first full sensitivity with the pipepline prototype

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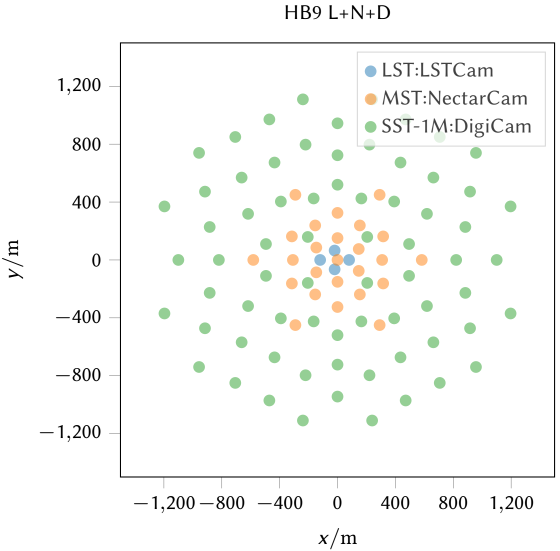
Array Layout



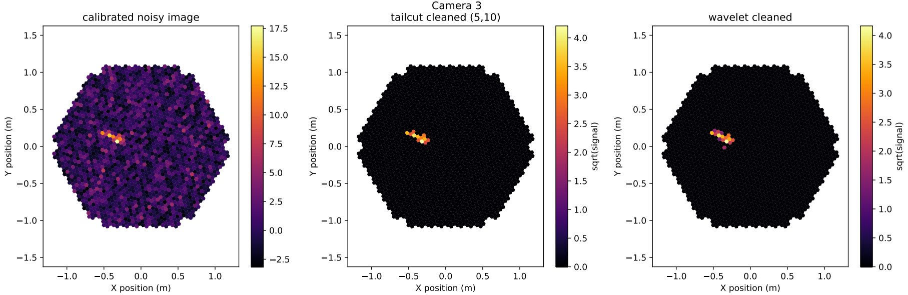
- prod3b
- Paranal HB9 layout
  (LST + Nectar + DigiCam)
- pointing north at 20°
- on-axis gammas,
  diffuse protons and electrons

Cleaning

comparing two cleaning methods:

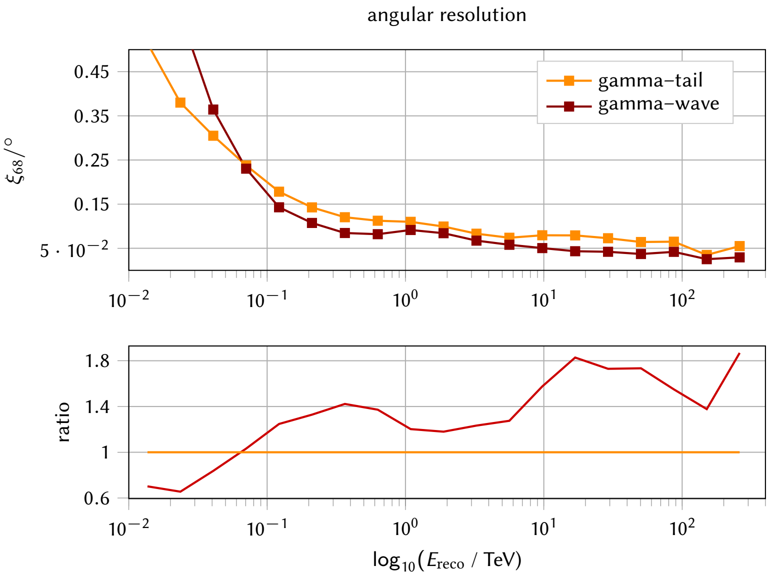
- two-step tailcuts (implemented in ctapipe)
- wavelet cleaning developed by Jérémie (to be merged into ctapipe)

- run the pipeline separately once for each cleaning method
- i.e. each cleaning does its own ML training, reconstruction, discrimination ...



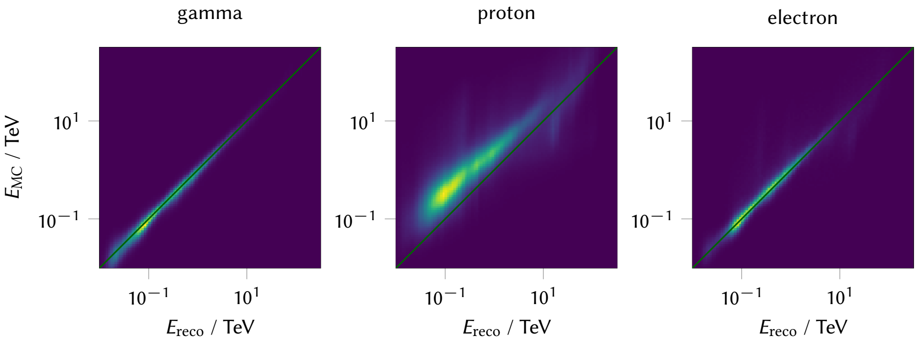
Shower Reconstruction – Direction

Angle between reconstructed and simulated direction

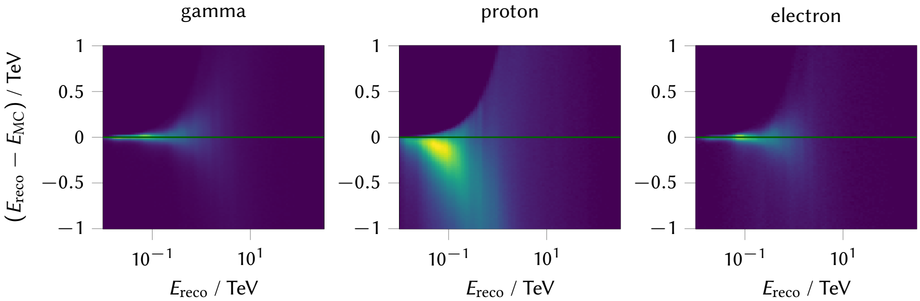


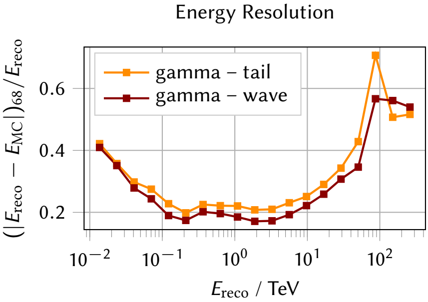
- train 1 Random Decision Forest for each telescope type
- follow a telescope-by-telescope approach

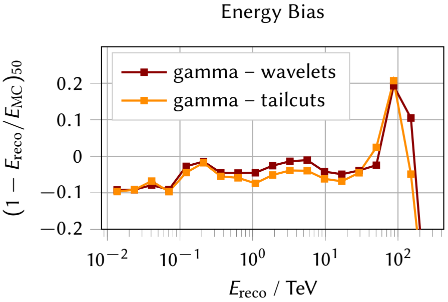
- then, for a given shower event, let the Forest estimate the energy from every telescope separately and combine them into a single energy estimator



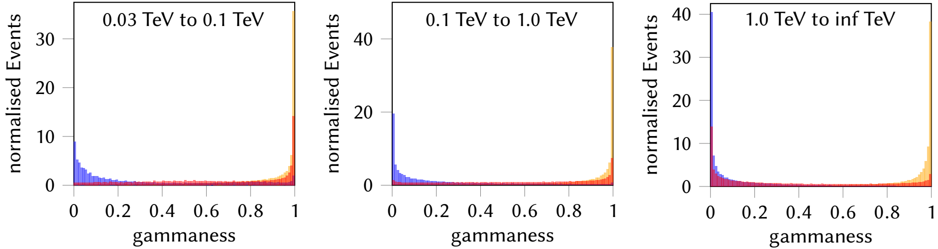
Shower Reconstruction – Shower Energy

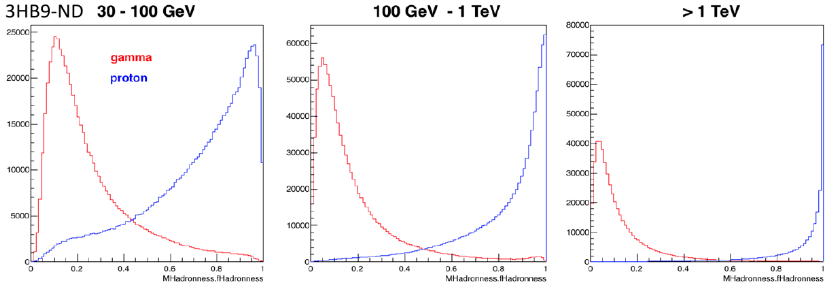






Next Stop: Event Classification





Full List of Features for RandomForest

- impact_dist - distance between telescope and reconstructed impact position
- sum_signal_evt - total signal on all selected telescopes in the event
- sum_signal_cam - total signal on the current camera
- max_signal_cam - signal of the highest intensity pixel in the camera
- N_LST - number of selected LSTs in the event
- N_MST - number of selected MSTs in the event
- N_SST - number of selected SSTs in the event
- Hillas width
- Hillas length
- Hillas skewness
- Hillas kurtosis
- h_max - reconstructed height of shower maximum
- err_est_pos - error estimator of the reconstructed impact position
- err_est_dir - error estimator of the reconstructed shower direction

Event Weights

- next step: reweighting of MC events to correspond to expected physical flux (e.g. Crab nebula for gammas, CR for protons)
- simple binned approach:
  - construct energy-binned selection efficiencies from MC
  - apply these on the energy-binned histogram of expected *arriving* events from the source
  - $\longrightarrow$ get the number of expected selected events

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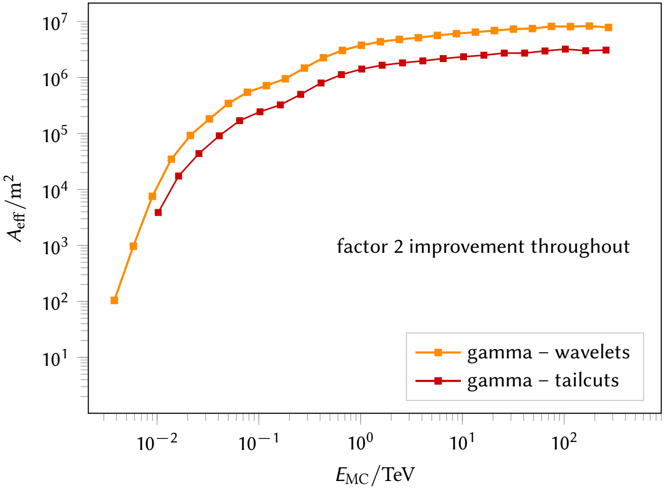
- **but:** it's binned... not optimal (but implemented anyway)

Event Weights

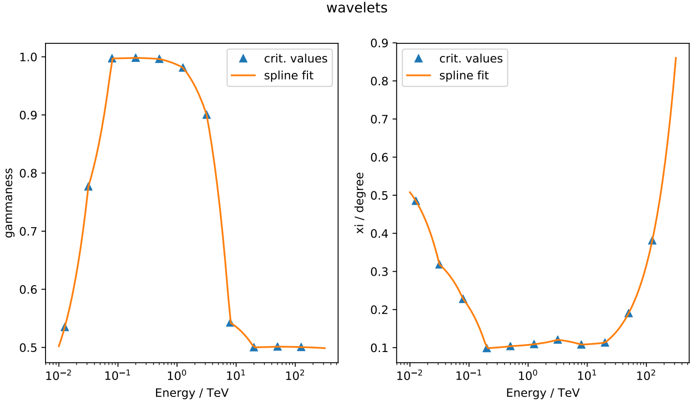
- next step: reweighting of MC events to correspond to expected physical flux (e.g. Crab nebula for gammas, CR for protons)
- instead: event-by-event weight that considers the generator spectrum:
- $w(E) = A_{\text{gen}} \times I_{\Theta} \times E^{\gamma} \times I_E \times T_{\text{obs}}/N_{\text{gen}}$
  with:
  - A_{gen}: MC generator Area
  - $I_{\Theta} = 2\pi(1 - \cos\vartheta)$: angular phase space factor for diffuse flux
  - E^{γ}: considers that MC events have been drawn with an E^{-2} spectrum
  - γ: spectral index of the MC generator (here equal 2)
  - $I_E = (E_{\text{max}}^{(1-\gamma)} - E_{\text{min}}^{(1-\gamma)})/(1-\gamma)$: energy phase space factor
  - T_{obs}: assumed observation time
  - N_{gen}: number of generated MC events
- $w(E) \times \Phi(E)$ gives weight for every MC event so that their energy distribution looks like the selected events from the assumed flux Φ

Effective Areas
after reconstruction



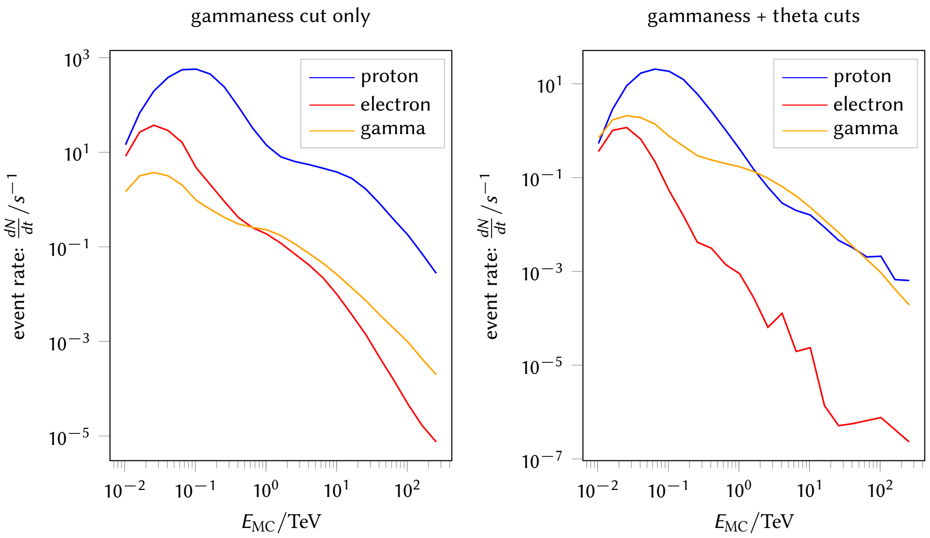
Quality cuts

- energy-binned finding cuts to minimise sensitivity
- numerical fit simultaneous in gammaness and direction error
- $N_\gamma > 10$ and $N_\gamma > 0.05 * (N_p + N_e)$ taken into account

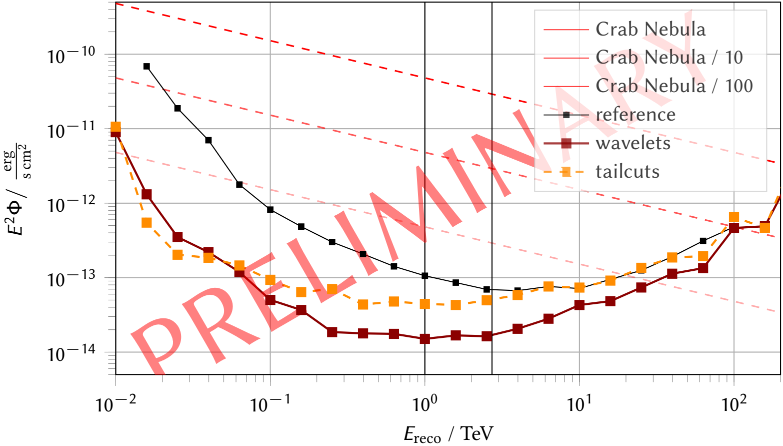


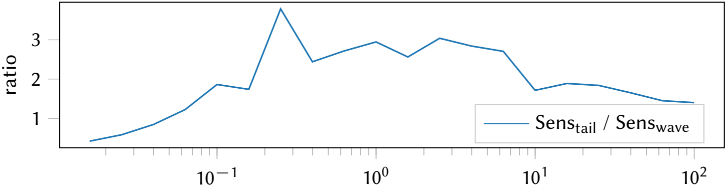
Event Rates

after gammaness only cut / after gammaness + theta cut



on-axis point-source Sensitivity





Summary

- ctapipe can produce sensitivity curves
- wavelets outperforms tailcuts
  - angular resolution: 30 % – 80 %
  - effective area: 100 %
  - sensitivity: 100 % – 200 %
- gain over reference at low energies very large
- maybe still normalisation problem?
- will investigate further