Fast simulation for LATTES

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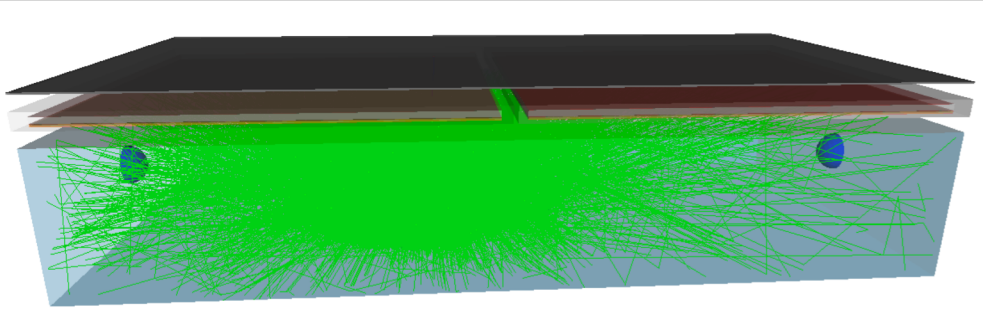
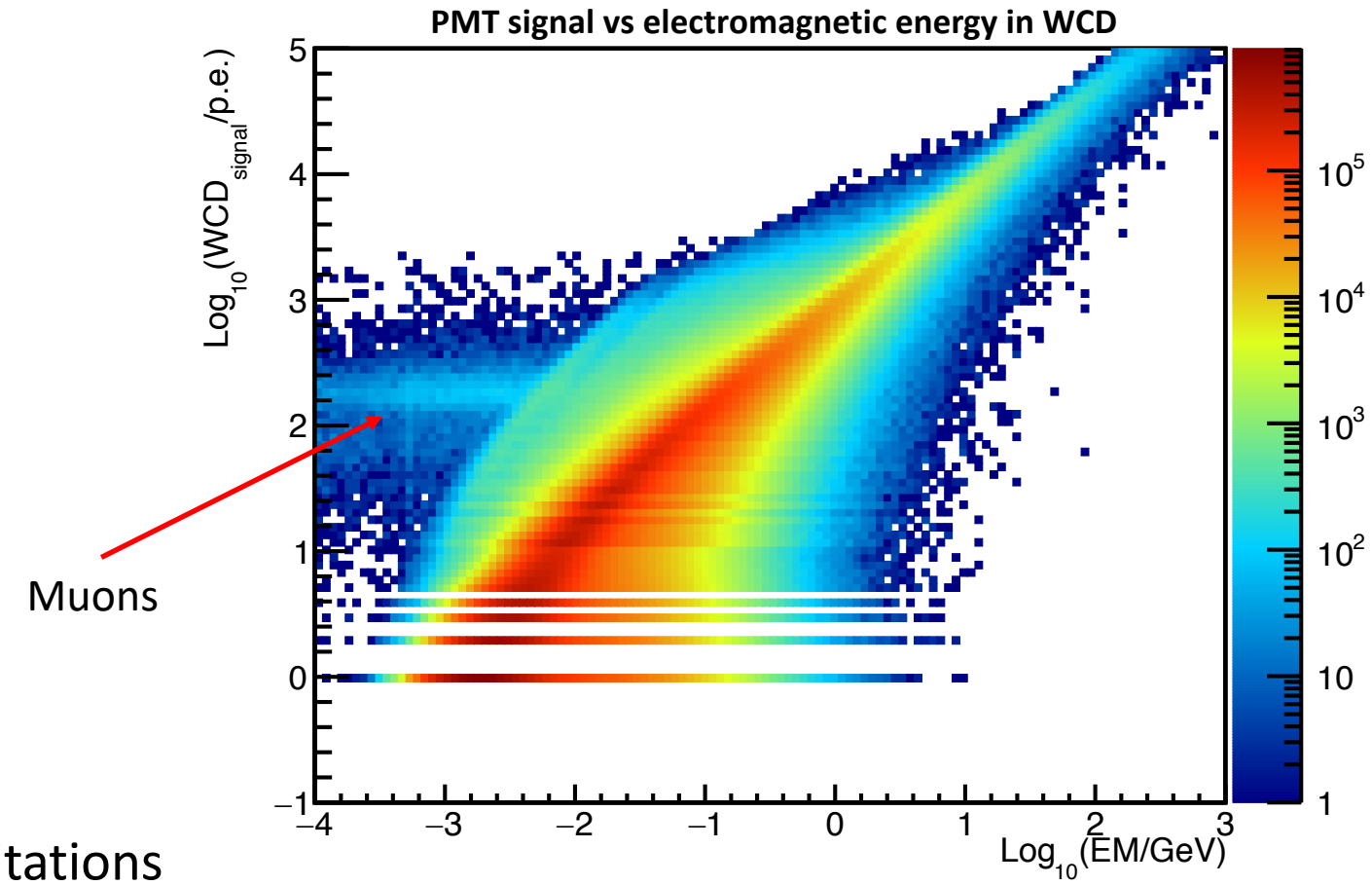
The need for a fast simulation

- Performance and optimization studies require large simulation sets (different angles, array configurations, …);
- In particular, studies of the sparse array are expected to be very time consuming…
- Bottleneck : propagation of the Cherenkov photons (large number of photons to track, large attenuation length, many reflections)



Brute force ("very fast simulation")

- Parametrize the PMT signal in function of the total electromagnetic energy entering the WCD



- Limitations
  - Assumes
  - Muon signal not properly accounted for; should be treated separately.

More educated approach ("fast simulation")

- Parametrize the PMT signal in function of the total emitted Cherenkov light;
- No need to even simulate the Cherenkov emission process: inside Geant4 just compute the Cherenkov yield:

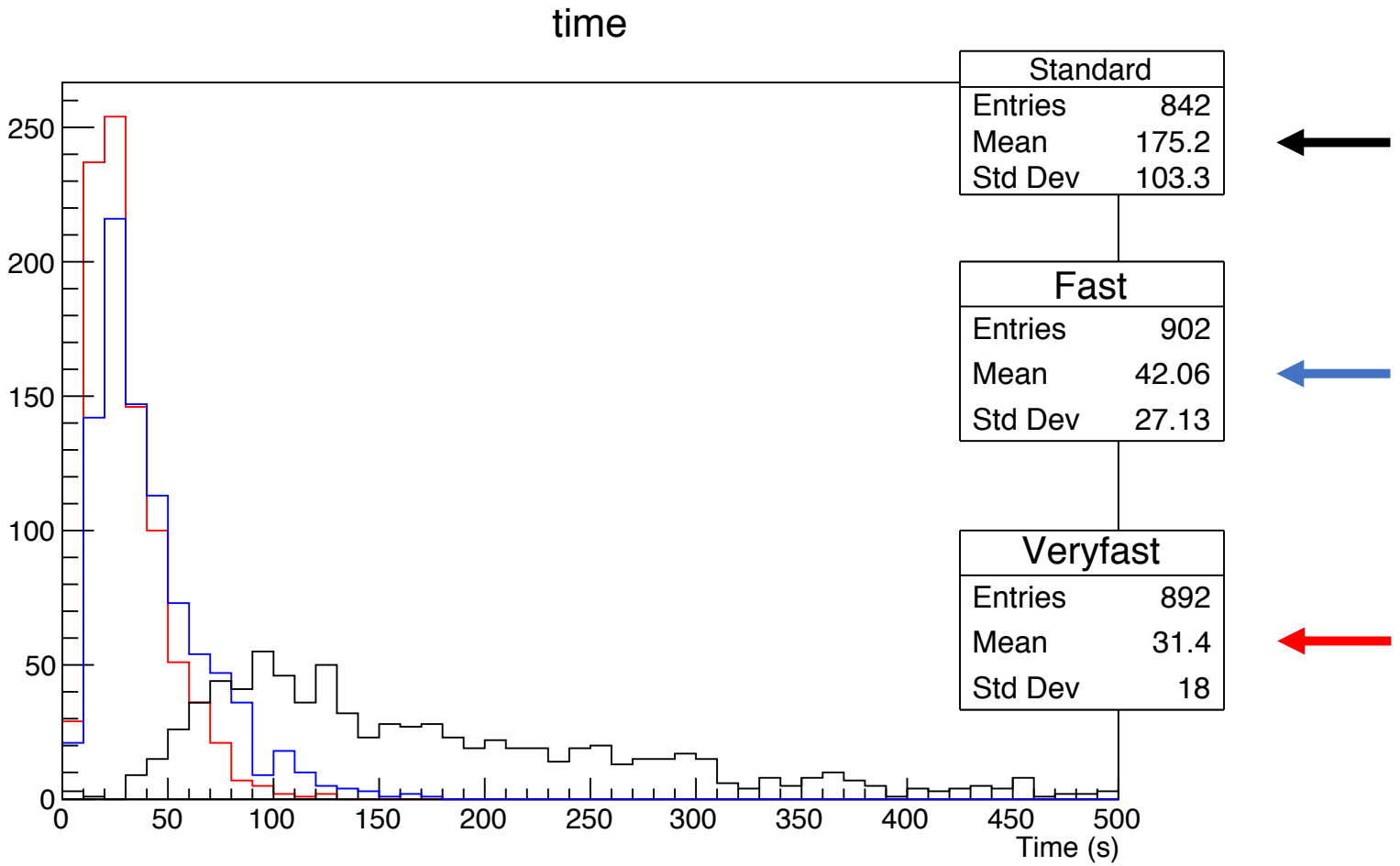
```
G4double stepLength = aStep->GetStepLength();
G4double beta = track->GetVelocity()/c_light;

const G4Material * material = physVolume->GetLogicalVolume()->GetMaterial();
G4MaterialPropertyVector * vIndex = 0;
if (material) {
  G4MaterialPropertiesTable * mpt = material->GetMaterialPropertiesTable();
  if (mpt)
    vIndex = mpt->GetProperty("RINDEX");
}

G4double nIndex = 1.0;
G4double dE = 0.0;
if (vIndex) {
  nIndex = vIndex->GetMaxValue();
  dE = vIndex->GetMaxLowEdgeEnergy() - vIndex->GetMinLowEdgeEnergy();
  if (beta*nIndex > 1)
  hit->fCherenkovStepLength = 370.0*(stepLength/cm)*(dE/eV)*pow(charge,2.0)*(1.0-1.0/(pow(beta*nIndex,2.0)));
}
}
```

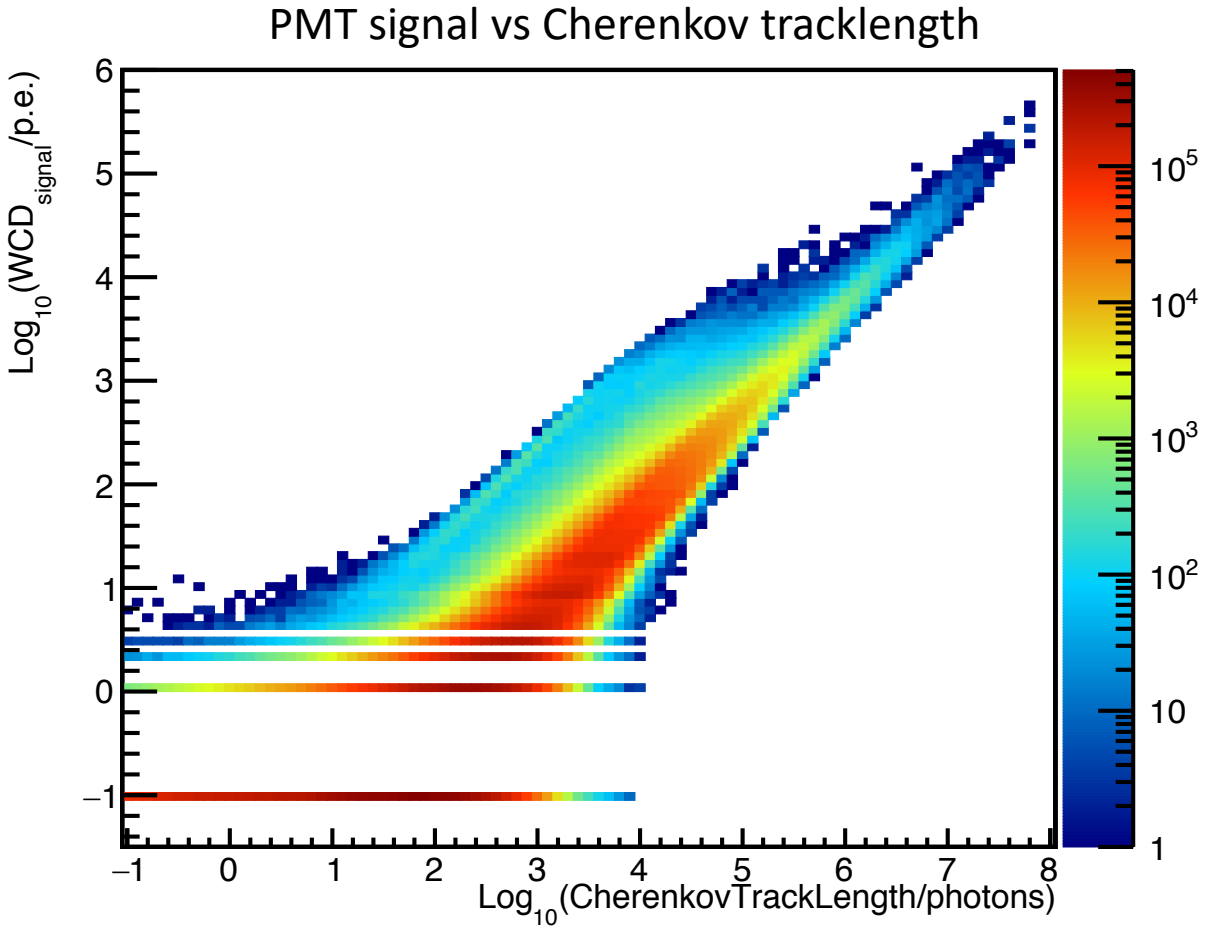
- For each station compute the total Cherenkov tracklength

Timming performances



- Fast sim :
  - 4x improvement;
  - good compromise between accuracy and timming.

Fastsim calibration



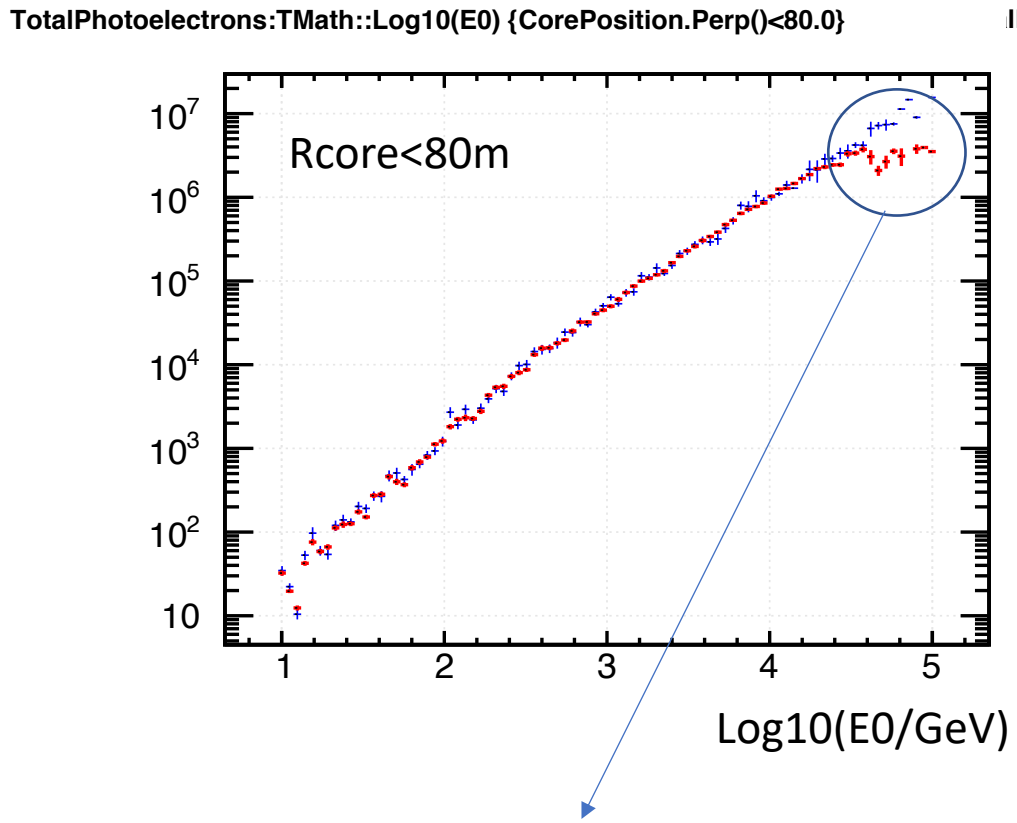
- Limitation :
  - PMT signals are independent;
  - Signal non-uniformity close to a PMT not accounted for.

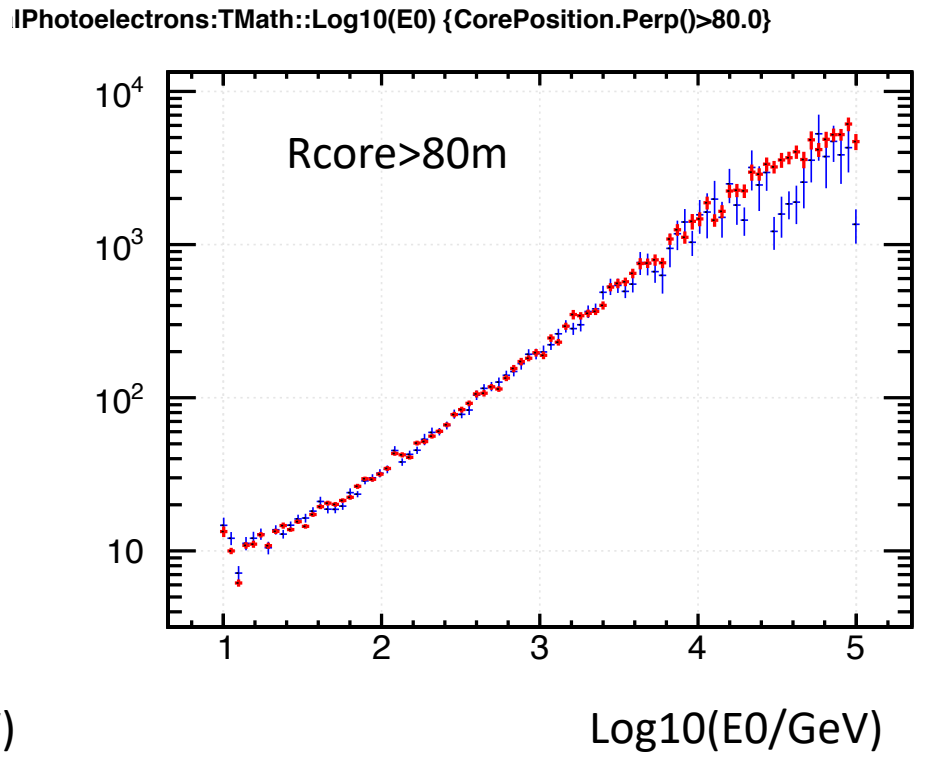
Fastsim validation

Total signal vs simulated energy

Red - full

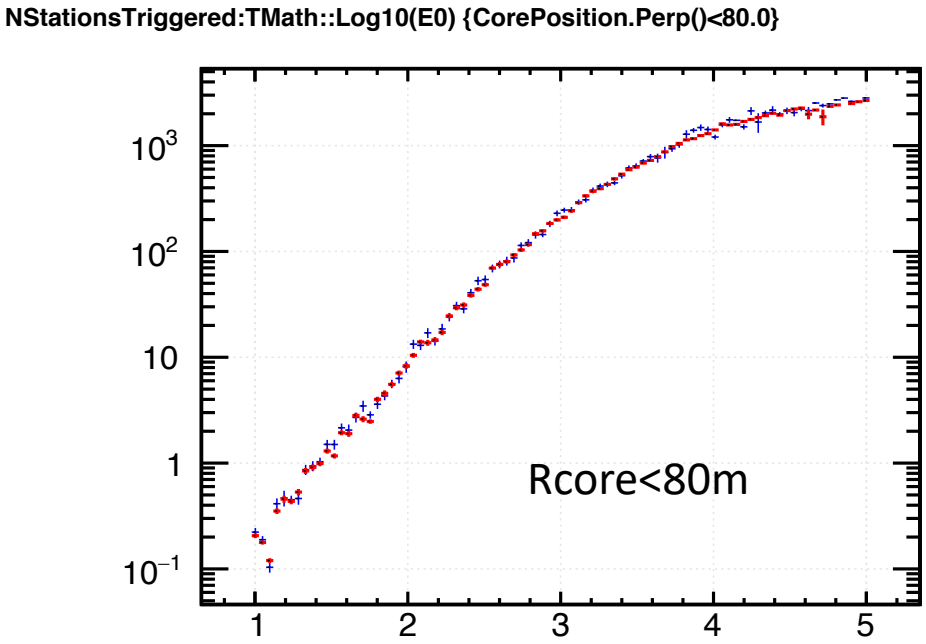
Blue – fast

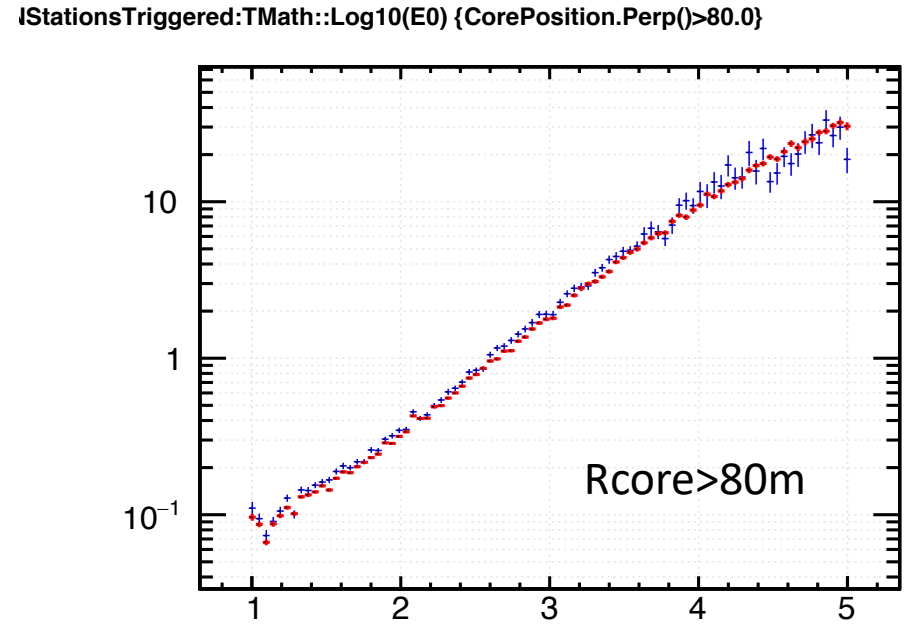




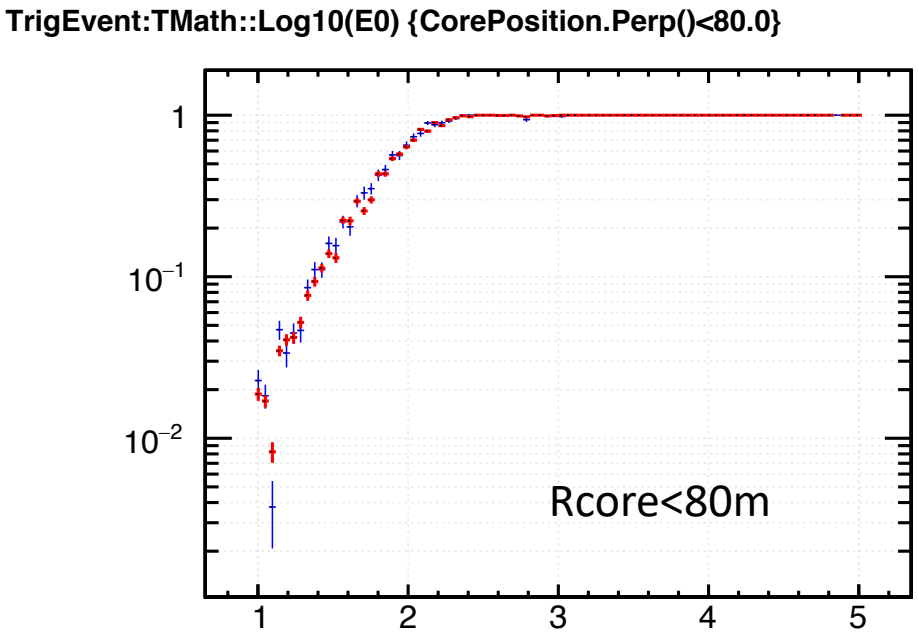
Abnormal termination of very high energy showers in the full simulation

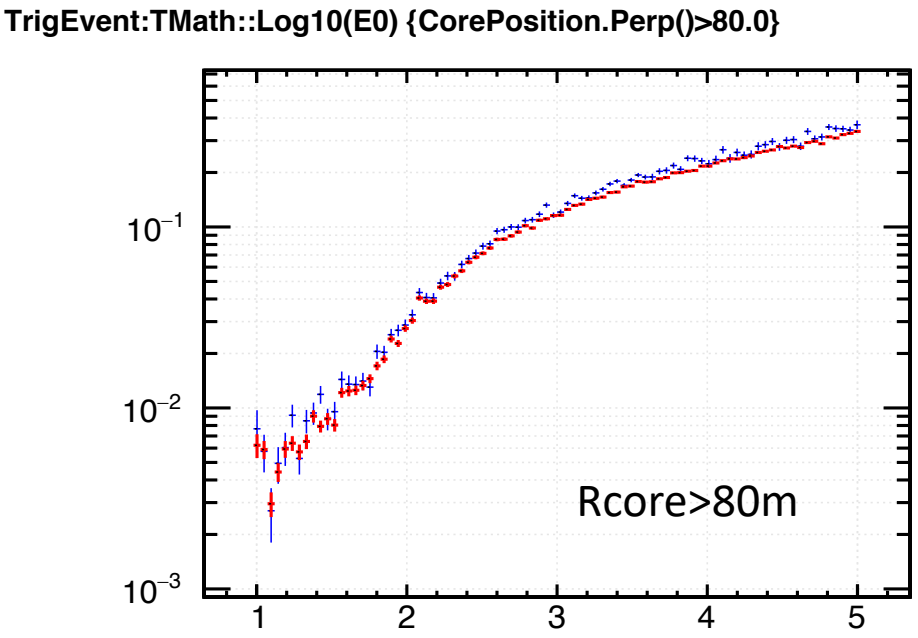
triggered stations vs simulated energy



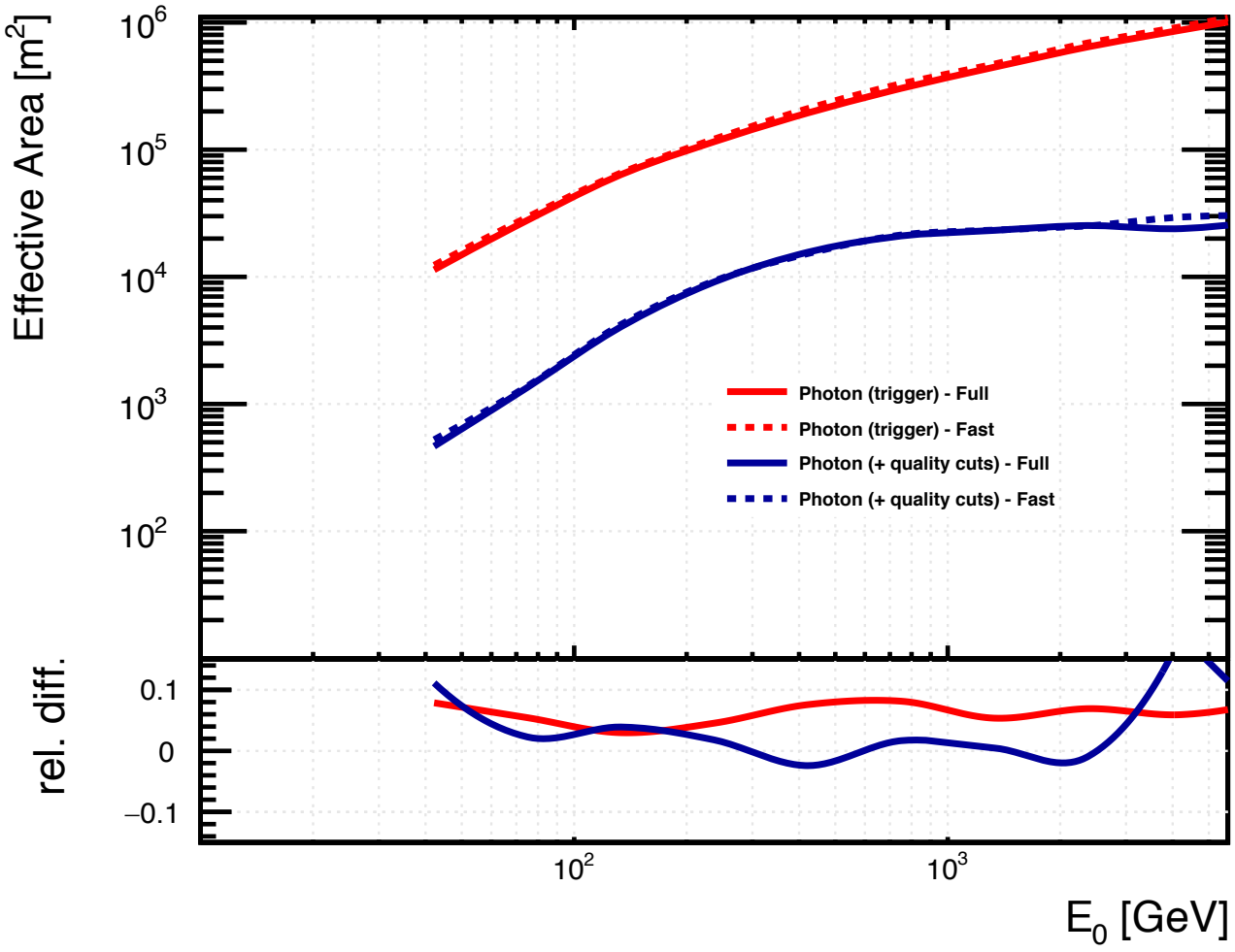


Event trigger probability vs simulated energy

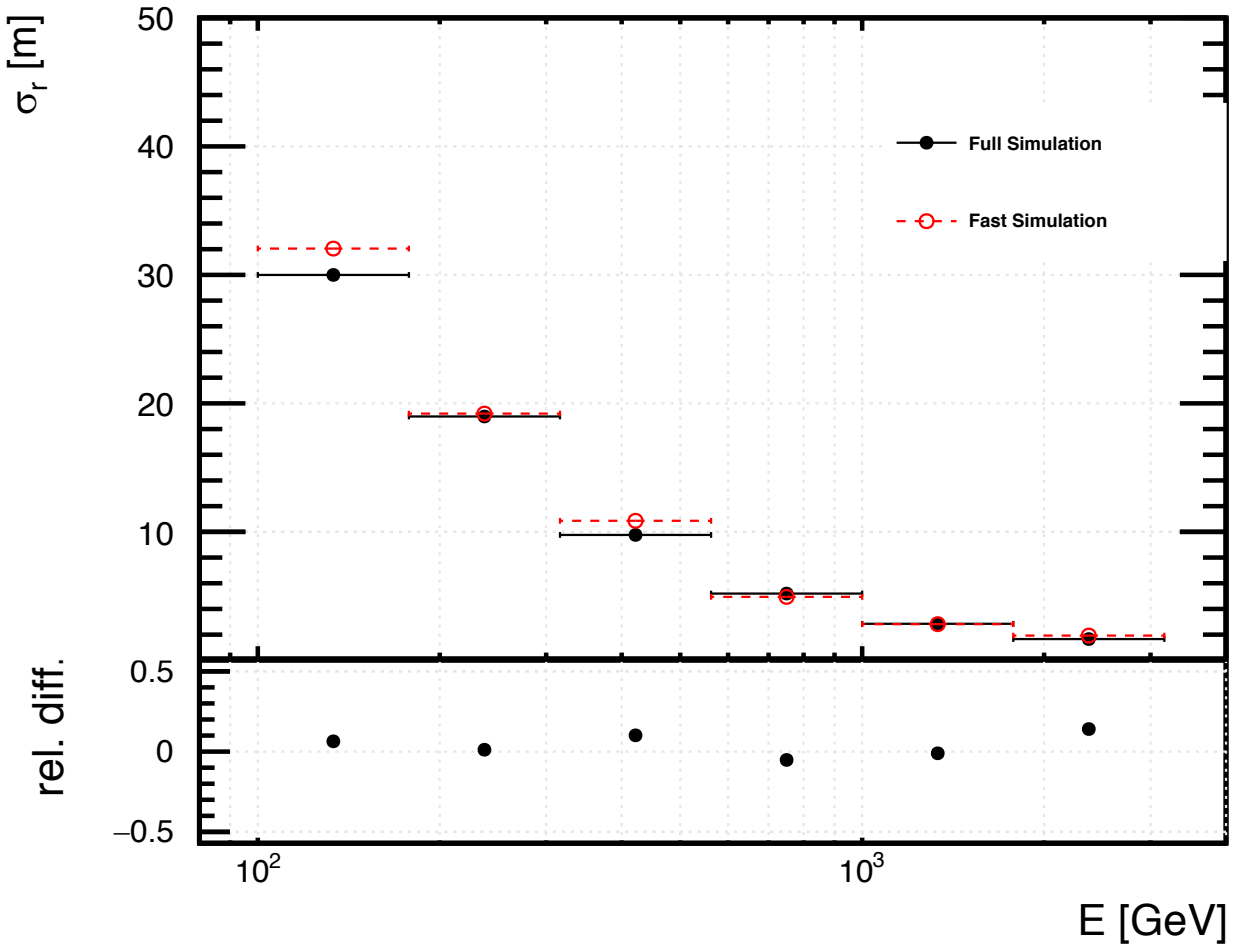




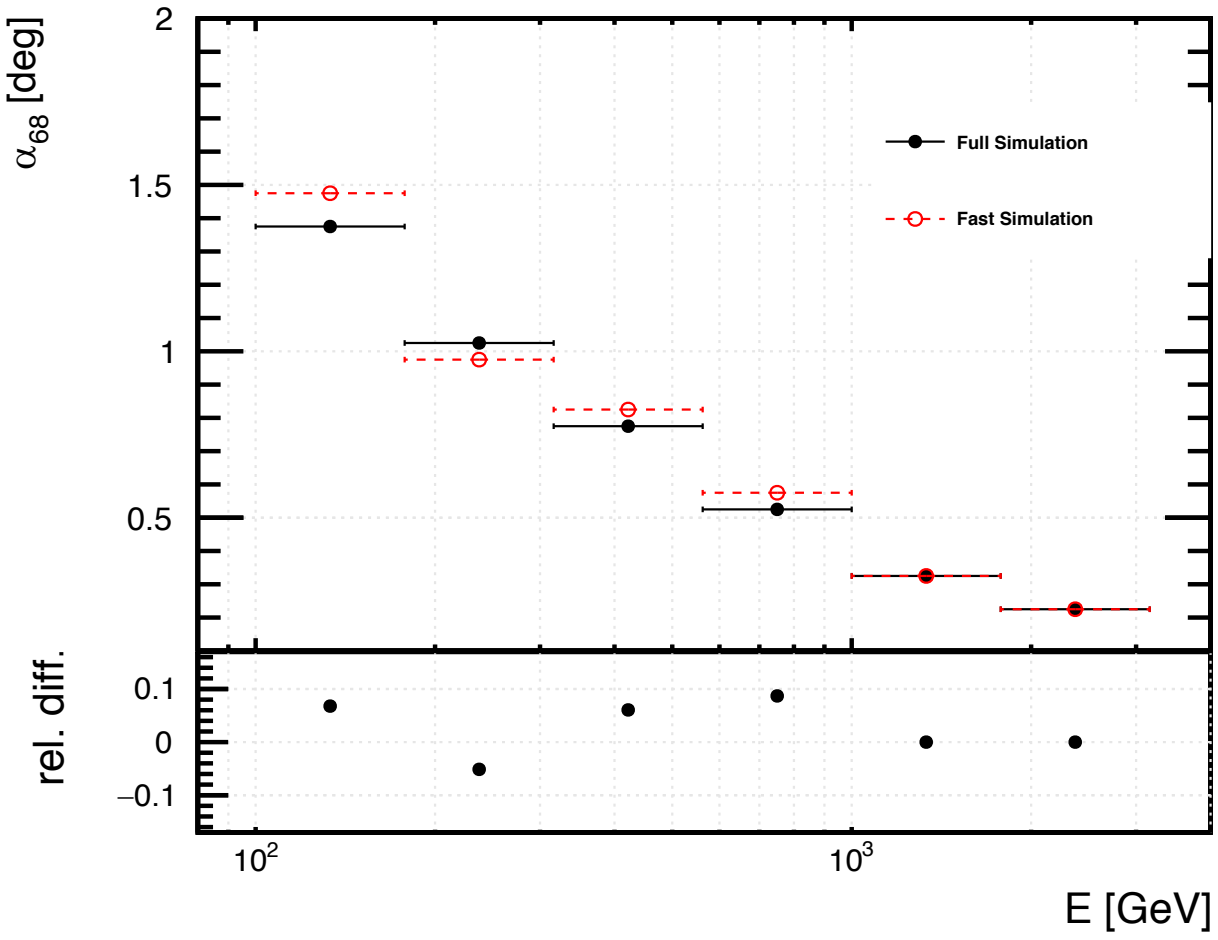
Effective area vs simulated energy



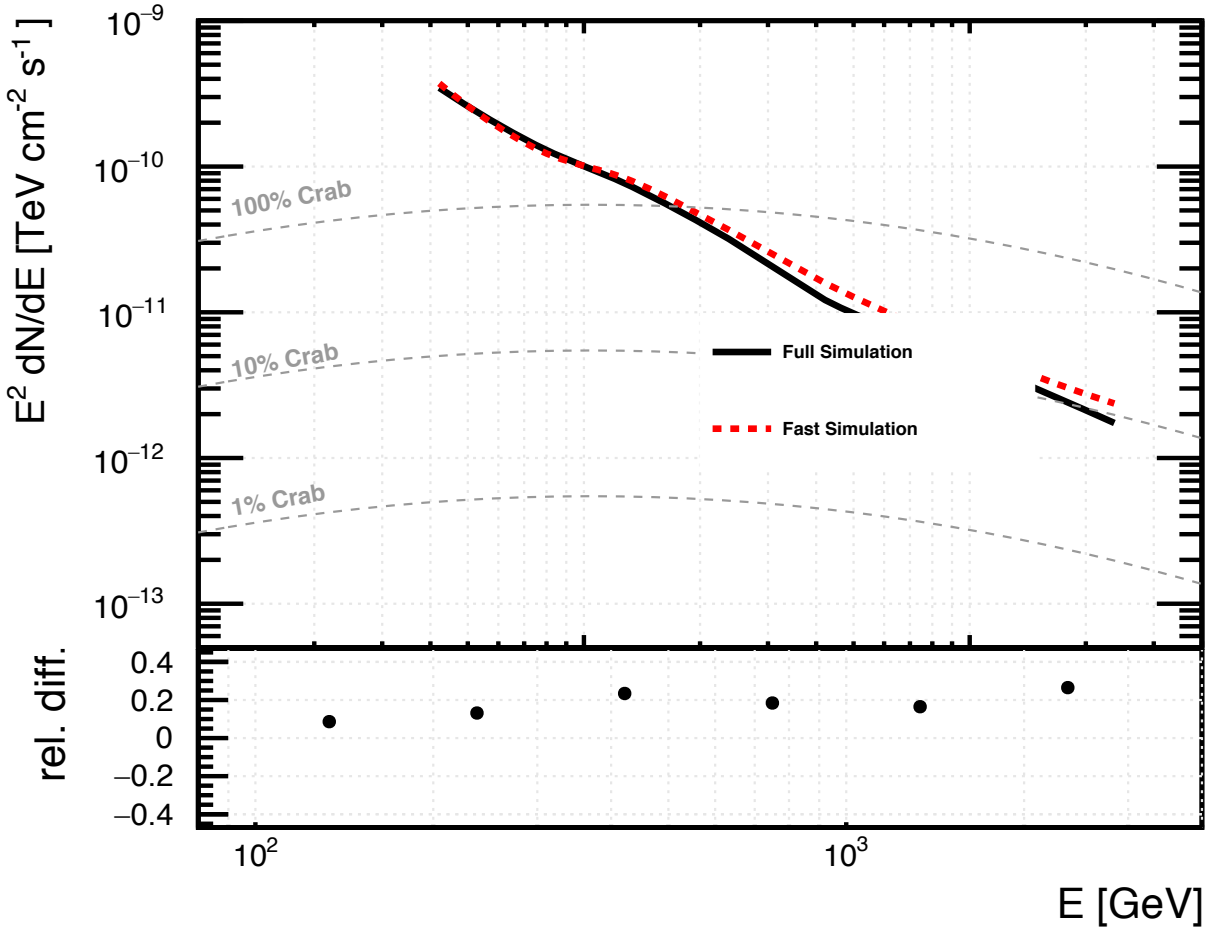
Core position resolution vs energy

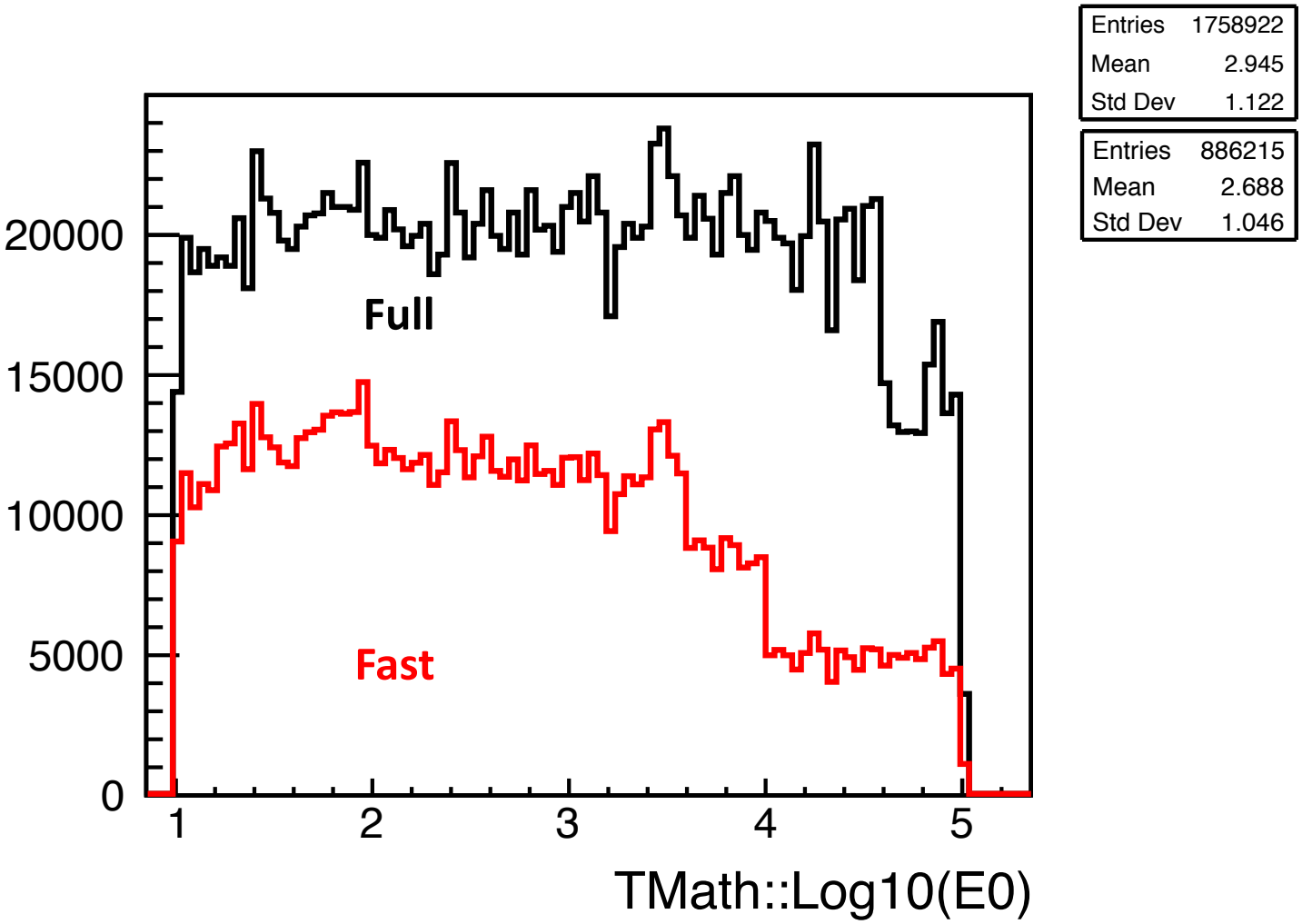


Angular resolution vs energy



Sensitivity




Entries 1758922
Mean 2.945
Std Dev 1.122
Entries 886215
Mean 2.688
Std Dev 1.046
20000
15000
10000
5000
0
Full
Fast
1
2
3
4
5
TMath::Log10(E0)

LATTES fast simulation

- WCD signal nonuniformities not accounted for;
- No approximations for the RPC simulation;
- Agreement with full simulation at the level of 10%;
- Factor 4x gain in processing time.

Acknowledgements