Simulation of a mixed array

Report on Hybrid-1 simulations: strategy, status and analysis

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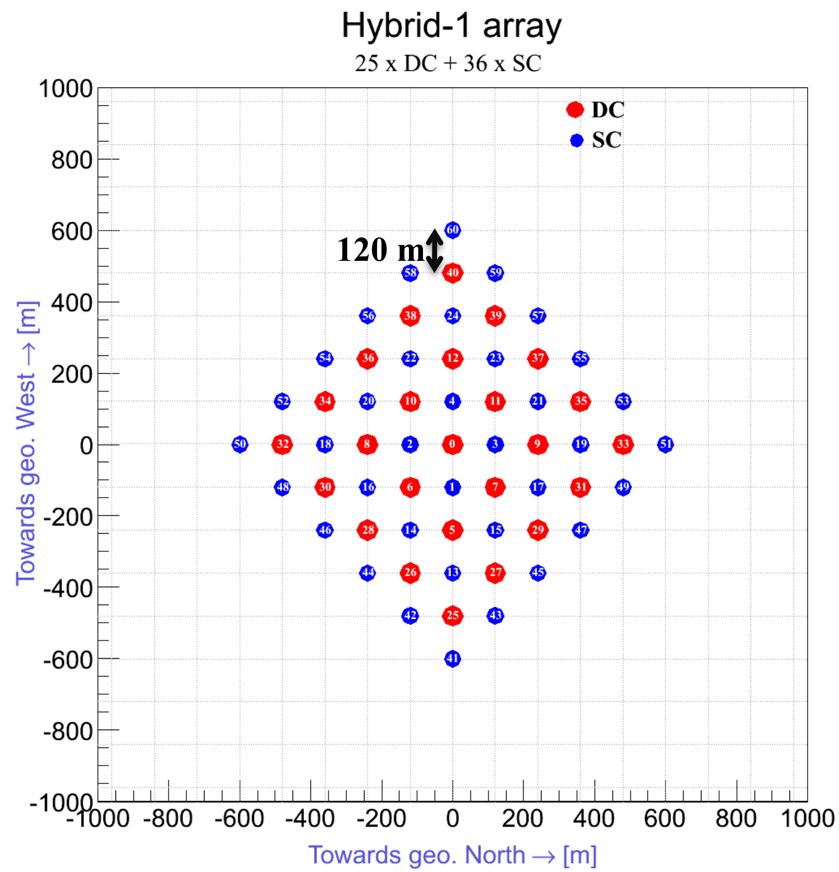
CTA-US meeting
Feb. 2012

Ideas

- Simulation of a mixed array: Schwarzschild-Couder (SC) & Davies-Cotton (DC) telescopes.
- Target energy range: 50 GeV - 30 TeV
- **GOAL:**
  - **assess the general performances of a mixed array**
  - **compare SC telescopes with DC telescopes**
- 1st: Trigger studies to setup trigger parameters
- 2nd: Production of simtel files w/enough statistics
- 3rd: **Analysis**: Eventdisplay etc.



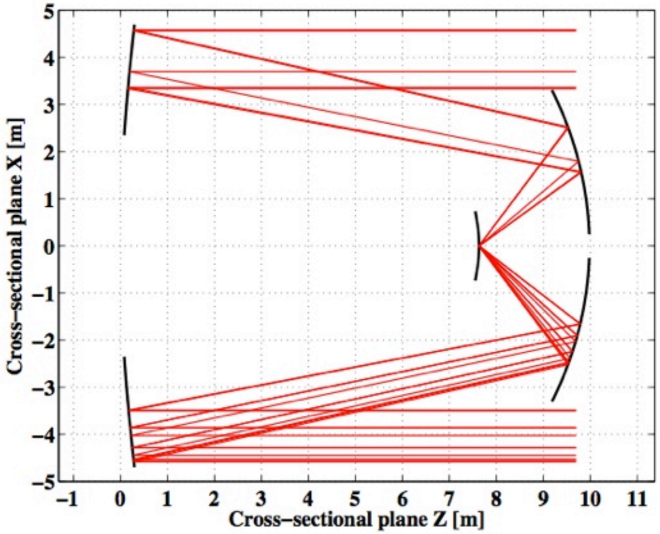
Status

- Trigger studies: done
- Production: done
- Checks: done
- Analysis: ongoing
- Sensitivity curve: coming very soon, next week or so
- Comparison SC/DC

Optics: memo & what is simulated

- DC: *cheap, easy alignment, better off-axis performances than other single-dish designs*
  - spherical-shaped (R = F) single-reflector, made of hundreds of spherical mirror tiles
  - each tile points to a point 2F on the optical axis (F: focal of the system)
  - for infinitesimal tiles, eliminates the spherical aberration
  - **simulated: intermediate design between DC and parabolic design** to decrease optical time spread (see K. Bernloehr/G. Hughes, 2010): 12m-diameter dish with increased radius of curvature compared to DC design, focal length 16m, F/D
- SC: *reduced aberrations and optical time spread, easily high FOV achieved*
  - aplanatic 2-reflector
  - short focal length of the system
  - smaller plate scale (0.067 deg/pixel)
  - curved focal plane

Vassiliev, 2006

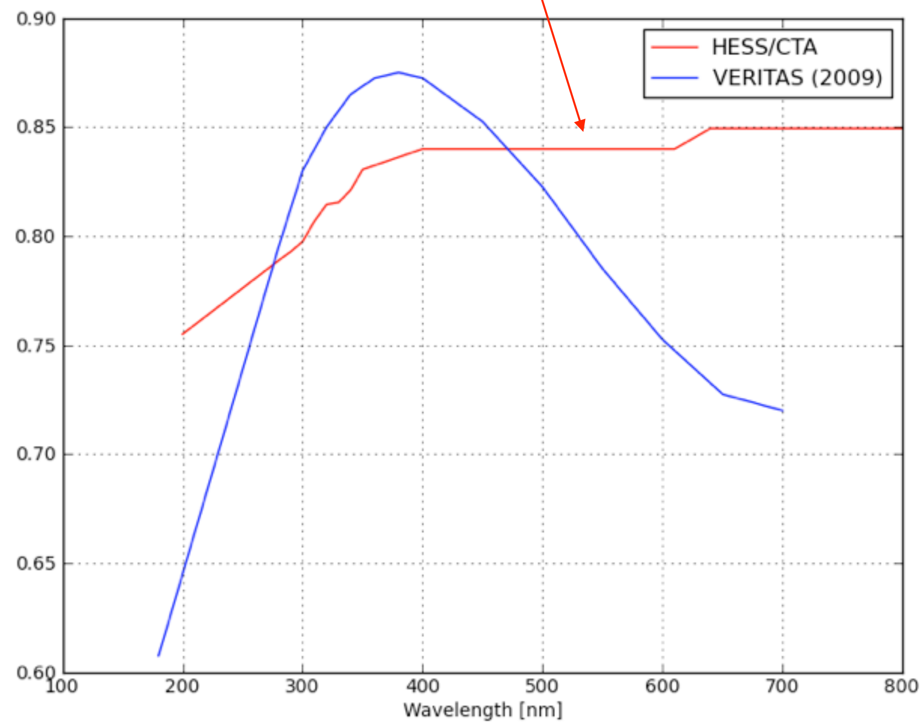


Optics: memo & what is simulated

Parameter	DC (intermediate design)
Focal length [m]	15.6
Aperture [m]	12.38
f/#	1.26
Projected area [m^2]	104
Design FoV [deg.]	8

Parameter \ OS Name	OS8
Focal Length [m]	5.5863
Aperture [m]	9.66
f/# [1]	$f/0.5781$
Primary Radius max [m]	4.8319
Primary Radius min [m]	2.1933
Secondary Radius max [m]	2.7083
Secondary Radius min [m]	0.3945
Effective light collecting area /unvignetted [m^2]	50.33
Unvignetted Size [deg]	3.50
Effective light collecting area at FoV edge [m^2]	47.73
Vignetting at the FoV edge [%]	−5.17
Primary projected area [m^2]	58.23
Secondary projected area [m^2]	22.55
Design FoV [deg]	8.00
Design FoV solid angle [deg^2]	50.35
PSF at the FoV edge (2MAX{RMS}) [arcmin]	3.81

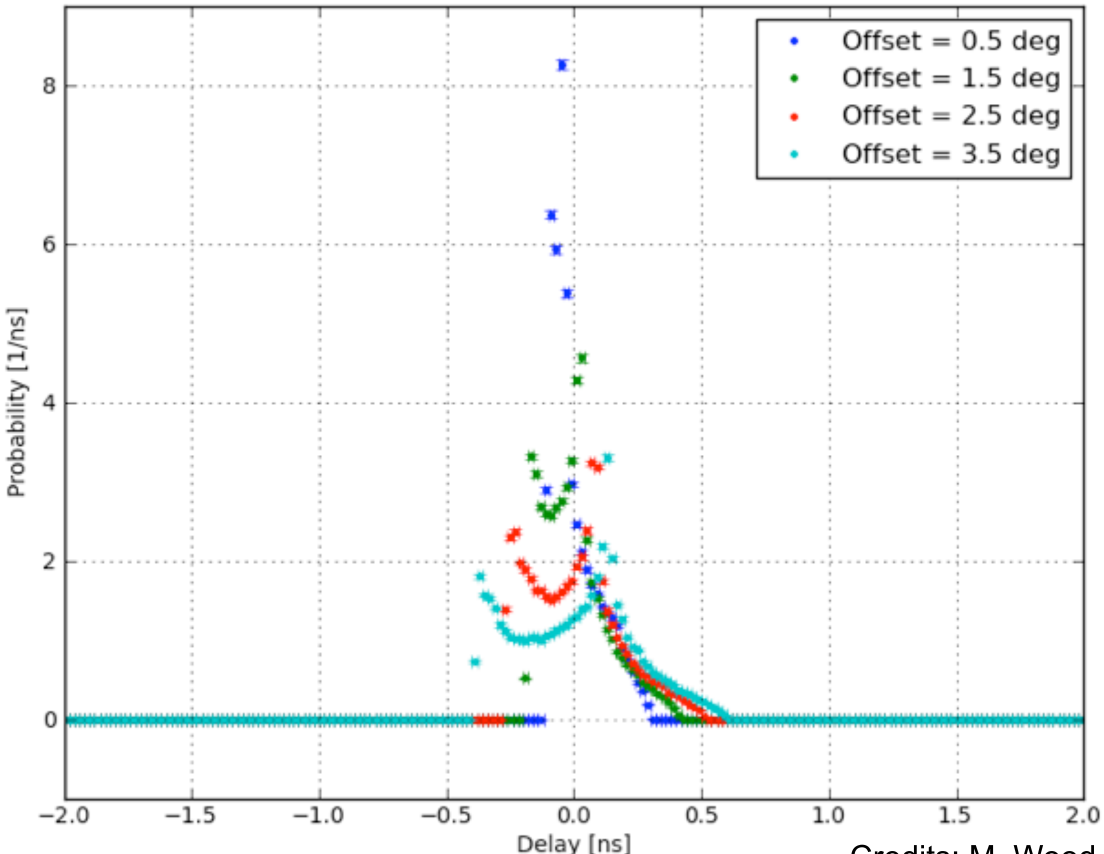
The HESS/CTA curve is used in the sims for both SC & DC



Mirror reflectivity vs wavelength

Optics performances

- For DC/parabolic intermediate optics: spread~0.6ns for Offset = 4.0 deg
- SC optics: very small time spread, ~3x narrower than for DC optics



Credits: M. Wood

For SC optics:
Time spread distribution for plane waves hitting the reflector at various angles

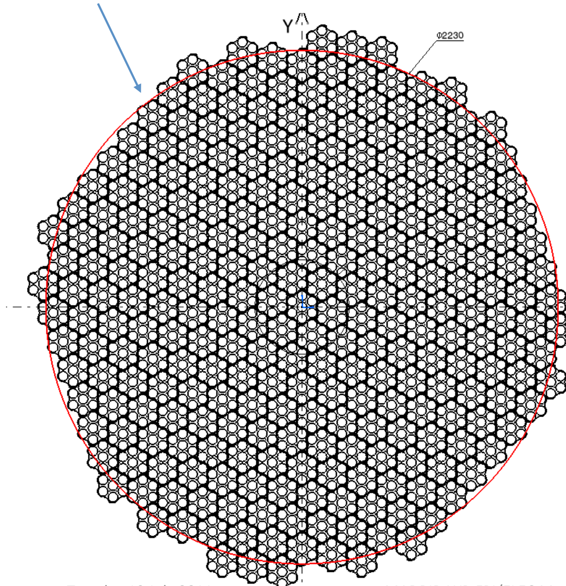
Camera: memo & what is simulated

FOCAL PLANE (MST)

Credits:

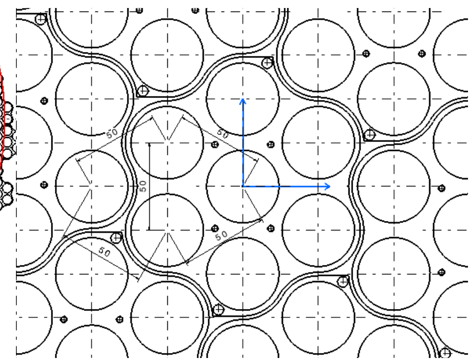
DC camera

Ø 2230mm



hese specifications we have !

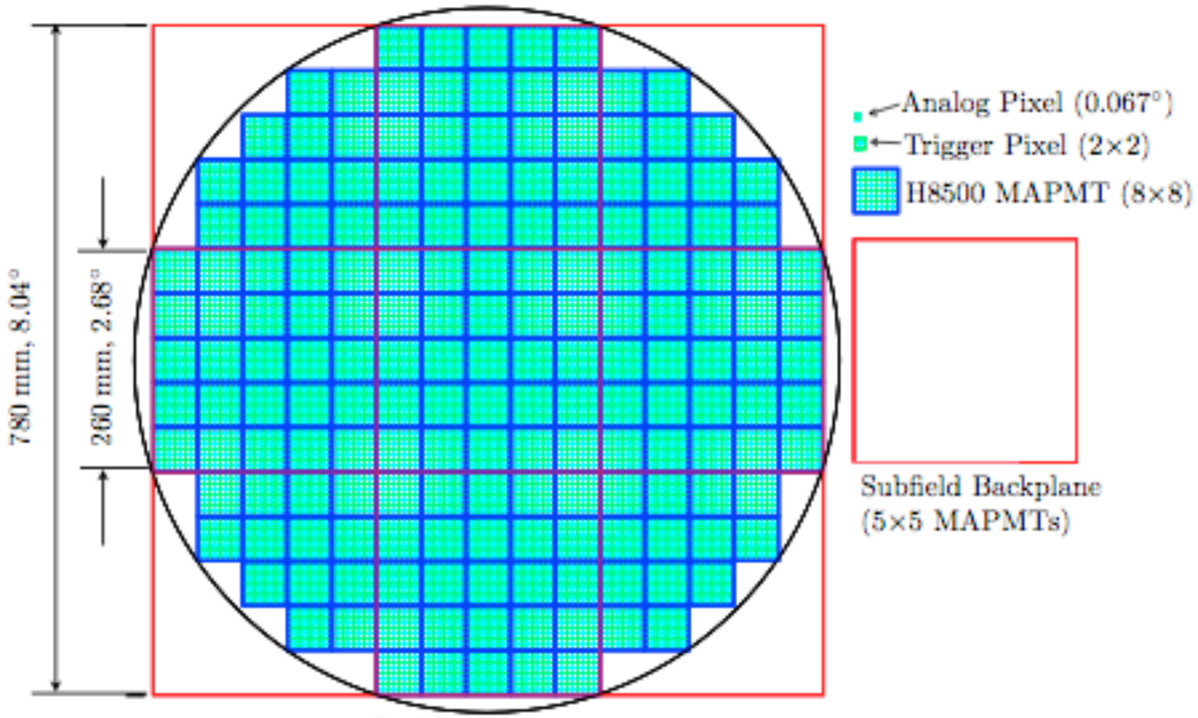
FOCAL PLANE	Number
Diameter of focal plane	Ø 2230mm
Pixel pitch	50.00mm
if we have a modularity	of 7 PM by clusters
Number of clusters 7 pixels	271 clusters
Total of pixels	1897 pixels

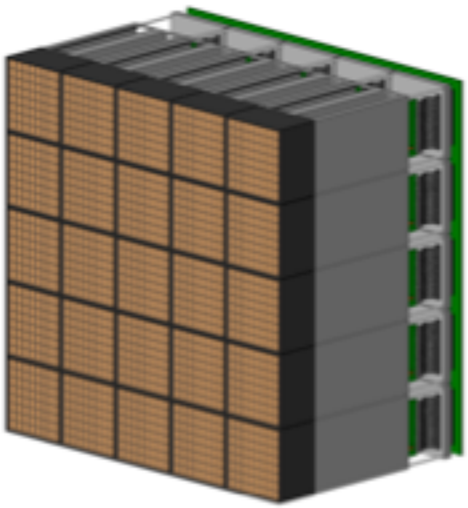


Tuesday 19 July 2011 MADRID WP:FPI/ELEC Manigot Pascal 3

- DC camera: 1897 pixels (Hamamatsu 9420), single-pe FHWM ~ 3ns, 5cm spacing, ~2.2m diameter, mean light cone efficiency ~85%, focal plane efficiency ~75%

Camera: memo & what is simulated





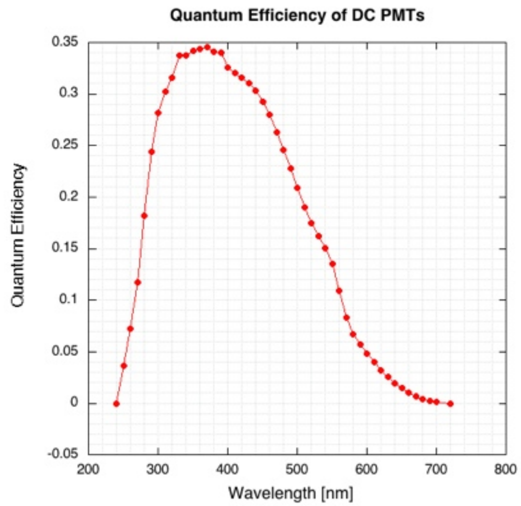
Hamamatsu H8500C

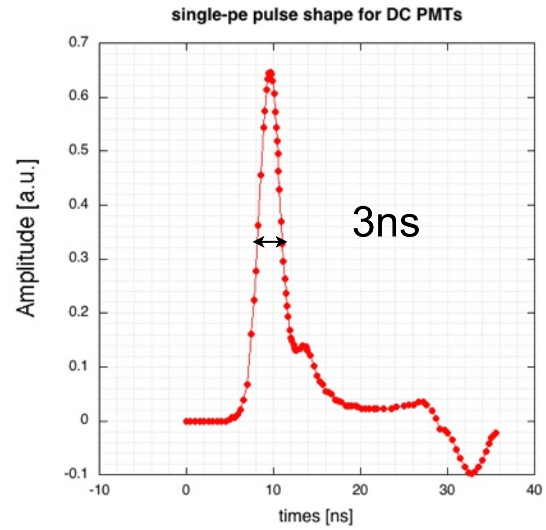
- SC camera: 11328 6mm squared pixel (MAPMT Hamamatsu 8500C), FHWM ~1ns, similar focal plane efficiency

Camera: memo & what is simulated

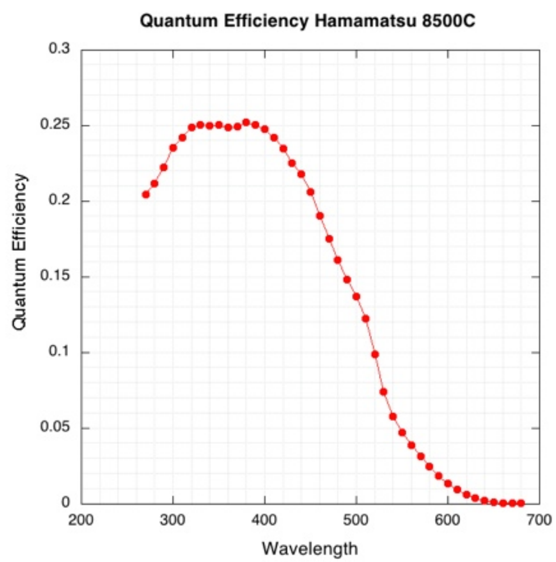
> PMTs characteristics

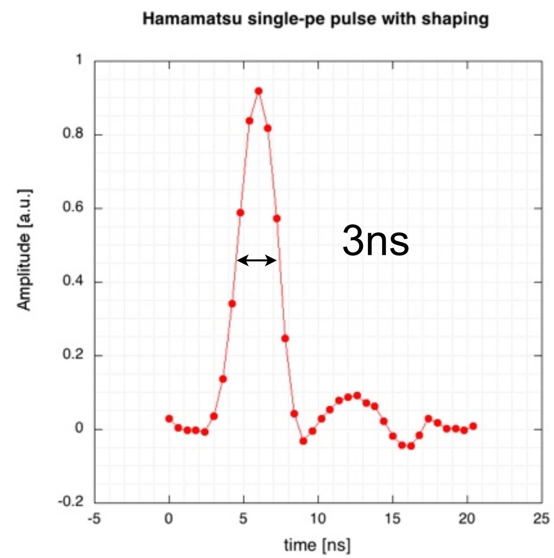
DC





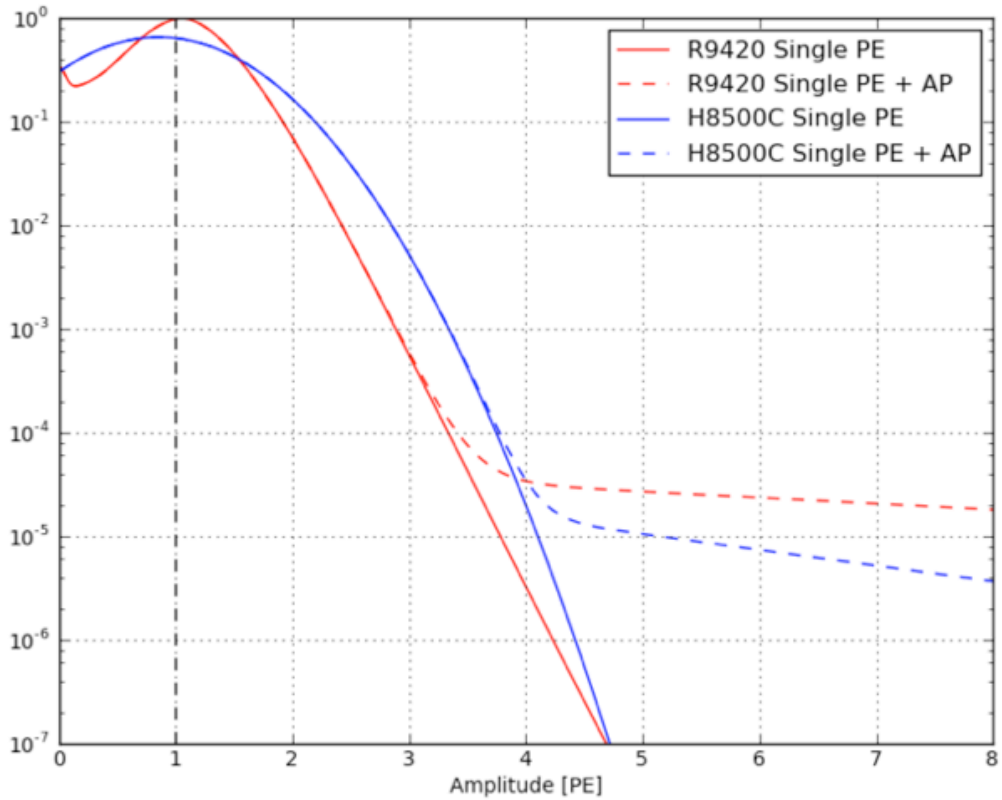
SC





Camera: memo & what is simulated

> PMTs characteristics



Distribution of the amplitude of single-pe pulse

AP rates:
$2e^{-4}$ (DC)
$1e^{-5}$ (SC)

Trigger definition

- Trigger scheme: Goal is to limit accidental (NSB) rate and preserve sensitivity at low energies
- Optimized parameters: *trigger threshold*, single-pe *pulse length*:
- DC:
  - Majority trigger 3 pixels out of 7 must exceed a threshold, central pixel must fire
  - 6ns coincidence window
  - 5.5 PE threshold: ~2kHz single-telescope accidental rate
- SC:
  - analog sum + majority trigger
  - analog sum of 2x2 pixels cluster
  - search for 3 connected cluster
    (each above a given threshold)
  - 6ns coincidence window
  - threshold 3.5 PE: ~3kHz accidental rate

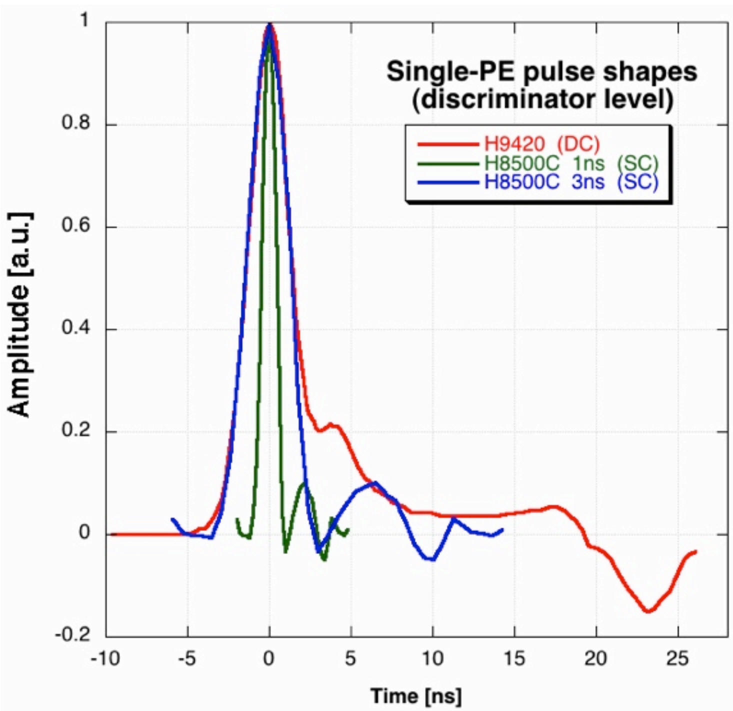
- Individual accidental NSB rate
  (dark conditions):
  - DC: 260 MHz
  - SC: 13 MHz

Trigger studies: SC

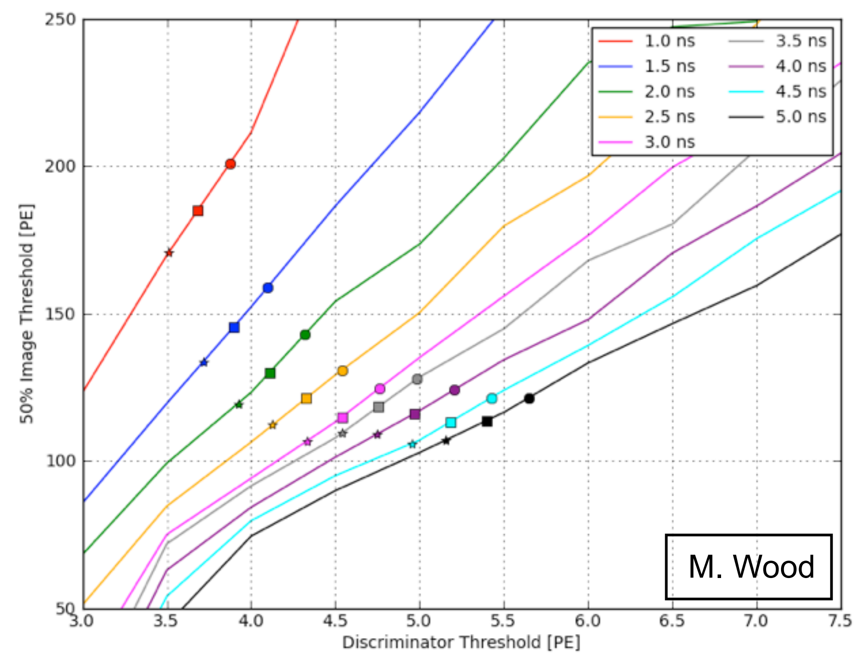
- Very quick single-pe pulse of the H8500C
- Pulse shape needed both for Trigger/DAQ

Effect of TARGET bandwidth: stretches the original pulse from 1 to 1.2ns

PMT: H8500C



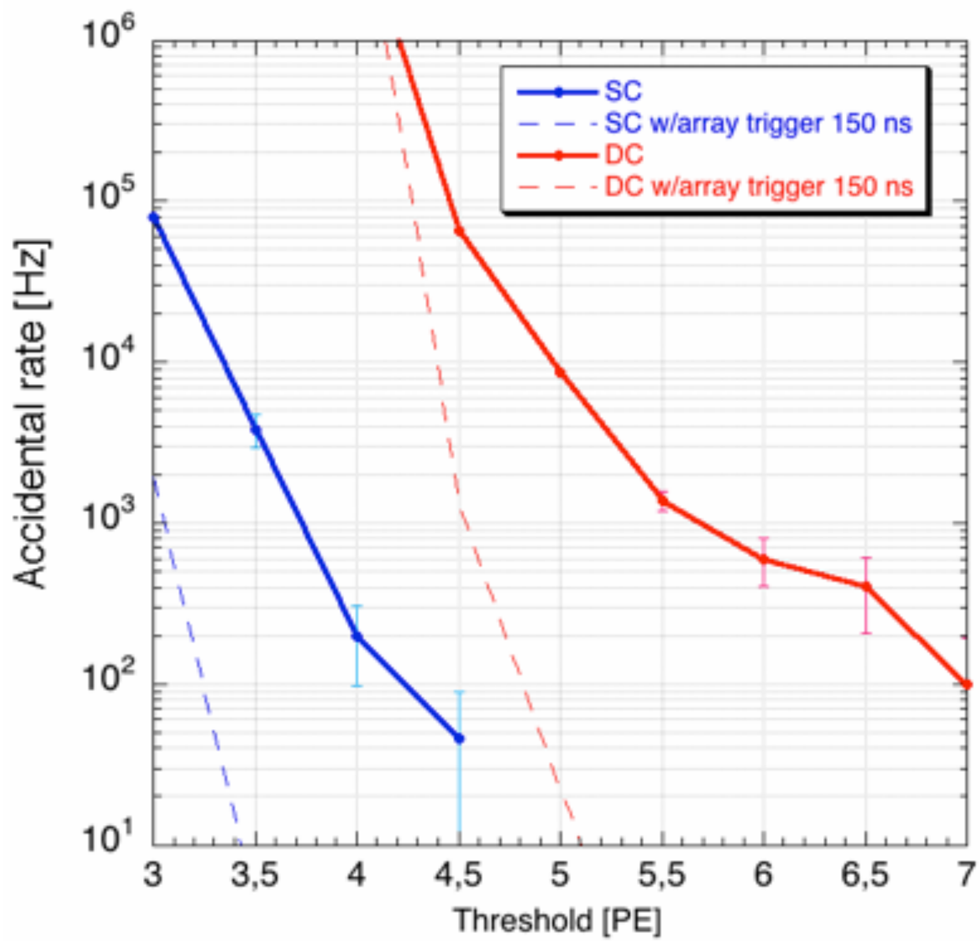
50% efficiency of the trigger vs threshold



3 markers: 1, 3 and 10 kHz accidental single-Tel rate

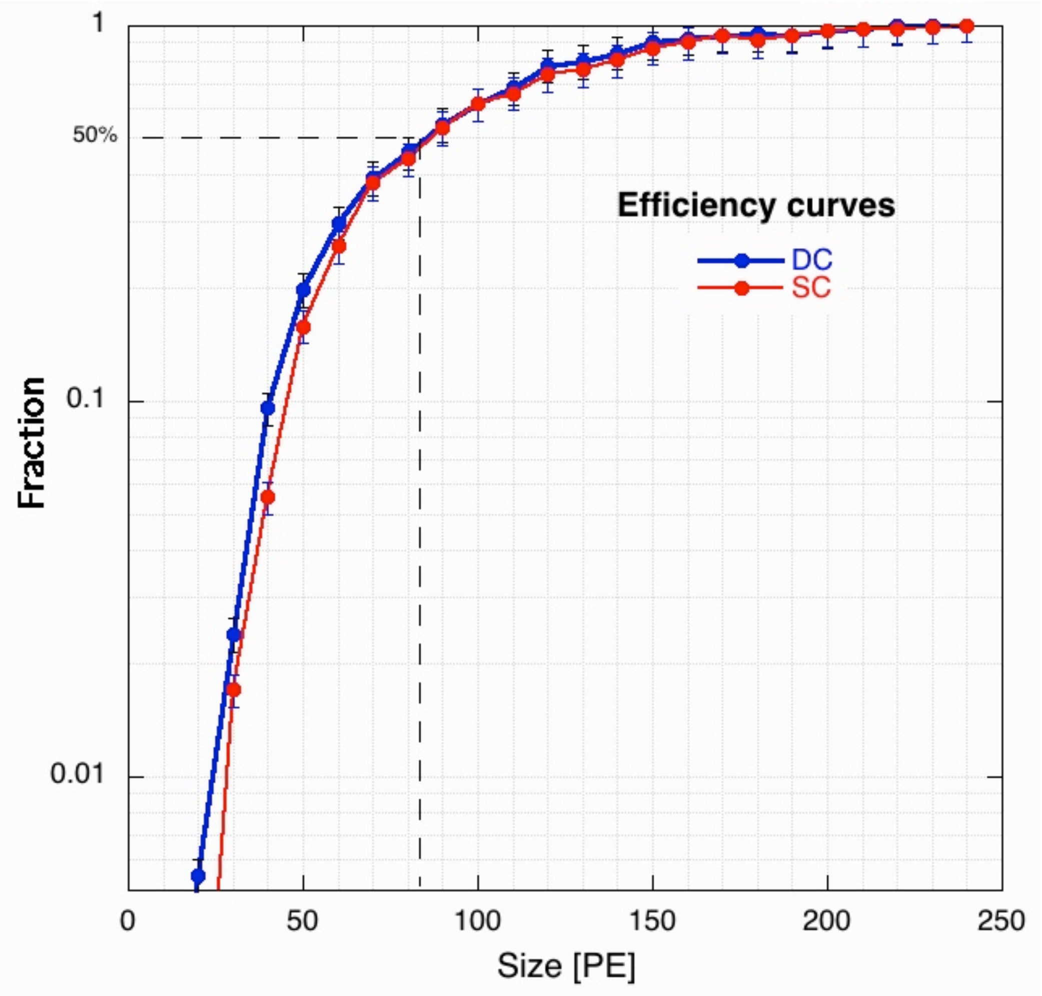
Trigger studies: SC and DC

- For Dark conditions
- Accidental rate must fall in the kHz regime



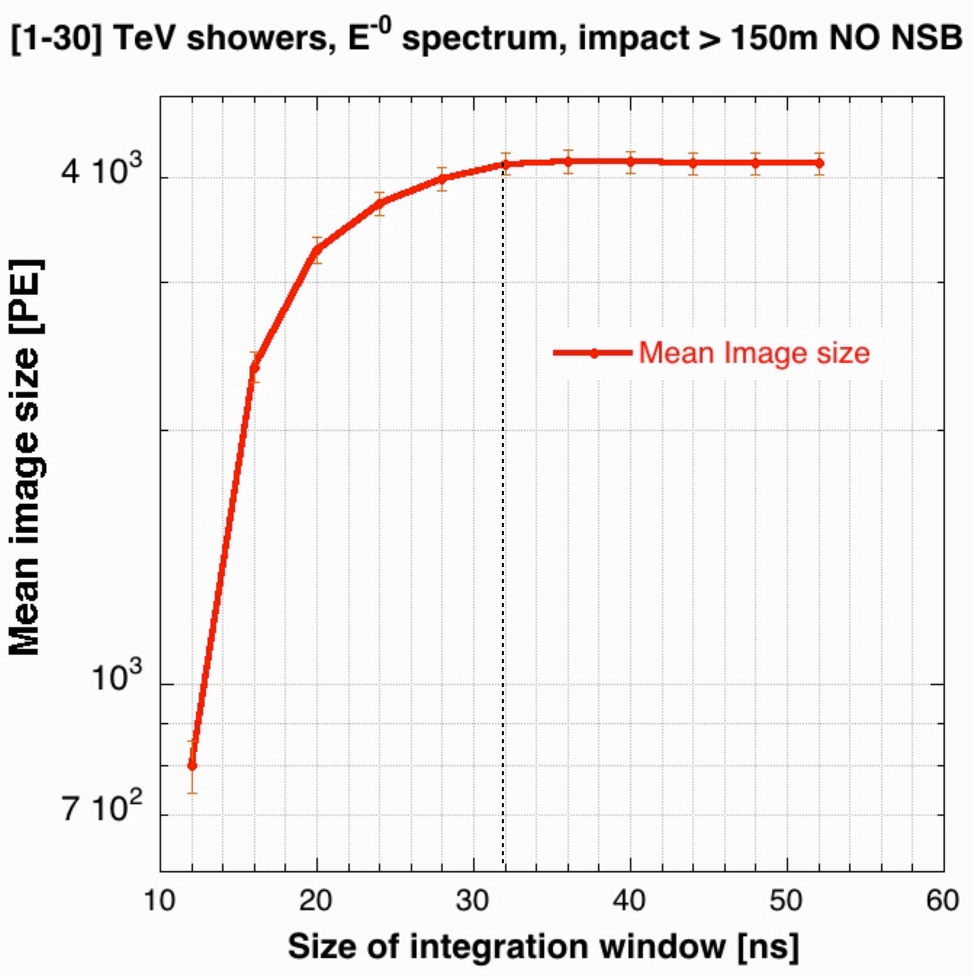
Trigger efficiency

- Comparison DC/SC
- A data set of gamma showers
  - 0-700 m impact
  - 100-10e3 GeV
  - True size (all registered PEs) of triggered images
- 50% efficiency of the trigger around 80 PEs (Reminder: SC pulse shaped to 3ns)



Readout window

- Sampled signal is readout for each pixel:
- What window size? (trade-off: data rate/disk space/loss of signal)



We picked 32ns

Analysis of the sims

- Sims available there:
  - DESY: http://styx.ifh.de/HYBRID-1-sims/ (CTA uname/pwd)
  - SLAC: http://srs.slac.stanford.edu/DataCatalog/ (account needed)
- 10^8 [10-30e^3] GeV gammas, 10^9 [30-100e^3] GeV protons, E^{-2} spectrum
- Nomenclature described on CTA wiki "Hybrid1"
  - http://www.cta-observatory.org/ctawpcwiki/index.php/Wp_mc_hybrid_config
- hessio format
- Analysis
  - convertion to root format (also available on the repository) and moment analysis with eventdisplay (better reconstruction methods soon) (DESY)
  - read_hess
- All the analyses are designed to assess and optimize the performances (plots of angular, energy resolutions and effective area/sensitivity)

Analysis of the sims

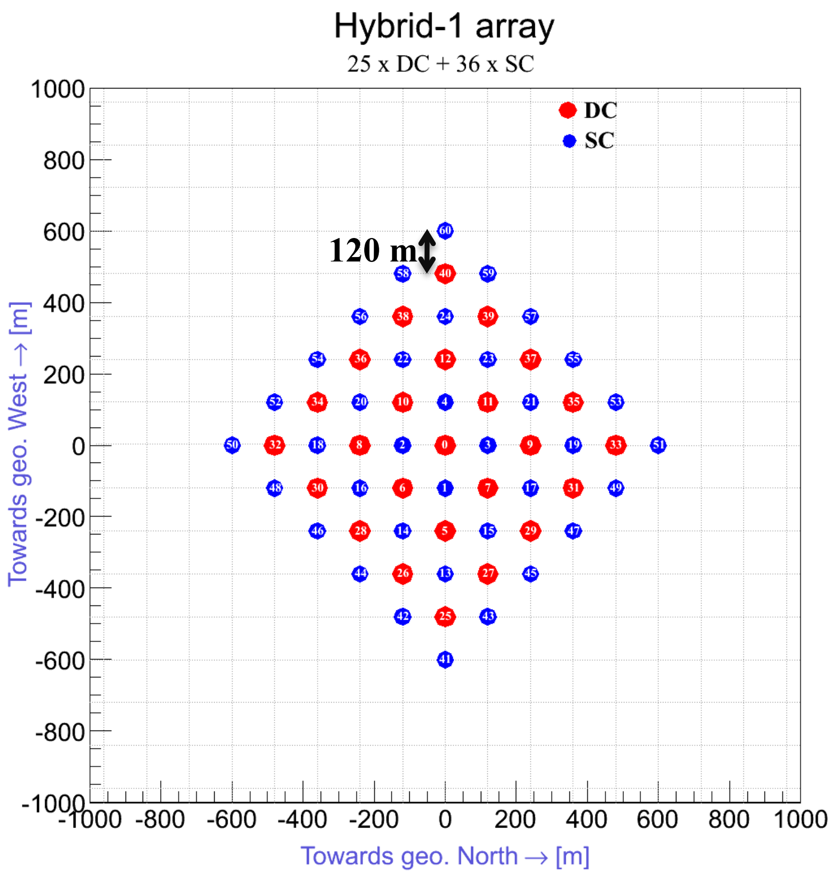
- Hillas style, with EventDisplay v400
- Reconstruction cuts/cleaning:
  - based on CTA simulations (array E)
  - telescope multiplicity (>1), image total size and number of fired tubes (>4), fraction of image lost out of the FOV etc.
  - rather loose cuts to keep flexibility, similar for DC and SC images
  - threshold/border cleaning
  - adapted for SC since NSB and size are different
- Gamma/hadron separation:
  - theta2, MSCW
- Effective areas: based on Mohanty et al. (1998)

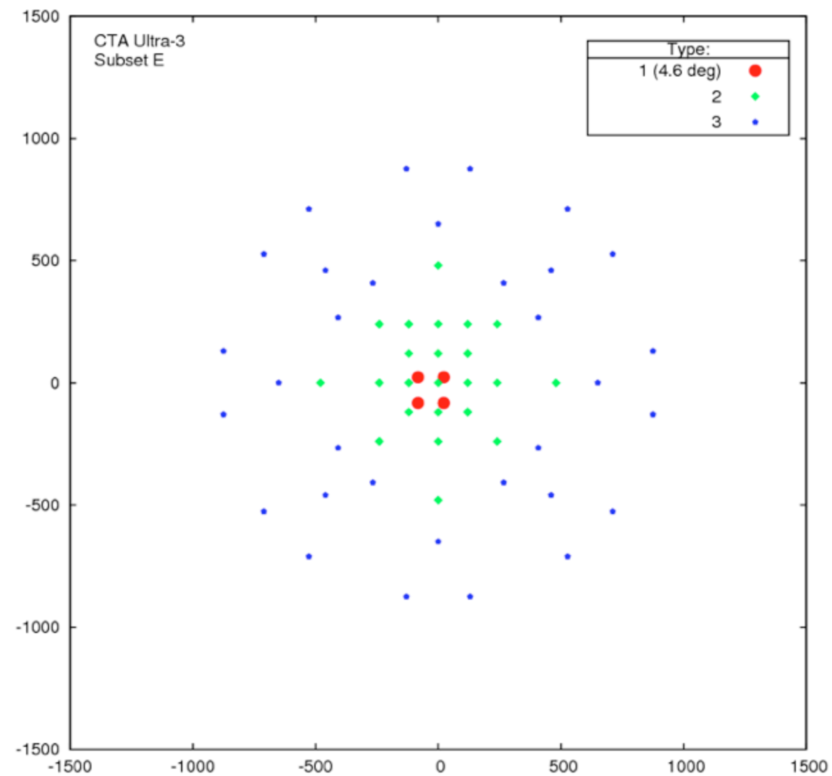
What we want to assess performances

- Angular resolution
  - for gammas from point source in the FOV center
  - for gammas from diffuse sources
- Energy resolution
- Effective areas
  - for gammas and protons
  - possibly helium, iron...
- Sensitivity curves
  - as soon as all effective areas are ready, sensitivity curves are immediate

What we want to assess performances

- I chose array E as a baseline
- ~same density + LSTs and SSTs though



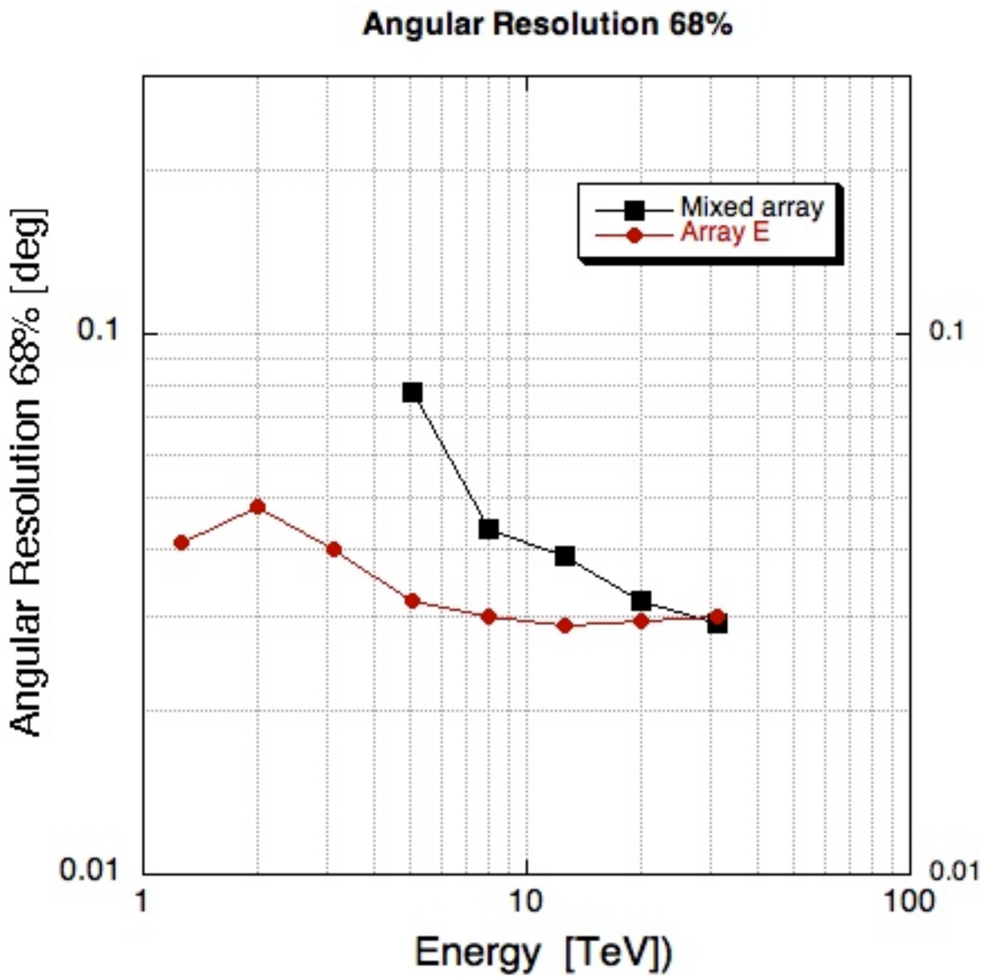


K. Bernloehr

Mixed array perfs

> Angular resolution for gamma on source

Very preliminary, need to solve the bug that prevents me to have points below 5 TeV!



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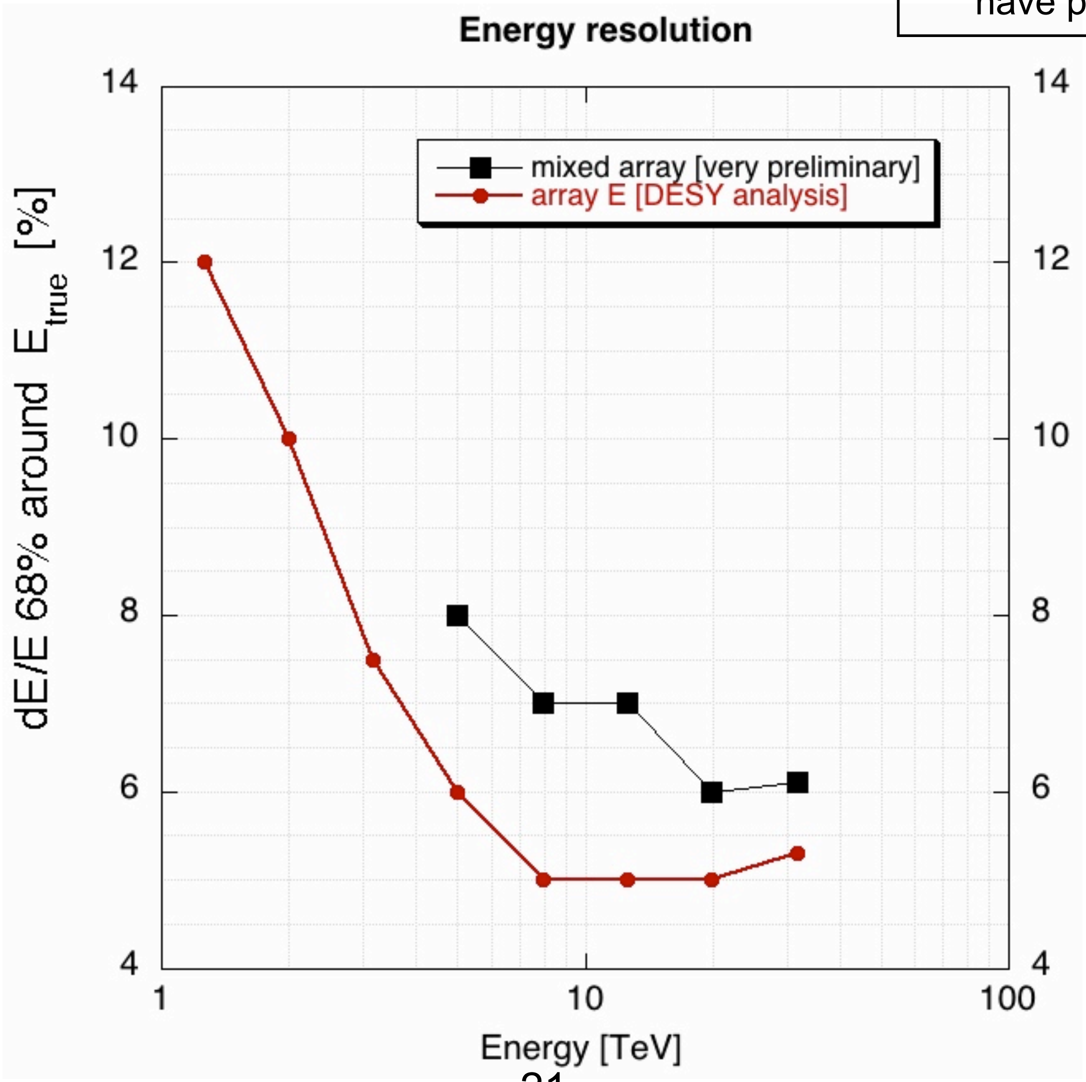


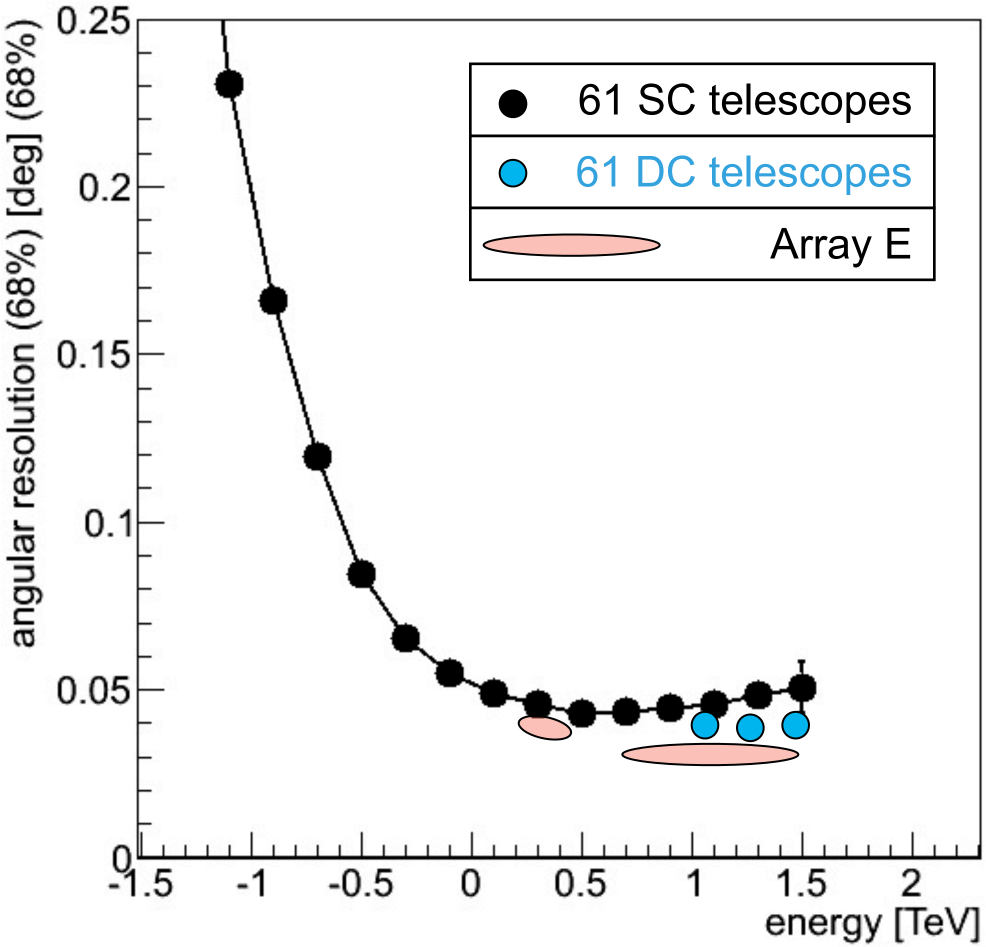
Mixed array perfs

- Sensitivity for gamma on Source

Very soon (protons jobs are
currently running at DESY)
Expect more within 1-2 weeks!

Pure-SC array perfs

> Angular resolution for gamma on source



This plot was computed 10 hrs ago, can't figure out why I have only 3 points for the pure-DC array yet

- Note that the pure-DC array analysis is much more optimized than the pure SC array
- Room for maneuver for agressive optimization
- These preliminary results are promising

Pure-SC array perfs

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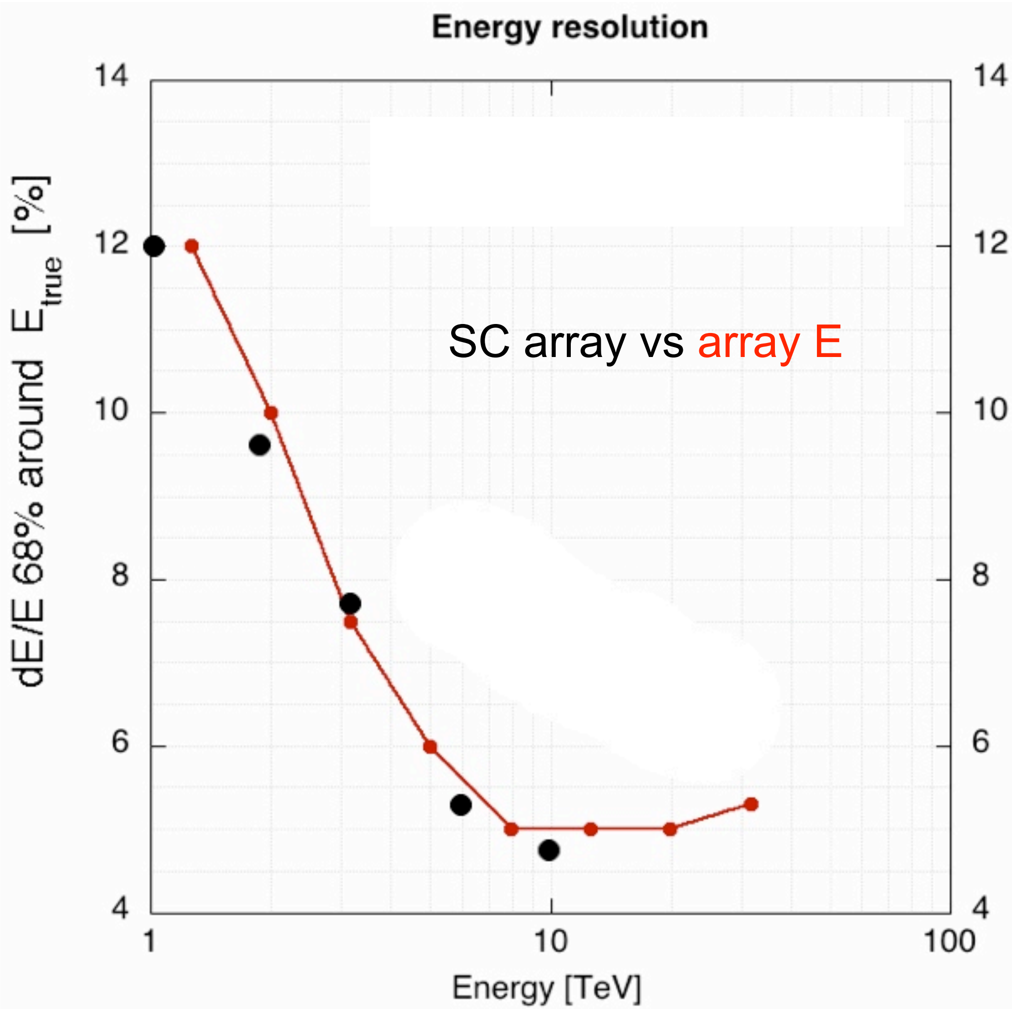

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Near future

- We have enough material to compare SC with DC in the core energy range (for low-energy range, more trigger optimization might be needed)
- Ongoing work to optimize Reconstruction (cuts/cleaning)
- To optimize the array design itself, we might then need...
  - Trigger optimization with regards to new Trigger strategies (TrigSim etc.), SiPM simulations...
  - Toy Model of Slava Bugaev (Wash U.): compare different telescope baselines and pixel sizes (allows rapid testing / optimization of different layouts, pixel sizes, etc.) ==> also represents a sanity check with Hybrid-1

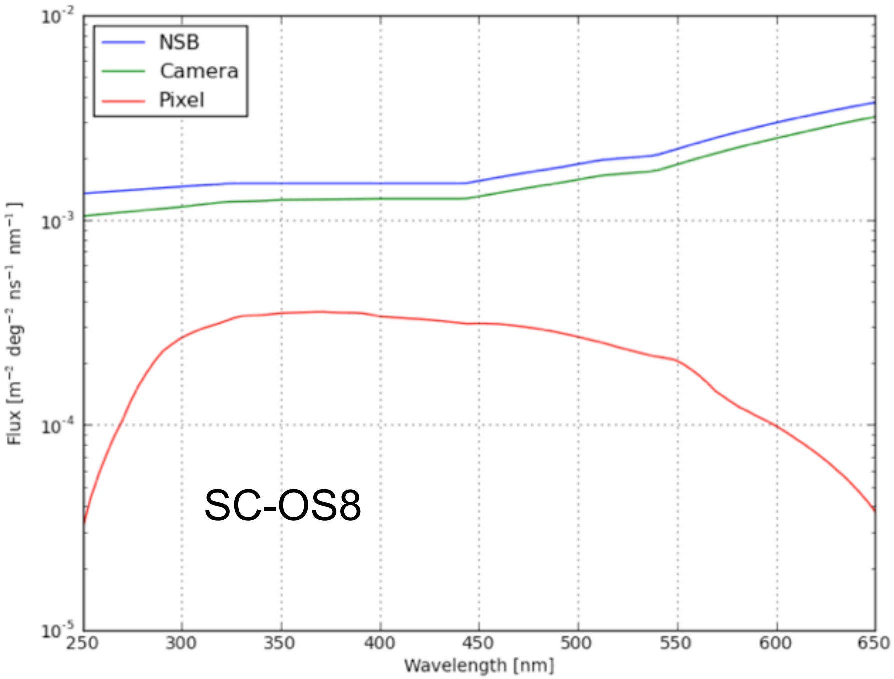
Take-home message

- First time we simulate mixed array of MSTs, some answers and general rules start to emerge
- Simulations and files are now complete and are available through http
- Simulations of a mixed array with completely non-optimized reconstruction show reasonable performances, close to std array E
- We are now able to compare DC with SC with standard image rec.
- Next step: a fair comparison below 200-300 GeV might need some trigger optimization and image cleaning optimization
- At the same time, we should switch to SiPM instead of MAPMT...
- It might make sense to use input from the Trigger specialists to setup the trigger schemes for this next round of sims (SumTrigger, *OR* trigger...)

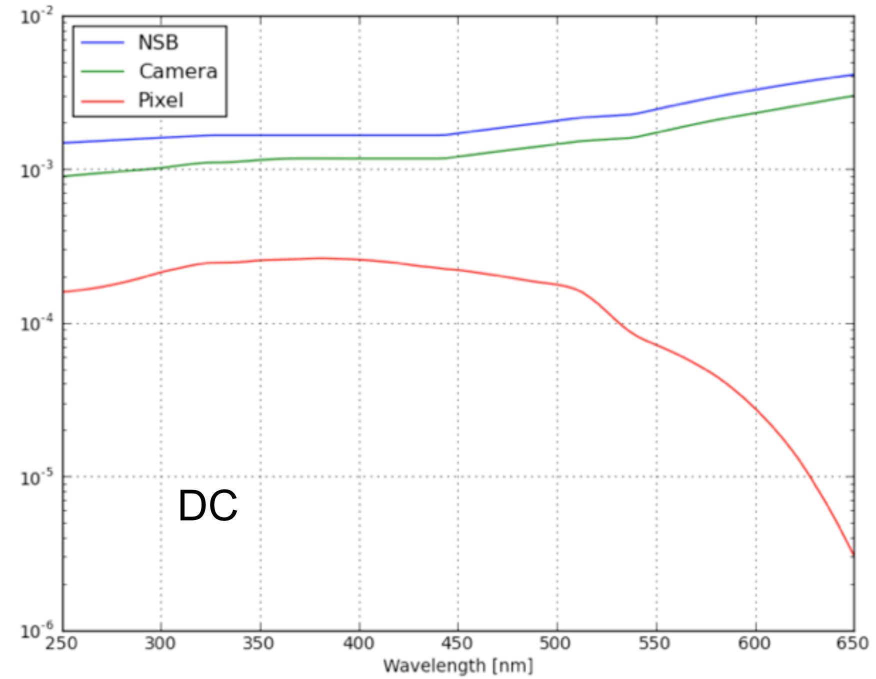
BACKUP

BACKUP

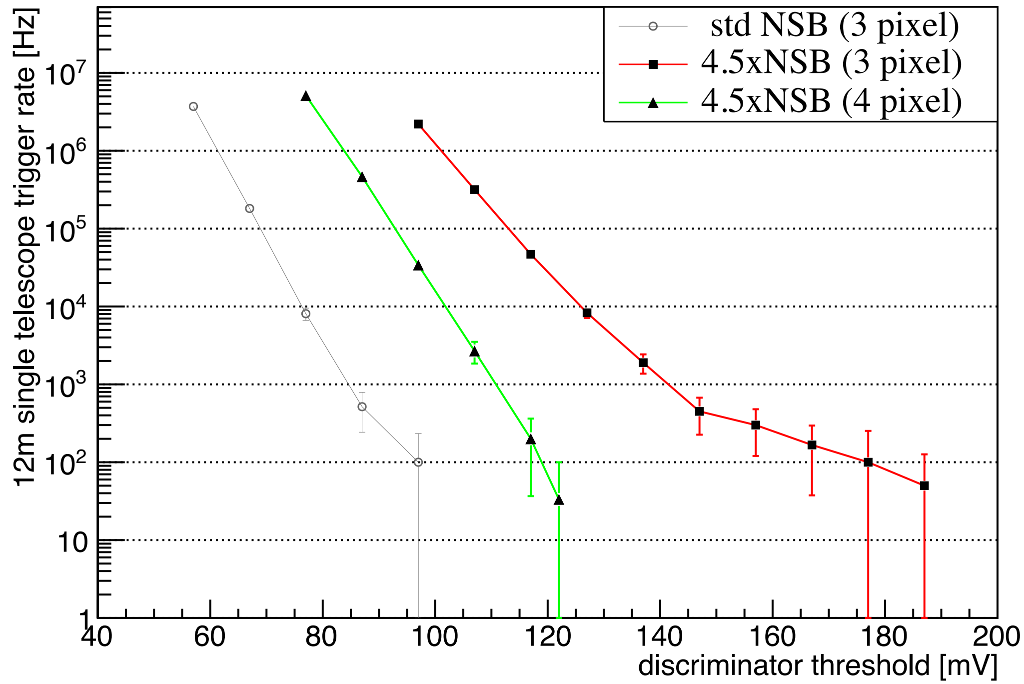
NSB flux



NSB
Camera
Pixel
SC-OS8
Flux [m⁻² deg⁻² ns⁻¹ nm⁻¹]
Wavelength [nm]



NSB
Camera
Pixel
DC
Wavelength [nm]



For comparison: the accidental rate curves in Prod1
Credits: H. Prokoph