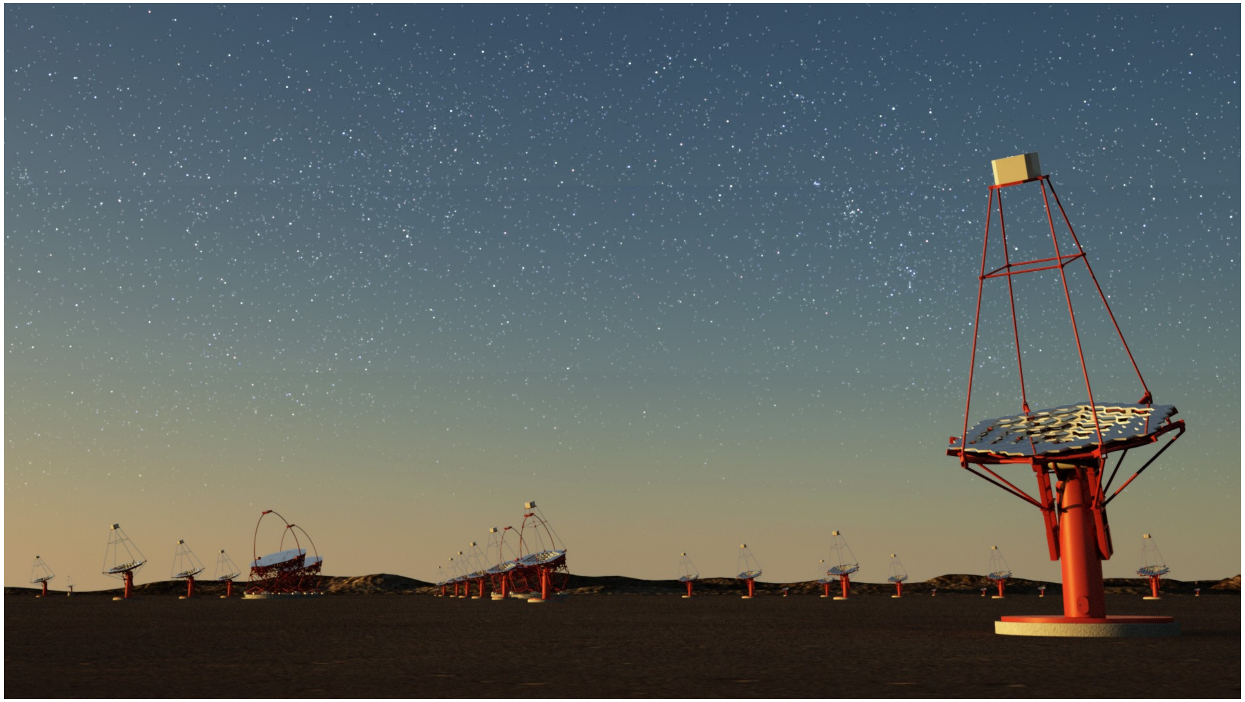


Status and results of Monte Carlo activities for CTA

F. Di Pierro
INAF Osservatorio Astrofisico di Torino

Outline

1. MC TOOLS
   - corsika
   - sim_telarray
   - MC pipeline

2. MC reconstruction and analysis software

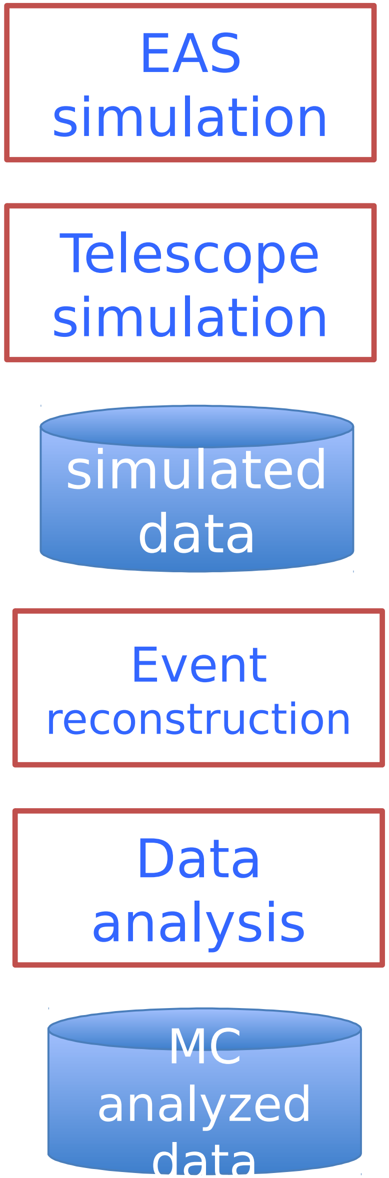
3. Second large scale MC production (Prod2)
   - description
   - results
   - site evaluation support

4. Third large scale MC production

5. Example of telescope simulation setup
   - checks

6. Examples of dedicated productions

THE MC PIPELINE



- It is a complex **instrument**, made of several subsystems both software and infrastructural (computing and storage resources).
- It is fully **operative**.
- **Products**: MC data, IRF (real data analysis, performances, science cases)...

MC Tools

CORSIKA

EAS simulation

- g and bkg events
- zenith, sites

sim_telarray

Telescope simulation

- Optics
- SiPM
- Electronics (FEE/BEE)

simulated data

- DL0 (adc raw)
- DL1 (calibrated, pe)

MC VALIDATION
=
cmp with REAL data (prototype, lab.) and with other sw.

EventDisplay
MARS/CHIMP
read_hess

Event reconstruction

- Calibration
- Cleaning
- Hillas

Data analysis

- Stereo/mono: E0, RA/DEC, h/g
- Angular/Energy res, sensitivity, eff. Areas...

MC analyzed data

- IRF

MC Tools

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MARS/CHIMP
read_hess

Data analysis

- Stereo/mono:
  E0, RA/DEC, h/g
- Angular/Energy res, sensitivity, eff. Areas...

MC analyzed data

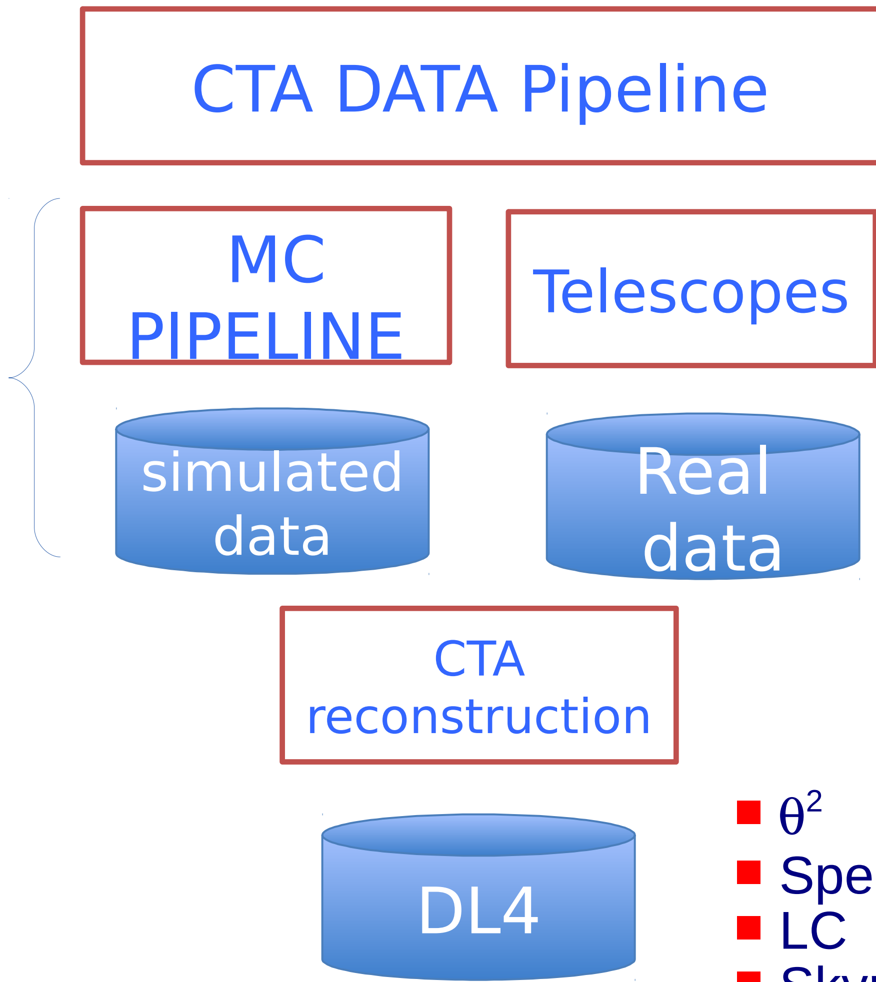
- IRF

- Description and instructions for installation and basic usage in the past meetings

CTA MC pipeline: simplified view

- *After* Observations, Dedicated simulations
    - Observing conditions
    - Hw conditions

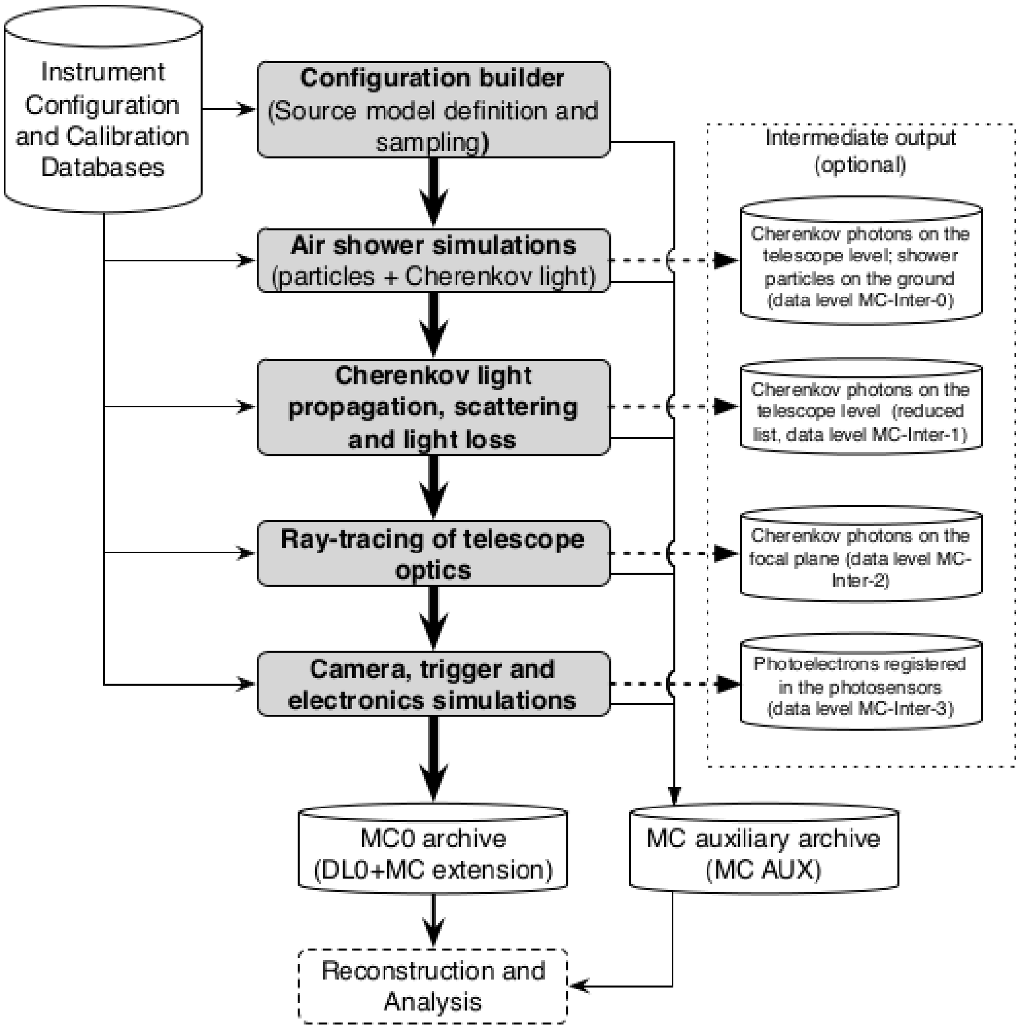
- Before Observations
  Science cases

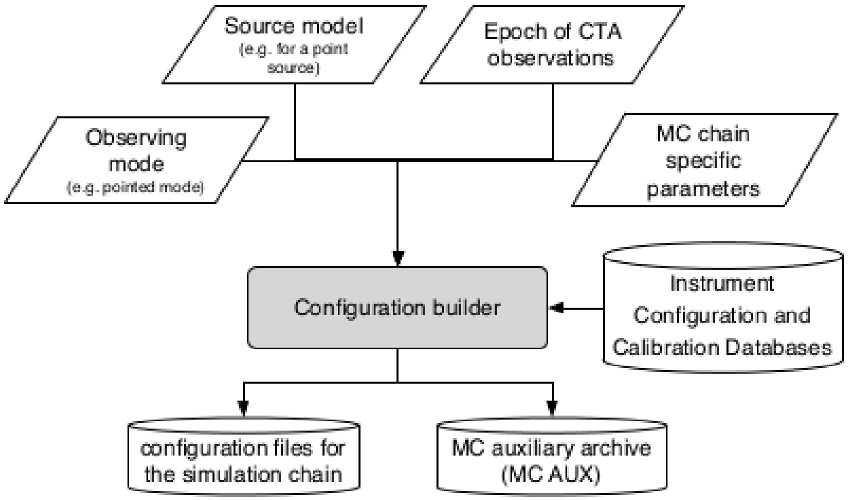


- θ^2
- Spectrum
- LC
- Skymap

Involved CTA WPs: MC, DM, PHYS

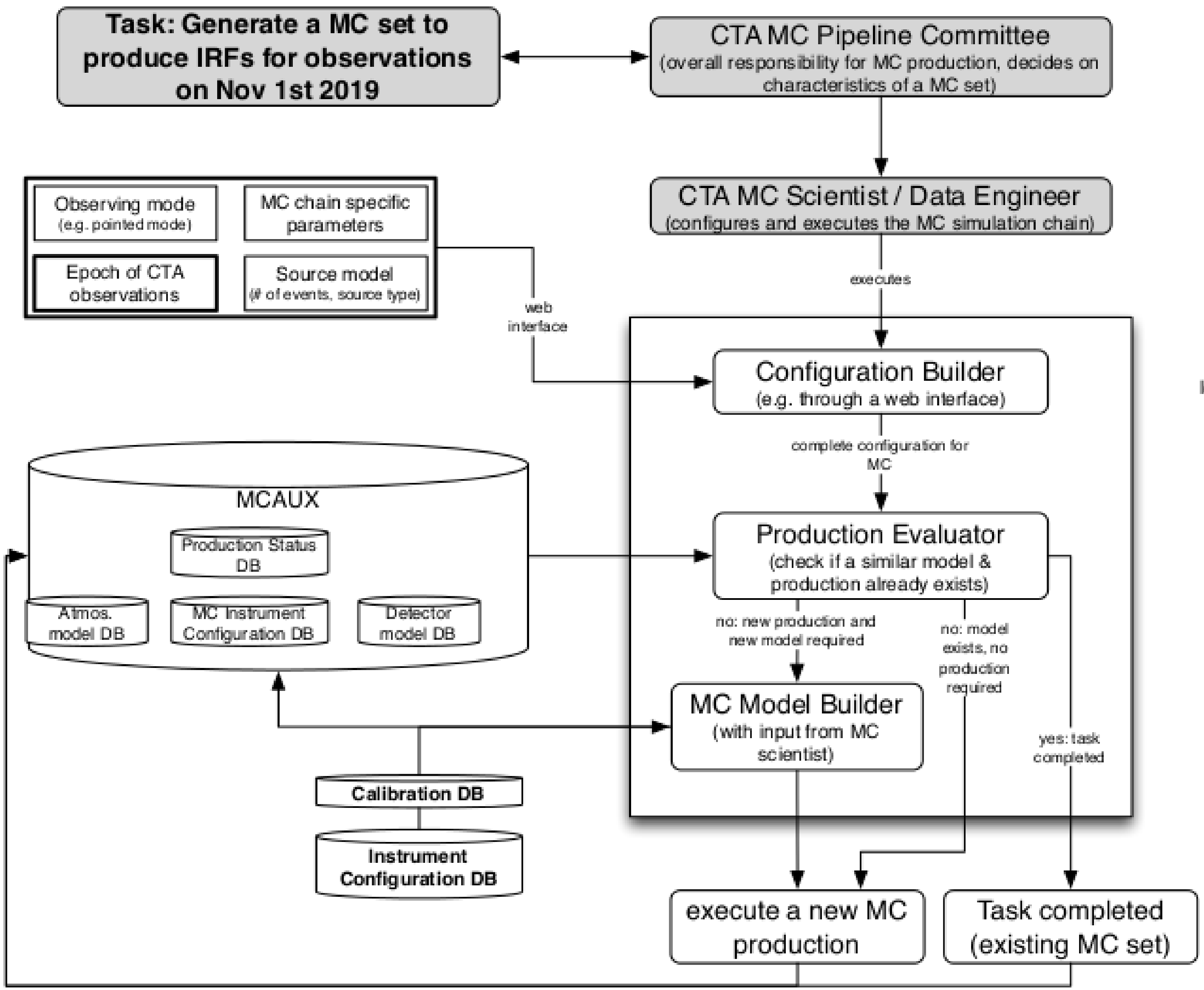
CTA MC pipeline: main components





credit G. Maier

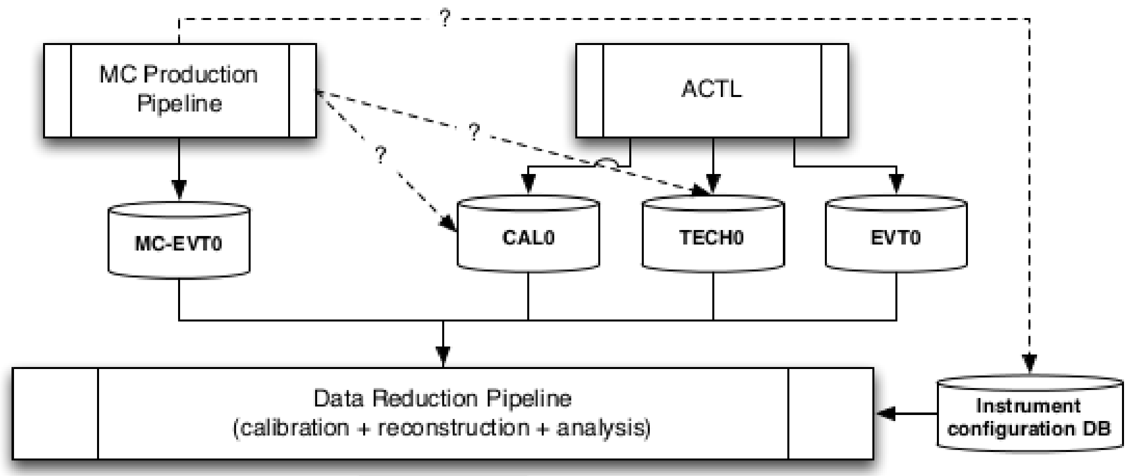
CTA MC pipeline: use case example



CTA MC pipeline: interface to Data pipe

Model 1 (TDR)

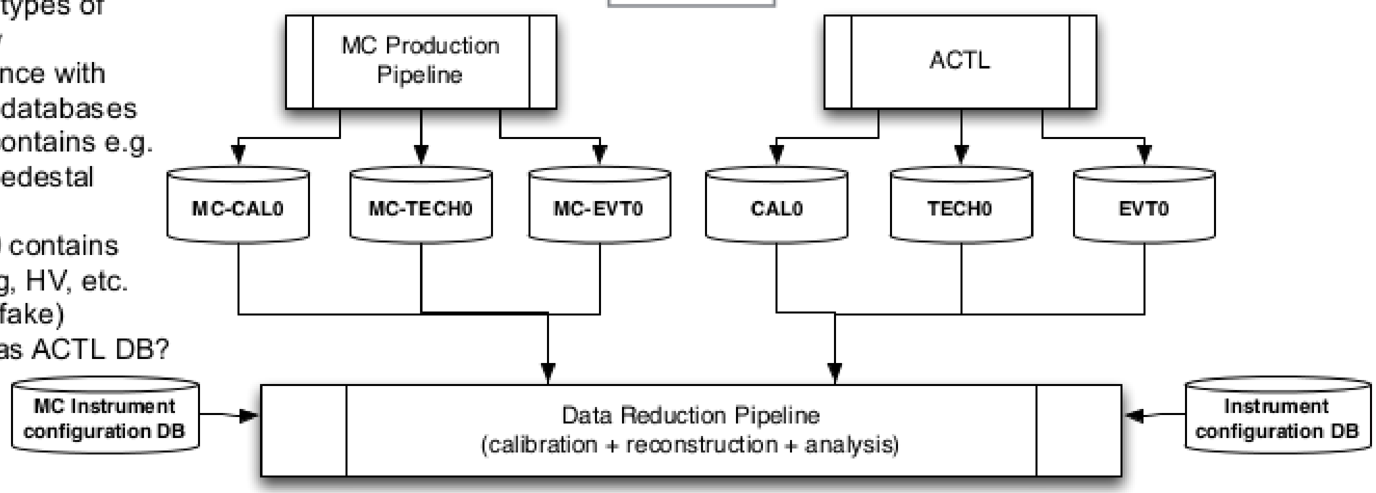
- First possibility: write and read all instrument configuration into MC-EVT0 file
- Second possibility: write MC to ACTL data bases (not sure if we want to do this)



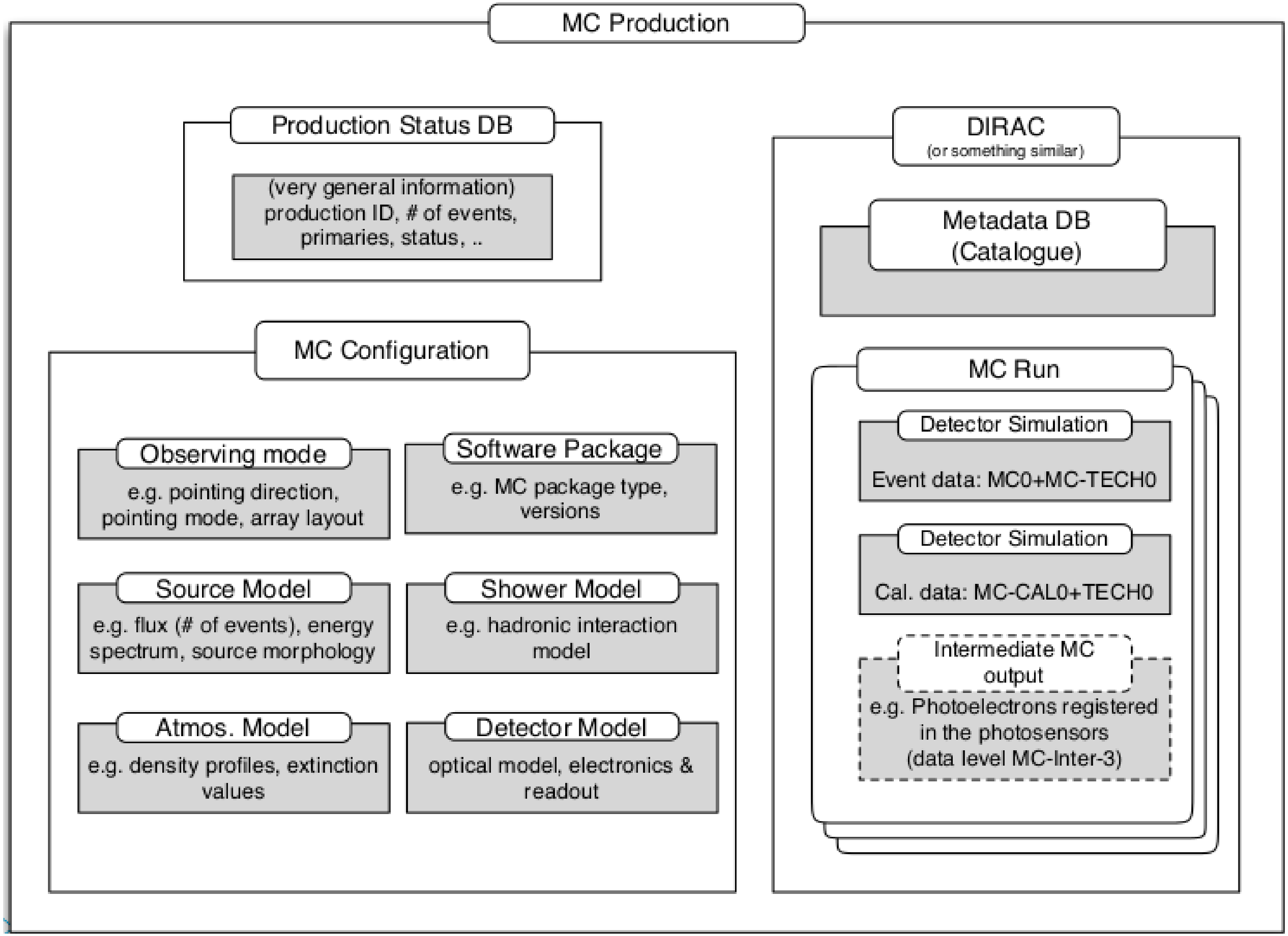
differences between data and MC events are handled by the data reduction pipeline

Model 2

- mirror data types of observatory
- no interference with ACTL filled databases
- MC-CAL0 contains e.g. simulated pedestal events
- MC-TECH0 contains e.g. tracking, HV, etc.
- access by (fake) timestamp as ACTL DB?



CTA MC pipeline: archive

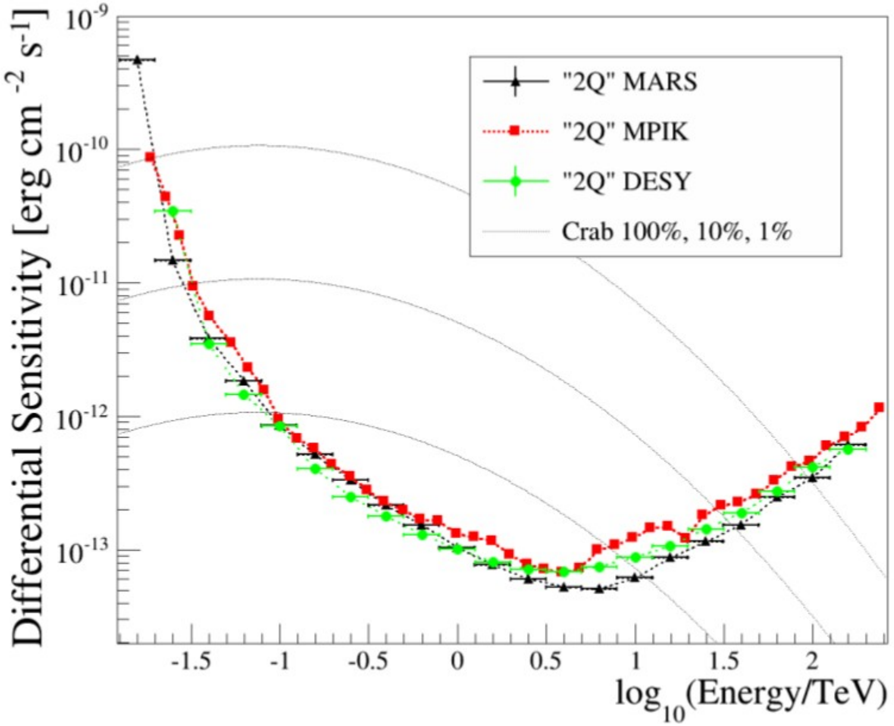


CTA MC reconstruction and analysis

1. From HESS, MAGIC, VERITAS

2. The standard common scheme:
   - trace integrataion
   - image cleaning
   - second-moment Hillas parameterization
   - stereo reconstruction
   - background suppression
   - energy (LUT)

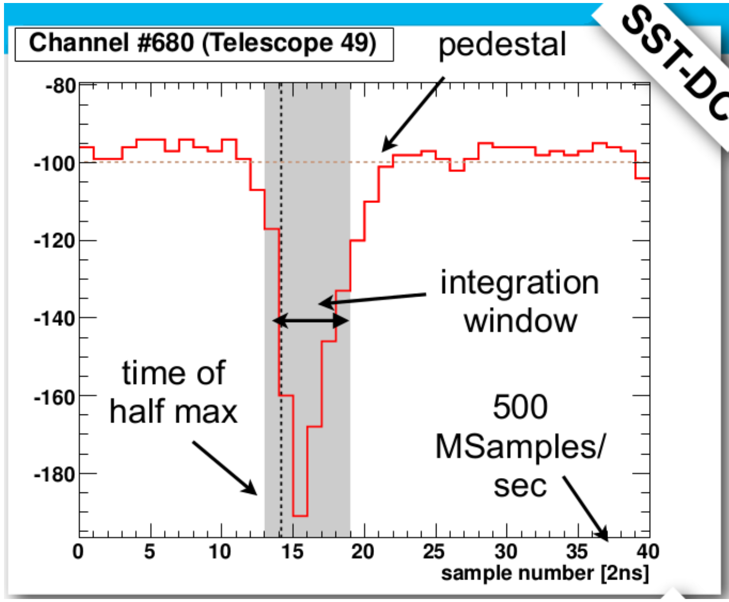
3. Differences
   - gamma/hadron separation
     - Random Forest
     - Boosted decision tree, multivariate analysis
     - mscw, mscl...
   - data format
     - ROOT
     - eventio



Event reconstruction scheme

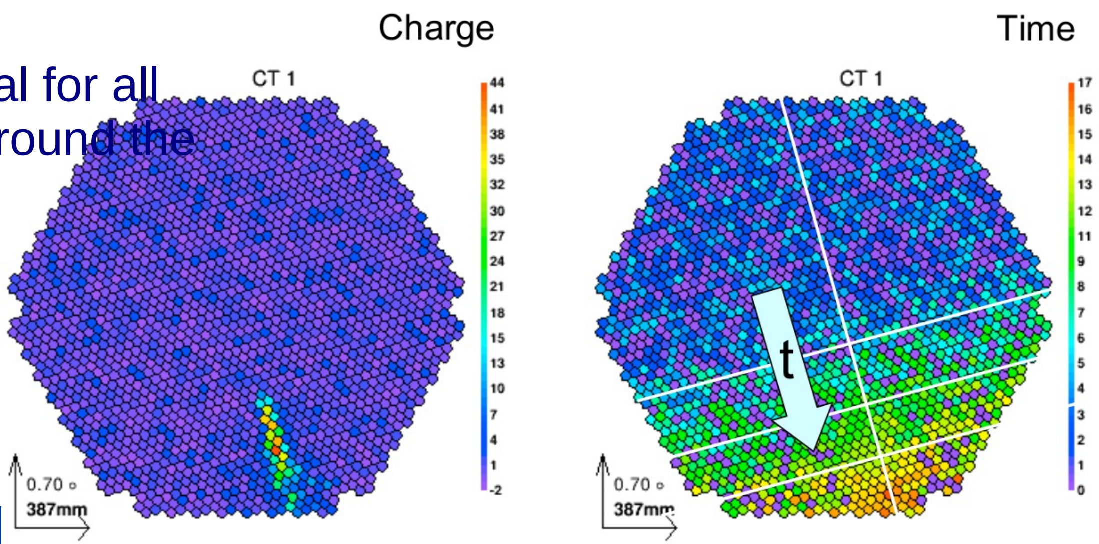
Pixel Charge reconstruction

Double-pass trace integration (to look for small pulses in a reduced time window)



First pass:
- "Local peak search" to find highest peak in each
 pixel. 4 slices for the peak search (3 for SC-SSTs),
 2 more for integration
- 2-level cleaning & image parametrization
- Time gradient along major axis obtained from
 (robust) linear fit

Second pass:
- If time fit is good: re-calculate signal for all non-core pixels, in a fixed window around the (pixel-dependent) time from the fit
- This reduces the noise in pixels, hence allows to lower the cleaning in the final analysis



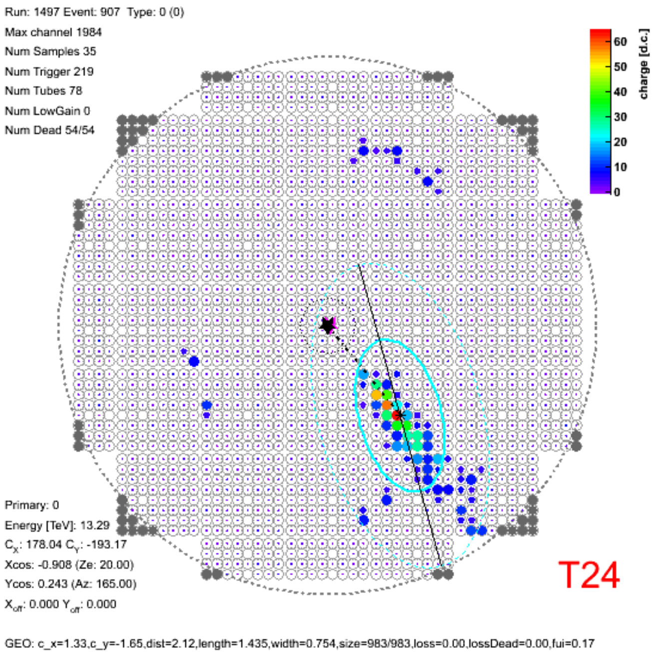
Event reconstruction scheme

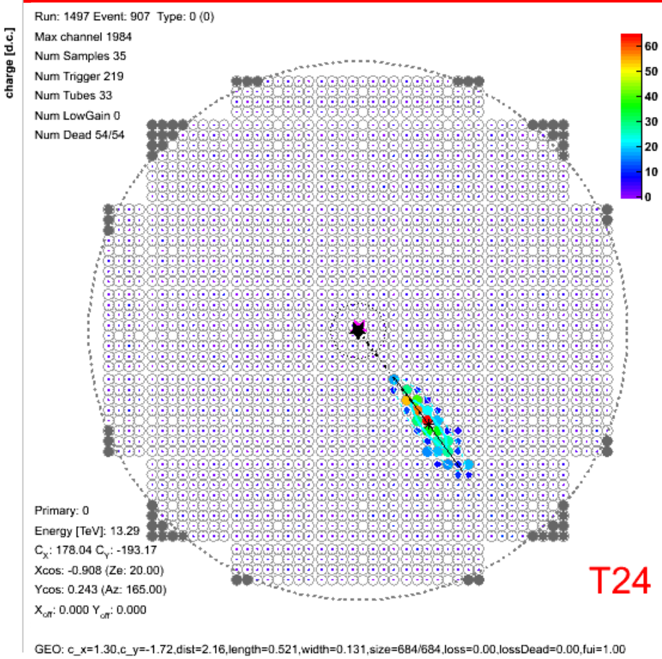
Image reconstruction

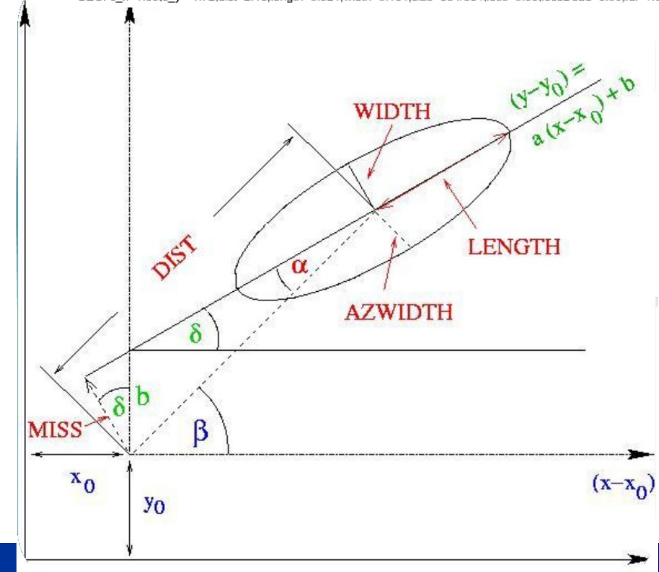
- **Image Cleaning**
  standard 2 levels cut,
  SC-SST mini-array = 2/4 p.e. (MARS), 3/6 (read_hess)

- **Hillas parameters**

- **Quality cuts**
  size (≥ 66 p.e.), n_pix (≥ 4), n_img (≥ 2), centroid pos., leakage, min. angle between tel.,...



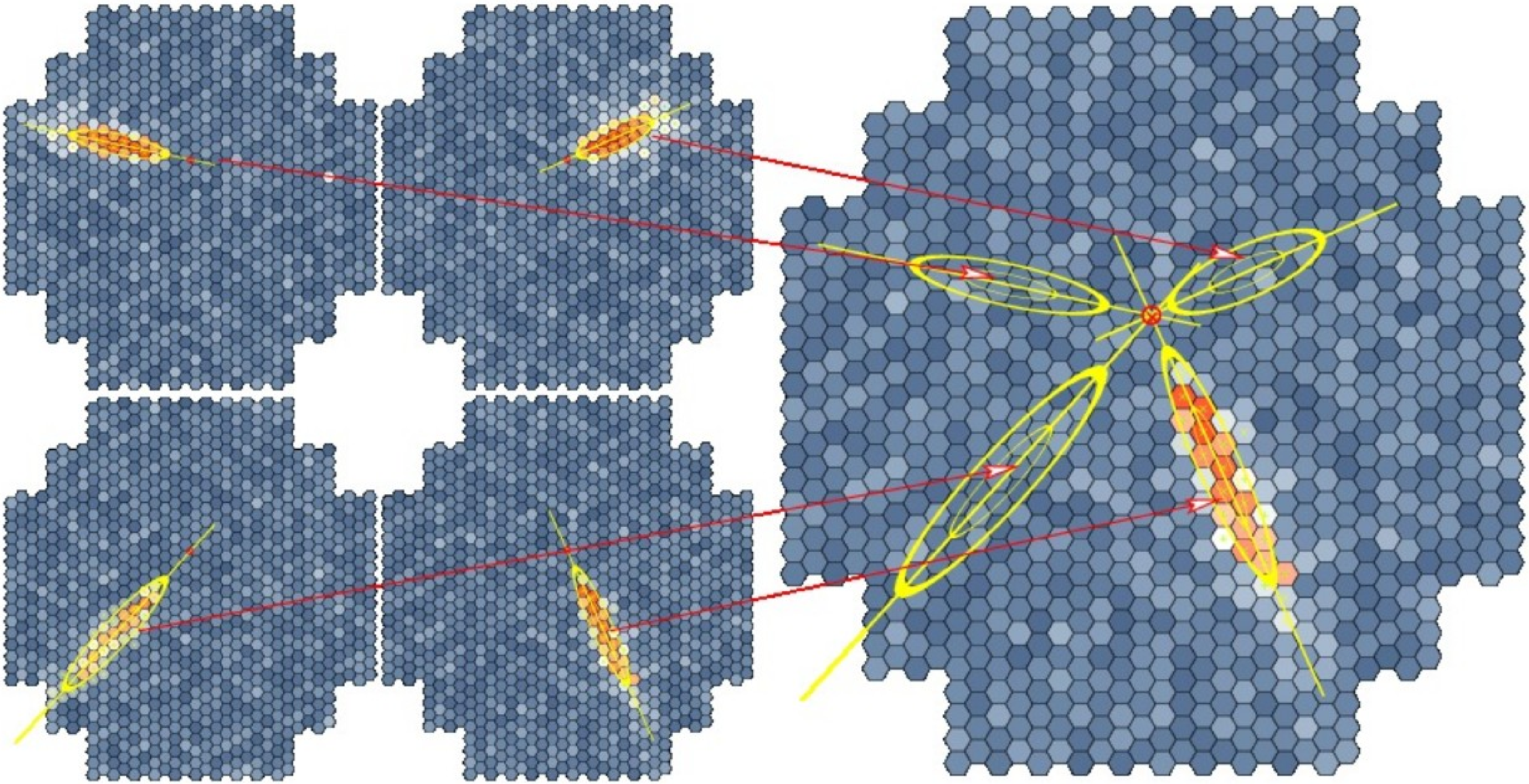




Event reconstruction scheme

Shower reconstruction: geometry

- Core position
- Arrival direction



Event reconstruction scheme

Shower reconstruction: geometry

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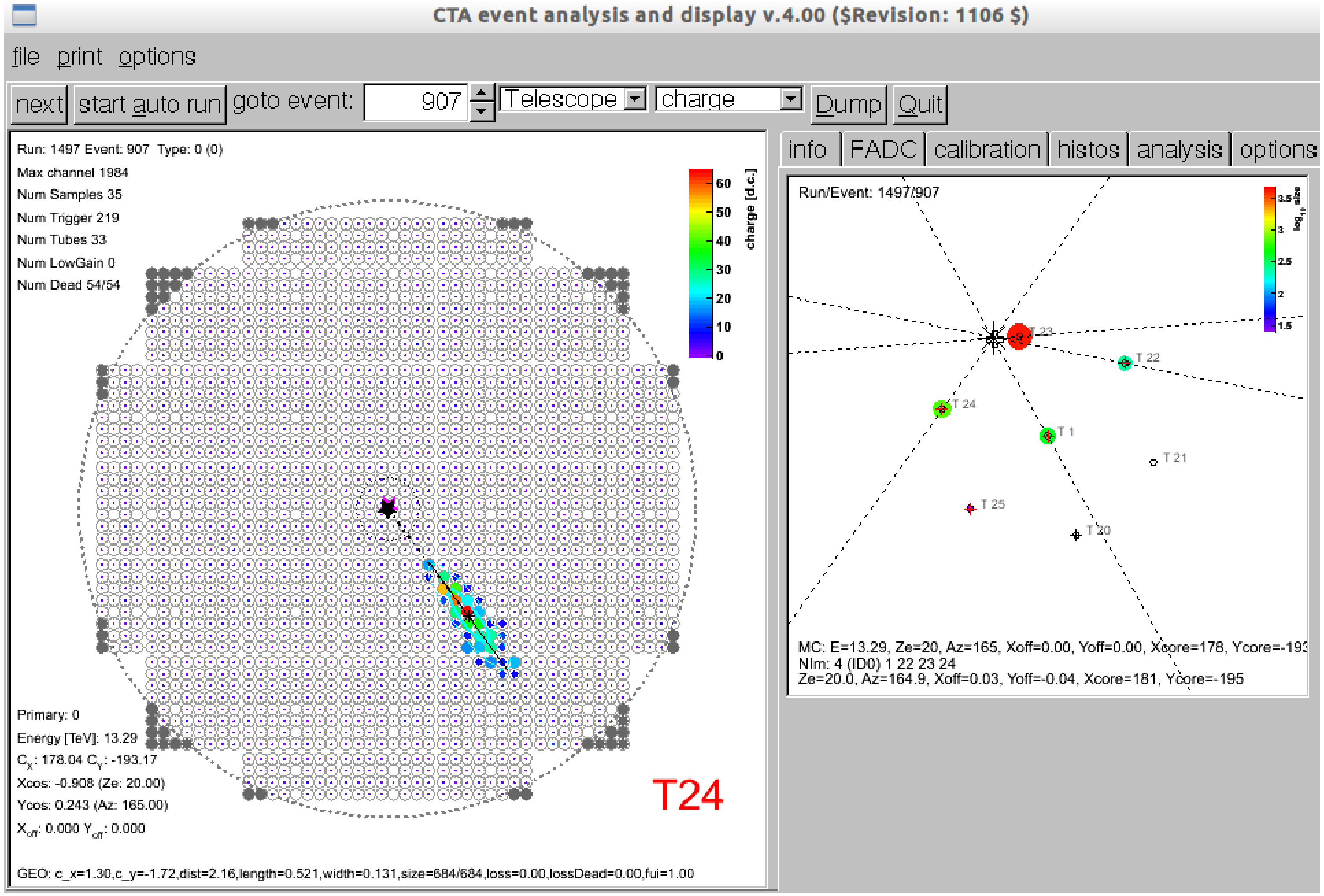
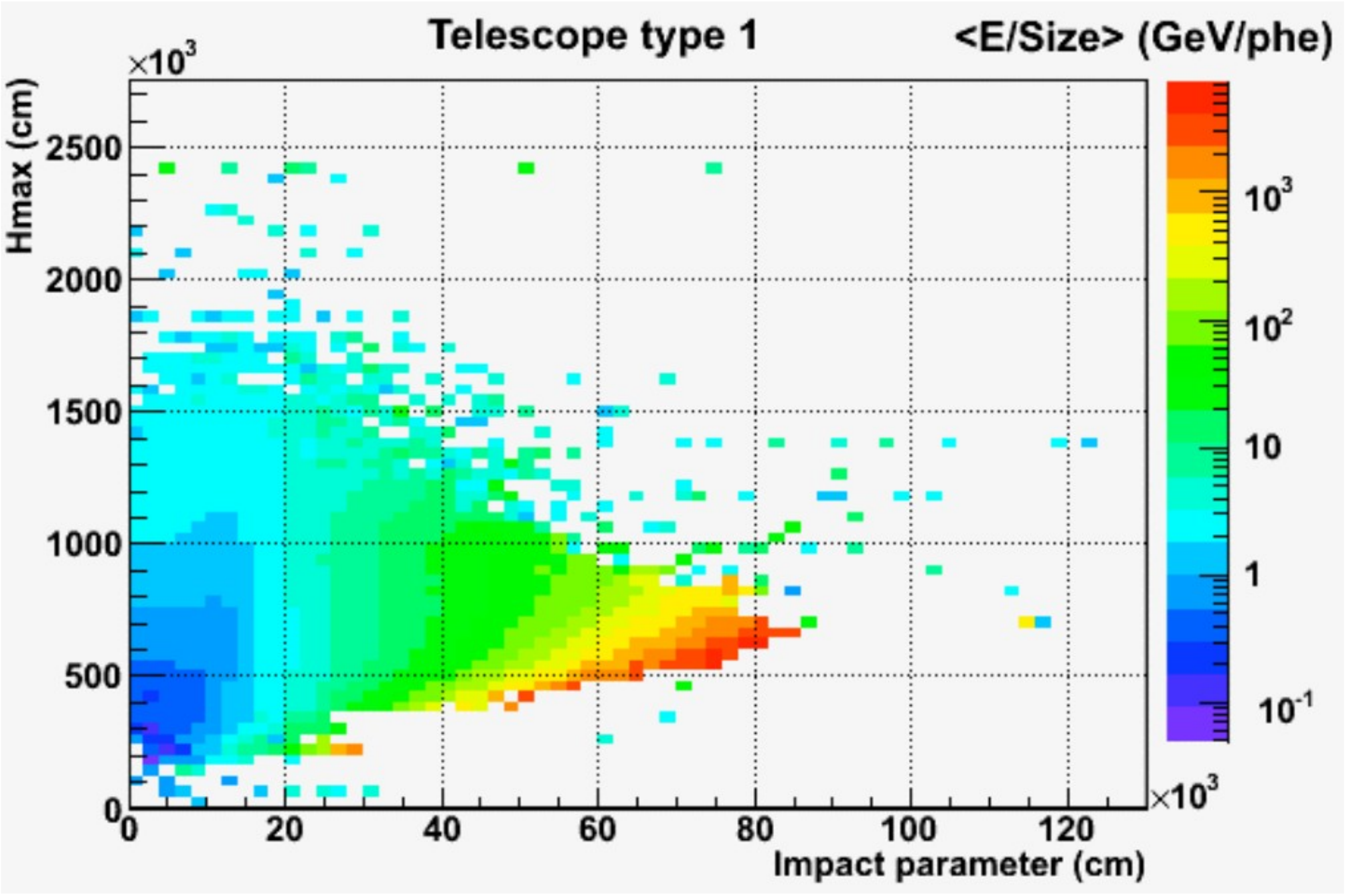


Event reconstruction scheme

Event reconstruction: energy

- Lookup tables of E/Size (mean and RMS) vs. impact parameter and height of shower maximum

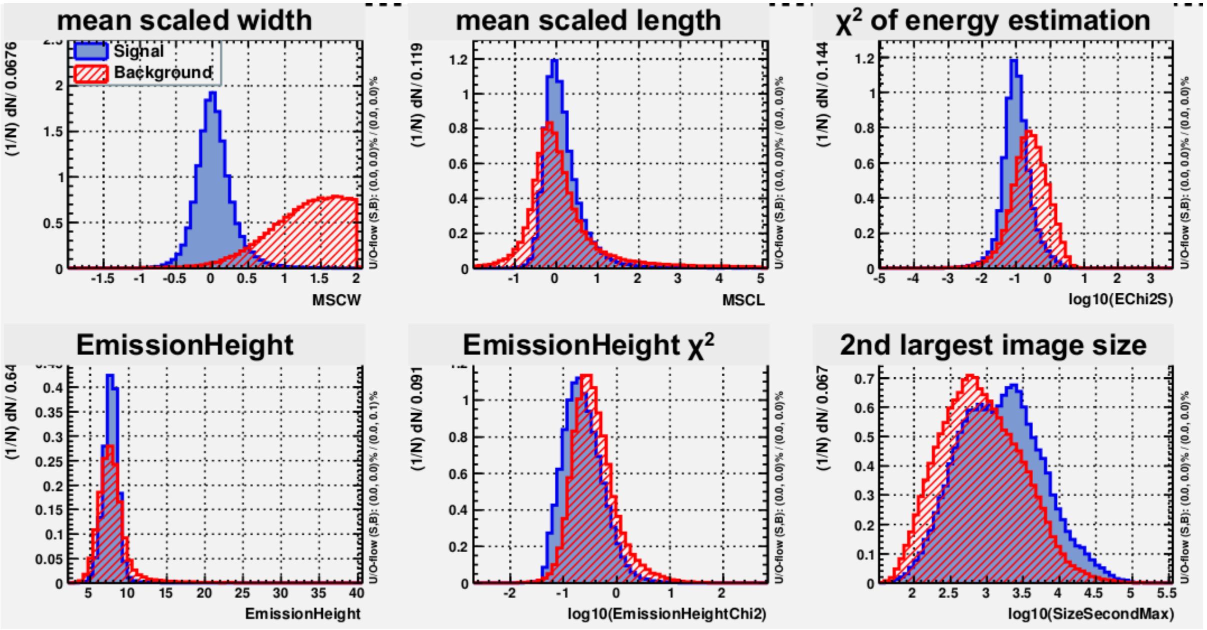
E_{est} = weighted average of N telescopes



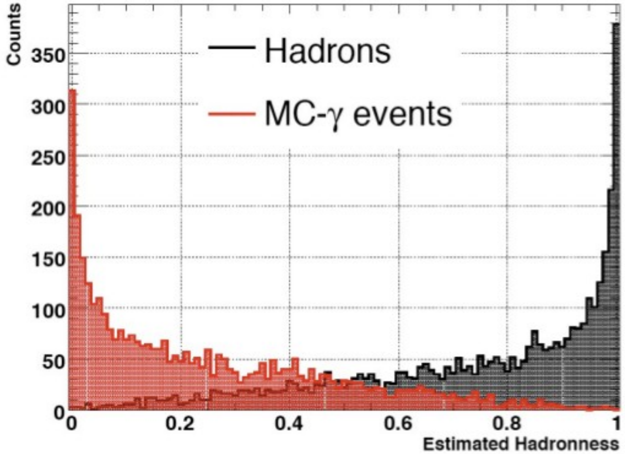
Event reconstruction scheme

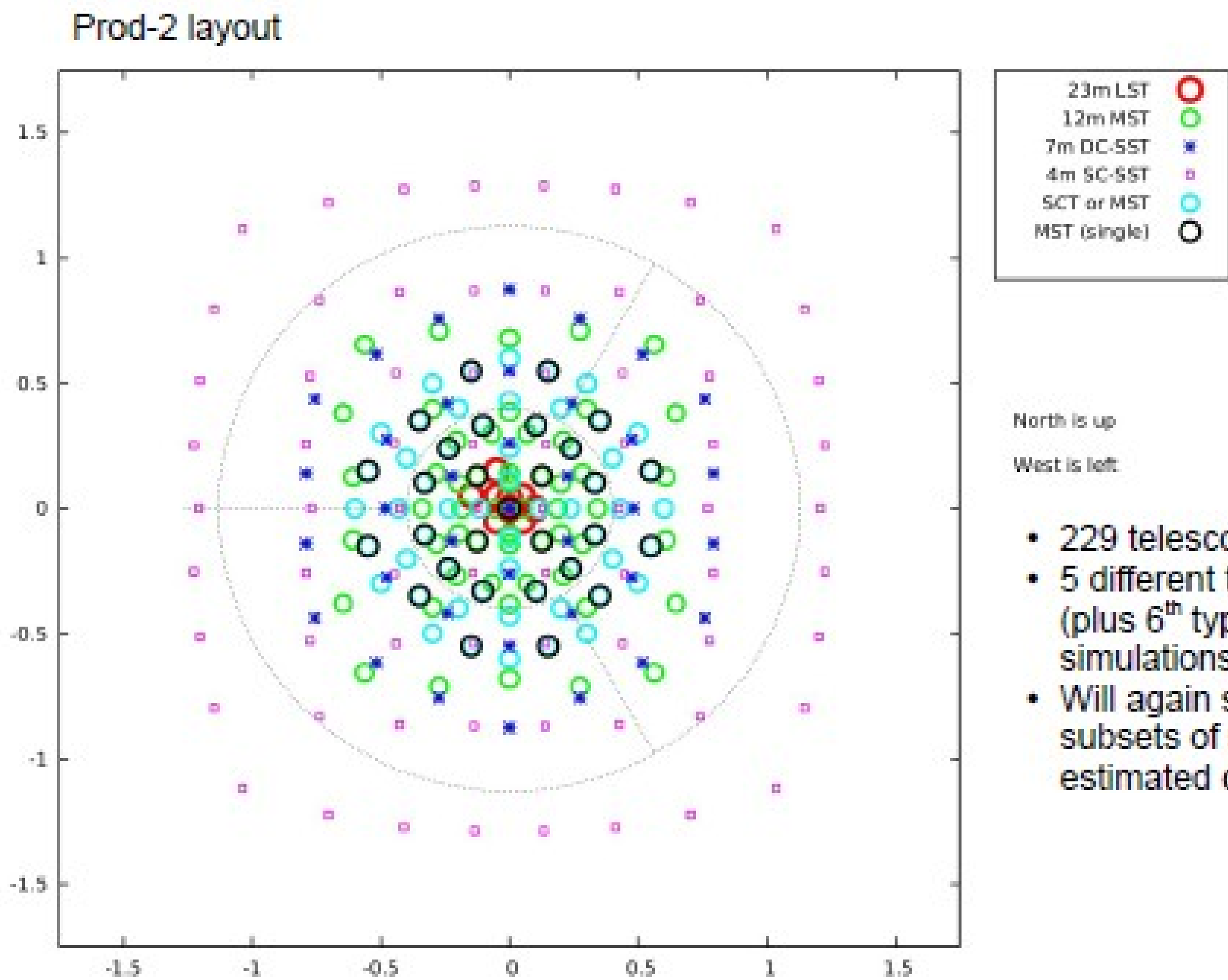
Event reconstruction: γ-like sel.

- Shape and other parameters, lookup tables (read_hess and EventDisplay)



- *Hadronness* (MARS)
  - Random Forest





- 229 telescopes.
- 5 different types (plus 6th type in some simulations).
- Will again select subsets of some estimated cost.

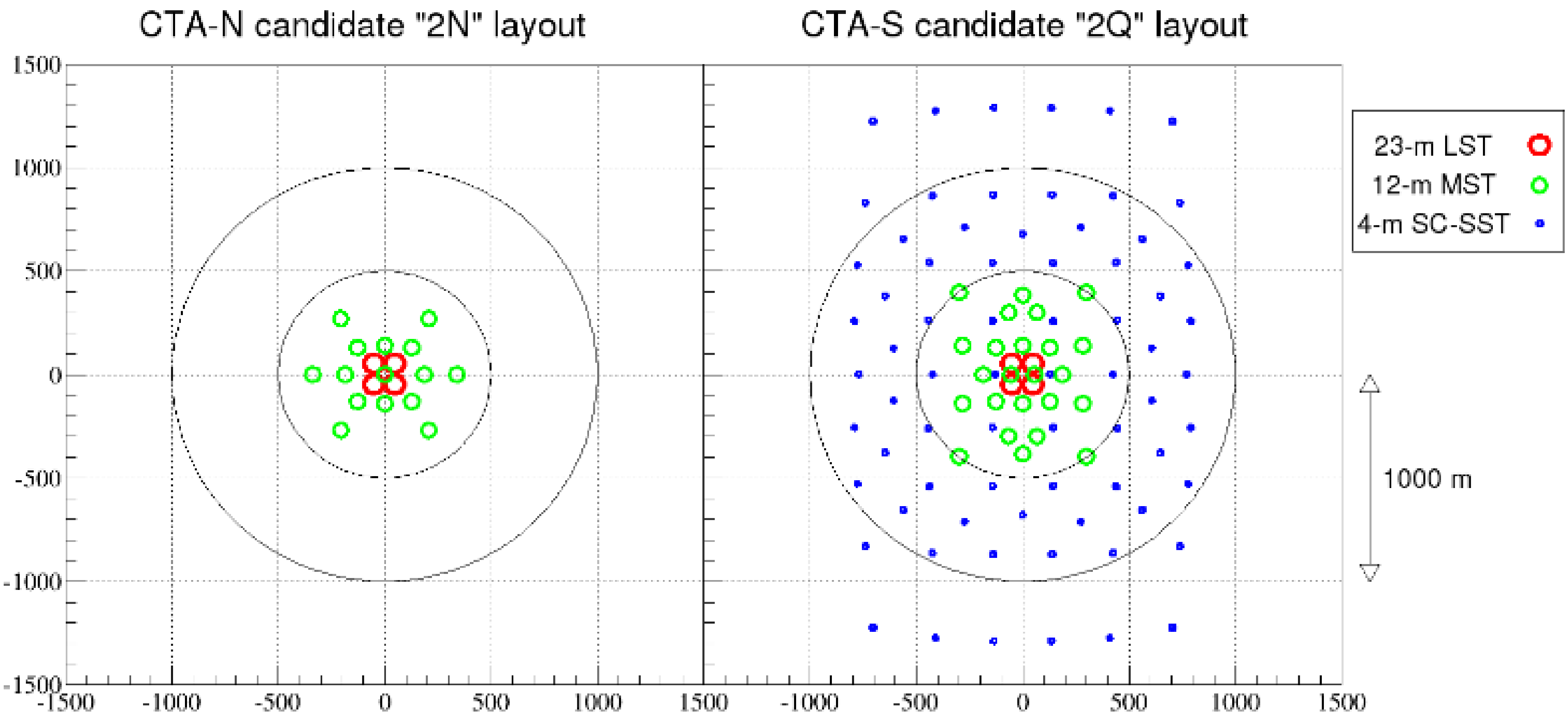
- Several equal cost full layouts and reduced layouts studied
- Several sites (geomagnetic field, altitude, atmospheric profile)
- zenith: 20°, 45°, azimuth: North/South
- different NSB levels

CTA MC Prod2

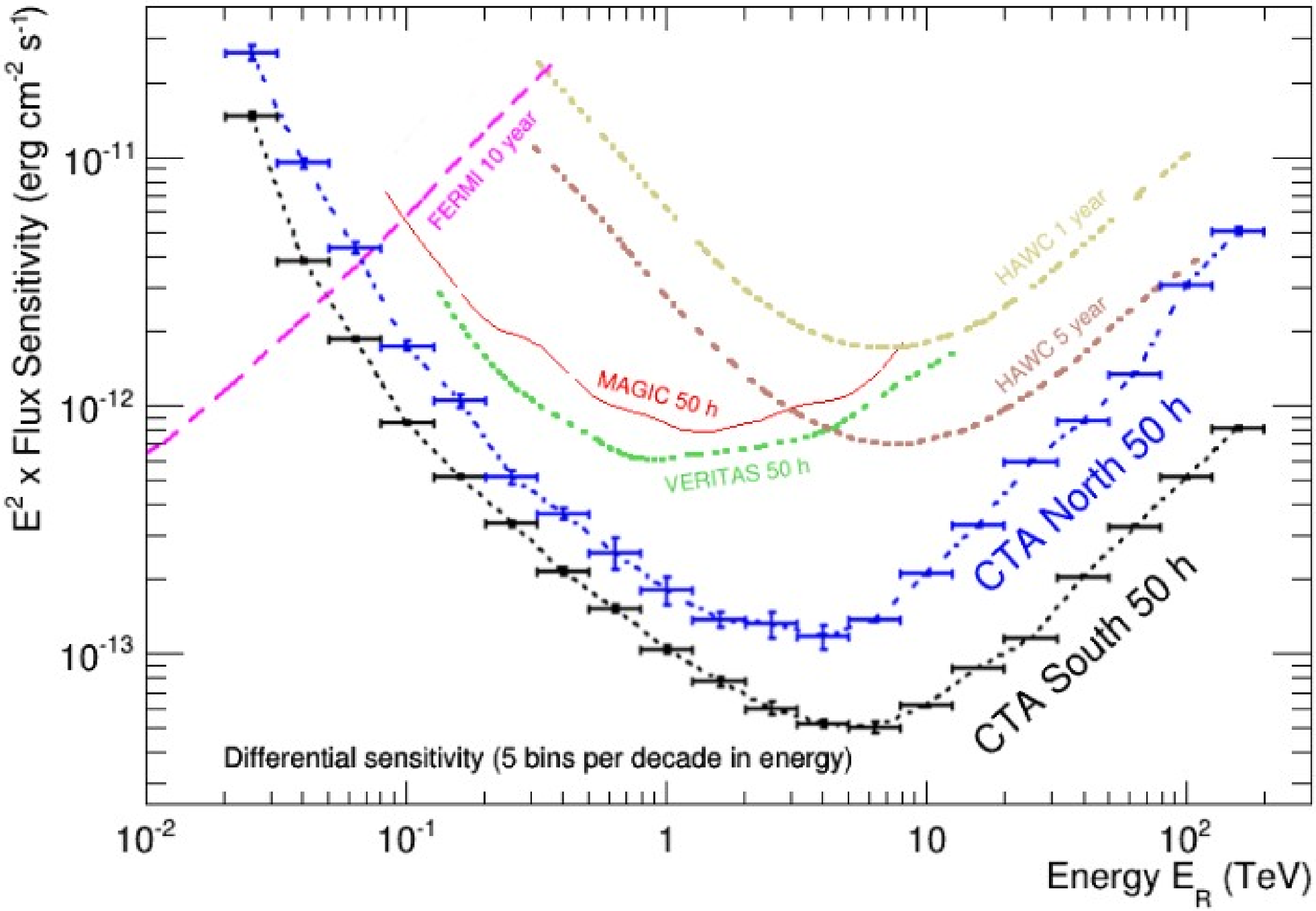
Core resampling 10 (g) , 20 (bkg), Radius 2500m (g) , 3000m (bkg) Viewcone 0° (point-like), 10° (diffuse), Spectral index -2.0 (rescaled in analysis step)

Primary	Energy [TeV]	Events [10^9]	Triggered [10^6]
Gamma (point)	0.003-330	5	36
Protons	0.004-600	100	68
Electrons	0.003-330	5.2	5
Helium	0.01-1200	7.6	6.6
Nitrogen	0.04-4000	0.52	1.2
Silicon	0.05-5000	0.52	1
Iron	0.06-6000	1.8	3.2
Gamma (diff.)	0.003-330	20	22

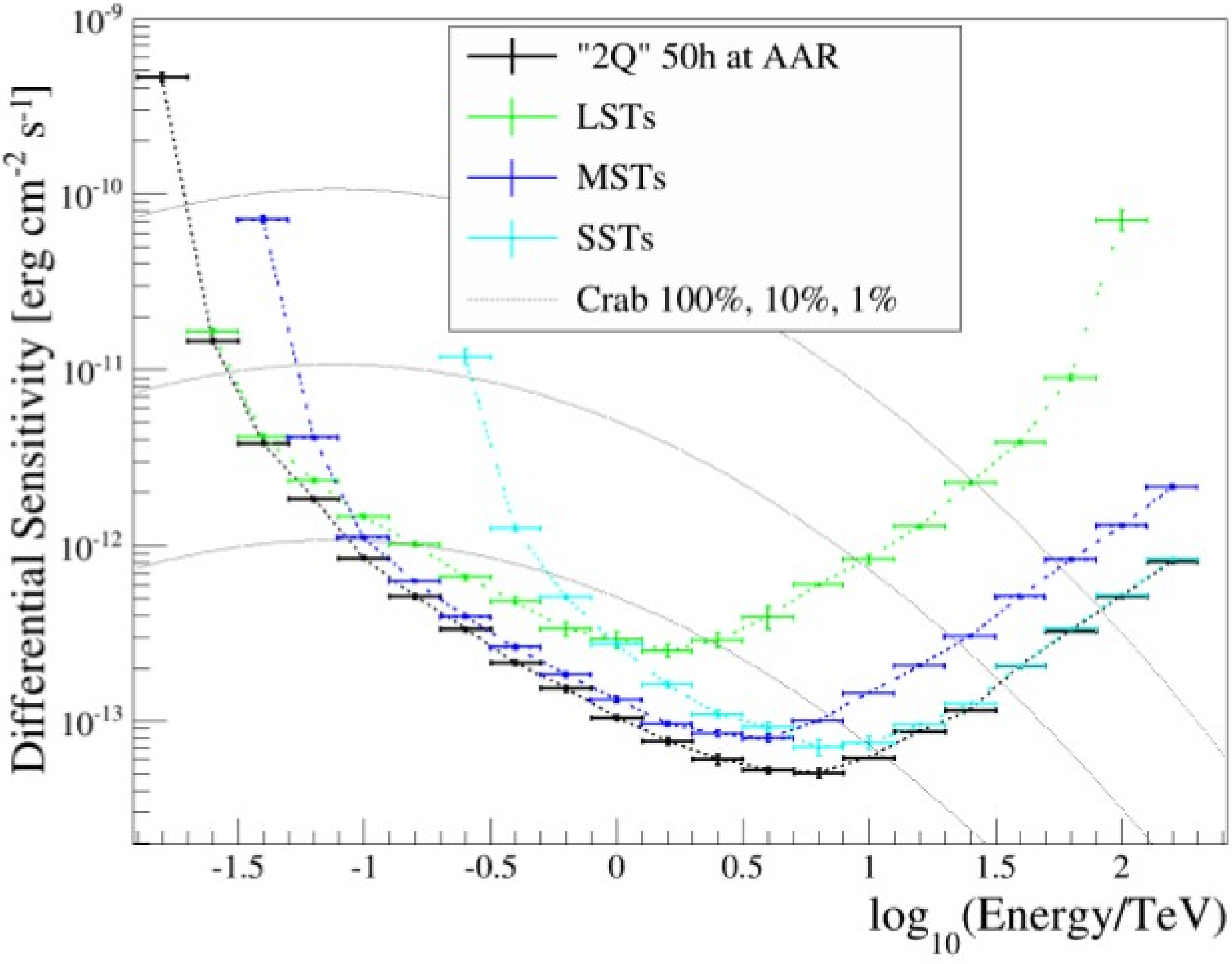
- run on GRID vo.cta.in2pr.fr and MPIK
- 10-20 10^6 HS06 CPU hours, 20 TB


CTA-N candidate "2N" layout
CTA-S candidate "2Q" layout
1500
1000
500
0
-500
-1000
-1500
-1500
-1000
-500
0
500
1000
1500
-1000
-500
0
500
1000
1500
23-m LST
12-m MST
4-m SC-SST
1000 m

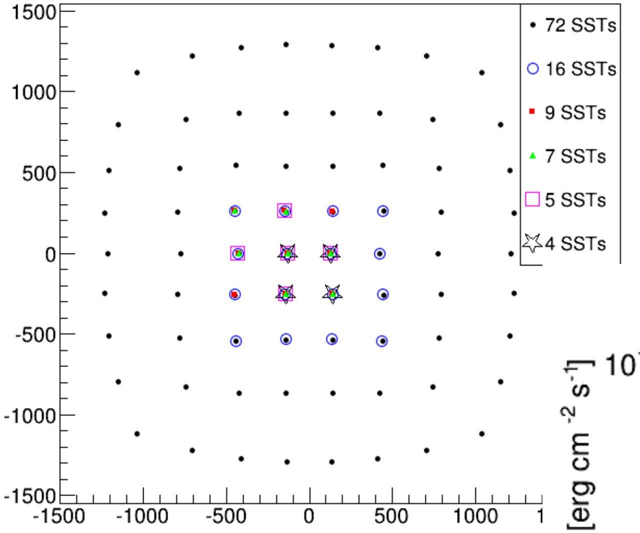
CTA MC Prod2: sensitivity

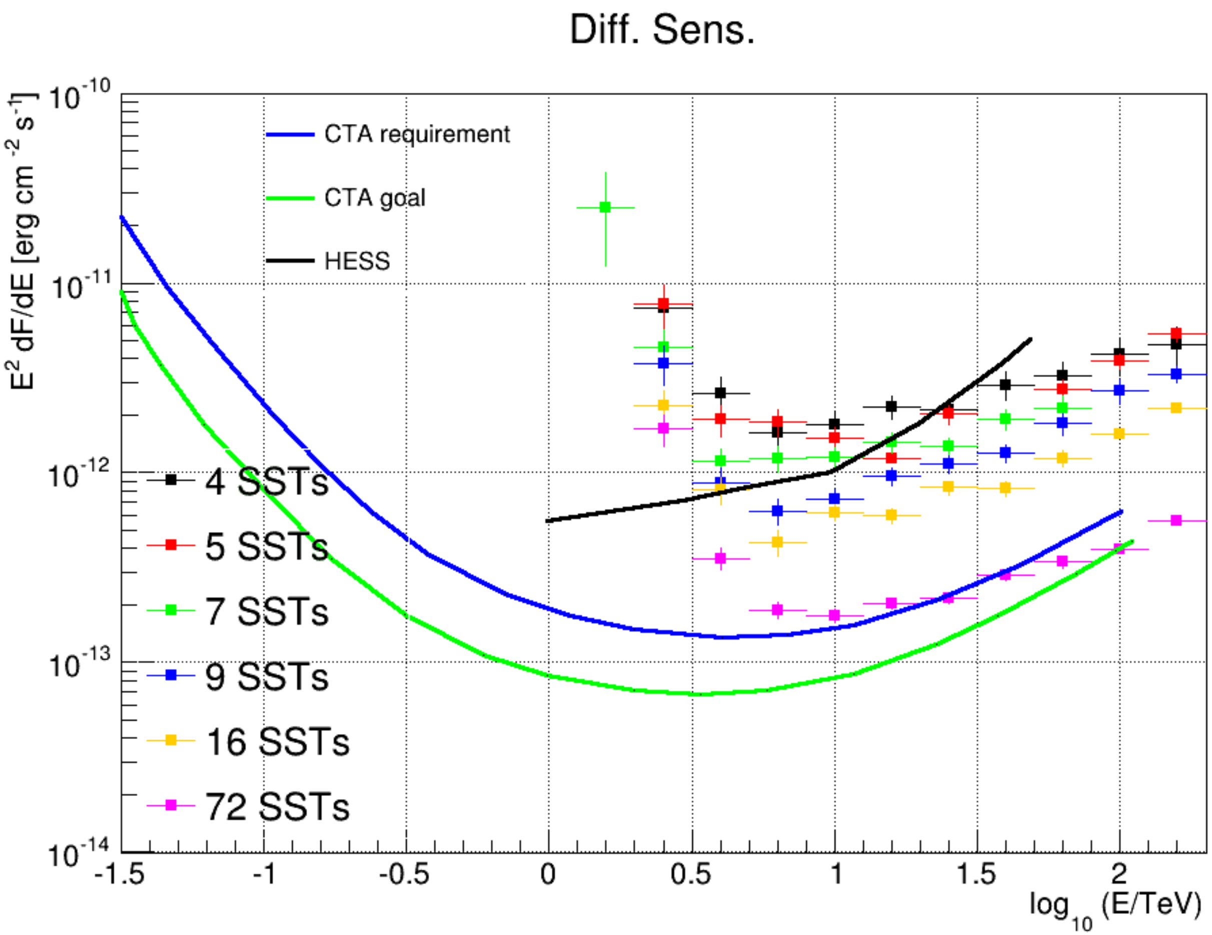


CTA MC Prod2: sensitivity, subarrays

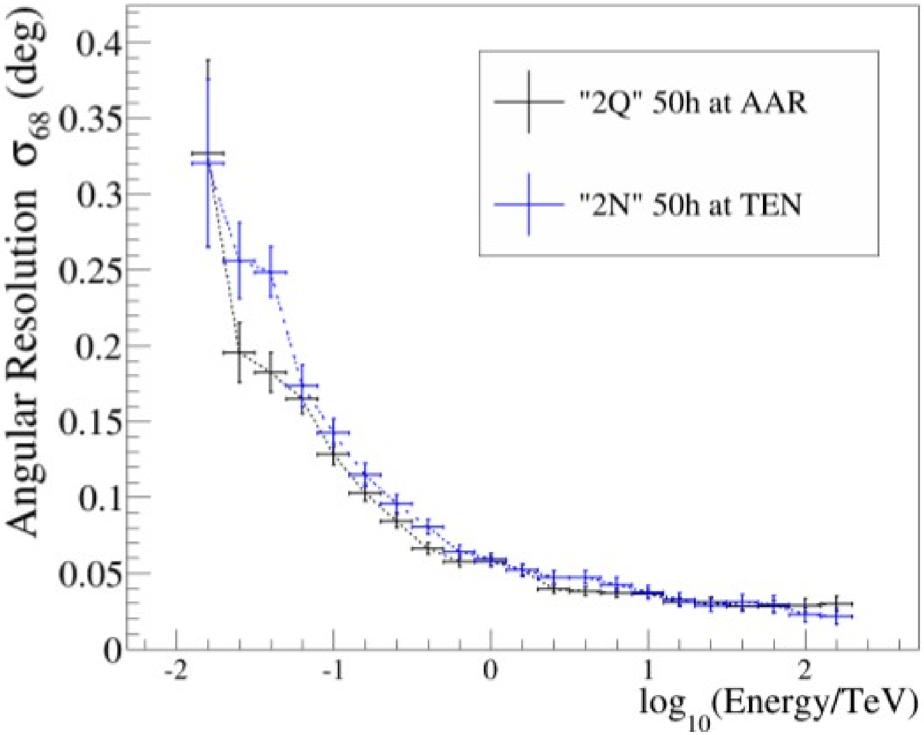


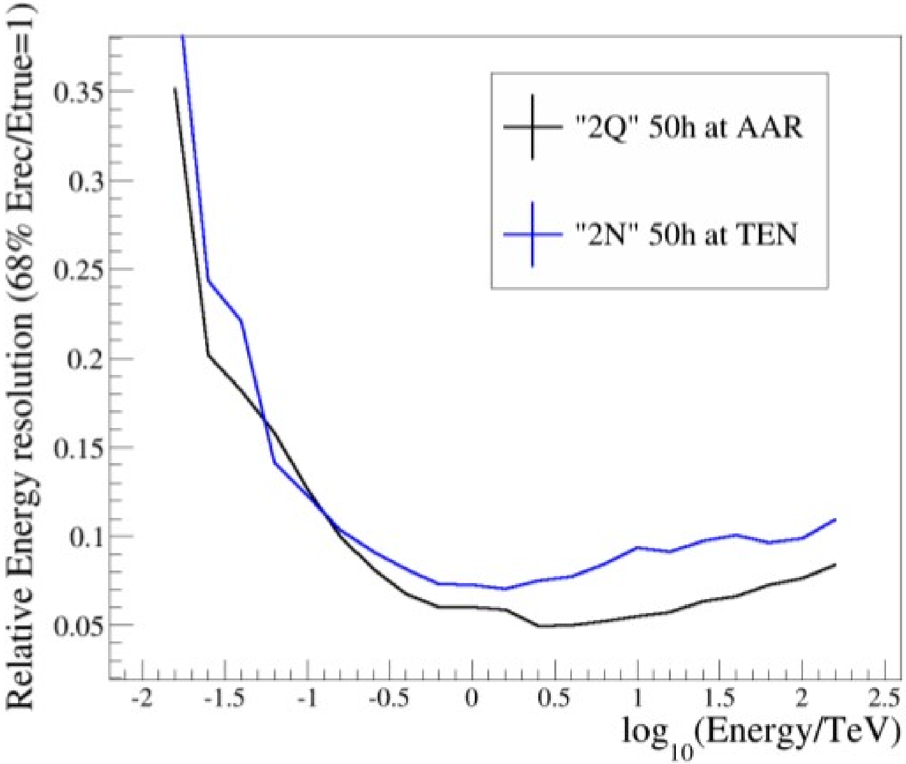
CTA MC Prod2: sensitivity, precursors



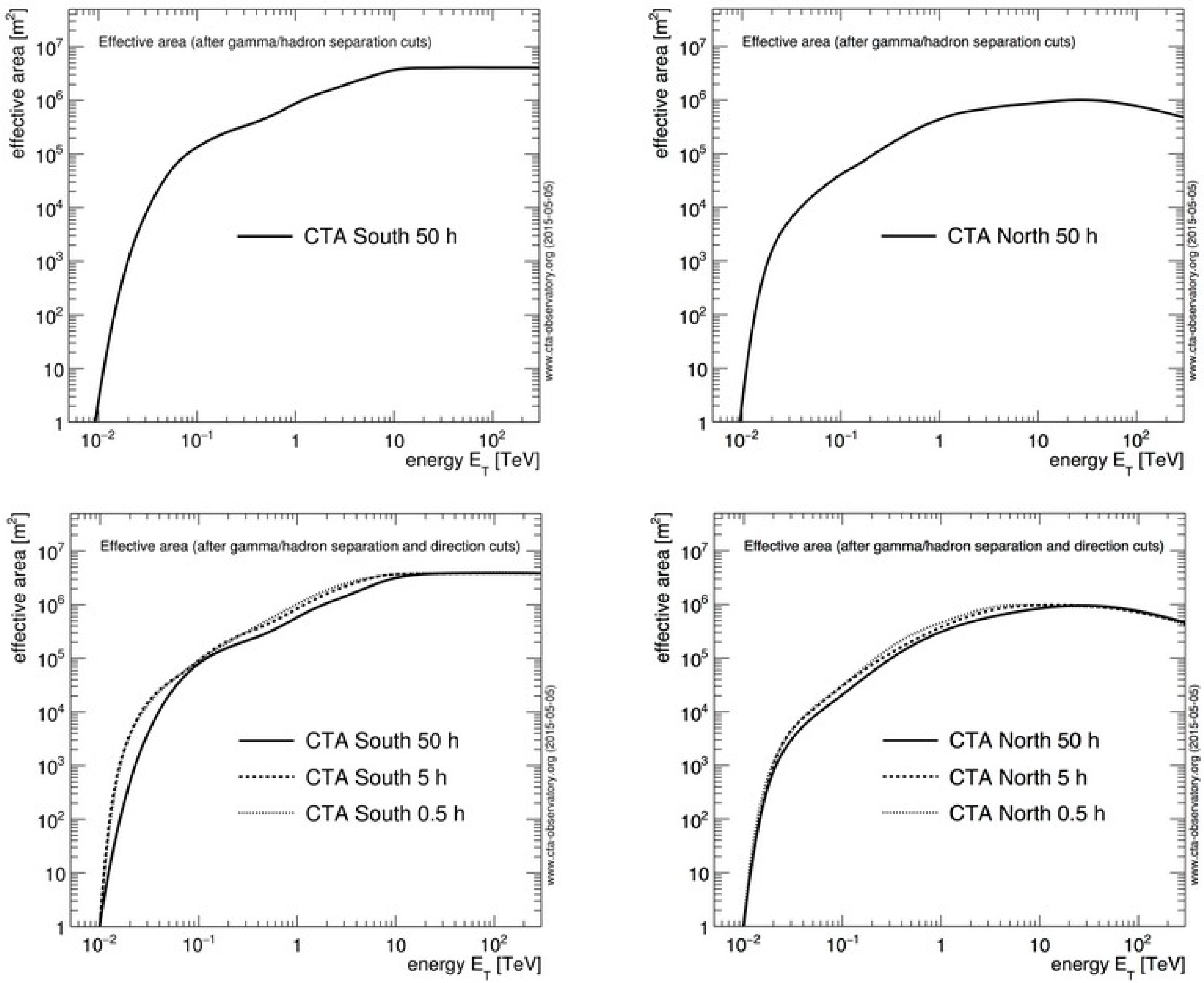


CTA MC Prod2: resolutions

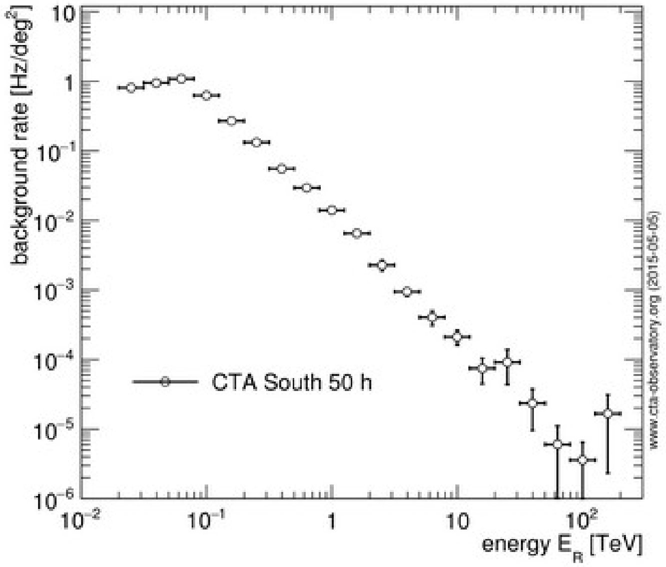


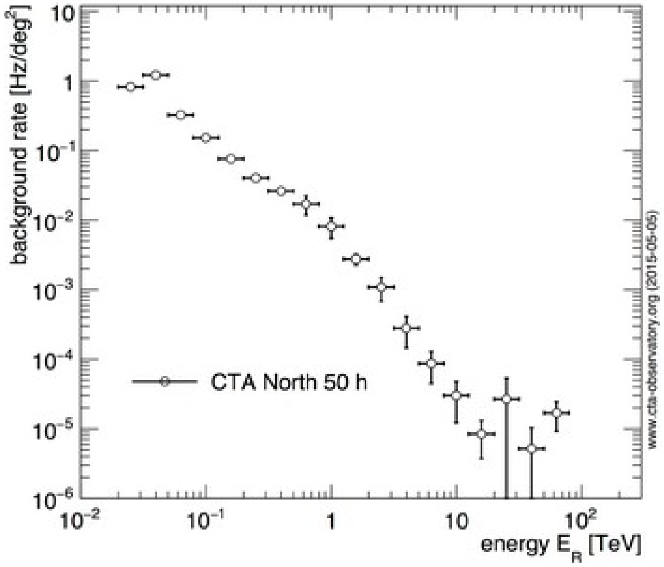


CTA MC Prod2: effective area

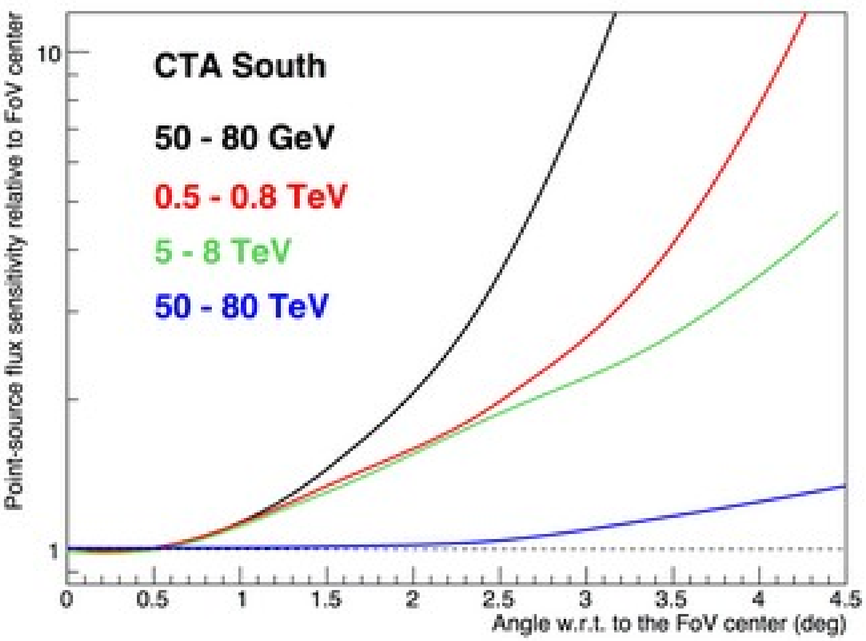


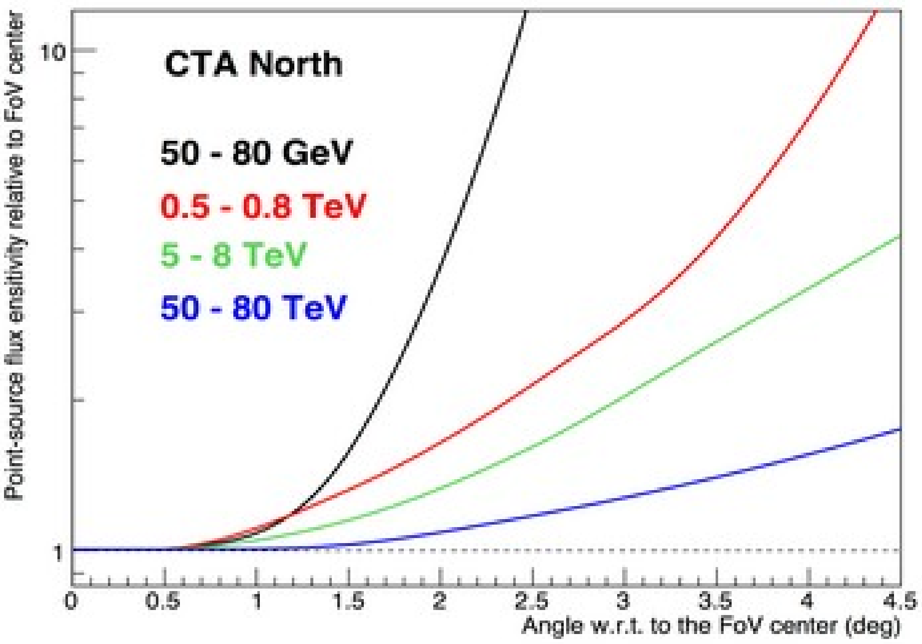
CTA MC Prod2: background rate





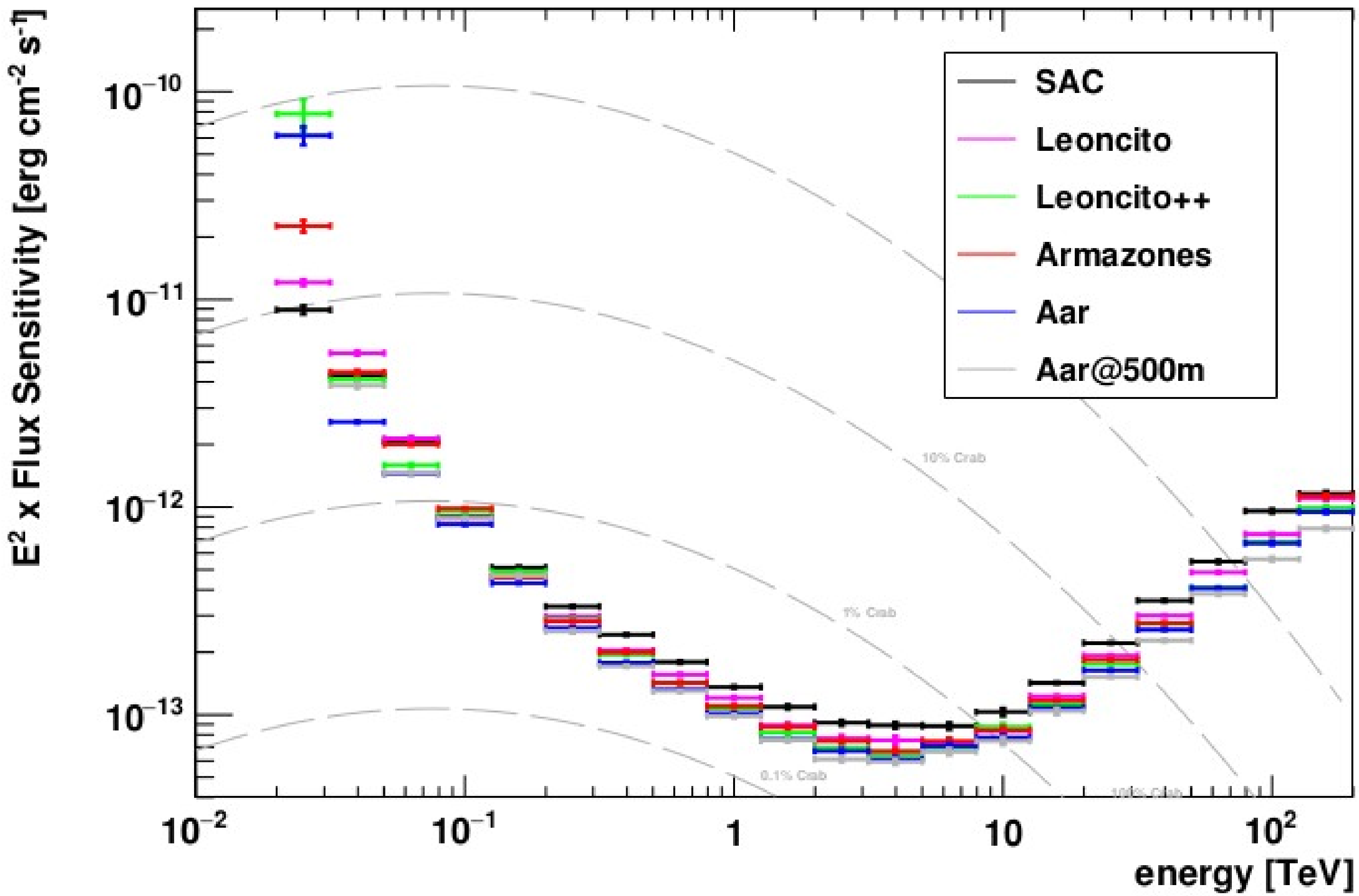
CTA MC Prod2: offaxis



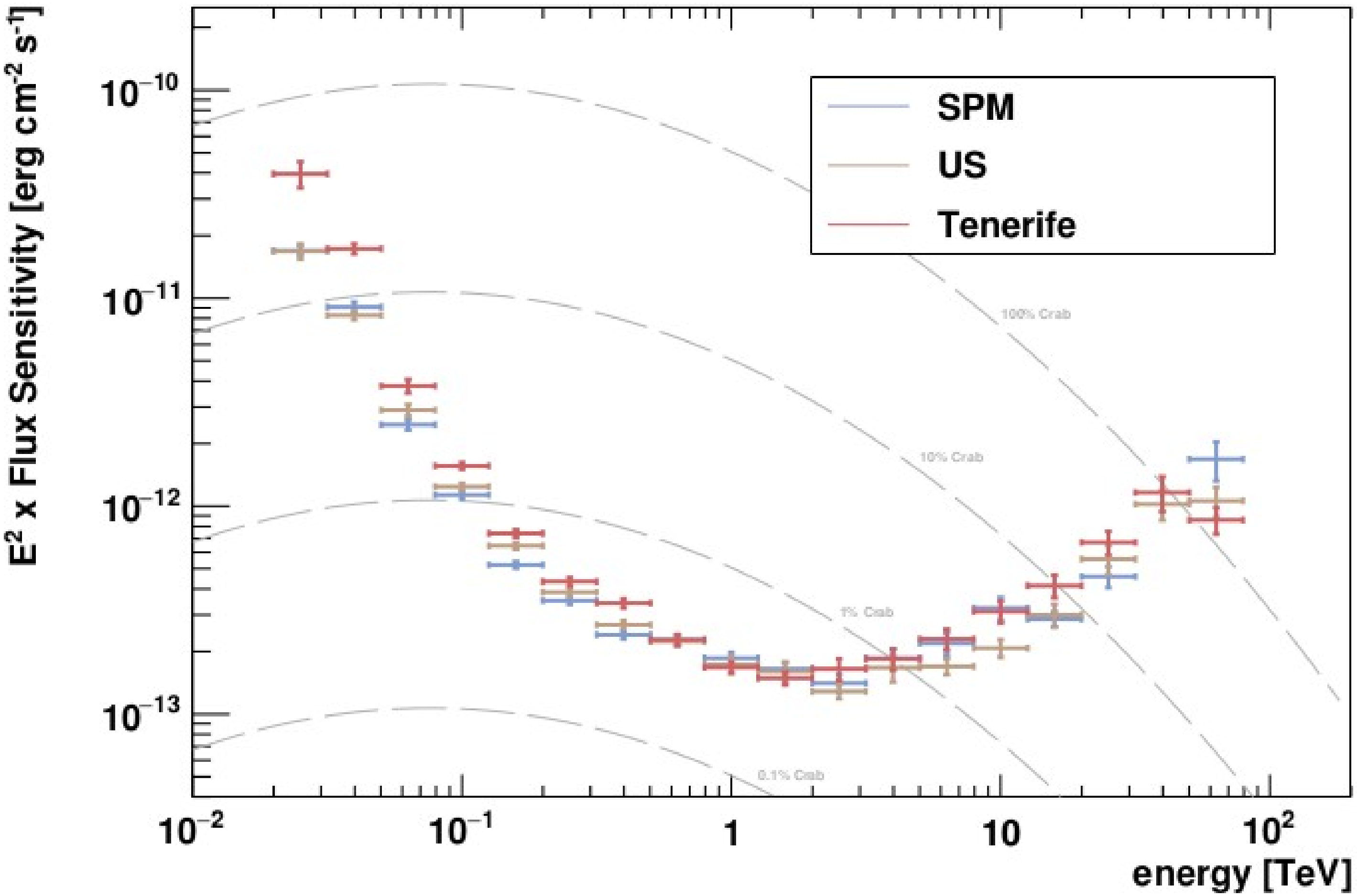


- Effective areas, angular and energy resolutions, background rates, off-axis performances are the input for high level simulations (see CTOOLS's presentation by Franz)

CTA MC Prod2: southern sites

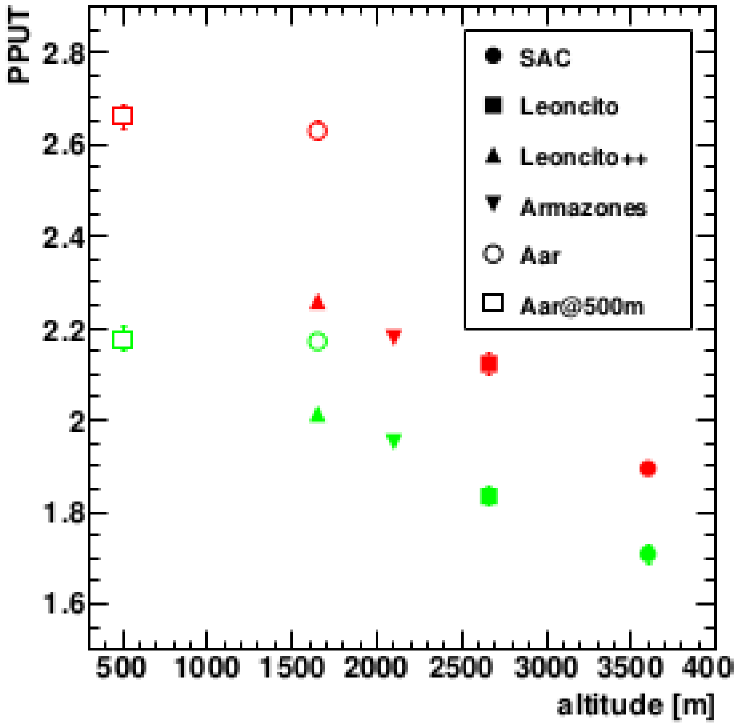


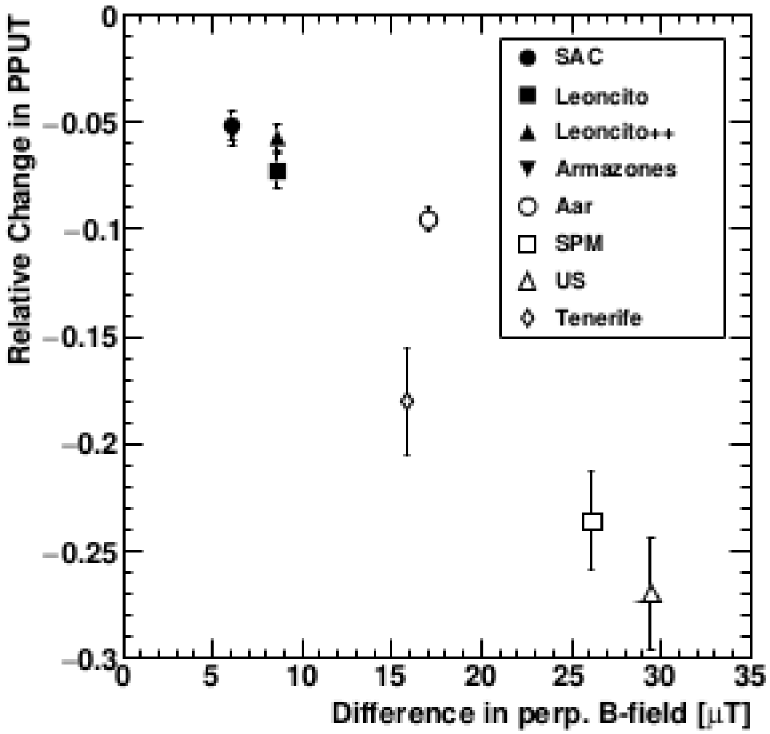
CTA MC Prod2: northern sites



- performance per unit time (PPUT)

$$\mathrm{PPUT} = \left(\prod_{Nbins} \frac{F_{sens,nom}}{F_{sens}} \right)^{1/N}$$



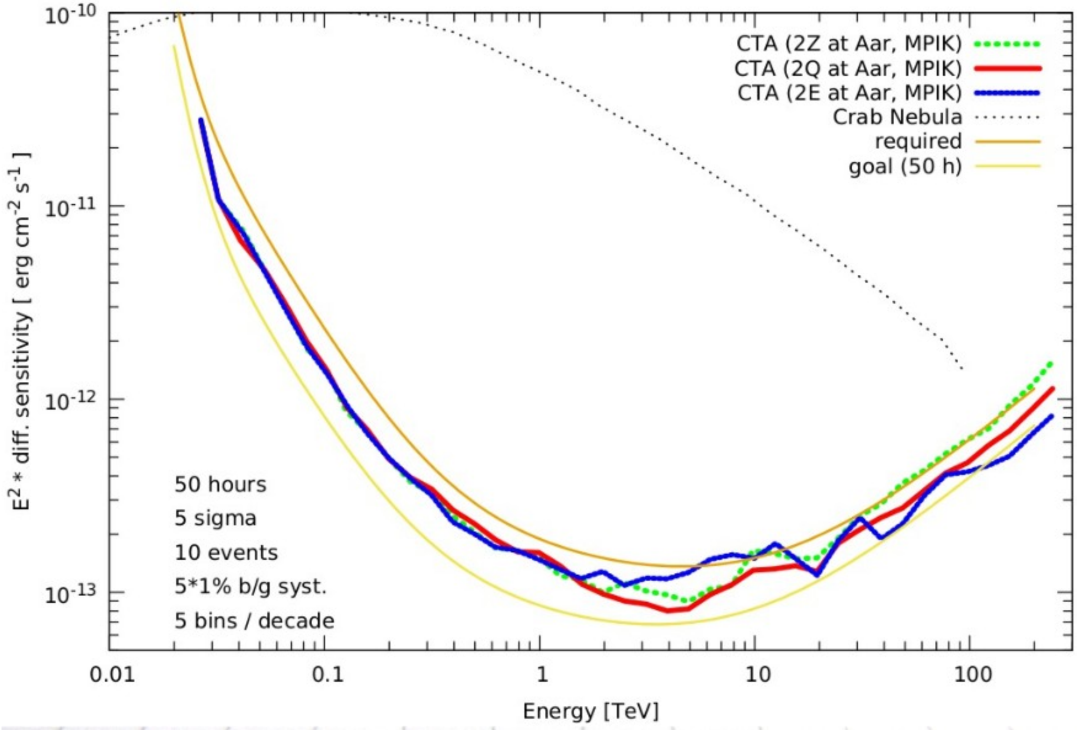


- red: pointing south, green: pointing north

The approaching Prod3

- Aims:
  - to update the simulation of the telescopes (examples, next slides)
  - to define the final (optimal!) CTA layout
    - depending on the site and on the number of telescopes...

- Several types of telescopes will be simulated:
  - LST
  - MST
  - SCT
  - SST-1M
  - SST-2M GCT-M
  - SST-2M GCT-S
  - SST-2M ASTRI



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  - LST
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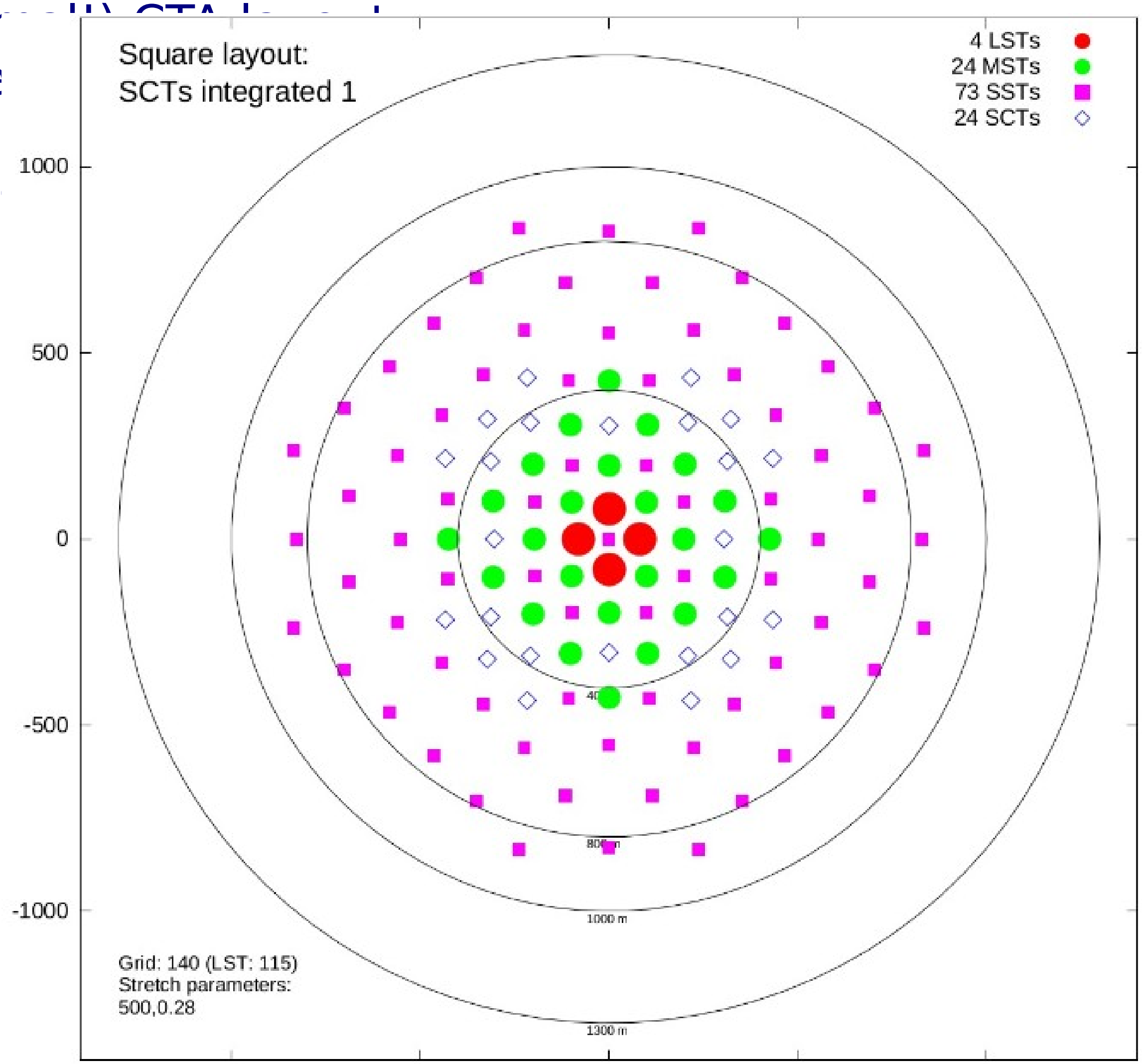
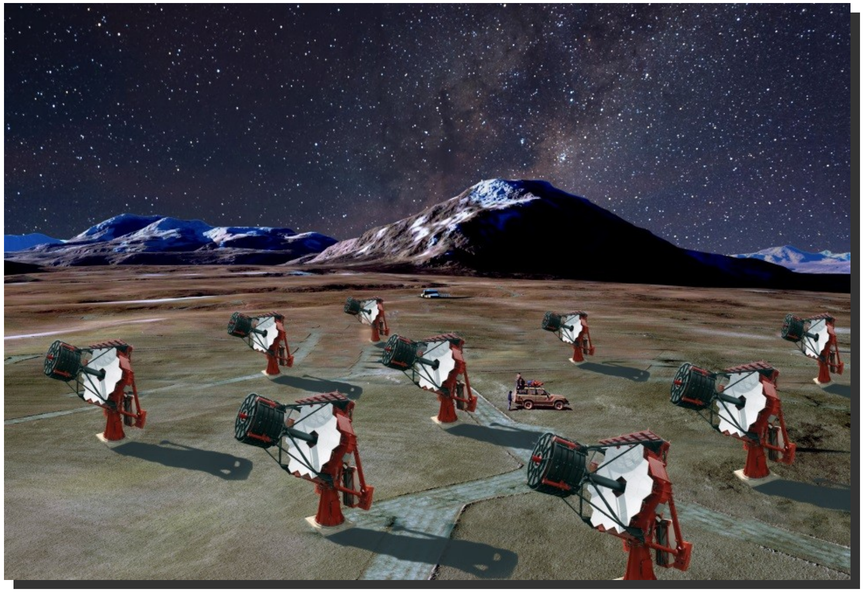
  - SCT
  - SST-1M
  - SST-2M GCT-M
  - SST-2M GCT-S
  - SST-2M ASTRI



Example of telescope configuration

ASTRI SST-2M

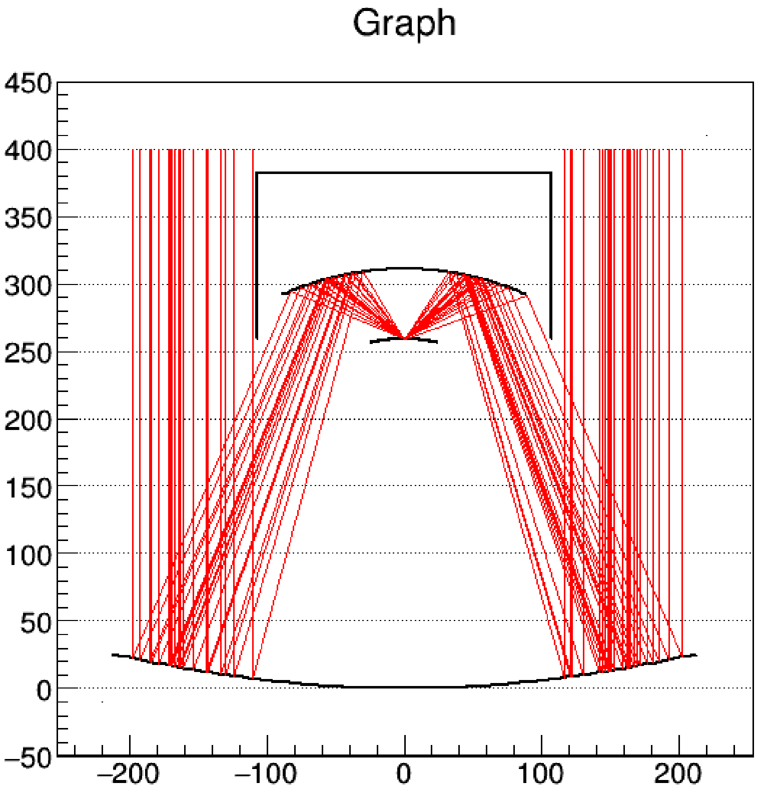


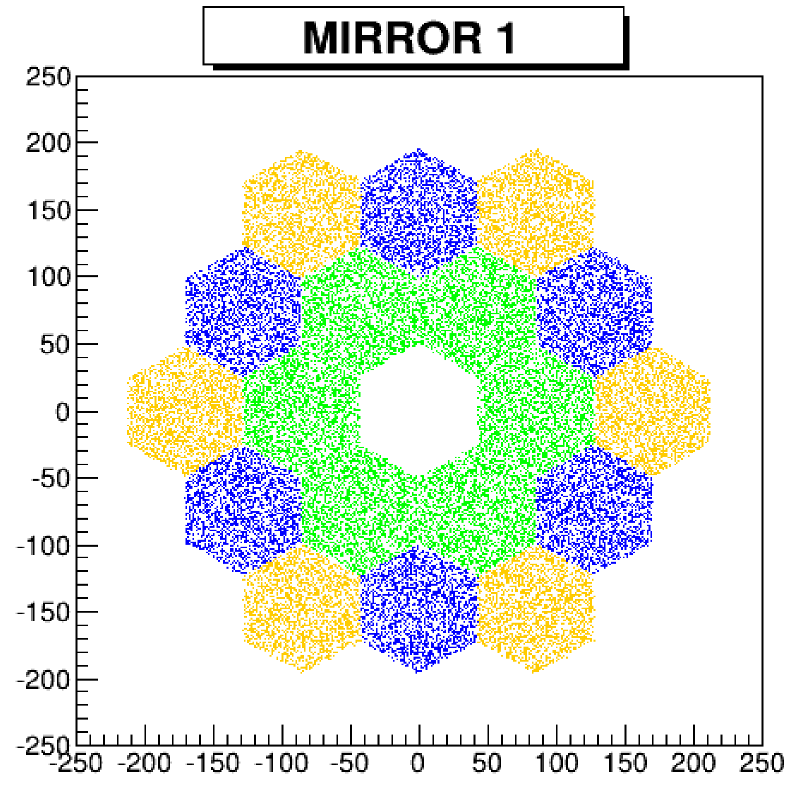
- ASTRI SST-2M implementation in Prod3
  - optics
  - camera
  - photosensors
  - FEE
  - BEE

Optical design

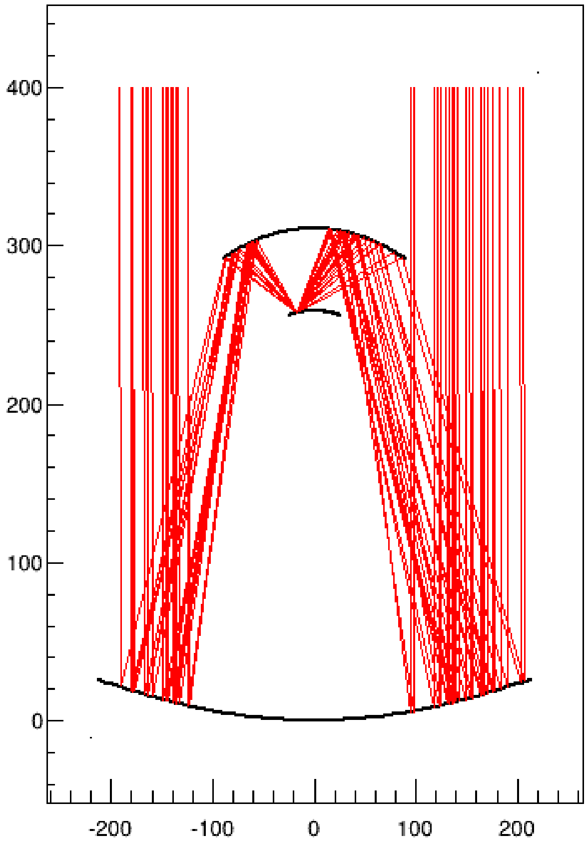
- M1 maximum diameter: 430 cm
- 18 hexagonal tiles (84.9 cm face to face)
- M2 diameter: 180 cm
- Equivalent focal length: 215.0 cm
- plate scale 37.5 mm/°

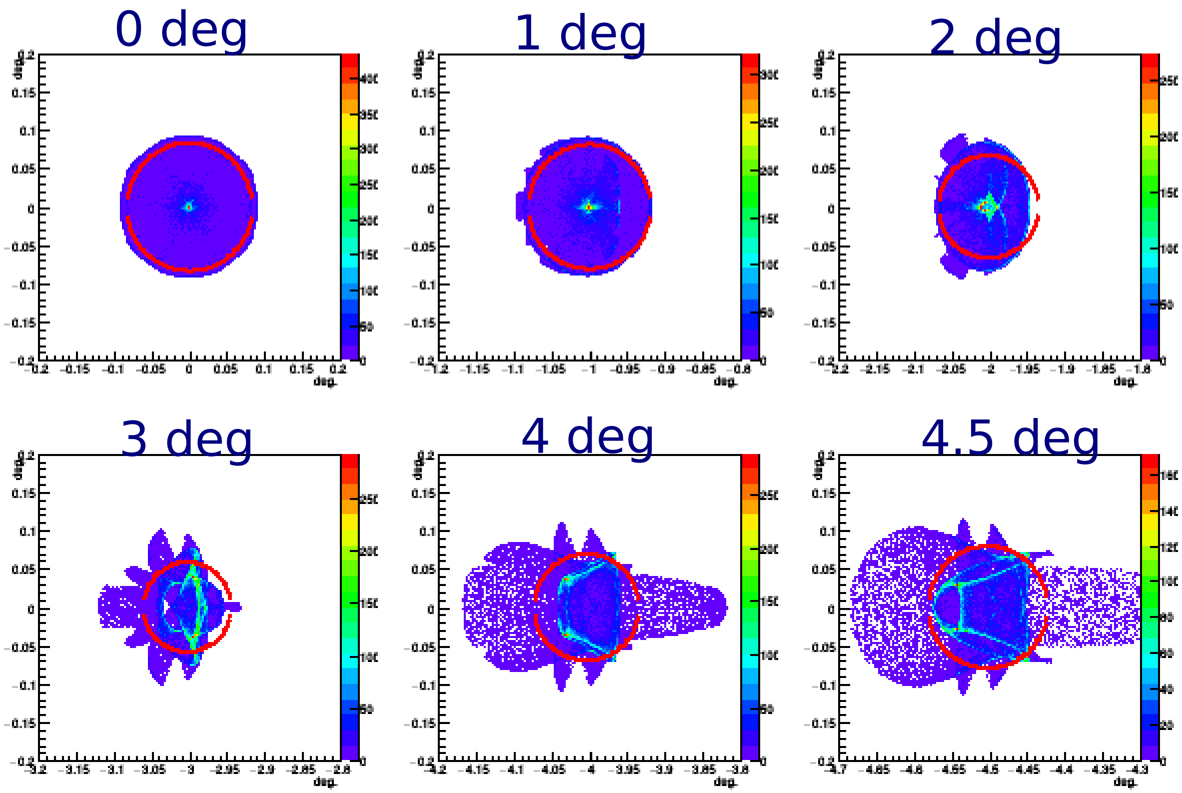
M1 segmentation,
M2 structure and baffle:
new features of
sim_telarray.



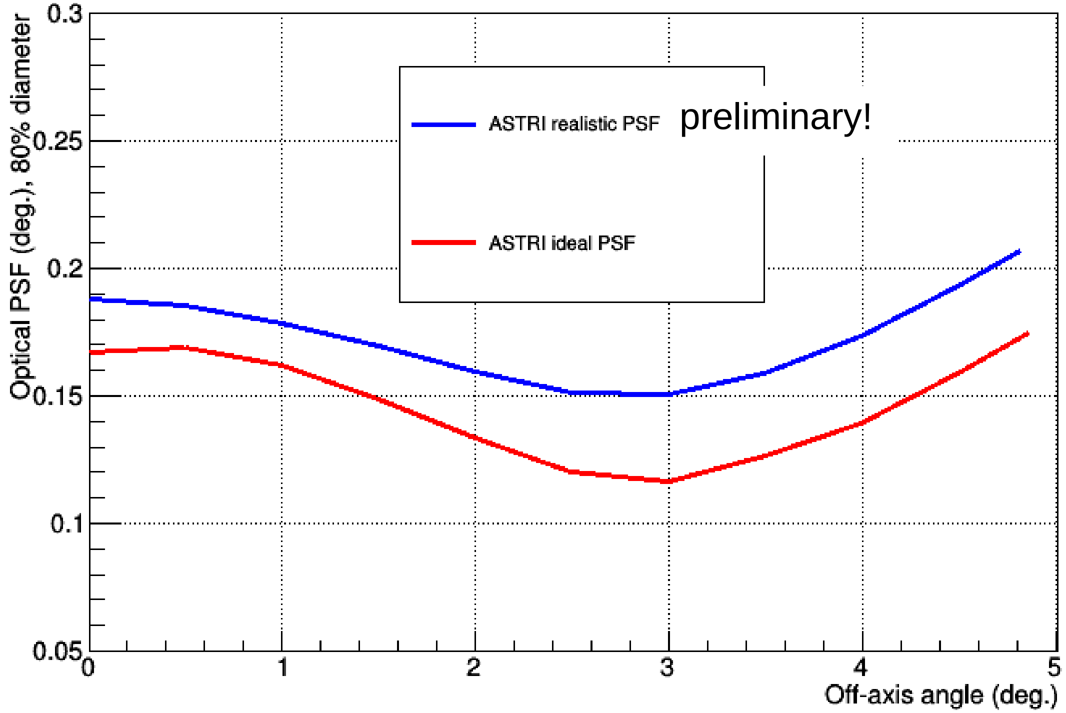


Optical PSF



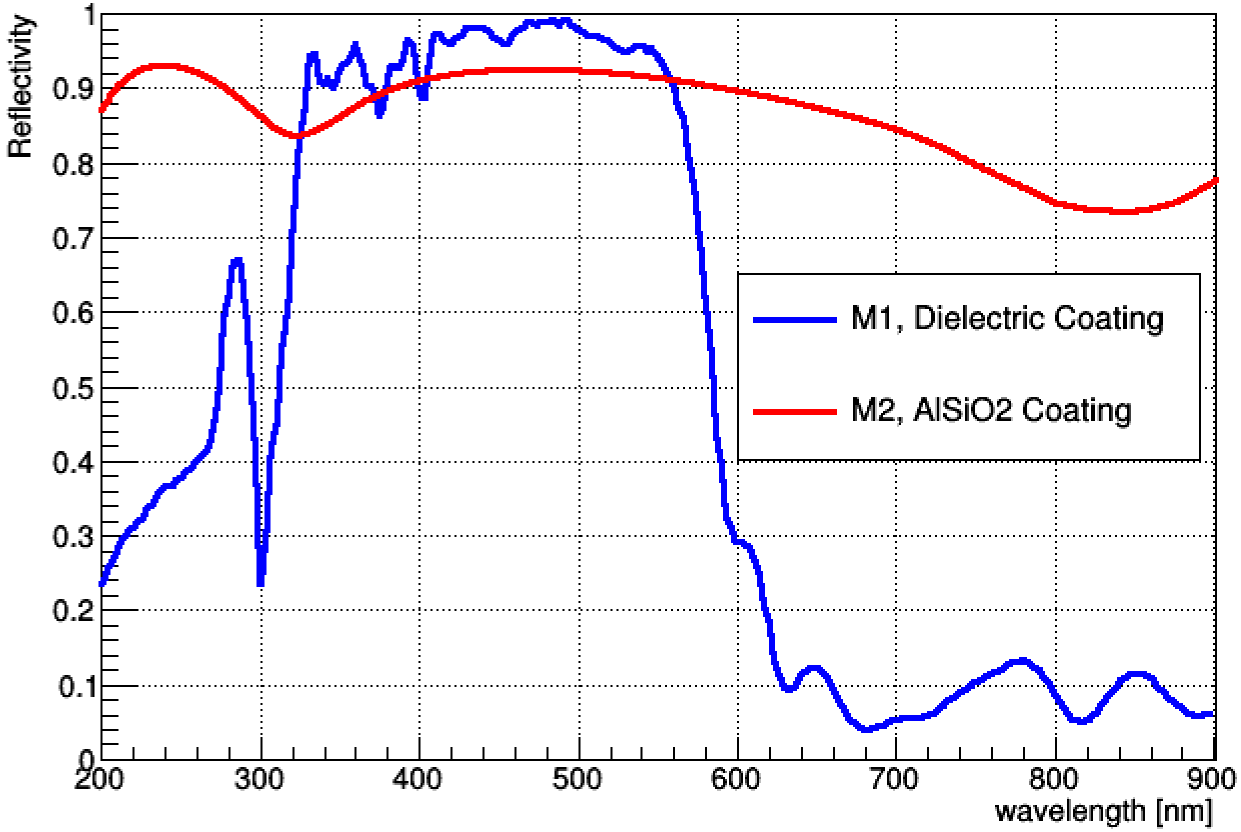


- Cross-checked with independent ray-tracing software (Zemax and astri_simulator)
  - star spots
  - PSF
  - incidence angles distributions (M1, M2, focal surface)



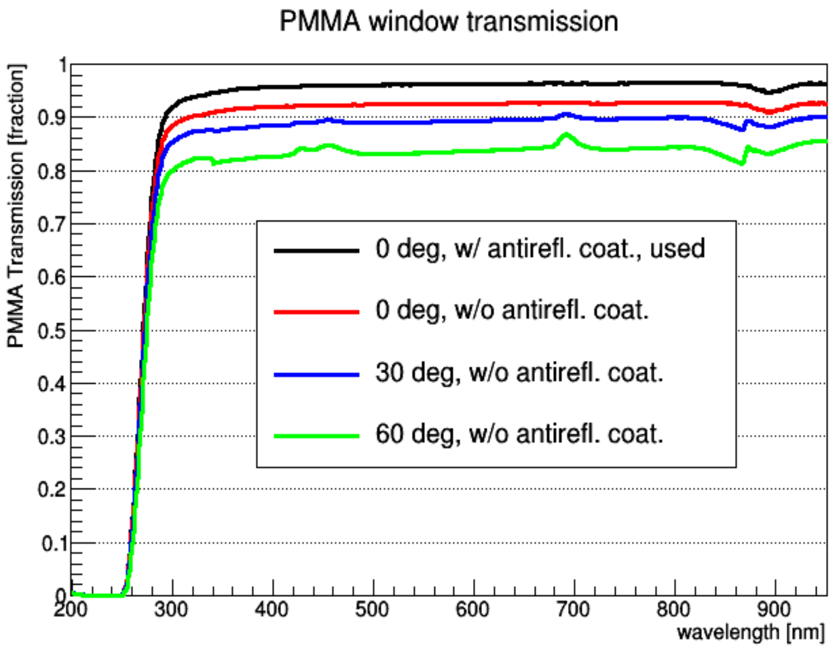
- Optical PSF within CTA requirements
- Additional random angle scattering to reproduce the expected real PSF (preliminary, 0.007°)

- M1 multilayer dielectric coating
  - baseline filter for wavelength > 600 nm, not the only considered option
  - measured focused reflectivity
- M2 standard $AlSiO_2$ coating
  - reflectivity for the mean incidence angle (33°)

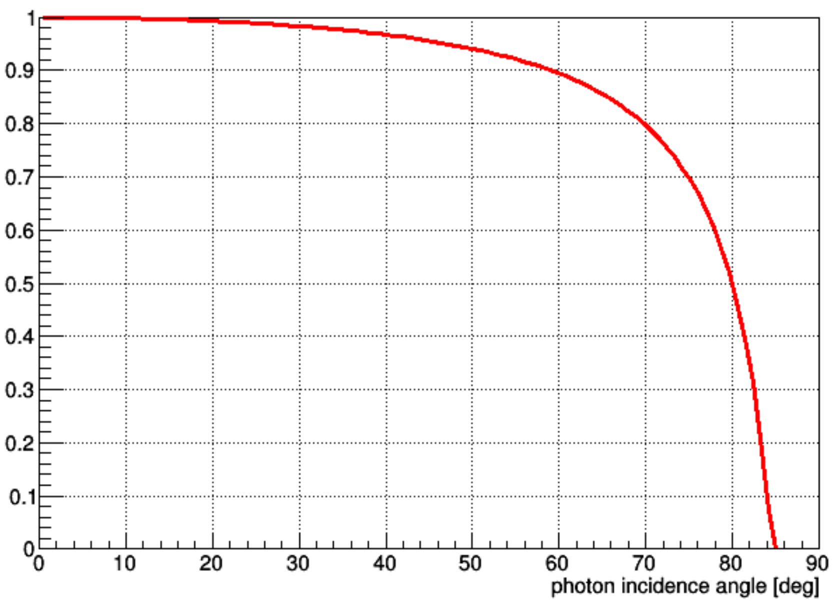


2 different reflectivities: new feature of sim_telarray

PMMA window transmission



Relative to 0deg

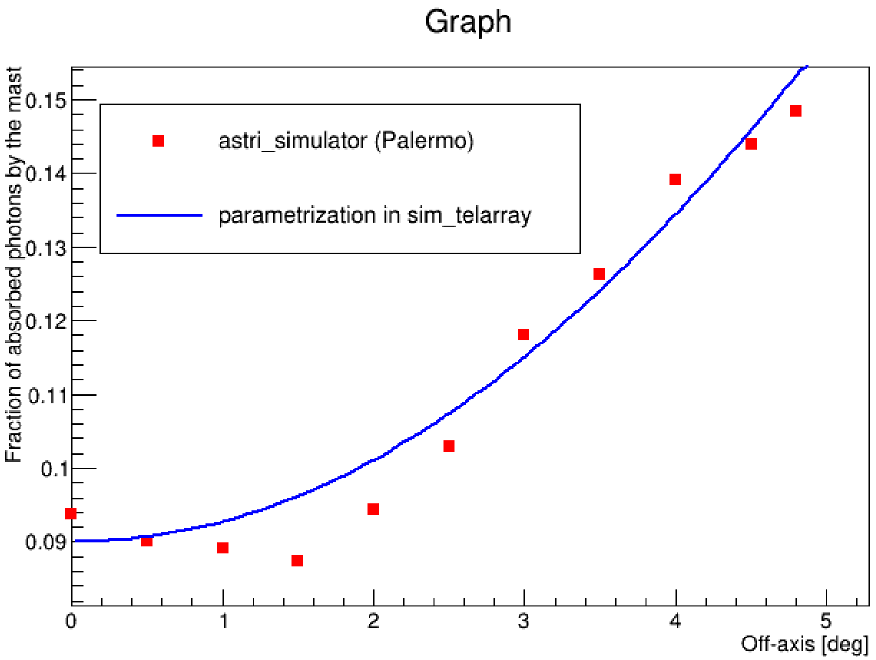


- Including anti-reflection coating expected improvement
- Agreement with other measurements of PMMA transmission

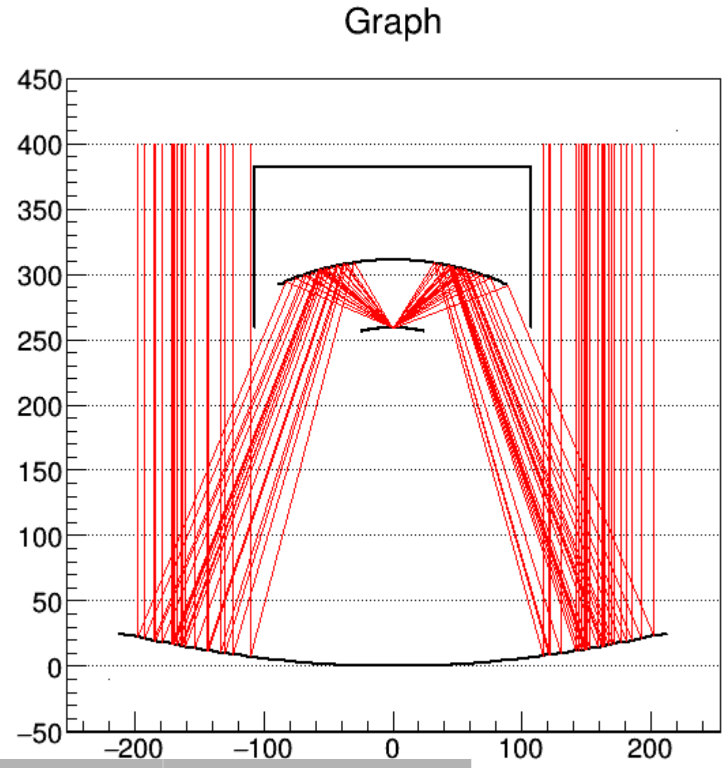
Obscurations

Directly simulated:
- M2 supporting structure
- Baffle
- M1 segmentation
- Camera body shadowing

Average photon loss:
- Masts



angle dependent telescope transmission: new feature of sim_telarray

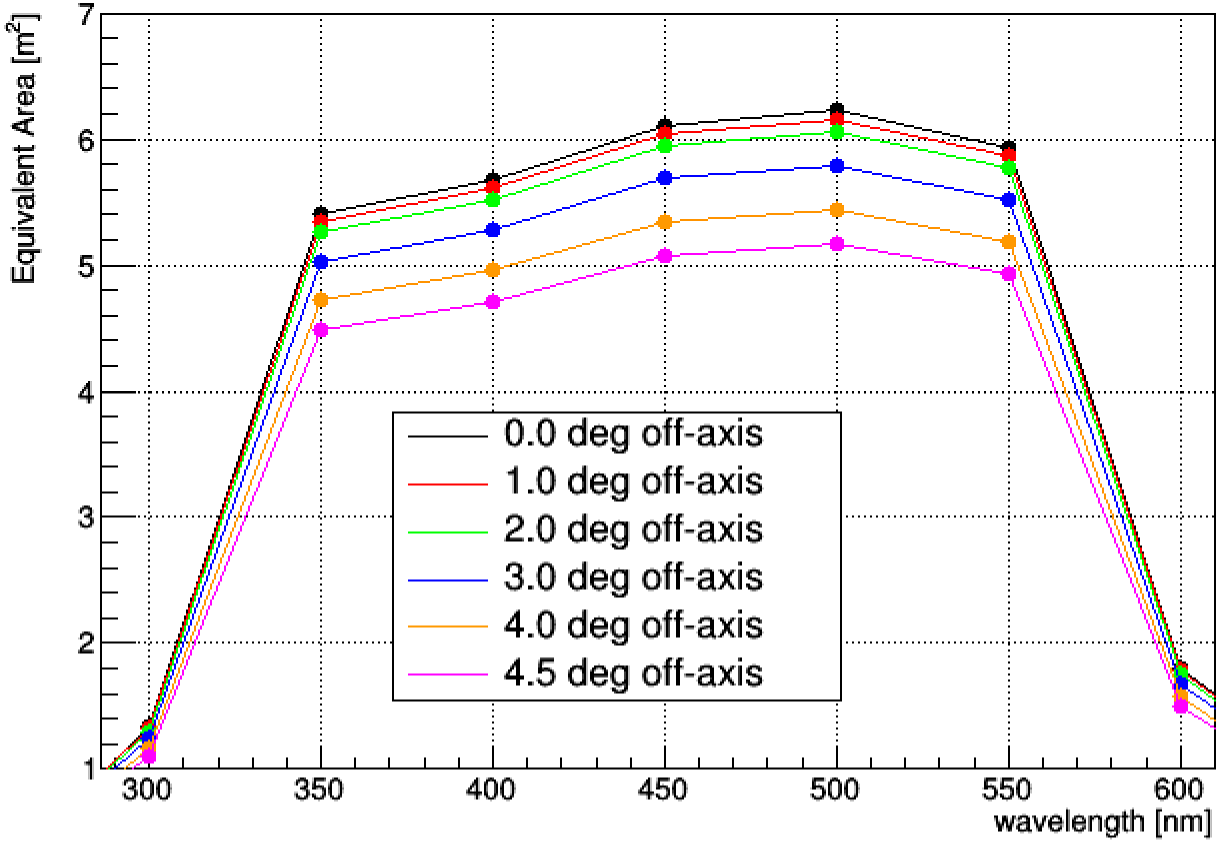


Off-axis [deg]	Equivalent Area [m2]
0	7.87
1	7.80
2	7.75
3	7.53
4	7.22
4.5	6.96

Only shadowing before reflectivities and pmma

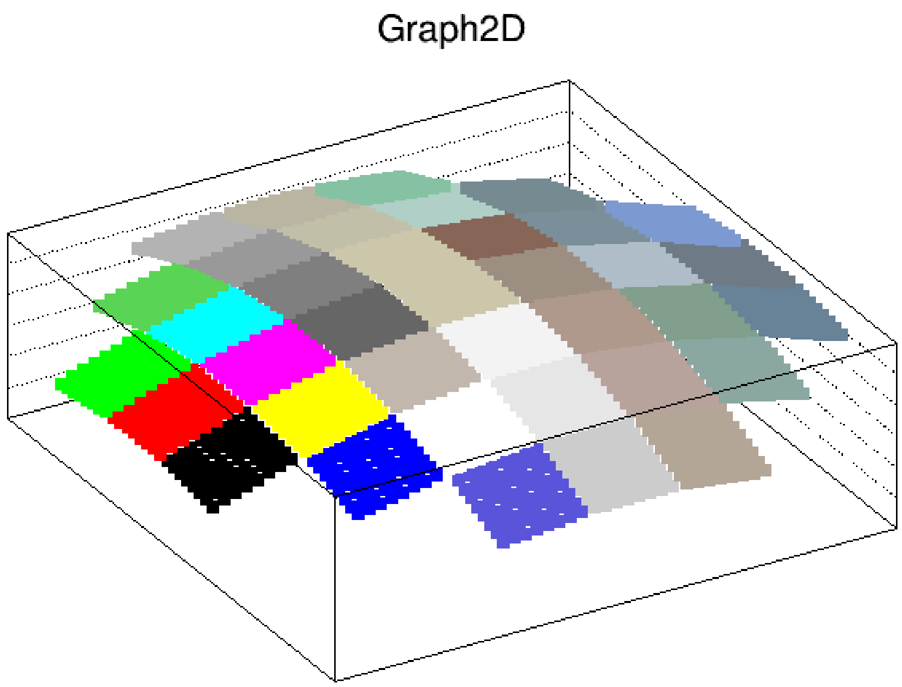
Optical efficiency

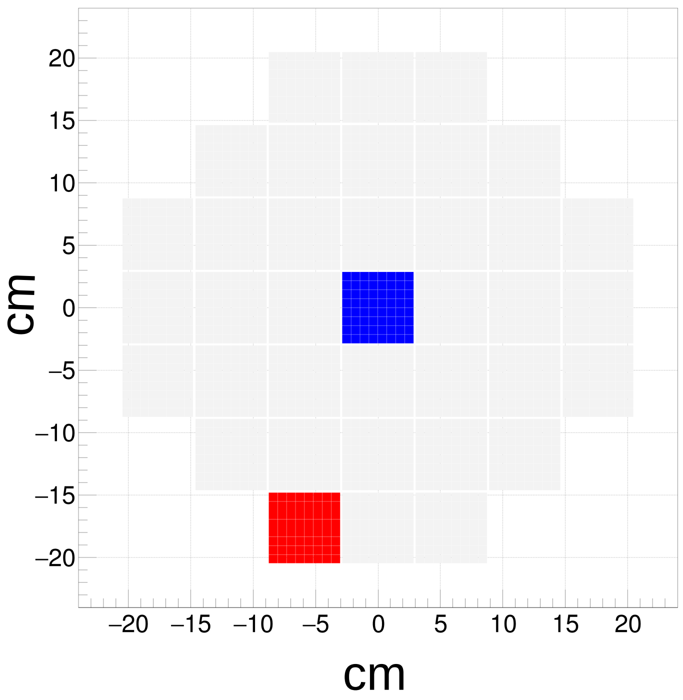
- After all shadowing (M2, M2 struct, baffle, M1, camera, masts) as a function of (θ) .
- and including: refl_m1(λ), refl_m2(λ), pmma_transmission(λ,θ)



Camera geometry

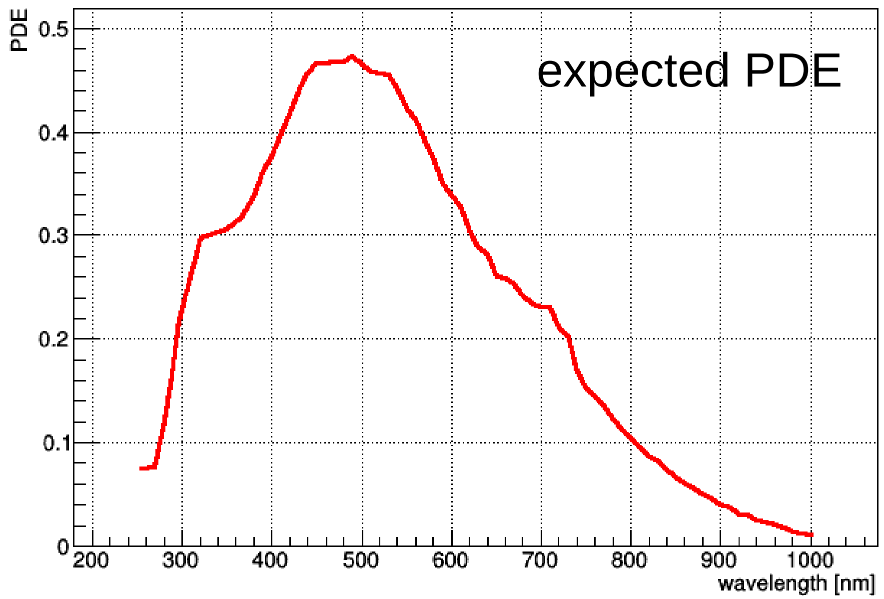
- 2368 pixels
- size: next generation 6.975 mm (0.19°), prototype 6.2 mm (0.17°)
- PDM filling factor 94%.
- 37 PDM, FoV: 9.6°
- focal surface radius of curvature: 1060 mm
- complete 3D camera model (x,y,z, tilts)
- new feature in sim_telarray: pixel orientation normal to surface

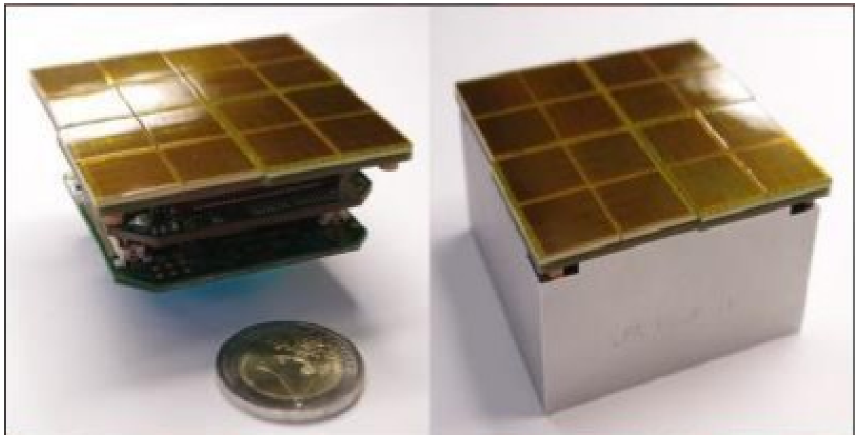




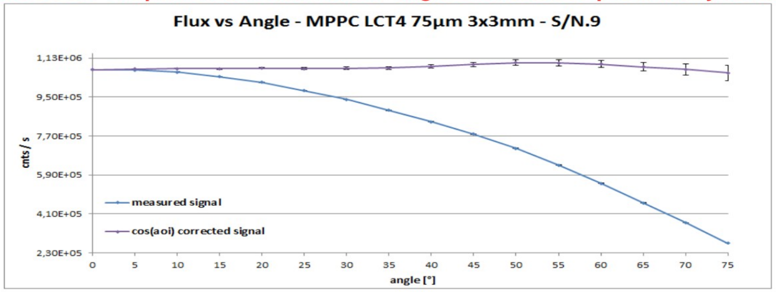
SiPM PDE

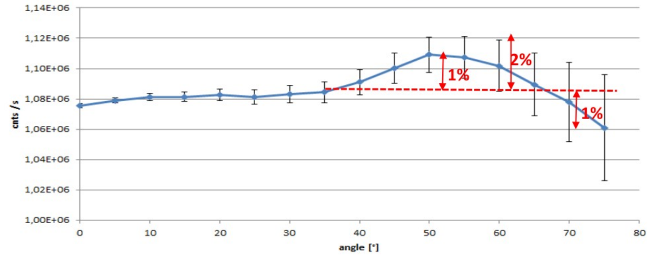
- New Hamamatsu SiPMs (LCT4)
  - higher filling factor
  - improved low wavelenght PDE
  - reduced cross-talk
  - no PDE loss with incidence angle





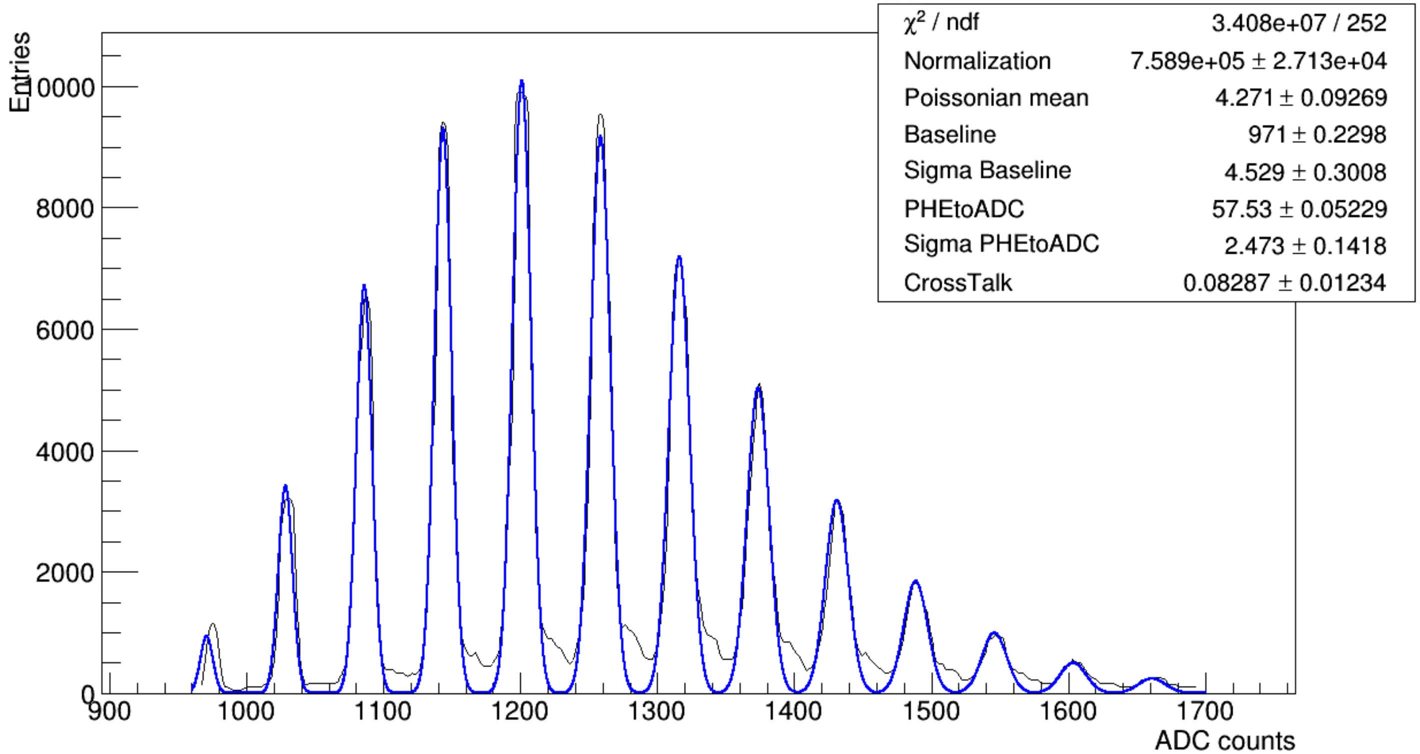
MPPC LCT4 75µm Photon flux versus angle of incidence preliminary results





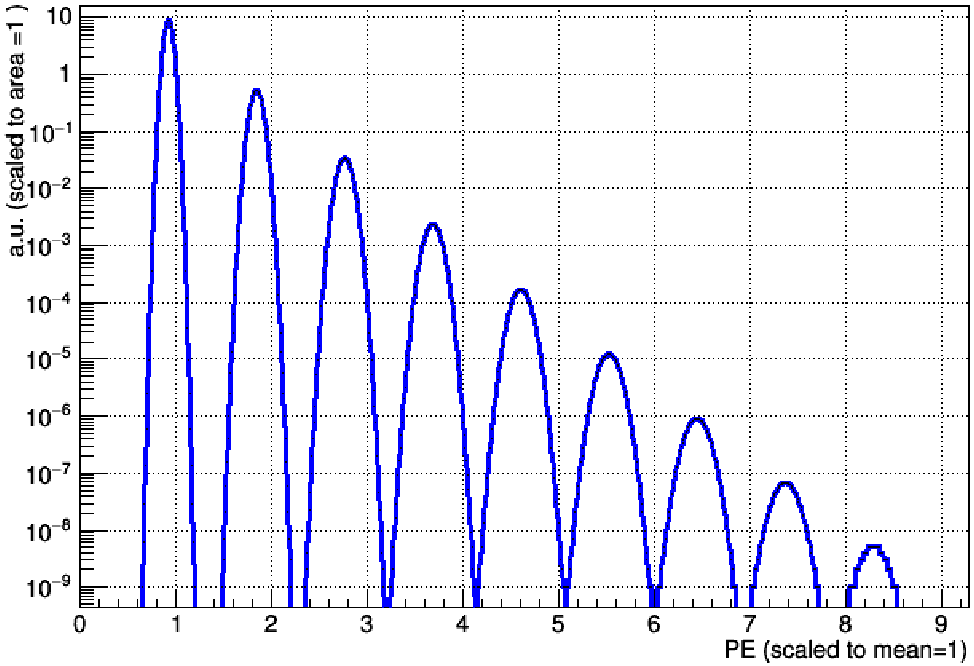
Calibration events

- We get several sensor and electronics characteristics from real data (led **calibration events**):
  - ADC pedestal
  - ADC noise
  - Single photoelectron spectrum (1 pe amplitude fluctuations and Xtalk)
  - ADC <-> Pe conversion factor



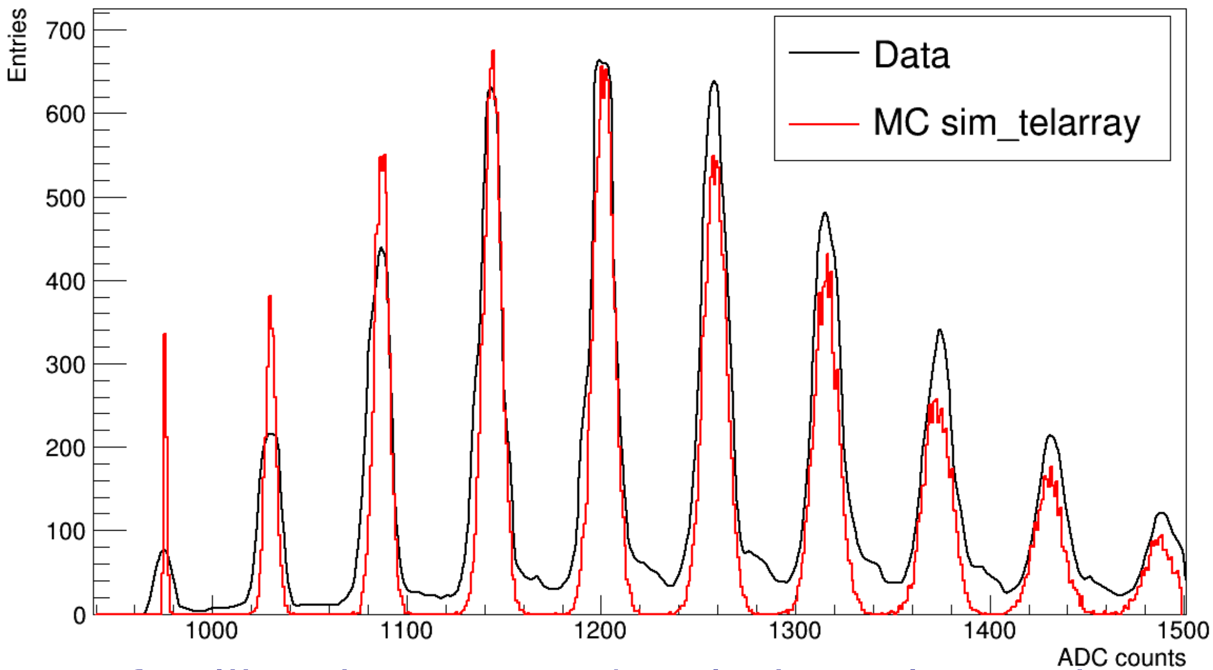
Single Photoelectron spectrum

- Single photoelectron spectrum (1 pe amplitude fluctuations and Xtalk)



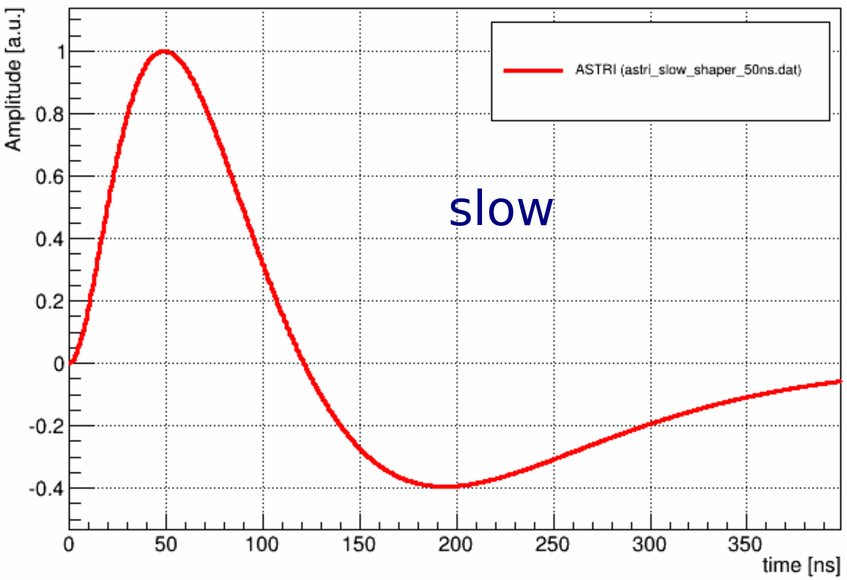
Calibration events

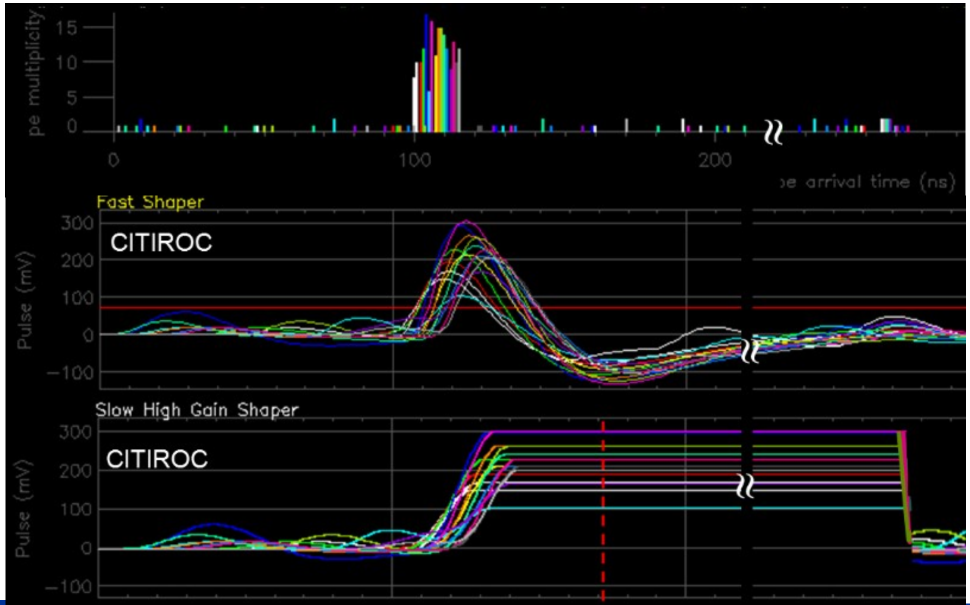
- We reproduce **calibration events** with sim_telarray, including the extracted parameters:
  - ADC pedestal
  - ADC noise
  - Single photoelectron spectrum (1 pe amplitude fluctuations and Xtalk)
  - ADC <-> Pe conversion factor

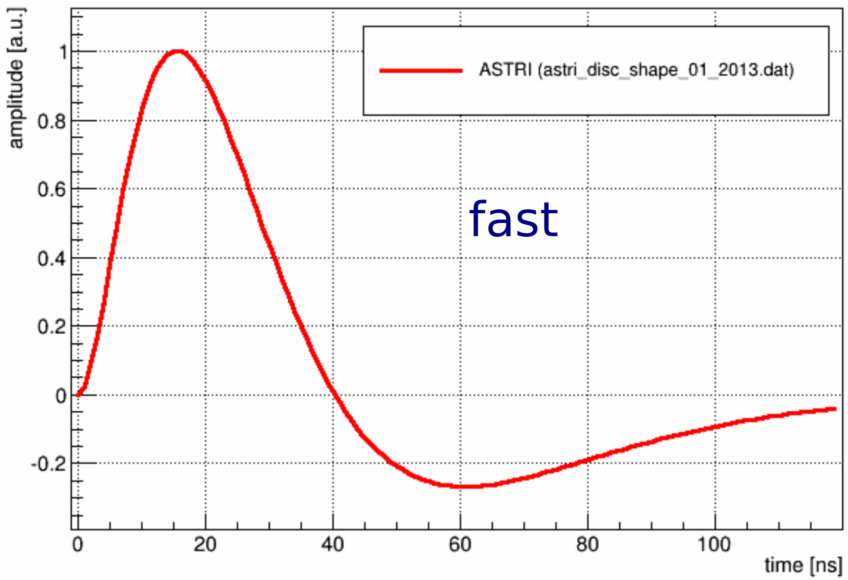


PRODUCTIONS of calibration events (exploring a large phase space) run at CNAF/Farm. See Ciro's talk.

- every photoelectron (NSB and Cherenkov) is generated with its arrival time and its amplitude is fluctuated accordingly to SPE.
- 2 pulse shapes:
  - readout signal (slow)
  - input to discriminator (fast)
- Pedestal and fluctuations are added to the final signal



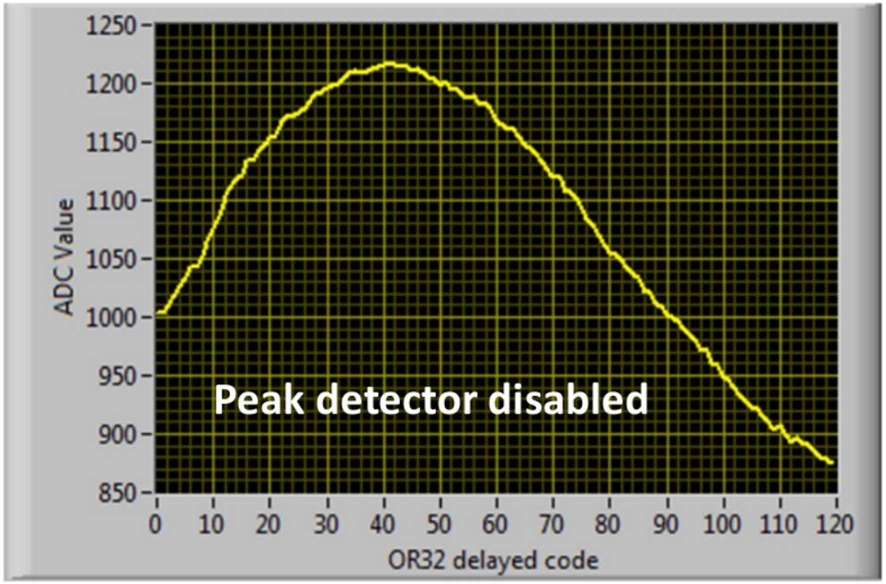


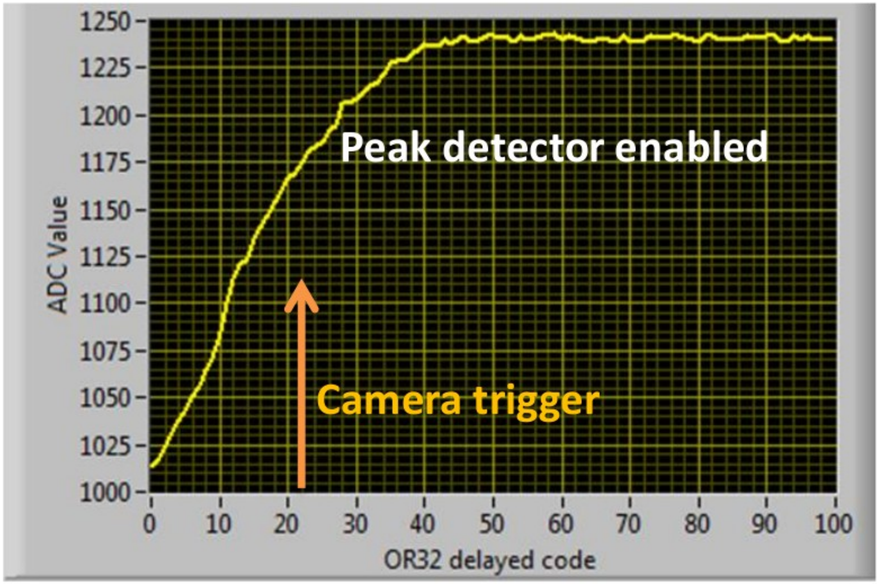


- The ASTRI FEE is based on the CITIROC ASIC
  - integrating and shaping the signal
  - peak detection

- We have checked that the sim_telarray signal simulation is equivalent to the simulation of the ASIC transfer function by means of Laplace transform.

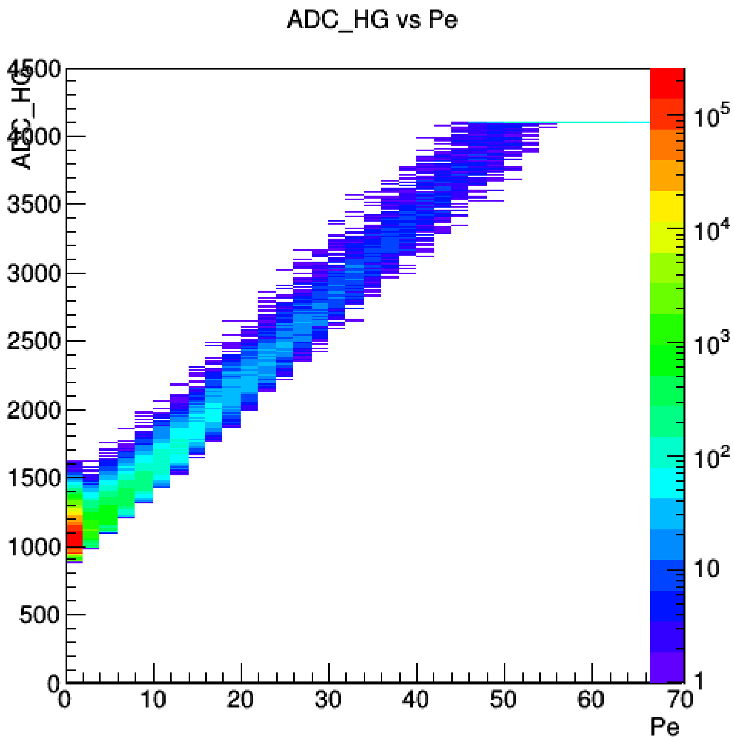
- The new sim_telarray version provides (*peak_sensing = 1*) the maximum value of every pixel traces (both HG and LG).

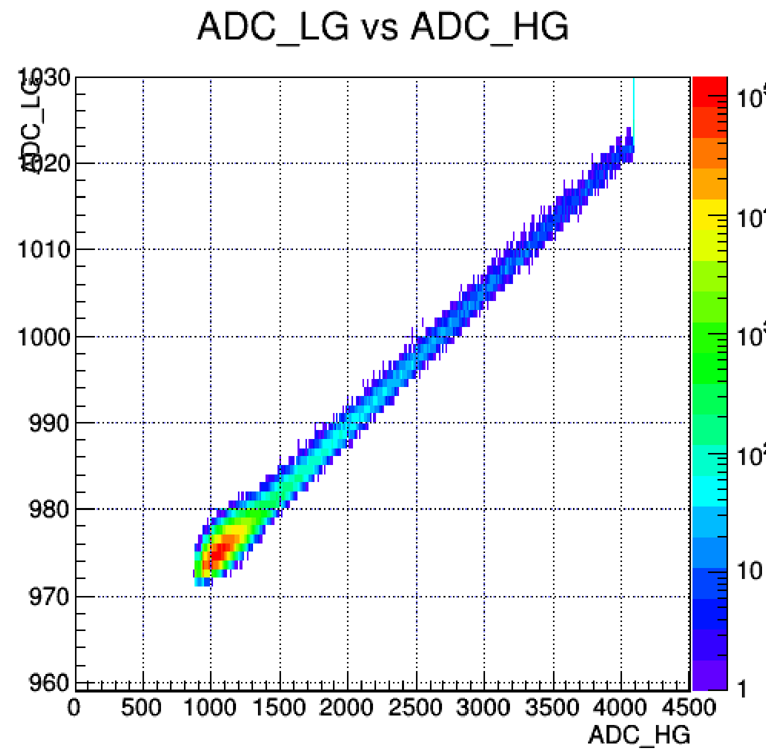




see A. Segreto's talk about ASTRI camera, SST session.

- dymanic range
  - set by maximum fadc signals: 12 bits = 4096 ADC ch.
  - ADC <-> pe and pedestals
  - relative gain LG/HG



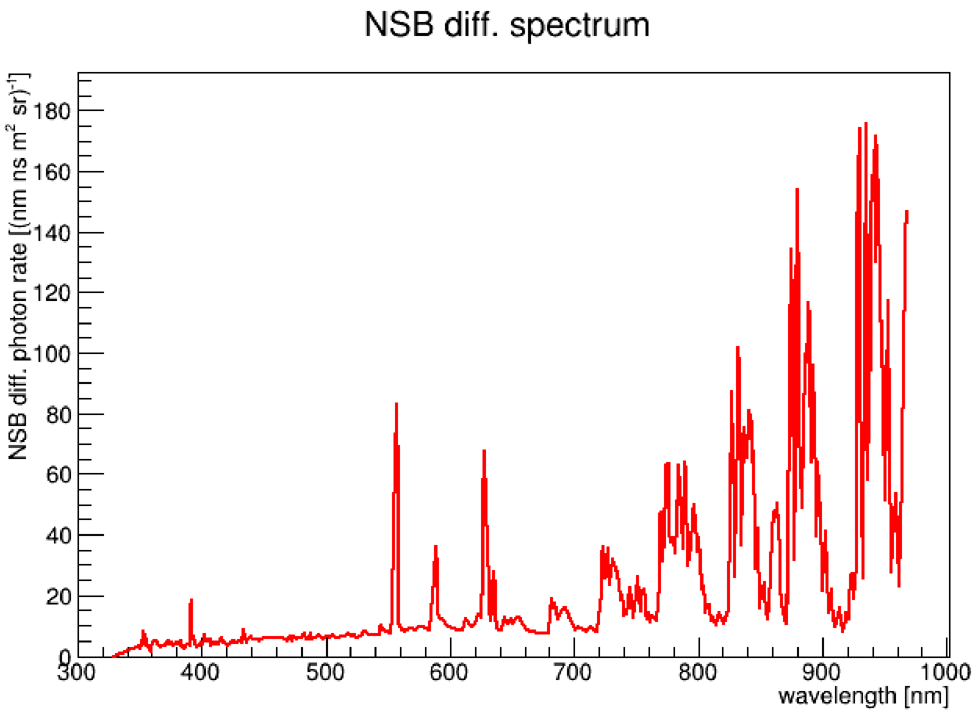


- reconstruction software have to be adapted to use 2 gains and the peak signals (i.e.: no further integration)

NSB rate

Convolution of:

- NSB photon spectrum
  - Benn and Ellison, LaPalma
- Telescope equivalent area
- Pixel fov
- Mirror reflectivities
- PMMA transmission
- PDE

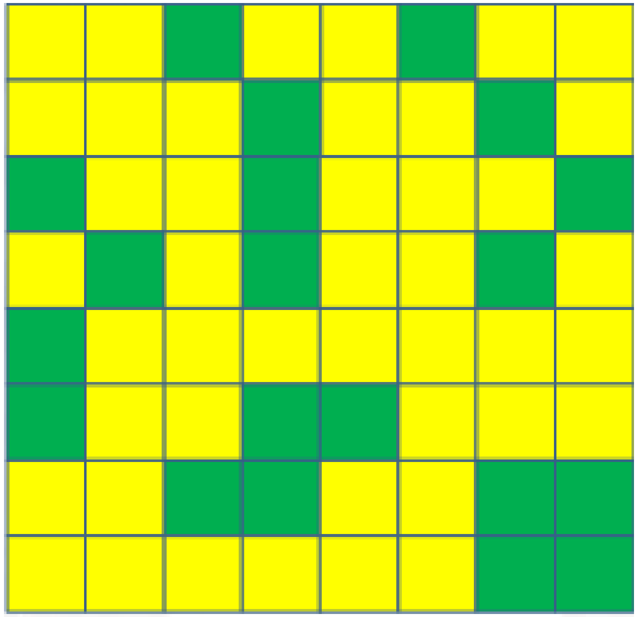


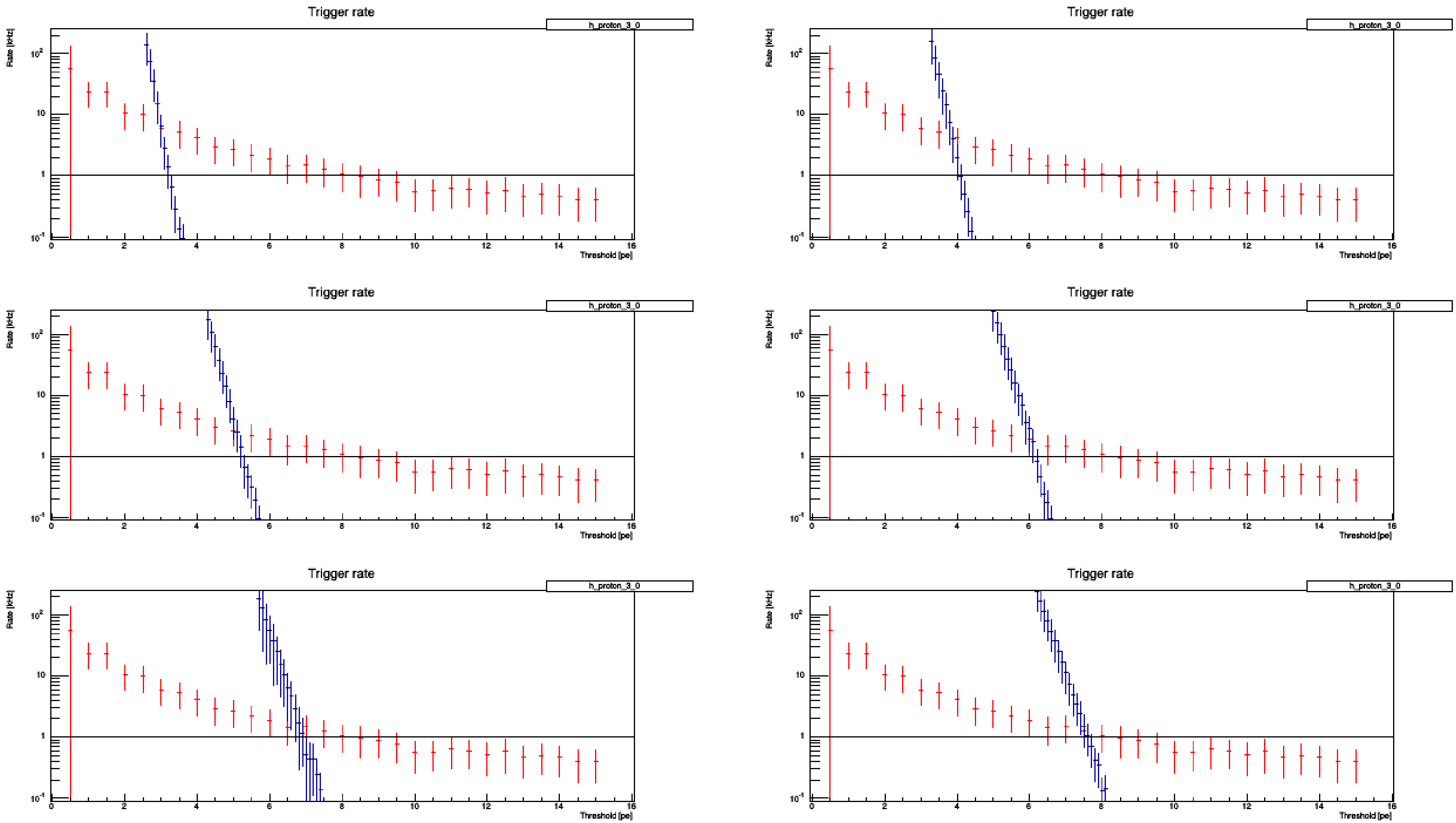
- Individual pixel pe rate: 44 MHz

Trigger

- **Camera trigger conditions:**
  - 4 (5) adjacent pixels (same PDM)
  - above discriminator threshold (1^{st} guess ≈ 5pe)
  - coincidence within 20 ns

- "safe trigger" threshold now under evaluation: CNAF/Farm production
  - 1.5 * proton trigger rate = 2 * NSB trigger rate

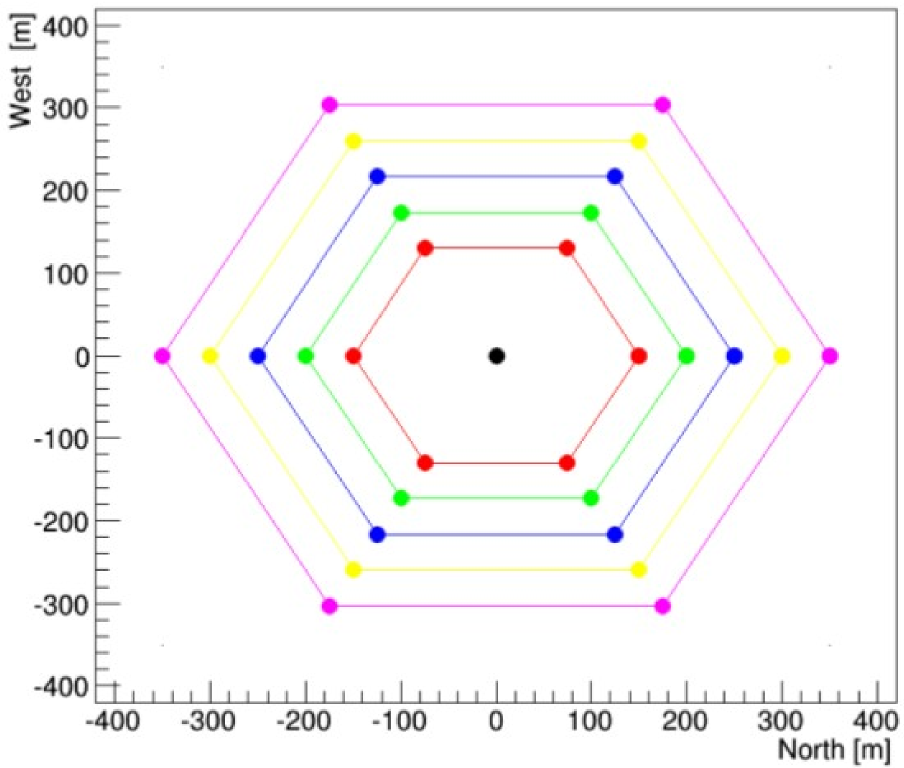




Single telescope trigger rate evaluation runs at CNAF/Farm. See Ciro's talk.

Dedicated productions

- The MC producitons may run:
  - locally (test productions, how-to in the last meetings)
  - CNAF/Farm (relatively large productions or many jobs productions, how-to see Ciro's talk)
  - CNAF/Grid or VO (via DIRAC, large productions)
    - examples: next slides

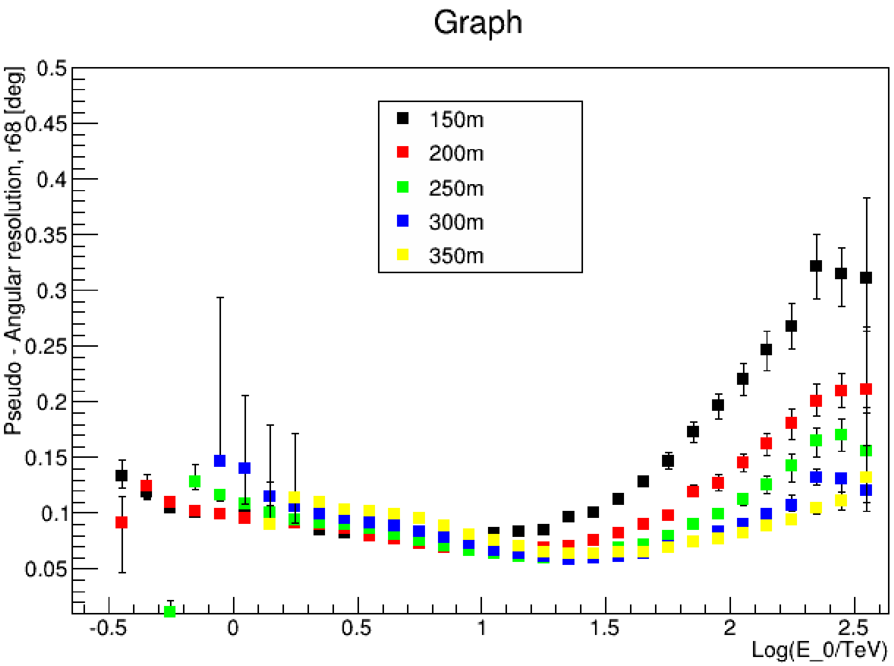


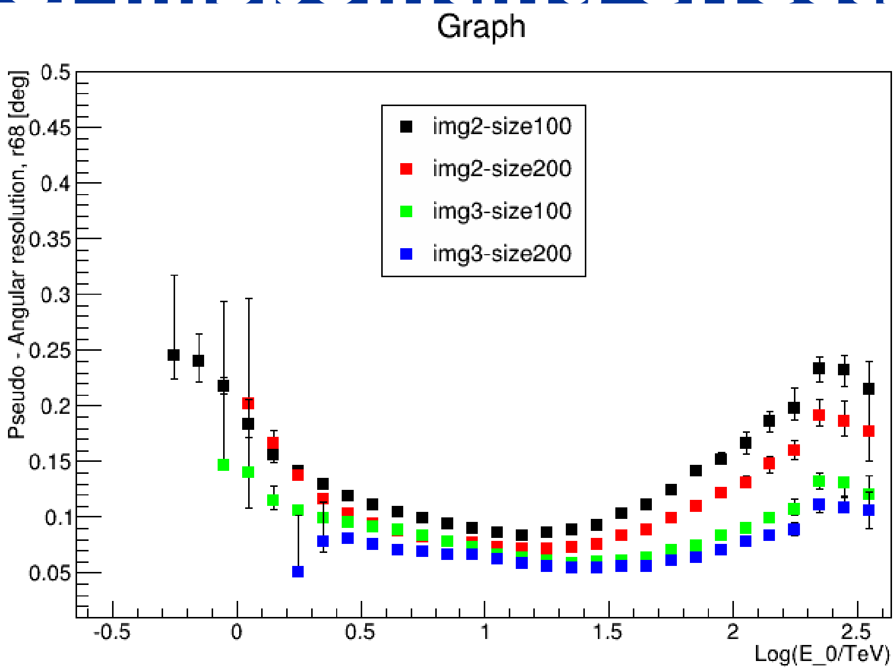
- site: Leoncito++ (for cmp with prod2)
- 31 telescopes
- 5 hexagonal mini-arrays (7 tel)
- Telescope distance 150-350 m

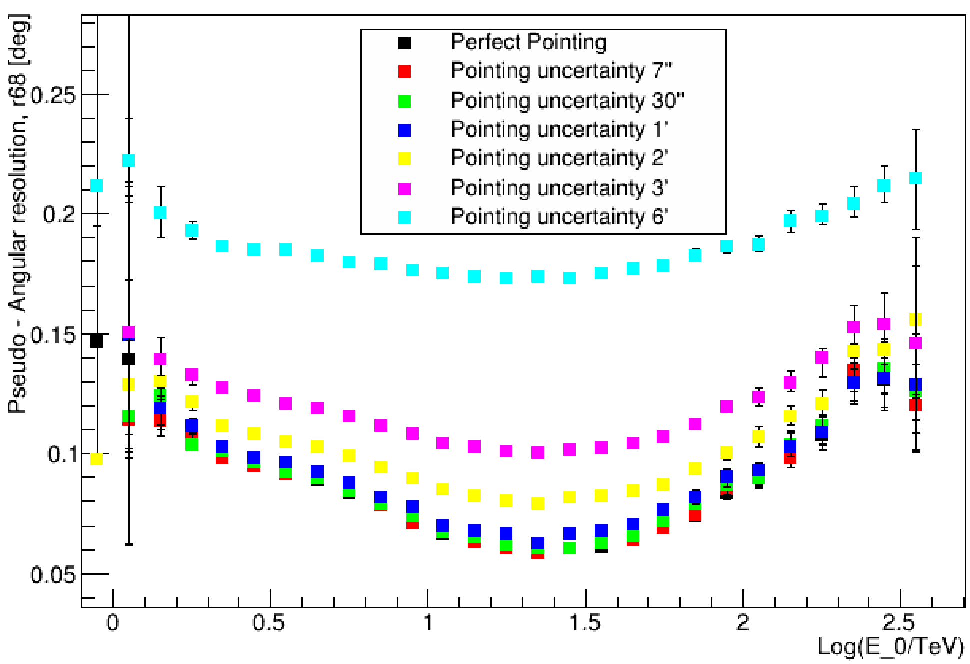
	Gammas	Protons
Sp. index	-2	-2
E min [GeV]	315	315
E max [GeV]	330e3	330e3
R max [m]	1000	1000
N showers	1e6	1e7
N events	1e7	2e8
Viewcone	0	10^{o}

- Aims:
  - test SST telescope simulations
  - test SST telescope handling in reconstruction software
  - provide a preliminary study of telescope distance effect on performance

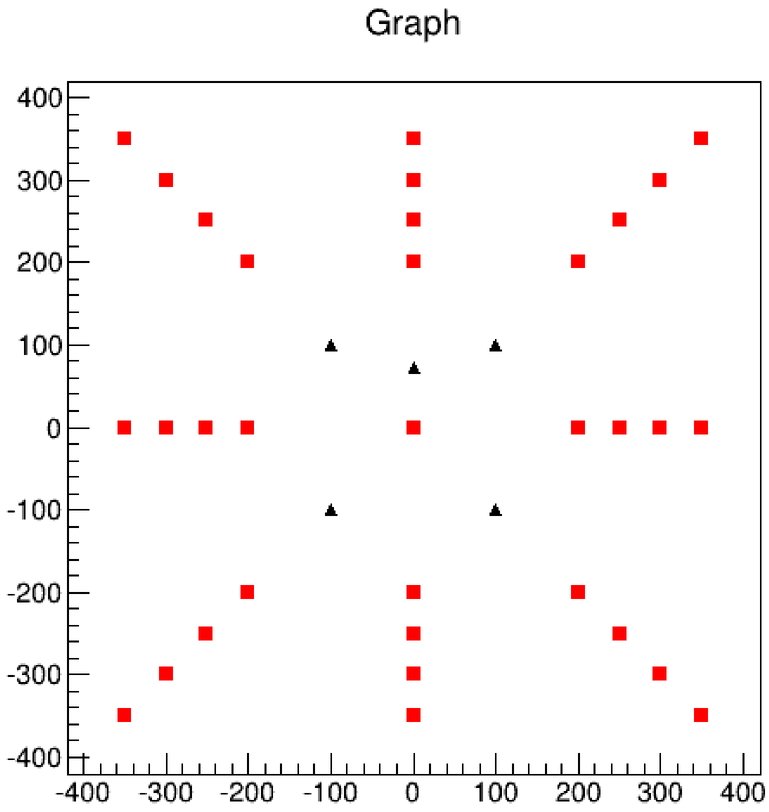
Example: mispointing effects







Dedicated productions



- Studies of not-std telescope configurations:
  - degraded psf, different coating, different camera geometry, different readout, different nsb levels.

- site: Armazones
- 33 SSTs + 5 MSTs
- 4 squared 3x3 mini-arrays (9 tel)
- Telescope distance 200-350 m
- Trigger: 1 and 2 telescopes
  - mono-analysis
  - single telescope trigger efficiency
  - **optimization of image cleaning**
    - Bug found in Eventdisplay, FIXED THRESHOLDS mode!
- Aims:
  - mini-arrays performance
  - telescope distances optimization

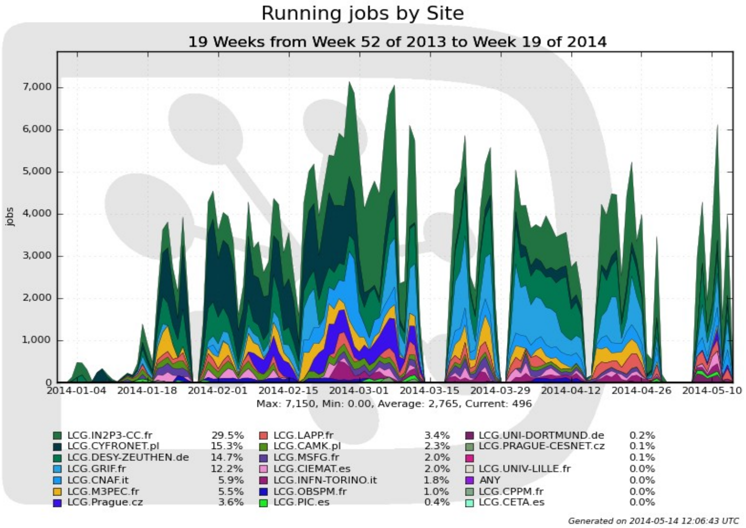
Using GRID

- The MC producitons may run:
  - locally (test productions, how-to in the last meetings)
  - CNAF/Farm (relatively large productions or many jobs productions, how-to see Ciro's talk)
  - CNAF/Grid or VO (via DIRAC, large productions)

DIRAC
THE INTERWARE

- Infrastrucures:
  - GRID (vo.cta.in2p3.fr)
    - Sept. 2013: 21 EGI, 7 countries
    - Storage ~ 1 Pb
    - Computing ~10^4 HS06

- *INFN (CNAF) is the third contributors in terms of storage and computing resources*



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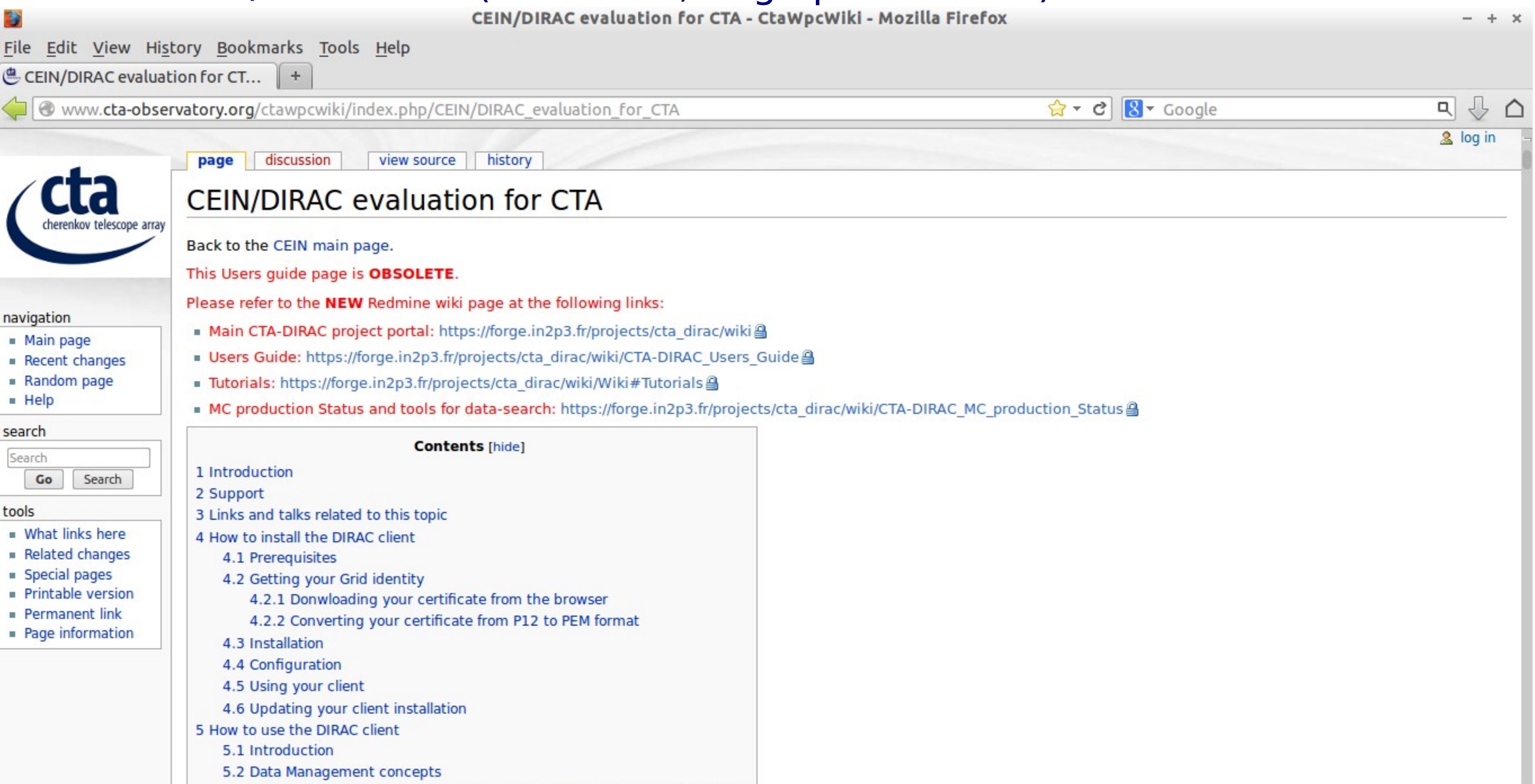
CEIN/DIRAC evaluation for CTA - CtaWpcWiki - Mozilla Firefox

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www.cta-observatory.org/ctawpcwiki/index.php/CEIN/DIRAC_evaluation_for_CTA

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cta cherenkov telescope array

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CEIN/DIRAC evaluation for CTA

Back to the CEIN main page.

This Users guide page is **OBSOLETE**.

Please refer to the **NEW** Redmine wiki page at the following links:

- Main CTA-DIRAC project portal: https://forge.in2p3.fr/projects/cta_dirac/wiki
- Users Guide: https://forge.in2p3.fr/projects/cta_dirac/wiki/CTA-DIRAC_Users_Guide
- Tutorials: https://forge.in2p3.fr/projects/cta_dirac/wiki/Wiki#Tutorials
- MC production Status and tools for data-search: https://forge.in2p3.fr/projects/cta_dirac/wiki/CTA-DIRAC_MC_production_Status

Contents [hide]

Using GRID

- First steps:
  - Getting a GRID certificate
  - Register to the VO
  - ...follow the nice instructions!

Getting your Grid identity

- To get a Grid certificate, you should contact your national Grid Certification Authority (CA):

```
https://www.eugridpma.org/members/worldmap/
```

- Register to the CTA VO (vo.cta.in2p3.fr):

```
https://cclcgvomsli01.in2p3.fr:8443/voms/vo.cta.in2p3.fr/
```

- Once you receive confirmation of your registration connect again to the following link and ask for the 'users' Role:

```
https://cclcgvomsli01.in2p3.fr:8443/voms/vo.cta.in2p3.fr/
```

- Running the CTA *standard* applications
  - corsika, sim_telarray, eventdisplay
  - just modify input/output in the python scripts

- It is also possibile to upload, to compile and to run modified versions of the sw