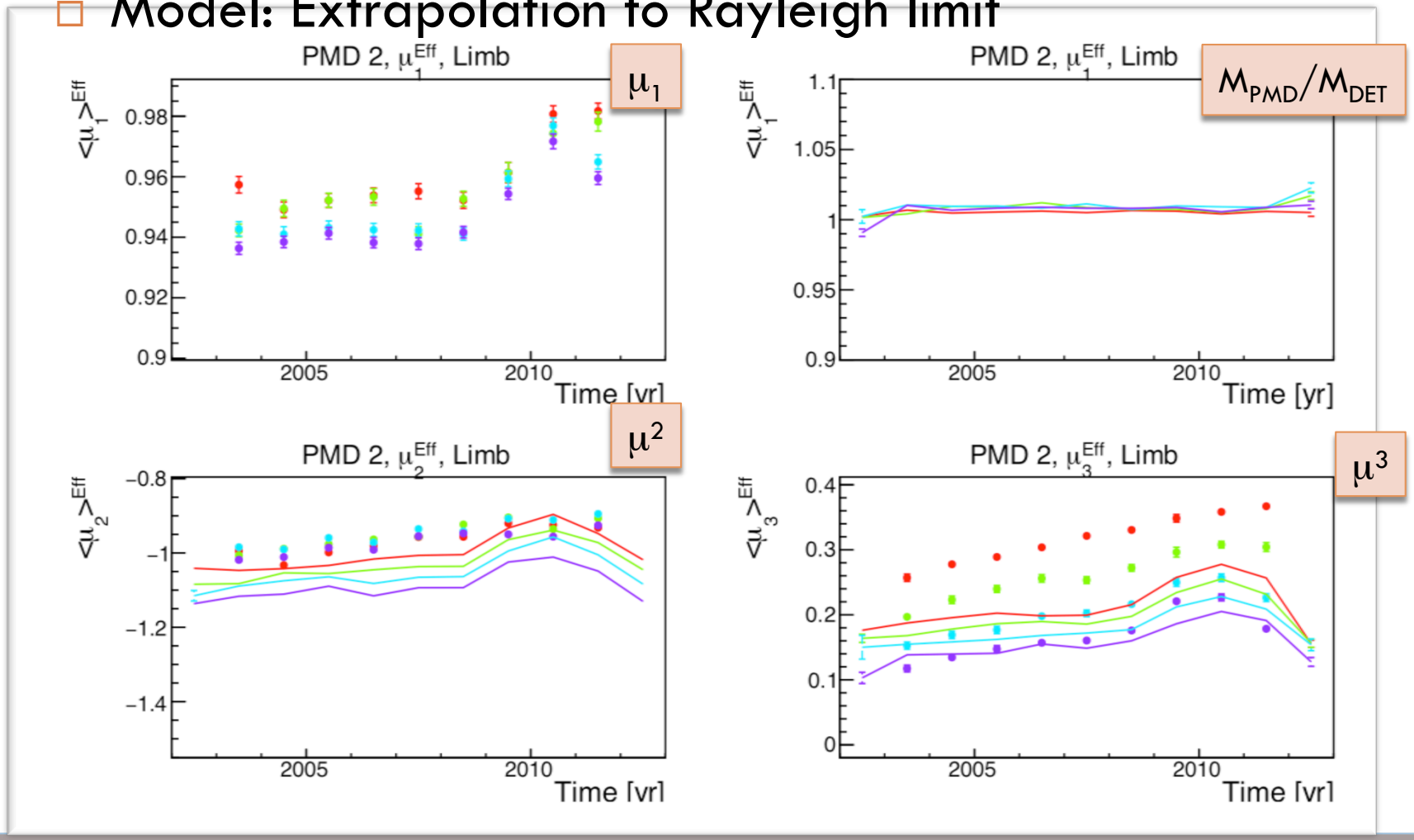
# PMD 1 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Stratospheric aerosol



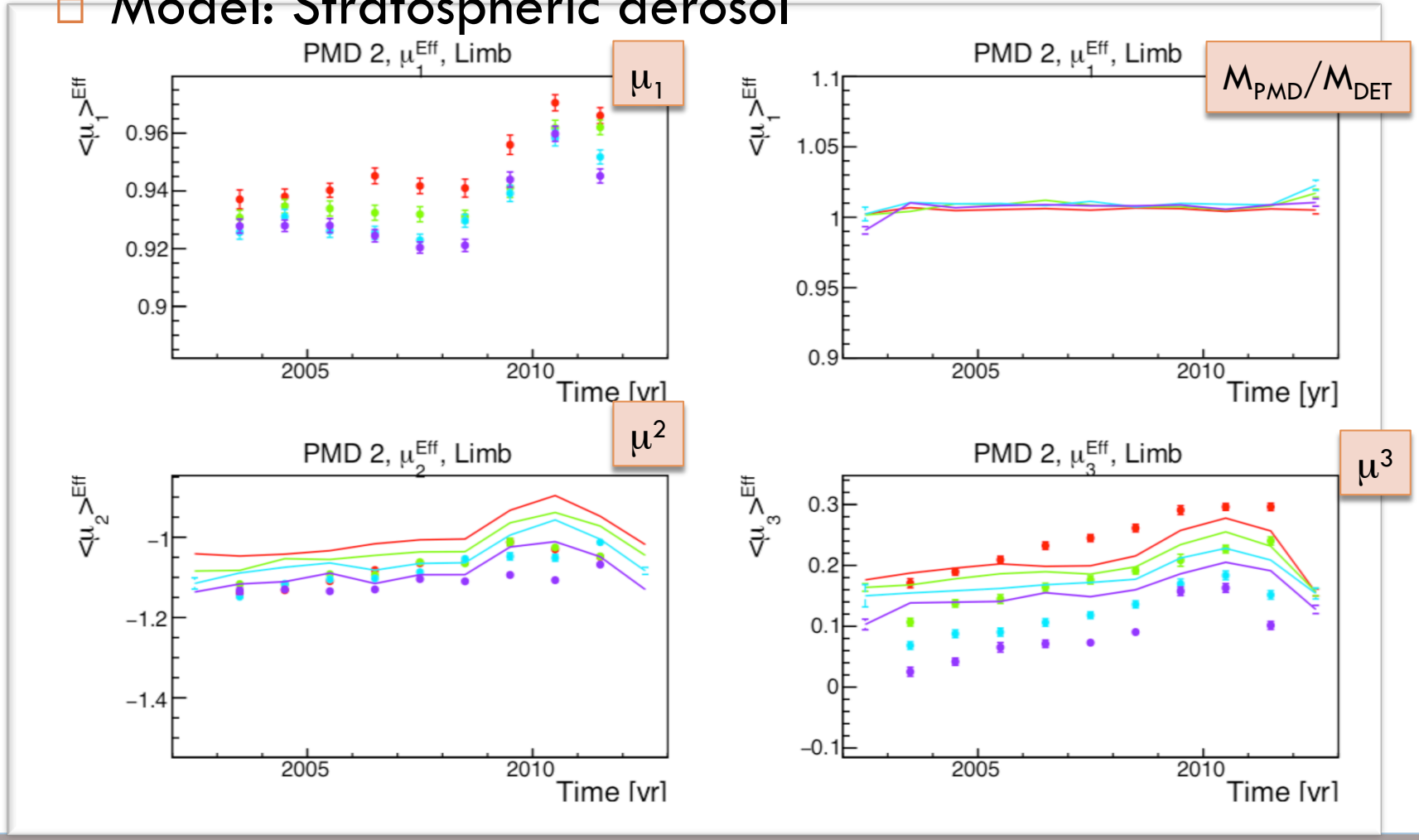
# PMD 2 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Extrapolation to Rayleigh limit



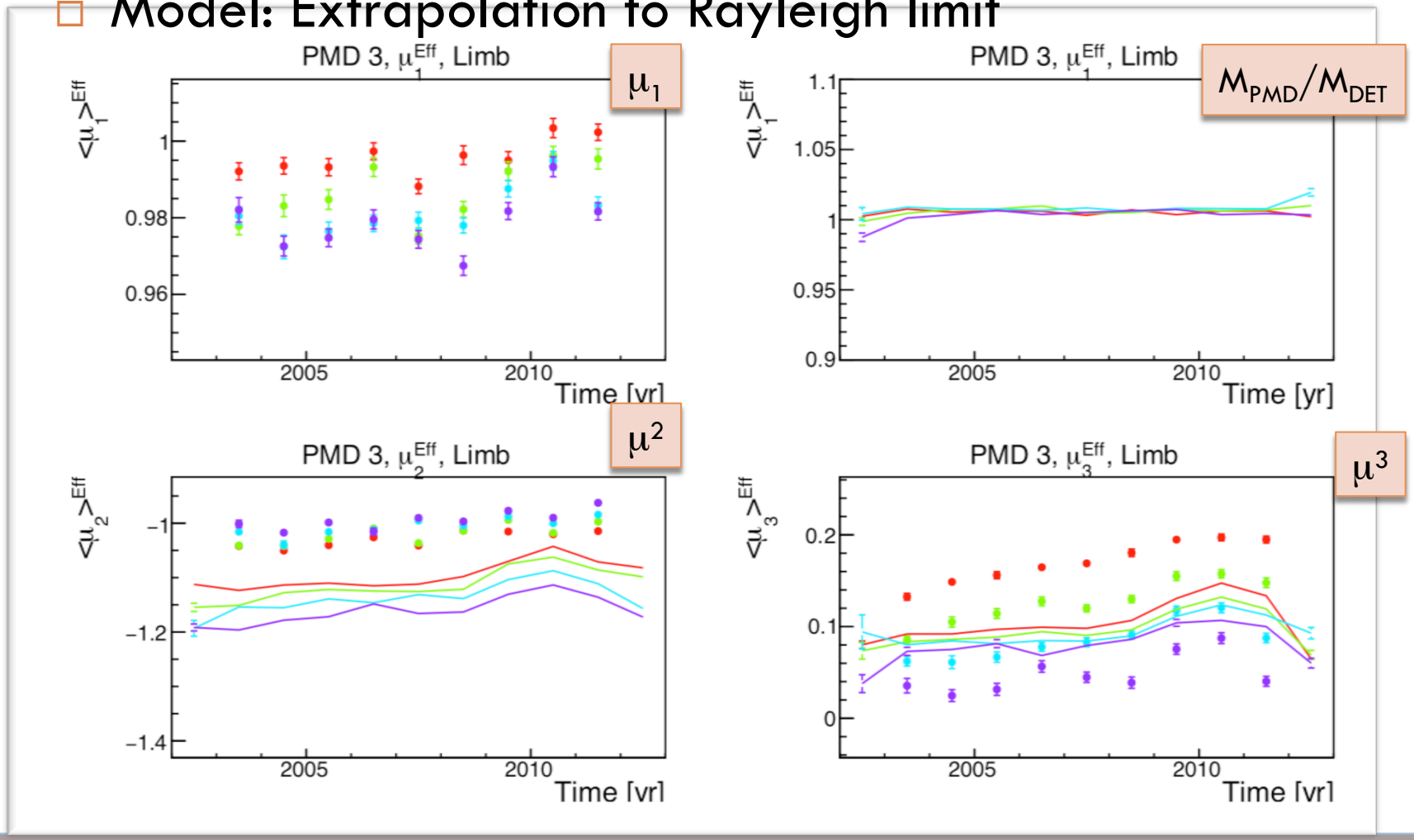
# PMD 2 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Stratospheric aerosol



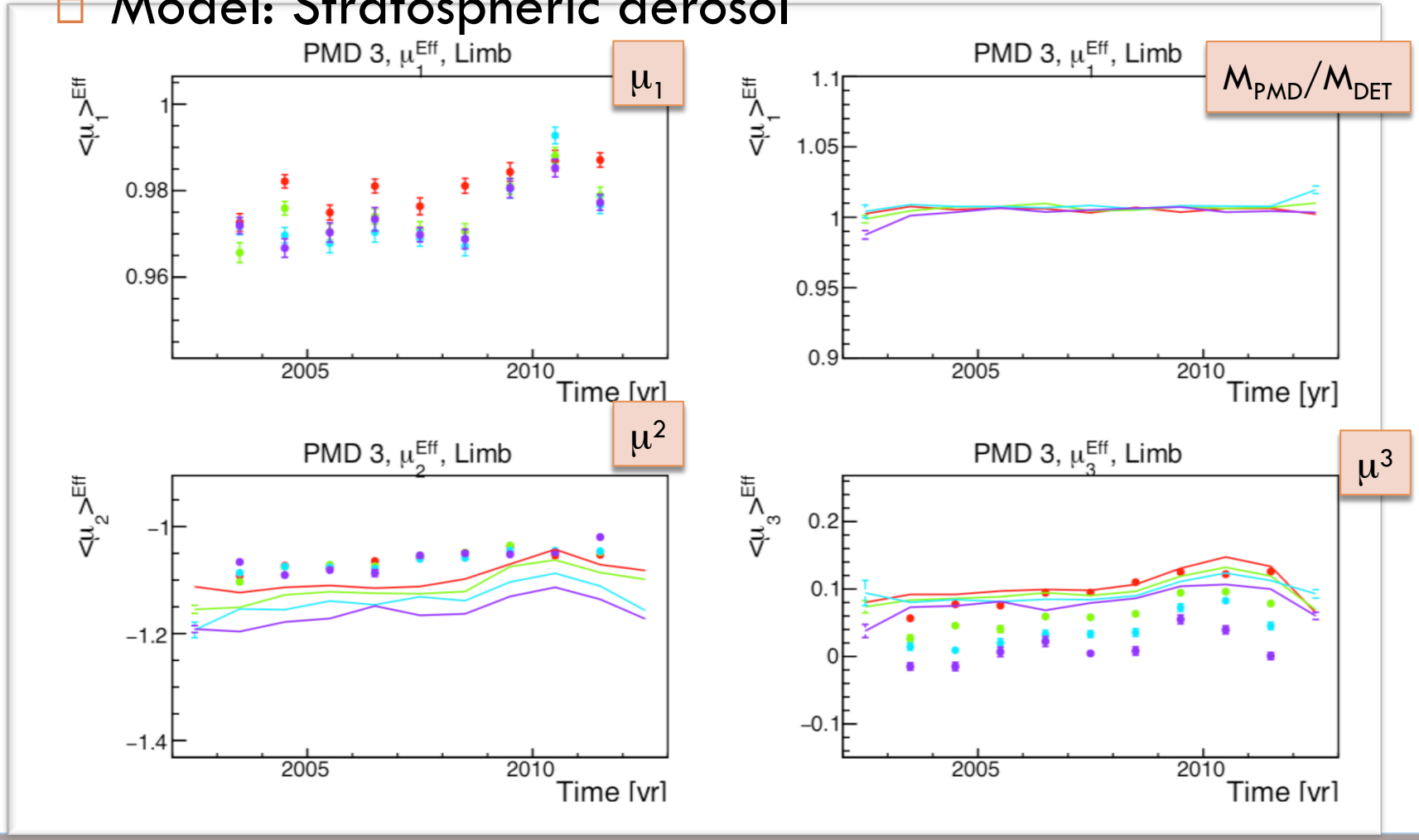
# PMD 3 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Extrapolation to Rayleigh limit



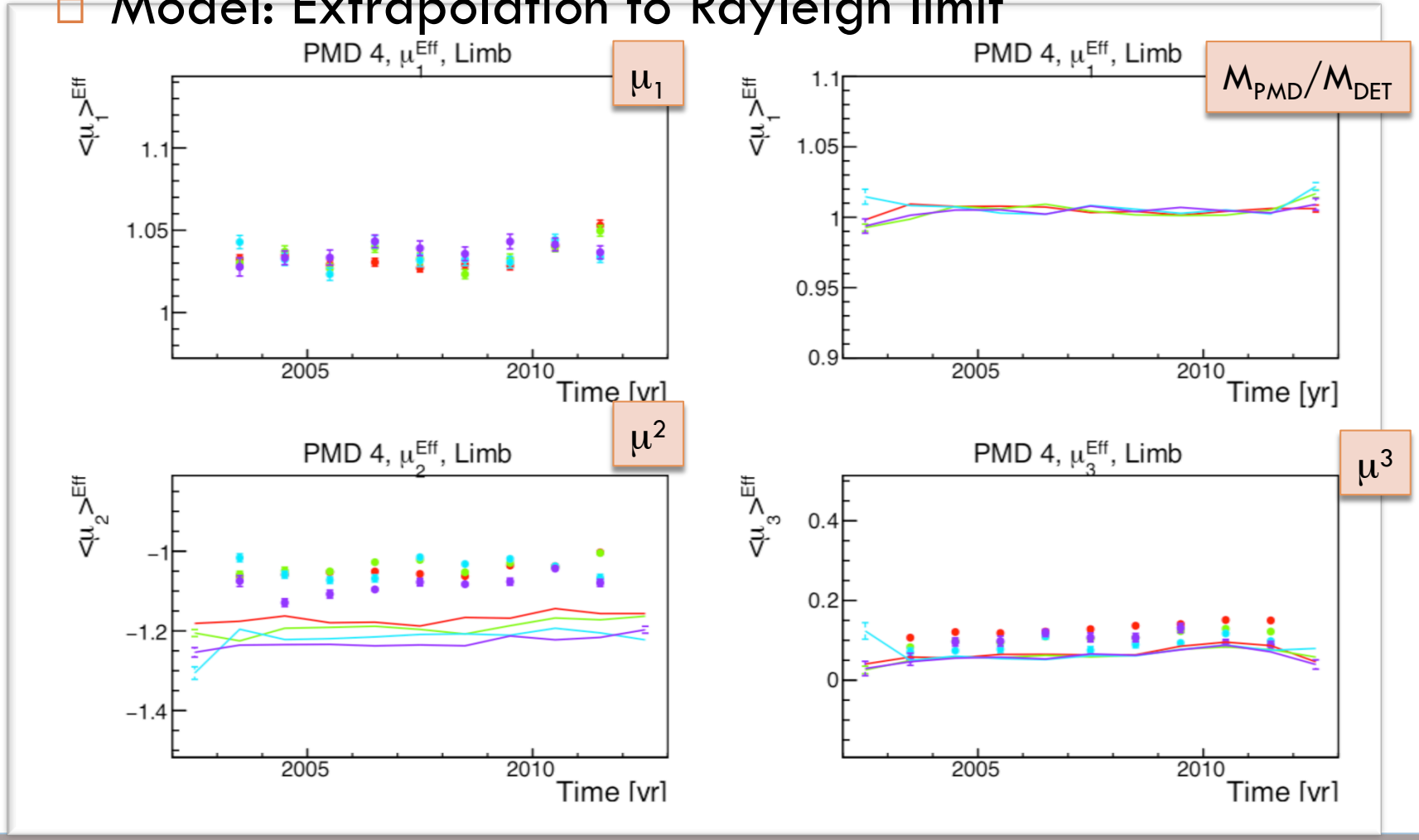
# PMD 3 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Stratospheric aerosol



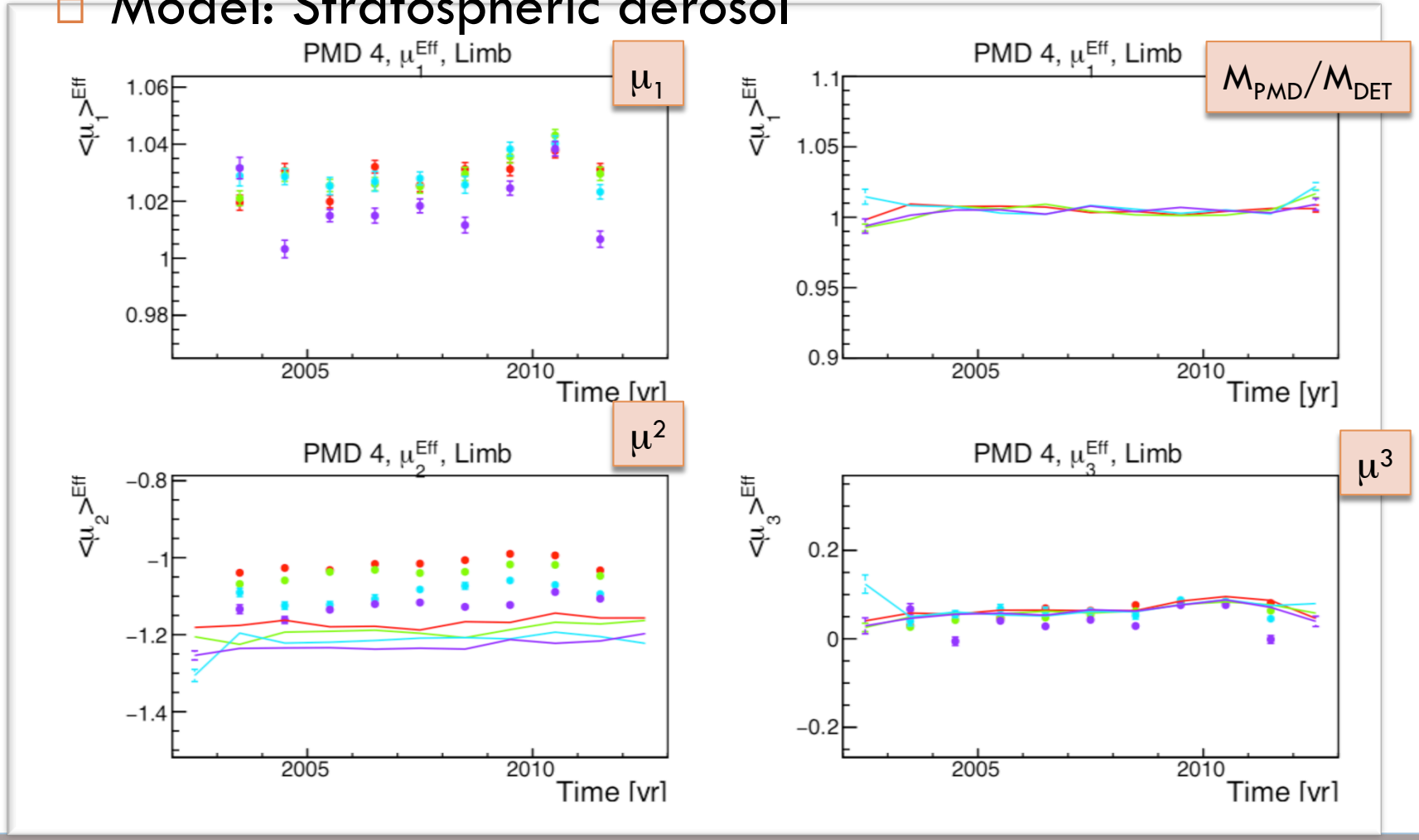
# PMD 4 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Extrapolation to Rayleigh limit



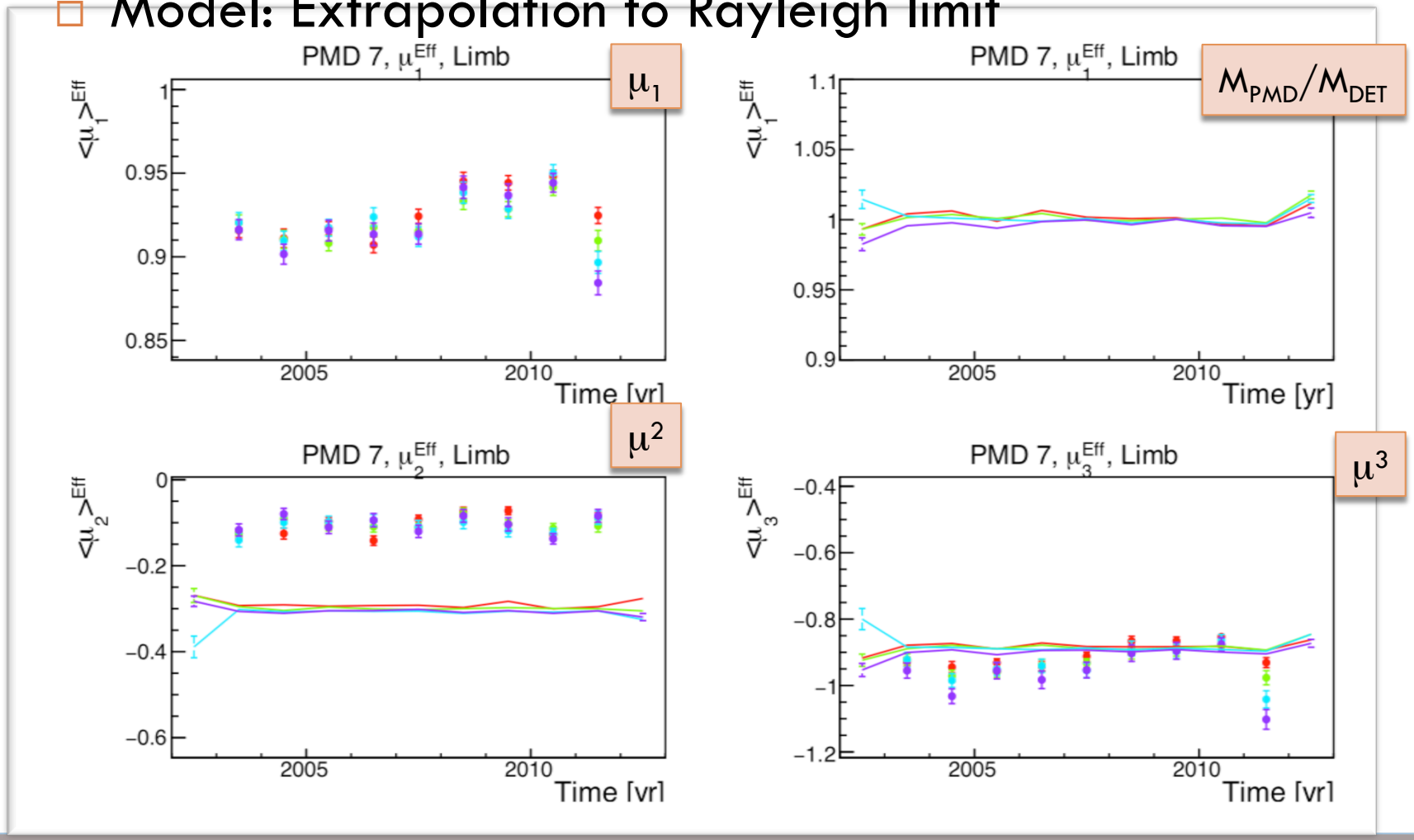
# PMD 4 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Stratospheric aerosol



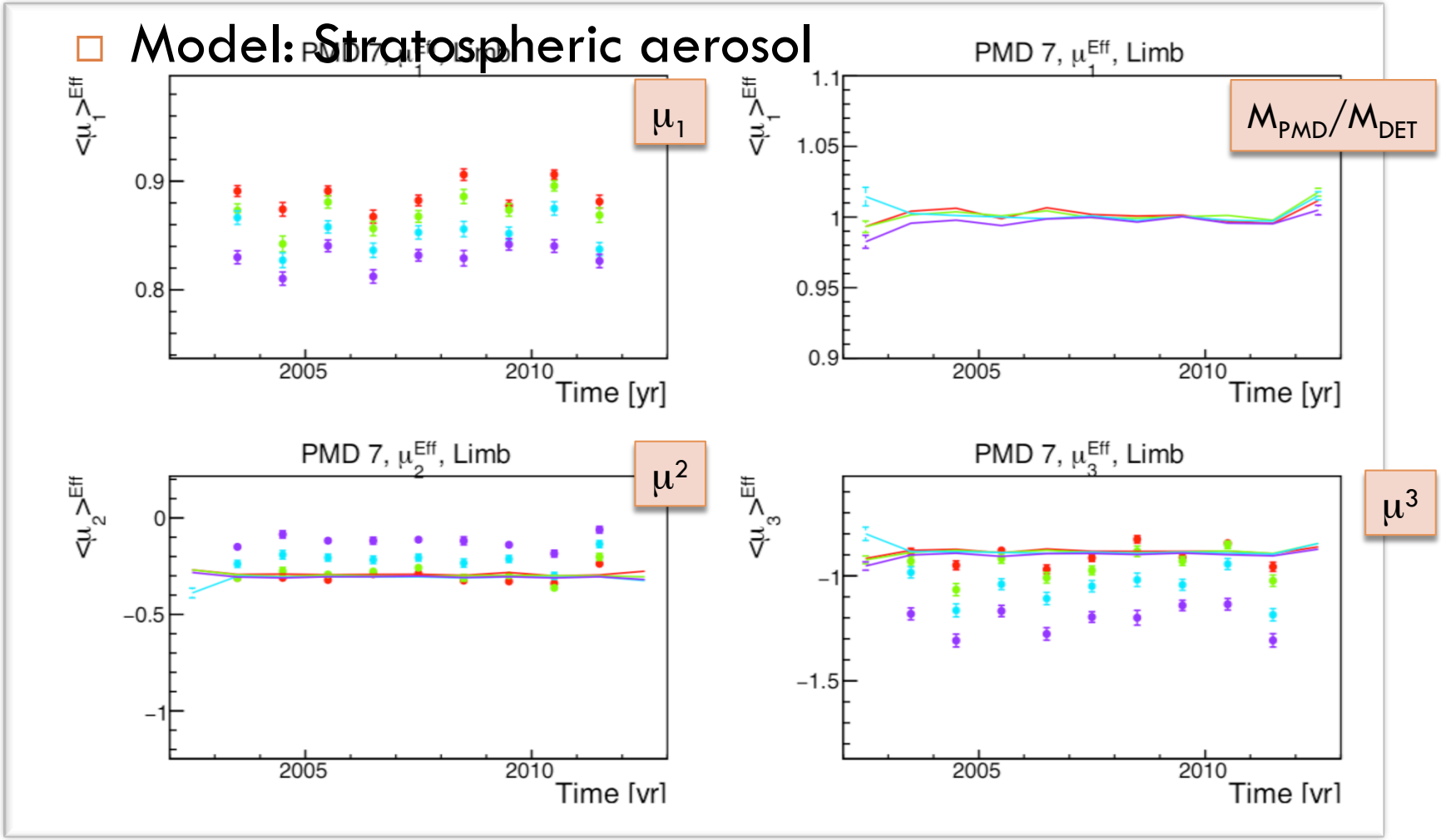
# PMD 7 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Extrapolation to Rayleigh limit



# PMD 7 Effective MMEs vs. V9, Limb

- Effective PMD sensitivities vs. time (1 year average)
- Model: Stratospheric aerosol





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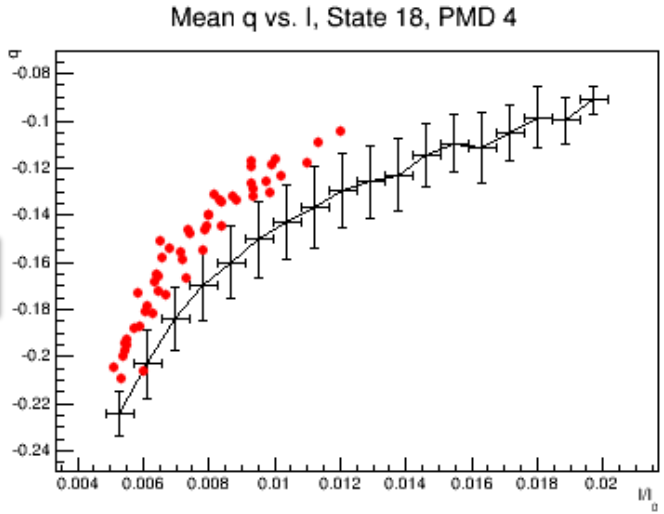
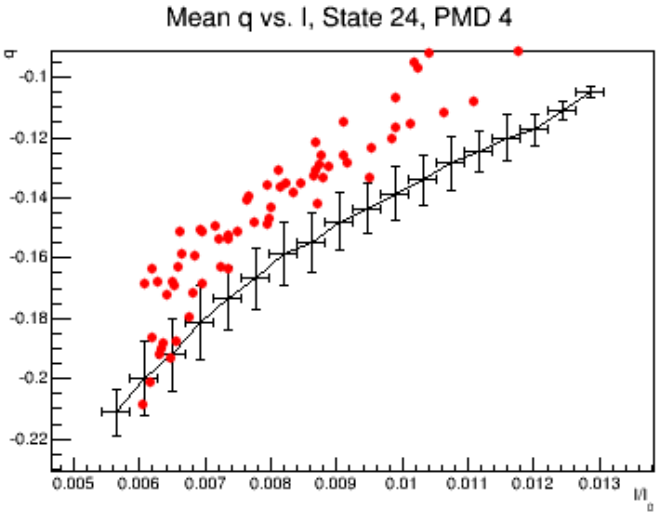
# Limb PMD 4/7 Compared to RTM, TH=28 km

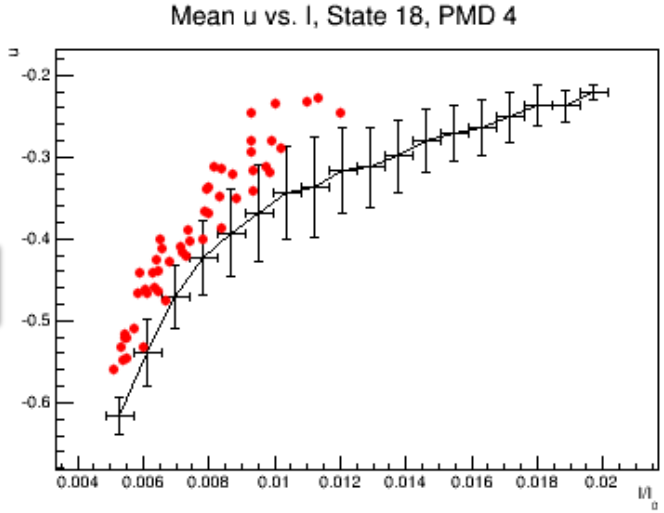
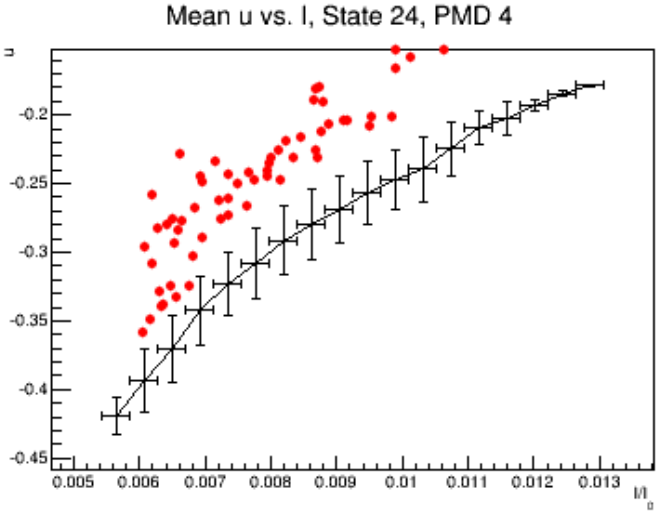
- q(u) vs. reflectance

q




Average of SCIATRAN runs

Data

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