CTA Large-Sized Telescope real data analysis using convolutional neural networks

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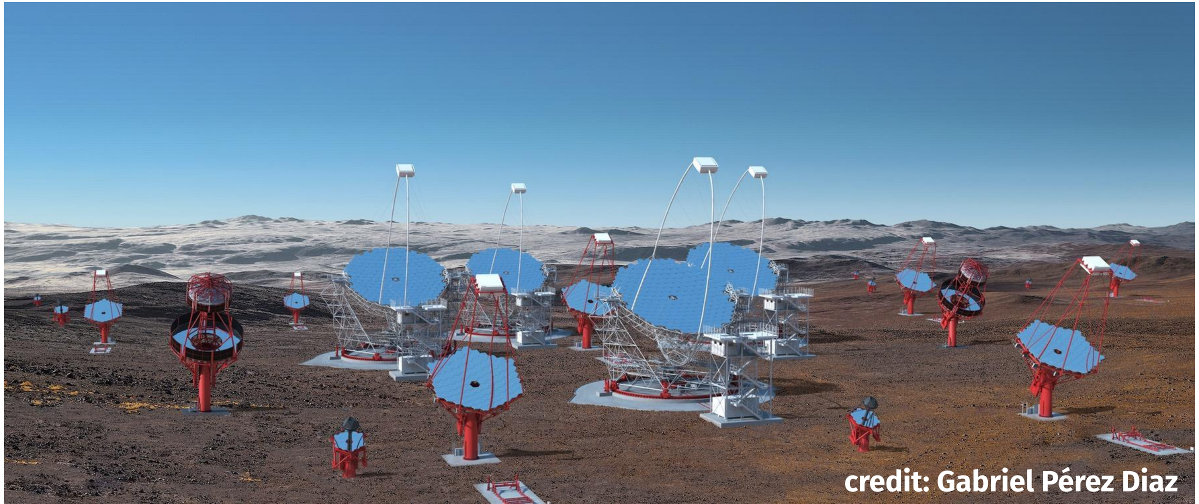
CTA, the next generation of IACT

- 5 to 10 times better sensitivity than the current generation
- An energy range from 20 GeV up to 300 TeV
- Two sites, La Palma (Spain) and Paranal (Chile)
- Three different sizes of telescopes, specialized in energy range

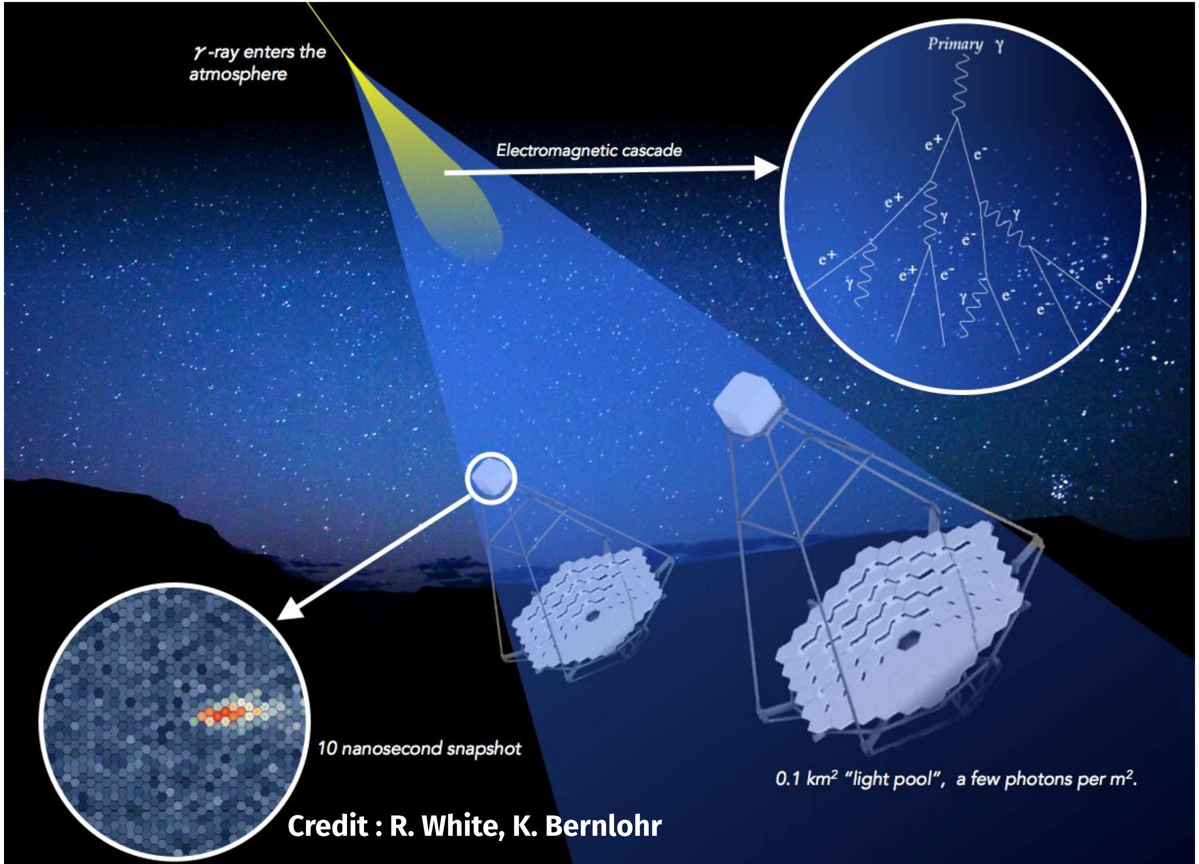


Website of the project :
www.cta-observatory.org

LST, a telescope focused on the low energies

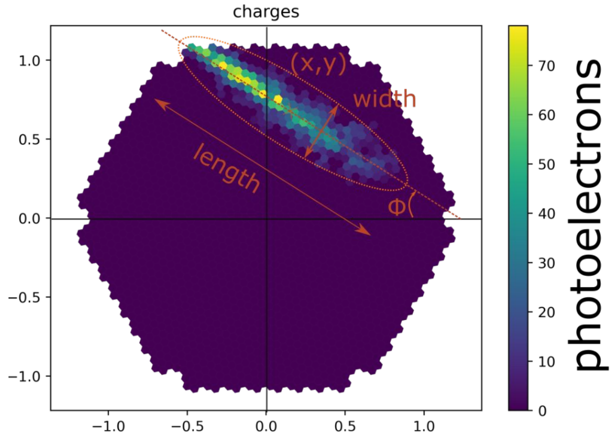
- A telescope of 23m diameter
- Low energy sensitivity for CTA (20-150 GeV)
- Fast repositioning (30s)

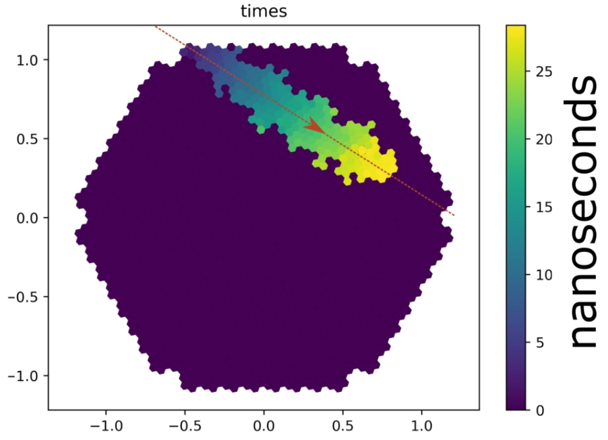
Detection of gamma rays by IACT



Hillas + RF reconstruction

- Standard method (serves here as reference)
- Based on images parameters extraction





Images parameters
+
random forests

$\Longrightarrow$

physical particle parameters
(type, energy, direction)

Why use deep-learning ?

- Better gamma/hadron separation
- Better angular and energy reconstruction

⇒ overall better sensitivity

- Fast application to data (compatible with real-time requirements)

GammaLearn : γ–PhysNet

- A single network
- Full-event reconstruction from LST1 data
  - Gamma/proton discrimination
  - Direction and energy reconstruction
- Hard parameter sharing
- Input: Image charge + temporal info
- Convolution block:
  - ResNet-56 backbone
  - Full pre-activation
  - Indexed Convolutions

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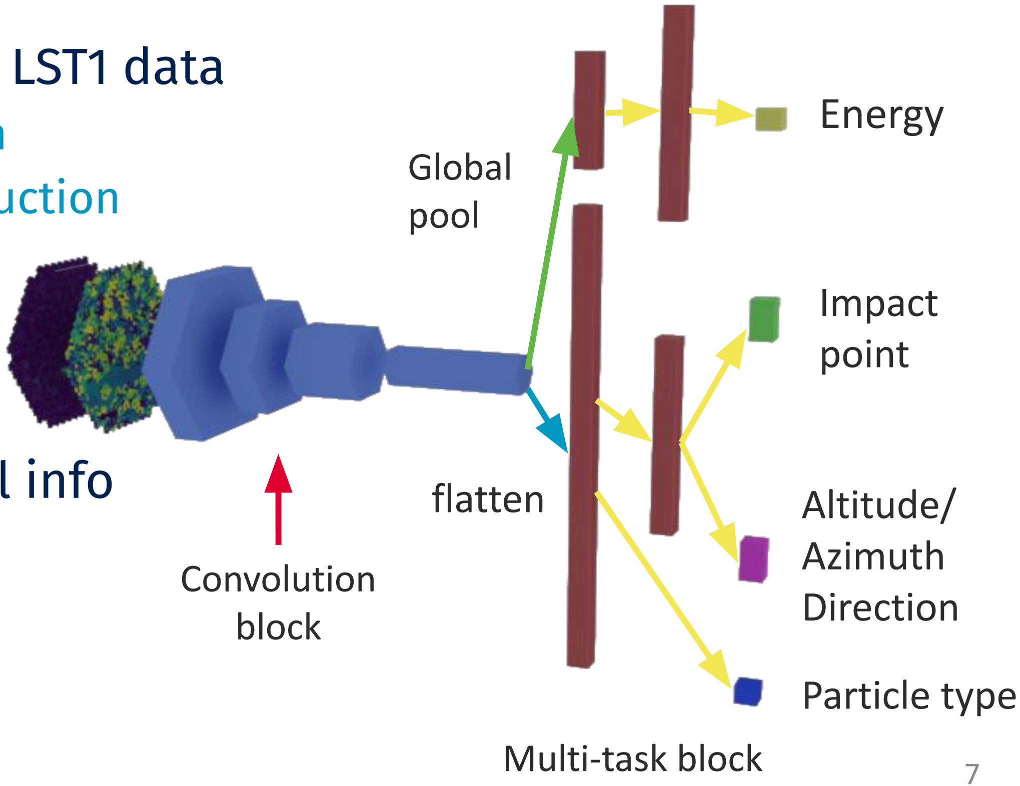
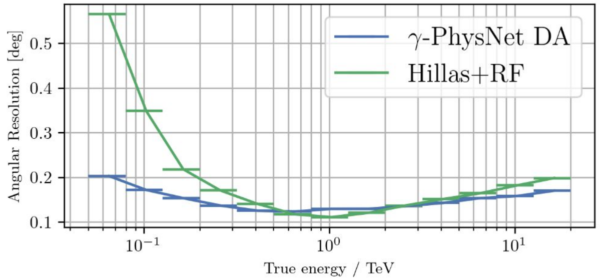
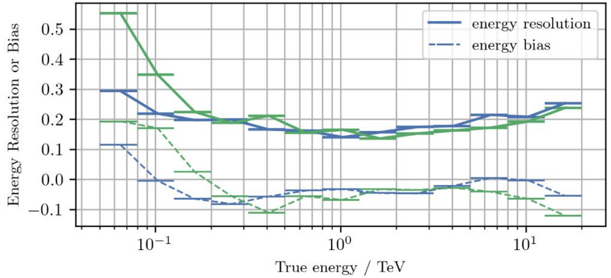
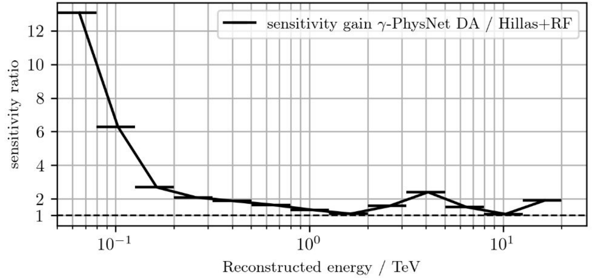
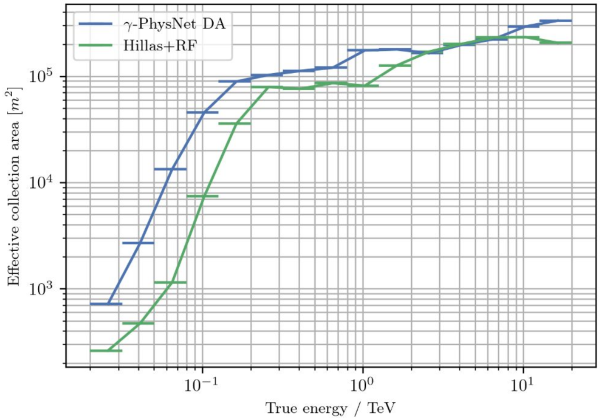


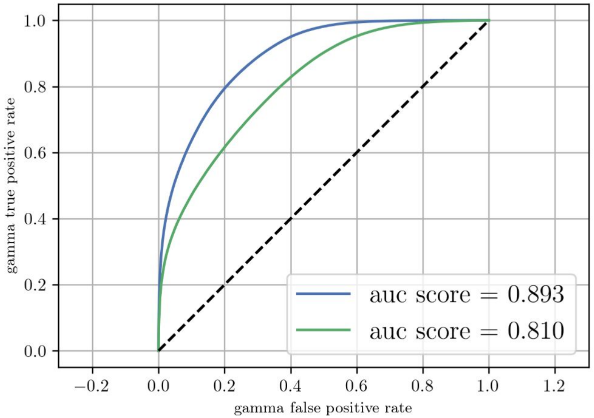
Analysis of simulated data











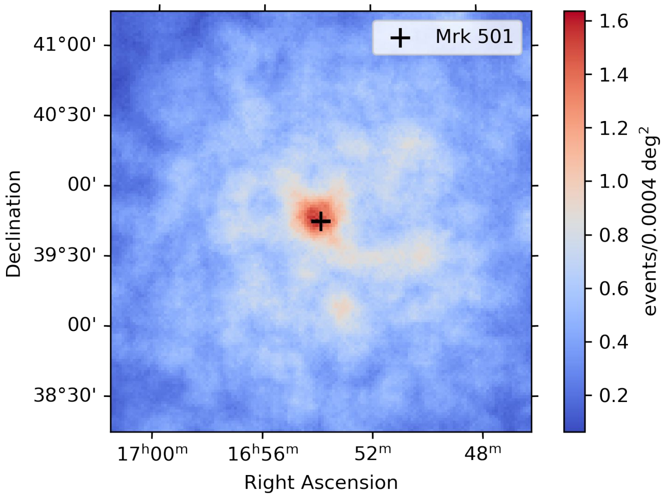
Gains in :

- Angular resolution
- Energy resolution
- Effective collection area
- Background rejection
- Sensitivity

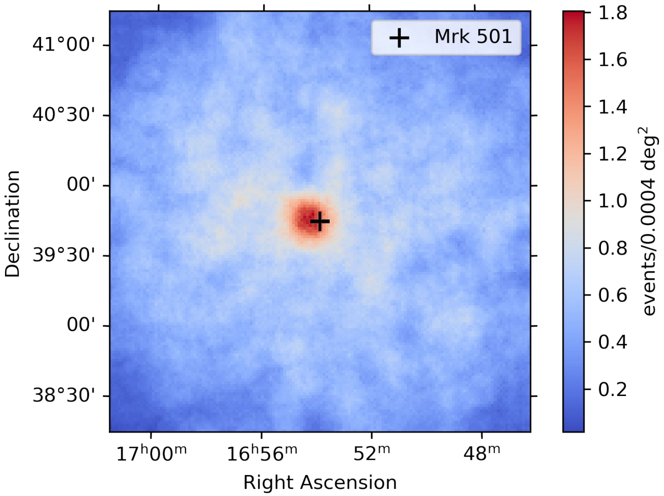
Detection of Markarian 501

- 4 runs taken on Markarian 501 in wobble with a 0.4° offset

Smoothed Count Maps around Mrk 501



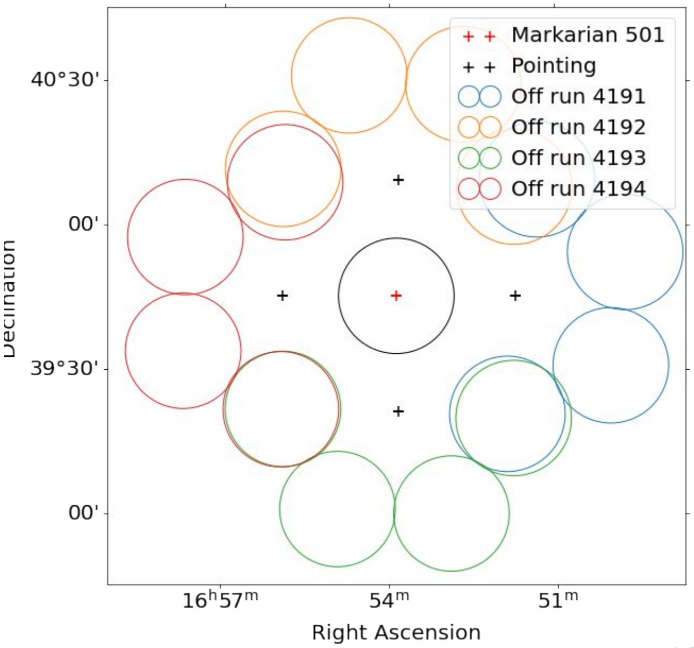
Hillas+RF



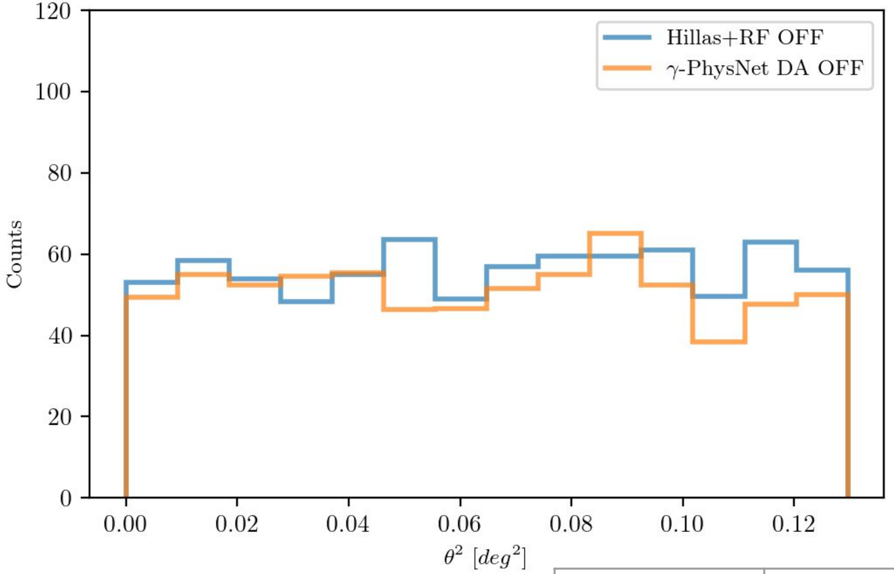
γ-PhysNet DA

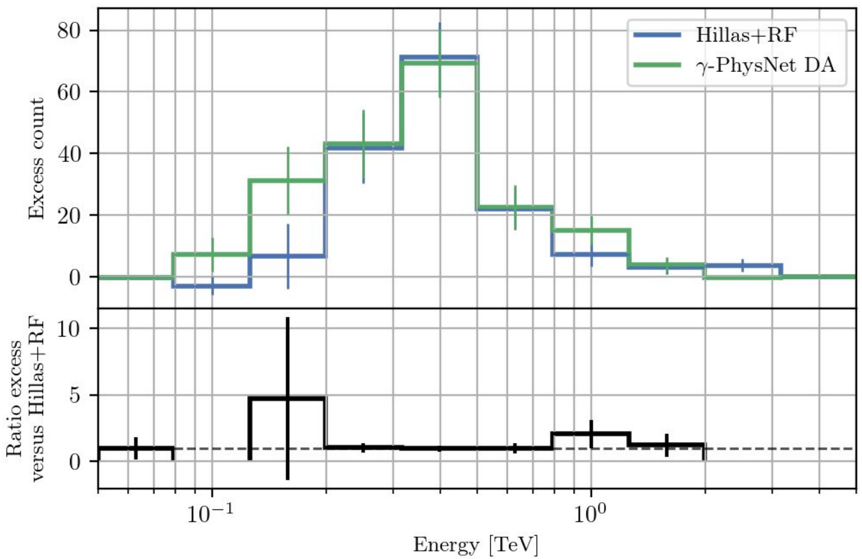
Mrk 501 - High level analysis

- Analysis performed with gammapy 0.18.2
- Multiple OFF background estimation



Mrk 501 - Significance





	Bkg	Excess	Significance
Hillas+RF	238.3	148.7	7.6 σ
γ-PhysNet DA	226.3	192.75	9.8 σ

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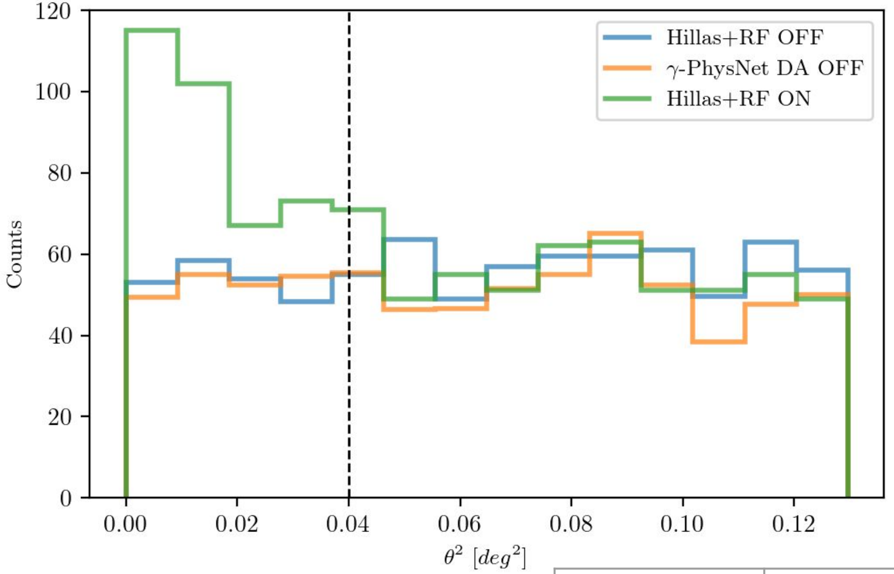

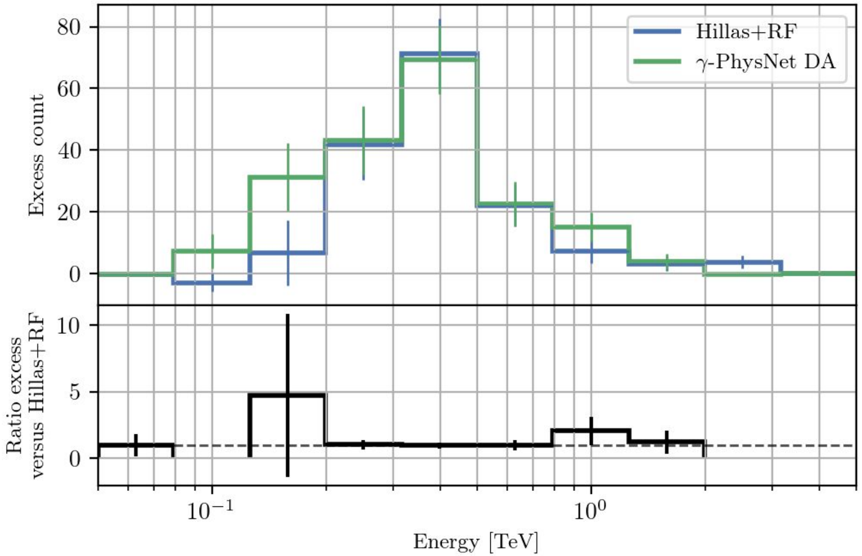

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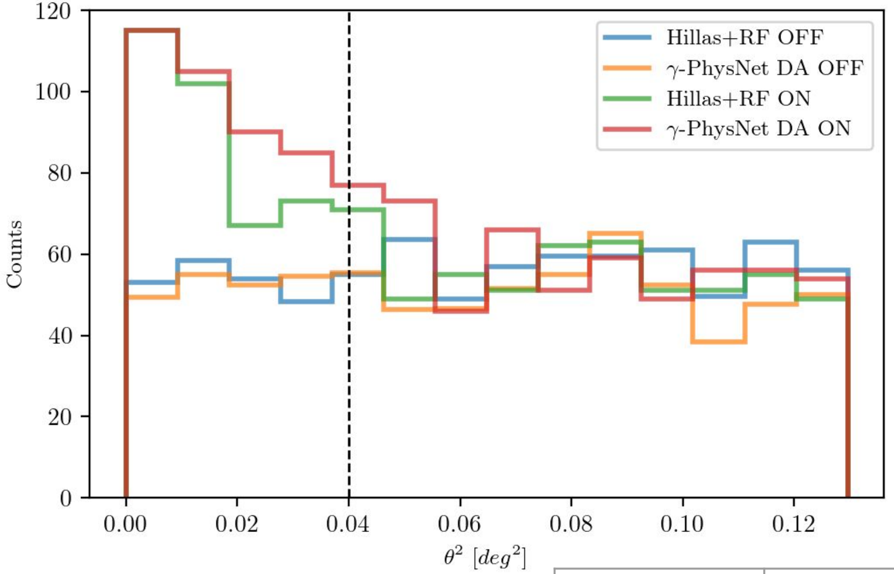

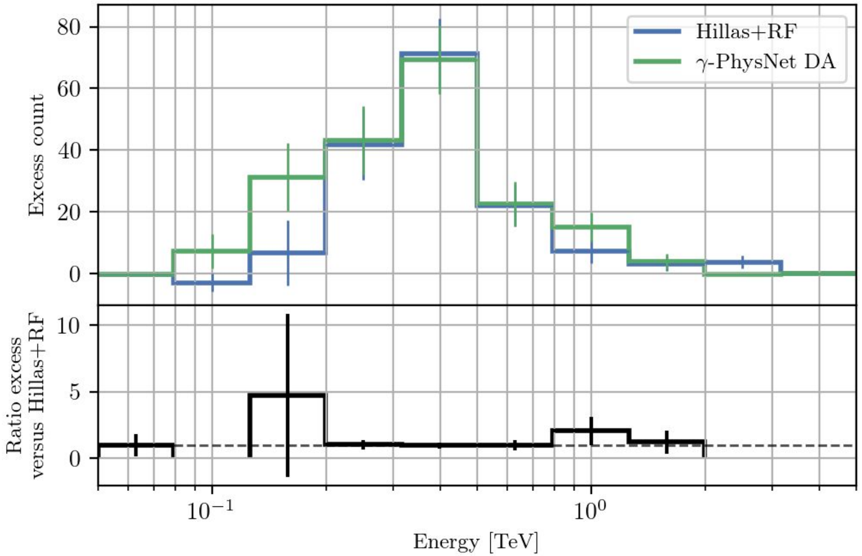

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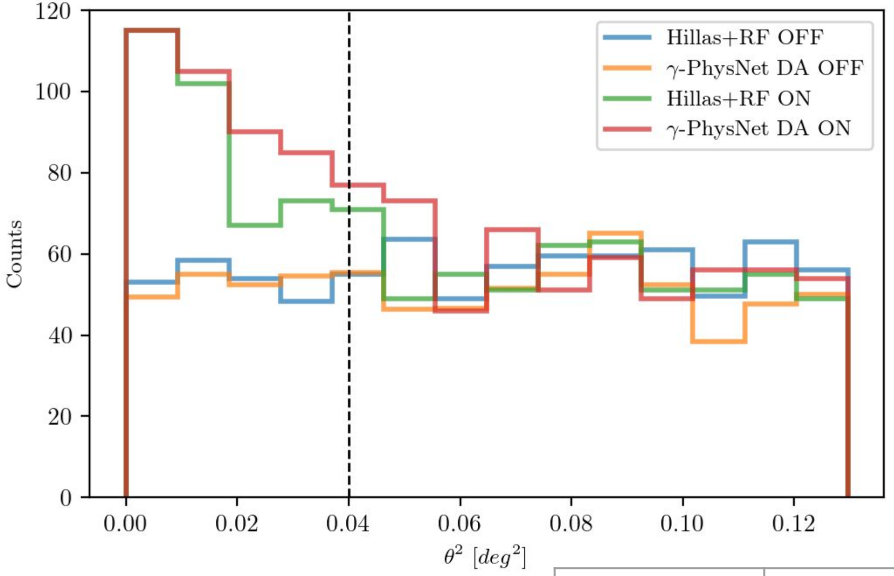
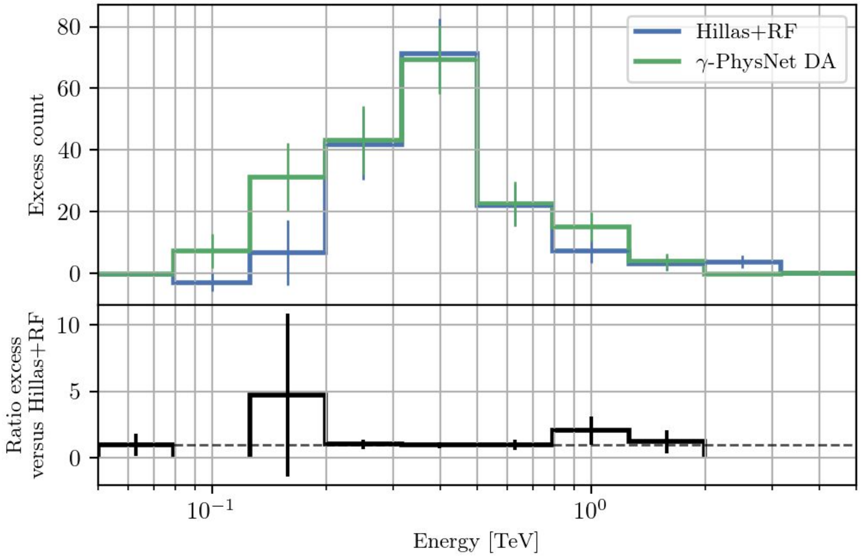


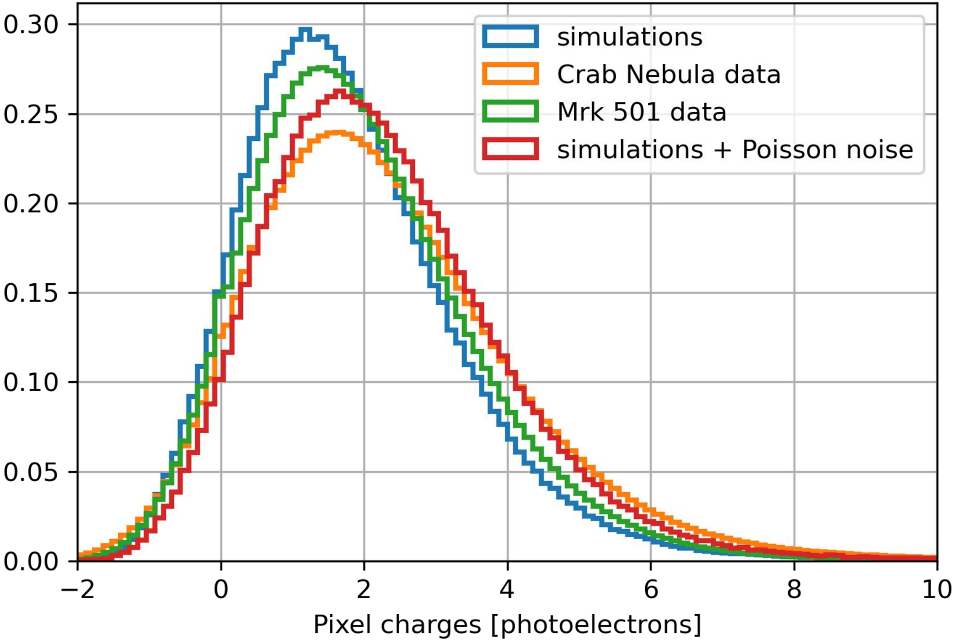


	Bkg	Excess	Significance
Hillas+RF	[illegible]	148.7	7.6 σ
γ-PhysNet DA	[illegible]	192.75	9.8 σ

+30%

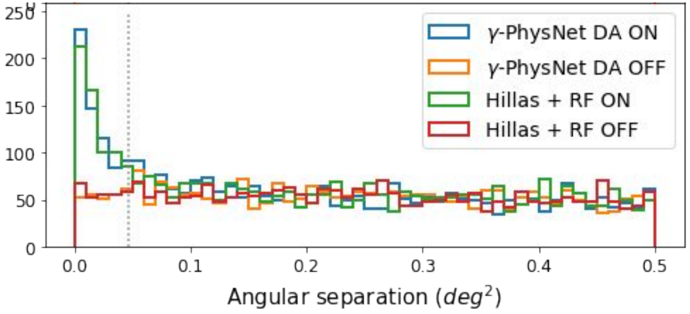
Detection of the Crab Nebula

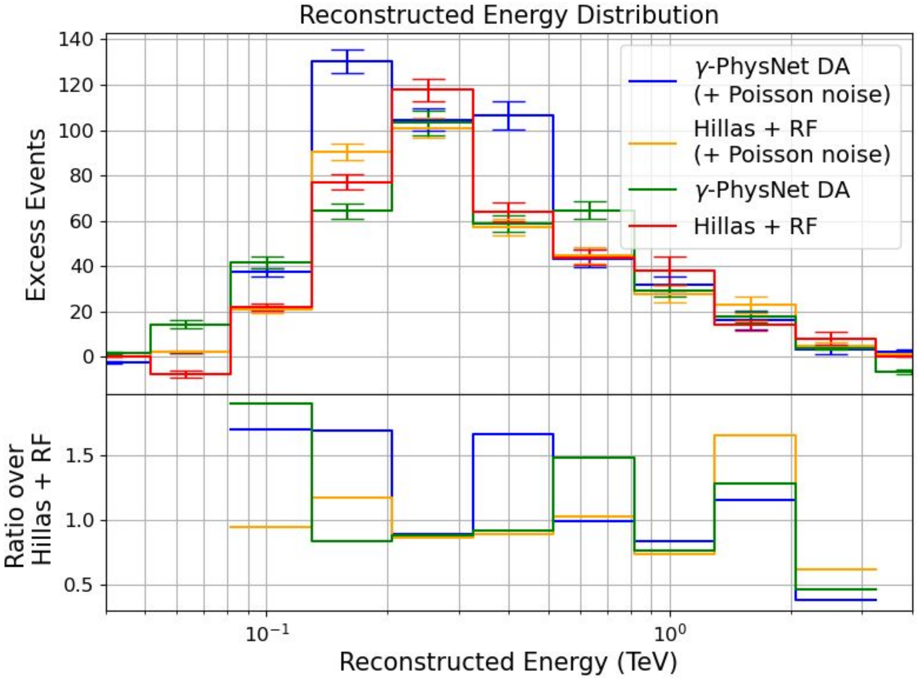
- 2 runs taken in ON/OFF mode on the Crab Nebula



Matching Night Sky Background (noise) distributions between simulations and observations by adding poissonian noise to simulated data

Detection of the Crab Nebula





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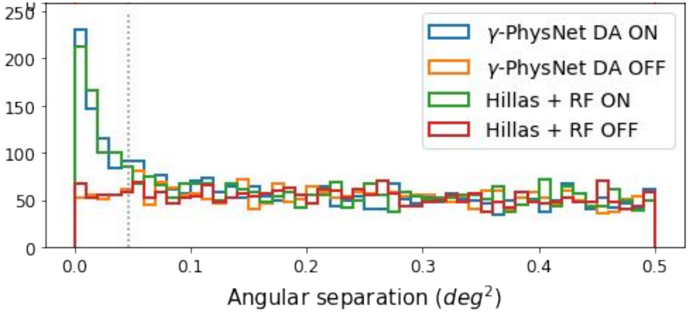
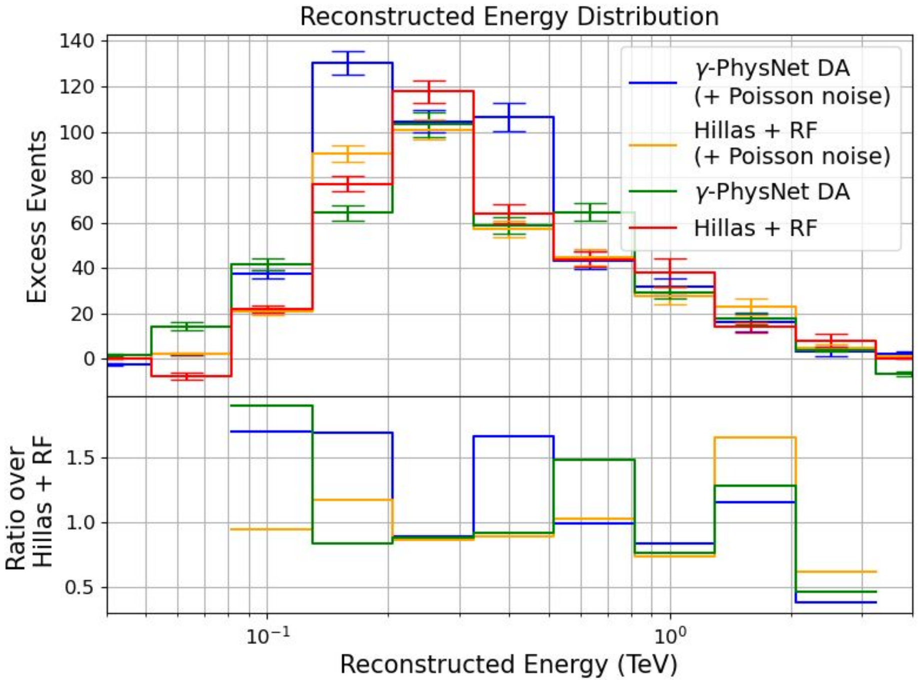


	Bkg	Excess	Significance
Hillas+RF	308	379	12.0 σ
Hillas + RF + noise	305	376	11.9 σ
γ-PhysNet DA	302	395	12.5 σ
γ-PhysNet DA + noise	317	476	14.3 σ



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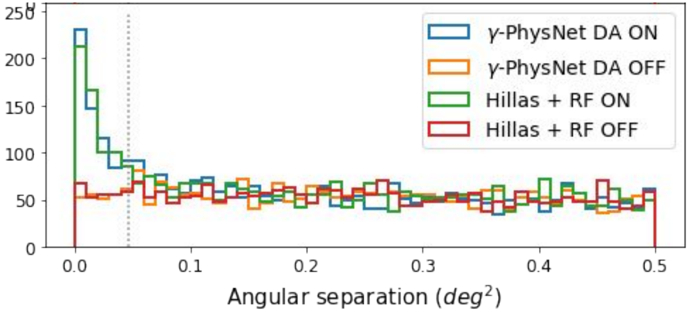

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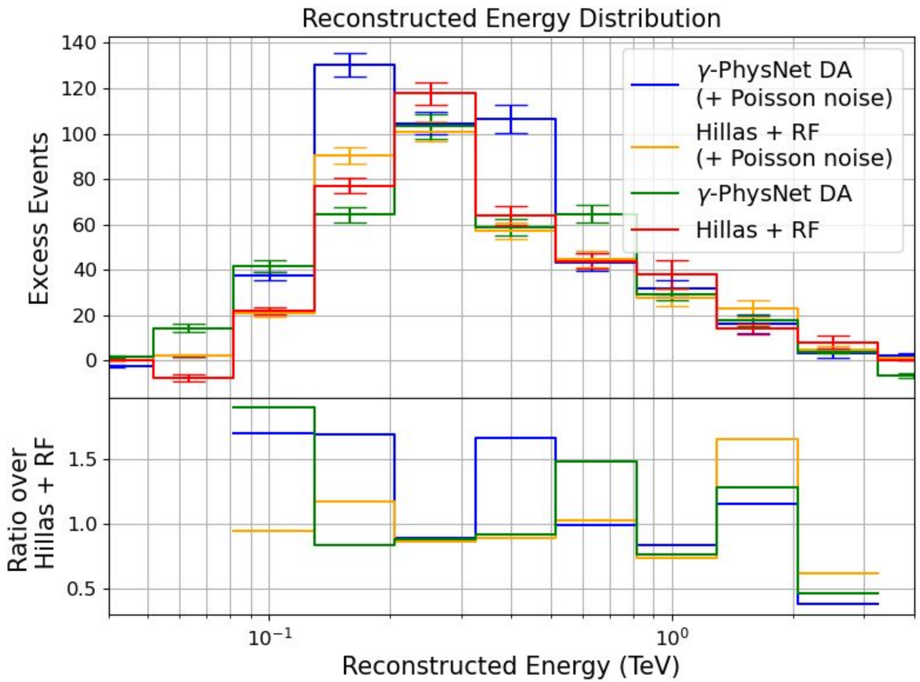
+26%



Conclusion and perspective

Results:

- Detection of two sources using convolutional neural networks on LST-1 data
- Higher sensitivity on simulated data confirmed on observed data
- Importance of close matching between simulations and observations

Future work:

- Spectral analysis
- Improve the robustness to simulations/observations differences