Photon reconstruction in ILD with GARLIC

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GARLIC - An algorithm for GAmma Reconstruction at the LInear Collider

- Try to improve clustering of photon contribution in jets
- Implemented in the MARLIN software framework
- For SiW ECAL: Prototype + ILD version (different cell sizes)
- Steering parameters available for tuning
- Clustering based on neighbour criterion
- Designed for pointing photons
- Works over whole solid angle
- Rejection via simple criteria (#hits, minimum energy, seed criteria,...)
- + Computation of cluster variables (eccentricity, width, direction, energy deposit in different regions,...) - ANN
- Correction for wafer guard ring and module gaps
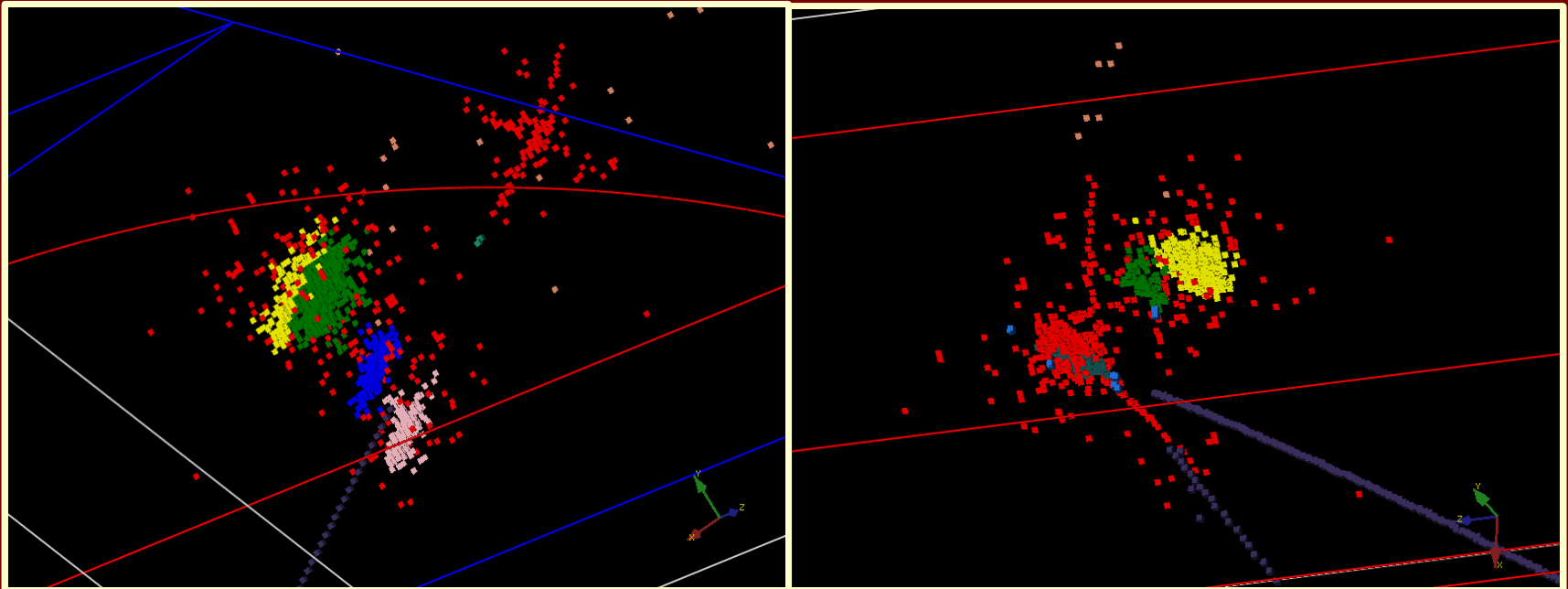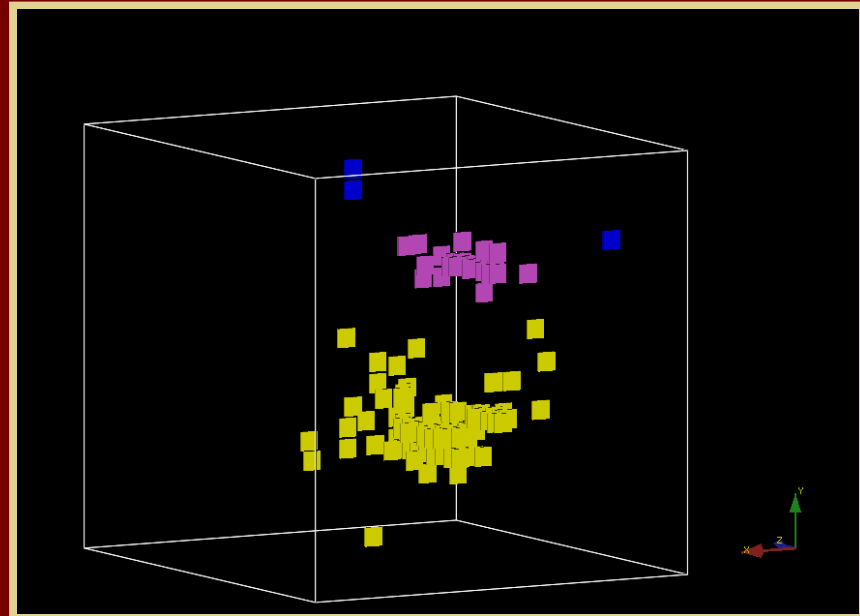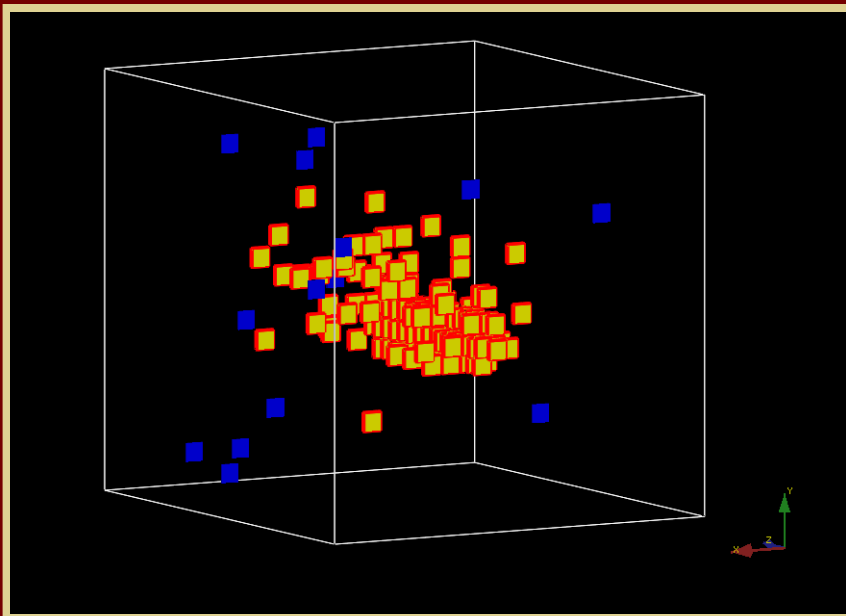
GARLIC for ILD
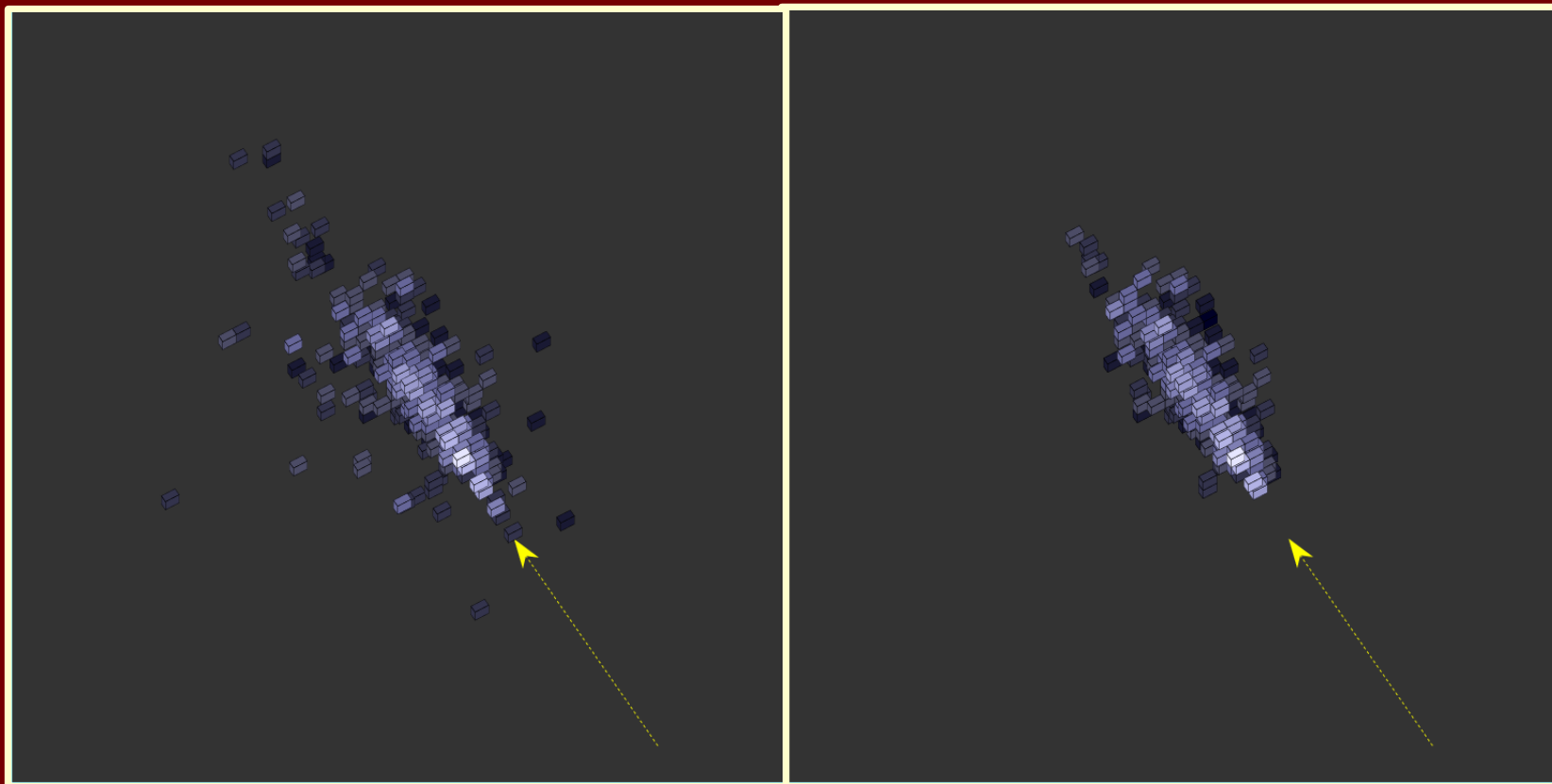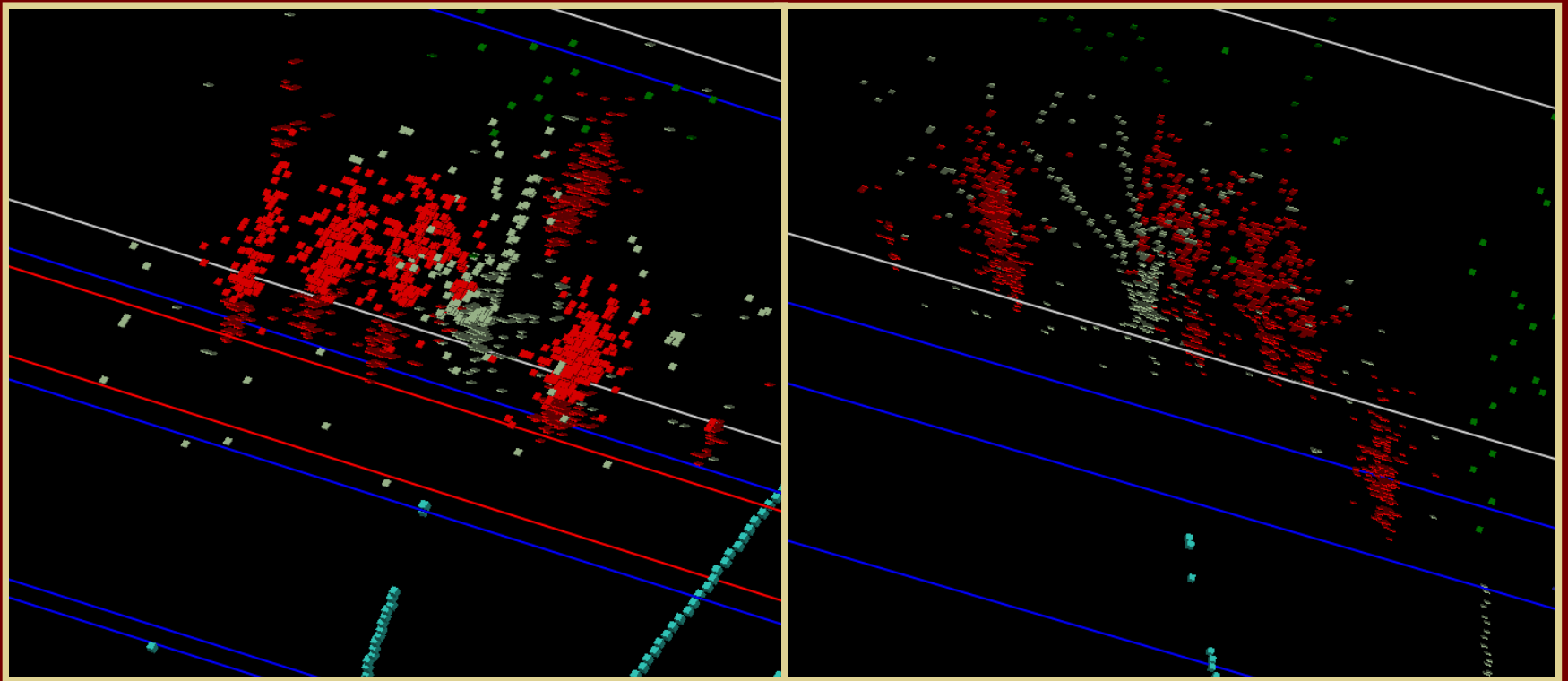
GARLIC for ILD

GARLIC on taus

GARLIC for the SiW ECAL prototype

GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)

Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

- Recursive with 20cm 3d distance

GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)

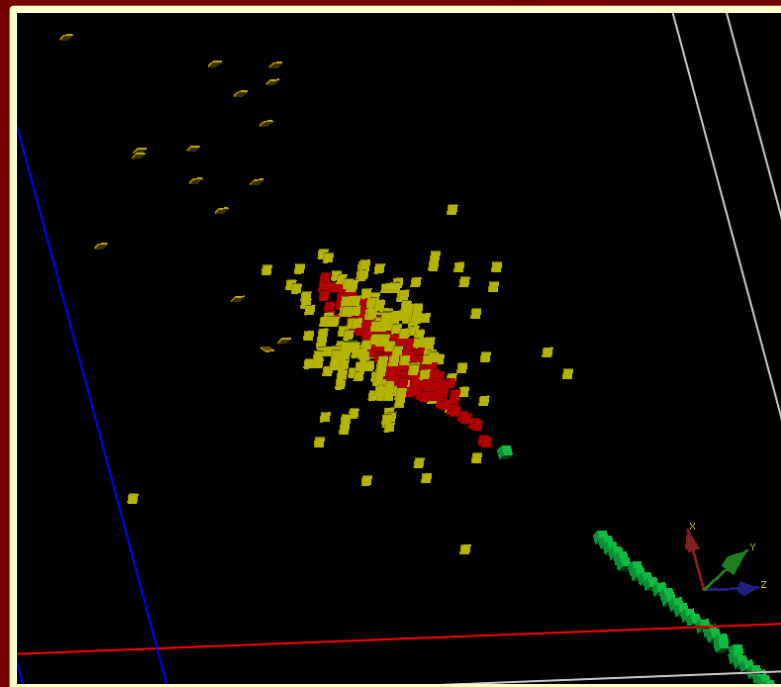Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

- Distance variable (default: 2 times cell-size)
- Important for rejection of charged hadrons

GARLIC GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)

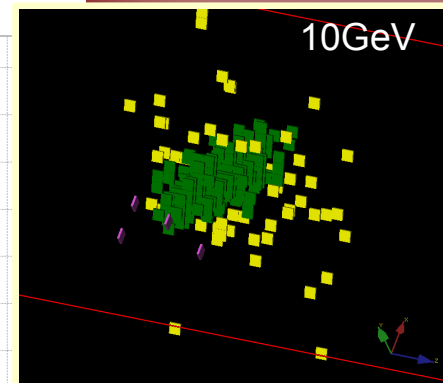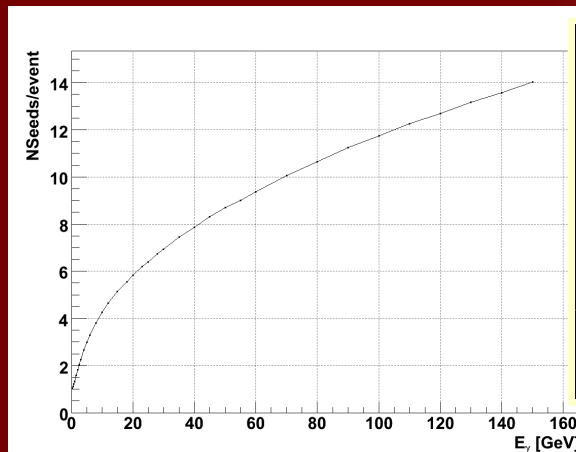Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

10GeV

- First 20 layers = ~0.5λ
- Use 12 first layers (7X_0)
- Projection depends on seed position:
  - Barrel: cylinder
  - Endcap: plane
  - Overlap: sphere
- Regroup histogram entries
- Seed validation with min en/hits
- List of seeds ordered by energy

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GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)

Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

- Pointing photons: shower direction is IP → seed
- Add hits with distance < 1*cell size from main axis
- Minimum hits in $10X_0$
- Reject longitudinal holes (one than 1 layer) in 2nd stack

GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)

Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

- Proceed from front to back
- Several iterations (default:3)
- Variable distance (default: $\sqrt{2}$*cell size)
- Same layer and two following
- Check for module/wafer gaps

GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)

Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

- 150 MeV minimum En
- 5 hits minimum
- 1.5*cell size distacne from nearest track

GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)
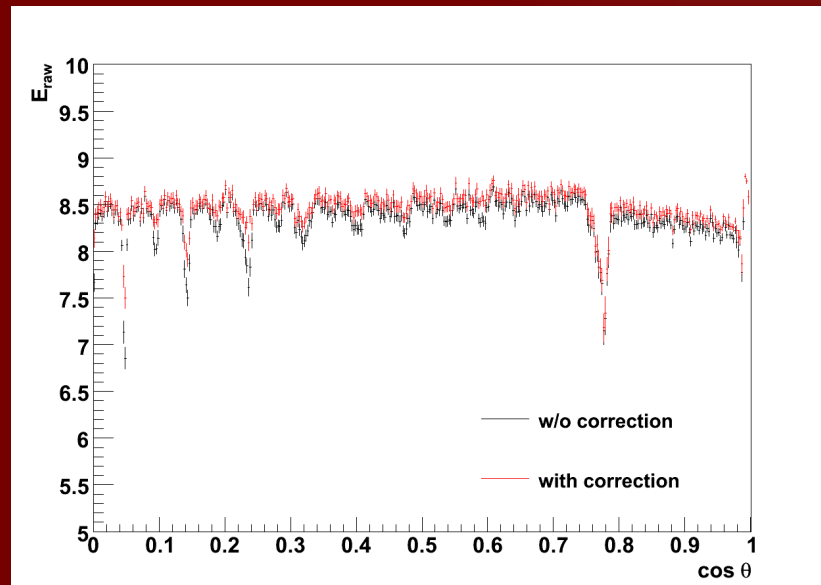
Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

- Conservative approach
- Add „Ghost hits" in gaps with linear extrapolation of surround hits
- Weighing by (gap area/cell size), cluster energy and θ

GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)
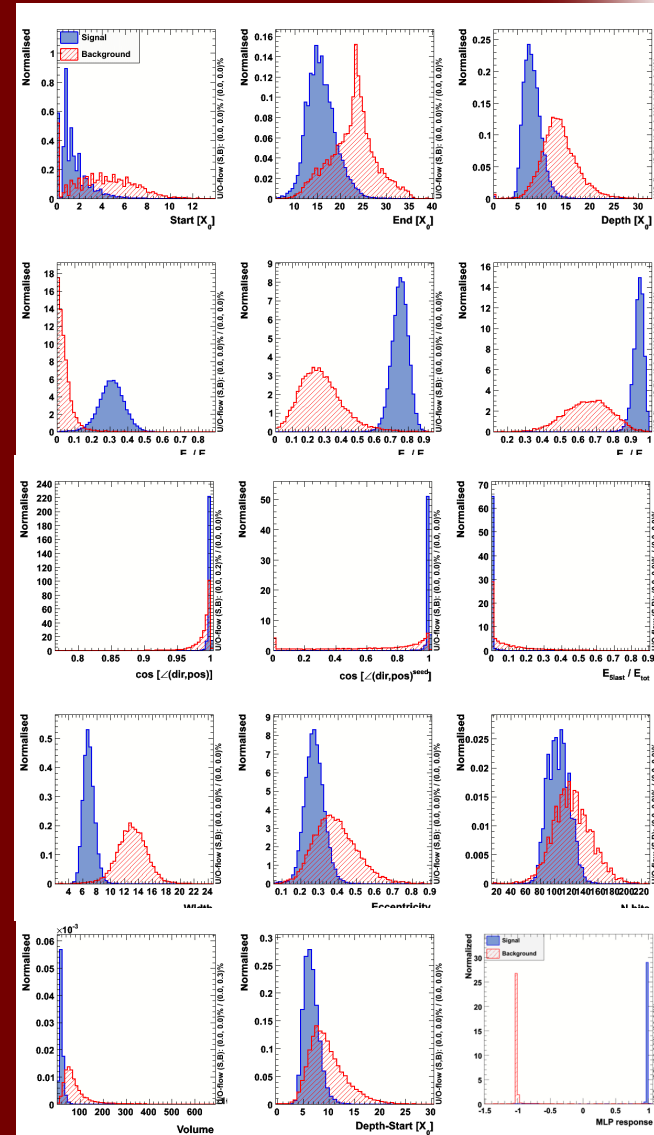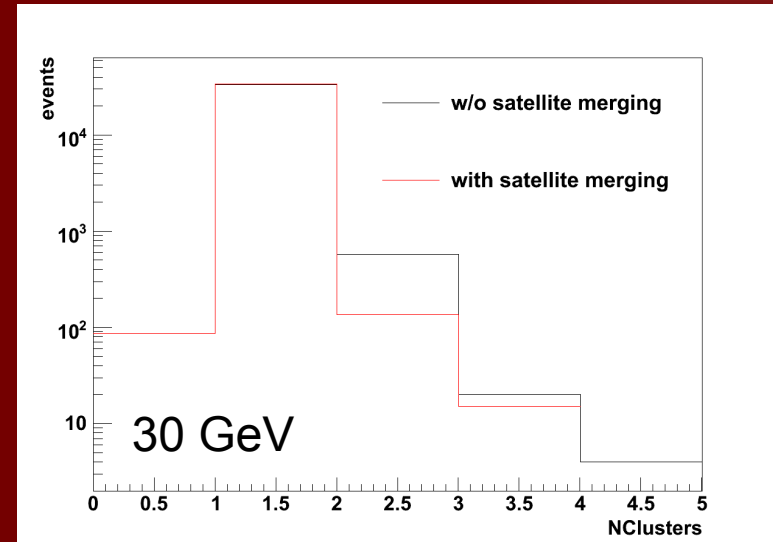
Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

3-5 GeV

- Several variables using longitudinal,transverse or overall shower shape
- Cuts per energy region (<20GeV) and location (endcap - barrel)

GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)

Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

ANN rejection

Satellite merging

Final energy estimation

30 GeV

- Remerge split showers
- Criteria
  - Distance
  - Energy ratio

GARLIC

Pre-Clustering via hit distance: RoI

Remove hits close to extrapolated tracks

Per RoI:

Seed finding: 2-dim energy projection

Per Seed:

Core building (hits close to seed axis)

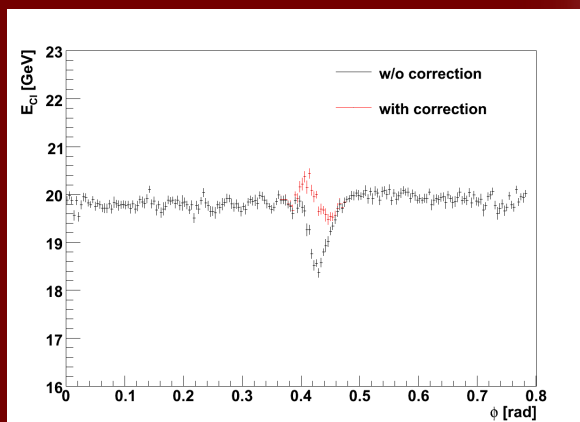Neighbor clustering (front to back)

Simple verification (min.en/hits,dist track)

Gap correction

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Satellite merging

Final energy estimation
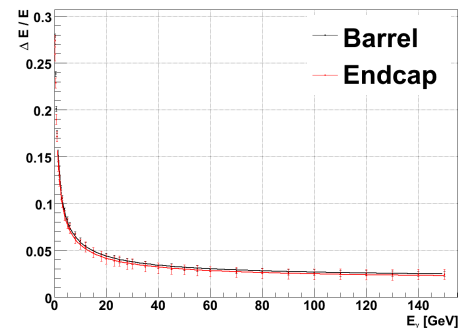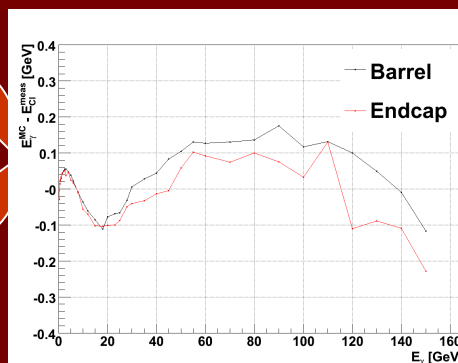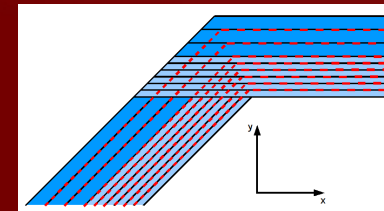
- Geometrical corrections
- Energy estimation with two 2nd order polynomials conected at 20GeV
- More precise energy estimation with fitted prefactors for 1st /2nd stack and number of hits

Single photon efficiencies

1GeV   10GeV   100GeV
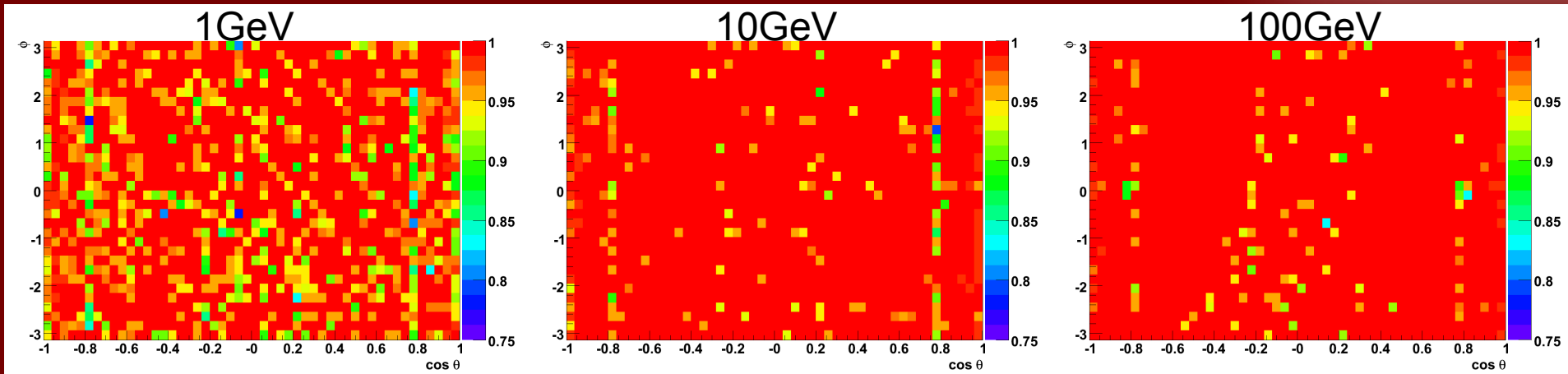
Uniform efficiency, except critical areas: barrel-endcap overlap, module transitions
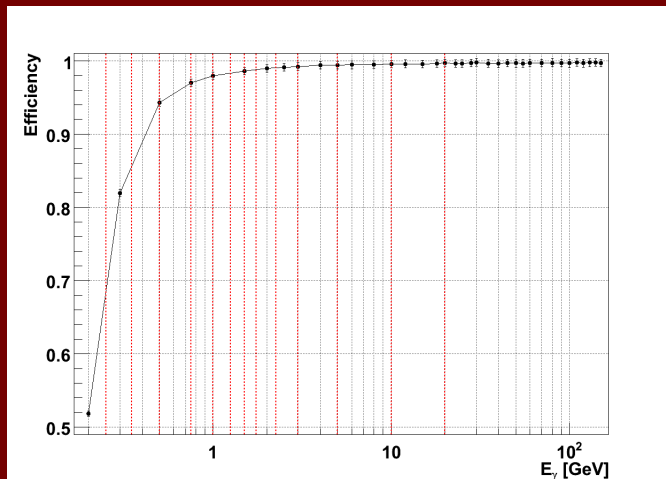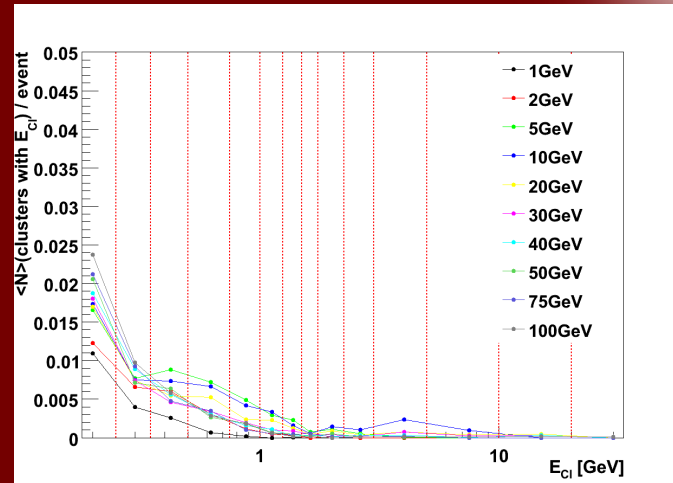

Works down to 150MeV
Efficiency:
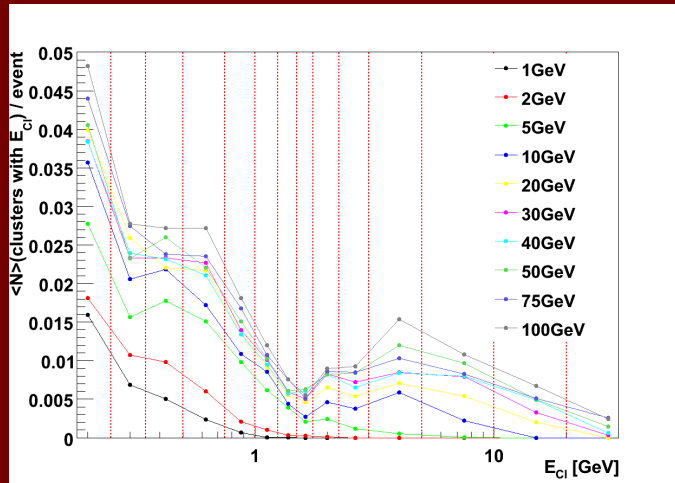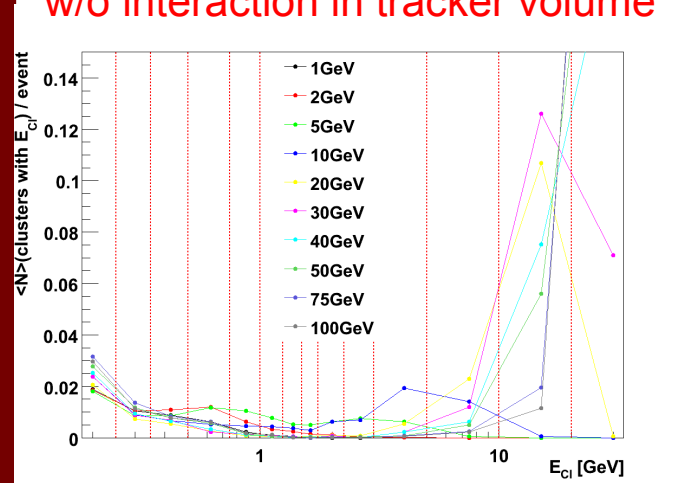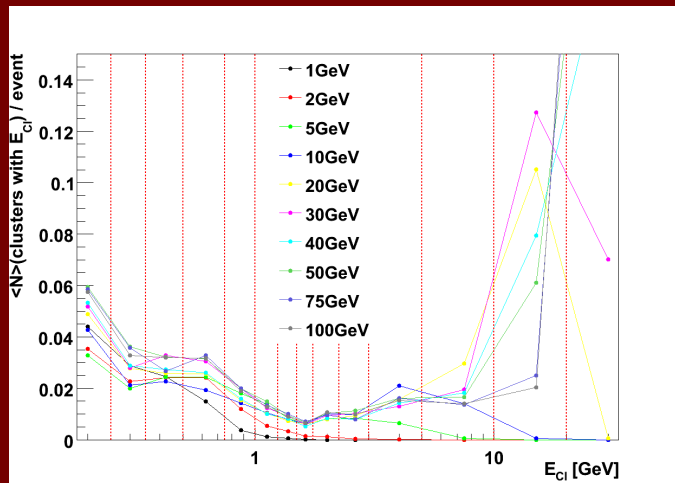>94% @ 500 MeV
98% @ 1GeV
>99% for E>2GeV

Rejection efficiencies

π⁻

K⁰ₗ

w/o interaction in tracker volume

Interactions in the tracker region double the number of fake clusters
(real π⁰ that are impossible to reject)

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Jets: uū at 500GeV
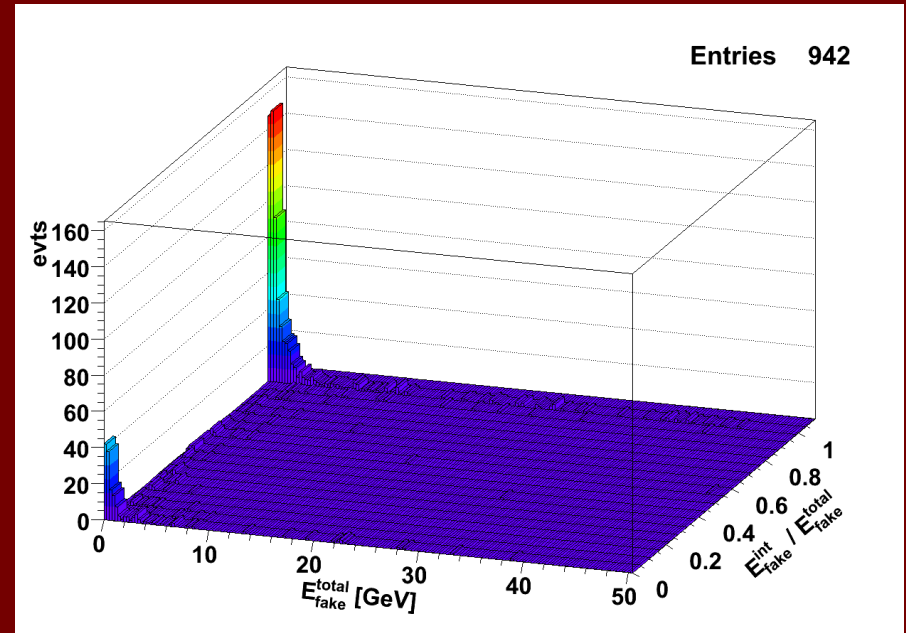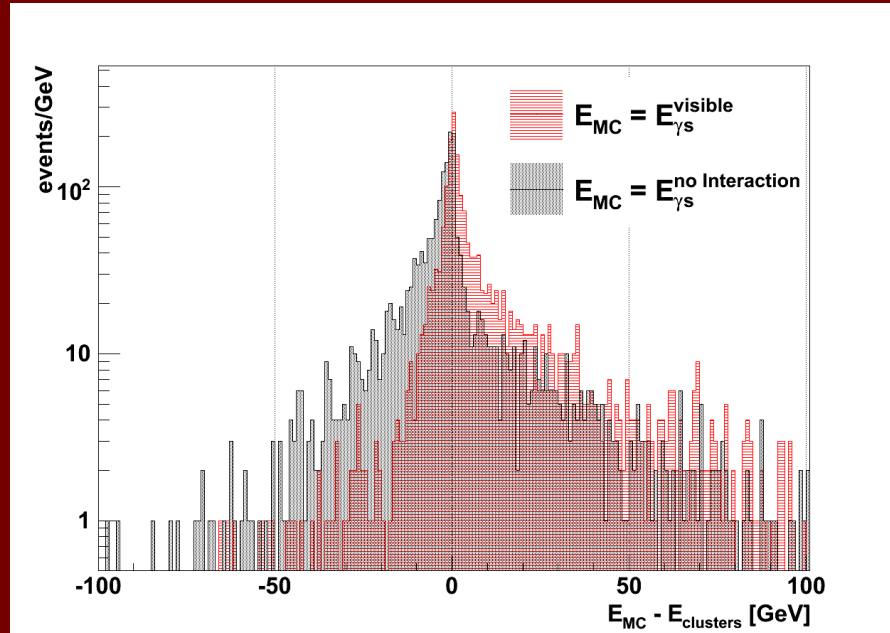
Visible photons: E>150MeV, pointing to ECAL volume
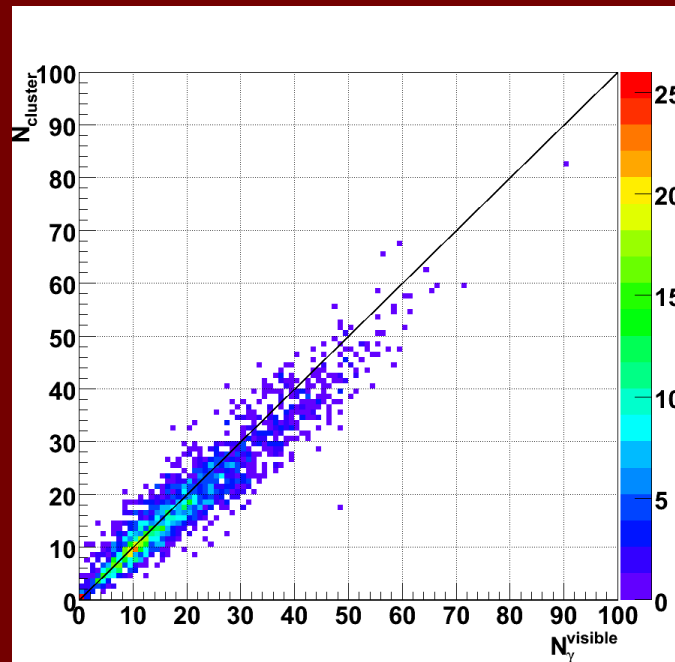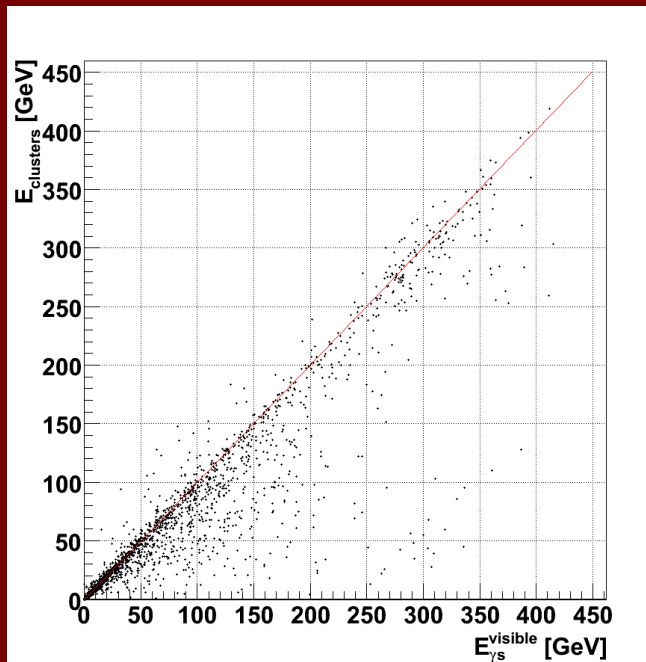
Correlations look good

Several cases where a big photon from radiative return to Z pole is lost

Jets: u$\bar{\text{u}}$ at 500GeV

Fraction of photons lost due to inefficiency and interaction
Part wise recovering of converted photons + fake clusters
Fake energy mostly from pion interactions

Conclusions

Satisfying performance:

- High, uniform efficiencies down to low energies
- Low level of fake clusters
- Good performance in jets
- Works with different cell sizes
- Easily tunable for different physics needs

But:

- Gap correction needs a more intelligent approach
- Establish criteria for neutral hadron rejection at high energies
- Refine geometrical corrections if necessary
- Need to loosen criteria where distance to track is used when going to 1TeV
- Still a rather private tool...