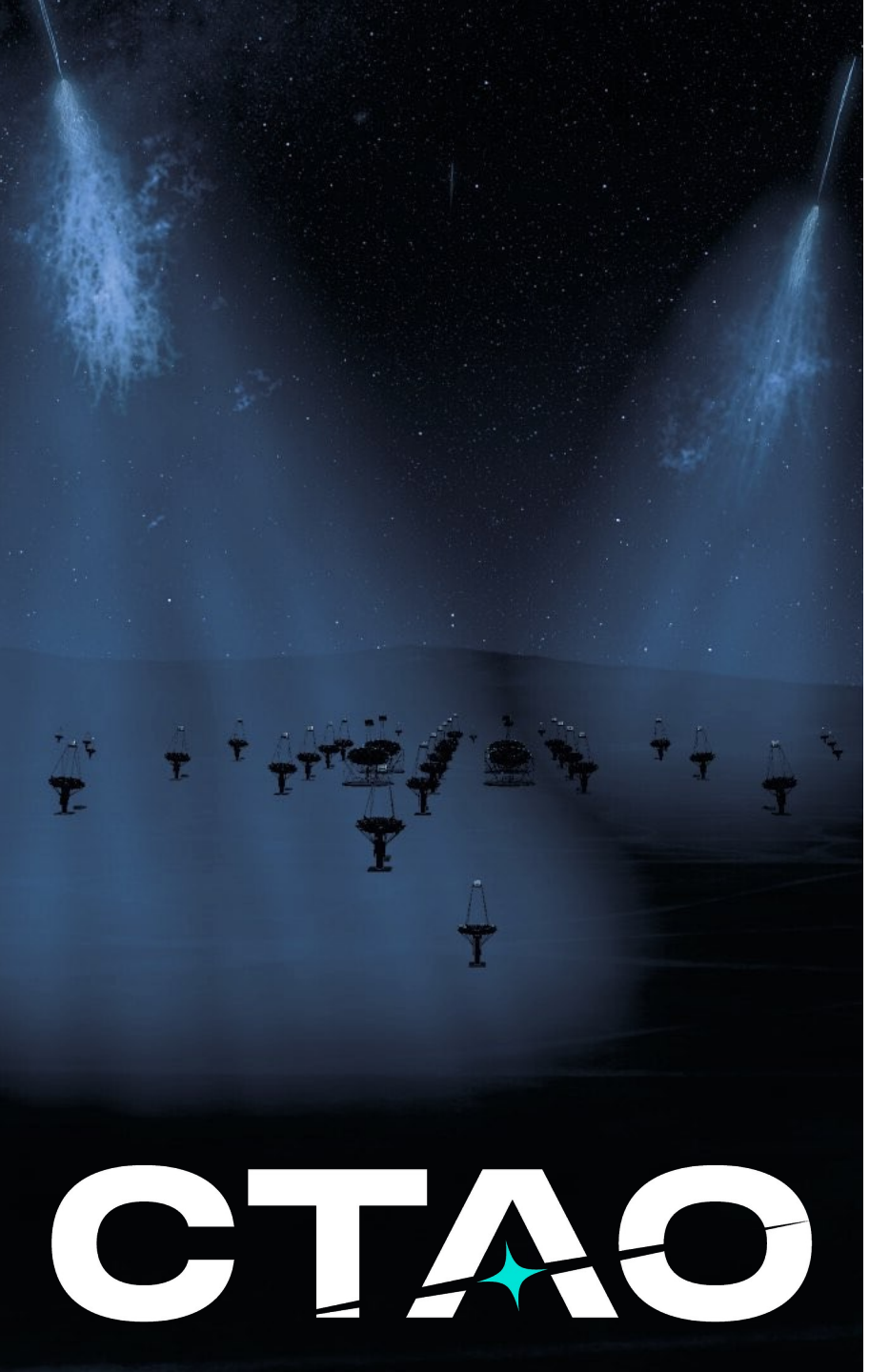


Simulation & Analysis

Status, Discussions, ...

Sabrina Einecke & Simon Lee

sabrina.einecke@adelaide.edu.au
simon.lee@adelaide.edu.au

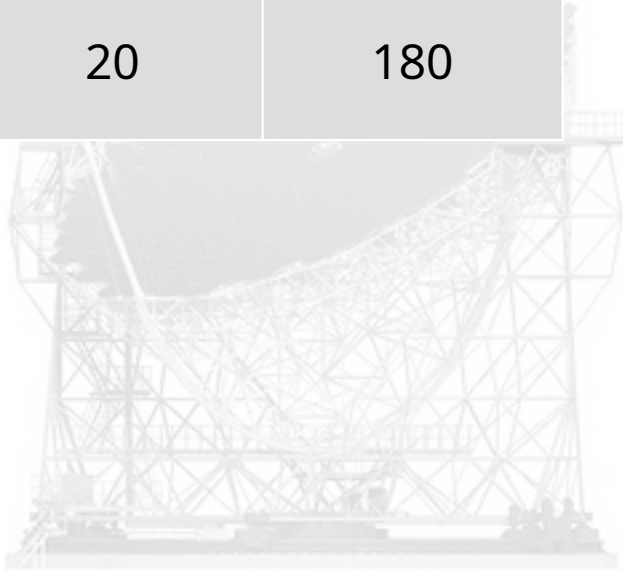
THE UNIVERSITY of ADELAIDE

May 31st, 2024

Production Settings (CORSIKA)

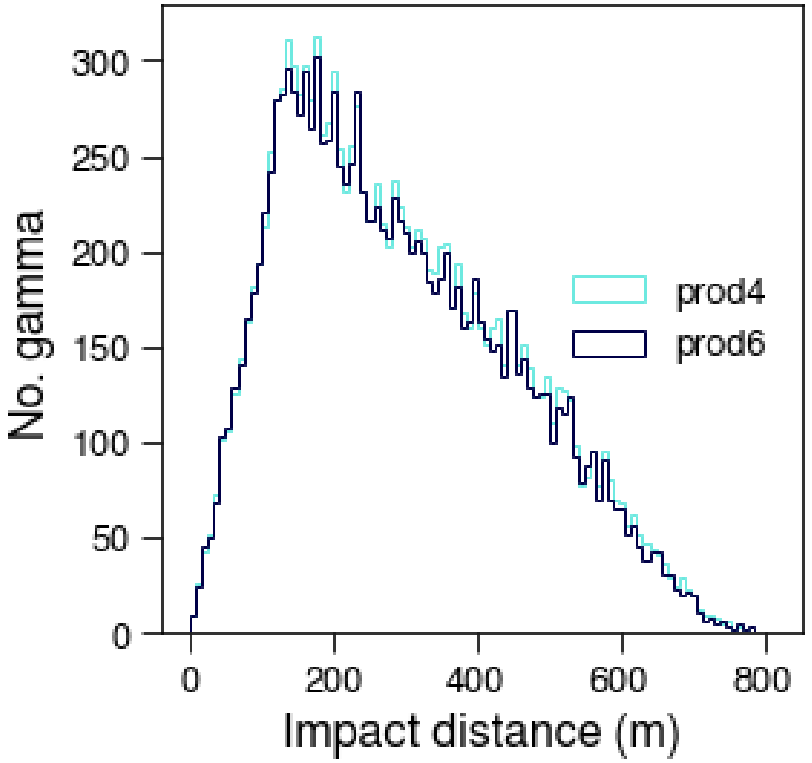
1SST at Paranal

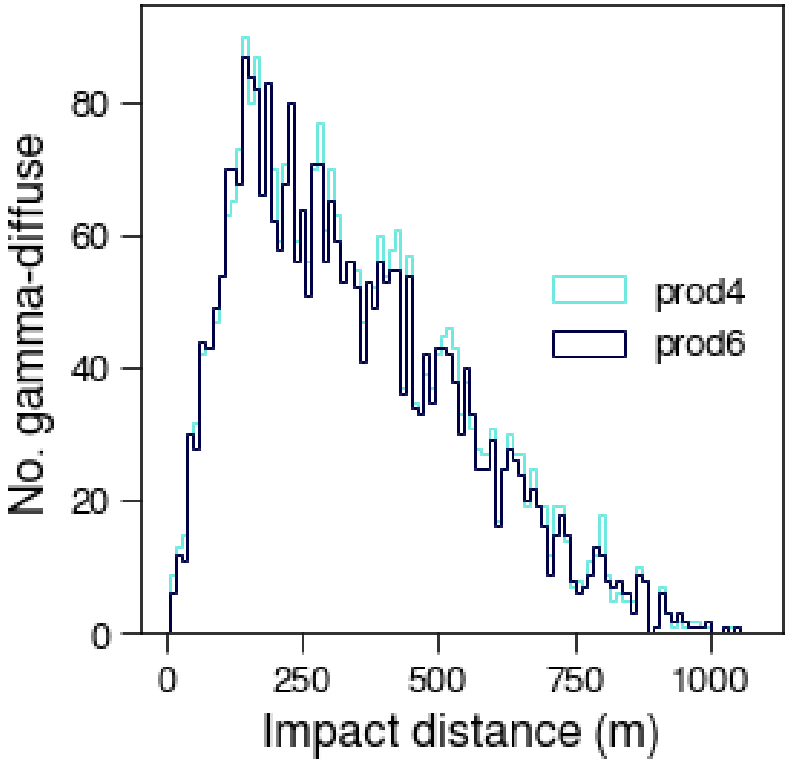
Particle Type	Spectral Index	Energy Range (TeV)	View Cone (deg)	Scatter Radius(m)	Number of Shower Reuses	Zenith (deg)	Azimuth (deg)
Gamma (on-axis)	**-1.5**	0.1 - 330	0	**900**	10	20	180
Gamma (diffuse)	**-1.5**	0.1 - 330	10	**1200**	20	20	180
Proton (diffuse)	**-1.5**	0.1 - 600	10	**1300**	20	20	180

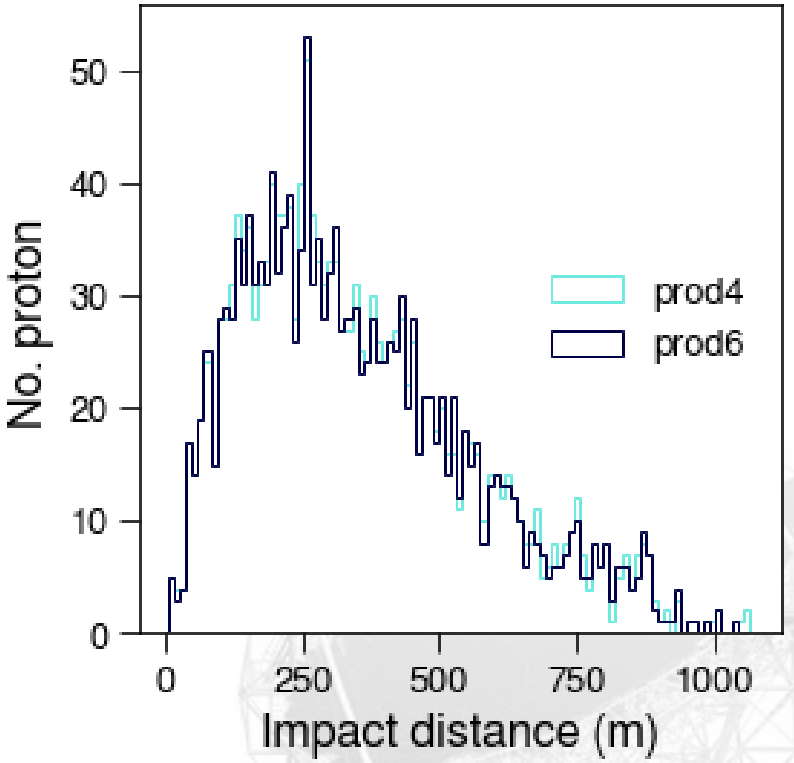


Scatter Radius

- Decreased from to 1000m to 800m (on-axis) and from 1500m to 1200m/1300m (gamma-diffuse/proton)





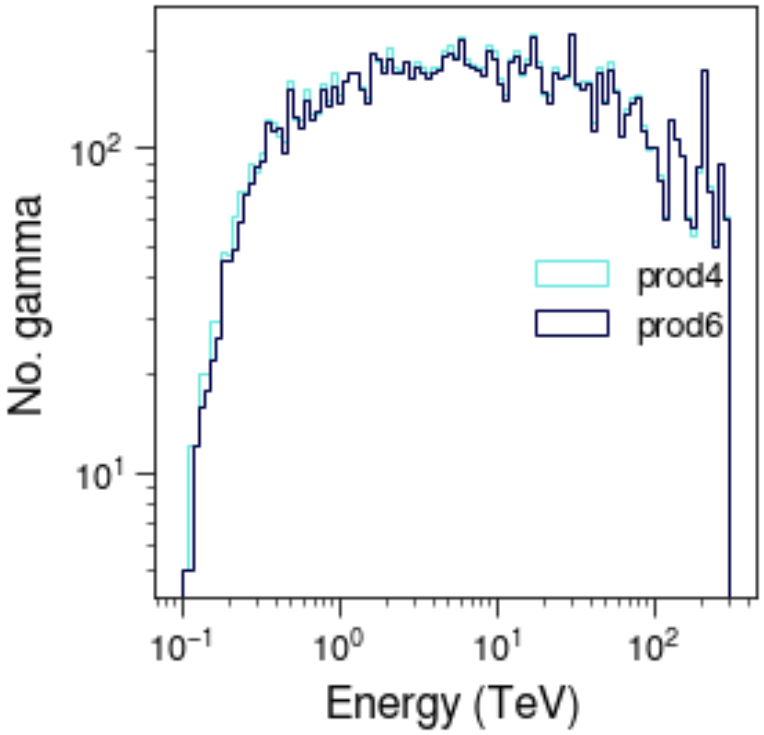


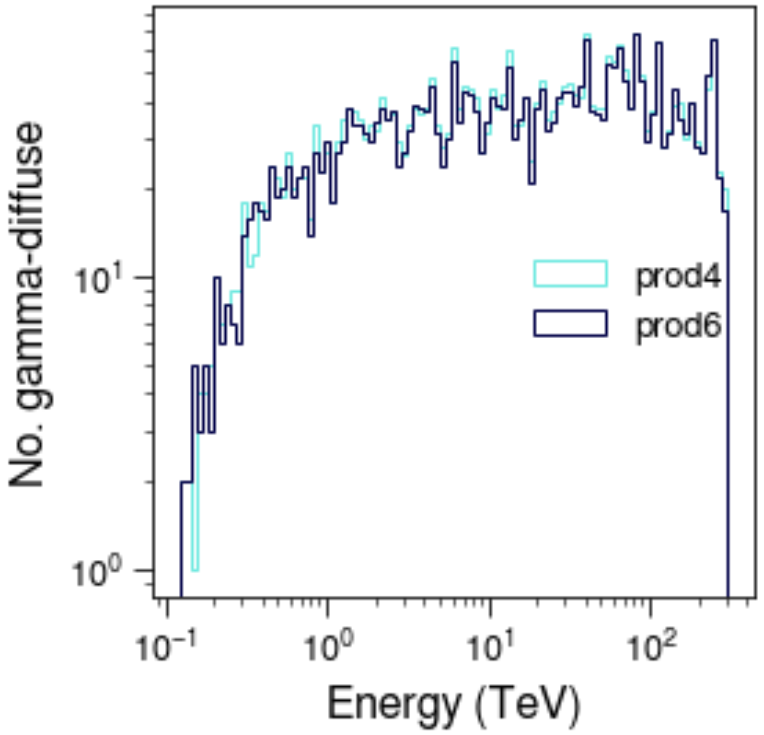
Current Production

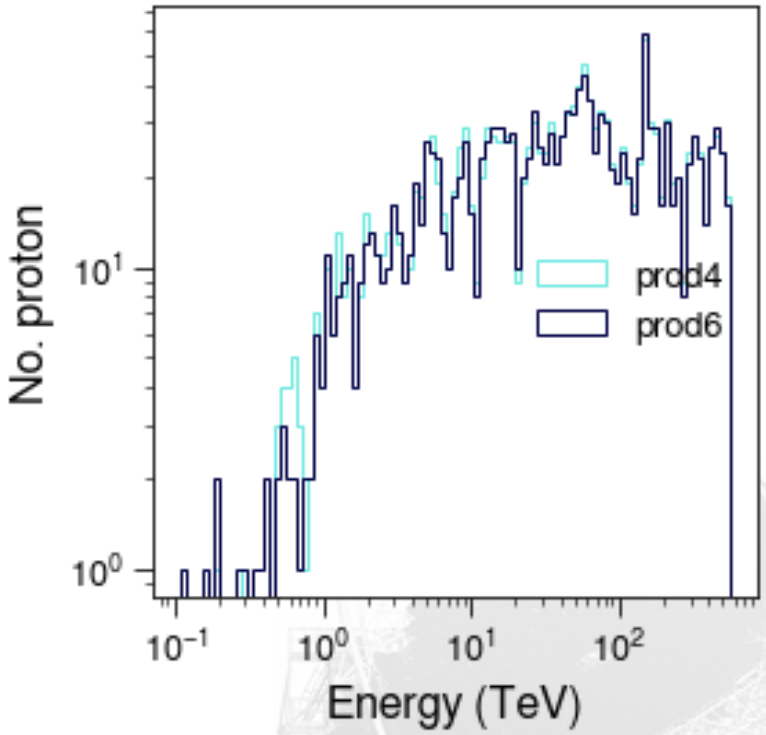
Particle Type	Number of Showers	Number of Events after Trigger		Number of Events after Cleaning		Number of Events after all Cuts	
		PROD4	PROD6	PROD4	PROD6	PROD4	PROD6
Gamma (on-axis)	200,000	13,892	14,243	13,439	13,076	?	?
Gamma (diffuse)	400,000	3392	3434	3249	3135	?	?
Proton (diffuse)	320,000	1680	1748	1618	1581	?	?

- Production and analysis ongoing...
- Priorities for future productions and analyses would be good to define (see later)

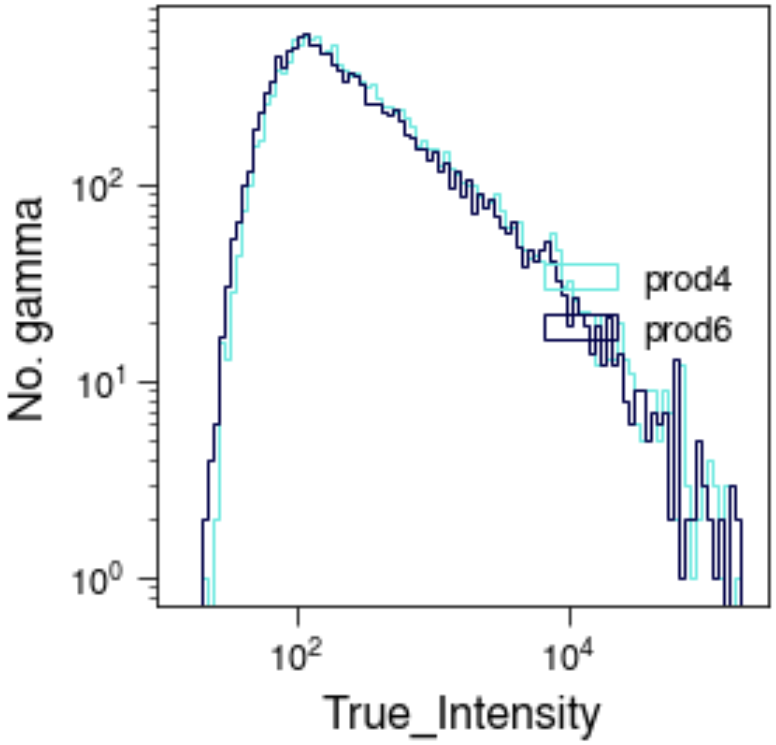
Parameter Distributions

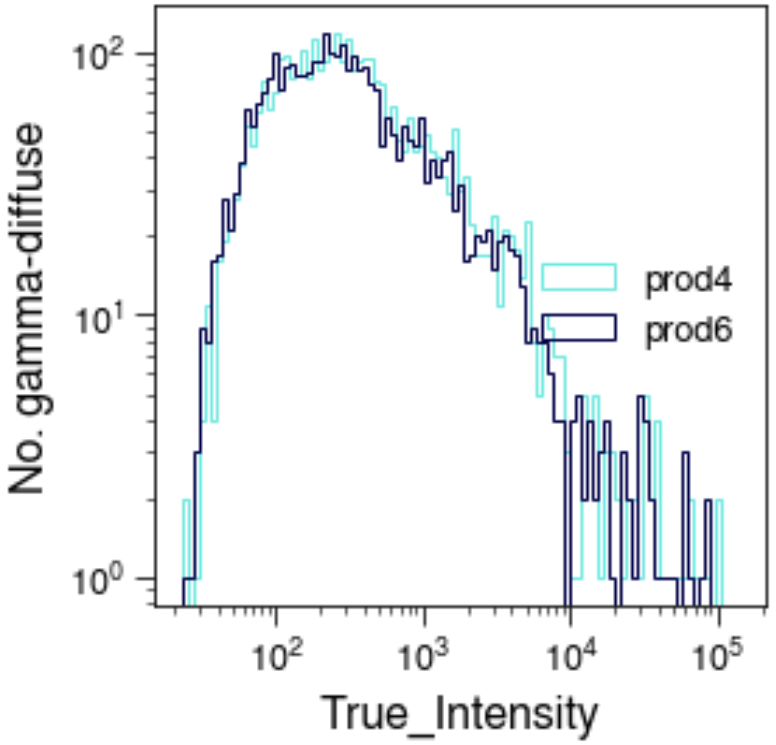


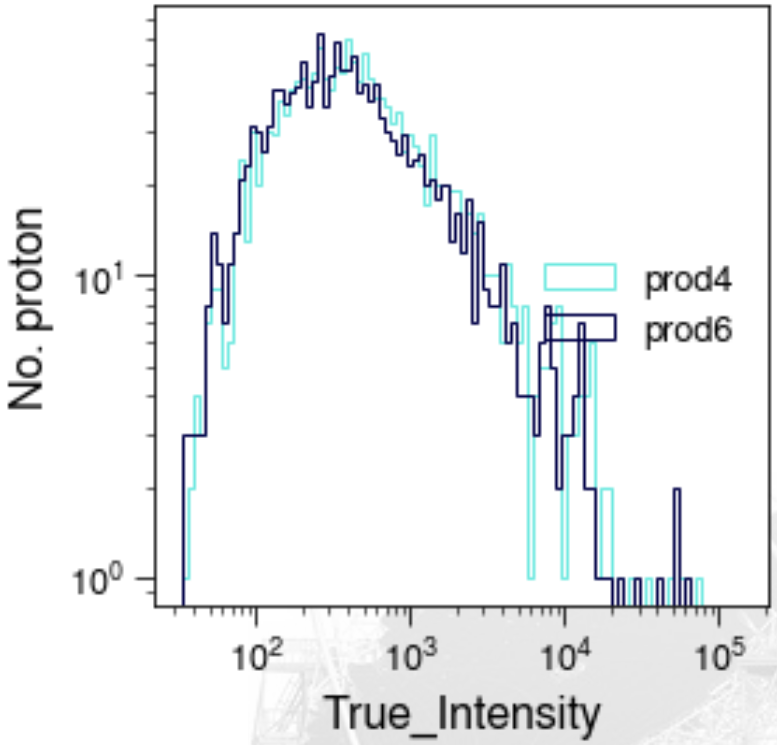




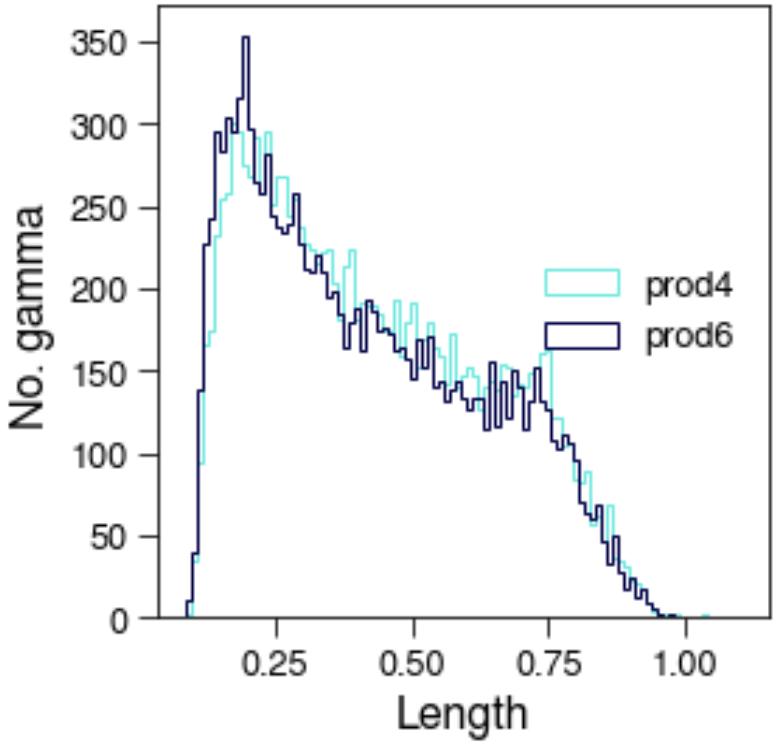
Parameter Distributions

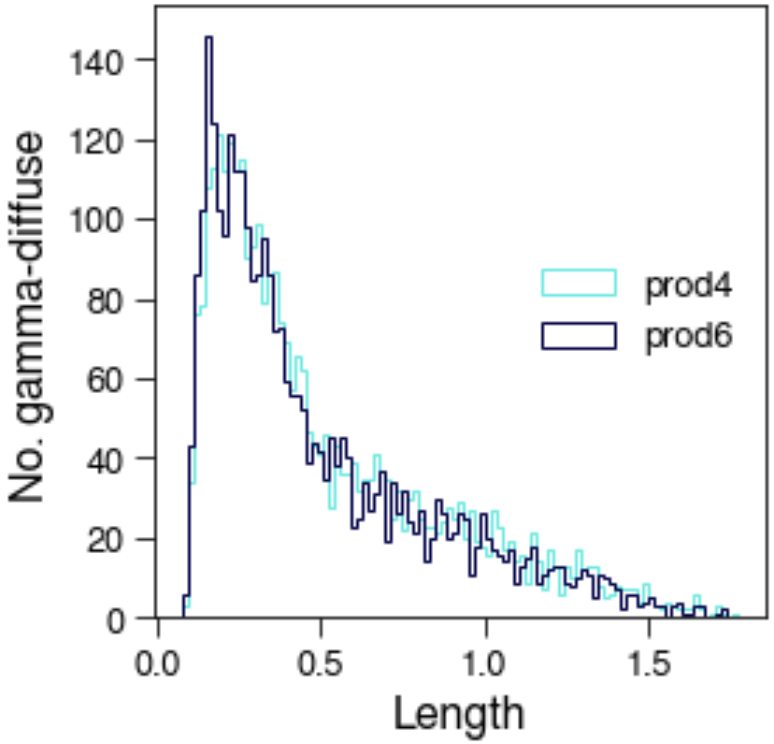


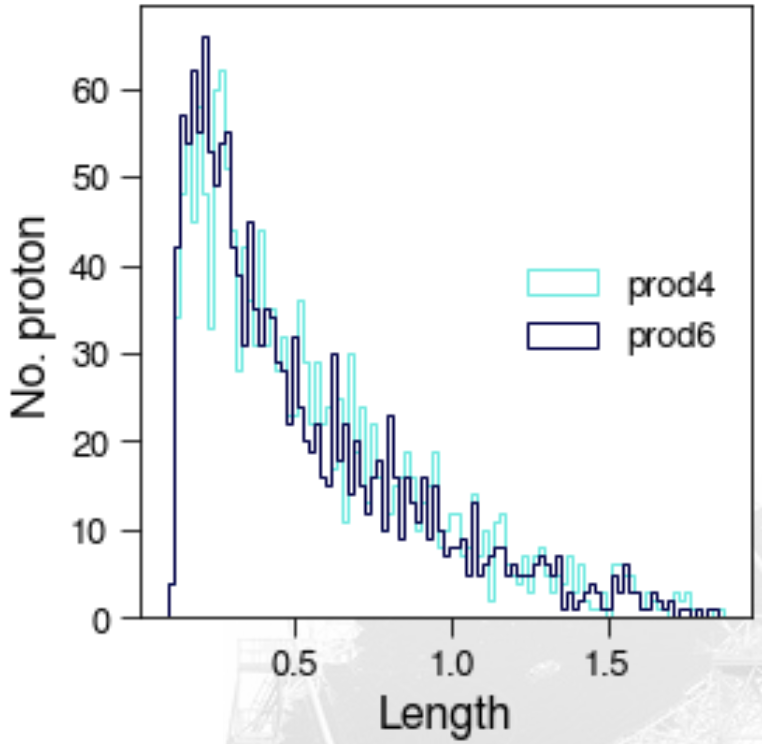




Parameter Distributions

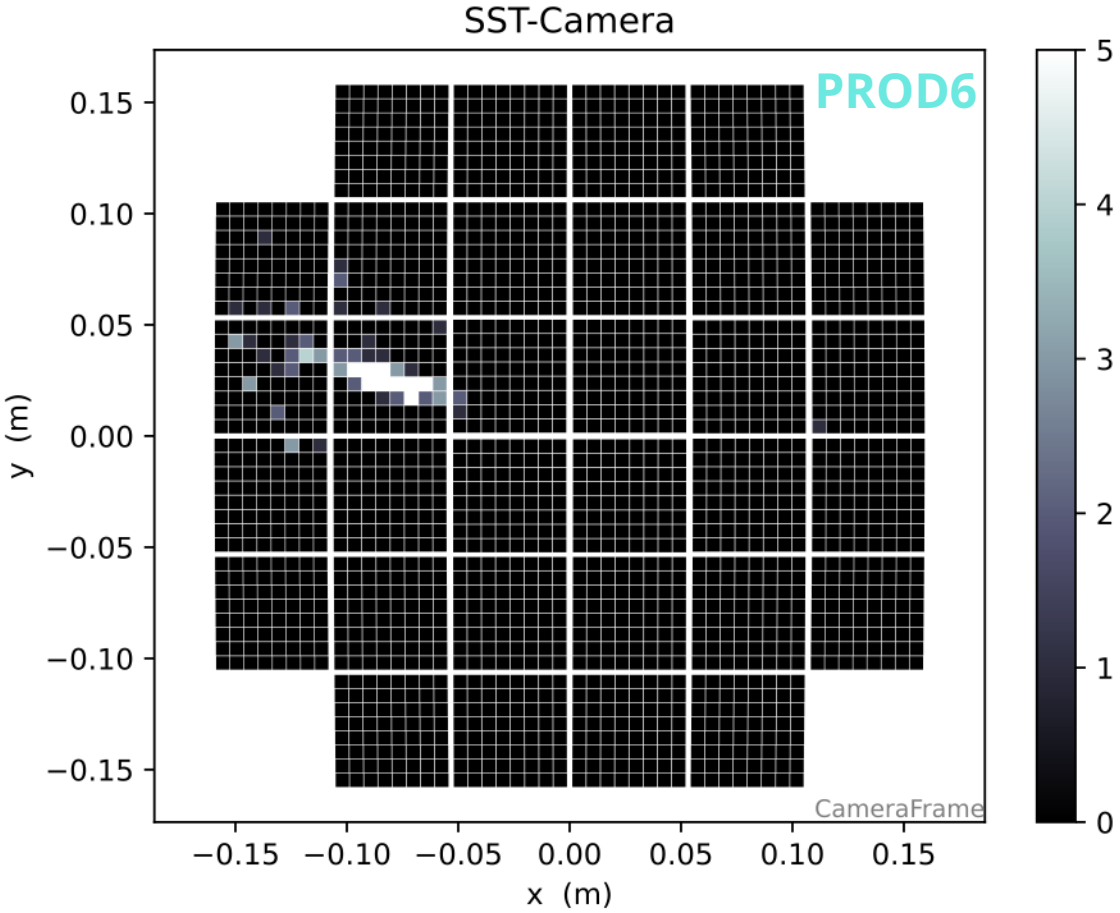


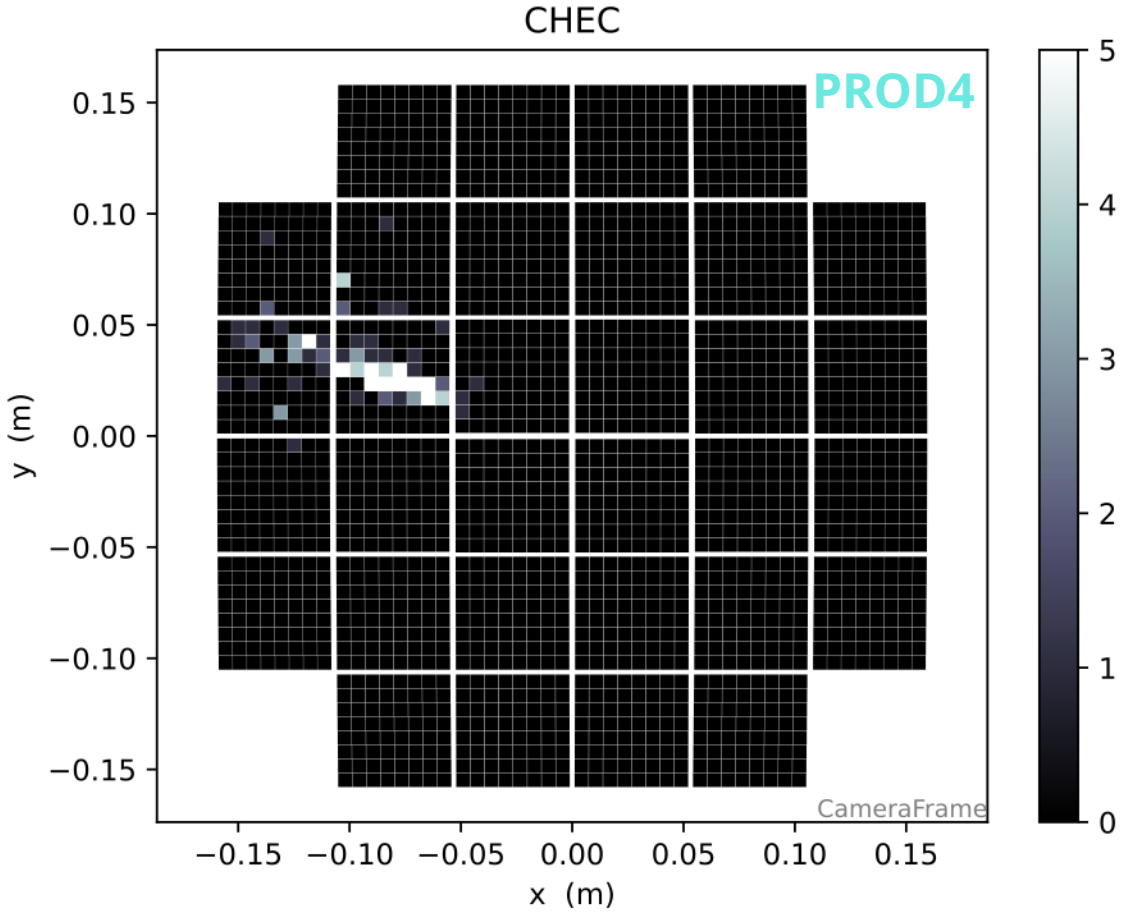




Camera Images

‘True’ Images = No NSB (for direct comparison)





Discussion

- Last MC update (May 2022) had some outstanding parameters that required attention:
  - **Pixel positions**: Requires to run “modular_camera” software (needs figuring out!)
  - **Quantum efficiency**: It was updated but “using 75um data” (should be 50um, but not important)
  - **Quantum efficiency variation**: Value of 3% needs to be confirmed (not reason it would be worse)
  - **FADC noise**: Needed to be confirmed (with lab-measured SPE spectrum)
  - **teltrig_min_time**: Needed to be clarified

Discussion

- What parameters have changed since then? What's the highest priority to check/update?
  - widow transmission vs wavelength & angle.
  - “We’re writing the spec’s now for the company, so this could be updated / checked soon.
- “Are there any simulations we should run (e.g. to compare with latest lab measurements)?
  - camera illuminated with a uniform beam with ~100 ps pulse
- Should we prepare shower simulations for the campaign (with a quarter camera?)?
  - if time allows
- What’s the planned processing pipeline?
  - CHECLabPy for low-level processing? (sstcam-analysis)
  - ctapipe instead of aict-tools for high-level processing? Are there currently used CLI configs?
- Is there anything else MC parameters/simulation/analysis related we should work on?
  - CDR plots & requirements verification

Tracking spreadsheet?

CHEC_ASWG_VV_ParamSummary

File Edit View Insert Format Data Tools Extensions Help

Share

Menus 100% View only

A1

	A	B	C	D	E	F	G	H	I	J	K	L
1								CHEC-S Prototype				
2	Parameter			Short Description	Default	Prod3 Values	unit	Comments	Understood	Value Chosen	Verfied	A
3	Camera											
4		Camera Type	1	Geometry of the camera, a value of 3 indicates a flexible definition	3	3		OK	☑	☑	☑	
5		Camera Pixels	2	Number of Pixels in camera	960	2048		OK	☑	☑	☑	
6		Camera Body Shape	3	Shape used for shadowing (0=circular, 1=hexagonal, 2=square)	0	2		OK	☑	☑	☑	
7		Camera Body Diameter	4	Shape used for shadowing	160 cm	42		AST raytracing what diameter is the most important.	☑	☐	☐	Need Confirm
8		Camera Depth	5	Depth used for shadowing	0 cm	50		OK	☑	☑	☑	
9		Camera Transmission	6	wavelength independent global factor	1	1		OK	☑	☑	☑	
10		Camera Filter	7	Wvelength (and angular) dependent transmission for window	none	none		EC-S performance on tel, use ASTRI window for that	☑	☑	☑	Needs Discu
11		Camera Config File	8	Additional flexible camera configuration	hess_camera.dat	camera CHEC-S GATE.dat		Updated, pixels from Duncan, trigger def checked	☑	☐	☐	
12		- > Pixel Type	9	Global: Always 1	1	1		OK	☑	☑	☑	
13		- > PMT Type	10	Global:Mustbe 0	0	0		OK	☑	☑	☑	
14		- > Cathode Shape Type	11	Global:shape of a pixel	0 (circular)	2		OK	☑	☑	☑	
15		- > Visible Cathode Diameter	12	Global: size of a pixel	2.1	0.623	cm	Confirm	☑	☑	☐	Need Confirm
16		- > Funnel Shape Type	13	Global: shape of any funnel (same as cathod if no funnel)	1	2		OK	☑	☑	☑	
17		- > Funner Diameter	14	Global: size of any funnel (same as cathode if no funnel)	4.15	0.623	cm	Same as pixel	☑	☑	☐	Need Confirm
18		- > Depth of Funnel	15	Global: depth of any funnel (0 if none)	5.1	0	cm	OK	☑	☑	☑	
19		- > Funnel Efficiency File (angle)	16	File containing data for angular efficiency of detector/funnel	hess_funnels.dat	pmma vs theta 20150422.dat		ctance of different Si coating or measure on sample	☑	☐	☐	Needs Measure
20		- > Funnel Efficiency File (wavelength)	17	File containing data for wavelength acceptance of detector/funnel	-	a_meas0deg_coat_82raws.dat		Needs Removing	☑	☑	☑	
21		- - > Pixel ID	18		-	Generic		OK Changed to match mapping of camera	☑	☑	☑	
22		- - > Pixel Type	19	must be 1	1	1		OK	☑	☑	☑	
23		- - > X/Y position	20	the x,y pixel position (flattened 3d points)	-	From CHEC-S CAD file	s	Checking, Need to chck if there is effect of offset?	☑	☑	☑	Needs Che
24		- - > Module Number	21	module number for each pixel, used for setting z position of pixels	-	0		OK, Changed to match mapping of camera	☑	☑	☑	
25		- - > Board in Module	22	dummy value	-	0		Not Used, OK	☑	☑	☑	
26		- - > Channel number n board	23	dummy value	-	0		Not Used, OK	☑	☑	☑	
27		- - > board ID number	24	dummy value (hex)	-	0x00		Not Used, OK	☑	☑	☑	
28		- - > Pixel is on	25	on/off	1	1		OK	☑	☑	☑	
29		- - > qe_rel	26	relative QE/PDE	-	-		Not Used, OK	☑	☑	☑	
30		- - > gain_rel	27	relative gain	-	-		Not Used, OK	☑	☑	☑	
31		- - > dz	28	displacement along z axis relative to focal or module surface	-	-		Not Used, OK	☑	☑	☑	
32		- - > pixrot	29	pixel rotation around axis	-	-		Not Used, OK	☑	☑	☑	
33		- - > ny, nx	30	pixel normal vector	-	-		Not Used, OK	☑	☑	☑	
34		Trigger Definitions	31	Manually define each trigger sector (group of 9 super pixels) within which we look for coincedence	-	9 pix sector		OK	☑	☑	☑	
35		Camera Scale Factor	32	Parameter to scale all pixel positions and sizes	1	-		Not Used, OK	☑	☑	☑	

This page intentionally left blank

Discussion: Future Productions

- Performance studies
  - 1 SST @ Paranal
  - >1 SST @ Paranal

→ 1 SST can reuse CORSIKAs of >1 SST

- Data / MC comparison (Tenerife campaign)
  - 1 SST with QCam @ Tenerife
  - Above with MC parameter adaptions

→ Same CORSIKAs (Tenerife) can be reused for different MC parameters

- MC parameter updates
  - Prod6
  - Prod6 with adaptions

→ Can reuse any CORSIKA

What's the priority? Which productions to start?

Proposal

1. Tenerife CORSIKAs
2. MC parameter updates
3. Qcam simtels
4. Performance Paranal

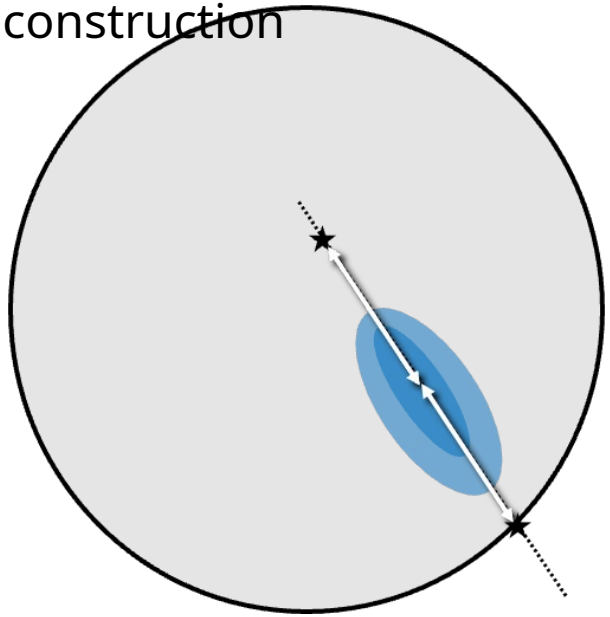
Computing Resources @ UofA

- *Phoenix* (university-wide)
  - 260 nodes (900 CPUs and GPUs)
  - 2PB file system (lustre)
  - SLURM scheduler
  - Our current storage: 15 TB (group) + 15 TB (Simon)

- *Gehrels* (group-wide)
  - 32 cores
  - Storage: 10 TB
  - No scheduler

Analysis Pipeline (Mono & Stereo)

- ctapipe for low-level reconstruction (calibration, cleaning, image parameterisation)
- Random Forests (sklearn) for energy & direction reconstruction, g/h separation
- Direction reconstruction includes
  - random forest for disp reconstruction (regression)
  - random forest for sign reconstruction (classification)



Publications of the Astronomical Society of Australia (2022), **39**, e041, 8 pages
doi:10.1017/pasa.2022.29

Research Article

doi:10.1017

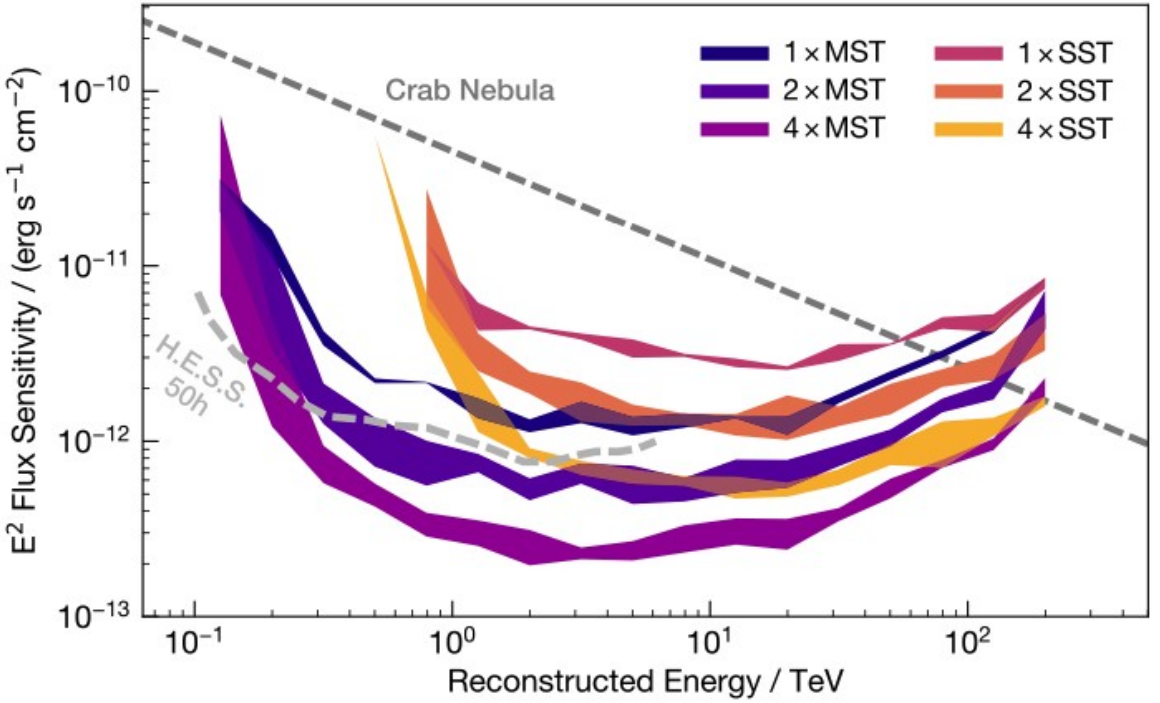
Performance of a small array of Imaging Air Cherenkov Telescopes sited in Australia

Simon Lee[1], Sabrina Einecke[1], Gavin Rowell[1], Csaba Balazs[2], Jose A. Bellido[1], Shi Dai[3], Dominik Elsässer[4], Miroslav Filipović[3], Violet M. Harvey[1], Padric McGee[1], Wolfgang Rhode[4], Steven Tingay[5], and Martin White[1]

[1]School of Physical Sciences, University of Adelaide, Adelaide SA 5005, Australia, [2]School of Physics and Astronomy, Monash University, Melbourne VIC 3800, Australia, [3]School of Science, Western Sydney University, Locked Bag 1797, Penrith NSW 2751, Australia, [4]Department of Physics, TU Dortmund University, 44221 Dortmund, Germany and [5]International Centre for Radio Astronomy Research, Curtin University, GPO Box U1987, Perth, WA, 6845, Australia

Abstract

As TeV gamma-ray astronomy progresses into the era of the Cherenkov Telescope Array (CTA), there is a desire for the capacity to instantaneously follow up on transient phenomena and continuously monitor gamma-ray flux at energies above 10^{12} eV. To this end, a worldwide network of Imaging Air Cherenkov Telescopes (IACTs) is required to provide triggers for CTA observations and complementary continuous monitoring. An IACT array sited in Australia would contribute significant coverage of the Southern Hemisphere sky. Here, we investigate the suitability of a small IACT array and how different design factors influence its performance. Monte Carlo simulations were produced based on the Small-Sized Telescope (SST) and Medium-Sized Telescope (MST) designs from CTA. Angular resolution improved with larger baseline distances up to 277 m between telescopes, and energy thresholds were lower at 1 000 m altitude than at 0 m. The ~300 GeV energy threshold of MSTs proved more suitable for observing transients than the ~1.2 TeV threshold of SSTs. An array of four MSTs at 1 000 m was estimated to give a **5.7**σ detection of an RS Ophiuchi-like nova eruption from a 4-h observation. We conclude that an array of four MST-class IACTs at an Australian site would ideally complement the capabilities of CTA.



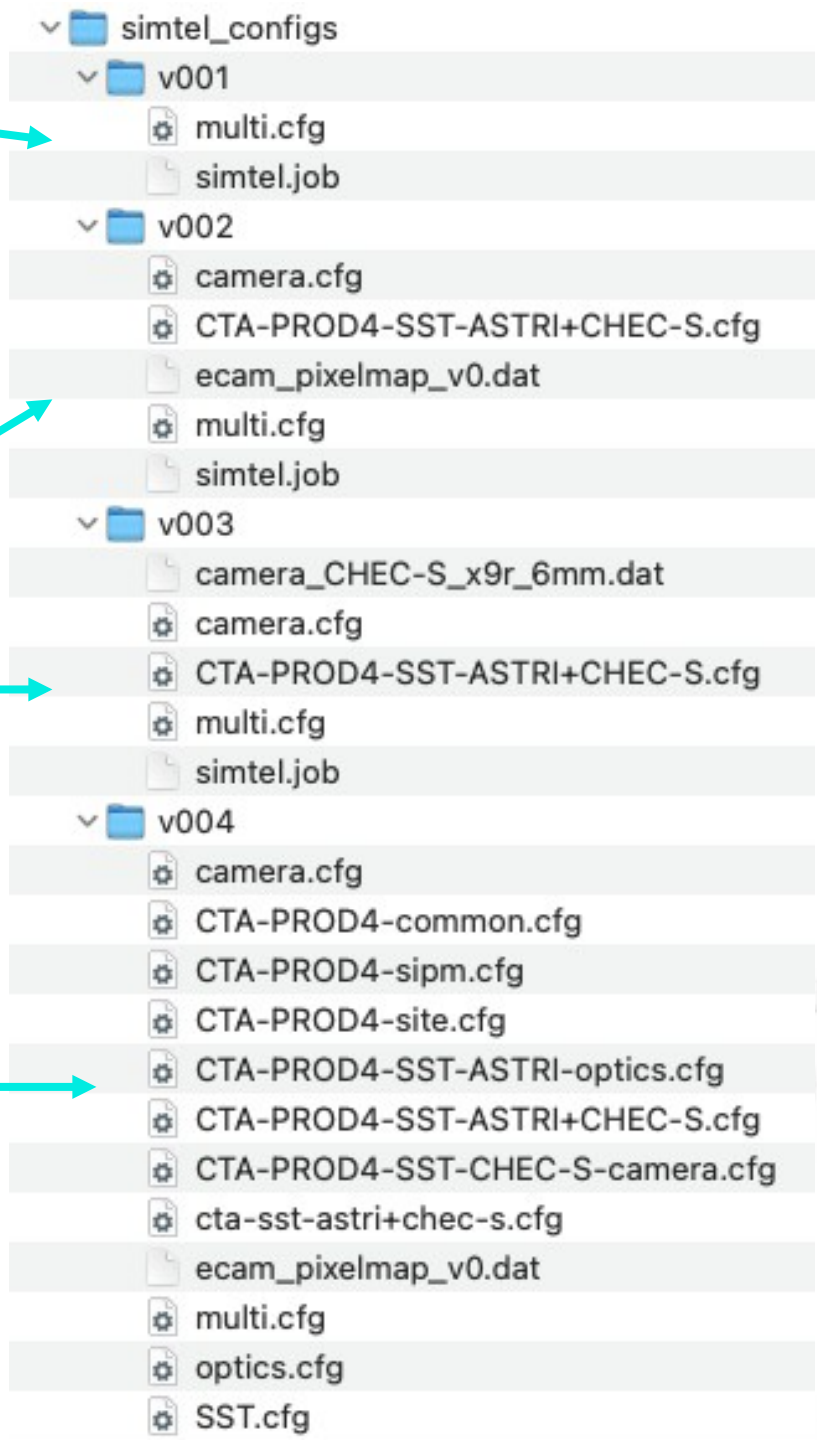
Simulation Setup

- Running CORSIKA and sim_telarray separately,
  to store and reuse CORSIKA showers for multiple productions/tests
- Setup with versioning and book-keeping for both CORSIKA and sim_telarray
  - Uses all config files etc. in version folder (otherwise defaults)

Default

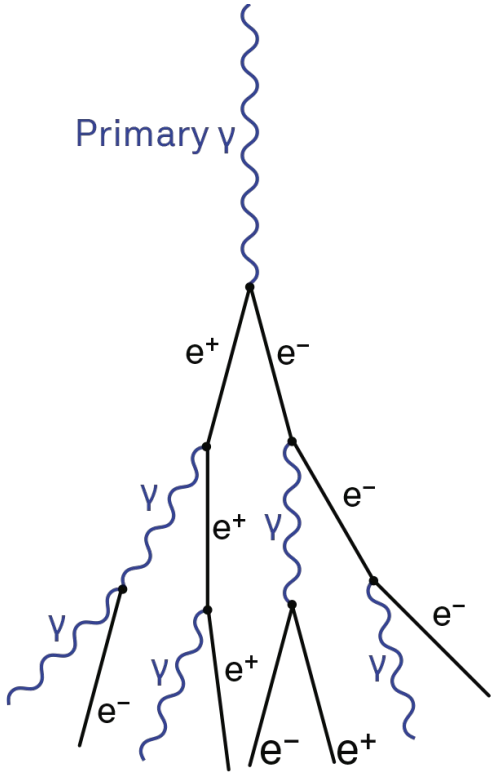
Comparison between different SiPMs

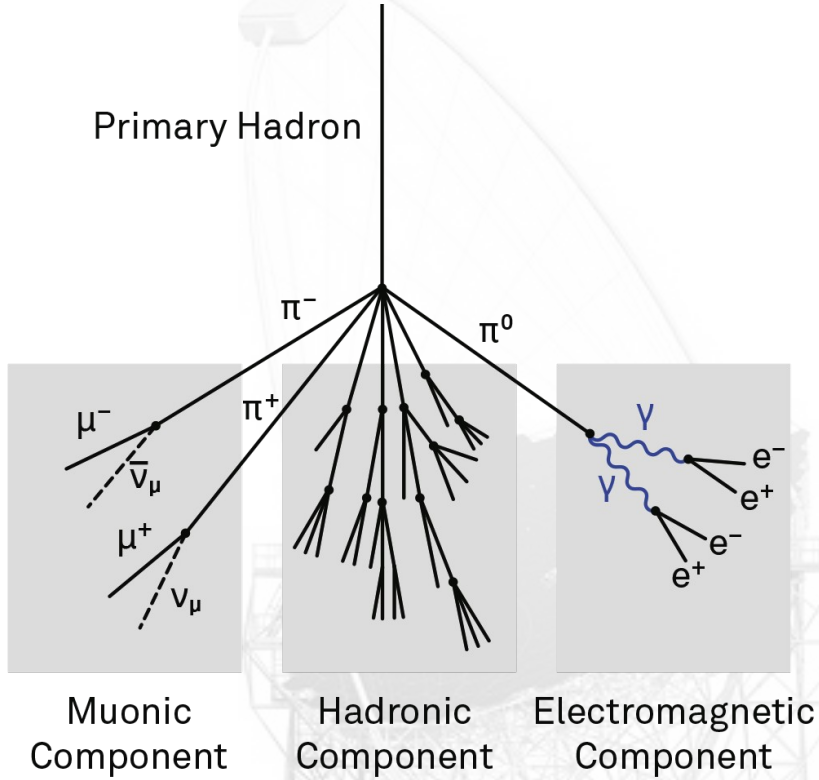
Many different settings in optics, site, SiPMs, ...



Gamma/Hadron Separation

- Differences in showers initiated by gamma rays and hadrons
  - Lateral distribution of Cherenkov photons
  - Arrival time distributions of Cherenkov photons
  - Number of islands
  - Depth of shower maximum
- Ratio of 1:1000 at best
- Classification of type (gamma vs hadron), e.g. with Random Forest



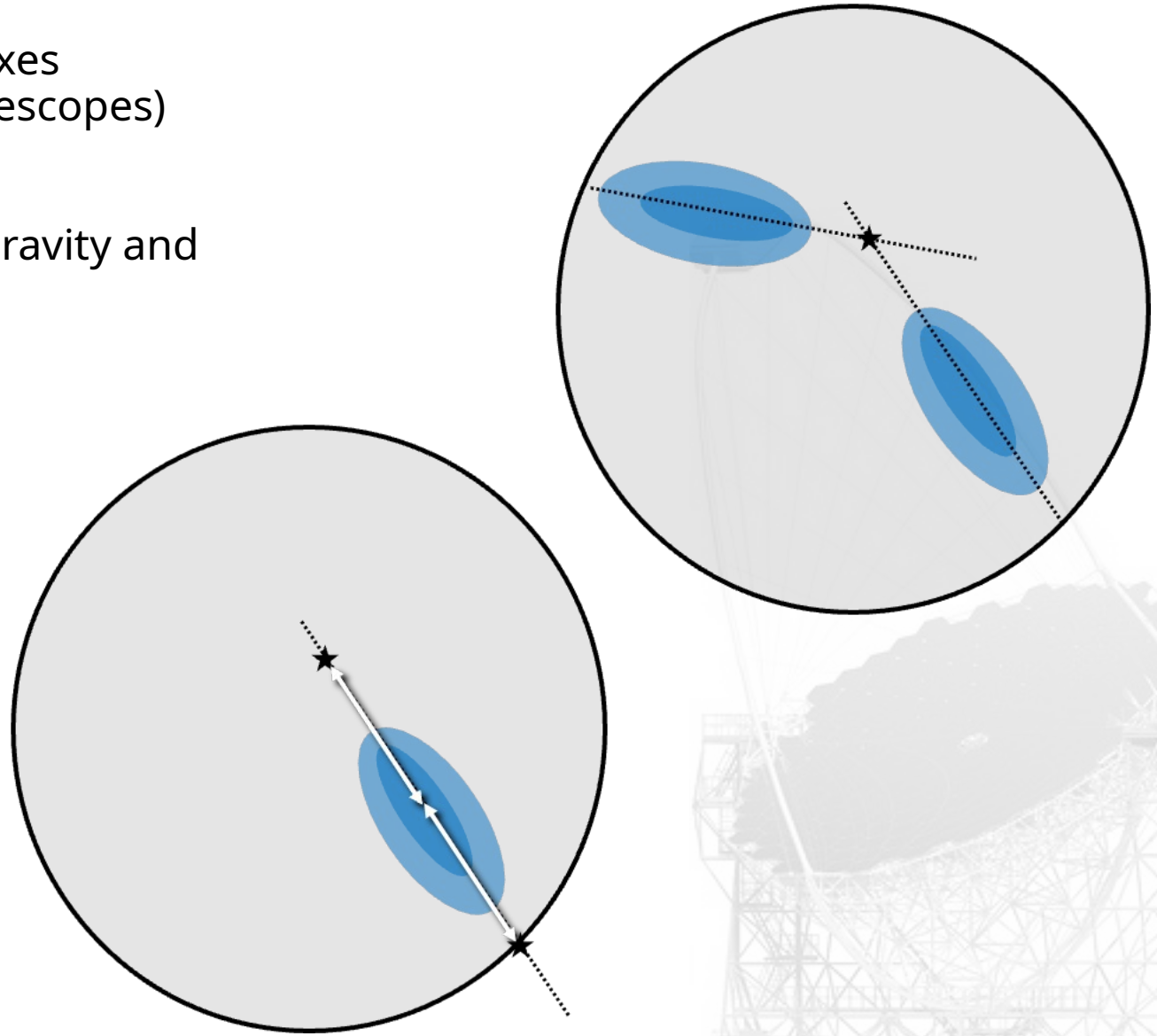


Energy Reconstruction

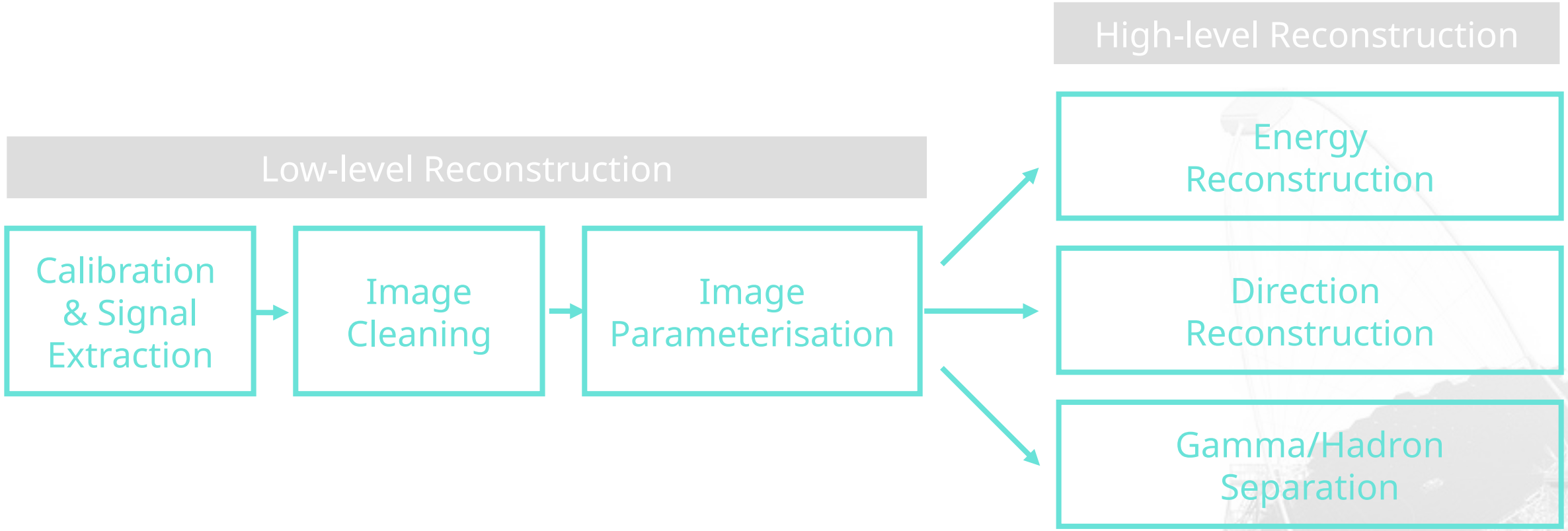
- No direct measurement of energy possible
- Amount of produced light depending on energy of primary incident
- Regression of energy, e.g. with Random Forest

Direction Reconstruction

- Geometrical approach: Intersection of major axes (only possible if event was seen by multiple telescopes)
- General approach:
  - Regression of distance between Centre of Gravity and source position along major axis, e.g. with Random Forest
  - Classification of direction along major axis, e.g. with Random Forest



Event Reconstruction



ctapipe