Biasing Study (WIP)

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Probability of rare process

$dn_1/dt = -\langle\sigma v\rangle n_1 n_2$. For constant v: $dn_1/vdt = -\langle\sigma\rangle n_1 n_2$

Distribution of Interaction length L_i:

$$P_{\sigma_i}(L_i) = \sigma_i e^{-\sigma_i L_i}$$

Probability of rare process happening:

$$P_{rare} = P(L_r < L_c \,\&\, L_r < D)$$

$$= P(L_c < D \,\&\, L_r < L_c) + P(L_c > D \,\&\, L_r < D)$$

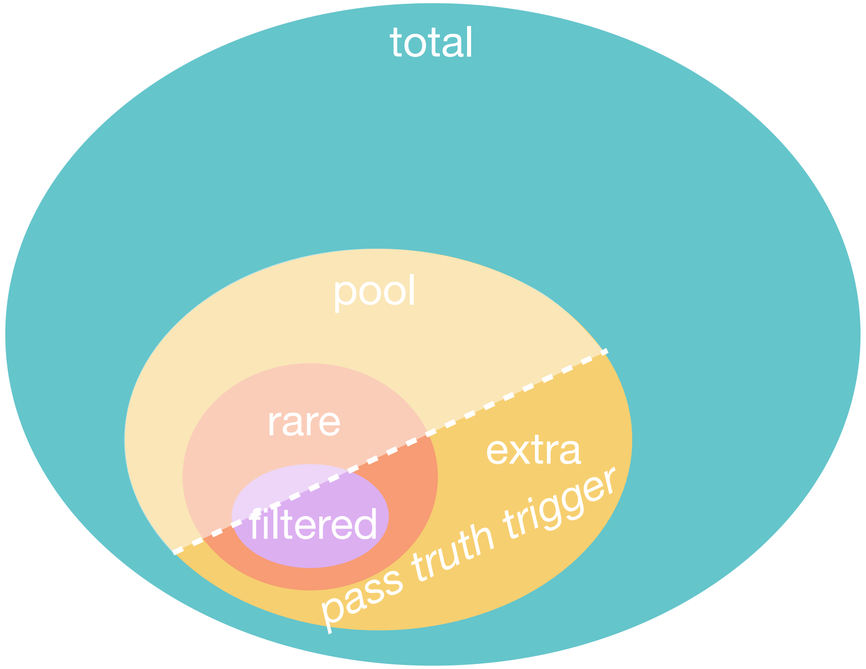
$$P(rare) = \int_0^D P_{\sigma_e}(L_e) \int_0^{L_e} P_{\sigma_r}(L_r)\, dL_r dL_e + \int_D^{+\infty} P_{\sigma_e}(L_e)\, dL_e \int_0^D P_{\sigma_r}(L_r)\, dL_r = \frac{\sigma_r}{\sigma_r + \sigma_e}\left(1 - e^{-(\sigma_r+\sigma_e)nD}\right)$$

With bias factor x: $\sigma_r \to x\sigma_r$, and let $k \equiv \frac{\sigma_r}{\sigma_c}, p \equiv \sigma_c D$

$$P(x) = \frac{kx}{kx+1}\left(1 - e^{-p(kx+1)}\right)$$

Event classification in biasing study

- **total:** Total beam on events
- **pool:** Produced **biasing particle**, and biasing particle pass BiasEmin cut
- **rare:** Successfully generate **biasing process**.
- **remain:** pool - rare
- With Bias Factor ↑, N_{rare} ↑, until N_{rare} = N_{pool} at saturation.
- Sometimes we add a final state cut (i.e. ΔE>2 GeV for EN), and only record **filtered** events.



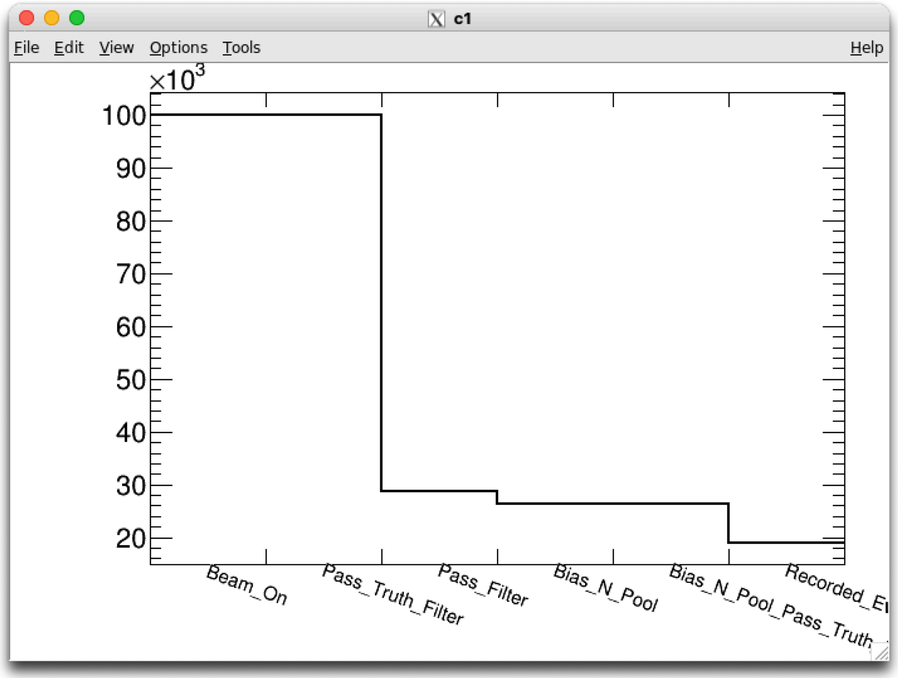
$$N_{rare} = Rate(rare) \times \epsilon_{filter} \times N_{EOT}$$

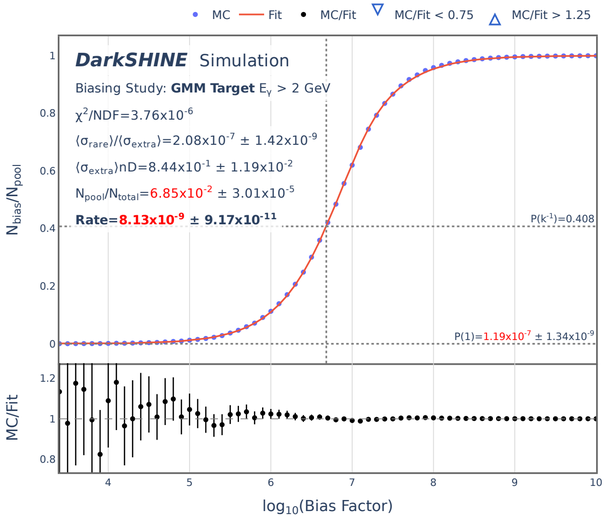
$$Rate(x) = \frac{n_{pool}}{n_{total}} \times P_{rare}(x)$$

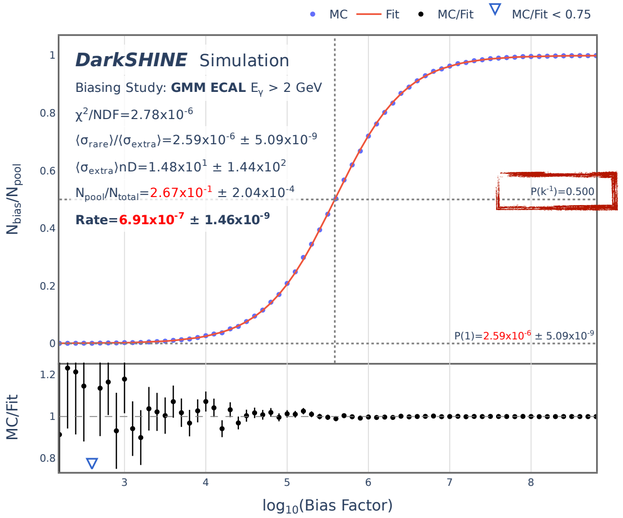
Methodology

Workflow will be uploaded to our git project

- Scan bias factor: use n_{rare}/n_{pool} to fit P(x)
- Use n_{pool} for each event instead of constant n_{pool} extracted by larger sample to eliminate statistical fluctuation.
- Add histogram truth_cutflow in DSimu output, to extract key data:
  - n_{pool} , n_{rare} , filter efficiency
  - Compatible with hadd merging file
- Apply filter (Apply trigger)
- Limit to at most 1 biased interaction in each event

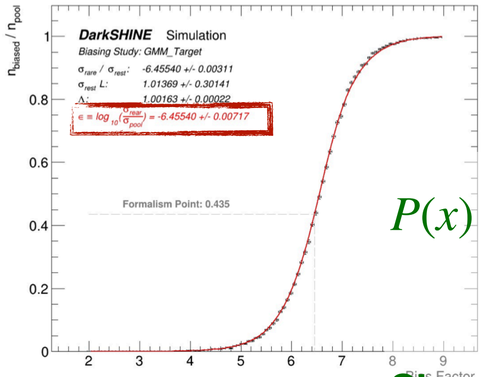


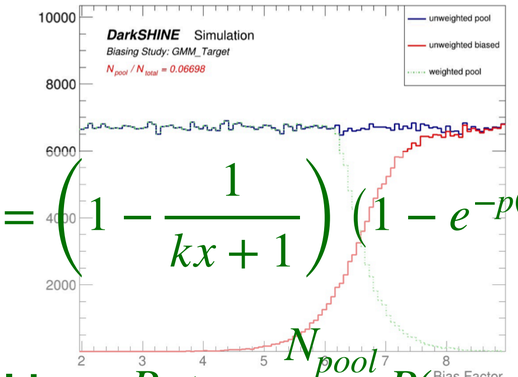




GMM Target

- σ_{biased} : cross-section of biased events
- σ_{pool} : cross-section of interested events
- ϵ : analog ratio between biased and interested eve
- Formalism point : ratio corresponded to the ϵ





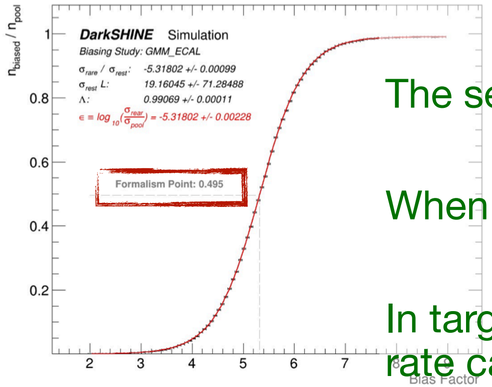
$$P(x) = \left(1 - \frac{1}{kx+1}\right)\left(1 - e^{-p(kx+1)}\right), \quad k \equiv \frac{\sigma_{rare}}{\sigma_{extra}}, p \equiv \sigma_{extra} D$$

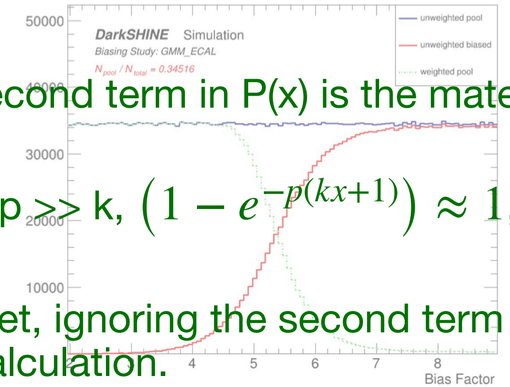
Should use $Rate = \frac{N_{pool}}{N_{total}} P(x = 1)$ **instead of** $Rate = \frac{N_{pool}}{N_{total}} \frac{\sigma_{rare}}{\sigma_{pool}}$

rel. to inclusive: 2.35×10^{-8}

GMM ECAL

The first term in P(x) is Branching ratio $\frac{\sigma_{rare}}{\sigma_{pool}} = \frac{\sigma_{rare}}{\sigma_{rare} + \sigma_{extra}}$





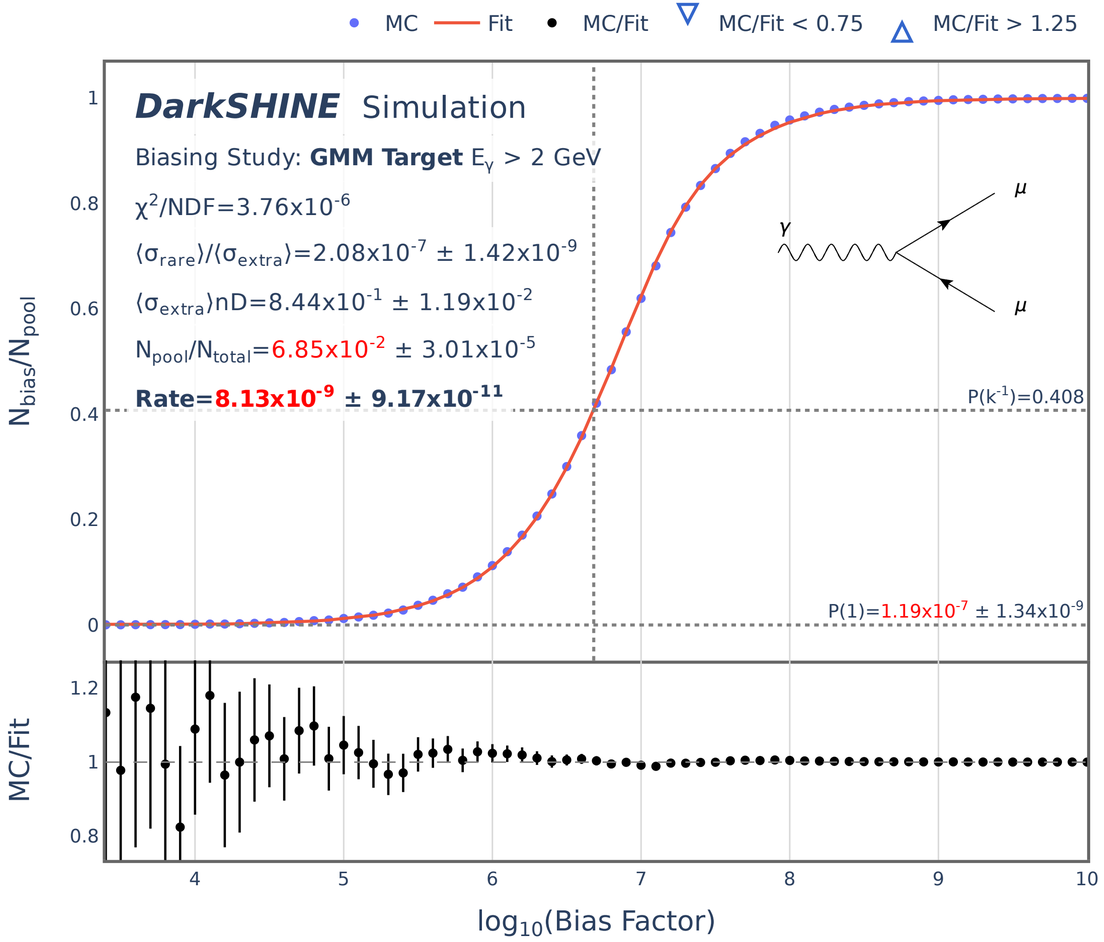
The second term in P(x) is the material length effect.

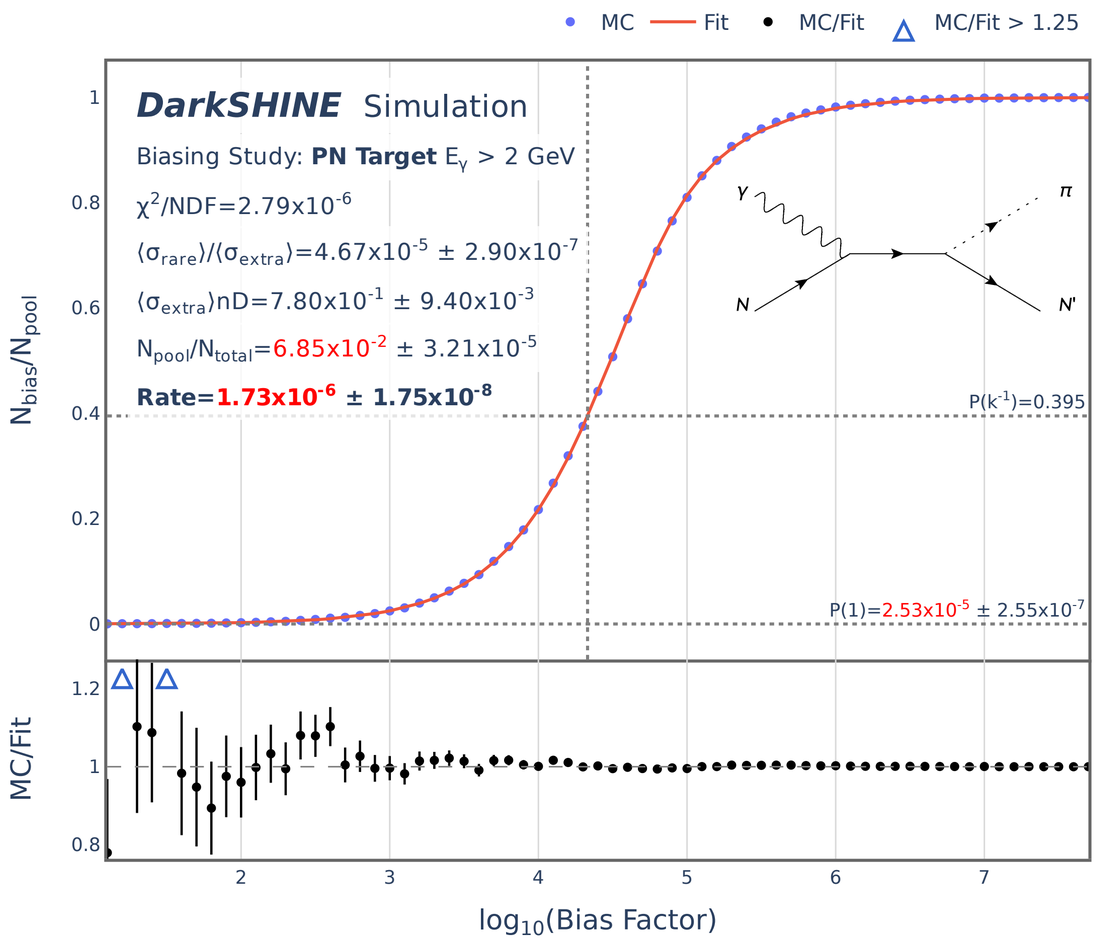
When p >> k, $\left(1 - e^{-p(kx+1)}\right) \approx 1$, i.e. ECAL, can ignore second term.

In target, ignoring the second term will cause a factor of **~2** to **~15** in rate calculation.

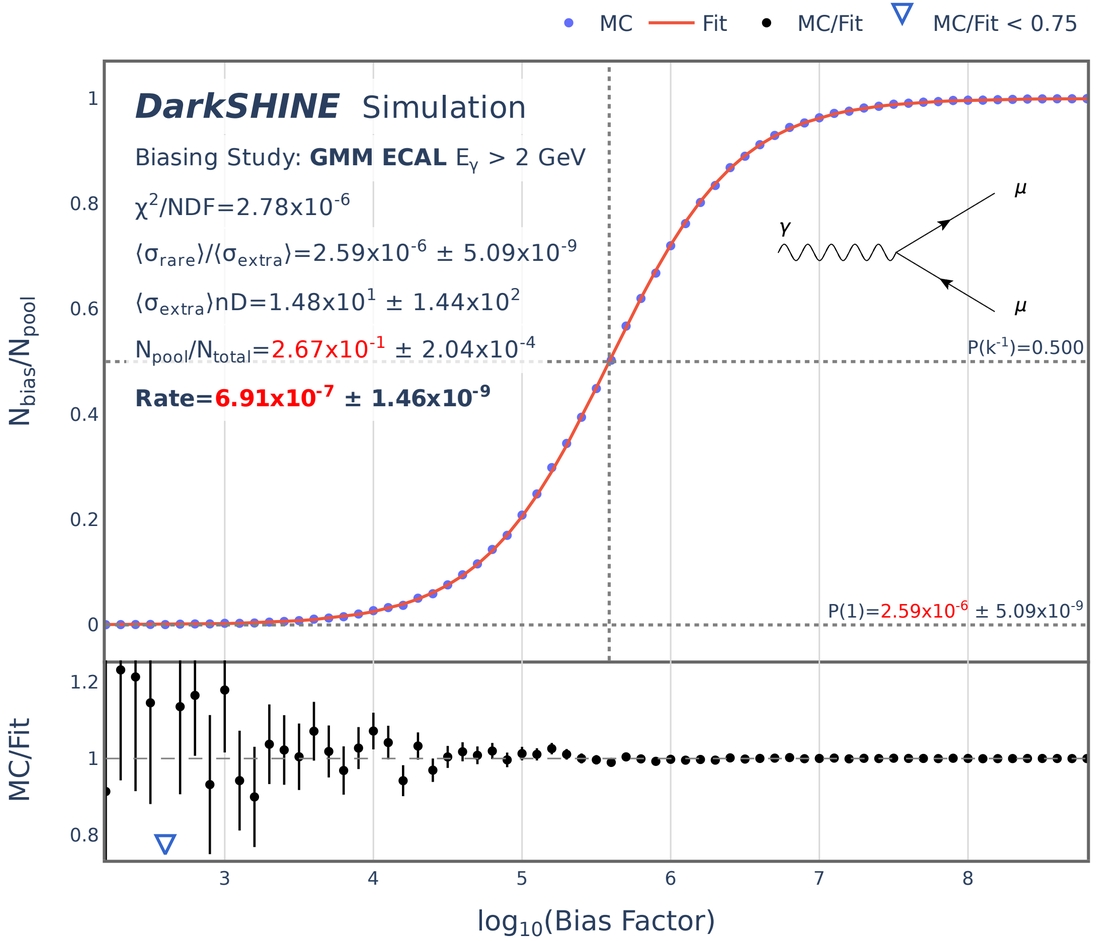
rel. to inclusive: 1.66×10^{-6}

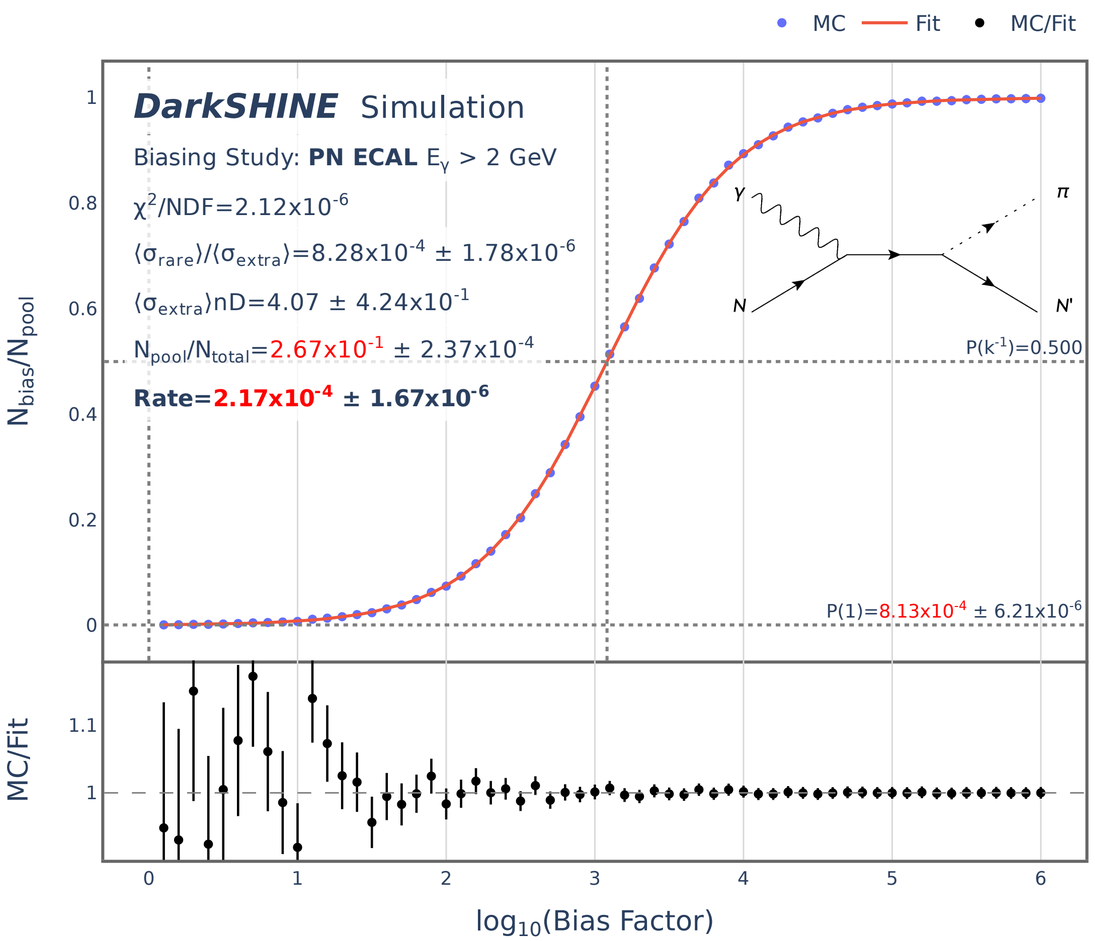
Target γ process



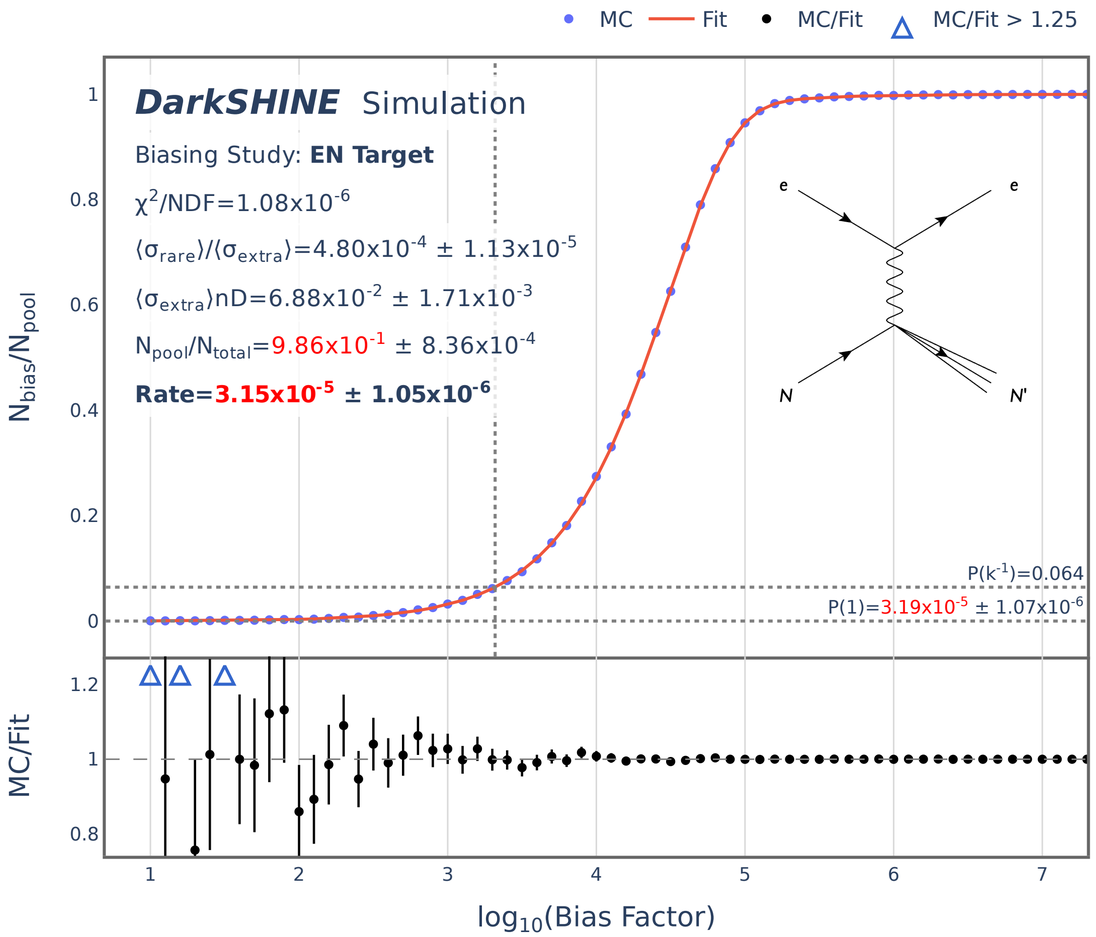


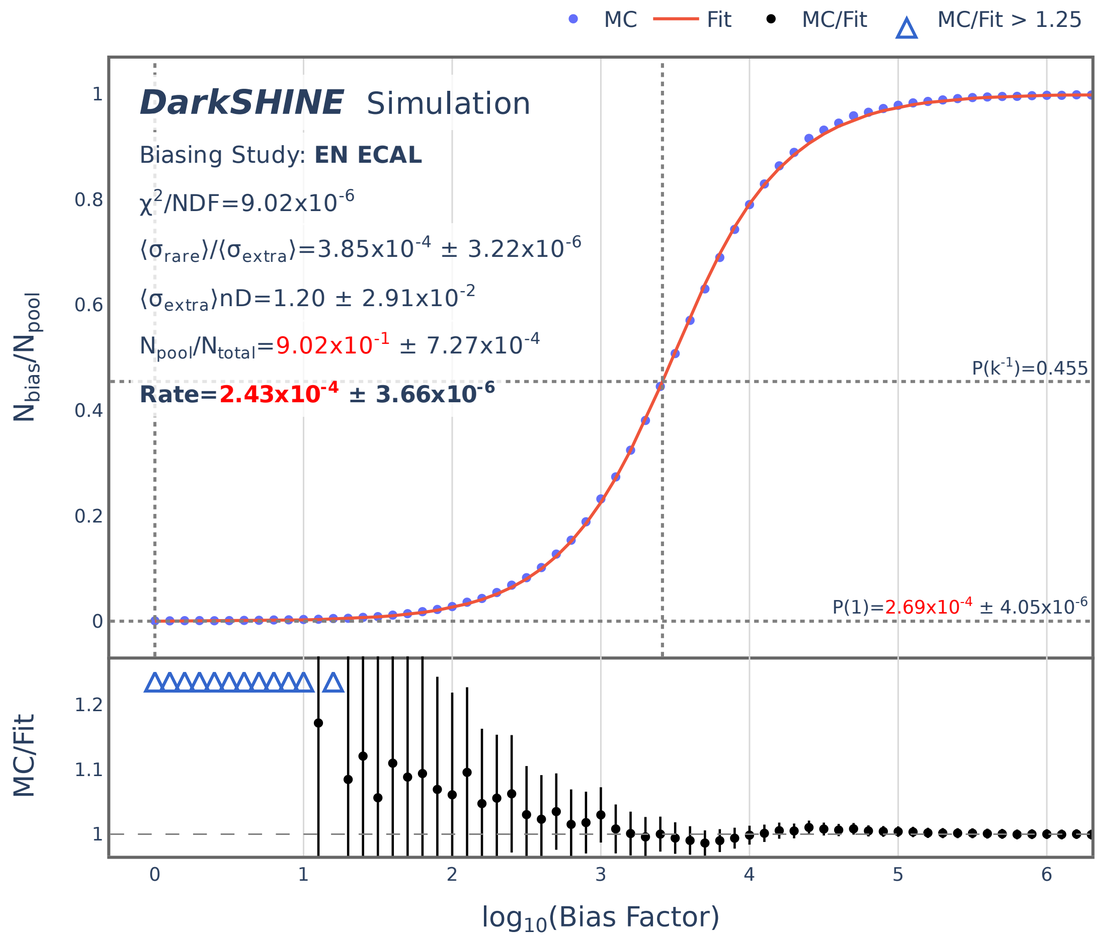
ECAL γ process





Electron Nuclear Target / ECAL





Branching ratio $\sim \sigma_r / \sigma_c$

$$N_{expect}(rare) = Br(rare) \times \epsilon_{filter} \times N_{EOT}$$

	Branching Ratio	Branching Ratio Error	Filter Efficiency	Filter Efficency Error	DSimu Trigger Efficency (missingP >1,	DSimu Trigger Efficiency Error
GMM Target (E_γ>2GeV)	**2.04118E-07**		**1.0**	0		
GMM ECAL (E_γ>2GeV)	**2.59802E-06**		**1.0**	0		
PN Target (E_γ>2GeV)	**4.62047E-05**		**1.0**	0		
PN ECAL (E_γ>2GeV)	**8.30026E-04**		**1.0**	0		
EN Target (E_e>2GeV)	**Running**		**Running**			
EN ECAL (E_e>2GeV)	**Running**		**Running**			

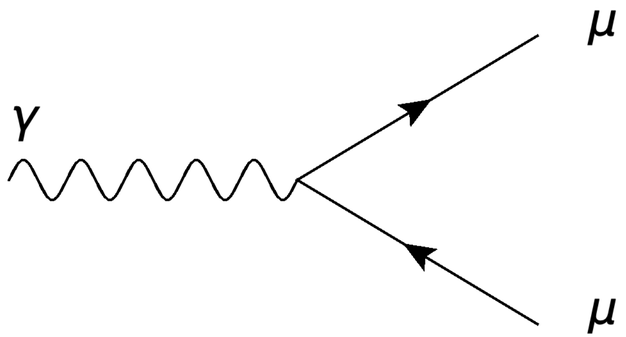
Todo

- Use ratio plot. add band by changing k by ~1% to see the sensitivity of the variable
- P_pool, EN Branching ratio calculation, Calculate DSimu Trigger Efficiency
- Validation:
  - Branching ratio in the inclusive sample
- Random seed be different for different bias type
- Validation: Check sum of track weight calculated by Geant4

Biasing cut, filter cut

Example diagrams for rare processes

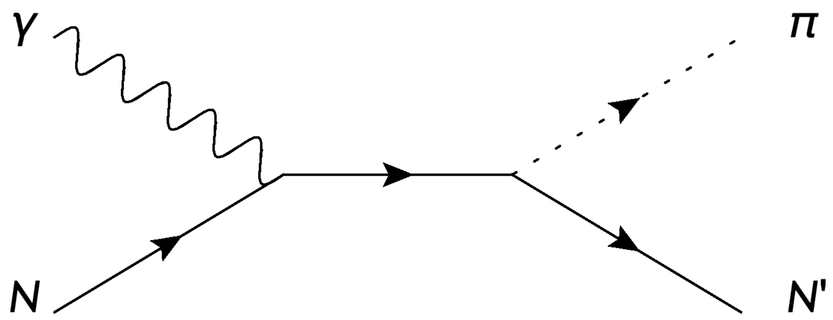
```
if (track->GetTotalEnergy() <= Emin) return nullptr;
```



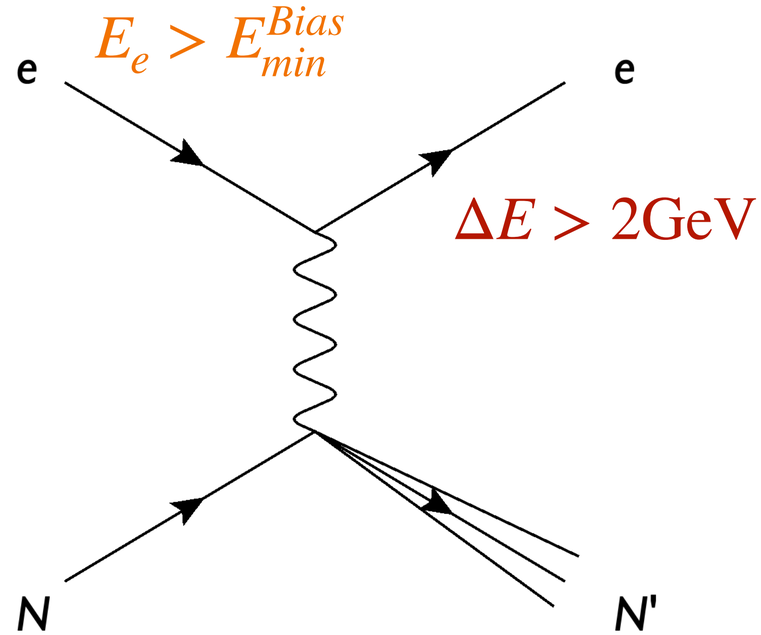
GMM

$n_{pool} : E_\gamma > E_{min}^{Bias} = 2\text{GeV}$

$filter : \Delta E = E_\gamma > 2\text{GeV}$



PN($\gamma N \rightarrow \pi N'$)



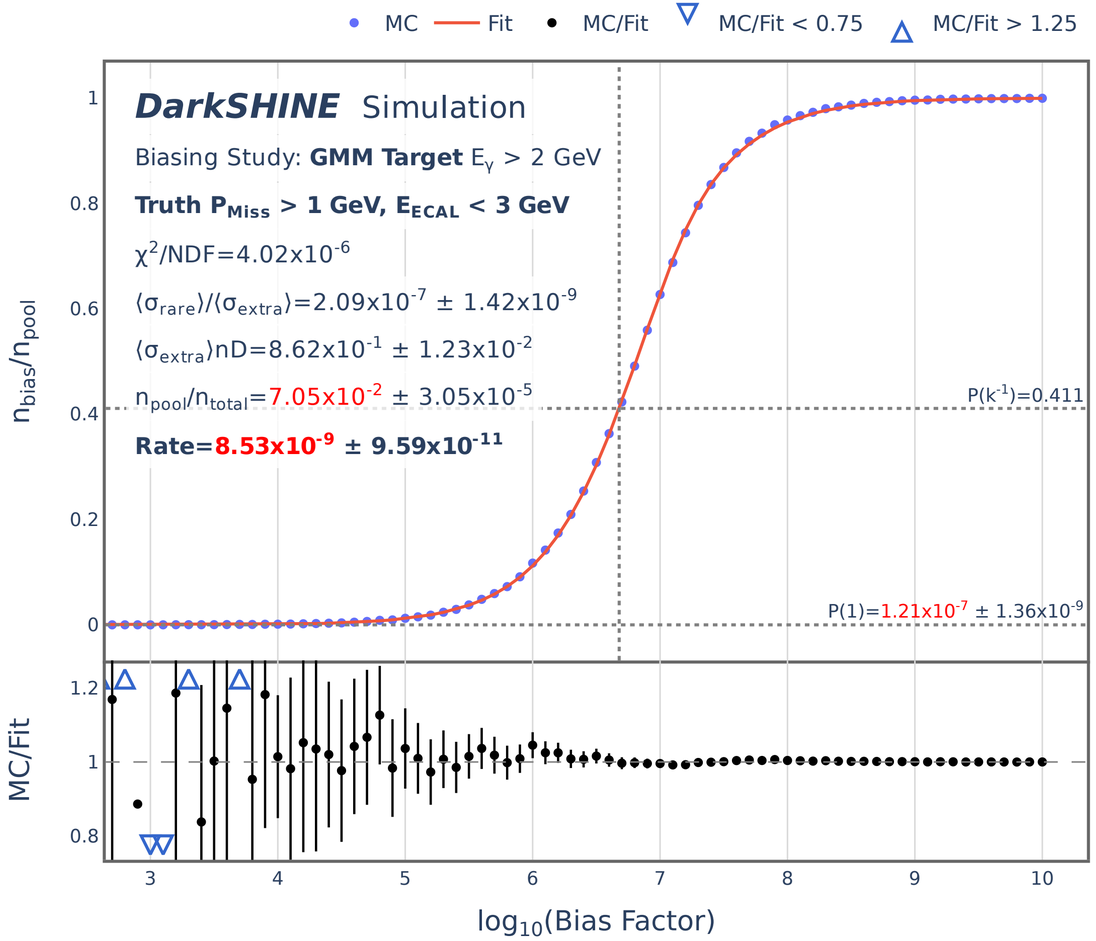
$E_e > E_{min}^{Bias}$

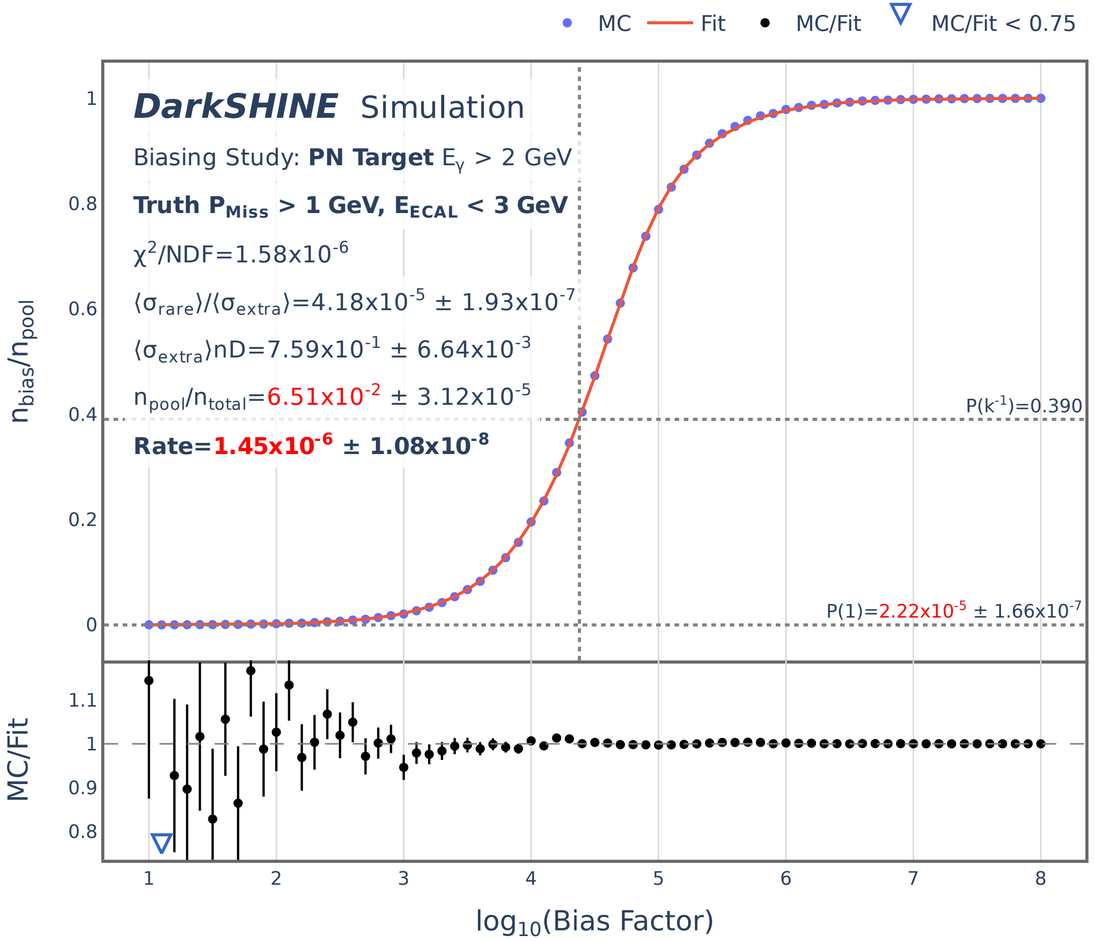
$\Delta E > 2\text{GeV}$

EN

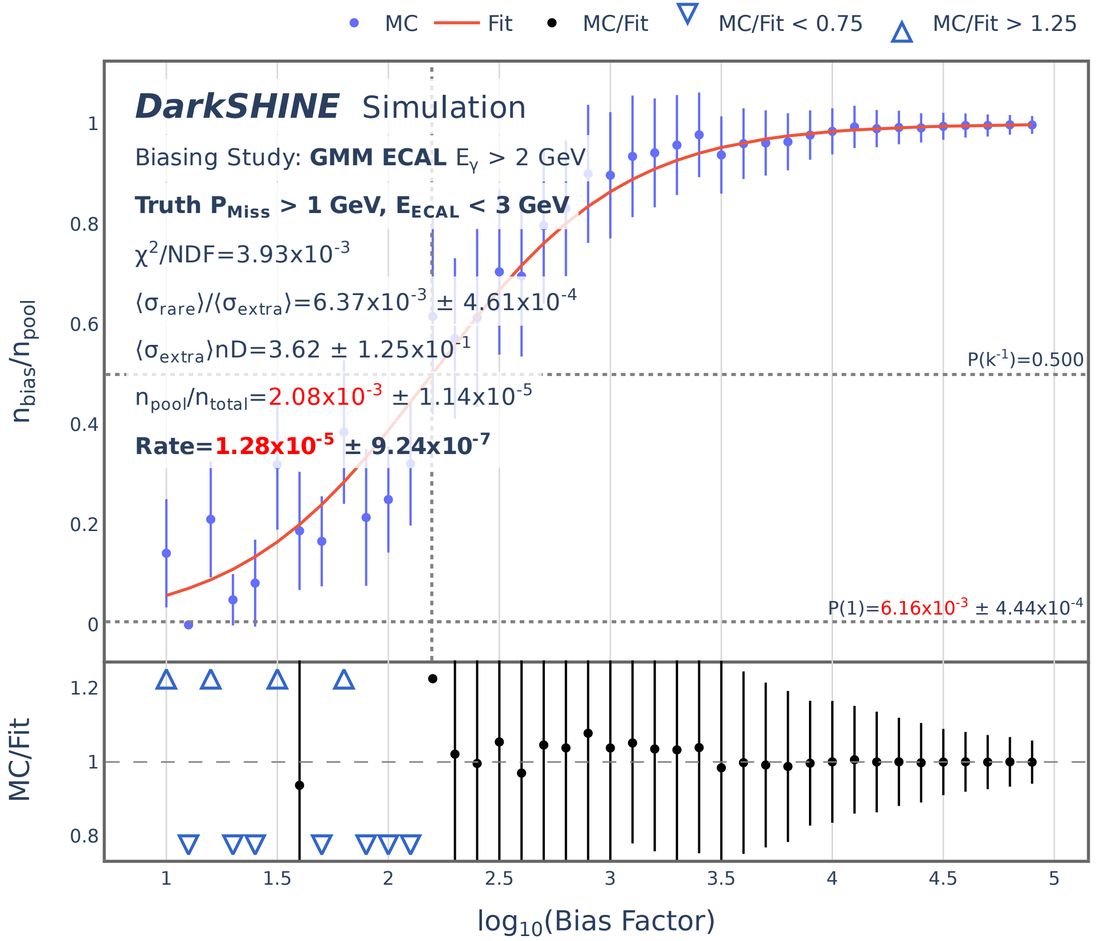
$N_{expect}(rare) = Br(rare) \times \epsilon_{filter} \times N_{EOT}$

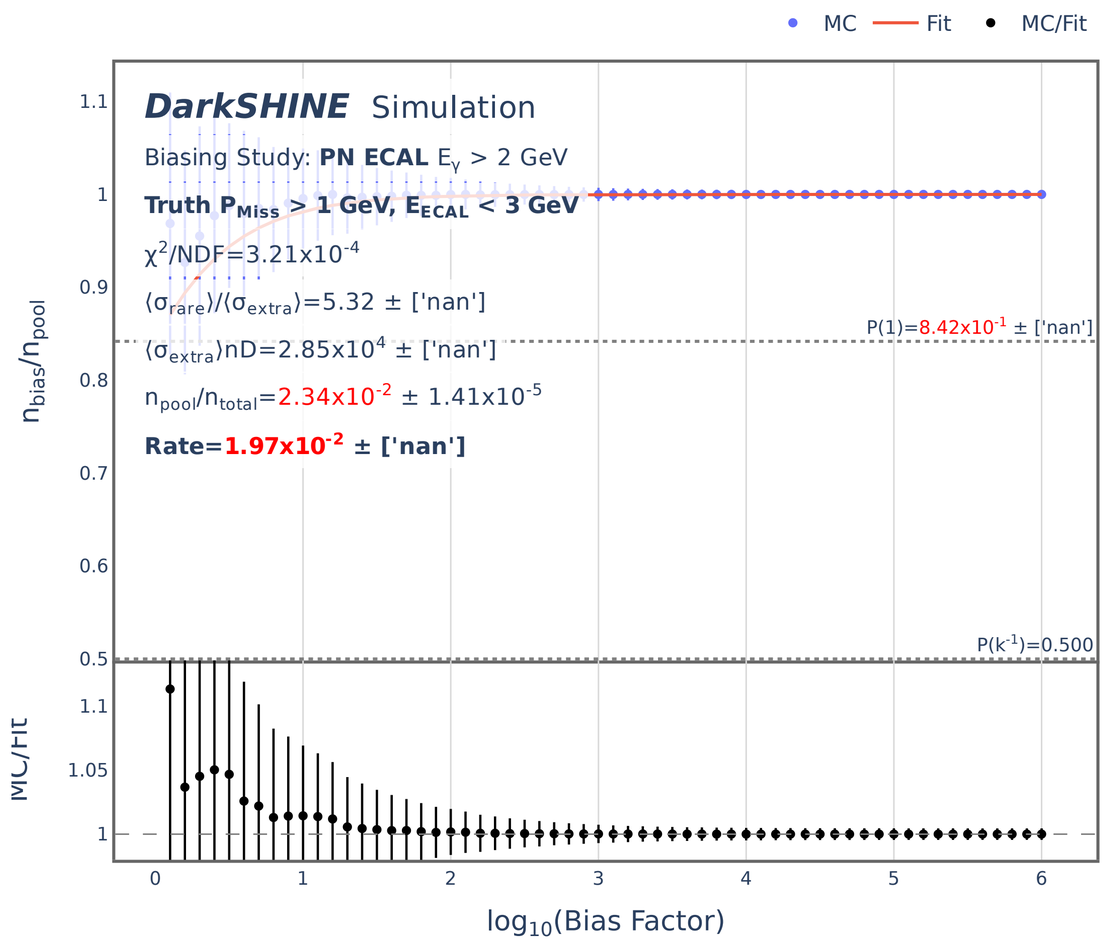
Target γ process w/ Truth Trigger





ECAL γ process w/ Truth Trigger





Target / ECAL Electron Nuclear w/ Truth Trigger