# CTA計画
# MAGIC

Takayuki Saito (ICRR)
On behalf of CTA-Japan Consortium
And MAGIC-Japan Consortium

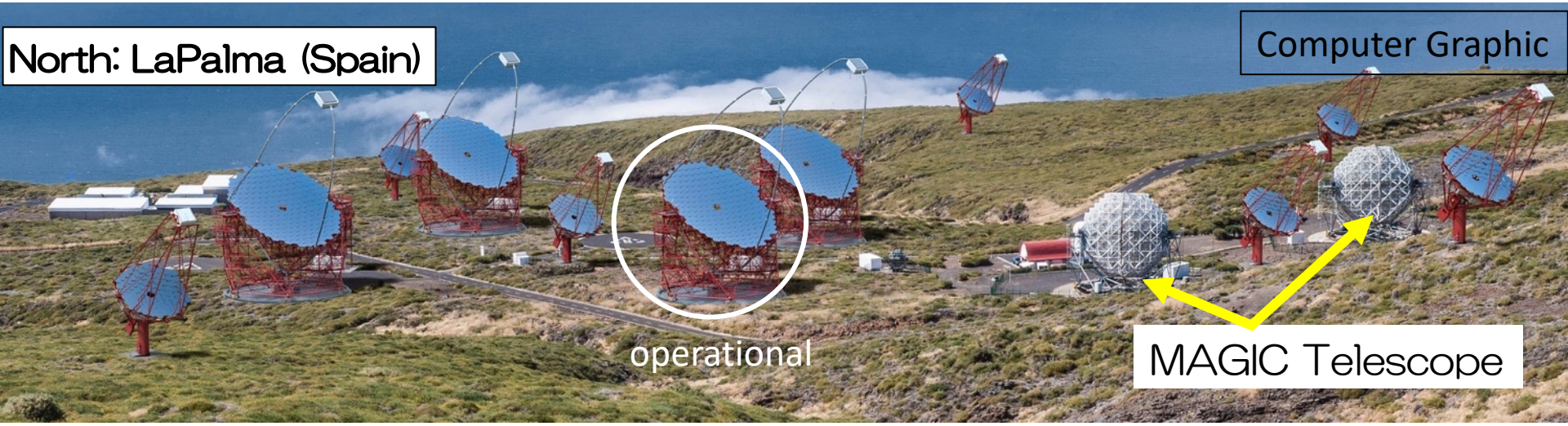
# 研究課題一覧

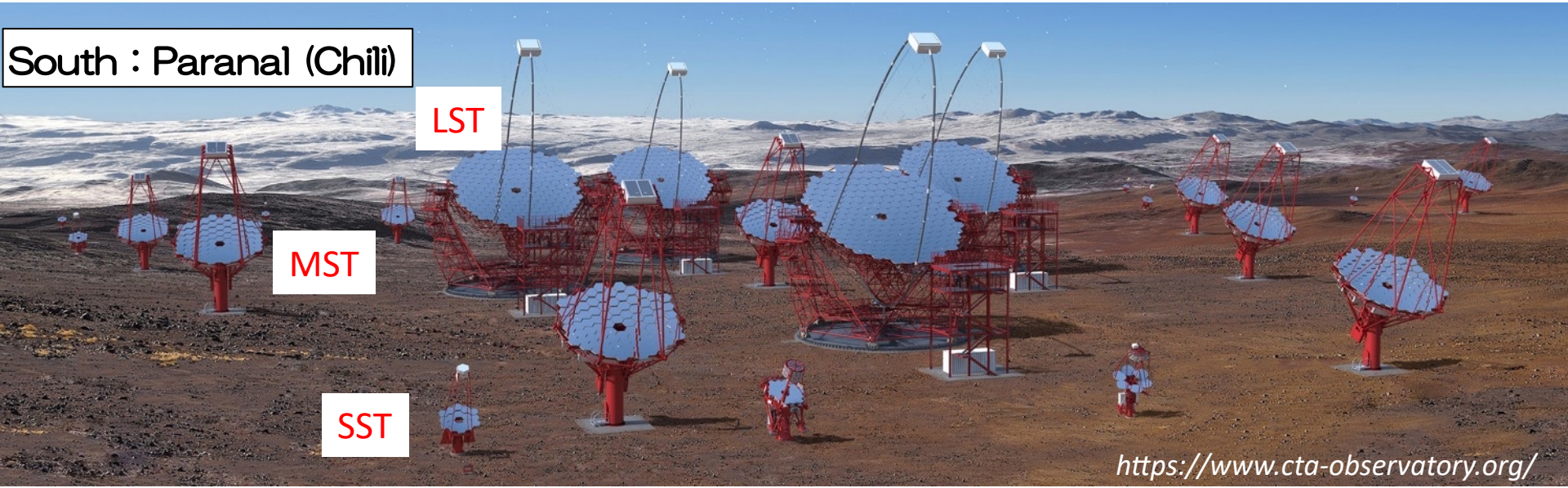
## 2020年度共同利用研究課題リスト　（4月2日運営委員会後決定）

| 部署 | メール番号 | 所属機関 | 部局名 | 職名 | 研究代表者 | 研究課題 | 新規継続 | 2020申請額（単位：千円） | | | 2020査定額（単位：千円） | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | 研究費 | 旅費 | 計 | 研究費 | 旅費 | 計 |
| C01 | 128 | 東京大学 | 宇宙線研究所 | 准教授 | 吉越　貴紀 | 明野観測所における小型大気チェレンコフ望遠鏡R＆D | 継続 | # | # | # | 29 | 67 | 96 |
| E01 | 75 | 東京大学 | 宇宙線研究所 | 教授 | 手嶋　政廣 | CTA 計画 | 継続 | # | # | # | 760 | 1,140 | 1,900 |
| E02 | 38 | 甲南大学 | 理工学部 | 教授 | 山本　常夏 | CTA大口径望遠鏡の焦点面検出器開発 | 継続 | # | # | # | 0 | 380 | 380 |
| E03 | 99 | 京都大学 | 大学院理学研究科 物理学第二教室 | 准教授 | 窪　秀利 | CTA大口径望遠鏡用読み出し回路の開発 | 継続 | # | # | # | 0 | 713 | 713 |
| E04 | 54 | 東京大学 | 宇宙線研究所 | 特任准教授 | MAZIN, Daniel | Engineering runs of the first Large Size Telescope of CTA and construction of LST2-4 in La Palma Canary Islands, Spain | 新規 | # | # | # | 0 | 428 | 428 |
| E05 | 56 | 東京大学 | 宇宙線研究所 | 特任助教 | Daniela HADASCH | Set-up and Commissioning of the onsite data center for CTA North in La Palma, Spain | 継続 | # | # | # | 380 | 0 | 380 |
| E06 | 69 | 東海大学 | 理学部 | 教授 | 西嶋　恭司 | 活動銀河核における超高エネルギーガンマ線放射領域の特定 | 継続 | # | # | # | 0 | 380 | 380 |
| E07 | 100 | 東京大学 | 宇宙線研究所 | 助教 | 齋藤　隆之 | CTA大口径望遠鏡による初期観測 | 継続 | # | # | # | 0 | 428 | 428 |
| E08 | 55 | 東京大学 | 宇宙線研究所 | 助教 | Ievgen Vovk | Development of the CTA/LST telescope control system | 新規 | # | # | # | 0 | 380 | 380 |
| E09 | 23 | 東京大学 | 宇宙線研究所 | 准教授 | 野田　浩司 | CTA大口径望遠鏡　反射鏡調整制御と電源システムの運用 | 継続 | # | # | # | 95 | 380 | 475 |
| E10 | 116 | 東京大学 | 宇宙線研究所 | 特任研究員 | 高橋　光成 | CTA大口径望遠鏡光電子増倍管の特性監視システムの開発 | 新規 | # | # | # | 0 | 380 | 380 |
| E11 | 105 | 京都大学 | 基礎物理学研究所 | 教授 | 井岡　邦仁 | CTA-Japan 物理研究 | 継続 | # | # | # | 0 | 238 | 238 |
| F02 | 124 | 茨城大学 | 理学部 | 教授 | 吉田　龍生 | 高エネルギーガンマ線でみる極限宇宙　2020 | 継続 | # | # | # | 0 | 475 | 475 |
| F04 | 107 | 名古屋大学 | 宇宙地球環境研究所 | 教授 | 田島　宏康 | CTA小口径望遠鏡用カメラの開発 | 継続 | # | # | # | 333 | 95 | 428 |
| F05 | 112 | 東京大学 | 宇宙線研究所 | 助教 | 大石　理子 | CTAモンテカルロシミュレーション | 継続 | # | # | # | 0 | 190 | 190 |
| F06 | 90 | 京都大学 | 大学院理学研究科 物理学第二教室 | 准教授 | 窪　秀利 | MAGIC望遠鏡を用いた高エネルギーガンマ線天体の研究 | 継続 | # | # | # | 0 | 475 | 475 |
| F07 | 132 | 仙台高等専門学校 | 総合工学科 | 助教 | 加賀谷　美佳 | 3次元シリコン半導体検出器を用いた電子飛跡コンプトンカメラの開発 | 継続 | # | # | # | 0 | 0 | 0 |

# Cherenkov Telescope Array

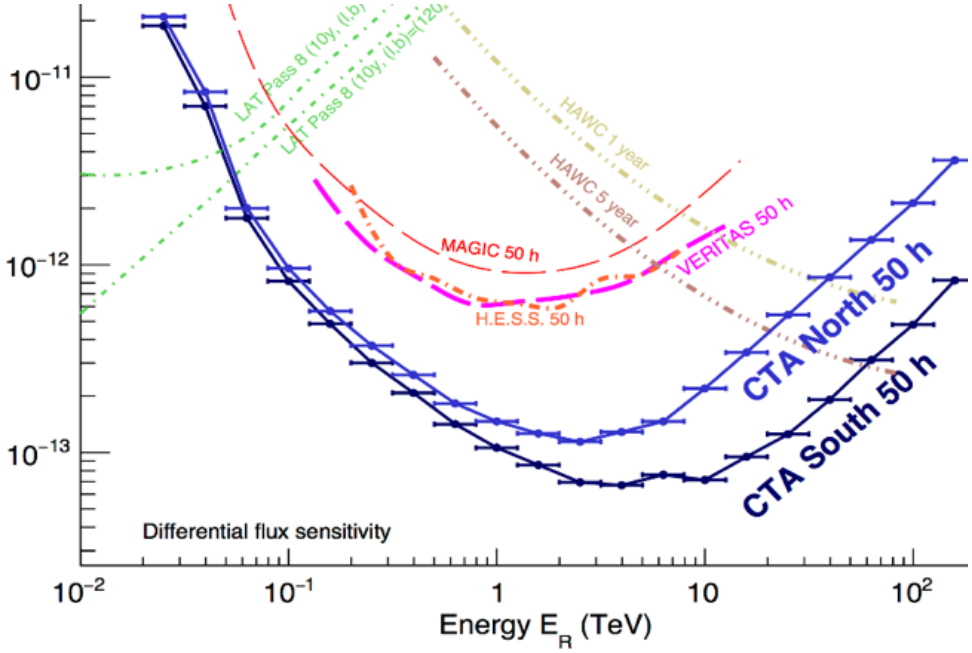
31 countries,
>1500 scientists

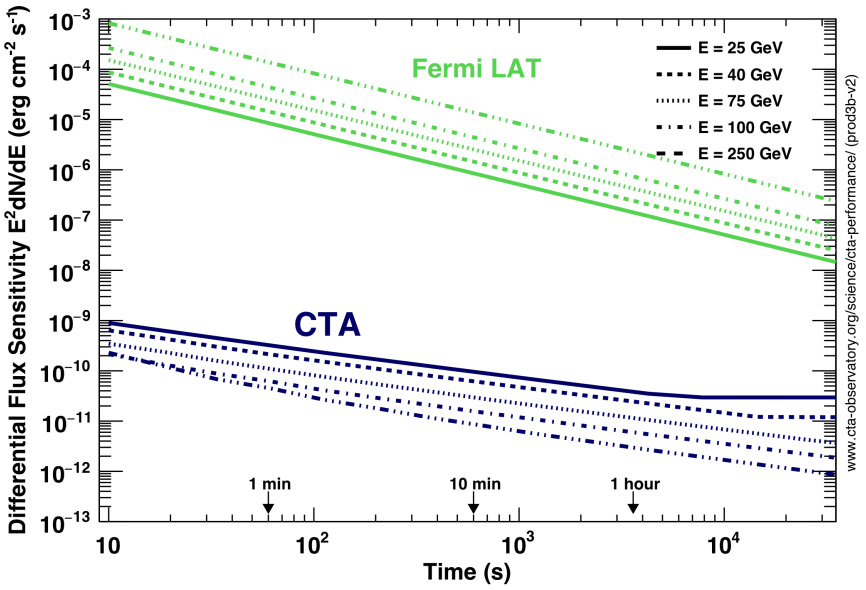


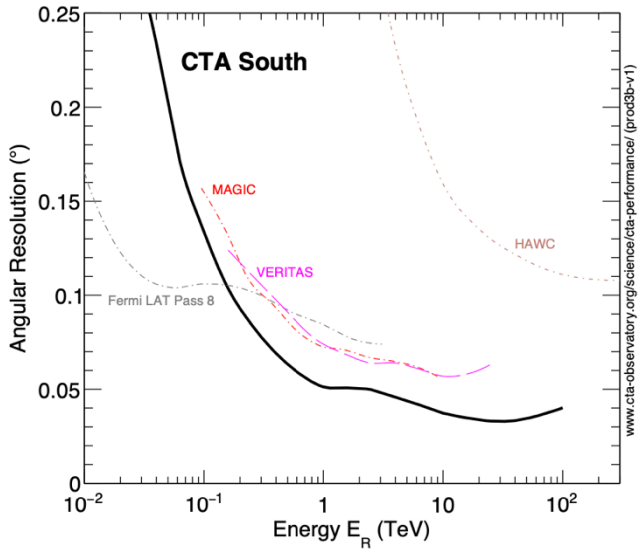




https://www.cta-observatory.org/

# CTA Sensitivity



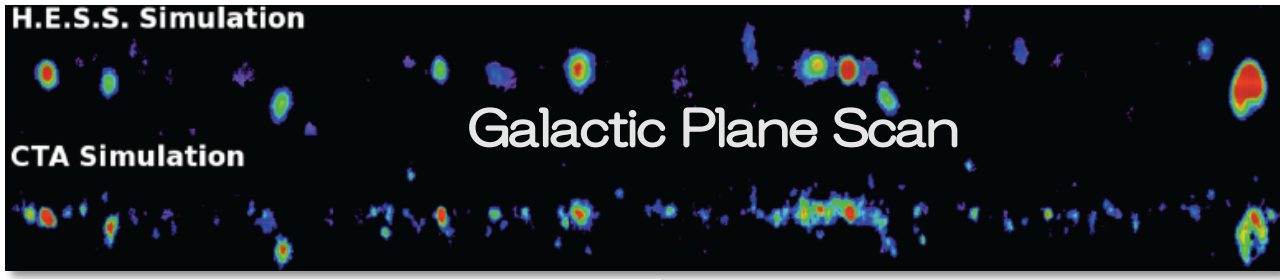

- Wide Energy Coverage from 20 GeV to > 300 TeV
- 1 order higher sensitivity
- 3 (2) arcmin angular resolution > 1 (10) TeV,

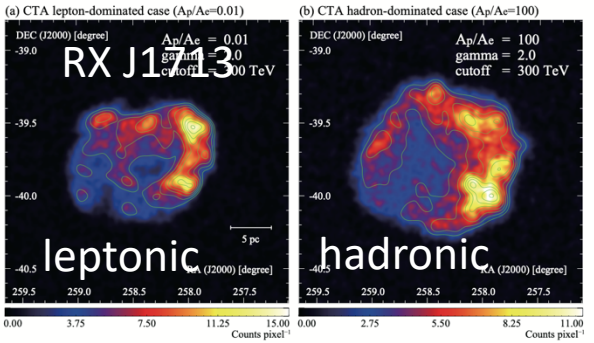
- **4-5 orders of magnitude higher sensitivity than Fermi-LAT for transient sources below 100 GeV**

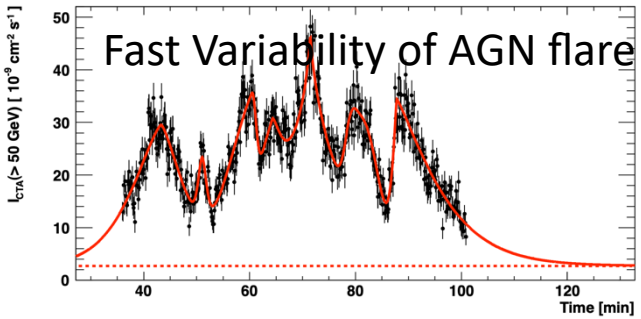
- **Detection of >1000 sources are expected**
- **Redshift up to 4 are reachable (GRB)**

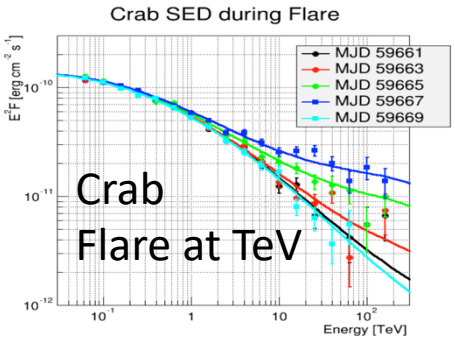
# Science with CTA

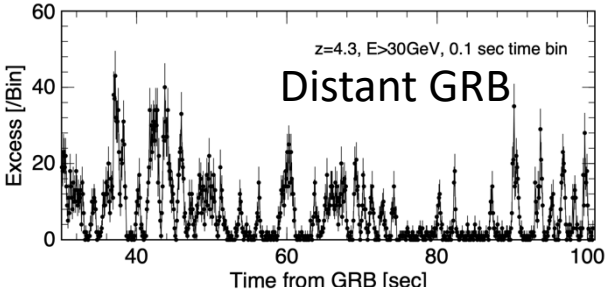
1. Understanding the origin of Cosmic Rays and their acceleration mechanism
2. Study of the physics in the vicinity of Black Hole and Neutron star
3. Contribution to the fundamental physics and cosmology using TeV photons

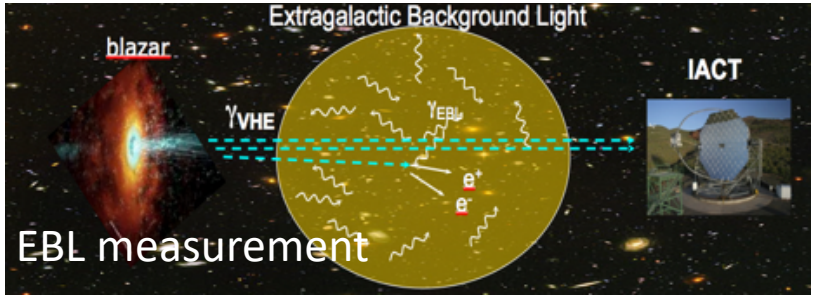


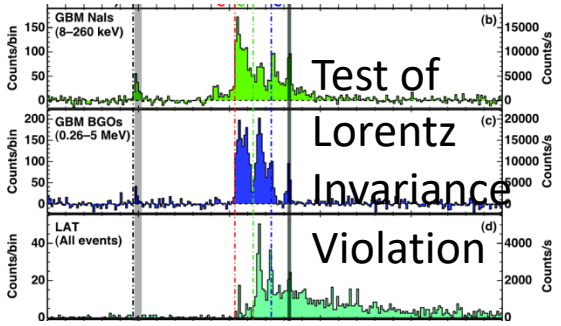



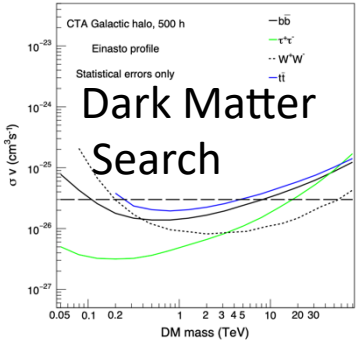



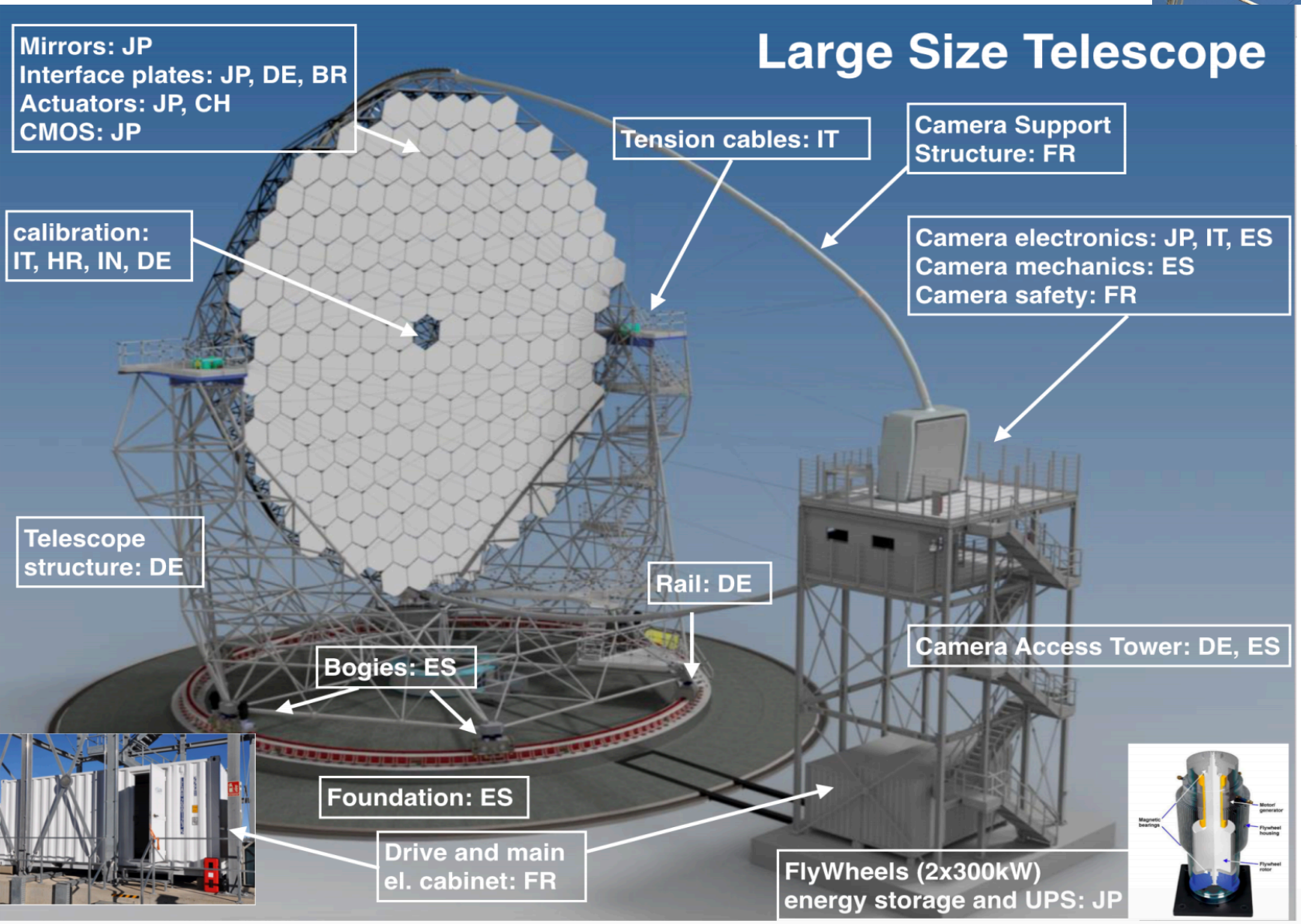



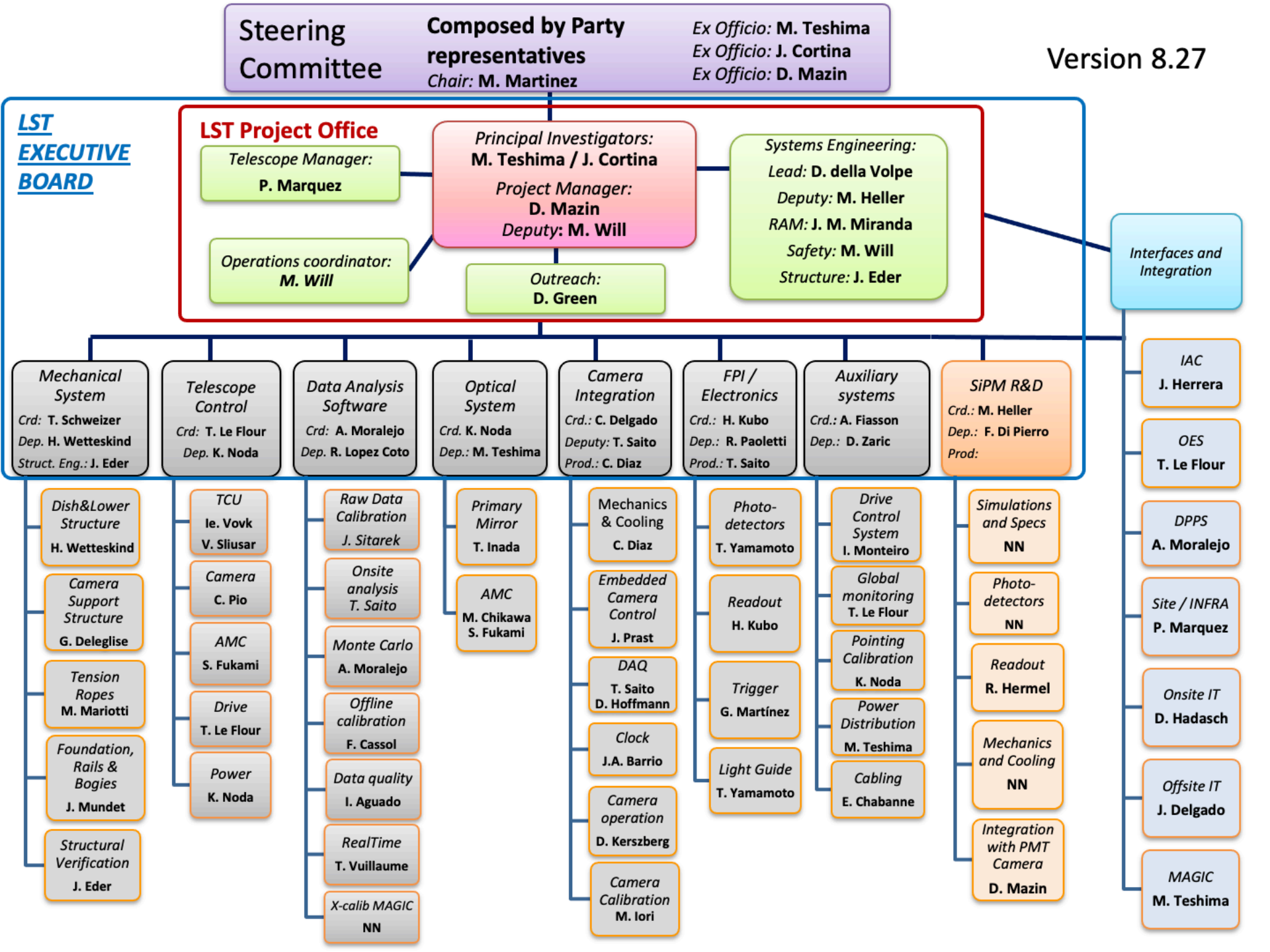



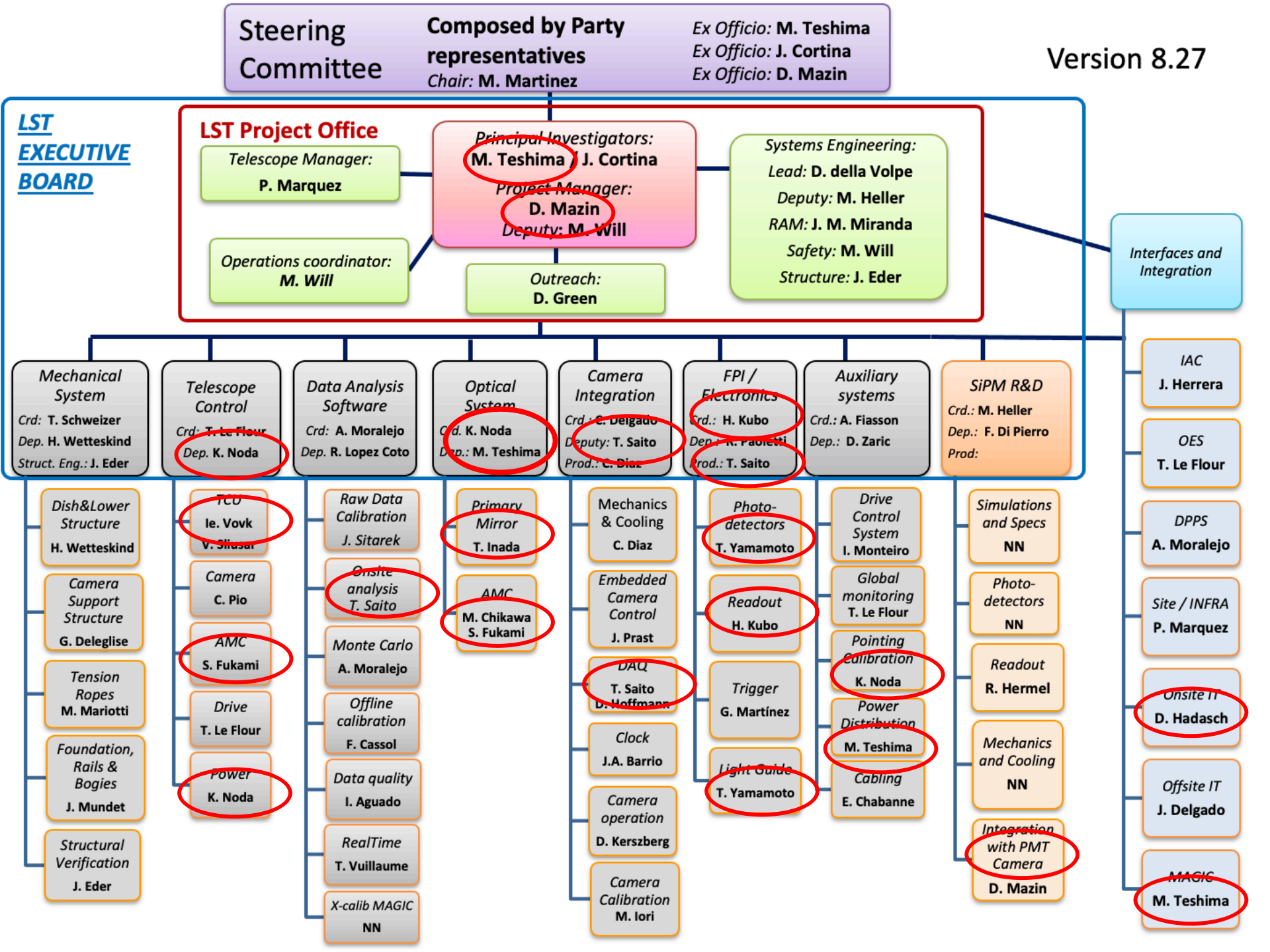



# Large Size Telescope




Steering Committee
Composed by Party representatives
Chair: M. Martinez
Ex Officio: M. Teshima
Ex Officio: J. Cortina
Ex Officio: D. Mazin
Version 8.27
LST EXECUTIVE BOARD
LST Project Office
Telescope Manager: P. Marquez
Principal Investigators: M. Teshima / J. Cortina
Project Manager: D. Mazin
Deputy: M. Will
Operations coordinator: M. Will
Outreach: D. Green
Systems Engineering:
Lead: D. della Volpe
Deputy: M. Heller
RAM: J. M. Miranda
Safety: M. Will
Structure: J. Eder
Interfaces and Integration
Mechanical System
Crd: T. Schweizer
Dep. H. Wetteskind
Struct. Eng.: J. Eder
Telescope Control
Crd: T. Le Flour
Dep. K. Noda
Data Analysis Software
Crd: A. Moralejo
Dep. R. Lopez Coto
Optical System
Crd. K. Noda
Dep.: M. Teshima
Camera Integration
Crd.: C. Delgado
Deputy: T. Saito
Prod.: C. Diaz
FPI / Electronics
Crd.: H. Kubo
Dep.: R. Paoletti
Prod.: T. Saito
Auxiliary systems
Crd.: A. Fiasson
Dep.: D. Zaric
SiPM R&D
Crd.: M. Heller
Dep.: F. Di Pierro
Prod:
Dish&Lower Structure H. Wetteskind
Camera Support Structure G. Deleglise
Tension Ropes M. Mariotti
Foundation, Rails & Bogies J. Mundet
Structural Verification J. Eder
TCU Ie. Vovk V. Sliusar
Camera C. Pio
AMC S. Fukami
Drive T. Le Flour
Power K. Noda
Raw Data Calibration J. Sitarek
Onsite analysis T. Saito
Monte Carlo A. Moralejo
Offline calibration F. Cassol
Data quality I. Aguado
RealTime T. Vuillaume
X-calib MAGIC NN
Primary Mirror T. Inada
AMC M. Chikawa S. Fukami
Mechanics & Cooling C. Diaz
Embedded Camera Control J. Prast
DAQ T. Saito D. Hoffmann
Clock J.A. Barrio
Camera operation D. Kerszberg
Camera Calibration M. Iori
Photo-detectors T. Yamamoto
Readout H. Kubo
Trigger G. Martínez
Light Guide T. Yamamoto
Drive Control System I. Monteiro
Global monitoring T. Le Flour
Pointing Calibration K. Noda
Power Distribution M. Teshima
Cabling E. Chabanne
Simulations and Specs NN
Photo-detectors NN
Readout R. Hermel
Mechanics and Cooling NN
Integration with PMT Camera D. Mazin
IAC J. Herrera
OES T. Le Flour
DPPS A. Moralejo
Site / INFRA P. Marquez
Onsite IT D. Hadasch
Offsite IT J. Delgado
MAGIC M. Teshima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MAGIC
M. Teshima

# LST: Drive

4 MJ is “stored” as a rotation energy of a flying cylinder.
It can be converted to electricity fast and efficiently.

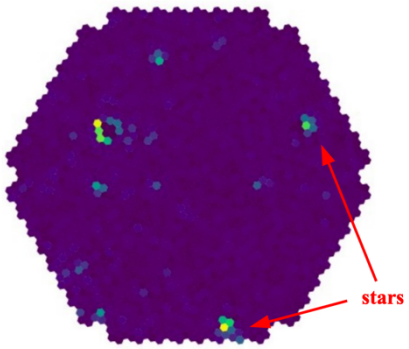
Each LST is quiped with 2 FW.

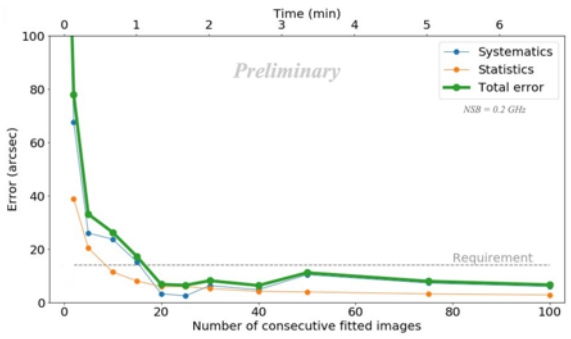
- ❑ Alt-Azimuth mount
- ❑ Steering 10t structure

- ❑ **180 degree rotation within 20 sec.**
- ❑ **This fast rotation requires a fast energy supply. “Flywheel” technology was adopted.**

## LST1 Drive Status

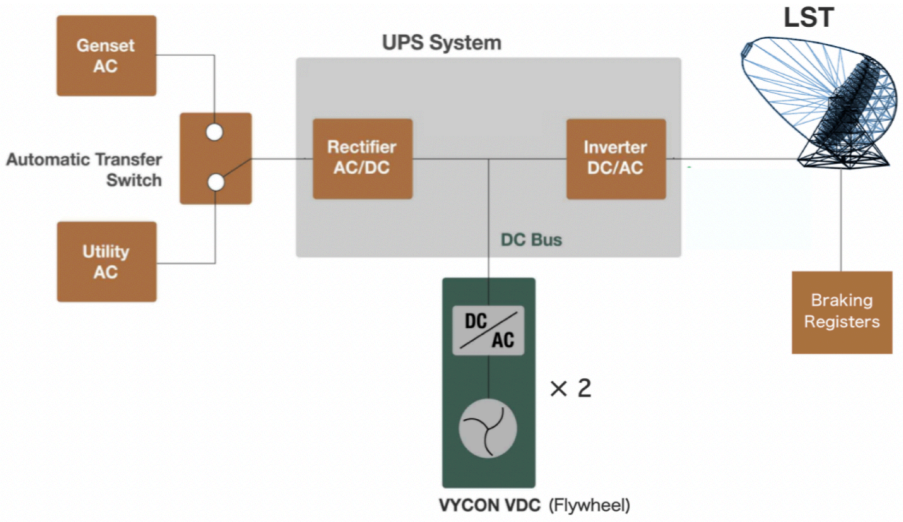
- Tracking accuracy is 2 arcmin。
- Offline correction using star images makes it 10 arcsec.
- Fast rotation has been tested.
- (but not ready to react on the GRB alert yet.)

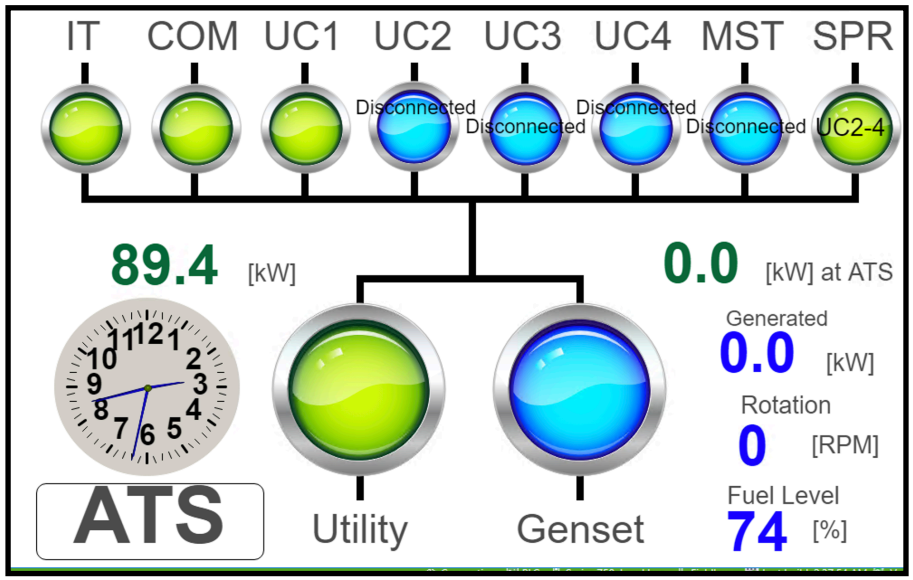


# LST: Energy status in 2020+

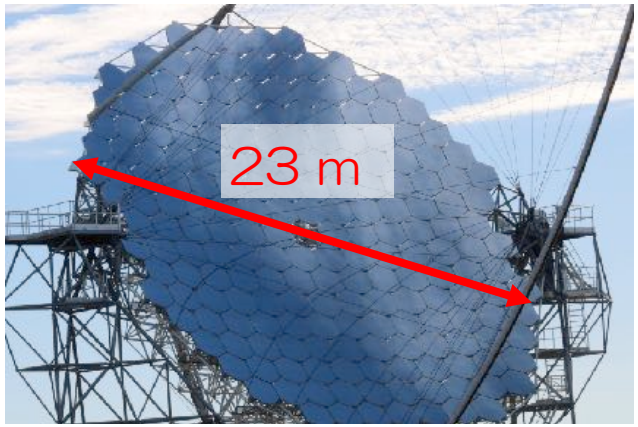
- UPS Container (UC) with two flywheels as a battery for the fast rotation (so-called GRB mode). 4 UCs for 4 LSTs procured by Japan
- Monitoring onsite (improved in the last year) not enough for checks from remote. Continuous logging became more crucial, but was unstable
  => **improved stability this year**
- Onsite monitoring of ATS/Genset improved, also **visible from remote**
- Prepared spare PLCs for monitoring (Programmable Logic Controllers)
- TBD: minor repairs and efforts for maintainability (bypassing, +1 A/C). UC2-4 will be moved to each site once the concrete pads are ready

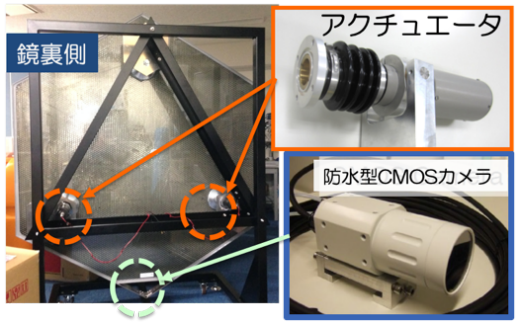


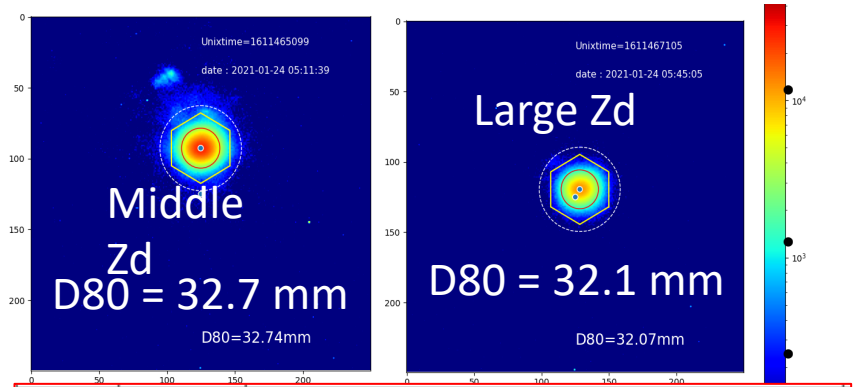




| | | |
|---|---|---|
| E09 | 野田 浩司 | CTA大口径望遠鏡 反射鏡調整制御と電源システムの運用 |

# LST: Mirror




- ***Delayed by storm and covid in Feb-May 2020,,, but significant improvements from remote for control & software***
- <u>Completed Look-Up Table mode</u>
  - Revisions of LUTs: in Aug, then after storm in Jan 2021
    - Large Zd: D80 (80%-contained diameter) was 36 mm before the revision. Improved to 32 mm.
    - Mid Zd: Pointing yet to be optimized.
  - Interpolation with low/mid/high Zd LUTs: started in Mar, tested in Aug
- Better logging: done, on the database
- Integration with Telescope Control Unit (TCU): ongoing

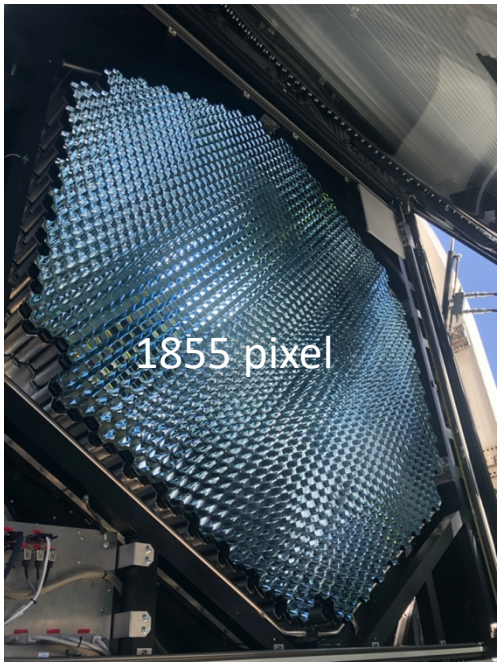
PSF measurement at off-axis in FoV: not yet. Repaired the star screen in June, improved telescope pointing in Dec. Ready now, can be done in Feb

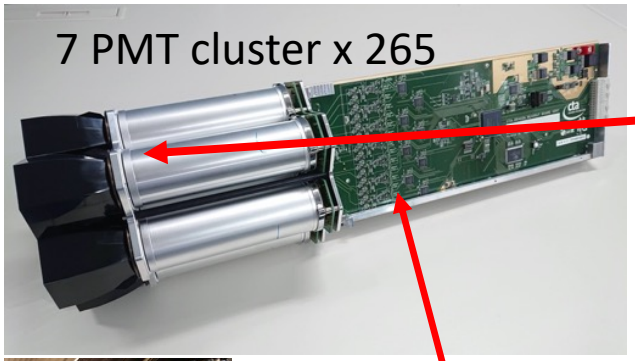
Finer adjustment with CMOS mode: In Feb and later on

Hardware upgrades for more stable LST1: purchased devices

| E09 | 野田 浩司 | CTA大口径望遠鏡 反射鏡調整制御と電源システムの運用 |
|---|---|---|

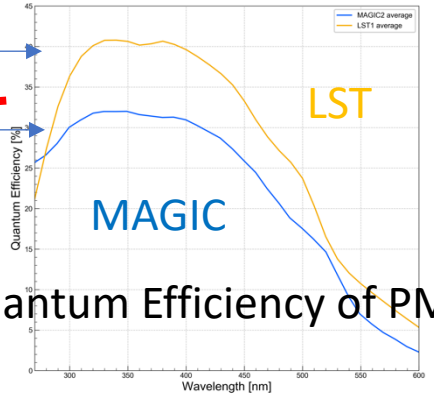
# LST: Camera



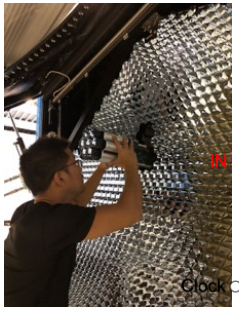



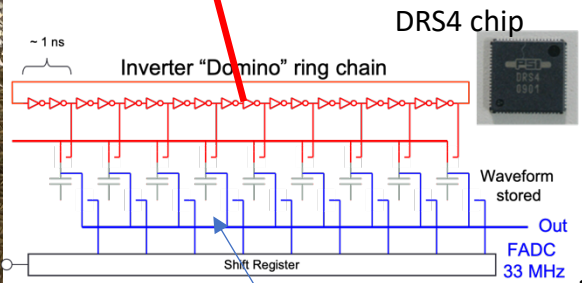

40%

30%

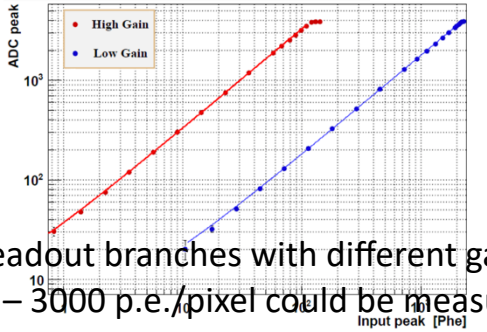



Quantum Efficiency of PMTs

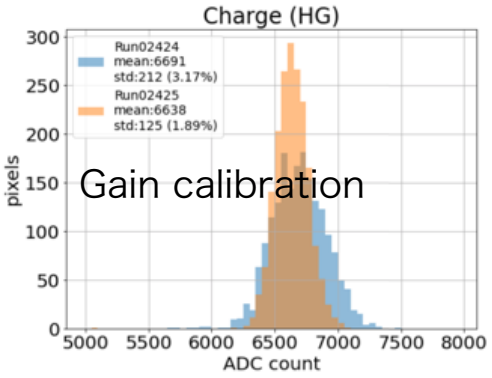


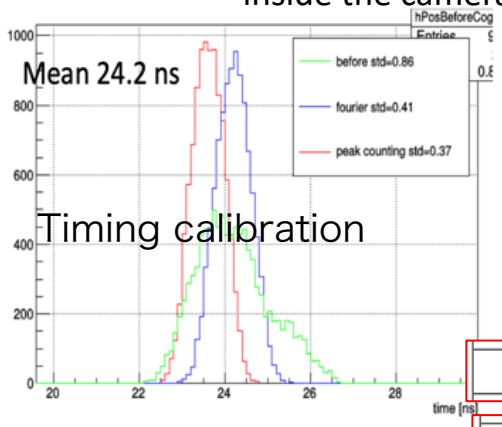

Digitize the signal waveform inside the camera.




2 readout branches with different gain.
0.2 – 3000 p.e./pixel could be measured




Bad pixels (443, 825) were excluded from calculation of mean and std. dev.

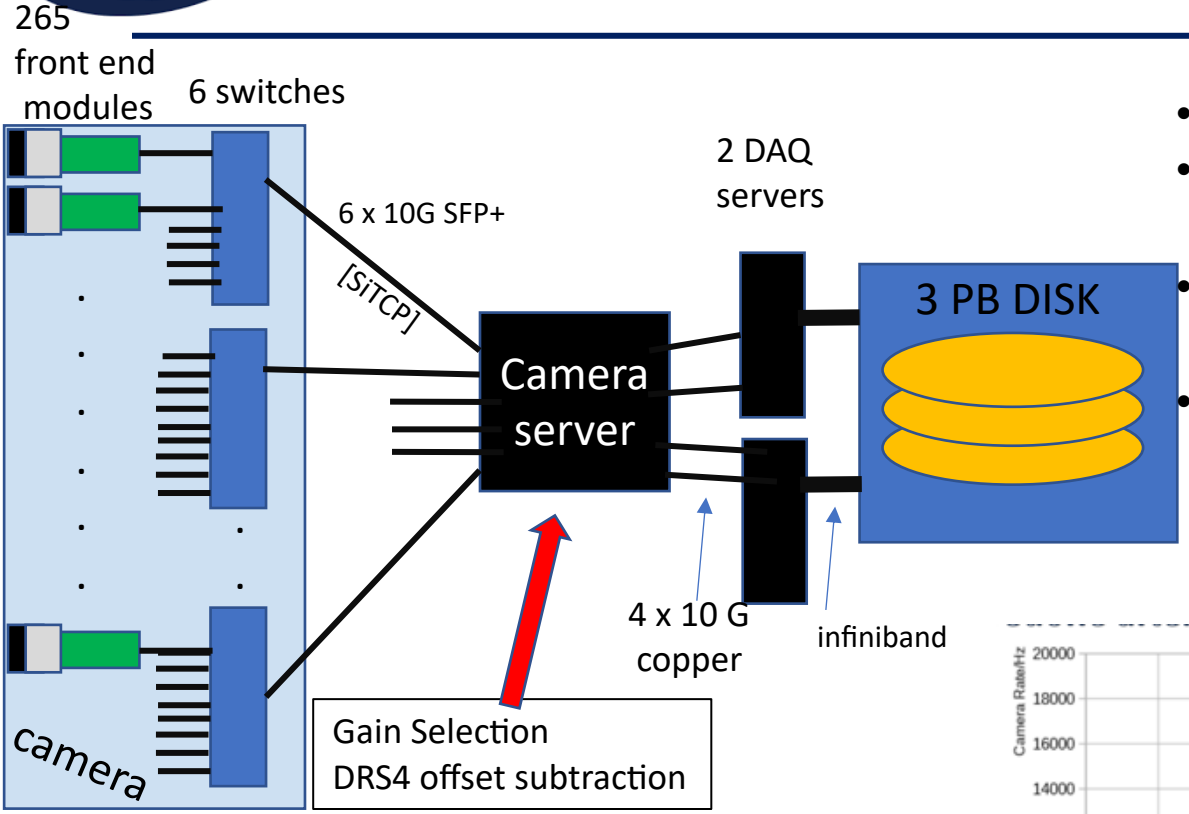



## LST1 Camera Status:

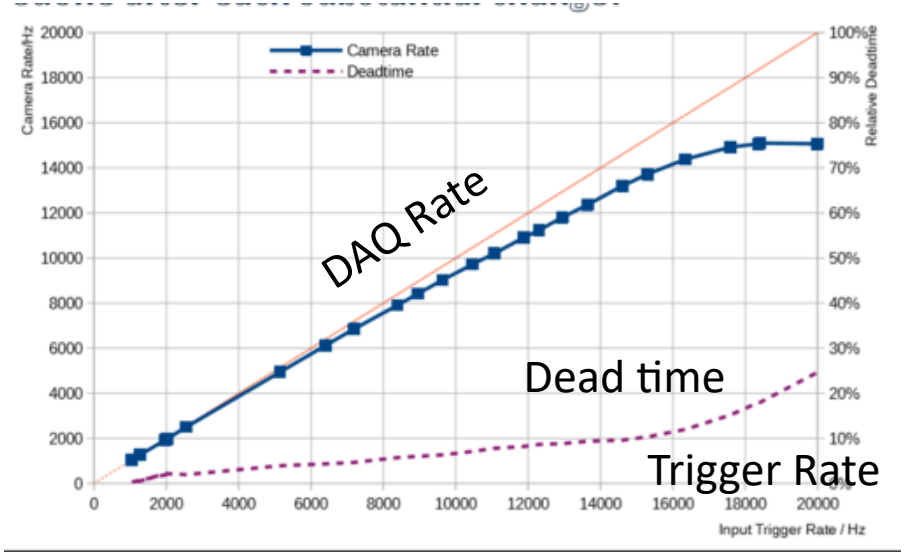
- PMT Gain calibrated within 2% precision
- Pixel timing calibrated within 0.4 ns precision
- All 1855 pixels are wokring without a problem

| | | | |
|---|---|---|---|
| E02 | 山本 常夏 | CTA大口径望遠鏡の焦点面検出器開発 | 継続 |
| E03 | 窪 秀利 | CTA大口径望遠鏡用読み出し回路の開発 | |

# LST: DAQ




- 1 event = 356 k byte.
- Hardware limit of DAQ bandwidth is 60 Gbit /sec = 7.5 GB/sec.
- Hardware limit of Trigger rate is ~21 kHz
- Requirement
  - 7.5 % dead time at 10 kHz trigger rate
  - 15 kHz DAQ should be. possible




**LST1 DAQ Status:**

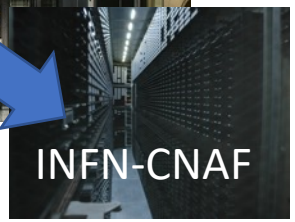
- Requirement has been fulfilled
- Data taking is possible even at 20 kHz trigger rate.

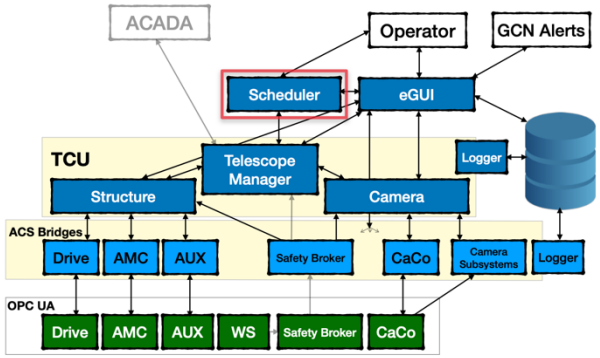
| | | |
|---|---|---|
| E03 | 窪　秀利 | CTA大口径望遠鏡用読み出し回路の開発 |

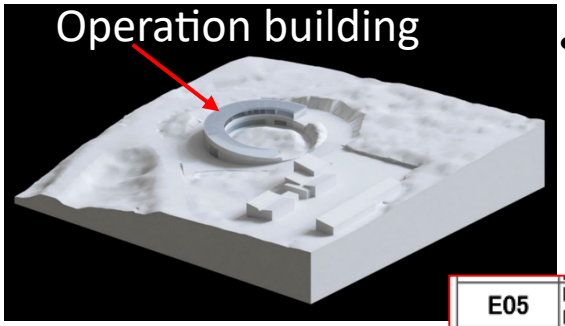
# LST: Control and Data Storage








- Tentative IT center is setup next LST1 in a container. Telescope control severs and computing servers are there.
- Total 2000 Cores, 16TB RAMS.
- 3 PB data storage disk
- Array control uses the ALMA Control Software (ACS).
- Data are temporarily stored in the local 3 PiB disk, but will be transferred to PIC/INFN-CNAF
- Operation building is being designed. It will be built in the observatory.

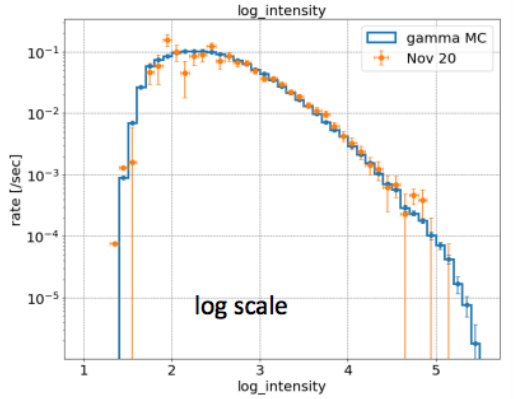


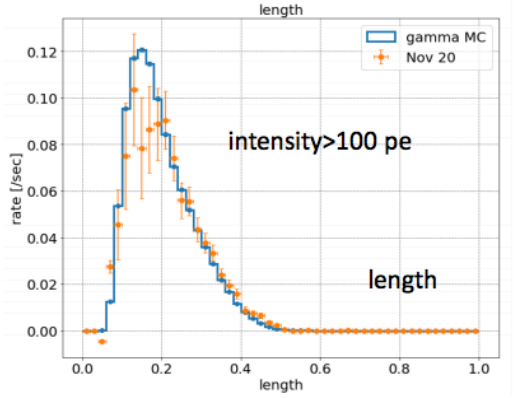
| | | |
|---|---|---|
| E05 | Daniela HADASCH | Set-up and Commissioning of the onsite data center for CTA North in La Palma, Spain |

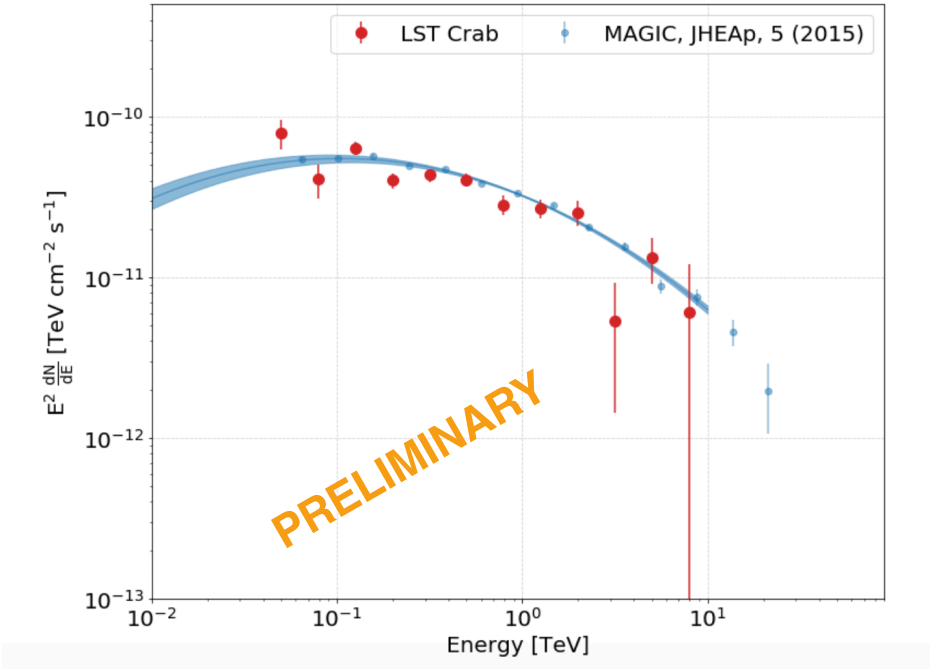
# Engineering runs

## Crab Nebula

- Crab Spectrum at the expected level
  - After tuning the MC to the telescope performance
  - In general, LST-1 is gradually approaching expectations in terms of performance



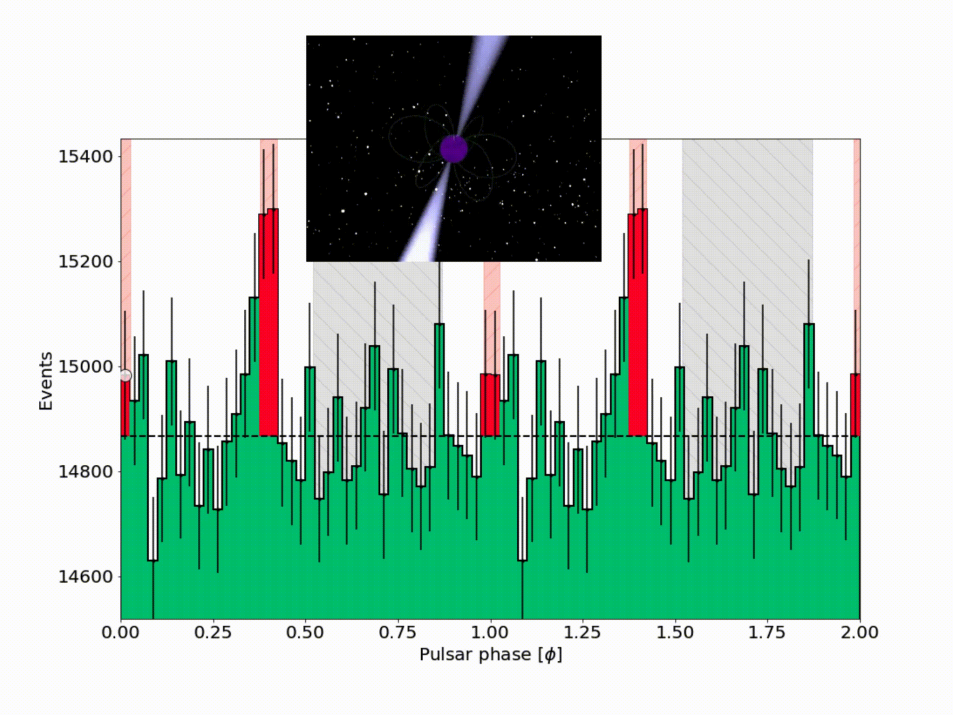



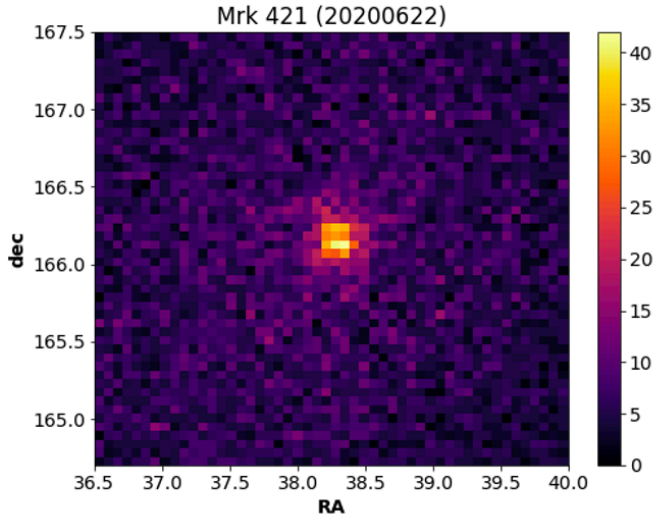

| | | |
|---|---|---|
| E04 | MAZIN, Daniel | Engineering runs of the first Large Size Telescope of CTA and construction of LST2-4 in La Palma Canary Islands, Spain |
| E07 | 齋藤　隆之 | CTA大口径望遠鏡による初期観測 |

# Engineering runs

- Crab pulsar
  - Challenging to detect a pulsar only with commissioning data (11.4 h from early 2020)
  - P2 clearly detected with significance 5.2 σ




- AGNs
  - Follow-up observations of flaring sources
  - Already detected Mrk 421, Mrk 501, 1ES J1959+650, 1ES 0647+250 (likely the most distant source detected by the LST)



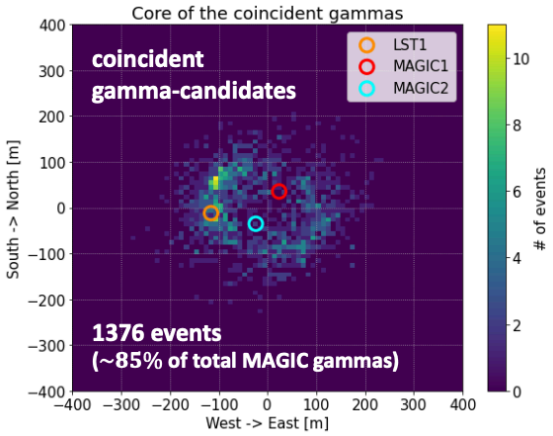

| | | |
|---|---|---|
| E04 | MAZIN, Daniel | Engineering runs of the first Large Size Telescope of CTA and construction of LST2-4 in La Palma Canary Islands, Spain |
| E07 | 齋藤　隆之 | CTA大口径望遠鏡による初期観測 |
| E11 | 井岡　邦仁 | CTA-Japan 物理研究 |

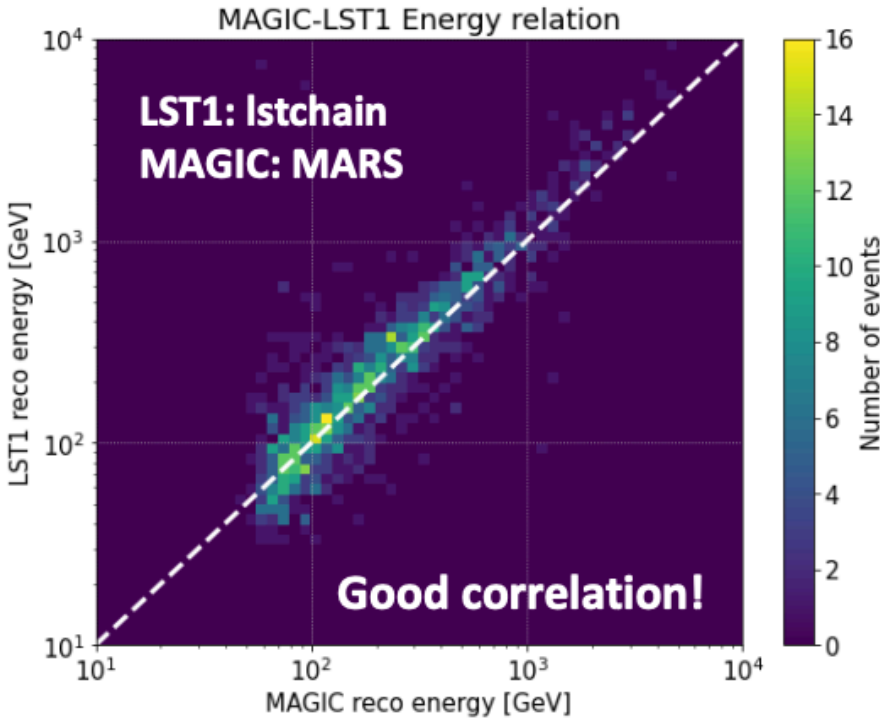
# Engineering runs

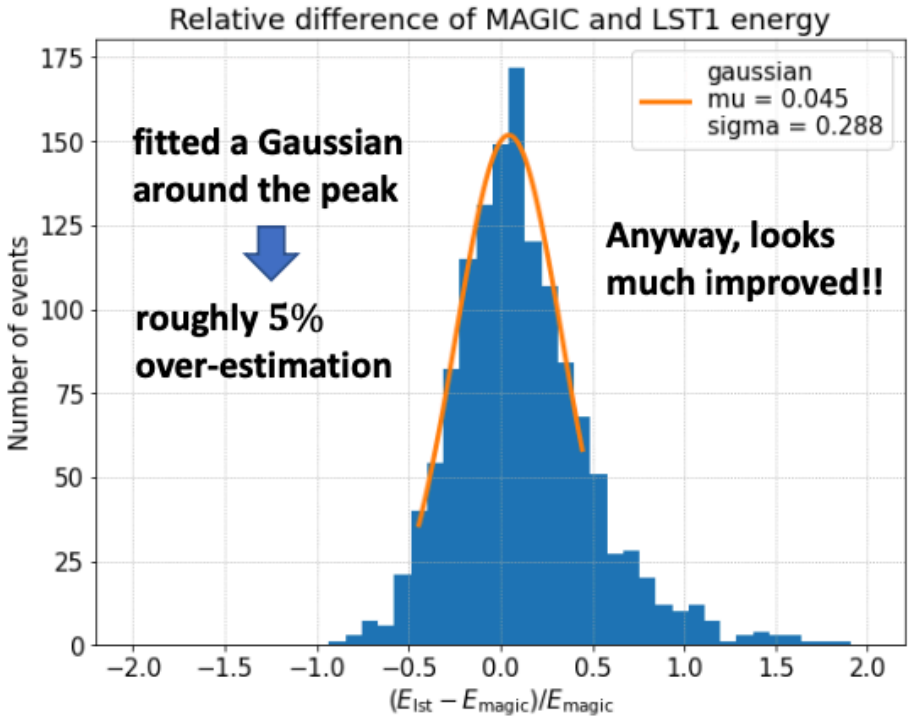
Y. Ohtani

## Cross-calibration with MAGIC

- Software stereo on Crab Nebula, 1.5h, good conditions, Jan 2020
- 1376 joint MAGIC-LST1 events survived all cuts (85% of MAGIC gamma-ray candidates)



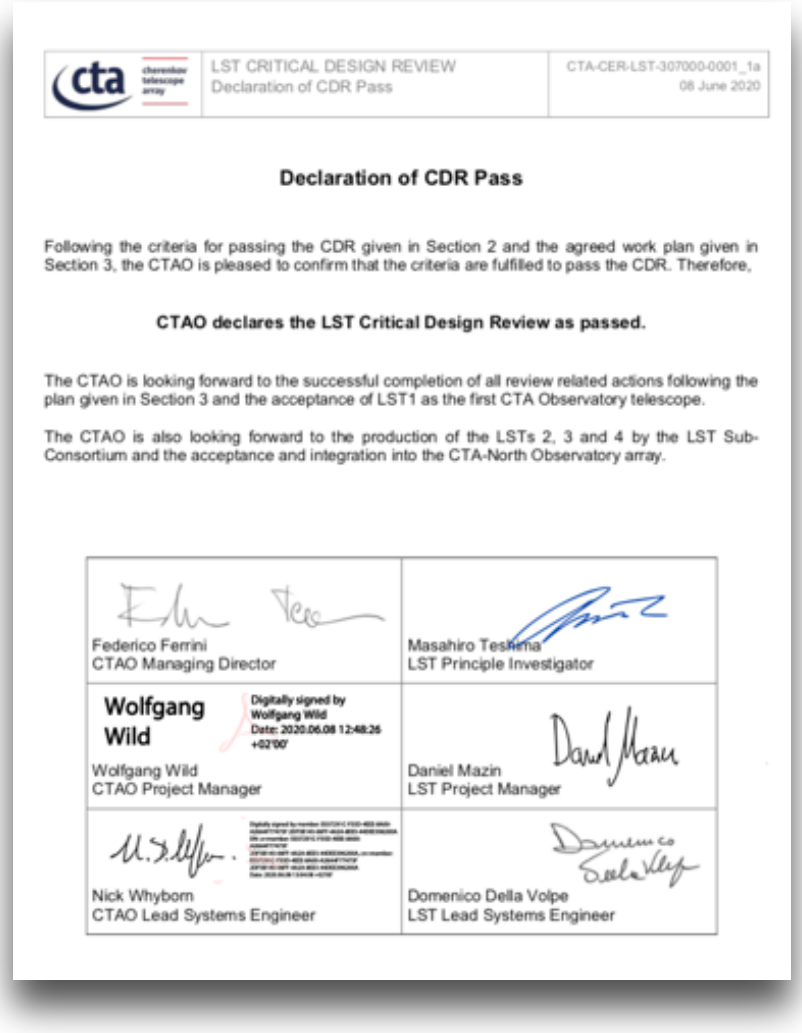



# Milestones achieved since 2019

## LST passed CDR of CTA

- Passed the CDR (Critical Design Review) through:
  - closing RIX concerning Quality Tests on CSS tension ropes
  - closing RIXs on CE assessment (means we have a plan how to do it)
  - closing RIX on Emergency Parking
  - Agreeing with CTAO on how to close other major RIXs.



LST CRITICAL DESIGN REVIEW
Declaration of CDR Pass

CTA-CER-LST-307000-0001_1a
08 June 2020

**Declaration of CDR Pass**

Following the criteria for passing the CDR given in Section 2 and the agreed work plan given in Section 3, the CTAO is pleased to confirm that the criteria are fulfilled to pass the CDR. Therefore,

**CTAO declares the LST Critical Design Review as passed.**

The CTAO is looking forward to the successful completion of all review related actions following the plan given in Section 3 and the acceptance of LST1 as the first CTA Observatory telescope.

The CTAO is also looking forward to the production of the LSTs 2, 3 and 4 by the LST Sub-Consortium and the acceptance and integration into the CTA-North Observatory array.

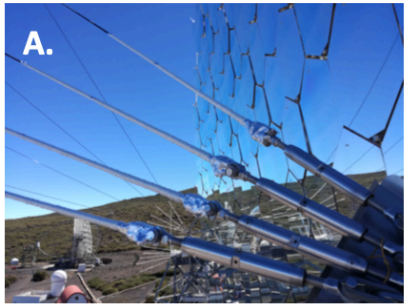
| | |
|---|---|
| Federico Ferrini<br>CTAO Managing Director | Masahiro Teshima<br>LST Principle Investigator |
| Wolfgang Wild<br>Digitally signed by Wolfgang Wild<br>Date: 2020.06.08 12:48:26 +02'00'<br>Wolfgang Wild<br>CTAO Project Manager | Daniel Mazin<br>LST Project Manager |
| Nick Whyborn<br>CTAO Lead Systems Engineer | Domenico Della Volpe<br>LST Lead Systems Engineer |

# LST1 status

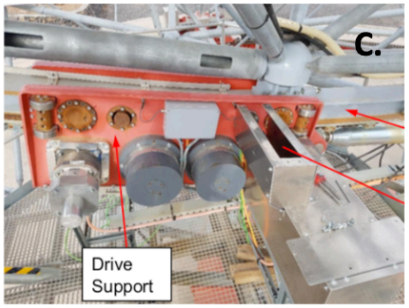
A. Protection from Sun focussing of tension ropes with glass fibre tape

B. Azimuth Locking System fully automatic

C. Elevation Locking System also automatic (being fine tuned)








**New camera shutter installed. Previous one was damaged during storm in Feb 2020**


- ➡ Better automation
- ➡ Internal PLC
- ➡ Absolute position sensor
- ➡ Springs to allow closing at any elevation (not yet installed)
- ➡ Manual control added

New Camera Shutter has been installed.

| | | |
|---|---|---|
| E04 | MAZIN, Daniel | Engineering runs of the first Large Size Telescope of CTA and construction of LST2–4 in La Palma Canary Islands, Spain |

# 課題名:CTA大口径望遠鏡光電子増倍管の特性監視システムの開発

目標　望遠鏡のエネルギー閾値に影響を及ぼす恐れのある
アフターパルス（AP）の発生頻度を監視

→ 過去の測定で夜光の暴露による発生頻度の変動が示唆

**大気圧下での頻度増加 と 夜光暴露による頻度減少はどちらが支配的？**

課題　過去の測定は暗箱を用いて実施。望遠鏡カメラ組み立て後、測定は夜光下のみで可能
**APをはるかに上回る頻度で夜光が到来するため識別が困難**（約250 MHz）

→ 到来時間の特性を利用しAPを識別
先行研究から水素およびヘリウム由来のAPが期待

結果　2020年7月に測定を実施、測定データを下に解析システムを開発

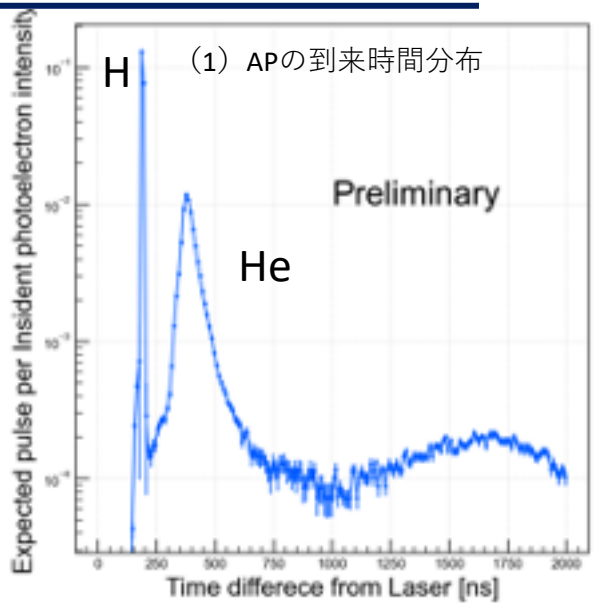
（1）時間分布：右上図のようなAPの時間構造がはっきりと確認

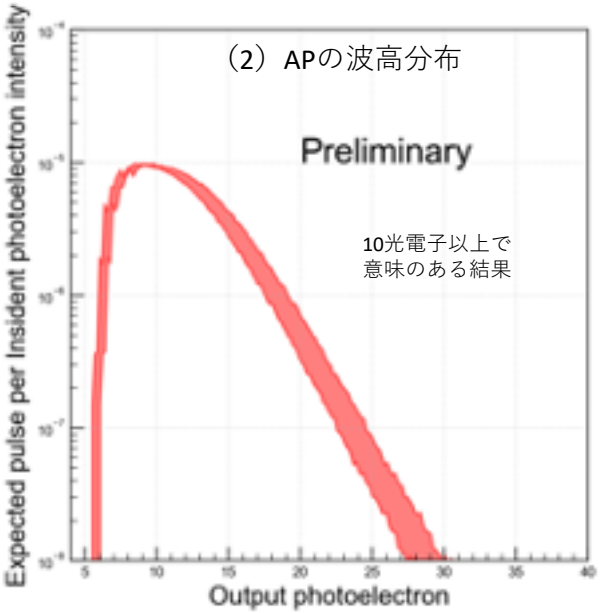
1.5 us付近のなだらかなピーク：以前から成分は未確定
Xe, Krなどの重い分子の可能性有。

（2）波高分布：ADC値から光電子数への変換の較正を確認中

展望　**測定から結果をまでのシステムがおおよそ完成**

毎月実施される望遠鏡の較正試験に組み込めるよう解析の高速化を目指す。

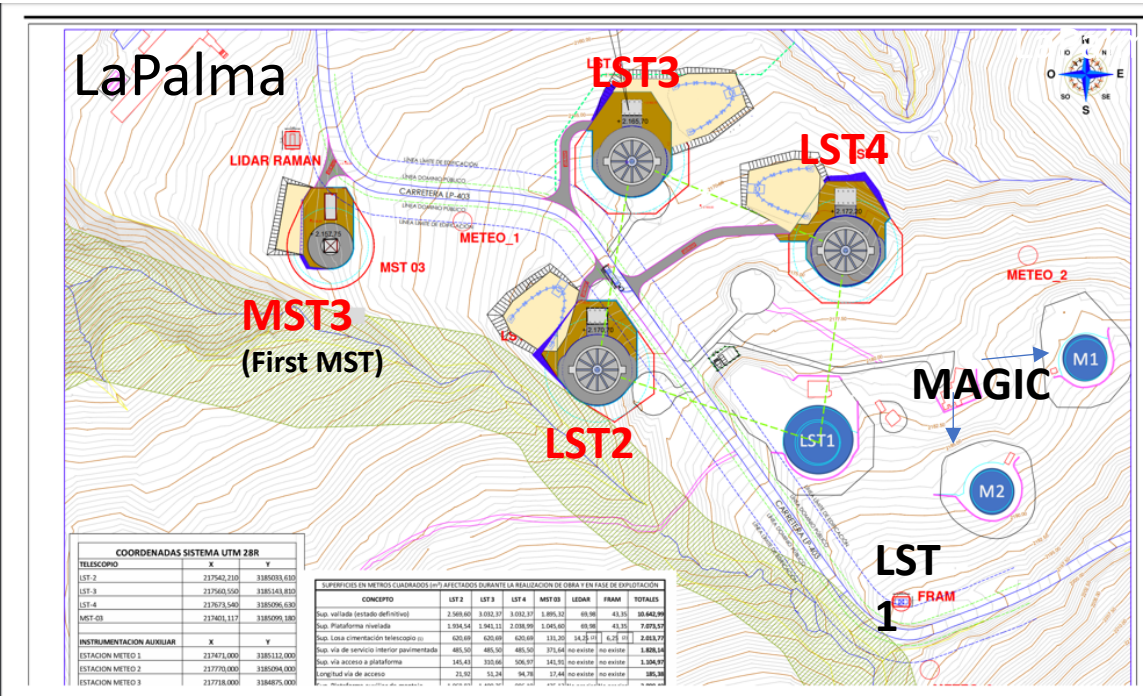



| | | | |
|---|---|---|---|
| E10 | 高橋　光成 | CTA大口径望遠鏡光電子増倍管の特性監視システムの開発 | 新規 |

# CTA North construction 2021

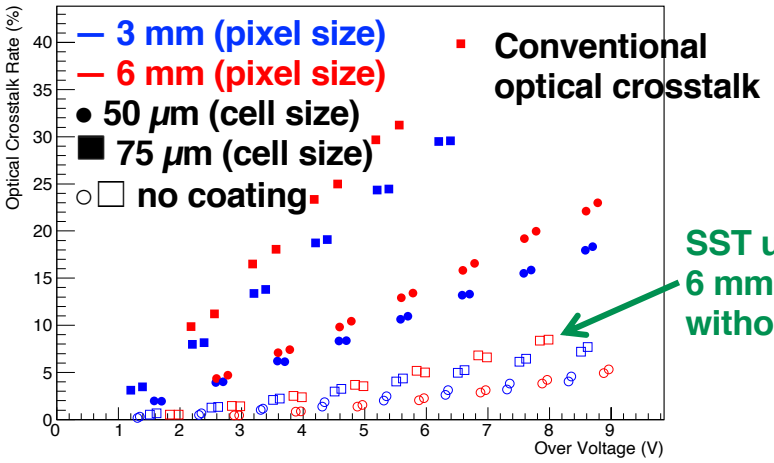
- CTA-North



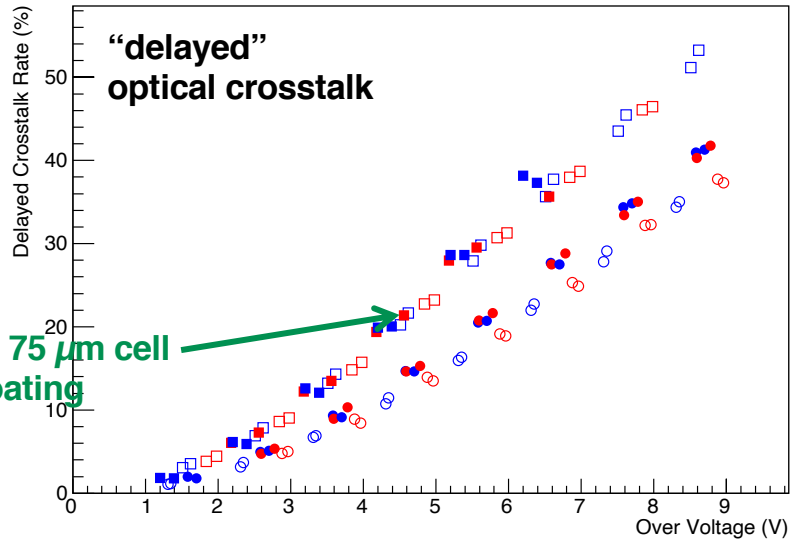

- The location of LST2,3,4 and MST3 has been decided.
- Paths of power lines and trigger exchange optical fibers have been decided.
- We expect construction licence in Q2 2021

# SiPM Camera for SST

- Nagoya group is in charge of SiPM for Small-sized telescope
  - Suppressing optical crosstalk of the SiPM is top priority
    - Reduce accidental triggers and performance degradation
  - Past development achieved:
    - Low optical crosstalk: less than pileup of night sky backgrounds
    - While retaining high photon detection efficiency > 1.5× PMT
  - This year, we found high rate of "delayed" optical crosstalk
    - Secondary photons propagate through SiPM substrate
    - We are investigating the effect of "delayed" optical crosstalk on the shower analysis




SST use
6 mm with 75 μm cell
without coating



# F05: CTA Monte Carlo Simulation

- Working on many research topics in **Analysis and Simulations** WG
- In CTA-Japan: Joint activities with **LST-ODA**(On-site Data Analysis)
- The annual meeting including beginners' training course was held
  - **Totally on-line, >30 participants**
  - **Instructions of the upgraded ICRR computer system (important resource to ASWG)**

**Research topics in CTA-Japan ASWG+LST ODA** (may not covering all, sorry!)

- LST calibration with the standard candle (Crab nebula) data
- Development of the efficient analysis method on Mono-data
- Cross-calibration of MAGIC−LST using coincidence events
- LST camera calibration using various technical runs
- Development intelligent gamma/hadron separation scheme with Neural Network
- Study on effect of hadronic interaction models on the CTA full array sensitivity
- Study on the efficient simulation of cosmic-ray protons using pre-selection in non-Cherenkov shower property

  ..... and more.....

| F05 | 大石　理子 | CTAモンテカルロシミュレーション |
|---|---|---|

**Presentations** (2020S)

- **7** presentations by students at JPS + ASJ annual meetings

**Theses**

- **>3** Master theses on ASWG + LST-ODA related topics

**Paper**

*"Effect of the uncertainty in the hadronic interaction models on the estimation of gamma-ray sensitivity of the Cherenkov Telescope Array"*

Ohishi et al., (to be) submitted *to J. of Phys. G.*
(+ talk at "virtual" CORSIKA workshop 2020 , by convener's invitation)

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

# GRB activities in 2020+

- Discovery **190114C** not finished
  - Bounds on Lorentz invariance violation: appeared in arxiv in Jan, published in Jul *in PRL*
  - Outreach in NHK in May (コズミックフロント☆NEXT) Teshima, Noda, and Takahashi


- Only 4 GRBs observed in 2019, but even with a shutdown for ~3 months, **>15 observed in 2020**
  - **201015A**: short? => long, low luminosity, hint by MAGIC (GCN)
    - **z = 0.43**, Eiso ~= 1e50 erg, so a **low luminosity GRB**
  - **201216C**: long, bright, 2nd detection by MAGIC (GCN, ATel)
    - Redshift ~1.1, farthest IACT source

- **160821B** (hint from a short GRB with kilonova) finally accepted in ApJ (arxiv in Dec): Noda and S. Inoue as the corr. authors
- Noda became one of Transient WG conveners since Jan 2021

| | | |
|---|---|---|
| F06 | 窪　秀利 | MAGIC望遠鏡を用いた高エネルギーガンマ線天体の研究 |

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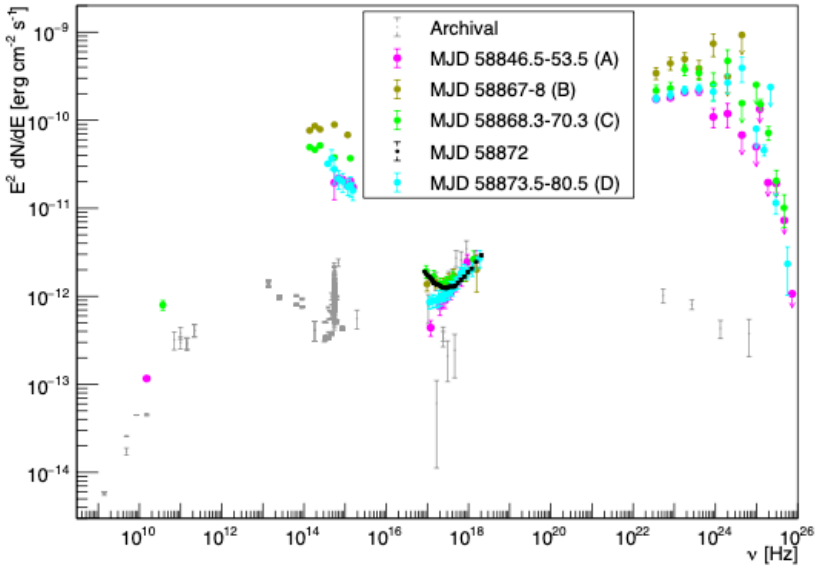
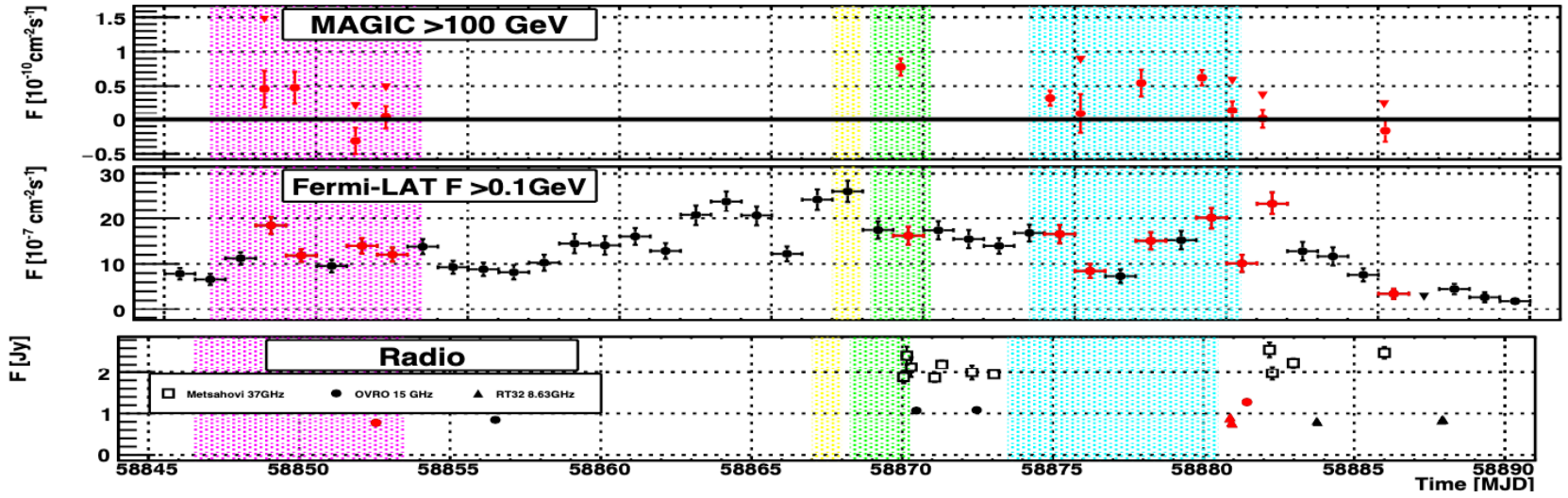
Gamma Imaging
Cerenkov Telescopes

# VHE gamma-ray detection of FSRQ QSO B1420+326 and modeling of its enhanced broadband state in 2020, A&A, in press

**Corresponding Autors: S. Nozaki and F. D'Ammando, R. Angioni, J. Sitarek**

- arXiv:2012.11380, accepted for publication in A&A
- QSO B1420+326 is FSRQ at z=0.682. Flare in January 2020, MAGIC participated in MWL campaign
- Rich data set, External Compton on Disk Torus model works fine

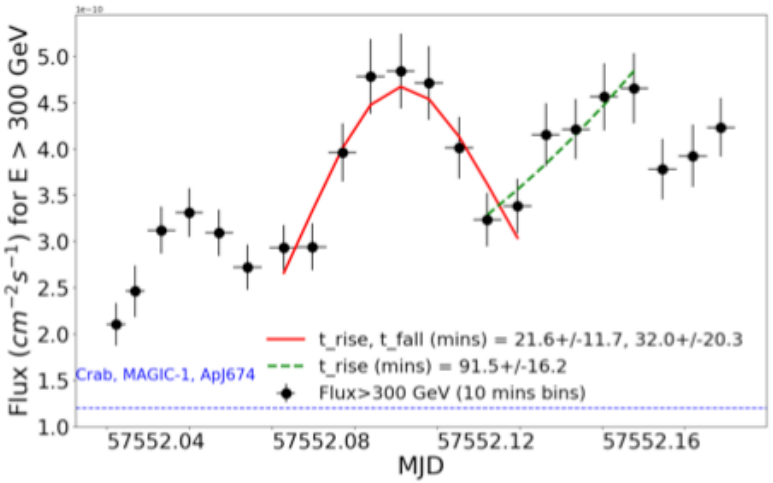


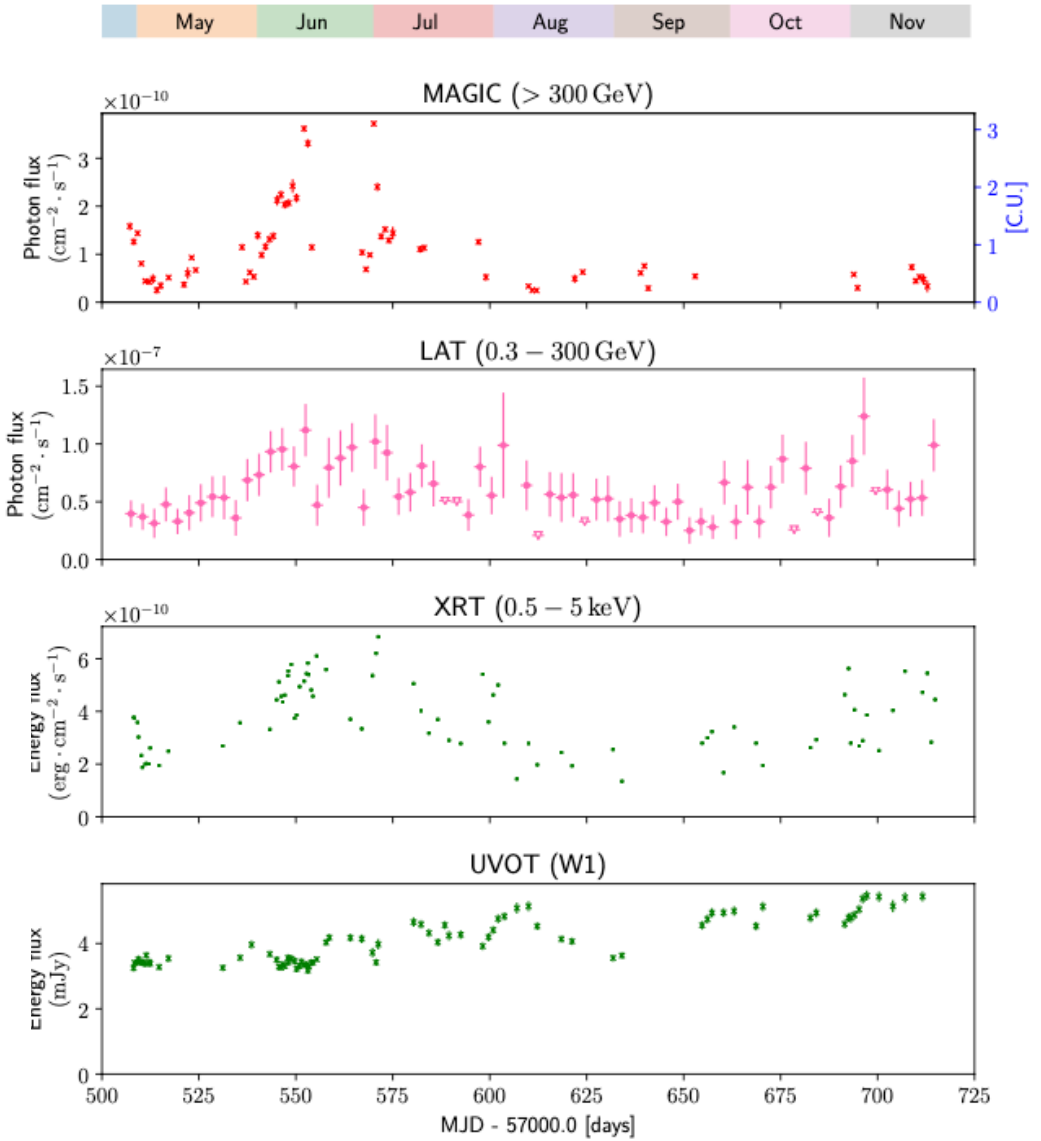



# Broadband characterisation of the very intense TeV flares of the blazar 1ES 1959+650 in 2016, A&A, 638, A14.

**Corresponding Autors: W. Bhattacharyya, M. Takahashi and M. Hayashida**

- 1ES1959+650 (z=0.048) is an HBL, known for orphan flares (TeV flare with no X-ray counterpart)
- MAGIC observer 1ES1959 in 2016 in various flux states, reaching 3 x Crab flux, participated in MWL campaign
- Flux variability down to < 1 hour
- Modeling: many possibilities
- Neutrino emission: improbable

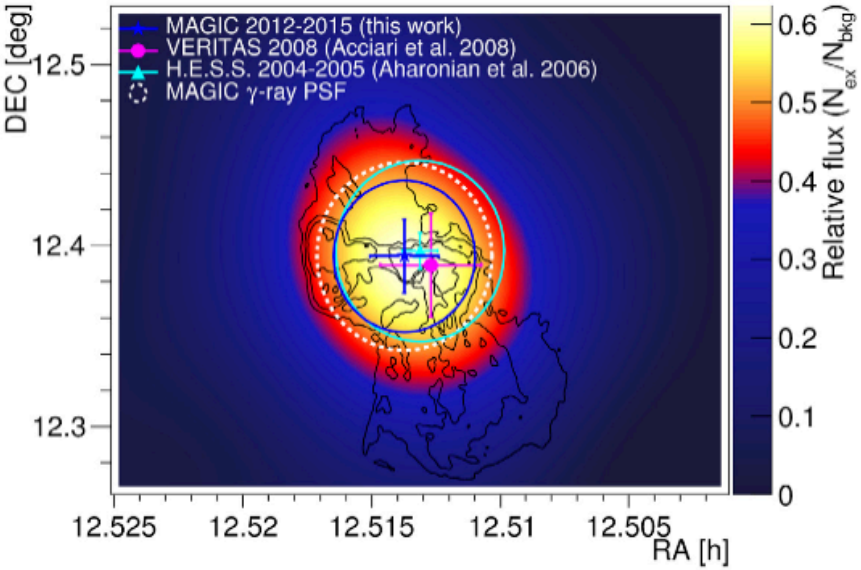


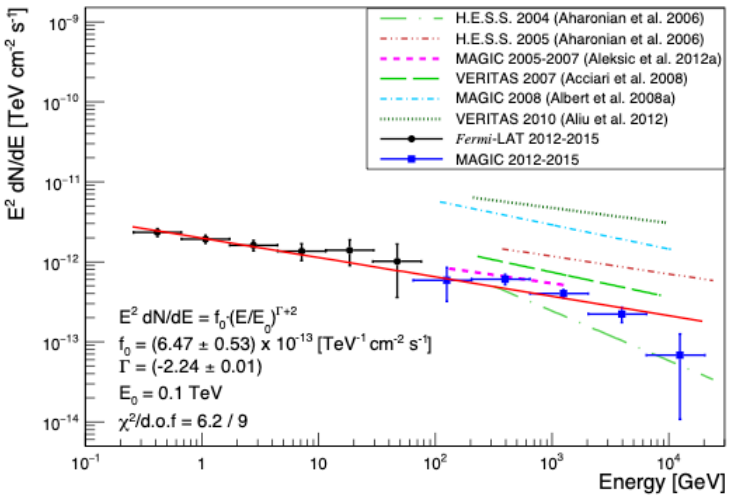



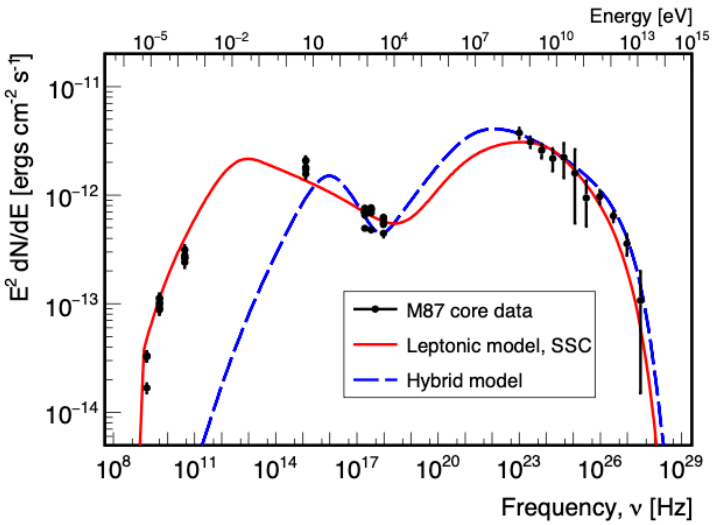
# Monitoring of the radio galaxy M 87 during a low-emission state from 2012 to 2015 with MAGIC, MNRAS, 492, 5354

**Corresponding Autors: D. Mazin, P. Bangale, M. Manganaro and C. Arcaro**

- M87 is a radio galaxy at (16.4+/-0.5) Mpc
- Monitored with MAGIC in 2012-2015, quiescent state
- gamma-ray emission zone and shape are compatible with the ones from flares



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# NGC1275

by TY. Harada

Observations:2018/11/16~2019/12/31(Total:40 Day)

2σ flux upper limit(E>100 GeV) : $<4.24 \times 10^{-12}$ $cm^{-2}$ $s^{-1}$
assuming PowerLaw (Γ=-3.4)

A. Hiramatsu is working on M87 analysis

| | | |
|---|---|---|
| E06 | 西嶋　恭司 | 活動銀河核における超高エネルギーガンマ線放射領域の特定 |

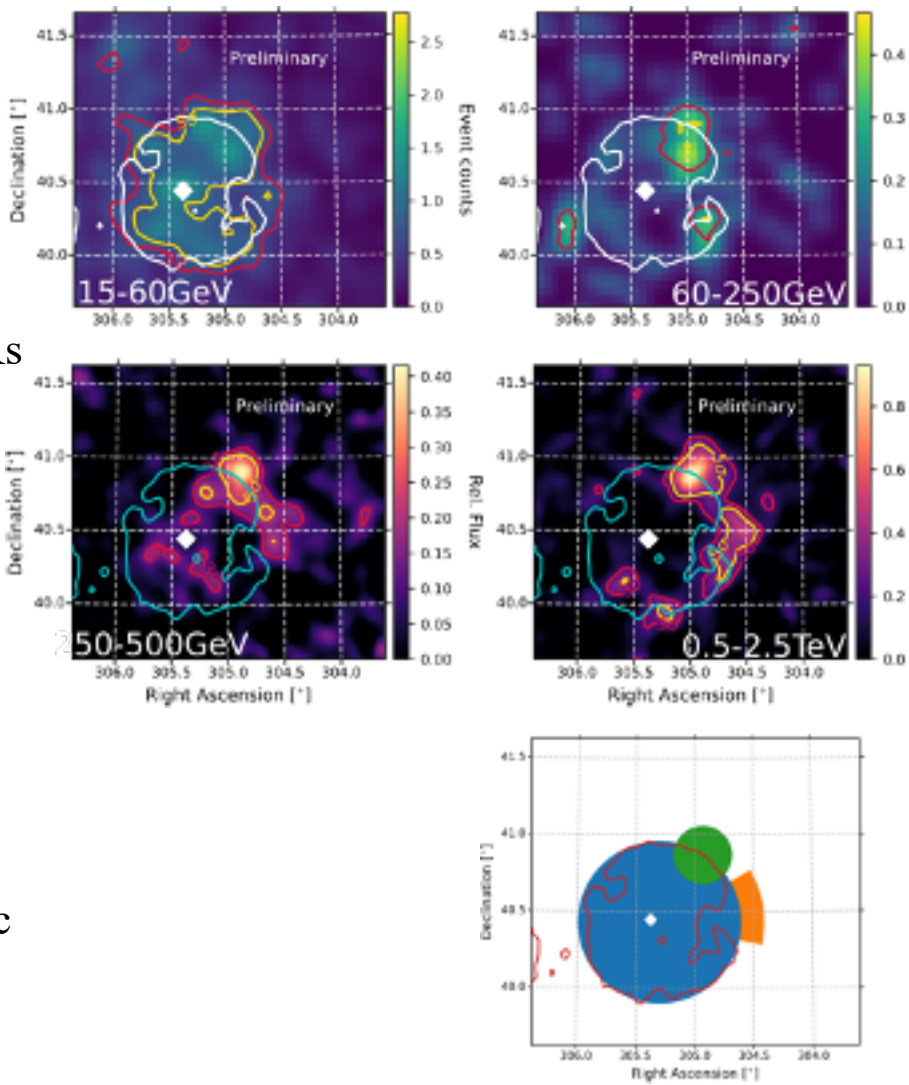
# MAGIC observations of CR escape from the $\gamma$ Cygni SNR

**γ Cygni supernova remnant:**

- debris of a core-collapse supernova;
- currently in the Sedov-Taylor (adiabatic expansion) phase of its evolution (~7000 years old);
- hence one can expect a significant amount of CRs to escape from the SNR shockwave.
-

**MAGIC observations & *Fermi*-LAT analysis:**

- deep 87 h long observational campaign with advanced analysis techniques;
- reanalysis of 9 yrs of *Fermi*-LAT data;
- detection of identification of several source components, which can be explained by hadronic CRs escaping and interacting with the ISM;
- in this scenario: $E_{max}$ at shock evolves like $\sim t^{-2.55}$ and turbulence




**Corresponding Autors: M. Strzys, S. Masuda, I. Vovk**

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

# SNR G106.3+2.7 (Boomerang PWN)

- Associate with the 100 TeV source HAWC J2227+610
- SNR/PWN complex

✓ Sum of head & tail spectra is consistent with VERITAS.

Whole

10 GeV 1 TeV 100 TeV

**100 TeV γ is emitted only from SNR tail?**

**Corresponding Autors: T. Oka, T. Saito, H. Kubo and M. Strzys**

MAGIC
Major Atmospheric
Gamma Imaging
Cerenkov Telescopes

# Binaries with MAGIC

**HESS J0632+057** (PI: D. Hadasch)

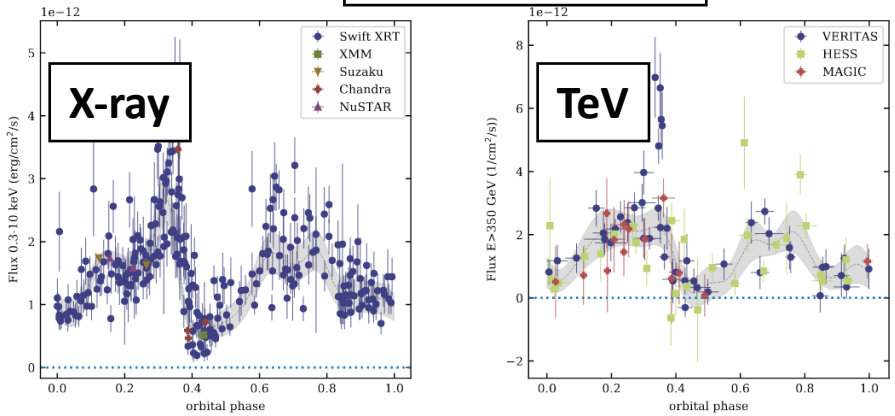
- Joined effort of H.E.S.S., MAGIC & VERITAS , X-ray and optical instruments (collaborator: Yuki Moritani, IPMU)
- Orbital period determined for the first time from gamma-ray data
- Updated X-ray analysis using all available XRT data → most accurate calculation of orbital period until now (317.3 d)
- Paper in internal referee process

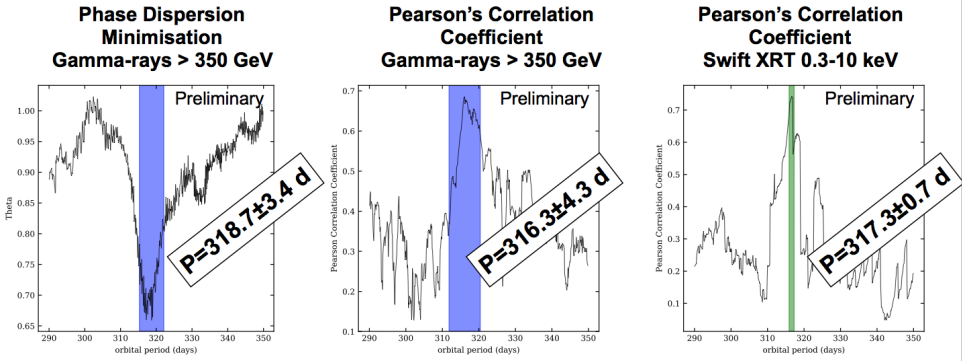
**LS I +61 303** (PI: D. Hadasch)

- New observation proposal for 2021 accepted
- Analysis of 4 years of data together with VERITAS and optical telescope LIVERPOOL on La Palma ongoing

**D. Hadasch became MAGIC Galactic Convener.**

**HESS J0632+057**



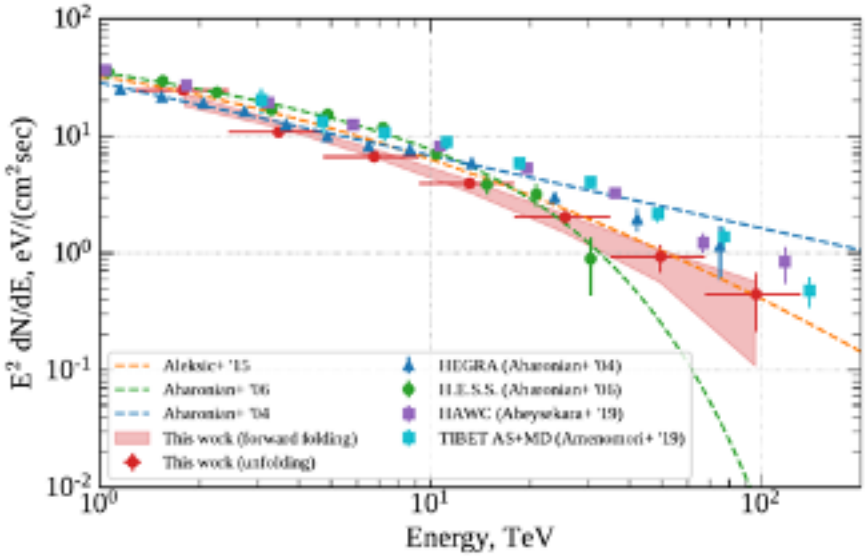
# MAGIC observations of Crab Nebula up to 100 TeV

**The Crab Nebula:**

- a reference object in high-energy astrophysics;
- leptonic emission by electrons up to $10^{15}$ eV;
- highest energy measurements require large exposure / collection area.

**MAGIC observations:**

- novel large zenith angle technique to boost the collection area to ~1 $km^2$;
- detection up to 100 TeV with no indication for a cut-off;
- disfavor putative significant hadronic emission contribution >10 TeV;
- data underline limitation of existing leptonic models




***Ievgen Vovk***

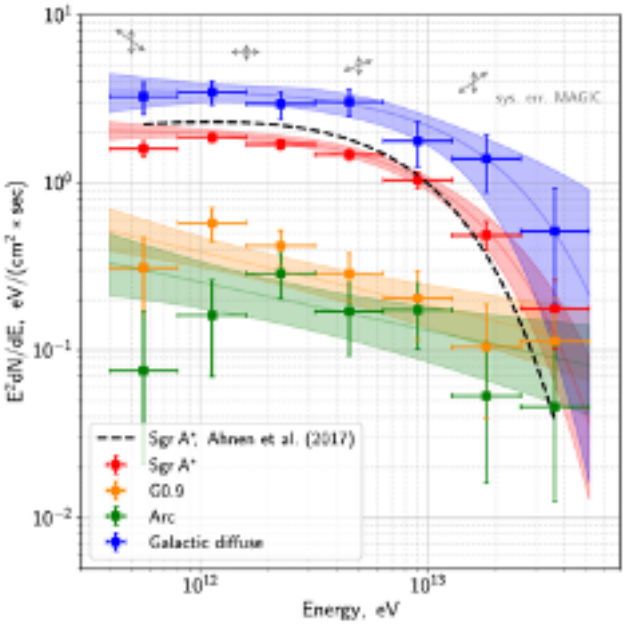
# MAGIC observations of the diffuse gamma-ray emission of the Galactic Center

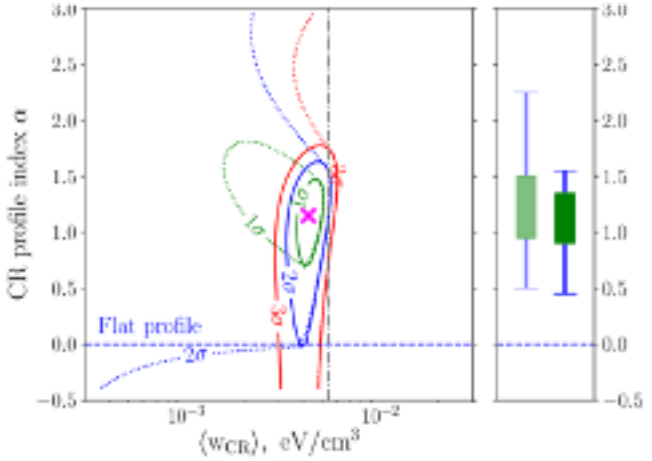
**Galactic Center region:**

- host to a variety of source capable of γ-ray radiation;
- host to a substantial amount of molecular gas;
- host to our Galaxy's supermassive black hole.

**MAGIC observations:**

- deep 5-year long observational campaign with advanced analysis techniques;
- detection of several sources, including the Galactic plane diffuse emission;
- confirm the presence of the peaked cosmic ray profile, centered at the supermassive black hole;
- indicate a cut-off in the cosmic ray spectrum;
- underline uncertainties stemming from the limited knowledge



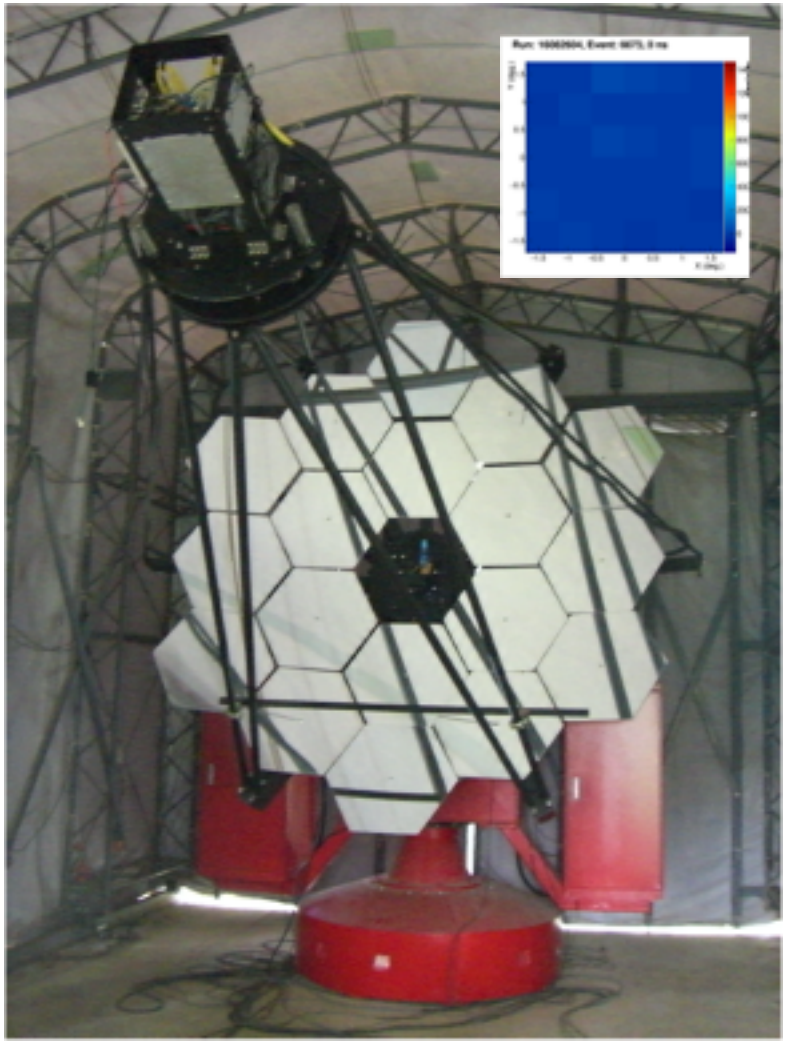
# MAGIC Publication in the last year

*Bold Red letters shows a paper of which corresponding authors include a magic-japan member.

- **[1] "MAGIC observations of the nearby short gamma-ray burst GRB 160821B", ApJ, in press.**
- [2] "Multiwavelength variability and correlation studies of Mrk 421 during historically low X-ray and $\gamma$-ray activity in 2015-2016", MNRAS, in press.
- [3] "Observation of a sudden cessation of a very-high-energy gamma-ray flare in PKS 1510-089 with H.E.S.S. and MAGIC in May 2016", A&A, in press. [with HESS collaboration]
- **[4] "VHE gamma-ray detection of FSRQ QSO B1420+326 and modeling of its enhanced broadband state in 2020", A&A, in press.**
- **[5] "Study of the GeV to TeV morphology of the $\gamma$-Cygni SNR (G78.2+2.1) with MAGIC and Fermi-LAT", A&A, in press.**
- [6] "Testing two-component models on very-high-energy gamma-ray emitting BL Lac objects", A&A, 640, A132.
- [7] "A search for dark matter in Triangulum II with the MAGIC telescopes", Phys. Dark Universe, 20, 100529.
- [8] "An intermittent extreme BL Lac: MWL study of 1ES 2344+514 in an enhanced state", MNRAS, 496, 3912. [with the FACT collaboration]
- [9] "Bounds on Lorentz invariance violation from MAGIC observation of GRB 190114C", PRL, 125, 021301.
- **[10] "Broadband characterisation of the very intense TeV flares of the blazar 1ES 1959+650 in 2016", A&A, 638, A14. [with the Fermi-LAT collaboration]**
- [11] "Detection of the Geminga pulsar with MAGIC hints at a power-law tail emission beyond 15 GeV", A&A, 643, A14.
- [12] "MAGIC observations of the diffuse $\gamma$-ray emission in the vicinity of the Galactic Centre", A&A, 642, A190.
- [13] "MAGIC very large zenith angle observations of the Crab Nebula up to 100 TeV", A&A, 635, A158.
- [14] "Monitoring of the radio galaxy M 87 during a low-emission state from 2012 to 2015 with MAGIC", MNRAS, 492, 5354.
- [15] "New hard-TeV extreme blazars detected with the MAGIC telescopes", ApJS, 247, 16.
- [16] "Statistics of VHE gamma-Rays in Temporal Association with Radio Giant Pulses from the Crab Pulsar", A&A, 634, A25.
- [17] "Study of the variable broadband emission of Markarian 501 during the most extreme Swift X-ray activity", A&A, 637, 86. [with the FACT collaboration]
- [18] "Studying the nature of the unidentified gamma-ray source HESS J1841-055 with the MAGIC telescopes", MNRAS, 497, 3734.
- [19] "The Great Markarian 421 Flare of 2010 February: Multiwavelength Variability and Correlation Studies", ApJS, 890, 97.
- [20] "Unravelling the complex behavior of Mrk 421 with simultaneous X-ray and VHE observations during an extreme flaring activity in April 2013", ApJS, 248, 29.

- - MAGIC ATels
- 14275 "GRB 201216C: MAGIC detection in very high energy gamma rays", 17 Dec 2020
- 14268 "MAGIC measures high flux state from the blazar 1ES0647+250", 15 Dec 2020
- 14090 "Detection of very-high-energy gamma-ray emission from B2 1811+31 with the MAGIC telescopes", 13 Oct 2020
- 14032 "Detection of a bright very-high-energy gamma-ray flare from BL Lac with the MAGIC telescopes", 20 Sep 2020
- 13963 "MAGIC detection of very-high-energy gamma-ray flaring activity from BL Lacertae during the current historical optical and high-energy gamma-ray flare", 22 Aug 2020
- 13412 "Detection of very-high-energy gamma-ray emission from B2 1420+32 with the MAGIC telescopes", 21 Jan 2020

# 明野観測所における
# 小型大気チェレンコフ望遠鏡Ｒ＆Ｄ



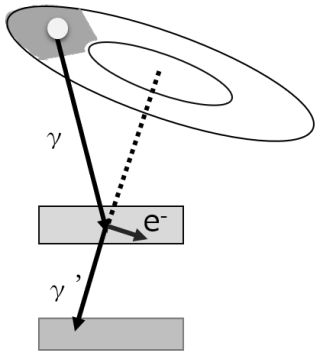
- 明野観測所施設利用（C01）
- 代表者：吉越貴紀（東大宇宙線研）
- 目的：明野観測所に設置した3 m口径大気チェレンコフ望遠鏡を整備・維持し、地上ガンマ線天文台将来計画等の各種R＆Dに利用する。
- 2020年度査定額：9.6万円
- 国内唯一の大気チェレンコフ望遠鏡
- 最近の活動：
  - 可視光Crabパルサー観測用システムを導入し、観測を実施（約10時間）。データ解析中。
  - CTA LST用SiPMカメラモジュールによる試験観測を検討中。

| | | |
|---|---|---|
| C01 | 吉越　貴紀 | 明野観測所における小型大気チェレンコフ望遠鏡R＆D |

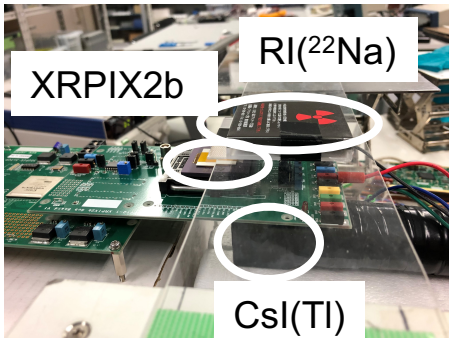
# Development of an advanced Compton camera using SOI pixel semiconductor

Mika Kagaya
(NIT, Sendai College)

**Advanced Compton camera using SOI pixel sensor for sub-MeV/MeV gamma-ray observation**




- Developed a prototype advanced Compton camera
- Advanced Compton camera can reduce background by detecting the recoil electron tracks
- Used the XRPIX2b sensor developed by Kyoto Univ.
- Pixel pitch: 30μm × 30μm (144pixel × 144pixel)
- Succeeded to detect recoil electron tracks released from 511-keV gamma rays.




Prototype Compton camera

We evaluated the detection capability of tracks of this prototype using Geant4 simulation (ICRR server).

| F07 | 加賀谷　美佳 | 3次元シリコン半導体検出器を用いた電子飛跡コンプトンカメラの開発 |
|---|---|---|

# Geant4 simulation using ICRR server

- Simulate by setting various incident angles of gamma rays
- Estimated recoil directions using images of tracks

The results of experiments and simulations are consistent. We demonstrated the detection capability of tracks using the prototype.

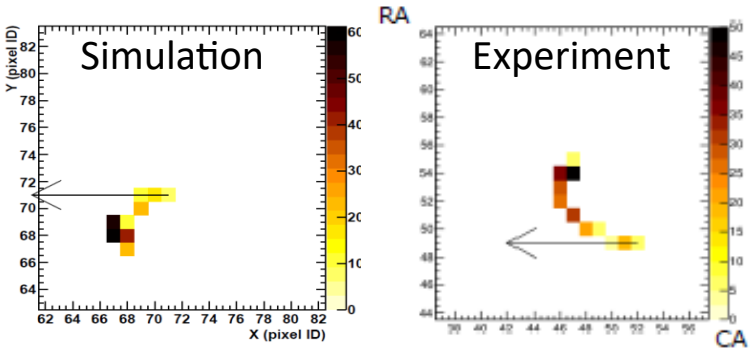
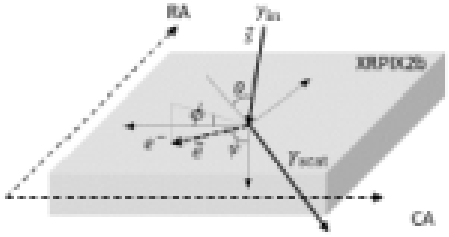
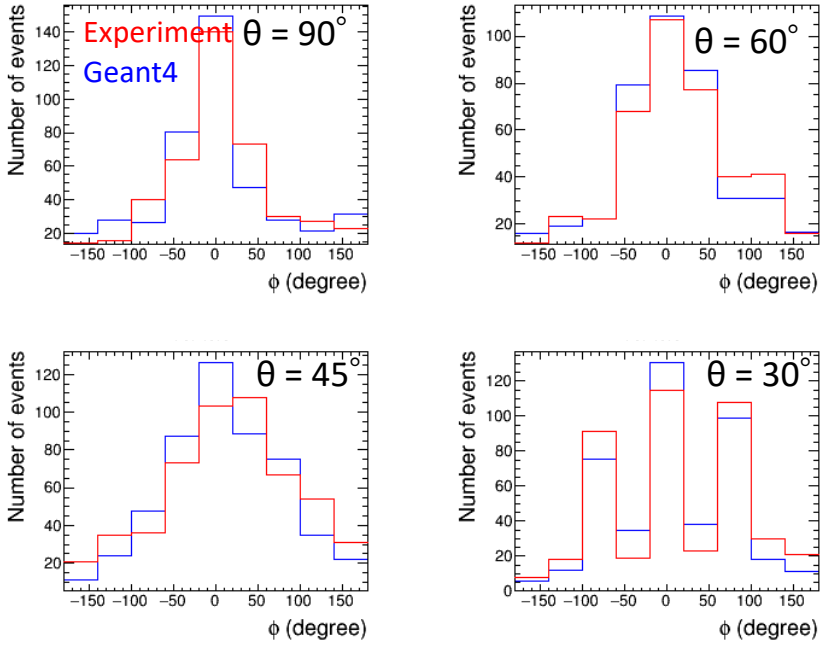



Image of recoil electron track




Definition of direction of recoil electron tracks




Distribution of recoil directions

**Future plan**

Simulate with various sensor (e.g., smaller sensor) for future sensor design.

# 結論

- MAGICは重要な結果を量産しつづけている
- CTA/LSTも順調に建設が進められている