EmCa

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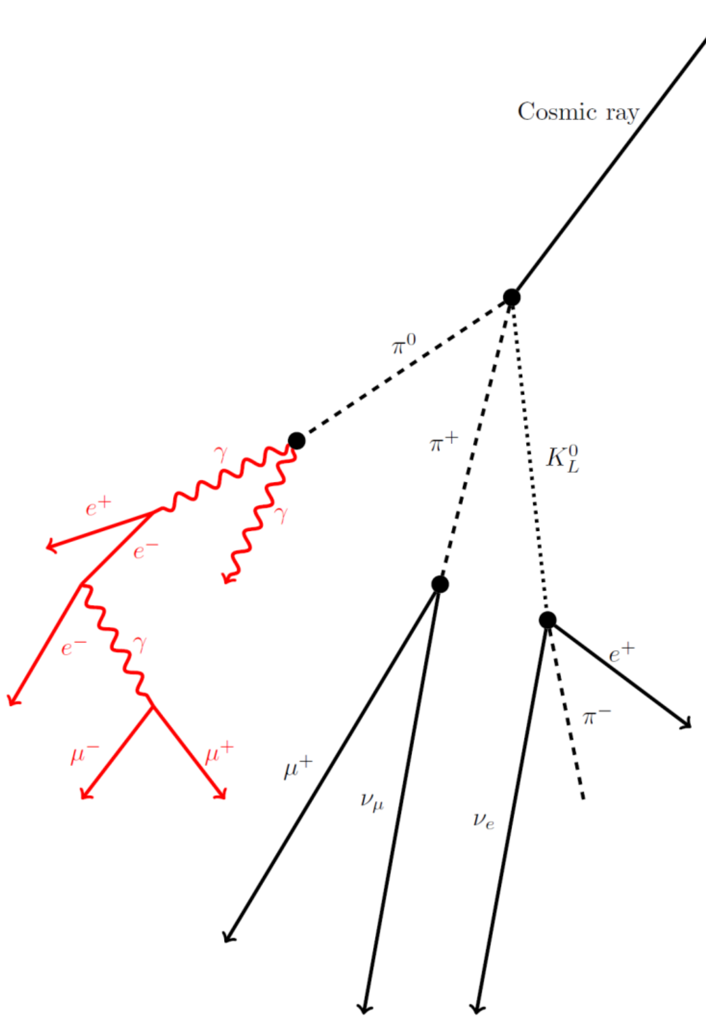
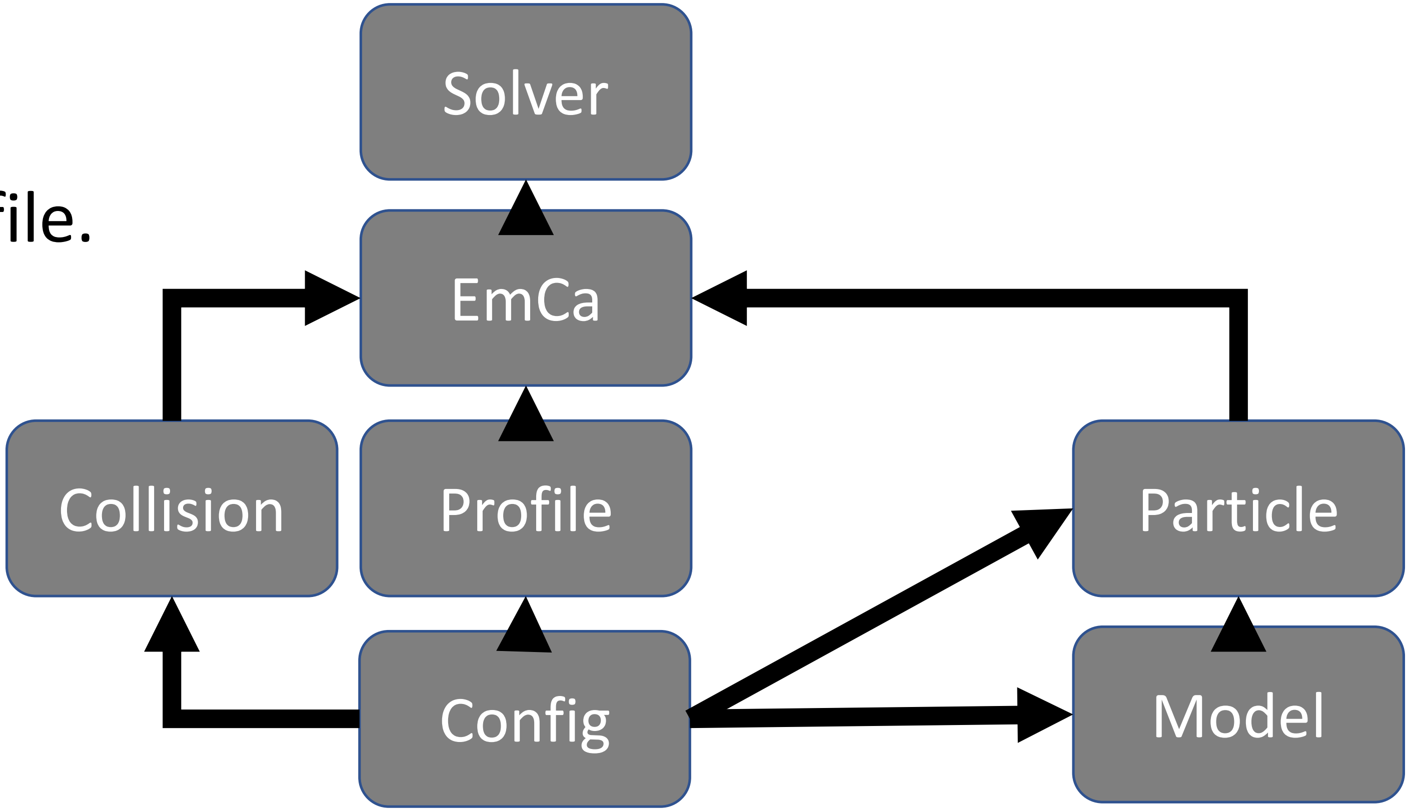


EmCa

- Python Package
- Run with python notebooks
- Advanced settings in config file.
- Easily extendible
- Provides integration method for discretization
- Full EM cascade simulations



Cascade Equations

- Cascade Equations

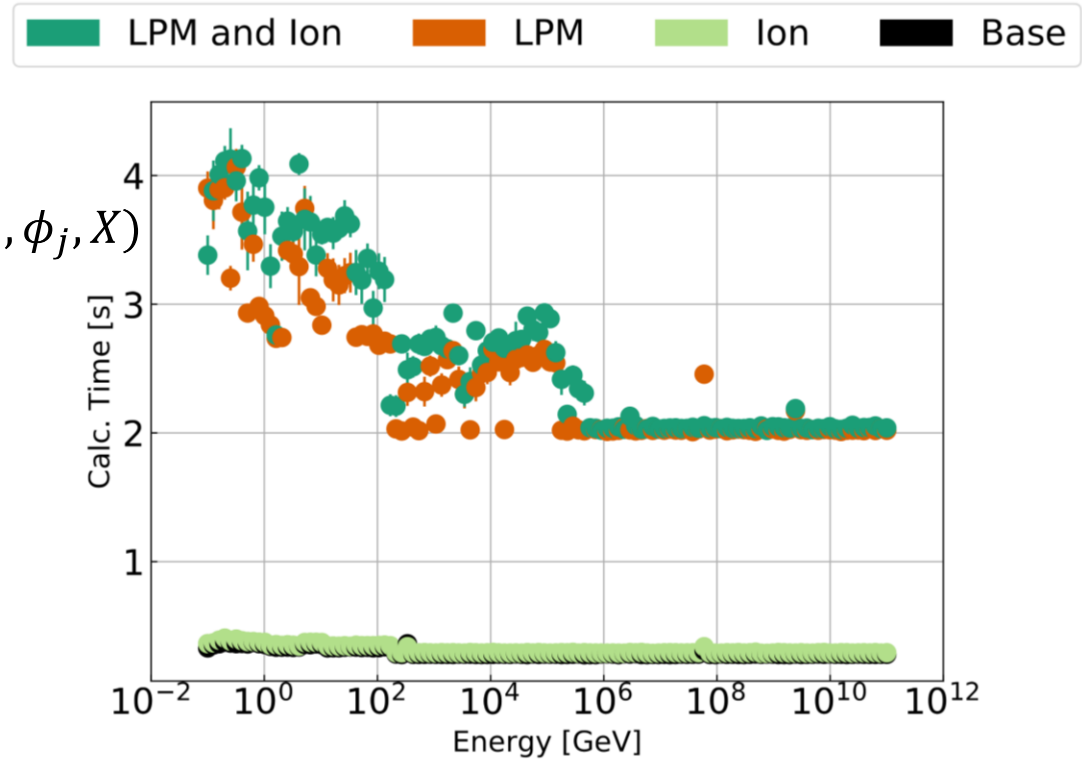
$$\frac{d\phi_i}{dX}(E_i, X) = -\frac{\phi_i(E_i,\ X)}{\lambda_i(\sigma_i, E_i)} - \partial_E(\mu(E)\phi(E_i, X) + \sum_j \Gamma_j(E_i, E_j, \sigma_{j\to i}, \phi_j, X)$$

- Discretize

$$c_{l(E_l)i(E_i)} = \Delta E_l \frac{1}{\sigma(E_l)} \left\langle \frac{d\sigma_{l(E_l)\to i(E_i)}}{d(E_i)} \right\rangle; \quad \Lambda^i_{int} = (\frac{1}{\lambda_i(E_0)}, \ldots, \frac{1}{\lambda(E_N)})$$

$$\to \frac{d\vec{\phi}}{dX} = (-1 + \hat{C})\Lambda_{\text{int}}\vec{\phi}$$

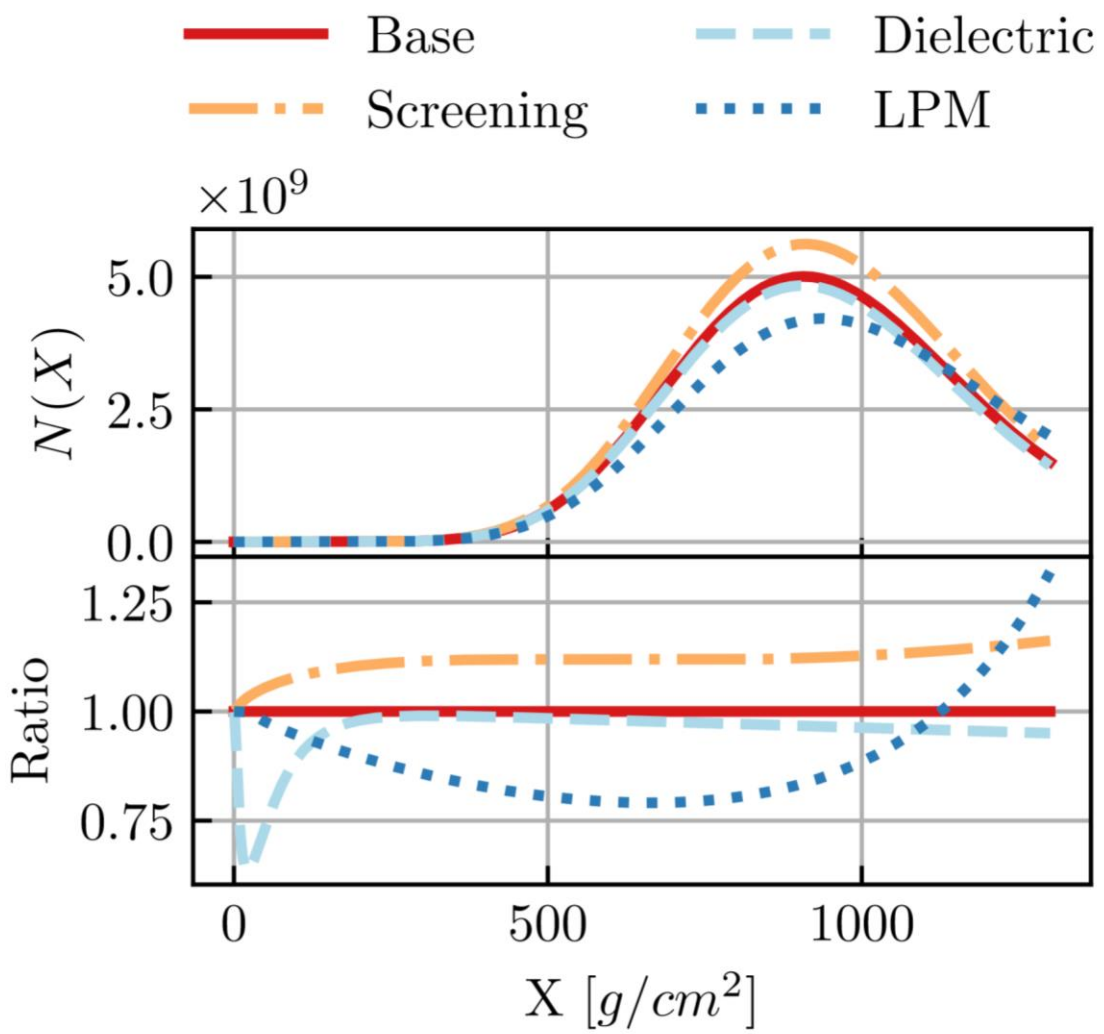
- Fast and Efficient



- Heavy lifting in the pre-tabulated matrices

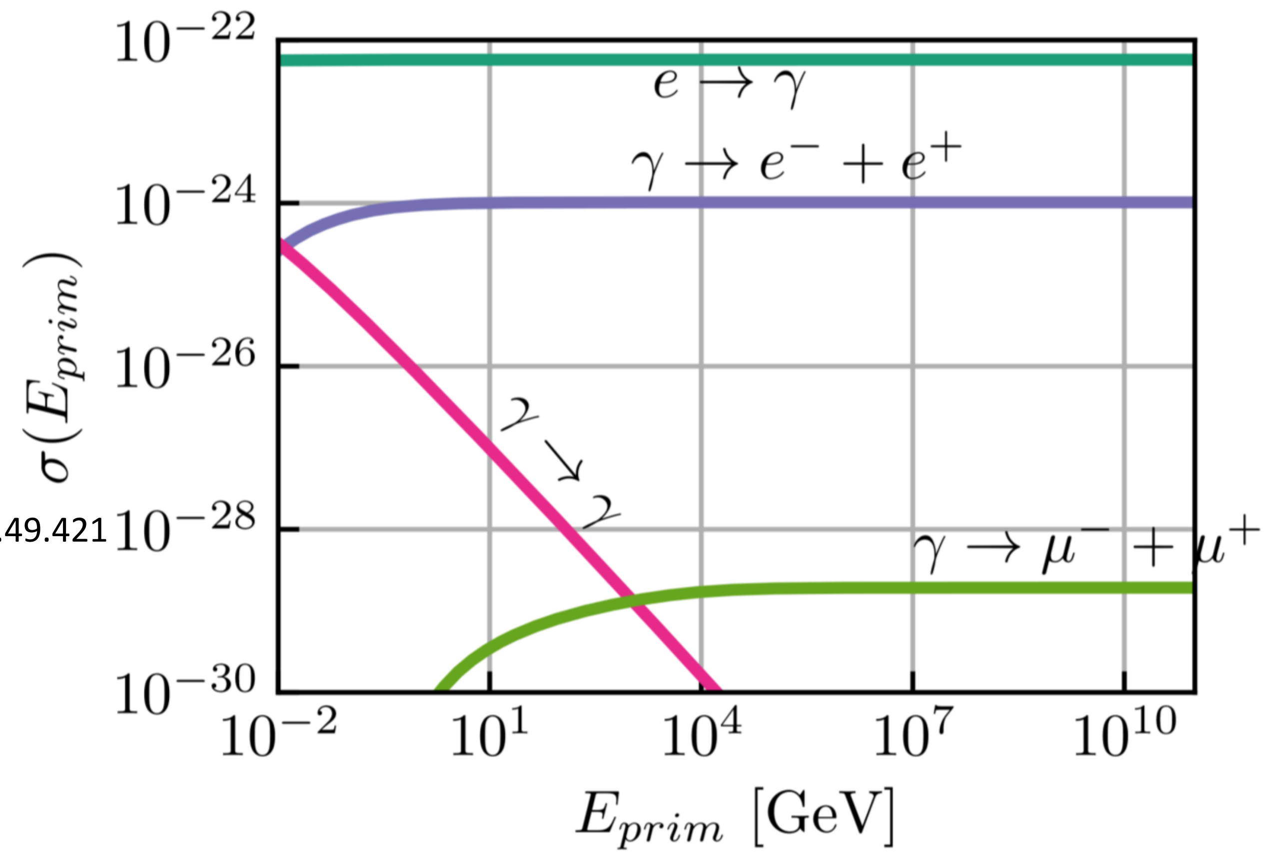
Why Electromagnetic Cascades?

- A more modern approach to EM
  - EGS does not include:
    - - Density Effects
      - LPM
      - Dielectric
  - Modern cross section definitions
  - No free parameters
  - Usable ionization definition



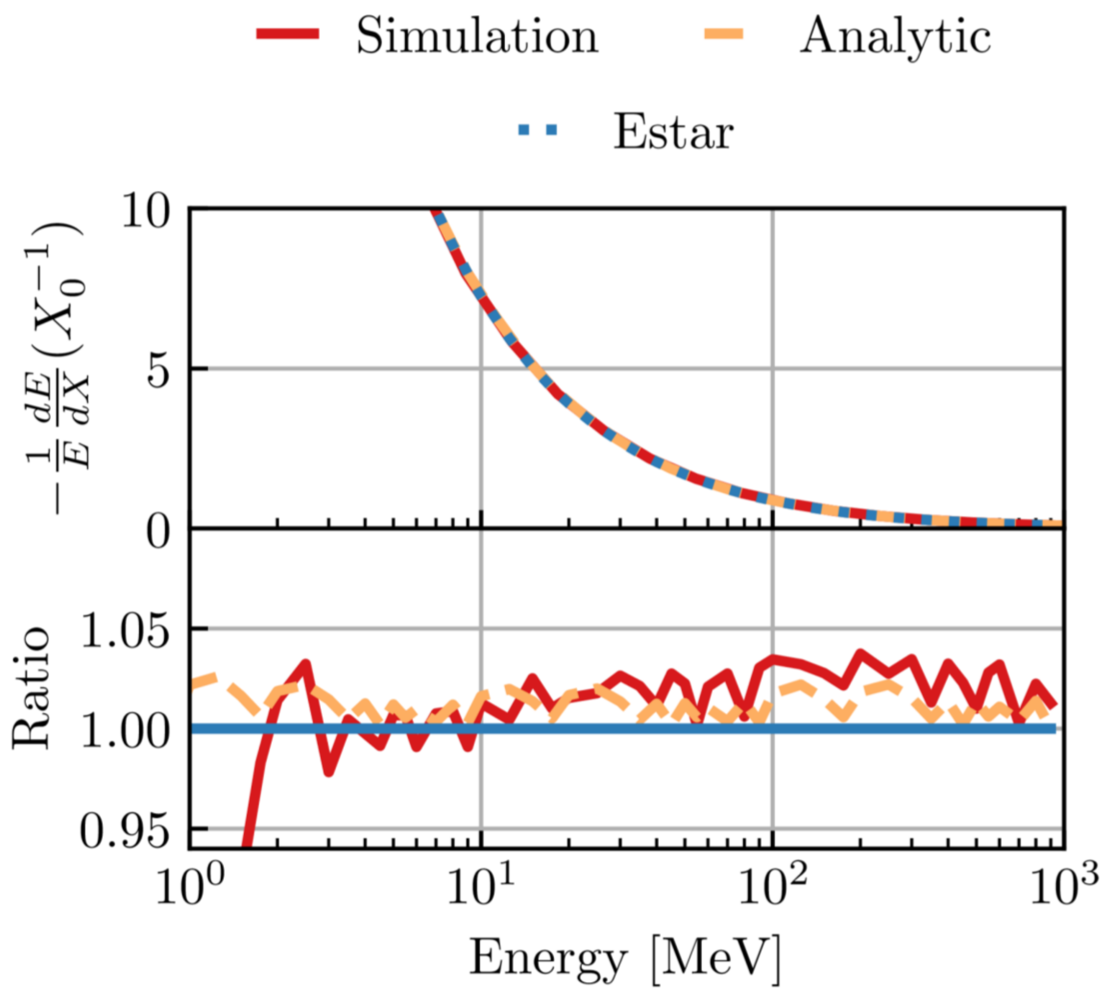
Electromagnetic Cascades

- Included in the Model
  - Ionization
    - ESTAR J. Berger, J.S. Coursey
    - doi:https://dx.doi.org/10.18434/T4NC7P.
  - Bremsstrahlung; Pair production
    - Tsai
    - doi:10.1103/RevModPhys.46.815,10.1103/RevModPhys.49.421
  - Compton-scattering
    - Klein, Nishina
    - doi:https://doi.org/10.1007/BF01366453



Numerics - Ionization

- Uses ESTAR tables
- Seven-point stencil method for discretization
- Cross check by propagating electrons

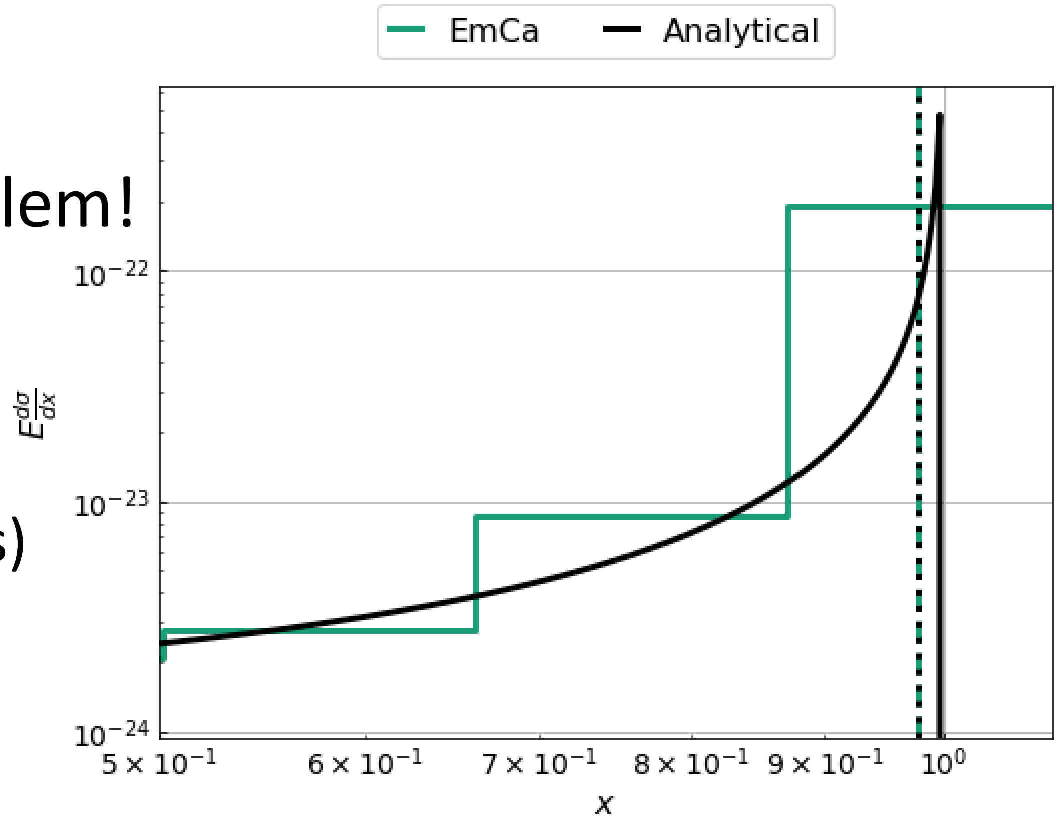


Numerics - Integration

- One un-binned version (0 GeV to 1EeV)
- One binned version (10 MeV to 1EeV)
- Discrepancies of 0.1% are a major problem!

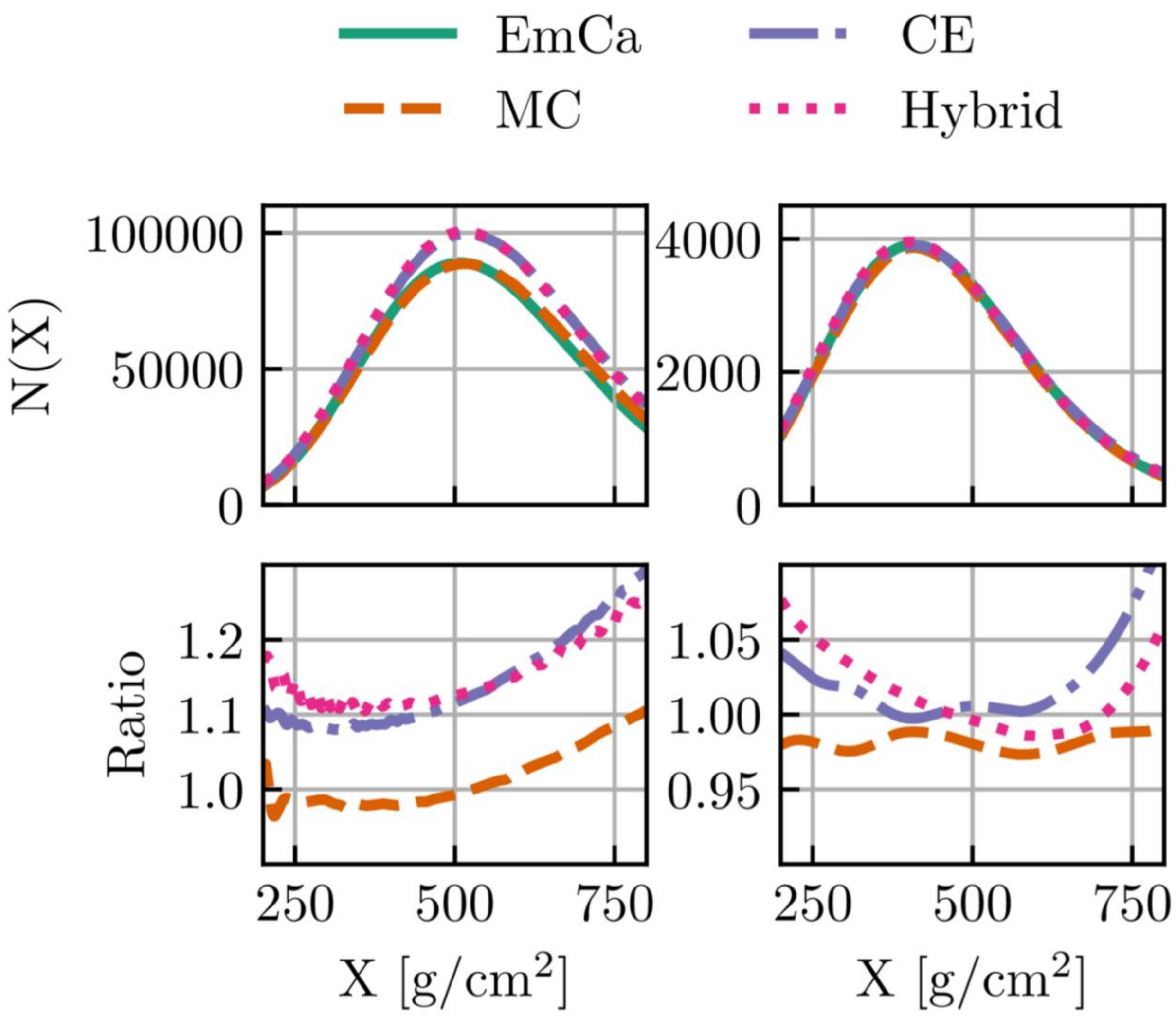
- New Method
  - Tranform $(E_{prim}, E_{sec}) \rightarrow (E_{prim}, x)$
  - Sinh-Tanh quadrature (with defined nodes)
  - 3-Moment Method

- No scaling required!



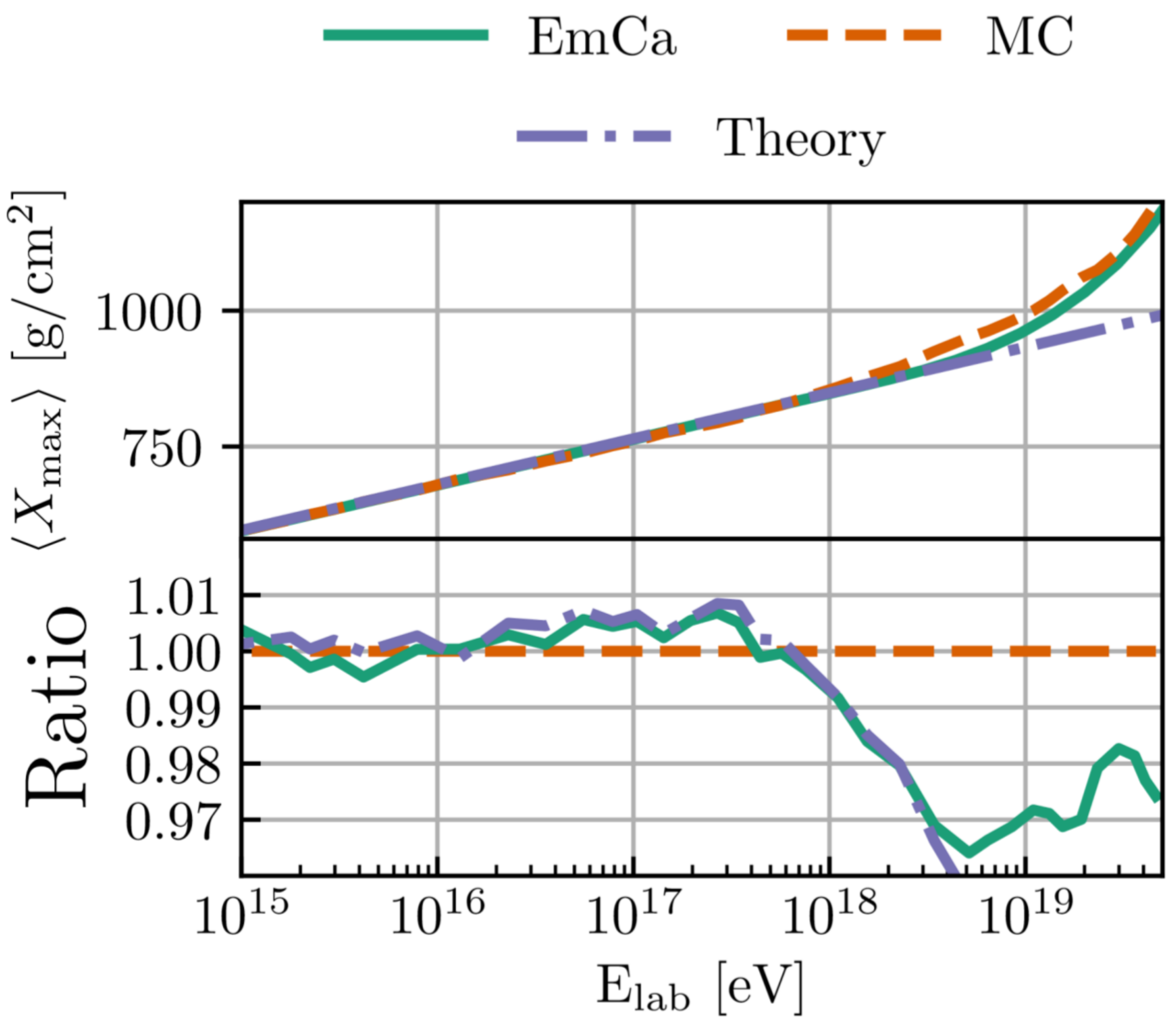
Air Shower

- Compare to CORSIKA / CONEX
  - From T. Bergmann et al.
  - arXiv:astro-ph/0606564
- Inject single 100 TeV Photon
  - 1 MeV Cut (left)
  - 1 GeV Cut (right)
- High agreement with CORSIKA
- Differences at low energies



Xmax

- Simulate Xmax
  - From M. Niechciol et al.
  - arXiv:1710.06586
- Low energy cut-off 86 MeV
  - Ionization plays a minor roll
- Include LPM
  - Differences due to treatment



Relevance for CORSIKA

- Cross check for electromagnetic cascades
  - Monte Carlo and CONEX results
- Integrator for cross sections
  - Energy and particle number conservation
- Replacement for EGS4?
  - In combination with PROPOSAL
- Future:
  - Cross check for 3D calculations
  - Inclusion of stochastic processes

Thank you for your attention
Questions?