COSMIC RAY COMPOSITION.

Towards a measurement of cosmic ray composition in the TeV range with IACTs

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for the VERITAS-Collaboration
HAP Composition workshop
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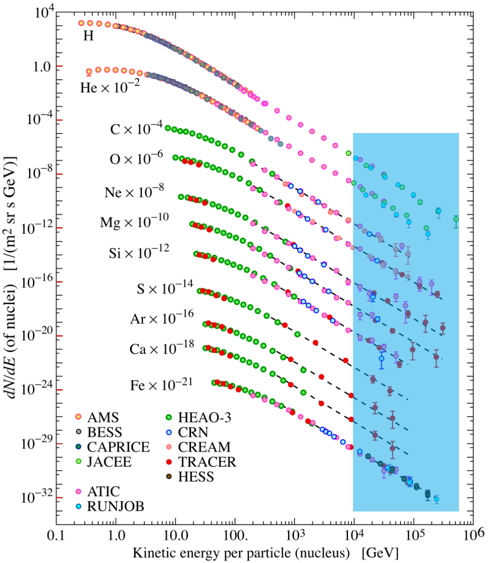
Alliance for Astroparticle Physics

Reminder — Cosmic Ray Spectrum

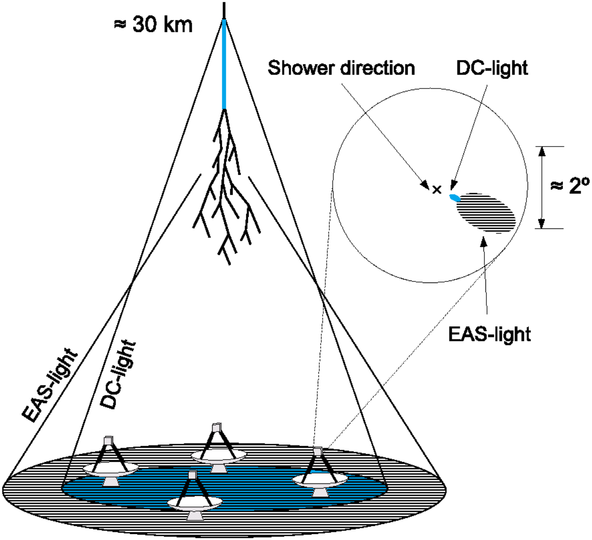


Beringer et al. [2012].

CRs in Imaging Cherenkov Telescopes

Direct Cherenkov (DC) light from primary particle:

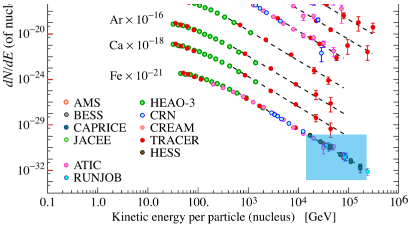
- Intensity $\propto Z^2 \cdot \sin^2(\theta_c)$.
- Heavy nuclei, eg. iron.
- 10–500 TeV.
- Charge resolution $\gtrsim 5\%$.
- Aharonian et al. [2007]; Kieda et al. [2001].



Source: Aharonian et al. [2007]

Previous Results (H.E.S.S. & VERITAS)

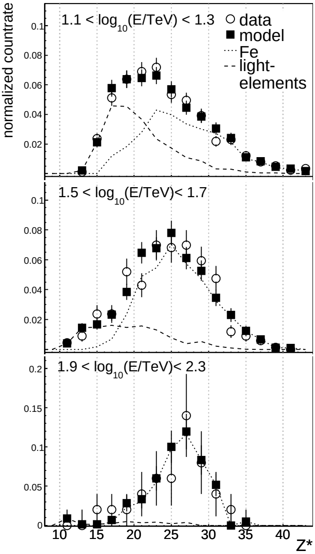
- Aharonian et al. [2007]: 'heavy' elements ($Z = 25 - 28$), 13 – 200 TeV.
- Wissel [2010]: iron, 20 – 140 TeV.
- Spectral shape: $F(E) = \phi_0 \cdot \left(\frac{E}{E_0}\right)^{-\gamma}$, see below.
- Dominant uncertainties: statistics, atmosphere, hadronic interaction model.
- Can we improve on that?



	E_0/TeV	$\phi_0 \cdot (m^2 \cdot s \cdot sr \cdot TeV)$	γ
H.E.S.S. (QGSJET)	1	$(2.2 \pm 0.9 \pm 0.6) \cdot 10^{-2}$	$2.62 \pm 0.11 \pm 0.17$
H.E.S.S. (SYBILL)	1	$(2.9 \pm 1.1 \pm 0.8) \cdot 10^{-2}$	$2.76 \pm 0.11 \pm 0.17$
VERITAS (QGSJET)	50	$(5.8 \pm 0.84 \pm 1.2) \cdot 10^{-7}$	$2.84 \pm 0.3 \pm 0.3$

Previous Results — Charge separation

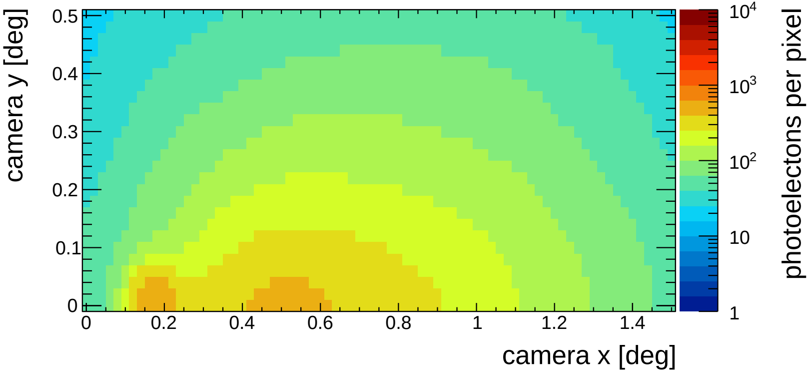
- Aharonian et al. [2007]
- Select images with direct Cherenkov contribution.
- Energy E from shower light
- Charge Z from DC light.
- 'heavy' elements ($Z = 25 - 28$) vs 'light elements'
- Fit fraction of 'heavy' elements per energy bin.



Source: Aharonian et al. [2007]

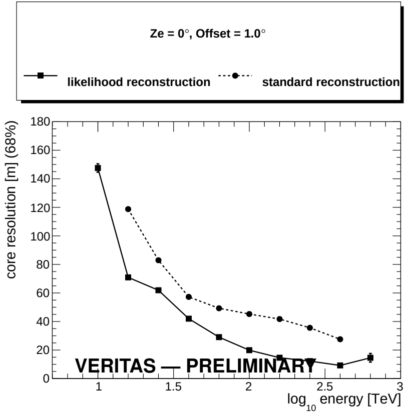
Template Method for Shower Reconstruction

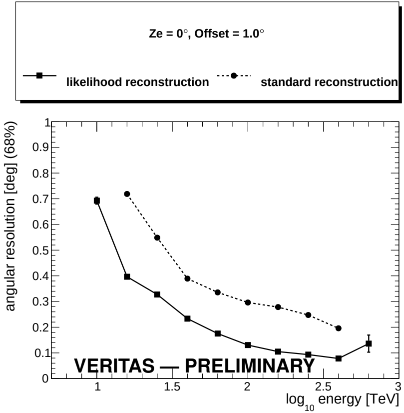
Likelihood fit of telescope images. See eg. [Fleischhack, 2015; Le Bohec et al., 1998]



Example: Iron, Ze=0°, Energy=30 TeV, Distance=80 m, First interaction Height=33 km

Energy and direction resolution

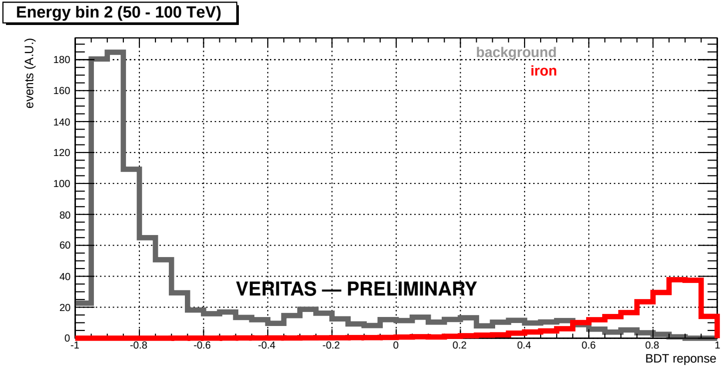




- Better reconstruction → better identification of DC pixel.
- Energy resolution is improved as well.

Charge separation

- Multivariate analysis combining DC light, image shape, . . .
- Composition measurement possible with this approach.



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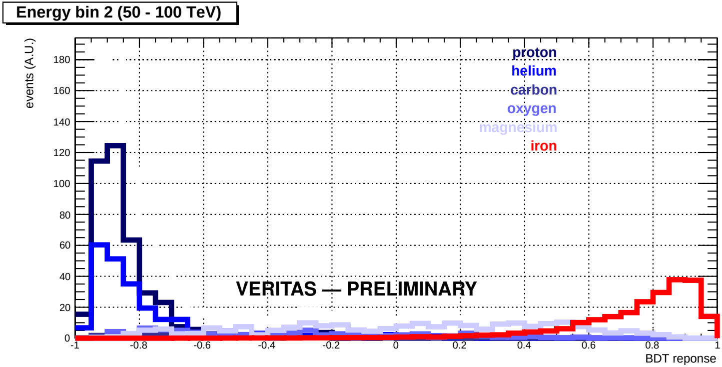

Outlook

Status and Plans:

- Improved measurement of the iron spectrum with VERITAS on the way.
- Improved statistics, reconstruction, charge separation, atmospheric modeling.
- Systematic uncertainties remain, esp. hadronic interaction models.

Future developments?

- CTA studies ongoing (see talk by S. Ohm later today).
- Would like to image heavy nuclei in DC light.
- Would need dedicated instruments:
  $\sim$ 100 m total mirror diameter, $\sim 0.01^\circ$ pixels/PSF .

Thank you for the attention!

Backup.

Bibliography

Aharonian, F. et al. (2007). First ground based measurement of atmospheric Cherenkov light from cosmic rays. *Phys.Rev.*, D75:042004.

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Wissel, S. (2010). *Observations of Direct Cerenkov Light in Ground-based Telescopes and the Flux of Iron Nuclei at TeV Energies*. PhD thesis, University of Chicago.